Ferrous Materials:

GEM Rotator

Eric King

Last Updated:

11-1-2023

Broad Overview

The GEM Rotator has the following currently-identified ferrous elements.

Roller bearings (cyan)

- General doc found for SKF says material is 100Cr6 [carbon steel]

Floor locks (green)

- Stainless & Carbon Steel, Connects are also carbon steel.

Motor (blue)

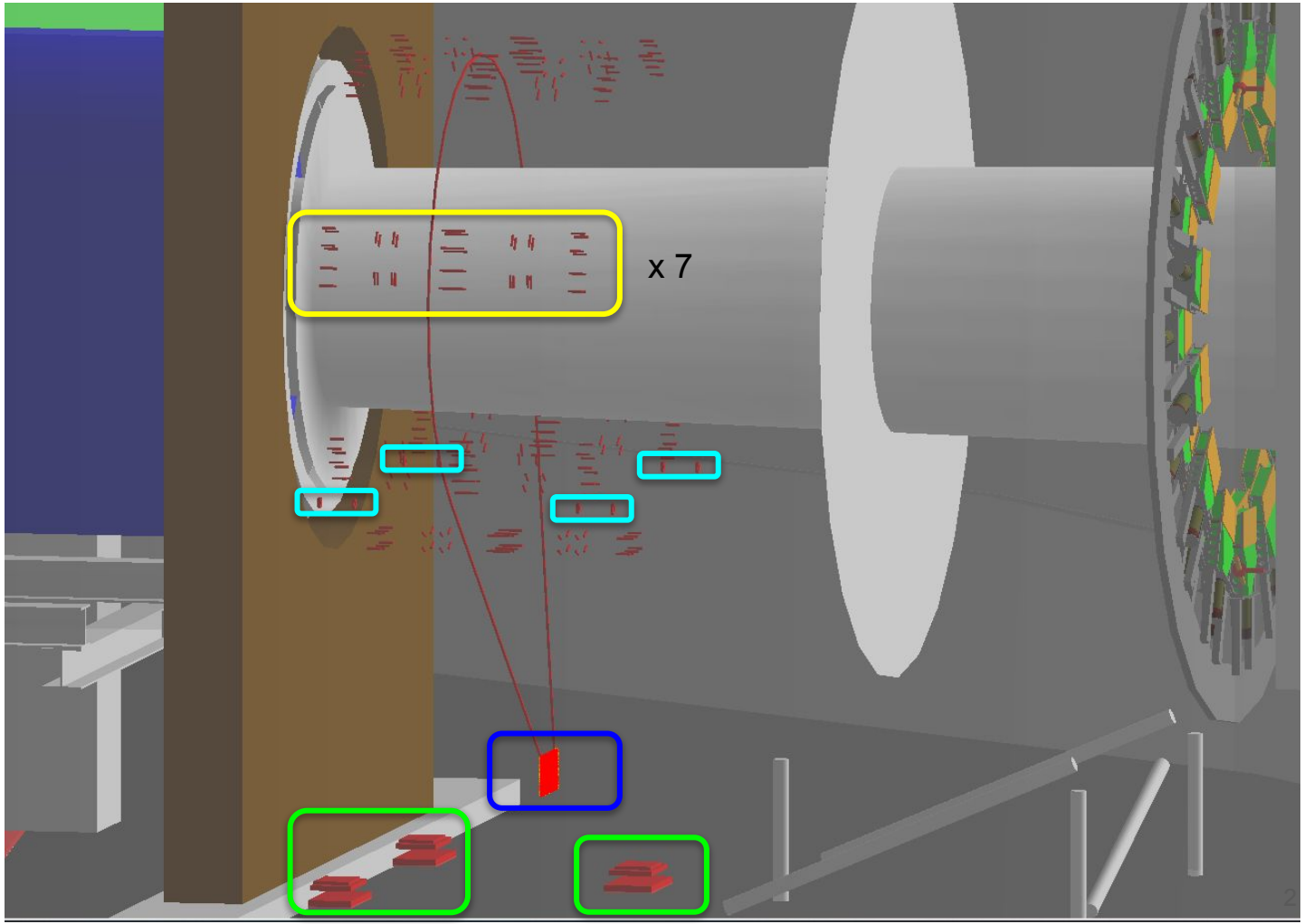
- Material specifics unknown, assume full magnetization 8%

Chain (long thing)

- Is overmodeled, SS316

Fasteners (yellow)

- SS316 [wrongly listed as Grade 5 in previous PDF version]



Broad Overview (Cont'd)

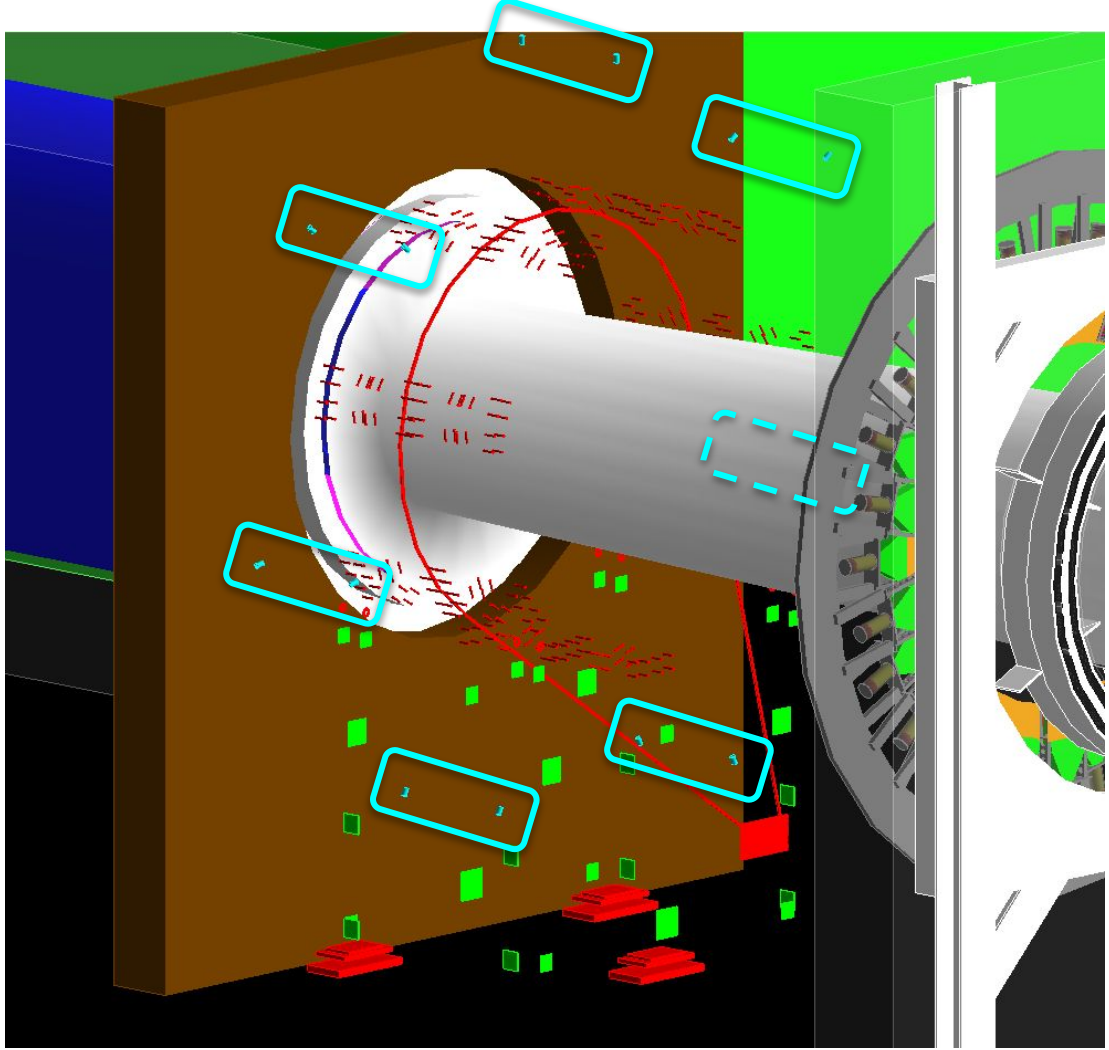
The GEM Rotator items added since previous slide now include:

Stepper Motor (cyan)

- 2 motors per septant so 14 total; magnetic cores modeled (reasonably well for first pass, see if GEM team has any more details); fully magnetized material.

T-Nut Fasteners (Green Squares)

- Toy geometry; accurate mass spread over regions of fastener coverage; represents about 50% of fastener areas; SS-304



Broad Overview (Cont'd)

The GEM Rotator items added since previous slide now include:

Wheel Pins (Green)

- Want to know if SS would be a problem.

Stepper Rods (Magenta)

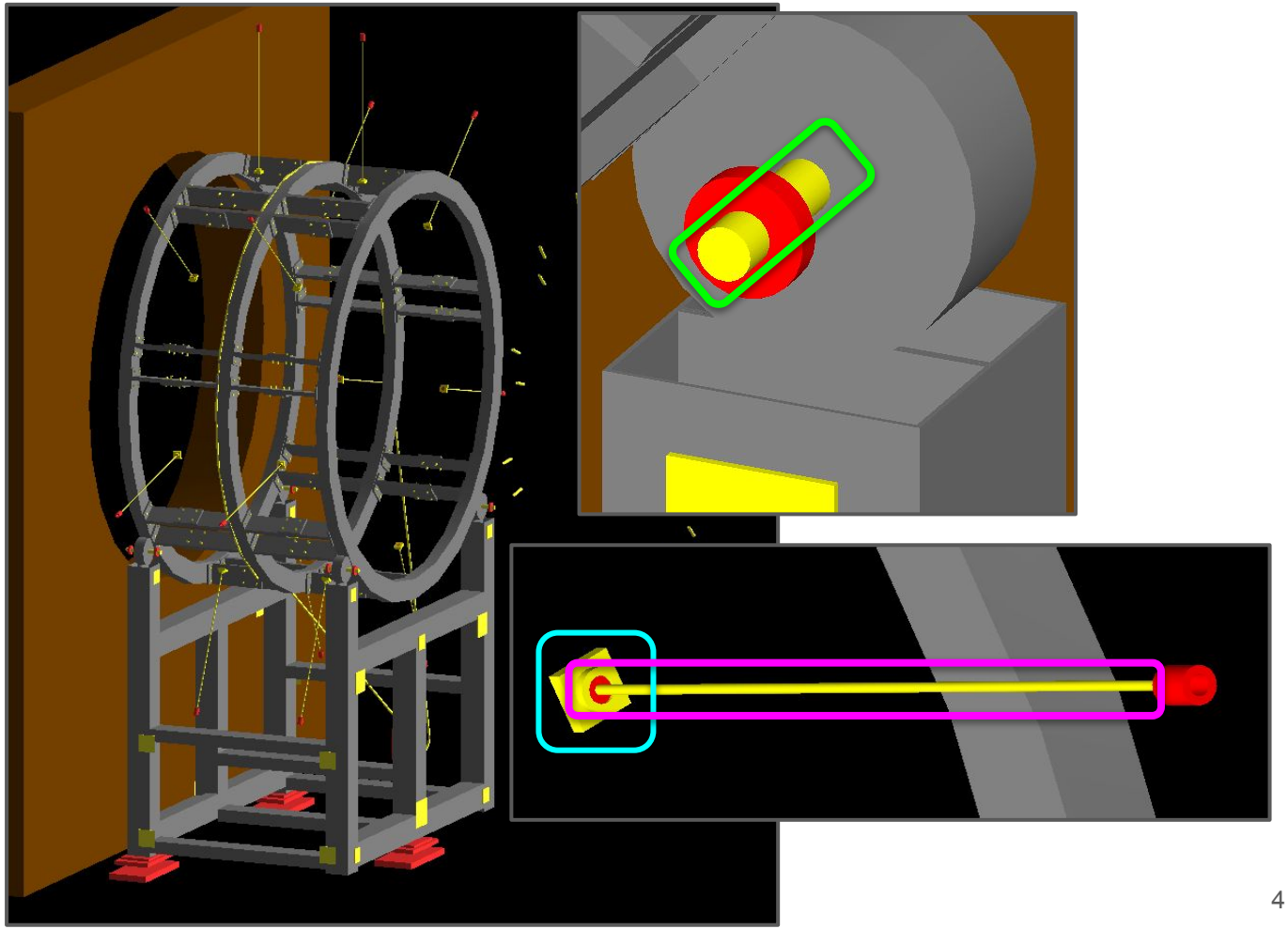
- Made of SS

Stepper Bearings
(Red geometry in cyan box)

- Made of carbon steel.

Stepper Bearing Housing
(Yellow geometry in cyan box)

- Made of SS



Broad Overview (Cont'd)

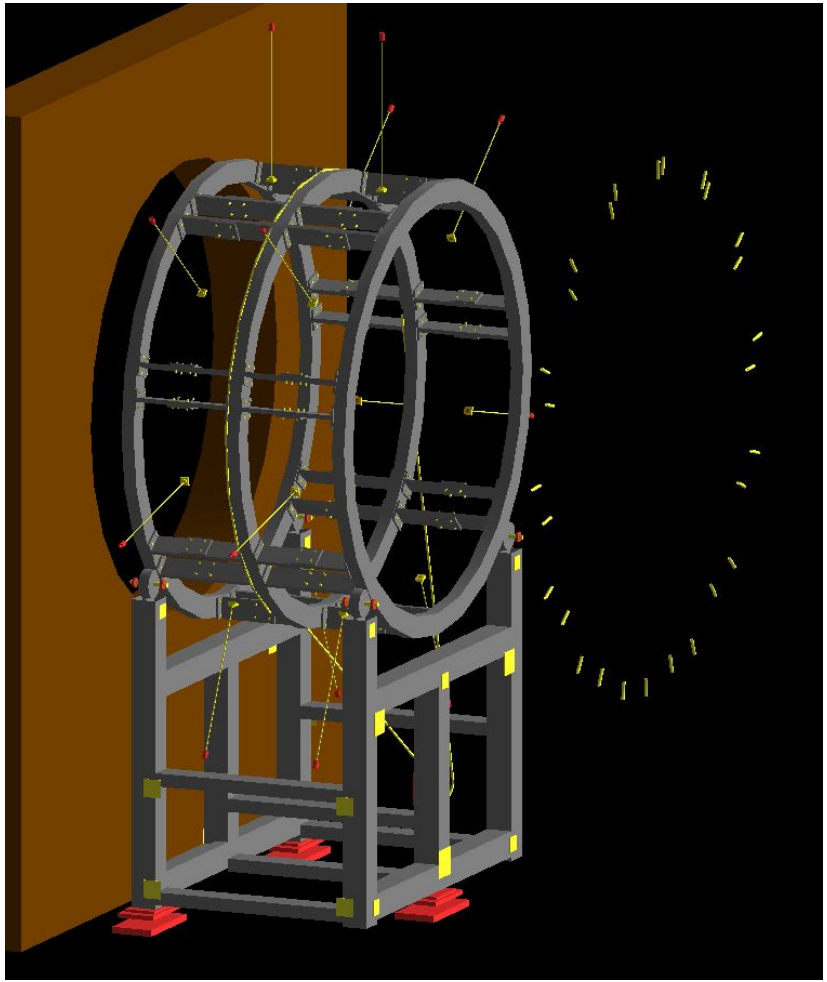
Adding Al mass:

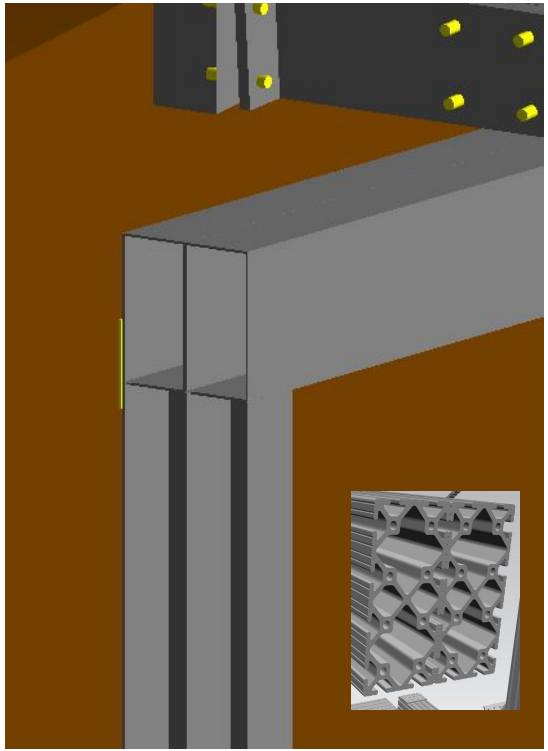
- Frame mass will scatter primaries
- Frame mass will have some degree of attenuation on secondaries coming from certain components.

Largest components of frame mass added in.

- Frame mass/length = model… double check this.
- Wheels solid? Can't tell from JT.

THIS IS NOT THE COMPLETE MASS. I WANTED TO GET ~50% OF IT IN THE MODEL DISTRIBUTED AROUND.





Note: Materials Permeability and Susceptibility

Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	*1E-08*	1E-05	1E-01
Brass/Bronze (Worst)	0.001	*1E-08*	1E-05	1E-01

Study done for CERN at Los Alamos in the 1990s

MAGNETIC PERMEABILITY OF STAINLESS STEEL FOR USE IN ACCELERATOR BEAM TRANSPORT SYSTEMS*

IV. CONCLUSIONS

The use of 310 with 310 weld rod or 20Cb-3 with 20Cb-3 weld rod appears to produce welds with the required permeability of not greater than 1.02, without the necessity of high-temperature solution annealing of large welded components. The availability of two metal/weld rod combinations allows the fabrication process and material to be selected on basis of cost of fabrication and availability of materials.

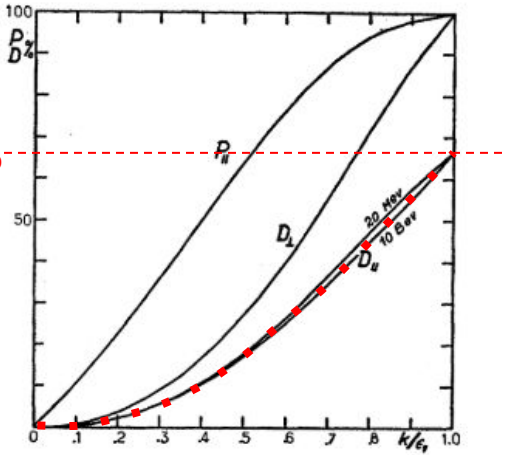
Table 1 - Magnetic Permeability - μ

Material	As Received	After Anneal [1]	After Electropolish	Weld Rod	After TIG Welding	Post-Weld Anneal [2]
304L	1.05-1.1	1.02-1.05	<1.01	E/ER 309	2.2-2.5	1.4+
316L [3]	<1.01	<1.01	<1.01	E/ER 316	1.6	1.10-
				E/ER 316L	1.6	1.02-1.05
				E/ER 316L [4]	1.4 [4]	1.02-1.05
				E/ER 310	1.02-1.05	<1.01
20Cb3	1.01-1.02	1.02-1.05	<1.01	E/ER20Cb3	<1.01	<1.01
310	<1.01	<1.01	<1.01	E/ER 310	<1.01	<1.01
Nitronic 33	<1.01	1.02-1.05	<1.01	NIT33	1.1	<1.01
Nitronic 40	<1.01	<1.01	<1.01	NIT40	1.1-1.15	1.02+
317LN	<1.01	<1.01	<1.01	E/ER 317	1.2-1.4	<1.01

1. Anneal conditions: 1800° for 75 min on 20Cb-3, 1980° for 40 min on all other types.
2. Post-weld anneal conditions: 1825° for 60 min in nitrogen at a pressure of approximately 4x10-5 torr on all samples.
3. The same 316L coupons were welded with four different weld rods.
4. Arc welded with coated rod.

*Table copy courtesy of Don

Note: Depolarization Considerations



66.6%

FIG. 5. Circular polarization of bremsstrahlung beam from longitudinally polarized electrons,

$$P_{\parallel}=P(\mathbf{p}_1,\zeta_{1\ \text{long}},\mathbf{e}_{\text{circ}}),$$

and depolarization of longitudinally polarized electrons,

$$D_{\parallel}=D(\mathbf{p}_1,\zeta_{1\ \text{long}})$$

and of transversely polarized electrons, $D_{\perp}=D(\mathbf{p}_1,\zeta_{1\ \text{trans}})$. Coulomb and screening effects are included. The curves for $P_{\parallel}$ and $D_{\perp}$ are valid for all elements and for any incident electron energy above $\approx$20 Mev. $D_{\parallel}$ depends slightly on the electron energy; curves are shown for incident electron energies 20 Mev and 10 Bev.

Photon and Electron Polarization in High-Energy Bremsstrahlung and Pair Production with Screening*

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AND

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(Received November 24, 1958)

I've highlighted the depolarization of longitudinally polarized electrons line in red.

Presuming bremsstrahlung losses a 100MeV electron from our primary ferrous simulations will have a depolarization of 66.6%

We use this 2/3 polarization loss figure when needing to account for polarization losses.

9300 – GEM Rotator Roller Bearings

Carbon Steel roller bearings.

1” ID
2.25” OD

Modeled as cylinder with spec’d ID and OD with a z-thickness enough to give the ring a mass of ~0.22kg (0.48 lb in specs).

Used G4-STAINLESS_STEEL in remoll for simulation.

https://www.skf.com/au/products/rolling-bearings/roller-bearings/tapered-roller-bearings/single-row-tapered-roller-bearings/productid-15578%2F15520

9300 – GEM Rotator Roller Bearings (cont'd)

https://www.skf.com/au/products/rolling-bearings/roller-bearings/tapered-roller-bearings/single-row-tapered-roller-bearings/productid-15578%2F15520

Material information sourced from SKF website.

(1) Confirm with Chandika specifics about the material for this specific. It's possible that I missed specific component materials in listing on the website. Other than that all I found was general information about SKF-made components.

Bearing rings −

The pressure at the rolling contact area and the cyclic overrolling creates fatigue in the bearing rings when the bearing is in operation. To cope with such fatigue, rings that are made of steel must be hardened.

The standard steel for bearing rings and washers is 100Cr6, a steel containing approximately 1% carbon and 1,5% chromium.

SKF bearing rings and washers are made of steel in accordance with SKF specifications. They cover all aspects that are relevant to providing a long service life for the bearing. Depending on specific requirements, SKF uses stainless steels or high-temperature steels.

Rolling elements −

The rolling elements (balls or rollers) transfer the load between inner and outer rings. Typically, the same steel is used for rolling elements as for bearing rings and washers. When required, rolling elements can be made of ceramic material. Bearings containing ceramic rolling elements are considered hybrid bearings and are becoming more and more common.

9300 – GEM Rotator Roller Bearings (cont'd)

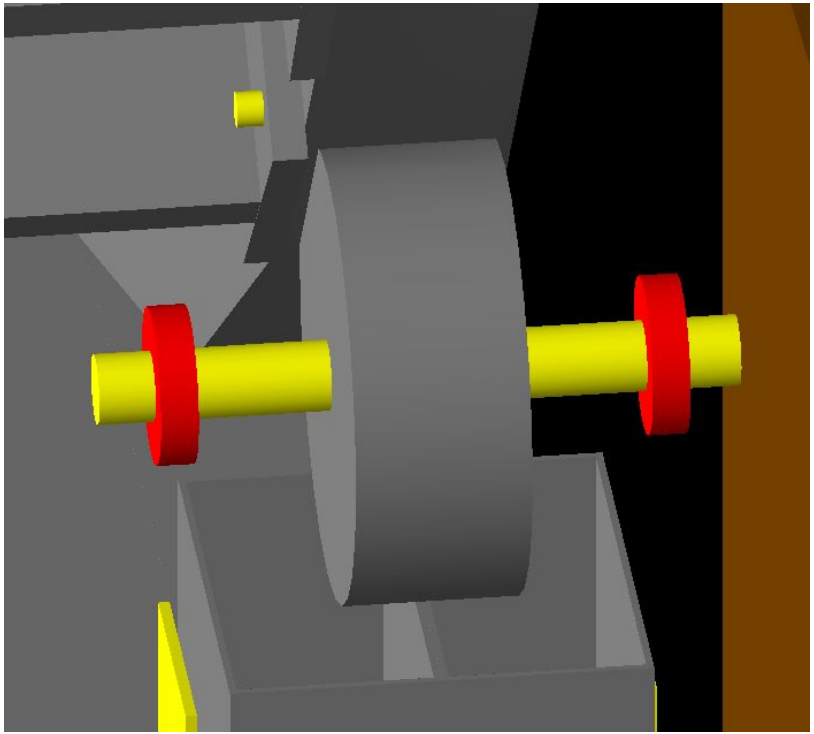
Previous modeling was just the roller bearings which are red in this screen snip.

Added is the wheel structure made of aluminum (gray) and wheel pin (yellow) which is stainless steel (modeled as such on request).

The additional materials should provide some shielding of primaries and attenuation of secondaries.

Note: There is some additional aluminum structure such as the plates which attach to the legs and hold the pins which are not modeled here.

NEW



9300: GEM Rotator Roller Bearings (ferrous material only)

Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	*1E-08*	1E-05	1E-01
Brass/Bronze (Worst)	0.001	*1E-08*	1E-05	1E-01

If the material is indeed 100Cr6 and assuming a relative permeability of our listed 'carbon steel' then we're above the limit by about a factor of 4.

Two considerations:
(1) Depolarization – divide ferrous background by 3.
(2) Aluminum roller structure missing.
  (a) I believe shielding & attenuation by the wheel structure would then sufficiently tamp this down to comfortable territory.

Sens Volume:	GEM Rotator Wheel Bearings
Sim Date:	9/15/2023
Detector #:	9300

OLD

GEM Rotator Wheel Bearings -- Unweighted By BField

Total Prim's:	15,000,000,000	
Total Sec's:	500,000	(per sens det)

Primary Counts		
Primaries	0	0&1
9300		105

Primary Fractional		
Primaries	0	0&1
9300		7.00E-09

(9928 MainDet) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9300	3355	2909

(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9300	6.71E-03	5.82E-03

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9300	4.70E-11	4.07E-11

(9911 PMT Region) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9300	12710	23089

(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9300	2.54E-02	4.62E-02

(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9300	1.78E-10	3.23E-10

9300: GEM Rotator Roller Bearings (ferrous material only)

Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	*1E-08*	1E-05	1E-01
Brass/Bronze (Worst)	0.001	*1E-08*	1E-05	1E-01

Sens Volume:	GEM Rotator Wheel Bearings
Sim Date:	10/31/2023
Detector #:	9300

*Simulation with wheel and frame mass (G4_Al)

NEW

GEM Rotator Wheel Bearings -- Unweighted By BField

Total Prim's:	20,000,000,000

Total Sec's:	500,000	(per sens det)

Primary Counts		
Primaries	0	0&1
9300		43

Primary Fractional		
Primaries	0	0&1
9300		2.15E-09

(9928 MainDet) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9300	26	487

(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9300	5.20E-05	9.74E-04

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9300	1.12E-13	2.09E-12

(9911 PMT Region) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9300	142	1677

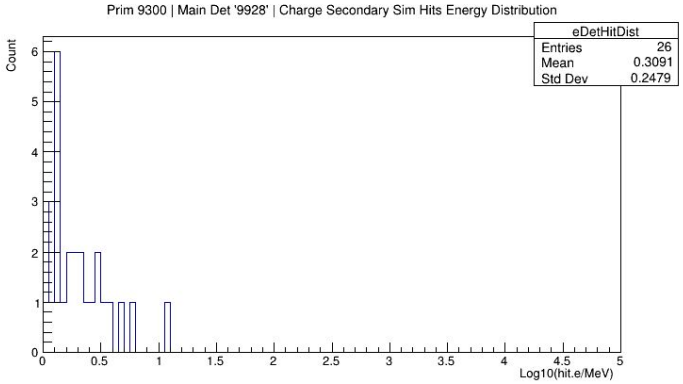
(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9300	2.84E-04	3.35E-03

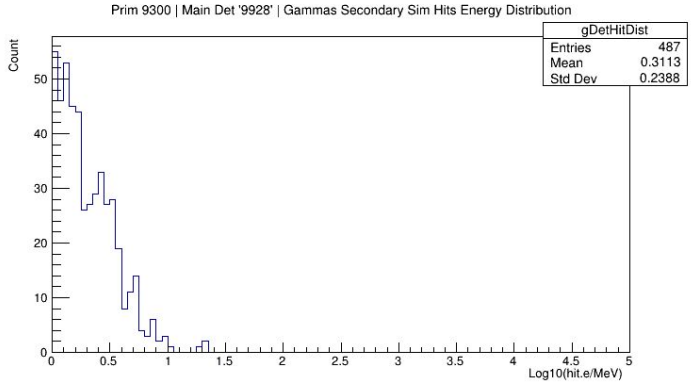
(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9300	6.11E-13	7.21E-12

- A factor of ~3.5 reduction in the fraction of primary hits.
- Secondary charge hits on the detector are reduced by two order of magnitude.
- ➢ It's not immediately clear why this is the case. I could make the SS pins sensitive in the secondary and assign a volume number to the Al structure.
- **Nonetheless, I think the results demonstrate that the bearings are 'safe'.**

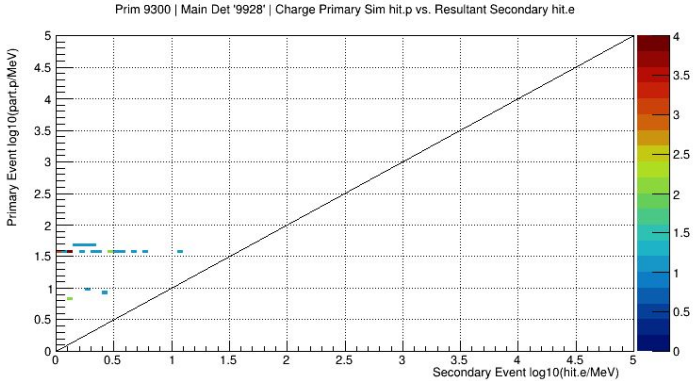
9300: GEM Rotator Roller Bearings

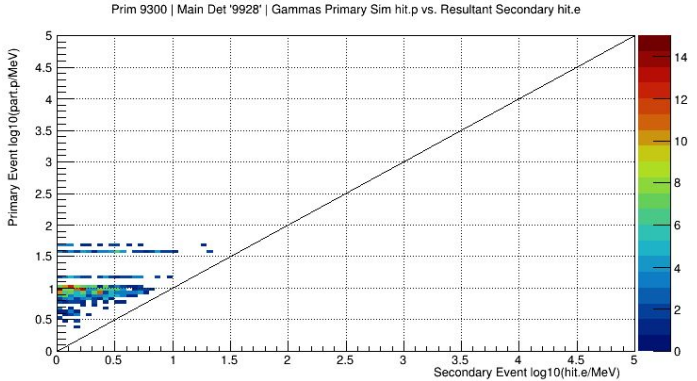
Backgrounds that hit detector '28'





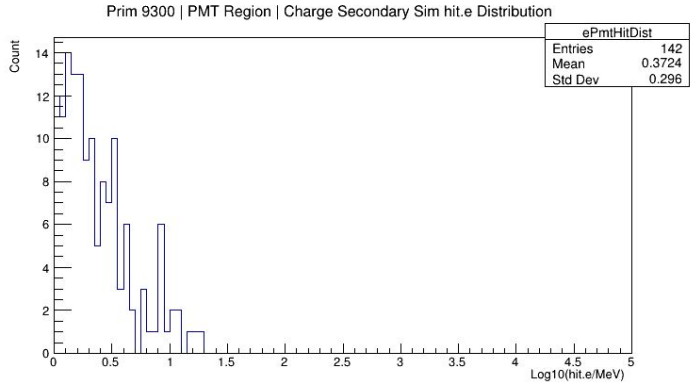
NEW

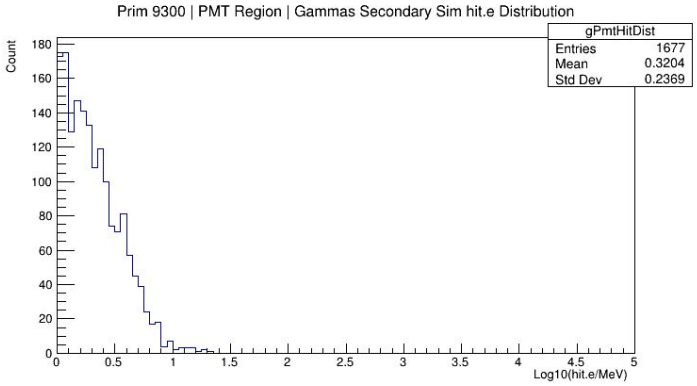




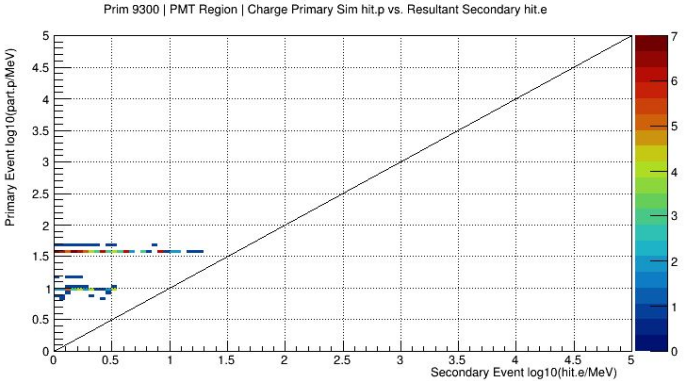
9300: GEM Rotator Roller Bearings

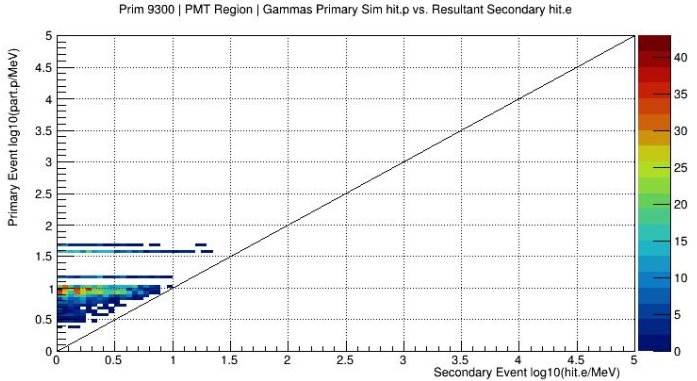
Backgrounds that hit PMT Region





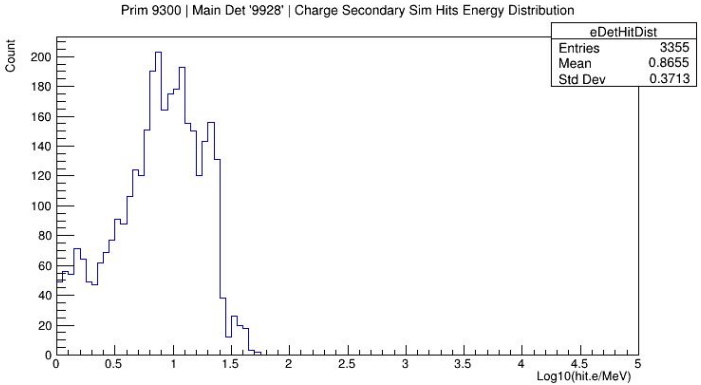
NEW

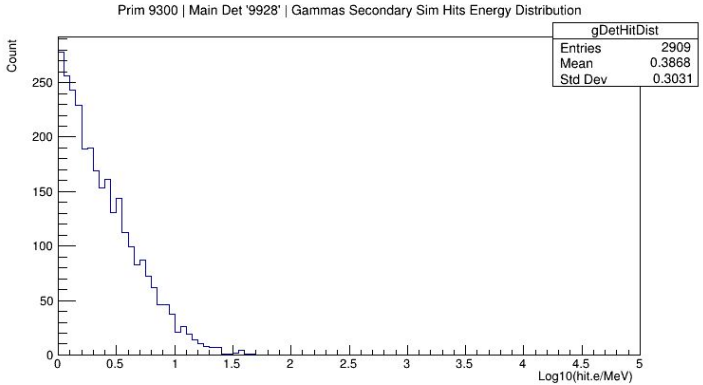




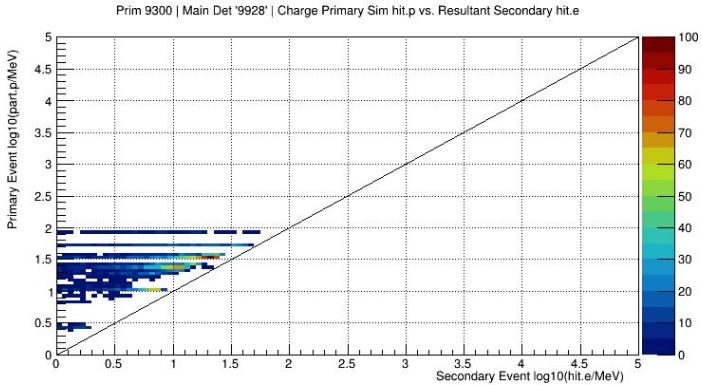
9300: GEM Rotator Roller Bearings

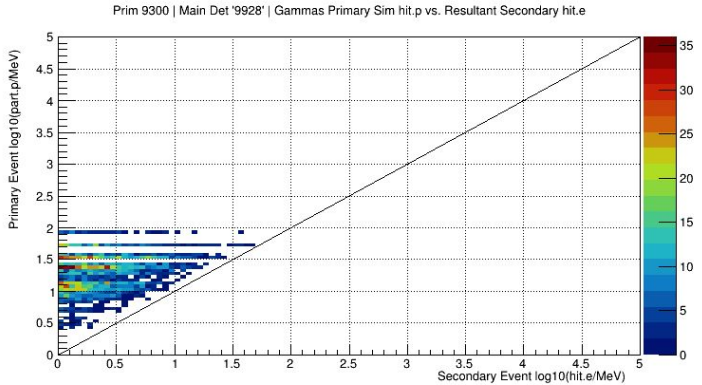
Backgrounds that hit detector '28'





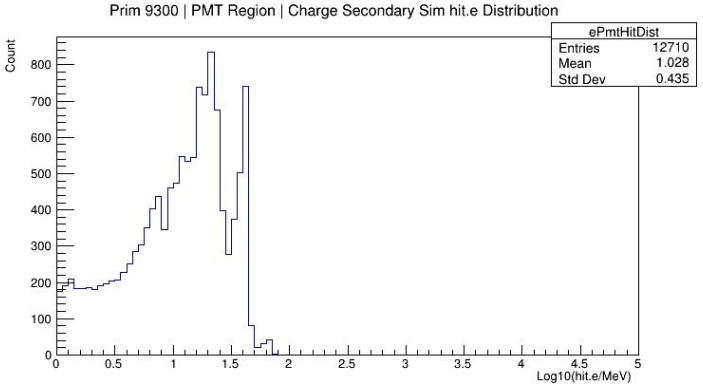
OLD

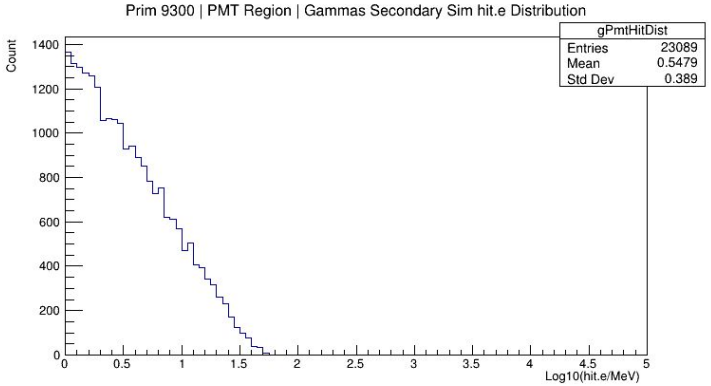




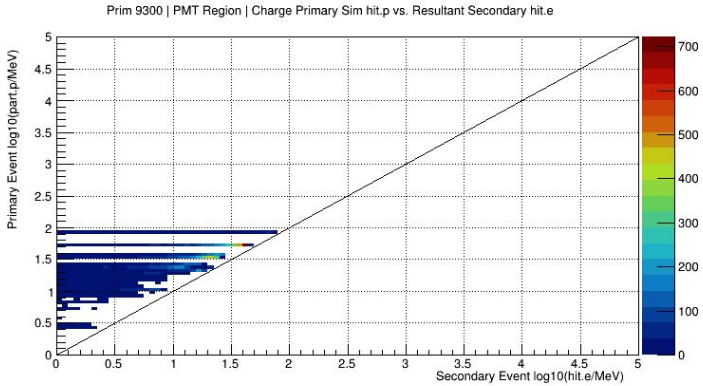
9300: GEM Rotator Roller Bearings

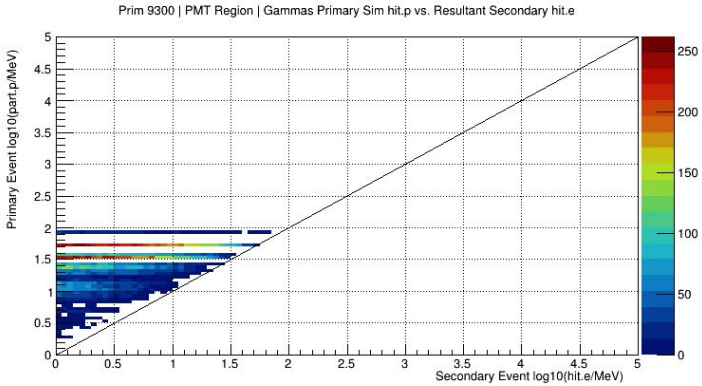
Backgrounds that hit PMT Region





OLD



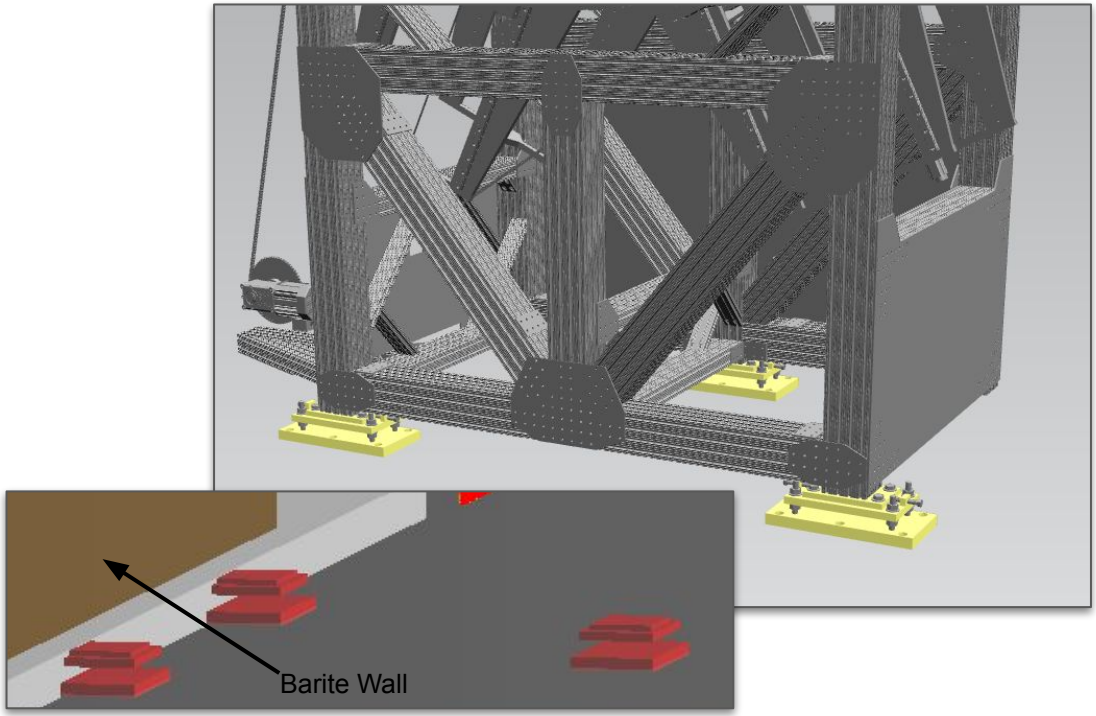


9301 – GEM Rotator Floor Locks

Floor locks built to spec from JT files.

Made of G4_STAINLESS-STEEL in remoll

Placed, in remoll, right behind the floor rail for the barite wall.



9301: GEM Rotator Floor Locks

Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	1E-08	1E-05	1E-01
Brass/Bronze (Worst)	0.001	1E-08	1E-05	1E-01

A factor of 3 reduction from depolarization can be considered.

This puts the results on the edge of comfortability.

Sens Volume:	GEM Rotator Floor Locks
Sim Date:	9/15/2023
Detector #:	9301

OLD

GEM Rotator Floor Locks -- Unweighted By BField

Total Prim's:	15,000,000,000	
Total Sec's:	500,000	(per sens det)

Primary Counts		
Primaries	0	0&1
9301		362

Primary Fractional		
Primaries	0	0&1
9301		2.41E-08

(9928 MainDet) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9301	613	59

(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9301	1.23E-03	1.18E-04

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9301	2.96E-11	2.85E-12

(9911 PMT Region) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9301	3052	339

(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9301	6.10E-03	6.78E-04

(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9301	1.47E-10	1.64E-11

9301: GEM Rotator Floor Locks

Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	*1E-08*	1E-05	1E-01
Brass/Bronze (Worst)	0.001	*1E-08*	1E-05	1E-01

Sens Volume:	GEM Rotator Floor Locks
Sim Date:	10/31/2023
Detector #:	9301

*Simulation with wheel and frame mass (G4_Al)

NEW

GEM Rotator Floor Locks -- Unweighted By BField

Total Prim's:	20,000,000,000

Total Sec's:	500,000	(per sens det)

Primary Counts		
Primaries	0	0&1
9301		202

Primary Fractional		
Primaries	0	0&1
9301		1.01E-08

(9928 MainDet) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9301	195	65

(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9301	3.90E-04	1.30E-04

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9301	3.94E-12	1.31E-12

(9911 PMT Region) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9301	1354	440

(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9301	2.71E-03	8.80E-04

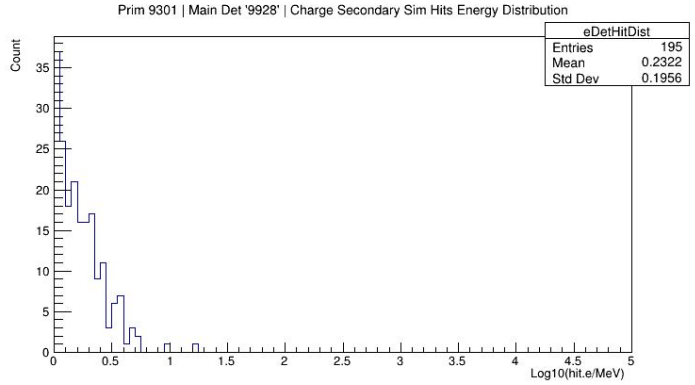
(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9301	2.74E-11	8.89E-12

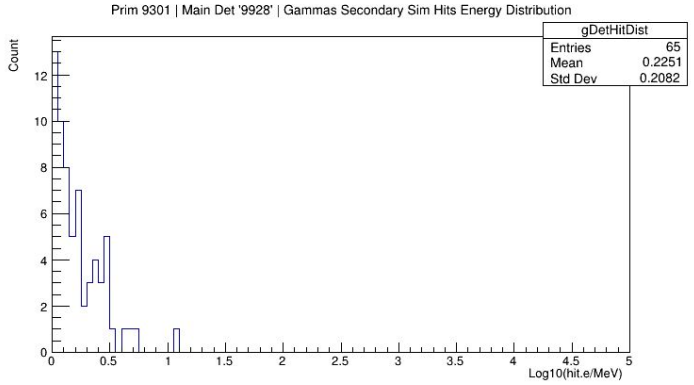
Overall reductions in primaries and secondaries.

While these were previously on the edge of comfortability, they are now within acceptable limits by about an order of magnitude after additional considerations (depolarization, etc.)

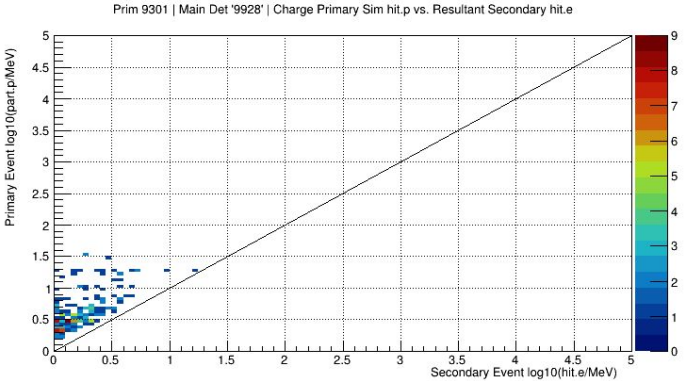
9301: GEM Rotator Floor Locks

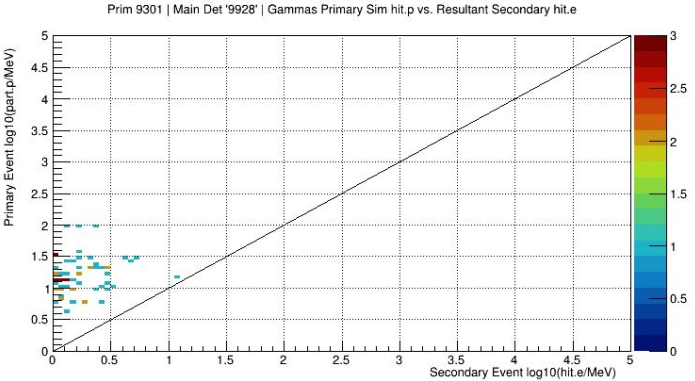
Backgrounds that hit detector '28'





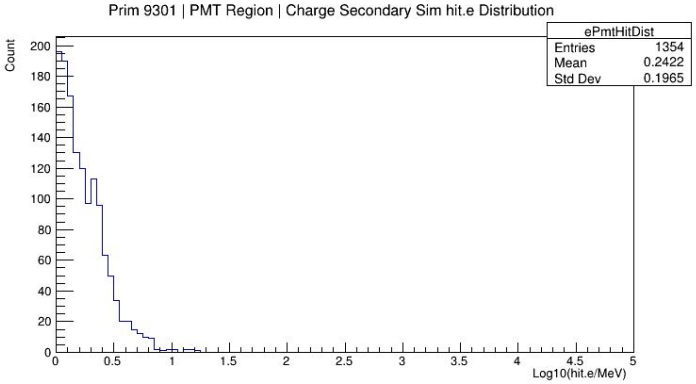
NEW

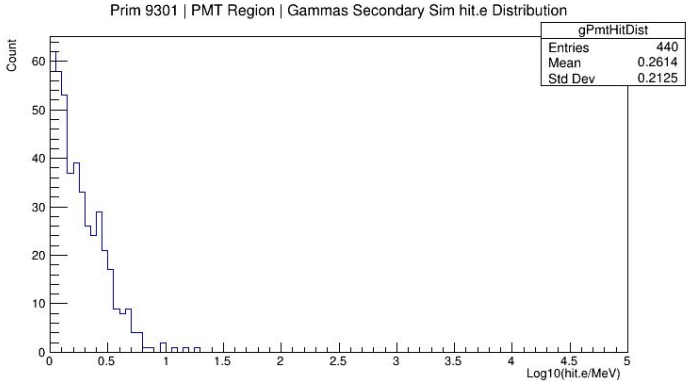




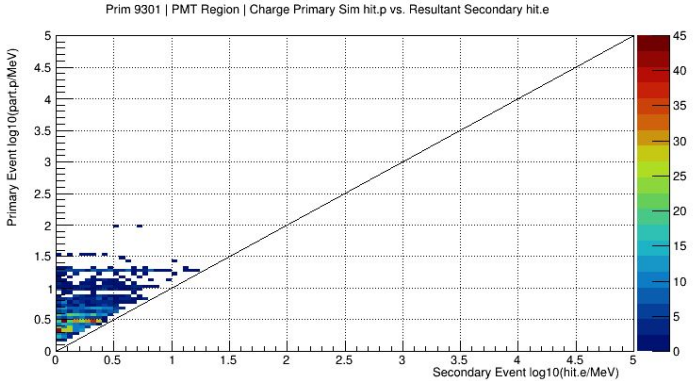
9301: GEM Rotator Floor Locks

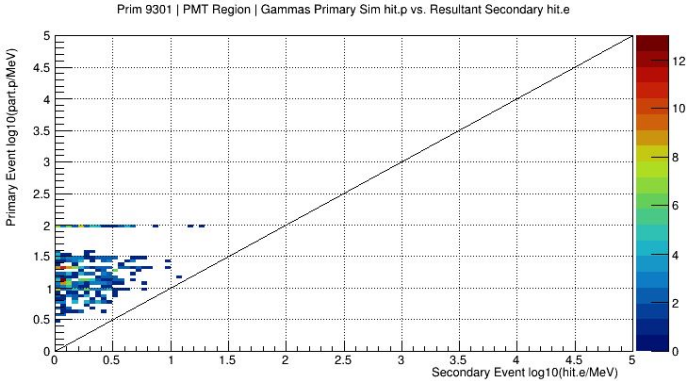
Backgrounds that hit PMT Region





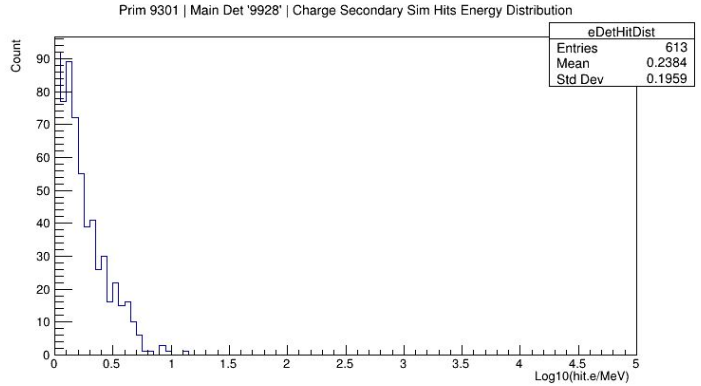
NEW

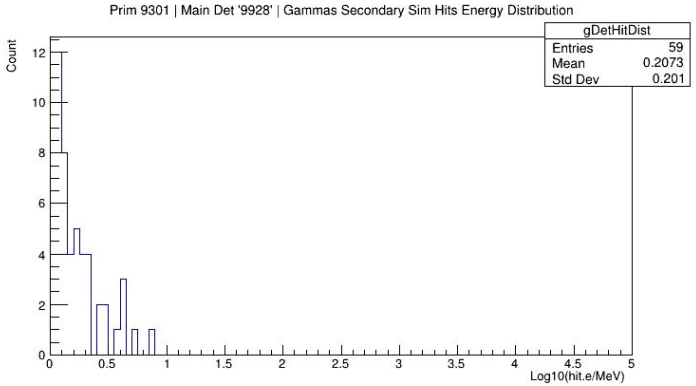




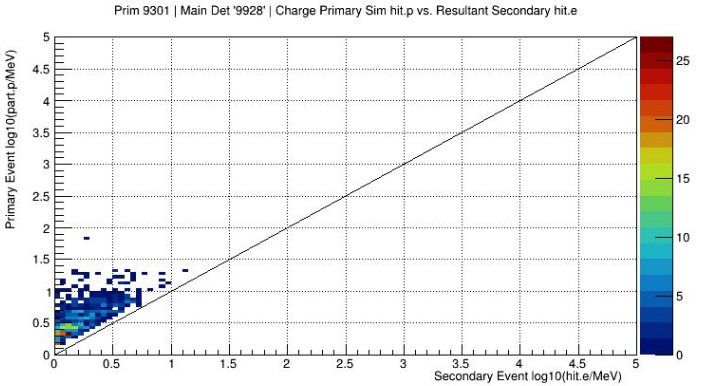
9301: GEM Rotator Floor Locks

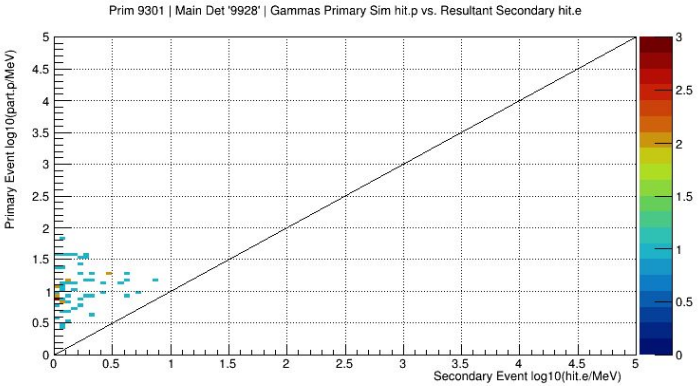
Backgrounds that hit detector '28'





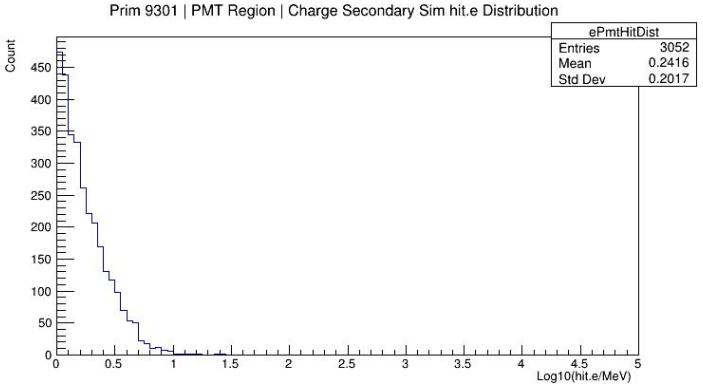
OLD

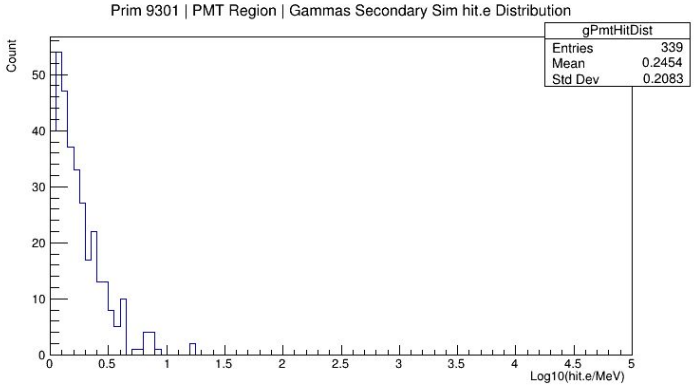




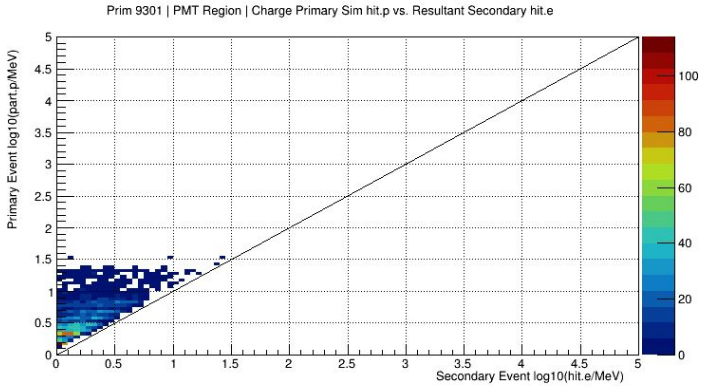
9301: GEM Rotator Floor Locks

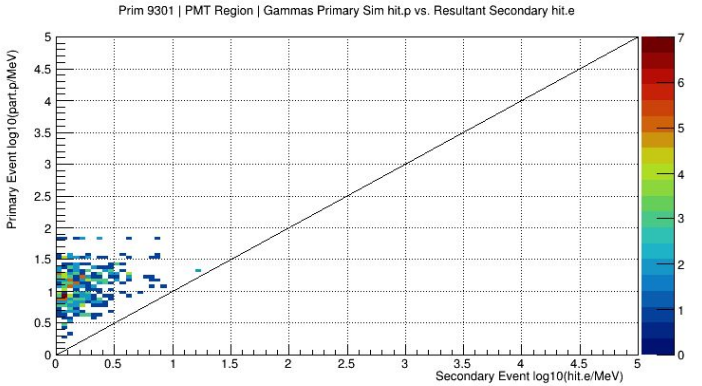
Backgrounds that hit PMT Region





OLD





9302 – GEM Rotator Gear Motor

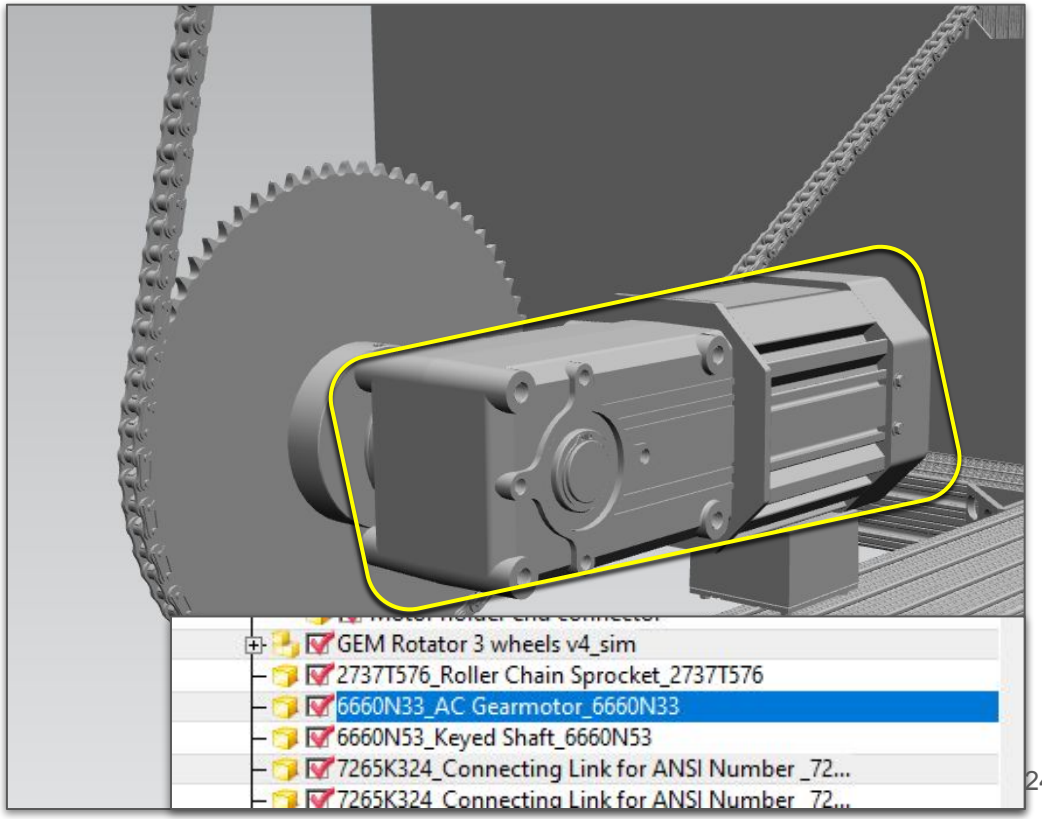
I went with a simple toy model for the GEM Rotator motor at this point.

I could not find information online about a “6660N33” gear motor.

> Your search - **"6660n33" ac gear motor** - did not match any documents.
>
> Suggestions:

So, I looked at similar looking models and many were in the 7-8kg range.

I went with a toy model [rectangle] the width and height of the motor in the JT file and made it thick enough in Z for 7kg of material.



>> *** Fully magnetized material fractional limit per e.o.t. is 10^{-12} *** <<

Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	*1E-08*	1E-05	1E-01
Brass/Bronze (Worst)	0.001	*1E-08*	1E-05	1E-01

9302: GEM Rotator Gear Motor

Sens Volume:	GEM Rotator Motor (Toy/Rect 7kg
Sim Date:	9/15/2023
Detector #:	9302

OLD

GEM Rotator Motor (Toy/Rect 7kg steel) -- Unweighted By BField

Total Prim's:	15,000,000,000	Total Sec's:	500,000 (per sens det)

Primary Counts		
Primaries	0	0&1
9302		39

Primary Fractional		
Primaries	0	0&1
9302		2.60E-09

(9928 MainDet) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9302	199	44

(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9302	3.98E-04	8.80E-05

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9302	1.03E-12	2.29E-13

(9911 PMT Region) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9302	1044	235

(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9302	2.09E-03	4.70E-04

(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9302	5.43E-12	1.22E-12

This toy model of the gear motor suggests that it's not an issue.

Depolarization reduces these numbers by a factor of 3.

While I presume there may be a variety of materials with varying susceptibilities, with a background fraction of 10^{-12} this is safely within any limit.

>> *** Fully magnetized material fractional limit per e.o.t. is 10^{-12} *** <<

Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	*1E-08*	1E-05	1E-01
Brass/Bronze (Worst)	0.001	*1E-08*	1E-05	1E-01

9302: GEM Rotator Gear Motor

Sens Volume:	GEM Rotator Motor (Toy/Rect 7kg
Sim Date:	10/31/2023
Detector #:	9302

*Simulation with wheel and frame mass (G4_Al)

NEW

GEM Rotator Motor (Toy/Rect 7kg steel) -- Unweighted By BField

Total Prim's:	20,000,000,000

Total Sec's:	500,000	(per sens det)

Primary Counts		
Primaries	0	0&1
9302		34

Primary Fractional		
Primaries	0	0&1
9302		1.70E-09

(9928 MainDet) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9302	146	41

(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9302	2.92E-04	8.20E-05

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9302	4.96E-13	1.39E-13

(9911 PMT Region) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9302	1045	180

(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9302	2.09E-03	3.60E-04

(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9302	3.55E-12	6.12E-13

Minor reduction in primary strikes, farther away from frame mass so this makes sense.

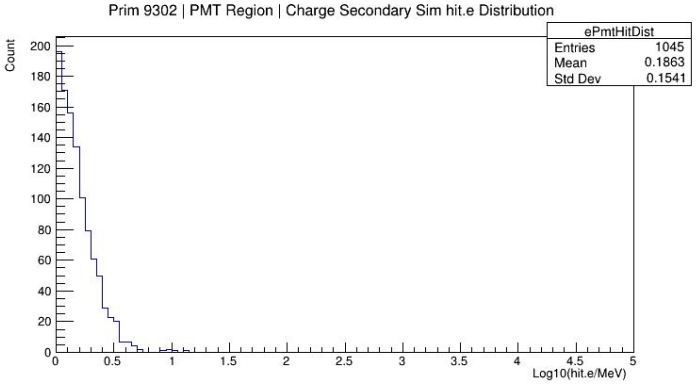
Considerations:

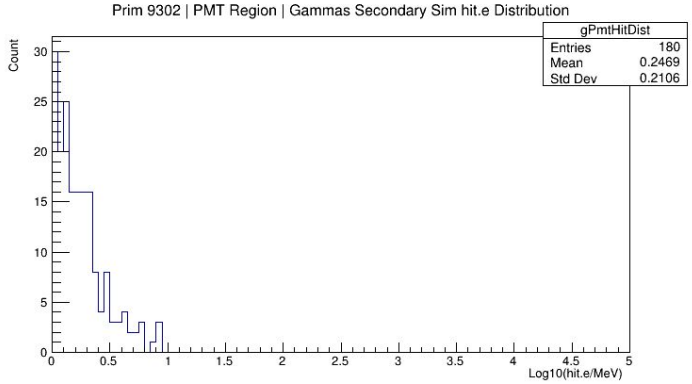
(1) Depolarization (reduce by 3x)
(2) Toy model→Right mass/surface area overmodeled

Simulation suggests this is safe.

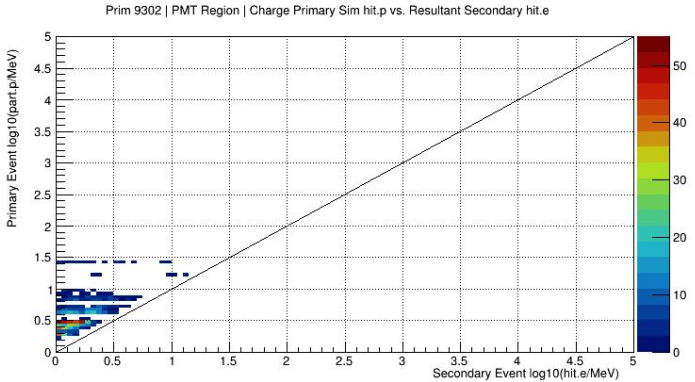
9302: GEM Rotator Gear Motor

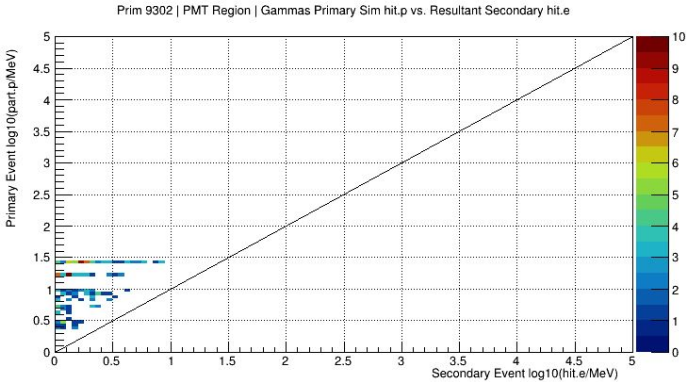
Backgrounds that hit detector '28'





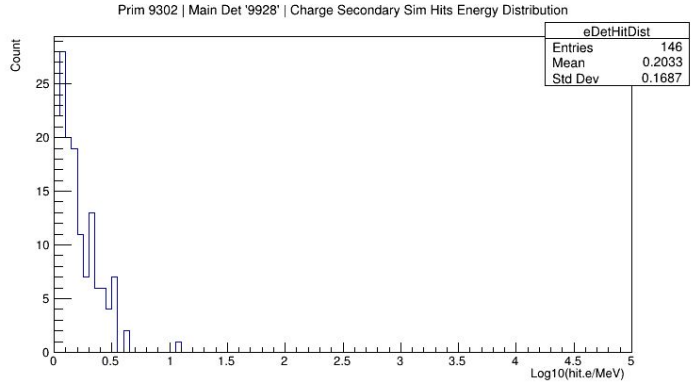
NEW

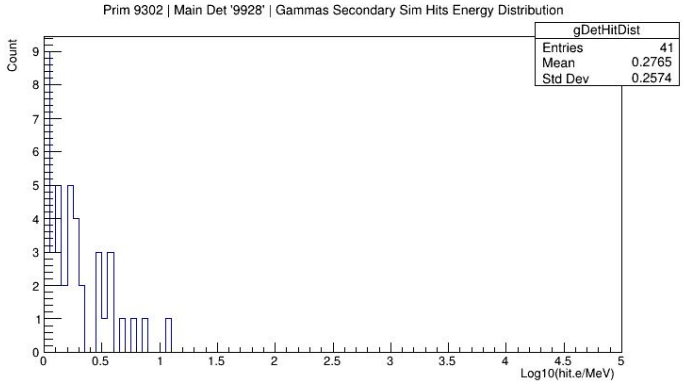




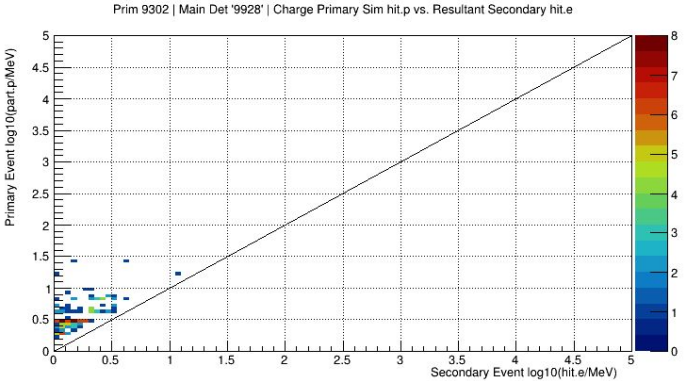
9302: GEM Rotator Gear Motor

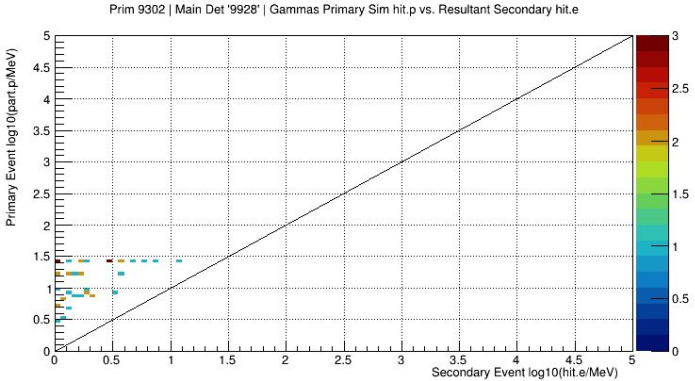
Backgrounds that hit PMT Region





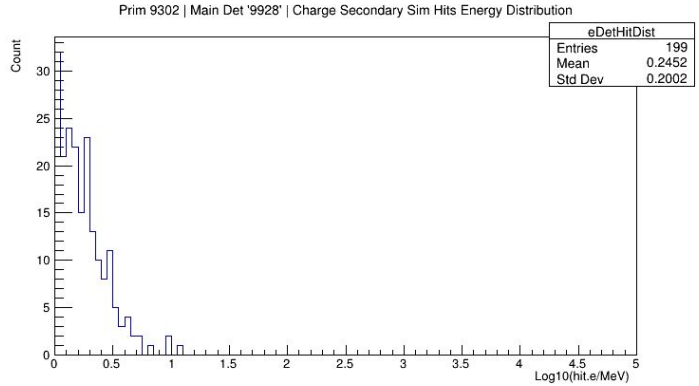
NEW

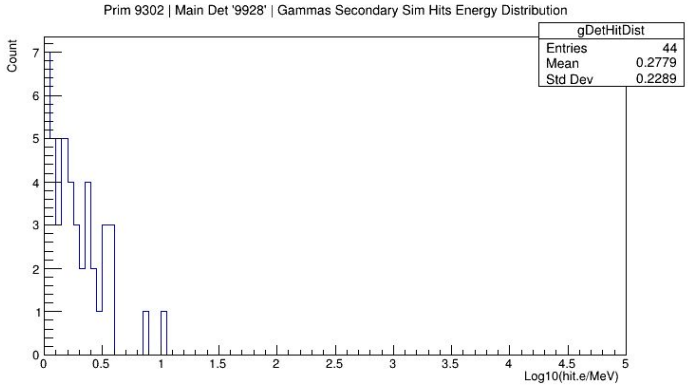




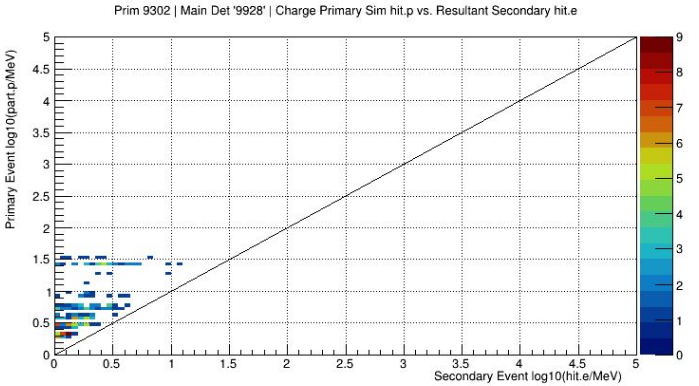
9302: GEM Rotator Gear Motor

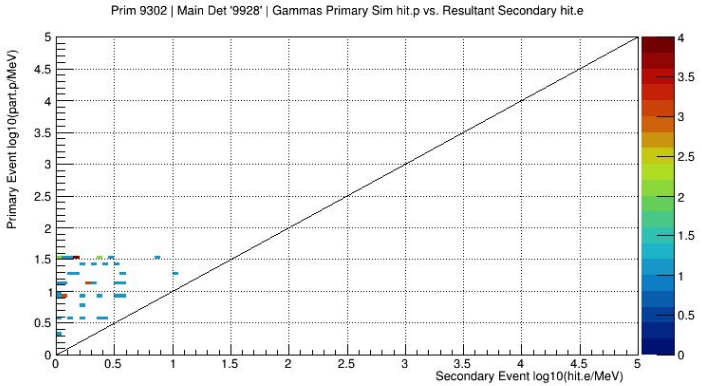
Backgrounds that hit detector '28'





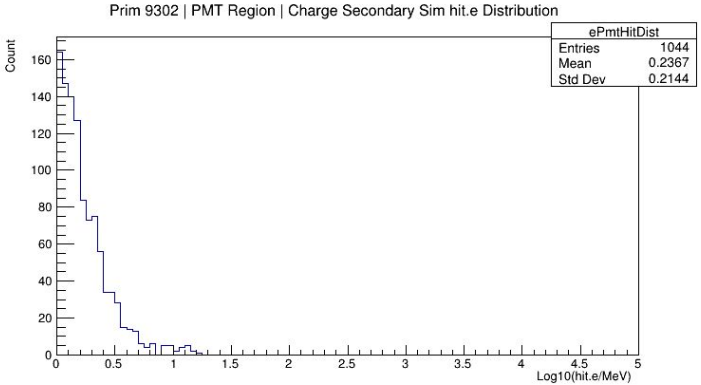
OLD

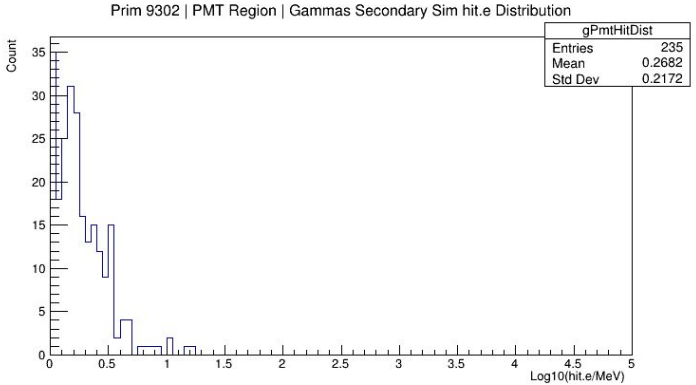




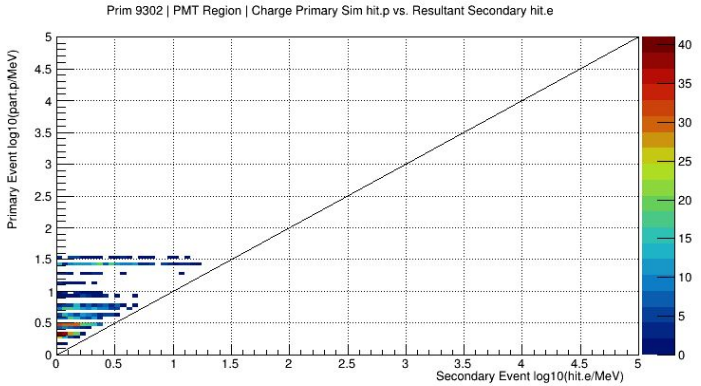
9302: GEM Rotator Gear Motor

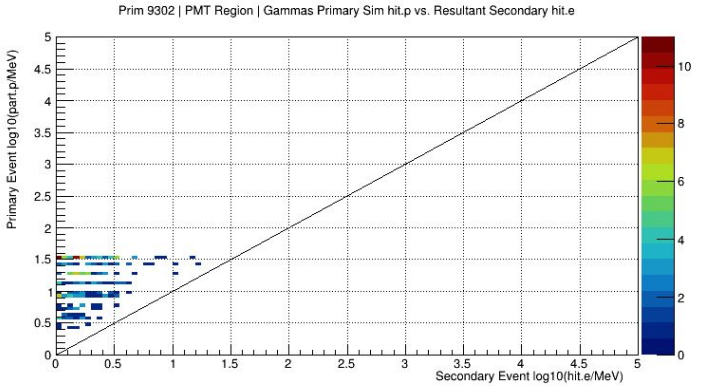
Backgrounds that hit PMT Region





OLD





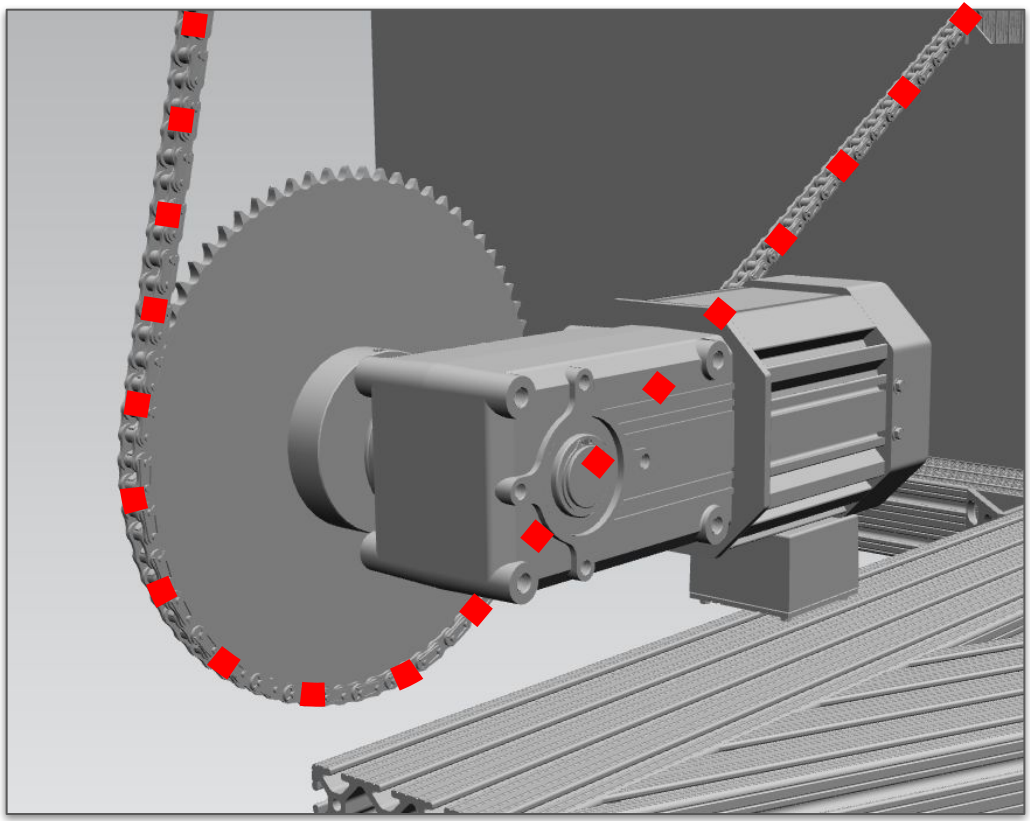
9303 – GEM Rotator Chain

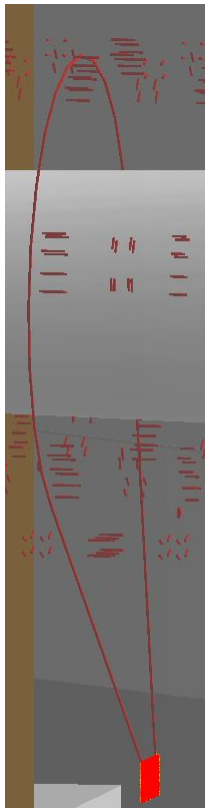
12mm high x 10mm deep

Modeled as the perimeter of two circles connected at common tangents with rectangle boxes

Material specified to be SS316

MAKE X/Y Plot for Primaries





9303: GEM Rotator Chain

Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	1E-08	1E-05	1E-01
Brass/Bronze (Worst)	0.001	1E-08	1E-05	1E-01

SS316 falls between ideal and worst stainless steel. Tolerable background limits would therefore be around 10^{-7}

We fall very nicely under that.

Additionally, the chain is over-modeled in size which would further reduce the background fraction. Depolarization and some shielding/attenuation from the rotator structure would also reduce the ferrous background fraction.

Sens Volume:	GEM Rotator Chain
Sim Date:	9/15/2023
Detector #:	9303

OLD

GEM Rotator Chain -- Unweighted By BField

Total Prim's:	15,000,000,000	
Total Sec's:	500,000	(per sens det)

Primary Counts		
Primaries	0	0&1
9303		2620

Primary Fractional		
Primaries	0	0&1
9303		1.75E-07

(9928 MainDet) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9303	5171	4600

(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9303	1.03E-02	9.20E-03

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9303	1.81E-09	1.61E-09

(9911 PMT Region) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9303	12962	19889

(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9303	2.59E-02	3.98E-02

(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9303	4.53E-09	6.95E-09

9303: GEM Rotator Chain

Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	*1E-08*	1E-05	1E-01
Brass/Bronze (Worst)	0.001	*1E-08*	1E-05	1E-01

Sens Volume:	GEM Rotator Chain
Sim Date:	10/31/2023
Detector #:	9303

*Simulation with wheel and frame mass (G4_Al)

NEW

GEM Rotator Chain -- Unweighted By BField

Total Prim's:	20,000,000,000

Total Sec's:	500,000	(per sens det)

Primary Counts		
Primaries	0	0&1
9303		2131

Primary Fractional		
Primaries	0	0&1
9303		1.07E-07

(9928 MainDet) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9303	1121	1670

(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9303	2.24E-03	3.34E-03

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9303	2.39E-10	3.56E-10

(9911 PMT Region) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9303	2071	5781

(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9303	4.14E-03	1.16E-02

(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9303	4.41E-10	1.23E-09

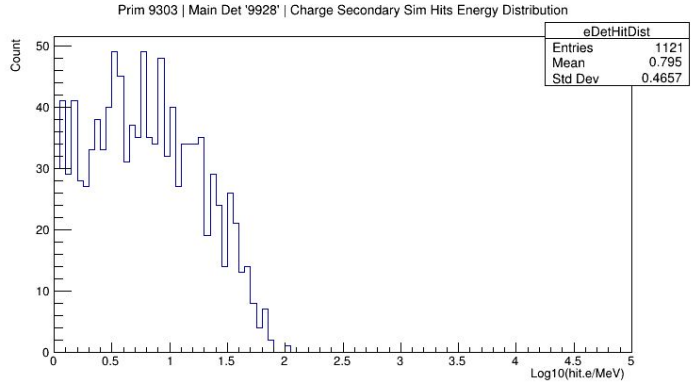
This fell well-under the tolerable limit previously 10^{-7} for SS316.

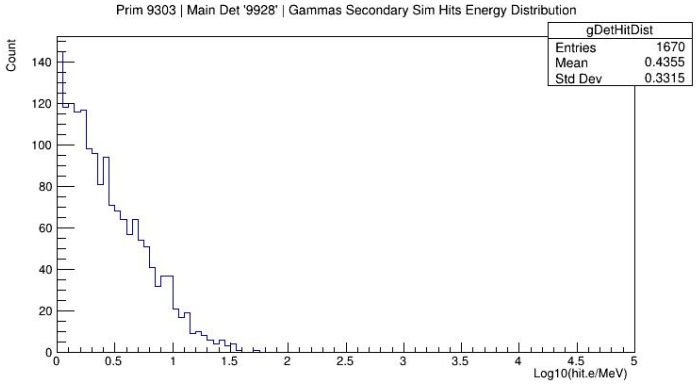
Simulated backgrounds fall by an order of magnitude after the addition of rotator frame mass.

The chain was already over-modeled a bit so we're a good three orders of magnitude under our imposed limit.

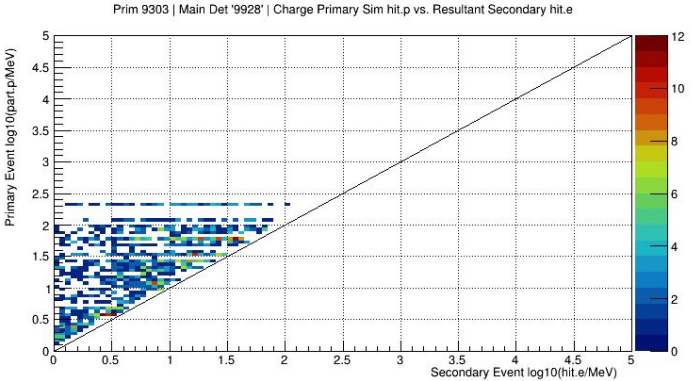
9303: GEM Rotator Chain

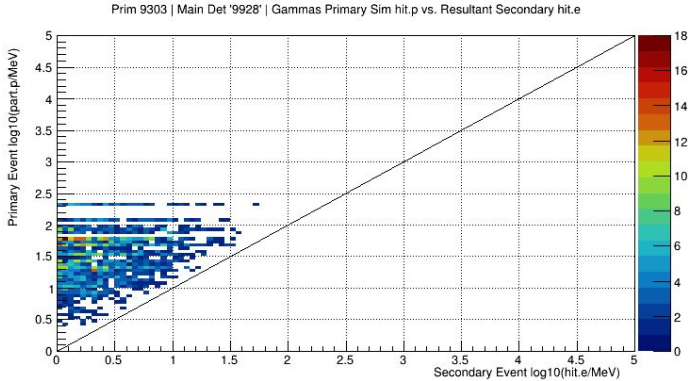
Backgrounds that hit detector '28'





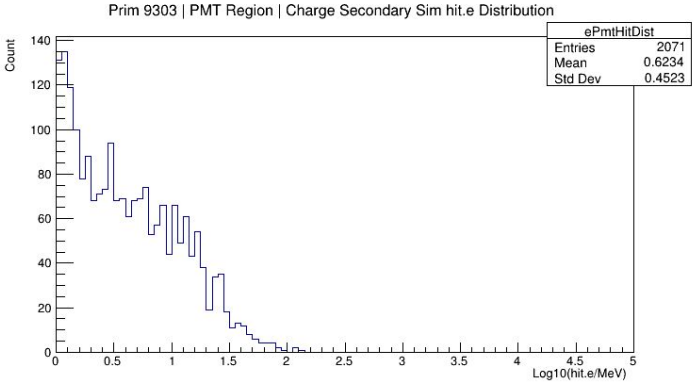
NEW

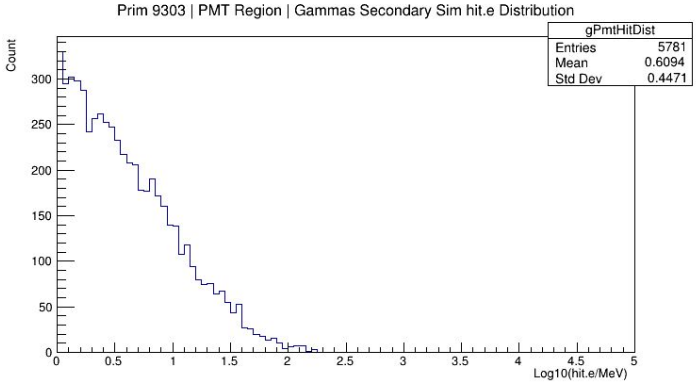




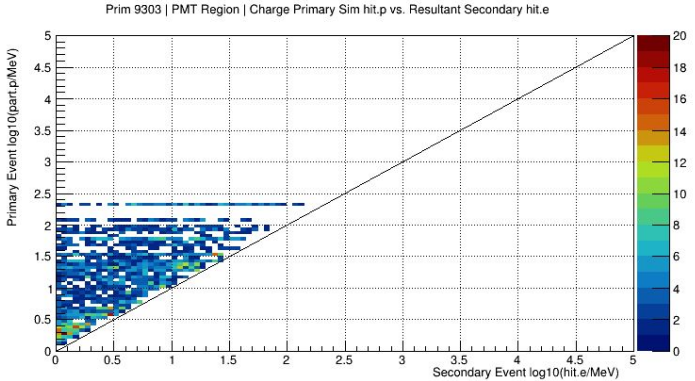
9303: GEM Rotator Chain

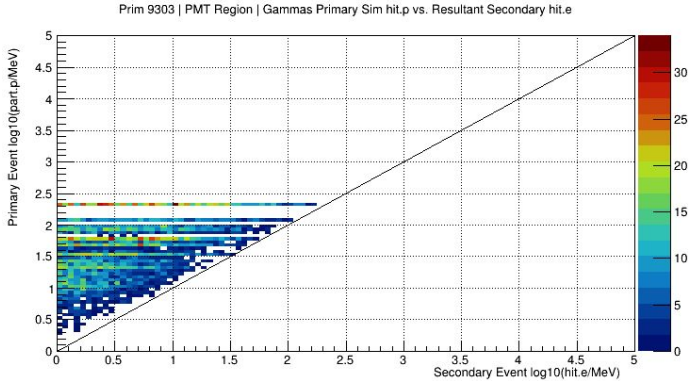
Backgrounds that hit PMT Region





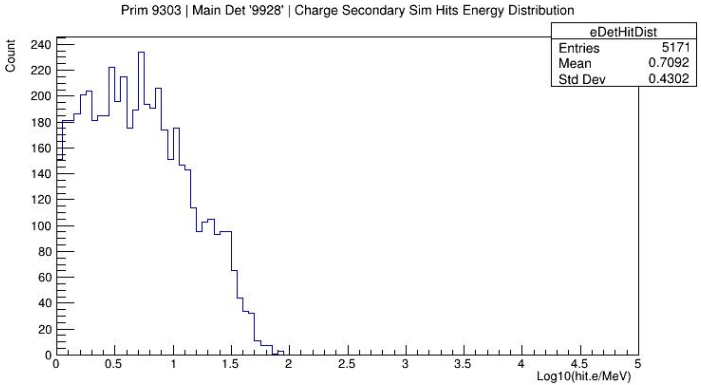
NEW

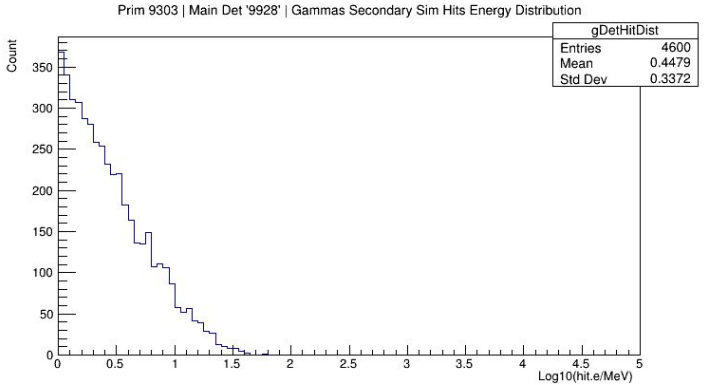




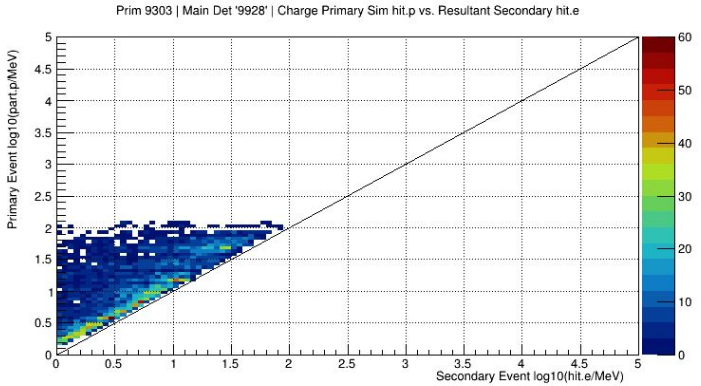
9303: GEM Rotator Chain

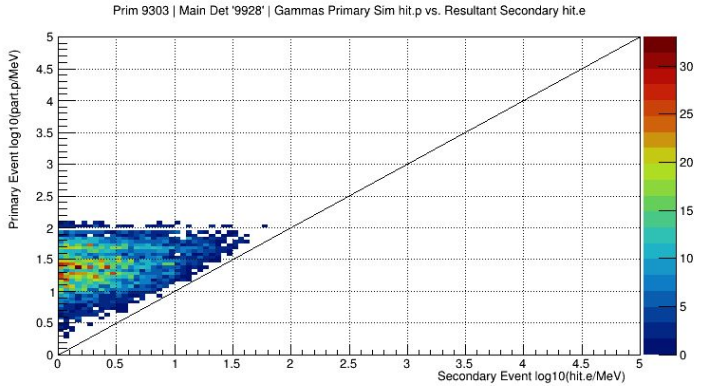
Backgrounds that hit detector '28'





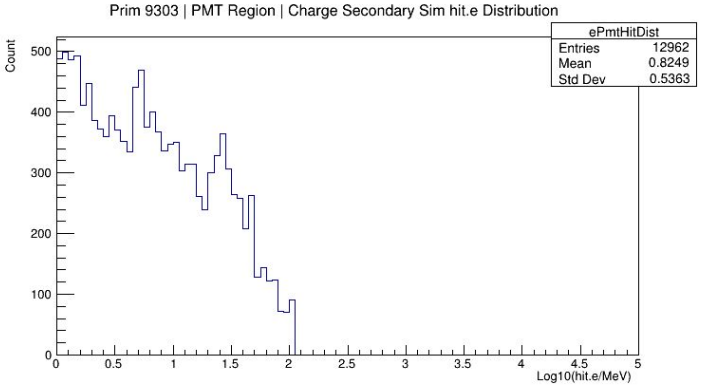
OLD

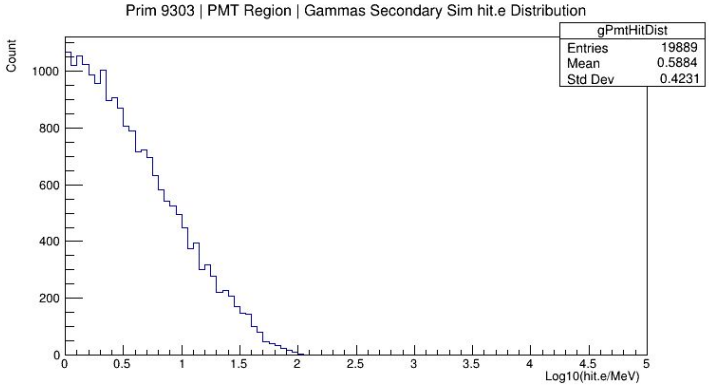




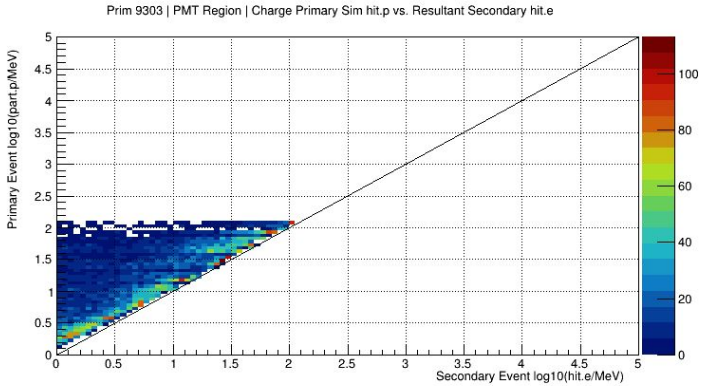
9303: GEM Rotator Chain

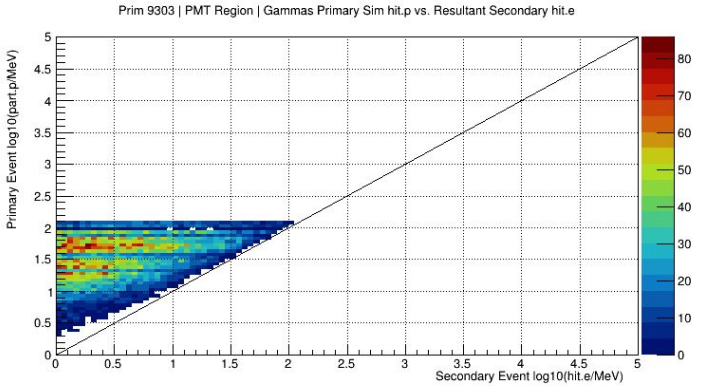
Backgrounds that hit PMT Region





OLD





9304 – GEM Rotator Fasteners

Three types of fasteners. Modeled 2 sets which were the bulk of the material.

Material specified to be SS316

Item specifics on next three slides.

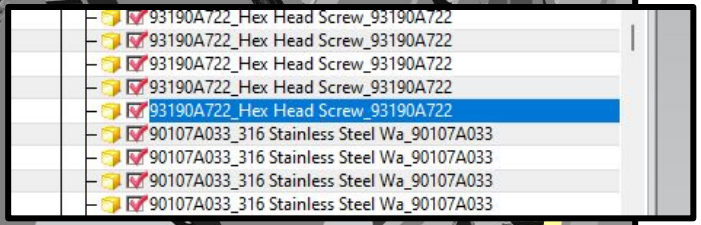
9304 – GEM Rotator Fasteners

https://www.parttarget.com/5305-01-576-2852_5305015762852_93190A721.html/-604EA34A-1530-4386-B042-EFB1DC88D8CF

	Agency	
FEAT	Special Features	Overall finish is plain
MATT	Material	Steel comp 316 overall
THSD	Thread Series Designator	UNC

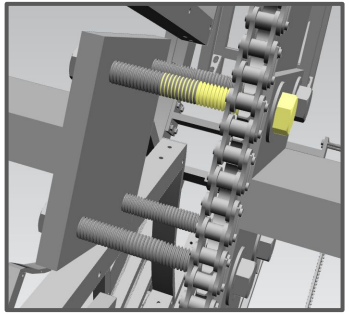
9304 – GEM Rotator Fasteners

https://www.parttarget.com/5305-01-514-2852_5305015142852_175252.html/-604EA34A-1530-4386-B042-EFB1DC88D8CF



CMLP	Thread Quantity per Inch	13
MATT	Material	Steel comp 316 overall
MDCL	Material Document and Classification	Astm A193 assn std single mate

I'll note that the 93190A722 bolt/screw overlaps in the center portion of the frame. I just unioned them together in remoll so they appear as one long continuous piece.



9304: GEM Rotator Fasteners

These weren't in the simulation. I had hit my deadline and figured that we could mass-scale the results if we were concerned about there being an issue.

Thread Fit	Class 3A
Head Type	Socket
Socket Head Profile	Standard
Drive Style	Hex
Thread Direction	Right Hand
Material	316 Stainless Steel
Finish	Passivated
Hardness	Rockwell B70
Tensile Strength	70,000 psi
RoHS	RoHS 3 (2015/863/EU) Compliant
REACH	REACH (EC 1907/2006) (06/10/2022, 224 SVHC) Compliant
Internal Code	0029

9304: GEM Rotator Fasteners

Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	1E-08	1E-05	1E-01
Brass/Bronze (Worst)	0.001	1E-08	1E-05	1E-01

SS316 falls between ideal quality and worst quality stainless.

A ferrous background of 10^{-7} would be considered the limit of what is tolerable and we fall over an order of magnitude under that without making considerations for depolarization or additional shielding/attenuation from the rotator structure itself.

Sens Volume:	GEM Rotator Fasteners
Sim Date:	9/15/2023
Detector #:	9304

OLD

GEM Rotator Fasteners -- Unweighted By BField

Total Prim's:	15,000,000,000	
Total Sec's:	500,000	(per sens det)

Primary Counts		
Primaries	0	0&1
9304		4414

Primary Fractional		
Primaries	0	0&1
9304		2.94E-07

(9928 MainDet) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9304	7133	4938

(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9304	1.43E-02	9.88E-03

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9304	4.20E-09	2.91E-09

(9911 PMT Region) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9304	18454	29055

(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9304	3.69E-02	5.81E-02

(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9304	1.09E-08	1.71E-08

9304: GEM Rotator Fasteners

Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	*1E-08*	1E-05	1E-01
Brass/Bronze (Worst)	0.001	*1E-08*	1E-05	1E-01

Sens Volume:	GEM Rotator Fasteners
Sim Date:	10/31/2023
Detector #:	9304

*Simulation with wheel and frame mass (G4_Al)

NEW

Was fine before… see notes on previous slide.

Background rates dropped by an order of magnitude with addition of rotator frame mass.

GEM Rotator Fasteners -- Unweighted By BField

Total Prim's:	20,000,000,000	Total Sec's:	500,000 (per sens det)

Primary Counts		
Primaries	0	0&1
9304		1735

Primary Fractional		
Primaries	0	0&1
9304		8.68E-08

(9928 MainDet) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9304	2918	7671

(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9304	5.84E-03	1.53E-02

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9304	5.06E-10	1.33E-09

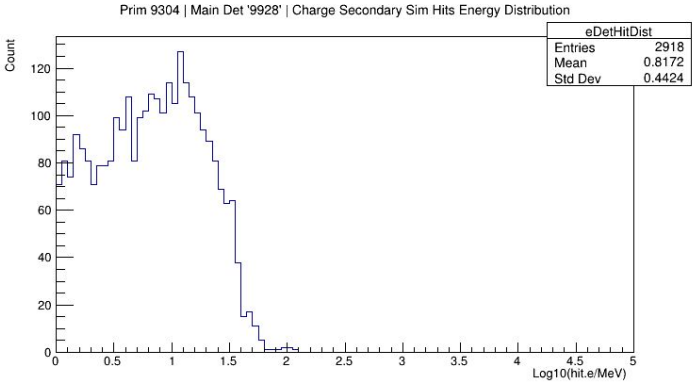
(9911 PMT Region) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9304	6626	35226

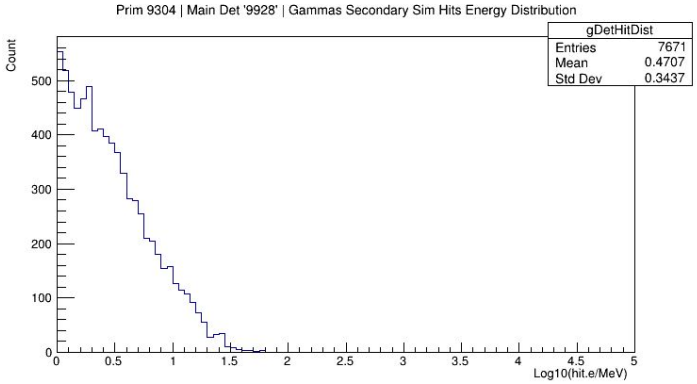
(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9304	1.33E-02	7.05E-02

(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9304	1.15E-09	6.11E-09

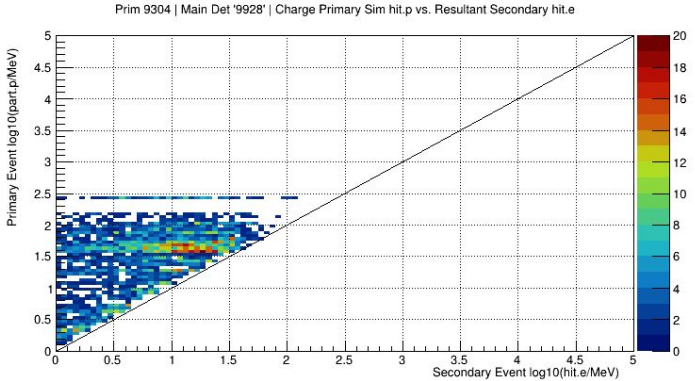
9304: GEM Rotator Fasteners

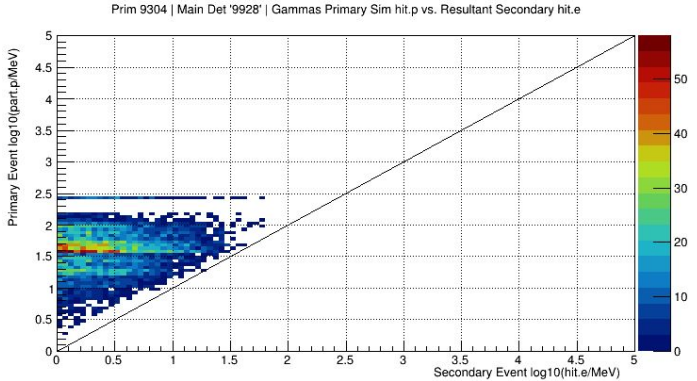
Backgrounds that hit detector '28'





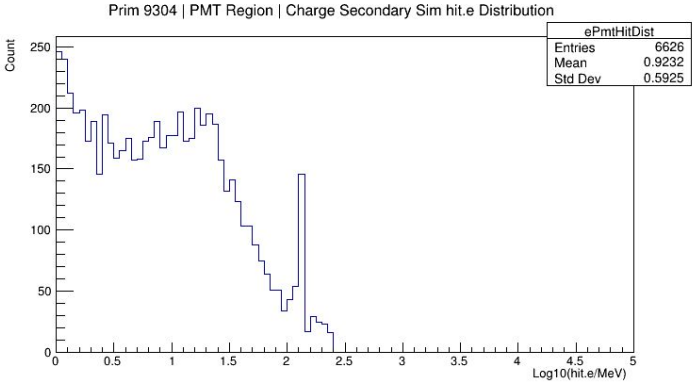
NEW

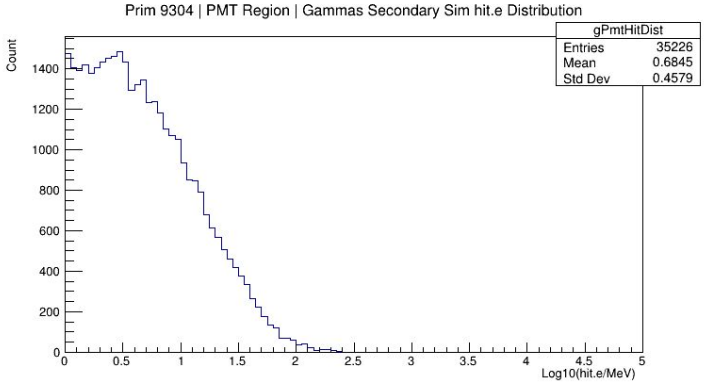




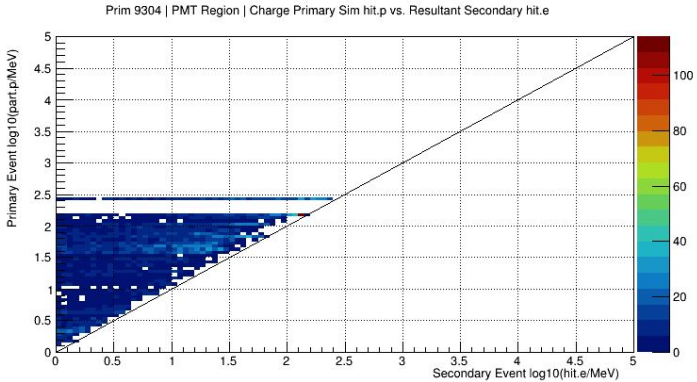
9304: GEM Rotator Fasteners

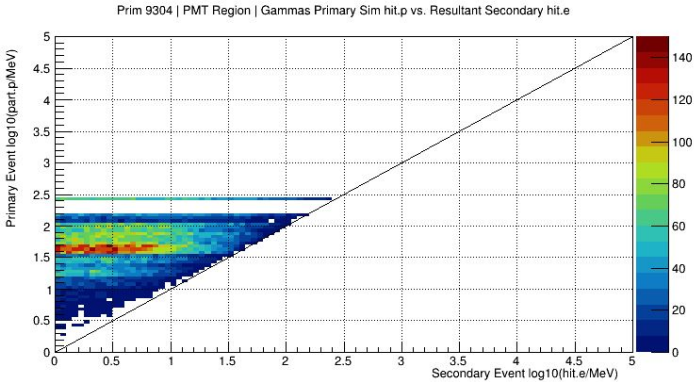
Backgrounds that hit PMT Region





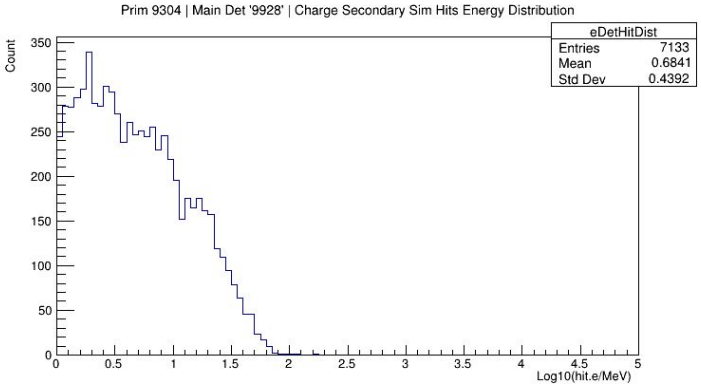
NEW

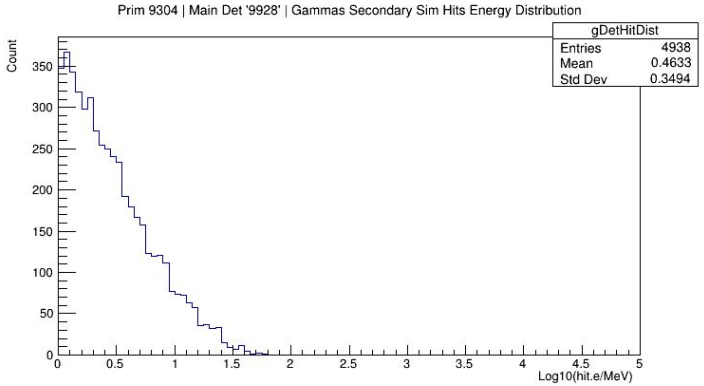




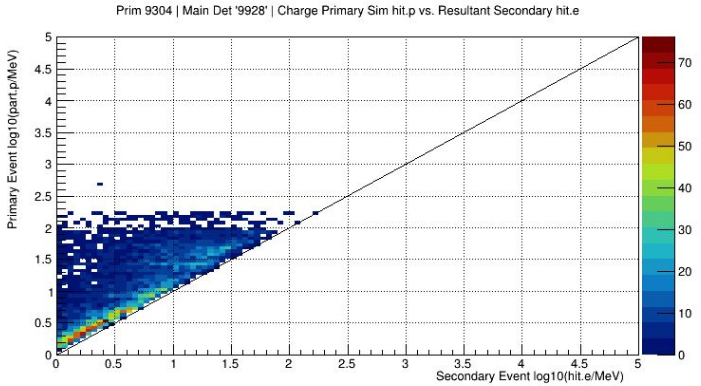
9304: GEM Rotator Fasteners

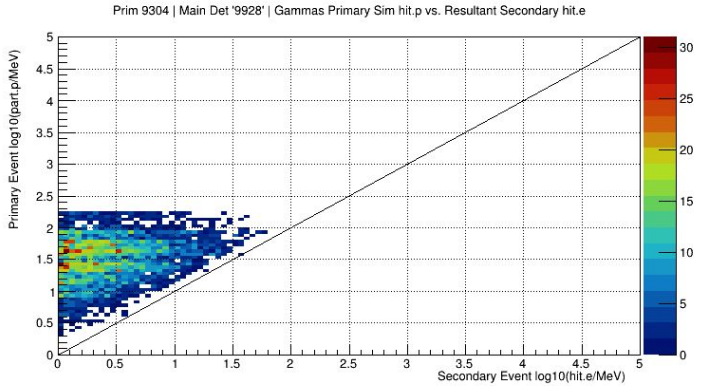
Backgrounds that hit detector '28'





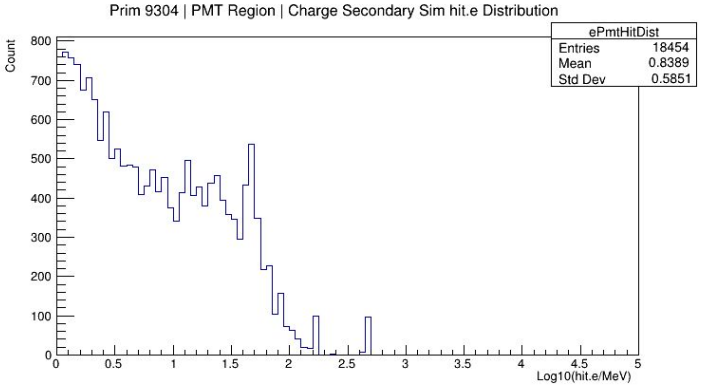
OLD

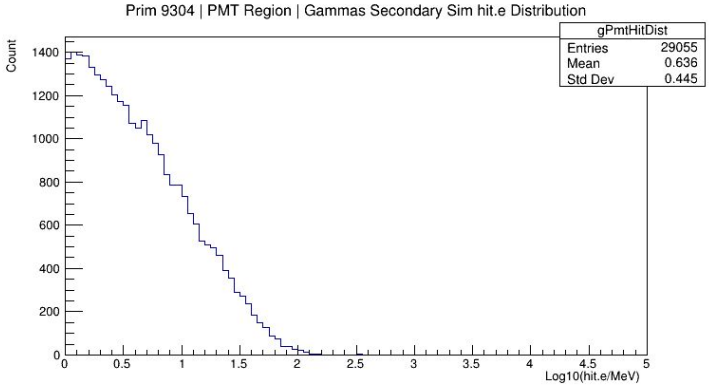




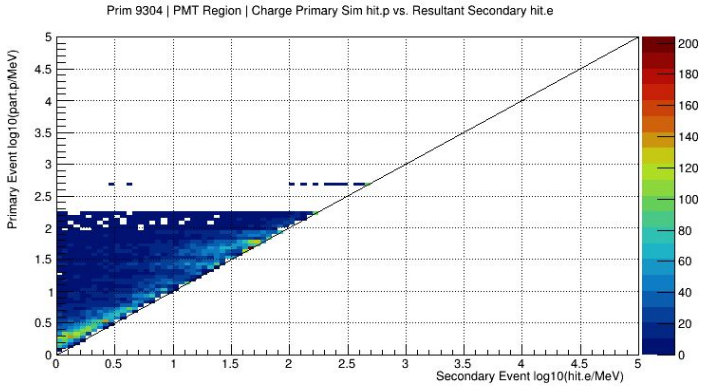
9304: GEM Rotator Fasteners

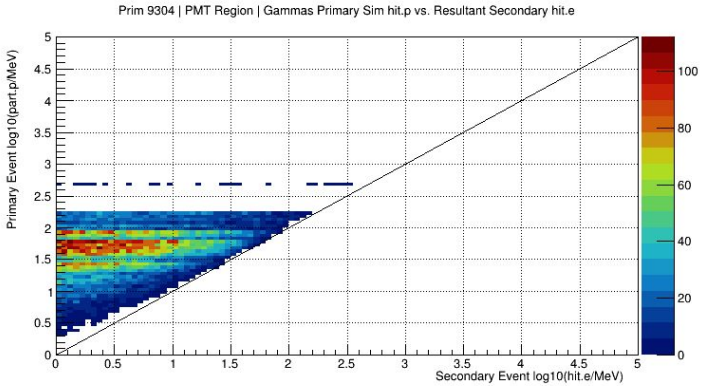
Backgrounds that hit PMT Region





OLD



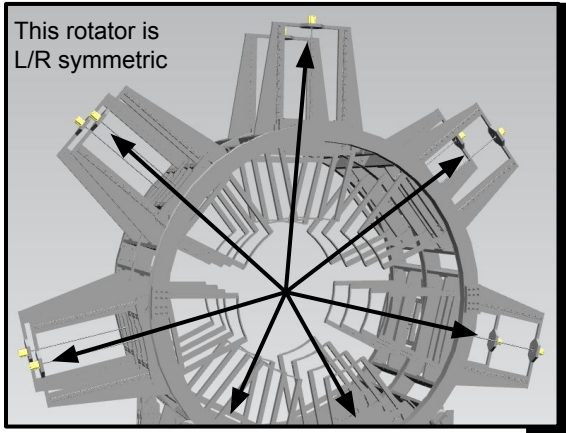


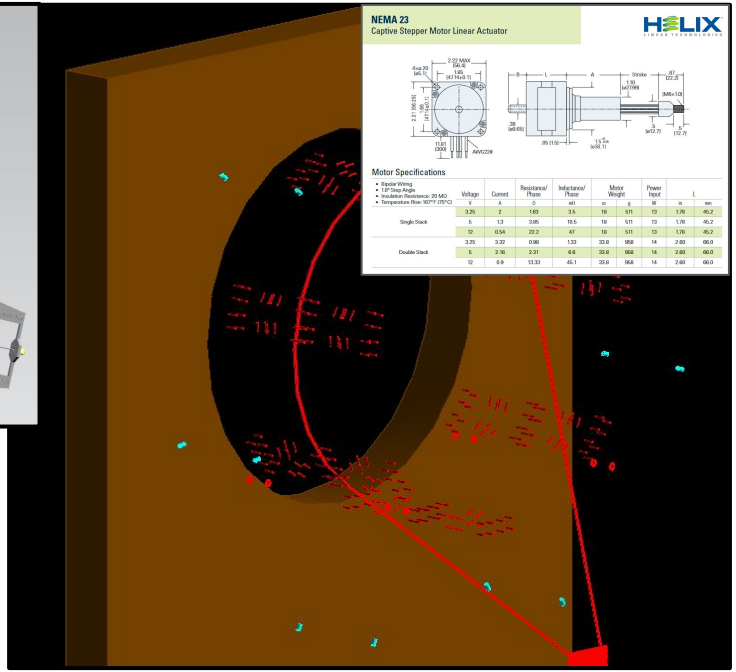
9305 – GEM Rotator Stepper Motors

Stepper motors.

Unsure of particular design of these.

Modeled the ferrous materials as a cylinder (rmin=8.5mm and rmax=15.5mm). Unsure of total material needed so just went with z=45mm; this is probably too much material but figured too much here was better than too little.





pi*(15.5*mm*15.5*mm-8.5*mm*8.5*mm)*45mm

NATURAL LANGUAGE | MATH INPUT | EXTENDED KEYBO

Input interpretation

π (15.5 mm (millimeters) × 15.5 mm (millimeters) − 8.5 mm (millimeters) × 8.5 mm (millimeters)) × 45 mm (millimeters)

Result

23 800 mm^3 (cubic millimeters)

Unit conversions

23.8 cm^3 (cubic centimeters)

ϱ_{Fe} ~ 7.8 g/cm^3

23.8 cm^3 x ϱ_{Fe} = 185.6 g (x 14)

~2.6kg of Fe in simulation

***** There could be model improvement with more information from GEM team if the information is on hand or known. I may very well have over-modeled the material in question.**

>> *** Fully magnetized material fractional limit per e.o.t. is 10^{-12} *** <<

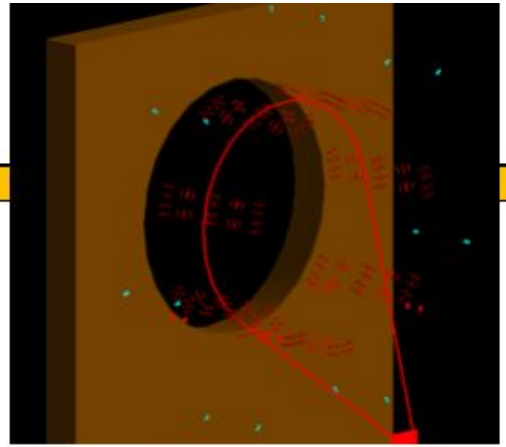
Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	1E-08	1E-05	1E-01
Brass/Bronze (Worst)	0.001	1E-08	1E-05	1E-01

9305: GEM Stepper Motors

Spin polarization of Fe is ~8%. So tolerable background limits on these motors is 10^{-12} per e.o.t.

As modeled (there may be some wiggle room for mass scaling) the ferrous backgrounds are high on the main detector area and also on the PMT boundary region.

Sens Volume:	GEM Rotator Stepper
Sim Date:	10/9/2023
Detector #:	9305



GEM Rotator Stepper -- Unweighted By BField

OLD

Total Prim's:	15,000,000,000

Total Sec's:	500,000	(per sens det)

Primary Counts		
Primaries	0	0&1
9305		57

Primary Fractional		
Primaries	0	0&1
9305		3.80E-09

(9928 MainDet) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9305	521	207

(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9305	1.04E-03	4.14E-04

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9305	3.96E-12	1.57E-12

(9911 PMT Region) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9305	1828	864

(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9305	3.66E-03	1.73E-03

(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9305	1.39E-11	6.57E-12

>> *** Fully magnetized material fractional limit per e.o.t. is 10^{-12} *** <<

Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	*1E-08*	1E-05	1E-01
Brass/Bronze (Worst)	0.001	*1E-08*	1E-05	1E-01

9305: GEM Stepper Motors

Sens Volume:	GEM Rotator Stepper Motors
Sim Date:	10/31/2023
Detector #:	9305

*Simulation with wheel and frame mass (G4_Al)

NEW

GEM Rotator Stepper Motors -- Unweighted By BField

Total Prim's:	20,000,000,000

Total Sec's:	500,000	(per sens det)

Primary Counts		
Primaries	0	0&1
9305		57

Primary Fractional		
Primaries	0	0&1
9305		2.85E-09

(9928 MainDet) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9305	560	49

(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9305	1.12E-03	9.80E-05

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9305	3.19E-12	2.79E-13

(9911 PMT Region) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9305	2092	203

(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9305	4.18E-03	4.06E-04

(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9305	1.19E-11	1.16E-12

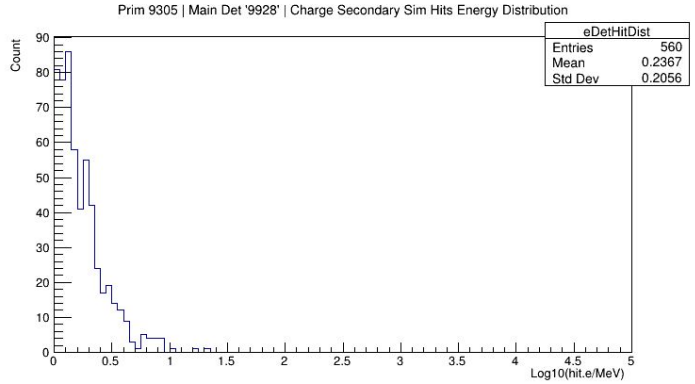
Ferrous background goal here is a limit of 10-12

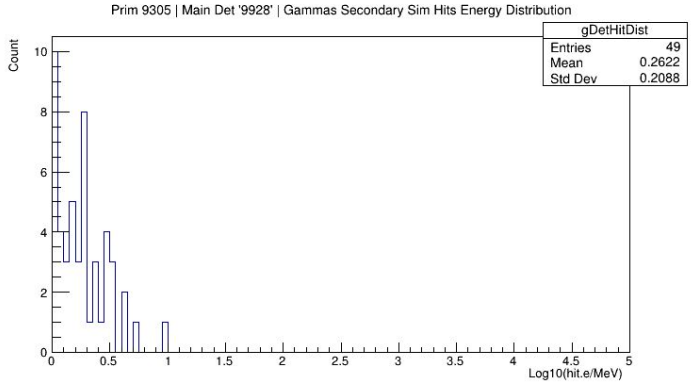
As would be expected, there was little change from the previous simulation. These stepper motors are far out with little mass around them.

However, with depolarization considerations we can take off a factor of 3 which puts us at the tolerable limit.

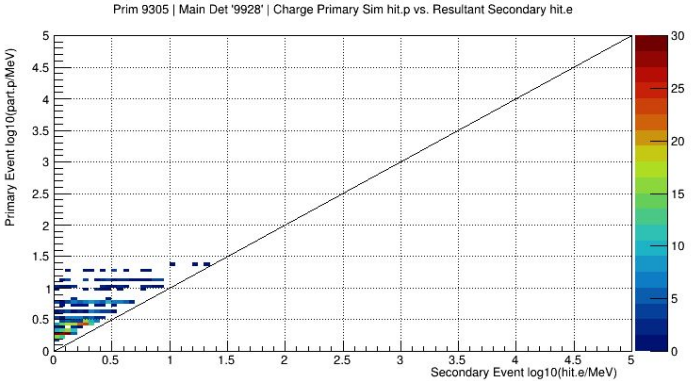
9305: Gem Rotator Stepper Motors

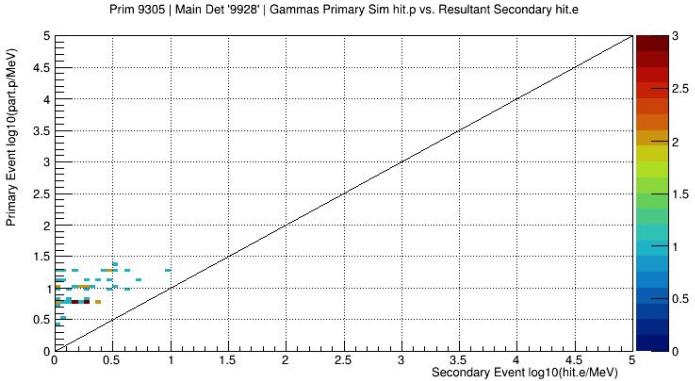
Backgrounds that hit detector '28'





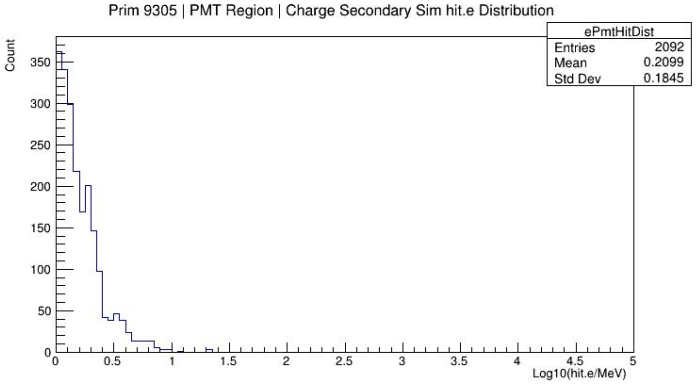
NEW

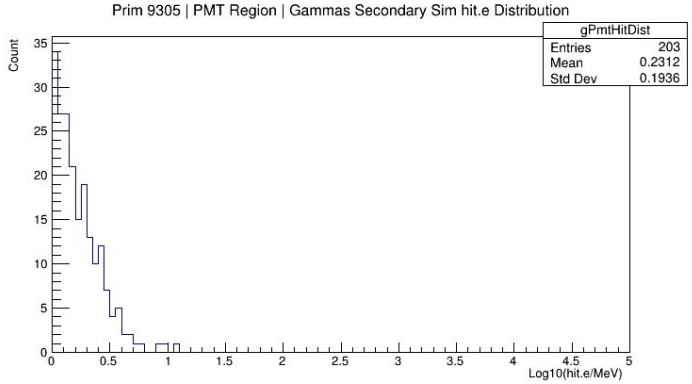




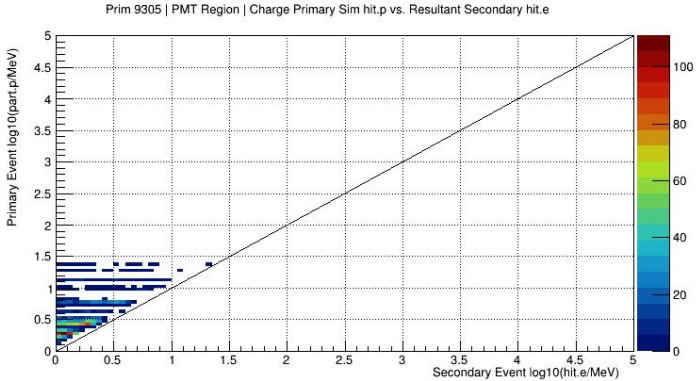
9305: Gem Rotator Stepper Motors

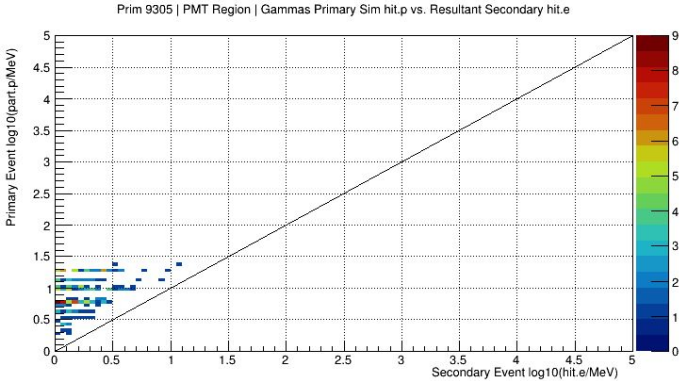
Backgrounds that hit PMT Region





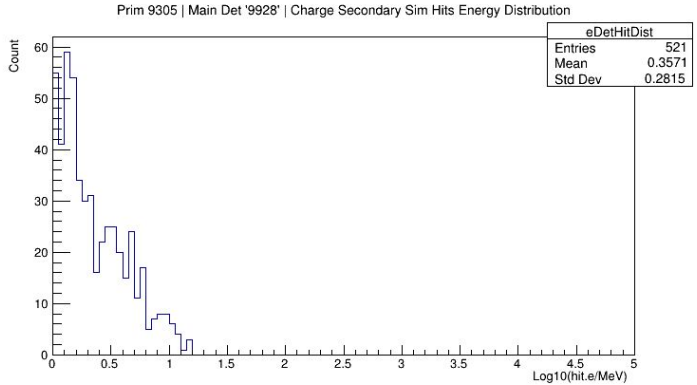
NEW

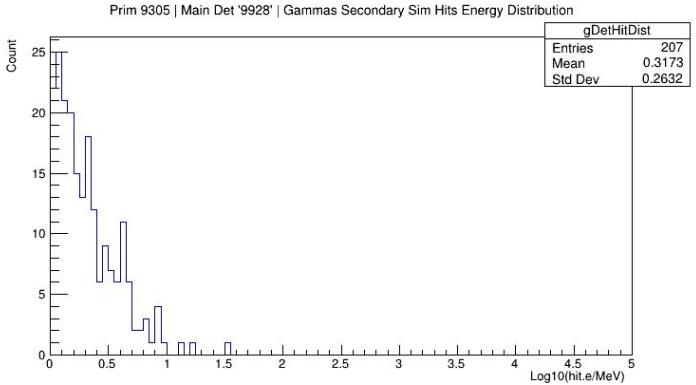




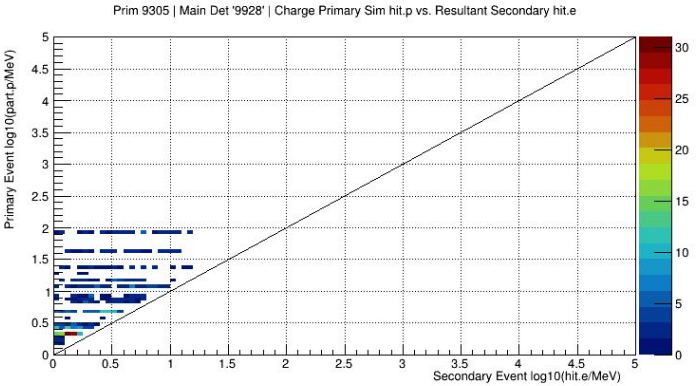
9305: Gem Rotator Stepper Motors

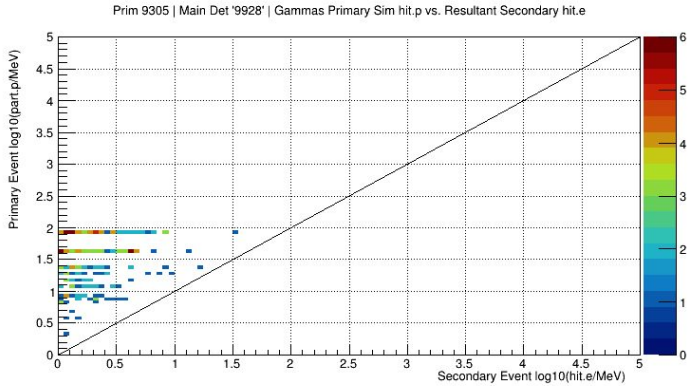
Backgrounds that hit detector '28'





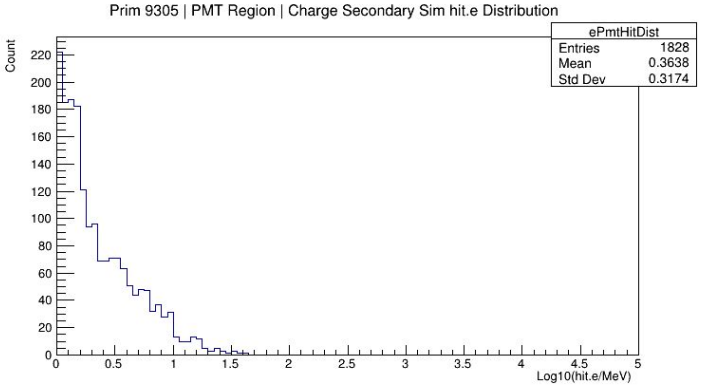
OLD

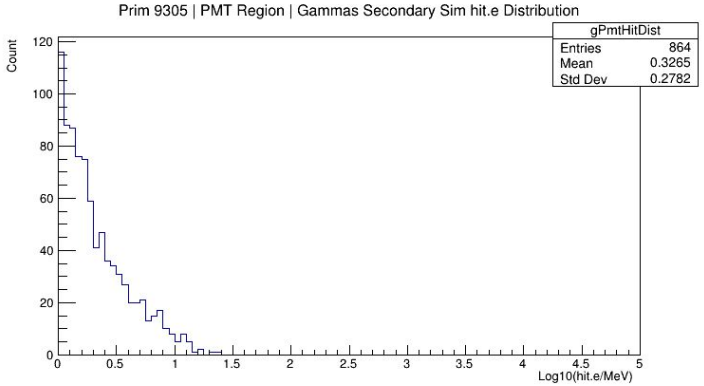




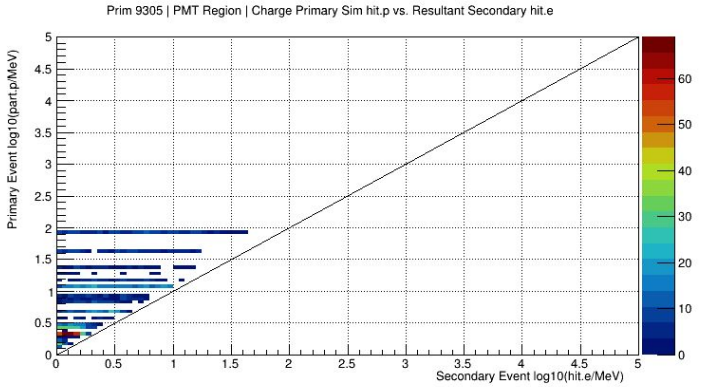
9305: Gem Rotator Stepper Motors

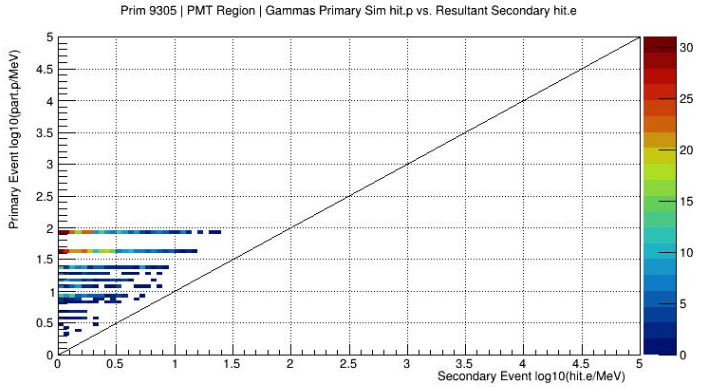
Backgrounds that hit PMT Region





OLD



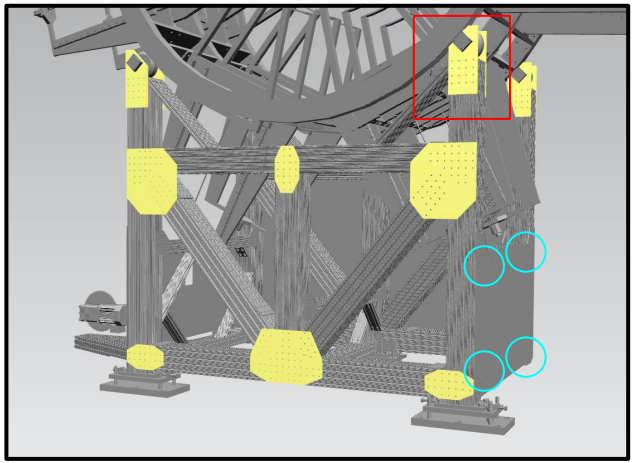


9306 – GEM Rotator T-Nuts (Toy Geometry)

- T-nuts SS304
  - https://8020.net/3607.html
  - https://8020.net/3678.html

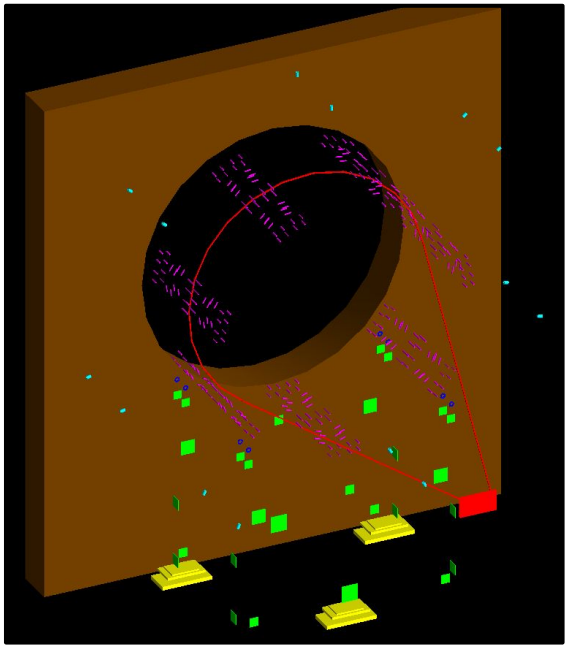
- Modeling all of these is too difficult and likely unnecessary.
  - Modeled SS plates of material with proper masses at locations shown (in image shown).
  - Masses taken from specs from website for one screw/nut pairs.
  - Used 4x4 fastener location (outlined in red) to get a generalized density of material–16 fasteners over about (16cm)^2 of space.
  - There are a handful of middle fasteners that I did miss.

- Additional areas modeled circled in cyan (done on left and right)



Mass of ~792 t-nut fasteners modeled (one of the areas near the motor was slightly different but I modeled like the other side for ease but otherwise mass is accurate for each area although area may be slightly off).

⇒ This is about 50% of the total t-nut fasteners and represents an accurate spatial distribution of the t-nut fasteners.



^^^ Green squares are the t-nut toy geometry.

9306: GEM T-Nuts (Toy Geometry)

			Global		Model									
Y-Center:	2959.1		1st GEM:	19280	1st GEM:	-576.5								
TNut	0.027	lbs	0.0594	kg		Nut+Screw	103.4	g		TNUT DIM				
Screw	0.02	lbs	0.044	kg		Density	0.00786	g/mm^3		L	1.113	in	28.2702	mm
										W	0.638	in	16.2052	mm
AdjThick	0.319	in	8.1026	mm	Thickness Adjustment:		1.45			Th	0.22	in	5.588	mm

Patches for TNuts: (F)ront (B)ack (L)eft (R)ight

								COPY TO XML MATRIX					
GENERAL INFORMATION					LOCAL COORDINATES			GLOBAL COORDINATES			DIMENSIONS		
PATCH	NUTS	MASS	THICK (mm)	LxW (mm)	XPOS	YPOS	ZPOS	XPOS	YPOS	ZPOS	HLX	HLY	HLZ
F1	20	2068	8.10	180.20	-962.8	224.0	-740.9	-962.8	-2735.1	19115.6	90.099	90.10	4.05
F2	66	6824.4	8.10	327.35	0.0	300.2	-740.9	0.0	-2658.9	19115.6	163.674	163.67	4.05
F3	20	2068	8.10	180.20	962.8	224.0	-740.9	962.8	-2735.1	19115.6	90.099	90.10	4.05
F4	47	4859.8	8.10	276.24	-916.2	1298.0	-740.9	-916.2	-1661.1	19115.6	138.120	138.12	4.05
F5	20	2068	8.10	180.20	0.0	1365.0	-740.9	0.0	-1594.1	19115.6	90.099	90.10	4.05
F6	47	4859.8	8.10	276.24	916.2	1298.0	-740.9	916.2	-1661.1	19115.6	138.120	138.12	4.05
F7A	16	1654.4	8.10	161.17	-1020.0	1860.4	-740.9	-1020.0	-1098.7	19115.6	80.587	80.59	4.05
F8A	16	1654.4	8.10	161.17	1020.0	1860.4	-740.9	1020.0	-1098.7	19115.6	80.587	80.59	4.05
F7B	16	1654.4	8.10	161.17	-1020.0	1860.4	-575.8	-1020.0	-1098.7	19280.7	80.587	80.59	4.05
F8B	16	1654.4	8.10	161.17	1020.0	1860.4	-575.8	1020.0	-1098.7	19280.7	80.587	80.59	4.05
B1	20	2068	8.10	180.20	-962.8	224.0	740.9	-962.8	-2735.1	20597.4	90.099	90.10	4.05
B2	66	6824.4	8.10	327.35	0.0	300.2	740.9	0.0	-2658.9	20597.4	163.674	163.67	4.05
B3	20	2068	8.10	180.20	962.8	224.0	740.9	962.8	-2735.1	20597.4	90.099	90.10	4.05
B4	47	4859.8	8.10	276.24	-916.2	1298.0	740.9	-916.2	-1661.1	20597.4	138.120	138.12	4.05
B5	20	2068	8.10	180.20	0.0	1365.0	740.9	0.0	-1594.1	20597.4	90.099	90.10	4.05
B6	47	4859.8	8.10	276.24	916.2	1298.0	740.9	916.2	-1661.1	20597.4	138.120	138.12	4.05
B7A	16	1654.4	8.10	161.17	-1020.0	1860.4	740.9	-1020.0	-1098.7	20597.4	80.587	80.59	4.05
B8A	16	1654.4	8.10	161.17	1020.0	1860.4	740.9	1020.0	-1098.7	20597.4	80.587	80.59	4.05
B7B	16	1654.4	8.10	161.17	-1020.0	1860.4	575.8	-1020.0	-1098.7	20432.3	80.587	80.59	4.05
B8B	16	1654.4	8.10	161.17	1020.0	1860.4	575.8	1020.0	-1098.7	20432.3	80.587	80.59	4.05
L1	28	2895.2	8.10	213.21	-1102.6	238.9	604.4	-1102.6	-2720.2	20460.9	106.607	106.61	4.05
L2	28	2895.2	8.10	213.21	-1102.6	238.9	-606.4	-1102.6	-2720.2	19250.1	106.607	106.61	4.05
L3	28	2895.2	8.10	213.21	-1102.6	831.3	606.4	-1102.6	-2127.8	20462.9	106.607	106.61	4.05
L4	28	2895.2	8.10	213.21	-1102.6	831.3	-606.4	-1102.6	-2127.8	19250.1	106.607	106.61	4.05
R1	28	2895.2	8.10	213.21	1102.6	238.9	606.4	1102.6	-2720.2	20462.9	106.607	106.61	4.05
R2	28	2895.2	8.10	213.21	1102.6	238.9	-606.4	1102.6	-2720.2	19250.1	106.607	106.61	4.05
R3	28	2895.2	8.10	213.21	1102.6	831.3	606.4	1102.6	-2127.8	20462.9	106.607	106.61	4.05
R4	28	2895.2	8.10	213.21	1102.6	831.3	-606.4	1102.6	-2127.8	19250.1	106.607	106.61	4.05

Copy of spreadsheet of locations for the patches of SS placed where t-nut fasteners are located.

*Represents about 50% of total t-nuts.

Should be about 16*cm square

Factor of 145% increase on thickness gets to right'ish coverage which seems right adding in the screw to the thickness of the TNut, which has a hole anyway.

**Modeled each area as a square patch so the area of coverage is centered correctly but may be slightly off due to shape.

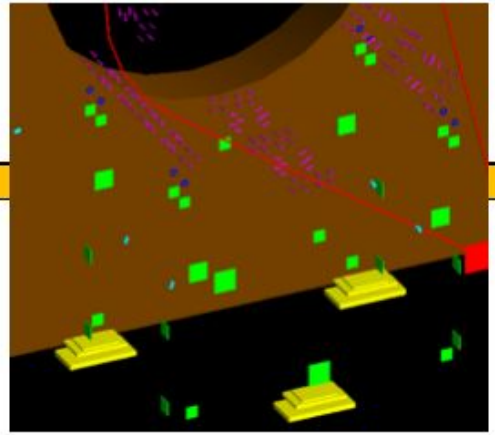
9306: GEM T-Nuts (Toy Geometry)

Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	1E-08	1E-05	1E-01
Brass/Bronze (Worst)	0.001	1E-08	1E-05	1E-01

SS-304 (Not great ferromagnetic quality, let's consider worst-case stainless). Tolerable limit per e.o.t. is on of the order 10^{-8}

OLD

Sens Volume:	GEM Rotator T-Nuts/Screws
Sim Date:	10/12/2023
Detector #:	9306



GEM Rotator T-Nuts/Screws -- Unweighted By BField

Total Prim's:	15,000,000,000

Total Sec's:	500,000	(per sens det)

Primary Counts		
Primaries	0	0&1
9306		717

Primary Fractional		
Primaries	0	0&1
9306		4.78E-08

(9928 MainDet) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9306	1773	585

(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9306	3.55E-03	1.17E-03

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9306	1.69E-10	5.59E-11

(9911 PMT Region) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9306	6132	2156

(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9306	1.23E-02	4.31E-03

(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9306	5.86E-10	2.06E-10

9306: GEM T-Nuts (Toy Geometry)

Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	1E-08	1E-05	1E-01
Brass/Bronze (Worst)	0.001	1E-08	1E-05	1E-01

Ferrous background was previously fine with a ferrous background limit of 10^{-8}

After depolarization considerations we sit ~3 orders of magnitude under out set limit.

Sens Volume:	GEM Rotator T-Nuts/Screws
Sim Date:	10/31/2023
Detector #:	9306

*Simulation with wheel and frame mass (G4_Al)

NEW

GEM Rotator T-Nuts/Screws -- Unweighted By BField

Total Prim's:	20,000,000,000	
Total Sec's:	500,000	(per sens det)

Primary Counts		
Primaries	0	0&1
9306		287

Primary Fractional		
Primaries	0	0&1
9306		1.44E-08

(9928 MainDet) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9306	1410	422

(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9306	2.82E-03	8.44E-04

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9306	4.05E-11	1.21E-11

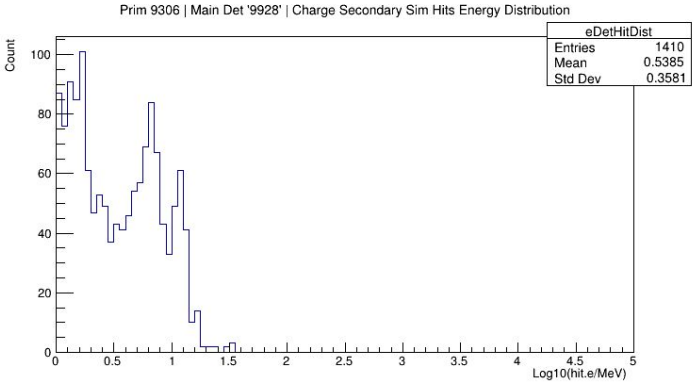
(9911 PMT Region) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9306	6019	2142

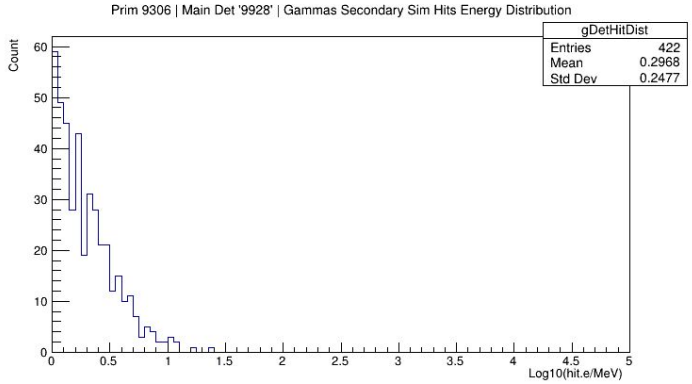
(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9306	1.20E-02	4.28E-03

(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9306	1.73E-10	6.15E-11

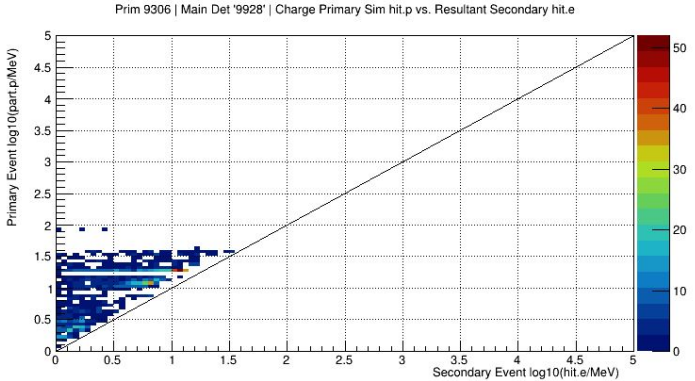
9306: GEM T-Nuts (Toy Geometry)

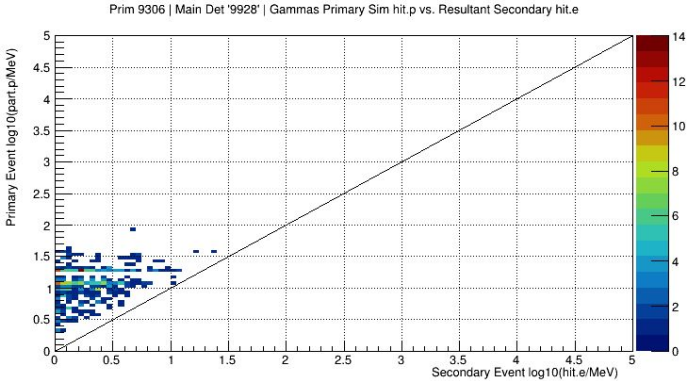
Backgrounds that hit detector '28'





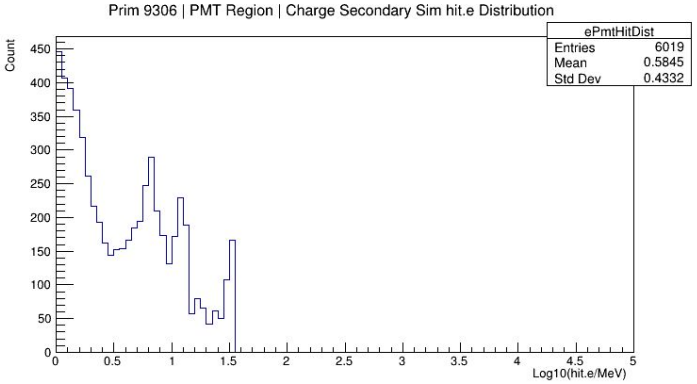
NEW

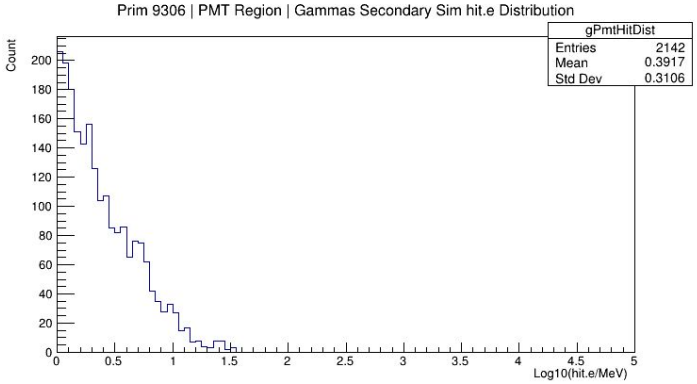




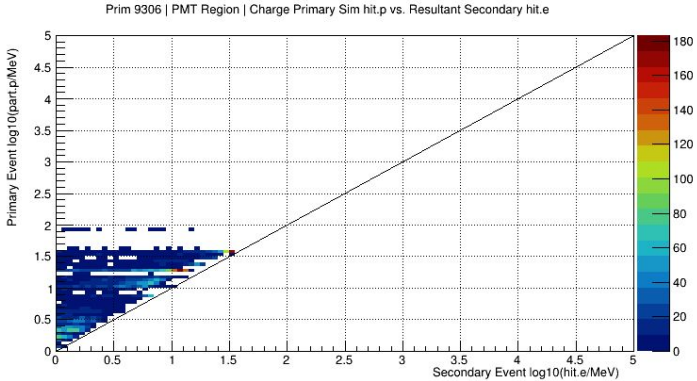
9306: GEM T-Nuts (Toy Geometry)

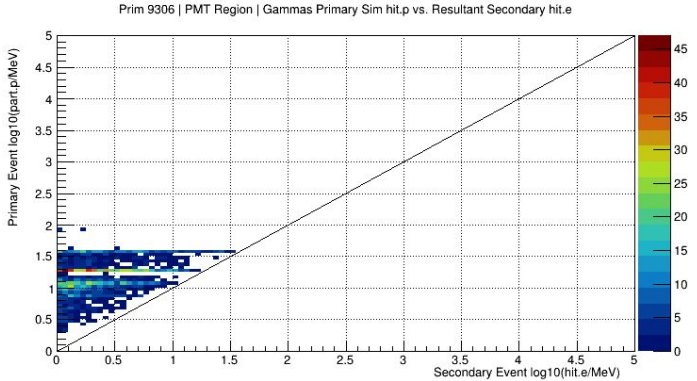
Backgrounds that hit PMT Region





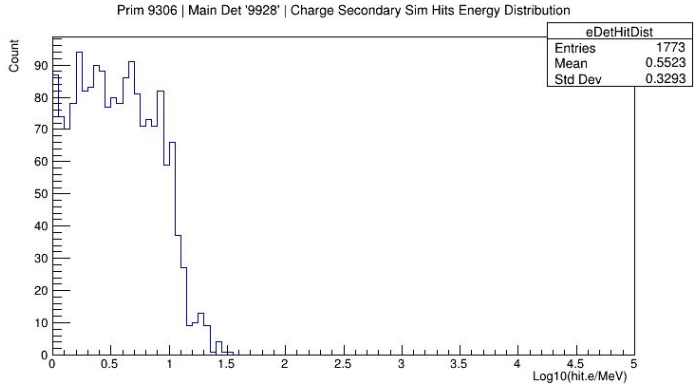
NEW

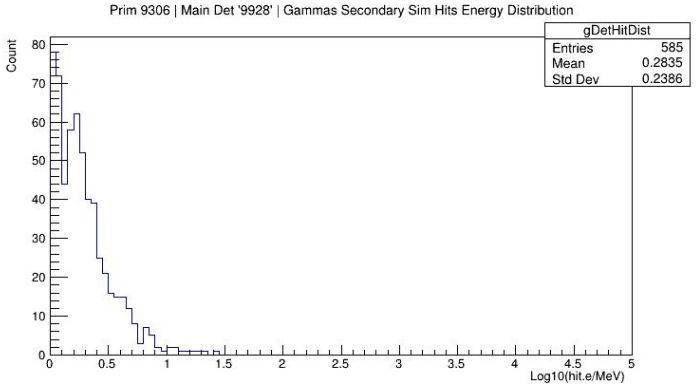




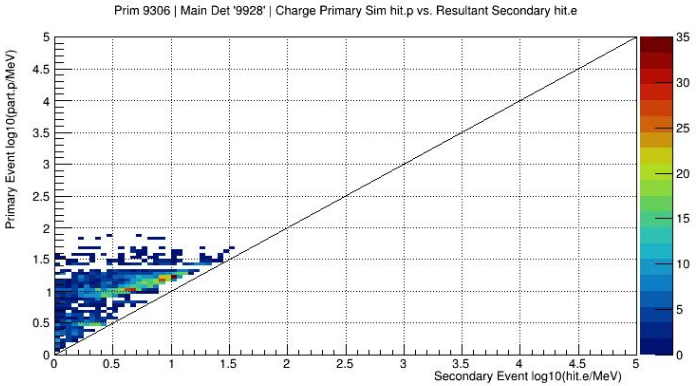
9306: GEM T-Nuts (Toy Geometry)

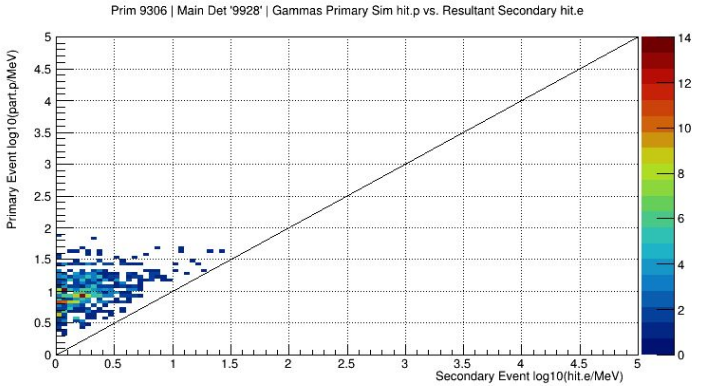
Backgrounds that hit detector '28'





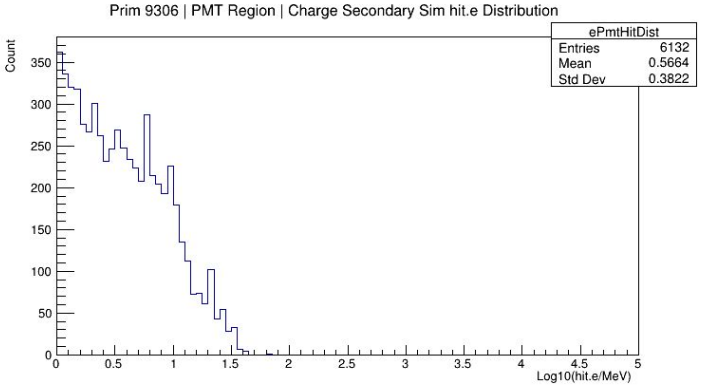
OLD

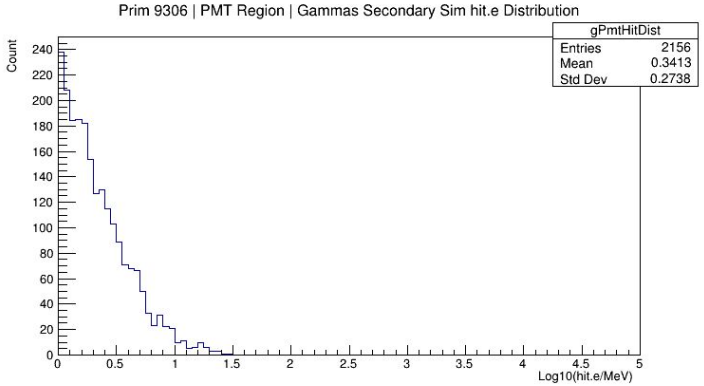




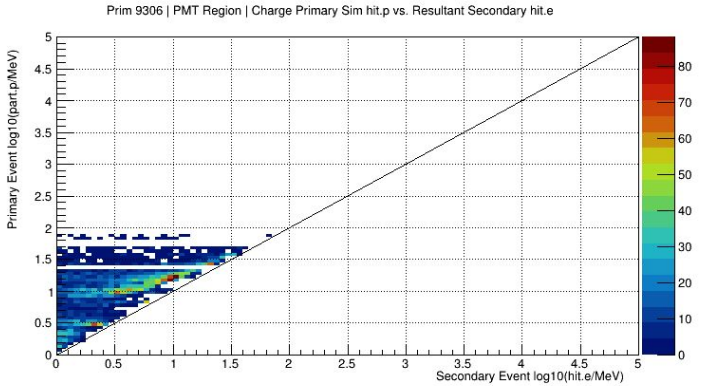
9306: GEM T-Nuts (Toy Geometry)

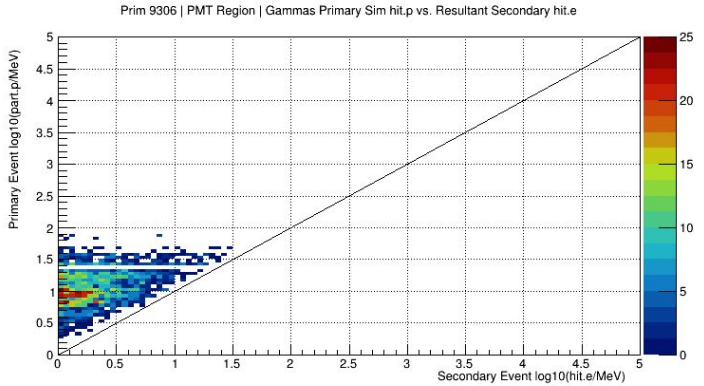
Backgrounds that hit PMT Region





OLD

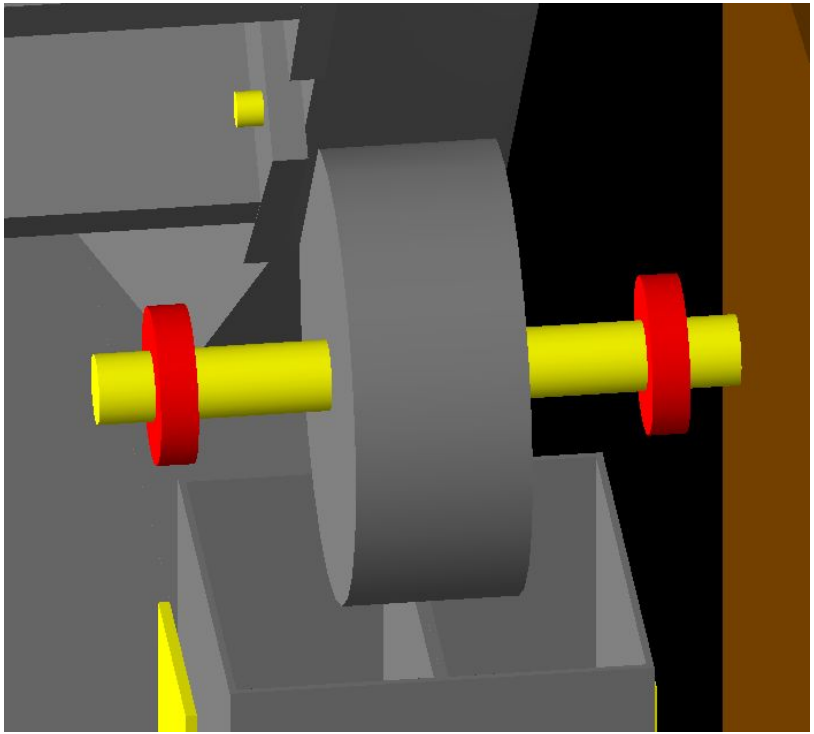




9307 – GEM Rotator Frame Wheel Pins

- Wheel pin design is currently for Al 6061-T6 and Chandika asked if we can determine whether or not it would be acceptable to use SS316 for the wheel pin.

- The large yellow cylinder is the wheel pin, the roller can be seen in gray and the bearings in red.



9307: GEM Rot Wheel Pins

Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	1E-08	1E-05	1E-01
Brass/Bronze (Worst)	0.001	1E-08	1E-05	1E-01

Sens Volume:	GEM Rotator Wheel Pins
Sim Date:	10/31/2023
Detector #:	9307

*Simulation with wheel and frame mass (G4_Al)

NEW

GEM Rotator Wheel Pins -- Unweighted By BField

Total Prim's:	20,000,000,000

Total Sec's:	500,000	(per sens det)

Primary Counts		
Primaries	0	0&1
9307		95

Primary Fractional		
Primaries	0	0&1
9307		4.75E-09

(9928 MainDet) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9307	161	424

(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9307	3.22E-04	8.48E-04

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9307	1.53E-12	4.03E-12

(9911 PMT Region) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9307	518	1090

(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9307	1.04E-03	2.18E-03

(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9307	4.92E-12	1.04E-11

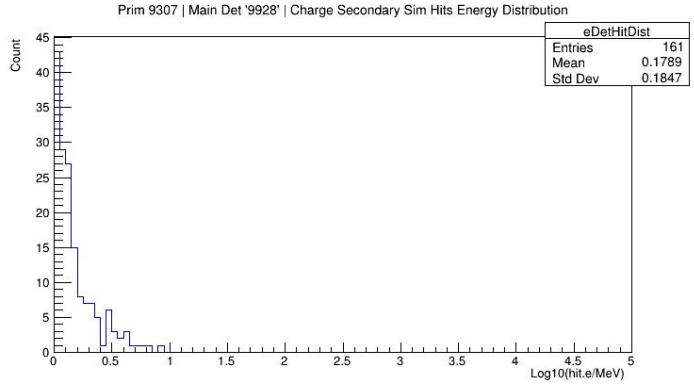
As a reminder, SS316 falls under the worst quality SS putting the acceptable limit of ferrous backgrounds at 10^{-8}

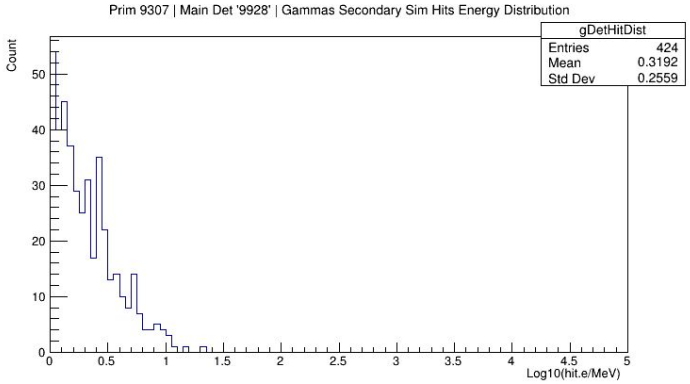
Simulated backgrounds fall four orders of magnitude under that.

It would be fine to make the wheel pins out of SS316 or better.

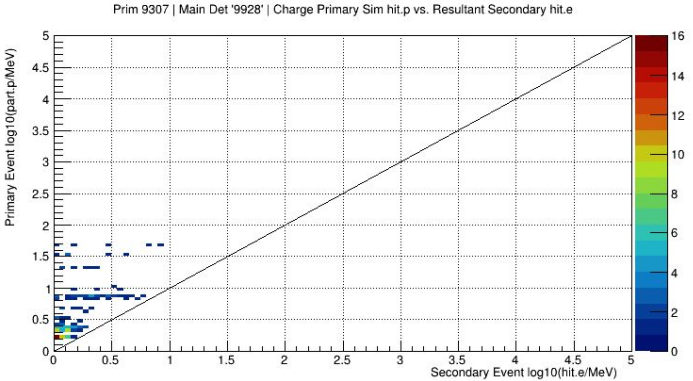
9307: GEM Rot Wheel Pins

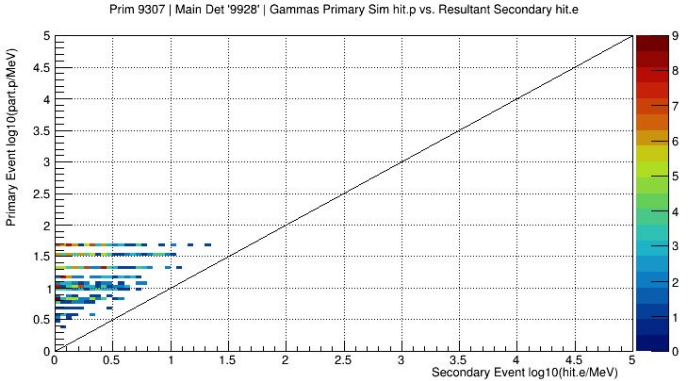
Backgrounds that hit detector '28'





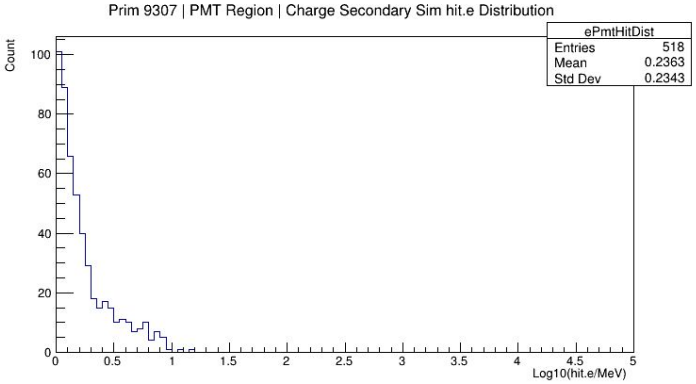
NEW

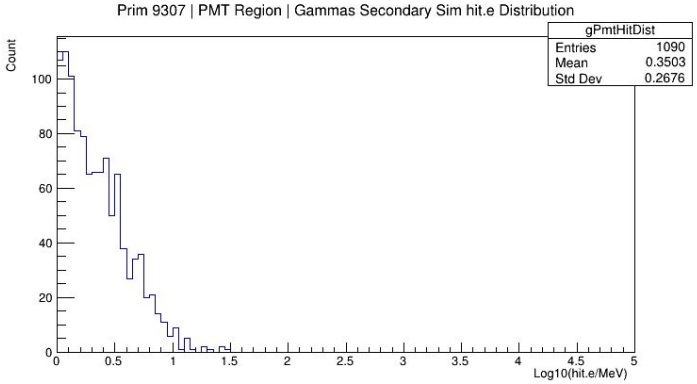




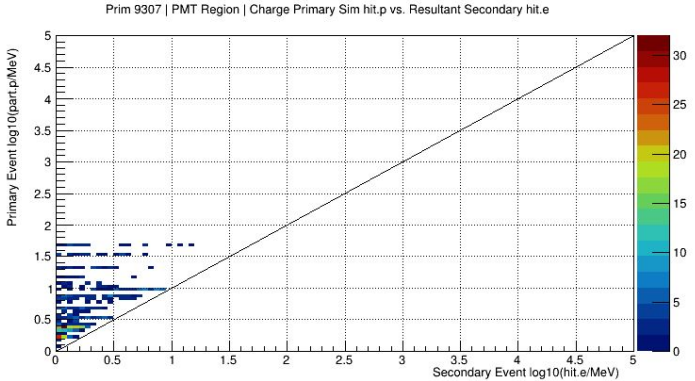
9307: GEM Rot Wheel Pins

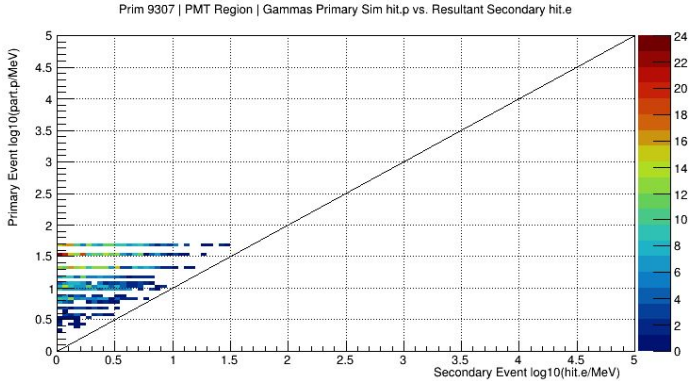
Backgrounds that hit PMT Region





NEW



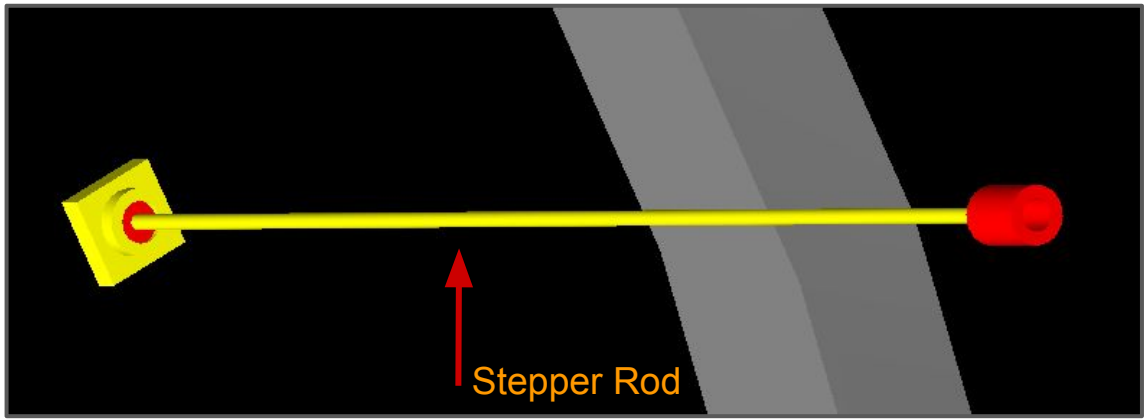


9308 – GEM Rotator Stepper Rods

- Material specs from website simply state that the material is stainless steel.

  https://www.helixlinear.com/Products/Stepper-Motor-Linear-Actuators-/Stepper-Motor-Linear-Actuator-External-/Stepper-Motor-Linear-Actuator-External-SMA-23E3.25-039196~SMA-23E3.25-039196#product-specifications

- Rod is of course long piece of material attached to the motor (on right in image) and bearing (on left in image).



9308: GEM Rot Stepper Rods

Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	1E-08	1E-05	1E-01
Brass/Bronze (Worst)	0.001	1E-08	1E-05	1E-01

The stepper motor rods are not problematic. SS316 or better is fine.

Sens Volume:	GEM Rotator Wheel Pins
Sim Date:	10/31/2023
Detector #:	9308

*Simulation with wheel and frame mass (G4_Al)

NEW

GEM Rotator Wheel Pins -- Unweighted By BField

Total Prim's:	20,000,000,000

Total Sec's:	500,000	(per sens det)

Primary Counts		
Primaries	0	0&1
9308		490

Primary Fractional		
Primaries	0	0&1
9308		2.45E-08

(9928 MainDet) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9308	821	752

(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9308	1.64E-03	1.50E-03

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9308	4.02E-11	3.68E-11

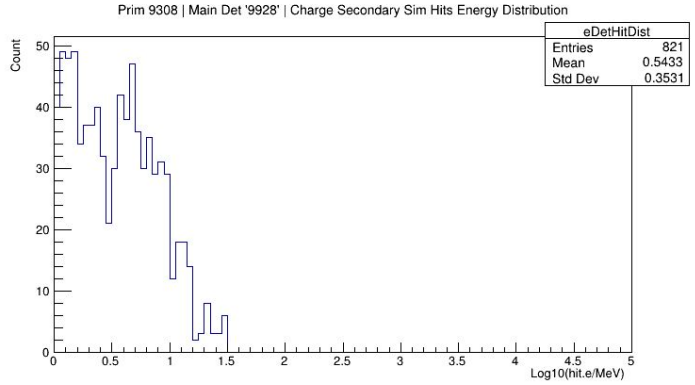
(9911 PMT Region) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9308	3529	3066

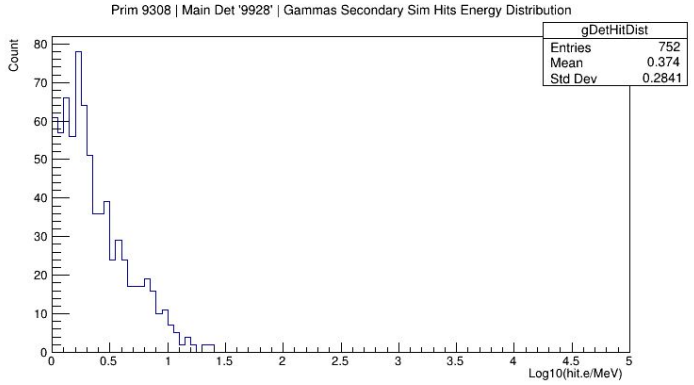
(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9308	7.06E-03	6.13E-03

(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9308	1.73E-10	1.50E-10

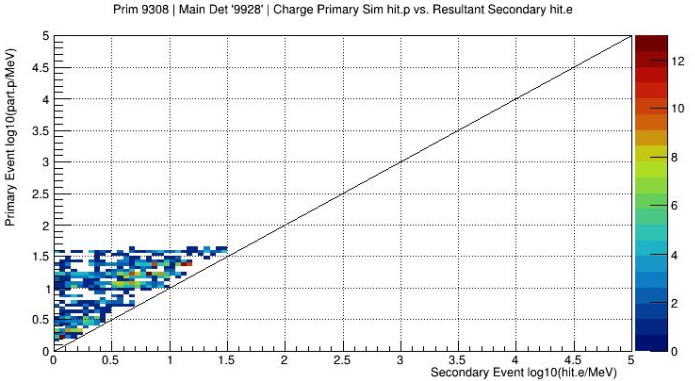
9308: GEM Rot Stepper Rods

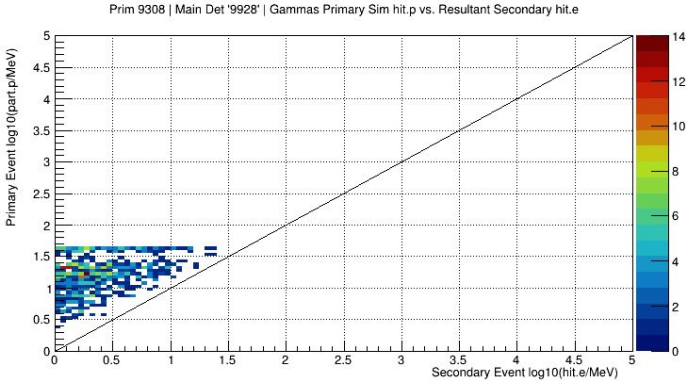
Backgrounds that hit detector '28'





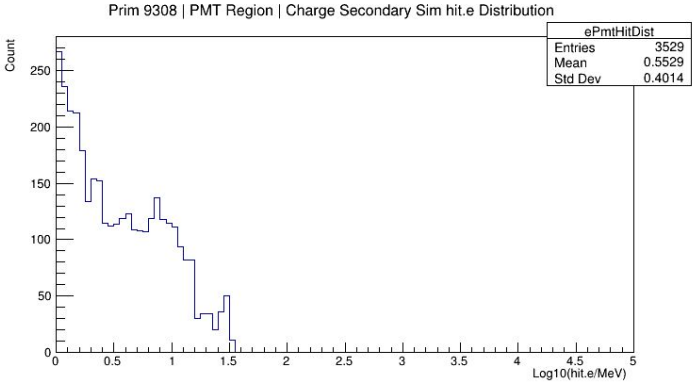
NEW

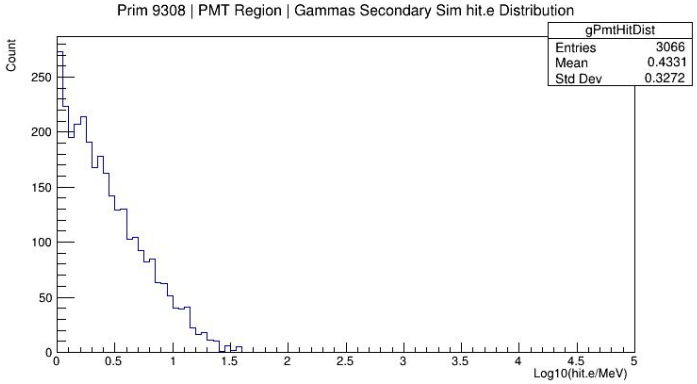




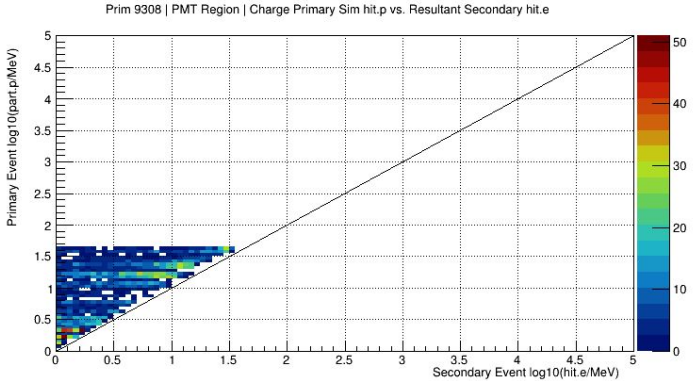
9308: GEM Rot Stepper Rods

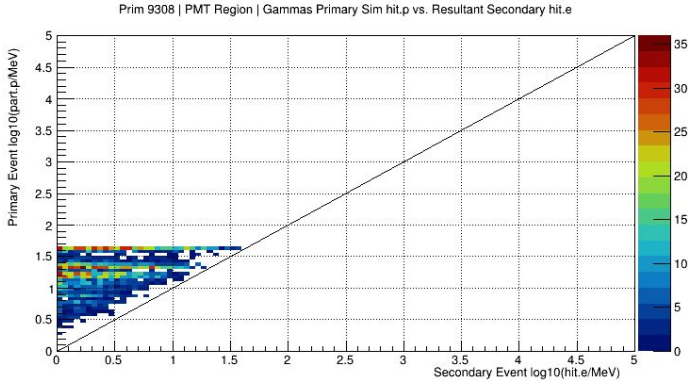
Backgrounds that hit PMT Region





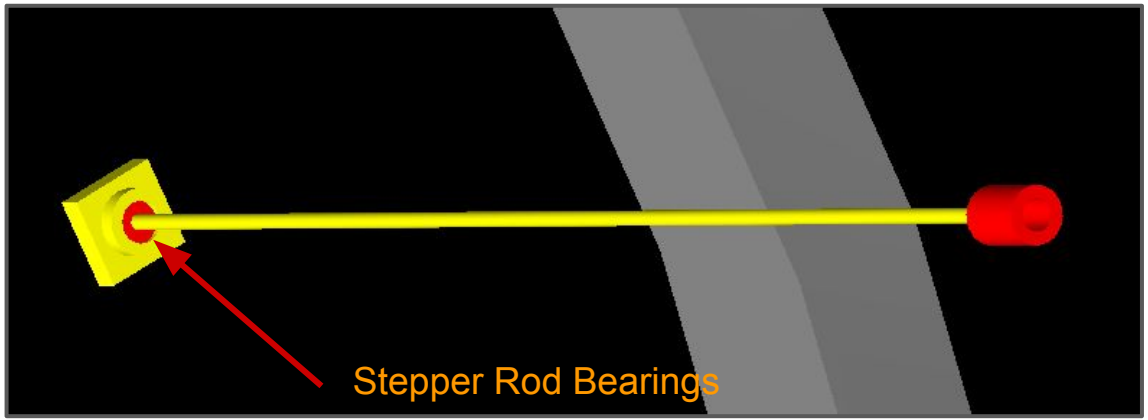
NEW





9309 – GEM Rotator Stepper Bearings

- Chandika informed me that the bearings will be some kind of carbon steel.
- Bearings are surrounded by a stainless steel housing (yellow square).
  - Chandika has been told by the manufacturer that the housing can be made of SS316.



- There is currently no Al frame material (shown in gray) surrounding these put into the ferrous simulation.
  - ⇨ Additional materials may help attenuate ferrous backgrounds from the steeper bearings as was the case with the wheel bearings although there is less material ‘in the way’ for stepper bearing ferrous backgrounds.

9309: Gem Rot Stepper Bearings

Material	X_r	Spin Polarization (P_f)	Frac e- on Target	Frac of events Per Moller
Mild Steel	2000	1E-02	1E-11	1E-07
Stainless Steel (Worst)	1	1E-05	1E-08	1E-04
Stainless Steel (Ideal)	0.01	1E-07	1E-06	1E-02
Aluminum	0.0001	1E-09	1E-04	1E+00
Inconel 625	0.001	1E-08	1E-05	1E-01
Brass/Bronze (Worst)	0.001	1E-08	1E-05	1E-01

Sens Volume:	GEM Rotator Stepper Bearings
Sim Date:	10/31/2023
Detector #:	9309

*Simulation with wheel and frame mass (G4_Al)

NEW

GEM Rotator Stepper Bearings -- Unweighted By BField

Total Prim's:	20,000,000,000

Total Sec's:	500,000 (per sens det)

Primary Counts		
Primaries	0	0&1
9309		219

Primary Fractional		
Primaries	0	0&1
9309		1.10E-08

(9928 MainDet) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9309	6131	8286

(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9309	1.23E-02	1.66E-02

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9309	1.34E-10	1.81E-10

(9911 PMT Region) Secondary Counts - 0&1		
Secondaries	Electrons	Gammas
9309	8576	37073

(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas
9309	1.72E-02	7.41E-02

(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9309	1.88E-10	8.12E-10

Stepper bearings are some type of carbon steel. This puts tolerable ferrous background limits at 10^{-11}.

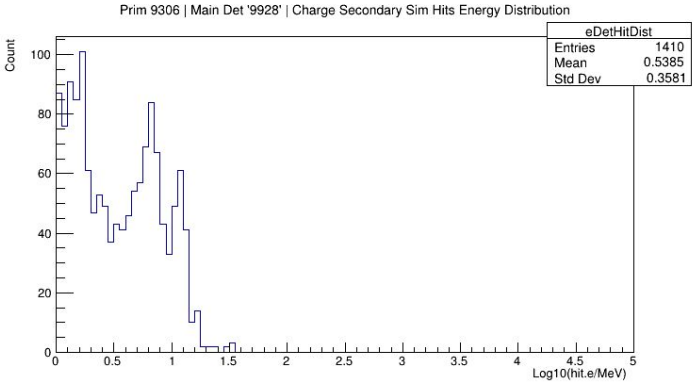
Raw simulation results give ferrous backgrounds at the ~1(10^{-10}) level.

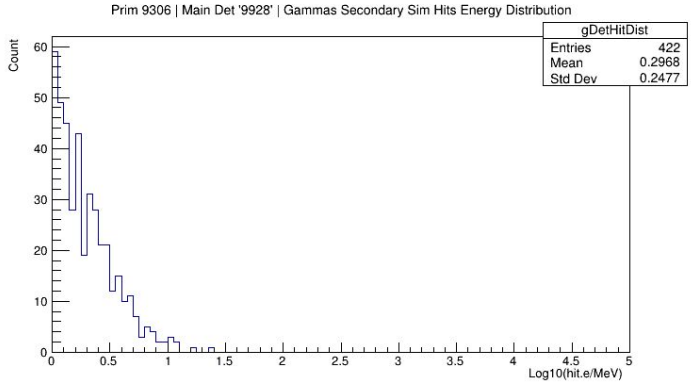
Depolarization considerations bring the raw simulation results to around 5(10^{-11}) still above our desired limit.

There are additional materials which can be modeled.

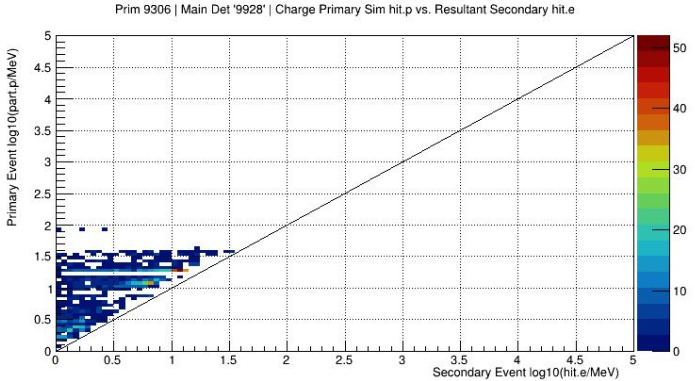
9309: Gem Rot Stepper Bearings

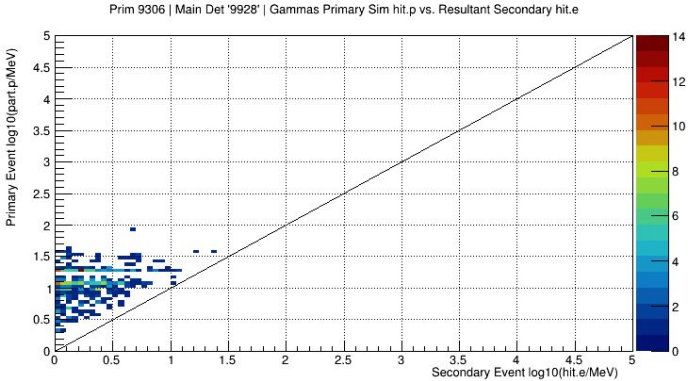
Backgrounds that hit detector '28'





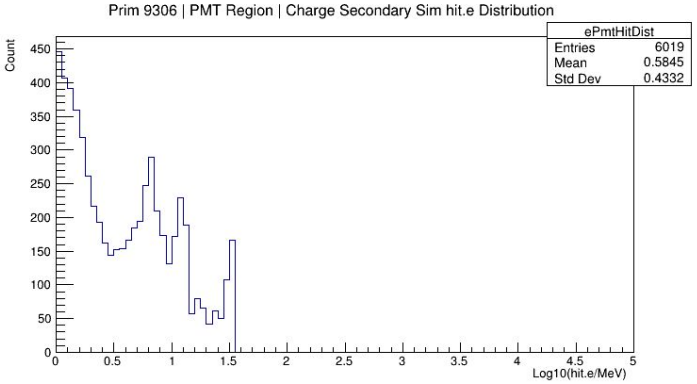
NEW

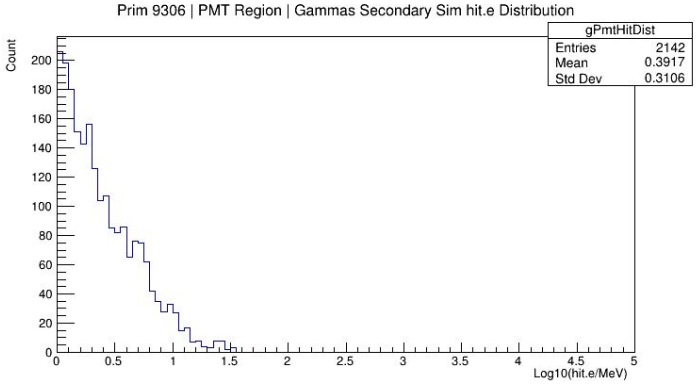




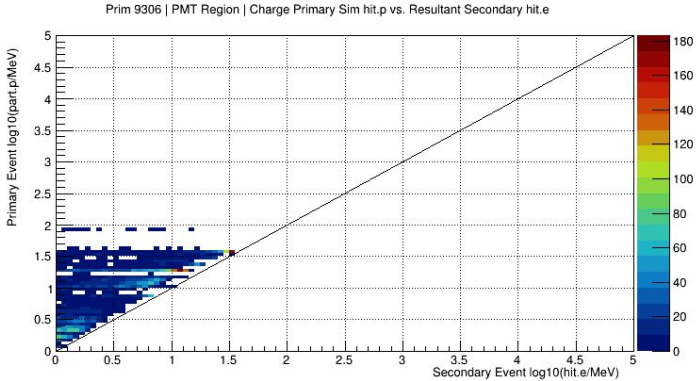
9309: Gem Rot Stepper Bearings

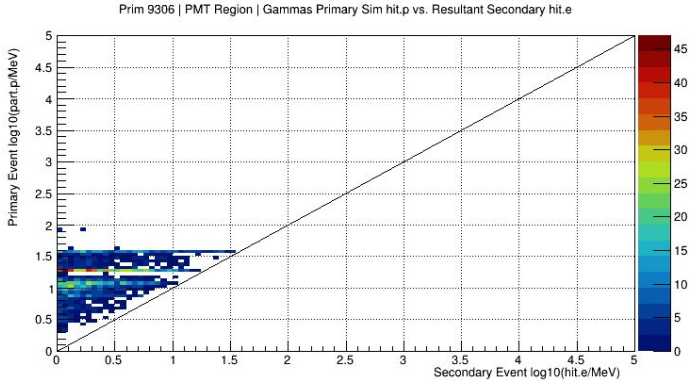
Backgrounds that hit PMT Region





NEW





Summary

and meeting comments/notes

(Updated) Simulation Summary & Comments

Ferrous Detector	Ferrous Volume Common Name	Material(s)	Ferrous BG[1] Limit [per e.o.t.]	OLD Main Det Sim BG[1] [per e.o.t]	NEW Main Det Sim BG[1] [per e.o.t]	Comment
9300	Roller Bearings	100Cr6 [Carbon Steel]	10^{-11}	< $2(10^{-11})$	~$5(10^{-13})$	Addition of large amounts of wheel materials and **stainless steel** wheel pins have reduced the ferrous backgrounds to tolerable limits.
9301	Floor Locks	Carbon Steel and SS	10^{-11}	~$1(10^{-11})$	~$4(10^{-12})$	Addition of wheel materials has dropped this by about a factor of 2 into tolerable range.
9302	Gear Motor	7kg Multiple Materials	10^{-12}	< $1(10^{-12})$	~$5(10^{-13})$	Assuming worst material limits we're still under the ferrous BG[1] limit.
9303	Chain	SS316	10^{-8}	~$2(10^{-9})$	~$3(10^{-10})$	Over-modeled slightly and safely within limits. Depolarization adds further comfort as does shielding and attenuation by GEM Rotator structure.
9304	Bolt Fasteners	SS316	10^{-8}	~$4(10^{-9})$	~$5(10^{-10})$	As expected, addition of wheel materials reduced backgrounds further. Bolt fasteners are not a concern.
9306	**Stepper Motors**	**Modeled as 2.6kg Fe**	**10^{-12}**	**~$4(10^{-12})$ ↓ ~$1.5(10^{-12})$**	**~$3(10^{-12})$ ↓ ~$2(10^{-12})$**	**As modeled, with depolarization considerations we are down to our limit. Current modeled mass is about 25% of the motor. So there may be some mass scaling needed (x2)**

[1]BG=Background

Simulation Summary & Comments (Cont'd)

Ferrous Detector	Ferrous Volume Common Name	Material(s)	Ferrous BG[1] Limit [per e.o.t.]	OLD Main Det Sim BG[1] [per e.o.t]	NEW Main Det Sim BG[1] [per e.o.t]	Comment
9306	T-Nut Fasteners	SS304	10^{-8}	~$2(10^{-10})$	$4(10^{-11})$	Model result was ~$4(10^{-11})$, doubling to account for unmodeled mass we come to <$8(10^{-11})$. Assuming that SS-304 is absolute worst quality this is still well below tolerable limits.
9307	Wheel Pins	SS316	10^{-8}	N/A	$2(10^{-12})$	Tolerable to be made of SS316 or better.
9308	Stepper Rods	SS [Unspecified Type]	10^{-8}	N/A	$4(10^{-11})$	Stepper Rods are fine.
9309	**Stepper Bearings**	**Carbon Steel**	**10^{-11}**	**N/A**	**$1.5(10^{-10})$ ↓ ~$5(10^{-11})$**	**These are closest to the beamline of any ferrous item in the rotator. High background rates are not surprising. Depolarization reduces by factor of 3. There's more wheel mass which isn't modeled, but I don't expect a drastic reduction like the wheel bearings.**
9310	Stepper Bearing Housing	SS316	10^{-8}	N/A		

[1]BG=Background

Recent Meeting Notes

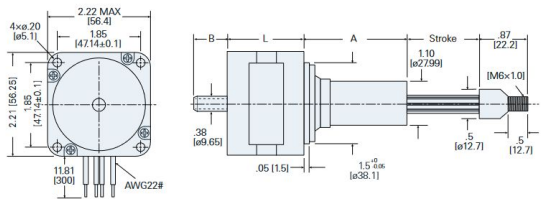
- Things to be added
- Revisions
-

Ferrous Materials Meeting Comments/Ongoing/New

- Re-sim with alum wheel pins
- Add mass around stepper bearings
- Investigate no hits on 9310 / 9309

NEMA 23
Captive Stepper Motor Linear Actuator

HELIX LINEAR TECHNOLOGIES



Motor Specifications

- Bipolar Wiring
- 1.8° Step Angle
- Insulation Resistance: 20 MΩ
- Temperature Rise: 167°F (75°C)

	Voltage	Current	Resistance/ Phase	Inductance/ Phase	Motor Weight		Power Input	L	
	V	A	Ω	mH	oz	g	W	in	mm
Single Stack	3.25	2	1.63	3.5	18	511	13	1.78	45.2
	5	1.3	3.85	10.5	18	511	13	1.78	45.2
	12	0.54	22.2	47	18	511	13	1.78	45.2
Double Stack	3.25	3.32	0.98	1.33	33.8	958	14	2.60	66.0
	5	2.16	2.31	6.6	33.8	958	14	2.60	66.0
	12	0.9	13.33	45.1	33.8	958	14	2.60	66.0