

# Ferrous Materials:

## GEM Rotator Stepper Motors and Bearings Shielding

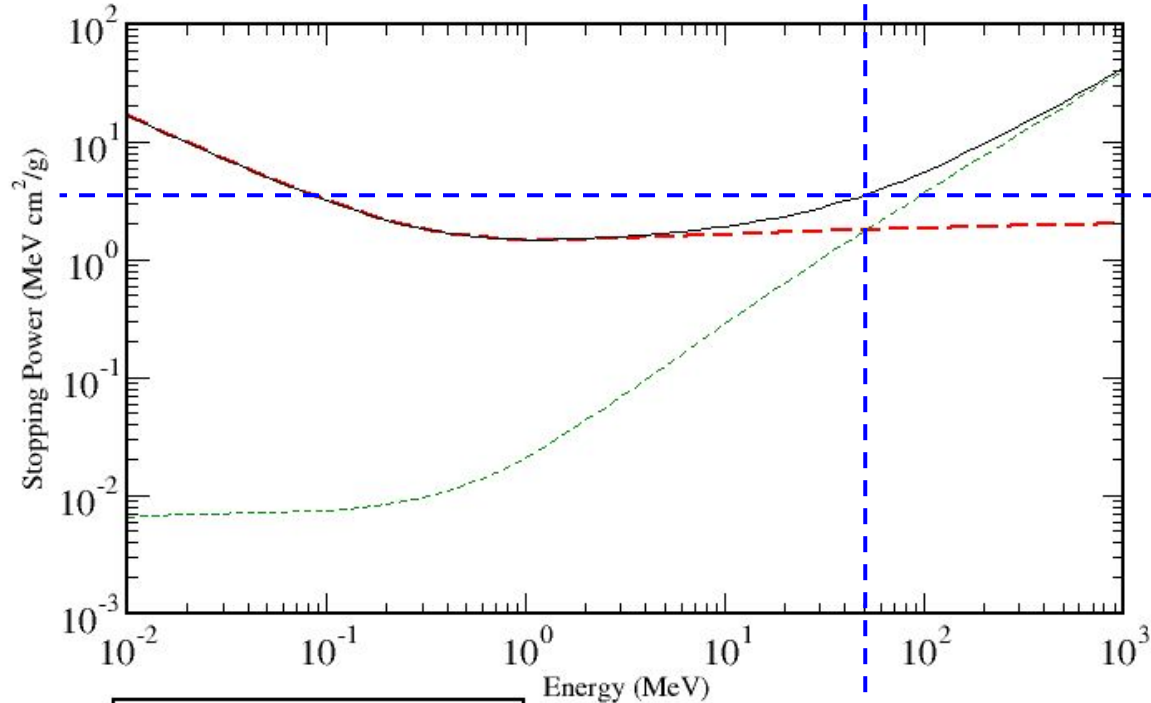
Eric King

Last Updated:

12-13-2023

# Stopping Power Information

# ALUMINUM



Stopping power:

3.5 MeV cm<sup>2</sup>/g

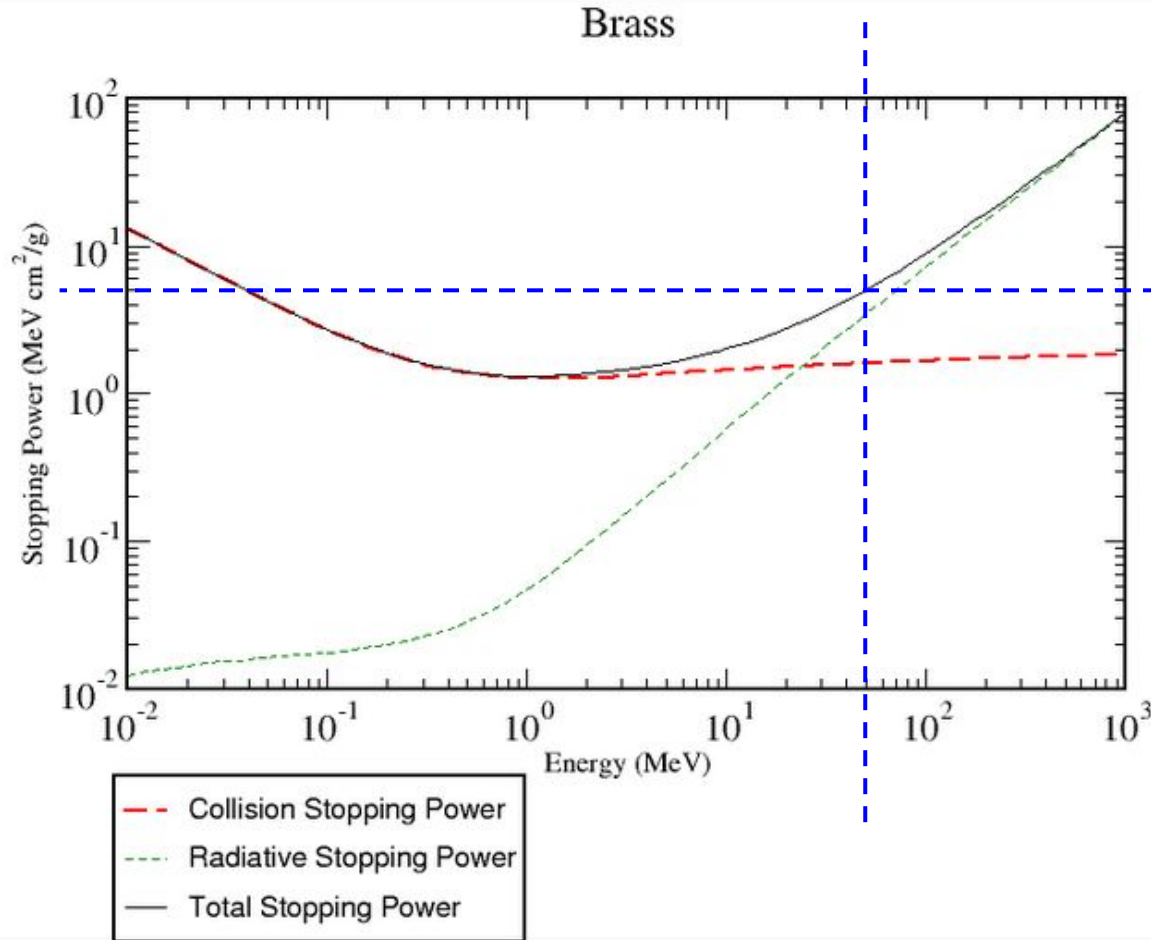
$$\rho_{\text{Al}} \sim 2.7 \text{ g cm}^{-3}$$

10 MeV per cm. Is that right?

2.54 cm of Al ... so, 25 MeV going in and 25 MeV going out?

Should be more than sufficient to shield against 30MeV backgrounds.

Stopping power:



<10 MeV cm<sup>2</sup>/g

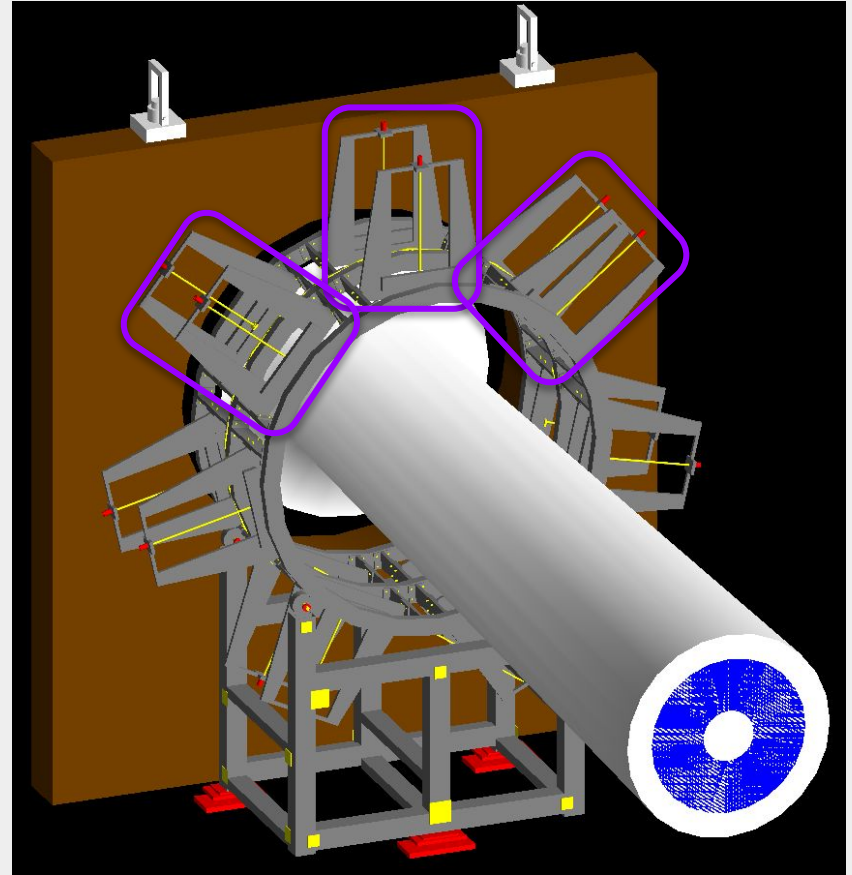
$$\rho_{\text{Brass}} \sim 8.65 \text{ g cm}^{-3}$$

86.5 MeV per cm.

So, that's about 60 MeV for about 7.5mm of material.

# Added Mass

GEM panel frames added

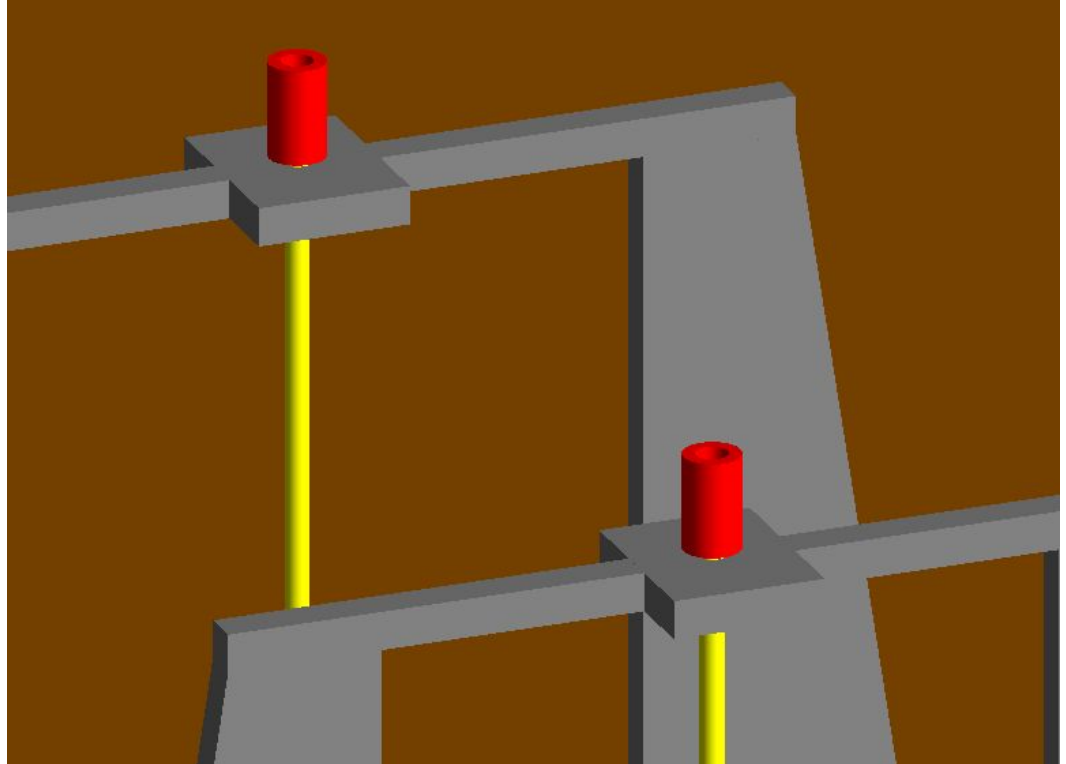


# Frame under the stepper motors

1" of material underneath the stepper motors

Just put square of material, had issues with tapered corners and wasn't dealing with it for now.

All of these parts are Aluminum.

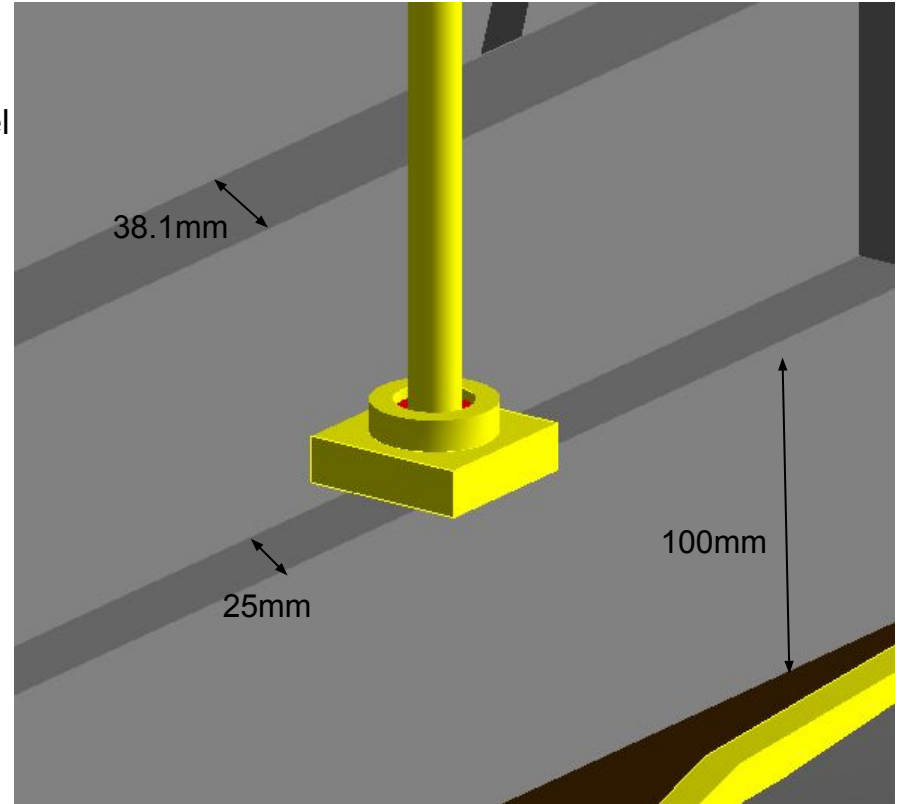
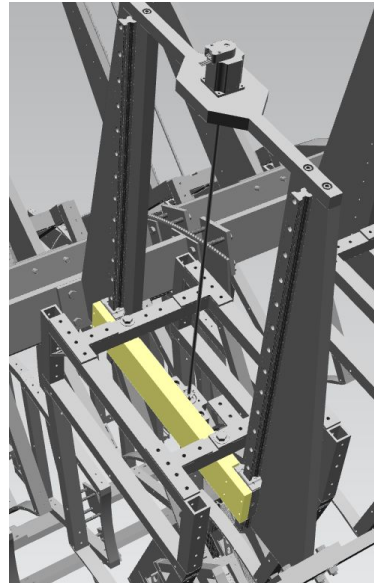


# Frame under and next to stepper bearings

Material of the GEM panel frame is below the bearing.

Additional “frame braces” located US (of upstream wheel half) and DS (of downstream wheel half).

Added parts are aluminum.



# Updated Ferrous Geometries



# New motors, rod and bearings

- Motor dimensions changed.
  - Doubled the mass of the magnetized iron in simulation.
  - Total Mass in simulation:  $5.3 \text{ kg} * 14$
- Rod radius changed from 5mm to 8mm
  - ~250% increase in mass
- Changes to bearing were comparatively smaller.
  - Modified according to JT provided by Chandika.

Review

# Summary of Ferrous Materials in GEM Rotator

Where we sat at the end of October

- 2 'problem' components

# (10/31/23) GEM Rotator Summary

*Note: Results in green may be updated in main docdb for gem rotator ferrous materials studies.*

Ferrous Detector	Ferrous Volume Common Name	Material(s)	Ferrous BG <sup>1</sup> Limit [per e.o.t.]	OLD Main Det Sim BG <sup>1</sup> [per e.o.t.]	NEW Main Det Sim BG <sup>1</sup> [per e.o.t.]	Comment
9300	Roller Bearings	100Cr6 [Carbon Steel]	10 <sup>-11</sup>	< 2(10 <sup>-11</sup> )	~5(10 <sup>-13</sup> )	Addition of large amounts of wheel materials and <b>stainless steel</b> wheel pins have reduced the ferrous backgrounds to tolerable limits.
9301	Floor Locks	Carbon Steel and SS	10 <sup>-11</sup>	~1(10 <sup>-11</sup> )	~4(10 <sup>-12</sup> )	Addition of wheel materials has dropped this by about a factor of 2 into tolerable range.
9302	Gear Motor	7kg Multiple Materials	10 <sup>-12</sup>	< 1(10 <sup>-12</sup> )	~5(10 <sup>-13</sup> )	Assuming worst material limits we're still under the ferrous BG <sup>1</sup> limit.
9303	Chain	SS316	10 <sup>-8</sup>	~2(10 <sup>-9</sup> )	~3(10 <sup>-10</sup> )	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 <sup>-8</sup>	~4(10 <sup>-9</sup> )	~5(10 <sup>-10</sup> )	As expected, addition of wheel materials reduced backgrounds further. Bolt fasteners are not a concern.
9305	Stepper Motors	Modeled as 2.6kg Fe	10 <sup>-12</sup>	~4(10 <sup>-12</sup> ) ↓ ~1.5(10 <sup>-12</sup> )	~3(10 <sup>-12</sup> ) ↓ ~2(10 <sup>-12</sup> )	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)

<sup>1</sup>BG=Background

# (10/31/23) GEM Rotator Summary (cont'd)

*Note: Results in green may be updated in main docdb for gem rotator ferrous materials studies.*

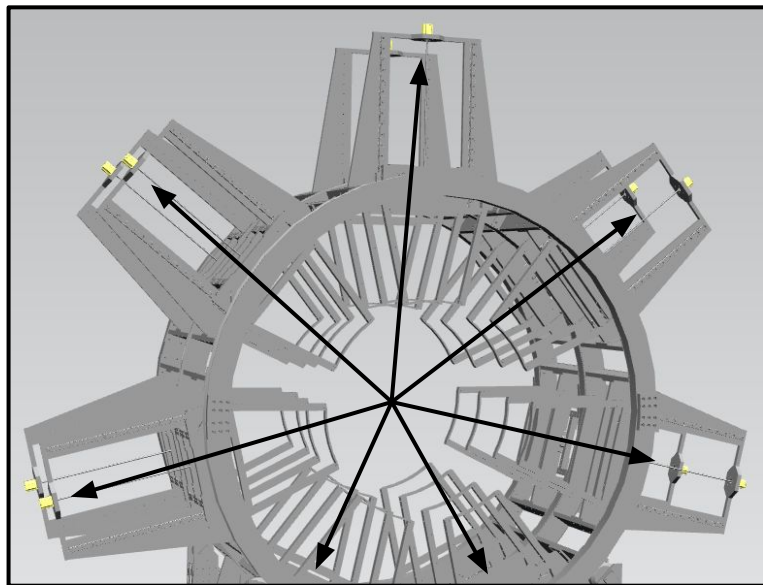
Ferrous Detector	Ferrous Volume Common Name	Material(s)	Ferrous BG <sup>1</sup> Limit [per e.o.t.]	OLD Main Det Sim BG <sup>1</sup> [per e.o.t]	NEW Main Det Sim BG <sup>1</sup> [per e.o.t]	Comment
9306	T-Nut Fasteners	SS304	10 <sup>-8</sup>	~2(10 <sup>-10</sup> )	4(10 <sup>-11</sup> )	Model result was ~4(10 <sup>-11</sup> ), doubling to account for unmodeled mass we come to <8(10 <sup>-11</sup> ). Assuming that SS-304 is absolute worst quality this is still well below tolerable limits.
9307	Wheel Pins	SS316	10 <sup>-8</sup>	N/A	2(10 <sup>-12</sup> )	Tolerable to be made of SS316 or better.
9308	Stepper Rods	SS [Unspecified Type]	10 <sup>-8</sup>	N/A	4(10 <sup>-11</sup> )	Stepper Rods are fine.
<b>9309</b>	<b>Stepper Bearings</b>	<b>Carbon Steel</b>	<b>10<sup>-11</sup></b>	<b>N/A</b>	<b>1.5(10<sup>-10</sup>)</b> ↓ <b>~5(10<sup>-11</sup>)</b>	<b>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.</b>
9310	Stepper Bearing Housing	SS316	10 <sup>-8</sup>	N/A		

<sup>1</sup>BG=Background

# New Results for 9305

Stepper Motors (9305)

## 9305 – GEM Rotator Stepper Motors (with GEM plane frame)



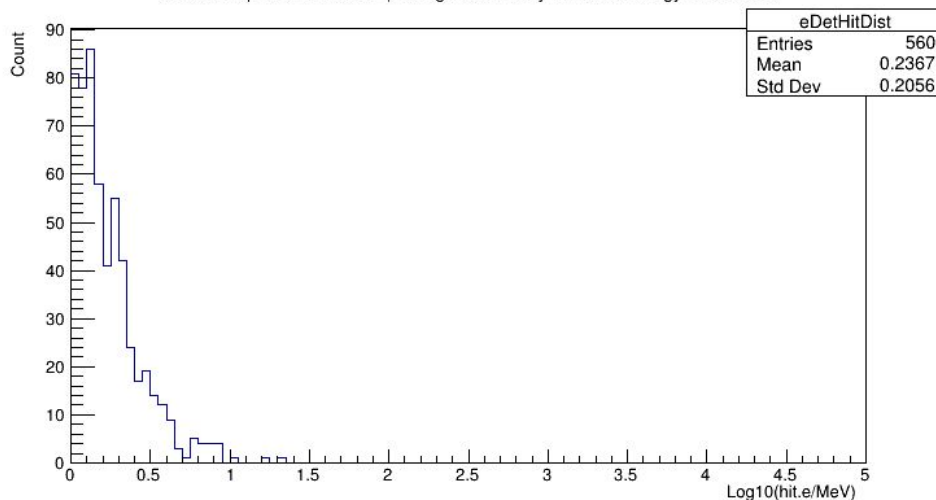
Stepper motors shown in yellow.

Thickness of GEM plane frame underneath the motor is 1" (2.54cm)

### PRIOR TO THE ADDITION OF THE GEM FRAME MASS

Charges which strike the detector originating from the stepper motors have energy  $<30\text{MeV}$  [ $10^{1.5}$ ] and largely  $<3\text{MeV}$  [ $10^{0.5}$ ]. One inch of Aluminum should provide plenty of attenuation.

Prim 9305 | Main Det '9928' | Charge Secondary Sim Hits Energy Distribution



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

# 9305: GEM Stepper Motors

New specifications and added wheel  
GEM panel frame pieces.

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 Motors
Sim Date:	12/13/2023
Detector #:	9305

# Updated

GEM Rotator Stepper Motors -- UPDATED GEM PLANE FRAME -- Unweighted

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

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

### Primary Counts

Primaries	0	0&1
9305		15

### Primary Fractional

Primaries	0	0&1
9305		7.50E-10

### (9928 MainDet) Secondary Counts - 0&1

Secondaries	Electrons	Gammas
9305	3	21

### (9928 MainDet) Secondary Fractional - 0&1

Secondaries	Electrons	Gammas
9305	6.00E-06	4.20E-05

### (9928 MainDet) Total Fractional - 0&1

Secondaries	Electrons	Gammas
9305	4.50E-15	3.15E-14

### (9911 PMT Region) Secondary Counts - 0&1

Secondaries	Electrons	Gammas
9305	12	97

### (9911 PMT Region) Secondary Fractional - 0&1

Secondaries	Electrons	Gammas
9305	2.40E-05	1.94E-04

### (9911 PMT Region) Total Fractional - 0&1

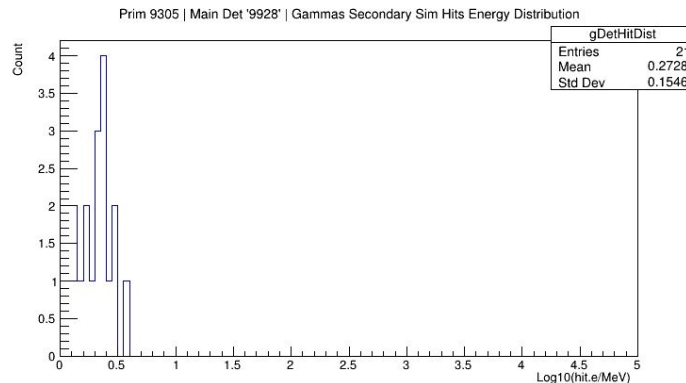
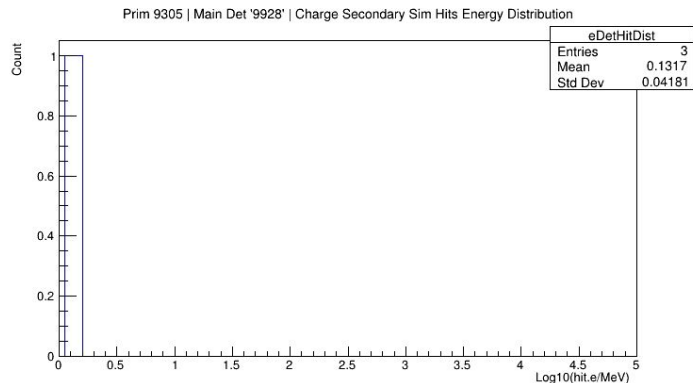
Secondaries	Electrons	Gammas
9305	1.80E-14	1.46E-13

Ferrous background goal here is a limit of  $10^{-12}$

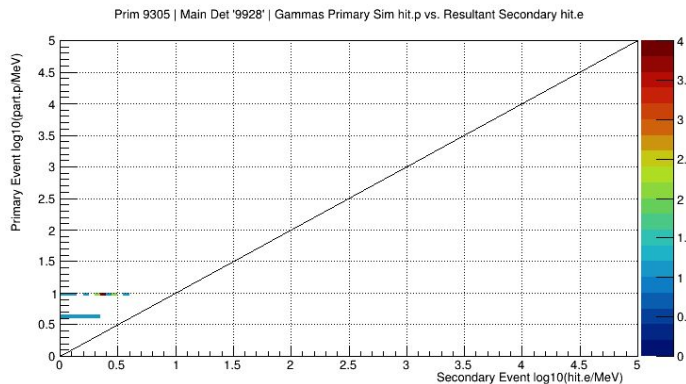
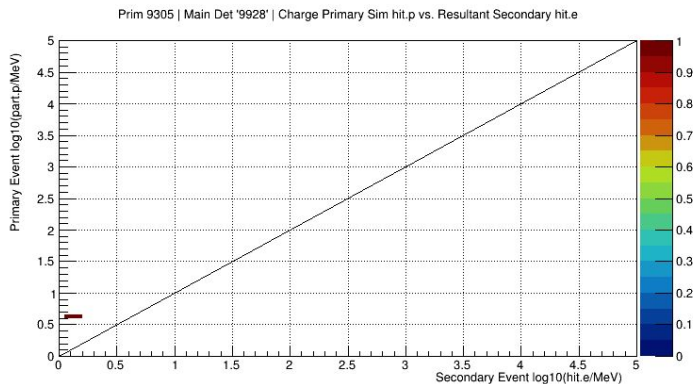
Adding the GEM plane frame into the simulation with 1" of Al below the stepper motors substantially decreases ferrous backgrounds.

# 9305: Gem Rotator Stepper Motors

*Backgrounds that hit PMT Region*



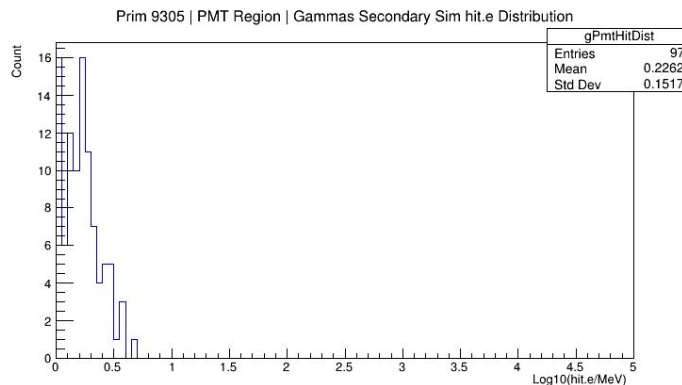
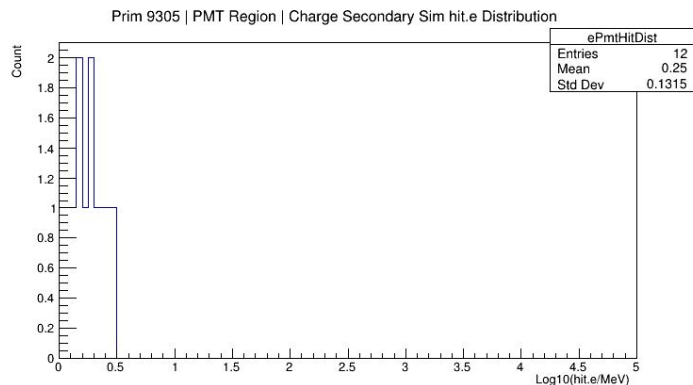
**NEW**



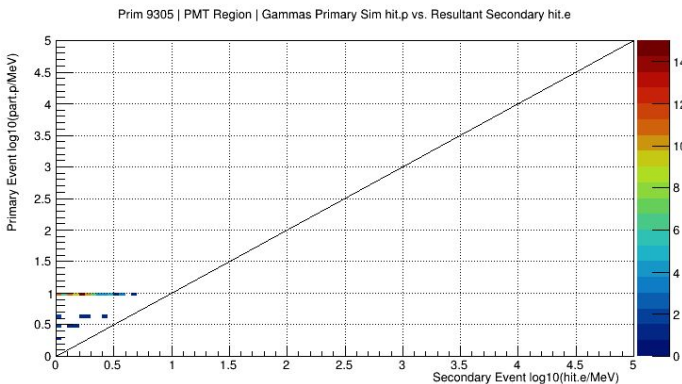
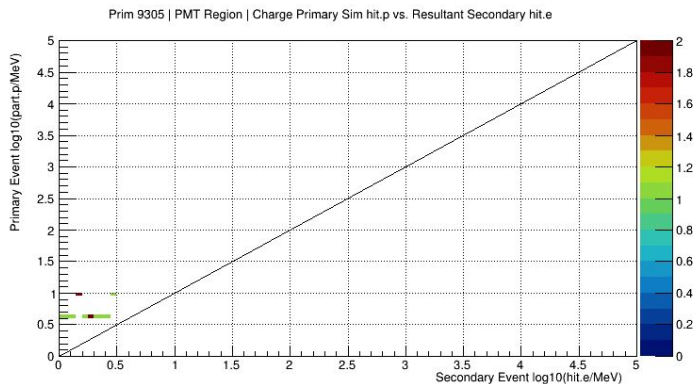


# 9305: Gem Rotator Stepper Motors

*Backgrounds that hit detector '28'*



**NEW**



# New Results for 9309

Stepper Bearings (9309)

# 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:	12/6/2023
Detector #:	9309

## Updated

GEM Rotator Stepper Bearings -- WITH ADDITIONAL FRAME -- Unweighted

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

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

Primary Counts		
Primaries	0	O&1
9309		109

Primary Fractional		
Primaries	0	O&1
9309		5.45E-09

(9928 MainDet) Secondary Counts - O&1		
Secondaries	Electrons	Gammas
9309	2330	18115

(9928 MainDet) Secondary Fractional - O&1		
Secondaries	Electrons	Gammas
9309	4.66E-03	3.62E-02

(9928 MainDet) Total Fractional - O&1		
Secondaries	Electrons	Gammas
9309	2.54E-11	1.97E-10

(9911 PMT Region) Secondary Counts - O&1		
Secondaries	Electrons	Gammas
9309	5390	71730

(9911 PMT Region) Secondary Fractional - O&1		
Secondaries	Electrons	Gammas
9309	1.08E-02	1.43E-01

(9911 PMT Region) Total Fractional - O&1		
Secondaries	Electrons	Gammas
9309	5.88E-11	7.82E-10

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

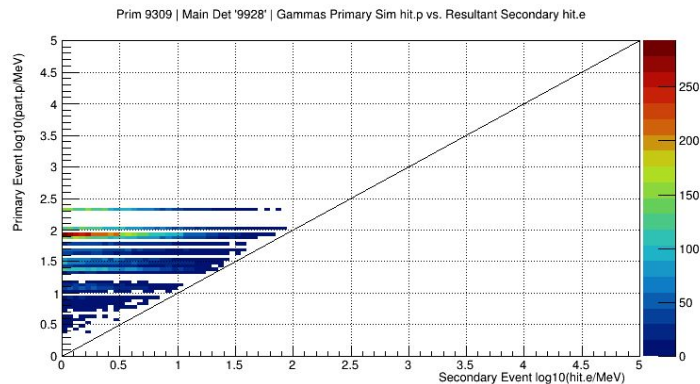
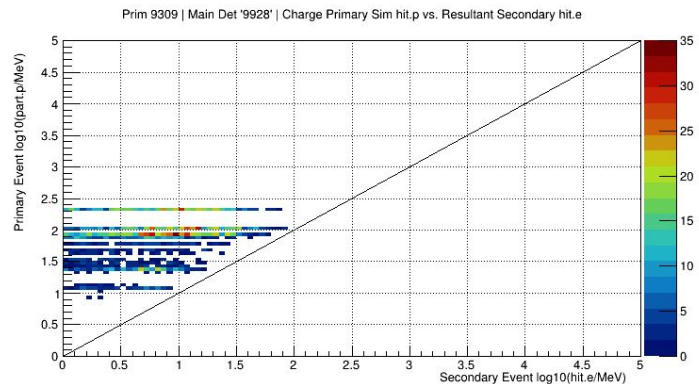
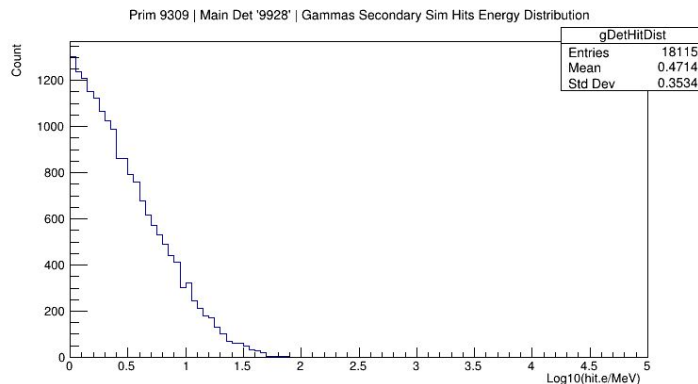
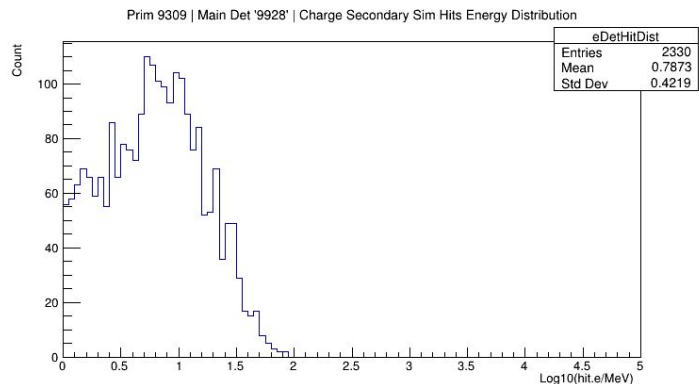
Raw simulation results give ferrous backgrounds at the  $\sim 3(10^{-11})$  level.

Depolarization considerations bring the raw simulation results to around  $\sim 1(10^{-11})$  right around our desired limit.

# 9309: Gem Rot Stepper Bearings

*Backgrounds that hit detector '28'*

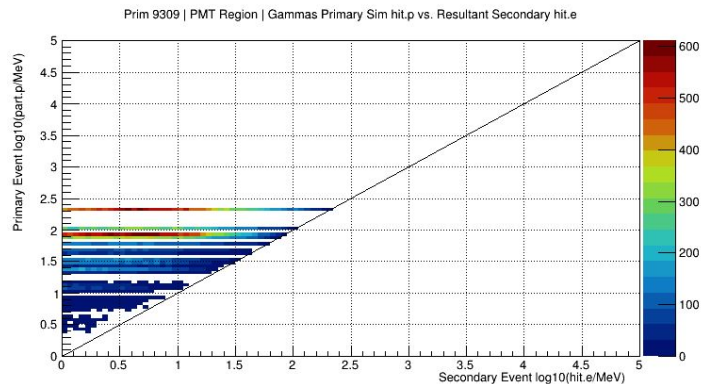
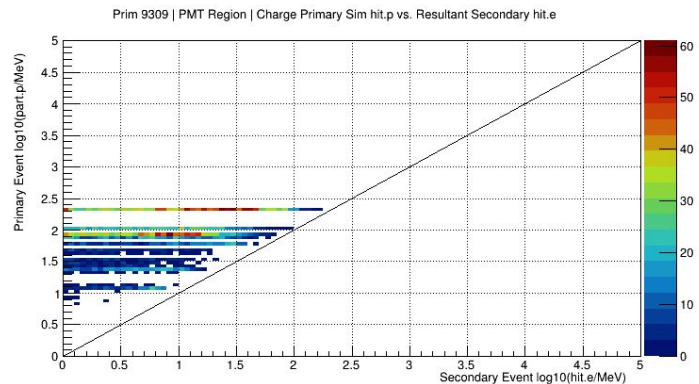
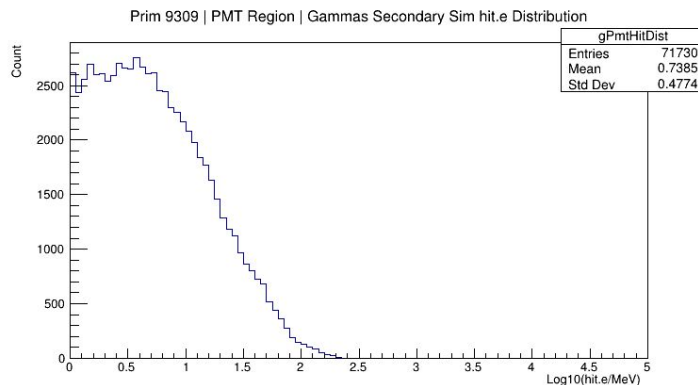
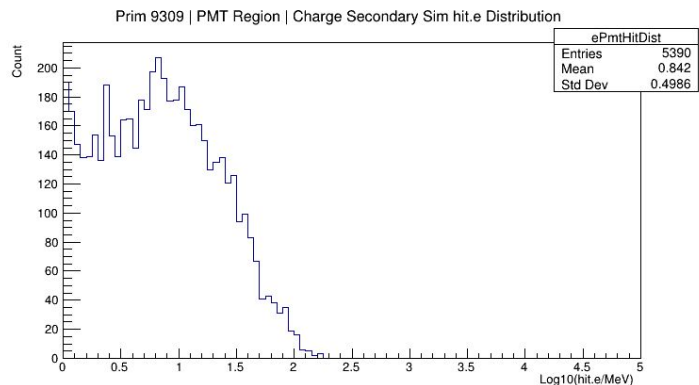
**NEW**



# 9309: Gem Rot Stepper Bearings

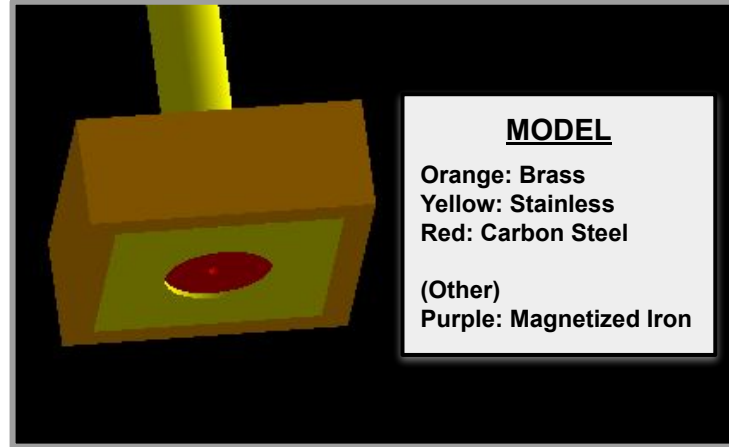
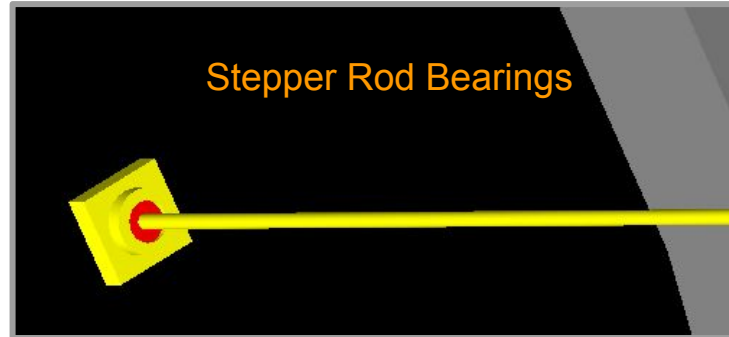
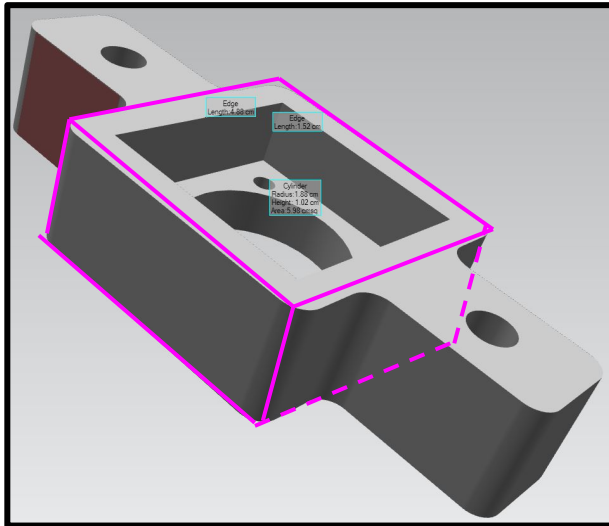
*Backgrounds that hit PMT Region*

**NEW**

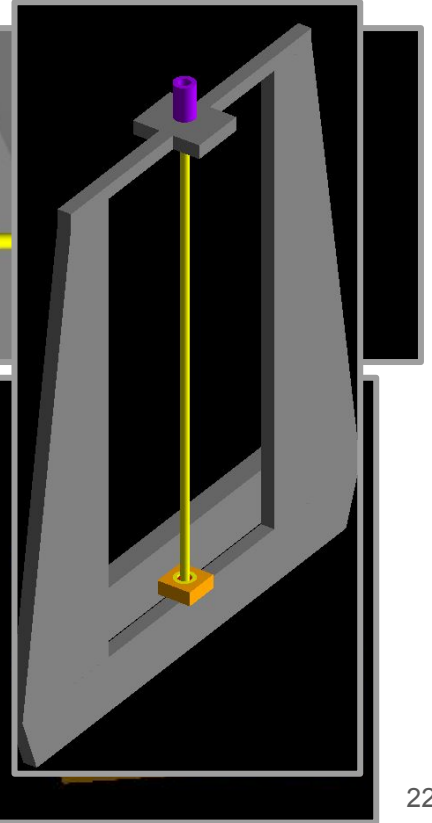


# 9309 – GEM Rotator Stepper Bearings (with plane frame & holder)

- Brass bearing holders added in simulation.
- Modeled the bearing holders as G4\_BRASS
- Only modeled portion outlined in magenta here.



<u>MODEL</u>
Orange: Brass
Yellow: Stainless
Red: Carbon Steel
(Other)
Purple: Magnetized Iron



# 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

## With Brass Holder

Sens Volume:	GEM Rotator Stepper Bearings
Sim Date:	12/12/2023
Detector #:	9309

GEM Rotator Stepper Bearings -- W/ BRASS BEARING HOLDER -- Unweighted

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

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

### Primary Counts

Primaries	0	0&1
9309		57

### Primary Fractional

Primaries	0	0&1
9309		2.85E-09

### (9928 MainDet) Secondary Counts - 0&1

Secondaries	Electrons	Gammas
9309	2440	20293

### (9928 MainDet) Secondary Fractional - 0&1

Secondaries	Electrons	Gammas
9309	4.88E-03	4.06E-02

### (9928 MainDet) Total Fractional - 0&1

Secondaries	Electrons	Gammas
9309	1.39E-11	1.16E-10

### (9911 PMT Region) Secondary Counts - 0&1

Secondaries	Electrons	Gammas
9309	6031	79182

### (9911 PMT Region) Secondary Fractional - 0&1

Secondaries	Electrons	Gammas
9309	1.21E-02	1.58E-01

### (9911 PMT Region) Total Fractional - 0&1

Secondaries	Electrons	Gammas
9309	3.44E-11	4.51E-10

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

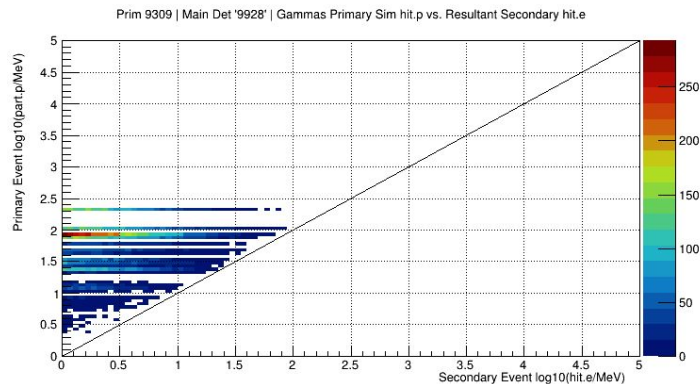
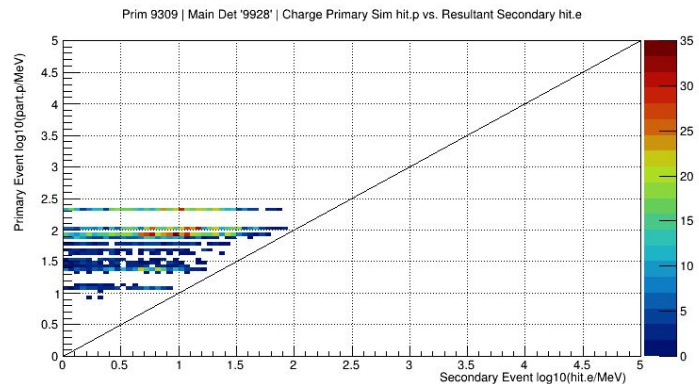
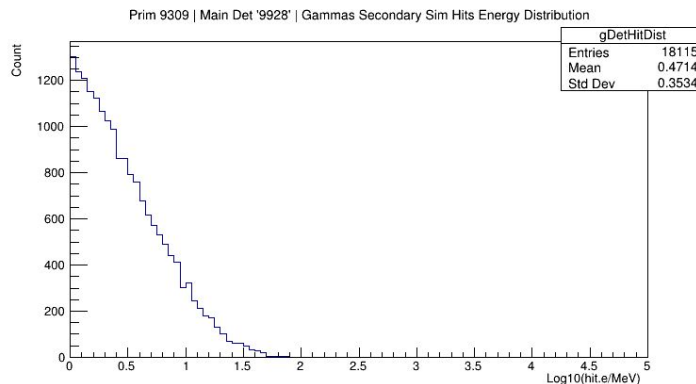
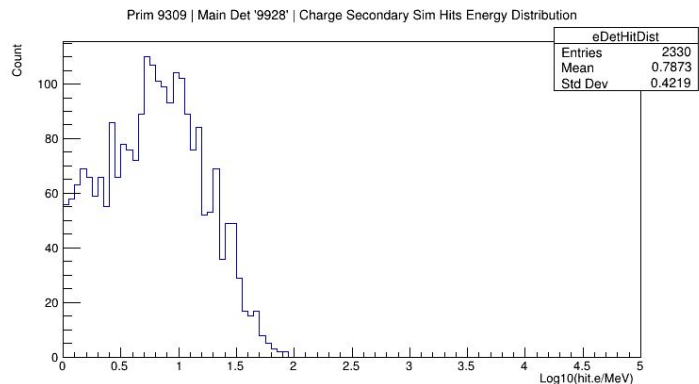
Raw simulation results give ferrous backgrounds at the  $\sim 1.4(10^{-11})$  level.

Depolarization considerations bring the raw simulation results to around  $\sim 5(10^{-12})$  which is below our tolerable limit.

# 9309: Gem Rot Stepper Bearings

*Backgrounds that hit detector '28'*

**With  
bearing  
holders**

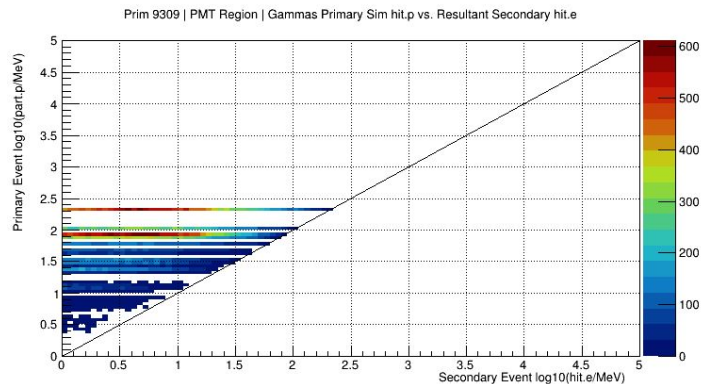
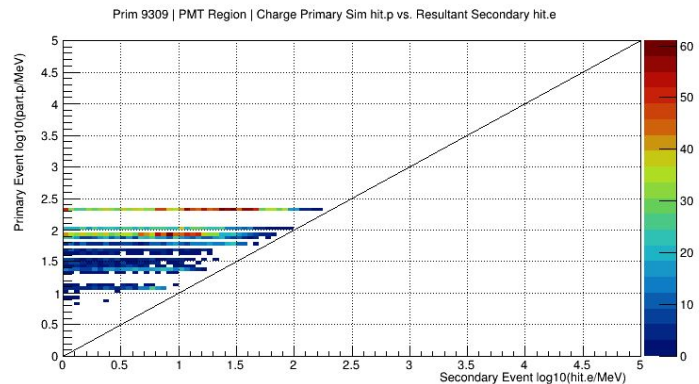
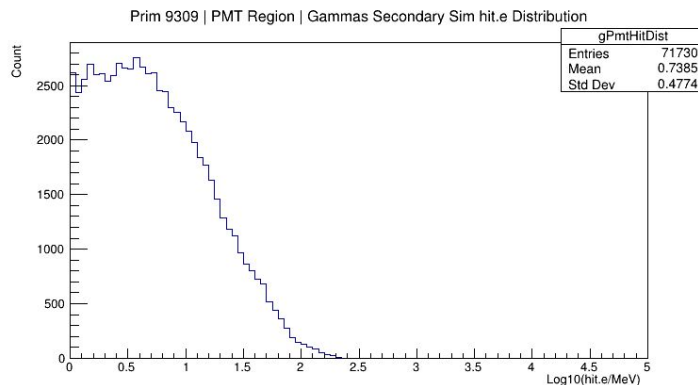
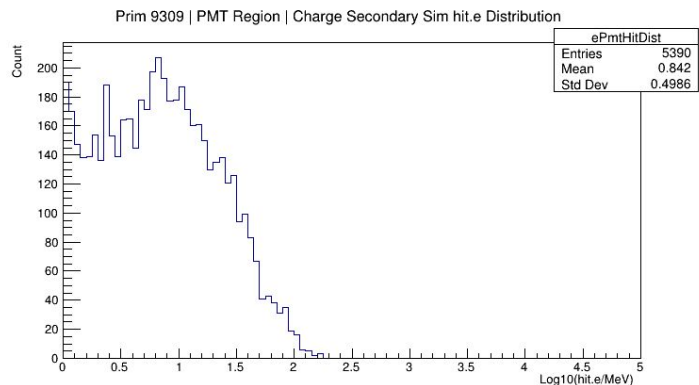




# 9309: Gem Rot Stepper Bearings

*Backgrounds that hit PMT Region*

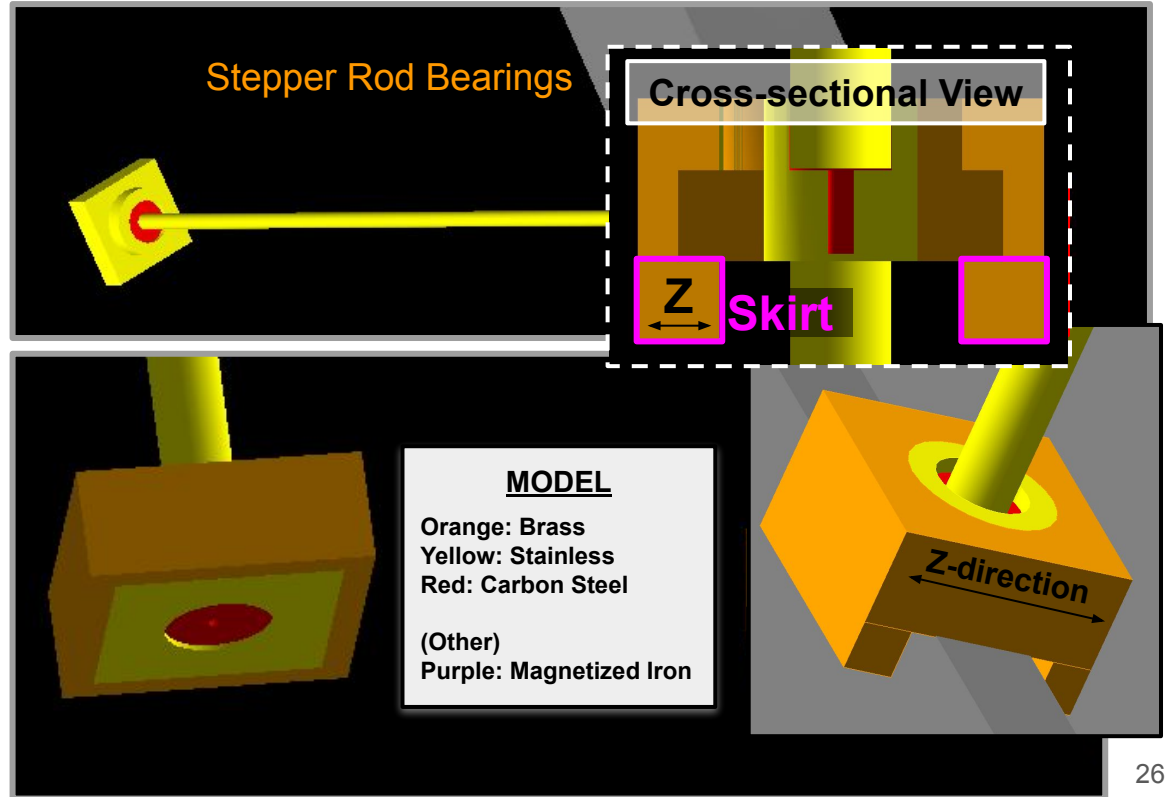
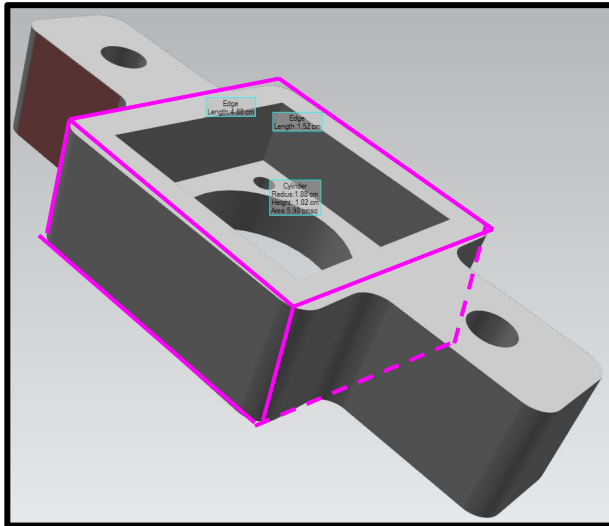
**With  
bearing  
holders**



# 9309 – GEM Rotator Stepper Bearings (with frame & holder+skirt)

- Brass bearing holders added in sim
- Small skirt added to sides

NOTE: Skirt z-thickness as positioned is 2x thicker than outerwall. This was an oversight on my part as I intended on same thickness (forgot to divide outer minus inner dimensions by 2).



# 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

## With Brass Holder+Skirt

Sens Volume:	GEM Rotator Stepper Bearings
Sim Date:	12/13/2023
Detector #:	9309

GEM Rotator Stepper Bearings -- W/ SKIRTED BRASS BEARING HOLDER -- Unwel

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

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

Primary Counts		
Primaries		O&1
9309	0	36

Primary Fractional		
Primaries		O&1
9309	0	1.80E-09

(9928 MainDet) Secondary Counts - O&1		
Secondaries	Electrons	Gammas
9309	929	8840

(9928 MainDet) Secondary Fractional - O&1		
Secondaries	Electrons	Gammas
9309	1.86E-03	1.77E-02

(9928 MainDet) Total Fractional - O&1		
Secondaries	Electrons	Gammas
9309	3.34E-12	3.18E-11

(9911 PMT Region) Secondary Counts - O&1		
Secondaries	Electrons	Gammas
9309	2096	27507

(9911 PMT Region) Secondary Fractional - O&1		
Secondaries	Electrons	Gammas
9309	4.19E-03	5.50E-02

(9911 PMT Region) Total Fractional - O&1		
Secondaries	Electrons	Gammas
9309	7.55E-12	9.90E-11

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

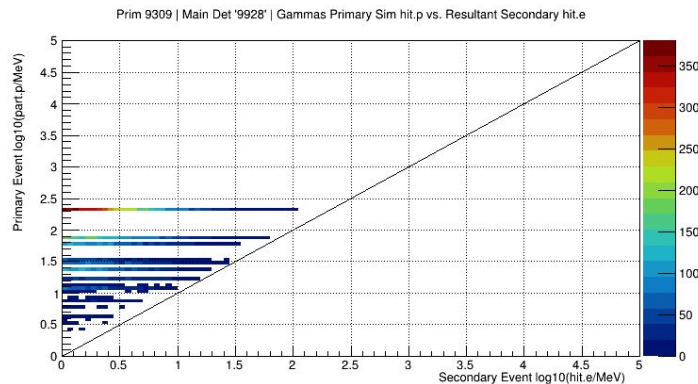
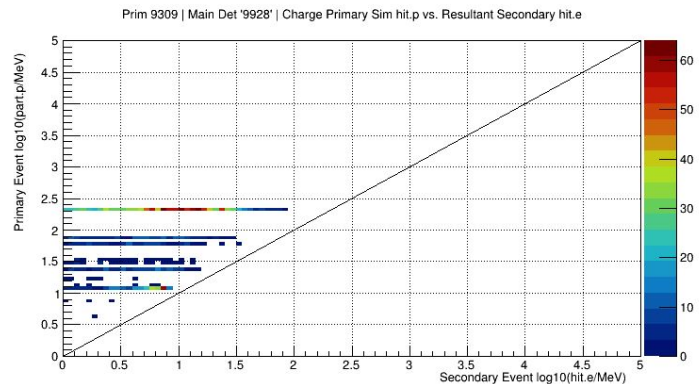
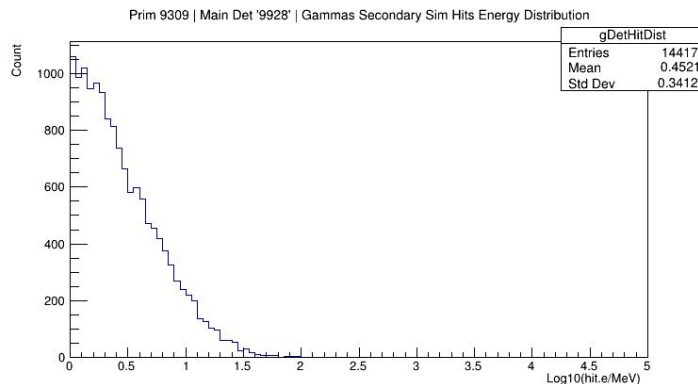
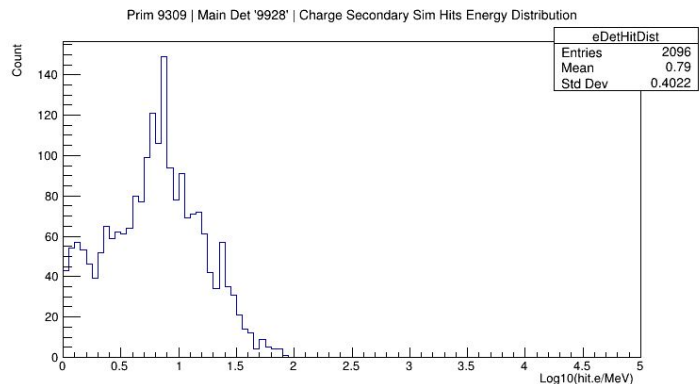
Raw simulation results give ferrous backgrounds at the  $\sim 3.3(10^{-12})$  level.

Depolarization considerations bring the raw simulation results to around  $\sim 1(10^{-12})$  which would be below our tolerable limit.

# 9309: Gem Rot Stepper Bearings

*Backgrounds that hit detector '28'*

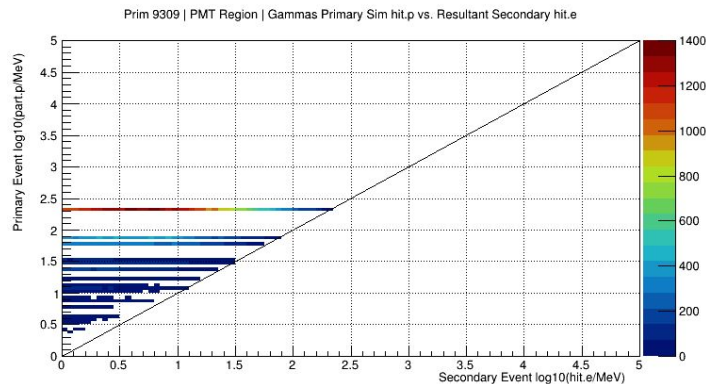
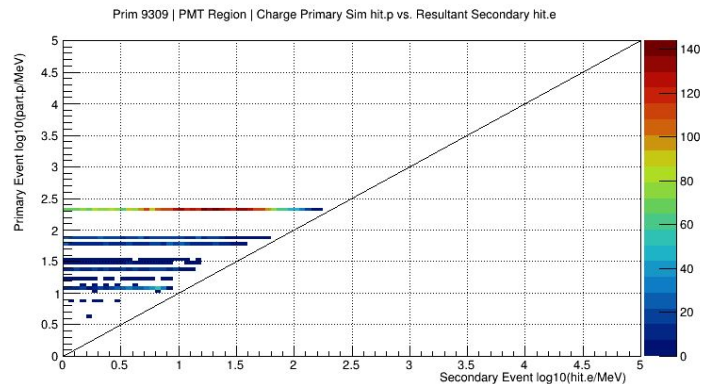
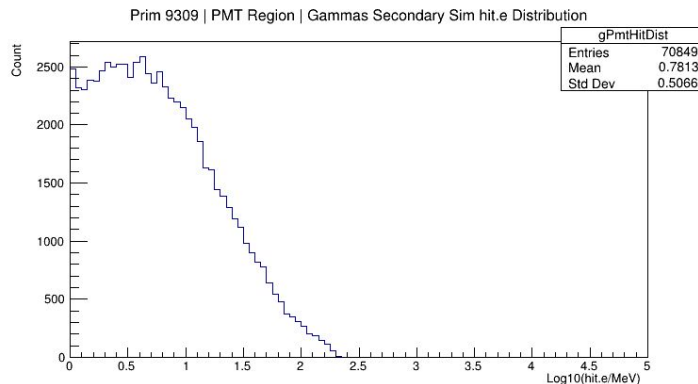
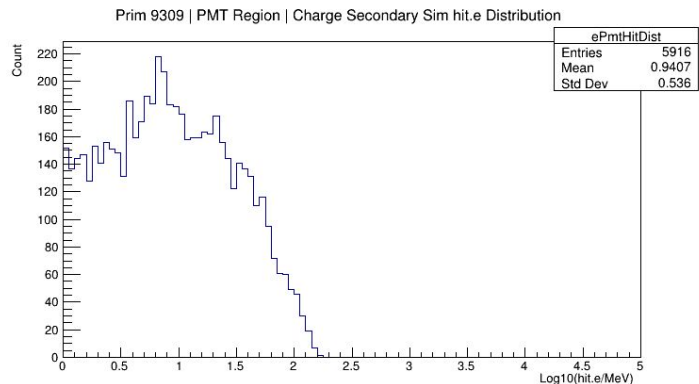
**With  
bearing  
holders  
+skirt**



# 9309: Gem Rot Stepper Bearings

*Backgrounds that hit PMT Region*

**With  
bearing  
holders  
+skirt**



Takeaway:

# Stepper Drive Bearings

	Partial Wheel	⇒	Full Wheel	⇒	Brass Holders	⇒	Skirted Holders
Raw	<b>1.5(10<sup>-10</sup>)</b>		<b>2.5(10<sup>-11</sup>)</b>		<b>1.4(10<sup>-11</sup>)</b>		<b>3.3(10<sup>-12</sup>)</b>
Depolz'n Consideration	<b>~4(10<sup>-11</sup>)</b>		<b>~1(10<sup>-11</sup>)</b>		<b>~5(10<sup>-12</sup>)</b>		<b>~1(10<sup>-12</sup>)</b>

→ Making the holders out of brass with specs in JT file should be sufficient.

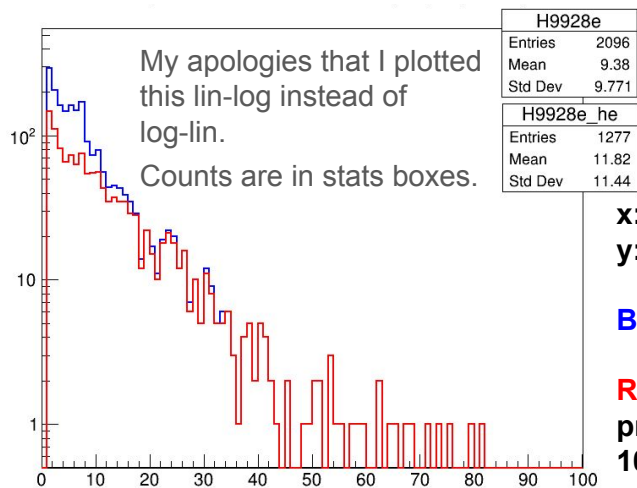
However, if we want to put a nail in the coffin on the issue adding an additional skirt to brass holders is probably the way to go. A thickness of 7.5mm of brass should have enough stopping power to attenuate about 60 MeV of e<sup>-</sup> energy.

# Stepper Drive Bearings

Takeaway (cont'd):

[My very cautious side] I would push to add a skirt (as thick in z as possible) to these as I'm not sure how great our sampling of high-energy primary events is with these particular MC seeds.

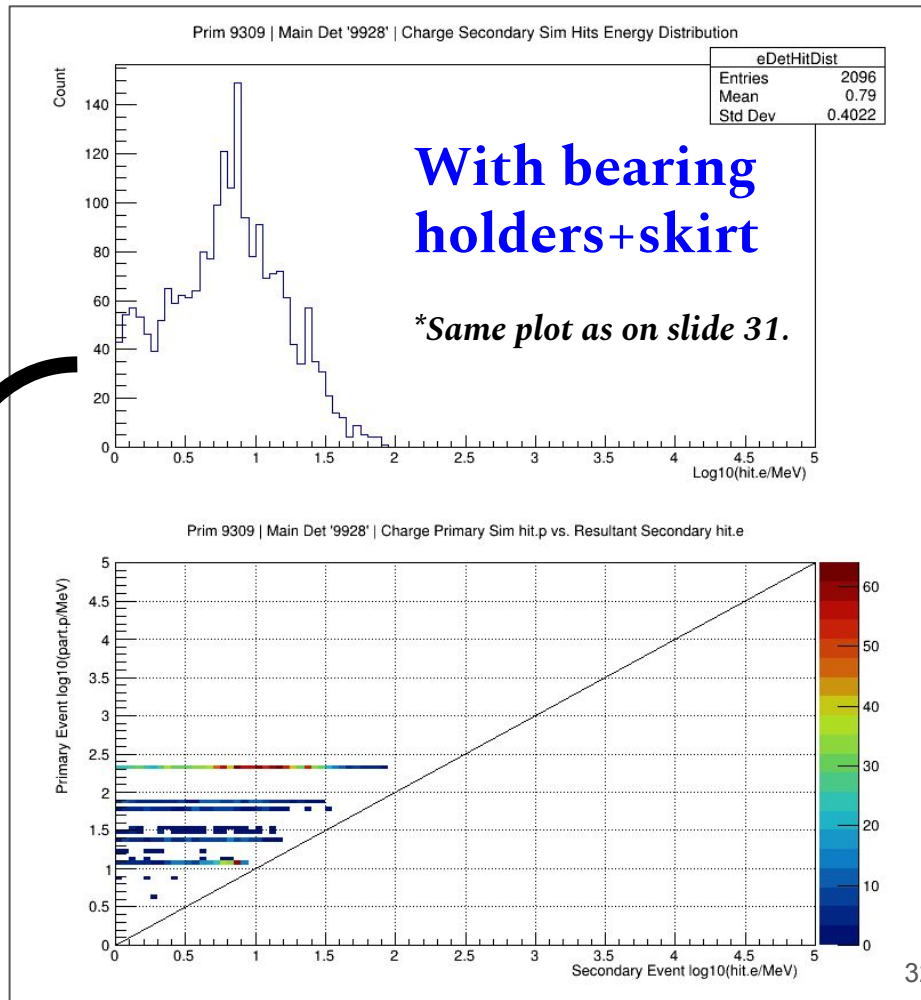
And then, the effect of asymmetric toroid fields???



**x: hit.e (MeV)**  
**y: count**

**Blue, all charges**

**Red, charges with primary above 100MeV (> 50%)**





# Stepper Motors

Total fractional charges per e.o.t:

On the order of  $10^{-15}$

Mass scaling for the actual iron mass inside motors (currently modeled as about 33% of total mass) will not affect this in any way that brings the ferrous background above our stated maximum thresholds.

An increase of 3x the mass would even out with depolarization considerations.

(9928 MainDet) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9305	4.50E-15	3.15E-14

(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9305	1.80E-14	1.46E-13

# Reference (Old Results):

Just for review if there are  
questions

# Stepper Motors (Previous 10/31/23 Results)

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

# 9305: GEM Stepper Motors

**\*\*Reminder as to where we were\*\***

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 Motors
Sim Date:	10/31/2023
Detector #:	9305

\*Simulation with wheel and frame mass (G4\_Al)

## Previous

### GEM Rotator Stepper Motors -- Unweighted By BField

Total Prim's:	20,000,000,000	Total Sec's:	500,000	(per sens det)
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Primary Counts			Primary Fractional		
Primaries	0	0&1	Primaries	0	0&1
9305		57	9305		2.85E-09

(9928 MainDet) Secondary Counts - 0&1			(9928 MainDet) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas	Secondaries	Electrons	Gammas
9305	560	49	9305	1.12E-03	9.80E-05

(9911 PMT Region) Secondary Counts - 0&1			(9911 PMT Region) Secondary Fractional - 0&1		
Secondaries	Electrons	Gammas	Secondaries	Electrons	Gammas
9305	2092	203	9305	4.18E-03	4.06E-04

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.

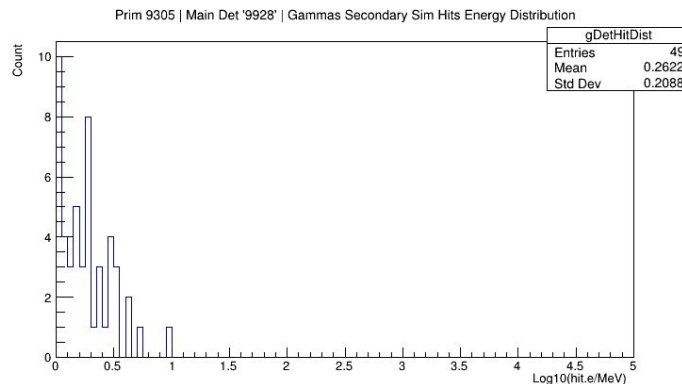
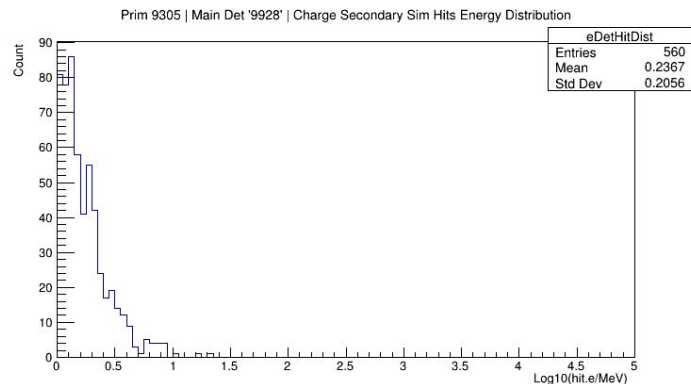
However, with depolarization considerations we can take off a factor of 3 which puts us at the tolerable limit.

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

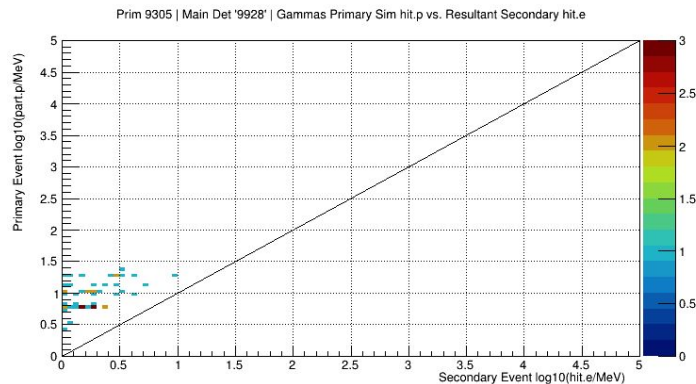
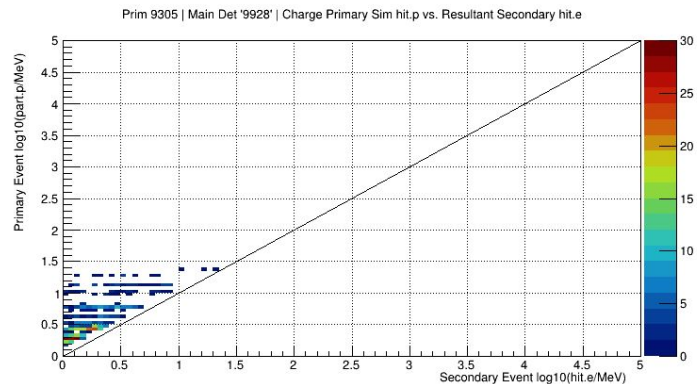
(9911 PMT Region) Total Fractional - 0&1		
Secondaries	Electrons	Gammas
9305	1.19E-11	1.16E-12

# 9305: Gem Rotator Stepper Motors

*Backgrounds that hit detector '28'*



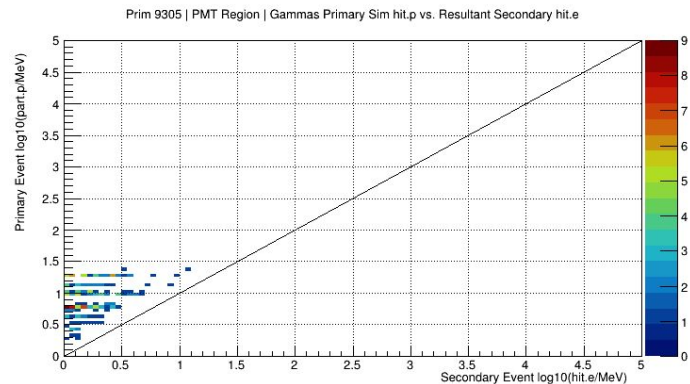
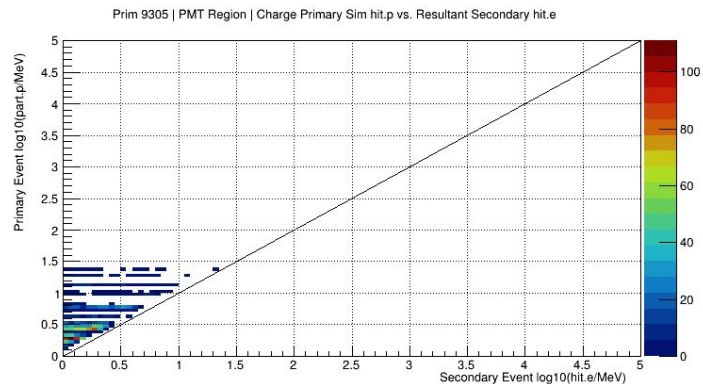
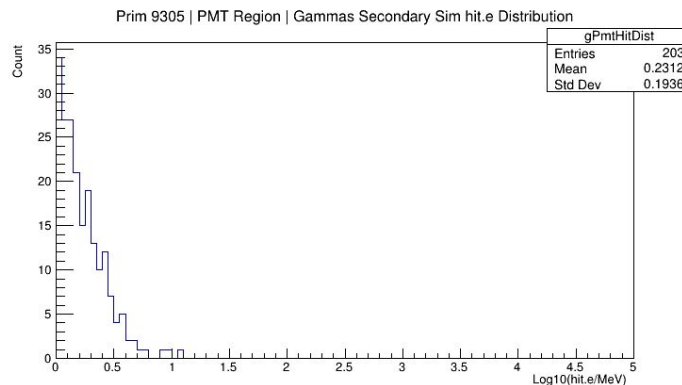
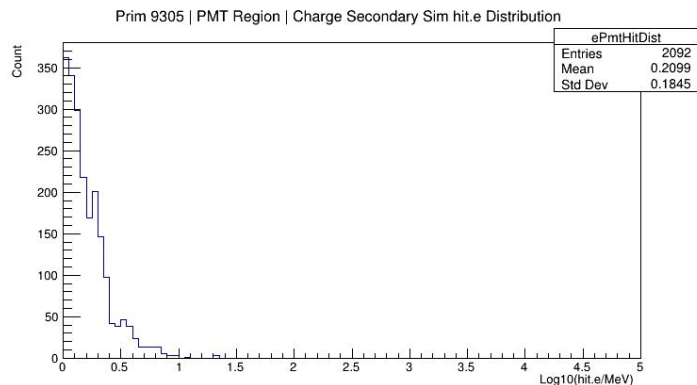
Prev



# 9305: Gem Rotator Stepper Motors

*Backgrounds that hit PMT Region*

Prev



# Stepper Drive Bearings (Previous 10/31/23 Results)

# 9309: Gem Rot Stepper Bearings

**\*\*Reminder as to where we were\*\***

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)

## Previous

### 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  $\sim 1(10^{-10})$  level.

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

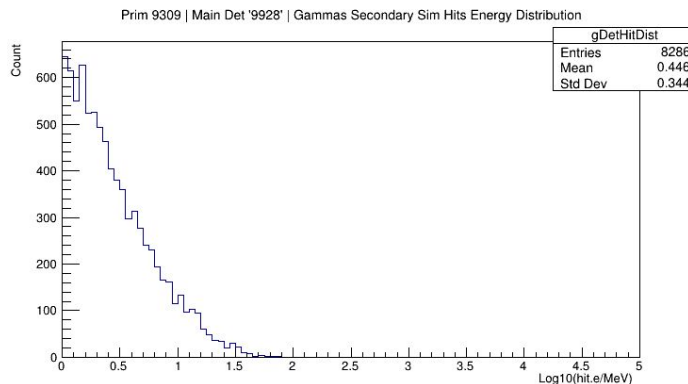
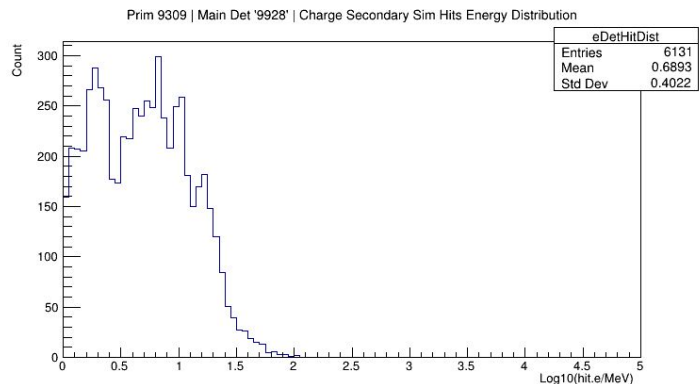
There are additional materials which can be modeled.



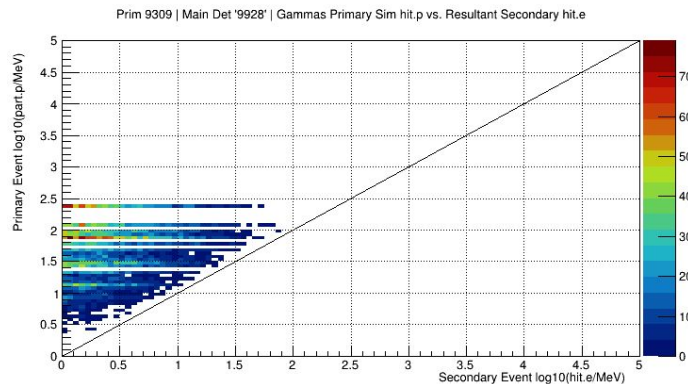
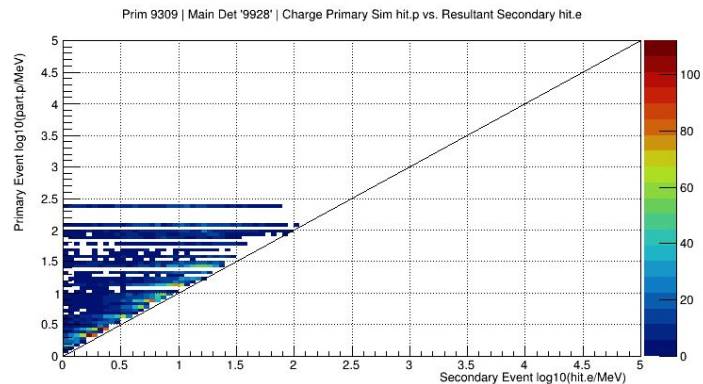
# 9309: Gem Rot Stepper Bearings

*Backgrounds that hit detector '28'*

**\*\*Reminder as to where we were\*\***



**Prev**



# 9309: Gem Rot Stepper Bearings

*Backgrounds that hit PMT Region*

**\*\*Reminder as to where we were\*\***

**Prev**

