# Ferrous Materials:

## GEM Rotator

Eric King

Last Updated:

10-13-2023

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)

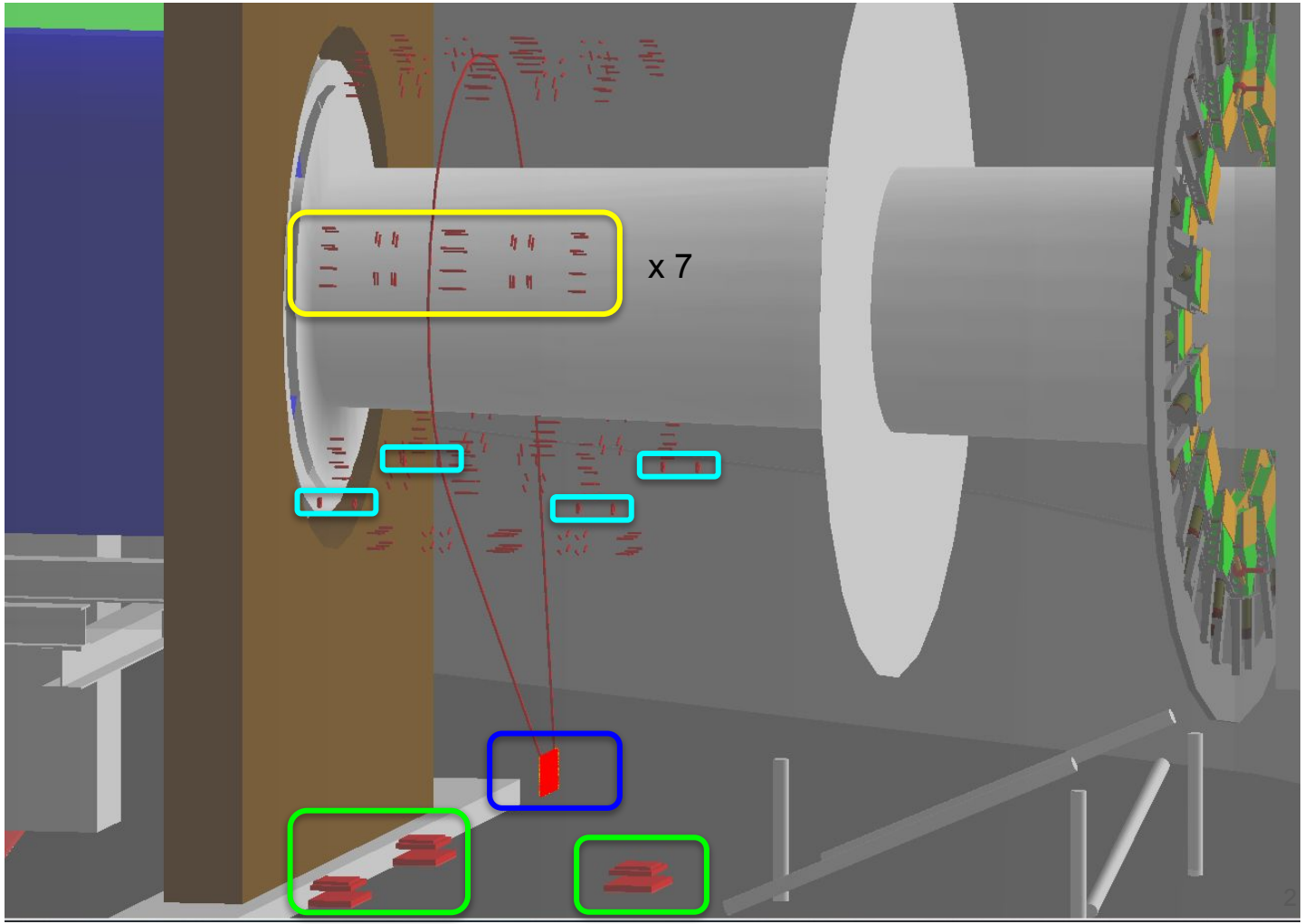
- Material specifics unknown, assume full magnetization 8%

Chain (long thing)

- Is overmodeled, SS316

Fasteners (yellow)

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



Broad Overview (Cont'd)

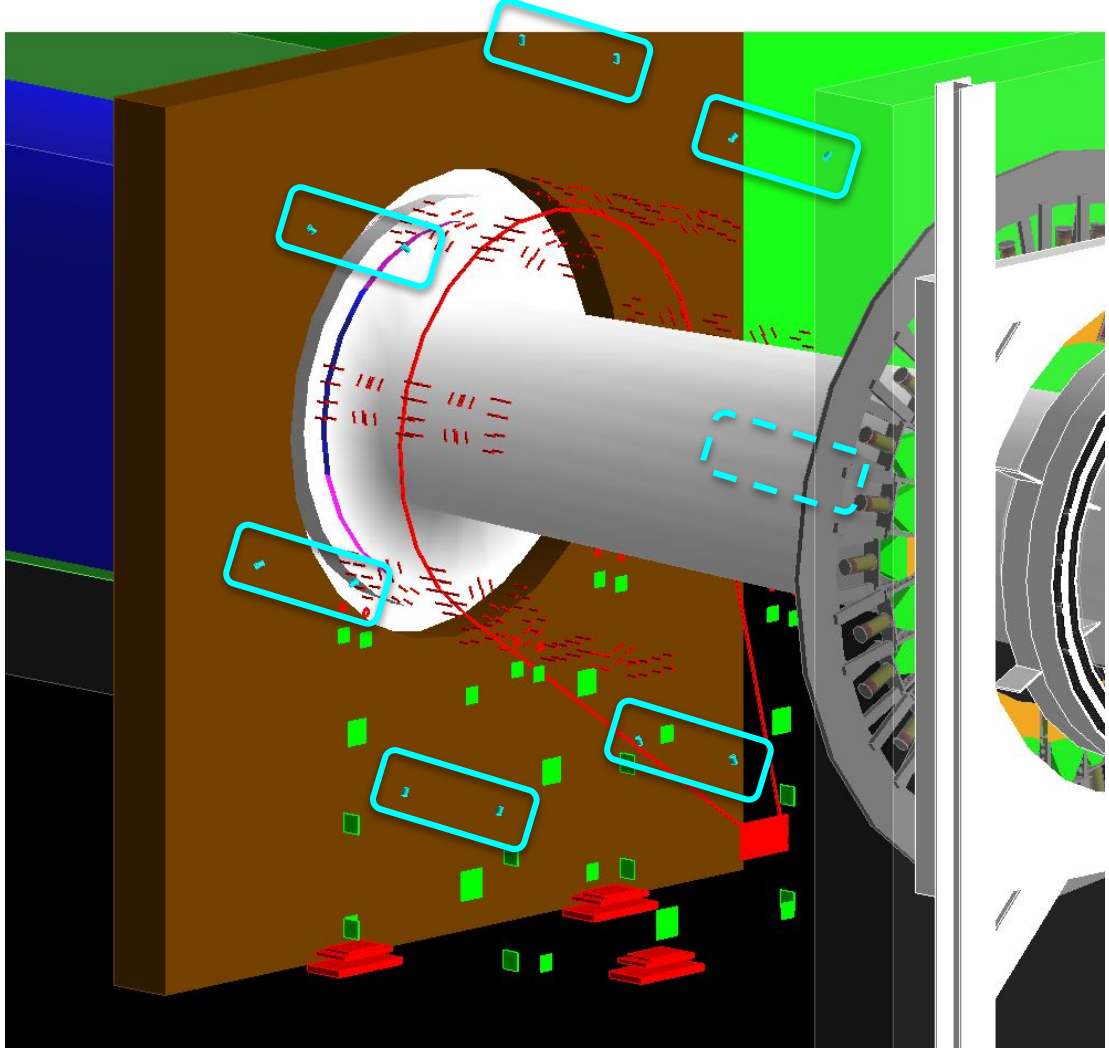
The GEM Rotator items added since previous slide now include:

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



# 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

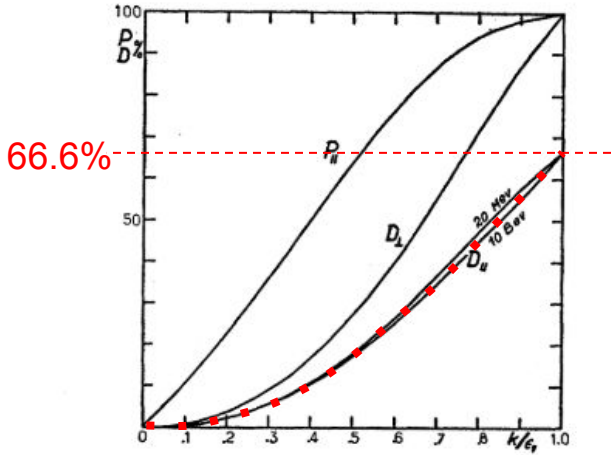



FIG. 5. Circular polarization of bremsstrahlung beam from longitudinally polarized electrons,

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

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

| 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 |

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 |

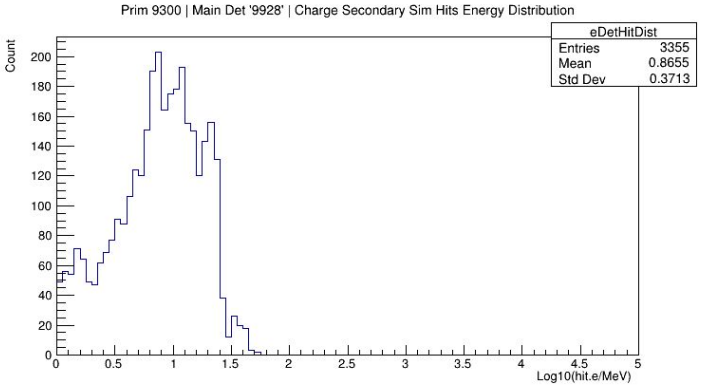
| (9911 PMT Region) Secondary Counts - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9300 | 12710 | 23089 |

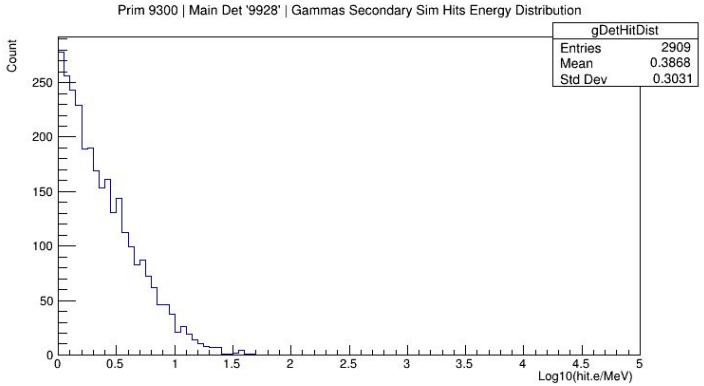
| (9911 PMT Region) Secondary Fractional - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9300 | 2.54E-02 | 4.62E-02 |

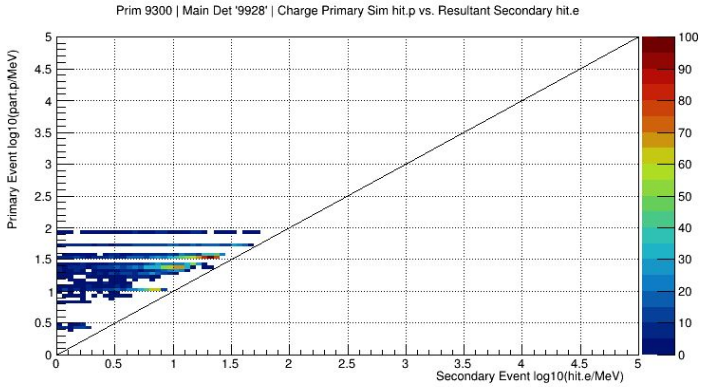
| (9911 PMT Region) Total Fractional - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9300 | 1.78E-10 | 3.23E-10 |

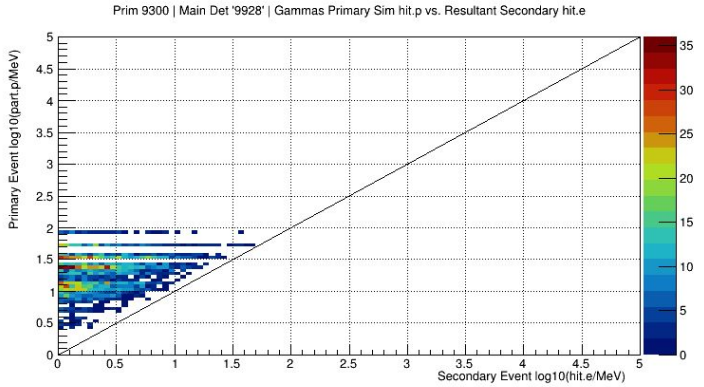
# 9300: GEM Rotator Roller Bearings

***Backgrounds that hit detector '28'***



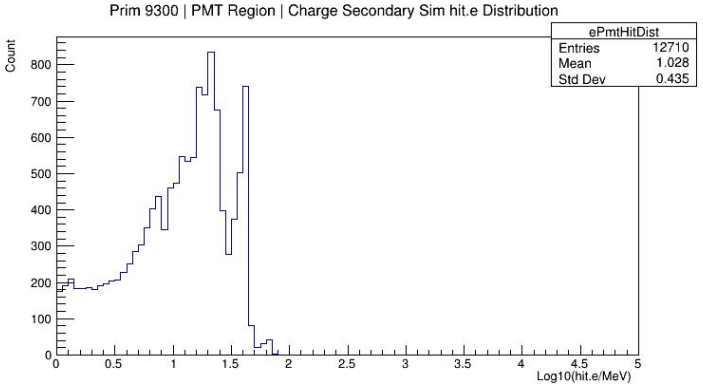



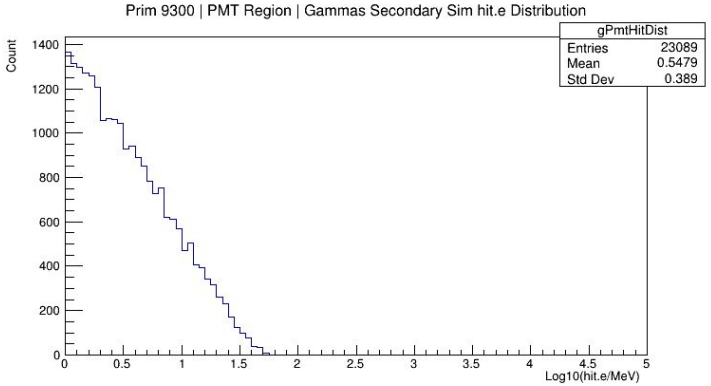



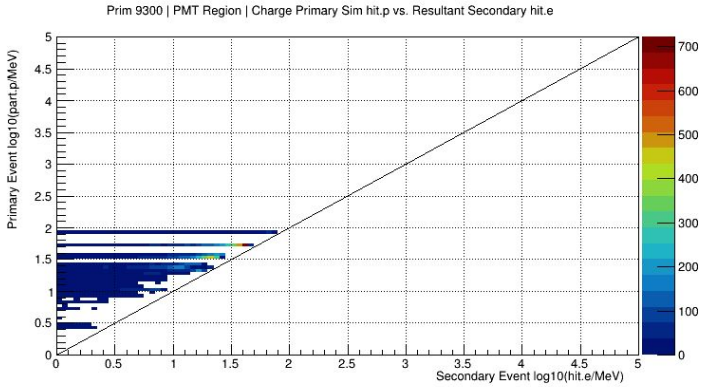



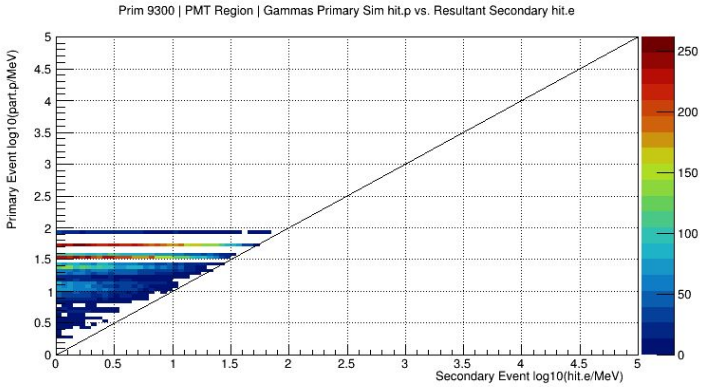
# 9300: GEM Rotator Roller Bearings

***Backgrounds that hit PMT Region***



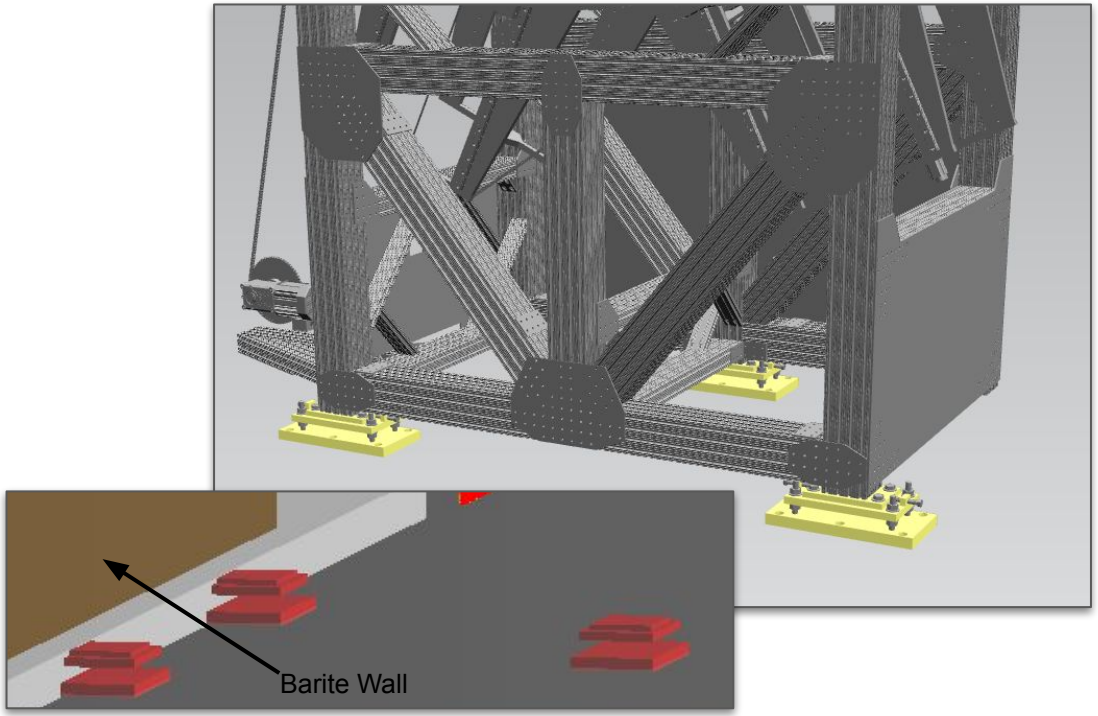



# 9301 – GEM Rotator Floor Locks

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 |

(From my notes after talking with David I simply noted these as “steel”)

⇒ If the plates are made of stainless steel then the ferrous backgrounds fall far below concernable limits.

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

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 |

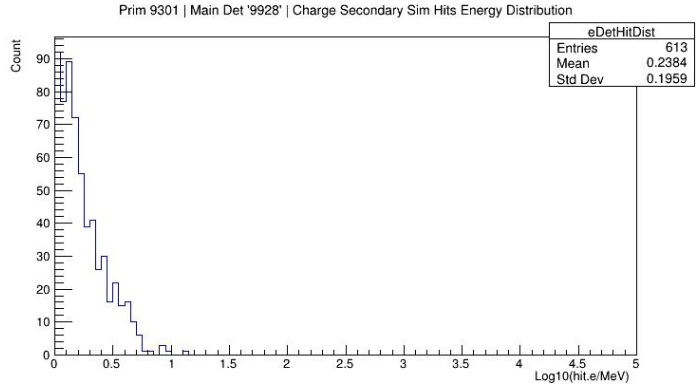
| (9911 PMT Region) Secondary Counts - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9301 | 3052 | 339 |

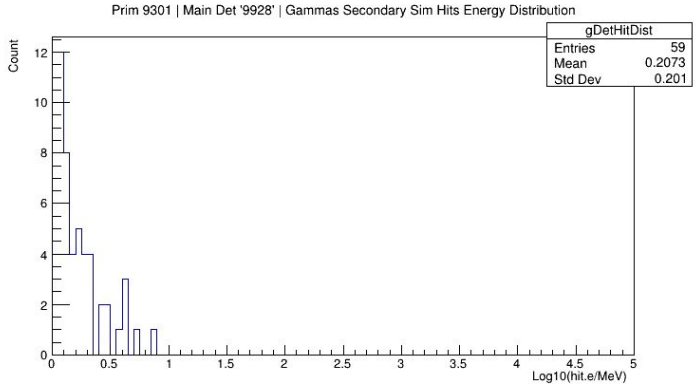
| (9911 PMT Region) Secondary Fractional - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9301 | 6.10E-03 | 6.78E-04 |

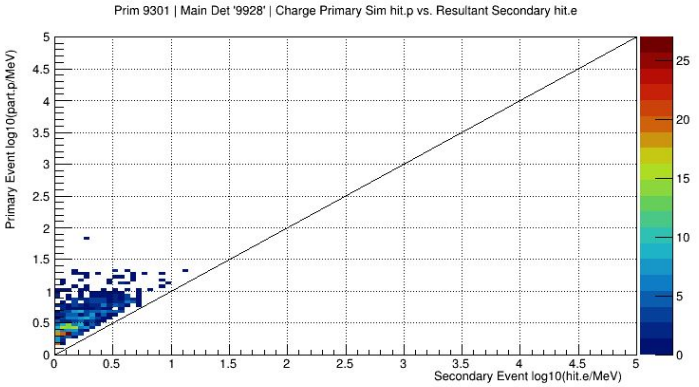
| (9911 PMT Region) Total Fractional - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9301 | 1.47E-10 | 1.64E-11 |

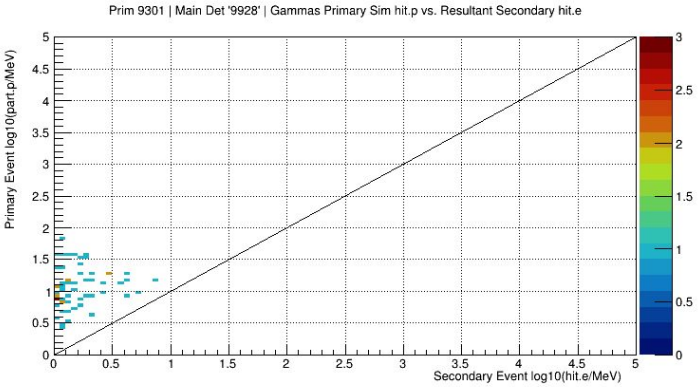
# 9301: GEM Rotator Floor Locks

***Backgrounds that hit detector '28'***



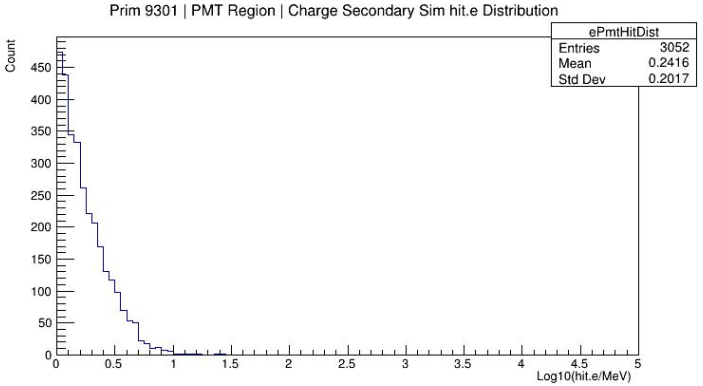



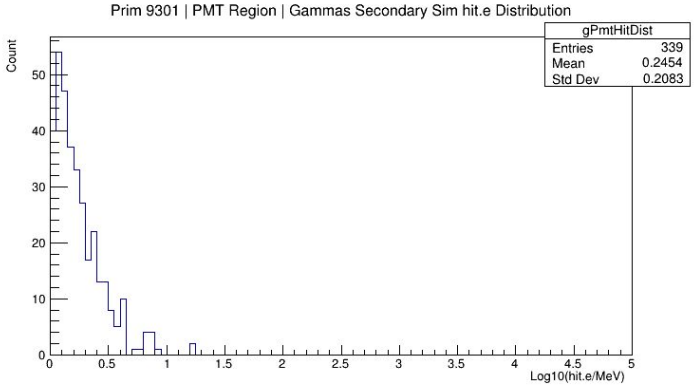



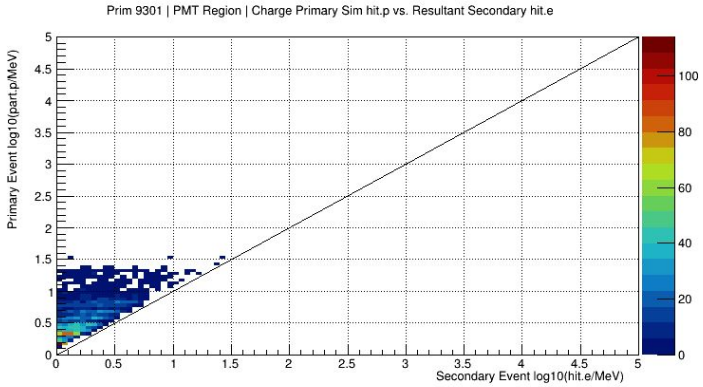



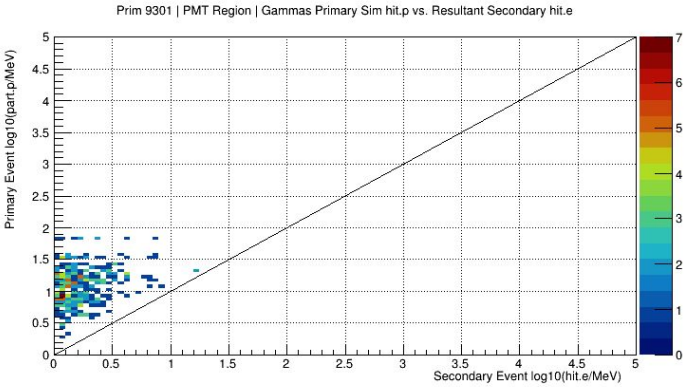
# 9301: GEM Rotator Floor Locks

***Backgrounds that hit PMT Region***



# 9302 – GEM Rotator Gear Motor

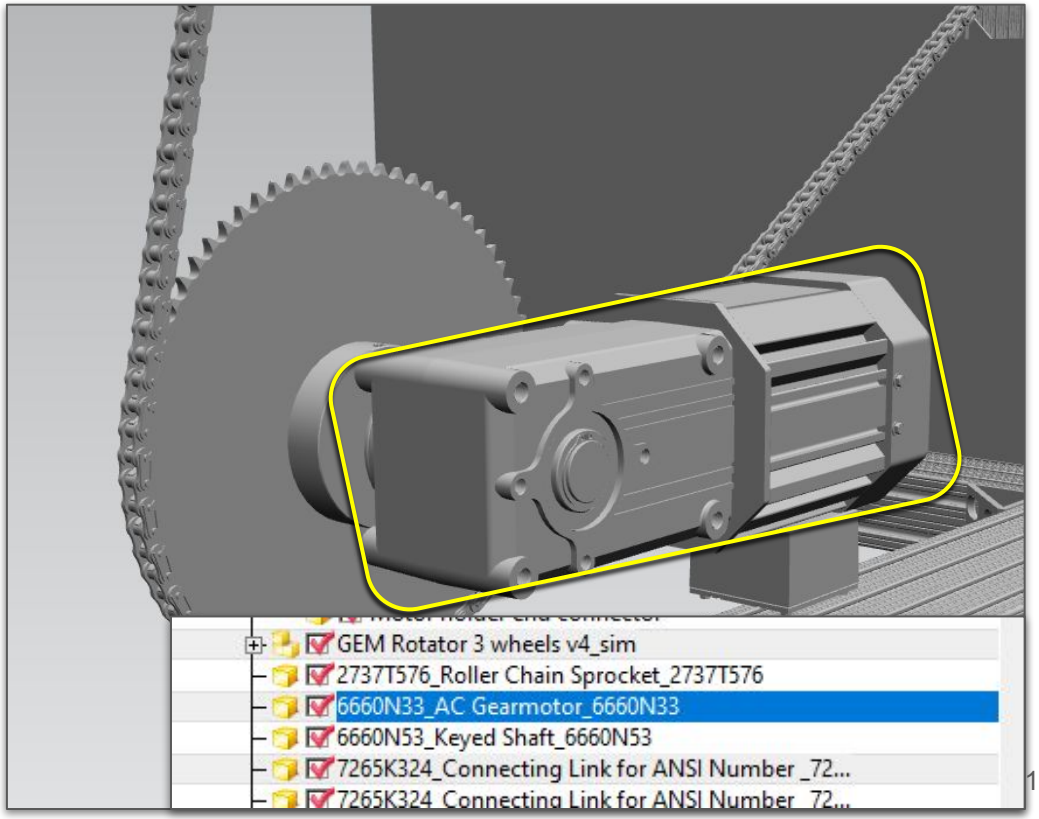
I went with a simple toy model for the GEM Rotator motor at this point.

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.



# 9302: GEM Rotator Gear Motor

| 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 |

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

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.

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

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 |

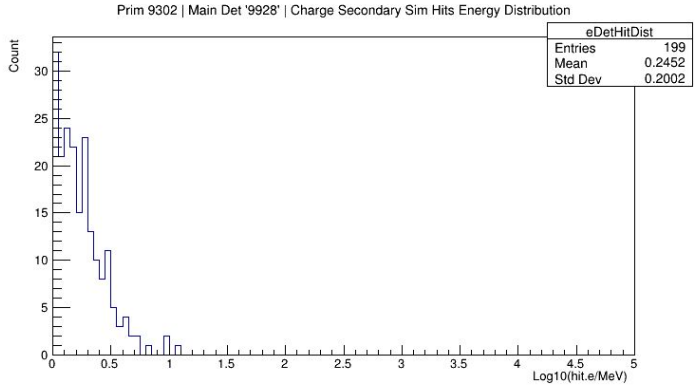
| (9911 PMT Region) Secondary Counts - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9302 | 1044 | 235 |

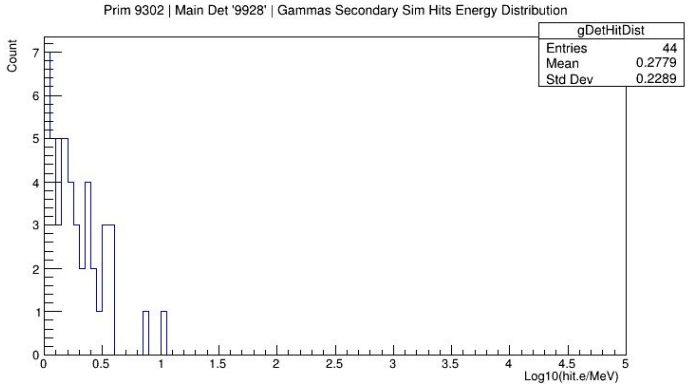
| (9911 PMT Region) Secondary Fractional - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9302 | 2.09E-03 | 4.70E-04 |

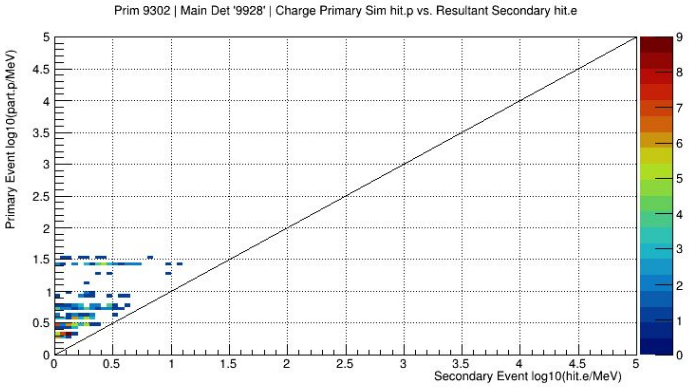
| (9911 PMT Region) Total Fractional - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9302 | 5.43E-12 | 1.22E-12 |

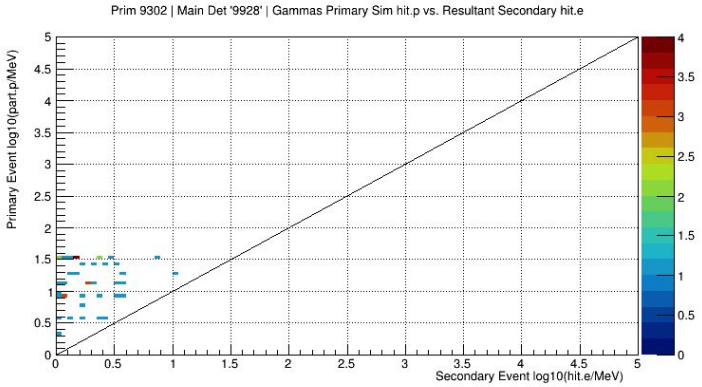
# 9302: GEM Rotator Gear Motor

***Backgrounds that hit detector '28'***



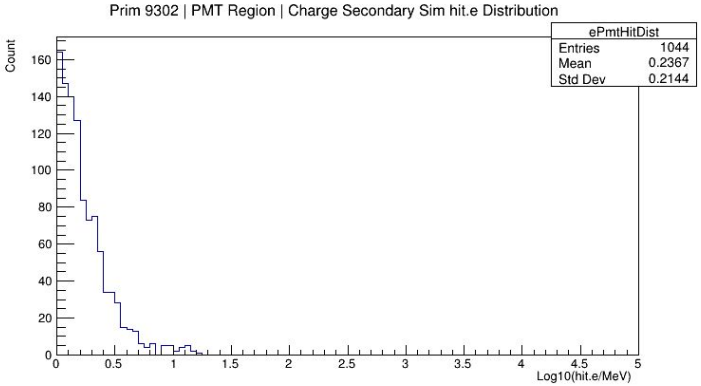



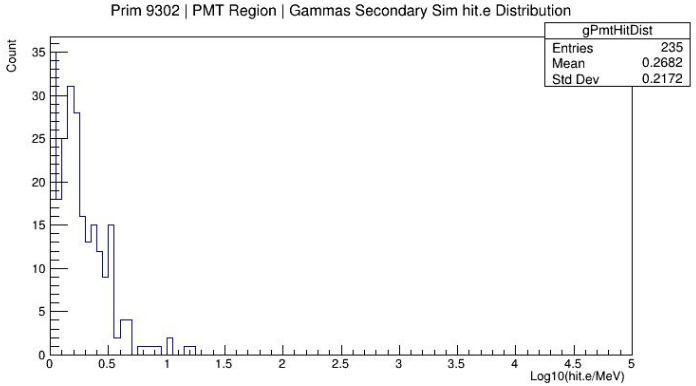



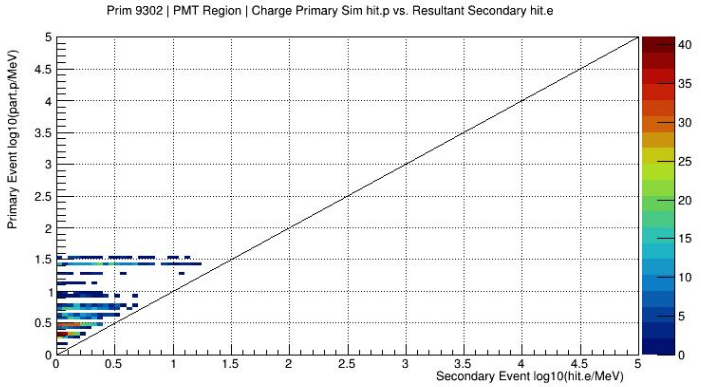



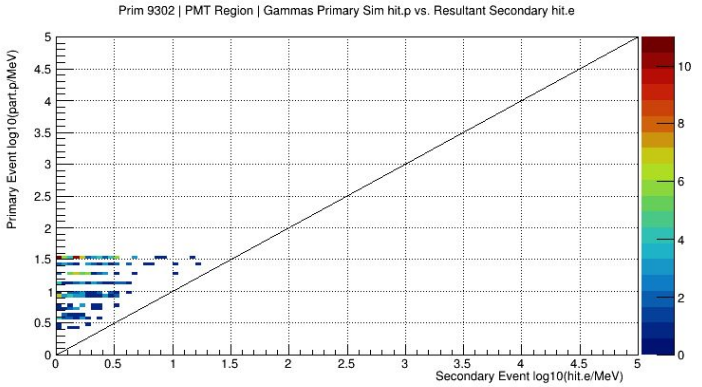
# 9302: GEM Rotator Gear Motor

***Backgrounds that hit PMT Region***



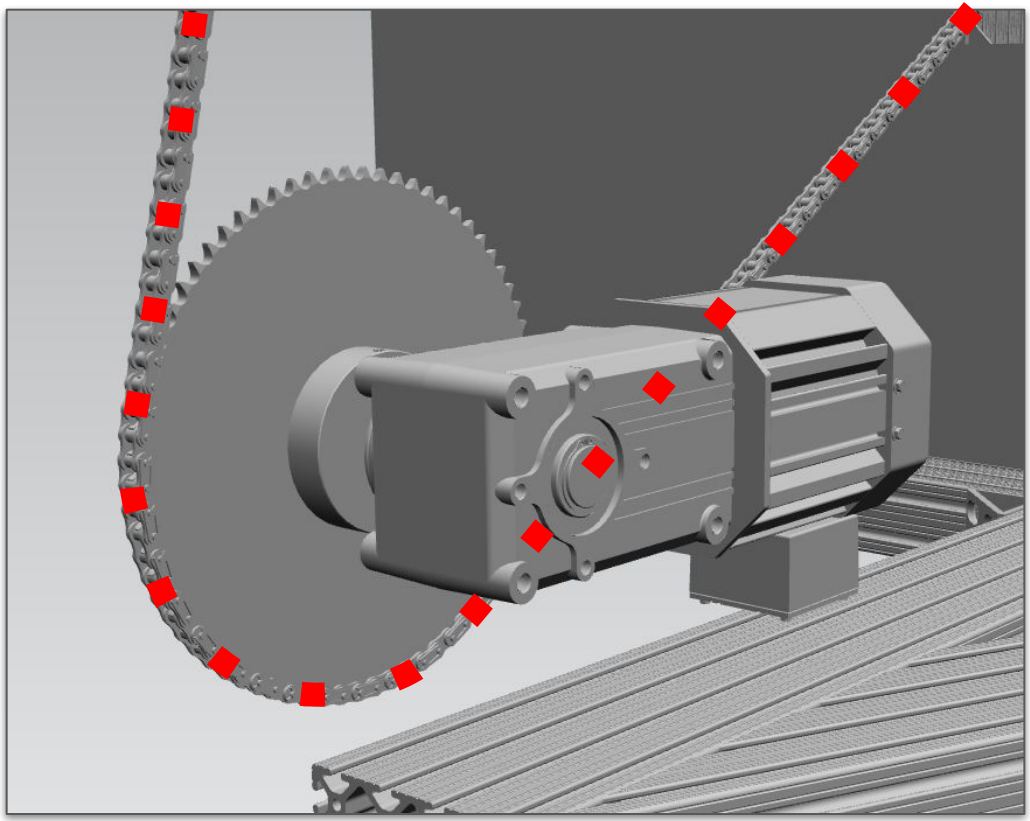
# 9303 – GEM Rotator Chain

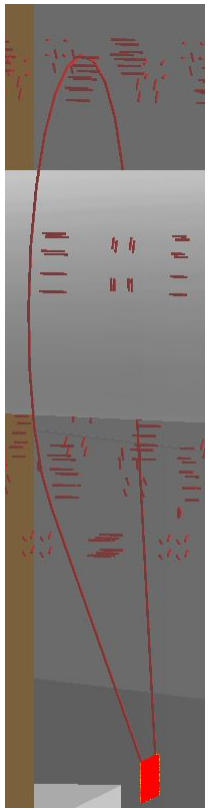
12mm high x 10mm deep

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 |

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 |

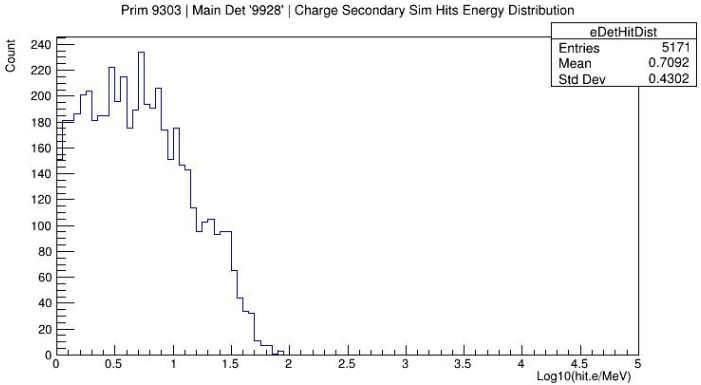
| (9911 PMT Region) Secondary Counts - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9303 | 12962 | 19889 |

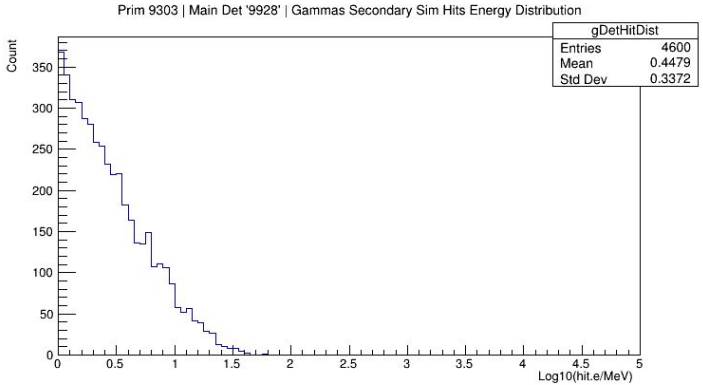
| (9911 PMT Region) Secondary Fractional - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9303 | 2.59E-02 | 3.98E-02 |

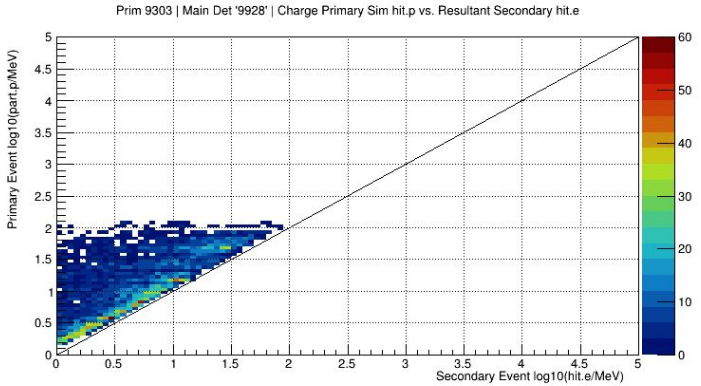
| (9911 PMT Region) Total Fractional - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9303 | 4.53E-09 | 6.95E-09 |

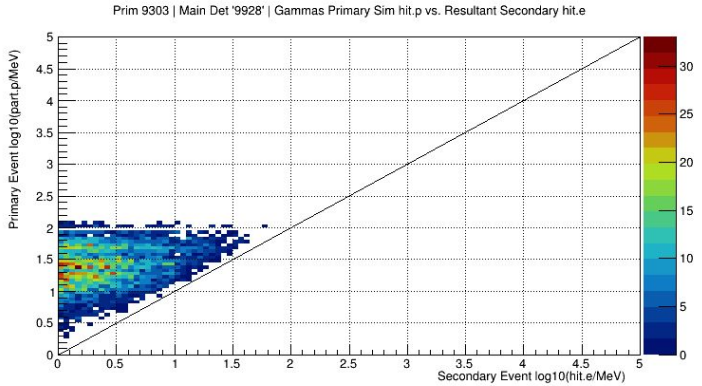
# 9303: GEM Rotator Chain

***Backgrounds that hit detector '28'***



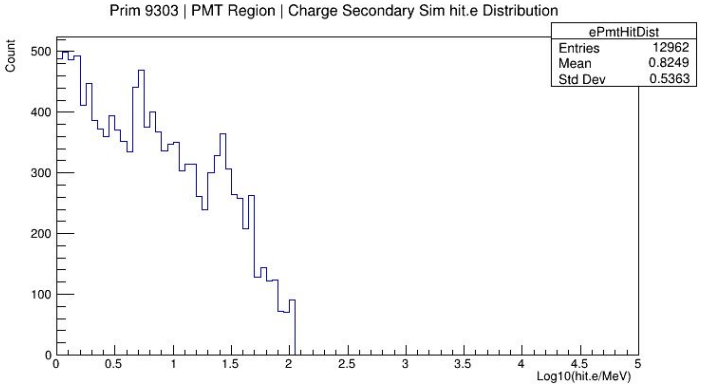



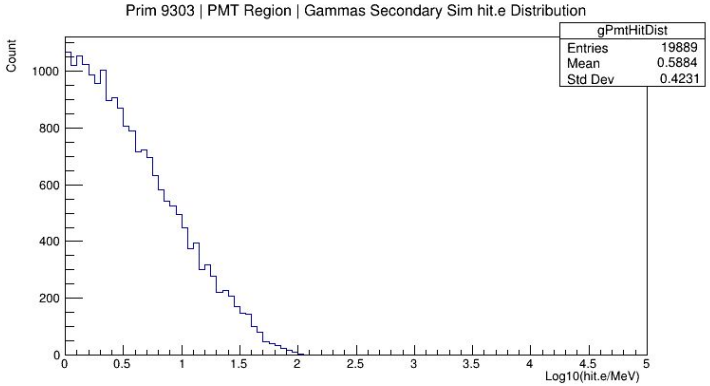



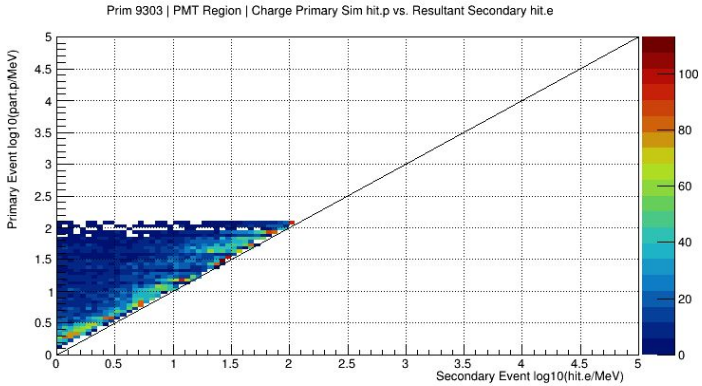



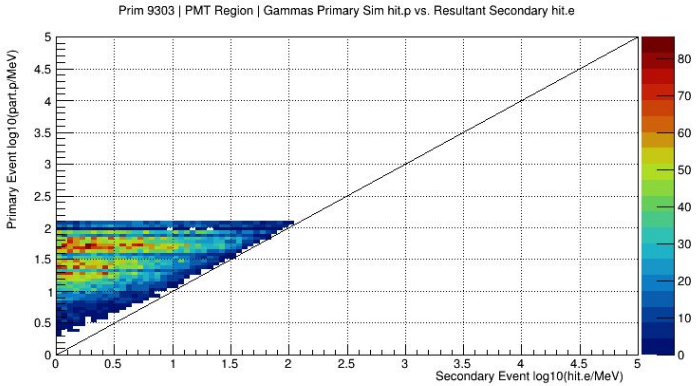
# 9303: GEM Rotator Chain

***Backgrounds that hit PMT Region***



# 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



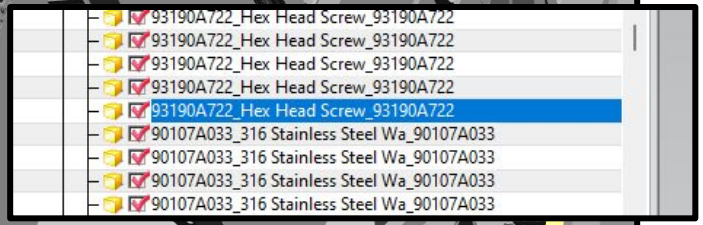




| | Agency | |
|---|---|---|
| FEAT | Special Features | Overall finish is plain |
| MATT | Material | Steel comp 316 overall |
| THSD | Thread Series Designator | UNC |

# 9304 – GEM Rotator Fasteners

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

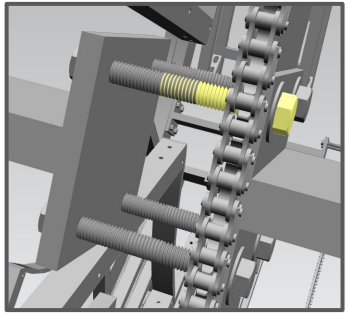






| | | |
|---|---|---|
| CMLP | Thread Quantity per Inch | 13 |
| MATT | Material | Steel comp 316 overall |
| MDCL | Material Document and Classification | Astm A193 assn std single mate |

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 |

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 |

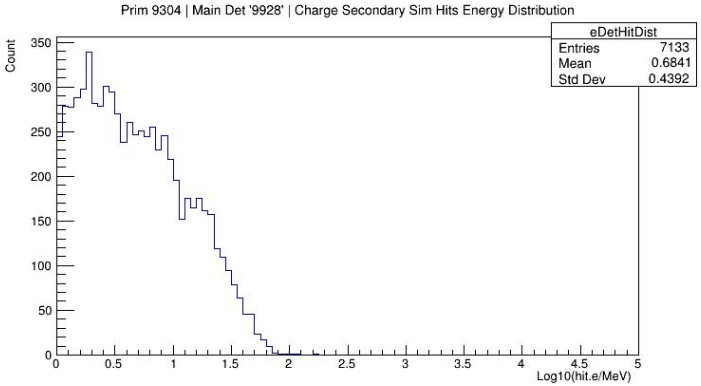
| (9911 PMT Region) Secondary Counts - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9304 | 18454 | 29055 |

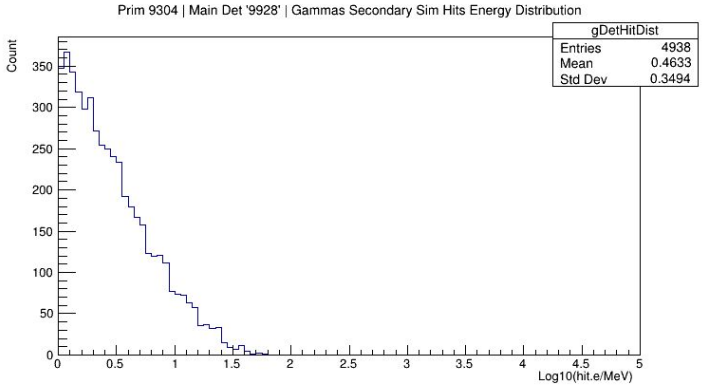
| (9911 PMT Region) Secondary Fractional - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9304 | 3.69E-02 | 5.81E-02 |

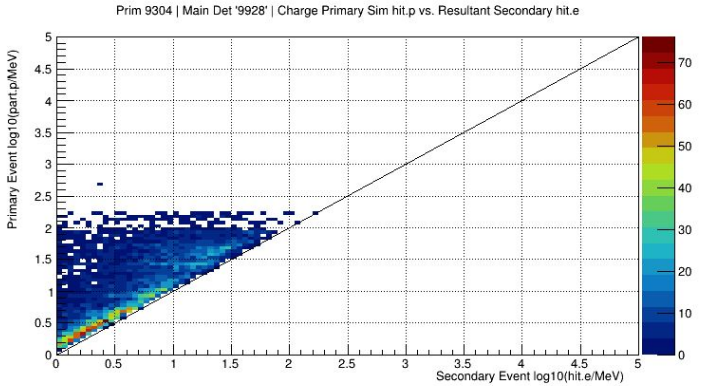
| (9911 PMT Region) Total Fractional - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9304 | 1.09E-08 | 1.71E-08 |

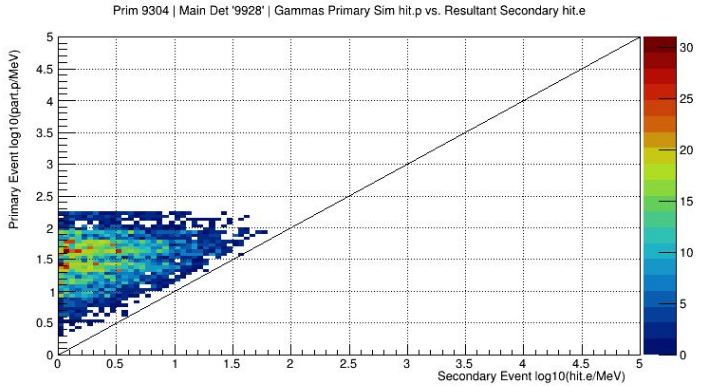
# 9304: GEM Rotator Fasteners

***Backgrounds that hit detector '28'***



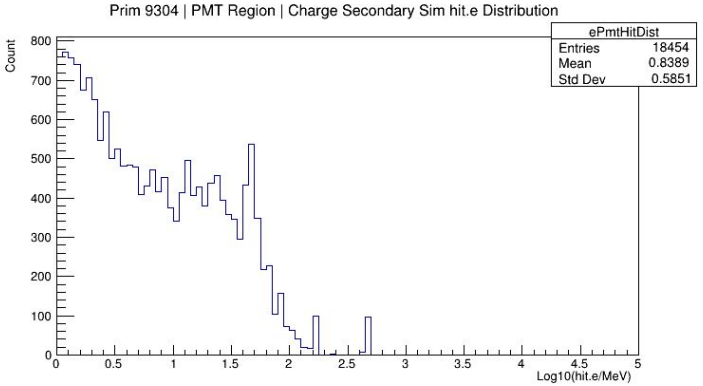



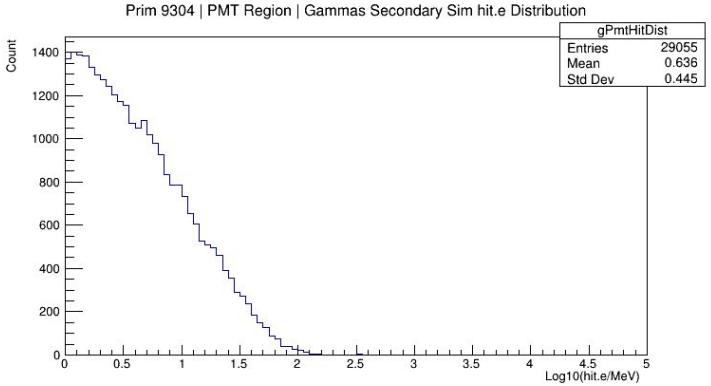



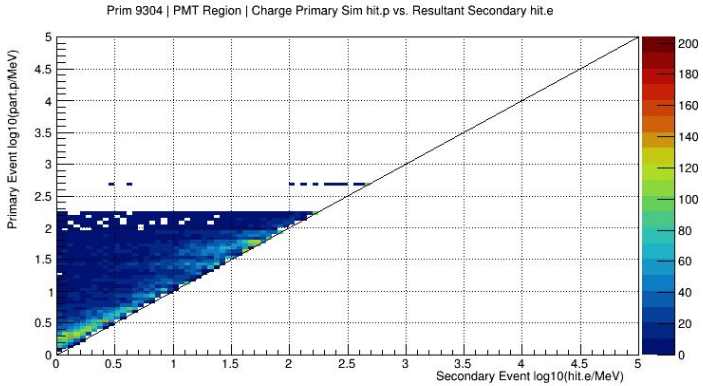



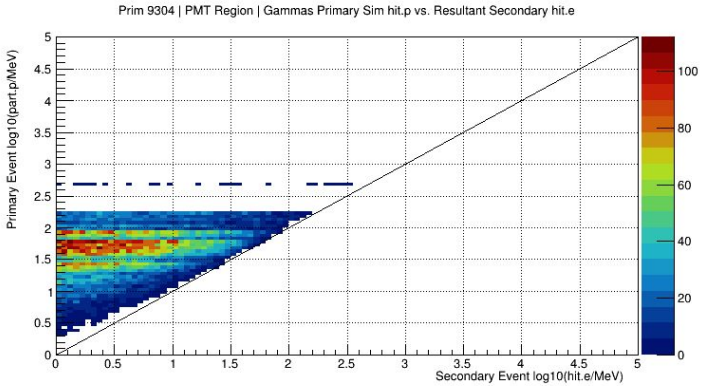
# 9304: GEM Rotator Fasteners

***Backgrounds that hit PMT Region***



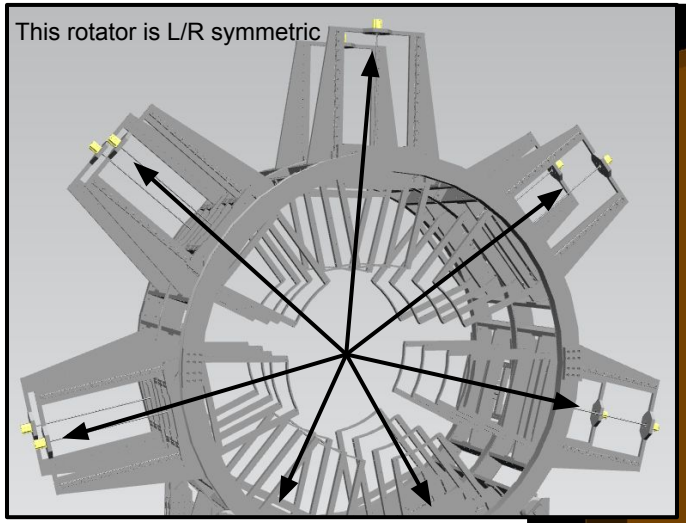



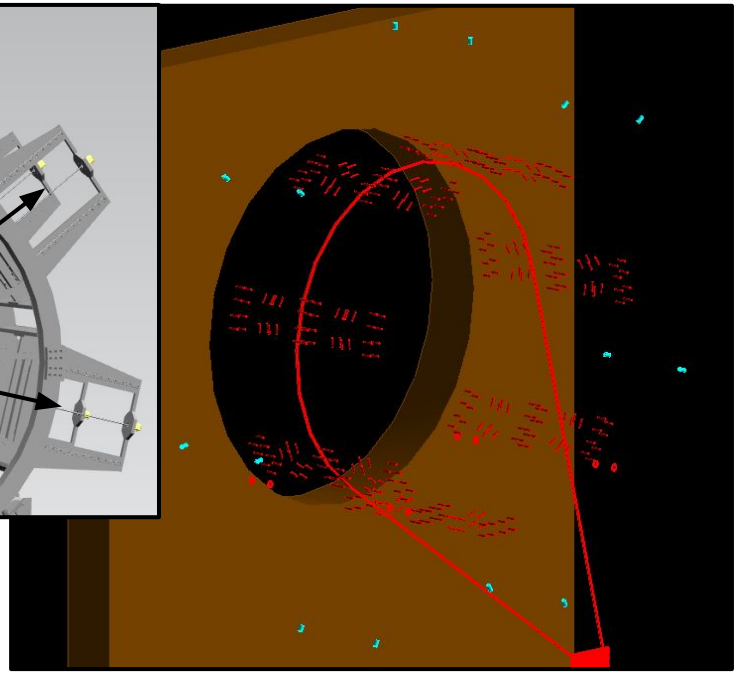
# 9305 – GEM Rotator Stepper Motors

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.

$\varrho_{Fe}$ ~ 7.8 g/cm$^3$

23.8 cm$^3$ x $\varrho_{Fe}$ = 185.6 g (x 14)

**~2.6kg of Fe in simulation**

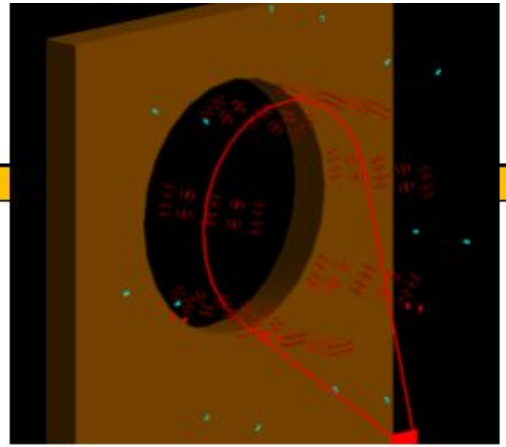
***** There could be model improvement with more information from GEM team if the information is on hand or known. I may very well have over-modeled the material in question.**

# 9305: GEM Stepper Motors

| 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 |

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

| 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 |

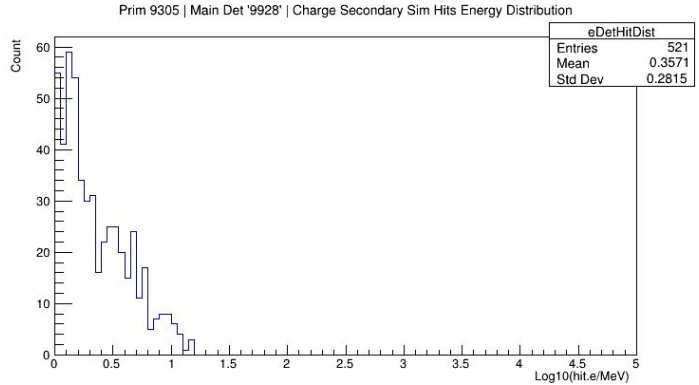
| (9911 PMT Region) Secondary Counts - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9305 | 1828 | 864 |

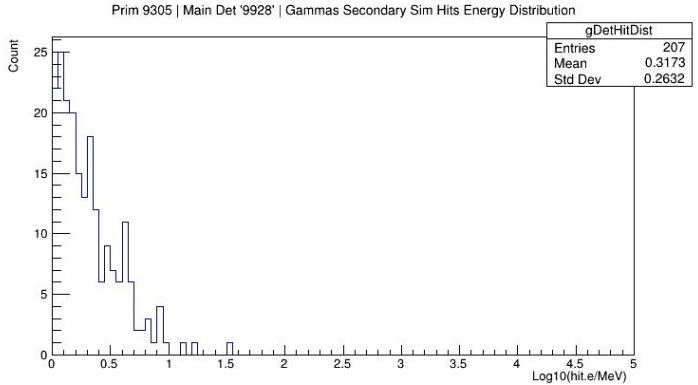
| (9911 PMT Region) Secondary Fractional - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9305 | 3.66E-03 | 1.73E-03 |

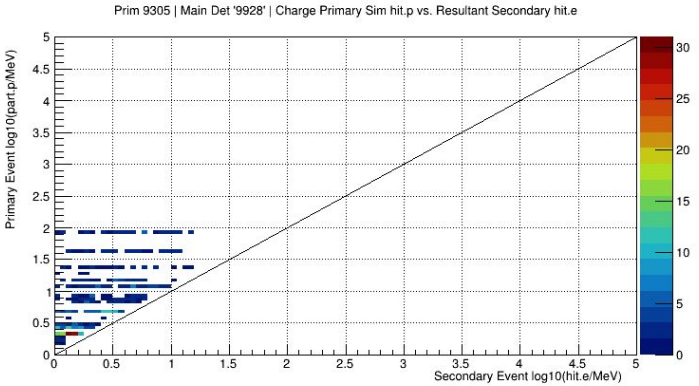
| (9911 PMT Region) Total Fractional - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9305 | 1.39E-11 | 6.57E-12 |

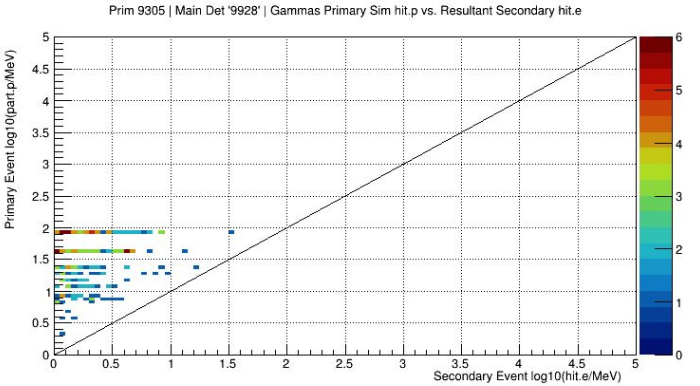
# 9305: Gem Rotator Stepper Motors

***Backgrounds that hit detector '28'***



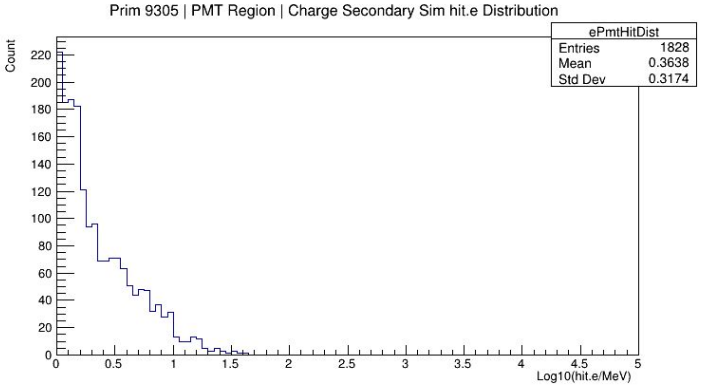



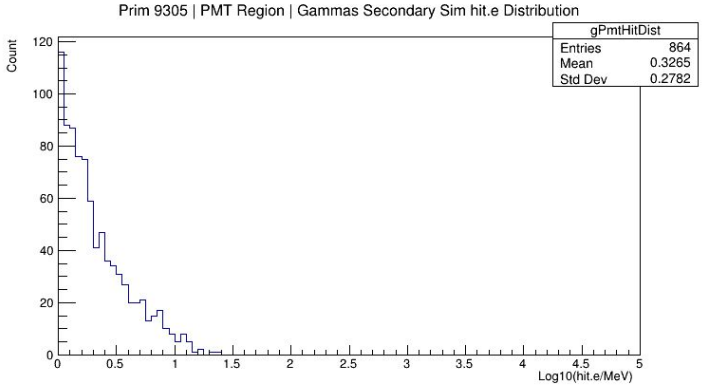



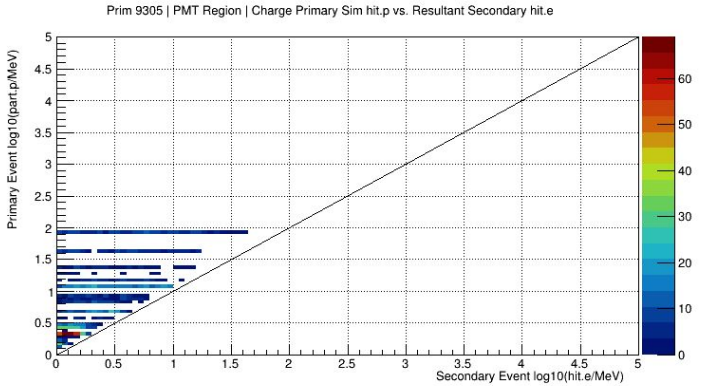



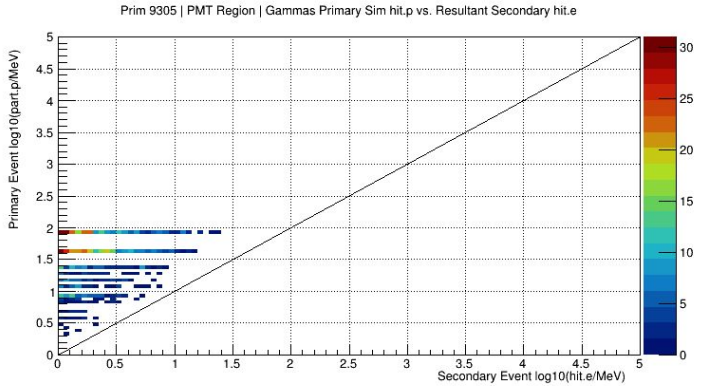
# 9305: Gem Rotator Stepper Motors

***Backgrounds that hit PMT Region***



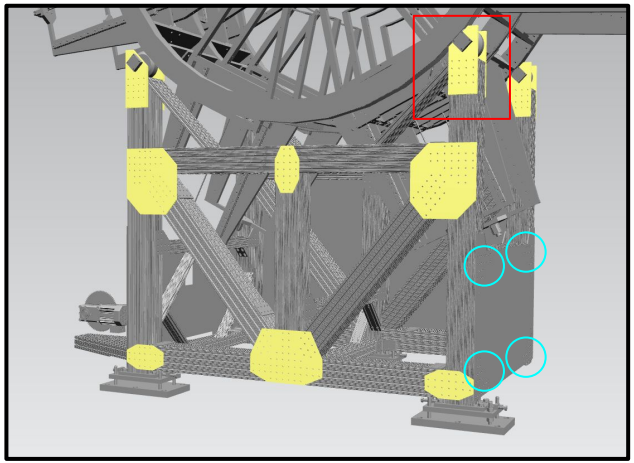



# 9306 – GEM Rotator T-Nuts (Toy Geometry)

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

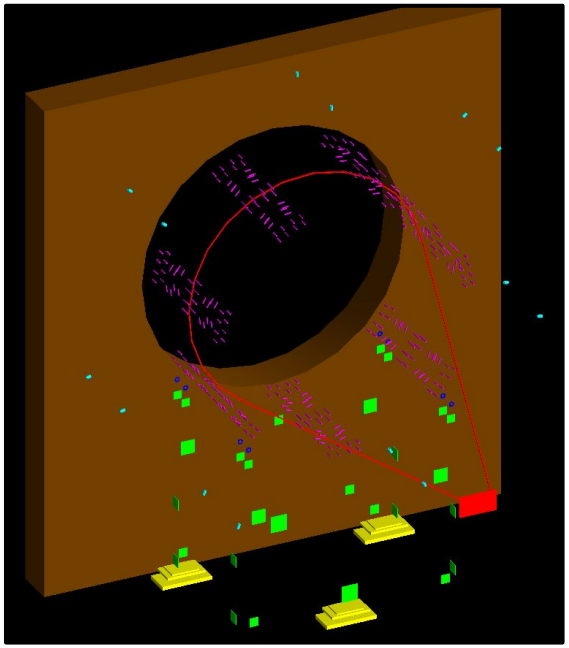
- Modeling all of these is too difficult and likely unnecessary.
  - Modeled SS plates of material with proper masses at locations shown (in image shown).
  - Masses taken from specs from website for one screw/nut pairs.
  - Used 4x4 fastener location (outlined in red) to get a generalized density of 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)

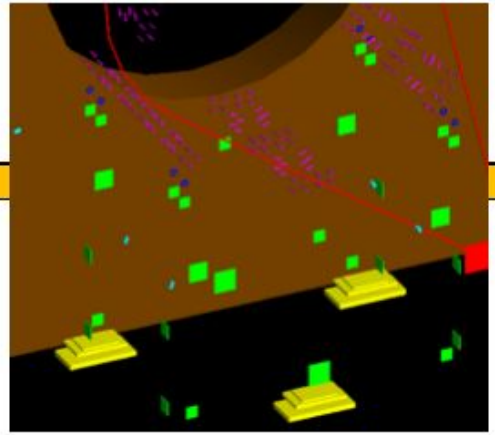
| Material | X_r | Spin Polarization (P_f) | Frac e- on Target | Frac of events Per Moller |
|---|---|---|---|---|
| Mild Steel | 2000 | 1E-02 | 1E-11 | 1E-07 |
| Stainless Steel (Worst) | 1 | 1E-05 | 1E-08 | 1E-04 |
| Stainless Steel (Ideal) | 0.01 | 1E-07 | 1E-06 | 1E-02 |
| Aluminum | 0.0001 | 1E-09 | 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 $10^{-8}$.

As modeled $1.7(10^{-10})$, doubling for unaccounted mass still not a problem.

| | |
|---|---|
| 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 |

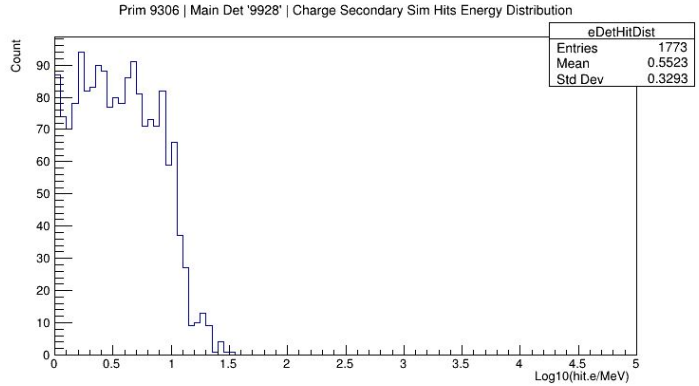
| (9911 PMT Region) Secondary Counts - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9306 | 6132 | 2156 |

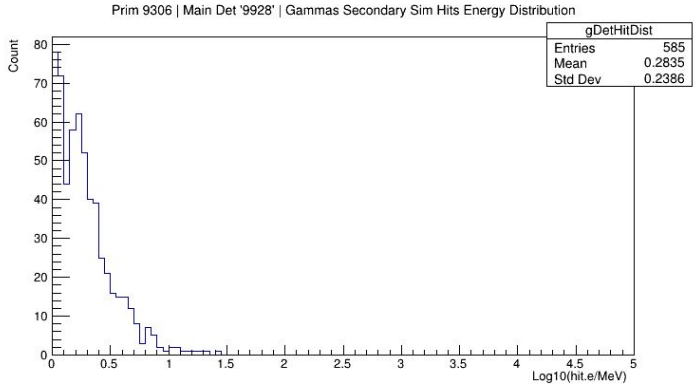
| (9911 PMT Region) Secondary Fractional - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9306 | 1.23E-02 | 4.31E-03 |

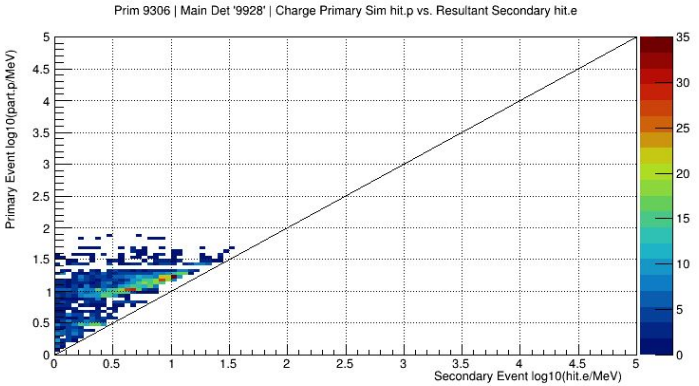
| (9911 PMT Region) Total Fractional - 0&1 | | |
|---|---|---|
| Secondaries | Electrons | Gammas |
| 9306 | 5.86E-10 | 2.06E-10 |

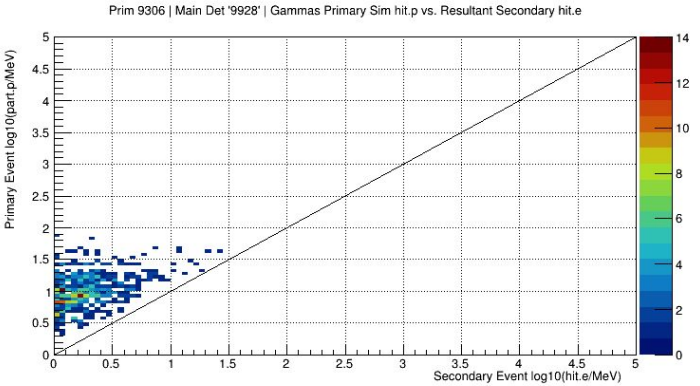
# 9306: GEM T-Nuts (Toy Geometry)

***Backgrounds that hit detector '28'***



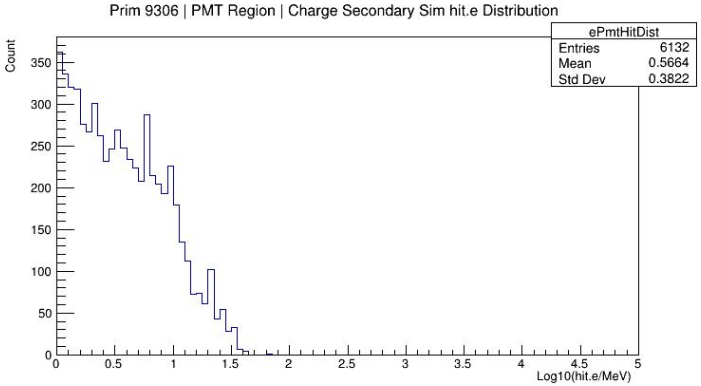



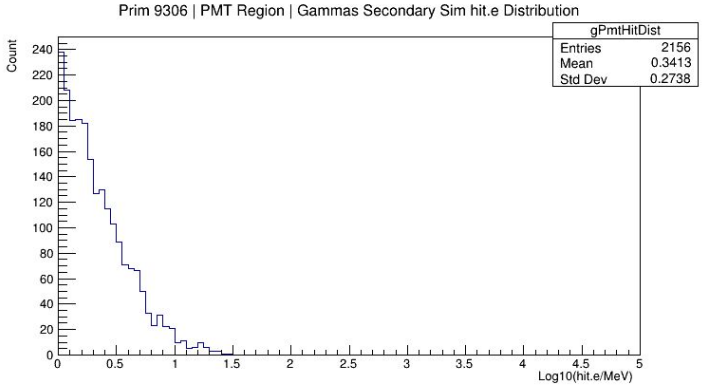



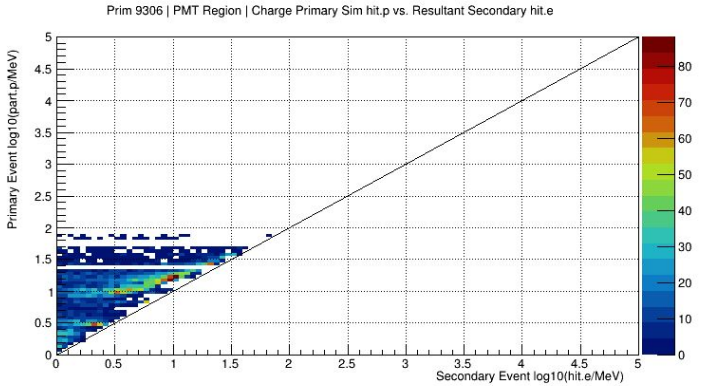



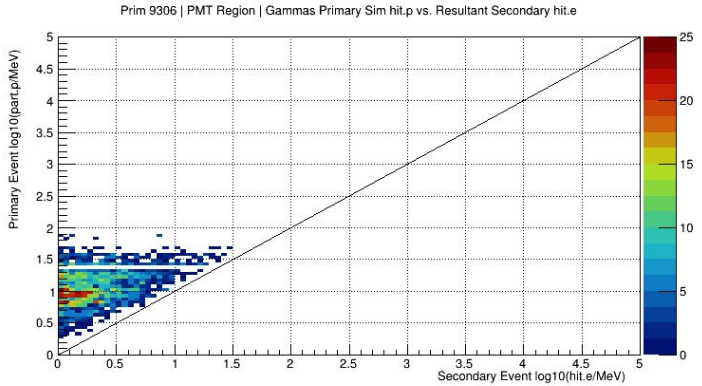
# 9306: GEM T-Nuts (Toy Geometry)

***Backgrounds that hit PMT Region***



# Summary

and meeting comments/notes

# Simulation Summary & Comments

| Ferrous Detector | Ferrous Volume Common Name | Material(s) | Ferrous BG[1] Limit [per e.o.t.] | Main Det Sim BG[1] [per e.o.t] | Comment |
|---|---|---|---|---|---|
| 9300 | Roller Bearings | 100Cr6 [Carbon Steel] | $10^{-11}$ | ~5($10^{-11}$) ↓ **< 1.66($10^{-11}$)** | On the edge but likely okay. Depolarization will reduce this by a factor of three (3) and there will be *some* shielding/attenuation by GEM Rotator structure not accounted for here. |
| 9301 | Floor Locks | Carbon Steel and SS | $10^{-11}$ | ~3($10^{-11}$) ↓ **~ 1($10^{-11}$)** | Close to the limit. Need to add more materials which will probably bring this above the limit. **Will need to investigate shielding.** |
| 9302 | Gear Motor | 7kg Multiple Materials | $10^{-12}$ | ~1($10^{-12}$) ↓ **< $10^{-12}$** | Assuming worst material limits we're still under the ferrous BG[1] limit. Depolarization adds further comfort as does shielding and attenuation by GEM Rotator structure. |
| 9303 | Chain | SS316 | $10^{-8}$ | ~2($10^{-9}$) ↓ **< $10^{-9}$** | 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($10^{-9}$) ↓ **~$10^{-9}$** | While adding in missing fasteners and nuts to simulation would increase this number. Depolarization and *some* shielding/attenuation by missing GEM Rotator mass would reduce this. TBolts to be added. |
| 9305 | Stepper Motors | Modeled as 2.8kg Fe | $10^{-12}$ | ~4($10^{-12}$) ↓ **~1.5($10^{-12}$)** | Depolarization would reduce by about a factor of three. Additional considerations need to be made for mass scaling. Outside rotator structure so I don't see much chance for additional attenuation. |
| 9306 | T-nut Fasteners | SS-304 | $10^{-8}$ | ~$10^{-10}$ | Model result was ~2($10^{-10}$), doubling to account for unmodeled mass we come to <4($10^{-10}$). Assuming that SS-304 is absolute worst quality this is still well below tolerable limits. |

[1]BG=Background

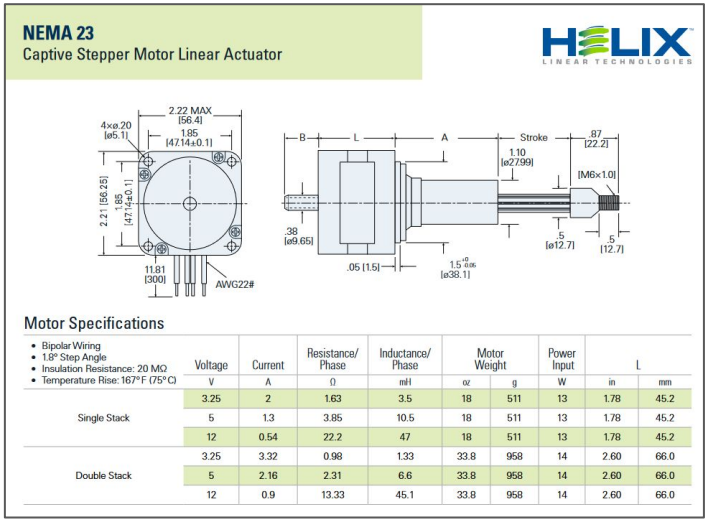
# Recent Meeting Notes

- Things to be added
- Revisions
-

# Ferrous Materials Meeting Comments/Ongoing/New

- ✓ Stepper Motors
- ✓ T-nuts
- Floor lock primary hits locations
  - Analysis item, do after modeling complete.
- ✓ Add rotator frame
- ✓ Rods SS316 → need to be modeled
- ✓ Bearings at the bottom of gem planes connecting to the rod → Carbon Steel (Sent CAD to JLab email)
  - Body: SS316, Bearing: Carbon steel
- ➢ Motor catalog item from David (JLab Email)
  - NEMA 23, seems to be double stack motor from dimensions in JT, says motor weight is 958 g… previous toy model is 185g **(~20% of motor weight)**
- ✓ Model the roller pin for Chandika as SS
  - Make the geometry

- Ferrous materials in HDMI connectors.
  - These are in the same general location of the stepper motors.



**NEMA 23**
Captive Stepper Motor Linear Actuator

HELIX LINEAR TECHNOLOGIES



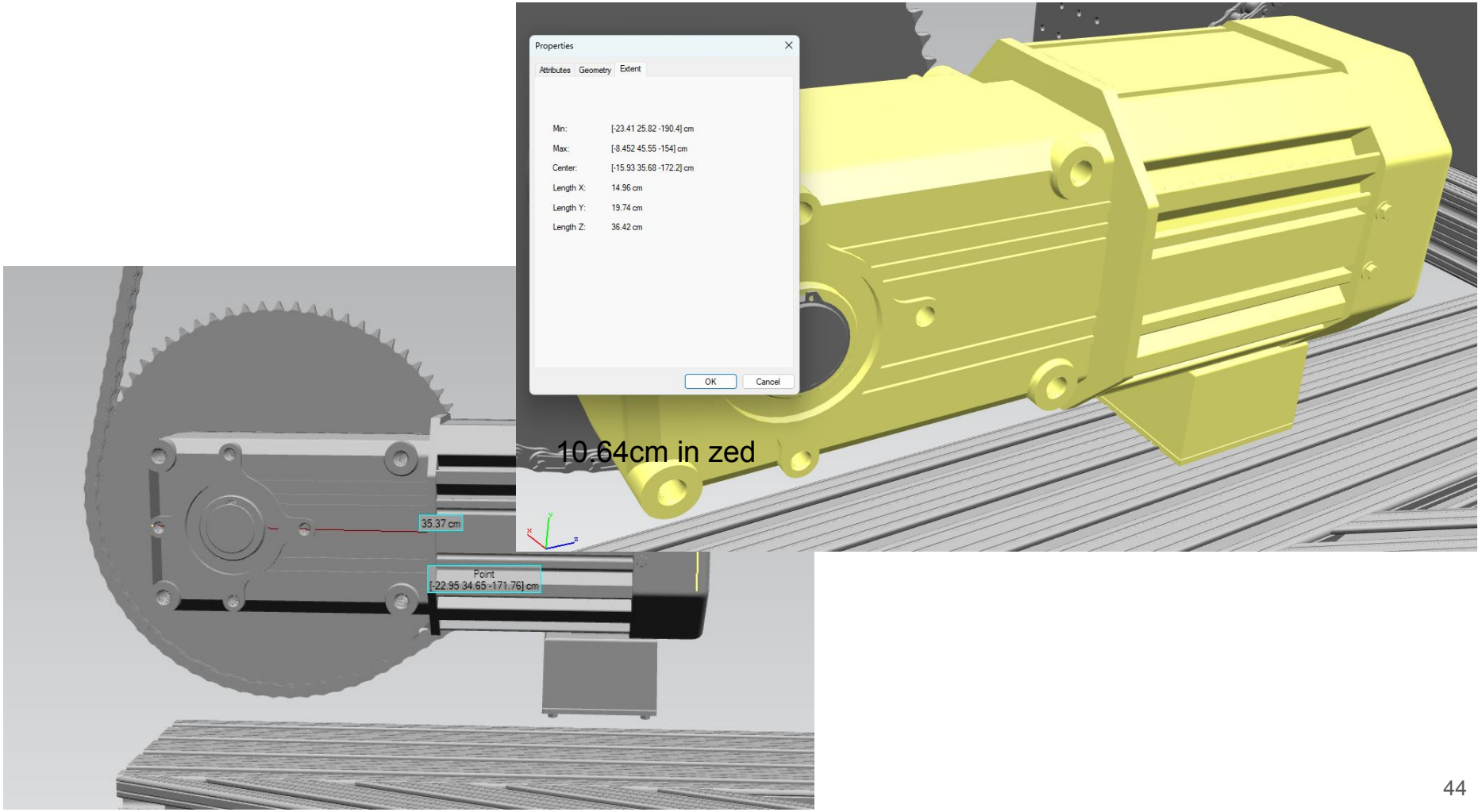
**Motor Specifications**

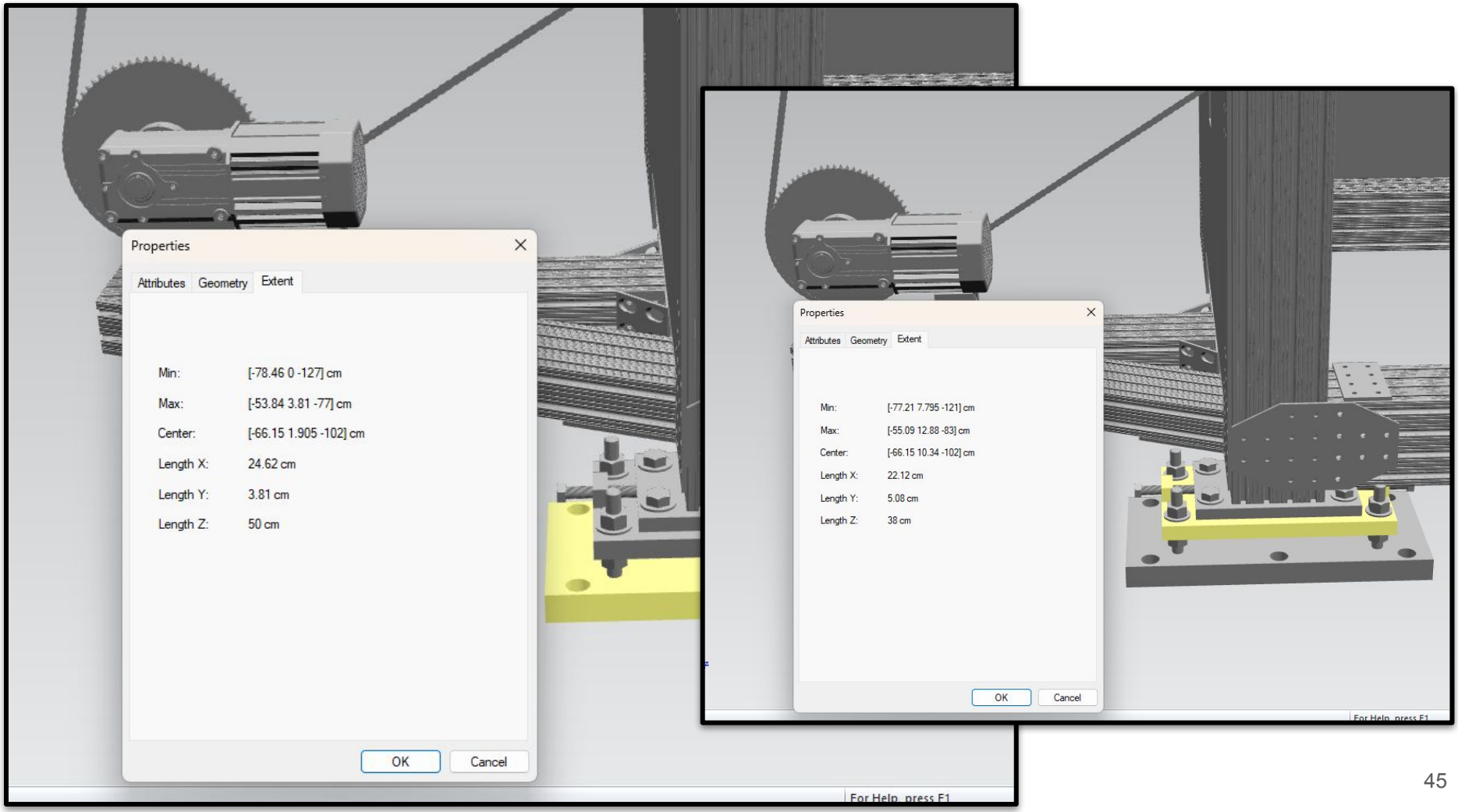
- Bipolar Wiring
- 1.8° Step Angle
- Insulation Resistance: 20 MΩ
- Temperature Rise: 167°F (75°C)

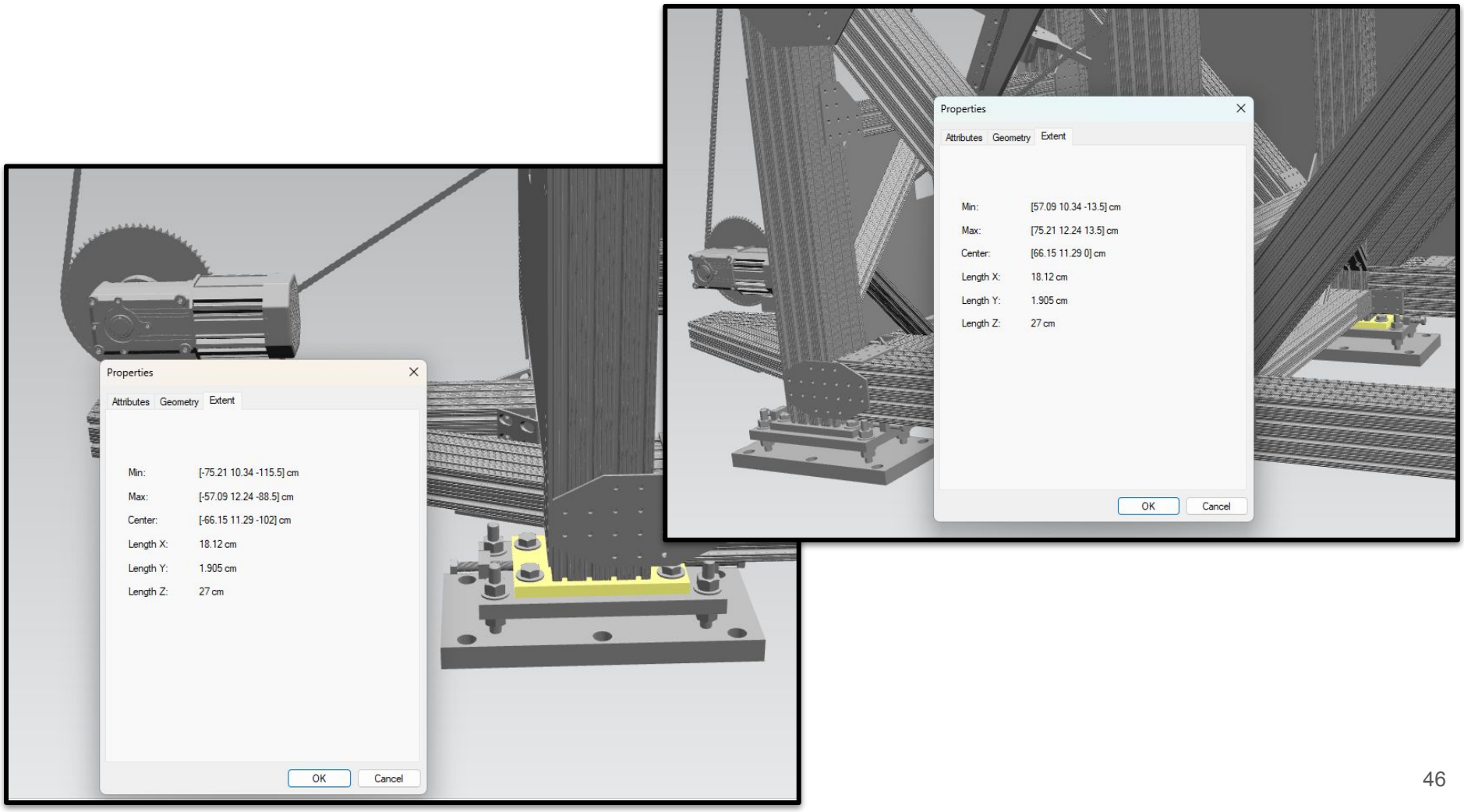
| | Voltage | Current | Resistance/ Phase | Inductance/ Phase | Motor Weight | | Power Input | L | |
|---|---|---|---|---|---|---|---|---|---|
| | V | A | Ω | mH | oz | g | W | in | mm |
| Single Stack | 3.25 | 2 | 1.63 | 3.5 | 18 | 511 | 13 | 1.78 | 45.2 |
| | 5 | 1.3 | 3.85 | 10.5 | 18 | 511 | 13 | 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 |

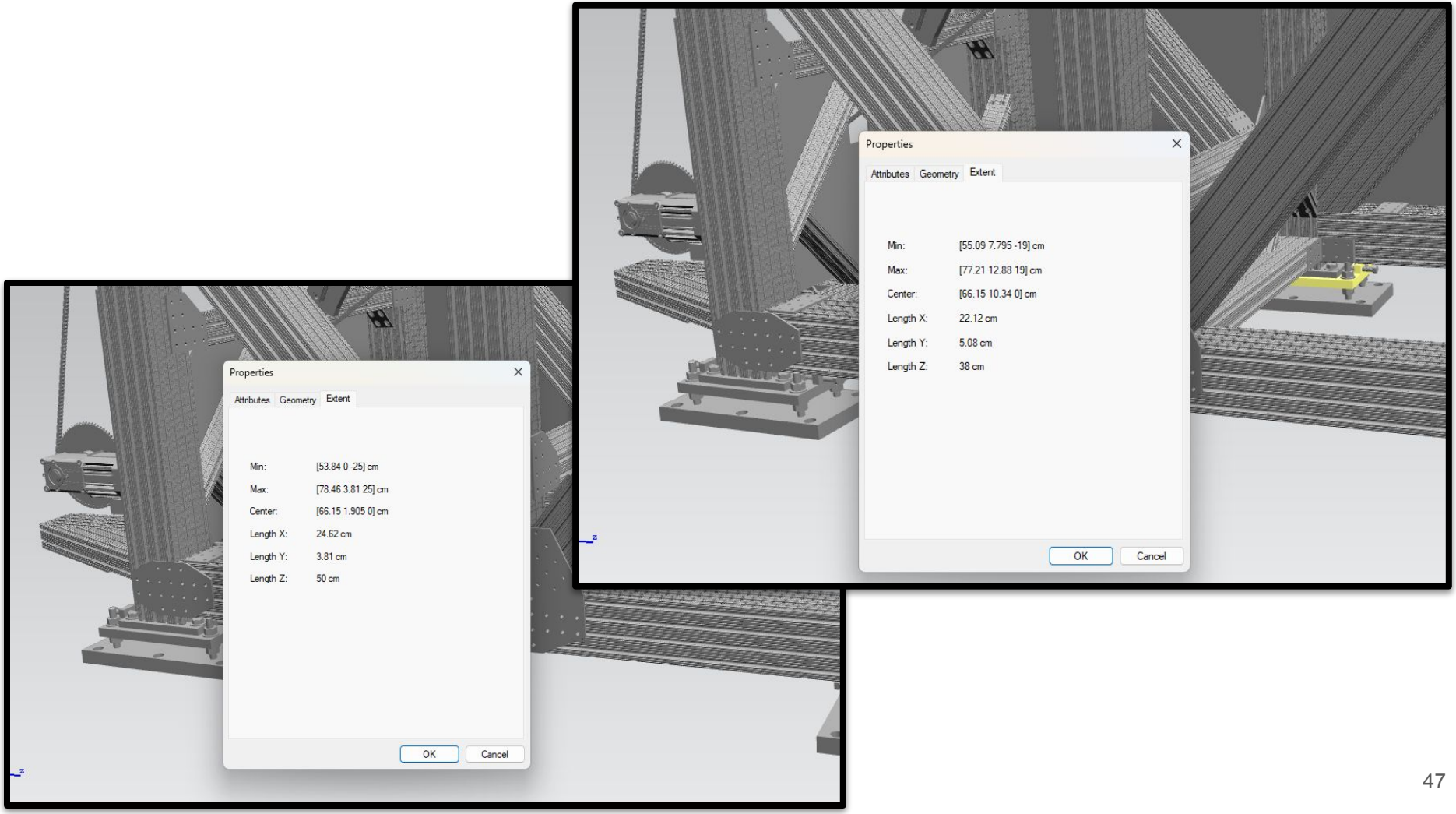
# Some of my original notes/screensnips.

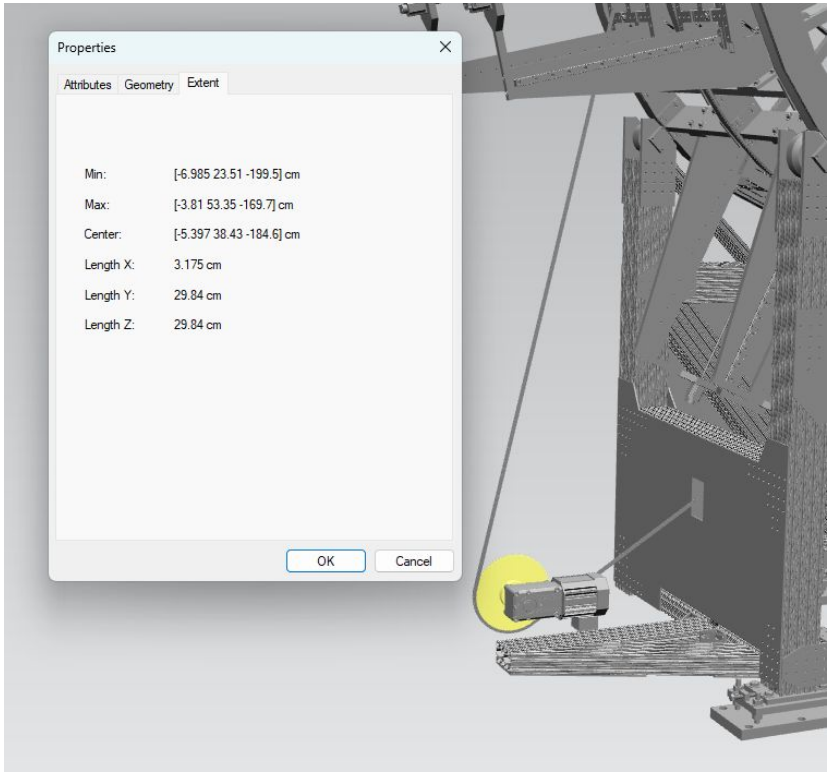
*Not necessary to view.*

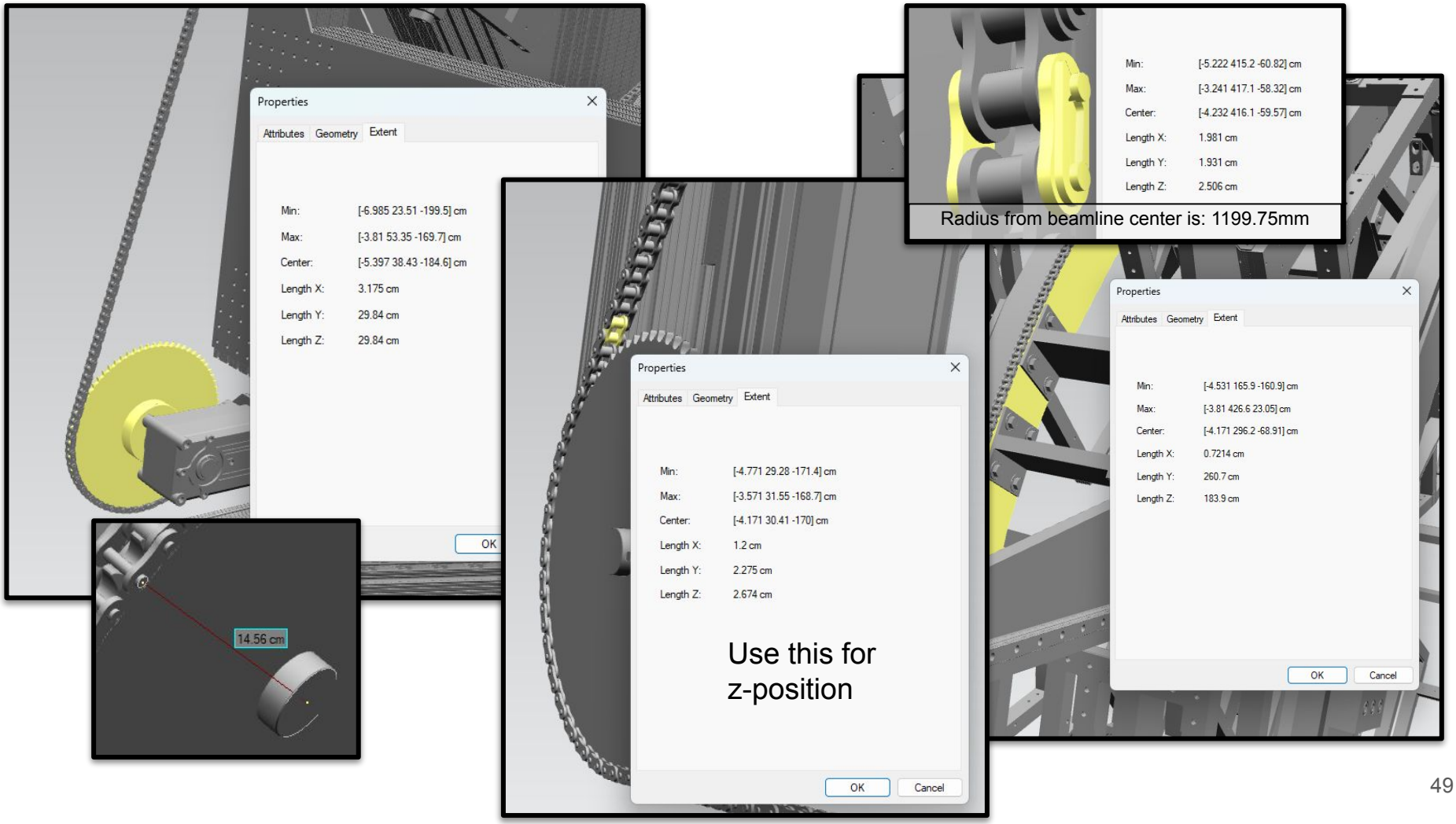

Properties
Attributes
Geometry
Extent
Min: [-23.41 25.82 -190.4] cm
Max: [-8.452 45.55 -154] cm
Center: [-15.93 35.68 -172.2] cm
Length X: 14.96 cm
Length Y: 19.74 cm
Length Z: 36.42 cm
OK
Cancel
10.64cm in zed
35.37 cm
Point
[-22.95 34.65 -171.76] cm

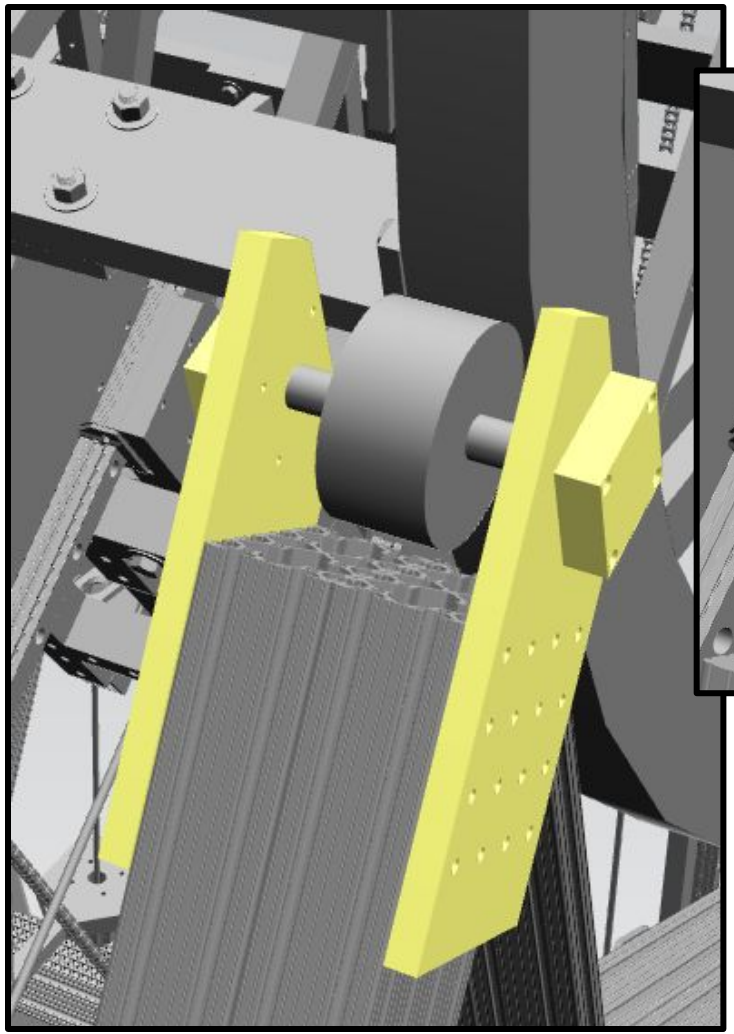

Properties
Attributes
Geometry
Extent
Min: [-78.46 0 -127] cm
Max: [-53.84 3.81 -77] cm
Center: [-66.15 1.905 -102] cm
Length X: 24.62 cm
Length Y: 3.81 cm
Length Z: 50 cm
OK
Cancel
For Help, press F1
Properties
Attributes
Geometry
Extent
Min: [-77.21 7.795 -121] cm
Max: [-55.09 12.88 -83] cm
Center: [-66.15 10.34 -102] cm
Length X: 22.12 cm
Length Y: 5.08 cm
Length Z: 38 cm
OK
Cancel
For Help, press F1

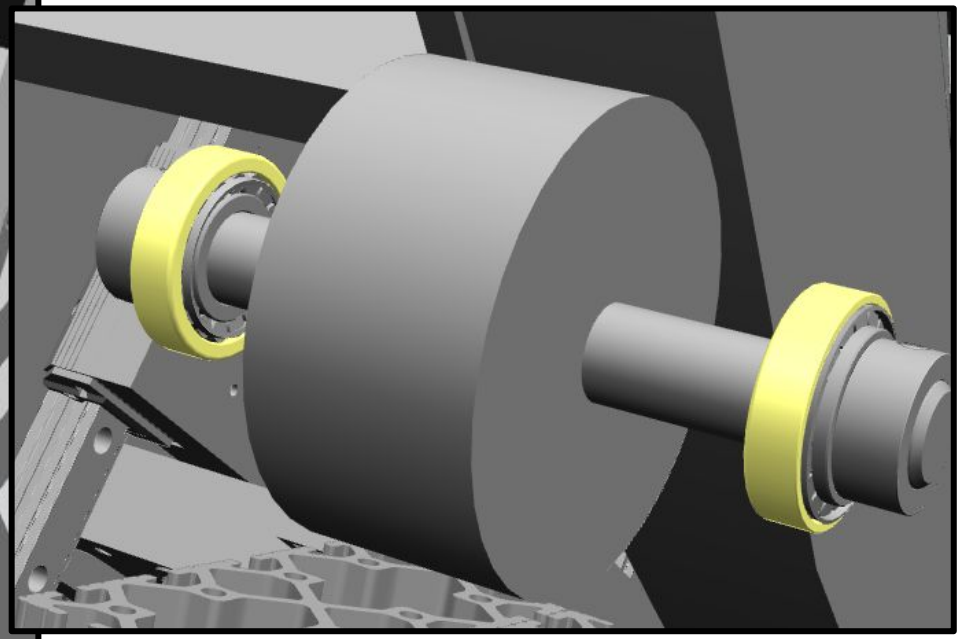

Properties
Attributes
Geometry
Extent
Min: [57.09 10.34 -13.5] cm
Max: [75.21 12.24 13.5] cm
Center: [66.15 11.29 0] cm
Length X: 18.12 cm
Length Y: 1.905 cm
Length Z: 27 cm
OK
Cancel
Properties
Attributes
Geometry
Extent
Min: [-75.21 10.34 -115.5] cm
Max: [-57.09 12.24 -88.5] cm
Center: [-66.15 11.29 -102] cm
Length X: 18.12 cm
Length Y: 1.905 cm
Length Z: 27 cm
OK
Cancel

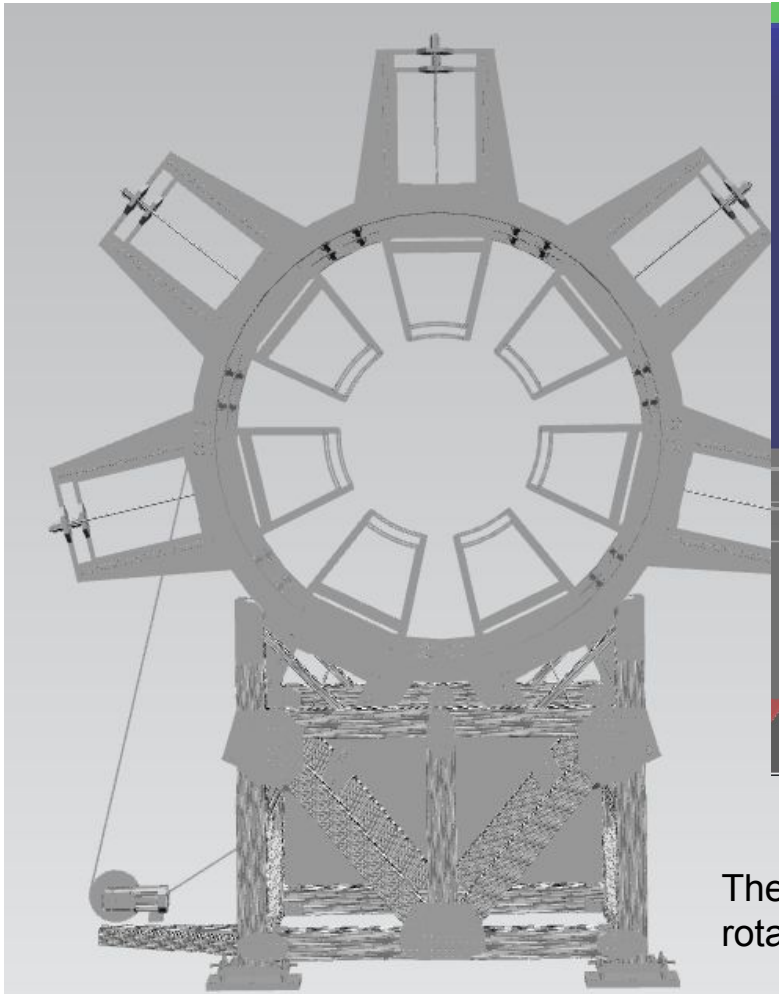

Properties
Attributes
Geometry
Extent
Min: [55.09 7.795 -19] cm
Max: [77.21 12.88 19] cm
Center: [66.15 10.34 0] cm
Length X: 22.12 cm
Length Y: 5.08 cm
Length Z: 38 cm
OK
Cancel
Properties
Attributes
Geometry
Extent
Min: [53.84 0 -25] cm
Max: [78.46 3.81 25] cm
Center: [66.15 1.905 0] cm
Length X: 24.62 cm
Length Y: 3.81 cm
Length Z: 50 cm
OK
Cancel

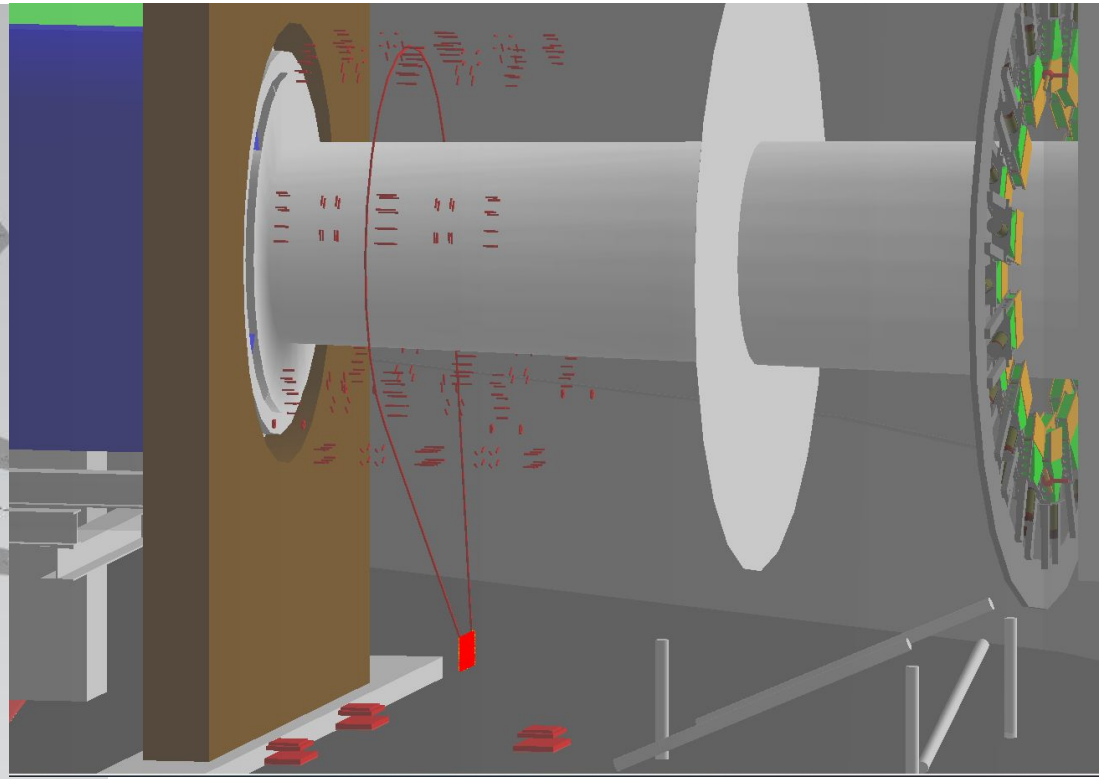

Properties
Attributes
Geometry
Extent
Min:
[-6.985 23.51 -199.5] cm
Max:
[-3.81 53.35 -169.7] cm
Center:
[-5.397 38.43 -184.6] cm
Length X:
3.175 cm
Length Y:
29.84 cm
Length Z:
29.84 cm
OK
Cancel


Properties
Attributes Geometry Extent
Min: [-6.985 23.51 -199.5] cm
Max: [-3.81 53.35 -169.7] cm
Center: [-5.397 38.43 -184.6] cm
Length X: 3.175 cm
Length Y: 29.84 cm
Length Z: 29.84 cm
OK
14.56 cm
Min: [-5.222 415.2 -60.82] cm
Max: [-3.241 417.1 -58.32] cm
Center: [-4.232 416.1 -59.57] cm
Length X: 1.981 cm
Length Y: 1.931 cm
Length Z: 2.506 cm
Radius from beamline center is: 1199.75mm
Properties
Attributes Geometry Extent
Min: [-4.771 29.28 -171.4] cm
Max: [-3.571 31.55 -168.7] cm
Center: [-4.171 30.41 -170] cm
Length X: 1.2 cm
Length Y: 2.275 cm
Length Z: 2.674 cm
Use this for z-position
OK
Cancel
Properties
Attributes Geometry Extent
Min: [-4.531 165.9 -160.9] cm
Max: [-3.81 426.6 23.05] cm
Center: [-4.171 296.2 -68.91] cm
Length X: 0.7214 cm
Length Y: 260.7 cm
Length Z: 183.9 cm
OK
Cancel









The JT file represents the angle orientation when the rotator is parked. GEMs will be retracted of course.