MC Study of LEG Design & Evaluation Process

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Outline

- 1. Principle of LEG Design
- 2. Basic Analysis Information
- 3. PSD Uncovered Leakage
- 4. PSD Covered Leakage
- 5. Gamma Detection
- 6. Conclusion

1. Principle of LEG Design

- LEG: Accept low-energy gamma events (< 15 GeV) and reject charged cosmic rays with CALO & PSD signals.
- The LEG trigger is designed and evaluated from both rejection and acceptance ability.
- Rejection: Evaluated with veto efficiency. The leakage of charged CRs include:
  - ✓ PSD uncovered leakage
    - Gap between Bars
    - Gap between Sectors
    - Bottom uncovered area
  - ✓ PSD covered no vetoed leakage
    - PSD&CALO ROI defi. leakage
    - PSD MIP detection leakage
- Acceptance: Accept gamma in certain energy range, evaluated with:
  - ✓ Acceptance of Gamma
  - ✓ Mis veto rate

◆ The evaluation processes and standard are introduced and to be discussed here, a PSD Geo. is evaluated as an example.

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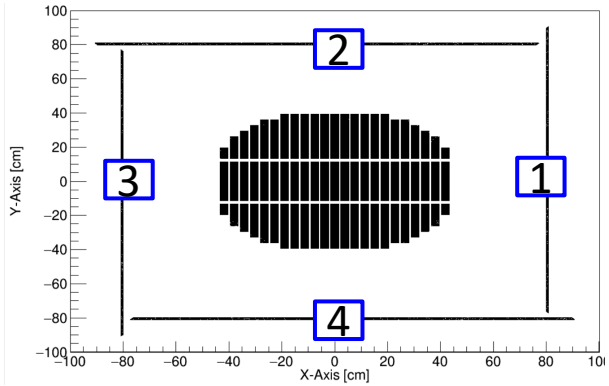
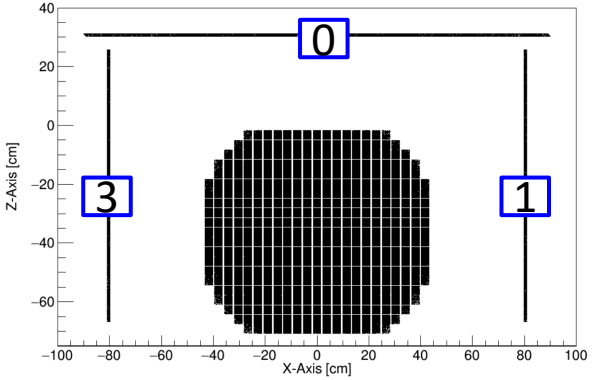
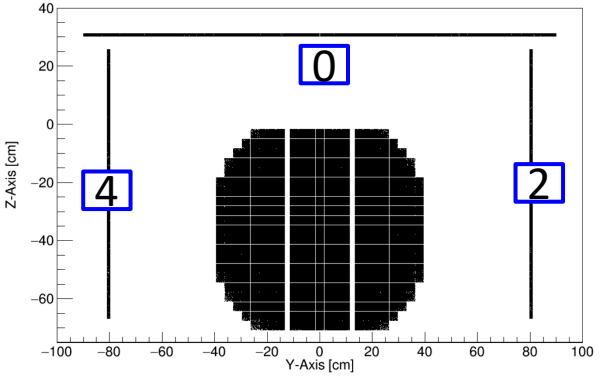
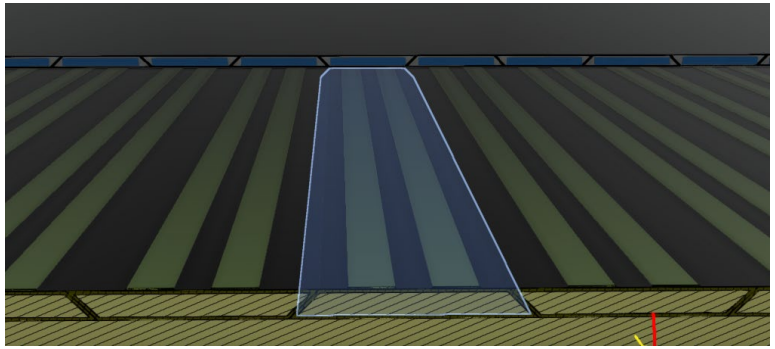
2.1 Geometry

Global Geometry



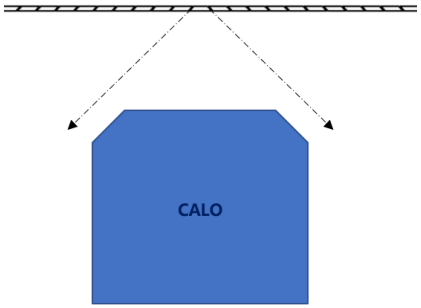






- Trapezoid PSD Unit – 45°
- Top PSD: 89.8x5x1 [cm^3]
- Side PSD: 92.5x5x1 [cm^3]
- Head-to-Head Gap: 5 mm
- Side-to-Side Gap: 1.4 mm

To be analyzed – Another kind of geometry of PSD



- ➢ The trapezoidal section in the middle and the parallelogram section on both sides.
- ➢ To be studied and will not be discussed in this report.

2.2 Data Production

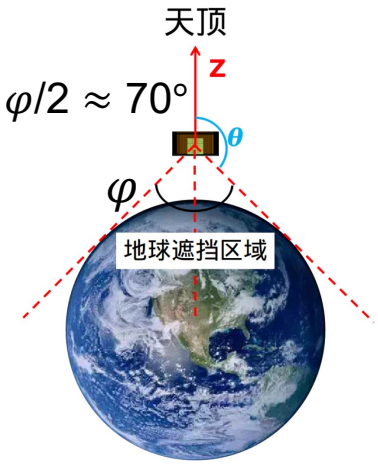
The data production is based on HERDOS software framework

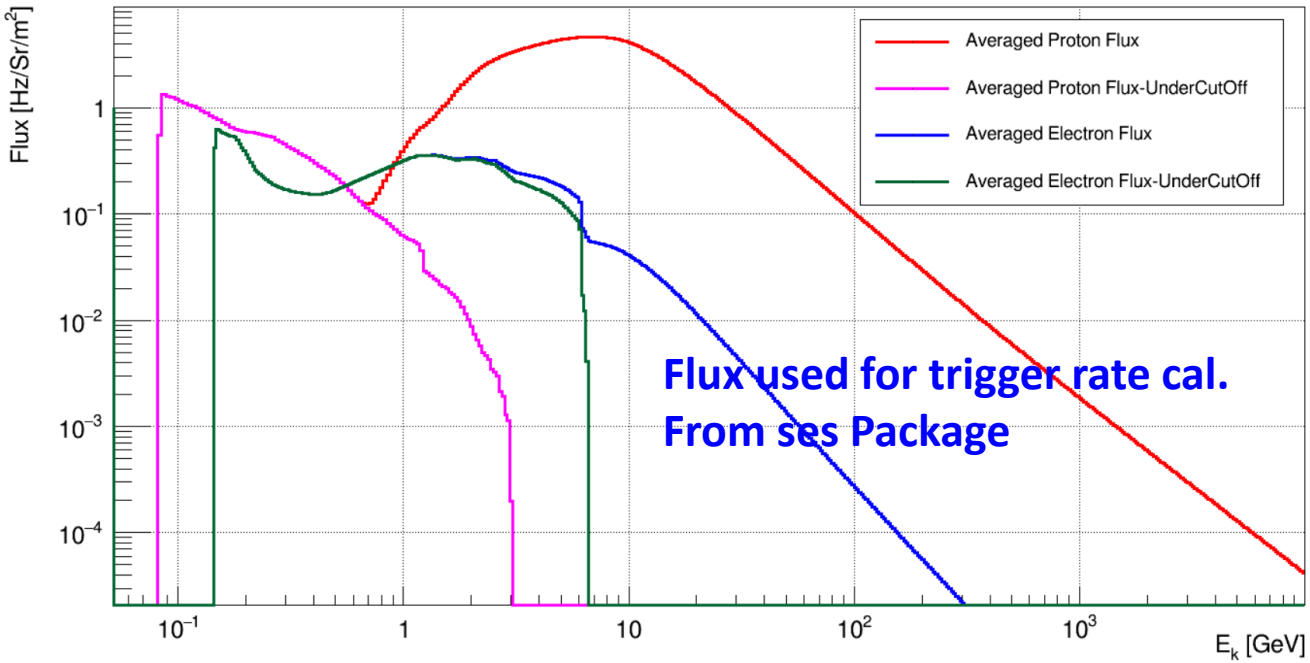
Particle	Counts	Energy Distribution	Angular distribution
Proton	5e7	0-70GeV, Evenly distributed	Spherical source with 1.8m radius, 4pi, cos angular distribution
Proton	1e8	0-10GeV, Pow Law distributed with index = -1	Spherical source with 1.8m radius, 4pi, cos angular distribution
Electron	5e7	0-30GeV, Evenly distributed	Spherical source with 1.8m radius, 4pi, cos angular distribution
Gamma	5e7	0-30GeV, Evenly distributed	Spherical source with 1.8m radius, 4pi, cos angular distribution

- Total 1.5e8 proton & 5e7 electron events are produced for the acceptance and trigger rate evaluation.
- Total 5e7 gamma events are produced for acceptance calculation.

2.3 Earth Shielding & Flux

Earth Shielding





- The trigger rate is calculated by convoluting the acceptance and flux.
- Flux above cutoff outside the earth shield (70°) are considered.
- Flux under cutoff (iso angular dis.) are all considered. (Over Estimate)
- To be updated with flux with angular distribution.

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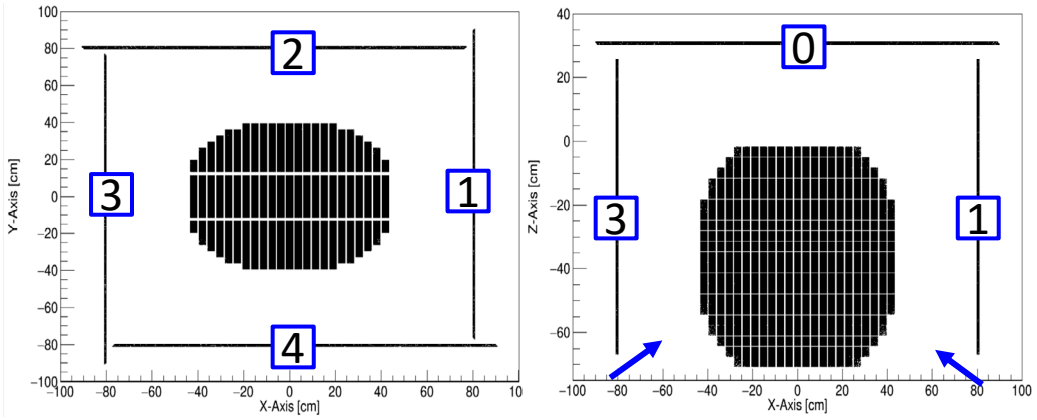
3.1 Geometric Leakage

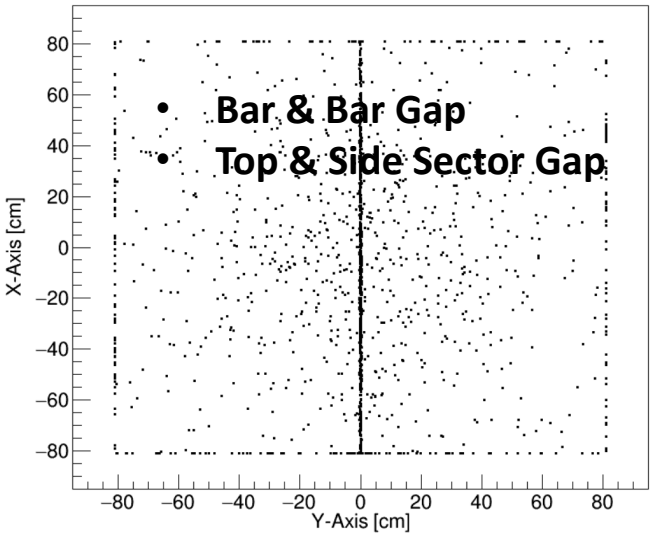
Analyzed with geantino.



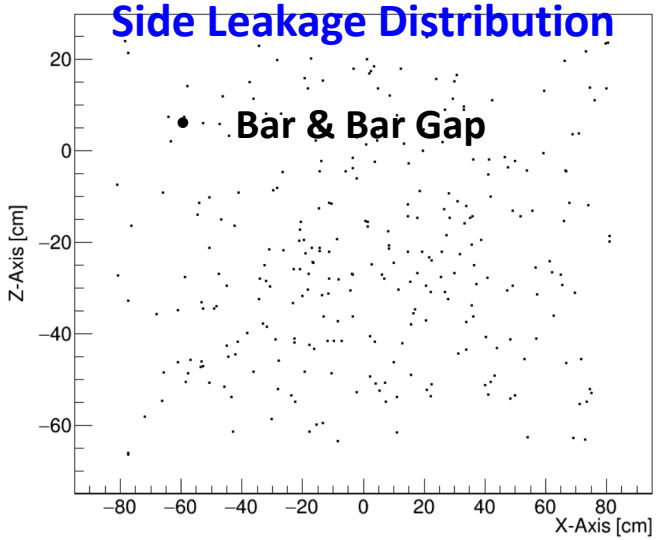
Trigger Pos.	Counts	Ratio [%]
CALO	3620638	100.0
PSD&CALO	3441444	95.05
Bott. Leakage (Z<-66.7)	176265	4.87
Top Leakage (Z>25.8)	1674	0.05
Side Leakage	1255	0.03

- The whole geometric leakage is acceptable after the bottom leakage is reduced.

Top Leakage Distribution

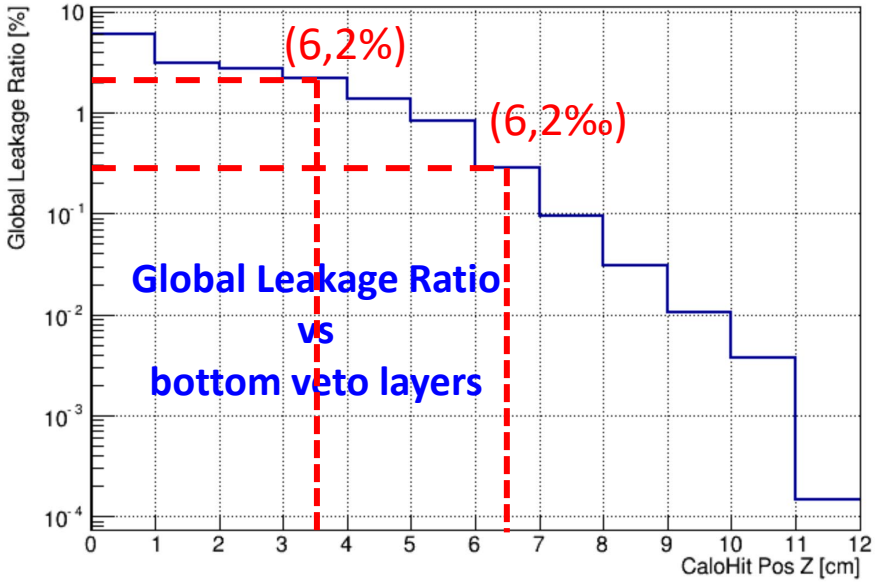


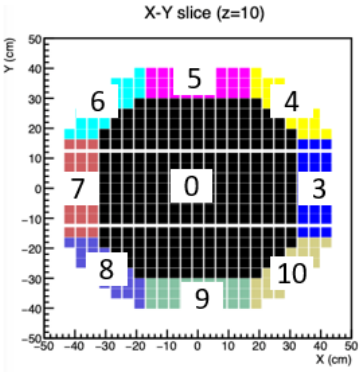
Side Leakage Distribution



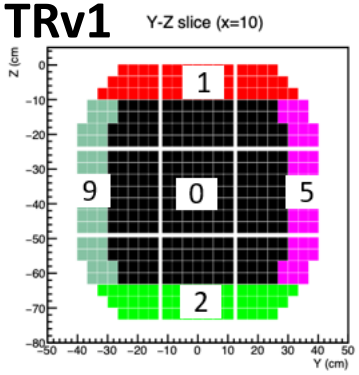
3.2 CALO Trigger Region

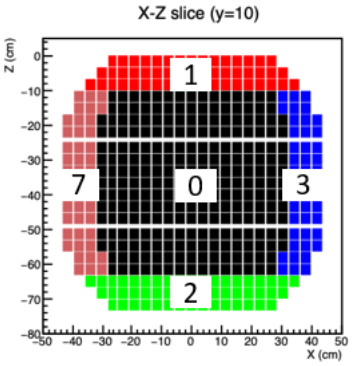
- Use the CALO bottom region for upgoing Leakage veto



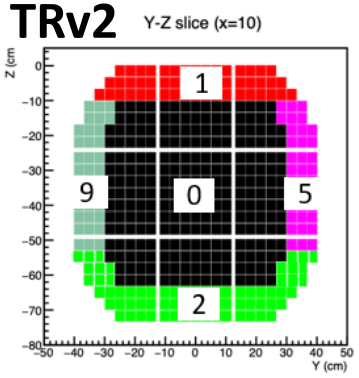


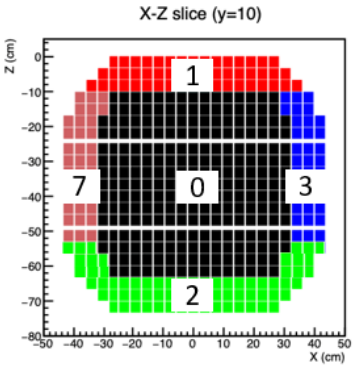
TRv1





TRv2





- Use 6 bottom shell layer for veto, the global leakage can be decreased to 2‰.
- Based on the CALO trigger region v1 provide by Jorge, a new trigger region def. v2 is used here for the LEG.

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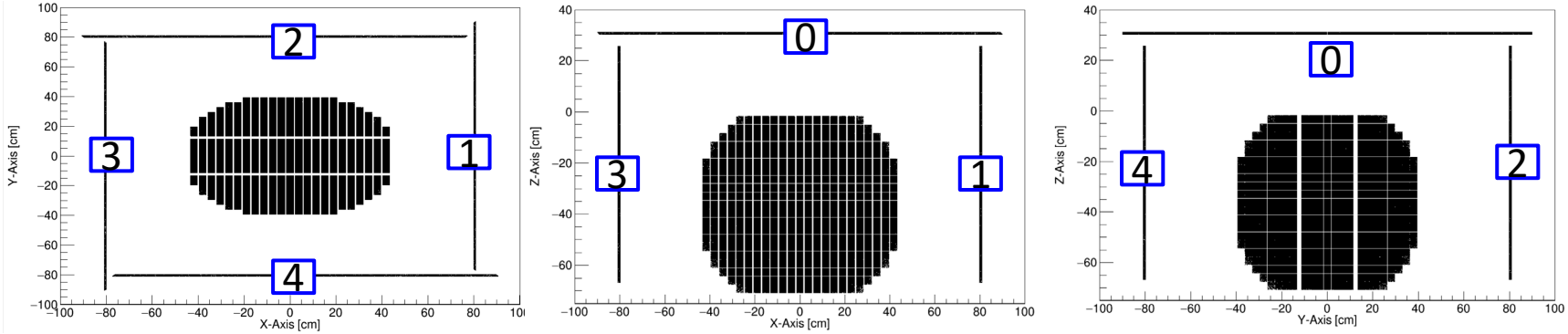
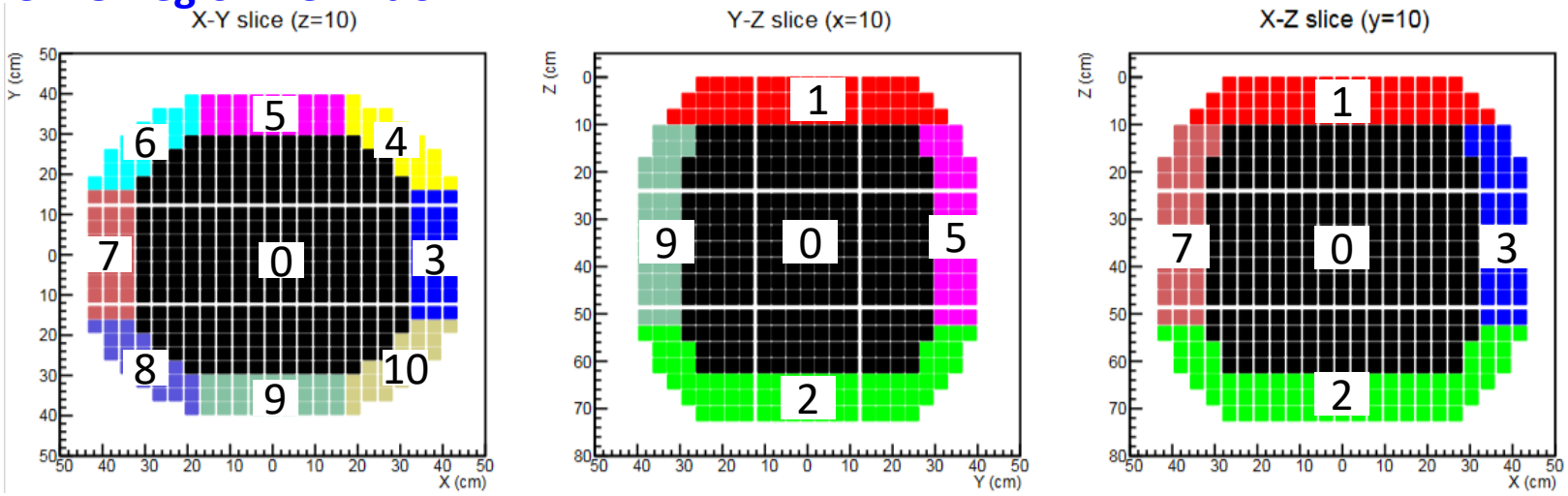
4.1.1 PSD&CALO ROI

PSD Region Definition

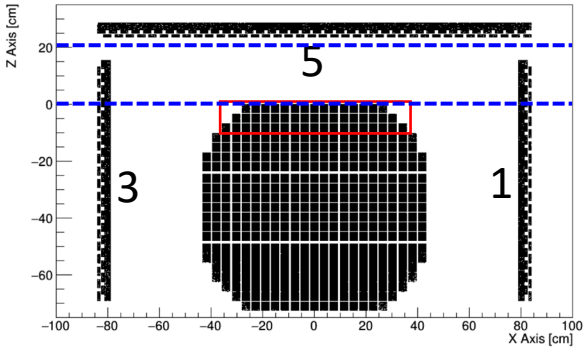


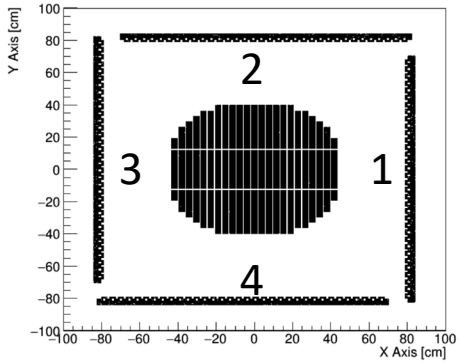
CALO Region Definition –v2



- One CALO trigger region corresponds to several PSD sectors.
- The ROI is defined by finding the PSD hitting area of certain CALO fired region.

4.1.2 PSD&CALO ROI – Top CALO



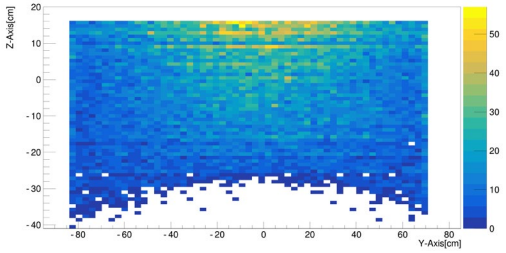


Analyzed with geantino.

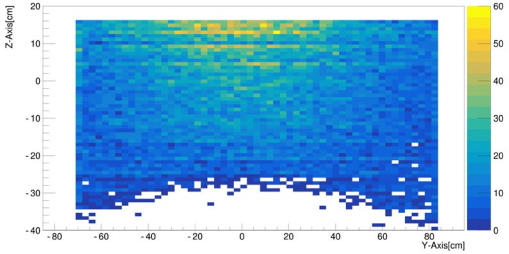
Hitting Top Calo [1]

Corresponding PSD Hitting Position

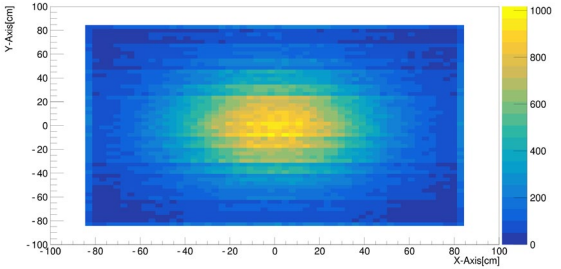
PSD1



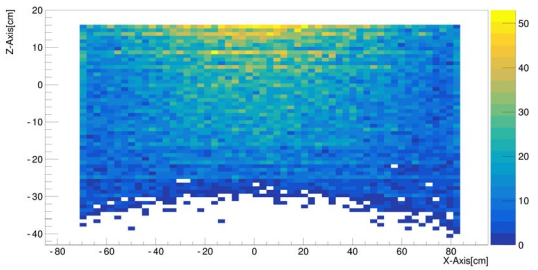
PSD3



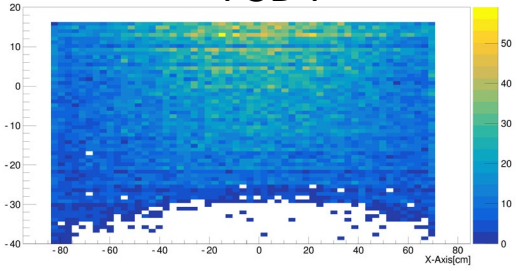
PSD5



PSD2

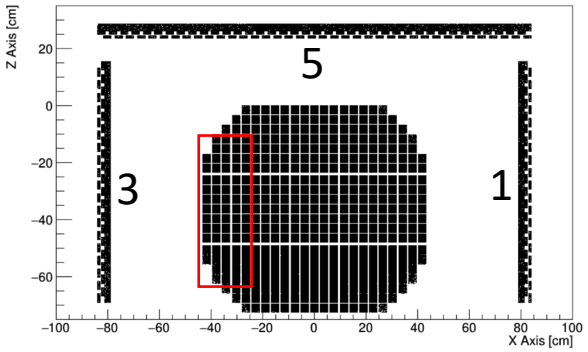


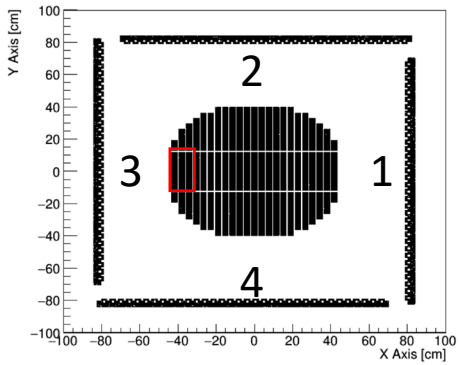
PSD4



- Top CALO should be vetoed with all five PSD regions.

4.1.3 PSD&CALO ROI – Side CALO 7



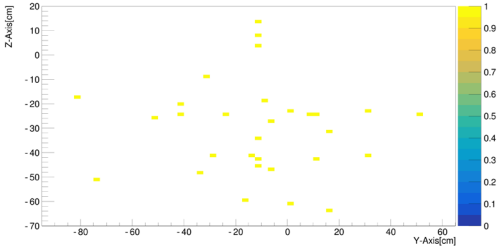


Analyzed with geantino.

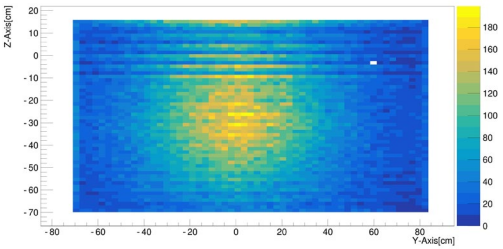
Hitting Top Calo [7]

Corresponding PSD Hitting Position

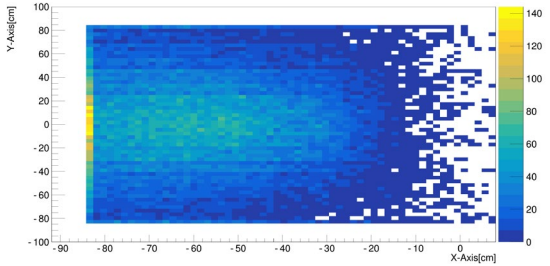
PSD1



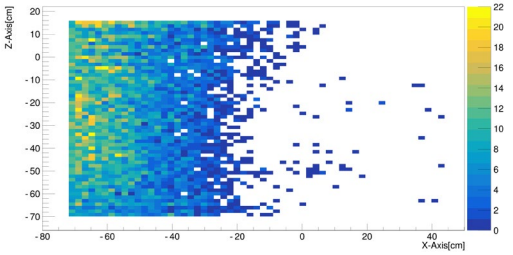
PSD3



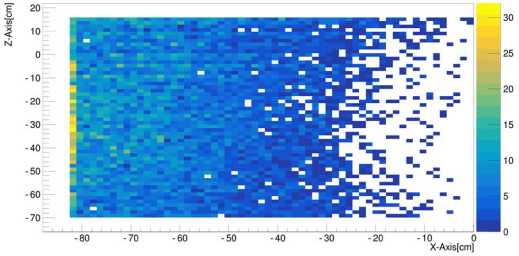
PSD5



PSD2

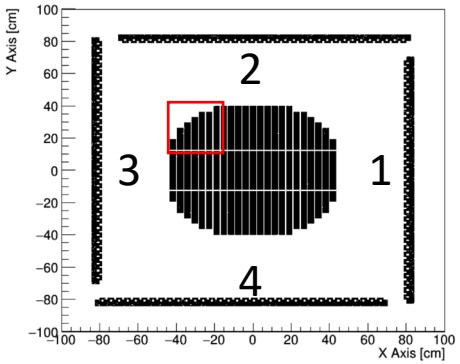


PSD4



- CALO[7] should be vetoed with PSD 2&3&4&5 regions.
- Sectors can be divided to small partitions.

4.1.4 PSD&CALO ROI – Side CALO 6

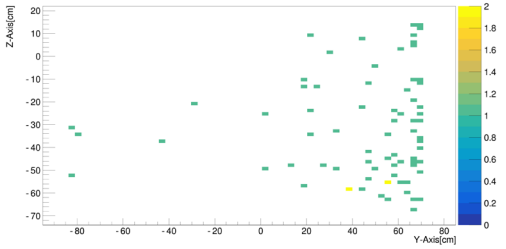


Analyzed with geantino.

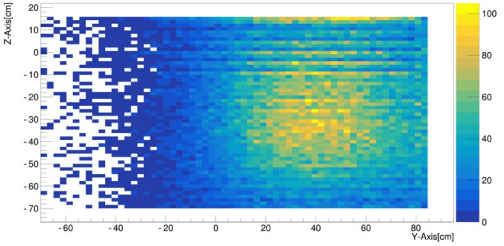
Hitting Top Calo [6]

Corresponding PSD Hitting Position

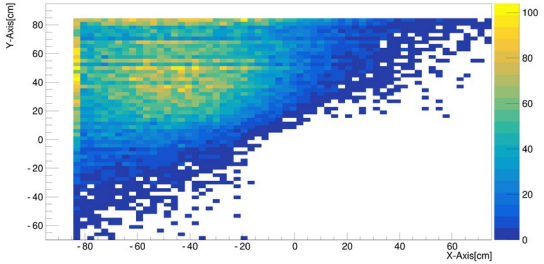
PSD1



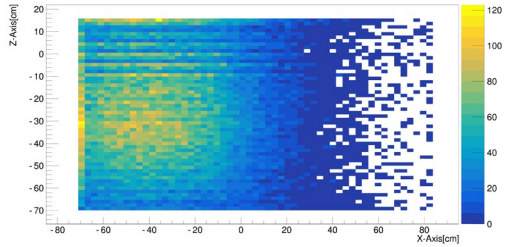
PSD3



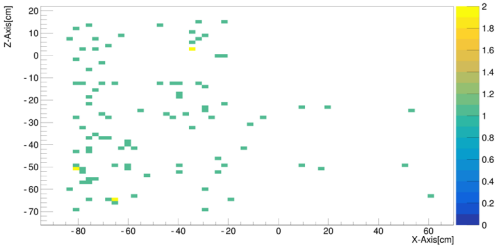
PSD5



PSD2



PSD4

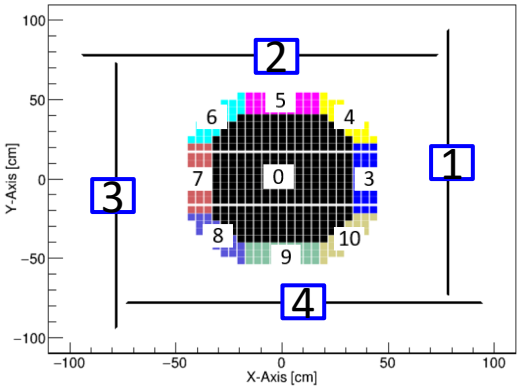


- CALO[6] should be vetoed with PSD 2&3&5 regions.
- Sectors can be divided to small partitions.

4.1.5 PSD&CALO ROI Design – v1

LEG ROI v1

Analyzed with geantino.

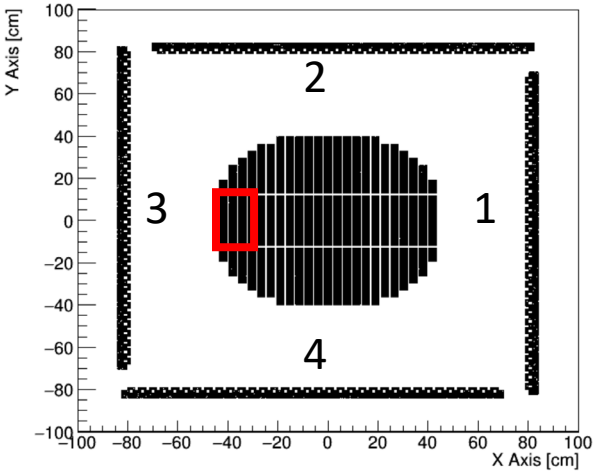


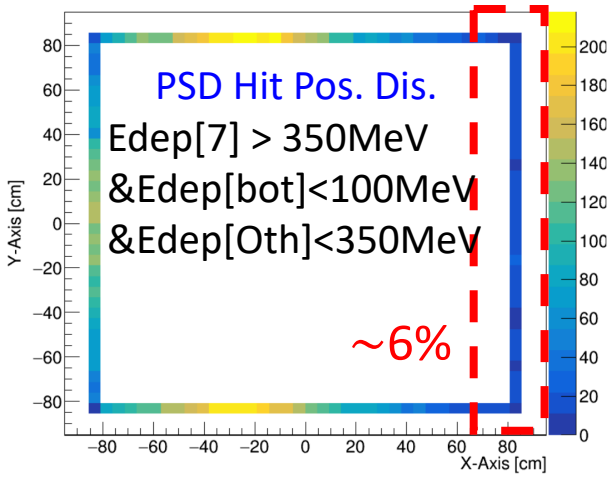
CALO No.	PSD No.	PSD Trigger Region Area [m^2]
1	0,1,2,3,4	9.456
3	0,1,2,4	7.902
4	0,1,2	6.348
5	0,1,2,3	7.902
6	0,2,3	6.348
7	0,2,3,4	7.902
8	0,3,4	6.348
9	0,1,3,4	7.902
10	0,1,4	6.348

- Based on 11 CALO trigger region, LEG ROI design v1 uses PSD region as the maximum matching unit.
- The ROI design v1 is based on the geantino hit, which is found to be unsuitable for proton events.

4.1.6 PSD&CALO ROI Design – v2

Analyzed with Proton events.





- Due to the shower leakage of proton, around 6% events deposit large energy in the opposite region.
- Full-Matching ROI Plan (v2)

LEG ROI v2

CALO	PSD	PSD Area [m^2]
1,3-10	0,1,2,3,4	9.456

- Once any PSD sector provide a veto signal, the event is rejected.
- The PSD responding area is the same for different CALO region.

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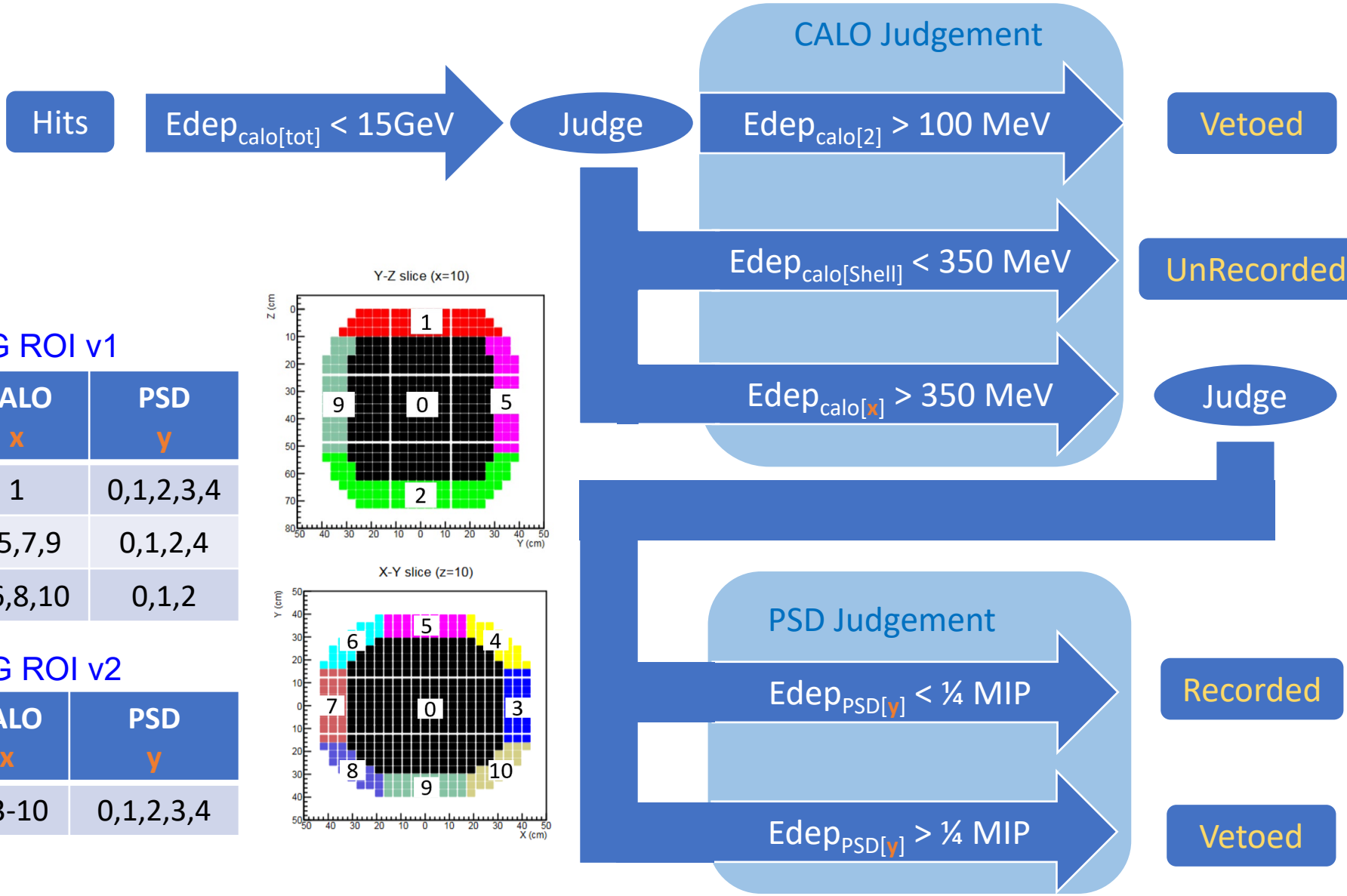
4.2.1 LEG trigger Logic



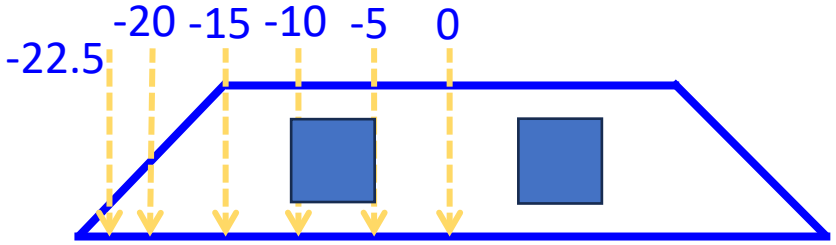
LEG ROI v1

CALO x	PSD y
1	0,1,2,3,4
3,5,7,9	0,1,2,4
4,6,8,10	0,1,2

LEG ROI v2

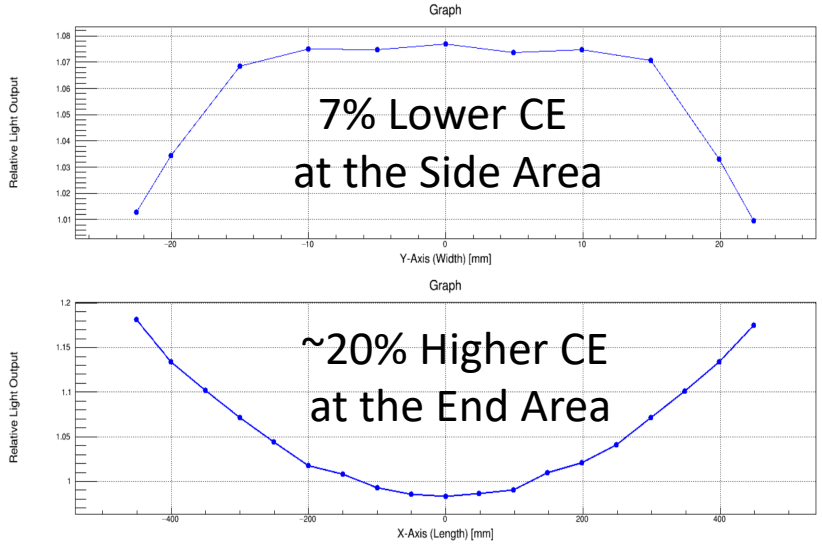
CALO x	PSD y
1,3-10	0,1,2,3,4

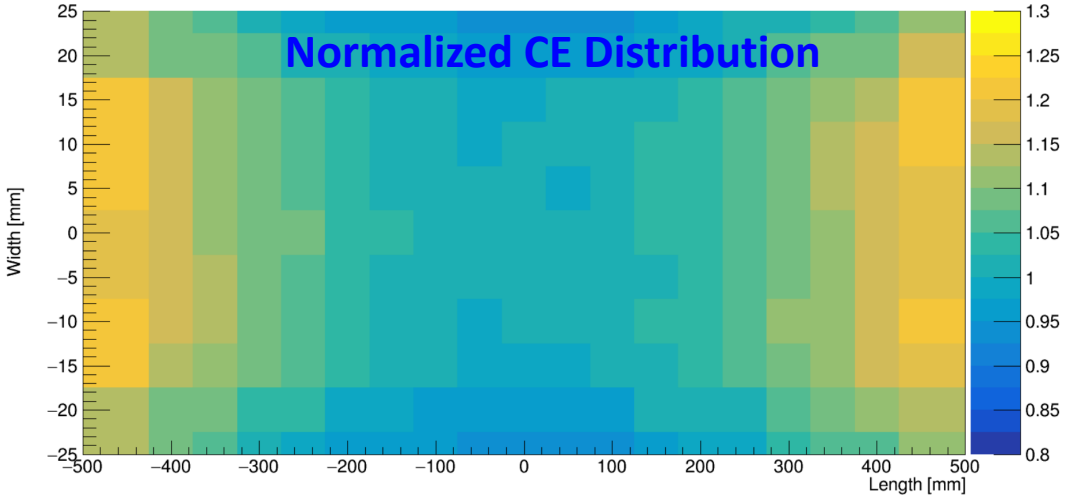
4.2.2 Light Transmission Efficiency



Two 6x6 mm^2 SiPM at each end

- The Collection Efficiency (CE) is simulation independently. (From Prof. Jifeng)
- The edep in PSD is weighted at step level with CE which is linearly interpolated and normalized with the middle position.
- Need to be verified with experimental results.





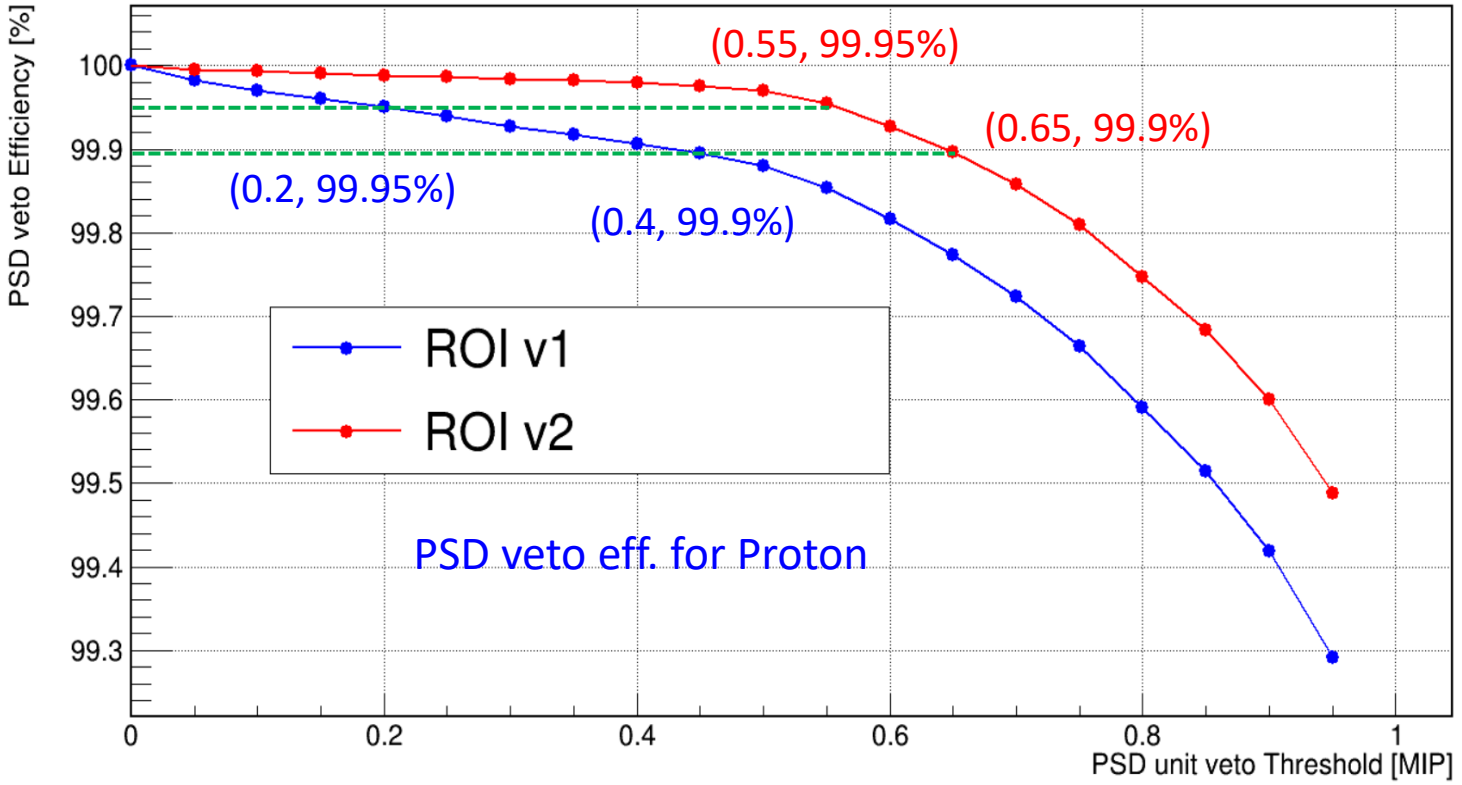
4.2.3 LEG PSD veto Efficiency

CALO Trigger: $Edep_{Calo[all]} < 15GeV$ & $Edep_{Calo[2]} < 100MeV$ & $Edep_{Calo[x]} > 350MeV$

LEG Trigger: $Edep_{PSD[y]} <$ PSD Threshold

$$\text{PSD veto Efficiency} = 1 - \frac{CALO\ \&\ LEG\ Trigger\ Rate}{CALO\ Trigger\ Rate}$$

Not adding the shielded flux under cutoff



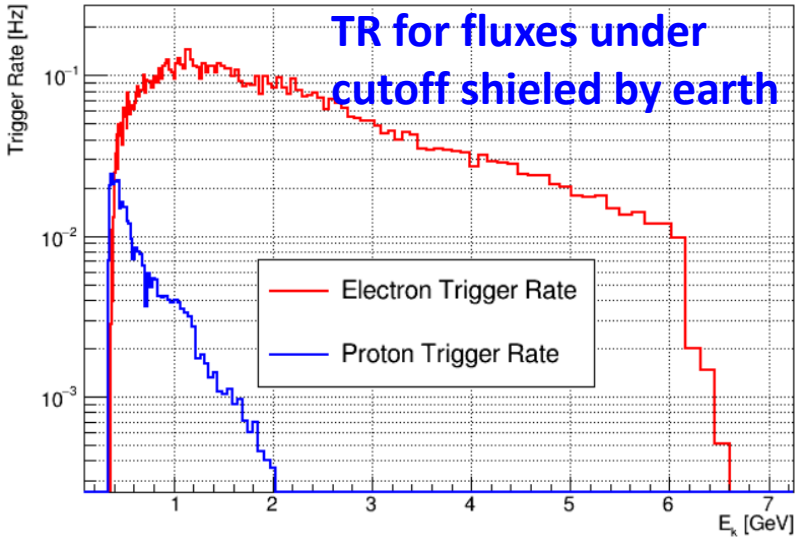
- 99.95% veto efficiency can be obtained with 0.55 MIP threshold for ROI v2.
- Still need to mention, the CE distribution should be checked with the experimental data.

4.2.4 LEG PSD Trigger Rate

TR for fluxes not shieled by earth **TR for fluxes under cutoff shieled by earth**

Bot. CALO Veto [MeV]	Shell & Top CALO Trigger [MeV]	PSD veto [MIP]	Average TR Proton [Hz]	Max. TR Proton [Hz]	Average TR Electron [Hz]	Max. TR Electron [Hz]
100 - ROI v1	350	1/4	0.72	7.00	0.42	0.57
100 - ROI v1	350	1/3	0.85	8.58	0.46	0.66
100 - ROI v2	350	1/4	0.14+0.34 (0.48)	1.68+0.38 (2.06)	0.32+7.64 (7.96)	0.45+9.0 (9.45)
100 - ROI v2	350	1/3	0.18+0.36 (0.54)	2.07+0.40 (2.47)	0.35+8.35 (8.70)	0.50+9.7 (10.2)

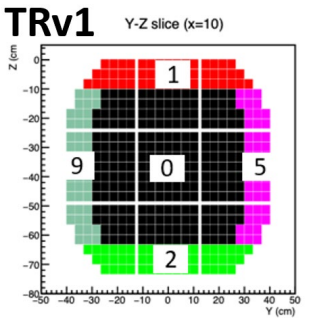
- ROI v2 can greatly improve the veto efficiency and lower the trigger rate.
- The trigger rate for fluxes under cutoff and shieled by earth is high, which is over-estimated.
- The flux is to be updated to be angular dependent. The equipment box is also to be added.

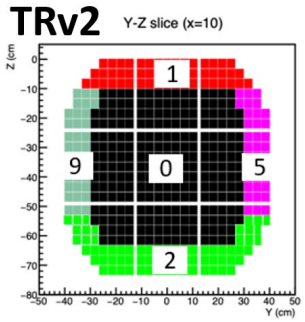


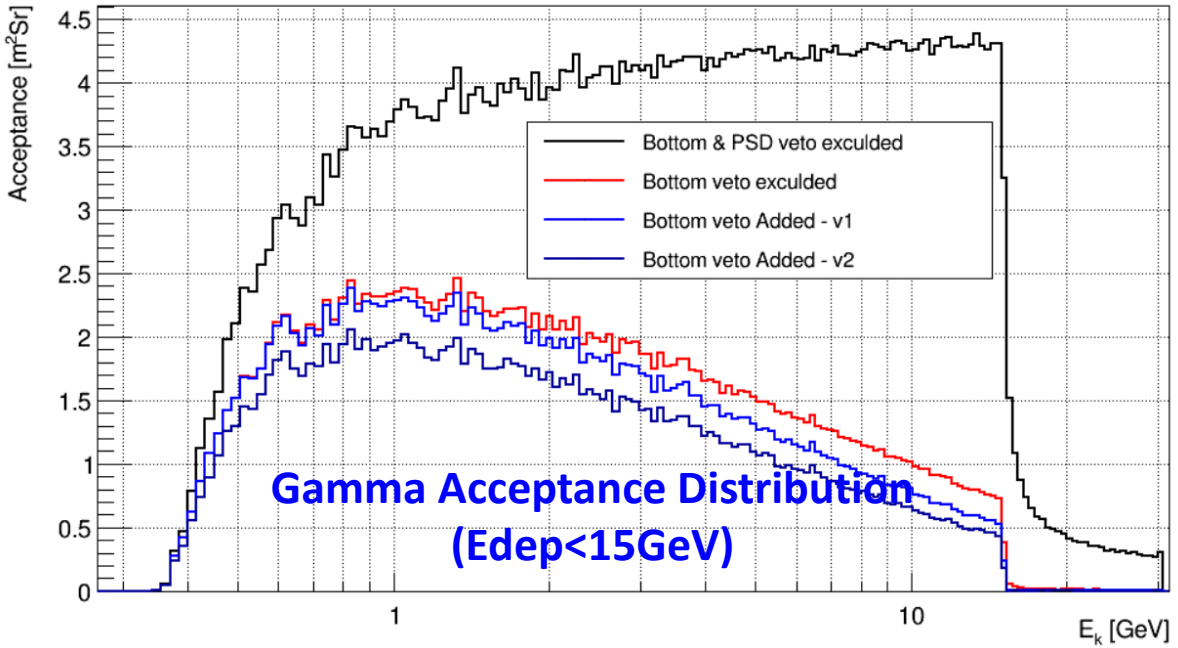
Outline

- 1. Principle of LEG Design
- 2. Basic Analysis Information
- 3. PSD Uncovered Leakage
- 4. PSD Covered Leakage
- 5. Gamma Detection
  - 5.1 Acceptance
  - 5.2 False veto Rate
- 6. Conclusion

5.1 Gamma Acceptance





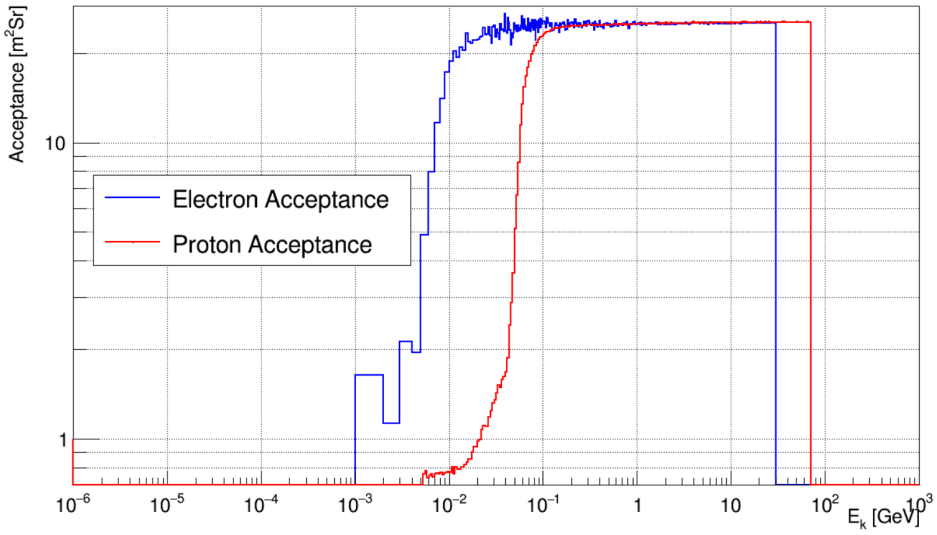


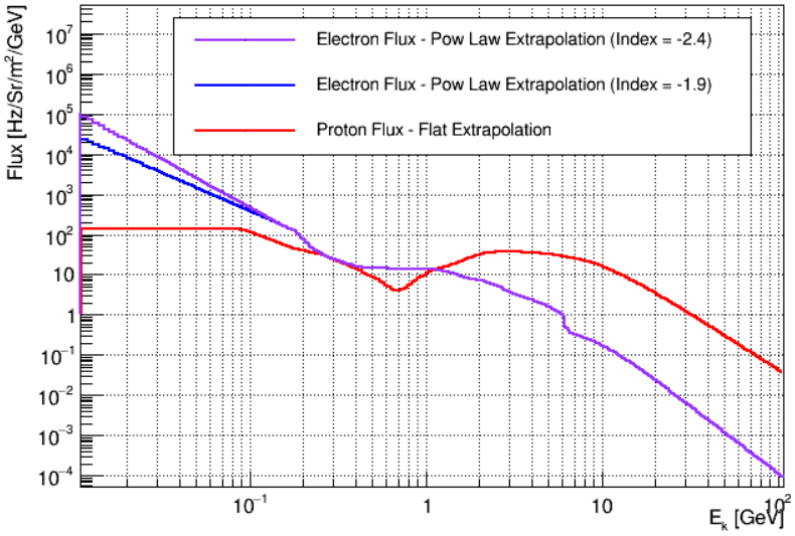
Bot. CALO Veto [MeV]	Shell & Top CALO Trigger [MeV]	PSD veto [MIP]	Ave. trigger rate Proton [Hz]	Max. trigger rate Proton [Hz]
no veto	350	1/4	8.3	78.4
TRv2 – 100 MeV	350	1/4	0.15	1.74
TRv1 – 100 MeV	350	1/4	0.7	7.0

- Acceptance and trigger rate are both lowered by introducing CALO bottom veto.

5.2.1 Mis Veto - Event Rate

False Veto: Gamma Events vetoed by a charged particle arriving at the same electronic coincidence time window.





	Proton	Electron (Index = -1.9)	Electron (Index = -2.4)
Event Rate [Hz/cm^2]	0.1	0.2	1.5

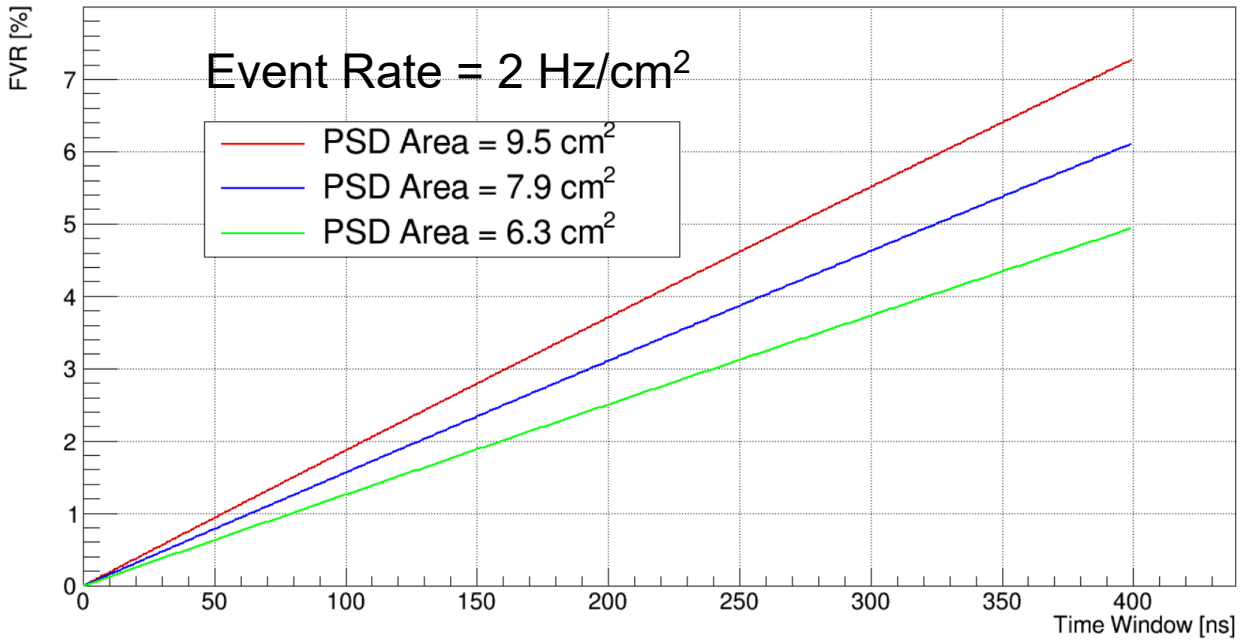
- The extrapolation of electron will greatly affect the results.
- An event rate = 2 Hz/cm^2 is used for further calculation.

5.2.2 False veto Rate (FVC)

False Veto Rate: Probability that gamma event is falsely vetoed within the time window.

Averaged False Veto Counts (FVC) = Event Rate x Time Window x PSD Area

$$False\ Veto\ Rate\ (FVR) = 1 - \frac{e^{-FVC}}{0!} FVC^0$$



- FVR is shown to be linearly connected with the coincidence time window.
- If the time window is small, FVR is not greatly affected by the PSD area (6.3->9.5).
- Noise of SiPM is to be added in the further update.

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6. Conclusion

1. A complete evaluation process for LEG has been basically realized.
2. A lot of details are to be modified, includes:
   - The bottom equipment box of HERD is to been added in the simulation
   - The fluxes are to be updated to be angular dependent.
   - The contribution to the mis-veto due to the noise of SiPMs is to be added.
   - The contribution to the mis-veto due to recoil of shower from gamma event is to be added. (Not severe below 15GeV)
   - The PSD unit collection efficiency should be tested.
   - Test LEG performance under various PSD layout plan
   - … More suggestions on improvements are welcomed.