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1905

Design and Performance of Si-CsI Detector System for LAMPS

Suhyun Lee, Songkyo Lee

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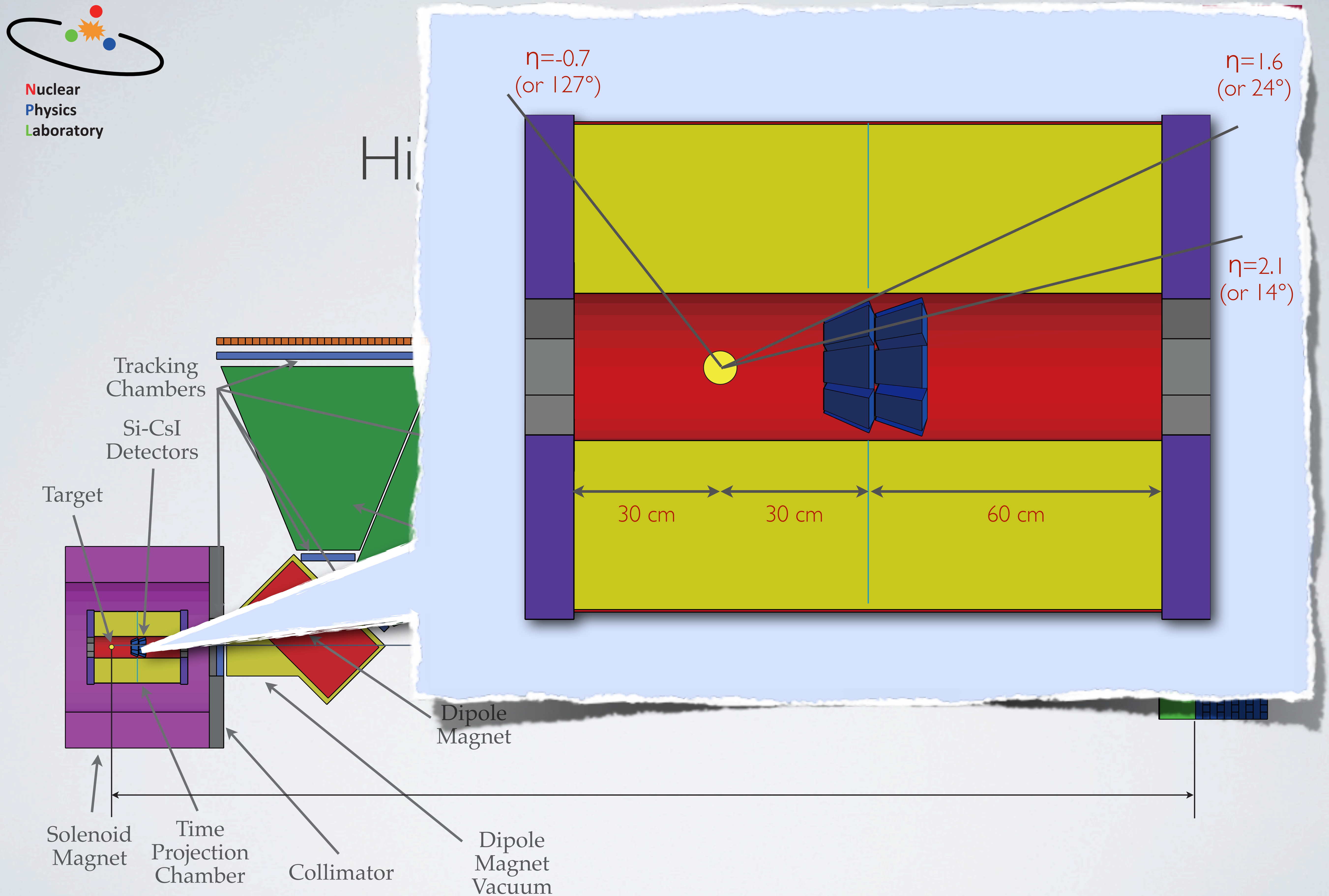
Contents

- Transmission Detector / Si-CsI array for LAMPS
- Isotope lines
- Measurable Range / Veto Counter
- Mass Plot / Simulation of Collision Event
- Various Designs & Scales / Multiplicity
- Conclusion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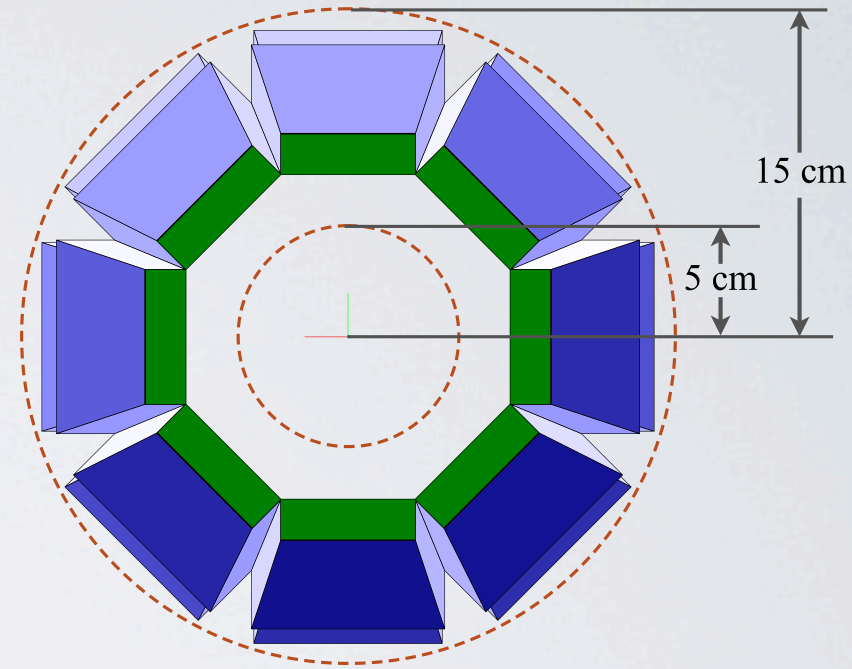
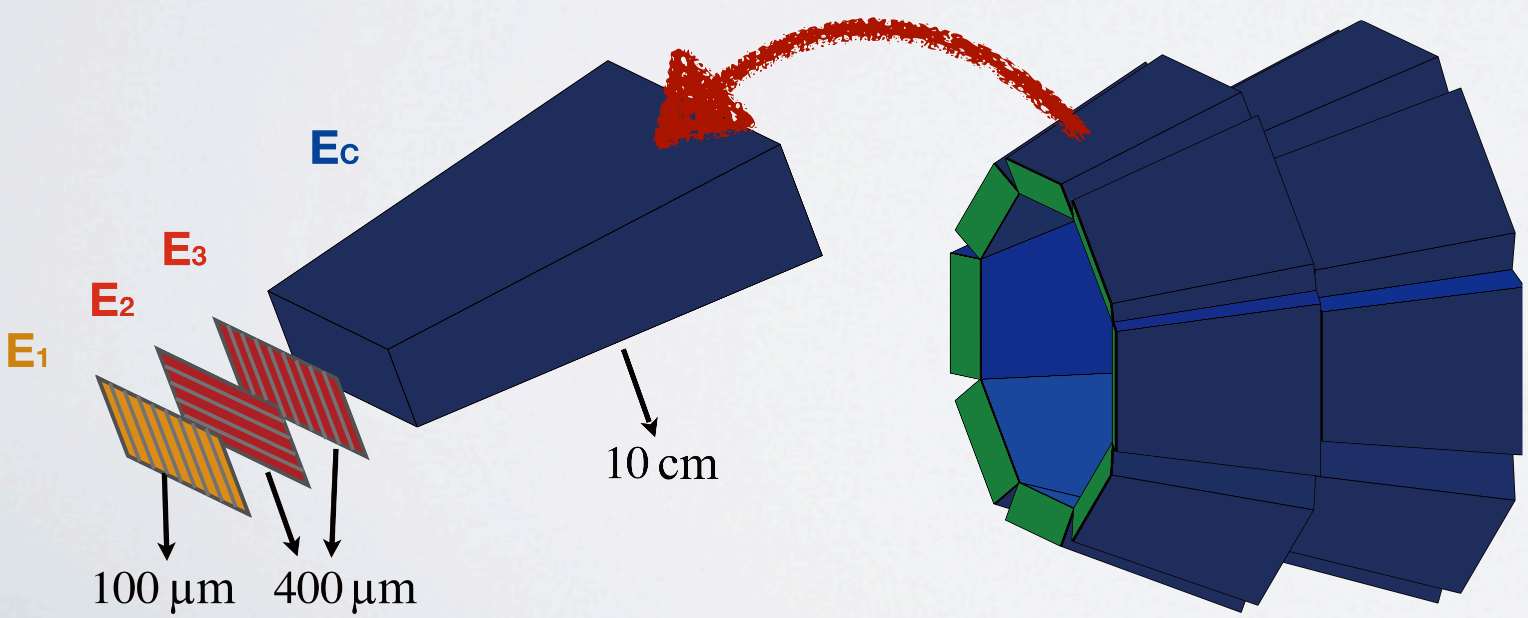
Hi
η=-0.7
(or 127°)
η=1.6
(or 24°)
η=2.1
(or 14°)
30 cm
30 cm
60 cm
Tracking
Chambers
Si-CsI
Detectors
Target
Dipole
Magnet
Solenoid
Magnet
Time
Projection
Chamber
Collimator
Dipole
Magnet
Vacuum

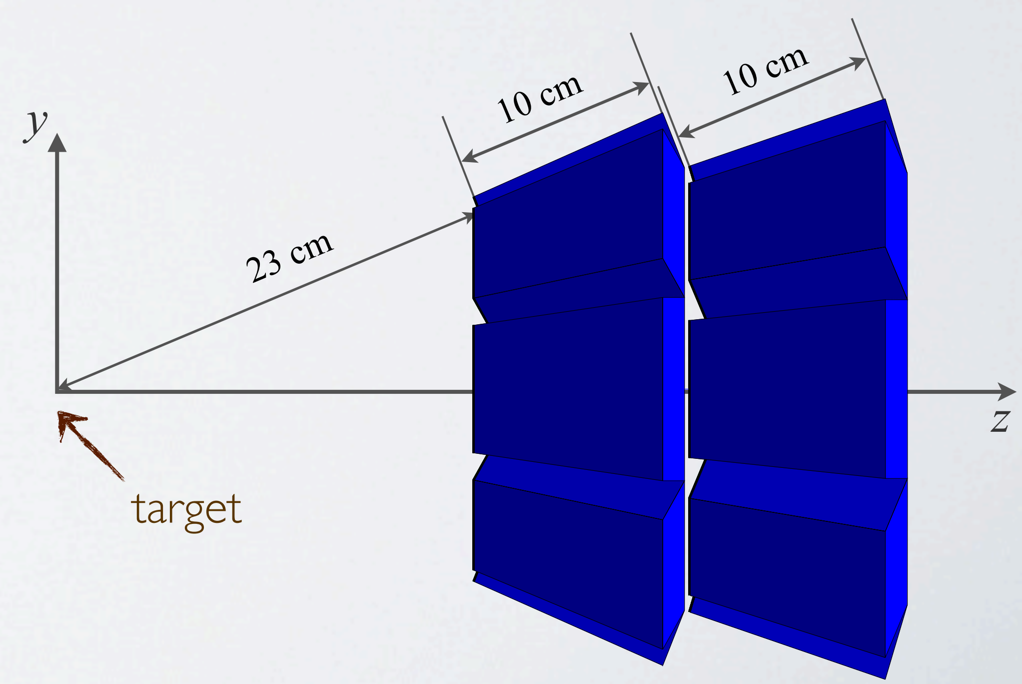
Si-CsI array for LAMPS

- Measurement of the charged particles in the forward region
  - pseudo-rapidity up to 2.1 in which TPC and two dipole arms cannot cover

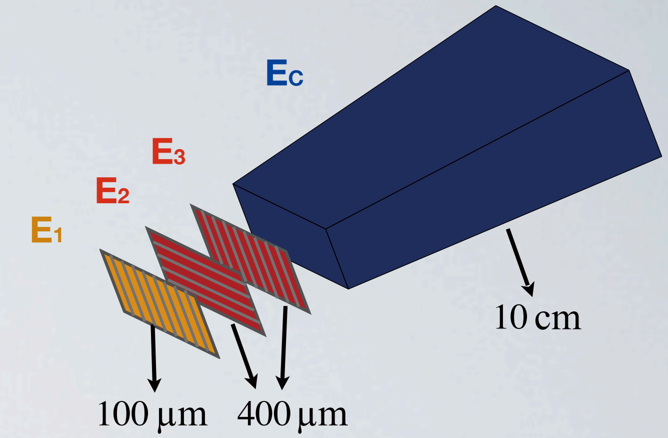


- Three Si layers and + one CsI crystal.
  - Si layers for ΔE & CsI for E
  - 14°~19° & 19°~24° (350 mSr each)



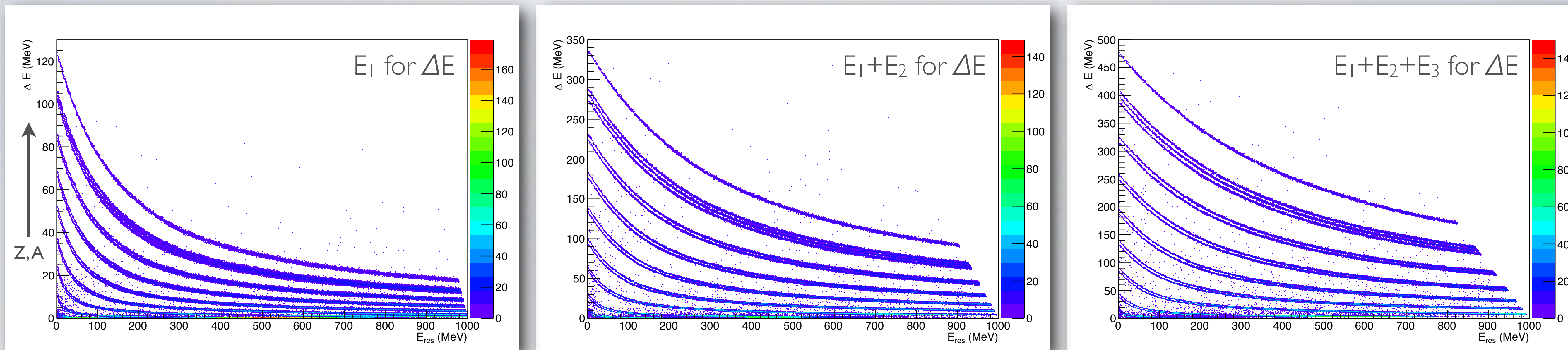


Isotope lines

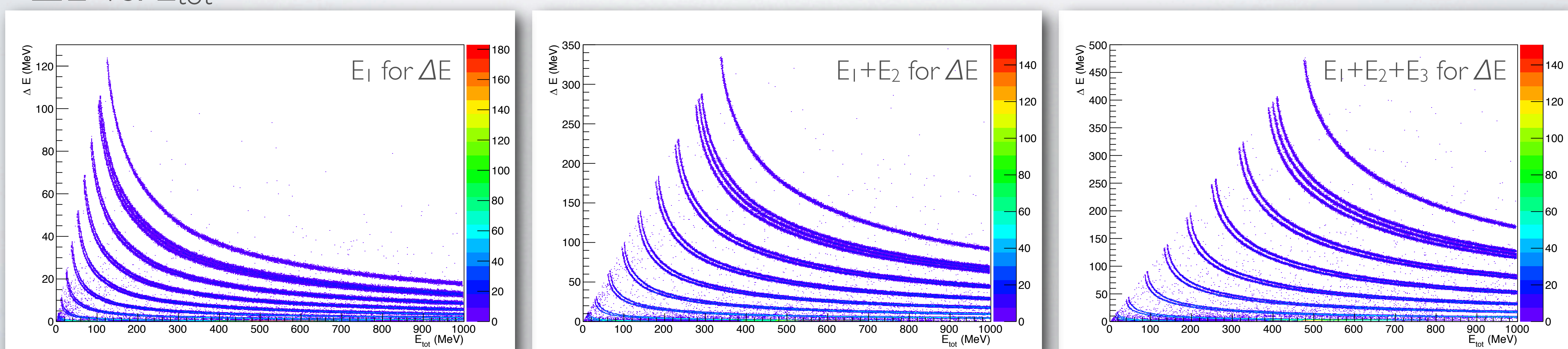


ΔE vs. E_{res}

Single Particle Monte Carlo

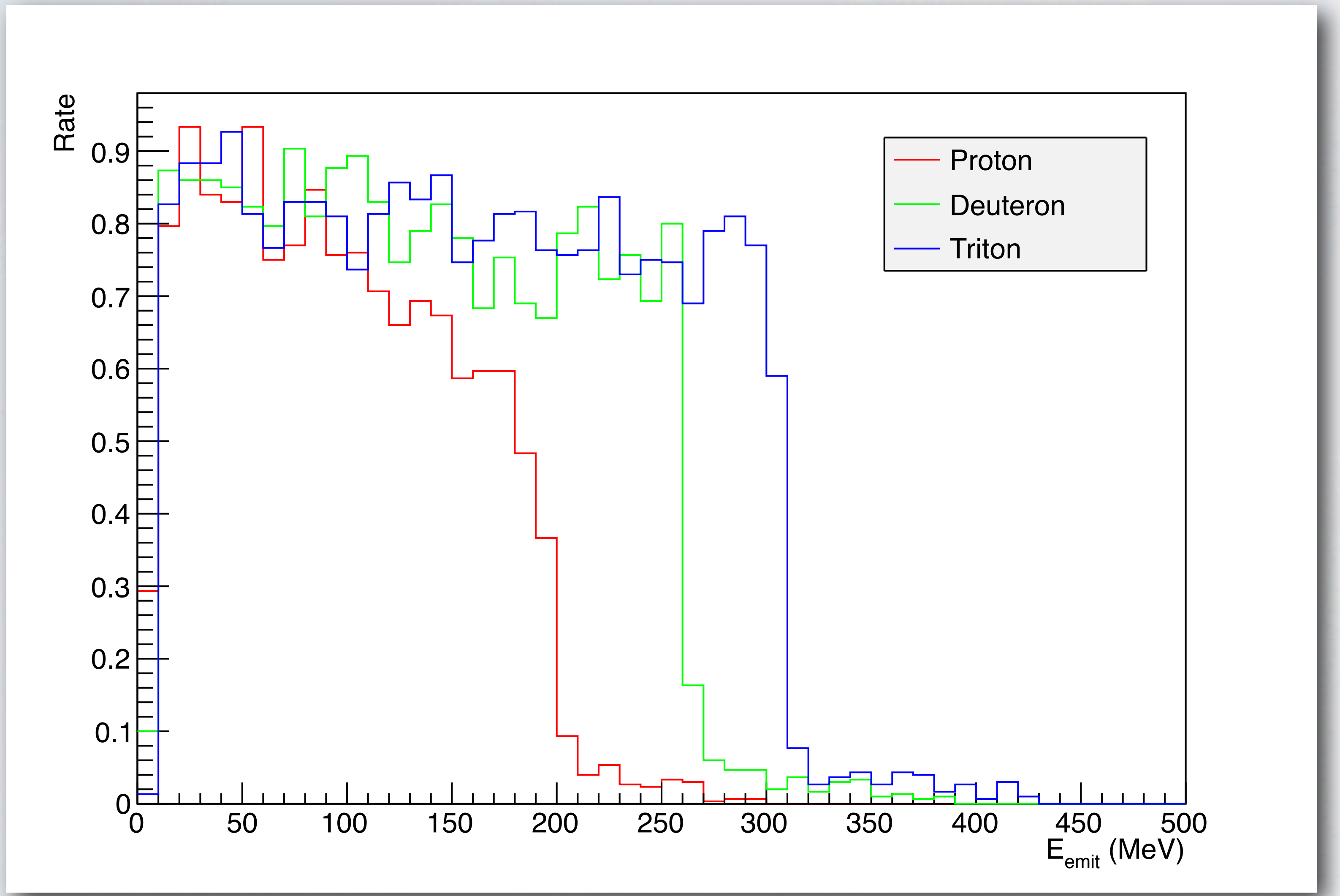


ΔE vs. E_{tot}

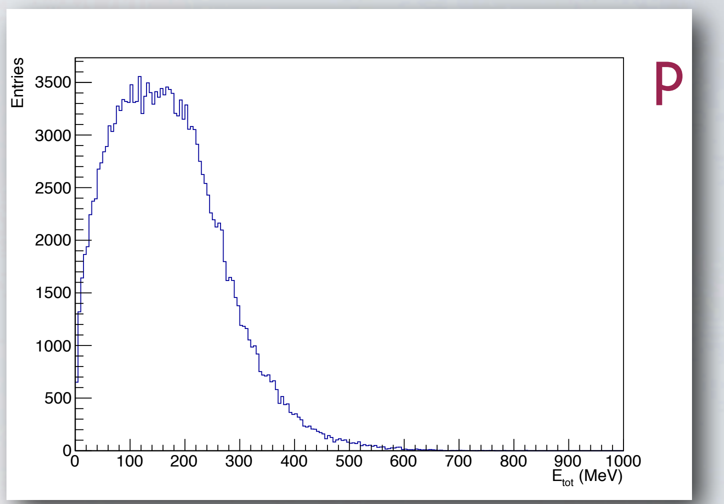


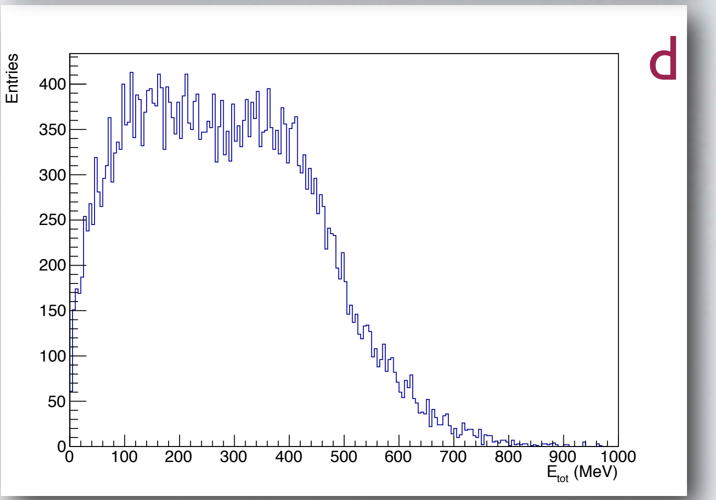
Measurable Range

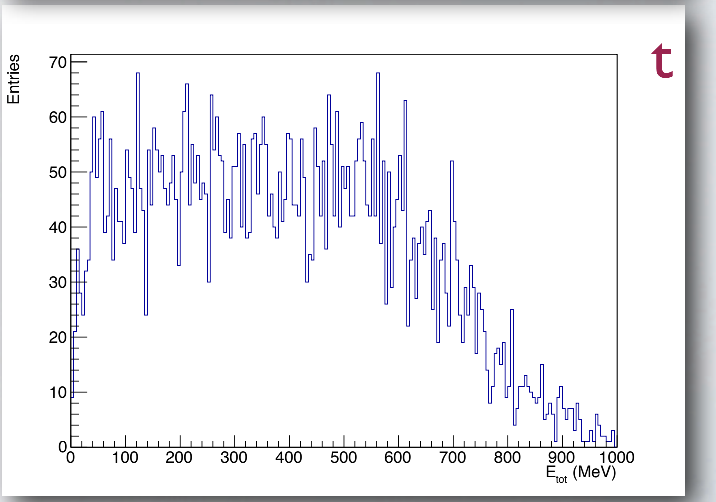
Isospin-dependent Quantum Molecular Dynamics (IQMD) Model
Fixed target events, Au-Au Collision, 250MeV/u,



$$\frac{E_{\text{emitted}} - E_{\text{dep}}}{E_{\text{emitted}}} \times 100 < 5\ \% \Longrightarrow \text{Success!!}$$







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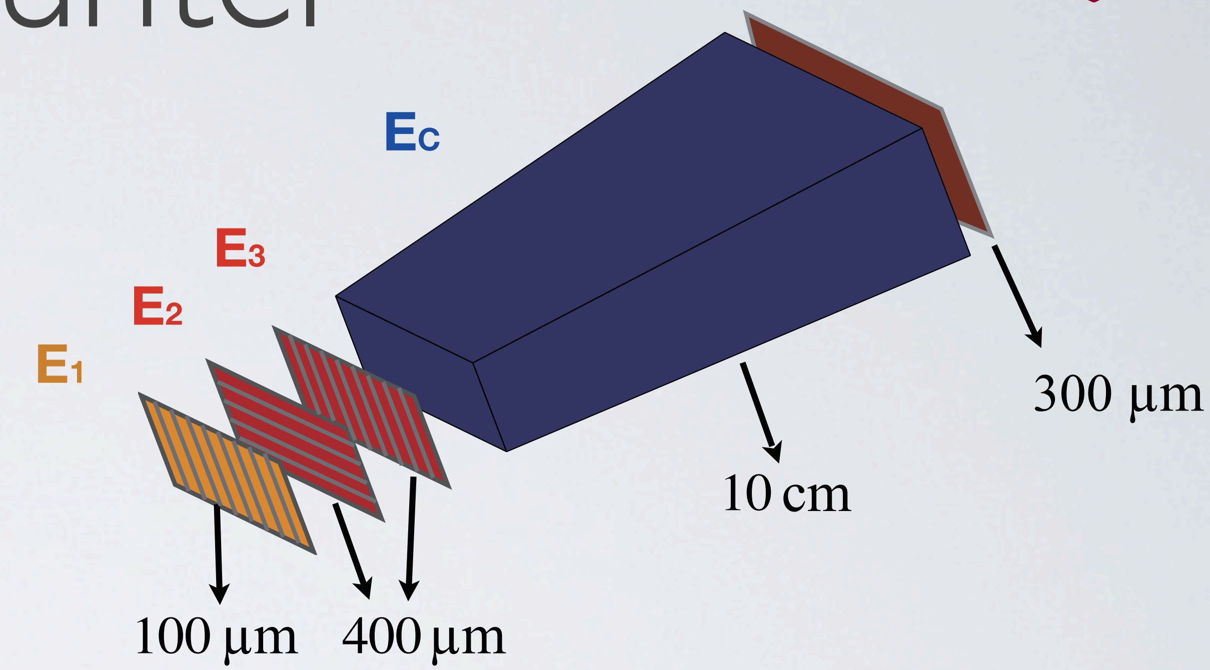
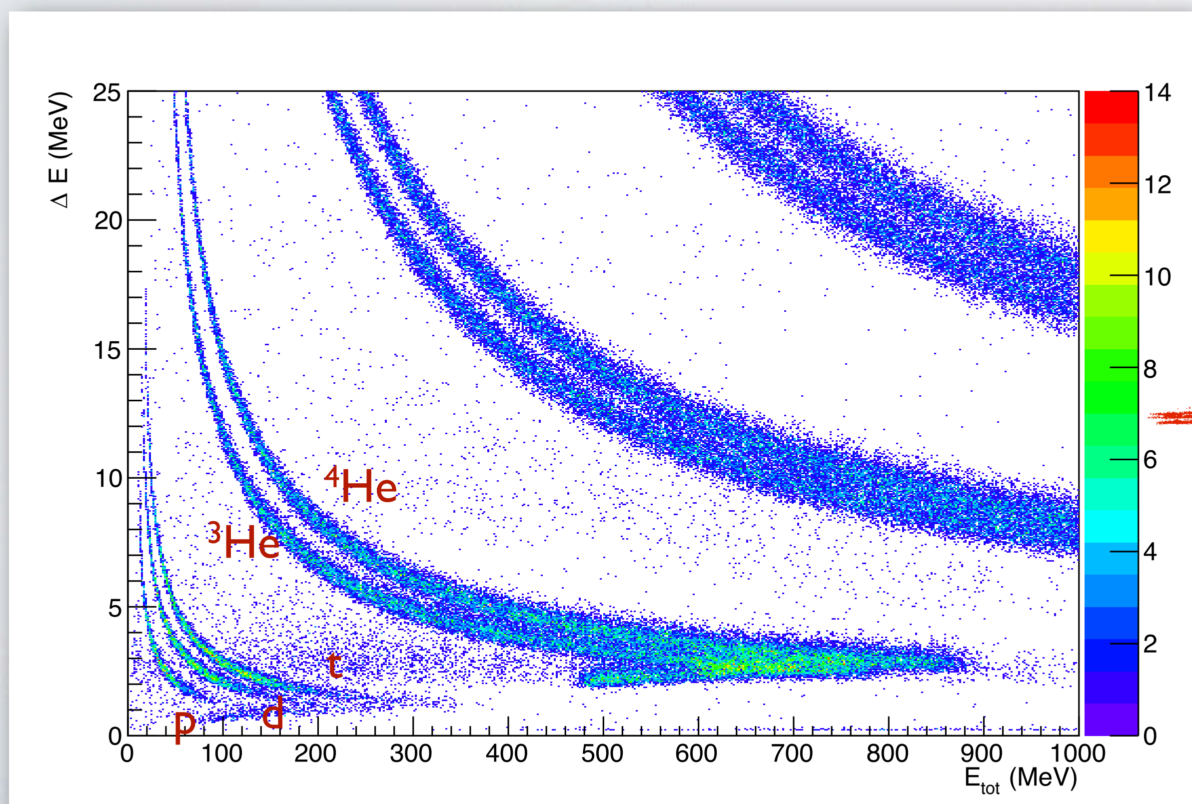
Veto Counter

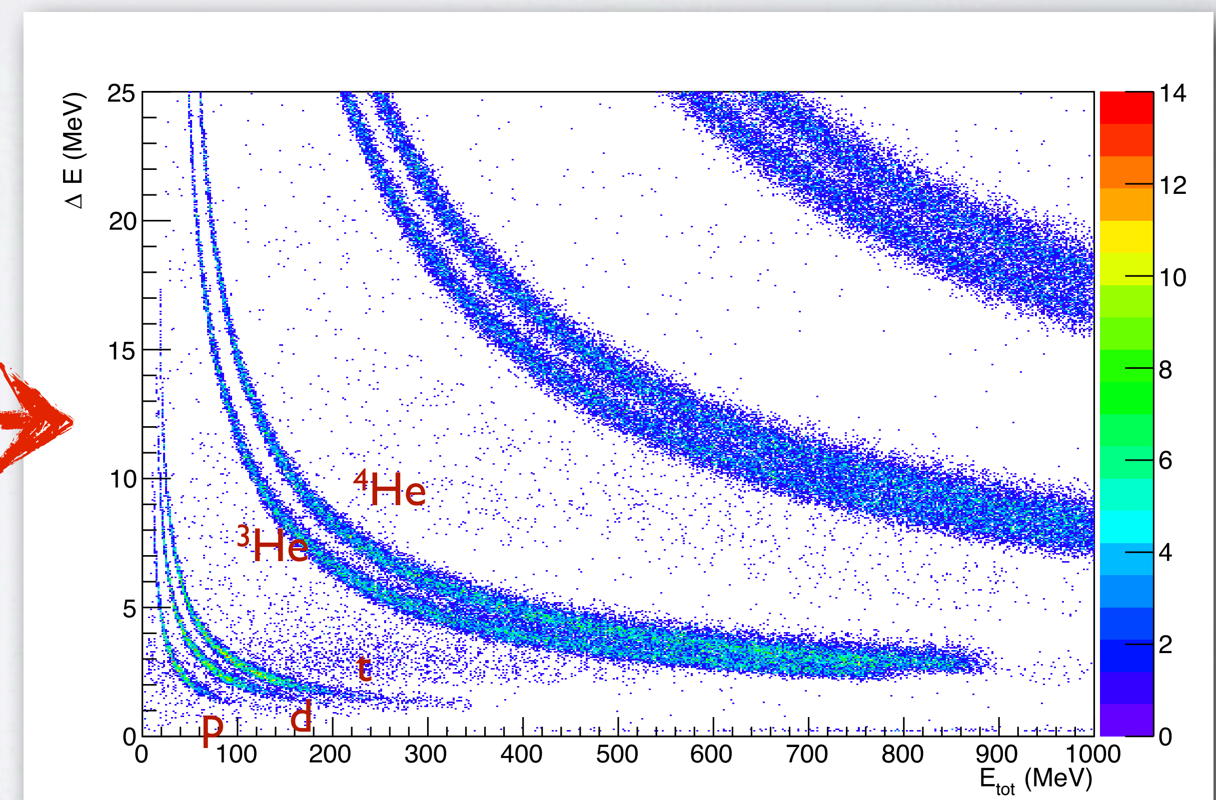
- The veto counter utilizes the silicon detector with the thickness of 300 μm.
- If a signal is guarantee in the veto counter, the event was rejected.



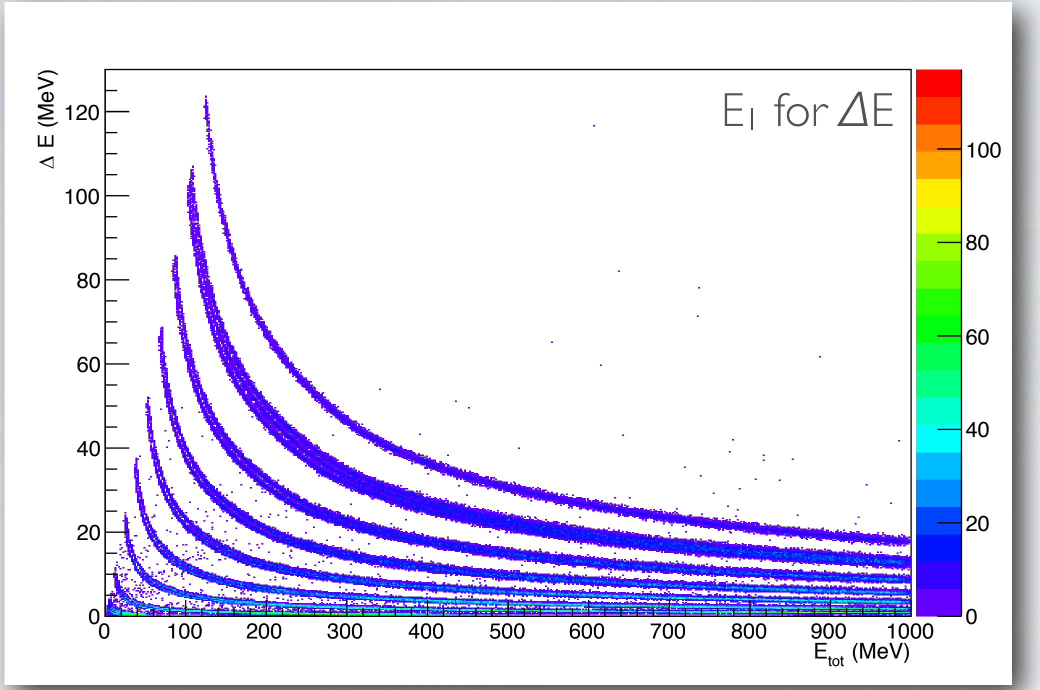
w/o veto

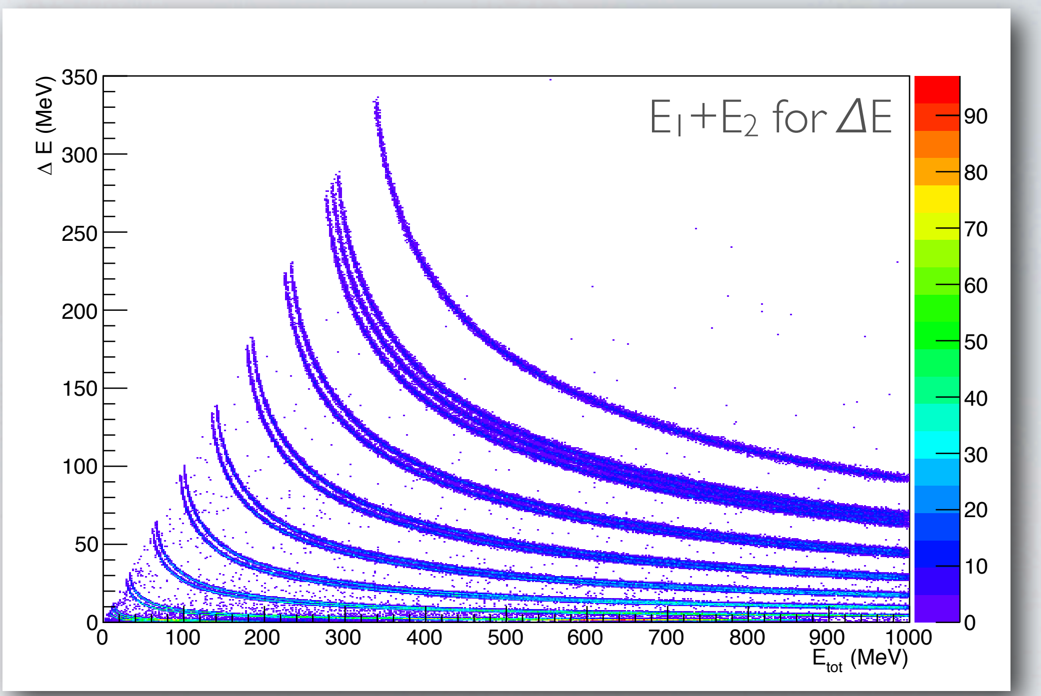


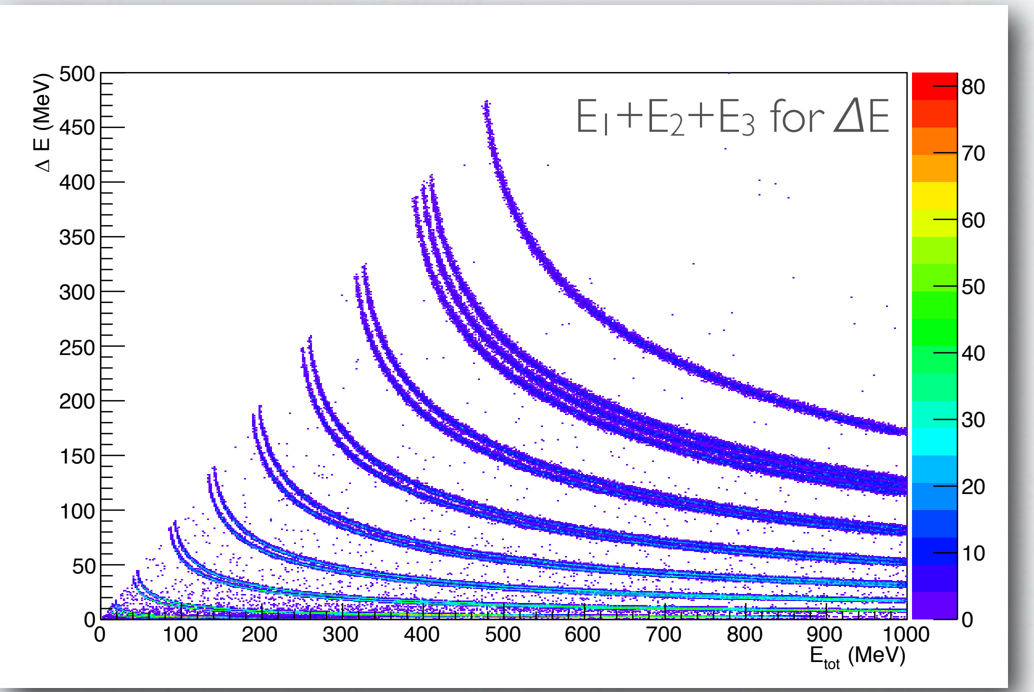
/w veto



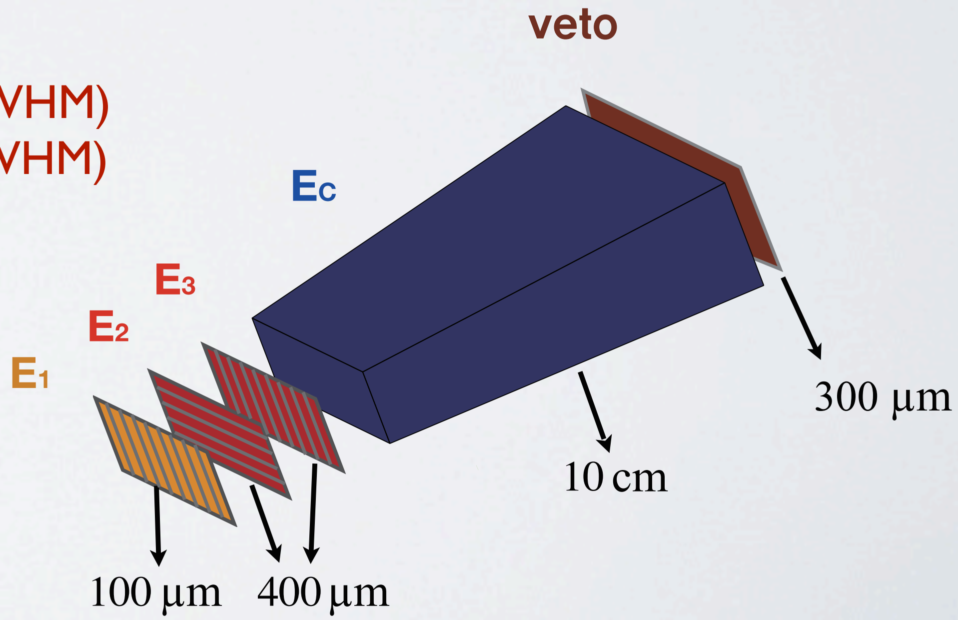
Isotope Lines with Veto



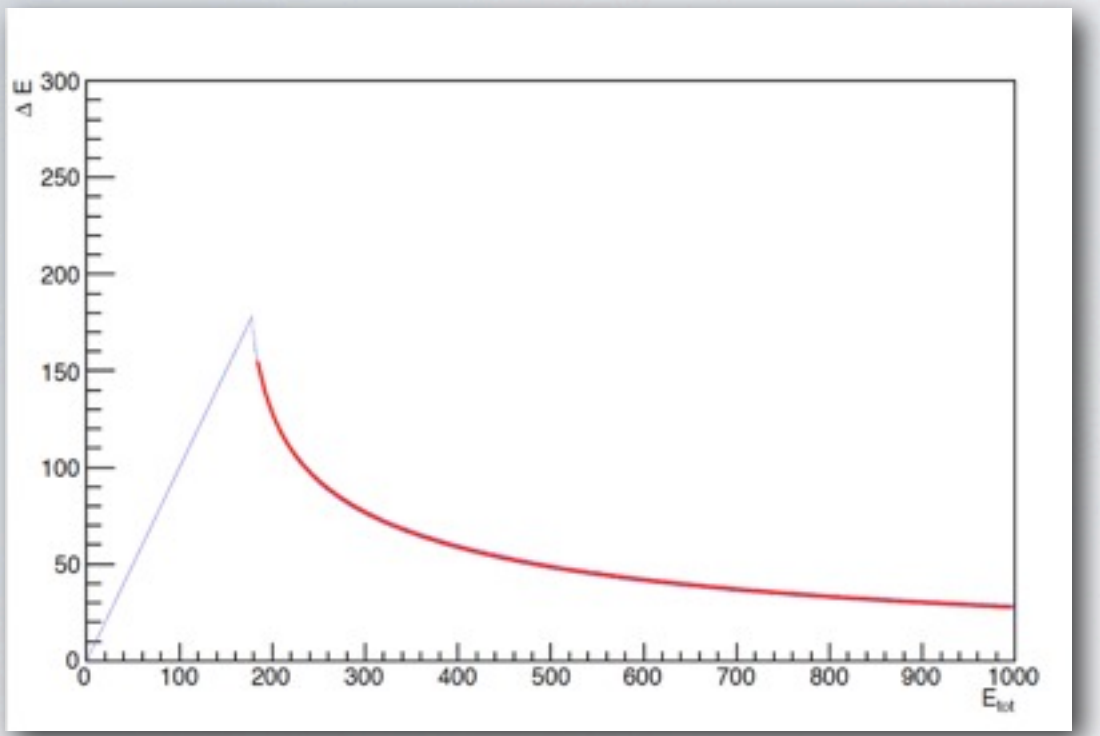


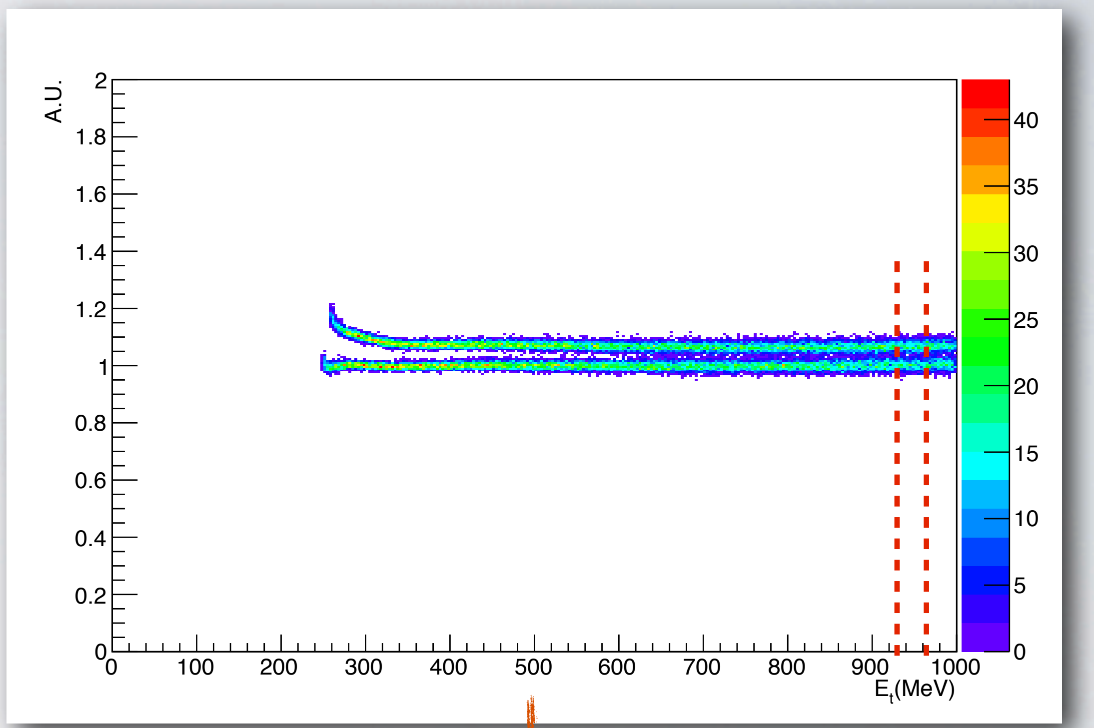


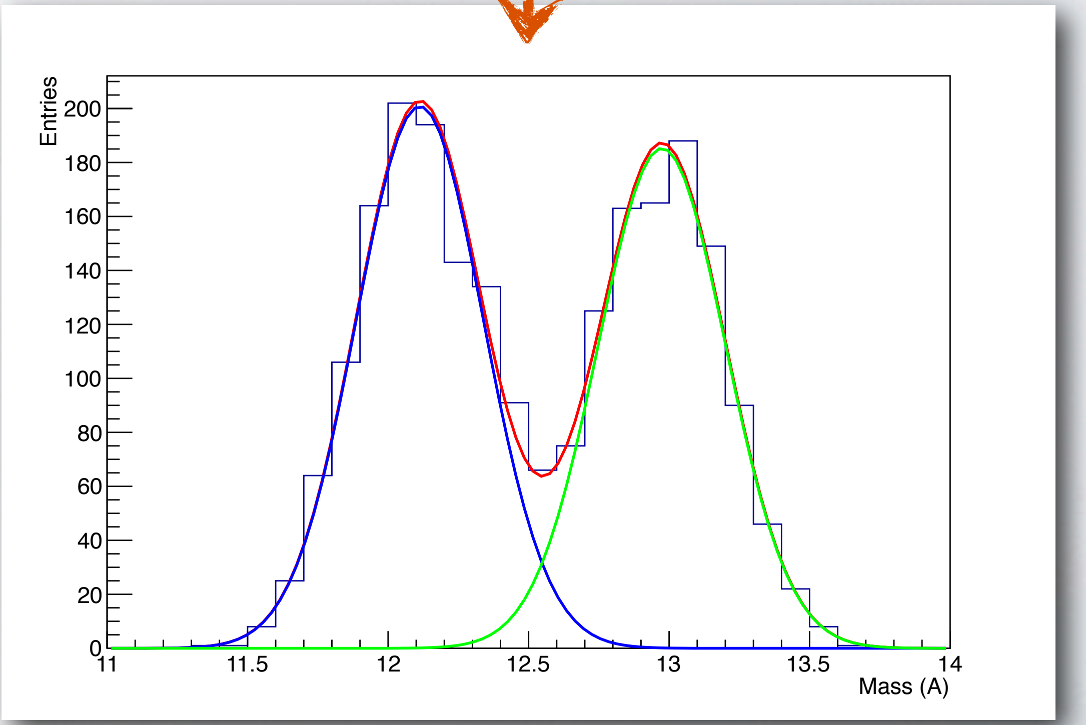
Si : 0.5 % (FWHM)
CsI : 2 % (FWHM)



Mass Plot with Si-CsI Array







- Linearize the mass distribution using empirical fit functions.
- By fitting each isotope with gaussian, we could estimate the yield.

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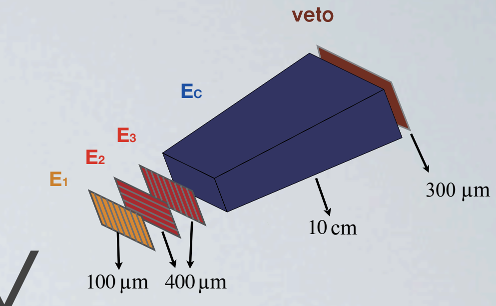
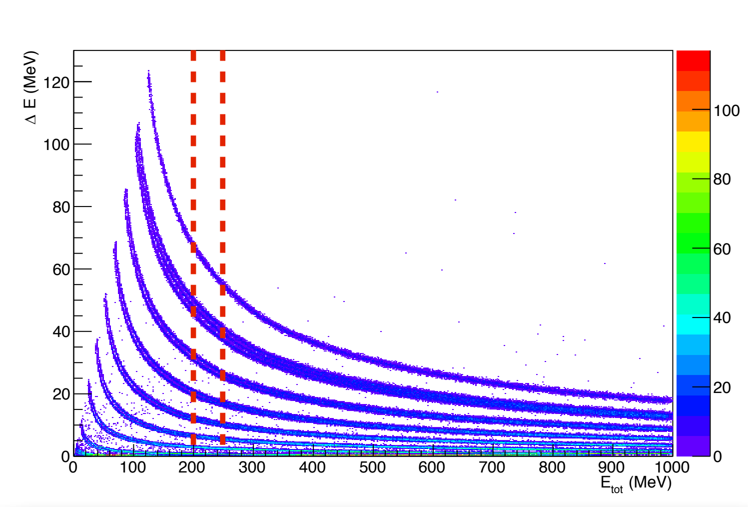
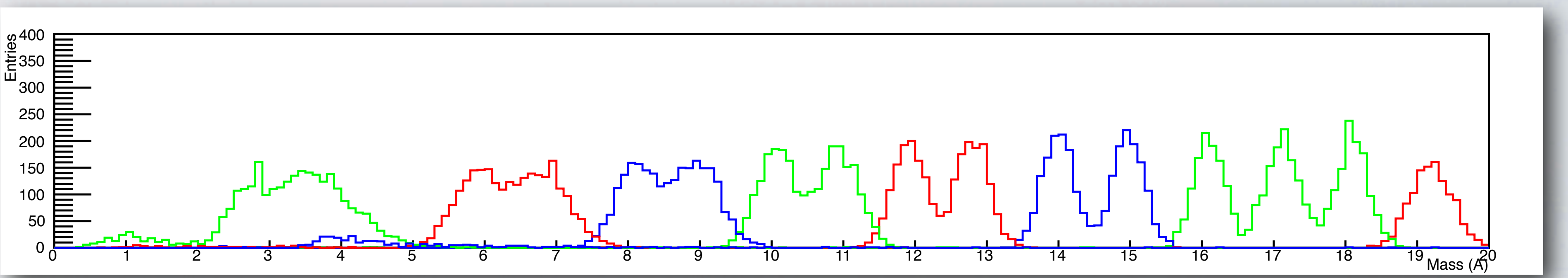
Mass Plot with Si-CsI Array



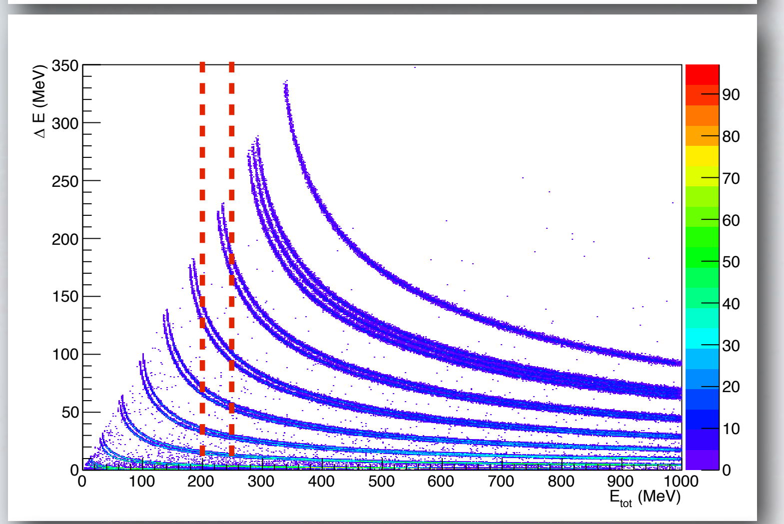
$200\ \text{MeV} < E_{tot} < 250\ \text{MeV}$

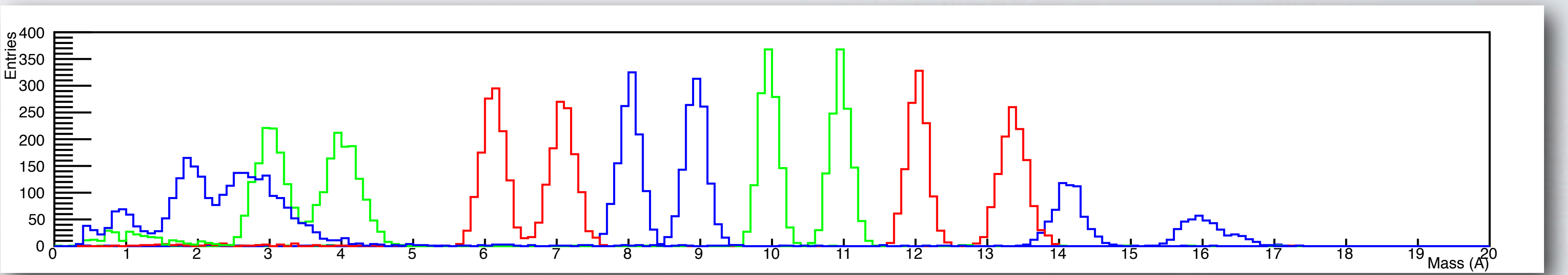
E_1 for ΔE



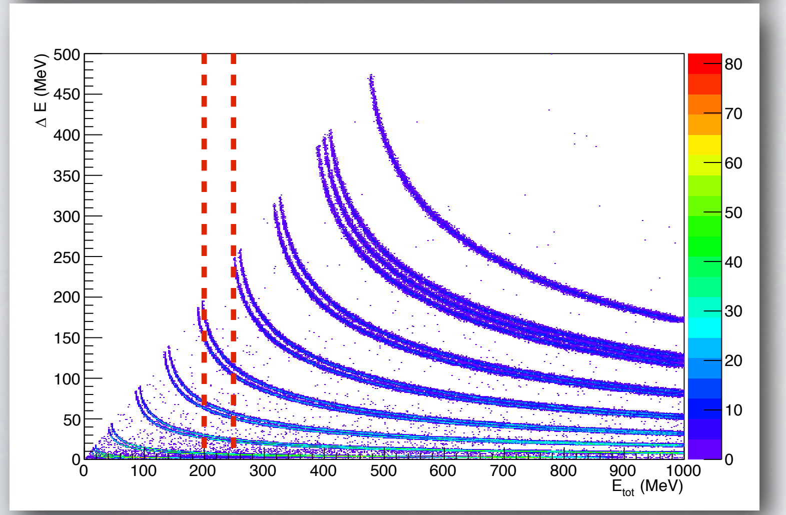


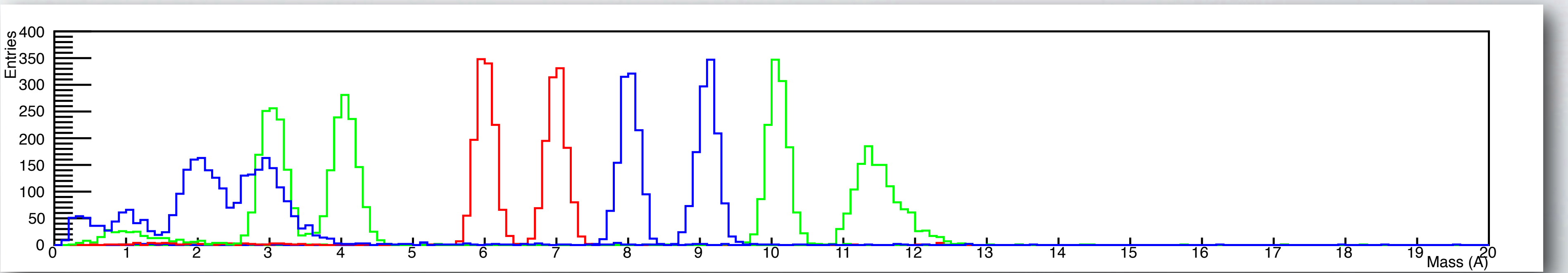
E_1+E_2 for ΔE





$E_1+E_2+E_3$ for ΔE





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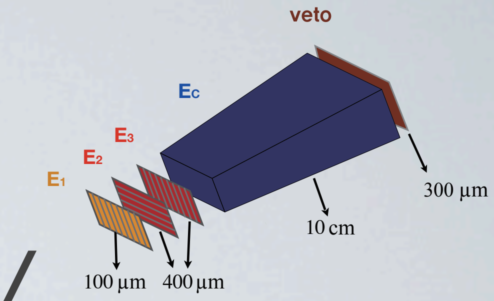
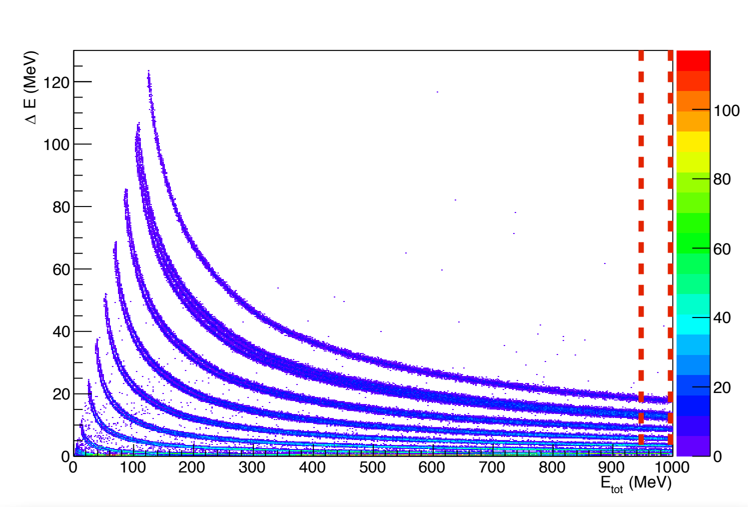
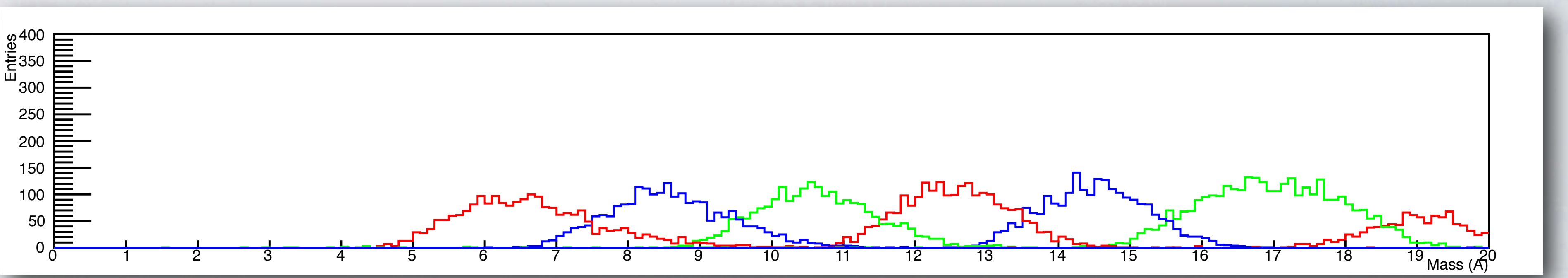
Mass Plot with Si-CsI Array

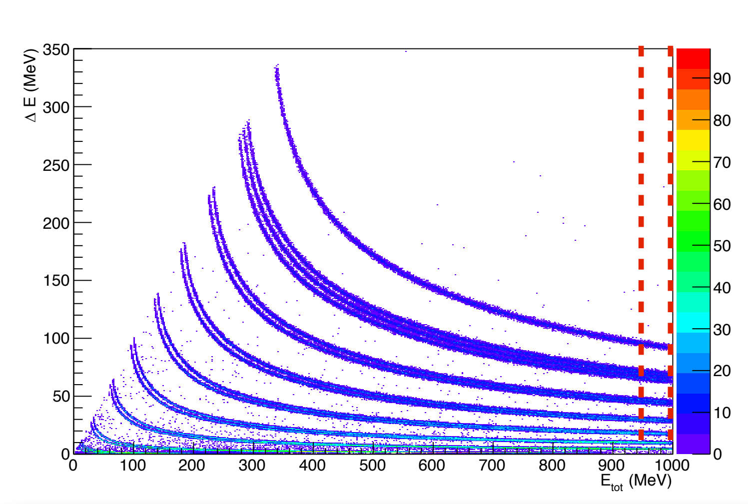


950 MeV < E_{tot} < 1000 MeV

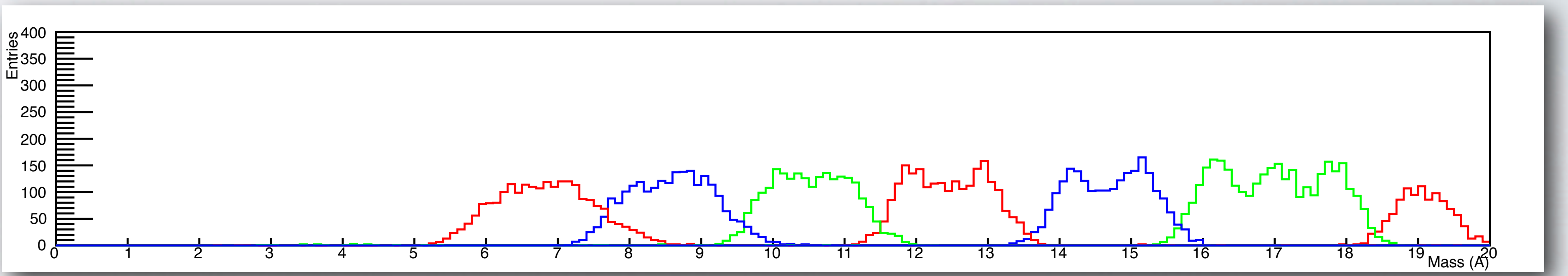


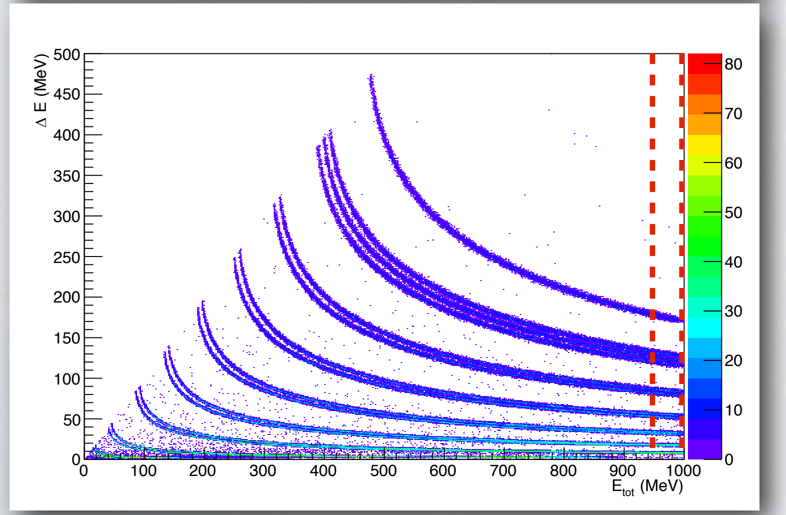
E_1 for ΔE



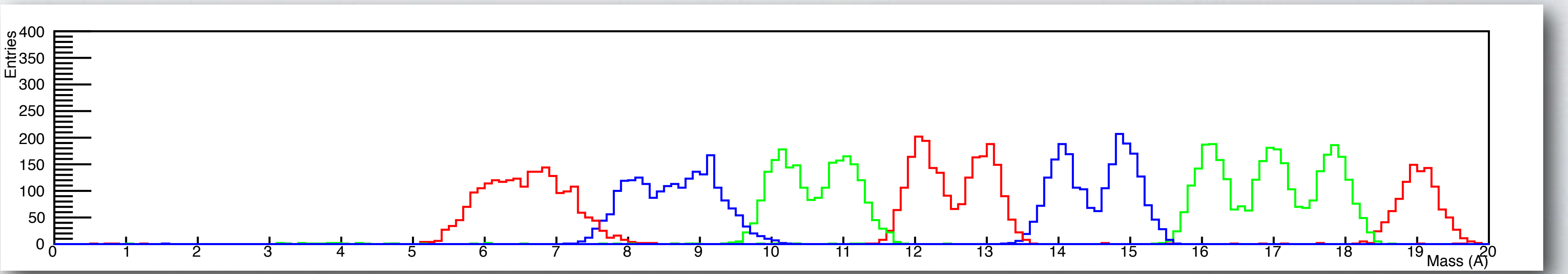


E_1+E_2 for ΔE





$E_1+E_2+E_3$ for ΔE



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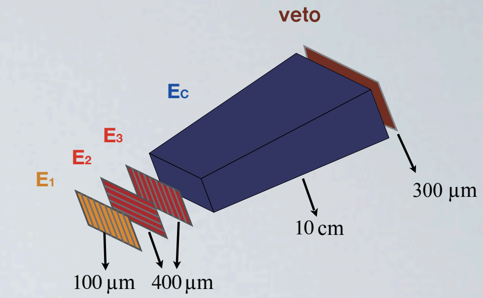
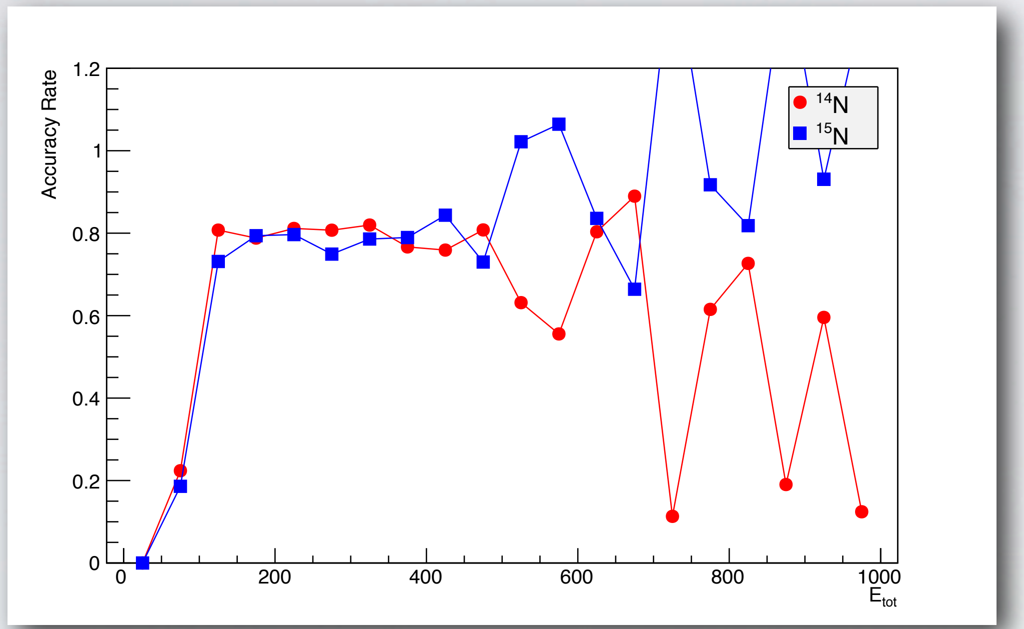
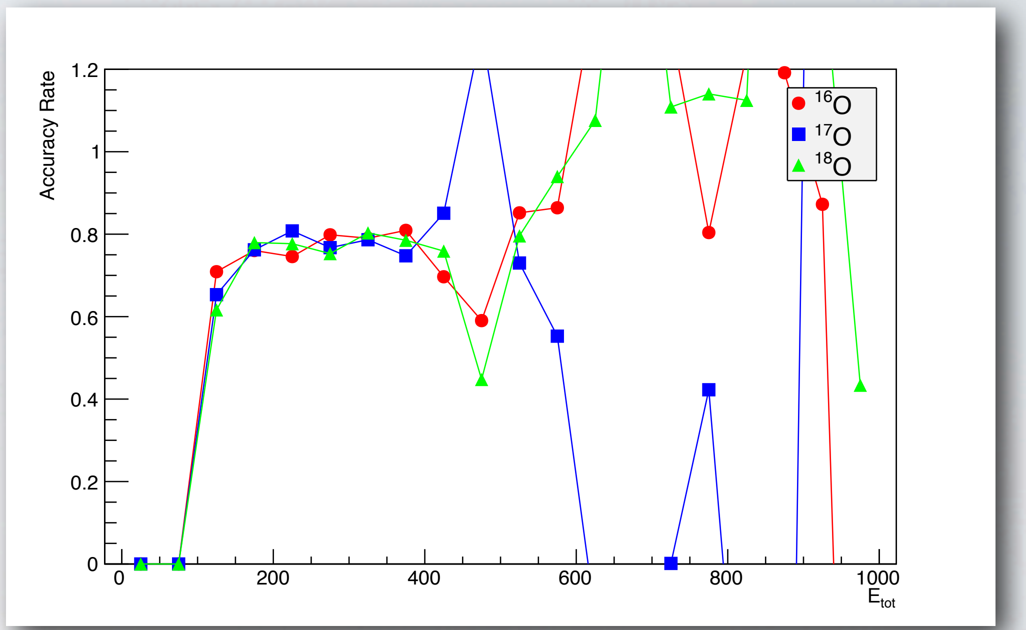
Efficiency



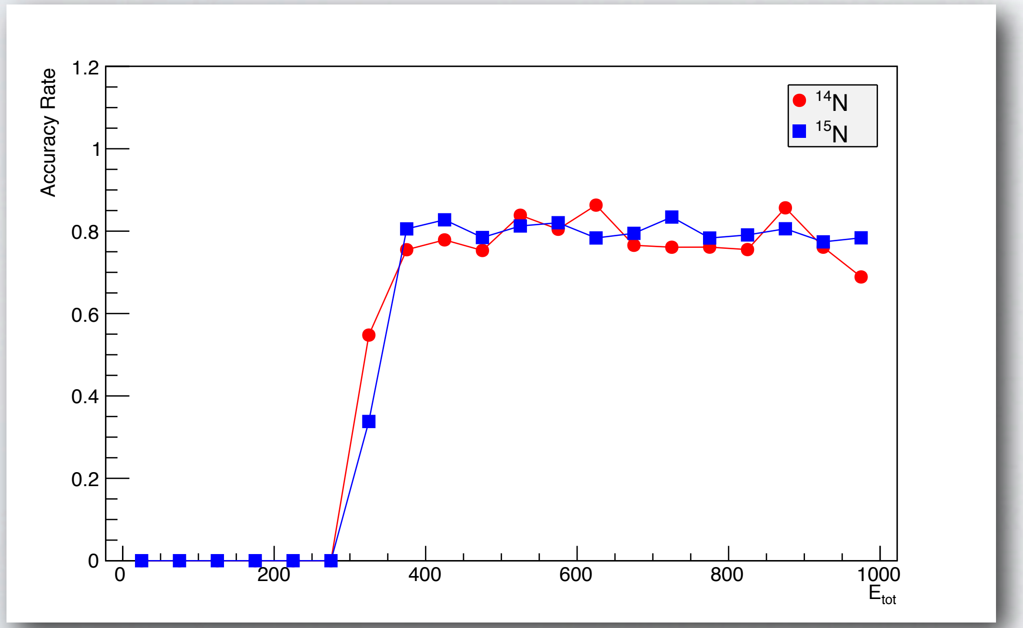
$$\text{Efficiency} = \frac{N_{\text{registered}}}{N_{\text{emitted to detection area}}}$$

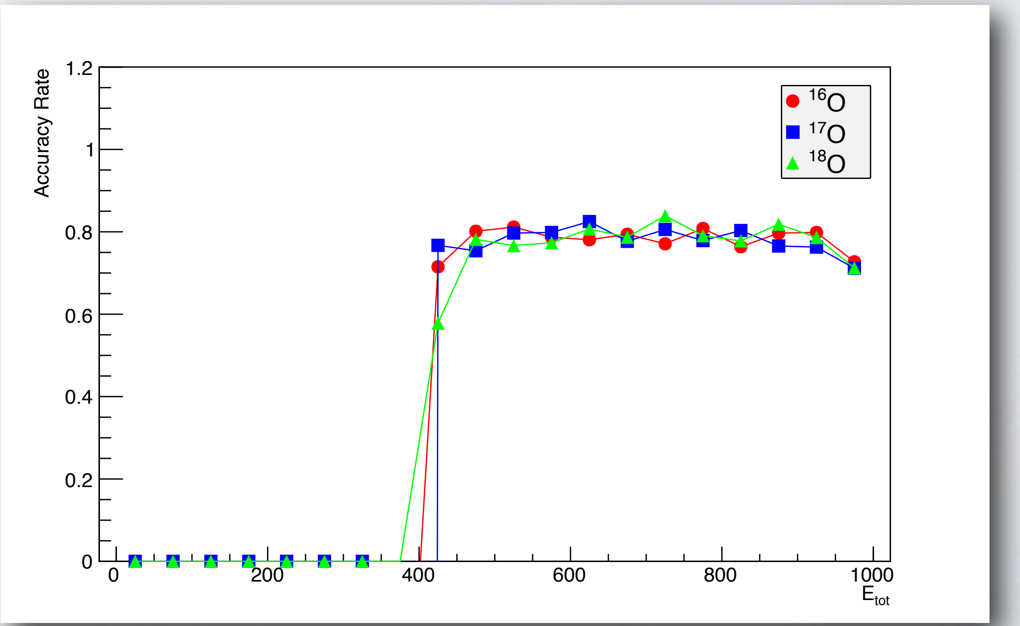
1-layered





3-layered





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Various Designs & Scales

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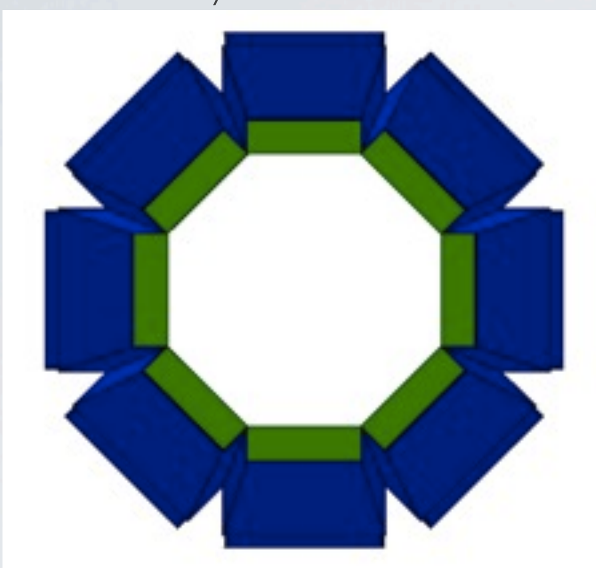
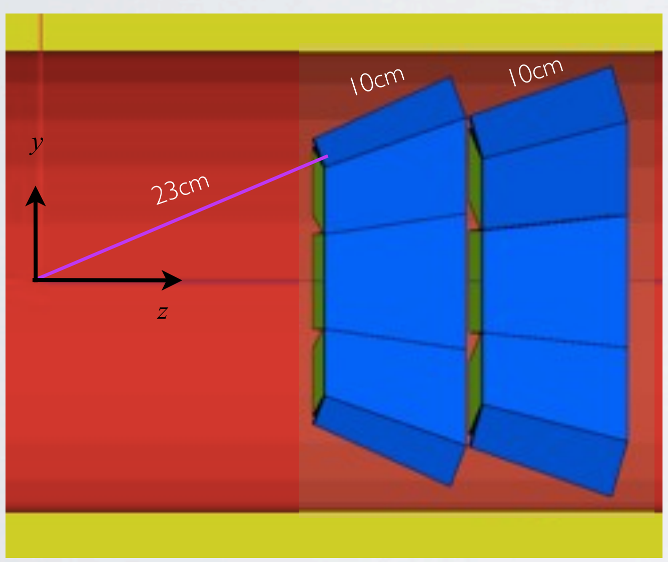
① : double layer





polar angle : 14°~24°

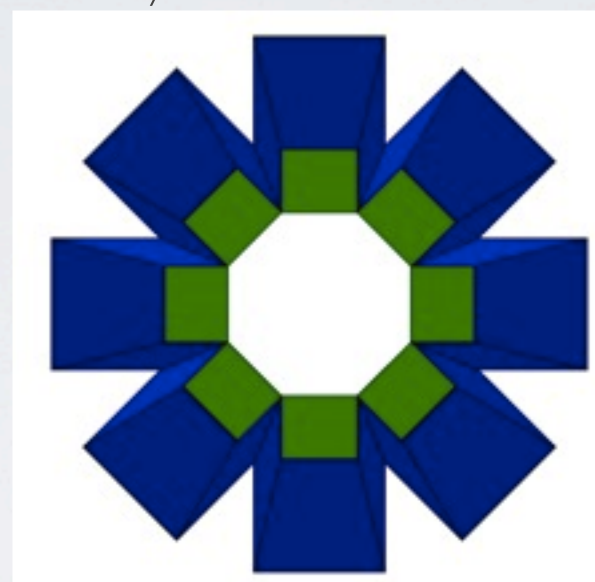
5.9 cm

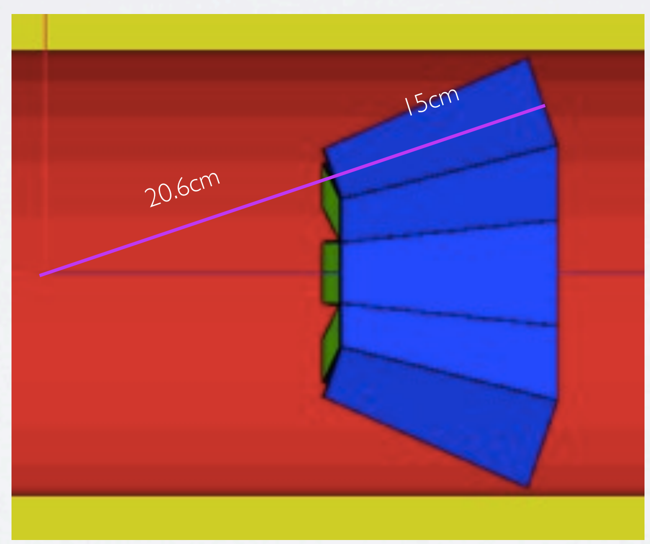
front 2.0 cm

x= 8.3 cm

back y = 2.9 cm

② : one layer





: 14°~24°

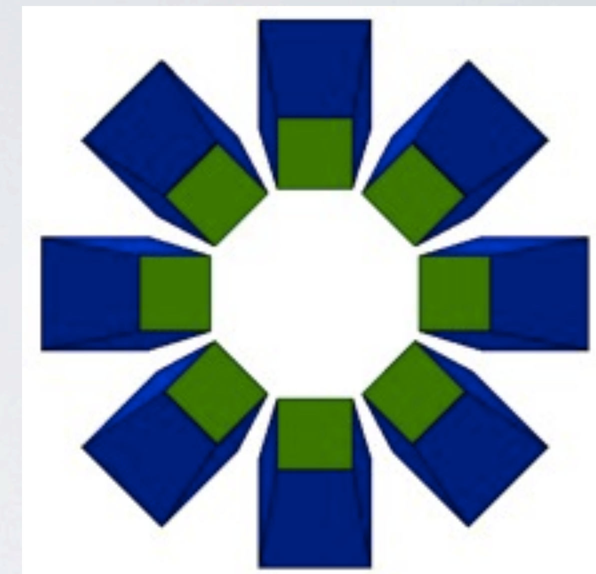
4.14 cm

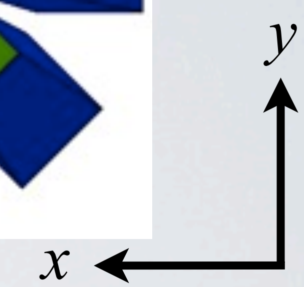
front 3.62 cm

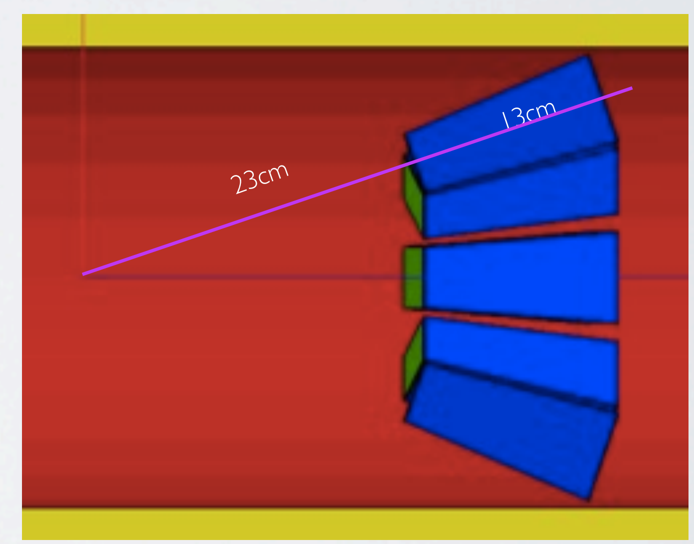
7.16 cm

back 6.25 cm

③ : one layer w/ square-shaped surface







: 14.2°~23.8°

4.00 cm

front 4.00 cm

6.00 cm

back 6.00 cm

16 Channels

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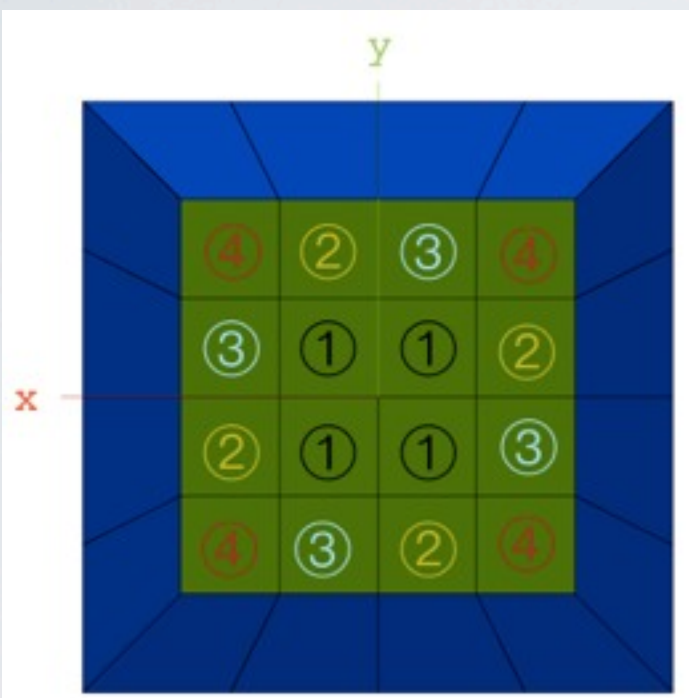
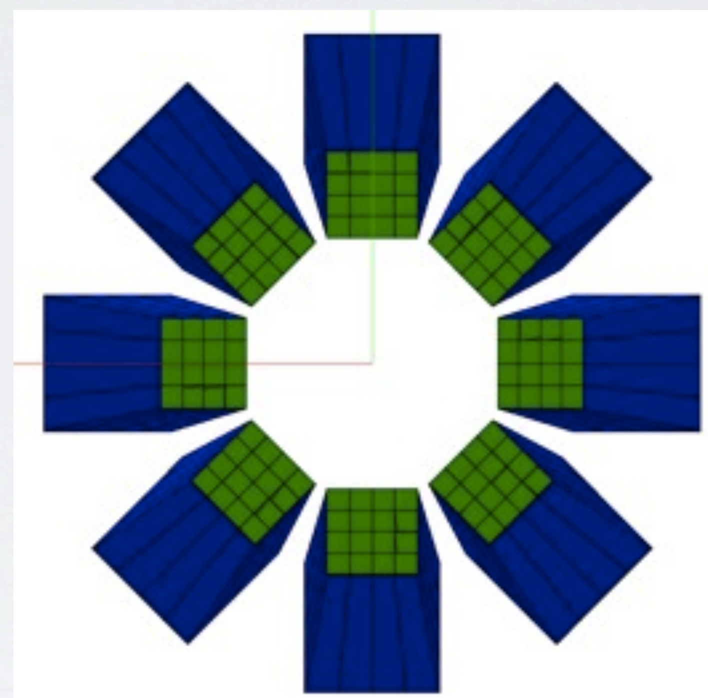
- 4 different shapes
- For each channel front surface = 1cm×1cm, back surface = 1.5cm×1.5cm



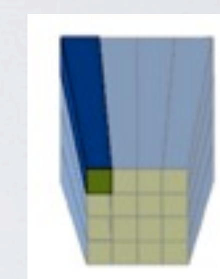


1. Particles entered into one detector

entries ~ 2

2. Particles entered into one channel

entries ~ 0.14



- 4×4=16 channels for 1 sector
- 8 sectors in total

⇒ 16×8 = 128 channels

Multi-channels & Collimator

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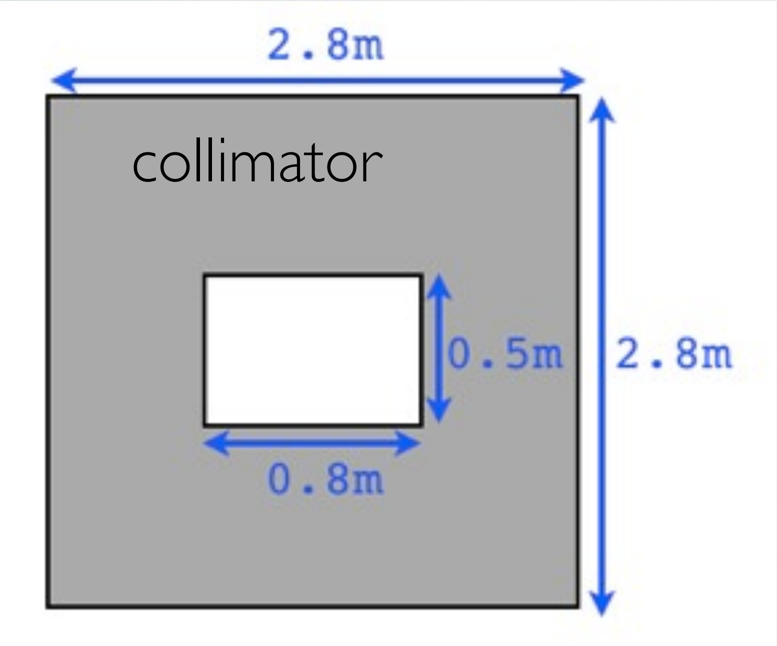
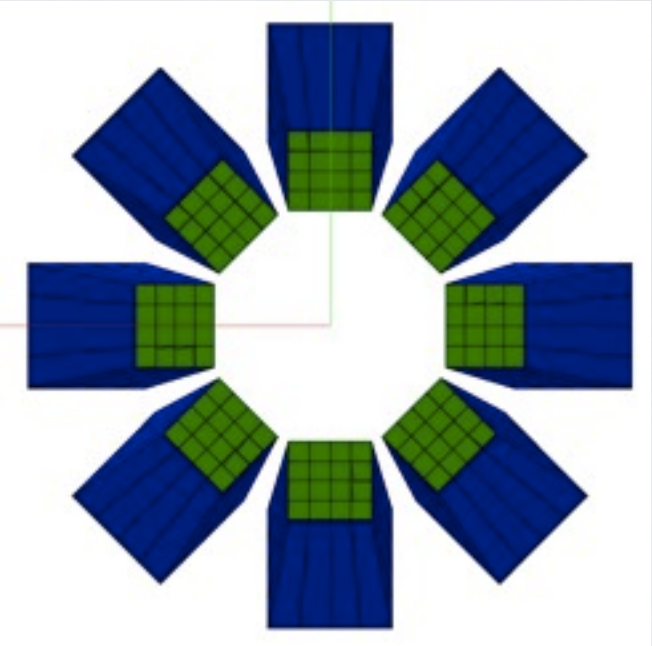
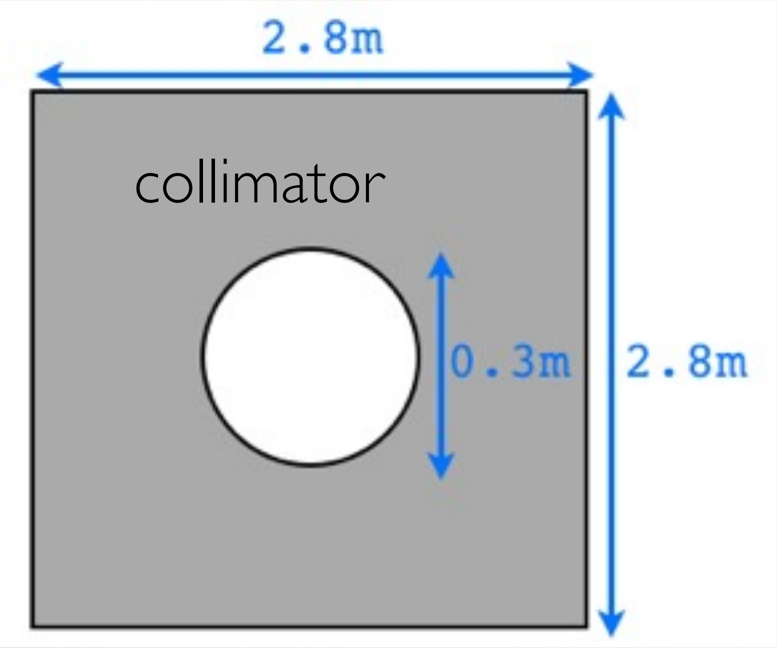
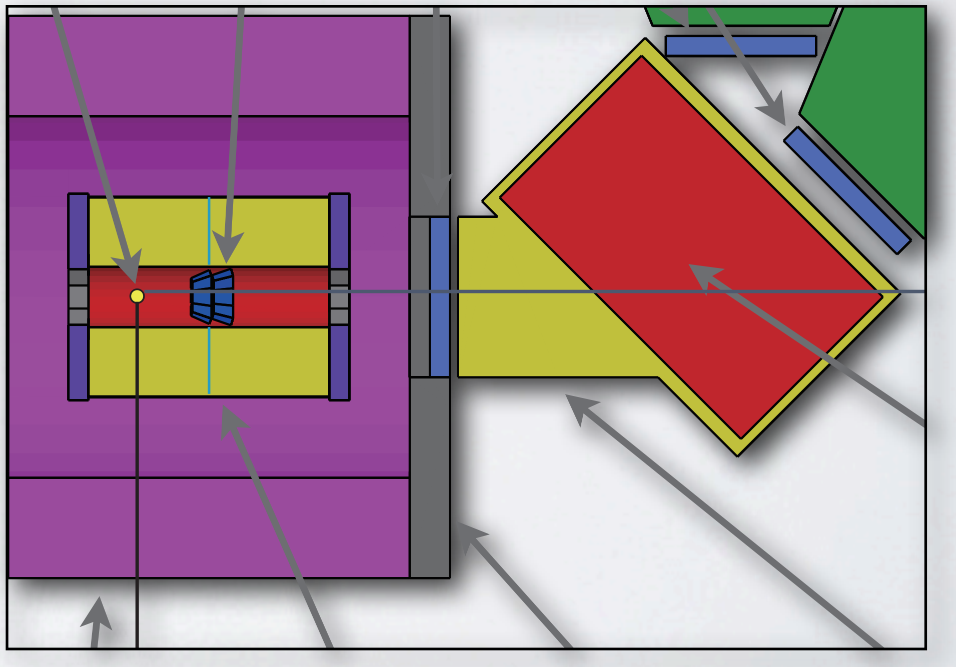




B-field





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Summary

- Thickness of Silicon layers?
  - Three silicon-strip layers (100, 400 and 400 μm) , veto?
  - A CsI crystal bar (10, 13 or 15 cm) → depth
- Design?
  - Double or single layer?
  - squared-shape?
- Channels
  - Strip or pixel? size?
  - Event generator
- Coverage
  - Collimator, aperture radius, # of layers....

Back up

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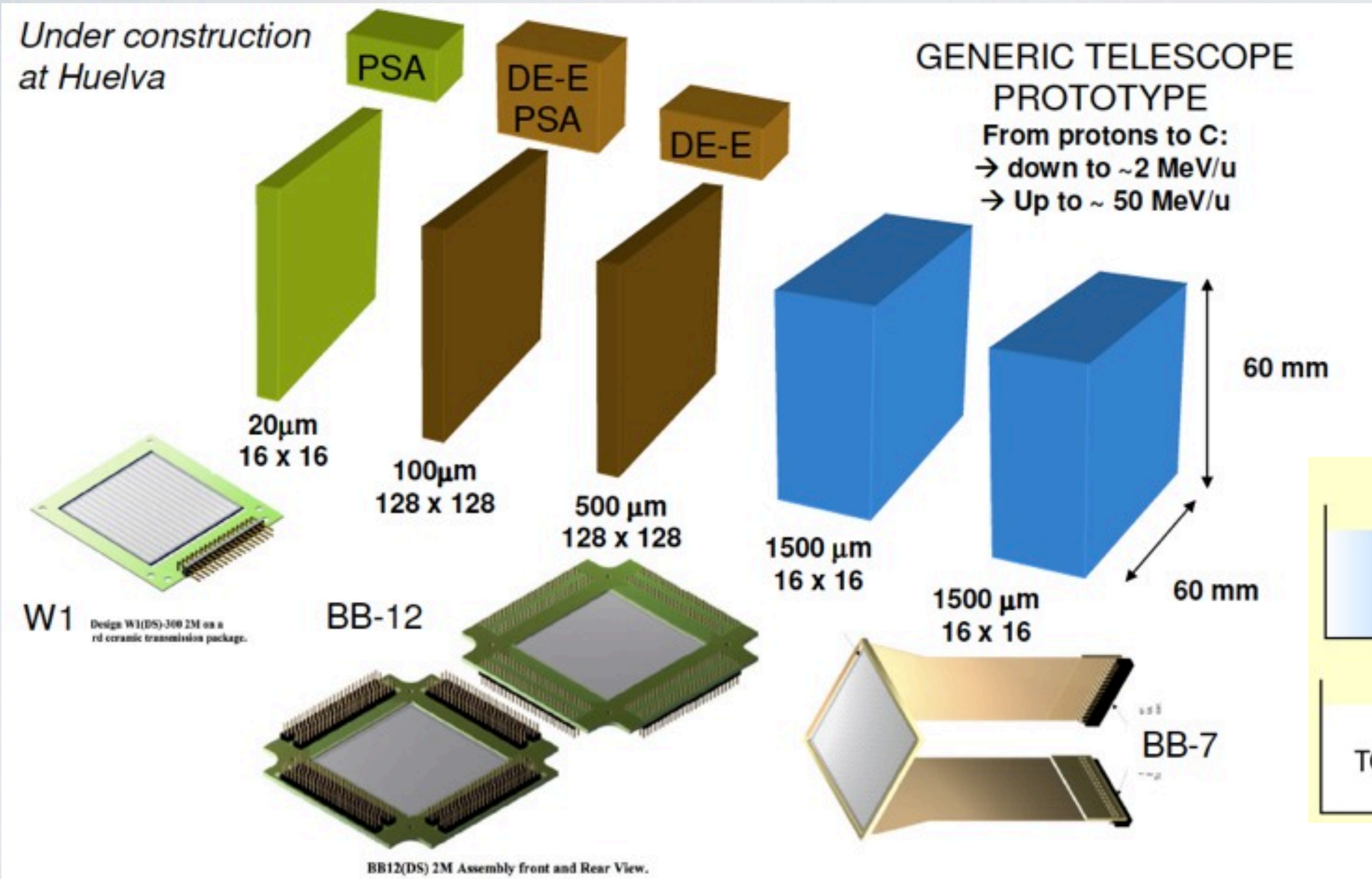
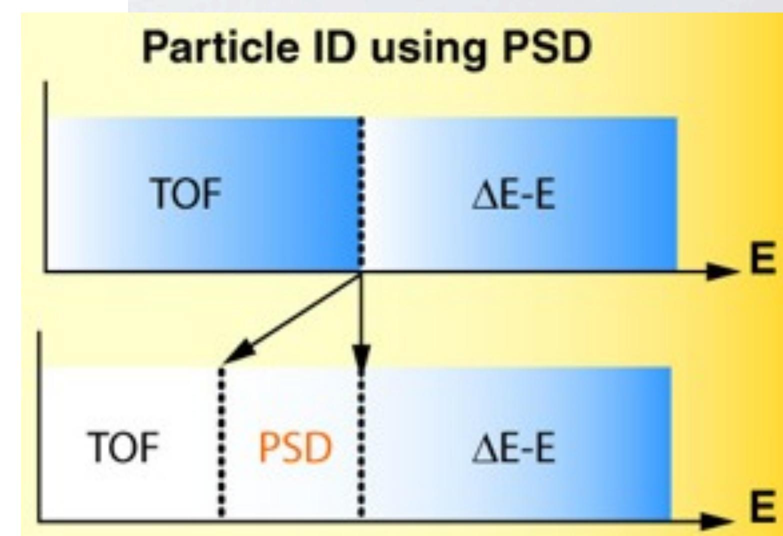
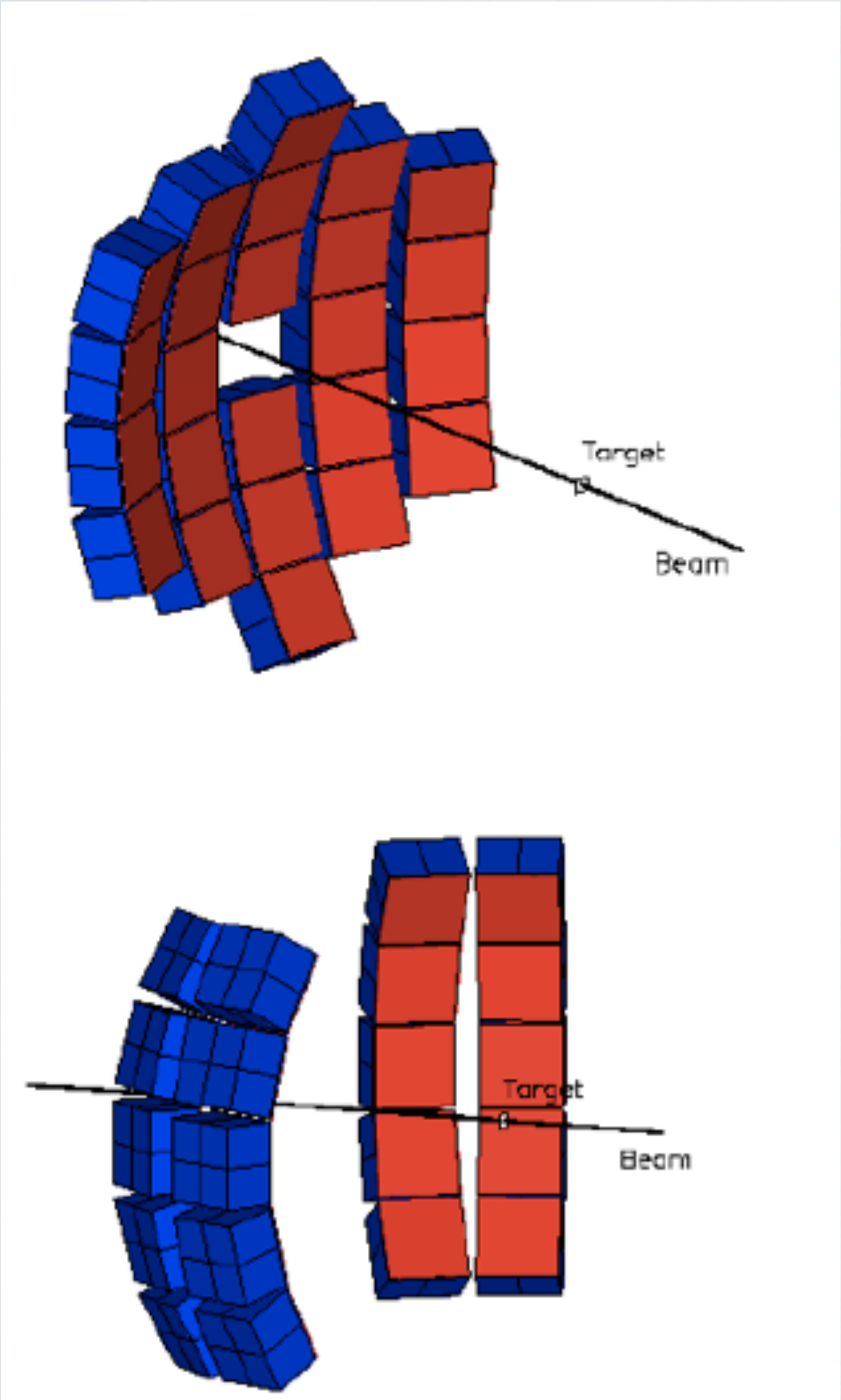
Si test telescope for GASPARD

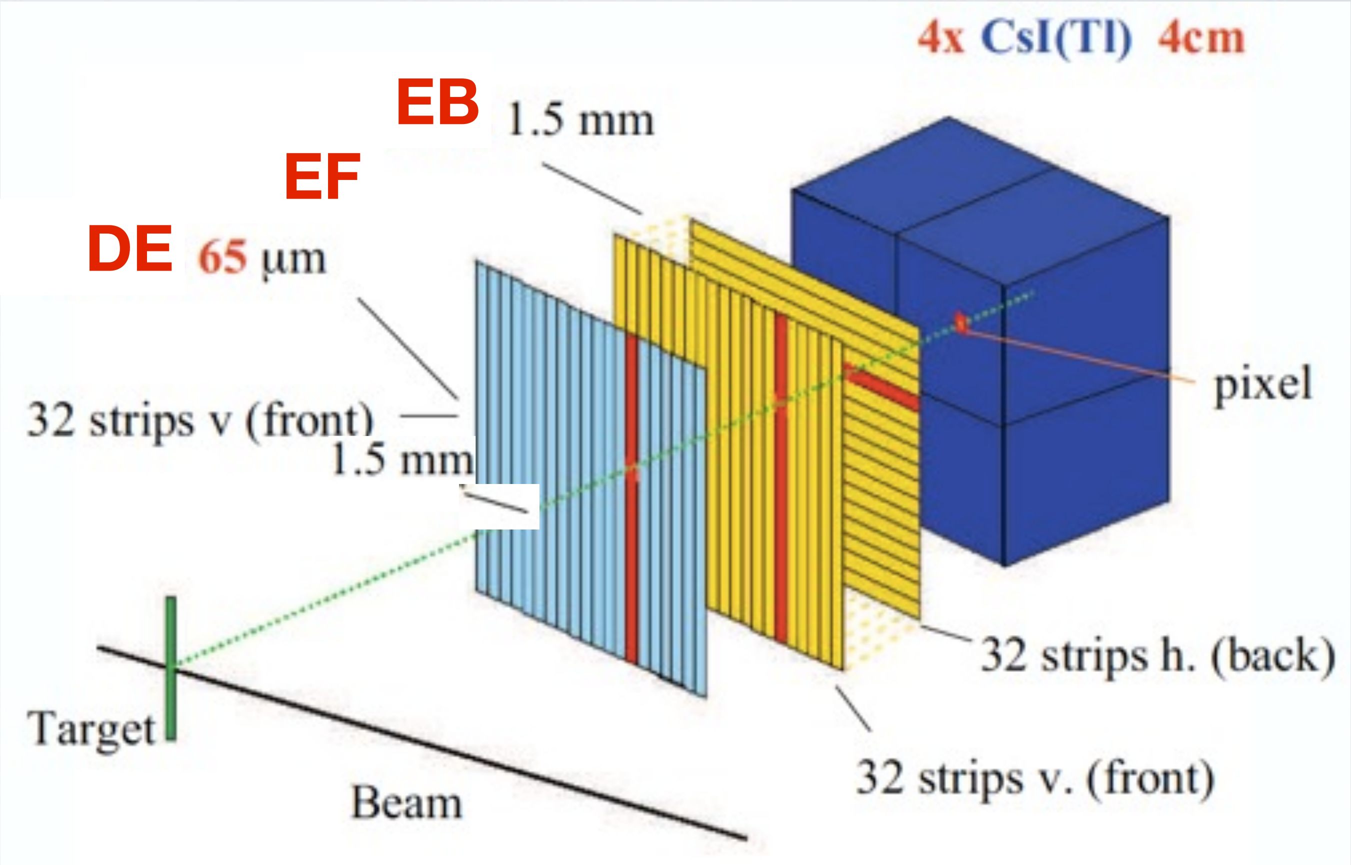


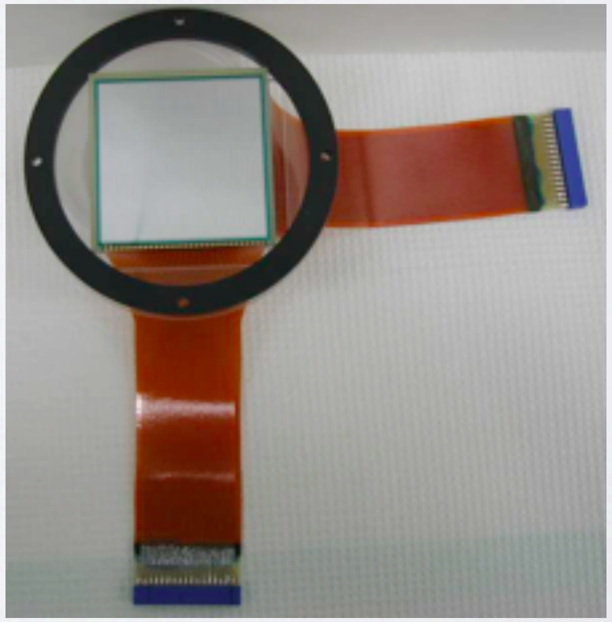
Possible test bench: (MUFEE+MUVI) + (PACI+MATAQ) + GANIL DAQ



The High Resolution Array, HiRA







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Conditions for Simulations

Beam	^{1}H, ^{2}H, ^{3}H ^{3}He, ^{4}He ^{6}Li, ^{7}Li ^{8}Be, ^{9}Be ^{10}B, ^{11}B ^{12}C, ^{13}C ^{14}N, ^{15}N ^{16}O, ^{17}O, ^{18}O ^{19}F
Samples	30000 per isotope
Energe range	(0 to 1) GeV
Geant4 ver.	Geant4 9.5, patch-01

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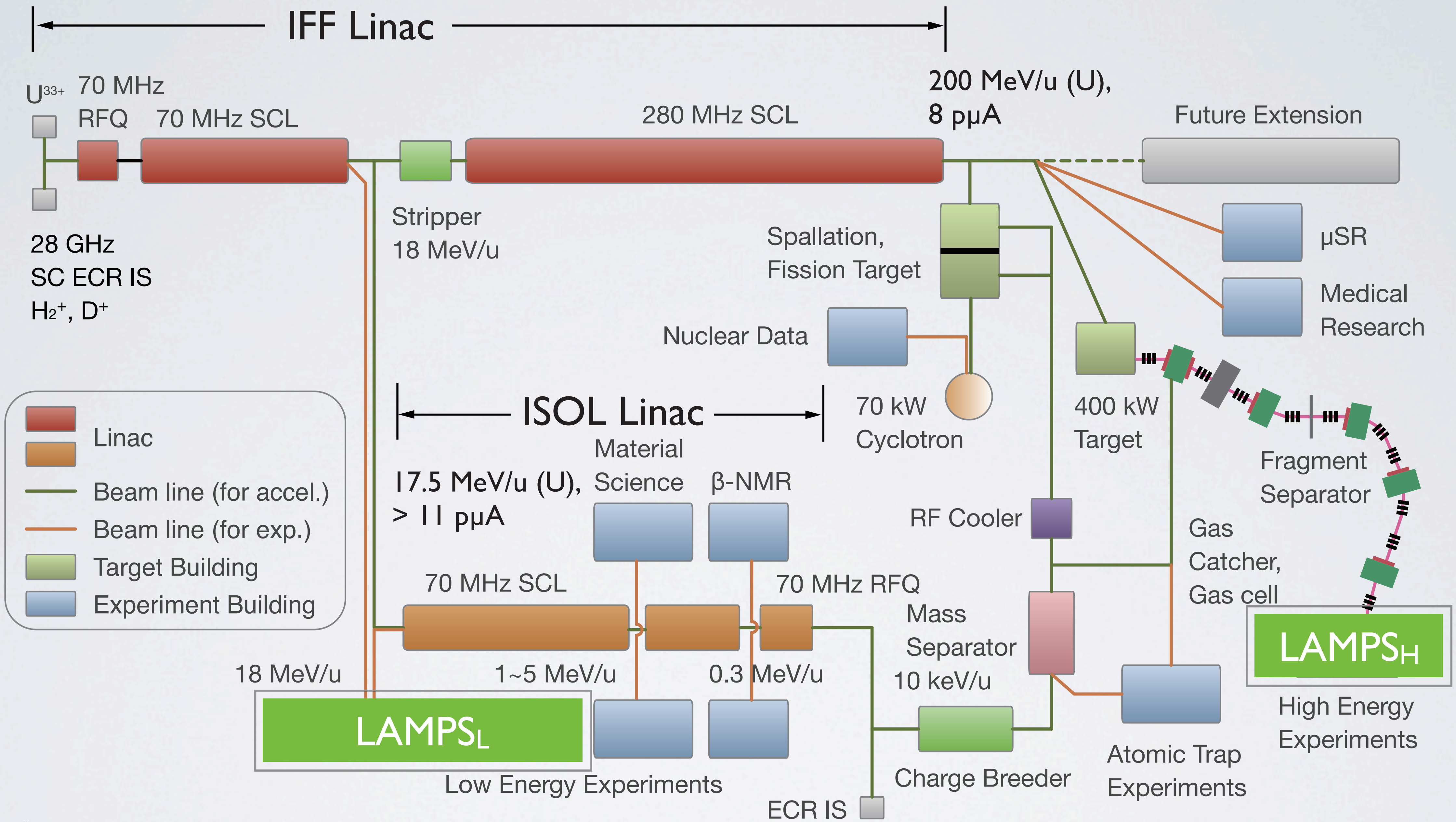
RAON

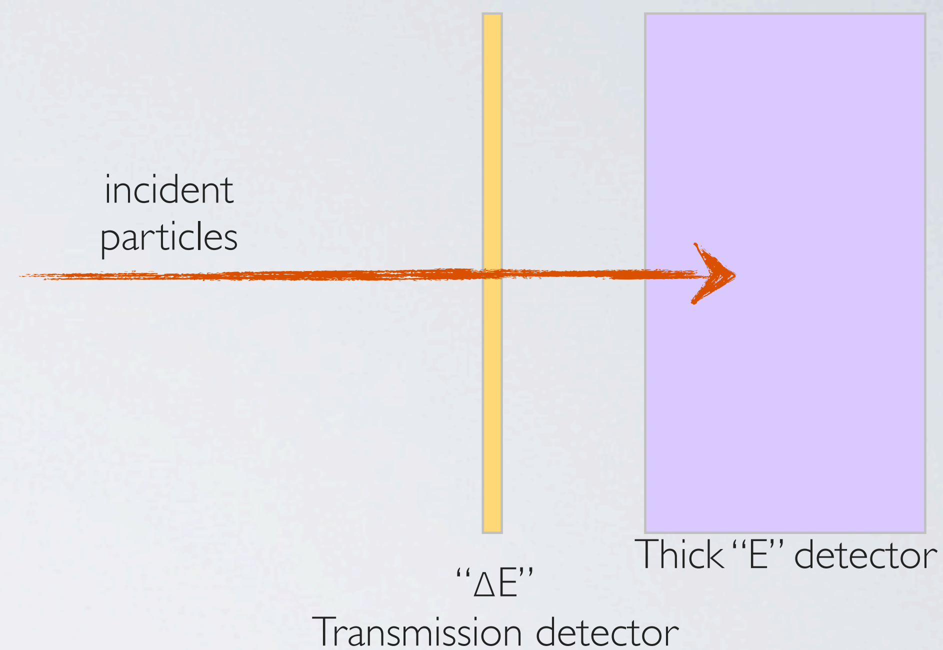


- RAON : Name of Rare Isotope accelerator complex (Pure Korean word: meaning "delight", "joyful", "happy")
- Large Acceptance MultiPurpose Spectrometer (LAMPS)

Transmission Detector (ΔE-E method)

- Bethe-Bloch formula

$$-\frac{dE}{dx} = \frac{4\pi}{m_e c^2} \cdot \frac{nz^2}{\beta^2} \cdot \left(\frac{e^2}{4\pi^2\epsilon_0}\right)^2 \cdot \left[\ln\left(\frac{2m_e c^2\beta^2}{I\cdot(1-\beta^2)}\right) - \beta^2\right]$$



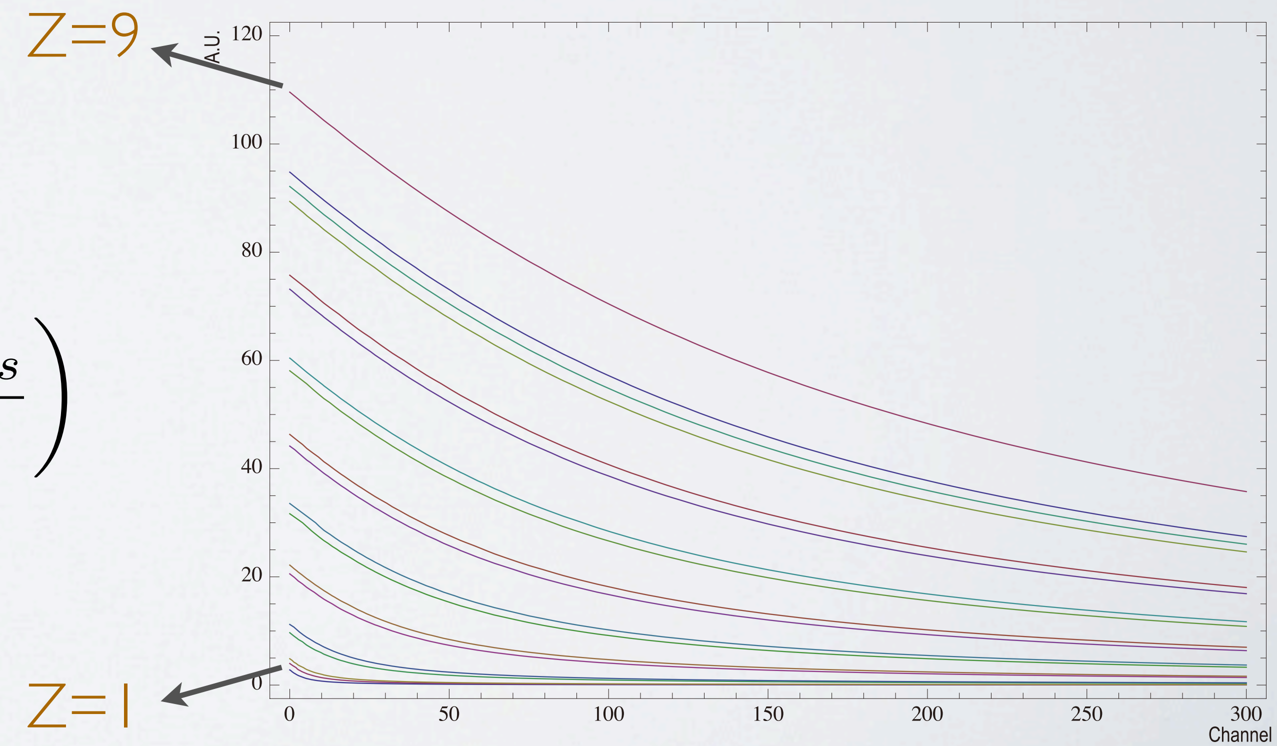
- Assuming that $\frac{v}{c} \ll 1$

$$-\frac{dE}{dx} = C_1 \frac{mz^2}{E} \cdot \ln\left(C_2 \frac{E}{m}\right)$$

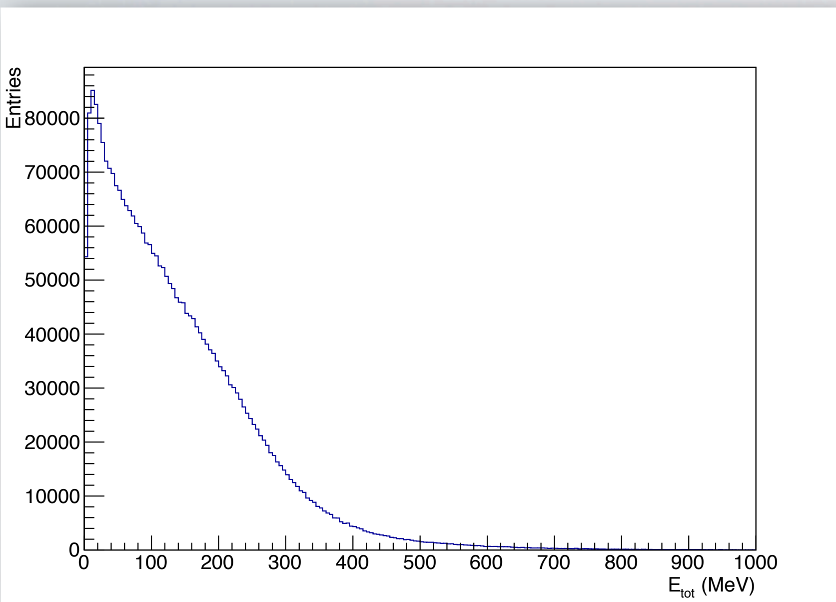
- For transmission detector

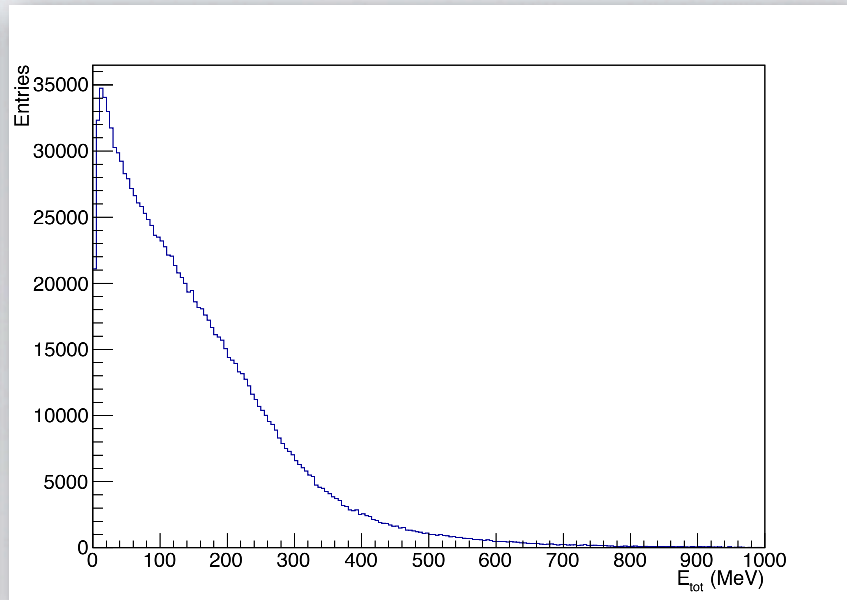
$$\Delta E = C_1 \frac{AZ^2}{\Delta E + E_{res}} \cdot \ln\left(C_2 \frac{\Delta E + E_{res}}{A}\right)$$

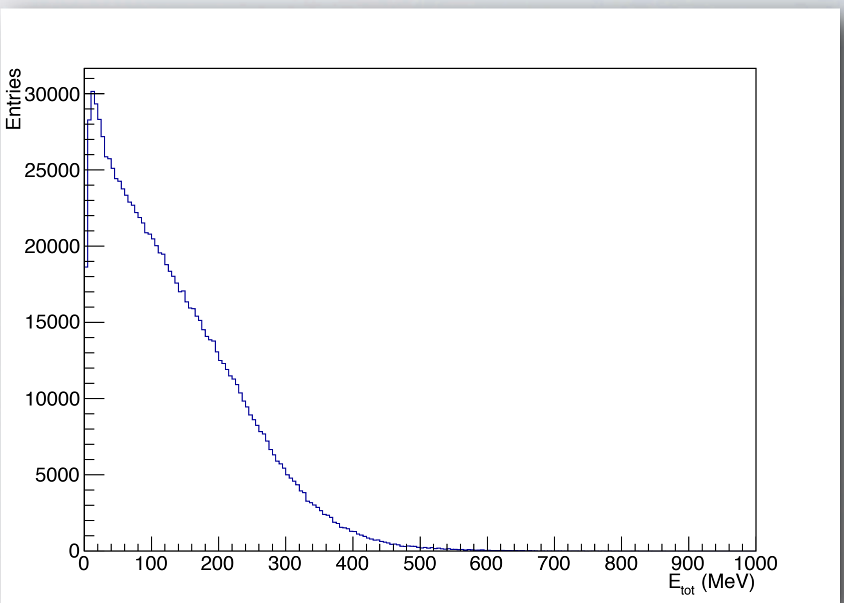
or $E_{tot} = \Delta E + E_{res}$

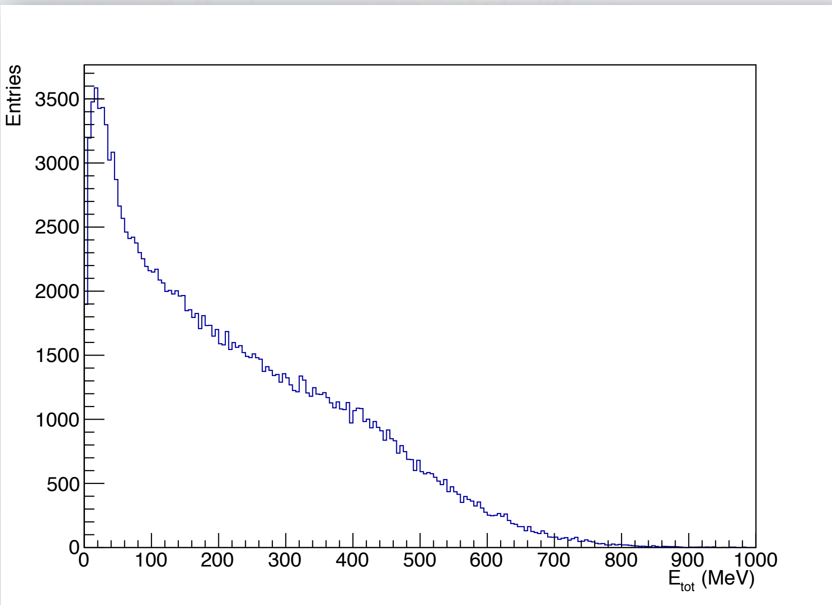


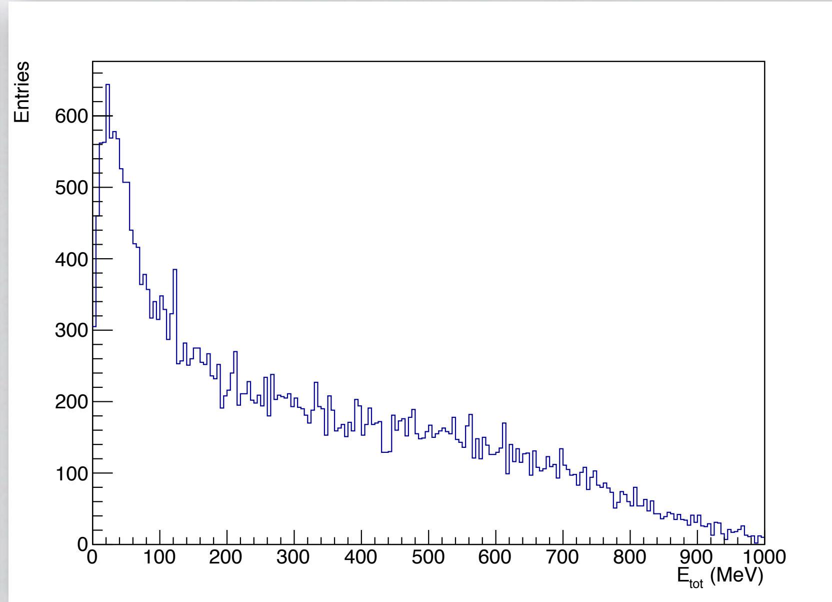
IQMD data (generate)

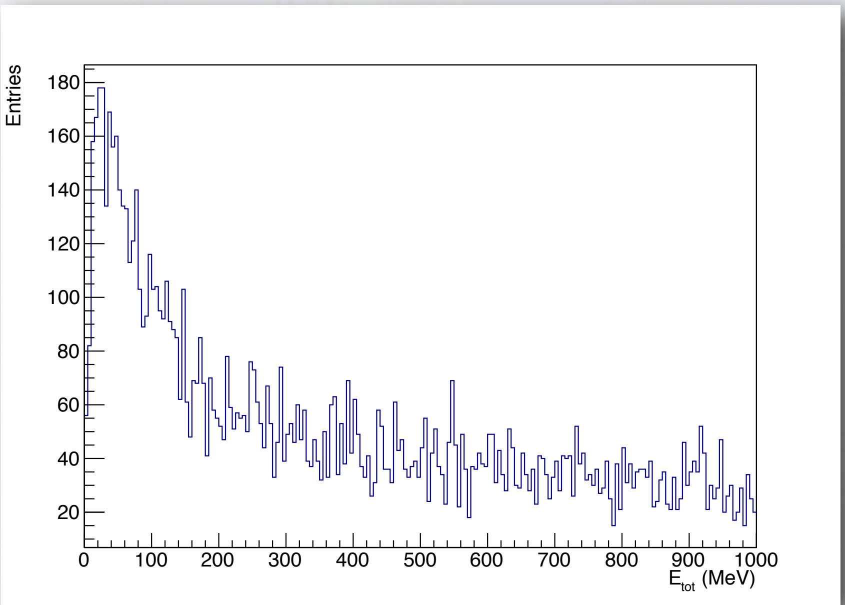












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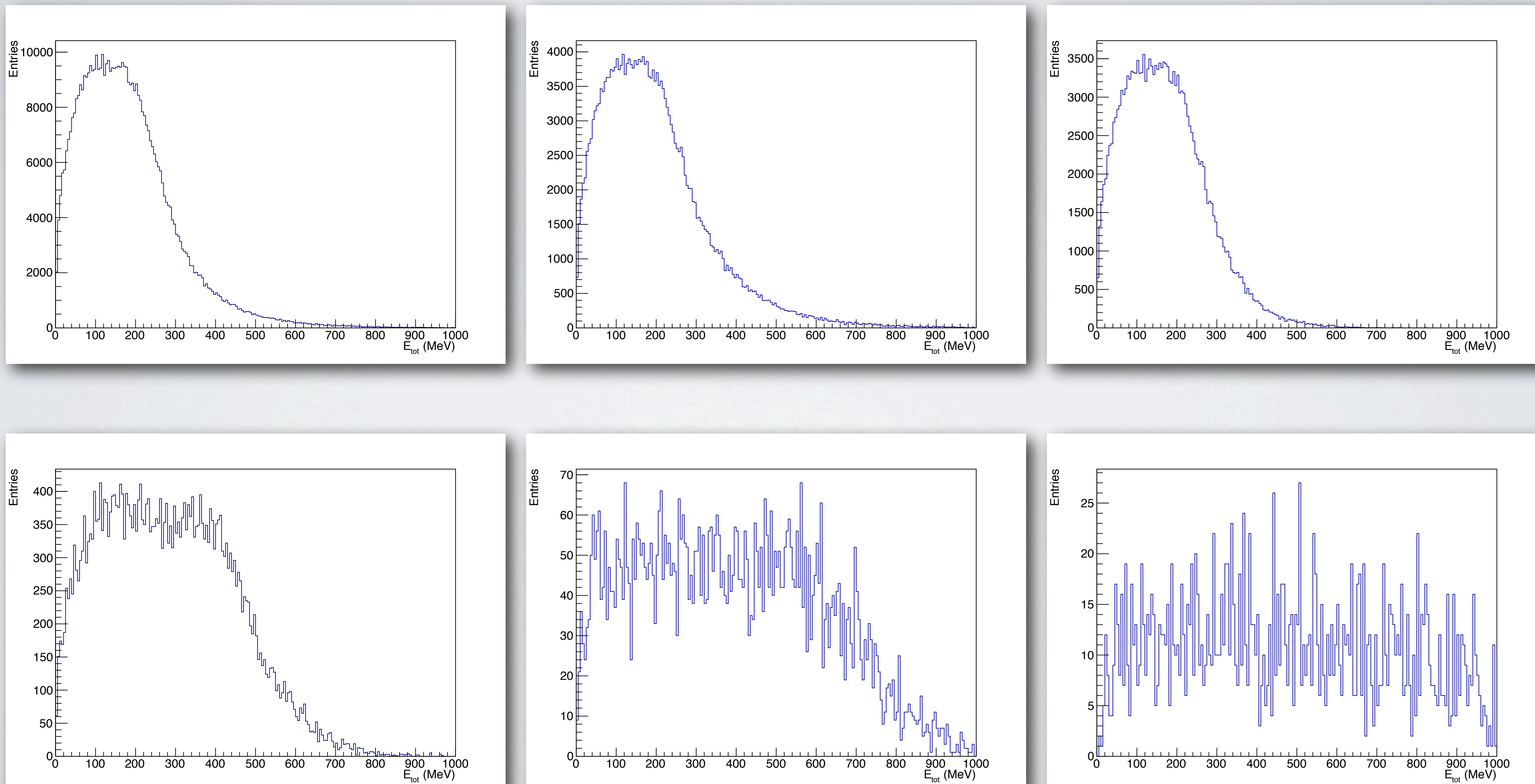
IQMD data (forward)



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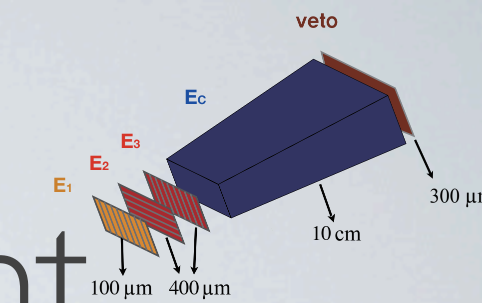
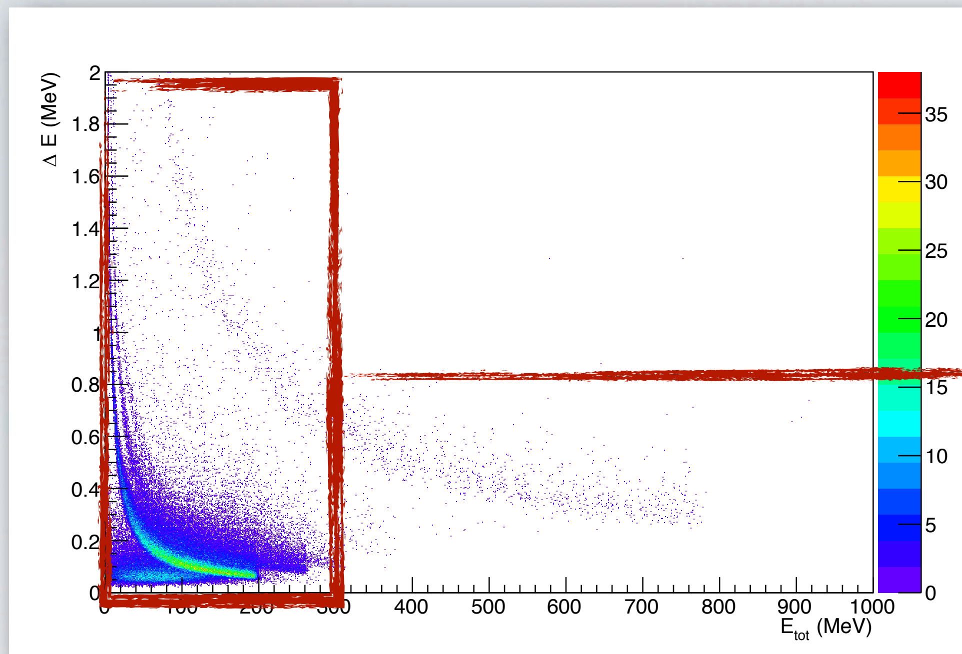
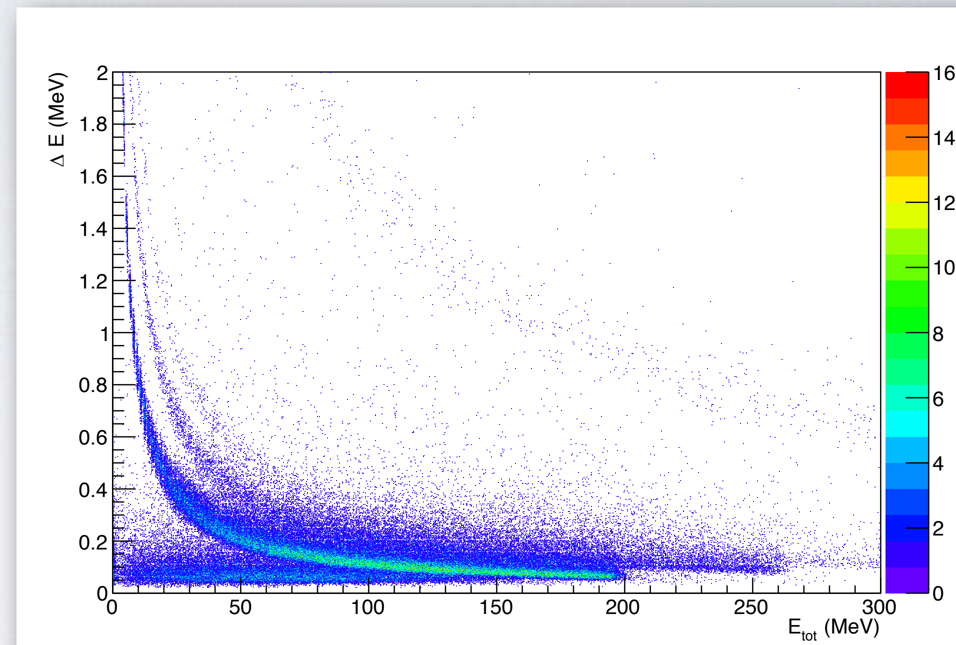
Simulation of Collision Event

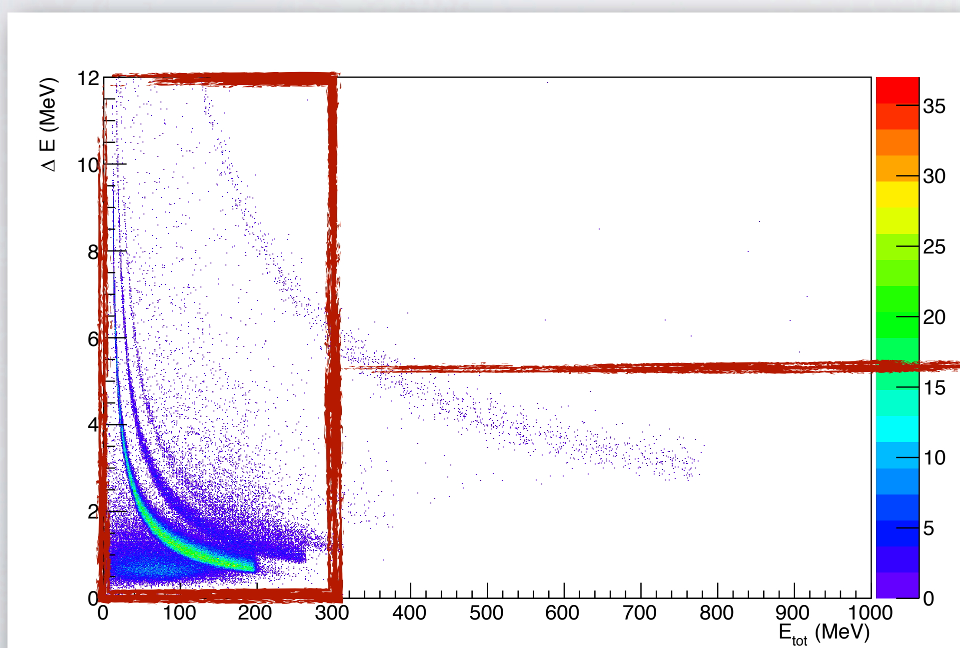


IQMD model

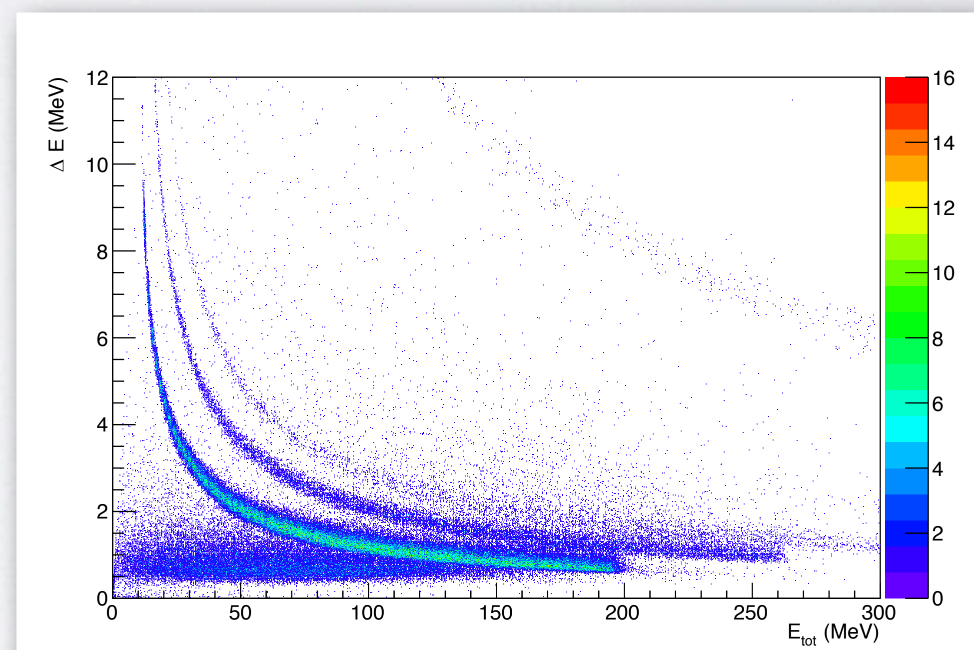


1-layered





3-layered



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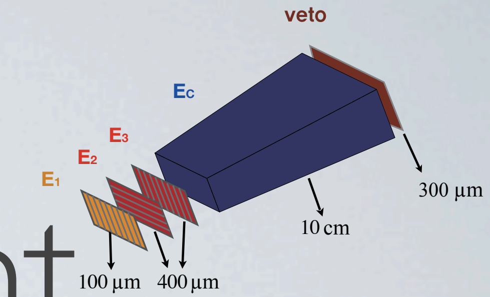
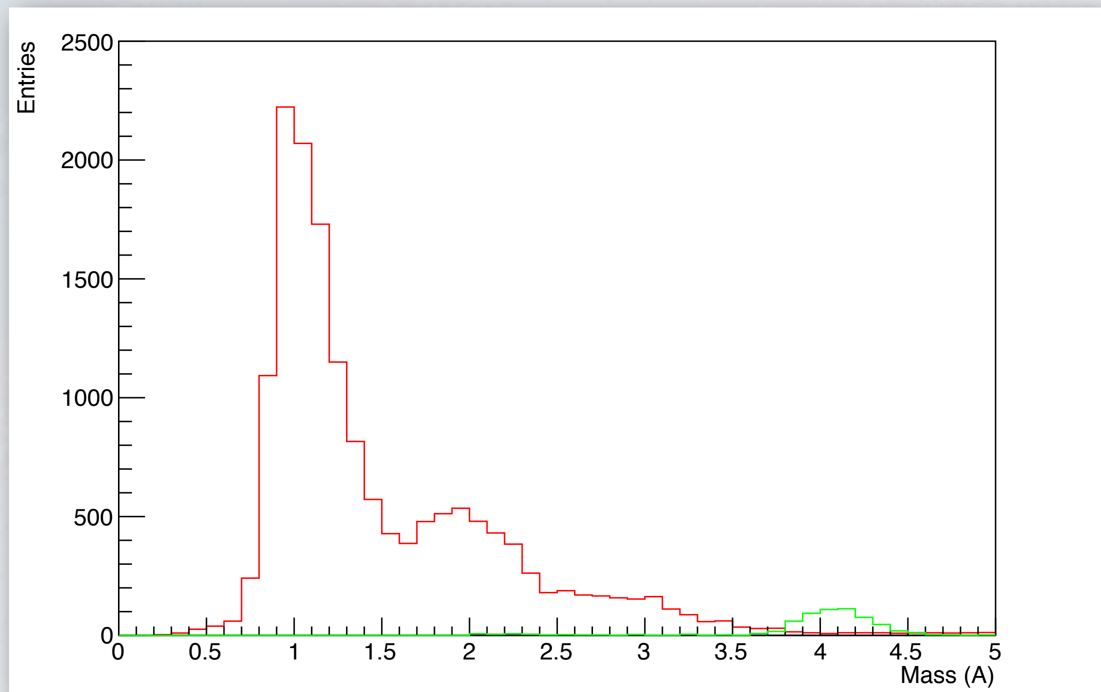
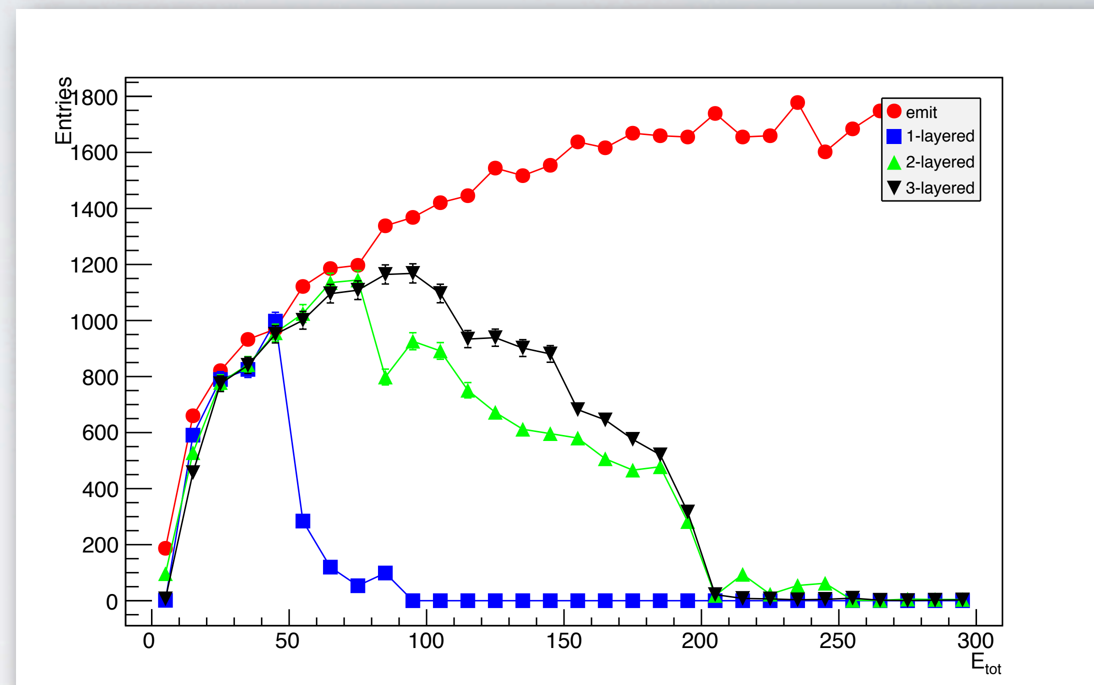
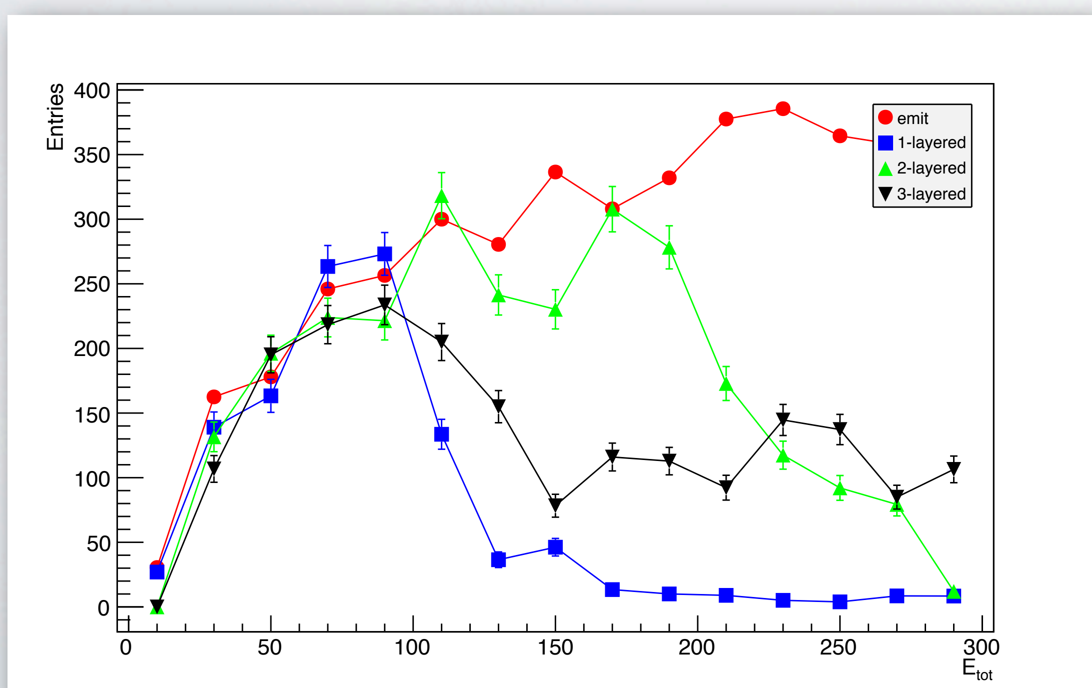
Simulation of Collision Event

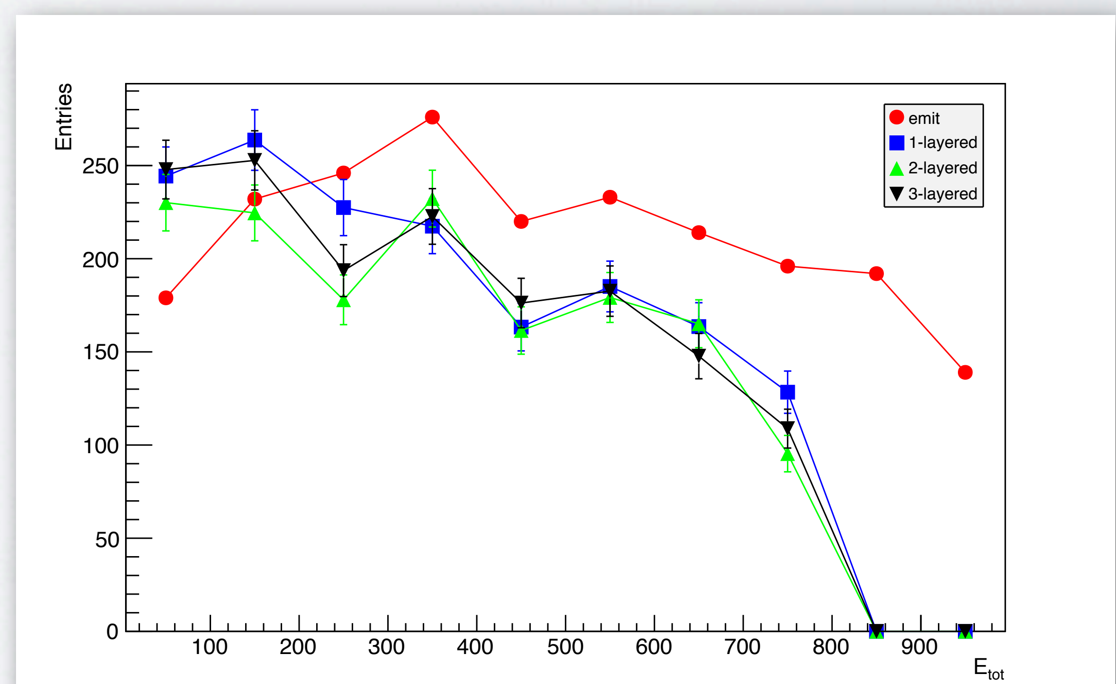


IQMD Model









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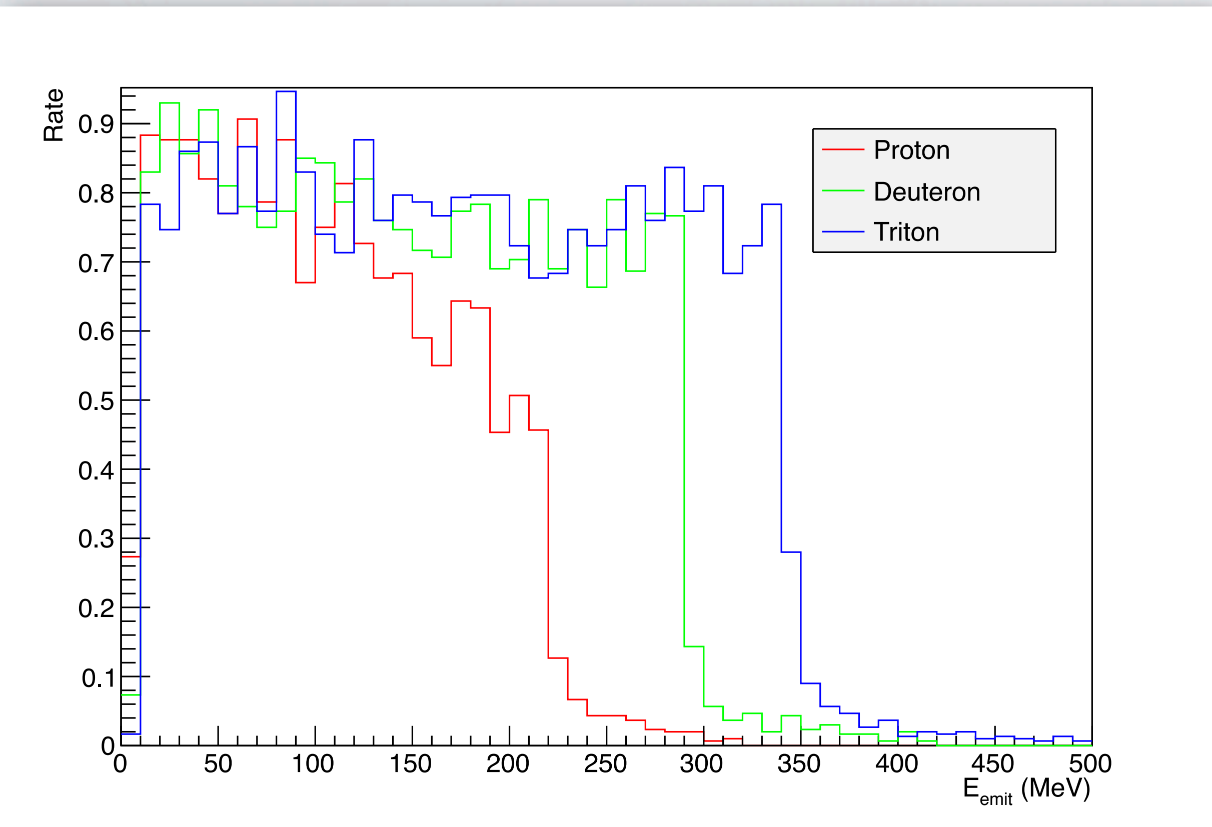
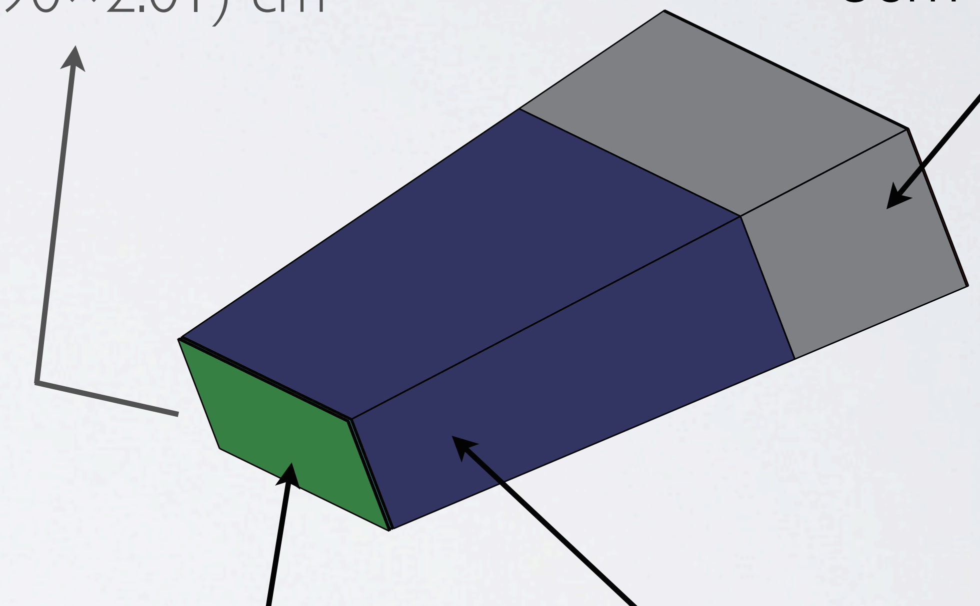
Hybrid Setup



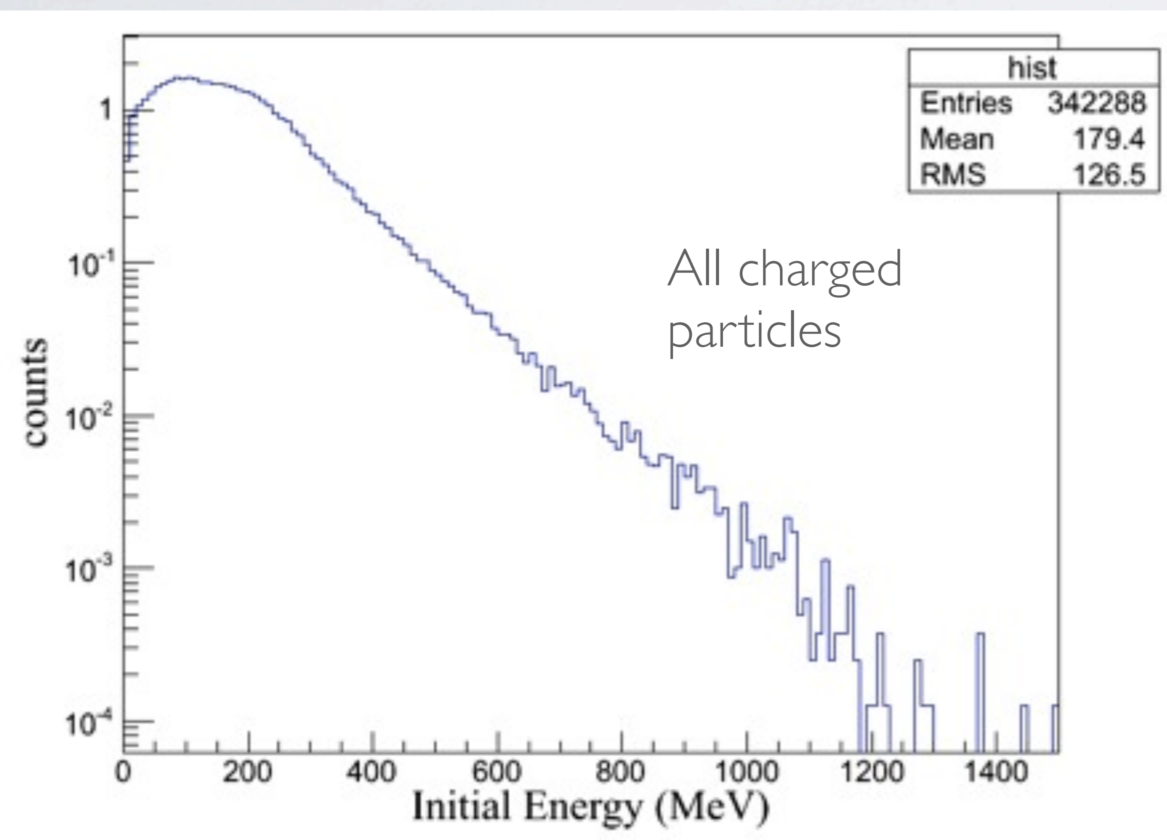


Multiplicity

Songkyo Lee (Korea Univ.)

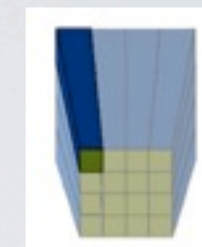
- IQMD data simulation
- Au-Au collision at 250 A·MeV
- Normalized by event num. (10000 events in total)

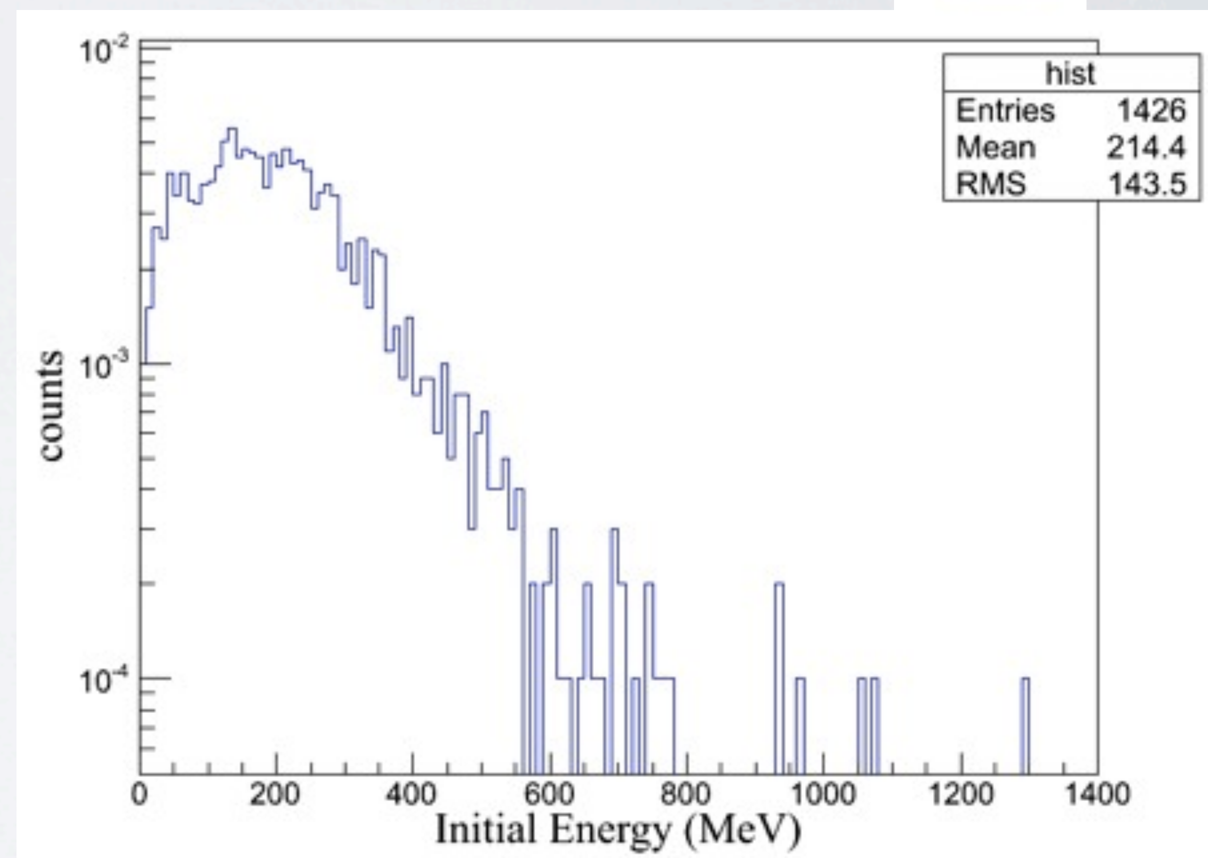
1. Particles entered into <u>one detector</u>



entries ~ 2

2. Particles entered into <u>one channel</u>





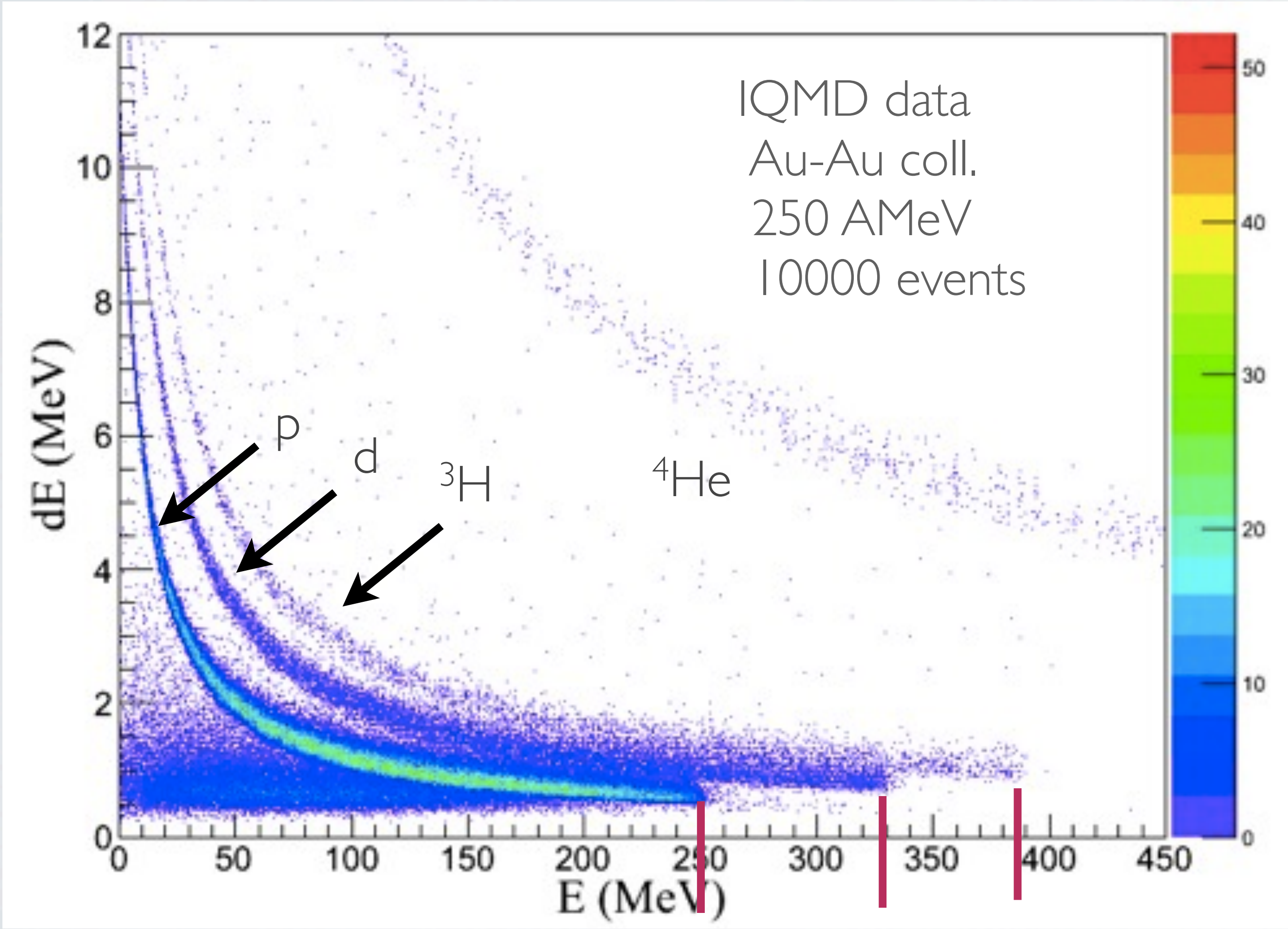
entries ~ 0.14

ΔE-E Graphs

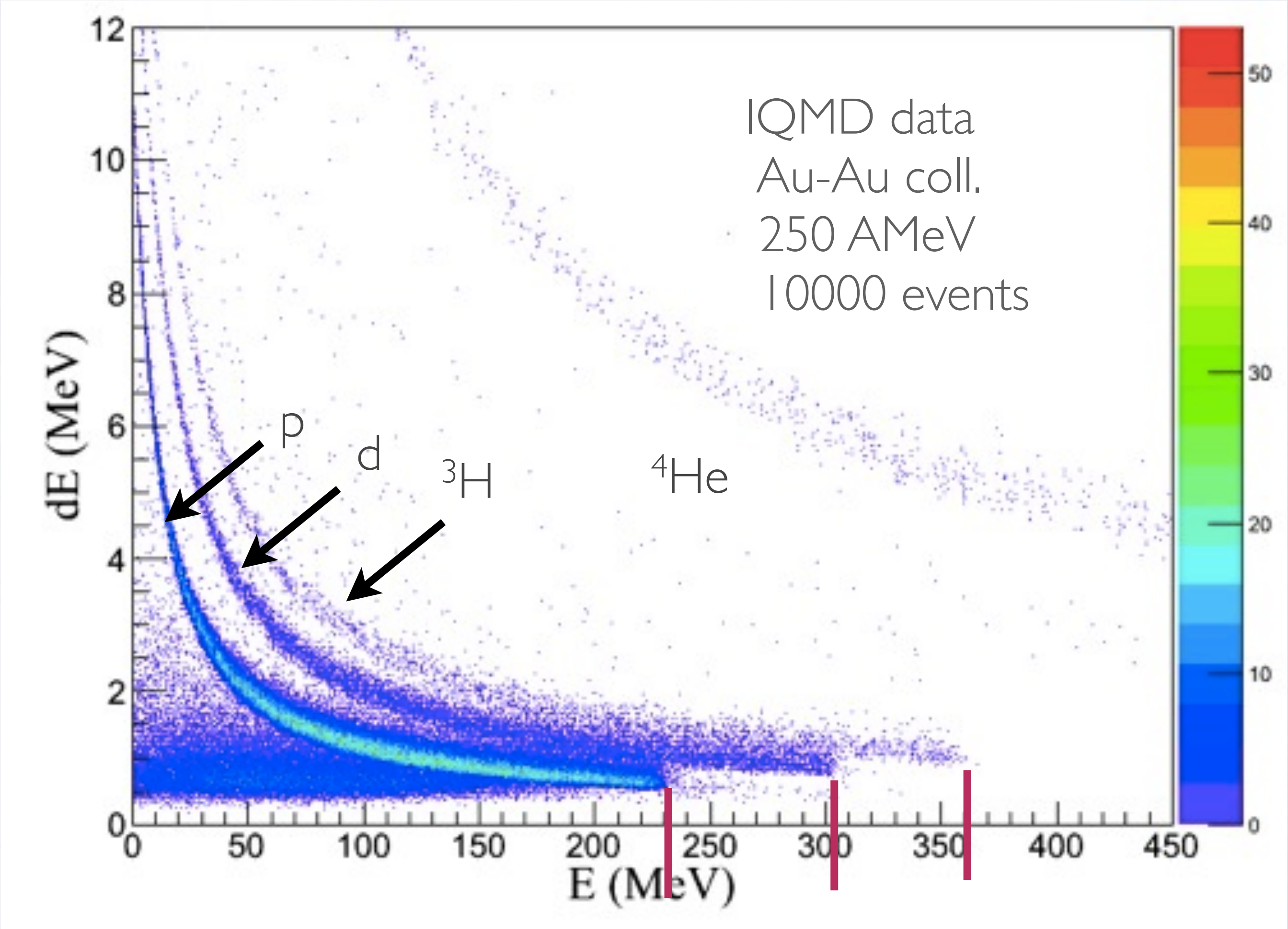
Songkyo Lee (Korea Univ.)

- material : CsI
- with veto counter

②



③



Nuclear Physics Laboratory

Properties of inorganic scintillators

Parameter:	ρ	MP^a	$X_0{}^b$	n^c	Relative output	Hydro- scopic	$d(\mathrm{LY})/dT^d$
Units:	g/cm^3	°C	cm				%/°C
NaI(Tl)	3.67	651	2.59	1.85	100	yes	-0.2
BGO	7.13	1050	1.12	2.15	21	no	-0.9
BaF_2	4.89	1280	2.03	1.50	36^s	no	-1.9^s
					4.1^f		$\sim 0.1^f$
CsI(Tl)	4.51	621	1.86	1.79	165	slight	0.3
CsI(pure)	4.51	621	1.86	1.95	3.6^s	slight	-1.3
					1.1^f		
$PbWO_4$	8.3	1123	0.89	2.20	0.083^s	no	-2.5
					0.29^f		
LSO(Ce)	7.40	2050	1.14	1.82	83	no	-0.2
$LaBr_3$(Ce)	5.29	788	1.88	1.9	130	yes	0.2

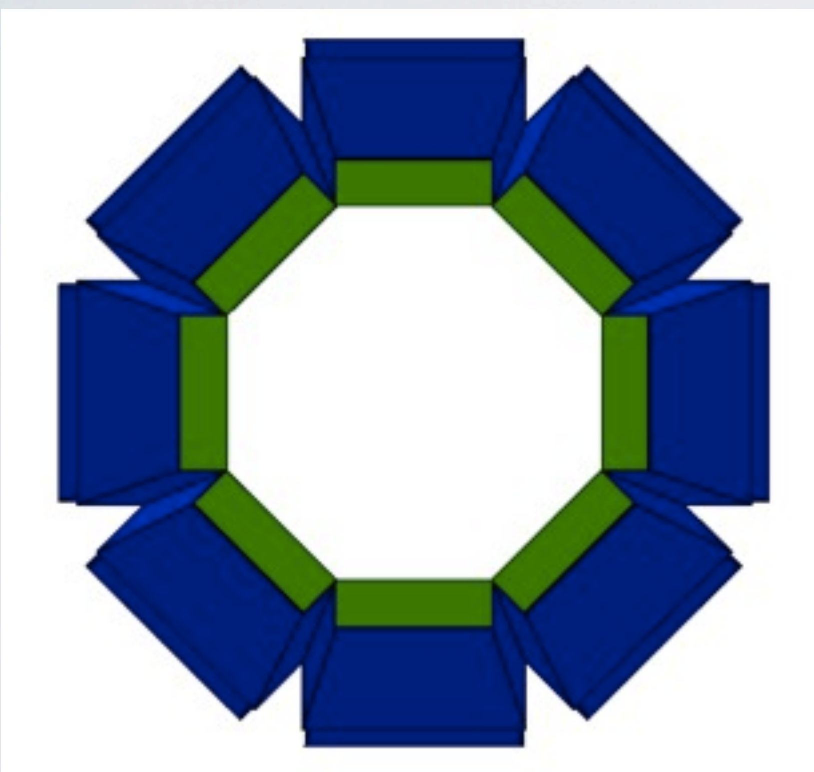
[a] Melting point.
[b] Radiation length.
[c] Index of reflection.
[d] Temperature dependence of the light yield.

Various Designs & Scales

Songkyo Lee (Korea Univ.)

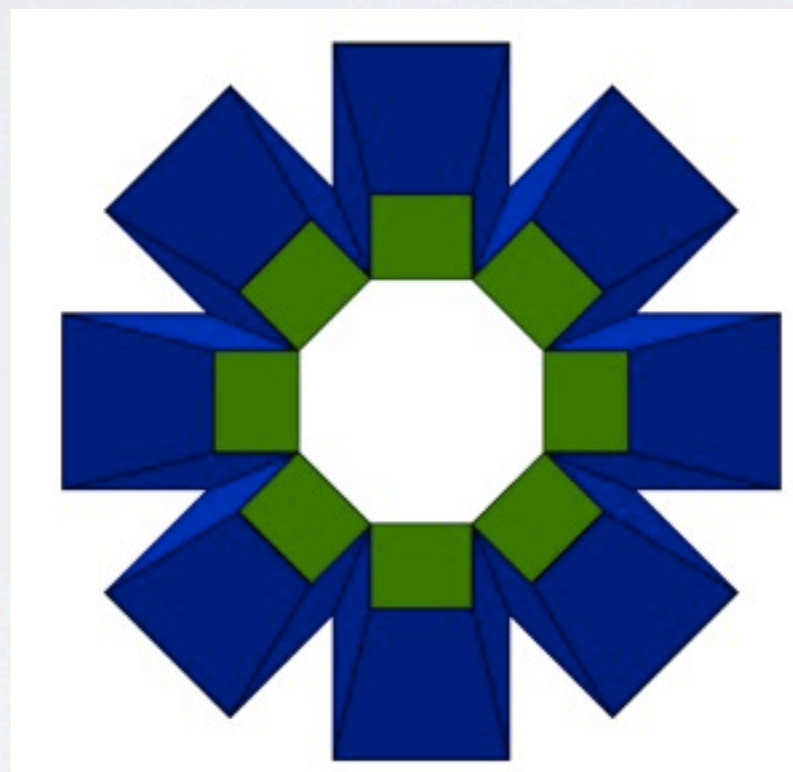
Front View

①



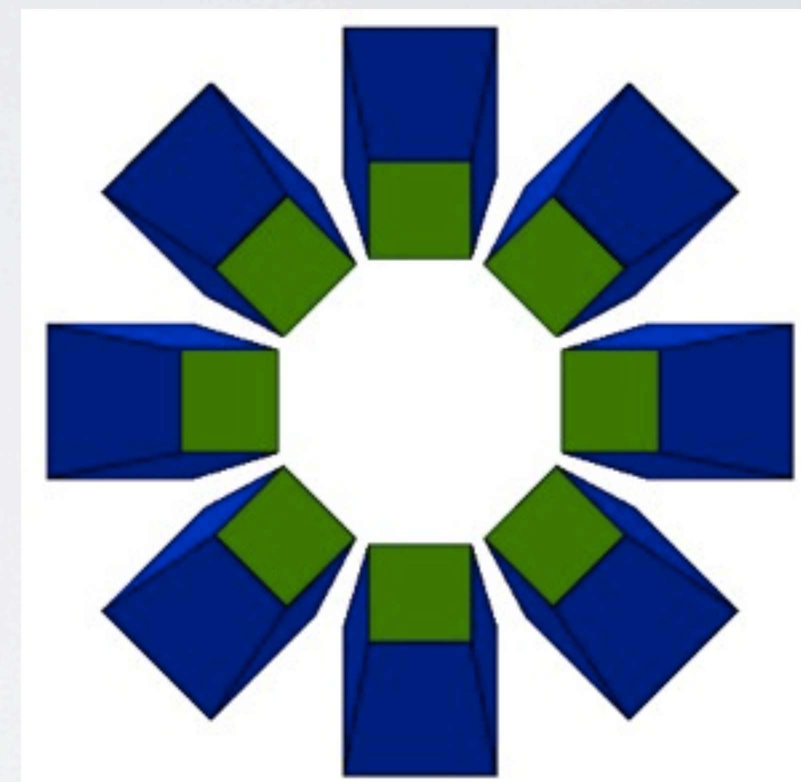
: double layer

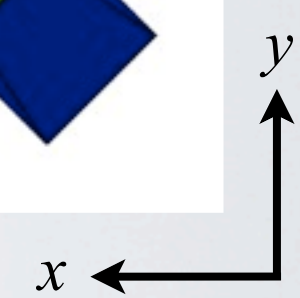
②



: one layer

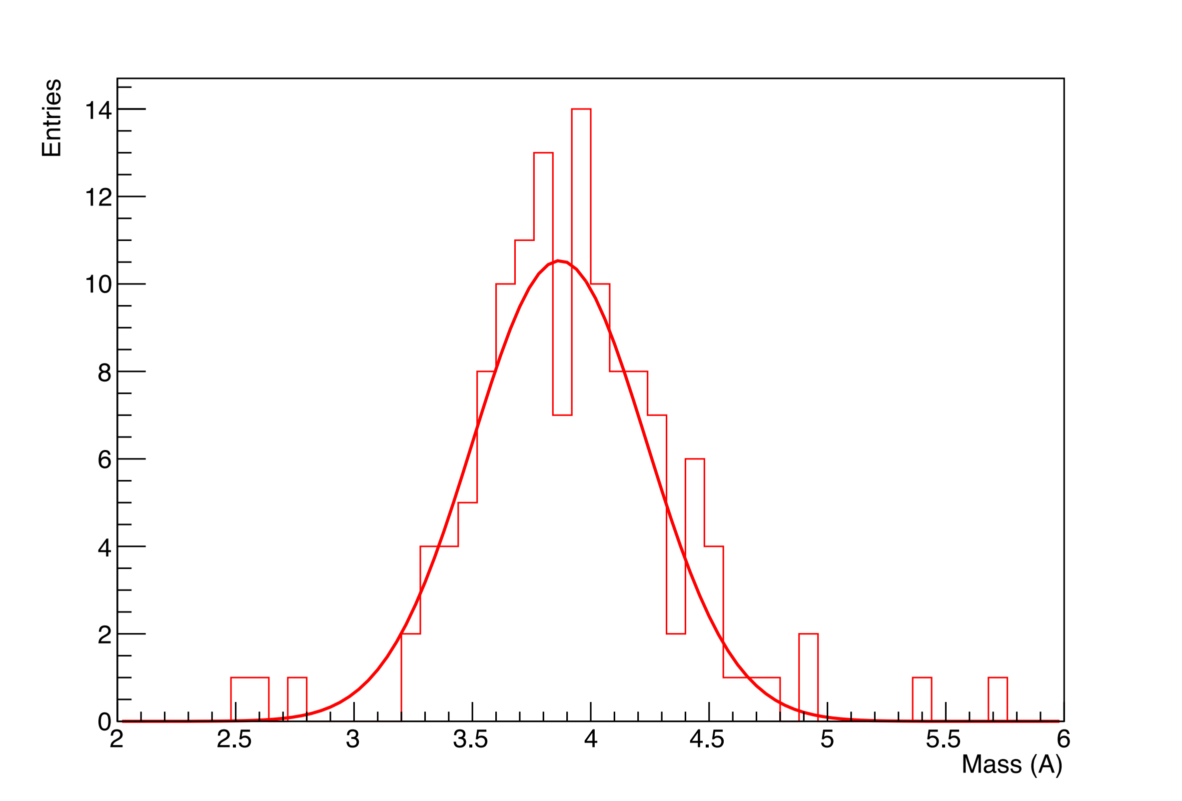
③

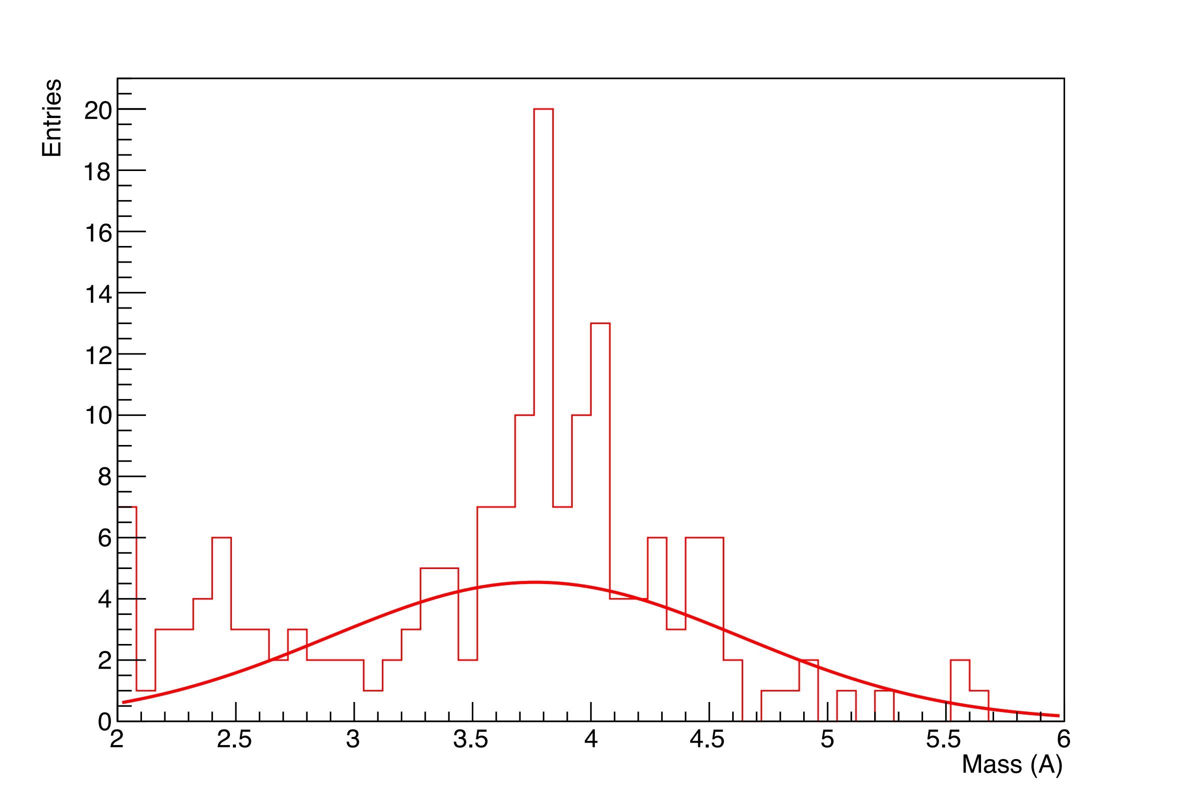




: one layer
w/ square-shaped
surface

For Mass Plot





χ^2 / ndf	1611 / 1119
p0	1.039e+07 ± 4.889e+06
p1	-2.438e+04 ± 1.414
p2	-2.986e+06 ± 1.414
p3	-1.404e+08 ± 9.932e+06

χ^2 / ndf	3295 / 10584
p0	0 ± 1.414
p1	7.741e-12 ± 1.414
p2	1.281e+06 ± 1.063e+08
p3	5.684e+05 ± 1.897e+07
p4	1.21e+08 ± 1.623e+07
p5	3.236e+11 ± 9.442e+09
p6	7.322e+10 ± 2.237e+09
p7	-1.275e+08 ± 3.658e+06
p8	1.582e+05 ± 1856
p9	-287.1 ± 3.67

Multiplicity

- IQMD data simulation
- Au-Au collision at 250 AMeV
- Normalized by event num. (10000 events in total)

1. All <u>charged</u> particles generated by simulation: entries ~ 130

   (cf: including neutral ptl ~ 300)

2. b/w 14-24 deg. (detector coverage range) :

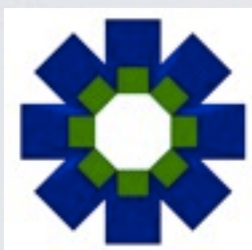
entries ~ 23 (53)

3. Particles entered into detector :

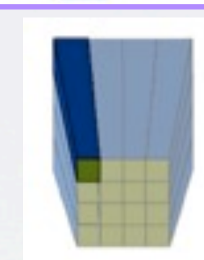
Design 1	Design 2
 entries ~ 21 (34)	 entries ~ 17

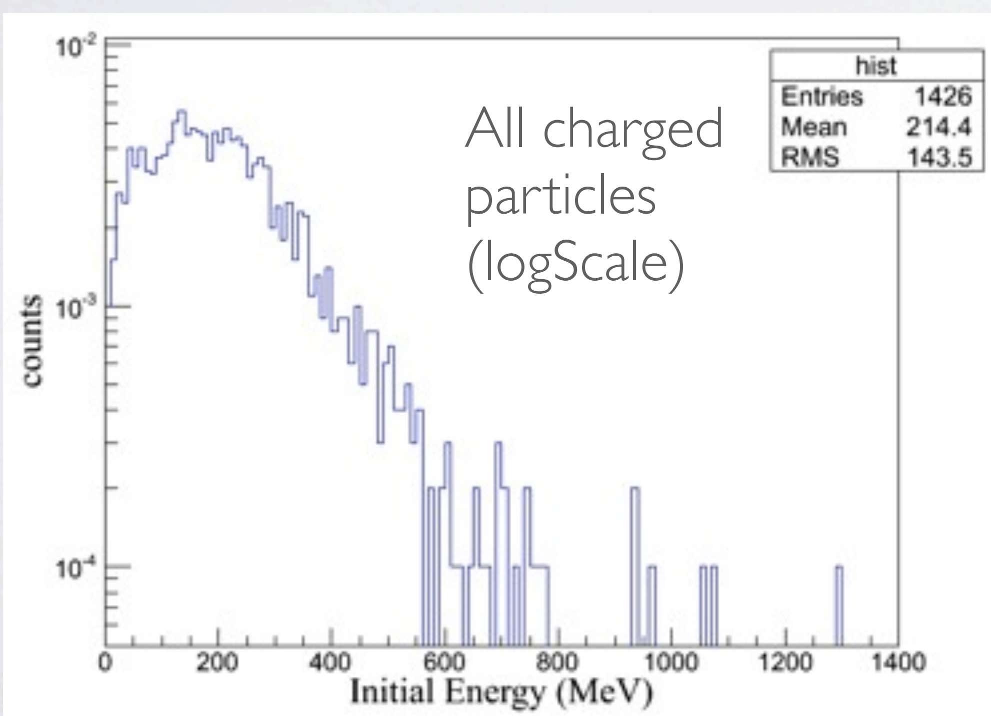
Multiplicity

4. Particles entered into <u>one detector</u> :

Design 1	Design 2
 entries ~ 3 (4)	 entries ~ 2

5. Particles entered into <u>one channel</u> (Design 2 only) :





avg entries ~ 0.14
(range 0.11-0.17)

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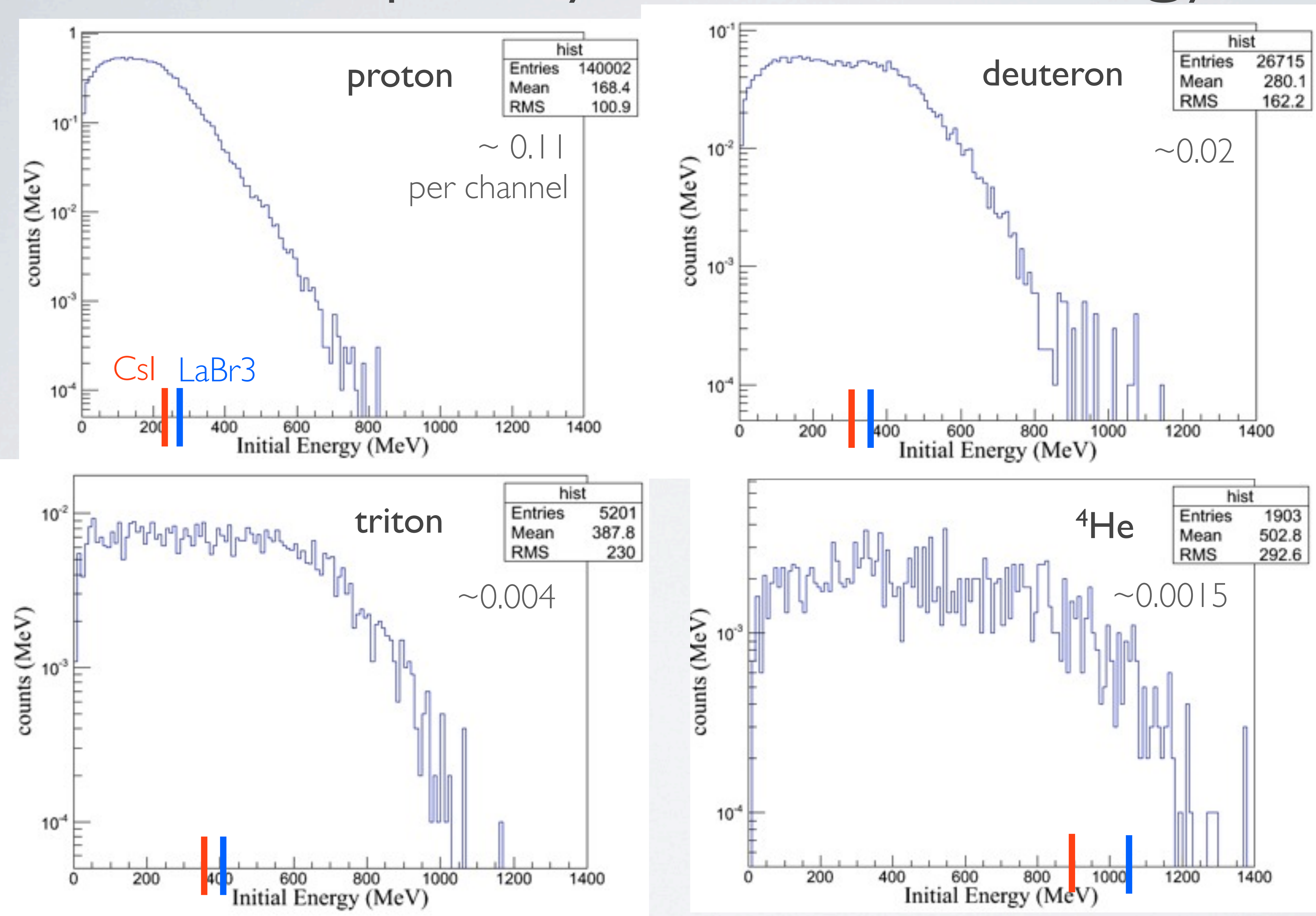
Multiplicity & Initial energy hist.



histogram :
per channel X
entered into detector
(veto ignored)