Geometric acceptance of the large and small absorbers for dark photons

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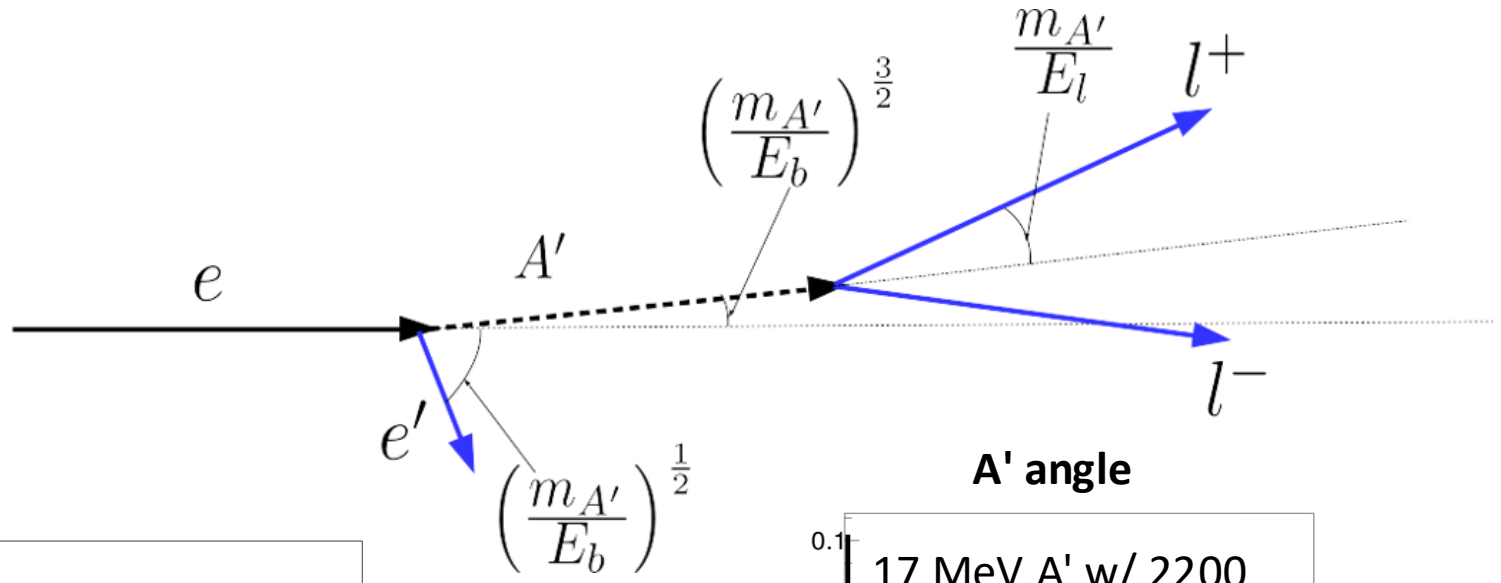
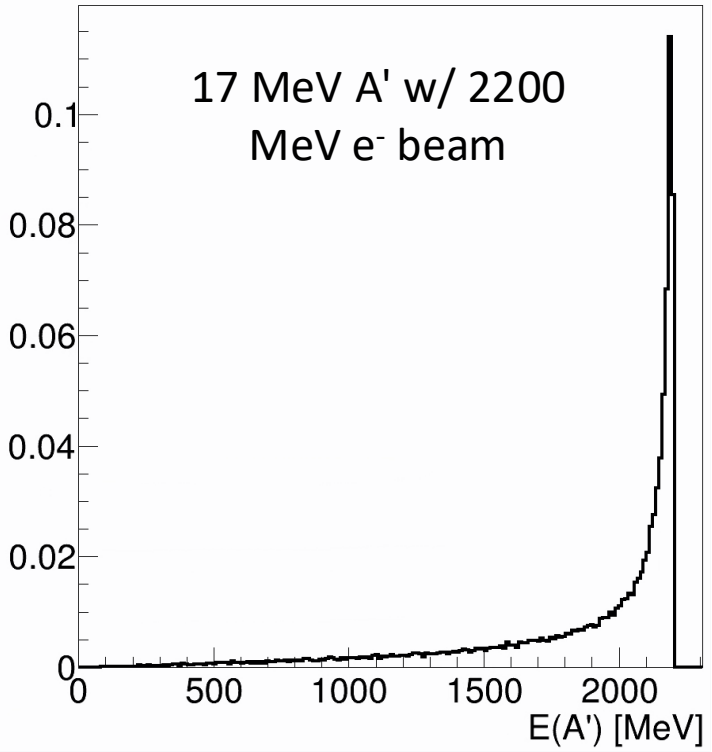
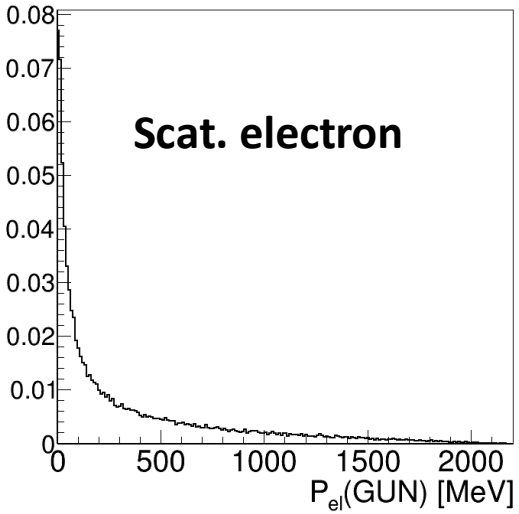
Electro-produced heavy photon kinematics on fixed targets

- Unlike Bremsstrahlung, A’ takes almost all the beam energy: $E_{A'} \sim E_b(1 - m_{A'}/E_b)$
- Peaked at forward angles: $(m_{A'}/E_b)^{3/2}$

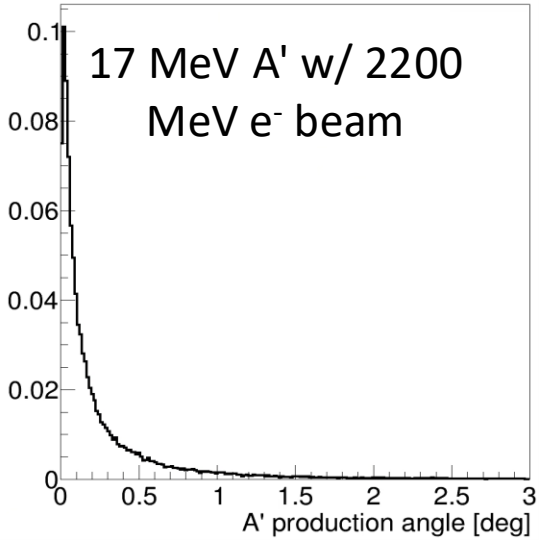


A' energy





A' angle



The Full simulation of the signal

MadGraph5 A' production → GEANT4 → Reconstruction → Analysis

$$e + Ta \rightarrow Ta\, e^- e^+ e^-$$

A' is generated for 5 different masses - M [MeV]: 10, 17, 25, 35, 55

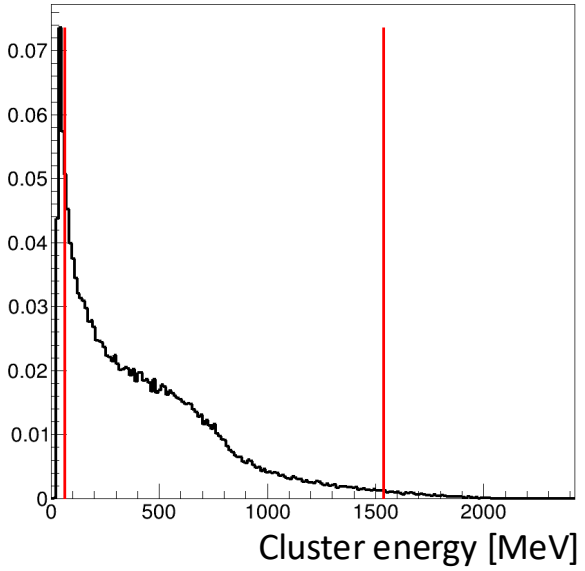
Analysis conditions

- Three or more clusters
- All clusters are charged,
- 0.03*Eb < Cluster energy < 0.7*Eb
- Sum of all three cluster energies > 0.7 *Eb

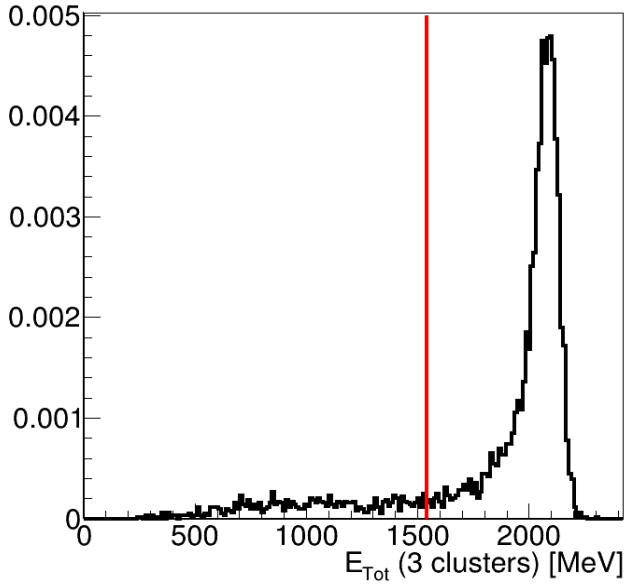
Slide from ERR. Plots represent the big absorber setup.

An example for 2200 MeV Beam and 17 MeV A'

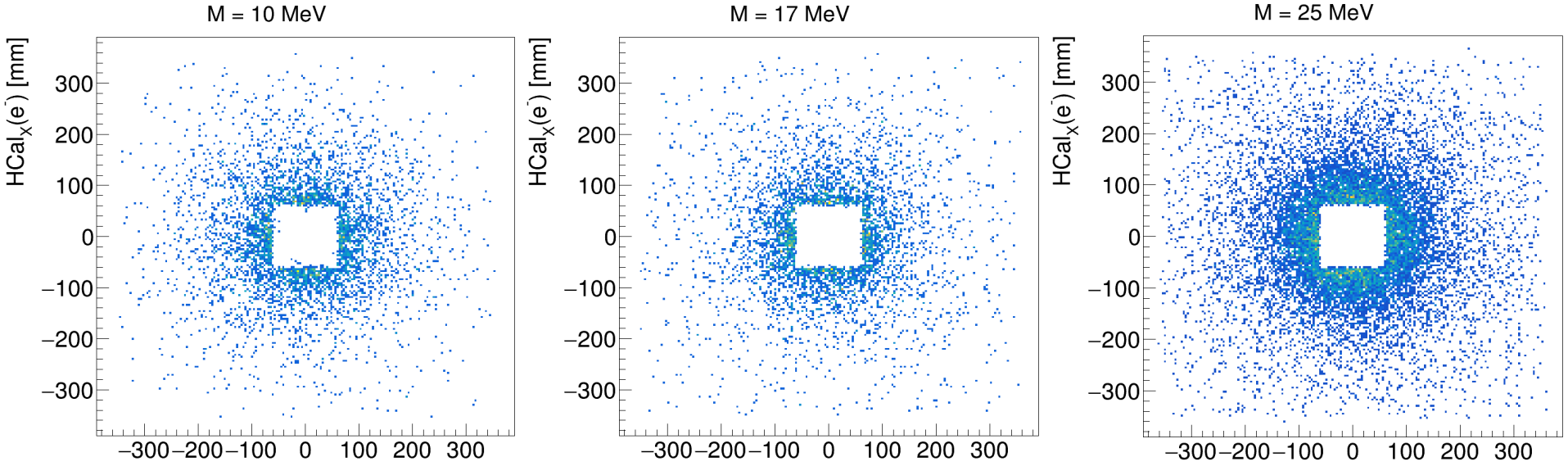
Single cluster energy

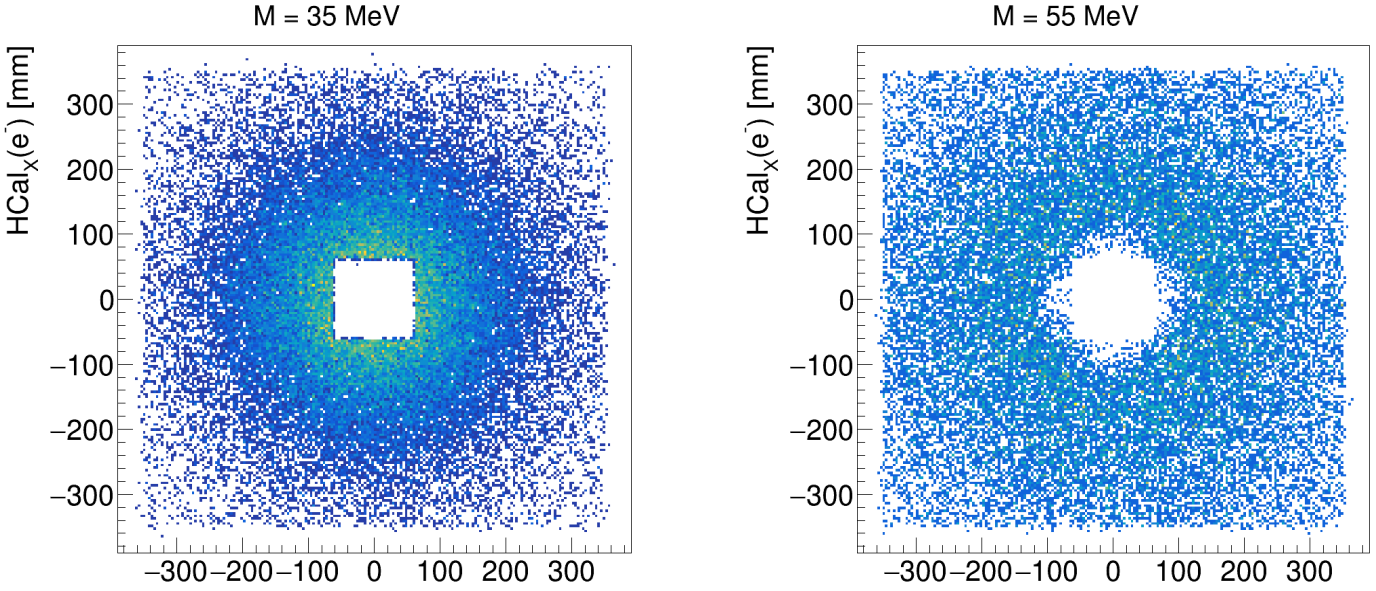


Energy sum of three clusters



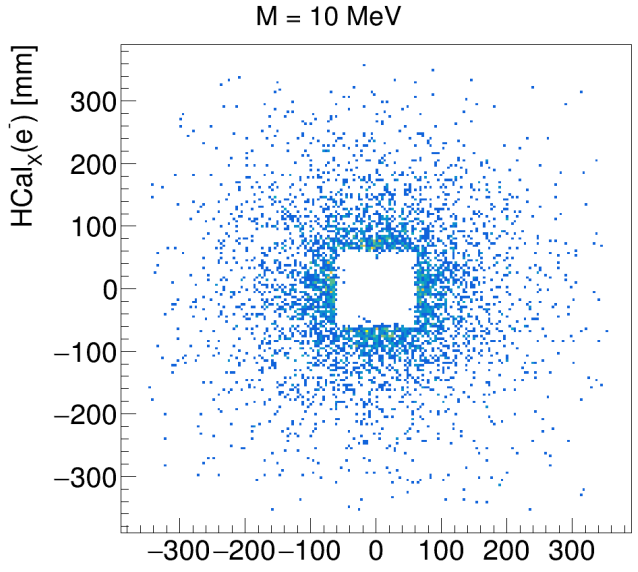
Decay electron on HCal face

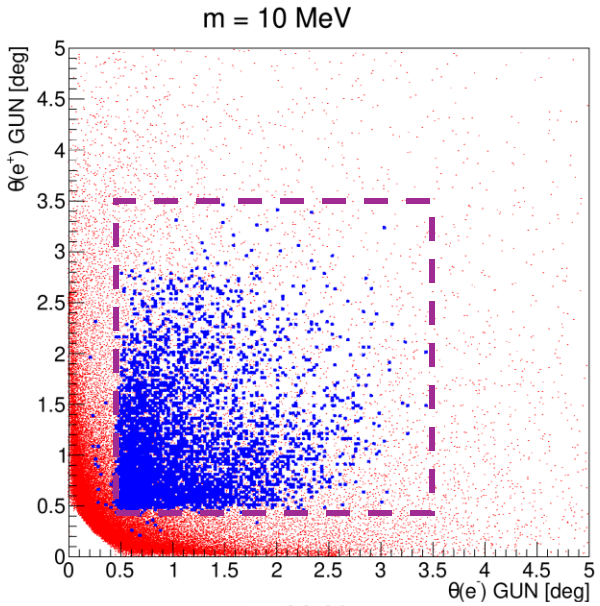


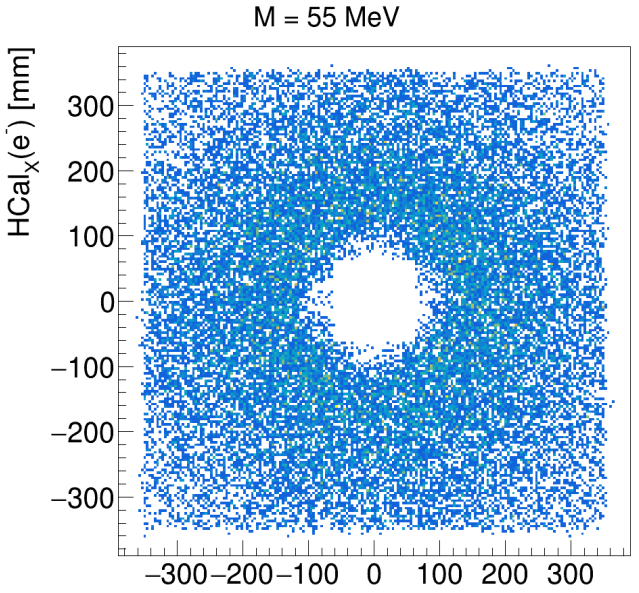


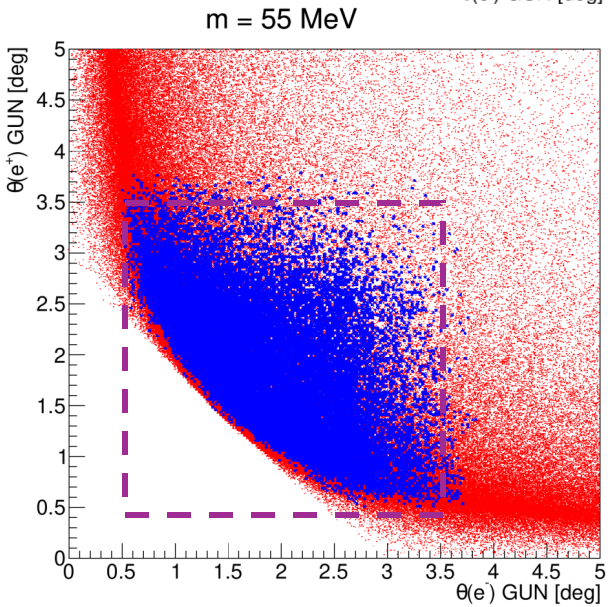
- At small masses (below 20 MeV) majority of decay electrons hit the 1st uncovered layer of HCal.
- Distributions for **positrons are identical**.
- The plan is to use the small absorber to increase acceptance for smaller masses and mitigate edge related effects.

Big absorber







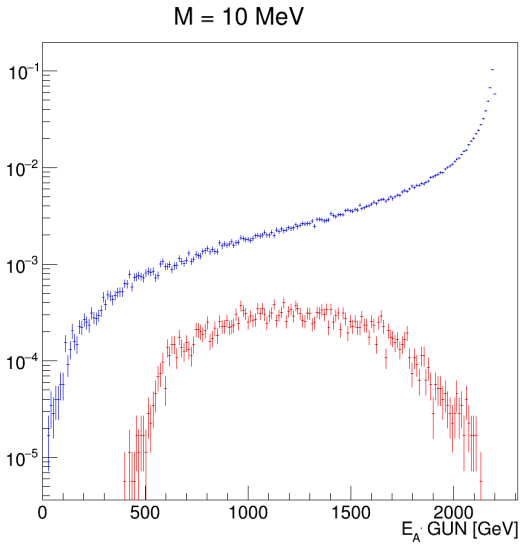


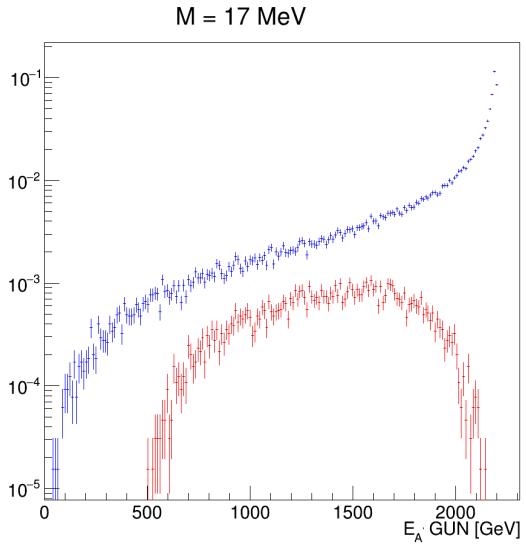
- Generated
- Accepted

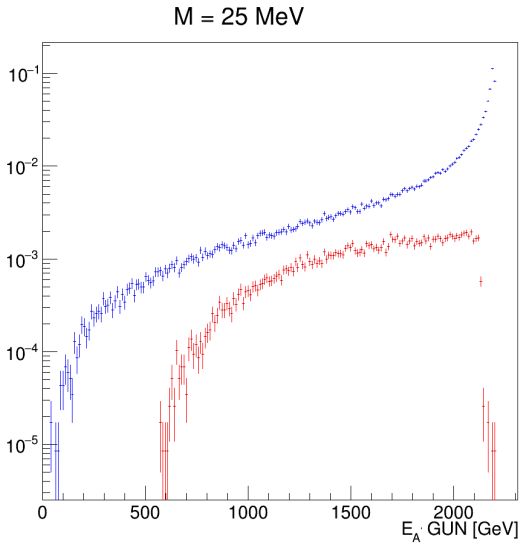
Smaller masses: Majority of undetected A's has one of decay leptons (e^- or e^+) either hit the absorber or go through the ECal Hole.

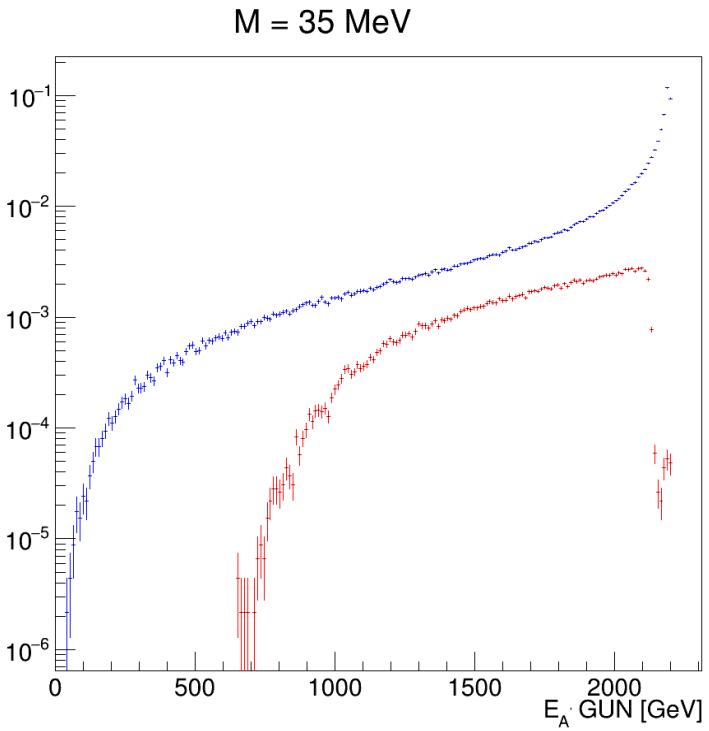
Higher masses: Majority of undetected A's has one of decay leptons (e^- or e^+) large polar angle to miss the Lead Tungsten part of the HyCal.

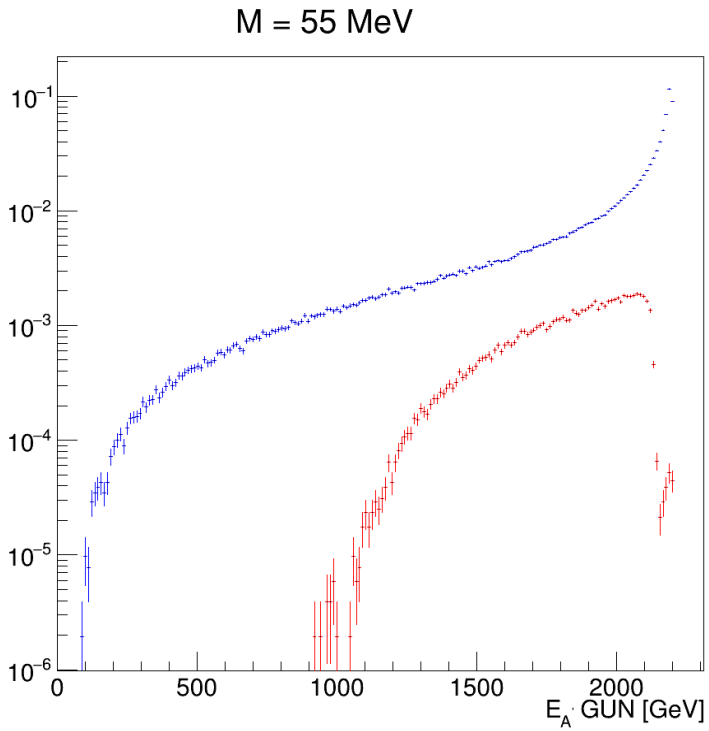
2200 MeV Energy of A'











- Generated
- Reconstructed (e-,e+,e-)

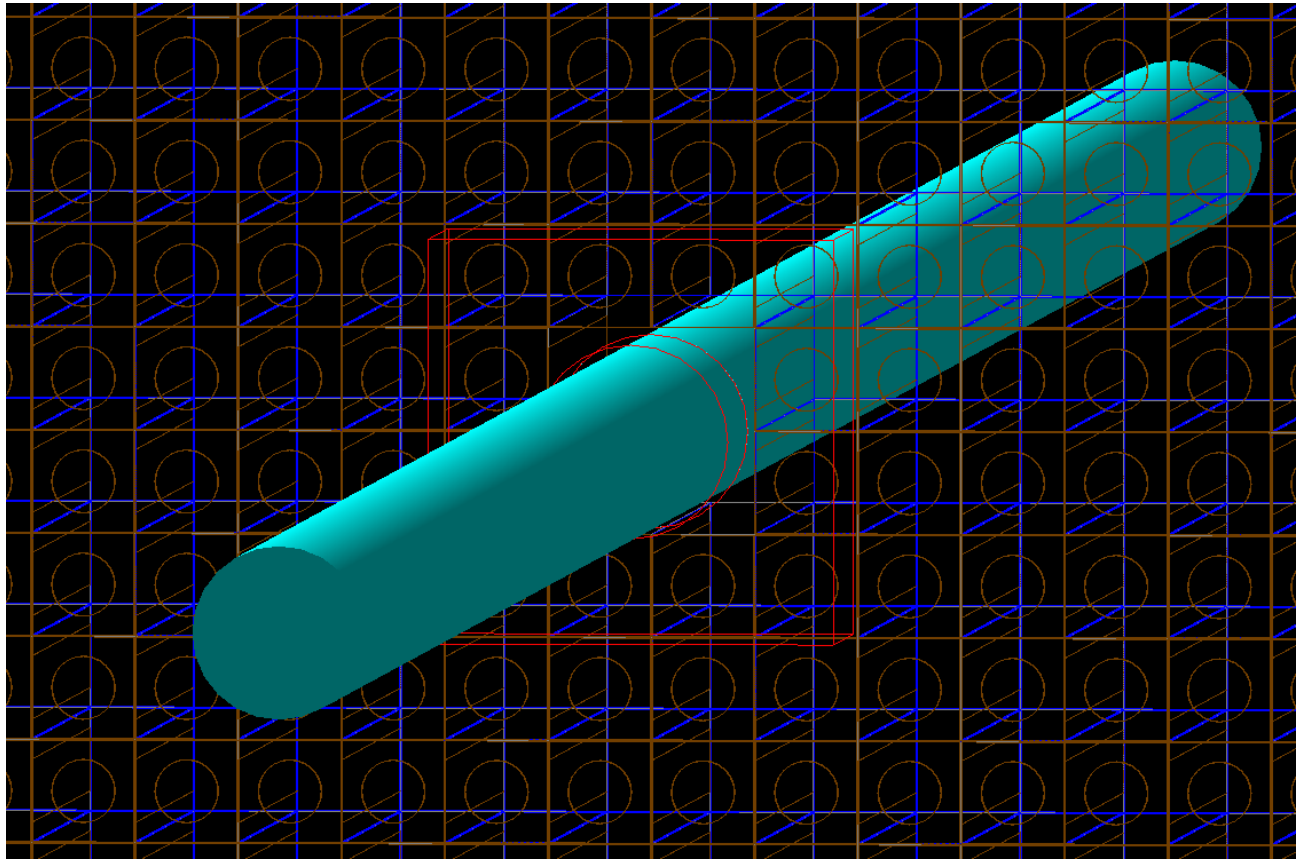
The loss at high A' energies is high especially at smaller masses

PRA

Simulations with smaller absorber

- Same generated A' events thrown to the new GEANT4 setup with smaller collimator, covering only 1st layer of crystals around the hole.

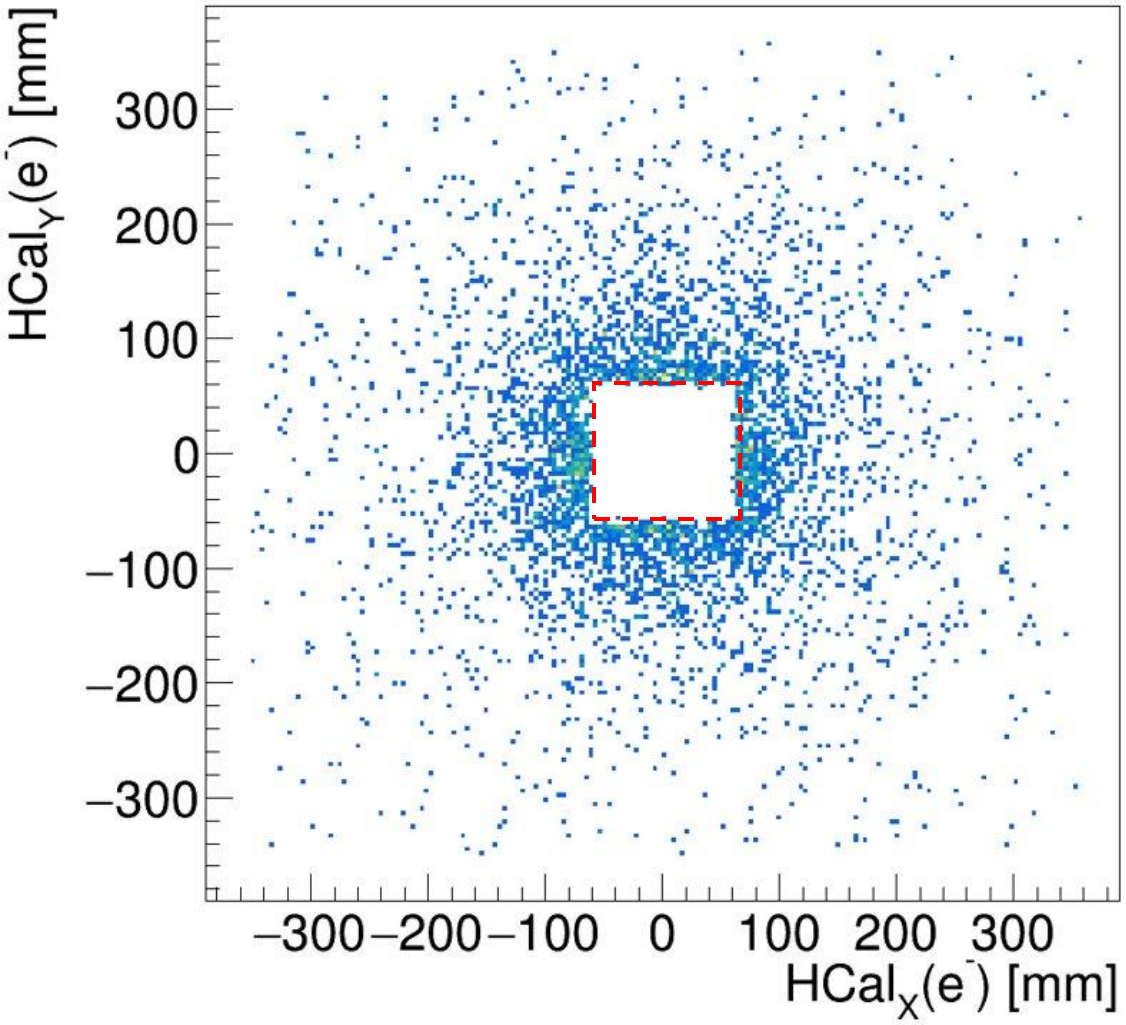
- In a similar manner events were reconstructed and analyzed.



Distribution on HCal face: Decay electron

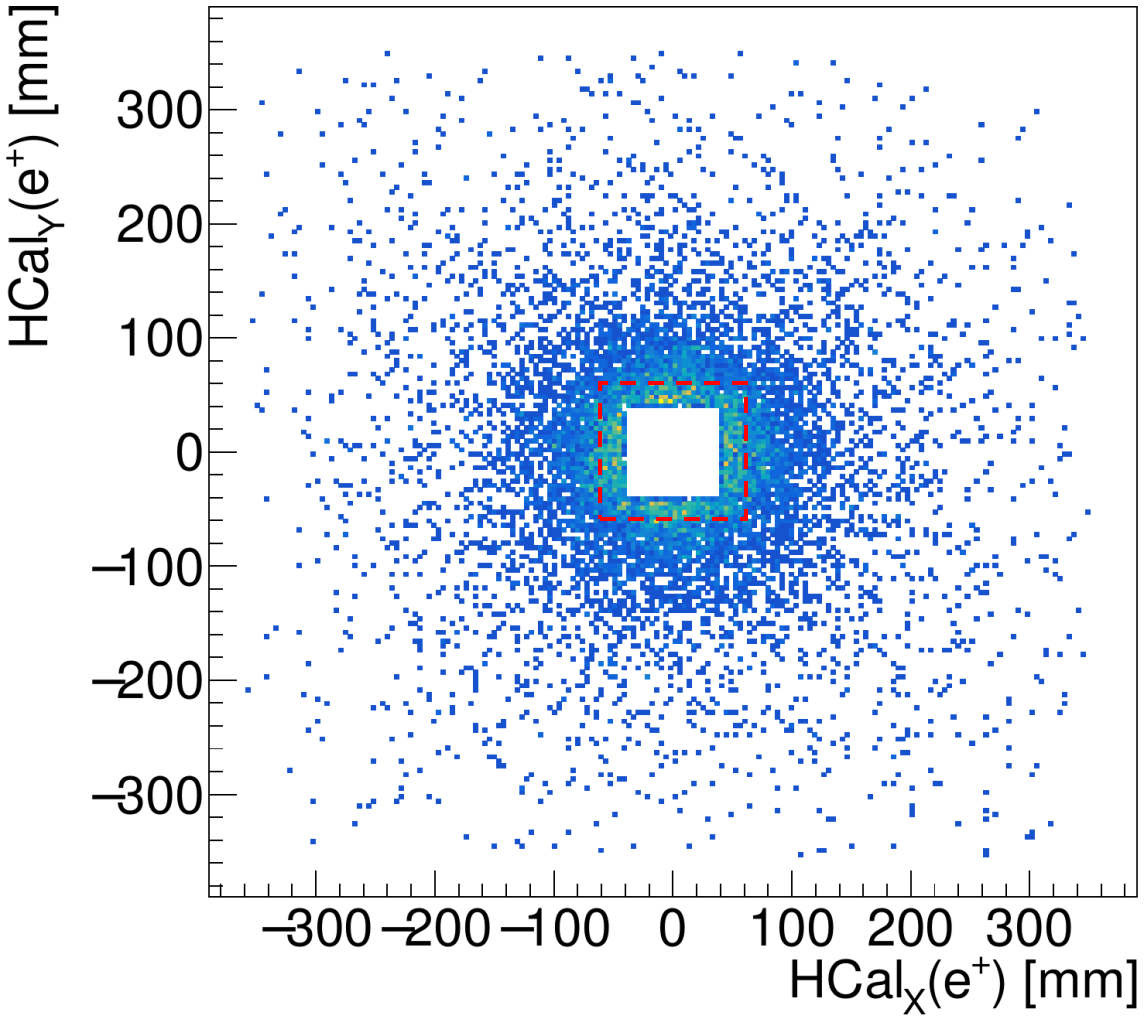
- Eb = 2200 MeV
- M(A') = 17 MeV

Big absorber



Small absorber

M = 17 MeV

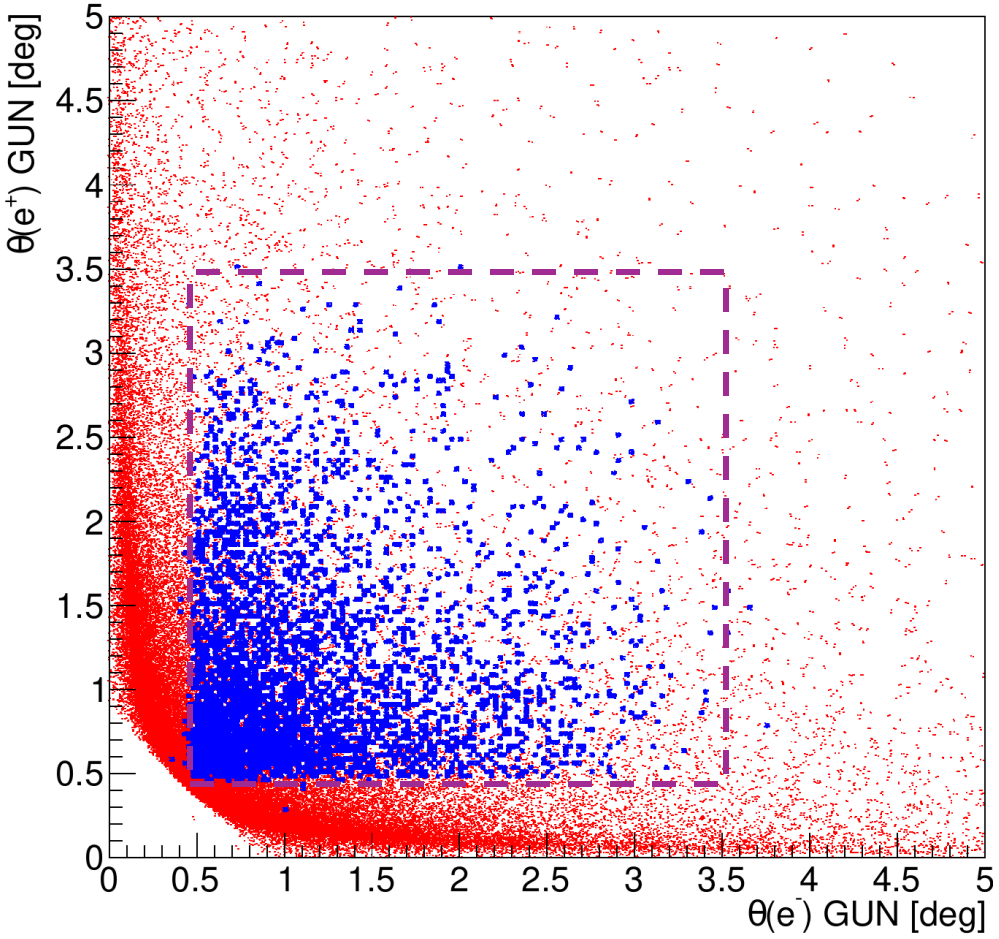


Angular distributions

Significant improvement for 17 MeV

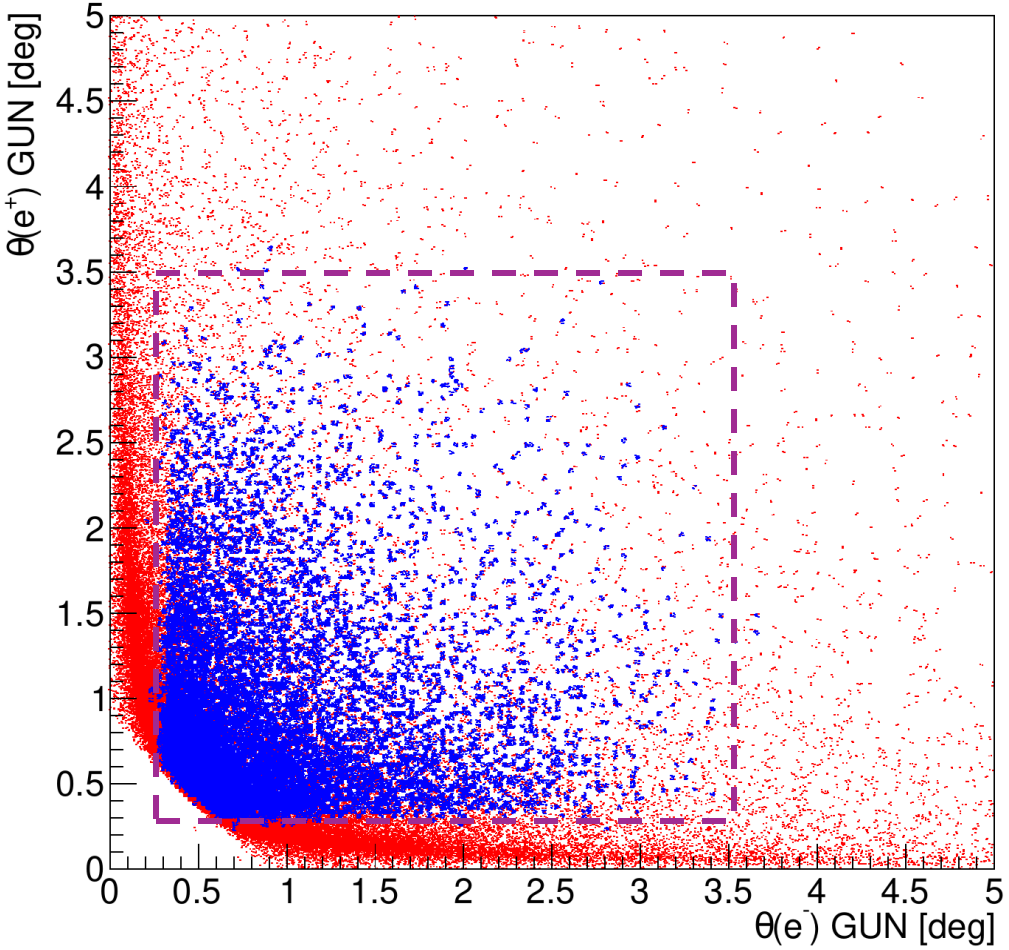
Big absorber

m = 17 MeV



Small absorber

m = 17 MeV

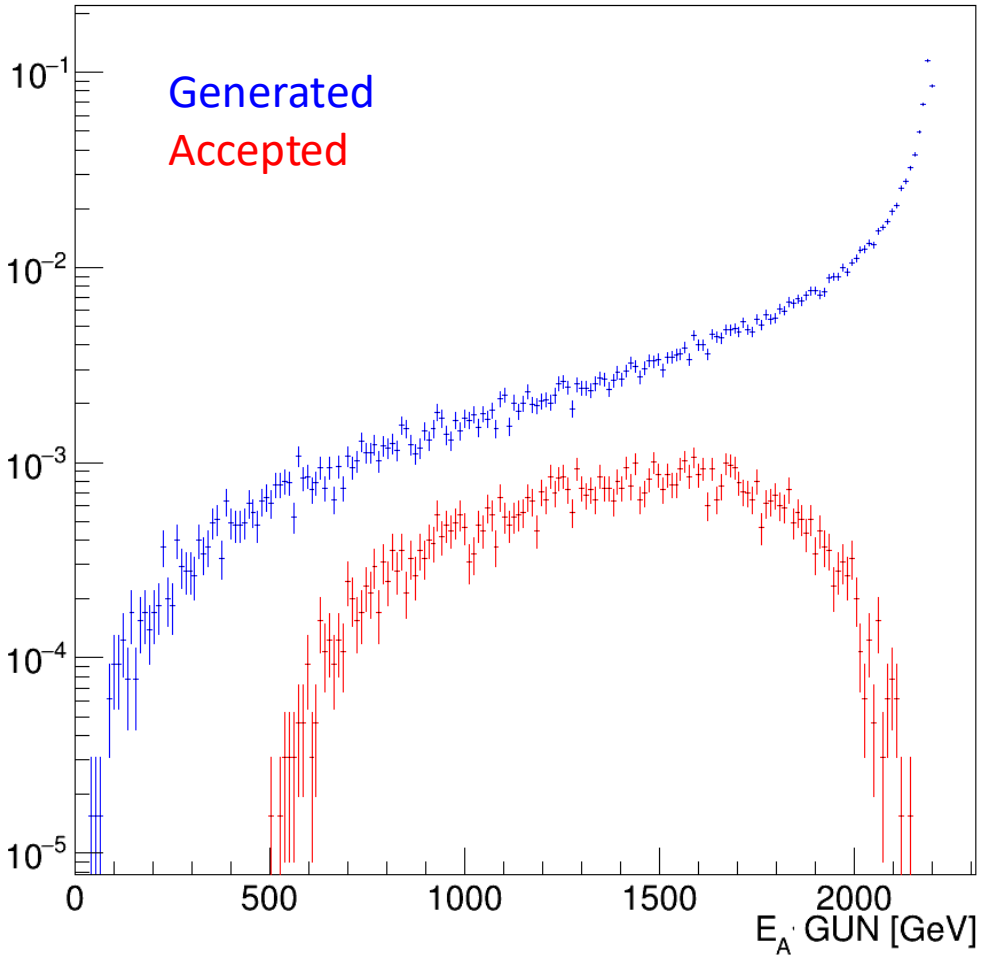


Energy sum distributions

Significant improvement for 17 MeV at high A' energies

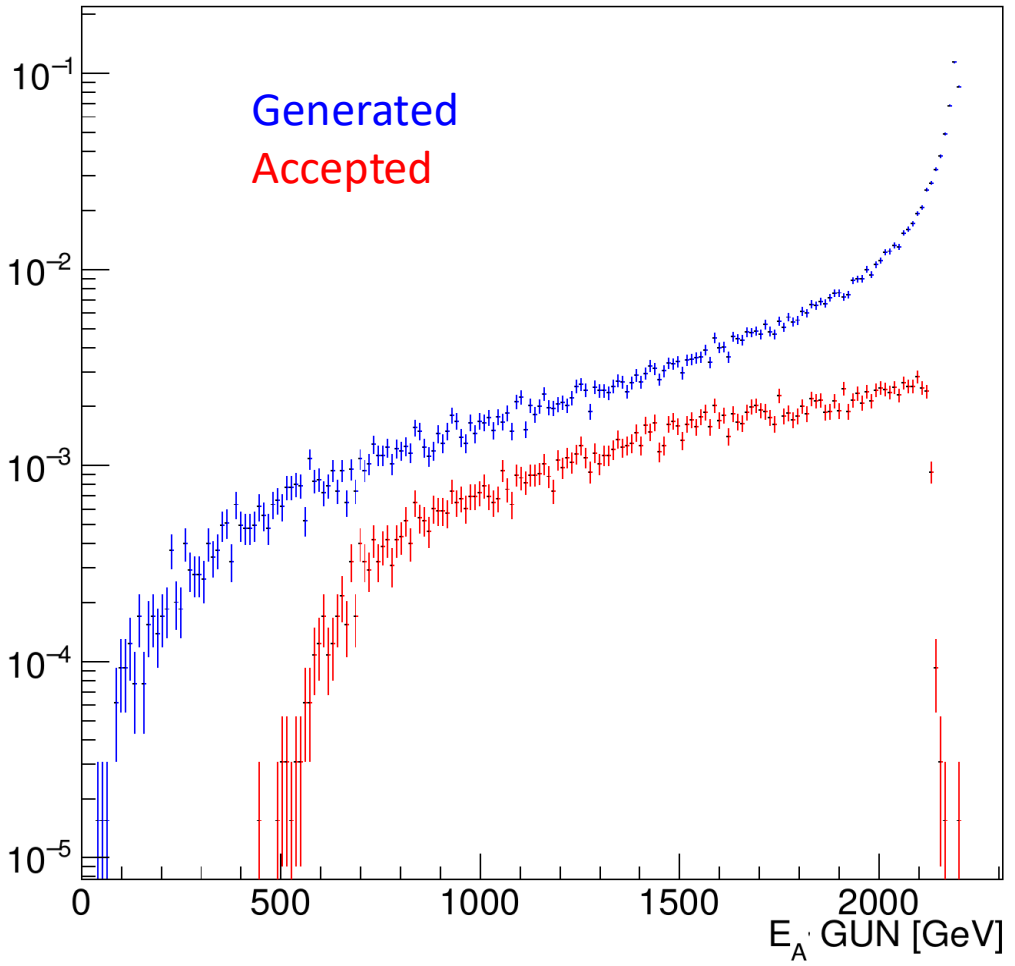
Large absorber

M = 17 MeV



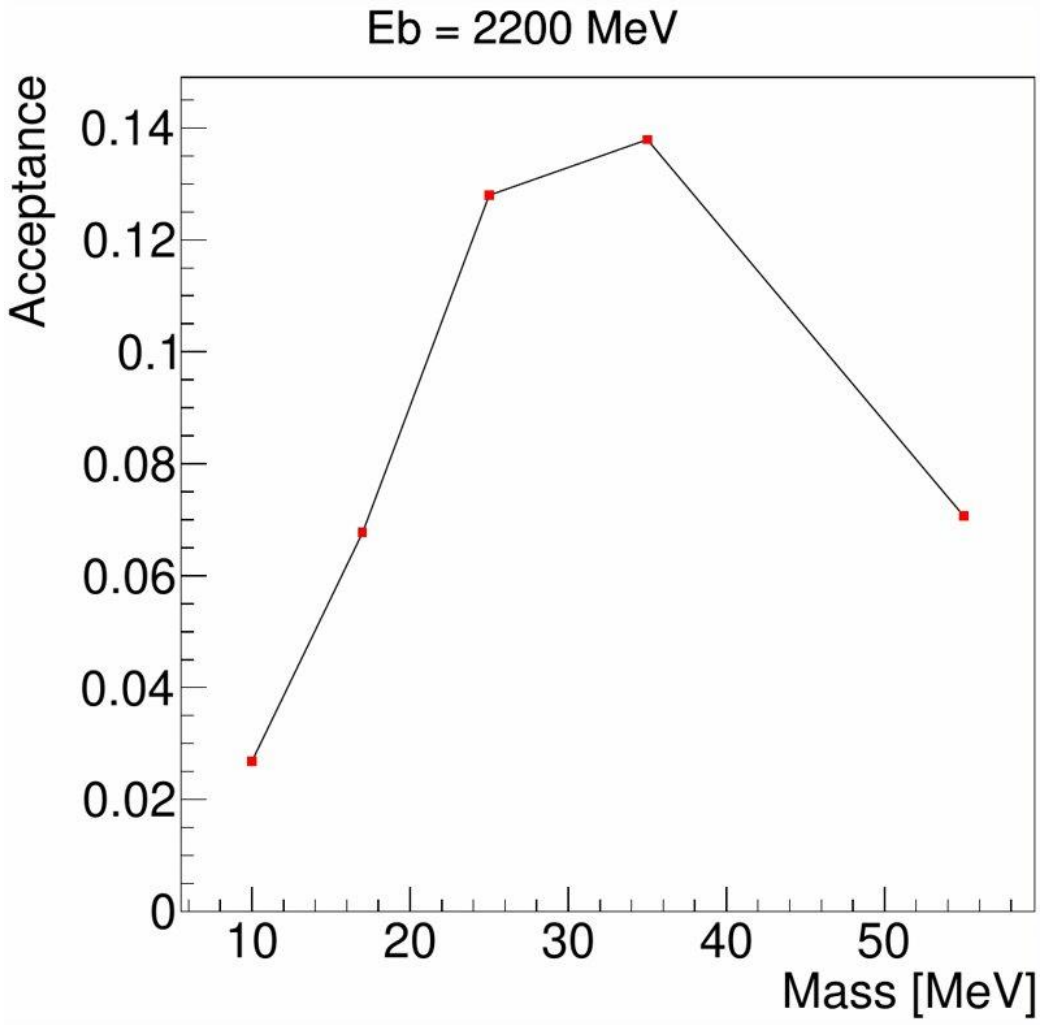
Small absorber

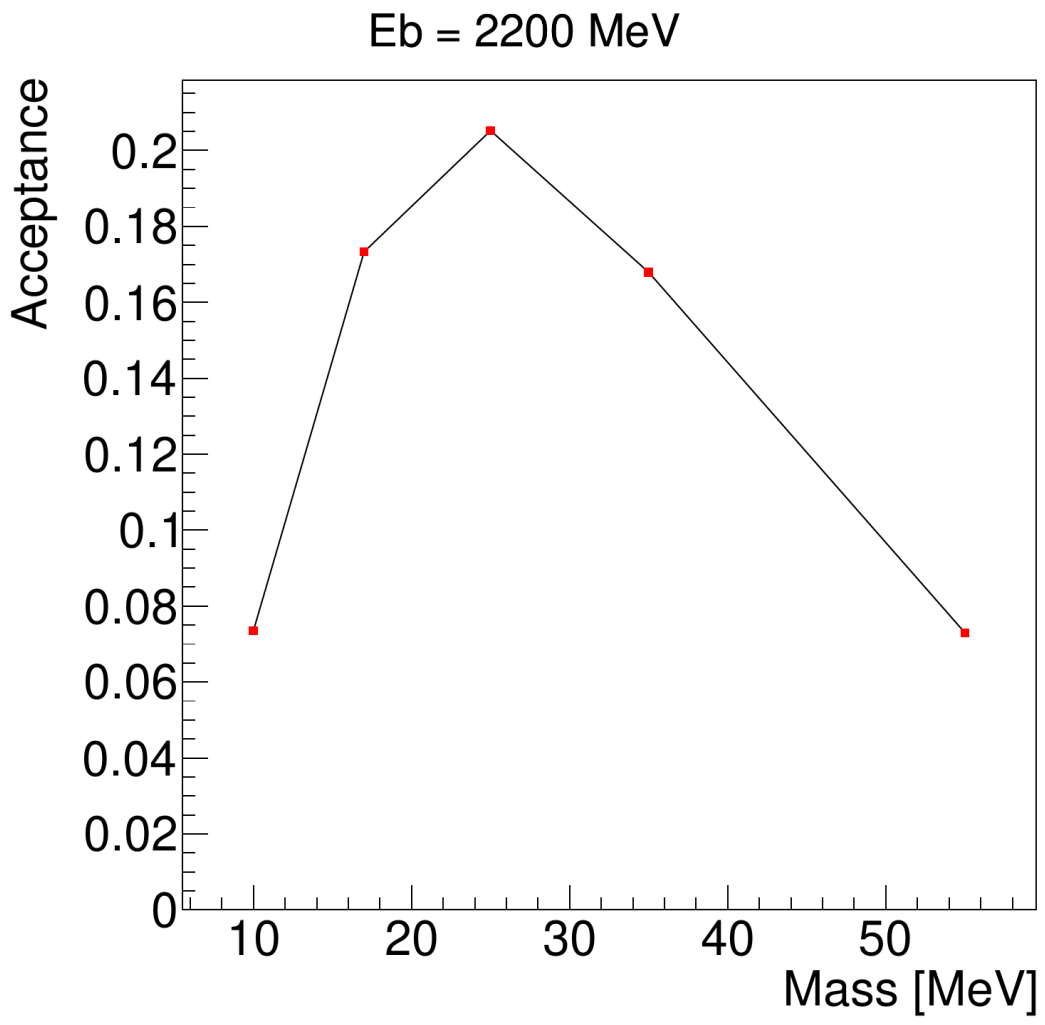
M = 17 MeV



A' acceptance at different masses

- @ 10 MeV the gain is x3
- @ 17 MeV the gain is about 2.5
- @ 55 MeV the gain is insignificant



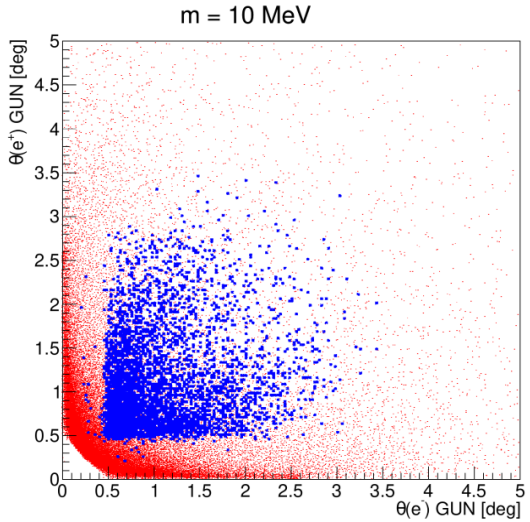


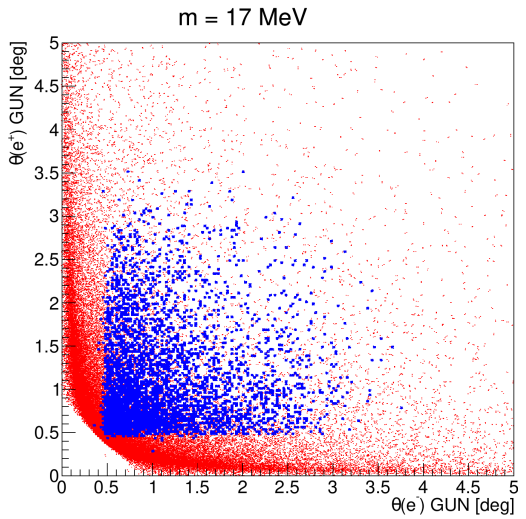
Summary

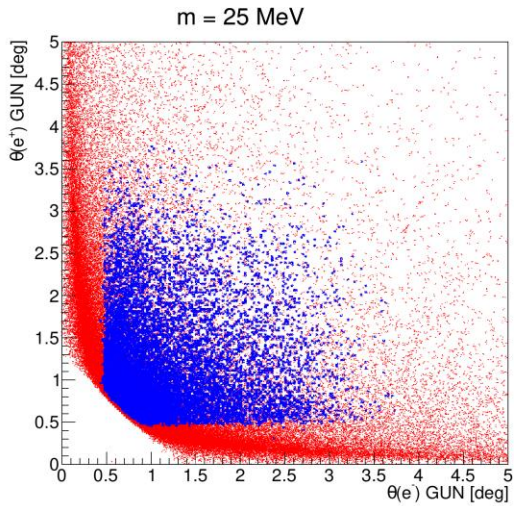
- At smaller masses (below 20 MeV) majority of A' decays have at least one of decay leptons either hit the absorber or travel through the beampipe
- Majority of survived A's have at smaller masses occupy the 1st uncovered layer of the HyCal
- At high masses > 50 MeV, the absorber doesn't play significant role in the acceptance
- Having smaller absorber increases the acceptance x3 for 10 MeV *x2.5 for 17 MeV)
  - Also will mitigate edge related effects.

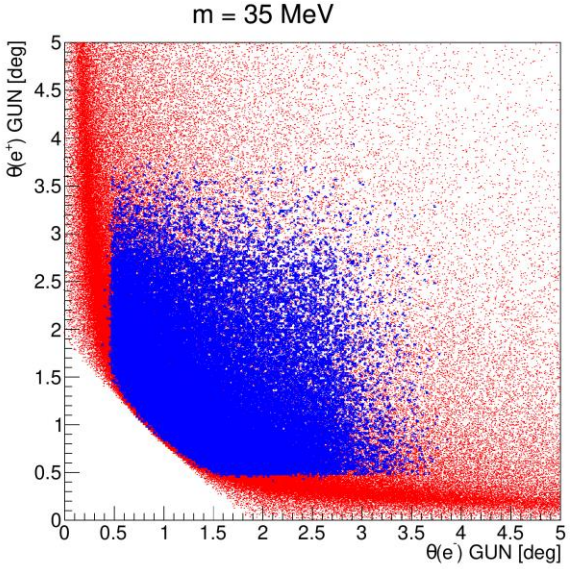
Backup

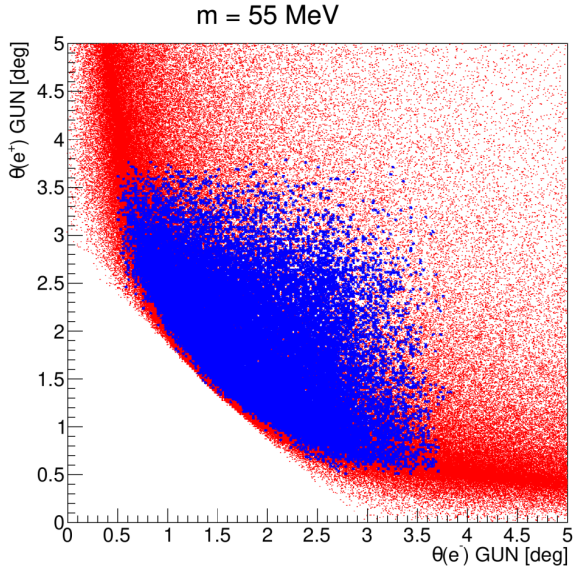
Big Absorber



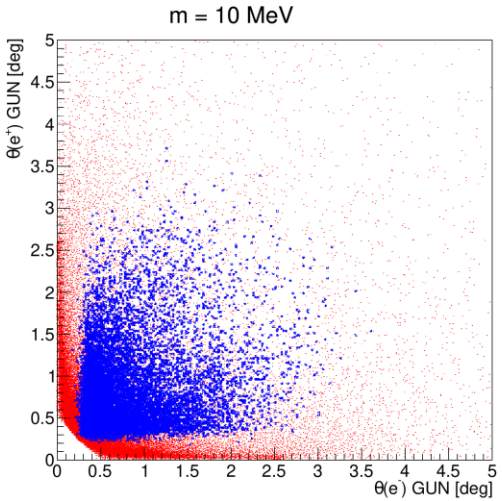


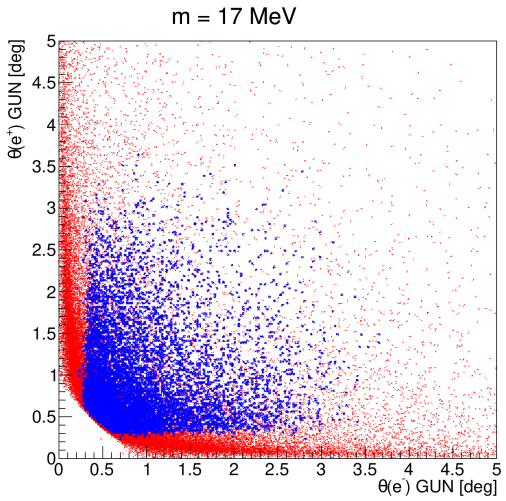


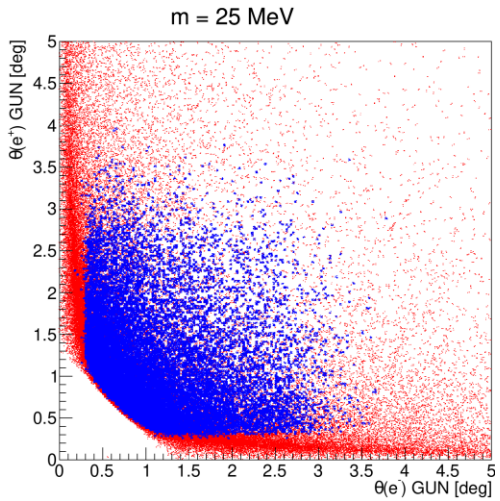


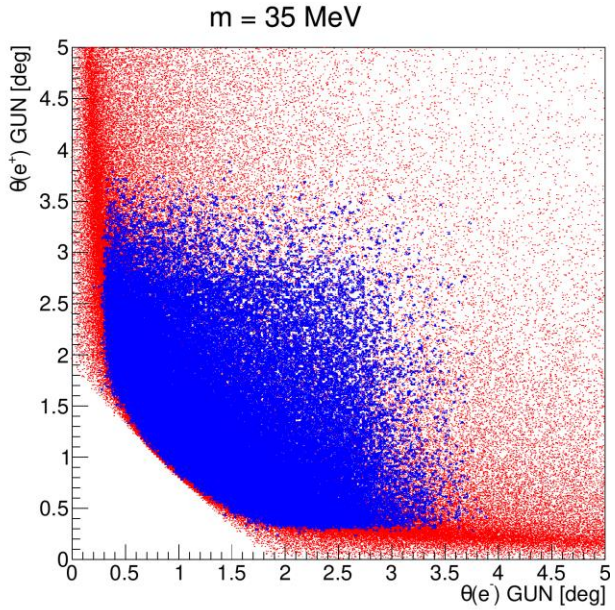


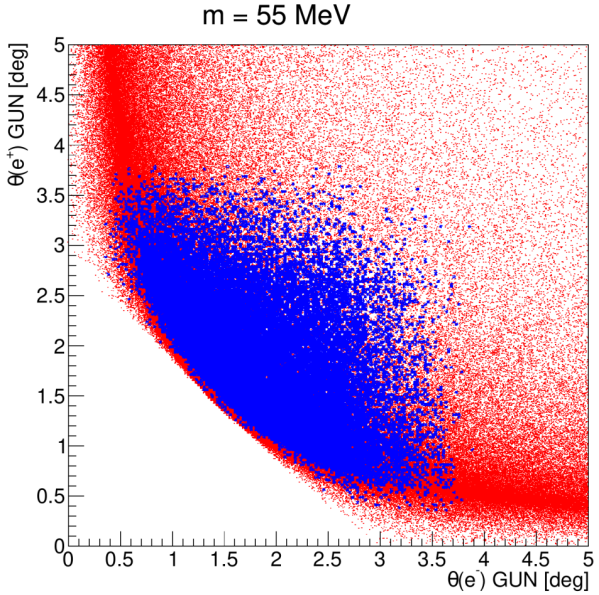
Small Absorber





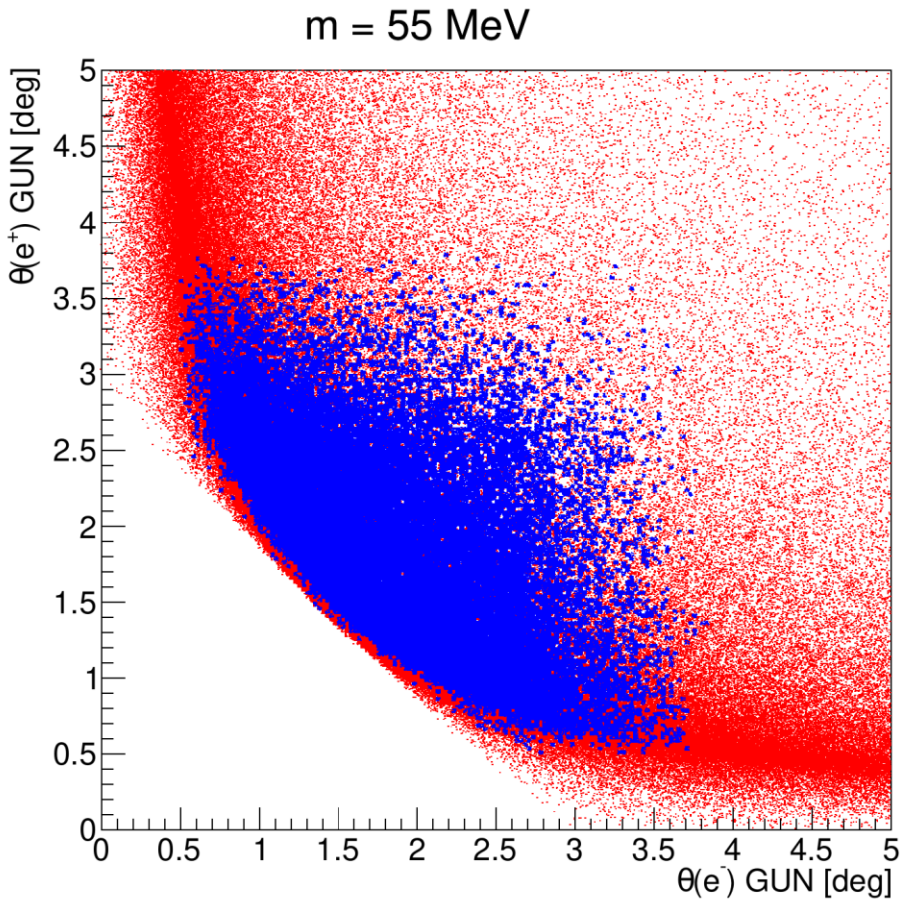




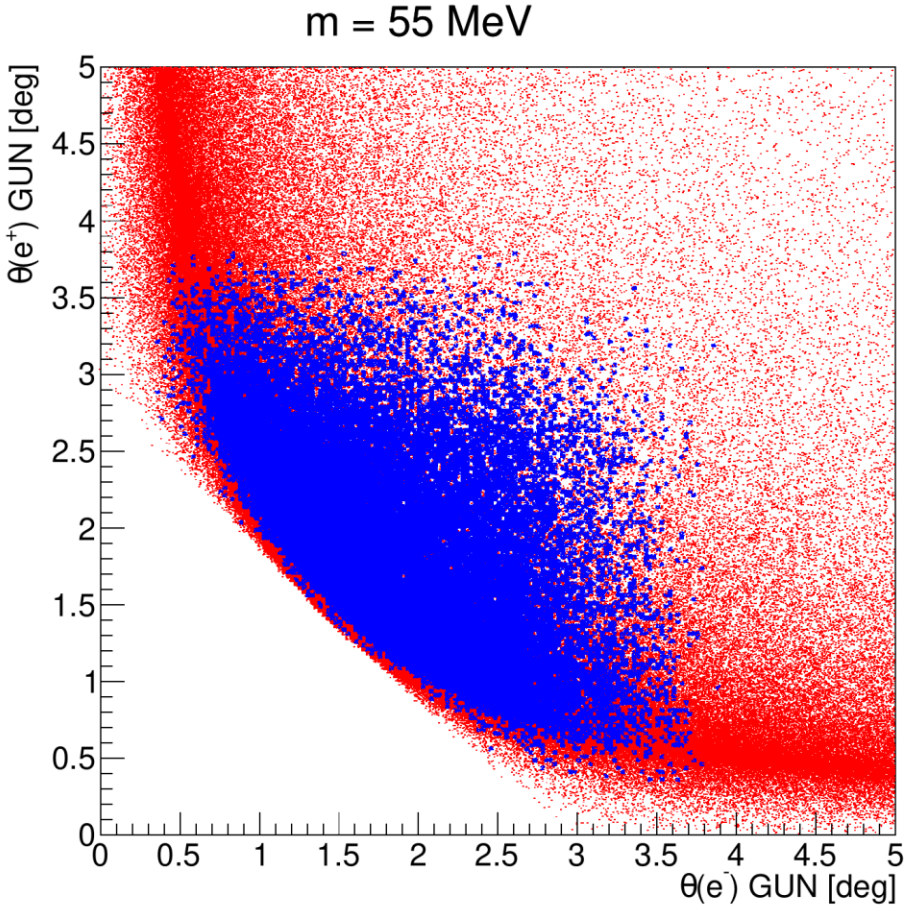


No significant improvement at high mass

Big absorber



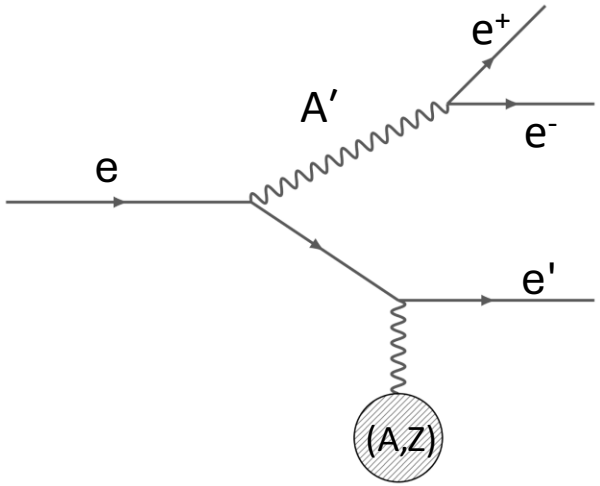
Small absorber



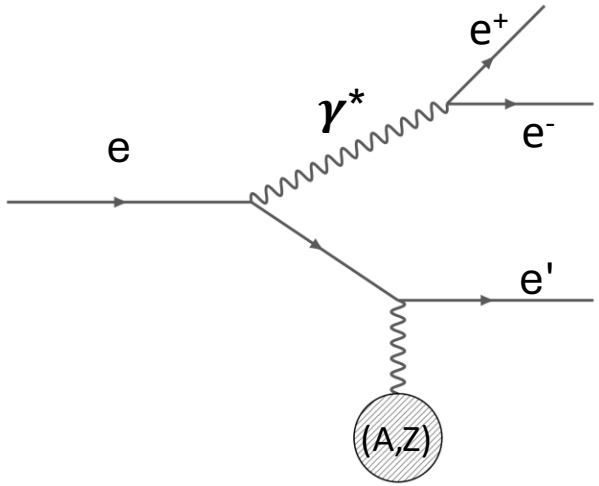
Background processes in A’ production w/e- beam off fixed target

Physics Background

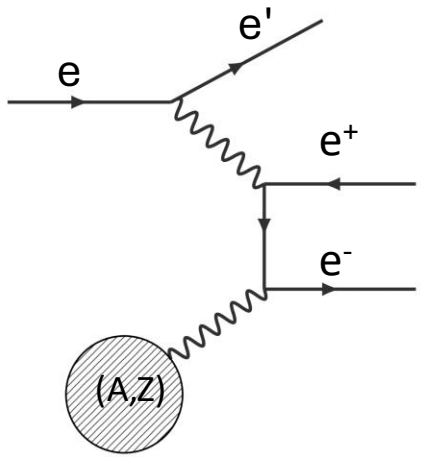
Production of A’ (signal) aka A' Strahlung



Radiative Tridents



Bethe Heitler



Have exactly same kinematics for the given mass of A'(γ^*).

- Signal has distinct shape
  - A' energy is peaked at close to beam energy
  - A' is produced at very forward angles
  - Scattered electron is soft

MadGraph5 generator is used to generate A' **assuming the signal particle is a dark photon**.