



UNIVERSITÉ
DE GENÈVE

FACULTÉ DES SCIENCES



SuperFGD

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Issues with “current” target detectors

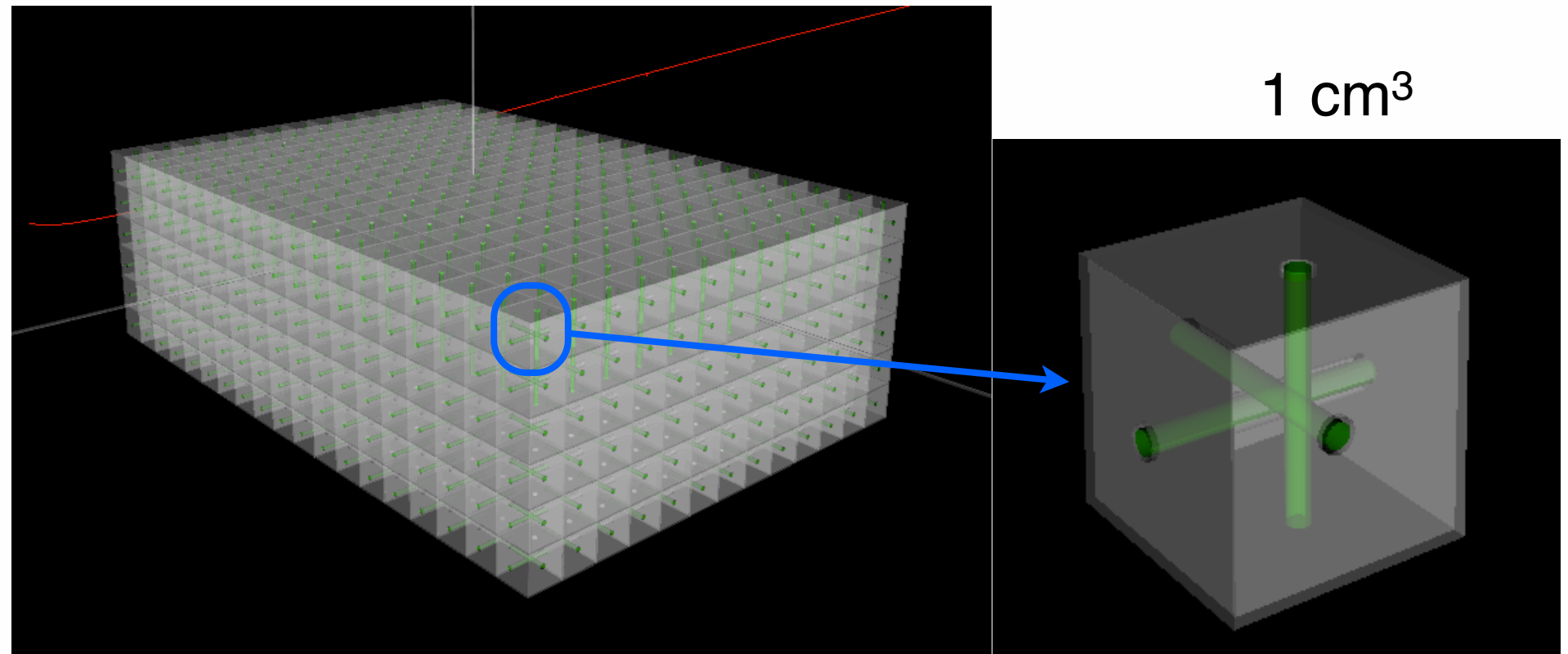
- FGD, not 4pi:
 - no tracking at high angle --> require track through
 - using bars --> require 6 hits, i.e. track length >5cm
 - momentum threshold not low enough (e.g. proton ~ 400 -500 MeV)
 - ~ 15 -20 p.e. per cm (MIP), old MPPC w/ phot->pe eff <20%
- WAGASCI, 4pi but:
 - with water \sim same momentum threshold as FGD
 - require 2 hits per 2 directions --> at least 1cm (if empty...)
 - if empty $\sim 30\%$ mass of 1 FGD
 - not good PID: ~ 10 -15 p.e. / bar (bar=3mm, MIP), RMS on # p.e. large depending on distance of interaction from the slit
- Need a target with a good tracking and PID at least as good as FGD but at 4pi
- A water target makes sense only if we can do a good job. 500 MeV threshold may be useless...

SuperFGD

- Fully active material of plastic scintillator

Example size

- Width = 180 cm
- Height = 60 cm
- Length = 130 cm



- Many cubes with 3 holes (3 directions), each containing a fiber
- Each cube coated with TiO_2 --> keep light entrapped inside the cube
- 1 interaction (energy released) would produce light collected in the 3 fibers at the same time --> 1 hit = 1 pt!!!
- Light collected by 3 fibers --> Tot # of p.e. \sim # of p.e. FGD x 3 (to be tested)
- Goal: excellent PID ($>\sim 100$ p.e. / cm for MIP) and tracking (1cm on the single hit, better than FGD and water-WAGASCI, not sure about empty-WAGASCI)

Mechanical constraints

- Objection made by Masashi: “I’m not sure we can build it”
- For 1cm³: 1 million cubes, holes of 1-1.5mm diameter, insert the fiber
- Discussed to Franck Cadoux (mechanical engineer at UniGe) and we conclude that:
 - take long plastic scint bar and cut in many cubes (ask company to serialize?)
 - put all the cubes in a bath of coating
 - make 3 holes (ask company to serialize?)
 - assembling the cubes: gluing on each face would take a very long time --> avoid it: put all the cubes in a box and screw (verify the mechanical constraint, but should be less problematic than water)
 - no problem inserting the fibers: take a rigid row (same diameter of fiber), glue it to the fiber and pull it inside the hole (standard technique)
- He said that it should be possible to build it. More expensive but probably still dominated by the electronics
- 42k channels for 1cm³ and 180x60x130cm (2 FGDs have ~11k channels)

Full simulation of SuperFGD

- Assuming same performance as FGD except MPPC
- Birks' equation is applied --> quenching in plastic scintillator
- Light collection in the fiber + Edep --> photon conversion

$$E_{vis} = \frac{E}{1 + k_B \frac{dE}{dx}}$$

`< elecSim.Scintillator.PhotPerMeV.fgd = 70.8 1/MeV >`

Constants are
taken from TN-103

- contains also the fiber light collection efficiency
- to be tested (better or worse than FGD?)
- Account for 3 fibers in the same plastic scint. cube
 - light collected by a fiber is shaded by the other fibers
 - assume $f_{\text{Coll}} = 10\%$ (double-cladding, PDG2016)
 - $N_{\text{shadow}} = \{ f_{\text{Coll}} + (1-f_{\text{Coll}}) * f_{\text{Coll}} + [1-(1-f_{\text{Coll}}) * f_{\text{Coll}}] * f_{\text{Coll}} \} / 3$
 - Apply factor: $f_{\text{shadow}} = N_{\text{shadow}} / f_{\text{Coll}} \sim 0.92$
- # of photons: $N_0 = E_{\text{dep}} * \text{PhotPerMeV.fgd} * f_{\text{shadow}}$

Full simulation of SuperFGD

- Light attenuation in the fiber: # of photons at fiber end

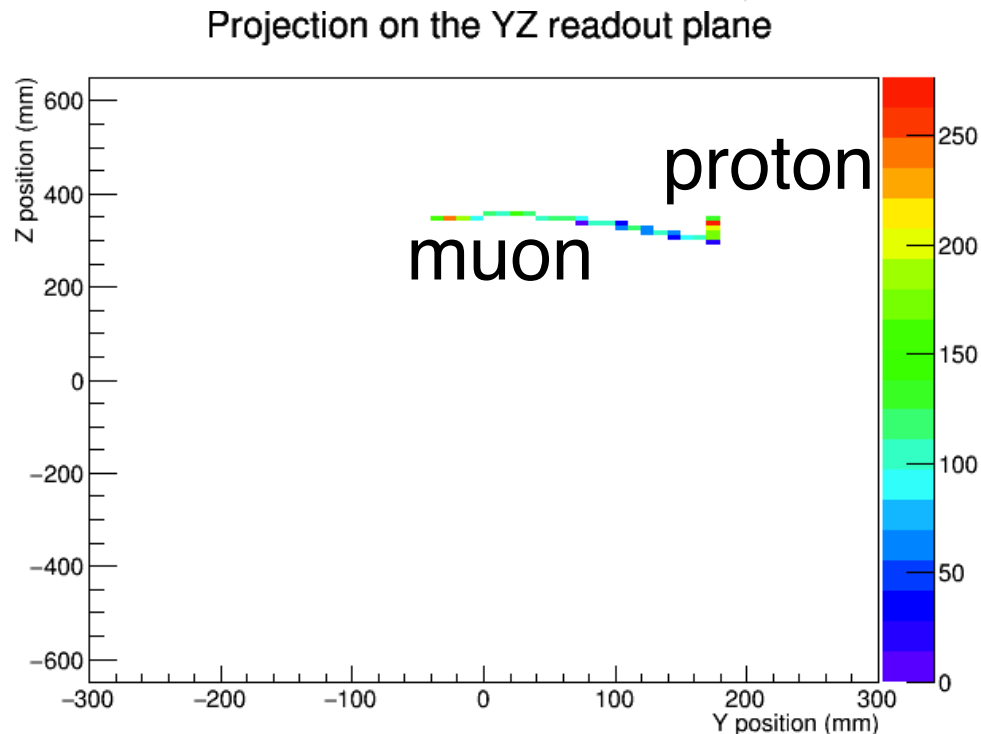
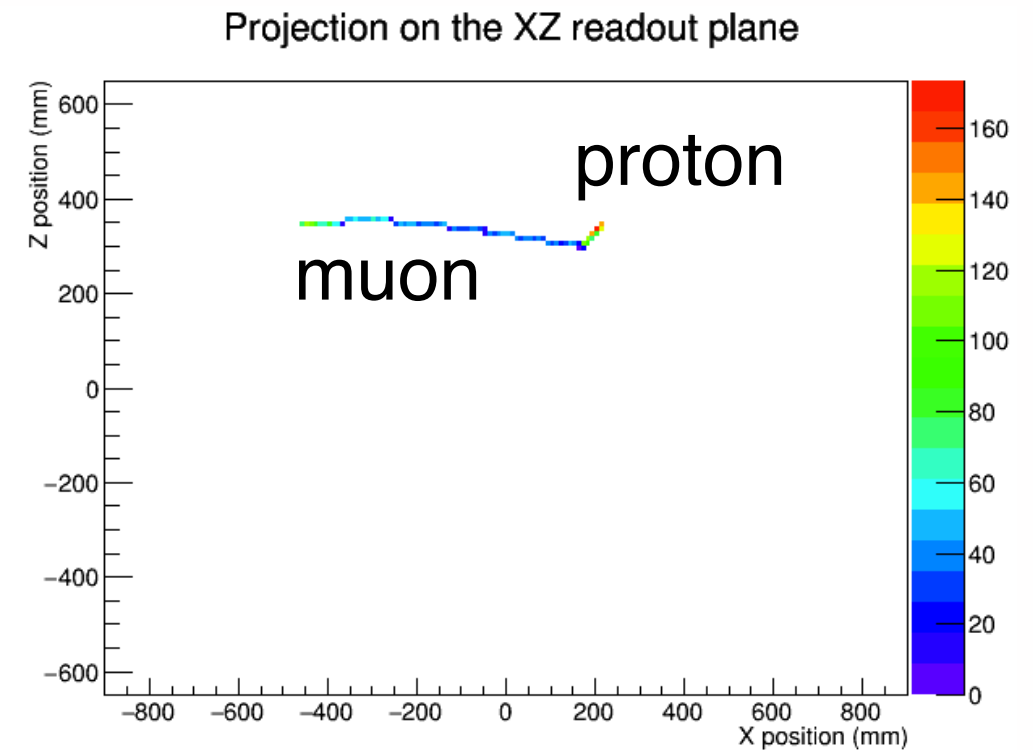
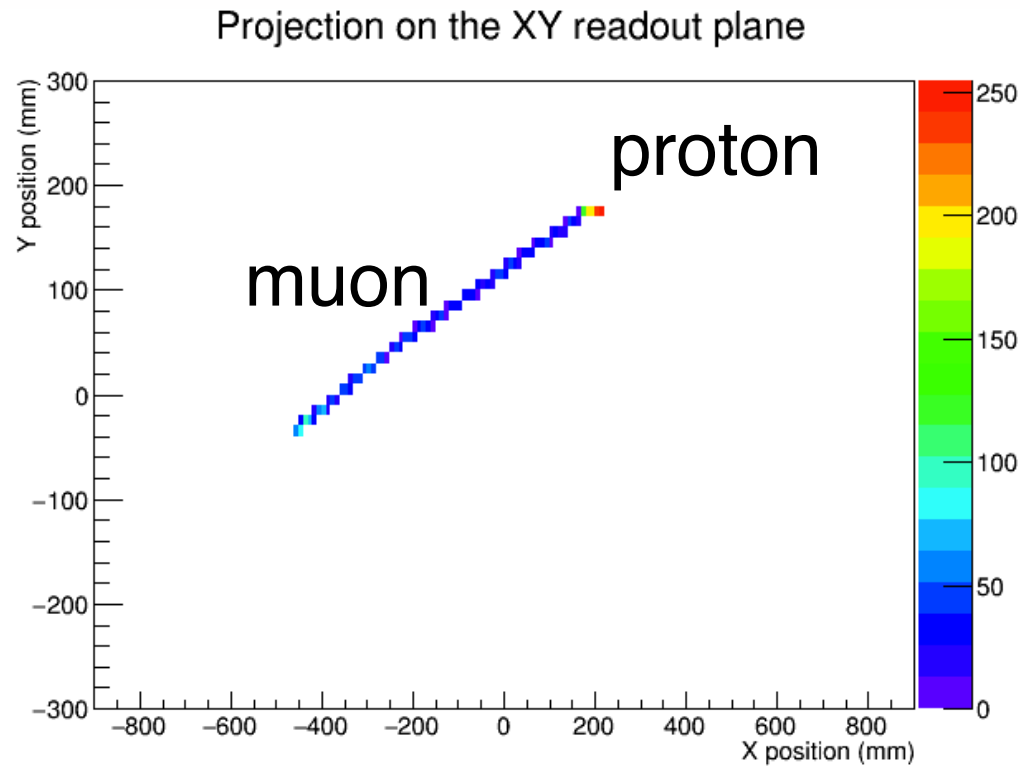
$$N(x) = N_0 \left(a e^{(-x-d)/L} + (1-a) e^{(-x-d)/S} \right) \left(1 - \frac{1}{2} (e^{-mx} + e^{-m(L-x)}) \right)$$

*End-of-fiber
effects are not
taken into account*

- d=41mm (distance end-of-fiber - MPPC) --> keep the same value as for FGD
- It could vary for different target technologies but should be almost negligible
- The read-out electronic is not simulated as in nd280-elecsim
- Assume 38% photon --> p.e. efficiency of newest MPPC --> obtain # of p.e.
- Also timing at the end of the fiber is computed
 - use same code as in WAGASCI stand-alone one
 - `time@MPPC = TransTimeInFiber * IXstep - XMPPCI`
 - `const G4double TransTimeInFiber = 1./28.; // 1cm/2.8e10[cm/s] * 1e9 [ns]`

Example of neutrino event

- From SuperFGD you can get all the 2D projections (Z is # of p.e.)
 - each bin corresponds to a different MPPC
 - only primary tracks, true CCQE



- # of p.e. at the 3 projections (end-of-fibers) must be consistent
- Validation: # of p.e. per step w/o attenuation must be identical for all projections --> OK!!!

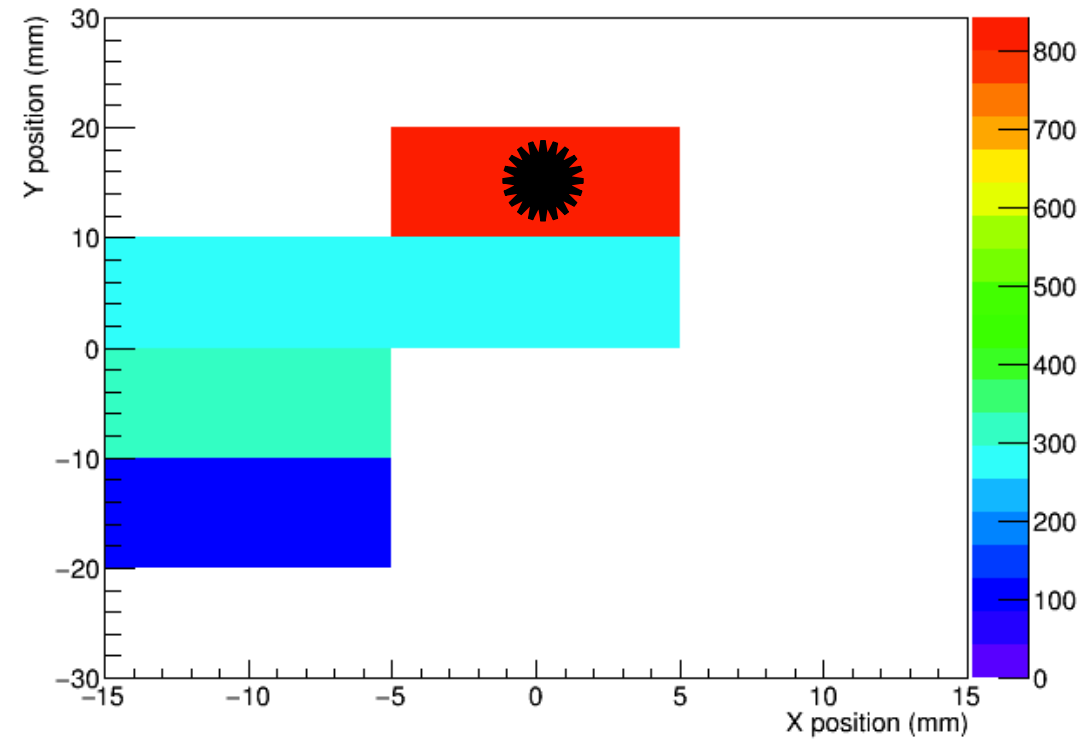
☼ beam

Particle guns: Muon

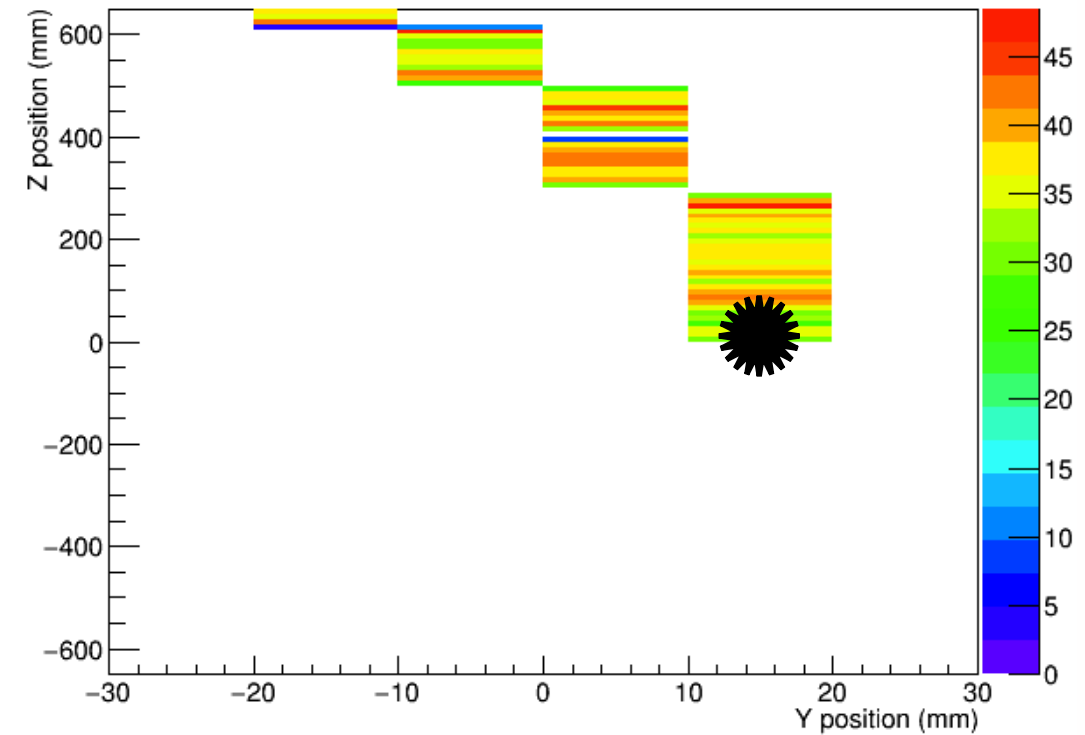
Muon, $E_{\text{kin}}=400\text{MeV}$
Pos(0,0,0), Dir(0,0,1)

- Along Z: 3x6x130 cubes (1cm^3)

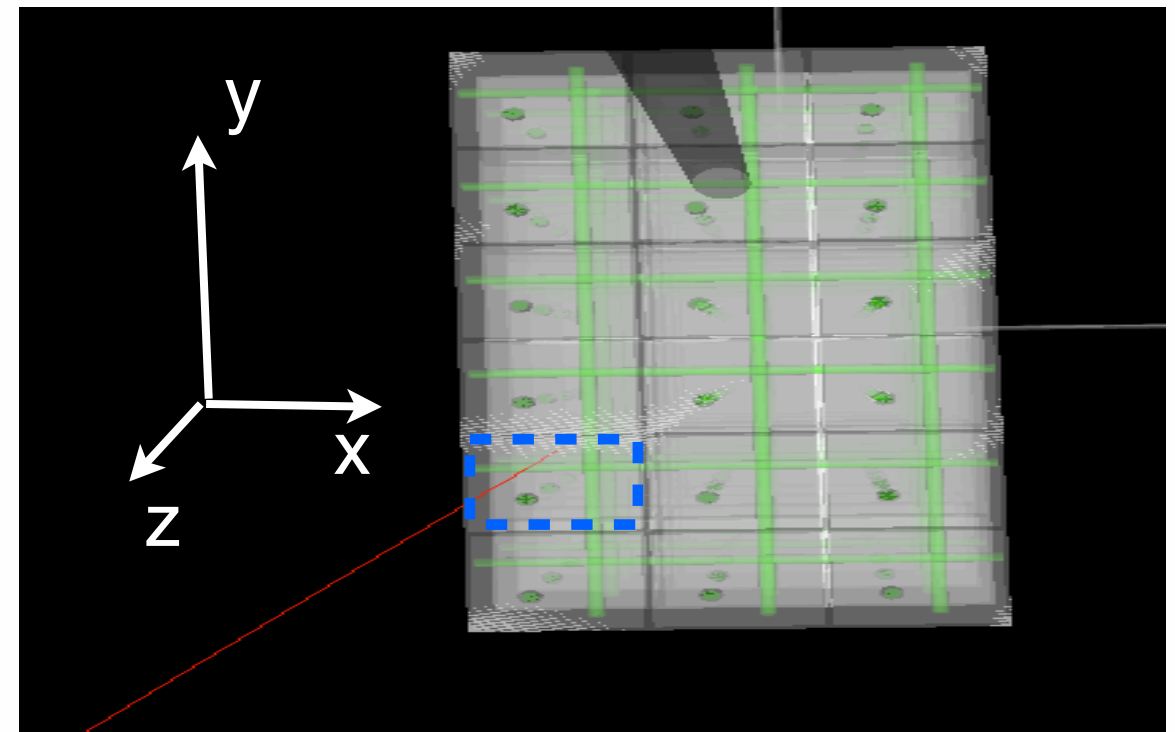
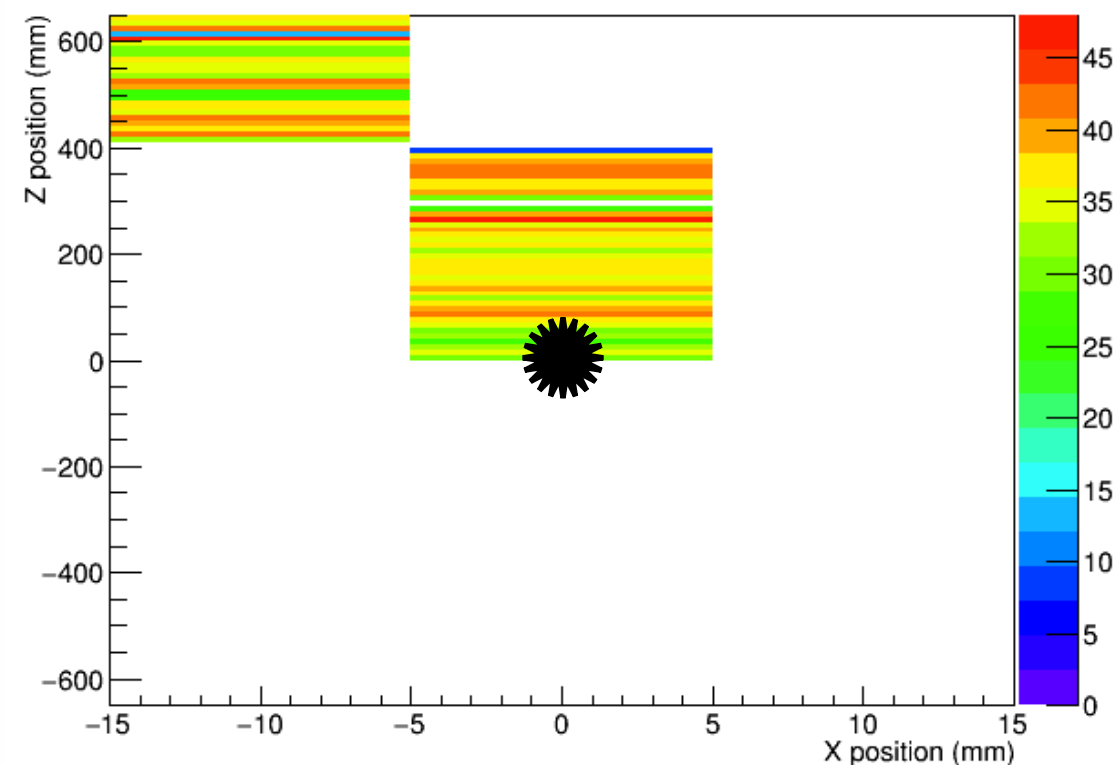
Projection on the XY readout plane



Projection on the YZ readout plane



Projection on the XZ readout plane



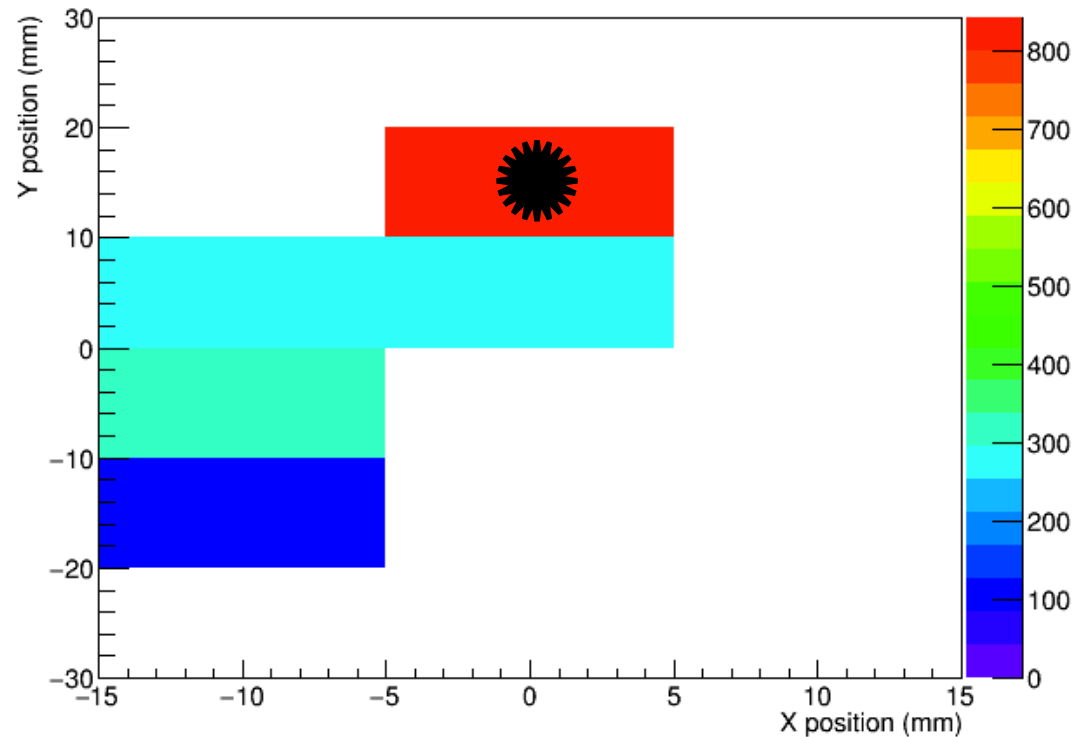
☼ beam

Particle guns: Muon

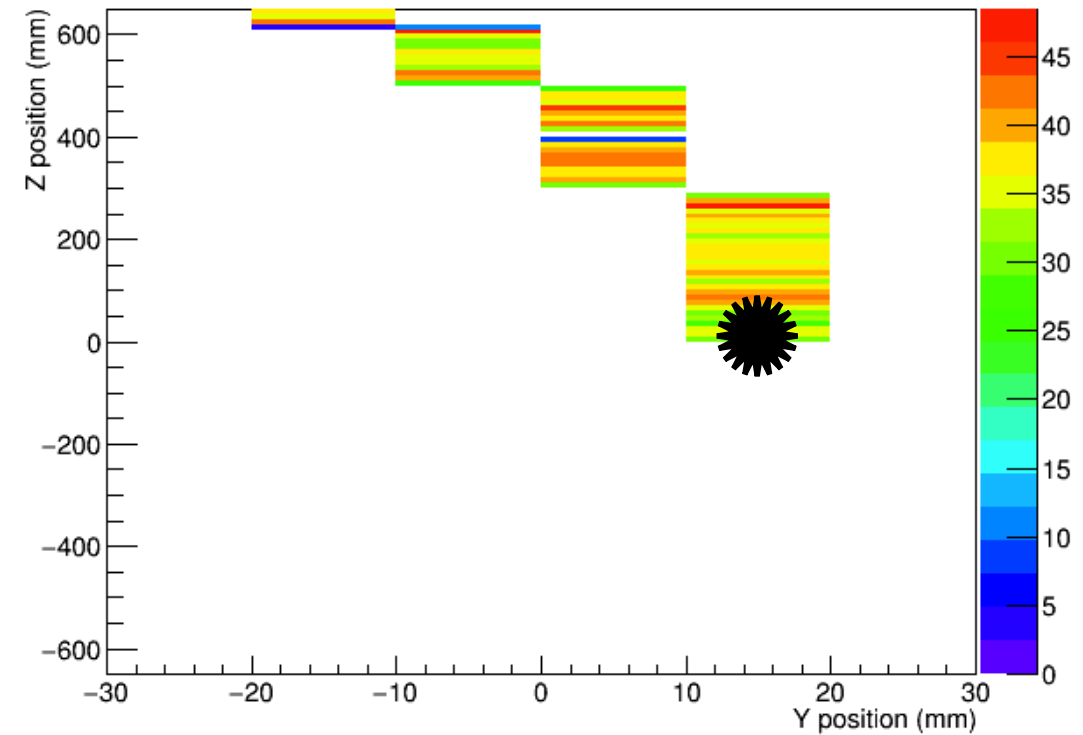
Muon, $E_{\text{kin}}=400\text{MeV}$
Pos(0,0,0), Dir(0,0,1)

- Along Z: 3x6x130 cubes (1cm^3)

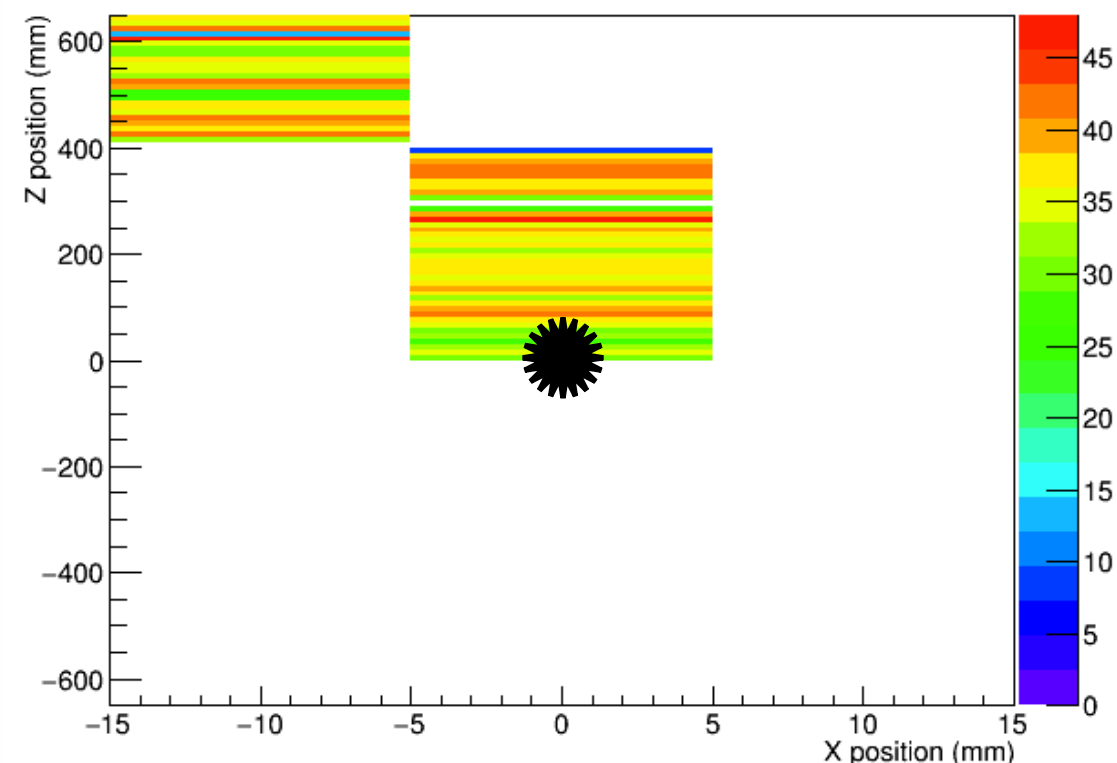
Projection on the XY readout plane



Projection on the YZ readout plane



Projection on the XZ readout plane



- The beam doesn't start from (0,0,0) in Target frame because the Basket is shifted by -16mm wrt World --> OK!!!
- Few hits are missing: coating, fibers,...
- # of p.e. / cm (MIP) $\sim 35\text{-}40$ p.e. / fiber
- FGD: # of p.e. / cm (MIP) $\sim 16\text{-}18$ / fiber (NIM)
- Better by about x2 (coming from MPPC eff)
- But we have 3 fibers / cm^3 --> ~ 100 p.e. / cm

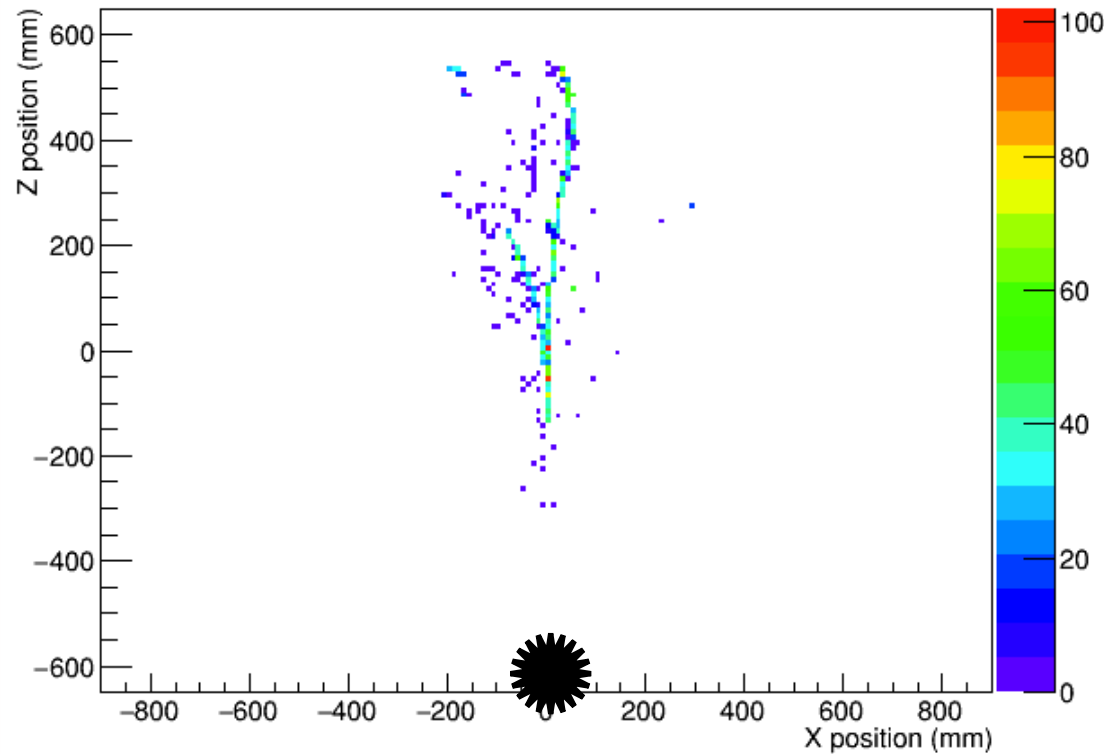
☀ beam

Particle guns: Gamma

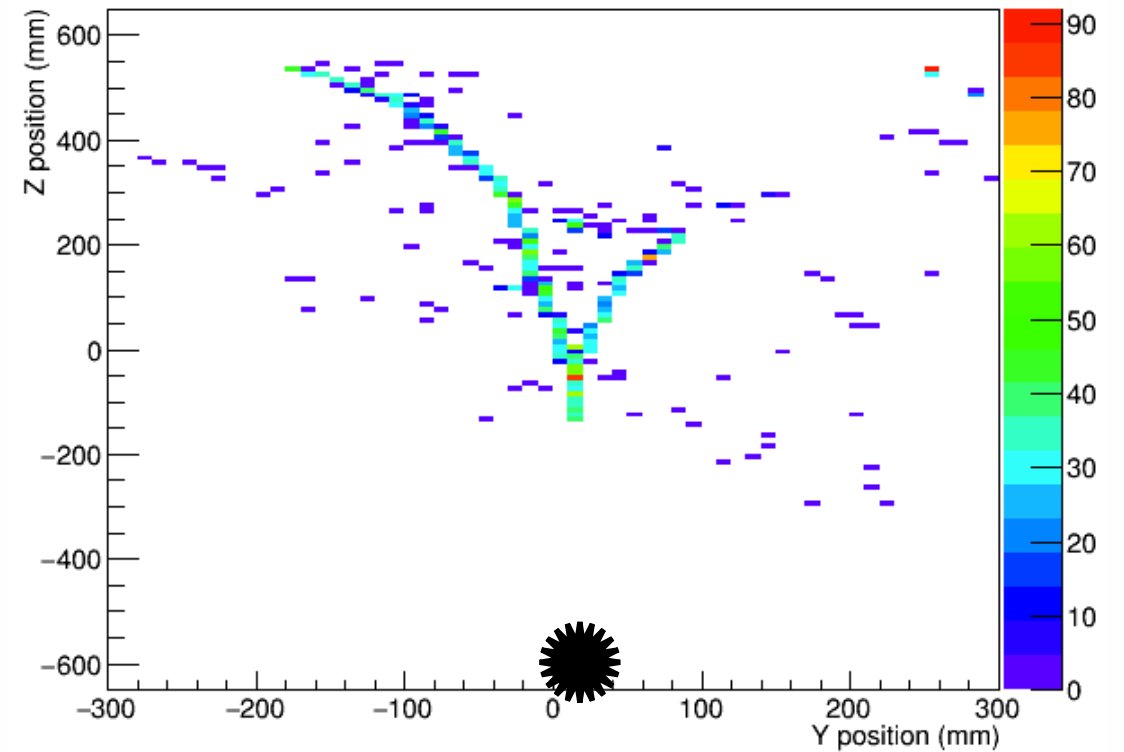
Gamma, $E_{\text{kin}}=400\text{MeV}$
Pos(0,0,-600), Dir(0,0,1)

- 180x60x130 cubes (1cm^3)

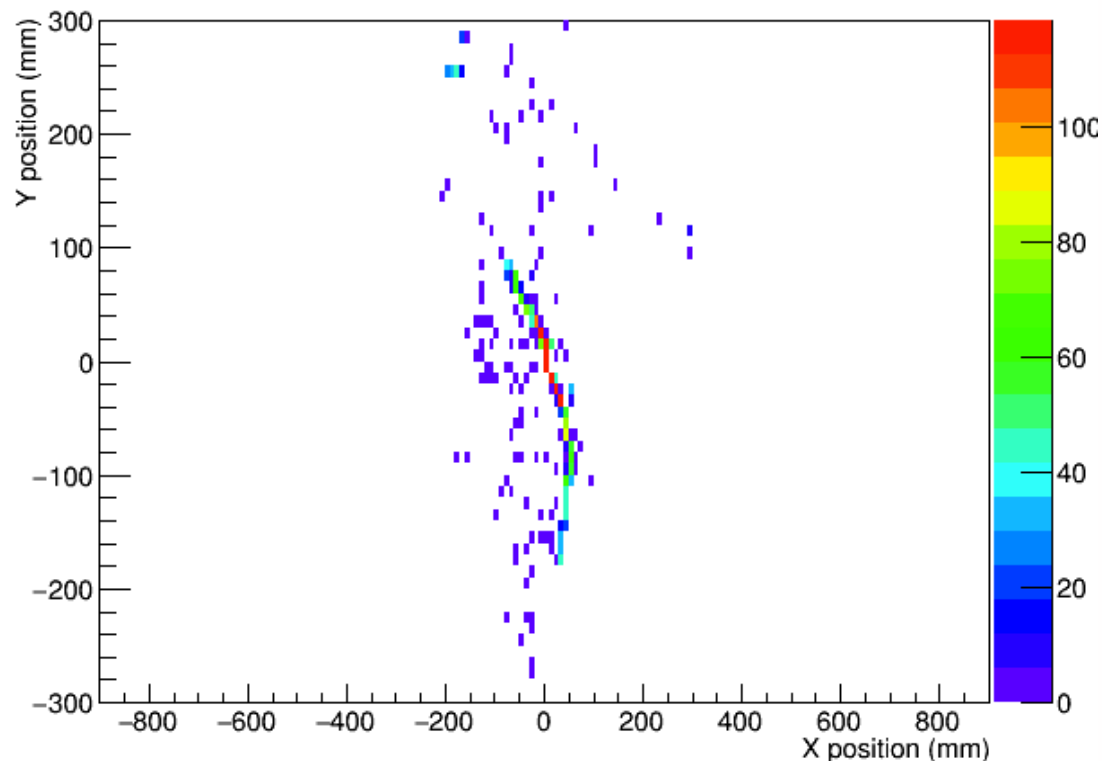
Projection on the XZ readout plane



Projection on the YZ readout plane



Projection on the XY readout plane



- Very clear event display
- Gamma is well detected inside the target and visible in all the projections
- both e^+ and e^- are stopping in the target

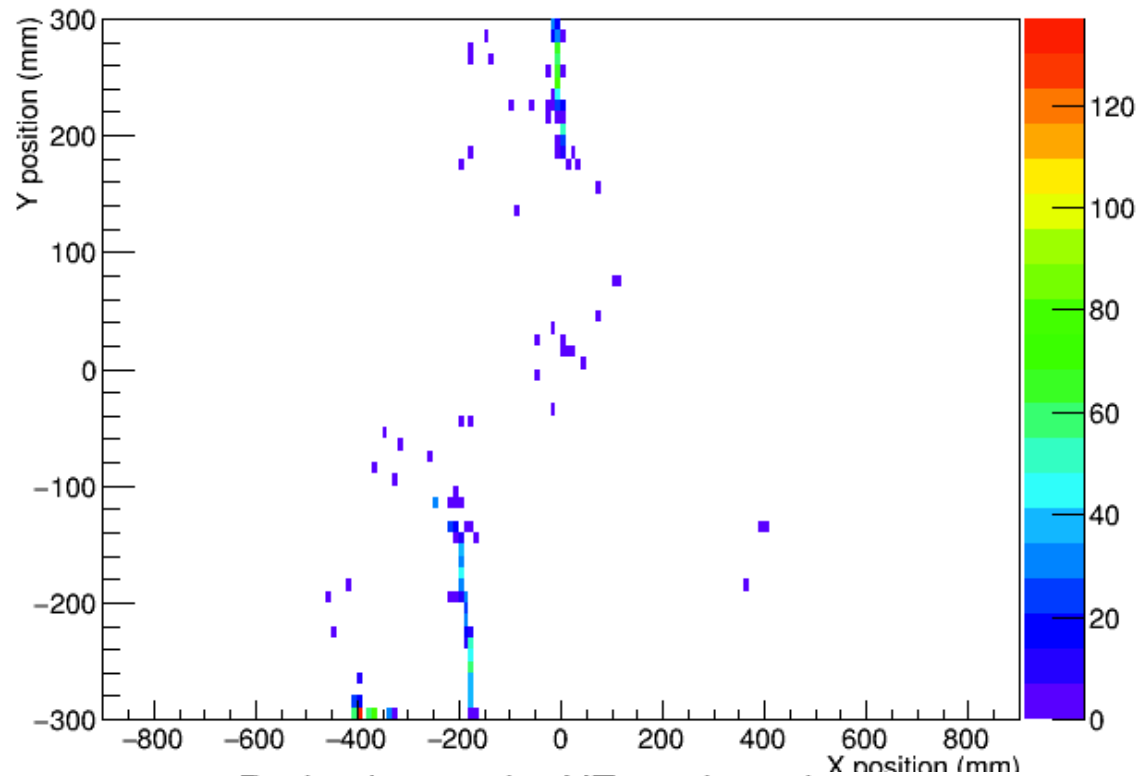
Particle gun: Gamma converted at the edge

Gamma, $E_{\text{kin}}=400\text{MeV}$

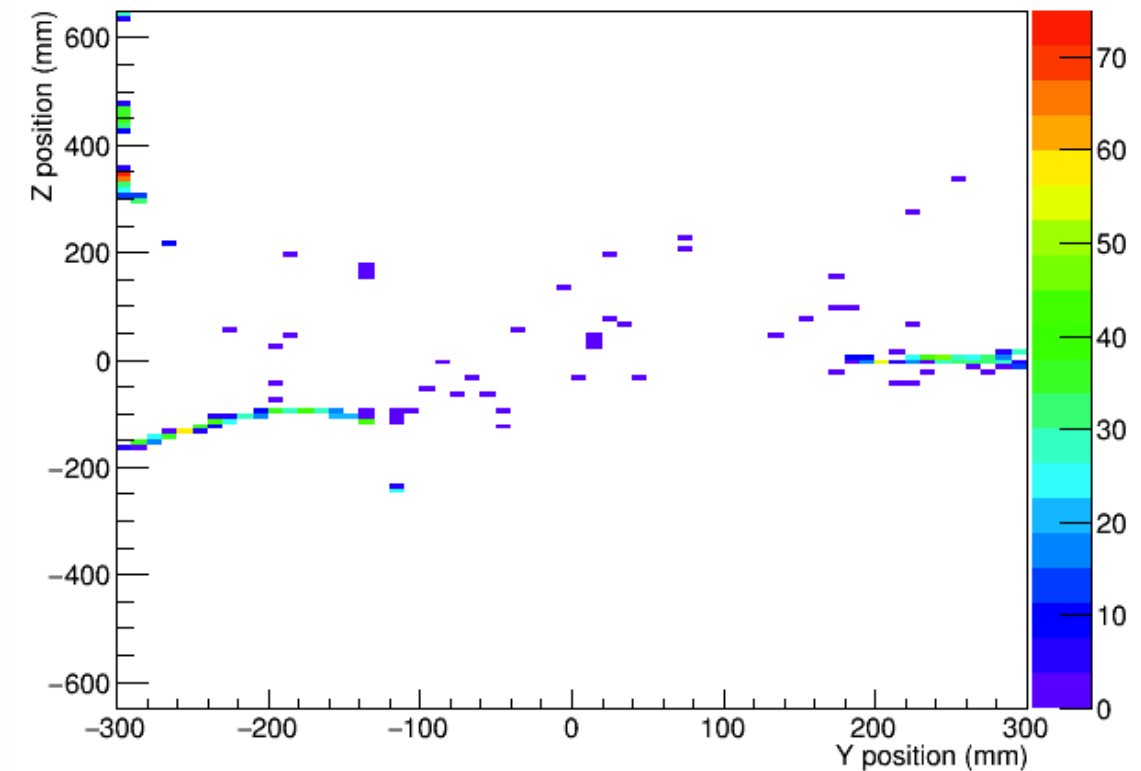
Pos(0,-300,0), Dir(0,1,0)

- 180x60x130 cubes (1cm^3)

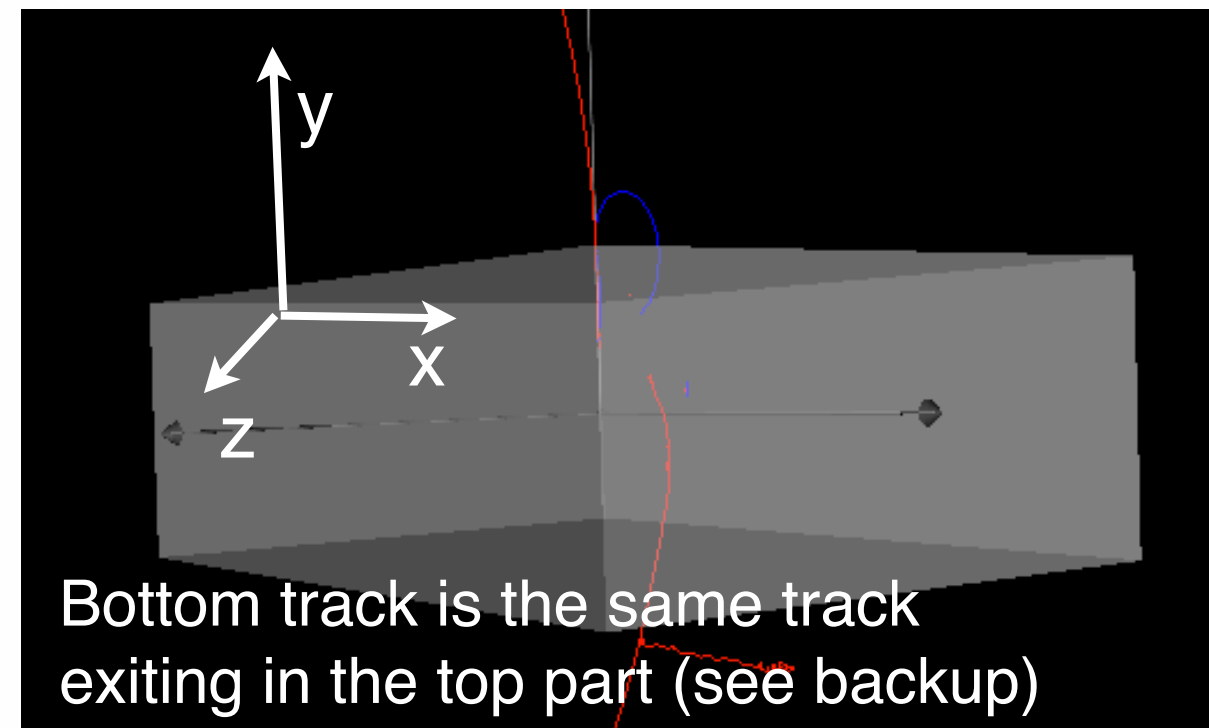
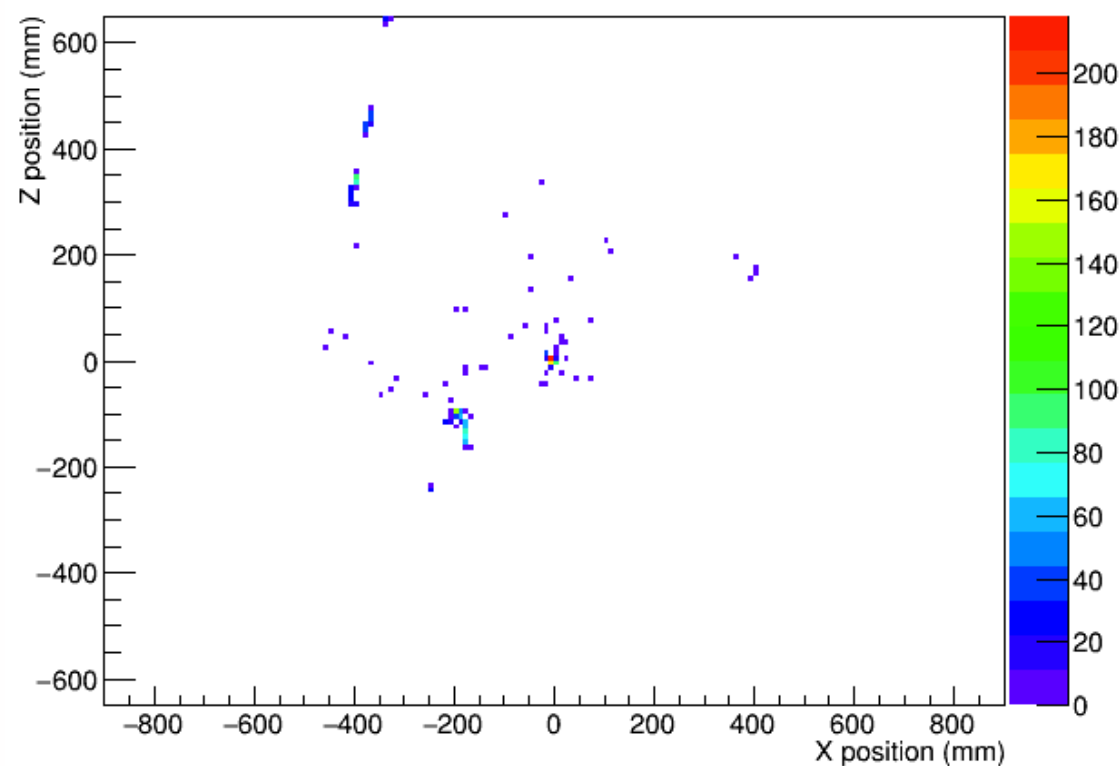
Projection on the XY readout plane



Projection on the YZ readout plane



Projection on the XZ readout plane

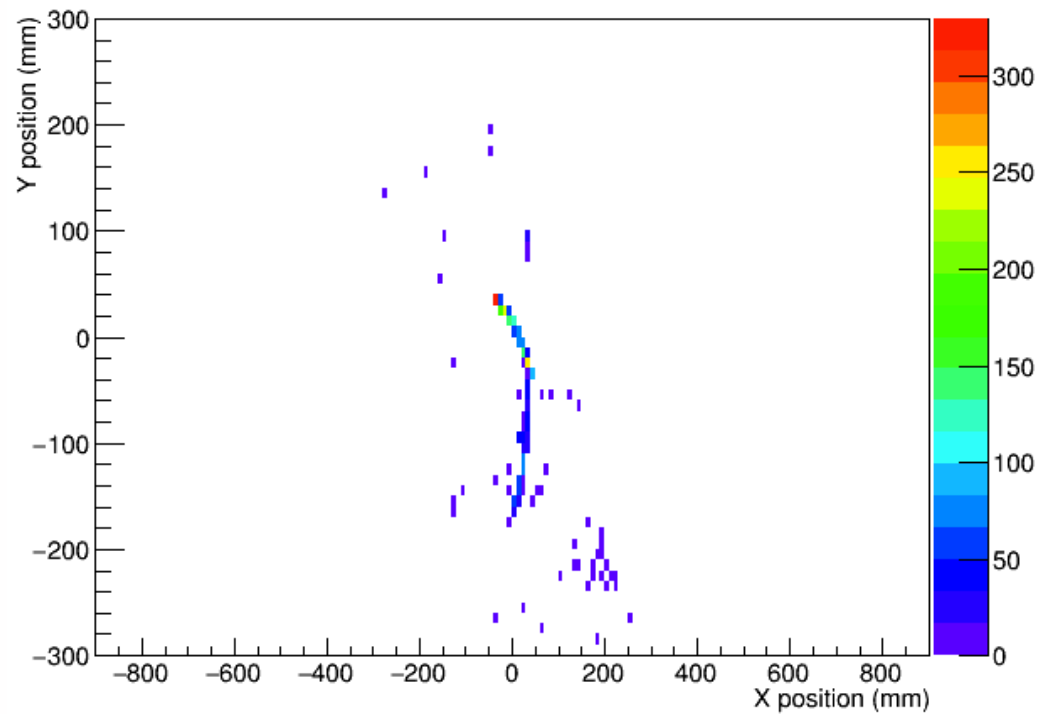


Particle gun: $\pi^+ \rightarrow \text{Michel } e^+$

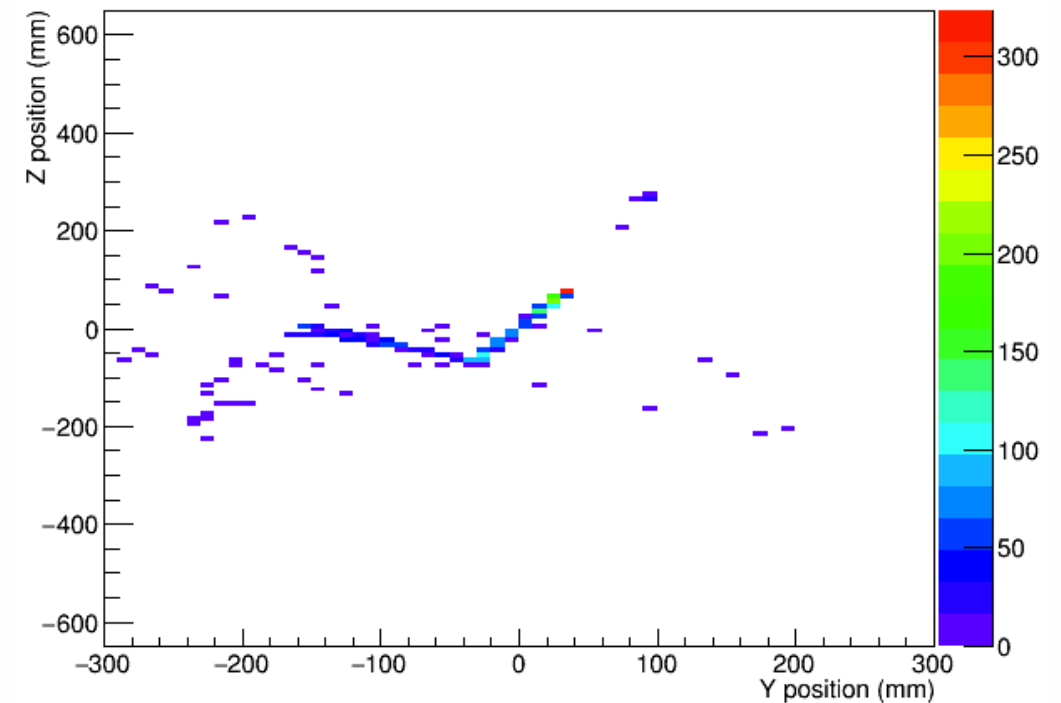
- 180x60x130 cubes (1cm^3)

π^+ , $E_{\text{kin}}=200\text{MeV}$
 $\text{Pos}(0,0,0)$, $\text{Dir}(0,0,1)$

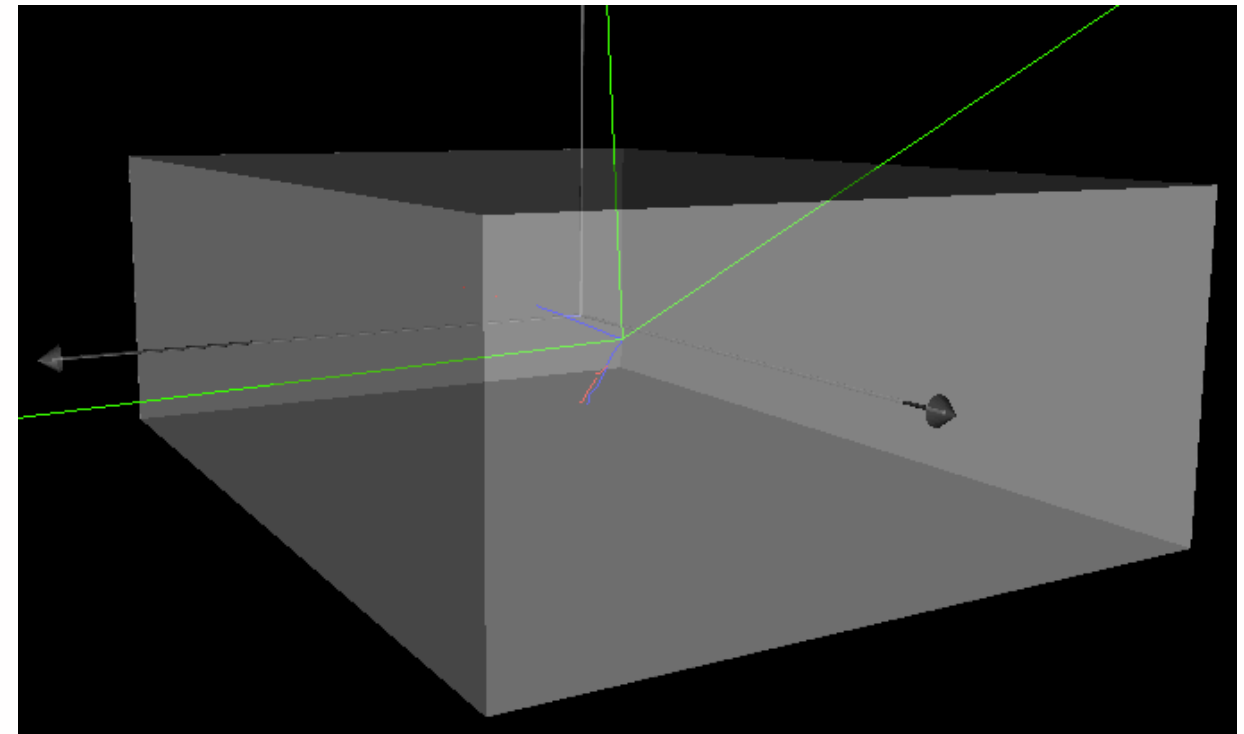
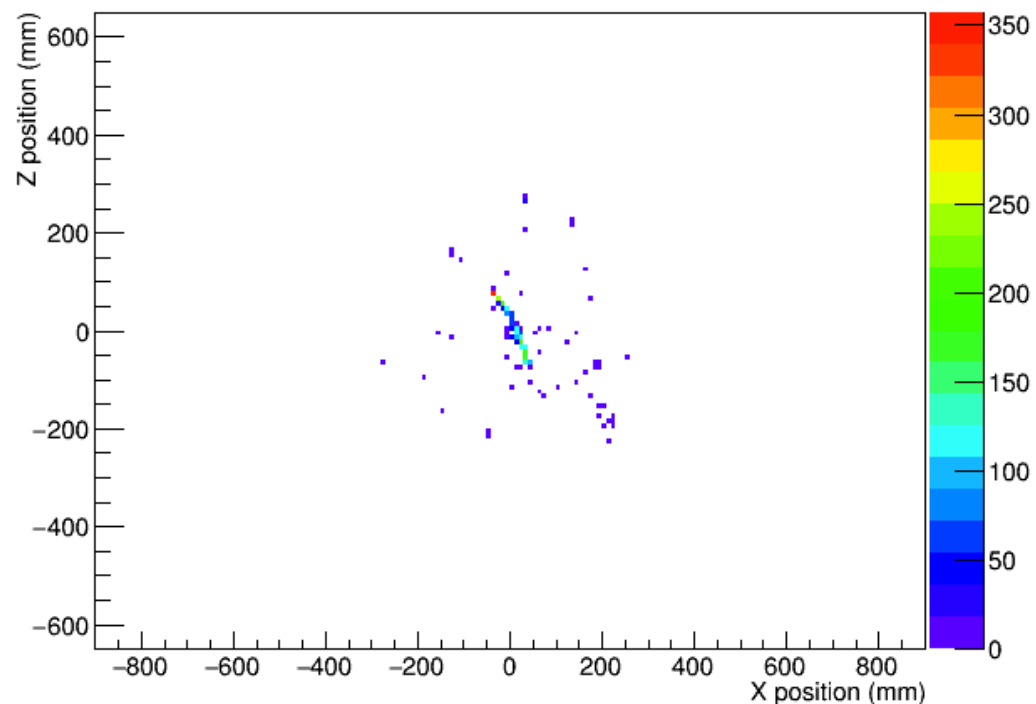
Projection on the XY readout plane



Projection on the YZ readout plane



Projection on the XZ readout plane

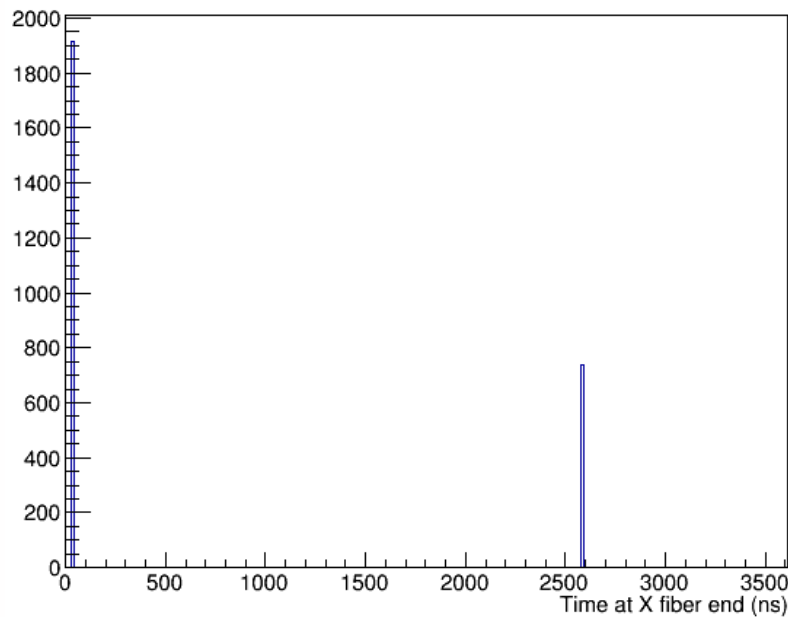


Particle gun: $\pi^+ \rightarrow \text{Michel } e^+$

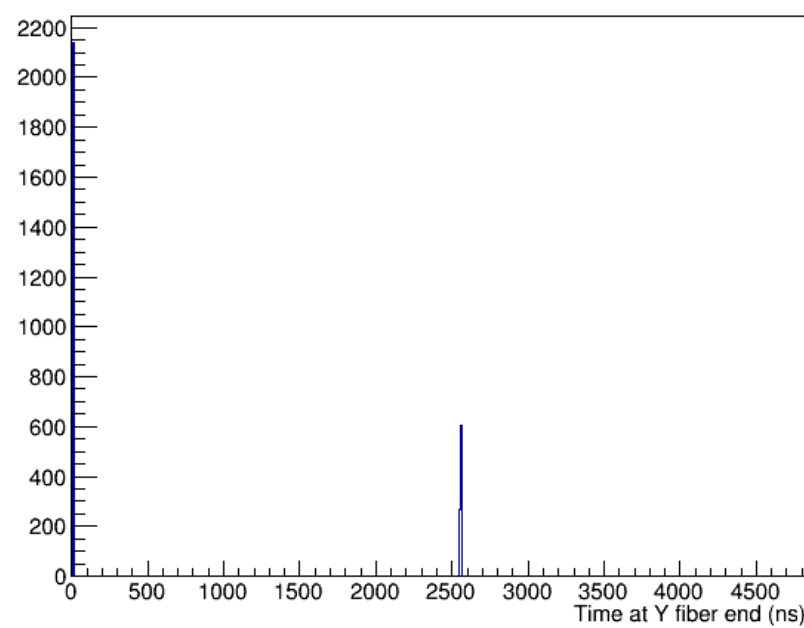
- 180x60x130 cubes (1cm^3)
- Measure the # of p.e. Vs time in MPPC (top)
- MPPC hit 2D position Vs time (bottom)

π^+ , $E_{\text{kin}}=200\text{MeV}$
 $\text{Pos}(0,0,0)$, $\text{Dir}(0,0,1)$

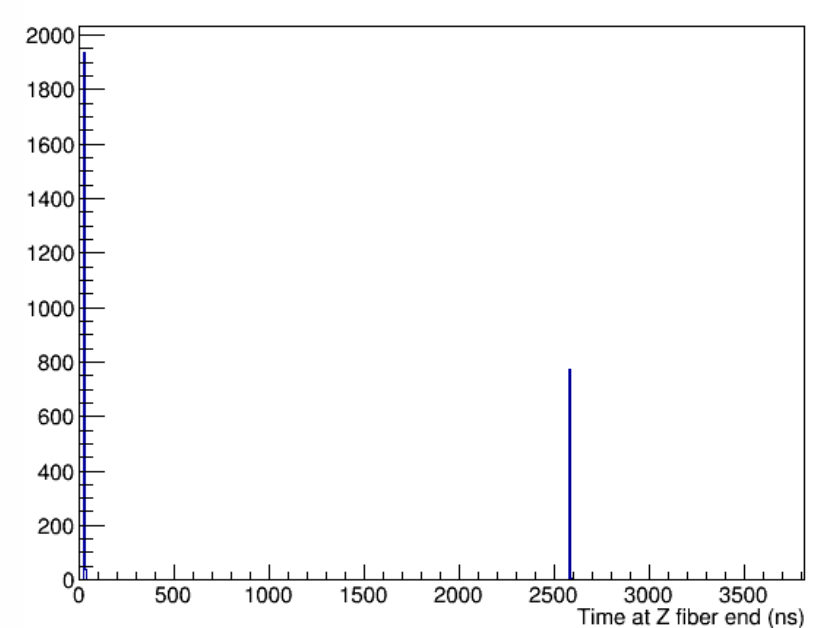
Time at end of X fiber



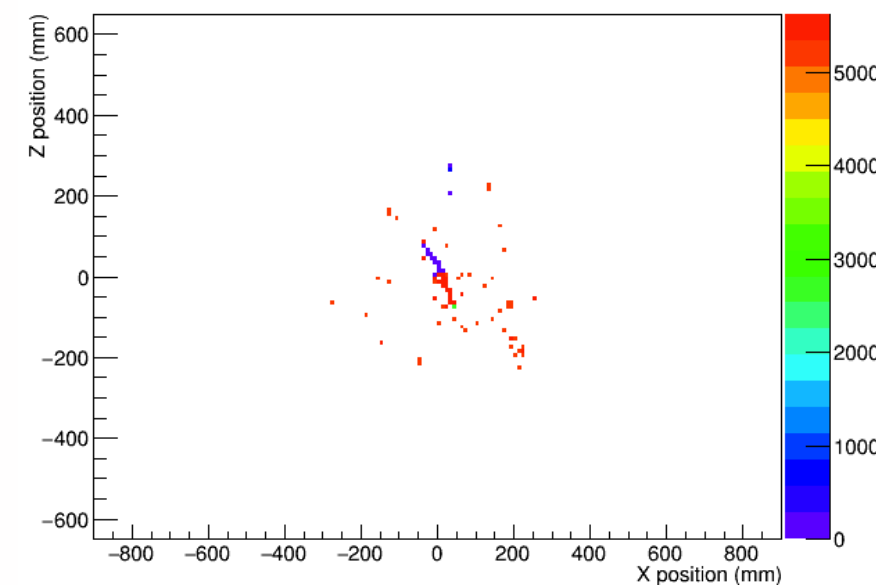
Time at end of Y fiber



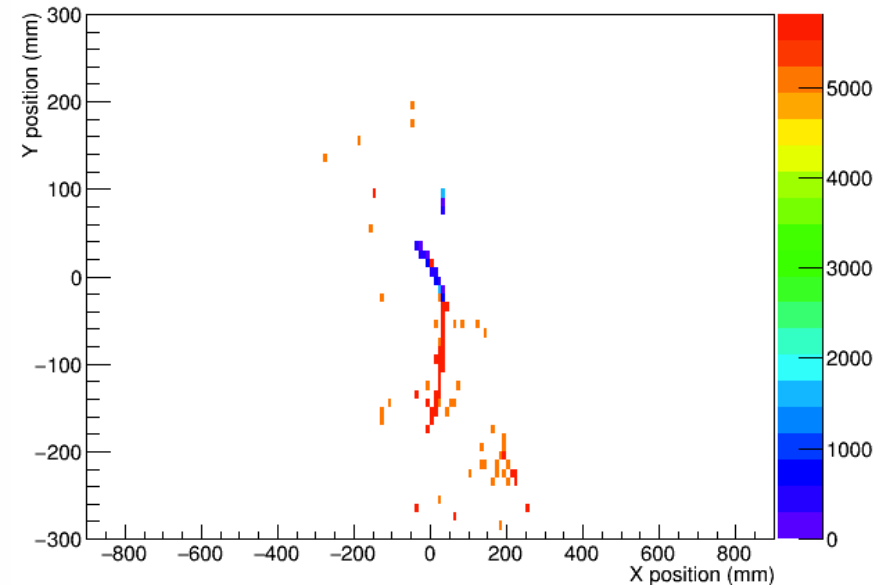
Time at end of Z fiber



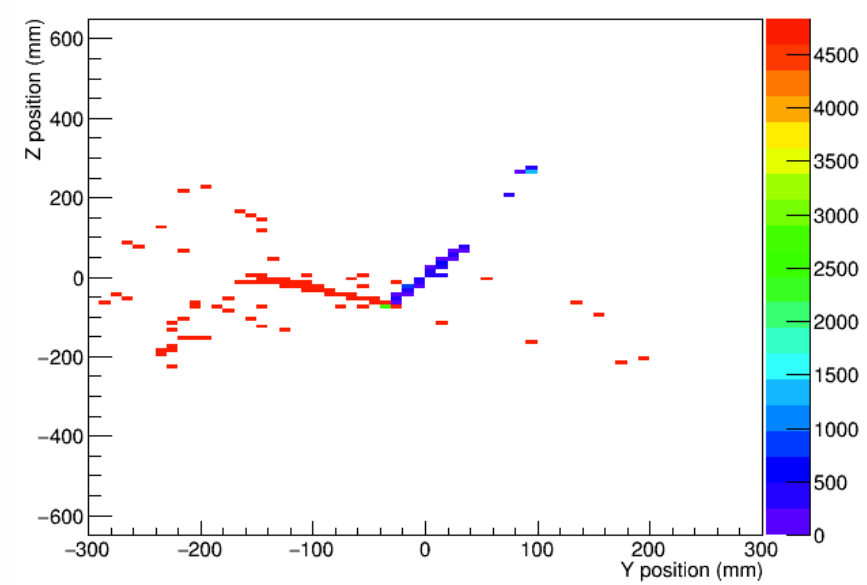
Projection on the XZ readout plane Vs Time



Projection on the XY readout plane Vs Time



Projection on the YZ readout plane Vs Time



- Clear signal of Michel electron
- Lot of stuffs at $t > 5-10 \mu\text{s}$ --> to check...

Conclusions

- Done a full simulation of SuperFGD and will work soon on reconstruction (tracking, PID)
- Working on simulation of other detectors for direct comparisons
- Already from event display we can see it may be a very powerful detector
- Need a small prototype to confirm our expectation:
 - 5x5x10 cm³ on a test beam?
 - test the fiber collection efficiency: should depends on the shape (smaller cube better efficiency?)
 - extract parameters to put into the simulation and obtain more reliable results
 - recycle material we already have? what can we already use?
- Cost should scale mostly with the # of channels (~40k): ~2-3M \$?
- Studies for mechanical constraint are needed if we try to avoid the gluing: may be integrated with the target “box” studies Franck is performing
- See backup for more event displays (particle guns)

BACKUP



beam

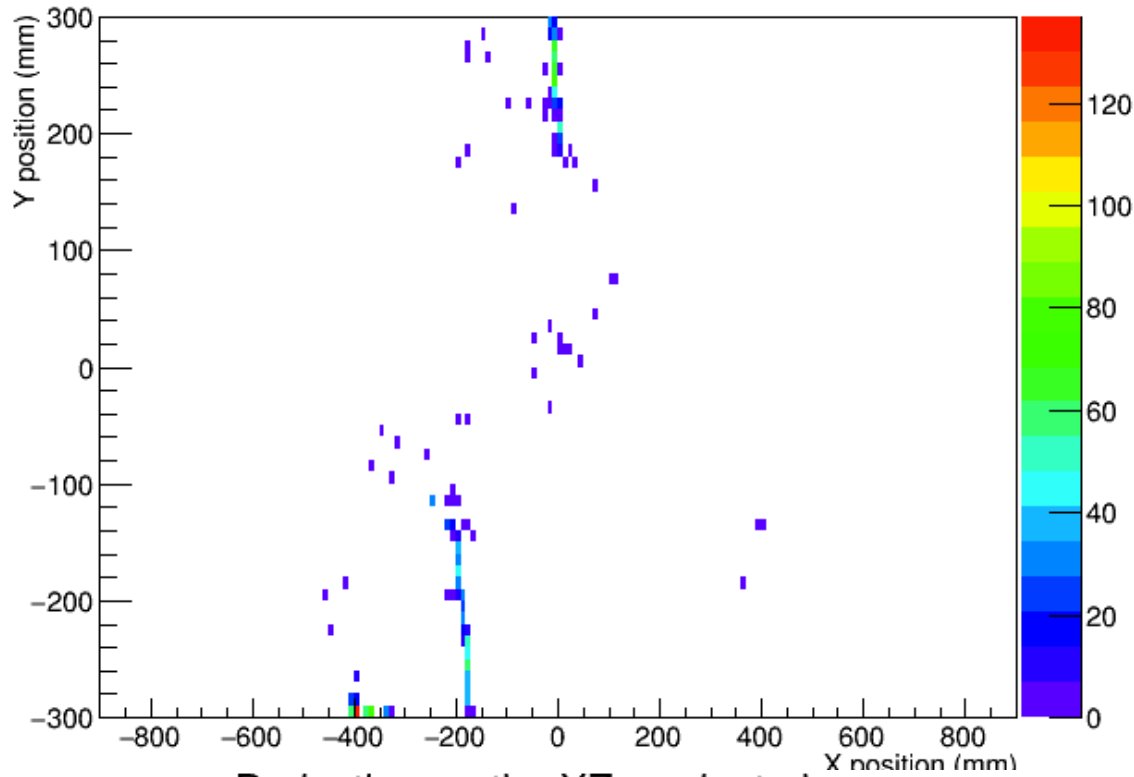
Validation III: particle guns (gamma)

Gamma, $E_{\text{kin}}=400\text{MeV}$

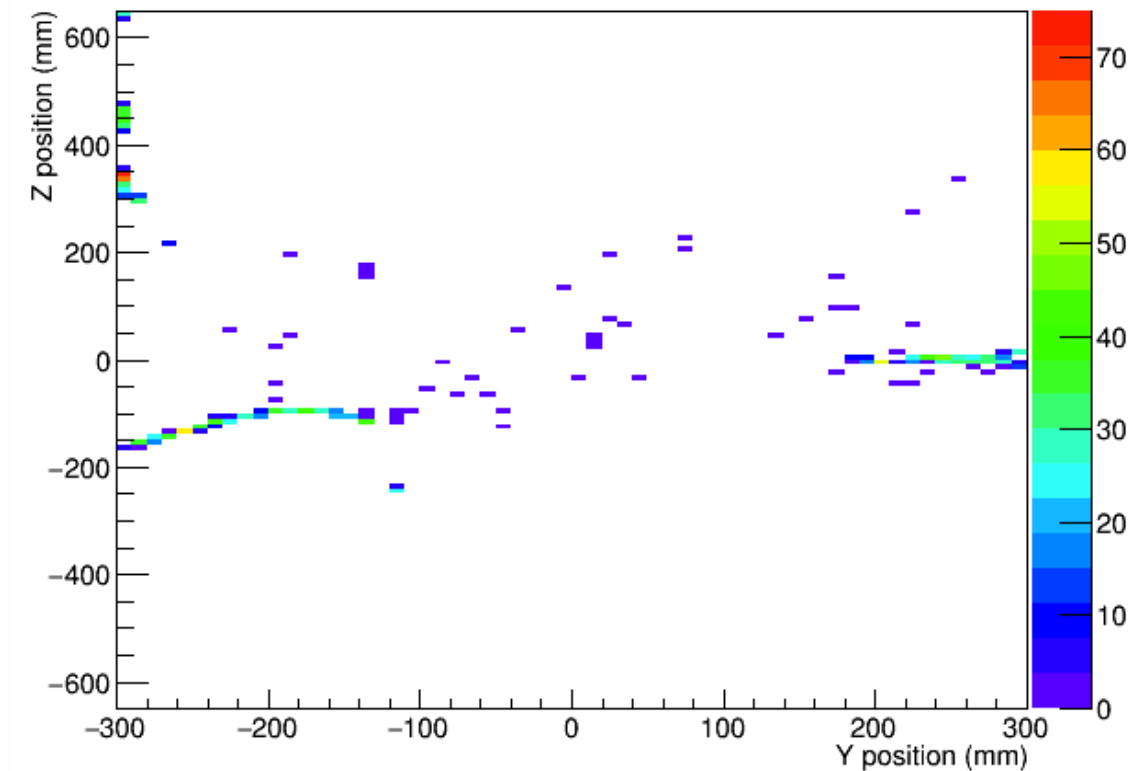
Pos(0,-300,0), Dir(0,1,0)

- Along Z: 3x6x130 cubes (1cm^3)

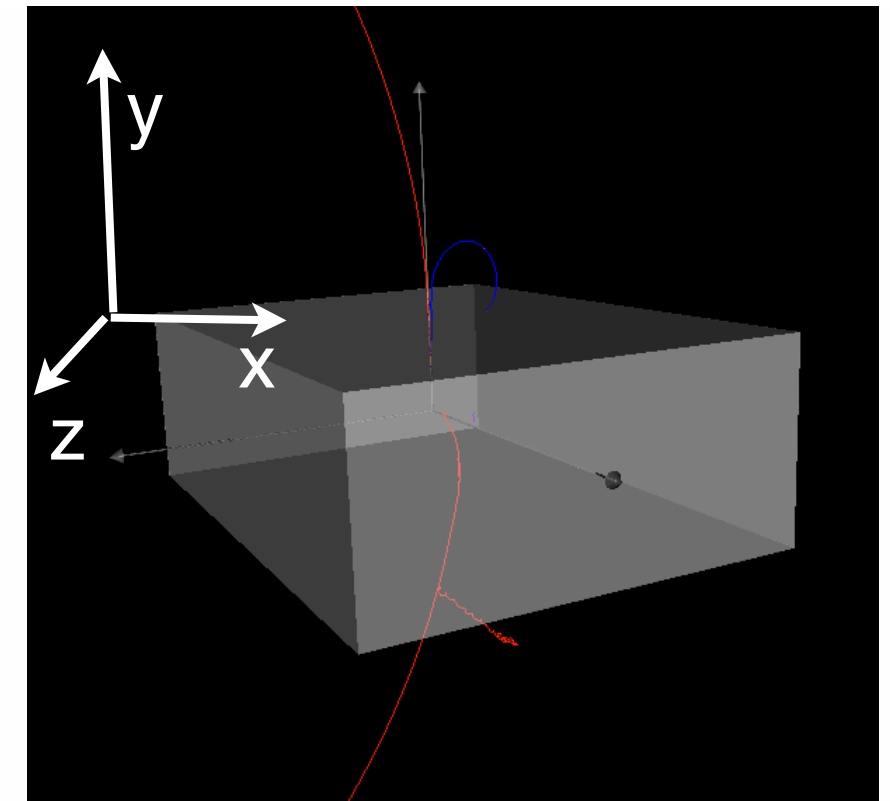
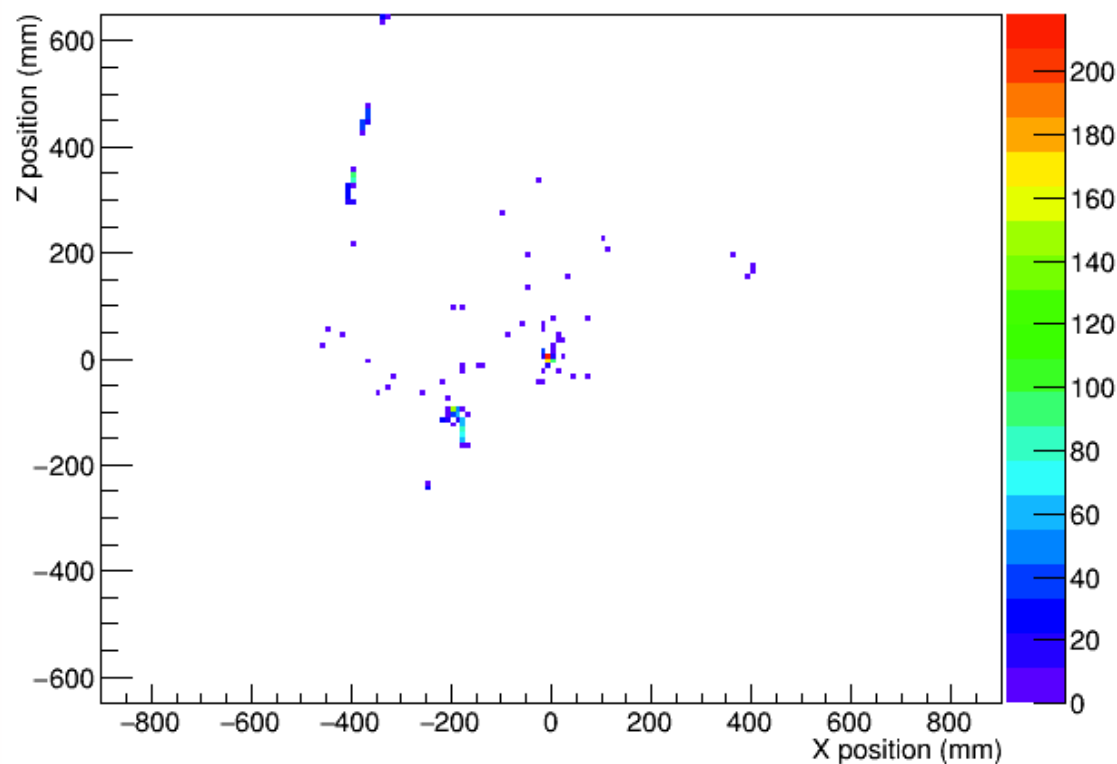
Projection on the XY readout plane



Projection on the YZ readout plane



Projection on the XZ readout plane





beam

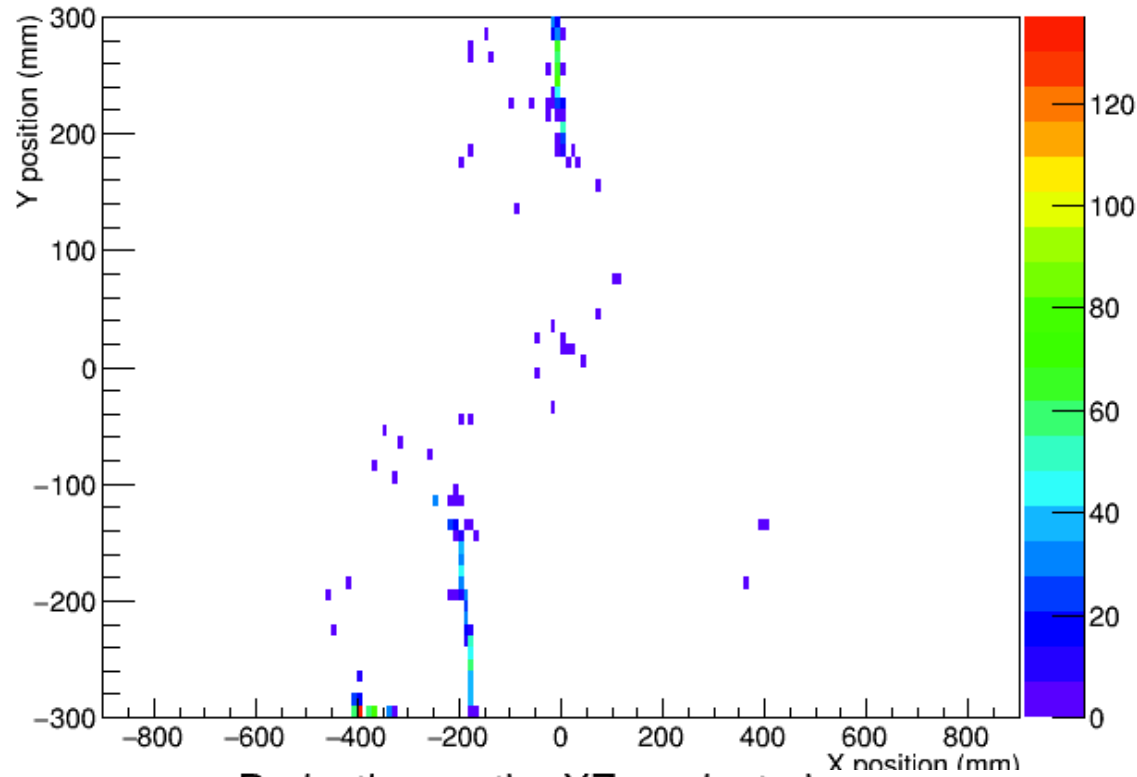
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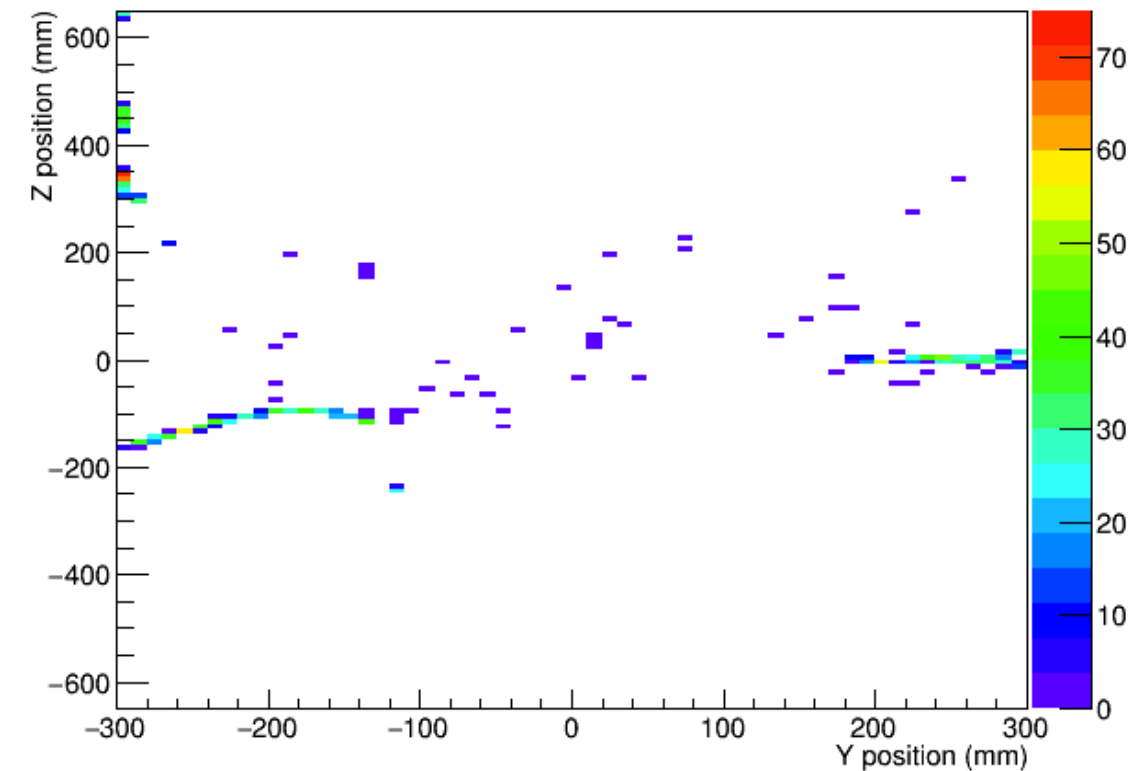
Pos(0,-300,0), Dir(0,1,0)

- Along Z: 3x6x130 cubes (1cm^3)

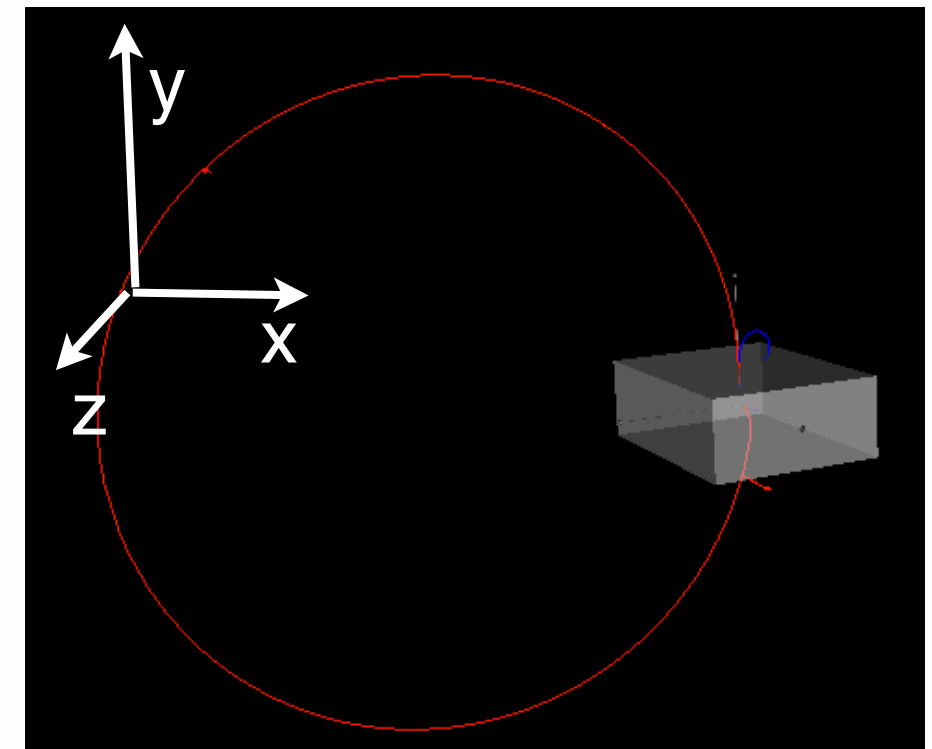
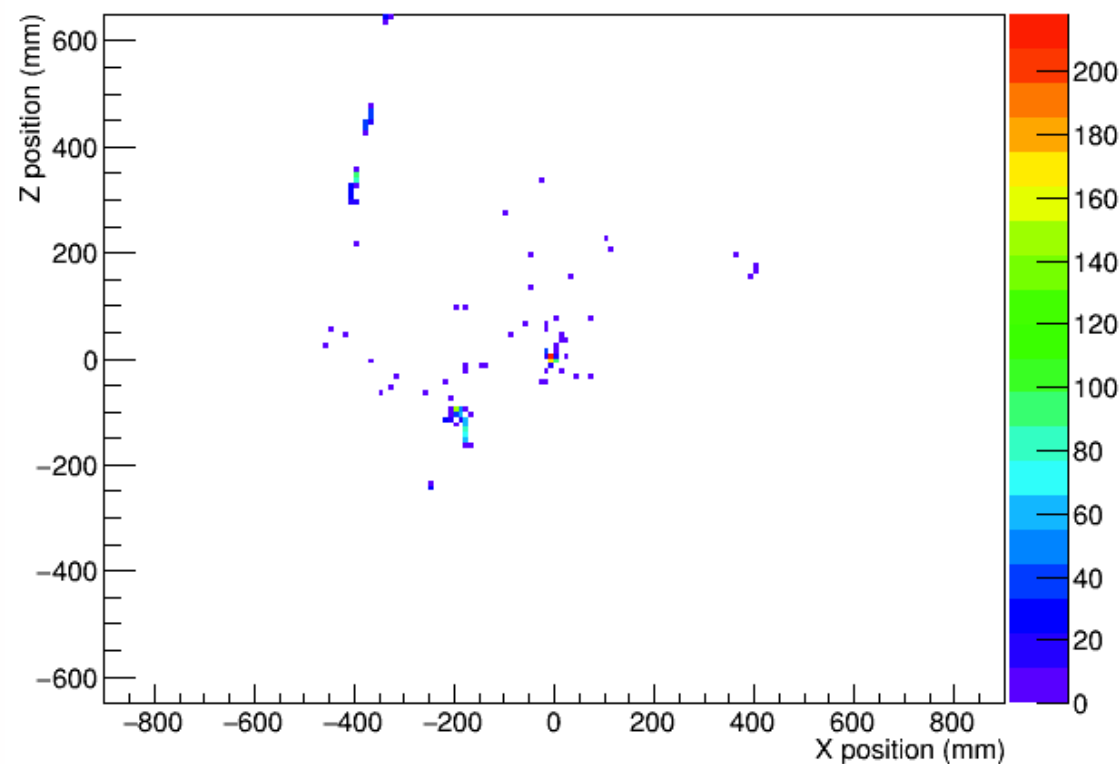
Projection on the XY readout plane



Projection on the YZ readout plane



Projection on the XZ readout plane





beam

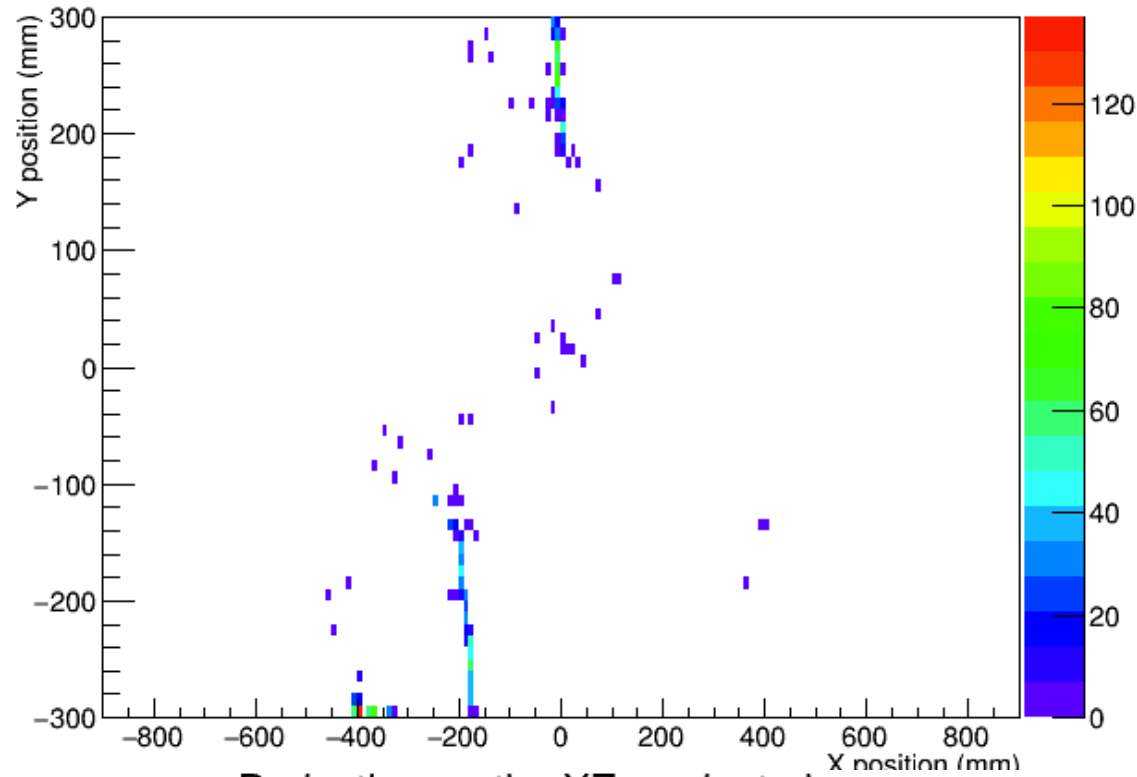
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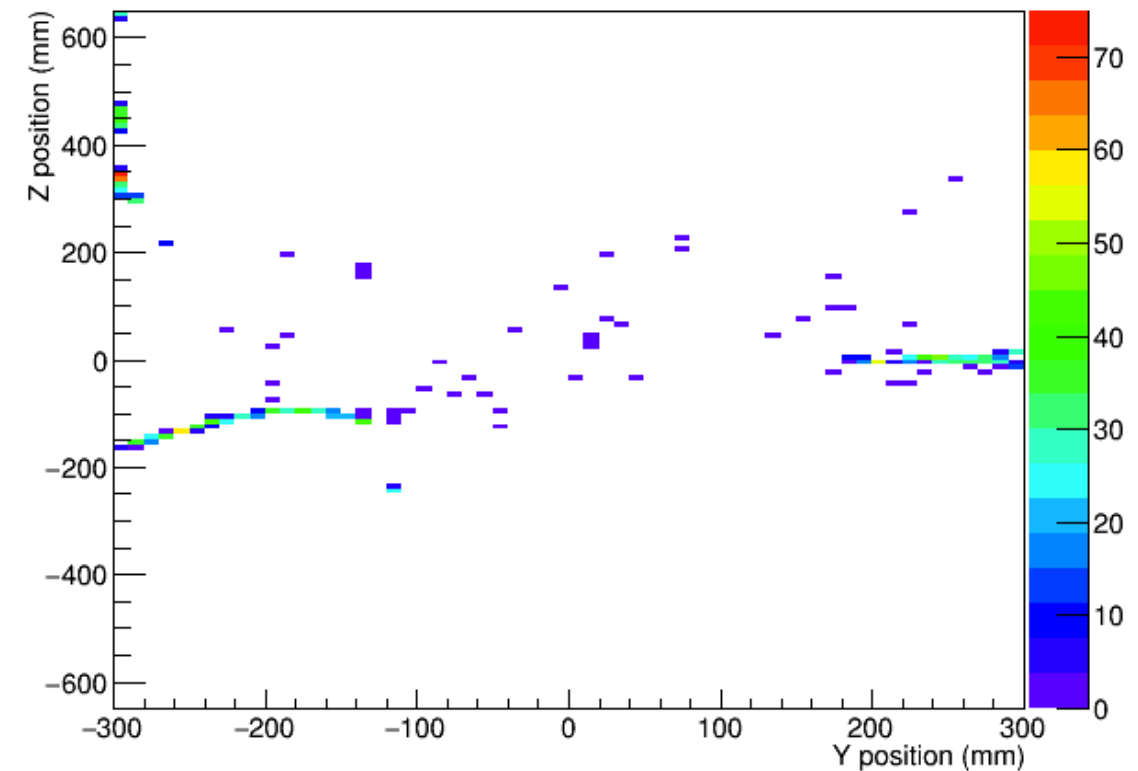
Pos(0,-300,0), Dir(0,1,0)

- Along Z: 3x6x130 cubes (1cm^3)

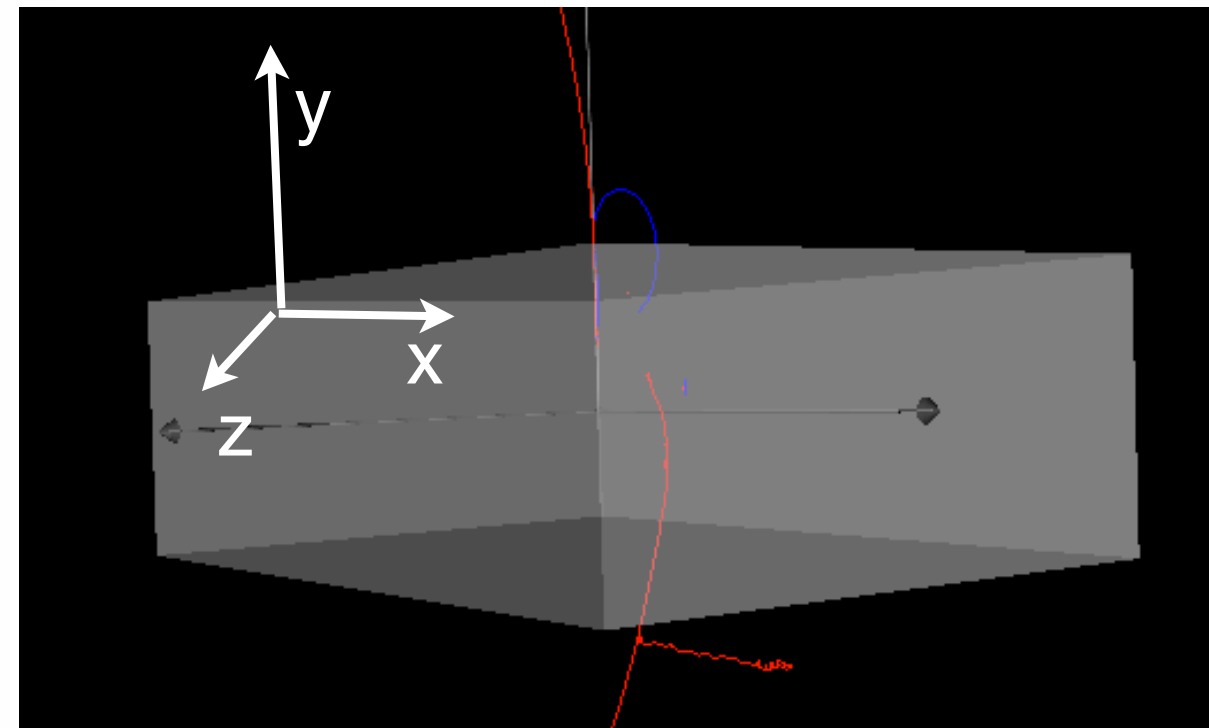
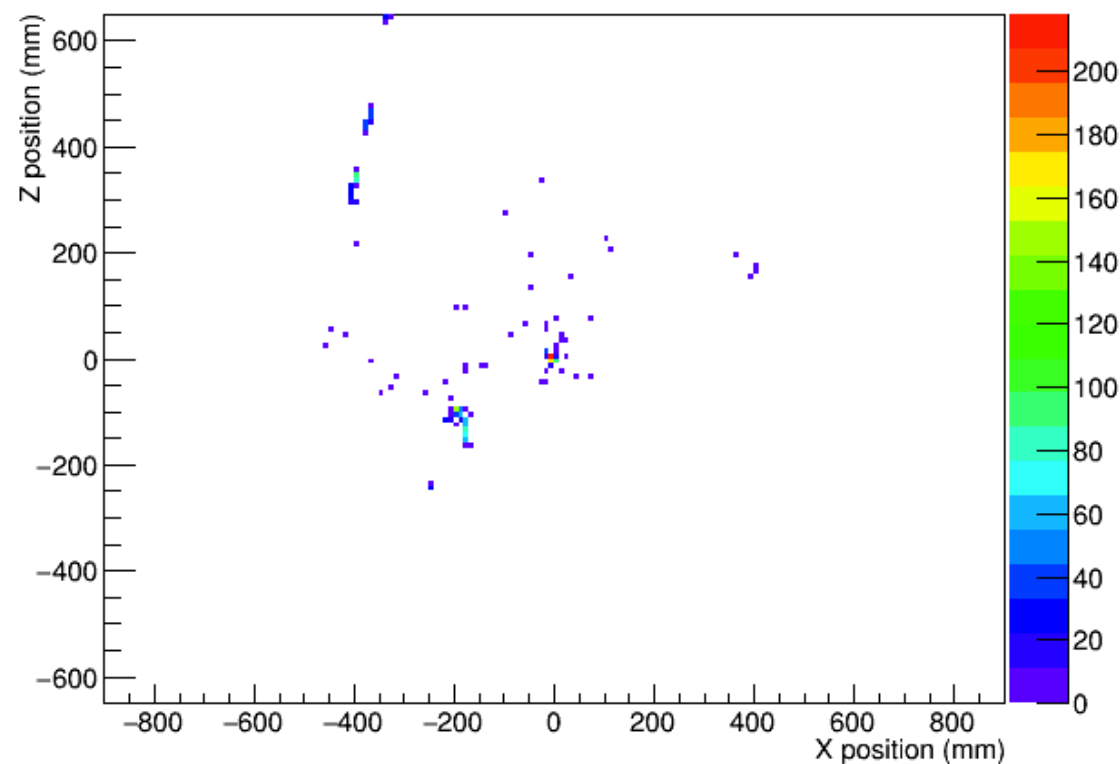
Projection on the XY readout plane



Projection on the YZ readout plane



Projection on the XZ readout plane



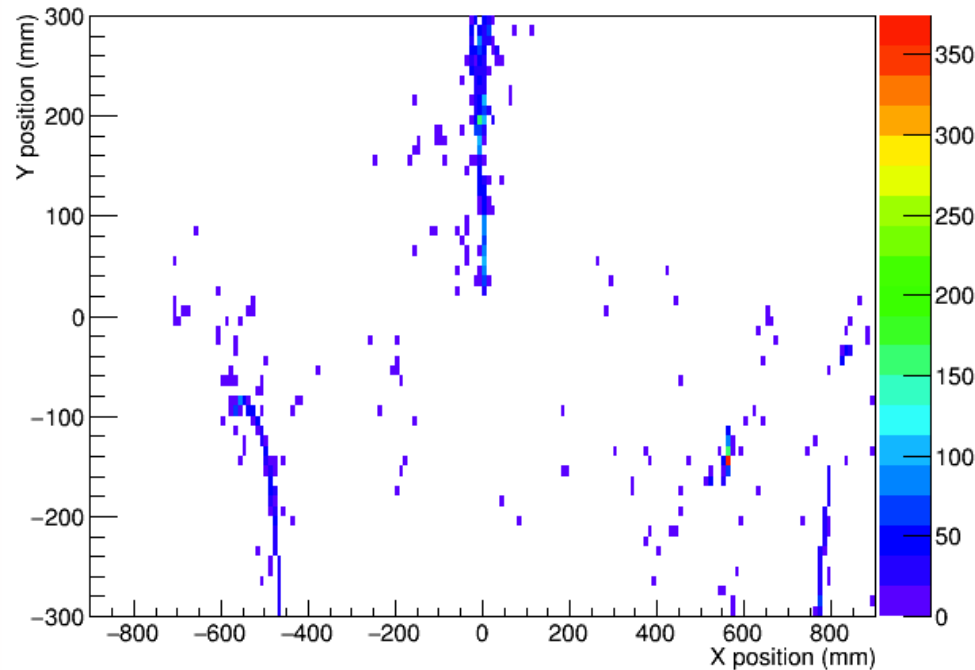
Validation III: particle guns (gamma)

Gamma, $E_{\text{kin}}=600\text{MeV}$

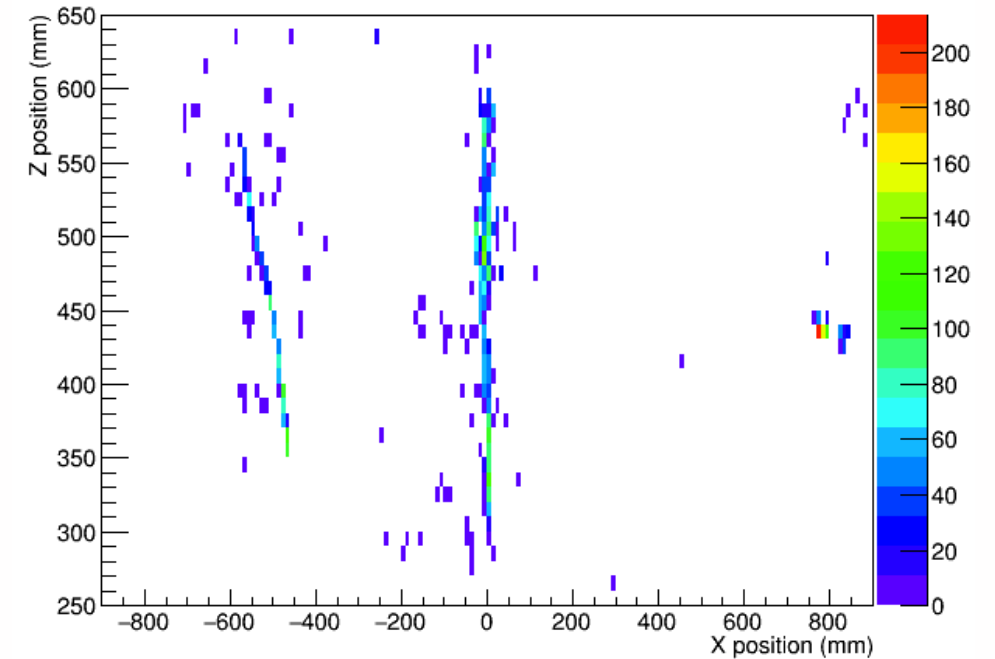
Pos(0,-300,0), Dir(0,1,1)

- Along Z: 180x60x130 cubes (1cm^3)

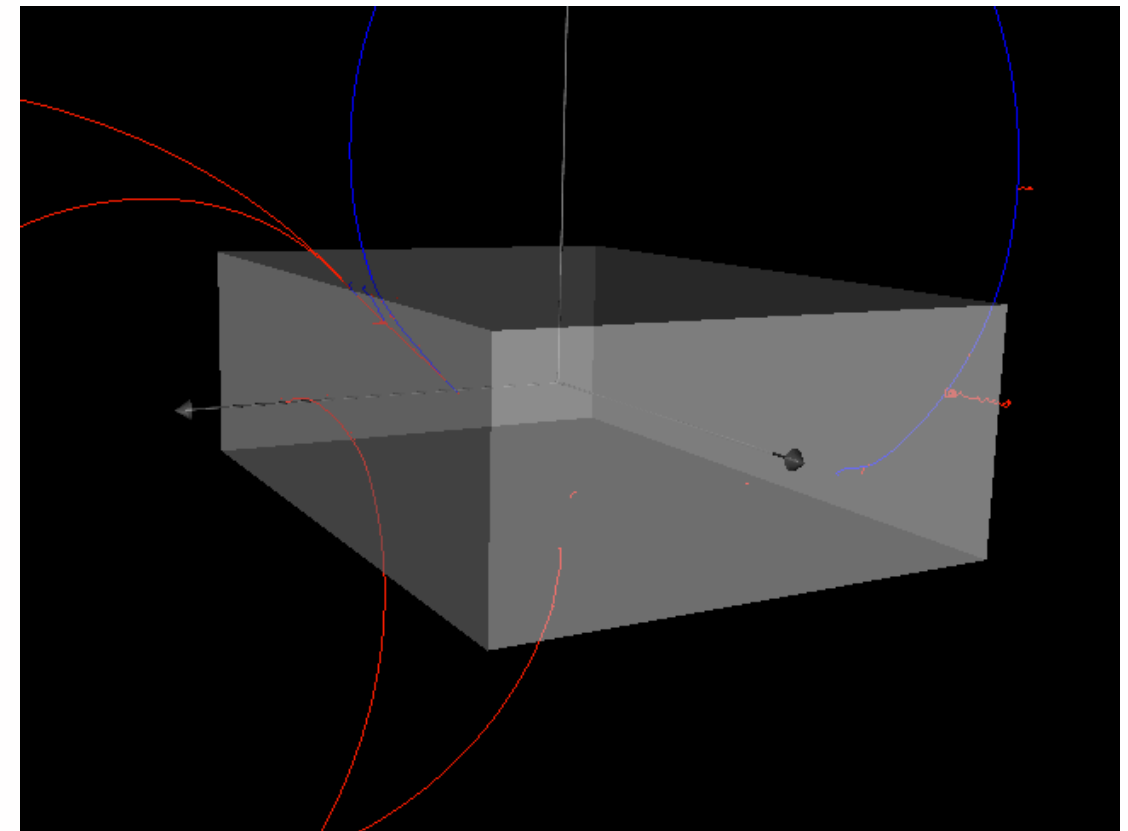
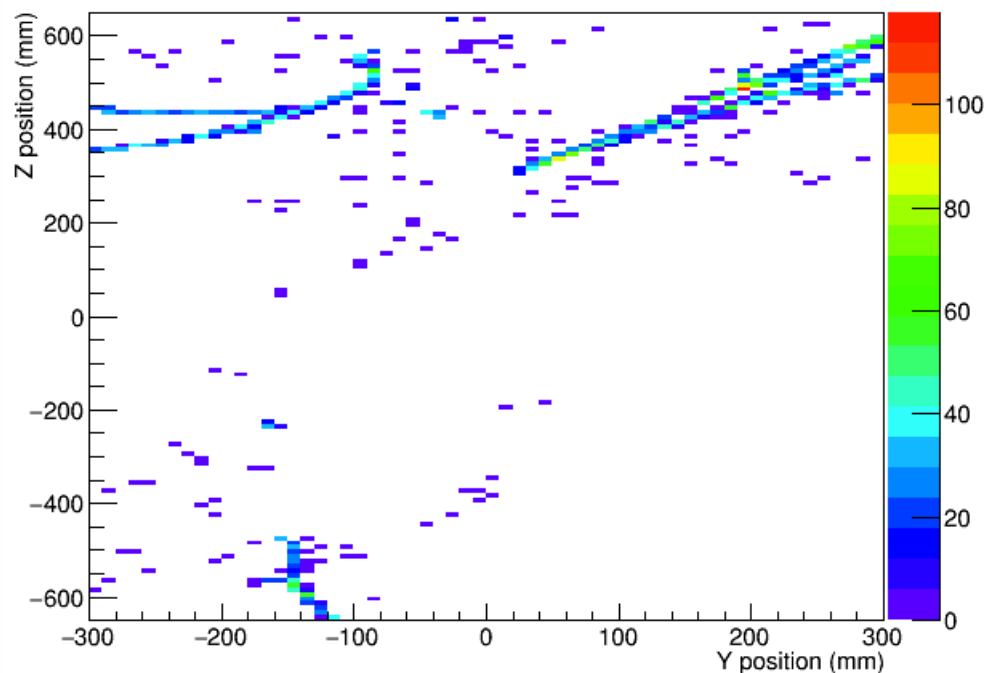
Projection on the XY readout plane



Projection on the XZ readout plane



Projection on the YZ readout plane



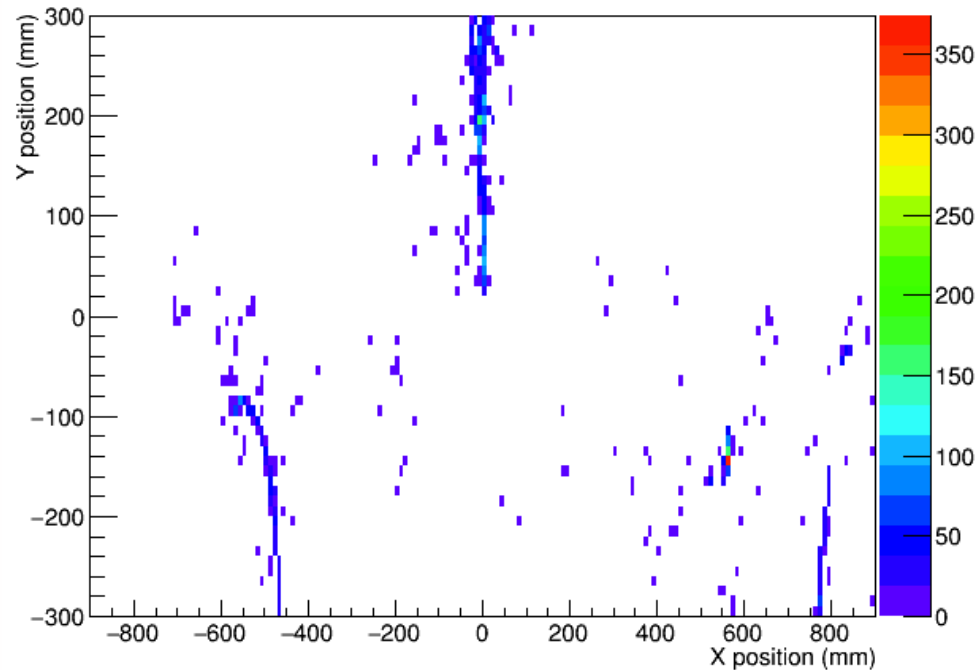
Validation III: particle guns (gamma)

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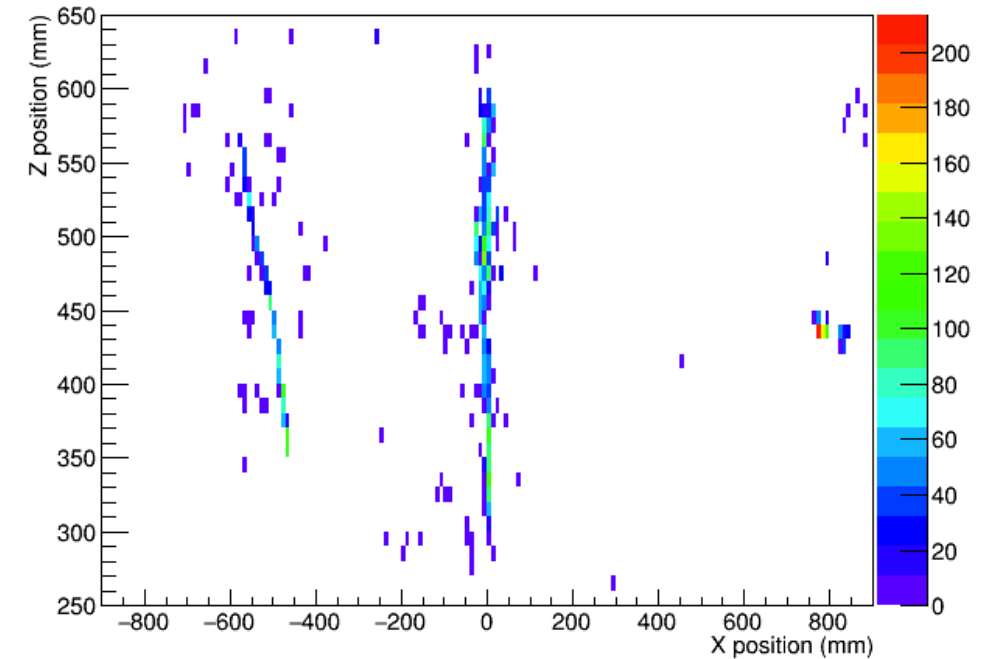
Pos(0,-300,0), Dir(0,1,1)

- Along Z: 180x60x130 cubes (1cm^3)

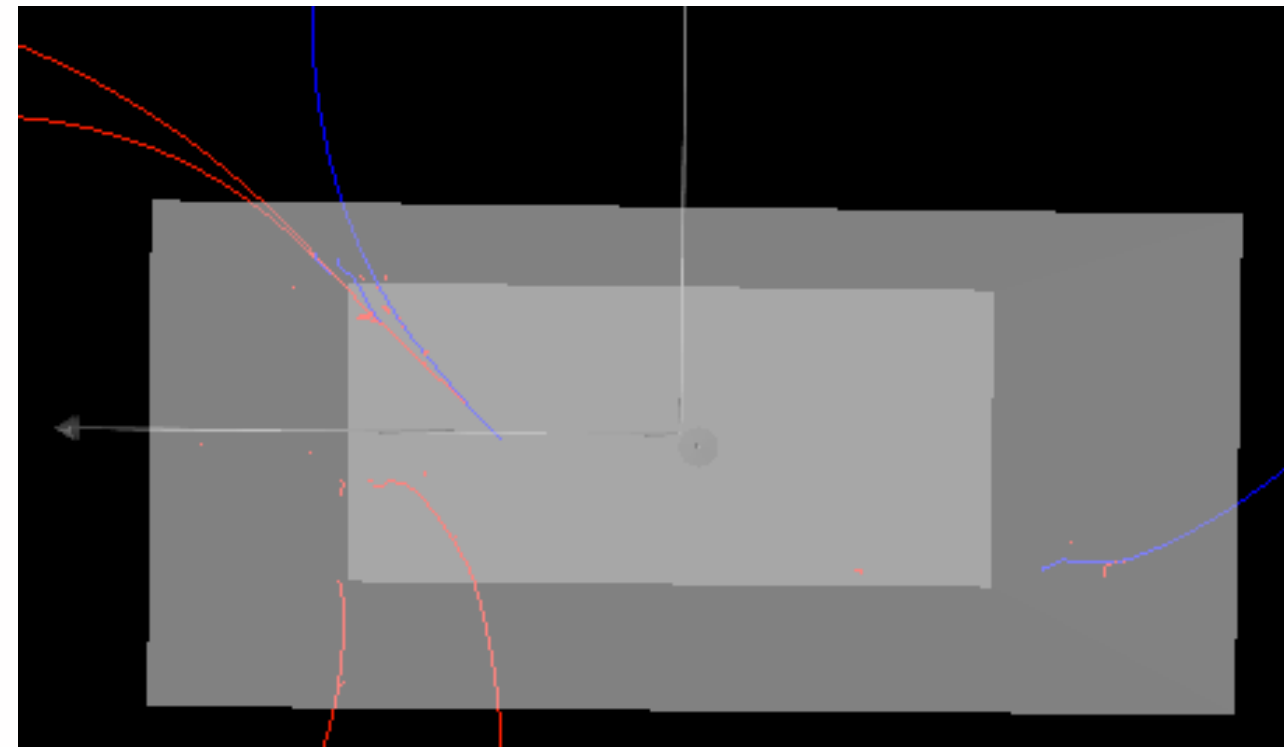
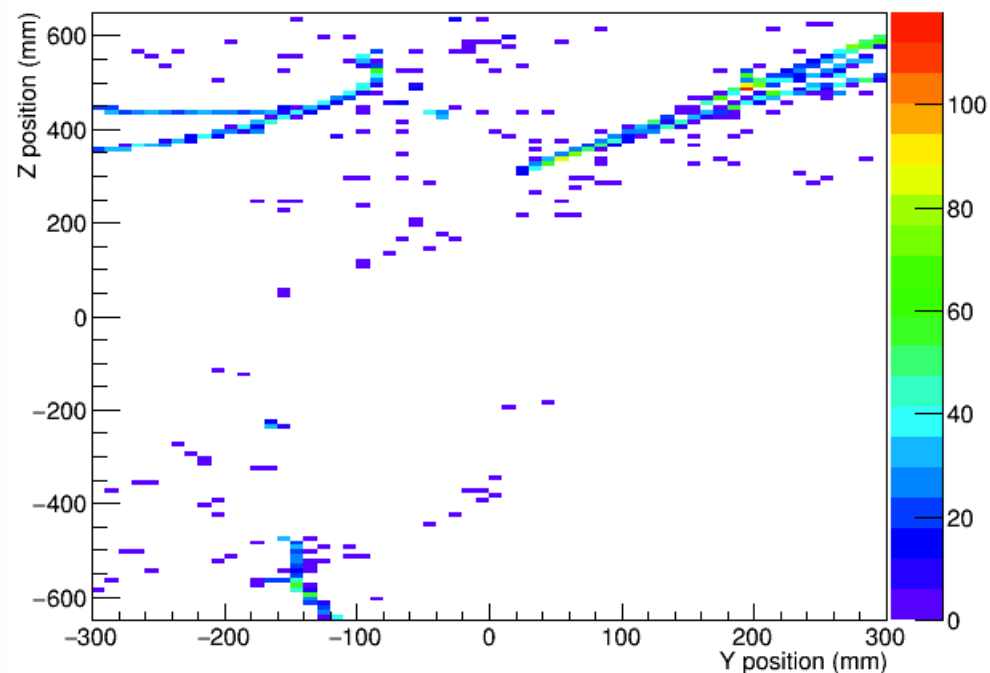
Projection on the XY readout plane



Projection on the XZ readout plane



Projection on the YZ readout plane





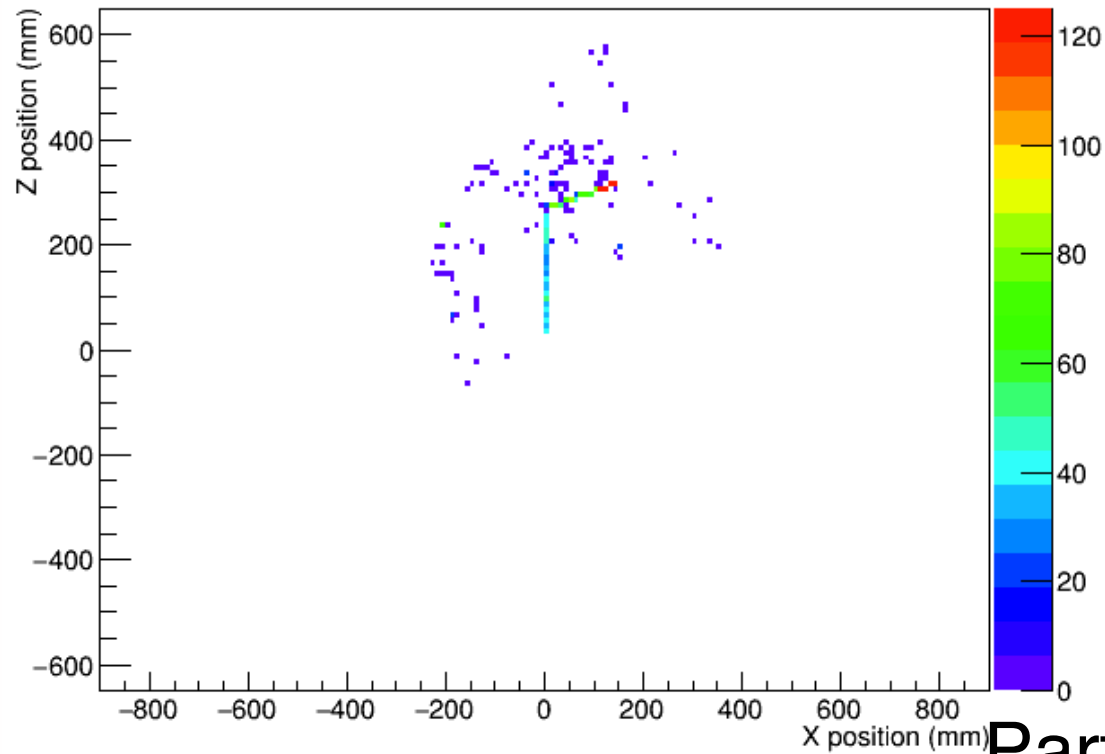
beam

Validation III: particle guns (pi-)

pi-, $E_{\text{kin}}=200\text{MeV}$
Pos(0,0,0), Dir(0,0,1)

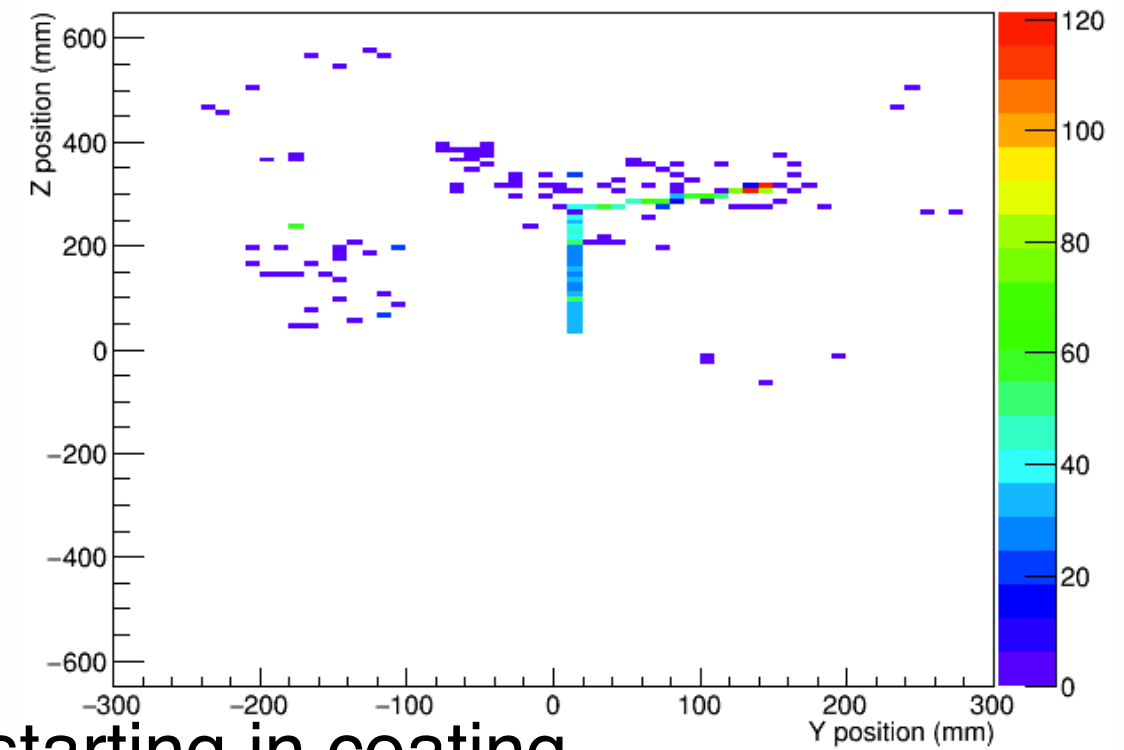
- Along Z: 3x6x130 cubes (1cm³)

Projection on the XZ readout plane

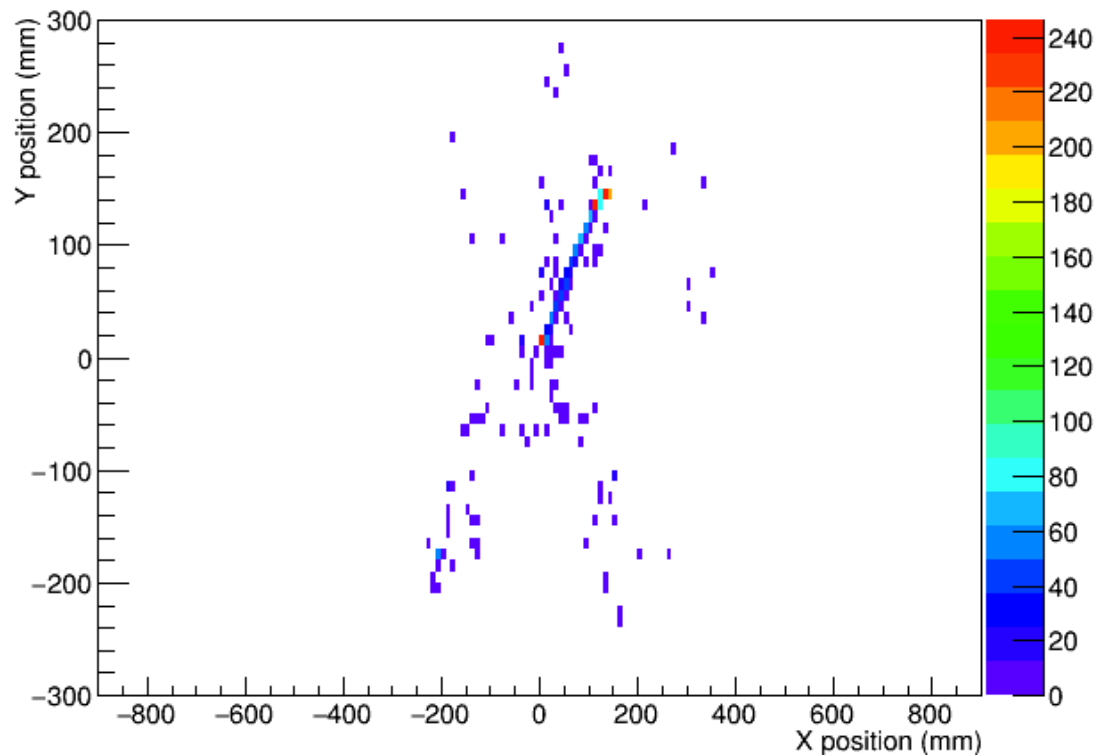


PDG:
-211
1000060110
1000030070
1000010020
2212
2112
11
22

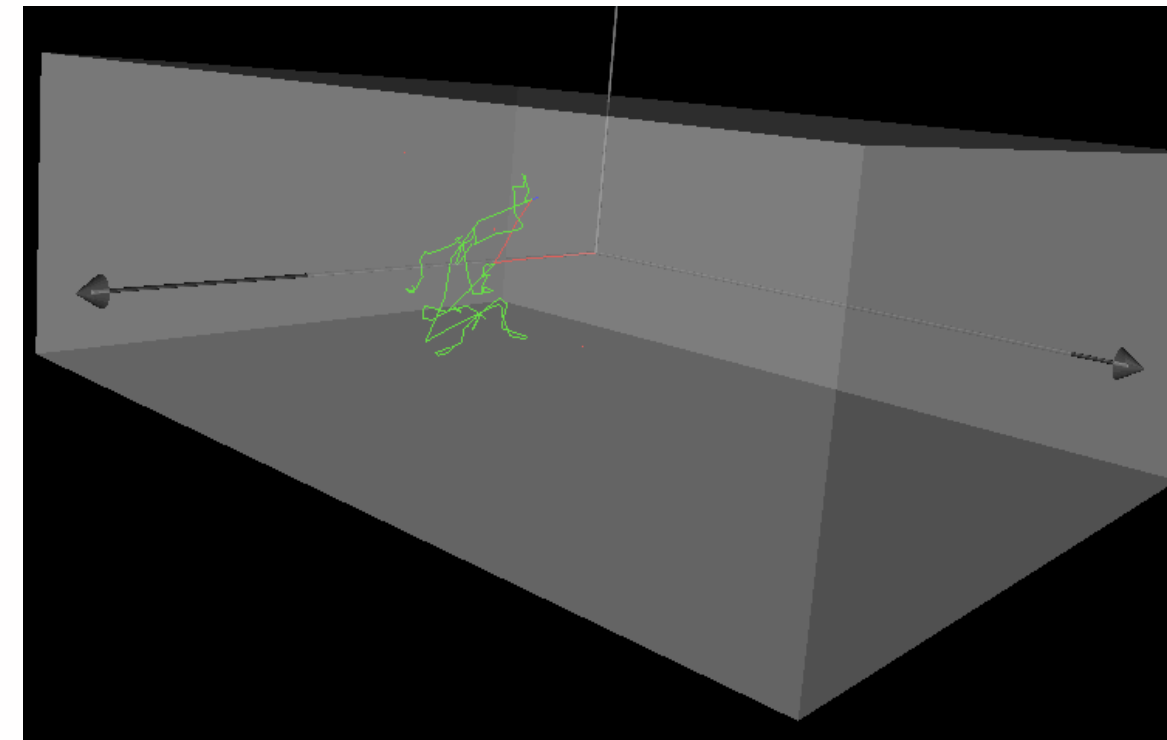
Projection on the YZ readout plane



Projection on the XY readout plane



Particle gun is starting in coating

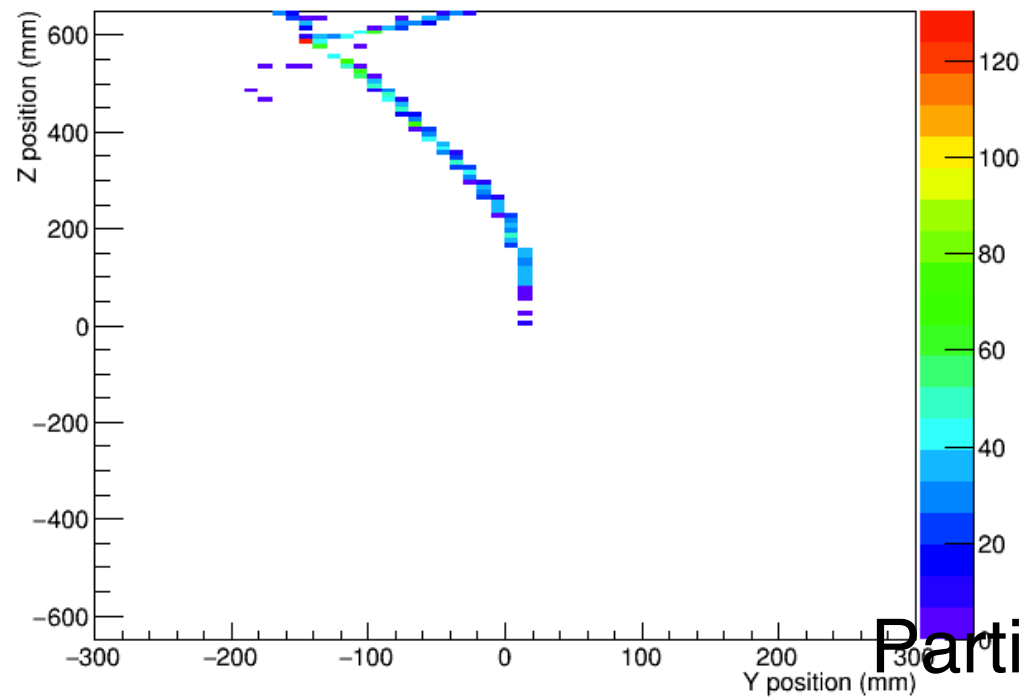


Validation III: particle guns (pi-)

- Along Z: 3x6x130 cubes (1cm³)
- Detect pi-, muon, e- as a function of X and time
(not many in pi-...)

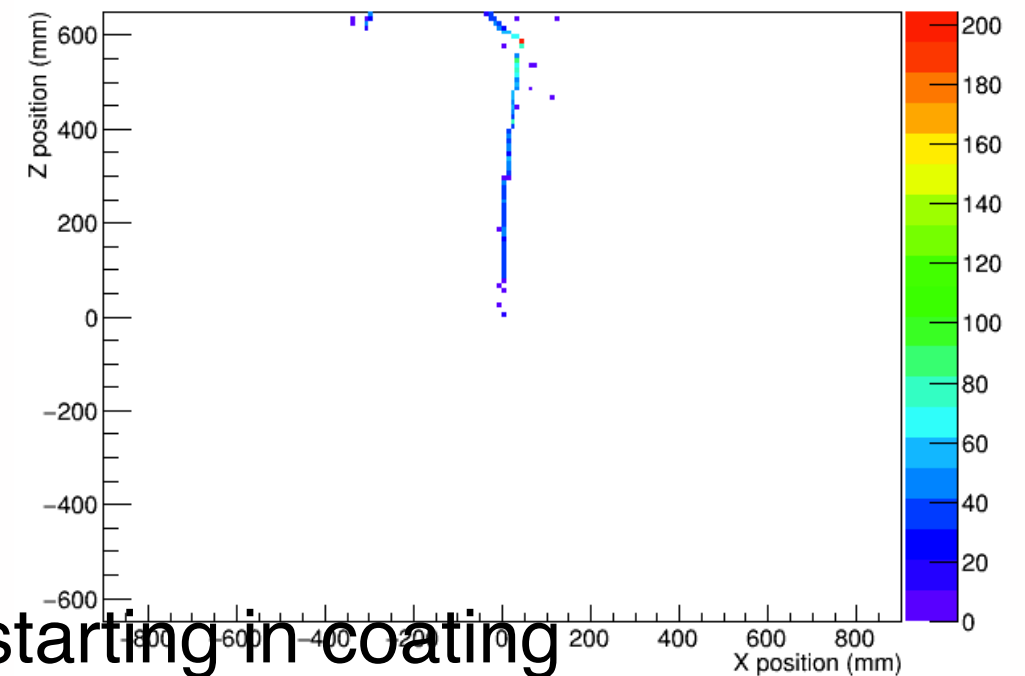
pi-, $E_{\text{kin}}=200\text{MeV}$
Pos(0,0,0), Dir(0,0,1)

Projection on the YZ readout plane



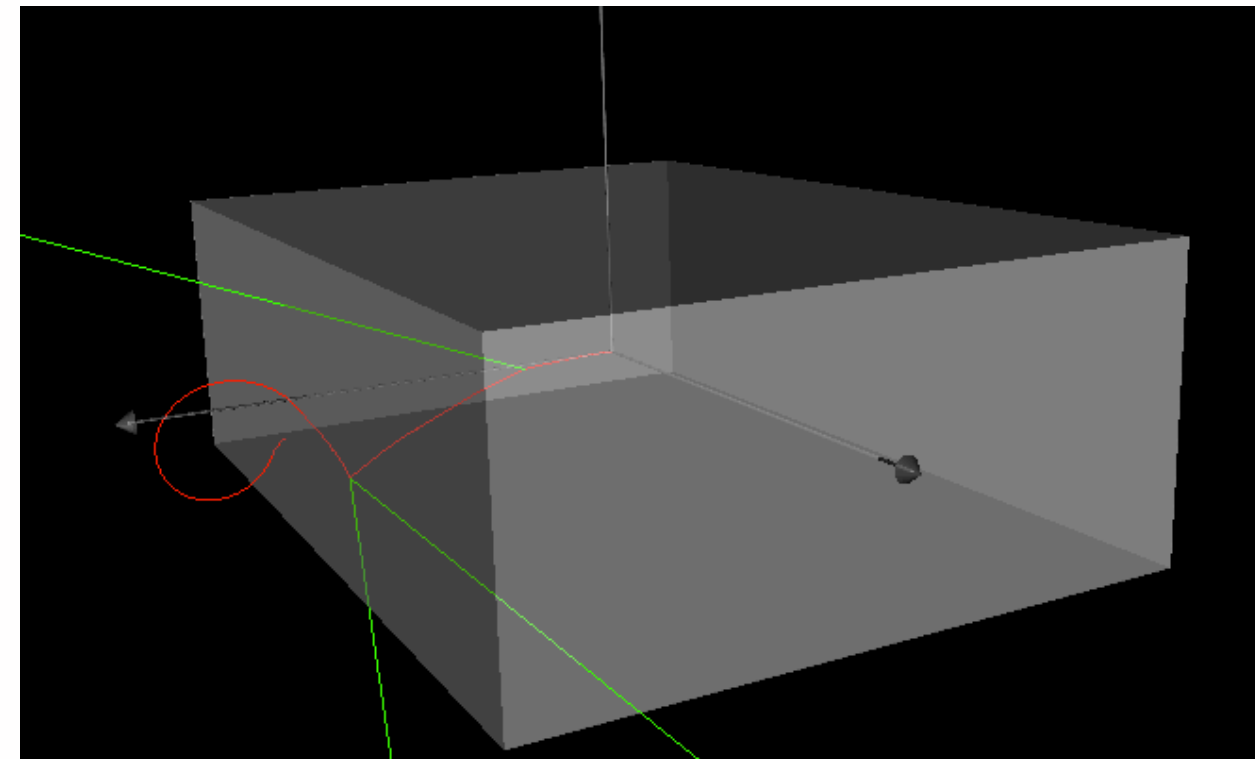
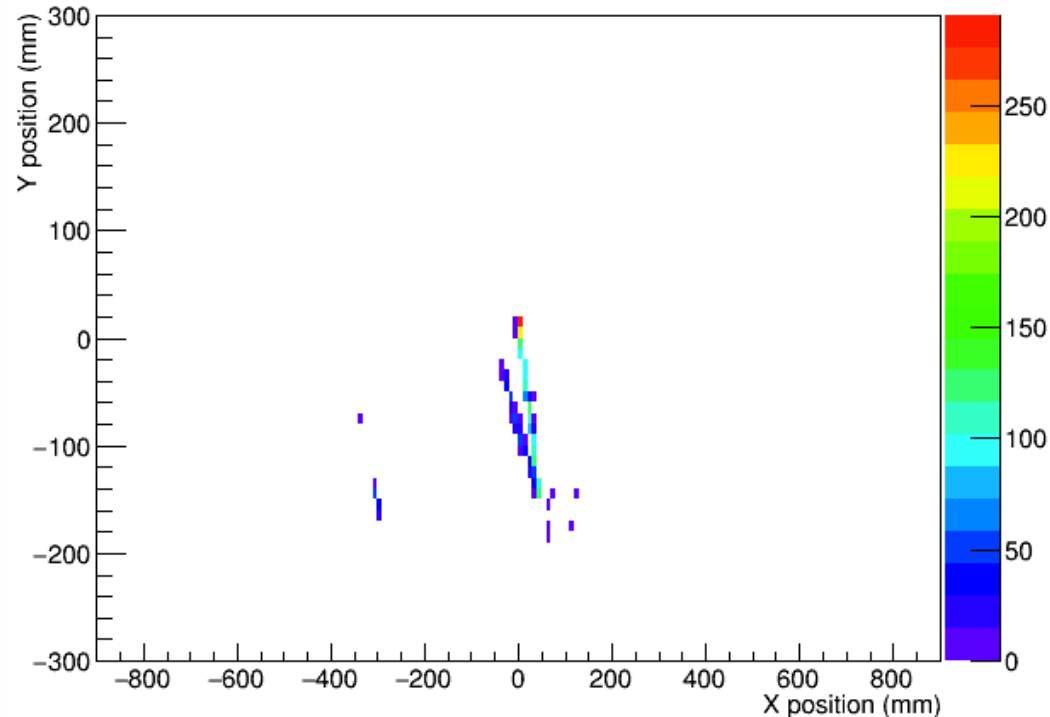
PDG
-211
13
11
22
11

Projection on the XZ readout plane



Particle gun is starting in coating

Projection on the XY readout plane

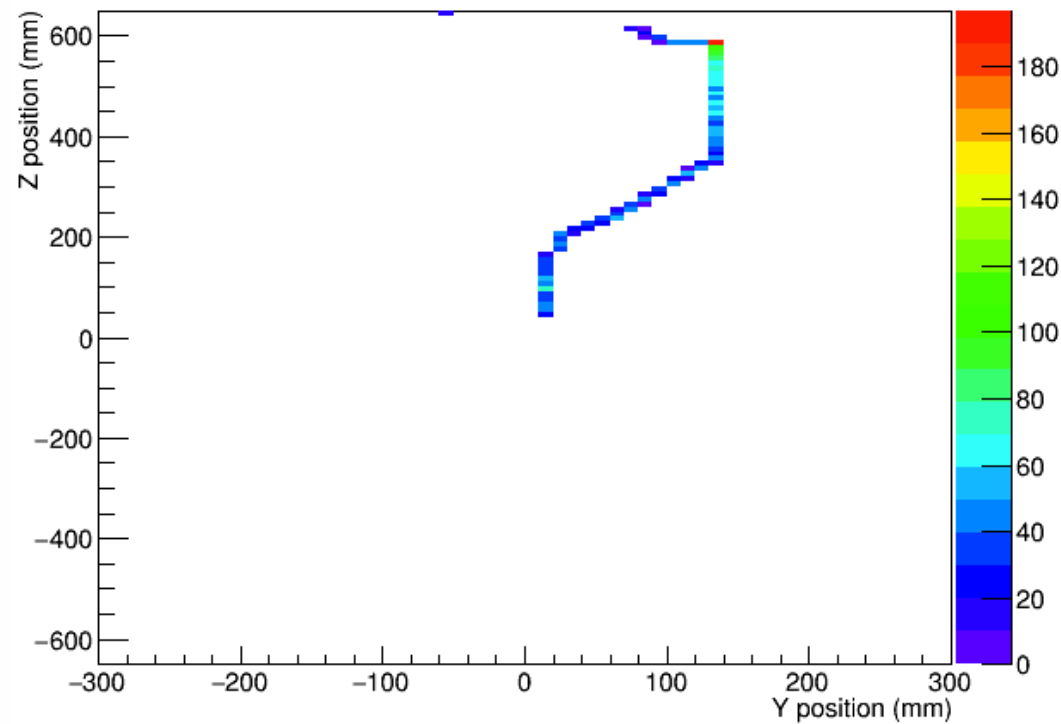


Particle guns: another $\pi^+ \rightarrow \text{Michel } e^+$

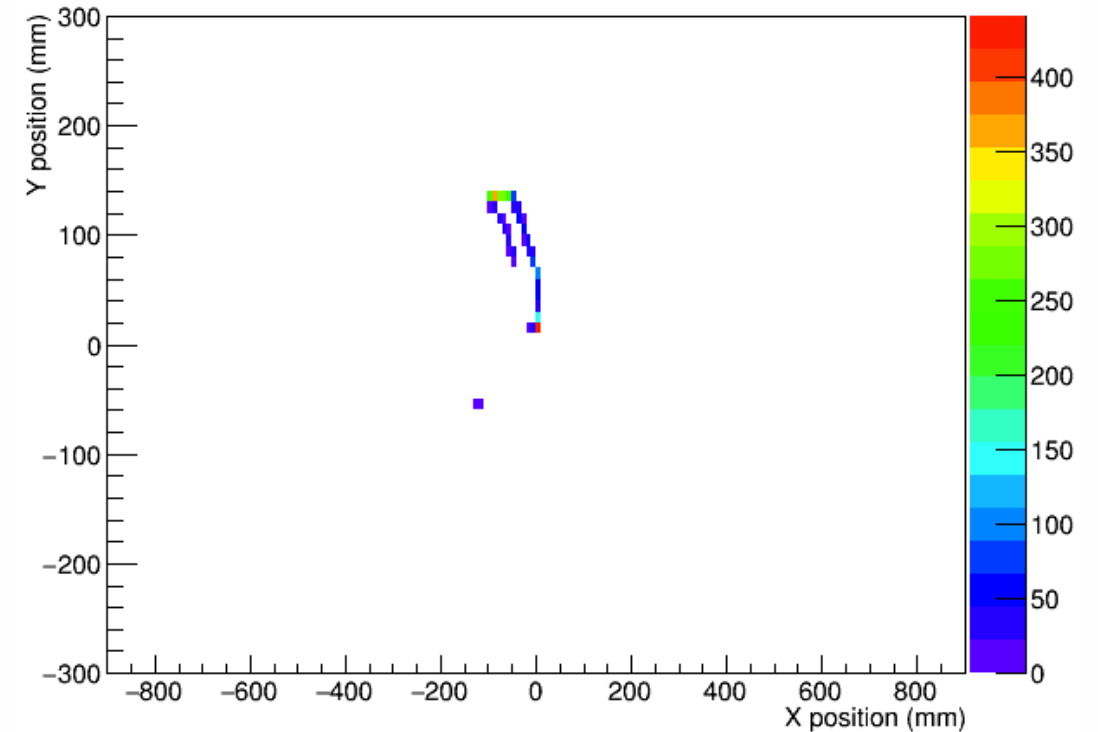
- Along Z: 3x6x130 cubes (1cm^3)
- Detect π^- , muon, e^- as a function of X and time

π^+ , $E_{\text{kin}}=200\text{MeV}$
 $\text{Pos}(0,0,0)$, $\text{Dir}(0,0,1)$

Projection on the YZ readout plane



Projection on the XY readout plane



Projection on the XZ readout plane

