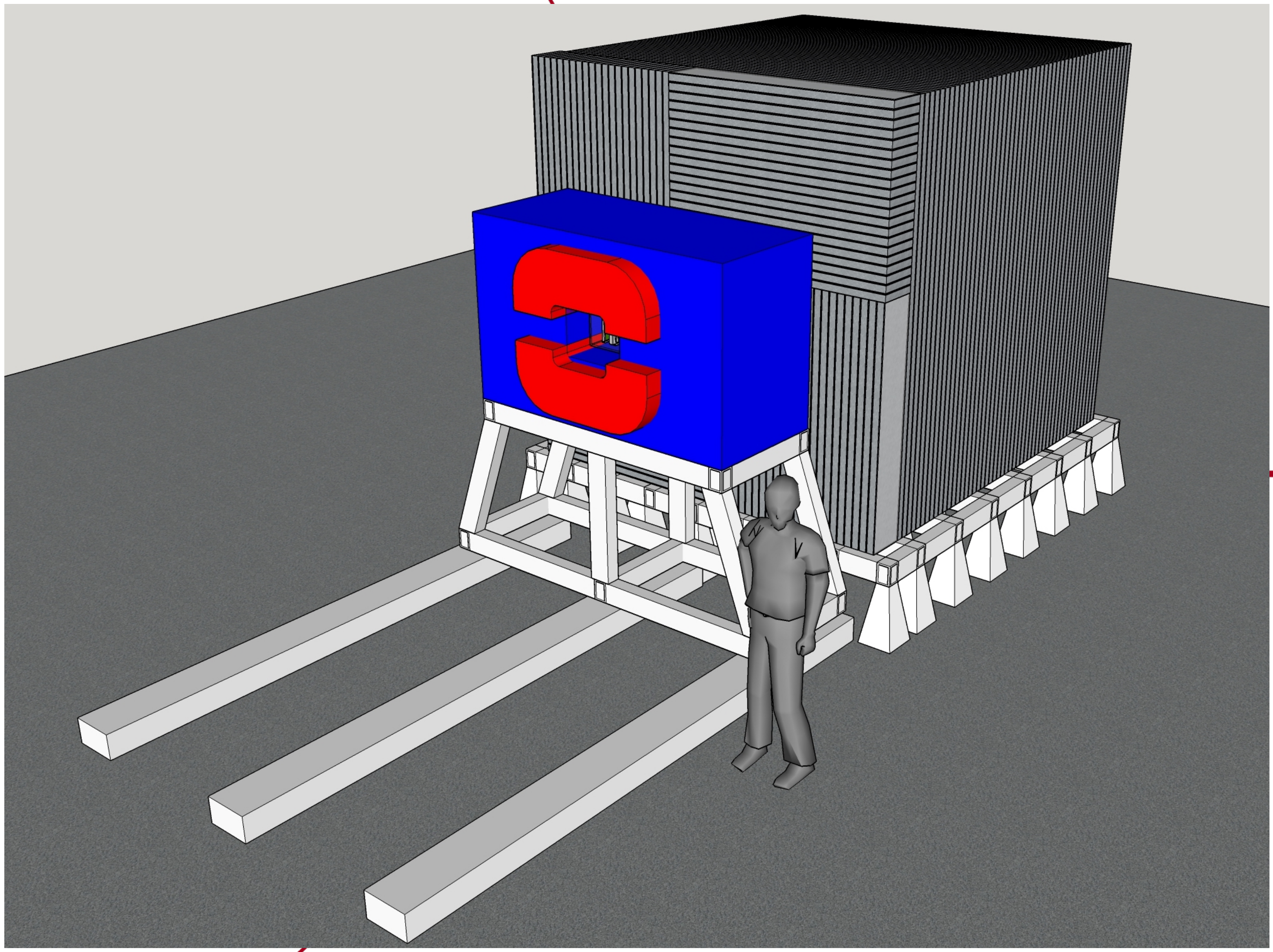
LDMX: Overview of Features and Possibilities



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March 11, 2018

U.S. DEPARTMENT OF ENERGY
Office of Science

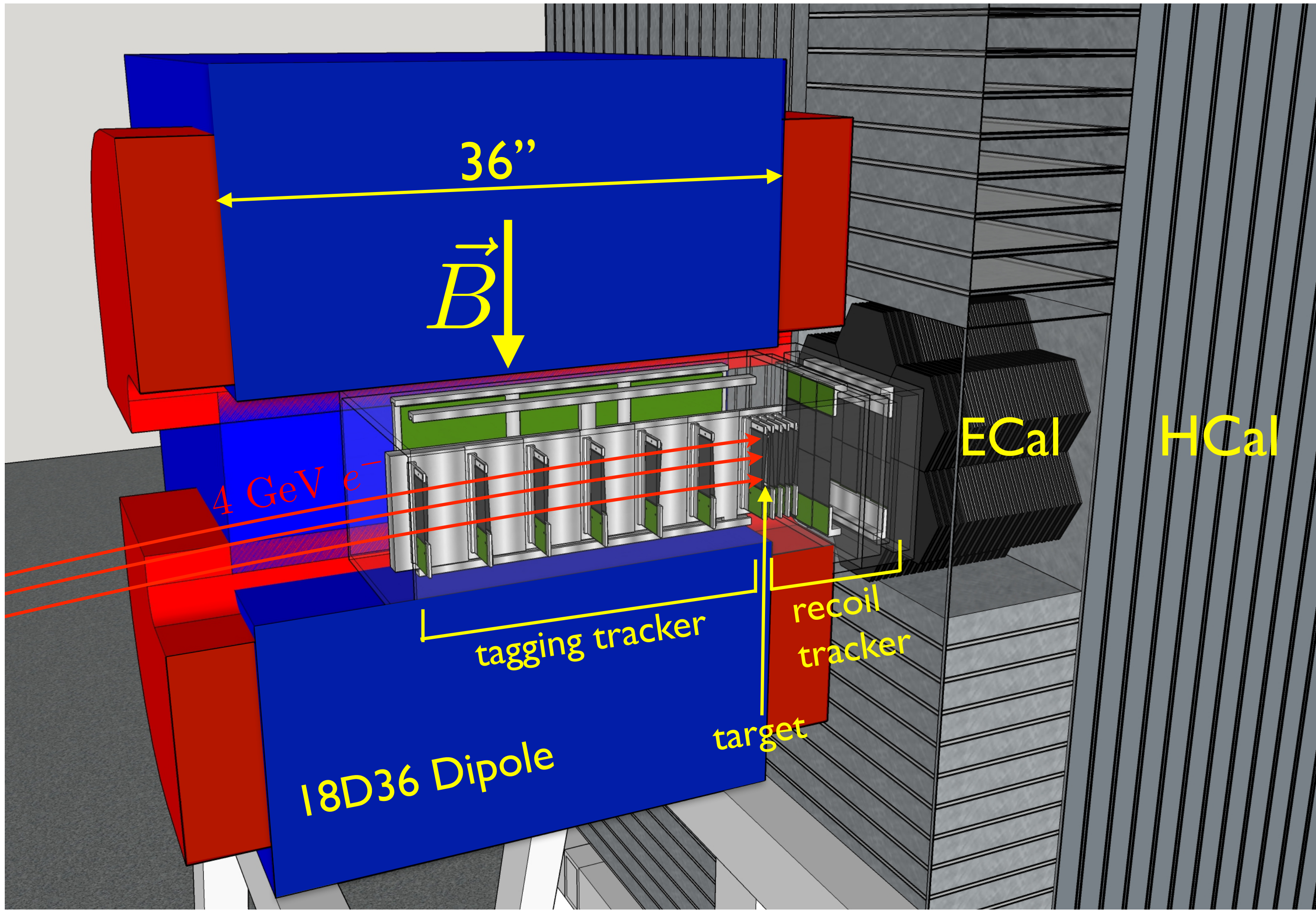
SLAC NATIONAL ACCELERATOR LABORATORY

LDMX Missing Momentum Experiment

Compact missing momentum experiment for up to 10^{16} EOT.

Leverages detector technologies developed for other HEP experiments

- Tracking from HPS
- ECal from CMS upgrades
- HCal from Mu2e / CMS



S30XL is preferred host beamline.

Requires minimal additional development and infrastructure to deploy: expected total cost is ~$10M (US accounting).

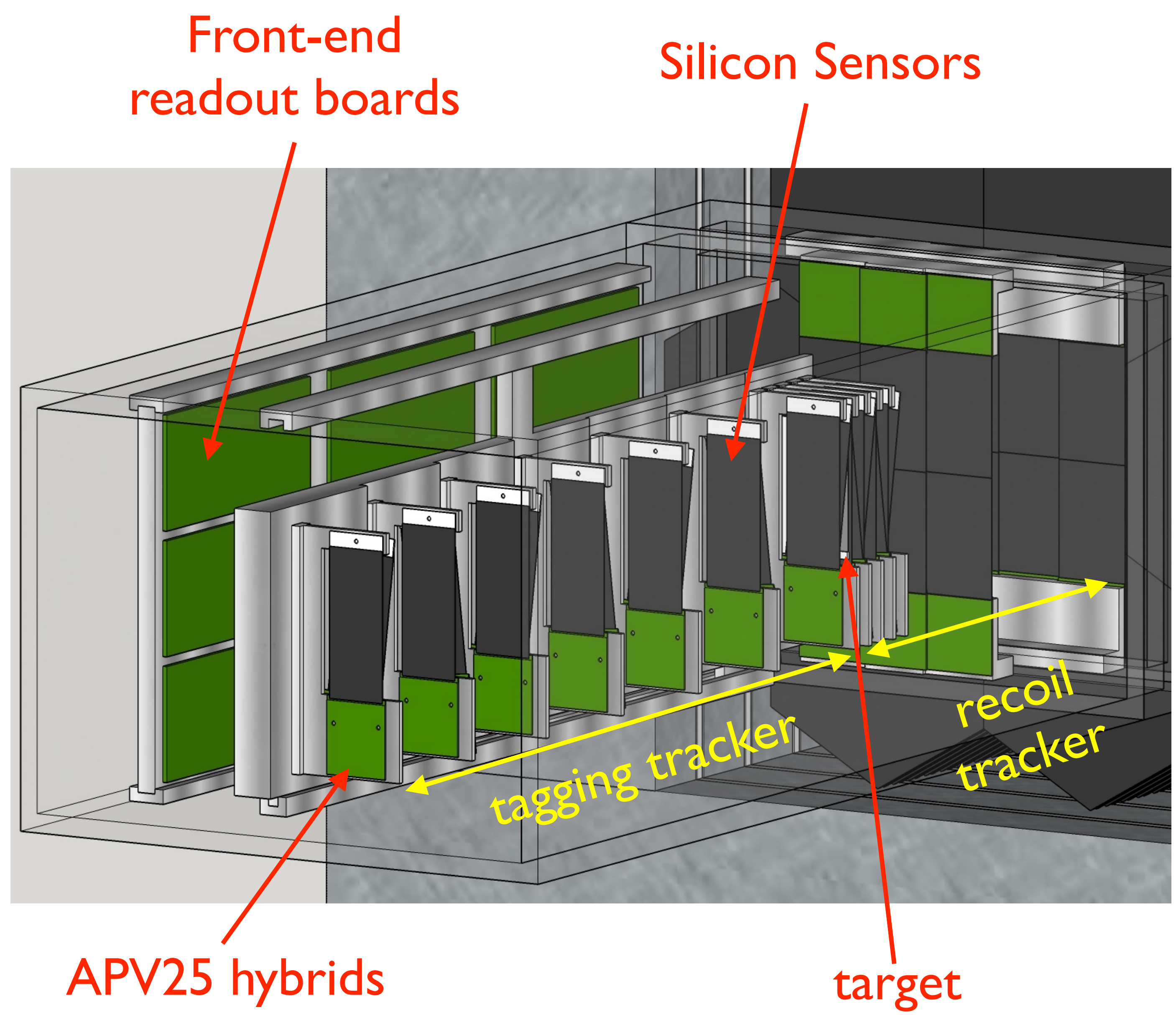
LDMX Tracking System(s)

In principle, there are two tracking systems, separated by the target.

- Tagging tracker, upstream of target, tags full-energy incoming electrons and precisely determines their momentum and position at the target.
- Recoil tracker, downstream of target, associates recoiling electrons with tags and precisely determines their momentum at the target

Together, the trackers measure the change in momentum across the target, the key signal discriminator.

Mechanically, however, the trackers share common support, cooling and readout and are technologically identical.



Spectrometer and Beamline Design

Similarly, one magnet, two fields:

18D36 Magnet with 14” vertical gap @ 1.5 T

Tagging Tracker in central field

- precision tracking for 4 GeV incoming electrons
- long/narrow to select against off-energy electrons

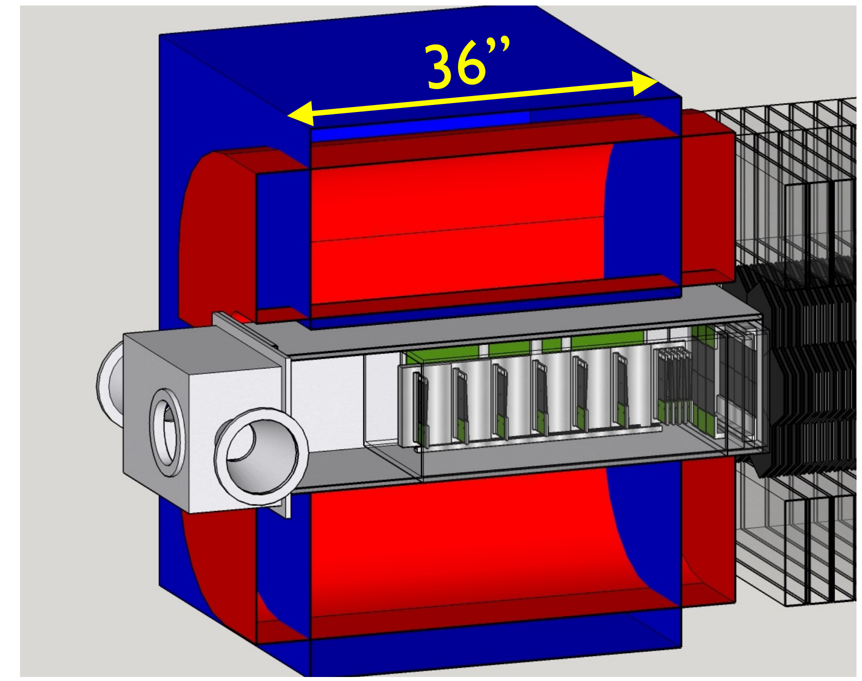
Recoil Tracker in fringe field

- tracking for low-energy recoils (down to ~50 MeV)
- short/wide to increase acceptance and allow ECal close to target

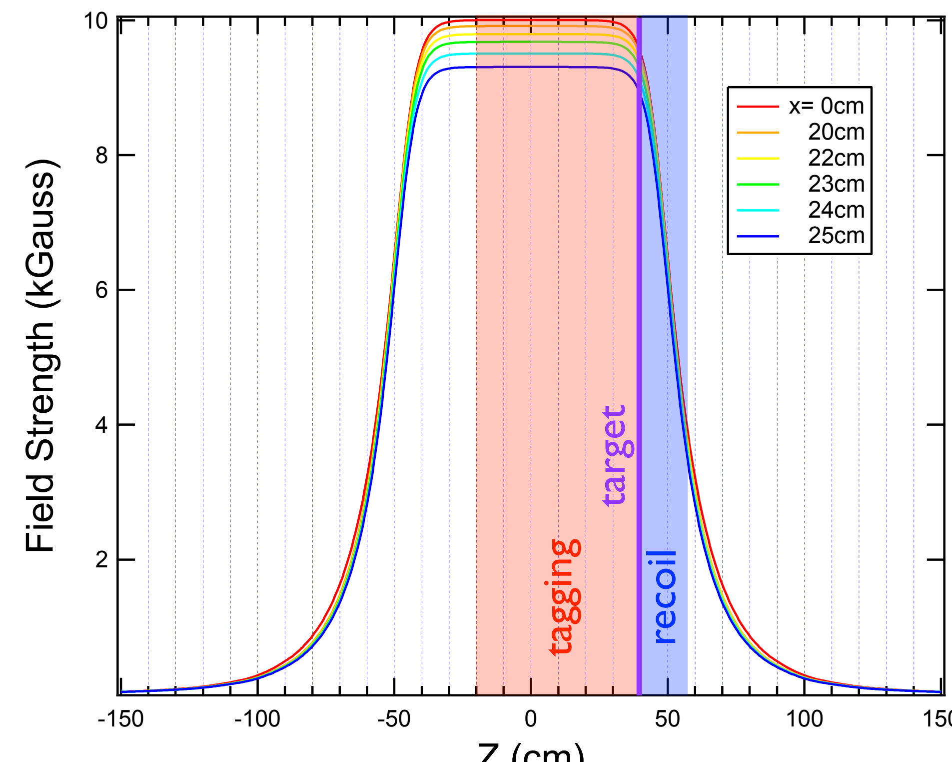
Tracking inside beam vacuum: no upstream vacuum that would contaminate the beam with secondaries

Target is inserted in 15mm space between trackers

- 10% X_0 tungsten sheet
- Thin PVT scintillator strips on both sides provide a level-0 trigger to veto empty beam buckets.



18D36 Dipole Magnet

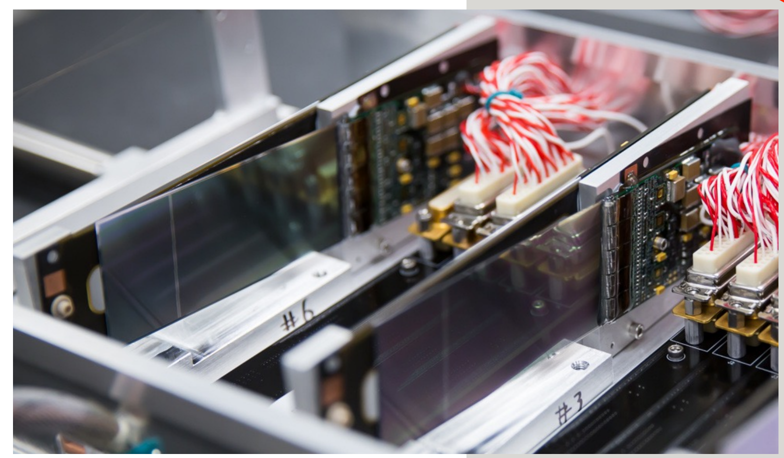


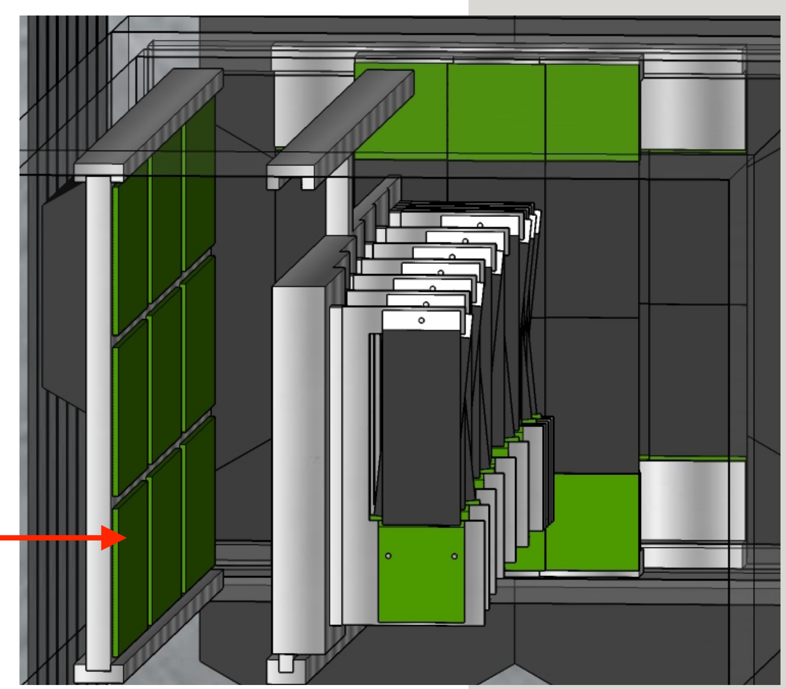
Tagging Tracker

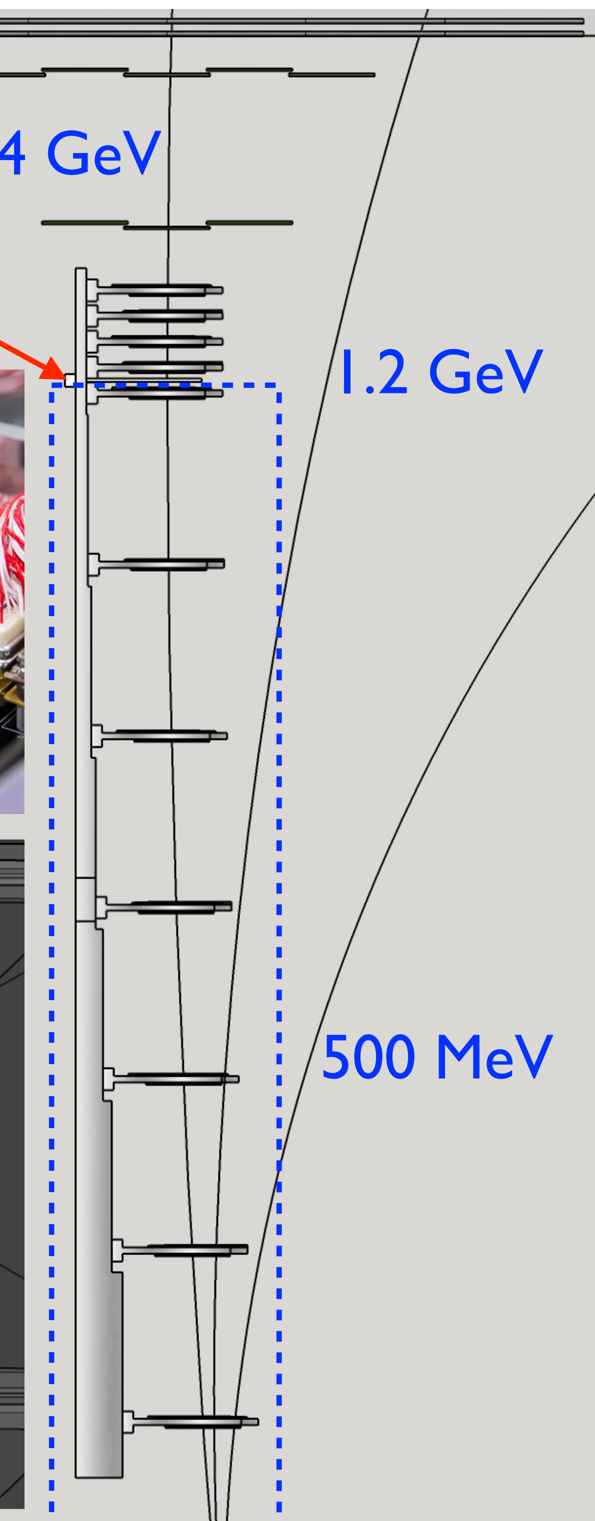
Designed around trajectory of 4 GeV e^-

- 7 layers, every 10 cm from 7.5 mm to 607.5 mm upstream of target
- Double-sided Si microstrip modules with vertical strips & 100 mrad stereo
- Modules are similar to those built for Layers 1-3 of HPS SVT
    - single-sided sensors with 30(60)μm sense(readout) on 300μm Si
    - 0.7% X_0 / 3d measurement
    - CMS APV25 readout with 2ns time resolution
    - Modules are mounted on a stepped support plate, liquid cooled
- Digitization, zero-suppression on Front End Boards (FEBs), same as HPS SVT

HPS L1-3 modules

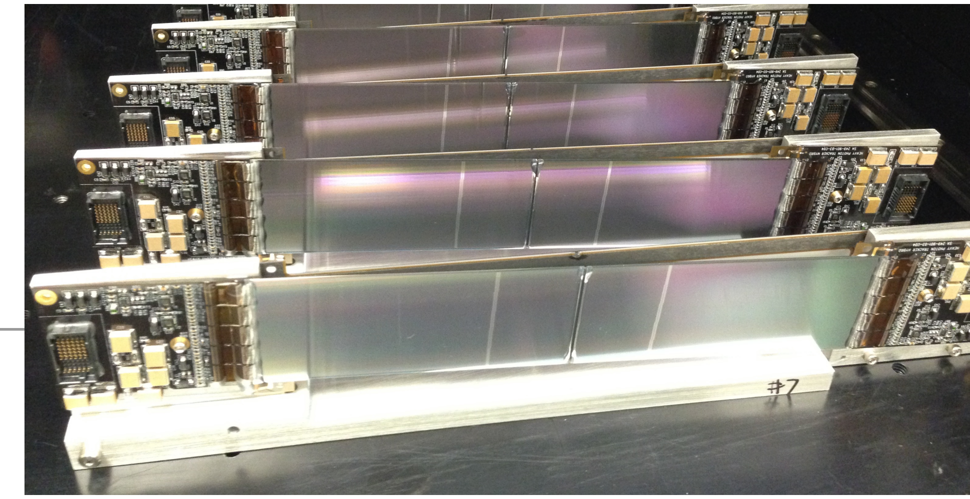






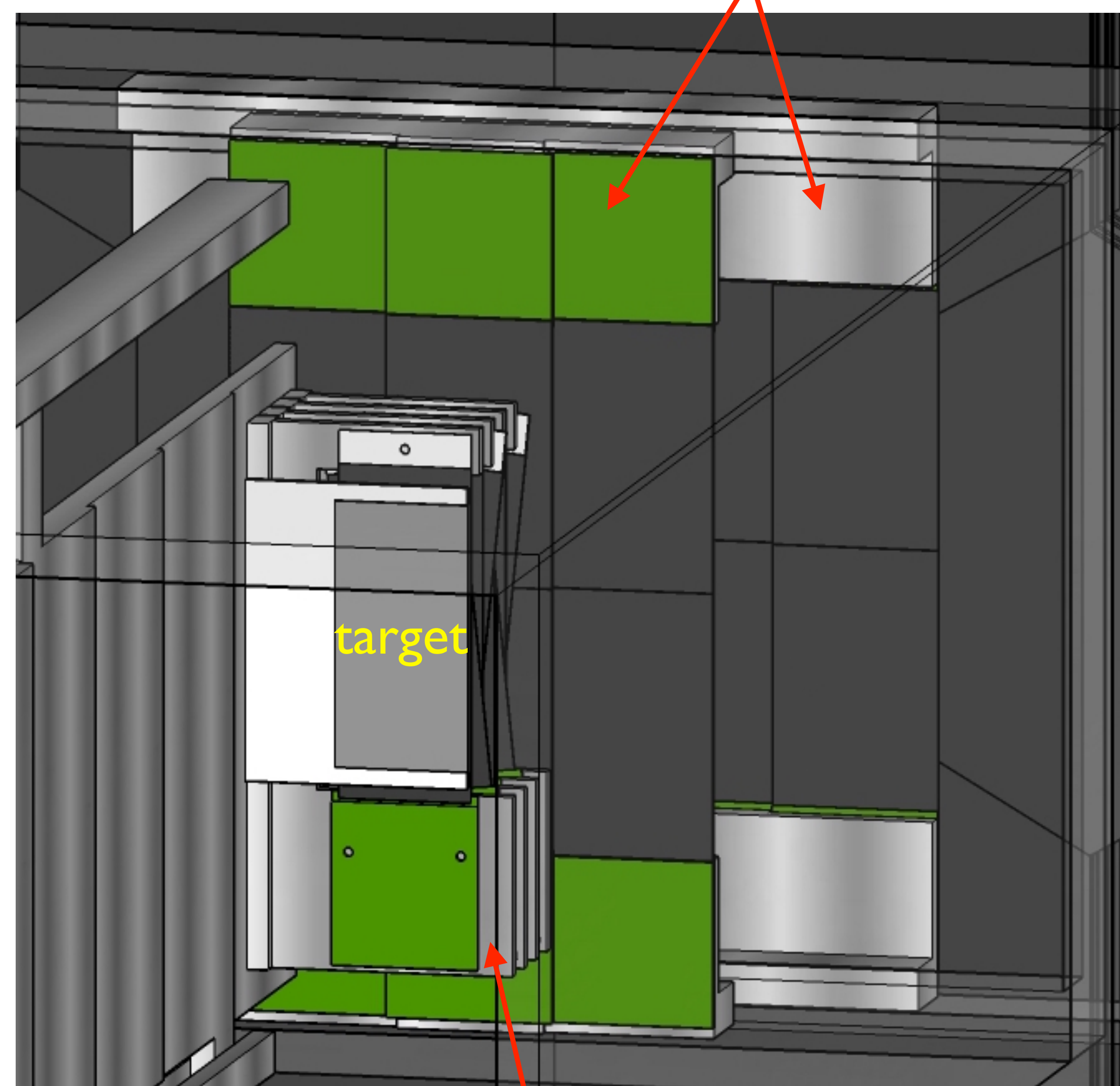
Recoil Tracker

HPS L4-6 modules



Designed for large angular and momentum acceptance in limited longitudinal space

- 4 stereo layers every 15mm from 7.5mm to 52.5mm downstream of target.
  - Same modules as tagging tracker
  - Mounted on the same support/cooling structure as the tagging layers and target
- 2 larger-area axial layers (vertical strips) at 90mm and 180mm downstream of target (ECal face @ ~200mm)
  - mounted on separate support structure
  - Modules similar to HPS SVT Layers 4-6
  - Shorter/wider sensor design but otherwise the same technology
- Read out by same FEBs as tagging tracker

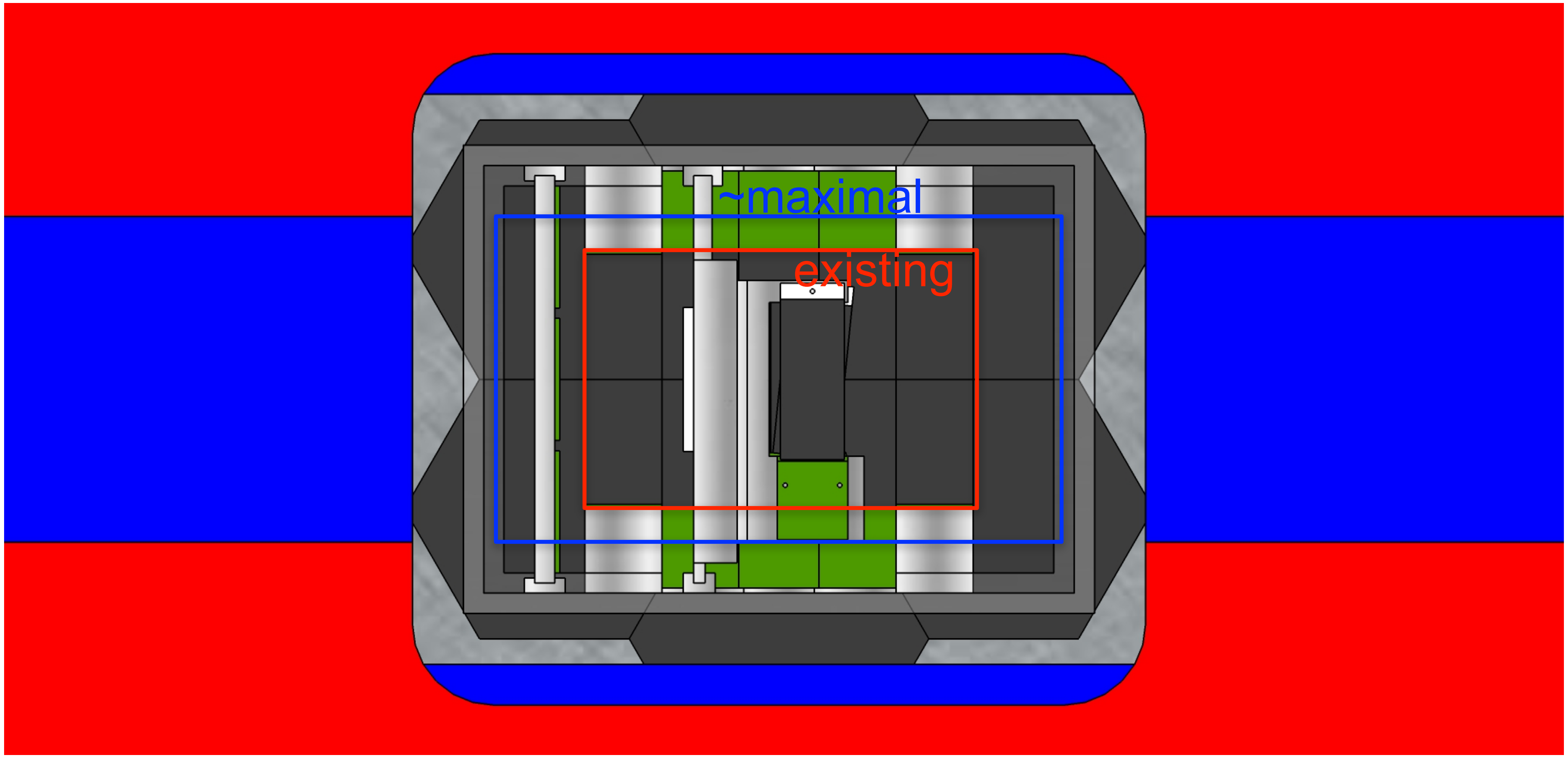


Increasing Recoil Tracker Acceptance

Modest increases in angular coverage are pretty easy, major increases (>90˚) are not.

Building multilayer tracking around this is problematic: really need to build 1/2 of a collider tracker (nested barrels/endcaps) instead, but…

Dipole field is (highly) non-optimal for tracks ~transverse to the beamline.

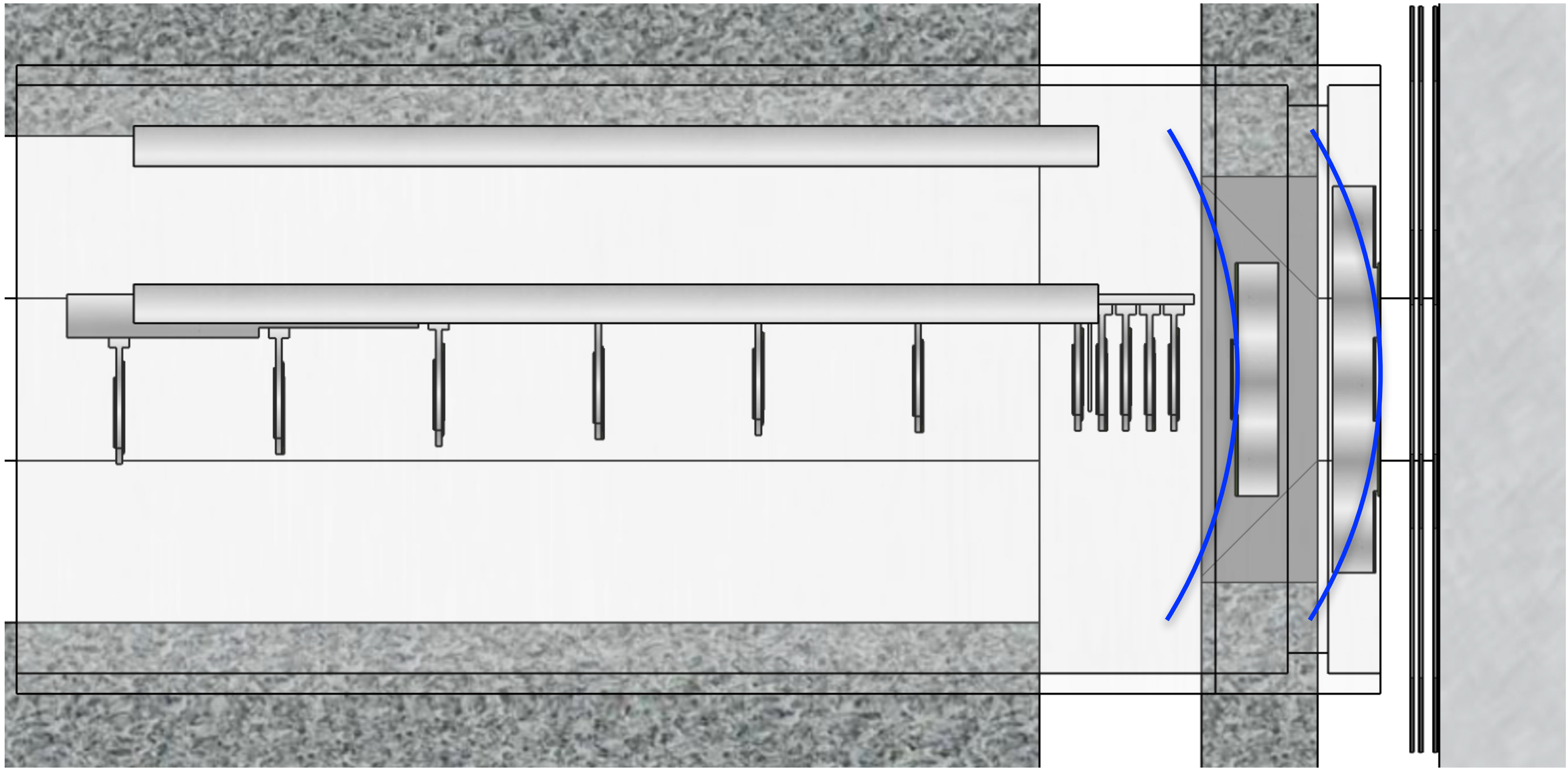


Another approach, more compact, might be scintillator-based tracking.

Optimization of Recoil Tracker Acceptance

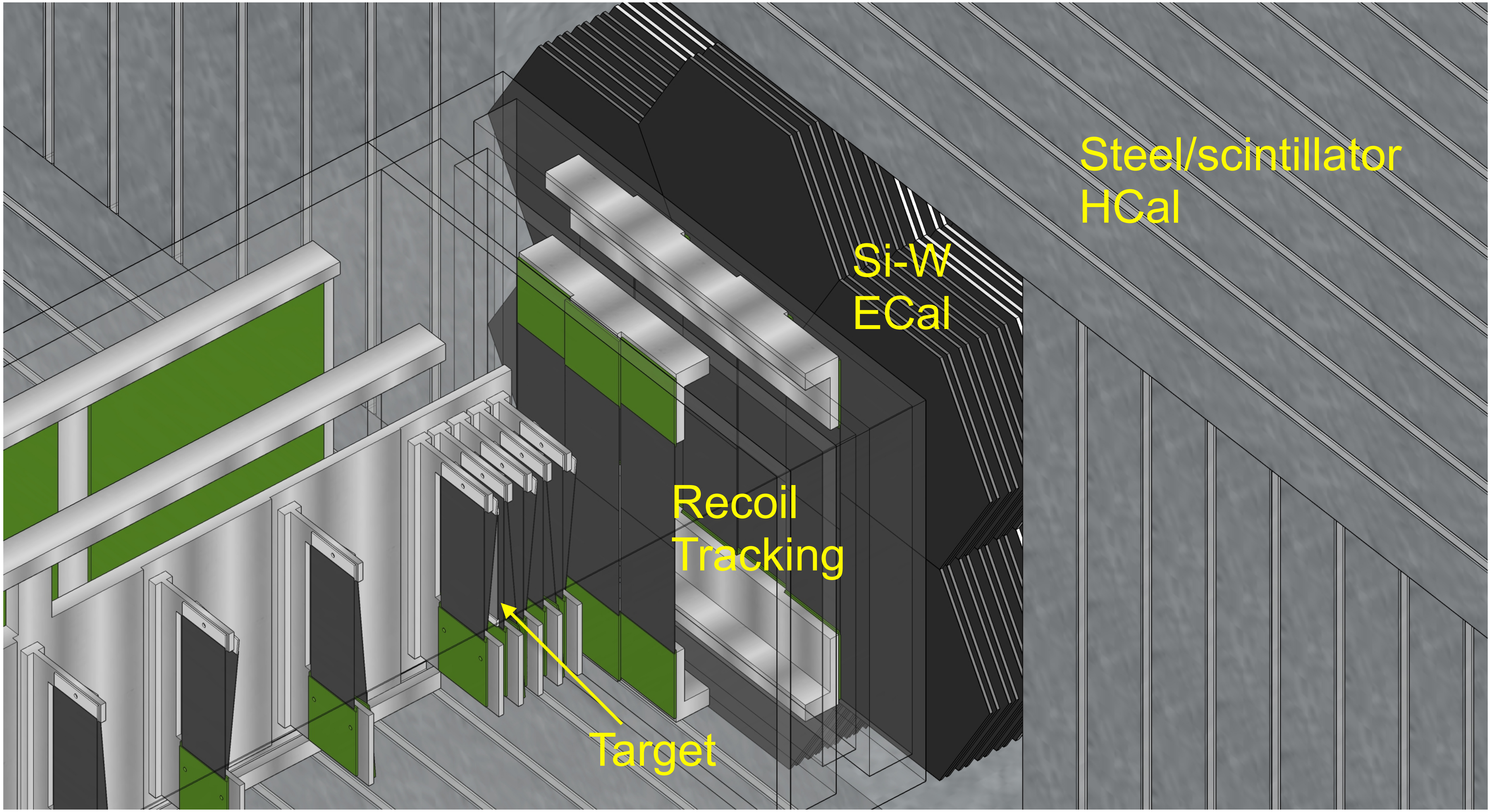
Minor optimization could get you from ~45 to ~55 degree coverage.

Lower field can increase low-momentum acceptance below 50 MeV, but will compromise resolution for high-momentum tracks.



Modifications to design to accommodate different, dimensionally thicker, targets is certainly possible.

Expanding ECal and HCal Acceptances



Expanding the ECal and HCal acceptances are expensive and require a larger magnet also

Final Thoughts

Recoil kinematics are pretty clear, seems that LDMX is reasonably well matched to the task.

Need to better understand the final state kinematics and multiplicities that are most interesting to study what changes would be most beneficial to achieve this.

Modestly increasing acceptance for the tracker is pretty easy.

Increasing acceptance for the ECal, or the granularity for the HCal (for wide-angle tracking) is a more radical/expensive proposition.

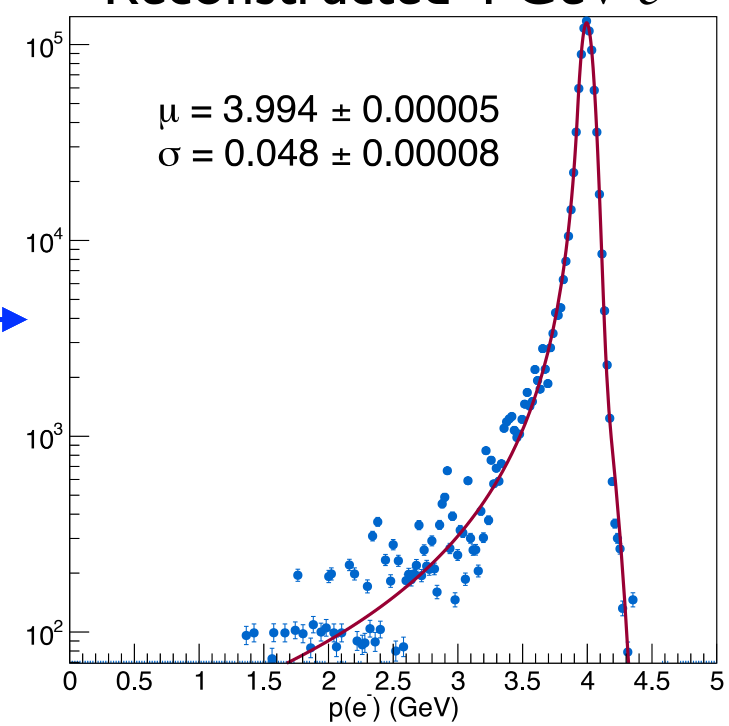
Would need to understand issues for all potential targets, decide how best to accommodate them.

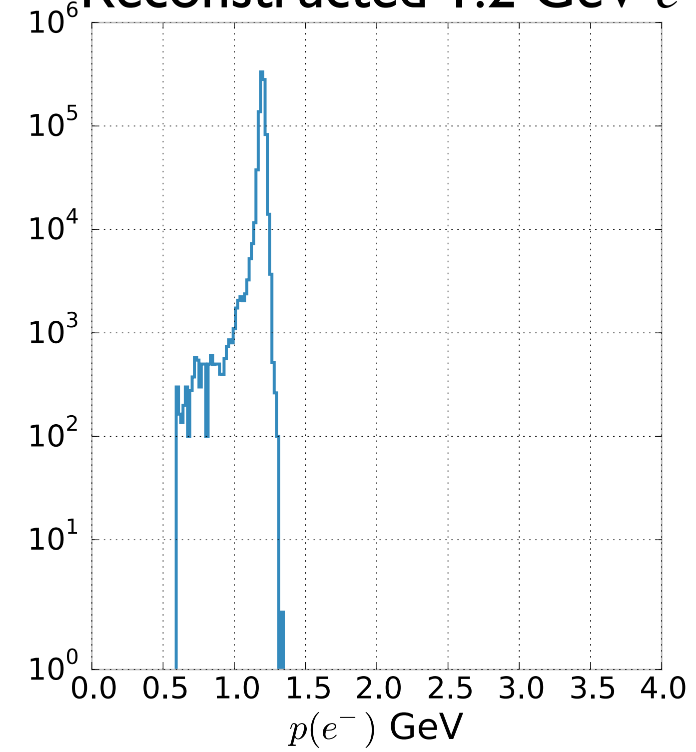
All of this needs more discussion and consideration!

Extra Slides

Tagging Tracker Performance

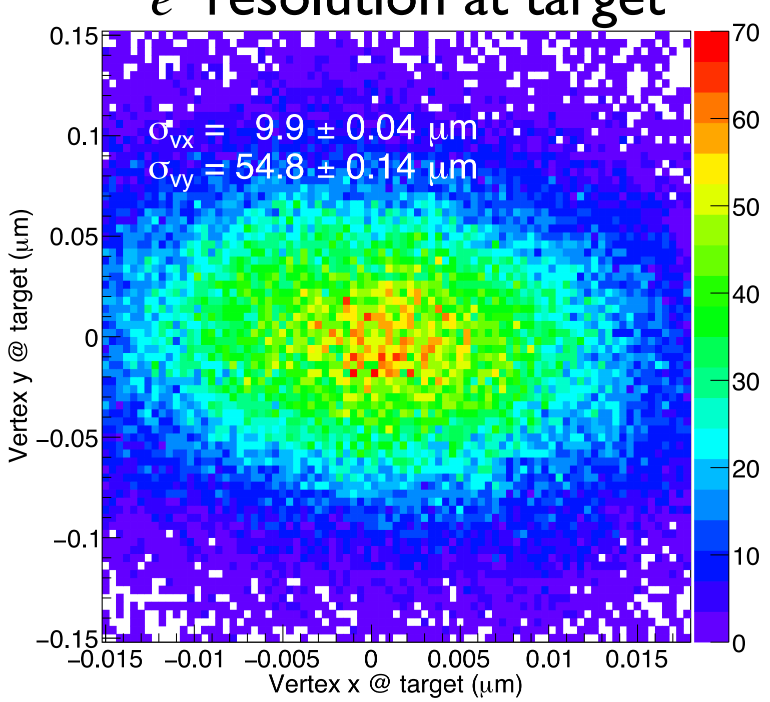
Tagger tracker cleanly separates tagged 4 GeV electrons from any off-energy component in beam →



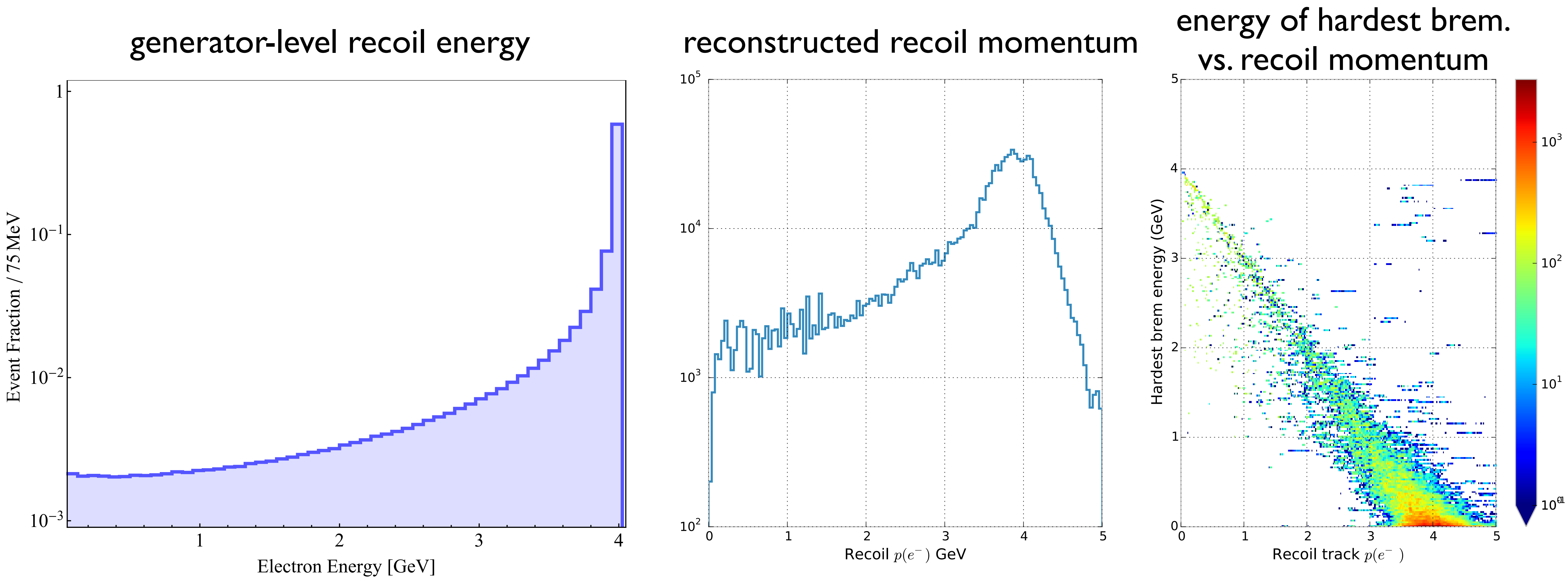


Resolution on (px, py) at target momentum at target is (1.0,1.4)MeV, small compared to 4 MeV smearing from multiple scattering in 10% X_0.

Excellent impact parameter resolution defines small "beamspot" for requiring a matched recoil track. →



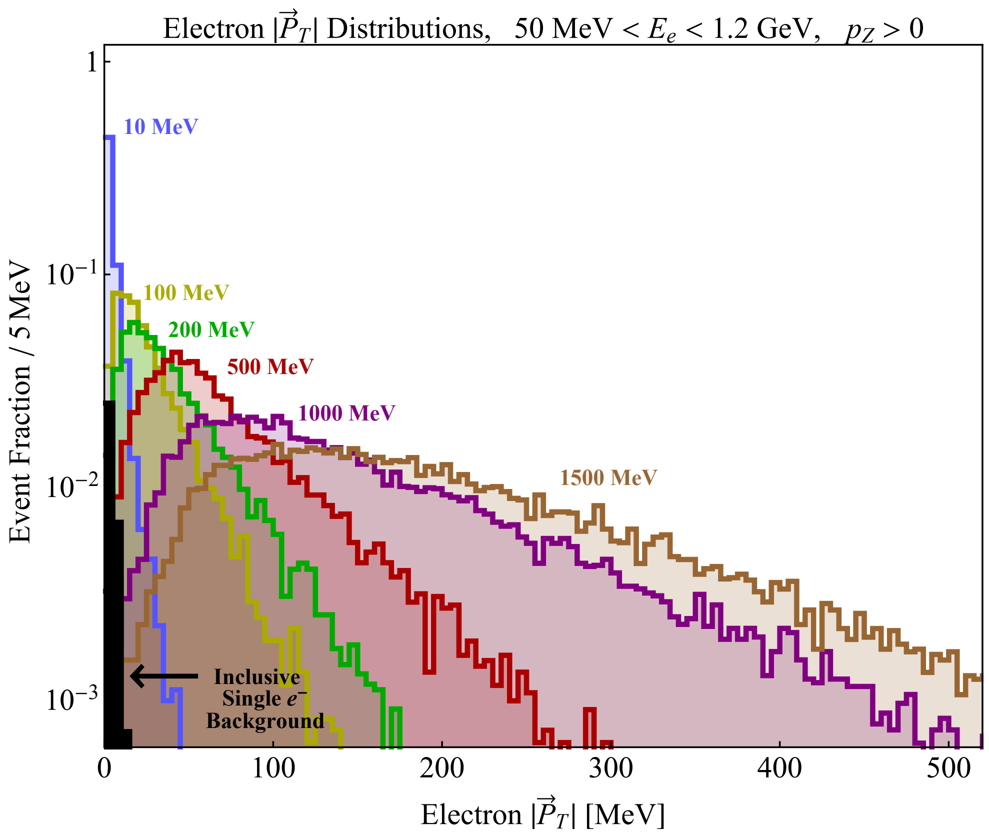
Recoil Tracker Momentum Resolution



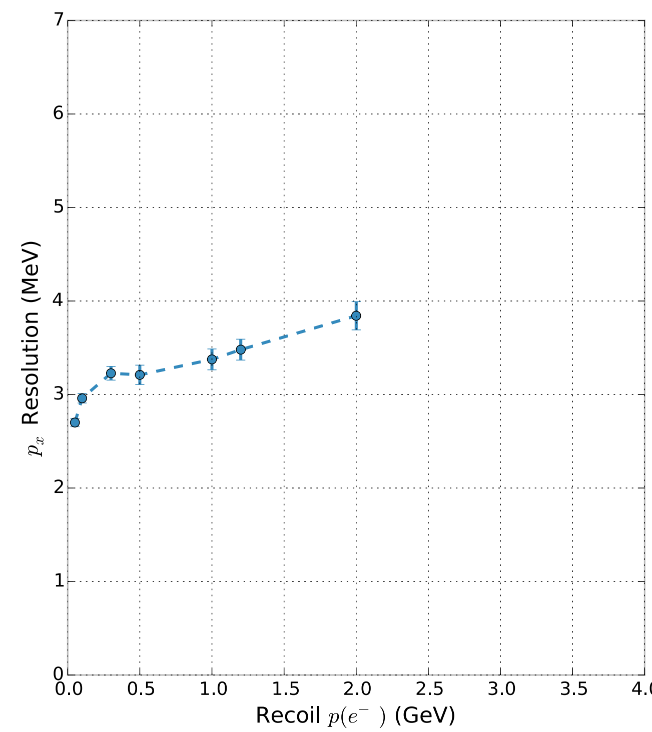
Despite compact size, recoil tracker has sufficient resolution to distinguish non-interacting 4 GeV electrons from low-momentum signal recoils.

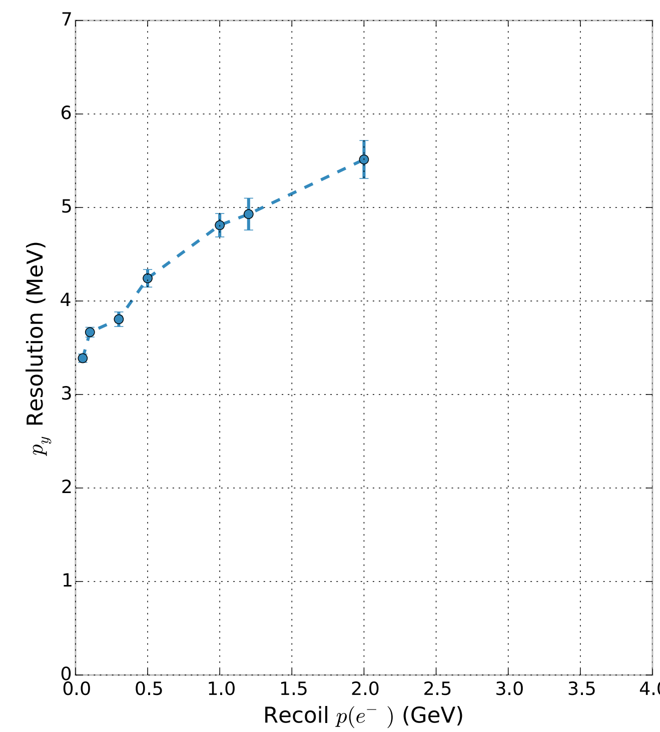
Recoil Tracker p_T and Impact Parameter Resolutions

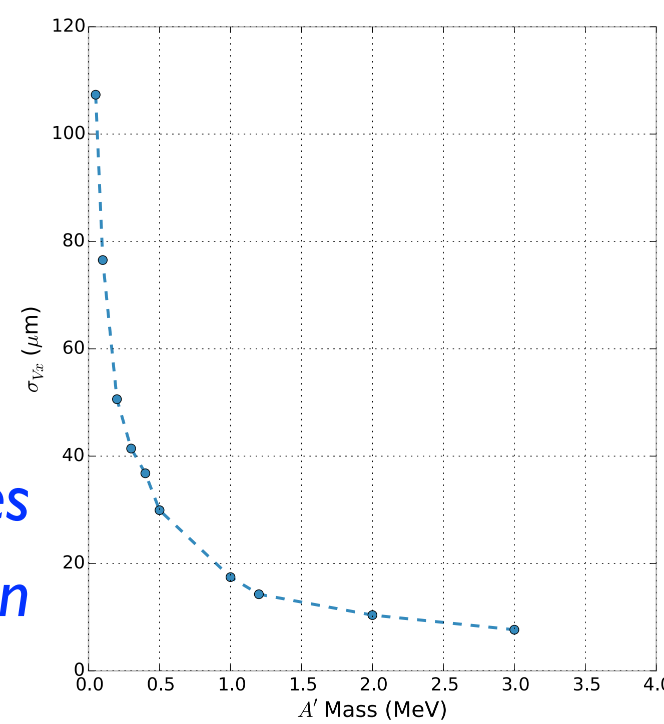
p_T distributions for signal, background

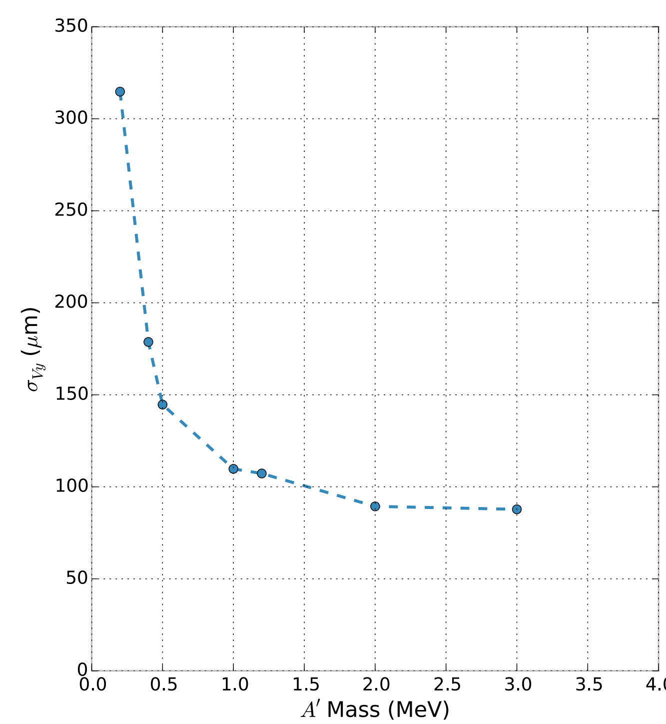


recoil p_T resolution is limited by scattering in target





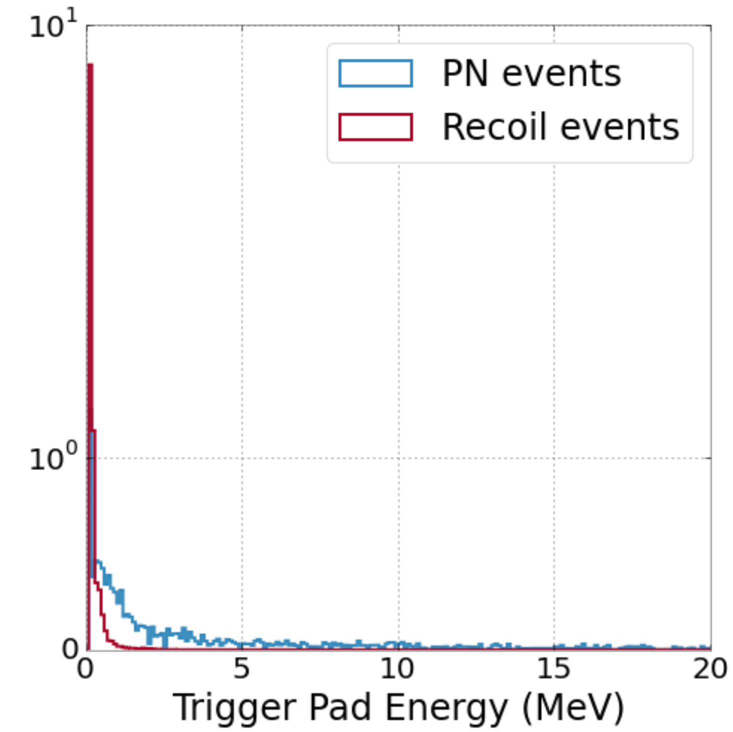




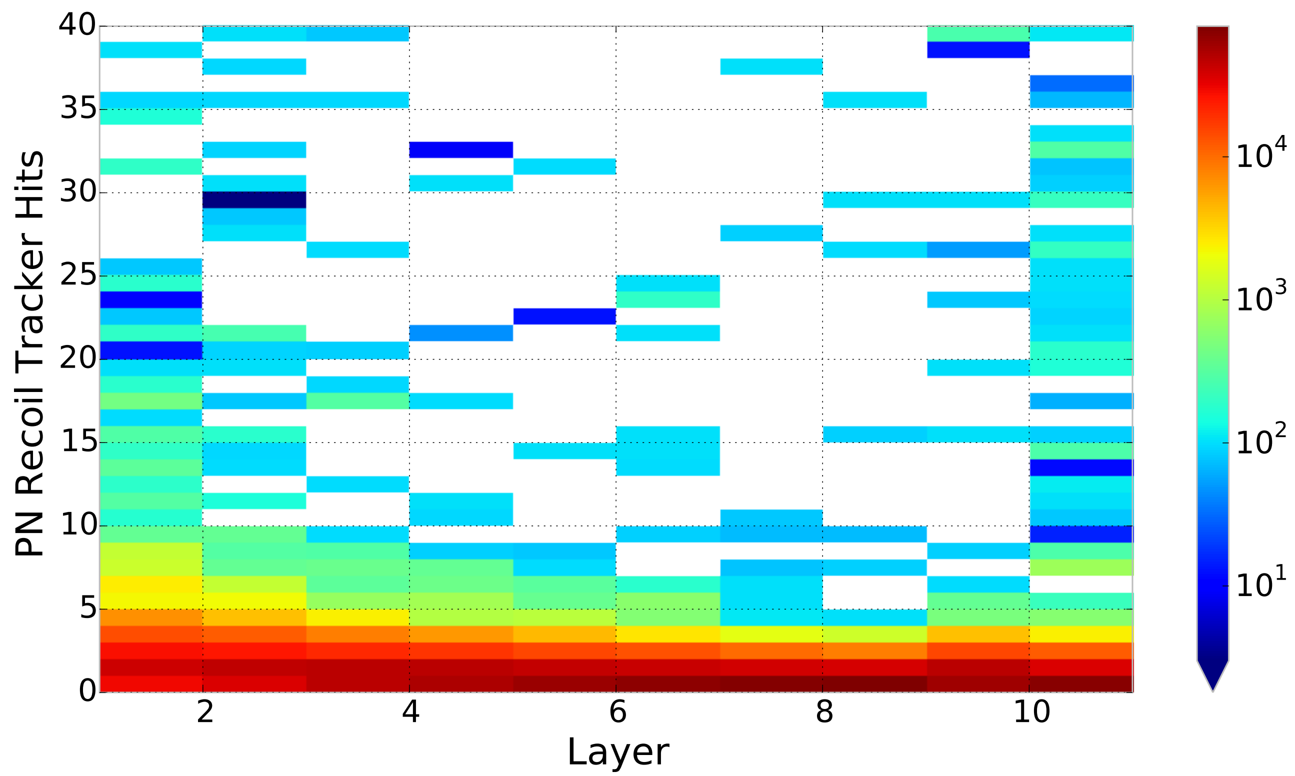
Impact parameter resolution enables tight matching criteria with tagged electron

Rejecting Photonuclear Reactions in Target

Trigger scintillator and recoil tracker can be used to reject events where a hard bremsstrahlung photon undergoes a photonuclear or electronuclear reaction in the target.



Recoil tracker occupancy from PN products
(recoil hits excluded)



efficiency vs. rejection for cut on trigger pad energy