LDMX -- Light Dark Matter eXperiment

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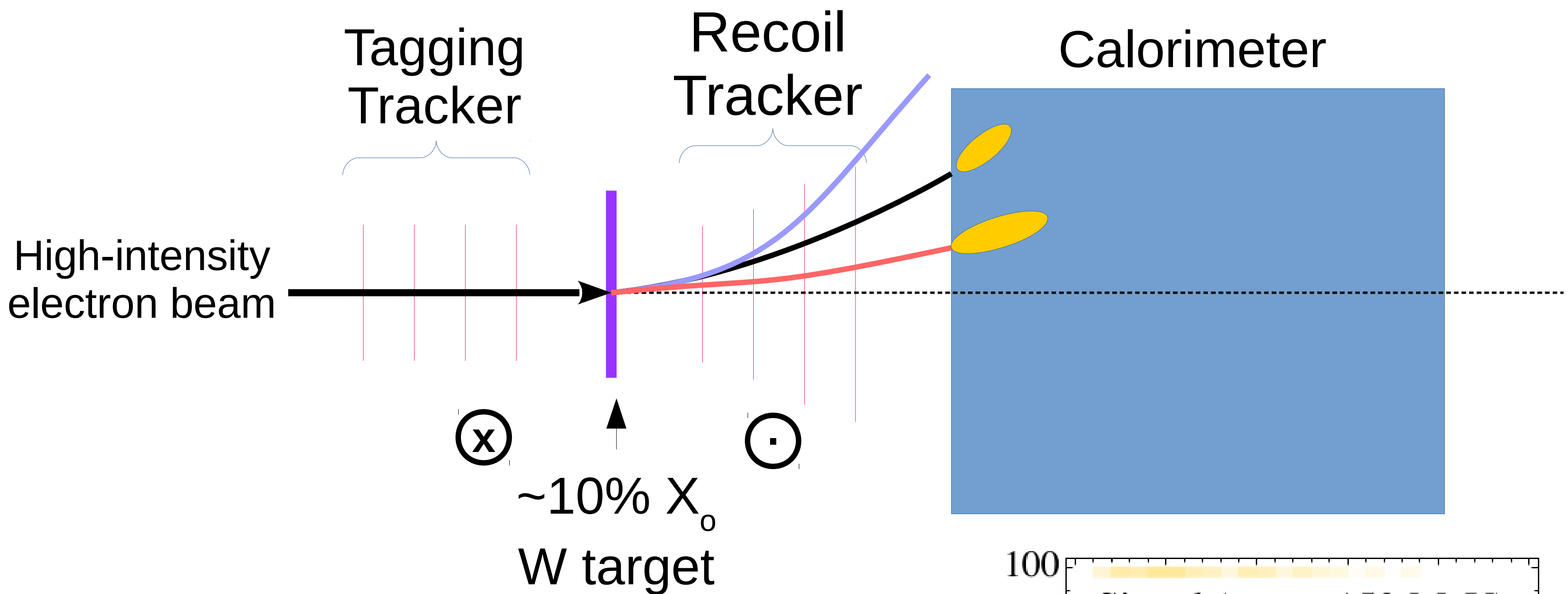
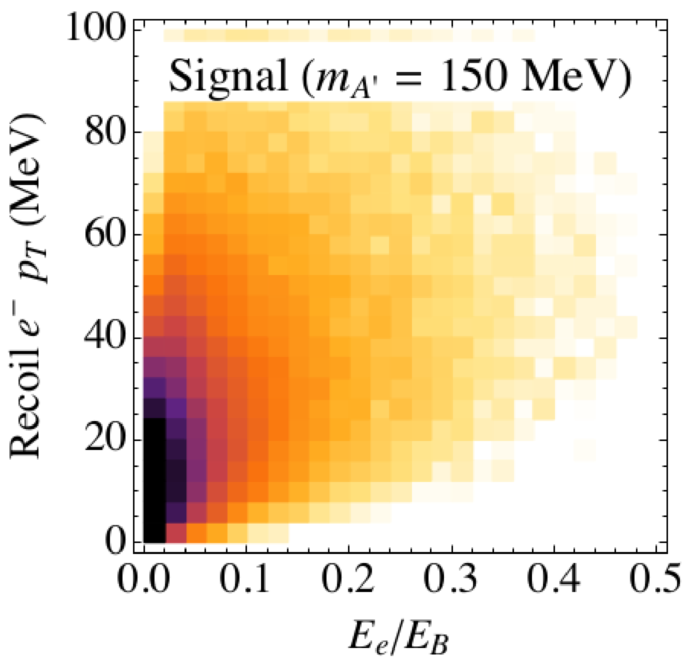
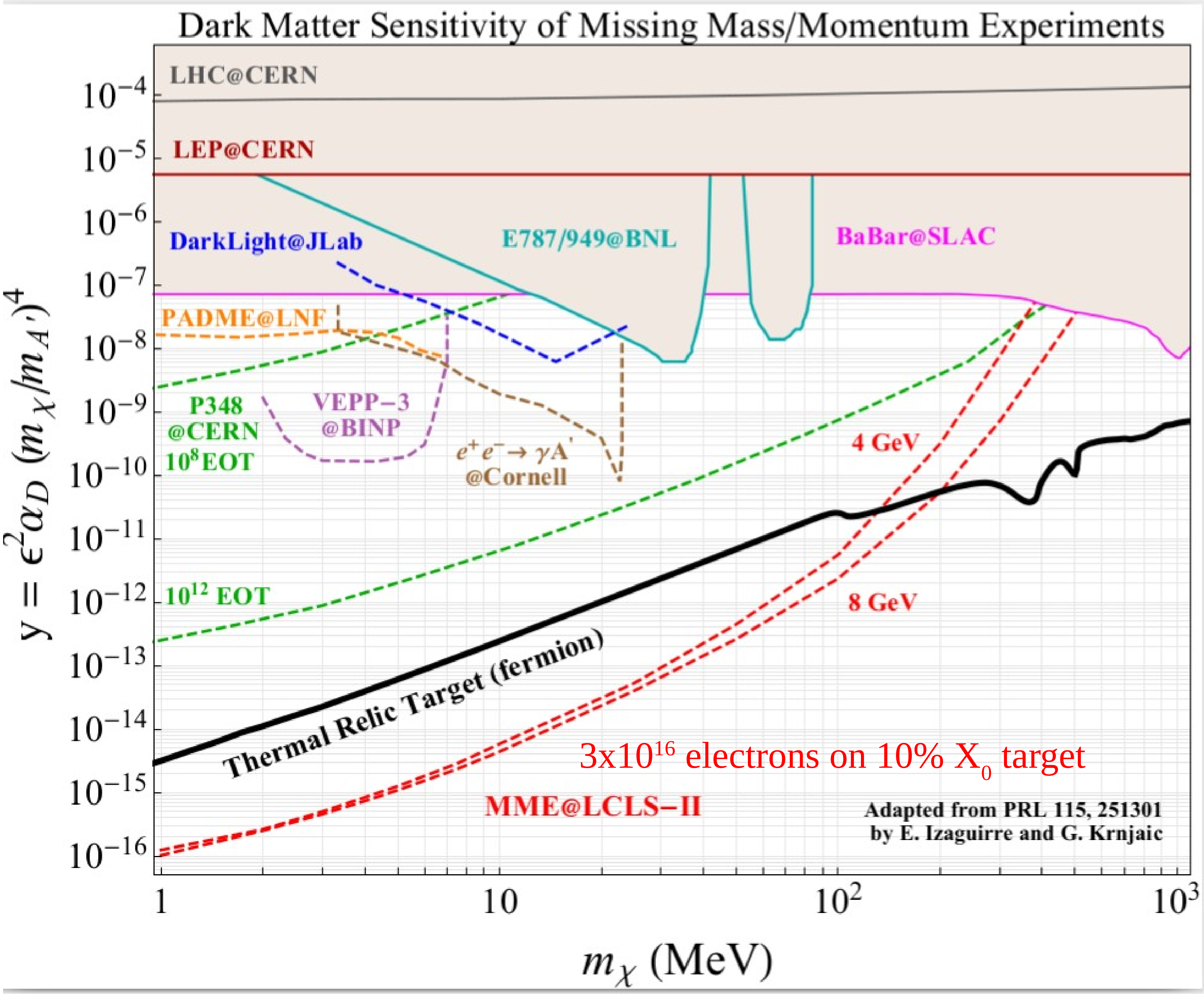
Cartoon Guide to LDMX



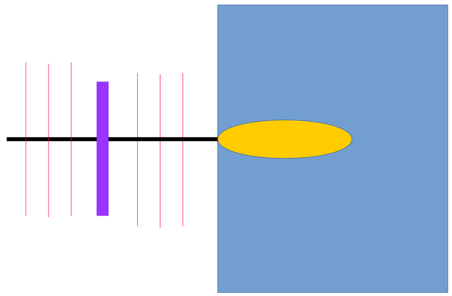


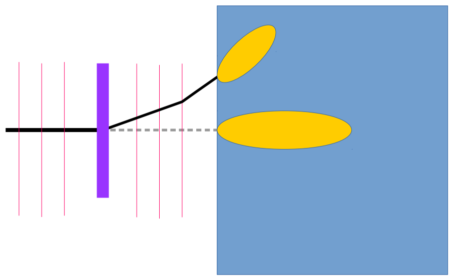
- **Signal definition is a low energy, moderate p_T electron and an otherwise empty calorimeter**
  - Recoil p_T between ~80 MeV and 800 MeV
  - Goal of 10^{15} – 10^{16} EOT

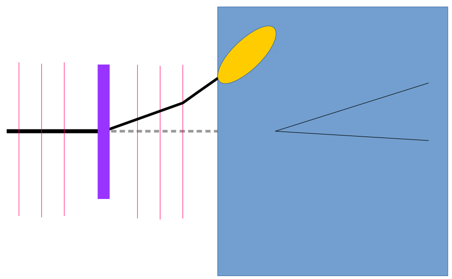
Potential Sensitivity



"Easy" Backgrounds

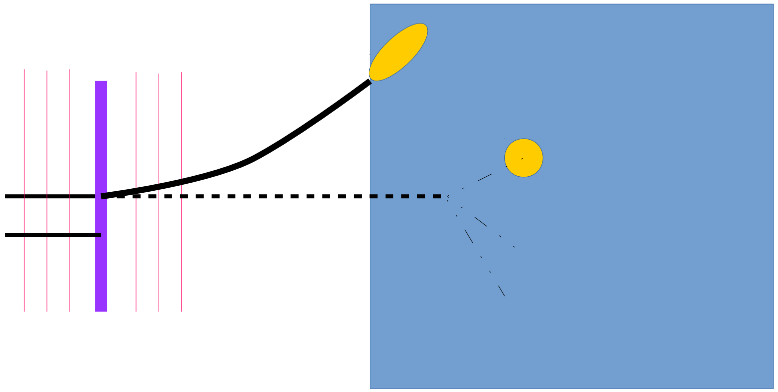


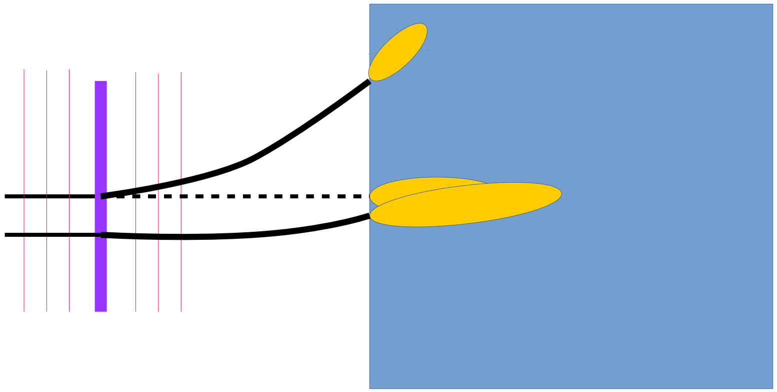




- **~Non-interacting beam**
  - Straight high-momentum track, full-energy cluster colinear* with incoming electron
- **Hard-brem**
  - Low momentum track, could be scattered at high angle
  - Fate of the photon
    - EM-shower: energetic cluster in calorimeter colinear with incoming electron
    - Hadronic interaction: often multiple charged particles (p,K,π,μ), sometimes nastier…

Hard Backgrounds/Signals

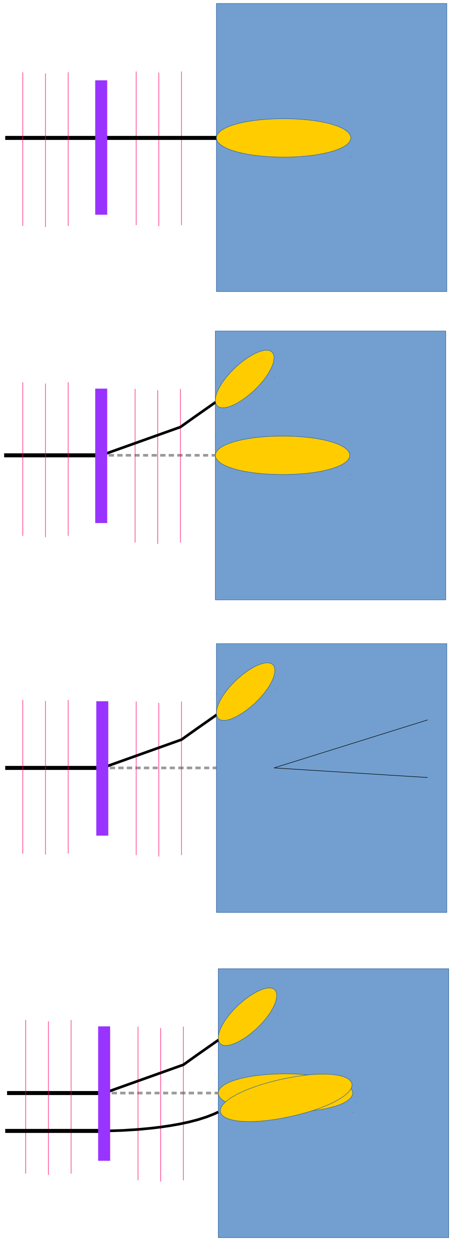




- **Neutron (and K_L) backgrounds**
  - $\gamma p \rightarrow \pi^+ n$
    - ~10^{-9}/EOT with forward π^+
    - *~10^{-11}/EOT with forward n*
  - $\gamma n \rightarrow n\bar{n}n$
    - ~10^{-9}/EOT

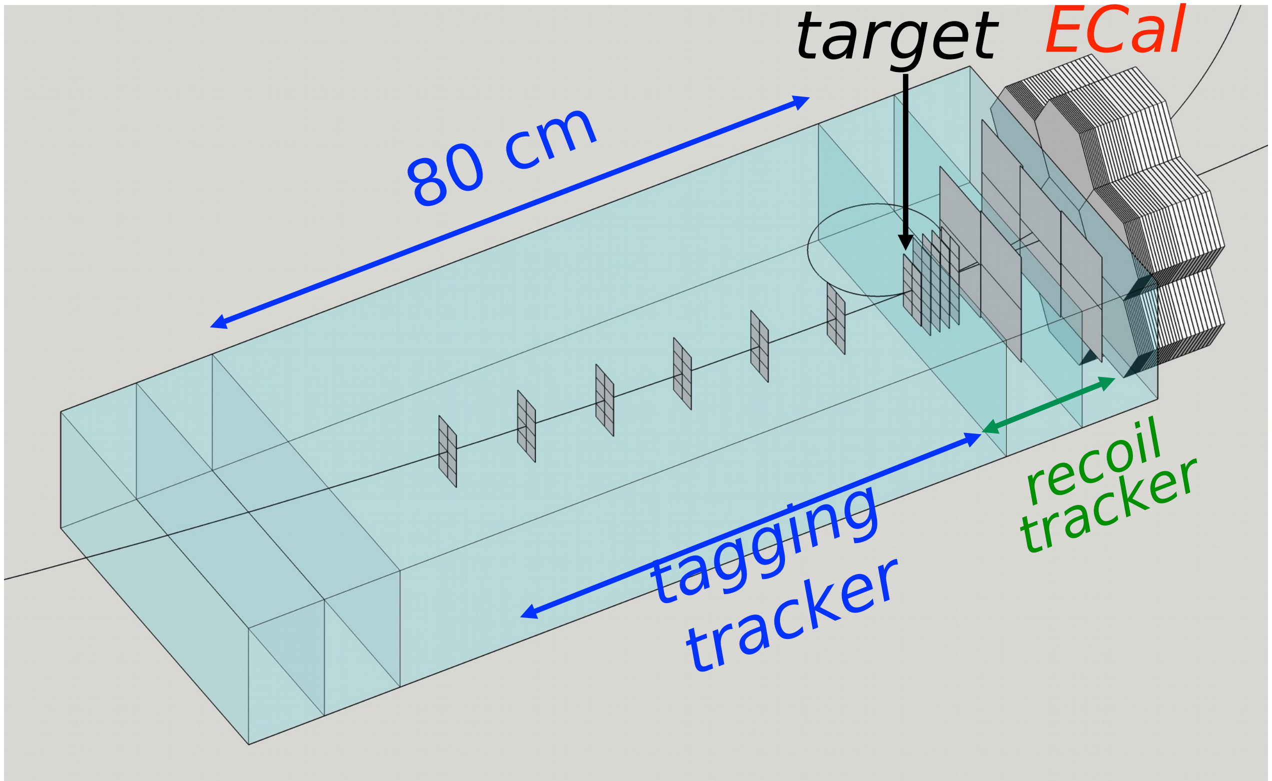
- **Pileup**
  - Background: "Medium" brem overlapping with 4 GeV electron shower
  - Signal: For ~1 GeV recoil electrons, overlap with 4 GeV primary electron

Requirements

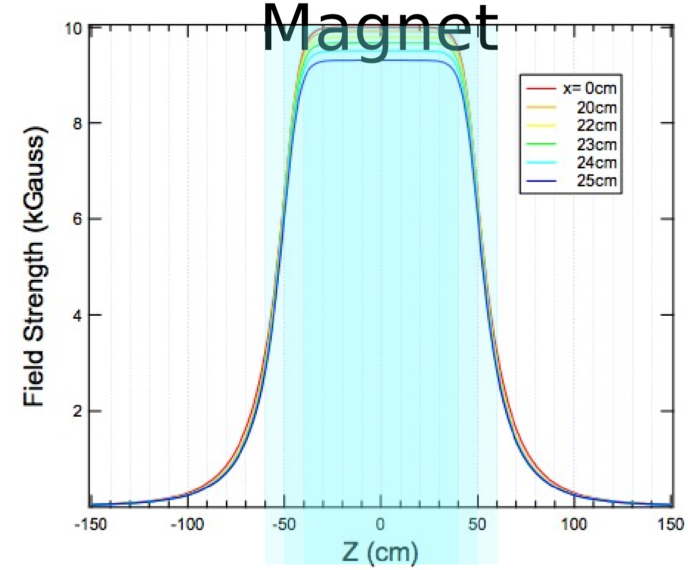


- Dense, fast calorimeter able to separate multiple showers to allow high-intensity beam
  - Must also be radiation-hard
- Incoming (tagger) tracking to pinpoint photon impact position, reject off-momentum incoming particles
- Outgoing (recoil) tracking to measure recoil electron, identify closely-spaced charged particles
- MIP-sensitivity in calorimeter to identify photonuclear processes

Experiment Concept



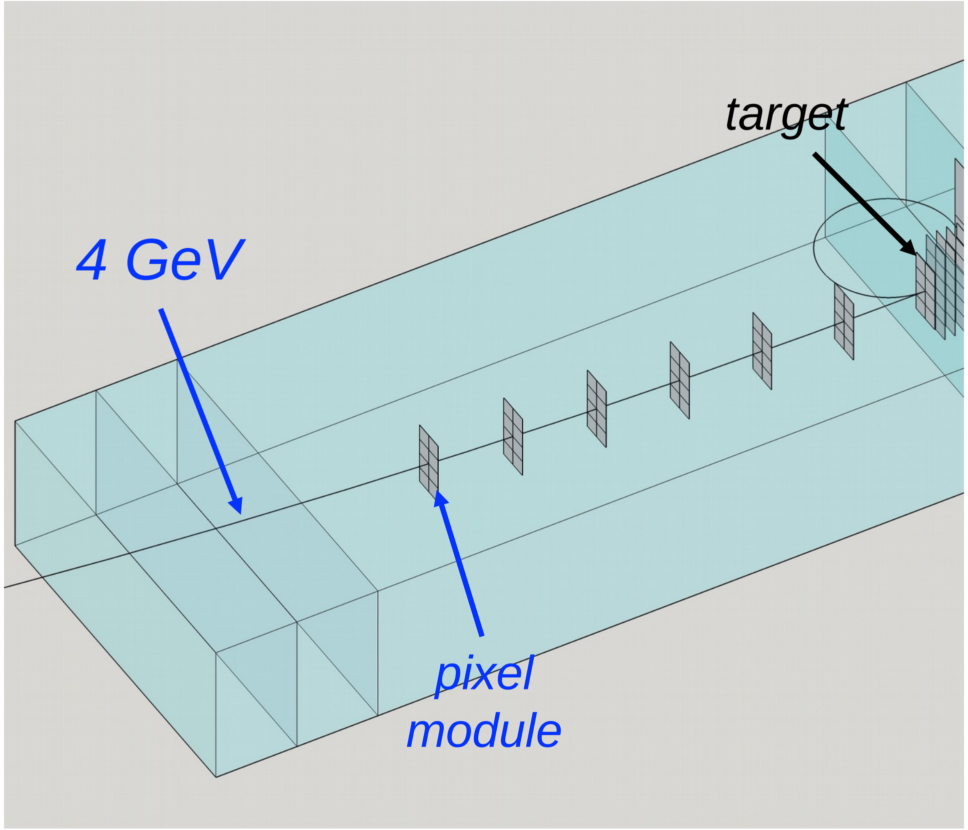
18D36 Dipole Magnet



- **Low mass trackers in dipole field and fringe field : leverage experience/technology from HPS and NA62**
- **Silicon/tungsten calorimeter for good shower separation and high rate capability: based on developments for CMS HL-LHC endcap calorimeter**

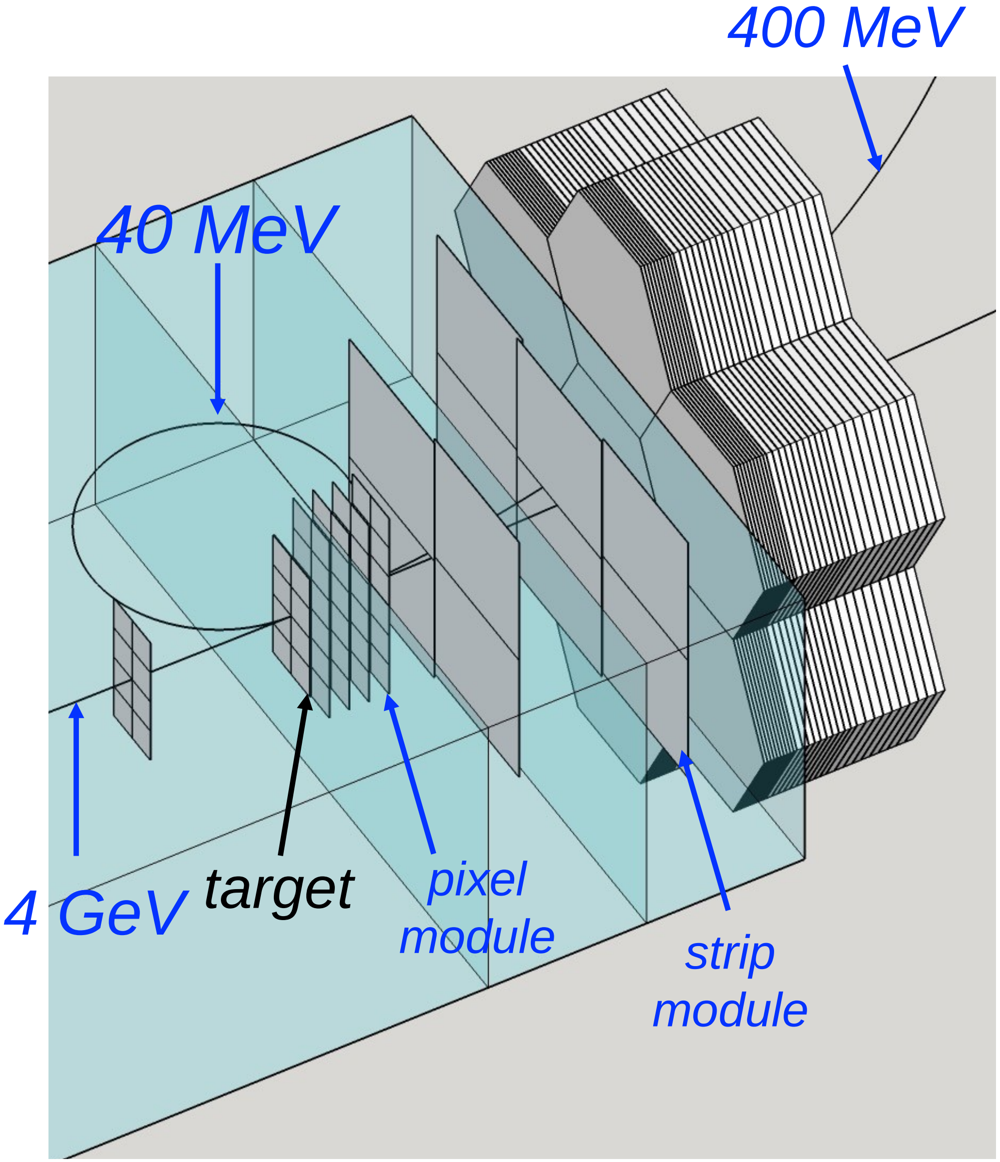
Tagging Tracker

- **Identify beam-energy electrons with extraordinary purity**
  - many layers over large lever arm in 1.5T field
  - low-mass construction in vacuum to minimize multiple scattering and production of secondaries
  - high S/N to minimize noise occupancy
  - fast readout, good time resolutionto reduce physics occupancy
- **For low intensities, silicon microstrips may work (~HPS)**
  - 0.7% X0/layer
  - 2 ns time resolution/hit
- **Highest intensities motivate pixels similar to NA62**
  - ≲0.5% X0/layer
  - microchannel CO_2 cooling
  - $100\mu m \times 100\mu m$ pixels
  - ≲1 ns time resolution

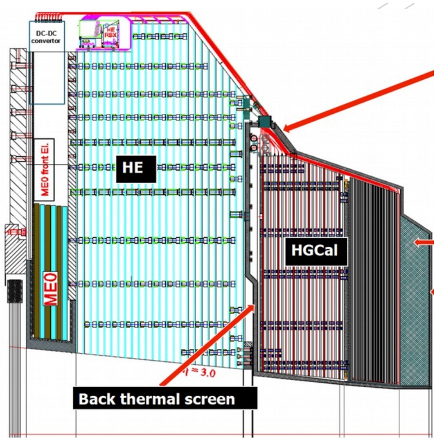


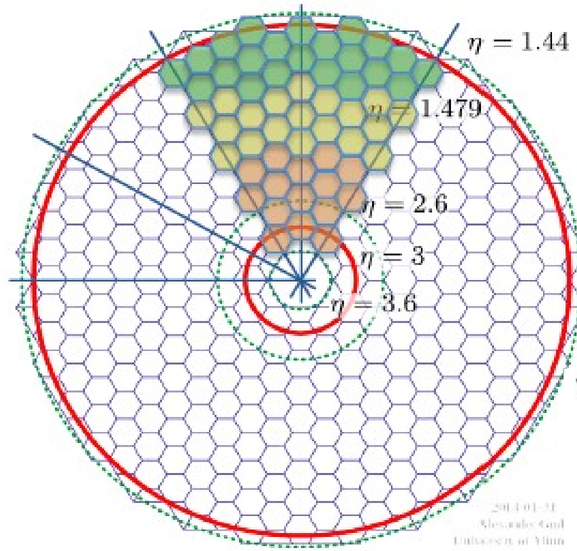
Recoil Tracker

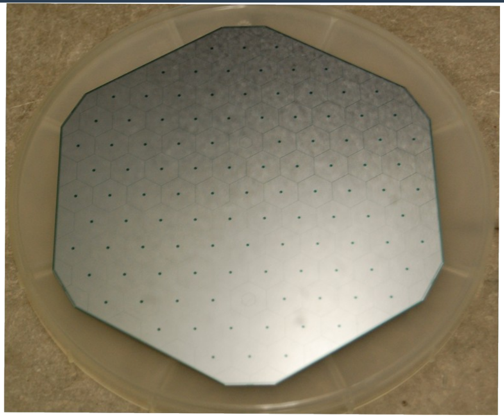
- **Measure E, pT of recoils, secondaries over large range in momentum and production angle in compact space**
  - many layers over **small** lever arm in **fringe field**
  - low-mass construction in vacuum to minimize multiple scattering and production of secondaries
  - high S/N to minimizes noise occupancy
  - fast readout, good time resolution to reduce physics occupancy
  - **readout must enable simple tracking in trigger, certainly for high intensities**
- **For low intensities, silicon microstrips may work**
  - 0.7% X0/layer
  - 2 ns time resolution/hit
- **Highest intensities and acceptance motivate pixels similar to NA62 for small layers closest to target**
  - ≲0.5% X0/layer
  - microchannel CO_2 cooling
  - 100μm × 100μm pixels
  - ≲1 ns time resolution

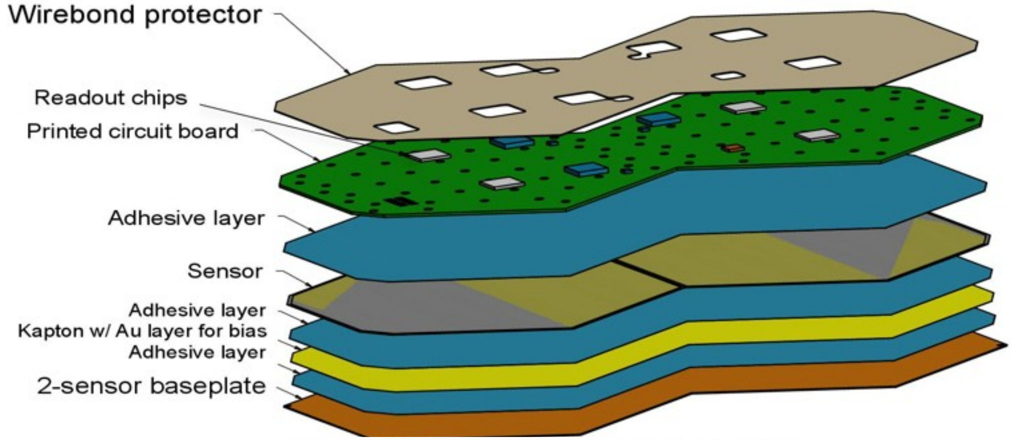


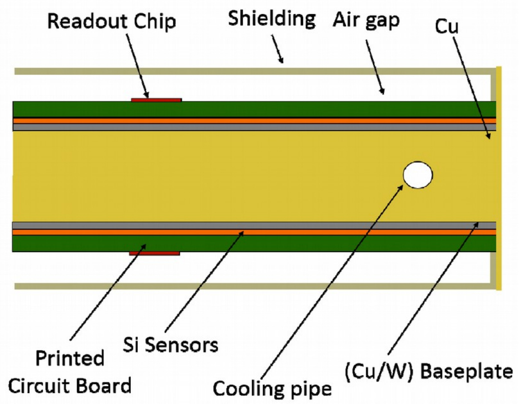
The CMS HL-LHC Endcap Calorimeter





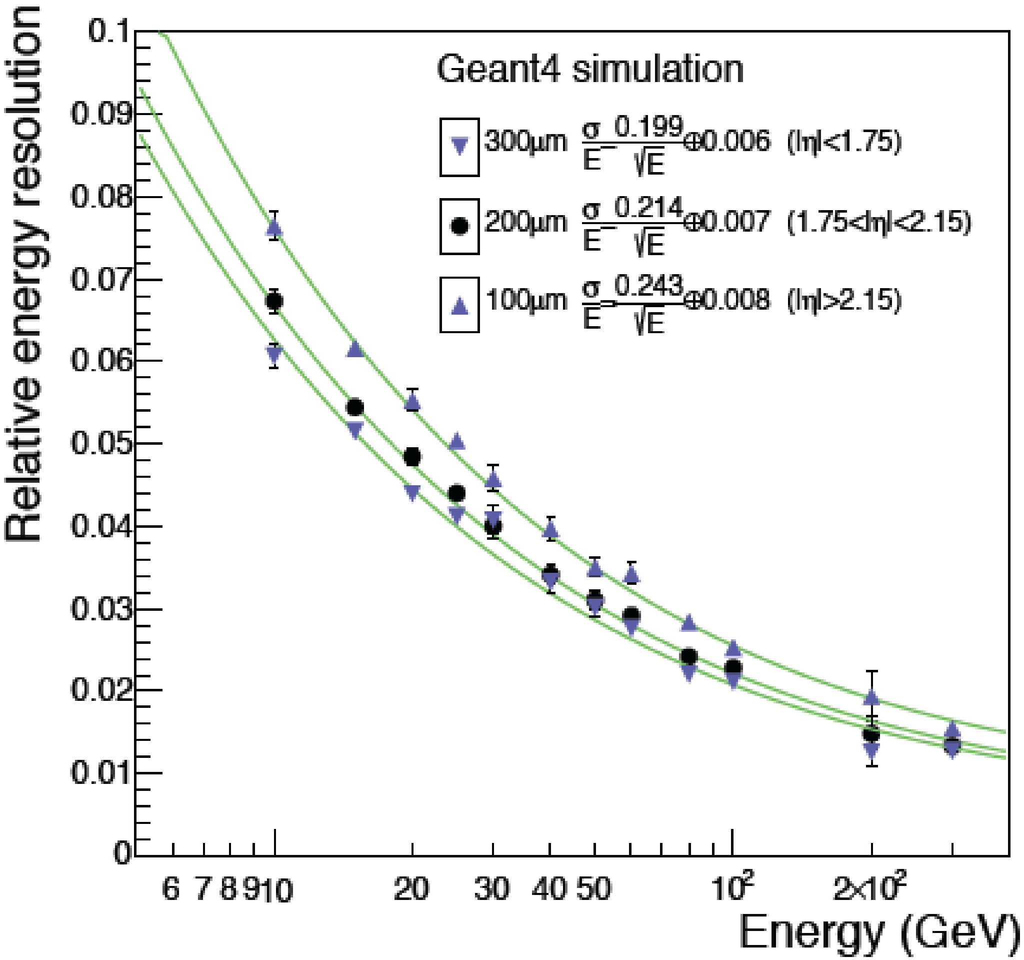






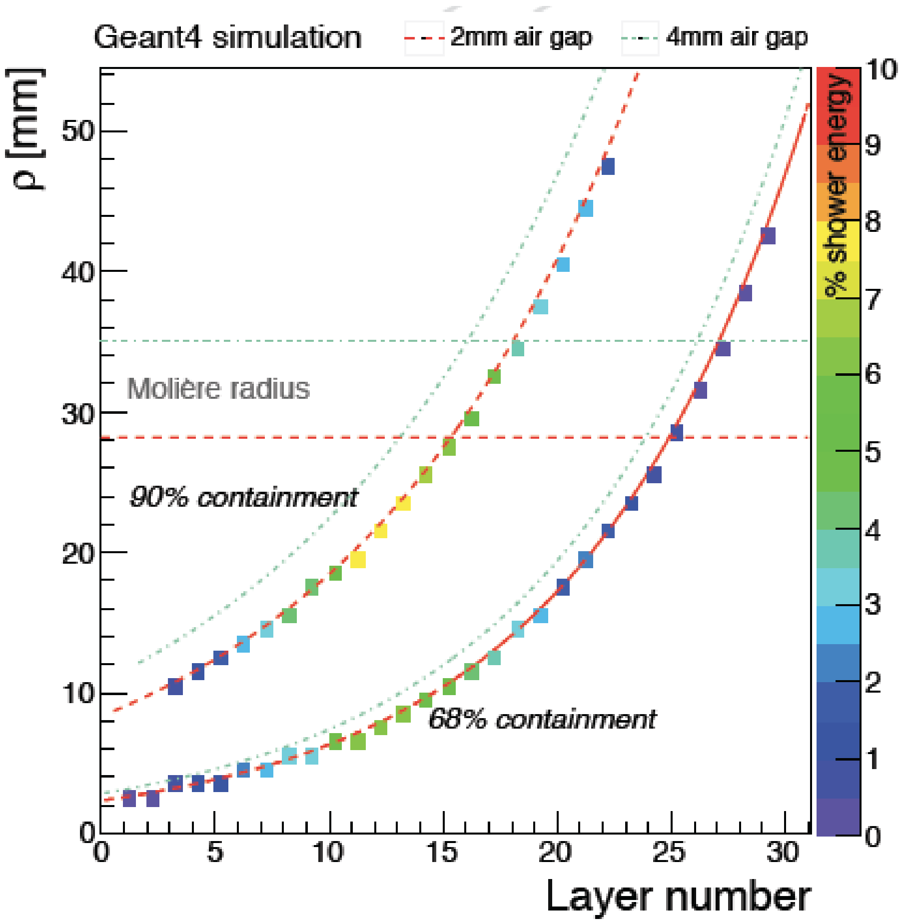
- **Modules consist of one or two hexagonal sensors with a copper/tungsten baseplate.**
- **Readout PCBs with integral readout ASICs glued on top and wirebonded down through holes in the PCB**
- **Copper cooling plates + CO_2 for heat removal**

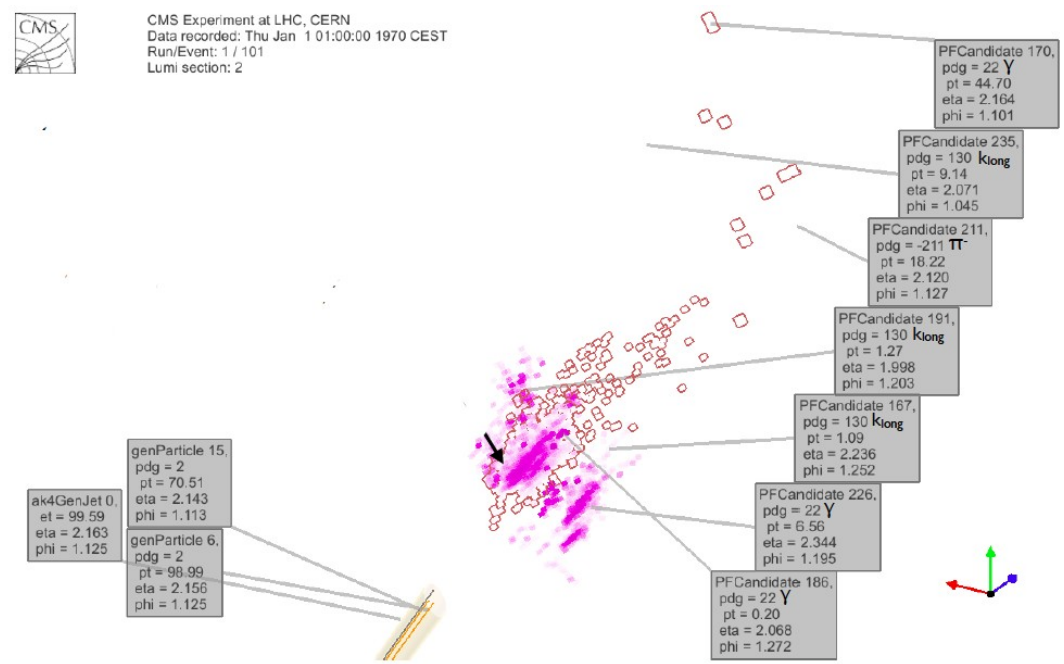
Performance of default design



- **Default design**
  - 10 layers with 0.65 X_0 spacing
  - 10 layers with 0.88 X_0 spacing
  - 8 layers with 1.25 X_0 spacing
- **For low-energy electrons, using 0.65 X_0 for more layers may be appropriate**
- **MIP sensitivity, S/N starts at 14, should stay above 7 for 10^{16} EOT**

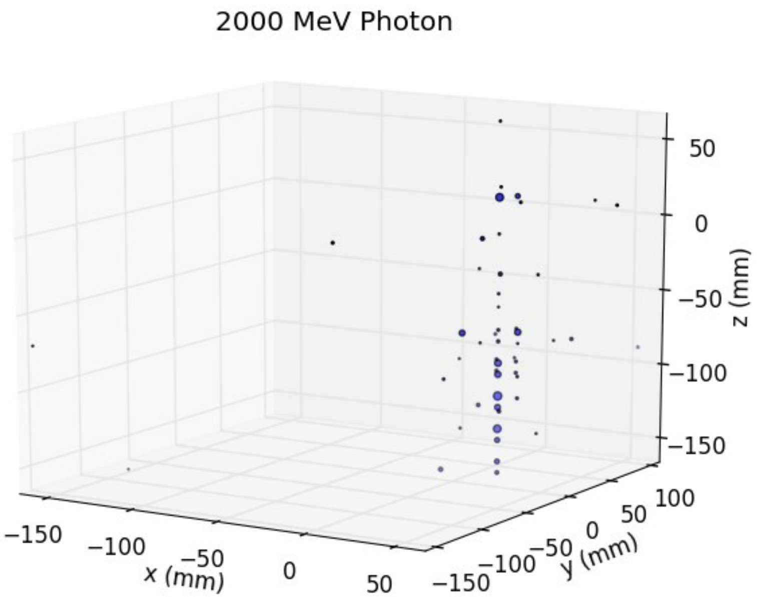
Cluster Separation



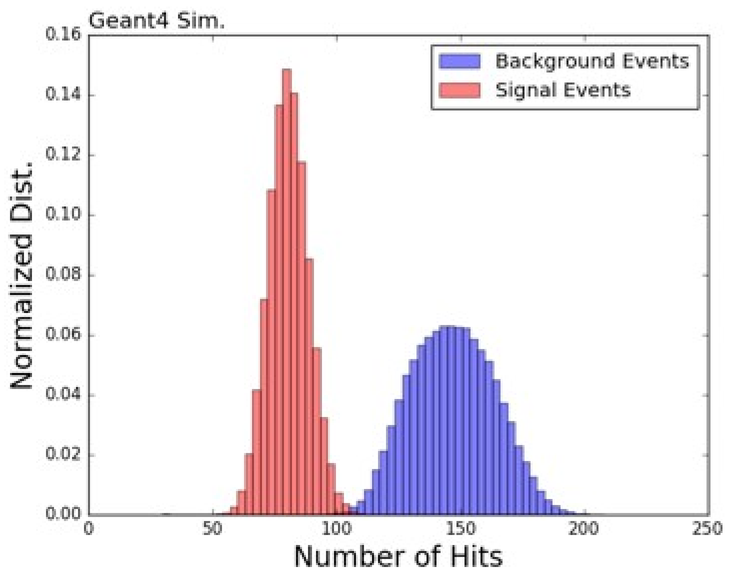


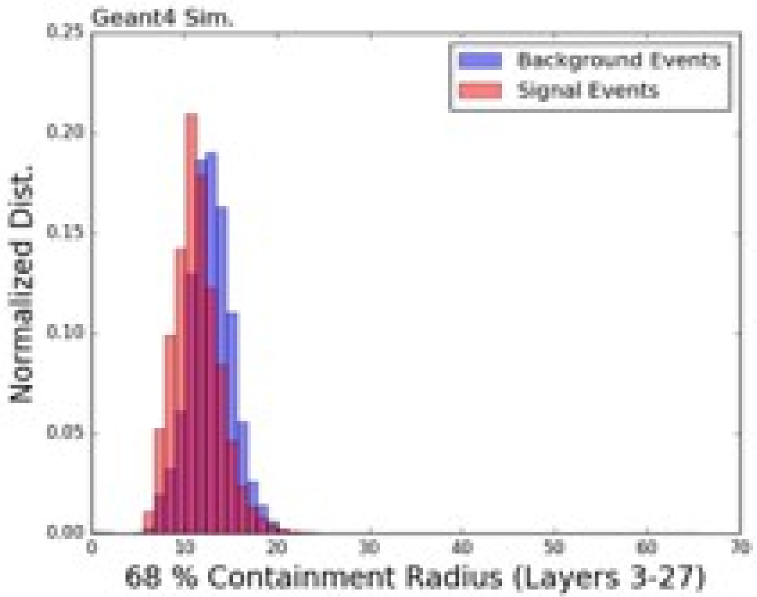
- **High-granularity in longitudinal shower development allows separation of closely-spaced showers by matching large amplitude signals at shower max with narrow signatures in the early layers**

Studies of Cluster Separation for LDMX

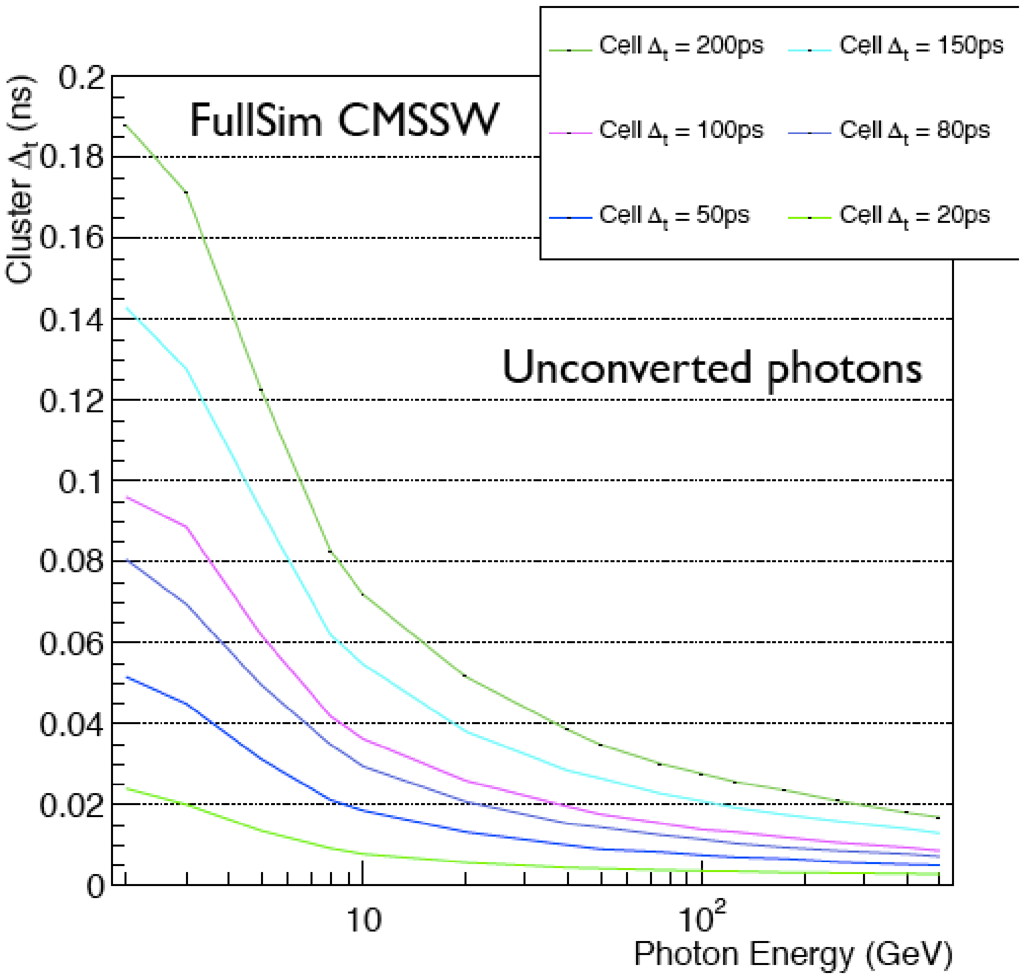


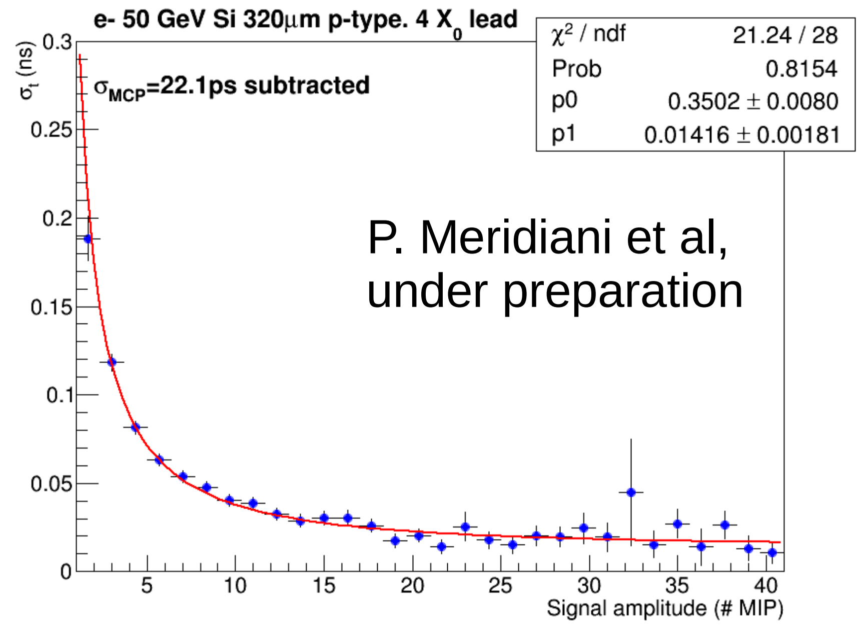
- **Study of separating a single 4 GeV electron from a 2-3 GeV brem photon plus a beam electron**
  - Hit counting and shower-shape variables are effective.





Potential of Timing

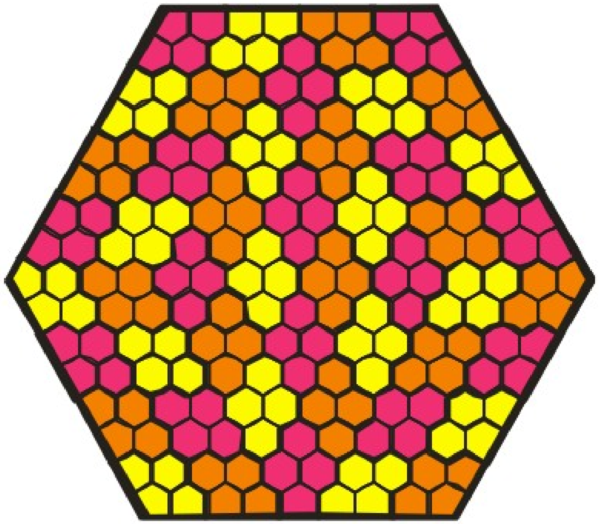


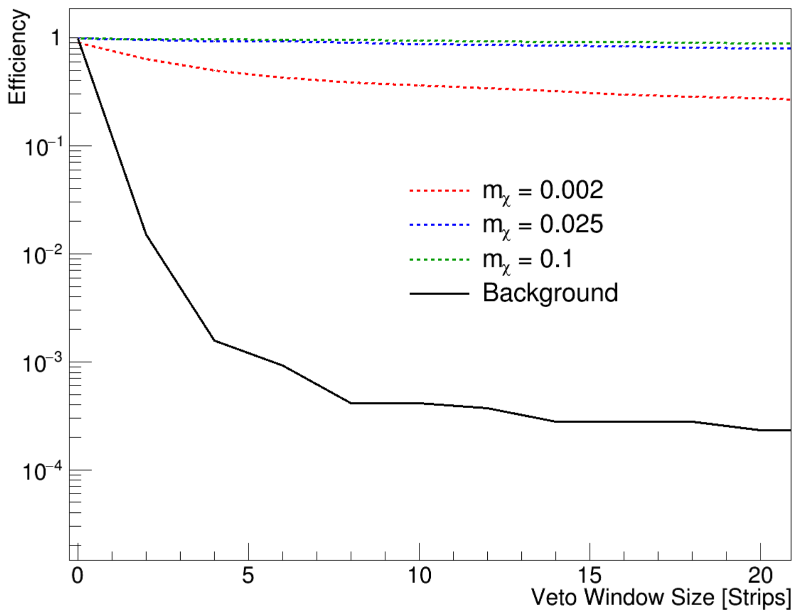


- **Simulation, backed by testbeam results, indicates that O(80 ps) timing should be possible for EM showers in the 2-4 GeV range**
  - Provides additional handle to separate clusters at higher beam current, correct effects of
  - Depending on beam configuration (e.g. deterministic RF dilution), can use for associating clusters with incoming beam particles

DAQ and Trigger

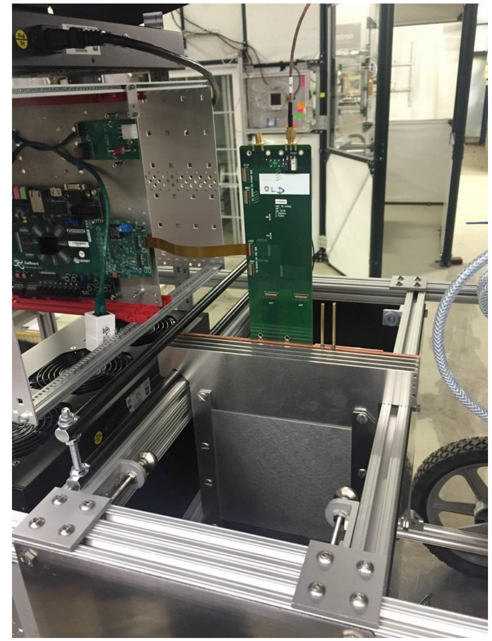
- **CMS FE-ASIC to produce 2x2 merged-cell trigger primitives (no TDC) at 40 MHz, full readout with TDC at 750 kHz**
  - Total 5 Gbps link count < 600 for full detector
  - Operational mode for 5ns bunch spacing with ASIC designed for 25ns requires study
- **Trigger algorithm required to drop rate to ~750 kHz**
  - 10^{16} EOT in a year implies ~1 GHz
  - At low intensities, trigger may be possible by looking for events with less than 2 GeV in the calorimeter
  - At higher intensities, trigger will likely require input from either tagging tracker or recoil tracker

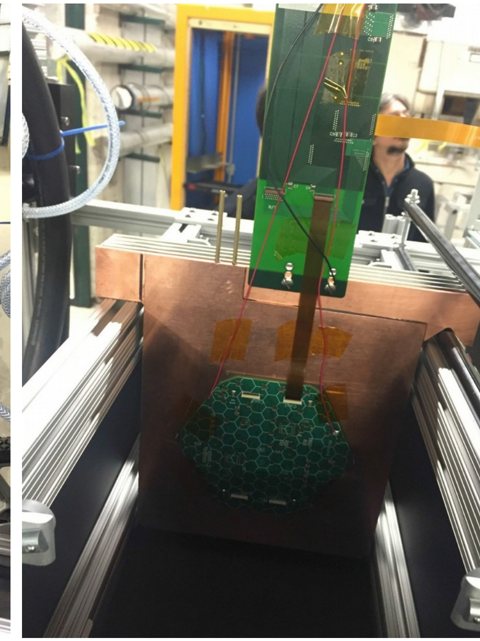




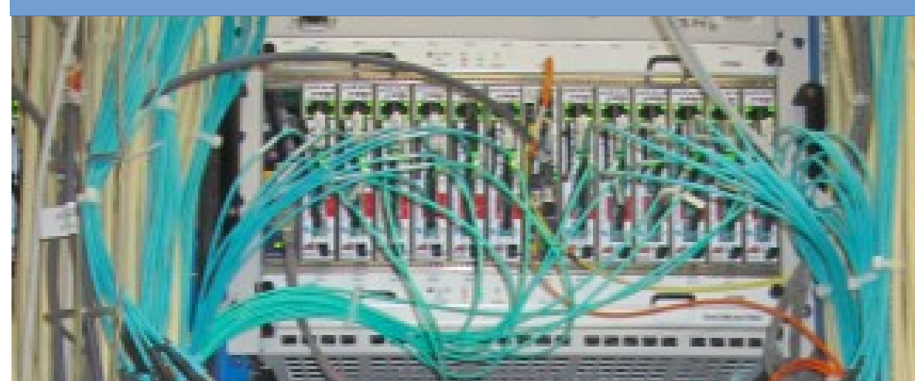
Status of the CMS HL-LHC Endcap R&D

- **Testbeam studies at FNAL in March and May 2016**
  - Production-candidate sensors with CALICE-type readout chip (low rate)
  - Results (preliminary!) are good for S/N and absence of anomalous signals
- **First full-scale FE-ASIC expected in 2017, much of readout chain technology already demonstrated**





CMS HCAL Phase 1 Readout Electronics



Conclusion

- **Physics potential for LDMX is very exciting**
  - Target large range of thermal relic phase phase, possibility for study of characteristics of dark matter in the case of discovery
- **Experiment is realistic based on technologies in use or under development for HL-LHC experiments**
- **More collaborators are welcome!**