THE LDMX EXPERIMENT

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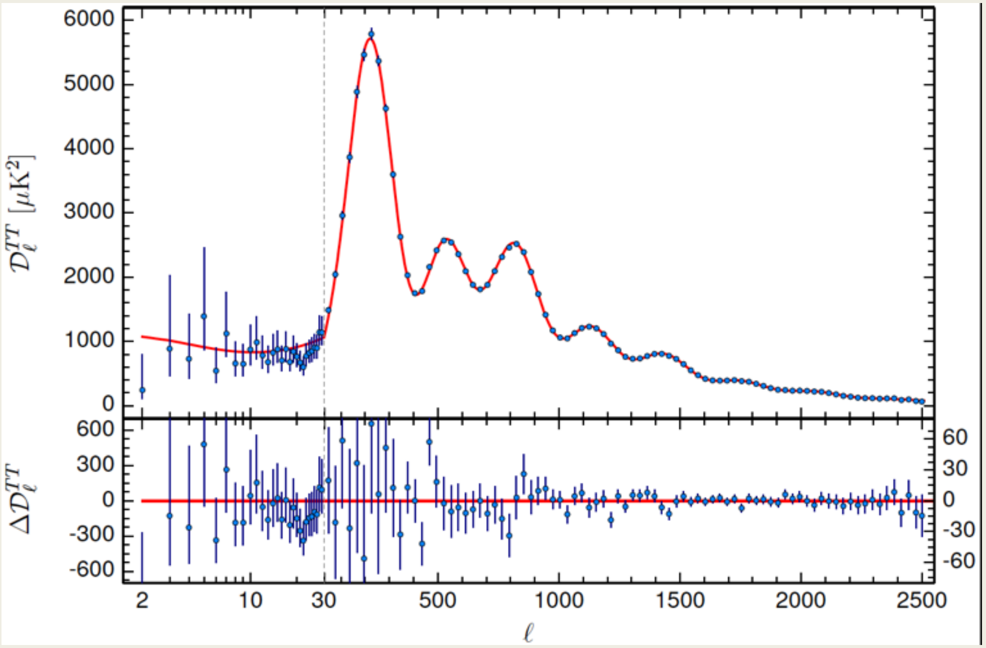
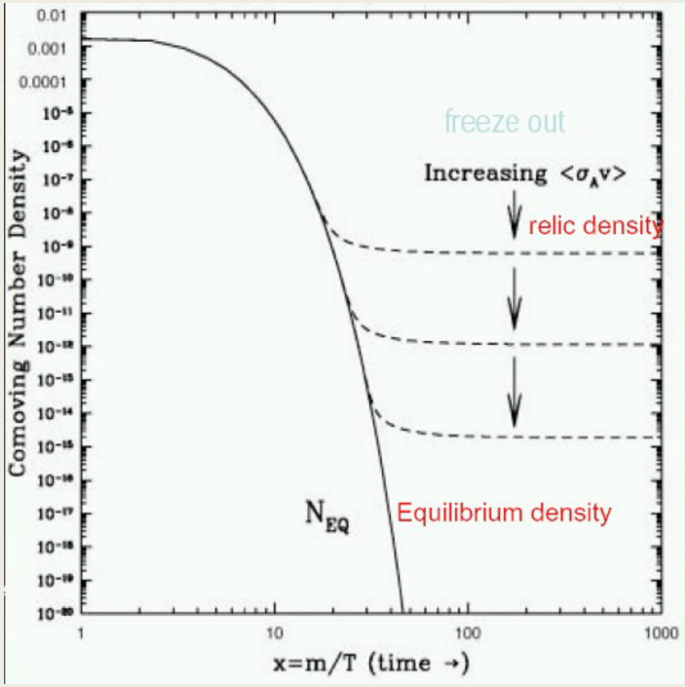
ON BEHALF OF THE LDMX TEAM
OCTOBER 25, 2016

The Thermal Relic Target





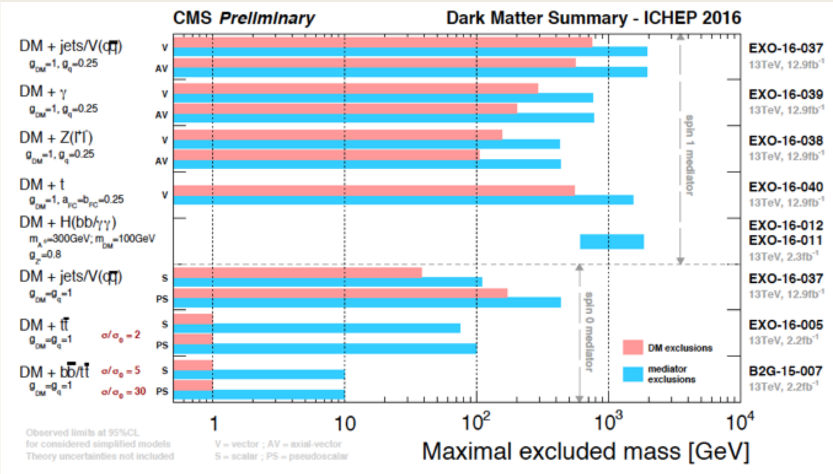
- The measurements of the cosmic microwave background establish a matter-density target for dark matter.
- If the dark matter is produced thermally, the observed abundance sets a requirement for the ratio between coupling and particle mass.

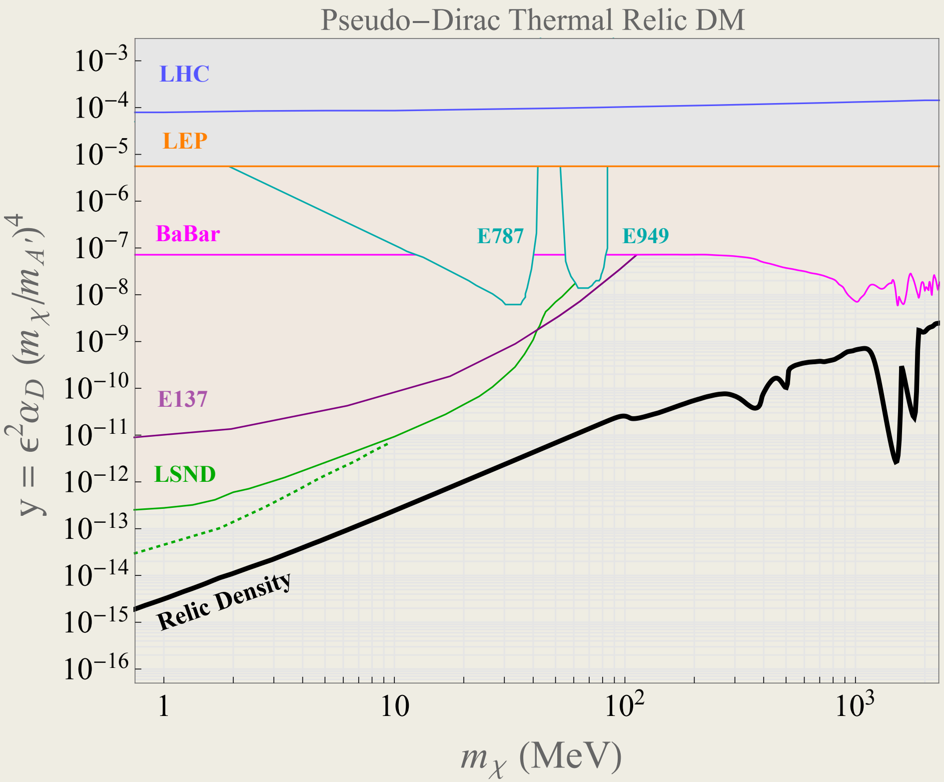
$$Y \sim \frac{1}{\langle \sigma v \rangle^2 m M_{pl}}$$

The lower the mass, the weaker the coupling!

WIMPs are dead, long live the LDM?

- Various searches at the LHC are excluding the most “naive” version of the WIMP miracle: a weak-scale-coupling which implies an ~100 GeV particle

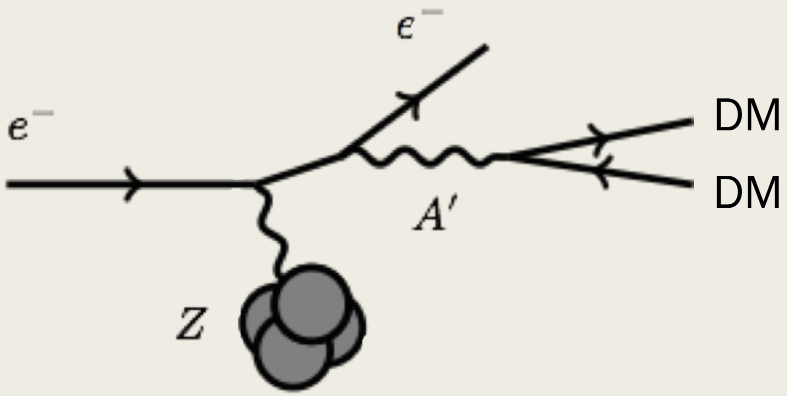




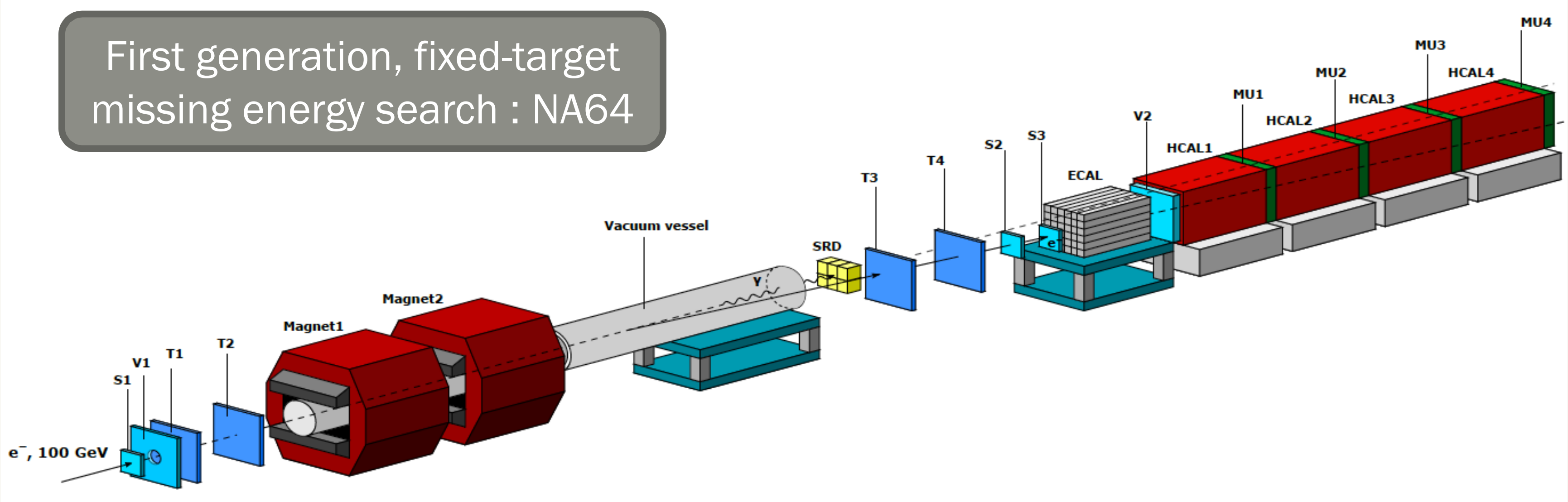
- The lighter part of the phase space is much harder to access – the coupling must be much lower, which makes it difficult to produce in a collider
- Fixed-target configurations are likely the only way to get large-enough luminosities

Missing Momentum Concept

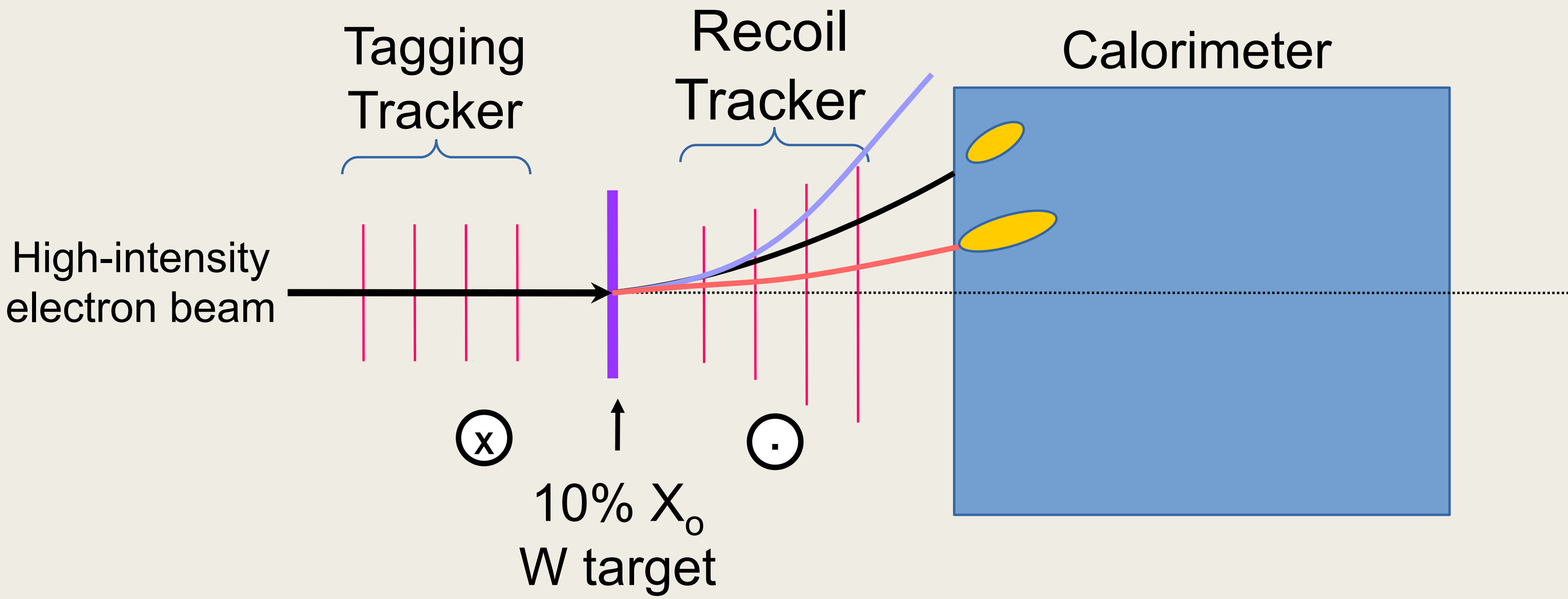
- Disappearance measurement: Use an electron beam on an active fixed target and identify events where momentum (energy) is lost
  - Use of a moderate energy electron beam suppresses neutrino backgrounds compared with proton beams



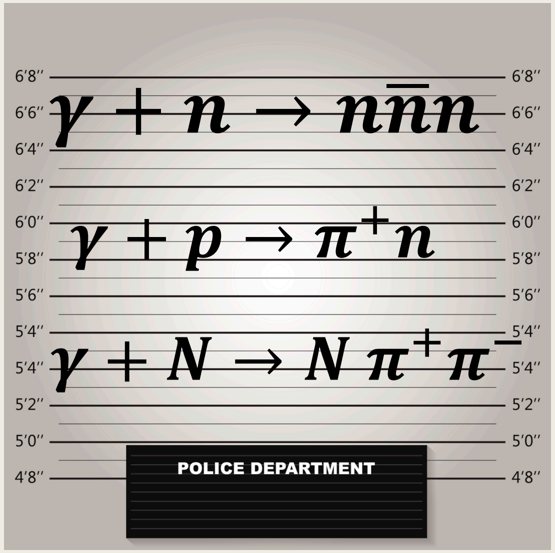
First generation, fixed-target missing energy search : NA64



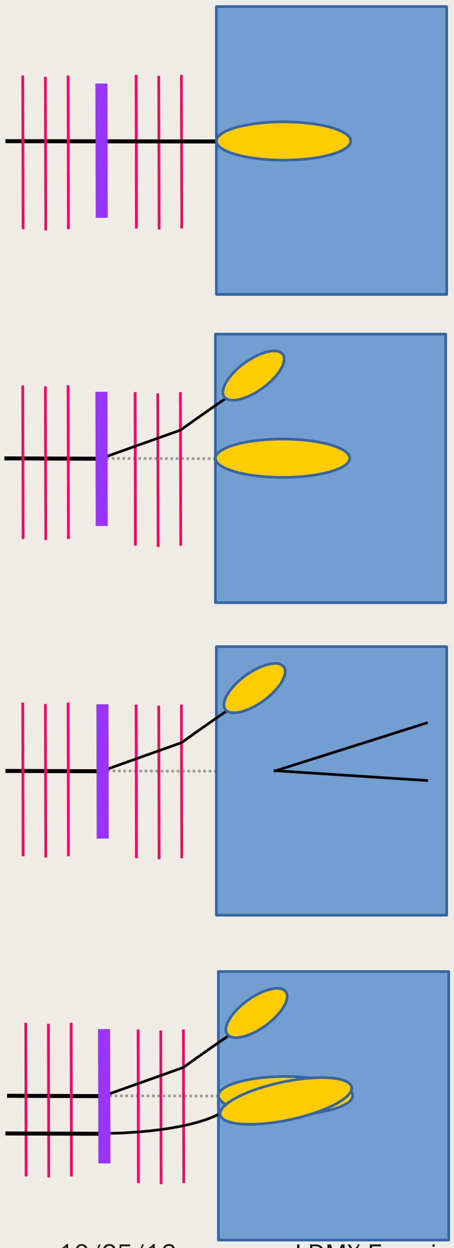
Cartoon Guide to LDMX



- Signal definition is a low energy, moderate p_T electron and an otherwise empty calorimeter given a full-energy beam electron
  - Recoil p_T between ~80 MeV and 800 MeV
- Backgrounds come from hard interactions in the target (e.g brehmstrahlung)
  - Several challenging backgrounds arise when the forward photon has a photonuclear interaction



Requirements

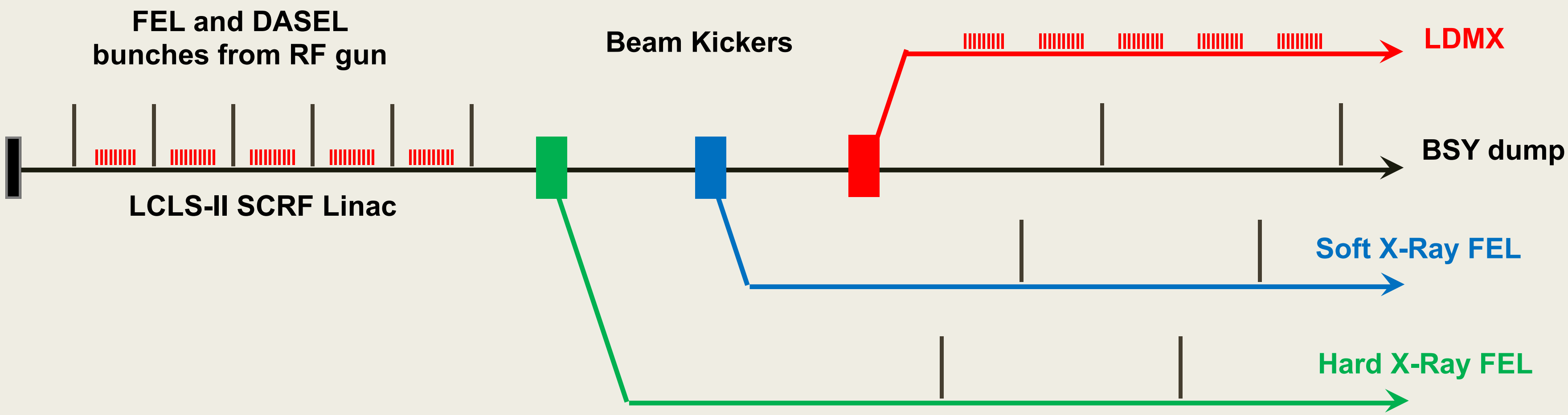


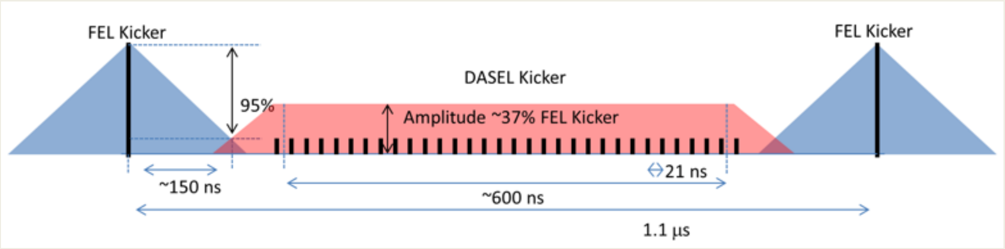
- Dense, fast calorimeter able to separate multiple showers to allow high-intensity beam
  - *Must also be radiation-hard*
- Incoming (tagger) tracking to pinpoint photon impact position, reject off-momentum incoming particles
- Outgoing (recoil) tracking to measure recoil electron, identify closely-spaced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

Beam requirements and concept

- To reach the thermal relic target, $O(10^{15} - 10^{16})$ electrons-on-target are required, at a one (few) at-a-time rate: high charge, low current

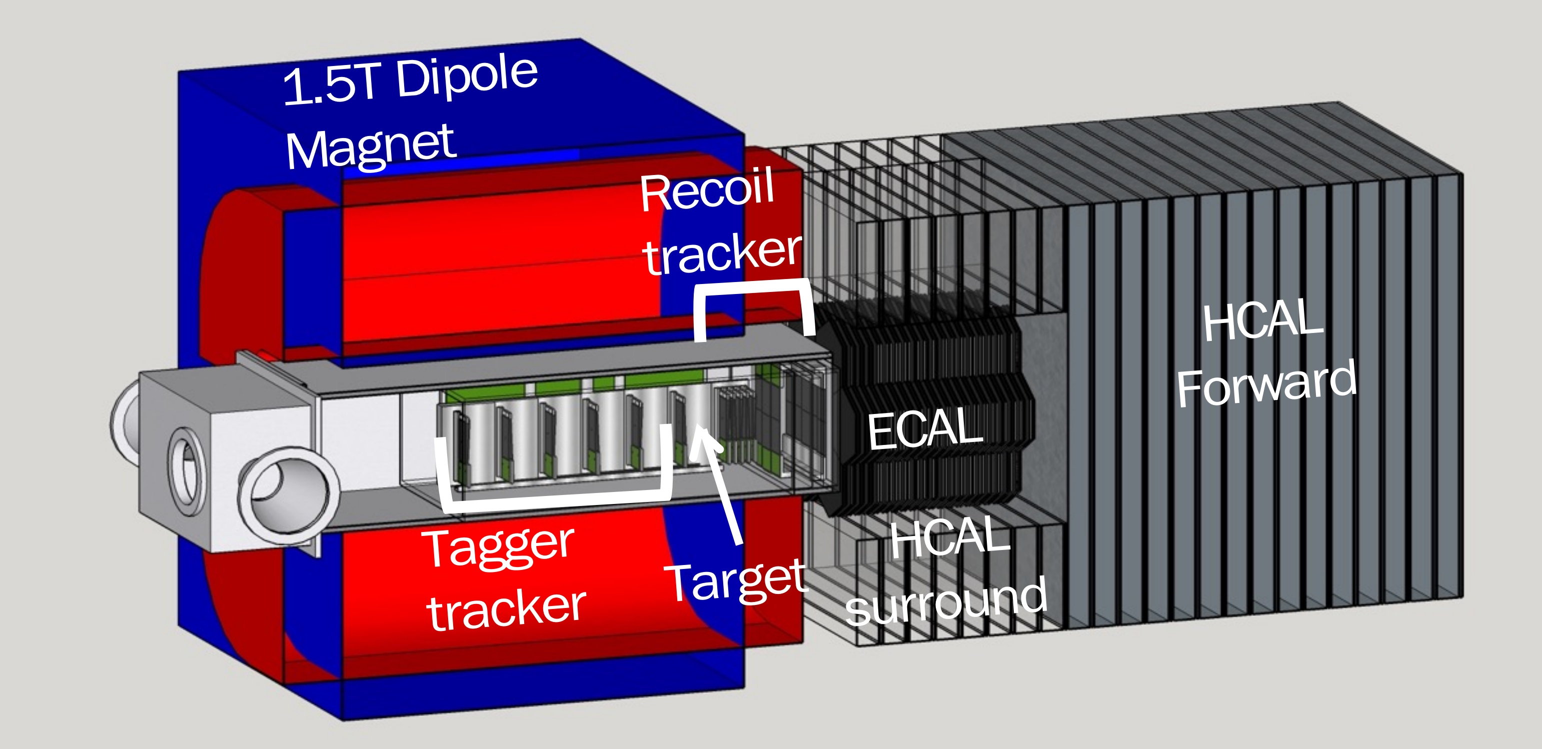
- DASEL concept has been developed to produce such a beam using the LCLS-II Linac at SLAC in a parasitic mode of operation





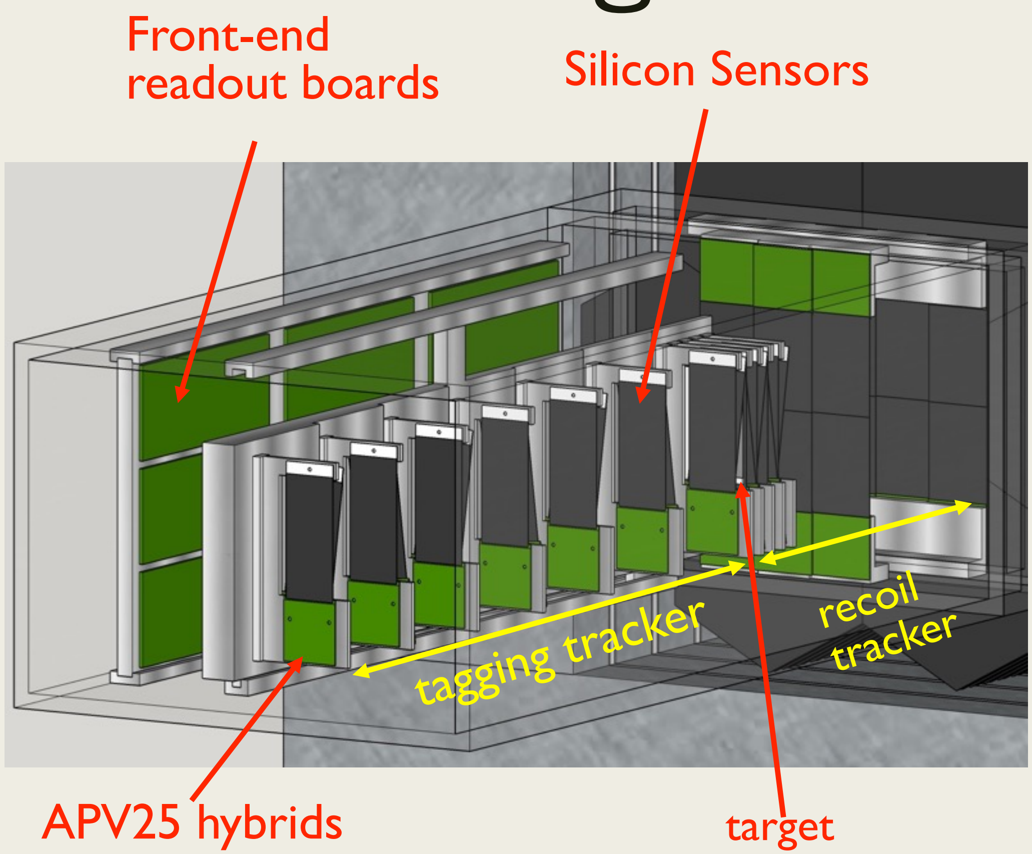
- Beamline concept is achievable at moderate cost. Logistics of integration and installation are being evaluated by the accelerator experts at SLAC

The LDMX Detector Concept



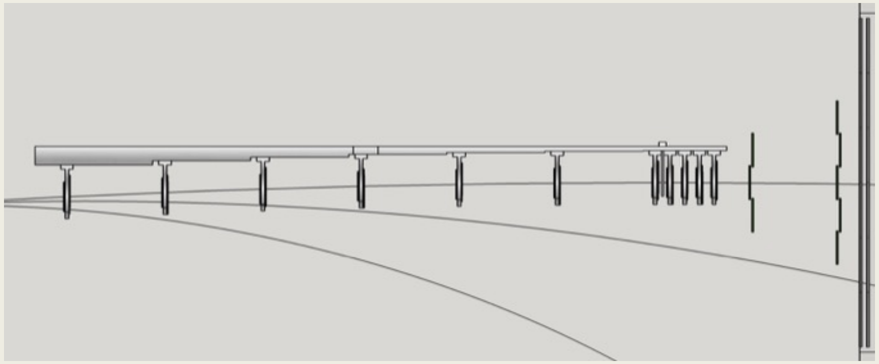
- Dual purpose Magnet and Tracking
  - *Collimated precision tagger tracker in full field → 10% X_0 target → compact and precision recoil tracker in fringe field*
- Si-W sampling calorimeter (ECAL)
  - *40 X_0, 30 Layers, 7 modules per layer of high efficiency, high granularity calorimetry*
- Scintillator-Steel sampling calorimeter (HCAL) behind and around ECAL
  - *15 layers, un-segmented for simplicity : Veto any event with hadronic activity*

Tracker designs based on HPS



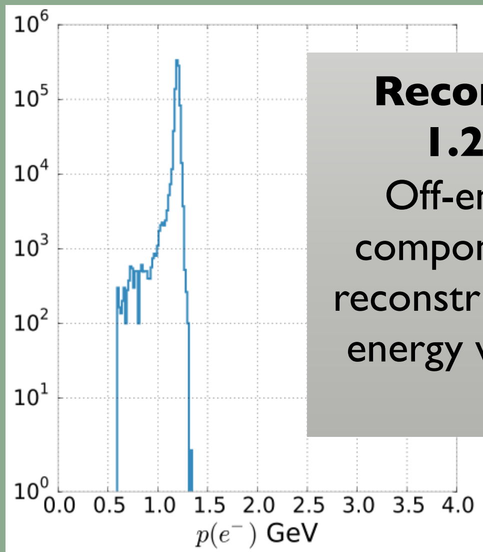
- Tagging tracker: Tag incoming e-
    - Precise p and (x,y) position at target.
- Recoil tracker:
    - Associate tag to recoil
    - Determine p after the target down to 50 MeV

- Screen out straggling (off E_{Beam}) electrons
- Measure Δp across target
    - The key discriminator

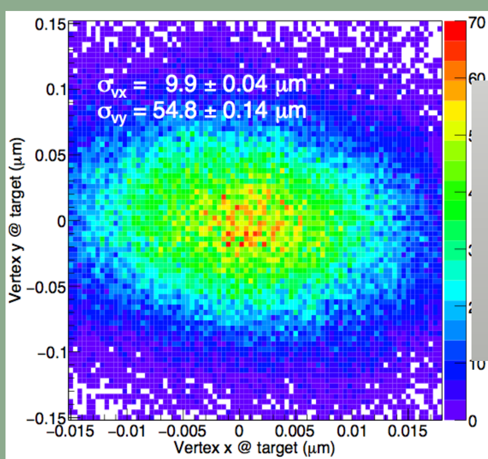


Expected Tracker Performance

Tagging Tracker

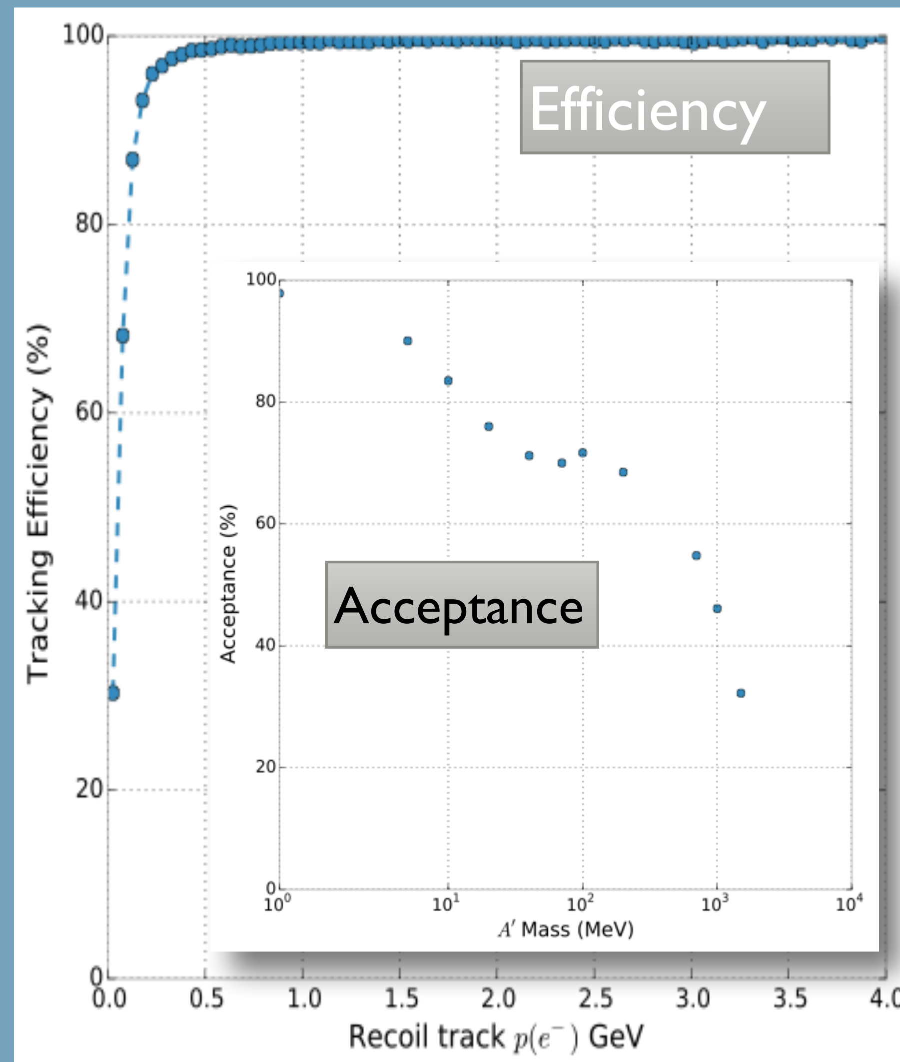


Reconstructed 1.2 GeV e^-
Off-energy beam components are not reconstructed into on-energy window (>3.5 GeV)



Position resolution at target for matching to recoil

Recoil Tracker

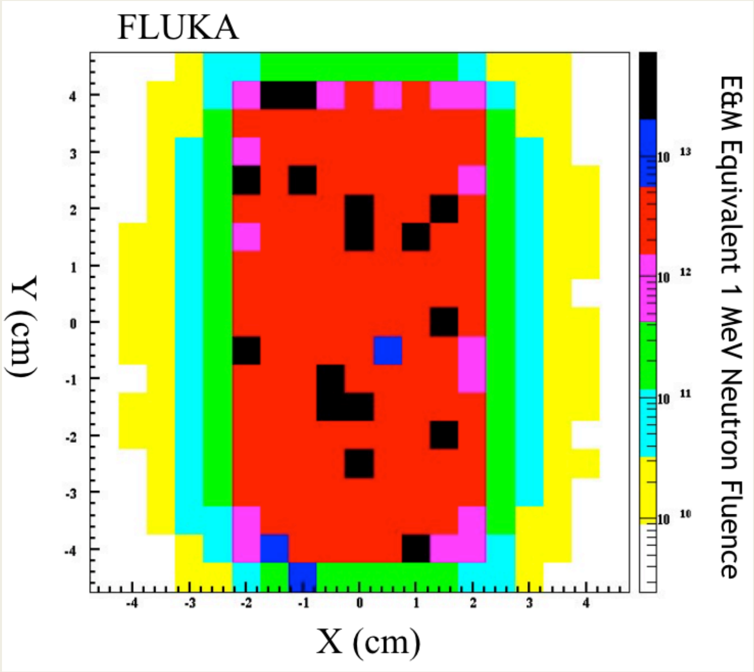


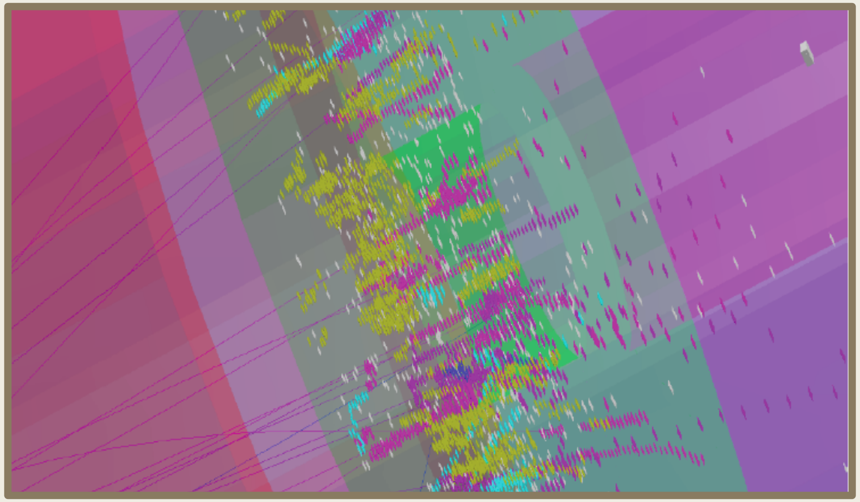
Efficiency

Acceptance

ECAL Requirements

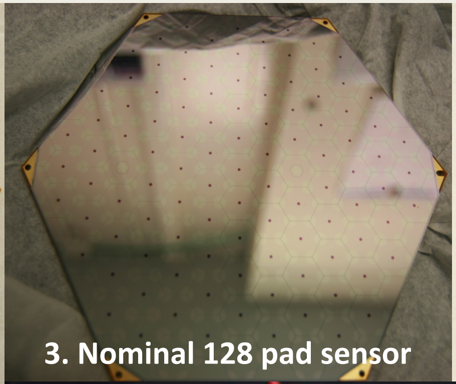
- LDMX ECAL is effectively the beam stop for the DASEL beamline
  - High rate requirement (46 MHz particle rep rate)
  - Significant radiation load for an active detector
- Proposed solution: adopt the technology chosen for an even more-extreme case (HL-LHC endcaps)

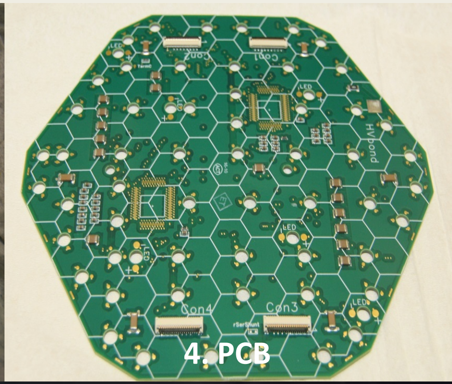


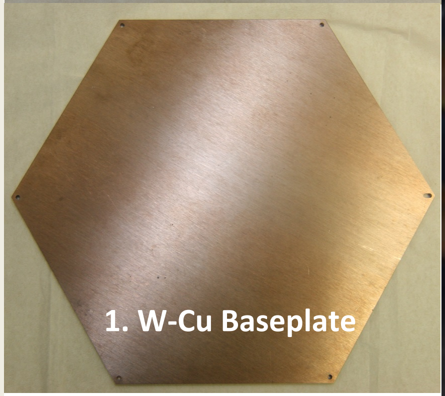


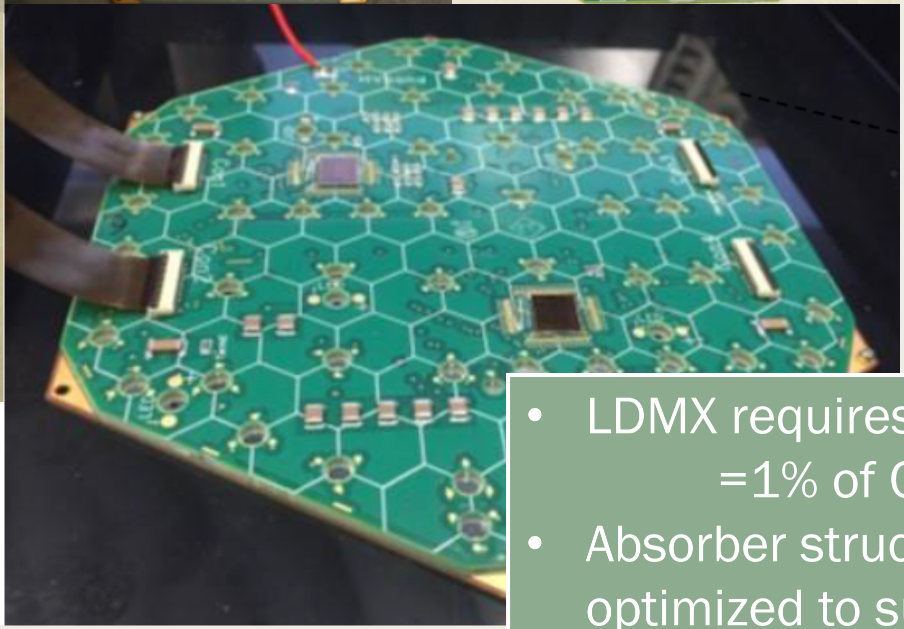
- Fast, granular detector with precise cluster-timing capabilities is ideal for high-luminosity fixed-target operation

CMS HL-LHC Endcap Calorimeter





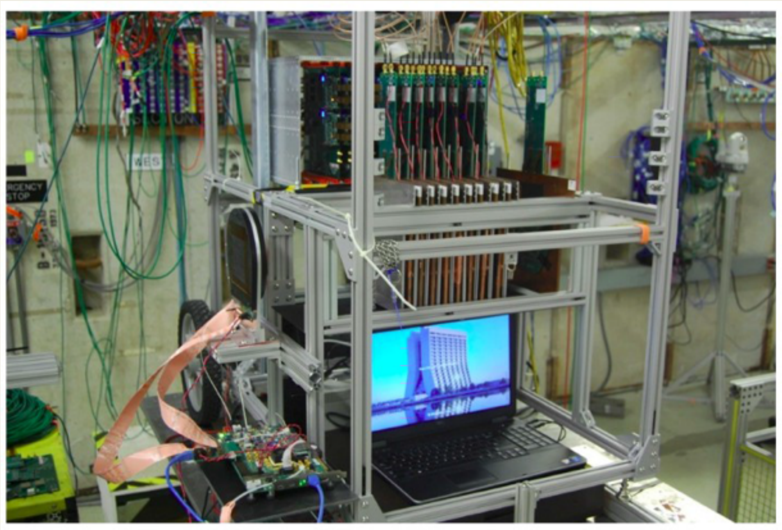


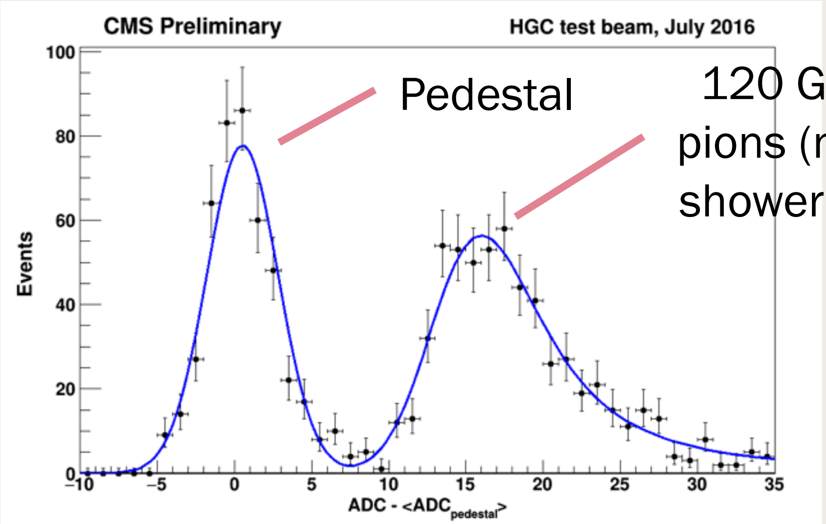


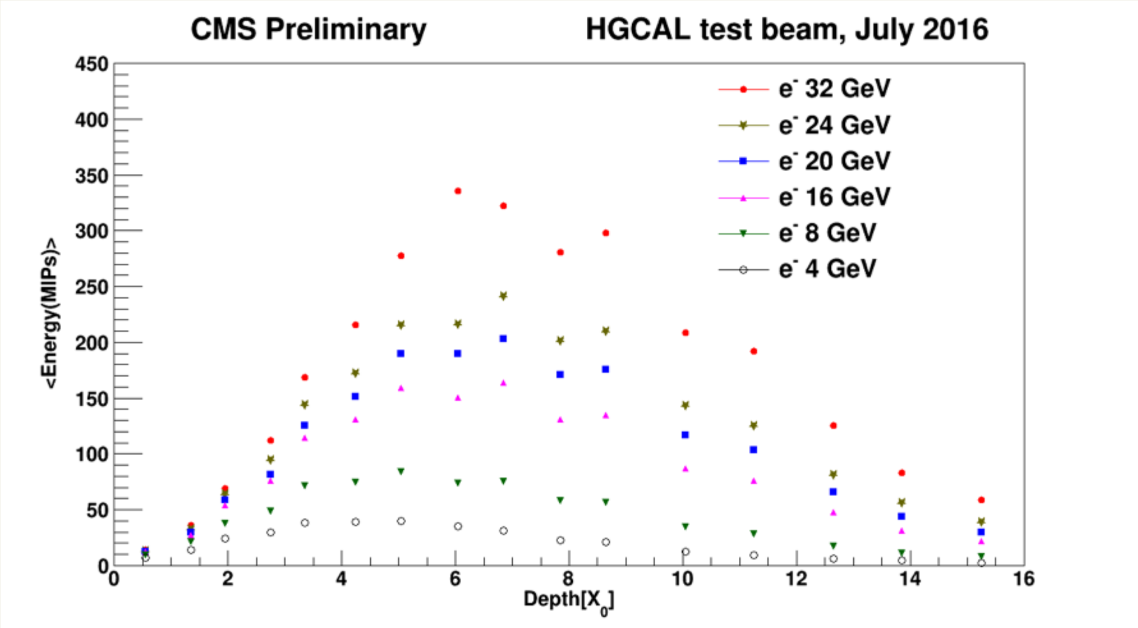
Successful test beams FNAL CERN in 2016

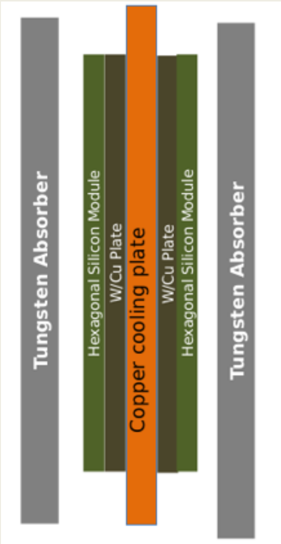
- LDMX requires 210 modules =1% of CMS
- Absorber structure of LDMX optimized to suppress unmeasured photonuclear events

Recent Testbeam Results









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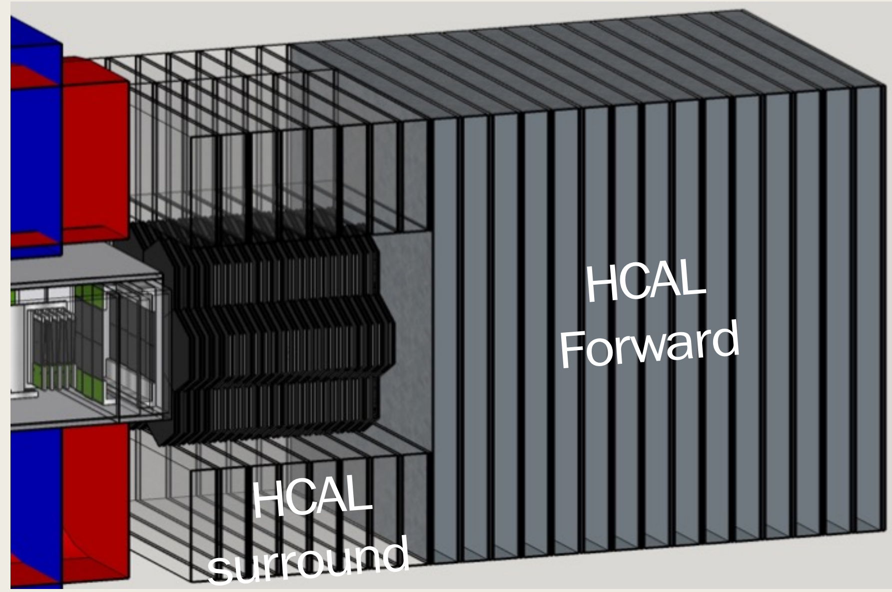
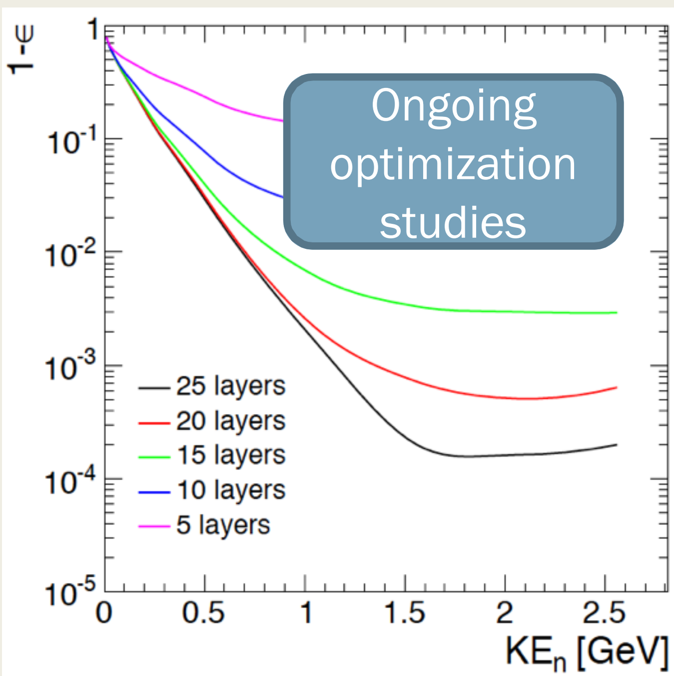
Hadronic Veto Calorimeter

- Critical role is in the identification of neutron-containing backgrounds
- Technology concept is based on iron absorber and plastic scintillator read out using CMS Phase 1 SiPM-based electronics



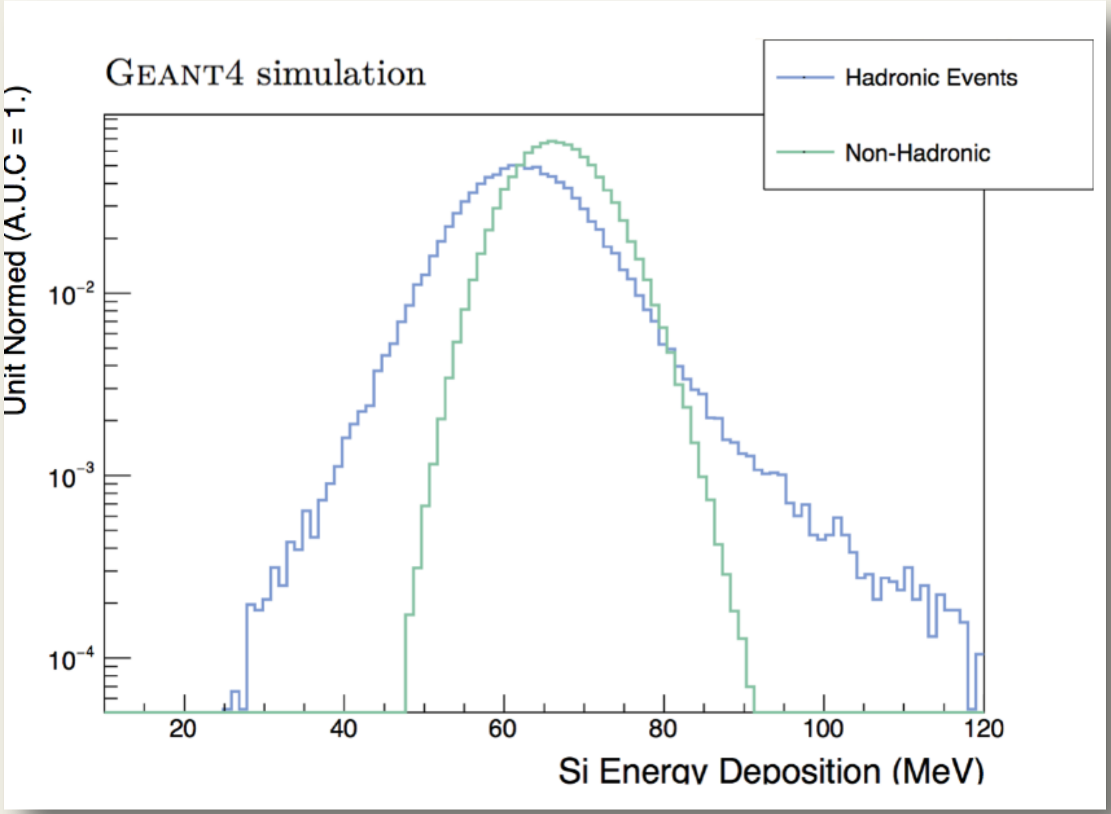


- Ongoing optimization studies including a “surrounding” HCAL to catch large-angle (45) neutrons and catch wide-angle brehmstrahlung in the target

Calorimeter performance

Studied 3 GeV photon corresponding to ~ 3•10^9 EOT in GEANT4 simulations =>

~80k of these have photonuclear reactions, rest are easily vetoed



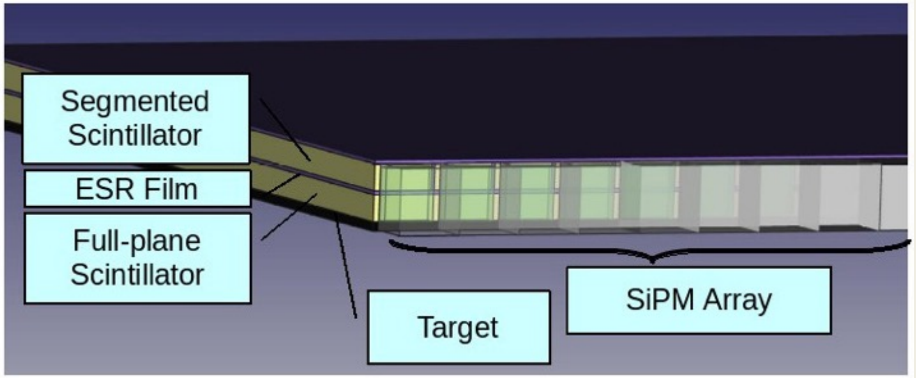
By applying a cut of 0.15 MeV in deposited energy for the ECAL and 8 MIPs in the HCAL, we achieve a rejection factor of ~10^8 on these backgrounds

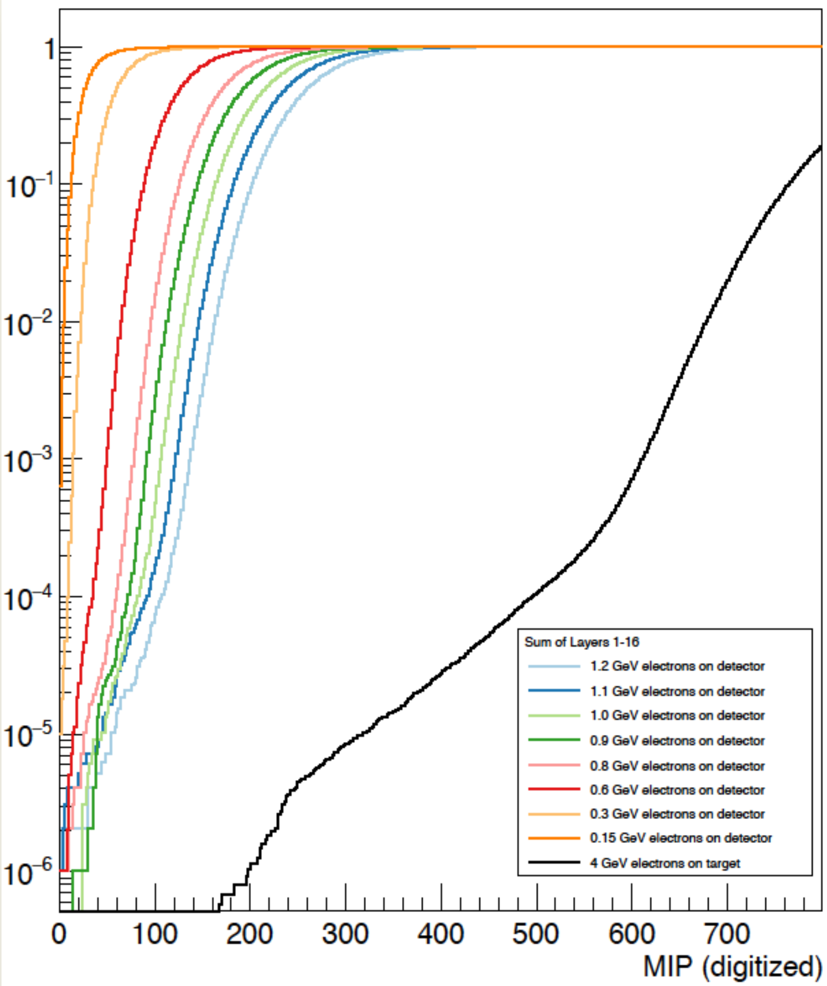
Additional design work going on for the hadron veto, as most remaining events have a leading neutron, often at large angle (>30°)

Target and Trigger

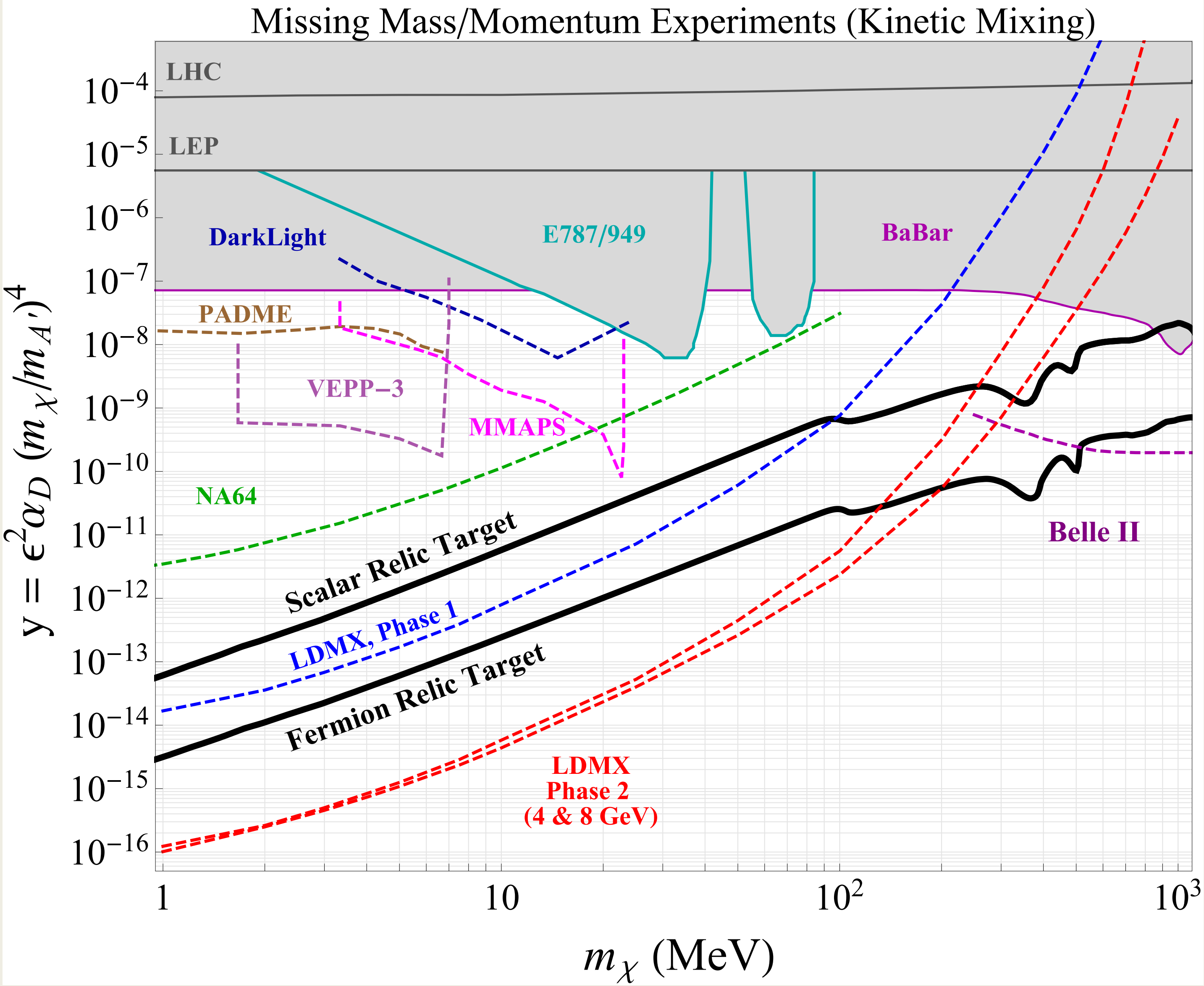
Physics trigger

- Energy sums performed using the first 16 layers of the calorimeter, combined with the input of the target scintillator
- Simulation indicates reduction factor of 2×10^{-5} possible with no inefficiency for signal
- DAQ requires a few $\times 10^{-4}$



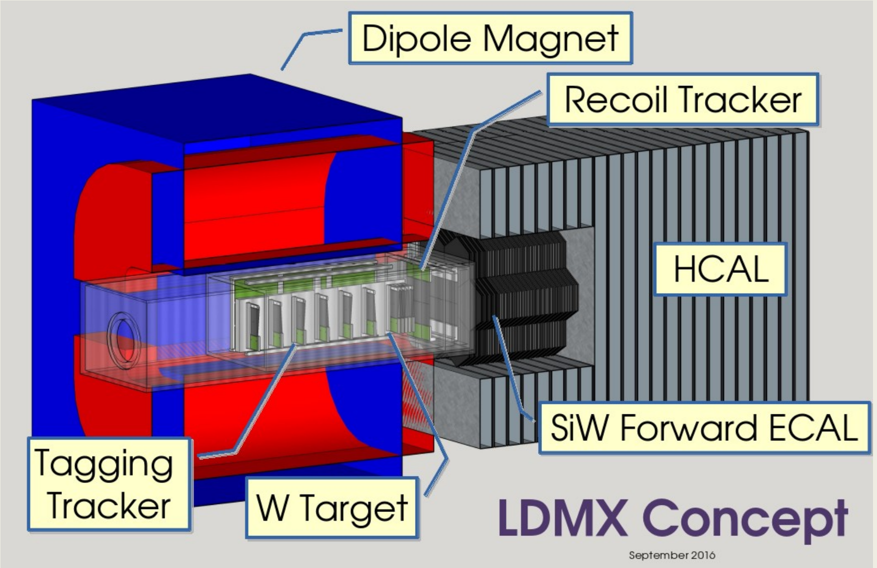


Physics potential



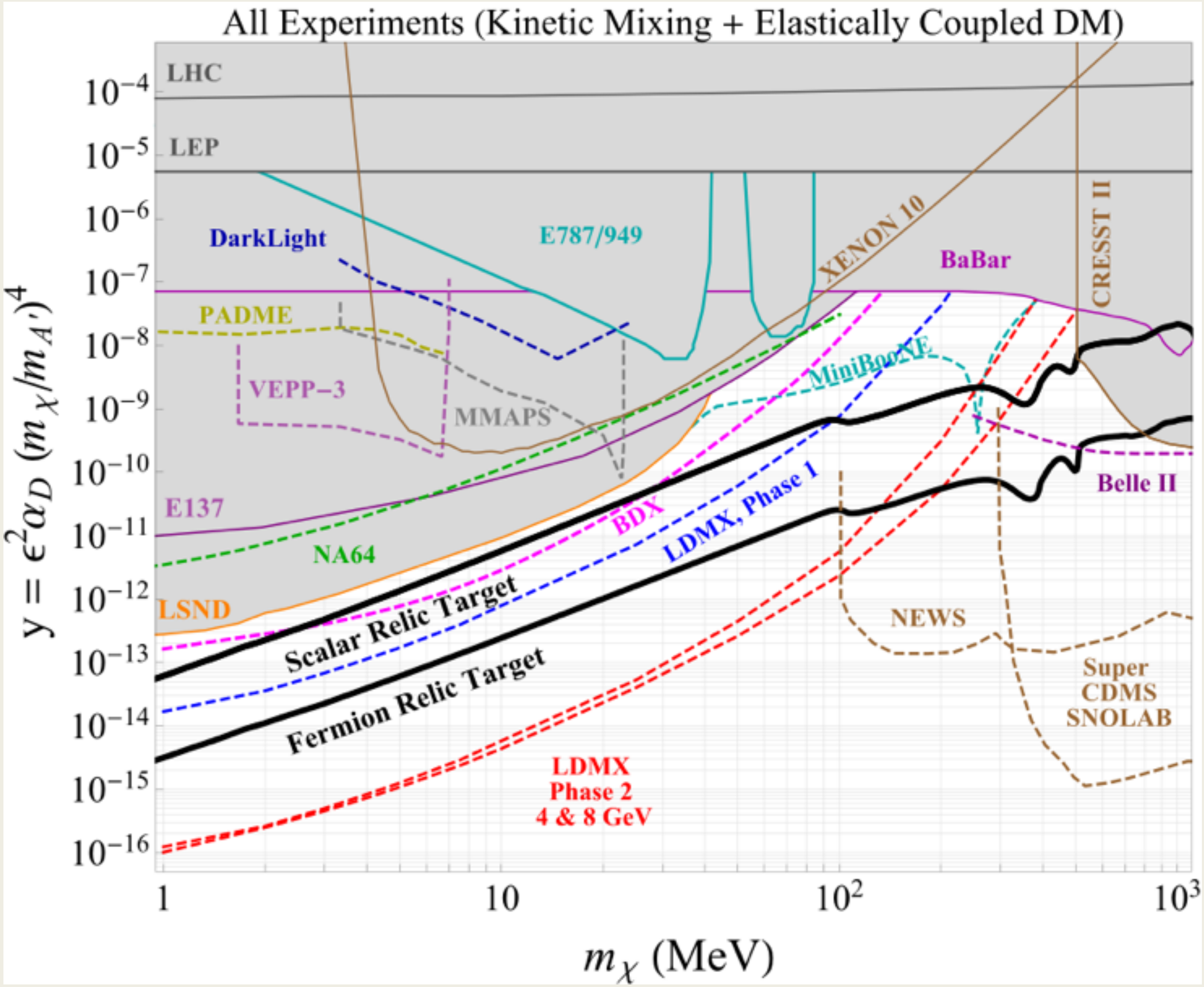
Project Status

- DASEL beamline design is at an advanced stage
  – *Project is being discussed with DOE to allow installation of the DASEL beamline during the LCLS-II construction stop in 2019*

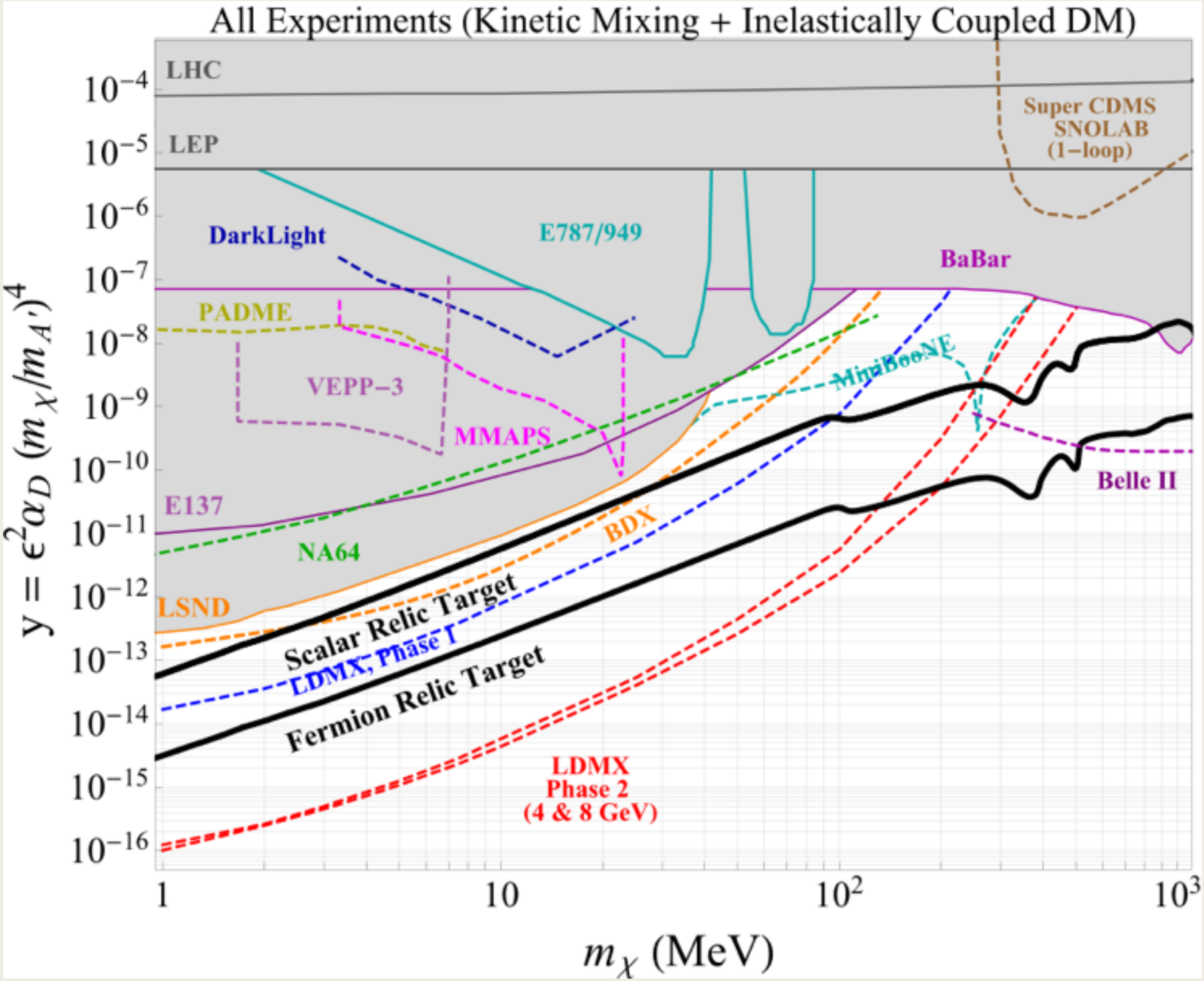


- LDMX experiment design process is making good progress
  – *Current studies are focused on identifying photonuclear backgrounds in the calorimeters and target*
- Construction schedule focused on 2020/21 operation
  – *Compatible with CMS endcap calorimeter construction schedule*

ADDITIONAL MATERIAL



Parameter space plot with existing and planned experiments' sensitivities from Dark Sectors 2016 community report (arXiv: 1608.08632)



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