The Light Dark Matter eXperiment

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on behalf of the LDMX collaboration

Snowmass 2021: EF10 meeting

September 22, 2020

Caltech Fermilab LUNDS UNIVERSITET UNIVERSITY OF MINNESOTA UCSB UNIVERSITY OF CALIFORNIA SANTA BARBARA

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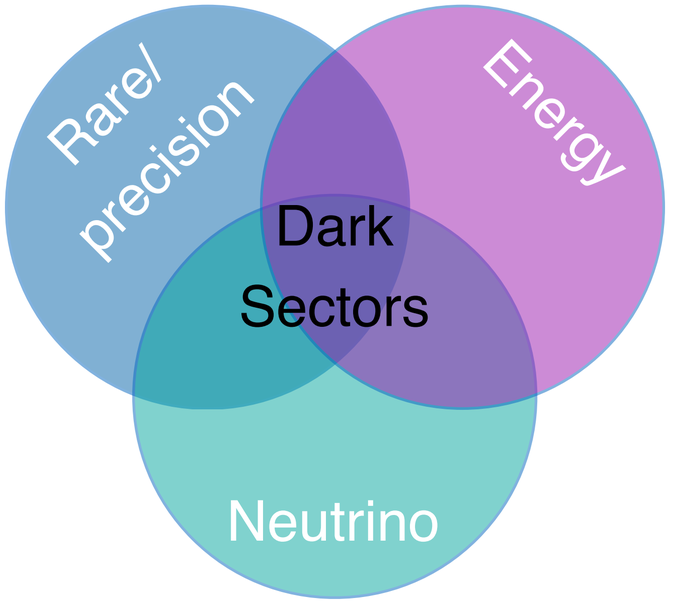
[LDMX LOI]

LDMX

Complementarity of LDMX to EF

- The energy frontier has long been a key player the hunt for WIMP dark matter
- In recent years a broader class of models has gained popularity and motivates a new region of the thermal DM paramter space: *hidden sector dark matter below* m_{proton}
  - Among many others, see theory overview in RF6 kickoff meeting for more information

- Facilities and technology from many areas of HEP can target dark sector models

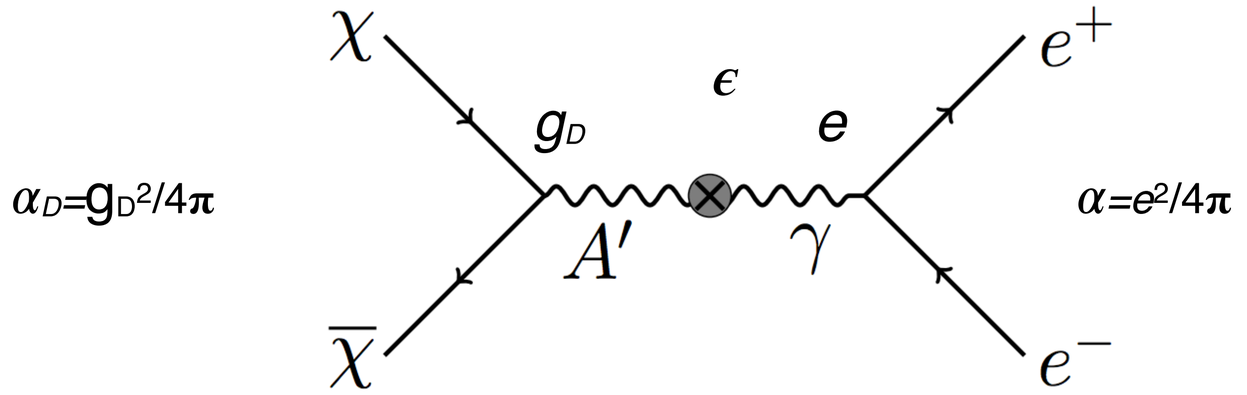


- There is an emergence of new experiments proposed to tackle various regions of this parameter space by leveraging this confluence of research areas

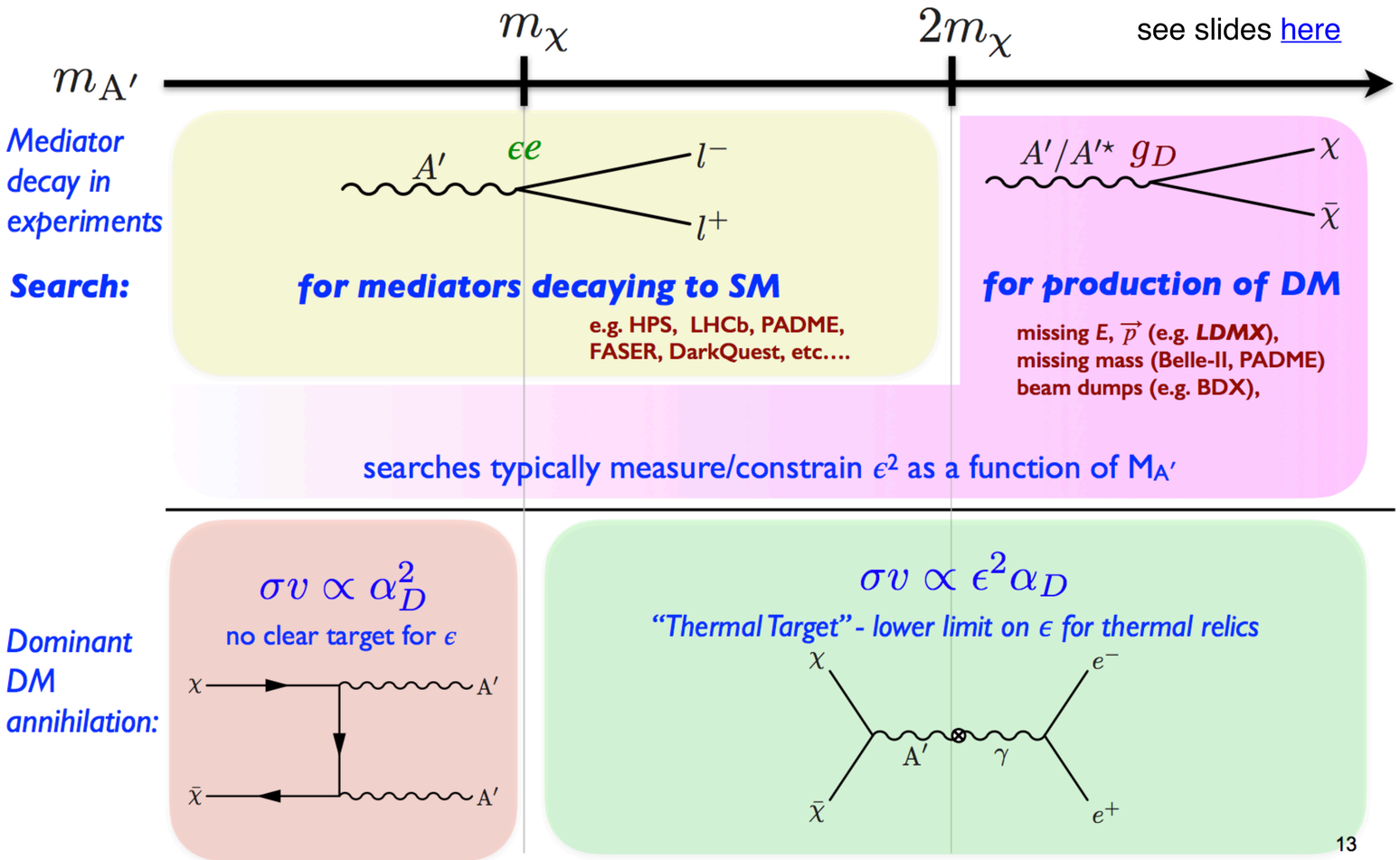
Vector portal models

- There is rich landscape to be explored

- LDMX will target cases where DM couples to electrons utilizing invisible signatures

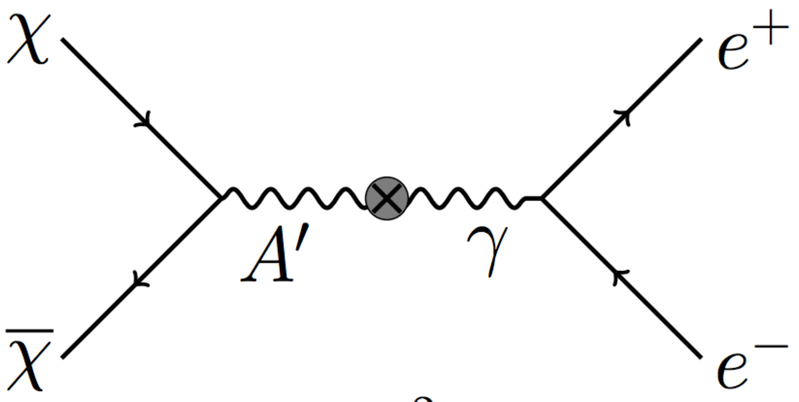


Credits: Tim Nelson
see slides here

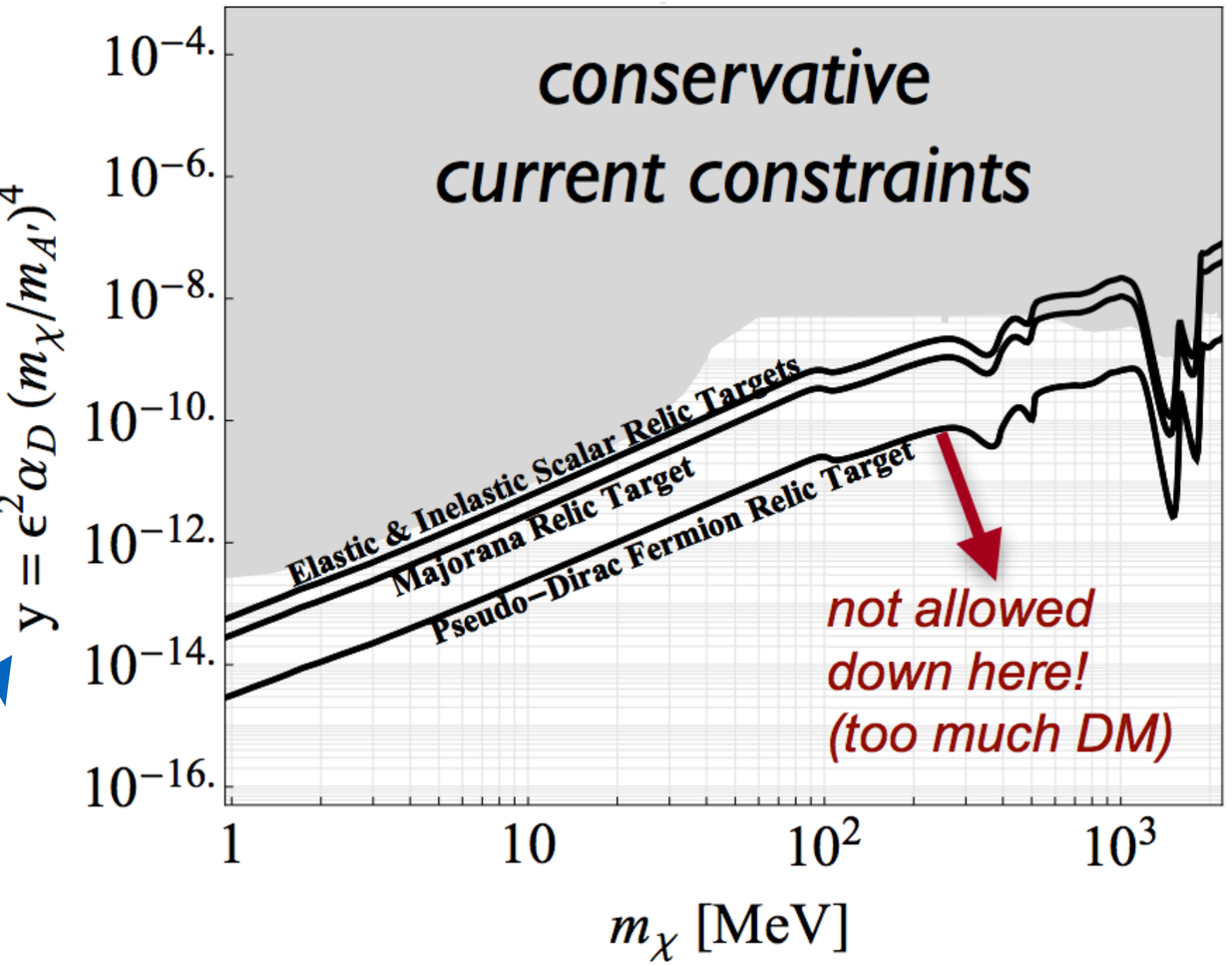


Thermal relic DM benchmarks

- Thermal relic DM provides predictable targets for experiments

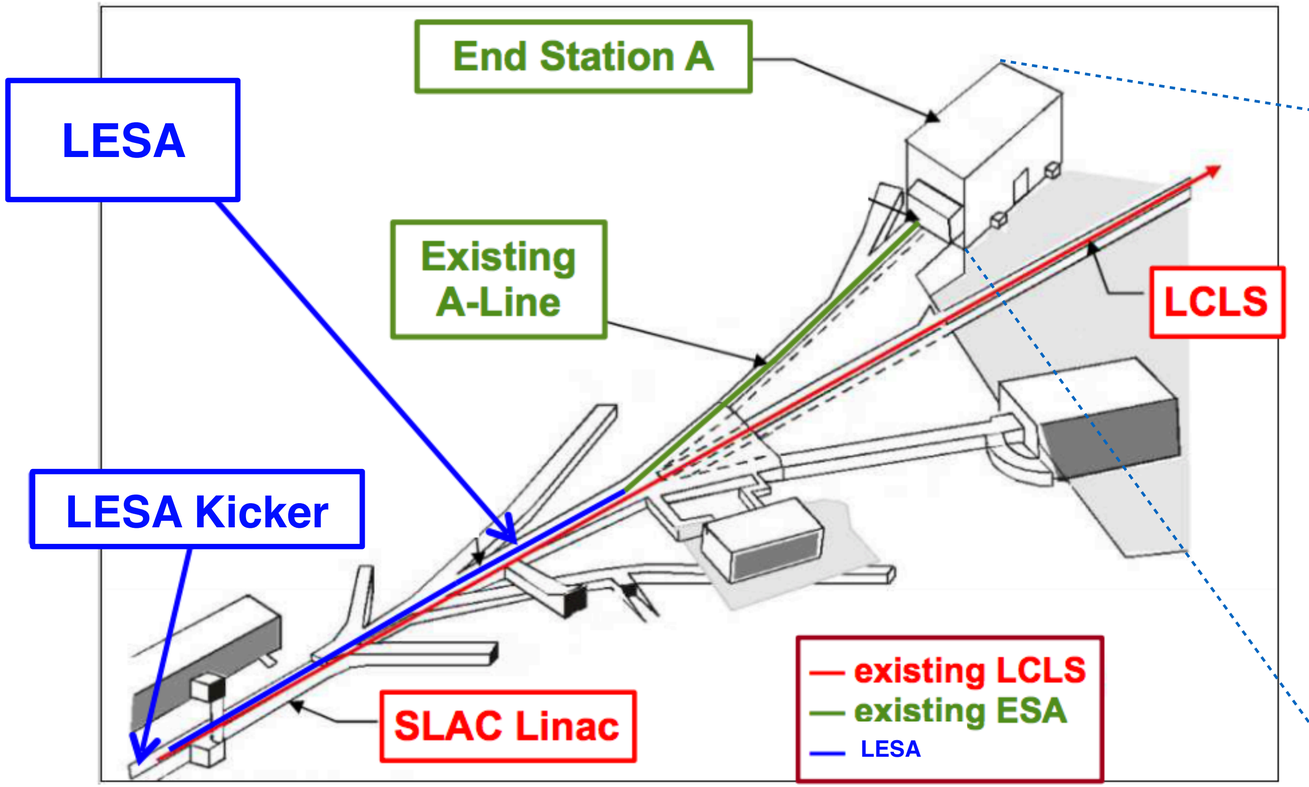


$$\sigma v \propto \epsilon^2 \alpha_D \frac{m_\chi^2}{m_{A'}^4} \equiv \frac{y}{m_\chi^2}$$

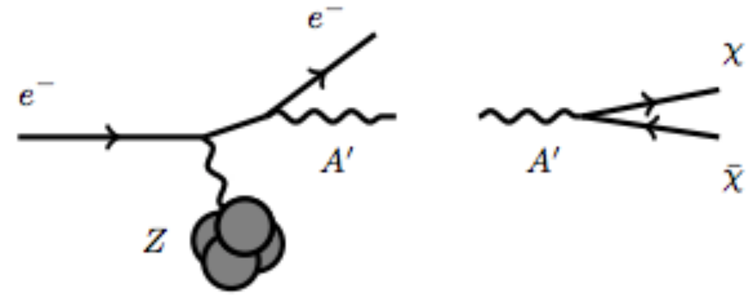


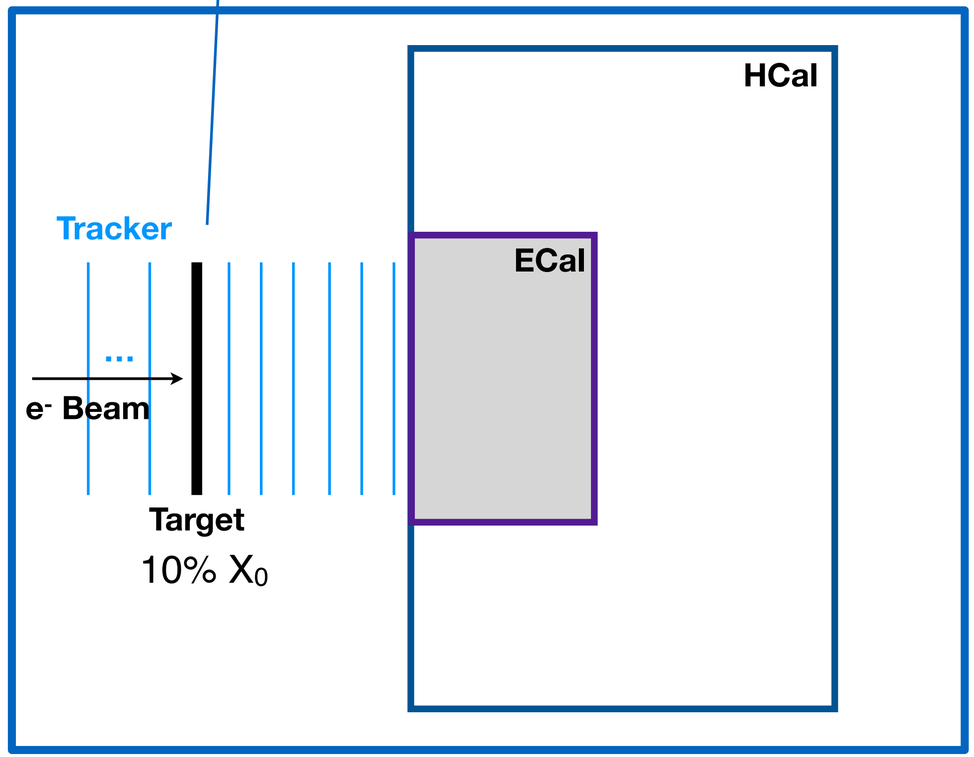
LDMX

LDMX Experimental concept



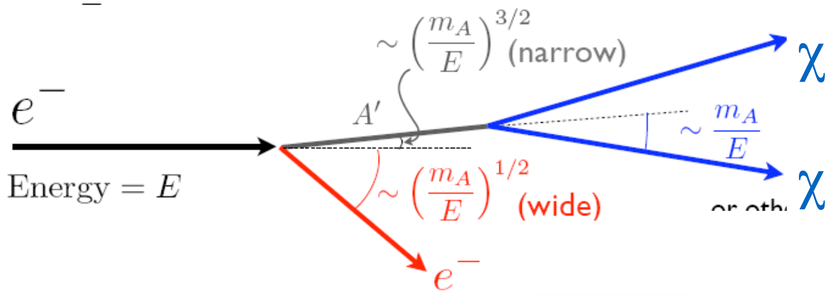
See also LESA test beam LOI here

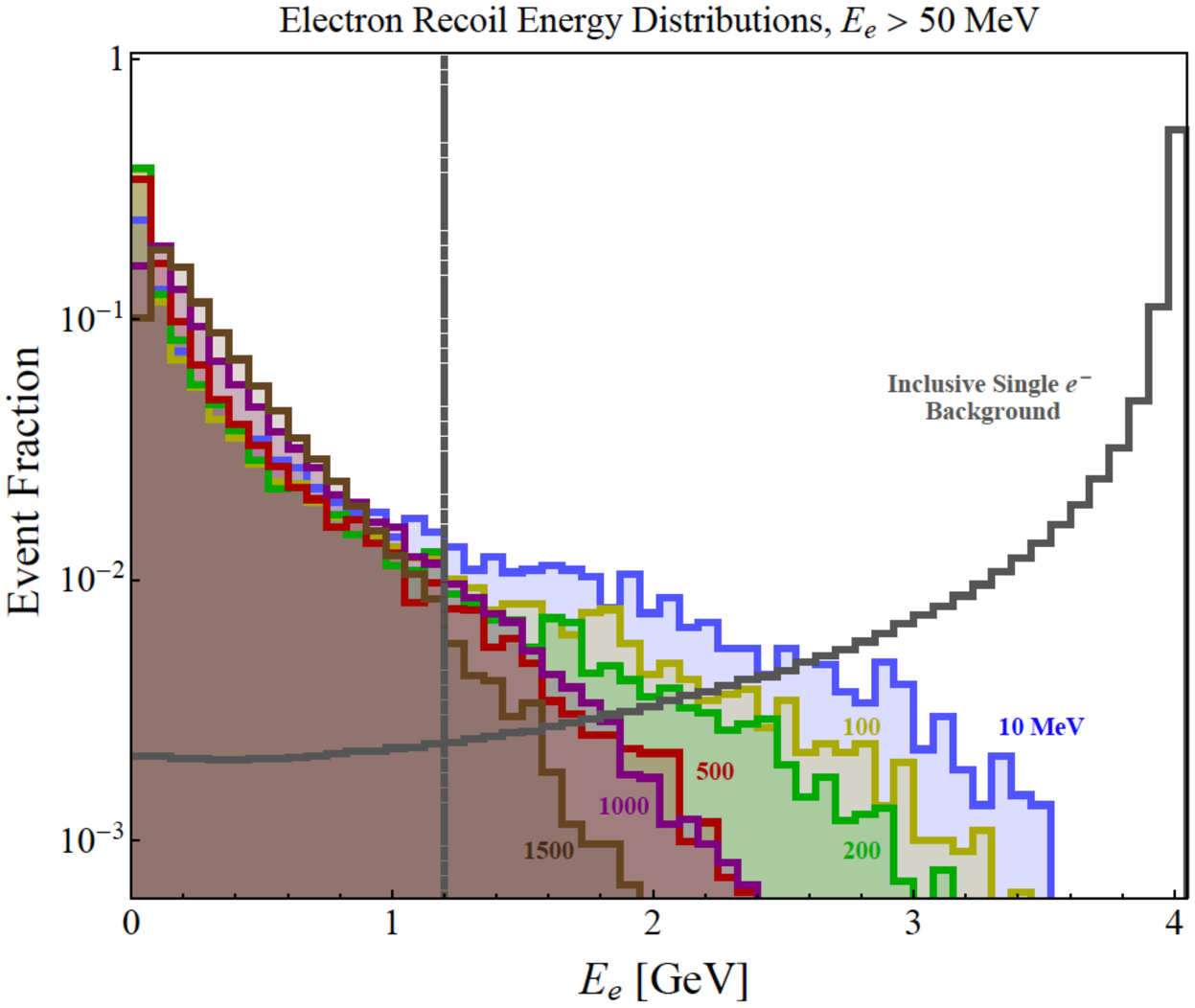


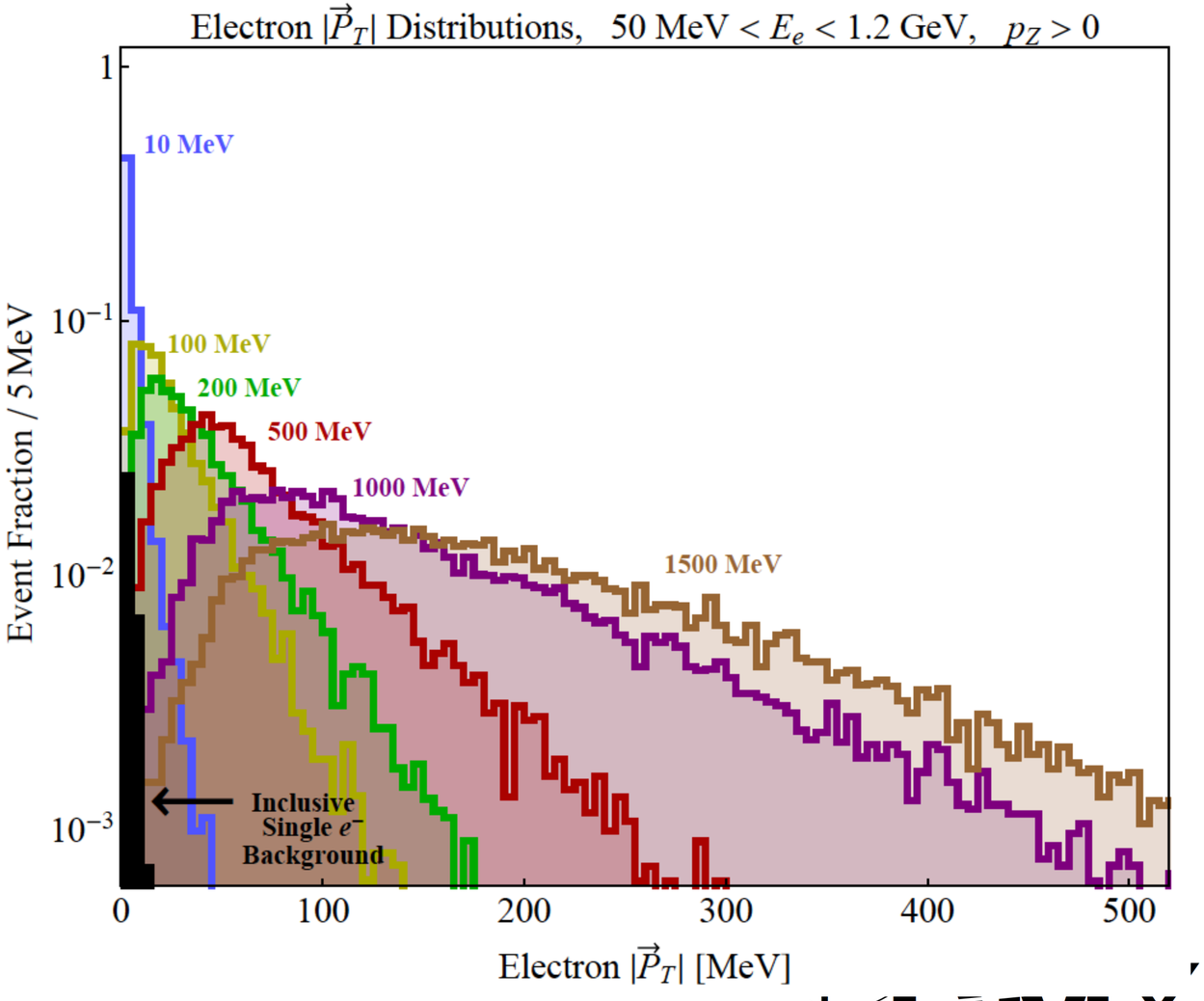


4/8 GeV beams possible

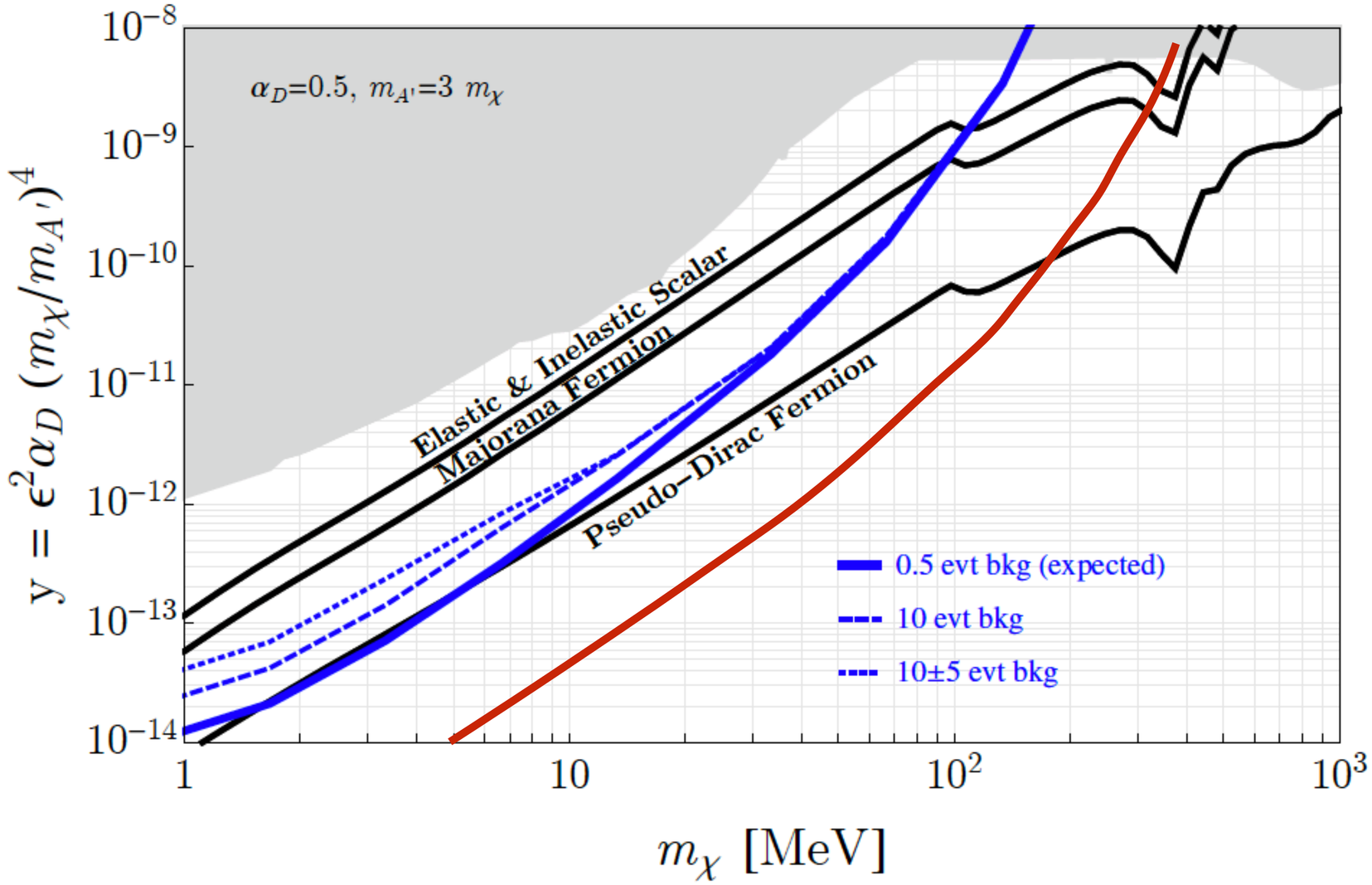
Kinematics for fixed target exp.







Projected sensitivity



4x10^{14} EoT
@ 4 GeV

1x10^{16} EoT
@ 8 GeV

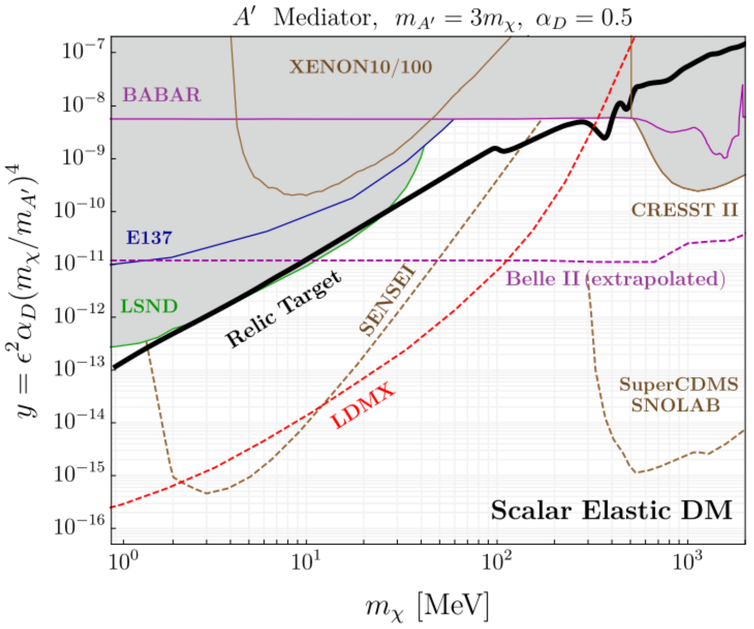
Note: $m_{A'} = 3m_\chi$ is conservative assumption

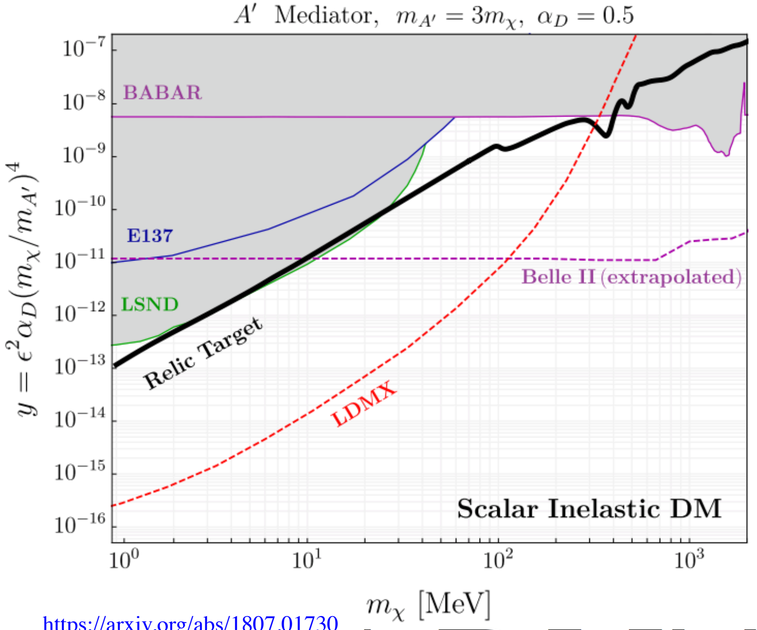
Summary

- LDMX is an electron fixed target experiment that aims to fully exploit the missing momentum technique
  - Impressive breadth of sensitivity thermal targets predicted by hidden sector dark matter models

- Sensitivity beyond dark matter:
  - More general exploration of hidden sector physics and other light degrees of freedom that couple to electrons is possible
    - e.g. displaced vertex signatures from visibly decaying mediators
  - Electronuclear measurements to support neutrino experiments

- Currently finalizing design concept using funding from the DOE through the Dark Matter New Initiatives program!





https://arxiv.org/abs/1807.01730

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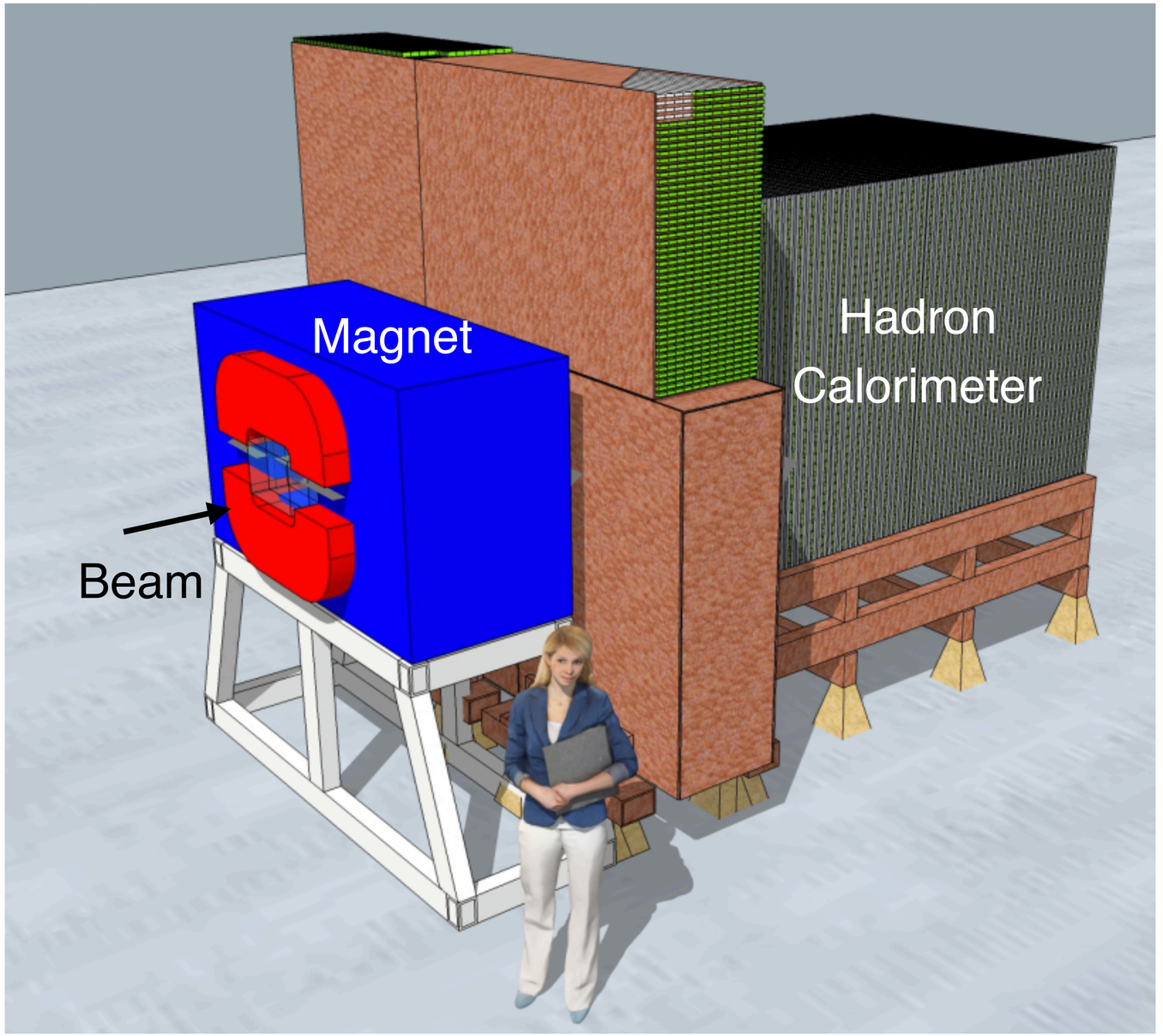
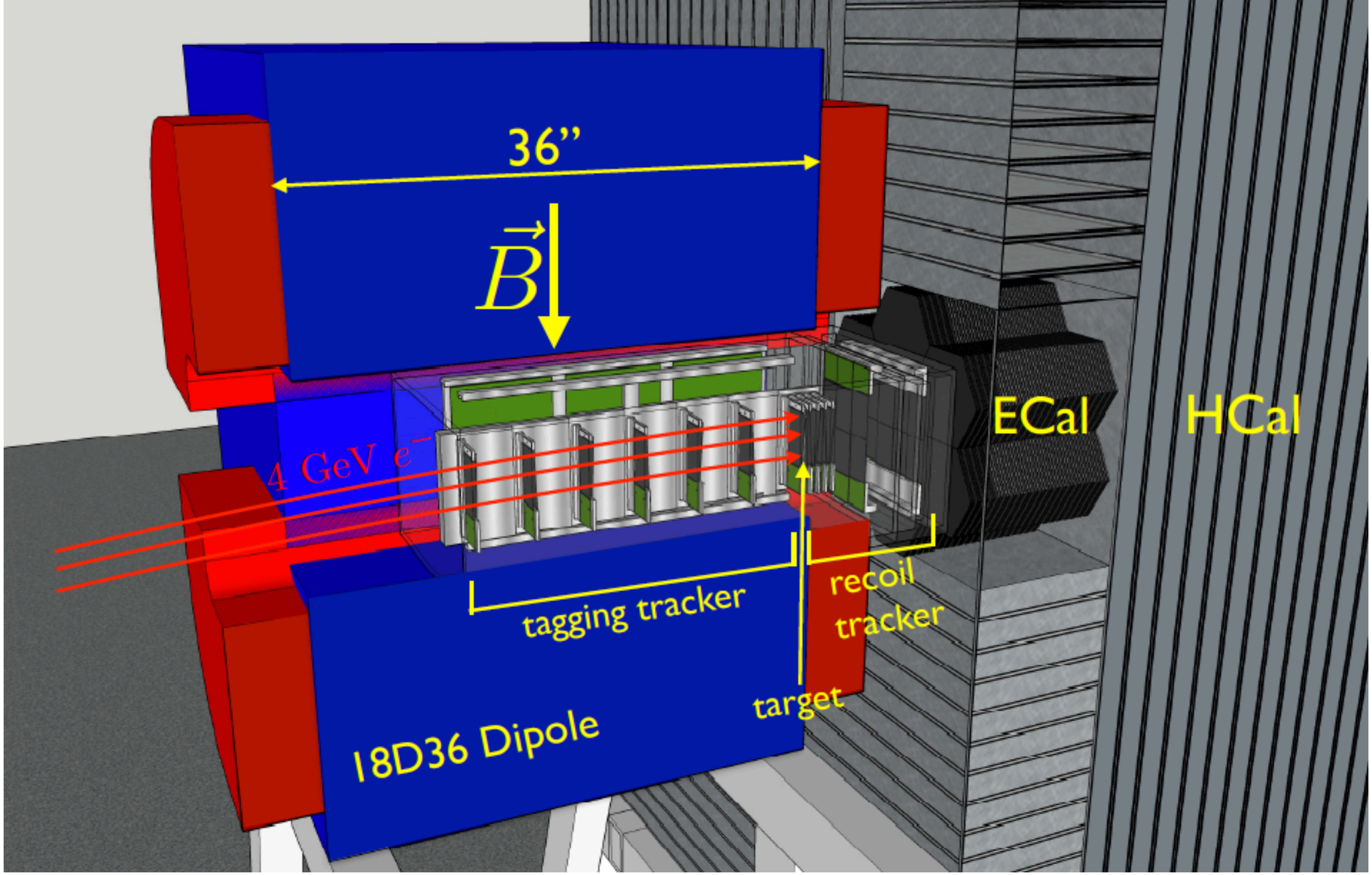
LDMX

Backup

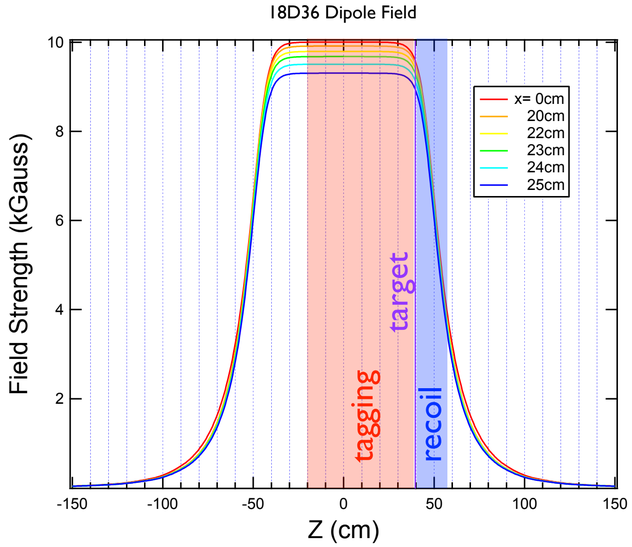
Detector concept

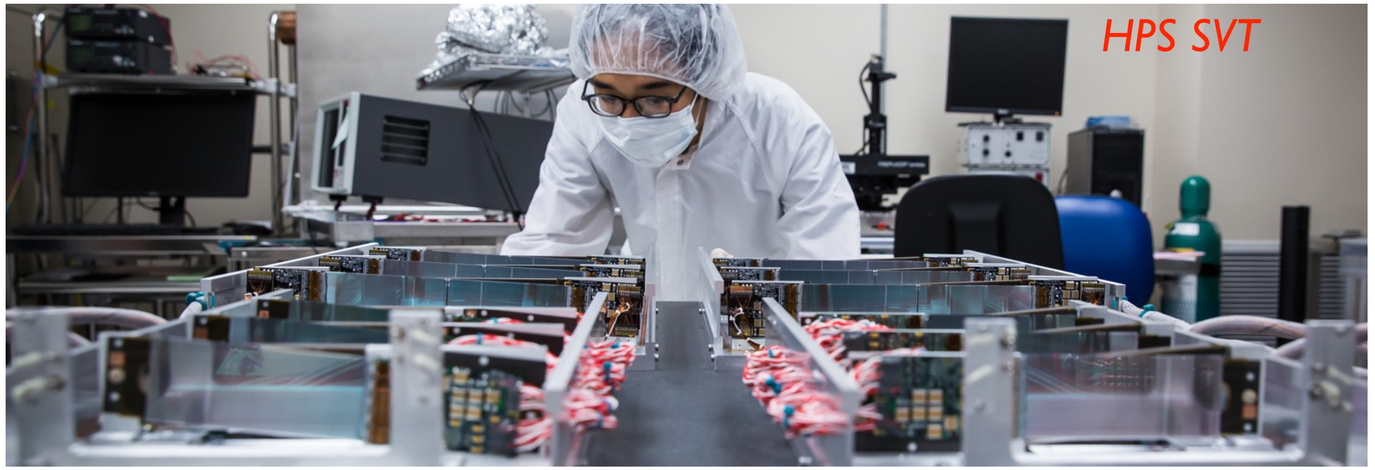


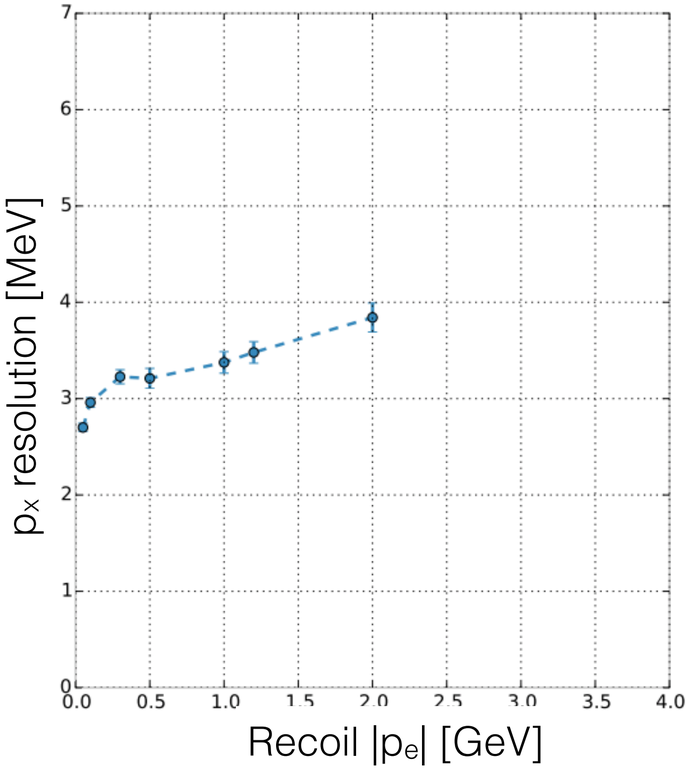

36”
$\vec{B}$
4 GeV e^-
ECal
HCal
tagging tracker
recoil tracker
target
18D36 Dipole

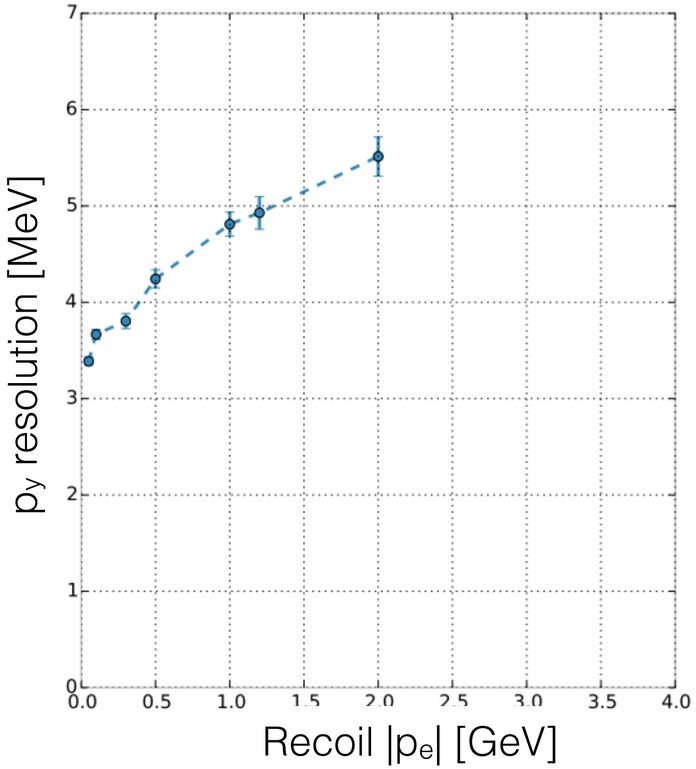
Tracking

- **Silicon strip spectrometers:**
  - single 1.5T dipole magnet with 2 field regions
  - tagger tracker: located in magnet bore
    - measure incoming momentum
    - efficiently identify off-energy beam components
  - recoil tracker: located in fringe field
    - measure outgoing momentum
    - good recoil momentum resolution (optimized for 1-2 GeV)



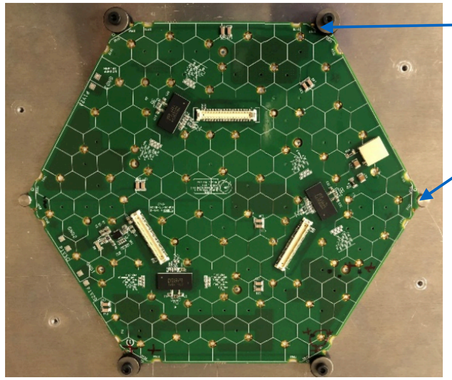


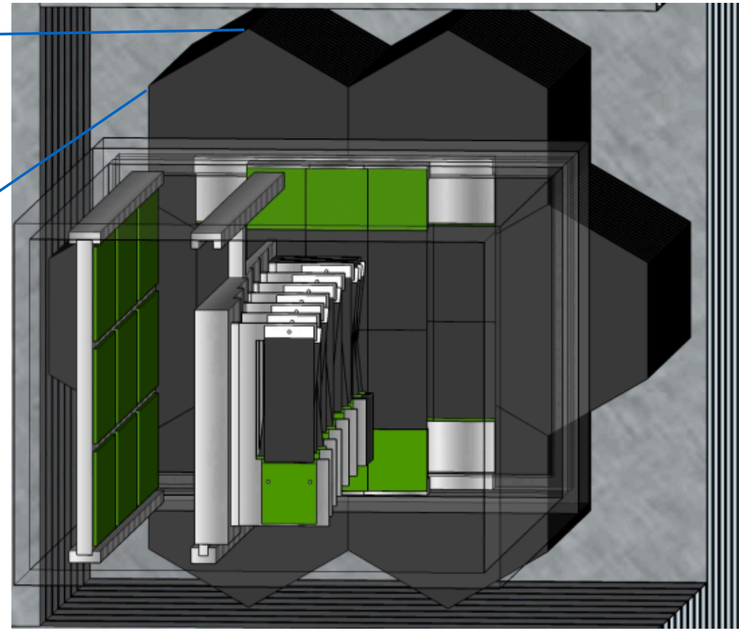


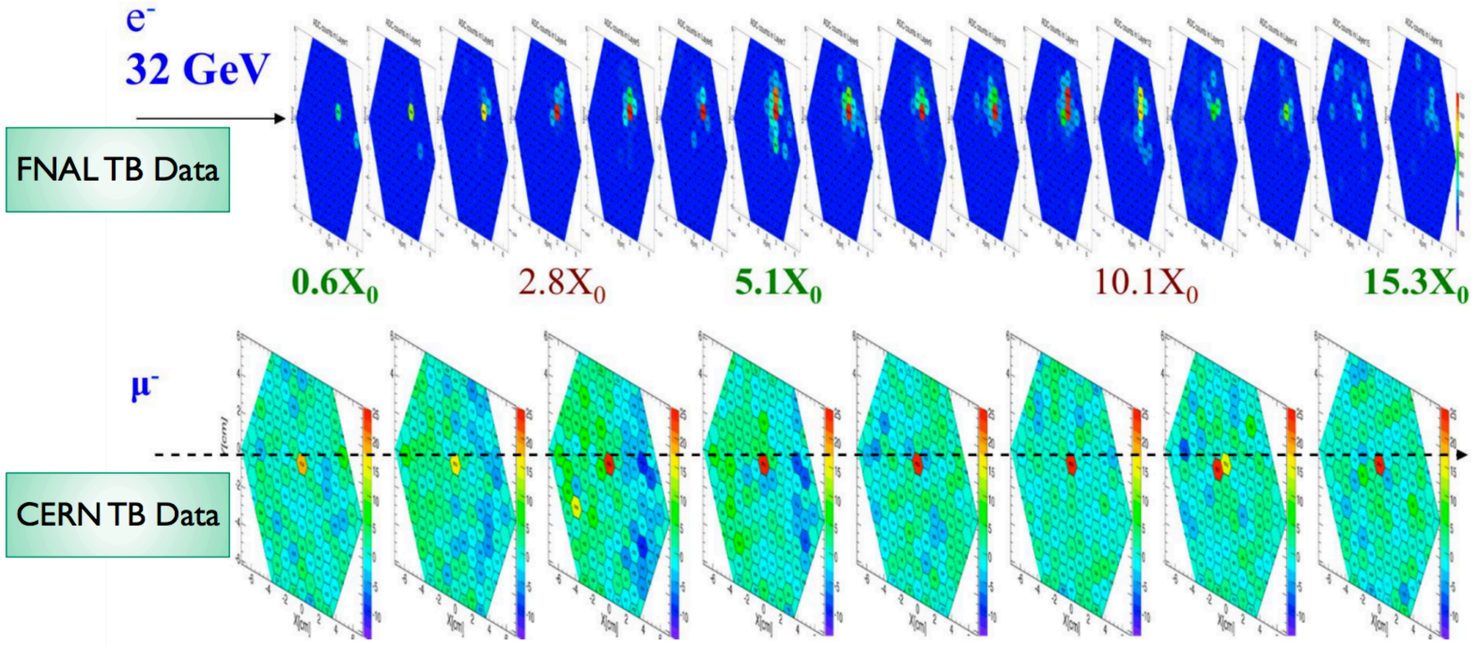


EM Calorimeter

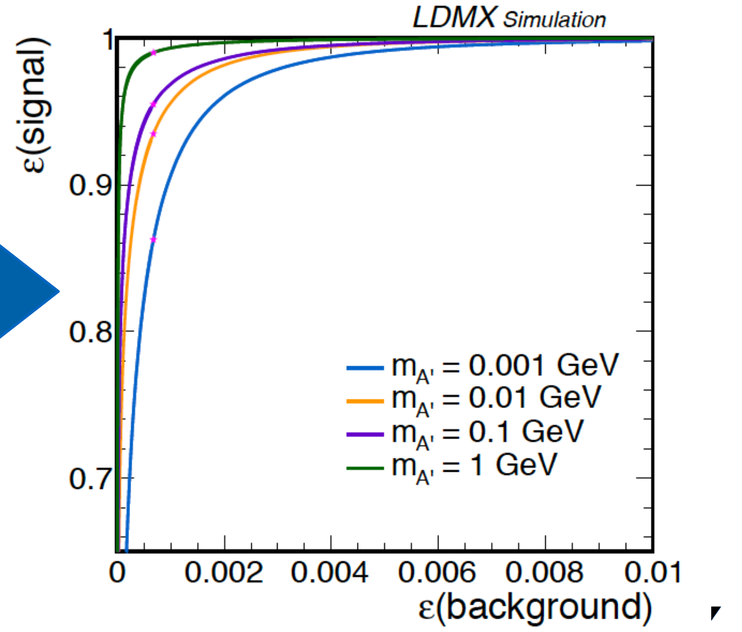
- 40 X_0 silicon-tungsten imaging calorimeter
  - high granularity: can exploit both transverse & longitudinal shower shapes to reject PN events
  - MIP sensitivity





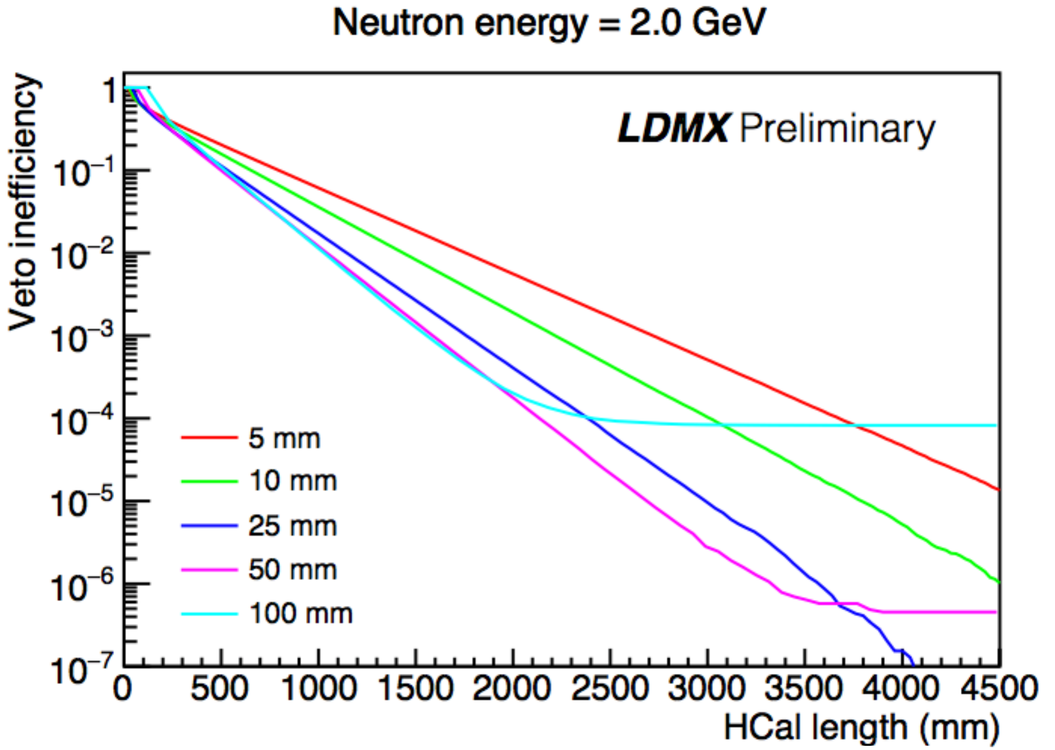


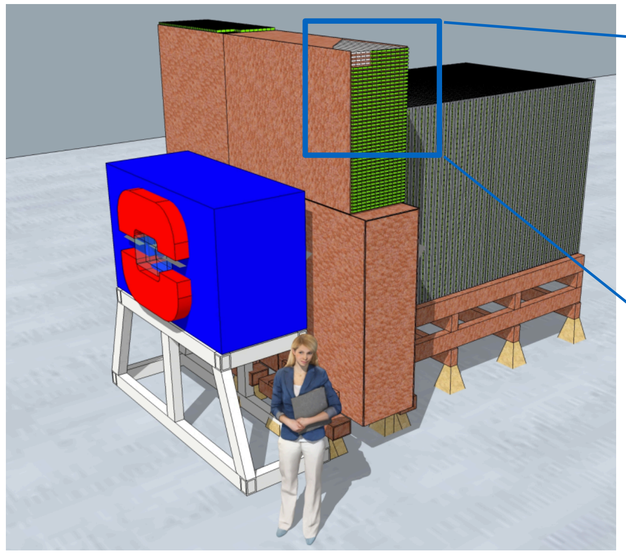
Boosted
Decision
Tree

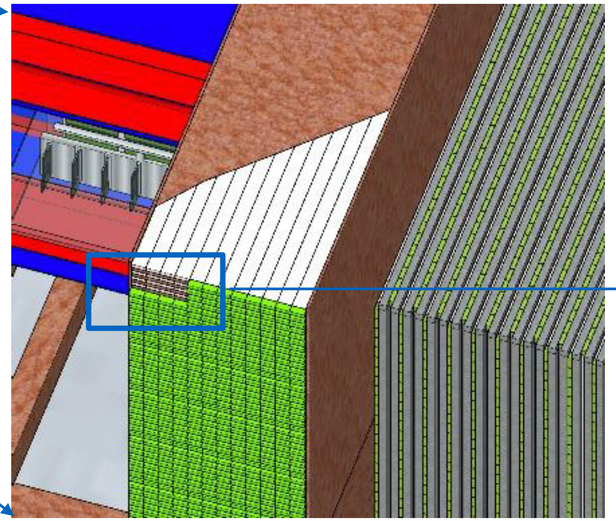


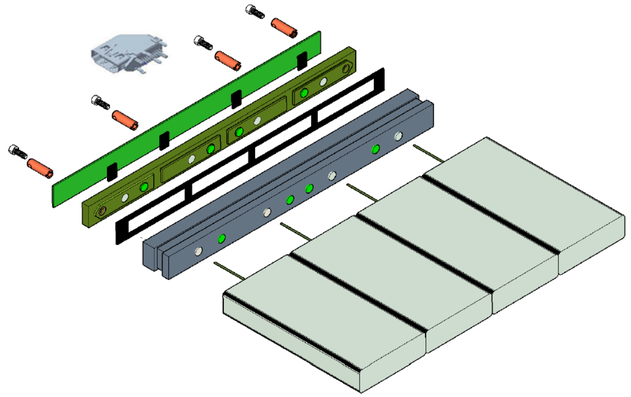
Hadron calorimeter

- Steel/plastic sampling calorimeter
  - read out with wavelength shifting fibers & SiPMs
  - enclose ECal as much as possible to detect:
    - wide-angle bremsstrahlung
    - hadrons from PN events



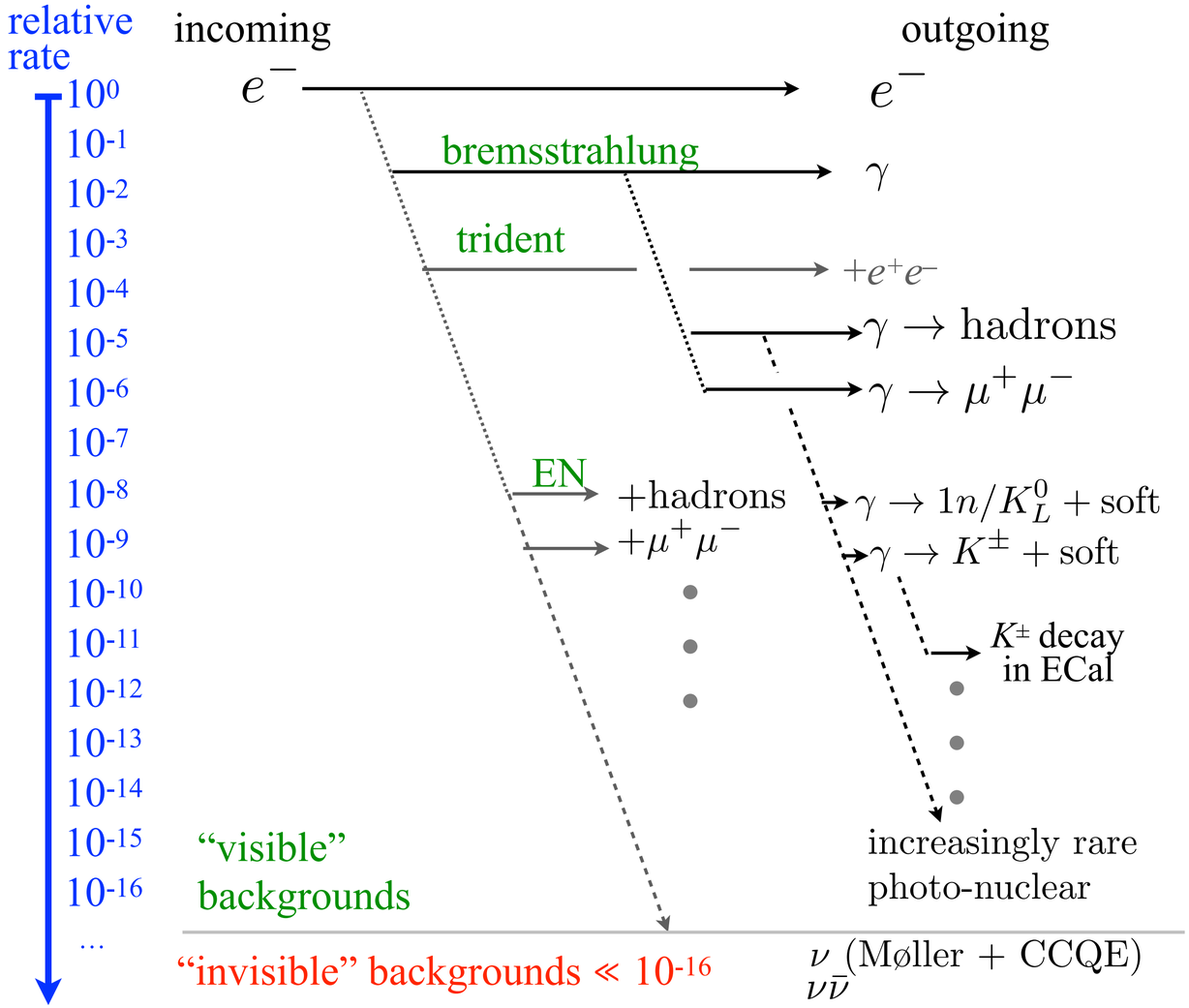


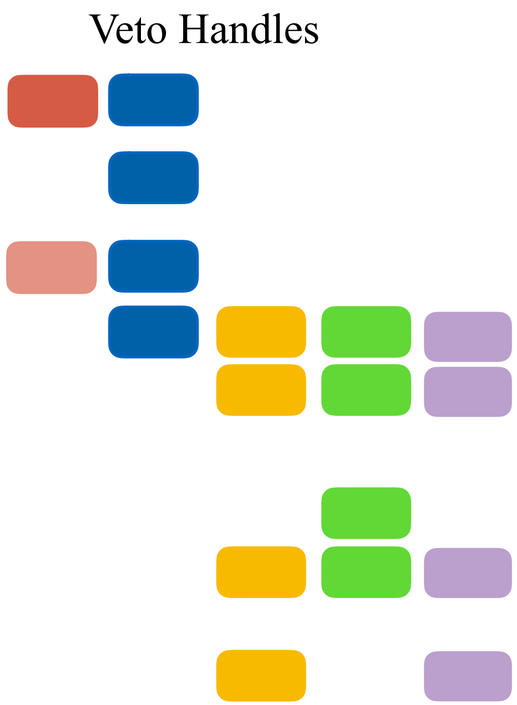




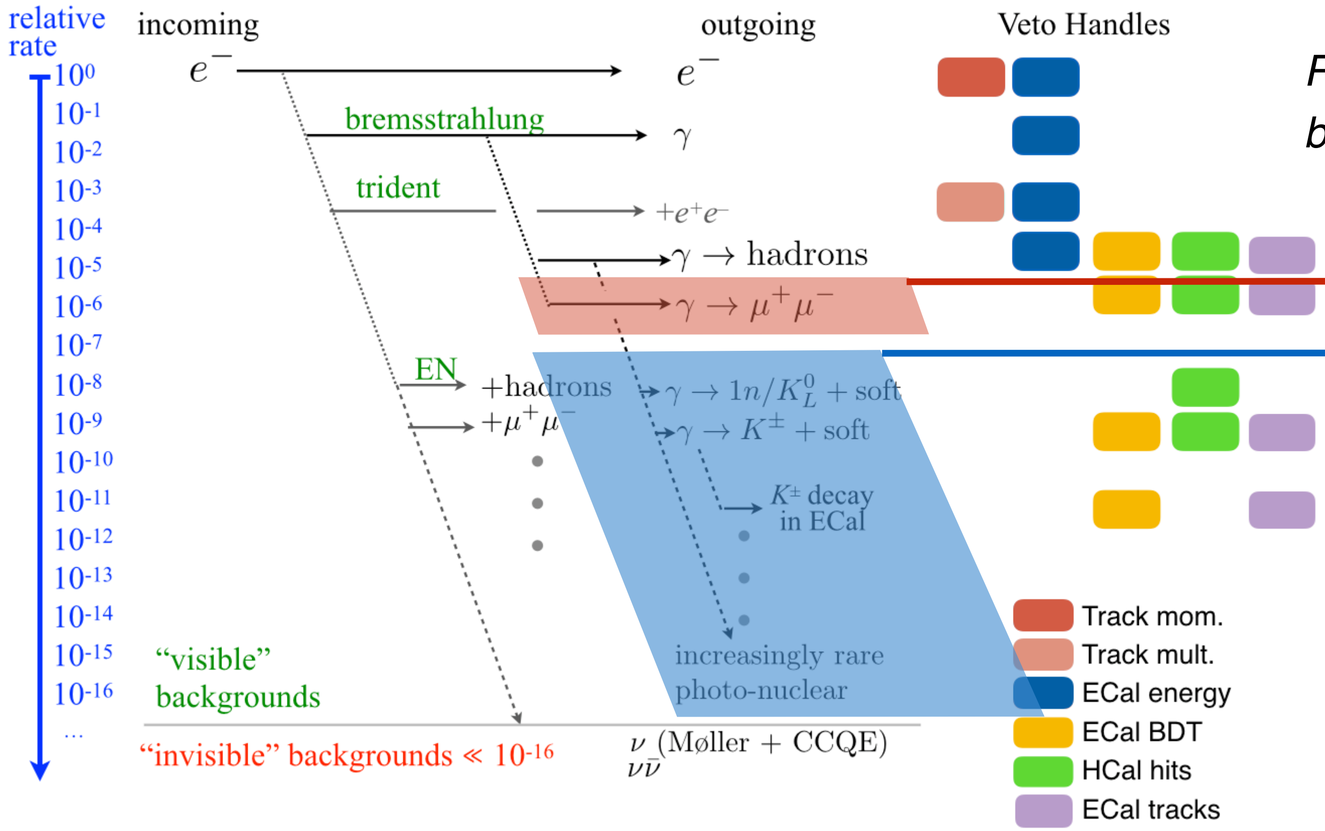
adapted from Mu2e
cosmic ray veto

Experimental handles





PN background rejection



Recent work exploring high-statistics MC samples & background veto performance: https://arxiv.org/abs/1912.05535

Integrated veto background performance

	Photo-nuclear		Muon conversion	
	Target-area	**ECal**	**Target-area**	**ECal**
EoT equivalent	4×10^{14}	2.1×10^{14}	8.2×10^{14}	2.4×10^{15}
Total events simulated	8.8×10^{11}	4.65×10^{11}	6.27×10^{8}	8×10^{10}
Trigger, ECal total energy < 1.5 GeV	1×10^{8}	2.63×10^{8}	1.6×10^{7}	1.6×10^{8}
Single track with $p < 1.2$ GeV	2×10^{7}	2.34×10^{8}	3.1×10^{4}	1.5×10^{8}
ECal BDT (> 0.99)	9.4×10^{5}	1.32×10^{5}	< 1	< 1
HCal max PE < 5	< 1	10	< 1	< 1
ECal MIP tracks = 0	< 1	< 1	< 1	< 1

PN background rejection

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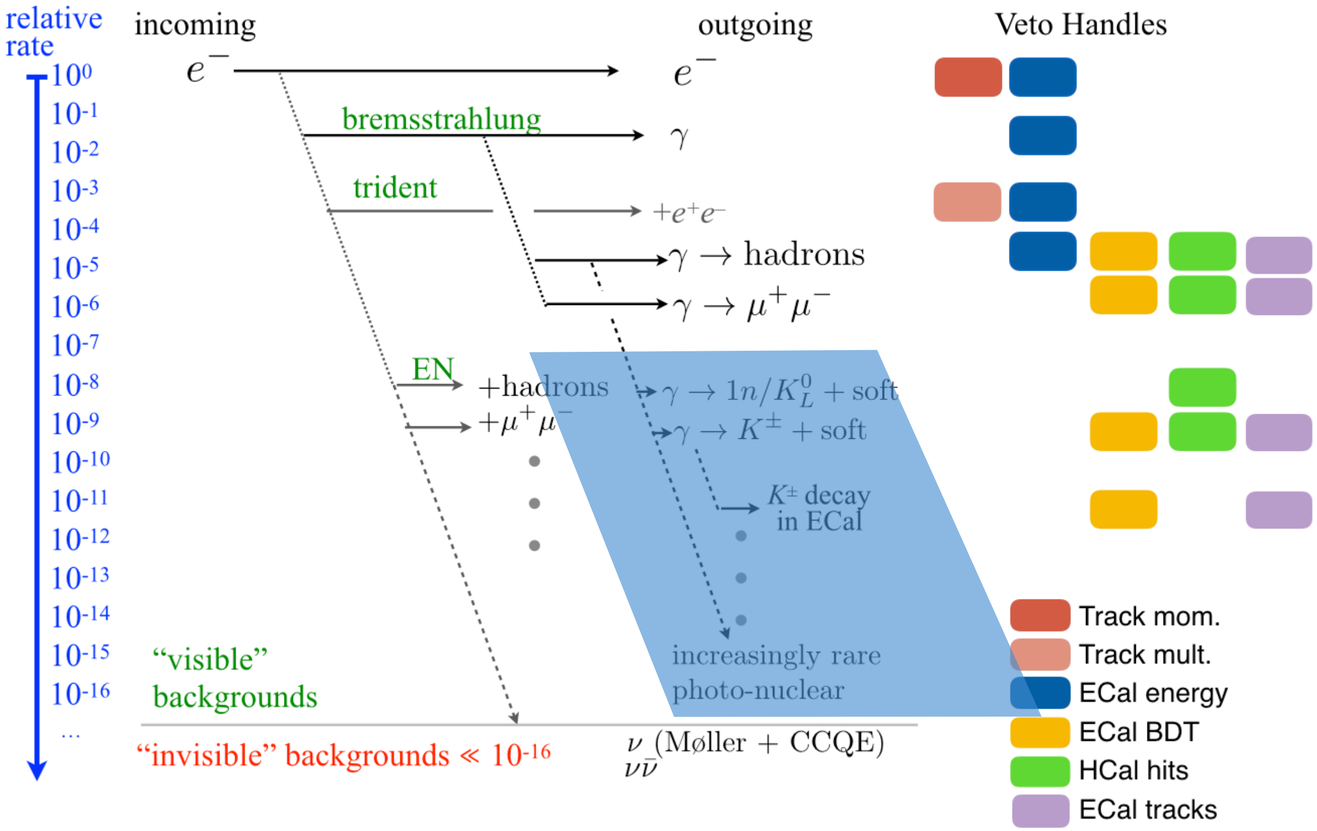
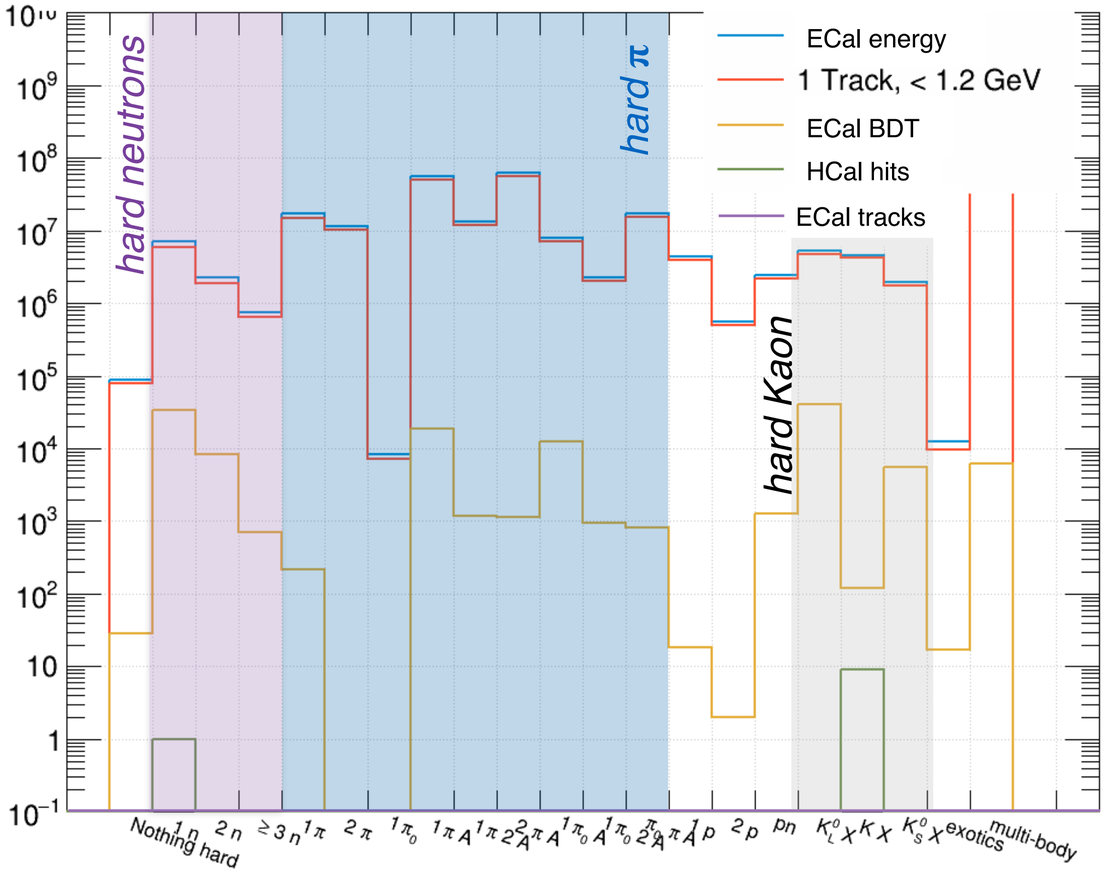


background veto performance vs final state

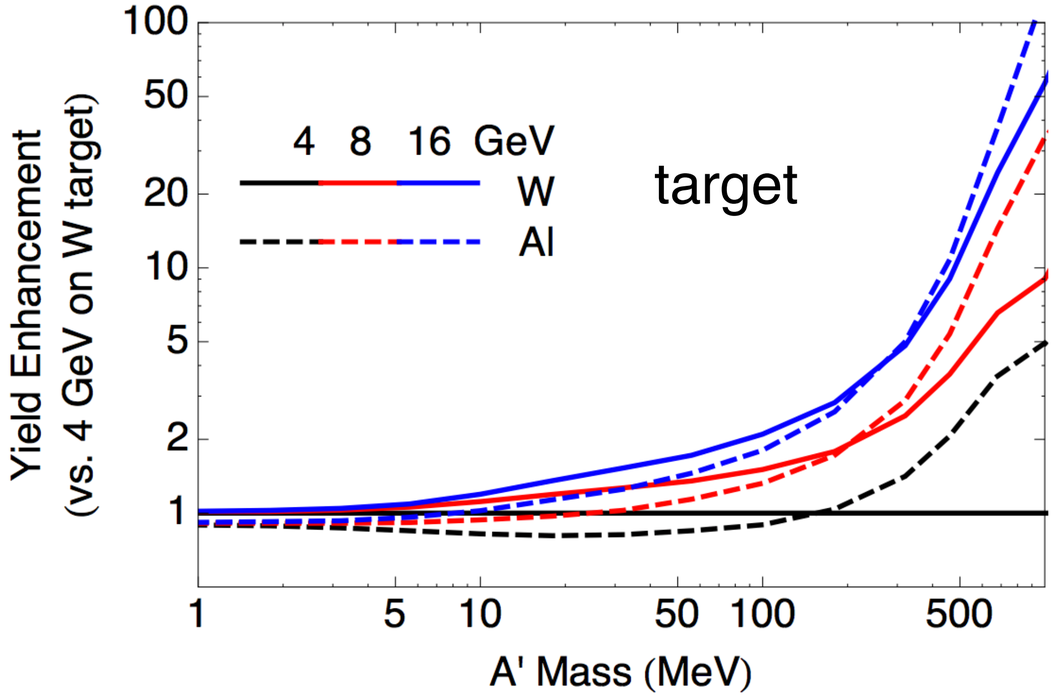


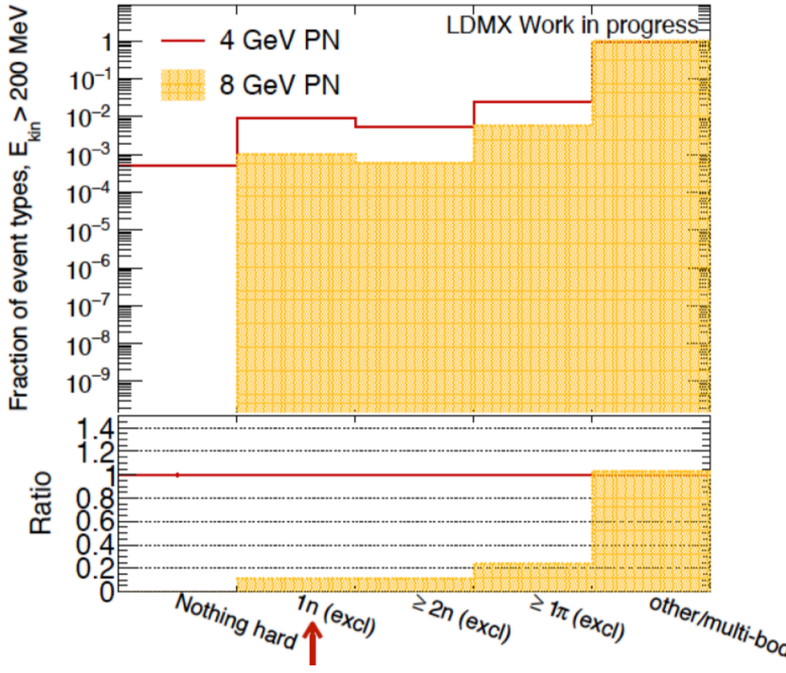
No events remain after all vetoes

signal efficiencies range from 30-50%

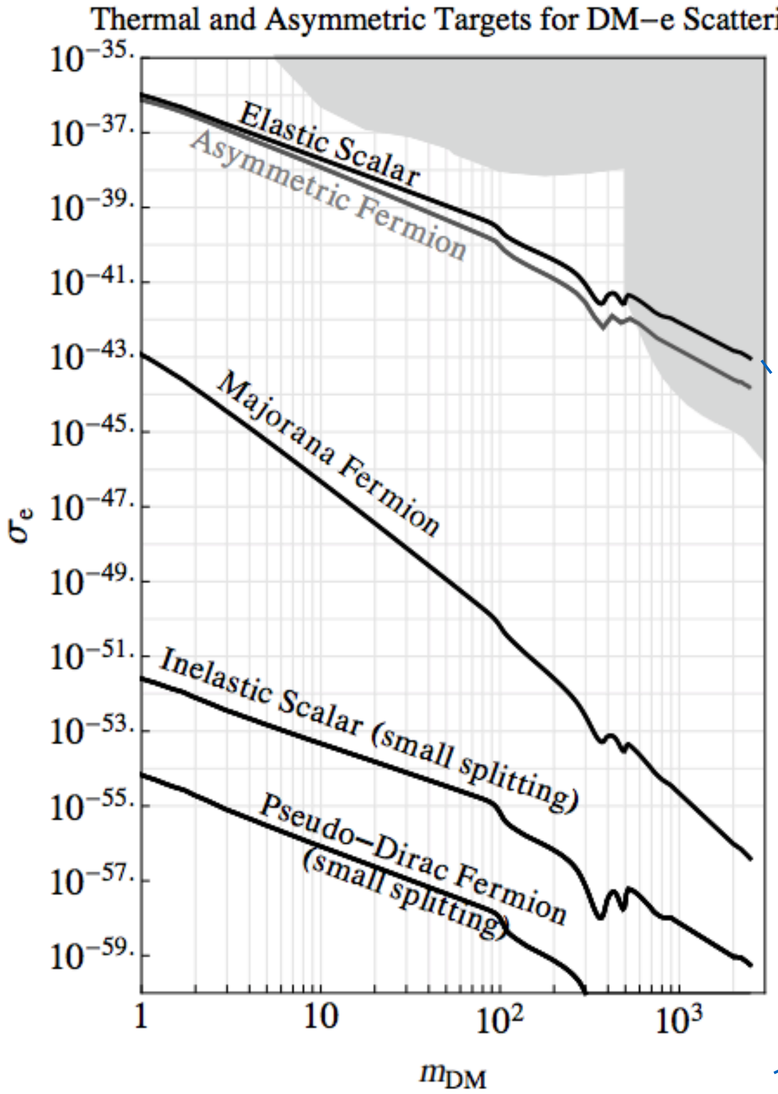
Ongoing work

- Optimizing high mass reach
  - higher energies
  - different targets
- Optimizing algorithms and analysis techniques
- Detector prototyping ramping up
  - Enabled by recent funding from DOE & Swedish foundation through Lund University

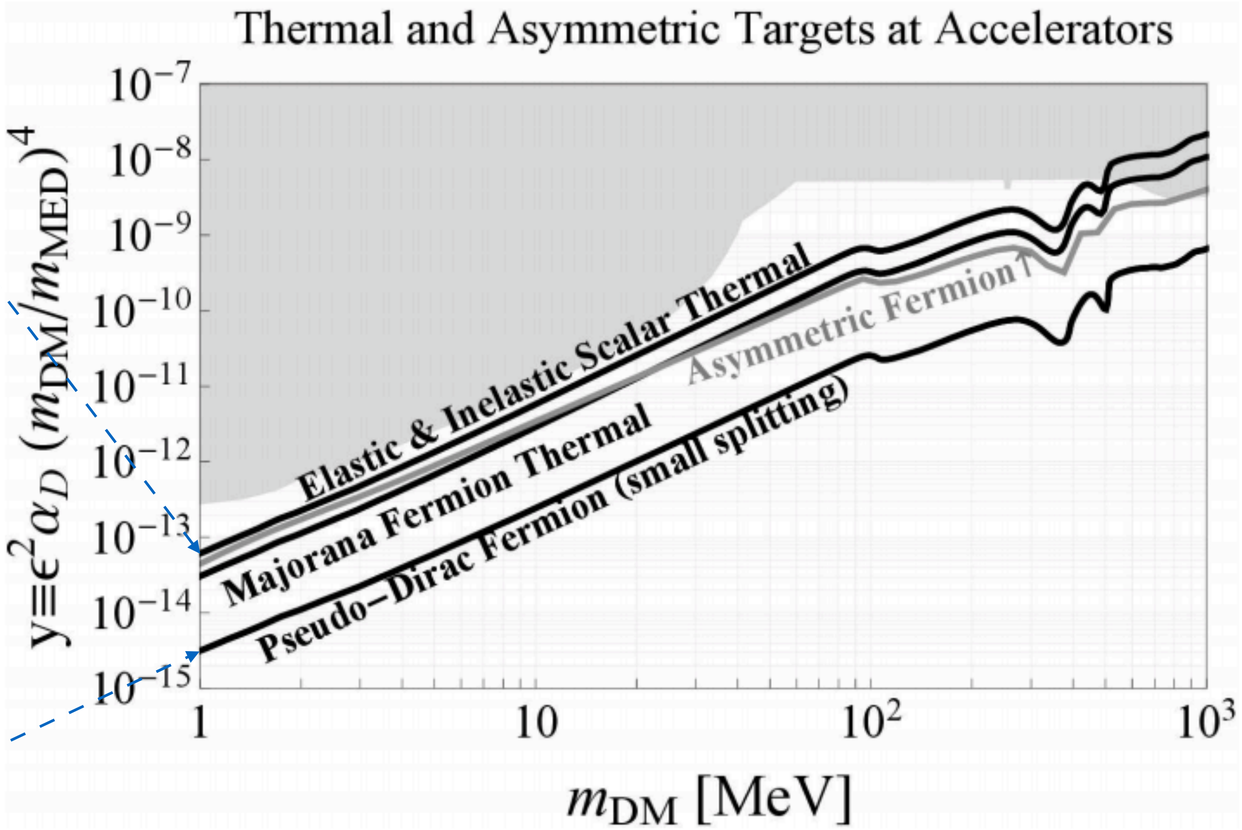




Light dark matter targets

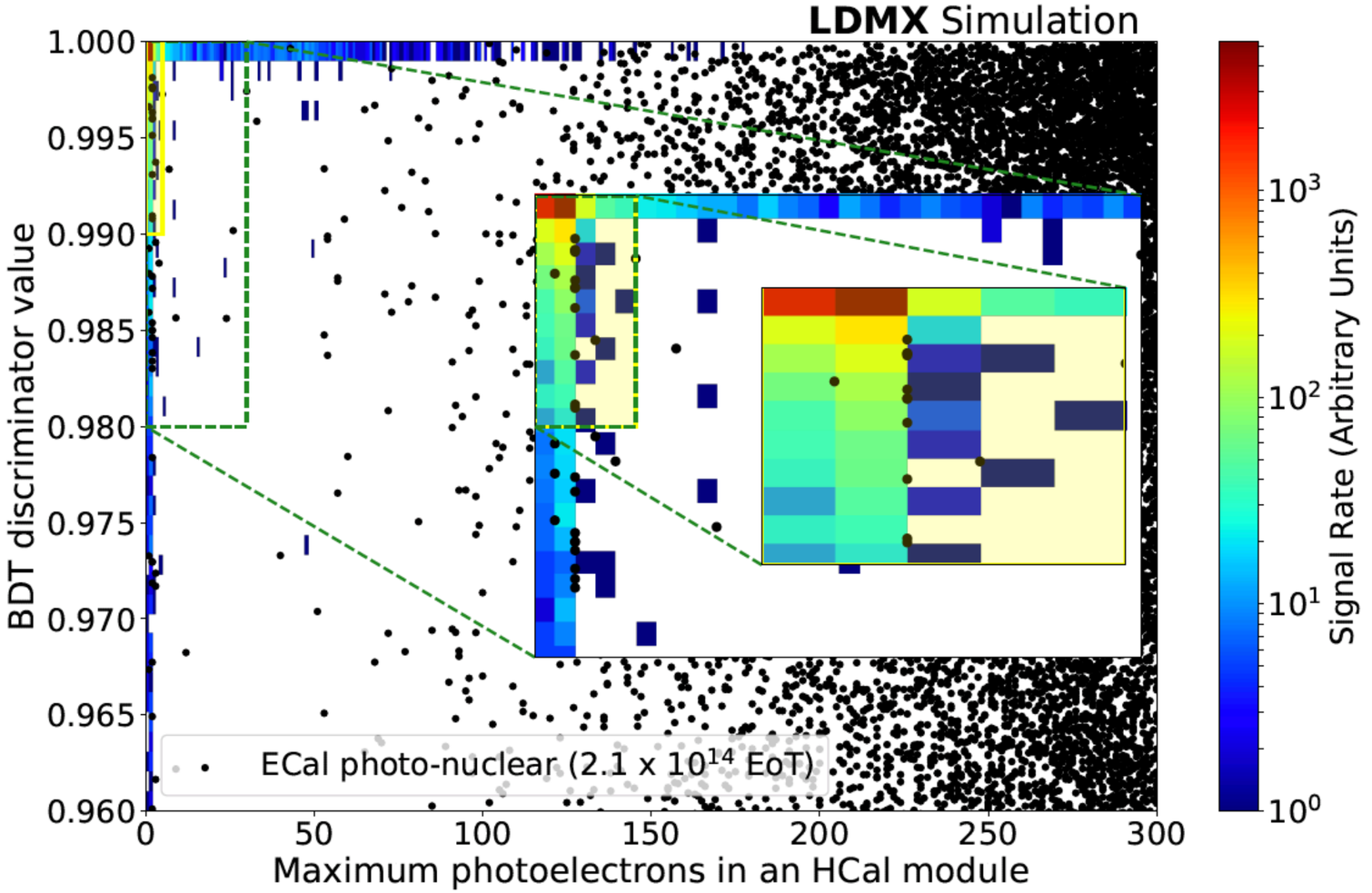


Accelerators produce dark matter relativistically, minimizing effect of different Lorentz structures.

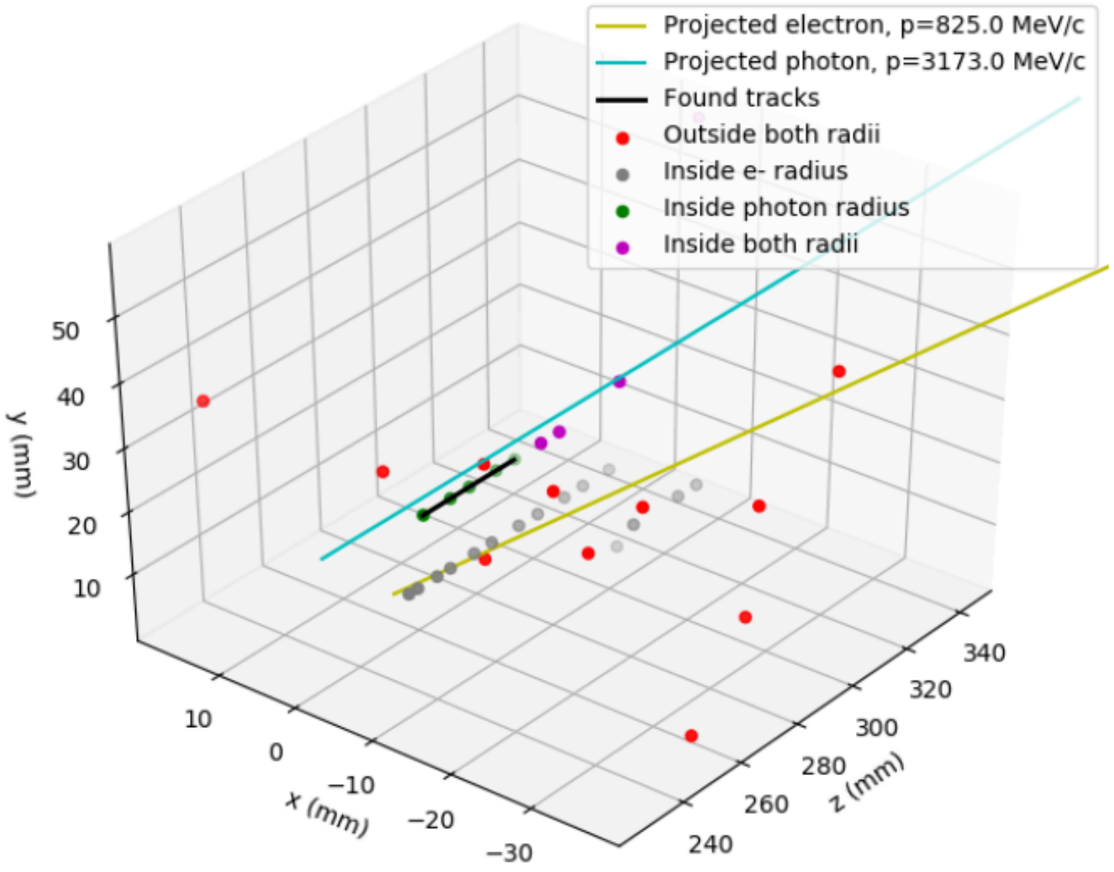


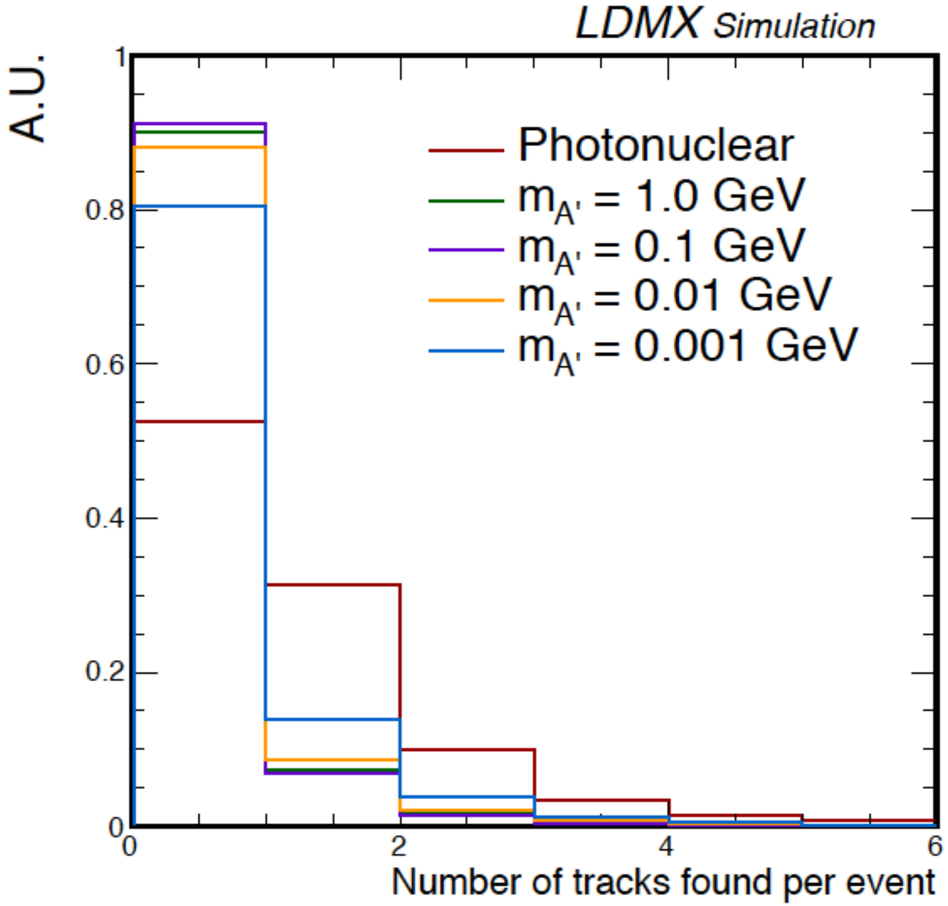
Thermal targets in non-relativistic ($\langle v \rangle \sim 10^{-3}c$) direct detection scattering is highly sensitive to Lorentz structure of interactions

ECal/HCal Vetoes



MIP tracking in ECal





LDMX sensitivity

- Varying $m_{A'}/2m_{\chi}$, LDMX remains sensitive over much of the parameter space where $m_{A'} > 2m_{\chi}$