The Light Dark Matter eXperiment

Andrew Whitbeck, Texas Tech University

on behalf of the LDMX collaboration

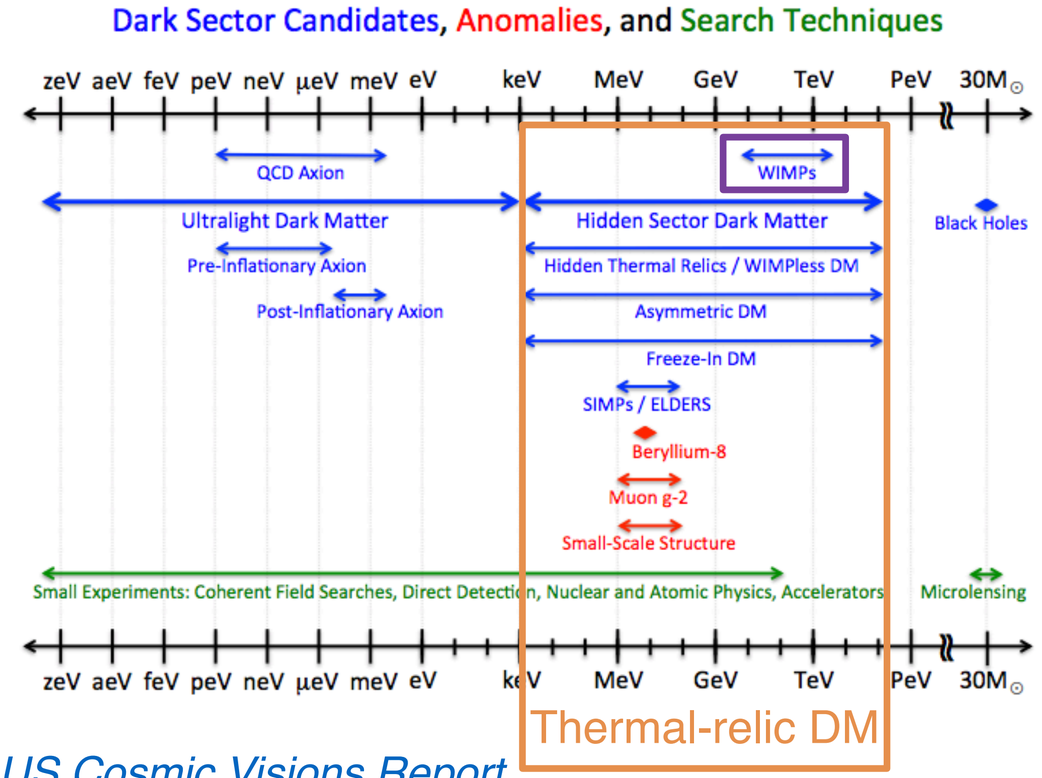
Caltech Fermilab LUNDS UNIVERSITET UNIVERSITY OF MINNESOTA UCSB UNIVERSITY OF CALIFORNIA SANTA BARBARA

SLAC NATIONAL ACCELERATOR LABORATORY STANFORD UNIVERSITY TEXAS TECH UNIVERSITY UNIVERSITY of VIRGINIA

LDMX

Dark Matter: a thermal-relic?

- A compelling and predictive explanation for the presence of a relic abundance of DM
- Much of the experimental effort has targeted WIMPs
- How do we build a comprehensive program to test the thermal-relic paradigm?
  - A focus of several *community driven workshop* to broaden DM program



US Cosmic Visions Report

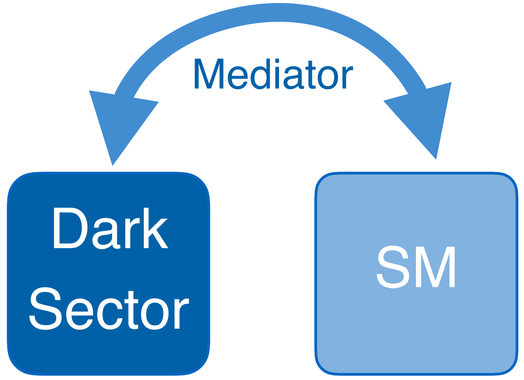
LDMX

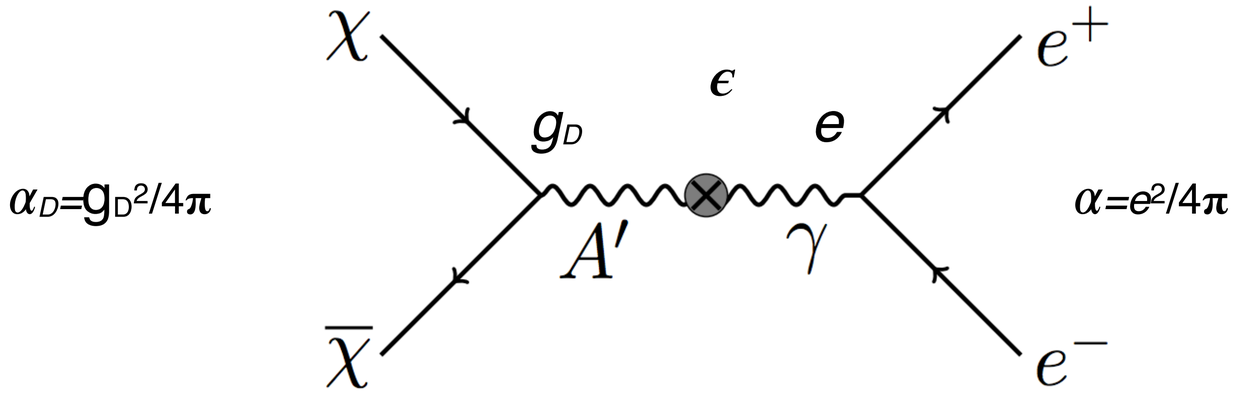
Light dark matter phenomenology

Light dark matter parameter space is a natural evolution of WIMP search program
Requires new light mediators:

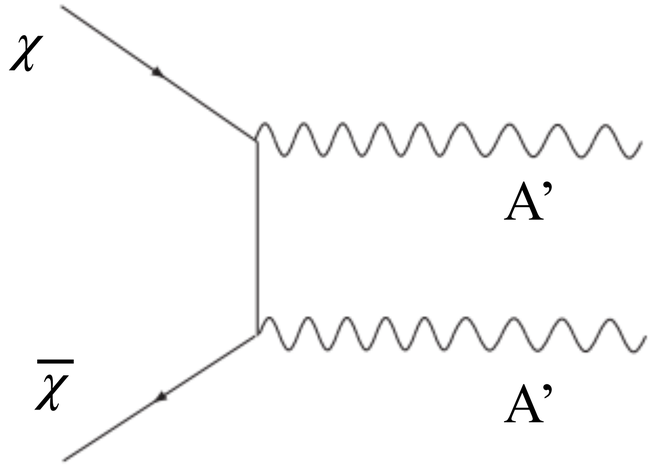
simple, predictive model: vector mediator which mixes with photon

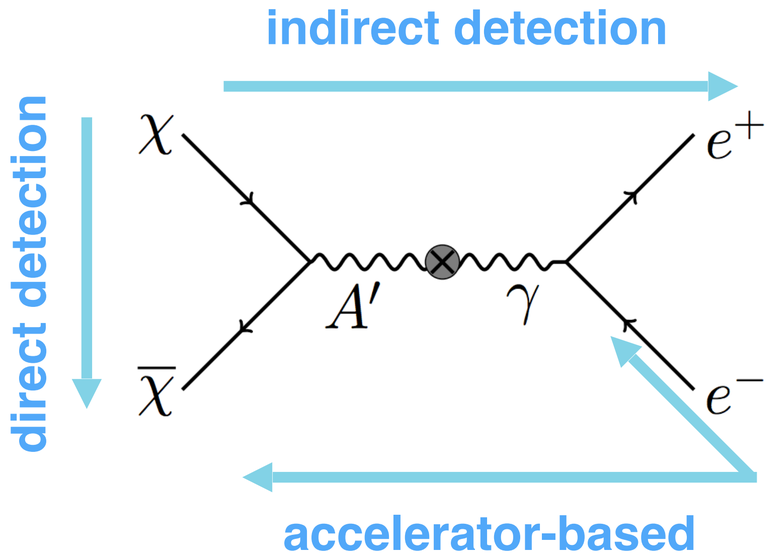
Electrons play a central role in dark matter & light mediator searches

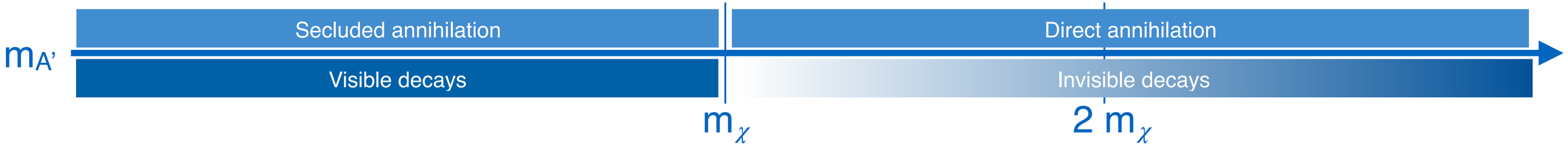




Light dark matter phenomenology







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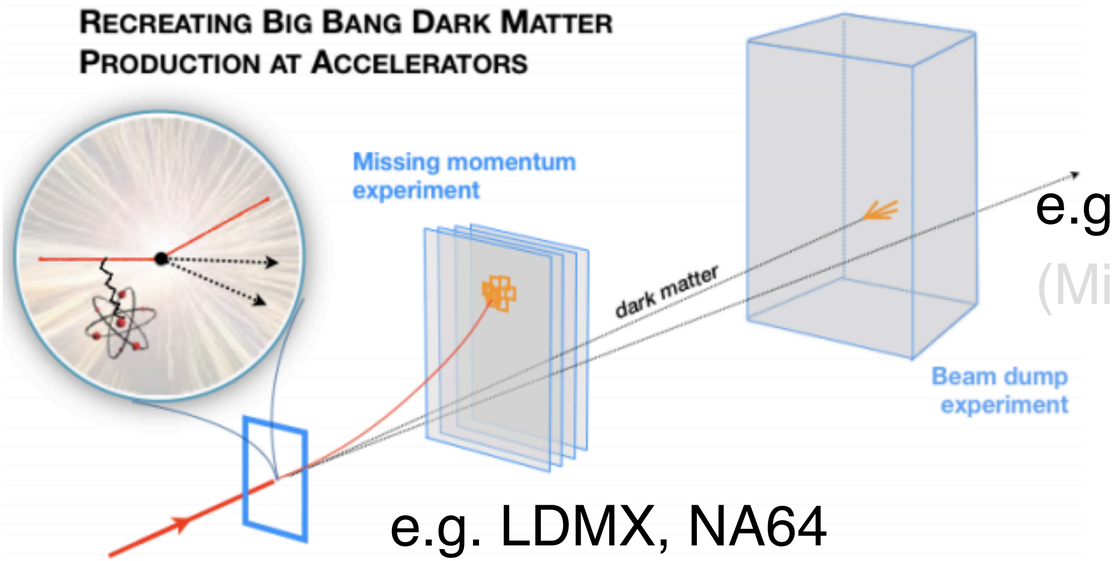
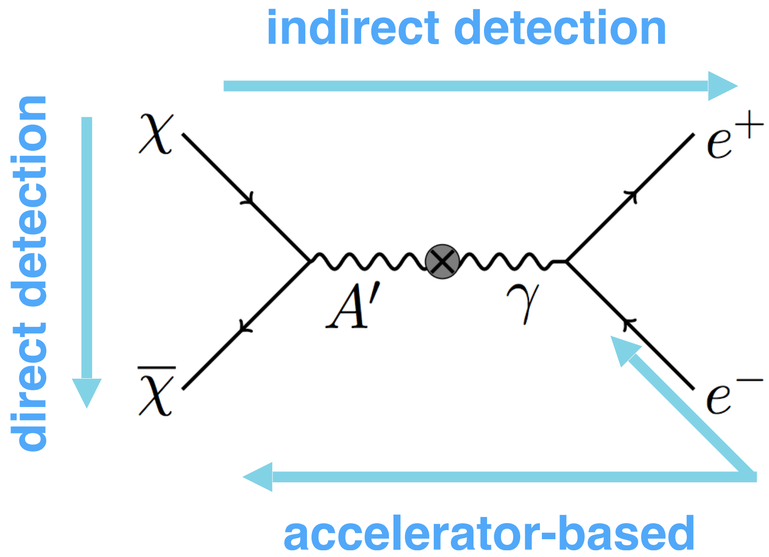
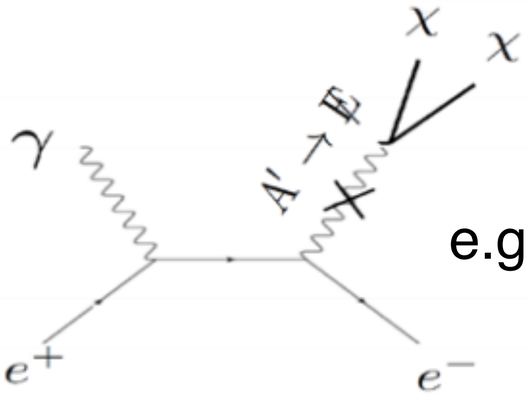


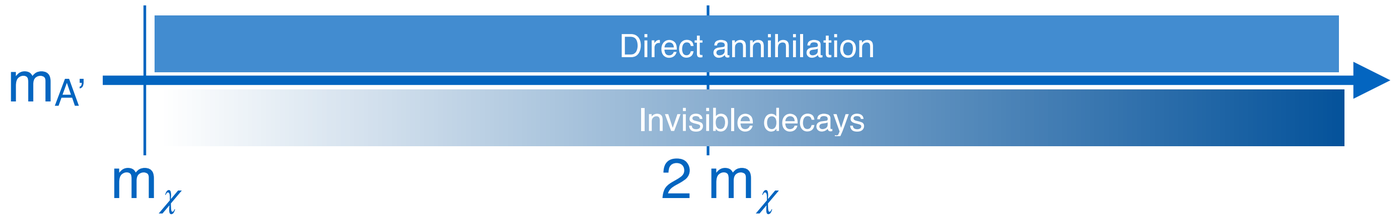
e.g. LDMX, NA64

e.g. BDX (MiniBoone)





e.g. Belle II (LHC)

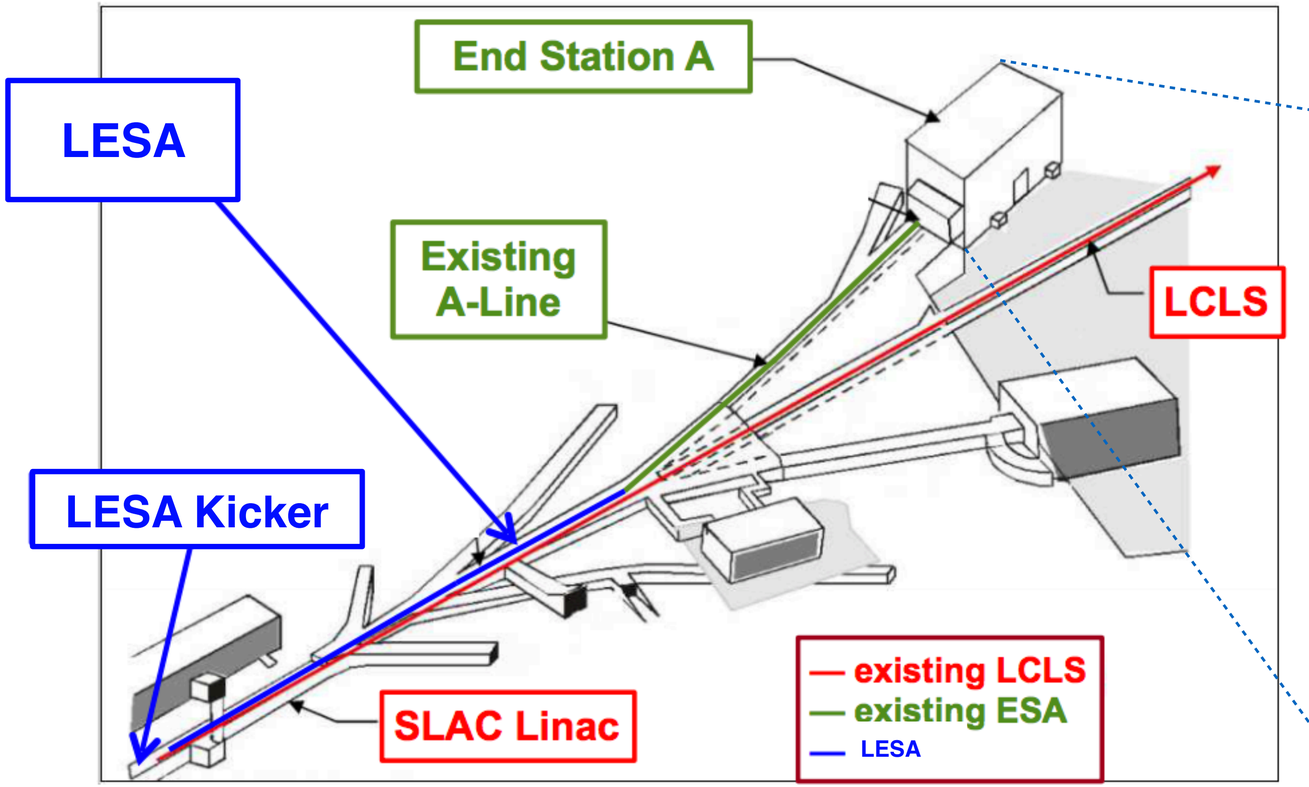


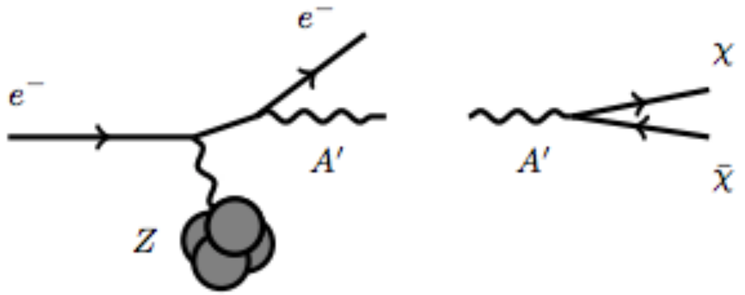
ICHEP 2020

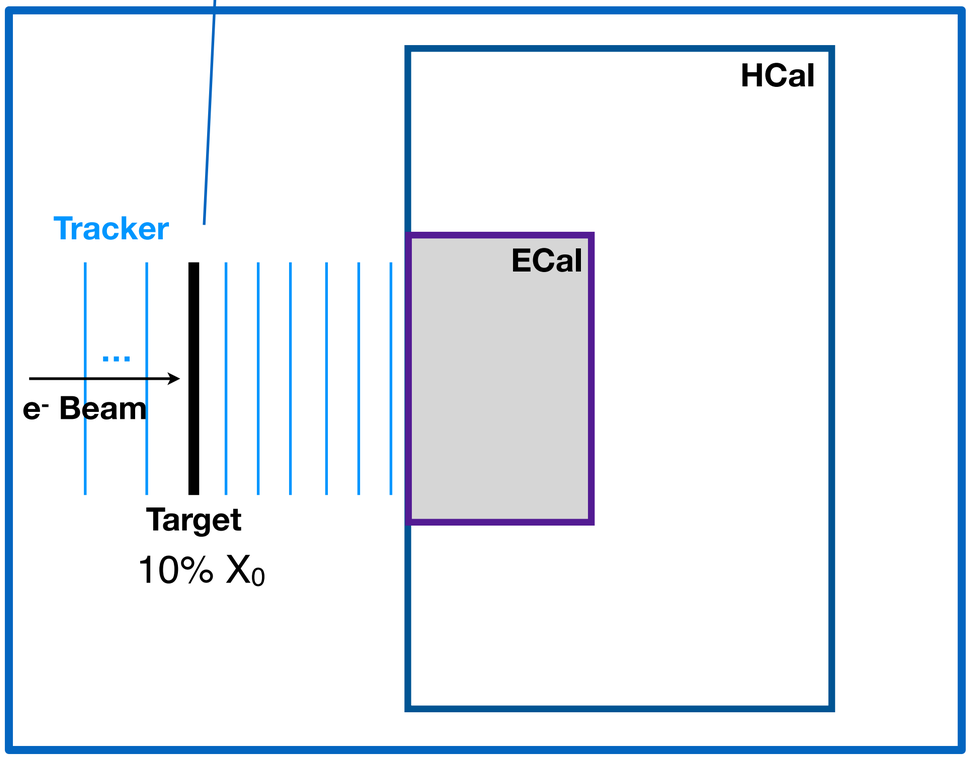
e.g. analogs with proton couplings

LDMX

LDMX Experimental concept







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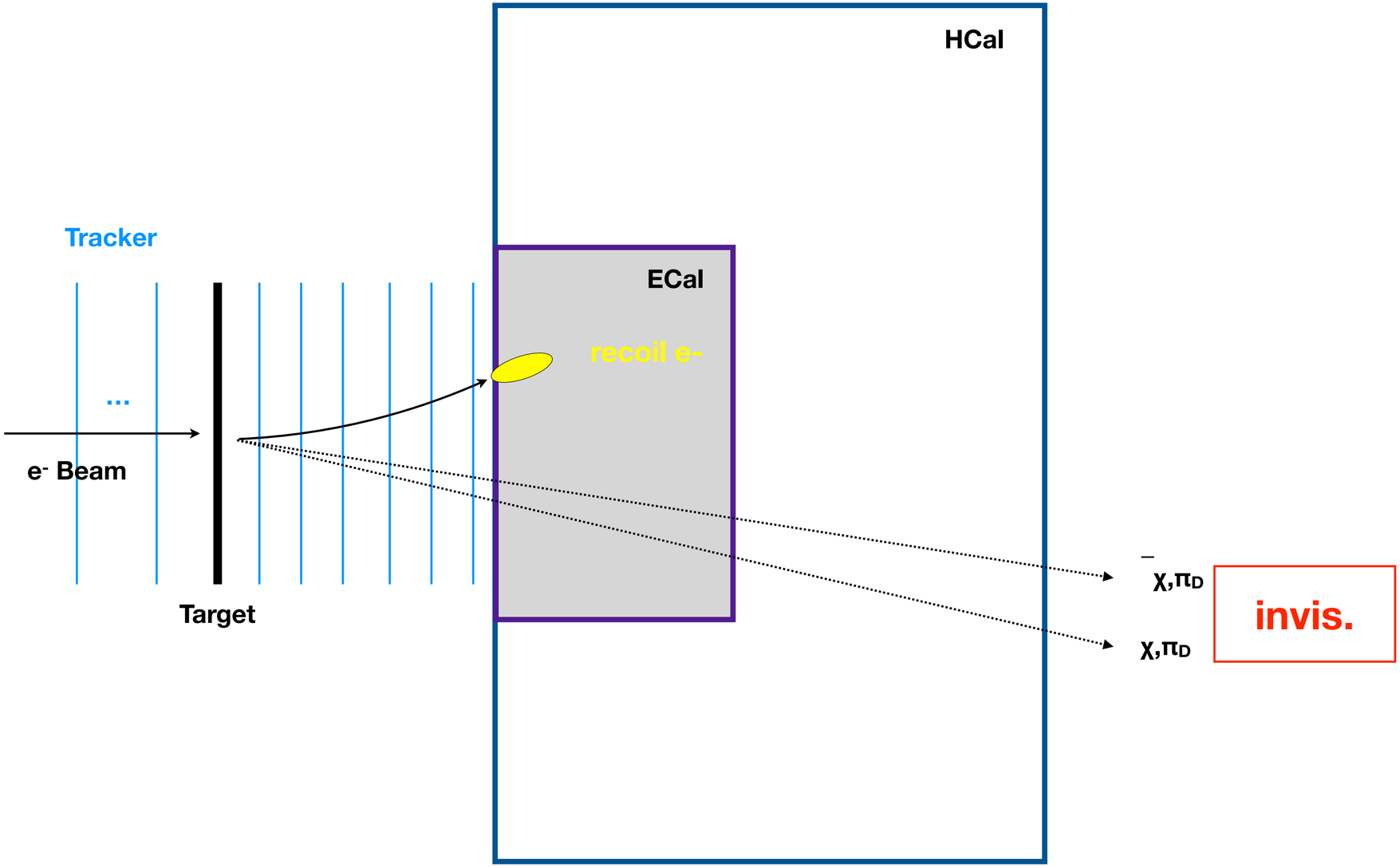
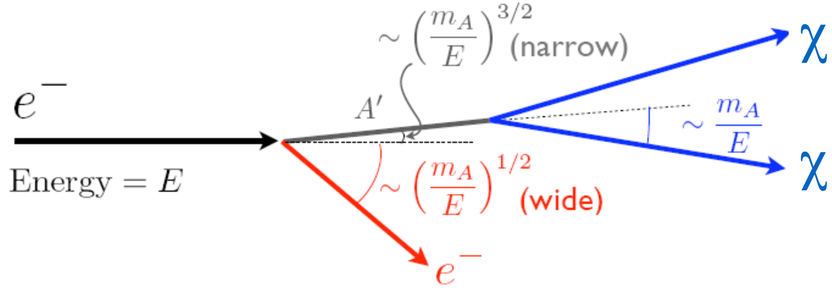
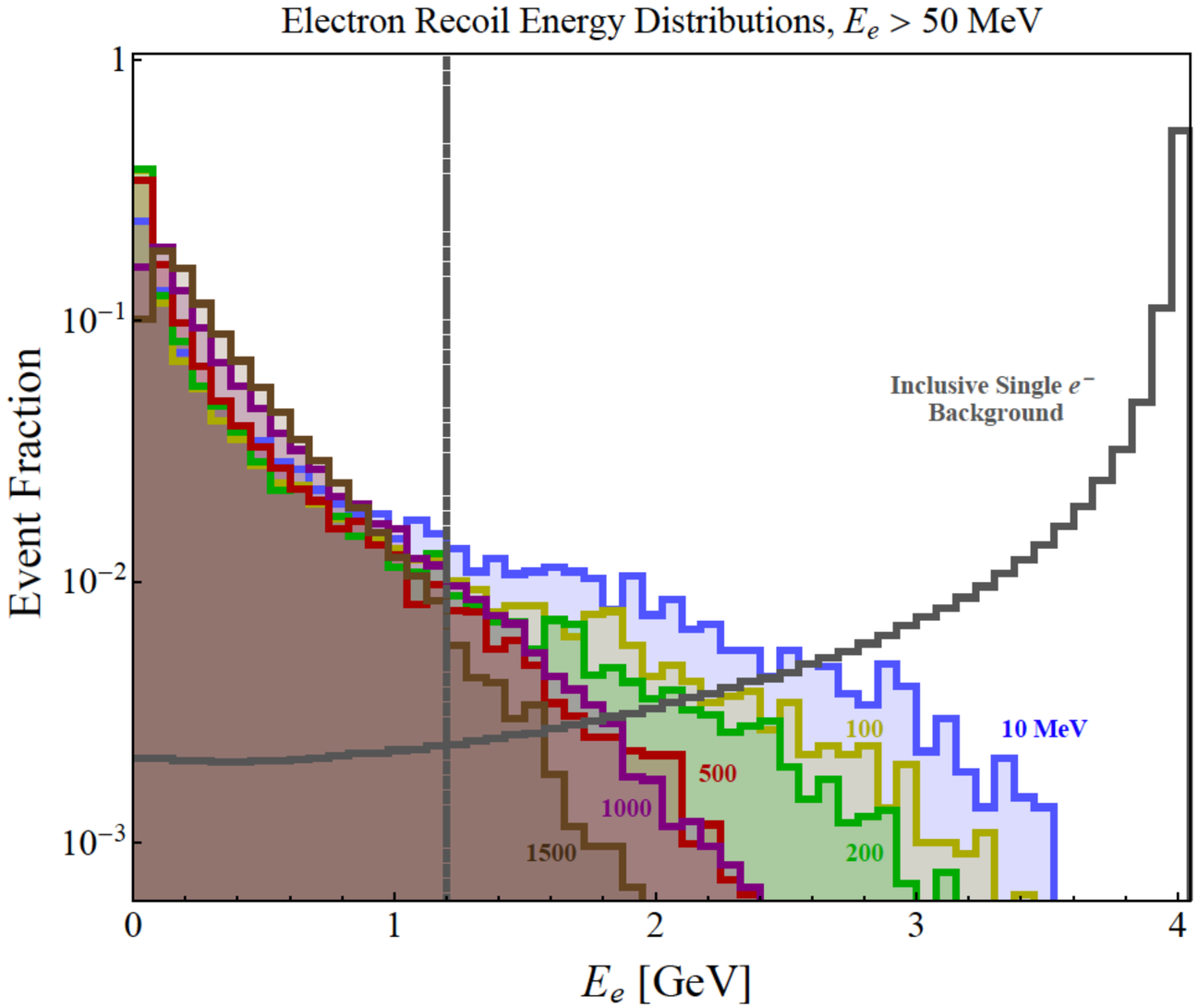


Signal kinematics

- A’ carries away mostly of the beam energy and converts it to invisible particles

- Recoil electron p_T spectrum of signal depends on $m_{A'}$ and is an important experimental handle
  - both for background discrimination and signal characterization





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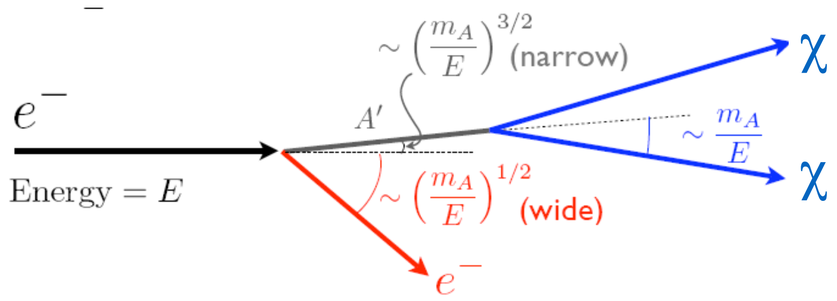

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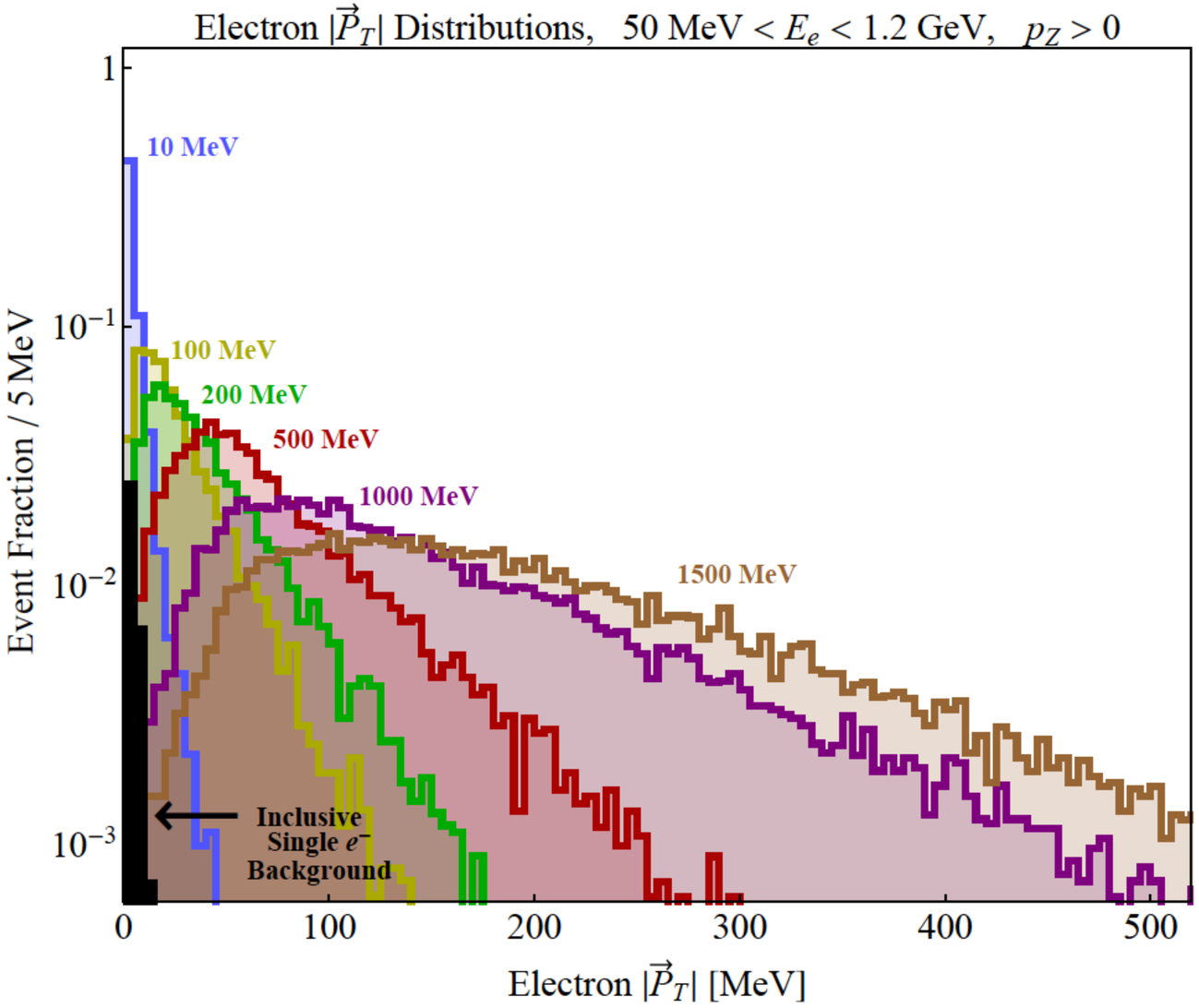
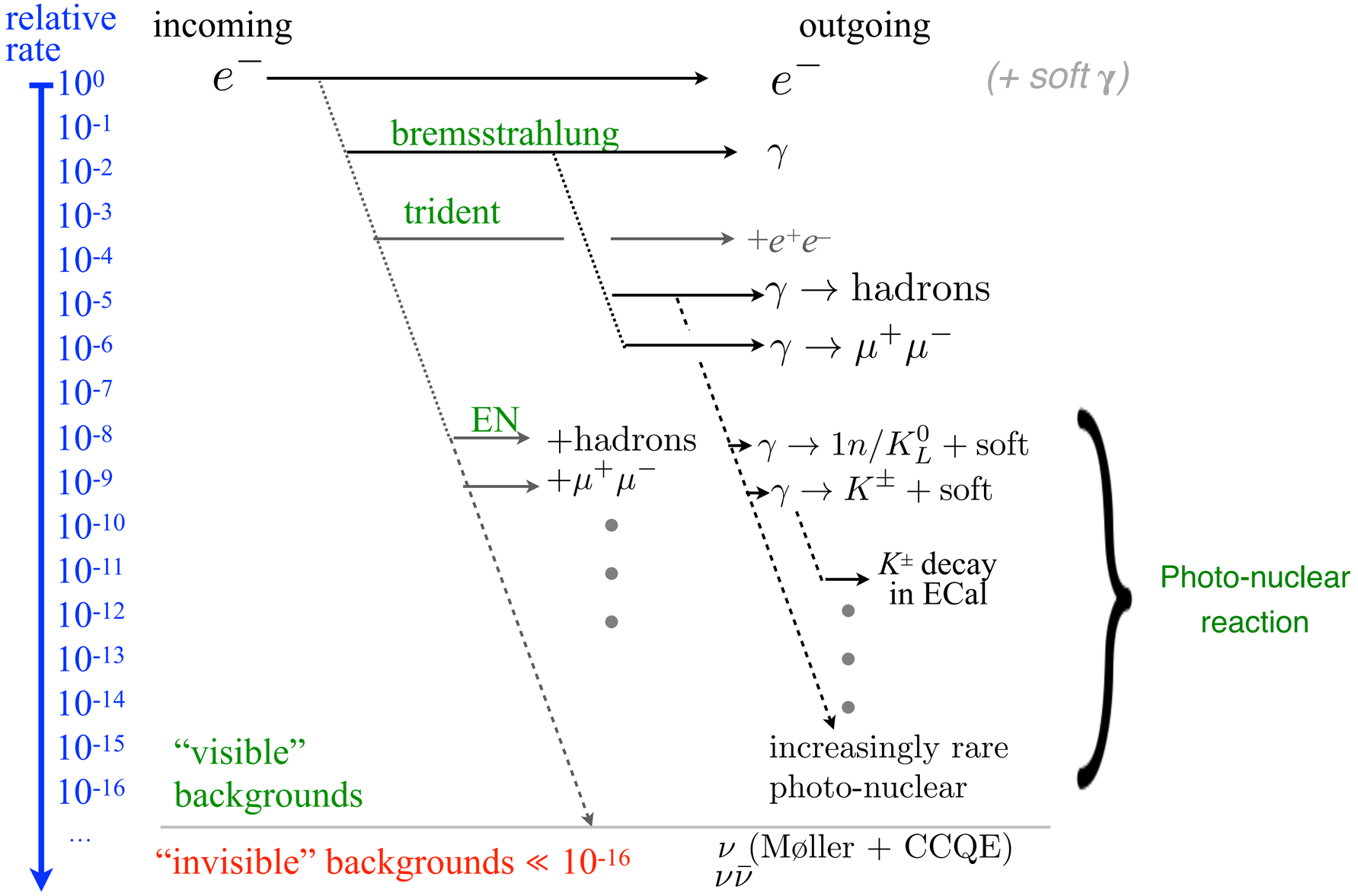
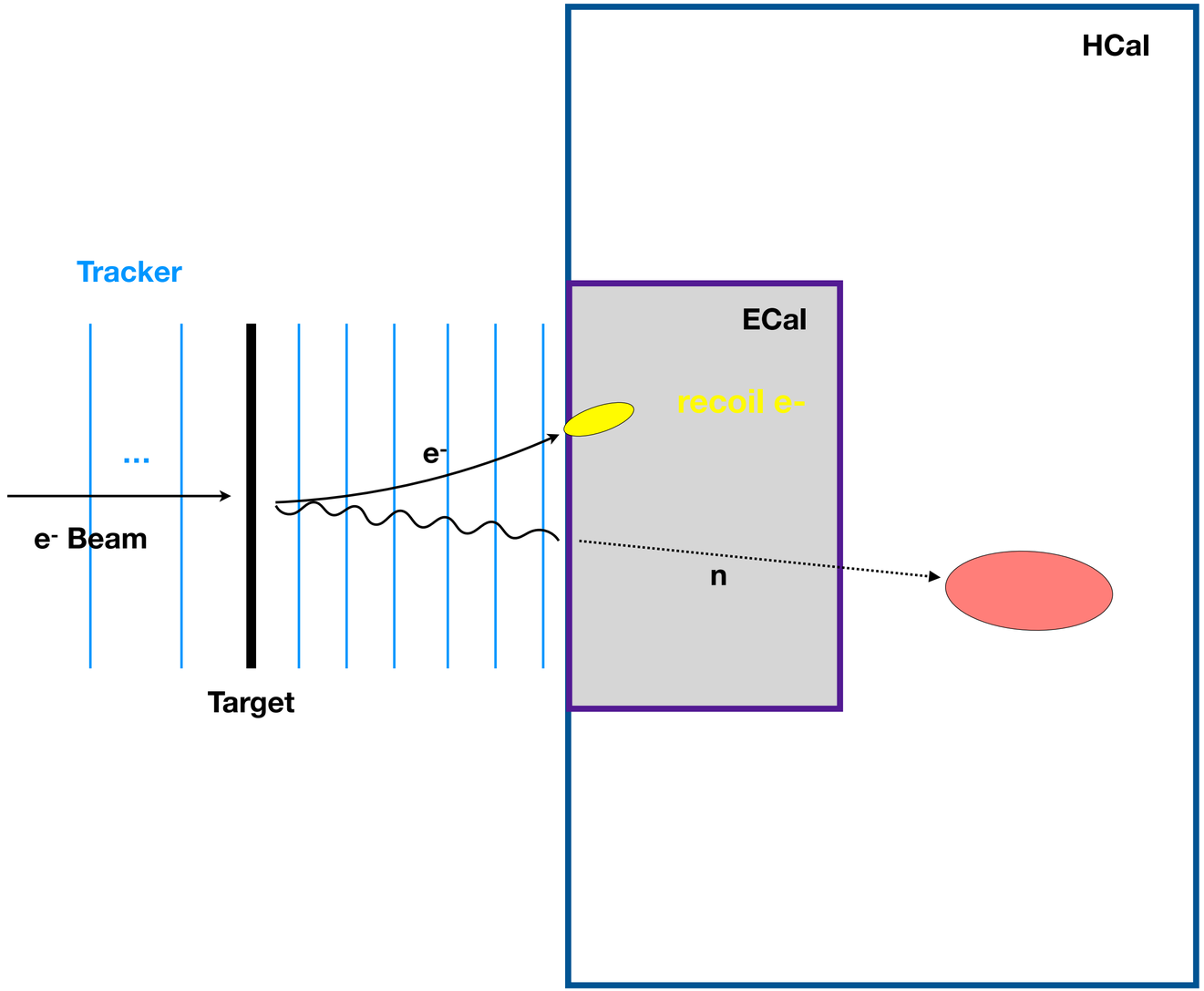


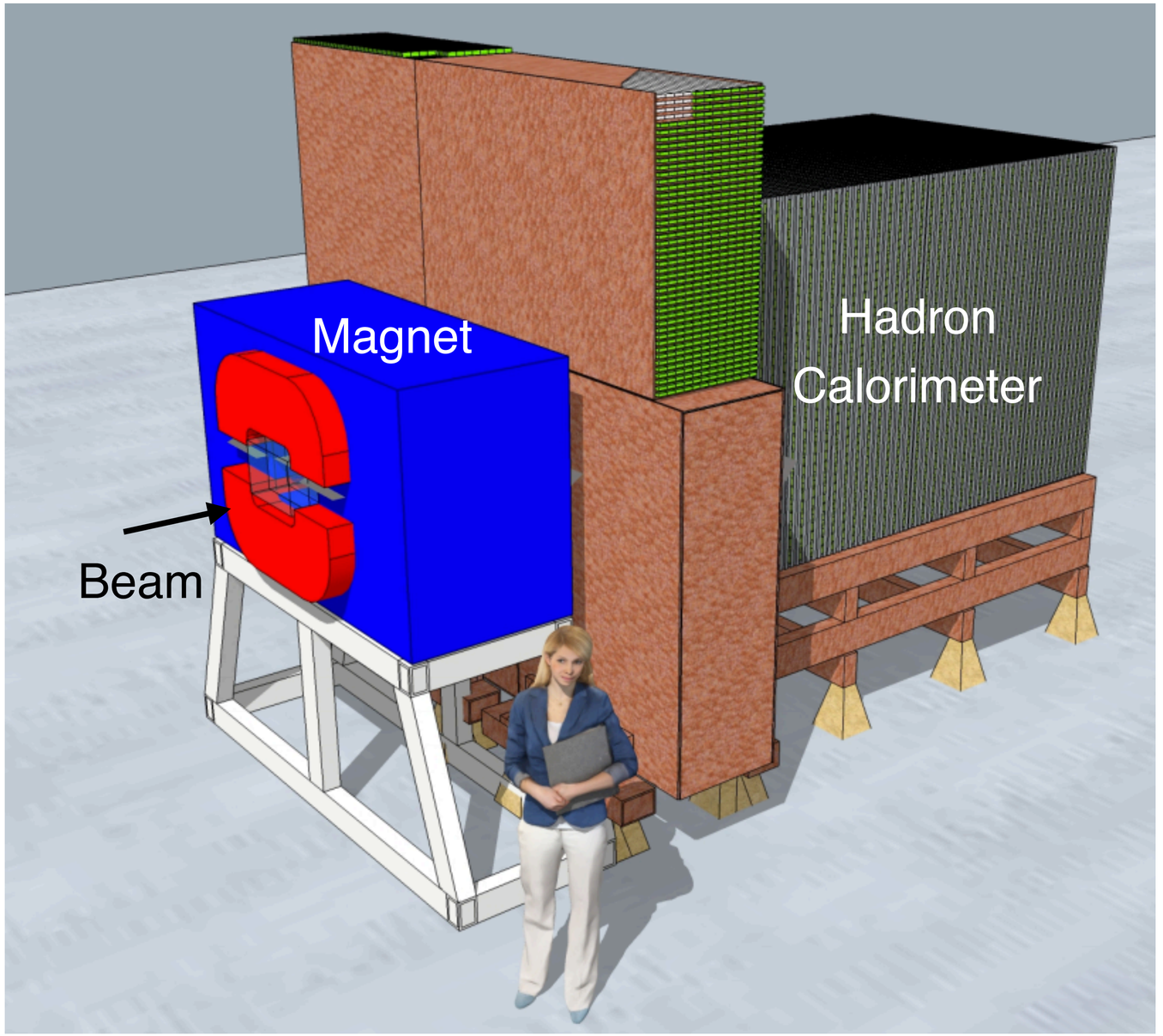
Backgrounds

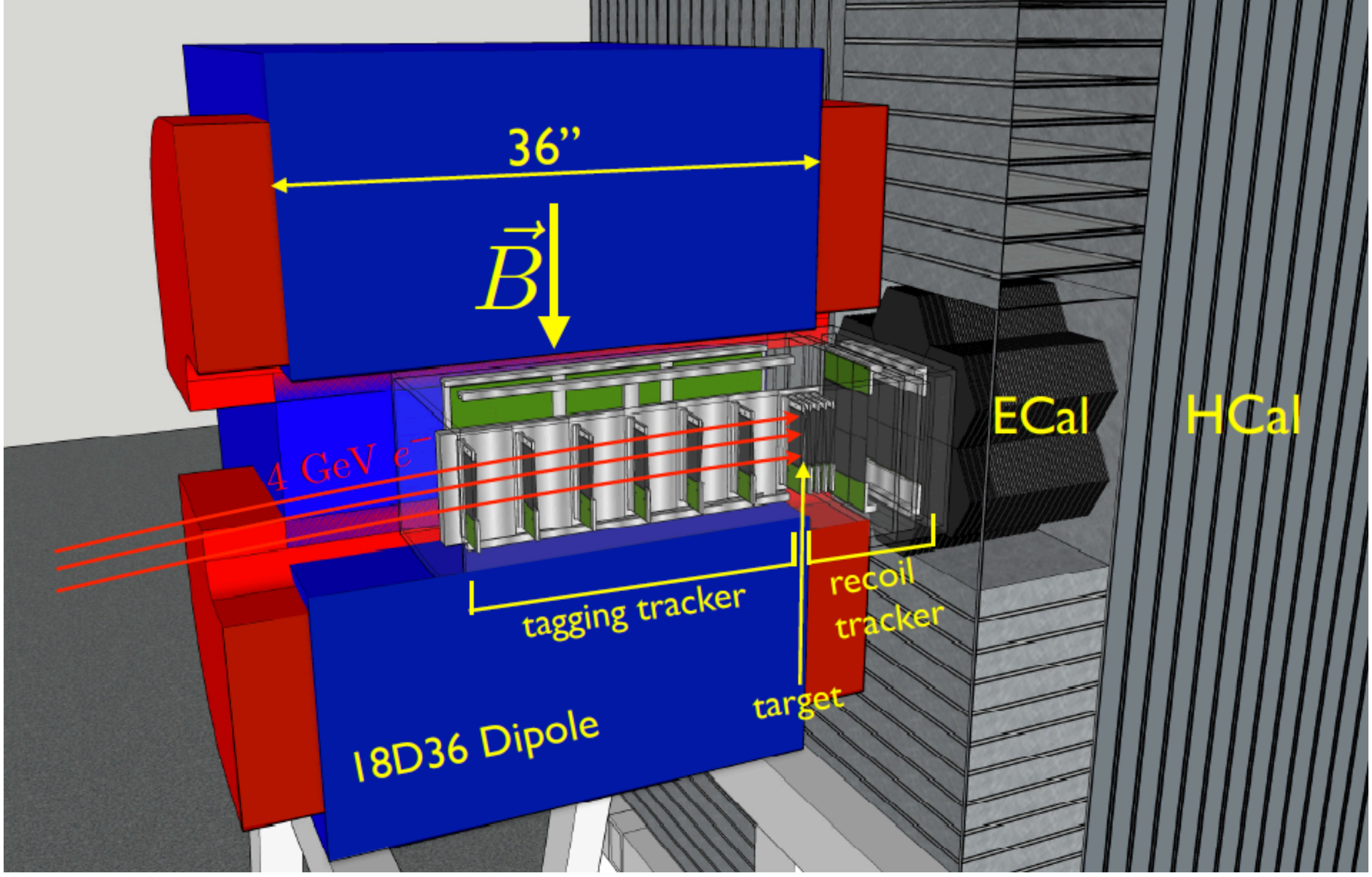


LDMX Experimental concept



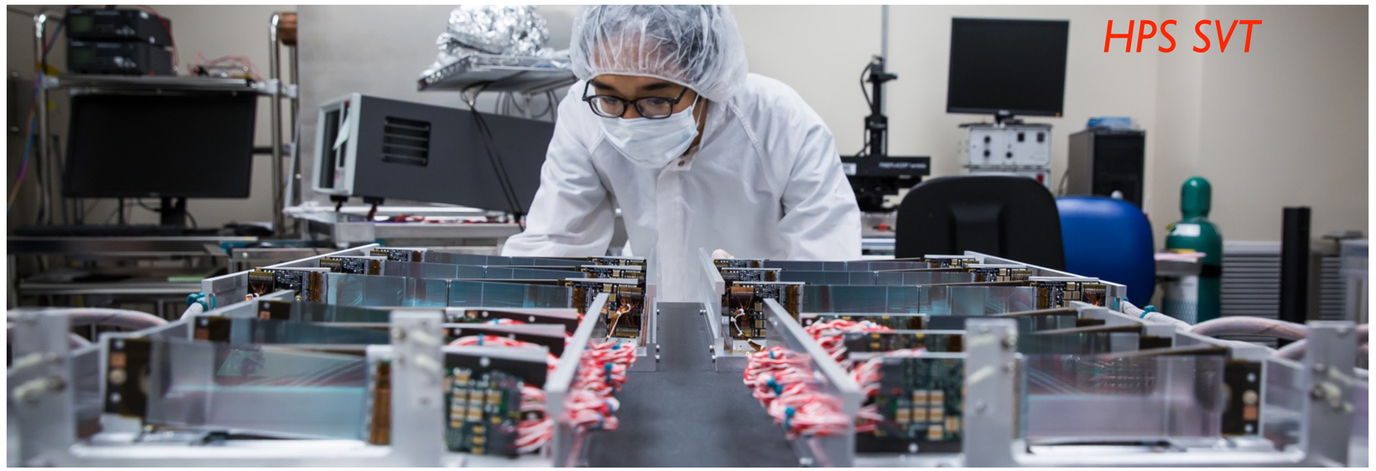
Detector concept

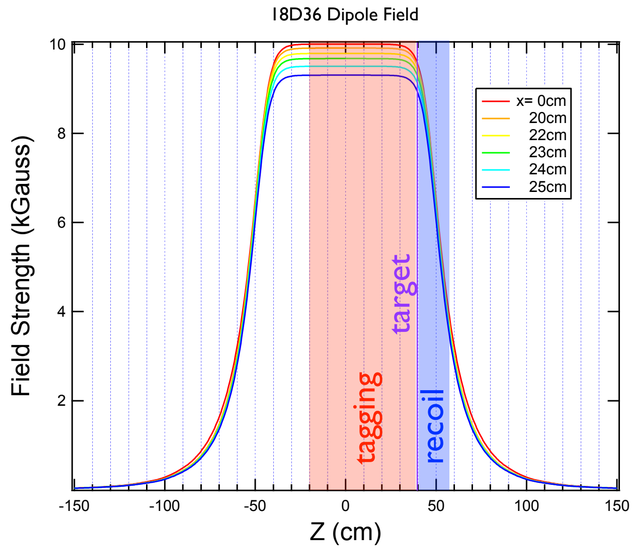


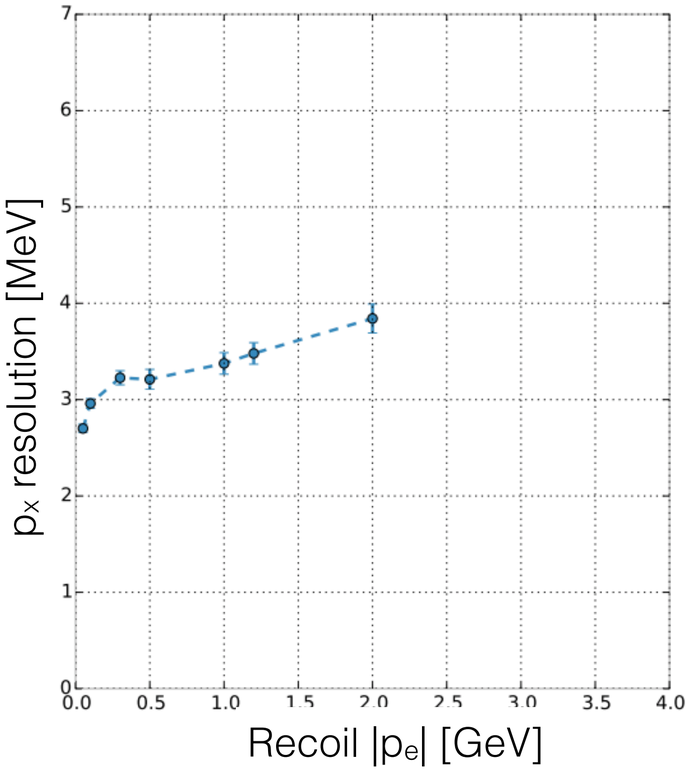

36”
$\vec{B}$
4 GeV e^-
ECal
HCal
tagging tracker
recoil tracker
target
18D36 Dipole

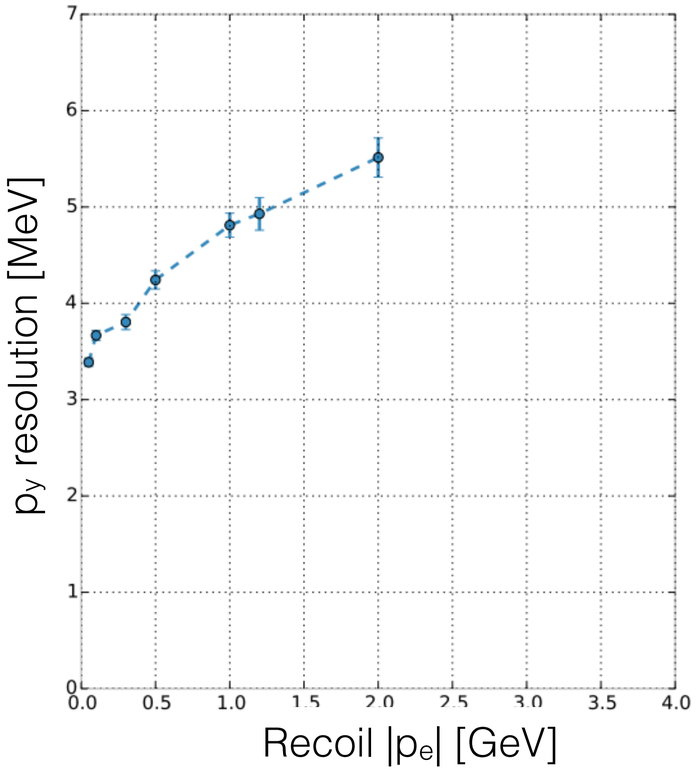
Tracking

- **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)



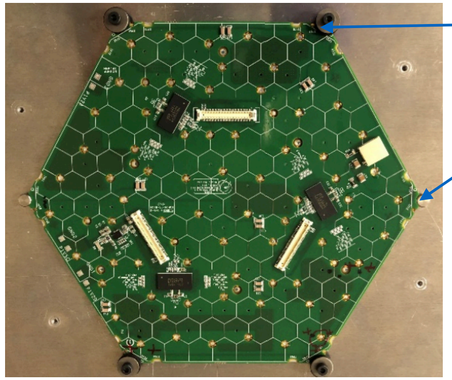


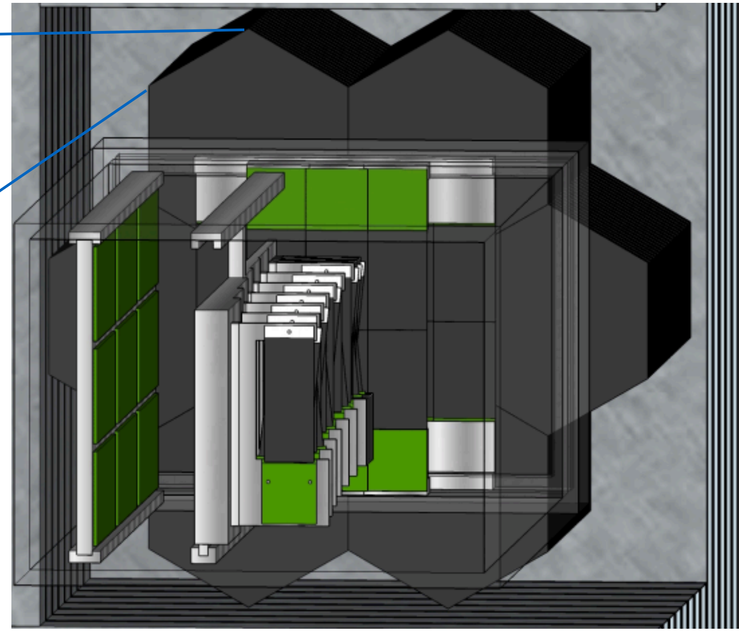


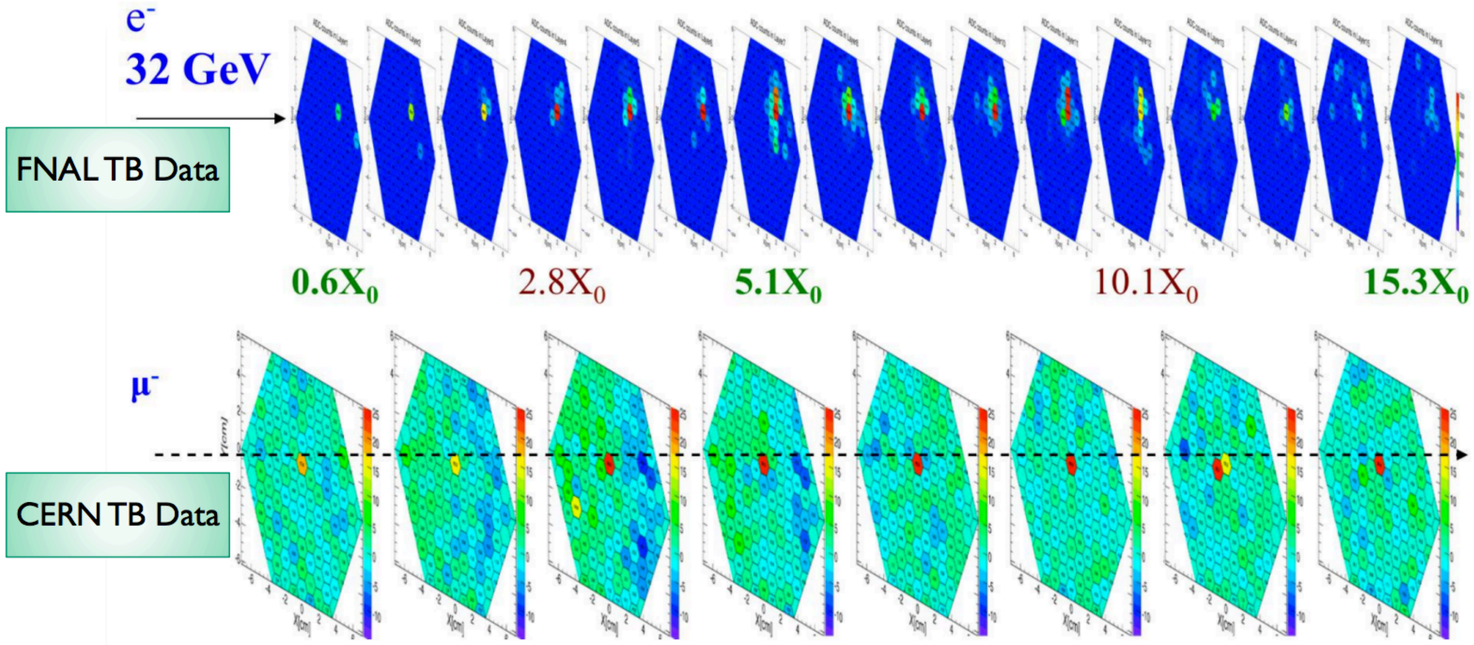


EM Calorimeter

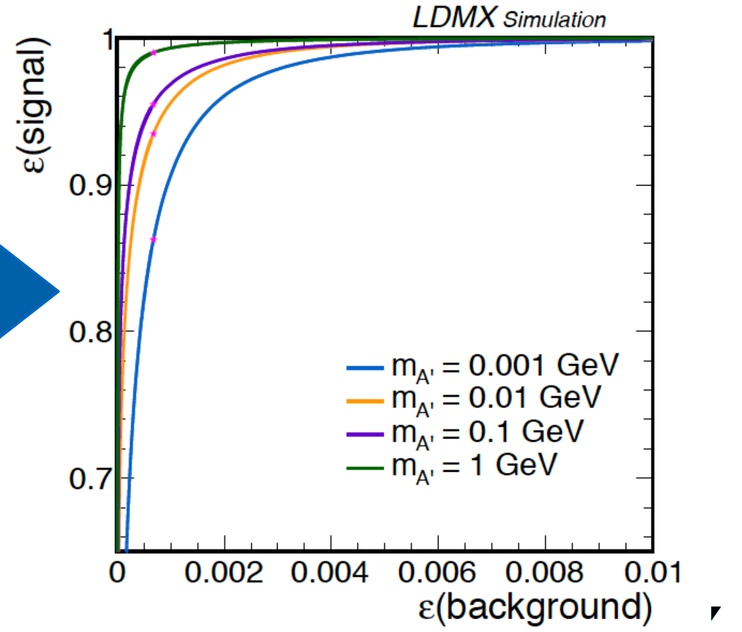
- 40 X_0 silicon-tungsten imaging calorimeter
  - high granularity: can exploit both transverse & longitudinal shower shapes to reject PN events
  - MIP sensitivity





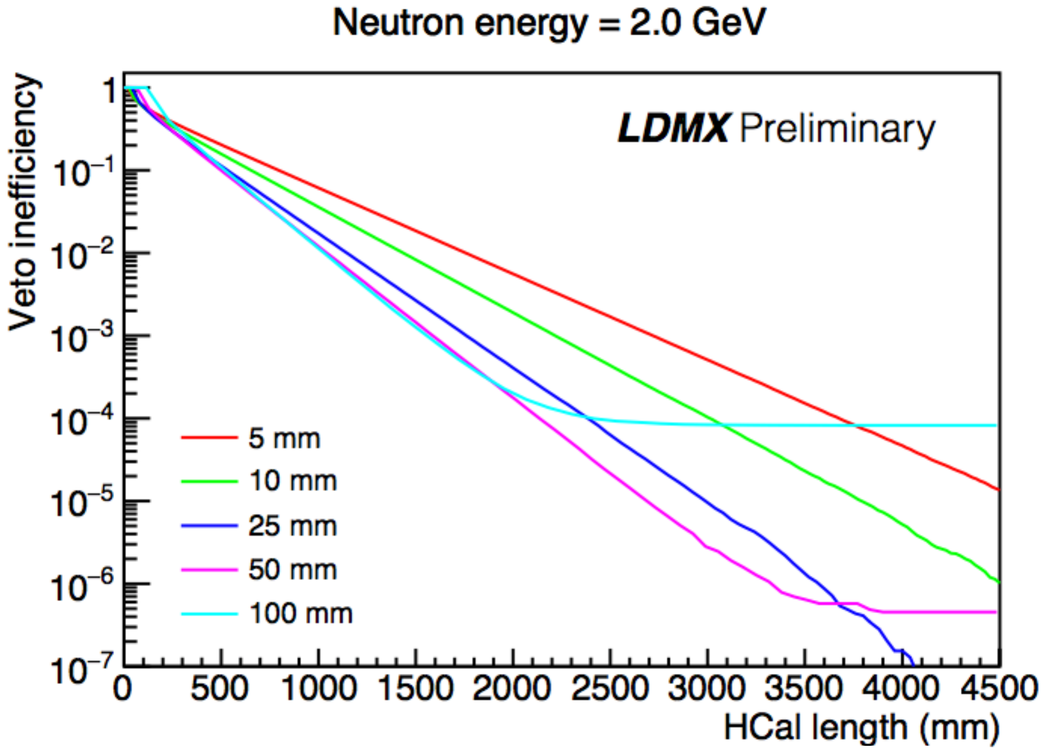


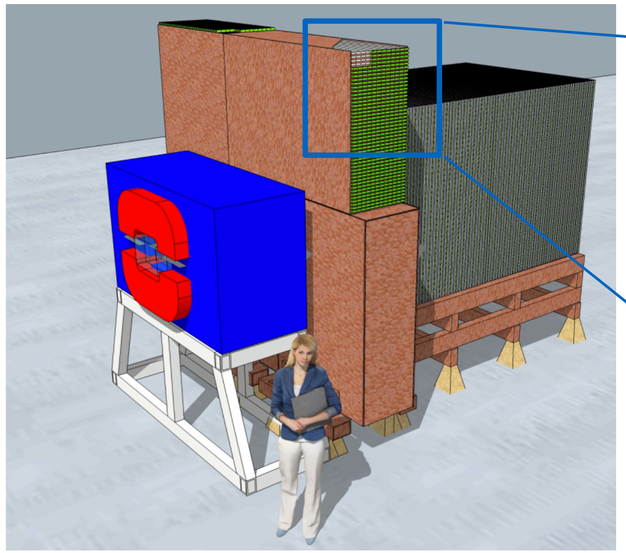
Boosted
Decision
Tree

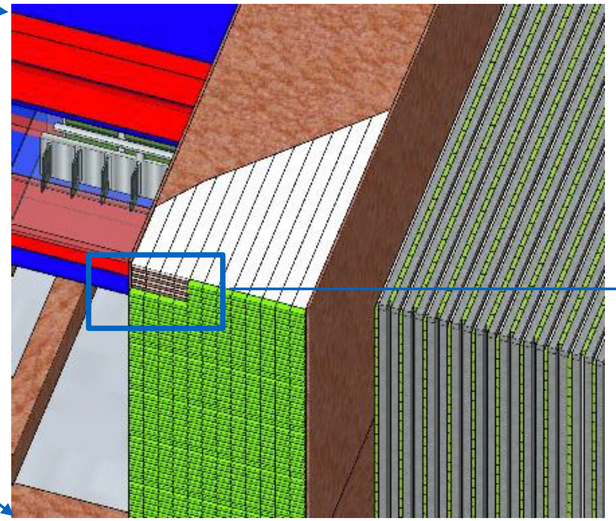


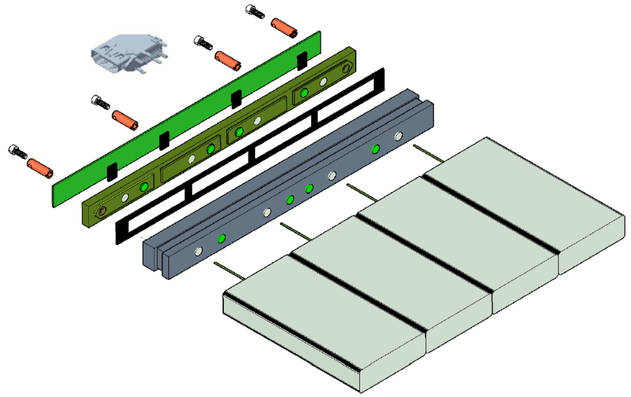
Hadron calorimeter

- 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



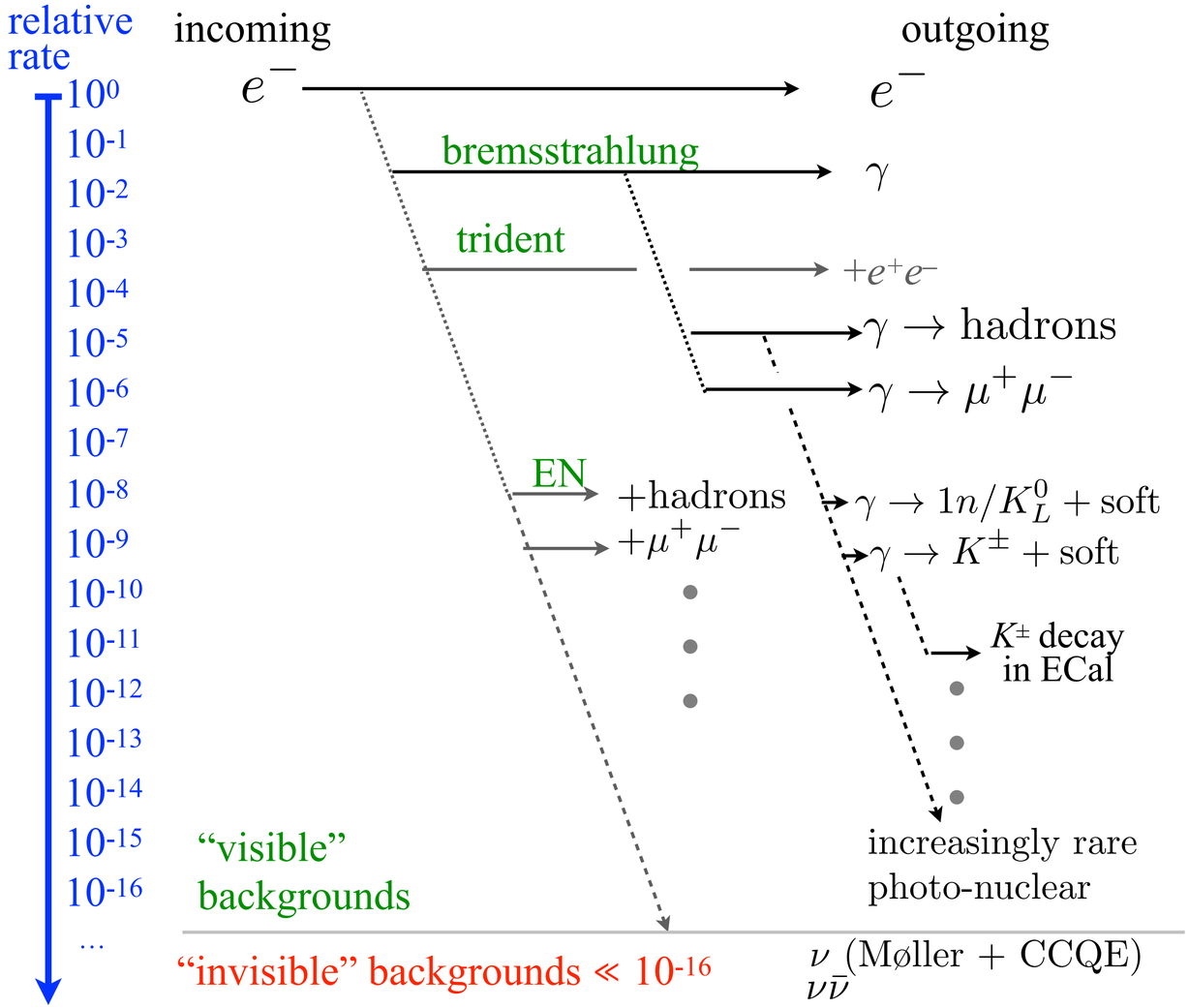


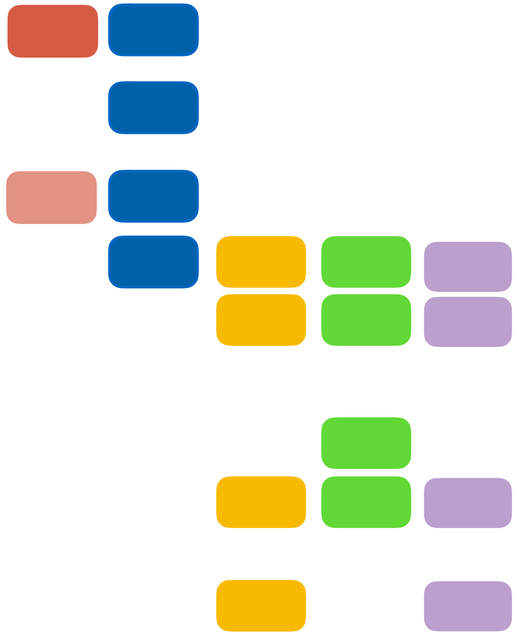




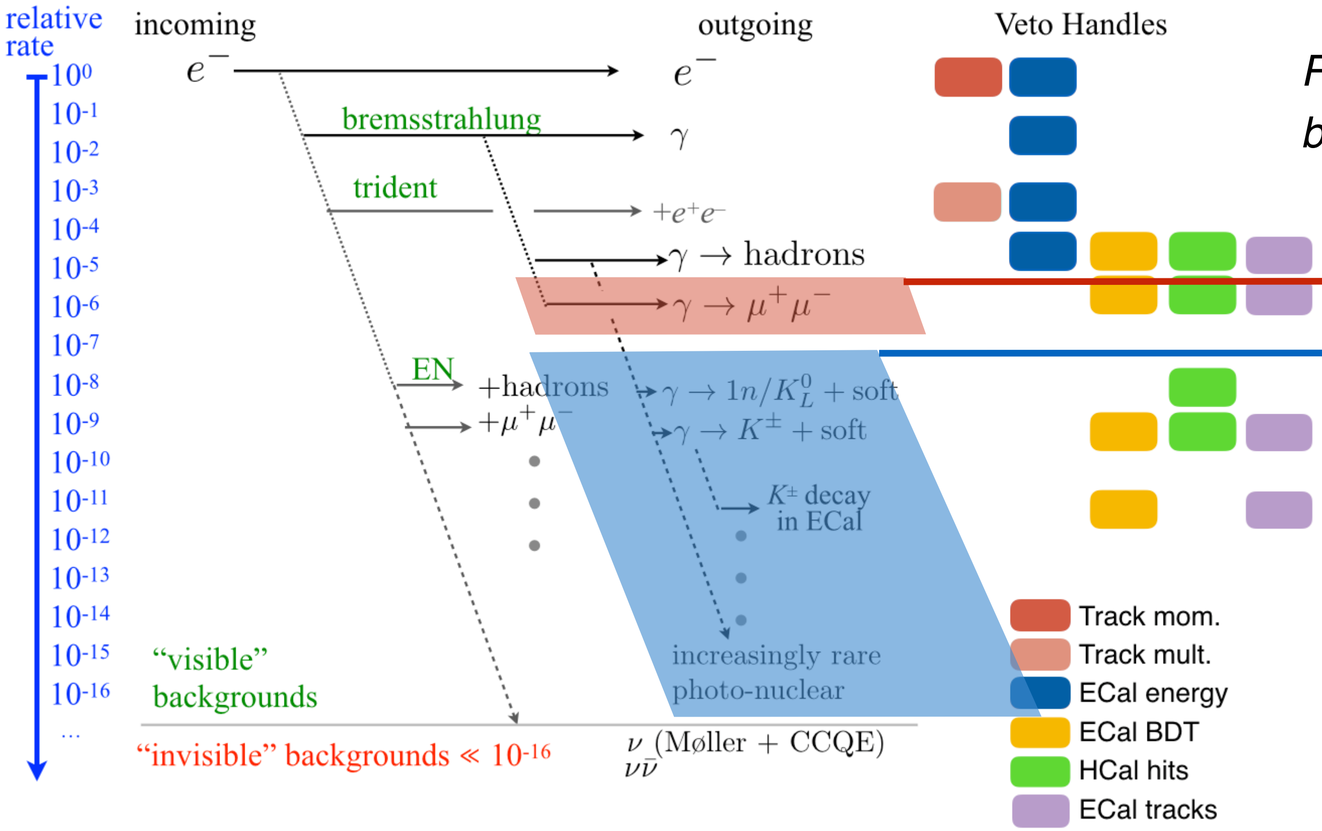
adapted from Mu2e
cosmic ray veto

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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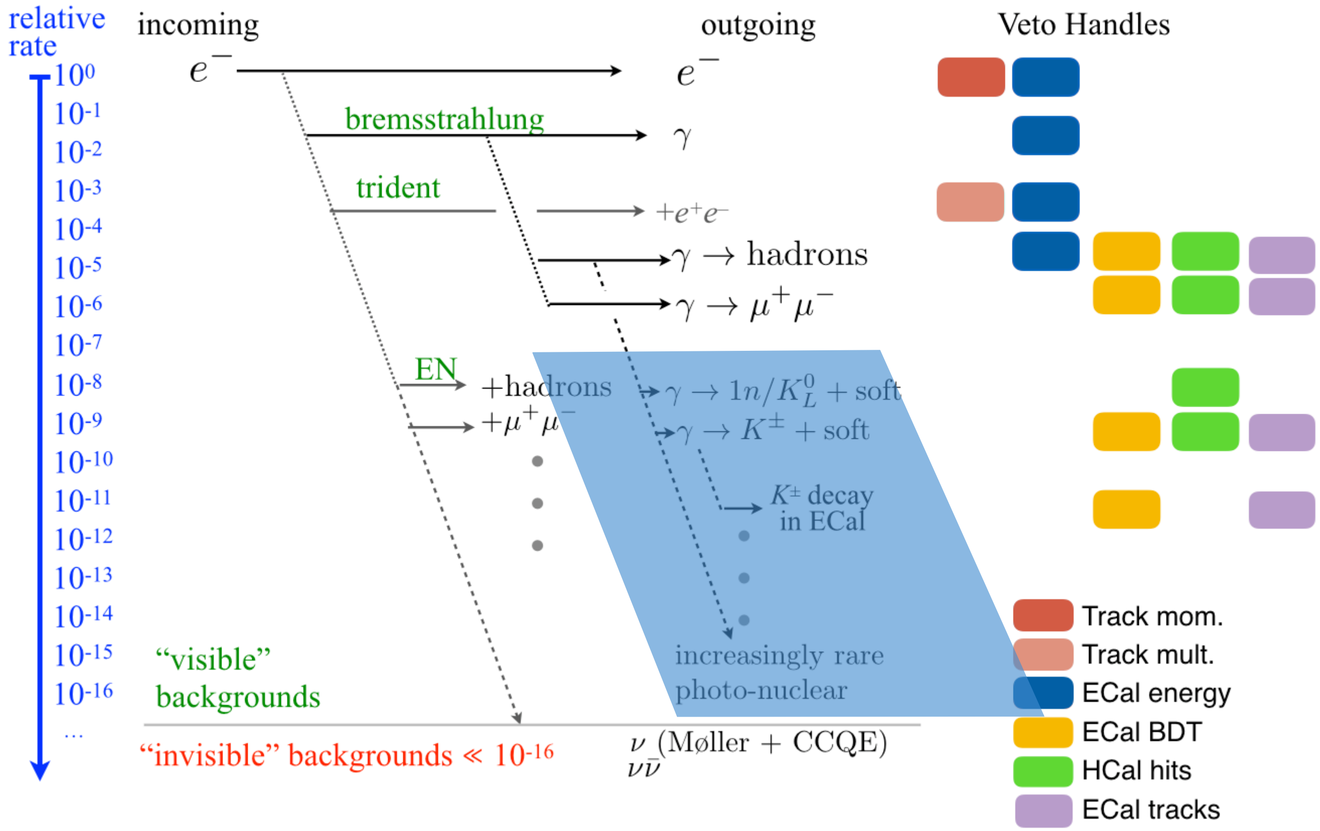
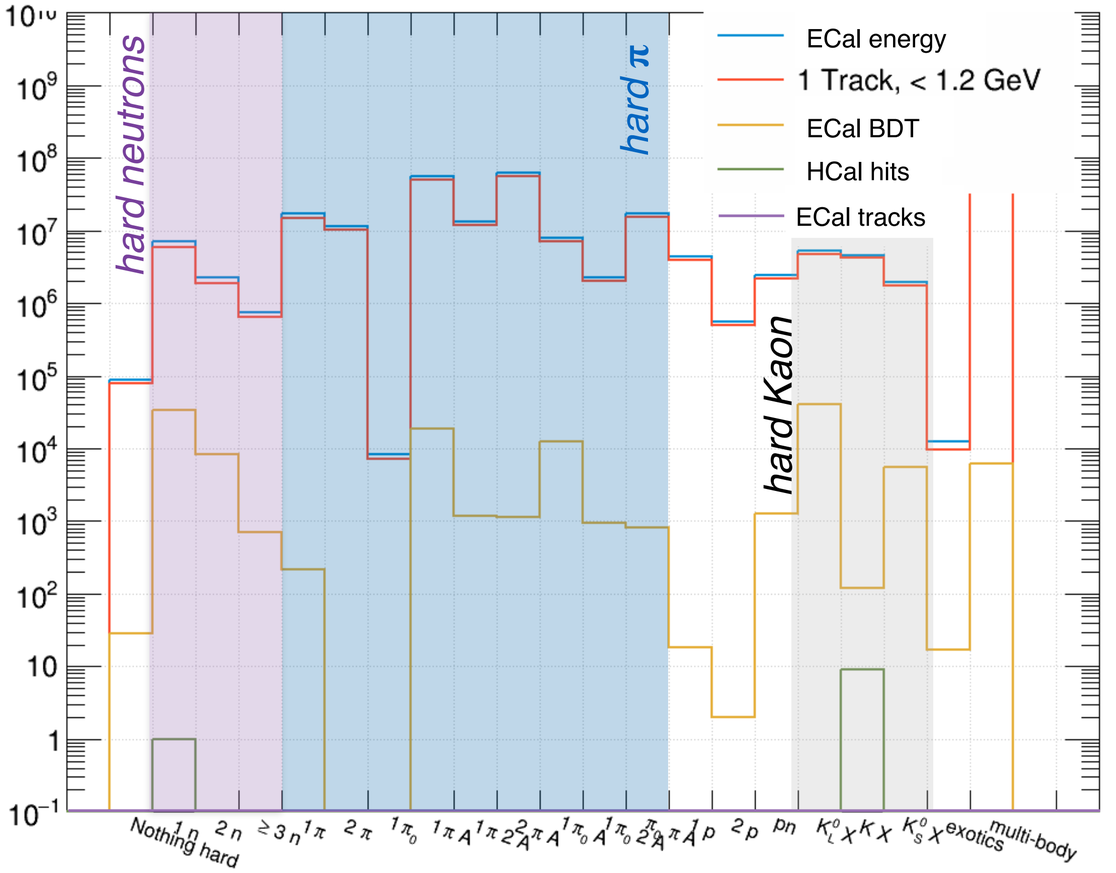


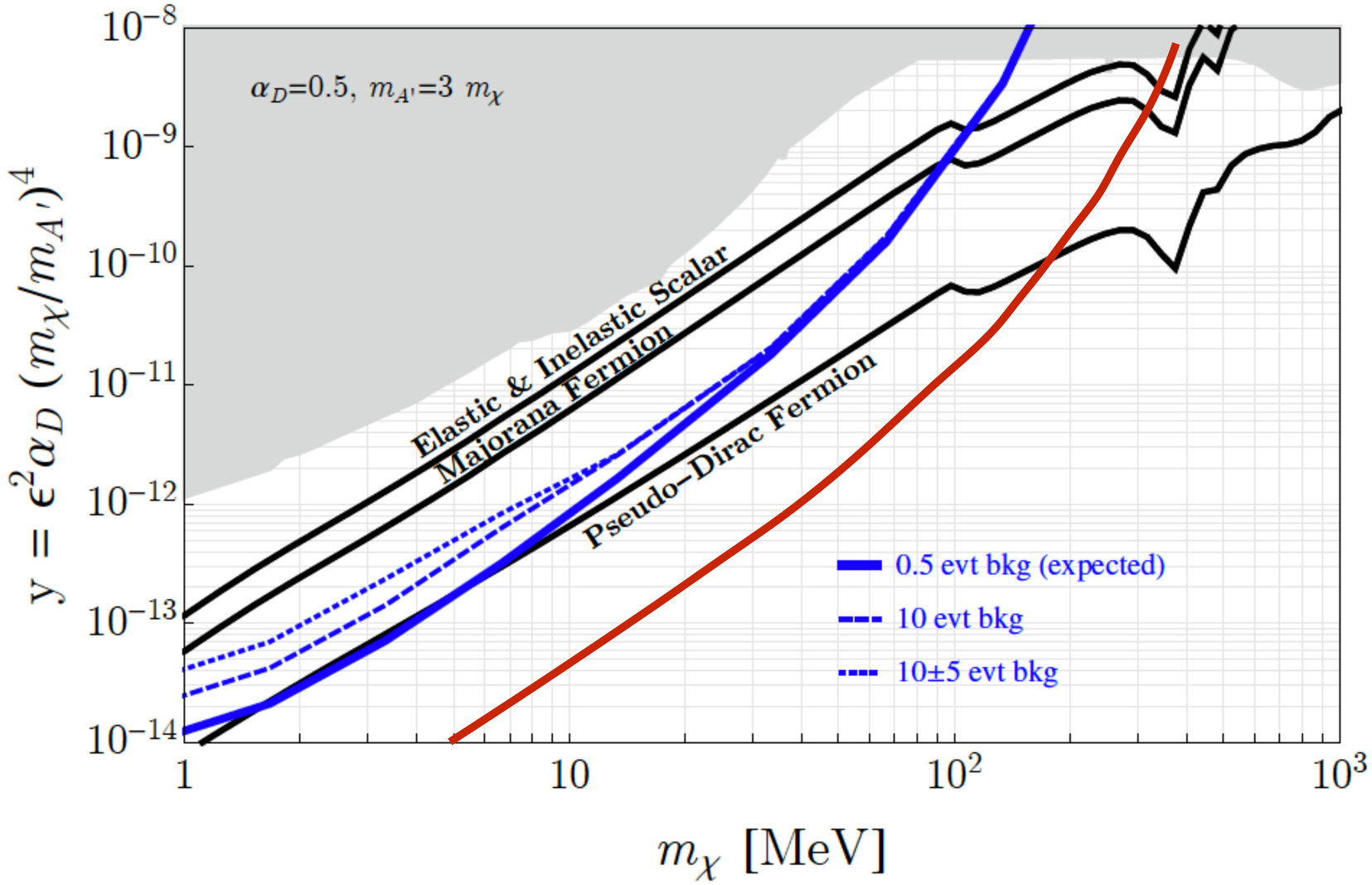
background veto performance vs final state



No events remain after all vetoes

signal efficiencies range from 30-50%

Projected sensitivity



4x10^{14} EoT
@ 4 GeV

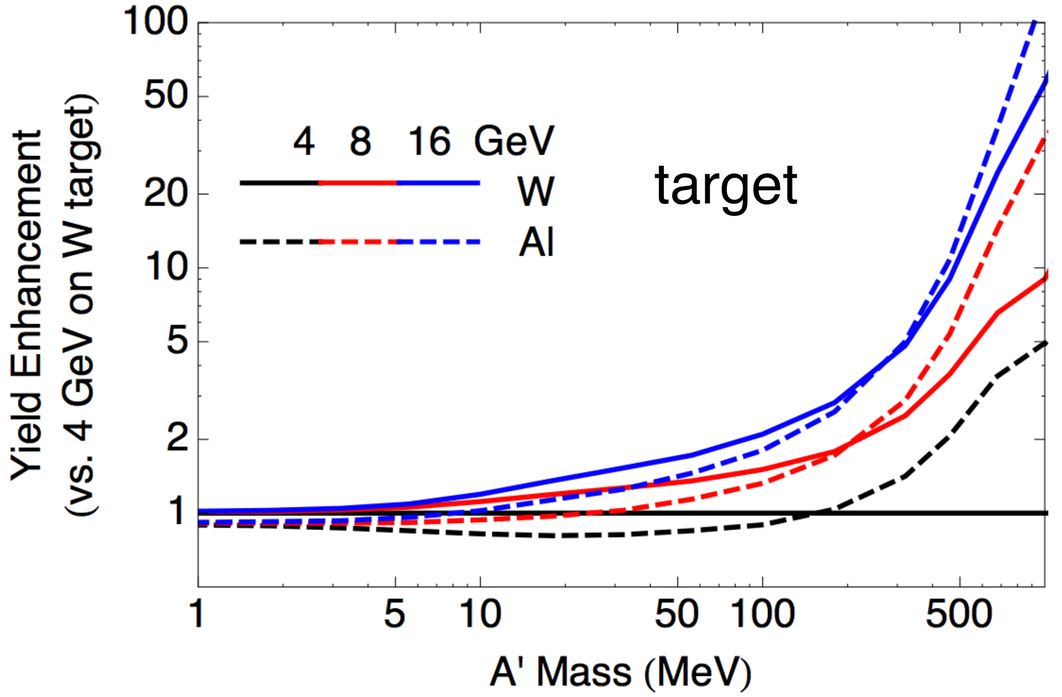
1x10^{16} EoT
@ 8 GeV

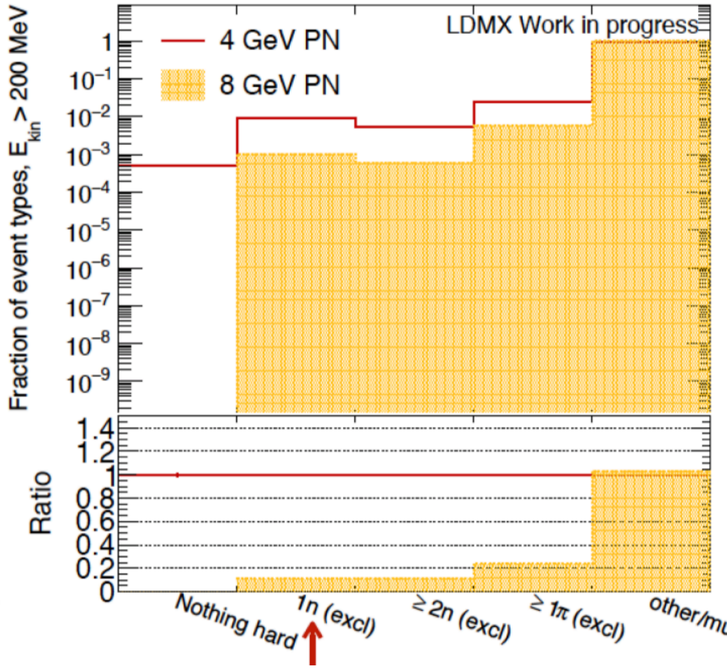
Note: $m_{A'} = 3m_\chi$ is conservative assumptions

LDMX

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



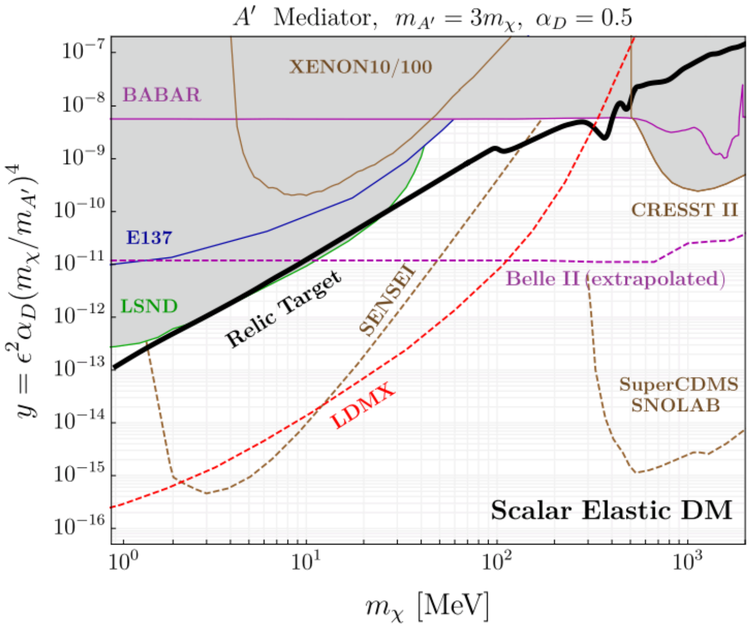


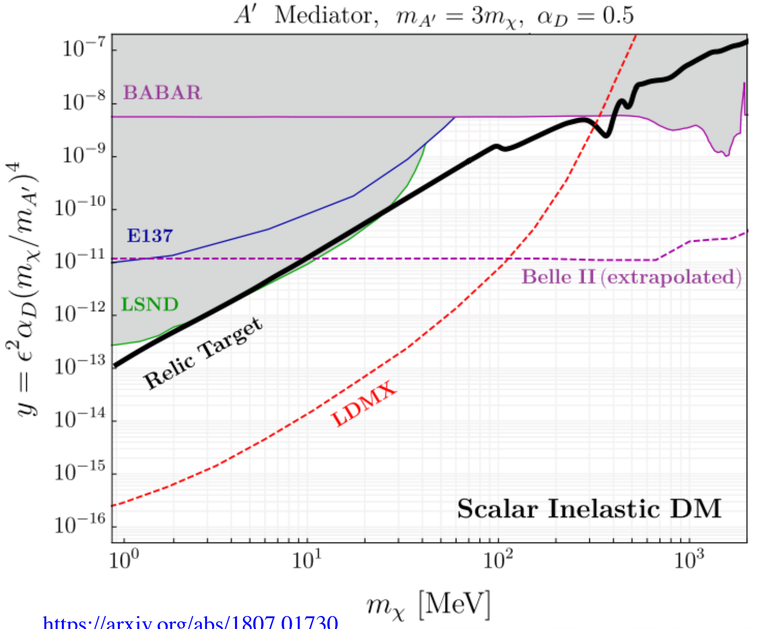
Summary

- LDMX is an electron fixed target experiment that aims to fully exploit the missing momentum technique
  - Impressive breadth of sensitivity to asymmetric, thermal scalar elastic, Majorana, and inelastic/Pseudo-Dirac scenarios

- 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

- This is an exciting time for LDMX as we begin to move from concept to creation!



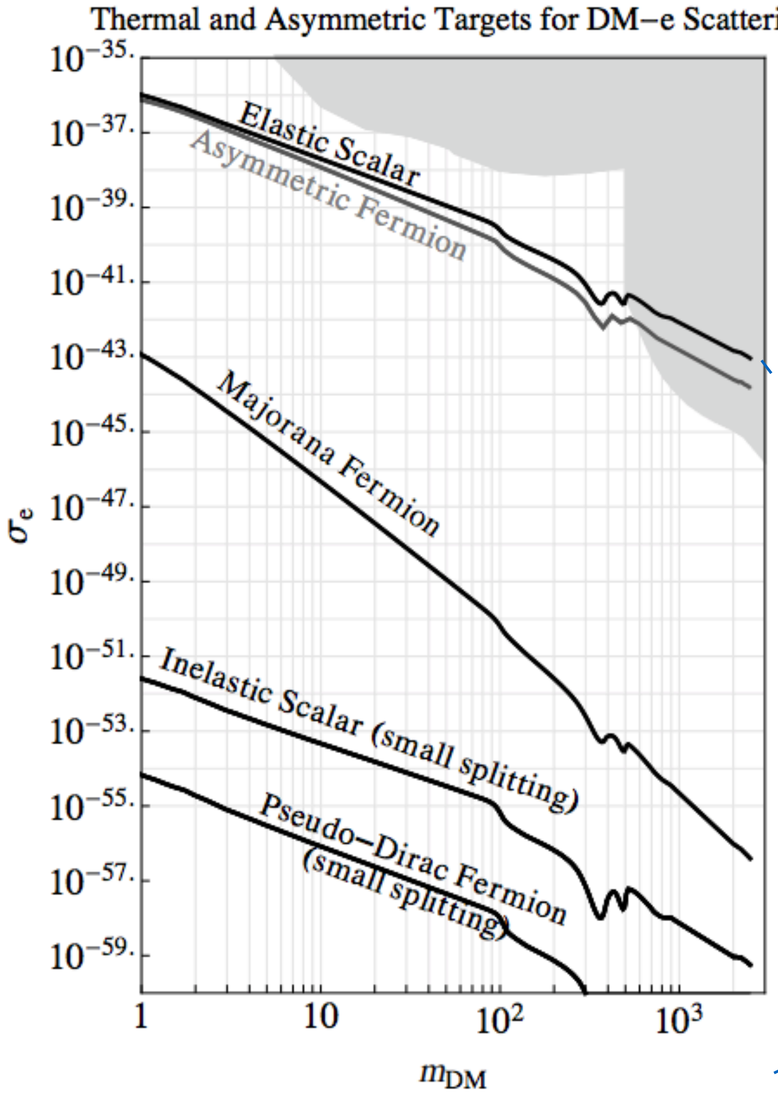


https://arxiv.org/abs/1807.01730

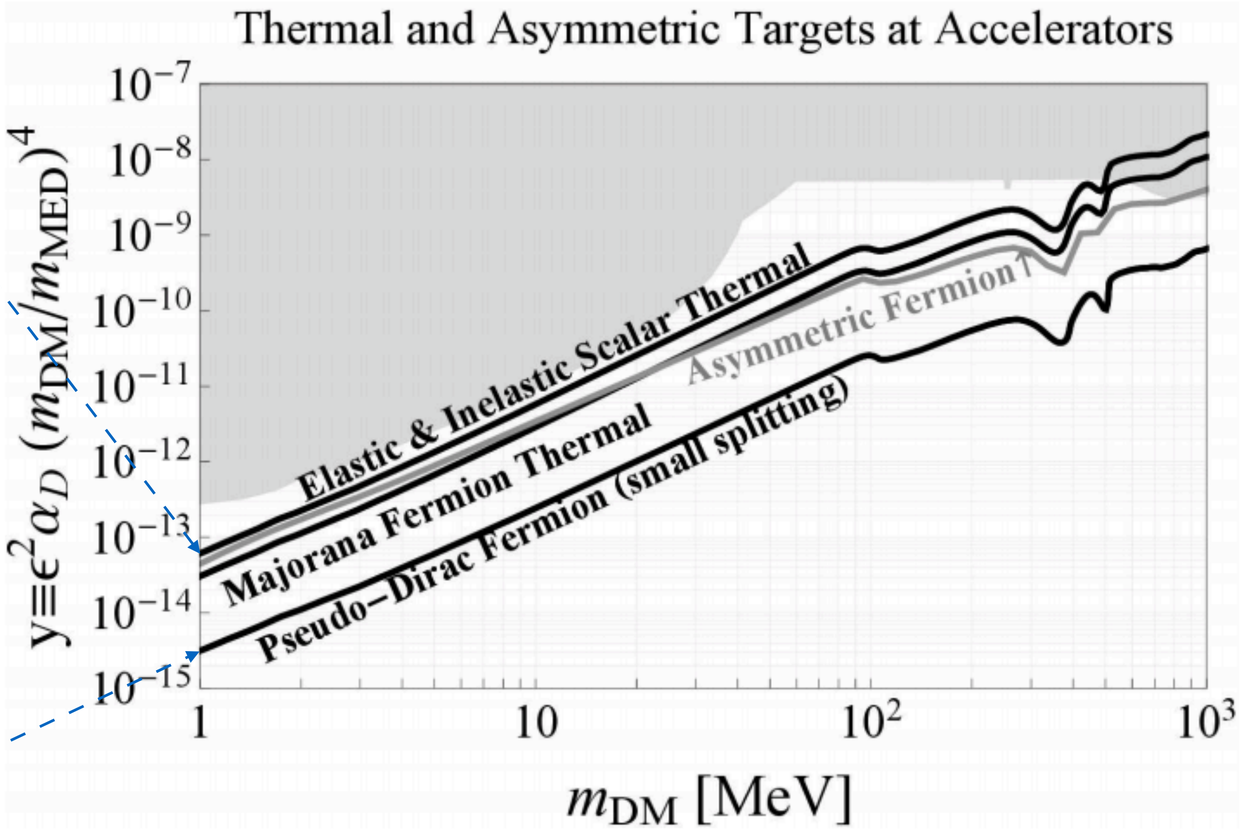
Caltech Fermilab Lunds Universitet University of Minnesota UCSB University of California Santa Barbara SLAC National Accelerator Laboratory Stanford University Texas Tech University University of Virginia

Backup

Light dark matter targets



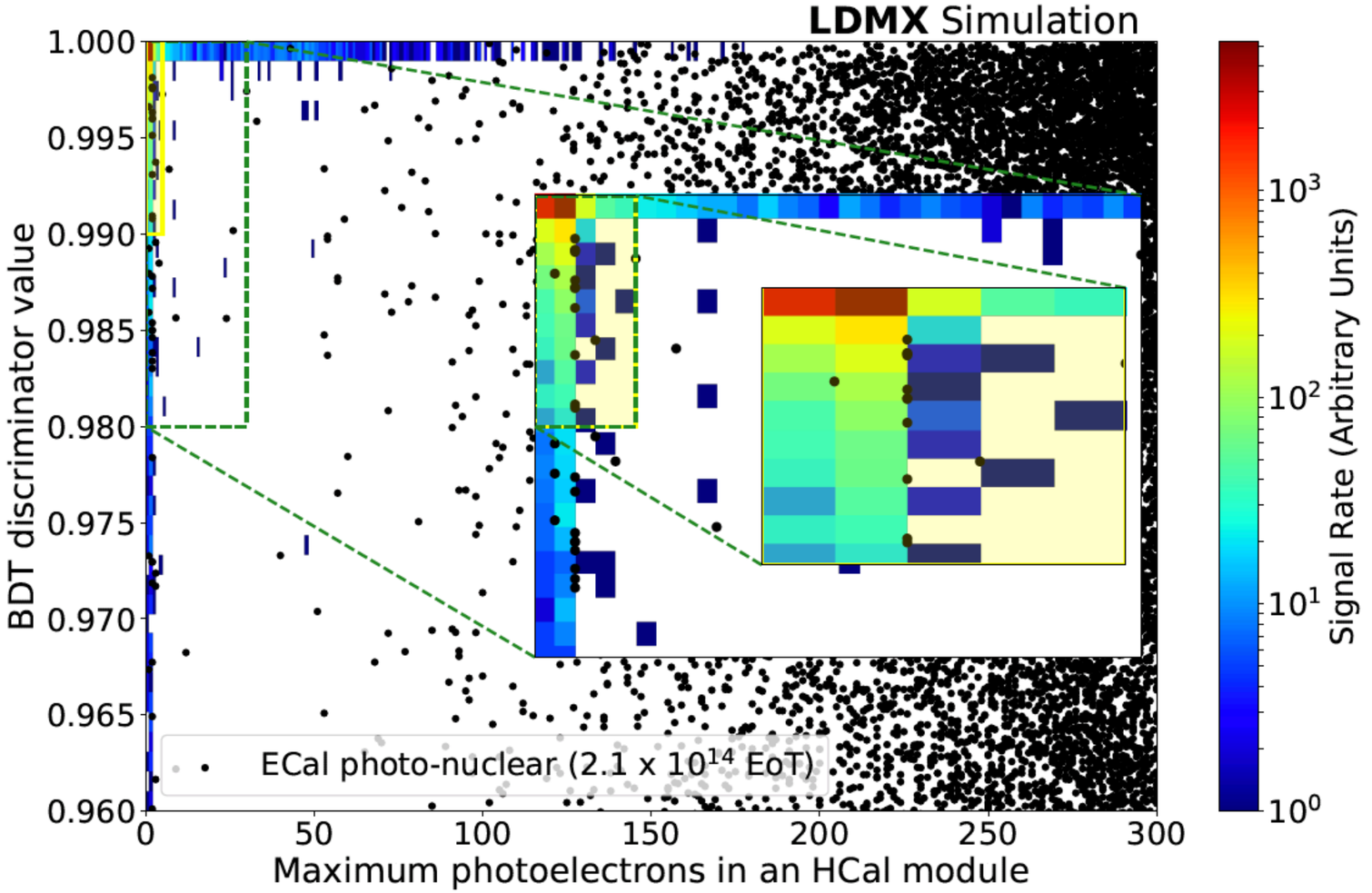
Accelerators produce dark matter relativistically, minimizing effect of different Lorentz structures.



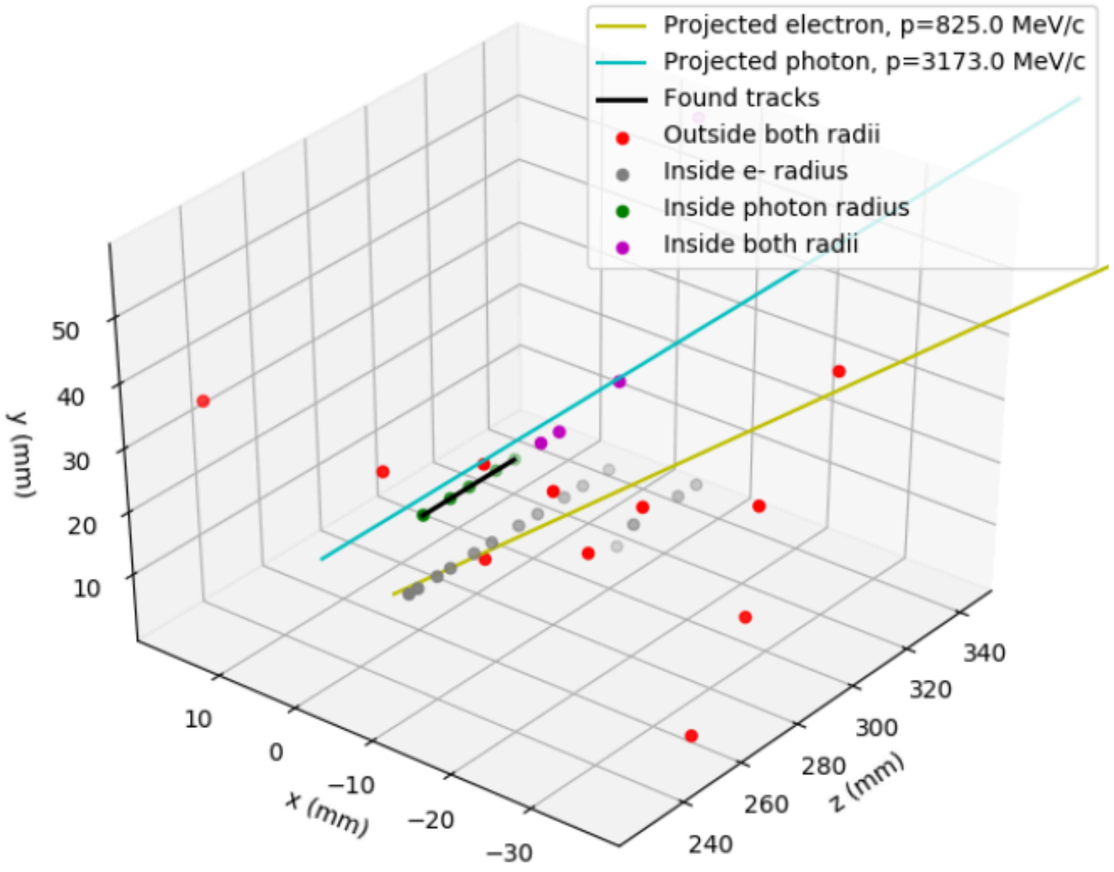
Thermal targets in non-relativistic ($\langle v \rangle \sim 10^{-3}c$) direct detection scattering is highly sensitive to Lorentz structure of interactions

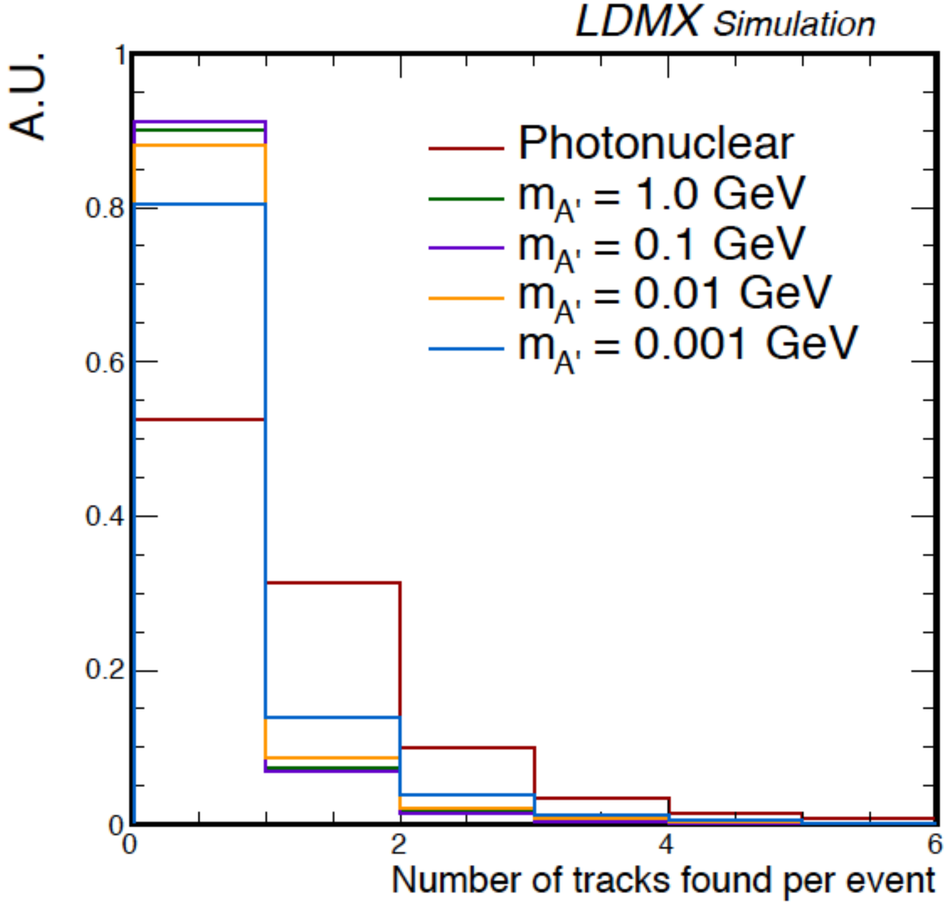
LDMX

ECal/HCal Vetoes



MIP tracking in ECal





LDMX sensitivity

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