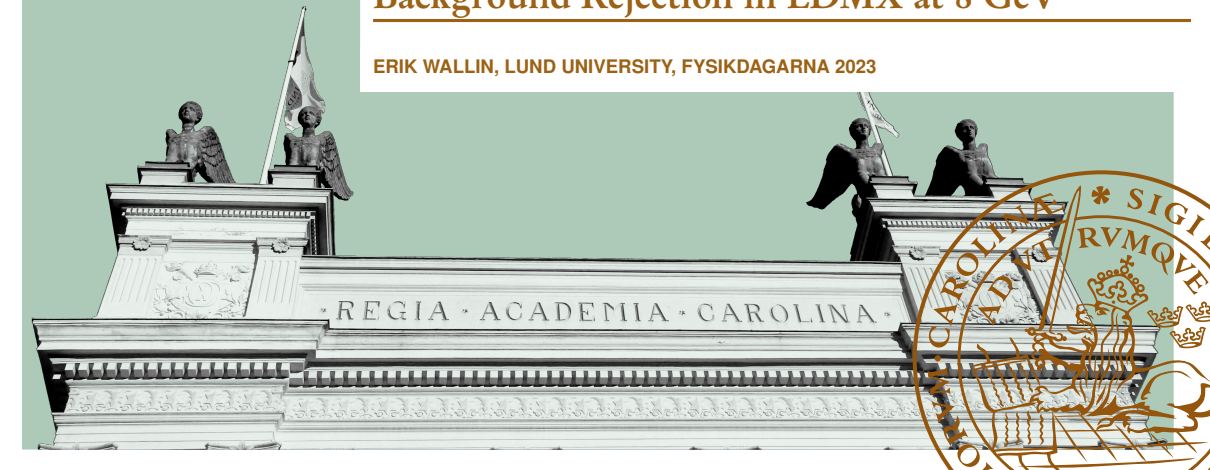
LUND UNIVERSITY

Background Rejection in LDMX at 8 GeV

ERIK WALLIN, LUND UNIVERSITY, FYSIKDAGARNA 2023

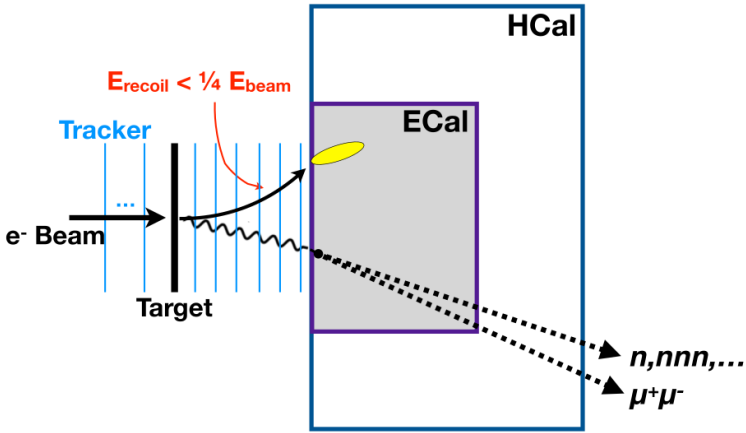


Background Rejection Studies

1. LDMX requires: Extensive discrimination between signal and background events!
2. Study goal: Out of 2×10^{14} electrons on the target, no background event should be misclassified as the DM signal.
3. Question: This worked 4 GeV beam energy, what about at 8 GeV?

LUND UNIVERSITY

Focus: Photon Induced Background



Simulated Samples

Certain backgrounds simulated in detail. Statistics comparable to, at least, 2×10^{14} electrons on target (EoT).

Simulated sample	Total events simulated	EoT equivalent
ECal Photo-nuclear	3.60×10^{11}	1.98×10^{14}
Ecal $\gamma \rightarrow \mu\mu$	8.00×10^{10}	2.40×10^{15}
Target Photo-nuclear	1.63×10^{12}	8.99×10^{14}
Target $\gamma \rightarrow \mu\mu$	9.45×10^{11}	9.45×10^{15}

Compare: Actual 8 GeV run expects, on the order of, 10^{16} EoT.

LUND UNIVERSITY

Why study LDMX at 8 GeV?

The LCLS-II accelerator at SLAC *will* be upgraded from 4 to 8 GeV, and is where most of our data will be taken!

Expected benefits at 8 GeV compared to 4 GeV:

- Energetic particles shower more clearly the in ECal
- Larger signal yield (in A' mediator model)
- Reduced rates of some challenging backgrounds

However:

- More boost means more limited by ECal resolution

LUND UNIVERSITY

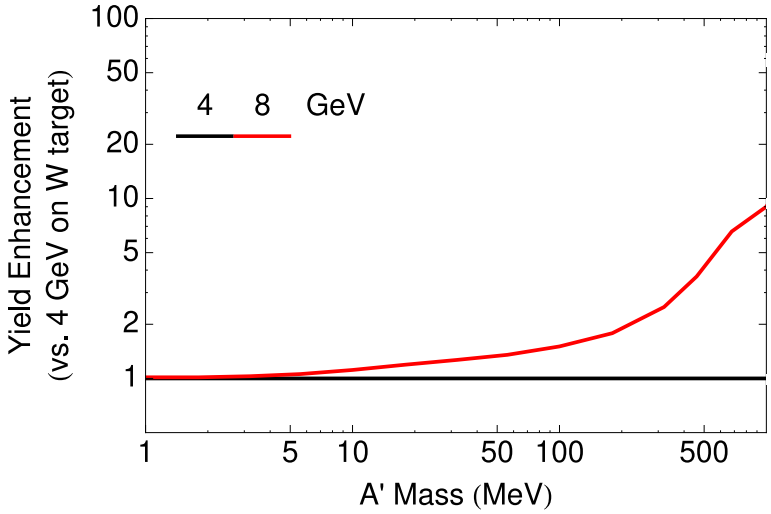
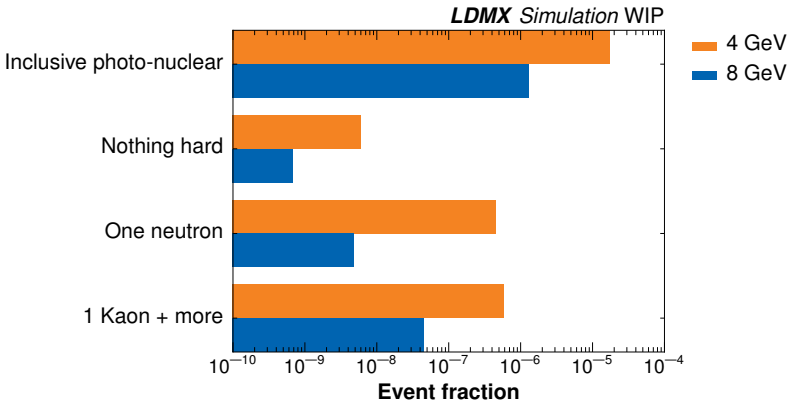
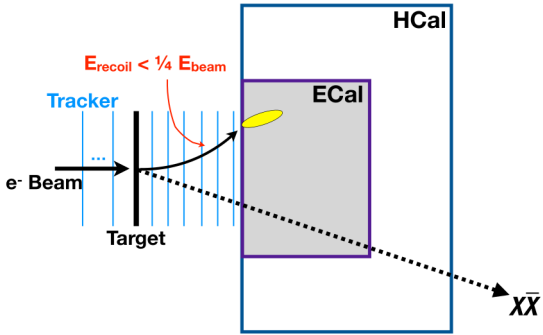


Photo-nuclear Events in the ECal

Rates of (triggered) photo-nuclear event final states:



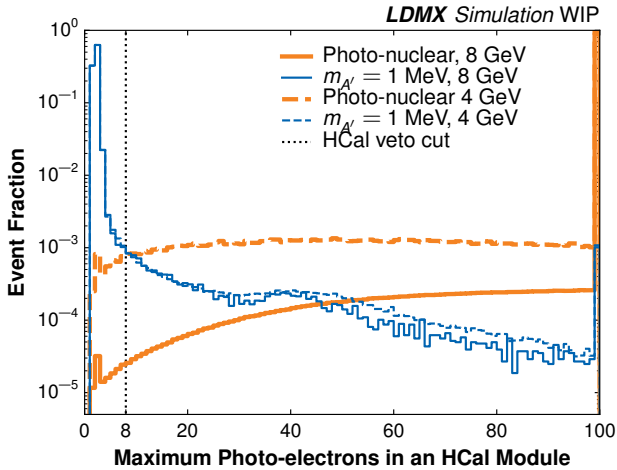
Background Rejection Procedure



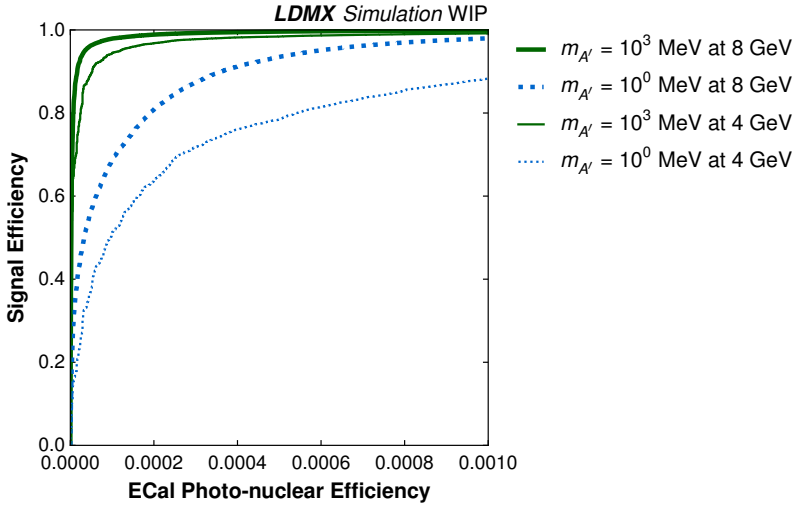
Signal signature:

1. ECal missing energy
2. Missing momentum in recoil tracker
3. **No activity in ECal beyond recoil electron shower (BDT)**
4. **No activity in HCal**
5. No track-like features in ECal

HCal Improvement



ECal BDT Improvement



Applying All Vetos

***LDMX** Simulation* WIP

	Photo-nuclear		Muon conversion	
	Target-area	**ECal**	**Target-area**	**ECal**
EoT Equivalent	2.00×10^{14}	2.00×10^{14}	2.00×10^{14}	2.00×10^{14}
Trigger	7.57×10^{7}	4.43×10^{8}	2.37×10^{7}	8.12×10^{7}
Missing ECal Energy	2.73×10^{7}	7.27×10^{7}	1.76×10^{7}	6.06×10^{7}
Missing Momentum	3.03×10^{6}	6.64×10^{7}	5.32×10^{4}	5.69×10^{7}
ECal BDT	1.50×10^{5}	1.04×10^{5}	< 1	< 1
HCal Activity	< 1	2.02	< 1	< 1
ECal MIP Tracking	< 1	< 1	< 1	< 1

Not a single simulated background event remaining!

LUND UNIVERSITY

What now?

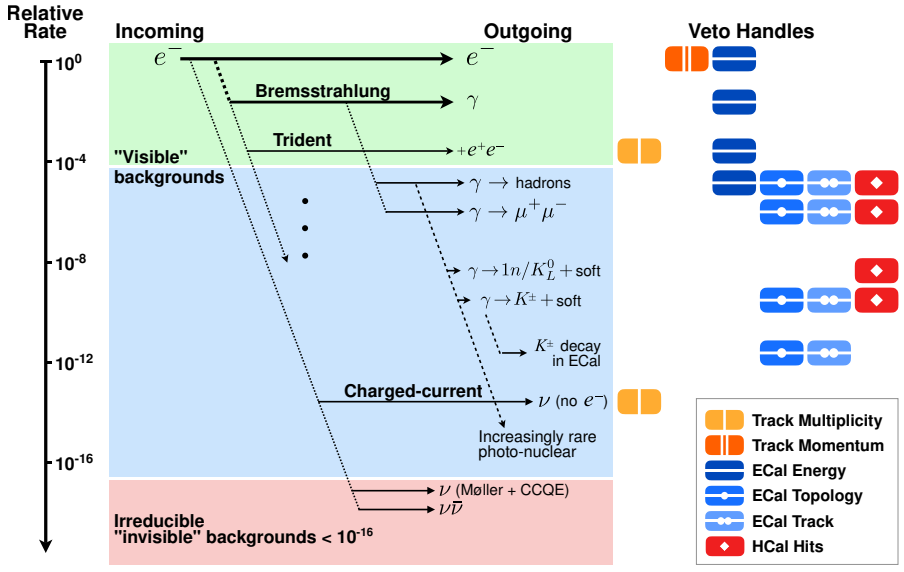
- Pile-up: Low intensity beam, but still a busier detector.
- Statistics: 10^{16} electrons on target or more expected in 8 GeV run. Compare to 2×10^{14} electrons simulated in this study. Clever simulation strategy needed!

Rejecting all of 2×10^{14} background events is a good first step!

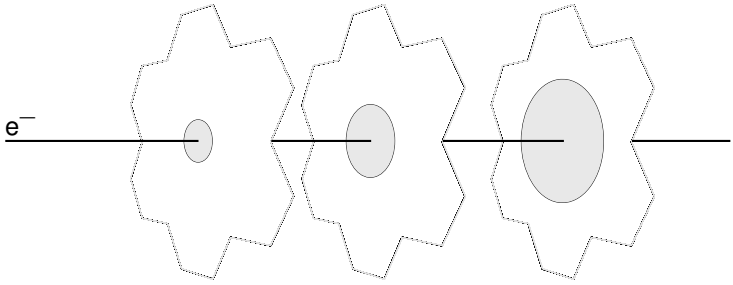
LUND UNIVERSITY

Thanks!

LUND UNIVERSITY



Containment Radii
A standard shower shape



Electron and photon trajectories are known from the recoil tracker.

Signal events expect no energy near the bremsstrahlung photon trajectory, only near the electron.

BDT Variables

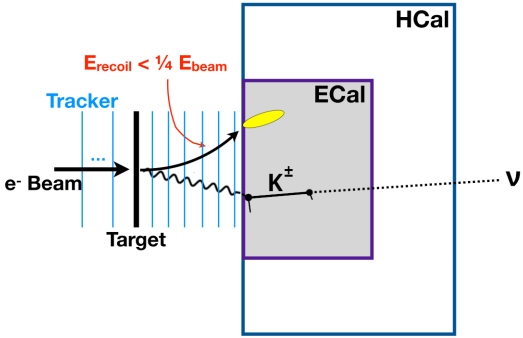
- Global features: Number of hits, summed energy of hits with no hits in neighbouring cells [...]
- Transverse features: Distribution of energy around the inferred electron and photon path [...]
- Longitudinal features: The average layer of a hit, layer of the deepest hit [...]

4 GeV Results

	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

LUND UNIVERSITY

Charged Kaon Background



$K^{\pm}$ may decay to neutrinos inside the ECal. Both the BDT and HCal may deem the event signal-like.

The $K^{\pm}$ can leave a short track before it decays. At 4 GeV, a tracking algorithm was implemented to find such short tracks.