The LDMX Photon Induced Background

LDMX BACKGROUND REJECTION AT 8 GEV

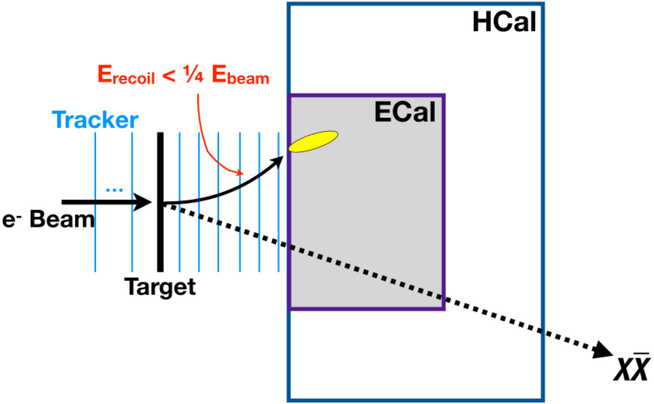
ERIK WALLIN, MASTER'S STUDENT AT LUND UNIVERSITY, PARTIKELDAGARNA 2021

LDMX Goals

1. Explore a range of light DM models, appearing as missing energy
2. Goal: Out of 10^{14} electrons on the target, no background event should be misclassified as the DM signal

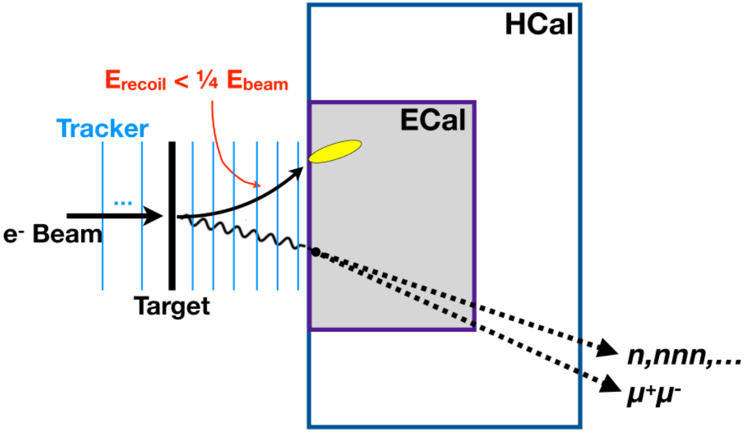
LUND UNIVERSITY

The Dark Matter Signature

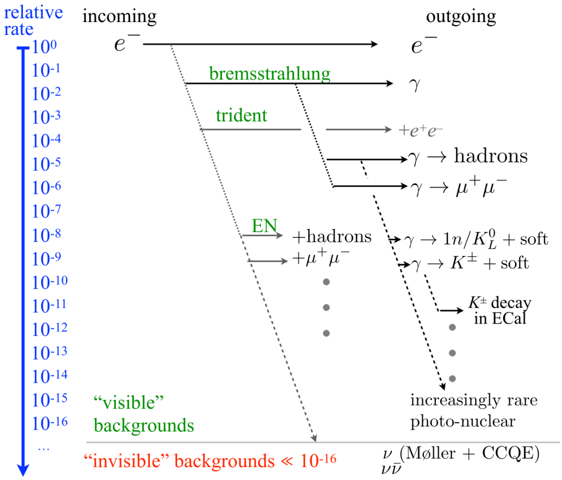


Images: [1]

Photon Induced Background



Background 'Ladder' at 4 GeV



Background Rejection

To distinguish signal and photo-nuclear background: A boosted decision tree is trained on ECal features, notably including the energy distribution around the projected electron and photon path. [1]

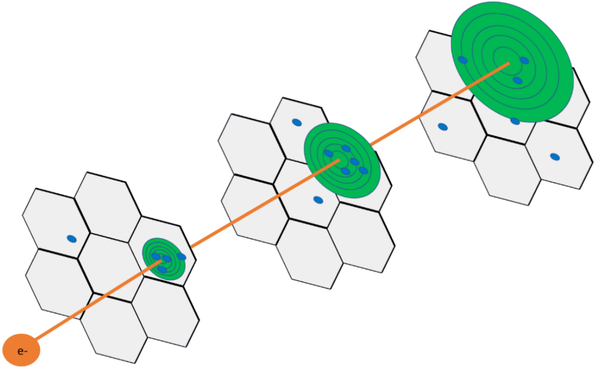


Image: [4]

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

After some cuts on the kinematics, the BDT cuts the background down by 99.94%.

	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 $p < 1.2\,\mathrm{GeV}$	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

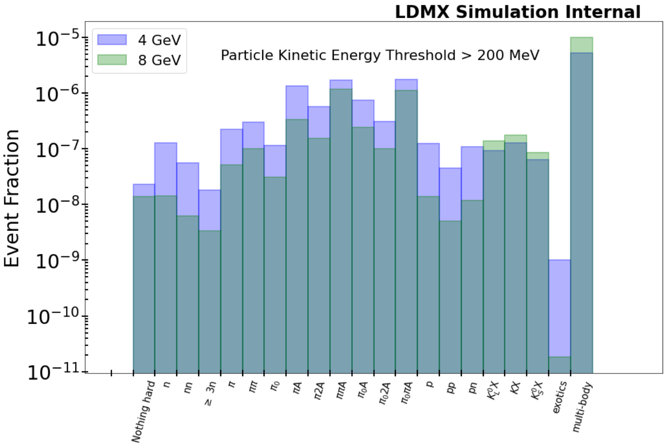
The HCal should see no activity at all, but even then some background events remain.

Kaon Background

The challenging background is photo-nuclear production of $\mathrm{K}^{\pm}$, which with their 10^{-8} second lifetime may decay into e.g. $\rightarrow \mu^{+}\nu_{\mathrm{e}}$ while still inside the calorimeter.

A simple tracking algorithm searching for short tracks is employed to remove these remaining kaon background events.[1]

Background at 8 GeV



Most photo-nuclear backgrounds are more rare at 8 GeV than at 4 GeV. However, the challenging kaon background is more common.

Increasing the Beam Energy

Some motivations for going to 8 GeV:

- Possibly clearer features in the ECal
- Better signal production in some models
- Some backgrounds are more rare

LUND UNIVERSITY

Background Rejection Efficiencies

Preliminary results at 8 GeV beam energy:

	Photo-nuclear		Muon conversion	
	Target-area	ECal	Target-area	ECal
EoT Equivalent		1.97×10^{14}		
Trigger, ECal total energy < 3160 MeV		2.67×10^{8}		
Single track with p < 2400 MeV		2.48×10^{8}		
ECal BDT (> 0.99988)		9.10×10^{3}		
HCal max PE < 8		< 1		
ECal MIP tracks $= 0$		< 1		

Seemingly no Kaon tracking needed. 15x better BDT efficiency than at 4 GeV.

Comparison

8 GeV:

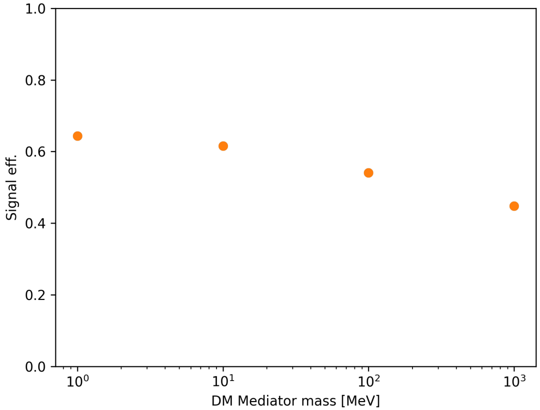
	Photo-nuclear		Muon conversion	
	Target-area	ECal	Target-area	ECal
EoT Equivalent		1.97×10^{14}		
Trigger, ECal total energy < 3160 MeV		2.67×10^{8}		
Single track with p < 2400 MeV		2.48×10^{8}		
ECal BDT (> 0.99988)		9.10×10^{3}		
HCal max PE < 8		< 1		
ECal MIP tracks $= 0$		< 1		

4 GeV:

	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

Signal Efficiencies

Signal efficiency around 50%, after kinematic and BDT cuts. (Optimized for a 1 MeV DM mediator mass)



Outlook

Every photo-nuclear background event, equivalent of $2 \cdot 10^{14}$ electrons on the target, is rejected. More than 50% of signal events still remain. The zero-background goal is reached at both 4 and 8 GeV.

From now on:

- The high granularity of the ECal makes it suitable for various machine learning studies[2][3], as there is a lot of geometric detail present in the events. The BDT does not utilize the full potential of the detector.
- Pile-up studies

Questions?

References I

- Torsten Åkesson et al. *A High Efficiency Photon Veto for the Light Dark Matter eXperiment*. 2019. arXiv: 1912.05535 [physics.ins-det].
- Leo Östman. *Imaging Using Machine Learning for the LDMX Electromagnetic Calorimeter*. LUP Student Papers. 2020.
- Huilin Qu and Loukas Gouskos. "Jet tagging via particle clouds". In: *Physical Review D* 101.5 (Mar. 2020). issn: 2470-0029. doi: 10.1103/physrevd.101.056019. url: http://dx.doi.org/10.1103/PhysRevD.101.056019.
- Harrison Siegel. *Implementation of Radius of Containment in Boosted Decision Tree for Light Dark Matter eXperiment (LDMX)*. July 2019.