LDMX test beam requirements

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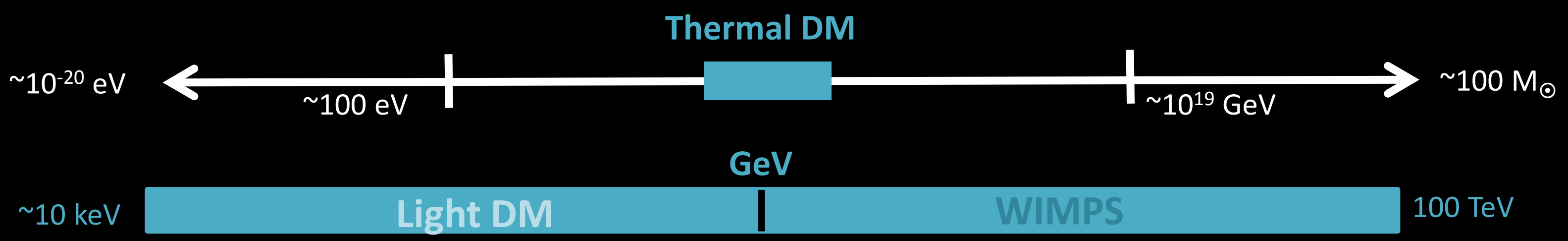
Thermal dark matter

The LDMX experiment will search for light (sub GeV) thermal dark matter and other light new particles using an electron beam hitting a fixed target and measuring the recoiling electron.



Thermal DM

~10^{-20} eV

~100 eV

~10^{19} GeV

~100 $M_\odot$

GeV

~10 keV

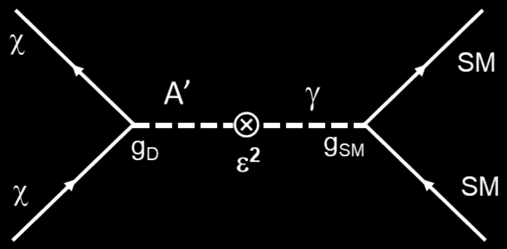
Light DM

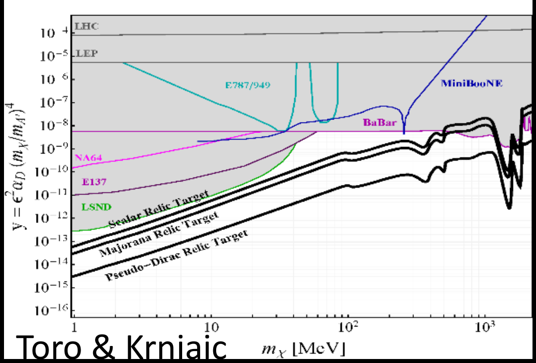
WIMPS

100 TeV

Freeze-out scenario with light dark matter requires new light mediator to explain the relic density, or dark matter is overproduced -> hidden sector light thermal dark matter

Dark photon A’ kinetically missing with strength ε





Toro & Krnjaic

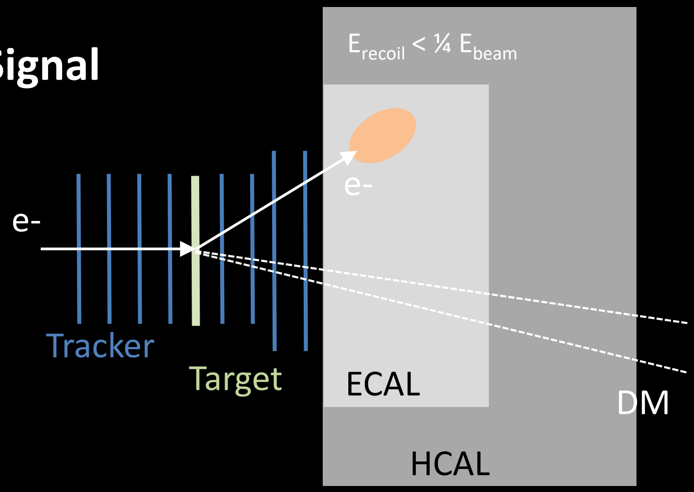
Definitive predictions as a function of mass and particle type !!!

LDMX experimental approach

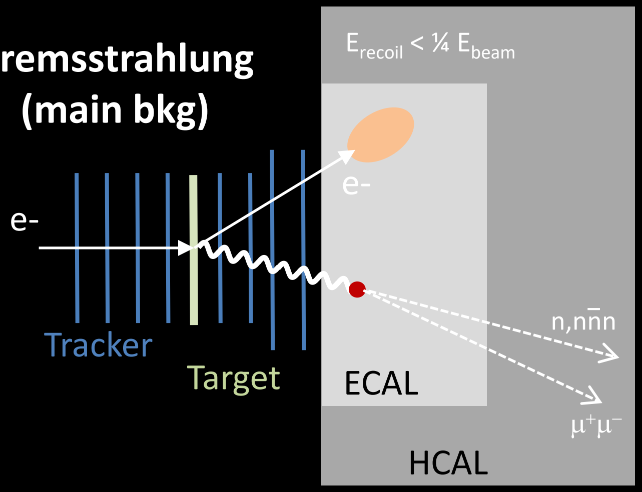
Produce dark matter in laboratory by shooting an electron beam, one at a time, on a thin target. Electrons can emit dark photons, which will decay into a pair of DM particles. The signal signature consists of a single low-energy scattered electron and nothing else.

A particularly challenging background arise from initial state radiation events, in which the photon initiates a photo-nuclear reactions inside the electromagnetic calorimeter producing a few energetic neutrons. These neutrons must be detected by the hadronic calorimeter with extremely high efficiency.

Signal



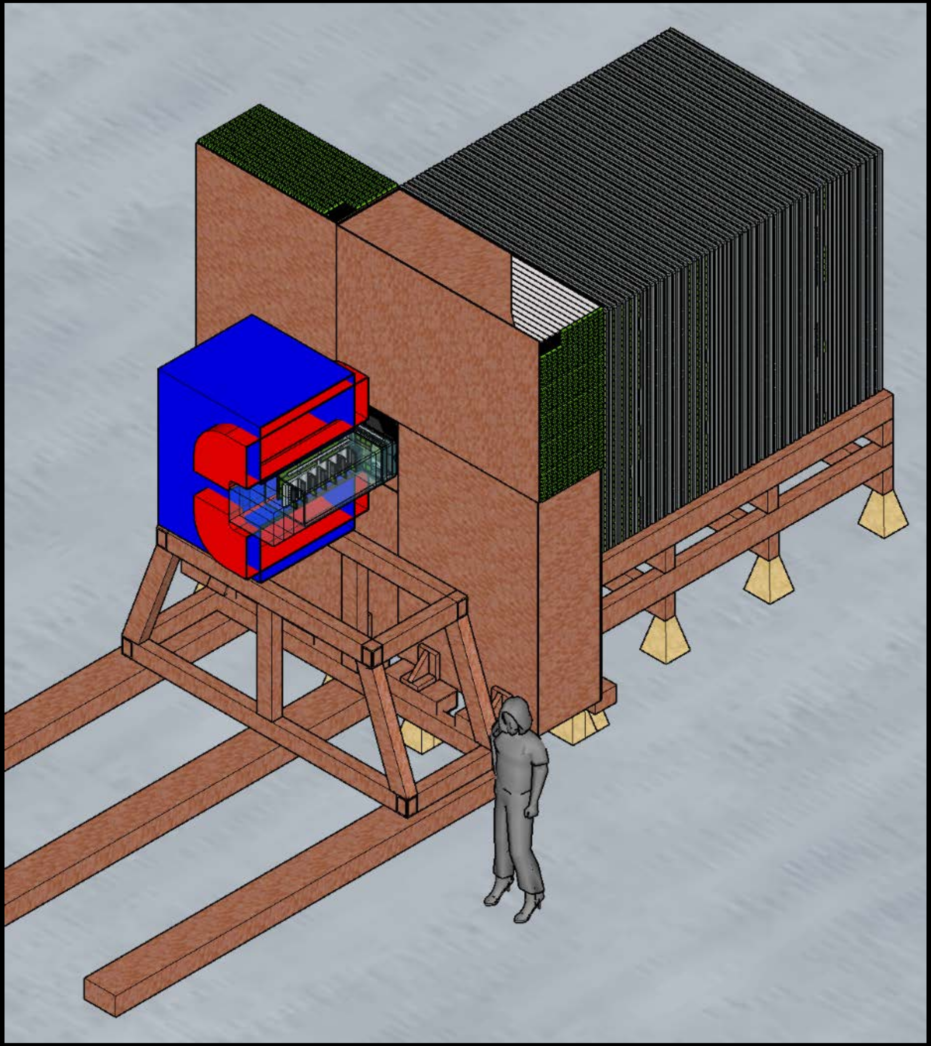
Bremsstrahlung (main bkg)



Particularly challenging: few body photo-nuclear reactions

The LDMX experiment

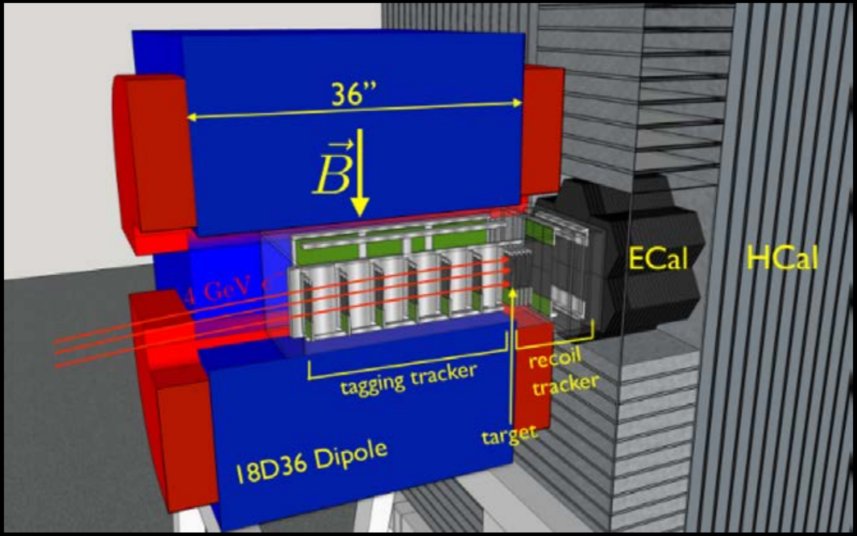
Disclaimer: all figures are slightly outdated



LDMX Whitepaper - arxiv:1808.05219

LDMX concept

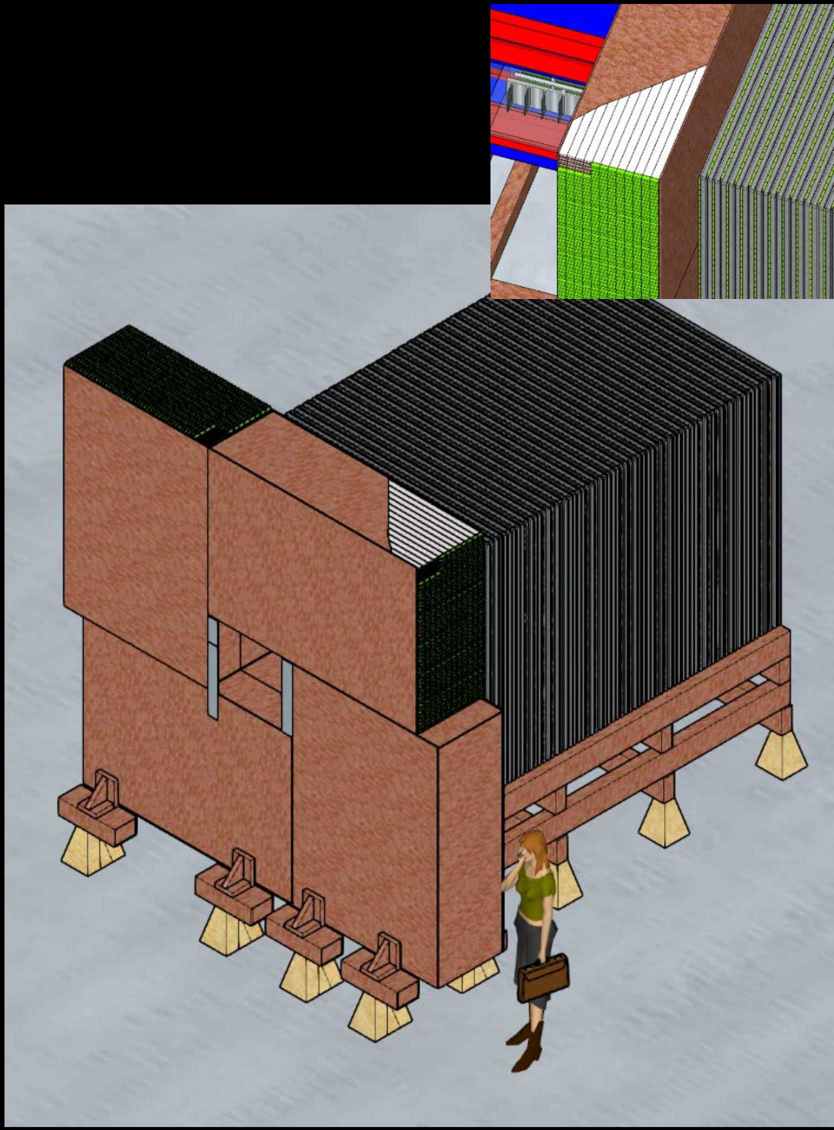
- Magnet: 18D36 at SLAC
- Tracking: Silicon Vertex Tracker similar to HPS
- ECal: CMS high-granularity calorimeter
- HCal: scintillator/steel sampling calorimeter a la Mu2e



Hadronic calorimeter

Steel / plastic scintillator sampling calorimeter (design still needs to be finalized)

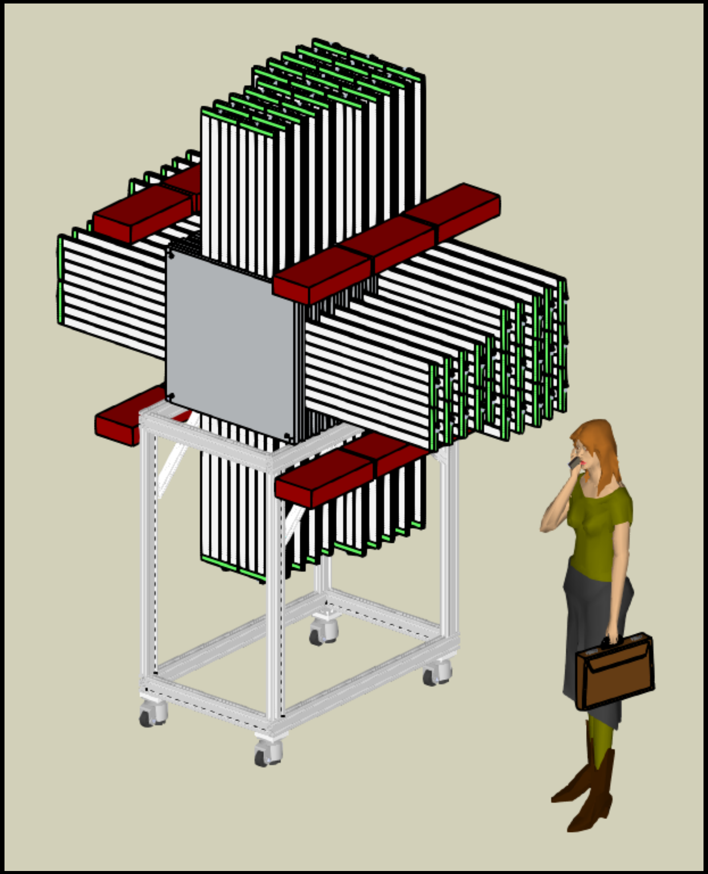
- Main role: veto hadronic PN events, in particular PN events emitting hard/soft neutrons or K_L
- Secondary role: physics with displaced signatures, electro-nuclear measurements, trigger
- Plastic scintillator bars with WLS fibers read out by SiPM (a la Mu2e CRV) and steel absorber.
- Current design has 25mm absorber plates with $\sim 13\lambda$ for the back HCal, 2m transverse size.
- Additional side HCal ($\sim 5\lambda$) surrounding the ECal with thinner absorber



Need to characterize the HCal response to tune the MC simulation

Hadronic calorimeter prototype

Build a prototype to determine the HCal performance with an electron/pion beam to tune the MC and test the components



HCal prototype design

- 20 layers with 25mm absorber:
  29 radiation length - 2.5 nuclear int. length
- Scintillator bar length ~2 m
- Support structure allows bars to be moved so that the response can be measured along the transverse direction.
- Weight is between 1500 – 2000 kg.

Hadronic calorimeter prototype

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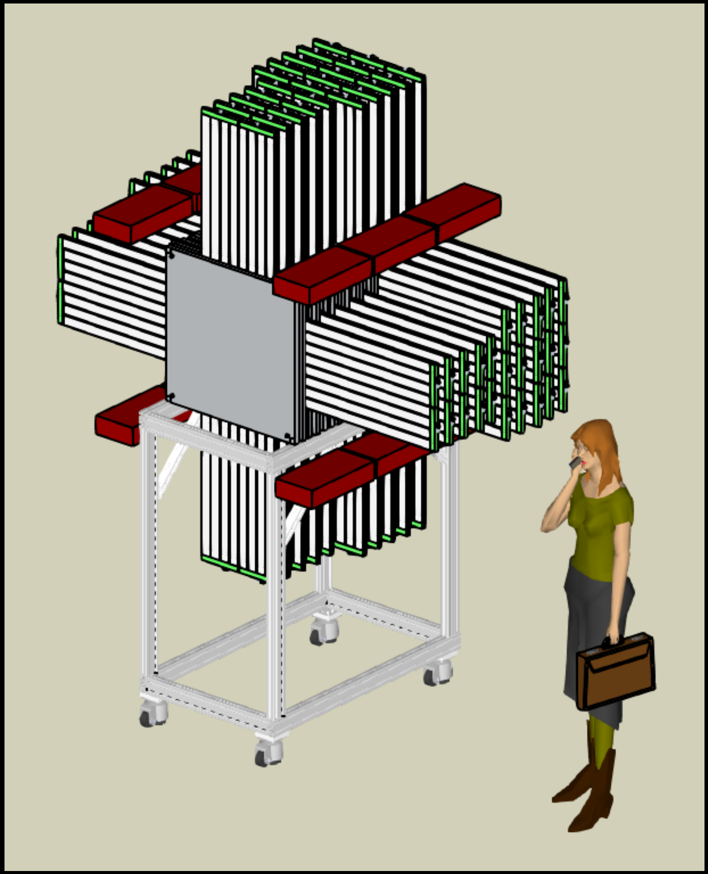
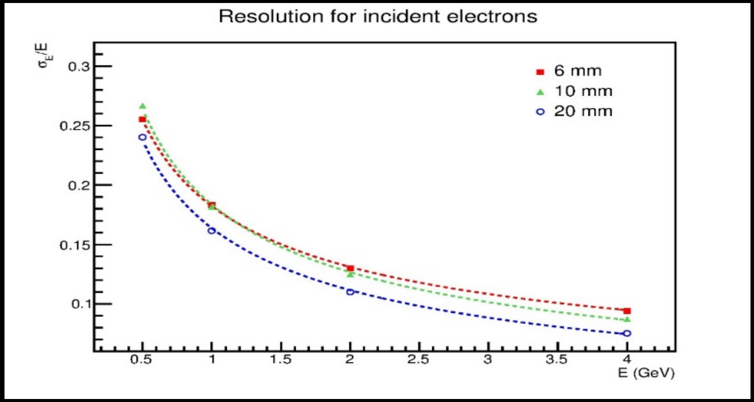
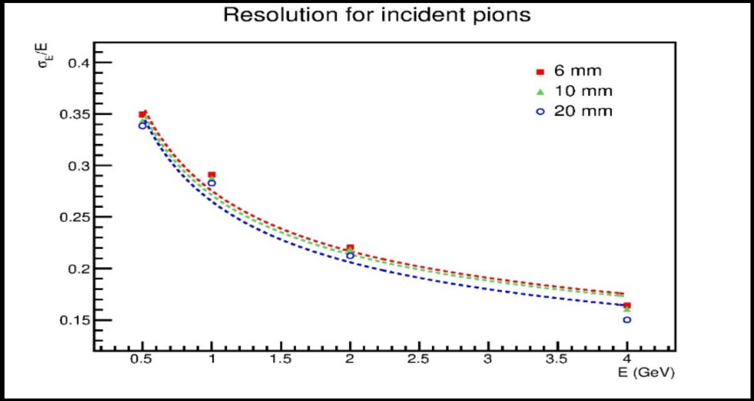


Old MC simulations: different configuration but indicative of expected performance





Test beam needs

We would like to have a beam with the following characteristics:

- Energy between ~300 MeV to ~4 GeV.
- Large fraction of electrons and pions, high-energy muons (protons are fine)
- Low particle multiplicity: one particle (in average)
- Energy spread <5-10% at low energy, < ~3% at higher energy – would not contribute substantially to the resolution
- Good particle identification capabilities for e,π,p (reasonable μ PID with Hcal)

Test beam area needs:

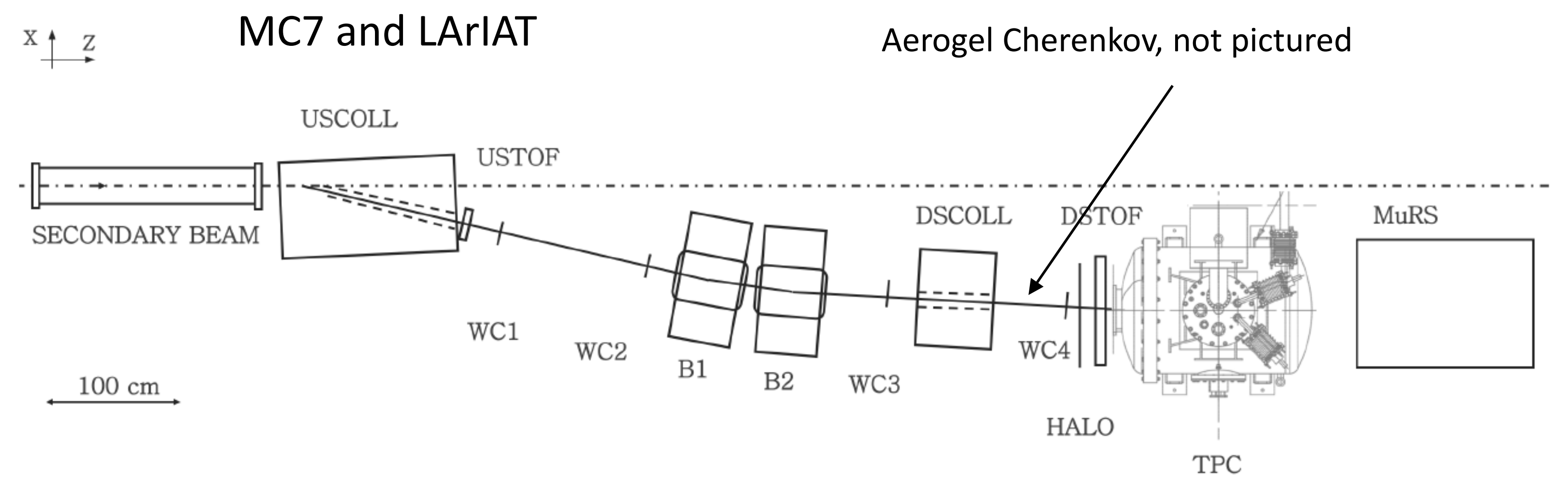
- Sufficient space to accommodate the prototype
- Lifting equipment
- No high voltage or gas

We would like to better understand:

- The beamline layout and beam characteristics.
- Constraints on installing a Cherenkov detector for π/e separation
- Possibility to find a Cherenkov detector somewhere at FNAL and install it in the beamline. That would be tremendously helpful!

From LArIAT paper

Some information extracted from the LArIAT paper (1911.10379)



USCOLL : upstream collimator
USTOF upstream time of flight
WC: Wire chambers

B? : bending magnets
HALO: beam halo veto counter
MuSR: muon range stack

Need a Cherenkov detector to separate electrons from pions

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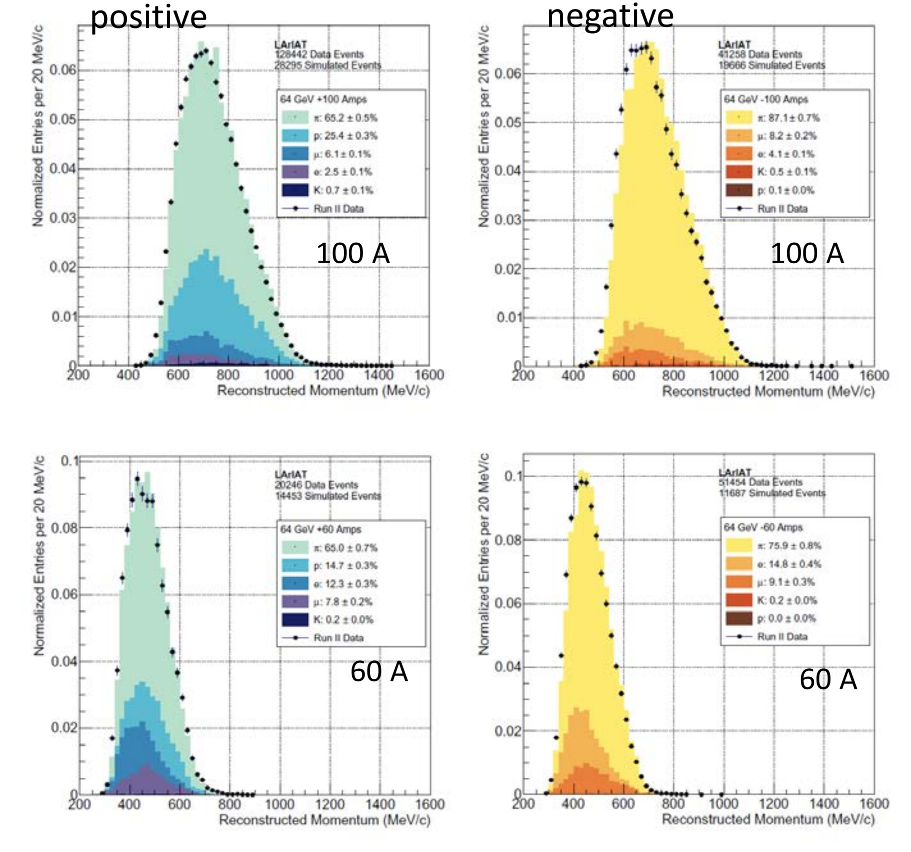
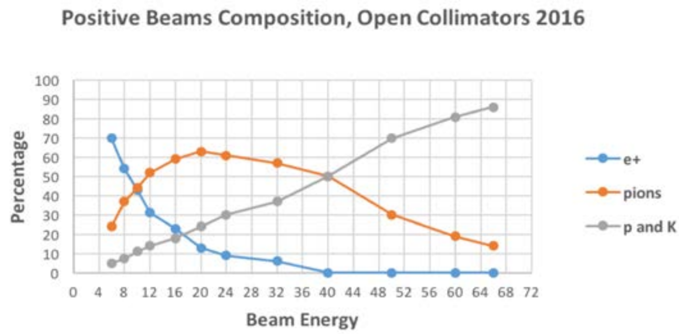
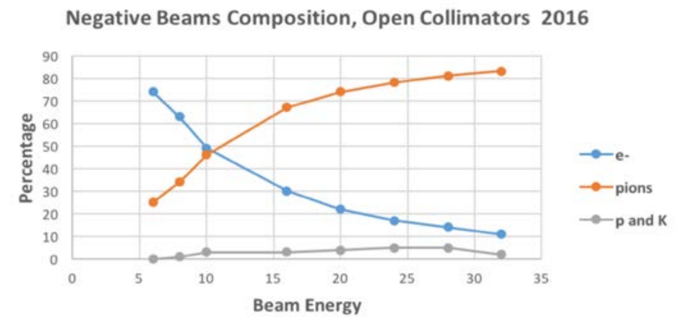
Tertiary beam line, different beam configuration (64 GeV secondary beam energy)



Secondary beam line





Very small kaon and antiproton amount

Are these plots representative of the beam energy spread? What is the particle multiplicity? What is the resolution of the beamline instrumentation?

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Time of flight performance

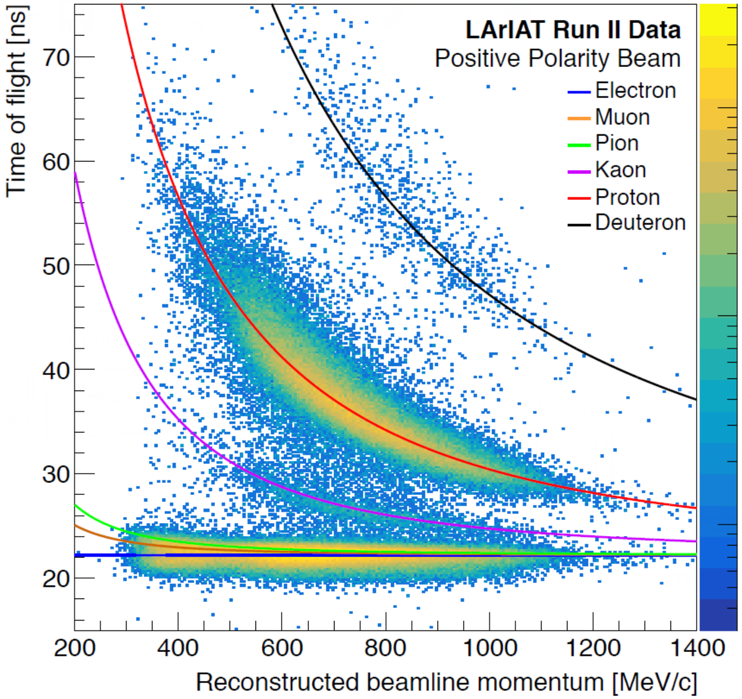

Figure 7. Measured time of flight vs. momentum in the beamline spectrometer system for data collected with a positive-polarity tertiary beam. The colored lines show the expectations for different particle species.

Looks like we can identify protons up to a few GeV

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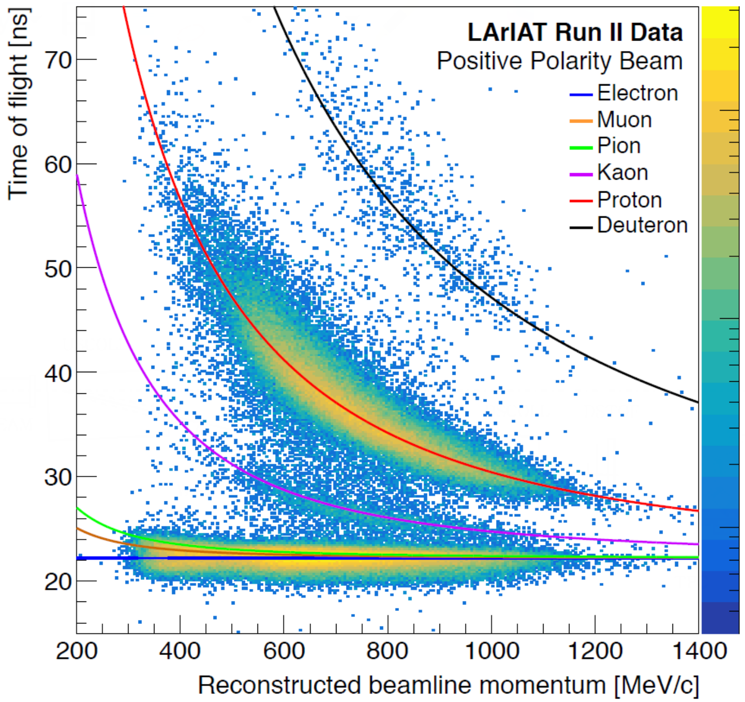

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