Searching for a Heavy Photon with DarkLight

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on behalf of the DarkLight collaboration

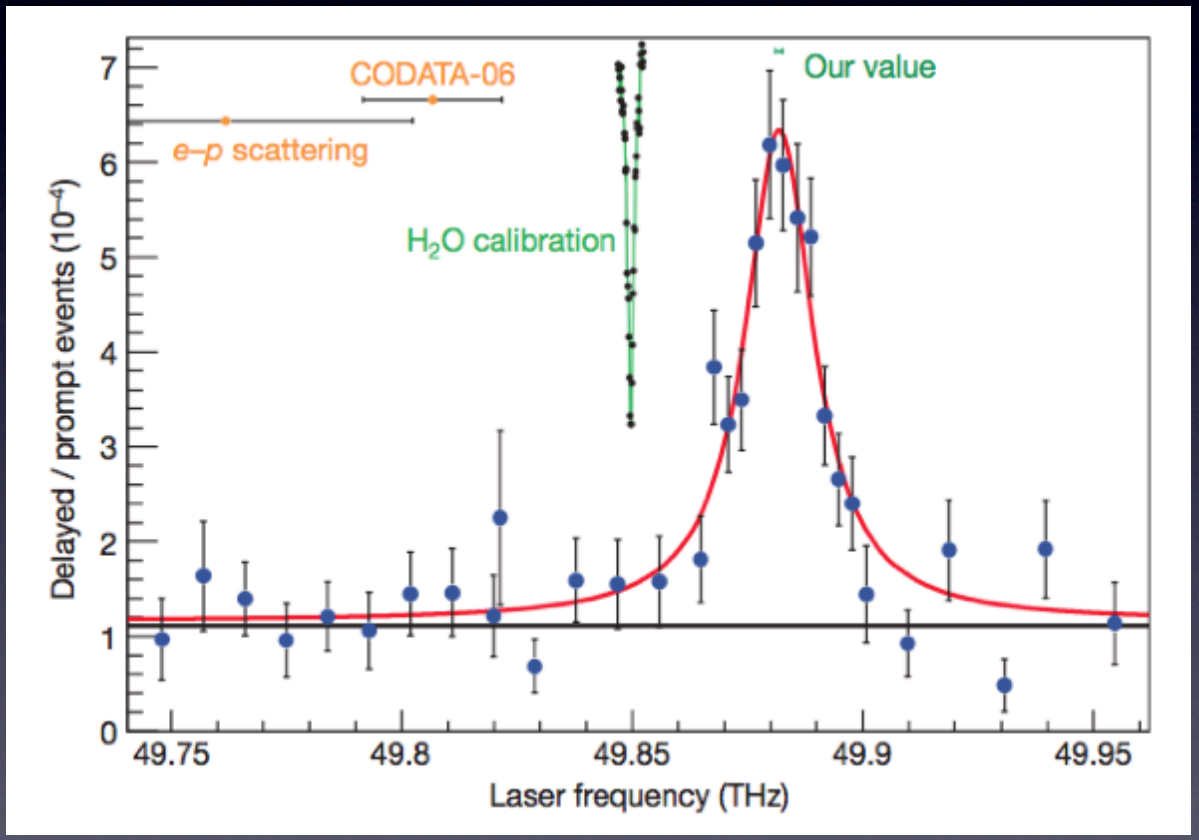
Intensity Frontier Workshop
Argonne National Lab
26 April 2013

Outline

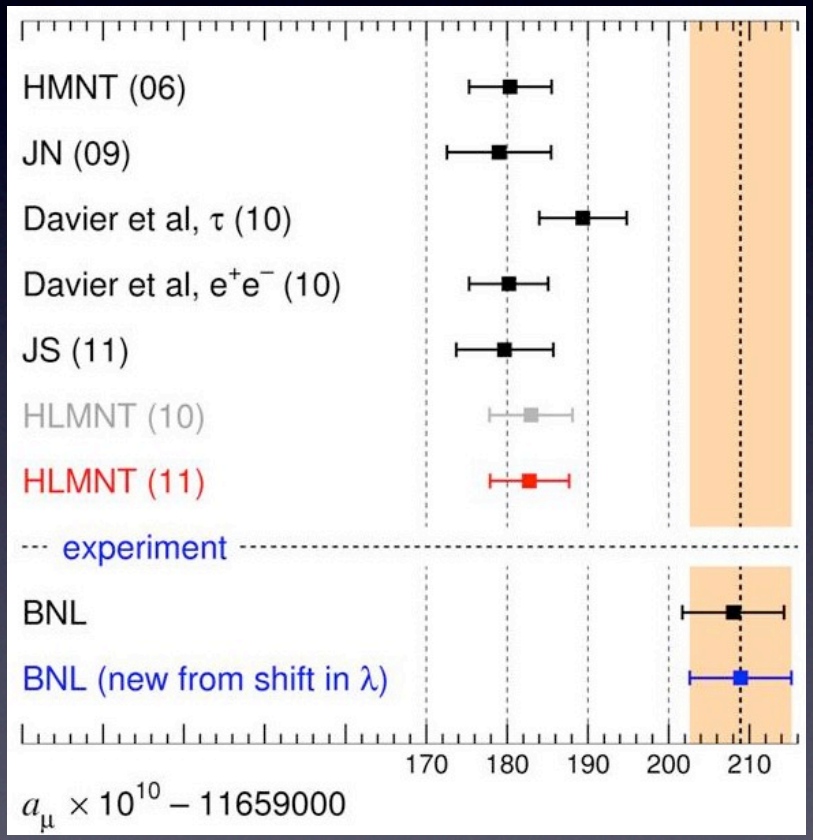
- Physics Motivation
- Experimental Requirements
- DarkLight Design
- Status

Physics

- Precision measurements of muonic QED interactions show deviations from theoretical expectations:



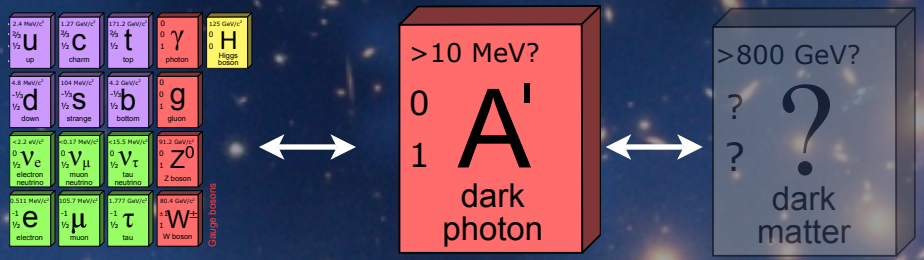
Muonic Proton Radius (Pohl et al.)



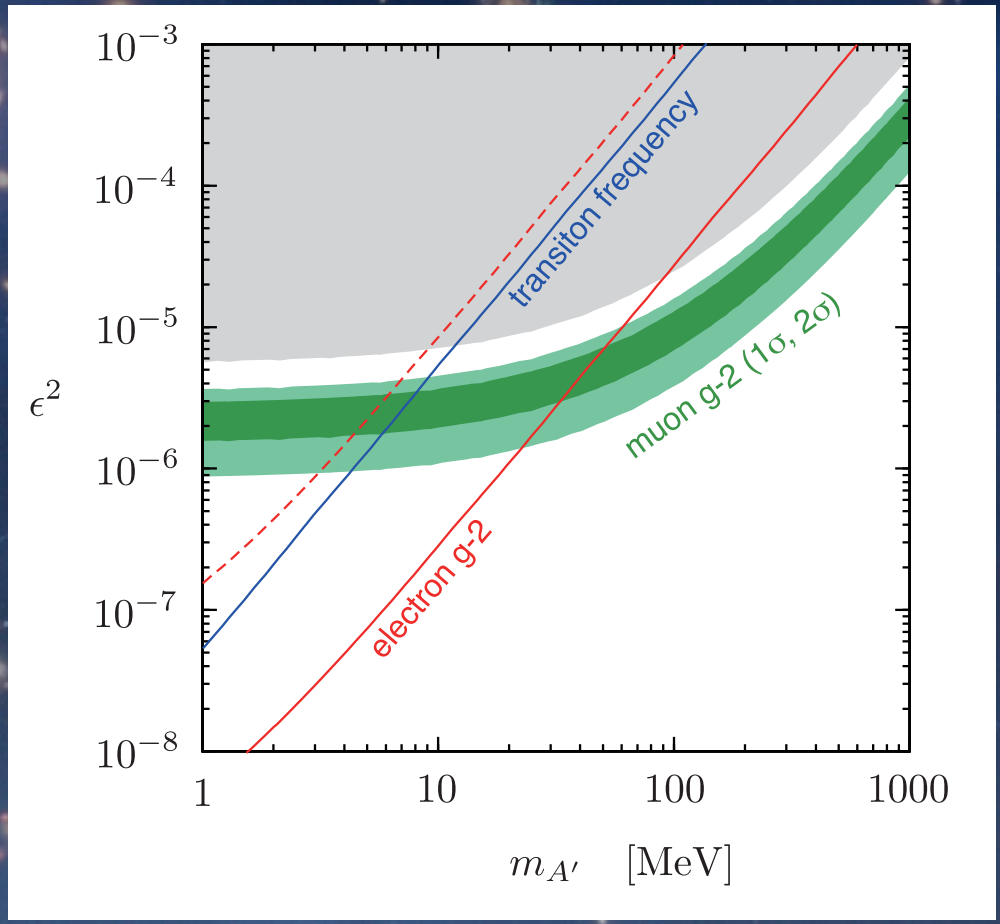
Muonic g-2 (E821)

Dark Forces

- A particle that explains this may also be connected to the dark sector, acting as a force carrier for Dark Matter

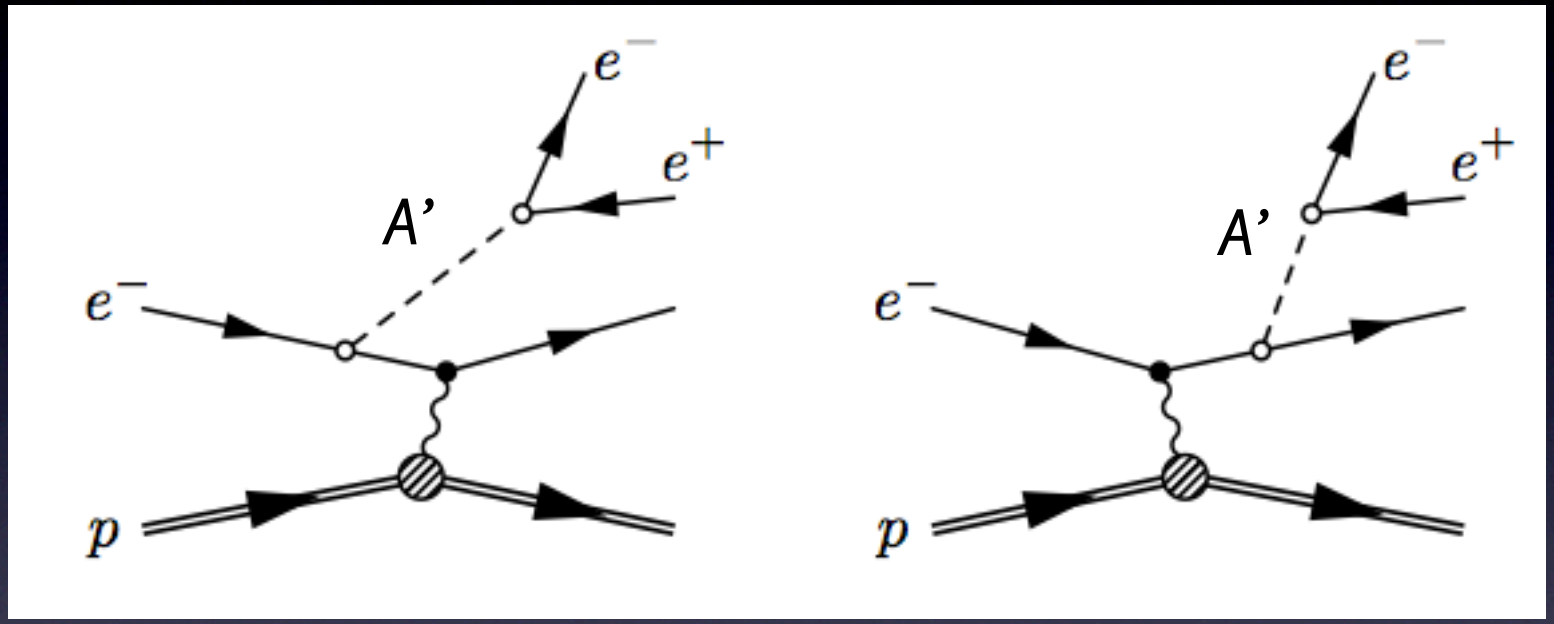


- g-2 measurement suggests where to look in coupling strength and mass:



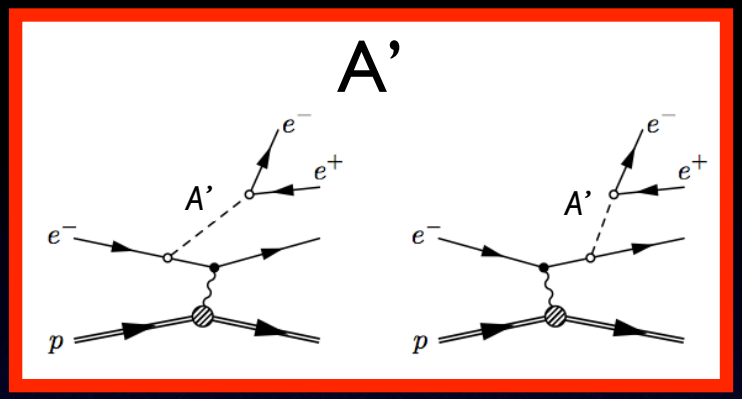
(muonic hydrogen not included)

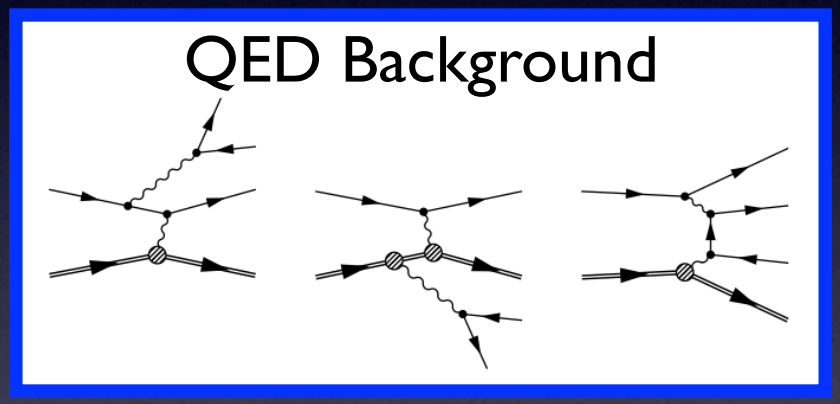
Producing A'



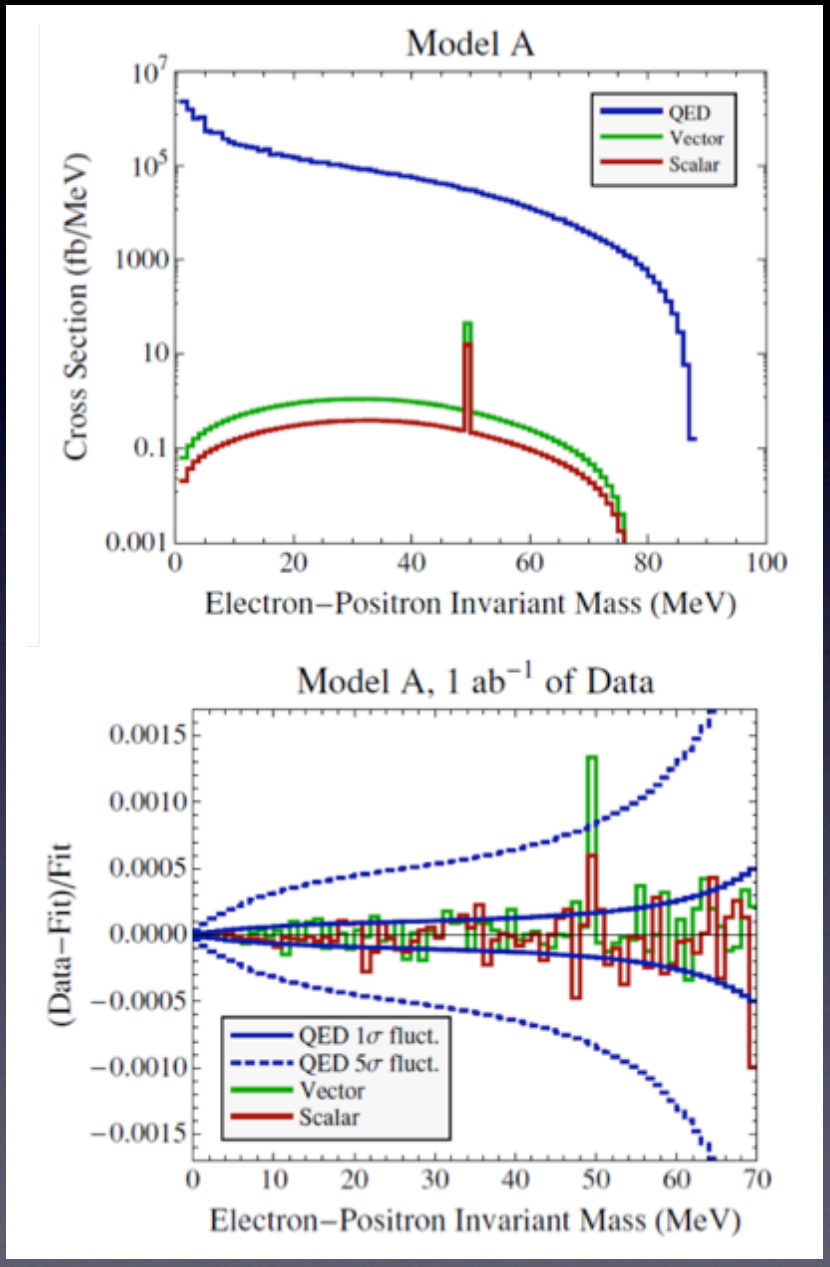
- The goal is to look for A' production in an environment where no other resonant meson production occurs. $\sqrt{s} < 100$ MeV

Reconstruction



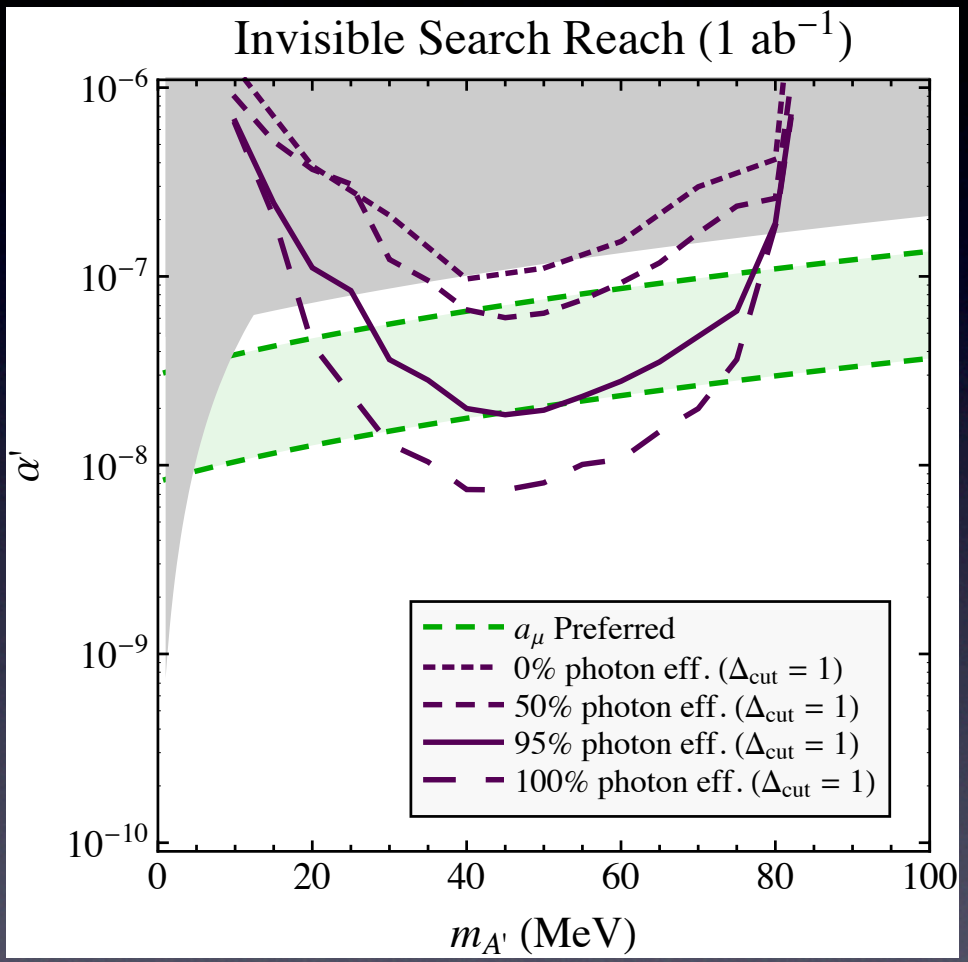


Reconstruct e^+e^- invariant mass, look for peak amidst smooth QED background



Other Measurements

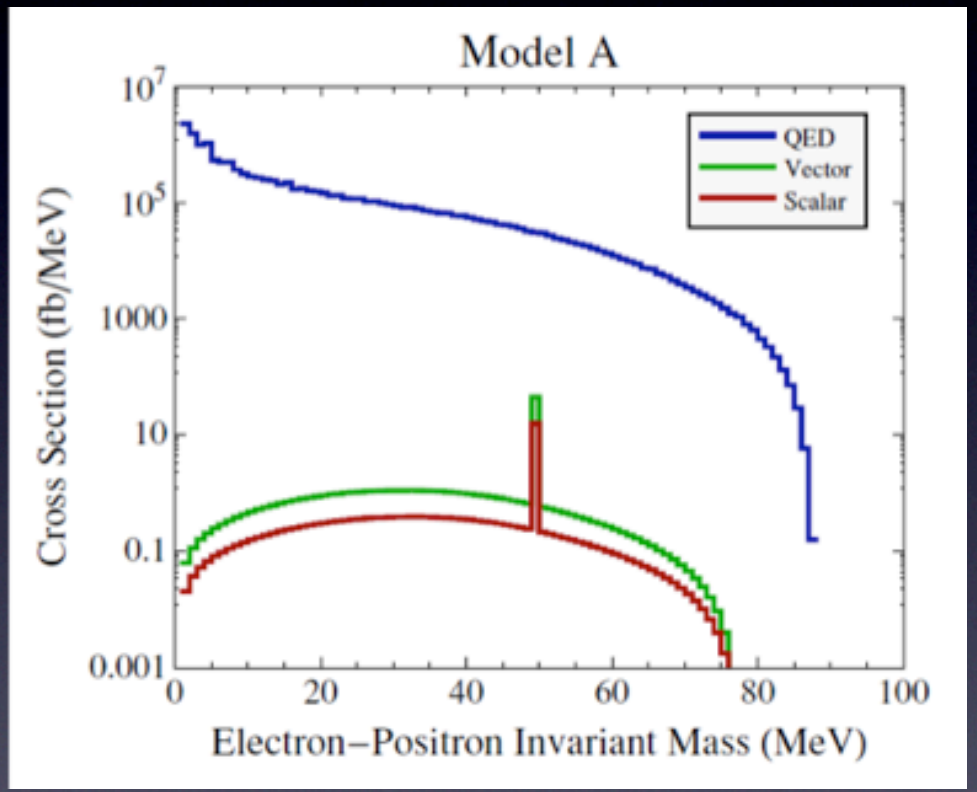
- In addition to A'→e^+e^-, the same apparatus can be used for:
  - A' to invisibles search
  - Proton radius measurement



ep→epA'→ep+M.E.

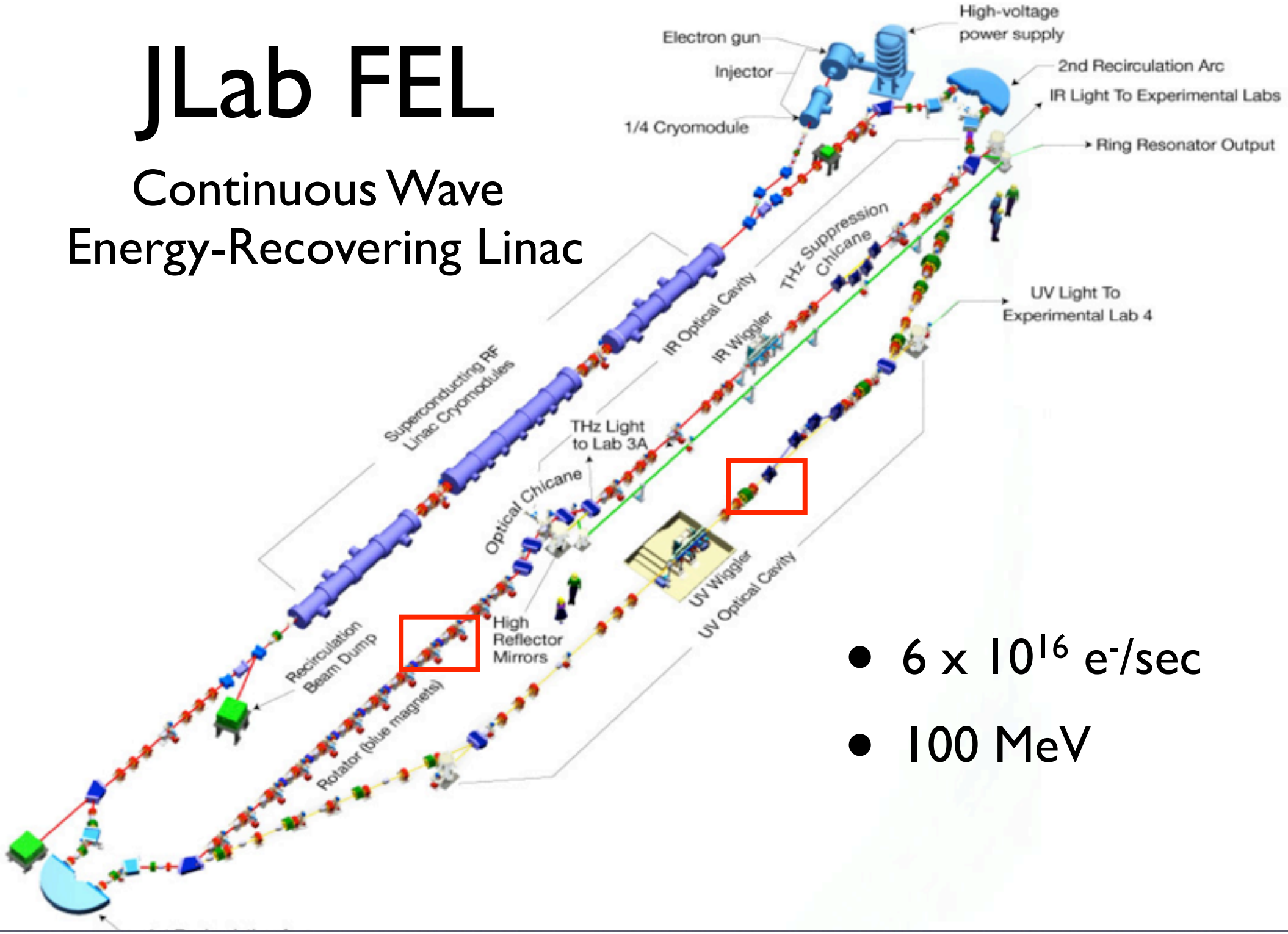
Design Needs

- Overcome small coupling: Intense beam will provide 0.5 ab^{-1}/month.
- Eliminate other production: Beam energy < 100 MeV is below the pion production threshold.
- Control QED background: Good momentum resolution in tracking detectors aim for A' mass reconstruction with 1 MeV accuracy.



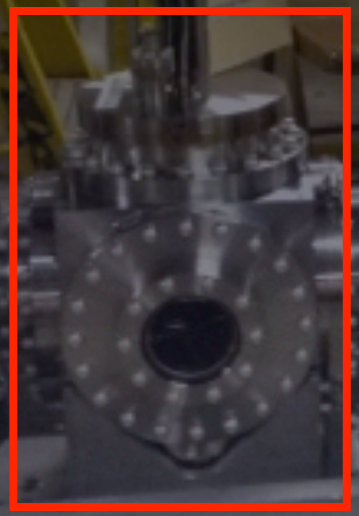
JLab FEL

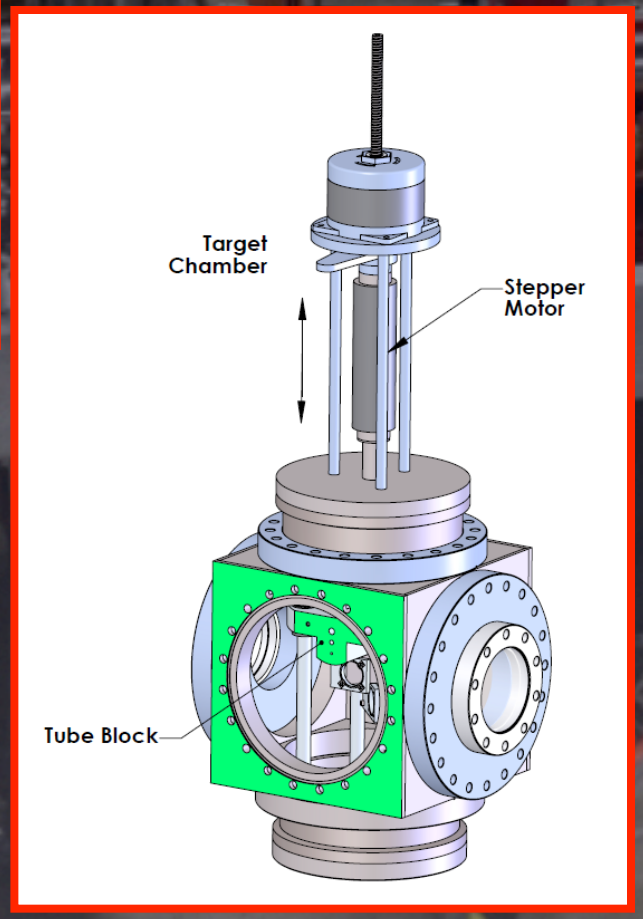
Continuous Wave Energy-Recovering Linac



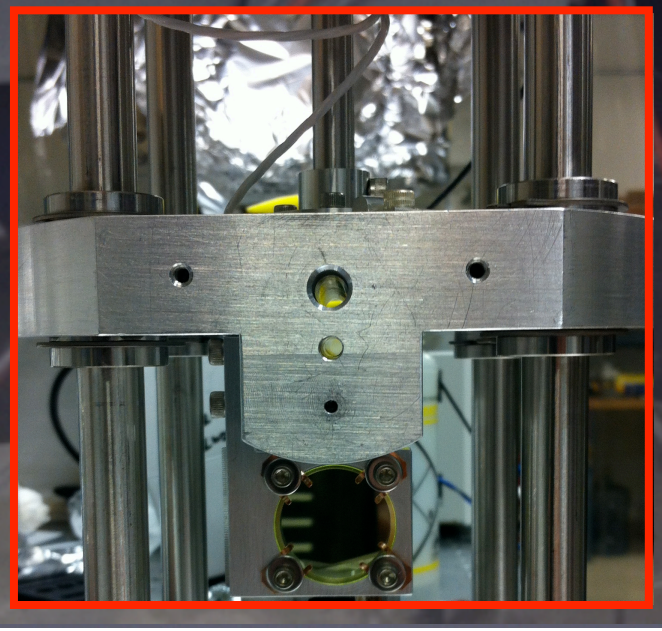
- 6×10^{16} e^-/sec
- 100 MeV

Beam Tests

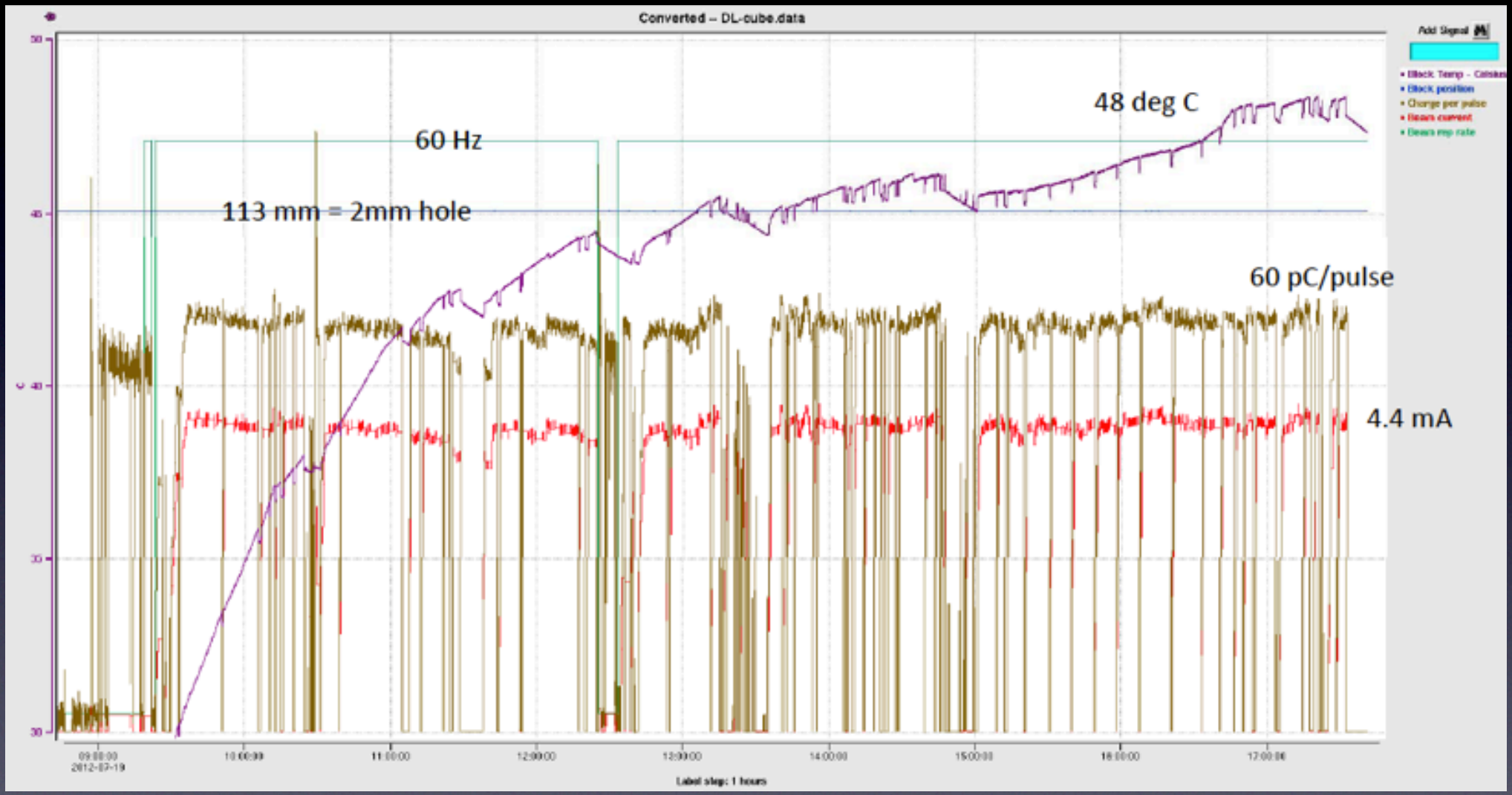




- Demonstrate beam can pass through 2mm diameter aperture
- Characterize photon and neutron backgrounds
- Verify trackers can operate in that environment

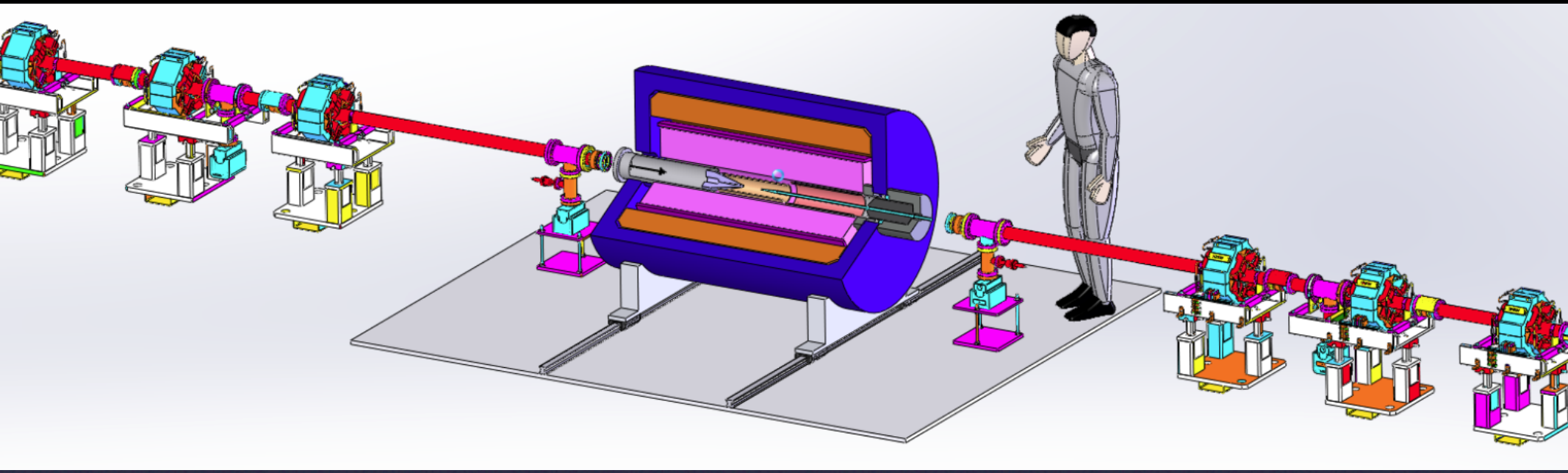


Beam Tests



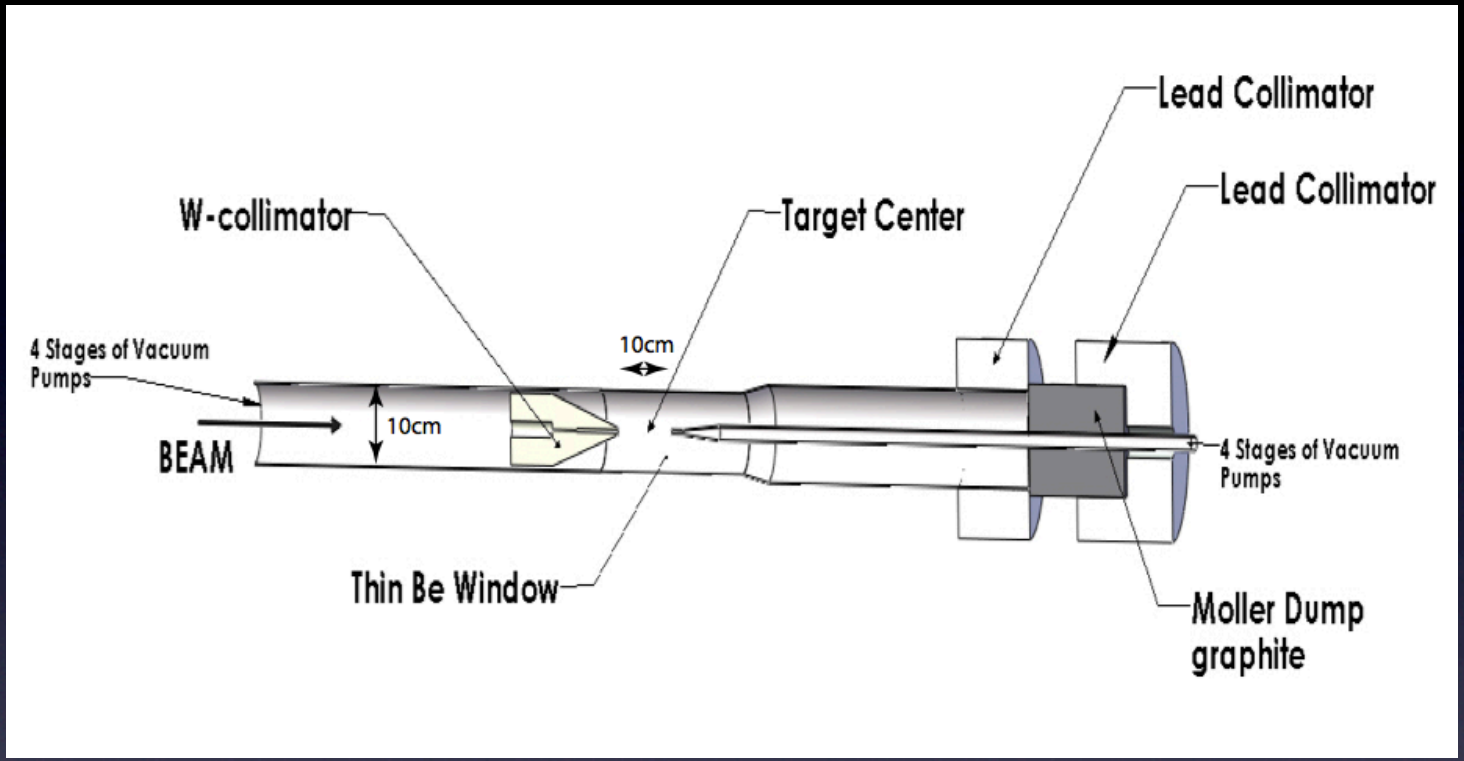
2mm hole, 8 hours, 75Mhz 4.4mA 60pC/pulse

Design



- Collimated electrons impinge on the hydrogen gas target.
- Proton recoil detected by inner silicon
- Leptons pass into Time Projection Chamber and Scintillators

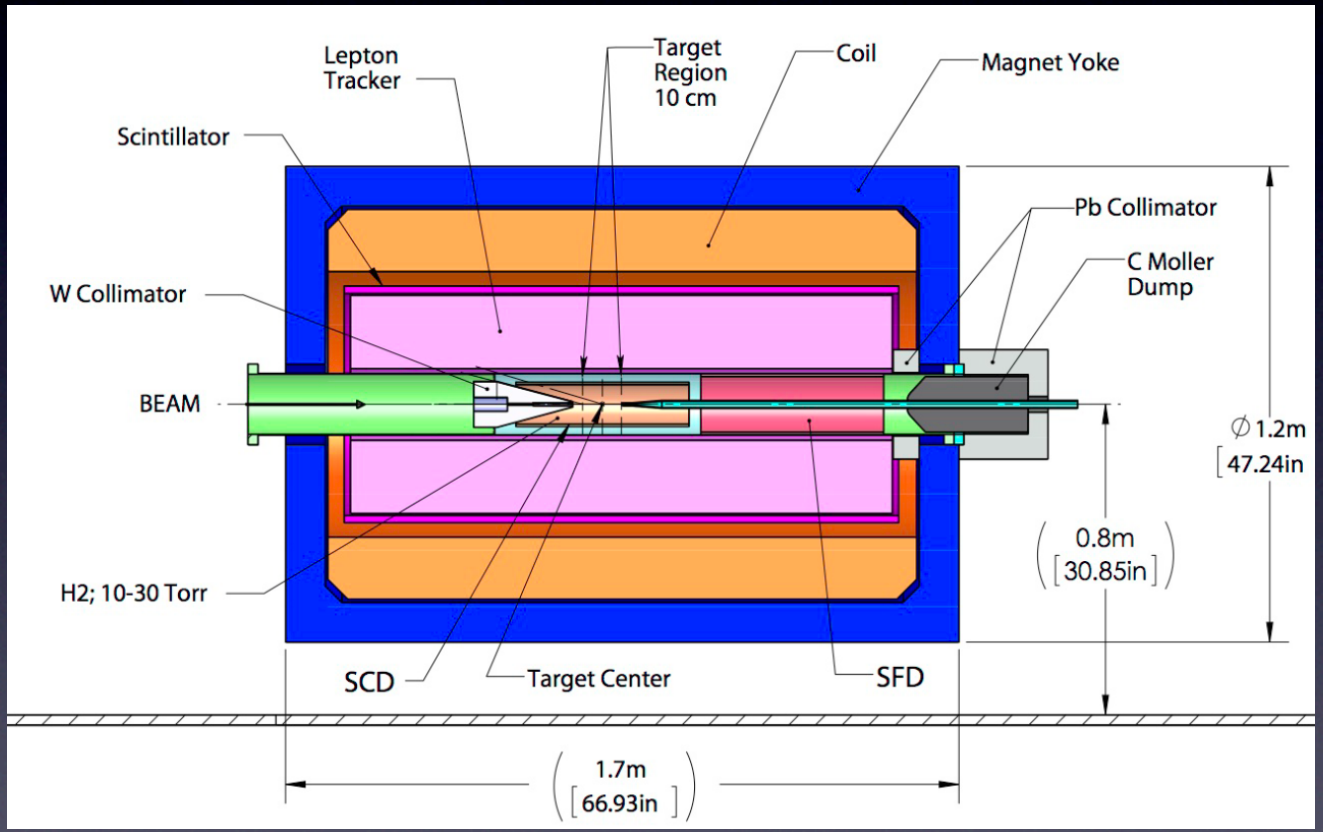
Target



- Windowless target, aggressively pumped
- Gas thickness ~10^{19}cm^{-2} with 10mA beam yields ~0.5 ab^{-1}/month
- Thin beryllium beampipe

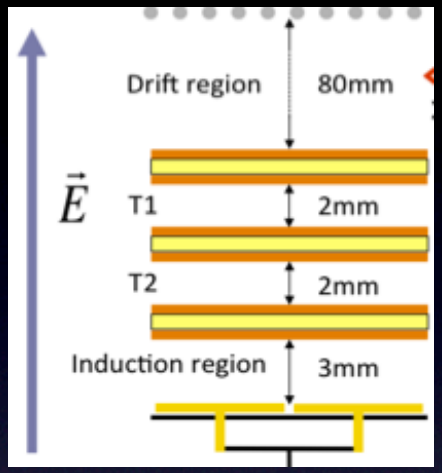
Tracking

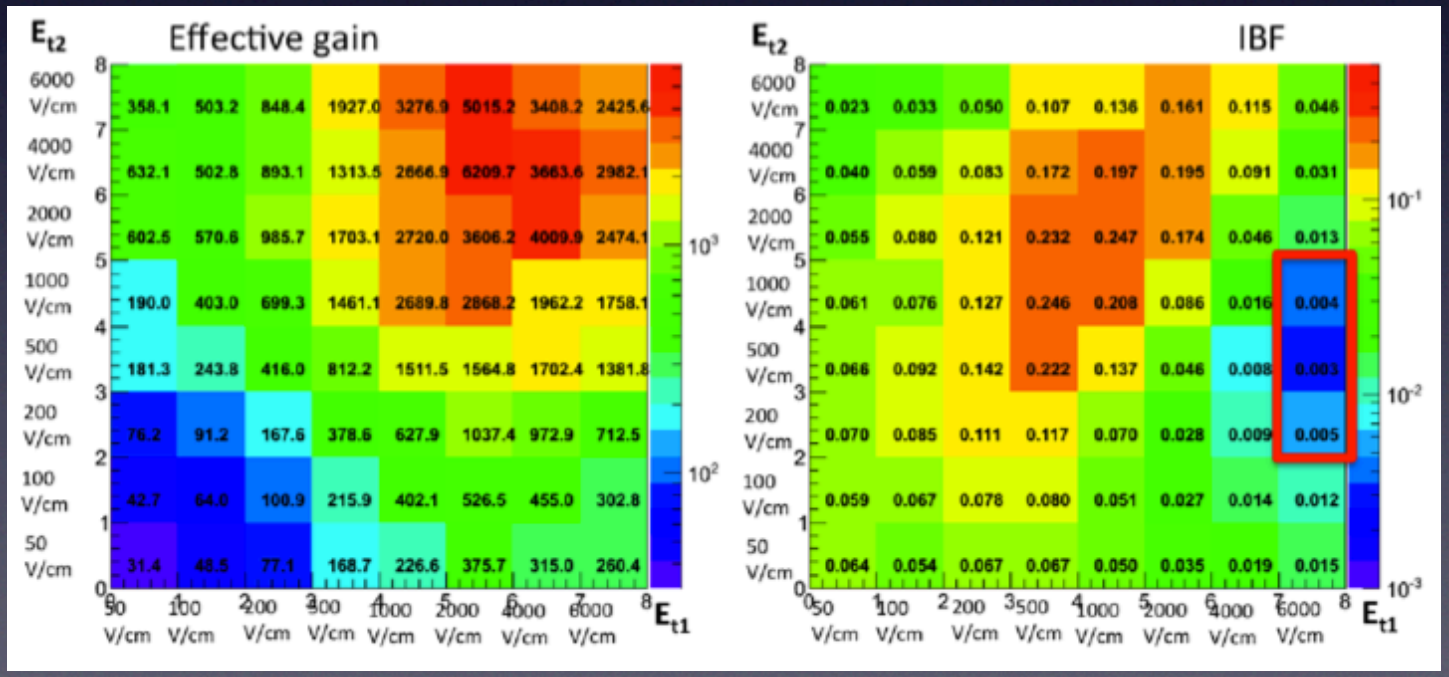
- Si detector for proton recoil
- TPC + 0.5 T magnet
  - High track density
  - ~250 μm hit res.
  - Magnet confines low-p_T backgrounds (e-p and Moller)
- Scintillators serves as veto for invisibles search

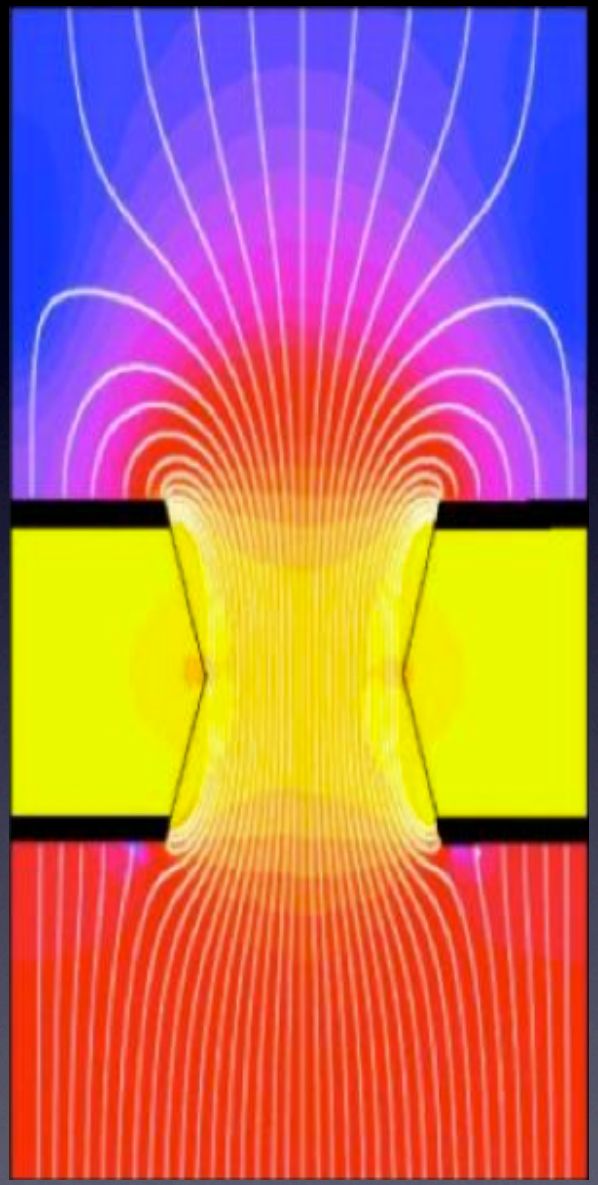


GEM TPC

- Rate forbids Gating Grid
- Ion Backflow can be controlled by GEM stack:

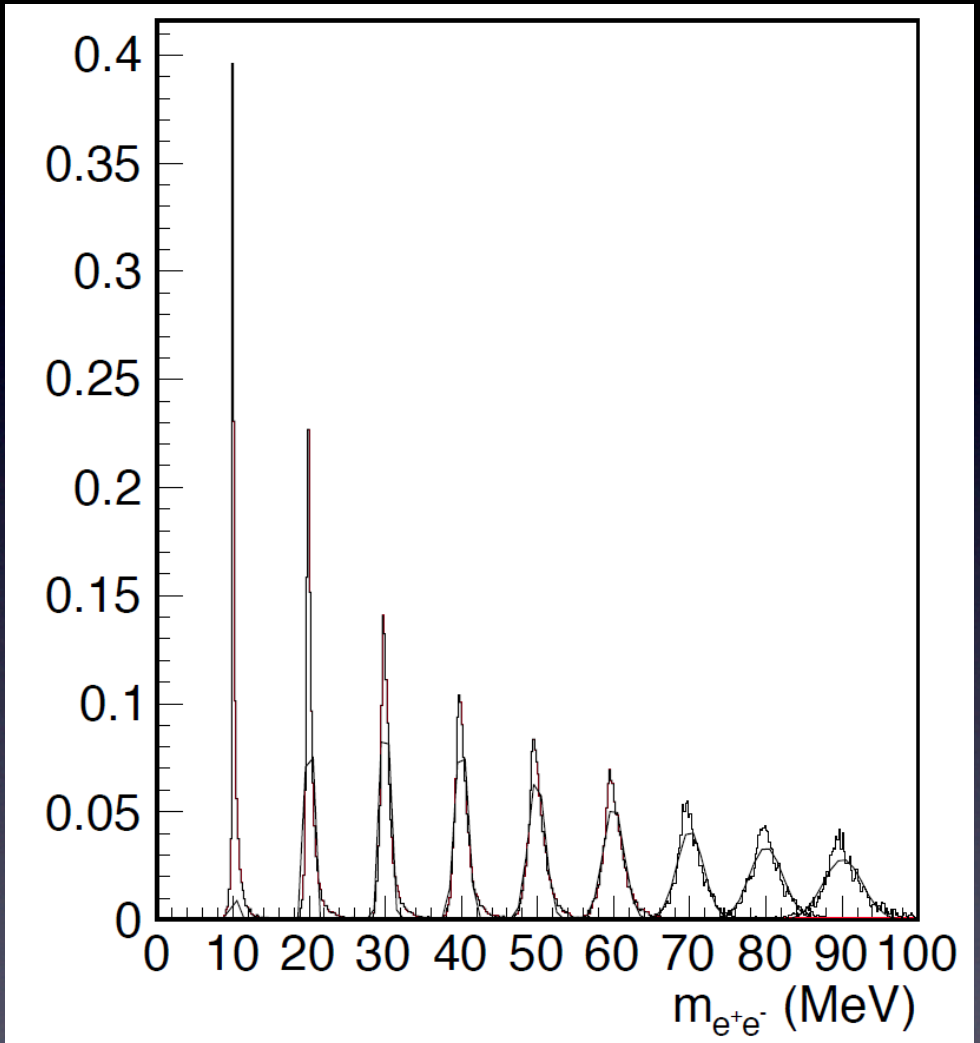






Simulated Performance

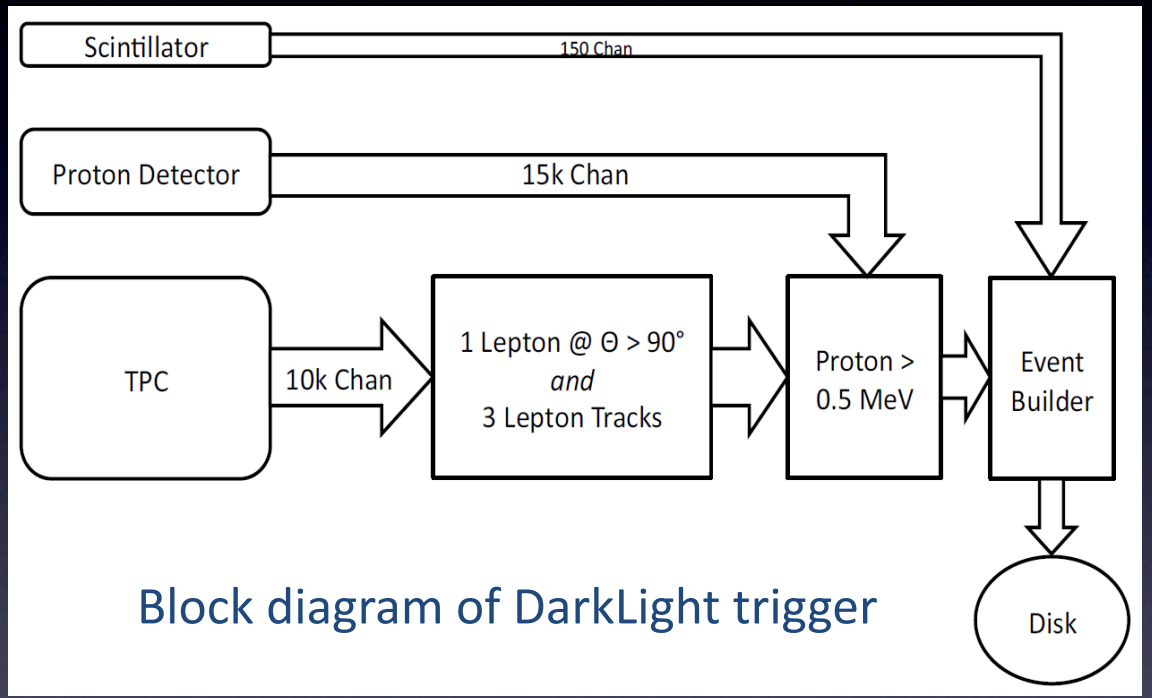
- Reconstruction of all final state particles is essential.
- Momentum resolution from early MC study shows $\sigma_{pT}/p_T = 0.06$ for 200 MeV tracks
- A' mass resolution 0.2-2 MeV/c^2



Fits to reconstructed mass of A' in various MC

Triggering

- Has to handle high input rate:
- 3-lepton events ~1MHz
- +recoil proton ~10 kHz

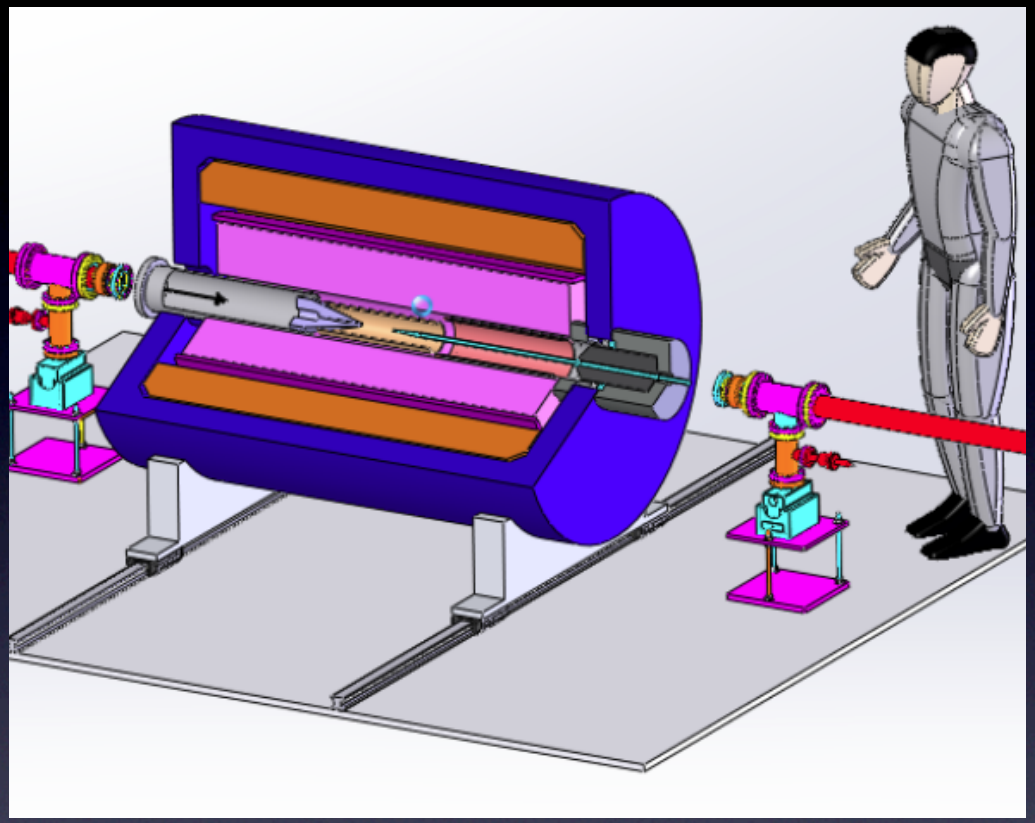


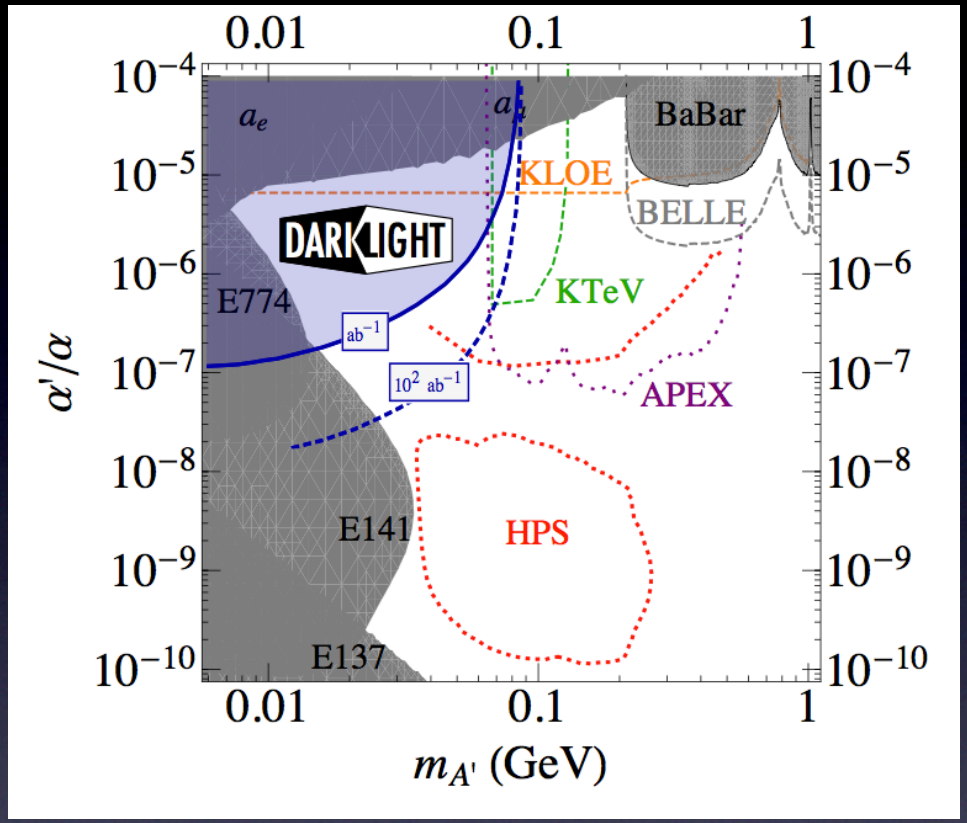
Block diagram of DarkLight trigger

Status

- Successful beam test has proven feasibility of target design at FEL
- In last stage of review at Jefferson Lab
  - if approved, will seek funding and move to technical design and review
- Hoping for commissioning run in 2015
- And data-taking runs in 2016

Summary





- DarkLight is a compact magnetic spectrometer for $e\text{-}p \rightarrow e^-pA' \rightarrow e^-pe^+e^-$ detection with $m_{A'}$ 10 - 90 MeV
- Complementary to other heavy photon searches
- Currently finalizing JLab approval

The DarkLight Collaboration

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A Theory of Dark Matter

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(Dated: January 20, 2009)

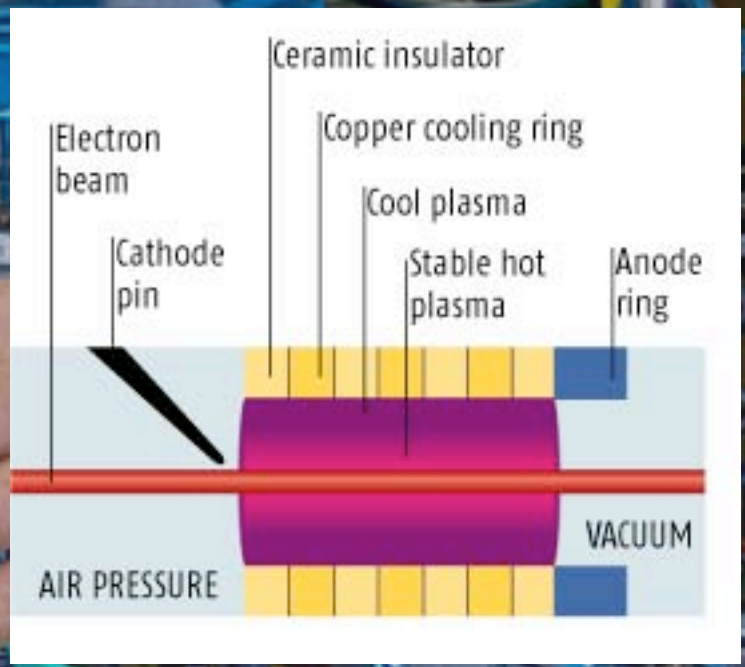
arXiv:0810.0713 [hep-ph], and others…

I. TABLE OF RATES FOR DARKLIGHT

Detector	FEL		Hall
	Target (Hz)	Halo (Hz)	(Hz)
Tracker track Rate	41M	1.6 M	32
Singles rate per readout pad	4.1k	570	0.001
Si Total Rate	30M	2.6M	16
Rate per strip	4.8 k	200	0.002

TABLE I: Total rates and rates per detector element for different sources. The rates per pads and per strips do not scale with each other because some of the processes result in single hits rather than tracks.

Plasma Windows



PANDA GEM TPC