Dark Forces Workshop
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Fixed Target Search for Heavy Photons

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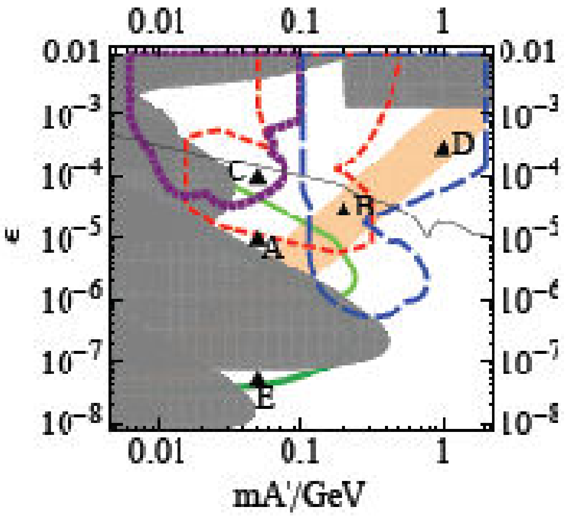
Outline

- Introduction
- Available beam
- JLab Hall B "Photon Dump"
- Experimental Apparatus
- Simulation
- Backgrounds
  - Occupancy
  - Track multiplicity
- Performance
  - Acceptance
  - Mass resolution
  - Vertex resolution
- Experimental reach
- Conclusions

Introduction

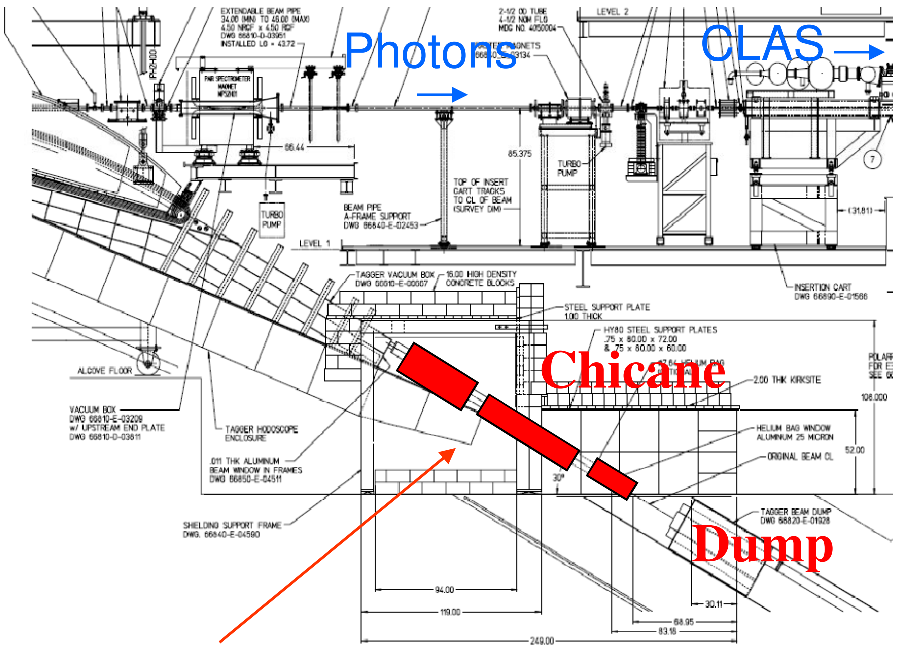
- Motivated by BEST paper (arXiv:0906.0580v1 hep-ph)
- Go after a region present JLab exps can't reach
  - Use both mass and vertex signatures
  - Compact, fast forward detector
- Focus on BEST Point B
  - $\varepsilon \sim 3 \times 10^{-5}$, mA' ~ 200 MeV, $\gamma c\tau \leq$ a few cm
  - Thin (0.01 X_0) tungsten target
- Try to setup a first experiment in ~1 year.
- Budgetary constraint
  - Use whatever available, NO R&D
  - Recycle/borrow detectors
  - Si microstrip detector, not pixel detector
- Find available beam
  - Energy > 1 GeV
  - High duty factor



Available beam

- SLAC
  - End Station A ? (not before 2011)
    - 14 GeV 0.25 nC@5 Hz
  - NLCTA
    - 200 MeV
  - FACET
    - 23 GeV 3 nC@30 Hz
  - Damping ring?
    - 1.2 GeV slow extraction
- JLab
  - Hall B "Photon Dump"
    - 6 GeV 100 nA CW

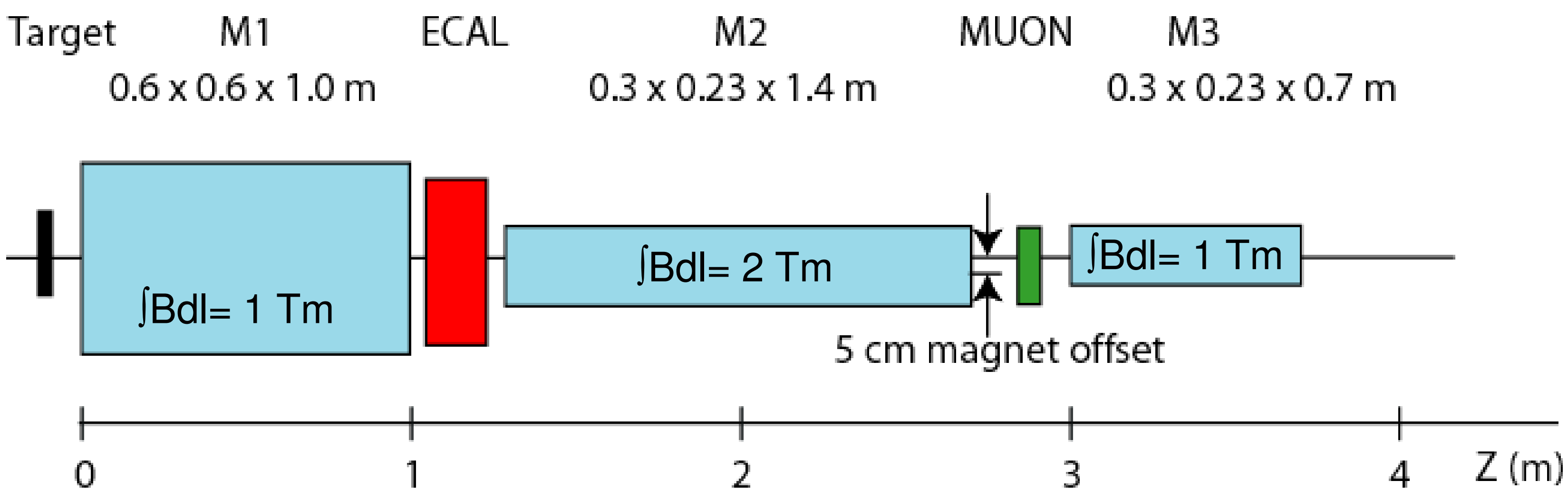
JLab Hall B "Photon Dump"



Possible location for heavy photon search

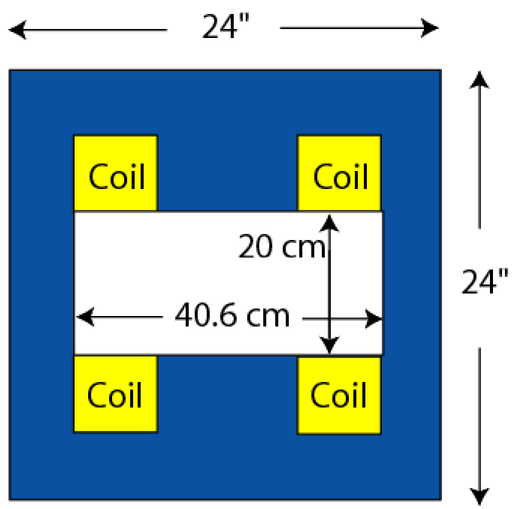
- 100 nA, 6 GeV e-, post-radiator "primary beam"
- Beam size ≤ 100 μm
- Tight ~5m space
- Avoid vertical bending plane containing primary beam, sync radiation, degraded electrons
- Beam must be directed to the dump.
  - Chicane magnets
- Parasitic run with CLAS

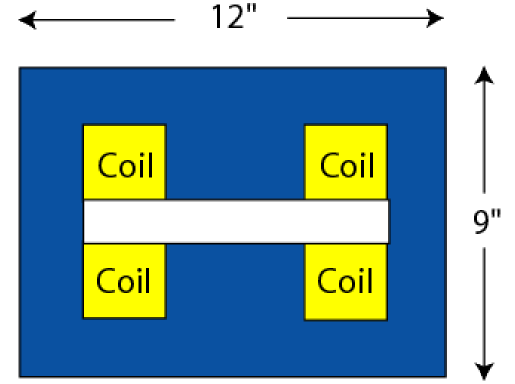
Experimental Apparatus



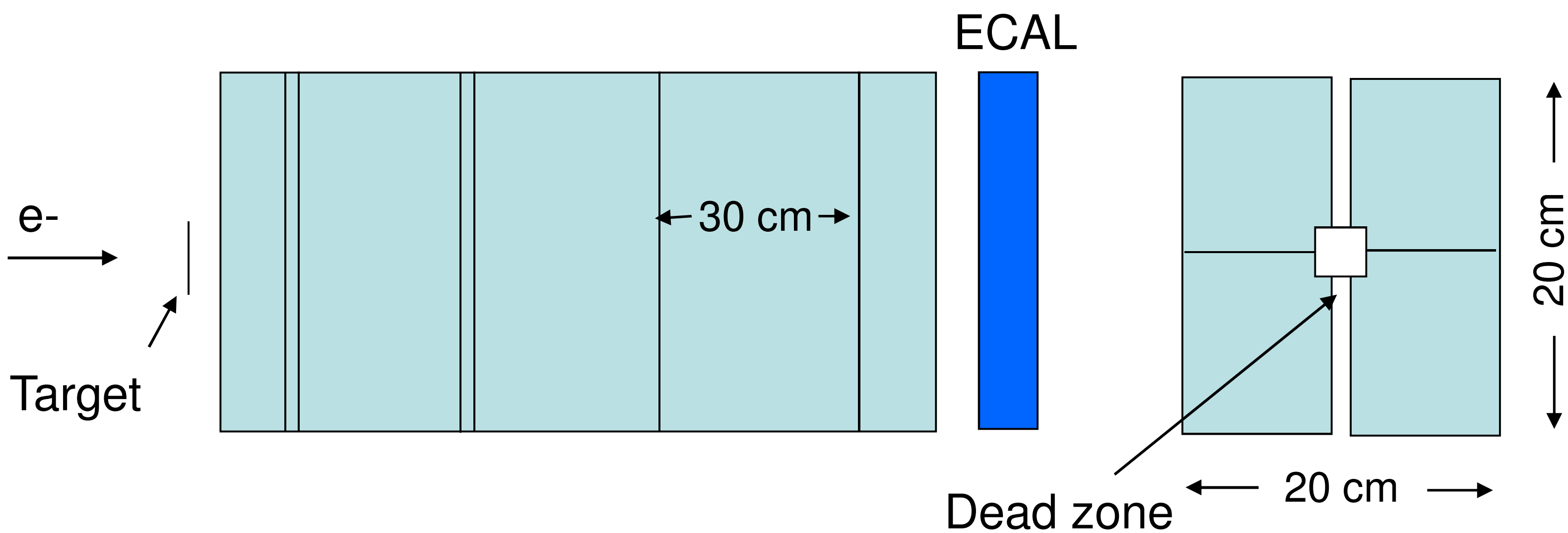
M1

Analyzing Magnet





Concept



- Hot beam, so minimize target thickness and avoid “fire” region
- Include vertexing, momentum analysis, and Ecal triggering
  - As close to the target as possible for acceptance
- Try to accept decay angles ($\theta_{min}/2$ - $2\theta_{min}$), where θ_{min} = mA’/E, momenta 1~5 GeV/c
- LHC style readout allows 25 ns livetime buckets, latency of 6 μs.
- Set-up for point B; scale beam energy and perhaps B-field for lower mass A’

Microstrips and Readout

- Possible sensors (Fermilab Run IIb)
  - 4 x 10 cm si μstrip detectors
  - 60 μm pitch with intermediate strips
- Readout Chips (Atlas tracker surplus)
  - Atlas strip readout ABCD3TA ASIC
  - 25 ns time resolution; 3 μs buffer
  - 50 μm pitch (needs adapter for sensors above)
  - 1-2% dead channels

DAQ

- Use SLAC LCLS High Data Rate System Architecture
- Must build front end and data concentrator boards (~100k$?)
- Signals transmission via optical fibers
- Use existing ATCA-standard RCE (Reconfigurable Cluster Element) to build event and send to storage
- Can handle high data rates ~10 Gbits/s
- No thought yet on software trigger!

Ecal Trigger

- More trigger studies are needed
- Ecal is split into left and right halves, divided by the “fire” plane
- Size 20 cm x (10-20) cm
- Fast. Readout every 25ns.
- Moderate energy resolution OK
- More Segmentation desirable

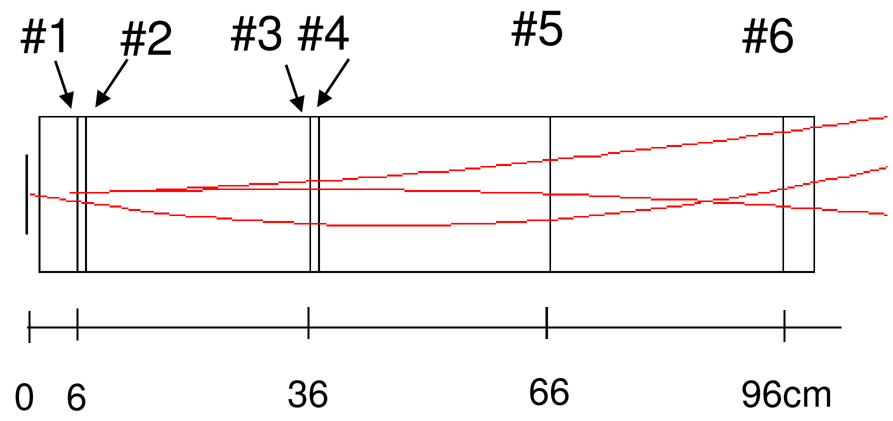
Detector simulation

Beam:

- 6 GeV e- 100 nA

Target:

- 0.01 X_0 Tungsten



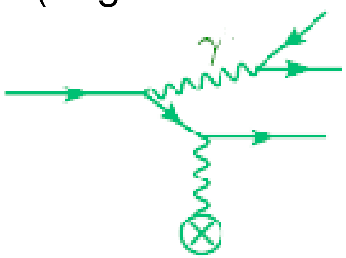
- Six planes of 300μm-thick Si in a 20cm×20cm×100cm volume with Bx=10 KG
- Layers #1 and #3 are vertical strips
- Layers #2, #4, #5 and #6 are horizontal strips
- Multiple scattering and interactions in the Si layers are simulated
- Digitization to strip is not simulated – x, y coordinates are smeared randomly by σ = 15μm.

EGS5, GEANT3, FLUKA are used for interaction simulations.
Ecut(e+/-) = 10 KeV, Ecut(γ) = 1 KeV

Backgrounds

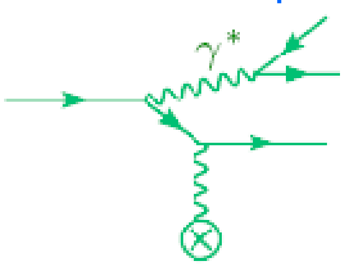
$\sigma(A')\sim 1$ pb

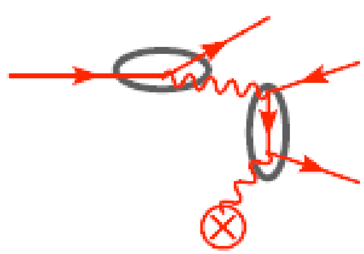
- Secondary particle production in the target
  - Bremstrahlung $\sigma\sim 1000$ b
  - Delta-rays
- Pair conversion of bremstrahlung photon
  - Two step process; the rate ~(target thickness)^2



$\sigma\sim 1$ b

- Virtual photon conversion and Bethe-Heitler processes



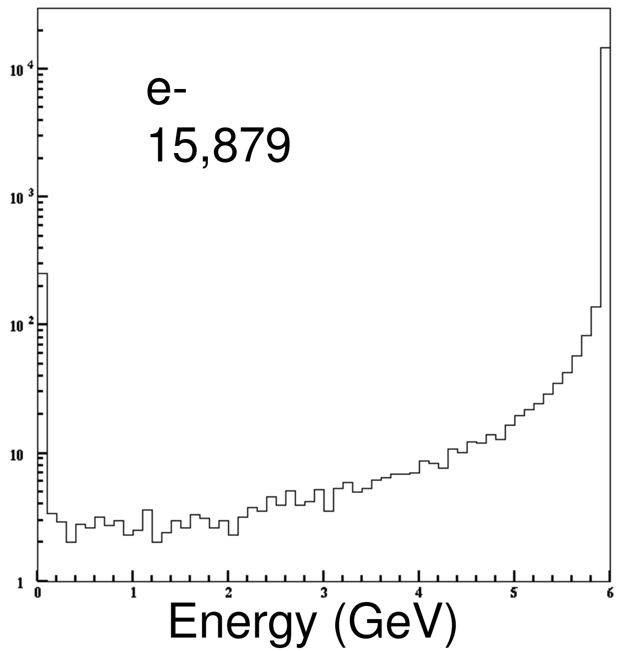


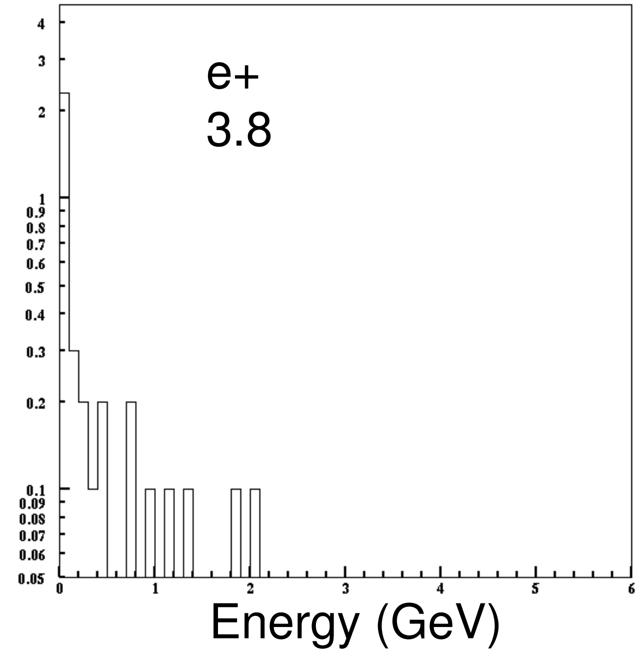
- Thin target to reduce the rate
- Magnetic field to remove low energy e-
- Define dead zone

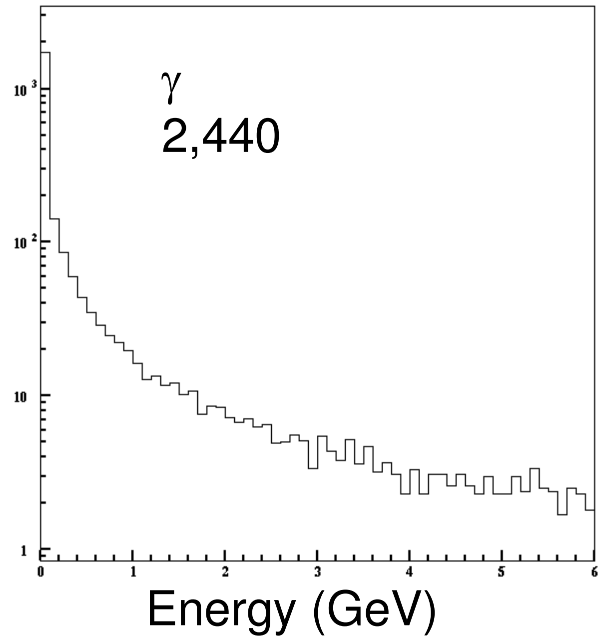
- Target thickness is 0.01 X_0
  - $\sigma(\gamma\rightarrow ee) \sim \sigma(\gamma^*\rightarrow ee)$

- Require
  - Ee- > 0.5 GeV
  - Ee+ > 0.5 GeV
  - Ee- + Ee+ > 4.5 GeV
  - Use M(e+e-) and vertexing for rejection

Background from the 0.01 X_0 target







6 GeV e- 15,625 incidents in 25 nsec@100 nA

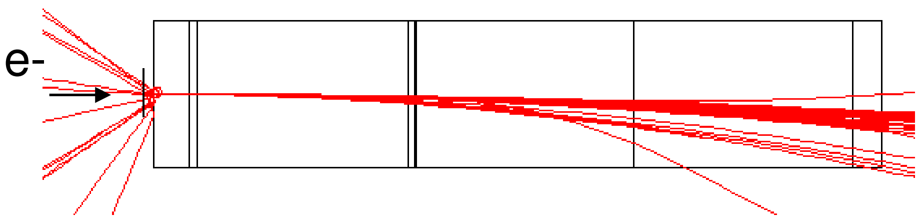
- Bremstrahlung and δ-ray production are proportional to the target thickness.
- Positron production is proportional to (thickness)^2.

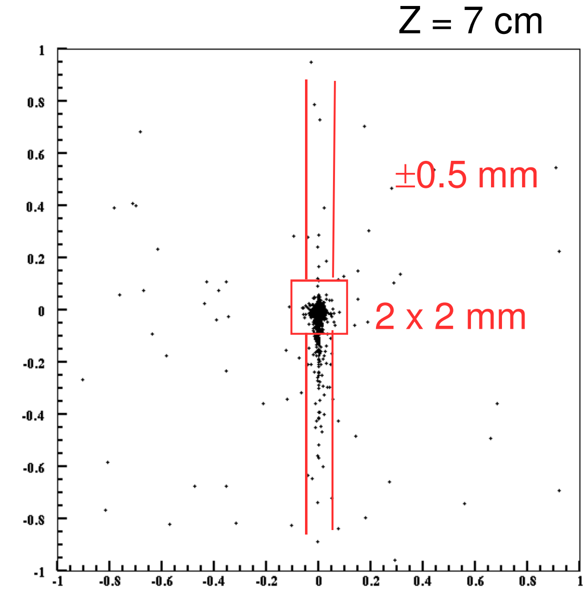
Dead zone

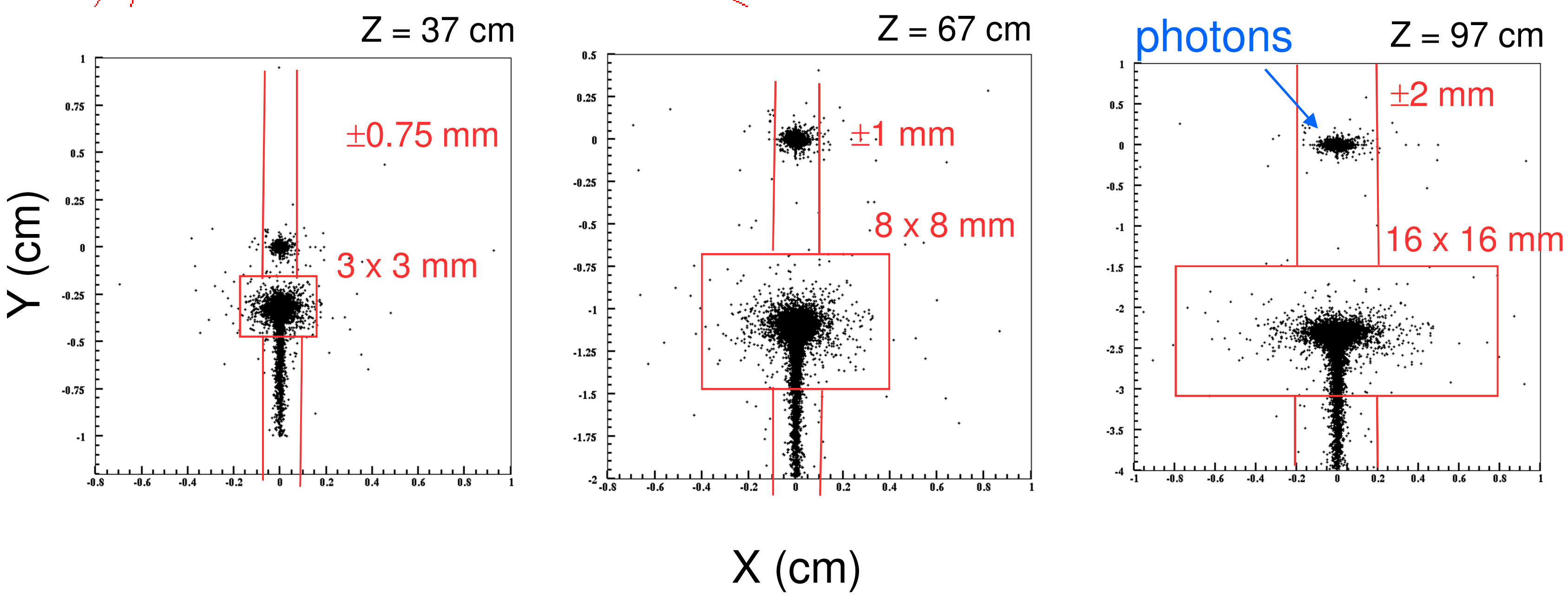
What track multiplicity can pattern recognition in Si strip tracker handle?

Dead zone is defined so that the track multiplicity is less than ~5.

Occupancy is < 1%.

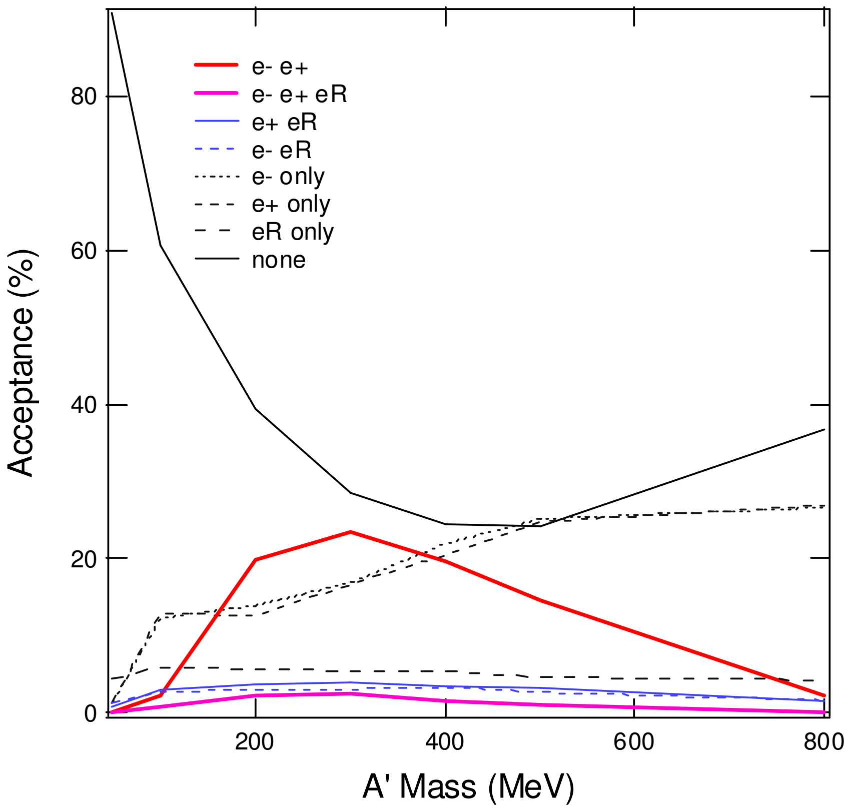






Tracker Acceptance

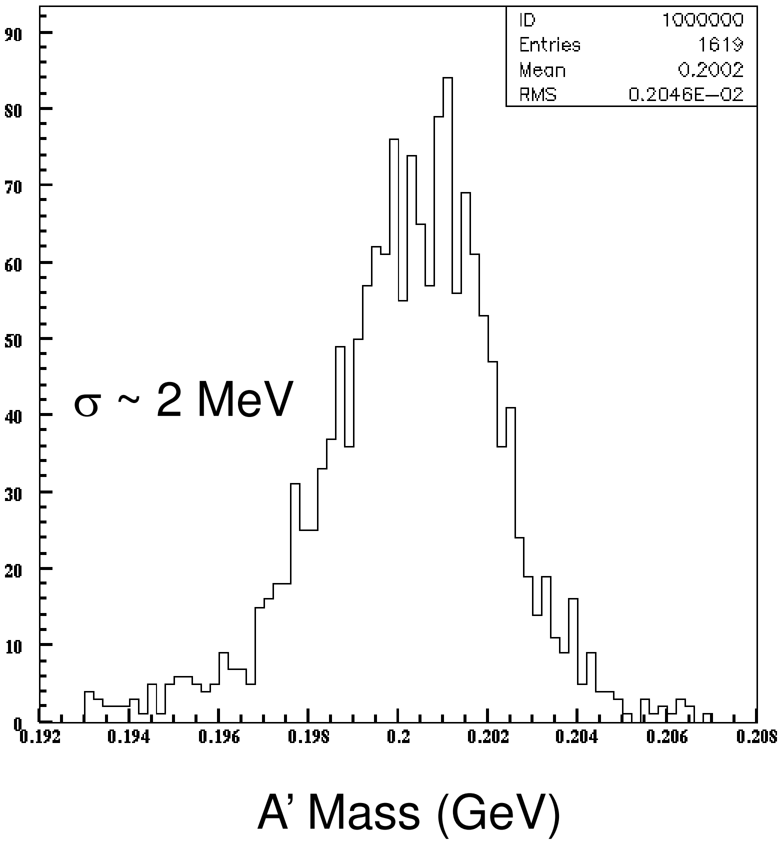
Require particle passing all six layers outsize the dead zone.

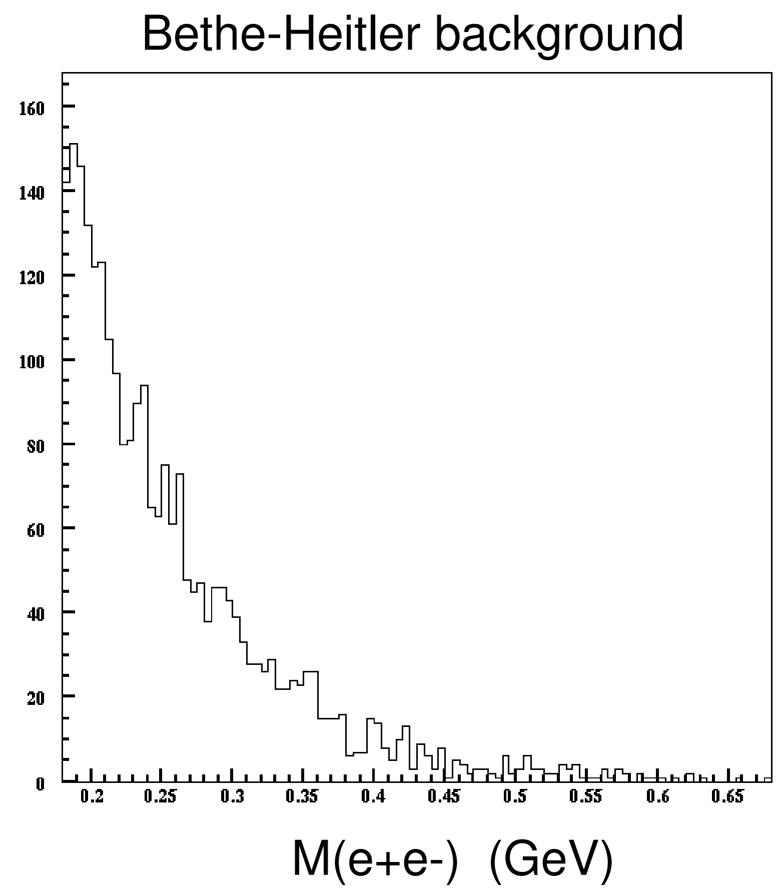


To increase acceptance

- in the higher mass side
  - Shorter detector
    - $\Delta p/p2 \sim 1/(B \bullet L^2)$
  - Wider detector
- in the lower mass side
  - Narrower dead zone
    - Track multiplicity goes up.
  - Lower beam energy

Mass resolution

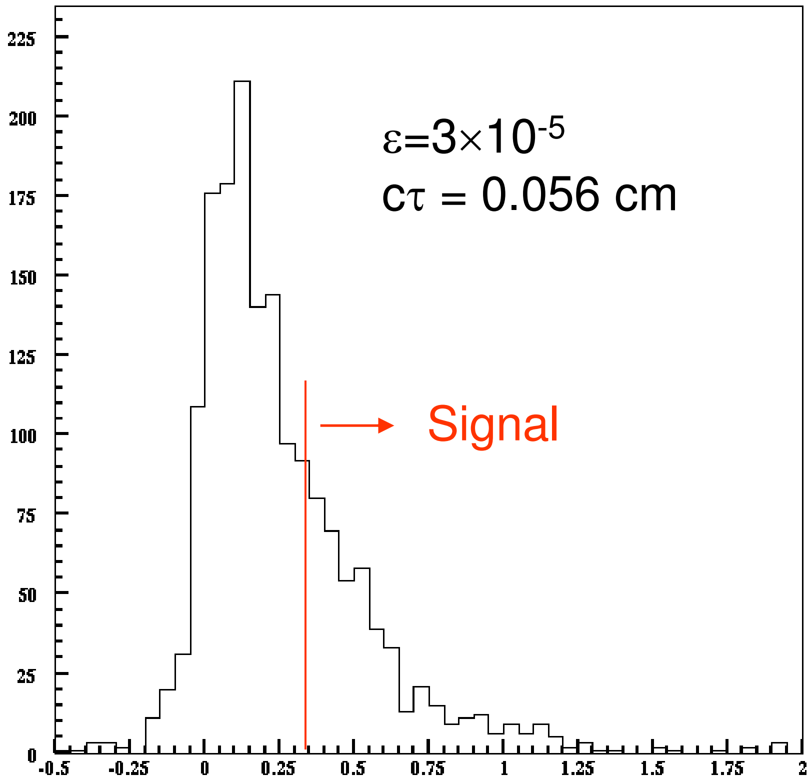




- Bump-hunting in steeply falling trident background.
- Good mass resolution is crucial.

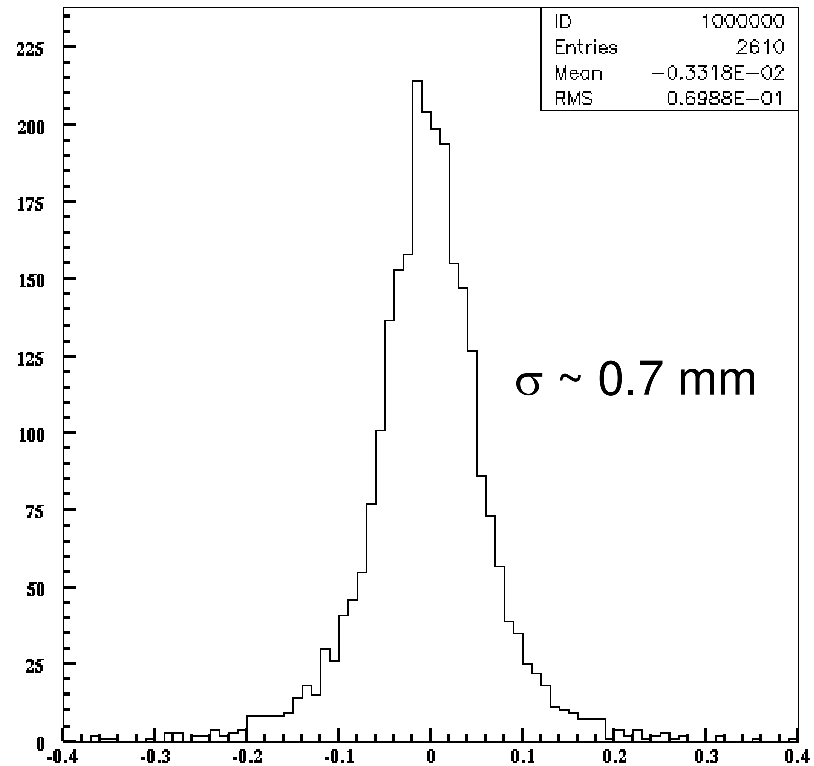
Vertex resolution

A' decay vertex



Z (cm)

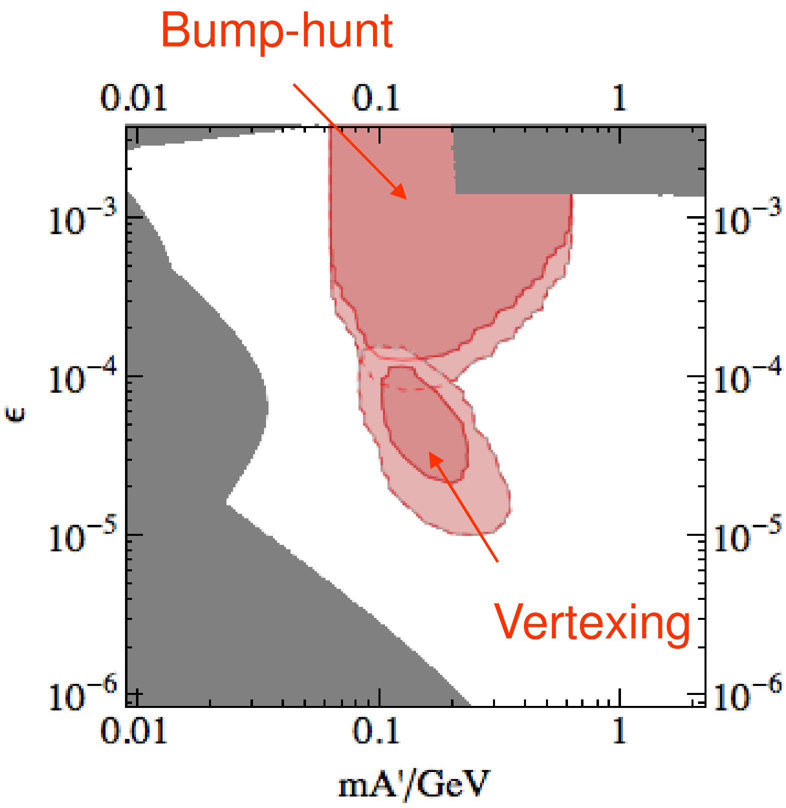
Bethe-Heitler background



Z (cm)

- $Z_{signal} > 5\times\sigma$
- Good vertex resolution is crucial.
  - Need to understand the non-Gaussian tail

Experimental Reach



- Bump-Hunt
  - Require S/sqrt(B) > 5 in 100 nA x 10^7 sec
- Vertexing
  - Require 10 events with z > 5•σ in 100 nA x 10^7 sec

Conclusions

- Compact detector with a good forward coverage could be built using mostly available resources.
- Good mass resolution $\Delta m/m \sim 1\%$ and vertex resolution $\Delta z \sim 0.7$ mm can extend the search region.
- An experiment at JLab Hall B in the “Photon Dump” line could probe an interesting range of heavy photon masses and couplings