Gordon Research Conference
Photonuclear Reactions

Heavy Photon Search experiment at JLAB

Rafayel Paremuzyan, on behalf of HPS collaboration

University of New Hampshire

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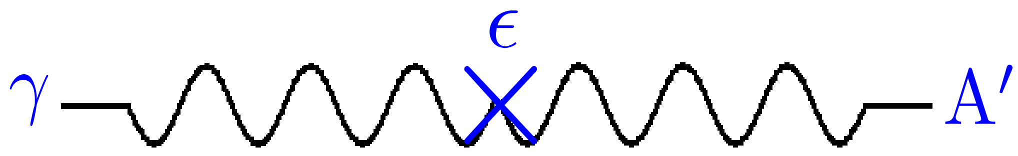
Introduction

What, if Nature contains an additional broken U(1) (Abelian) force mediated by a massive vector boson, A'? Bob Holdom, Phys.Lett.,B166, 2, (1986)

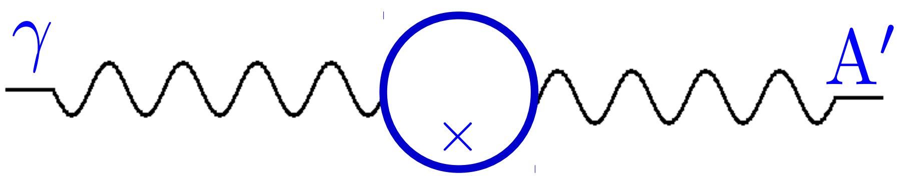
$$\mathcal{L} = \mathcal{L}_{SM} + \frac{\epsilon}{2} F^{Y,\mu\nu} F'_{\mu\nu} + \frac{1}{4} F'^{\mu\nu} F'_{\mu\nu} + m_{A'^2} A'^{\mu} A'_{\mu}$$

Kinetic Mixing



ϵ is the mixing strength

generated by heavy particles $\times$ interacting with γ and A'

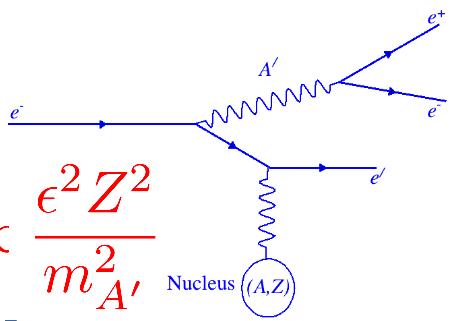


Many Dark Matter searches are based on this hypothesis

Producing A' in fixed target experiments

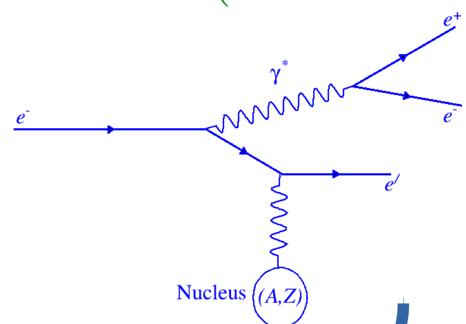
Since A' "can" couple to electric charge, then it is possible to expect it to be produced in a Bremsstrahlung process

A' production

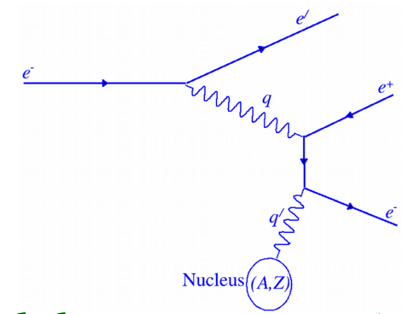


$$\sigma \propto \frac{\epsilon^2 Z^2}{m_{A'}^2}$$

Prodution of Timelike photon (radiative Tridents)

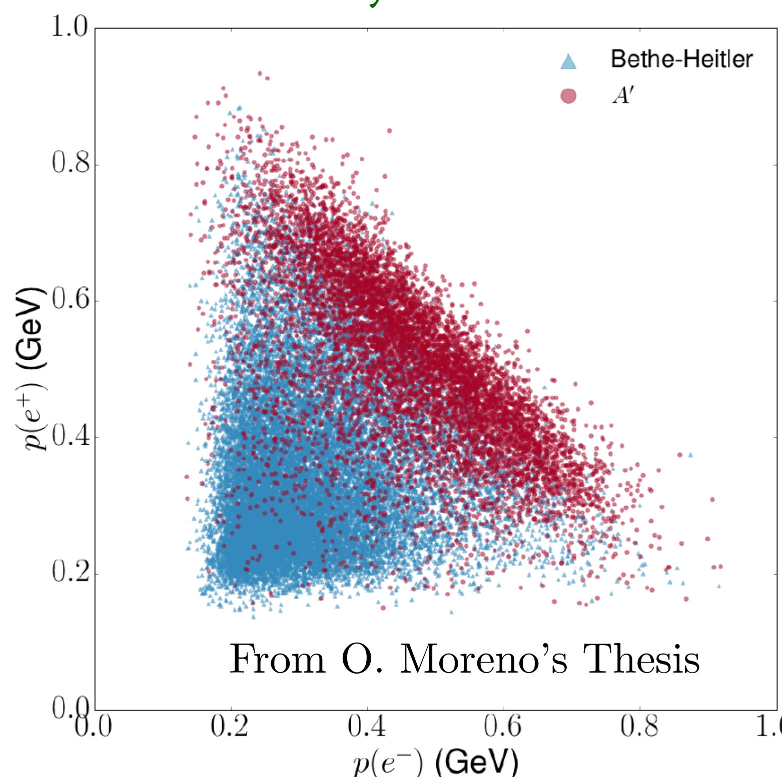


Bethe Heitler



Much larger cross section,
But very different kinematic

Similar kinematics for fixed $M(e^- e^+)$



Angle: Forward

$$\theta_{A'\,\max} \sim \max\left(\frac{\sqrt{m_{A'} m_e}}{E_0}, \frac{m_{A'}^{3/2}}{E_0^{3/2}}\right)$$

Energy: takes almost all the beam energy

$$\frac{E_{A'}}{E_{beam}} \sim 1 - max\left(\frac{m_e}{m_{A'}}, \frac{m_{A'}}{E_0}\right)$$

$$\frac{\sigma(eA \to e' A'(\to e^- e^+))}{\sigma(eA \to e' \gamma^*(\to e^- e^+))} = \left(\frac{3\pi\epsilon^2}{2N_f \alpha}\right) \frac{m_{A'}}{\delta m}$$

The CEBAF, Hall B and HPS

CEBAF Energy: 2.2 GeV/pass   5 pass

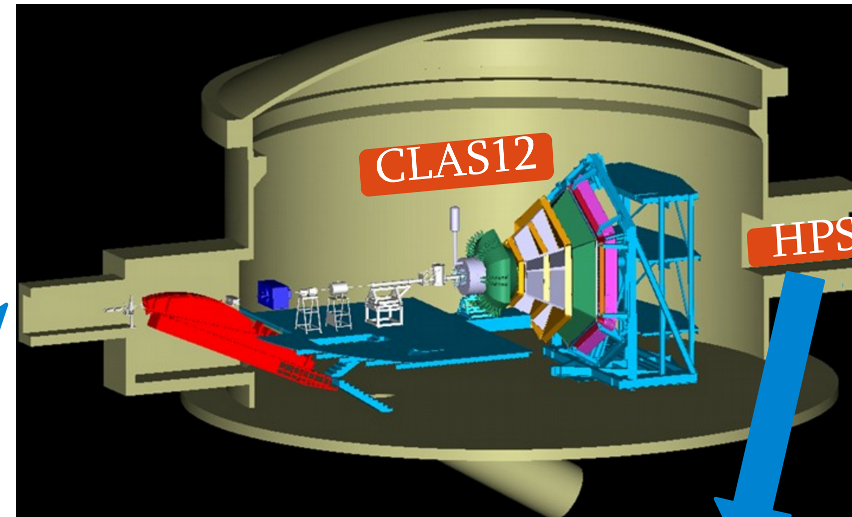
Simultaneous delivery to 4 Halls

Hall D

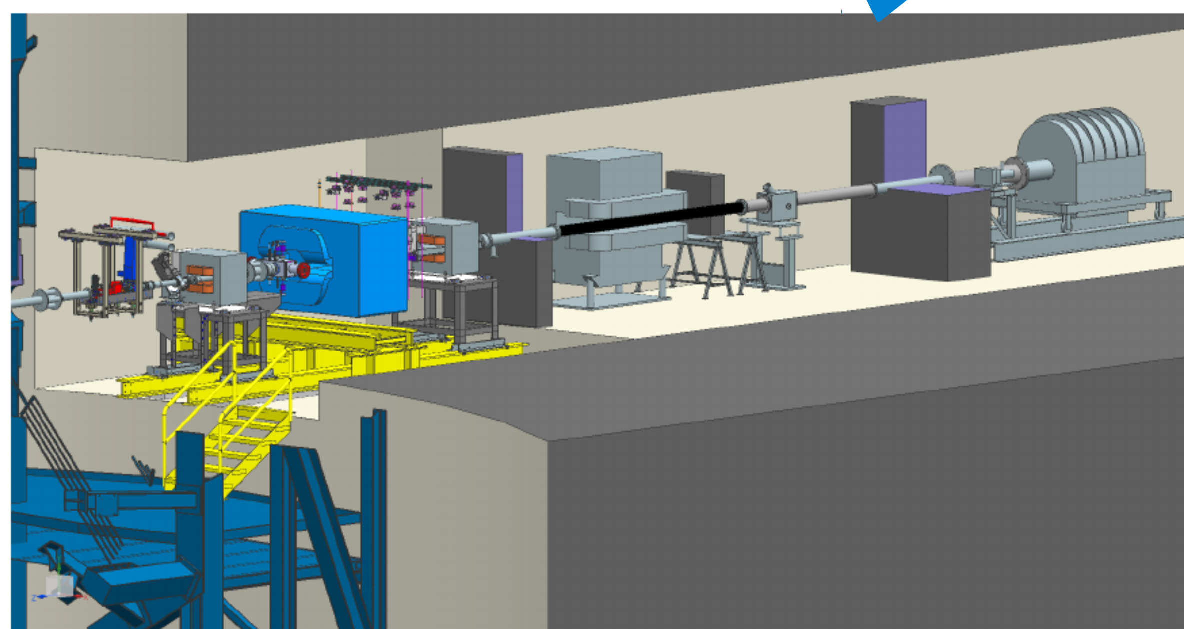
Hall A

Hall C

Hall B



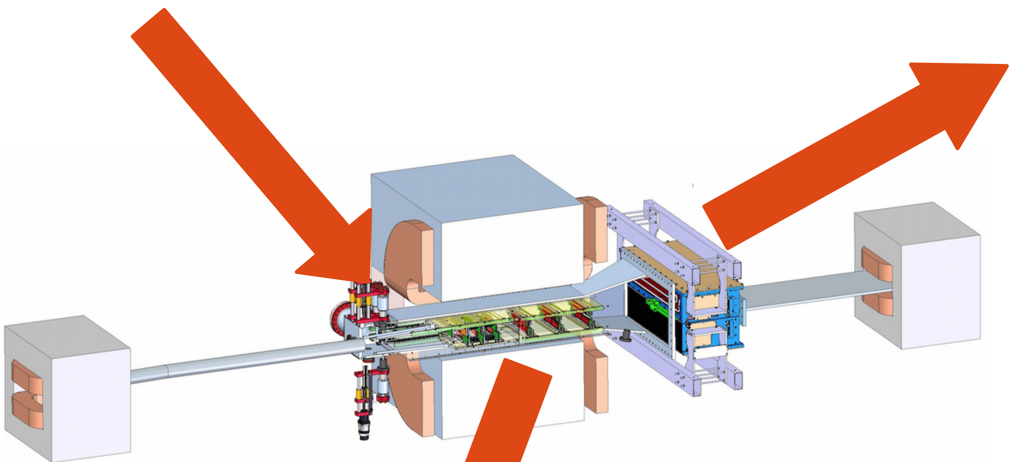
Alcove

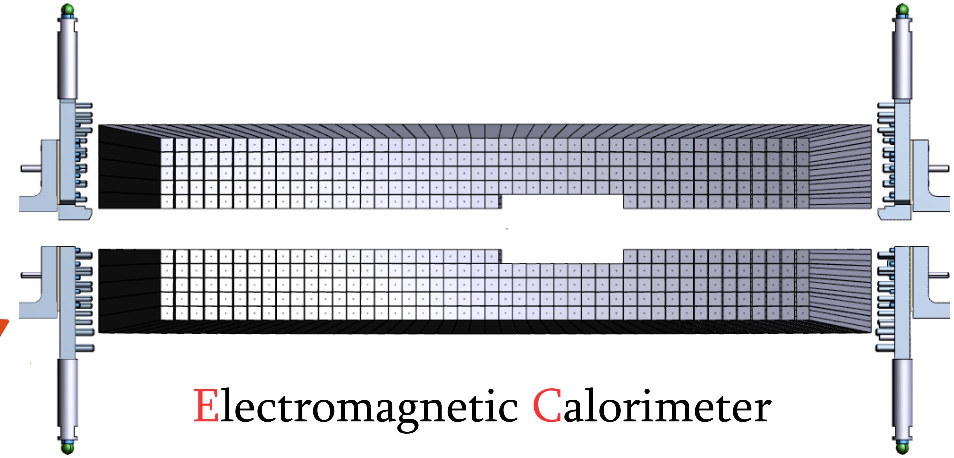


HPS experimental setup

Chicane system with 3 dipole magnets

4 μm tungsten target





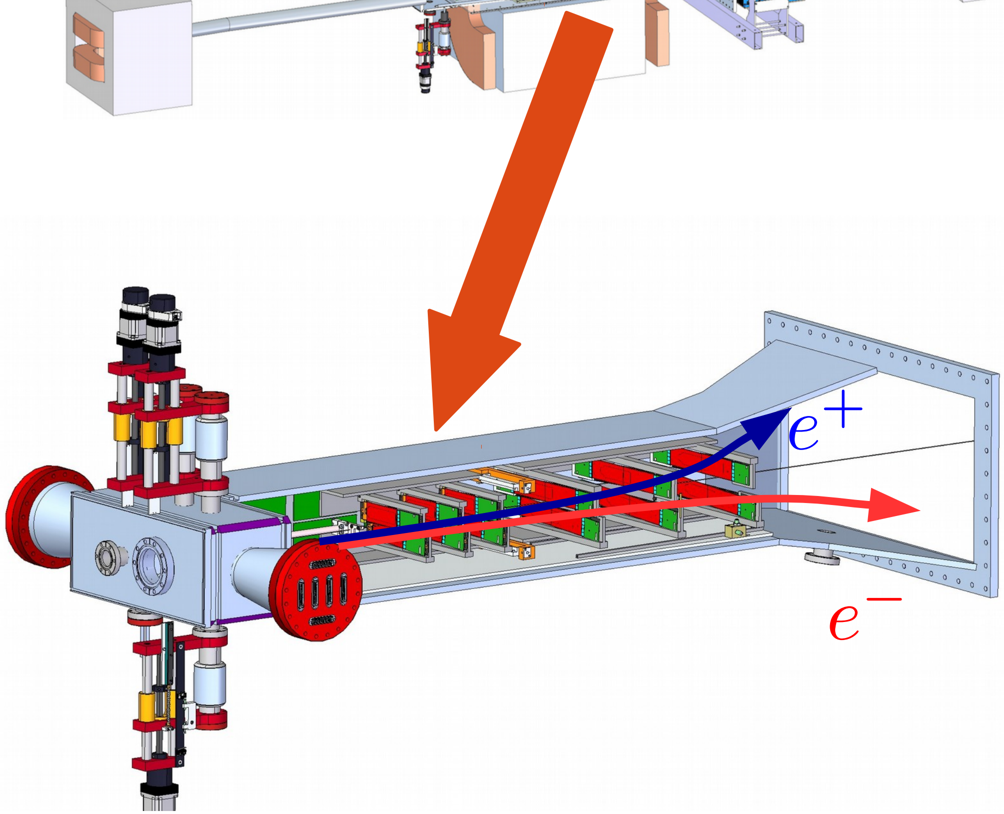
Electromagnetic Calorimeter

442 $PbW0_4$ Crystals

Initiates the trigger (Main, and 3 diagnostic)

Measures particle's energy

Resolution $\frac{4\%}{\sqrt{E}}$ at 1 GeV



Silicon Vertex Tracker

6 layers of silicon

1^{st} layer of silicon is at 0.5 mm from the beam

Measures charged particle's momentum

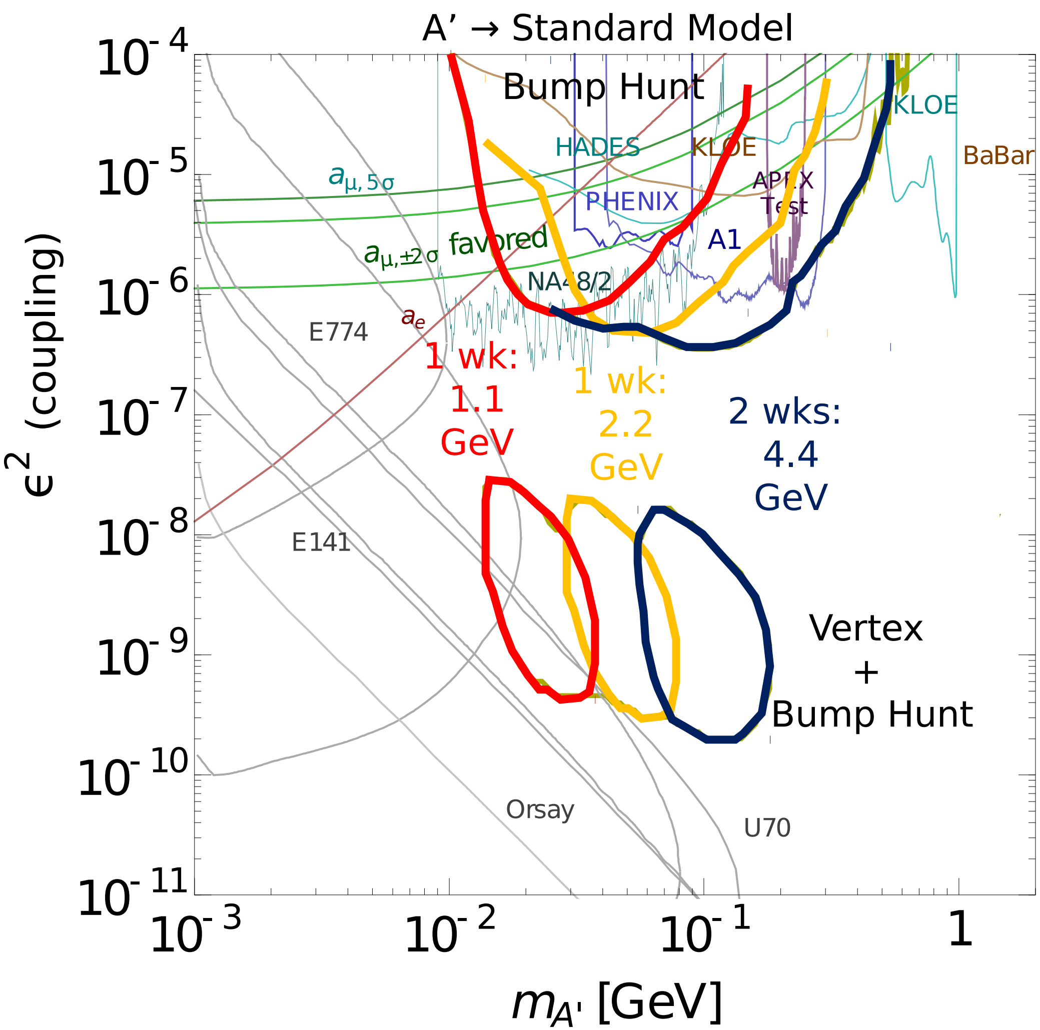
Vertical hit resolution $\approx 6\ \mu m$

Horizontal hit resolution $\approx 60\ \mu m$ (1st 3) and $\approx 120\ \mu m$ (3 other layers)

HPS reach

180 approved days

Opportunistic runs:
Run only after work hours (2015)
And only on weekends (2016)



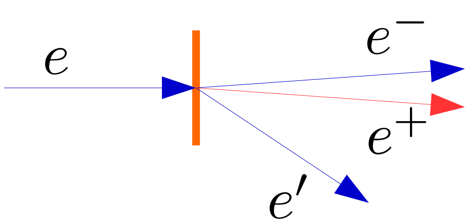
2015 Spring:

Beam current: 50 nA
Beam energy: 1.05 GeV
30% of proposed amount of production data

2016 Spring:

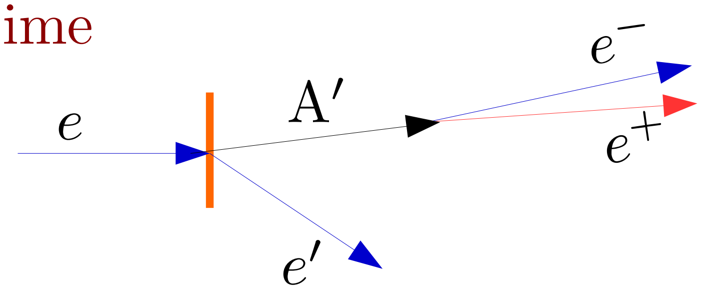
Beam current: 200 nA
Beam energy: 2.3 GeV
77% of proposed amount of production data

Prompt decay, but large coupling



Find a peak over a large background

Small coupling, but longer decay time



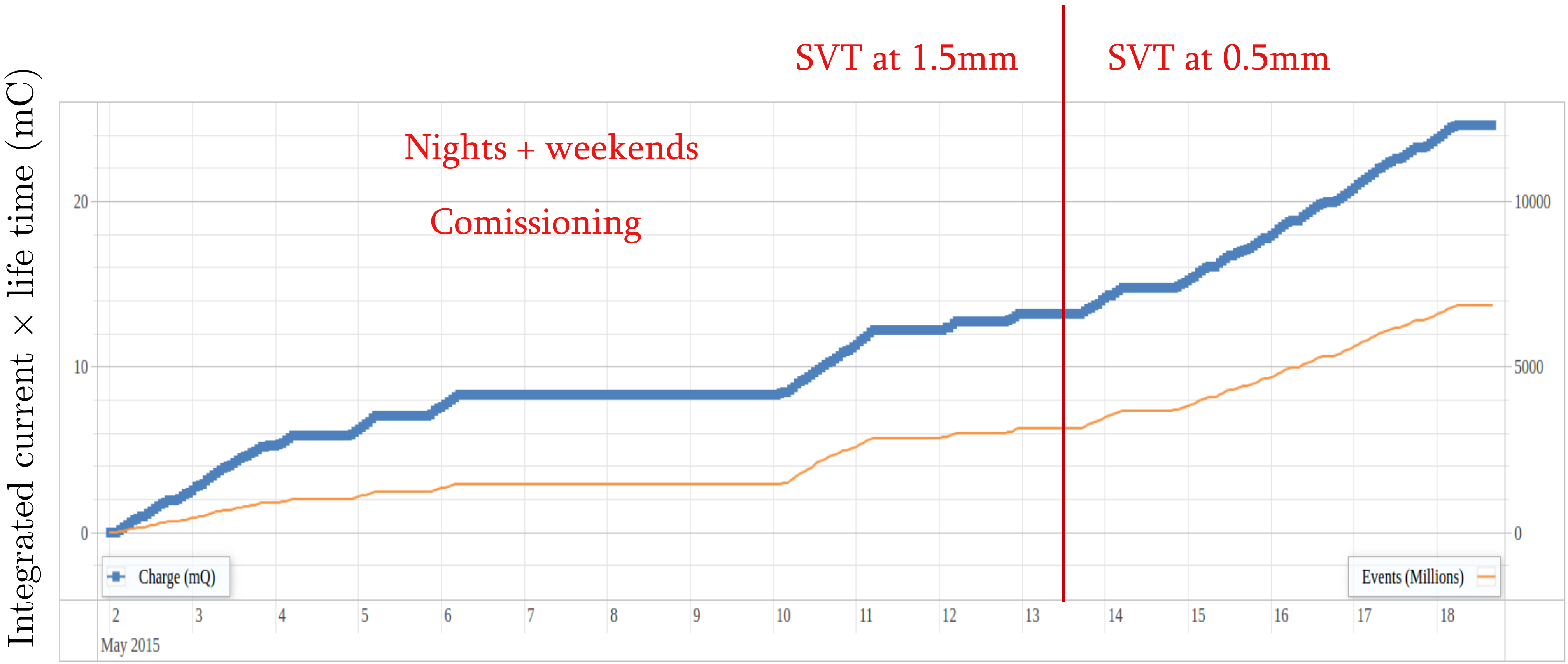
No background, few events are enough

2015 run

1.05 GeV

Goal: 30 mC

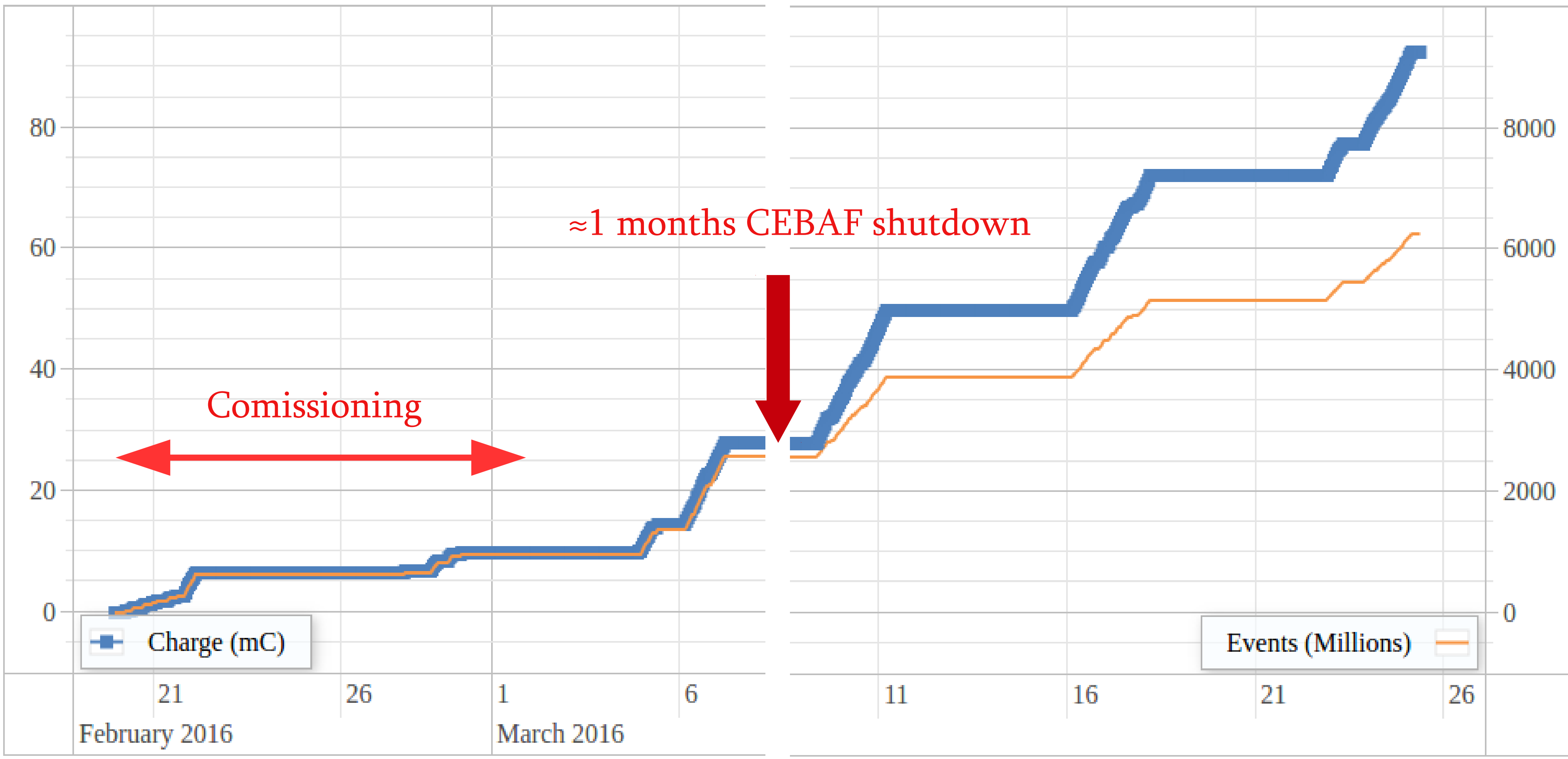
Achieved: 10 mC with SVT at 1.5 mm, 10 mC with SVT at 0.5 mm



2016 run

Goal: 120 mC 2.3 GeV Only weekends

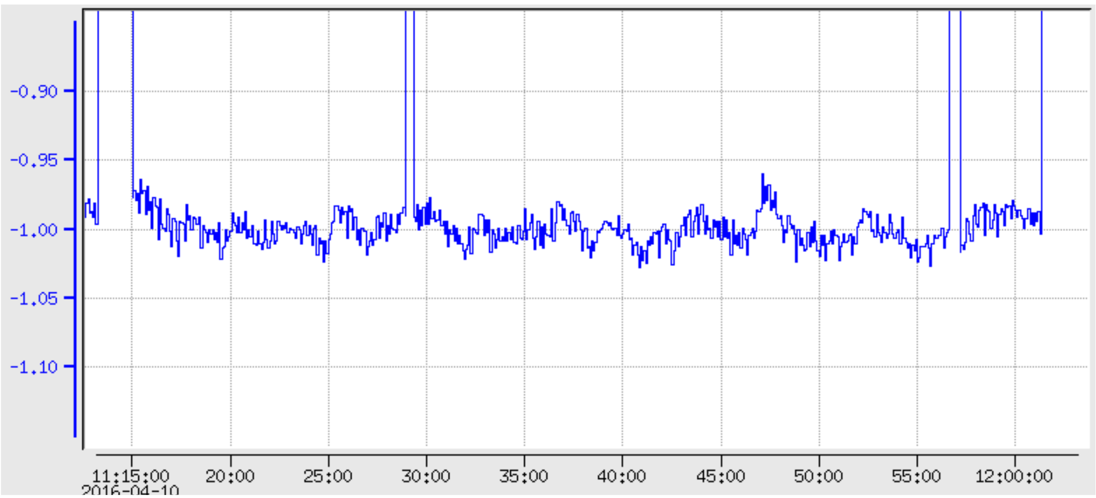
Achieved: 92.5 mC 6.3×10^9 triggers (77% of proposed running)



Beam properties

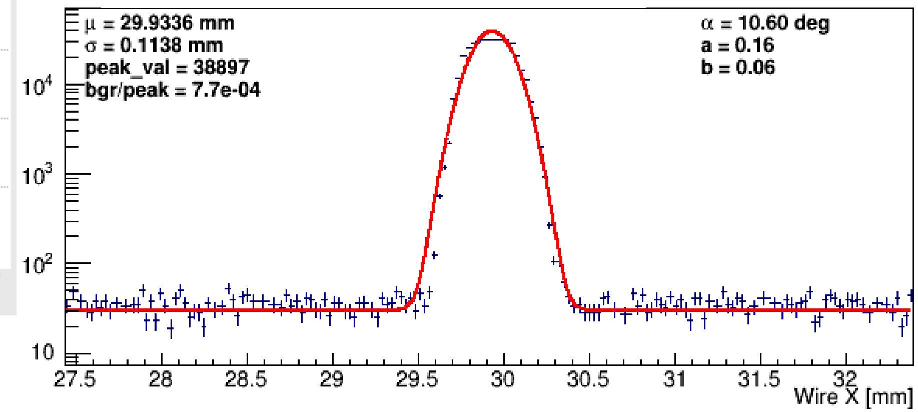
Before moving SVT to 0.5 mm beam properties were extensively studied

Good Beam position stability

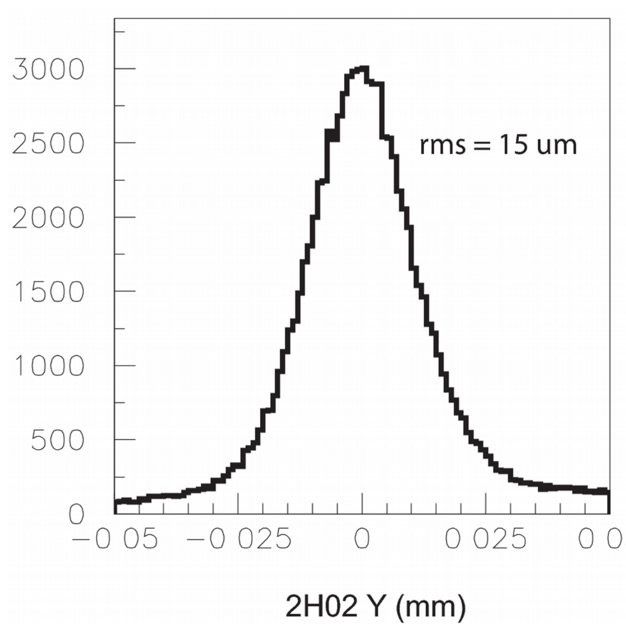


Narrow vertical beam size at the target: $\approx 50\ \mu m$

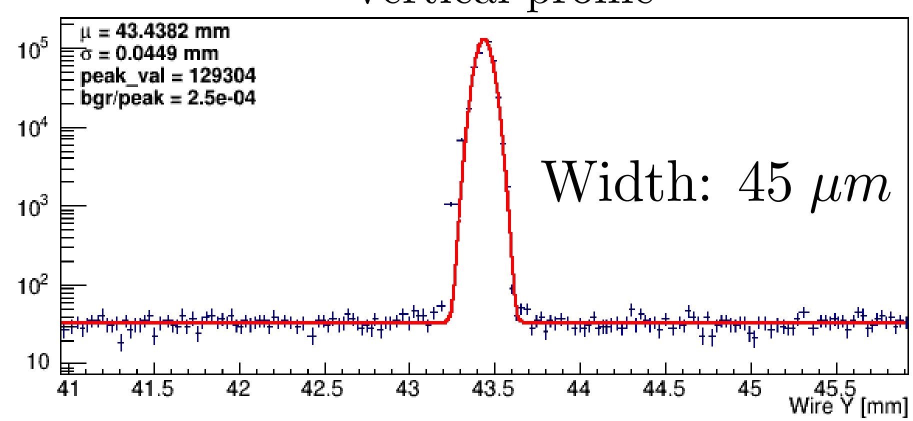
Horizontal profile



Vertical beam position distribution



Vertical profile



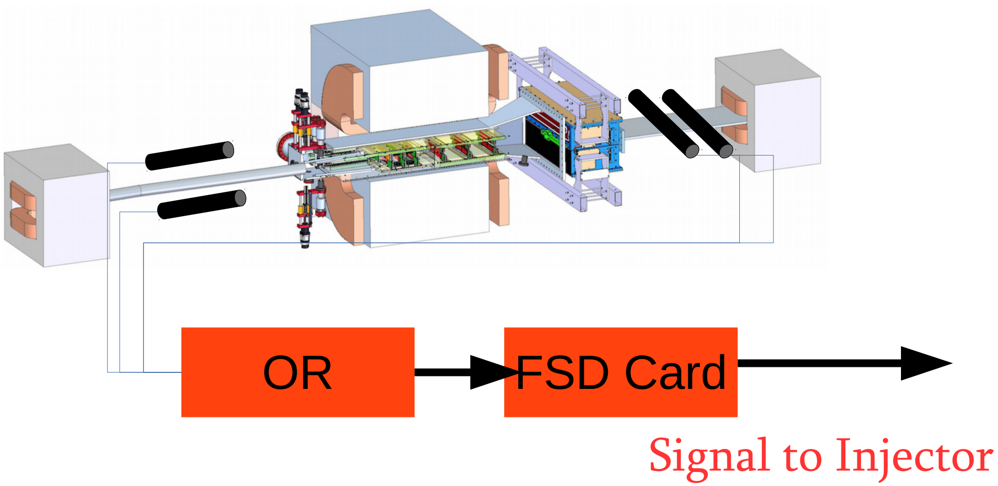
Width: $45\ \mu m$

Beam motion studies

Small vertical beam motions ($\sim 0.5\ mm$) can damage silicon

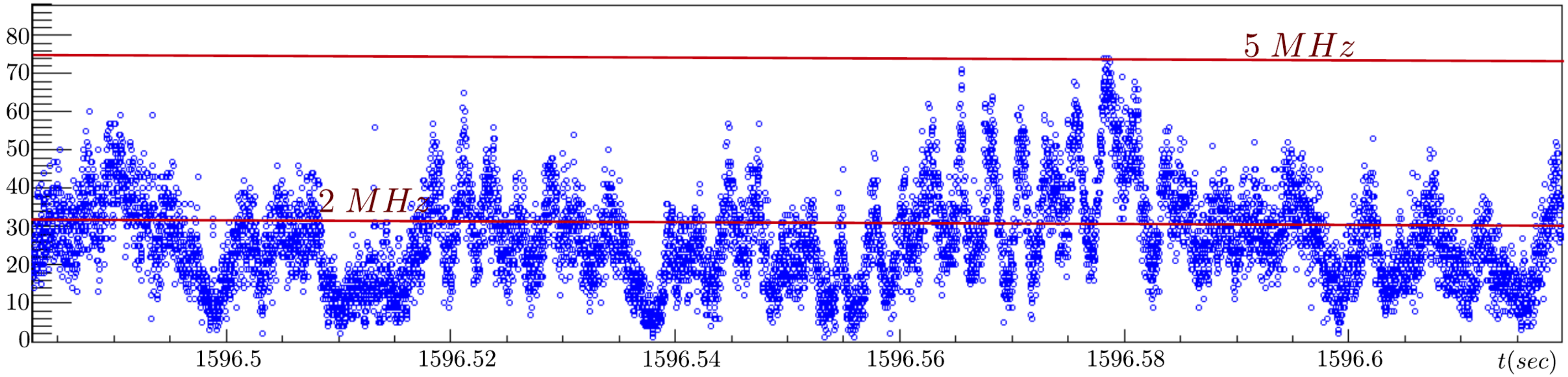
Signals from four halo counters summed up and as an input sent to Fast ShutDown card

Integration time: $1\ ms$



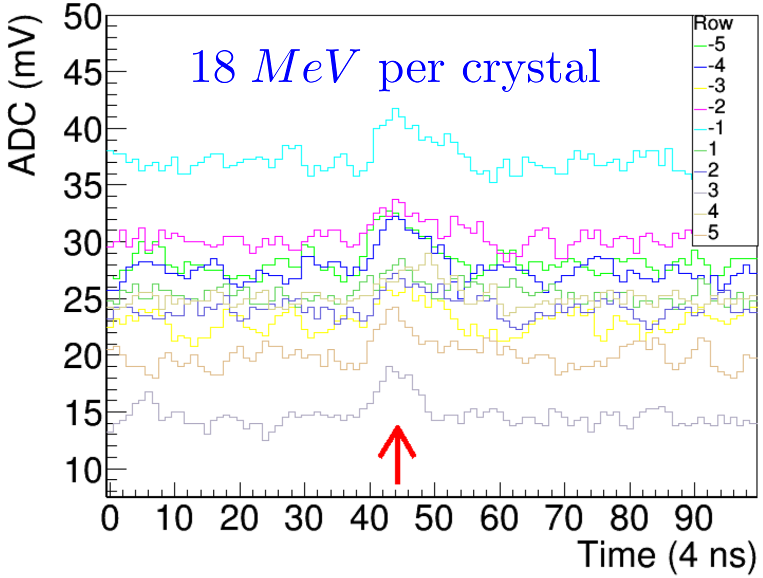
Placing harp wire close to the beam, with fast Struck scaler, we have measured fast beam motions

We have estimated the fast motion amplitude: less than $20\ \mu m$

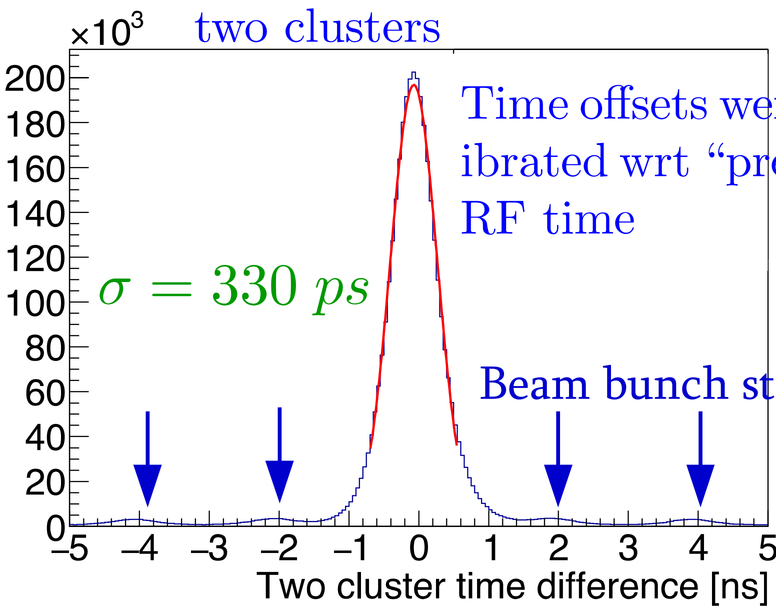


2016 Ecal performance

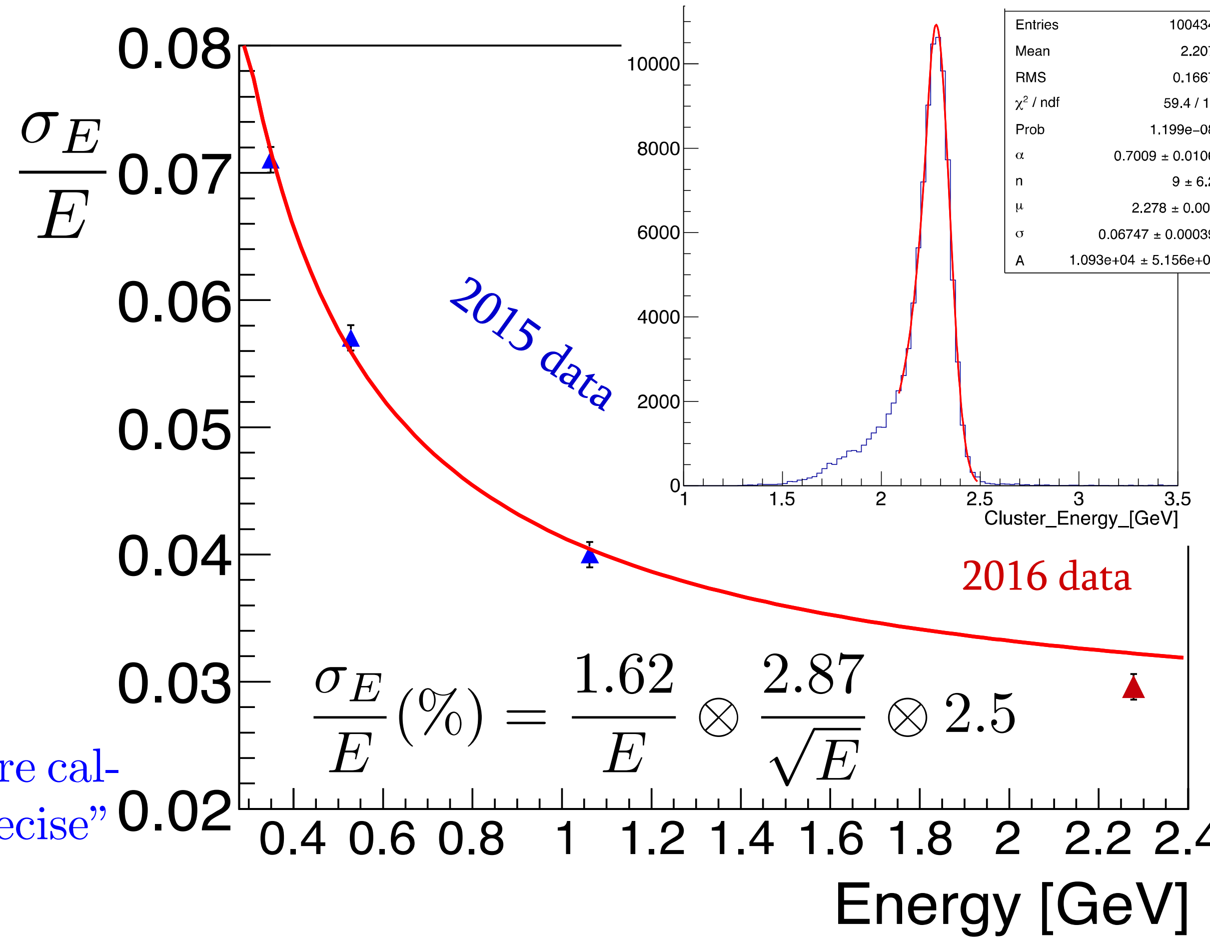
Cosmic gains for initial callibration



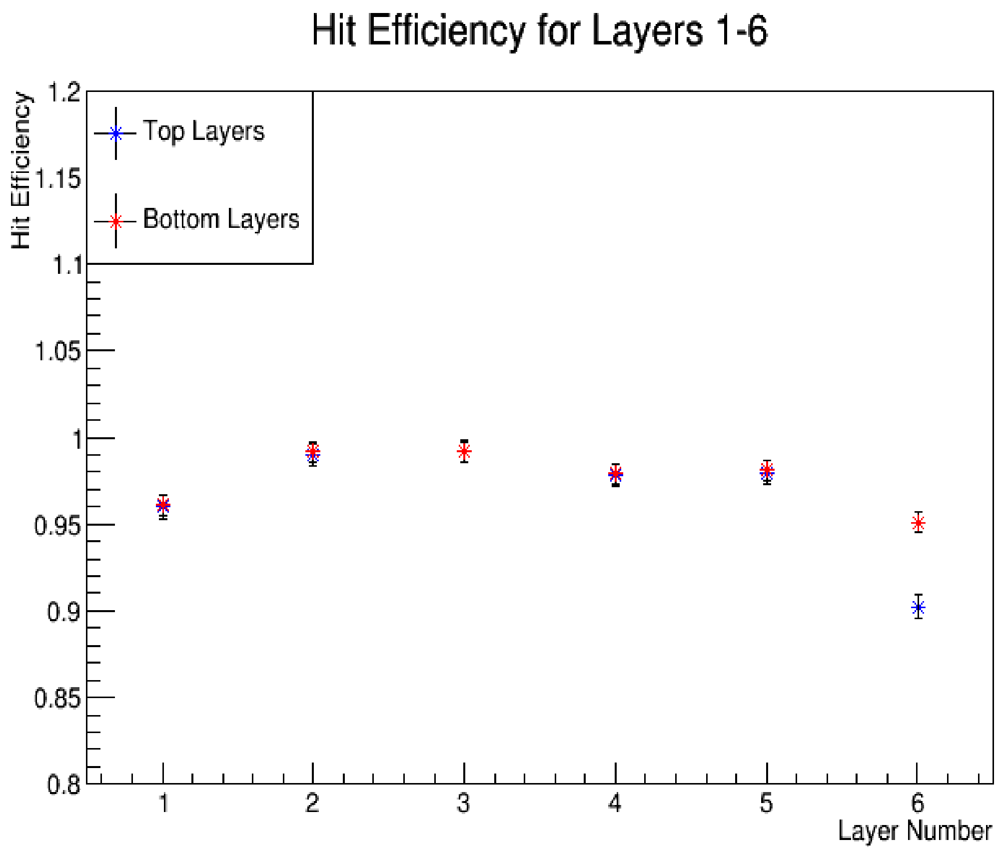
Time difference between two clusters

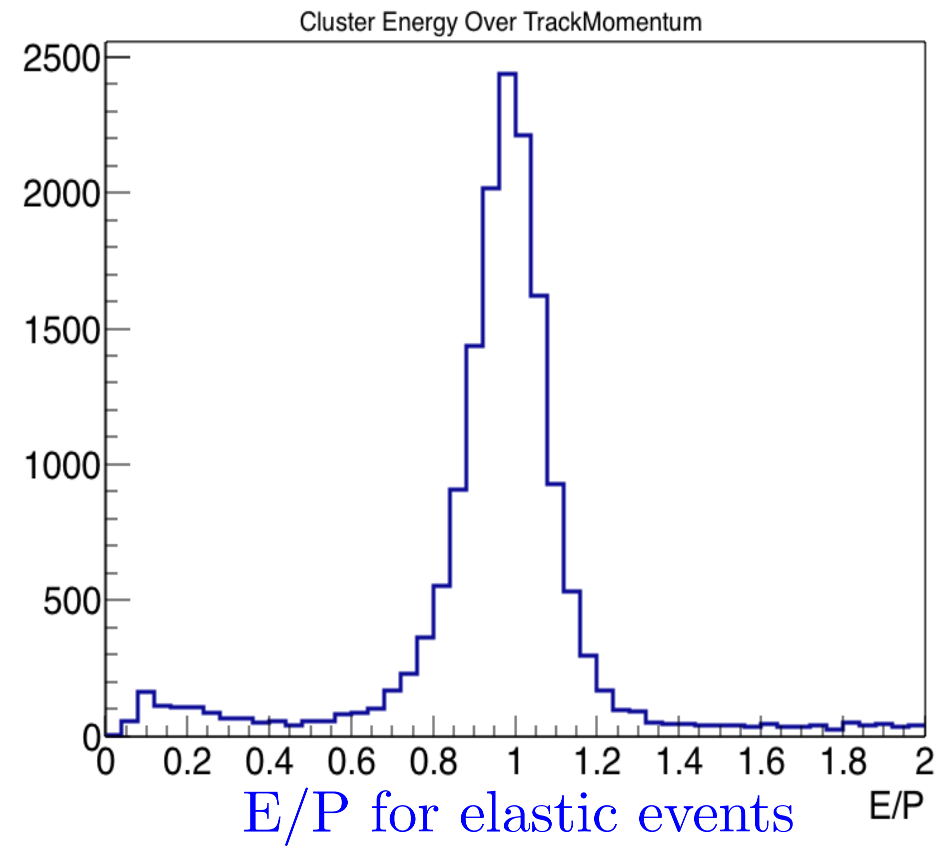


FEE peak in fiducial region



2016 SVT performance

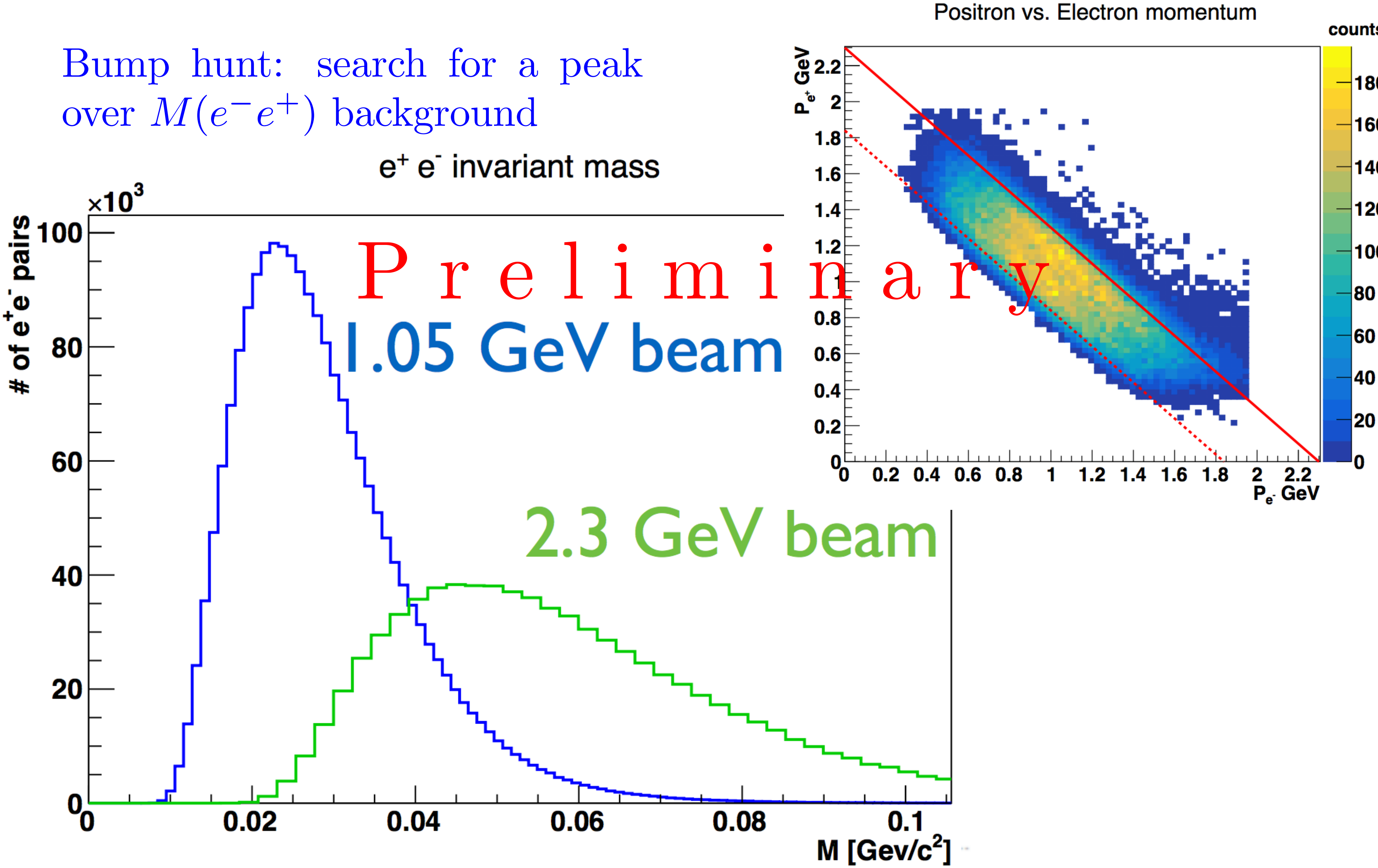




Momentum resolution is $\sim 7\%$ at $1\ GeV$

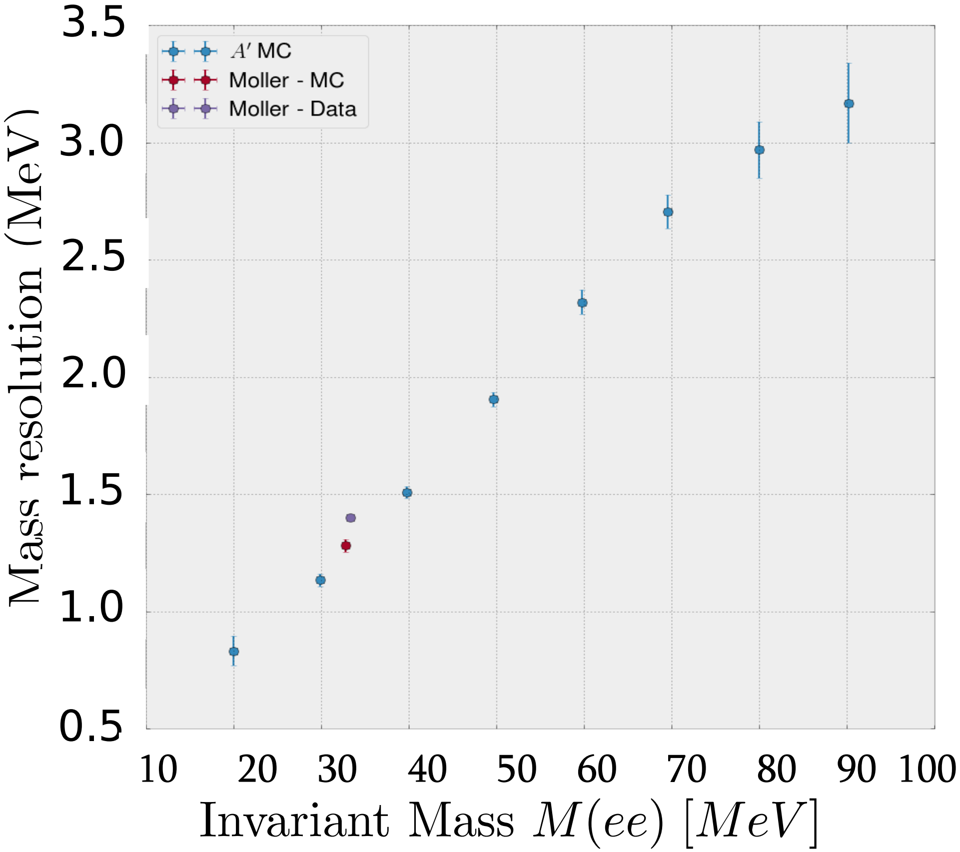
Final selection sample

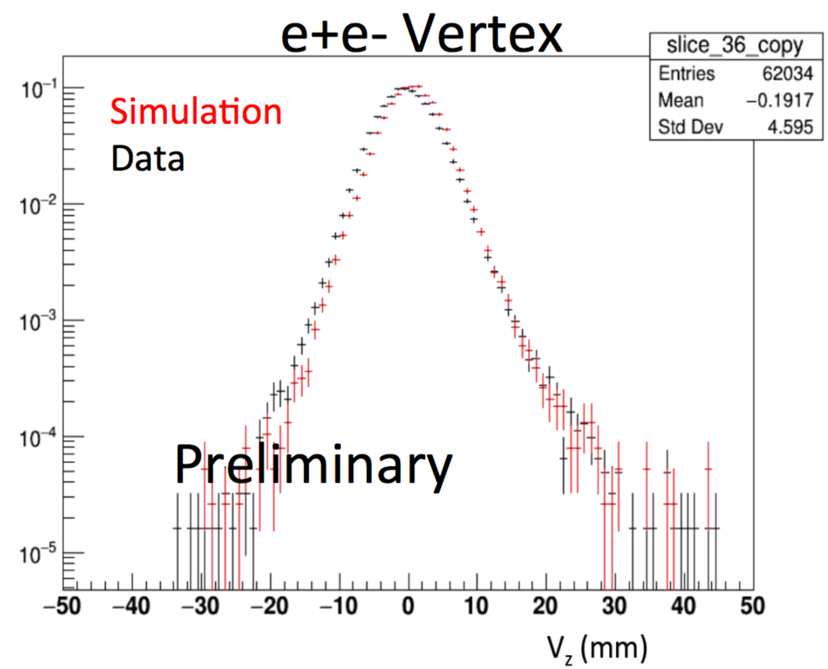
Bump hunt: search for a peak over $M(e^-e^+)$ background



2015 Analysis

We need this for bump hunt





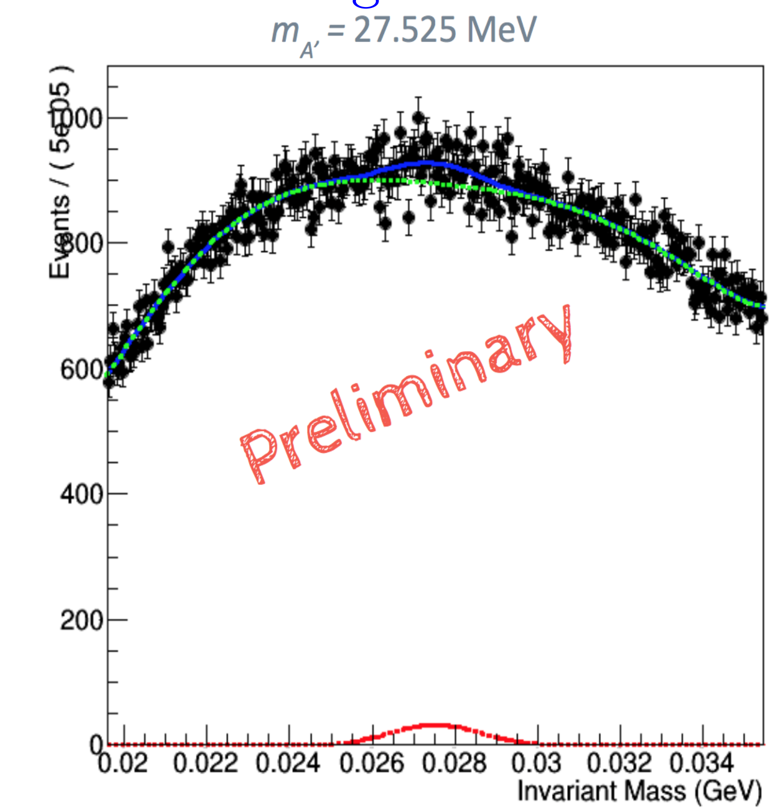
Parameter	Proposal value	Measured value
Beam current	50 nA	50 nA
SVT occupancy	<1%	1%
DAQ/trigg. rate	18 kHz	19 kHz
Pair mass res. @ 34 MeV/c²	1.5 MeV	1.5 MeV
Pair vertex res. @ 40 MeV/c²	4.4 mm	4.6 mm

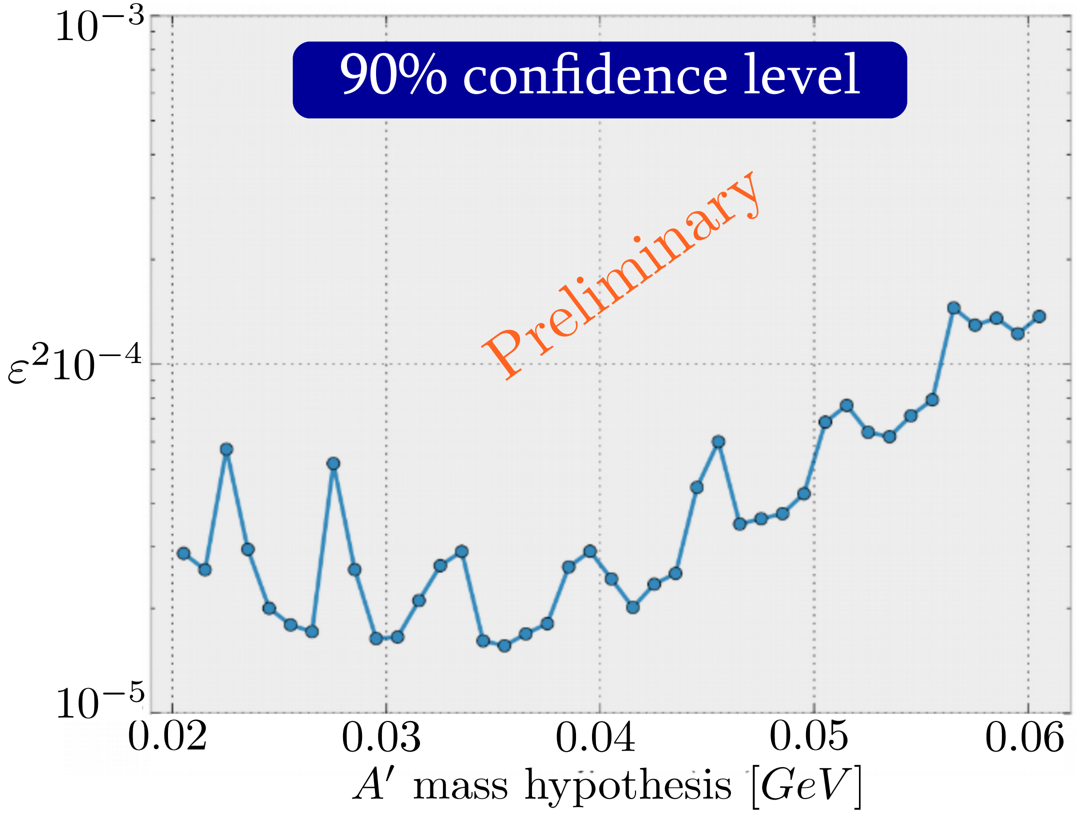
Blind analysis

Blind analysis: 10% of the data, 74 nb^{-1}

Bump hunt in the mass range 20-60 MeV

Most significant Poll





Background: 7-th order polynomial
Signal width is fixed according to mass resolution

Summary

- HPS experiment allows heavy photon search through bump hunt and displaced vertex search
- HPS has completed successfully data taking in 2015 and 2016
- 165 days still remain: We expect next physics runs in 2018 and later
- Data analysis demonstrated good ECal and SVT performance during these runs, and instrumentation papers are in preparations for beamline, SVT and Ecal.
- Analysis codes are now close to be finalized, and we expect 1st publications before the end of 2016