mercredi 21 octobre 2015

Heavy Photon Search

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PROJET FINANCÉ PAR L'ANR - PROJECT FUNDED BY THE ANR

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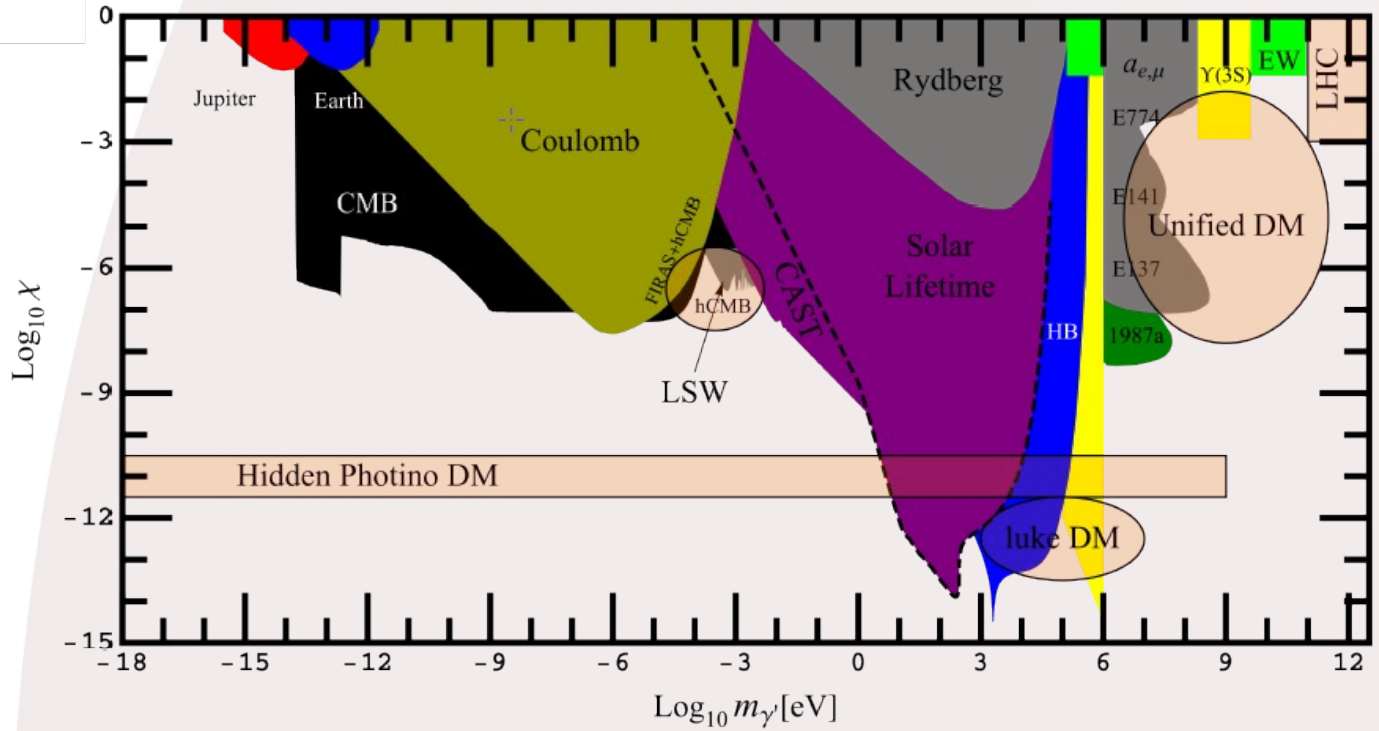
The Heavy Photon Motivations



➔ **The heavy photon (A') is a conjectured new particle that can mix with SM photon**

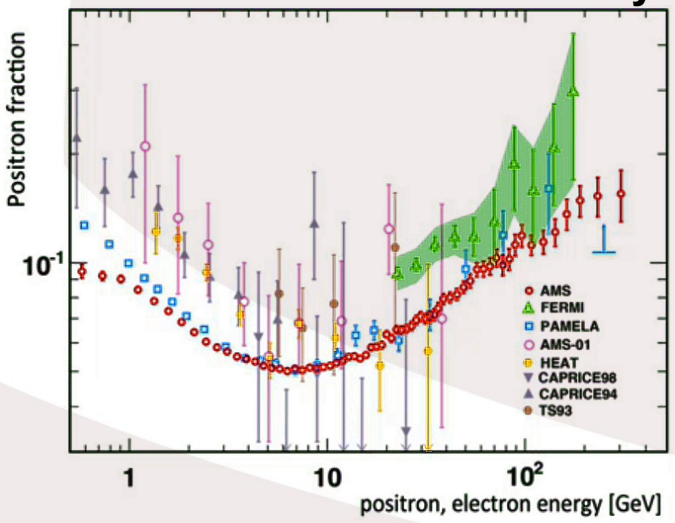
- **A U(1) boson with small coupling to electrons (reduced by ε)**
- **Hidden sectors can be accessed through gravity and "*portals*"**

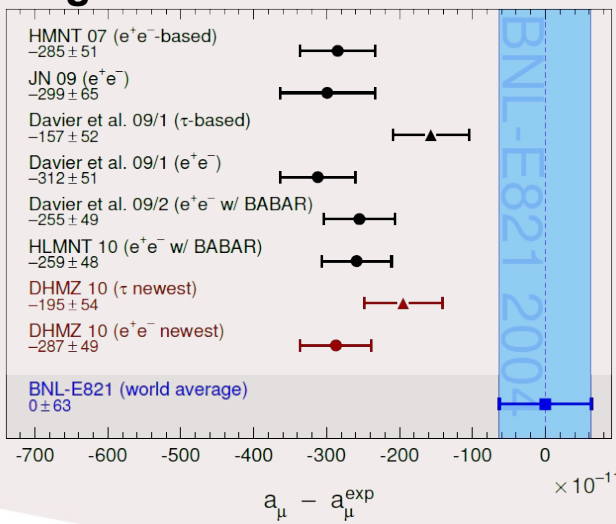
The *photon portal* , through which the SM photon mixes with the hidden sector photon, can allow our world to interact with the hidden sector

➔ **String theories and other BSM theories generate hidden sectors with additional U(1)'s**

The Heavy Photon Motivations

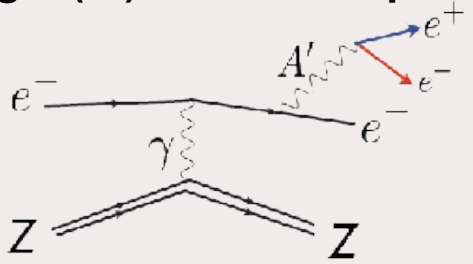
- **Impact on direct dark matter searches**
  - It is possible to explain various unexpected and apparently contradicting results using a new force in the dark sector
  - In particular discrepancies between direct dark matter searches (CDMS & XENON100 vs DAMA/LIBRA & CoGeNT)
- **Observation of the flux of positrons can be explained by a coupling of A' to DM**
  - Mass > MeV
- **Could help solve the muonic g-2 discrepancy (3σ)**
  - By adding new diagrams the presence of a new force would modify the theoretical g-2





Production of the Heavy Photon

- **Production by bremsstrahlung like process**
  - **High Z target (W) to enhance production mechanism)**



- **Important QED backgrounds**

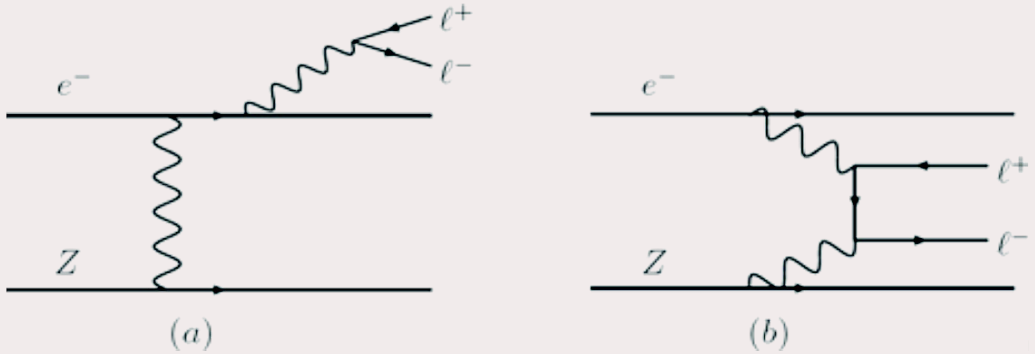
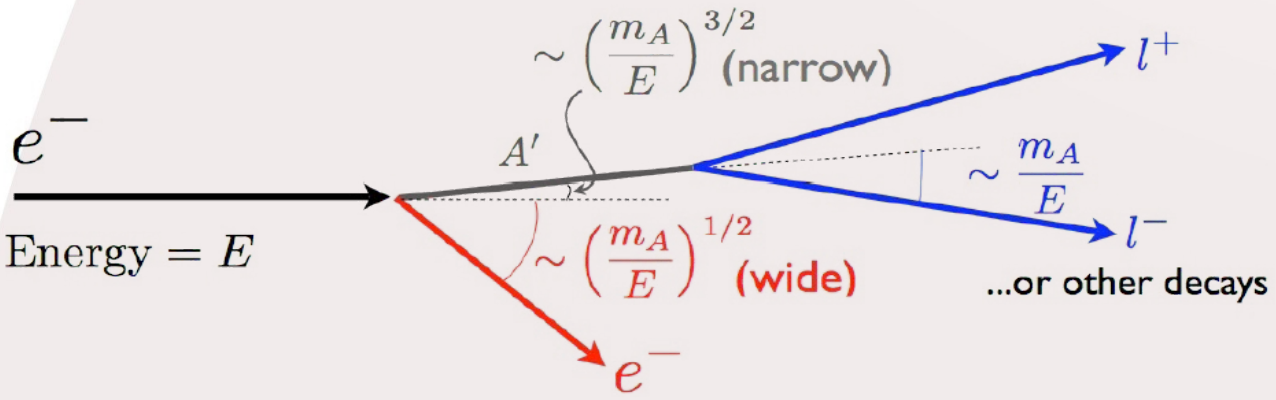


FIG. 4: Sample diagrams of (left) radiative trident (γ^*) and (right) Bethe-Heitler trident reactions that comprise the primary background to the $A' \to l^+l^-$ search.

- **Use very thin target (0.00125 RL) to reduce hadronic backgrounds and multiple scattering**
  - **High beam intensity with thin target limited by heat problems**

Detection of the Heavy Photon

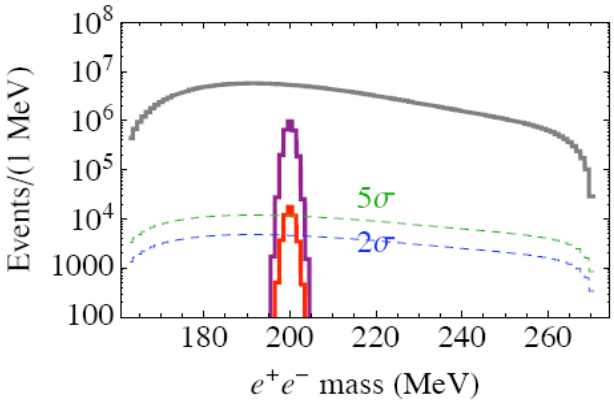


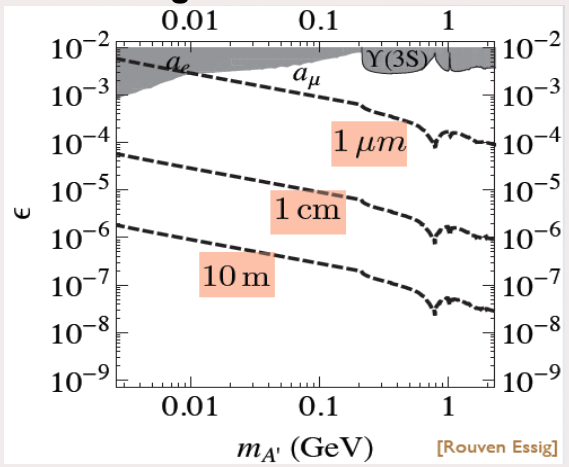
➔ **Search based on a bump hunt**

- ➔ Looking for a peak in the large QED background
- ➔ Limited at very low coupling

➔ **Supplemented by displaced vertex**

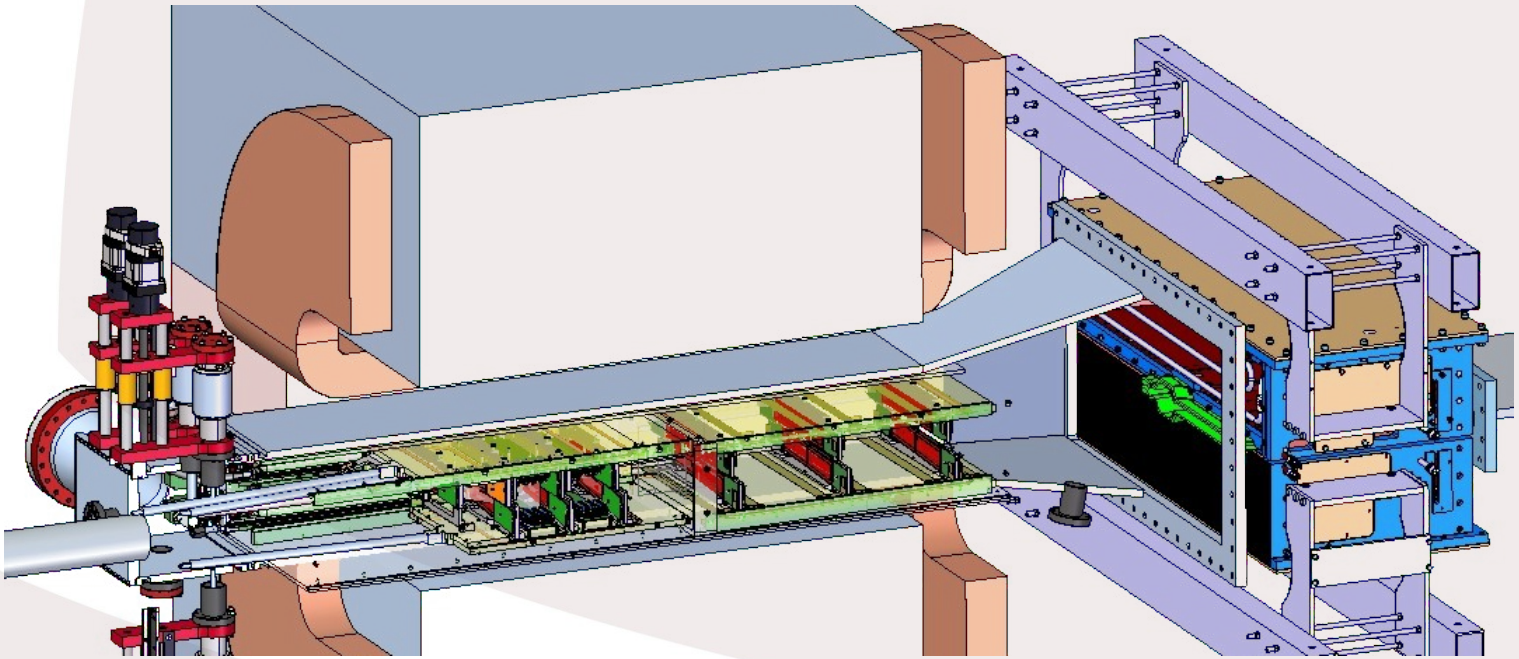
- ➔ Reduce drastically the QED background
- ➔ Limited at high coupling because we need a long life time





HPS Experimental Setup

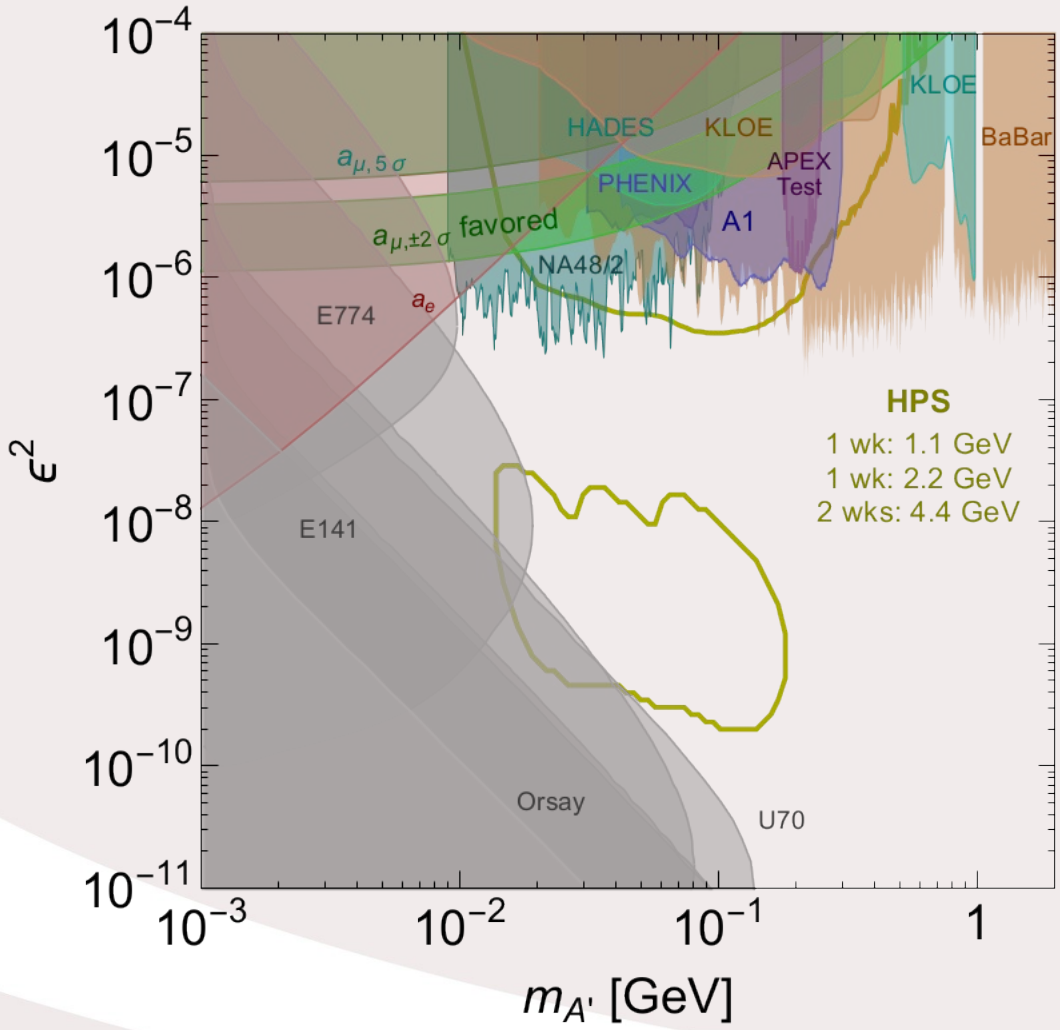
- **Forward, compact spectrometer and vertex detector**
  - **Silicon detector in ~1T dipole magnet**
  - **First silicon detectors are placed only half a millimeter from the center of the beam!**
- **EM Calorimeter provides the trigger signal**
  - **Allows to identify electrons and positrons**
  - **PbWO4 Crystals refurbished from CLAS IC calorimeter**



HPS performance

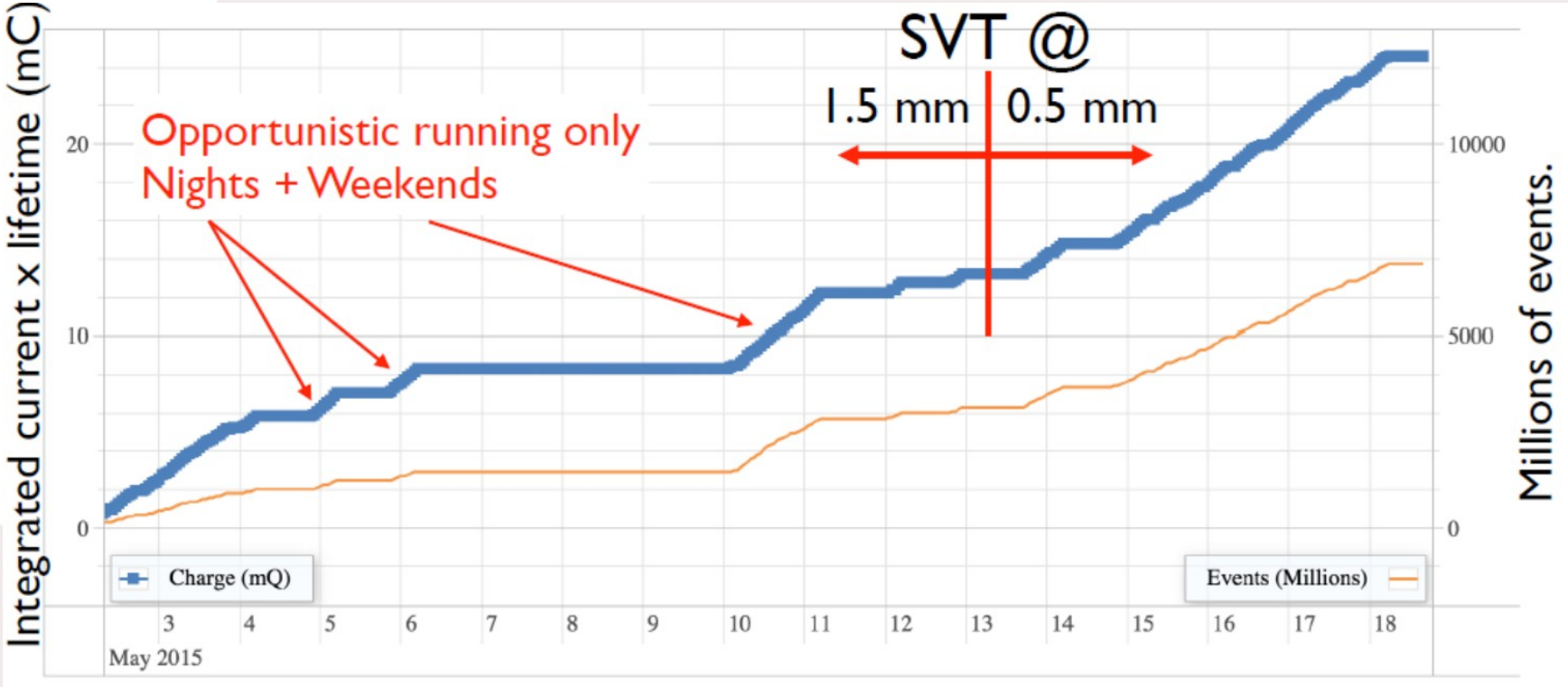
➔ **Reach of the experiment for the simple bump hunt and the displaced vertex methods**

➔ **Combined data at 1.1, 2.2 and 6.6 GeV**



2014-2015 Commissioning runs

- **We met our goals!**
  - Demonstrated that HPS works as designed
  - Recorded some good quality data
    maybe enough for first published results
- **Lots of critical contributions**
  - CEBAF accelerator physicists and operators
  - Hall B leadership and support staff
  - All HPS sub-systems up and ready
  - HPS shift-takers, subsystem experts, and Run Coordinators
- **Now working on**
  - Detector calibration and alignment
  - Data processing
- **Now we're ready for HPS Physics Runs**



Beam Characteristics

➔ **HPS will use up to 500 nA electron beam of 1.1, 2.2 and 6.6 GeV and a thin W target**

➔ **The size of the beam is very important because of**

- ➔ **The proximity of the silicon tracker (0.5 mm from the beam)**
- ➔ **The heat load that can be taken by the target**
- ➔ **The precise vertex reconstruction we want to measure**

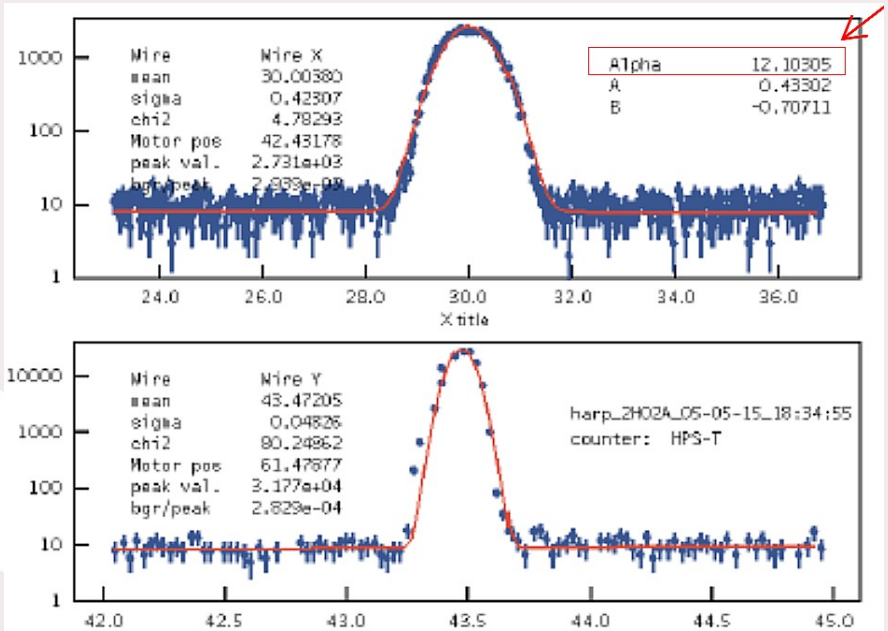
➔ **Asymmetric profile is needed in order to satisfy all these criteria**

Parameter	Requirement			Unit
E	1100	2200	6600	MeV
$\delta E/E$	$< 10^{-4}$			
Current	< 200	< 400	< 500	nA
Current Instability	< 5			%
σ_x	< 300			μm
σ_y	< 50			μm
Position Stability	< 30			μm
Divergence	< 100			μrad
Beam Halo ($> 5\sigma_Y$)	$< 10^{-5}$			

TABLE I: Required beam parameters.

420 µm in x

50 µm in y



Silicon Vertex Tracker

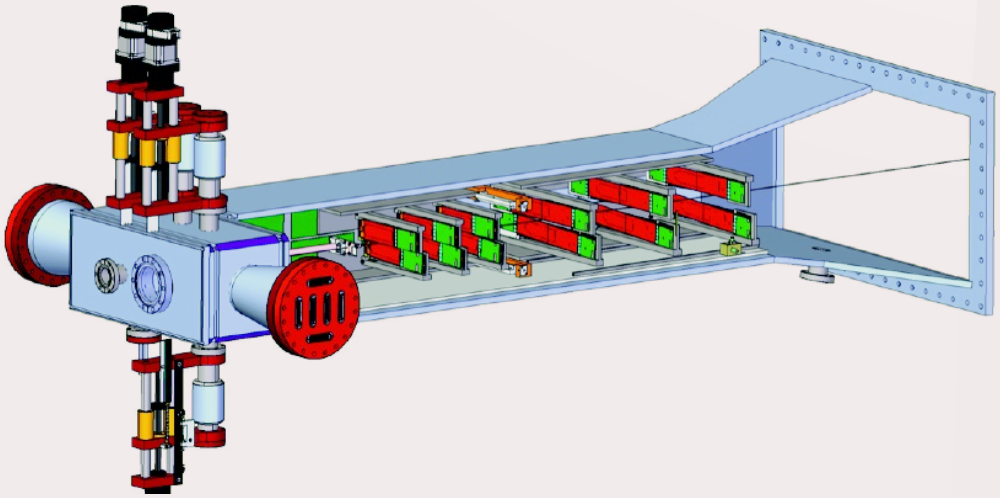
➔ **Will be installed in the vacuum inside the analyzing magnet**

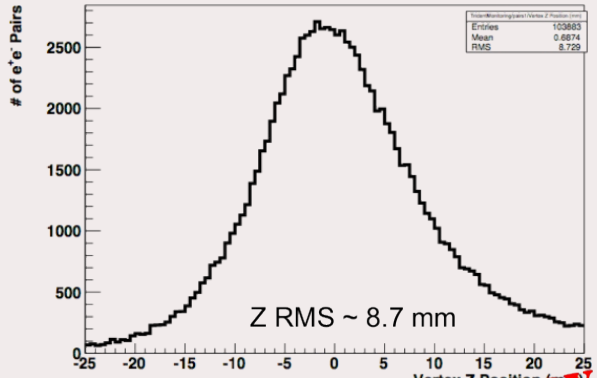
- ➔ **First layer is located at 10 cm from the target for maximum precision on vertex position**
- ➔ **the first layer of silicon sensor is only 0.5 mm from the center of the beam to detect small A' masses**

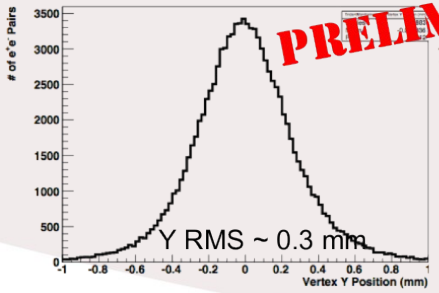
➔ **Silicon is actively cooled to retard radiation damage**

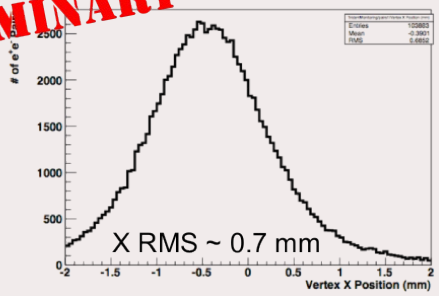
➔ **The sensors have 60 μm readout pitch**

➔ **The sensors are read out continuously at 40 MHz**



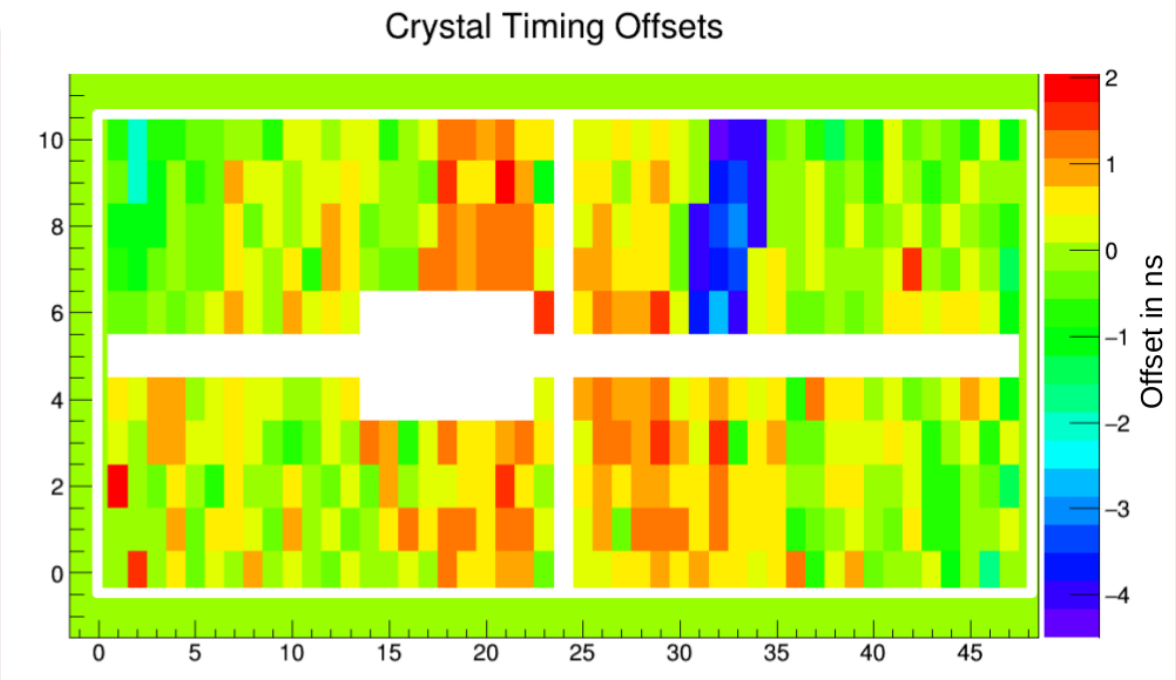




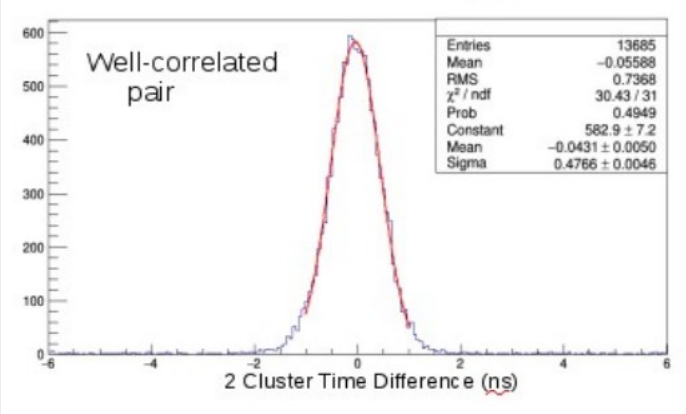


PRELIMINARY

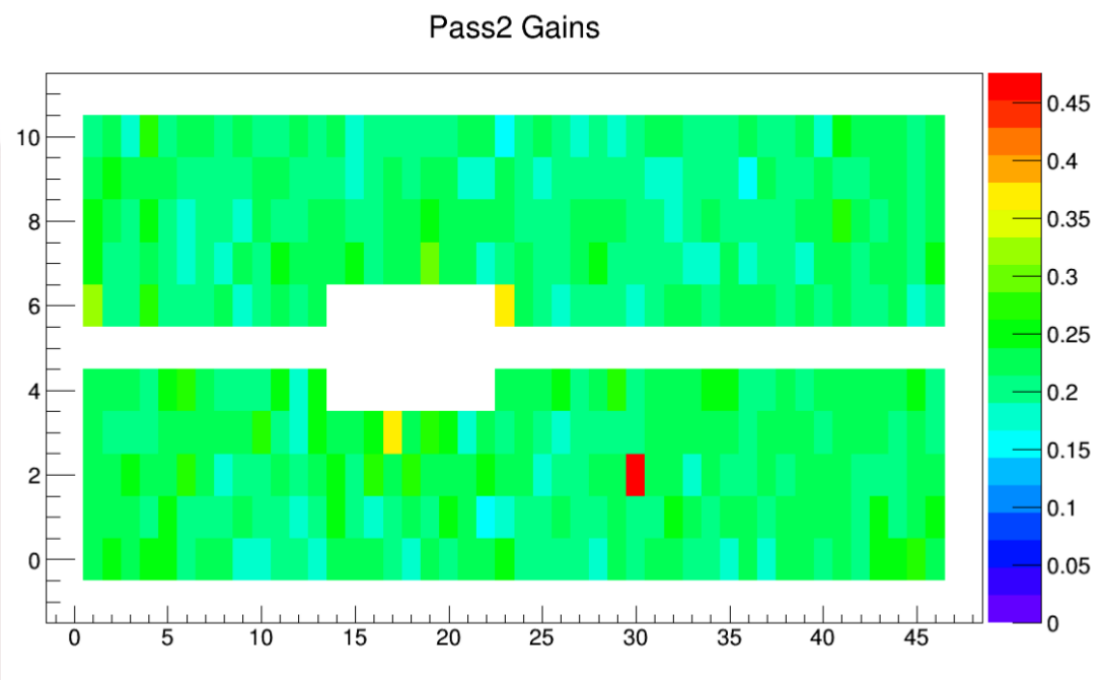
ECal Timing Calibration



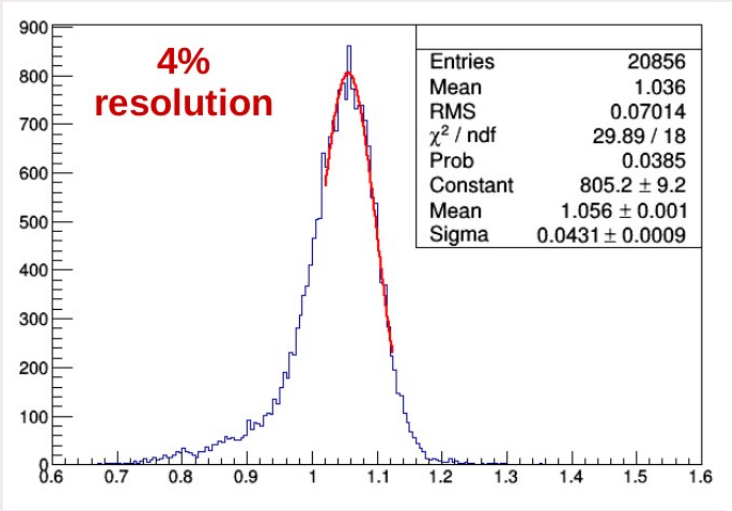
- **Time calibration is performed using the RF time as reference**
  - Good results
- **Time resolution ~400ps**
  - Using 4 ns sampling of FADC!
  - It varies with energy
  - Time resolution is very good for seed hits (200 MeV and more): <300ps



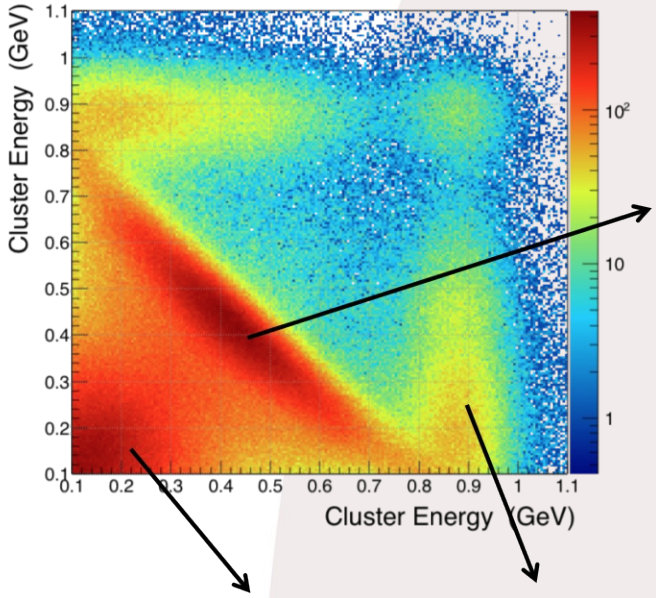
ECal Energy Calibration



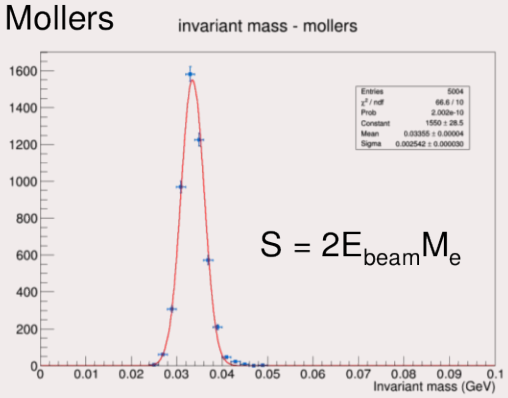
- **Gains are calibrated**
  - **Work based on cosmics and full energy electrons**
- **Energy resolution ~4% for FEE (1 GeV e^-)**
  - **Slight variations with position**
  - **Appears slightly wider than simulation**
- **Improvements are explored**



First Observations



Mollers



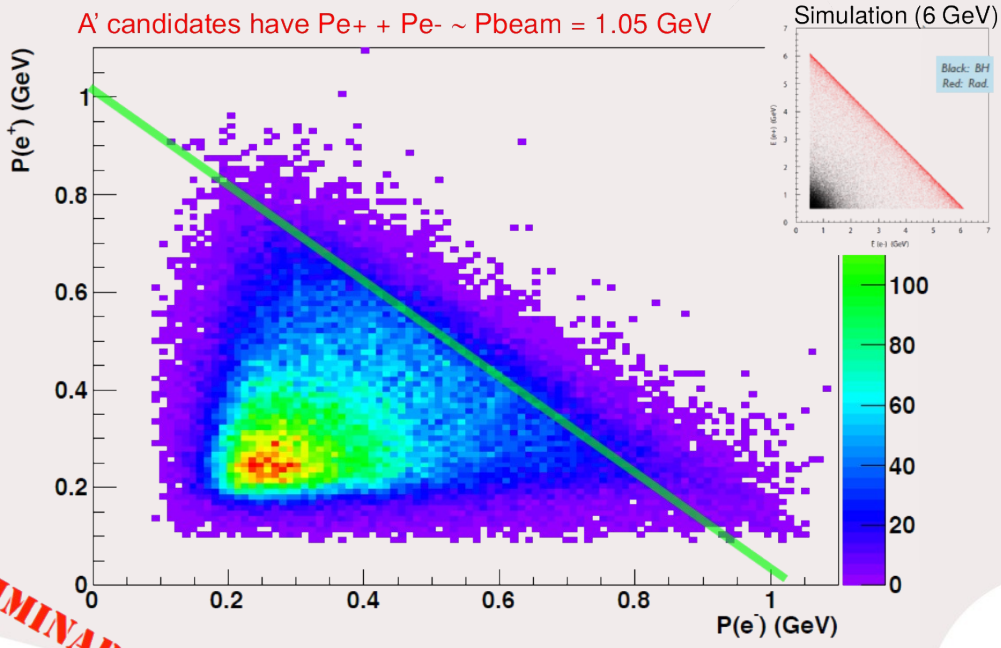
- Momentum/energy calibration
- Mass resolution

➔ **Events with two clusters in the ECal**

➔ **We see the expected processes**

➔ **Moller background can help for calibration**

A' candidates have Pe+ + Pe- ~ Pbeam = 1.05 GeV



PRELIMINARY

➔ **e^+ e^- pairs show the expected behavior**

➔ **Green line limits the zone of interest for A'**

Outlooks

- Scientific program with a wide reach
  - Search for A'
  - Search for true muonium
- Development & Constructions completed
- Commissionning completed
  - SVT function at 0.5 mm from the beam!
  - ECal and trigger behave as expected
- First data taking is very promising
- Future
  - More running
    - Plans at 2, 4 and 6 GeV
    - Highly dependent on accelerator and CLAS 12 schedule in the near future
  - Addition of a muon detctor