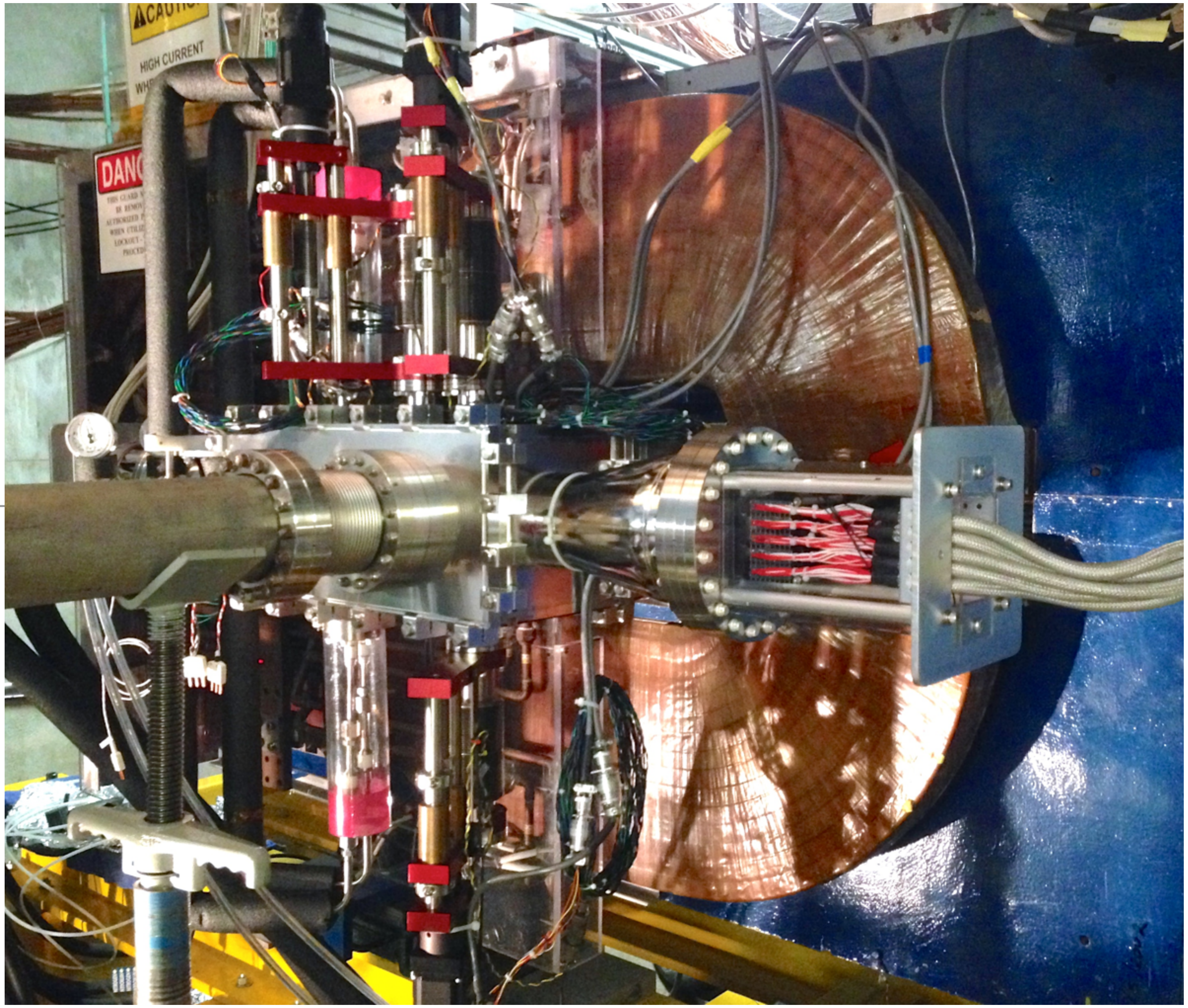
HPS
Status and Plans



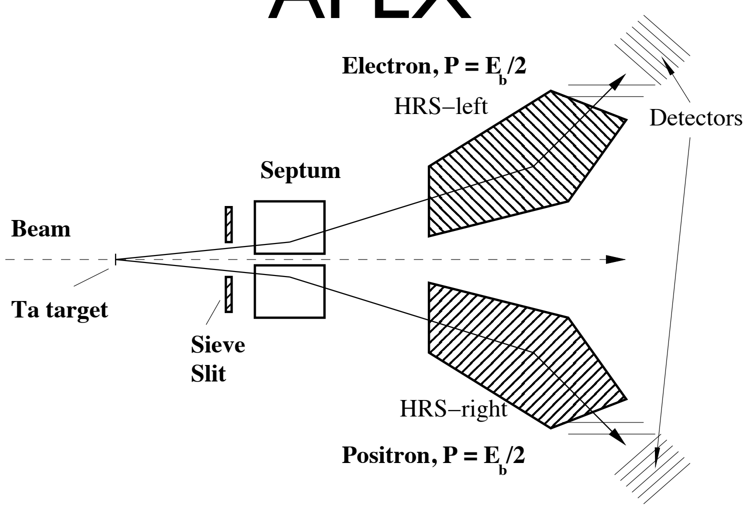
Tim Nelson - SLAC

APEX Collaboration Meeting

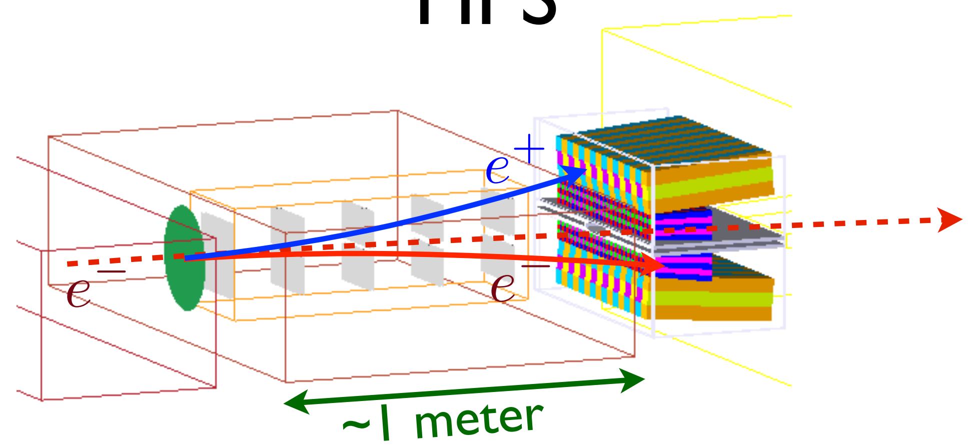
April 19, 2015

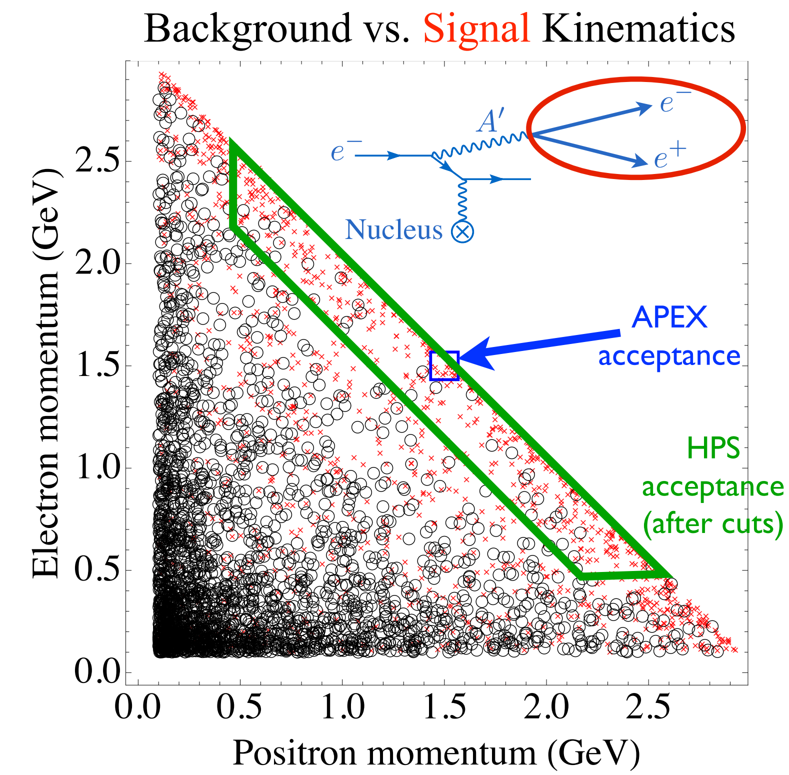
HPS for APEX Experts

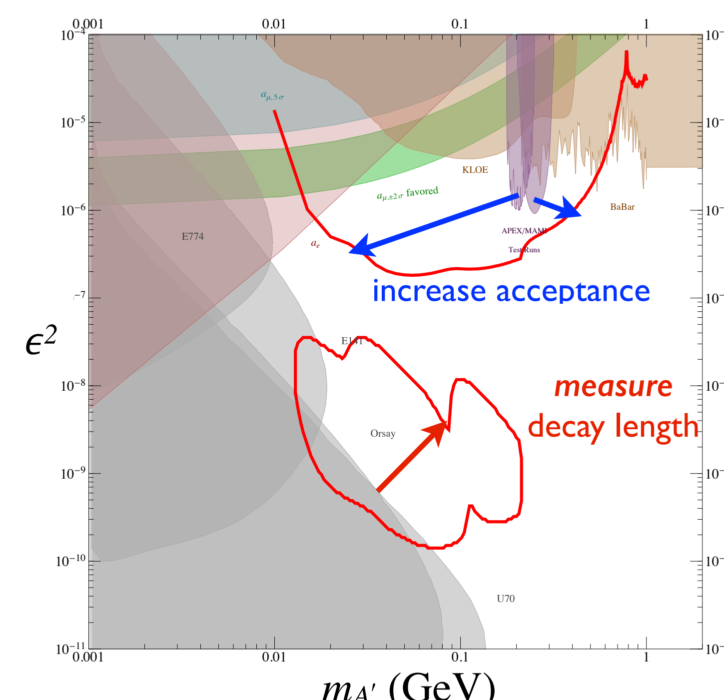
APEX



HPS



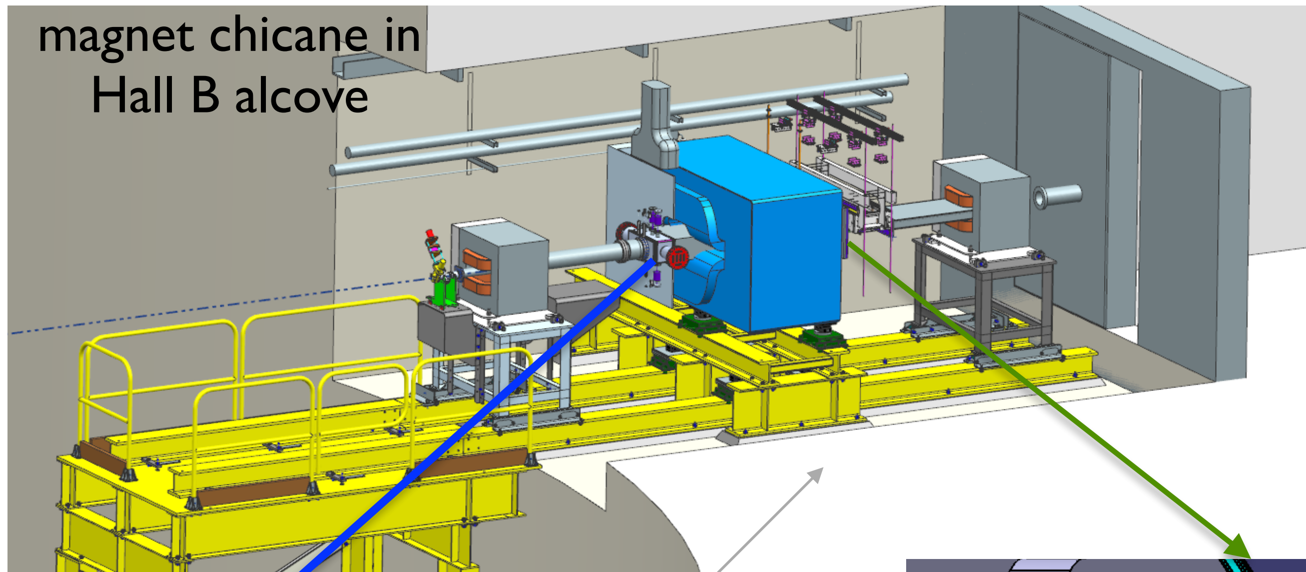




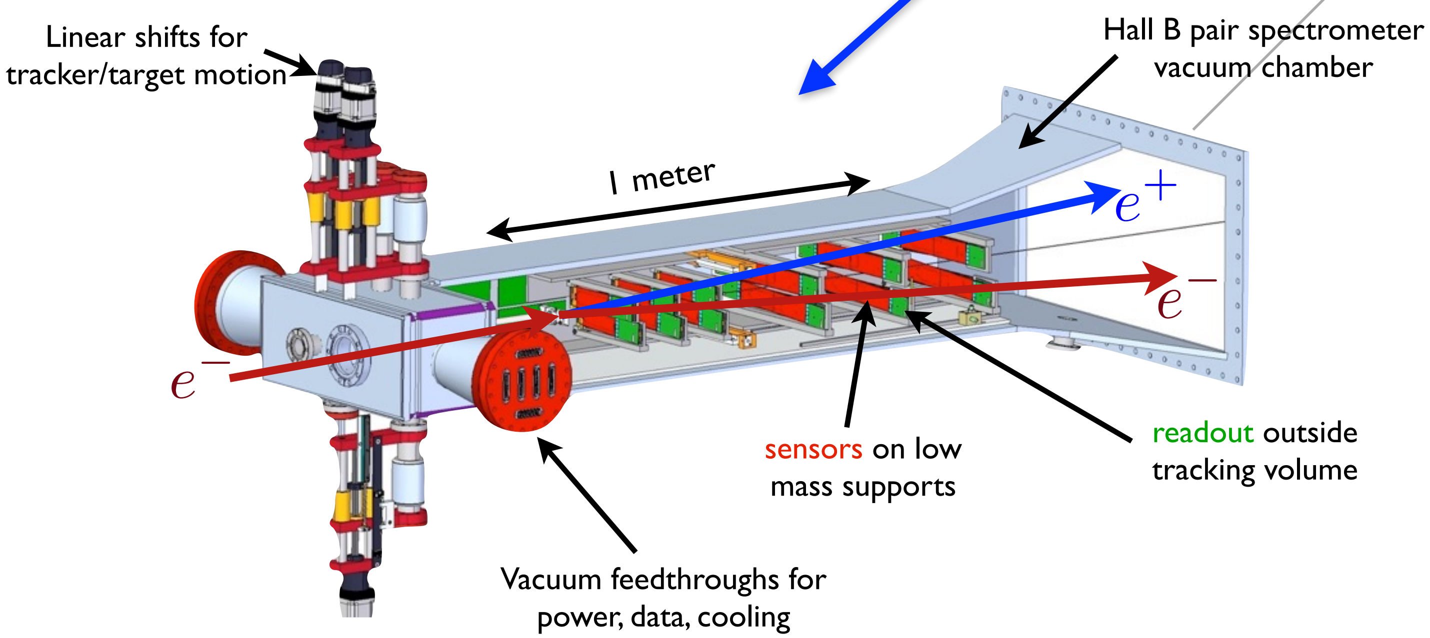
Relative to APEX, HPS is much closer to the target, and therefore…

- is much smaller but still has much larger acceptance
- uses lower currents and thinner targets (~0.125% X_0 @ ~200 nA)
- has much better vertex resolution (order 1mm or so)
- has much worse mass resolution (order 1% or so)
  - compensated for by acceptance
- must deal with close passage of primary beam (down to 500 μm)
  - *requires excellent beam quality, operation in vacuum, high-speed DAQ, high radiation tolerance, tracker movability*

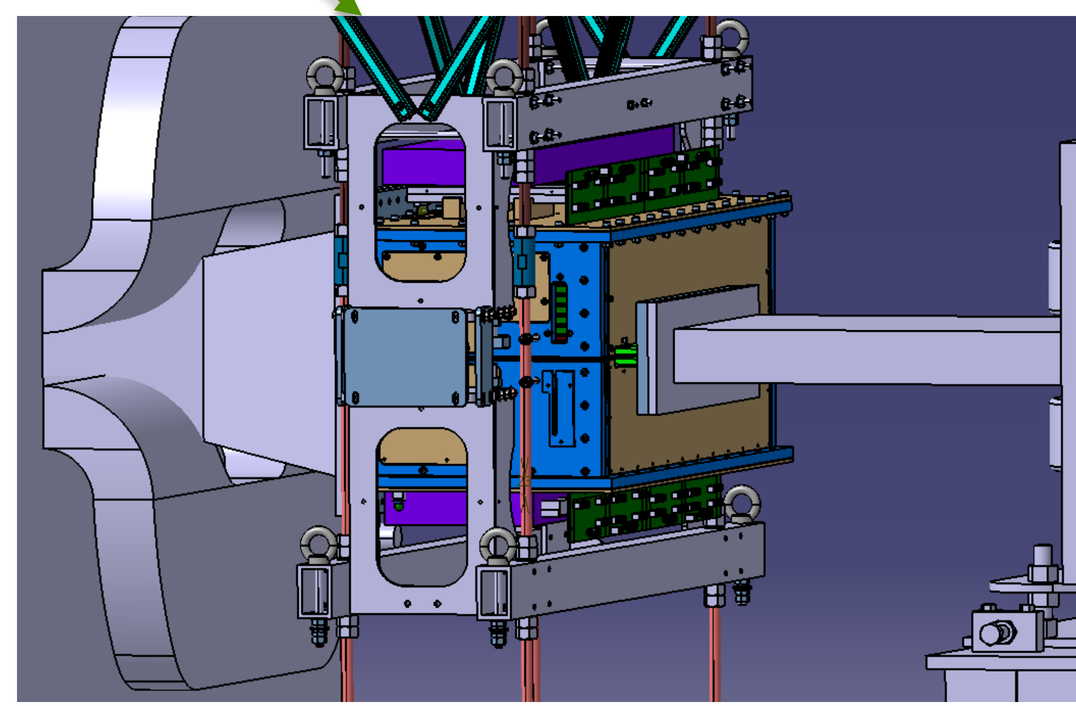
HPS Design Overview



Silicon Vertex Tracker
installed Feb. 2015

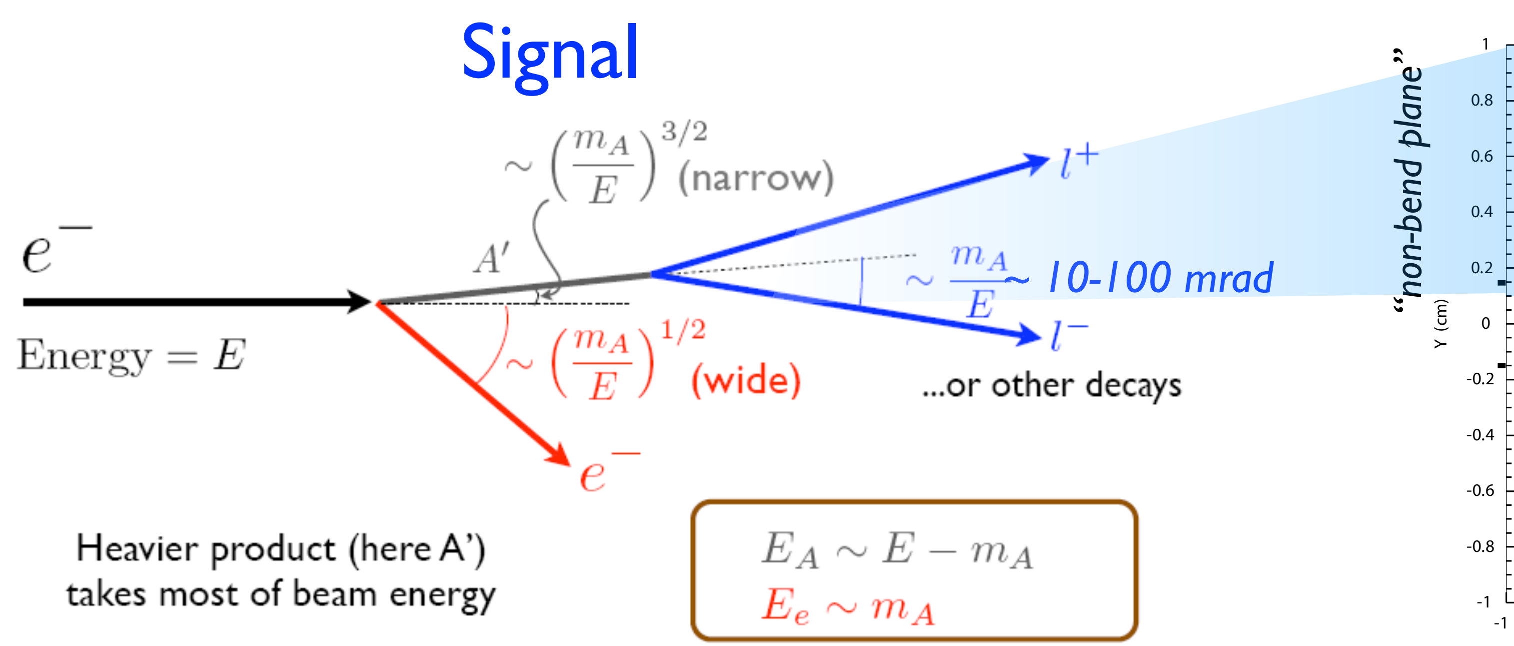


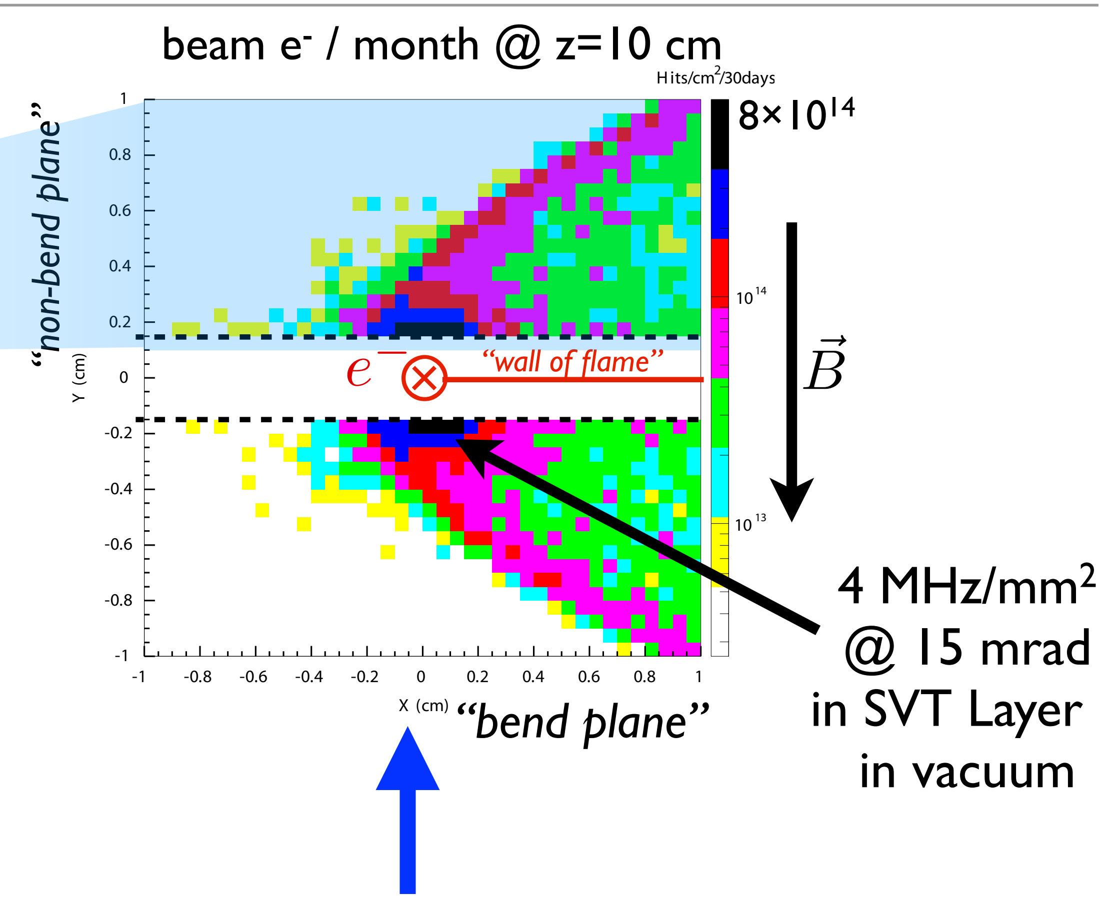
ECal
installed Sept. 2014



- The e^+e^- pairs are measured by the Si Vertex Tracker inside an analyzing magnet.
- A $PbWO_4$ ECal provides a fast trigger.
  https://confluence.slac.stanford.edu/display/hpsg/Heavy+Photon+Search+Experiment

Beam Requirements





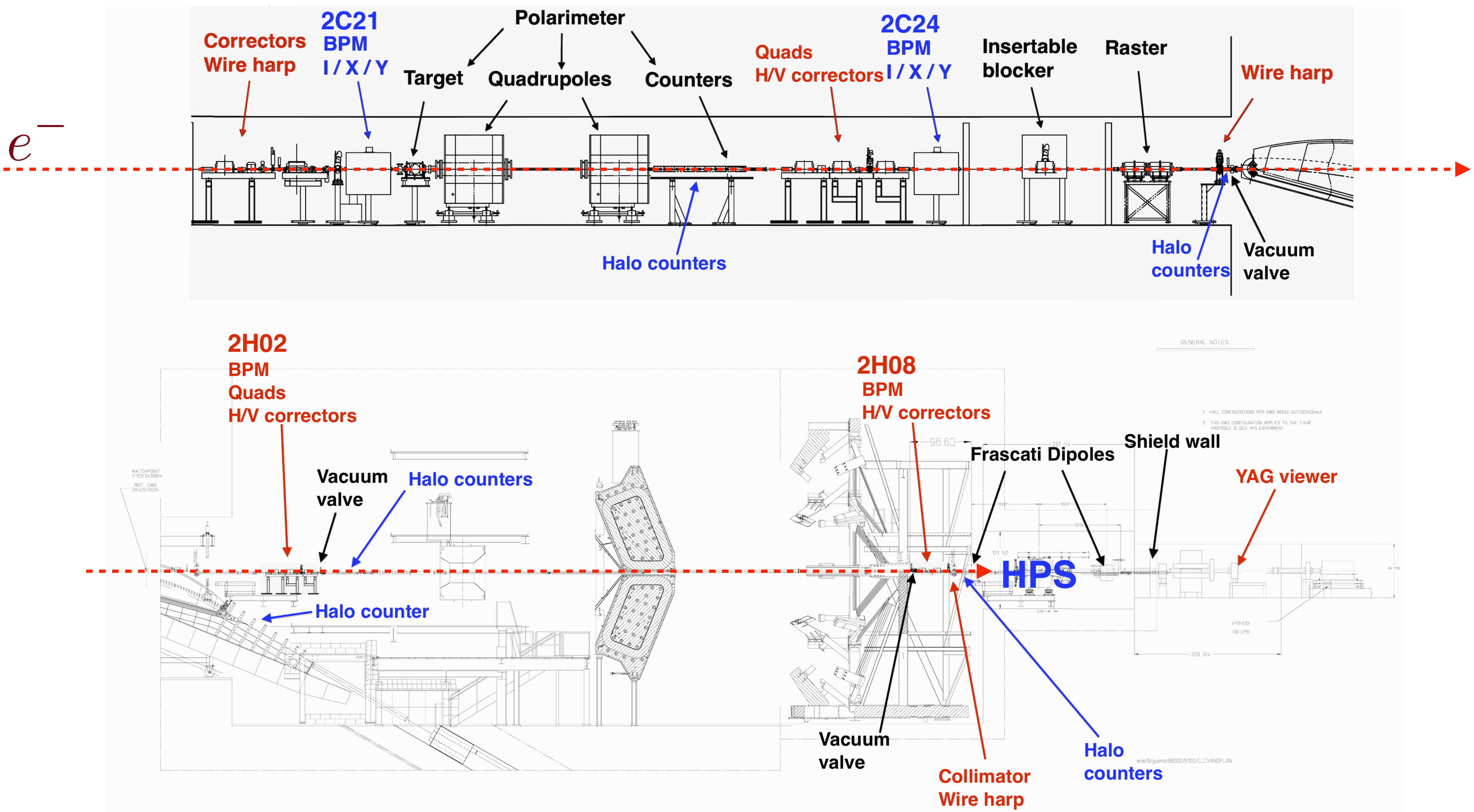
Parameter	Requirement			Unit
E	1100	2200	6600	MeV
δE/E	$< 10^{-4}$			
Current	< 200	< 400	< 500	nA
Current Instability	< 5			%
σ_x	< 300			μm
σ_y	< 50			μm
Position Stability	< 30			μm
Divergence	< 100			μrad
Beam Halo ($> 5\sigma_Y$)	$< 10^{-5}$			

- For vertexing, SVT L1 10 cm from target
- Requires excellent beam quality and stability
- Requires protection of SVT
    - SVT collimator
    - Counters for fast beam shutdown
    - Many BPMs and harps/scanners

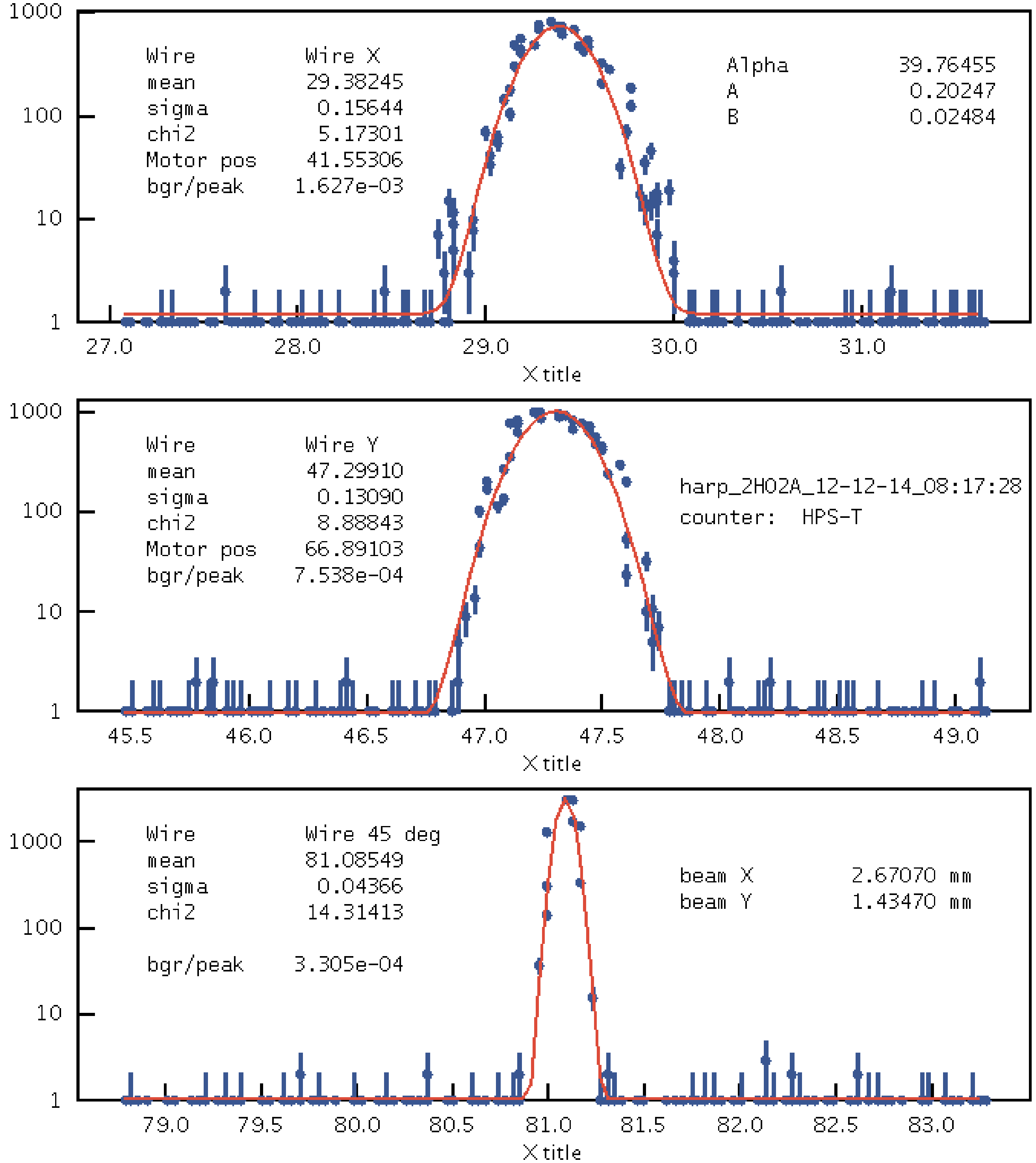
HPS Beamline

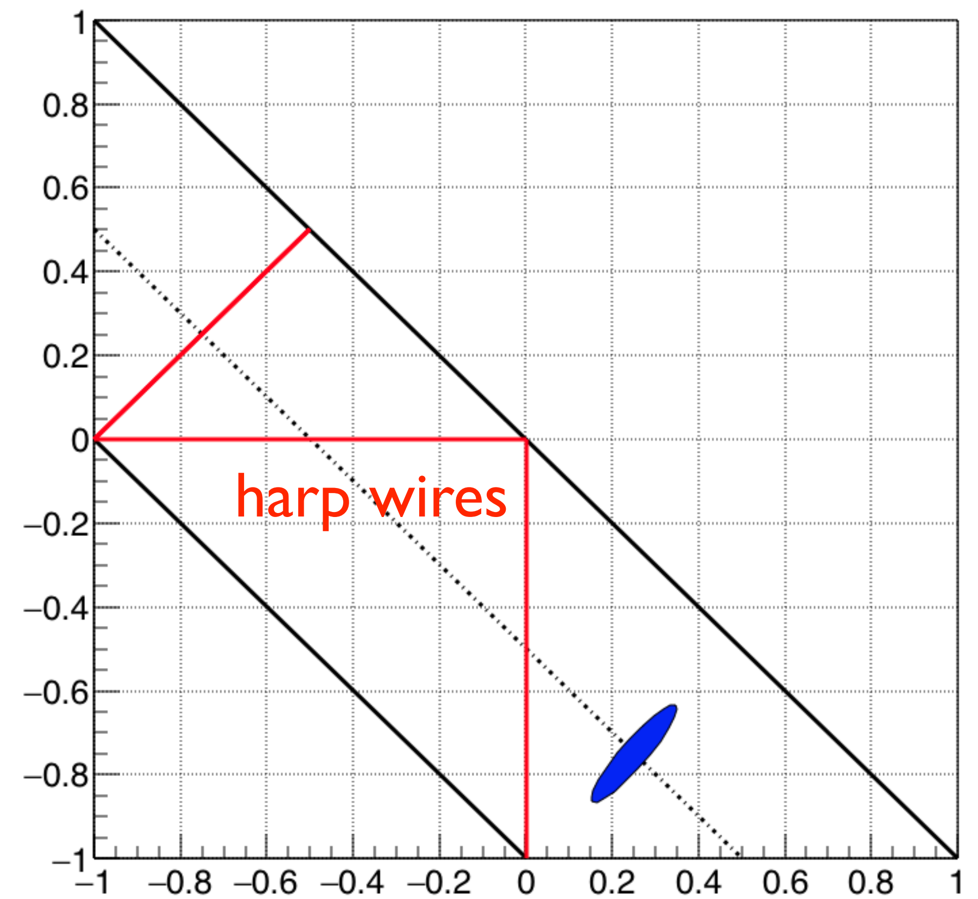
For a complete photographic tour of the beam line components, see:

https://confluence.slac.stanford.edu/download/attachments/184715057/hps_ColMeet_beamline_overview.pdf



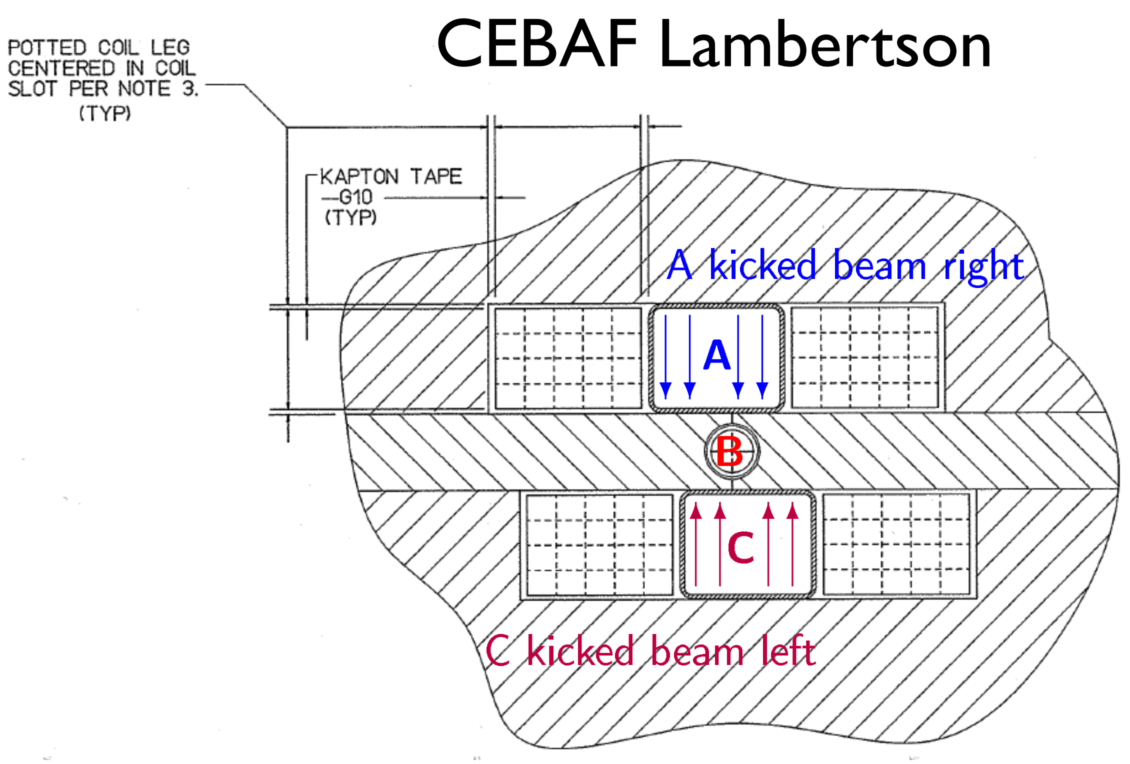
First CEBAF12 Beam - Fall 2014

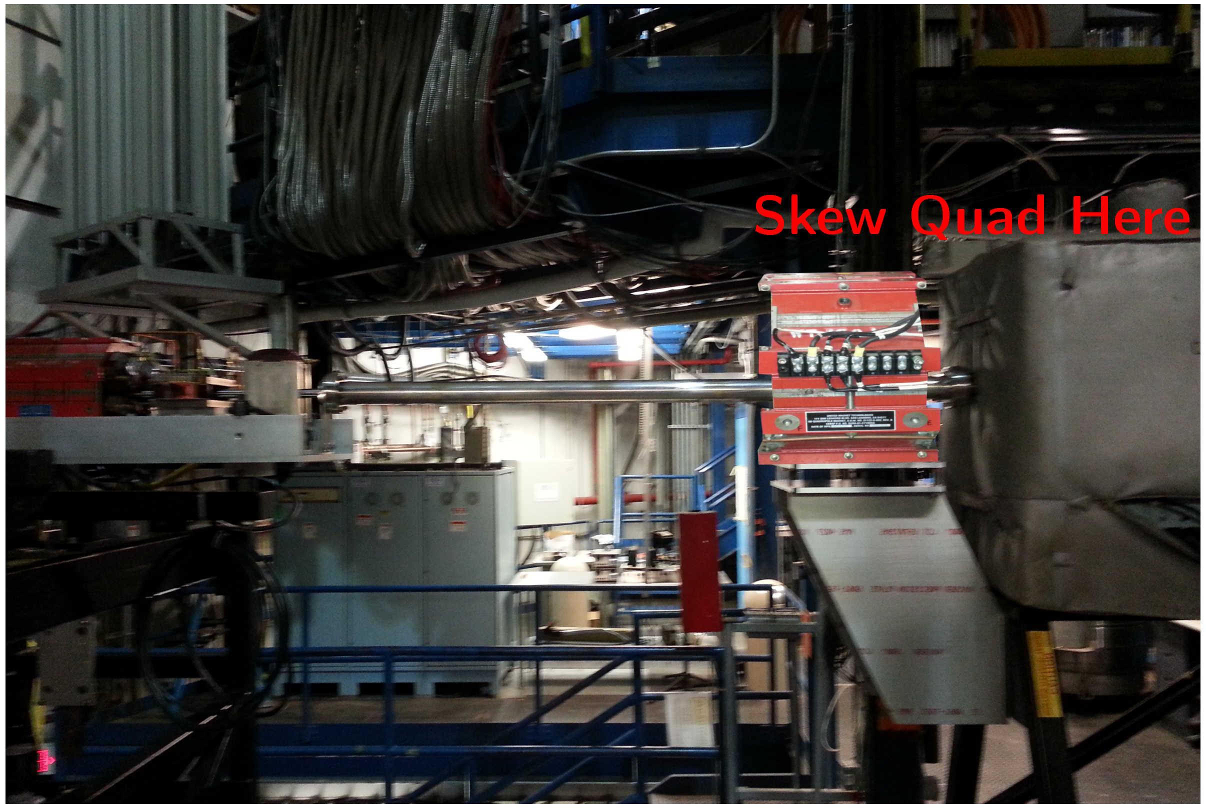




Beam spot profile as desired but tilted !

Beam Skew

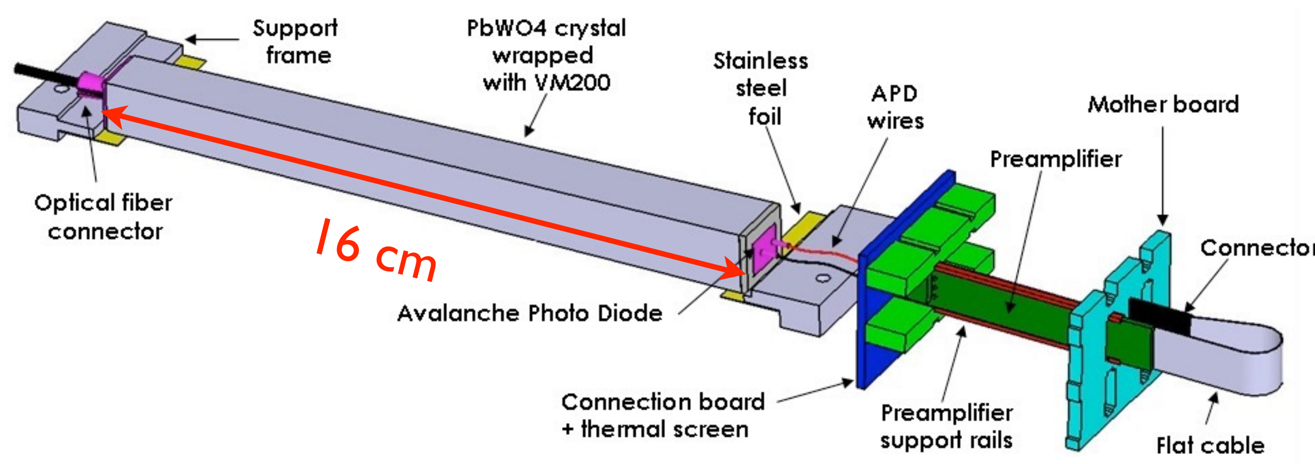


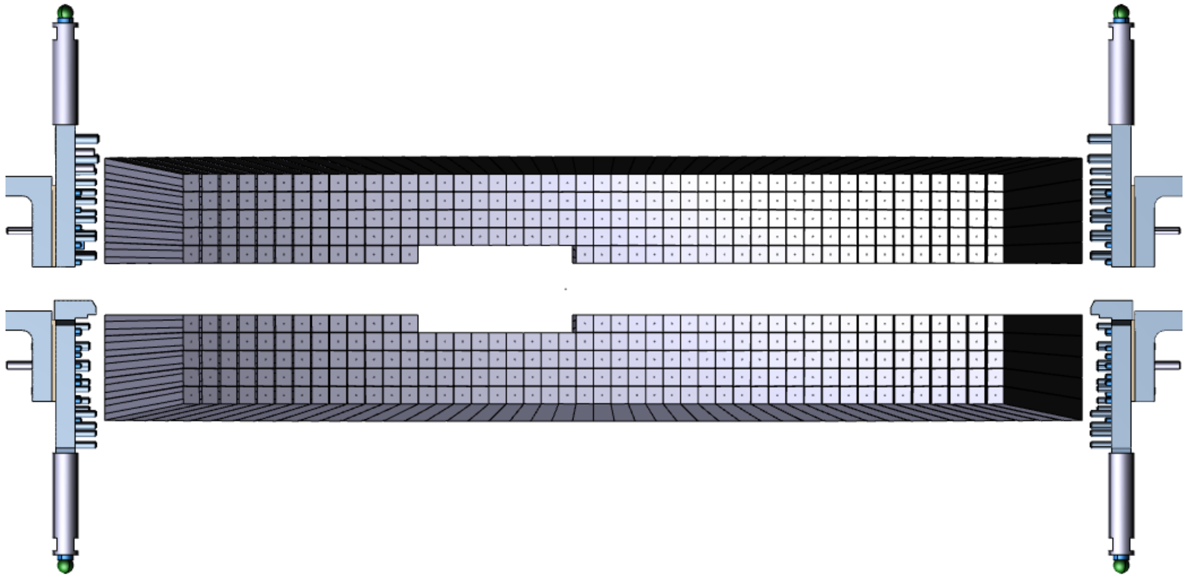


- Beam skew originates with passage through CEBAF Lambertson.
- Skew quad added to beam line in Hall B to correct skew
- Additional beam diagnostics installed for monitoring skew

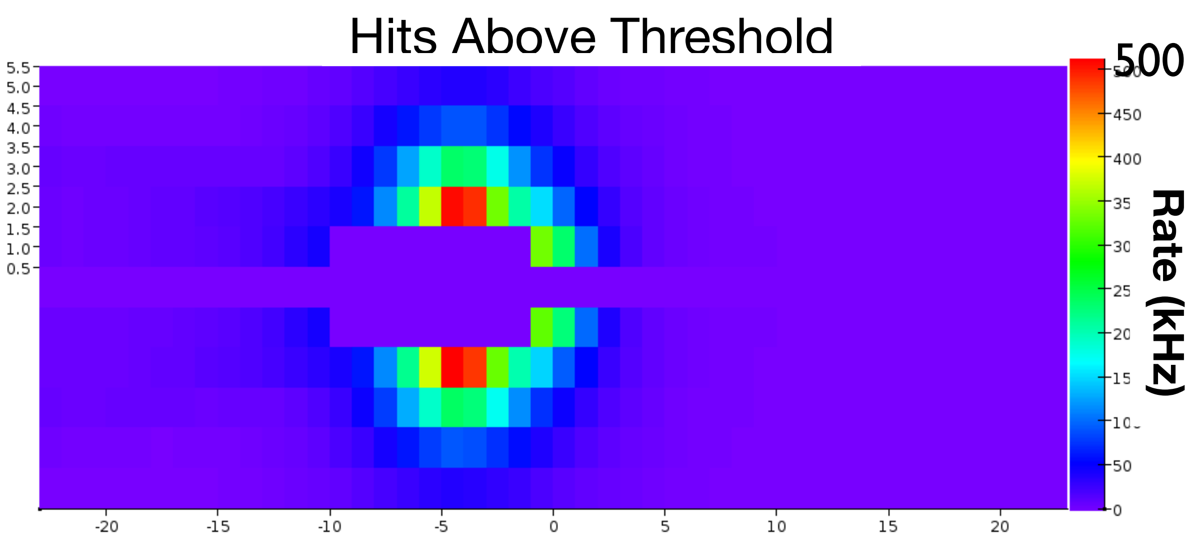
ECal/Trigger Basics - same as test run

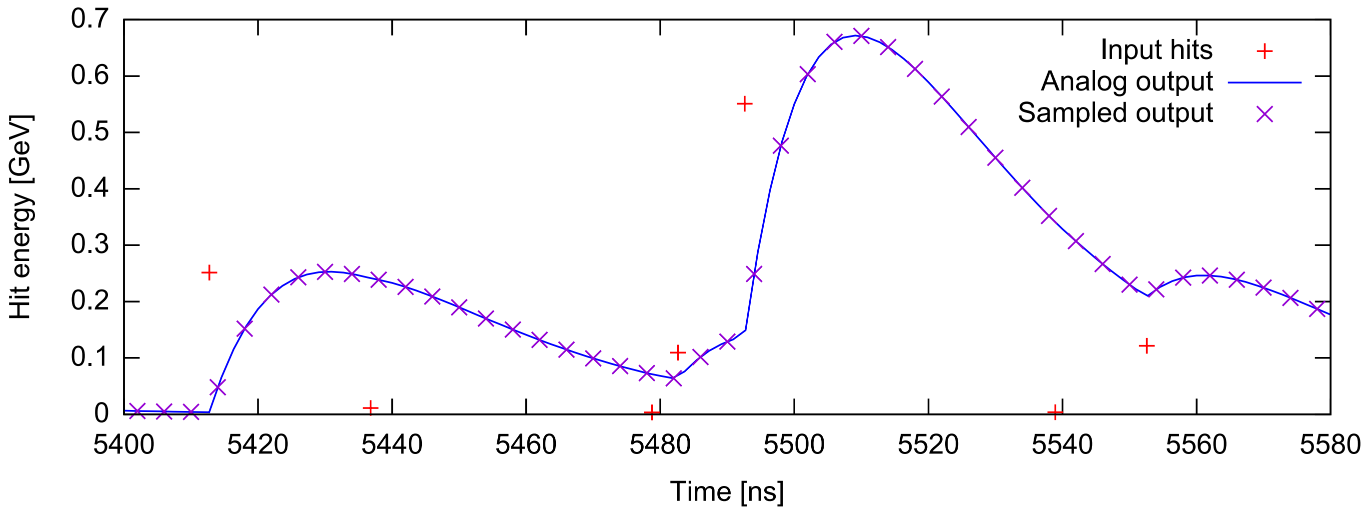
PbW0$_4$ crystals with APD readout are fast, radiation tolerant.





250 MHz Flash ADC readout allows high-rate trigger with precision timing.





HPS ECal Upgrades

Completely new motherboard design

- based on extensive experience at IPN-Orsay and INFN-Genova
- simplified design with fewer layers, shorter traces, lower trace density

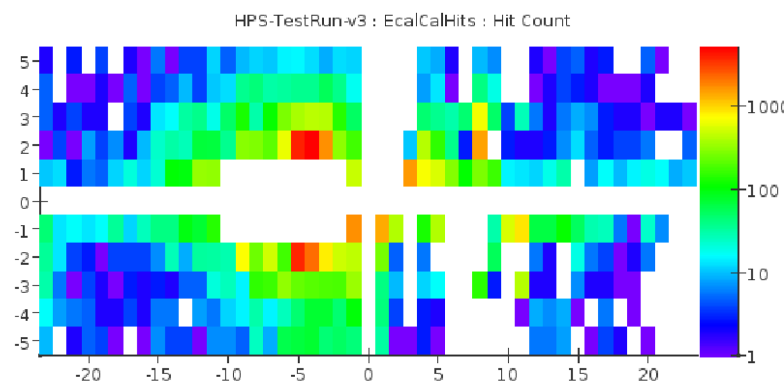
Replace S8644 0.5x0.5 cm^2 APD (CMS) with new HPK LAAPD S8664-1010 1.0x1.0 cm^2

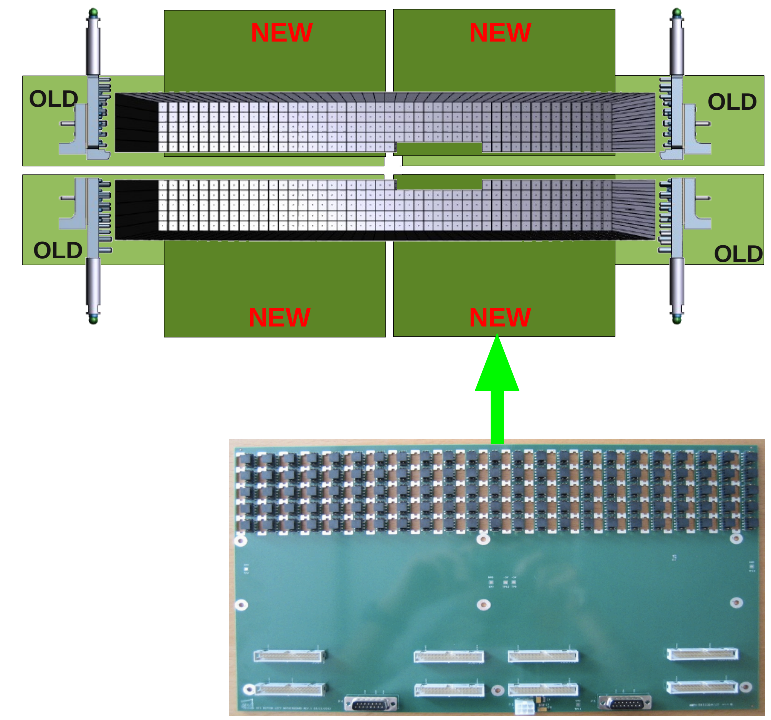
- 10% gain-matched
- 4x more light
- Better S/N w/ new IPN-Orsay preamps

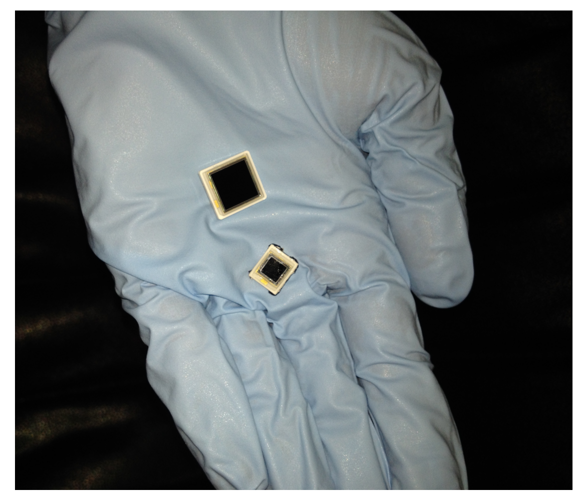
Light monitoring system

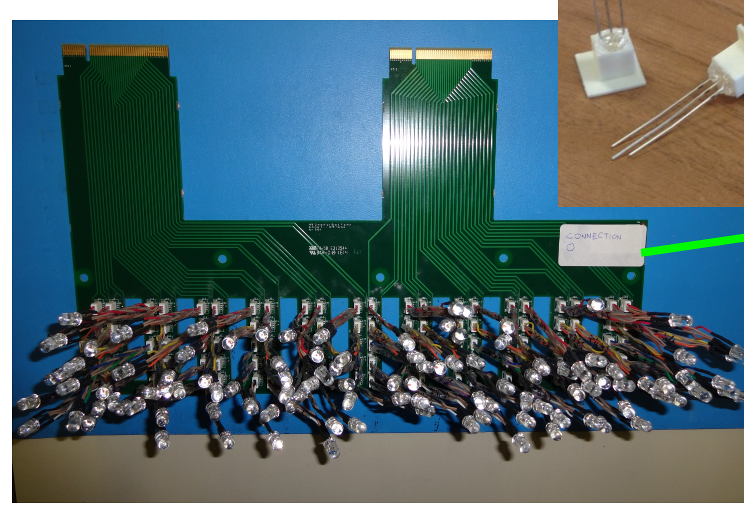
- RAPID 56-0352 blue/red LED
- Monitoring for both radiation damage and APD response

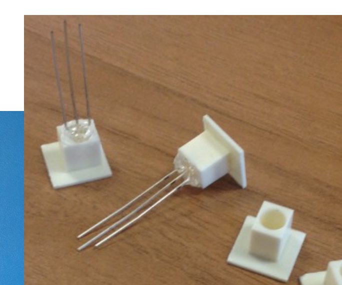
Goal: $\sigma_E/E \approx 2\%/\sqrt{E}$ (GeV)

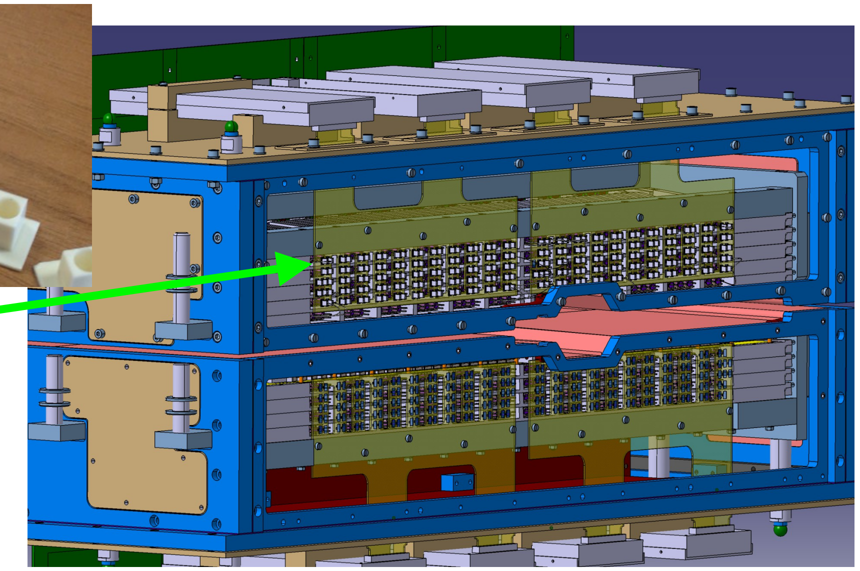






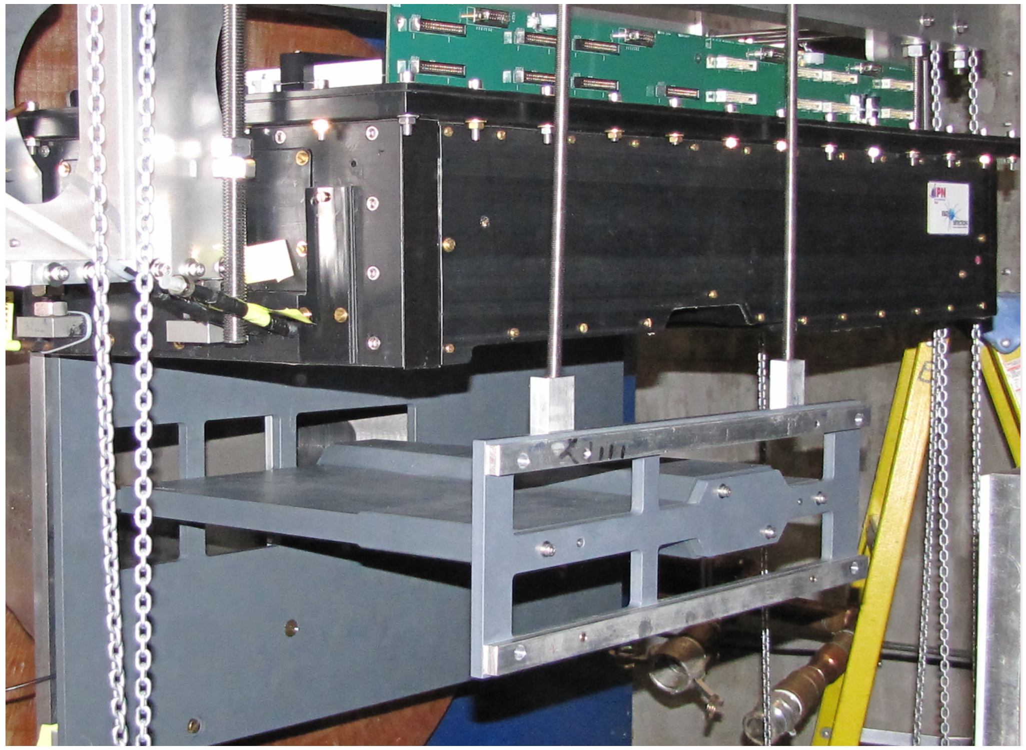


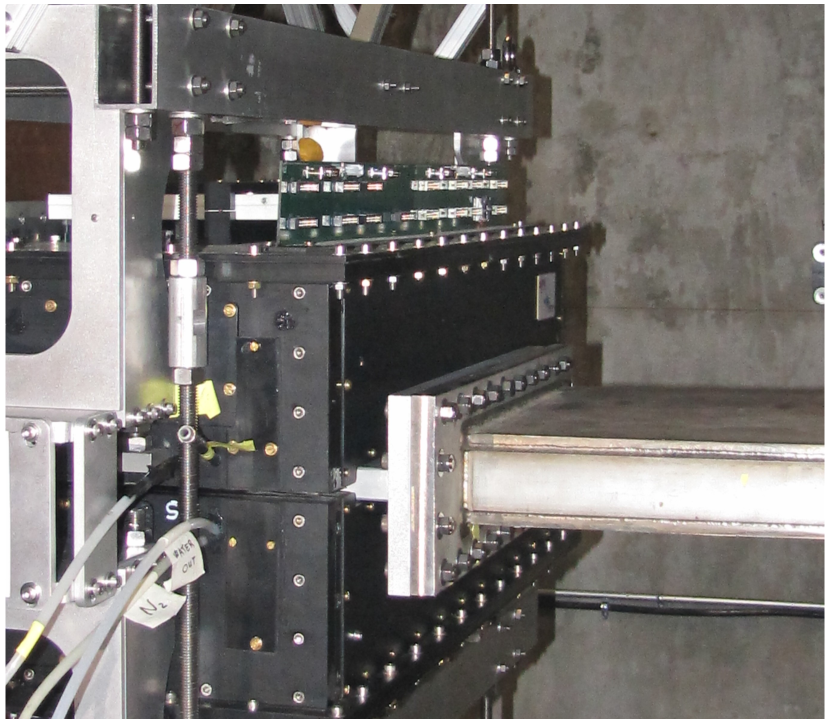




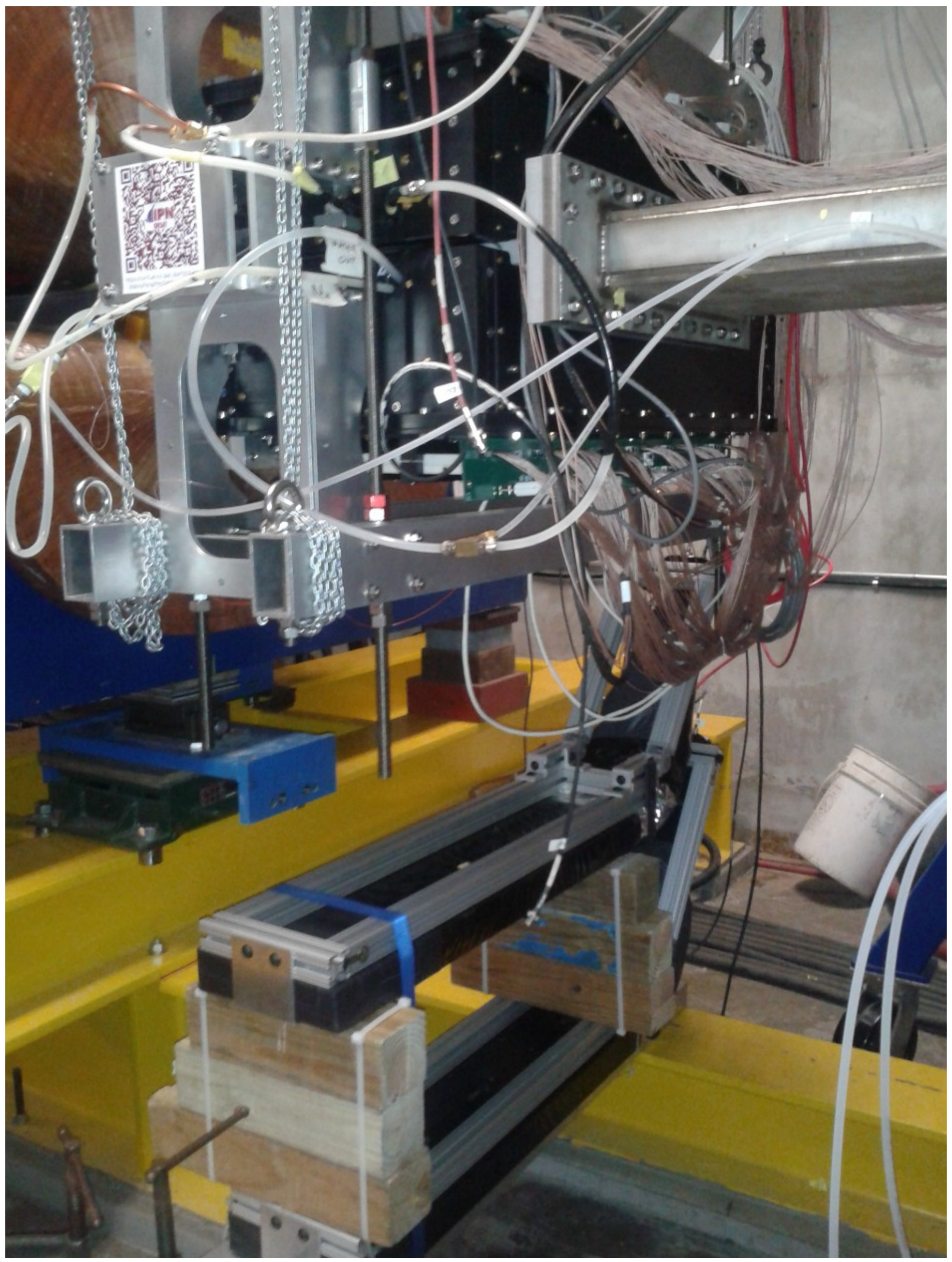
ECal Installation: Sept.-Oct. 2014

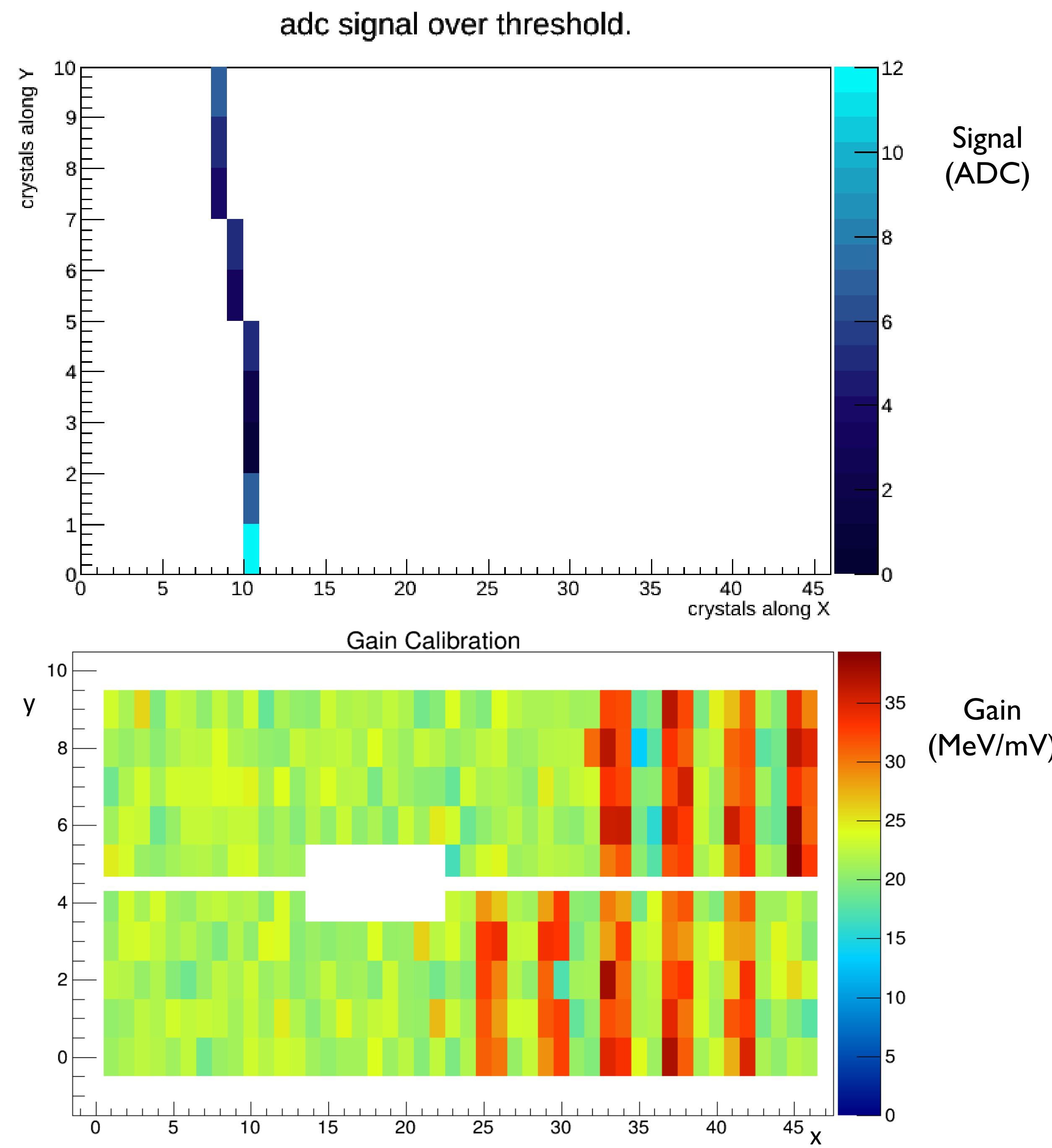






ECal Cosmic Calibration



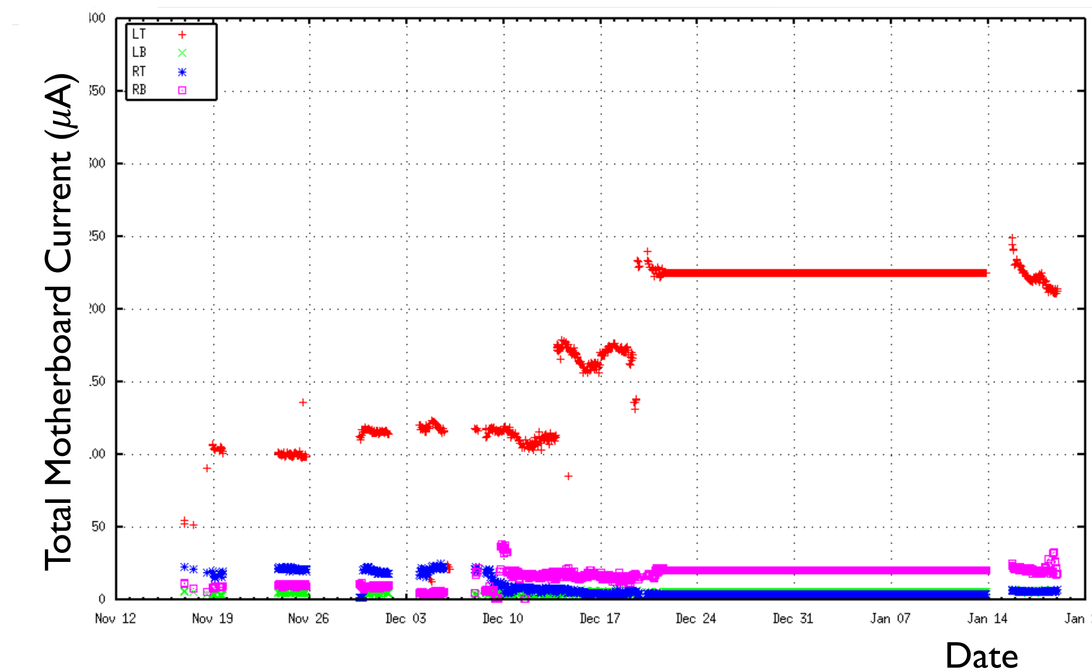


Some HV supplies are faulty ⇒ repaired/replaced

Other ECal Issues

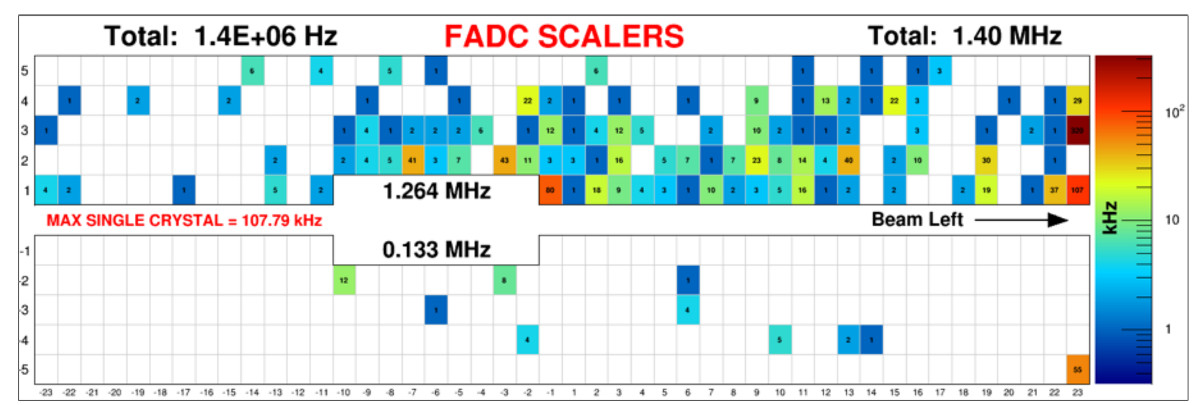
Higher currents seen in some channels.

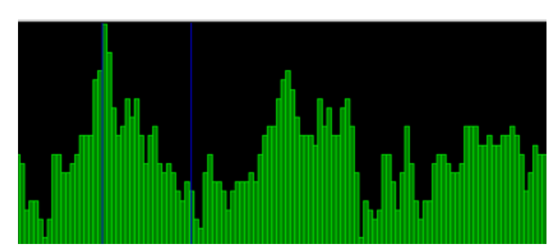
Traced to labels on preamplifier circuit boards. Labels removed ⇒ fixed.

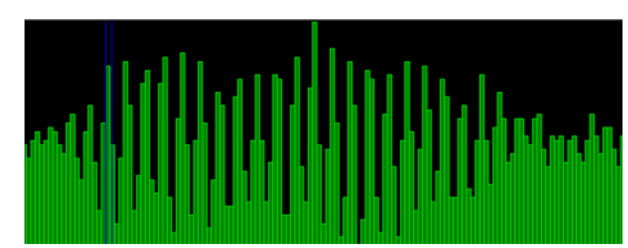


Intermittent noise of varying amplitude in some sections of ECal, both low and high frequency.

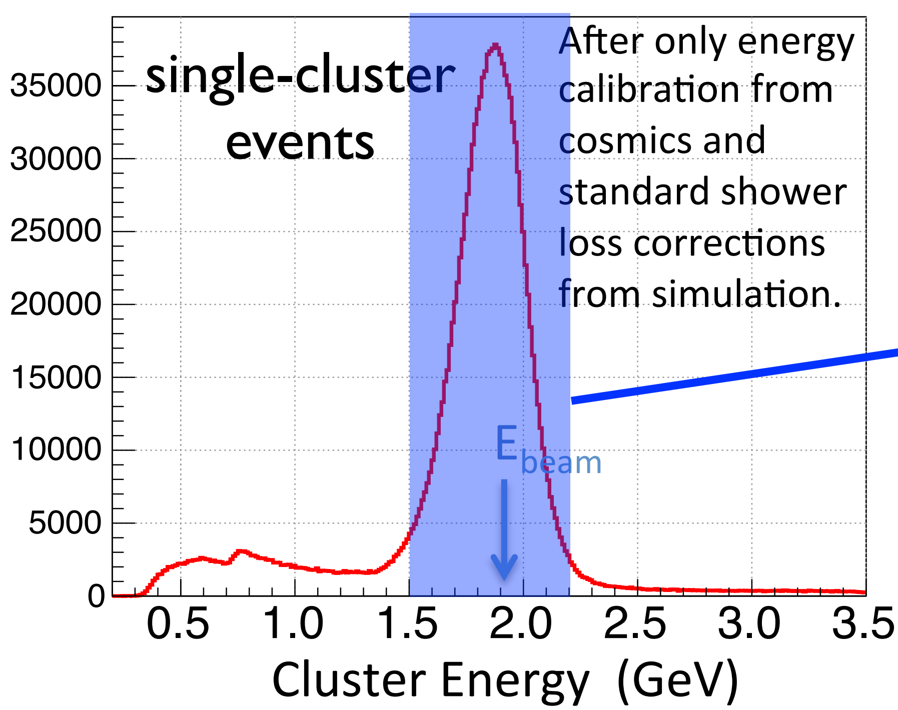
Still working to track down problem, though it won't affect ECal as a trigger.

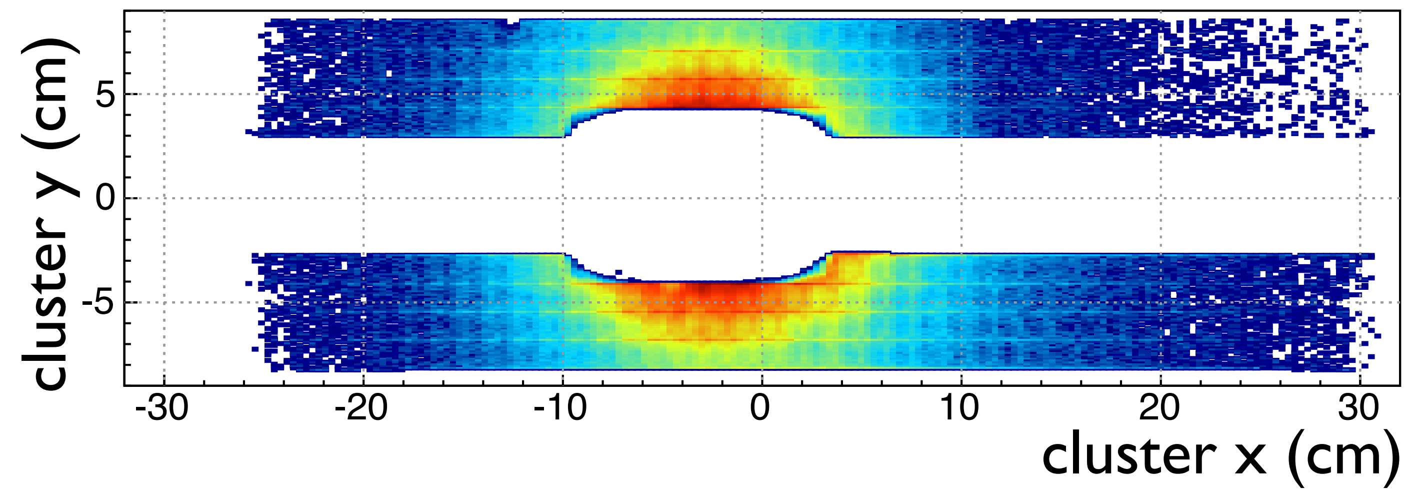


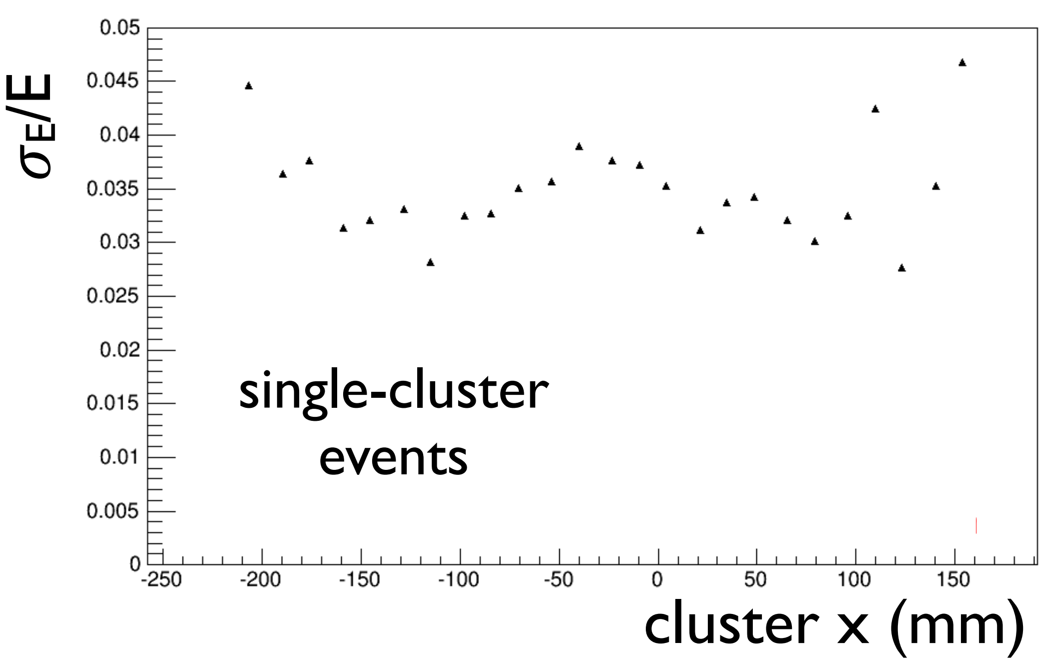


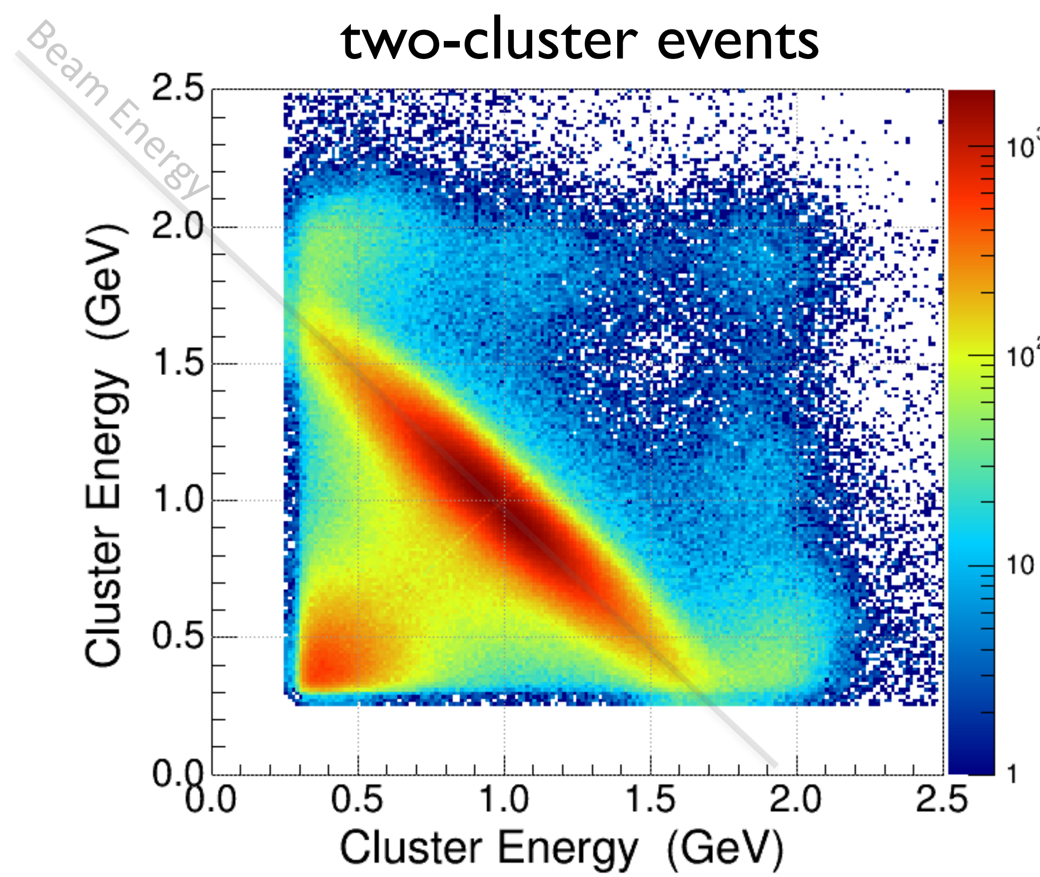


ECal First Data: Dec. 2014







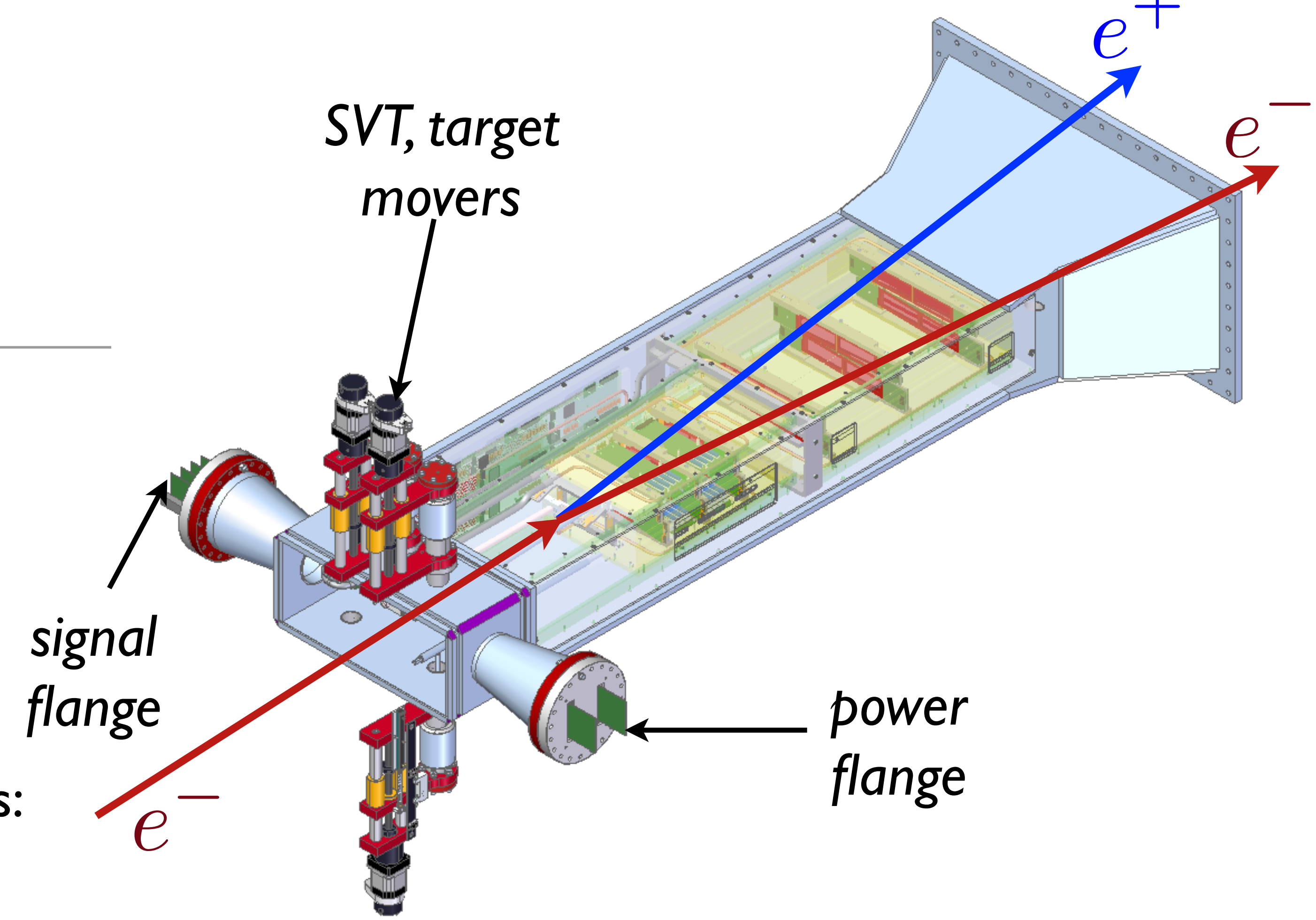


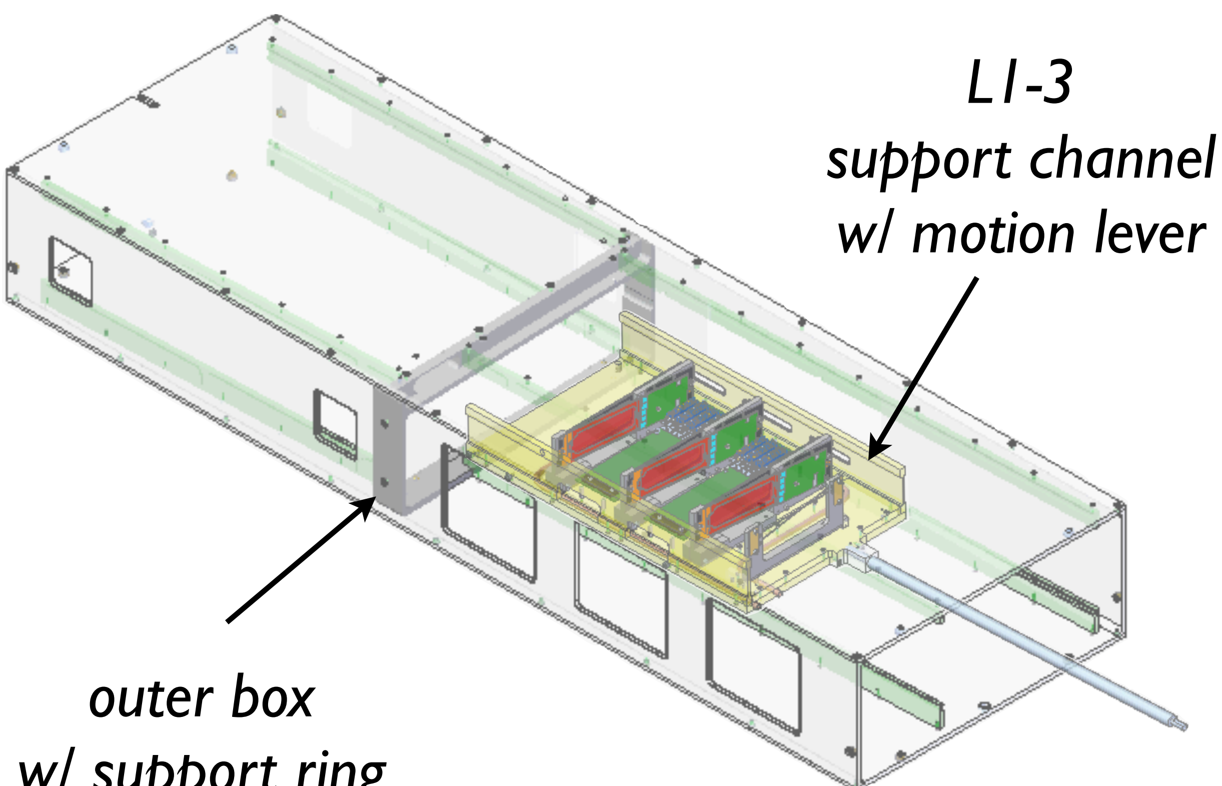
Expect major improvements with higher energy calibration

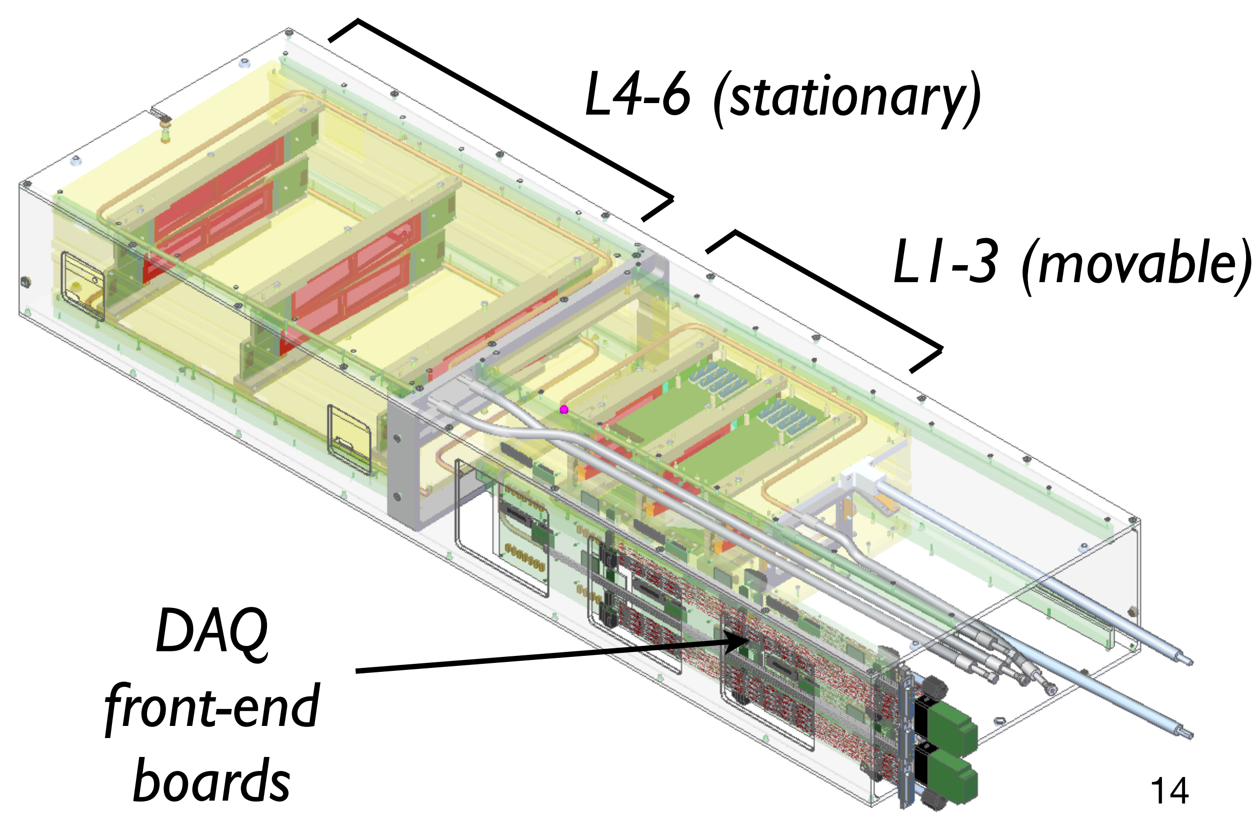
HPS SVT Design

- Installs inside beam vacuum
- High-speed readout with 2 ns t_{hit} resolution
- Radiation-tolerant sensors, cooled to -20 °C
- Thin to reduce scattering:
  0.7% X_0/3d-measurement (0.07% X_0 support)
- Edge of Layer 1 sensors 0.5 mm from beam axis:
  first three layers retractable from beam
- modular assembly for serviceability.

better cooling, mechanical precision relative to test run



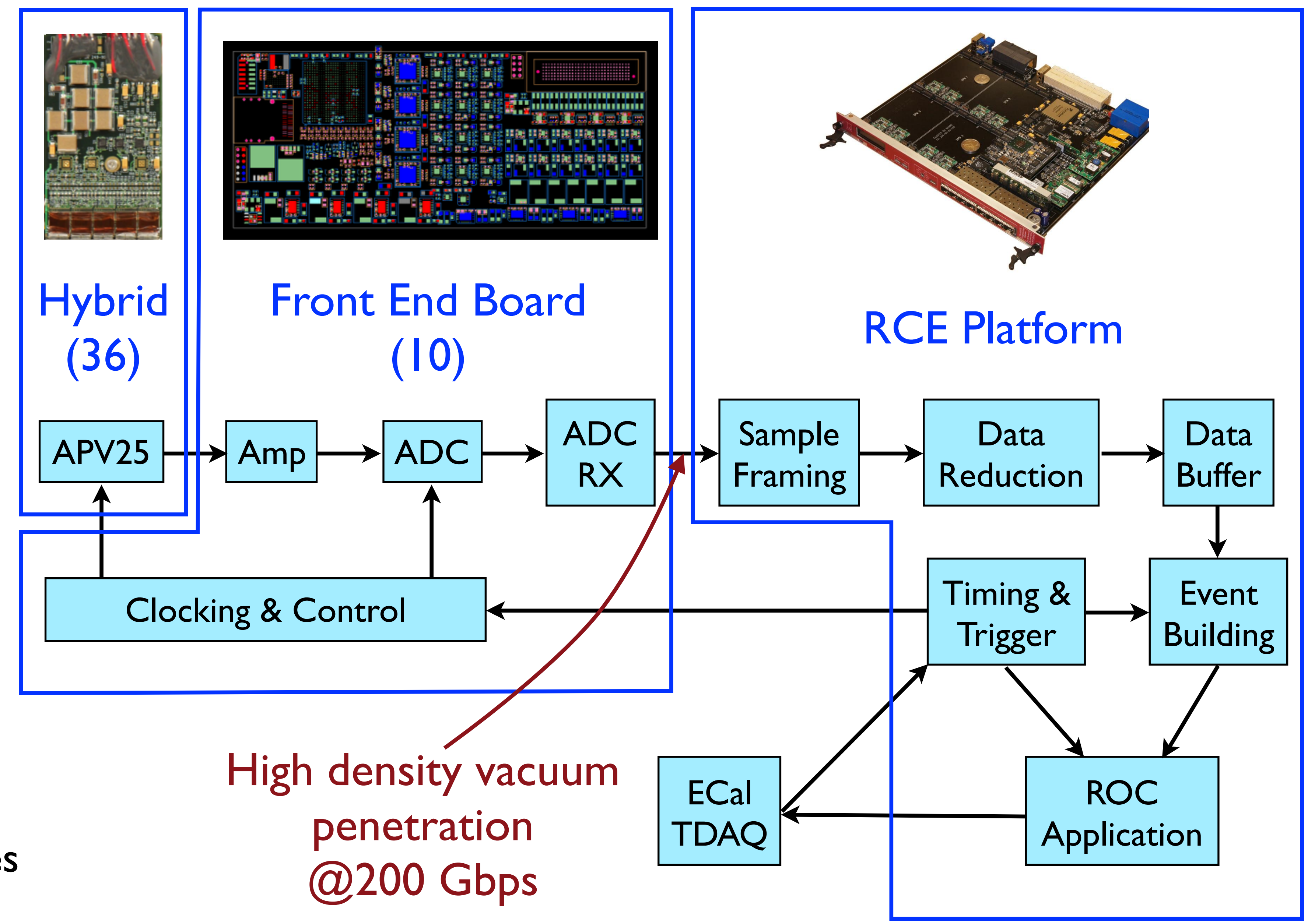




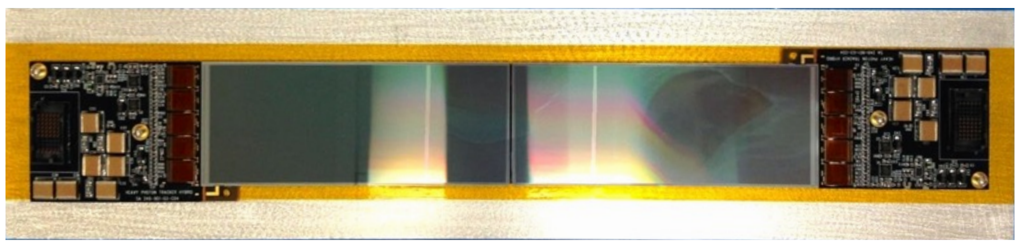
SVT DAQ

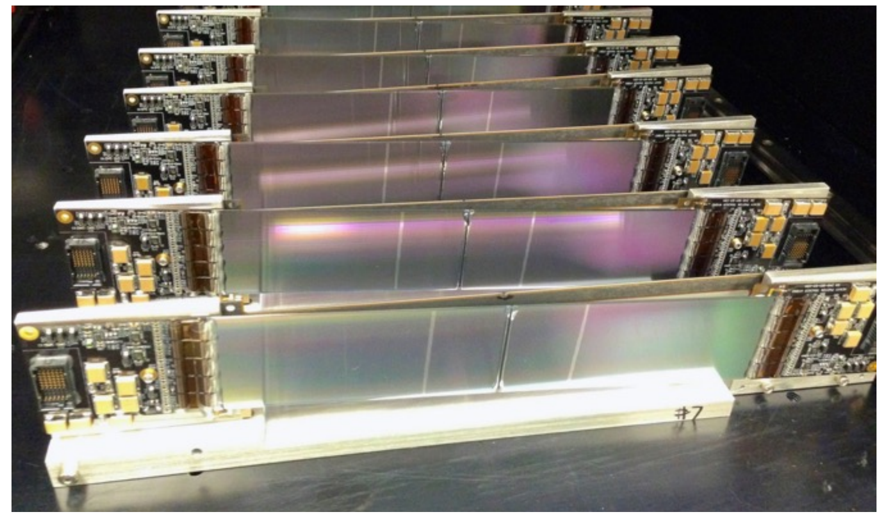
- Hybrids hosting
  5 CMS APV25 each
- In-vacuum ADC, voltage generation and power distribution/control on Front End Boards
- Penetration for digital signals via high-density PCB through flange. Optical conversion on outside of flange.
- Firmware support for APV25 burst trigger mode (50 kHz trigger rate for 6 samples)
- Wiener MPOD power supplies

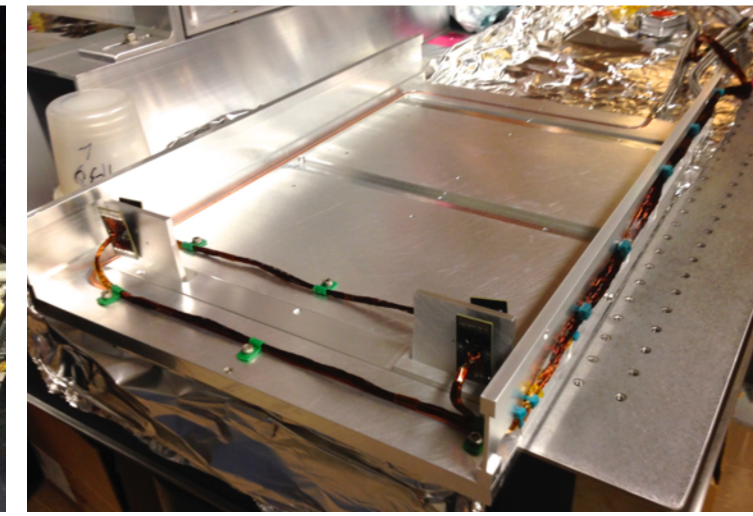
Much more powerful and flexible than test run DAQ.

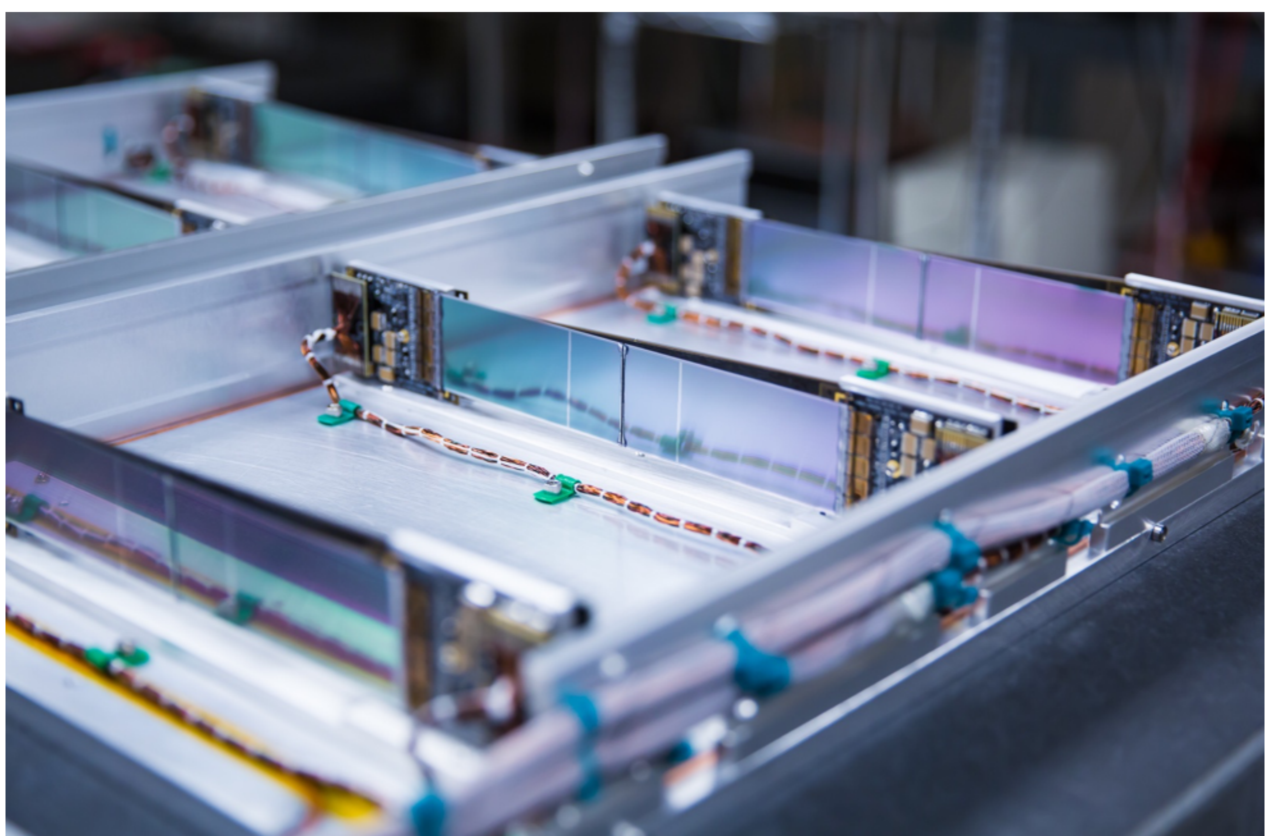


SVT Assembly at SLAC

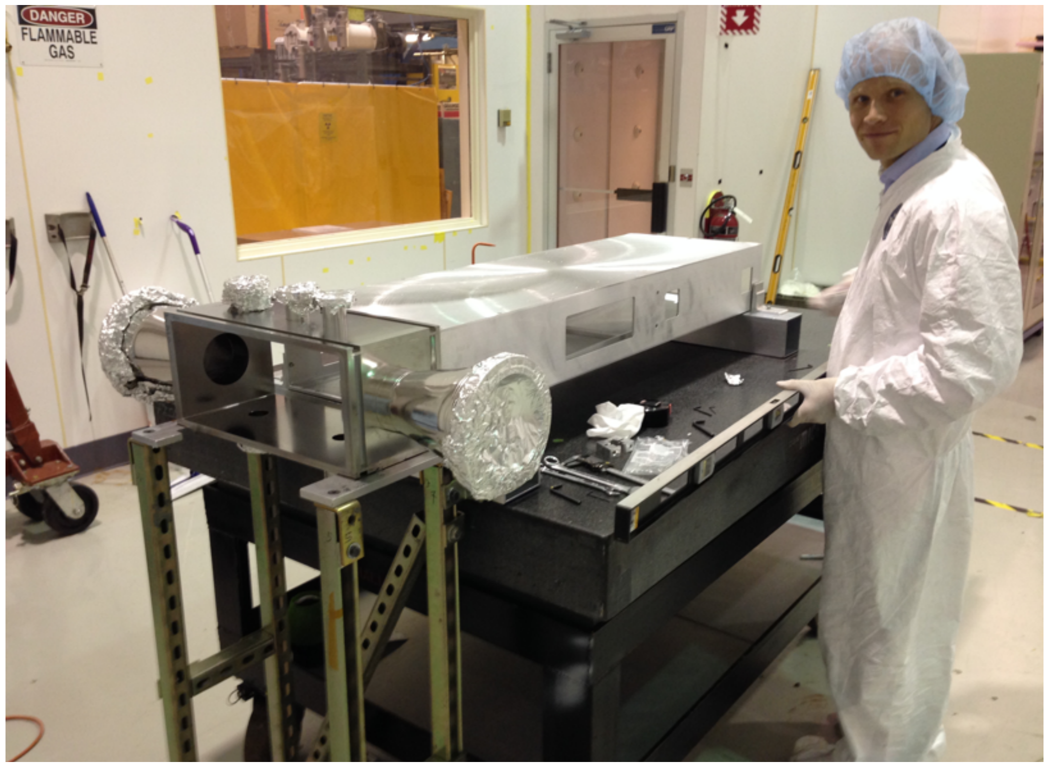


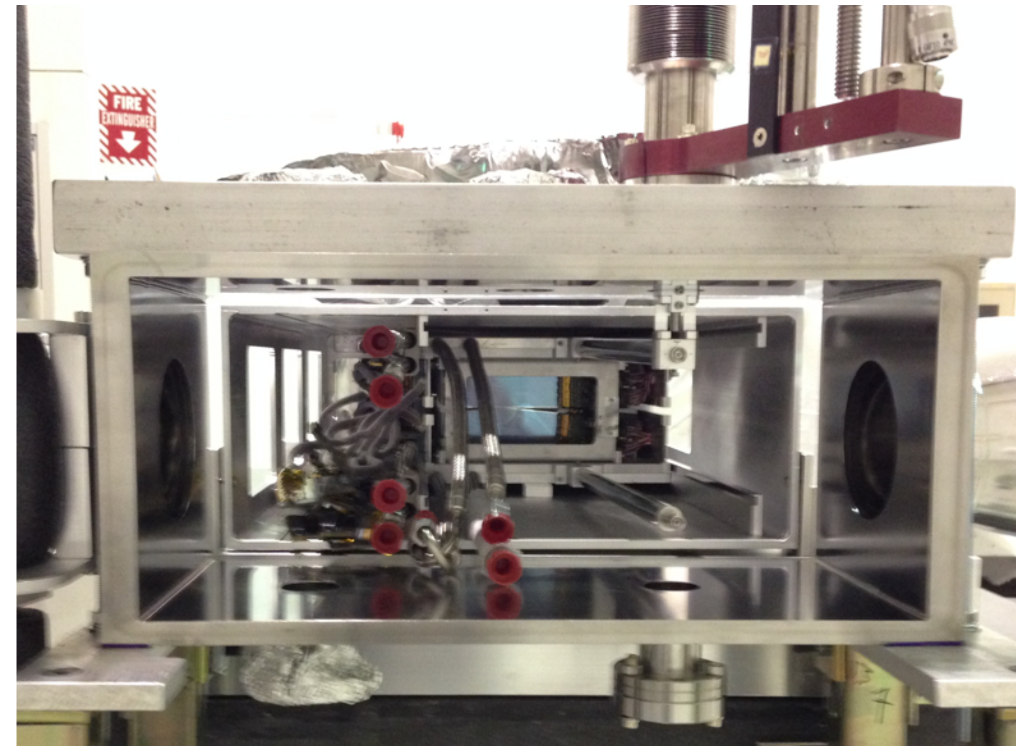




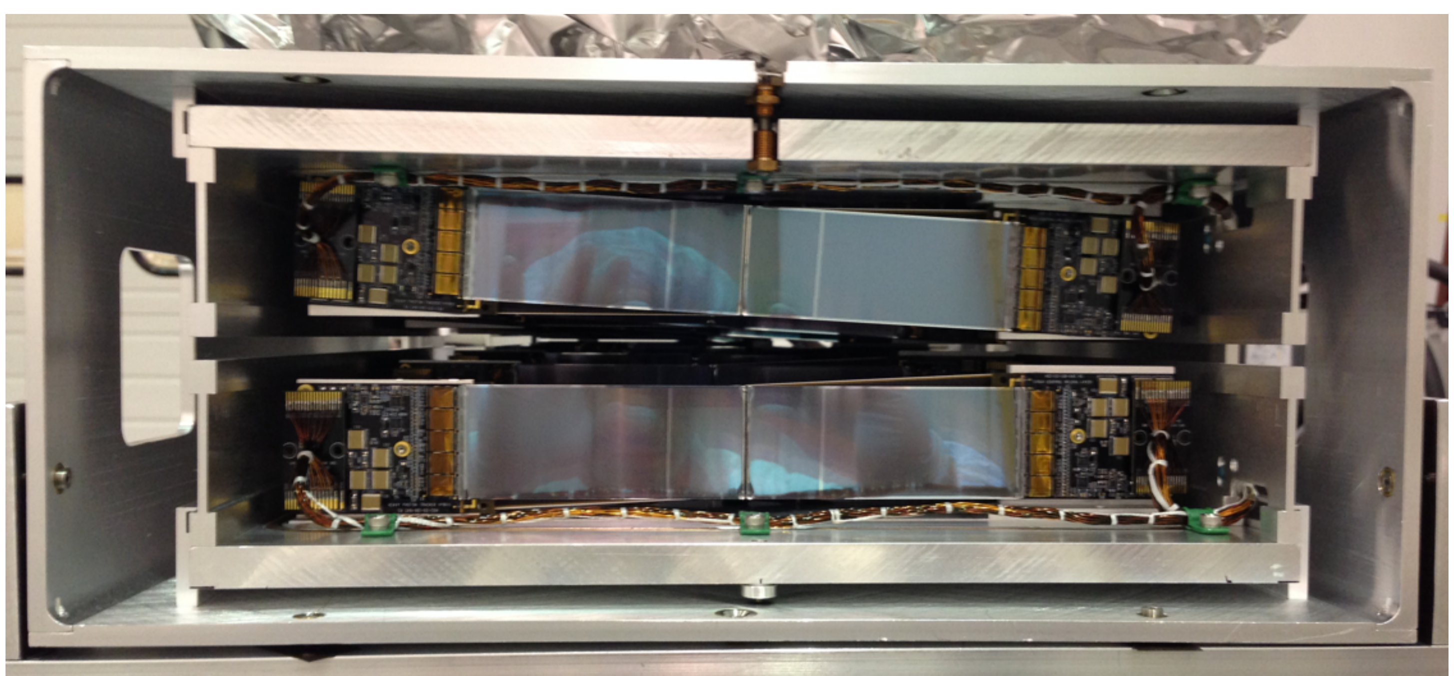


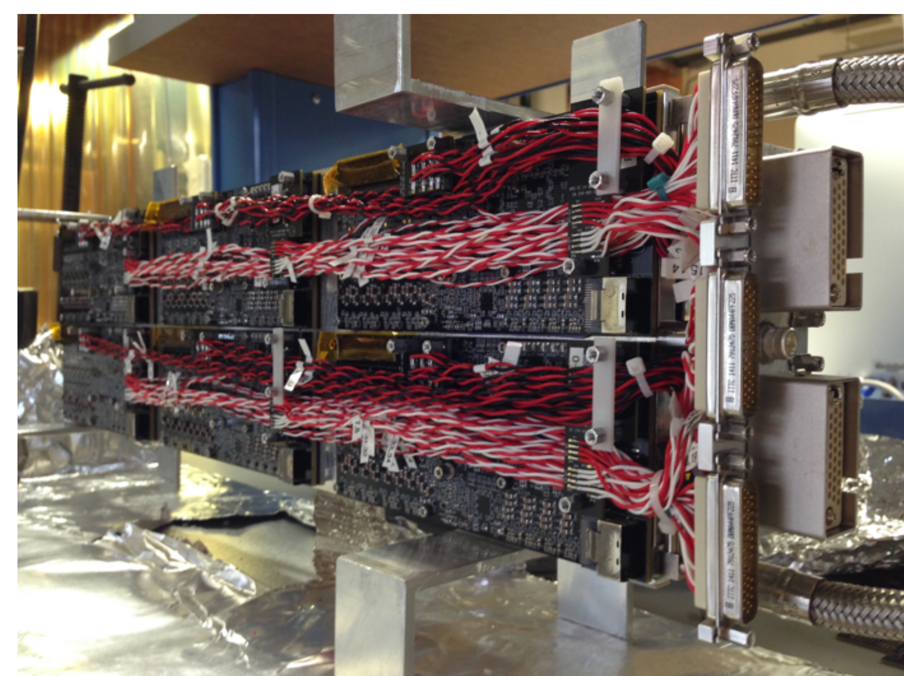
SVT Re-assembly at JLab



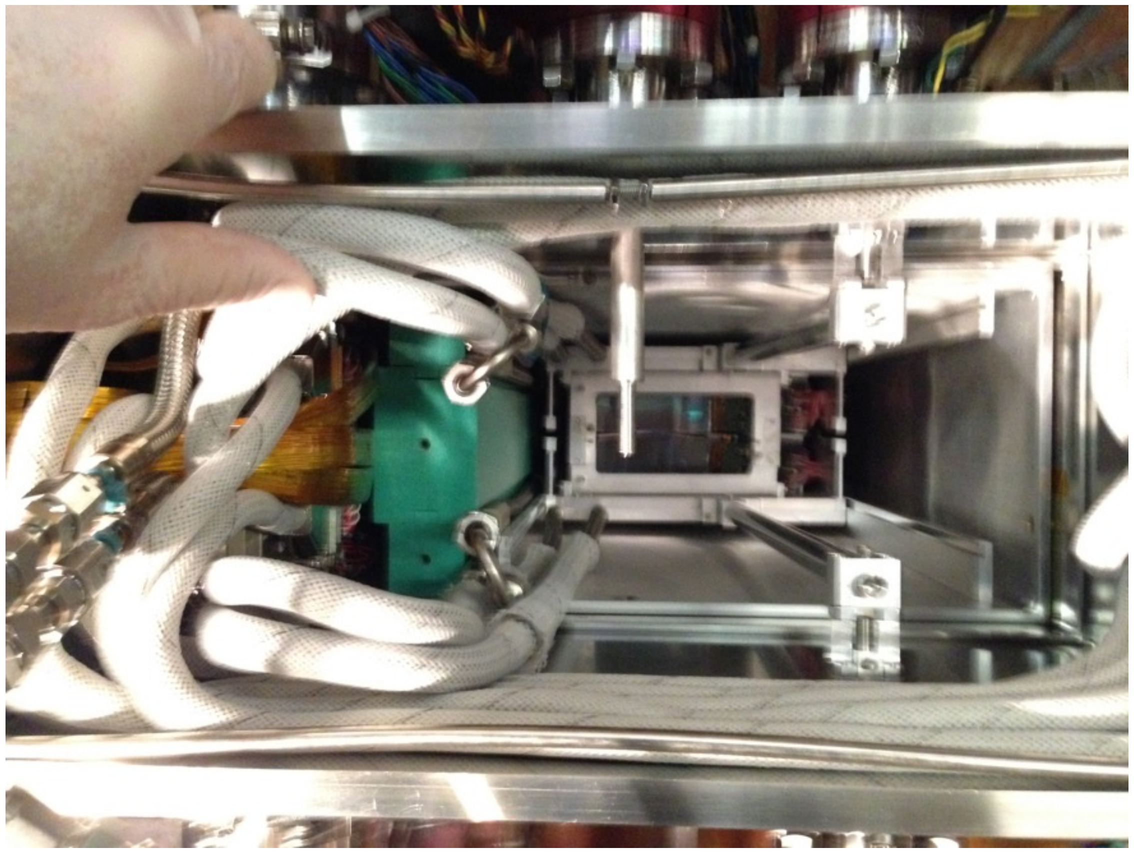


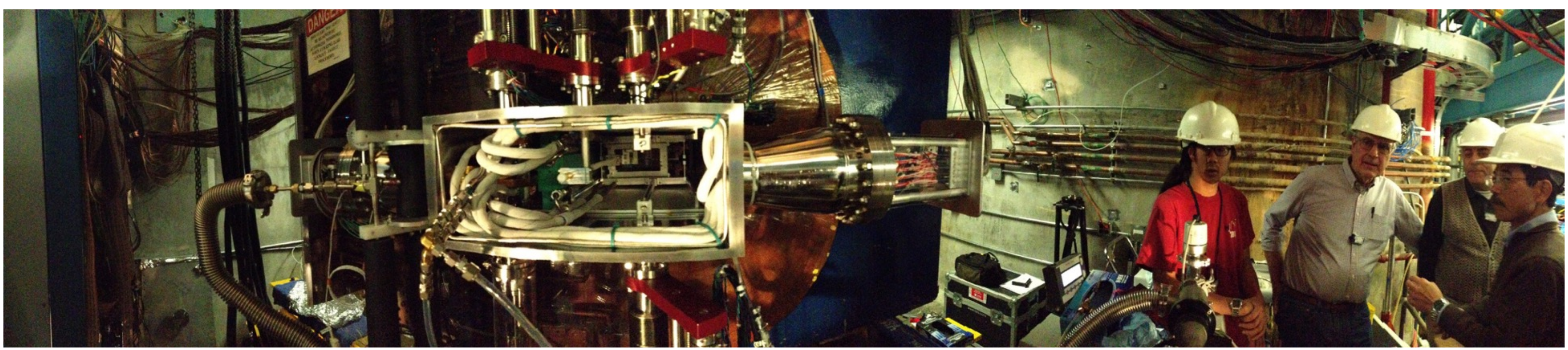
SVT is assembled to within precision of survey (75 μm).



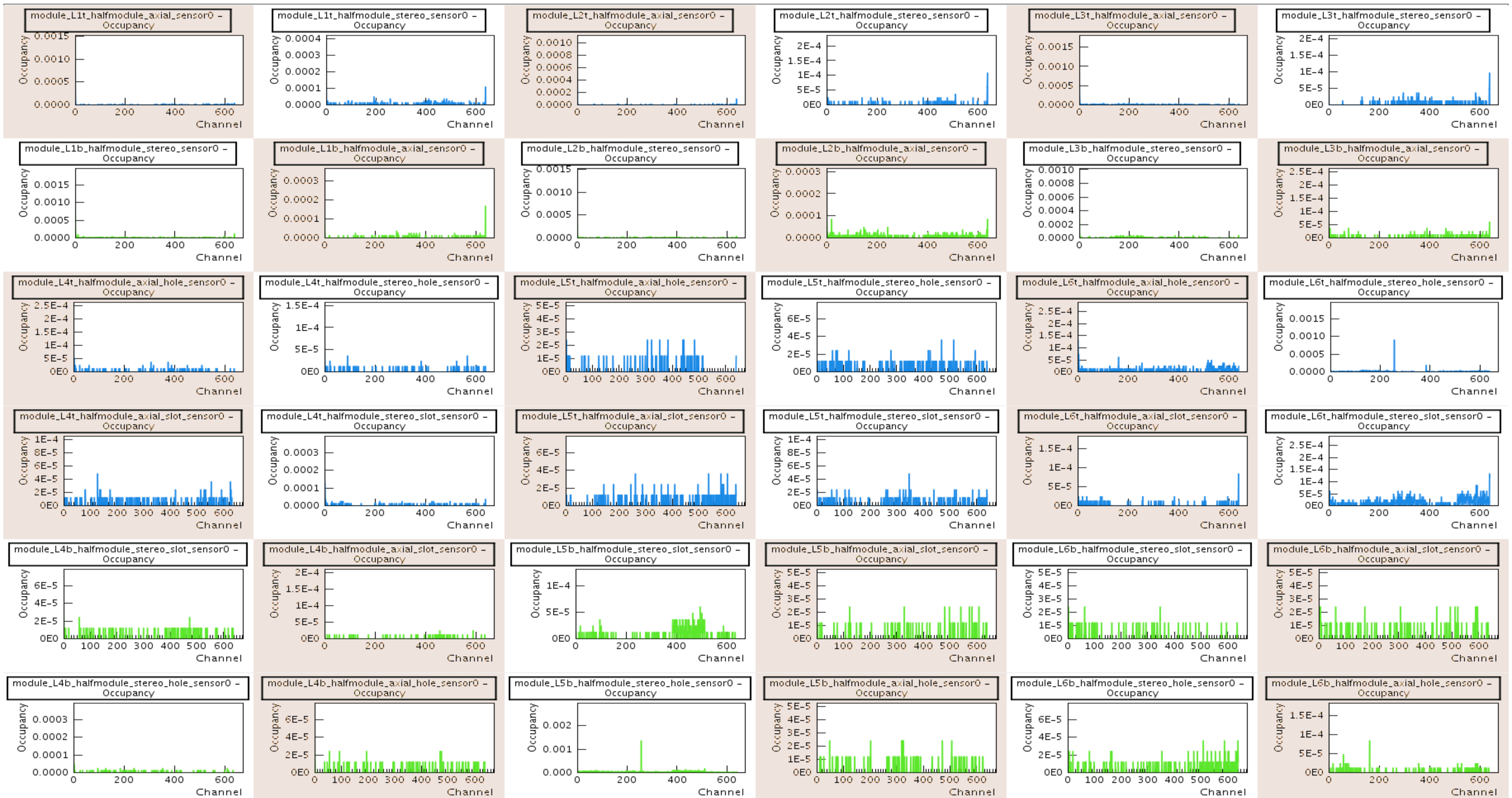


HPS SVT Installation



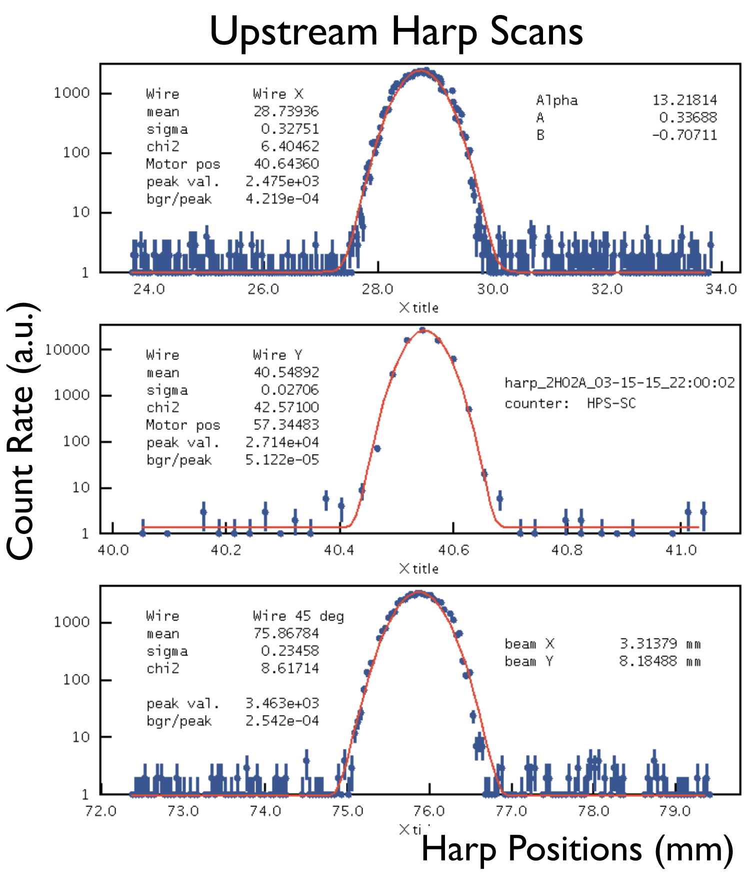


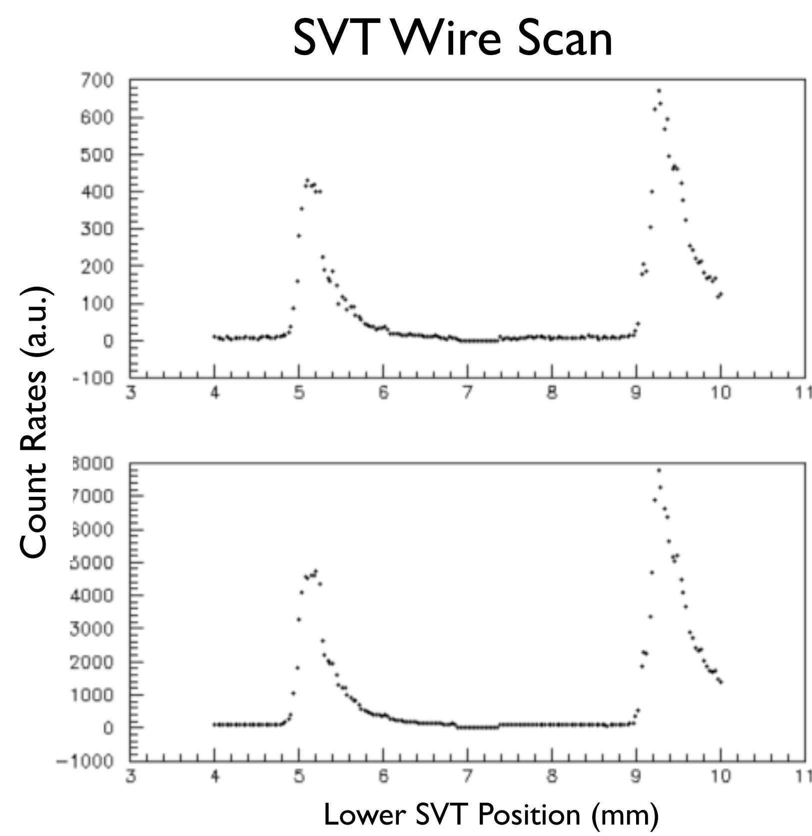
HPS SVT Testing and Commissioning

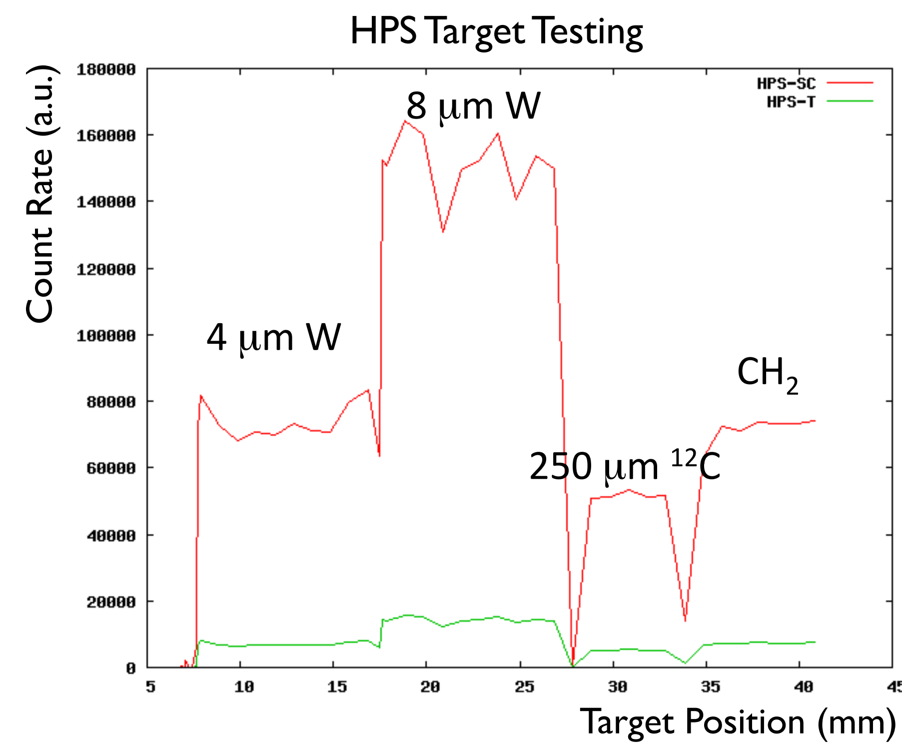


Four of 23004 channels are bad. A few more have noise occupancy above 10^{-4}.

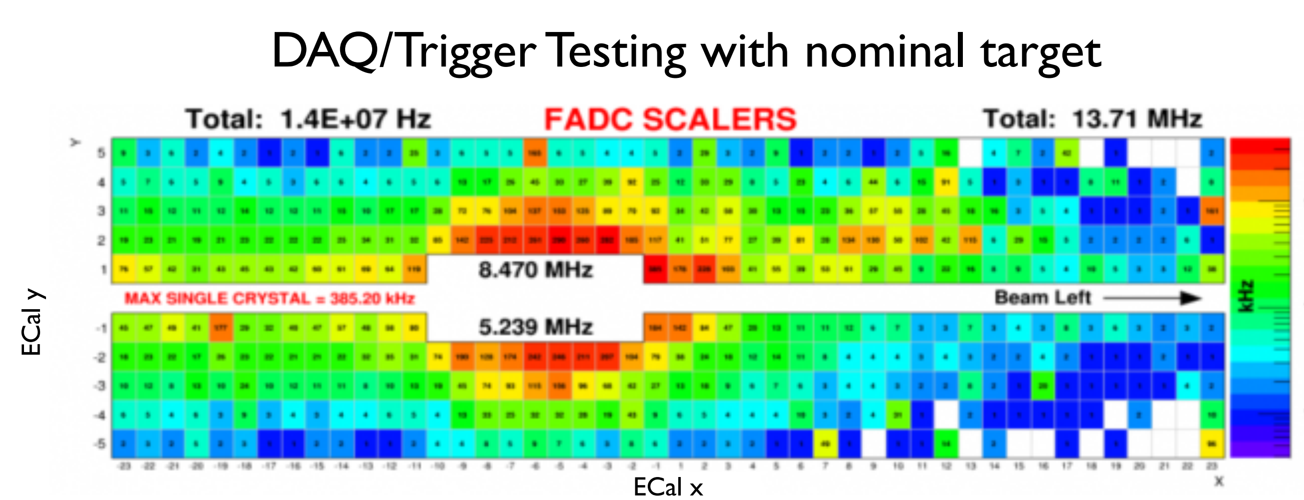
Spring 2015 Engineering Run







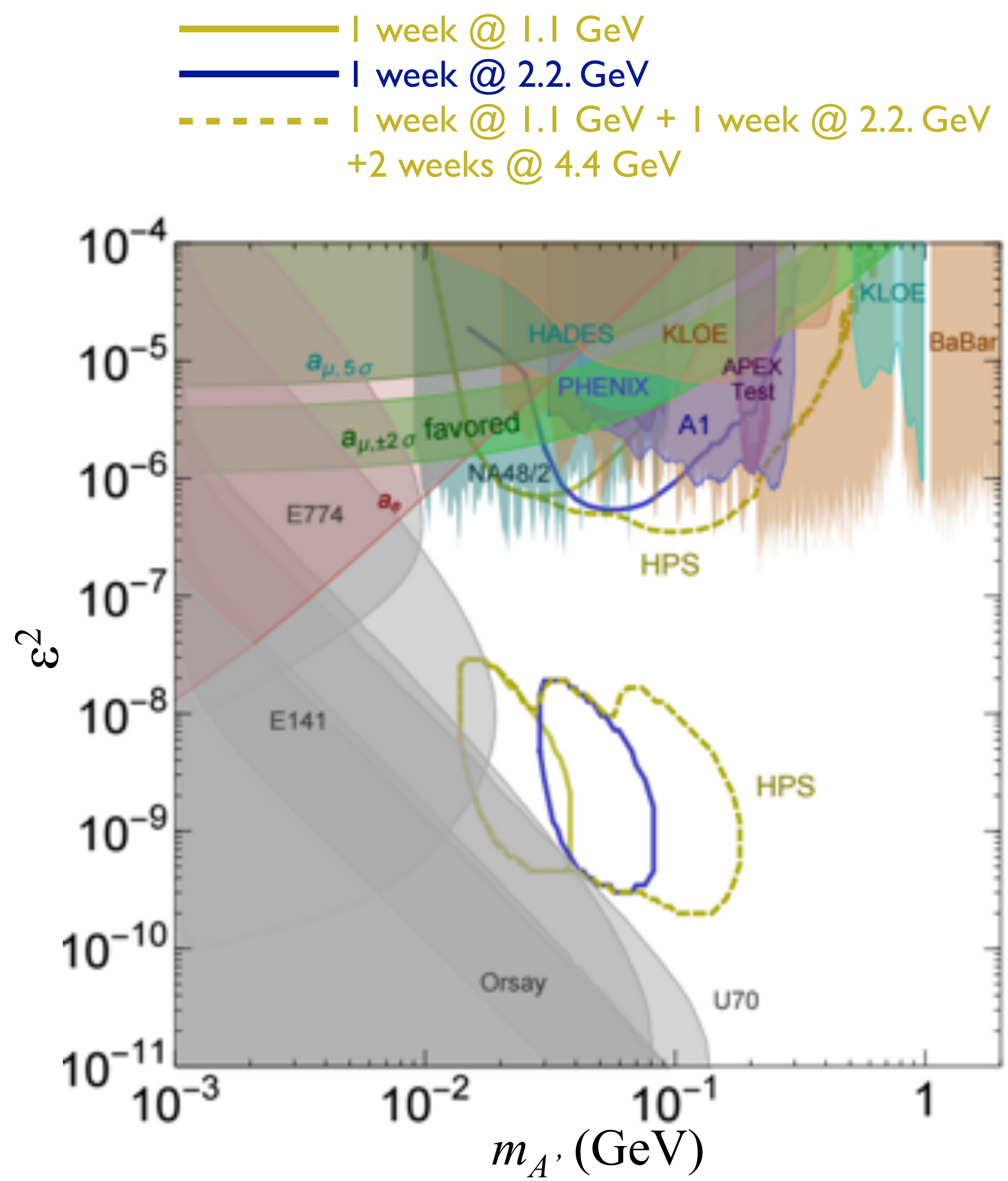
- March largely consumed by commissioning beam for HPS. Wire scans and target testing successful.
- Testing and re-commissioning of ECal trigger and DAQ with HPS target successful
- SVT DAQ commissioning without beam complete. *At 3/26 SVT meeting: "Let's turn it on with beam!"*



Current Status

- Catastrophic failure of substation powering CEBAF on 3/25.
  One helium liquefier seriously damaged.
- Silver lining? CEBAF has restarted with only CHL2 running.
  - HPS will get 1.06 GeV beams.
  - 1 GeV running is simpler for both machine and HPS detector.
  - Covers unique territory, nearly impossible to arrange with CEBAF 12

Never a dull moment!



Future HPS Running

The official line:

- HPS is scheduled to get more running in Fall 2015, thanks to strong support of JLab management.
- HPS is eager for additional running in FY2016. However, time in Hall B must be shared with magnet construction and commissioning for the CLAS12 Detector over the next year.
- HPS running in Spring 2016 is currently TBD, pending demonstration of HPS operation and a better understanding of demands on Hall B resources.
- HPS must be prepared to take advantage of additional running, so besides analysis of the 2015 data, we are planning to staff shifts, operate the experiment, and analyze data through FY2016.
- In the longer term, HPS expects to run at higher energies in FY2017 and beyond.

Summary

- HPS Test Run is a closed book: http://arxiv.org/abs/1406.6115v2
- Full HPS detector is complete, installed and ready to run
- HPS beamline, ECal and trigger are now well-sorted after lessons of commissioning run in late 2014.
- SVT installation went smoothly and the detector looks great.
- Things have not been so smooth with beam this spring, but we are up and running again at 1 GeV (knock wood).
- Exciting times ahead for HPS as we open up new terrain in the search for dark photons over the next few years.
- no shortage of ideas for what comes next…

Beyond HPS

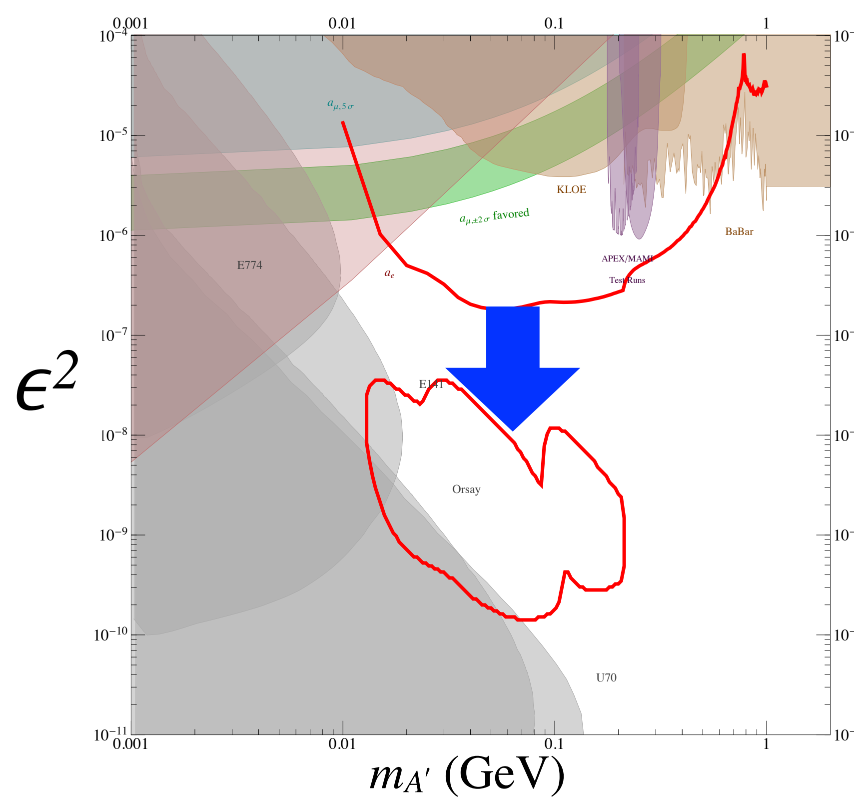
Extending high-coupling reach:

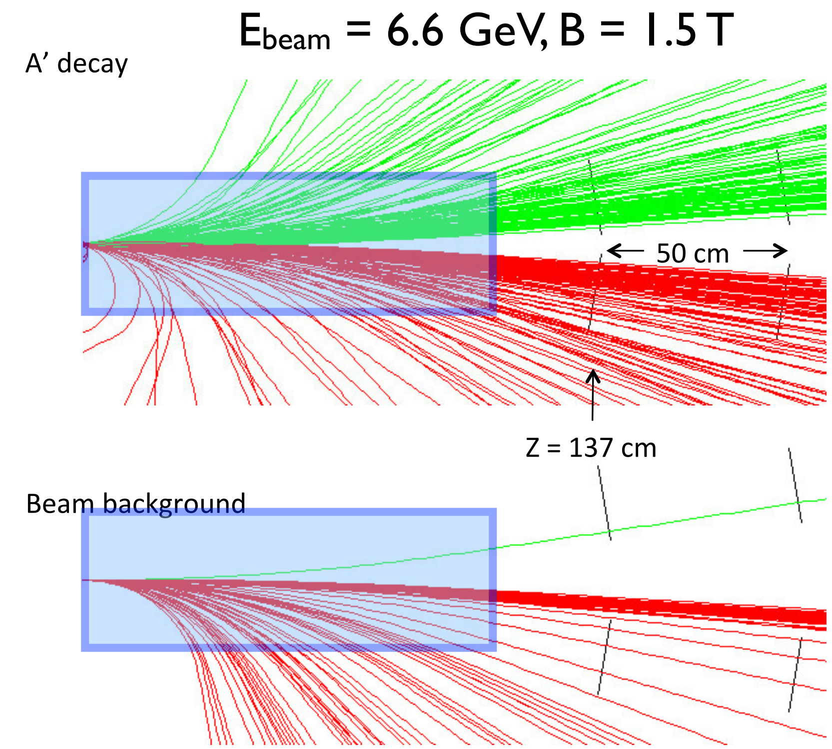
- 2-3 orders of magnitude more data: more time won't work

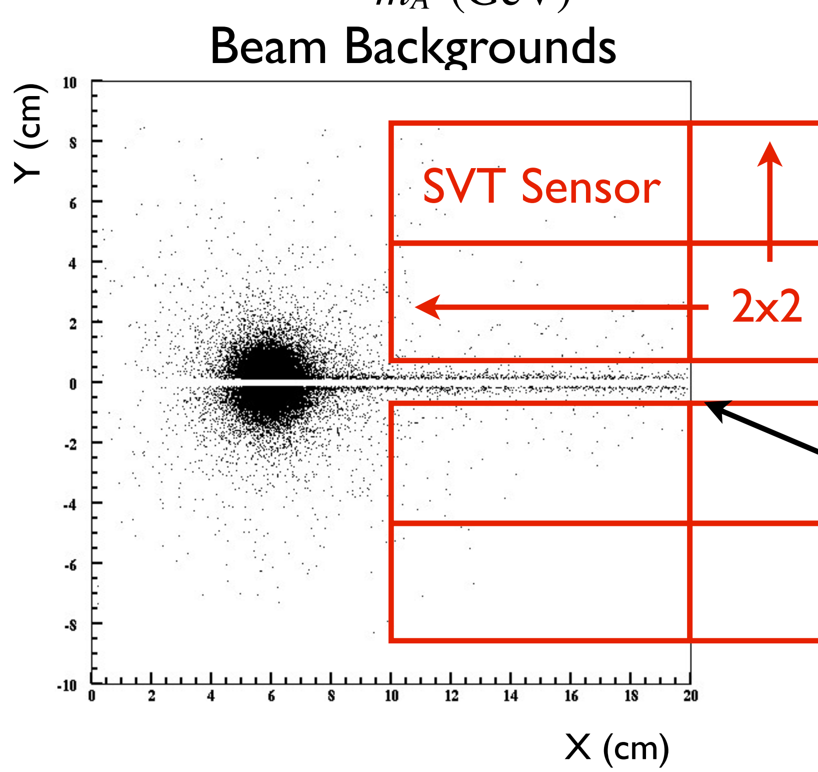
➡ More luminosity×acceptance

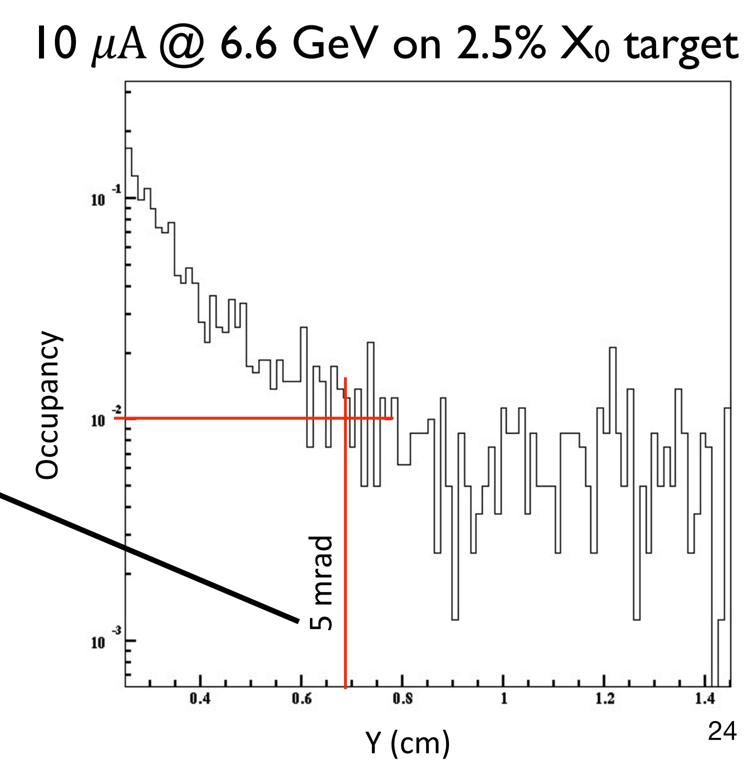
Two-armed HPS downstream of existing dipole?

- A high-rate, high acceptance version of APEX
- Capable of ~200× luminosity of HPS
- Dead zone reduced to 5 mr: better low mass acceptance than HPS (but no vertexing) with modest loss at high mass

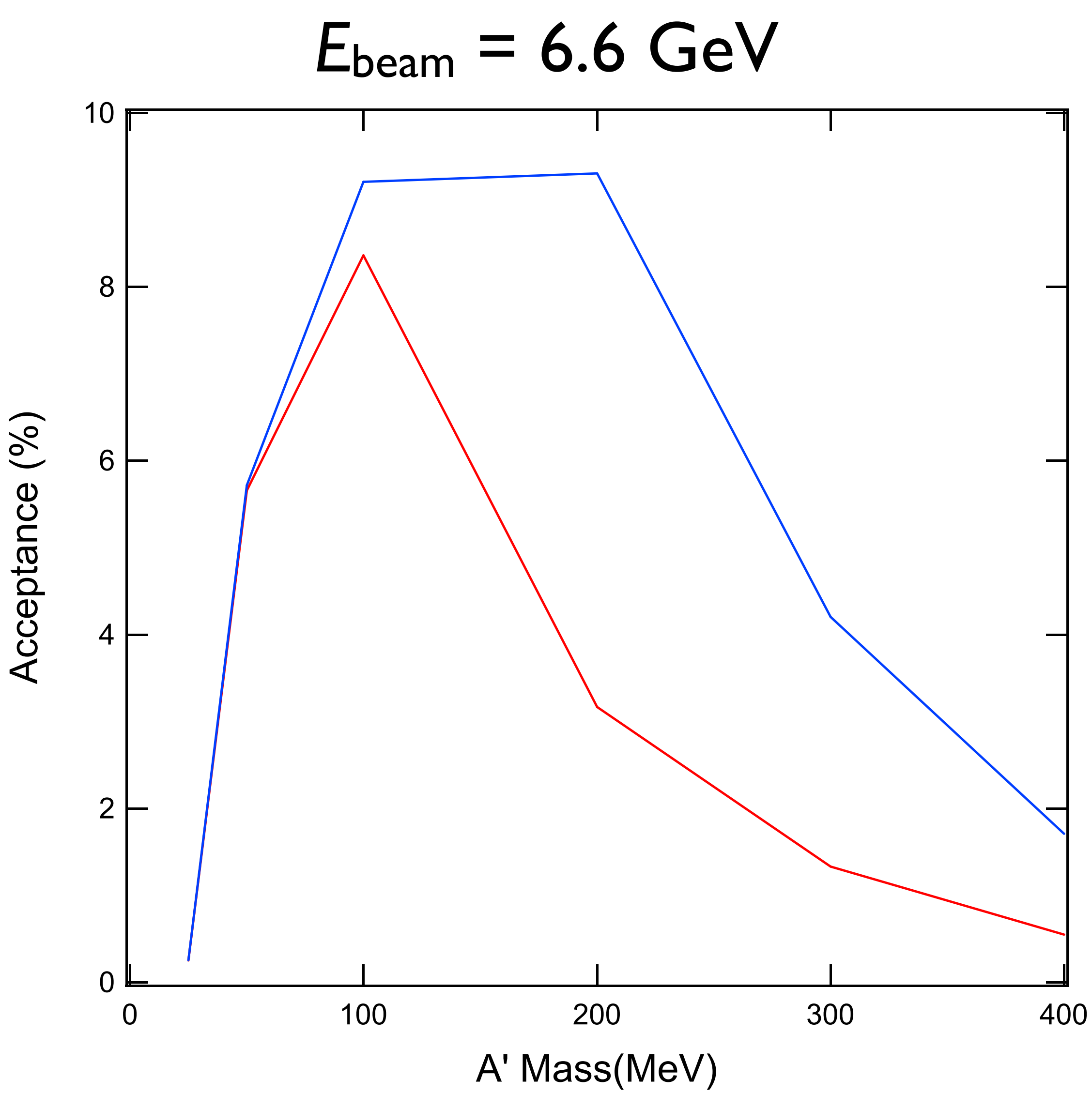








Two-armed HPS Reach



15 days, 6.6 GeV 10 μA w/ 2.5% X_0 target