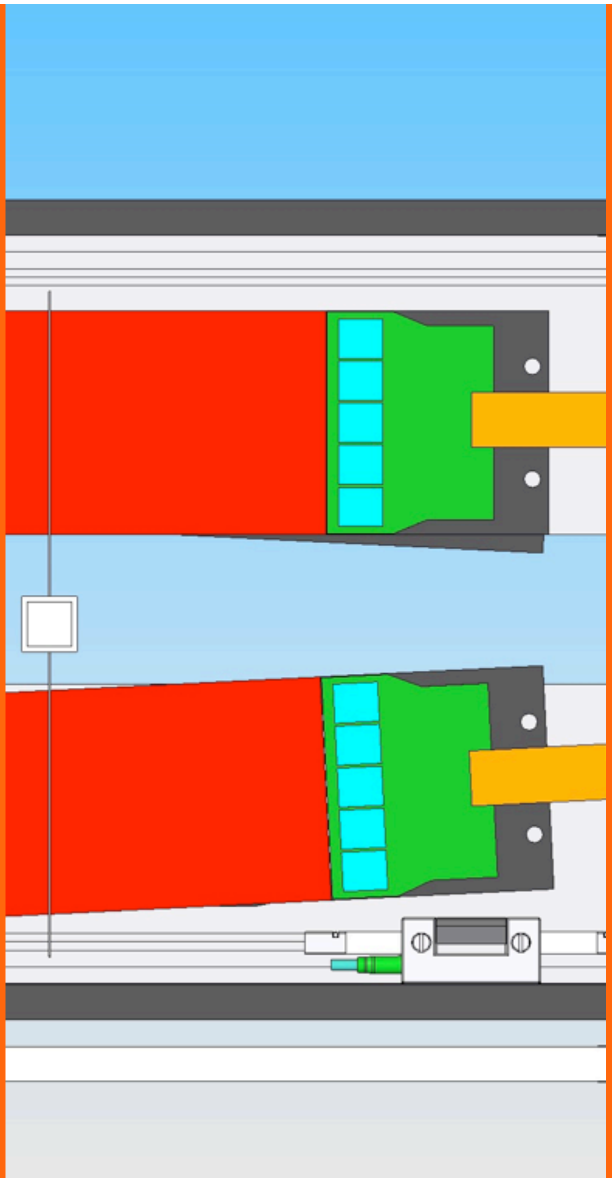
HPS *Test Run*

Tracking and Vertexing



Tim Nelson - SLAC

HPS Collaboration Meeting - JLab

5/26/2011

HPS Tracking Group

	Personnel	**Critical Expertise**	**Key Resources**
SLAC	Nelson Oriunno Haller/Herbst Partridge Graham + students, technicians	silicon tracking, radiation-tolerant silicon design, silicon operation in vacuum, low-noise electronics, high-speed DAQ, analysis techniques	Silicon cleanroom including probe station, multi-sensor CMM, assembly space, DAQ space, laser test setup
UCSC	Grillo Fadeyev + students, technicians	radiation-tolerant silcion design, low-noise electronics, DAQ, wirebonding, sensors	Silicon lab including probe station, wirebonder, space for DAQ
FNAL	Cooper + technicians	Run IIb sensors, composite design and fabrication, cooling	*SiDet*, composites lab

Test Run Objective

To ensure that the HPS tracker concept has no critical faults

- technical (e.g. operation in vacuum, adjacent to beam, etc.)
- physics environment (e.g. occupancies from primaries and secondaries)

➡ Operation of a few tracker planes in the most challenging conditions proposed for the full experiment will address these issues

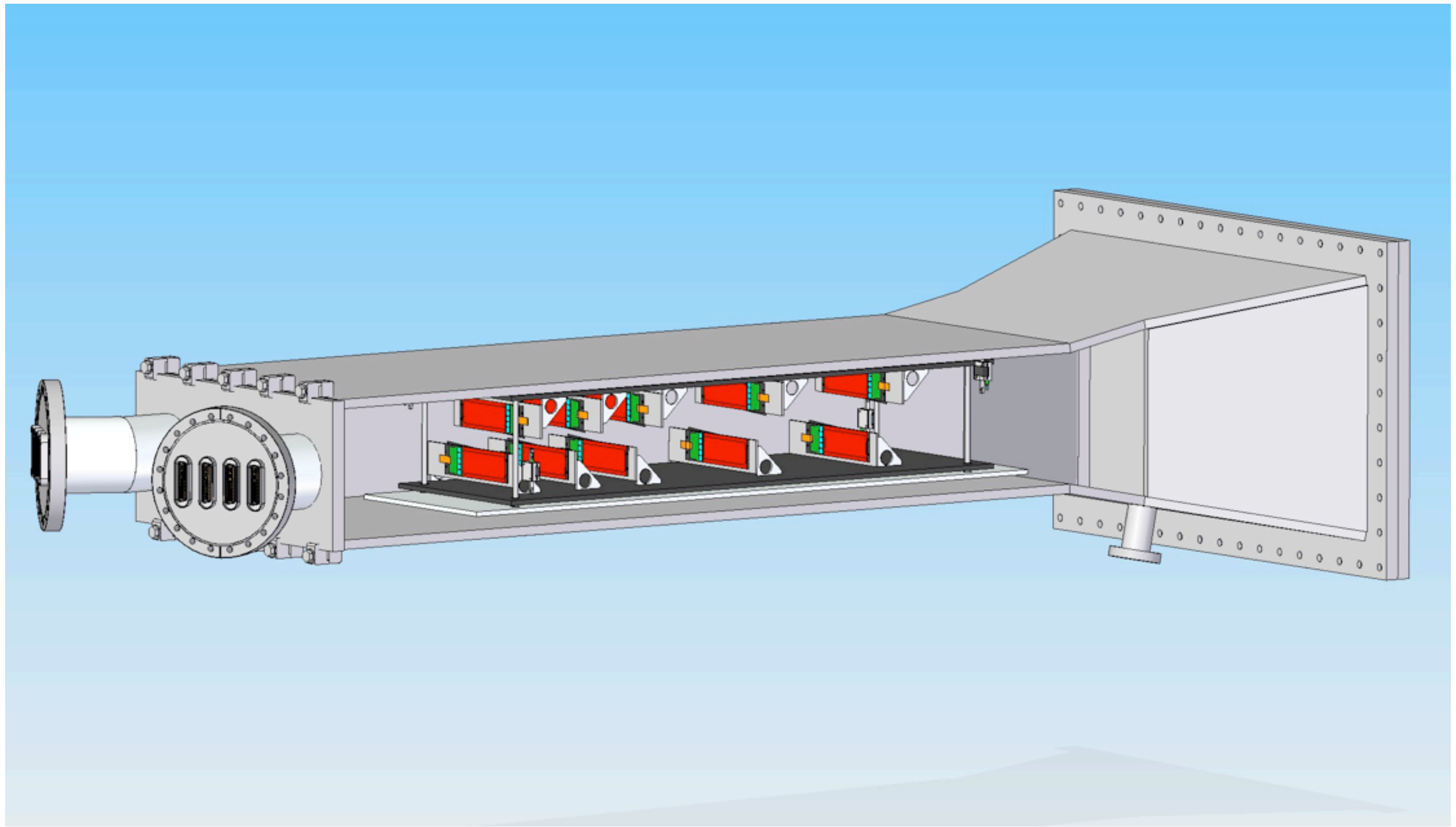
Sensitivity to physics* in the test run requires some additional work (and luck), but *naturally promotes these objectives

Challenges

- At relevant beam energies and interesting A′ masses, decay products tend to be electrons with momenta order a few GeV. Multiple scattering...
  - dominates both mass and vertexing measurement errors
  - leads to pattern recognition mistakes in dense environments
- Proximity to target means primary beam must pass through apparatus.
  - scattered beam sweeps out a "dead zone" of extreme occupancy and radiation, compounded by beam-gas interactions
  - puts low-mass acceptance in opposition to longevity and tracking purity
- Long-lived A′ signal very small: vertexing must be exceedingly pure to eliminate fakes.
- Small experiment on a hot topic: time and money are precious.

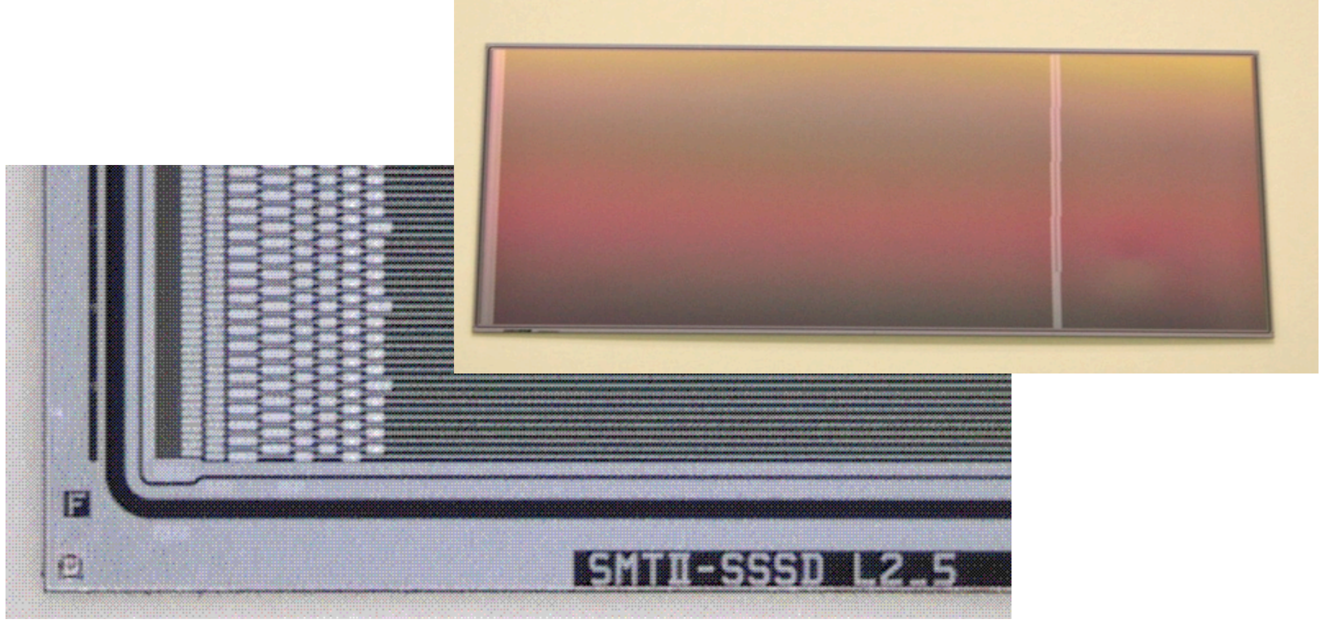
Challenges ⇒ Design Principles

- Mass and vertex resolution
  - low-mass construction
- Occupancies and radiation
  - fast, robust sensors / readout
  - movability / replaceability
  - operation in vacuum
- Acceptance/Purity
  - optimized sensor layout
- Schedule/Budget sensitivity
  - reuse and recycle



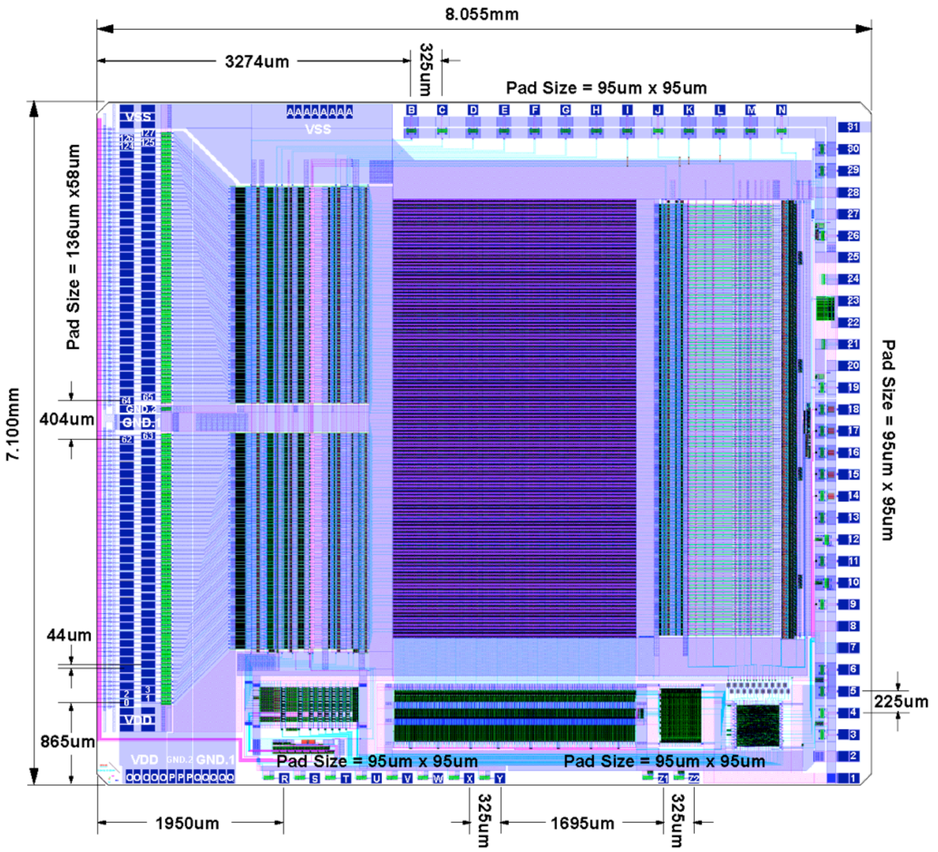
Sensors

- pixels too massive, costly, complex: microstrips are the simple, lightweight solution
- Production Tevatron RunIIb sensors
  - many capable of 1000V bias: fully depleted to $> 4\times10^{15}$ e^{-}/cm^{2}
  - Fine readout granularity
  - Available in sufficient quantity



Cut Dimensions (L×W)	100 mm × 40.34mm
Active Area (L×W)	98.33 mm × 38.34mm
Readout (Sense) Pitch	60µm (30µm)
# Readout (Sense) Strips	639 (1277)
Breakdown Voltage	>350V
Total Interstrip Capacitance	<1.2 pF/cm
Defective Channels	<1%

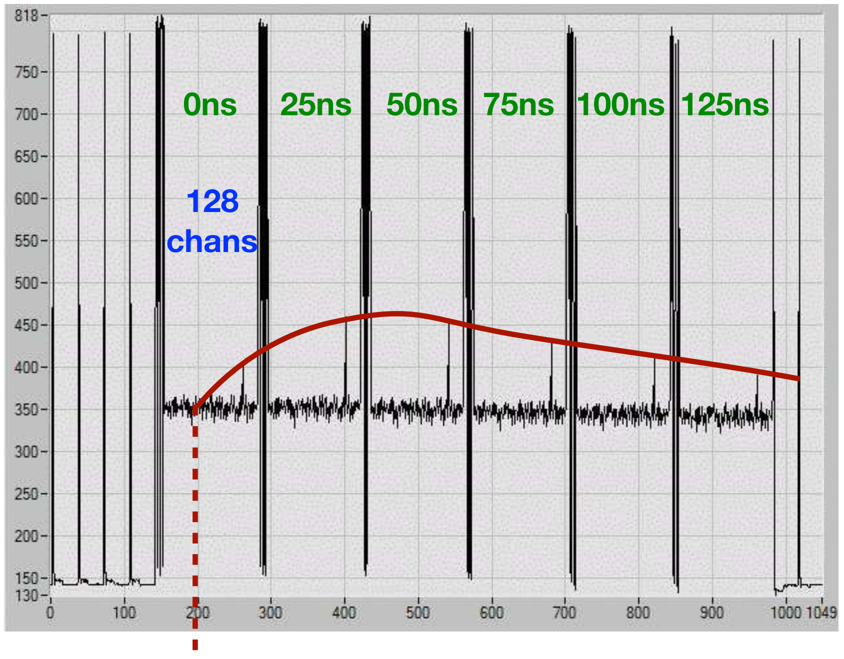
Readout ASIC: APV25

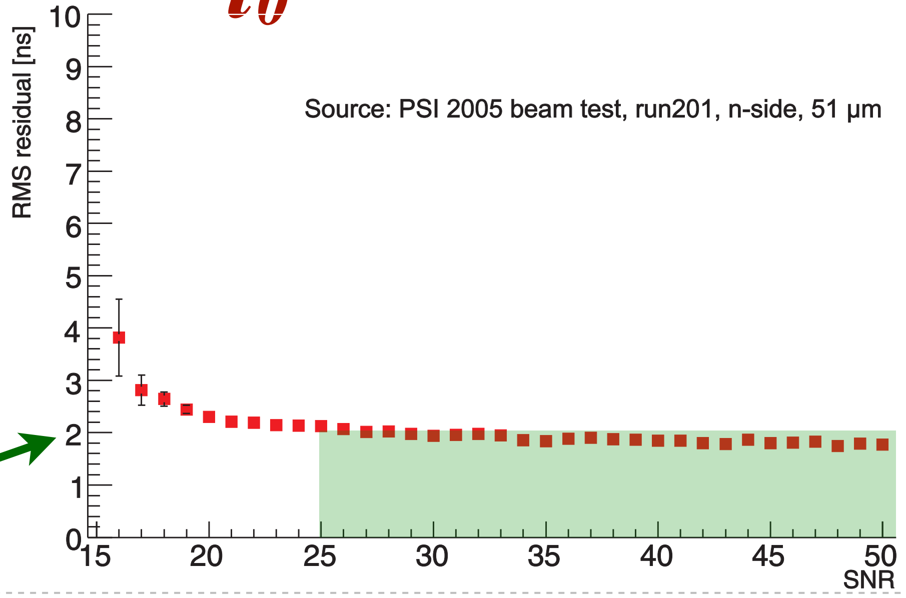


# Readout Channels	128
Input Pitch	44 µm
Shaping Time	50ns nom. (35ns min.)
Noise Performance	270+36×C(pF) e^- ENC
Power Consumption	345 mW

Developed for CMS

- readily available
- radiation tolerant
- low noise: S/N = 34
- 2 ns t_0 resolution

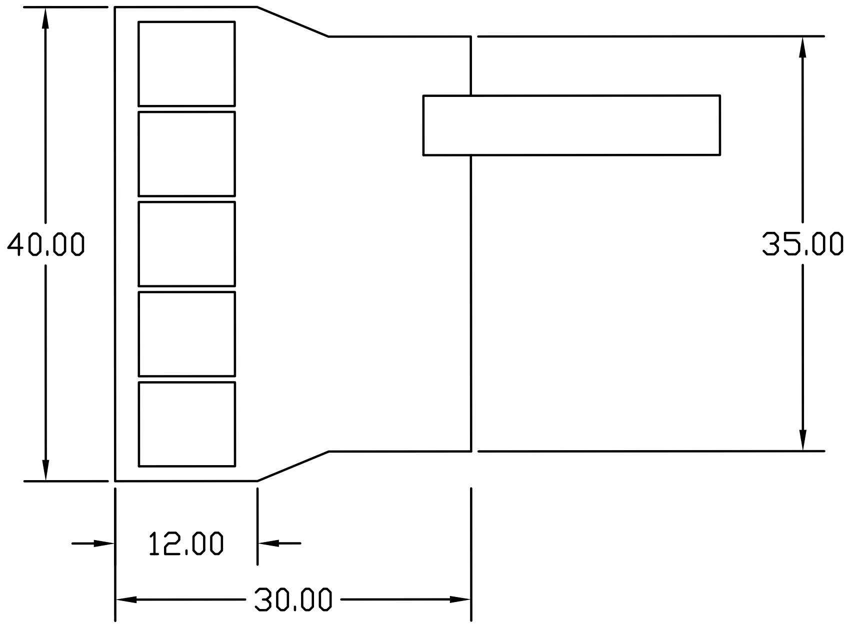


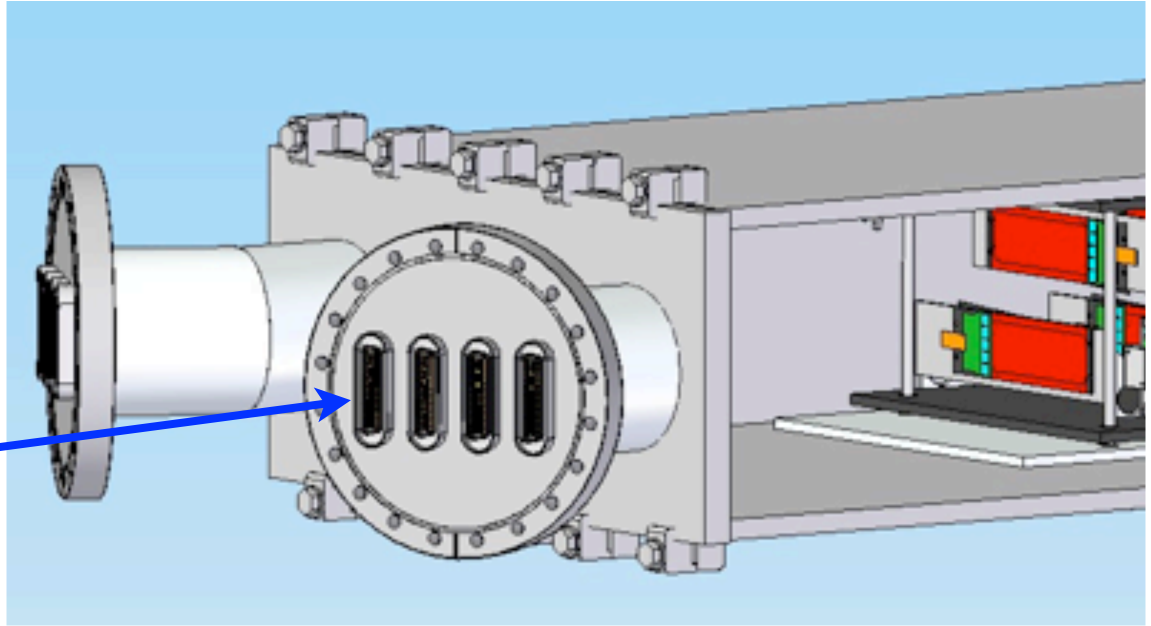


Source: PSI 2005 beam test, run201, n-side, 51 µm

DAQ: APV25 Hybrids

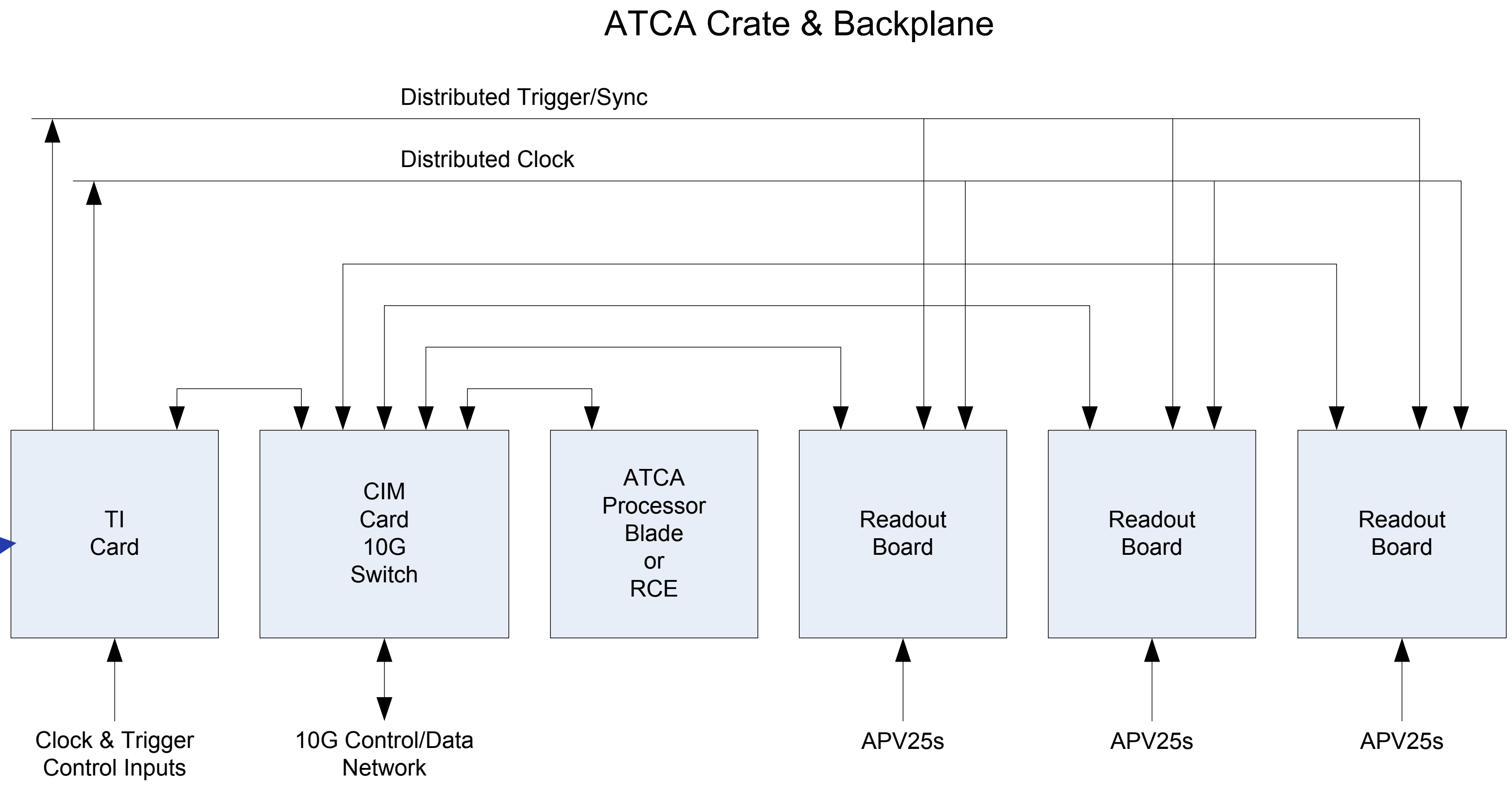
- Hybrid design derived from CMS schematics
- Layout is similar to CMS TIB hybrids (but with 5 chips instead of 4)
- Cooling design allows use of FR4 or kapton for substrates
- Similarity of sensor and hybrid pitches eliminates necessity for pitch adapters
- Short kapton pigtails on hybrids connect to extension cables to vacuum flanges





DAQ: ATCA

- Entire DAQ is only a few cards in a single crate
- Readout boards based on ATCA architecture, standard at SLAC
- Trigger Interface (TI) is key to integrating SVT DAQ (SLAC ATCA) with ECal DAQ (JLab VME)



ATCA Crate & Backplane

Distributed Trigger/Sync

Distributed Clock

TI Card

CIM Card 10G Switch

ATCA Processor Blade or RCE

Readout Board

Readout Board

Readout Board

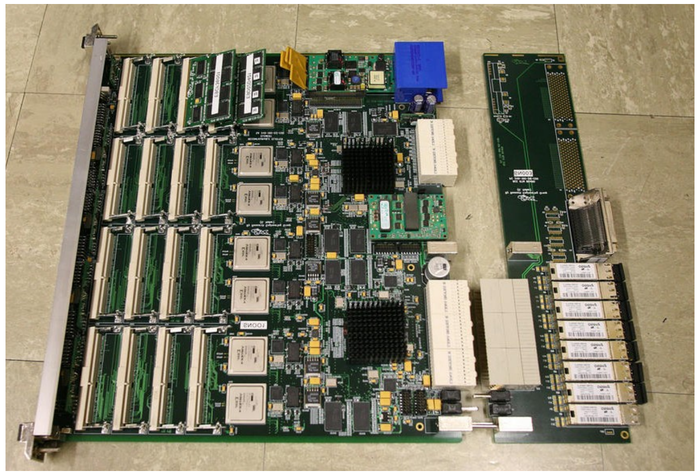
Clock & Trigger Control Inputs

10G Control/Data Network

APV25s

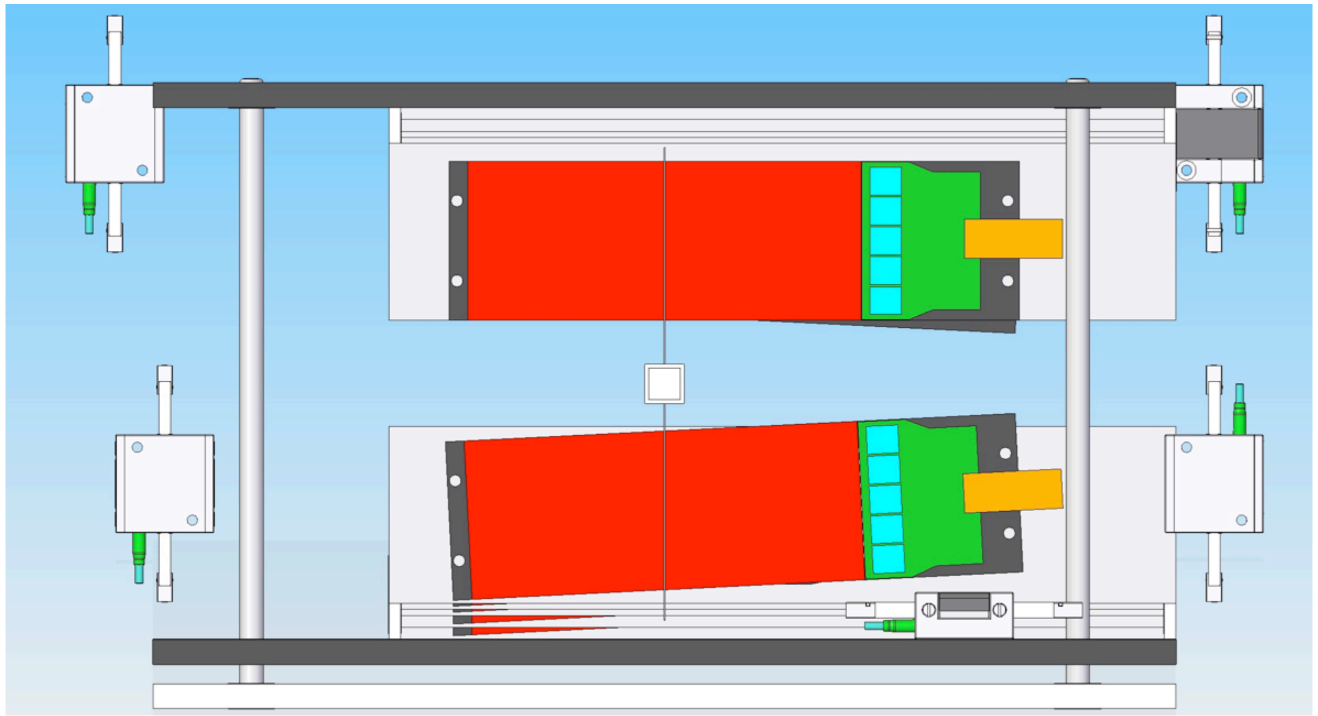
APV25s

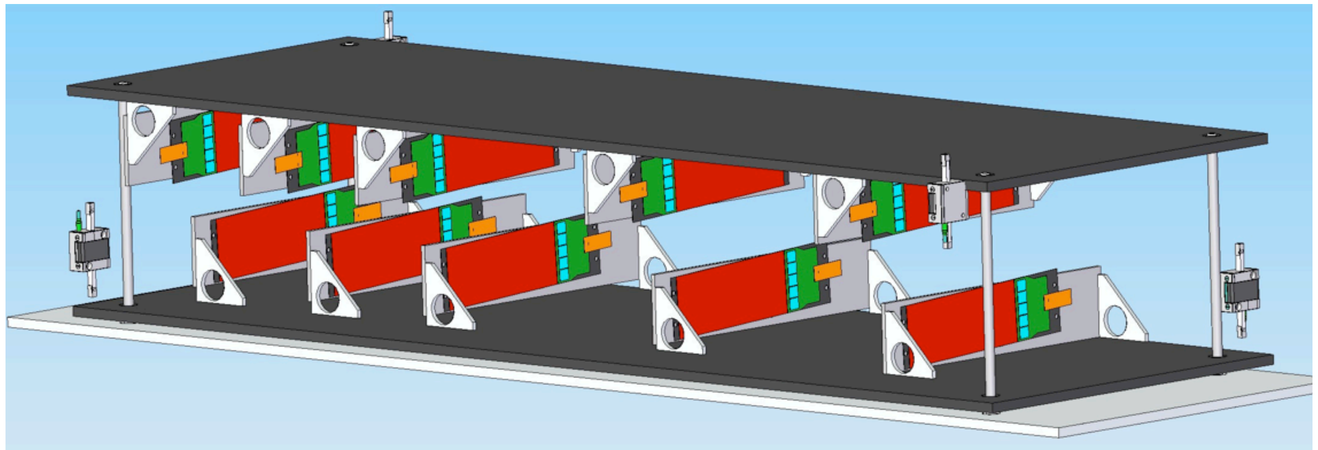
APV25s



Support and Cooling

- CF-composite/rohacell-foam modules
  - 1.0% X_0/layer
  - material dominated by Si
- H_20/glycol at -10°C
  - outside tracking volume
  - vacuum minimizes heat load on sensors
- Modules mount on Al support plates
  - support plates travel on vertical rails
  - z-stages at both ends adjust dead zone
  - base plate slides into vacuum chamber

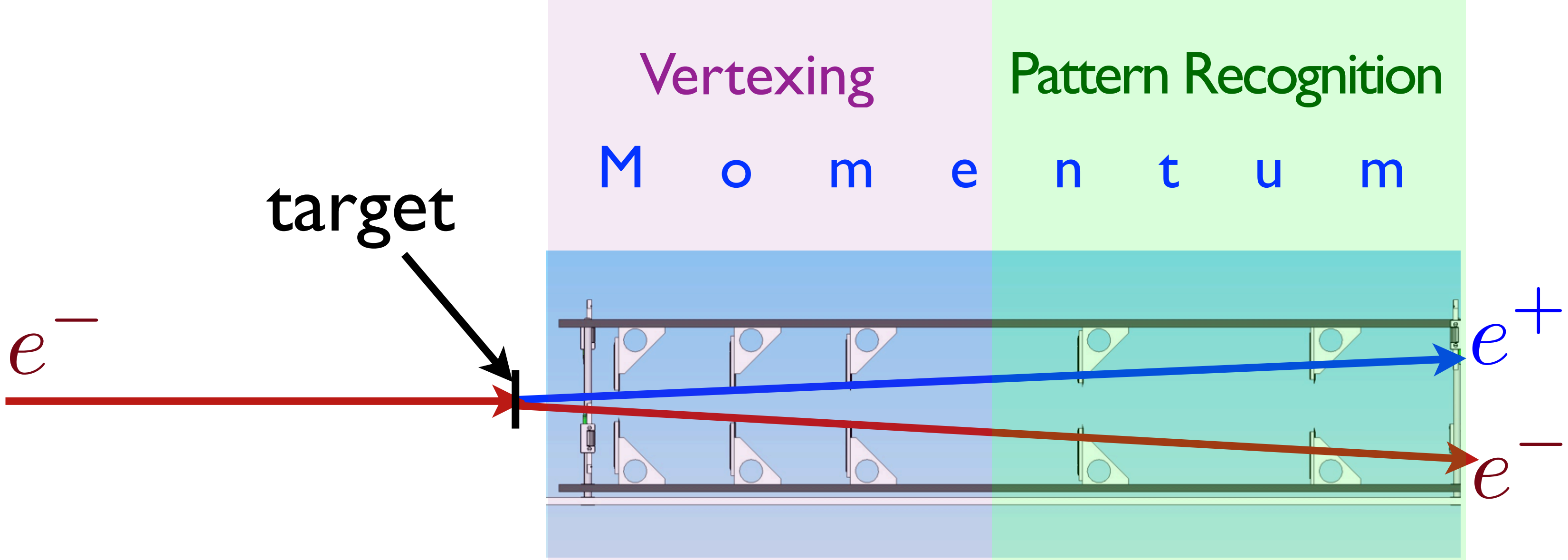




Detector Layout

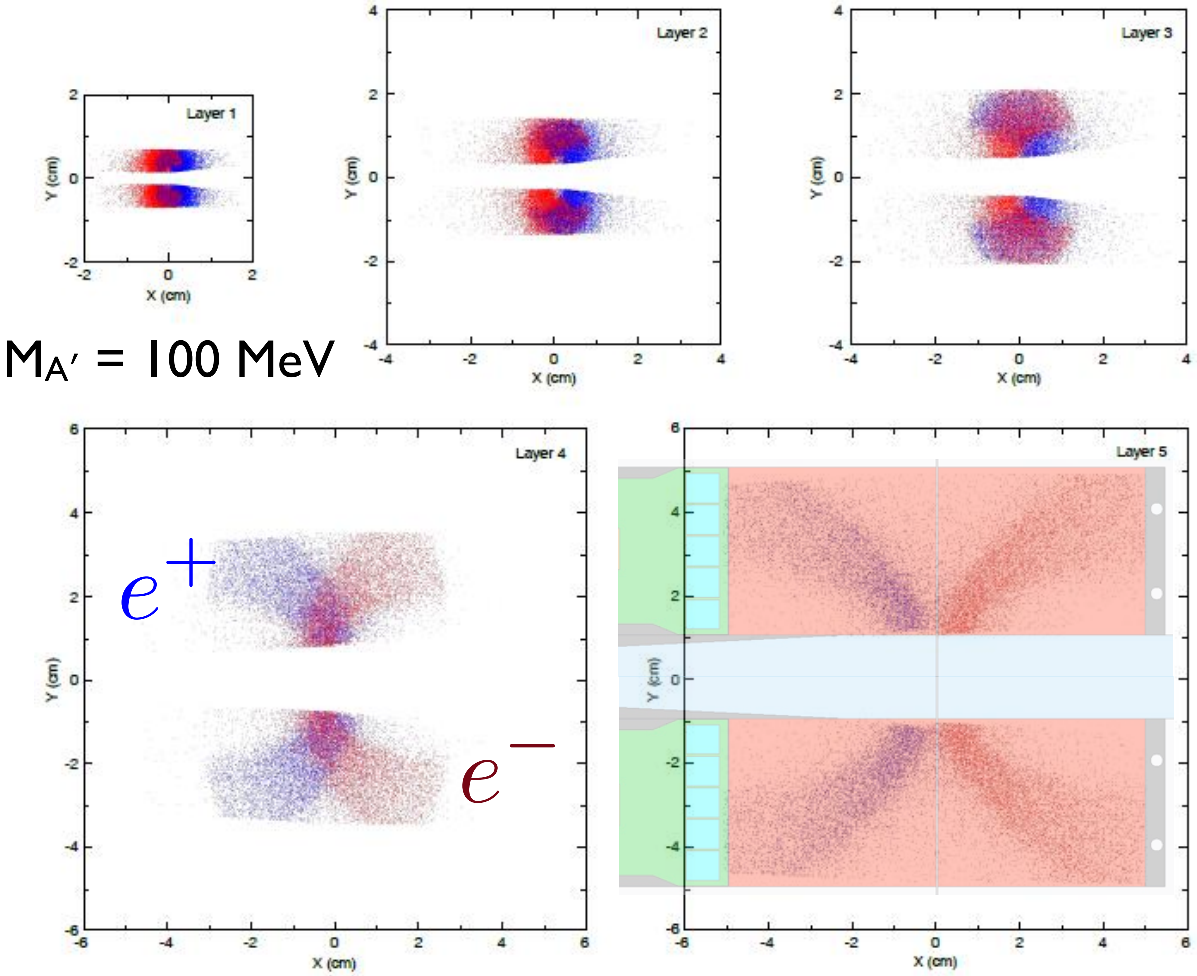
- Layers 1-3: vertexing
- Layers 4-5: pattern recognition with adequate pointing into Layer 3.
- Bend plane measurement in all layers: momentum
- 20 sensors/hybrids
- 100 APV25 chips
- 12780 channels

	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5
z position, from target (cm)	10	20	30	50	70
Stereo Angle	100 mrad	100 mrad	100 mrad	50 mrad	50 mrad
Bend Plane Resolution (µm)	≈ 60	≈ 60	≈ 60	≈ 120	≈ 120
Non-Bend Resolution (µm)	≈ 6	≈ 6	≈ 6	≈ 6	≈ 6
# Bend Plane Sensors	2	2	2	2	2
# Stereo Sensors	2	2	2	2	2
Dead Zone (mm)	±1.5	±3.0	±4.5	±7.5	±10.5
Power Consumption (W)	7	7	7	7	7

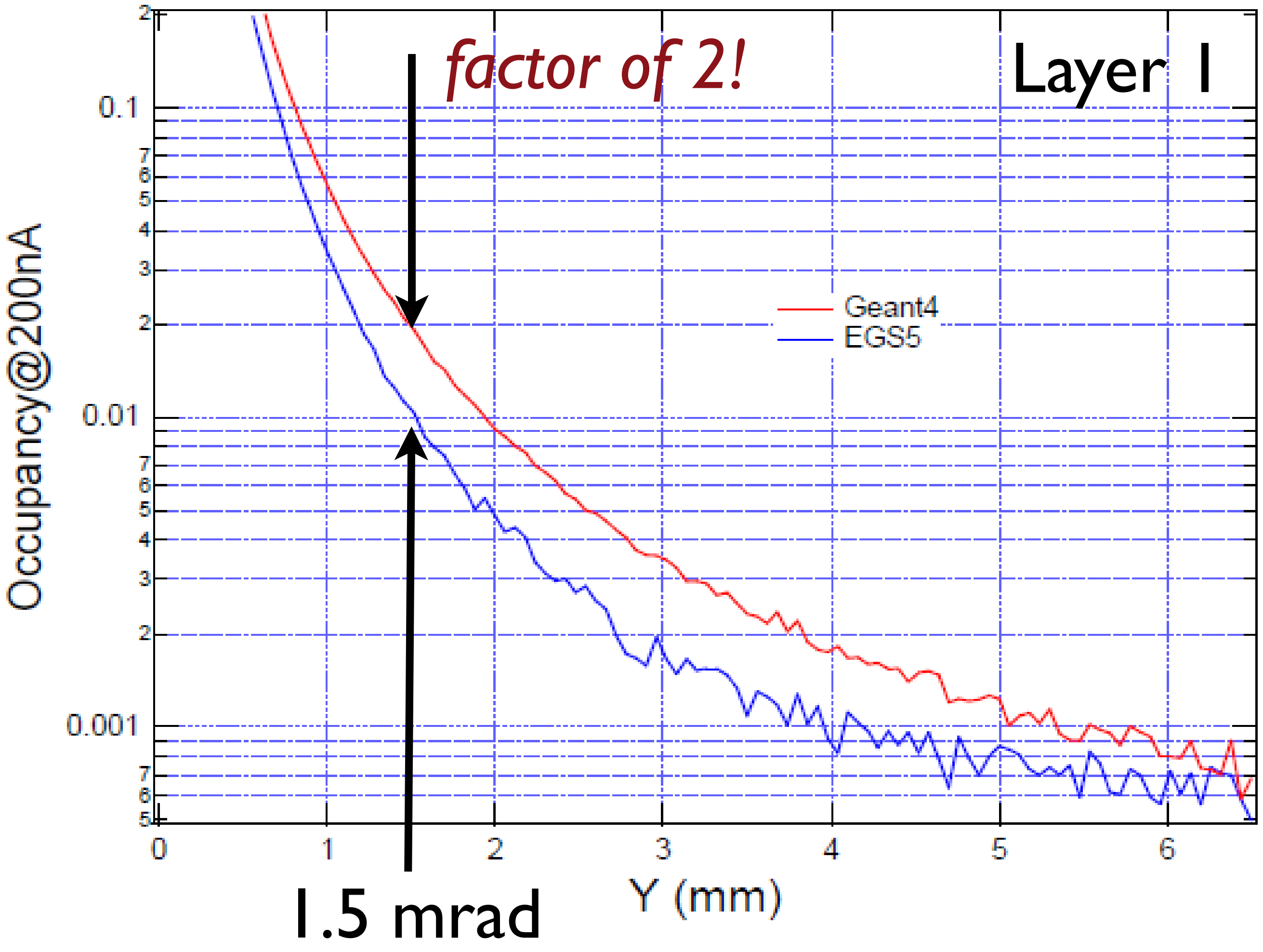


Dead Zone

Size of dead zone determines low-mass acceptance: nominally 1.5 mrad



$M_{A'}$ = 100 MeV



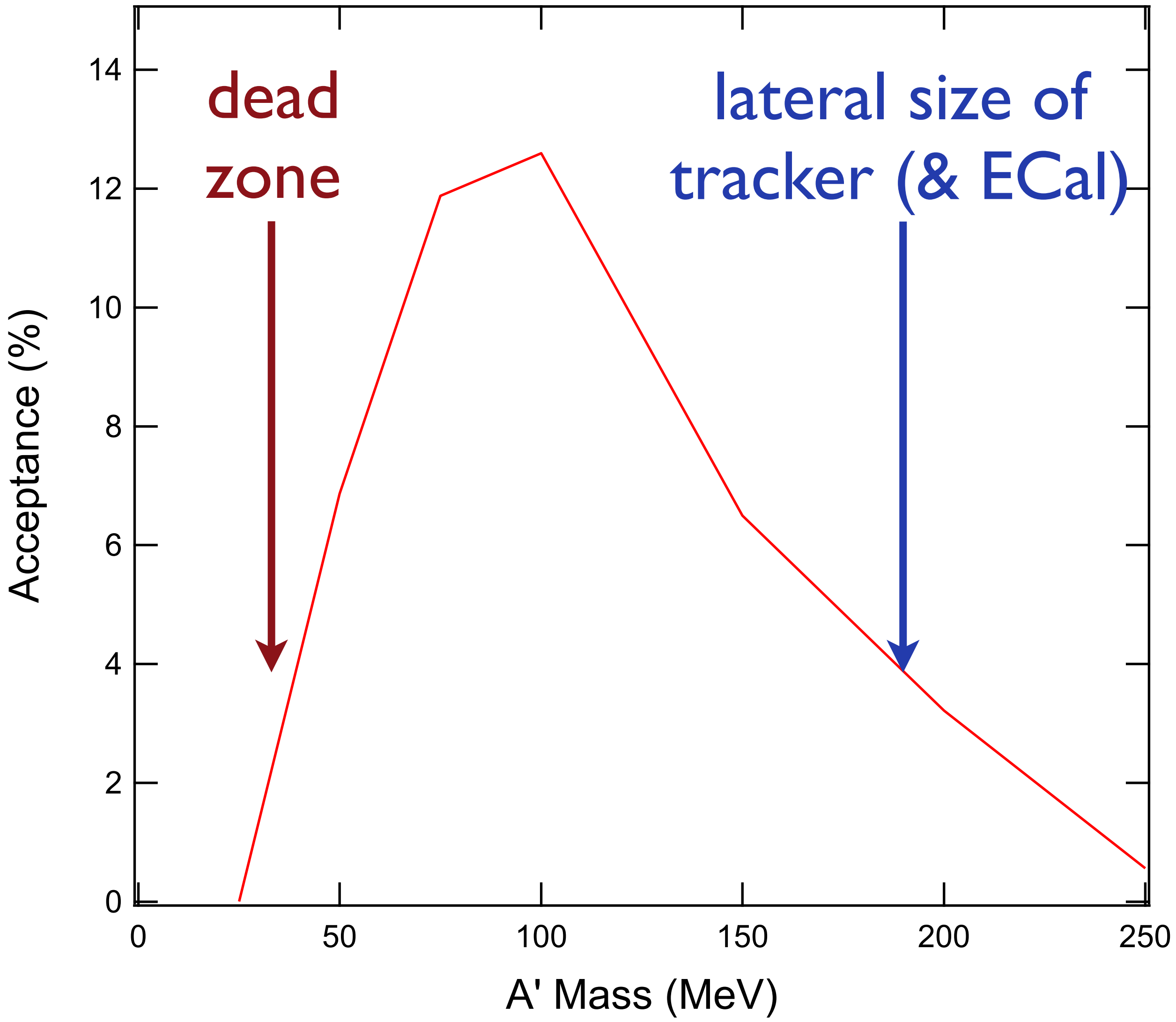
factor of 2!

1.5 mrad

Limited by acceptable occupancies and radiation dose: *very uncertain!*

Acceptance

- At smaller masses, dead-zone limits acceptance
- At larger masses, losses due to limited coverage in layers 4 and 5 become important.
- Effective solid angle of dead zone increases with increasing z-vertex position: correlation between mass and coupling in vertexing reach.



Many Details...

- Simulations and Performance - Matt Graham
- Mechanical Design - Marco Oriunno
- Readout and DAQ - Ryan Herbst

COFFEE!!!

- Status, Schedule, Plans and Discussion - TKN and All

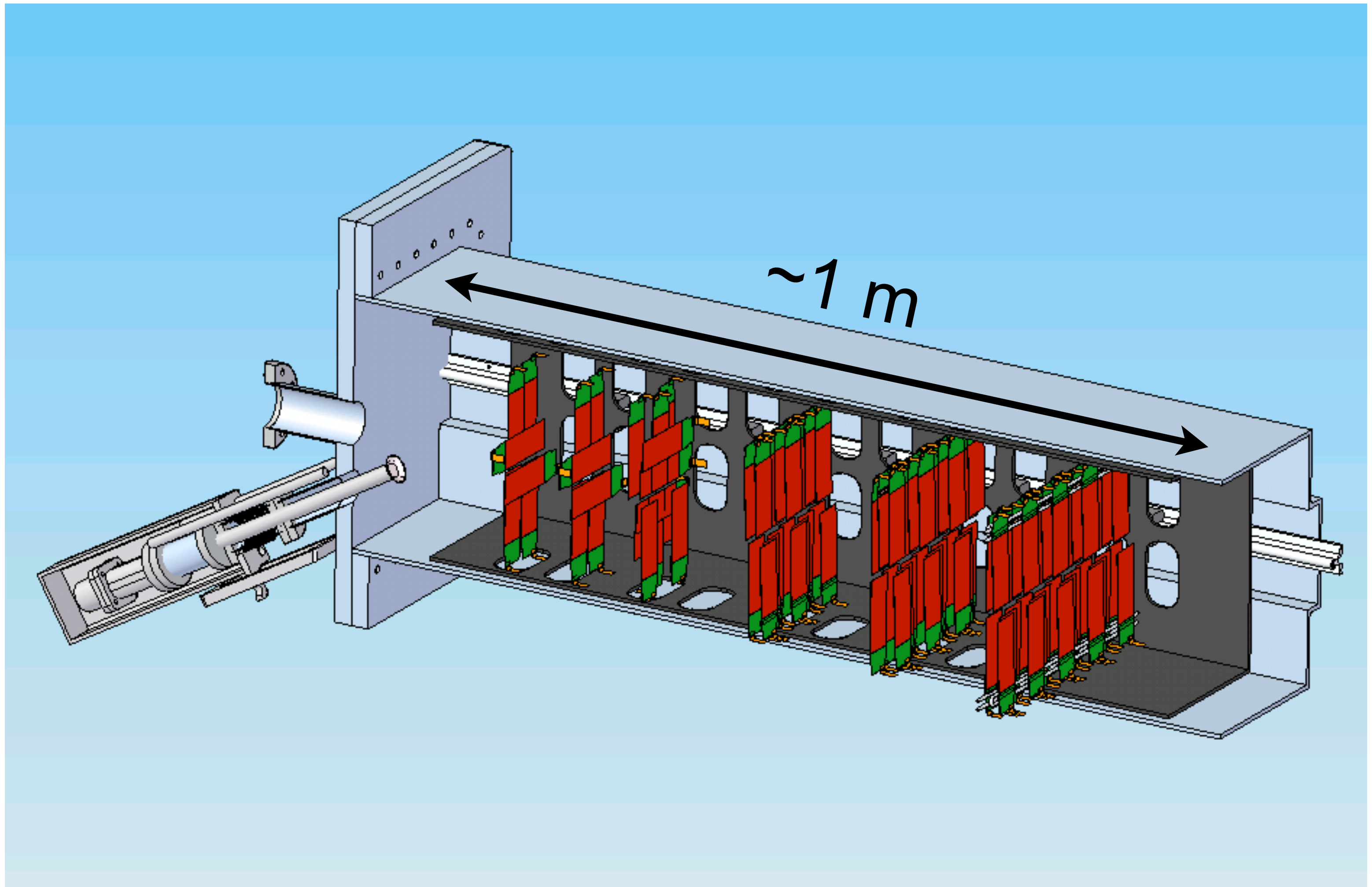
Additional Slides

Slides on the Full HPS Experiment

SLAC

Challenges ⇒ Design Principles

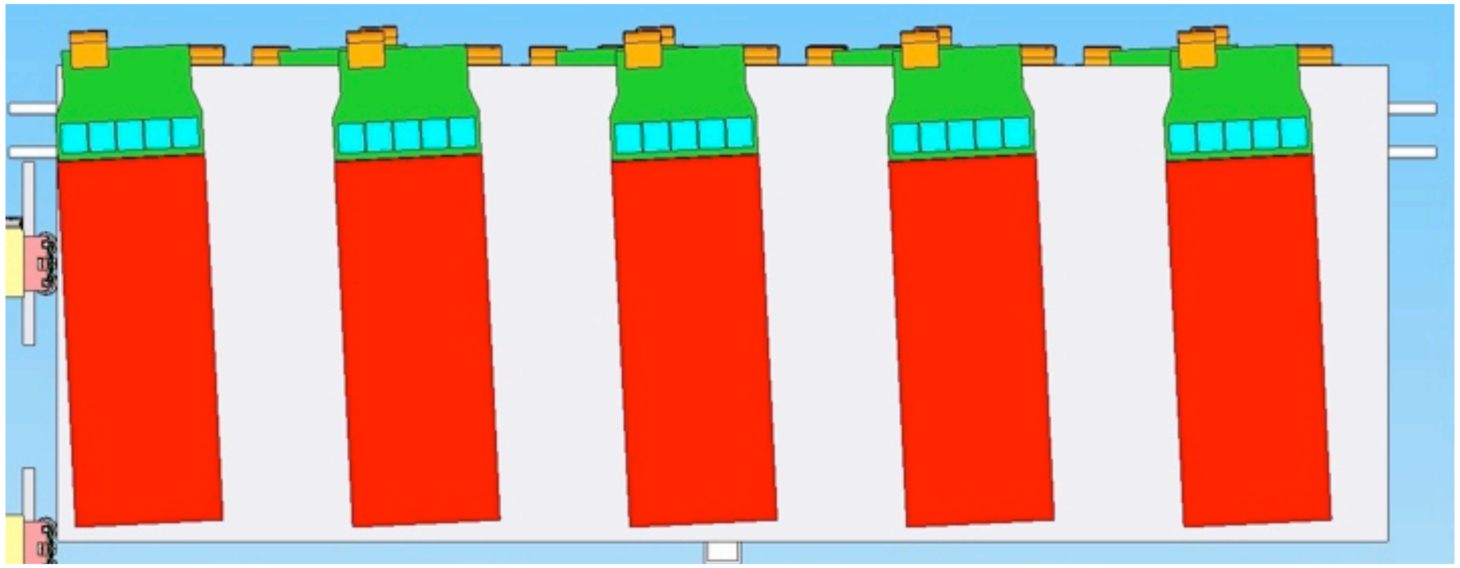
- Mass and vertex resolution
  - low-mass construction
- Occupancies and radiation
  - fast, robust sensors / readout
  - movability / replaceability
  - operation in vacuum
- Acceptance/Purity
  - optimized sensor layout



SLAC/FNAL

Low Mass Support/Cooling

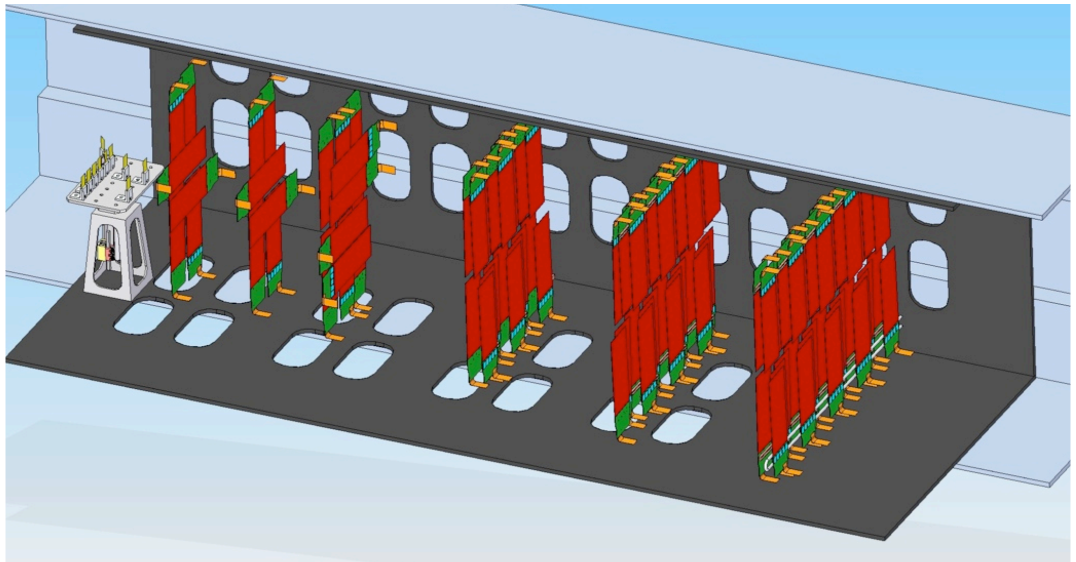
- CF-composite/rohacell-foam
  - 1.0% X_0/layer
  - dominated by Si
- H_20/glycol at -10°C
  - outside tracking volume
  - vacuum minimizes heat load on sensors



	Radiation Length (mm)	Thickness (mm)	Coverage/Unit Acceptance	Scattering Material (% X_0)
Silicon	**93.6**	**0.320**	**1.2**	**0.410**
Rohacell Foam	13800	3.0	0.5	0.011
Carbon Fiber	242	0.150	0.5	0.031
PGS Passivation	256	0.101	1.25	0.049
Epoxy	290	0.050	0.5	0.009
Total	-	-	-	**0.510**

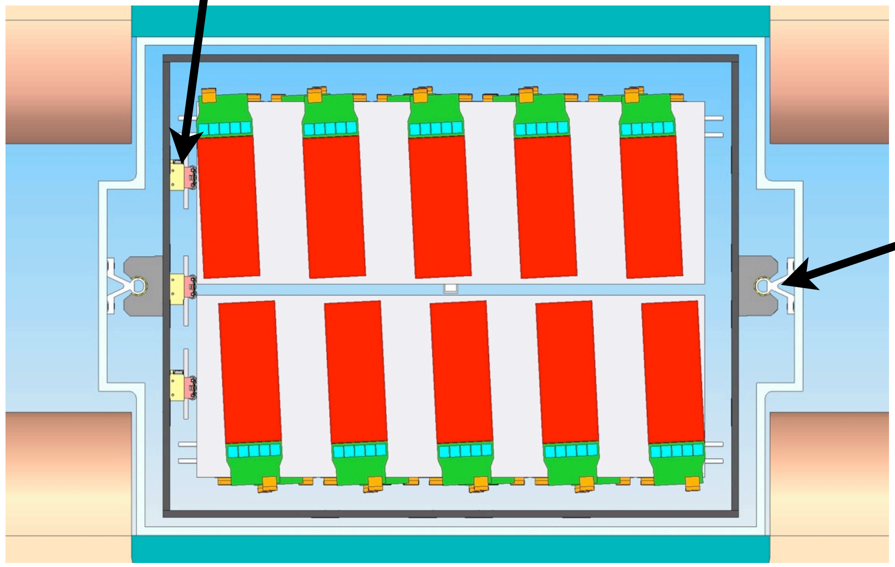
SLAC/FNAL

Moveable/Replaceable

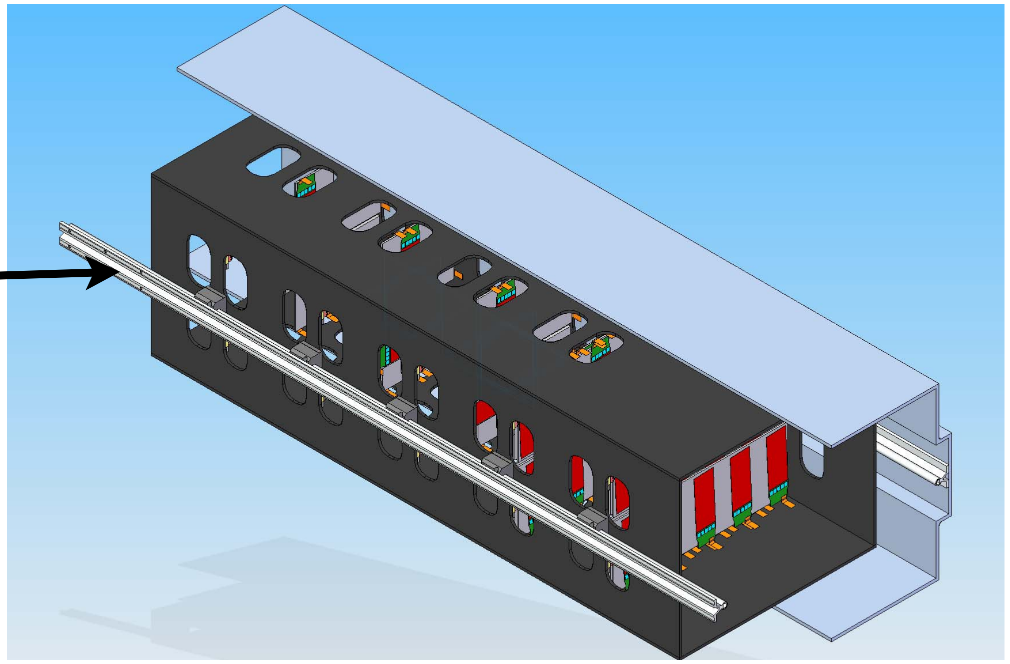


piezo motors allow retraction of planes

carbon fiber support box inside vacuum chamber



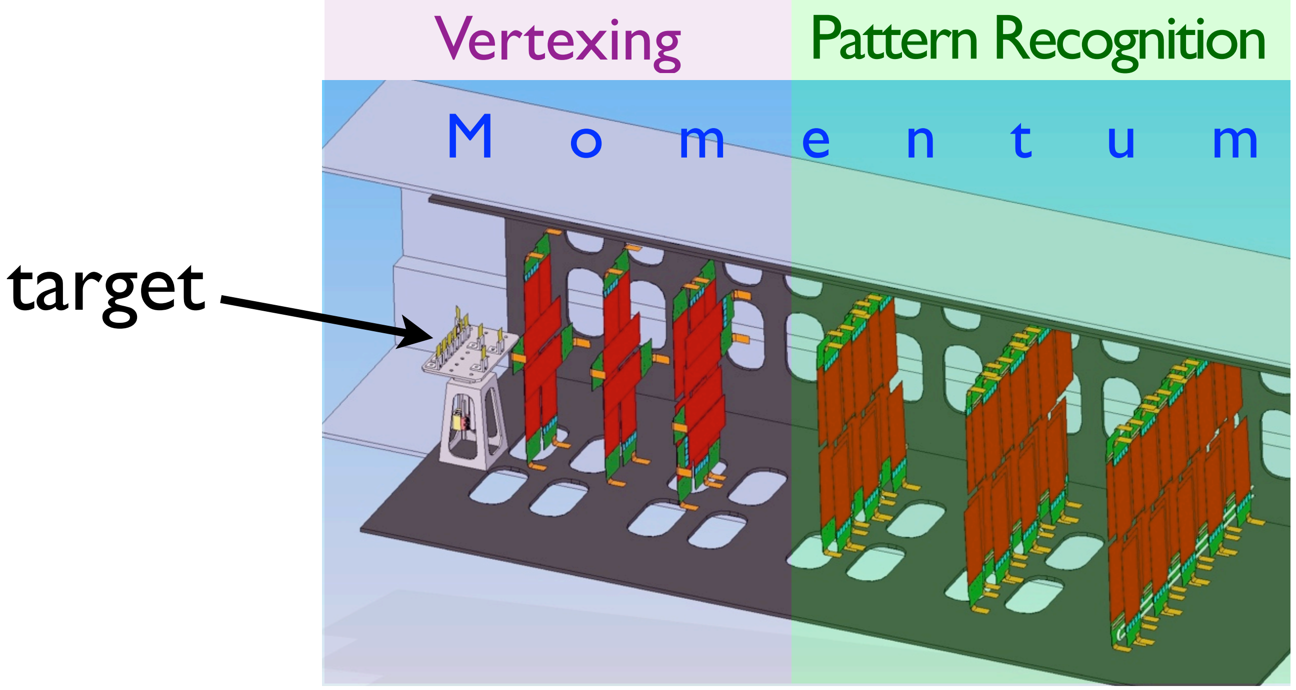
rail system for easy removal of tracker



Detector Layout

- Layers 1-3: vertexing
- Layers 4-6: pattern recognition with adequate pointing into Layer 2.
- Bend plane measurement in all layers: momentum
- 106 sensors/hybrids
- 530 APV25 chips
- 67840 channels

	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6
z position, from target (cm)	10	20	30	50	70	90
Stereo Angle	90 deg.	90 deg.	90 deg.	50 mrad	50 mrad	50 mrad
Bend Plane Resolution (μm)	≈ 6	≈ 6	≈ 6	≈ 6	≈ 6	≈ 6
Stereo Resolution (μm)	≈ 6	≈ 6	≈ 6	≈ 120	≈ 120	≈ 120
# Bend Plane Sensors	4	4	6	10	14	18
# Stereo Sensors	2	2	4	10	14	18
Dead Zone (mm)	±1.5	±3.0	±4.5	±7.5	±10.5	±13.5
Power Consumption (W)	10.5	10.5	17.5	35	49	63



Dead Zone and Acceptance

Hits from A′ daughters within acceptance;
E_{beam}=5.5 GeV, $m_{A'} = 300\ \text{MeV}/c^2$

75 ns of beam at Layer 1