The sPHENIX Detector

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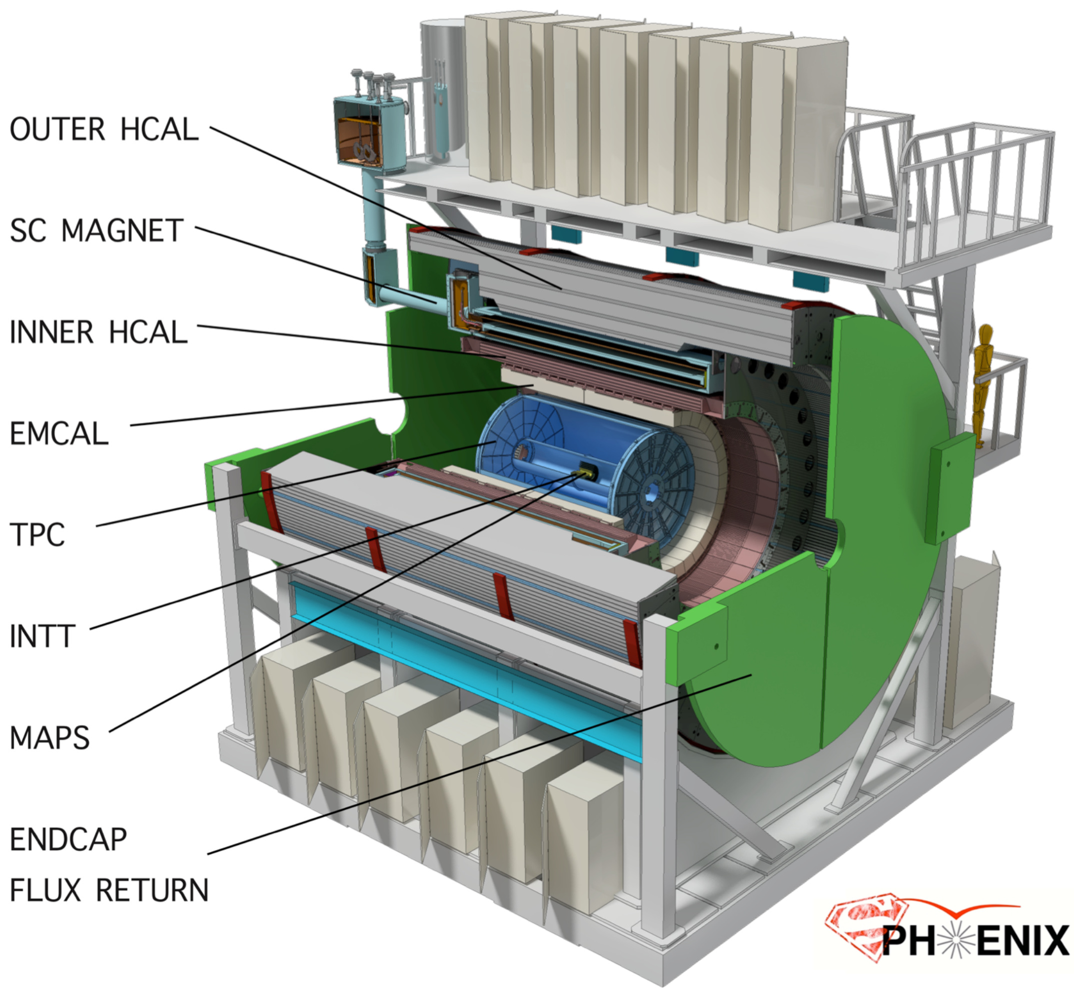
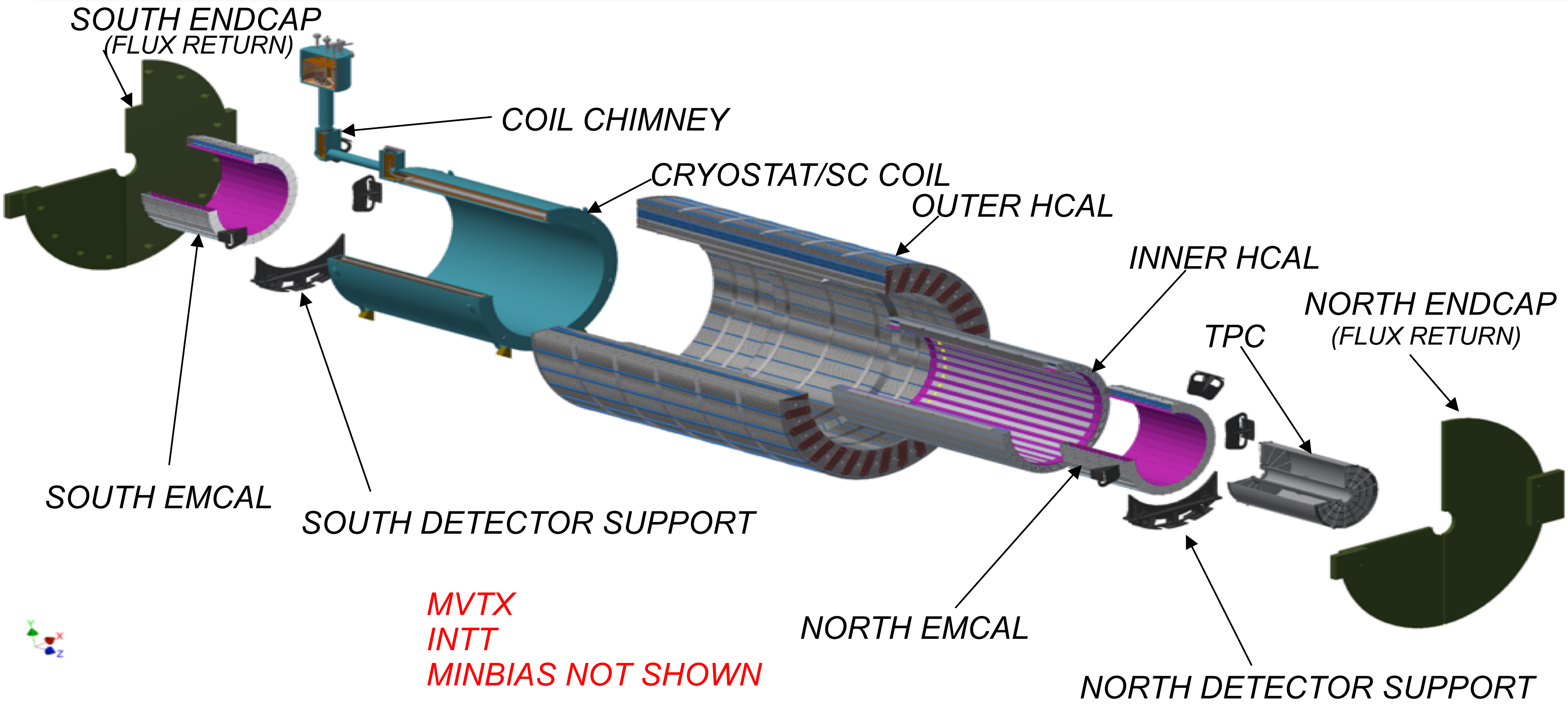
BNL

What is sPHENIX?

- sPHENIX is a proposal for a major upgrade to the PHENIX detector capable of making high statistics measurements of:
  - Jets with tracking and calorimetric reconstruction
  - Jet correlations
  - Upsilon states
- The physics program drives the detector design
  - Uniform electromagnetic and hadronic calorimetry
  - Precision charged particle tracking capable of good efficiency in heavy ion collisions

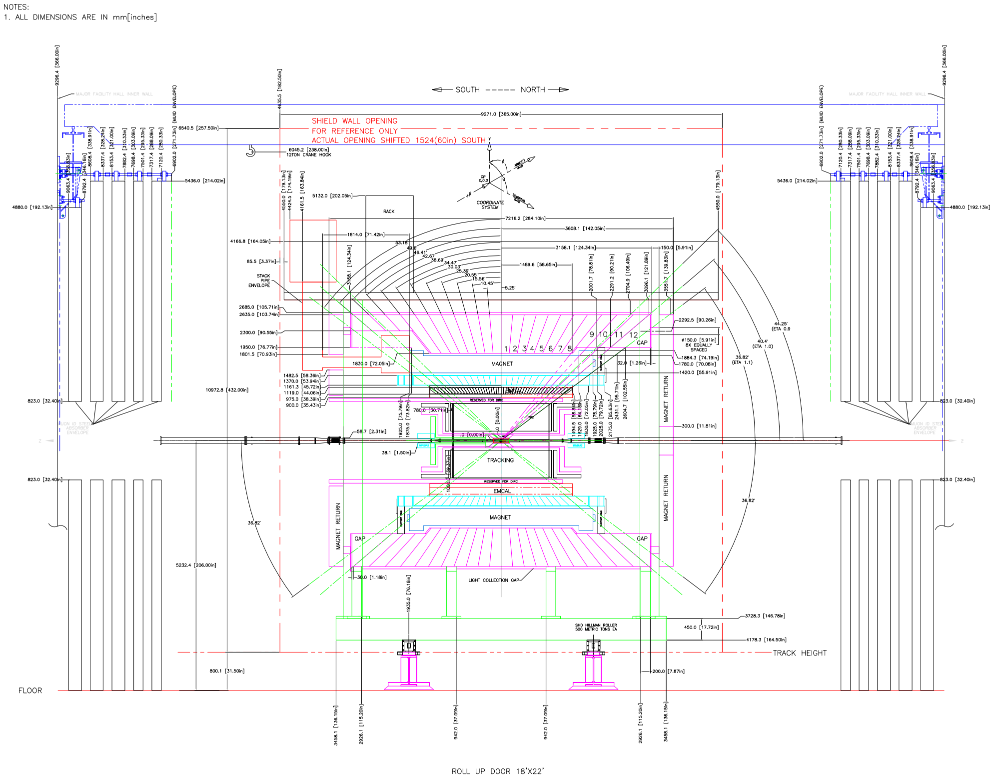

OUTER HCAL
SC MAGNET
INNER HCAL
EMCAL
TPC
INTT
MAPS
ENDCAP
FLUX RETURN

SPHENIX EXPLODED VIEW



MVTX
INTT
MINBIAS NOT SHOWN

Envelope drawing



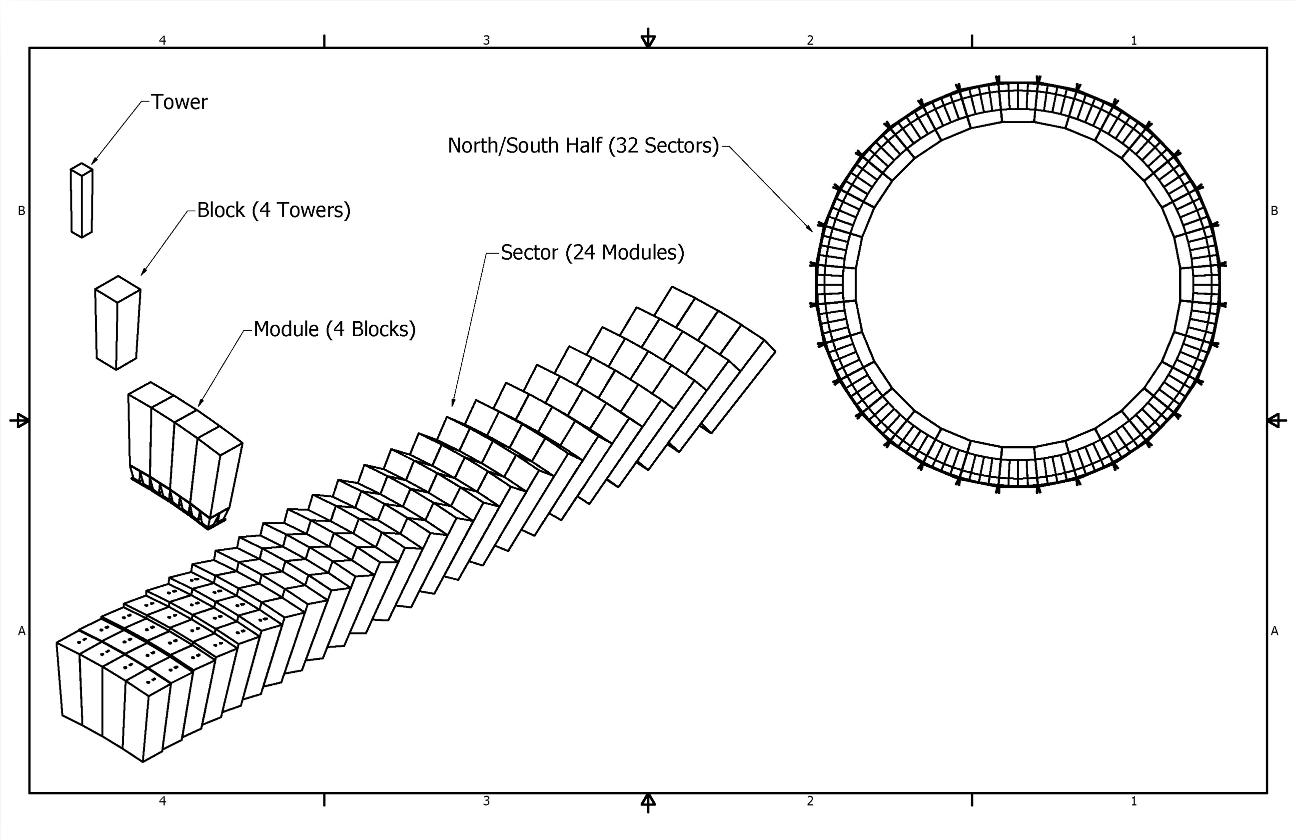
The sPHENIX Detector—Calorimetry

- Novel sampling hadronic and electromagnetic calorimetry
  - "Tilted plate" HCAL populated with extruded scintillating tiles with light collected by embedded fiber
  - Tungsten-scintillating fiber SPACAL with ~7 mm radiation length allows for compact design which can fit inside the solenoid
  - In both calorimeters, light collected to SiPM's which are
    - Compact
    - Don't require high voltage
    - Work in magnetic field
    - Large signal that allows us easily to cable out analog signal
  - Common electronics including low cost 60 MHz waveform digitizers

EMCAL

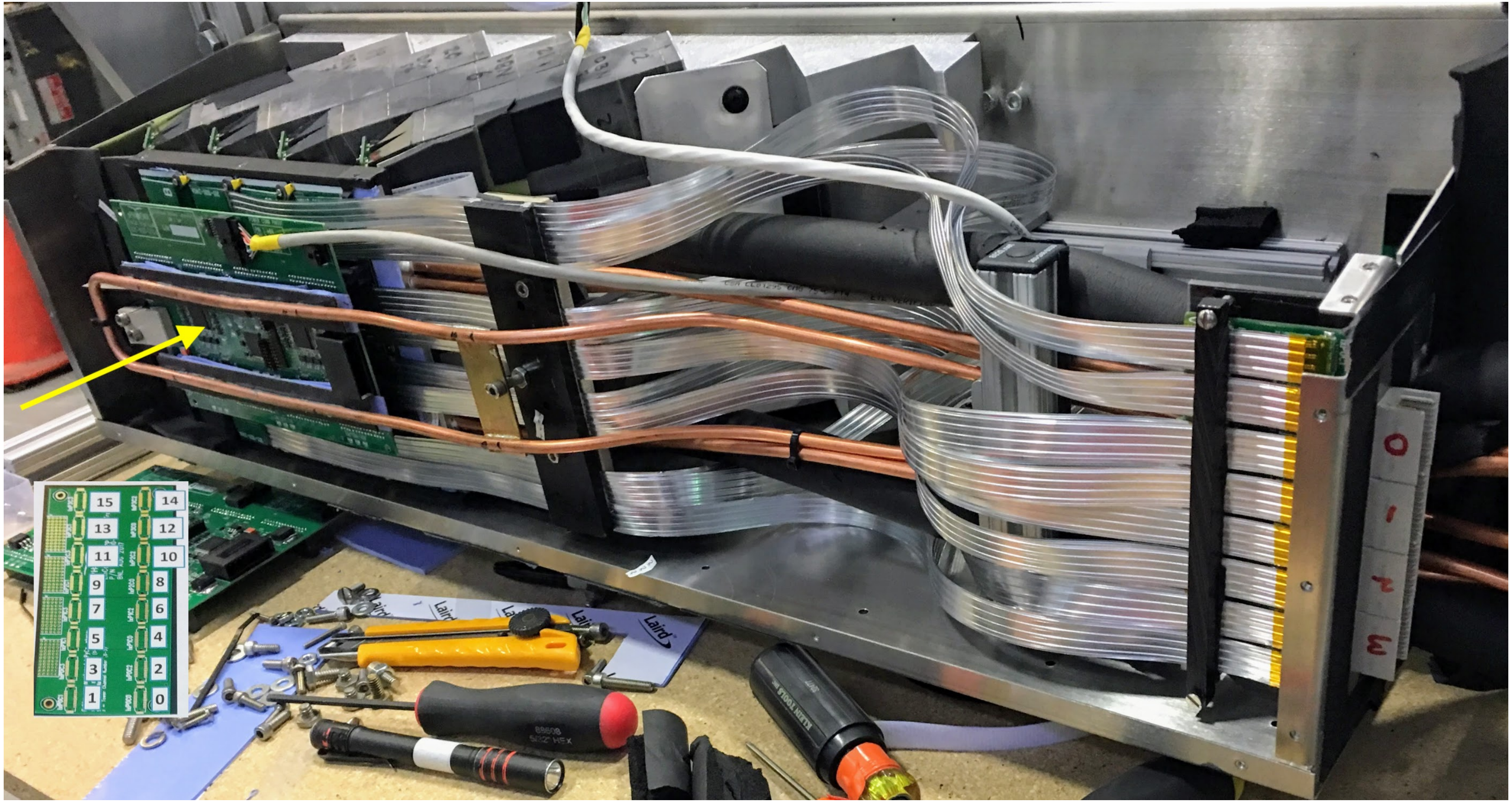
- Coverage: $\pm$ 1.1 in η, 2π in ϕ (descoped/MIE coverage $\Rightarrow \pm$ 0.85 in η)
- Segmentation: $\Delta\eta \times \Delta\phi \approx 0.025 \times 0.025$
- Readout channels (towers): 96x256 = 24576 (descope/MIE 72x256 = 18432)
- Tungsten powder and epoxy with embedded scintillating fiber
  - 667 fibers/tower
- Radiation length 7 mm
  - Moliere radius 23 mm (approximate tower size)
  - About 18 X_0 deep
- 2.3% sampling fraction
- Energy Resolution: "$\sigma_E/E < 15\%/\sqrt{E}$"
- Provide an e/h separation > 100:1
- Approximately projective in η and ϕ
- Compact, works inside 1.4T magnetic field

EMCAL sector design



- 64 sectors (32+32)
- 90 < r < 116 cm
- 1.7 m long
- 450 kg/sector
- Read out on inner radius

EMCAL V2.1



More on EMCAL

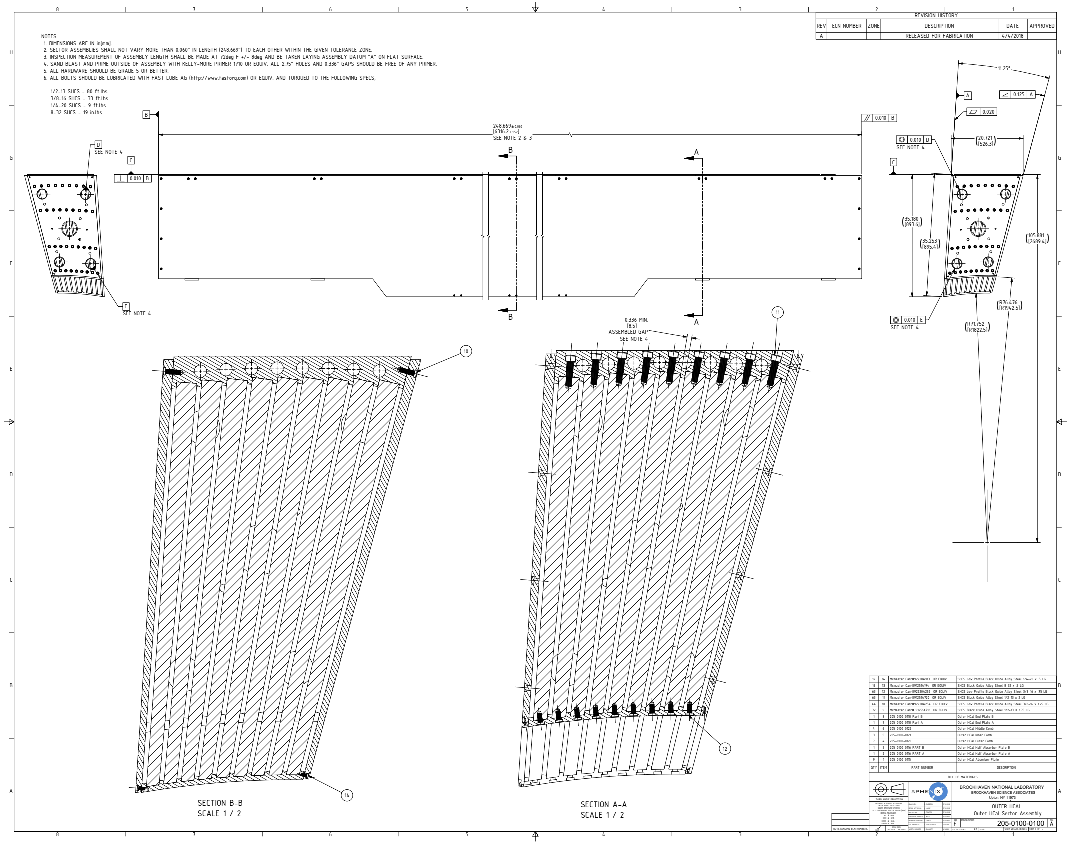
That’s all I’ll say on the EMCAL…

- Craig Woody will describe more about the detector and testing
- Anne Sickles will describe the construction of the blocks

HCAL

- HCAL requirements driven by measuring jets in heavy ion collisions
  - **No gaps**
  - **$-1.1 < \eta < 1.1$**
  - **2π in ϕ**
  - **$\Delta\eta \times \Delta\phi \sim 0.1 \times 0.1$ for jets with R<0.4**
  - **$24 \times 64 = 1536$ channels**
  - **Sampling fraction 2.8-3.7% (varies in depth)**
- The Outer HCAL doubles as the flux return of the solenoid

Outer HCAL absorber

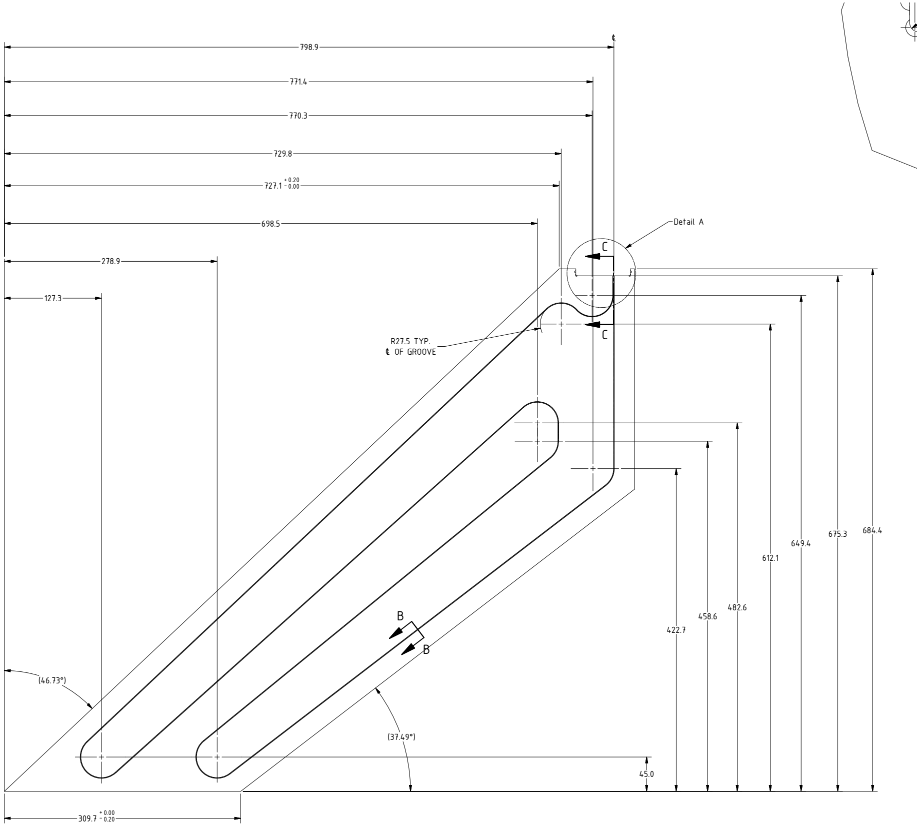


- 32 sectors
- 1.9 m < r < 2.6 m
- 6.3 m long
- 13.5 tons

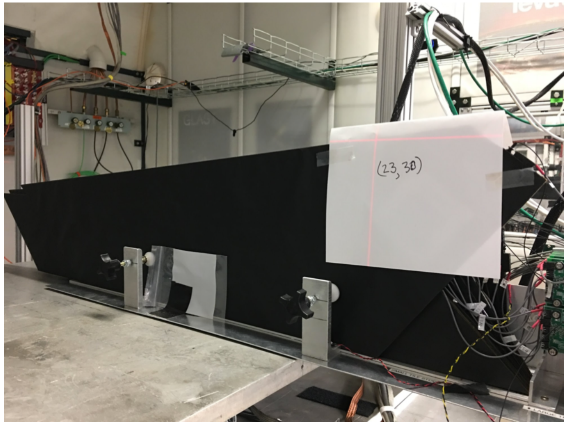
Outer HCAL tiles

- 12 shapes of tiles
- 7 mm thick extruded polystyrene with 1 mm WLS fiber embedded in a milled slot
- 5 tiles per tower combined at a 12° tilt
- Each tower an analog sum of 5 SiPM’s

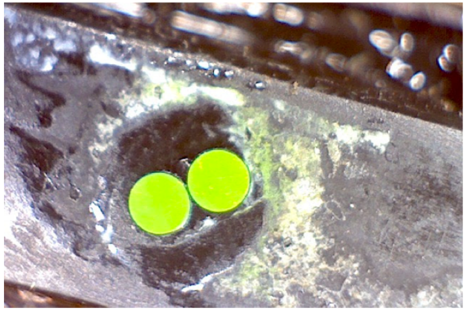
Tiles



Tile #12



Mapping tile response in test beam



Fiber exit

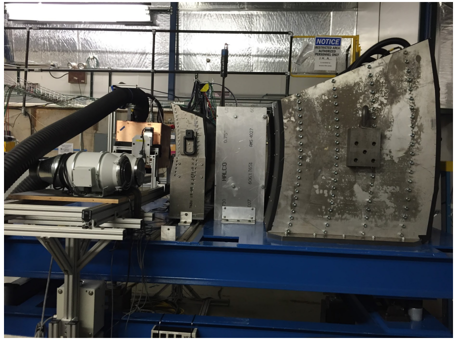
Inner HCAL

- The inner HCAL is potentially another longitudinal sample of the shower which has been descoped in the DOE-funded detector
- No sampling of the shower between 1.2 m < r < 1.9 m
- Uninstrumented Al frame supports EMCAL, but design permits instrumentation at a later time

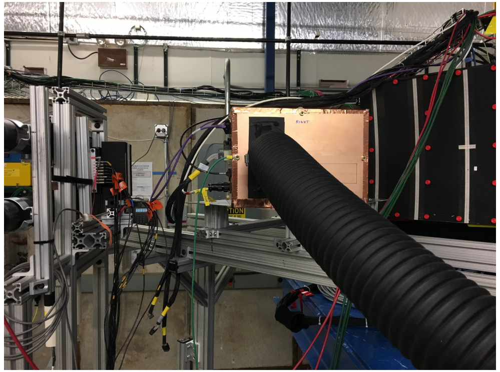
Calorimeter beam tests

sPHENIX

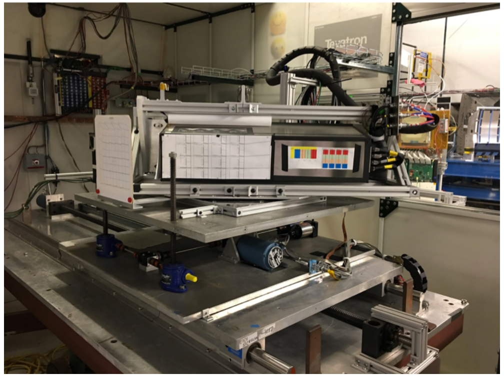
February 2014
Proof of principle



February 2016
η~0
sPHENIX geometry
https://arxiv.org/abs/1704.01461
(submitted to IEEE TNS)

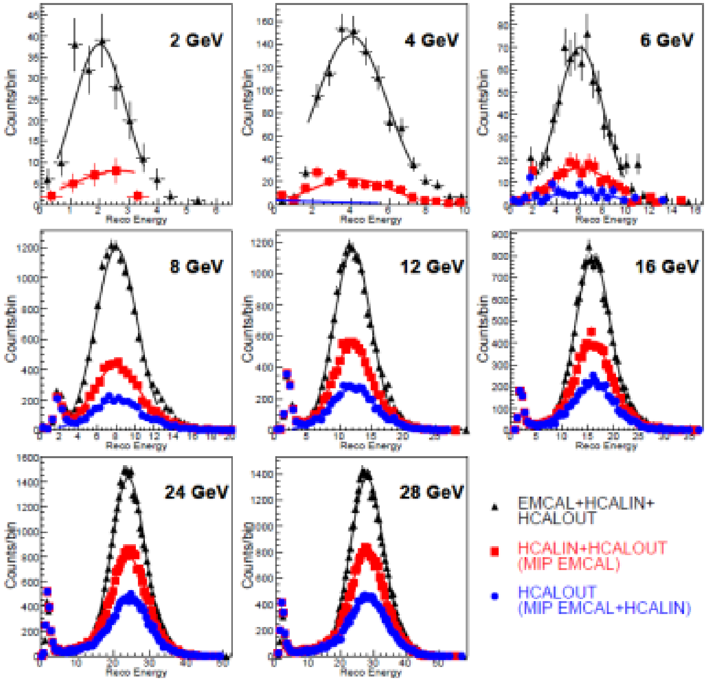


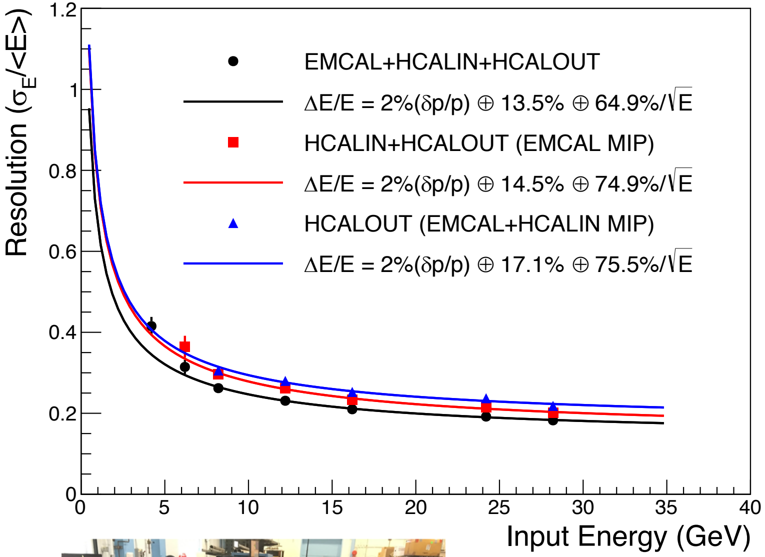
February 2017
η~0.9



February 2018

HCAL beam tests

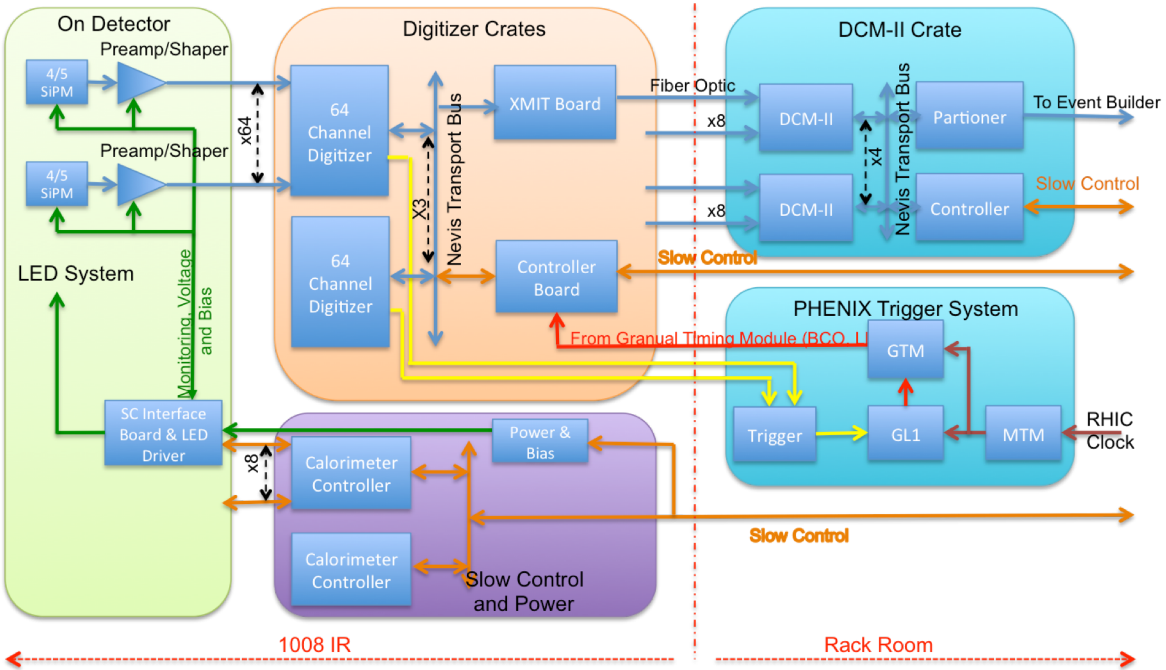




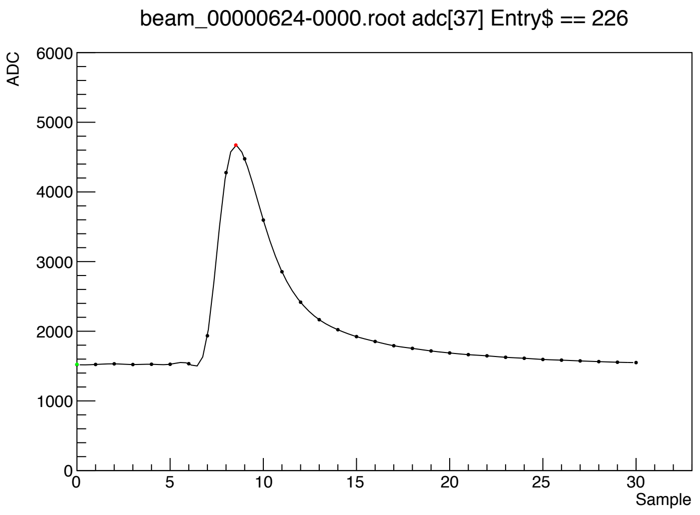
Calorimeter electronics

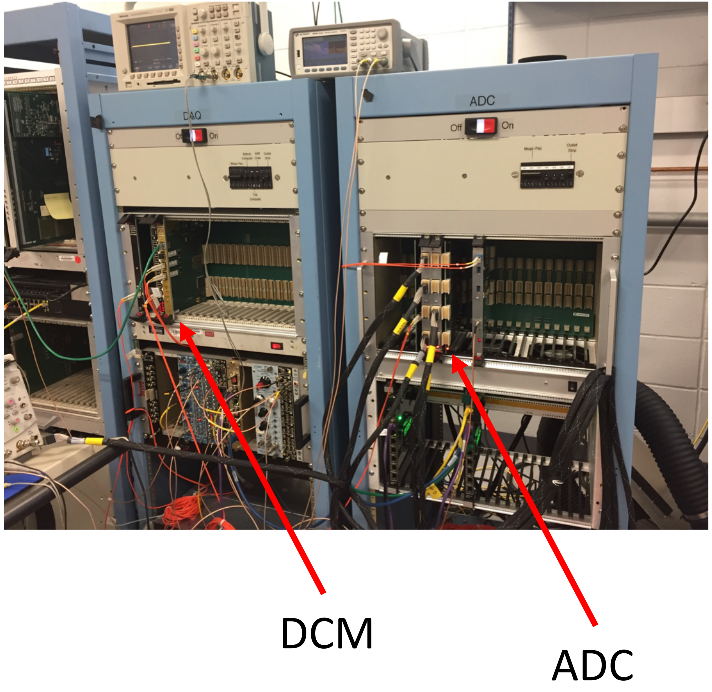
- SiPM photodetector selected
- Plans for purchase and characterization of SiPM's being developed
- Preamplifiers on the detector which drive differential analog signals out to racks about 10 m away
- Waveform digitizers (60 MHz) packaged in VME which transmit data to DCM II's in counting house
- Low voltage, bias voltage, control, temperature compensation

Calorimeter electronics



Digitizer





- 60 MHz FADC
- 14 bit waveform digitizers
- Digital trigger data available on every crossing
- Transmit 192 channels in <40 μs

Solenoid

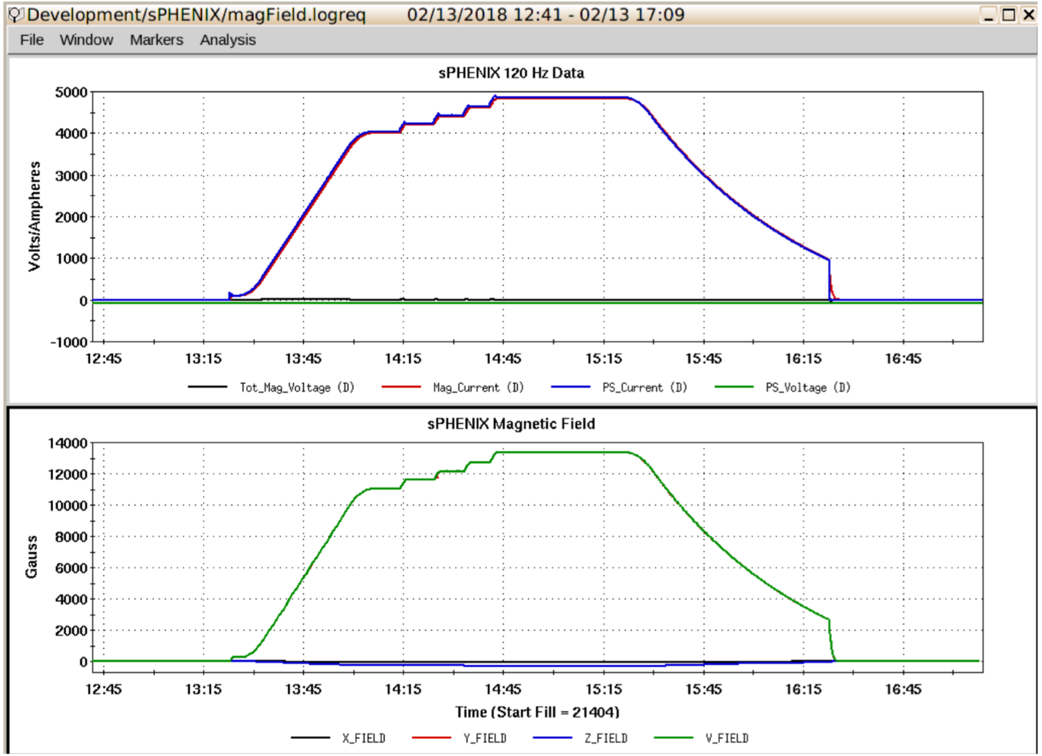
- Former BaBar magnet provides a platform for high resolution tracking
  - **1.4 T**
  - **2.8 m bore**
  - **3.8 m long**
- Cryo, power supply, quench protection developed for high field test is largely the same as will be used in 1008 (however cryo system will be RHIC)
- Reviewed with the help of Pasquale Fabbricatore and Wesley Craddock experts on the BaBar solenoid, and RHIC cryo and power supply experts

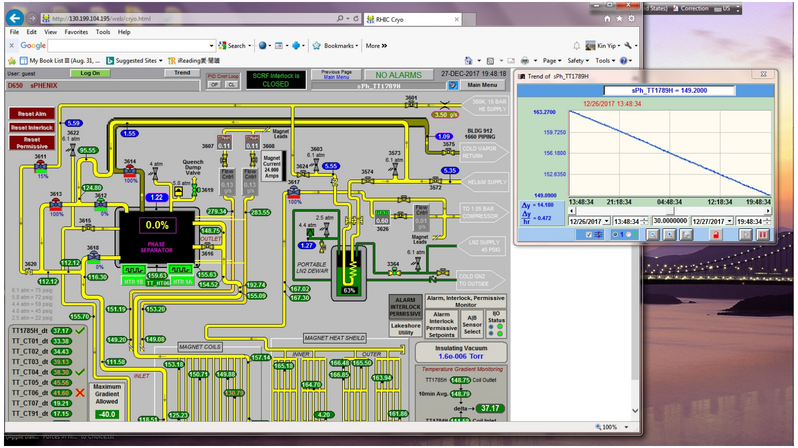
Solenoid

February 2015 leaving SLAC

January 2018 high field test

High field test



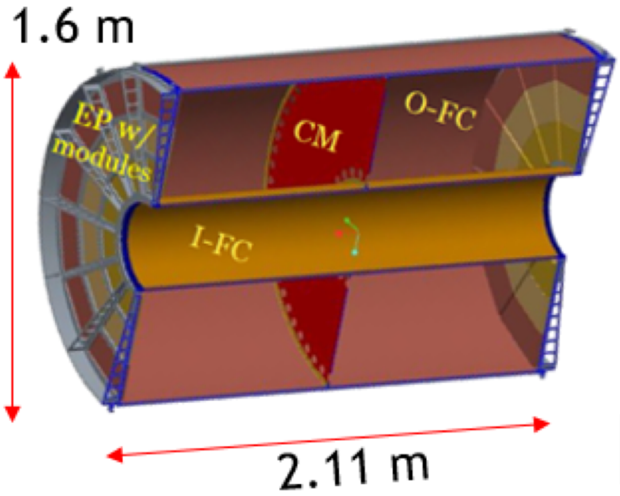


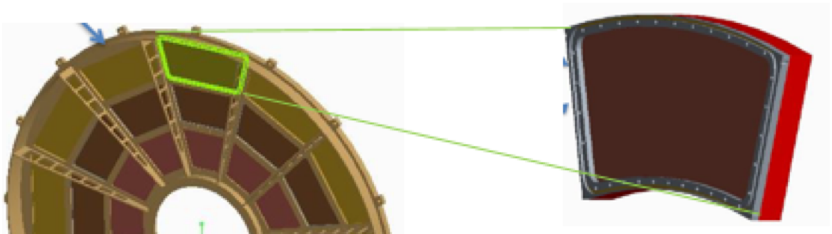
Power supply, quench protection, control and monitoring RHIC-ready, tested with new “valve box extension” designed and built at BNL

TPC key features

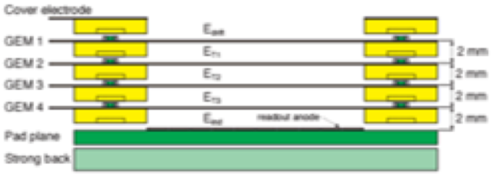
- Compact—outer radius 80 cm
- 3 (radial) x 12 (azimuthal) GEM chambers per end
- FEE board being developed around SAMPA ASIC to be used by ALICE and STAR iTPC
- Fast gas low diffusion to achieve position resolution < 200 μ
- Field distortions minimized by
  - Minimize Ion Back Flow by judicious choice of electric field between GEM foils, pioneered by ALICE
  - Gas choice (low mass, fast drift)
  - High electric field
  - Inner field cage 30→20 cm
- Continuous streaming readout

TPC detector overview



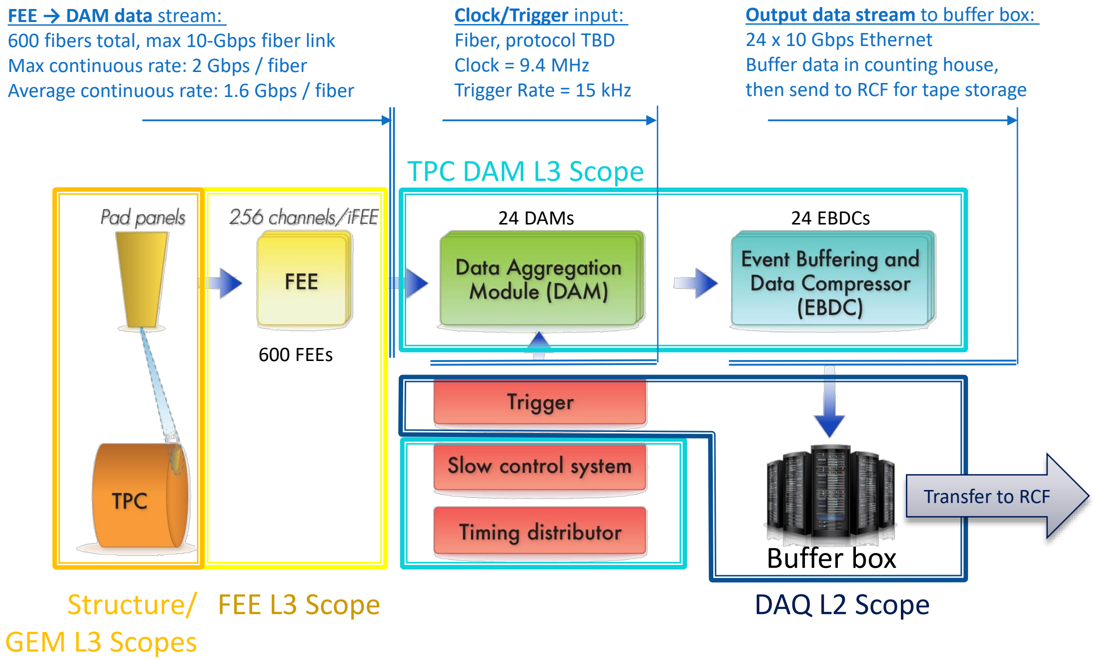


72 modules
2(z), 12(ϕ), 3(r)

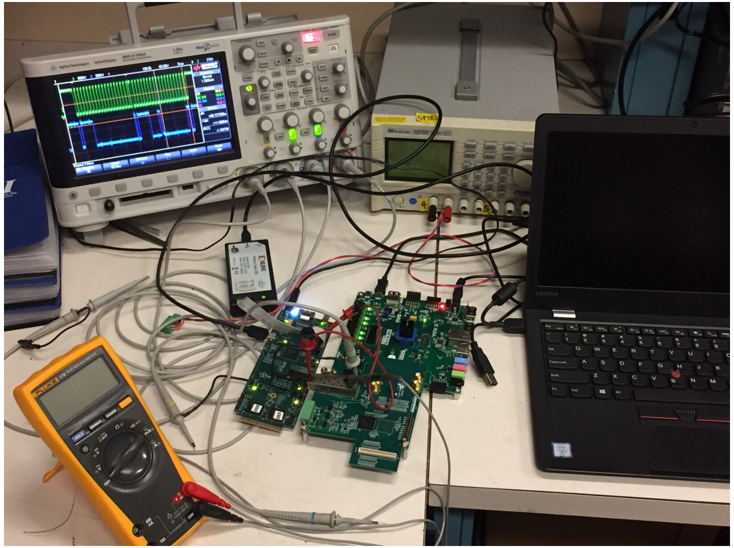


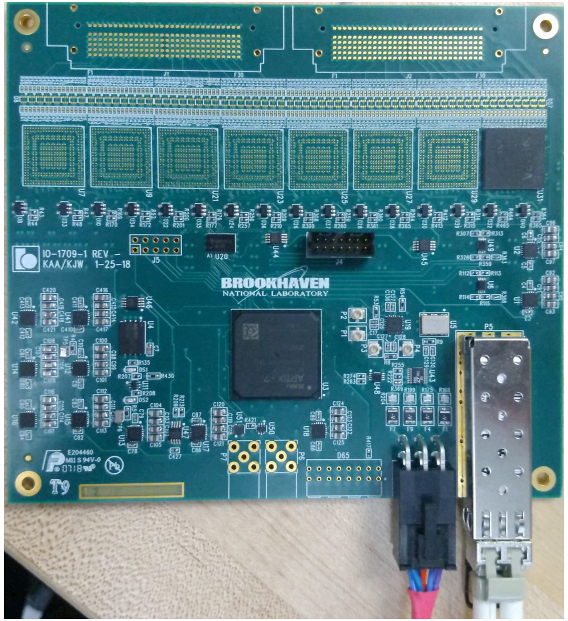
Quad-GEM Gain Stage
Operated @ low IBF

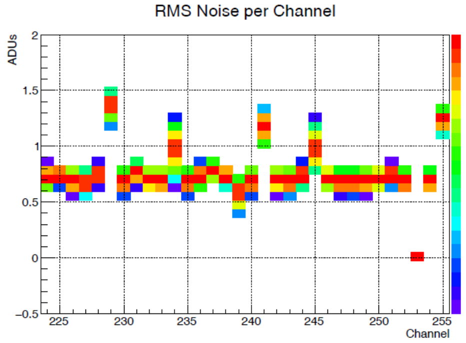
TPC electronics overview



TPC Electronics





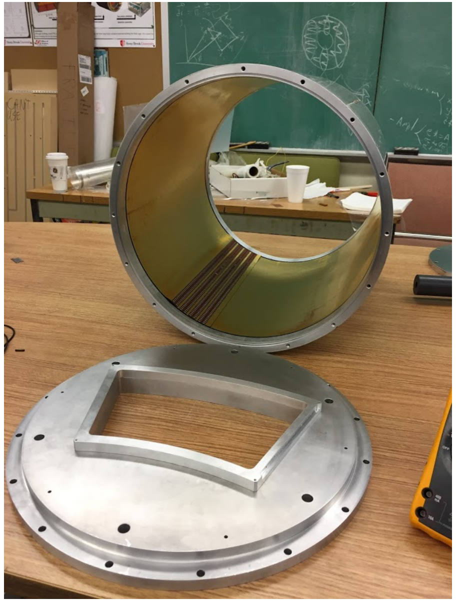


- TPC readout based on
  - ALICE SAMPA
  - ATLAS FELIX

1/8 SAMPA on FEE prototype

Noise tests

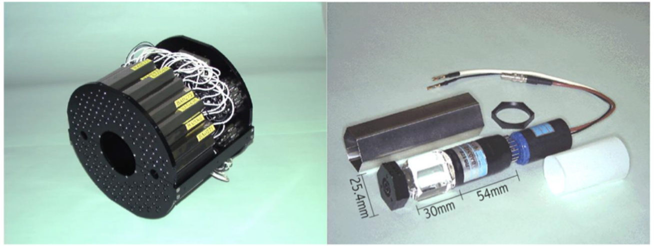
TPC Detector Status

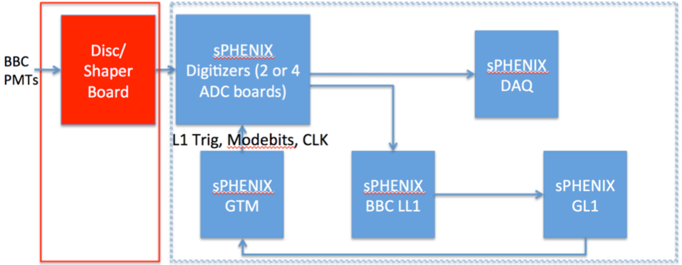


Full size prototype field cage and a small development field cage being built at SBU

Minimum Bias Detector

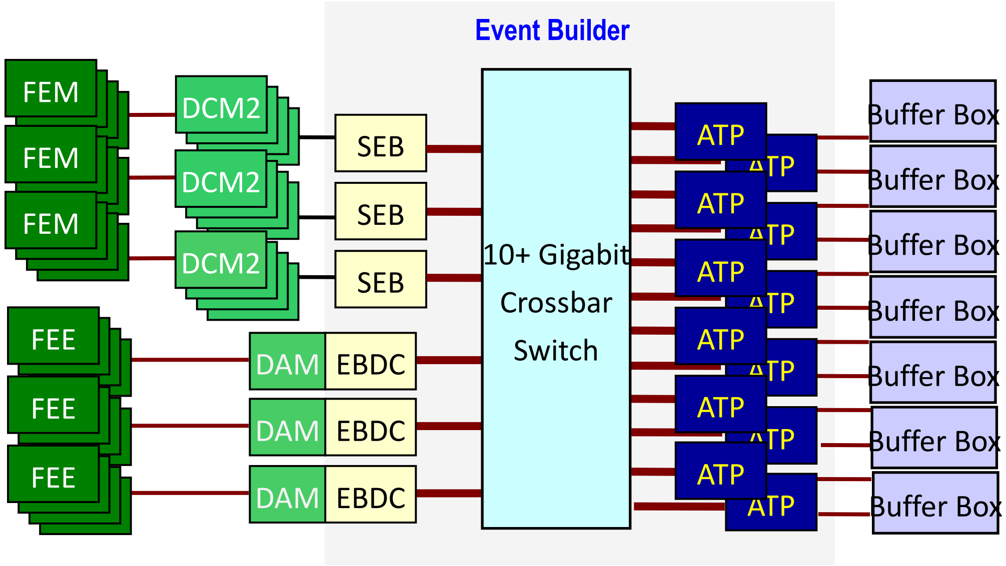
- This detector was the PHENIX BB counter and we expect to use it in sPHENIX
- Existing electronics could be resurrected, but development of a relatively simple shaper board would allow us to use the new calorimeter electronics
- PHENIX BB operated in a magnetic field, some testing and judicious choice of location is needed
- Trigger based on technology being developed for calorimeter trigger





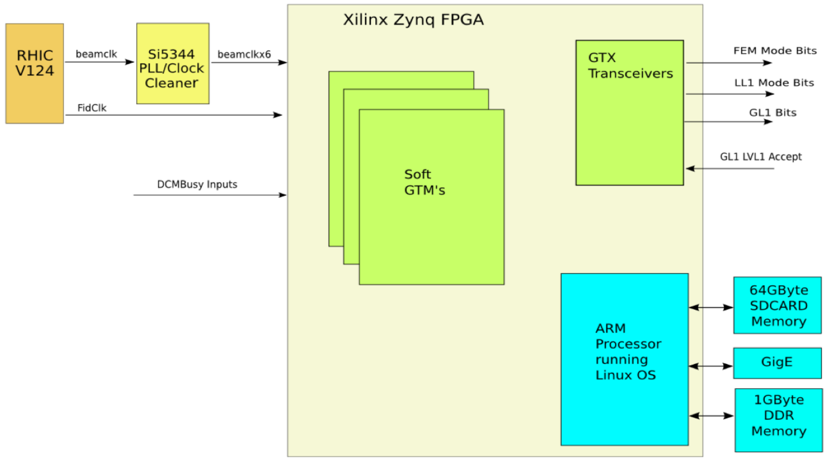
DAQ

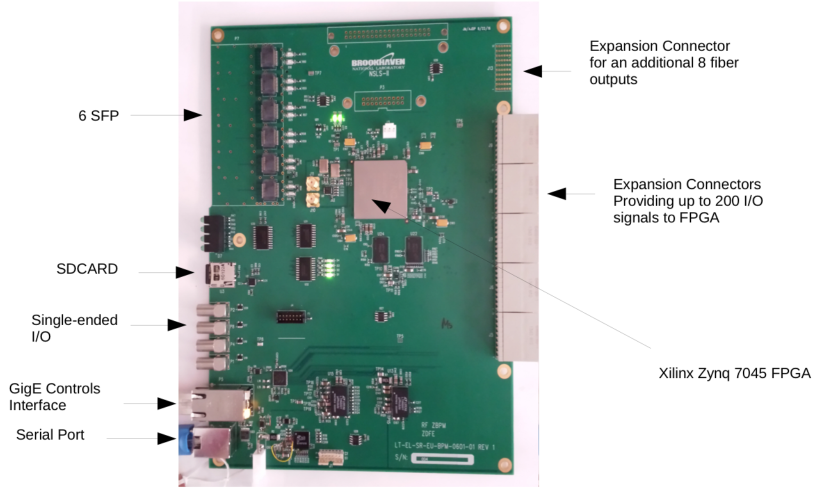
- Calorimeter readout uses a modest number of DCM II's developed for PHENIX, as does INTT
- Tests with DCM II achieved 15 kHz/90% live
  - **Pipelining, digitizing-while-transmitting, multievent buffering on front end are what made this possible**
- Modest redesign of timing system and trigger manager ("GTM" and "GL1" in PHENIX parlance)
- TPC readout is a significant challenge in data volume and rates, prototyping under way will allow system testing and characterization
- Data logging rate feasible today, likely to be even more feasible in five years



- “Conventional” triggered readout merged with untriggered or streaming readout from TPC
- <100 Gbit/s to RCF

sPHENIX Timing System



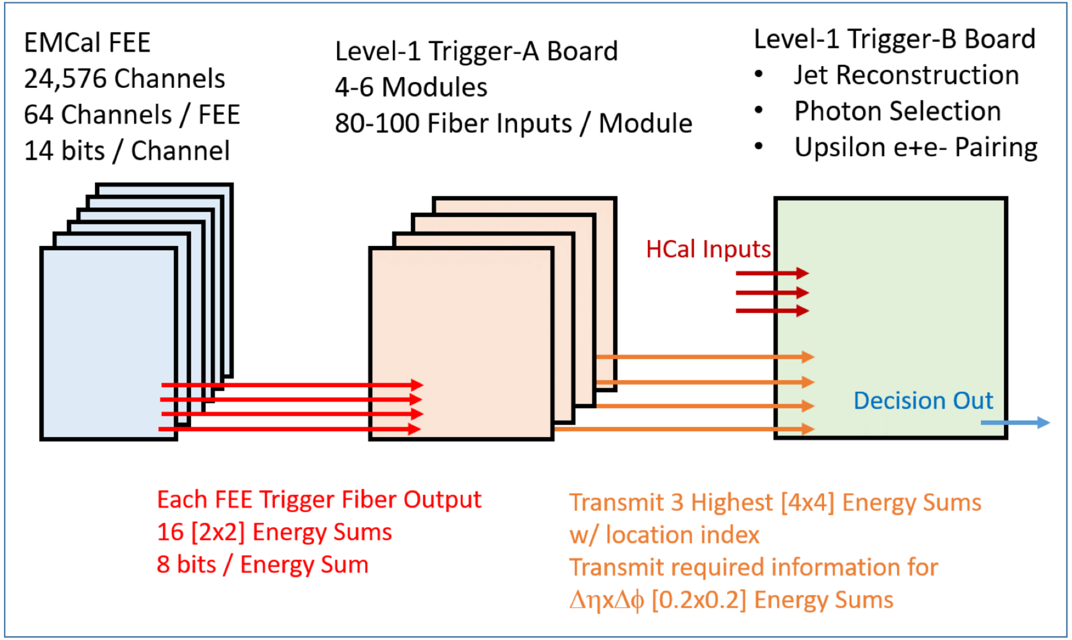


Development platform

- Technology update of PHENIX timing system
- Still need to accommodate clock variation through acceleration
- Link stability, jitter major design goals

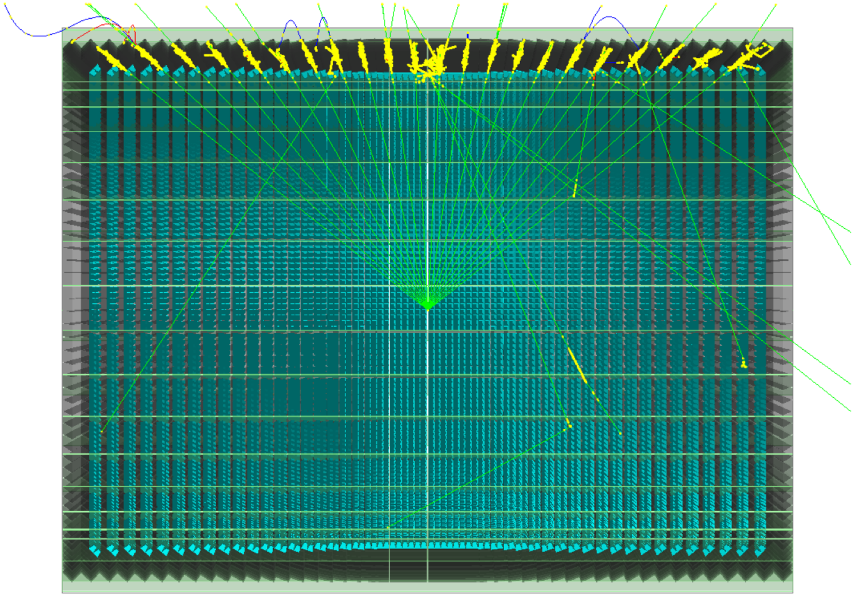
Trigger

- Calorimeter electronics is designed to drive for trigger primitives on fiber at crossing rate
- Trigger studies and simulation under way, but based on experience and practice in PHENIX



Simulation

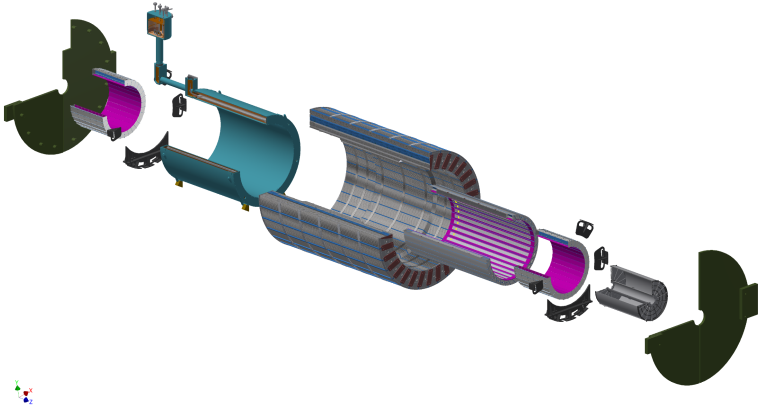
- Designing a detector like this needs simulation every step of th
way
- Jin Huang will describe the simulation framework and results tomorrow
- Look for yourself:
https://www.phenix.bnl.gov/WWW/sPHENIX/doxygen/html/

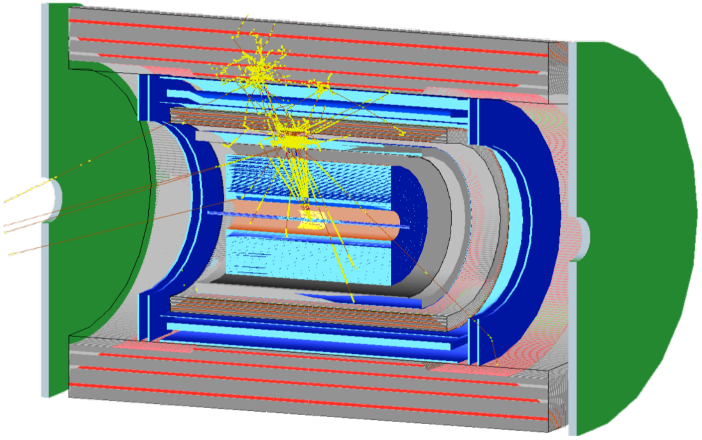


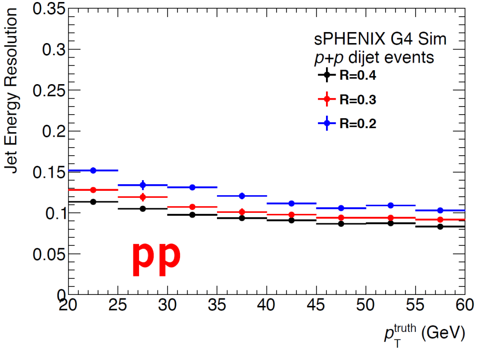
Beyond the baseline

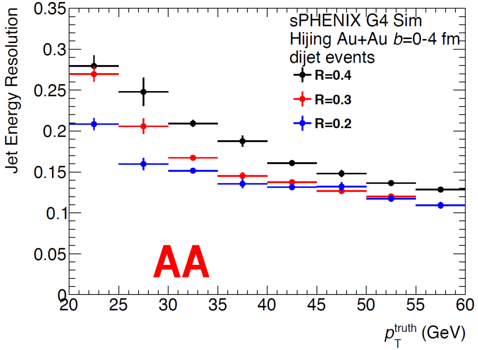
- The INTermediate Tracker (INTT) is a silicon strip detector just inside the inner TPC radius which furnishes precision points in space and time to seed the track
  - **Funded and built by RIKEN**
- The MVTX is a Monolithic Active Pixel Sensor detector just outside the beam pipe which provides precision vertex detection enabling heavy quark physics
  - **Funded as an upgrade project to sPHENIX**
  - **Talk by Ming Liu later today**

Design, prototype, simulation









- Continued design, engineering, and analysis
- Ever increasing fidelity to simulations
- Continuing beam test program
- System tests of other detector systems

Summary

- We are building sPHENIX with a philosophy of prototype/test/simulate/review to limit surprises at first collisions
- Calorimeter and calorimeter electronics very far along the development arc and have achieved required performance; could be ready for production next year, with experience of constructing and handling full size prototypes
- The magnet has been tested at full field
- The TPC and the TPC electronics are deep into development, and rely on technology being developed for ALICE and STAR
- The MBD detector exists and needs a modest amount of testing and development
- DAQ and Trigger build on PHENIX experience, some of the components exist already and have been tested in test beam experiments, more will follow