sPHENIX Detector Overview

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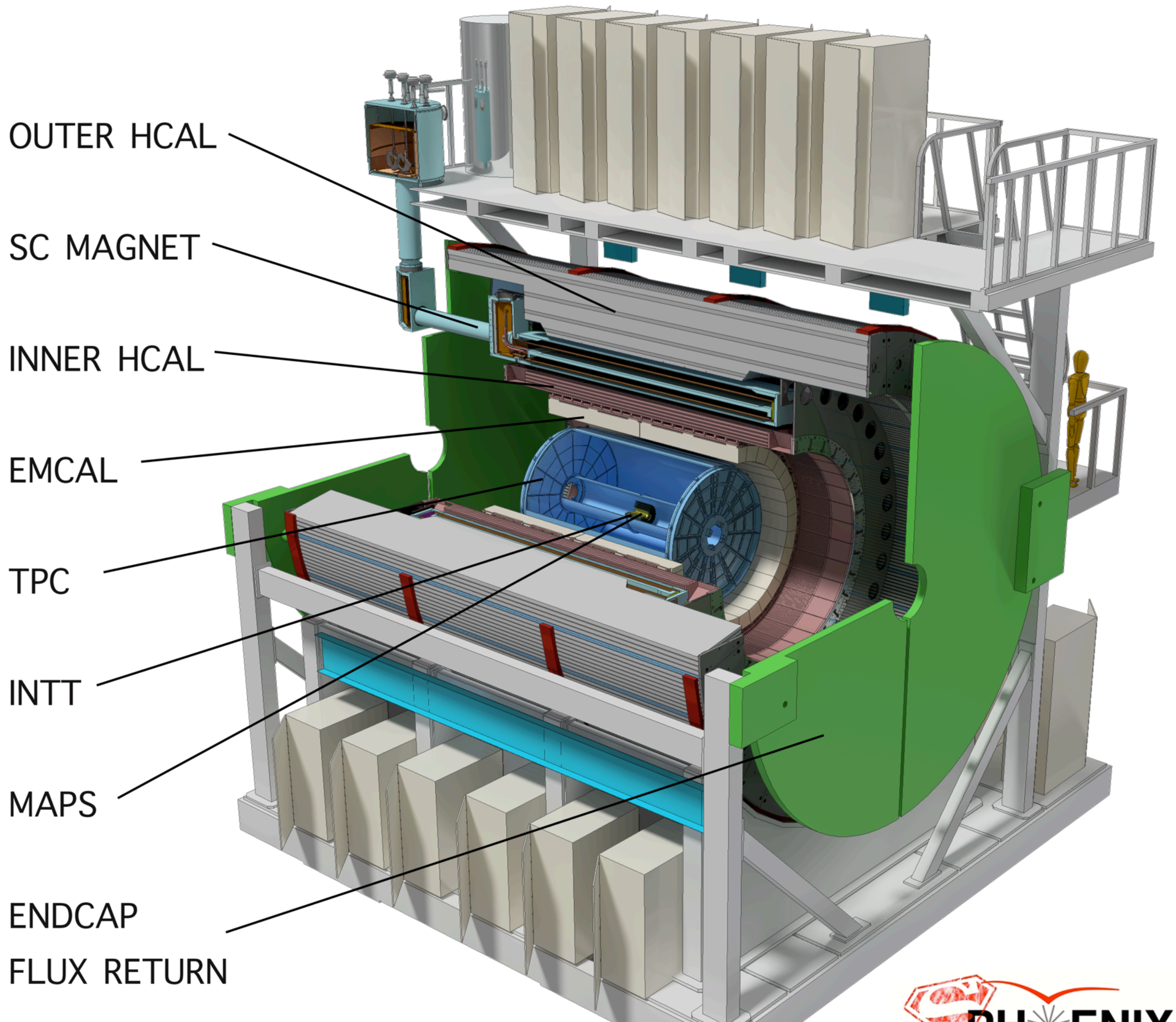
What is sPHENIX?

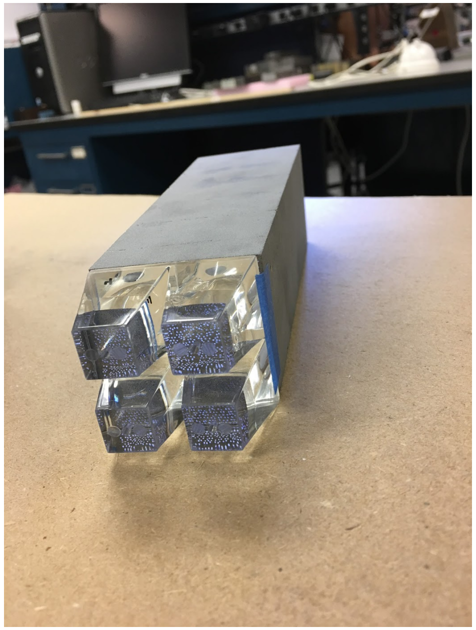
- sPHENIX is a proposal for a major upgrade to the PHENIX detector capable of making high statistics measurements of:
  - Jets with tracking and calorimetric reconstruction
  - Jet correlations
  - Upsilon states
- A proposal in July 2012 led to the DOE reviews in July 2014 and May 2015 affirmed the science case which was subsequently included in the September 2015 NSAC Long Range Plan and led to a CD-0 approval September 2016
- A new sPHENIX collaboration was formed in December 2015 which continues to grow to realize this detector and harvest its physics


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

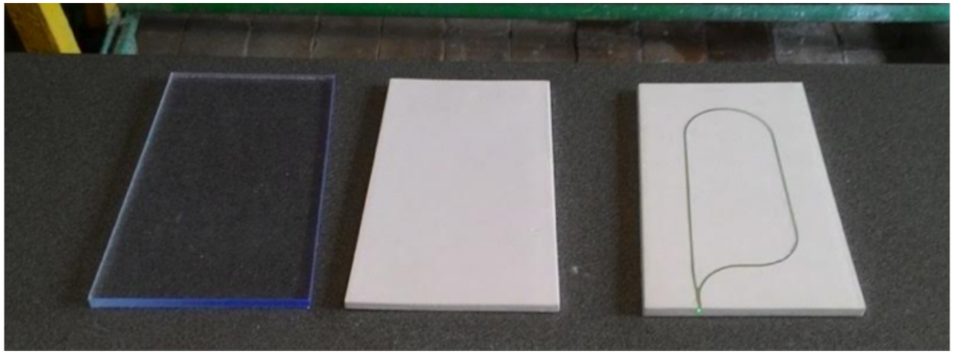
The sPHENIX Detector—Calorimetry

- 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

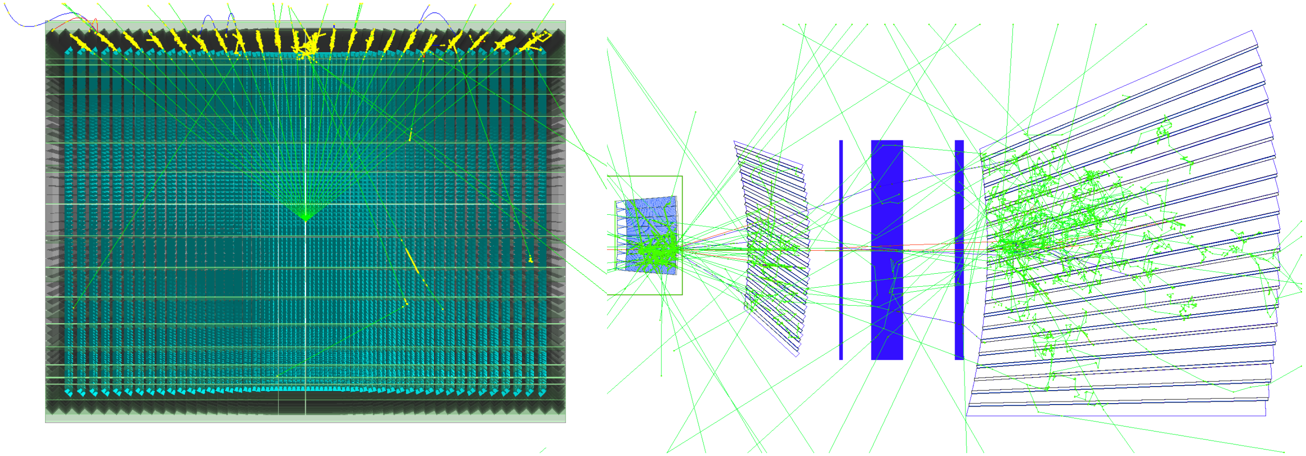
Calorimeters



EMCAL towers



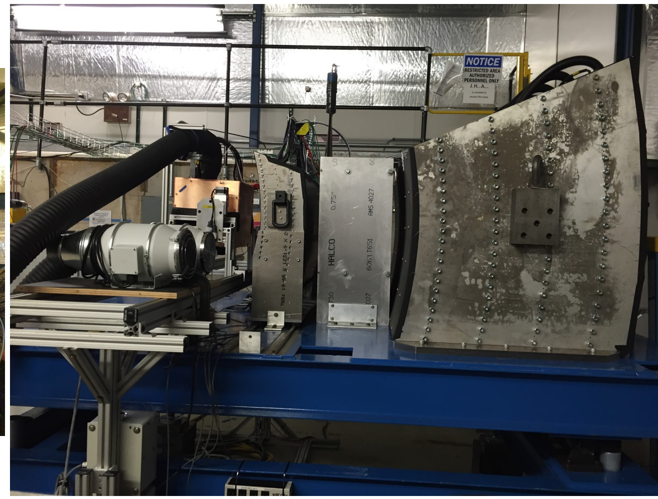
HCAL tiles



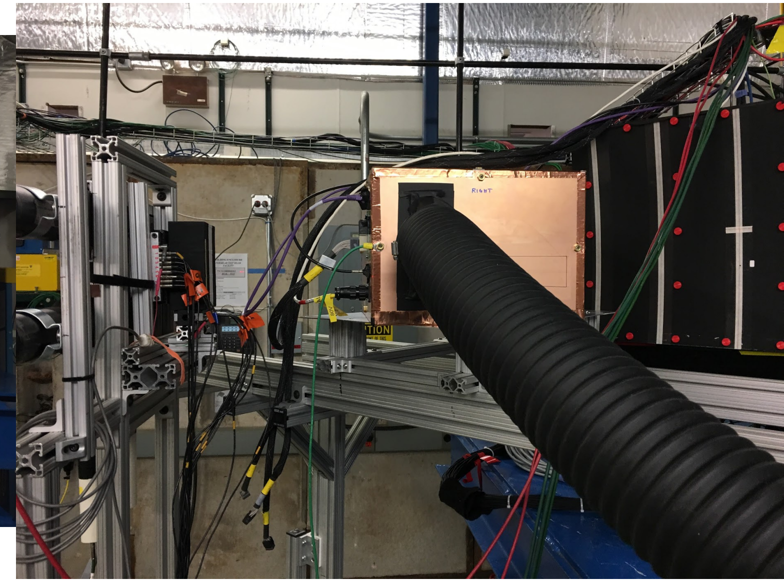
GEANT4 simulation

Calorimeter beam tests

February 2014
Proof of principle



February 2016
η~0
sPHENIX geometry

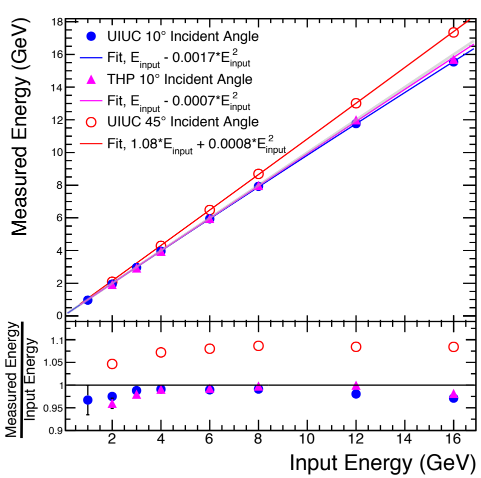


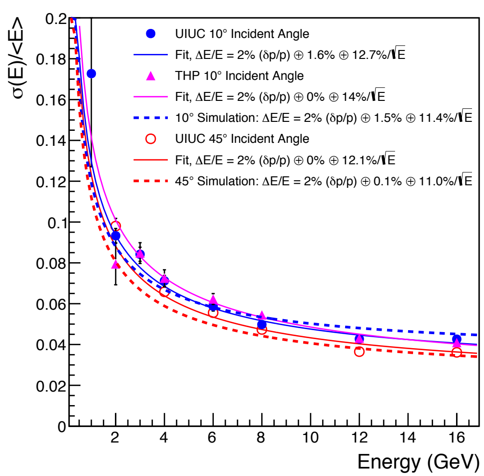
February 2017
η~0.9

https://arxiv.org/abs/1704.01461
(submitted to IEEE TNS)

EMCAL beam tests

- Uniformity of tower response studied extensively in beam with electron showers led to better understanding of boundaries and how to minimize the degradation in resolution
- Results consistent with simulation
- Beam tests of η~0 (2016) and η~0.9 (2017) leading to a final η~0.9 test in 2018 that will meet requirements

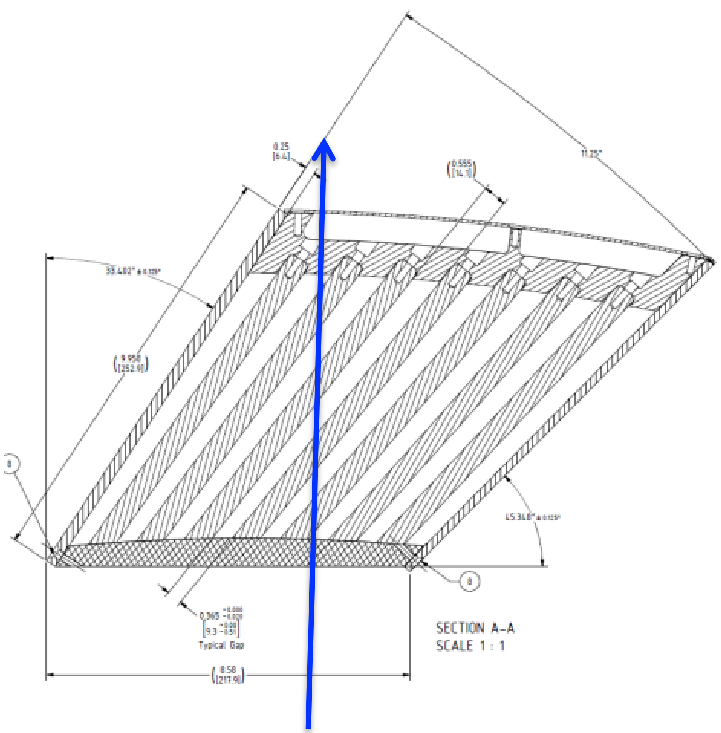


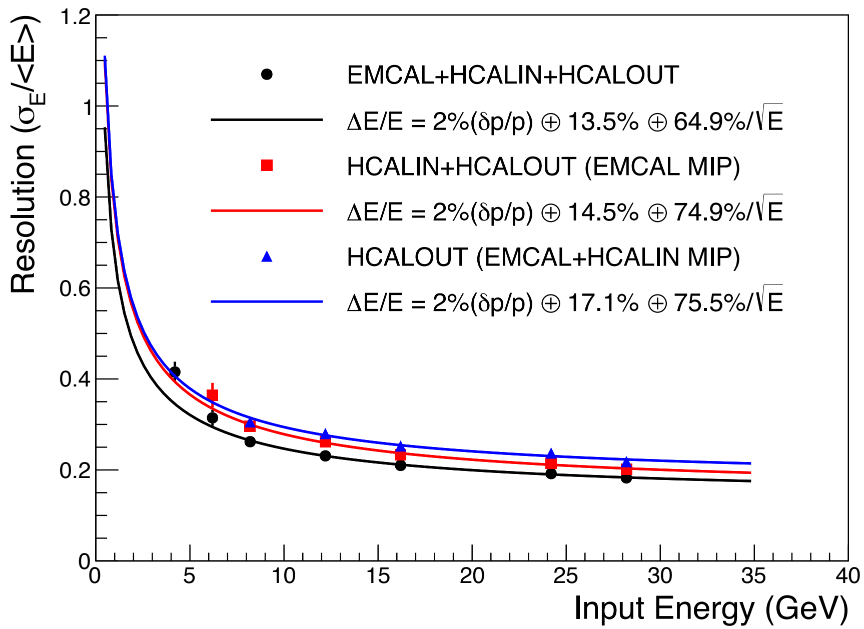


Resolution at tower center

HCAL beam tests

- Learned calibration techniques, energy response uniformity in tiles





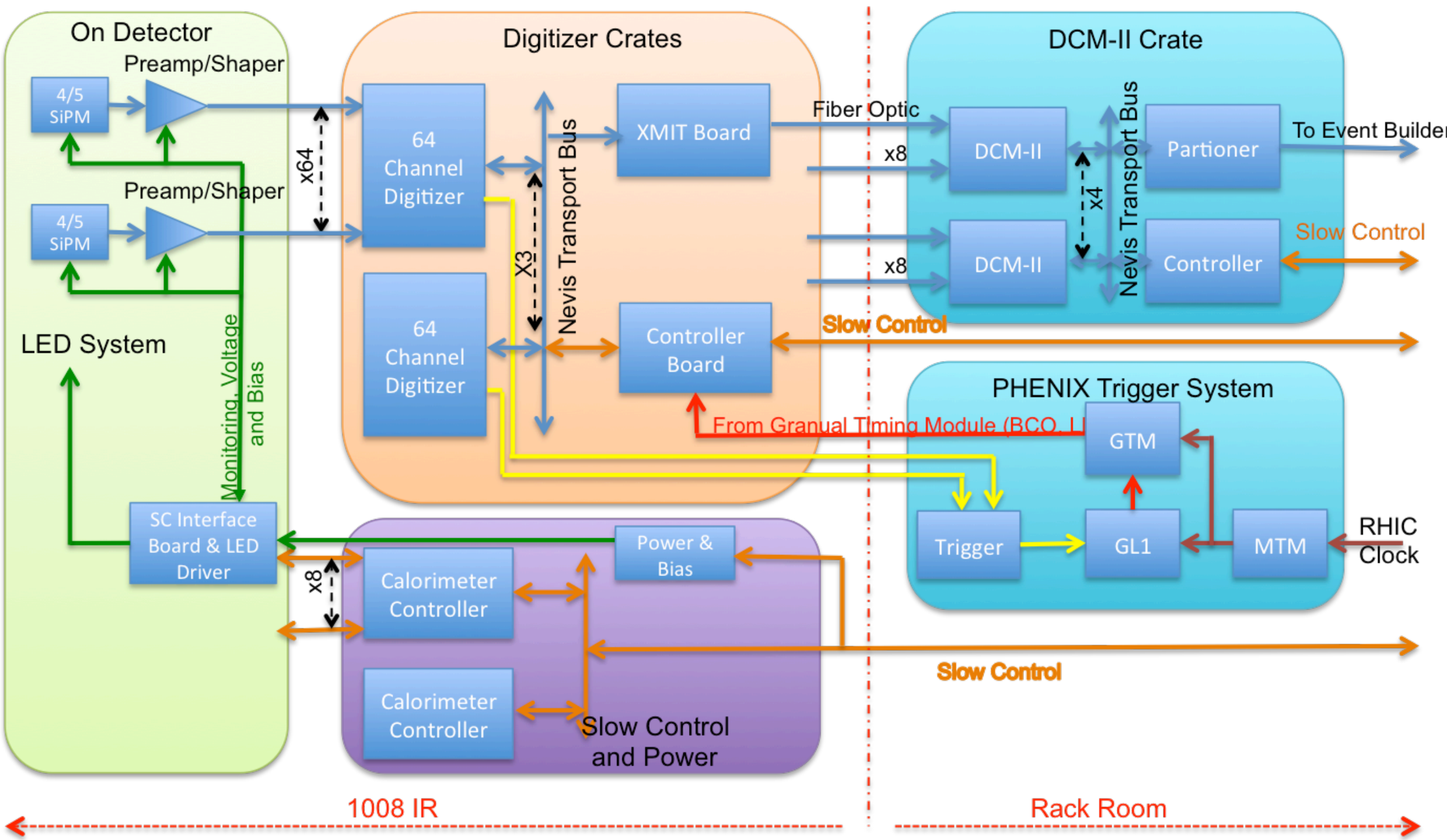
Next steps in calorimetry

- “Module 0” prototypes of HCAL this year, half-sector of EMCAL next year
- Back to test beam February 2018 with new “production” η~0.9 calorimeters, new “production” digitizers
- By this time next year, we aim to have built and operated every piece of the EMCAL and HCAL

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



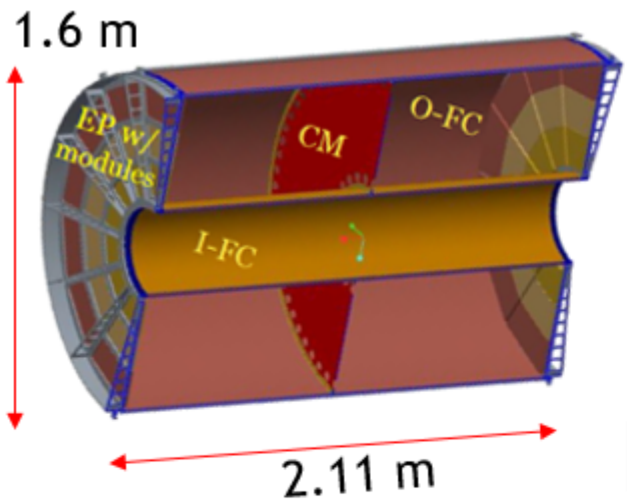
Solenoid magnet

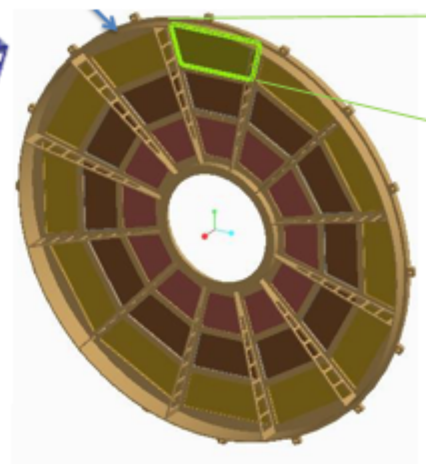
- High resolution tracking translates to high field
  - 1.5 T
  - 2.8 m bore
  - 3.8 m long
- BaBar solenoid arrived at BNL in February 2015
  - Low field test March 2016
  - Preparing now for high field test September 2017
- Cryo, power supply, and quench protection for 1008 under development
- By this time next year, we aim to have tested the magnet at full field

TPC key features

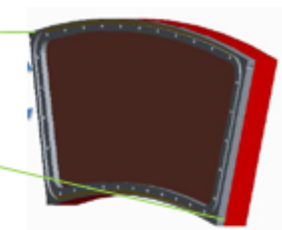
- Compact—outer radius 80 cm
- 3 (radial) x 12 (azimuthal) GEM chambers per end
- FEE board being developed around SAMPA ASIC to be used by ALICE and STAR iTPC (no new ASIC development)
- Fast gas low diffusion to achieve position resolution < 200 μ
- Field distortions minimized by
  - Minimize Ion Back 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 readout

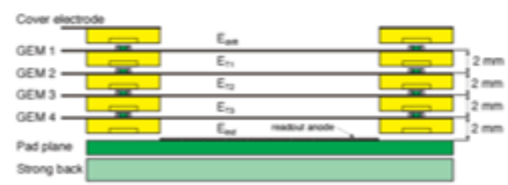
TPC detector overview





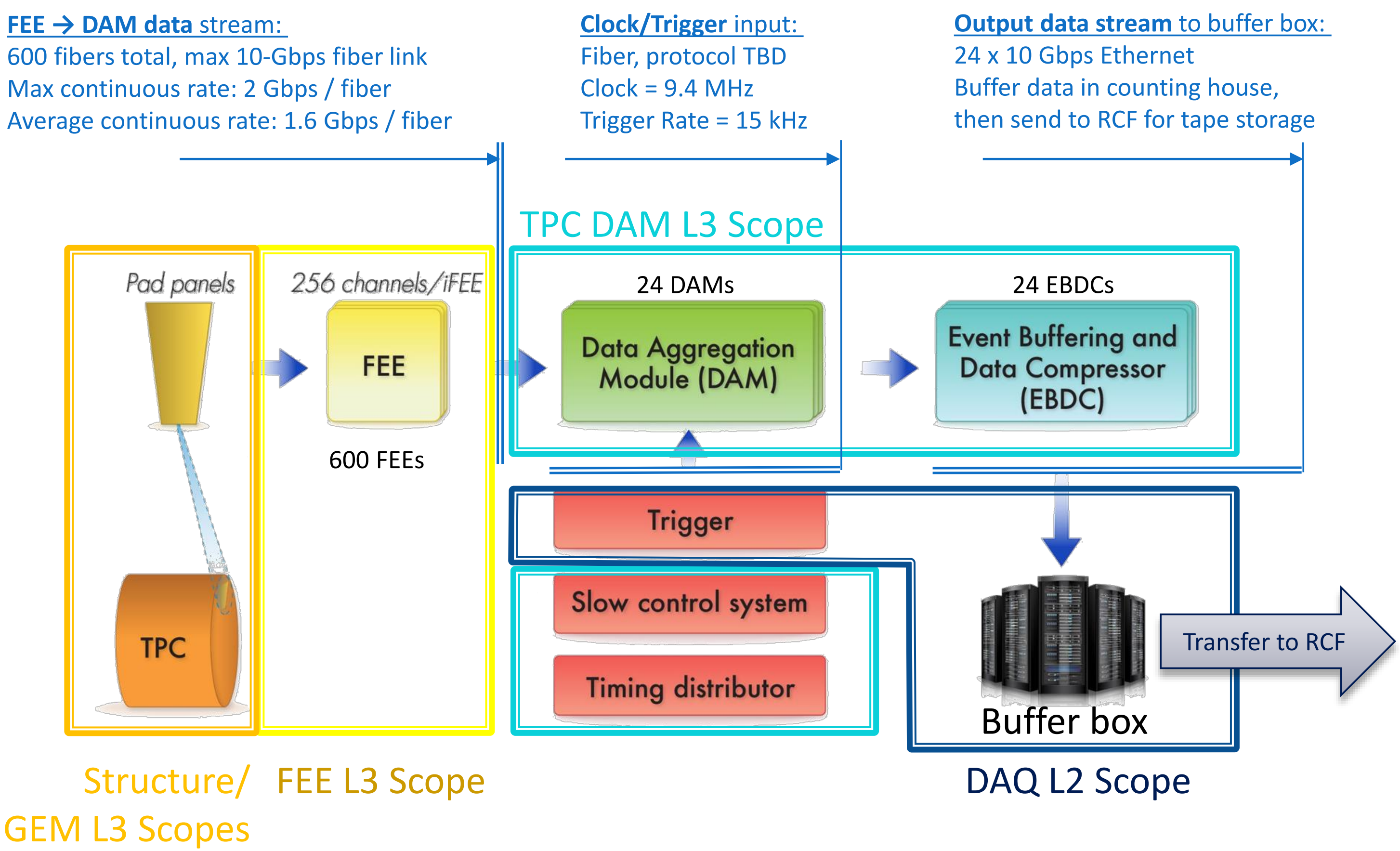
72 modules
2(z), 12(ϕ), 3(r)





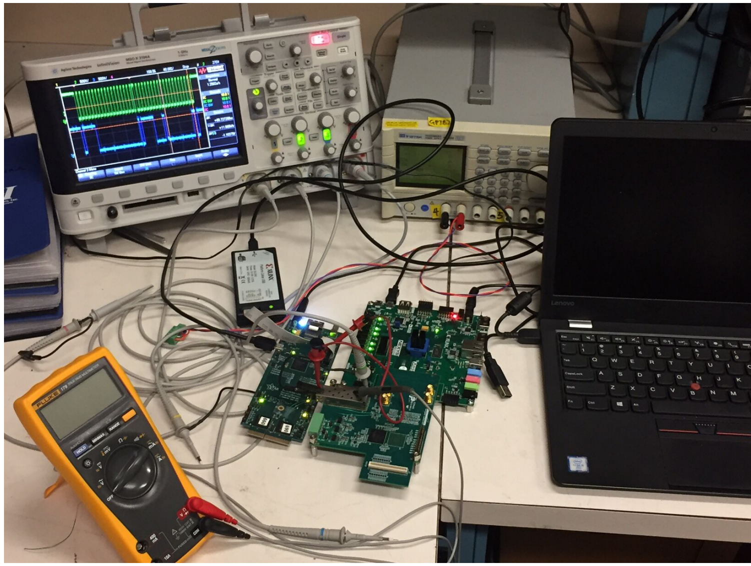
Quad-GEM Gain Stage
Operated @ low IBF

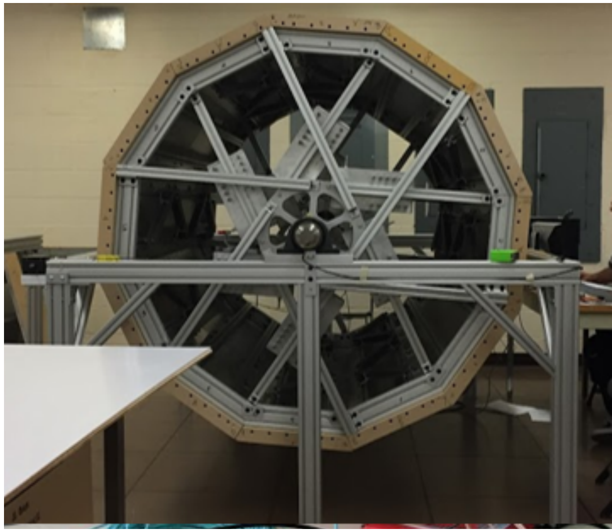
TPC Electronics Overview



Next steps in TPC

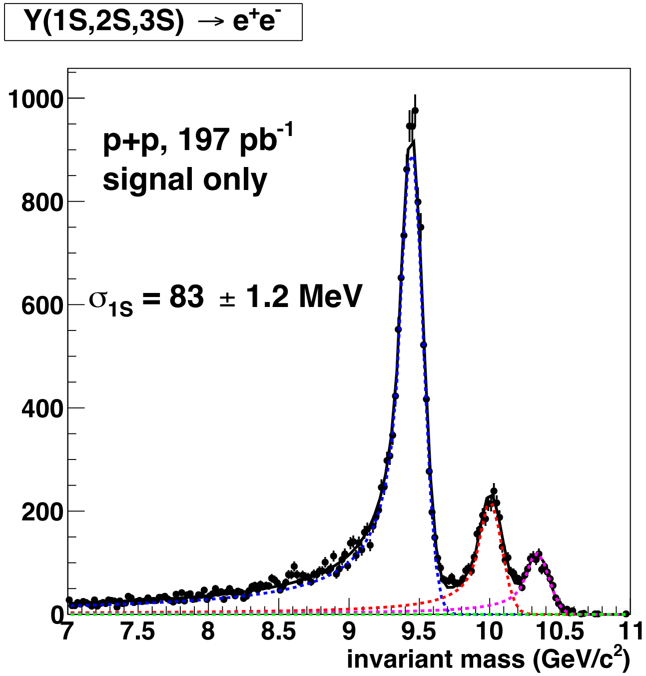
- Mechanical design and analysis very advanced
- Full size prototype under construction at SBU
- Up to 80 kV high voltage material tests
- Attempt to optimize pad design
- Complete and test prototype field cage
- Prototype FEE card
- Set up tests with FELIX board
- Inner Region Integration Task Force
- Simulations
- Consider how we can do a truly comprehensive system test





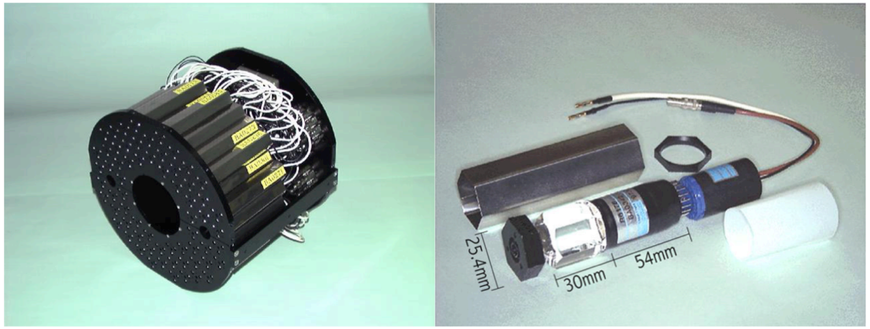
Tracking simulation

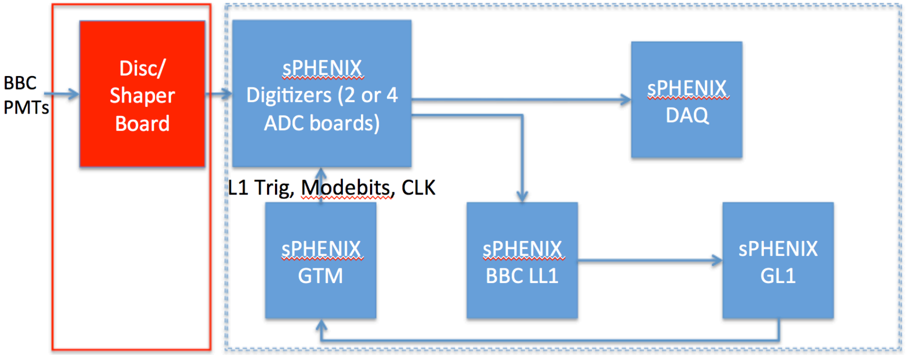
- Comprehensive tracking simulation and reconstruction is under way and aim to model realistic cluster size and two hit resolution
- Material budget and incorporation of hits from INTT and MVTX to be included
- Pattern recognition and fitting under intense scrutiny, mass resolution ~90 MeV



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



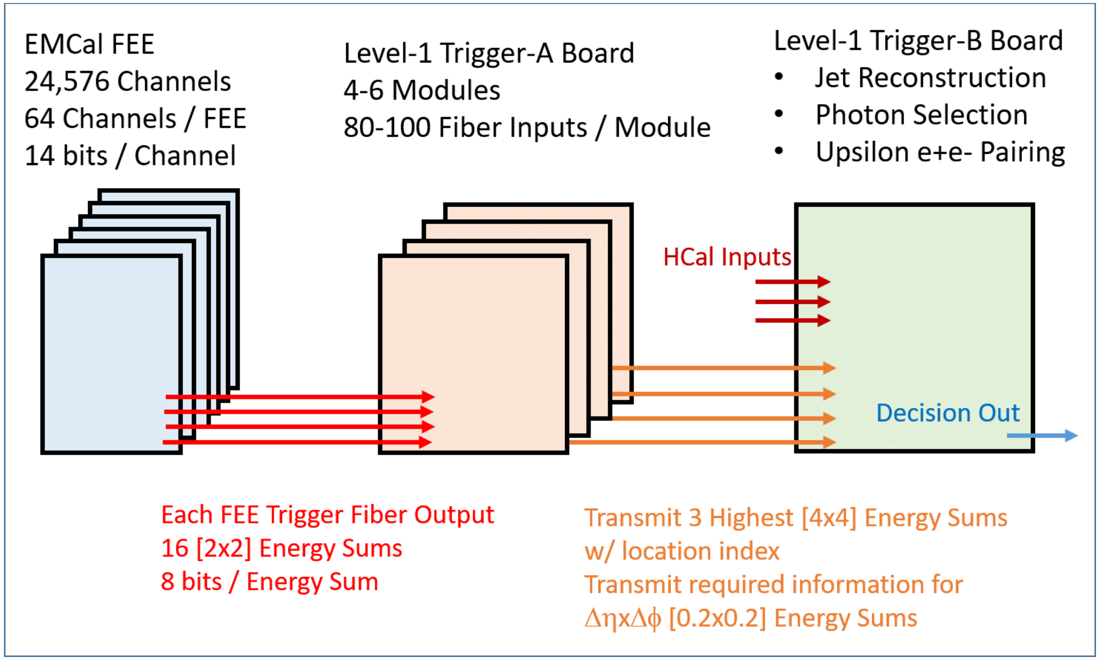


DAQ

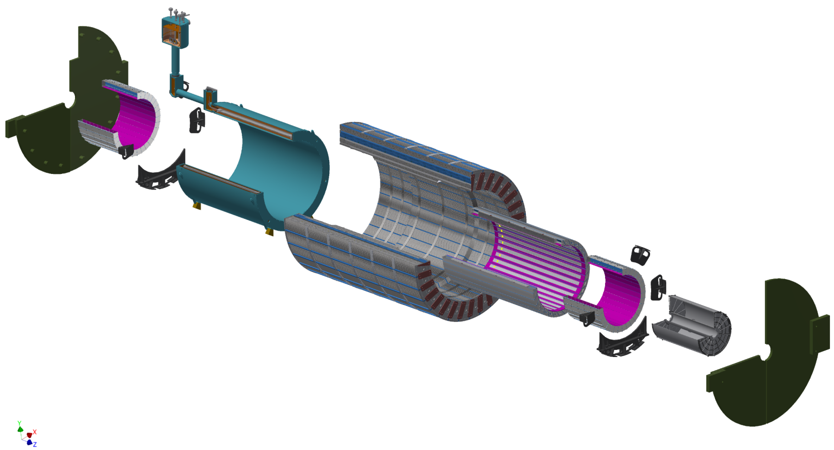
- Calorimeter readout uses a modest number of DCM II's developed for PHENIX, as does INTT
- Tests with DCM II achieved 15 kHz/90% live
- Modest redesign of timing system and trigger manager ("GTM" and "GL1" in PHENIX parlance)
- TPC readout is a significant challenge in data volume and rates, prototyping under way will allow
- Data logging rate feasible today, likely to be even more feasible in five years

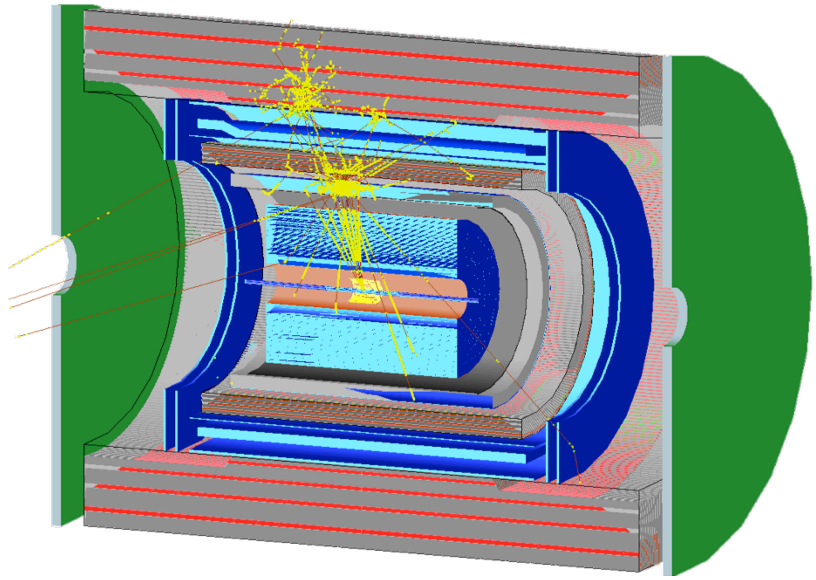
Trigger

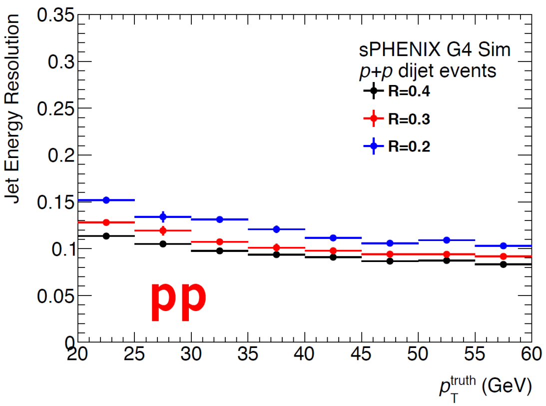
- Calorimeter electronics is designed to drive for trigger primitives on fiber at crossing rate
- Trigger studies/simulation under way

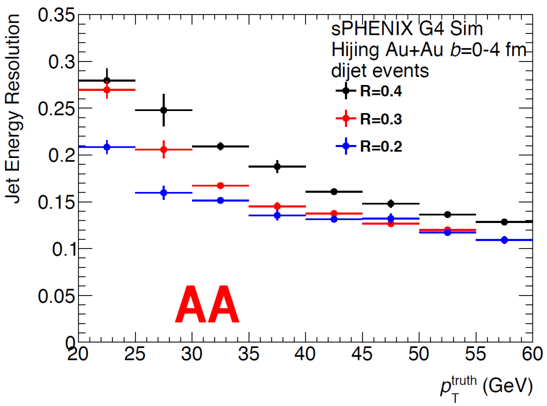


Design, prototype, simulation









- Continued design, engineering, and analysis
- Ever increasing fidelity to simulations
- Another beam test 2/2018
- 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 will be tested at full field in the next few months
- 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, but need the first round of hardware to establish that the reference design is practical