The sPHENIX experiment at RHIC

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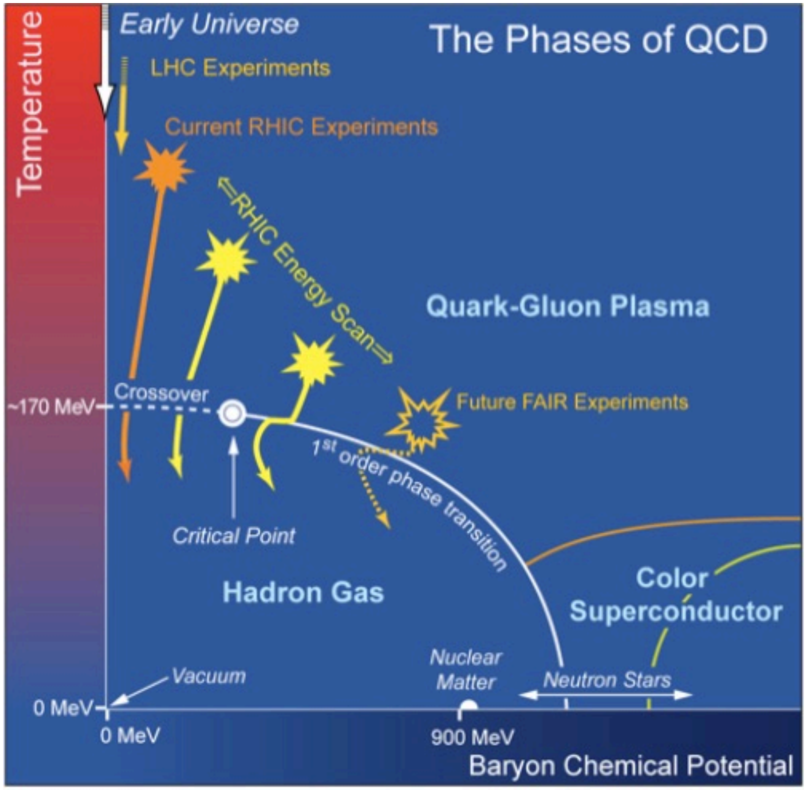
Quark Gluon Plasma (QGP)



Ultra-relativistic heavy ion collisions create hot, dense medium of quarks and gluons.

Relativistic Heavy Ion Collider (RHIC) at BNL, NY on the task for last 16 years:

- Extremely versatile machine
- Only collider with polarized beam

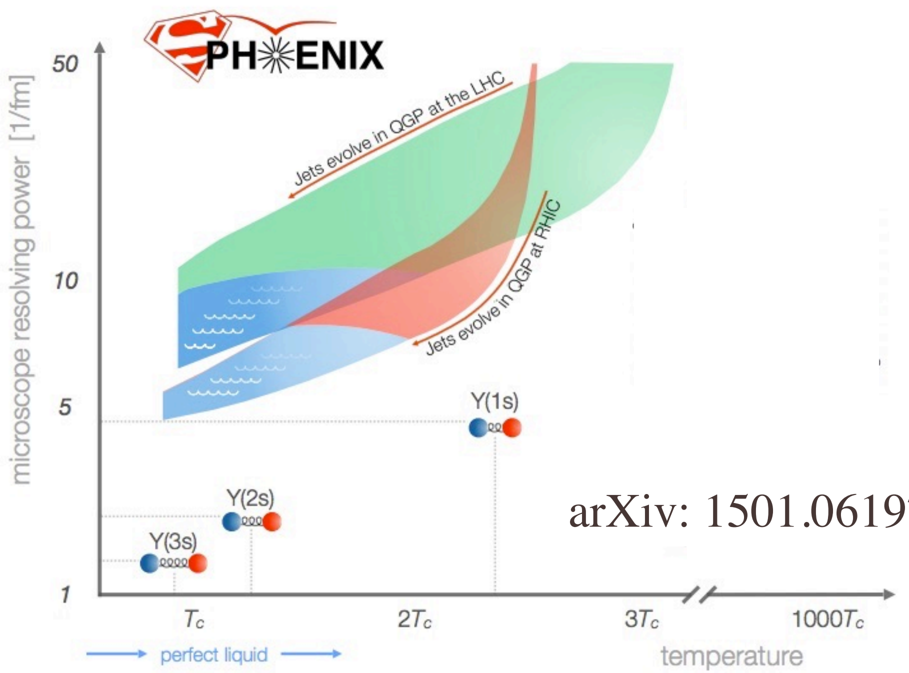
Recommendation from 2015 Nuclear Science Advisory Committee:

"The upgraded RHIC facility provides unique capabilities that must be utilized to explore the properties and phases of quark and gluon matter.."

http://science.energy.gov/~/media/np/nsac/pdf/2015LRP/2015_LRPNS_091815.pdf

Next generation physics goals?

How do asymptotically free quarks and gluons create the near-perfect liquidity of the QGP?



arXiv: 1501.06197

An experimentalist's answer: Deploy probes with a resolution that reaches well below the thermal ~1fm scale of the bulk:

Jets and b-quark (Upsilon) states

Requirements of sPHENIX

- High Statistics!
- Jet Structure/γ-Jet:
  - Single particle resolution: $\sigma/E < 100\%/\sqrt{E}$
  - Jet: $\sigma_E/E < 120(150)\%/\sqrt{E}$ in p+p(Au+Au)
  - Photon Energy resolution $\sigma/E<15\%/\sqrt{E}$
  - dp/p ~ 0.2%p to > 40 GeV/c
- Upsilons:
  - Mass resolution: $\sigma_M < 100$ MeV/c^2
  - Good e/π separation
- b-jets:
  - electron ID
  - DCA < 100 μm

Full azimuthal acceptance: |η|<1

15 kHz DAQ rate

HCal

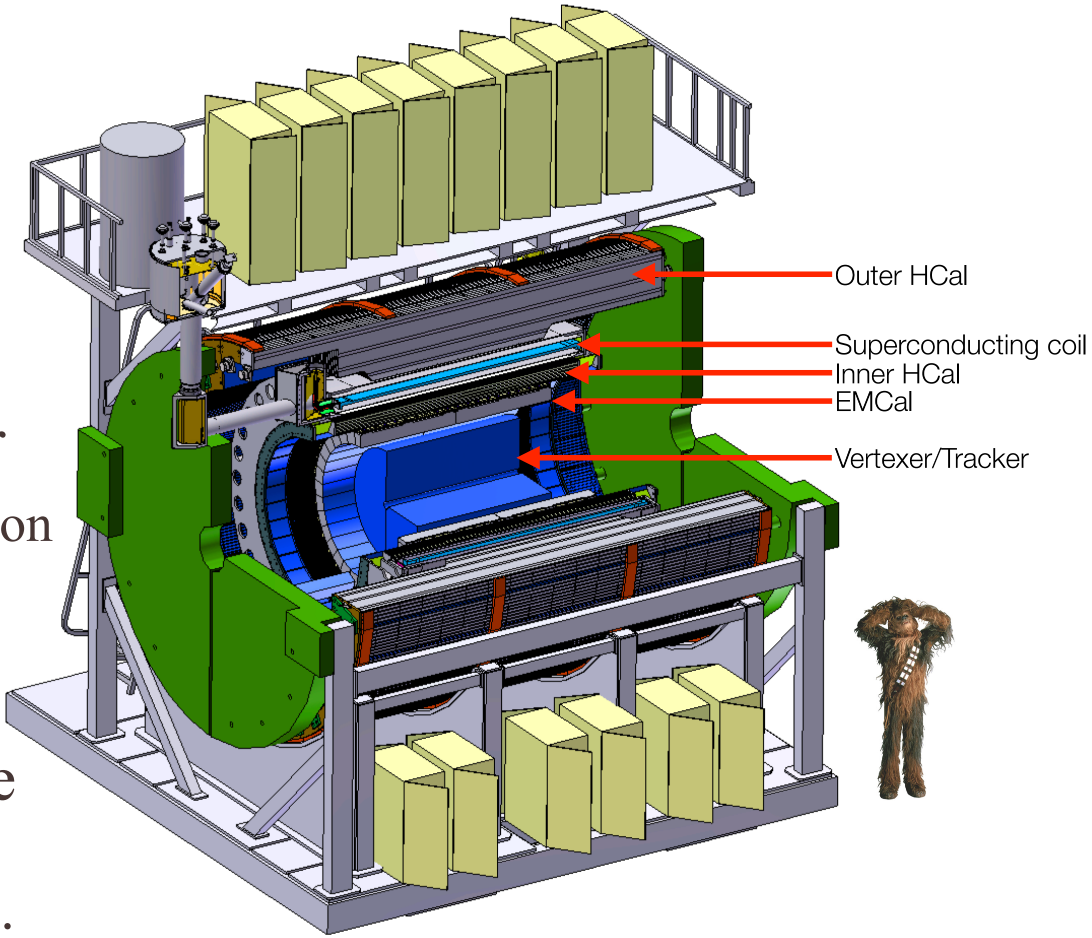
EMCal

Tracker

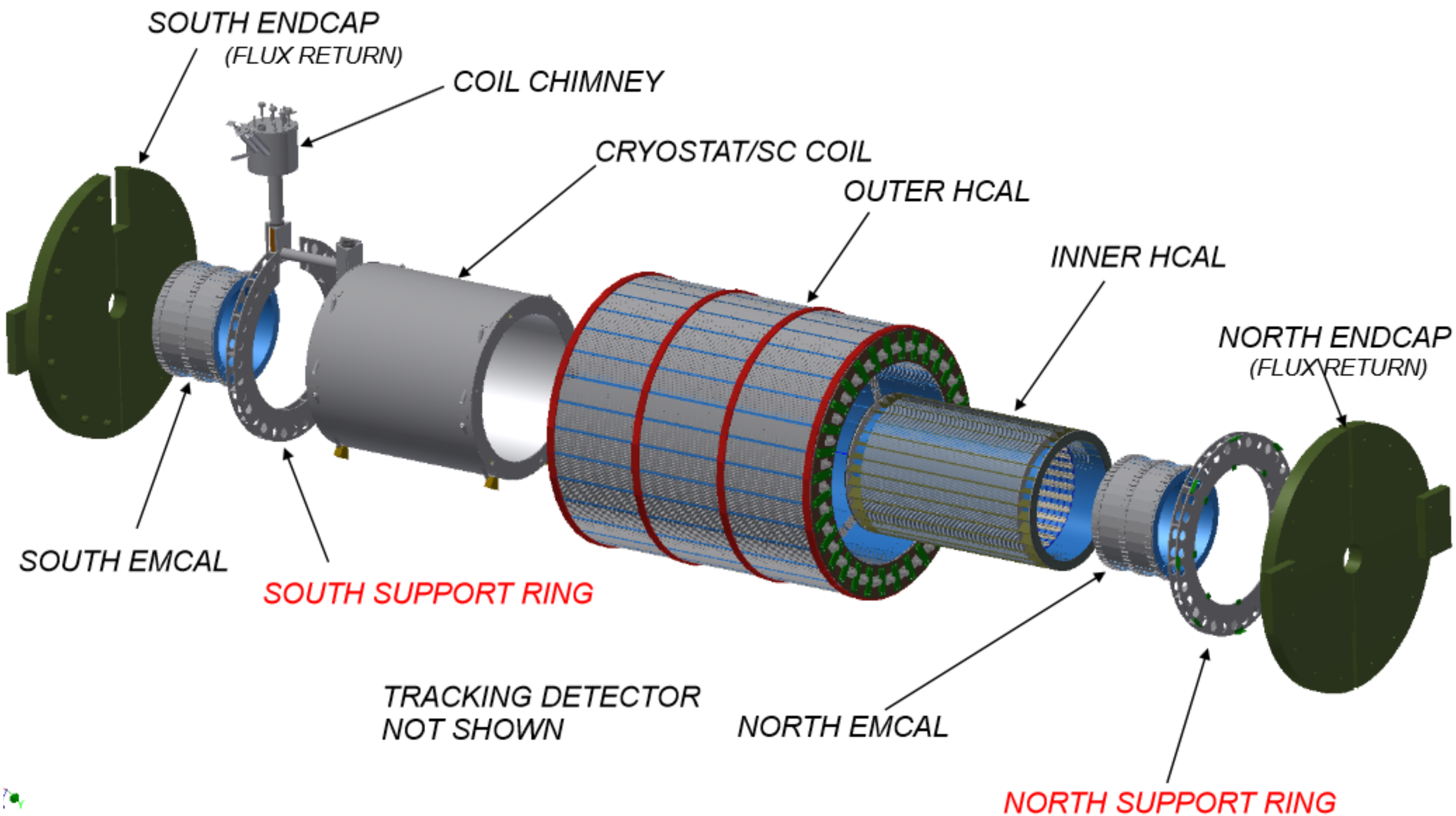
"State of the art jet detector"

sPHENIX Detector Design

- Uniform acceptance
  - $-1<\eta<1$ and $0<\varphi<2\pi$
- Superconducting solenoid
- Hadronic calorimeter
  - Also works as flux return
- Electromagnetic calorimeter
  - Compact and fine segmentation
- Solid state photodetectors
  - work in a magnetic field
- 15 kHz DAQ speed for large unbiased MB data sample
- Utilization of infrastructure in an existing PHENIX experimental hall.



Putting it all together



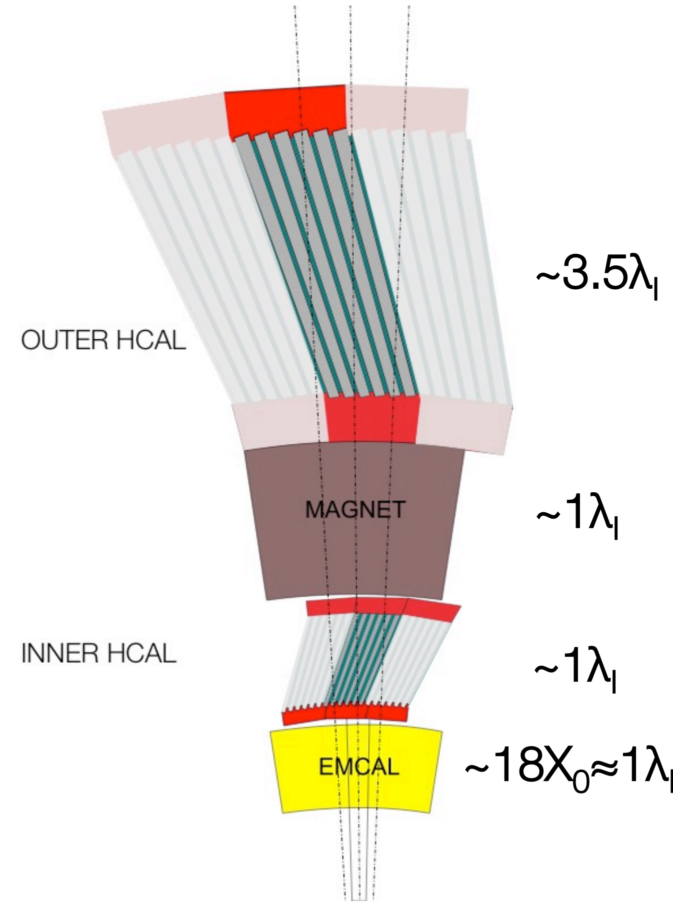
Magnet

- BaBar magnet fulfills our needs
  - 1.5 T central field
  - 2.8 m diameter
  - 3.8 m long
- ~ 1 year ago arrived at BNL
- Low power cold testing successful

Calorimeters reference design

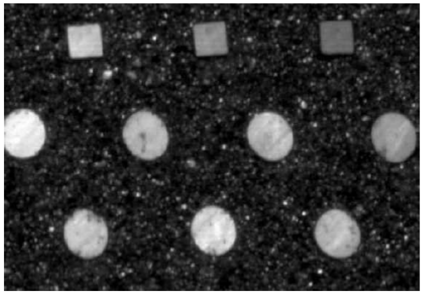
- EMCAL Tungsten + scintillating fiber
  - $\Delta\eta \times \Delta\varphi \approx 0.025 \times 0.025$
  - 96 x 256 readout channels
  - EMCal $\sigma_E/E < 15\%/\sqrt{E}$ (single particle)
- HCAL steel and scintillating tiles + wavelength shifting fiber
  - Outer + Inner HCal around the solenoid
  - $\Delta\eta \times \Delta\varphi \approx 0.1 \times 0.1$
  - 2 x 24 x 64 readout channels
  - $\sigma_E/E < 100\%/\sqrt{E}$

(all readouts with silicon photomultipliers)



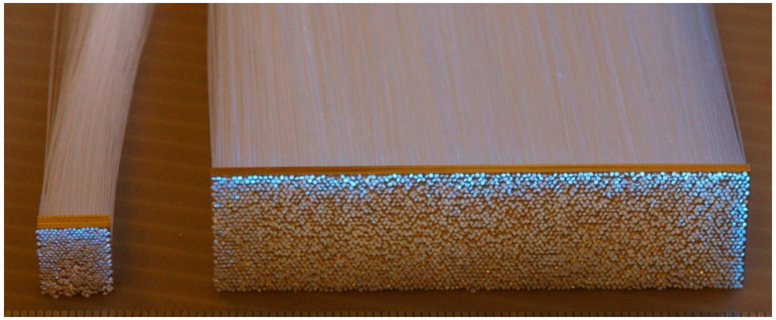
EMCAL

W/SciFi SPACAL (originally developed by Oleg Tsai at UCLA)



Absorber

- Matrix of tungsten powder and epoxy with embedded scintillating fibers
- Density ~ 10 g/cm^3
- X_0 ~ 7 mm (18 X_0 total), R_M ~ 2.3 cm
- Energy resolution ~ 12%/$\sqrt{E}$

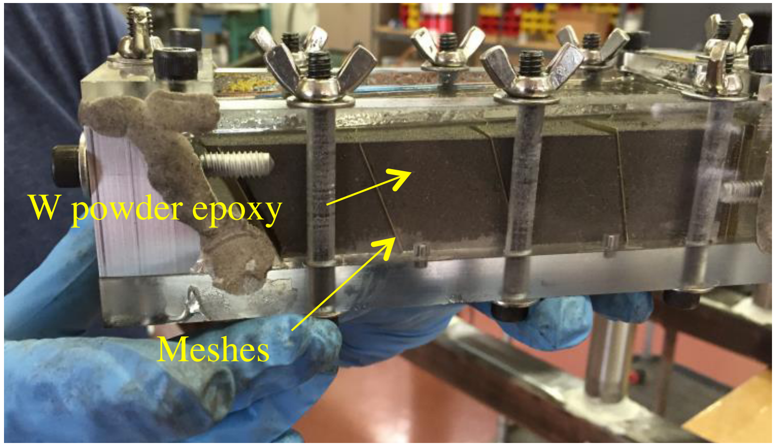


Scintillating fibers (Kuraray SCSF78)

- Diameter: 0.47 mm, Spacing: 1 mm
- Sampling Fraction ~ 2.3 %

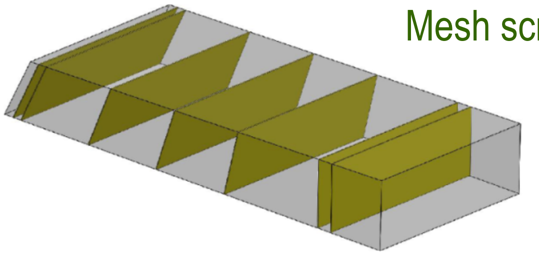
- Modules are formed by pouring tungsten powder and epoxy into a mold containing an array of scintillating fibers

- Fibers are held in position with metal meshes spaced along the module

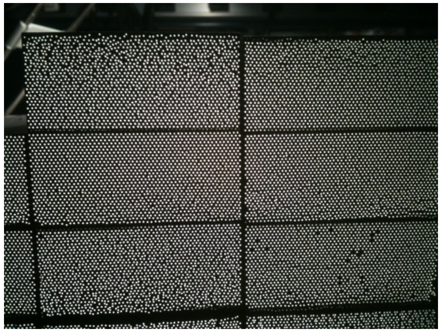


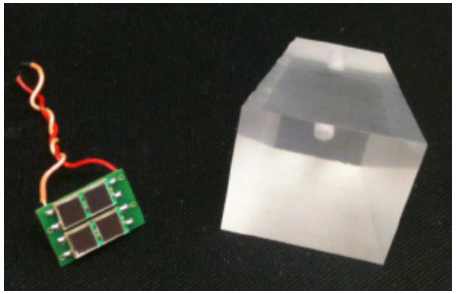
w/SciFi Modules

1D Projective

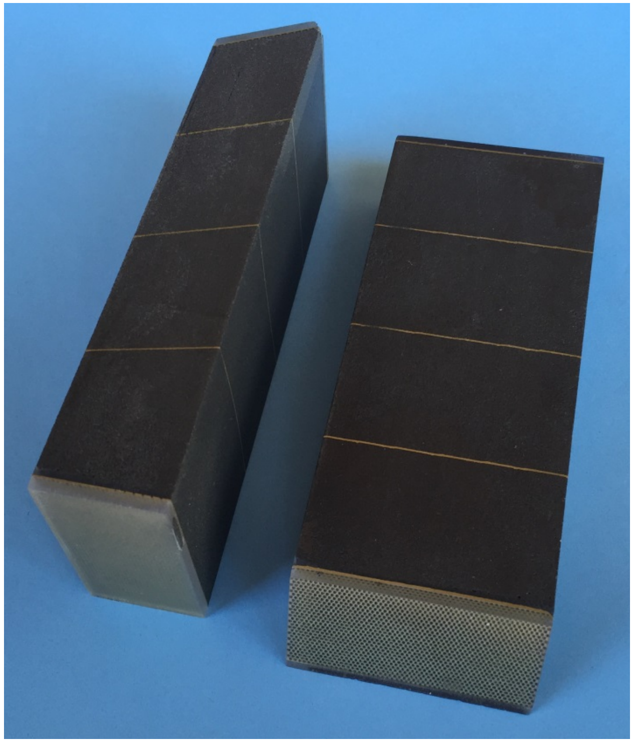


Fiber ends are finished by with fly cutting

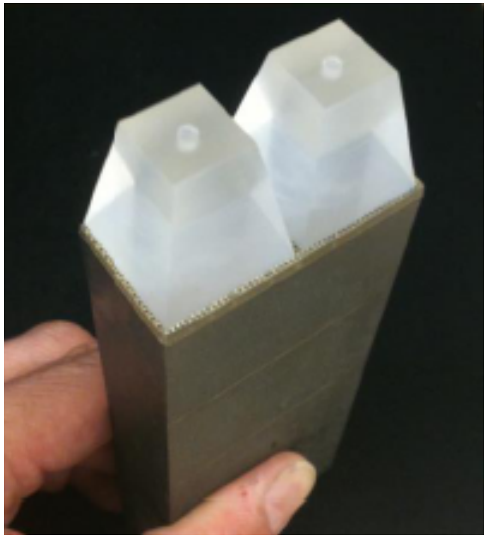




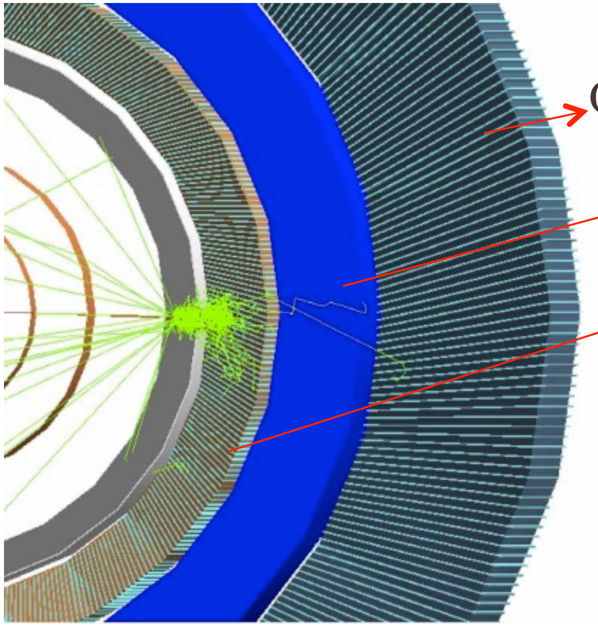
Produced at UCLA, BNL, UIUC and THP



Light guides and SiPMs are attached to module ends to form towers

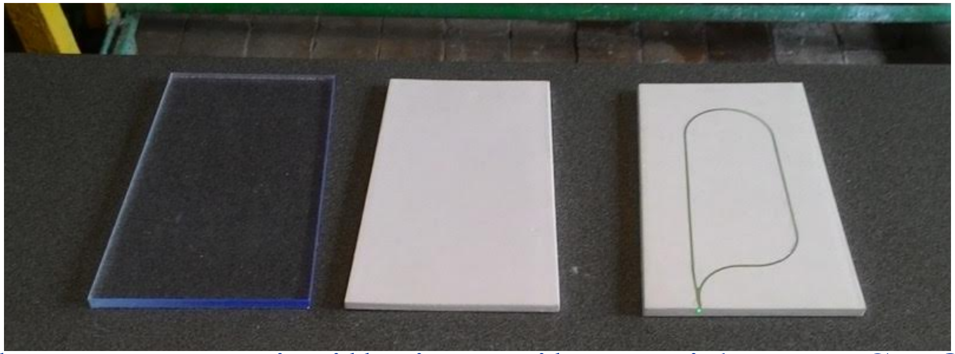


HCAL



A tilted plate design with alternating layers of tile and steel absorbers:

- Prevents particle to traverse without encountering the steel.
- Less variations of sampling fractions.

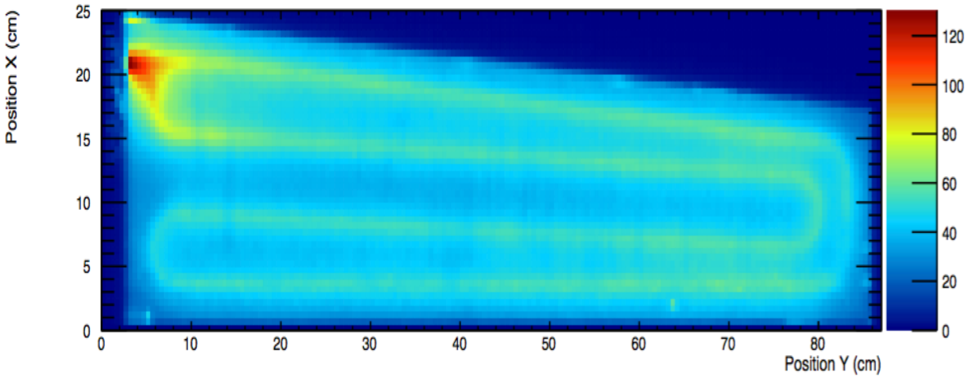


Polystyrene scintillating tiles with WLS fiber in groove. One SiPM reads out both ends of fiber. SiPMs from 5 tiles summed together to form one tower

Sampling fraction changes with depth (~25%)

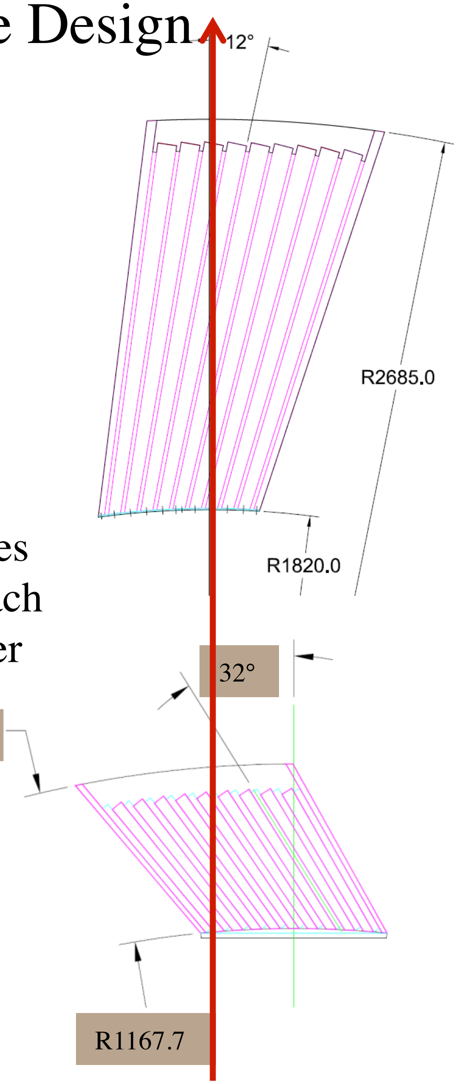
HCAL Prototype

Tile response map with LEDs



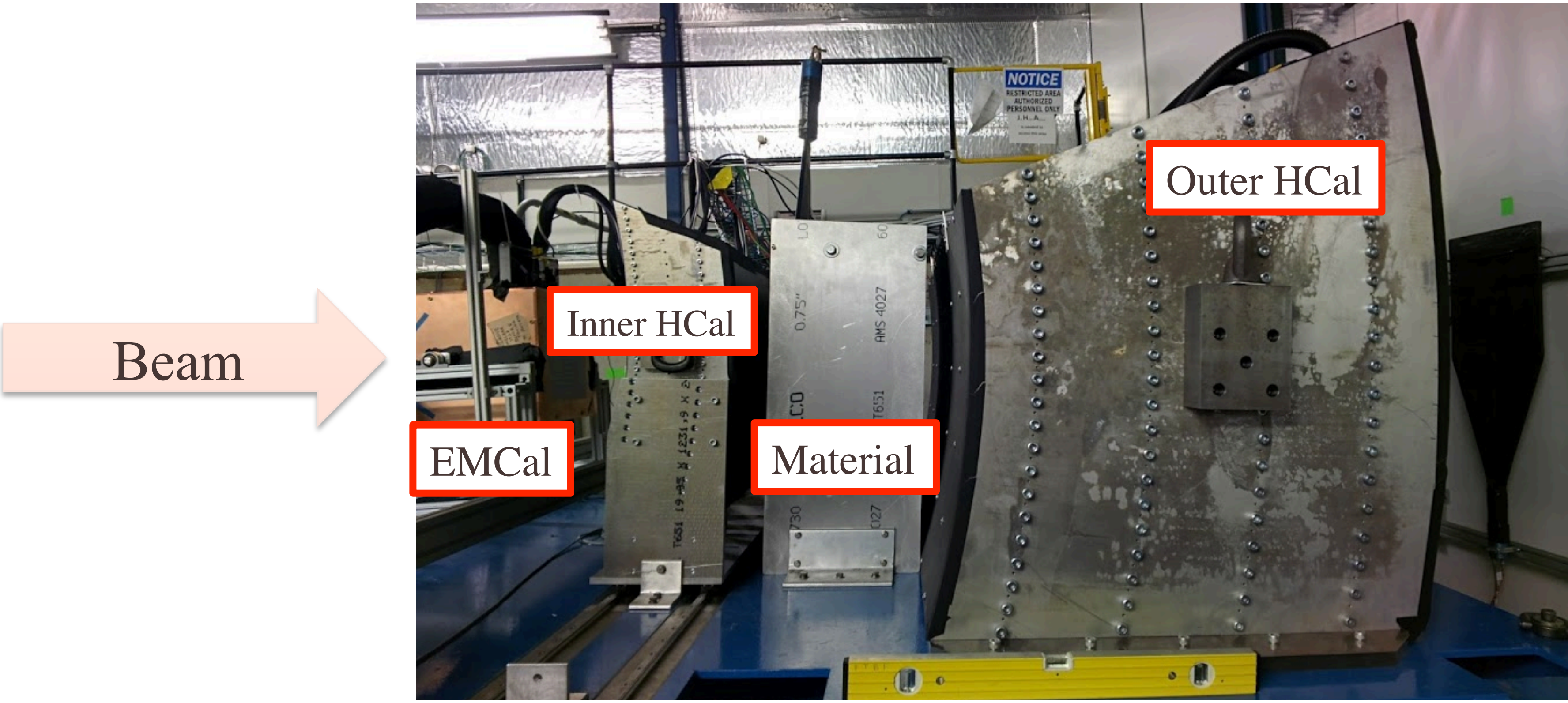
Outer HCAL prototype with assembled steel plates and readout electronics

Tilted Plate Design



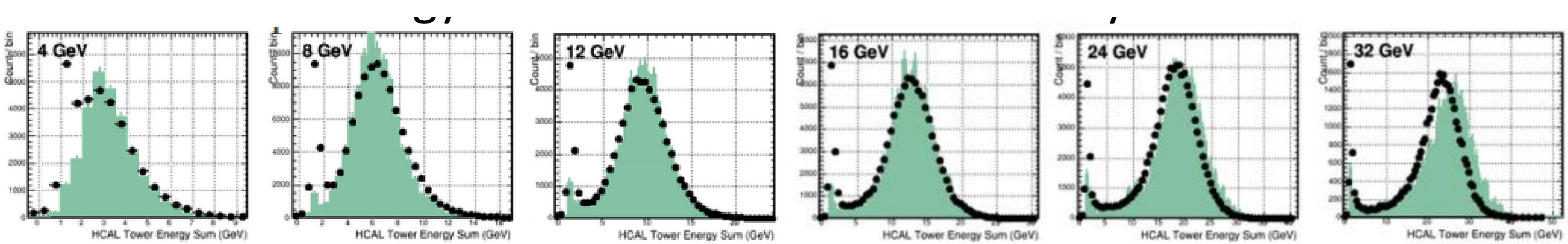
MIP crosses 4 tiles in each calorimeter

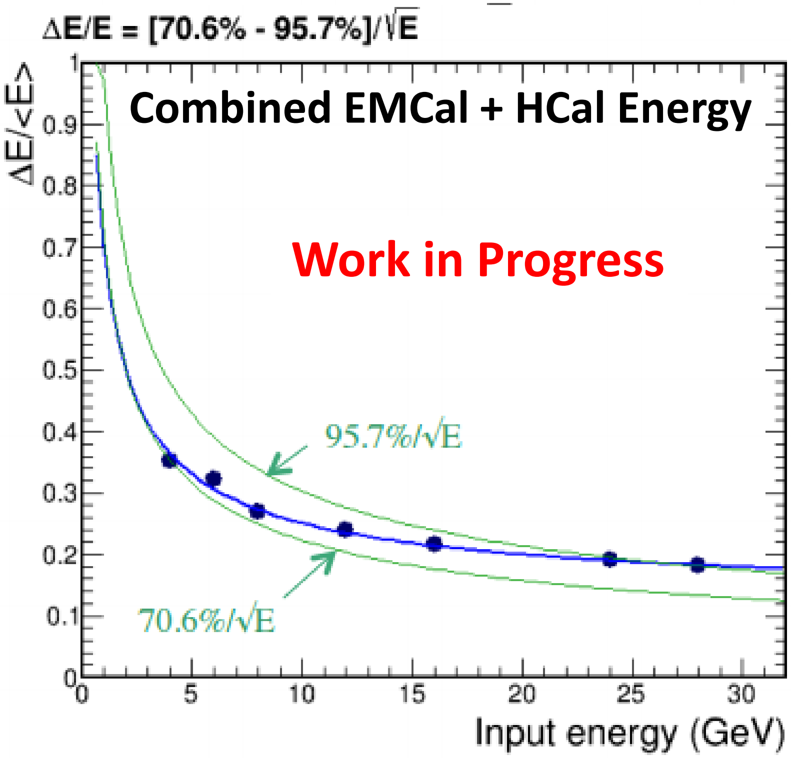
Test Beam Setup



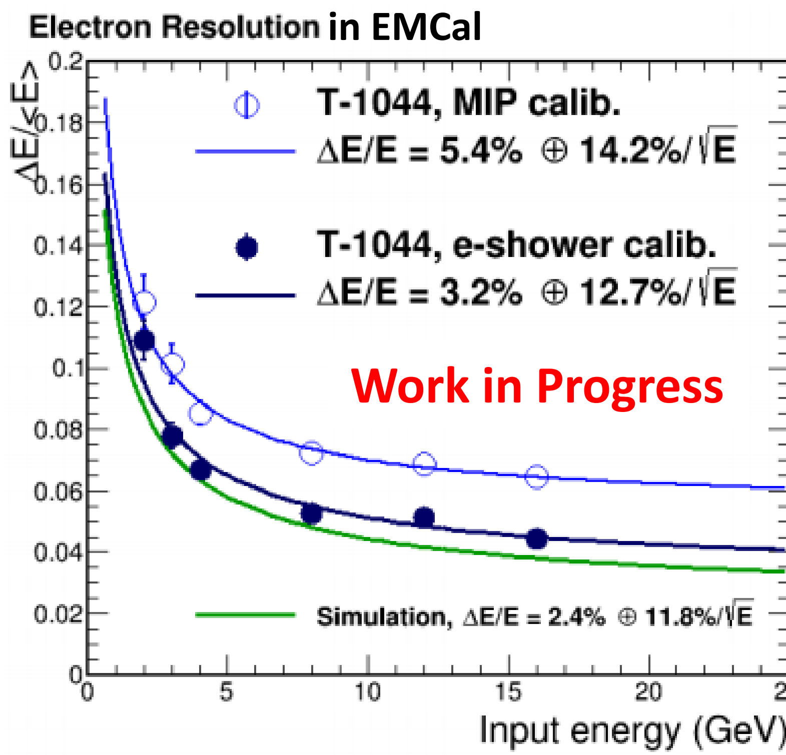
- Conducted testbeam studies at Mtest at Fermilab Test Beam Facility (talk by A. Franz, Thrusday, August 4th).
- EMCAL was calibrated with 120 GeV proton beams.
- HCAL was calibrated with cosmic muons.

Early Preview of Test Beam Results





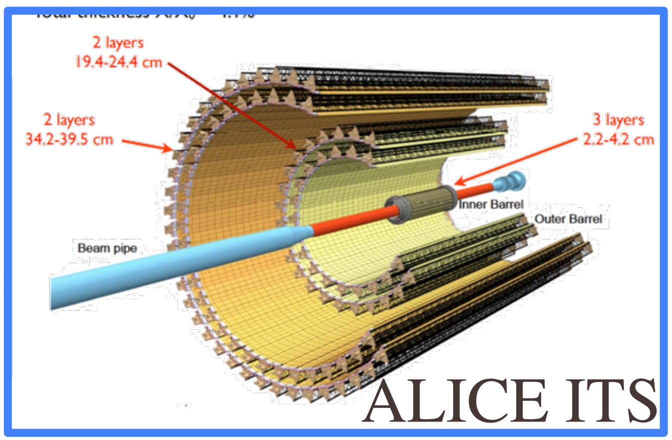
Final calibrations ongoing!



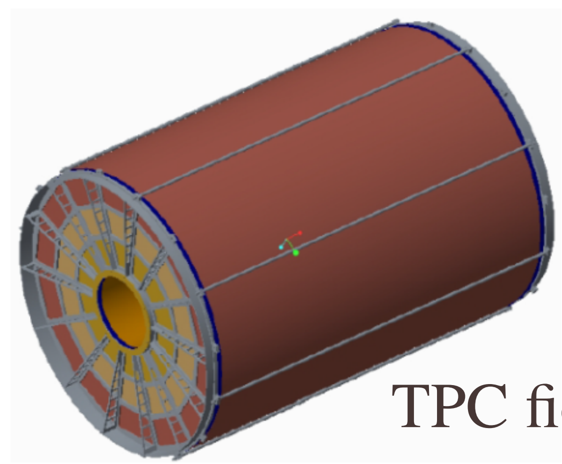
- Simulation shows good agreement with early **data** results
- Results fall within required performance

Tracking options

- Inner Tracker
  - MAPS (ALICE ITS Upgrade)
- Outer tracker
  - Compact TPC w/GEM readout (ALICE Upgrade)



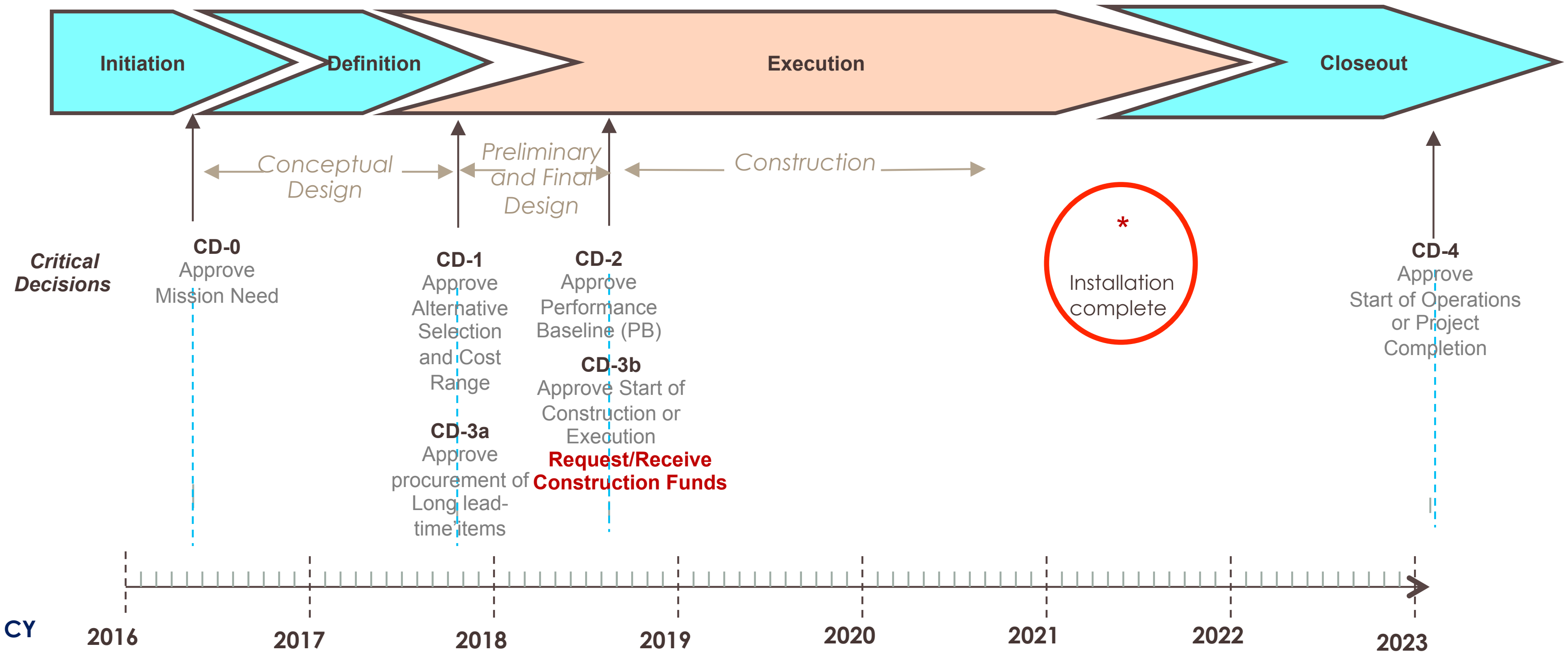
ALICE ITS



TPC field cage

Tracking review Fall 2016 to evaluate all options

sPHENIX Timeline



CD-0	2016
CD-1/CD-3a	Nov 2017
CD-2/3	Jul 2018
Installation complete	Jun 2021
Ready for Beam	Jan 2022
CD-4	Jan 2023

- pCDR November 2015 went very well
- No recommendations from May, 2015 scientific review

Summary

- sPHENIX will allow high statistics measurements for jets and quarkonia at 200 GeV
- Scientific case for sPHENIX has been demonstrated
- Collaboration is established
- Design, Simulation, and R&D progressing rapidly
- Looking forward to starting data collection in January 2022
- More information:
  - http://www.phenix.bnl.gov/phenix/WWW/publish/documents/sPHENIX_proposal_19112014.pdf

All are welcome to join the fun!

BACK-UPS

Nuclear Science Long Range Plan

RECOMMENDATION 1

The progress achieved under the guidance of the 2007 Long Range Plan has reinforced U.S. world leadership in nuclear science. The highest priority in this 2015 Plan is to capitalize on the investments made.

- Complete and run CEBAF 12 GeV upgrade
- Complete FRIB at MSU
- Targeted program in neutrinos and fundamental symmetries.
- **The upgraded RHIC facility provides unique capabilities that must be utilized to explore the properties and phases of quark and gluon matter in the high temperature of the early universe and to explore the spin structure of the proton.**

http://science.energy.gov/~/media/np/nsac/pdf/2015LRP/2015_LRPNS_091815.pdf