Performance Characterization Studies of sPHENIX Hadronic Calorimeter Scintillating Tiles

Saif Ali for the sPHENIX Collaboration

Georgia State University

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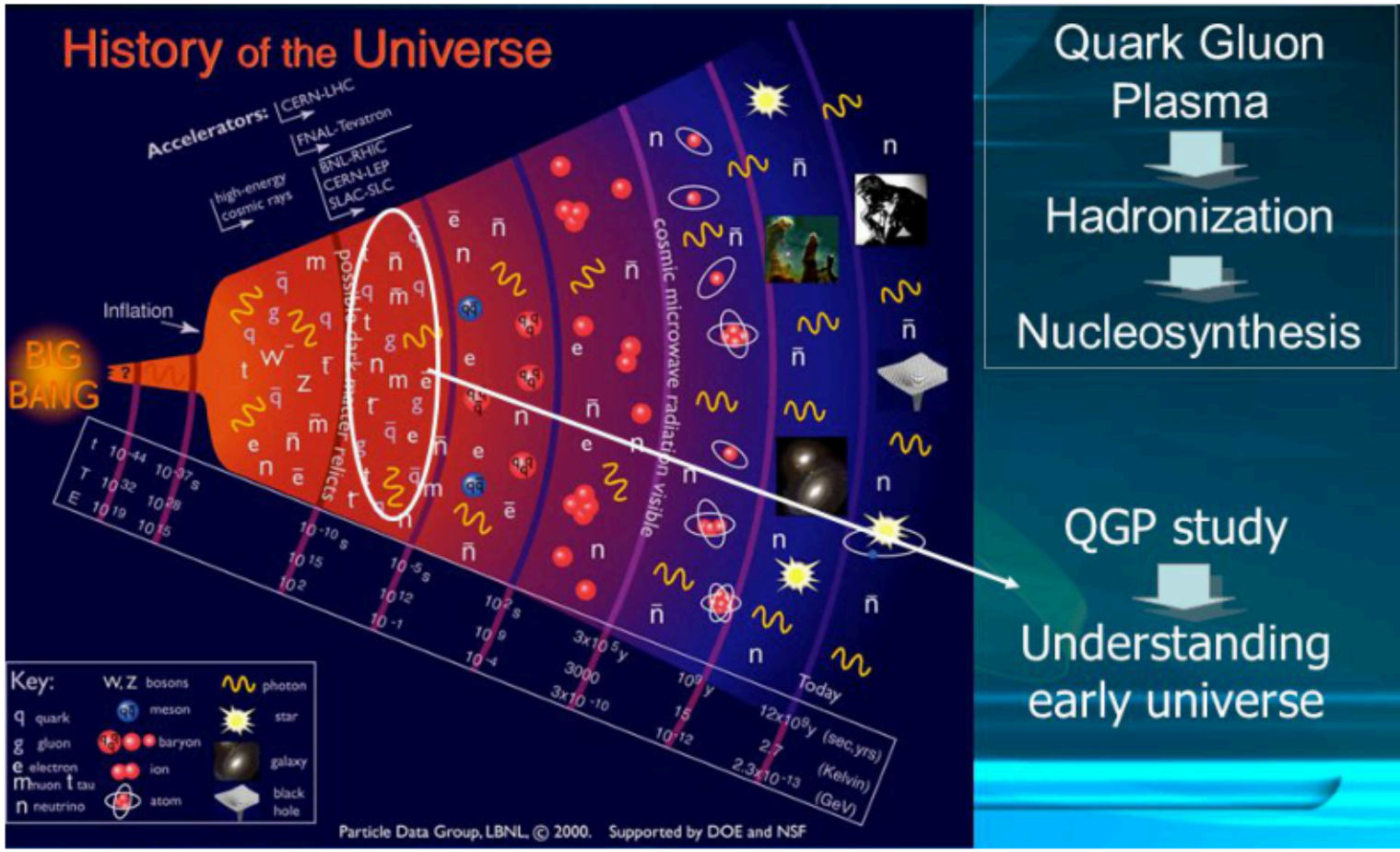
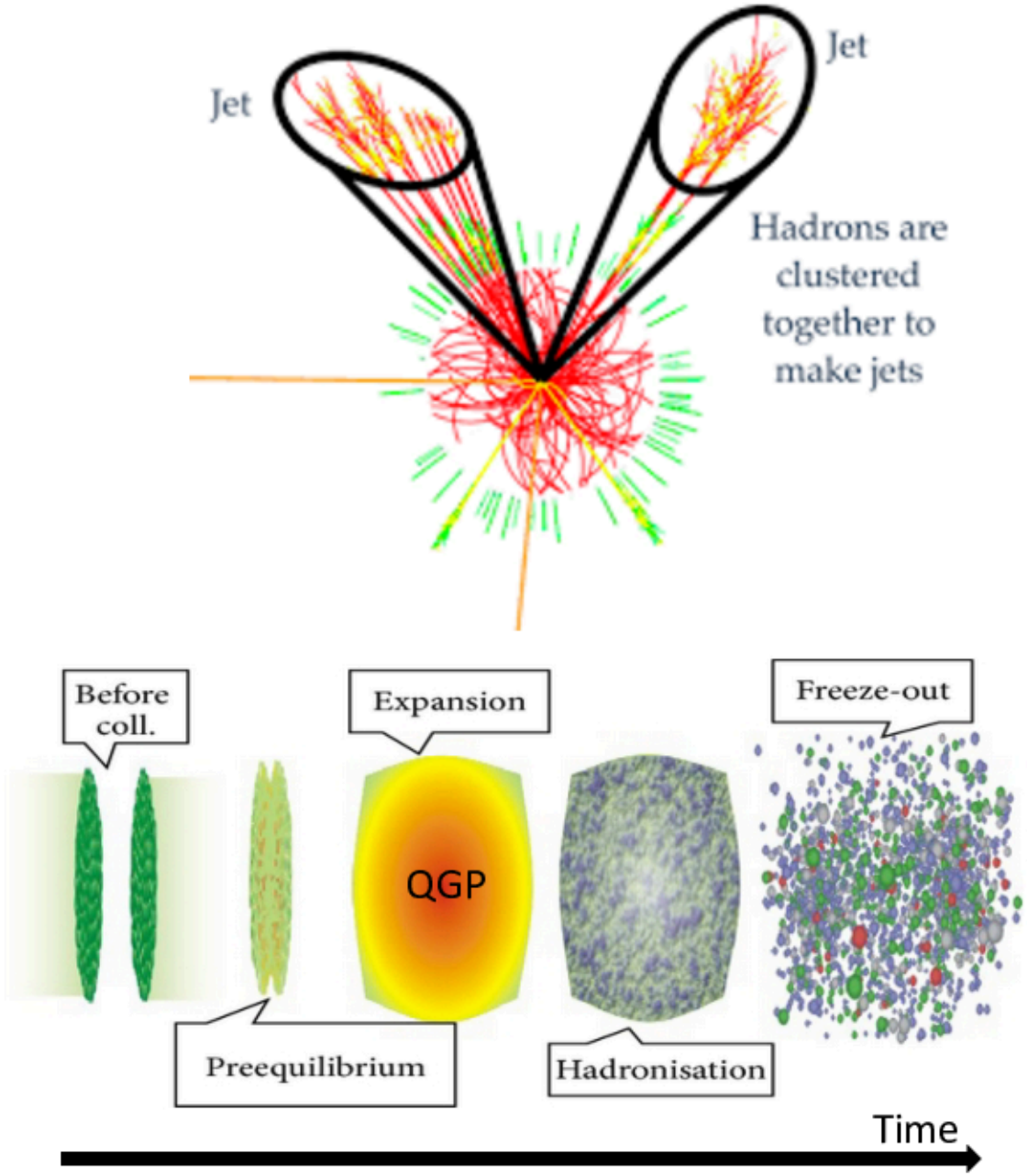
Quark Gluon Plasma (QGP)

- A few millionths of a second after Big Bang
- Hot, dense soup of quarks and gluons
- Everyday time/length scale → quarks and gluons confined to hadrons
- High energy regime of QGP → quarks and gluon are deconfined
- Re-created by particle accelerators
  - Ultrarelativistic heavy ion collisions such as Au+Au, Pb+Pb



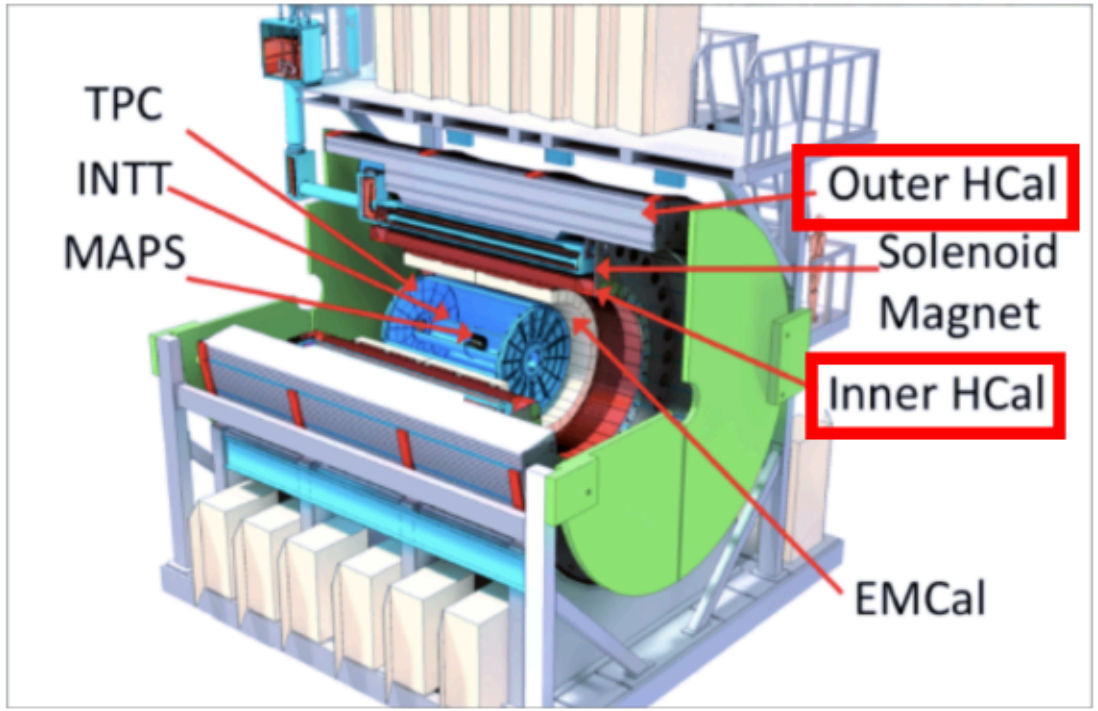
Jets

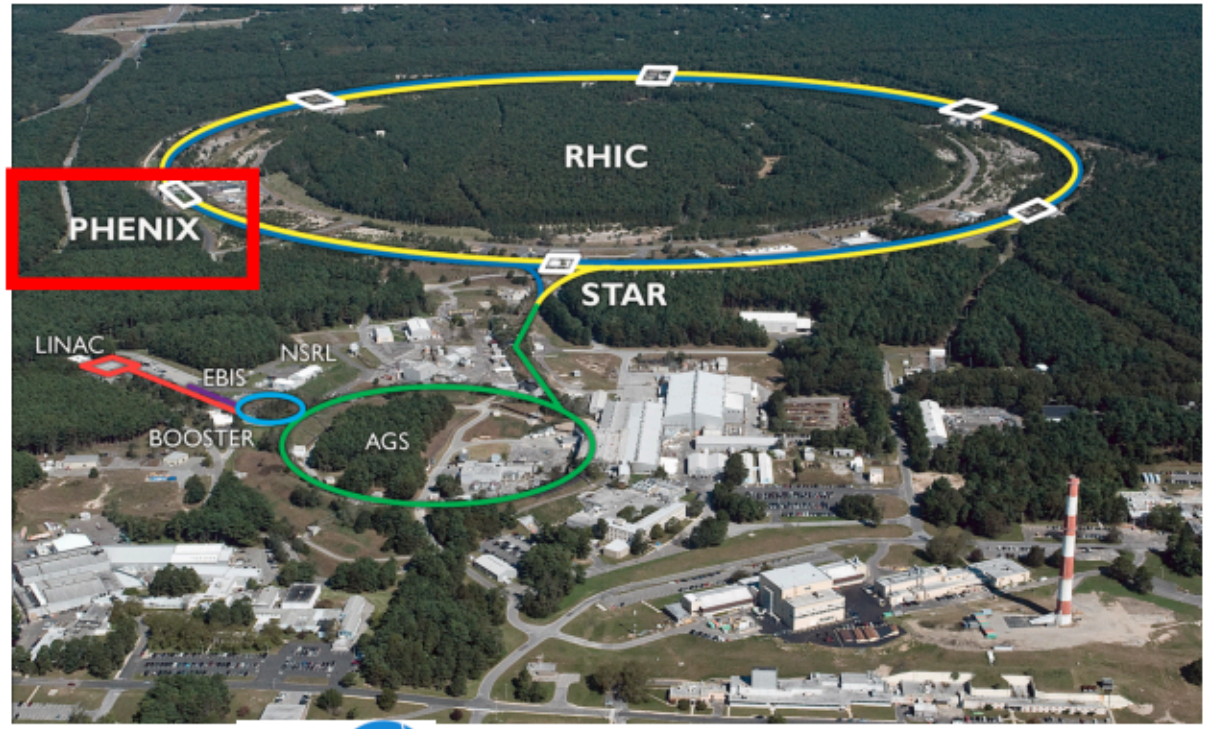
- High momentum partons traverse QGP
  - Originates from hard parton scatterings
  - Fragmentation of partons → collimated sprays of particles
- Tool to study and teach about QGP and QCD
  - Quarks & gluons traverse QGP and lose energy
  - Jet energy loss reconstruction → done via particle accelerator and detector



sPHENIX

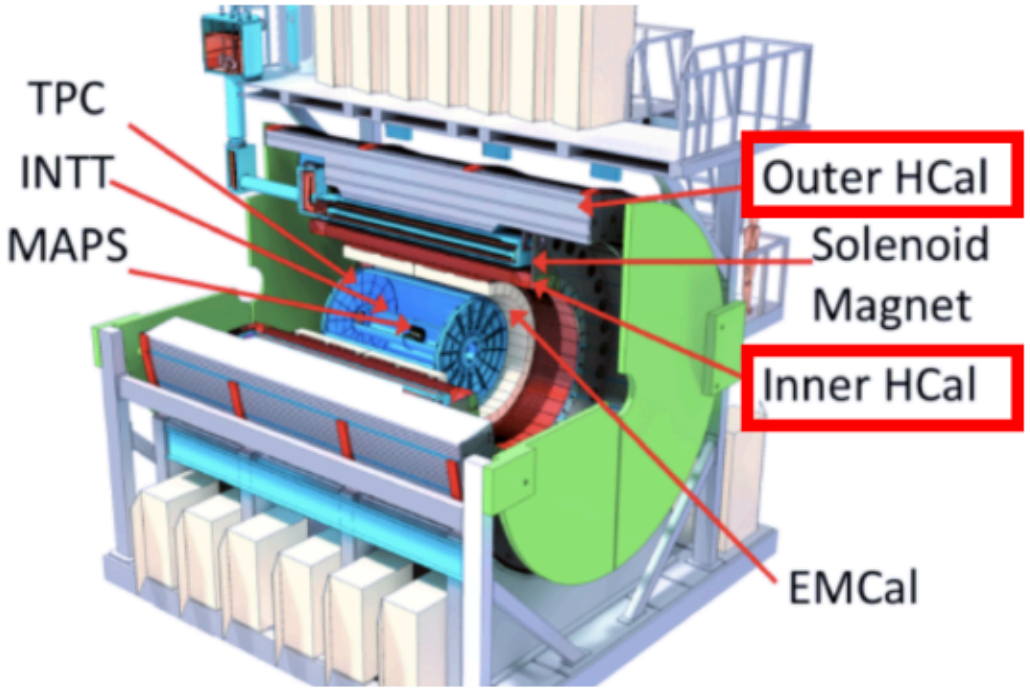
- Particle detector at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL)
- Goal: Measure jets & upsilons in Au+Au collisions of 200 GeV to study energy-transport properties of QGP
- GSU focuses on the Hadronic Calorimeter (HCal) which is currently under construction at BNL



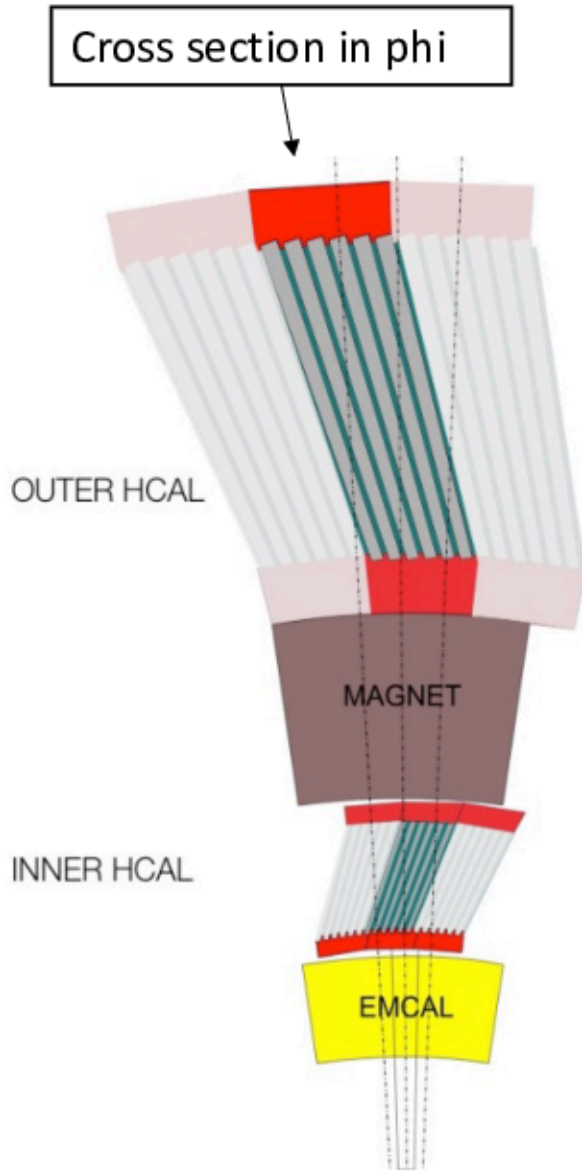


Hadronic Calorimeter (HCal)

- Measures energy of hadrons that compose jets produced in heavy-ion collisions
- Key for precision jet measurements
- Beam tests conducted at Fermilab
  - Demonstrated successful energy reconstruction

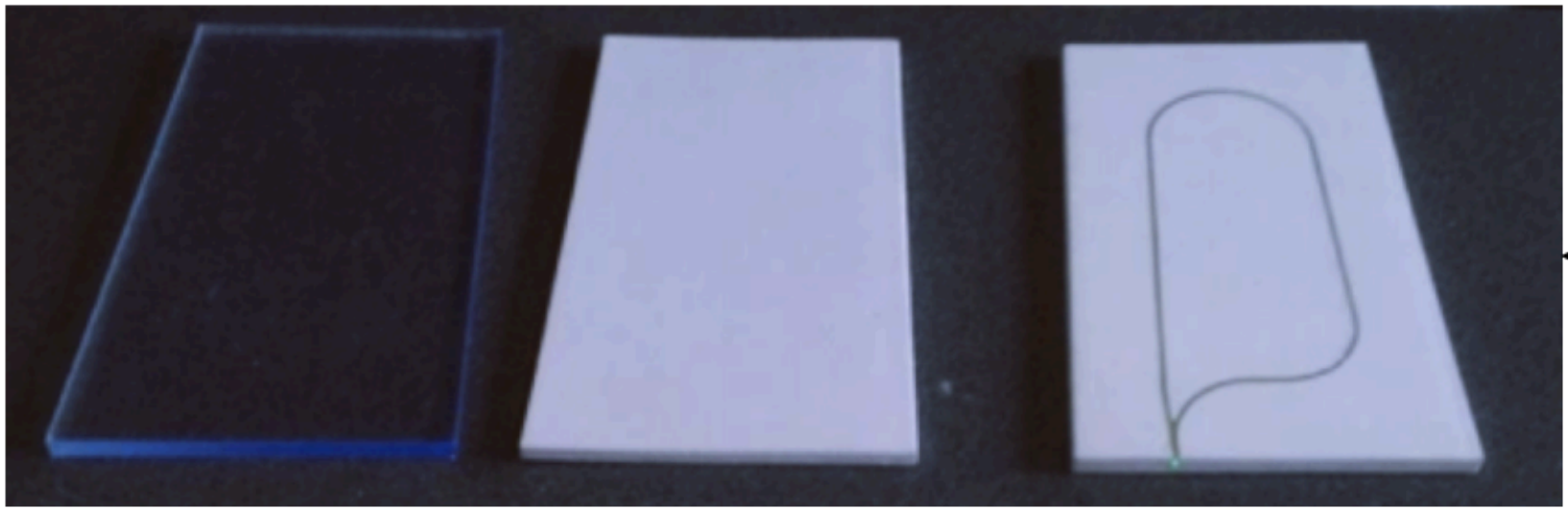


- Full 2π coverage in azimuth: $0 < \varphi < 2\pi$
- Pseudorapidity coverage: $|\eta| < 1.1$
- Magnet ≈ $1.4X_0$
- Outer HCal ≈ $3.5\lambda_1$
- Inner HCal ≈ $1\lambda_1$
- EMCal ≈ $18X_0 \approx 1\lambda_1$



Scintillating HCal Tiles

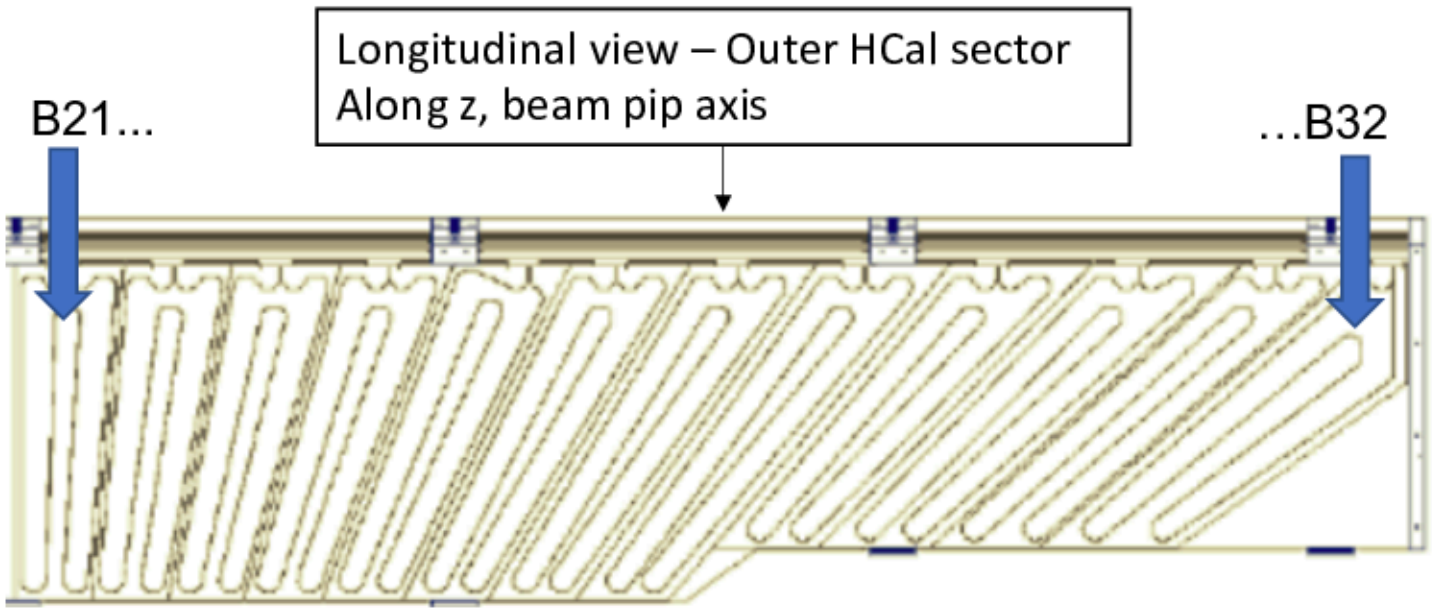
- Produced by a company called Uniplast based out of Russia
- Tile Composition
  - Scintillating Plastic (Extruded Polystyrene)
  - Reflective Coating
  - Wavelength shifting fiber bonded by an optical epoxy
- Outer HCal composed of 7,680 tiles.
  - We have received and tested 95% of them at GSU.



Prototype Inner HCal Tile for R&D

Scintillating HCal Tiles

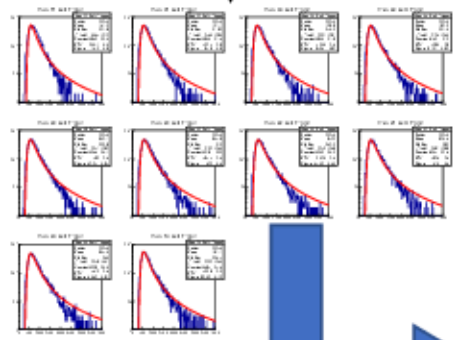
- HCal tiles' SiPM signals aggregated into calorimeter towers
- Each towers' set of tiles have similar performance
  - Goal: to optimize the HCal's performance
- 12 tile shapes based on pseudorapidity

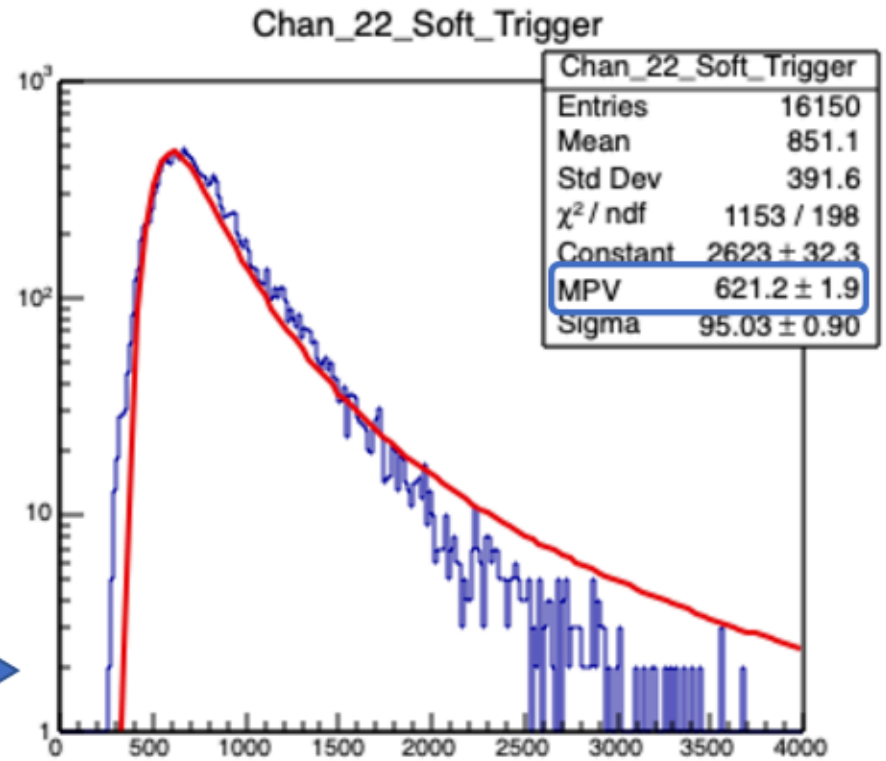


Tile Testing

- Tiles' performance measured via response to cosmic rays – readout via SiPM powered by CAEN DT5702
- Test eight tiles at a time along with two reference tiles for 20 minutes
  - Same reference tiles used for every test of each shape
  - Reference tiles provide a baseline to test against to track changes in tiles' performance

Test Output – ADC Distributions for 8 tiles + 2 ref. tiles





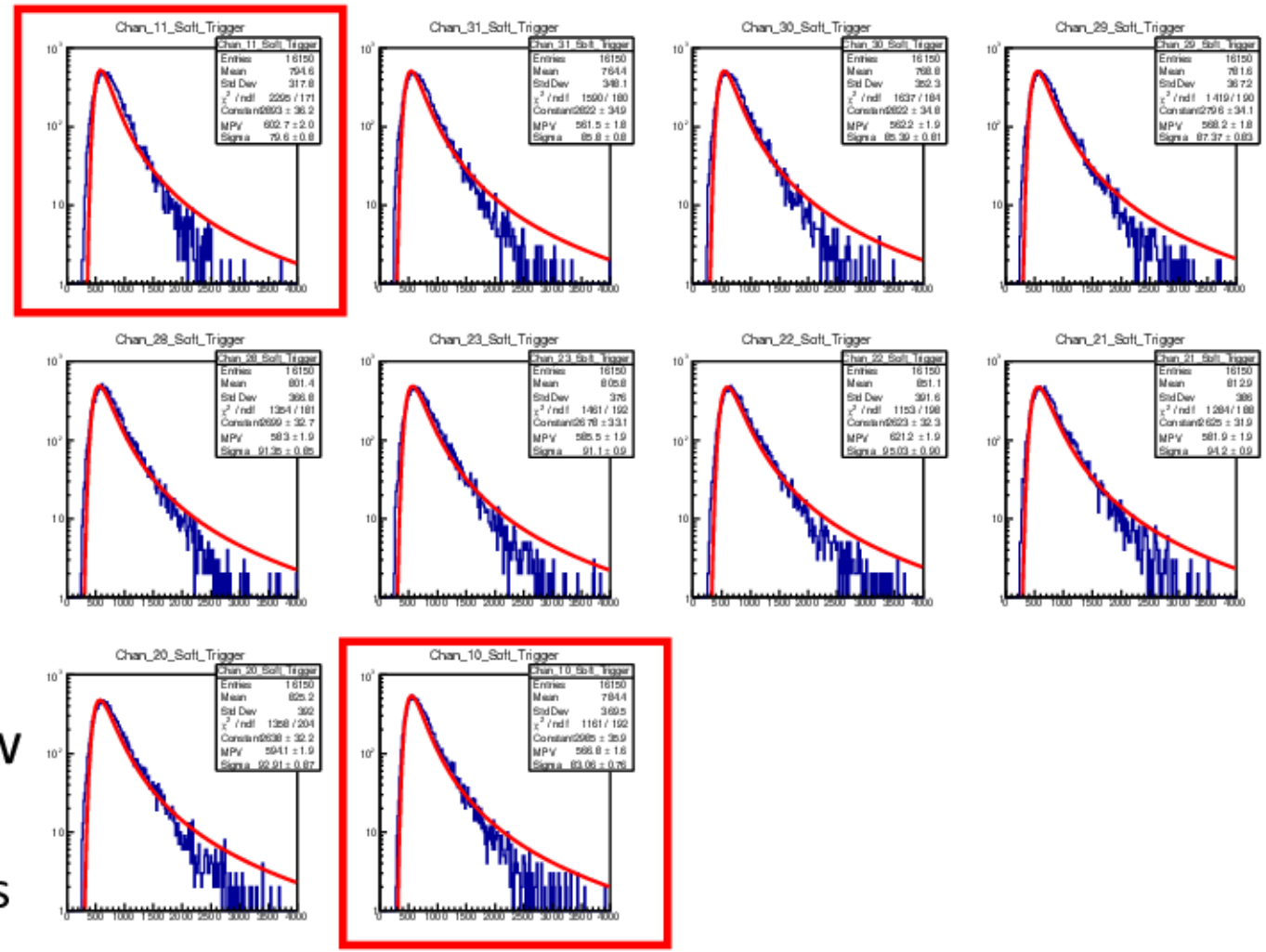
Test Stand @ GSU

Performance Characterization

- Tiles' cosmic ray response results in landau ADC distribution
- MPV extracted from landau fit
- MPV of each tile is divided by avg. of top and bottom reference tiles

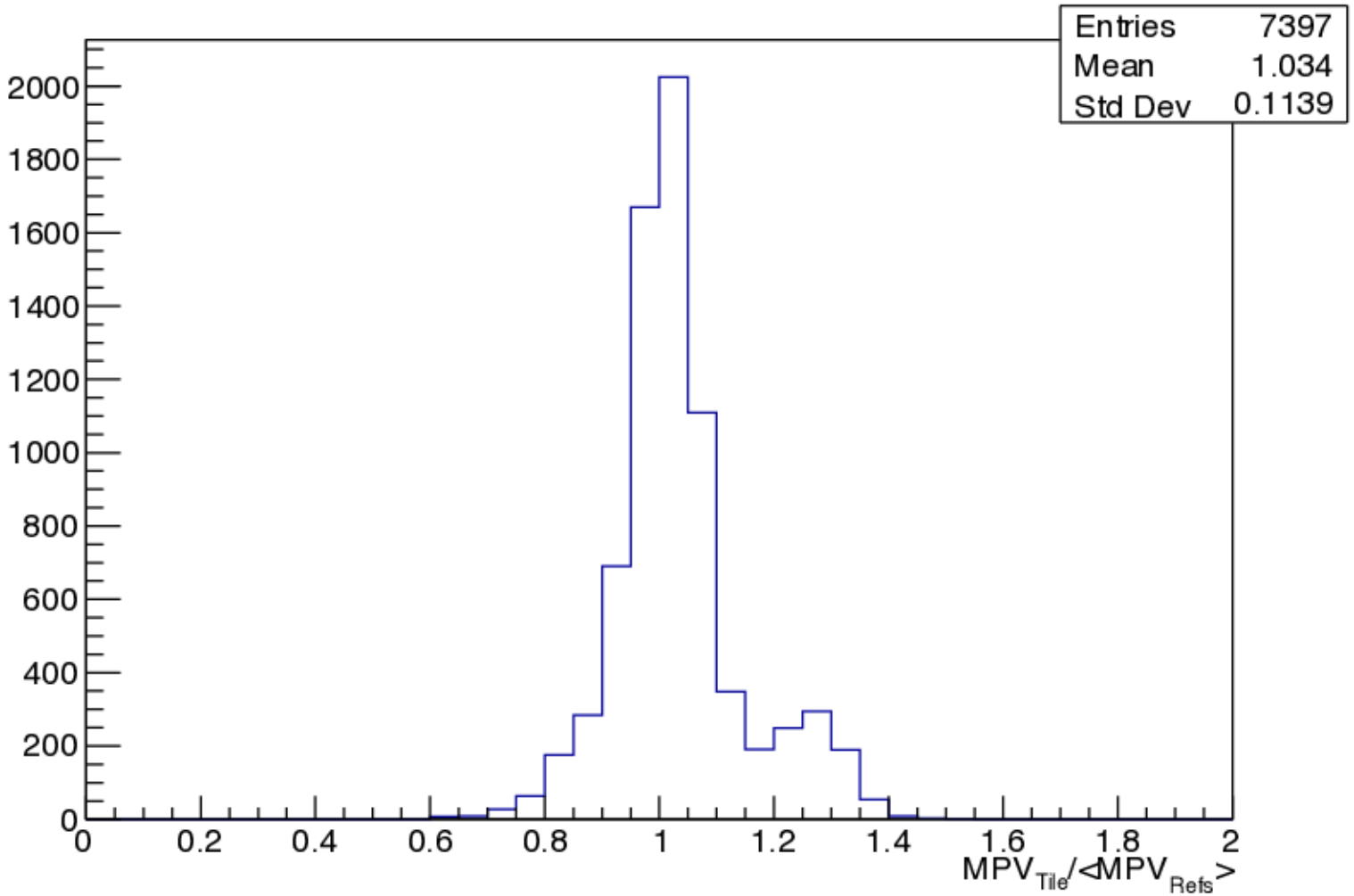
$$PR = \frac{MPV_{TILE}}{< MPV_{REFs} >}$$

- Performance ratio (PR) will dictate how the tiles are sorted in the HCal towers
  - Tiles with similar PRs grouped into towers



Global Performance Ratios

- Global distribution of PRs from all OHCal tiles tested
- Outer HCal Tile Progress: 95% tiles tested
- 1.5% w/ PR < 0.8
  - Tiles w/ PR < 0.8 considered low performing because of low light yield



COVID-19

- GSU's lab shutdown in March, re-opened w/ safety protocols in June
- Despite three-month shutdown, HCal schedule remains mostly intact
- Other sPHENIX detector subsystems up and running
  - On schedule for initial 2023 run

June 11, 2020 → Oct 13, 2020

Conclusion

- 95% OHCal tiles tested
  - Inner tile testing to start imminently
- GSU data used to group tiles into towers at BNL
  - Then, cosmic ray studies w/ towers at BNL to be used for calibration procedure
- Assembly of HCal and towers has begun at BNL

Summer 2019 → Summer 2020

Back-Up

Test Beam

- Prototype successfully reconstructed at Fermilab Test Beam Facility
- Hadron energy resolution measured with combined EMCal+HCal
- Results meet physics requirements of sPHENIX (<100%/$\sqrt{E}$)