Measuring Global Observables with PHENIX

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Particle Distributions in
Hadronic and Nuclear Collisions
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The PHENIX Collaboration

Brazil:	Universidade deSao Paulo
Canada:	McGill University
China:	China Institute of Atomic Energy
Institute of High Energy Physics	Peking University
Germany:	University of Muenster
India:	Banaras Hindu University
Bhabha Atomic Research Centre	
Israel:	Weizmann Institute
Japan:	University of Tokyo
Hiroshima University	KEK
Kyoto University	Nagasaki Institute of Applied Science
RIKEN Institute	Tokyo Institute of Technology
University of Tokyo	University of Tsukuba
WasedaUniversity	
Korea:	Korea University
Yonsei University	
Russia:	IHEP, Protvino
JINR, Dubna	Kurchatov Institute
PNPI, Leningrad	St. Petersburg State Technical Univ.
Sweden:	Lund University
United States:	
Univ. of Alabama, Huntsville	Brookhaven National Lab
Univ. of Califonia, Riverside	Columbia University
Florida State University	Georgia State University
Iowa State University	Lawrence Livermore National Lab
Los Alamos National Lab	Louisiana State University
University of New Mexico	New Mexico State University
SUNY-Stony Brook	Oak Ridge National Lab
University of Tennessee	Vanderbilt University
Yale University	

44 Participating Institutions representing 11 Countries

PHENIX Physics Philosophy

Observation and systematic study of QGP via simultaneous measurement of many different probes/signatures as a function of energy density

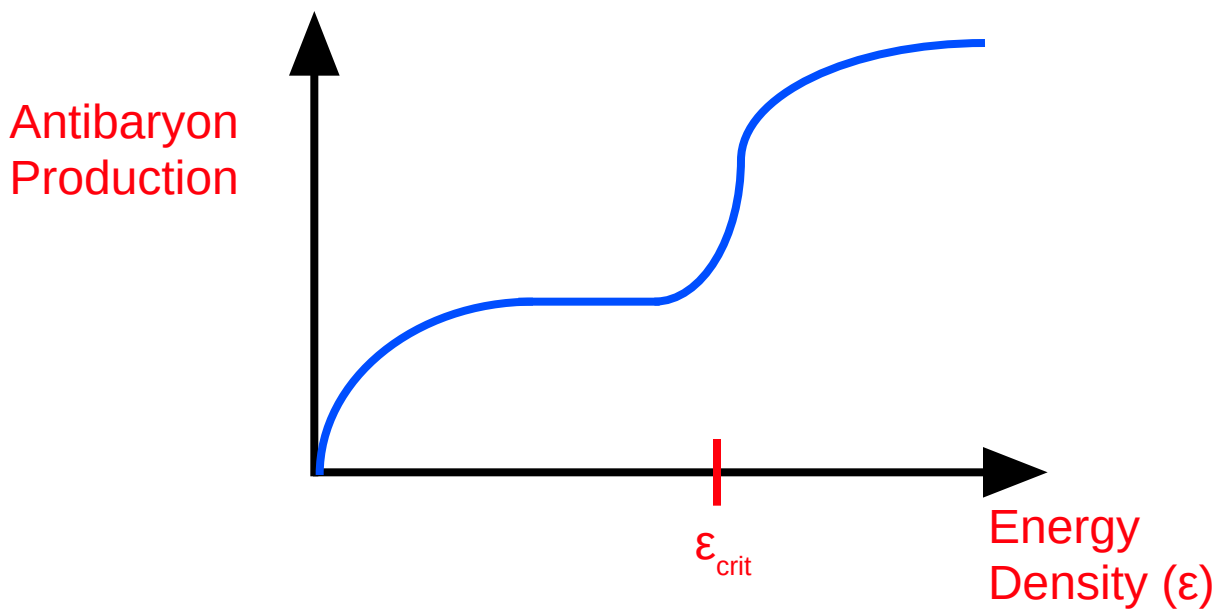
- Hadrons
  - Charged Particle Tracking and Identification in central rapidity region
  - Neutrals by leptonic,electromagnetic decay, calorimetry
- Leptons
  - Electron Tracking and Identification in central rapidity region
  - Muon Tracking and Identification at higher rapidities
- Photons
  - Identification via calorimetry in central rapidity region

PHENIX Physics Topics

Quantity to be measured	Physics Objective
$e^+e^-, \mu^+\mu^-$:	
· $\rho \rightarrow \mu^+\mu^-$ / $\rho \rightarrow \pi\pi$, $d\sigma/dp_\perp$	*Basic dynamics(T,τ...) for hot gas,*
$\omega \rightarrow e^+e^-$ / $\omega \rightarrow \pi\pi$, $d\sigma/dp$	*transvere flow, etc*
· φ width and $m_\varphi \rightarrow e+e-$	Mass shift from chiral transition (CT)
$\varphi \rightarrow e^+e^-$ / $\varphi \rightarrow K^+K^-$	Branching ratio change from CT
φ meson yield ($\mu^+\mu^-$, e^+e^-)	*Strangeness production*
• *J/Ψ → e^+e^-, $\mu^+\mu^-$*	*Yield suppression and distortion*
Ψ' → $\mu^+\mu^-$	*of p_T spectra from Debye screening*
Υ → $\mu^+\mu^-$	
• *$l < m_T$ (l^+l^-) < 3 GeV*	*Thermal radiation of hot gas, QGP*
• *m_{l+l-} > 3 GeV → $\mu^+\mu^-$*	*A dependence of DY, thermal $\mu^+\mu^-$*
· $\sigma \rightarrow \pi\pi, e^+e^-, \gamma\gamma$	Mass shift, narrow width from CT
eμ coincidence	
• *eμ, e (p_T > 1 GeV/c)*	*cc background, charm cross section*
Photons	
· 0.5 < p_T < 3 GeV/c γ	Thermal radiation of hot gas, QGP
· p_T > 3 GeV/c γ	A-dependence of QCD γ
· π^0,η spectroscopy	Dynamics of hot gas, strangeness in η
• *N (π^0)/N(π^++π^-) fluctuations*	*Isospin correlations and fluctuations*
· High p_T π^0,η from jet	Reduced dE/dx of quarks in QGP
Charged Hadrons	
• *p_T spectra for π,K,p,pbar,d,dbar*	*Basic dynamics, flow, T, baryon density, stopping, 2nd rise in p_T*
• *φ → K^+K^-*	*Branching ratio, mass width*
• *K/π ratios*	*Strangeness production*
• *ππ, KK HBT*	*Collision evolution, $R_\perp$, Hadronization t*
• *Antinuclei*	*High Baryon susceptibility due to CT*
• *High p_T hadrons from jet*	*Reduced dE/dx of quarks in QGP*
Global	
• *N_{tot} (total multiplicity)*	*Centrality of collisions*
• *dN/dη, $d^2N/d\eta d\phi$, dET/dη*	*Fluctuations, droplet sizes*

Observing the QGP Transition

Systematic Behavior of Proposed Signature With Respect to Global Property of the Event



$$\varepsilon \quad \frac{1}{\pi R^2 \tau_0} \frac{dE_T}{dy} \approx \frac{1}{\pi R^2 \tau_0} \sqrt{\left\langle p_T^2 \right\rangle + m_\pi^2} \frac{dN_\pi}{dy}$$

J.D.Bjorken, PRD27,140 (1983)

Charged Particle Multiplicity

$dN_{ch}/d\eta$, $dN_{ch}/d\eta d\phi$

Multiplicity and Vertex Detector (MVD)

Transverse Energy

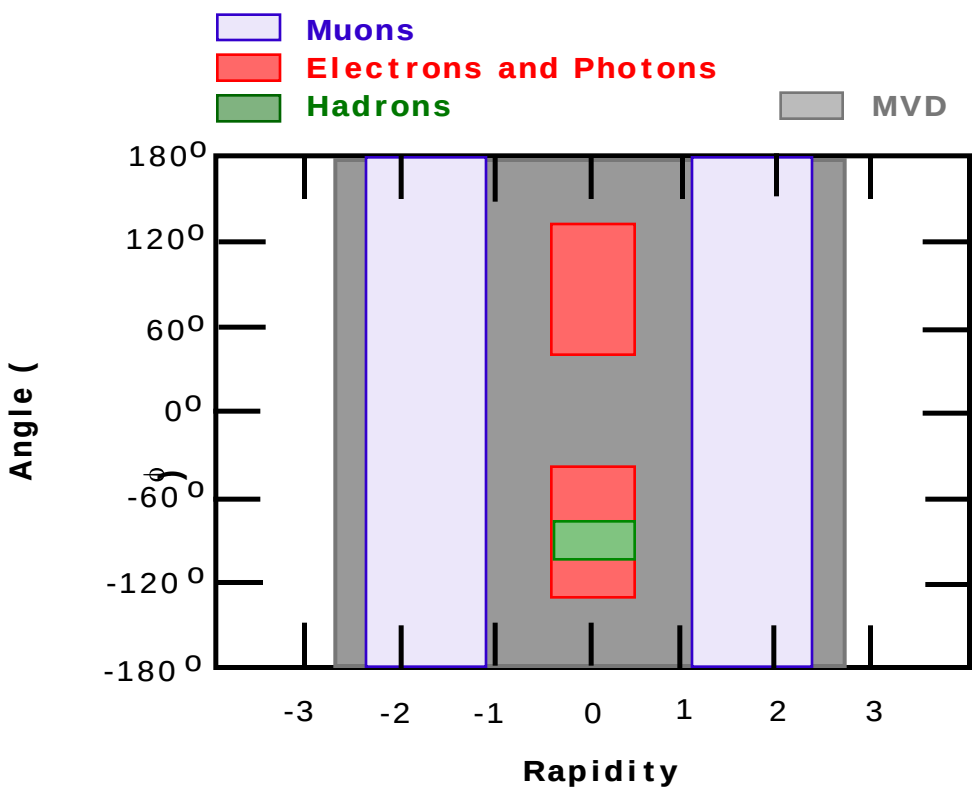
$dE_T/d\eta$, $dE_T/d\eta d\phi$

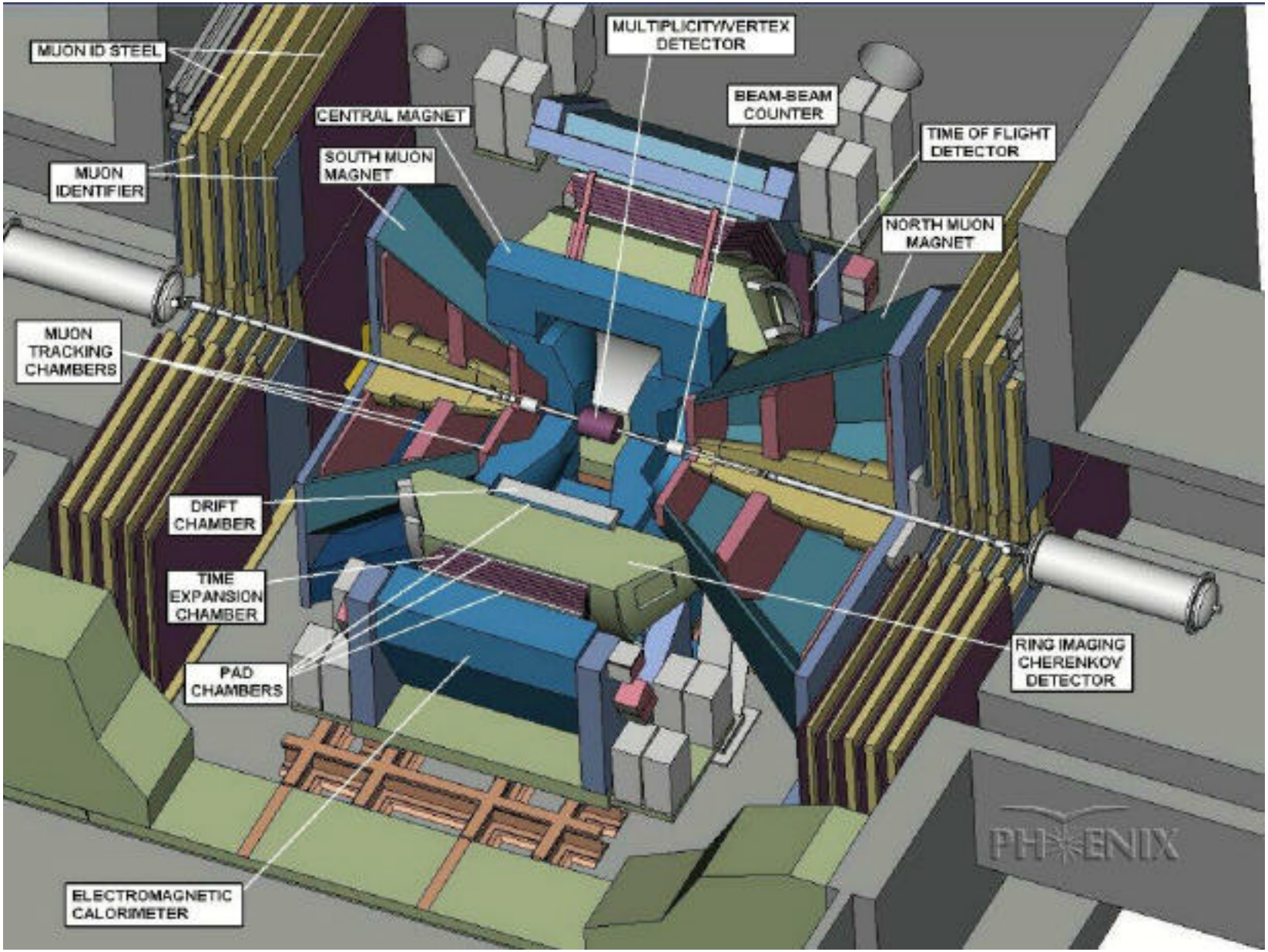
Electromagnetic Calorimeter (EMCal)

Central Arm Tracking

Mean Transverse Momentum

Central Arm Tracking

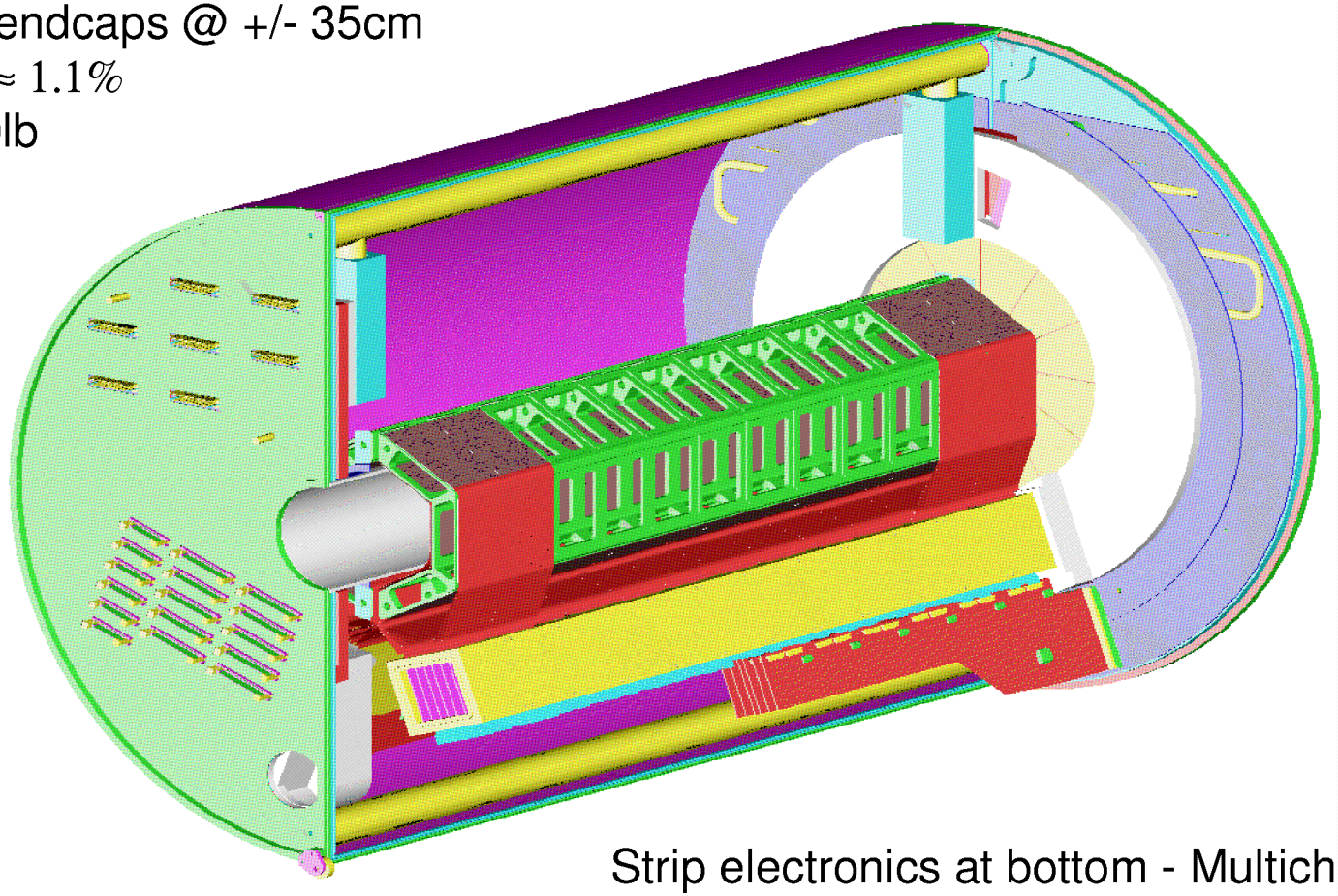



MUON ID STEEL
MULTIPLICITY/VERTEX DETECTOR
BEAM-BEAM COUNTER
CENTRAL MAGNET
TIME OF FLIGHT DETECTOR
SOUTH MUON MAGNET
MUON IDENTIFIER
NORTH MUON MAGNET
MUON TRACKING CHAMBERS
DRIFT CHAMBER
TIME EXPANSION CHAMBER
RING IMAGING CHERENKOV DETECTOR
PAD CHAMBERS
ELECTROMAGNETIC CALORIMETER

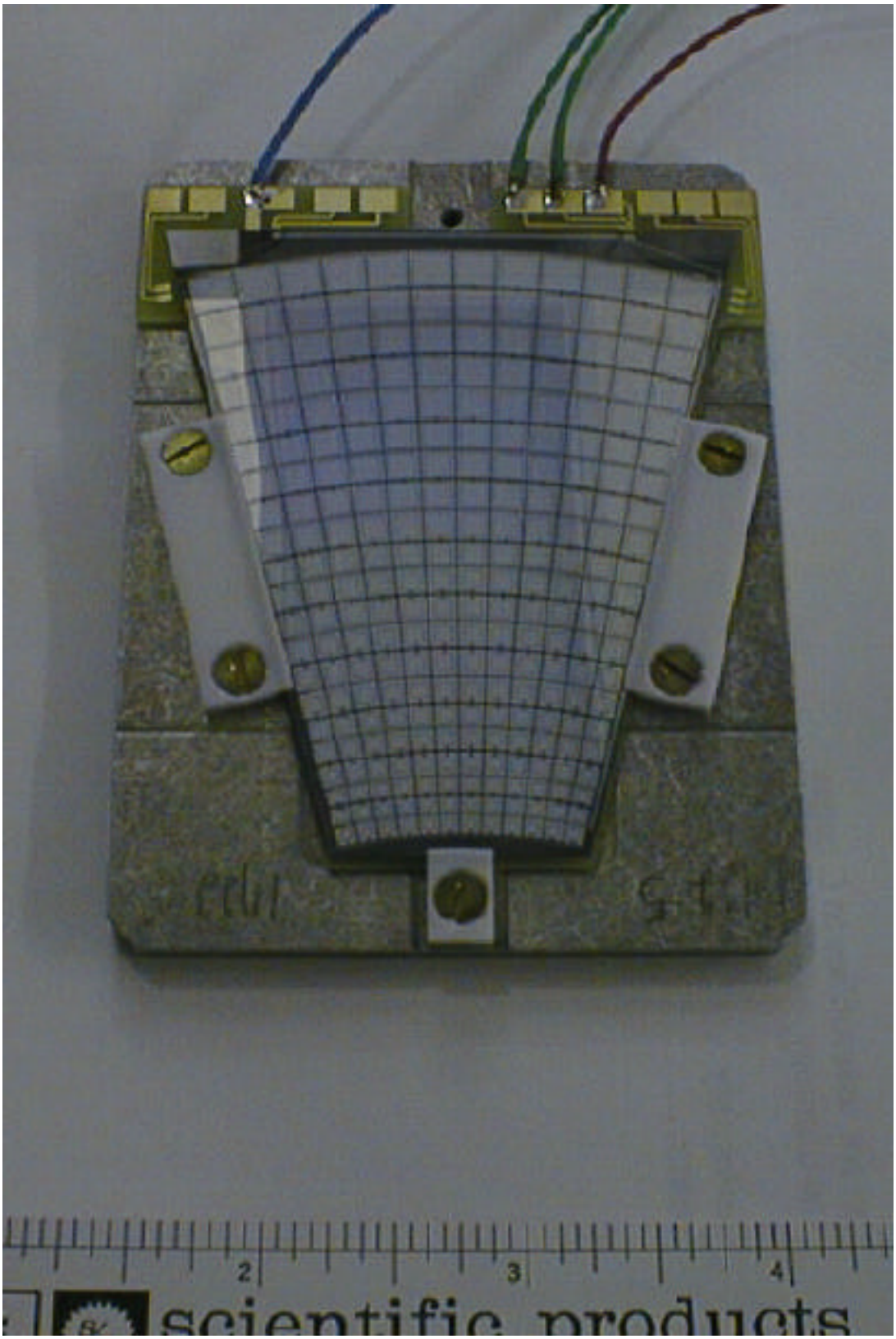
PHENIX Main Facility Hall

The Multiplicity Vertex Detector

Clamshell design - mounts to magnet pole faces.
Inner and outer barrels of silicon strip detectors, 200μm, 64cm length
Silicon pad endcaps @ +/- 35cm
Rad length ≈ 1.1%
Weight < 30lb



Strip electronics at bottom - Multichip Module
256 channels/detector
Channel count = 34,816


2
3
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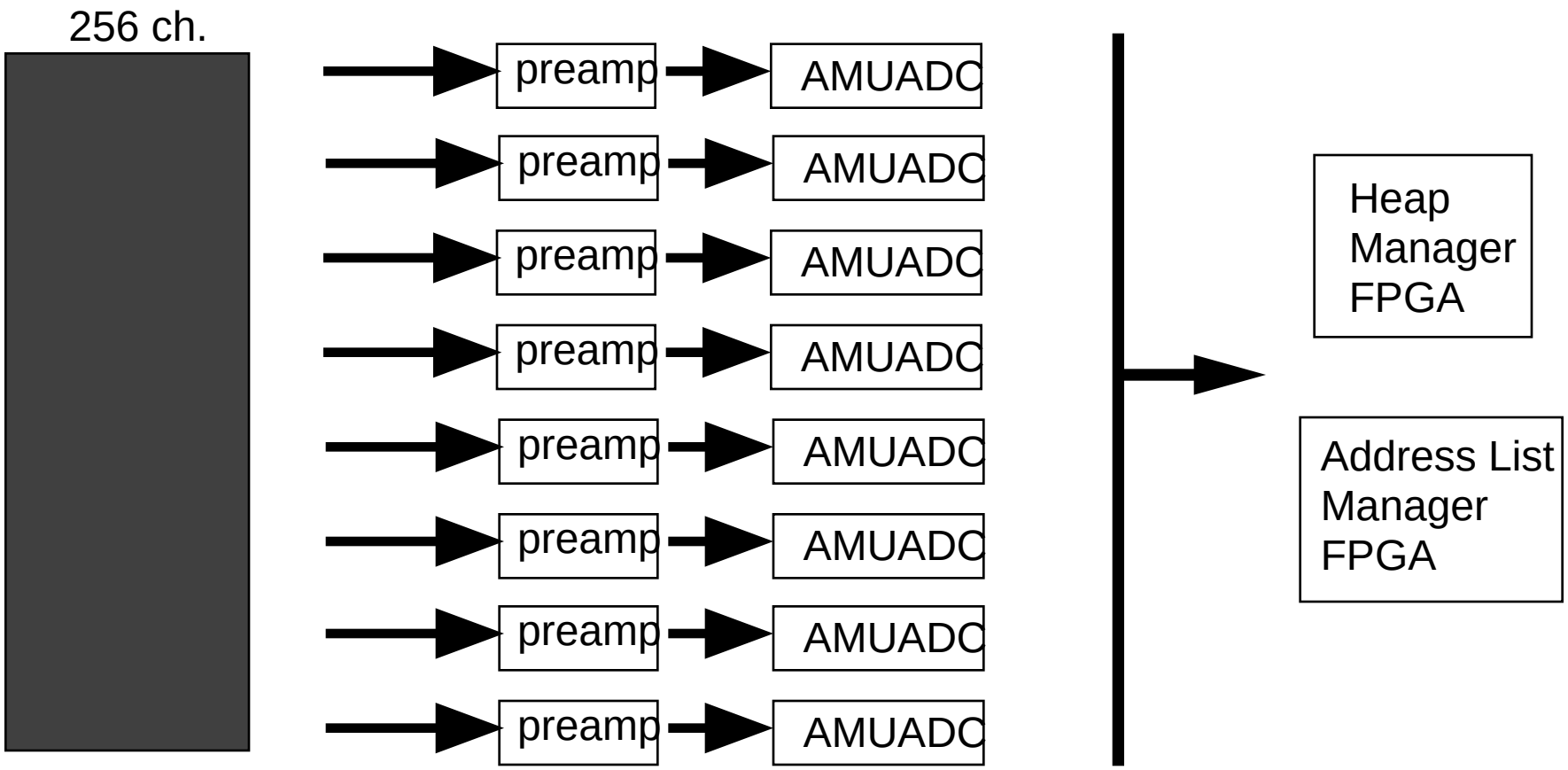
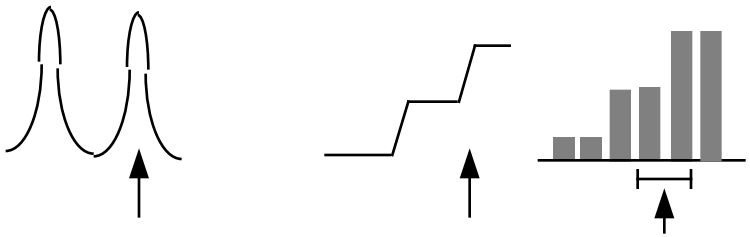
scientific products

Front End Electronics:





dN/dηdϕ in the MVD

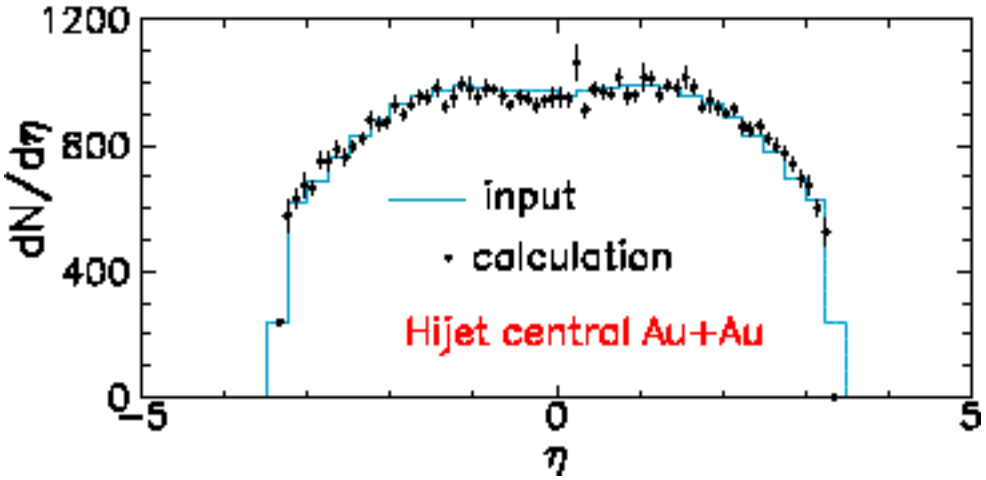
Strip Detectors:

Gain-corrected ADC values are adjusted for path length in Si, summed over some chosen grouping of strips, then divided by average MIP energy deposition to get number of hits. Can be binned in η,ϕ

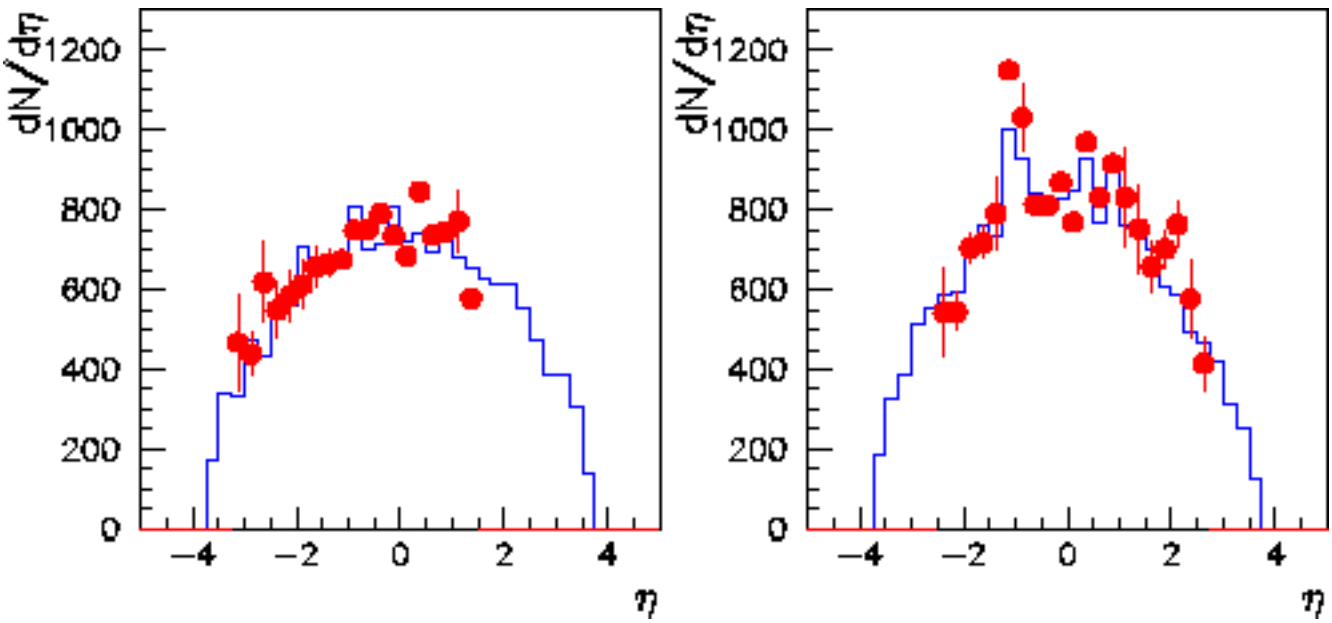
Pad Detectors:

Gain-Corrected ADC values are adjusted for path length in Si, then normalized to expected MIP value. Number of hits for this pad are assigned based on Poisson statistics and overall occupancy. Each pad covers Δη=0.04 and ~2.5° in ϕ.

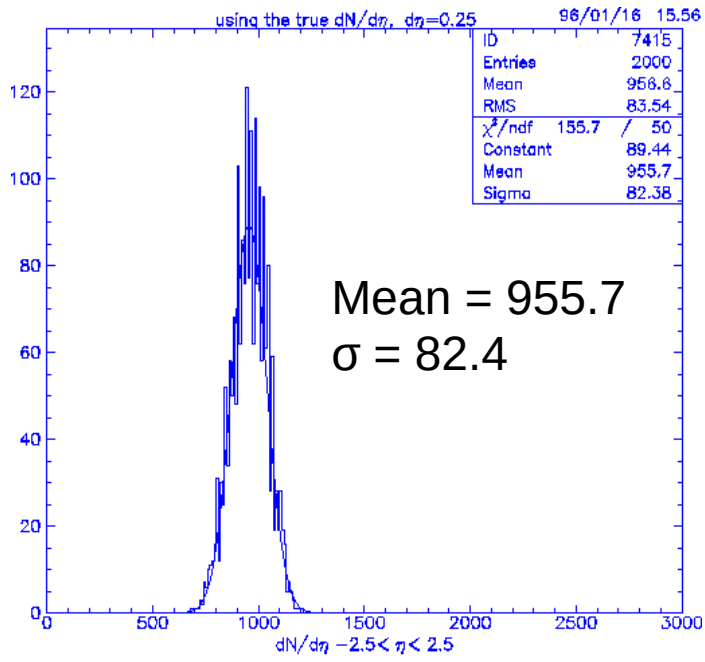
Average dN/dη, 125 HIJET events

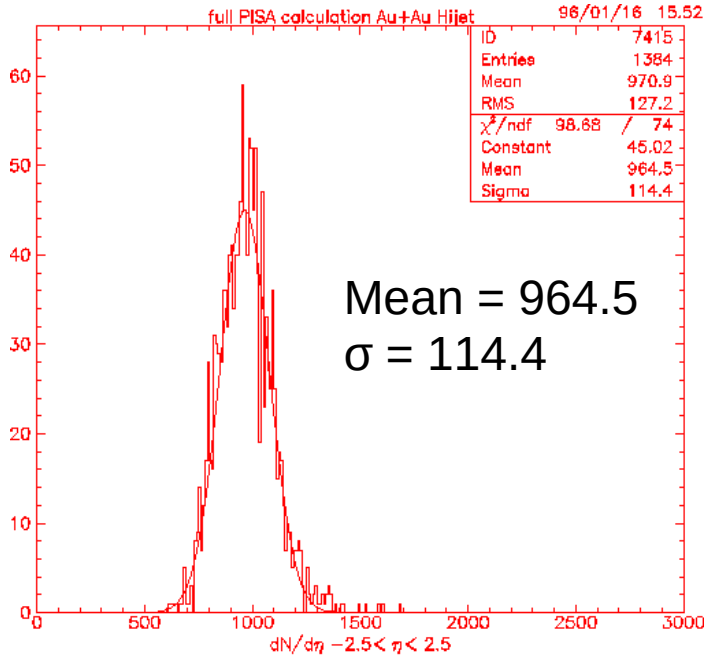


dN/dη for Single HIJING Events



Spread in intrinsic and MVD dN/dη (HIJET events -2.5 ≤ η ≤ 2.5)





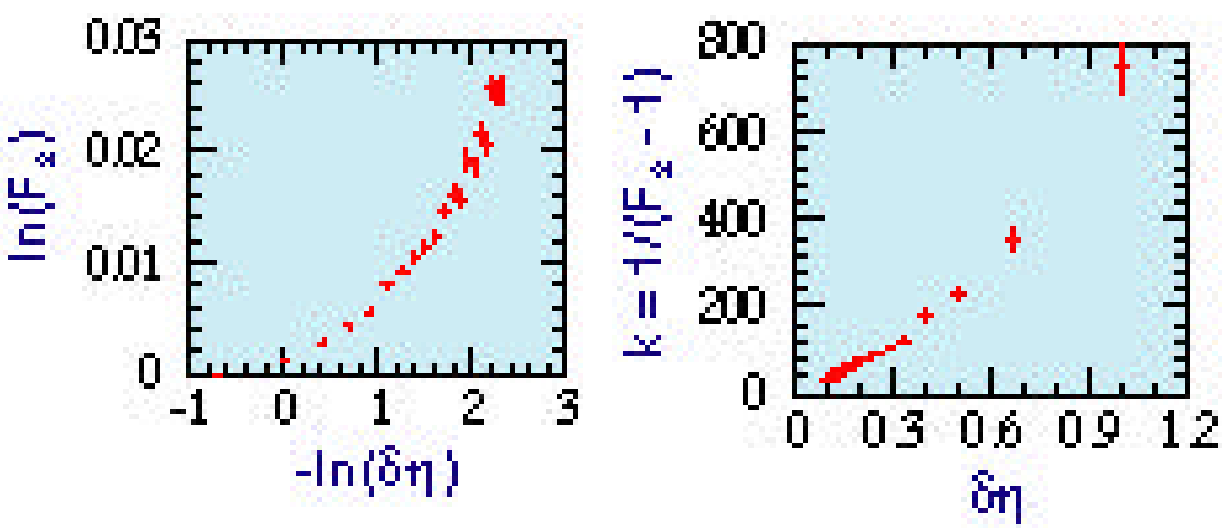
Intermittency

• Indicates absence of a well-defined length scale, can be studied by normalized factorial moments or negative binomial distributions (NBD)

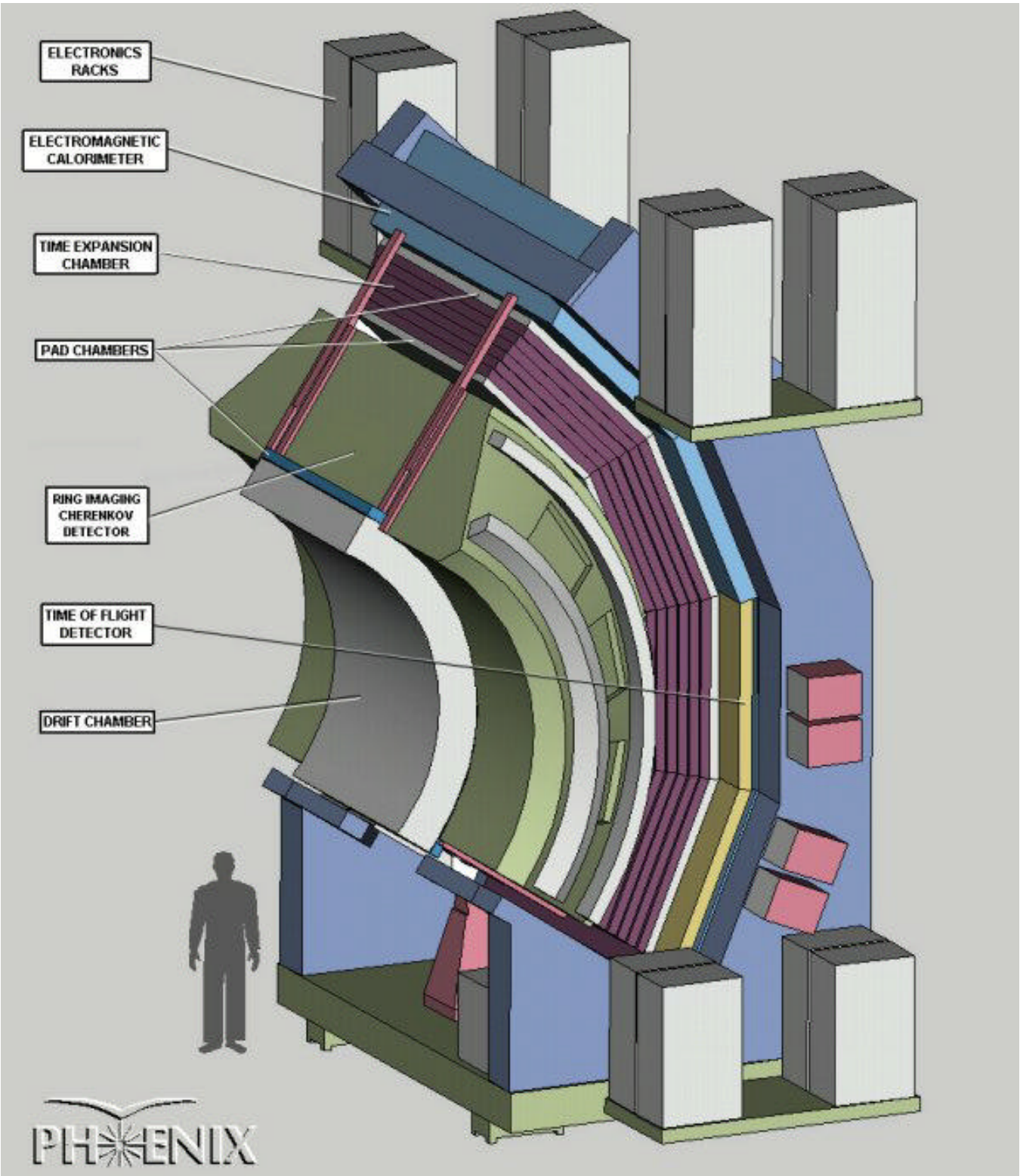
• If there is no intermittency, the factorial moment of 2nd order, F_2, and the k parameter are both independent of δη

• If intermittency is present, $\ln(F_2)$ is linearly related to $-\ln(\delta\eta)$, and k is linearly related to δη

• In practice, finite detector acceptance can result in an intermittent-like signal; a true intermittency signal must have slopes in excess of those resulting from acceptance effects.



Central Arm Tracking Detectors



Electromagnetic Calorimeter

Central rapidity ($-0.35 \leq \eta \leq 0.35$, $70° \leq \theta \leq 110°$)

180° ϕ coverage

- Pb-Scintillator "Shish-Kebab" (135° in ϕ)
- Pb-Glass (45° in ϕ)

Good energy resolution

- Pb-Scintillator $7.8\%/\sqrt{E} + 1.5\%$
- Pb-Glass $5.8\%/\sqrt{E} + 1\%$

High Segmentation

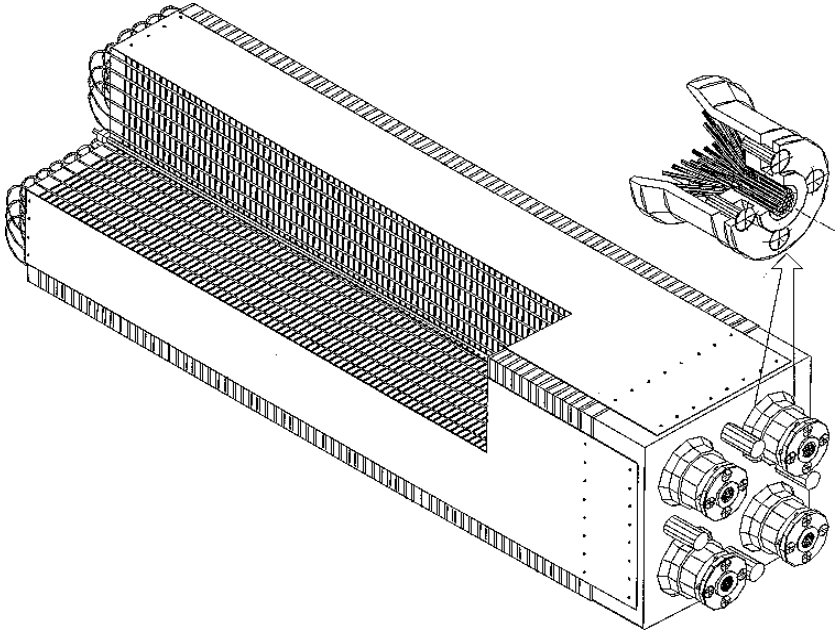
- Pb-Scintillator ~15500 towers
- Pb-Glass ~10000 modules

Primarily Electron,Photon ID (~18 X_o)

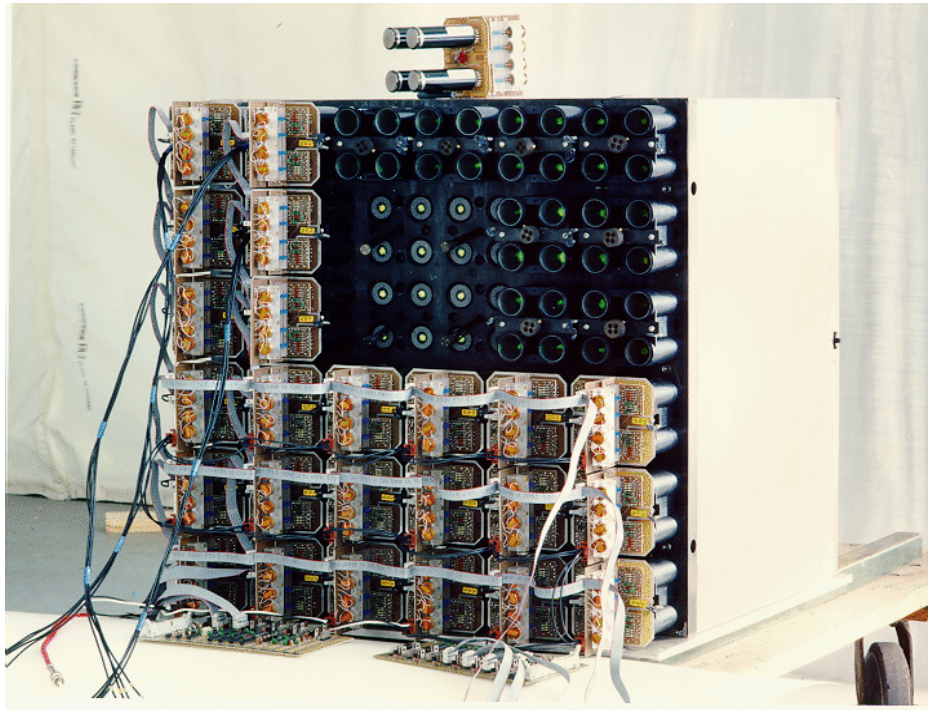
- Straight-through ~225 MeV (PbSc)
  ~500 MeV (PbGl)
- Mean pion p_T (HIJING) ~300 MeV

E-M Calorimeter Pb-Scintillator

"Shish-Kebab" Module

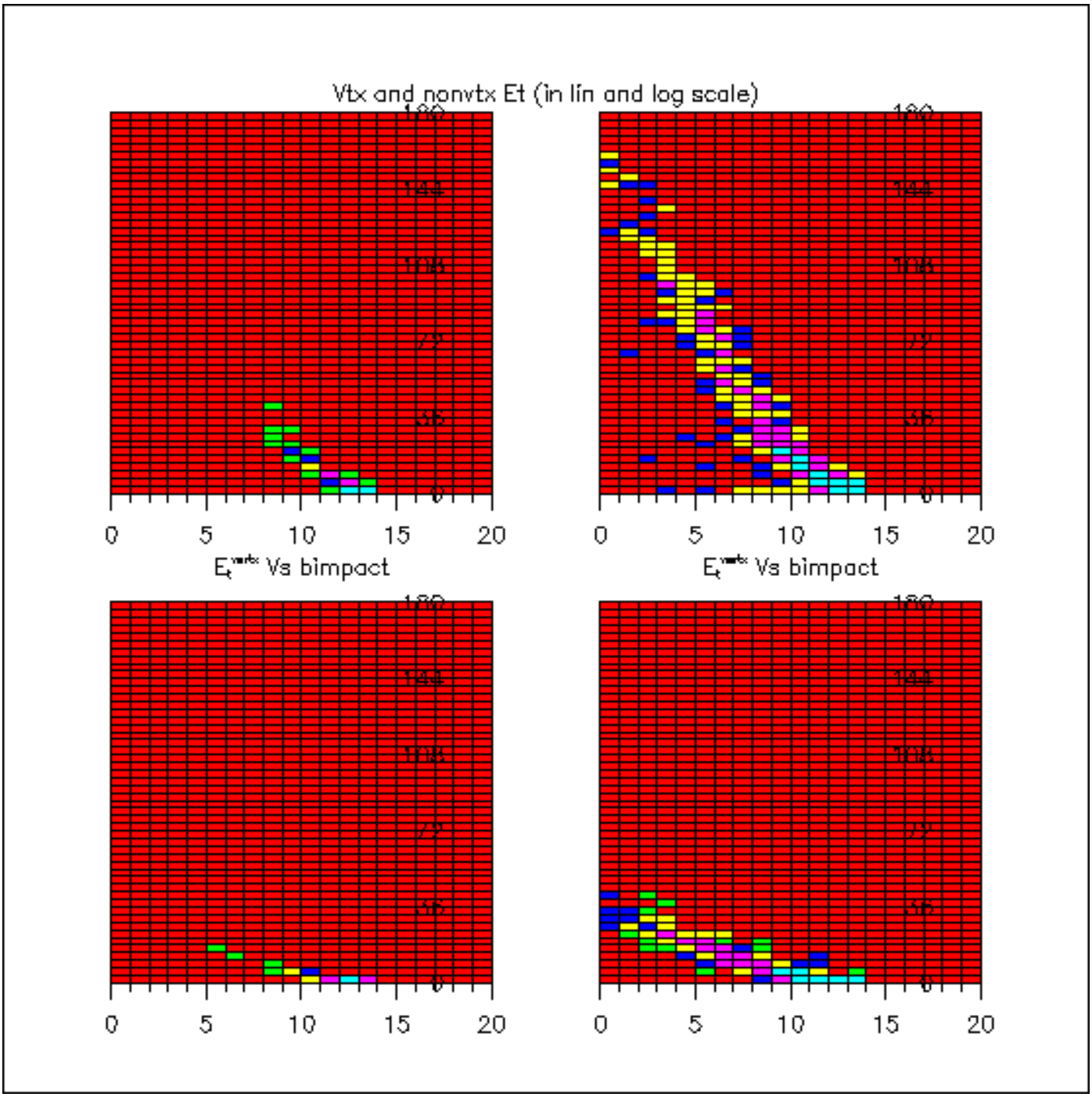


6 x 6 Super-Module

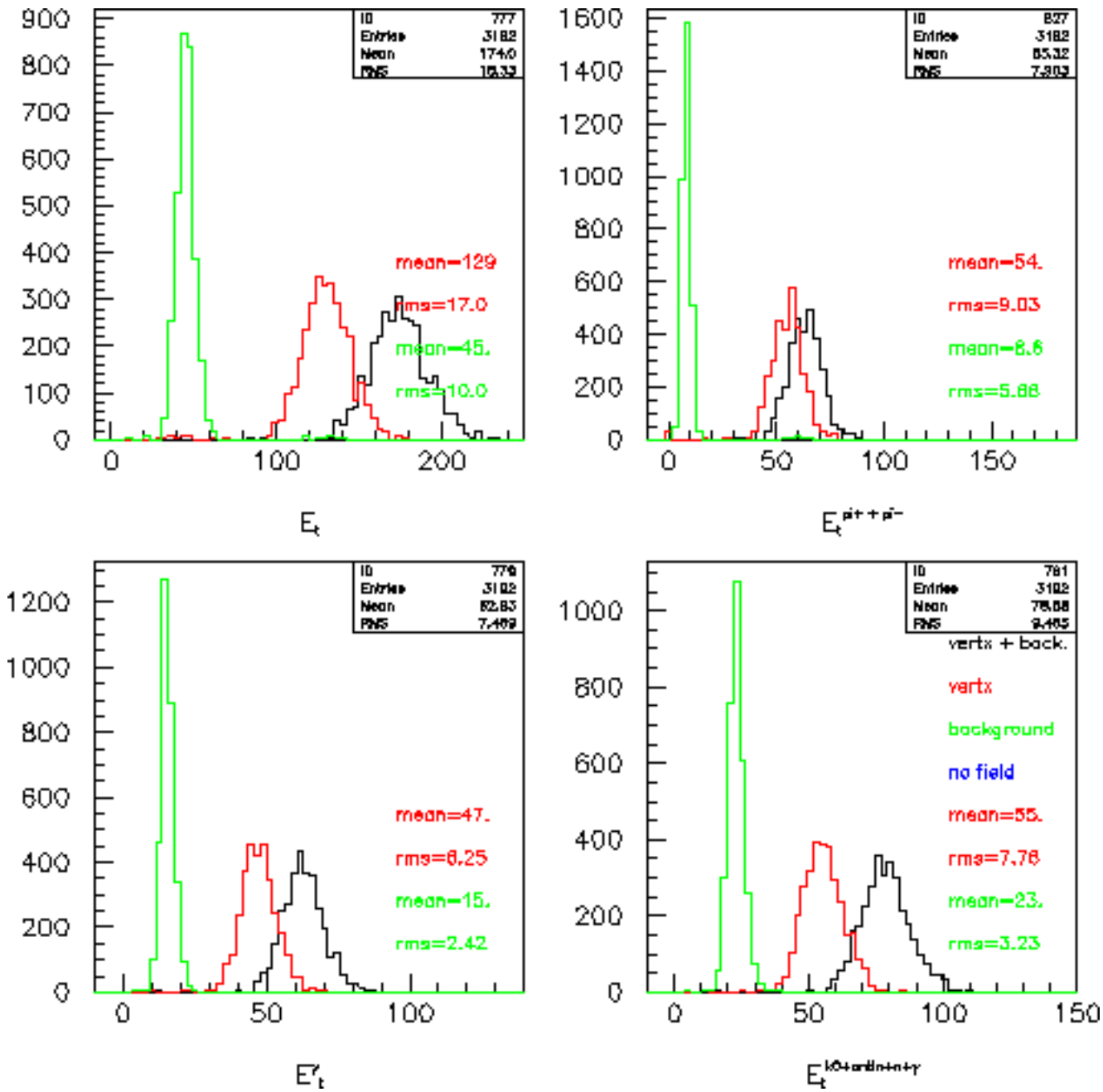


Transverse Energy in EMCal

PRELIMINARY SIMULATIONS



Particle Mix in the EMCal



Central Arm Tracking

Central Rapidity ($-0.35 \leq \eta \leq 0.35$)

Covers 180° in ϕ

Trajectory Information

Pad Chambers, Drift Chambers, Time-Expansion Chambers (TEC)

Track Finding Efficiency >~90%

Momentum Reconstruction via interpolation using highly segmented lookup table

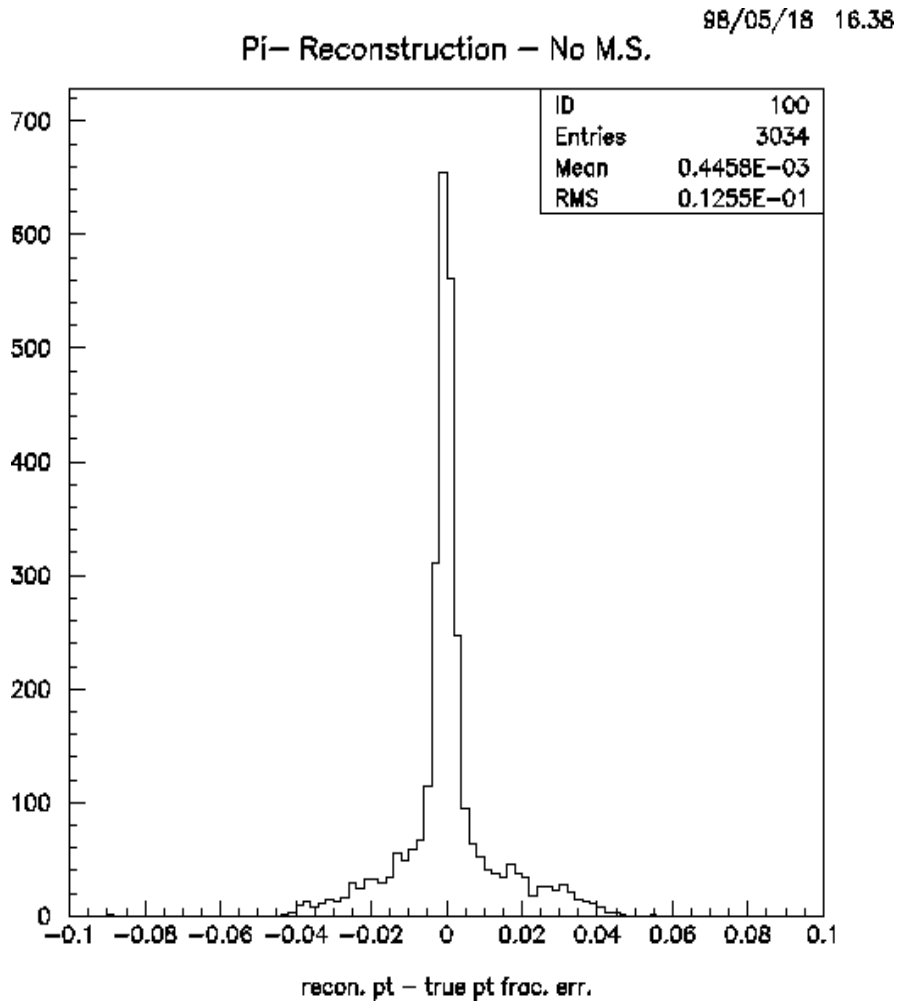
Particle ID Information

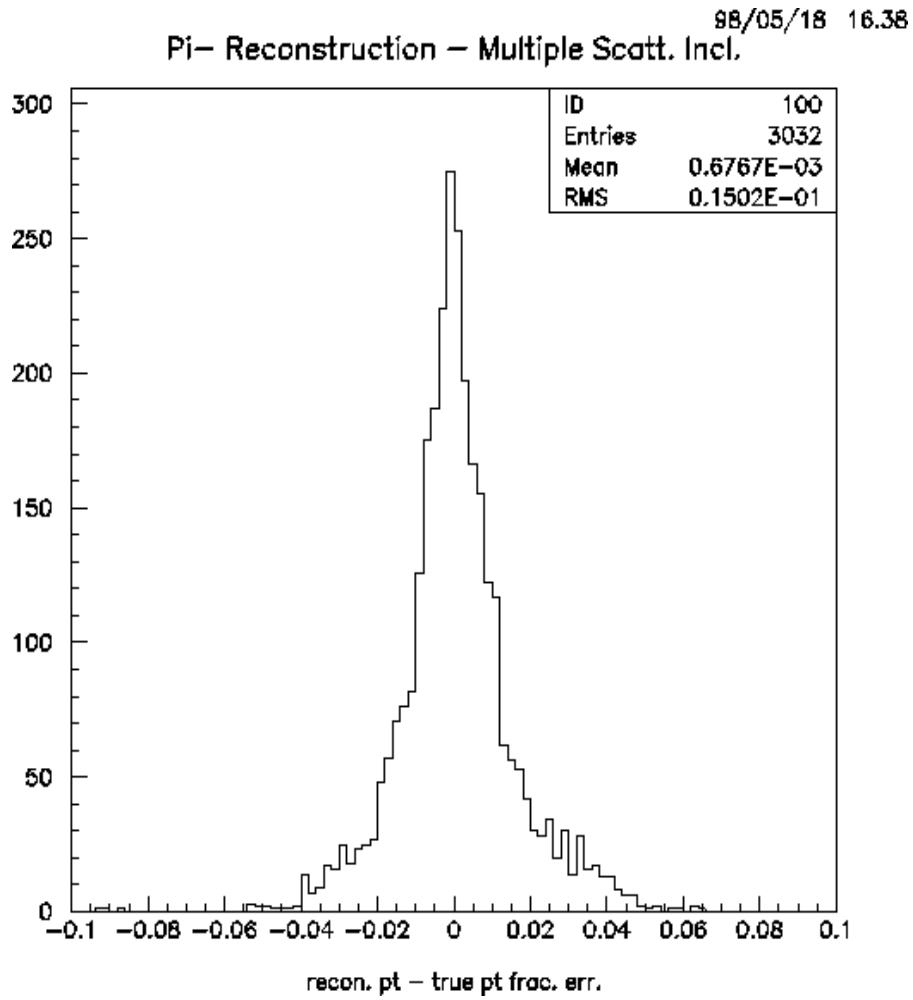
Time-of-Flight Scintillator Wall, TOF and energy from EMCal, dE/dx from TEC, Ring-Imaging Cerenkov

Excellent e/π separation ($>10^4$ pion rejection)

Intrinsic Momentum Resolution (Perfect Tracking)

Preliminary Simulations





Summary

- PHENIX will be able to measure $dN_{ch}/d\eta d\phi$, $dE_T/d\eta d\phi$, $\langle p_T \rangle$

- Should be sensitive to both large-scale and localized fluctuations in all of these

- Can simultaneously measure a number of proposed QGP signatures, and investigate their systematic behavior w.r.t global event characteristics

- Global event characteristics will be included in an "event tag" database for analysis event selection

- Global distributions should be among some of the first physics out of RHIC