

# Study of Charged Hadrons Spectra with the Time Expansion Chamber of the PHENIX Experiment at the Relativistic Heavy Ion Collider

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# The Relativistic Heavy Ion Collider (RHIC)



## Project objectives:

To detect and study a new state of matter, quark-gluon plasma (QGP)

from Au-Au collisions:

in 2000 at C.M. energy of 130 GeV;

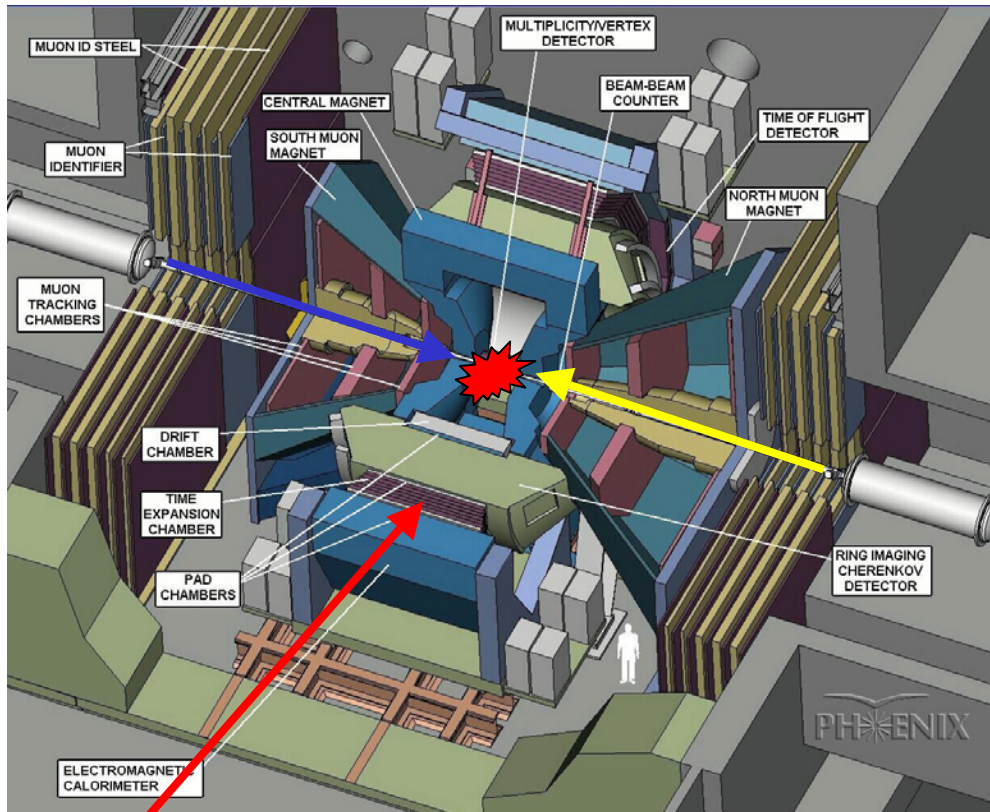
in 2001 at C.M. energy of 200 GeV (design);

To understand the spin structure of the nucleon

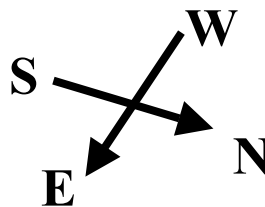
from proton-proton collisions:

in 2001 at C.M. energy of 200 GeV.

# Pioneering High Energy Nuclear Interaction eXperiment (PHENIX)



The Time  
Expansion  
Chamber



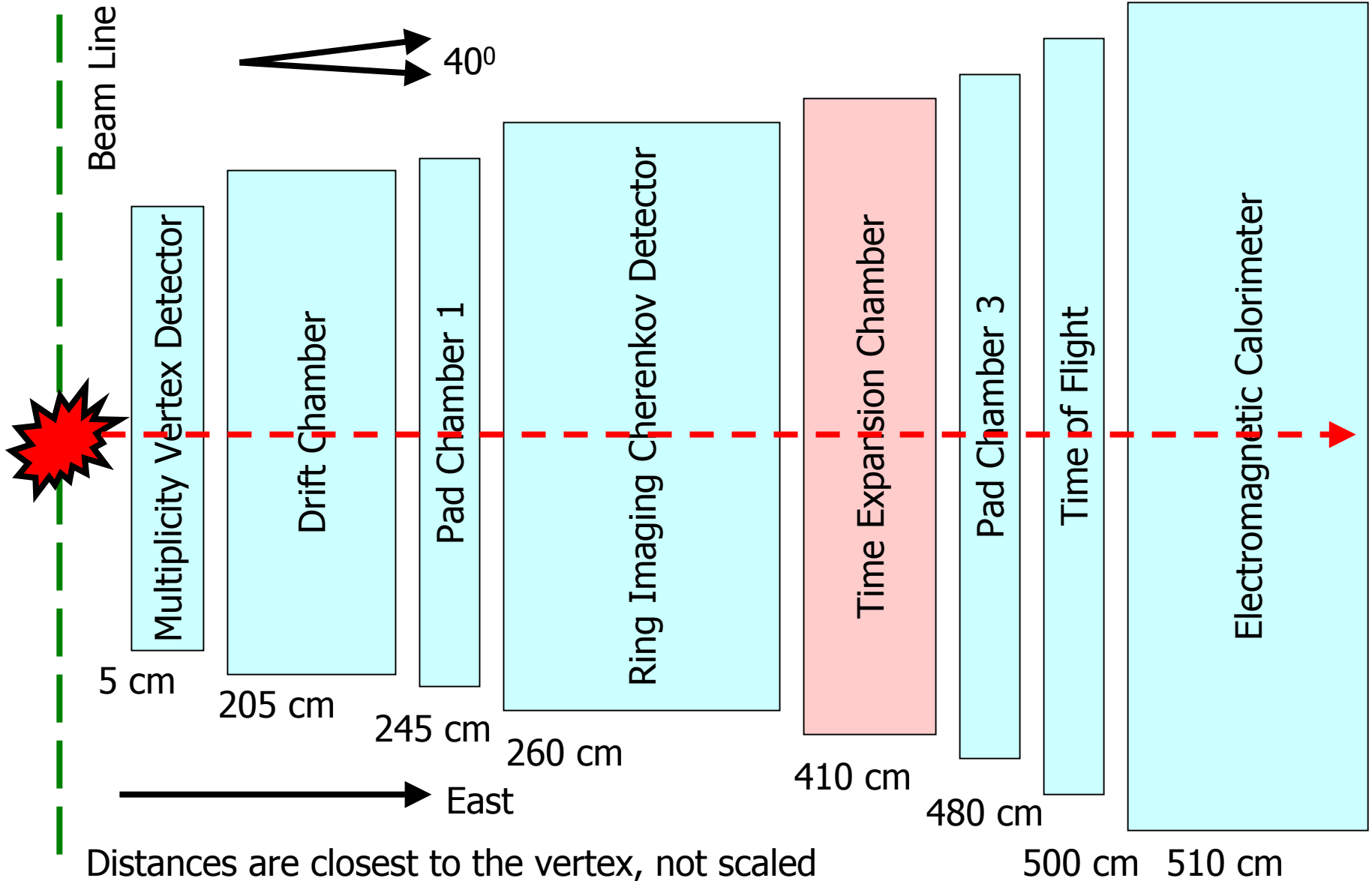
To study signatures of QGP through kinematical and dynamic properties of electrons, muons, hadrons, and photons coming out of the collision point.

Array of 11 subsystems for unbiased research.

**2000:** 4 million Au-Au minimum bias (all impact parameters) events recorded;

**2001:** 170 million Au-Au minimum bias events recorded (with 92 million minimum bias and 14 million rare events available for analysis) and 190 million p-p events.

# Passage of a Track through the PHENIX East Central Arm





# Functions of the Time Expansion Chamber (TEC) in the PHENIX

A) Measures charged particle ionization energy losses ( $dE/dx$ ):

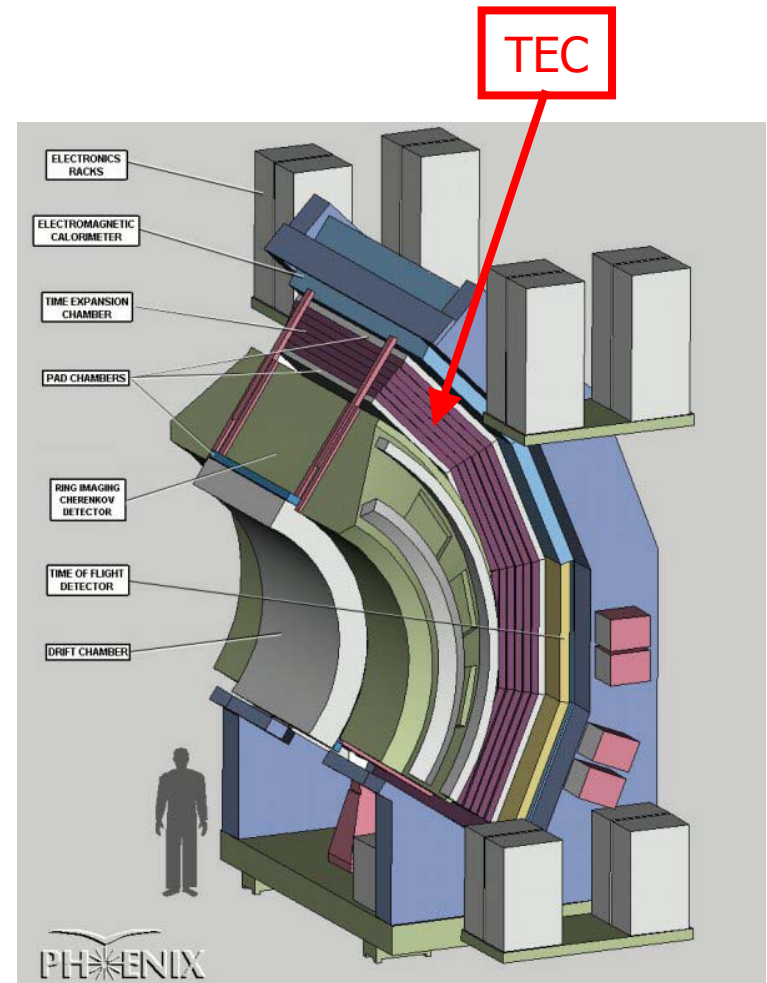
Separation of electrons from pions:

- 1) over a momentum range 0.25 -3 GeV ( $e/\pi$  is 5% at 500 MeV),
- 2) after upgraded to the Transition Radiation Detector (TRD), over a momentum range 0.25-50 GeV via transition X-radiation detection ( $e/\pi$  is 1.5% at 500 MeV).

B) Tracks all charged particles and produces direction vectors that match tracking information from the Drift and Pad Chambers to complete track determination in the PHENIX.

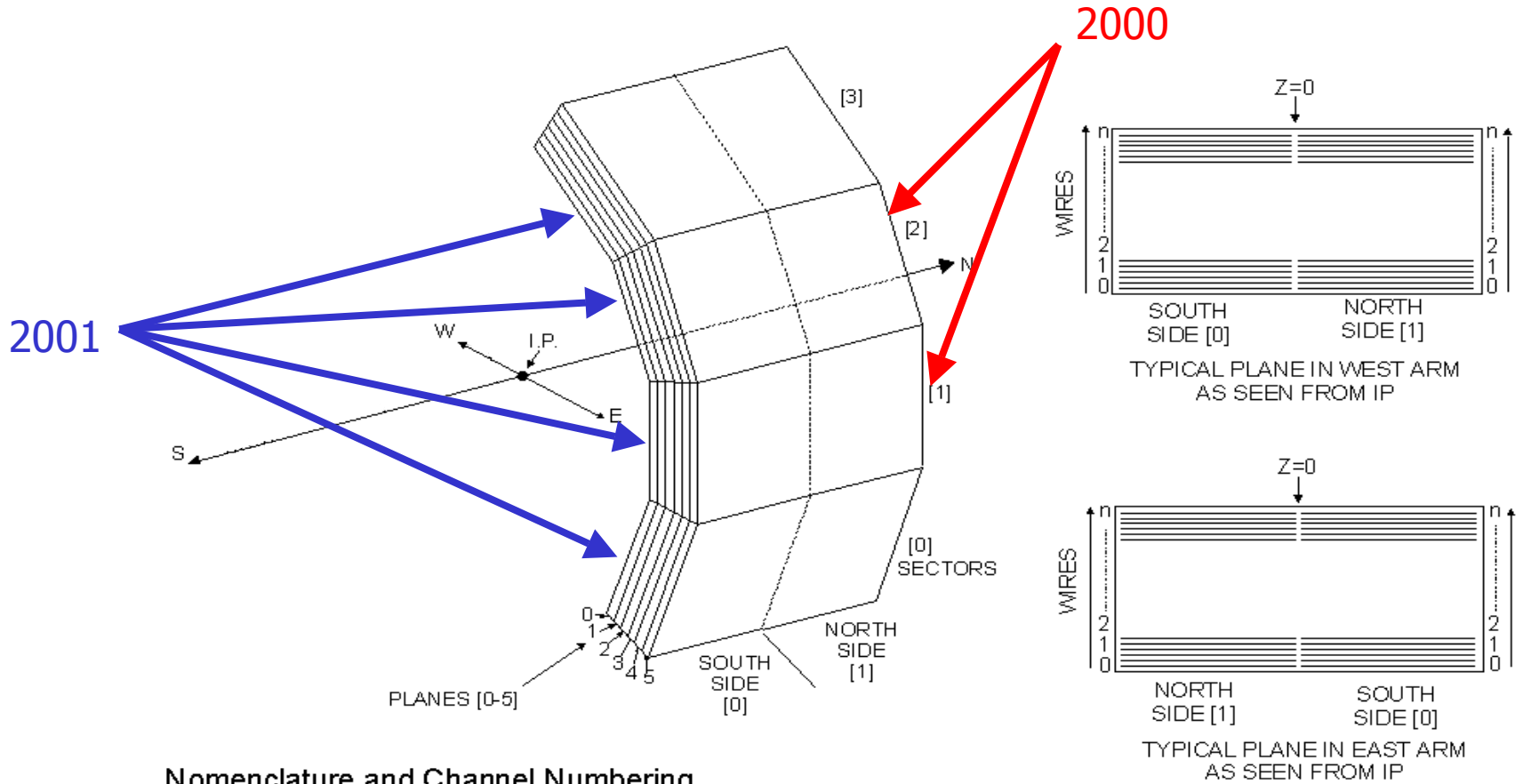
Single point track resolution of 250  $\mu\text{m}$  and two track separation of 2 mm.

C) Measuring the transverse momentum of a charged particle.



PHENIX East Central Arm

# Geometry of the TEC



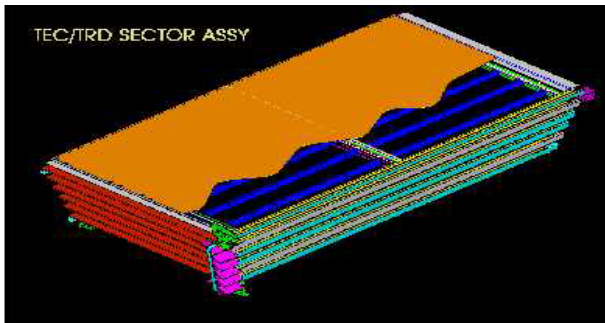
## Nomenclature and Channel Numbering for TEC

Format of channel number statement:  
Arm [0-1], Side [0-1], Sector [0-3], Plane [0-5] , Wmre [0-n]

(WIRES ARE SPLIT AT Z=0)  
(Number of wires varies  
from plane to plane)

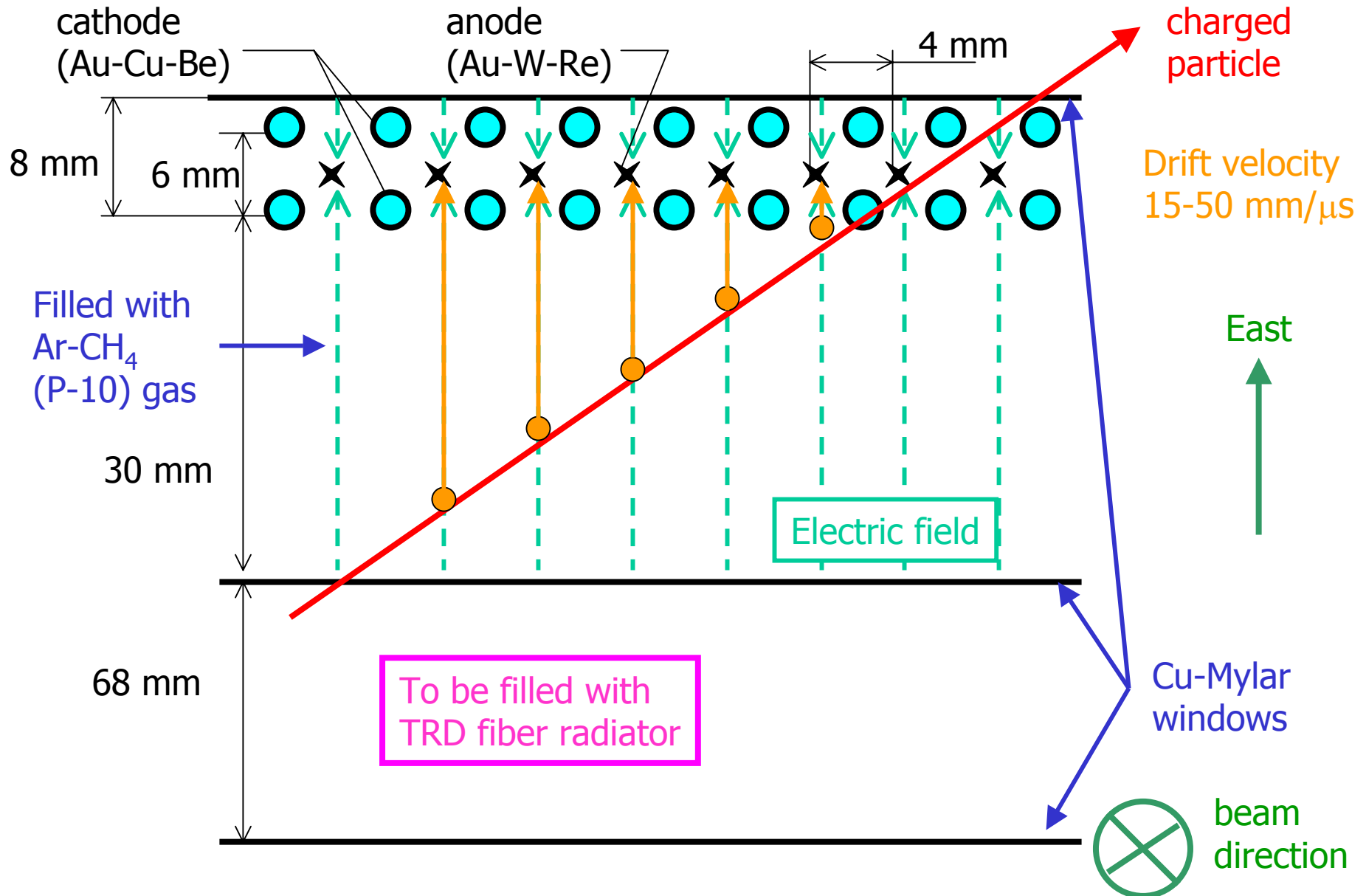
# Design Parameters of the TEC

- 1) Arranged in 6-plane 4 sectors (in 2000 and 2001 only 4 planes were instrumented electronically).
- 2) Covers  $90^\circ$  of the PHENIX azimuthal angle  $\phi$  and 0.35 units of pseudorapidity  $\eta$  (approximately  $40^\circ$  of the polar angle  $\theta$ ).
- 3) Distance from the collision vertex approximately  $R = 410\text{-}457$  cm.
- 4) 64,080 wires and 20,480 readout channels.
- 5) Filled with Ar-CH<sub>4</sub> (P-10) gas (90% of argon and 10% of methane) with the effective gas gain of 10000 (in 2000 and 2001 the effective gas gain was 2000-5000). (Gain is the number of electrons produced in a signal wire by one electron knocked out by a charged track).
- 6) Dimensions of the planes: 3.00 m x 1.69 m for the smallest and 3.49 x 1.90 m for the largest.
- 7) 320 Front-End Modules (FEM) and 640 Preamplifier/Shaper Boards (PS) (in 2001 216 FEMs and 432 PS Boards).



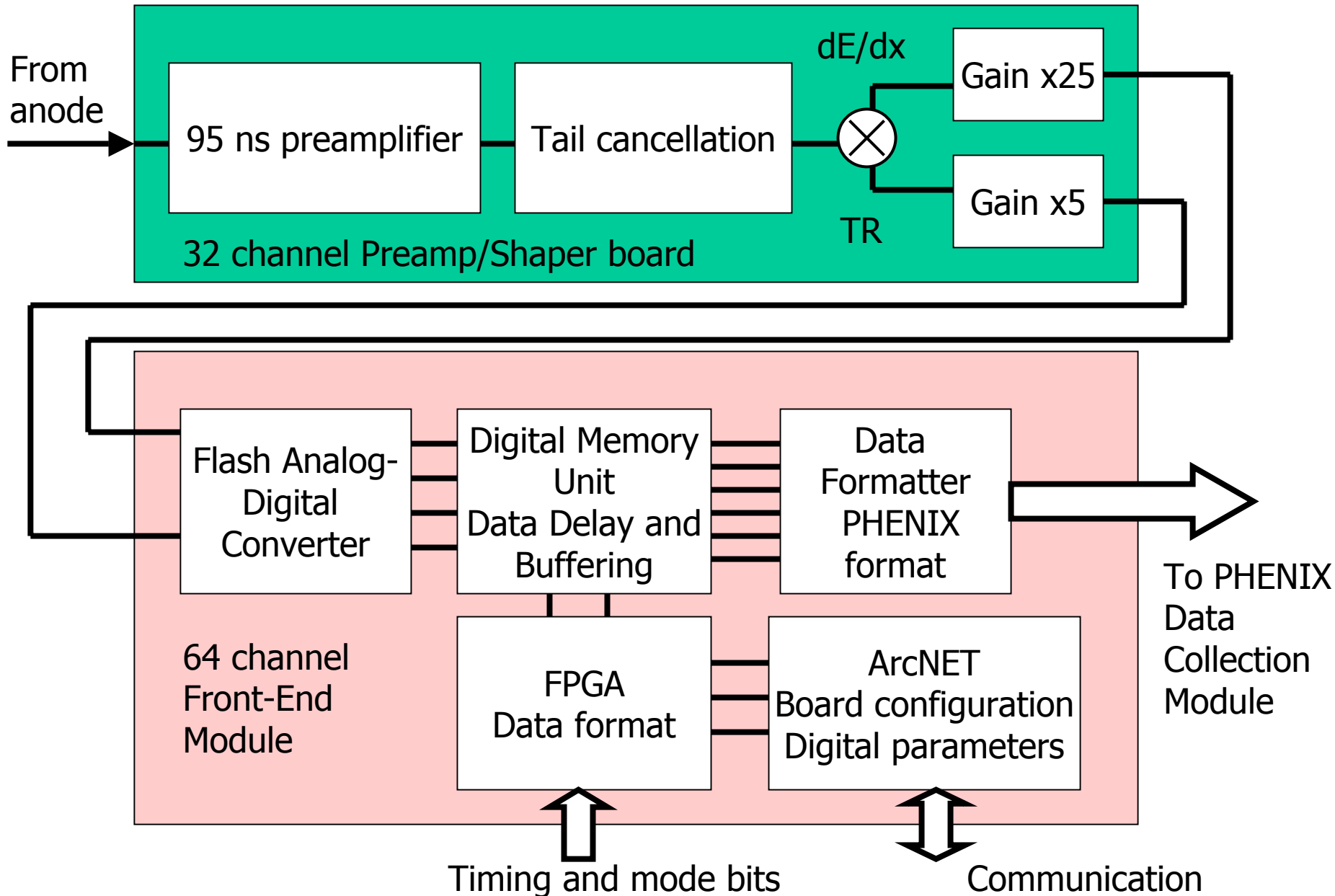
← TEC six-plane sector

# Mechanical Design of the Plane

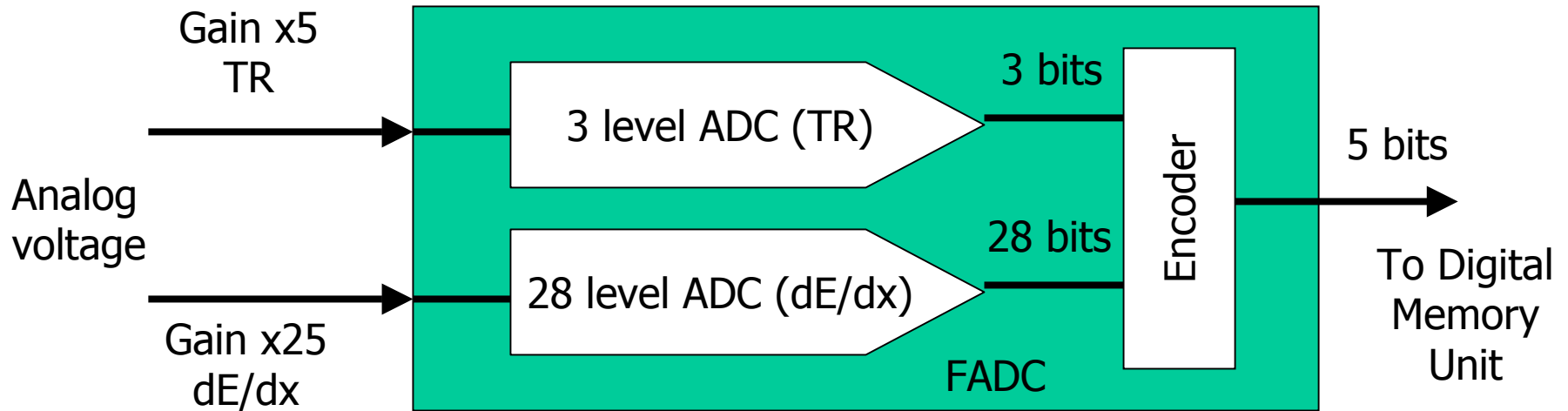




# Electronics chain



# Signal sampling

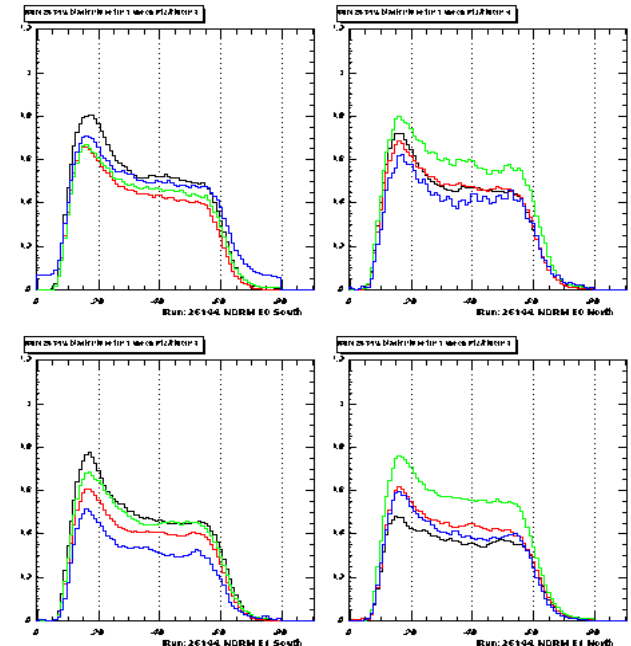


dE/dx signal: 0.2-0.3 keV (MIP in Xe)  
TR signal: 3-10 keV (X-rays in Xe)

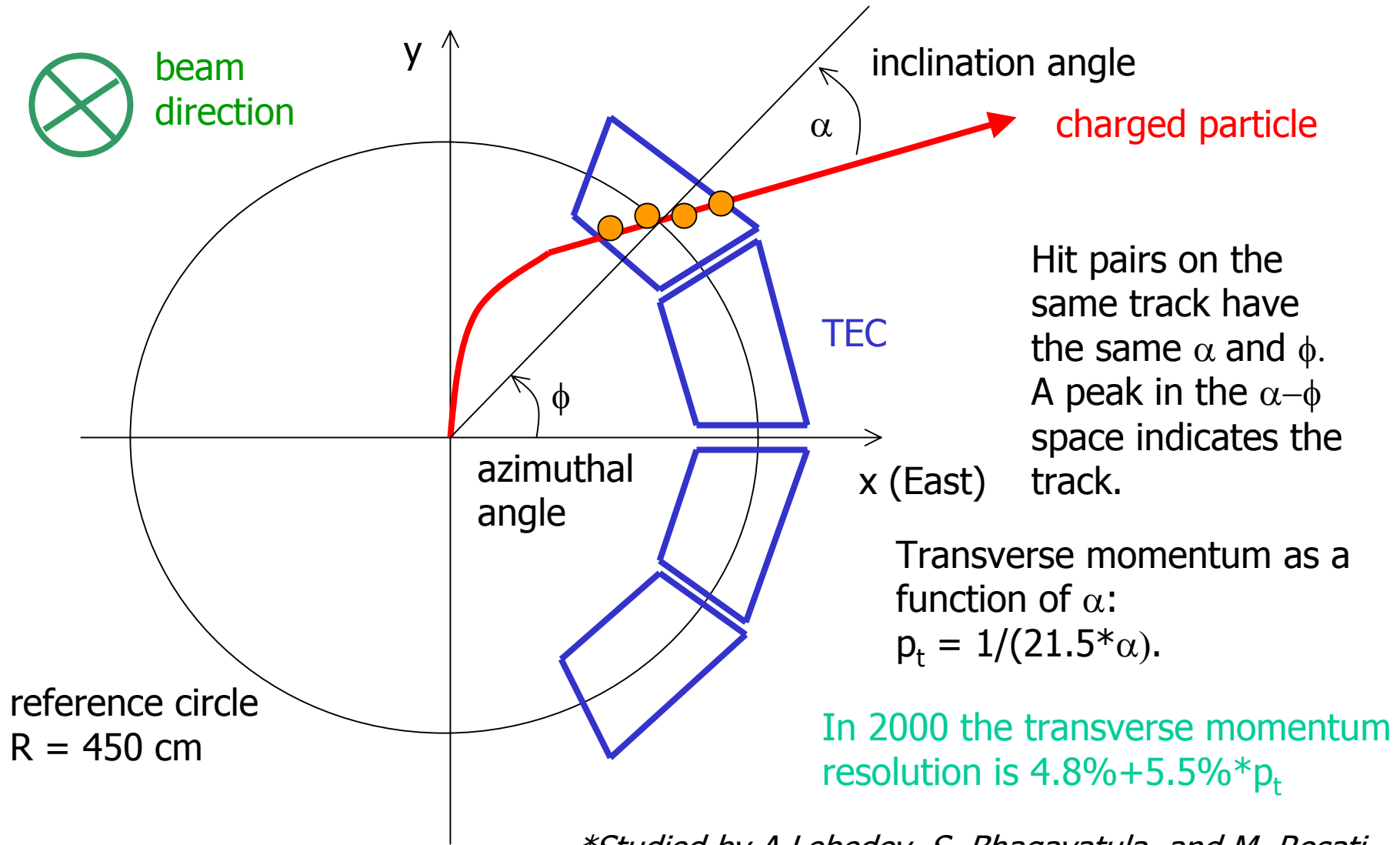
Timing distributions  
for reconstructed charged  
particles



NORM Timing Histogram : Sector E0 and E1  
Data from Run: 26144 File: 0008  
2001\_08\_22 18:51:19



# Track reconstruction



*\*Studied by A. Lebedev, S. Bhagavatula, and M. Rosati*

# Data Sample from the Run-2000

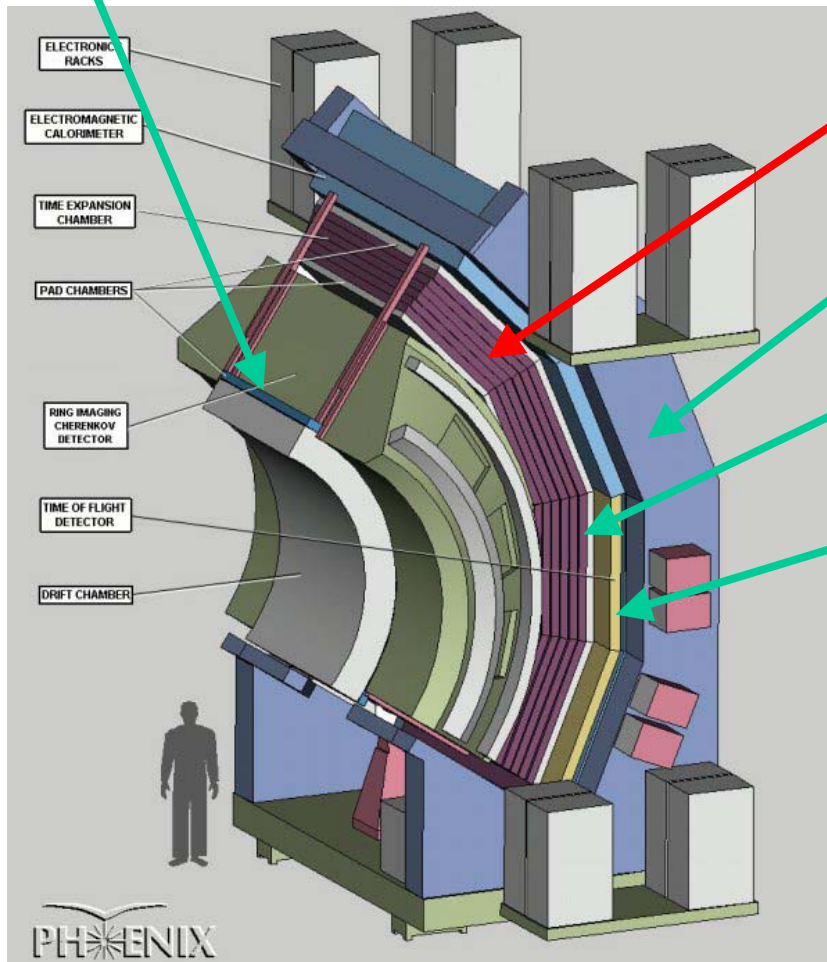
Pad Chamber 1

Time Expansion Chamber

Electromagnetic Calorimeter

Pad Chamber 3

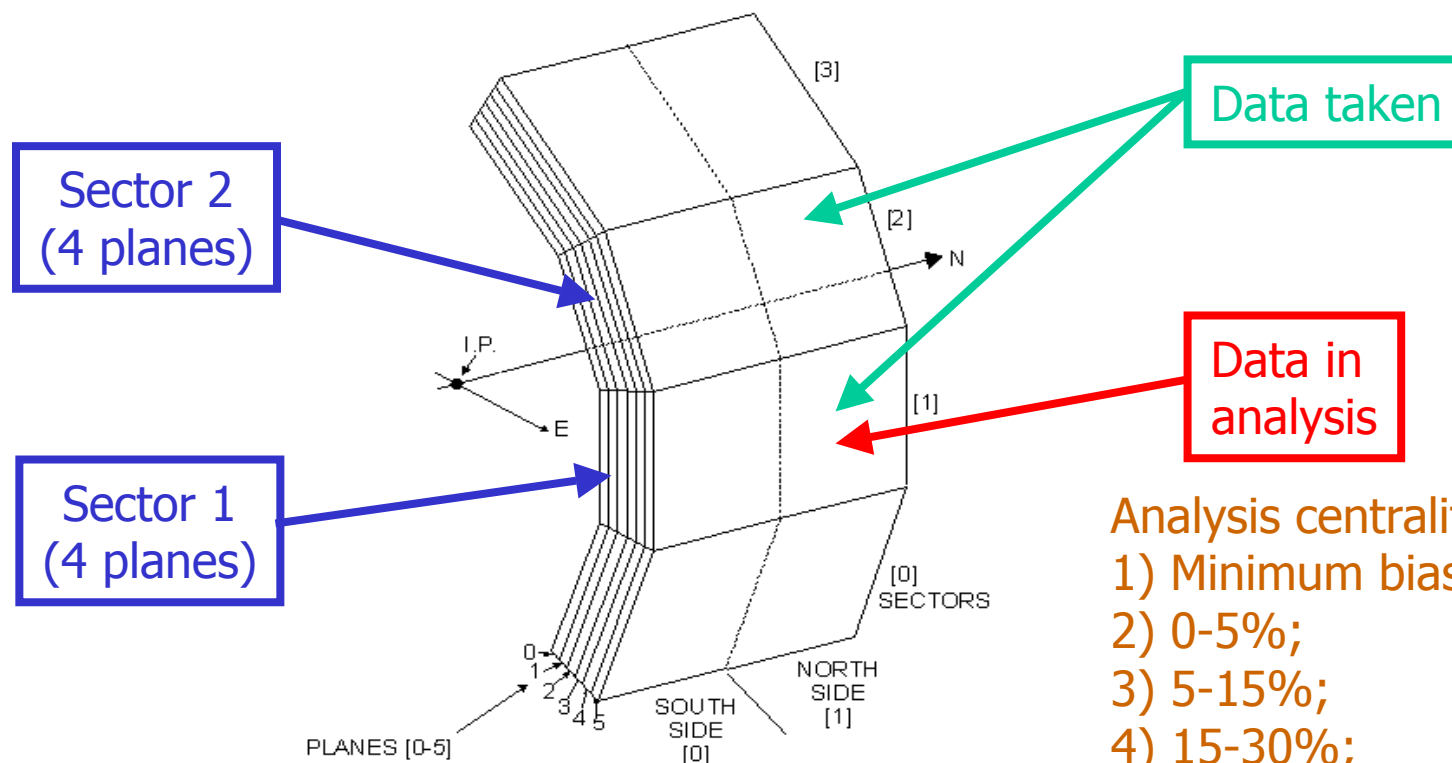
Time of Flight



Tracks reconstructed in the Time Expansion Chamber in association with hits in the Pad Chamber 1 (PC1), Pad Chamber 3 (PC3), Time of Flight (TOF), and Electromagnetic Calorimeter (EMC).  
No Drift Chamber Tracks.

PHENIX East Central Arm

# TEC Tracks in 2000



1.3 million minimum bias events and  
11 million tracks

Analysis centrality selection:

- 1) Minimum bias;
- 2) 0-5%;
- 3) 5-15%;
- 4) 15-30%;
- 5) 30-60%;
- 6) 60-92%;
- 7) 0-10%.

Analysis is performed separately for positive  
and negative particles for each centrality bin.

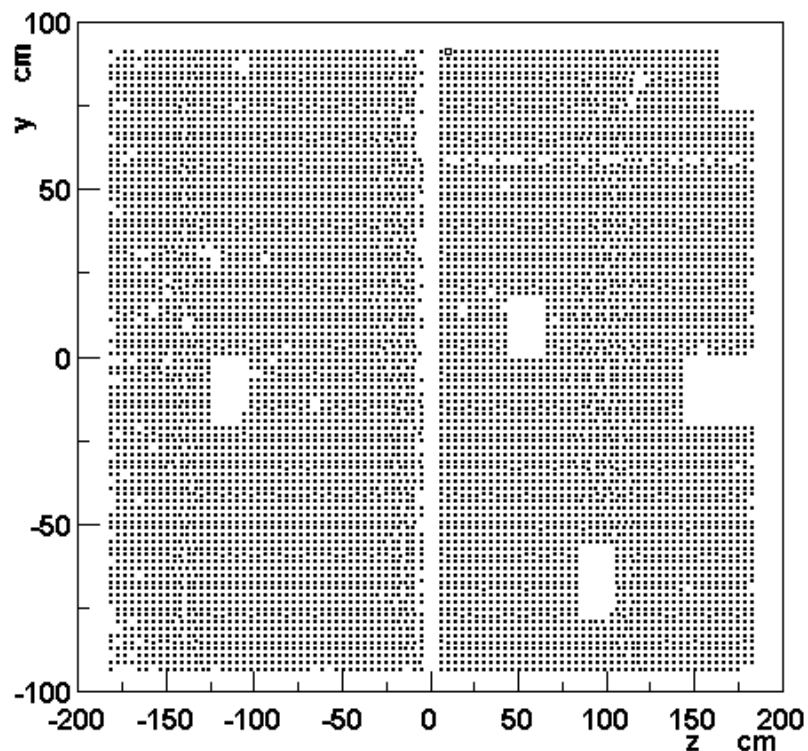


# Corrections

1. Ghost tracks, i. e. “unphysical” background is found though Z-flip method of subsystem’s hit and performing track association with flipped hit.
2. Association cut efficiency.
3. Acceptance.
4. Surviving probability.
5. Physical background.
6. Momentum resolution  $4.8\% + 5.5 \cdot p_t\%$ .
7. Tracking efficiency.
8. Track splitting and merging (negligible in TEC, found as ratio of angles  $\Phi$  between two tracks from mixed events and the same events).

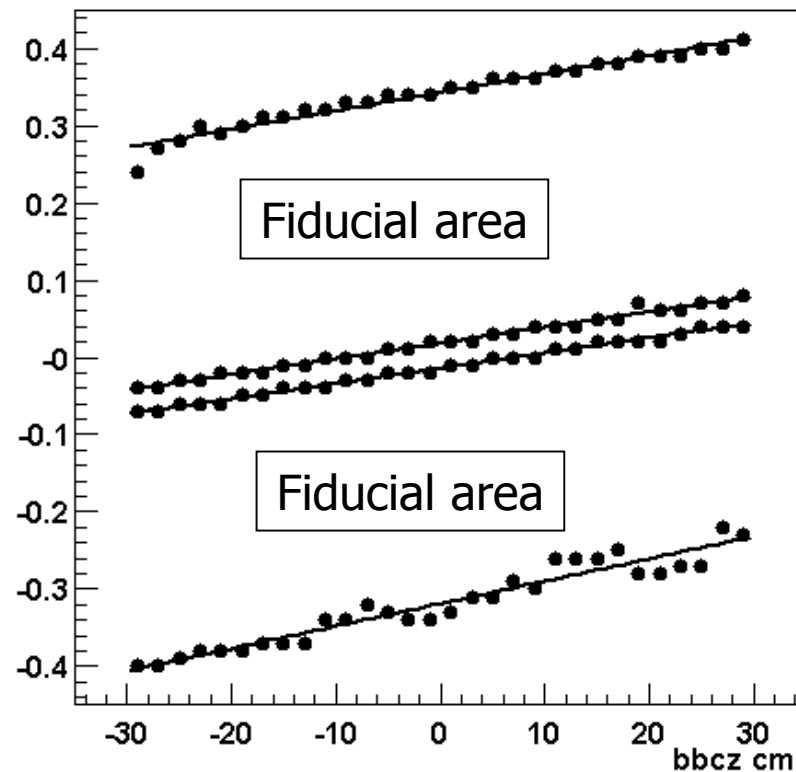
# Acceptance

PC3 Acceptance



Hardware acceptance:  
dead areas are 8%

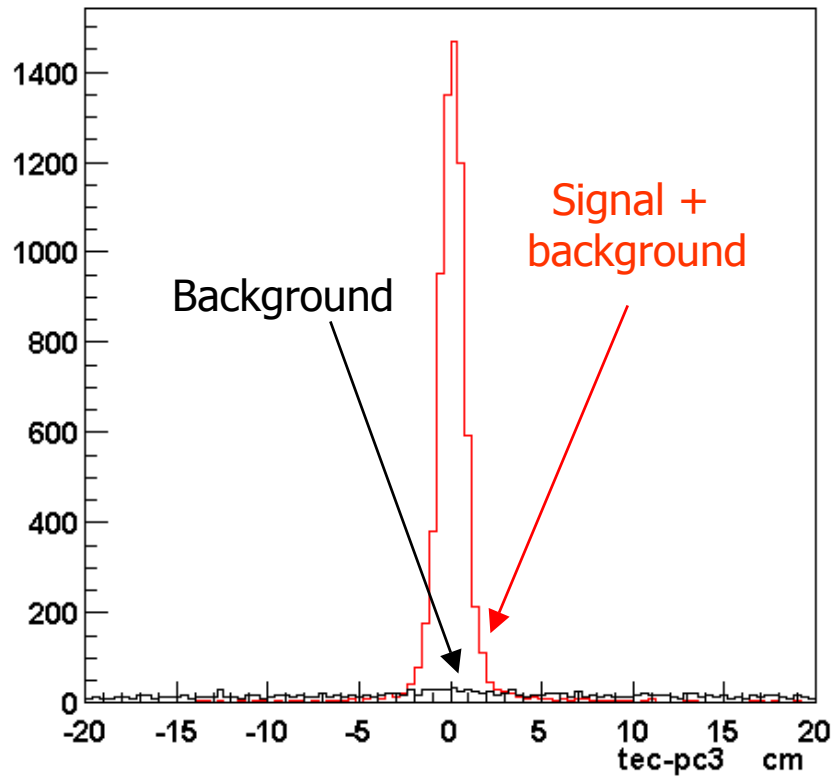
Fiducial cuts in pseudorapidity



Vertex range:  
 $-30\text{cm} < Z < 30\text{cm}$

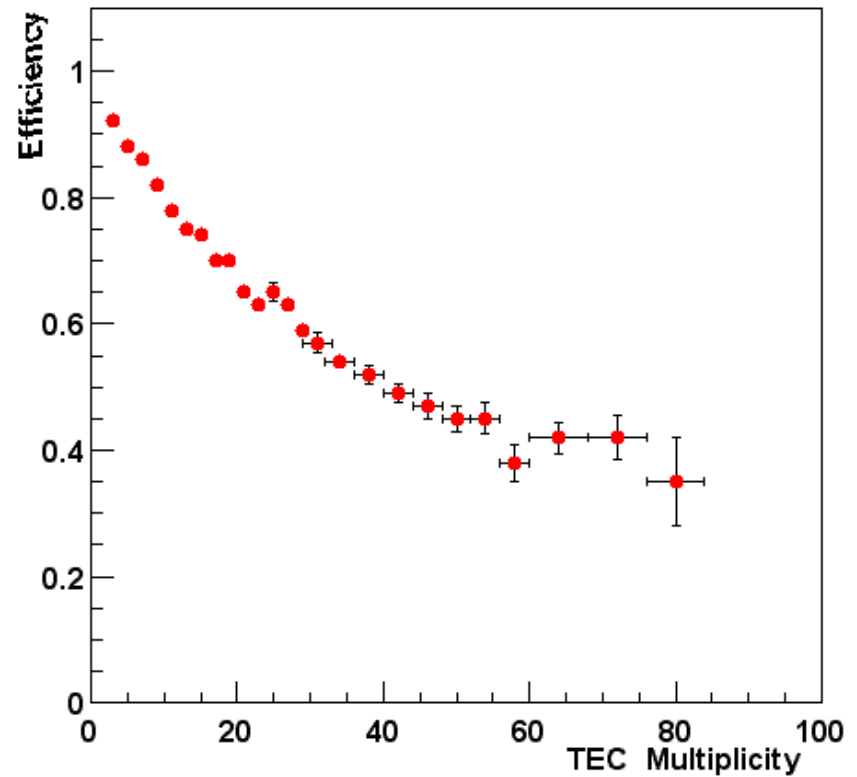
# Track association and tracking efficiency

TEC-PC3 minus 60-80% 1.2GeV



Measure closest distances between TEC tracks and associated hits in PC1, PC3, TOF, EMC, and between projection of the tracks to the collision vertex and the vertex for 60-80% peripheral events.

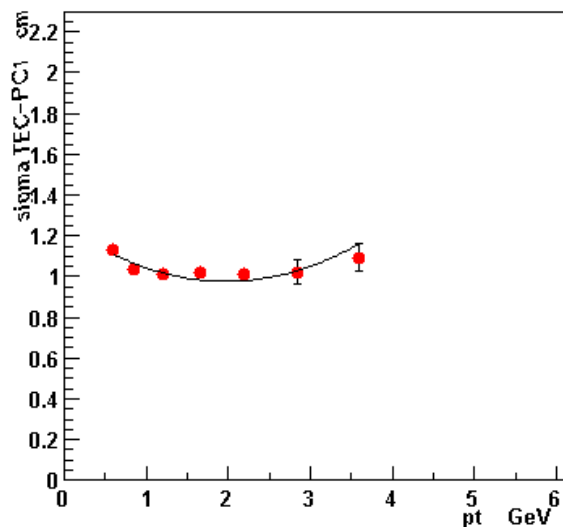
Tracking efficiency



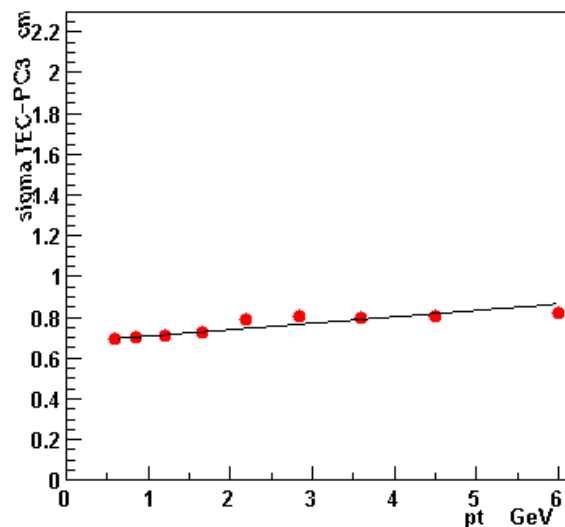
Tracking efficiency found as a ratio of the number of **found** simulated tracks embedded into data tracks to the **total** number of embedded tracks. Function of the number of data tracks.

# Relative spatial resolution

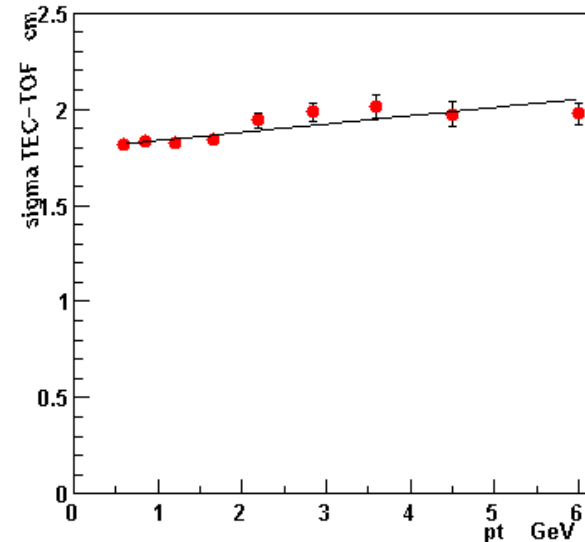
Relative resolution TEC-PC1 60-80% positive



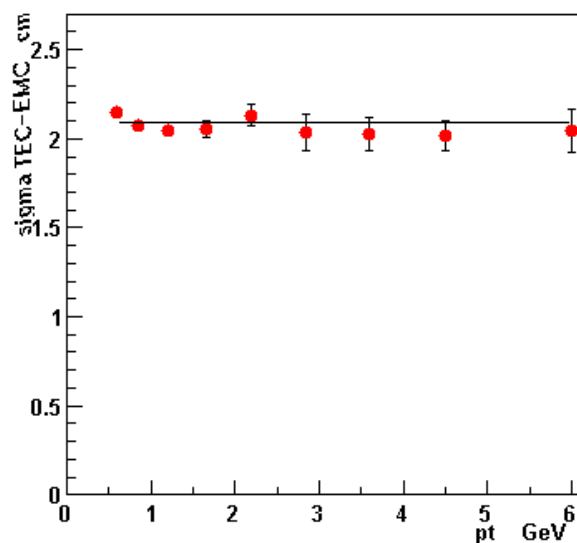
Relative resolution TEC-PC3 60-80% positive



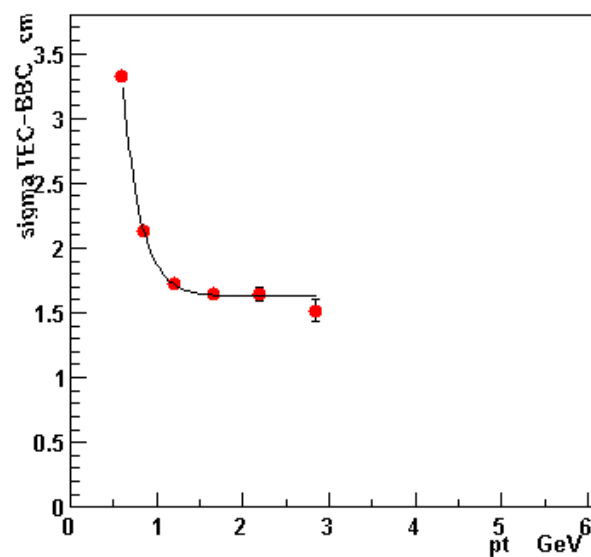
Relative resolution TEC-TOF 60-80% positive



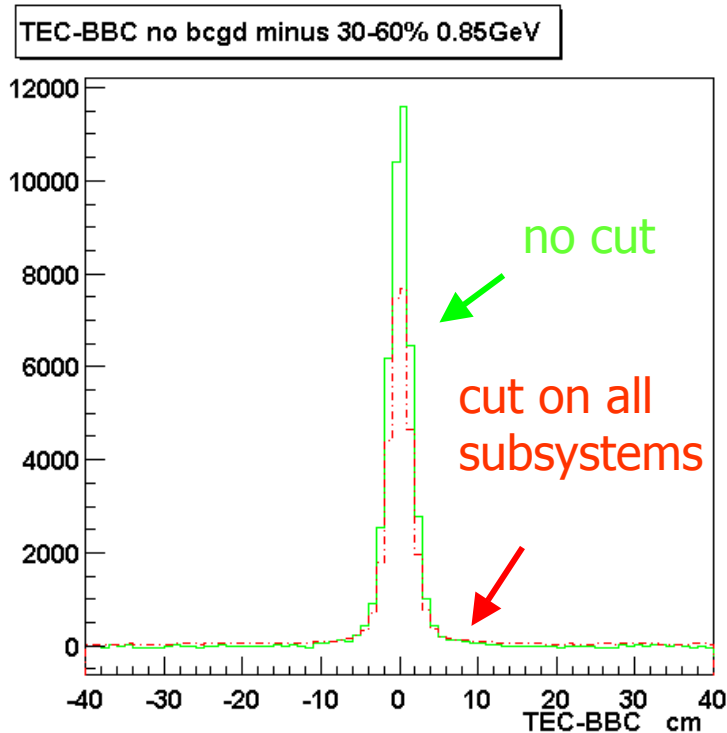
Relative resolution TEC-EMC 60-80% positive



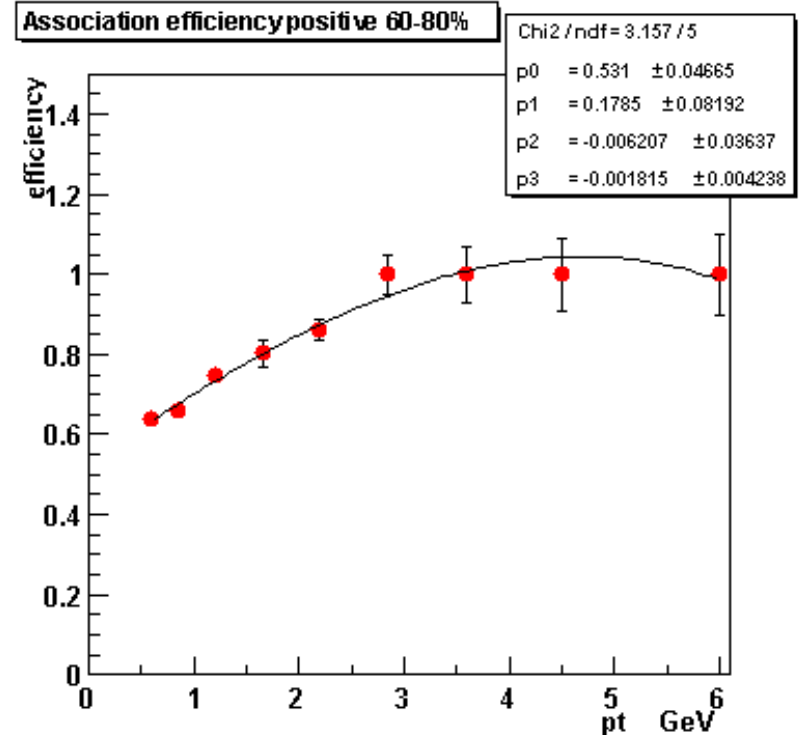
Relative resolution TEC-BBC 60-80% positive



# Track association efficiency



Plot the distributions of TEC track association with the collision vertex:  
1) without making any association cut on any subsystem; 2) making  $3\text{-}\sigma$  (or  $2\text{-}\sigma$ ) cuts on all subsystems.  
Find the ratio of the maxima of these distributions, which will be the association cut efficiency.

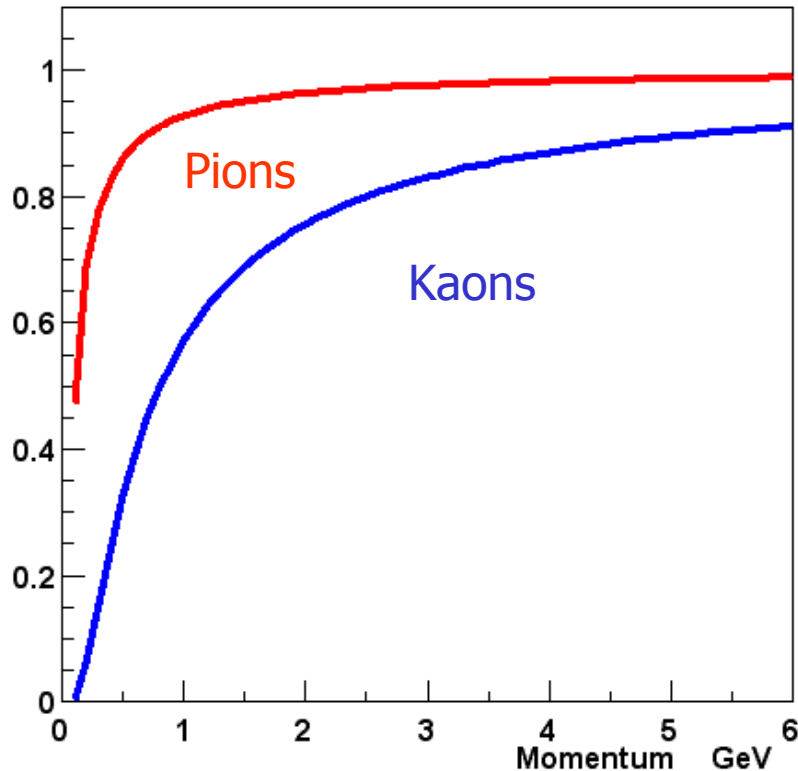


Efficiency of association cuts as function of transverse momentum for 60-80% peripheral events



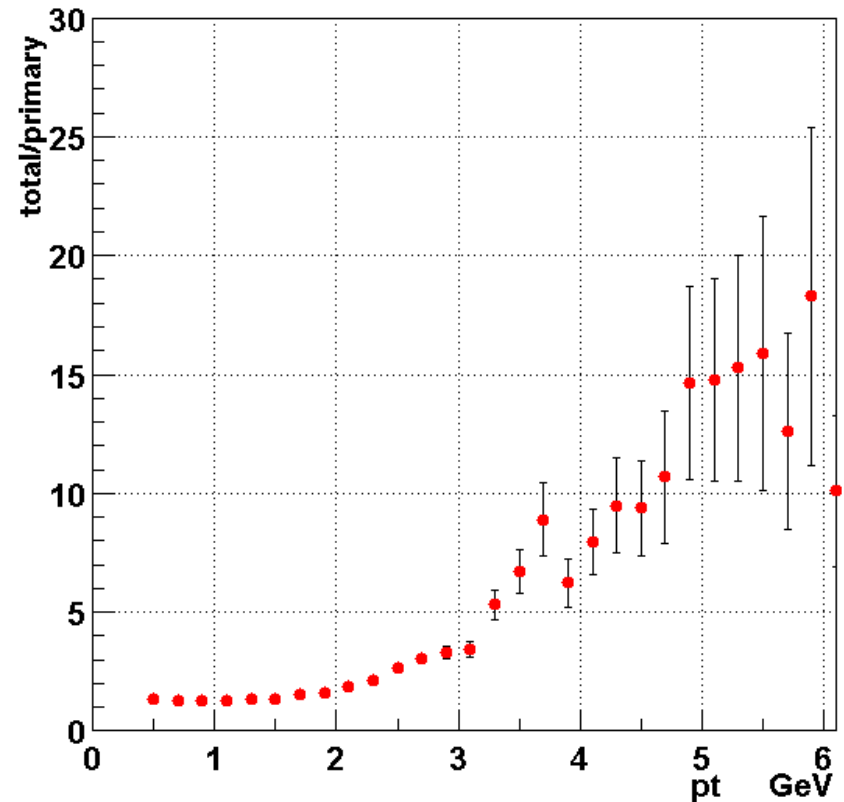
# Surviving probability and physical background

Surviving probability at 440 cm



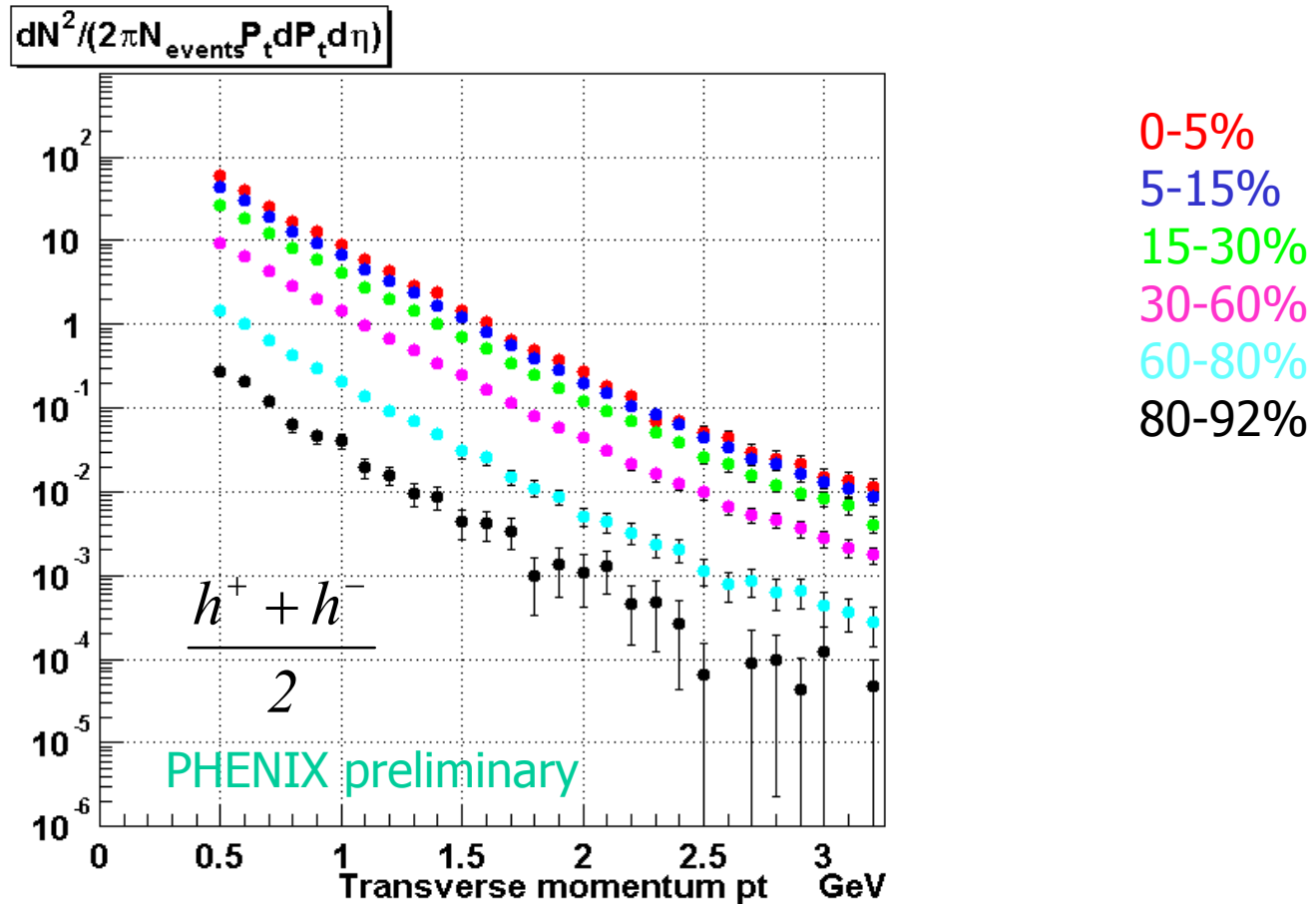
Probability that hadrons would decay prior reaching the TEC

Particles ratio total/primary

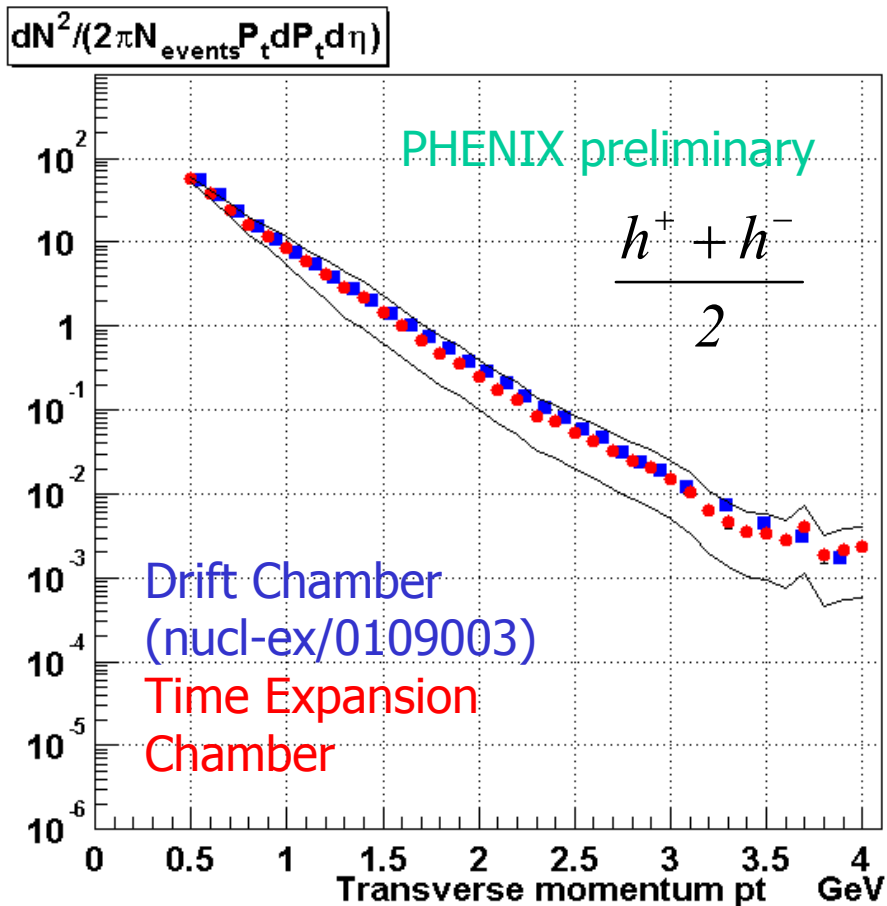


Physical background correction function is found through simulation as ratio of the total number of particles found in the TEC to the number of primary particles found in the TEC.

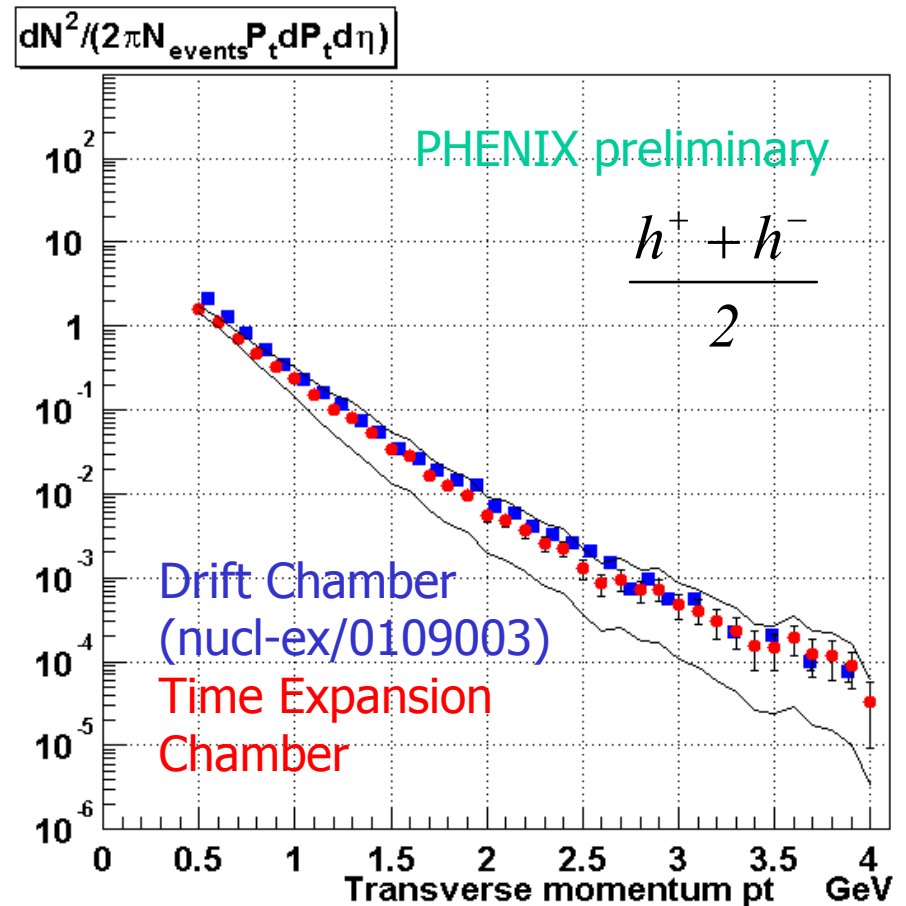
# Transverse momentum spectra



# Comparison with the Drift Chamber results



0-10% central events



60-80% peripheral events

# Future

1. Upgrade into the Transition Radiation Detector (capable of pion/electron separation for momenta beyond 50 GeV) by:
  - a) electronically instrumenting from 4 to 6 planes,
  - b) installing polypropylene fiber radiators in front of each wire plane,
  - c) use xenon-helium-methane (Xe-He-CH<sub>4</sub>) gas mixture.  
(To be done by October 2002.)
- 2) Possible construction of the TEC in the PHENIX West Central Arm (2004/2005).