New Results from CERES

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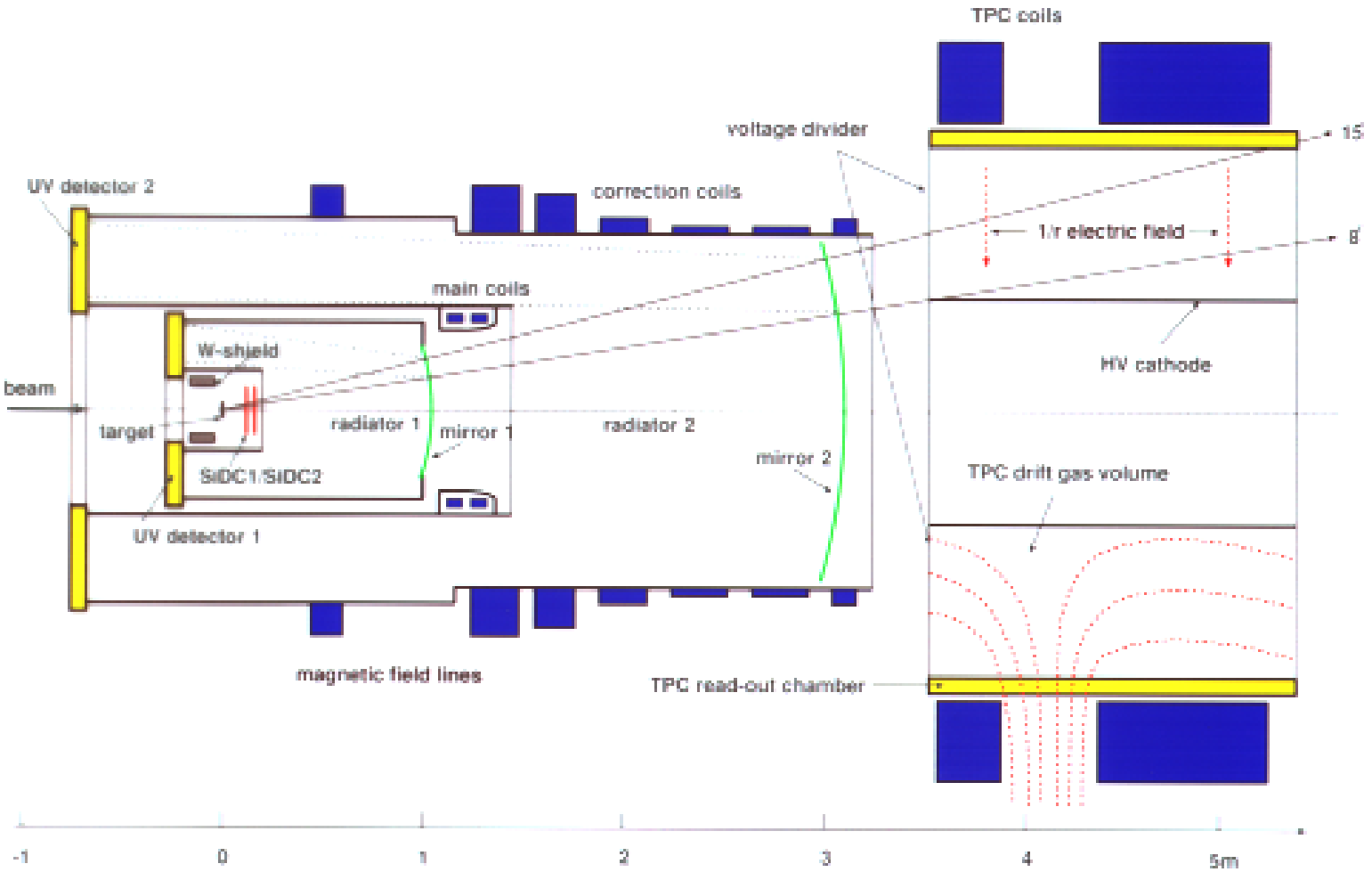
for the CERES collaboration

- Experimental Setup
- Hadronic Observables
  - Spectra, Azimuthal Correlations and HBT
  - Event-by-Event Mean p_t Fluctuations
- Leptonic Observables
  - 40 AGeV Pb+Au e^+e^- Pair Analysis
- High p_t Pion Correlations
- Summary and Outlook

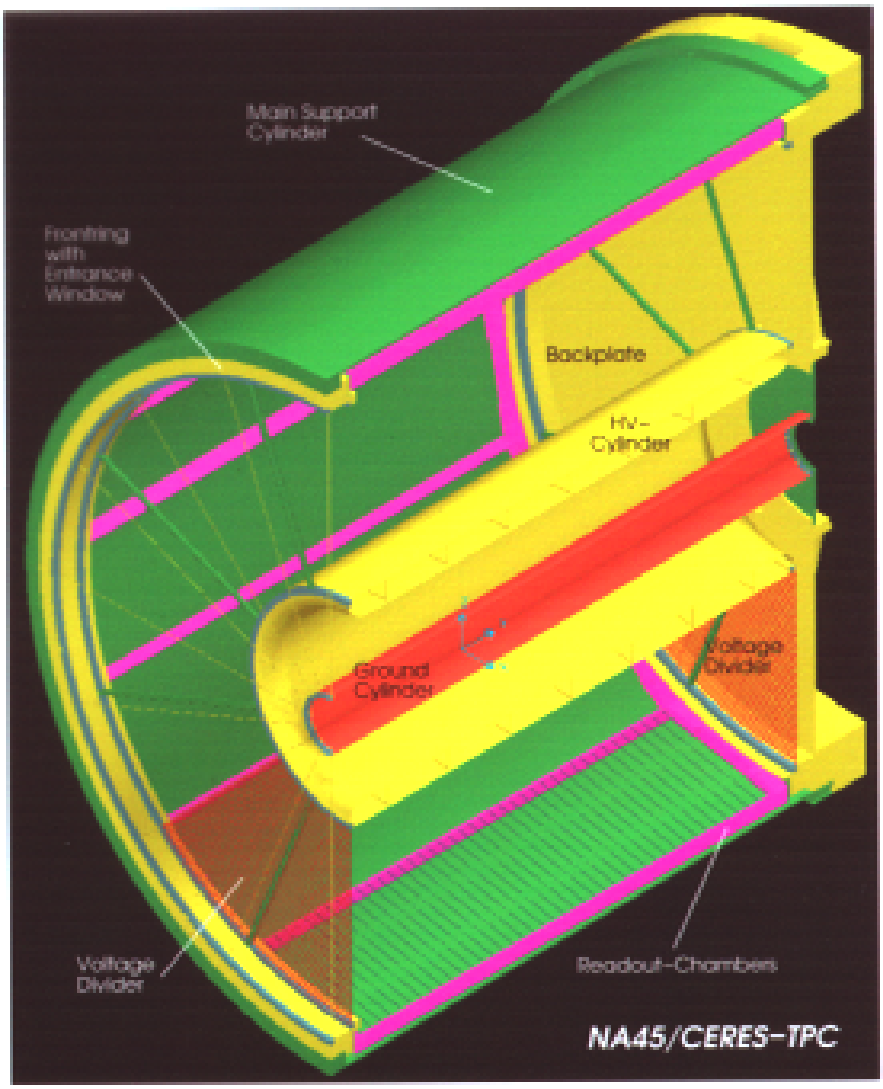
CERES/NA45 Experimental Setup



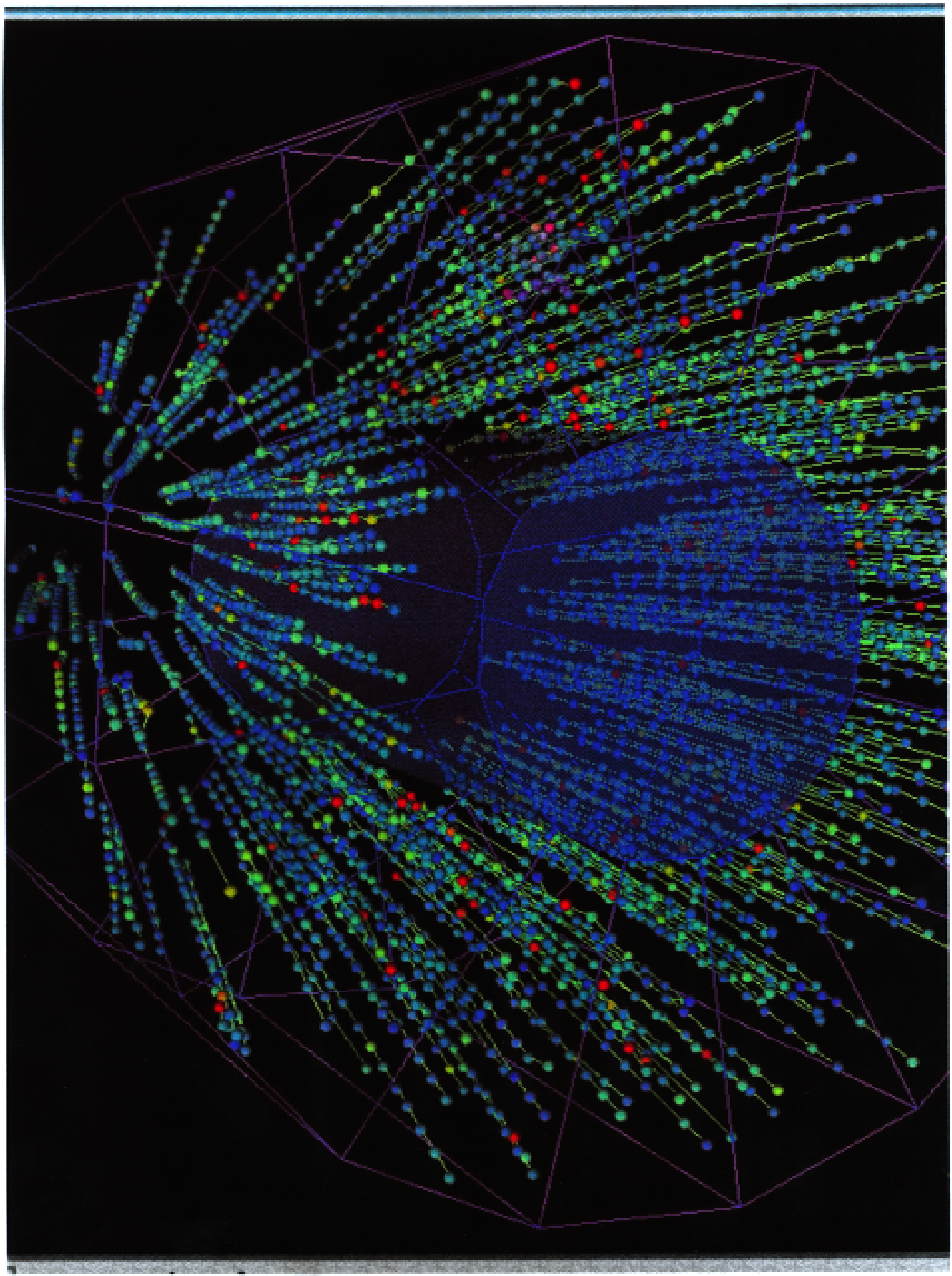
- SiDC1+2: Vertex reconstruction and angle measurement
- RICH1+2: Electron ID and angle measurement
- New cylindrical Time Projection Chamber with radial drift field, length 2 m, outer diameter 2.6 m
- New magnet system

  1999→: Azimuthal deflection inside TPC, no more B-field between RICHes

CERES-TPC



- Radial drift field (-30 kV)
- Gas mixture Ne(80%)CO_2(20%)
- 20 space points per track
- 15360 readout channels (typical: 200 kByte at 5% occupancy)



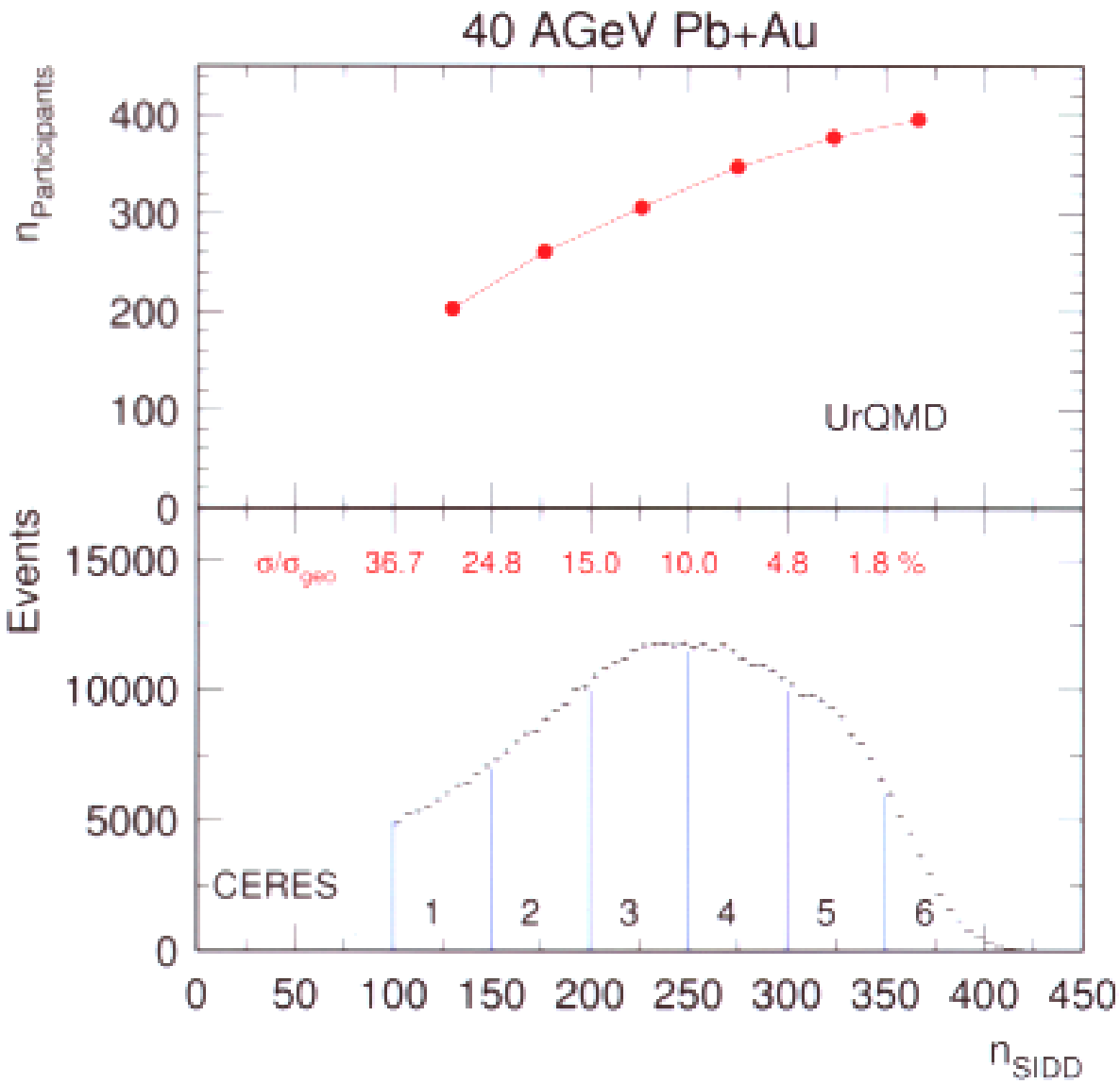
Data Set

Year	E_{beam}		Events
2000	80	AGeV Pb+Au	0.5 M
	158	AGeV Pb+Au	33 M
1999	40	AGeV Pb+Au	8 M
1996	158	AGeV Pb+Au	43 M

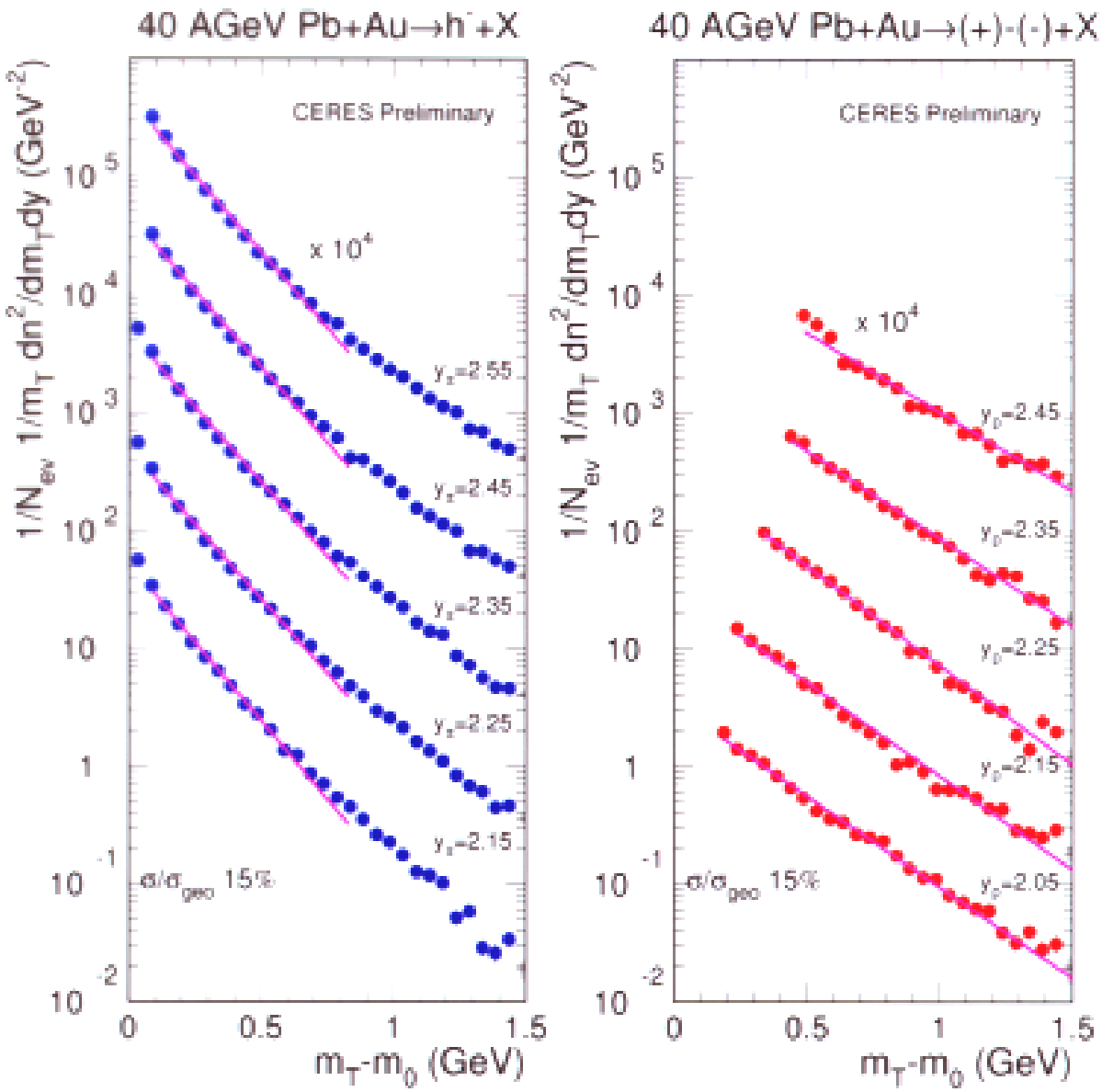
Centrality

Centrality determination:

- Charged particle multiplicity in SiDD
- $n_{\text{participants}}$ from model



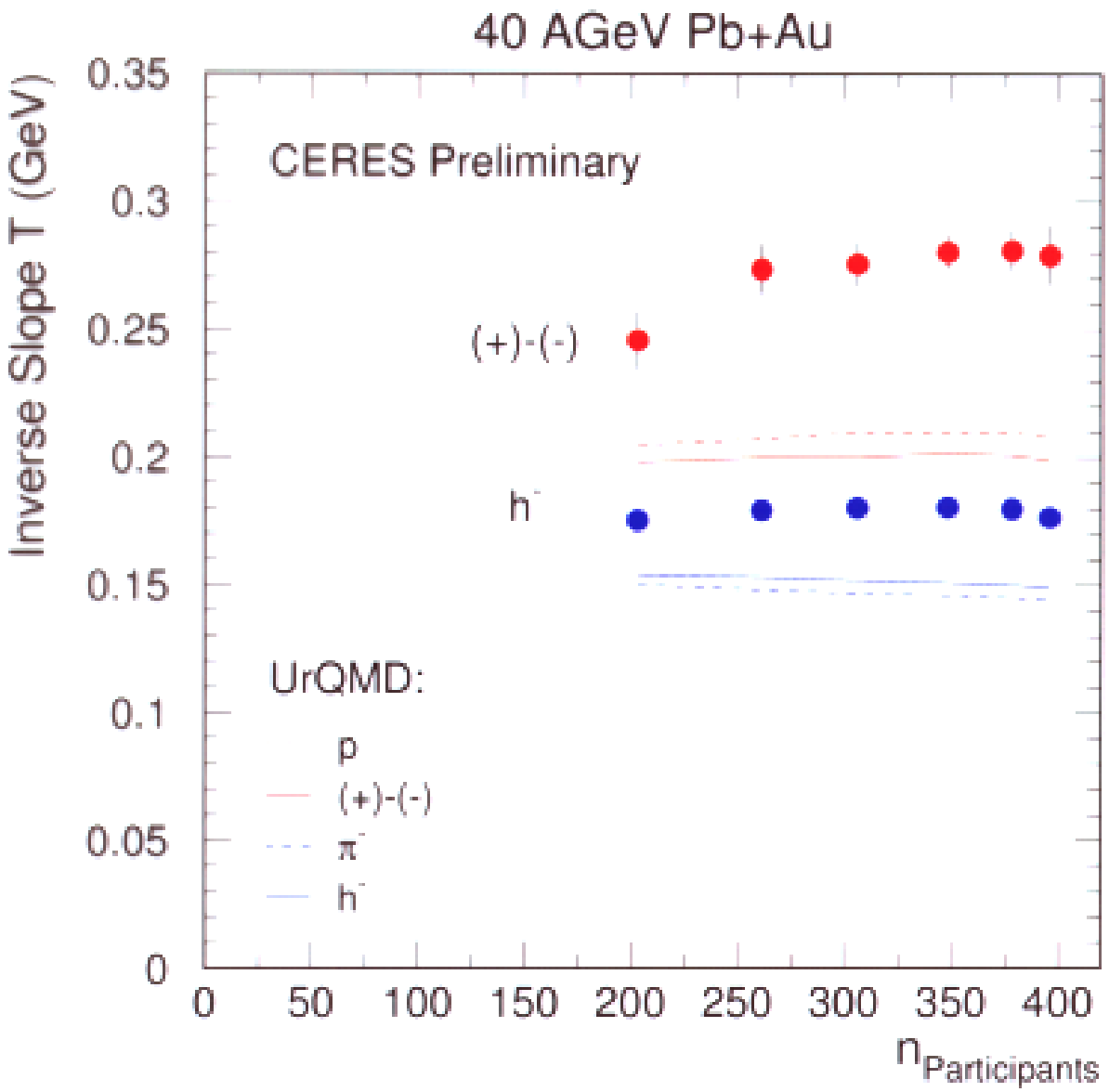
Transverse Mass Spectra



Fit:

$$\frac{1}{m_T}\frac{dn}{dm_T} = \exp\left(-\frac{m_T}{T}\right)$$

Inverse Slopes



Fit:

$$\frac{1}{m_T}\frac{dn}{dm_T} \sim \exp\left(\frac{-m_T}{T}\right)$$

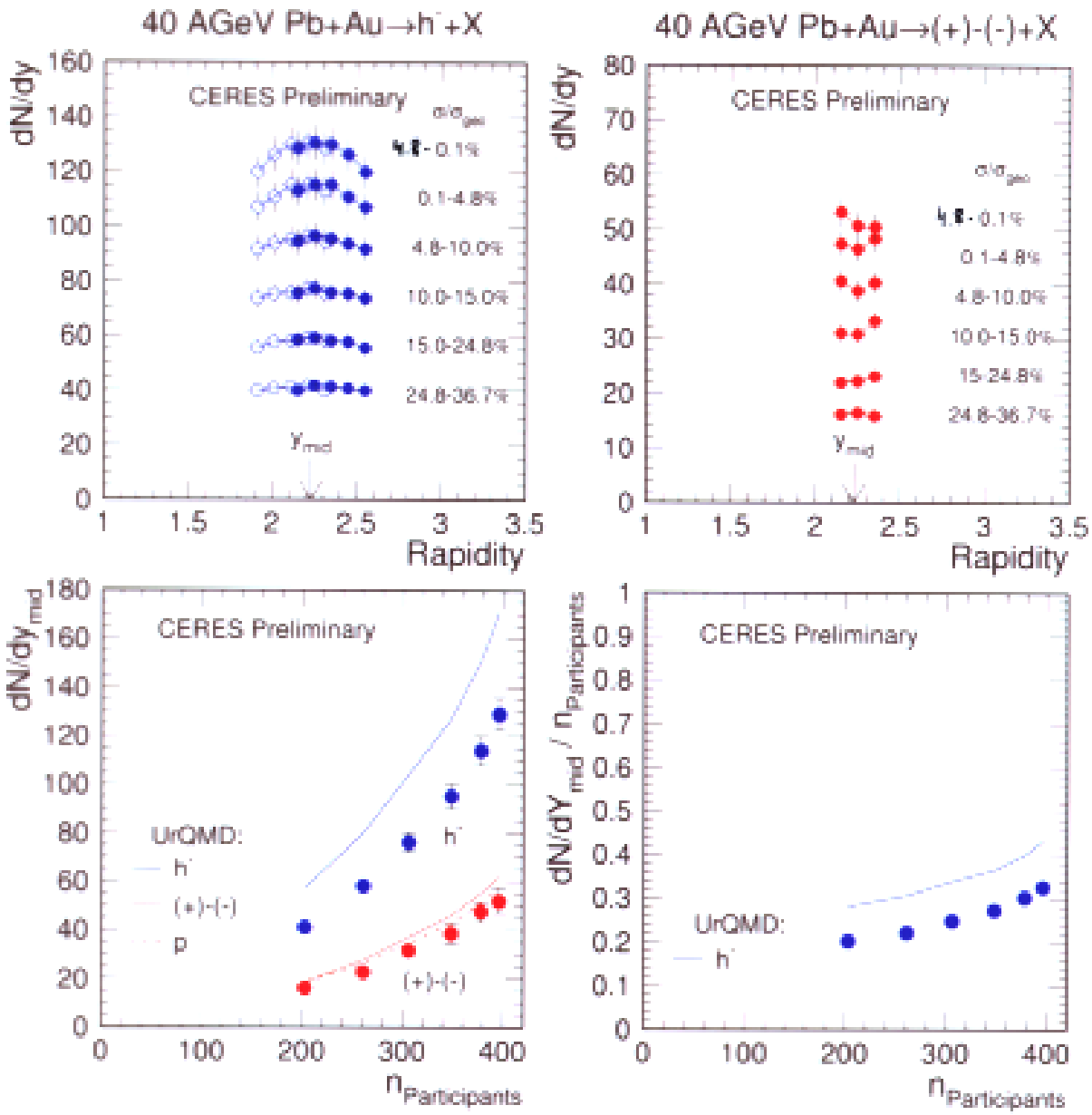
Range:

$0.3 < m_T < 1.0$ GeV h^-

$1.35 < m_T < 2.5$ GeV $(+)-(-)$

Hadron Yields

⇒ Extrapolation to $p_T = 0$

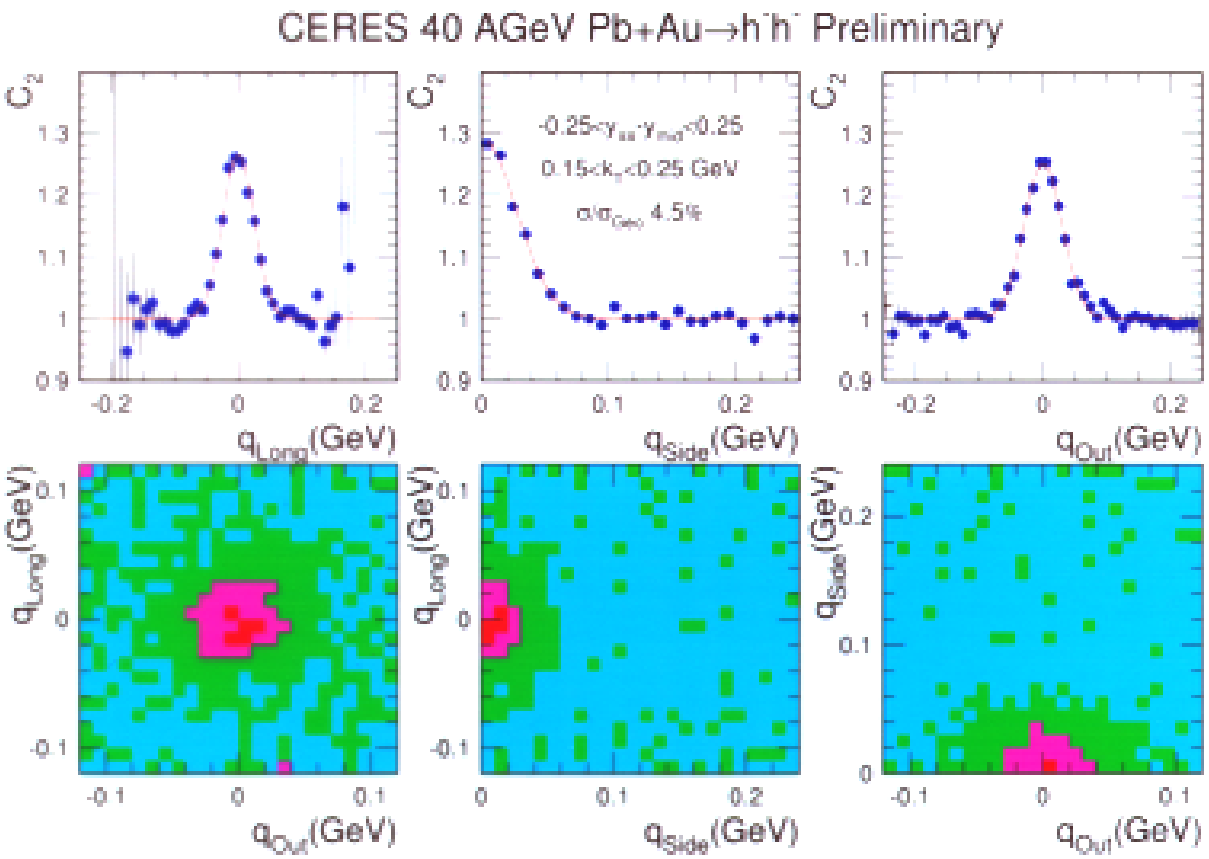


Pion HBT Analysis

h h and h' h':

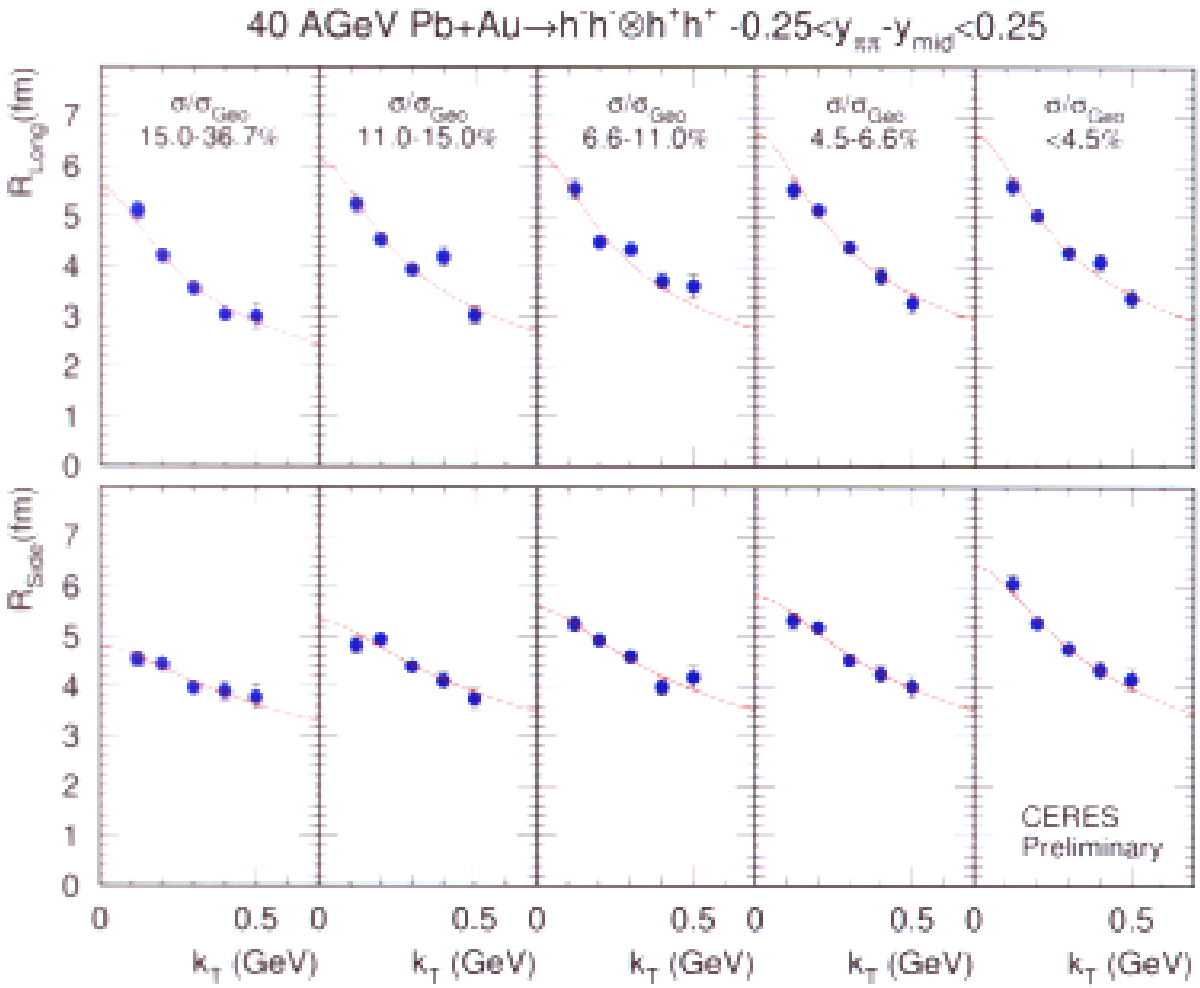
$$C_2 = \lambda \cdot \exp(-q_{\mathrm{Long}}^2 R_{\mathrm{Long}}^2 - q_{\mathrm{Side}}^2 R_{\mathrm{Side}}^2 - q_{\mathrm{Out}}^2 R_{\mathrm{Out}}^2 - 2 q_{\mathrm{Out} q_{\mathrm{Long}}} R_{\mathrm{OutLong}}^2)$$

- -0.25 $< y_{\pi\pi} - y_{\mathrm{mid}} <$ 0.25
  in bins of centrality and pair transverse momentum k_T
- Finite source size Coloumb correction
- Pair opening angle cut: 10 mrad



Transverse Momentum Dependence

$$k_T = \frac{1}{2}(\vec{p}_{T,1} + \vec{p}_{T,2})$$



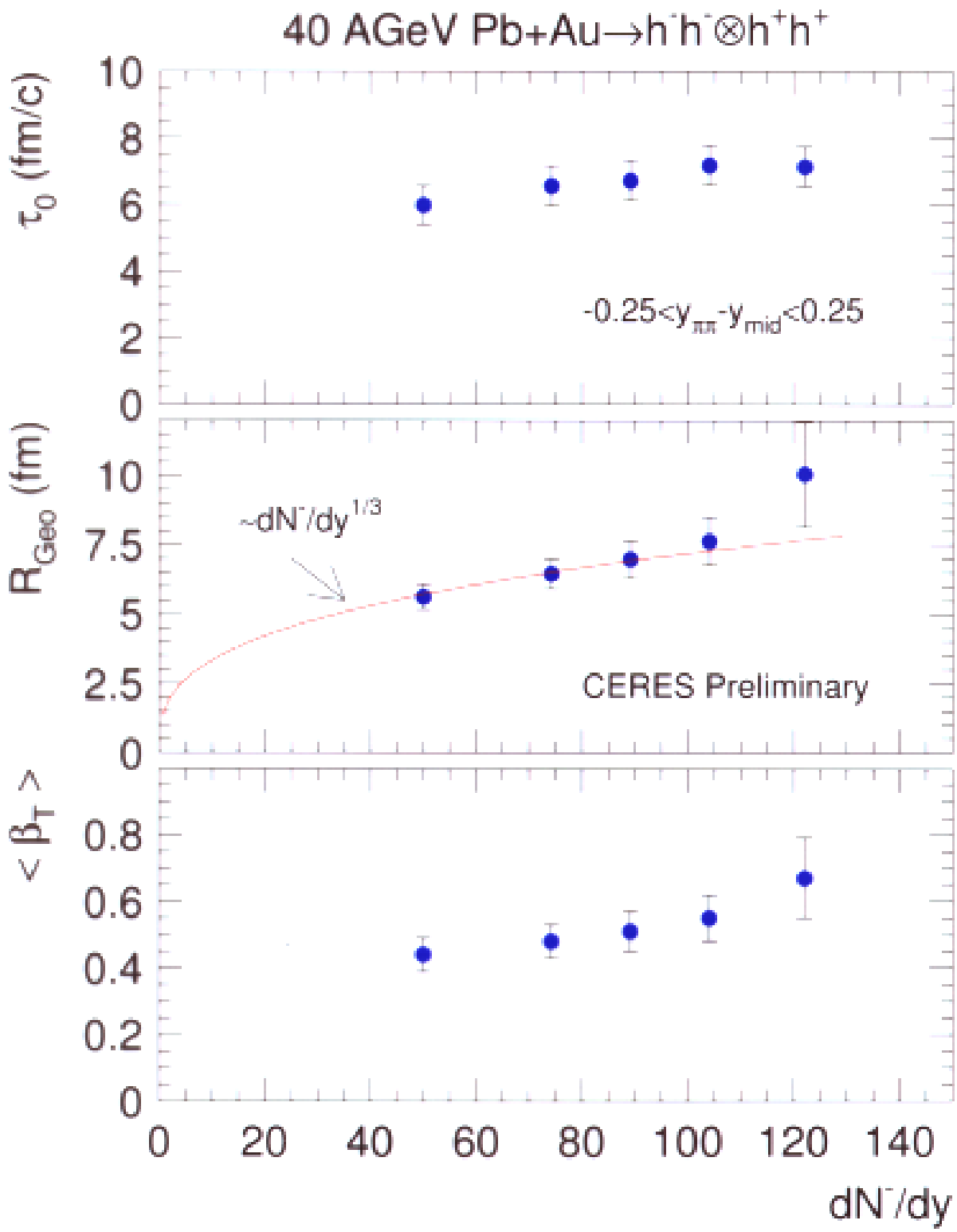
Longitudinal boost-invariant expansion:

$$R_{\mathrm{Long}} = \tau_0 \sqrt{\frac{T}{m_T}}$$ Sinyukov

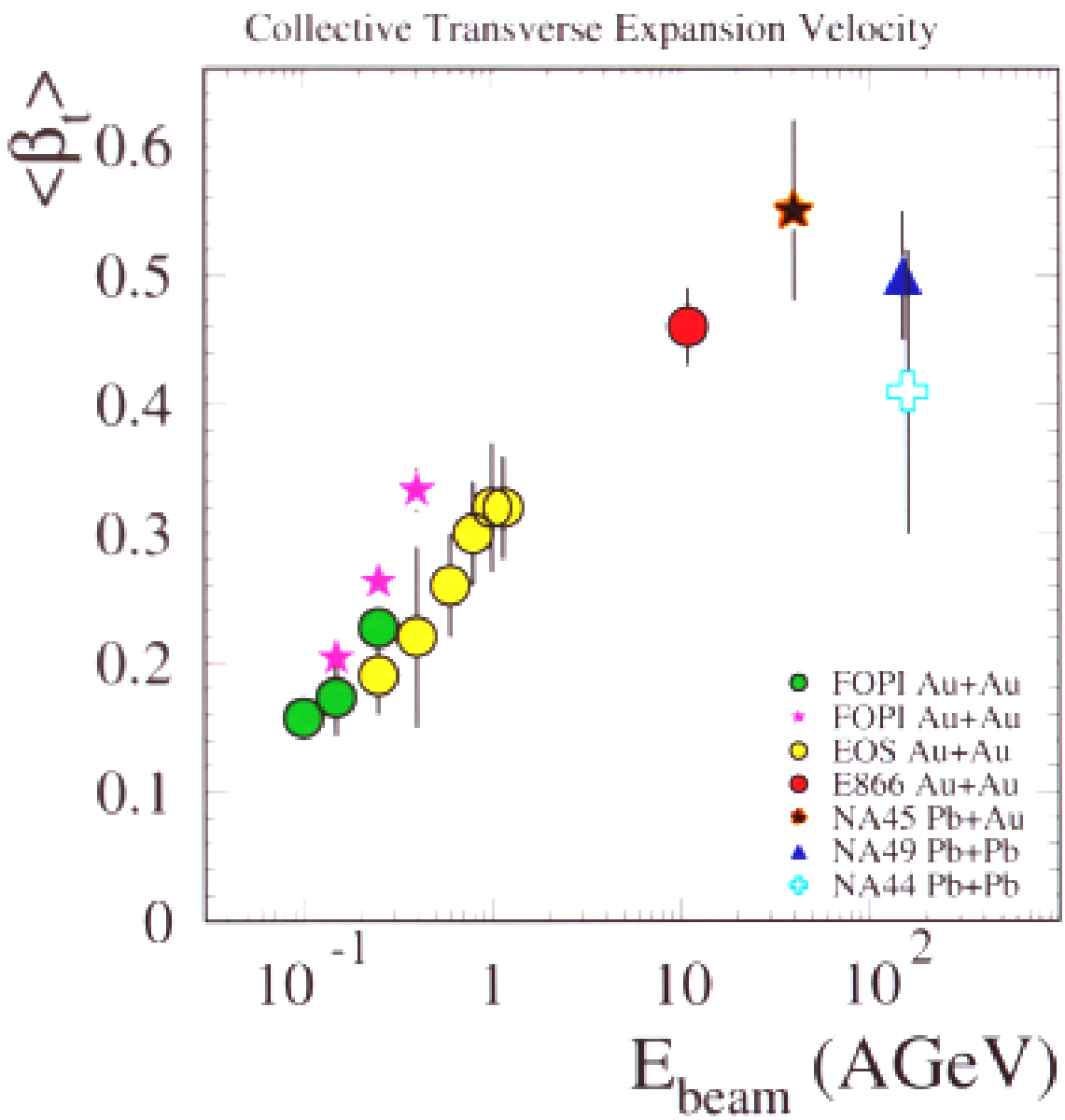
Radial flow:

$$R^2_{\mathrm{Side}} = \frac{R^2_{\mathrm{Geo}}}{1 + \frac{\eta_f^2}{T} m_T}$$ Heinz, Tomasik, Wiedemann

Freezeout Parameters



$< \beta_t >$ vs Beam Energy



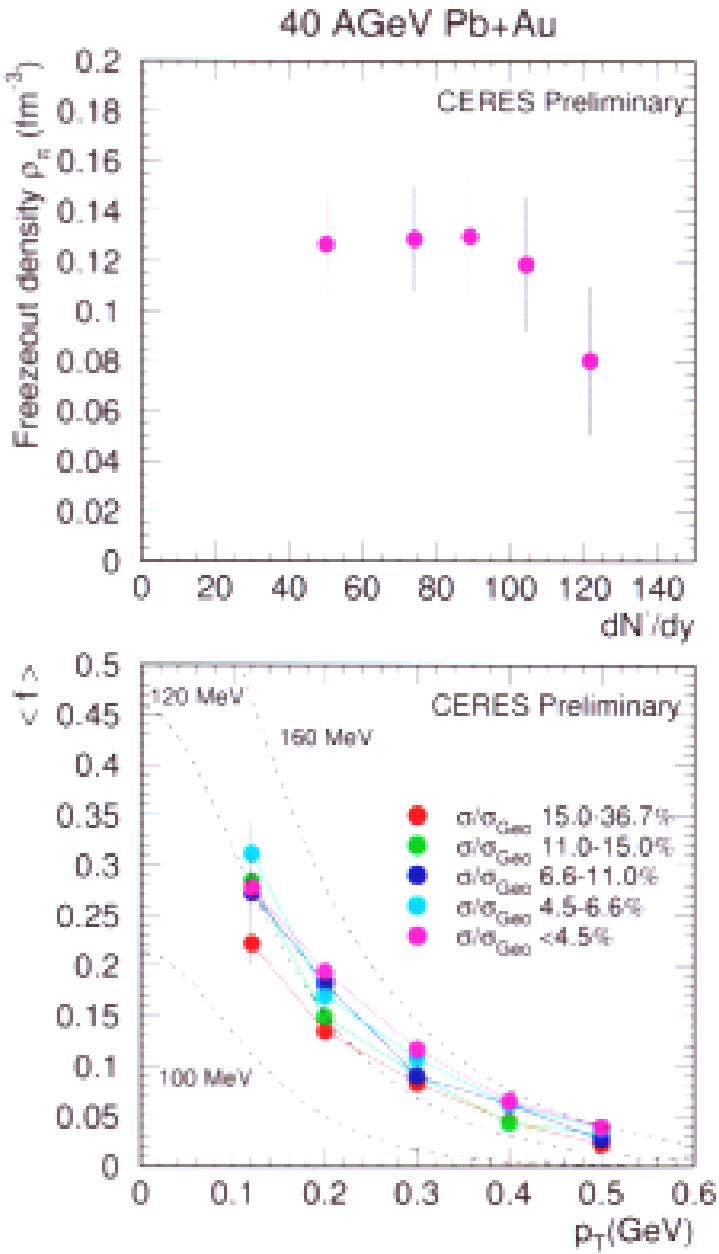
Pion Freeze-out

Freeze-out density:

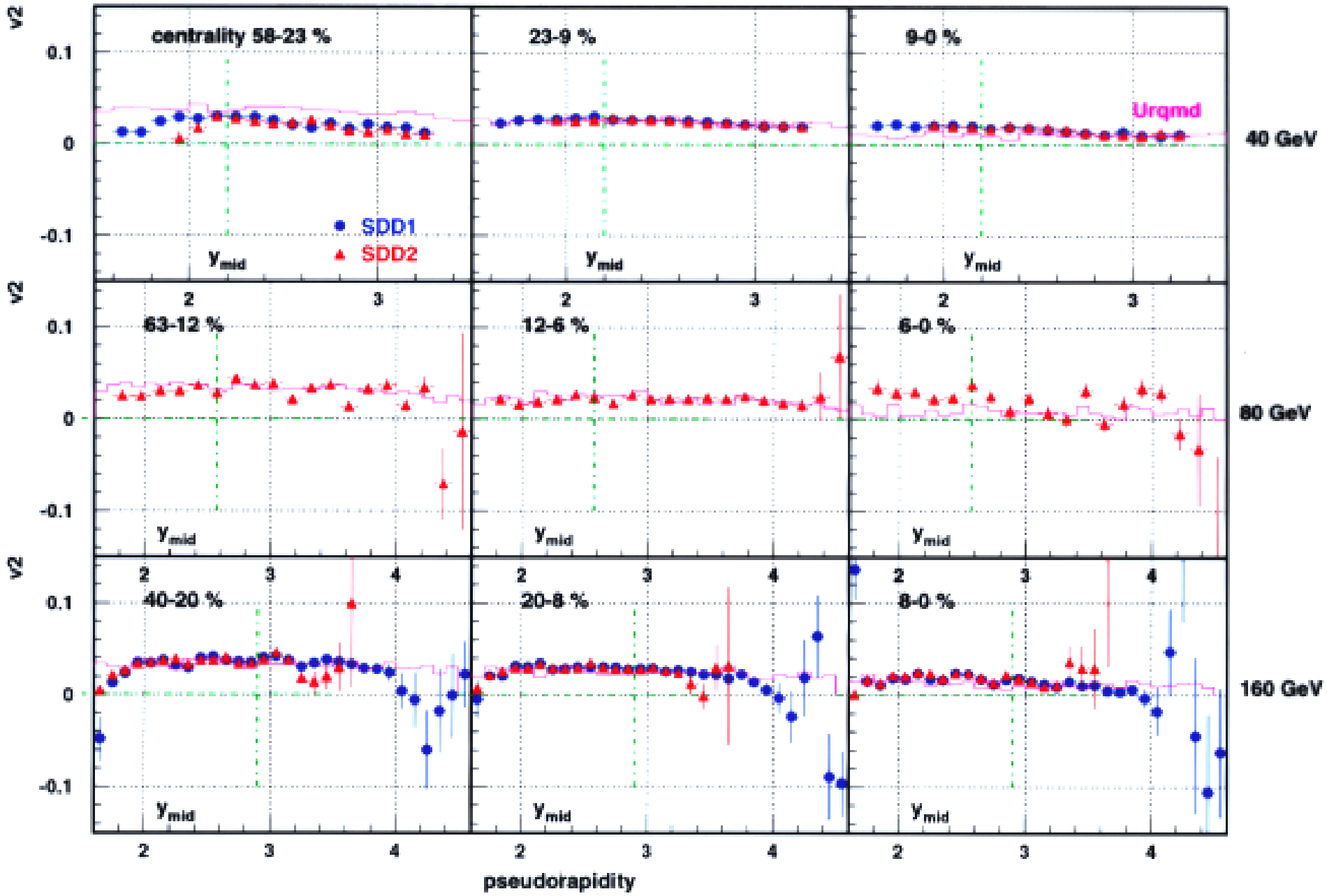
$$\rho_\pi = \frac{dn/dy}{2\pi \cdot R^2_{Geo} \cdot \tau_0}$$

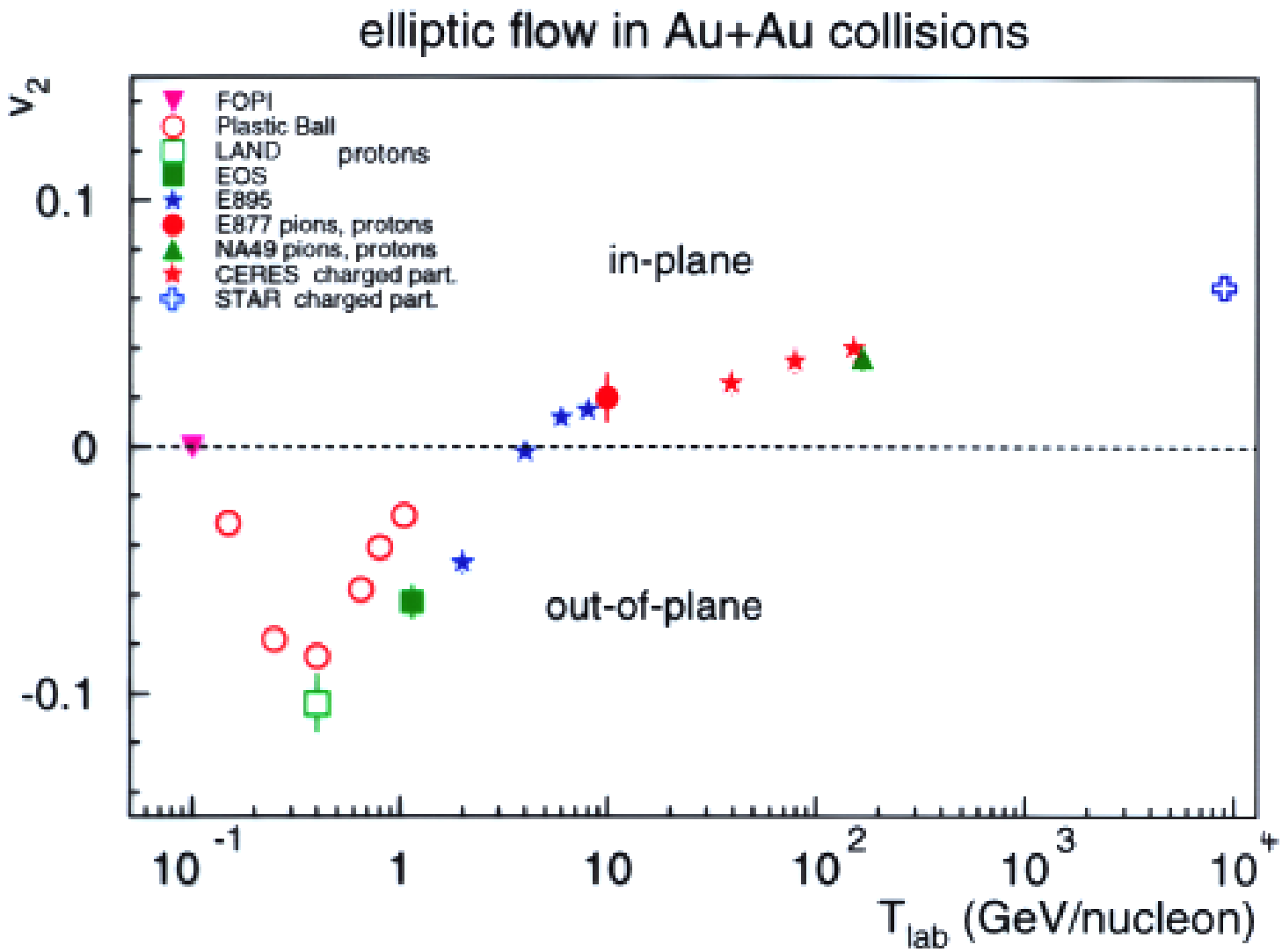
Phase-space density (Bertsch):

$$< f > (p_T, y) = \sqrt{\lambda(p_T, y)} \frac{\frac{dn^-}{dy} \frac{1}{2\pi T^2_{eff}(y)} e^{-p_T/T_{eff}(y)}}{\pi^{-3/2} m_T \cosh y \cdot R^2_{Side}(p_T, y) \cdot R_{Long}(p_T, y)}$$



rapidity and beam momentum dependence of elliptic flow

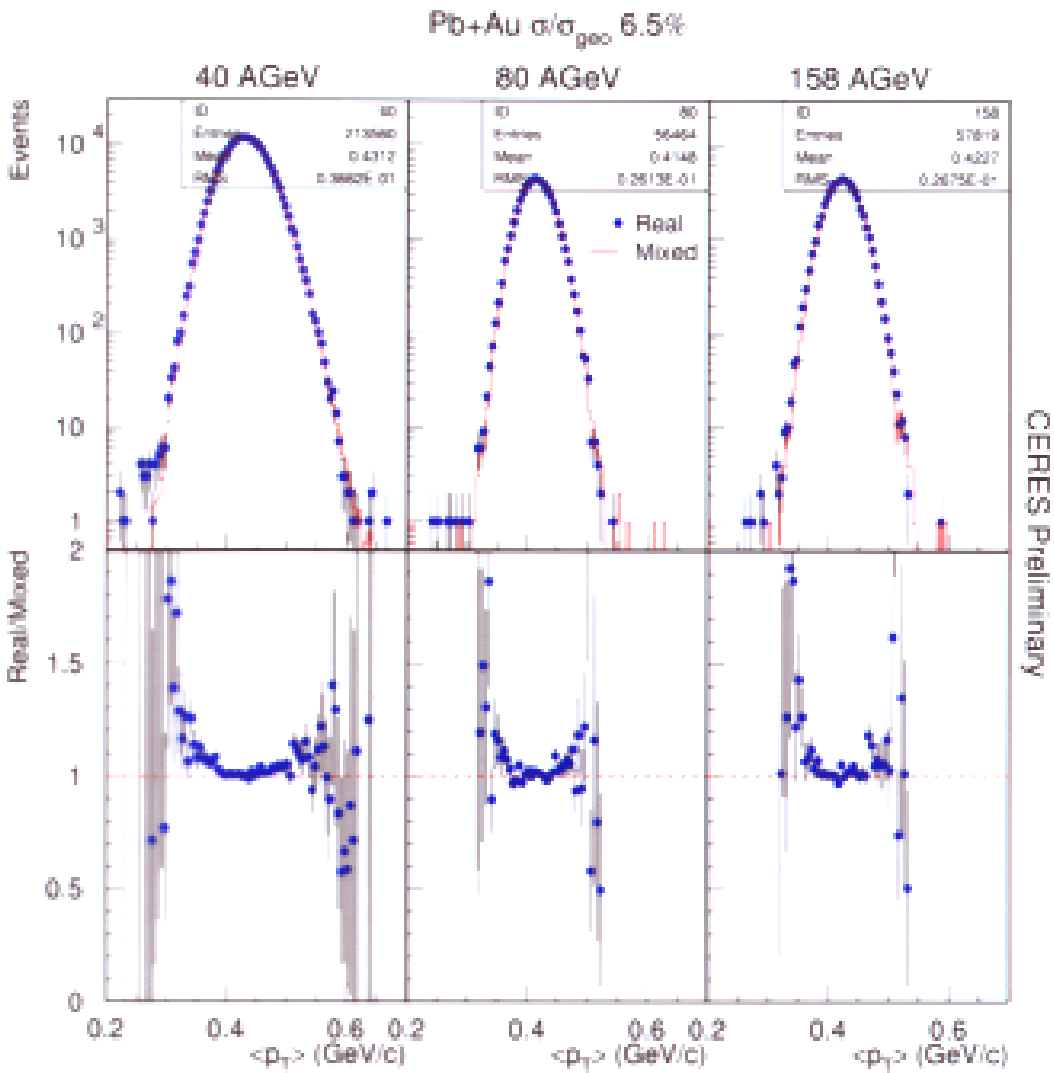



elliptic flow in Au+Au collisions
v_2
FOPI
Plastic Ball
LAND
protons
EOS
E895
E877 pions, protons
NA49 pions, protons
CERES charged part.
STAR charged part.
in-plane
out-of-plane
0.1
0
-0.1
10^{-1}
1
10
10^2
10^3
10^4
T_{lab} (GeV/nucleon)

Event-by-Event $< p_T >$ Fluctuations

	N_{events}	$< N_{tracks} >$	Φ_{p_T} real (MeV)	Φ_{p_T} mix (MeV)
40 AGeV	216881	77.8	5.5 ± 0.7	0.0 ± 0.2
80 AGeV	56464	128.7	3.7 ± 0.9	-0.5 ± 0.8
158 AGeV	57819	129.4	7.8 ± 0.9	1.0 ± 0.9

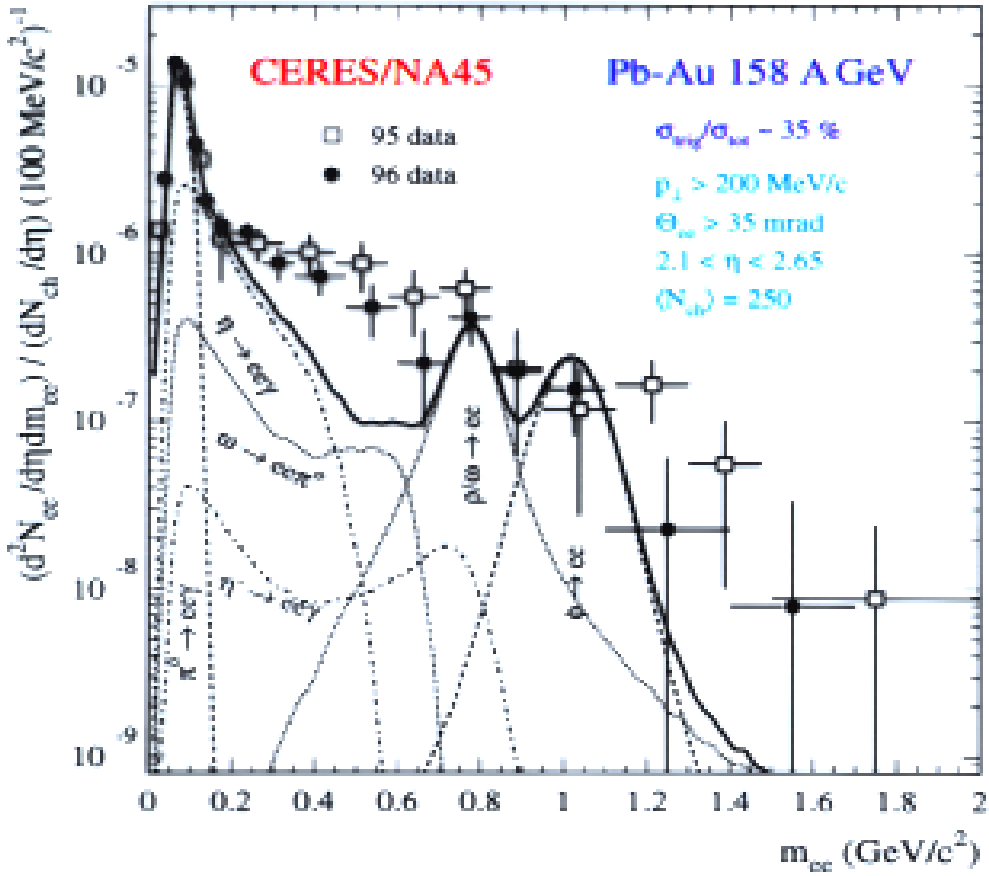
$$0.05 < p_T < 1.5 \text{ GeV}$$



⇒ Upper limit for dynamical fluctuations: $\frac{\sigma_{dyn}}{<p_T>} < 3\%$

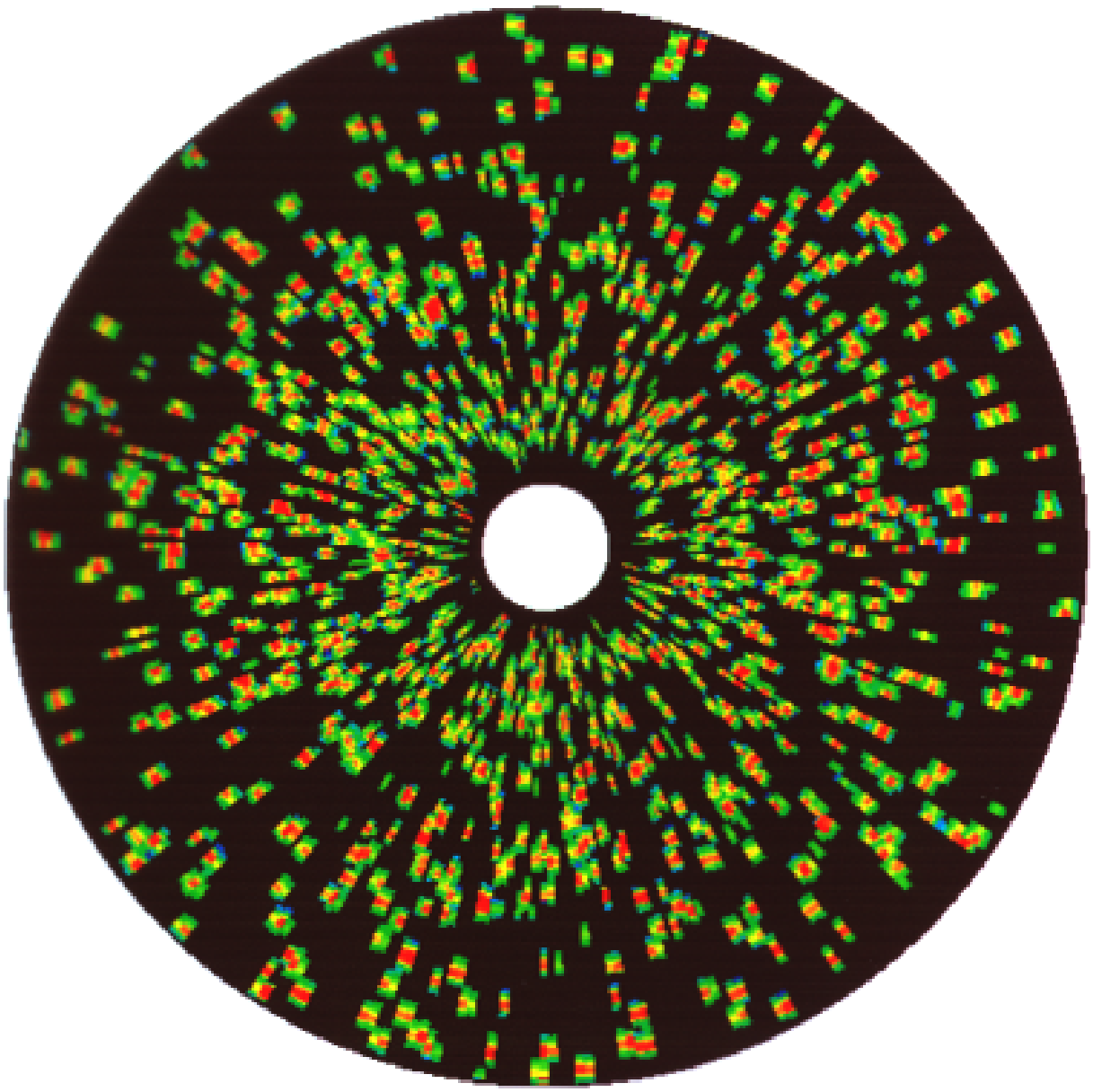
e^+e^- from Pb-Au collisions

B.Lenkeit, PhD thesis, Heidelberg, 1998



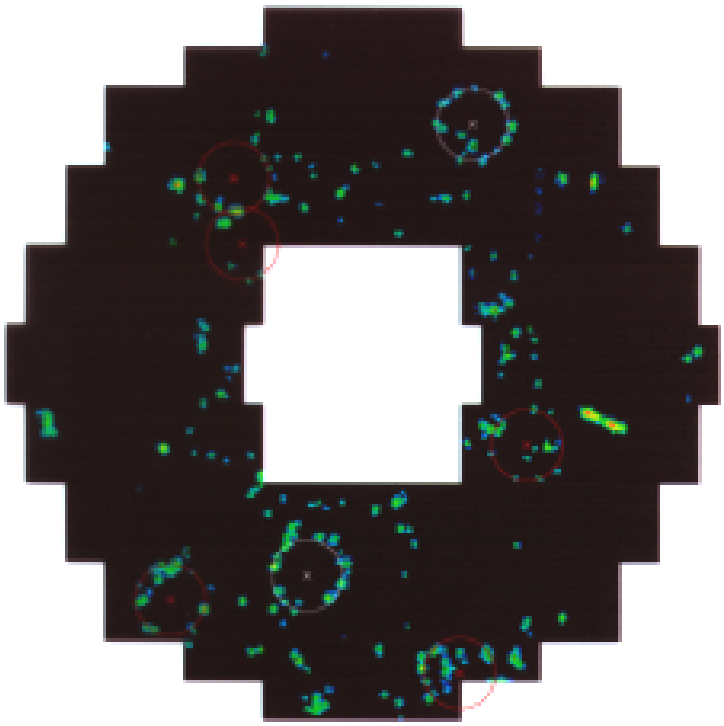
- particle ratios taken from a thermal model fitted to measured ratios in Pb-Pb collisions (T=175 MeV, μ_B=270 MeV)
- y and p_t distributions follow measured systematics in Pb-Pb collisions
- enhancement ($0.25<m_{ee}<0.7$ GeV/c^2):
  2.6 ± 0.5(stat.) $\pm$ 0.6(syst.) ('96 data)
  3.9 ± 0.9(stat.) $\pm$ 0.9(syst.) ('95 data) PLB 422(1998) 405-412

SiDD Event Display

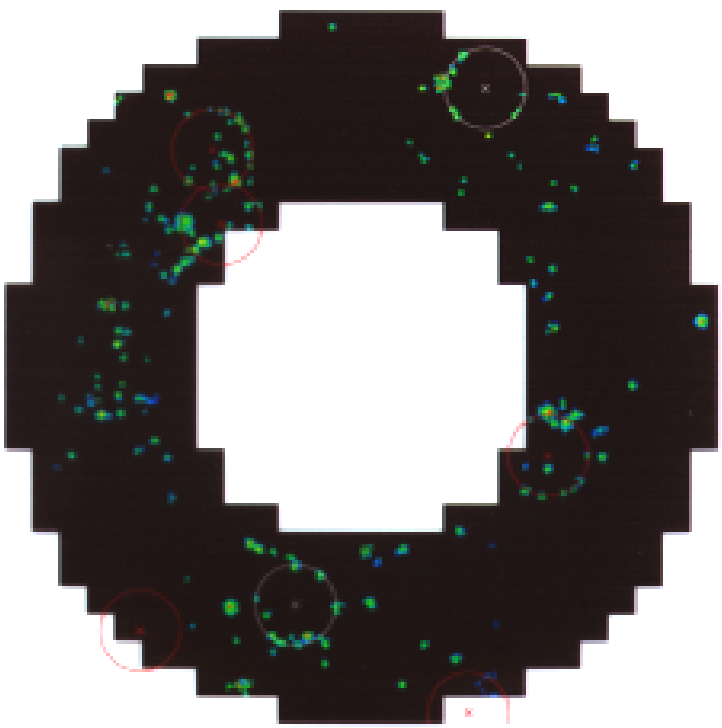


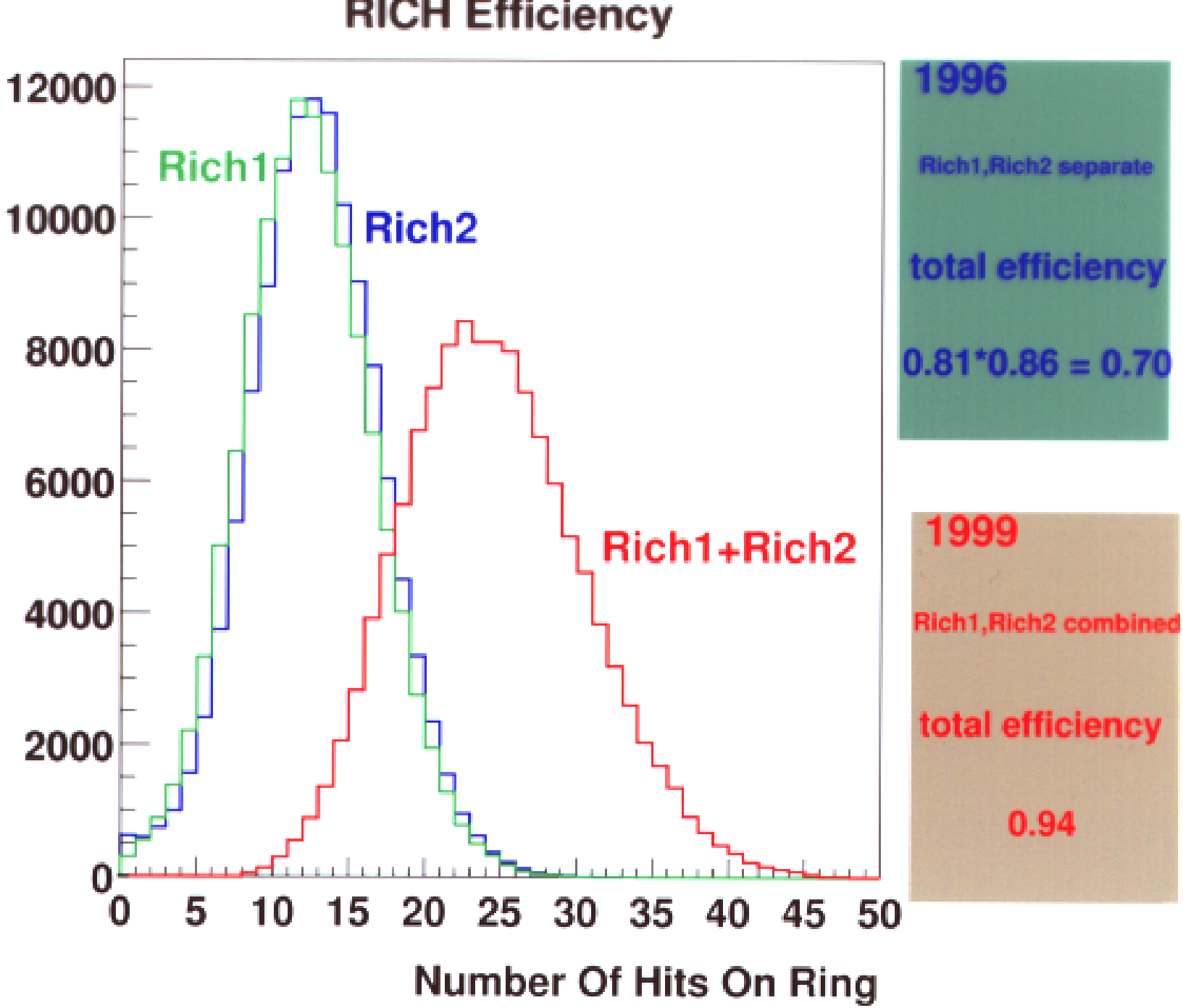
RICH Event Display

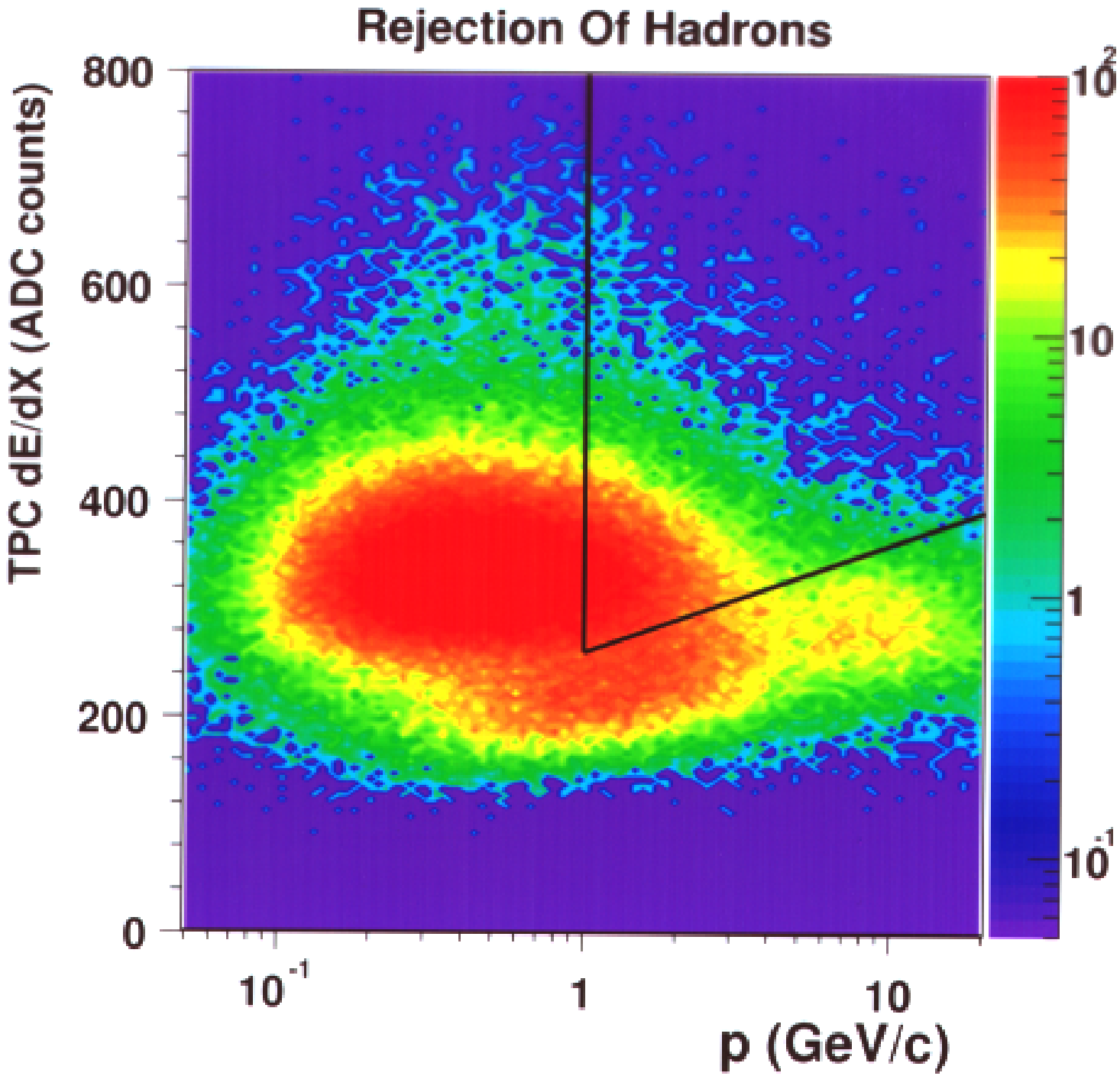
RICH 1:

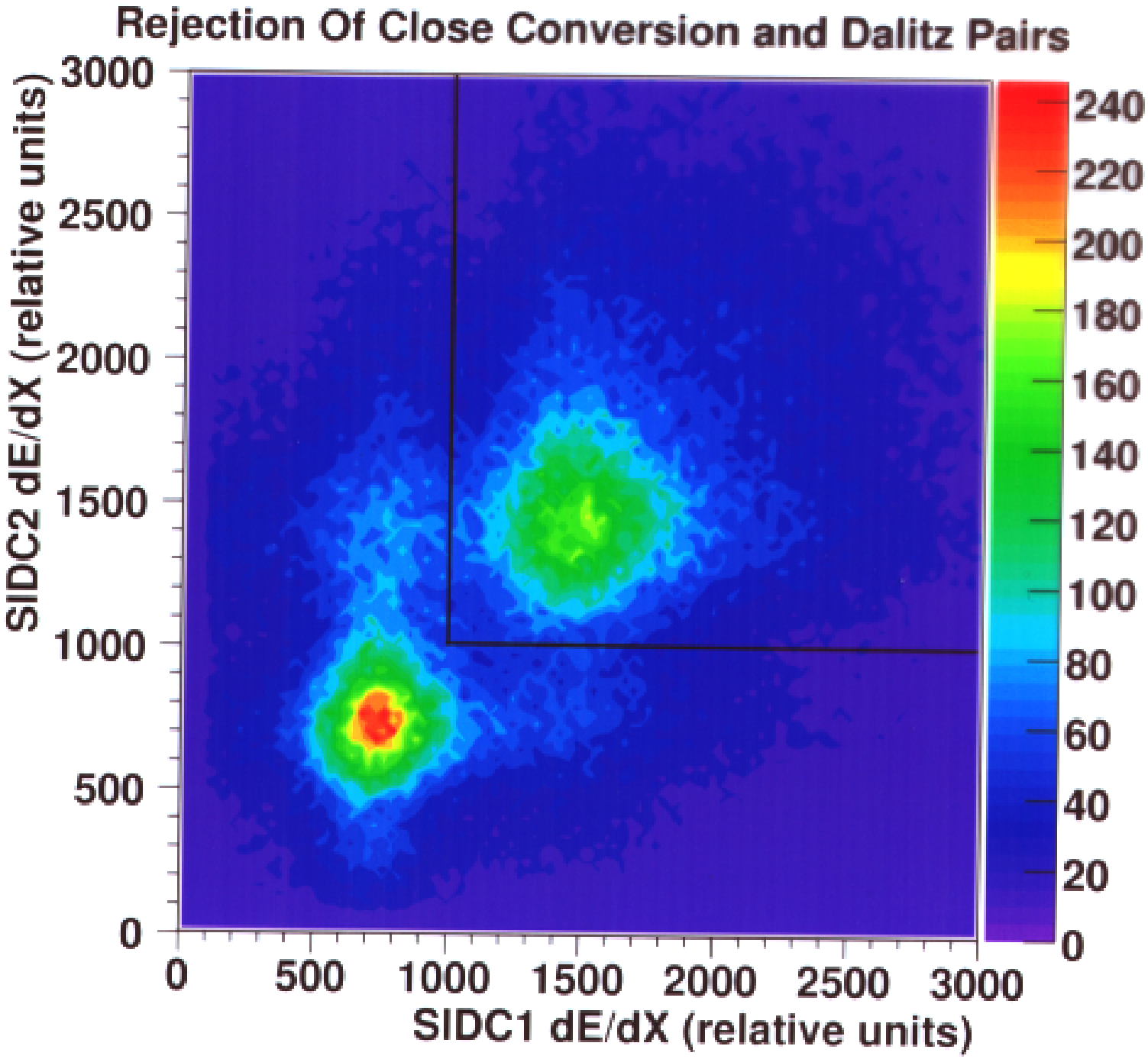


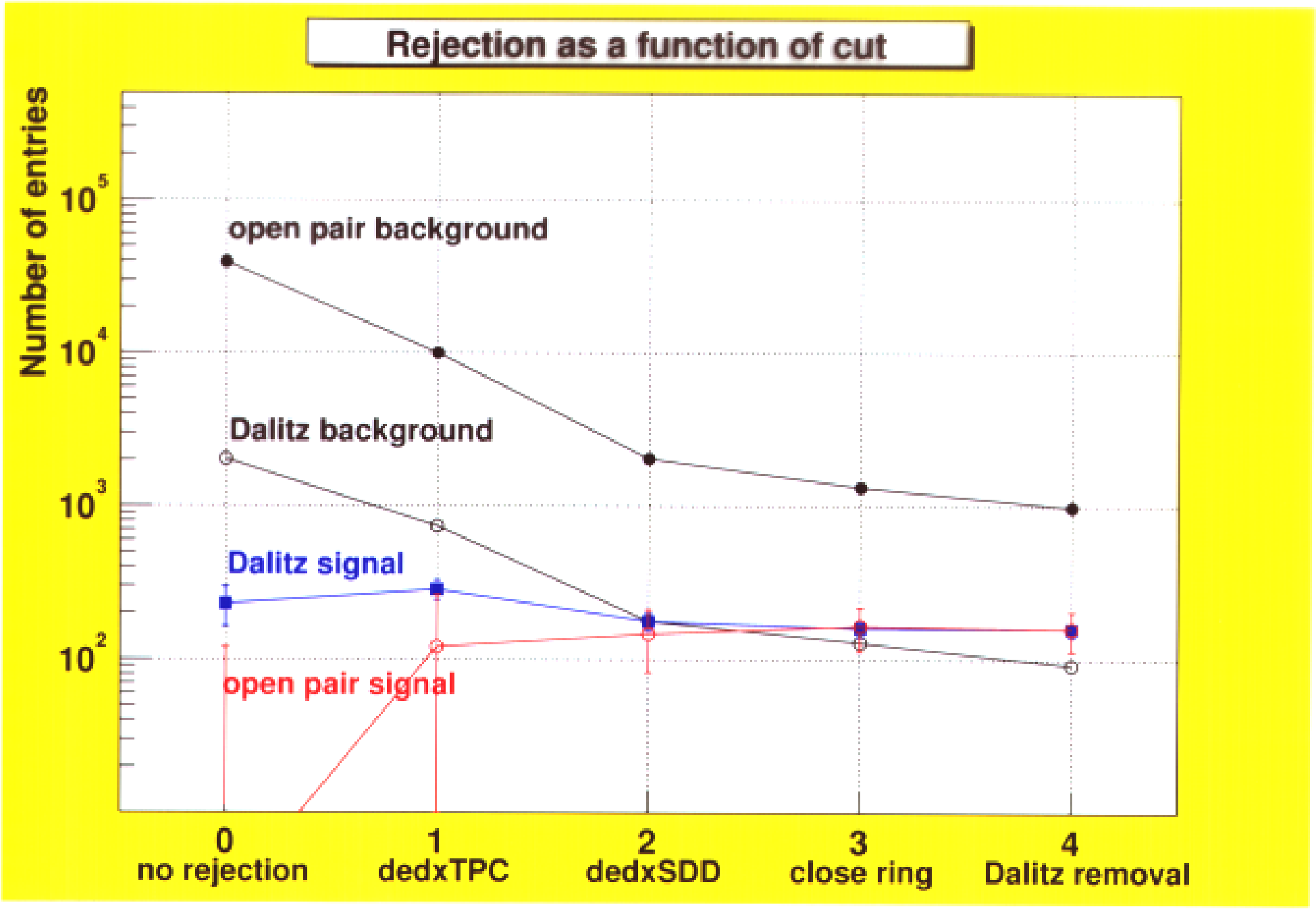
RICH 2:



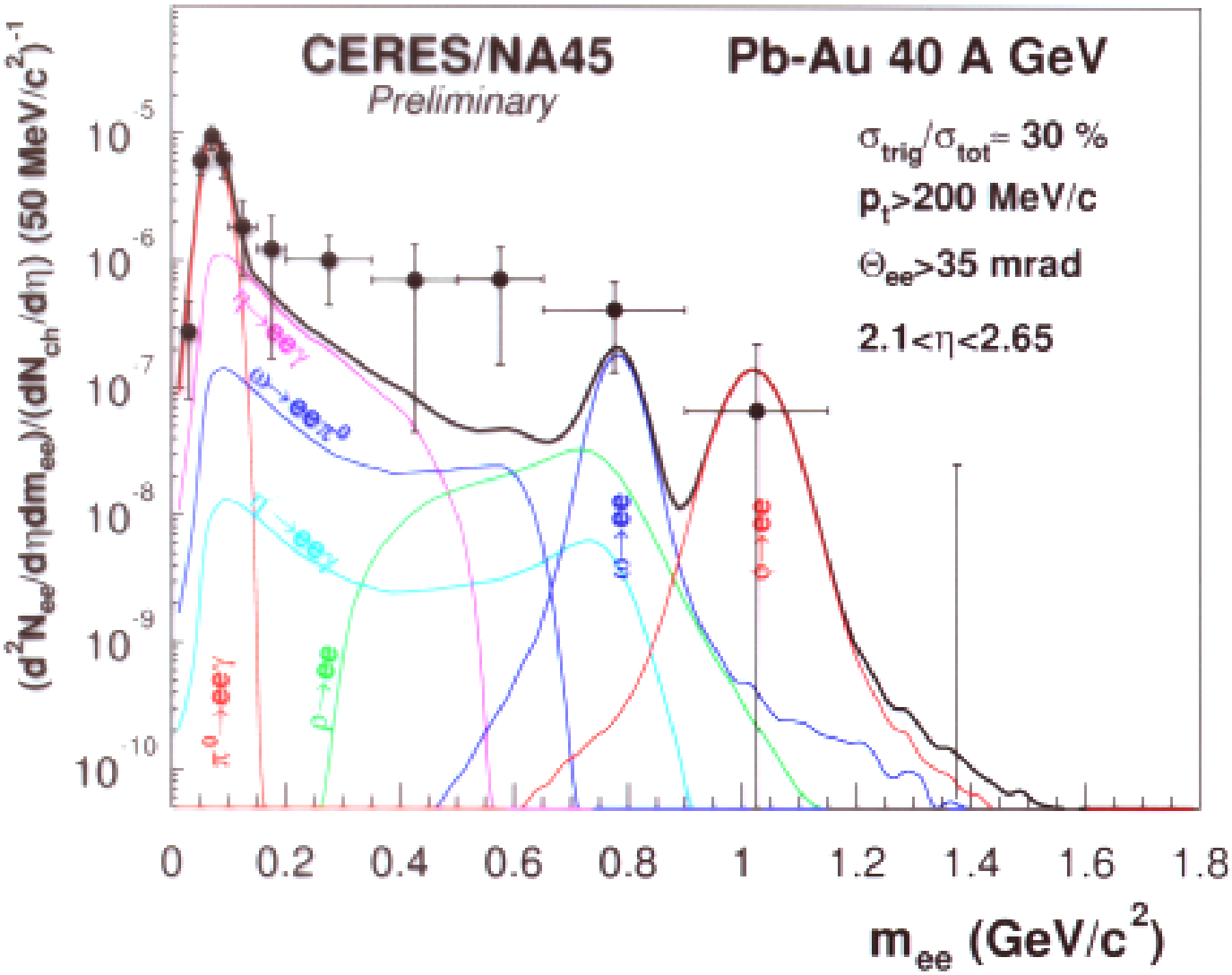

RICH Efficiency
12000
10000
8000
6000
4000
2000
0
0
5
10
15
20
25
30
35
40
45
50
Number Of Hits On Ring
Rich1
Rich2
Rich1+Rich2
1996
Rich1,Rich2 separate
total efficiency
0.81*0.86 = 0.70
1999
Rich1,Rich2 combined
total efficiency
0.94


Rejection Of Hadrons
TPC dE/dX (ADC counts)
800
600
400
200
0
10^{-1}
1
10
p (GeV/c)
10^{2}
10
1
10^{-1}


Rejection Of Close Conversion and Dalitz Pairs
SIDC2 dE/dX (relative units)
SIDC1 dE/dX (relative units)
0
500
1000
1500
2000
2500
3000
0
20
40
60
80
100
120
140
160
180
200
220
240


Rejection as a function of cut
Number of entries
10^5
10^4
10^3
10^2
open pair background
Dalitz background
Dalitz signal
open pair signal
0
no rejection
1
dedxTPC
2
dedxSDD
3
close ring
4
Dalitz removal

Invariant Mass Spectrum



Total number of pairs for m > 0.2 GeV/c ^{2}

S=159 +- 46

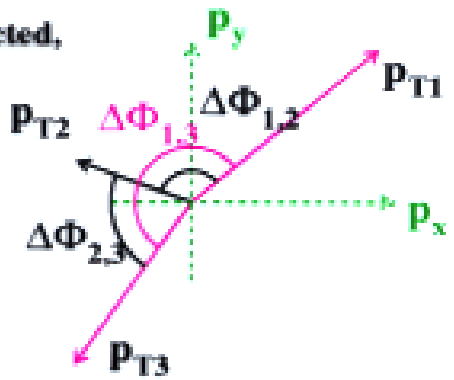
Ratio Signal/Background

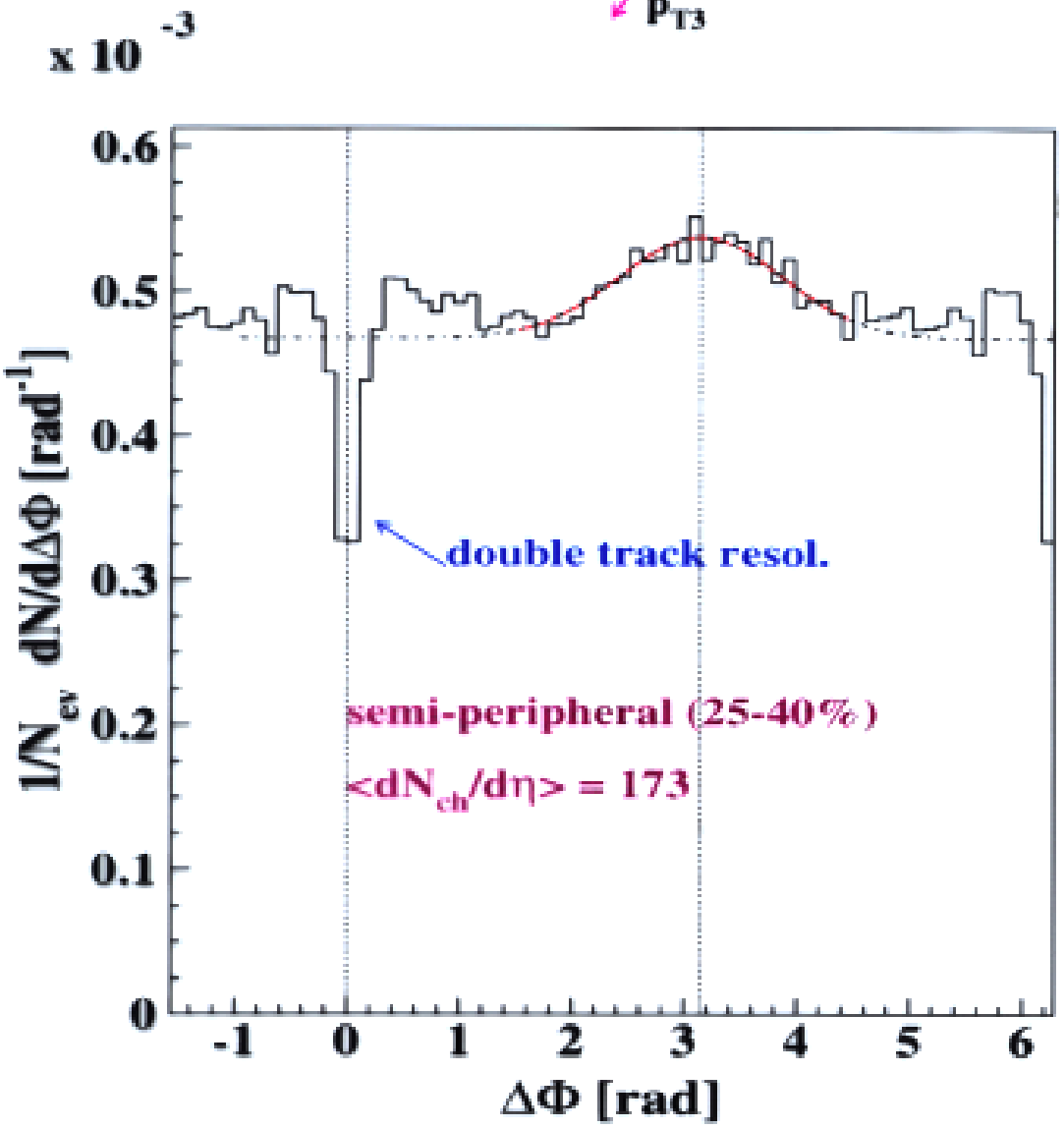
S/B=1/6

$\pi\pi$ azimuthal correlations
Pb-Au 160 A.GeV/c

43.2Mevents analyzed
4.10M π-π pairs reconstructed,

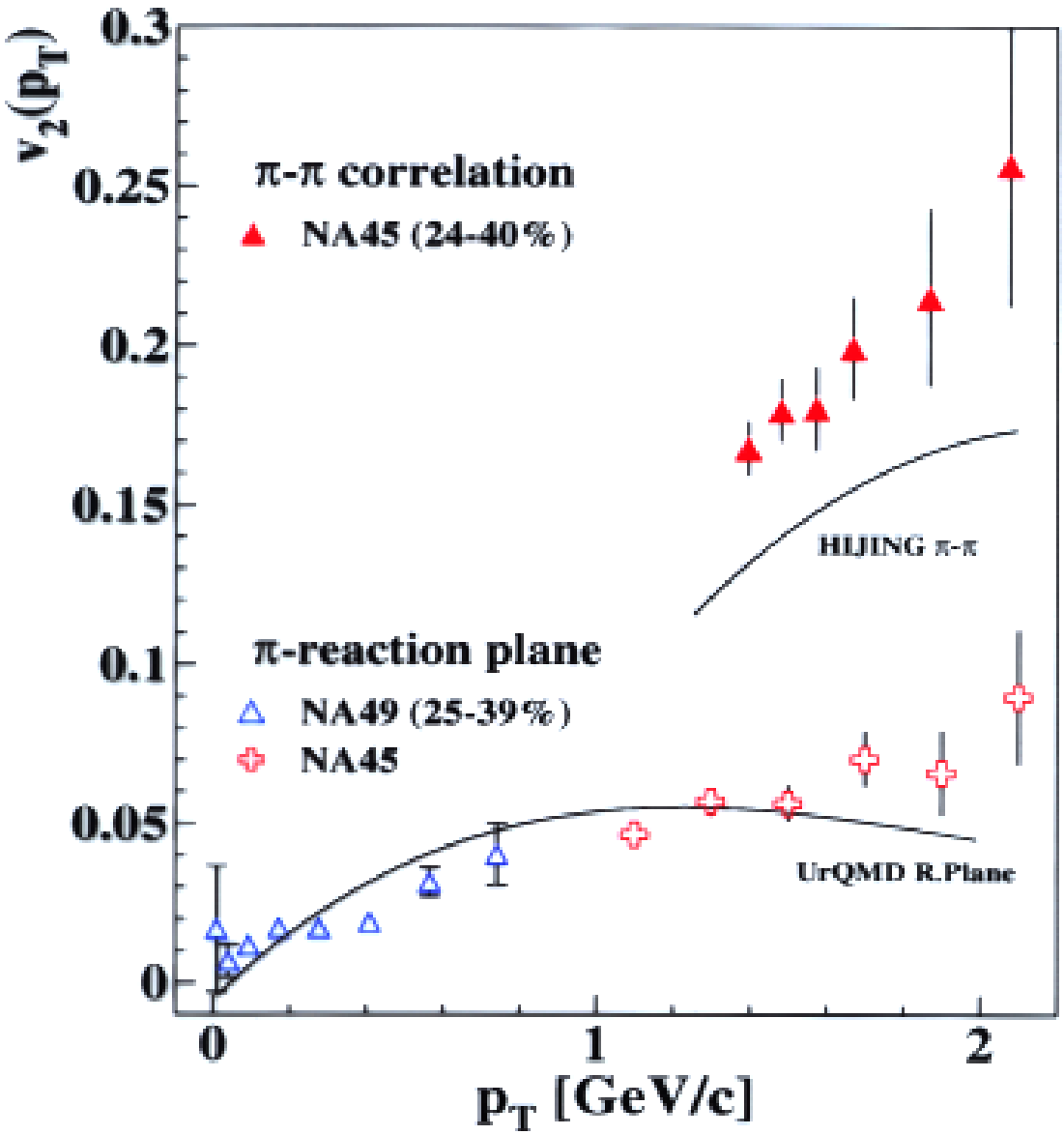
p_T>1.2GeV/c





parallel session Friday 19, Jan Rak : *"Observation of dijet-like azimuthal .."*

v_2 at SPS



- v_2 from $\pi\pi$ correlations exceeds v_2 values derived from standard flow analysis.
- NA45 standard-flow v_2 values follow a linear extrapolation of NA49 data to larger $p_\perp$.

Summary

The TPC era has begun!!

- Hadron spectra and HBT provide useful information about the space-time evolution and freeze-out conditions of 40 AGeV Pb+Au collisions
- v_2 at 40, 80 and 158 AGeV fit into the overall E_{Beam} systematics
- Small but significant event by event $< p_{\mathrm{T}} >$ fluctuations are observed
- First preliminary measurement of e^+e^- production in 40 AGeV Pb+Au
- Indications of dijet-like azimuthal correlations of high p_{T} pions in 158 AGeV Pb+Au
  $\Rightarrow$ Talk by Jan Rak this afternoon

Outlook

- Continuation of 40 AGeV hadron and electron analysis

- 2000 data: 33 M events on tape
  $\Rightarrow$ Spectroscopy of ρ/ω and ϕ

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