Global observables in the PHENIX experiment

Transverse Dynamics at RHIC
BNL, March 6-8, 2003

David Silvermyr, LANL
for the PHENIX Collaboration

Outline

E_T and N_{ch} at midrapidity

- ✓ Measurement technique
- ✓ Centrality selection
- ✓ Centrality dependence
- ✓ $\sqrt{s_{NN}}$ dependence

Something new since QM02 and afterwards:

- ✓ More peripheral collisions at $\sqrt{s_{NN}}$=130 and 200 GeV included
- ✓ $\sqrt{s_{NN}}$= 19.6 GeV results
- ✓ More theoretical model comparisons

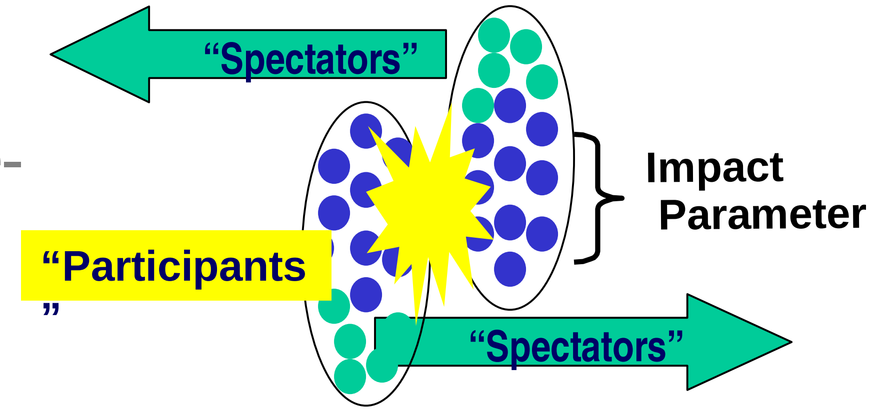
PHENIX

Global Observables

- **WHAT ?**

  * $dN_{ch}/d\eta$, $dE_T/d\eta$

  * Reflect conditions well after freeze-out and resonance decays



- **WHY ?**

  * "Easy" measurements

  * Characterize collision geometry

  * Constrain models

  * Initial conditions

Centrality defined as percentile of σ_{tot} ⟹ N_{part} , N_{coll} , b thru Glauber model

PHENIX Setup, Year-2

Charged Multiplicity

Pad Chambers:

R_{PC1} = 2.5 m

R_{PC3} = 5.0 m

$|\eta|<0.35$, $\Delta\varphi=\pi$

Transverse Energy

Lead-Scintillator EMCal:

R_{EMC} = 5.0 m

$|\eta|<0.38$, $\Delta\varphi = (5/8)\pi$

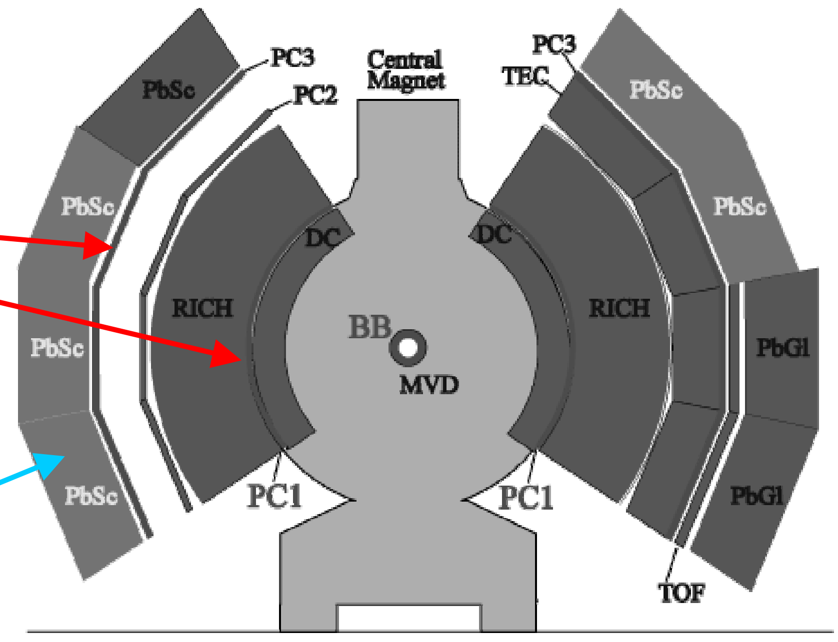
Trigger

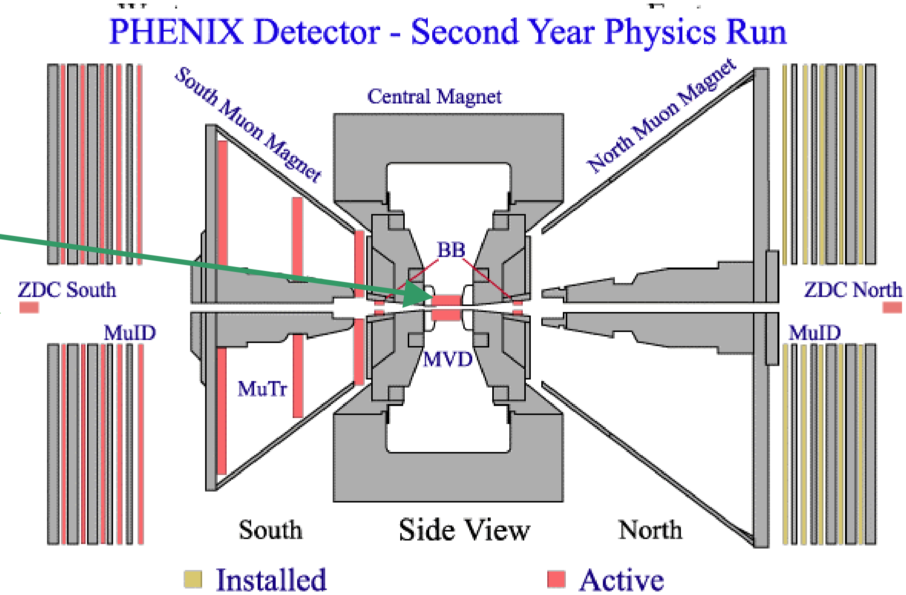
Beam-Beam Counters:

$3.0<|\eta|<3.9$, $\Delta\varphi = 2\pi$

Zero-Degree Calorimeters:

$|\eta| > 6$, $|Z|$=18.25 m



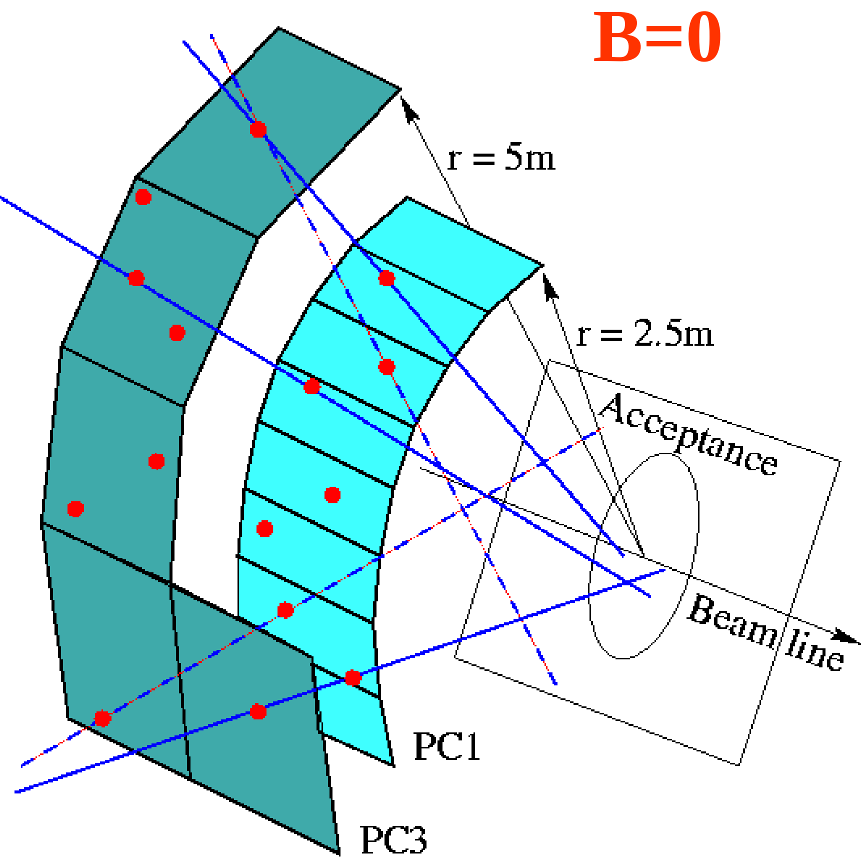


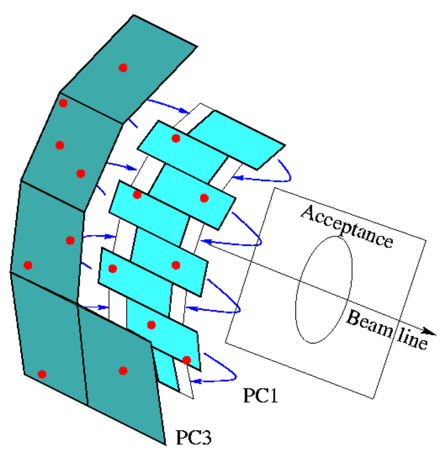
PHENIX

Charged Multiplicity Measurements

Count tracks on a statistical basis (no explicit track reconstruction)

- Combine all hits in PC3 with all hits in PC1.
- Project resulting lines onto a plane through the beam line.
- Count tracks within a given radius.
- Determine combinatorial background by event mixing technique





PHENIX

Transverse Energy Measurements

Convention: $E_T = \sum_i E_i \sin\theta_i$

$E_i = E_i^{tot} - m_N$ for baryons

$E_i = E_i^{tot} + m_N$ for antibaryons

$E_i = E_i^{tot}$ for others

EMCal is "almost" hadronic calorimeter:

$E_{EMC} = 1.0 * E_{tot}$ for γ, π^0

$E_{EMC} = 0.7 * E_{tot}$ for $\pi^\pm$

***$E_{EMC} \rightarrow E_T$* transformation:**

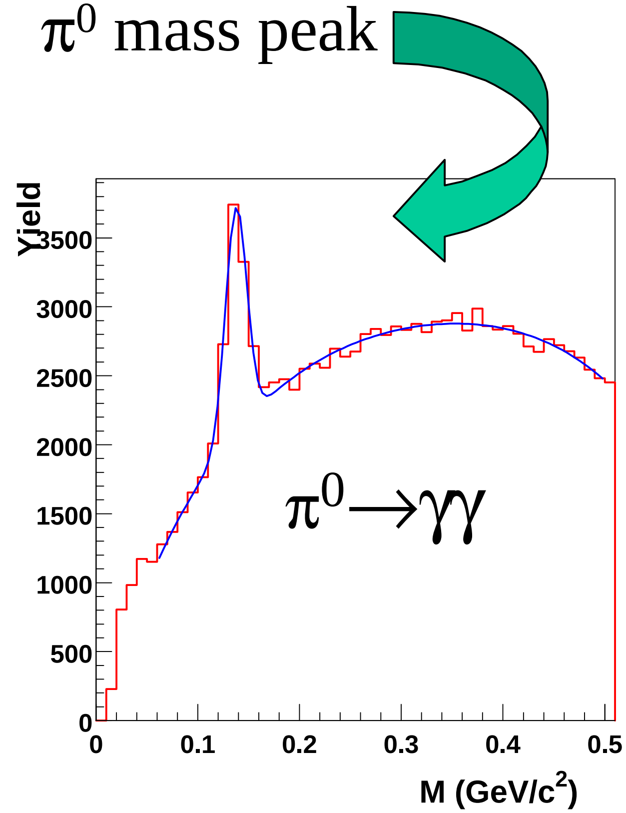
$E_T = 1.23 * E_{EMC}$

EMCal absolute energy calibration

MIP peak

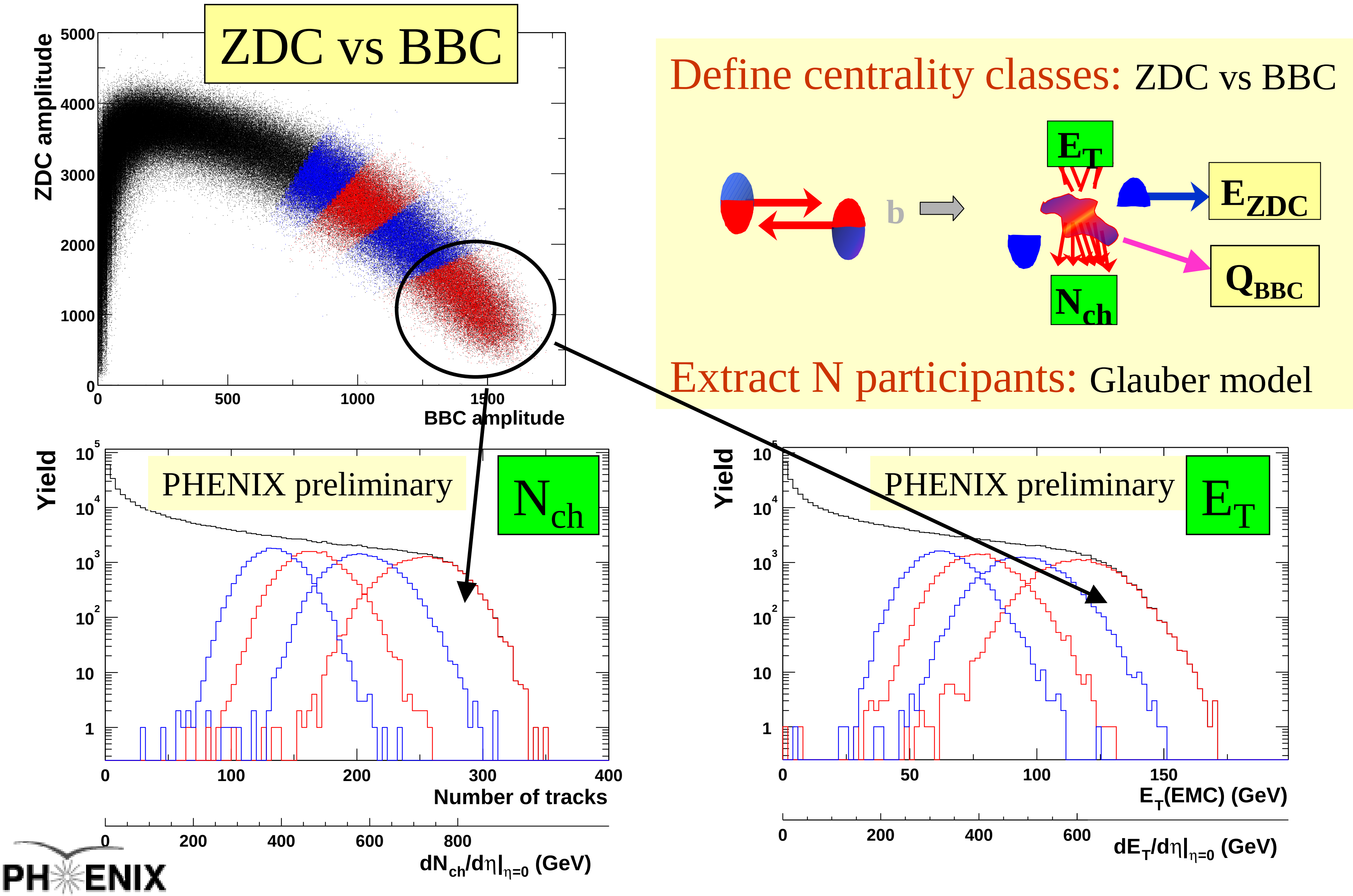
E/p matching peak for $e^\pm$

π^0 mass peak

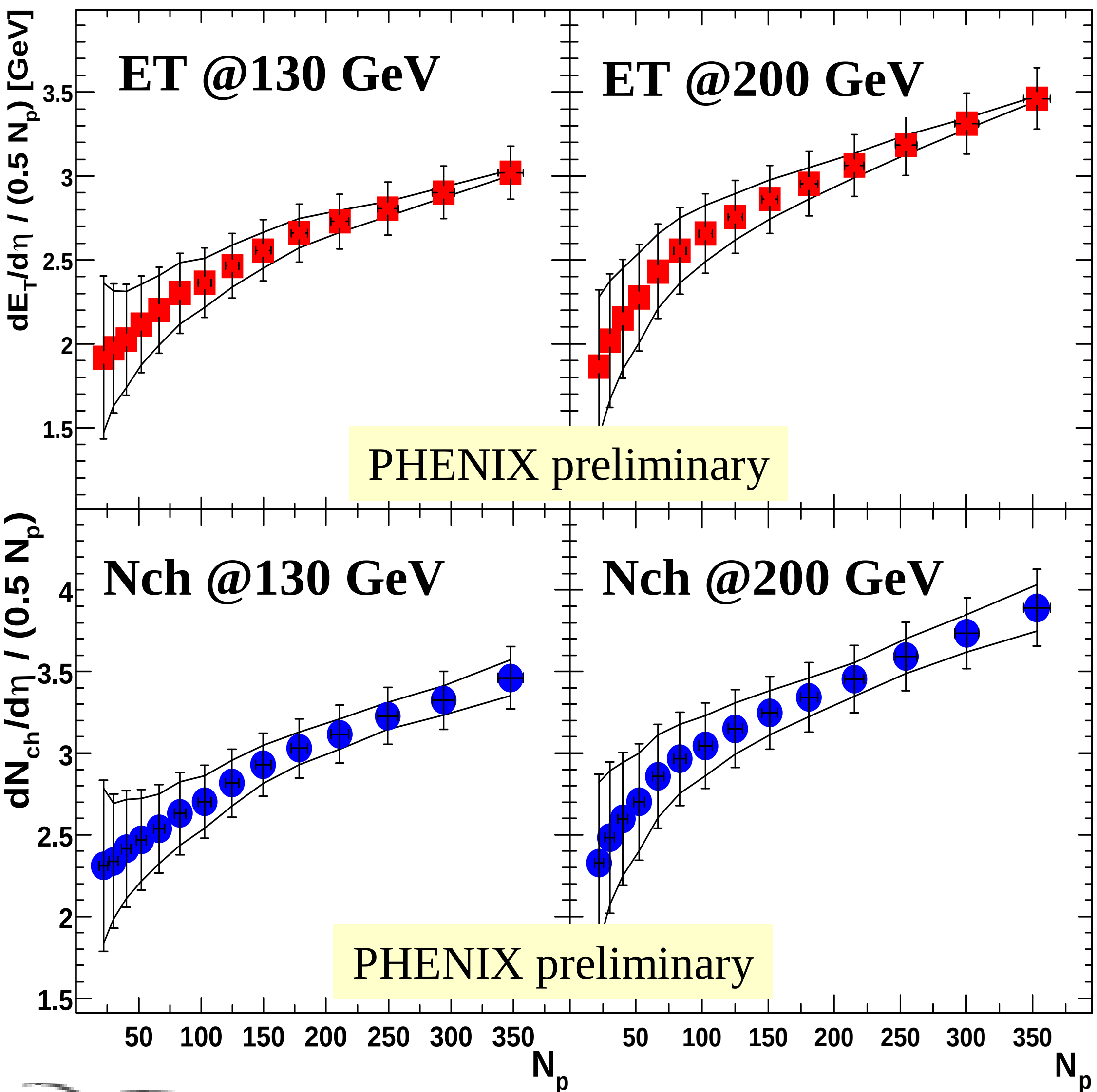


PHENIX

Centrality Selection



Centrality dependence



E_T and N_{ch} exhibit consistent behavior at $\sqrt{s_{NN}}$=130 GeV and 200 GeV

Stat. errors

Negligible

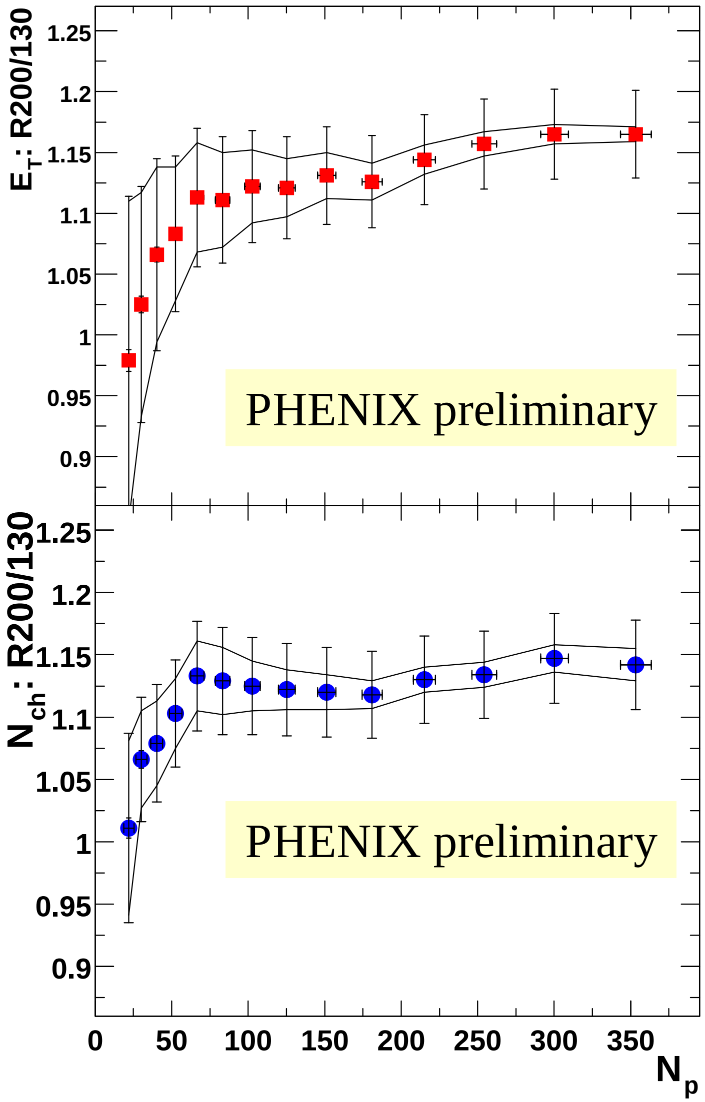
Syst. errors

Band: possible common tilt

Bars: total syst. error

PHENIX

200 GeV / 130 GeV



For the most central collisions:

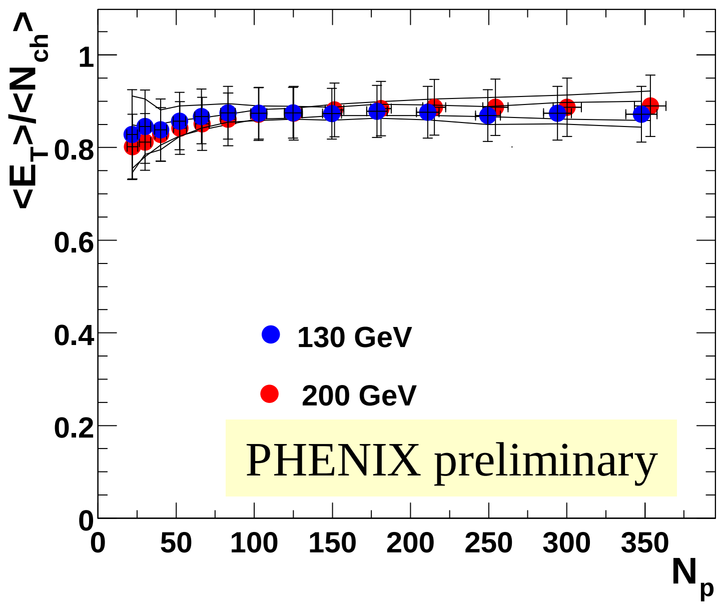
$$\frac{E_T(200\,GeV)}{E_T(130\,GeV)} = 1.16 \pm 0.035$$

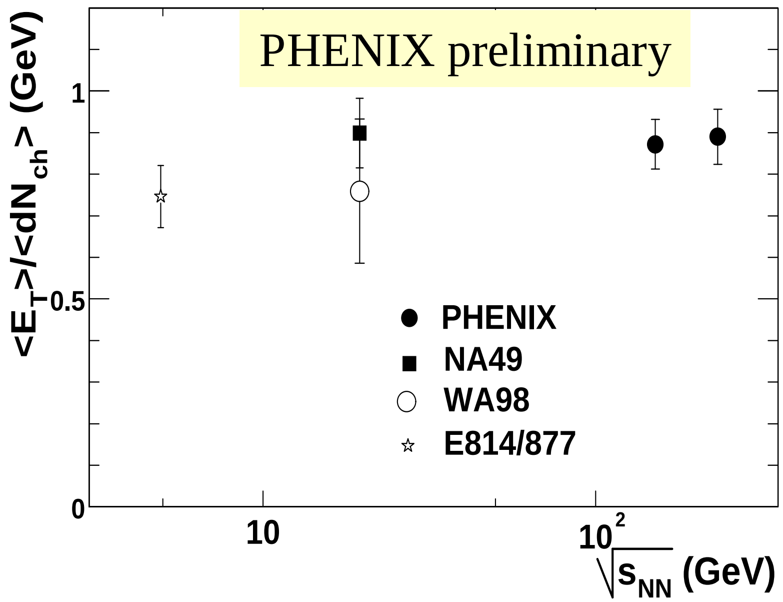
$$\frac{N_{ch}(200\,GeV)}{N_{ch}(130\,GeV)} = 1.14 \pm 0.035$$

- ❑ Constant scaling from central to semi-peripheral collisions
- ❑ Drop in peripheral collisions (N_{part}~70) ?

PHENIX

$<E_T> / <N_{ch}>$





Weak dependence from centrality

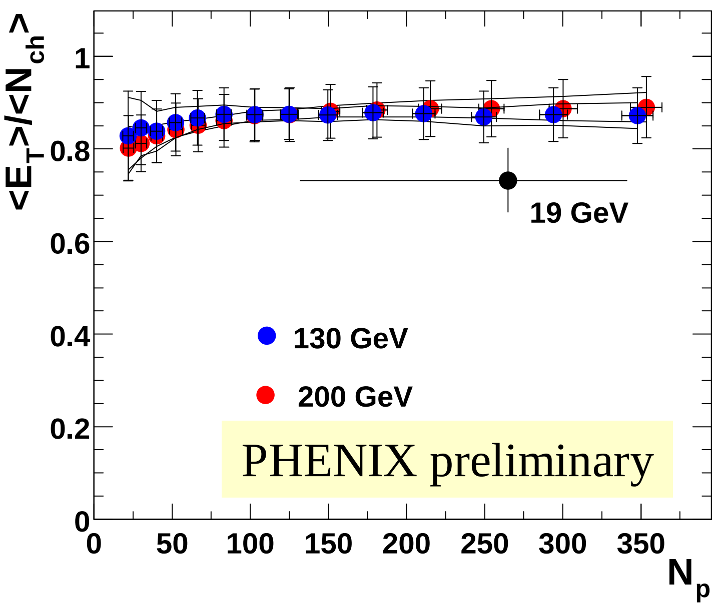
Weak (no) dependence from energy

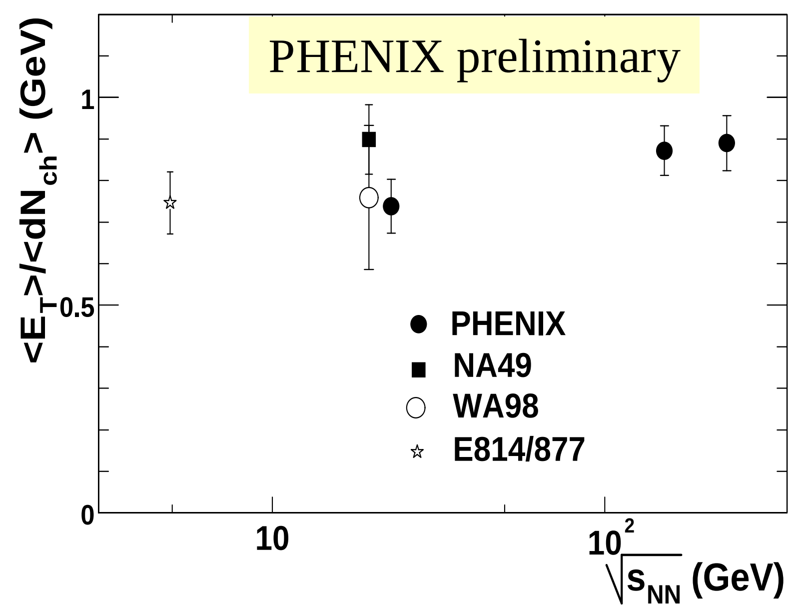
$<E_T> / <N_{ch}>$ + 19.6 GeV results

19.6 GeV data:

✓centrality determination not yet finalized, coming soon…

✓E_T/N_{ch} is not effected by this error (same centrality classes)



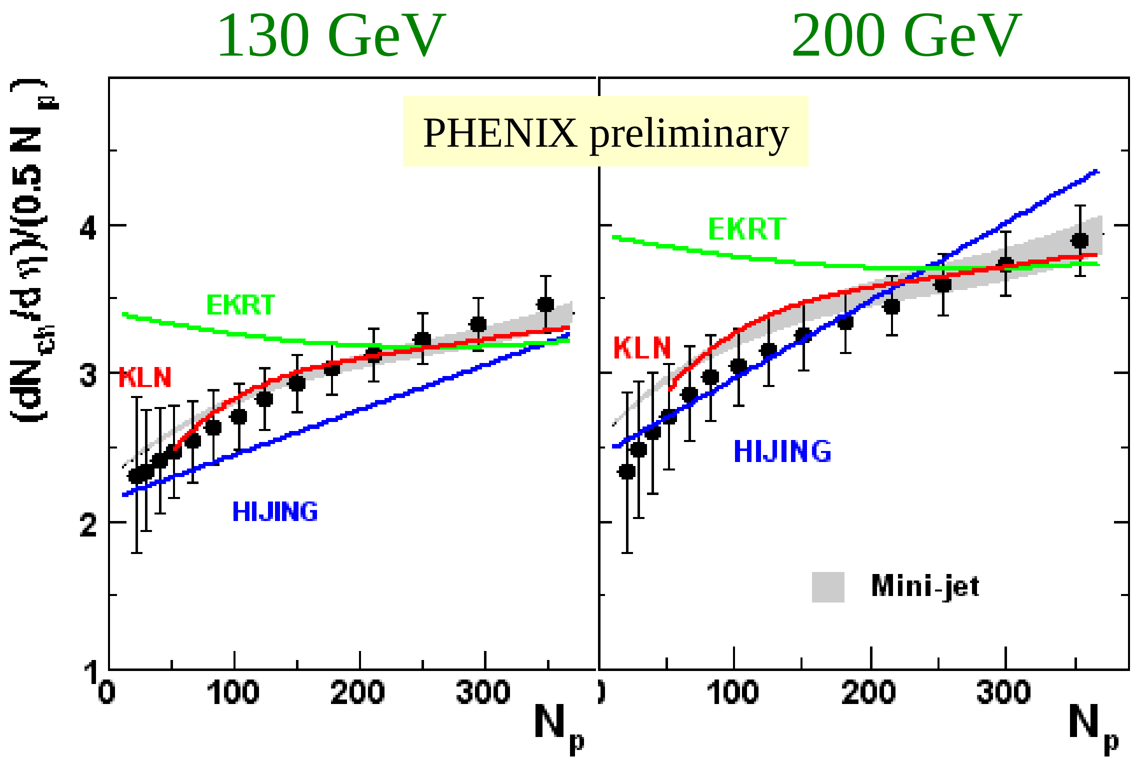


RHIC point at ~SPS energy:

$$\frac{\langle E_T \rangle / \langle N_{ch} \rangle (200GeV)}{\langle E_T \rangle / \langle N_{ch} \rangle (19GeV)} \approx 1.20$$

PHENIX

Nch: Comparison to theory



HIJING
X.N.Wang and M.Gyulassy,
PRL 86, 3498 (2001)

Mini-jet
S.Li and X.W.Wang
Phys.Lett.B527:85-91 (2002)

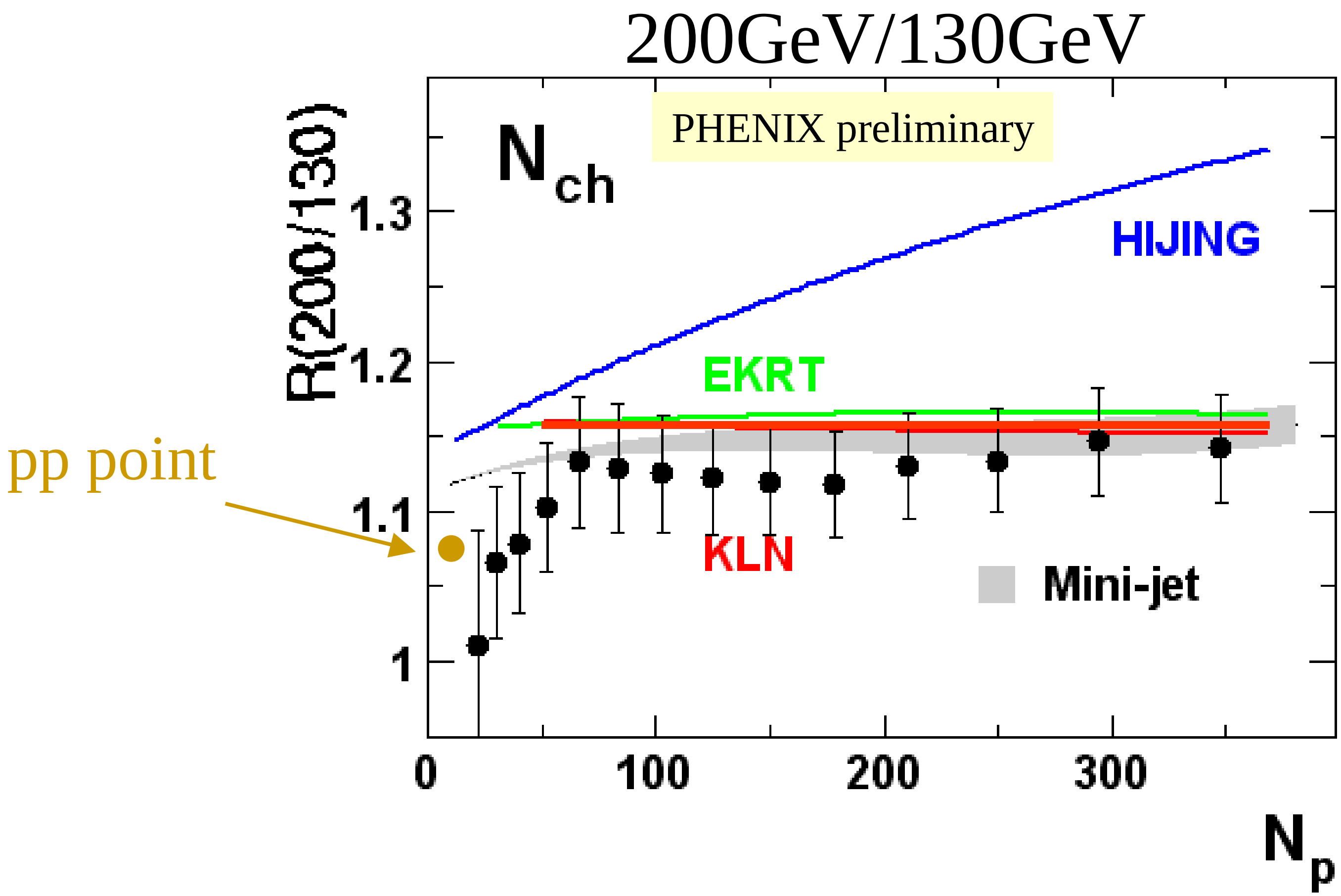
EKRT
K.J.Eskola et al,
Nucl Phys. B570, 379 and
Phys.Lett. B 497, 39 (2001)

KLN
D.Kharzeev and M. Nardi,
Phys.Lett. B503, 121 (2001)
D.Kharzeev and E.Levin,
Phys.Lett. B523, 79 (2001)

✓ Mini-jet and KLN: describe data well
✓ HIJING: not too bad

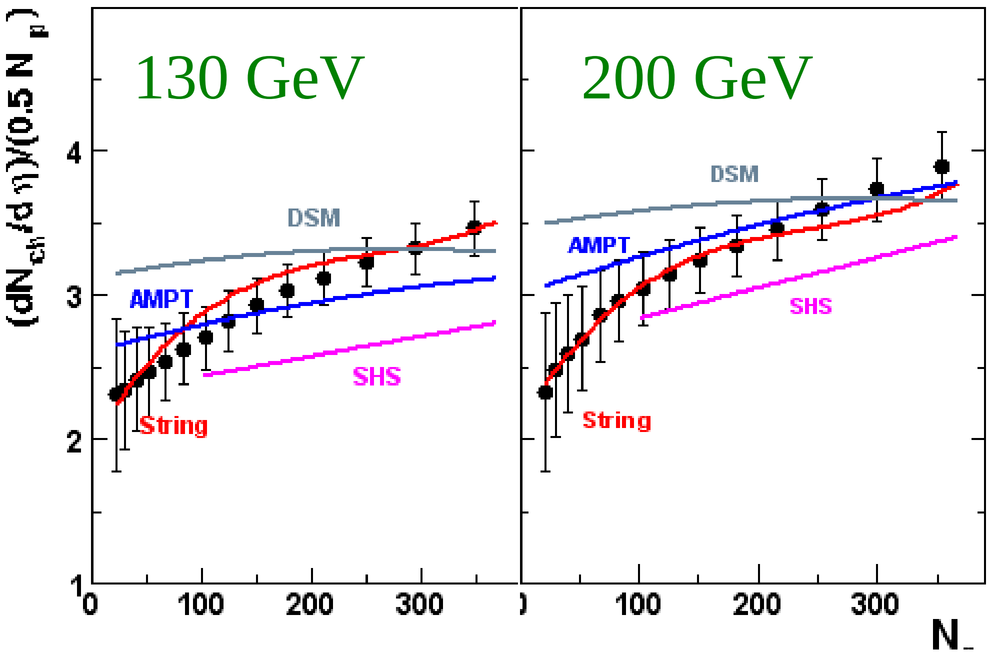
PHENIX

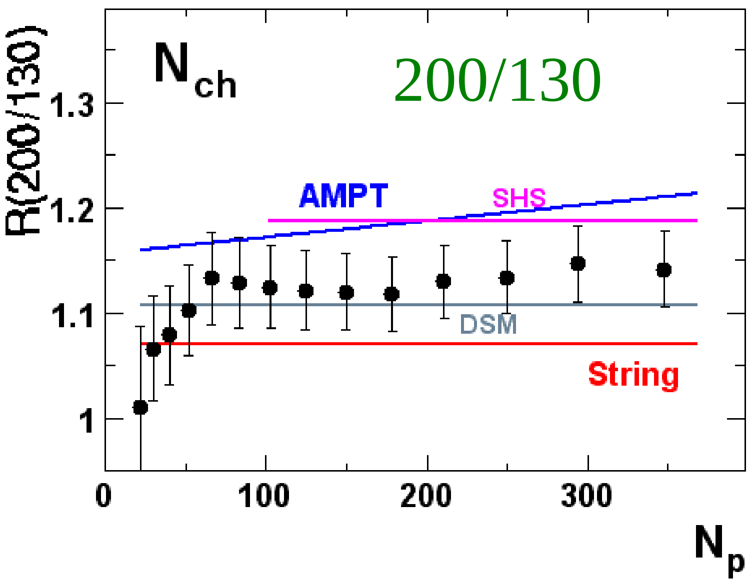
Nch: Comparison to theory



- ✓ HIJING is also out of the game
- ✓ N_{part}~70 limit for KLN (gluon saturation) model application?

Nch: More models





AMPT (multiphase transport model)
B.Zhang et al, Phys.Rev.C 61, 067901 (2000); nucl-th/0011059

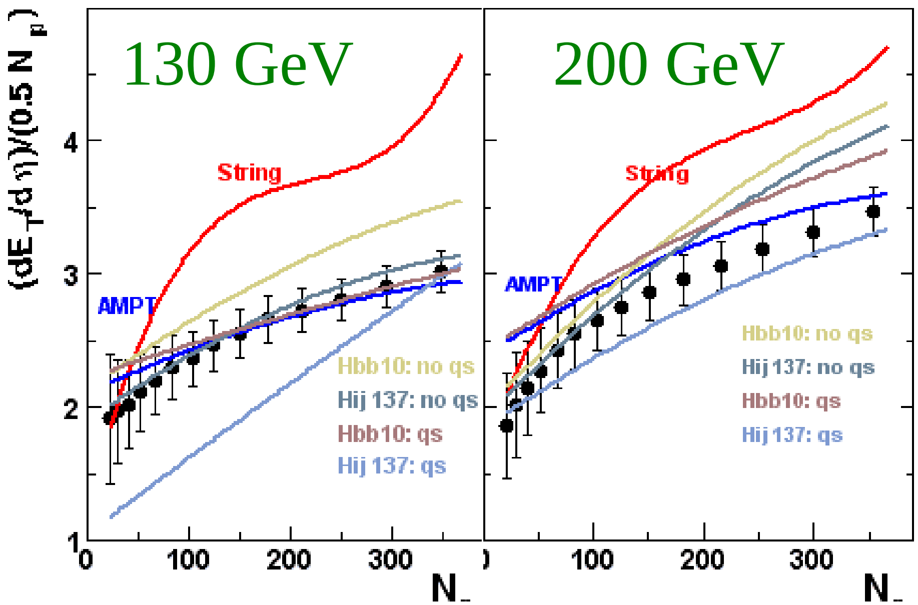
String fusion model
N.Armesto et al, Phys.Lett. B527, 92 (2002)
N.S.Amelin et al, Eur.Phys.J C22, 149 (2001)

Semi-Hard Scattering
A. Accardi, Phys.Rev.C64:064905,2001

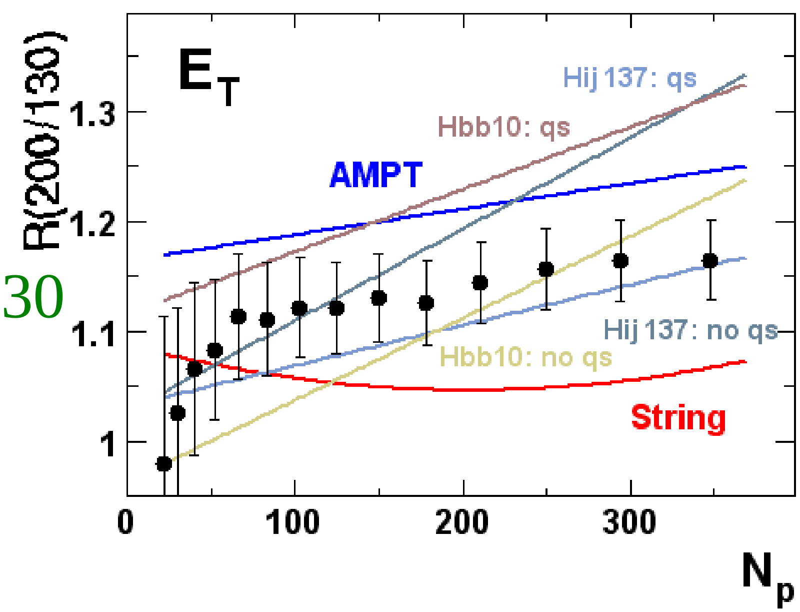
Dual String Model
R. Ugoccioni et al., Phys.Lett.B491:253-256,2000

Not too bad…
And what about ET?

ET: Comparison to theory



200/130

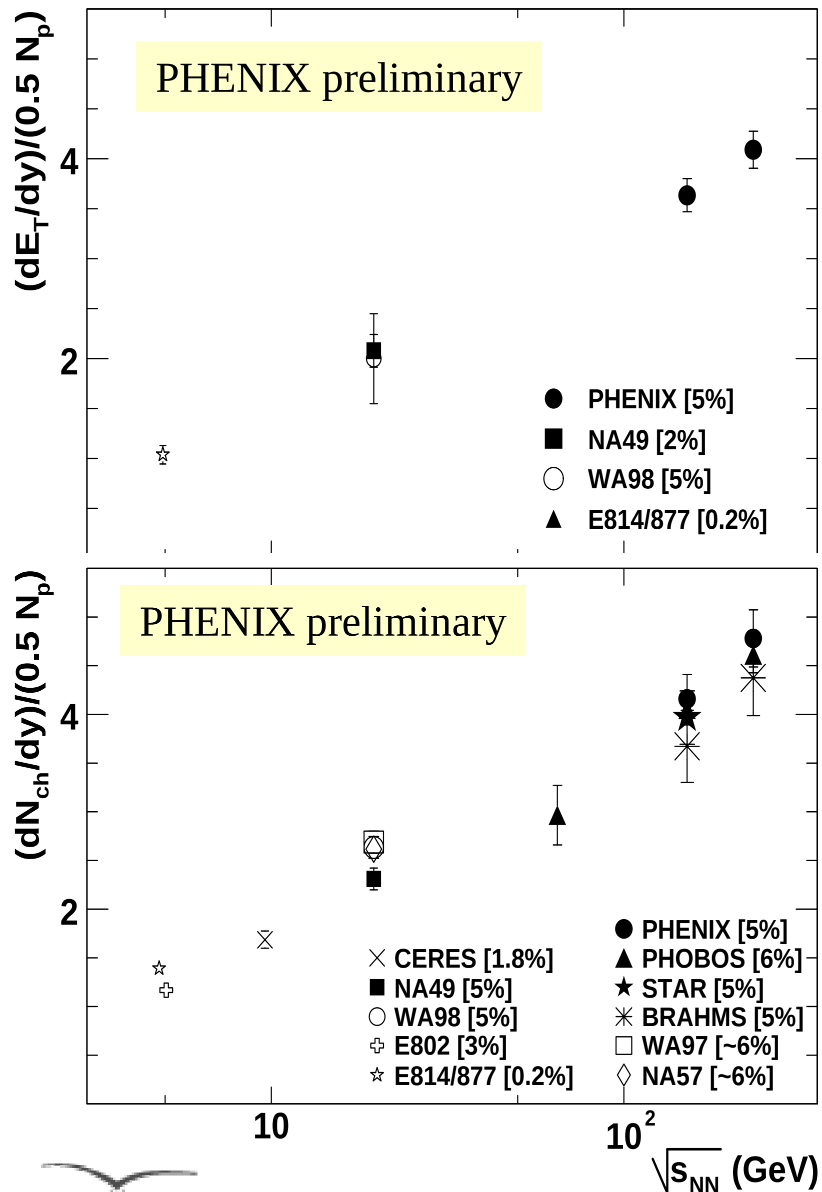


String fusion model: overestimate ET

AMPT seems to overestimate the R(200/130)

Hijing 1.37, Hijing BbarB 1.0 with quenching and shadowing: Overestimates R(200/130), for central collisions.

Energy Dependence



Energy density (Bjorken):

$$\varepsilon = \frac{1}{\pi R^2 \tau} \frac{dE_t}{dy} \qquad R = 1.18\, fm \cdot A^{1/3} \qquad \tau = 1\, fm/c$$

2% most central at $\sqrt{s_{NN}}$=200 GeV:

$\varepsilon \approx 5.5$ GeV/fm^3

Considerably bigger than $\varepsilon_{critical} \approx$ 1GeV/fm^3

From AGS, SPS to RHIC:

Transverse energy and charged particle multiplicity densities per participant consistent with logarithmic behaviour

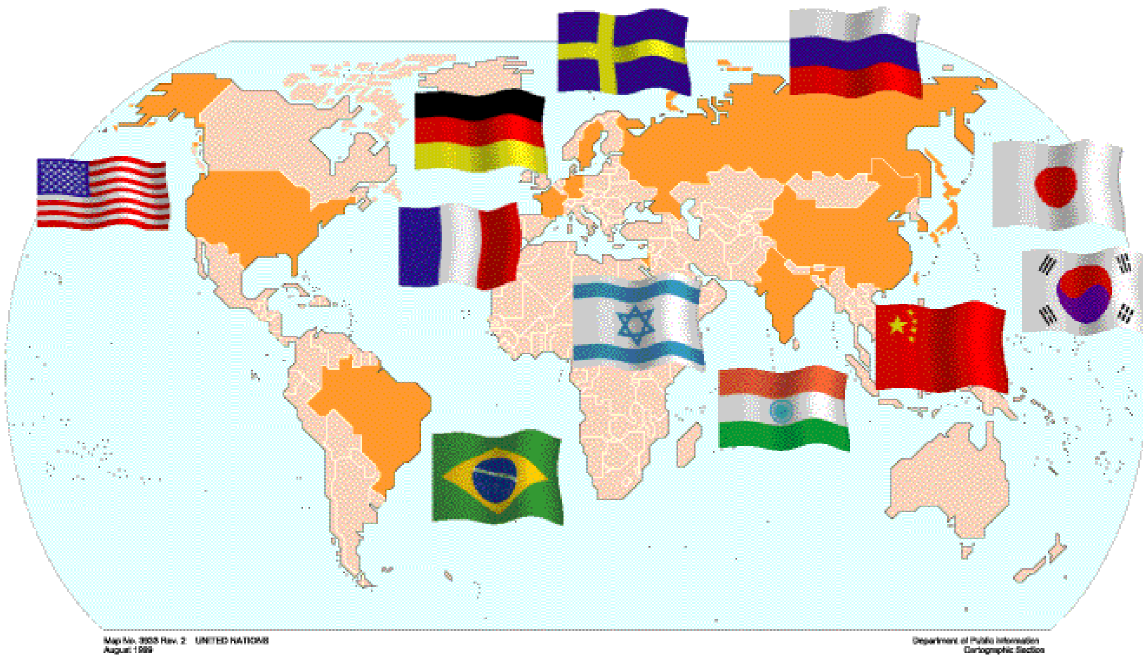
19 GeV points coming soon

Summary

- Centrality dependence of $dN_{ch}/d\eta$ and $dE_T/d\eta$ have been measured at $\sqrt{s_{NN}}$ = 130 GeV and 200 GeV in Au+Au collisions; $\sqrt{s_{NN}}$ = 19.6 GeV results coming
- Both $dN_{ch}/d\eta$ and $dE_t/d\eta$ per participant increase with centrality:
  - ✓ the increase is stronger than at SPS
  - ✓ N_{ch} data well described by KLN and Mini-jet model predictions
  - ✓ Room for improvement regarding theory description for E_T
- The ratio R(200/130) consistent with constant scaling vs centrality from central to semi-peripheral collisions and drops at $N_{part}<70$
  - ✓ Sets the peripheral limit of gluon saturation (KLN) model application
- $<dE_T>/<dN_{ch}>$ measured at $\sqrt{s_{NN}}$ = 19, 130 and 200 GeV
  - ✓ Weak dependence on centrality
  - ✓ Decreased ~20% from $\sqrt{s_{NN}}$ = 200 to 19.6 GeV
- d - Au (at $\sqrt{s_{NN}}$ = 200 GeV) results coming soon…

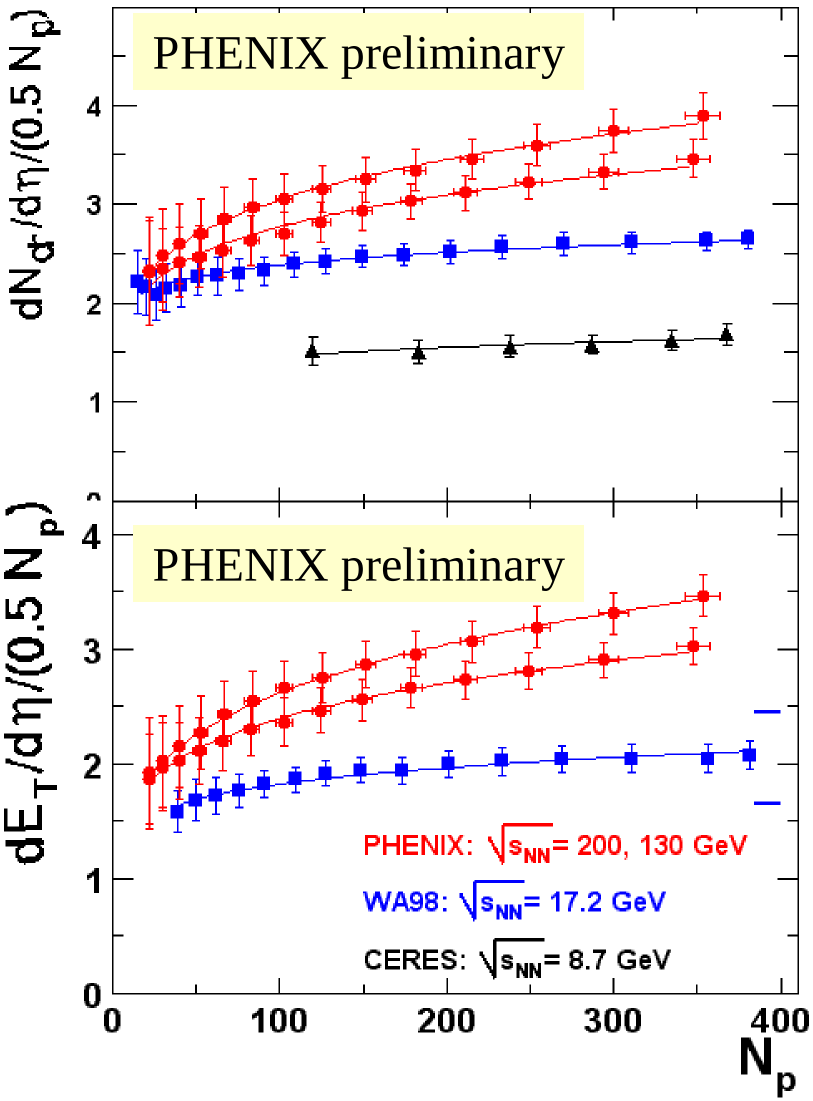
PHENIX

PHENIX



University of São Paulo, São Paulo, Brazil
Academia Sinica, Taipei 11529, China
China Institute of Atomic Energy (CIAE), Beijing, P. R. China
Laboratoire de Physique Corpusculaire (LPC), Universite de Clermont-Ferrand, 63170 Aubiere, Clermont-Ferrand, France
Dapnia, CEA Saclay, Bat. 703, F-91191, Gif-sur-Yvette, France
IPN-Orsay, Universite Paris Sud, CNRS-IN2P3, BP1, F-91406, Orsay, France
LPNHE-Palaiseau, Ecole Polytechnique, CNRS-IN2P3, Route de Saclay, F-91128, Palaiseau, France
SUBATECH, Ecole des Mines at Nantes, F-44307 Nantes, France
University of Muenster, Muenster, Germany
Banaras Hindu University,Banaras, India
Bhabha Atomic Research Centre (BARC),Bombay, India
Weizmann Institute, Rehovot, Israel
Center for Nuclear Study (CNS-Tokyo), University of Tokyo, Tanashi, Tokyo 188, Japan
Hiroshima University, Higashi-Hiroshima 739, Japan
KEK, Institute for High Energy Physics,Tsukuba, Japan
Kyoto University, Kyoto, Japan
Nagasaki Institute of Applied Science, Nagasaki-shi, Nagasaki, Japan
RIKEN, Institute for Physical and Chemical Research, Hirosawa, Wako, Japan
University of Tokyo, Bunkyo-ku, Tokyo 113, Japan
Tokyo Institute of Technology, Ohokayama, Meguro, Tokyo, Japan
University of Tsukuba, Tsukuba, Japan
Waseda University, Tokyo, Japan
Cyclotron Application Laboratory, KAERI, Seoul, South Korea
Kangnung National University, Kangnung 210-702, South Korea
Korea University, Seoul, 136-701, Korea
Myong Ji University, Yongin City 449-728, Korea
System Electronics Laboratory, Seoul National University, Seoul, South Korea
Yonsei University, Seoul 120-749, KOREA
Institute of High Energy Physics (IHEP-Protvino or Serpukhov), Protovino, Russia
Joint Institute for Nuclear Research (JINR-Dubna), Dubna, Russia
Kurchatov Institute, Moscow, Russia
PNPI: St. Petersburg Nuclear Physics Institute, Gatchina, Leningrad, Russia
Lund University, Lund, Sweden
Abilene Christian University, Abilene, Texas, USA
Brookhaven National Laboratory (BNL), Upton, NY 11973
University of California - Riverside (UCR), Riverside, CA 92521, USA
Columbia University, Nevis Laboratories, Irvington, NY 10533, USA
Florida State University (FSU), Tallahassee, FL 32306, USA
Georgia State University (GSU), Atlanta, GA, 30303, USA
Iowa State University (ISU) and Ames Laboratory, Ames, IA 50011, USA
LANL: Los Alamos National Laboratory, Los Alamos, NM 87545, USA
LLNL: Lawrence Livermore National Laboratory, Livermore, CA 94550, USA
University of New Mexico, Albuquerque, New Mexico, USA
New Mexico State University, Las Cruces, New Mexico, USA
Department of Chemistry, State University of New York at Stony Brook (USB), Stony Brook, NY 11794, USA

Backup: Centrality dependence vs $\sqrt{s_{NN}}$



Fit: $dX/d\eta \propto N_{part}^{\alpha}$:

CERES ($\sqrt{s_{NN}}$=8.7 GeV)

$dN_{ch}/d\eta$: α=1.09

WA98 ($\sqrt{s_{NN}}$=17.2 GeV)

$dN_{ch}/d\eta$: $\alpha=1.07\pm0.04$

$dE_T/d\eta$: $\alpha=1.08\pm0.06$

PHENIX ($\sqrt{s_{NN}}$=130 GeV)

$dN_{ch}/d\eta$: $\alpha=1.18\pm0.05$

$dE_T/d\eta$: $\alpha=1.16\pm0.05$

PHENIX ($\sqrt{s_{NN}}$=200 GeV)

$dN_{ch}/d\eta$: $\alpha=1.20\pm0.05$

$dE_T/d\eta$: $\alpha=1.17\pm0.05$

Not yet fair comparison of dX/dη in C.M. and Lab. systems

PHENIX