TO-DAY: ALL YOU WANTED TO KNOW ABOUT HEAVY ION COLLISIONS BUT DID NOT DARE TO ASK

TOMORROW: WHY DATA SEEM TO BE MUCH SIMPLER THAN THE EXPLANATIONS OF IT?

AND PREDICTIONS FOR LHC

Many thanks to Alex Mott, Yen-Jie Lee and Andre Yoon for help with many of the plots, and Y.Yilmaz for N_{PART} calculations for PbPb at LHC
For a very broad range of energies and geometry of the collision:

- For $\sqrt{s_{NN}}$ from $<10$ GeV to $200$ GeV
- For $N_{\text{PART}}$ from 2-350
- And over the entire rapidity range

- The global distributions of charged particles produced in pp, pA, AA, and even $e^+e^-$ collisions show remarkably similar trends, and data is found to factorize into an energy dependent part and a geometry, or incident system dependent part

- The trends allow us to “predict” with high precision several important results that will be seen in PbPb at LHC. More important, an understanding of what happens in AA collisions must include an explanation of these trends and the broad range over which they seem to apply
Au + Au

PHOBOS, Gunther Roland QM 2005
Warning: rapidity \( y \neq \) pseudorapidity \( \eta \)

\[
\tanh^{-1} \beta \neq \tanh^{-1} \cos \theta
\]

change of reference frame:

\[
\begin{align*}
\eta' &= \eta + \Delta y_{\text{relative}} \\
y' &= y + D y_{\text{relative}}
\end{align*}
\]

\[
\eta - y = \tanh^{-1} \cos \theta - \tanh^{-1} b
\]

\[
h - y = \tanh^{-1} \frac{p_l}{p} - \tanh^{-1} \frac{p_l}{E}
\]
Figure 1: PHOBOS Preliminary dNch/dη/⟨Npart⟩/2 vs |η| – ybeam for 0-6% Central Au+Au and Cu+Cu collisions at 200 GeV, 130 GeV, 62.4 GeV, and 19.6 GeV.

PHOBOS, Hofman, QM2006

Figure 2: dN/dy vs y-ybeam for π− at various energies and beam types.

π−

E895

NA49

STAR π0

BRAHMS

PHOBOS, Hofman, QM2006

Figure 3: a) dNch/dη vs η+y_target for pPb E178 collision at √sNN = 19.6 GeV, 13.7 GeV, and 9.69 GeV. b) dNch/dη vs η-y_beam for pPb E178 collision at √sNN = 19.6 GeV.


Veres, QM2005

PHOBOS, Hofman, QM2006

Veres, QM2005
\( \eta' = \eta - y_{\text{beam}} \)


ISR (23.6,45.2) Nucl.Phys B 129 365 (1977)

Elliptic Flow


19.6 - 200 GeV
Experimental Control of Centrality or Impact Parameter

“Spectators”

Zero-degree Calorimeter

“Participants”

Paddle Counter

“Spectators”

200 GeV

ZDC Mean Energy (a.u.)

6% Central

Paddle Mean (a.u.)

Counts

6% Central

Paddle Mean (a.u.)
PHOBOS, Phys. Rev. C74 021902 (R) 2006


- W. Busza et al. PRL34 (1975) 836


Data compiled by PHOBOS, R. Nouicer, PANIC 05

\[ \frac{dN}{d\eta} \] for PbPb @ \( \sqrt{s} = 5.5\text{TeV} \) Extrapolated from Lower Energy Data

\[ N_{\text{PART}} = 360 \]
Linear scaling in $N_{\text{PART}}$ and $dN/d\eta$

$\ln \sqrt{s}$ scaling in $\eta$ and $dN/d\eta$

$\frac{dN}{d\eta}$ for PbPb @ $\sqrt{s}=5.5$ TeV Extrapolated from Lower Energies

PHOBOS, Hofman, QM2006
11.3 GeV - 38.8 GeV


\[ \ln \sqrt{s} \] scaling in \( \eta \) and \( dN/d\eta \)

\[ p\text{-Emulsion} \]

\[ N_{\text{PART}} \text{ for } p\text{-emulsion} = 3.4 \]

p-Emulsion Scaled to 5.5 TeV

Data from compilation in review of particle physics scaled by $\ln \sqrt{s}$ in $\eta$ and $dN/d\eta$
Scaling Laws

Au+Au 0-6%  
200GeV  
130GeV  
62.4 GeV (prel)  
19.6 GeV

Au+Au 35-40%  
200GeV  
130GeV  
62.4 GeV (prel)  
19.6 GeV

PbPb @ 5.5TeV Scaled From AuAu @ 200GeV (Phobos Data)

0-6% Centrality  
35-45% Centrality


AuAu: PHOBOS, PRL 91 (2003) 052303
Au\textsubscript{Au}: PHOBOS: PRL 94 122303 (2005)

Cu\textsubscript{Cu}: PHOBOS: PRL accepted for publication

G. Roland, PANIC 05
Au+Au  

PHOBOS 0-40% centrality: PRL 97, 012301 (2006)
Energy and Geometry Factorization seems to apply to $p_T$ spectra.
Au+Au $\sqrt{s_{NN}} = 200\text{GeV}, 0-10\%$

PHENIX preliminary

- $\pi^0$
- $\eta$
- dir. photon

new for QM

B. Sahlmüller, QM06
SPS and RHIC suppression looks the same!
(Figs. from Enrico Scoparino)
p+A collisions

Various final states: \(\phi, \pi^+, \pi^-, p, n, \Lambda, K^0, \Xi, K^+, K^-\)

Various beam energies: 24, 100, 300, 400 GeV


E451, PRD27 (1983) 2580

\[ \sigma_{pA} = \sigma_0 A^\alpha \]

\[ x_F \]

G. Veres, QM05

\[ J/\psi \]

Skupic et al.

\[ \Lambda/\Lambda \]

At \( \sqrt{s} = 23.8 \) GeV

Be & Pb targets
Summary of Main “Predictions”

Total charged multiplicity in central ($N_{\text{PART}} = 386$) PbPb collisions at ($\sqrt{s} = 5.5$ TeV) = 15000 +/- 100

Total charged multiplicity in NSD pp collisions at ($\sqrt{s} = 14$ TeV) = 72 +/- 8
Final Comments

• If these “predictions” turn out to be correct, more than ever, any model which claims to explain the phenomena observed in heavy ion collisions at ultra relativistic velocities, must contain an explanation for the observed trends, as well as the broad range of systems, energies and rapidities over which the trends are observed.

• If these “predictions” turn out to be false, it will be a direct indication of the onset of new phenomena at LHC energies.

• If the observed trends are a consequence of some very general principles, it means that the data on the global properties is not sensitive to the details of the system formed in AA collisions. It then follows that we learn little from models that agree with this data, unless at the same time the models explicitly explain the trends.