

Soft Physics at the LHC



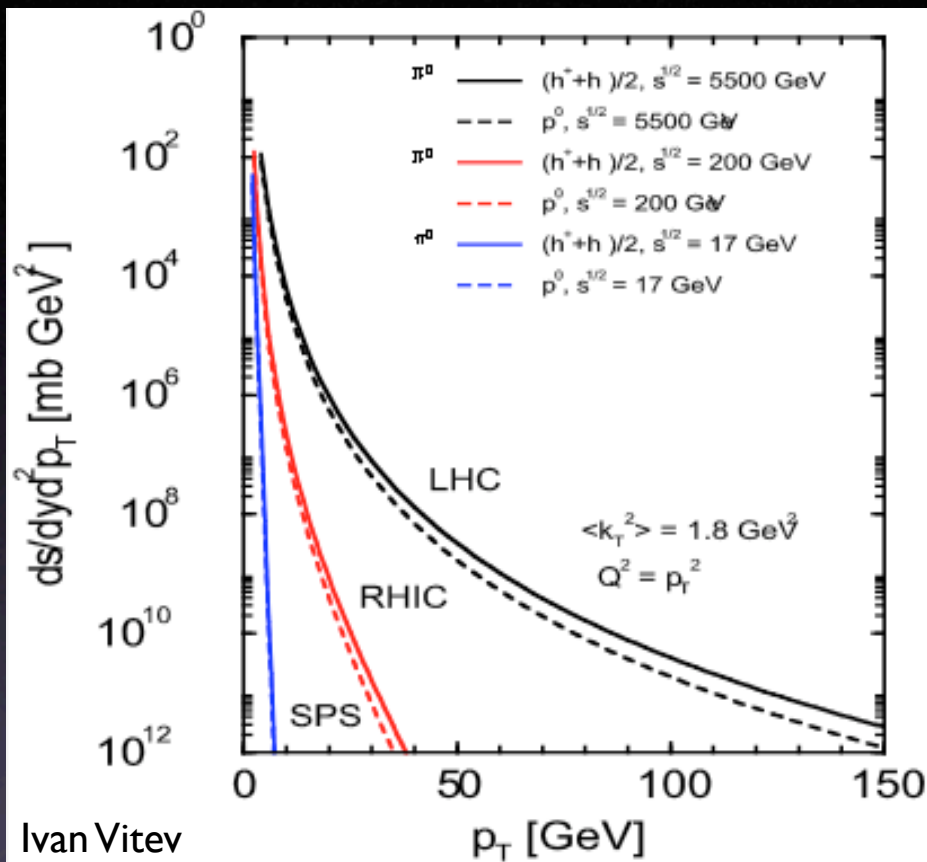
*Heavy Ion Physics at the LHC
PANIC 2005
Santa Fe, Oct 22 2005*



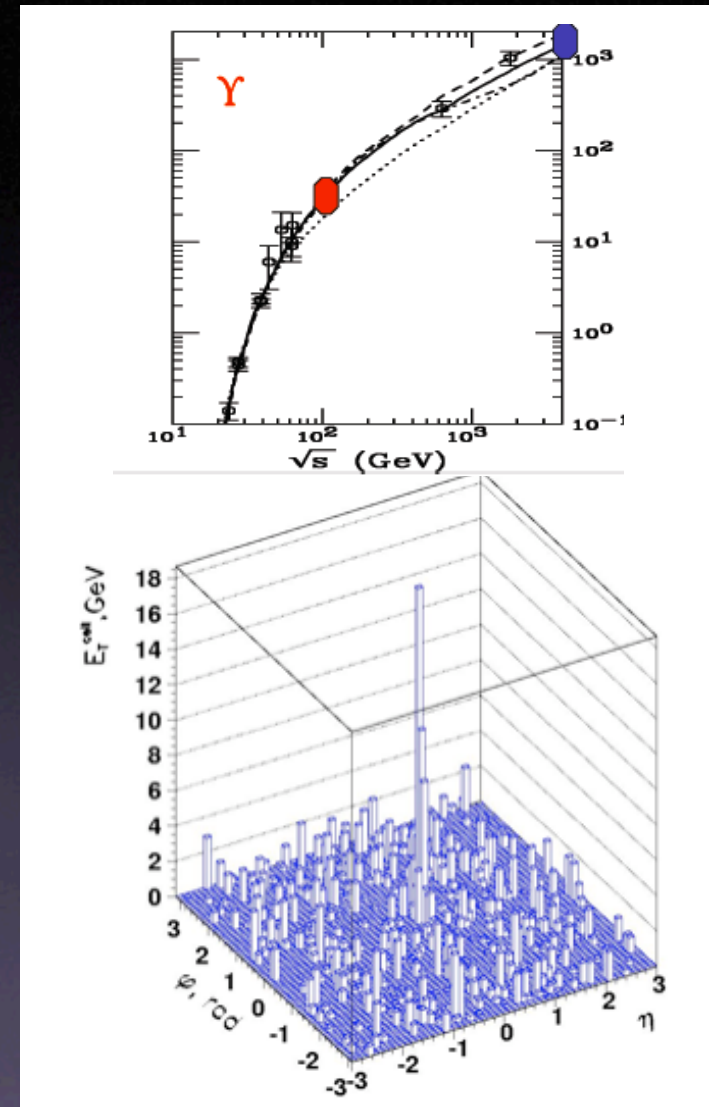
Gunther Roland



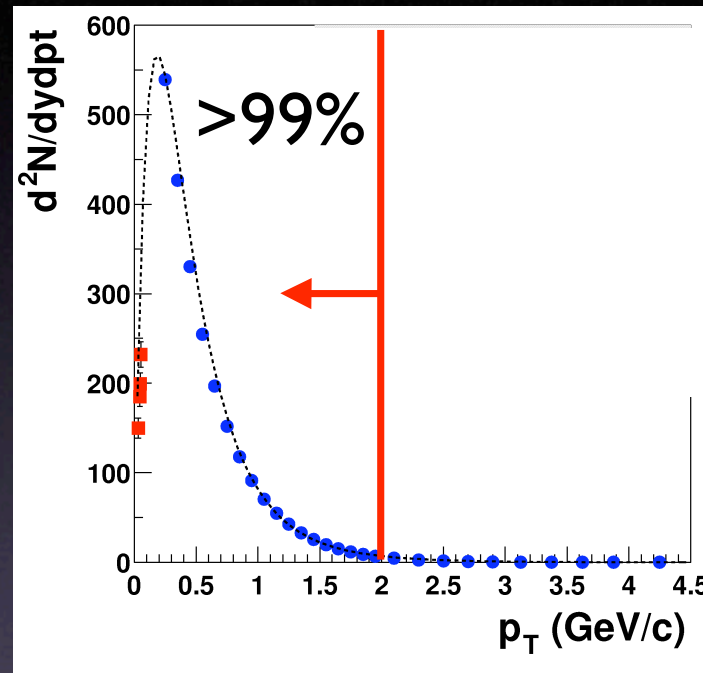
Heavy Ion Physics at the LHC



Factor 28: Largest step in \sqrt{s} in history of our field



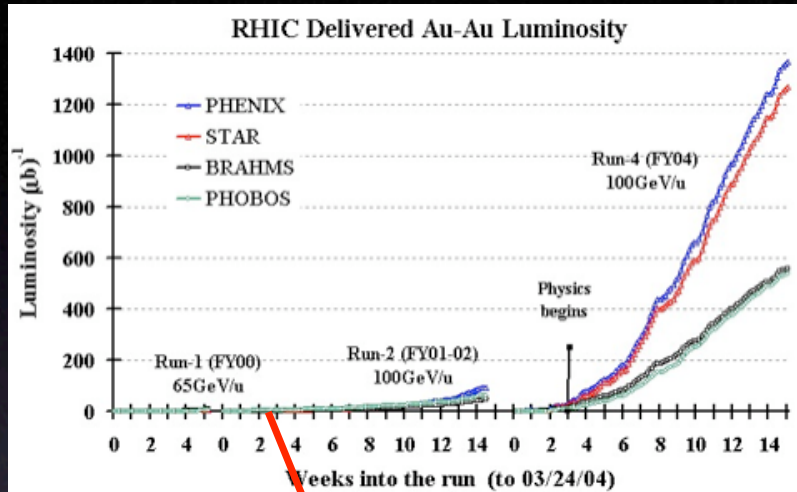
“Soft Physics”



“Soft Physics”: Particle production with $p_T < 2\text{GeV}/c$

Day-1 Physics

RHIC

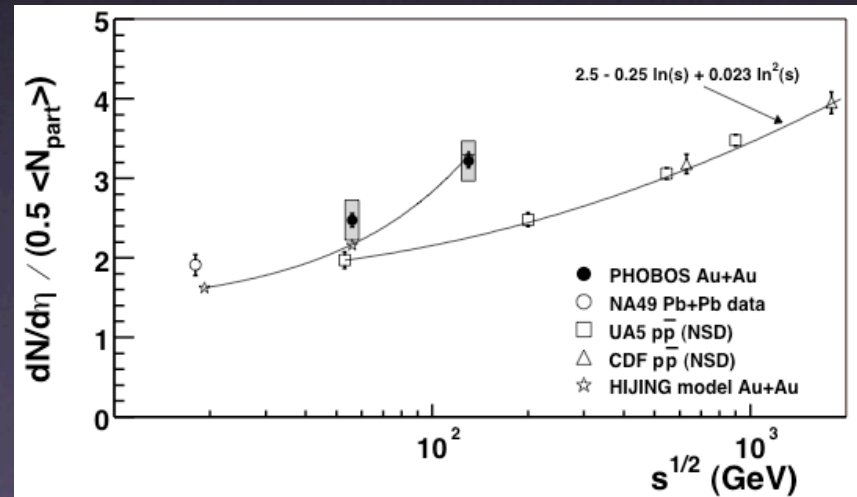


hep-ex/0007036

Charged particle multiplicity near mid-rapidity in central Au+Au collisions at $\sqrt{s} = 56$ and 130 AGeV

B.B.Back¹, M.D.Baker², D.S.Barton², S.Basilev⁵, R.Baum⁸, R.R.Betts^{1,7}, A.Bialas⁴, R.Bindel⁸, W.Bogucki³, A.Budzanowski³, W.Busza⁵, A.Carroll², M.Ceglia², Y.-H.Chang⁶, A.E.Chen⁶, T.Coghren³, C.Conner⁷, W.Czyz⁴, B.Dąbrowski³, M.P.Decowski⁵, M.Despet³, P.Fita⁷, J.Fitch⁵, M.Friedl⁵, K.Galuszka³, R.Ganz⁷, E.Garcia-Solis⁸, N.George¹, J.Godlewski³, C.Gomes⁵, E.Griesmayer⁵, K.Gulbrandsen⁵, S.Gushue², J.Halik³, C.Halliwell⁷, P.Haridas⁵, A.Hayes⁵, G.A.Heintzelman², C.Henderson⁵, R.Hollis⁷, R.Holyński³, B.Holzman⁷, E.Johnson⁹, J.Kane⁵, J.Katzy^{5,7}, W.Kita³, J.Kotula³, H.Kraner², W.Kucewicz⁷, P.Kulinich⁵, C.Law⁵, M.Lemler³, J.Ligocki³, W.T.Lin⁶, S.Manly^{9,10}, D.McLeod⁷, J.Michalowski³, A.Mignerey⁸, J.Mülmenstädt⁵, M.Neal⁵, R.Nouicer⁷, A.Olszewski^{2,3}, R.Pak², I.C.Park⁹, M.Patel⁵, H.Pernegger⁵, M.Plesko⁵, C.Reed⁵, L.P.Remsberg², M.Reuter⁷, C.Roland⁵, G.Roland⁵, D.Ross⁵, L.Rosenberg⁵, J.Ryan⁵, A.Sanzgiri¹⁰, P.Sarin⁵, P.Sawicki³, J.Scaduto², J.Shea⁸, J.Sinacore², W.Skulski⁹, S.G.Steadman⁵, G.S.F.Stephans⁵, P.Steinberg², A.Strączek³, M.Stodulski³, M.Strek³, Z.Stopa³, A.Sukhanov², K.Surowiecka⁵, J.-L.Tang⁶, R.Teng⁹, A.Trzupek³, C.Vale⁵, G.J.van Nieuwenhuizen⁵, R.Verdier⁵, B.Wadsworth⁵, F.L.H.Wolfs⁹, B.Wosiek³, K.Woźniak³, A.H.Wuosmaa¹, B.Wyslouch⁵, K.Zalewski⁴, P.Zychowski³ (PHOBOS collaboration)

Within the vertex fiducial volume we found a total of **103** central events for the low energy and **151** central events in the high energy data set. For the



First “soft physics” paper 6 weeks after first collisions

Gunther Roland PANIC 2005 Santa Fe



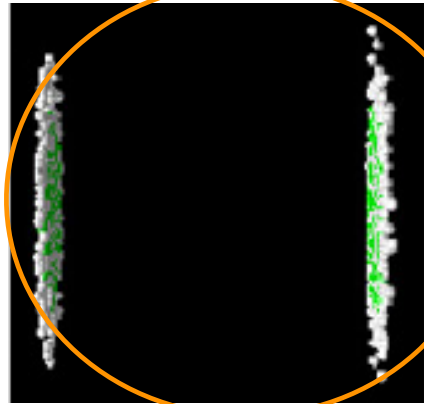
Soft Look at a Heavy Ion Collision

Spectator Calorimetry

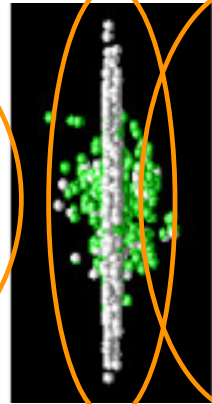
Fractional x-section

Reaction Plane

Geometry



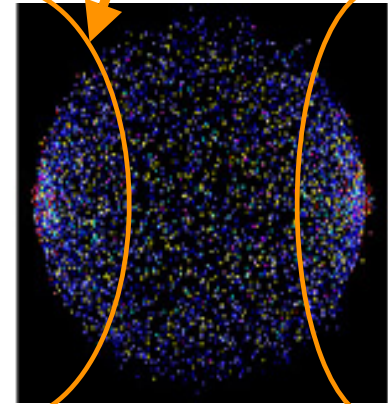
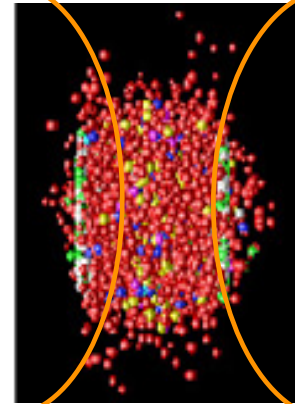
Elliptic Flow
Thermalization



Particle Ratios

Particle Yields

Hadronization



Entropy Production

Energy Deposition

Multiplicity

E_T Calorimetry

Net Baryon Distribution

Hydro Evolution

Elliptic Flow

Radial Flow

Spectra

HBT

Kinetic Freezeout

Overall Timescale

Spectra

HBT

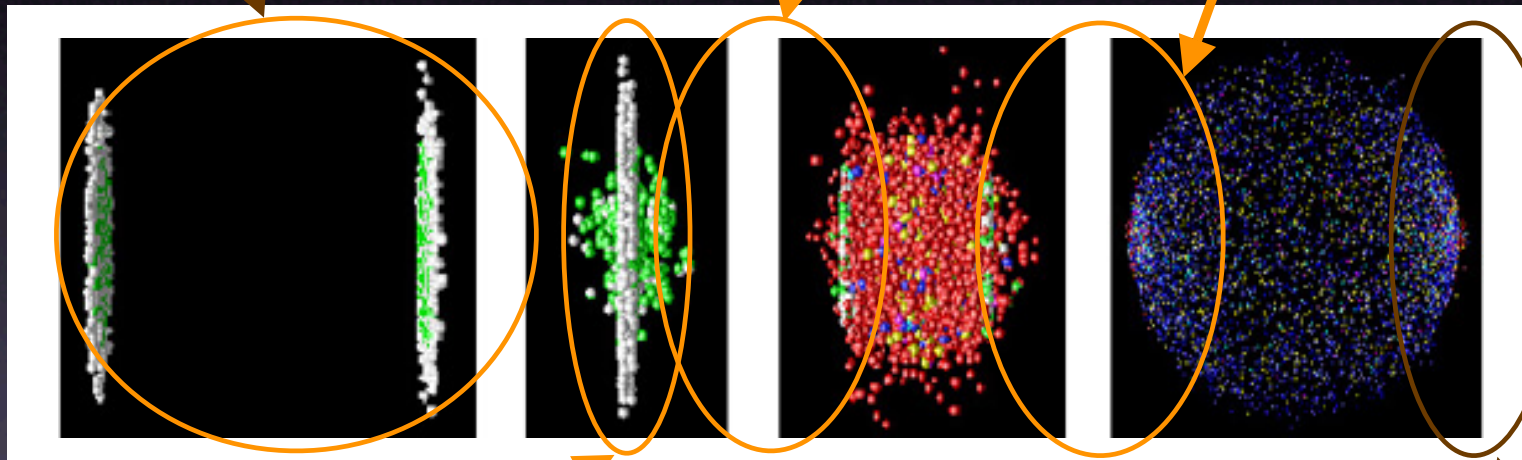


Soft Look at a Heavy Ion Collision

Spectator Calorimetry
 Fractional x-section
 Reaction Plane
 Geometry

Elliptic Flow
 Thermalization

Particle Ratios
 Particle Yields
 Hadronization



Entropy Production
 Energy Deposition
 Multiplicity
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Hydro Evolution
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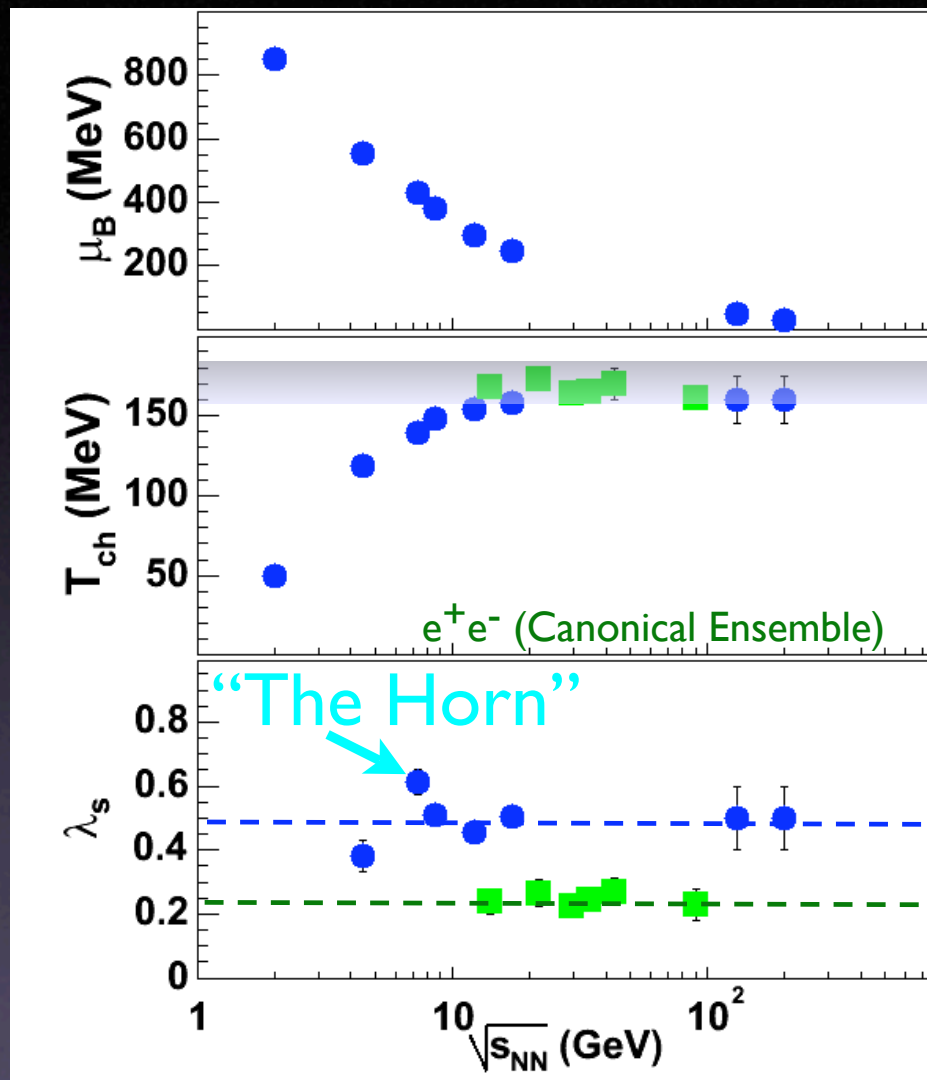
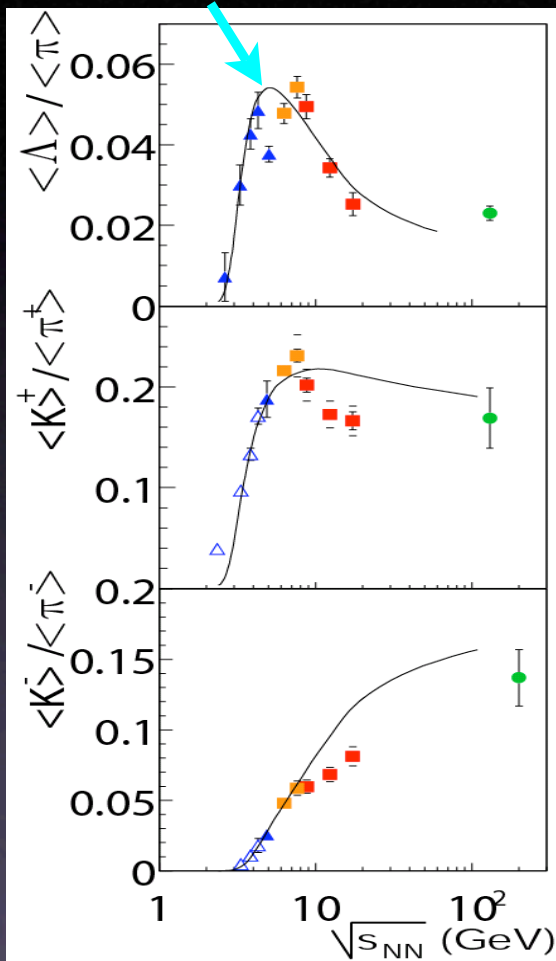
Kinetic Freezeout
 Overall Timescale
 Spectra
 HBT

Net Baryon Distribution



Energy Dependence of Particle Ratios

“The Horn”



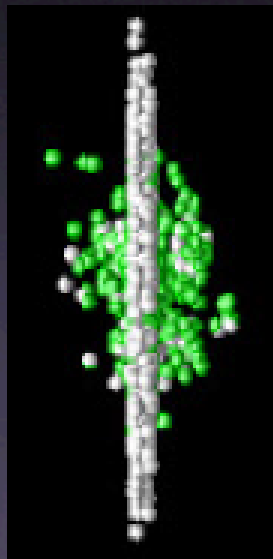
LHC



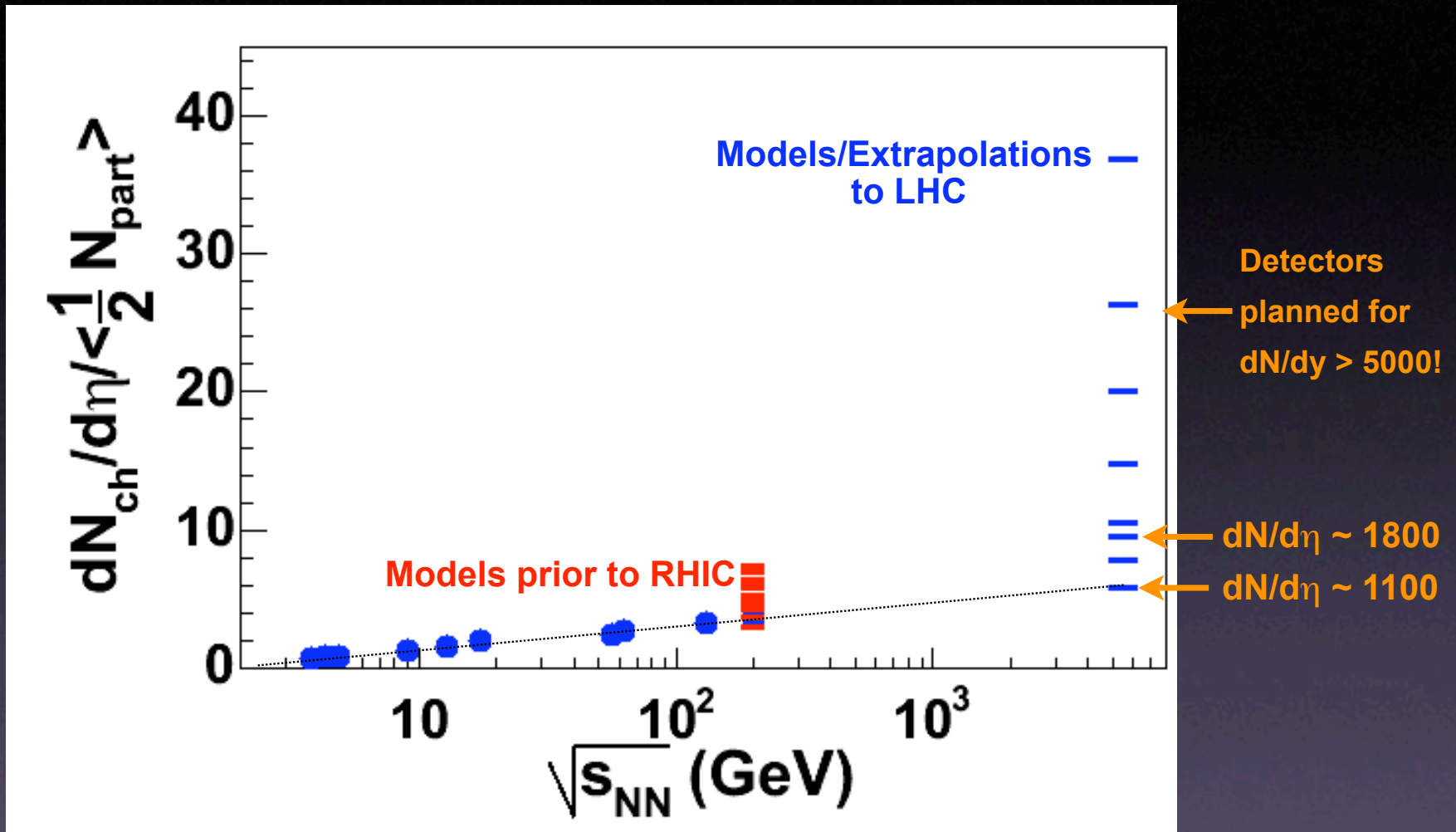
Non-monotonic behavior at AGS/SPS boundary
Smooth evolution between SPS and RHIC



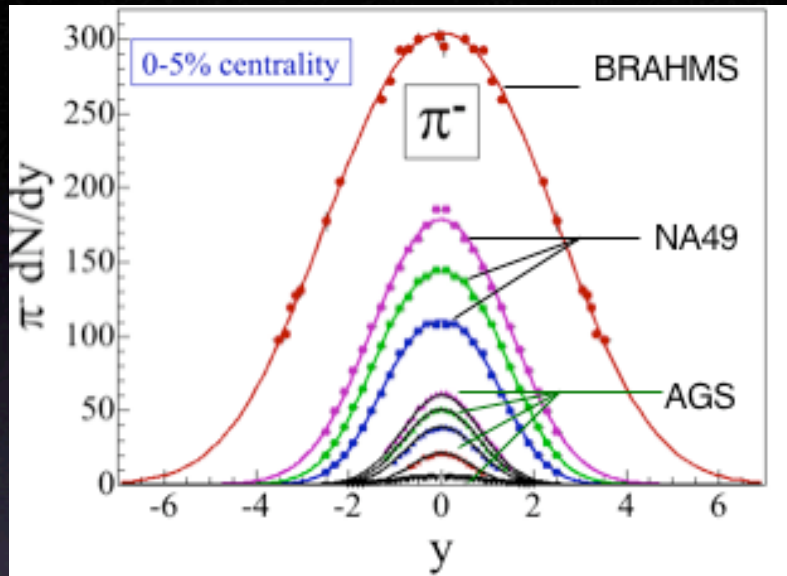
Hadron Multiplicities



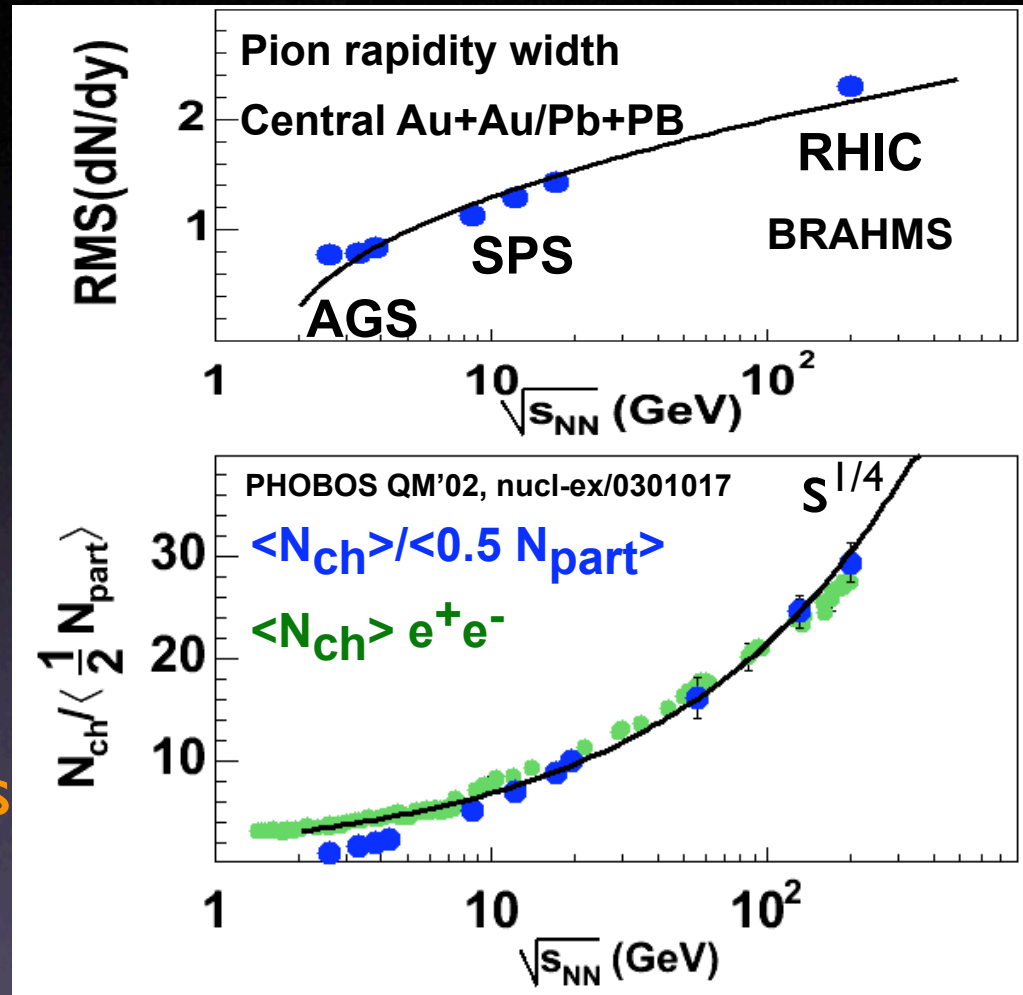
Energy Dependence of Hadron Multiplicities



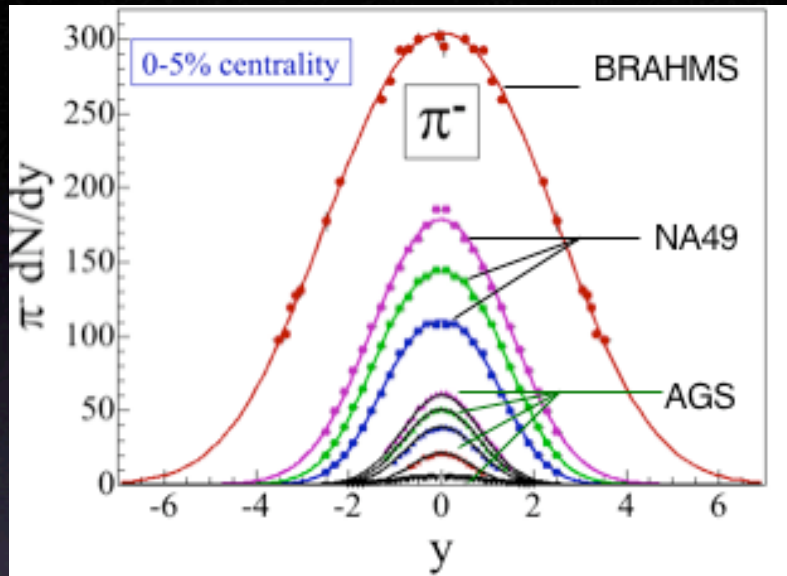
Rapidity Distributions



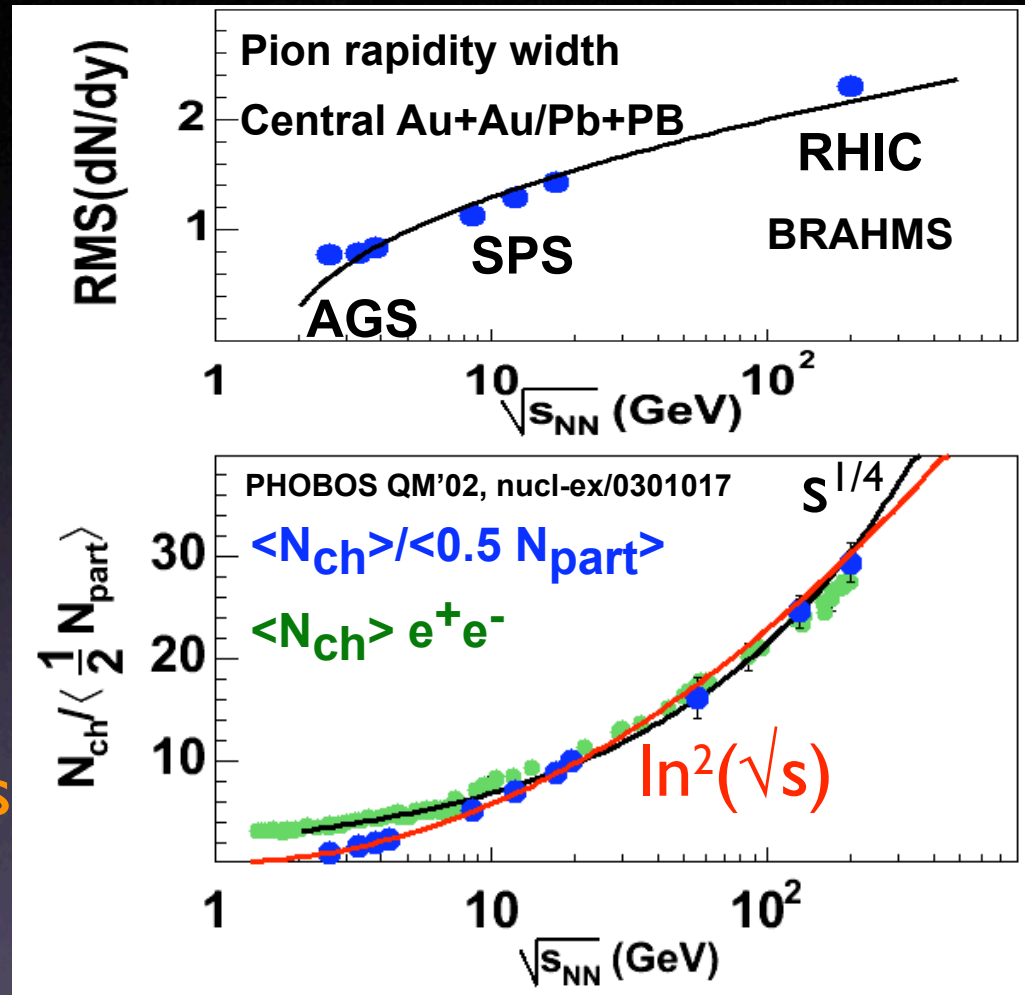
Meson rapidity distributions are approximately Gaussian - reminiscent of Landau?



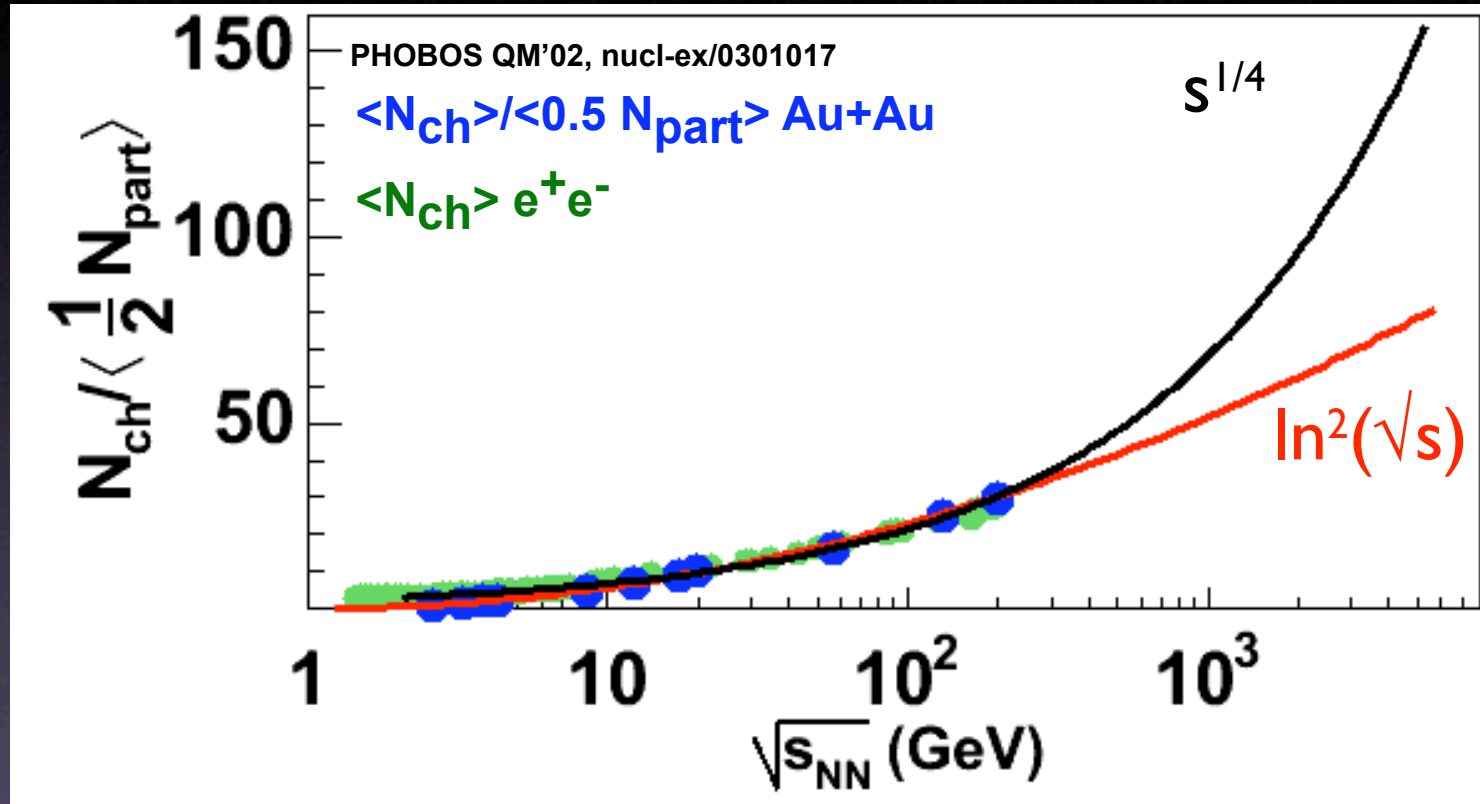
Rapidity Distributions



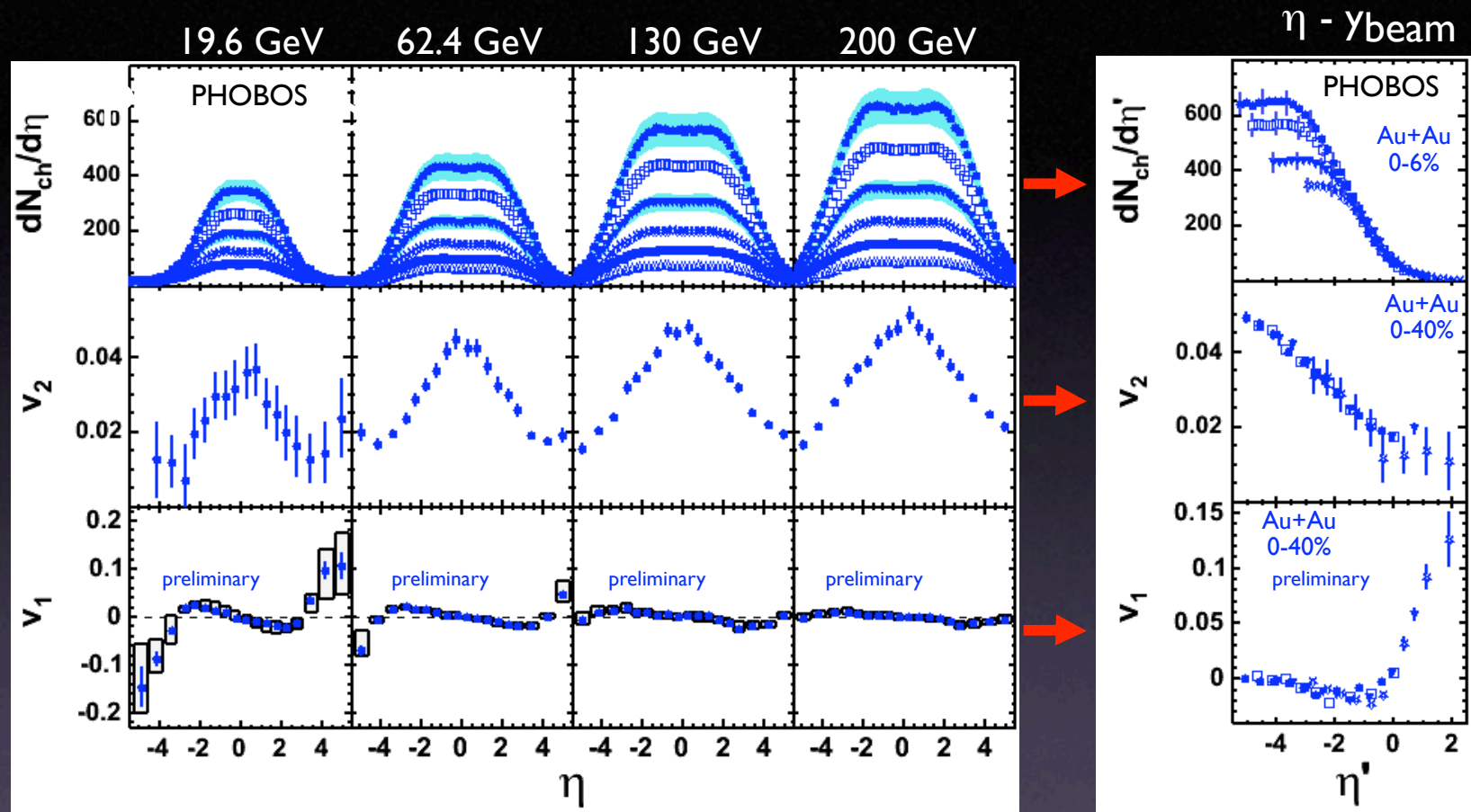
Meson rapidity distributions are approximately Gaussian - reminiscent of Landau?



Extrapolating to LHC



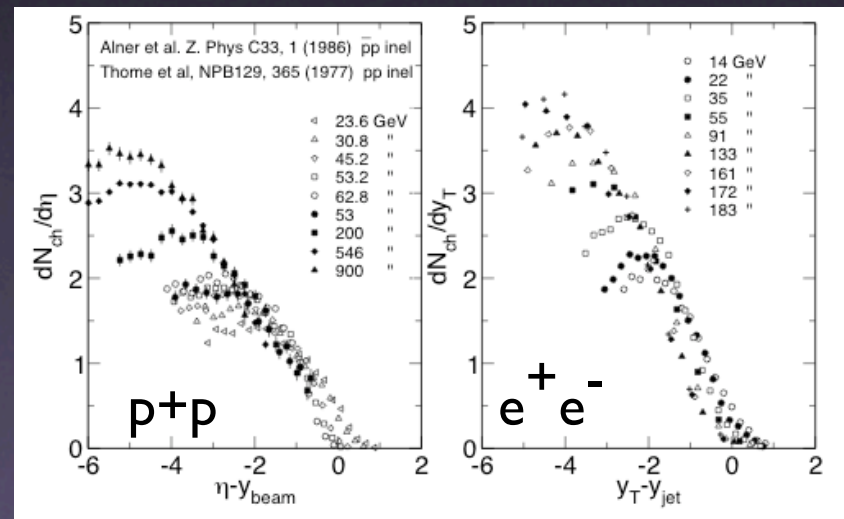
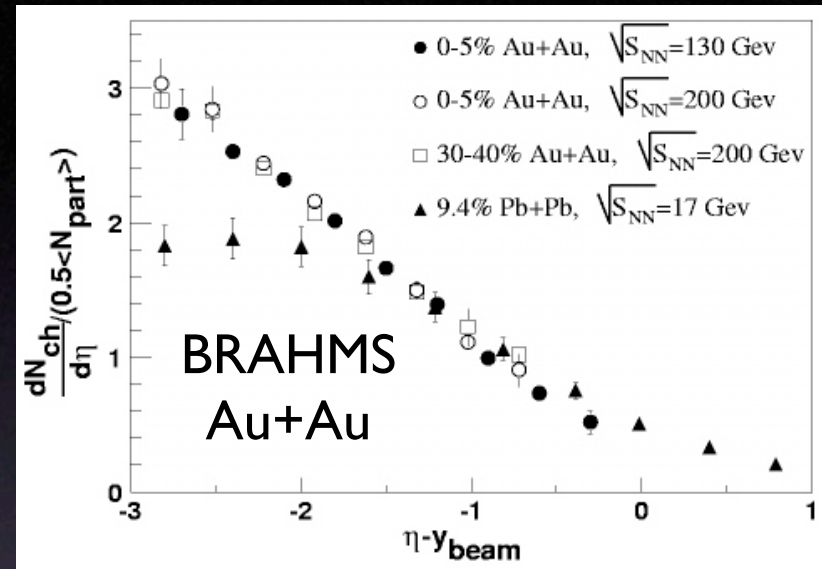
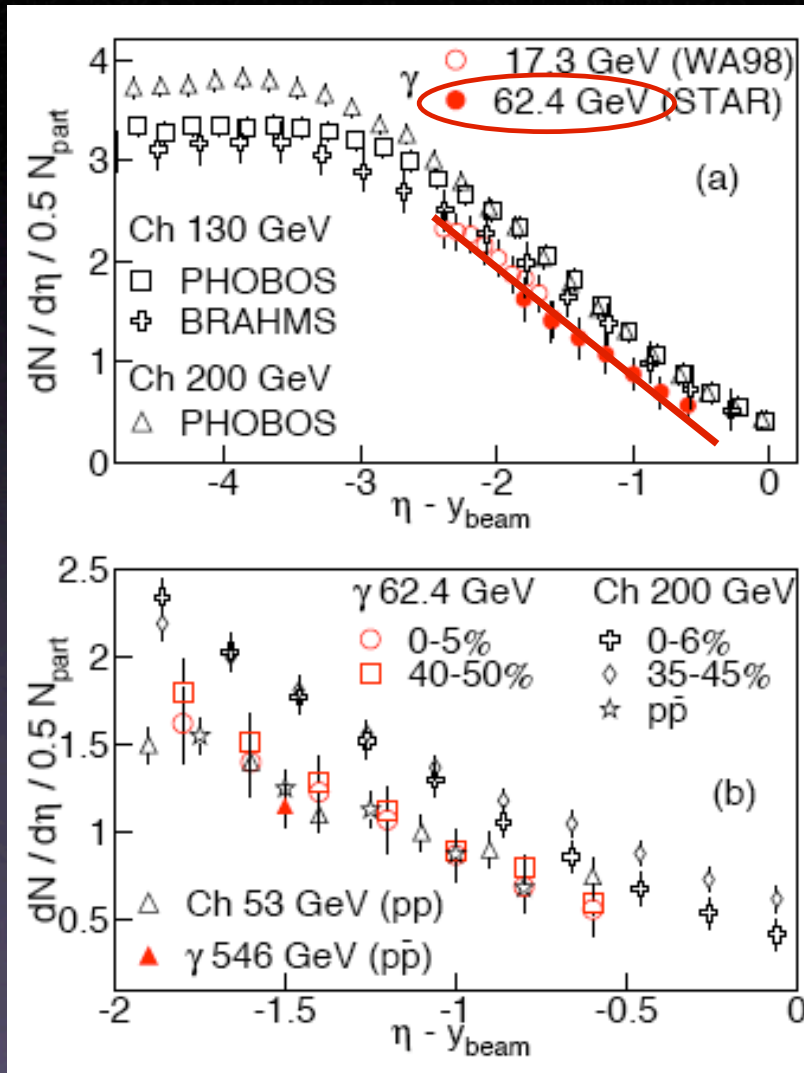
Extended longitudinal scaling



“Extended longitudinal scaling” (aka limiting fragmentation) of all longitudinal distributions



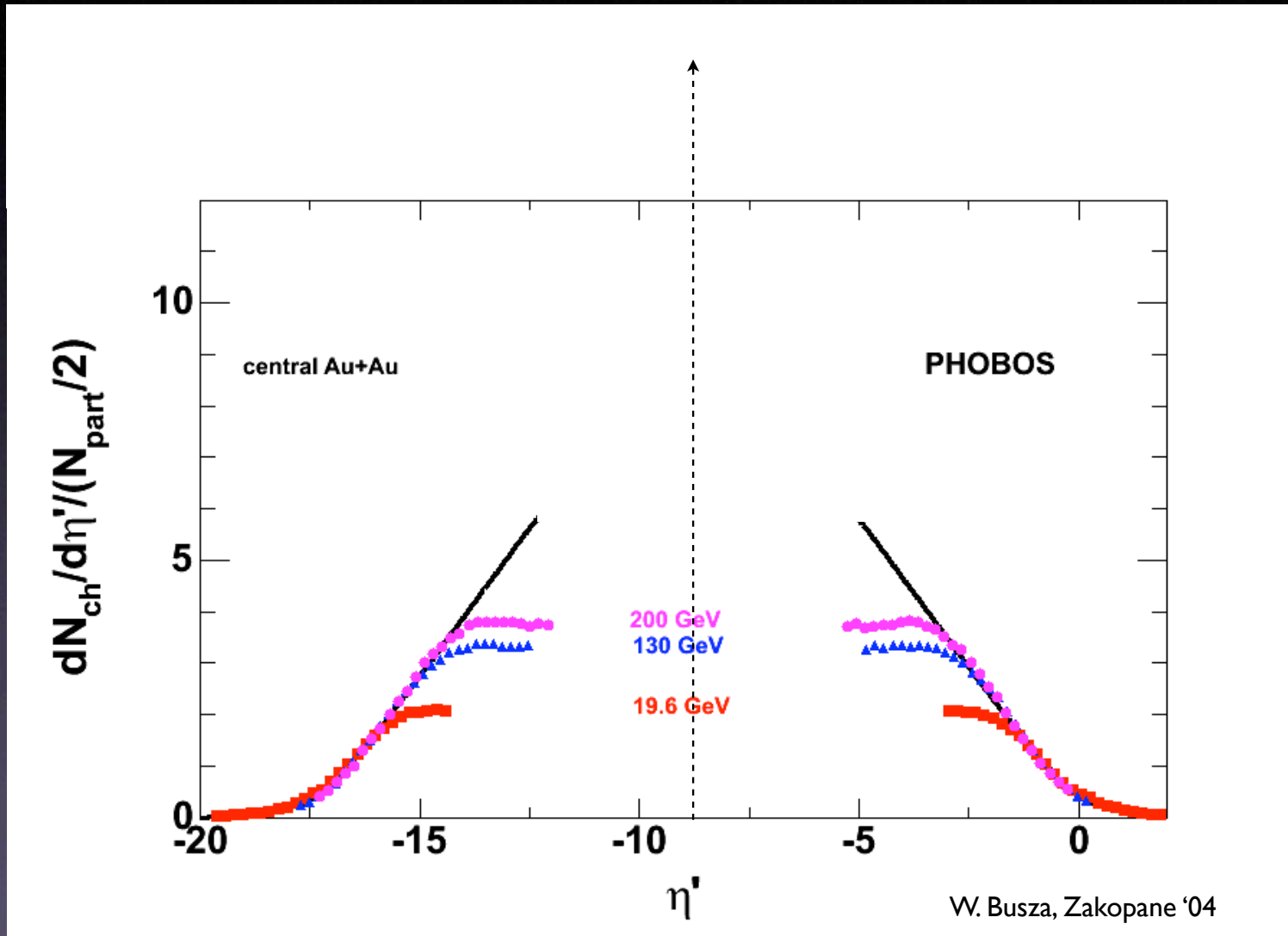
Limiting Fragmentation: Universal phenomenon



nucl-ex/0502008



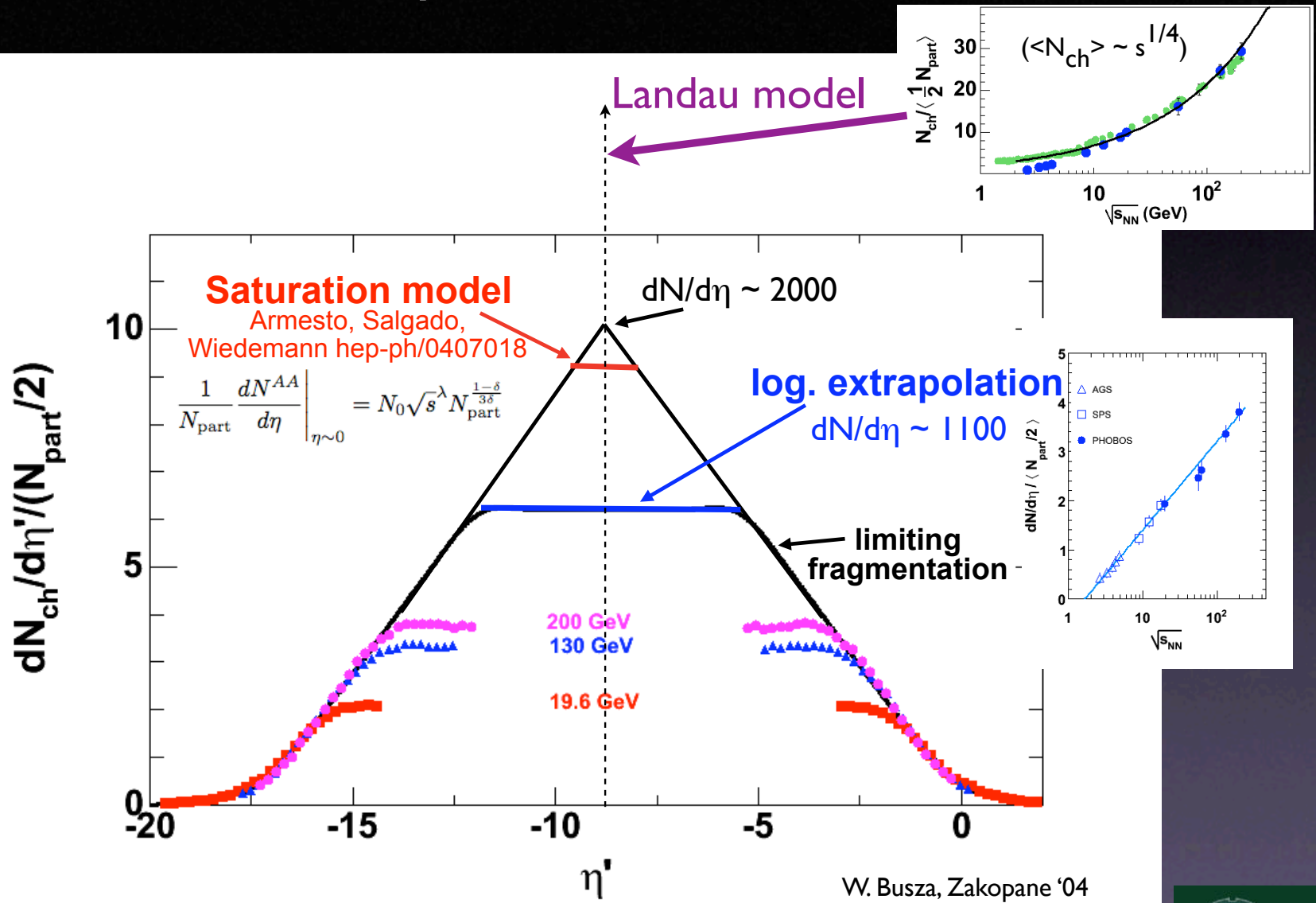
Extrapolation to LHC



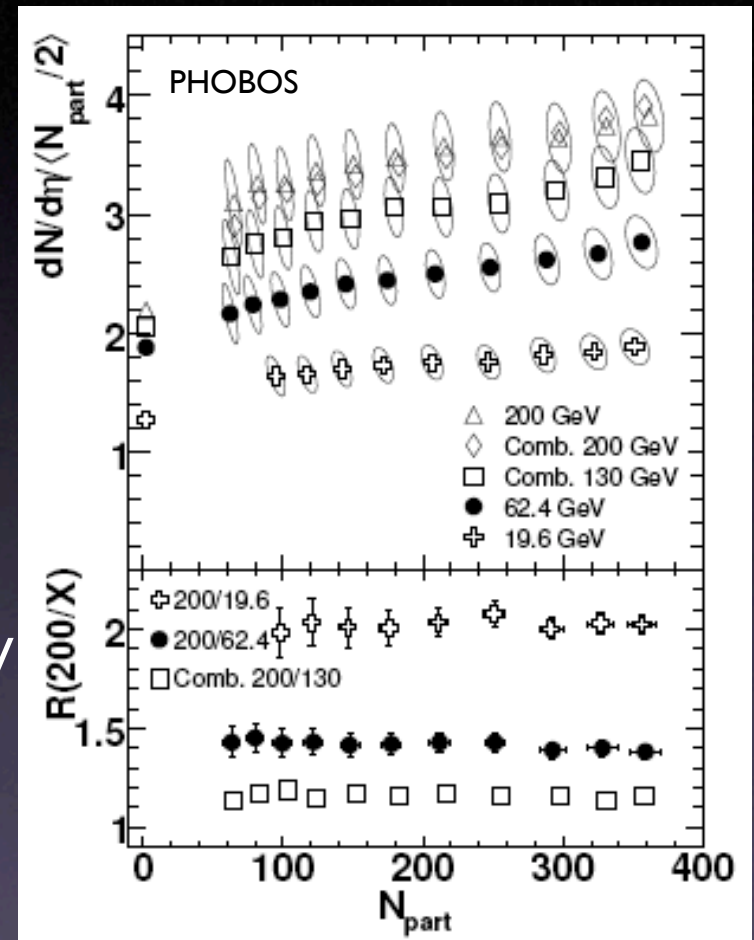
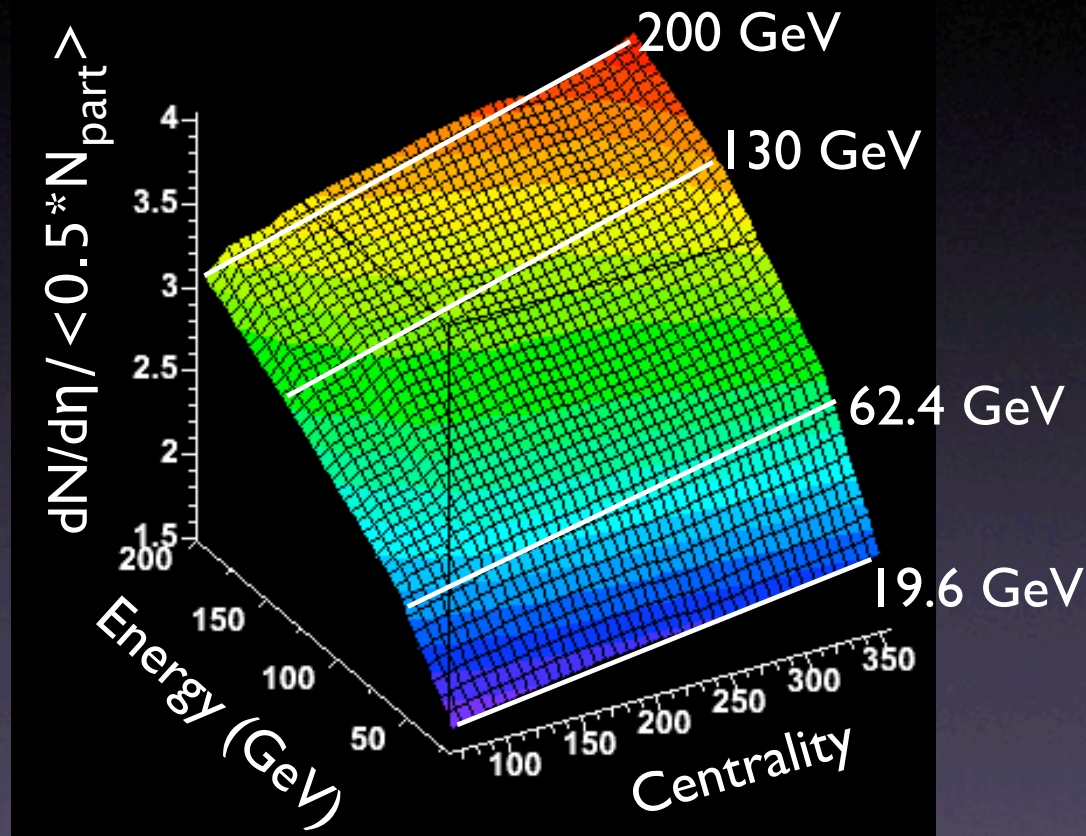
W. Busza, Zakopane '04



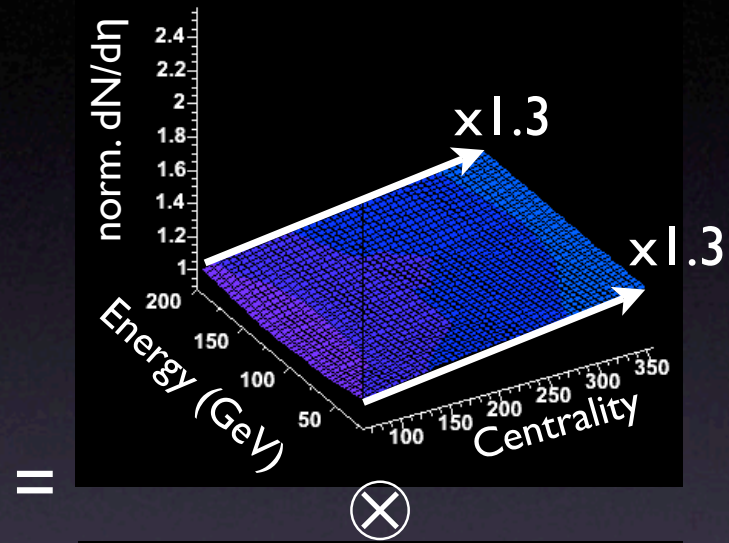
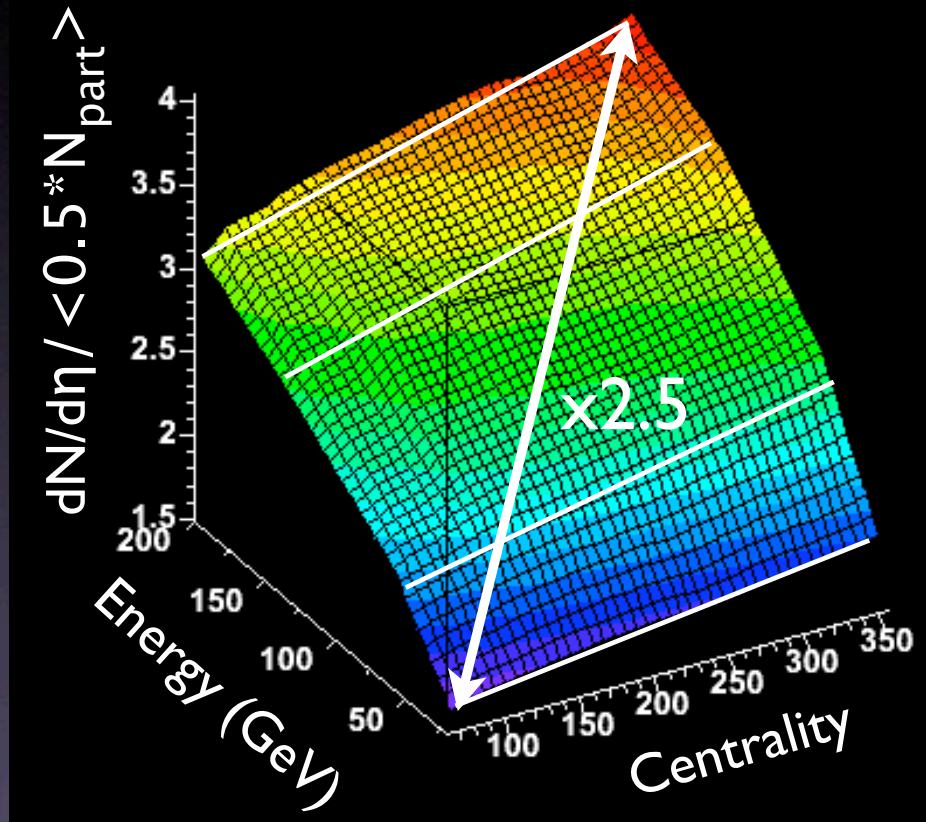
Extrapolation to LHC



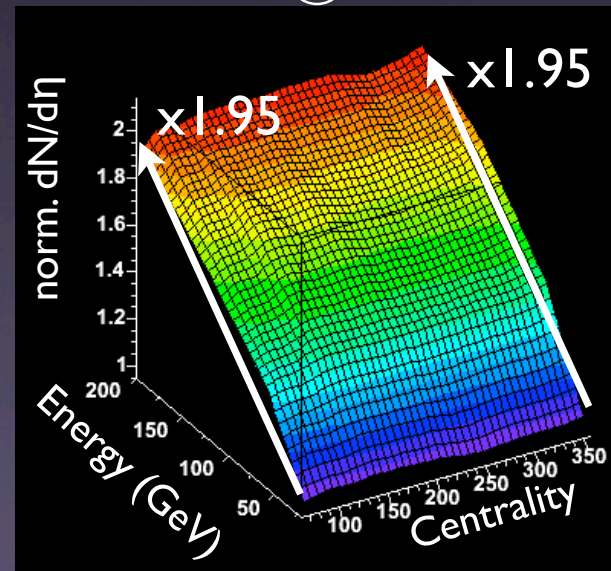
Mid-rapidity $dN/d\eta$ vs \sqrt{s} and N_{part}



$dN/d\eta$ vs \sqrt{s} and N_{part}

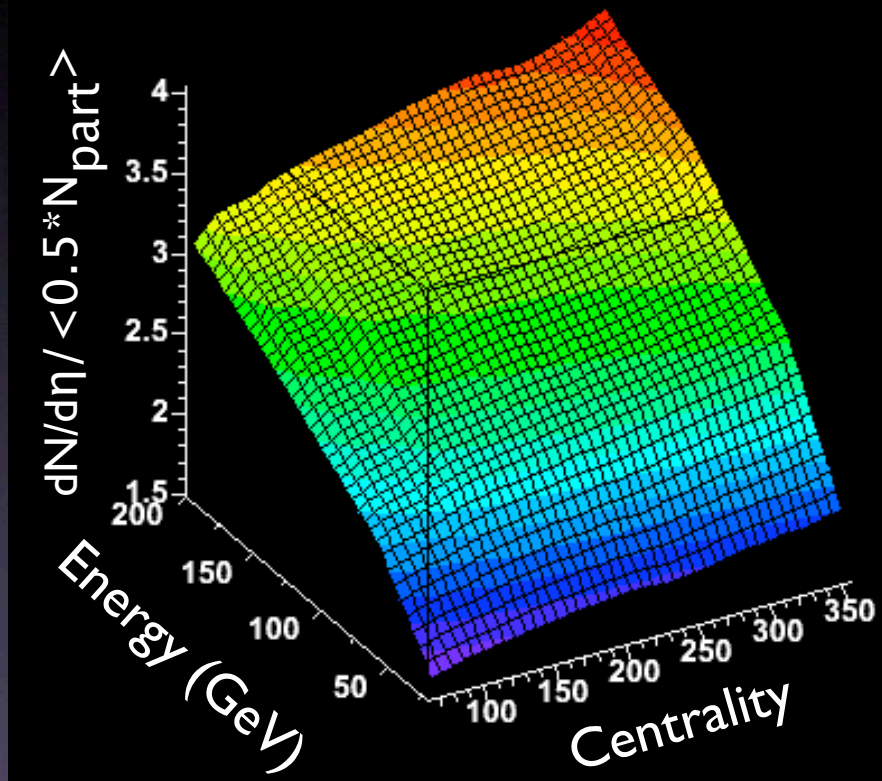


||

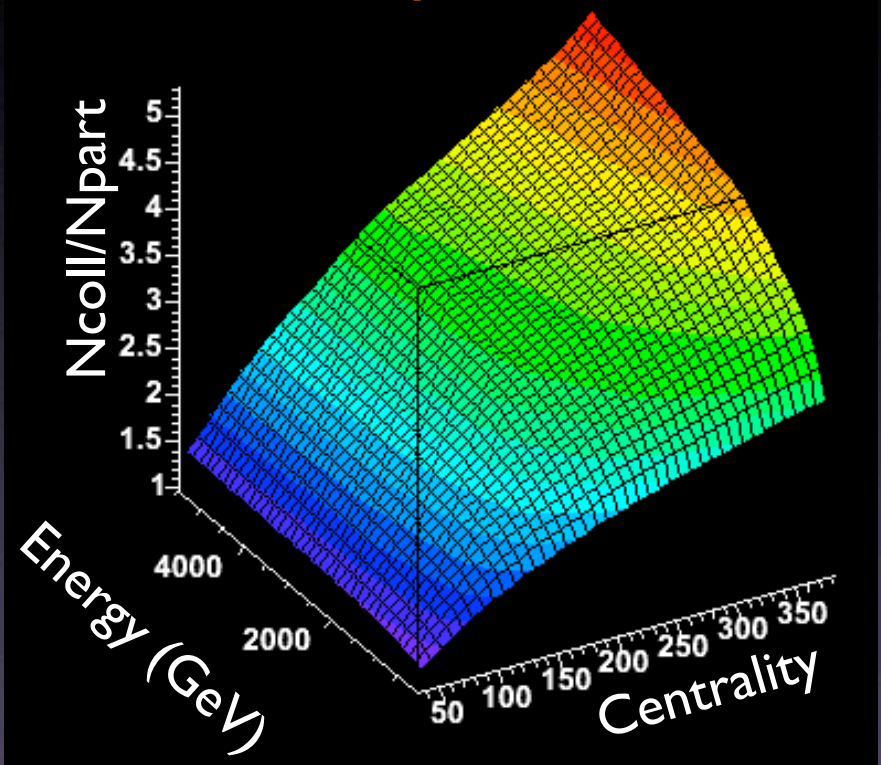


$N_{\text{coll}}/N_{\text{part}}$ vs \sqrt{s} and N_{part}

$dN/d\eta$ (Data)



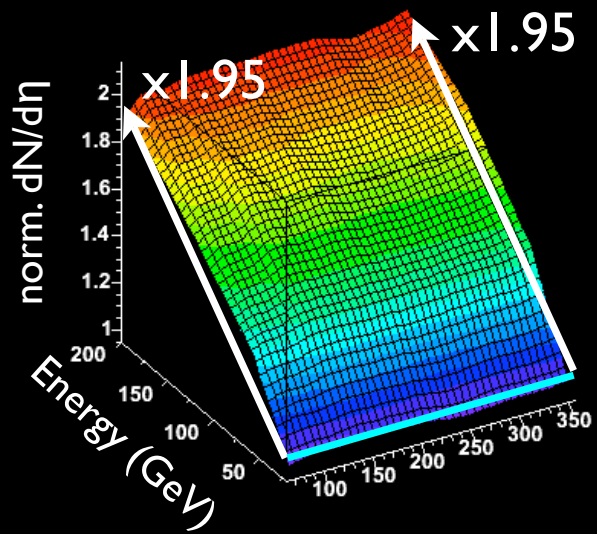
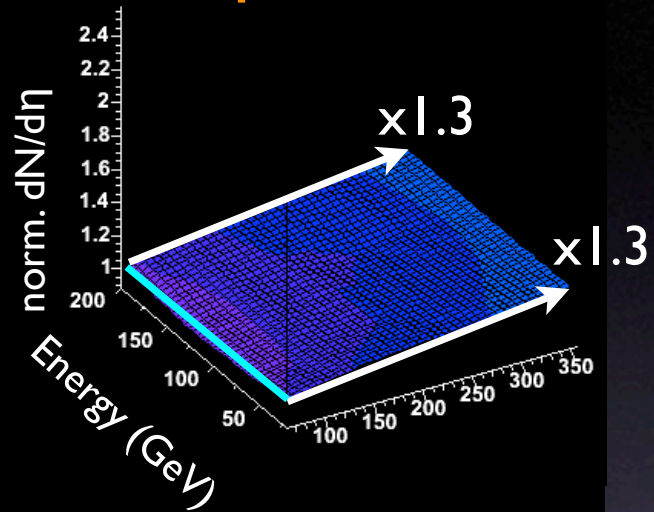
$N_{\text{coll}}/N_{\text{part}}$ (MC)



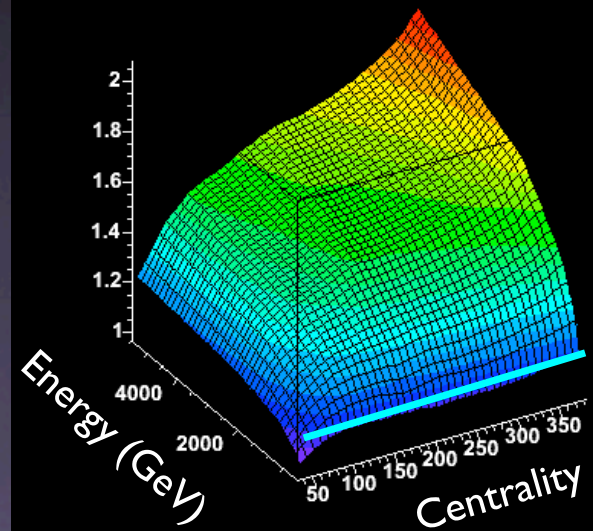
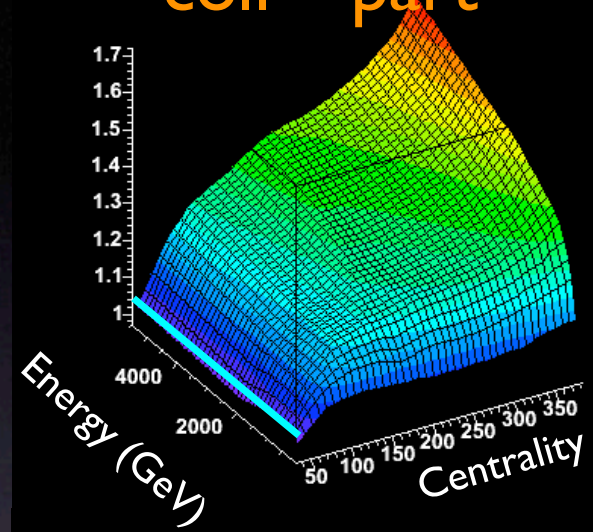
Factorization in a hard/soft picture?



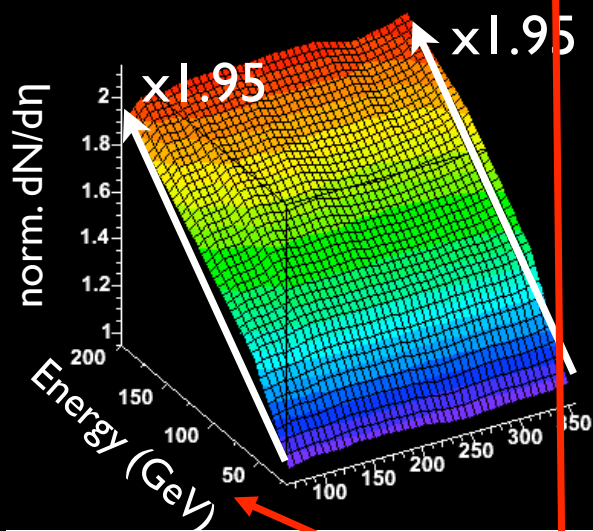
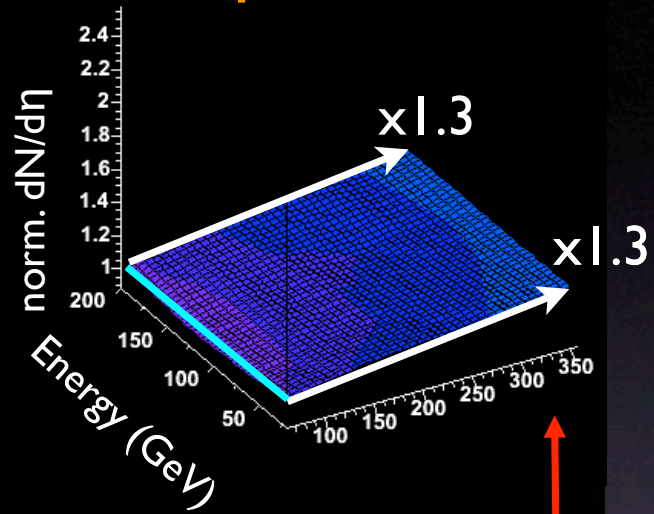
$dN/d\eta/N_{part}$ (Data)



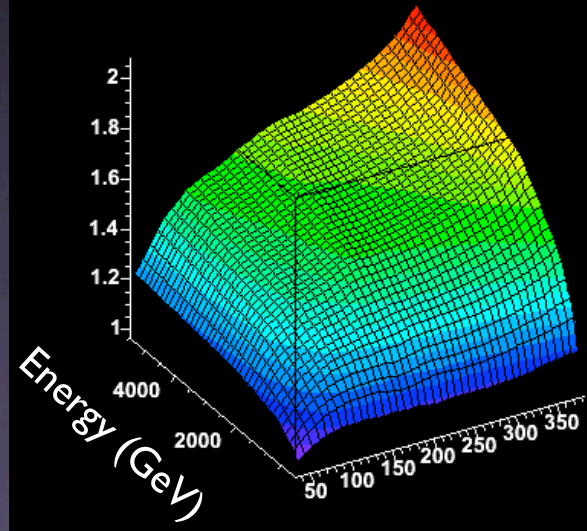
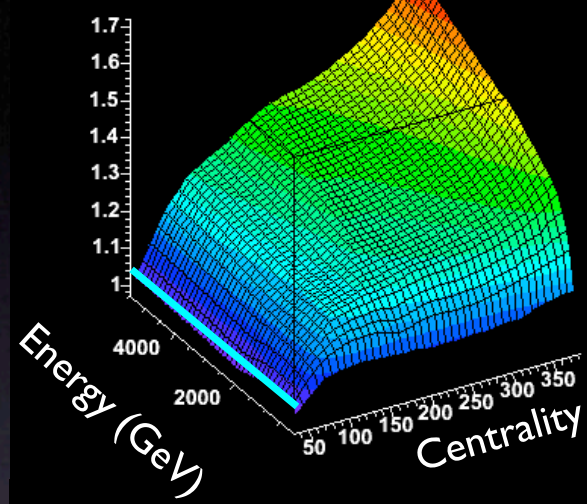
N_{coll}/N_{part} (MC)



$dN/d\eta/N_{part}$ (Data)



N_{coll}/N_{part} (MC)



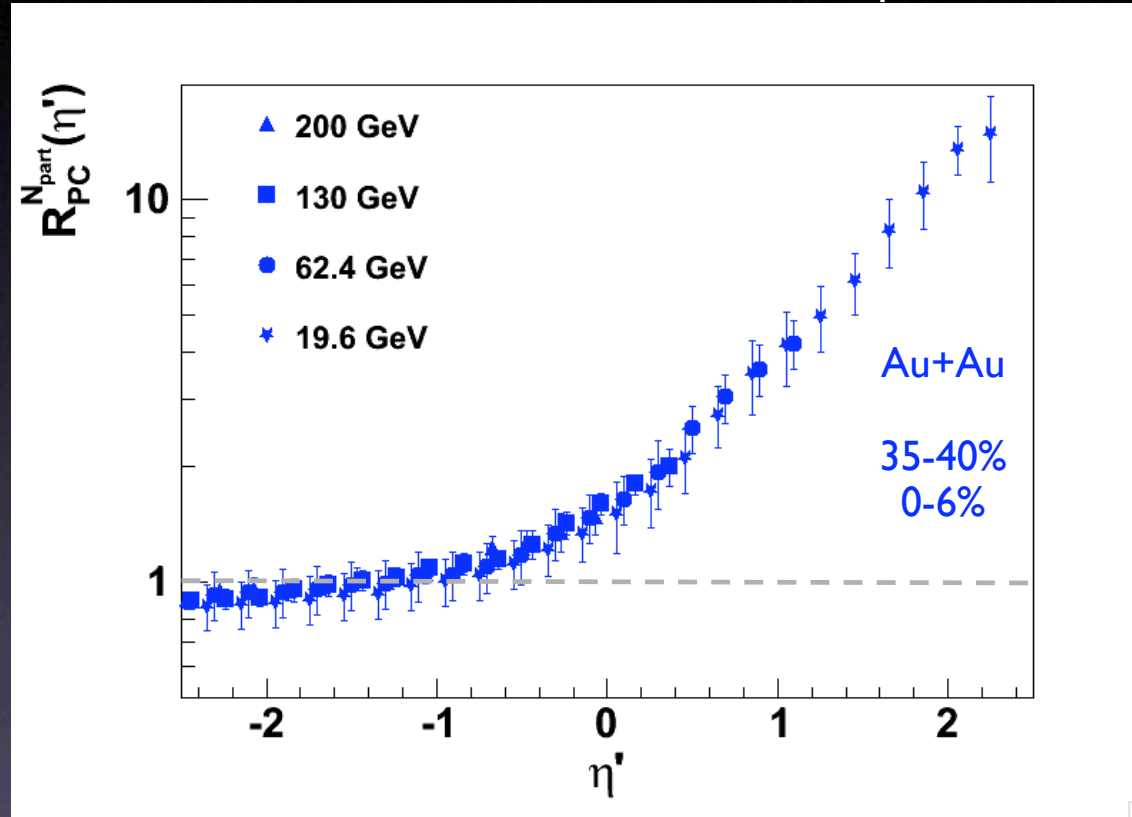
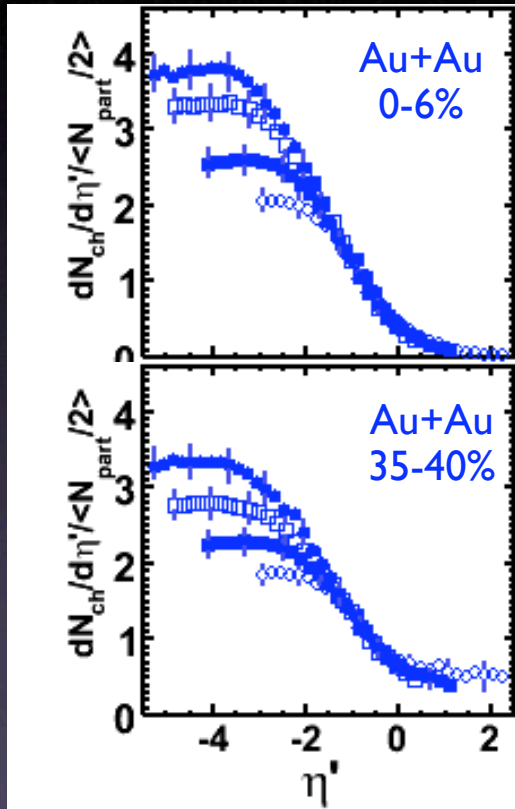
$$\frac{1}{N_{part}} \left. \frac{dN^{AA}}{d\eta} \right|_{\eta \sim 0} = N_0 \sqrt{s}^\lambda N_{part}^{\frac{1-\delta}{3\delta}}$$

Armesto, Salgado, Wiedemann hep-ph/0407018



Factorization of Longitudinal Dynamics

Ratio of 0-6% and 35-40% centrality bins, each normalized by N_{part}

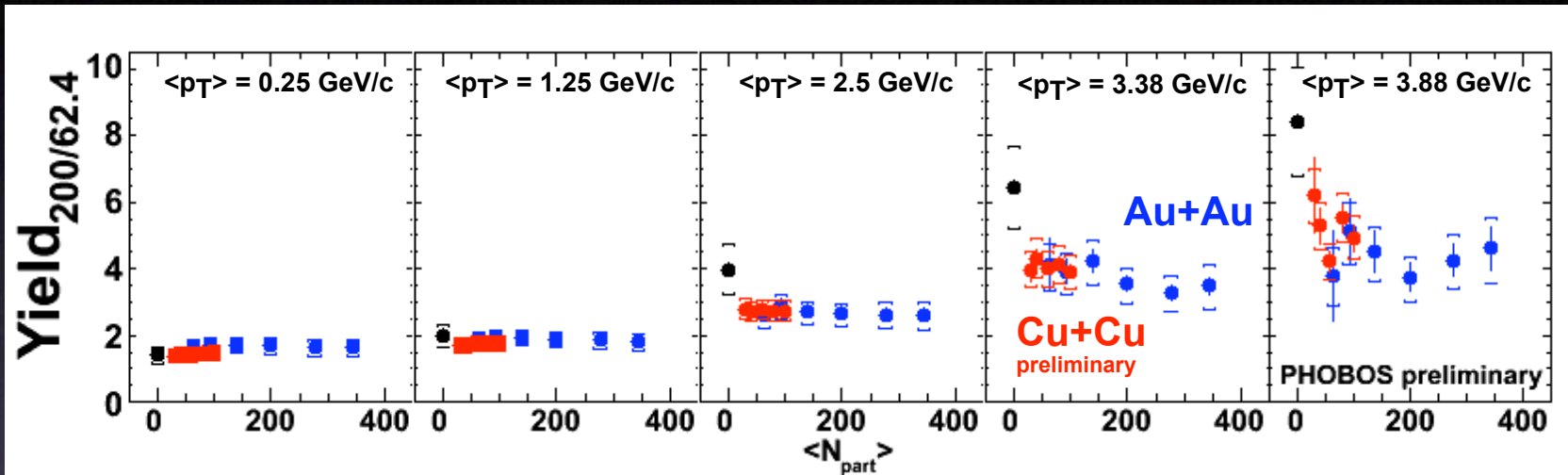


Dominance of Collision Geometry?



Factorization of Transverse Dynamics

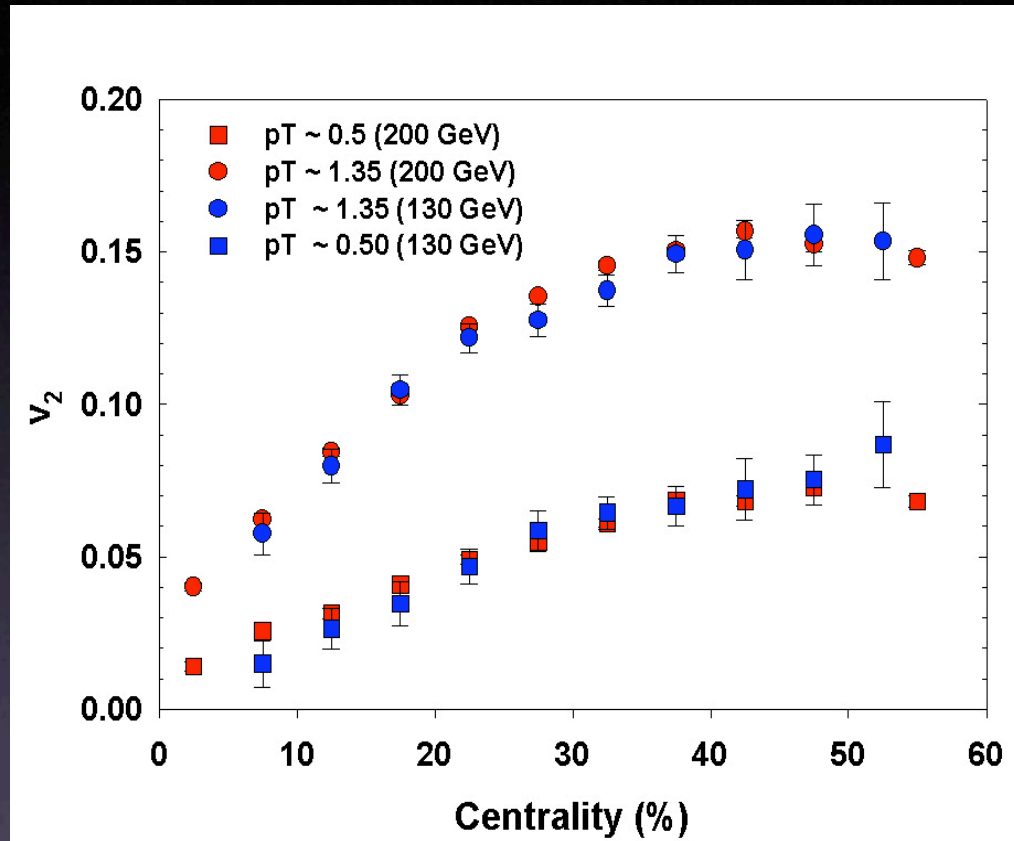
Ratio of yields in bins of p_T
between 200 and 62 GeV



Dominance of Collision Geometry?



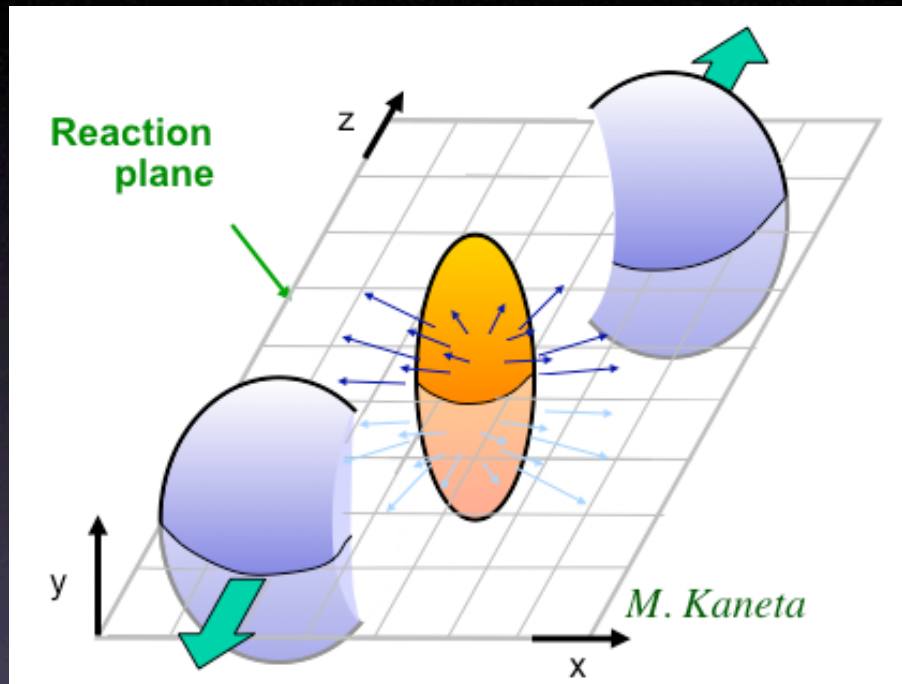
Energy independence of $v_2(p_T, N_{part})$



Factorization!

Dominance of Collision Geometry?

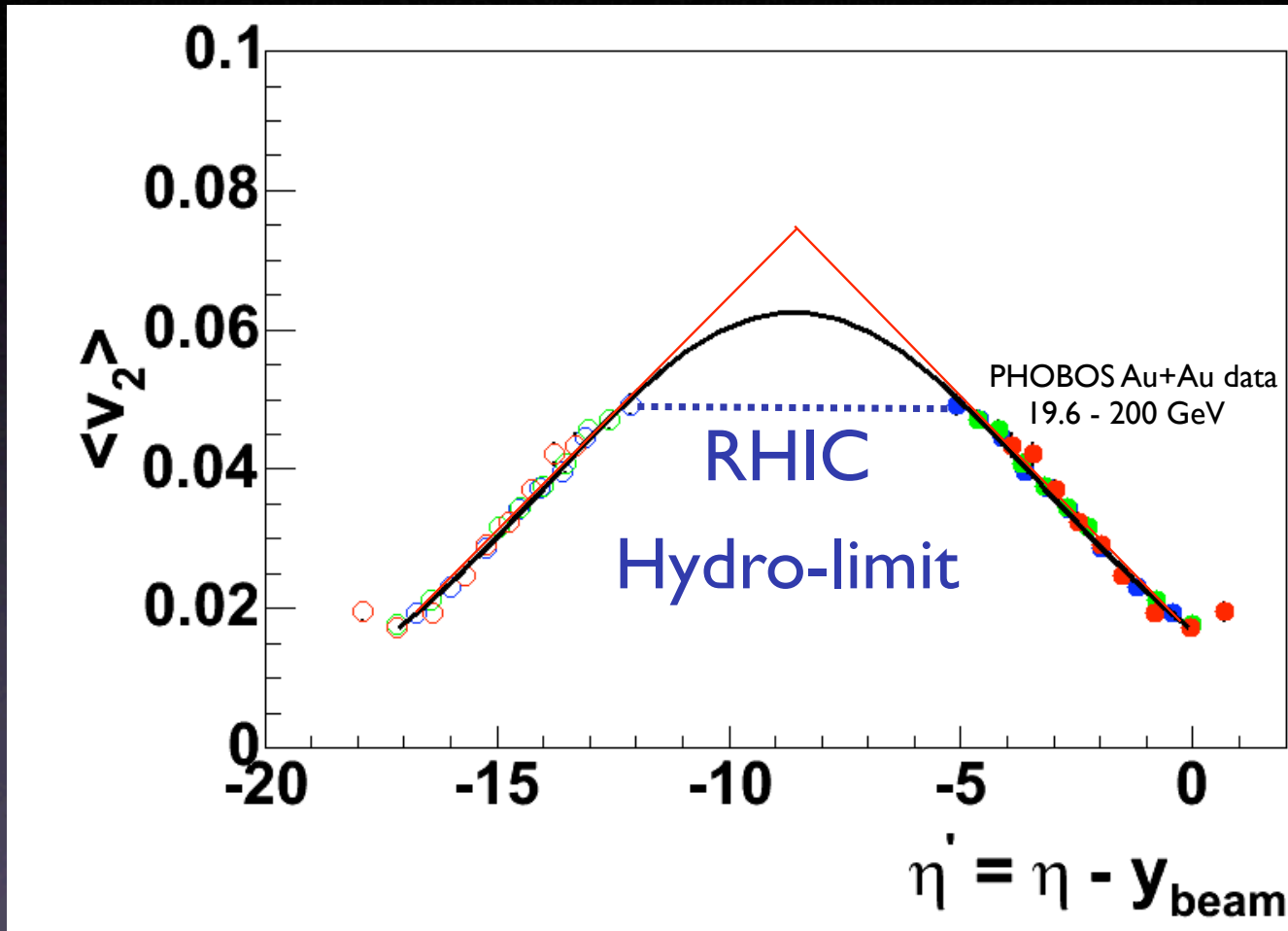
Azimuthal Anisotropy

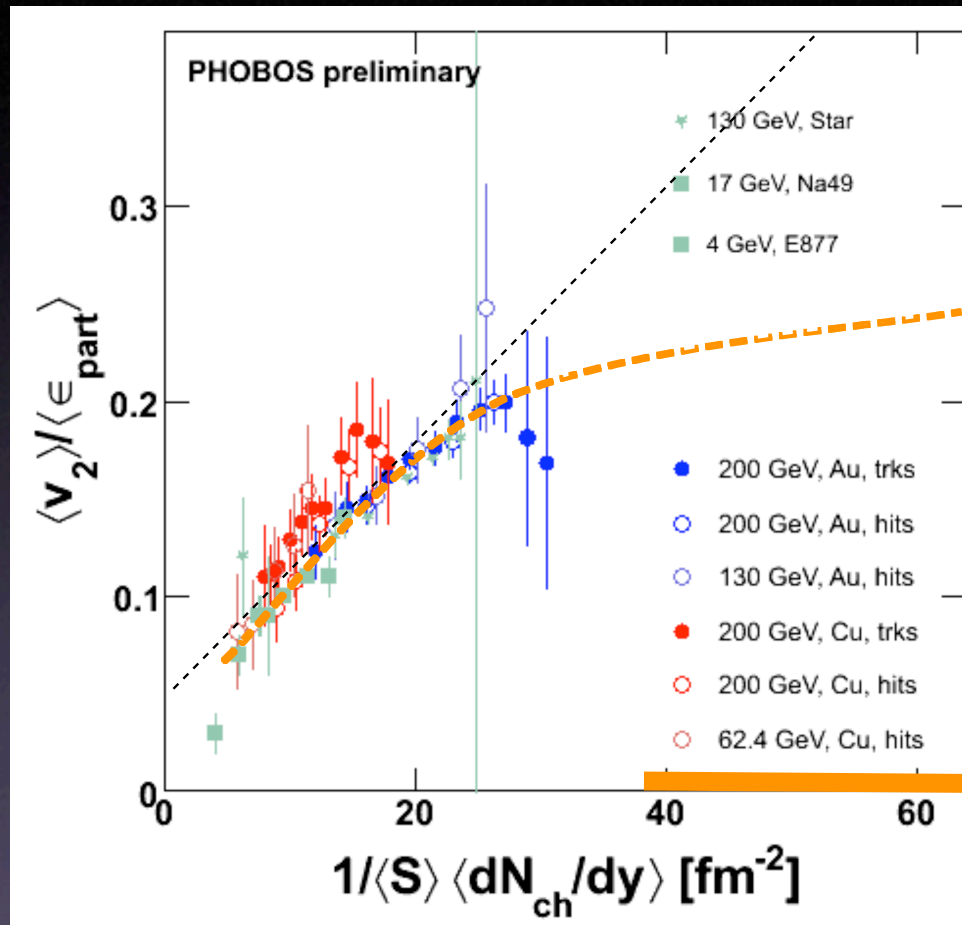


Initial State Anisotropy $\xrightarrow{\text{Interaction!}}$ Final State Anisotropy
Coordinate Space \longrightarrow Momentum Space



Elliptic Flow at LHC





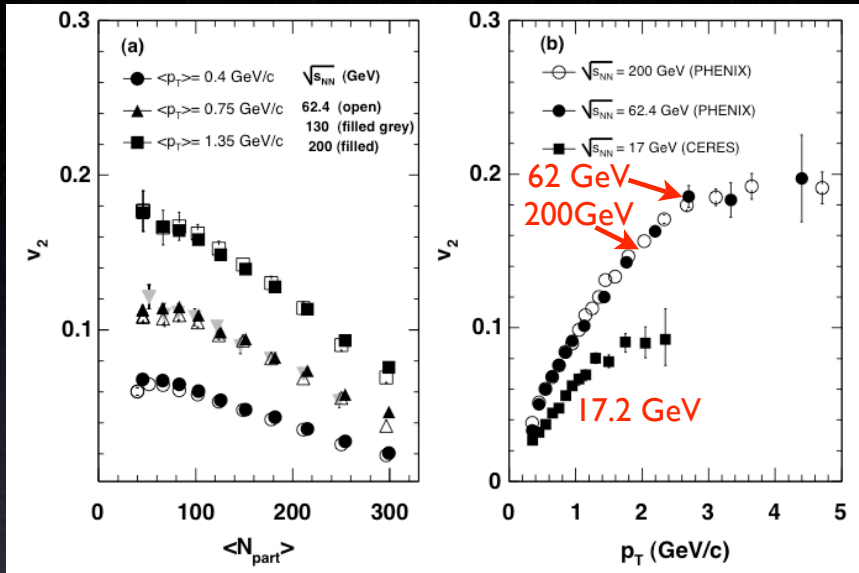
LHC

Low Density Limit:
 STAR, PRC 66 034904 (2002)
 Voloshin, Poskanzer, PLB 474 27 (2000)
 Heiselberg, Levy, PRC 59 2716, (1999)

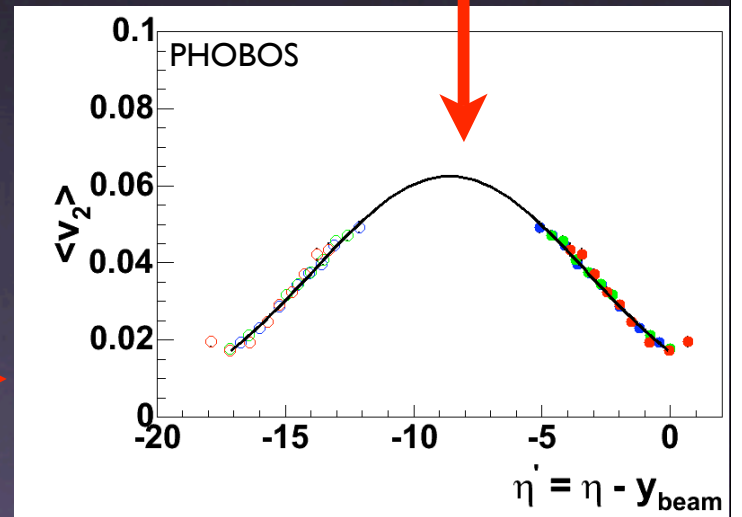
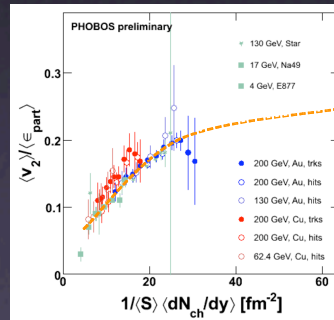
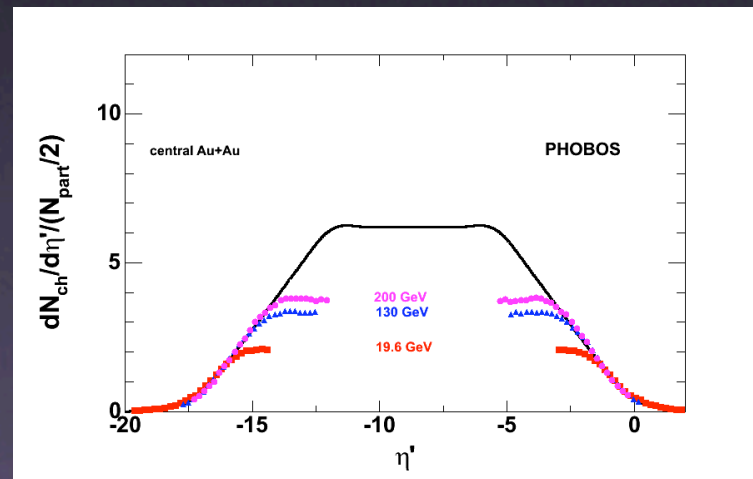
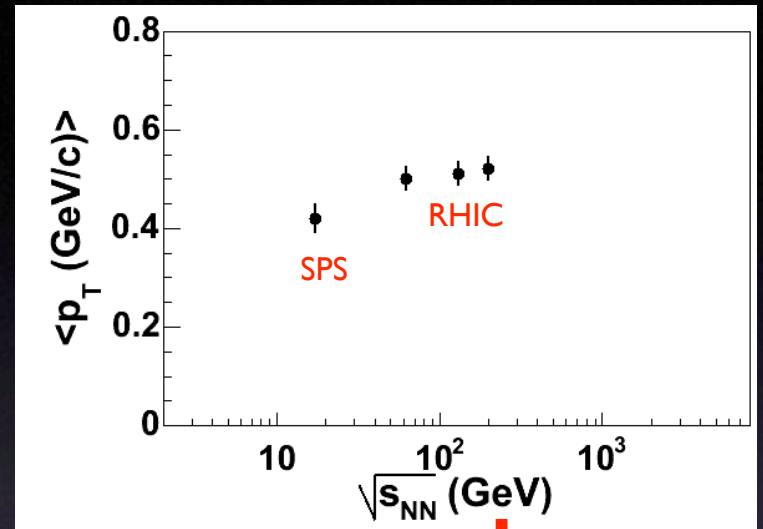


v_2 vs p_T

PHENIX nucl-ex/0411040



$\langle p_T \rangle$ vs \sqrt{s}



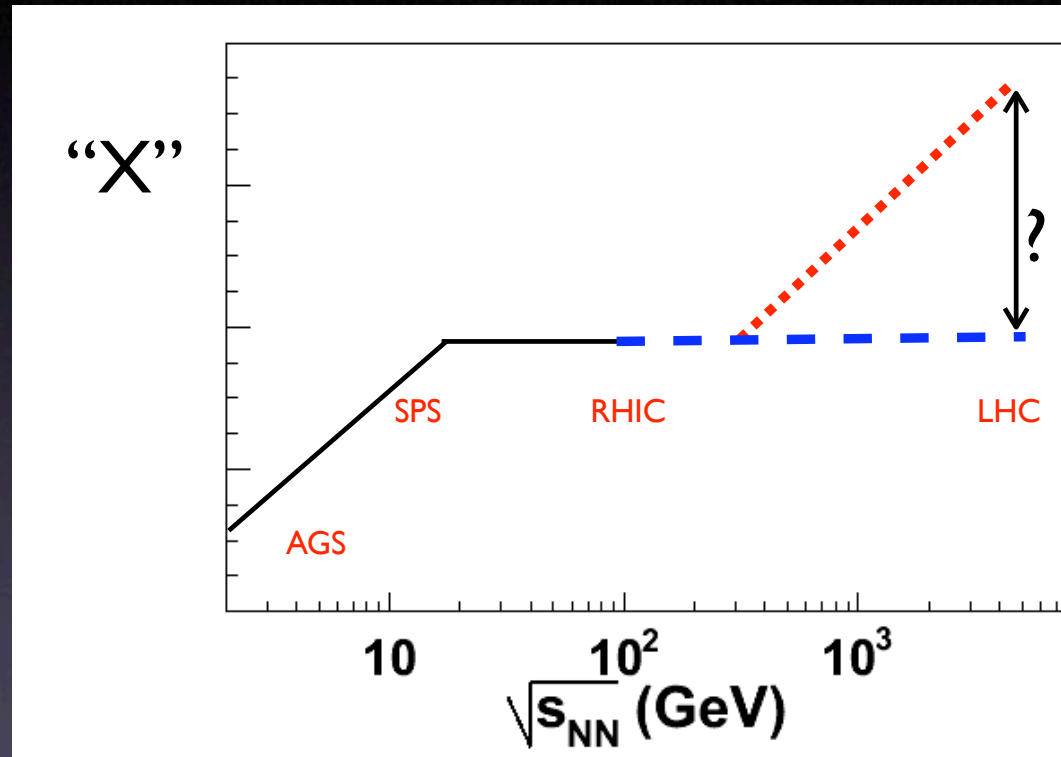
$dN/d\eta'$ vs \sqrt{s}

$v_2(\eta')$ vs \sqrt{s}



Summary

First exciting LHC results will be on “soft physics”



win/win
situation!

Dynamical connection between soft observables?

