p-p minimum-bias dijets and nonjet quadrupole in relation to conjectured collectivity (flows) in high-energy nuclear collisions

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ISMD 2015

Agenda

- ***"Ridge-like" structure in p-p and p/d-A angular correlations are said to imply "collective" motion in smaller collision systems:***

- ***Correlations associated with flows in A-A collisions appear in smaller systems $\Rightarrow$ "collectivity" extends to smaller systems***

- ***That argument could be reversed $\Rightarrow$ no "collectivity"***

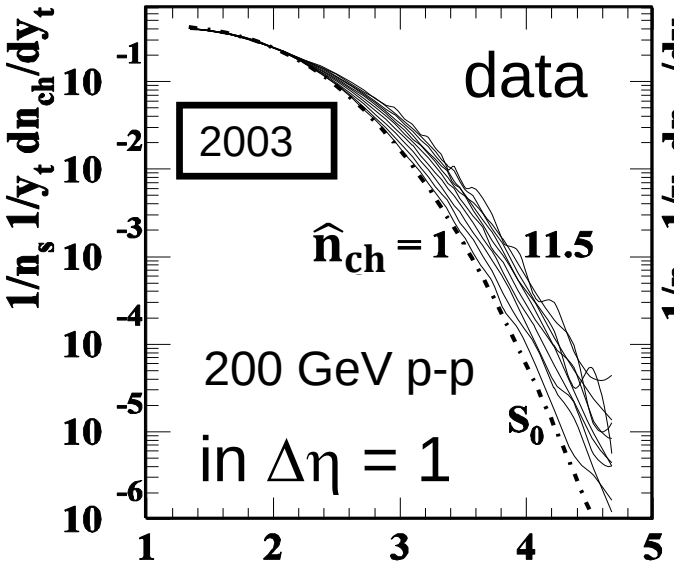
- ***Combined p-p, p-A and A-A data from RHIC and LHC suggest that soft, dijet and NJ quadrupole trends are inconsistent with hadron production from a bulk medium exhibiting hydrodynamic flows***

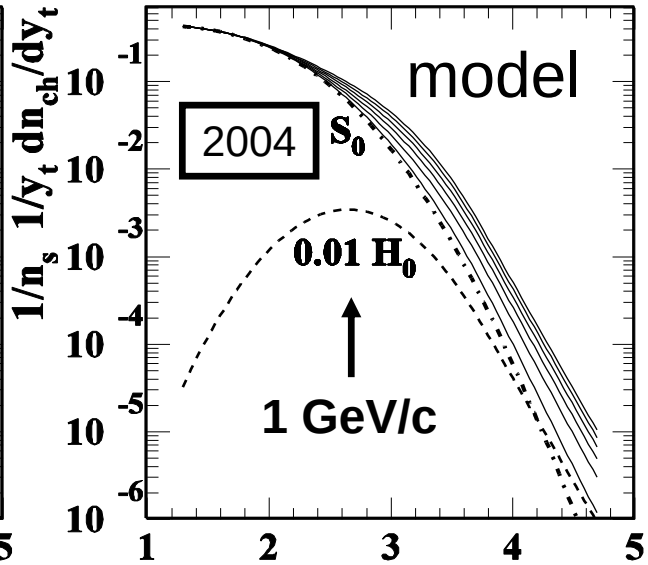
p-p Two-component Spectra – TCM

TCM: two-component (soft + hard) model

S soft:
projectile-nucleon dissociation

H hard:
hard-scattered-parton fragmentation

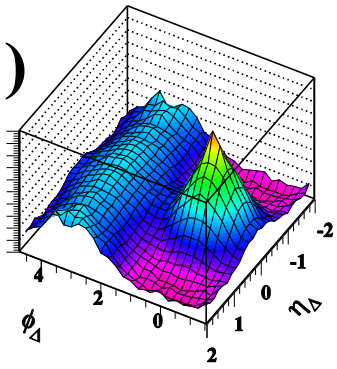


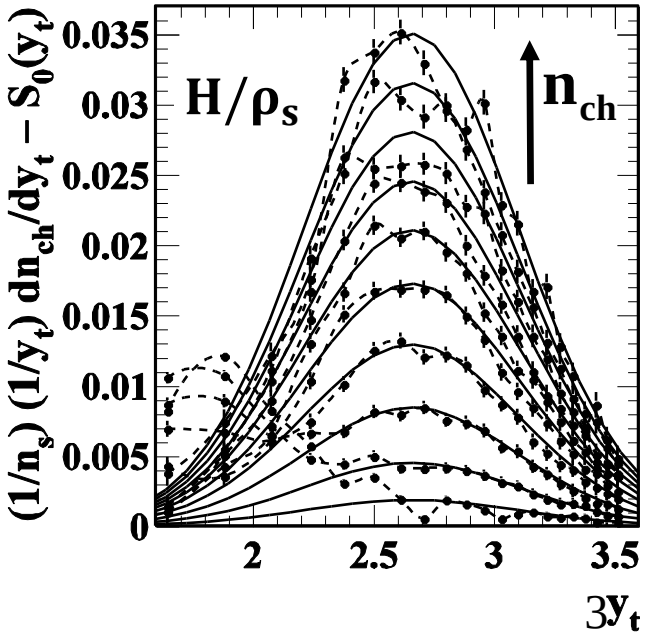


$$y_t = \ln[(m_t + p_t)/m_h]$$

$$\frac{1}{n_s}\frac{1}{y_t}\frac{dn_{ch}}{dy_t} = S_0(y_t) + \alpha\, n_s\, H_0(y_t)$$

phenomenology





$S_0(y_t)$ Lévy distribution on m_t

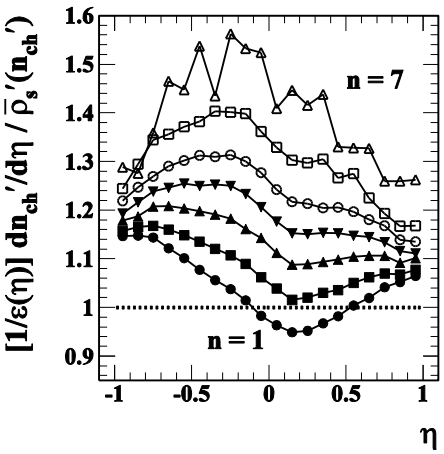
$H_0(y_t)$ Gaussian plus QCD power law on y_t

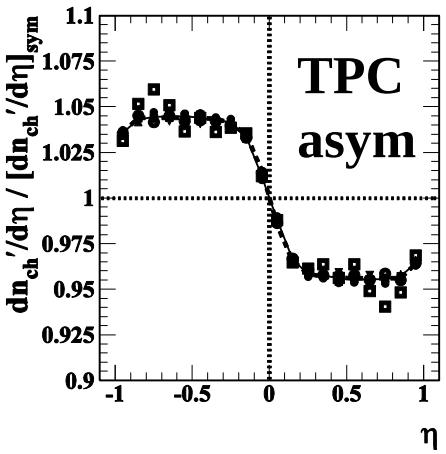
STAR PRD 74, 032006 (2006)

200 GeV p-p η Distribution TCM

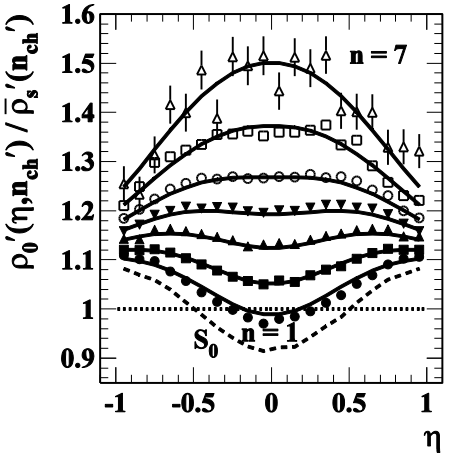
complementary to y_t spectrum TCM

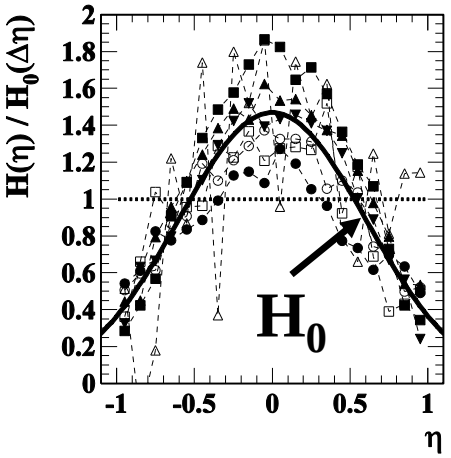
$(1/\rho_s)dn_{ch}/d\eta$



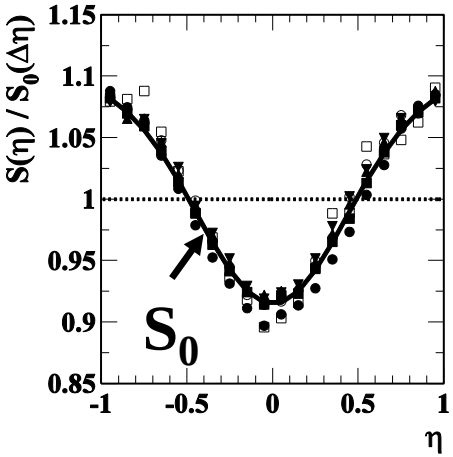


uncorrected





corrected for TPC asymmetry



soft component

$$\rho_0(\eta)=\rho_s S_0(\eta) + \rho_h H_0(\eta)$$

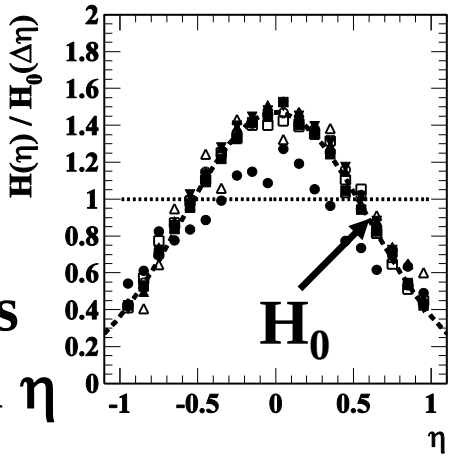
$$\rho_h=\alpha\rho_s^2$$

η-y_z Jacobian

$\propto \rho_s$

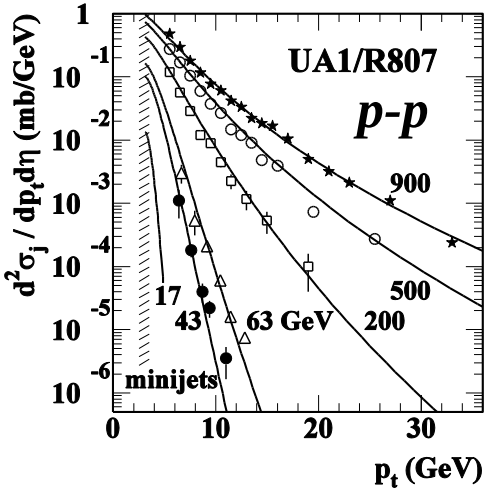
MB dijets from low-x gluons sharply peaked on η

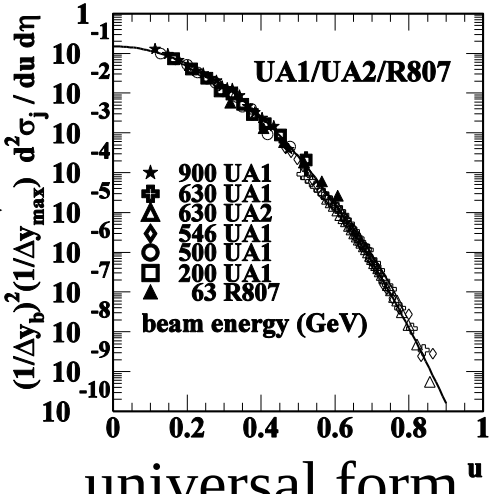
$\rho_h \propto \rho_s^2$



hard component

p-p y_t Hard Component and pQCD



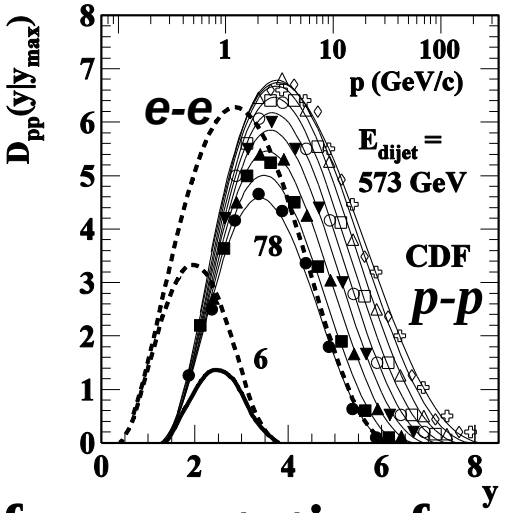


universal form

JS – MB jet spectra

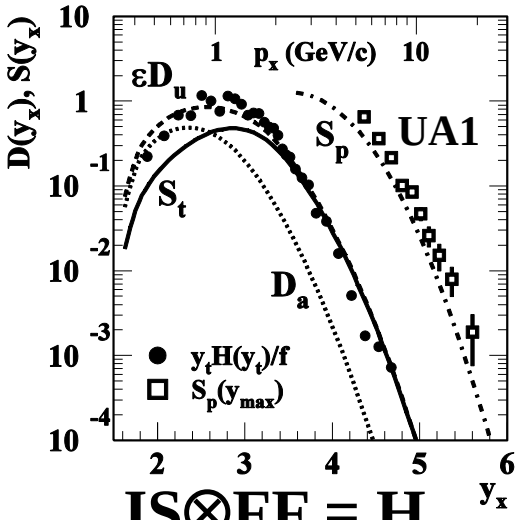
PRD 89, 094011 (2014)

⊗



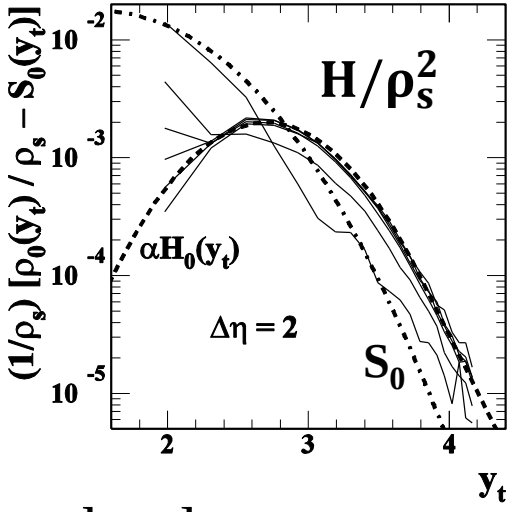
FF – fragmentation functions

PRD 74, 034012 (2006)

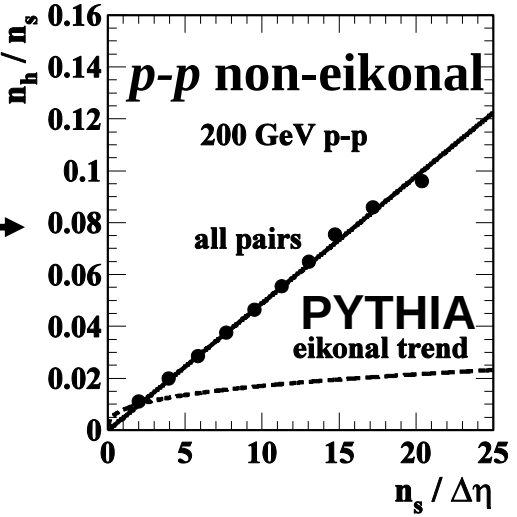


JS⊗FF = H

JPHYSG 42, 085105 (2015)



hard components

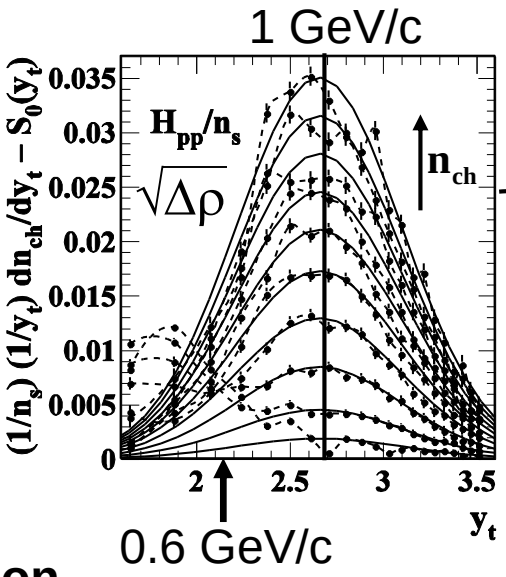


dijet production

p-p Correlations TCM

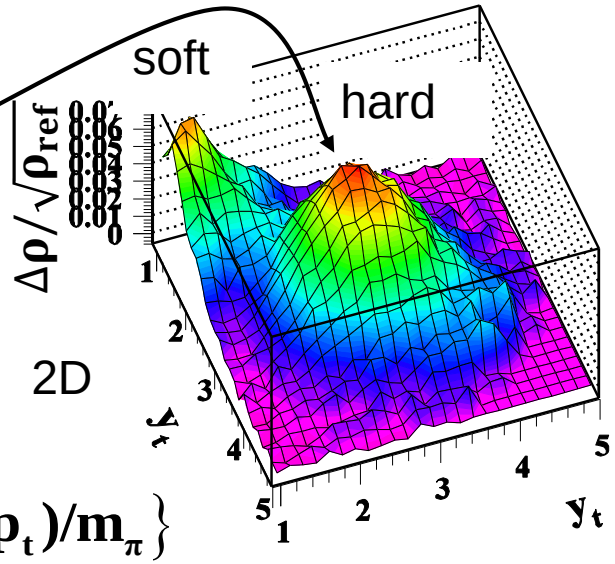
y_t spectrum hard component

PRD 74, 032006 (2006)



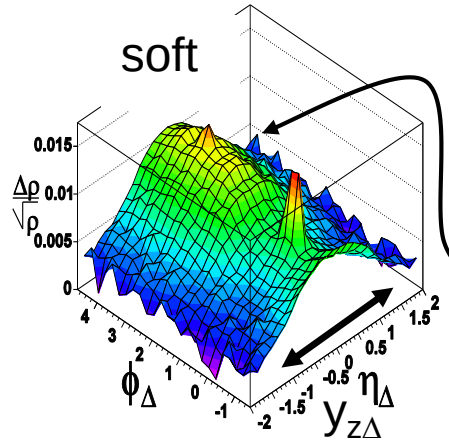
1D **2005** 2D

parton fragments

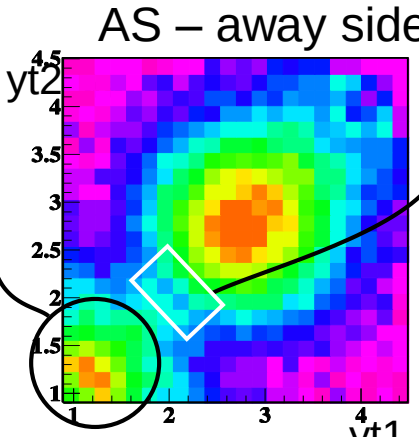


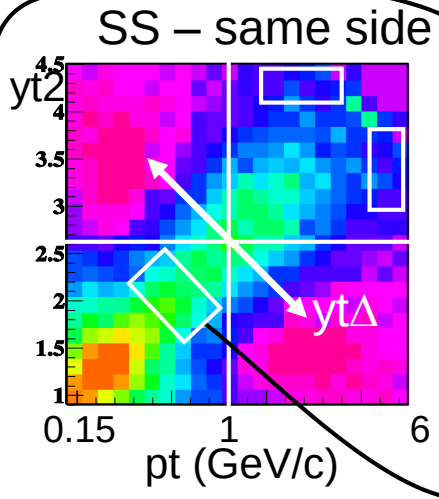
$$y_t \equiv \ln\{(m_t + p_t)/m_\pi\}$$

no trigger condition

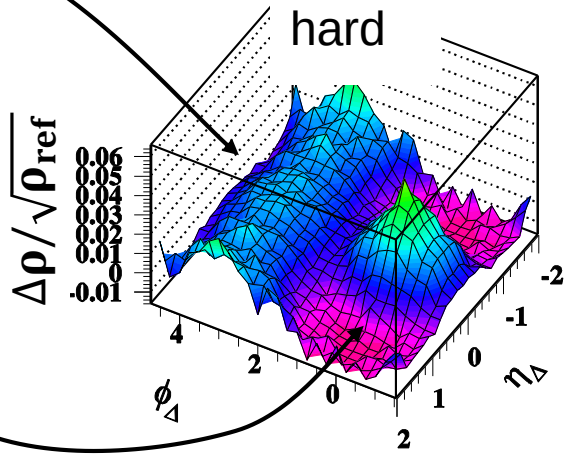


proton fragments





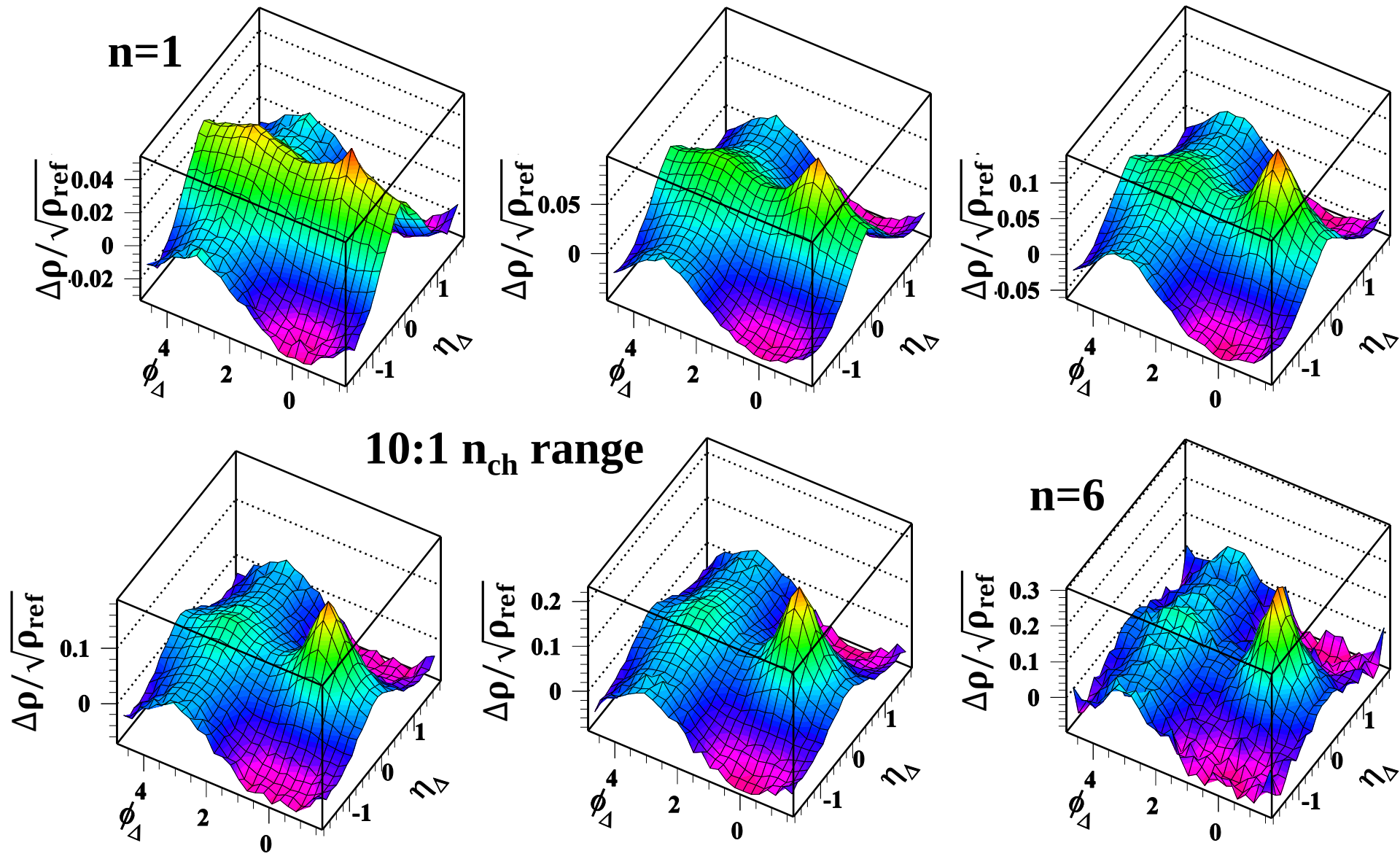
hadron $p_t \approx 0.6$ GeV/c



parton fragments

JPhysConfSer 27, 98 (2005); PoS CFRNC2006, 004 (2006)

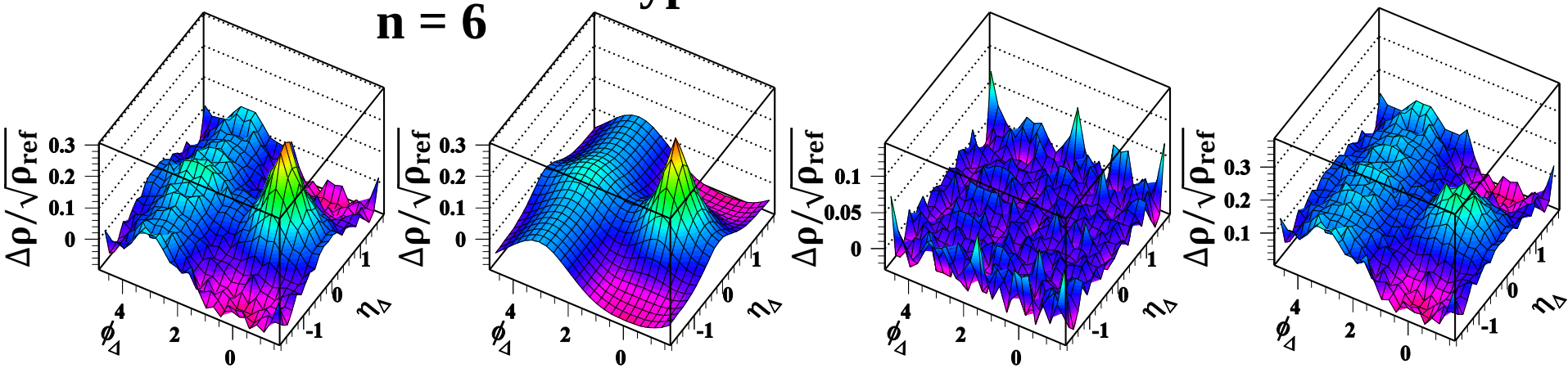
p-p Angular Correlations vs n_{ch}



p-p Angular Correlations – Model Fits

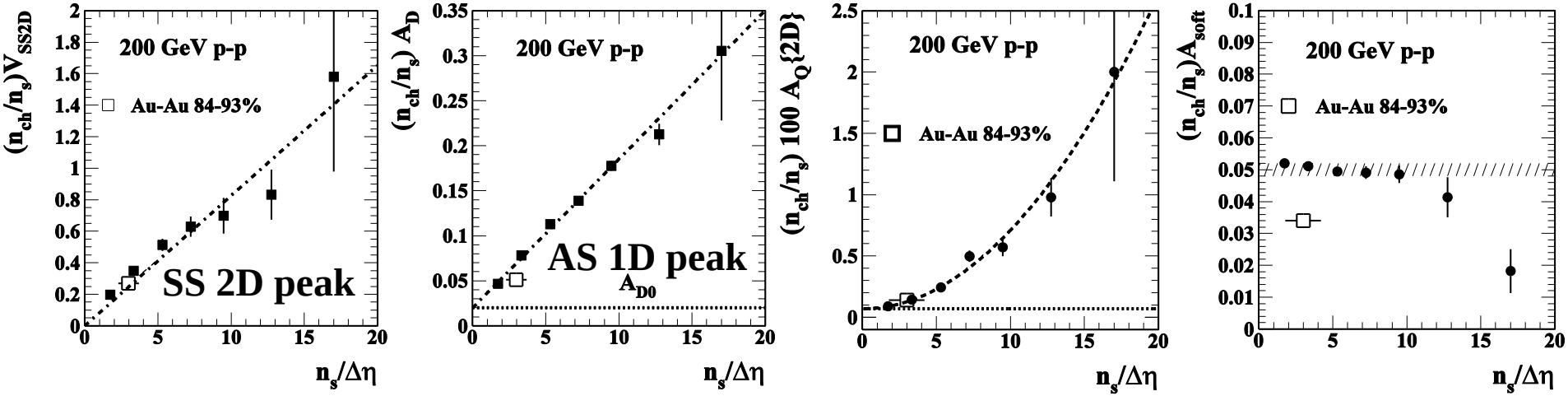
typical model fit

n = 6



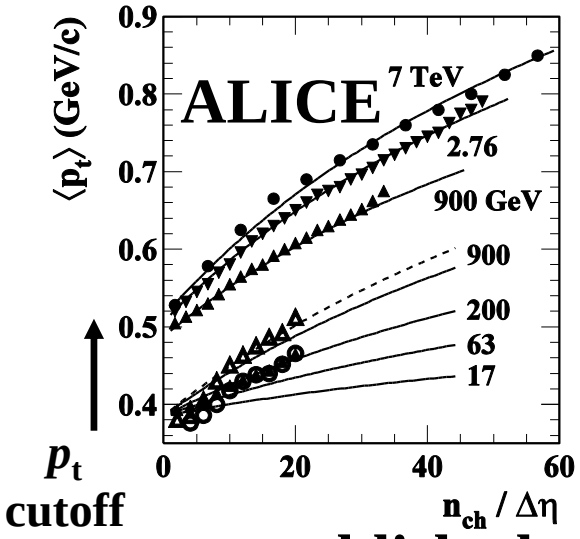
data | model | fit residuals | dijets + quad

per-participant (per low-*x* gluon) model-parameter trends

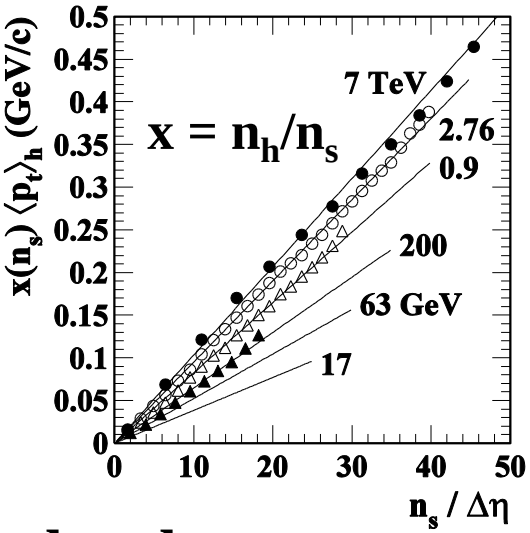


dijets $\propto \rho_s^2$ | quadrupole $\propto \rho_s^3$ | soft $\propto \rho_s$

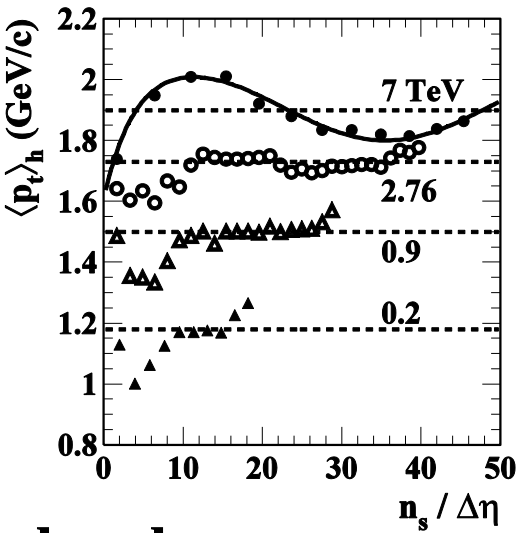
LHC *p*-*p* Ensemble-mean p_t TCM



as published

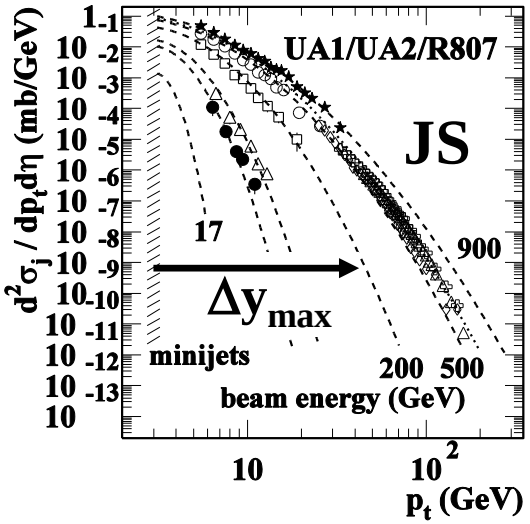


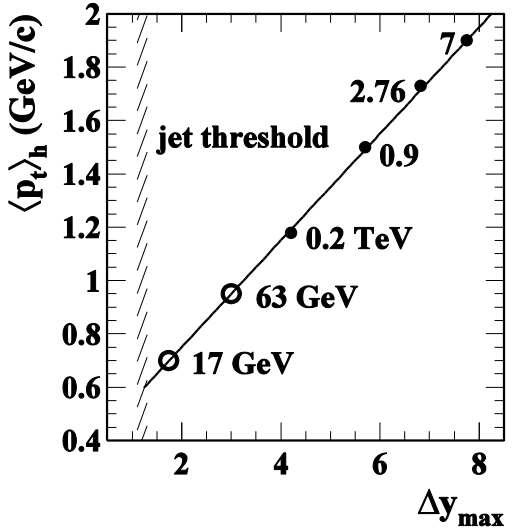
hard components



hard components

PRC 90, 024909 (2014)



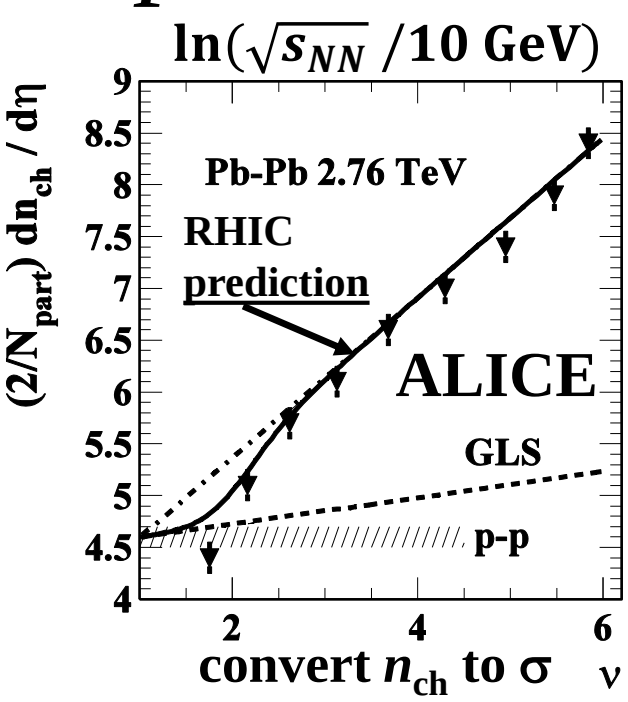


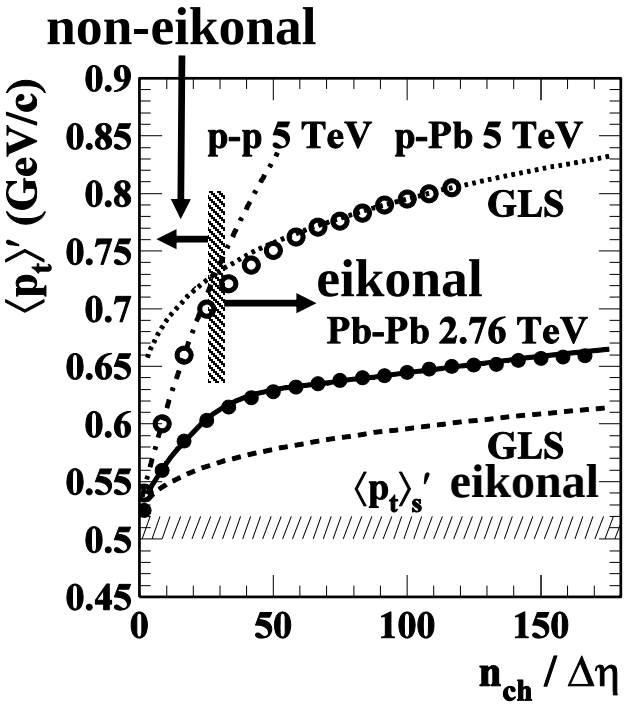
hard-component mean scales with MB jet spectrum width

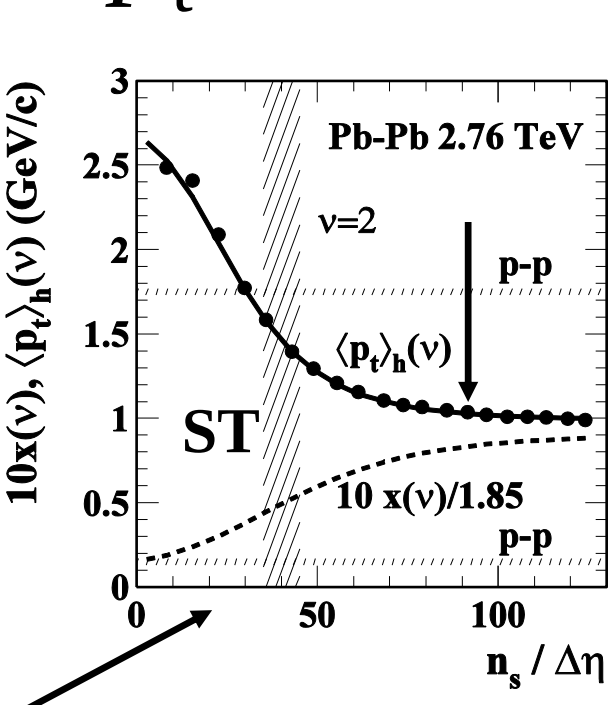
variation dominated by dijets

MB jet spectrum width $\propto \Delta y_{max} = \log\left(\sqrt{s}/3\ \mathrm{GeV}\right)$

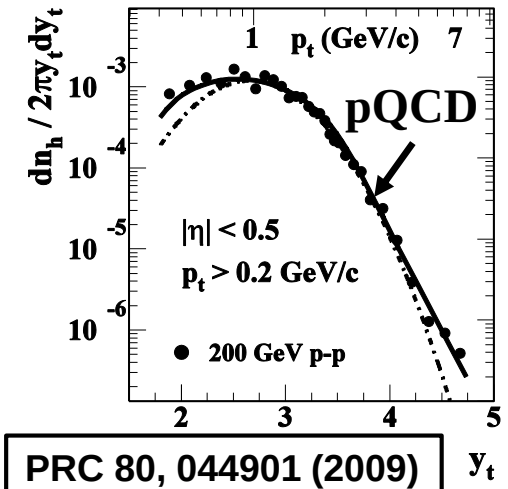
p-A, A-A Ensemble-mean p_t TCM



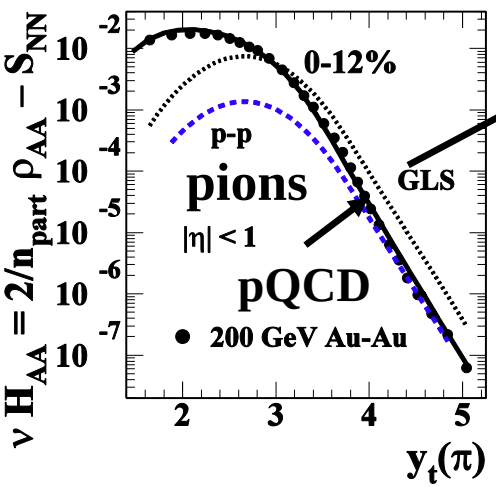




PRC 90, 024909 (2014)



PRC 80, 044901 (2009)



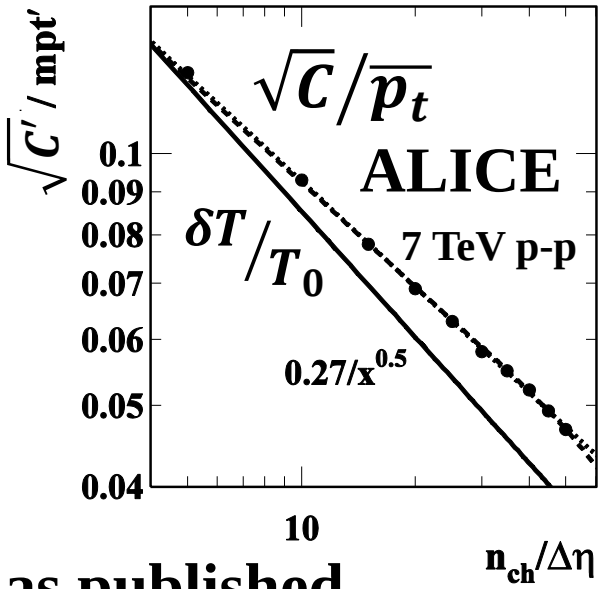
A-A hard-component mean-p_t falls with increasing centrality

FF modification!

Monte Carlos falsified

hard components predicted by pQCD

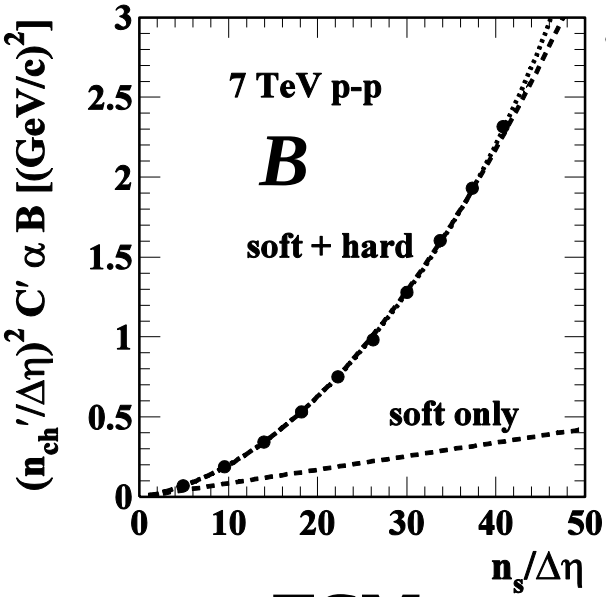
LHC *p*-*p* p_t fluctuations TCM



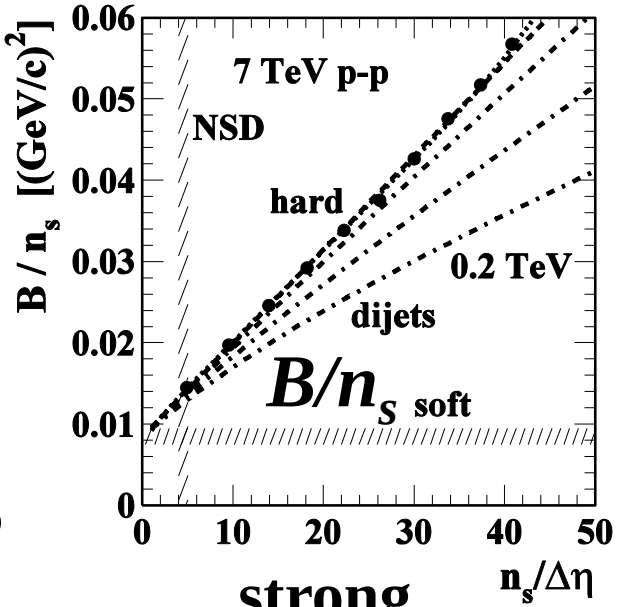
as published

$\Rightarrow$ "collectivity,"

no energy dependence



TCM dominated by MB dijets



strong energy dependence

arXiv:1503.02197, PRC

$$C = \frac{B}{n(n-1)} \sim \frac{1}{n_s}$$

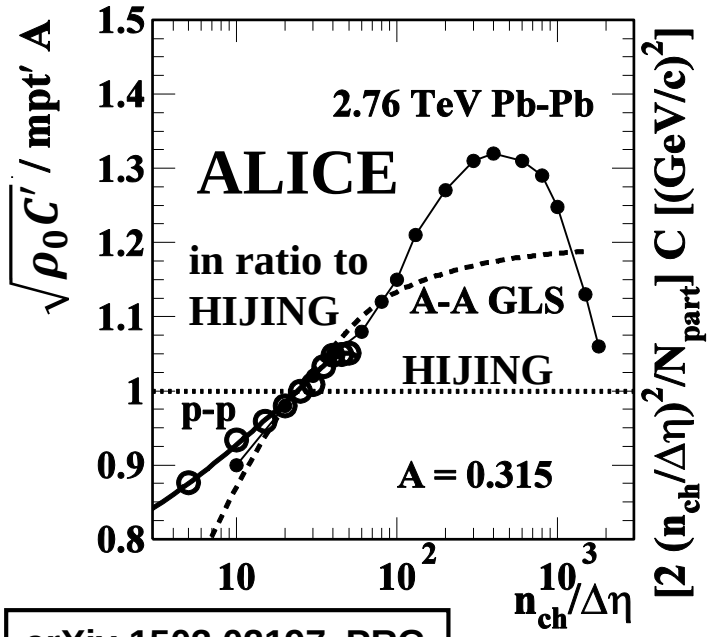
intensive

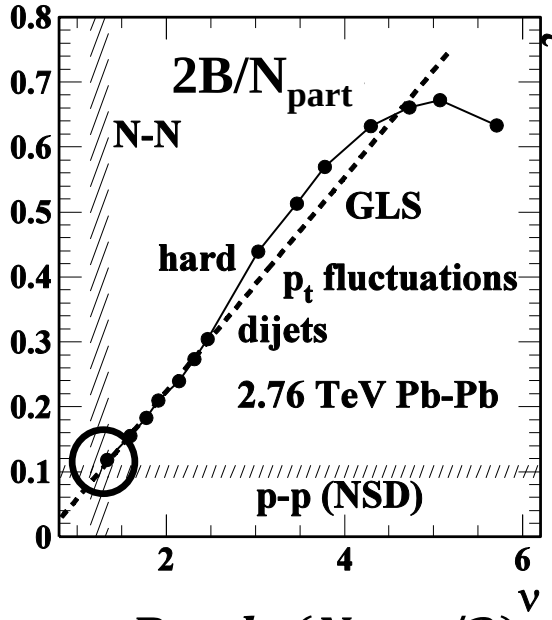
$$B \equiv \overline{(P_t - n\,\overline{p_t})^2} - \bar{n}\sigma_{p_t}^2 = b_s n_s + b_h\,\alpha n_s^2$$

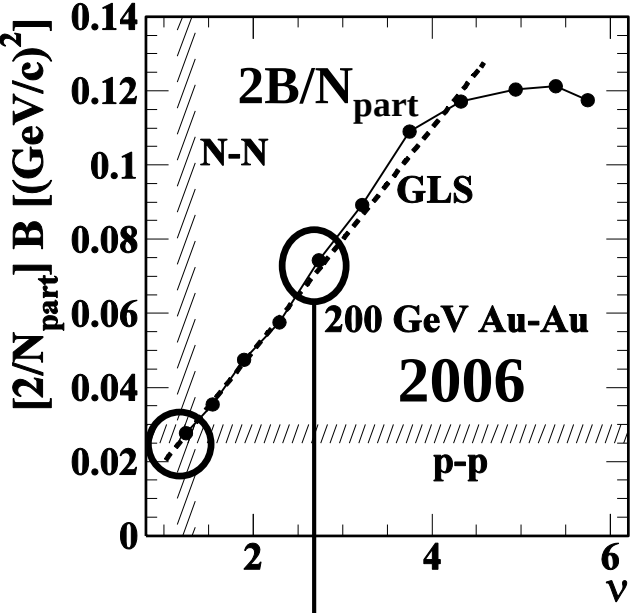
extensive

$\sqrt{C}/\overline{p_t}$ ratio of ratios conceals MB dijet contribution

A-A p_t fluctuations TCM





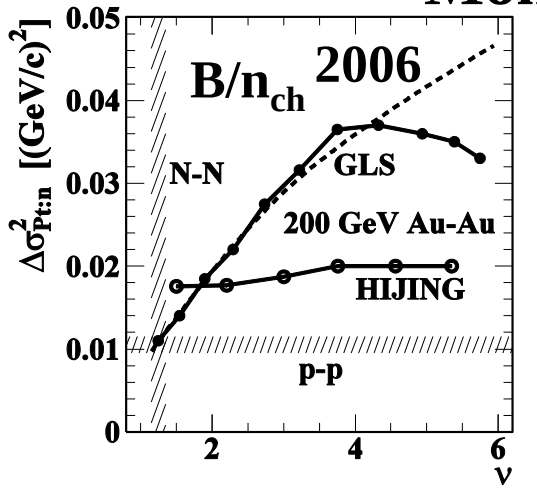


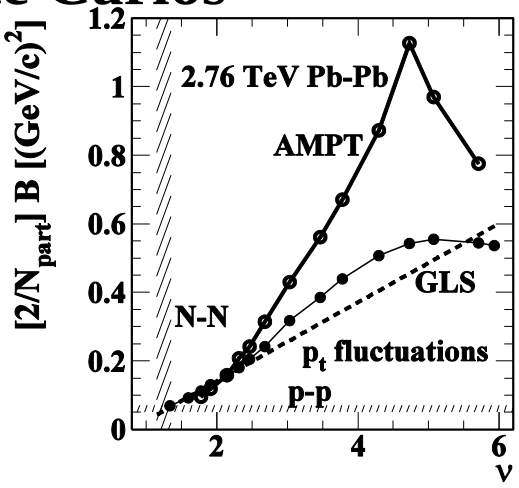
arXiv:1503.02197, PRC

Monte Carlos

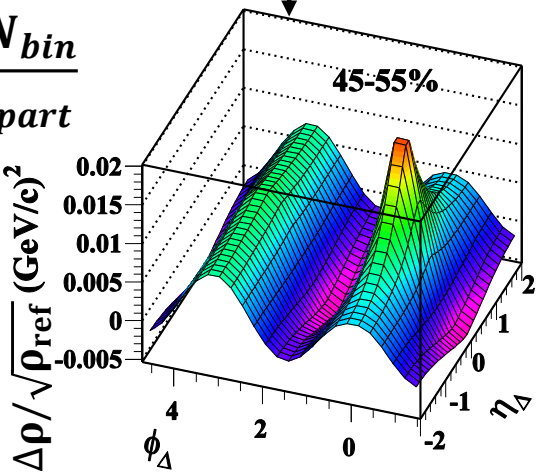
$$B = b_s(N_{part}/2) + b_h N_{bin}$$

inversion





$$\nu = \frac{2N_{bin}}{N_{part}}$$



bare HIJING

with "rescattering"

dijet dominated

v_2 NJ Quadrupole Trends – I

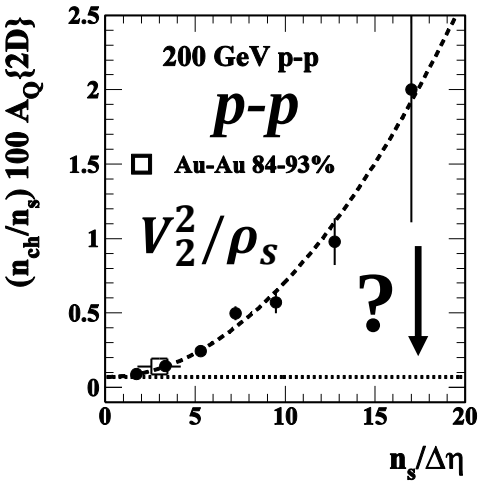
$A_Q \equiv \rho_0 v_2^2$ **(per particle)** $V_2^2 \equiv \rho_0^2 v_2^2$ **(all correlated pairs)**

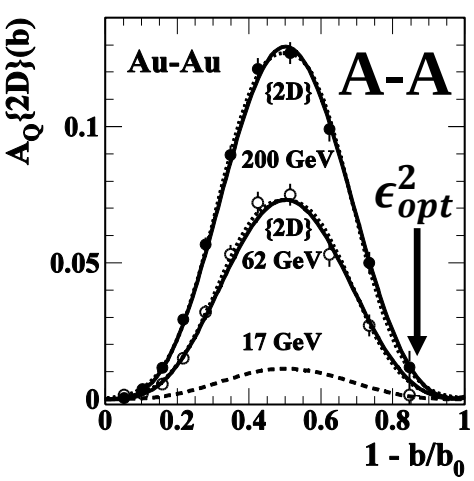
n_{ch} trends: **2008** JPHYSG 42, 025102 (2015)

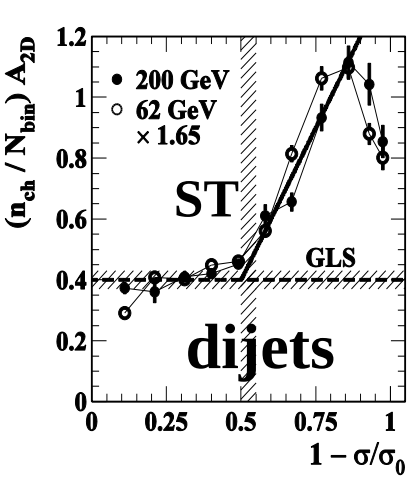
A-A $V_2^2 \propto \rho_s \rho_h \propto \rho_s^{7/3} \propto N_{part} N_{bin} \epsilon^2_{optical}$ **(eikonal)**

p-p $V_2^2 \propto \rho_s \rho_h \propto \rho_s^3 \propto N_{part} N_{bin}$ **(non-eikonal, no "centrality")**

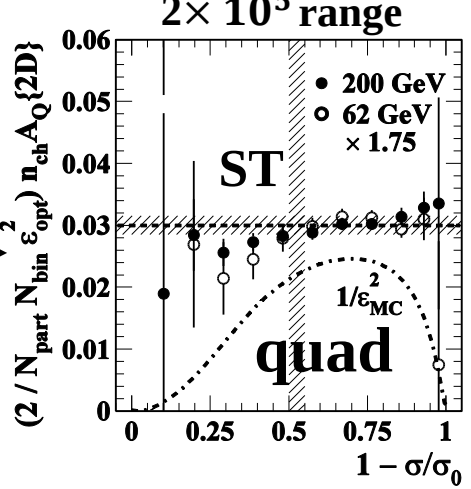
quad energy trend: $\propto \log(\sqrt{s_{NN}}/10\ \text{GeV})$ **same as dijets**







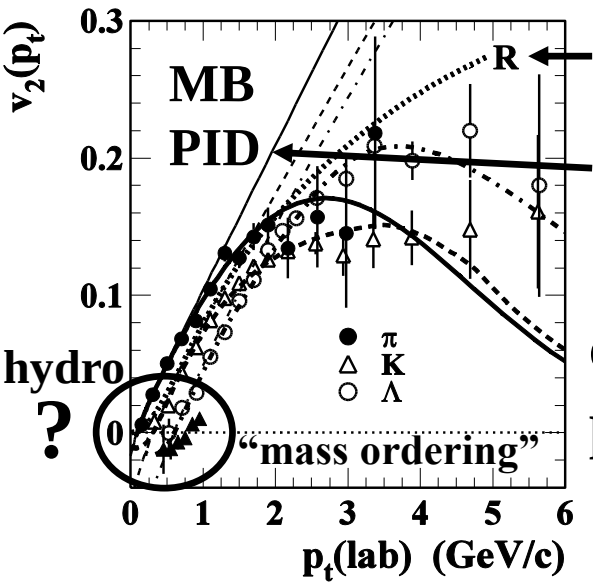
2× 10^5 range



$V_2^2 \propto \rho_s^3$ $V_2^2 \propto N_{part} N_{bin} \epsilon^2_{optical}$ **A-A centrality dependence: no bulk medium**

PRC 78, 064908 (2008)

NJ Quadrupole Trends – II

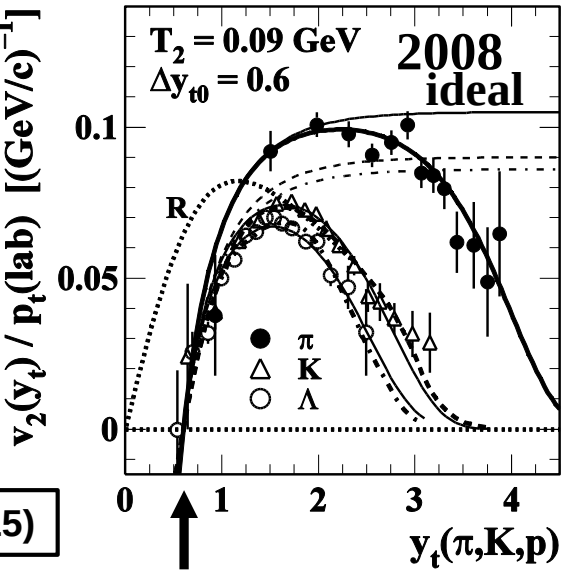


viscous hydro

ideal hydro

$\propto p_{t,boost}$

conventional presentation

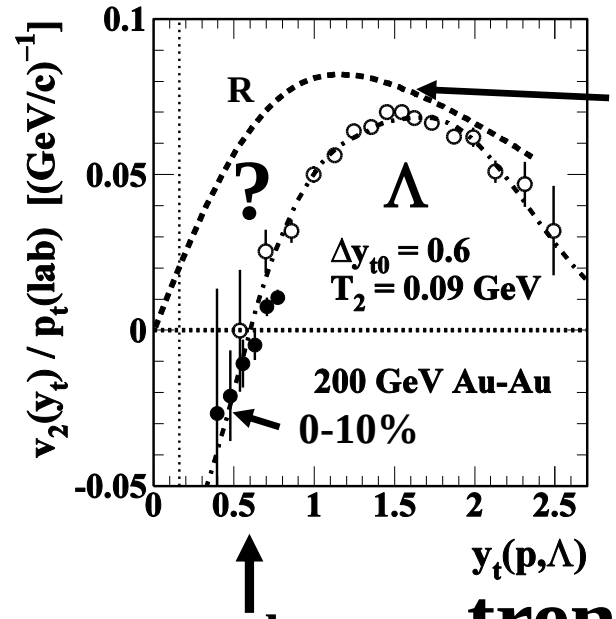


on rapidity

common source boost

rapidity

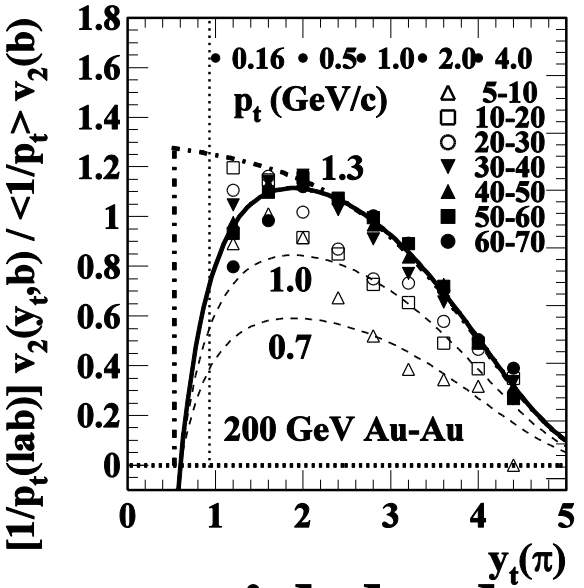
PRC 91, 064910 (2015)



hydro falsified

thin cylindrical shell – no Hubble

source boost



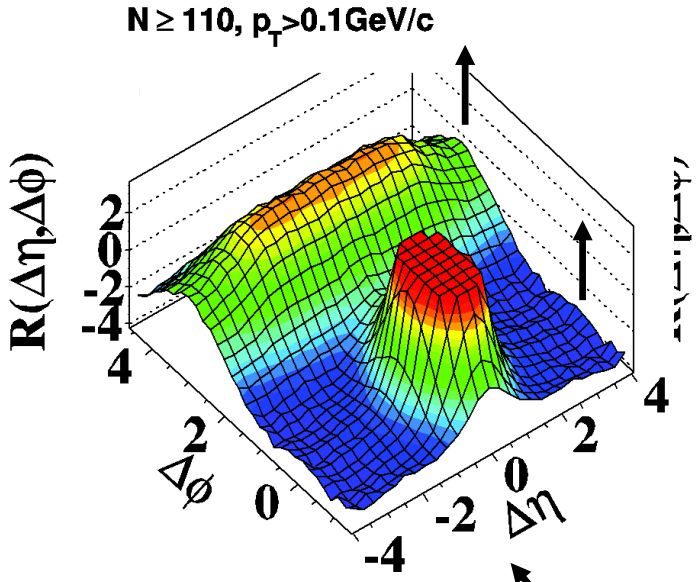
fixed source boost

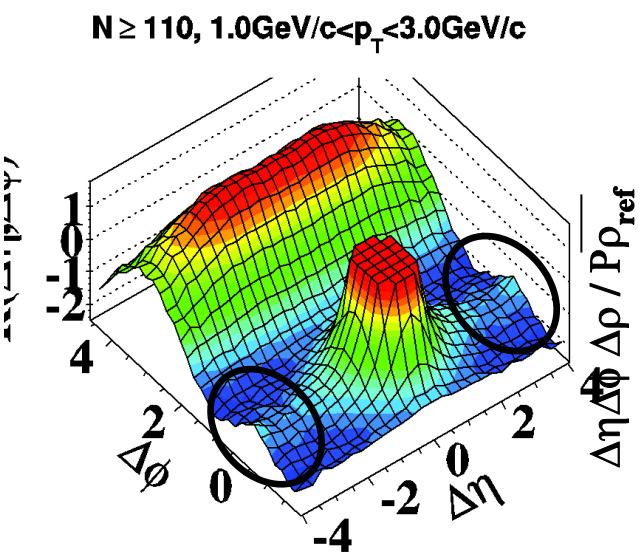
no A-A centrality dependence

trends inconsistent with hydro

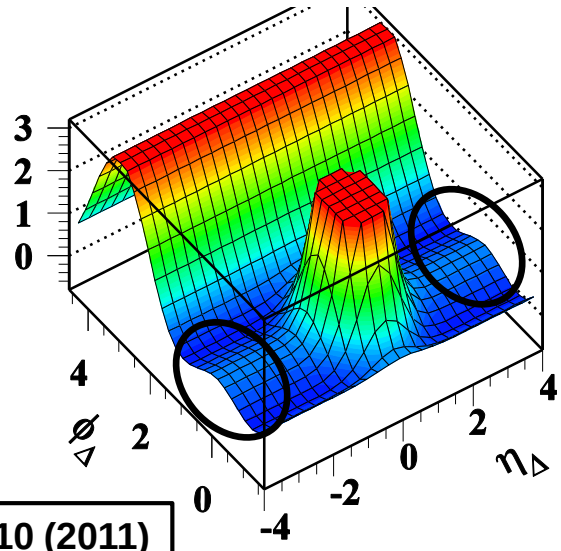
$dn_{ch}/d\eta$ CMS *p*-*p* Ridge – 2010

110/4 = 27.5 = 6xNSD





extrapolation from 200 GeV



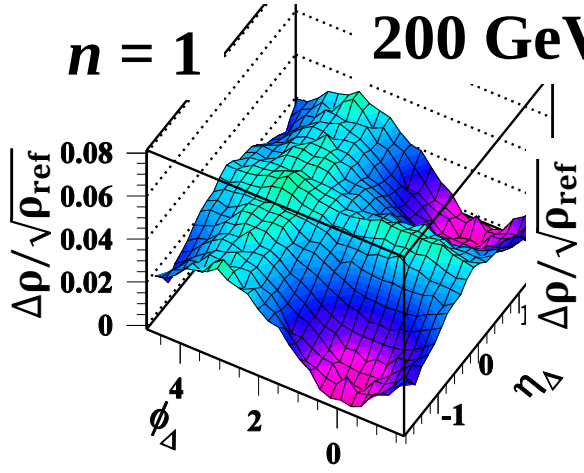
PRC 84, 024910 (2011)

0.7xNSD

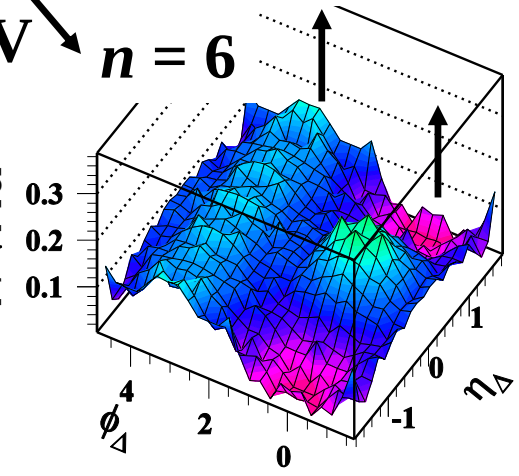
18.7 = 7.5xNSD

200 GeV

***n* = 1**



***n* = 6**



<u>1000-fold</u> increase in NJ quadruple with n_{ch}

NJ quadrupole component extrapolated from RHIC explains CMS "ridge"

Summary

- ***TCM describes collision systems accurately***
- ***Dijets dominate high-energy nuclear collisions***
- ***“Ratios of ratios” conceal large dijet contributions***
- ***p-p collisions are non-eikonal (quantum system)***
- ***NJ quadrupole trends are inconsistent with hydro***
- ***CMS p-p “ridge” is NJ quadrupole manifestation***