PHENIX measurements of E_T distributions in p-p, d+Au and Au+Au at $\sqrt{s_{NN}}$=200 GeV and analysis based on Constituent-Quark-Participants

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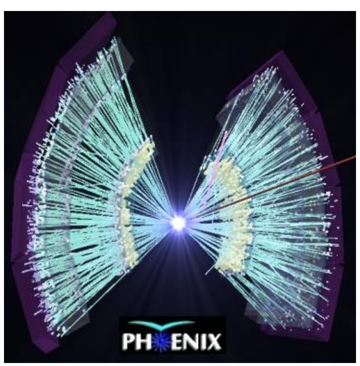

Heavy Ion Forum
CERN, Geneva, SZ
December 12, 2013

One of the more memorable of the proposals from my service on Bob Wilson's Program Advisory Committee at FNAL from 1972-75

NAL Proposal NO. 178
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June, 1972

A study of the average multiplicity and multiplicity distributions in hadron-nucleus collisions at high energies

W. Busza, J. I. Friedman, H. W. Kendall and L. Rosenson
Massachusetts Institute of Technology, Cambridge, Massachusetts

ABSTRACT

In a simple counter experiment requiring about 40 hours of data taking time we propose to study the detailed shape of the multiplicity distribution for larger values of n and the average charged particle multiplicity in hadron-nucleus collisions at 100 and 200 Gev.

The results of the experiment should be a valuable input for comparison with theoretical models, in particular they should provide a sensitive test of whether multiparticle production in hadron-nucleon collisions proceeds through a one or two step process.

This was the first accelerator experiment specifically designed to study the charged multiplicity in high energy p+A collisions

Wit proposed ONE photomultiplier!

T_1, T_2 & V : Scintillation Counters
$\check{C}_1$ & $\check{C}_2$: Čerenkov Counters with Polystyrene Radiators
$\check{C}_3 - \check{C}_6$: Čerenkov Counters with Pilot 425 Radiators

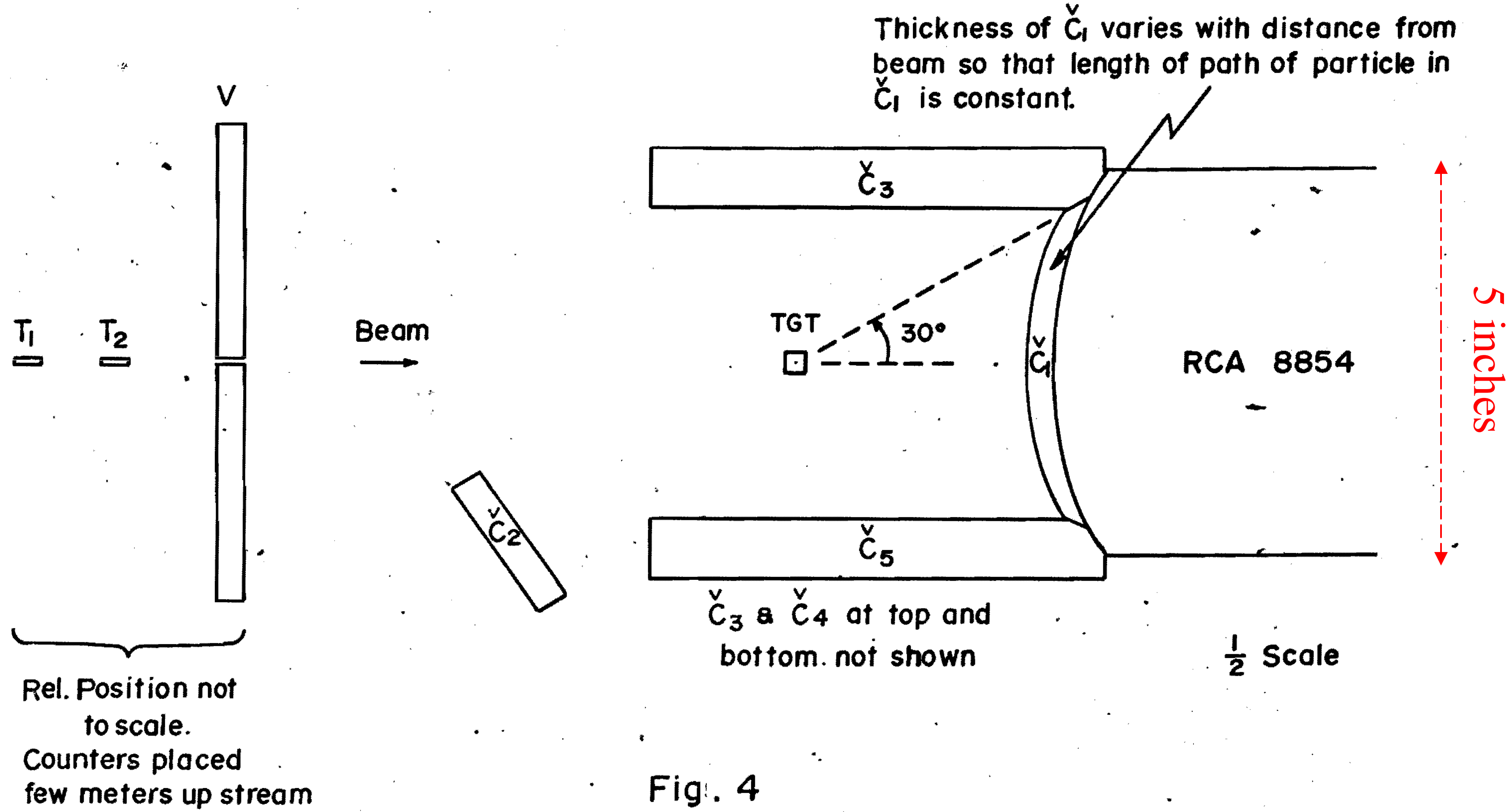
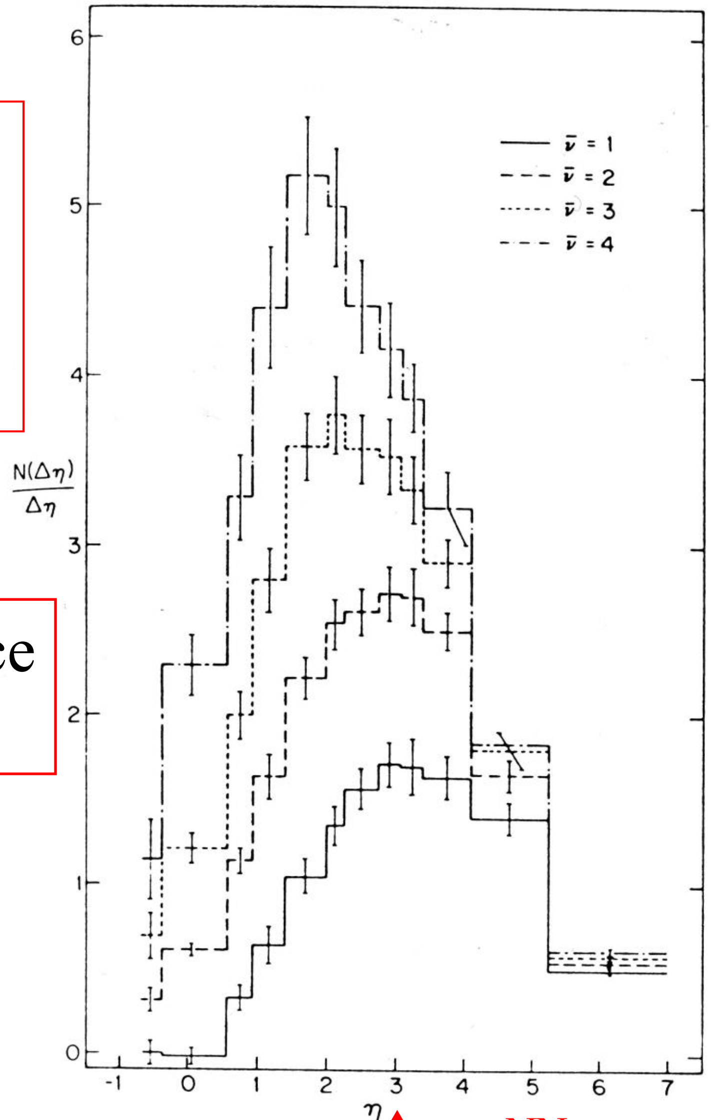


Fig. 4

Result of E178 was revolutionary-I

p+A where A is represented by average number of collisions $\overline{\nu}$

Strong dependence on rapidity



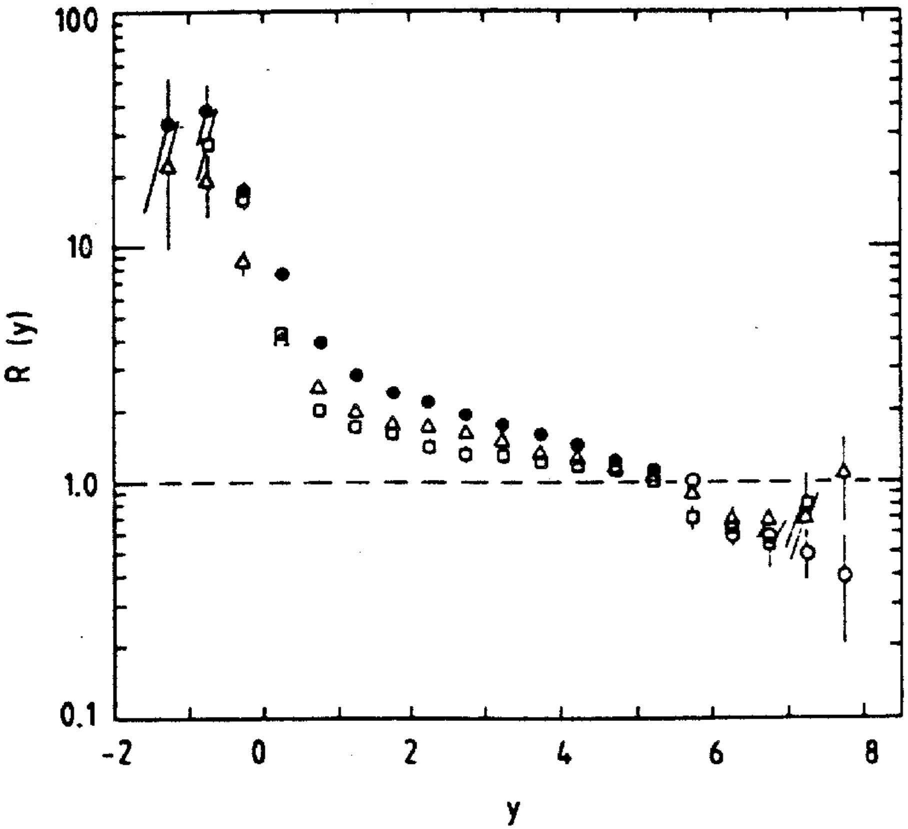
200 GeV fixed target ↑ y^{NN}_{cm}=3.0

PRL **39**, 1499 (1977)

- NO CHANGE (η>5)
  Forward fragmentation
  proton passes through!!
- Tremendous Activity
  Target region (η<0.5)

★ Mid rapidity: $dn/d\eta$ increases with A with small shift backwards with increasing A

Same Features from CERN streamer Chamber



PRD **29** (1984) 2476

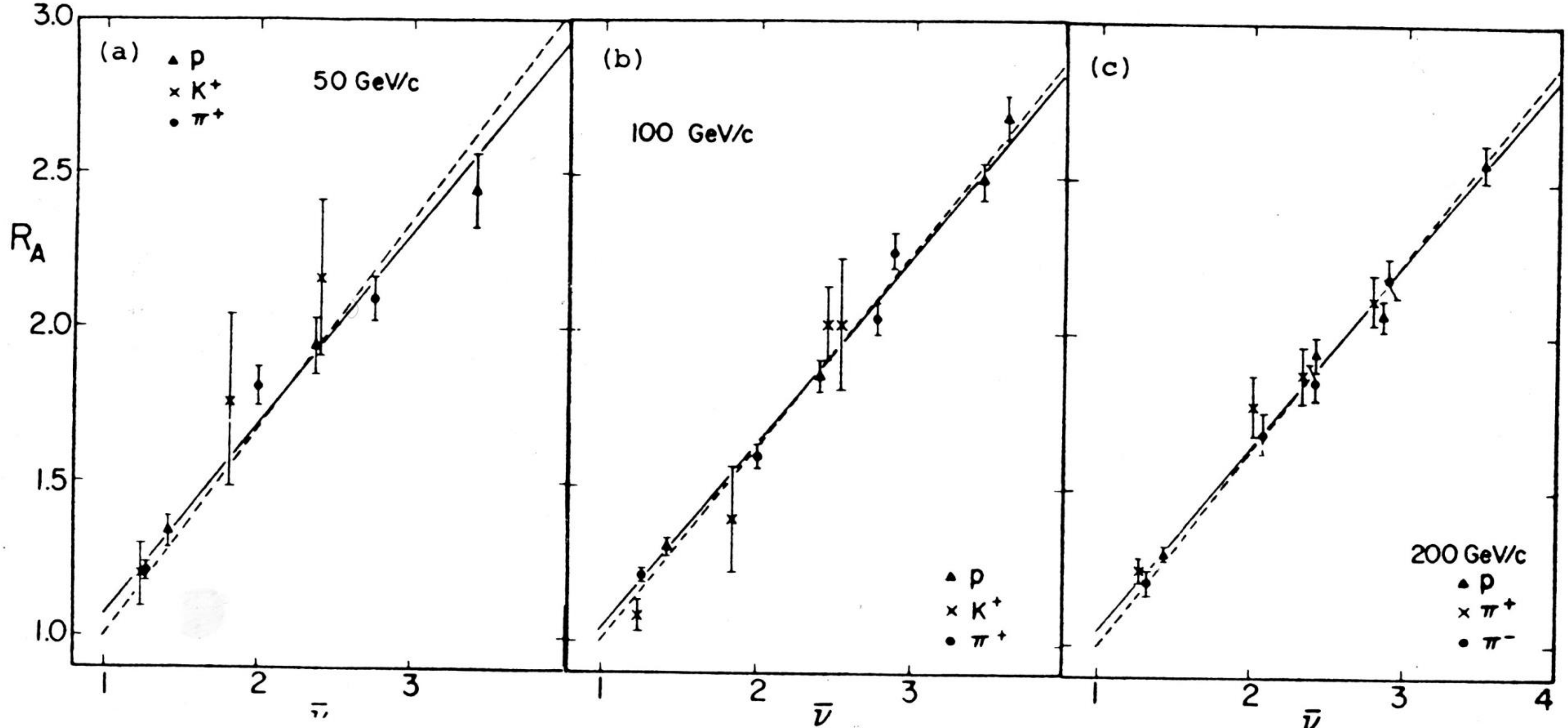
★ The beauty of mid-rapidity

The charged particle multiplication ratio R(y)=(dn^{pA}/dy)/(dn^{pp}/dy) for fixed target 200 GeV/c protons on Ne(squares) , Ar(ν=2.4,triangles), Xe(ν=3.3,circles). The 3 distinct regions are clear here, Target (y<0.5), Fragmentation (y>5); mid-rapidity (1<y<5). Although the distributions are not symmetric about y^{NN}_{cm}=3.0, integrals in the region up to Δy~±2 around mid-rapidity, y_{cm}, give the same <dn/dy> as at y^{NN}_{cm}.

Result of E178 was revolutionary-II

PRD **22**, 13 (1980) : N_{part} rather than N_{coll} governs particle production.

Confirms the wounded nucleon model: Bialas, et al, NPB**111**, 461 (1976)



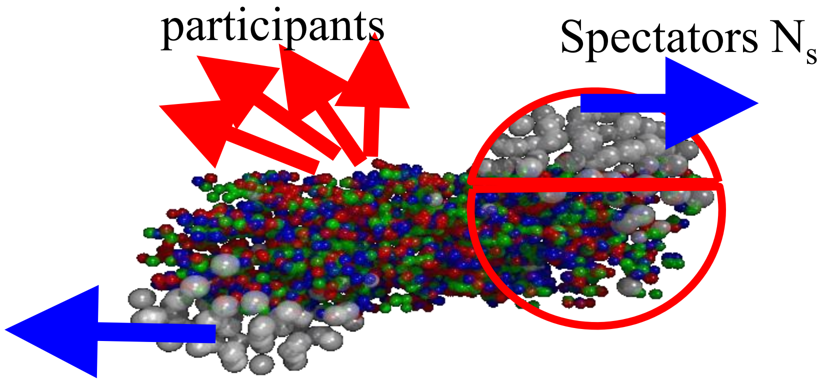
$R_A = \langle n\rangle_{pA} / \langle n\rangle_{pp} = (1+\langle \nu\rangle) / 2$

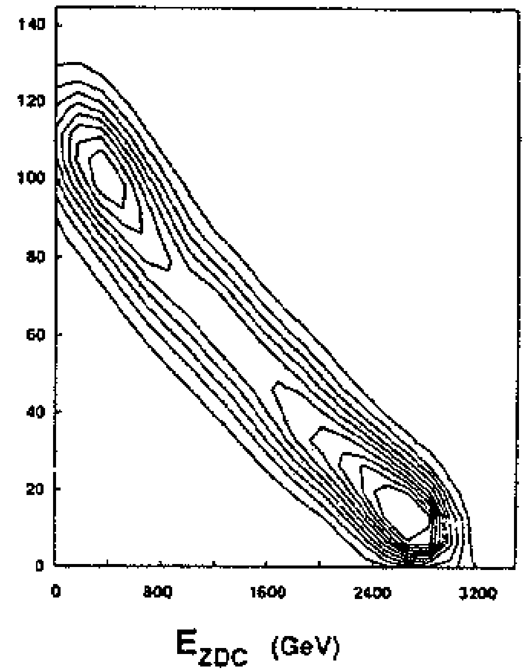
$\langle Npart\rangle_{pA}$ $\langle Npart\rangle_{pp}$

Extreme-Independent or Wounded Nucleon Models c. 1980

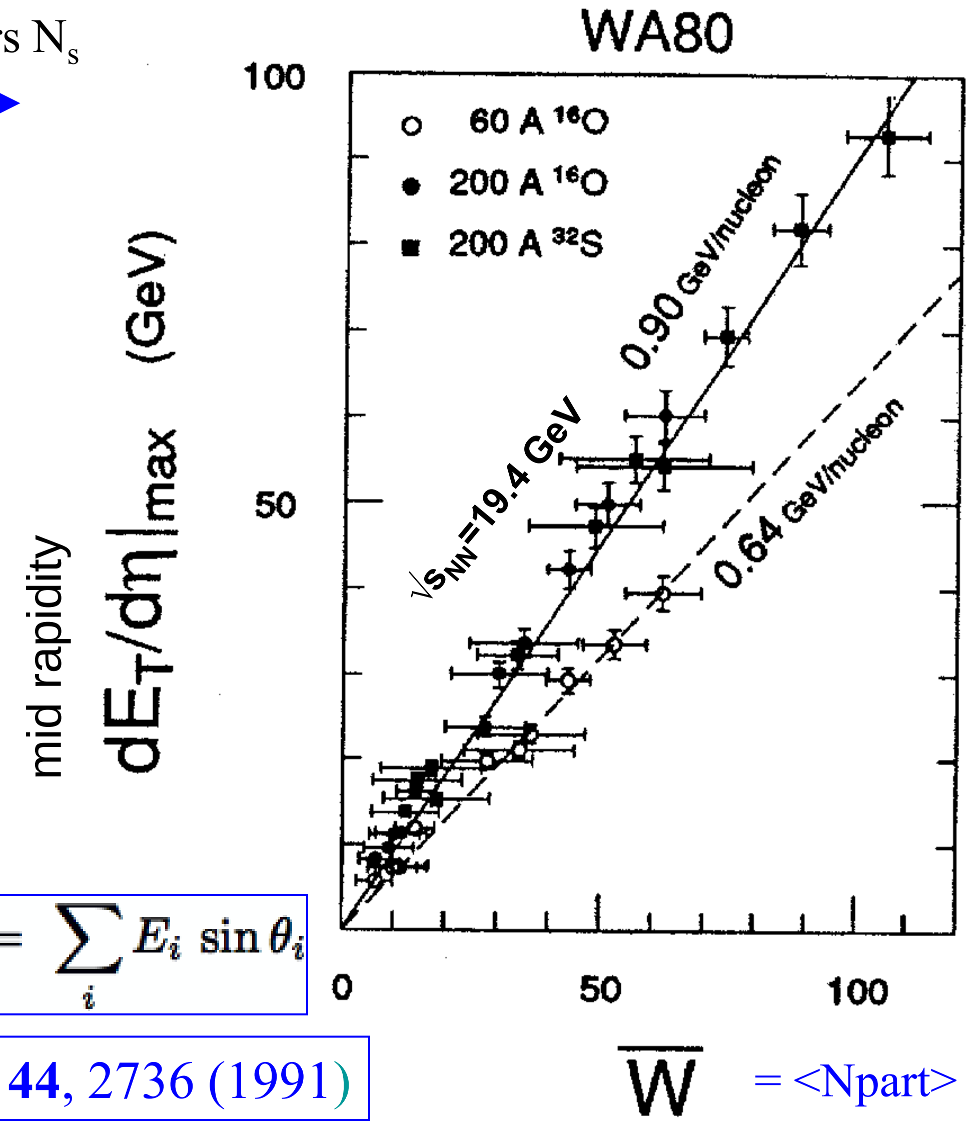
- Number of Spectators (i.e. non-participants) N_s can be measured directly in Zero Degree Calorimeters (more complicated in Colliders)
- Enables unambiguous measurement of (projectile) participants = A_p -N_s
- For symmetric A+A collision N_{part}=2 $N_{projpart}$ =2 (A_p -N_s)
- Uncertainty principle and time dilation prevent cascading of produced particles in relativistic collisions γ h/m_πc > 10fm even at AGS energies: particle production takes place outside the Nucleus in a p+A reaction.
- Thus, Extreme-Independent models separate the nuclear geometry from the dynamics of particle production. The Nuclear Geometry is represented as the relative probability per B+A interaction w_n for a given number of total participants (WNM), projectile participants (WPNM), wounded projectile quarks=color-strings (AQM), constituent quarks or other fundamental element of particle production.
- The dynamics of the elementary underlying process is taken from the data: e.g. the measured E_T distribution for a p-p collision represents, 2 participants, 1 n-n collision, 1 wounded projectile nucleon, a predictable convolution of quark-quark collisions.

WA80: proof of Wounded Nucleon Model at midrapidity for 60, 200 A GeV using ZDC



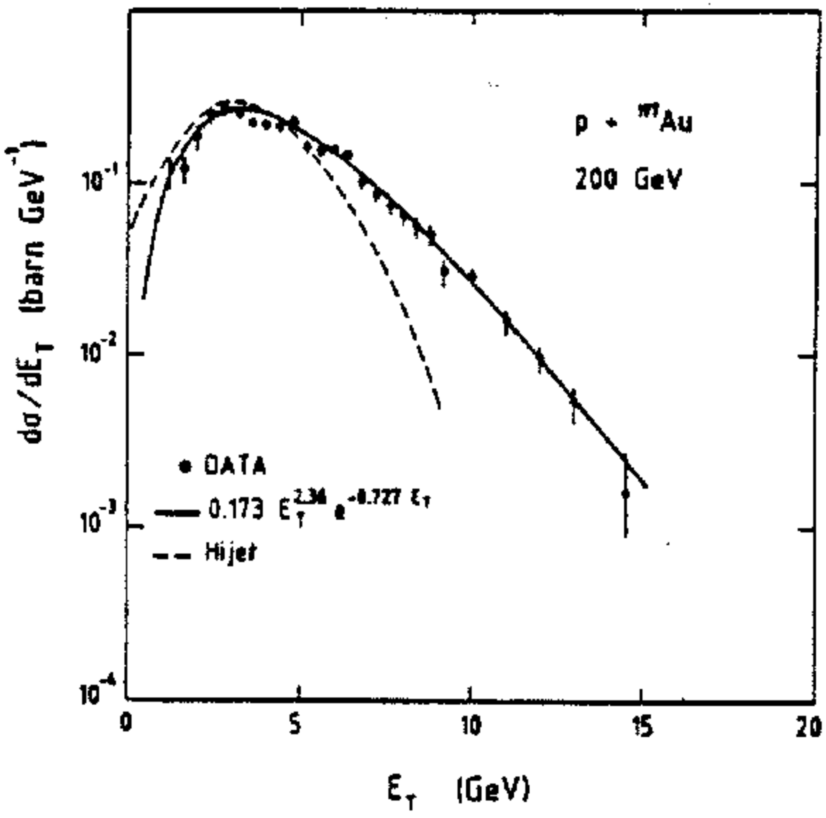


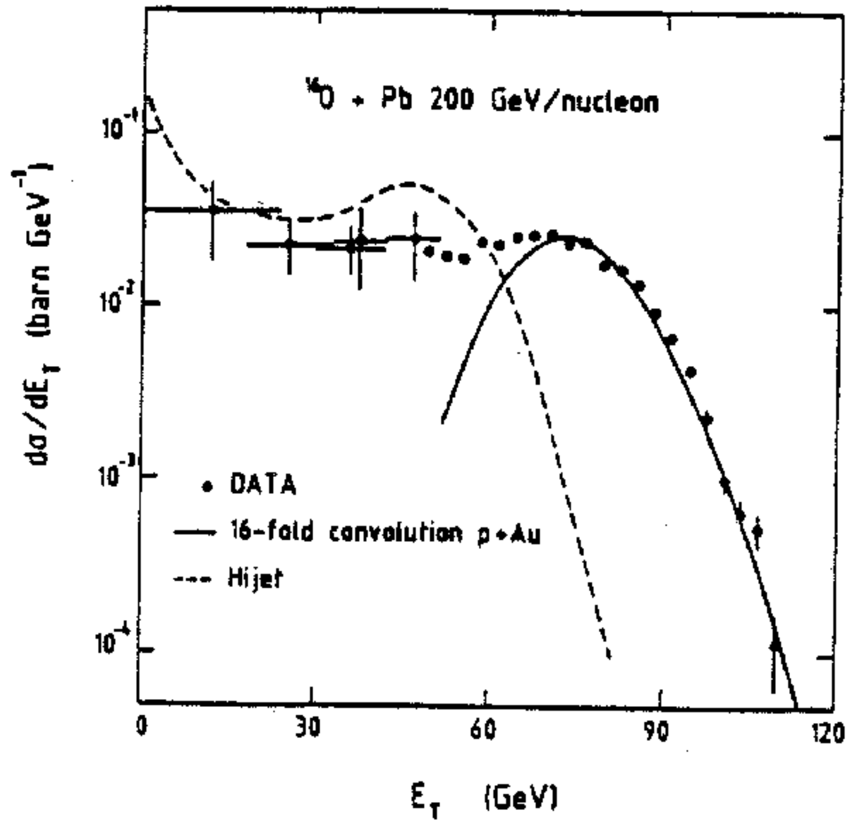
$$E_T = \sum_i E_i \sin\theta_i$$



PRC **44**, 2736 (1991)

First RHI data NA35 (NA5 Calorimeter) CERN $^{16}O+Pb$ $\sqrt{s_{NN}}=19.4$ GeV midrapidity



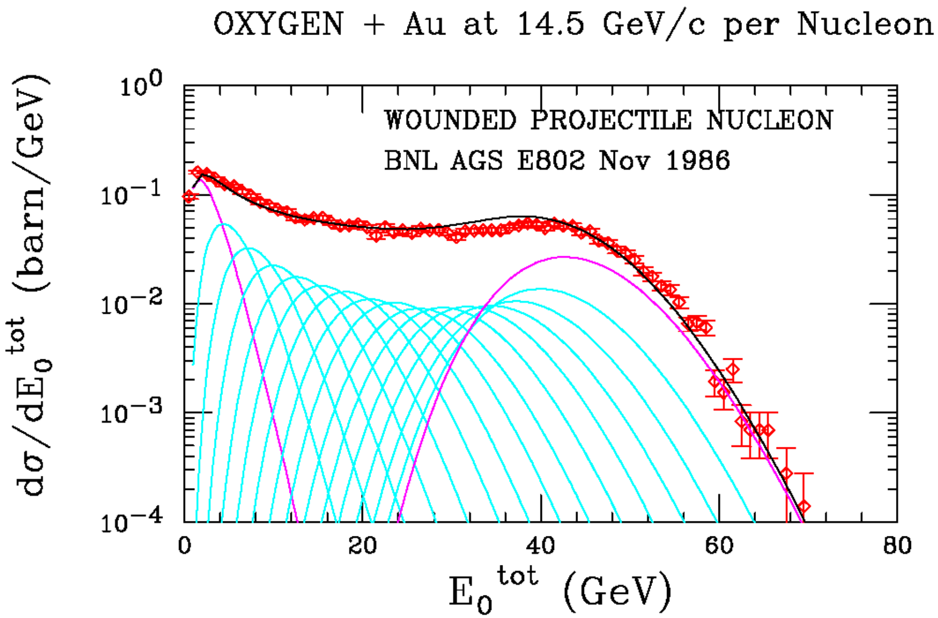


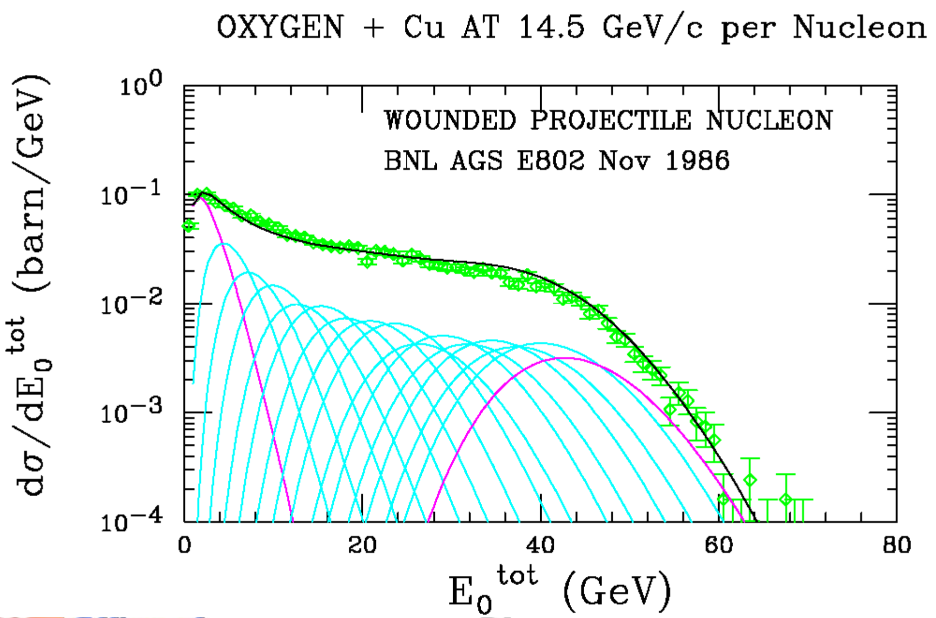
p+Au is a Γ dist p=3.36

PLB **184,** 271 (1987)

Upper Edge of O+Pb is 16 convolutions of p+Au. WPNM!!

WPN=Wounded Projectile Nucleon=projectile participant

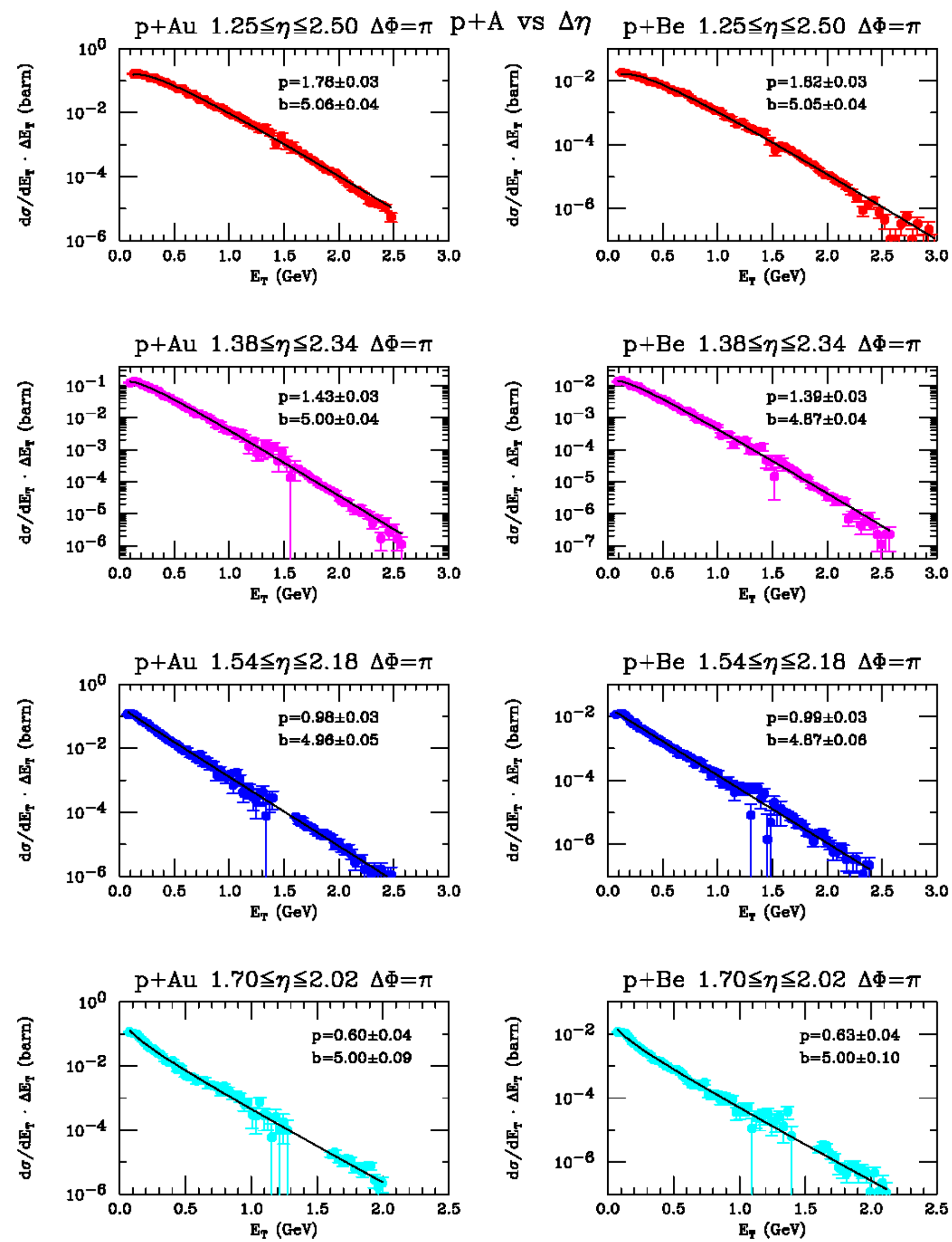




E802-O+Au, O+Cu midrapidity at AGS $\sqrt{s_{NN}}$=5.4GeV WPNM works in detail

PLB **197**, 285 (1987)
ZPC **38**, 35 (1988)

- Maximum energy in O+Cu ~ same as O+Au--Upper edge of O+Au identical to O+Cu dσ/dE * 6
- Indicates large stopping at AGS ^{16}O projectiles stopped in Cu so that energy emission (mid-rapidity) ceases
- Full O+Cu and O+Au spectra described in detail by WPNM based on measured p+Au **BUT**

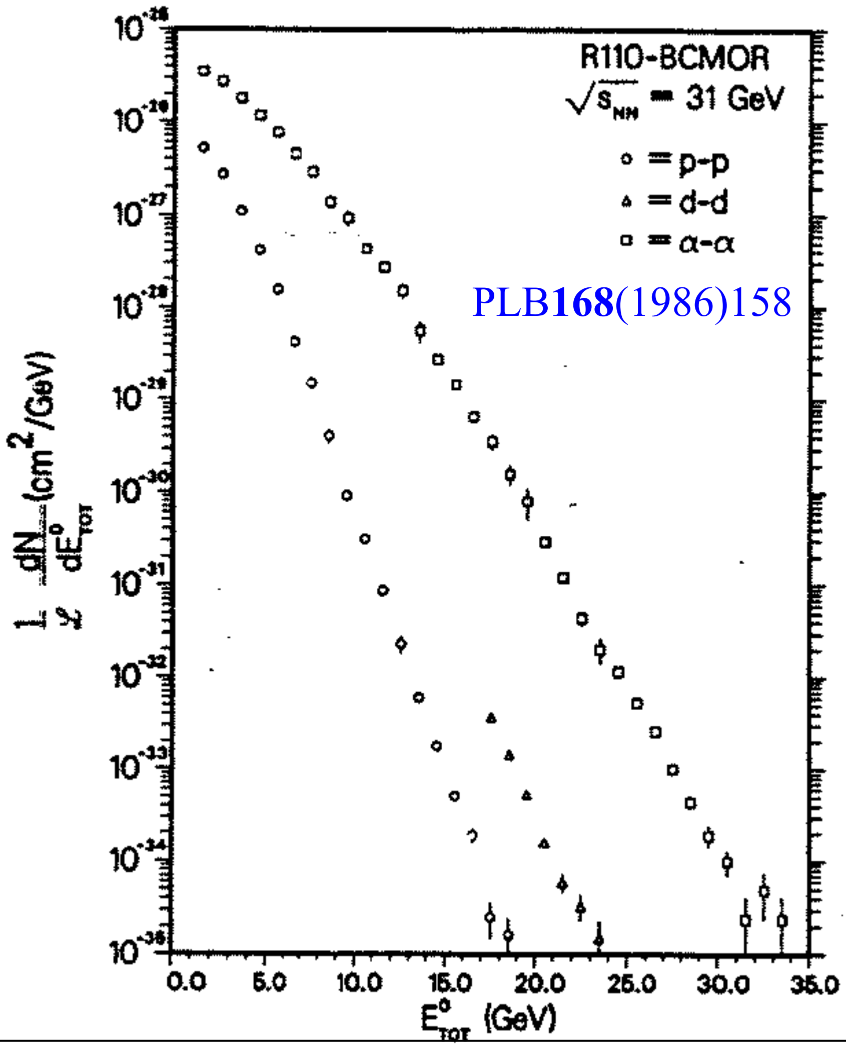


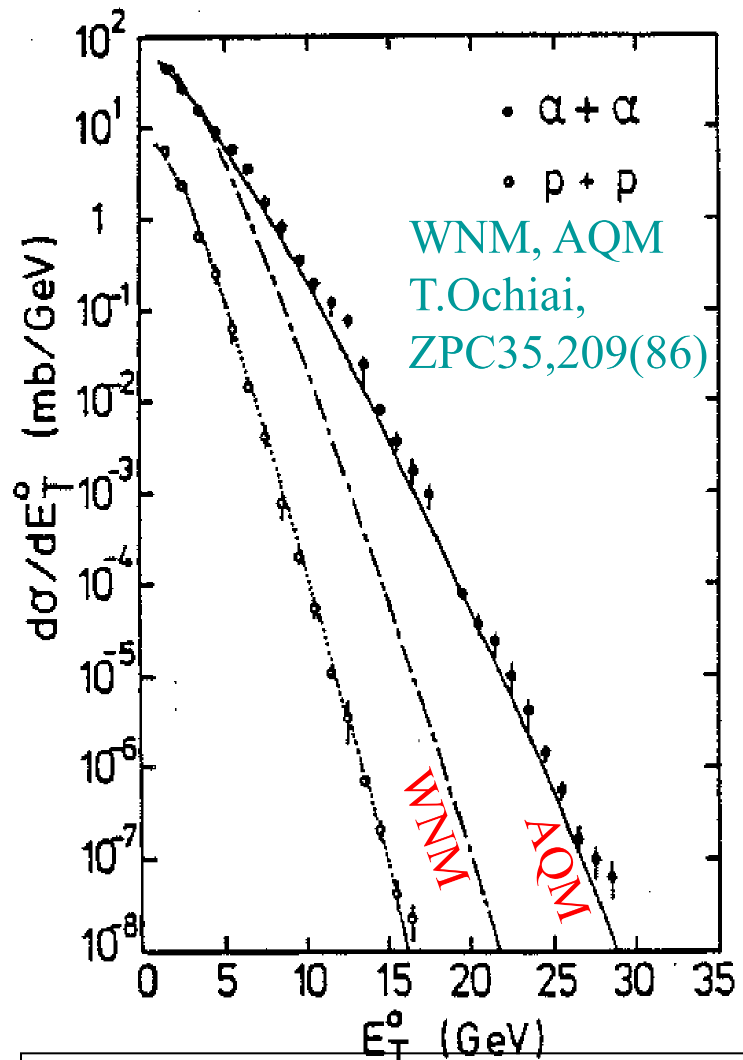
E802-AGS Midrapidity stopping! pBe & pAu have same shape at midrapidity over a wide range of δη

PRC **63**, 064602 (2001)

- confirms previous measurement PRC **45**, 2933 (1992) that pion distribution from second collision shifts by > 0.8 units in y, out of aperture. Explains WPNM.

ISR-BCMOR-αα $\sqrt{s_{NN}}$=31GeV: WNM FAILS! AQM works





Both p-p and alpha-alpha data are beautiful Γ-distributions with analytical convolution.

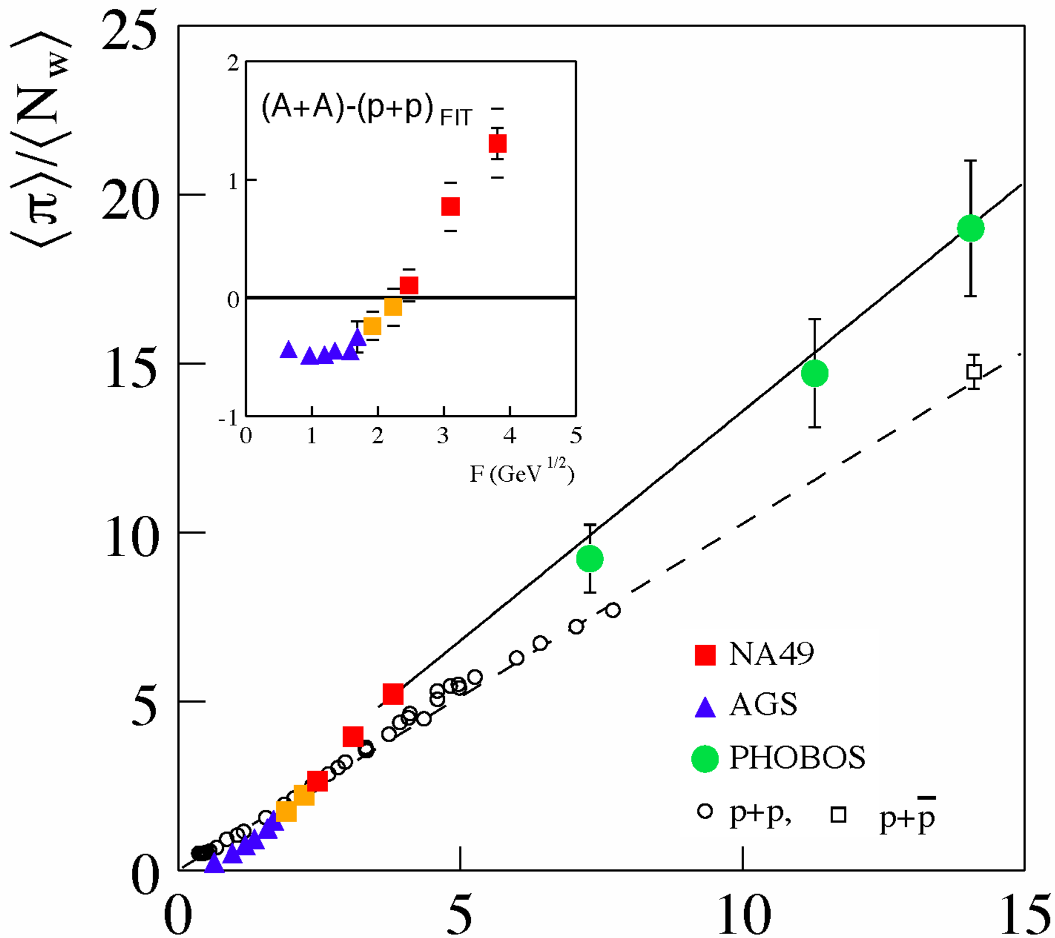
WNM edge is parallel to p-p data! This is due to dominance of 4th pp convolution

Summary of Wounded Nucleon Models at mid-rapidity c. 1991

- The classical Wounded Nucleon (N_{part}) Model (WNM) of Bialas, Bleszynski and Czyz (NPB **111**, 461 (1976)) works at mid-rapidity only at CERN fixed target energies, $\sqrt{s_{NN}}$~20 GeV.
- WNM overpredicts at AGS energies $\sqrt{s_{NN}}$~ 5 GeV (WPNM works at mid-rapidity)--this is due to stopping, second collision gives only few particles which are far from mid-rapidity. E802
- WNM underpredicts for $\sqrt{s_{NN}} \geq 31$ GeV---Additive Quark Model Works. BCMOR + Ochiai
- This is the explanation of the 'famous' kink, well known as p+A effect since QM87+QM84

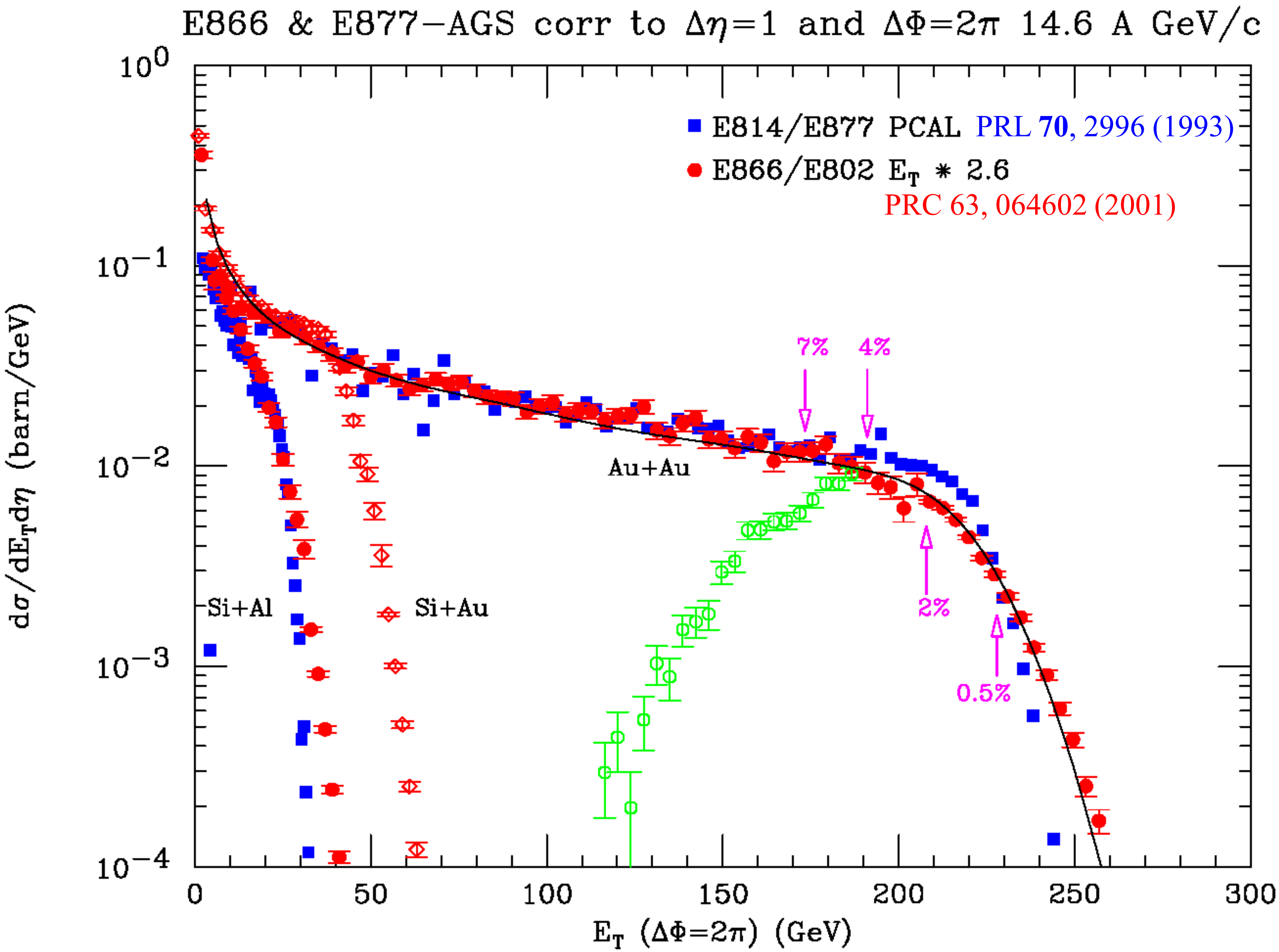
i.e. The kink is a p+A effect well known since 1987-seen at FNAL,ISR,AGS

Marek Gazdzicki
QM2004, QM 2001…
Pions per participant

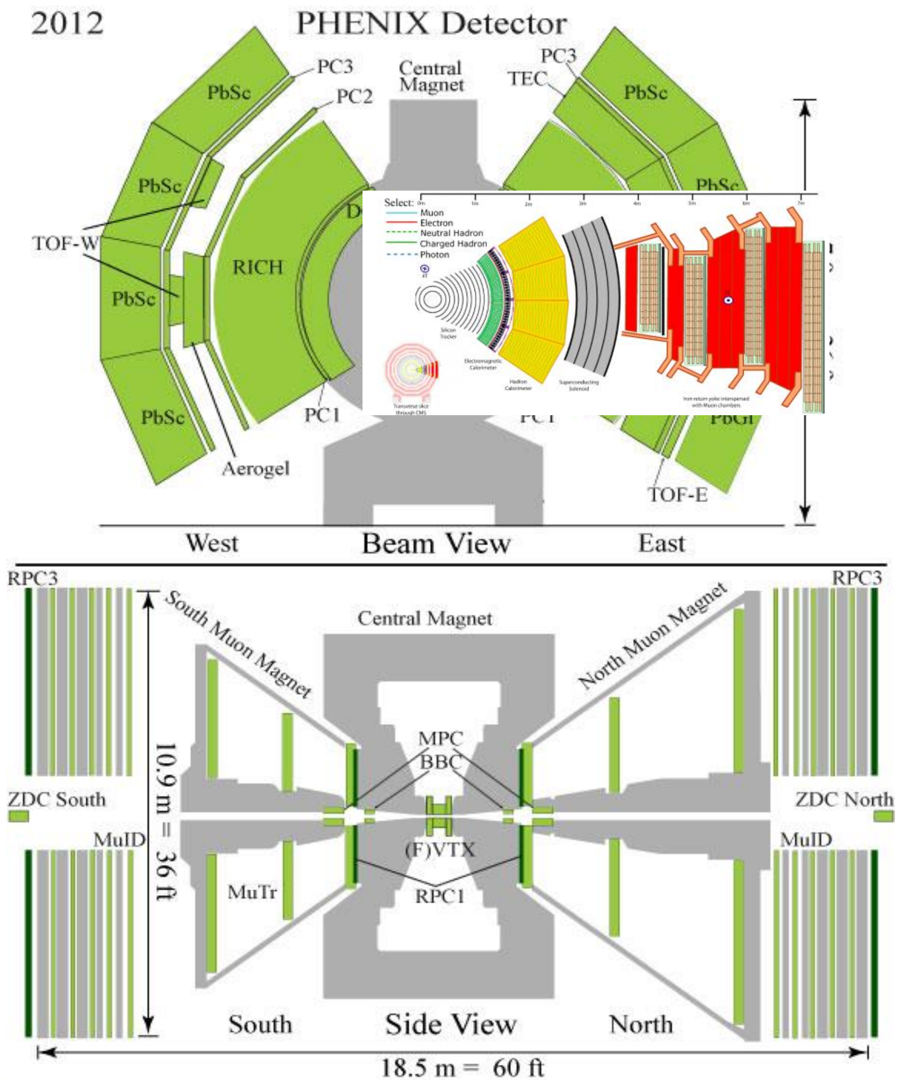


$F\ (GeV^{1/2}) \approx s^{1/4}$

E_T distributions in RHI collisions $\sqrt{s_{NN}}$=5.4 GeV



We designed PHENIX explicitly to make this measurement (and lots of others)



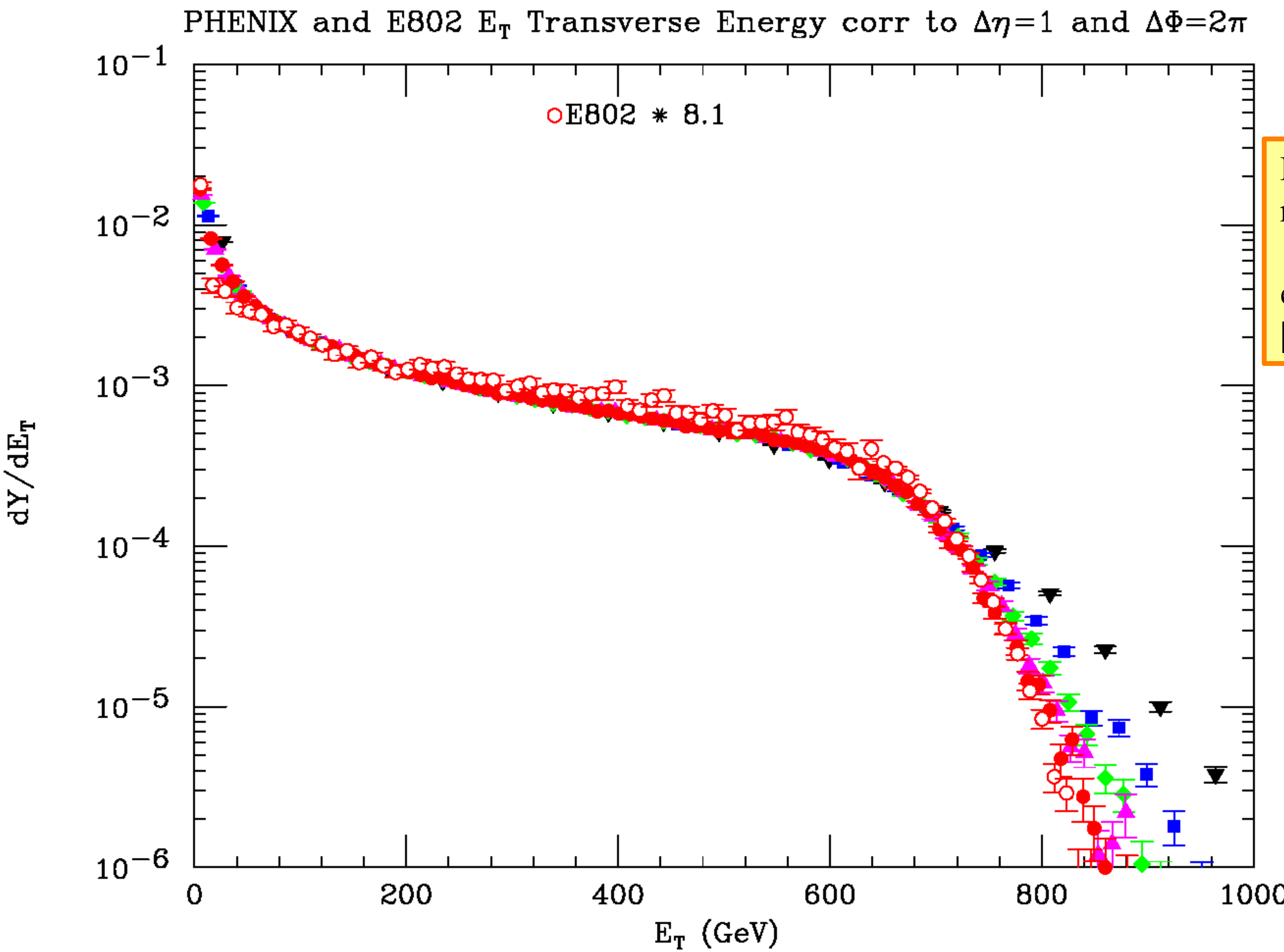
- **PHENIX is a special purpose detector designed and built to measure *rare processes* involving *leptons and photons* at the *highest luminosities.***

✓ *possibility of zero magnetic field on axis*
✓ *minimum of material in aperture 0.4% X_o*
✓ *EMCAL RICH $e^{\pm}$ i.d. and lvl-1 trigger*
- *γ π^0 separation up to $p_T \sim 25$ GeV/c*
- *EMCAL and precision TOF for $h^{\pm}$ pid*

For the record: I was always skeptical of J/ψ suppression for the QGP because it was also "suppressed" in p+A collisions

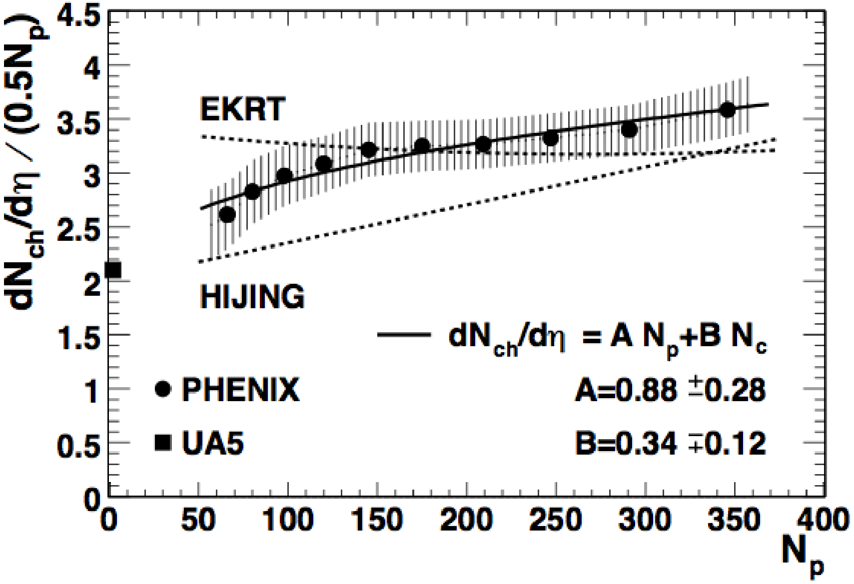
Comparison to scale with a wedge of CMS

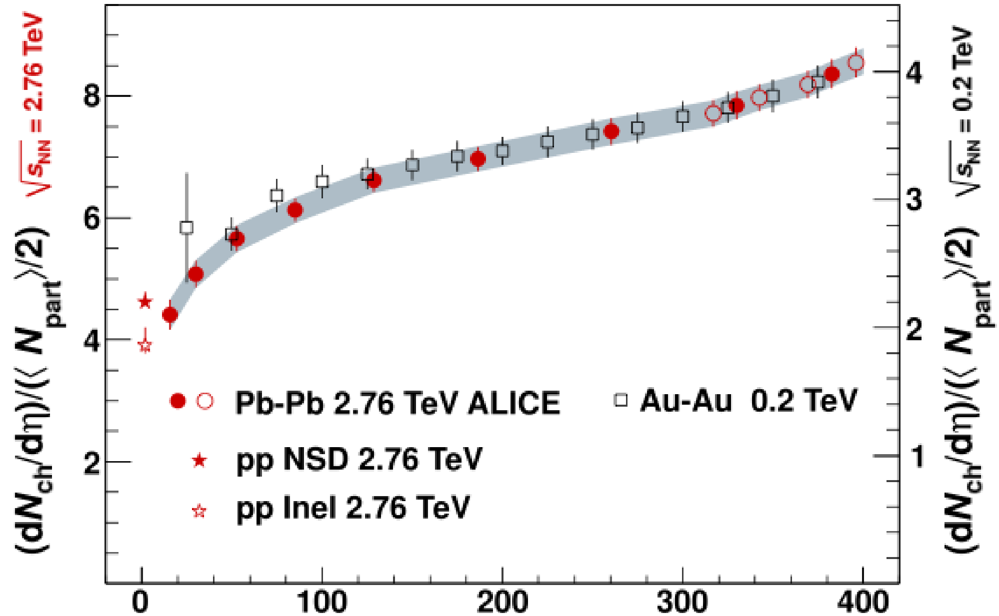
Au+Au E_T spectra at AGS and RHIC are the same shape!!!



PHENIX E_T results in 1,2,3,4,5 sectors each with $|\eta|<0.38, \Delta\Phi=\pi/8$

From RHIC to LHC to RHIC evolution of mid-rapidity $dN_{ch}/d\eta$ with centrality, N_{part}





PHENIX $\sqrt{s_{NN}}$=130 GeV, PRL86 (2001)3500

ALICE $\sqrt{s_{NN}}$=2.76 TeV PRL 106(2011)032301

Against my strong objections, PHENIX included the following fit in PRL86

$$dE_T{}^{AA}/d\eta = [(1-x)\ \langle N_{\rm part}\rangle\ dE_T{}^{pp}/d\eta/2 + x\ \langle N_{\rm coll}\rangle\ dE_T{}^{pp}/d\eta]$$

The N_{coll} term implied a hard-scattering component for E_T, known to be absent in p-p

Important Observation

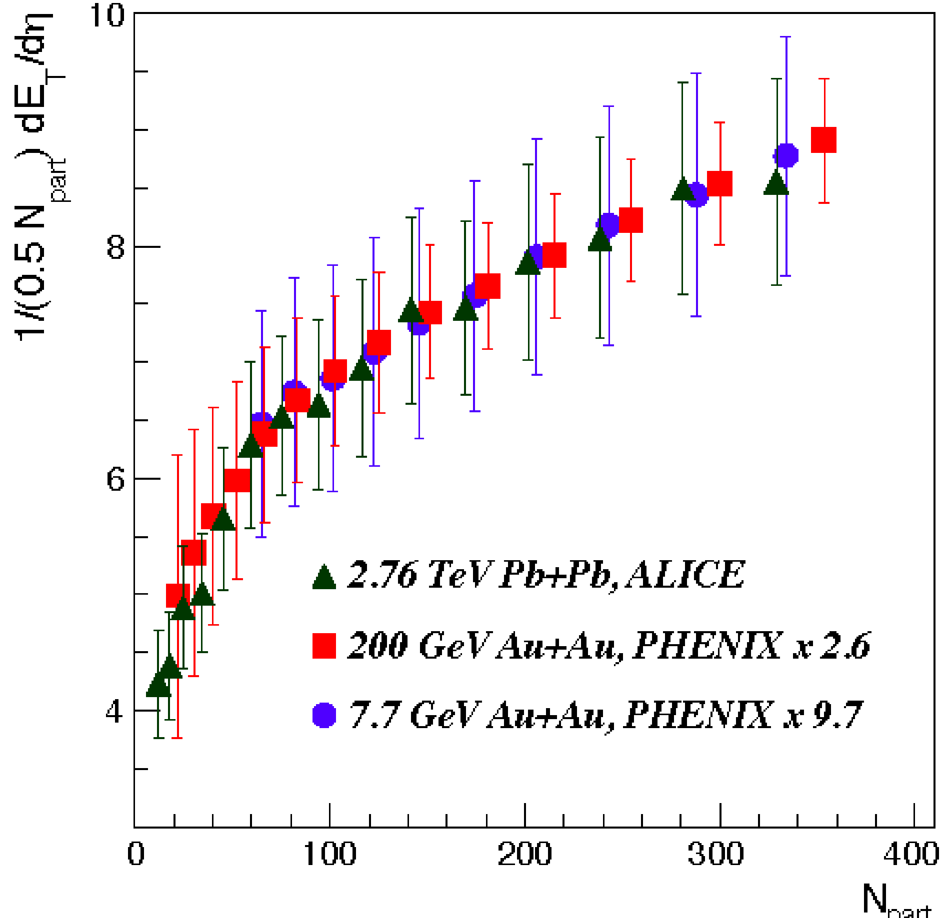
- PHENIX (2001) $dN_{ch}/d\eta \propto N_{part}^{\alpha}$ with α=1.16±0.04 at $\sqrt{s_{NN}}$=130 GeV
- ALICE (2013) $dN_{ch}/d\eta \propto N_{part}^{\alpha}$ with α=1.19±0.02 at $\sqrt{s_{NN}}$=2760 GeV

⊙Exactly the same shape vs. N_{part} although $\langle N_{coll} \rangle$ is a factor of 1.6 larger and the hard-scattering cross section is considerably larger.

- Strongly argues against a hard-scattering component and for a Nuclear Geometrical Effect.

Identical shape of distributions indicates a nuclear-geometrical effect

New RHIC data for Au+Au at $\sqrt{s_{NN}}$ =0.0077 TeV show the same evolution with centrality

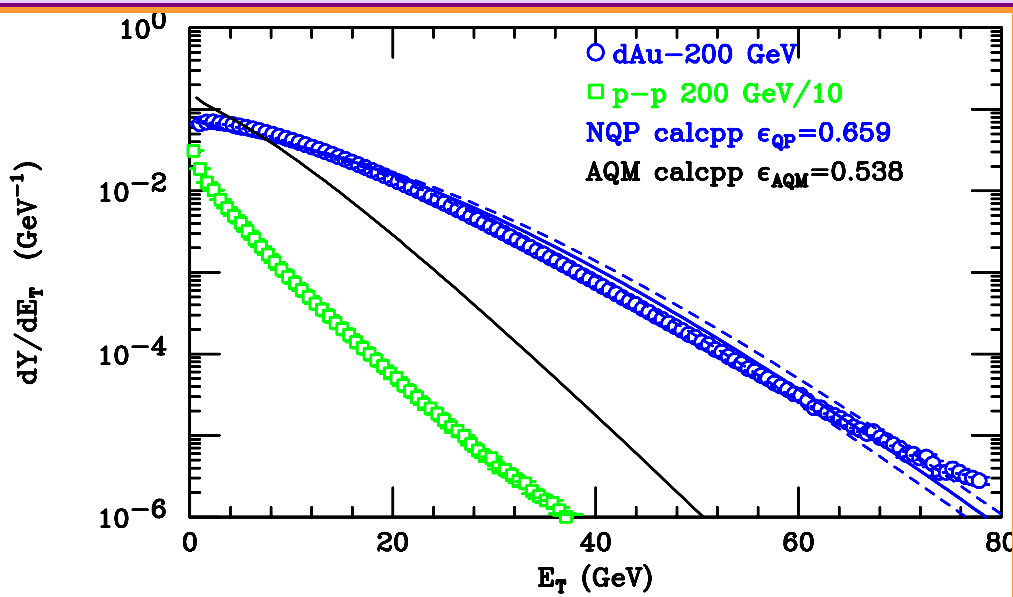


The geometry is the number of constituent quark participants/nucleon participant

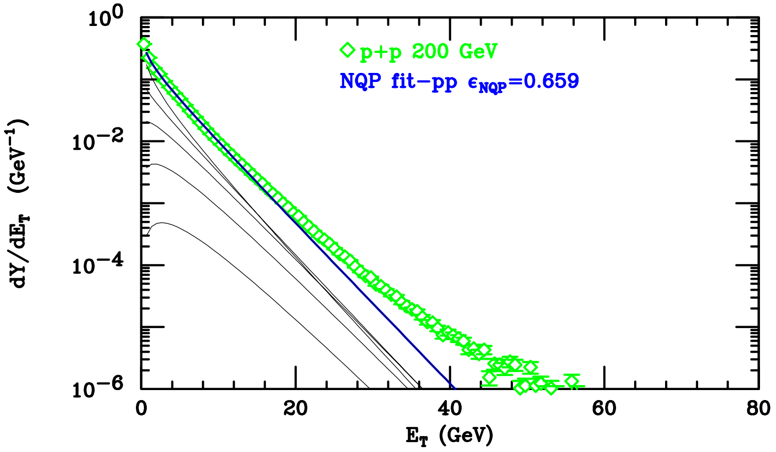
Eremin&Voloshin, PRC 67, 064905(2003) ; De&Bhattacharyya PRC 71; Nouicer EPJC 49, 281 (2007)

But symmetric A+A collisions can't distinguish AQM (color strings) from constituent quarks

The Additive Quark Model (AQM), Bialas and Bialas PRD20(1979)2854 and Bialas, Czyz and Lesniak PRD25(1982)2328, is really a color string model. In the AQM model only one color string can be attached to a wounded quark. For symmetric systems, it is identical to the Quark Participant model (NQP). However for asymmetric systems such as d+Au it is a ``wounded projectile quark'' model since in this model, only 6 color strings can be attached to the d while the Au can have many more quark participants. PHENIX data shows that in fact it is the NQP not the color string model that works



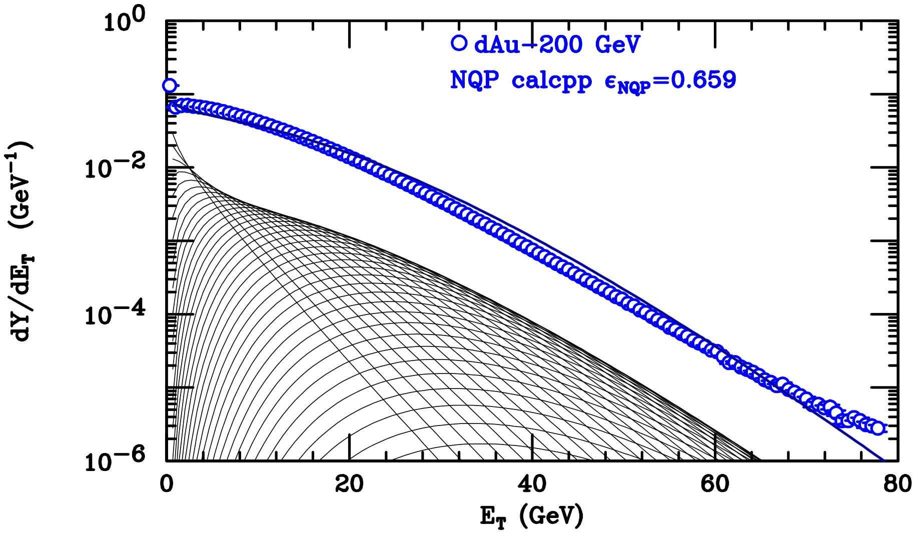
New PHENIX measurements of E_T distributions in pp, dAu AuAu---and quark participants

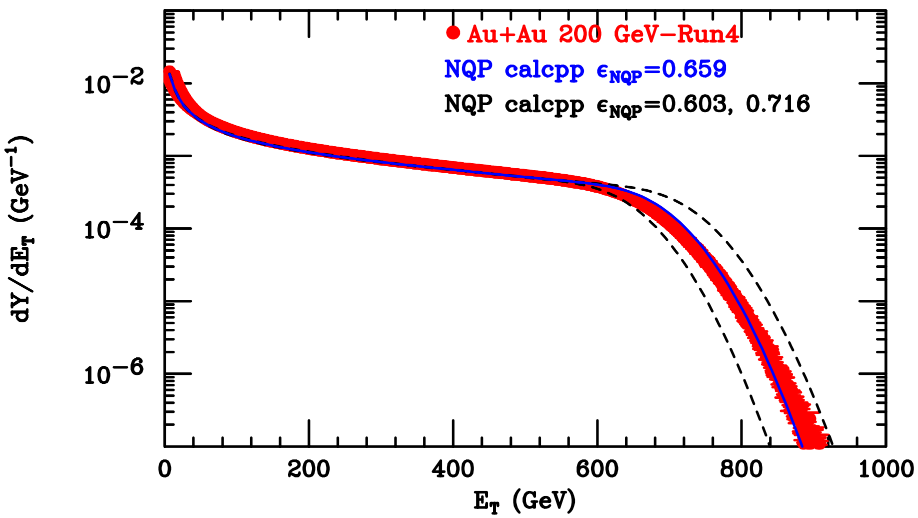


Generate 3 constituent quarks around nucleon position distributed according to proton charge distribution. Gives a physical basis for "proton size fluctuations"

Deconvolute p-p E_T distribution to the sum of 2—6 quark participant (QP) E_T distributions taken as Γ distributions

Calculate dAu and AuAu E_T distributions as sum of QP E_T distributions



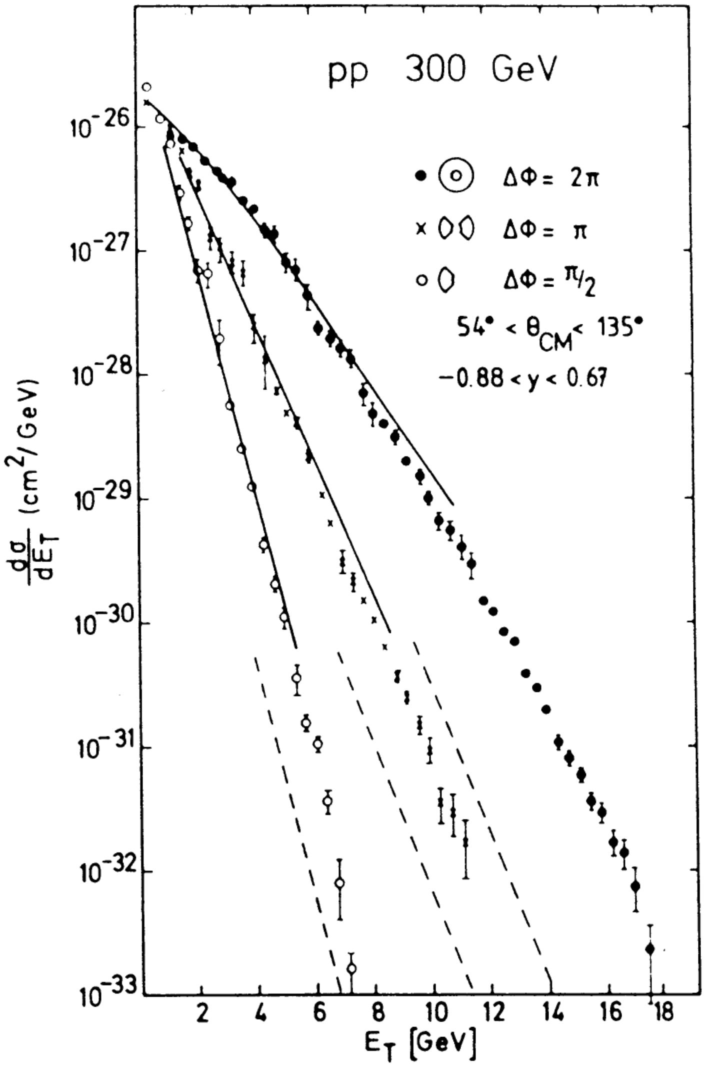


Details

- From the Jet Fiasco in High Energy Physics in 1978-82, it is known that E_T and multiplicity distributions are soft. Hard scattering does not enter for the first 3 or 4 orders of magnitude.
- Constituent Quarks are Gell-Mann (and Zweig)'s 300 MeV quarks that make up hadrons, not the massless partons visible in DIS and p-p hard-scattering only for $Q^2>(2\text{ GeV/c})^2=(0.1\text{fm})^{-2}$. Massless quark-partons are also called "current-quarks".
- The calculation of the positions of the 3 constituent quarks around their parent nucleon gives a physical basis for "proton size fluctuations" and other transversely fluctuating initial conditions, recently discussed.
- The ansatz $[(1\text{-}x)N_{part}/2+x\, N_{coll}]$ can not be calculated sensibly in an extreme-independent model but only as an event-by-event nuclear geometric object, in a Glauber calculation, that represents the number of emitting sources, called "ancestors" by ALICE [PRC **88** (2013) 044909]
- The ansatz (or ancestor) is nothing other than an empirical proxy for a constituent quark, so that the N_{coll} term does not represent a hard-scattering component in E_T distributions. Thus ALICE's "ancestors" are really constituent quarks.

NA5-the coup-de-grâce to jets (1980)

- Full azimuth calorimeter $-0.88<\eta^*<0.67$ (→ NA35, NA49)

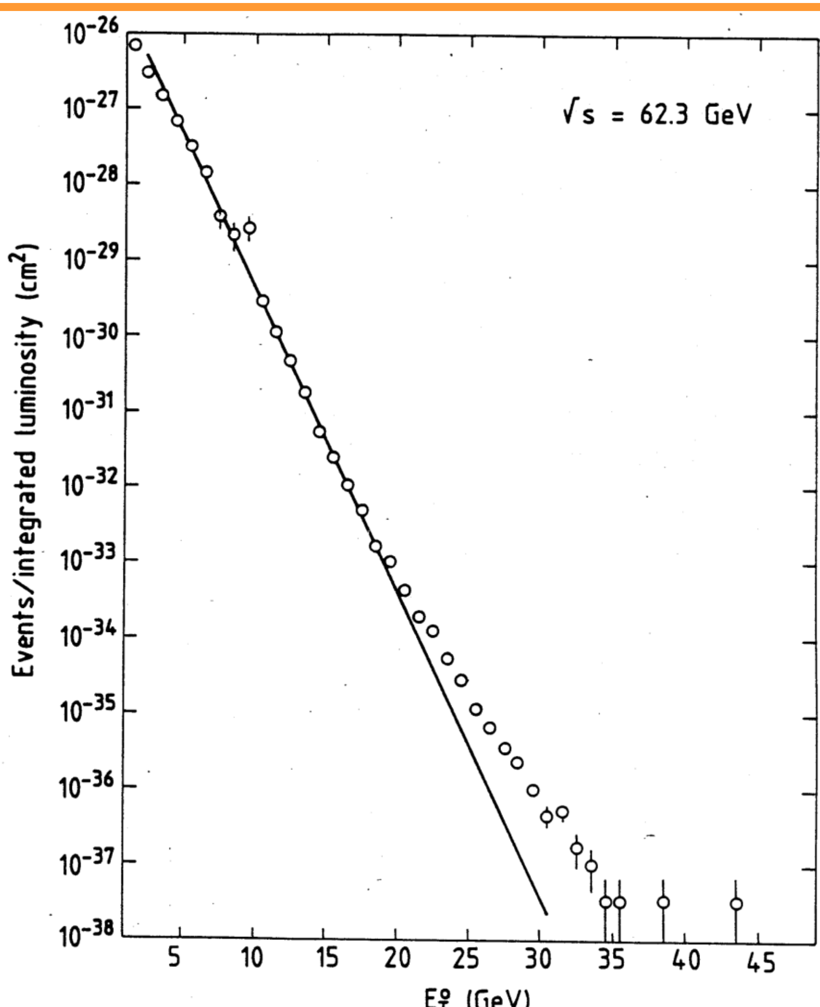


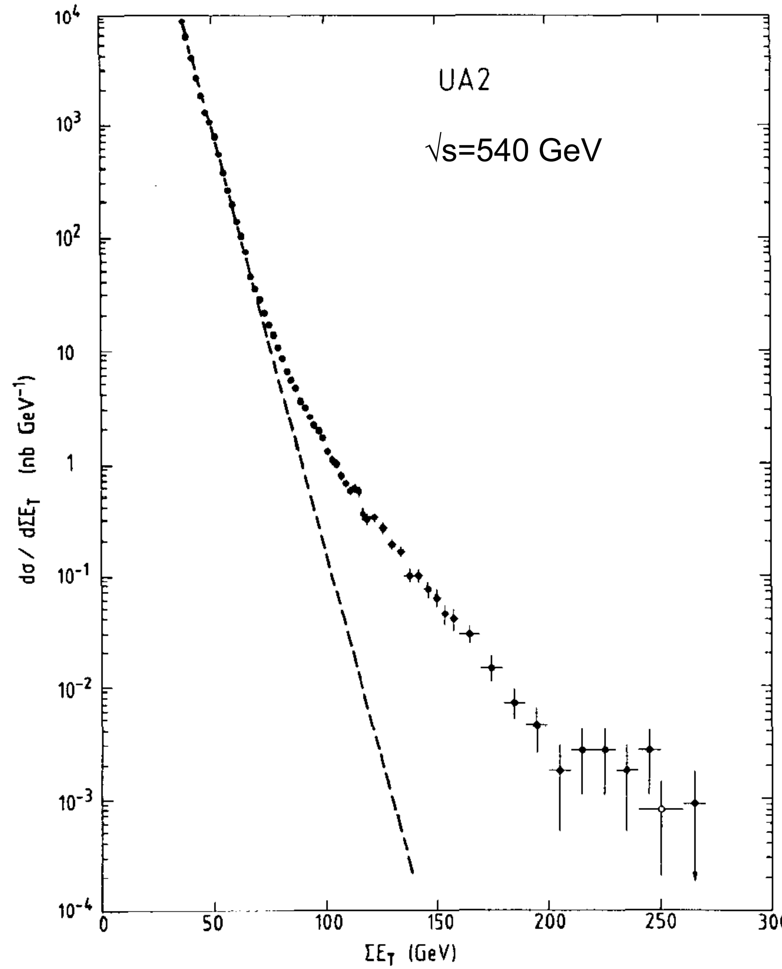
- plus triggered in two smaller apertures corresponding to FNAL-E260 jet claim.
- No jets in full azimuth data
- All data way above QCD predictions--------
- The large E_T observed is the result of "a large number of particles with a rather small transverse momentum"--the first E_T measurement in the present terminology.

K. Pretzl, Proc 20th ICHEP (1980)
C. DeMarzo et al NA5, PLB**112**(1982)173

For more on E_T see MJT IJMPA **4** (1989)3377

Jets are a $<10^{-3}$ effect in p-p E_T distributions



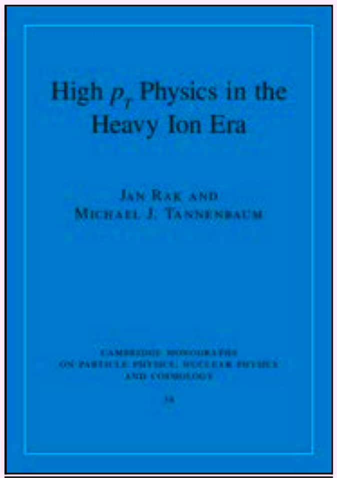


COR PLB**126**(1983)132 E_T in $\Delta\Phi=2\pi$, $|\eta|<0.8$ EMCal. Break above 20 GeV is due to jets.

UA2 PLB**138**(1984)430 (from DiLella) Break from jets ~5-6 orders of magnitude down for E_T in $\Delta\Phi=2\pi$, $|\eta|<1.0$

I rushed through the "Jet Fiasco" because:

This and many other relevant High Energy Physics issues in RHI physics are available in the new book by Jan Rak and Michael J. Tannenbaum, "High p_T physics in the Heavy Ion Era"



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High-pT Physics in the Heavy Ion Era

Jan Rak, University of Jyväskylä, Finland
Michael J. Tannenbaum, Brookhaven National Laboratory, New York

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Aimed at graduate students and researchers in the field of high-energy nuclear physics, this book provides an overview of the basic concepts of large transverse momentum particle physics, with a focus on pQCD phenomena. It examines high-pT probes of relativistic heavy-ion collisions and will serve as a handbook for those working on RHIC and LHC data analyses. Starting with an introduction and review of the field, the authors look at basic observables and experimental techniques, concentrating on relativistic particle kinematics, before moving onto a discussion about the origins of high-pT physics. The main features of high-pT physics are placed within a historical context and the authors adopt an experimental outlook, highlighting the most important discoveries leading up to the foundation of modern QCD theory. Advanced methods are described in detail, making this book especially useful for newcomers to the field.

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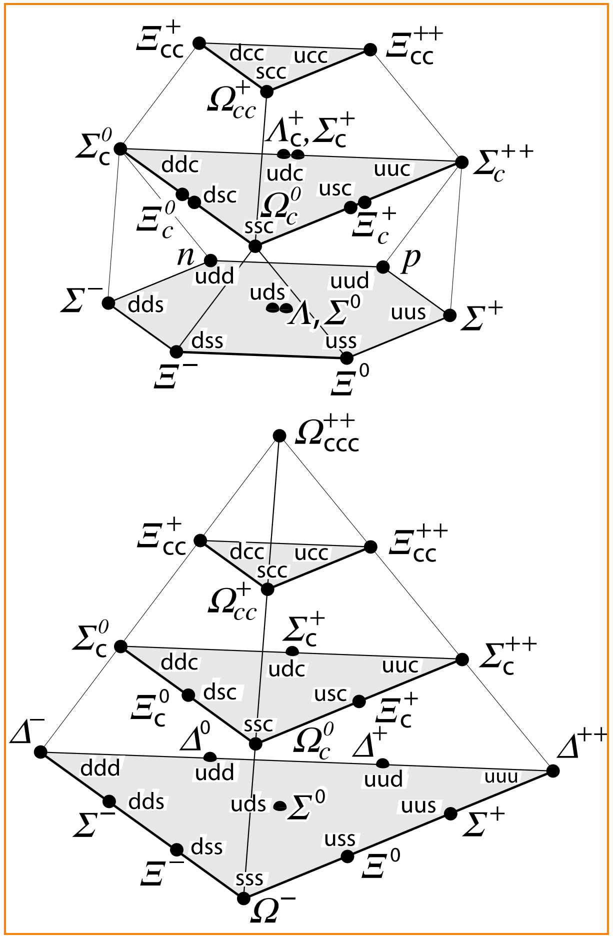
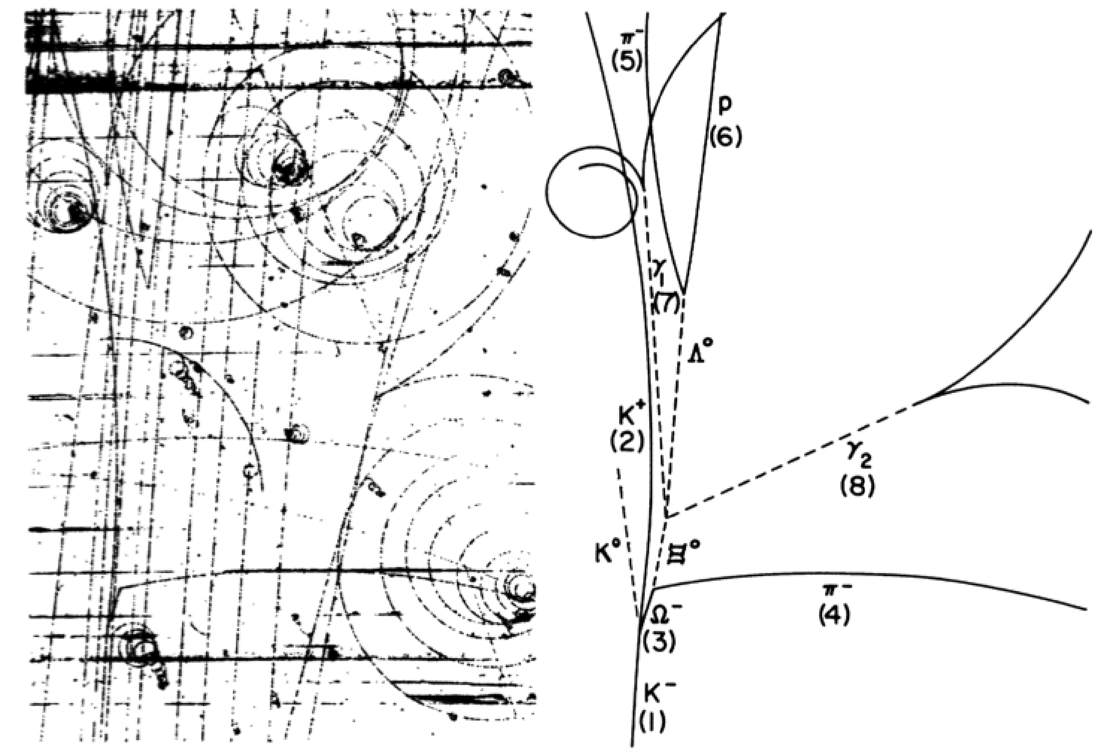
Constituent quarks are Gell-Mann's quarks from Phys. Lett. **8** (1964)214



Constituent quark model of Baryons



Ω^- (sss)

BNL-Barnes, Samios *et al.*, PRL**12**, 204 (1964)

Details of NQP calculation

The NQP calculation for a B+A reaction

$$\left(\frac{d\sigma}{dE_T}\right)_{\mathrm{NQP}} = \sigma_{BA} \sum_{n=1}^{B} w_n P_n(E_T) \qquad (15)$$

- σ_{BA} is the measured B+A cross section in the detector aperture,
- w_n is the relative probability for n quark participants in the B+A reaction from a Glauber Monte Carlo.
- $P_n(E_T)$ is the calculated E_T distribution on the detector aperture for n **independently interacting** quark participants.
- If $f_1(E_T)$ is the measured E_T spectrum on the detector aperture for one quark participant, and p_0 is the probability for the elementary collision to produce no signal on the detector aperture, then, the correctly normalized E_T distribution for one quark participant is:

$$P_1(E_T) = (1-p_0) f_1(E_T) + p_0 \delta(E_T) \quad , \qquad (16)$$

where $\delta(E_T)$ is the Dirac delta function and $\int f_1(E_T)\, dE_T = 1$.

- $P_n(E_T)$ (including the p_0 effect) is obtained by convoluting $P_1(E_T)$ with itself $n-1$ times

$$P_n(E_T) = \sum_{i=0}^{n} \frac{n!}{(n-i)!\, i!} p_0^{n-i} (1-p_0)^i f_i(E_T) \qquad (17)$$

where $f_0(E_T) \equiv \delta(E_T)$ and $f_i(E_T)$ is the i-th convolution of $f_1(E_T)$:

$$f_i(x) = \int_0^x dy\, f(y)\, f_{i-1}(x-y) \quad . \qquad (18)$$

Apart from generating the positions of the 3 quarks per nucleon this is standard method for calculations of E_T distributions as in slide 10. See PHENIX ppg-100 for further details. Also see MJT PRC69(2004)064902

3 quarks are distributed about the center of each nucleon with a spatial distribution $\rho(r)=\rho(0)\exp(-ar)$ where $a=\sqrt{12}/r_m=4.27$ fm^{-1} and $r_m=0.81$ fm is the rms charge radius of the proton. Hofstadter RevModPhys 28(1956)214 The q-q inelastic scattering cross section is adjusted to 9.36 mb to reproduce the 42 mb N+N inelastic cross section at $\sqrt{s_{NN}}=200$ GeV

Gamma distribution is used because it fits and because n-th convolution is analytical

$$f(x) = \frac{b}{\Gamma(p)} (bx)^{p-1} e^{-bx}$$

$$f_n(x) = \frac{b}{\Gamma(np)} (bx)^{np-1} e^{-bx}$$

Find p_0 in p-p collisions by measuring the E_T cross section with same method as for π^0

n.b. Tail is due to pileup. 0.9% of data for E_T>15 GeV <E_T> of fits and data differ by <0.6%

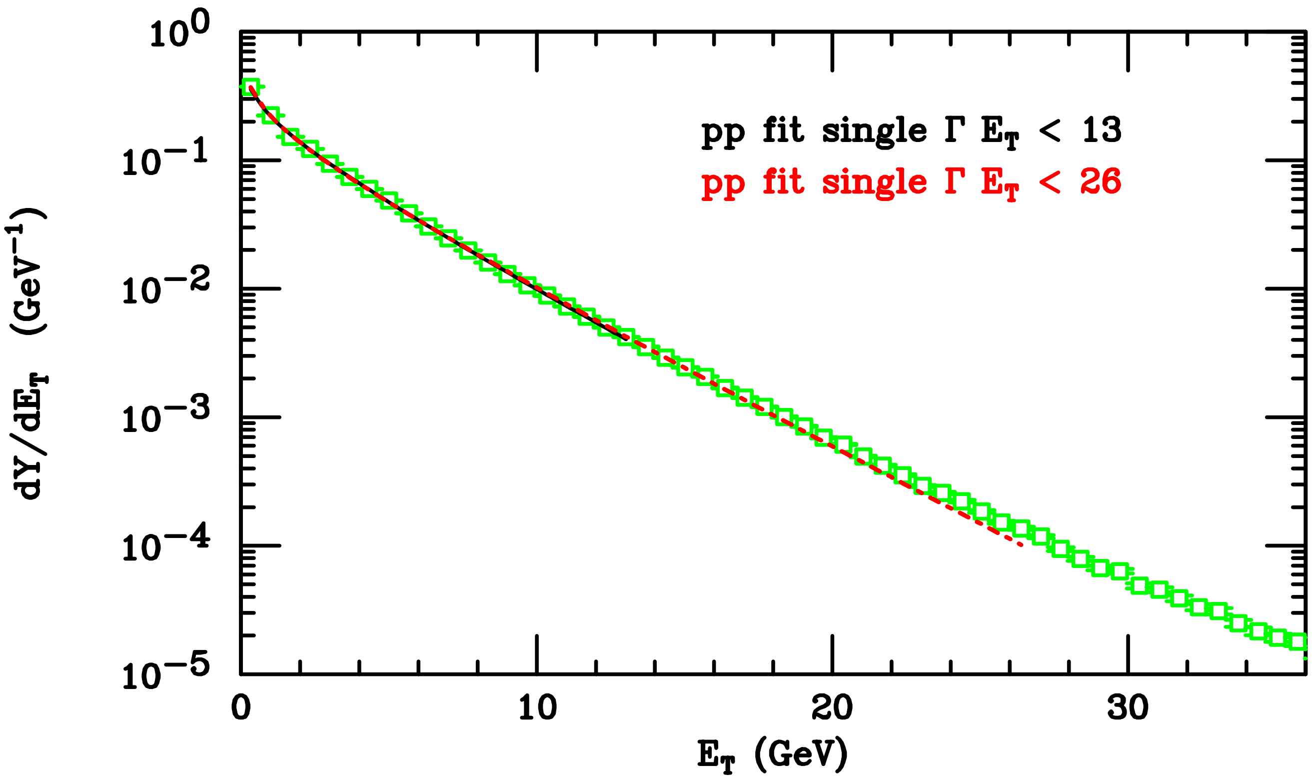
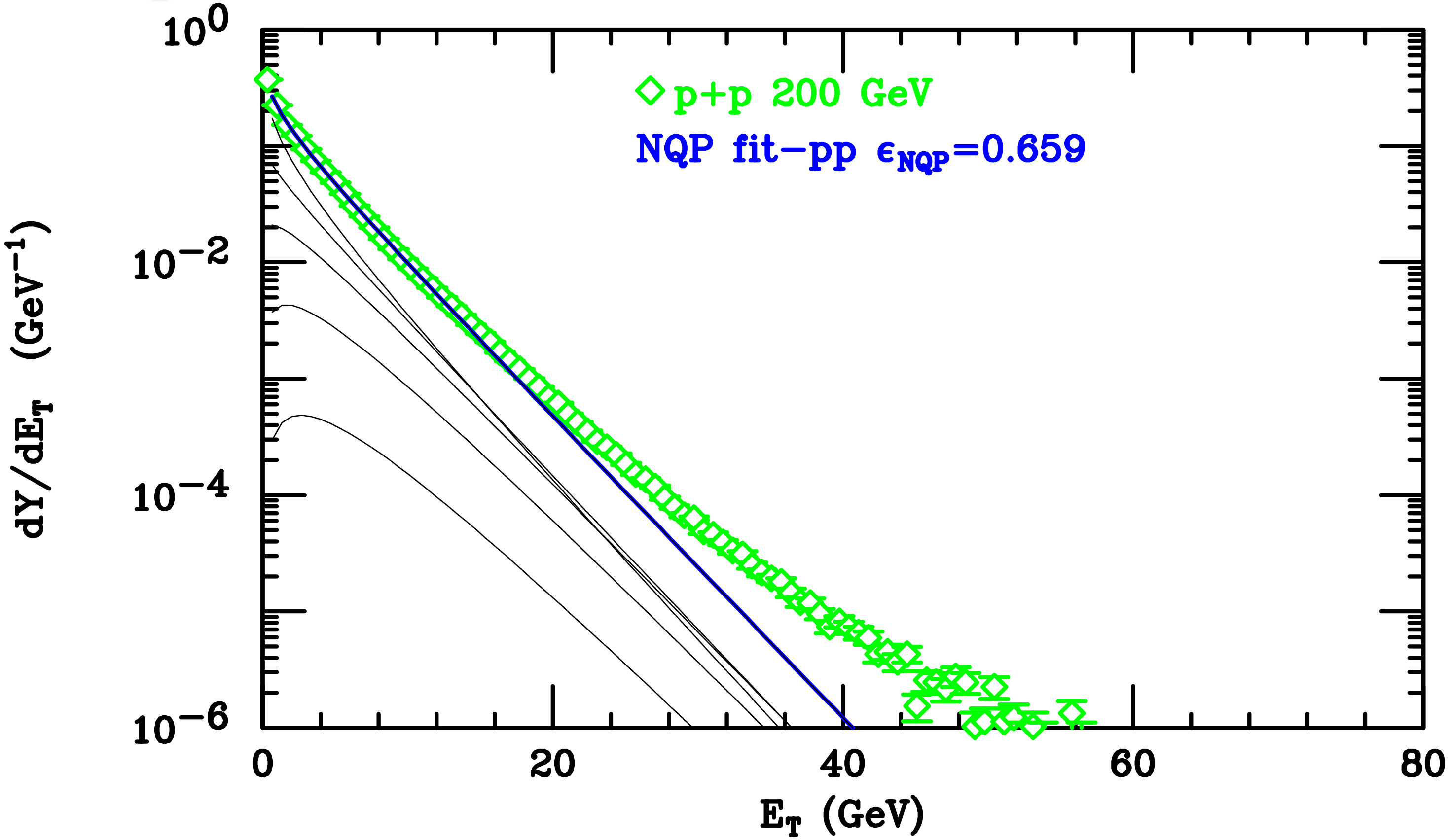


TABLE X: Fitted parameters Y_Γ^{pp} b, p of p+p data, and calculated $1-p_0$. Note that the standard errors on these parameters using $\chi^2 = \chi^2_{\rm min}+1$ have been multiplied by $\sqrt{\chi^2_{\rm min}/{\rm dof}}$ in each case.

System	Y_Γ^{pp}	b (GeV)$^{-1}$	p	$\langle E_T\rangle^{\rm ref}$ GeV	$\chi^2_{\rm min}$/dof	$1-p_0$
p+p $E_T<13.3$	0.933 ± 0.006	0.273 ± 0.003	0.724 ± 0.010	2.64	4866/17	0.647 ± 0.065
p+p $E_T<26.6$	0.952 ± 0.004	0.263 ± 0.003	0.692 ± 0.007	2.63	6715/37	0.660 ± 0.066

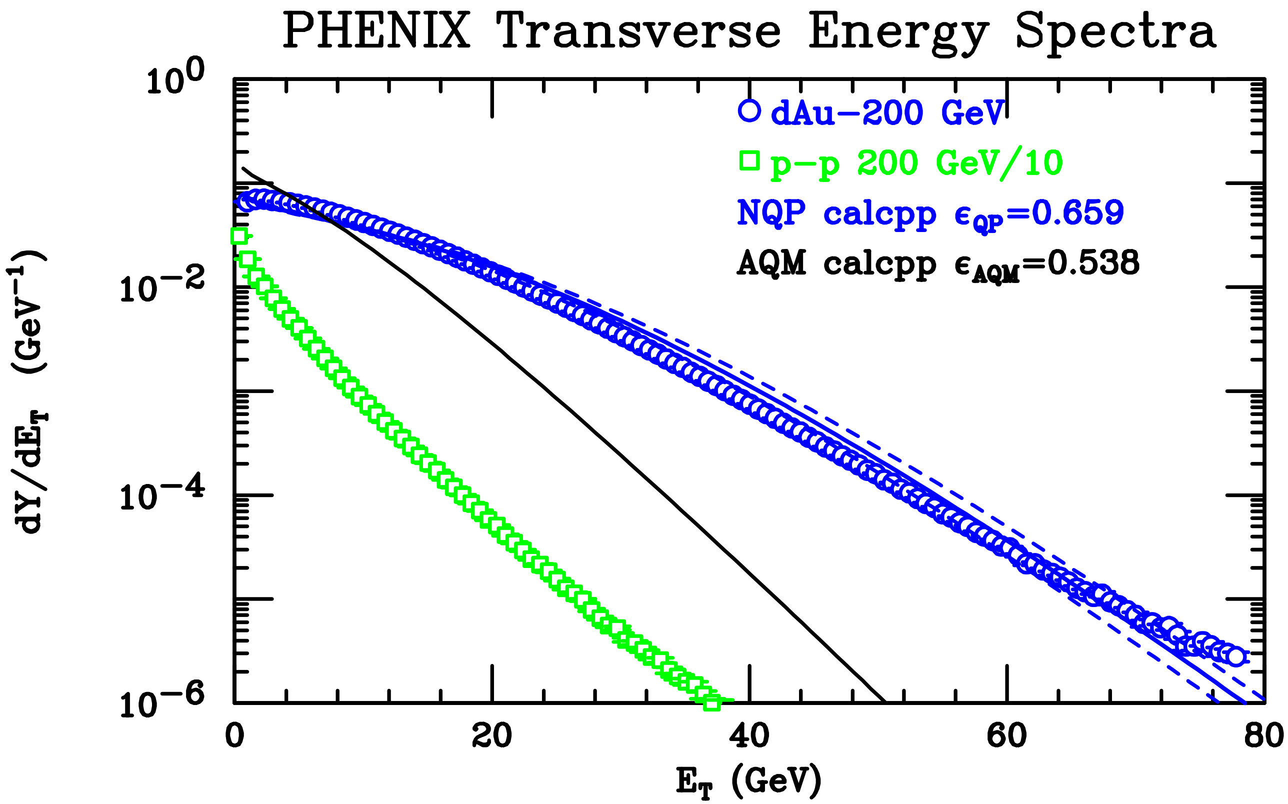
$$1-p_0 = \frac{1}{\sigma_{\rm INEL}} \frac{23.0\,{\rm mb}\pm 9.7\%}{0.79\pm0.02} Y_\Gamma^{pp} = 0.693(\pm 10\%)\, Y_\Gamma^{pp}$$

Deconvolute the p-p E_T distribution to find the E_T distribution of a quark-participant



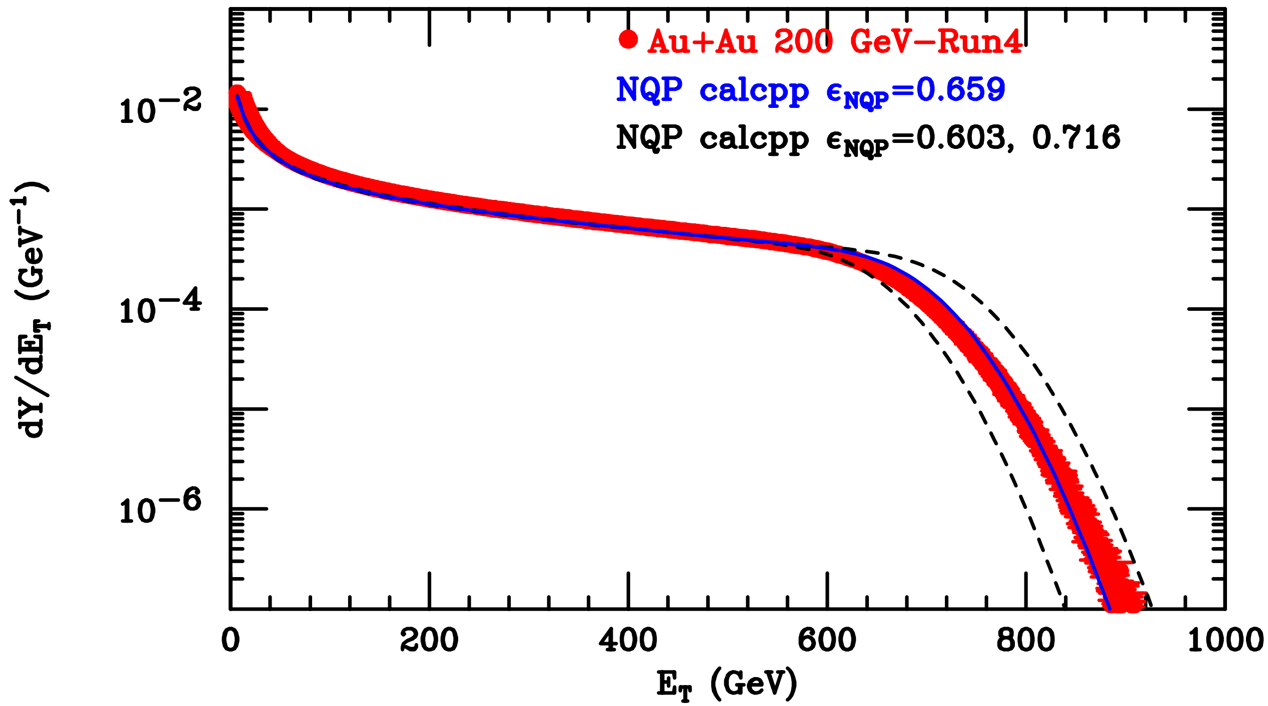
p-p E_T distribution fit to the sum (blue) of properly weighted E_T distributions of 2,3,4,5,6 constituent-quark-participants with constituent-quark ε_{NQP}=1-p_0=0.659 (black lines) [Γ distributions].

Calculate d+Au and Au+Au E_T distributions



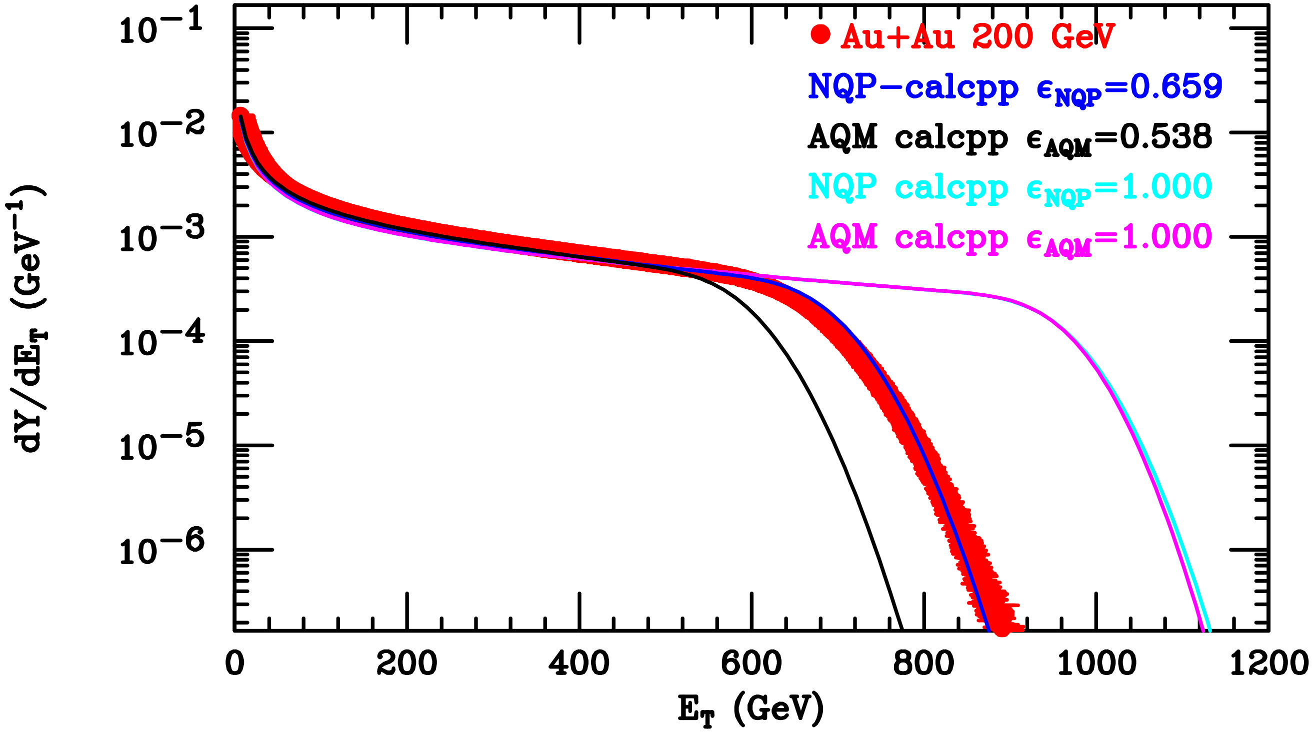
The NQP calculation is in excellent agreement with the d+Au measurement in shape and in magnitude over a range of a factor of 1000 in cross section, while the AQM calculation disagrees both in shape and magnitude, with a factor of 1.7 less E_T emission than the measurement, clearly indicating the need for the emission from additional quark-participants in the target beyond those in the projectile deuteron.

Calculate d+Au and Au+Au E_T distributions



Both the shape and magnitude of the NQP calculation are in excellent agreement with the Au+Au measurement. The upper edge of the calculation using the central $\varepsilon_{NQP}=1-p_0=0.659$ is essentially on top of the measured E_T distribution, well within the systematic error shown. The systematic error is predominantly from the 10% uncertainty in p_0 calculated from the measured E_T cross section.

Au+Au AQM NQP calculations w/wo p_0



The AQM calculation with ε_{AQM}=1-p_0=0.538 for a color-string shows around 12% less E_T than the NQP calculation with ε_{NQP}=1-p_0=0.659 due to the different efficiencies; but this is within the systematic uncertainty shown on previous slide. Thus, the symmetric Au+Au system can't distinguish the models with the present systematic uncertainties. As a check that the calculations would give the same answer for the AQM and NQP in a symmetric system for perfect efficiency, the calculations were repeated for Au+Au with 100% efficiency and are indeed one on top of each other. c

Previous analyses using PHOBOS data have shown that Quark Participant Model works in Au+Au but could have been the AQM

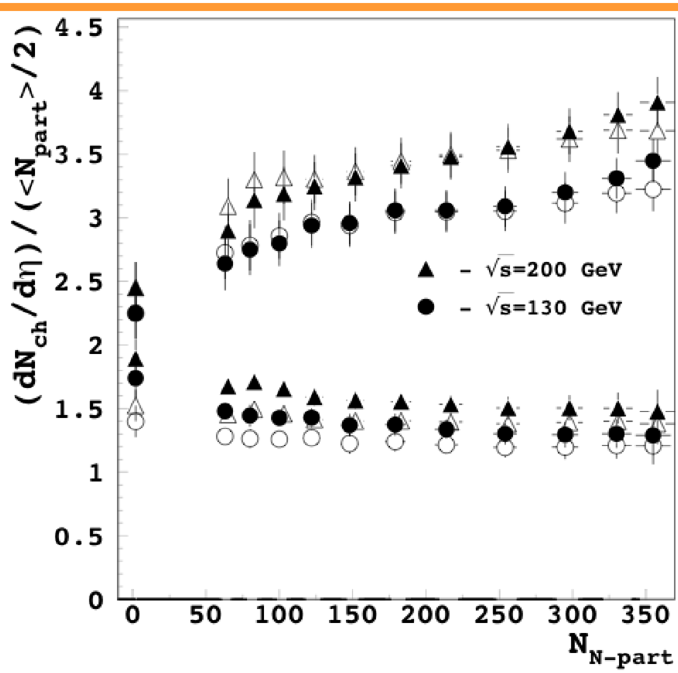
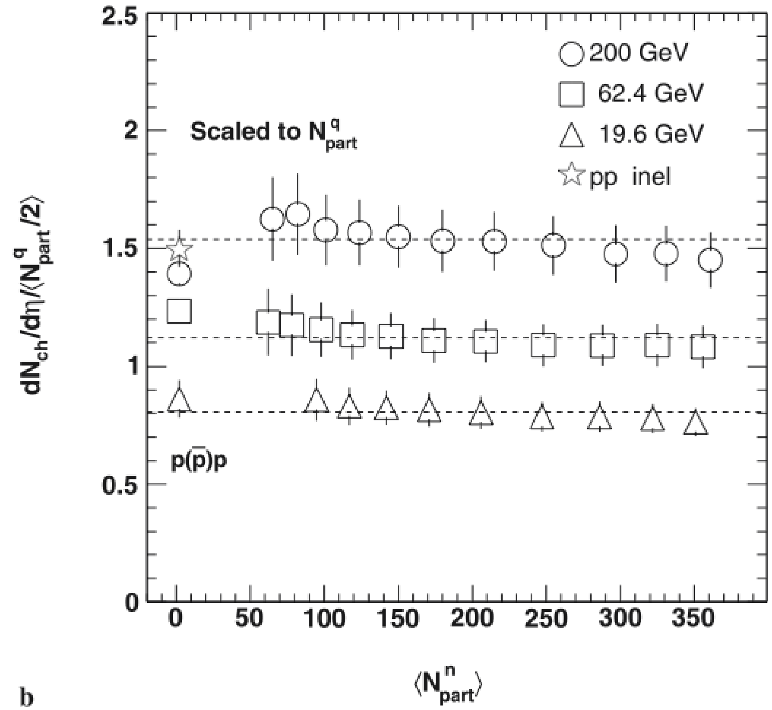


FIG. 3. (Color online) N_{ch} per nucleon and quark participant pair vs centrality. The results for quark participant pair are shown for $\sigma_{qq}=4.56$ mb (solid symbols) and $\sigma_{qq}=6$ mb (open symbols).

Eremin&Voloshin, PRC **67** (2003) 064905

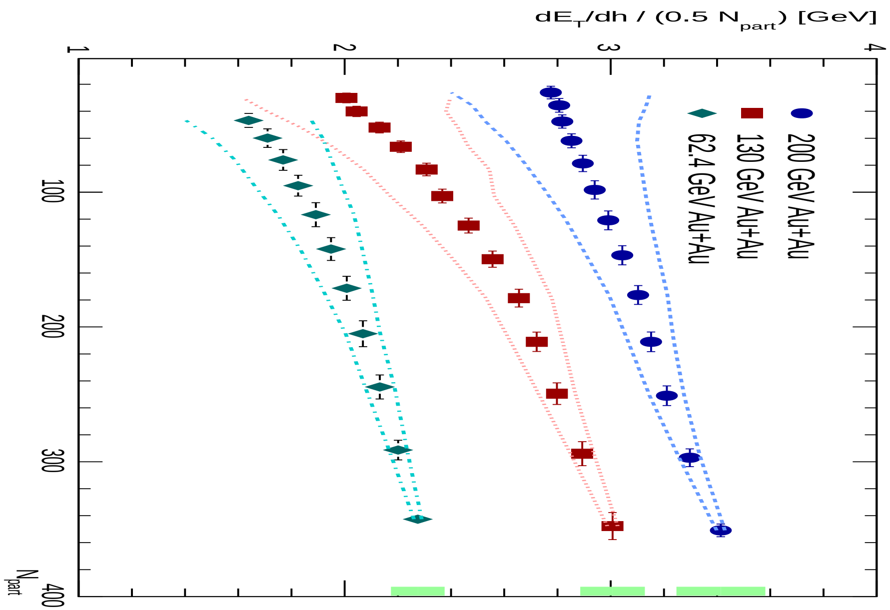


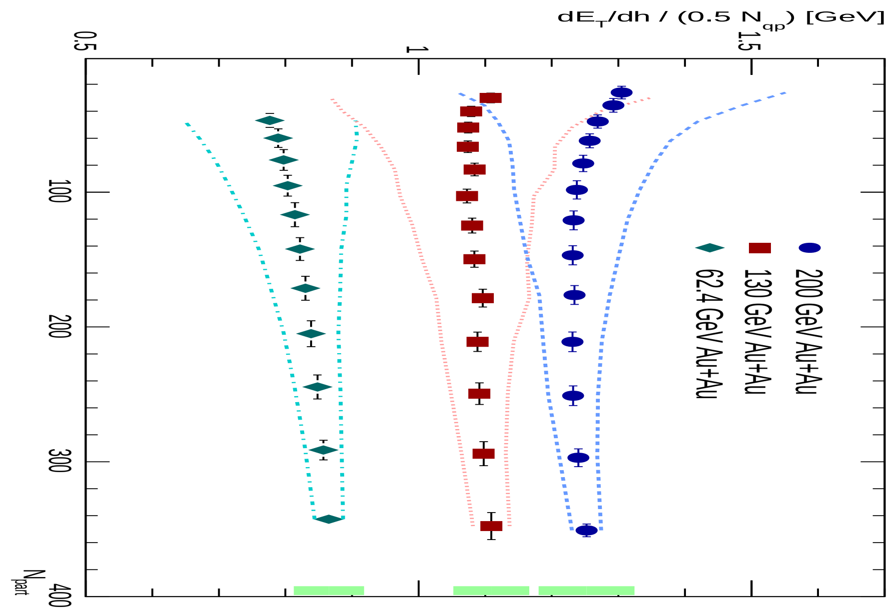
b

Nouicer, EPJC **49** (2007) 281

These analyses didn't do entire distributions but only centrality-cut averages. PHENIX has also done this and learned something VERY interesting.

PHENIX results cut on centrality for 3 $\sqrt{s_{NN}}$



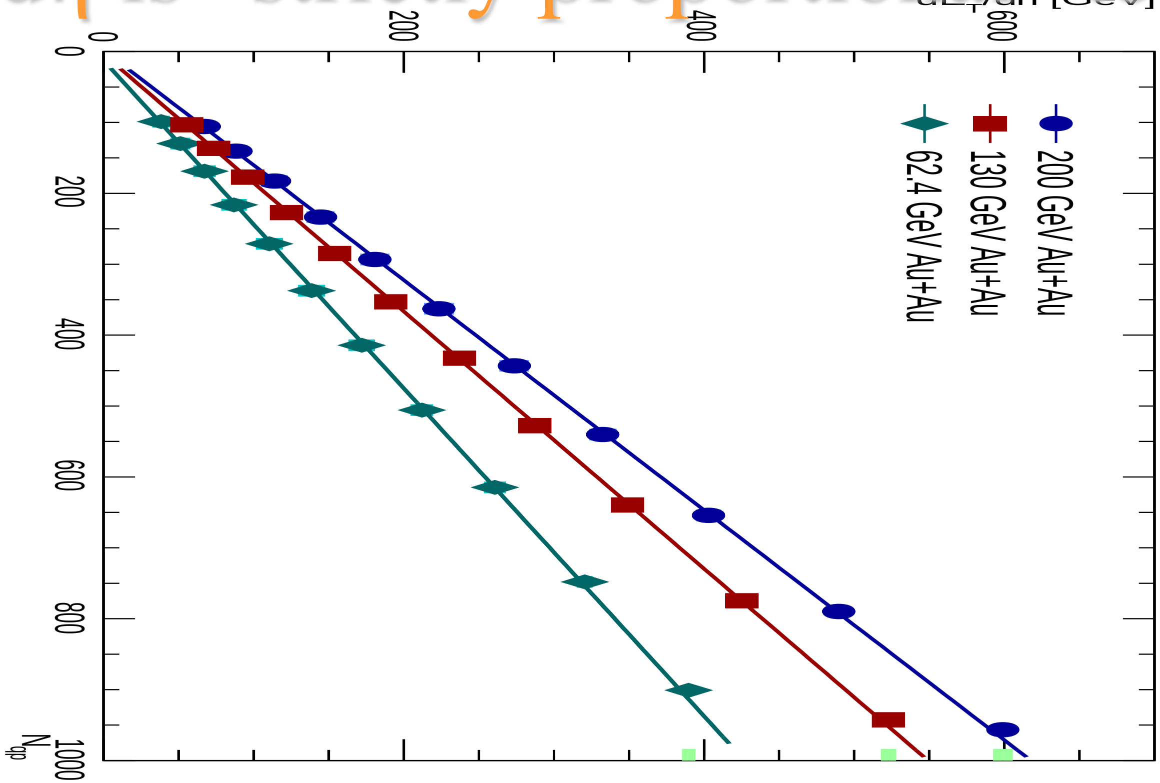


$dE_T/d\eta/(0.5\ N_{part})$ is not constant vs. centrality, N_{part}, as shown in slide 20

$dE_T/d\eta/(0.5\ N_{quarkpart})$ is constant vs. centrality, N_{part}, for the 3 $\sqrt{s_{NN}}$

Even more impressive is to plot $dE_T/d\eta$ directly vs. N_{qp}

$dE_T/d\eta$ is "strictly proportional" to Nqp



A fit of $dE_T/d\eta = a \times N_{qp} + b$ at each $\sqrt{s_{NN}}$ gives b=0 in all 3 cases which establishes the linearity of $dE_T/d\eta$ with N_{qp}

$\sqrt{s_{NN}}$ (GeV)	a (GeV)	b (GeV)
200	0.617 ± 0.023	1.2 ± 7.0
130	0.551 ± 0.020	-2.1 ± 6.5
62.4	0.432 ± 0.019	-5.4 ± 5.4

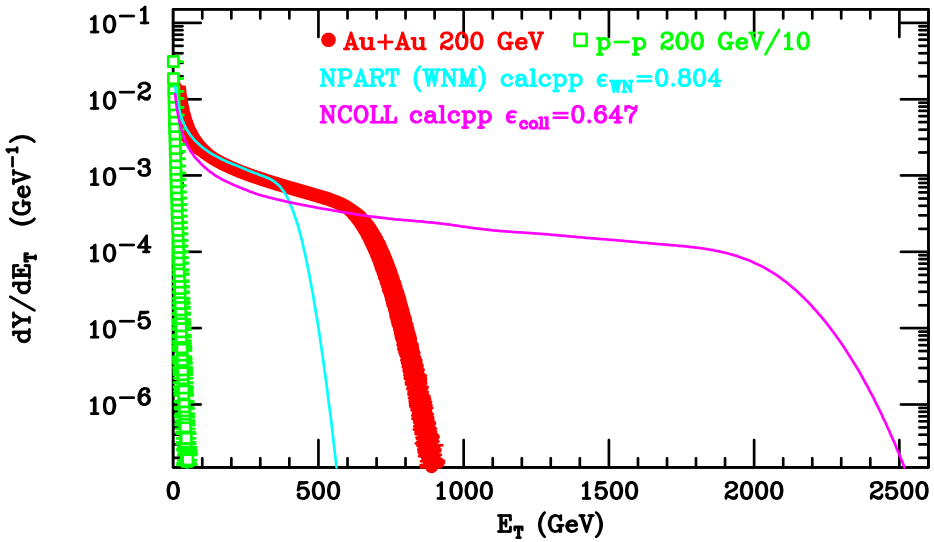
How I learned to love the Ansatz-Autumn 2013

In addition to my disliking the formula below because

$$dE_T{}^{AA}/d\eta = [(1-x)\ \langle N_{\rm part}\rangle\ dE_T{}^{pp}/d\eta/2 + x\ \langle N_{\rm coll}\rangle\ dE_T{}^{pp}/d\eta]$$

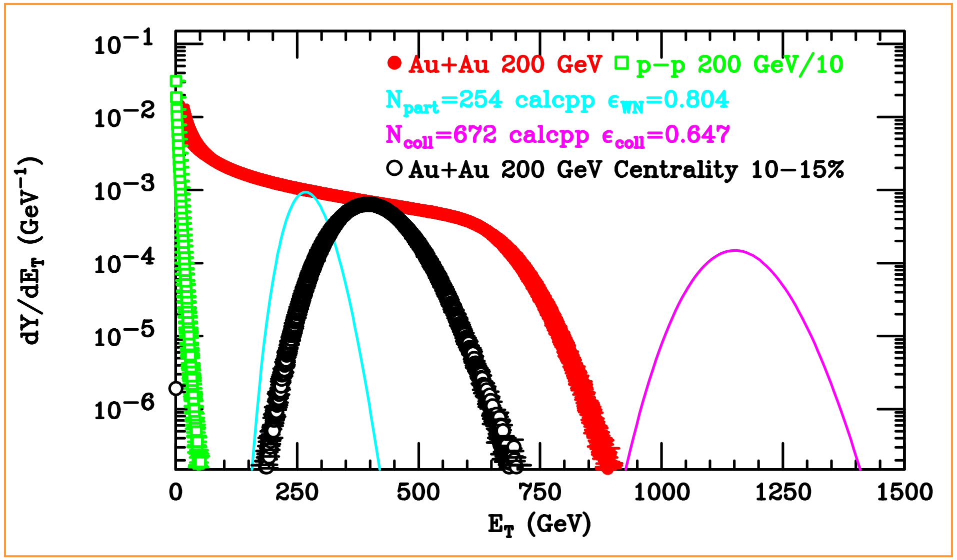
the N_{coll} term implied a hard-scattering component for E_T, known to be absent in p-p.

I disliked it even more because it couldn't be sensibly computed as a distribution in an Extreme Independent framework. For instance, once $dE_T{}^{pp}/d\eta$ is known, I get:

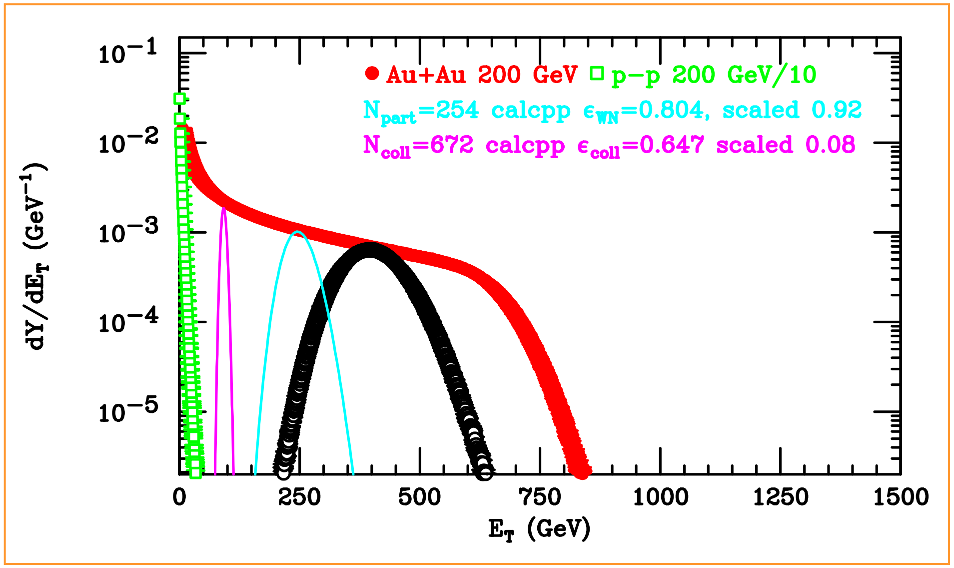


The weighted average of the Npart and Ncoll distributions looks nothing like the measured Au+Au distribution, nor any other E_T distribution ever measured.

It doesn't work cut on centrality either



The weighted sum of the average of the N_{part} and N_{coll} distribution might equal the average of the measured distribution but the weighted sum of the Npart and N_{coll} distributions looks nothing like the measured distribution (black)



No, dummy, said one of my colleagues, you shift the scales of the N_{part} and N_{coll} distributions by x and 1-x respectively and sum them. That doesn't work either.

Didn't ATLAS and ALICE show that it worked? Yes, But. Then the Aha moment!

At the LHC, ATLAS showed that computing the ansatz $[(1\text{-}x)N_{part}/2+x\,N_{coll}]$ on an event-by-event basis as a nuclear geometry distribution in a standard Glauber calculation agrees very well with their measured E_T distribution in 2.76 TeV Pb+Pb collisions over the range $3.2<|\eta|<4.9$ [PLB707(2012)330]. Actually this was only for use in determining the centrality. But if the ansatz works as a nuclear geometry element and a constituent quark also works THEN said Bill Zajc the chair of our internal review committee, "the success of the two component model is not because there are some contributions proportional to N_{part} and some going as N_{coll}, but because a particular linear combination of N_{part} and N_{coll} turns out to be an empirical proxy for the number of constituent quarks".

Et voilà, we checked and it worked: the ratio of $N_{qp}/[(1\text{-}x)N_{part}/2+x\,N_{coll}]=3.38$ on the average and varies by less than 1% over the entire centrality range in 1% bins, except for the most peripheral bin where it is 5% low and for p-p collisions where it is 2.99

After this epiphany, we found out that a more recent paper on centrality by ALICE [PRC 88 (2013)044909] with an event-by-event Glauber calculation similar to ATLAS realized that this implied that the ansatz represented the number of emitting sources of particles, which they named "ancestors". Thus the "ancestors" are constituent-quarks!

PHENIX Calculation vs Centrality Au+Au

x=0.08

Centrality	$\langle N_{part} \rangle$	$\langle N_{qp} \rangle$	$\langle N_{coll} \rangle$	ansatz	$\langle N_{qp} \rangle$/ansatz
0-5%	350.9 ± 4.7	956.6 ± 16.2	1064.1 ± 110.0	246.5	3.88
5-10%	297.0 ± 6.6	789.8 ± 15.3	838.0 ± 87.2	203.7	3.88
10-15%	251.0 ± 7.3	654.2 ± 14.5	661.1 ± 68.5	168.3	3.89
15-20%	211.0 ± 7.3	540.2 ± 12.3	519.1 ± 53.7	138.6	3.90
20-25%	176.3 ± 7.0	443.3 ± 10.4	402.6 ± 39.5	113.3	3.91
25-30%	146.8 ± 7.1	362.8 ± 12.2	311.9 ± 31.8	92.5	3.92
30-35%	120.9 ± 7.0	293.3 ± 11.0	237.8 ± 24.2	74.6	3.93
35-40%	98.3 ± 6.8	233.5 ± 9.2	177.3 ± 18.3	59.4	3.93
40-45%	78.7 ± 6.1	182.7 ± 6.8	129.6 ± 12.6	46.6	3.92
45-50%	61.9 ± 5.2	140.5 ± 5.3	92.7 ± 9.0	35.9	3.91
50-55%	47.6 ± 4.9	105.7 ± 5.5	64.4 ± 8.1	27.0	3.91
55-60%	35.6 ± 5.1	77.3 ± 6.8	43.7 ± 7.6	19.9	3.89
60-65%	26.1 ± 4.7	55.5 ± 7.1	29.0 ± 6.5	14.3	3.87
65-70%	18.7 ± 4.0	39.0 ± 6.7	18.8 ± 5.3	10.1	3.86
70-75%	13.1 ± 3.2	27.0 ± 4.9	12.0 ± 3.6	7.0	3.86
75-80%	9.4 ± 2.1	19.0 ± 3.2	7.9 ± 2.2	5.0	3.83
80-92%	5.4 ± 1.2	10.3 ± 1.5	4.0 ± 1.0	2.8	3.67
$p+p$	2	2.99 ± 0.05	1	1	2.99

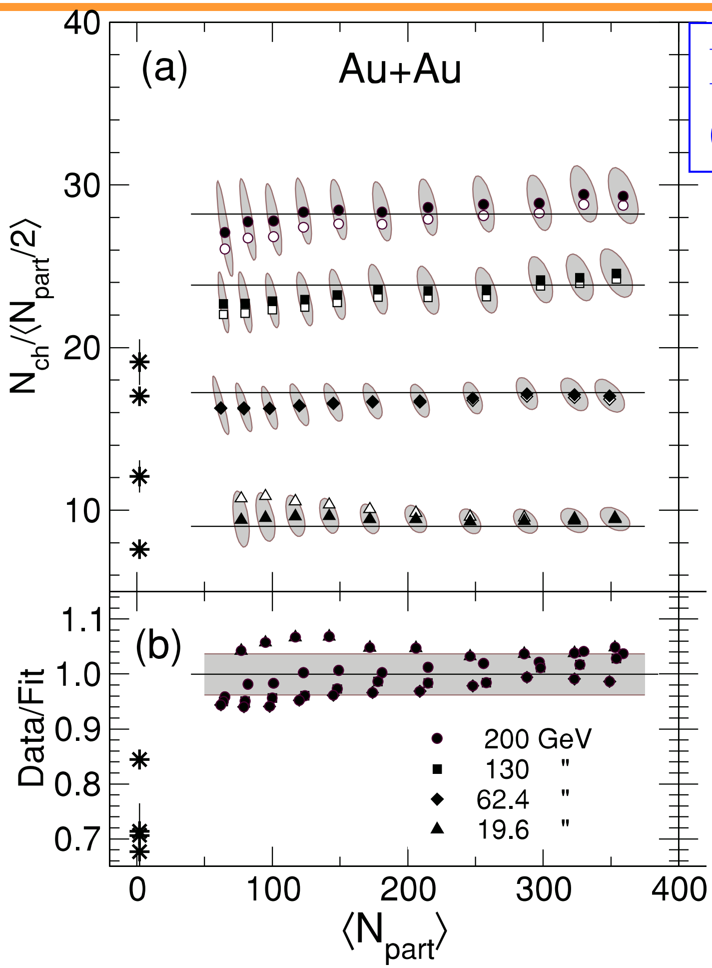
The Constituent Quark Participant Model works at mid-rapidity for A+A collisions in the range 62.4 GeV< $\sqrt{s_{NN}}$< 2.76 GeV. The two component ansatz $[(1-x)N_{part}/2+x\ N_{coll}]$ also works but does not imply a hard-scattering component in N_{ch} and E_T distributions. It is instead a proxy for N_{qp} as a function of centrality. Thus, ALICE's "ancestors" are constituent-quarks. Everybody is Happy.

Conclusions

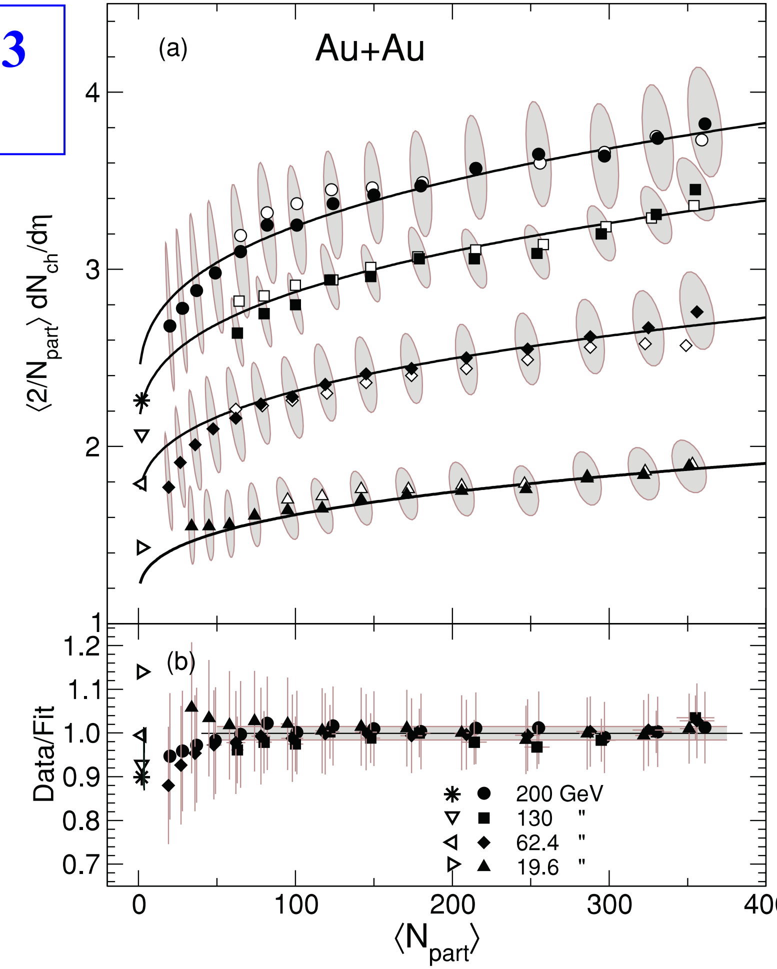
- The Constituent Quark Participant Model (N_{qp}) works at mid-rapidity for A+B collisions in the range (31 GeV) 62.4 GeV< $\sqrt{s_{NN}}$< 2.76 GeV.
- The two component ansatz [$(1-x)N_{part}/2+x\ N_{coll}$] also works but does not imply a hard-scattering component in N_{ch} and E_T distributions. It is instead a proxy for N_{qp} as a function of centrality.
- Thus, ALICE's "ancestors" are constituent-quarks.
- Everybody's happy. (OK probably not everybody).

EXTRAS

PHOBOS-Final Multiplicity Paper 2011



PHOBOS PRC **83** (2011) 024913

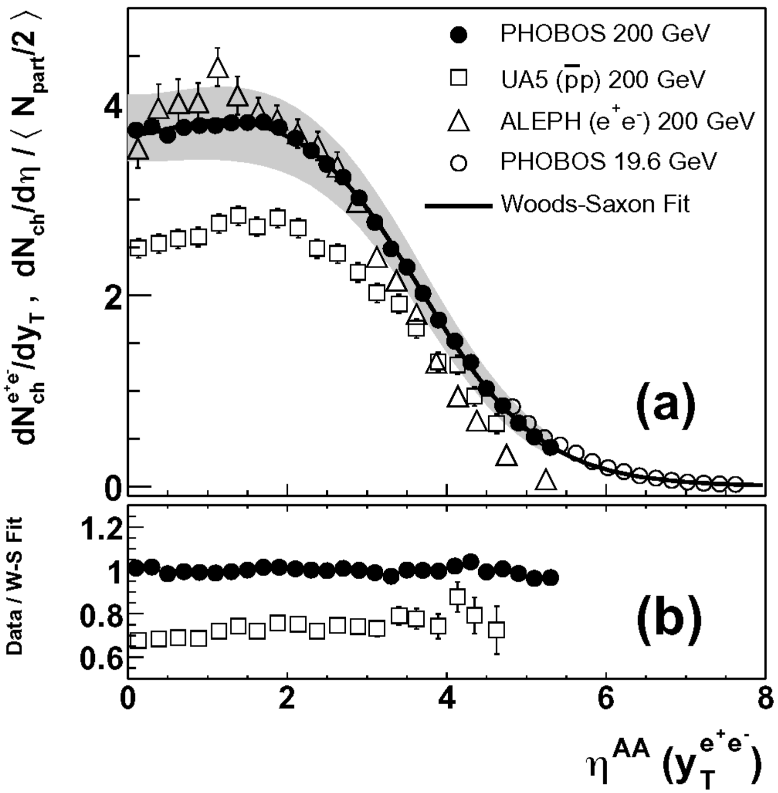


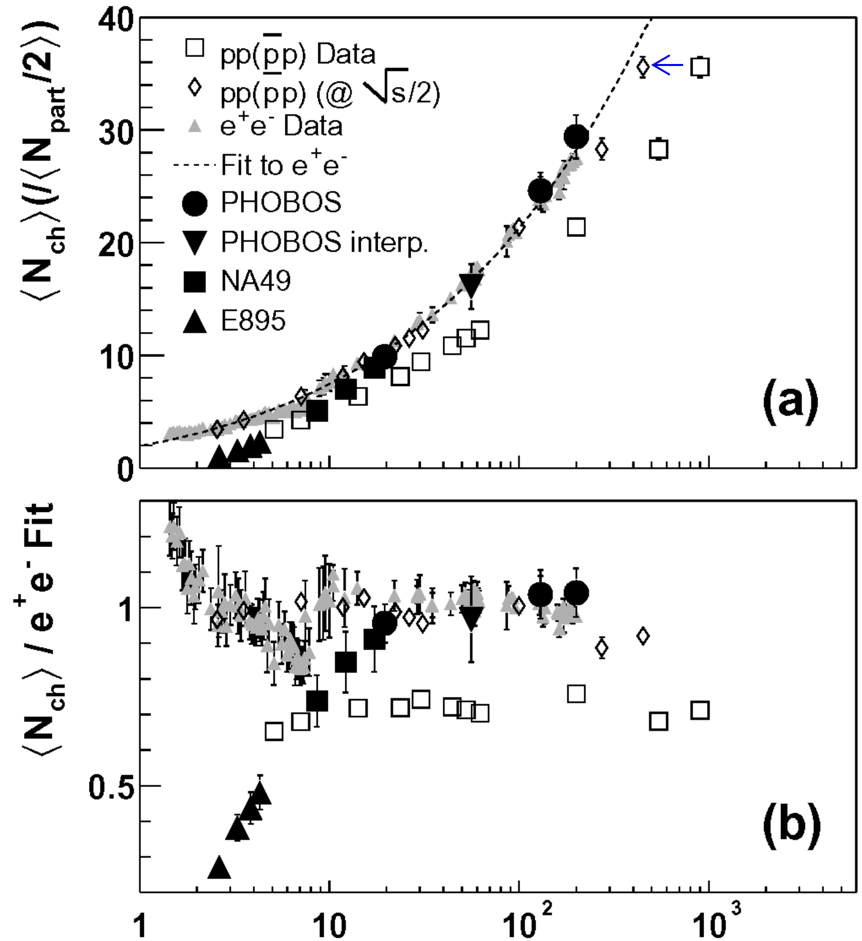
Using full rapidity range, total $N_{ch}/(0.5N_{part})$ does follow WNM (in AA only) but mid-rapidity $dN_{ch}/d\eta/(0.5N_{part})$ shows different but apparently universal dependence first seen by PHENIX and recently at LHC.

MJT-Erice 2003-For Nino PHOBOS dn/dη, N_{ch}

cf. M.Basile, A. Zichichi et al, PL **B92**, 367 (1980); **B95**, 311 (1980)

From 1993,published PRC74(2006)021902





$N_{ch}/\langle N_{part}/2\rangle$ Au+Au @ $\sqrt{s_{NN}} \sim e^+e^-$ = pp@ $\sqrt{s}=2\sqrt{s_{NN}}$

Leading particle effect-in pp--Zichichi—vanishes in AuAu

But this effect disagrees with the WNM because the basic assumption is that what matters is whether or not a nucleon was struck, not how many times it was struck. The good news is that the quark-participant model solves this problem because the multiplicity increases due to more constituent quarks/wounded nucleon being struck, from 1.5 in a p-p collision to 2.3-2.7 in central Au+Au