Highlights from BNL and RHIC 2016

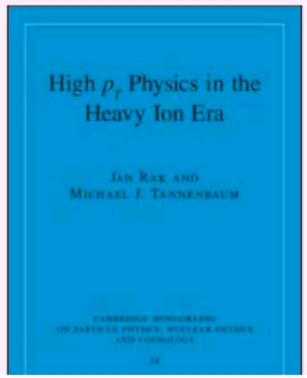
For previous years with more details see:

2009: IJMPA **26** (2011)5299 1406.0830

2011-2013: IJMPA **29** (2014)1430017 1406.1100

2014: arXiv1504.02771

2015: arXiv1504.02771



High-pT Physics in the Heavy Ion Era
Jan Rak, University of Jyväskylä, Finland
Michael J. Tannenbaum, Brookhaven National Laboratory, New York

Hardback

Series: Cambridge Monographs on Particle Physics, Nuclear Physics and Cosmology(No. 34)

ISBN:9780521190299

396pages
202 b/w illus.
Dimensions: 247 x 174 mm
Weight: 0.87kg

Availablity: In Stock

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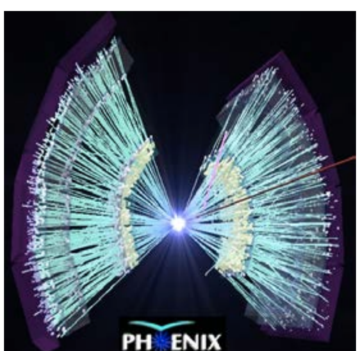
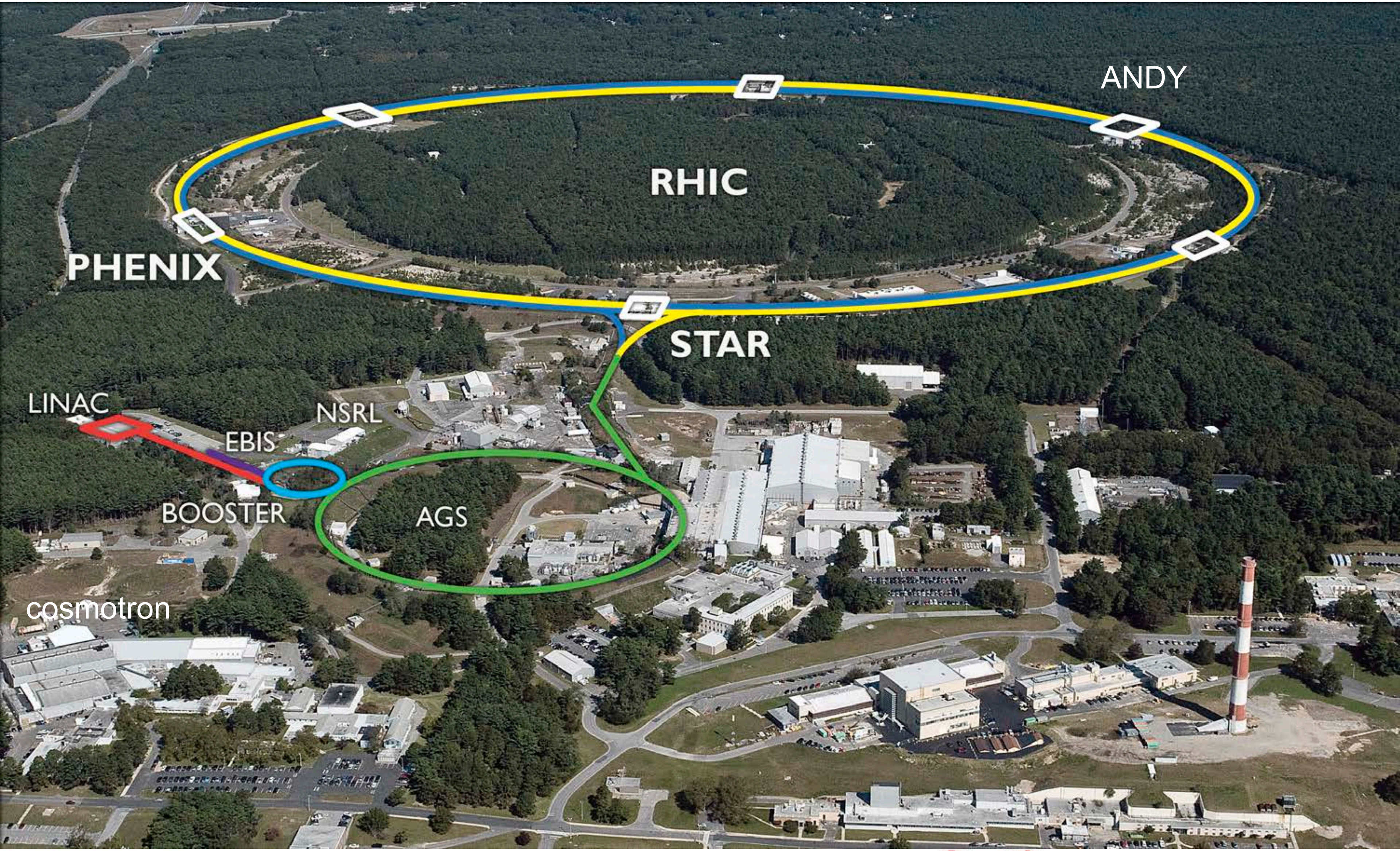


International School of Subnuclear Physics,
"The New Physics Frontiers in the LHC-2 Era"
54th Course-Erice, Sicily, Italy June 15-22, 2016

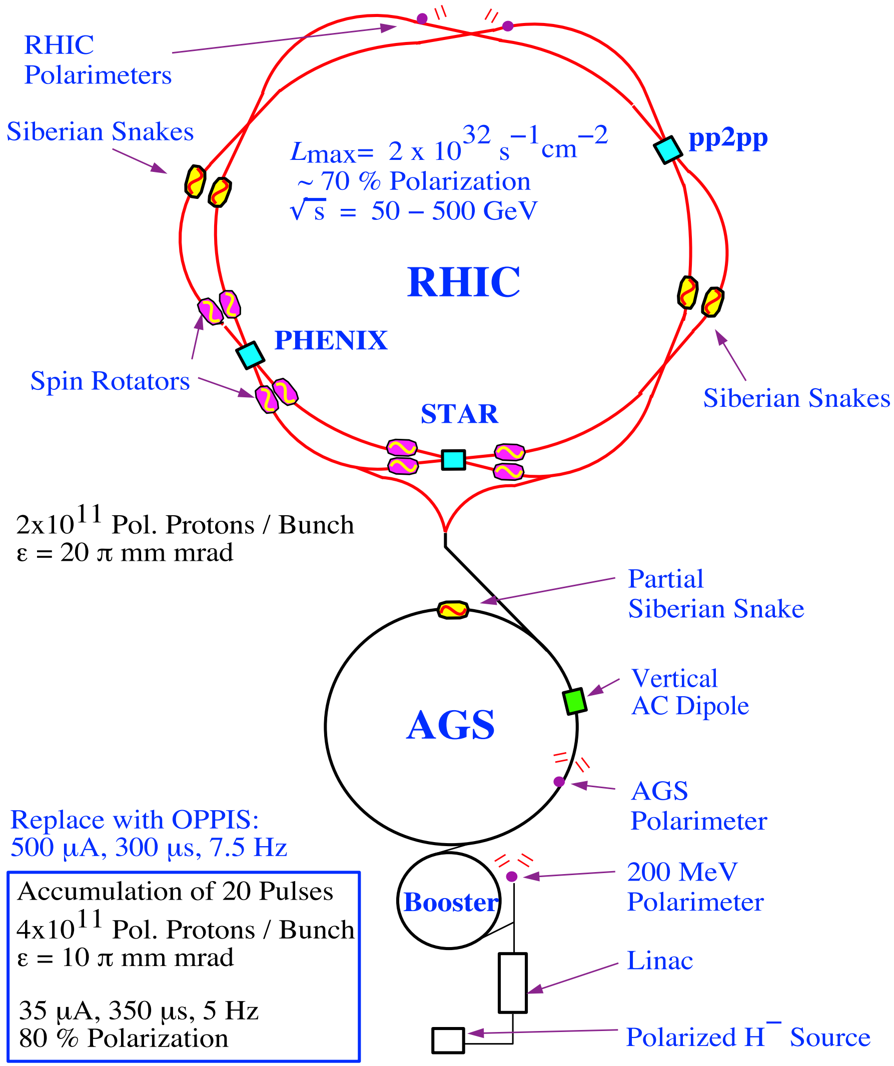
The Relativistic Heavy Ion Collider (RHIC) at BNL is 1 of the 2 remaining hadron colliders BNL also has many other facilities

Brookhaven National Laboratory (BNL)

RHIC with AGS injector

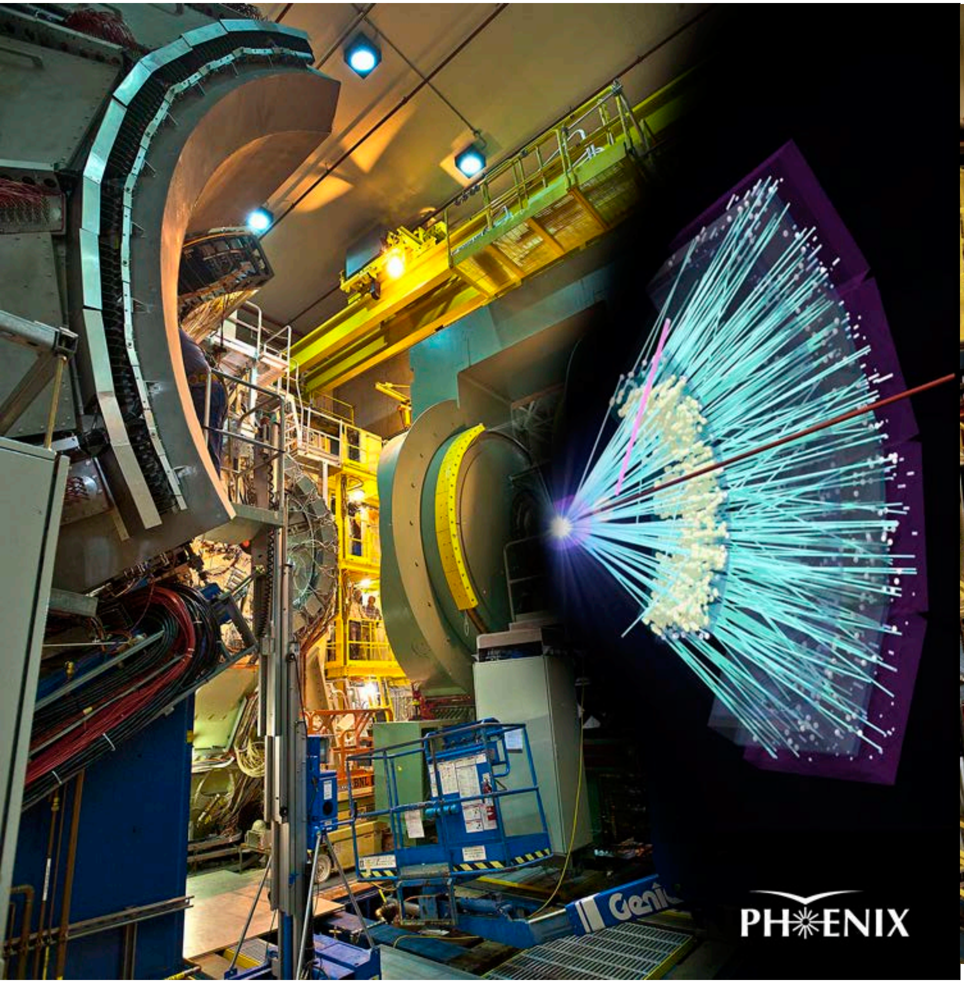


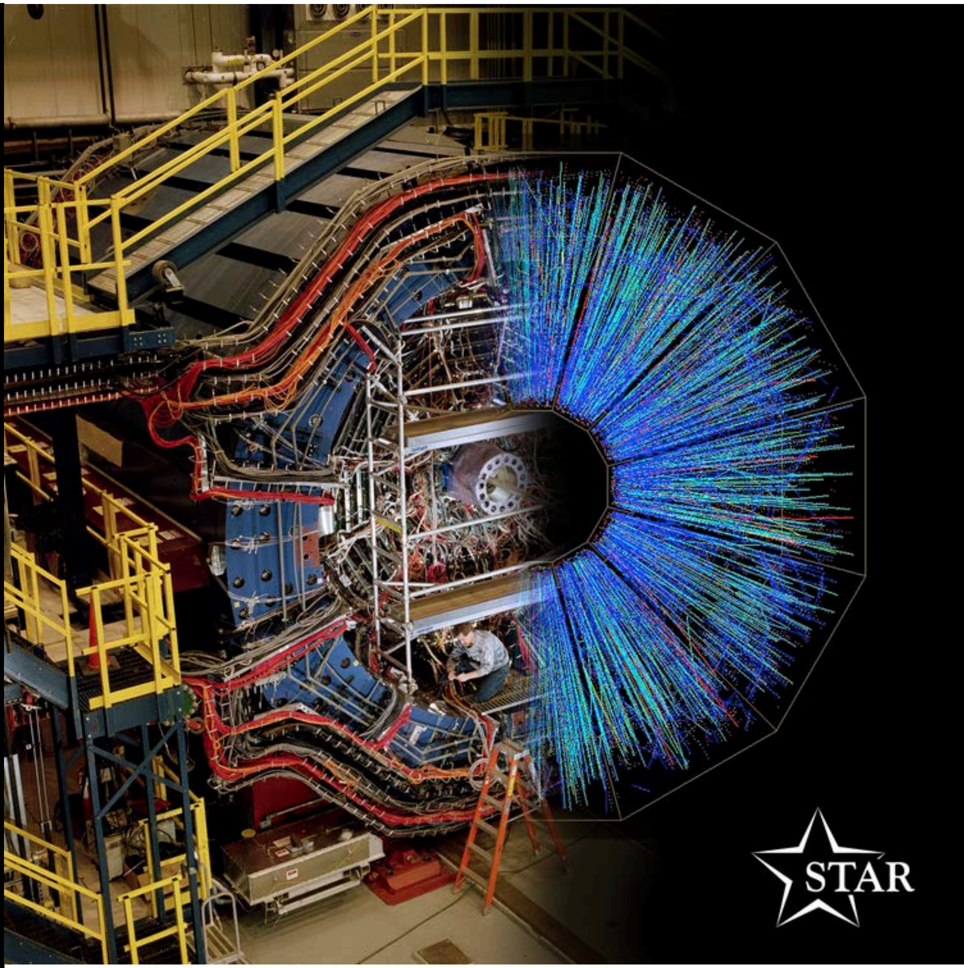
RHIC First and only polarized proton collider



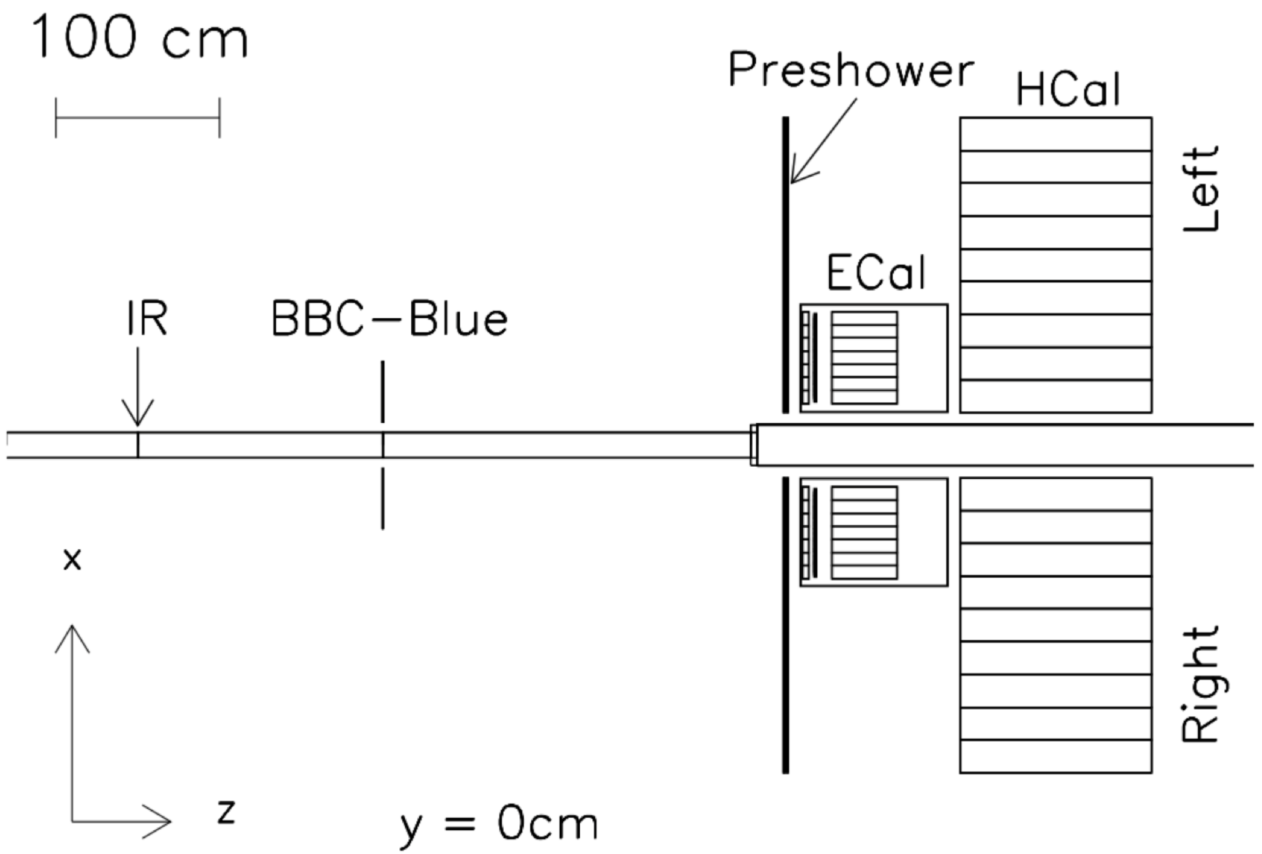
siberian snake is a magnet that flips the spin of the polarized protons half way around the ring to preserve the polarization by cancelling imperfections

Two Major Detectors



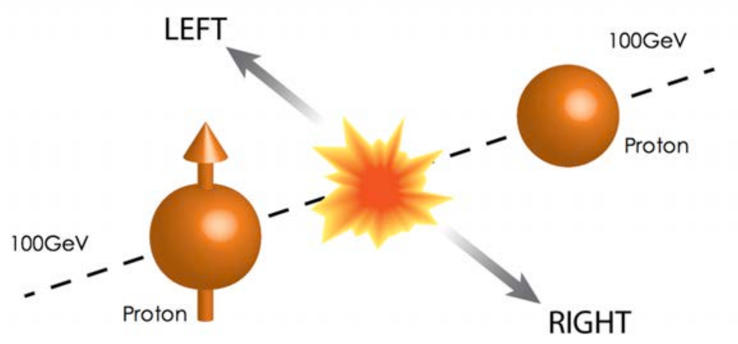


One new experiment ANDY



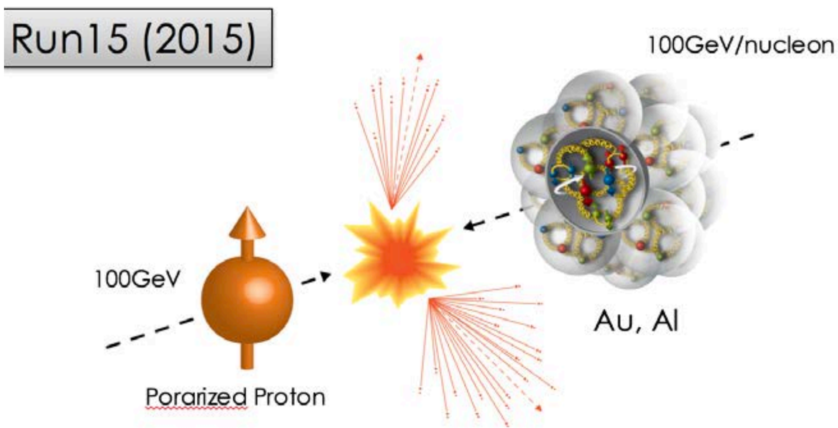
Purpose is to measure transverse spin asymmetry of Drell-Yan which is predicted to be negative, opposite in sign to that measured in single pion production in DIS positive increasing with p_T Hermes, PRD64,097101

Single spin transverse asymmetry A_N



$$A_N = \frac{d\sigma_L - d\sigma_R}{d\sigma_L + d\sigma_R}$$

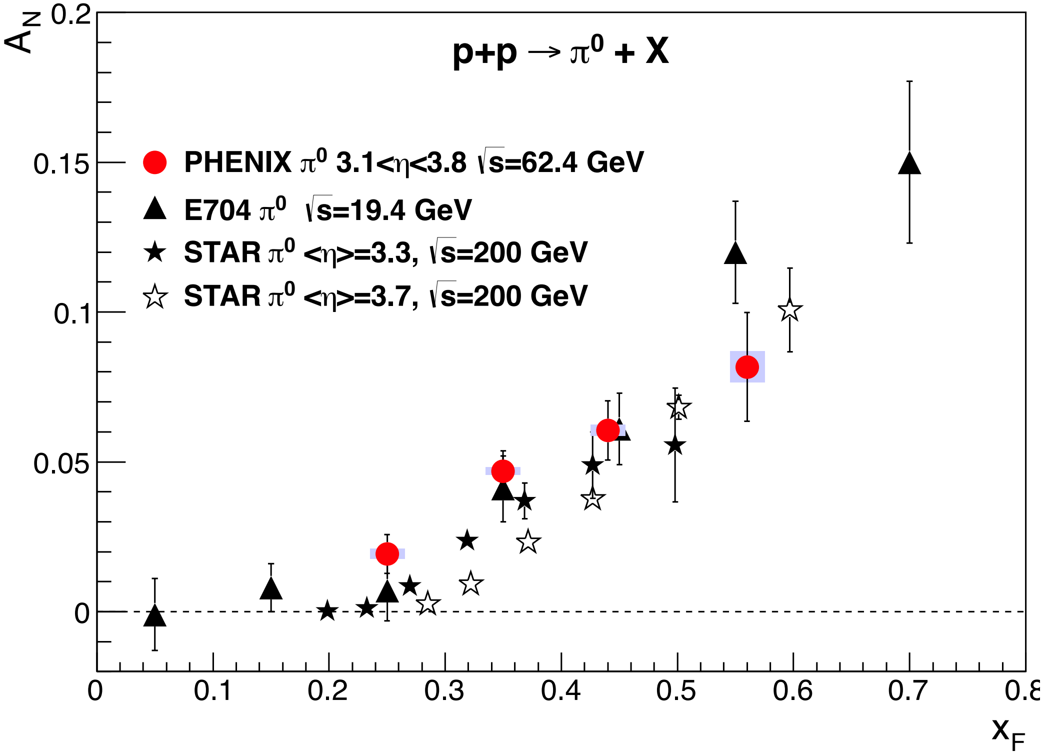
Many topics: both initial and final state effects

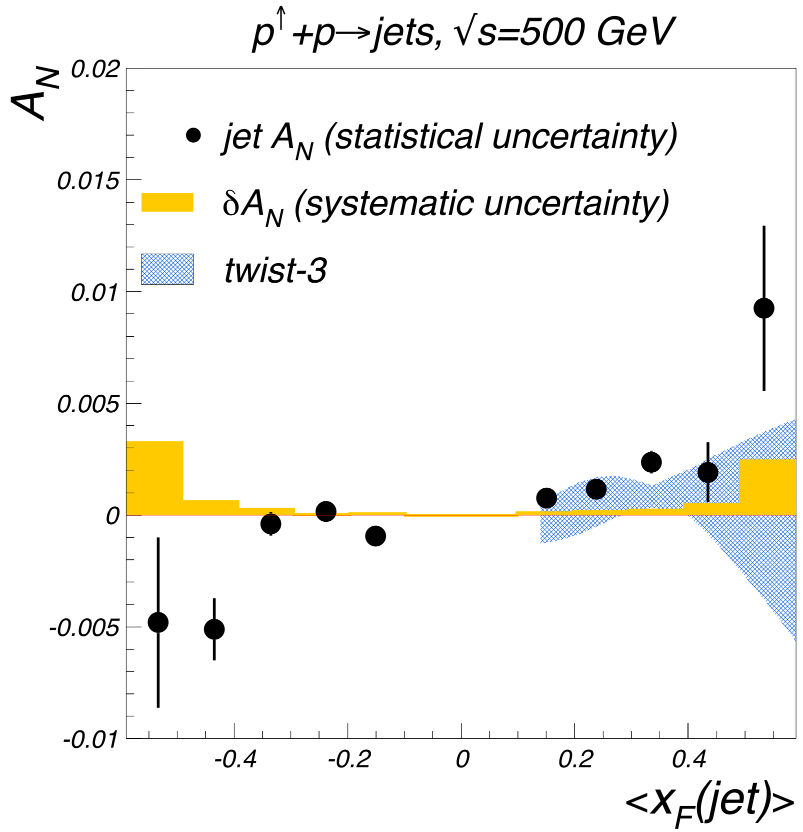


The first-ever p$^{\uparrow}$+A collisions:

Huge nuclear effect in forward neutron A_N !

Single spin A_N measurements



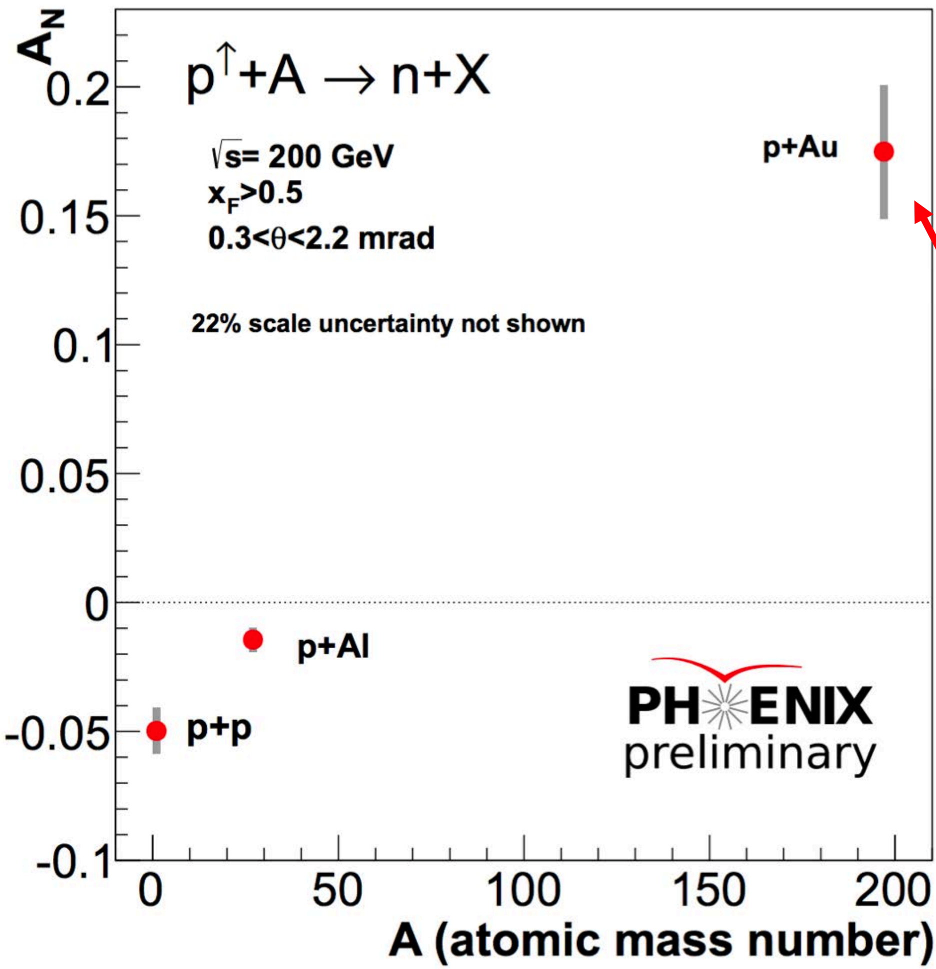


Transverse single spin asymmetry AN
PHENIX PRD90(2014) 012006
Note that E704 is PRL36(1976) 929

A_N much smaller in jets than in single particles

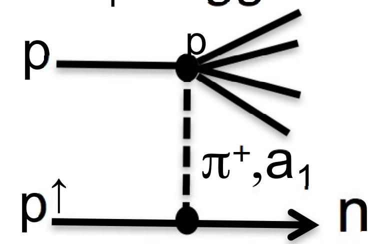
Old subject, new measurements, no clear understanding

Forward neutron A_N



Known effect in p↑p

Well described by interference between π and a_1 Reggeon



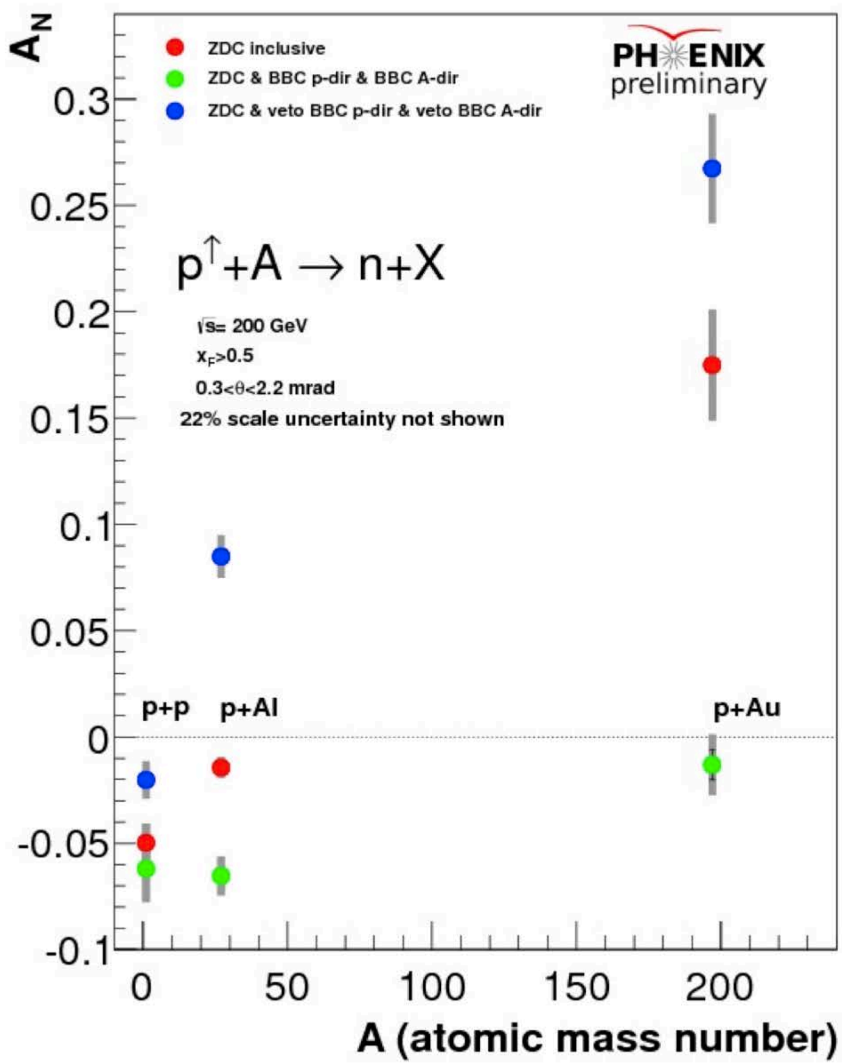
Surprise — huge A dependence:

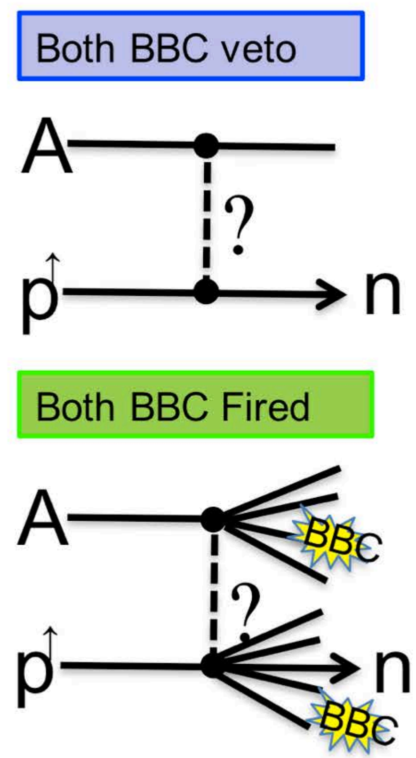
factor of ~ 3 increase in magnitude

Even the sign changes

Simple π -a_1 interference predicts small dependence

Investigating nuclear effects in forward neutron A_N





- Multiple mechanisms contribute?
- UPC or/and high parton density effect?

Need theoretical input !

RHIC performance Run 16

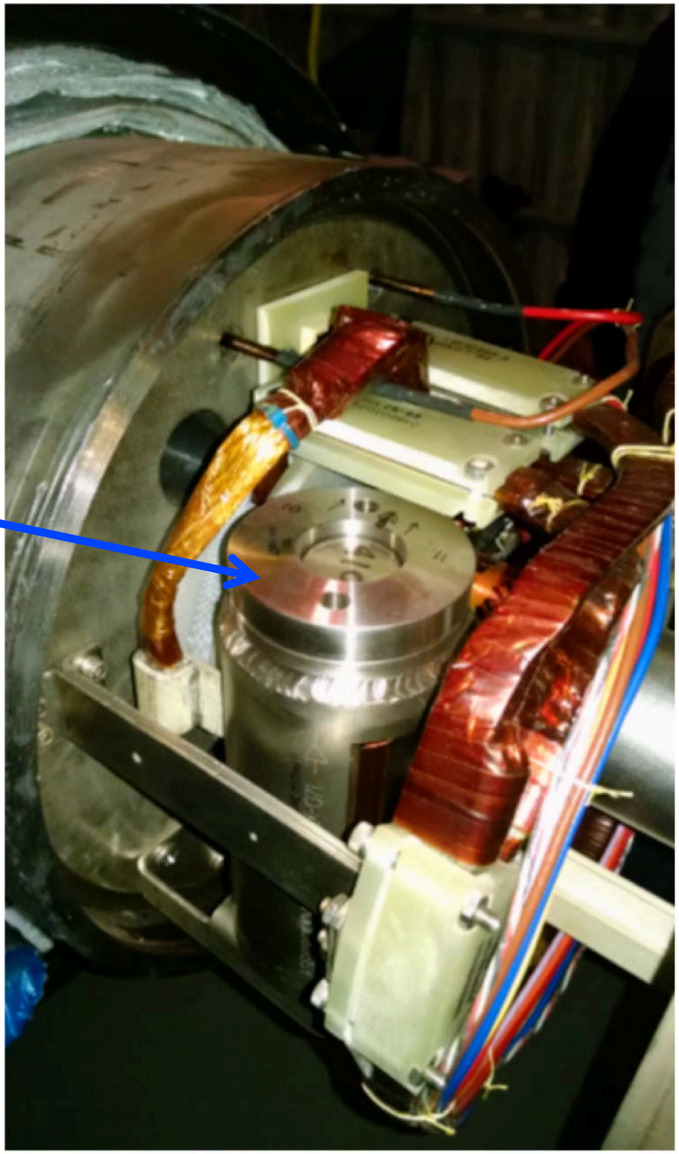
RHIC Run 16 from talk by Berndt Mueller Associate Lab director

- High luminosity 200 GeV Au-Au run (10 weeks)
- Goal: Study heavy flavor flow, especially charmed baryons, parton energy loss in QGP, quarkonium studies (for NP milestone DM12)
- d+Au beam energy scan (5 weeks)
- Goal: Study beam energy dependence of small system collectivity and QGP properties
- Proof of Principle test of coherent electron cooling (1 week)

- Run-16 went very well until …. a diode inside a dipole magnet in the blue ring malfunctioned on March 18.
- Repair required warm-up of sector 10-11, opening of dipole, replacement of the diode, and cool-down. Run-16 resumed April 6

- Low power costs allow run be extended to July 1 make up for (most of the) lost time

Replace quench protection diode



New quench protection diode

BNL’s future plan 2014

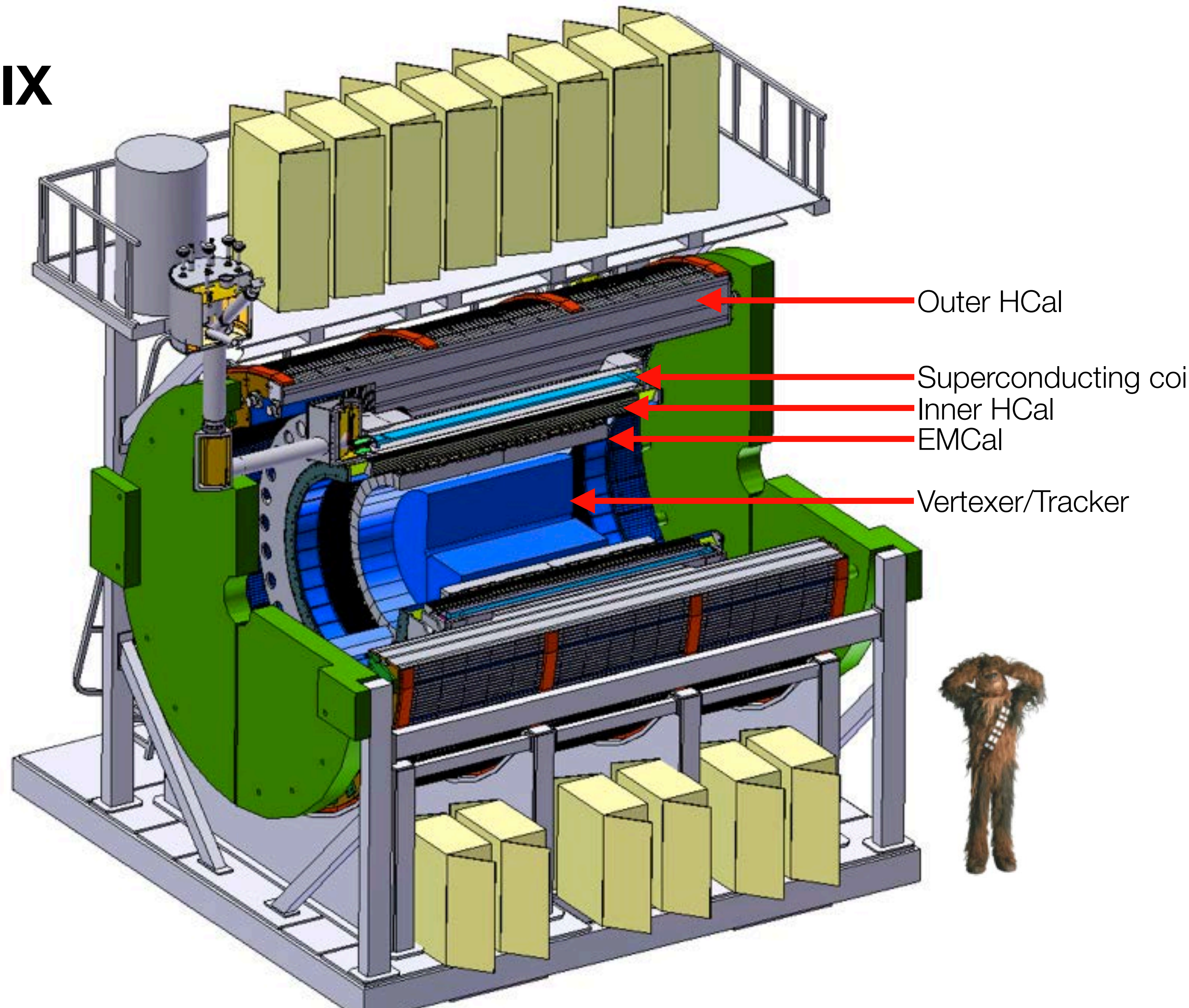
Years	Beam Species and	Science Goals	New Systems
2014	Au+Au at 15 GeV Au+Au at 200 GeV ^{3}He+Au at 200 GeV	Heavy flavor flow, energy loss, thermalization, etc. Quarkonium studies QCD critical point search	Electron lenses 56 MHz SRF STAR HFT STAR MTD
2015-16	p↑+p↑ at 200 GeV p↑+Au, p↑+Al at 200 GeV High statistics Au+Au Au+Au at 62 GeV ?	Extract η/s(T) + constrain initial quantum fluctuations Complete heavy flavor studies Sphaleron tests Parton saturation tests	PHENIX MPC-EX STAR FMS preshower Roman Pots Coherent e-cooling test
2017	p↑+p↑ at 510 GeV	Transverse spin physics Sign change in Sivers function	
2018	No Run		Low energy e-cooling install. STAR iTPC upgrade
2019-20	Au+Au at 5-20 GeV (BES-2)	Search for QCD critical point and onset of deconfinement	Low energy e-cooling
2021-22	Au+Au at 200 GeV p↑+p↑, p↑+Au at 200 GeV	Jet, di-jet, γ-jet probes of parton transport and energy loss mechanism Color screening for different quarkonia Forward spin & initial state physics	sPHENIX Forward upgrades ?
≥ 2023 ?	No Runs		Transition to eRHIC

BNL's future plan 2016

Years	Beam Species and	Science Goals	New Systems
2014	Au+Au at 15 GeV Au+Au at 200 GeV ^{3}He+Au at 200 GeV	Heavy flavor flow, energy loss, thermalization, etc. Quarkonium studies QCD critical point search	Electron lenses 56 MHz SRF STAR HFT STAR MTD
2015-16	p↑+p↑ at 200 GeV p↑+Au, p↑+Al at 200 GeV High statistics Au+Au ~~Au+Au at 62 GeV ?~~ d+Au @ 200, 62, 39, 20 GeV	Extract η/s(T) + constrain initial quantum fluctuations Complete heavy flavor studies Sphaleron tests Parton saturation tests	PHENIX MPC-EX STAR FMS preshower Roman Pots Coherent e-cooling test
2017	p↑+p↑ at 510 GeV	Transverse spin physics Sign change in Sivers function	
2018	~~No Run~~ isobars	96Zr+96Zr and 96Ru+96Ru to test chiral magnetic effect on observed Au+Au charge separation effects	Low energy e-cooling install. STAR iTPC upgrade
2019-20	Au+Au at 5-20 GeV (BES-2)	Search for QCD critical point and onset of deconfinement	Low energy e-cooling
2022-23 ~~2021-22~~	Au+Au at 200 GeV p↑+p↑, p↑+Au at 200 GeV	Jet, di-jet, γ-jet probes of parton transport and energy loss mechanism Color screening for different quarkonia Forward spin & initial state physics	sPHENIX Forward upgrades ?
≥ 2023 ?	No Runs		Transition to eRHIC

One Future experiment sPHENIX June 2016

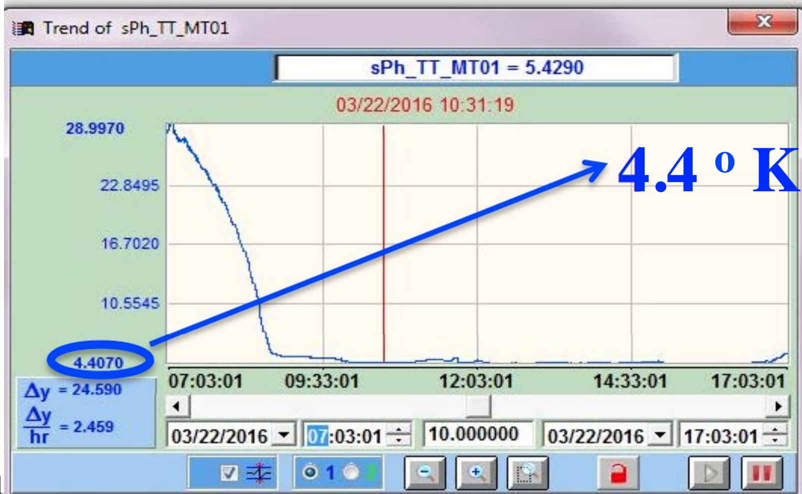
sPHENIX

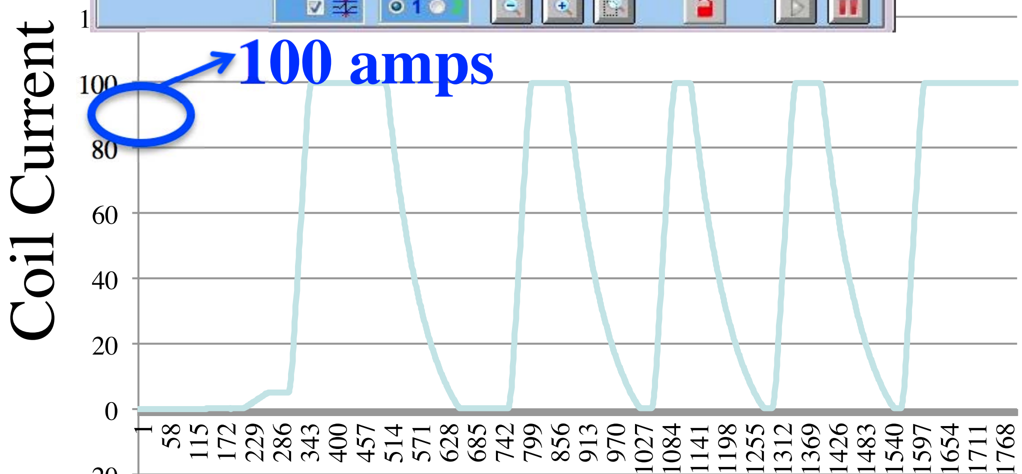


Low-Field Test of sPHENIX Magnet - Mar 2016

The sPHENIX Magnet was successfully cooled to 4K and ramped to 100A. The field measure was exactly as expected for this current.

Magnet cold test results





Time (S)

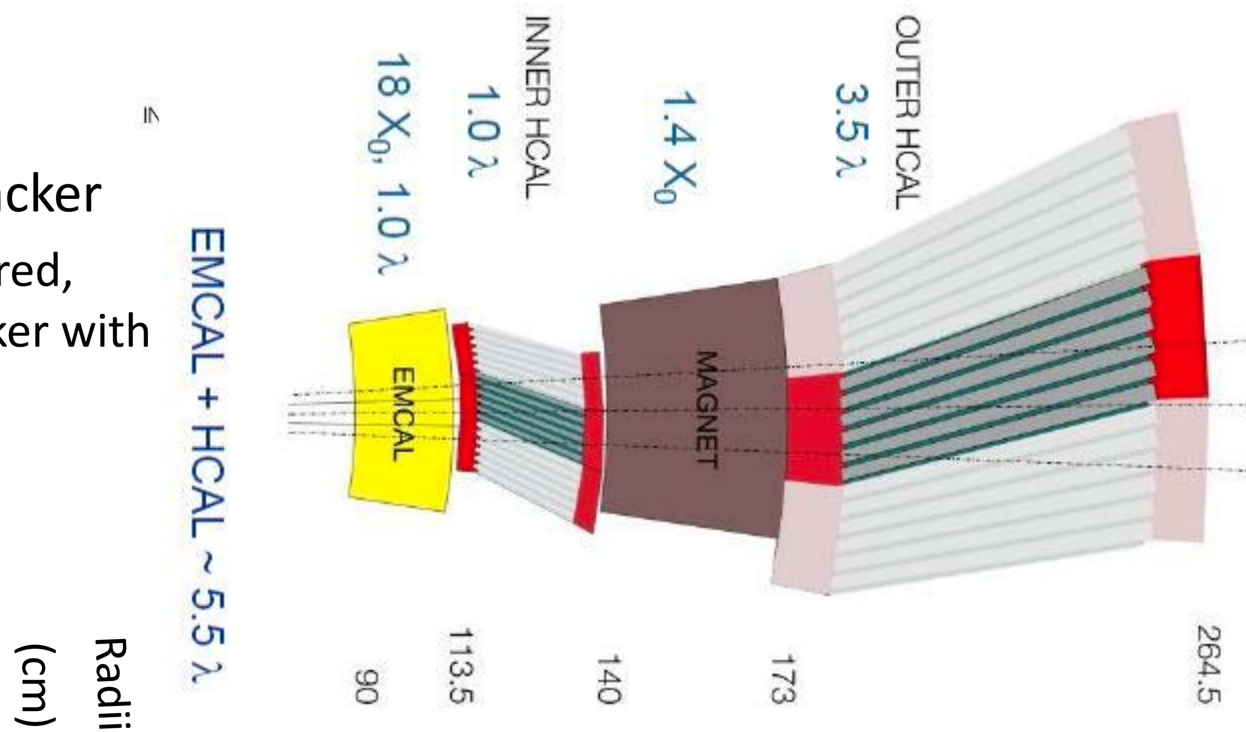
Ramp rate 2.5 A/S

At 4.4 º K we put 100 amps on the magnet coil and the solenoid field generated was 256 G, as expected. The coil was superconducting.

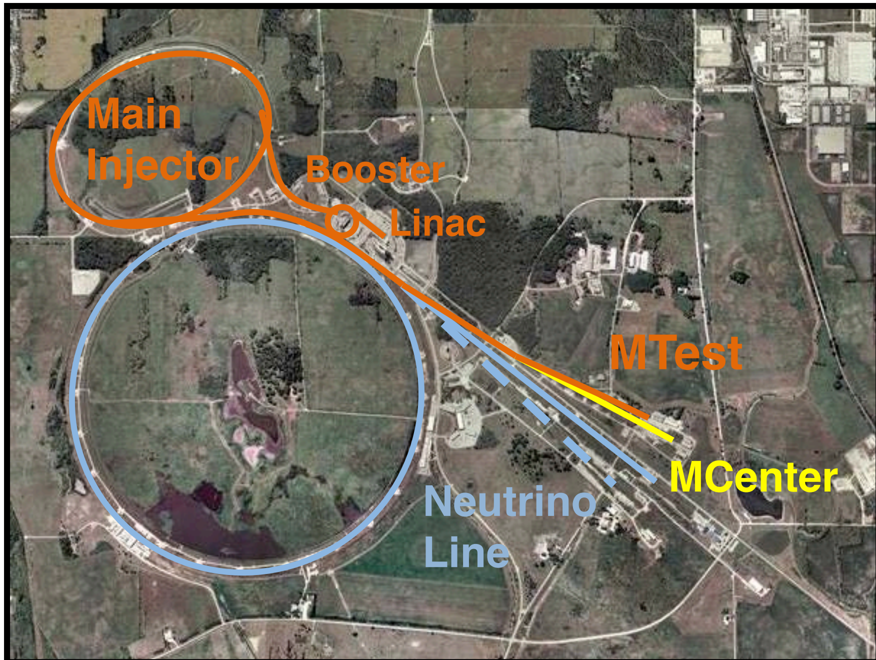
Babar/Ansaldo magnet works like new

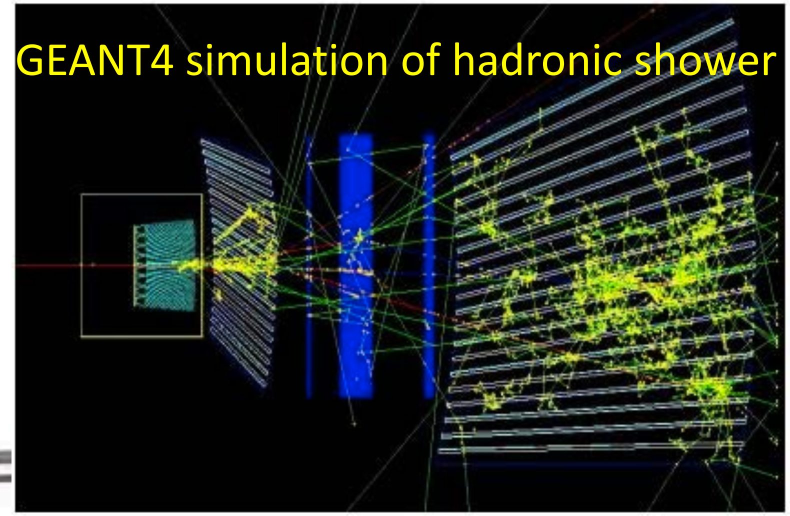
Progress on sPHENIX Calorimeter Design

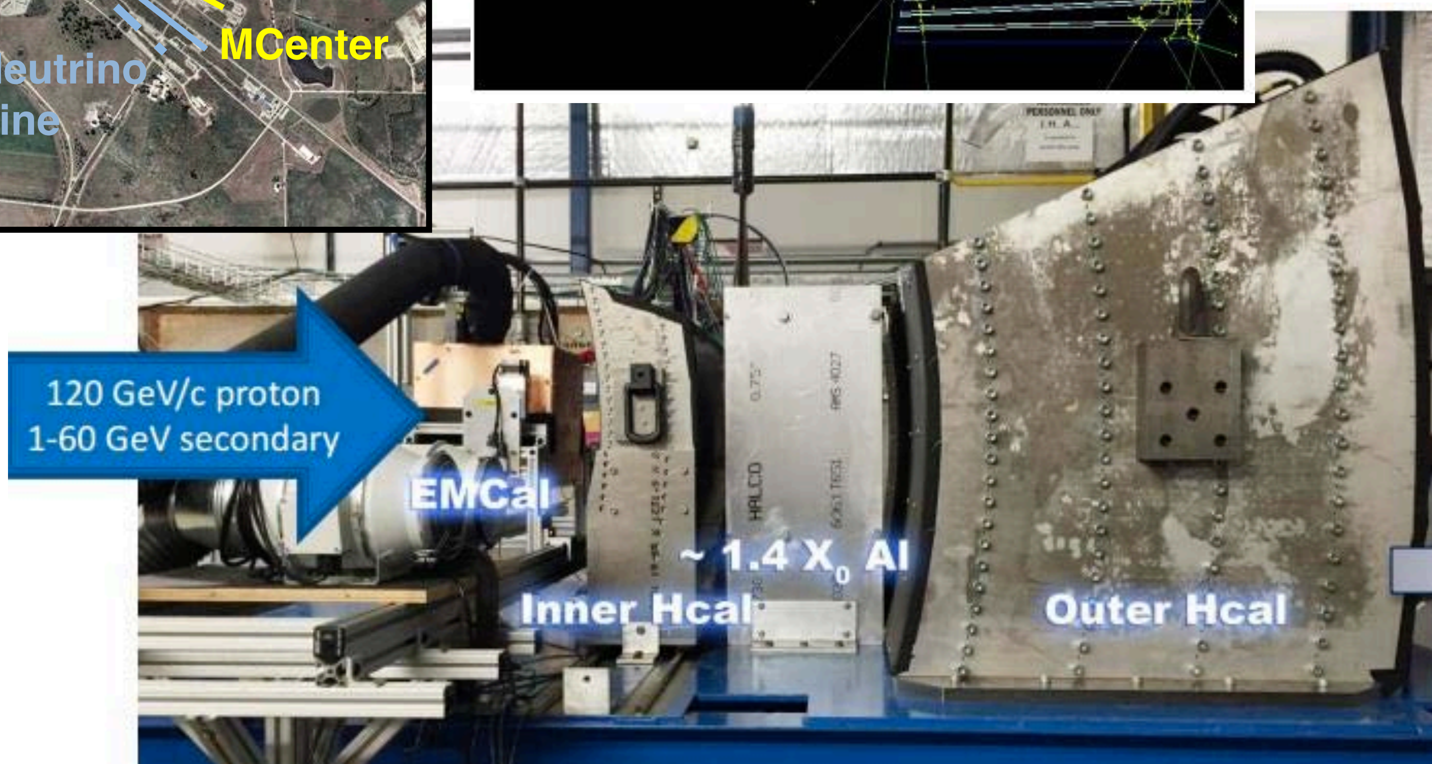
- HCal: Tilted Steel-Si plates
  - Inner and Outer HCal
  - $\Delta\phi \times \Delta\eta = 0.1 \times 0.1$
- 1.5T Superconducting magnet
  - From BaBar, cold tested at BNL
- EMCal: W-Si fiber
  - $\Delta\phi \times \Delta\eta = 0.025 \times 0.025$
- Tracker: vertex + outer tracker
  - Options still being considered, including MAPS inner tracker with gateless TPC



Test Beam at FermiLab







sPHENIX Present Status

- Dec 2015: Inaugural Collaboration Meeting at Rutgers
  - ✓ Bylaws approved
- Spokespersons elected (D. Morrison and G. Roland)
- Recent Collaboration Meeting at BNL May 18-20, 2016
- Still looking for new name of collaboration.

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By Karen McNulty Walsh | June 15, 2016 PRINT

Introducing sPHENIX!

A new collaboration takes aim at understanding how the ultra-hot, ultra-dense plasma that formed our early universe gets its intriguing properties.

Members of the new sPHENIX collaboration at a meeting held at Brookhaven Lab in May 2016, with co-spokespersons Dave Morrison (green T-shirt, jeans) and Gunther Roland (blue shirt, black jeans) front and center. + ENLARGE

From the very beginning, there were hints that particle collisions at the Relativistic Heavy Ion Collider (RHIC) were producing something unusual. This U.S. Department of Energy (DOE) Office of Science User Facility at Brookhaven National Laboratory was designed to recreate the incredibly hot and dense conditions of matter in the early universe by colliding atomic nuclei at high enough energies to “melt” their constituent protons and neutrons. The collisions would “free” those particles’ inner building blocks—quarks and gluons—so nuclear physicists could study their behavior unbound from ordinary

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Calorimeter Components Put to the Test


Superconducting Magnet Powers Up After Cross-Country Journey


Retired Brookhaven Lab Physicist Derek Lowenstein Returns to Receive International Accelerator Prize


A Broader Perspective: Brookhaven Lab's Smart Grid Collaborations Go International


Meet the New Security Police Officers

Physics by Press release—one that's deserved

Contacts: Karen McNulty Walsh, (631) 344-8350 or Peter Genzer, (631) 344-3174

PRINT

Physicists Measure Force that Makes Antimatter Stick Together

First ever measurement of antiproton interactions that make possible the existence of antimatter nuclei

November 4, 2015

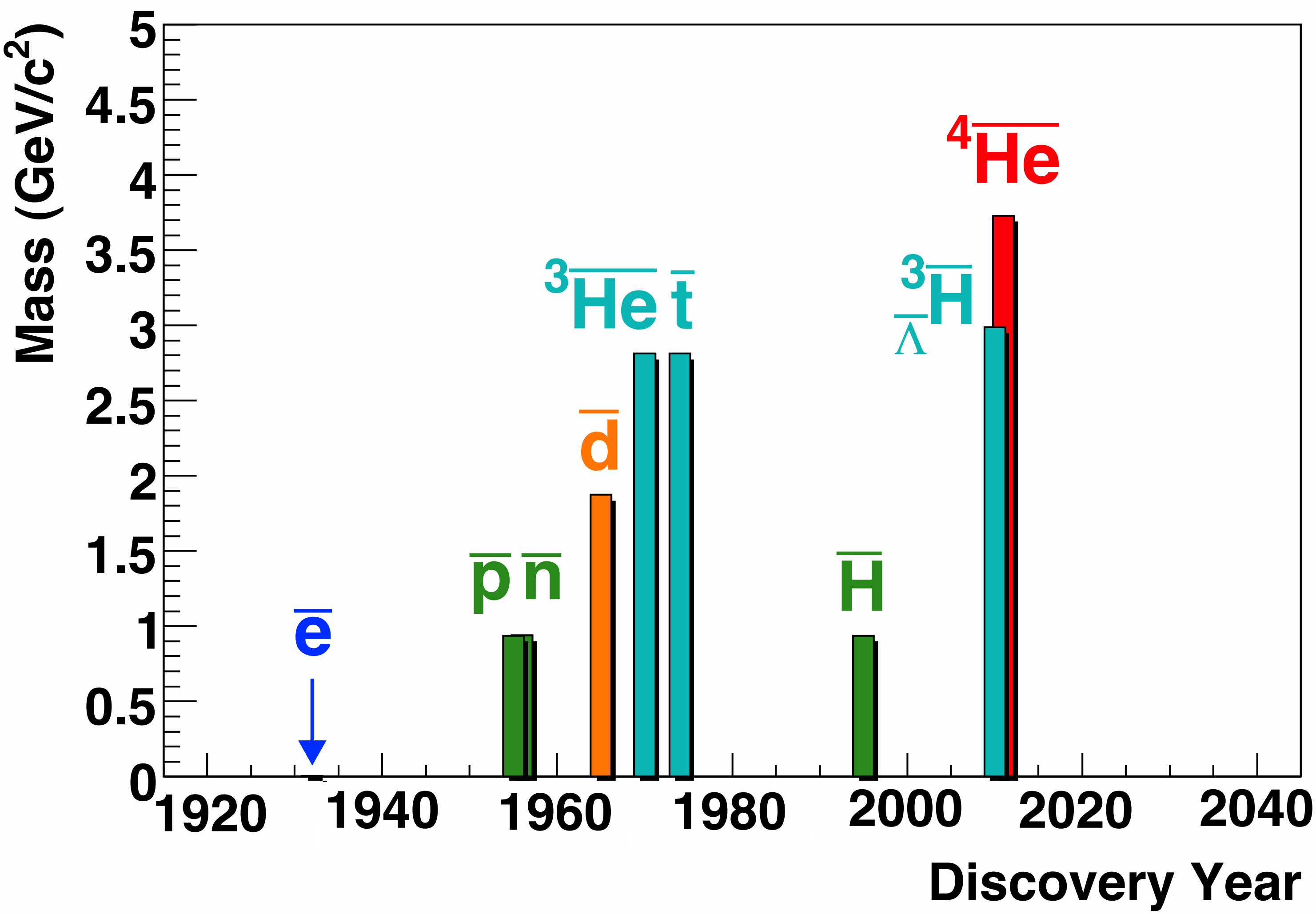
UPTON, NY—Peering at the debris from particle collisions that recreate the conditions of the very early universe, scientists have for the first time measured the force of interaction between pairs of antiprotons. Like the force that holds ordinary protons together within the nuclei of atoms, the force between antiprotons is attractive and strong.

+ ENLARGE

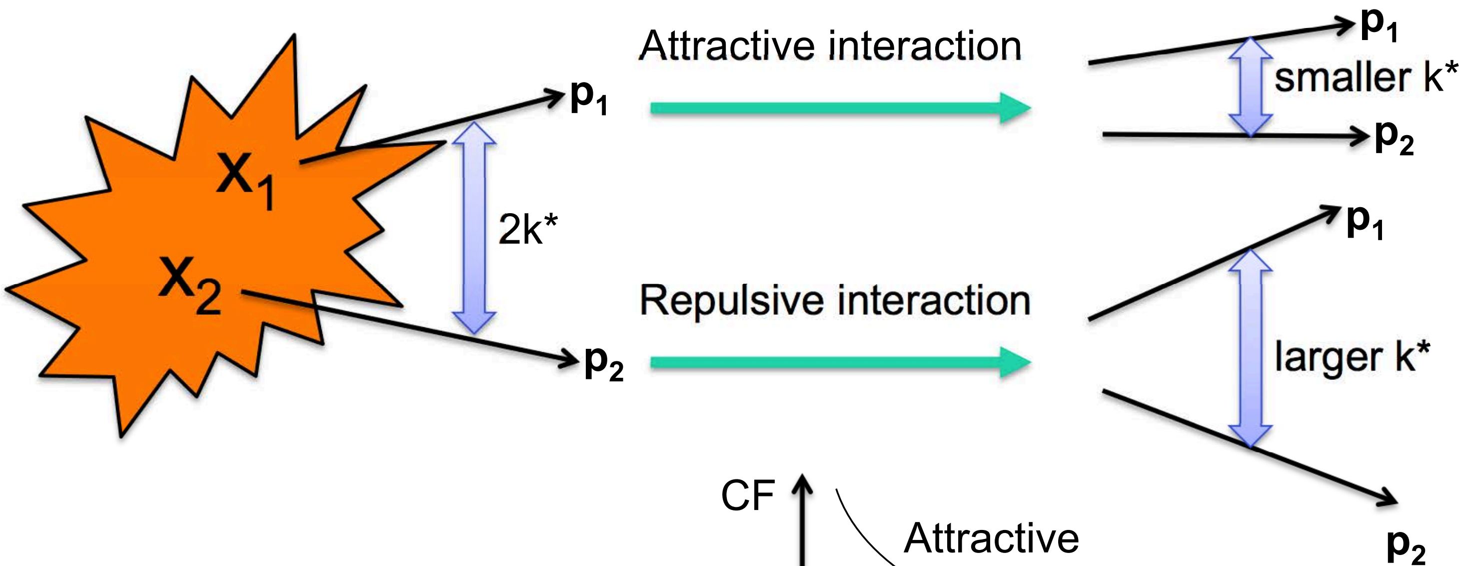
Zhengqiao Zhang, a graduate student from the Shanghai Institute of Applied Physics, with STAR physicist Aihong Tang at the STAR detector of the Relativistic Heavy Ion Collider (RHIC).

The experiments were conducted at the Relativistic Heavy Ion Collider (RHIC), a U.S. Department of Energy Office of Science User Facility for nuclear physics research at DOE's Brookhaven National

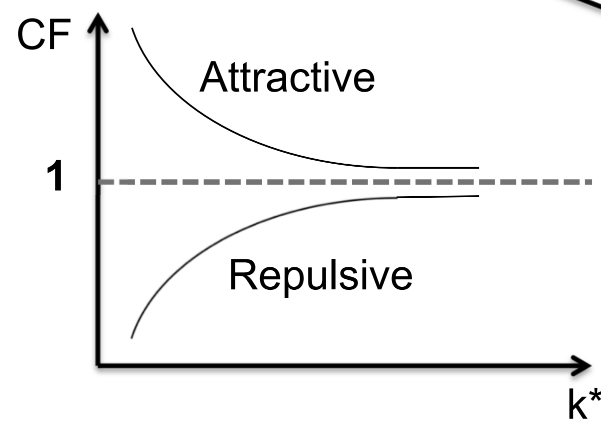
Antimatter History



Correlation analysis



For example, if there is only Coulomb interaction between two particles



Two-particle correlation function is sensitive to the separation distribution of the source and interaction in the final state.

Nuclear force : scattering length (f_0) and effective range (d_0)

f_0 is related to the cross section.

At low energy limit, the scattering cross section is given by

$$\sigma = 4\pi f_0^2$$

d_0 is related to the range of the potential.

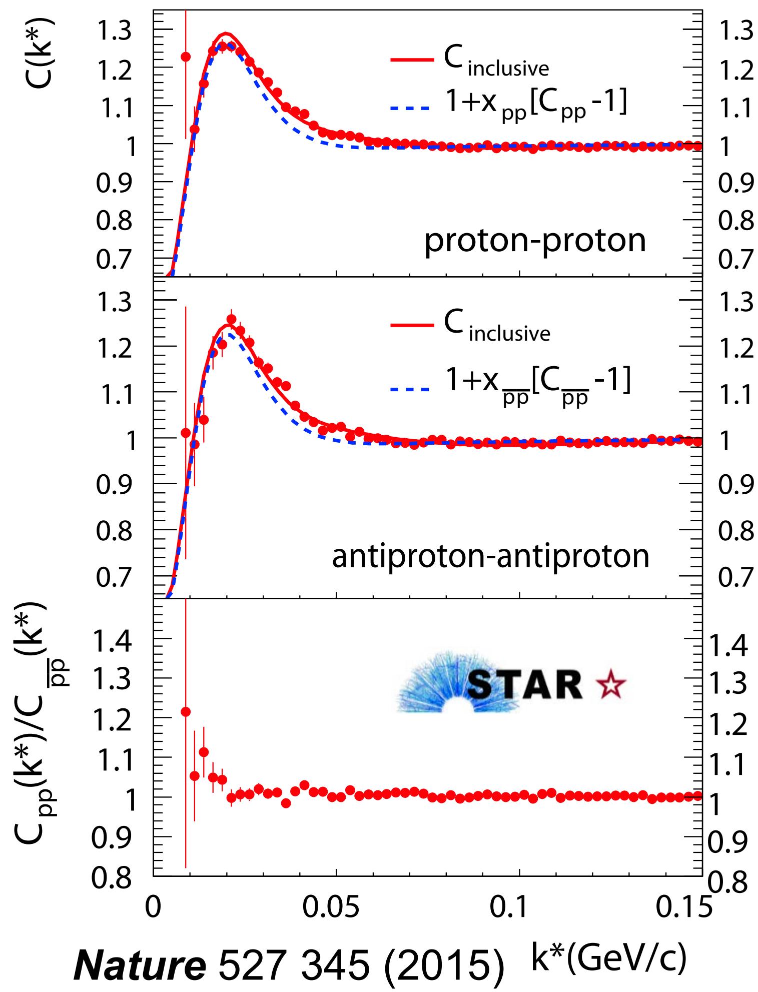
In the case of square well potential, d_0 is the range (radius) of the potential.

For a short range potential, f_0 and d_0 are related to the s-wave scattering phase shift δ_0 and the collision momentum k by :

$$k\cot(\delta_0) \approx \frac{1}{f_0} + \frac{1}{2} d_0 k^2$$

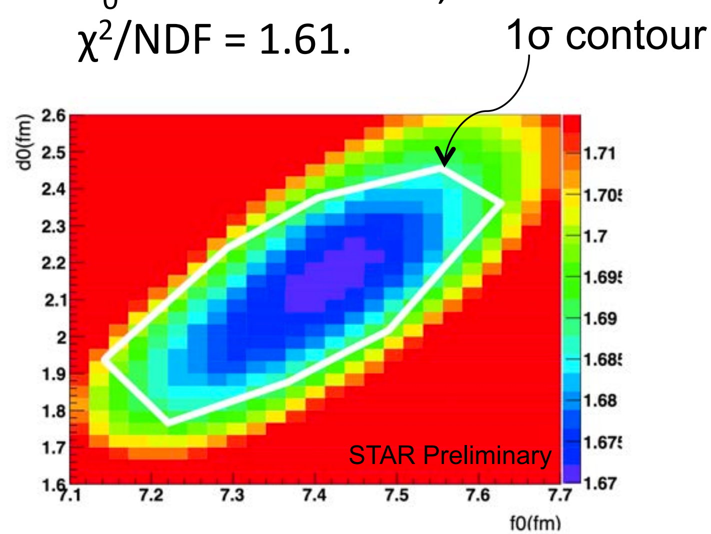
dip at 0 is Fermi statistics, bump is attractive singlet s wave interaction

Correlation functions

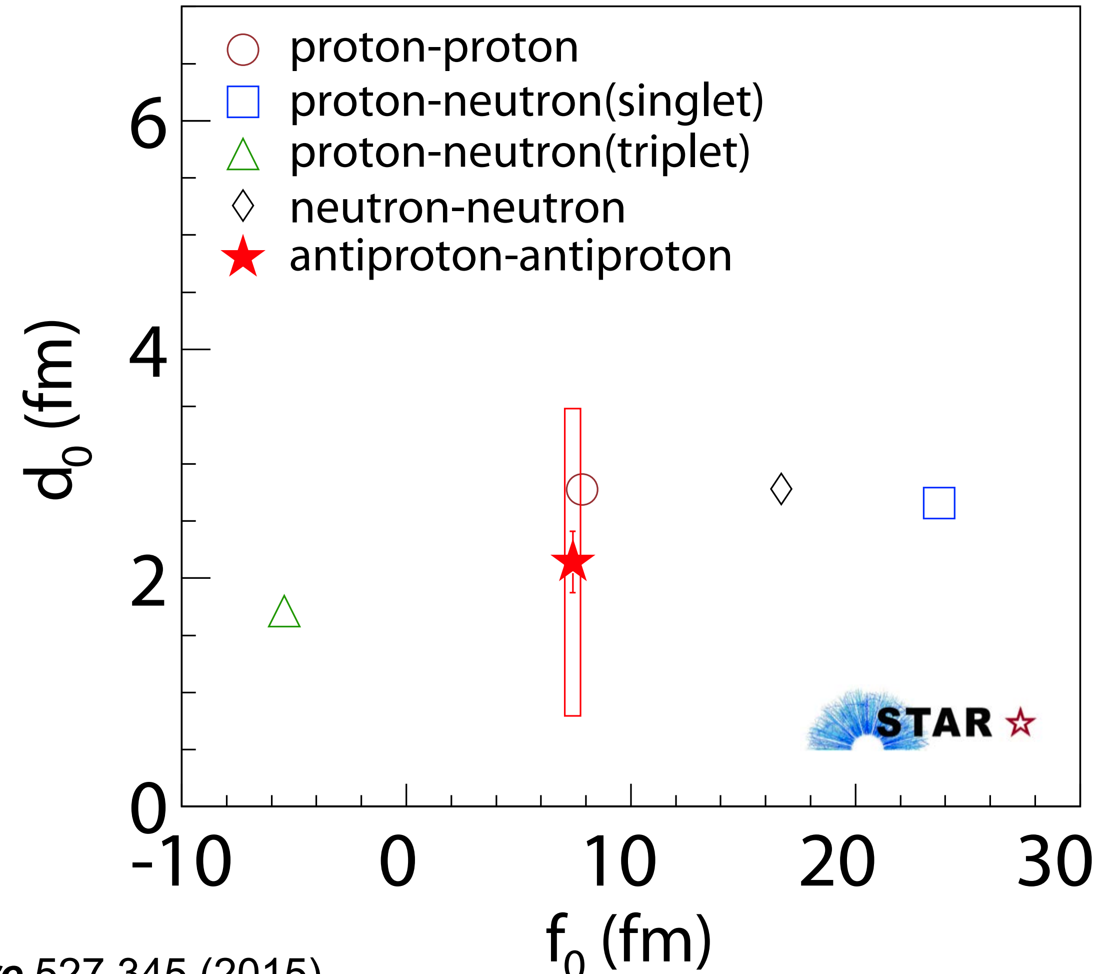


Nature 527 345 (2015)

- For proton-proton CF
  R = 2.75 ±0.01 fm;
  χ^2/NDF = 1.66.
- For antiproton-antiproton CF
  R = 2.80 ±0.02 fm;
  f_0 = 7.41 ± 0.19 fm;
  d_0 = 2.14 ± 0.27 fm;
  χ^2/NDF = 1.61.



f_0 and d_0



Nature 527 345 (2015)

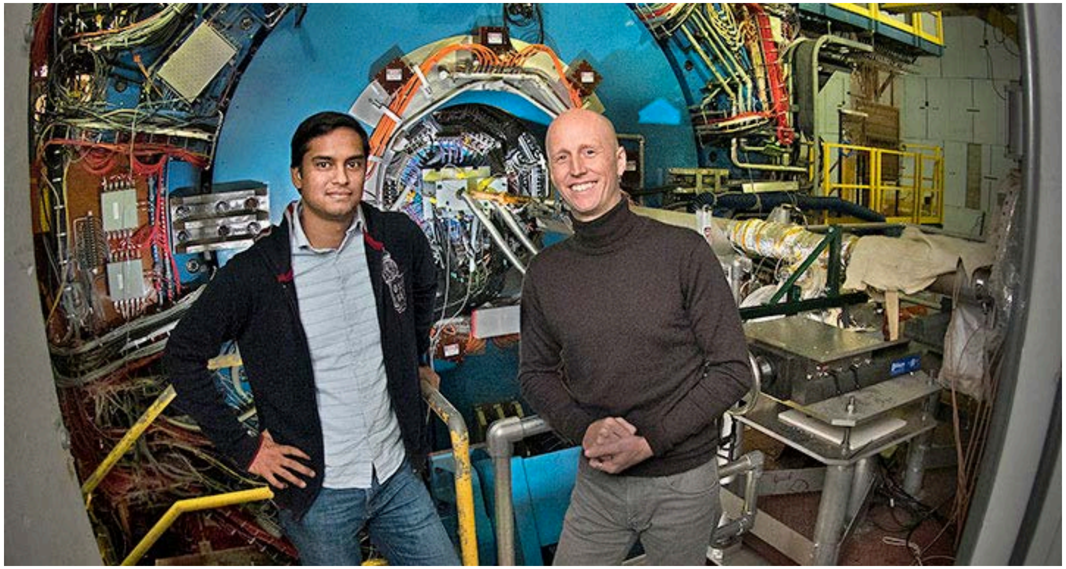
Physics by Press Release---not deserved

Contacts: Karen McNulty Walsh, (631) 344-8350 or Peter Genzer, (631) 344-3174

RHIC Particle Smashups Find that Shape Matters

Scientists colliding football- and sphere-shaped ions discover evidence supporting a paradigm shift in the birth of the quark-gluon plasma

Monday, December 7, 2015



+ENLARGE Postdoc Prithwish Tribedy and Brookhaven physicist Paul Sorensen at the STAR detector at the Relativistic Heavy Ion Collider (RHIC).

Before these measurements, the standard picture suggested that the number of particles produced would depend on the number of collisions, so these results directly rule out that picture. The new results are consistent with at least two models that don't require a dependence on the number of collisions.

"One of these is the gluon saturation model—which is why we think that model did a better job at predicting how well we'd be able to resolve the tip-tip vs. body-body collisions," Sorensen said.

"This result is just one piece of evidence. But it does support a new picture of how particles are born and that picture looks in many ways a lot like gluon saturation," Sorensen said. Future research will focus on further testing the idea of gluon saturation in comparison with other alternative explanations.

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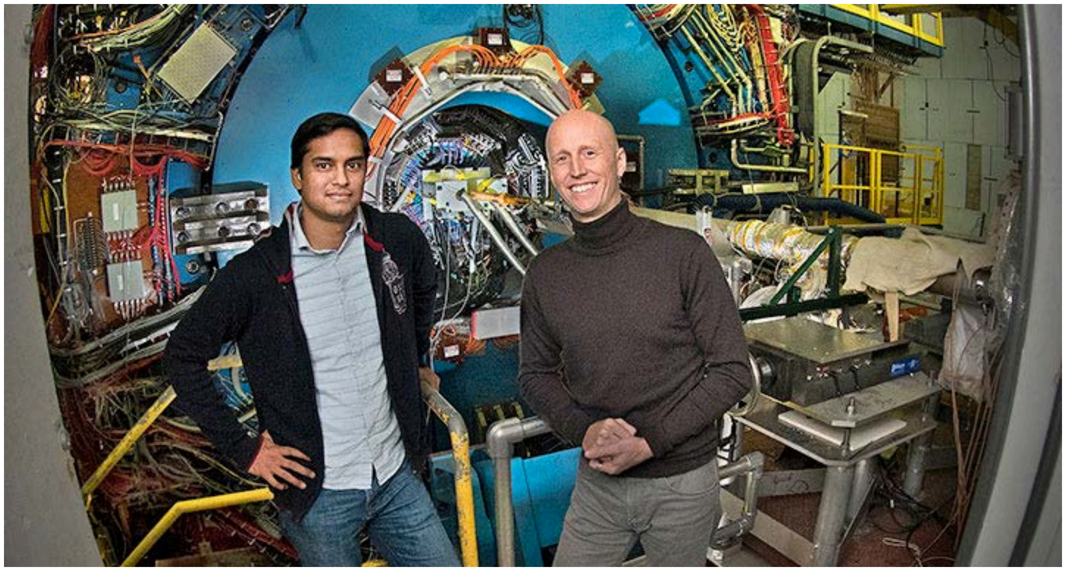

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In 2014 it was established that Ncoll was not correct. It was well known in HEP that hard scattering is not relevant for N_{ch} and E_T which are predominantly from low p_T particles. Constituent Quarks are the fundamental elements of N_{ch} and E_T

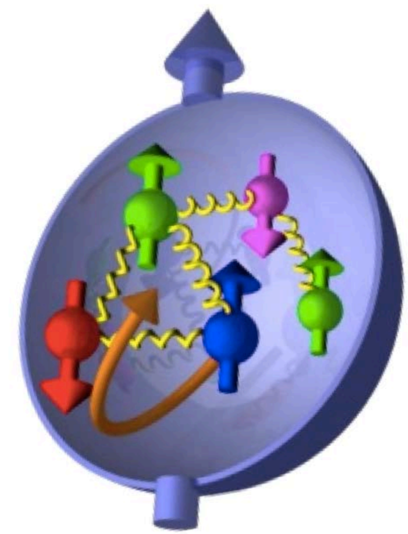
PHENIX PRC**89** (2014) 044905

Constituent Quarks cf. Partons

Constituent quarks are Gell-Mann's quarks from Phys. Lett. 8 (1964)214, proton=uud [Zweig's Aces].These are relevant for static properties and soft physics, low $Q^2<2$ GeV^2 ; resolution> 0.14fm

For hard-scattering, $p_T>2$ GeV/c, $Q^2=2p_T^2>8$ GeV^2, the partons (~massless current quarks, gluons and sea quarks) become visible

1.6fm



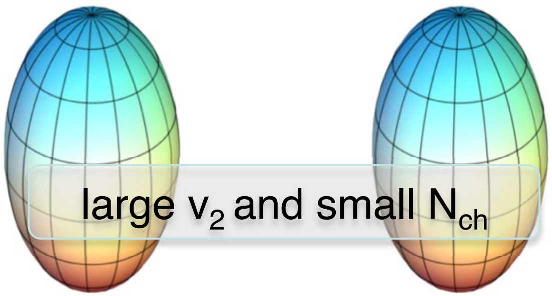
Resolution ~0.5fm

Resolution ~0.1fm

Resolution <0.07fm

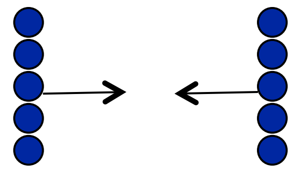
Selecting Body-body or Tip-tip

In two-component model, multiplicity depends on the N_{part} and N_{coll} and since v_2 is propotional to initial eccentricity



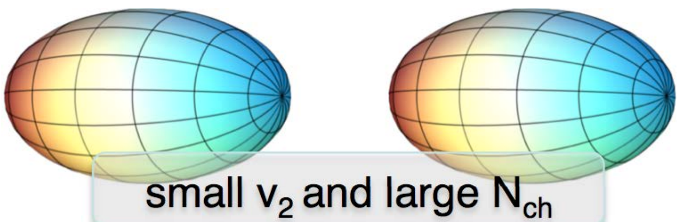
fully overlapping

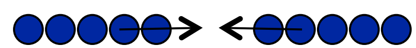
$$n_{AA} \propto n_{pp}[(1-x_{hard})\frac{N_{part}}{2} + x_{hard}N_{coll}]$$



N_{part}=10
N_{coll}= **5**

**idealizations*





N_{part}= 10
N_{coll}= **25**

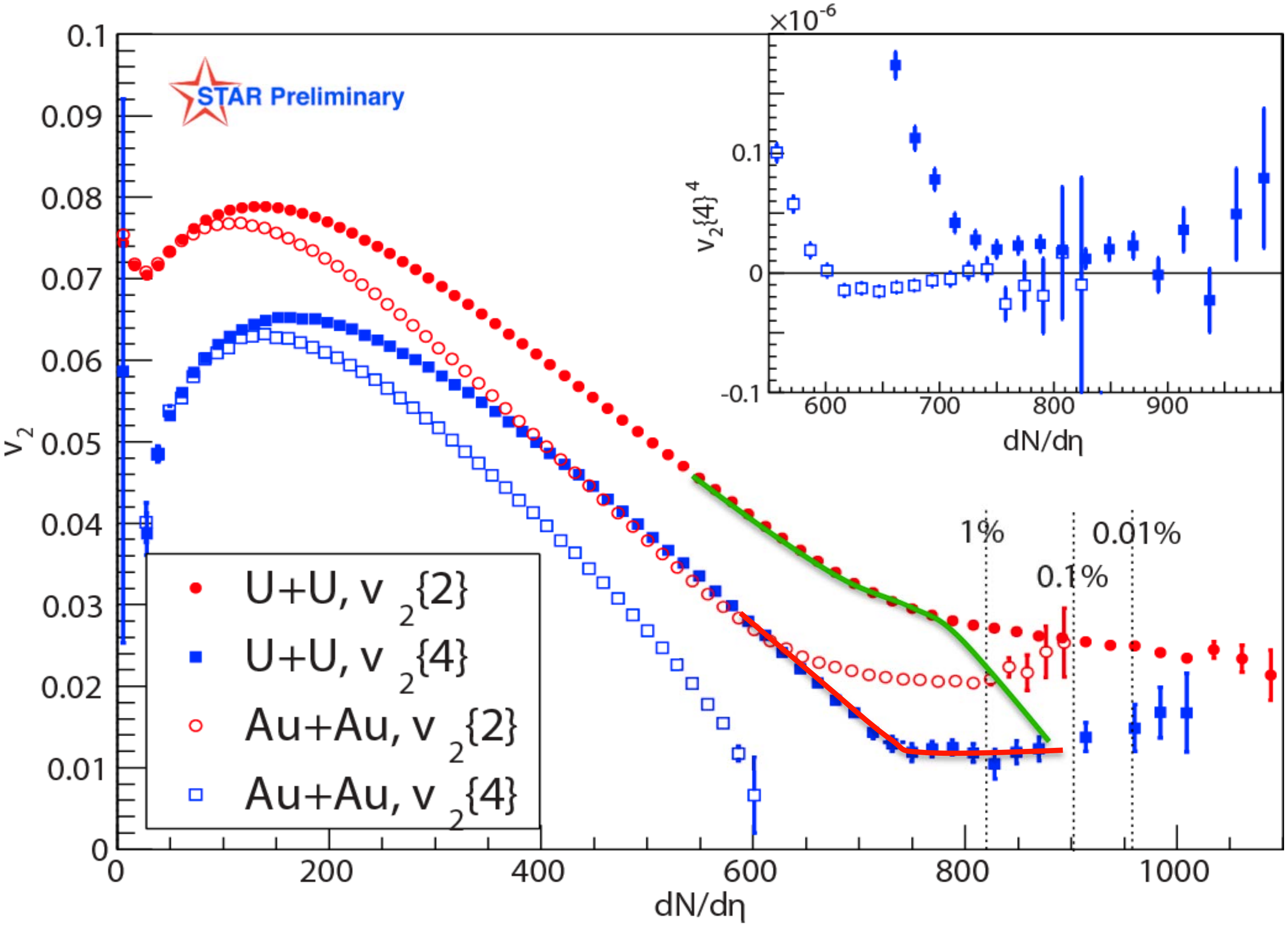
This is wrong they will be disappointed

If dN/dη depends on N_{coll}, large dN/dη should correlate with small v_2.

➪ *Central U+U collisions are ideal for testing particle production*

Strategy: select events with few spectators (fully over-lapping), then measure v_2 vs. multiplicity: **how strong is the correlation?**

Minimum-bias U+U and Au+Au



No evidence of knee structure for central U+U

- ✓Glauber plus 2-component model suggests knee structure at ~2% centrality
- ✓Knee washed out by additional multiplicity fluctuations?1
- ✓Other interpretations? Yes,Nqp!!!

[1]Maciej Rybczyński, et. al. Phys.Rev. C87 (2013) 044908

The U+U $v_2\{4\}$ results are non-zero in central

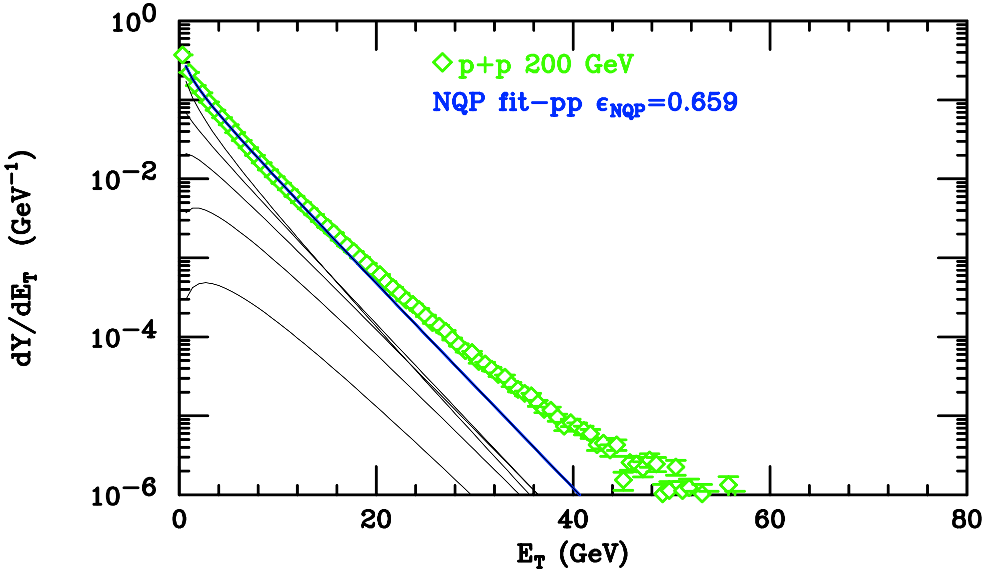
✓Result of intrinsic prolate shape of the Uranium nucleus
✓Au $v_2\{4\}$4 becomes consistent with zero

Dashed lines represent top centrality percentages for U+U collisions based on multiplicity, curves are used to guide the eye

$v_2\{4\}$ data: we see the prolate shape of the Uranium nucleus ✓

The lack of a knee indicates a weakness in Ncoll multiplicity models

PHENIX NQP model: Data driven pp→ dAu, AuAu

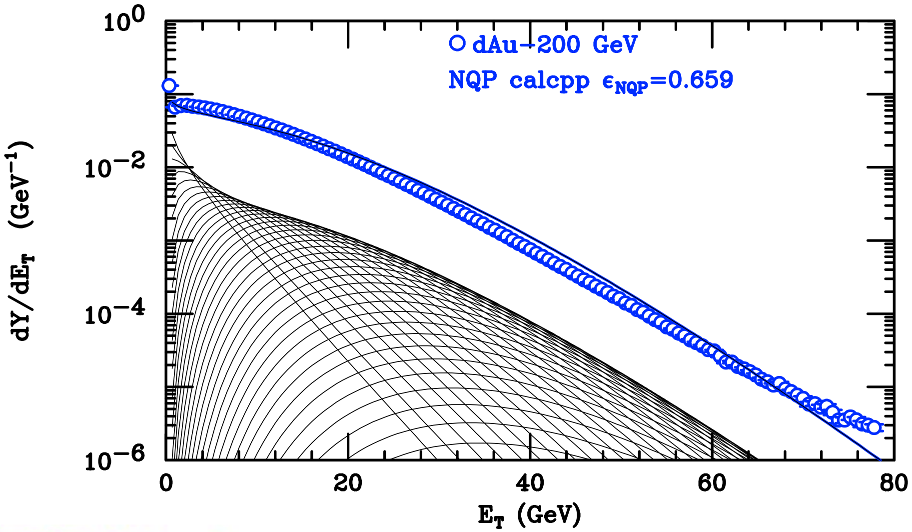


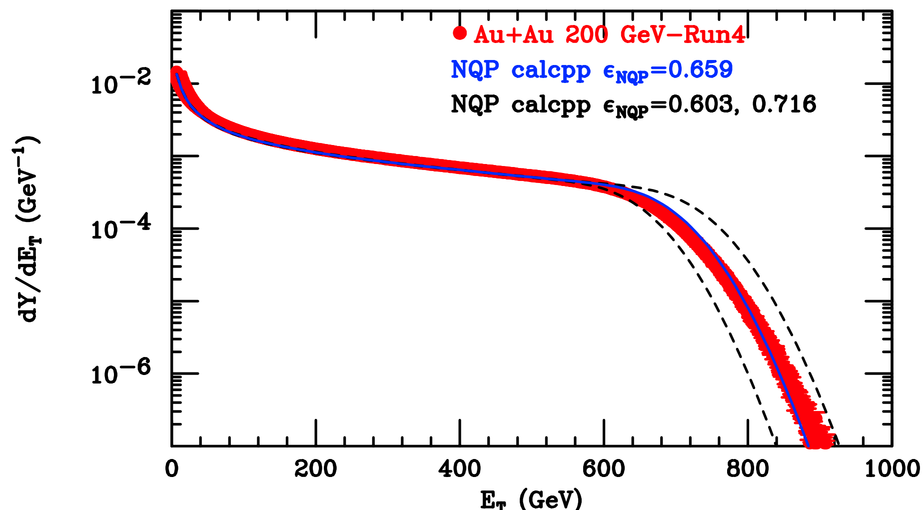
PHENIX PRC**89** (2014) 044905

1) Generate 3 constituent quarks around nucleon position, distributed according to proton charge distribution for pp, dA, AA

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

3) Calculate dAu and AuAu E_T distributions as weighted sum of QP E_T distributions





How we generated the quarks around the nucleon position in PHENIX2014

PHENIX2014 [6], the spatial positions of the the three quarks were generated around the position of each nucleon in the Glauber monte carlo calculations for $p+p$, d+Au and Au+Au collisions using the proton charge distribution corresponding to the Fourier transform of the form factor of the proton [24]:

$$\rho^{\text{proton}}(r) = \rho_0^{\text{proton}} \times \exp(-ar), \tag{4}$$

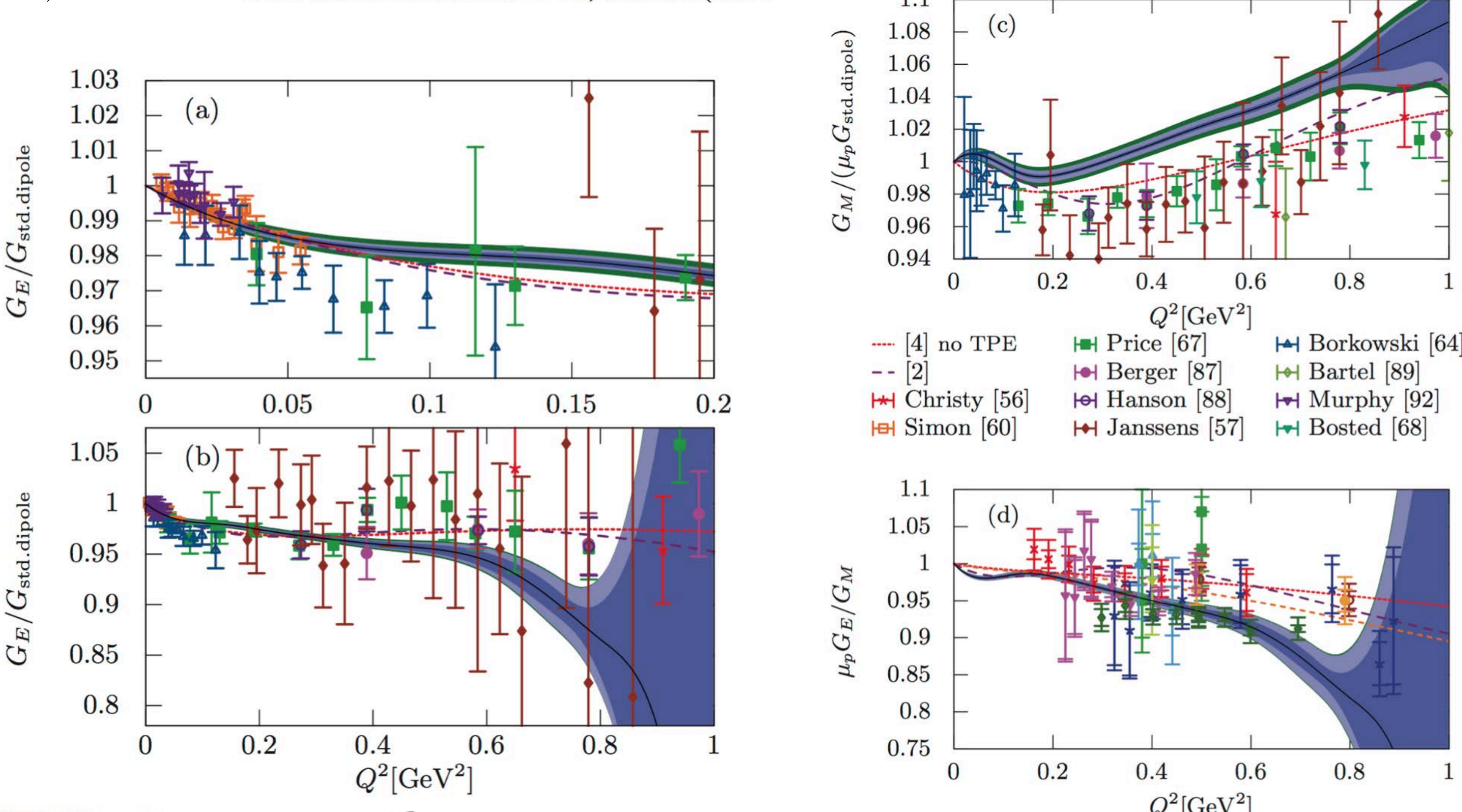
where $a = \sqrt{12}/r_m = 4.27\ \text{fm}^{-1}$ and $r_m = 0.81$ fm is the r.m.s radius of the proton weighted according to charge [2]

$$r_m = \int_0^\infty r^2 \times 4\pi r^2 \rho^{\text{proton}}(r) dr \quad . \tag{5}$$

The corresponding proton form factor is the Hofstadter dipole fit [25] now known as the standard dipole [26]:

$$G_E(Q^2) = G_M(Q^2)/\mu = \frac{1}{(1+\frac{Q^2}{0.71\mathrm{GeV}^2)})^2} \qquad (6)$$

Mainz, Bernauer etal PHYSICAL REVIEW C **90**, 015206 (2014

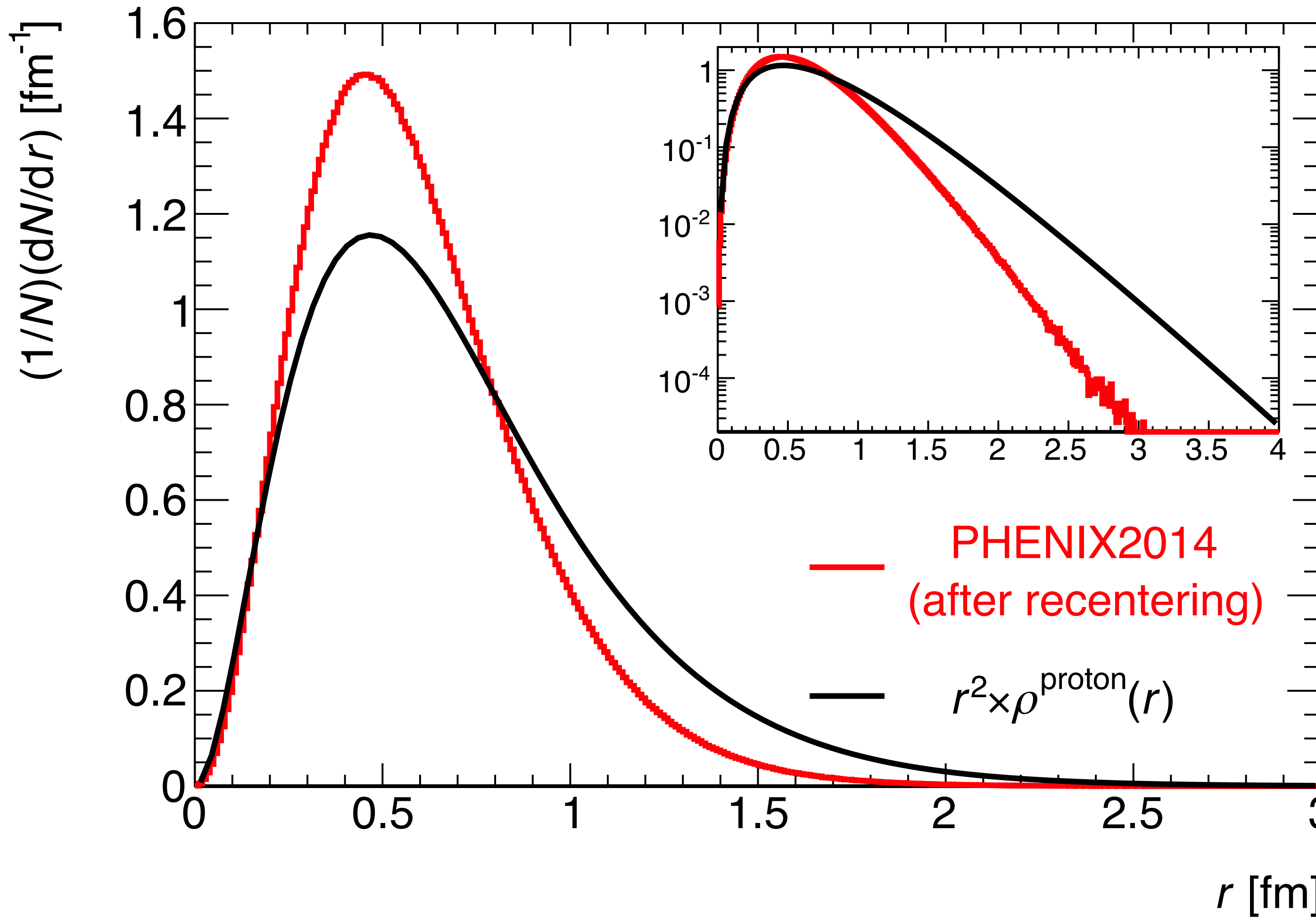


We got a comment from Adam Bzdak via Pete Steinberg 6 months after the paper appeared in PRC that our method didn't preserve the radial charge distribution about the c.m. of the three generated quarks

- This statement is correct so several of us got together to figure out how to generate 3 quarks about a nucleon that would preserve the c.m. position and the charge distribution about this c.m and how this would affect our results from PHENIX2014.

- We found 3 new methods that preserve both the original proton c.m. with the correct charge distributions about the c.m. I discuss 2.
- See Mitchell, Perepelitsa, Tannenbaum and Stankus PRC93,054910 (2016)

Radial charge distribution about the c.m for PHENIX2014 compared to Eq.4 $r^2\rho^{proton}(r) = r^2 \exp -4.27r$



Planar Polygon

Generate one quark at (r,0,0) with r drawn from r^2 e^{-4.27r}. Then instead of generating cos θ and Φ at random and repeating for the two other quarks as was done by PHENIX2014, imagine that this quark lies on a ring of radius r from the origin and place the two other quarks on the ring at angles spaced by 2π/3 radians. Then randomize the orientation of the 3-quark ring spherically symmetric about the origin. This guarantees that the radial density distribution is correct about the origin and the center of mass of the three quarks is at the origin but leaves three quark triplet on each trial forming an equilateral triangle on the plane of the ring.

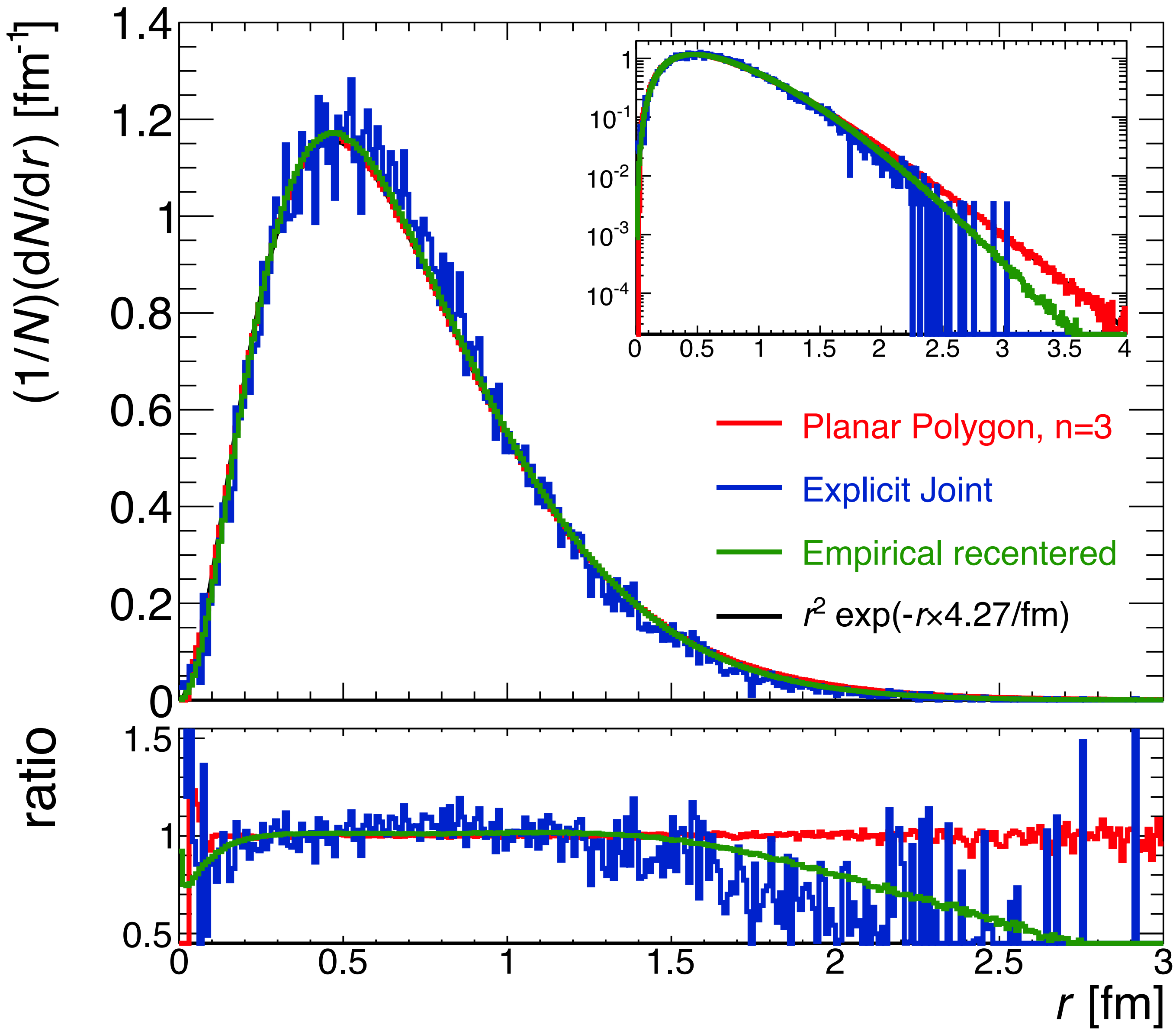
DVP—Empirical Radial distribution Recentered

$$f(r) = r^2\rho(r) = r^2 e^{-4.27r}(1.21466 - 1.888r + 2.03r^2)$$
$$(1 + 1.0/r - 0.03/r^2)(1 + 0.15r)$$

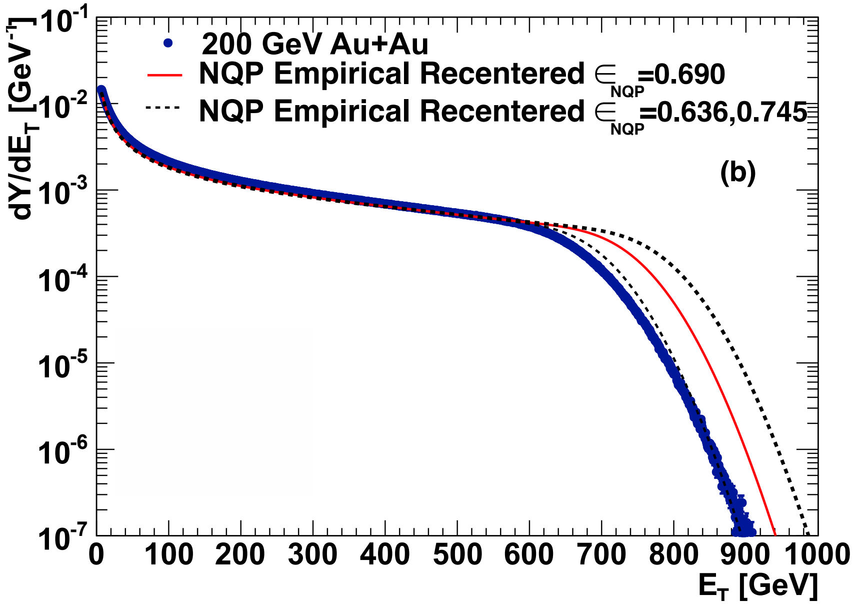
where r is the radial position of the quark in fm.

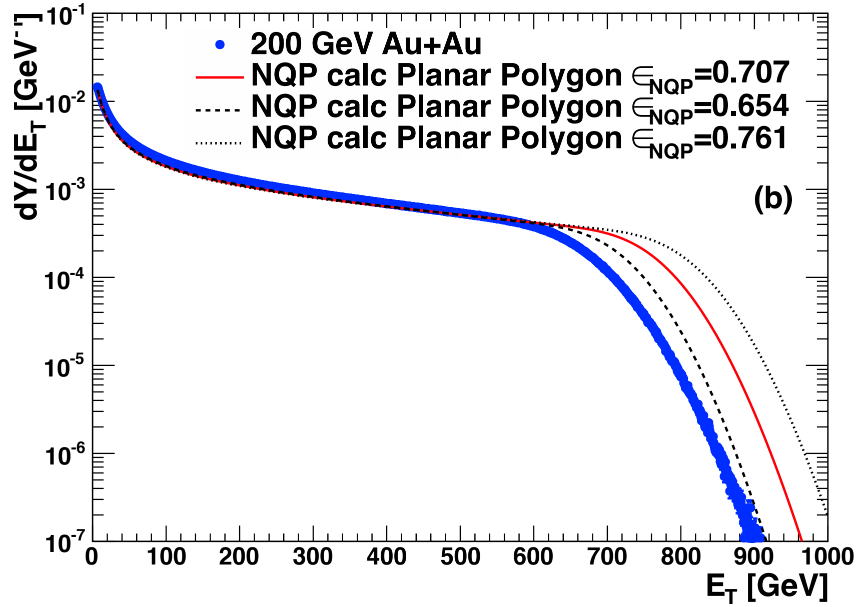
- the three constituent-quark positions are drawn independently from the auxiliary function *f(r)* above. Then the center of mass of the generated three-quark system is re-centered to the original nucleon position. This function was derived through an iterative, empirical approach. For a given test function f^{test}(r), the resulting radial distribution ϱ^{test}(r) was compared to the desired distribution ϱ^{proton}(r) in Eq. 4. The ratio ϱ^{test}(r) / ϱ^{proton}(r) was parameterized with a polynomial function of *r* or *1/r*, and the test function was updated by multiplying it with this parametrized functional form. Then, the procedure was repeated with the updated test function used to generate an updated ϱ^{\rm test}(r) until the ratio ϱ^{test}(r) / ϱ^{proton}(r) was sufficiently close to unity over a wide range of r values.

Radial charge distribution about the c.m

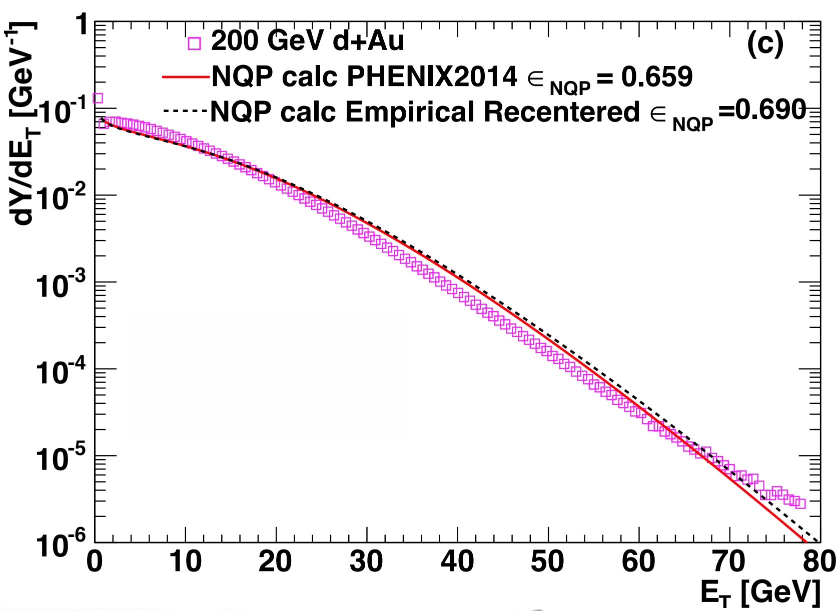


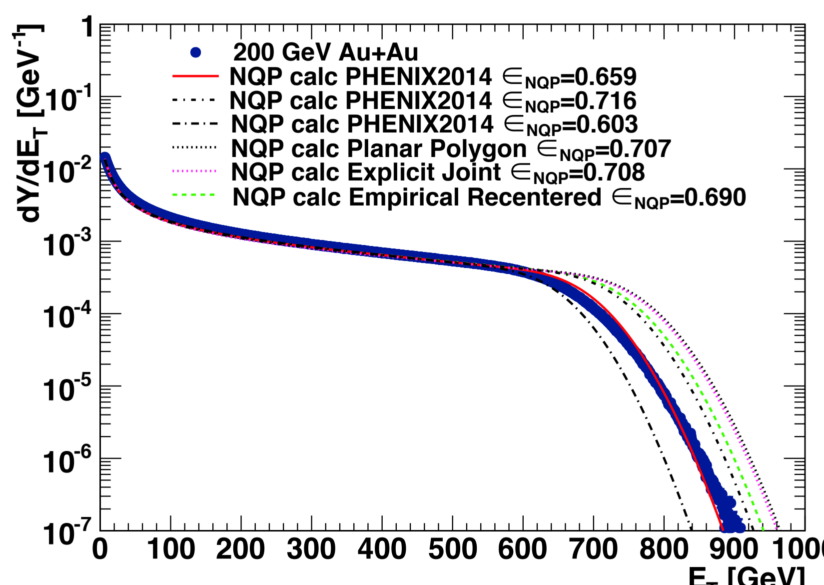
NQP centered with PHENIX2014 data



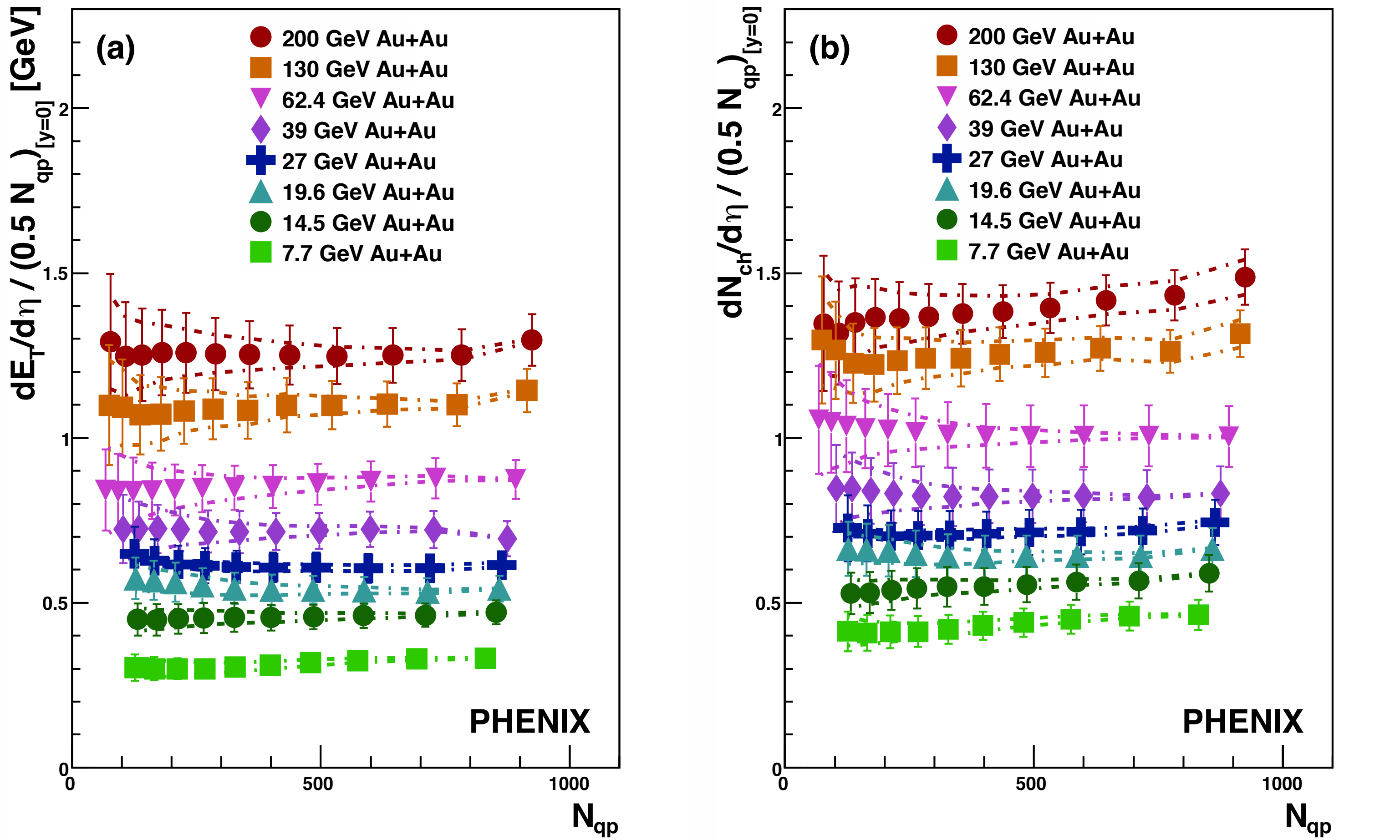


all work within 1 standard deviation





Constituent-quark-participant scaling-N_{qp}

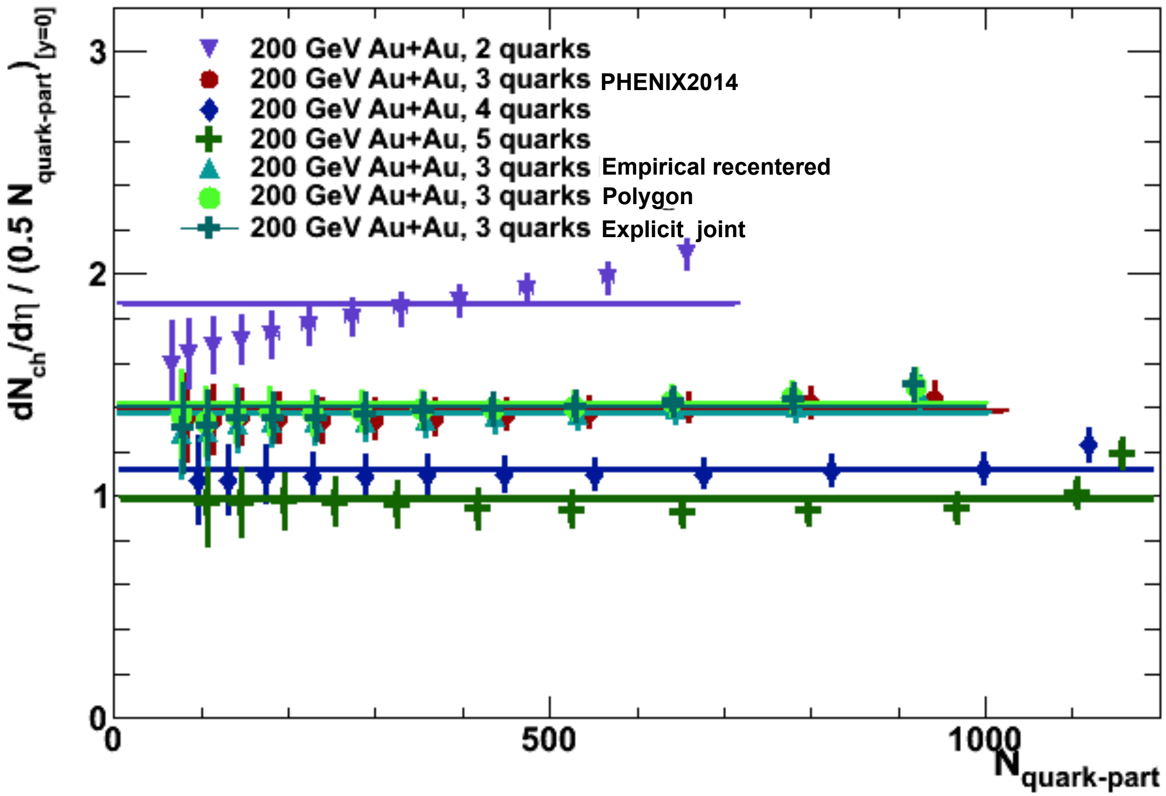


PHENIX PRC93(2016)024901

Uses Empirical Recentered---now standard

What happens with 2,3,4,5 quarks

- since many people had asked why do you stop at 3 quarks: why not 2, 4, 5, we looked into this too with (dNch/dη)/0.5Nqp



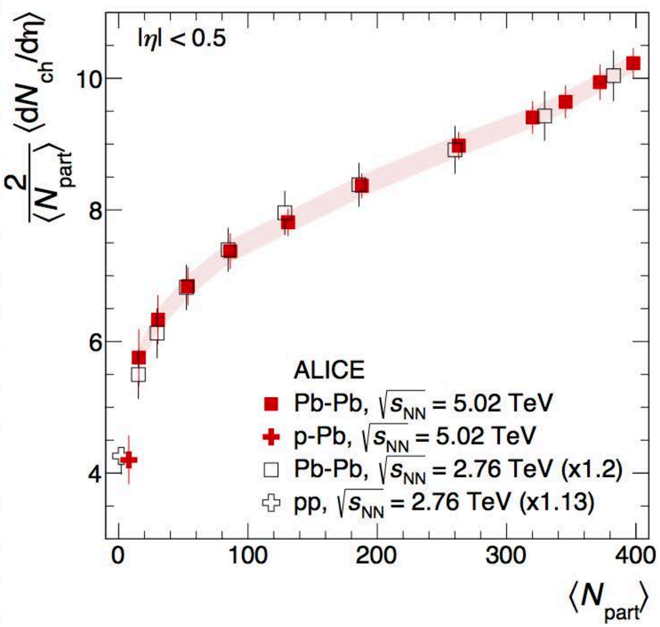
- 2 is rejected; 3 give the same result for all 4 methods; 4,5 seem to work as well as 3 in the PHENIX2014 calculation

Agreement from ALICE

Pseudorapidity density in Pb-Pb

Run 2

Centrality dependence of the charged-particle multiplicity density at mid-rapidity in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV [9]



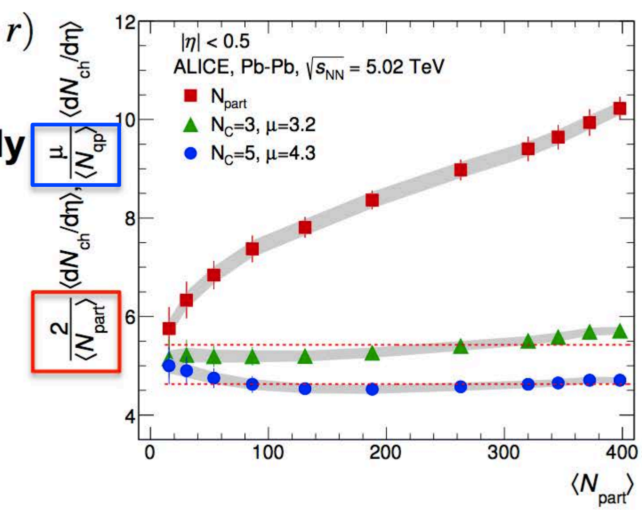
- **Decrease by 1.8** from the most central $<N_{part}>$ to the most peripheral
- Ratio between 5.02 TeV and 2.76 TeV is **flat** within the uncorrelated uncertainties

Glauber MC with quark scaling [10]

Single quark position determined with proton density:

$$\rho(r) = \rho_0^{proton} \exp(-a \cdot r)$$

particle multiplicity density **scales linearly** with the number of constituent quark participants [8]



[8] **ALICE** Collaboration, ALICE-PUBLIC-2015-008

[9] **ALICE** Collaboration, arXiv:1512.06104 [nucl-ex]

[10] C. Loizides, arXiv:1603.07375 [nucl-ex]

Agreement from ALICE

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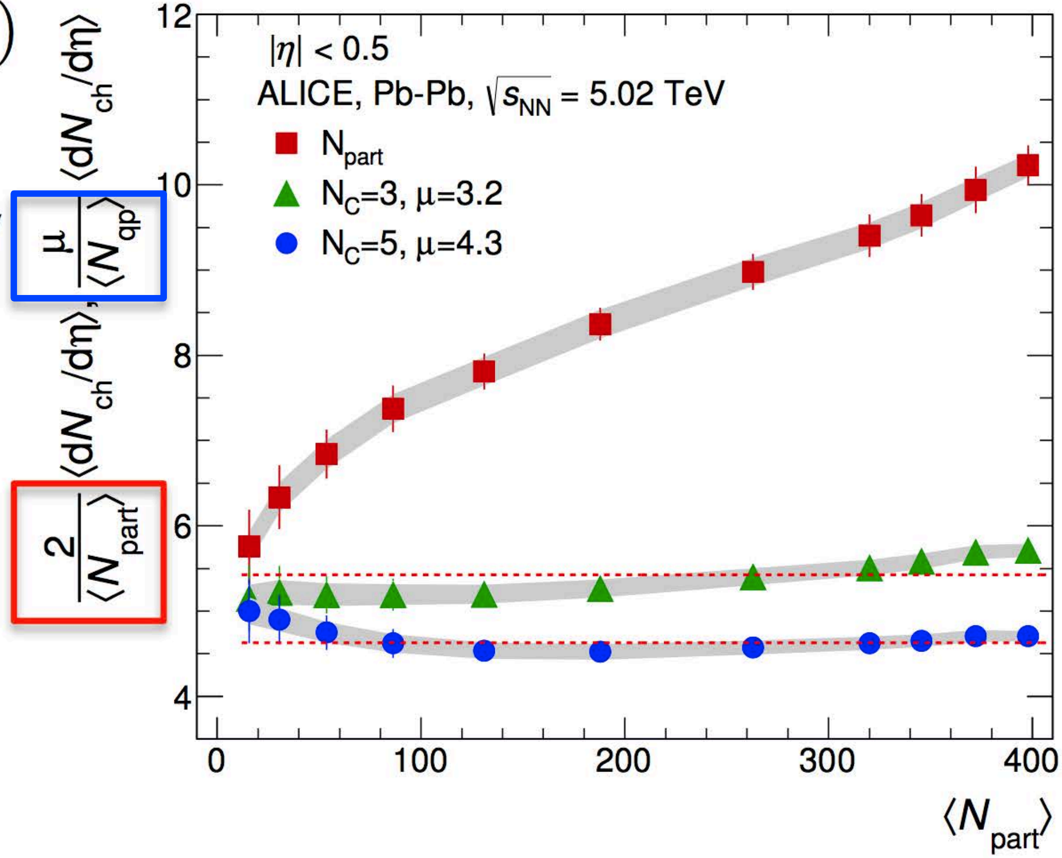

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)4 [nucl-ex]
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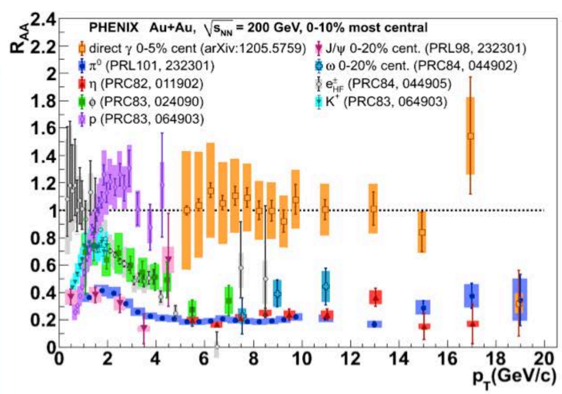
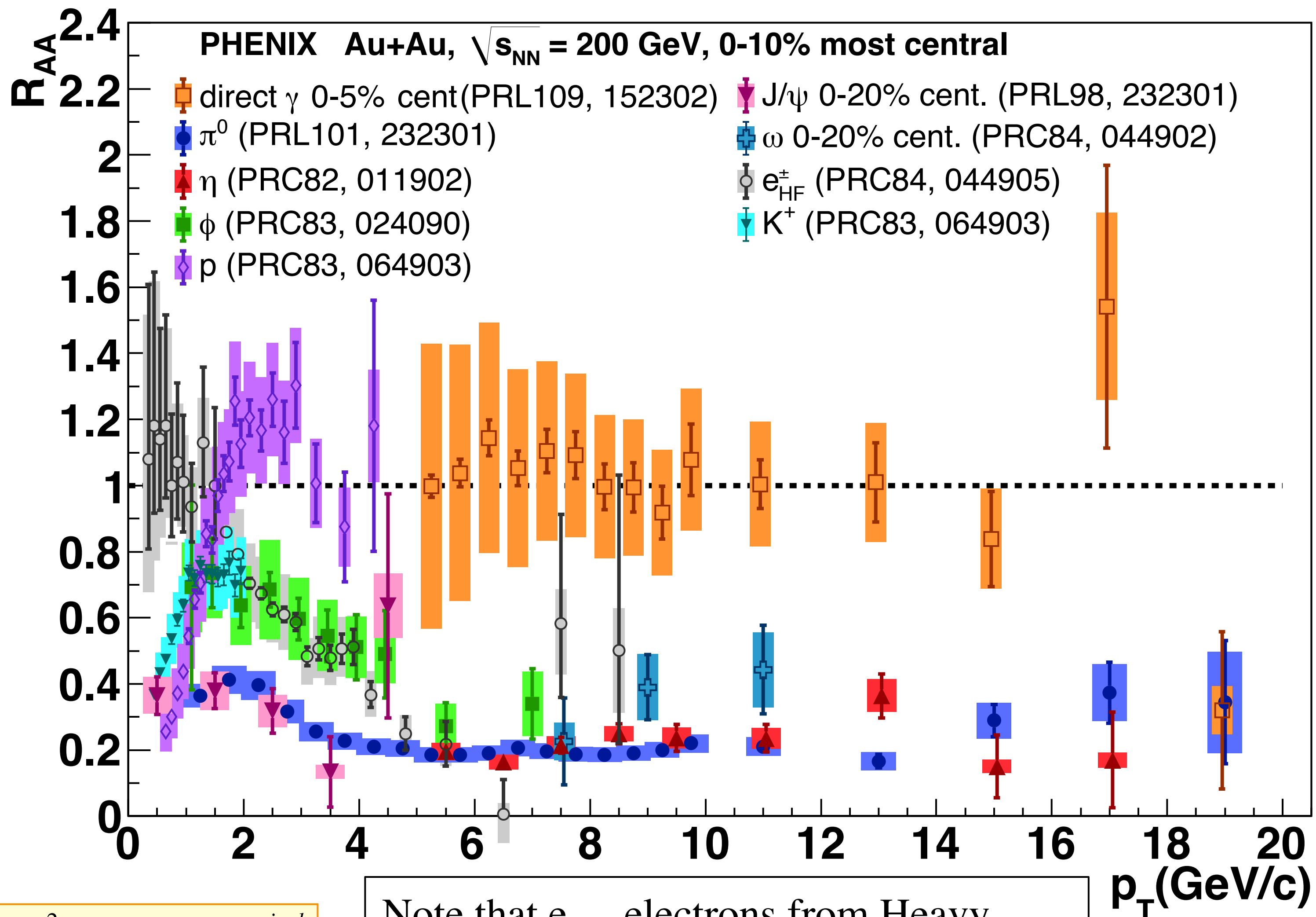
T-Shirt Plots
our most important measurements



- Mike's PHENIX T-shirt Plot from Megan Connor's sPHENIX Talk
- What will be the sPHENIX Tshirt plot

Suppressed high p_T hadrons aka Jet Quenching

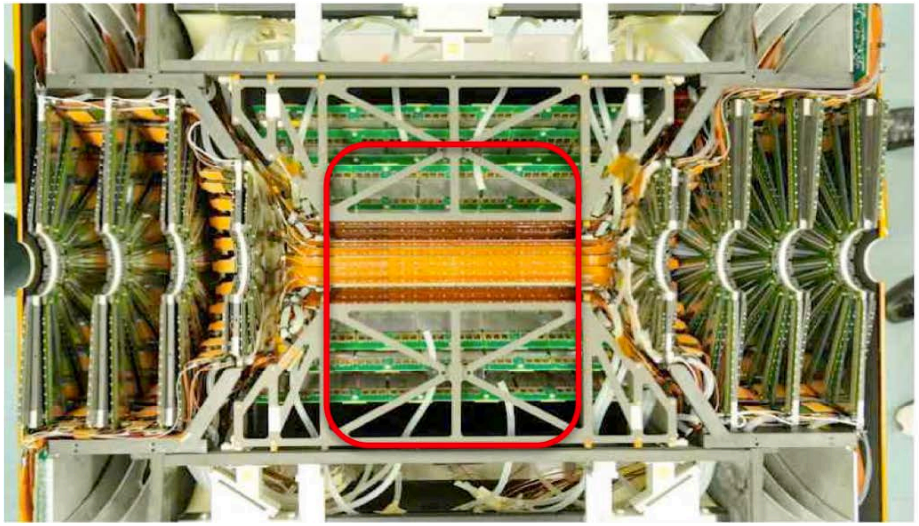


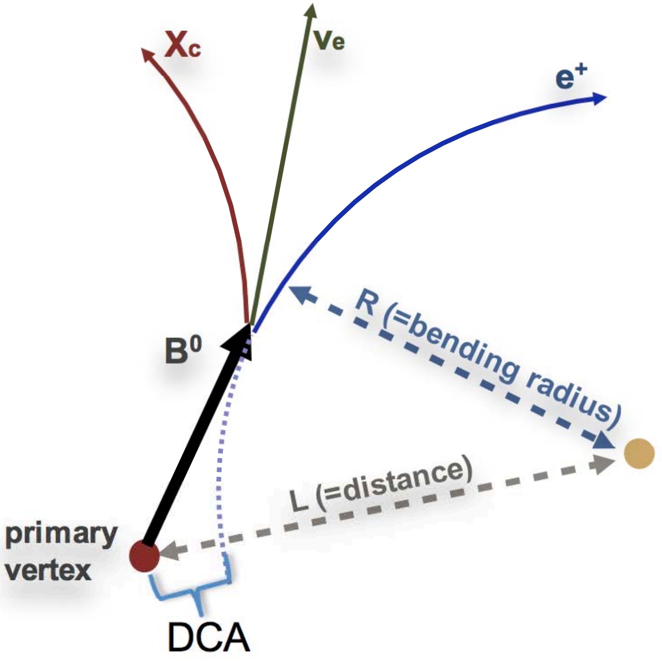
$$R_{AA}(p_T) = \frac{d^2N^{\pi}_{AA}/dp_T dy N^{inel}_{AA}}{\langle T_{AA}\rangle d^2\sigma^{\pi}_{pp}/dp_T dy}$$

Note that e_{HF}, electrons from Heavy Flavor decay, are suppressed as much as π^0 from light quarks for p_T 5-6 GeV/c

PHENIX PRC93,034904 (2016)

c/b separation by secondary vertex





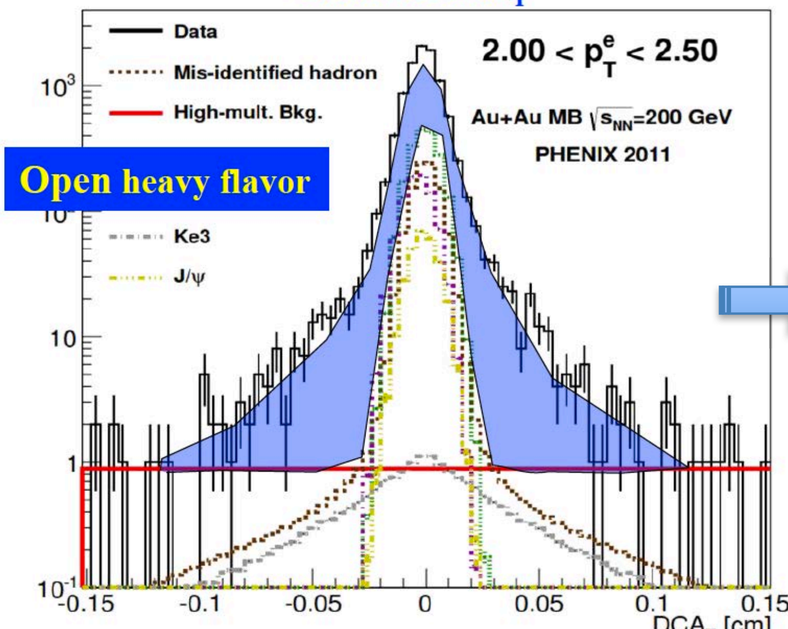
VTX detector

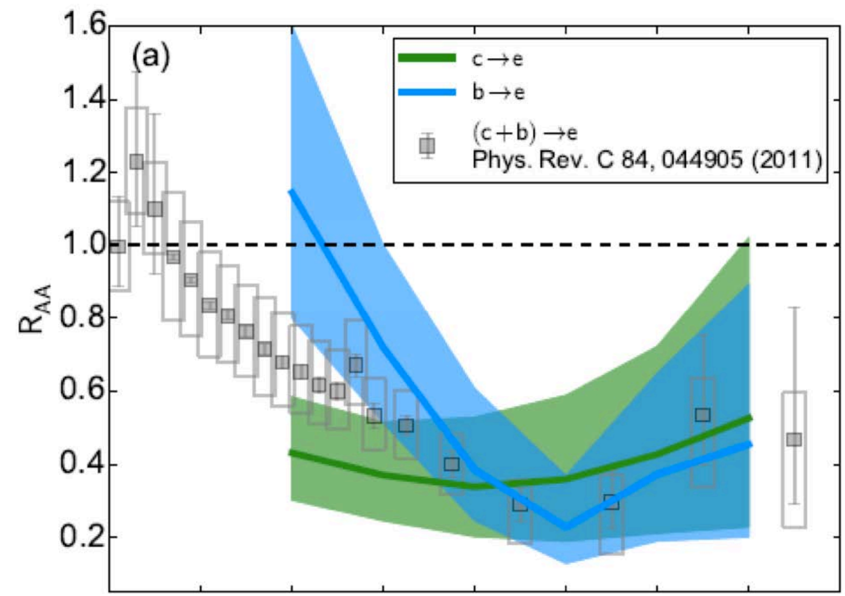
PHENIX PRC93,034904 (2016)

R_{AA} for electrons from charm and bottom

Unfolding to obtain b/(c+b) electron fraction in Au+Au
Combine with previous results in pp from correlation analysis
→ R_{AA} for c→ e and b→ e separately!

Electron DCA_T





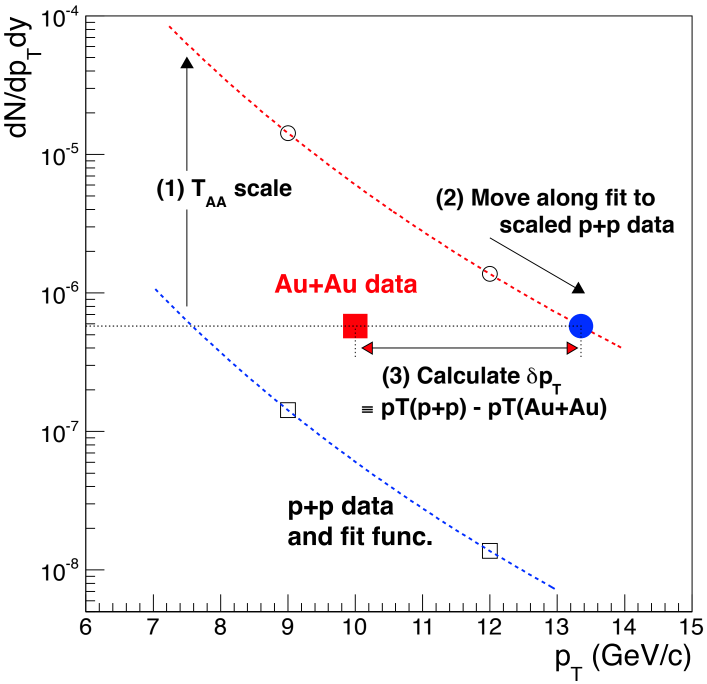
Phys. Rev. C93, 034904 (2016)

Charm and bottom similarly suppressed at high p_T
Bottom less below ~ 3 GeV/c !
A factor of ~ 20 more statistics from Run 14 & 16 !
Stay tuned for future updates !

U.S. DEPARTMENT OF ENERGY

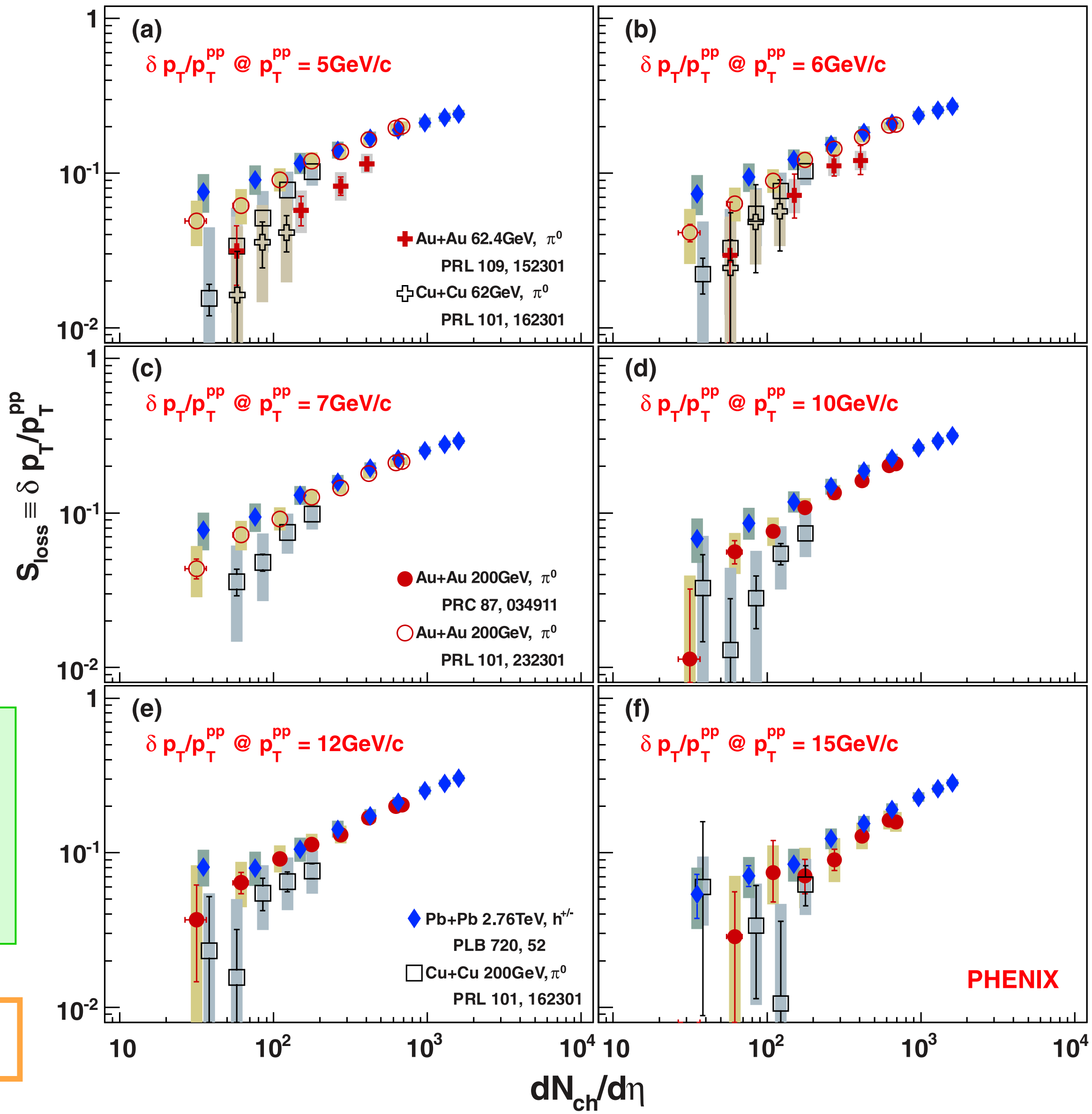
NATIONAL LABORATORY

π^0 Fractional energy loss propto dNch/deta



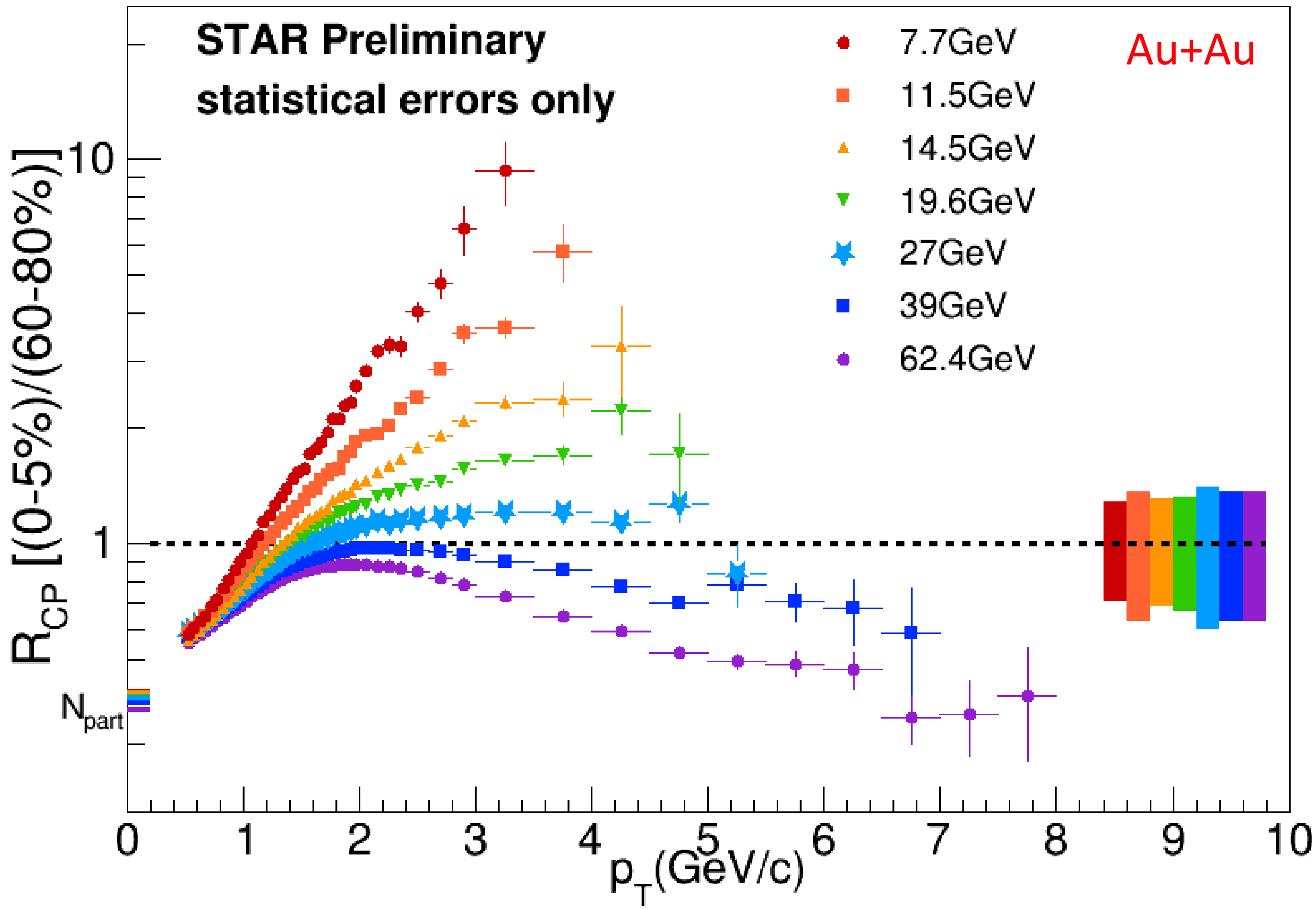
After a decade of the ratio R_{AA} we are now paying more attention to δp_T the shift in the p_T spectrum as an indicator of energy loss in the QGP

PHENIX PRC93(2016)024911



STAR high p_T R_{cp} unidentified charged How low in $\sqrt{s_{NN}}$ does suppression hold

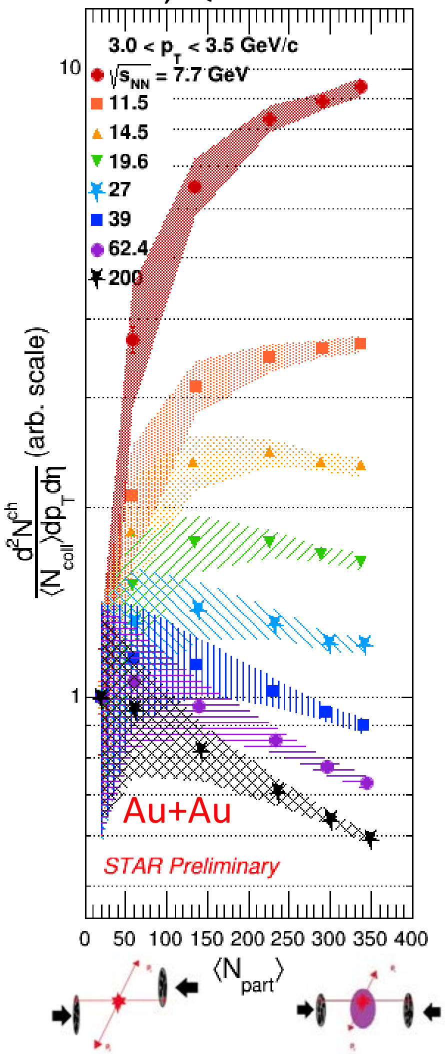
S. Horvat, QM2015



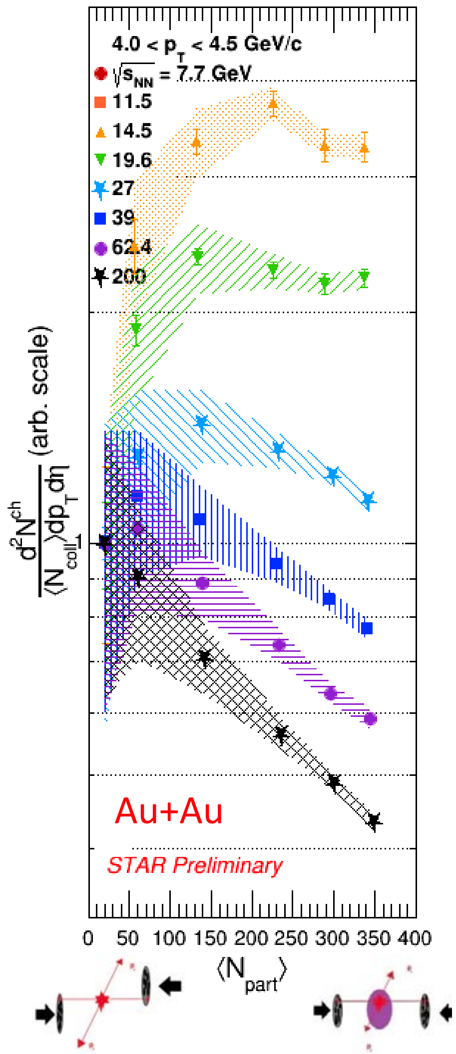
R_{cp} is not a good variable because peripheral may be suppressd also

STAR new variable: Ncoll scaling vs centrality for a given p_T

S. Horvat, QM2015



S. Horvat, QM2015

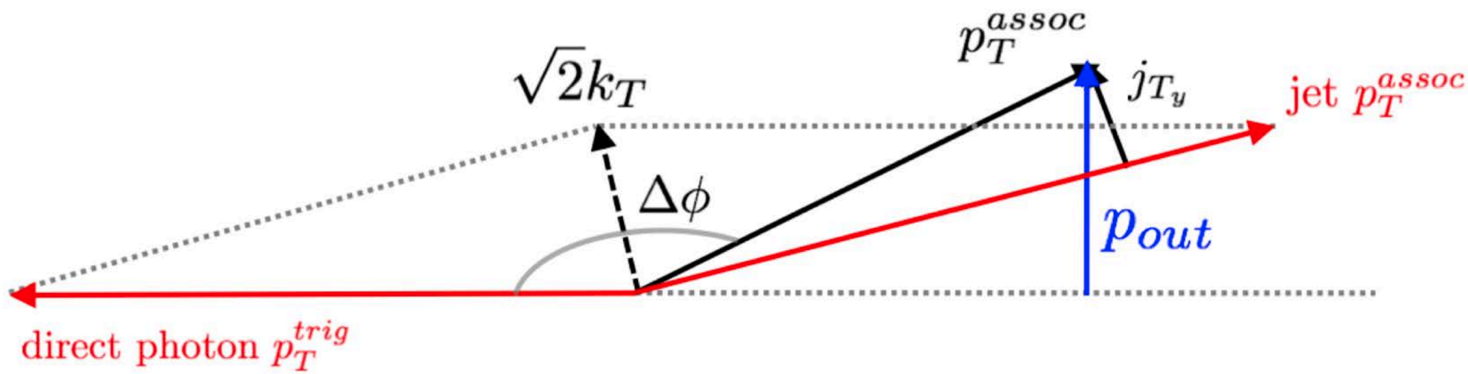


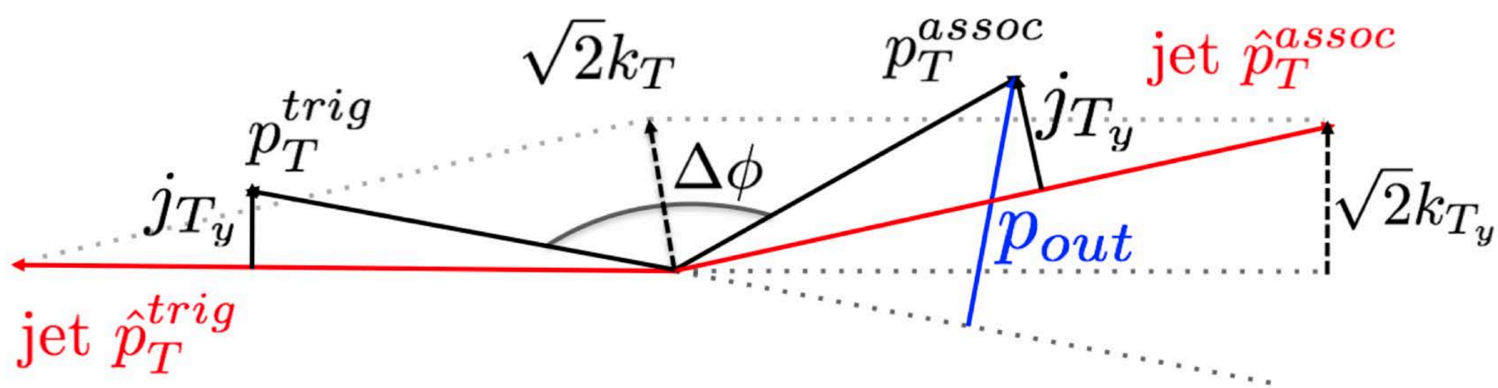
Rising=Cronin effect
Flat=Ncoll scaling: no suppression
Falling=suppression: QGP

Clear suppression for $\sqrt{s_{NN}} \geq 27$ GeV QGP

Small Cronin+Flat 19.6,11.5 GeV
Likely Hadron Resonance-Gas
need Lattice QCD at this $\sqrt{s_{NN}}$

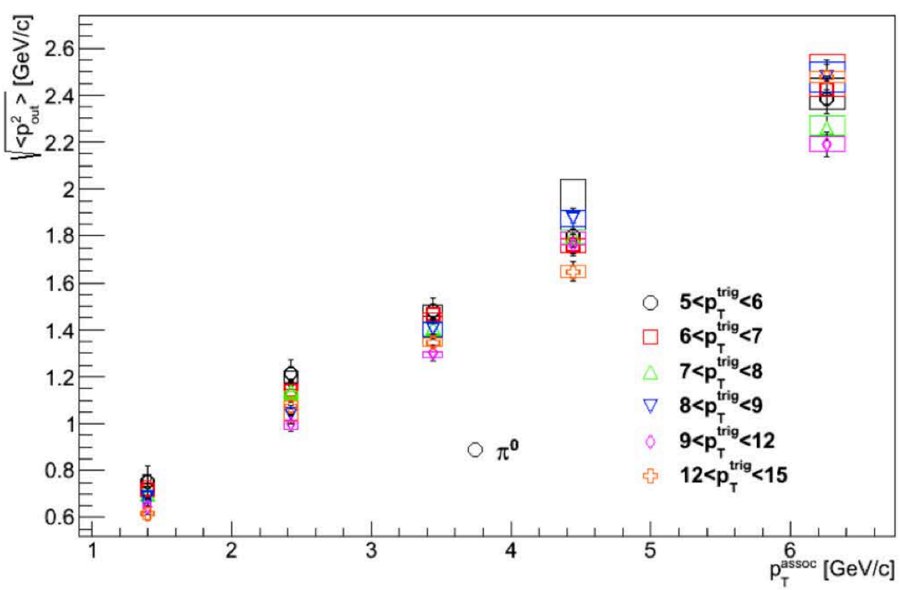
2 particle azimuthal correlations and k_T quark `intrinsic' transverse momentum

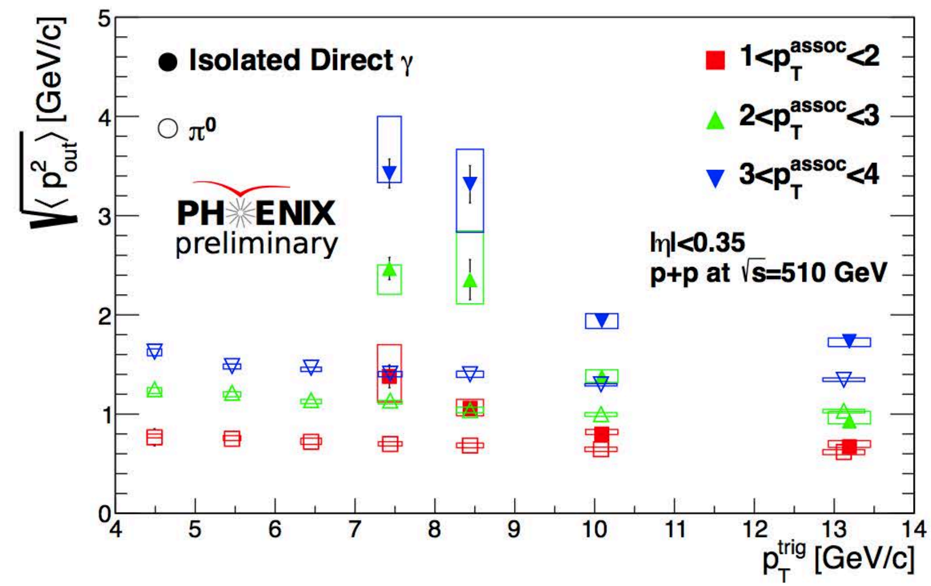




Dijets and dihadrons are not back to back in azimuth because of k_T, mean quark transverse momentum in a nucleon, named by Feynman, Field and Fox NPB128,1-65

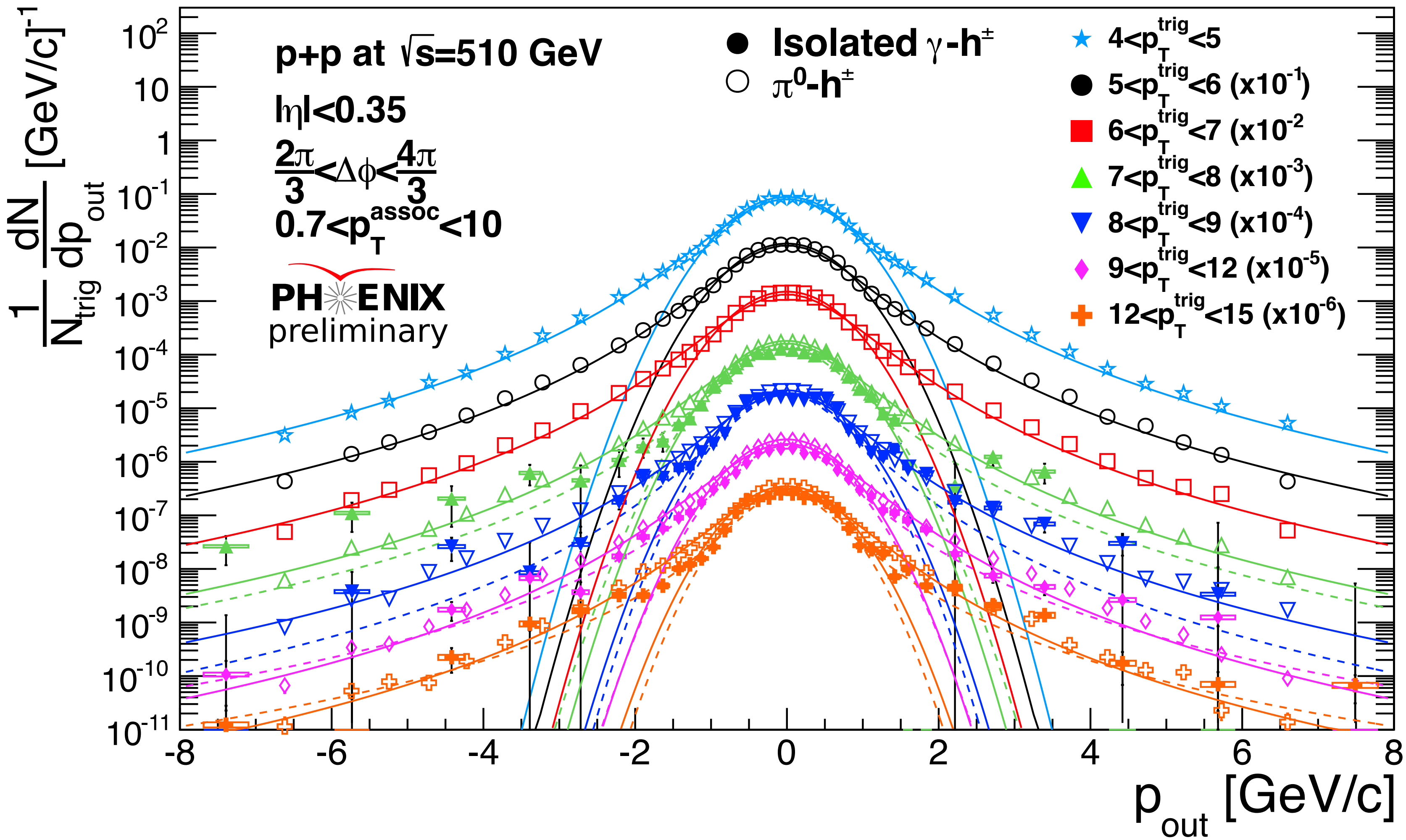
$\pi^0\ \sqrt{\langle p^2_{out}\rangle}$ increases with p_{Ta} for fixed p_{Tt}
$\pi^0\sqrt{\langle p^2_{out}\rangle}$ for fixed p_{Ta} is ~independent of p_{Tt}
$\gamma\ \sqrt{\langle p^2_{out}\rangle}$ for fixed p_{Ta} decreases with p_{Tt}





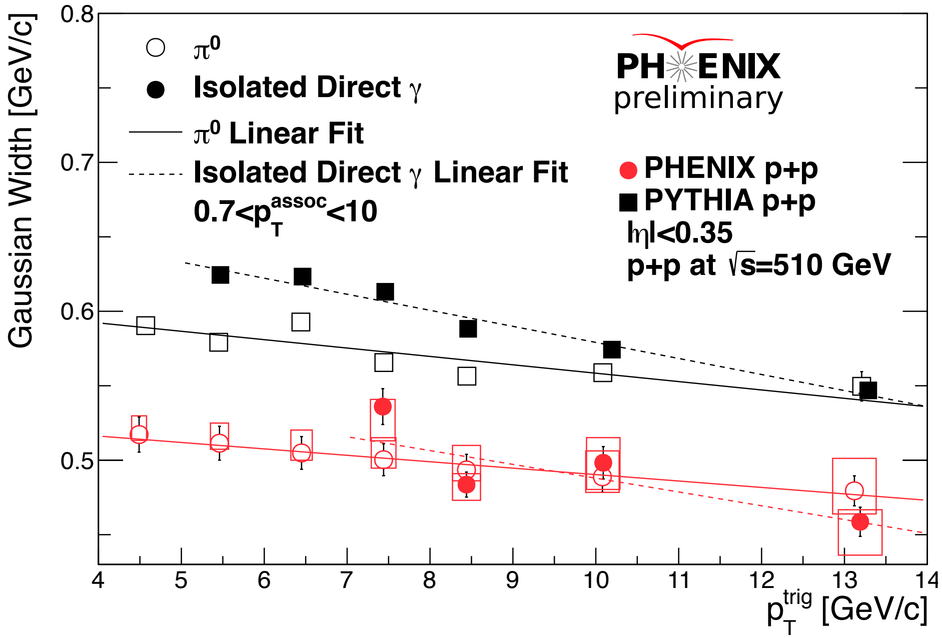
Something dramatic becomes evident when one plots the p_{out} distribution for fixed p_{Tt} integrated over all p_{Ta}

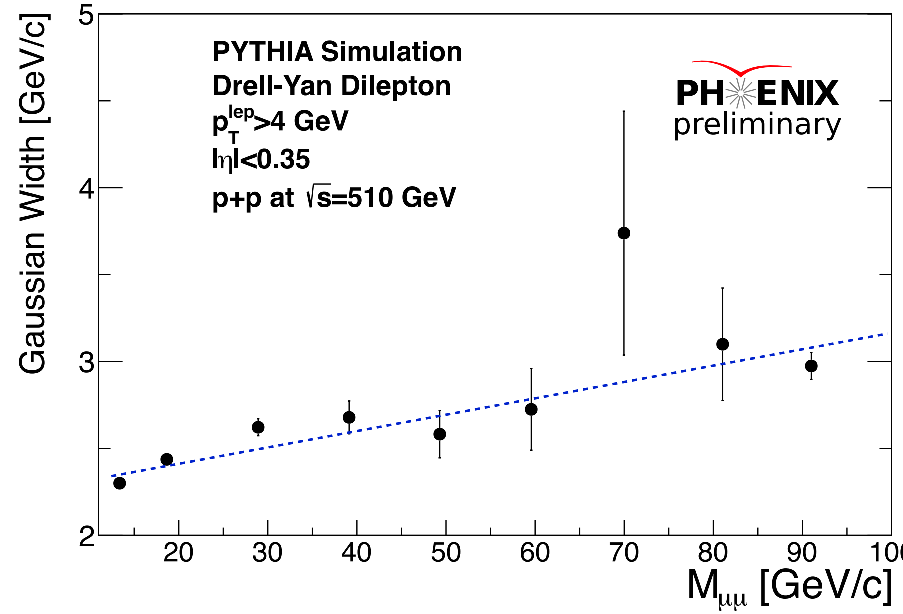
p_{out} distribution vs p_{Tt}



Gaussian for pout<1.5 GeV/c likely represents the intrinsic k_T while the power law for pout>1.5 GeV/c is likely standard QCD gluon radiation

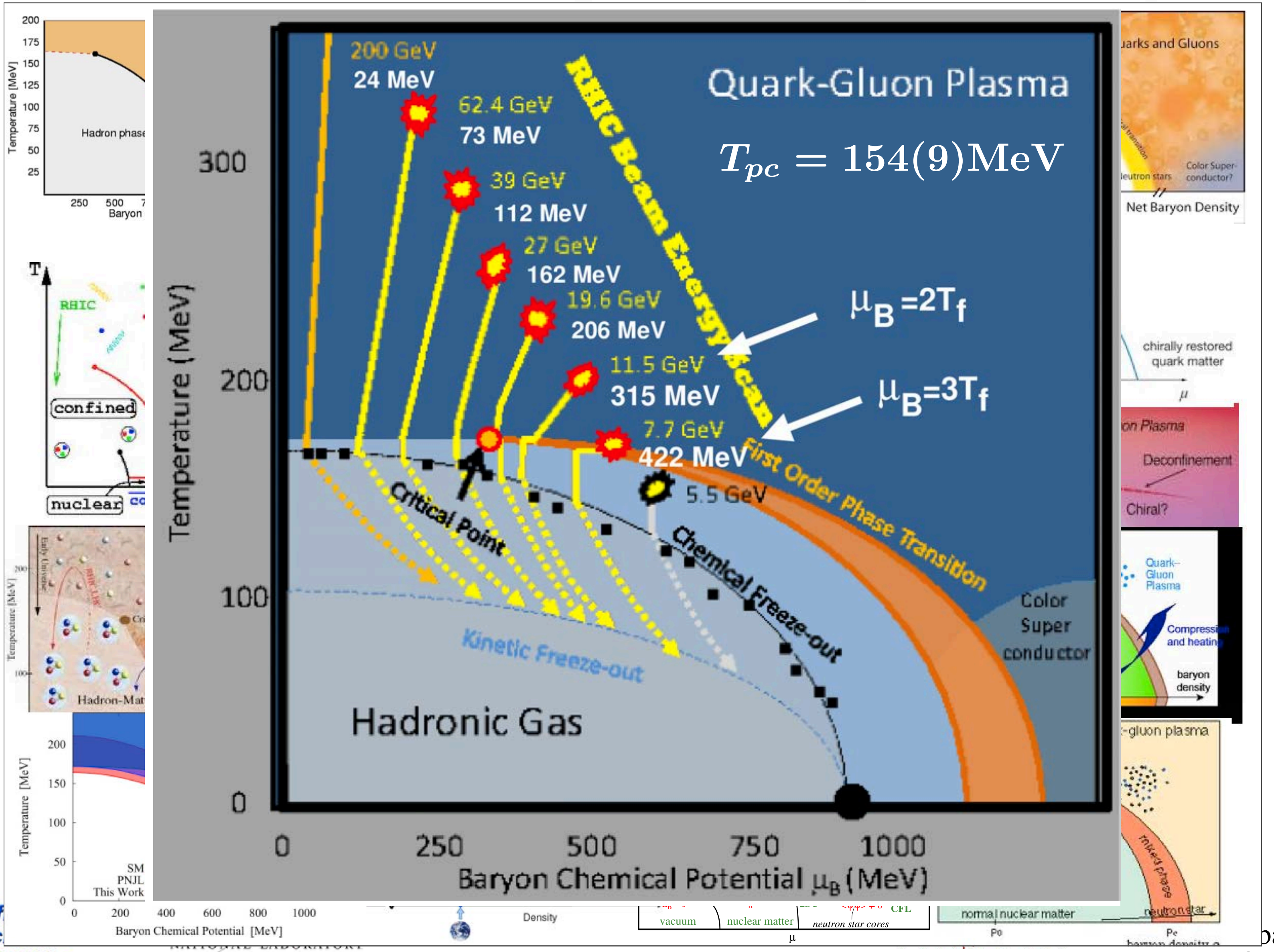
Gaussian width decreases with p_{Tt} for both π^0-h and γ-h





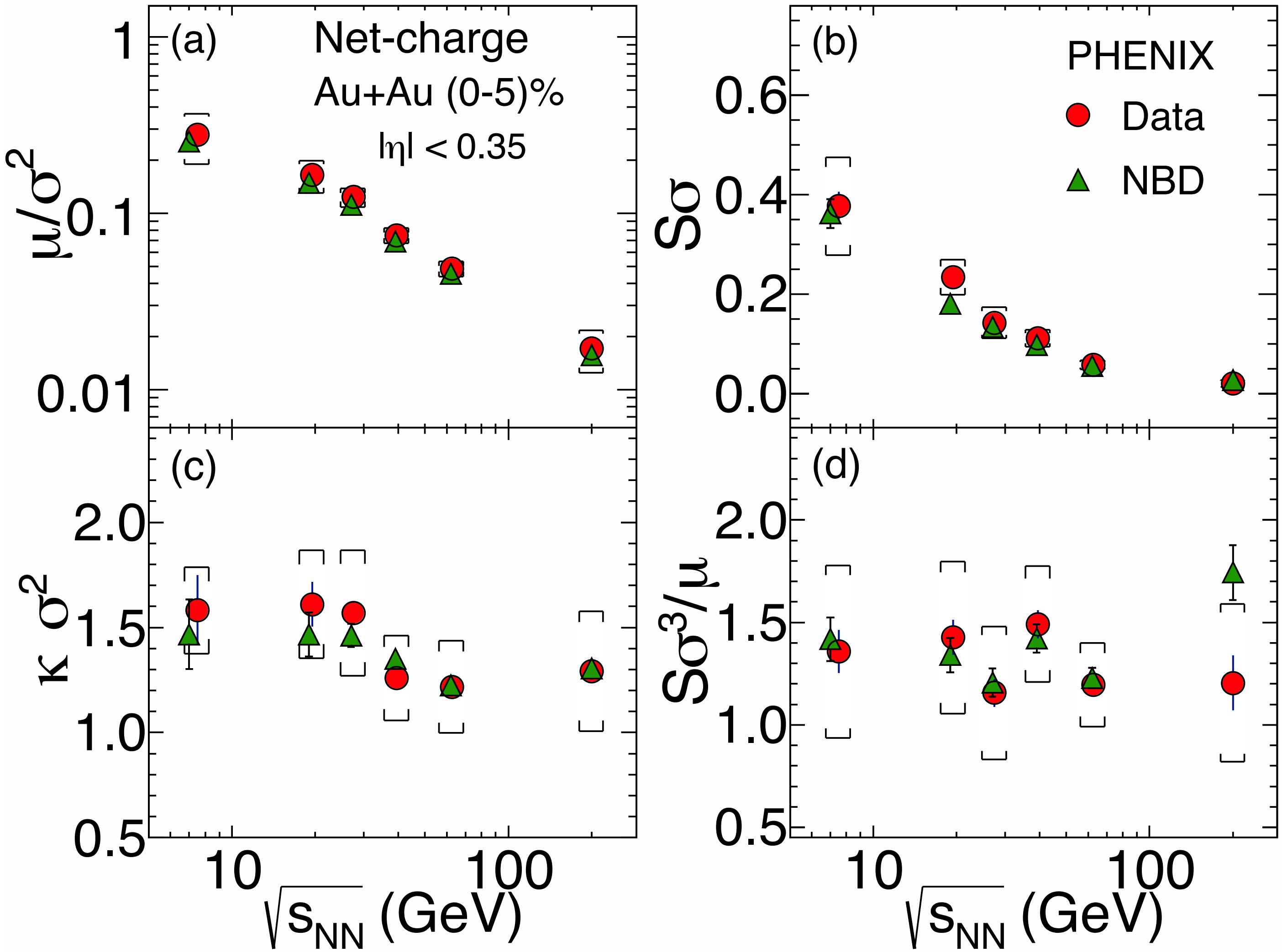
This is different from the expected effect in Drell Yan in PYTHIA simulation which may be important perhaps a contradiction for Transverse Momentum Dependent parton distribution ideas.

Net charge fluctuations from last year
Search for critical point on phase diagram



PHENIX central cumulant ratios vs $\sqrt{s_{NN}}$

PHENIX PRC93,011901(R)(2016)



Note that the ``data'' • calculations from the $\Delta N_{ch}=N^+ - N^-$ distributions agree with the NBD fits to the N^+ and N^- distribution and the NBD Cumulant Theorem.