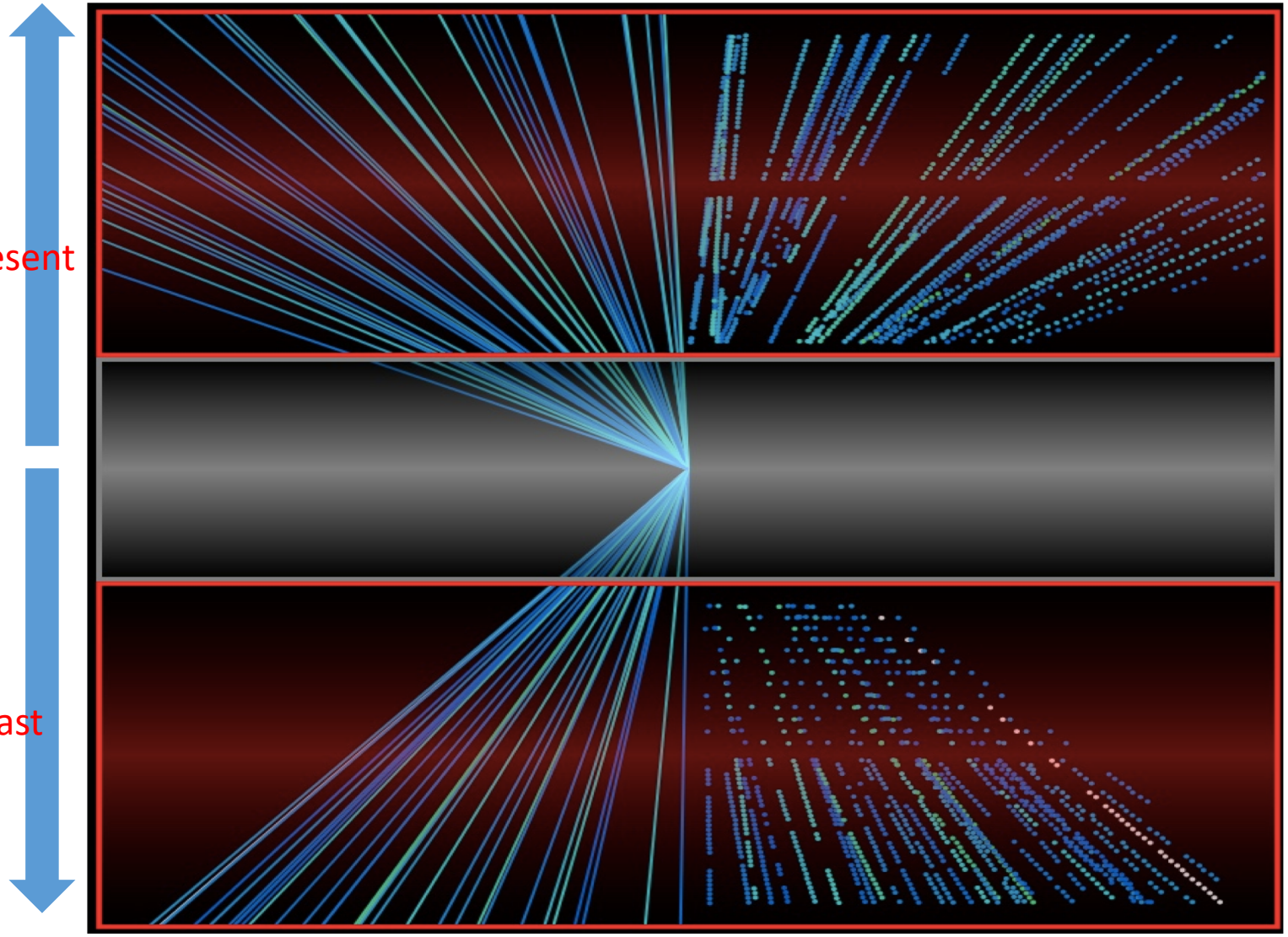
Update on STAR Analyses



Zhangbu Xu
(Brookhaven National Lab)

- Overview of STAR Analysis Activities
- Highlights of published and Preliminary results
- BES-I data publications
- Blinding Analysis of isobar dataset
- Analysis progress from recent runs
- Summary

Many results will be covered in
Helen Caines
Jim Drachenberg
and
Elke Aschenauer's talks

U.S. DEPARTMENT OF ENERGY | Office of Science

Collaboration Activities since June 2018

- 5 new institutions joined:
  Abilene Christian University (ACU)
  American University in Cairo (AUC)
  IISER Berhampuer, India
  IIT Patna, India
  IISER Tirupati, India

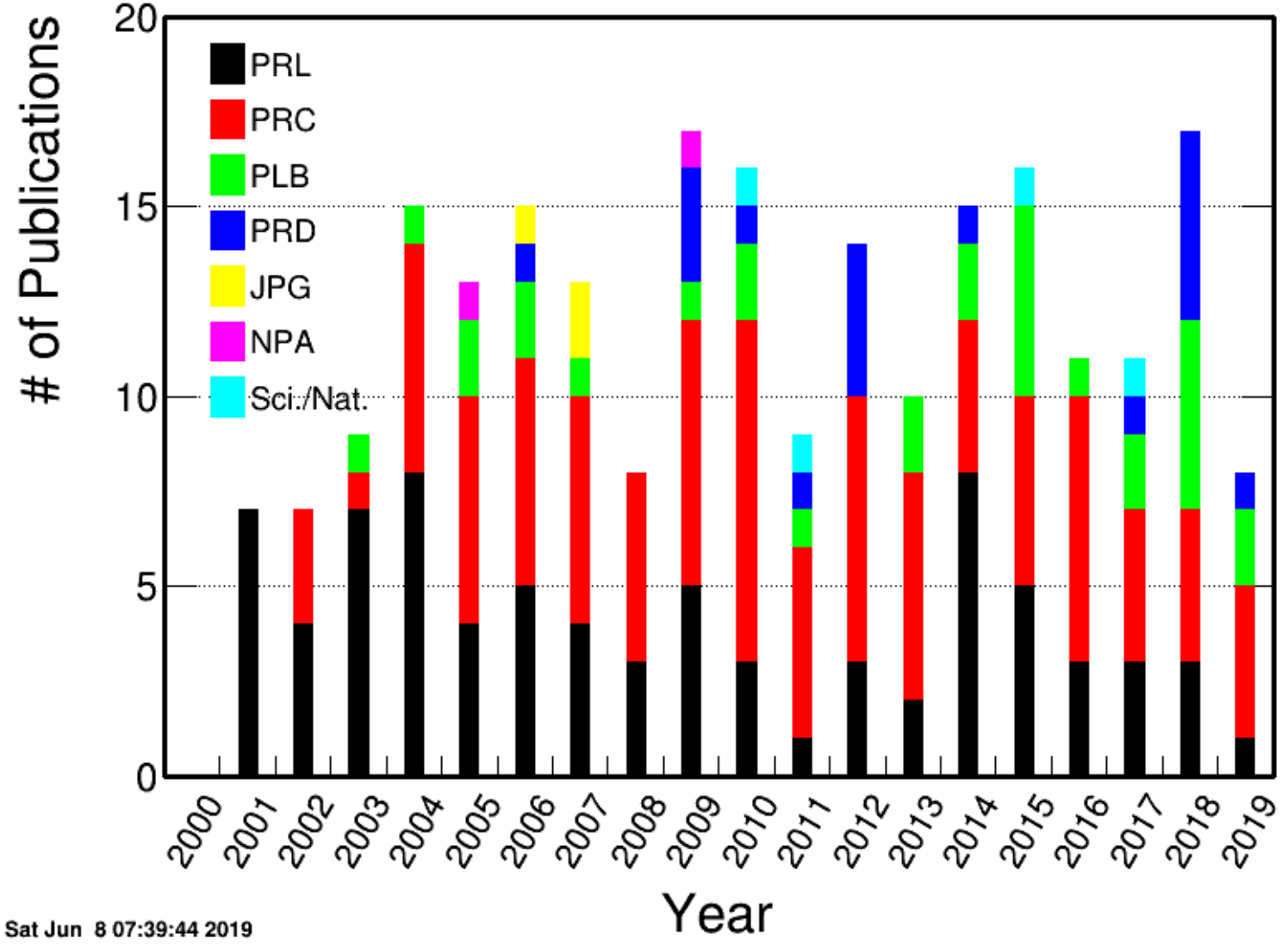
- 17 PHD graduates

- Run 19 data-taking about to complete
- 17 papers submitted
  22 papers published,
  10 in journal review
- 28 paper committees in action

69 institutions from 14 countries over 690 scientists

- STAR Collaboration Meeting
  Mar. 29 - Apr 2, 2019, BNL
- STAR Analysis Meeting
  Dec. 12-14, 2018, BNL
- ALICE-STAR Indian Meeting
  Sep. 17-21, 2018, NISER, India
- STAR Regional Meeting
  Oct. 31 - Nov. 2, 2018,USTC, China
- STAR-CBM Joint Workshop
  Sep 29, 2018,
  Physikalisches Institut, Heidelberg, Germany
- STAR Collaboration Meeting
  July 16-21, 2018,
  Lehigh University

STAR Recently Published Papers



- **2018**: 17 published 3 PRL, 5 PLB, 4 PRC, 5 PRD
- **2019**: 8 publish + accepted 1 PRL, 2 PLB, 4 PRC, 1 PRD

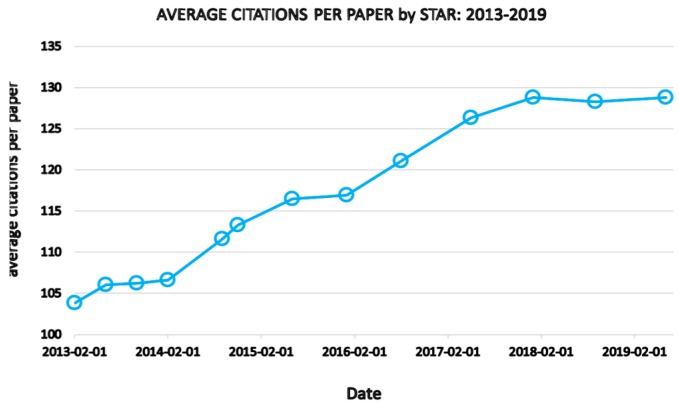
STAR Citation Summary

Citesummary excluding self-citations or RPP citations

Generated on 2019-06-07

228 papers found, 228 of them citeable (published or arXiv)

Citation summary results	Citeable papers	Citeable papers excluding self cites
Total number of papers analyzed:	228	228
Total number of citations:	29,362	19,725
Average citations per paper:	128.8	86.5
Breakdown of papers by citations:		
Renowned papers (500+)	11	6
Famous papers (250-499)	19	11
Very well-known papers (100-249)	48	31
Well-known papers (50-99)	54	51
Known papers (10-49)	73	87



Citations (as per June 7, 2019)

- 29,362 citations
- 228 peer-reviewed scientific papers
- 2005 white paper: 2892
- average citations/paper: 128.8

Published Papers in 06/18-06/19

- Global Polarization of Lambda Hyperons in Au+Au Collisions at 200 GeV
  - Phys. Rev. C 98 (2018) 014910 Submit: 5/11/2018; Publish: 7/23/2018
- Systematic Study of Azimuthal Anisotropy in Cu+Au Collisions at 200 GeV
  - Phys. Rev. C 98 (2018) 014915 Submit: 12/5/2017; Publish: 7/31/2018
- Correlation measurements between flow harmonics in Au+Au collisions at RHIC
  - Phys. Lett. B 783 (2018) 459 Submit: 3/11/2018; Publish: 8/10/2018
- Beam Energy Dependence of Rapidity-Even Dipolar Flow in Au+Au Collisions
  - Phys. Lett. B 784 (2018) 26 Submit: 4/23/2018; Publish: 9/10/2018
- Harmonic decomposition of three-particle azimuthal correlations at RHIC
  - Phys. Rev. C 98 (2018) 034918 Submit: 1/24/2017; Publish: 9/28/2018
- Energy Dependence of Moments of Net-kaon Multiplicity Distributions at RHIC
  - Phys. Lett. B 785 (2018) 551 Submit: 9/2/2017; Publish: 10/10/2018
- Constraining the initial conditions and temperature dependent transport with three-particle correlations in Au+Au collisions, Phys. Lett. B 790 (2019) 81 Submit: 1/23/2017; Publish: 3/10/2019
- The proton-Omega correlation function in Au+Au collisions at sqrt(s_{NN})=200 GeV
  - Phys. Lett. B 790 (2019) 490 Submit: 8/7/2018; Publish: 3/10/2019
- Collision Energy Dependence of p_T Correlations in Au+Au Collisions at RHIC
  - Phys. Rev. C 99 (2019) 044918 Submit: 1/3/2019; Publish: 4/26/2019
- Azimuthal Harmonics in Small and Large Collision Systems at RHIC Top Energies
  - Phys. Rev. Lett. 122 (2019) 172301 Submit: 1/23/2019; Accept: 4/4/2019
- Collision Energy Dependence of Second-order Off-diagonal and Diagonal Cumulants of Net-charge, Net-proton and Net-kaon Multiplicity Distributions in Au+Au Collisions, Submitted to Phys. Rev. C: 3/13/2019, accepted 06/07/2019

11 Bulk Properties and Soft Correlations

Published Papers in 06/18-06/19

- Longitudinal Double-Spin Asymmetries for π^0's in the Forward Direction for 510 GeV Polarized pp Collisions
  - Phys. Rev. D 98 (2018) 032013 Submit: 5/24/2018; Publish: 8/17/2018
- Longitudinal Double-Spin Asymmetries for Dijet Production at Intermediate Pseudorapidity in Polarized p+p Collisions at 200 GeV
  - Phys. Rev. D 98 (2018) 032011 Submit: 5/29/2018; Publish: 8/17/2018
- Transverse spin transfer to Lambda and anti-Lambda hyperons in polarized proton-proton collisions at sqrt(s)=200 GeV
  - Phys. Rev. D 98 (2018) 091103 Submit: 8/24/2018; Publish 11/29/2018
- Improved measurement of the longitudinal spin transfer to Lambda and anti-Lambda hyperons in polarized proton-proton collisions at sqrt(s)=200 GeV
  - Phys. Rev. D 98 (2018) 112009 Submit: 8/23/2018; Publish: 12/20/2018
- Measurement of the longitudinal spin asymmetries for weak boson production in proton-proton collisions at sqrt(s)=510 GeV
  - Phys. Rev. D 99 (2019) 051102 Submit: 12/12/2018; Publish: 3/14/2019

5 ColdQCD/Spin

Published Papers in 06/18-06/19

- J/psi production cross section and its dependence on charged-particle multiplicity in p+p collisions at sqrt(s)=200 GeV
  - Phys. Lett. B 786 (2018) 87 Submit 5/11/2018; Publish 11/10/2018
- Erratum: observation of D^0 meson nuclear modifications in Au+Au collisions at sqrt(sNN)=200 GeV
  - Phys. Rev. Lett. 121 (2018) 229901 Submit: 9/24/2018; Publish: 11/28/2018
- Centrality and transverse momentum dependence of D^0 meson production at mid-rapidity in Au+Au collisions at sqrt(sNN)=200 GeV
  - Phys. Rev. C 99 (2019) 034908 Submit: 12/26/2018; Publish: 3/20/2019
- Beam Energy Dependence of Jet-Quenching Effects in Au+Au Collisions at sqrt(sNN) = 7.7, 11.5, 14.5, 19.6, 27, 39, and 62.4 GeV
  - Phys. Rev. Lett. 121 (2018) 032301 Submit: 7/11/2017; Publish: 7/19/2018
- Low p_T e^+e^- pair production in Au+Au collisions at sqrt(s_{NN})=200 GeV and U+U collisions at sqrt(s_{NN})=193 GeV at STAR
  - Phys. Rev. Lett. 121 (2018) 132301 Submit: 6/6/2018; Publish: 9/25/2018
- Beam Energy Dependence of (anti-)deuteron Production in Au+Au Collisions at RHIC
  - Phys. Rev. C (in press) Submit: 3/29/2019; Accept: 5/9/2019

2 Heavy-Flavor, 2 Light-Flavor Spectra/UPC, 1 Jet & Correlations

Papers in Journal Review

- Polarization of Lambda (anti-Lambda) hyperons along the beam direction in Au+Au collisions at sqrt(sNN) = 200 GeV, Submitted to Phys. Rev. Lett: 5/28/2019
- Charge-dependent pair correlations relative to a third particle in p+Au and d+Au collisions at RHIC, Submitted to Phys. Rev. Lett: 6/10/2019
- Measurements of dielectron production in Au+Au collisions at sqrt(sNN)=27, 39 and 62.4 GeV from the STAR experiment, Submitted to Phys. Rev. Lett.: 10/29/2018
- Precise measurement of the mass difference and the binding energy B_Lambda of hypertriton and anti-hypertriton, Submitted to Nature Physics: 4/24/2019
- Strange hadron production in Au+Au collisions at sqrt(sNN)= 7.7, 11.5, 19.6, 27, and 39 GeV, Submitted to Phys. Rev. C: 6/10/2019
- Longitudinal double-spin asymmetry for inclusive jet and dijet production in pp collisions at sqrt(s)=510 GeV, Submitted to Phys. Rev. D: 6/6/2019
- Observation of excess of J/psi yield at very low transverse momenta in Au+Au collisions at sqrt(sNN)=200 GeV and U+U collisions at sqrt(sNN)=193 GeV by the STAR experiment, Submitted to Phys. Rev. Lett: 4/26/2019
- First observation of directed flow of D0 and D0bar in Au+Au collisions at sqrt(sNN)=200 GeV, Submitted to Phys. Rev. Lett: 5/6/2019
- Measurements of the transverse-momentum-dependent cross sections of J/ψ production at mid-rapidity in proton+proton collisions at $\sqrt{s} =$ 510 and 500 GeV with the STAR detector, Submitted to Phys. Rev. D: 5/16/2019
- Measurement of inclusive J/psi suppression in Au+Au collisions at sqrt(sNN) = 200 GeV through the dimuon channel at STAR, Submitted to Phys. Rev. C: 5/31/2019

2 BulkCorr, 3 LFS/UPC

1 ColdQCD/Spin, 4 HF

Papers in Collaboration Review

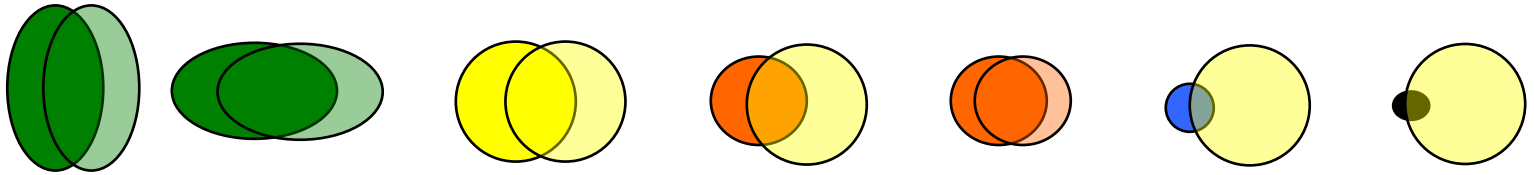
- Search for the Chiral Magnetic Wave with anisotropic flow of identified particles at RHIC
  - Collaboration review: 2/6/2019
- Beam-energy dependence of identified two-particle angular correlations in Au+Au collisions at RHIC
  - Collaboration review: 4/29/2019

- Measurement of jet correlation devoid of flow background in Au+Au collisions at sqrt(sNN)=200 GeV
  - Collaboration review: 10/18/2017
- Underlying Event Measurements in p+p Collisions at sqrt(s)=200 GeV
  - Collaboration review: 6/8/2019

- Bulk properties of the system formed in Au+Au collisions at sqrt(sNN) =14.5 GeV using the STAR detector at RHIC
  - Collaboration review: 4/29/2019

2 BulkCorr, 2 JetCorr, 1 LFSUPC

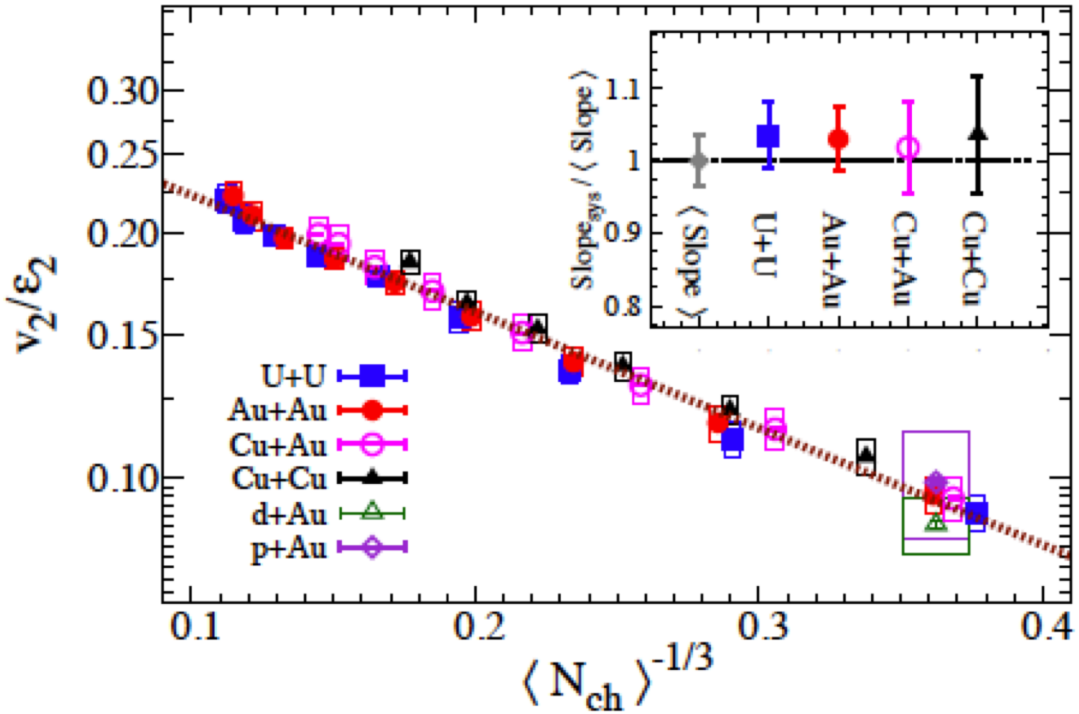
Small and Large Systems at RHIC top energy



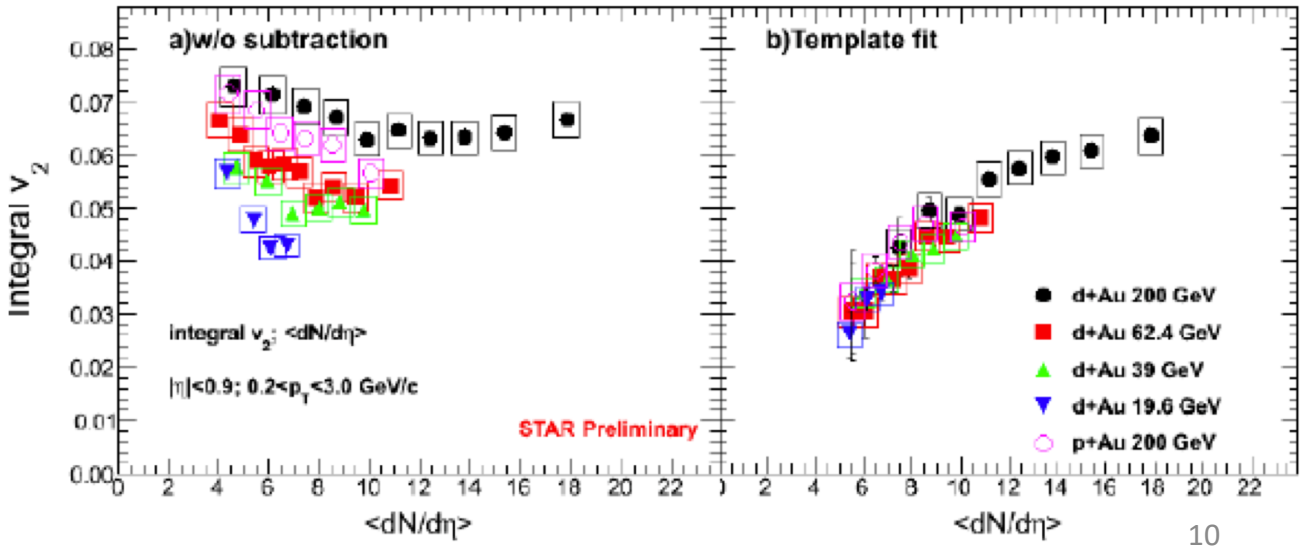
U + U | Au + Au | Cu + Au | Cu + Cu | d + Au | p + Au

Different colliding species → initial state effects and transport coefficients.

STAR, Phys. Rev. Lett. 122 (2019) 172301



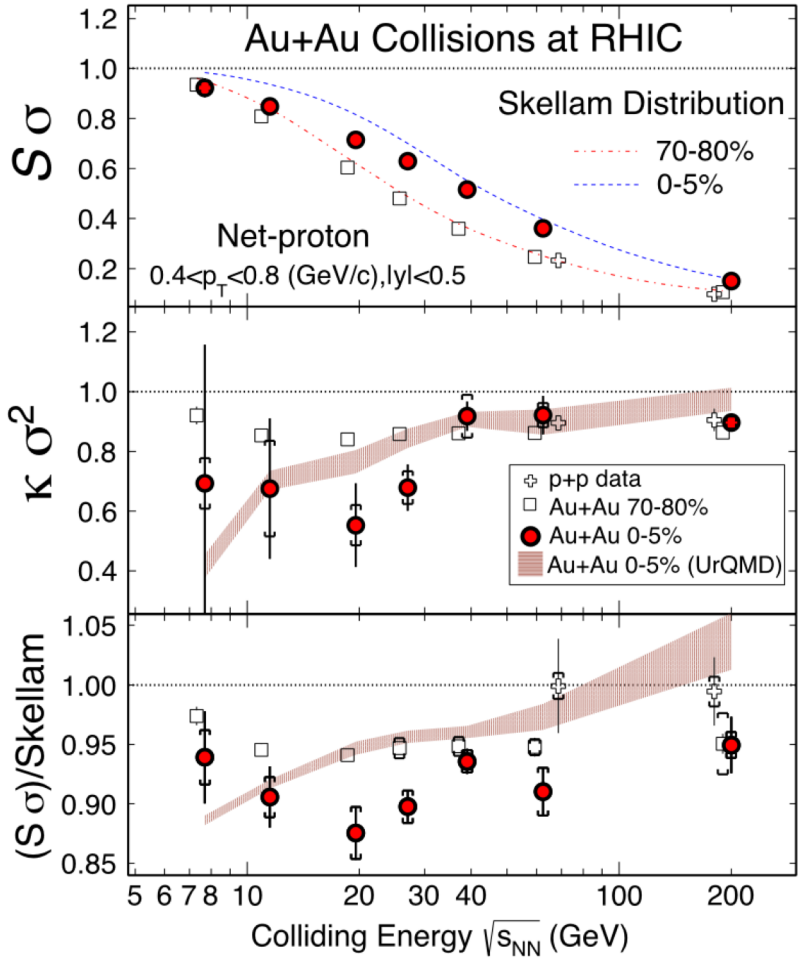
- Azimuthal anisotropy is system-dependent.
- Scale by system size after dividing by eccentricity
- Similar behavior for d+Au in BES after non-flow correction (model).



First publication from **run 15**

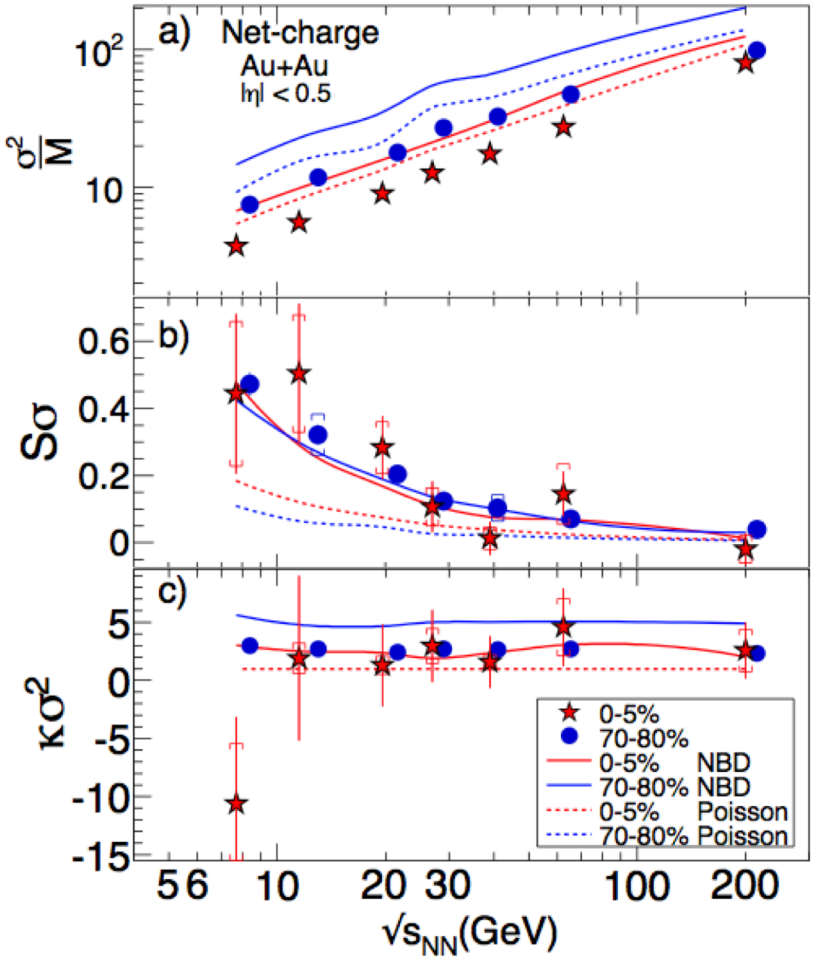
BES-I (2010-2014) : Net-Particle Fluctuation Measurements

Net-Proton



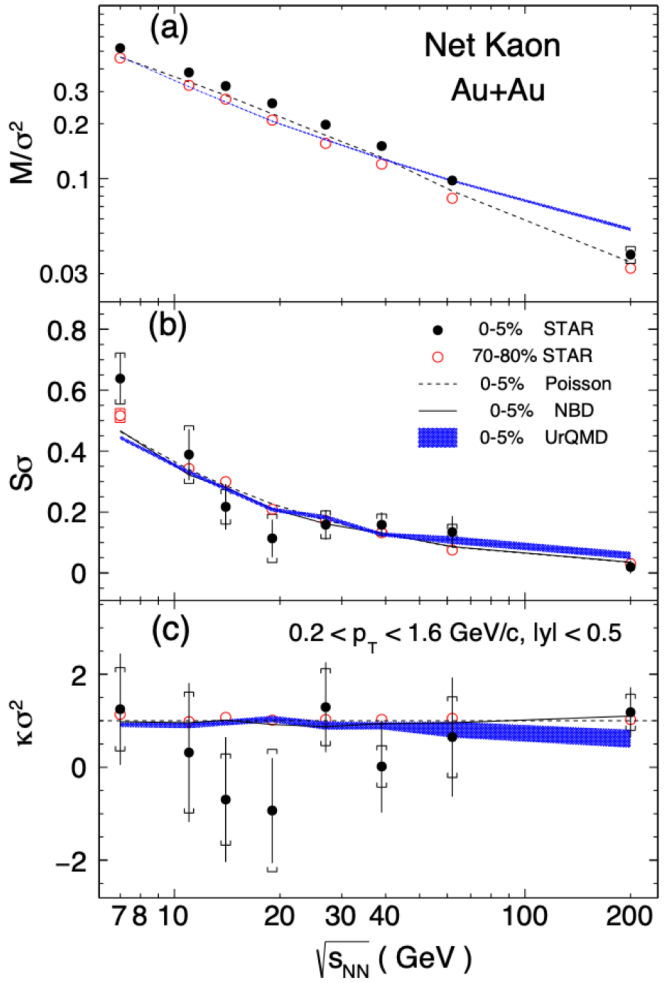
Phys. Rev. Lett. 105, 022302 (2010).
Phys. Rev. Lett. 112, 032302 (2014).

Net-Charge



Phys. Rev. Lett. 113 092301 (2014).

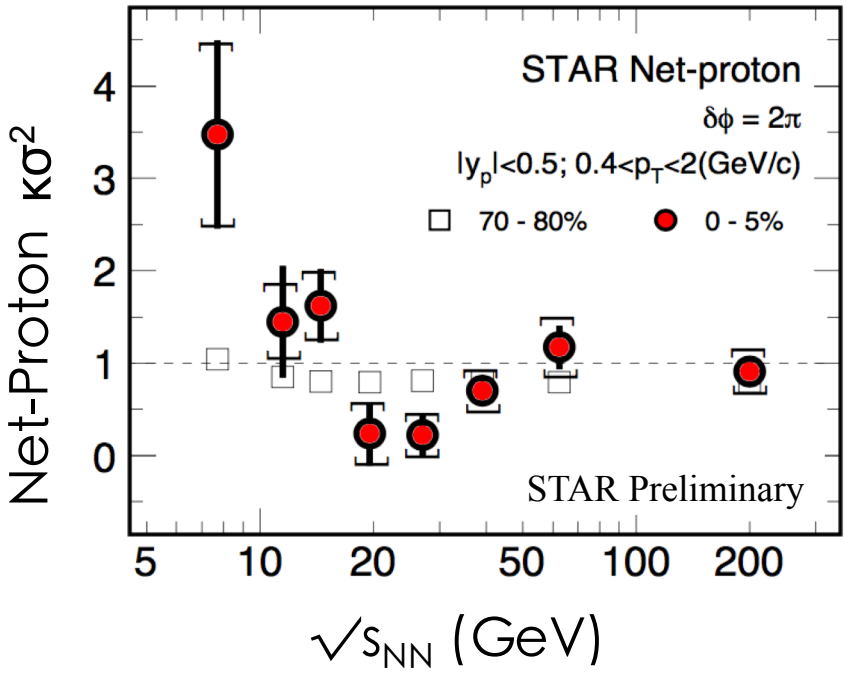
Net-Kaon



Phys. Lett. B 785, 551 (2018).

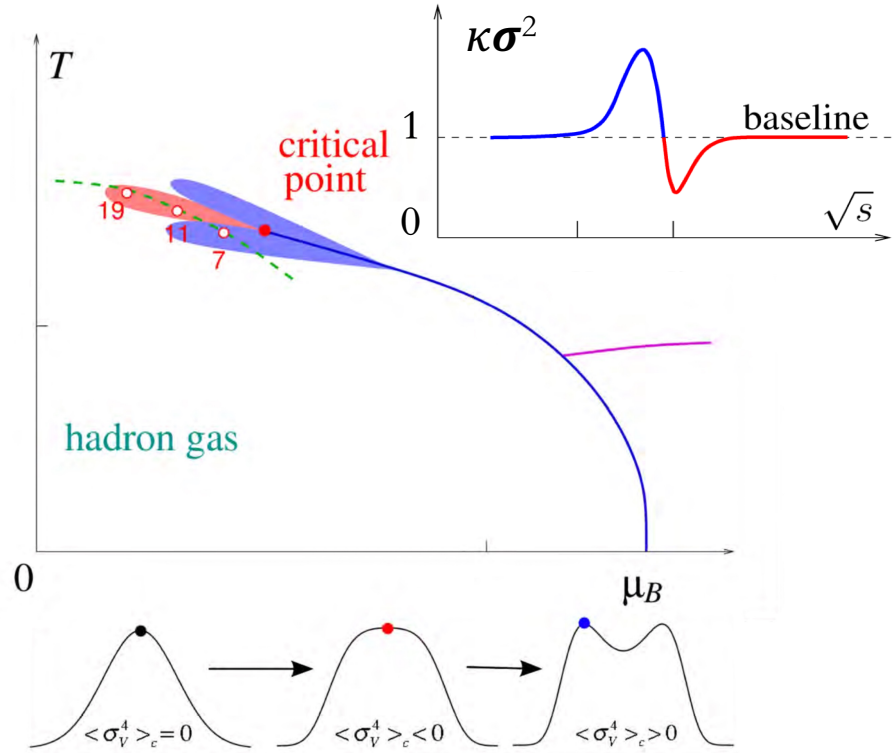
Net-Proton Fluctuations

Experimental Measure



STAR: Phys. Rev. Lett. 105, 022302 (2010).
Phys. Rev. Lett. 112, 032302 (2014).
PoS CPOD2014 (2015) 019.

Theoretical calculations



M. Stephanov, PRL107, 052301(2011)
J. Phys. G: 38, 124147 (2011).

➢ First observation of the non-monotonic energy dependence of fourth order net-proton fluctuations. Hint of entering Critical Region ?

Net-Proton Fluctuation Paper Plan

Net-proton number fluctuations and QCD critical point

Collision of heavy-ions at relativistic energies have established the formation of two distinct phases of matter in the temperature (T) versus baryonic chemical potential (μ_B) phase diagram of strong interactions. The two phases corresponds to the high T de-confined state of quarks and gluons (basic building blocks of visible matter) and their confined state of hadrons at a lower T. A dedicated program to study the properties (viscosity, opacity, conductivity, vorticity, etc.) of the phases and to look for details related to the phase structures (nature of phase transition and critical point) associated with this Quantum Chromodynamics (QCD) phase diagram, by varying the collision energy, was launched in the year 2010 at the Relativistic Heavy-Ion Collider (RHIC) facility. Here we present results related to the search for critical point (CP) in the QCD phase diagram. When the system with N particles passes through the critical region it gets endowed with special properties, like the density fluctuations increase dramatically as a positive power of N and when away from the region the density fluctuations are small $\sim N^{-1/2}$. These fluctuations which are related to the correlation length and the susceptibilities of the system are captured by the moments of the multiplicity distributions. As the strongly interacting system produced in heavy-ion collisions are of short length (few 10's of femtometer) and time (10^{-21}–10^{-22} seconds) scales, non-monotonic variations in the collision energy dependence of higher order moments of conserved number (Baryon, Charge or Strangeness) distributions is the experimental signature for the existence of the CP in the QCD phase diagram. We report here the first observation

Short Paper :

Target Journal: Nature Physics

1. The paper draft is almost **ready.**
2. **Analysis note ready.**
3. Paper Proposal : **done**

Next step:
Request PWGC **Preview and** GPC

Long Paper :

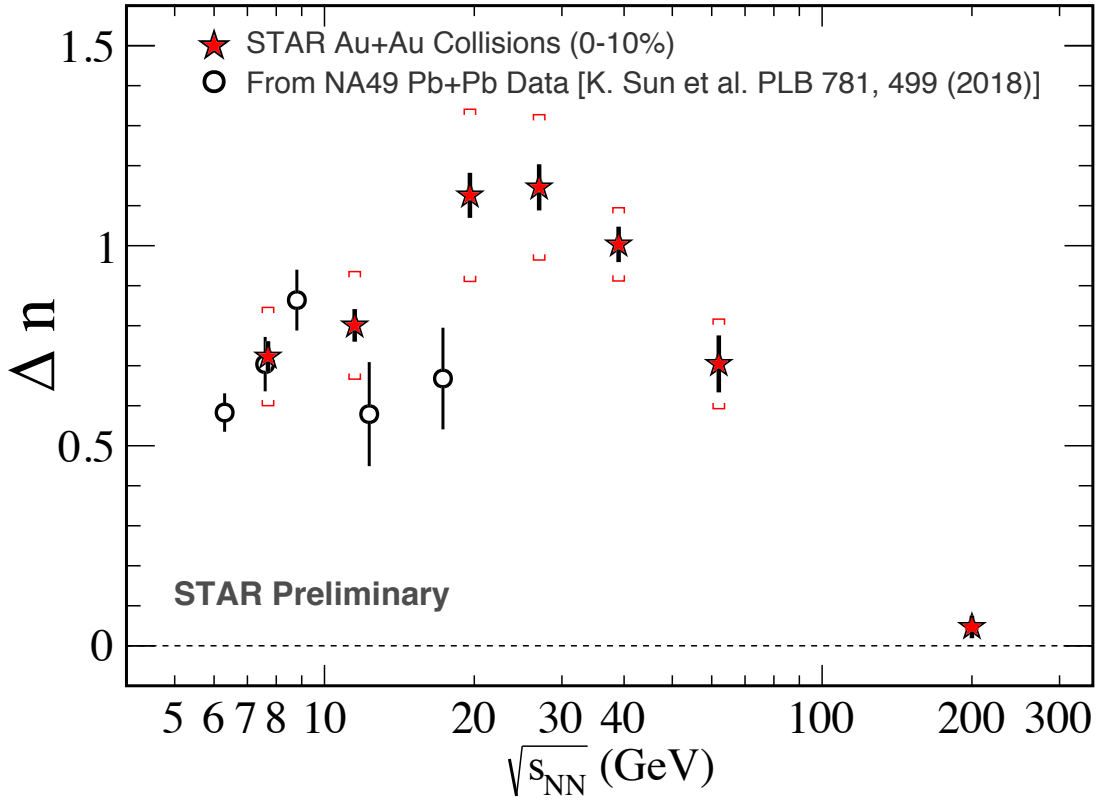
Figures **for long paper are ready.**
Working on the text.

Will submit both short **and long paper together to journals.**

Nucleon Density Fluctuations

The particle ratios of light nuclei is sensitive to the **nucleon density fluctuation** at kinetic freeze-out. This conclusion is based on **coalescence model.**

$$N_d = \frac{3}{2^{\frac{1}{2}}}\left(\frac{2\pi}{m_0 T_{eff}}\right)^{3/2} N_p\langle n\rangle(1+\alpha\Delta n) \qquad N_t = \frac{3^{3/2}}{4}\left(\frac{2\pi}{m_0 T_{eff}}\right)^{3} N_p\langle n\rangle^2[1+(1+2\alpha)\Delta n]$$



Dingwei Zhang, NN2018

If assume α=0.

$$\frac{\langle(\delta n)^2\rangle}{\langle n\rangle^2} = \Delta n = \frac{1}{g}\frac{N_t N_p}{N_d^2} - 1$$

N_t : Triton yield, N_d : Deuteron yield
N_p : Proton yield

Neutron density fluctuation Δn shows a non-monotonic behavior on collision energy.

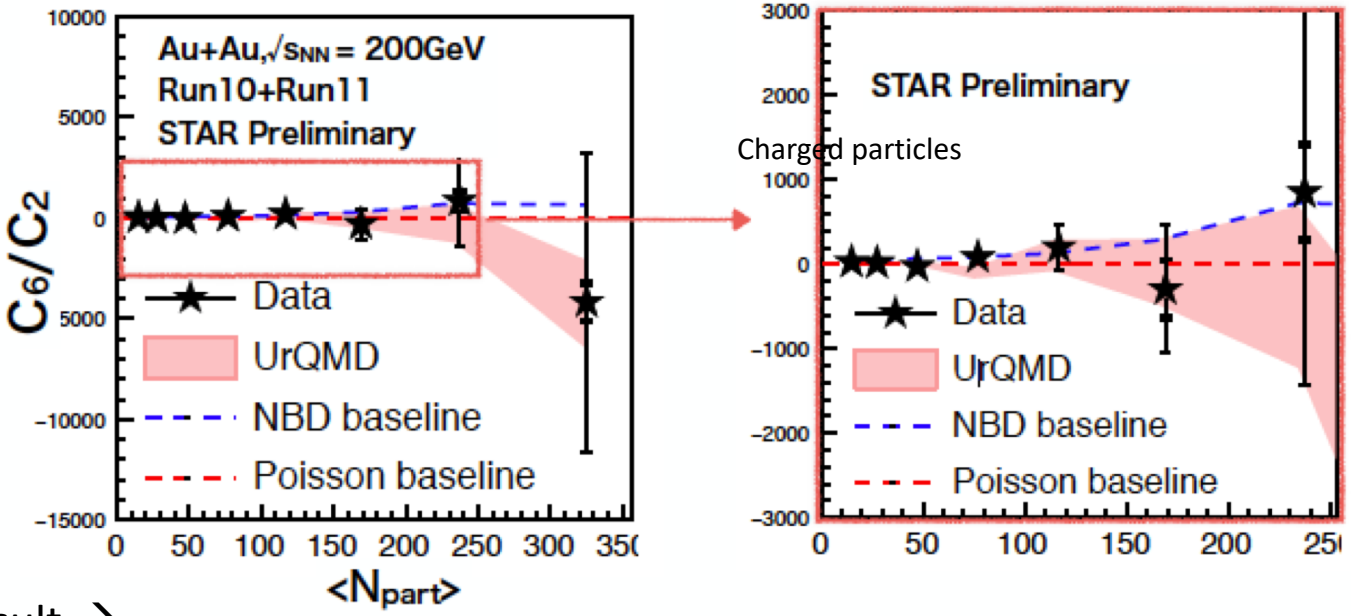
Peak around 20 GeV.

K. J. Sun, L. W. Chen, C. M. Ko, Z. Xu, Phys. Lett. B774, 103 (2017).
K. J. Sun, L. W. Chen, C. M. Ko, J. Pu, Z. Xu, Phys. Lett. B781, 499 (2018).
Edward Shuryak and Juan M. Torres-Rincon, NPA 982, 831 (2019)

Sixth-order cumulants

- The 6th-order fluctuations are sensitive to the phase transition.

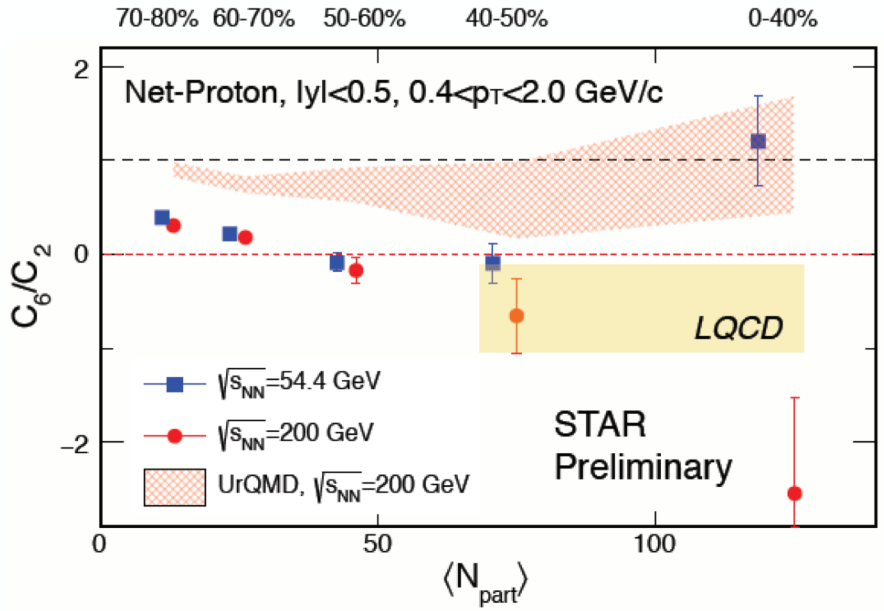
- QCD predictions suggest $C_6/C_2 < 0$ at beam √s > 60GeV.



- Updated procedure for **charged particles** result → Individual efficiency calculation per particle. Still statistically limited.

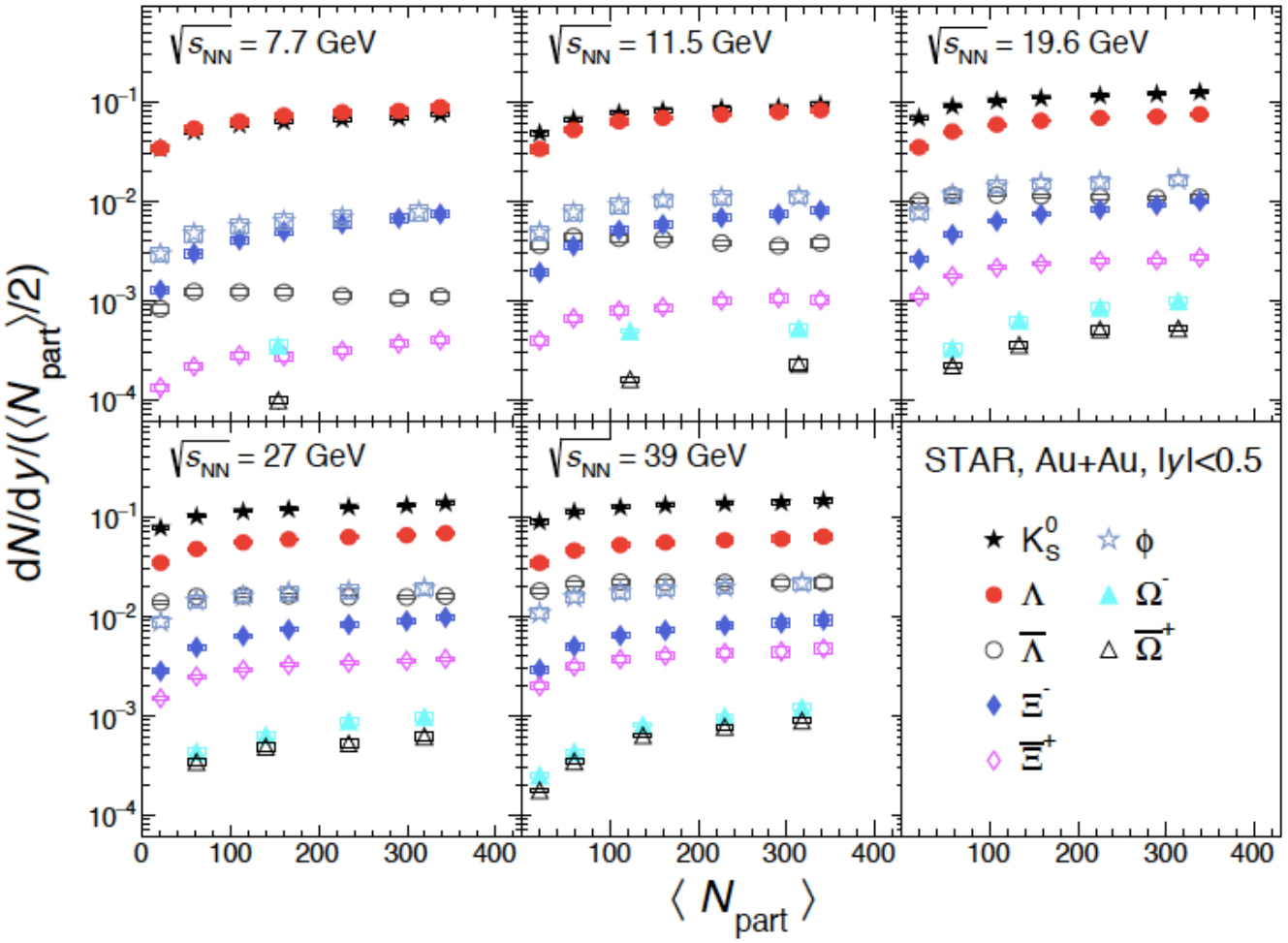
- For **net protons**: $C_6/C_2 > 0$, at √s = 54.4 GeV (run17)
  $C_6/C_2 < 0$, at √s = 200 GeV

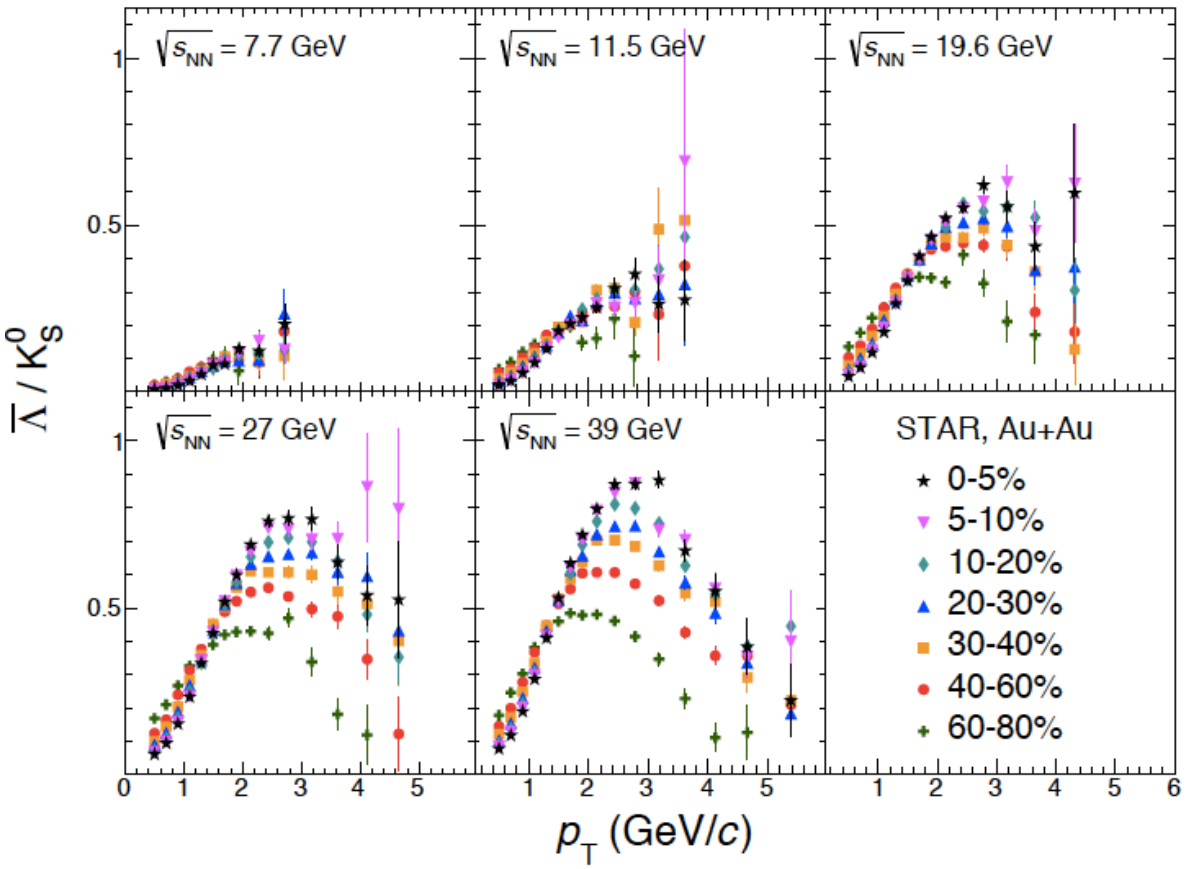
  → Cross over?



LQCD : A. Bazavov et al, PhysRevD.95.054504

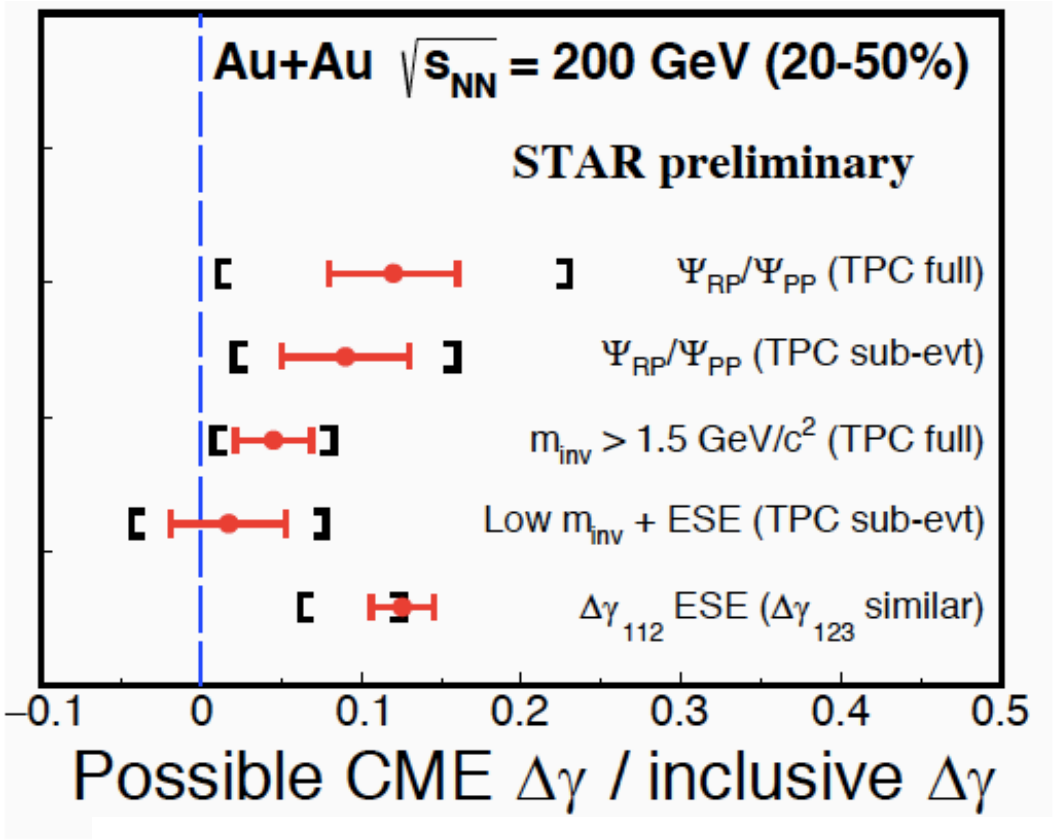
Strangeness hadron production from BES-I

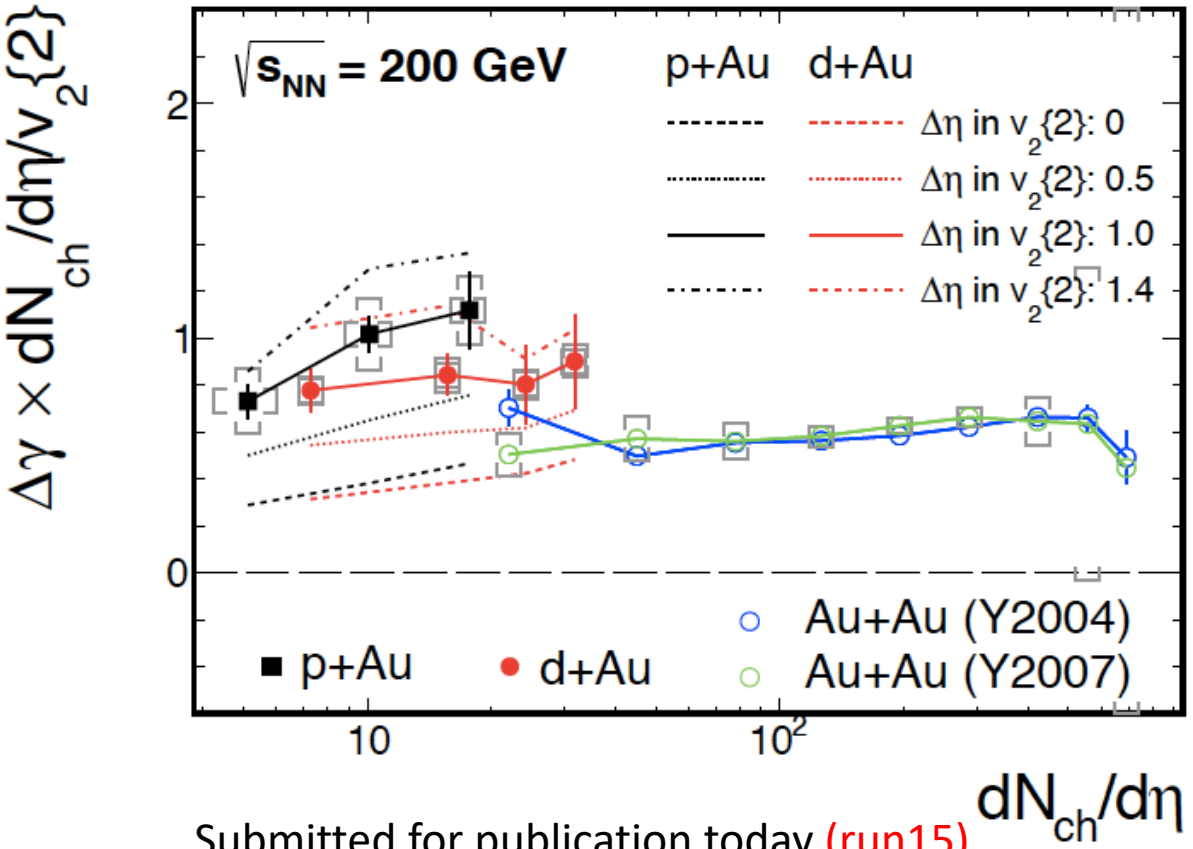




Wealthy set of beautiful data from BES-I, submitted today to PRC

Chiral Magnetic Effect in Au+Au





Submitted for publication today (run15)

A set of papers based on these analyses are in the pipeline going through the collaboration reviews

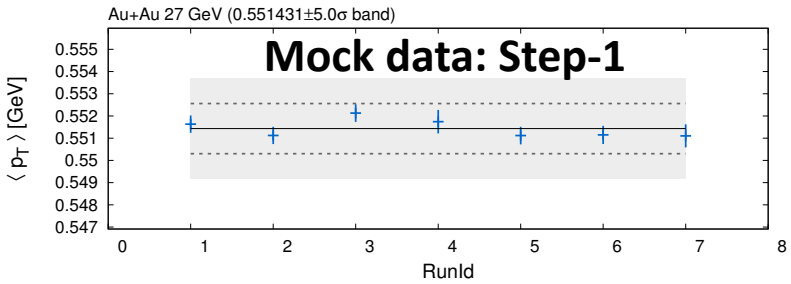
One paper review committee for all these papers

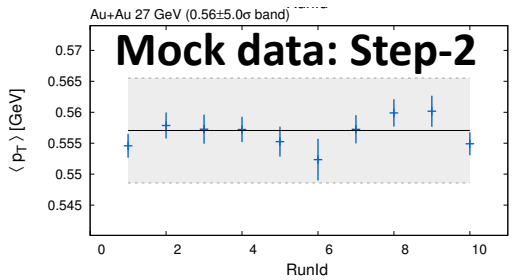
Blind Analysis Plan and Status

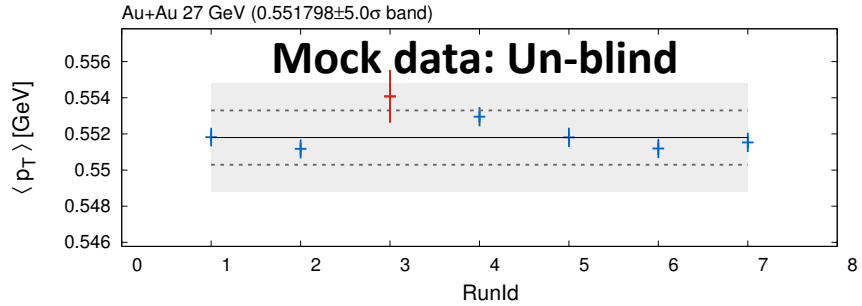
Analysis Blinding Committee recommendation: https://drupal.star.bnl.gov/STAR/starnotes/private/psn0683

- *A draft of the recommendation is written for submission to the arXiv*

Initial steps: "Mock data challenge" *Sanity-check of feasibility and implementation*



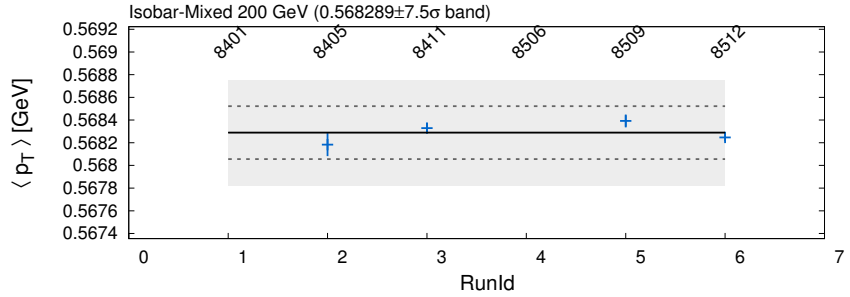




- *Au+Au 27 GeV data produced and analyzed in same way as blind isobar analysis*

Step-1: Provided output files composed of events from a ***mix*** of the isobar species

- *Production and analysis Q/A underway*

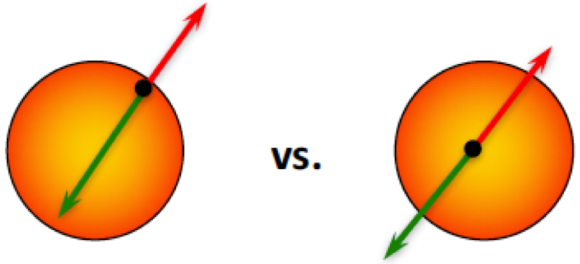


Step-2: Provide files that obscure true runnumber but do ***not*** mix events across different runs

- Only allow run-by-run corrections and code alteration directly resulting from these corrections

Full un-blinding

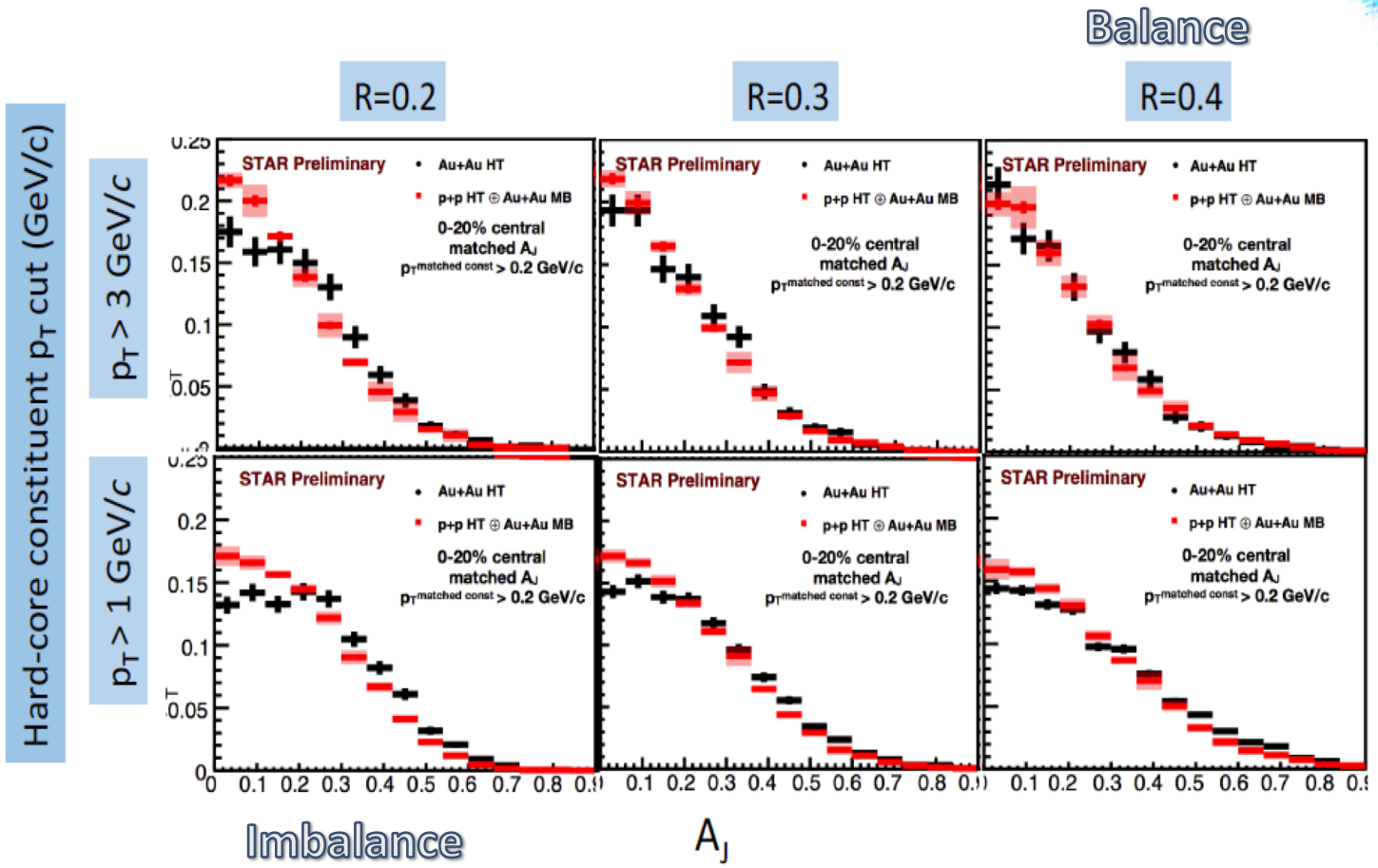
Di-jet imbalance



Di-jet imbalance from two situations?

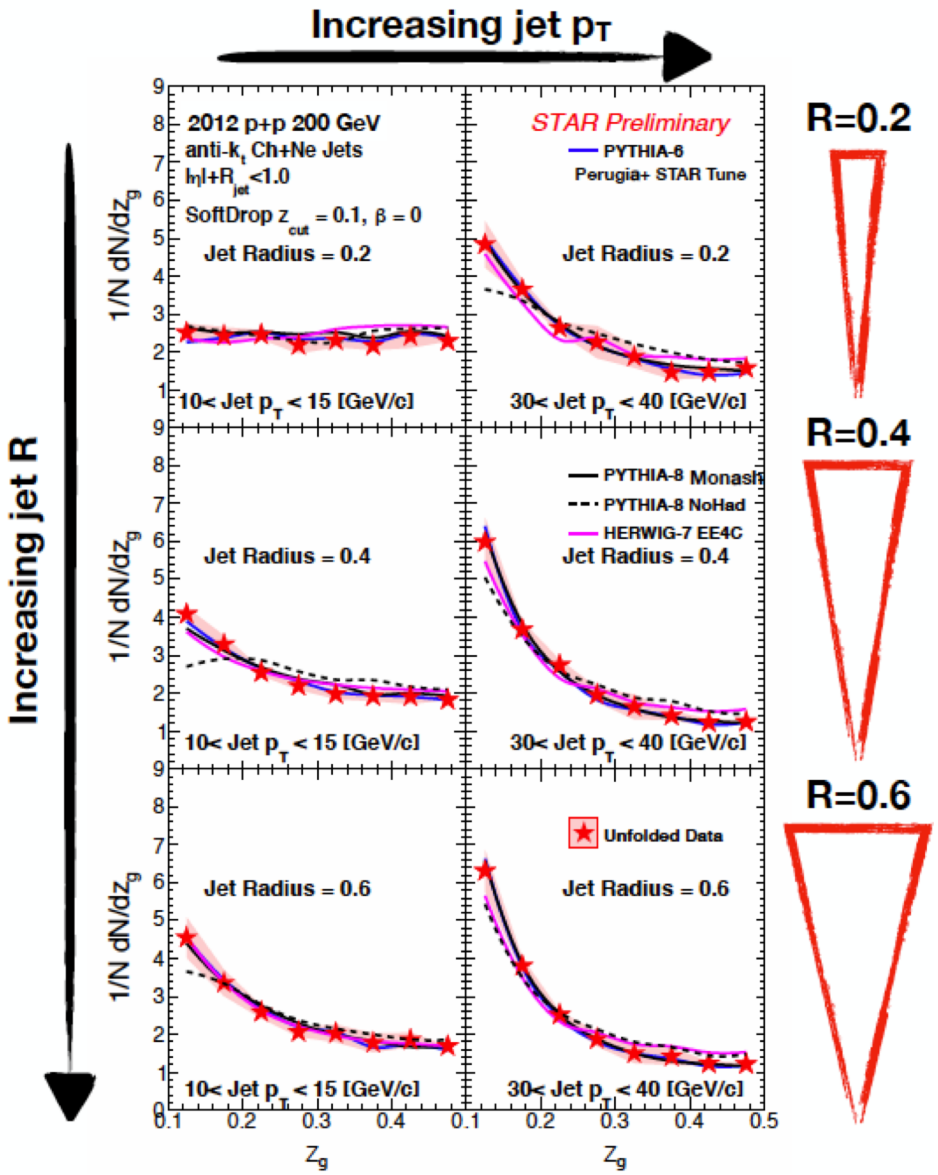
Varying the jet definition to control the path length of jets in the medium.

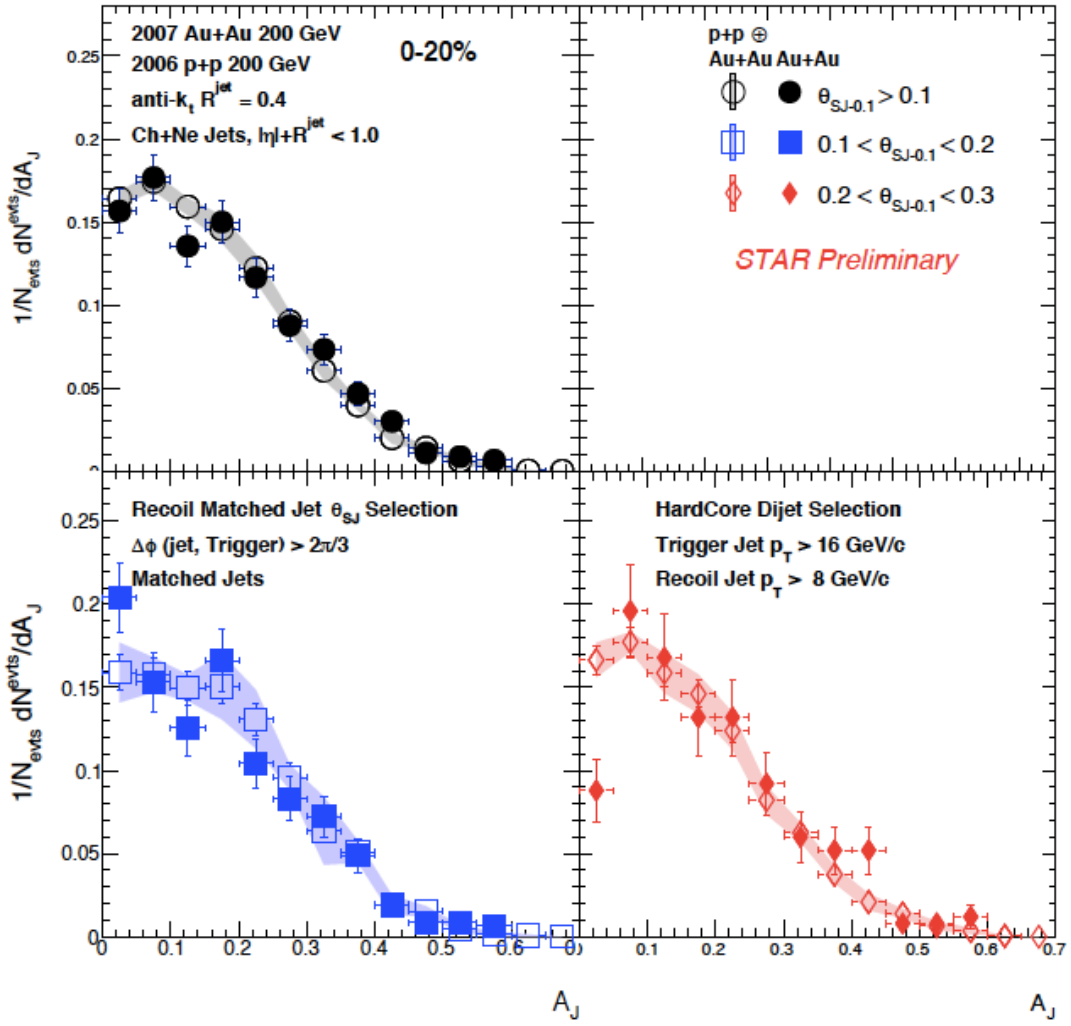
$$A_J = \frac{p_T^{\mathrm{Lead}} - p_T^{\mathrm{SubLead}}}{p_T^{\mathrm{Lead}} + p_T^{\mathrm{SubLead}}}$$



- Imbalance at small resolution parameters.
- Balance restored with increased R (≈0.35) when soft particles are included.
- Capability to control the extent of the energy loss using jet kinematic cuts → Jet Geometry Engineering.
- Also new preliminary results of fully unfolded jet substructure in p+p.

Jet Substructure



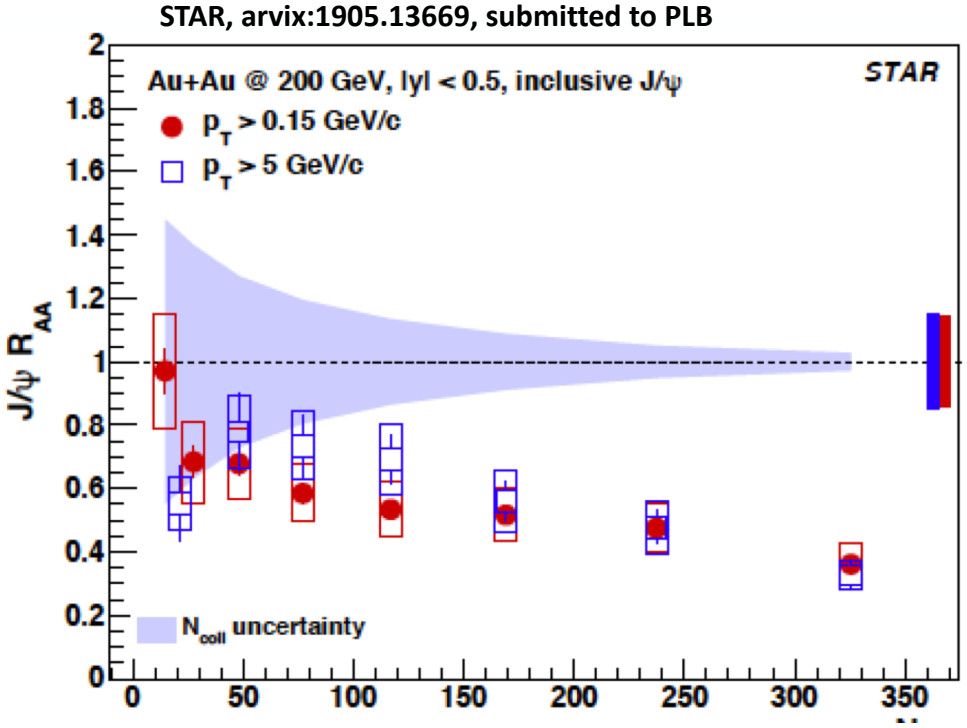


-Shapes of z_g, R_g in p+p collisions at RHIC are reproduced by LO-MC event generators

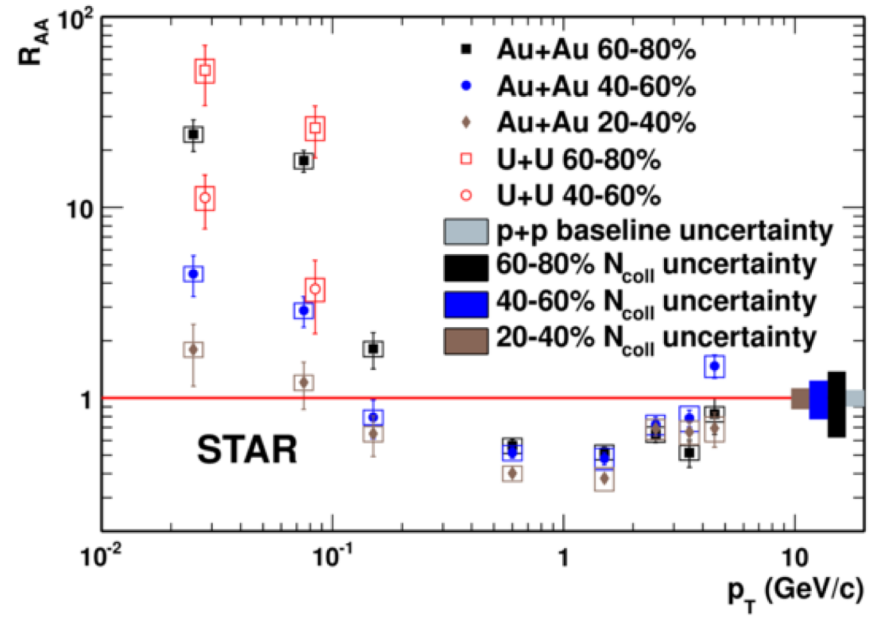
- PYTHIA6 tuned to STAR data - excellent prediction of jet substructure.
- Matched jet-dijet imbalance for different sub-jet angles
- No significant different of Aj on different sub-jet angle

Quarkonium in p+p and Au+Au

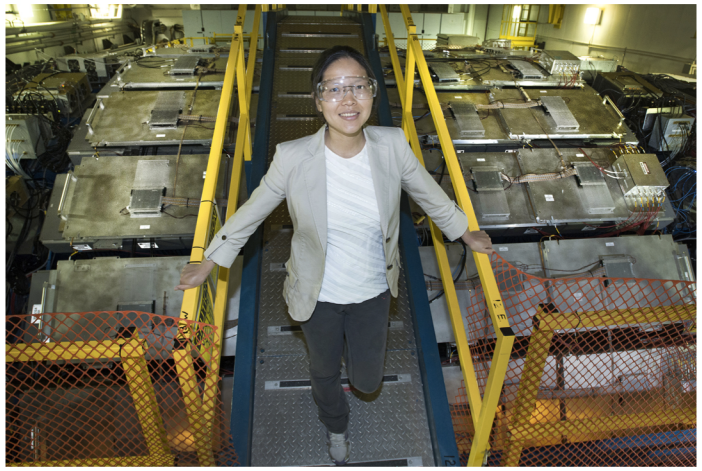
STAR, arvix:1905.13669, submitted to PLB



STAR, arvix:1904.11658, submitted to PRL

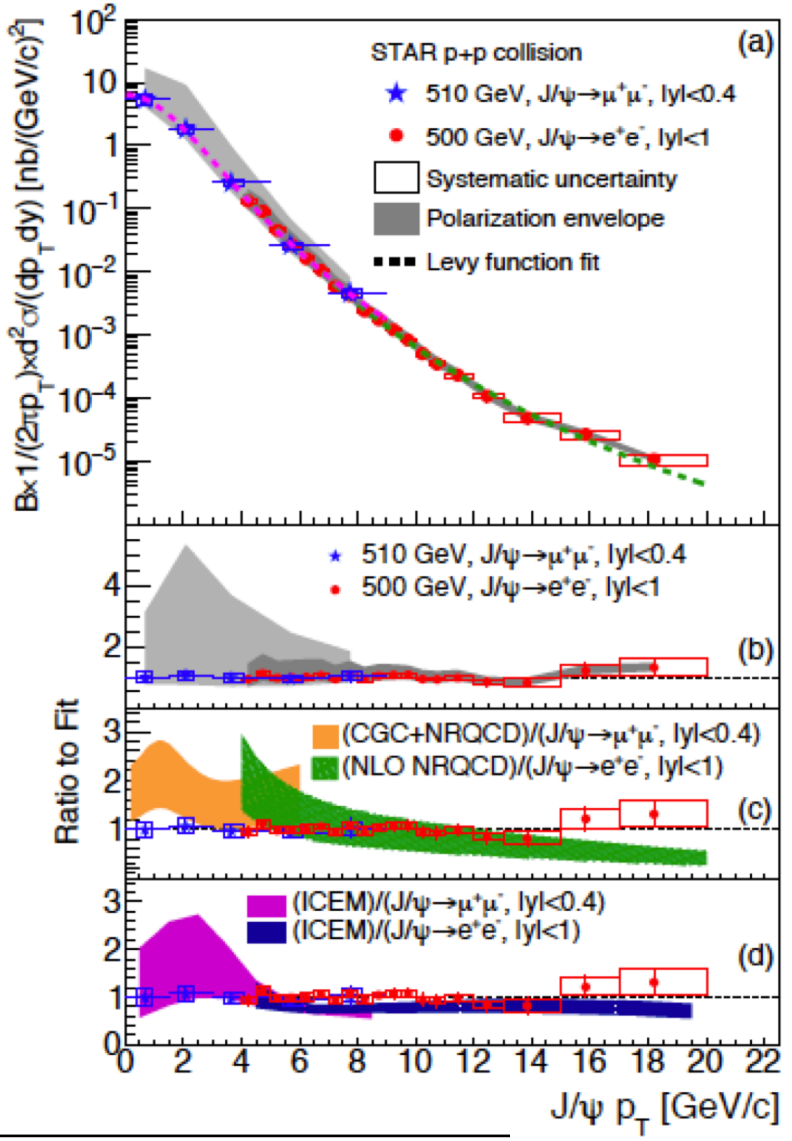


MTD Data from **run 13-16**



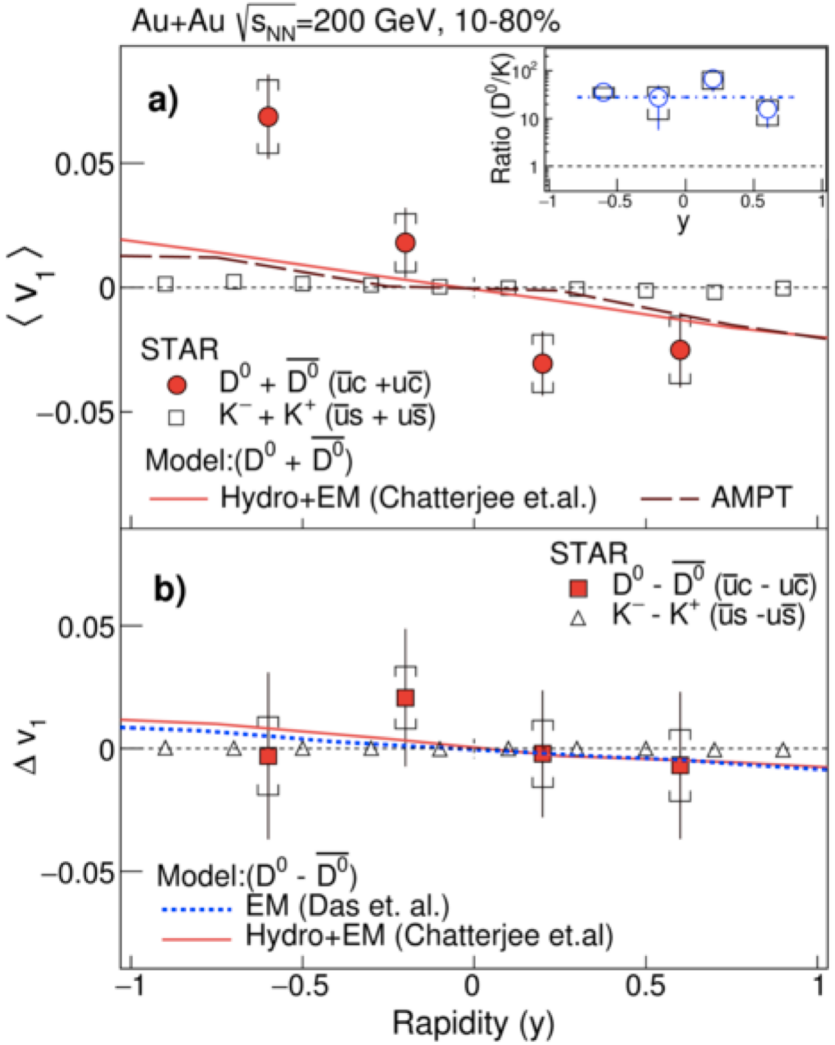
-Yields of J/ψ $0<p_T<20$GeV/c
- Increasing J/ψ suppression towards central Collisions
- And suppression level at high-pt and low-pt converge, opposite to LHC
-Significant excess of J/ψ yield at low p_T for peripheral collisions
→ originated from coherent photon- nucleus interactions.

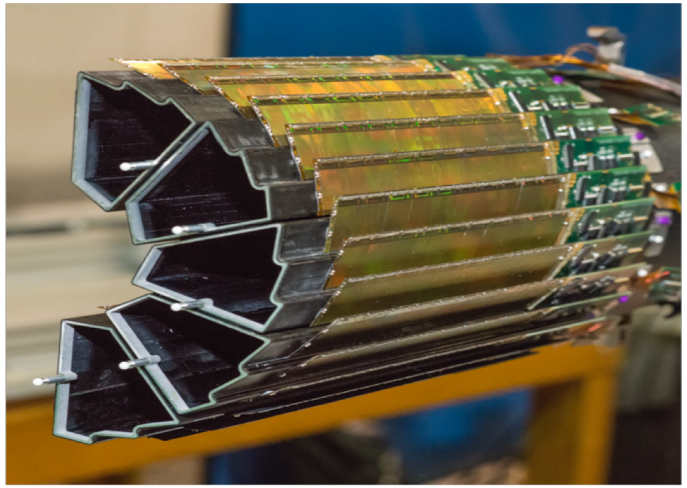
STAR, arvix:1905.06075, submitted to PRD

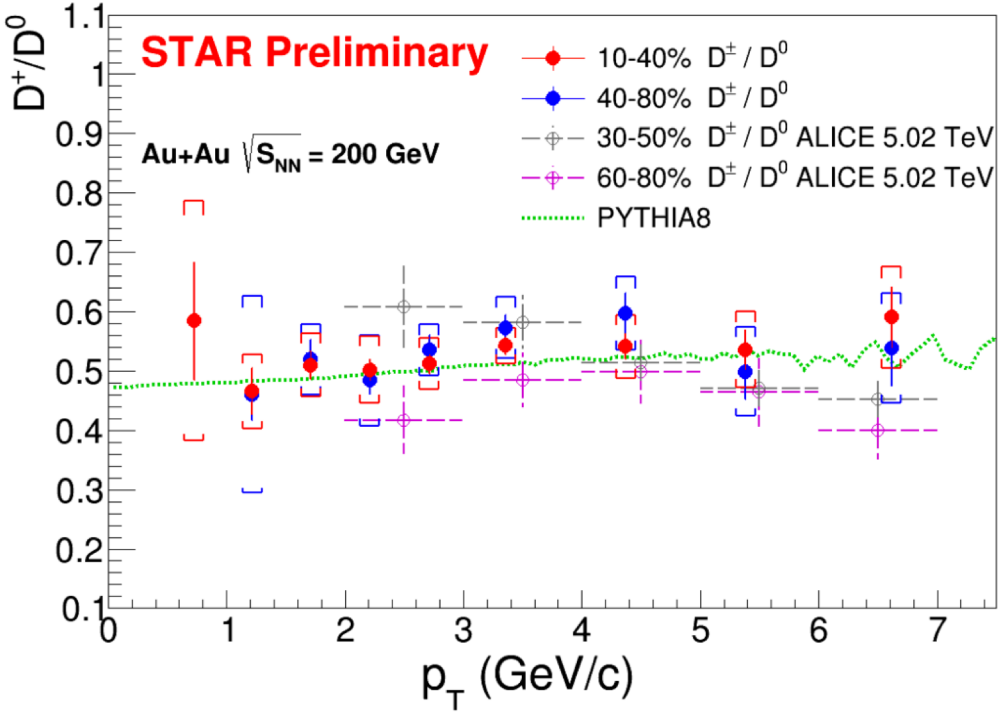


Continue with HFT charm

arXiv:1905.02052

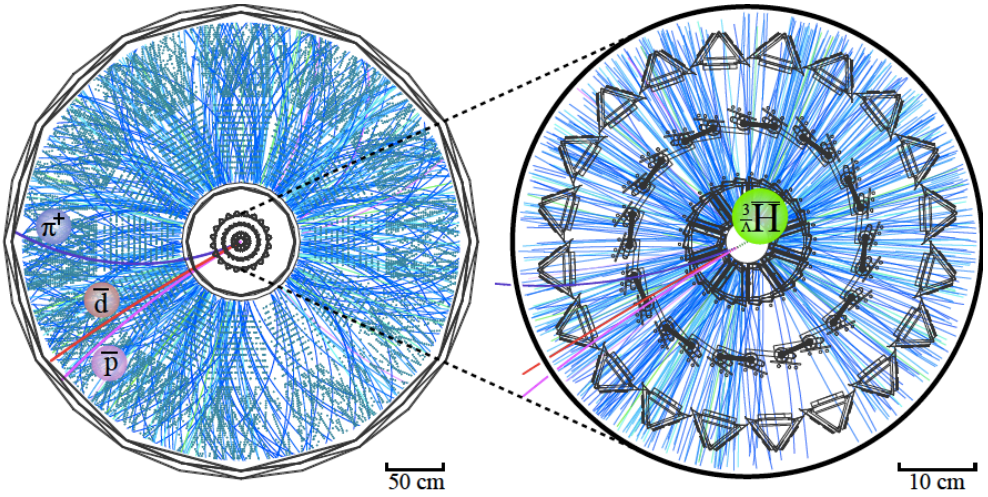




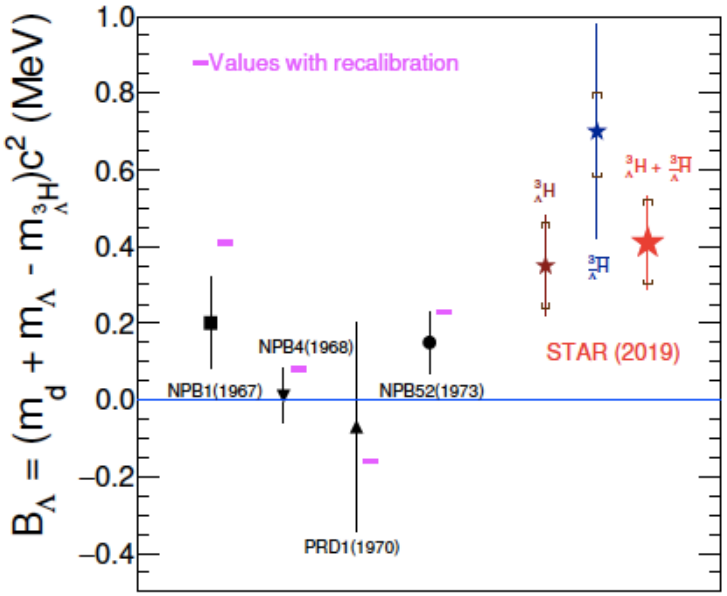


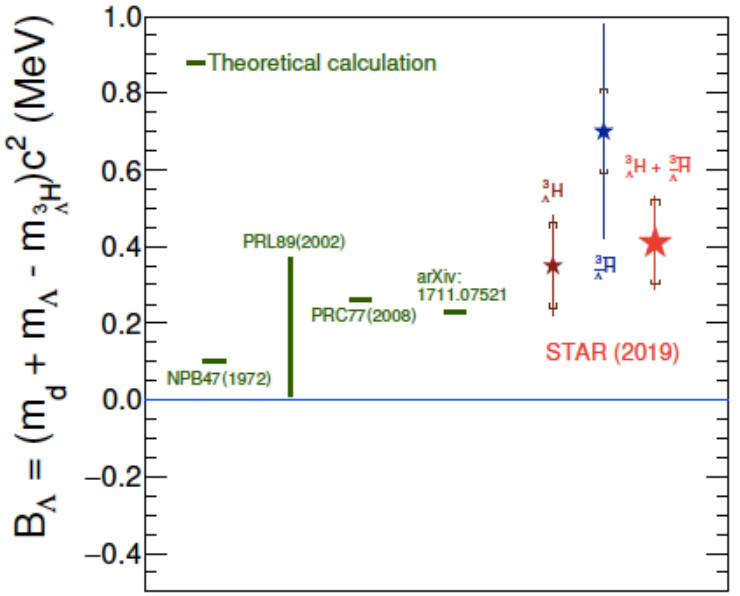
- First measurement of charm v_1 and it is large
- No modification to $D^{+/-}/D^0$ ratio compared to PYTHIA, indicates similar R_{AA}.
- Improved presicion for several open charm measurements with multi-variative techniches.

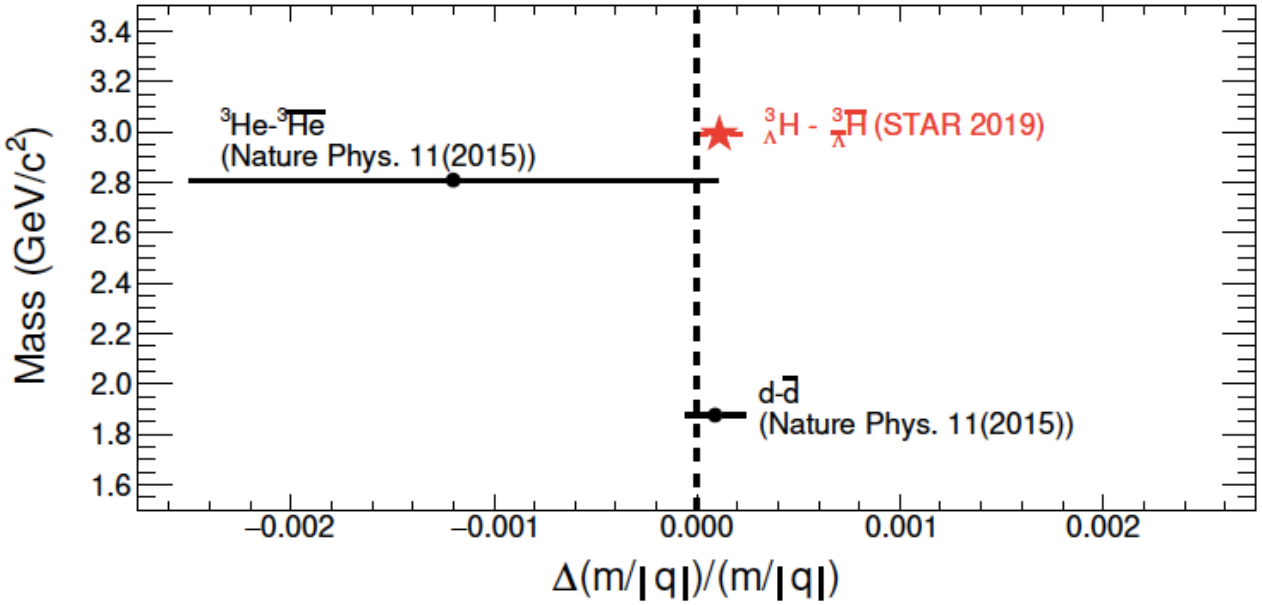
Use HFT to measure hypertriton mass



arXiv:1904.10520 submitted to Nature Physics







- Good example of good detector used for different purpose
- Measure hypertriton binding energy (best ever) and systematically larger than previous measured
- Measure antimatter and matter mass difference

PROSPECTS FOR SPIN PHYSICS AT RHIC

Gerry Bunce,[1] Naohito Saito,[2] Jacques Soffer,[3] and Werner Vogelsang[4]

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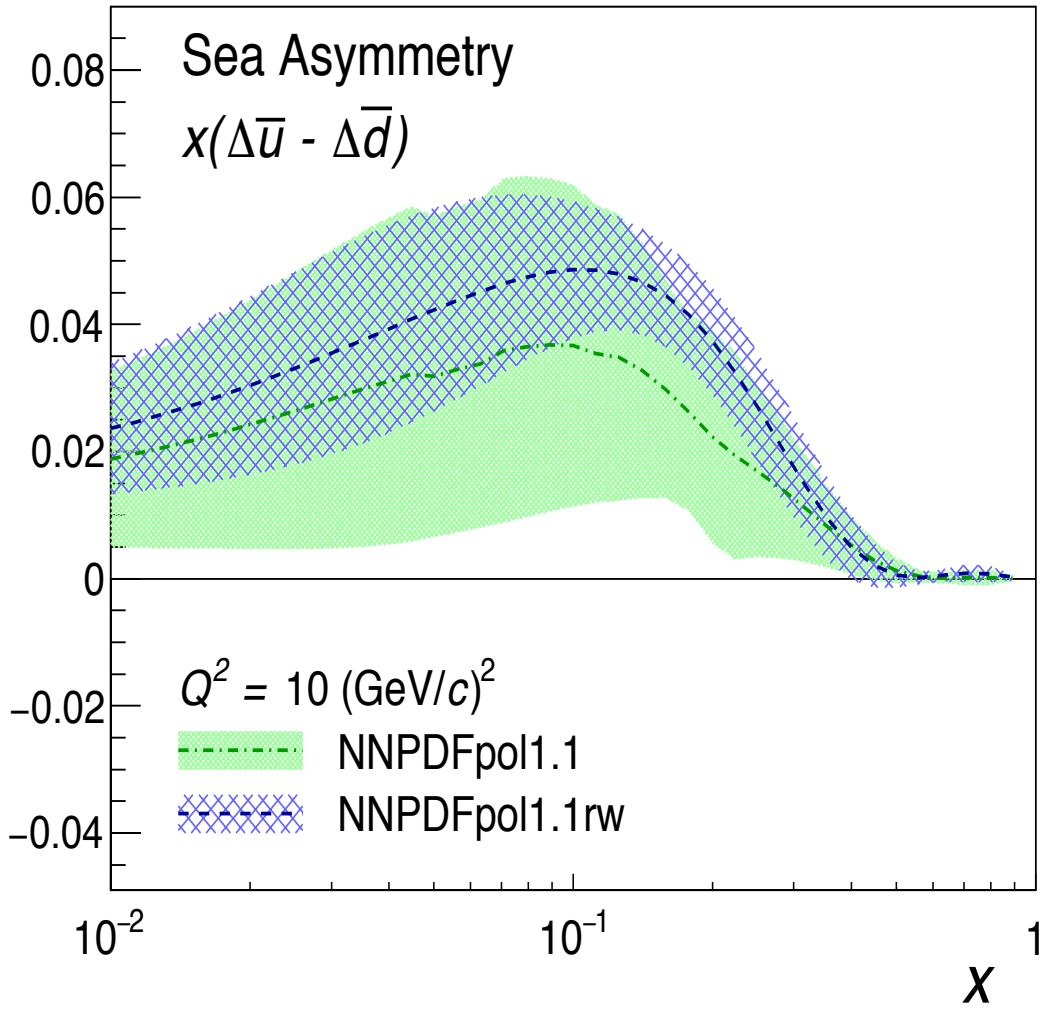
Prof. Soffer passed away earlier this year.

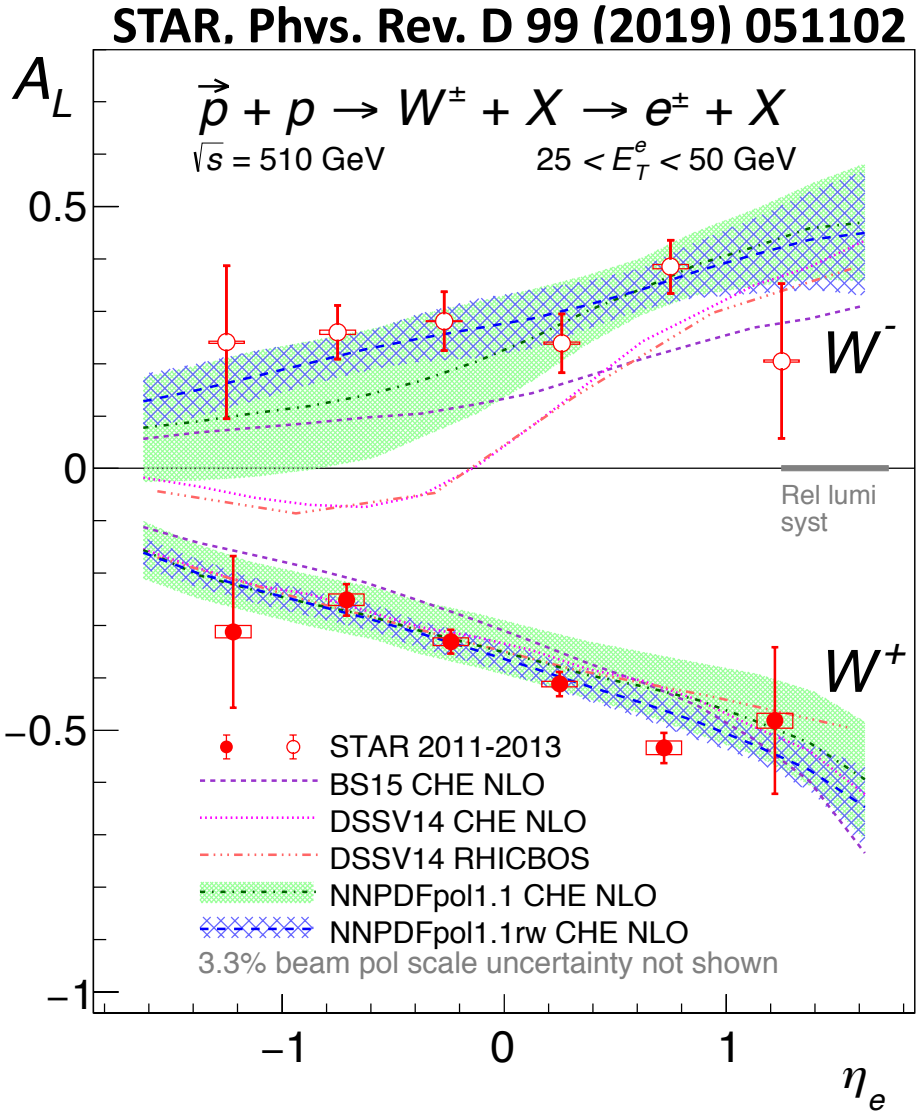
Key Words proton spin structure, spin asymmetries, quantum chromodynamics, beyond the standard model

■ **Abstract** Colliding beams of 70% polarized protons at up to $\sqrt{s} = 500$ GeV, with high luminosity, $L = 2 \times 10^{32}\,cm^{-2}\,sec^{-1}$, will represent a new and unique laboratory for studying the proton. RHIC-Spin will be the first polarized-proton collider and will be capable of copious production of jets, directly produced photons, and W and Z bosons. Features will include direct and precise measurements of the polarization of the gluons and of $\bar{u}$, $\bar{d}$, u, and d quarks in a polarized proton. Parity violation searches for physics beyond the standard model will be competitive with unpolarized searches at the Fermilab Tevatron. Transverse spin will explore transversity for the first time, as well as quark-gluon correlations in the proton. Spin dependence of the total cross section and in the Coulomb nuclear interference region will be measured at collider energies for the first time. These qualitatively new measurements can be expected to deepen our understanding of the structure of matter and of the strong interaction.

STAR, Phys. Rev. D 99 (2019) 051102



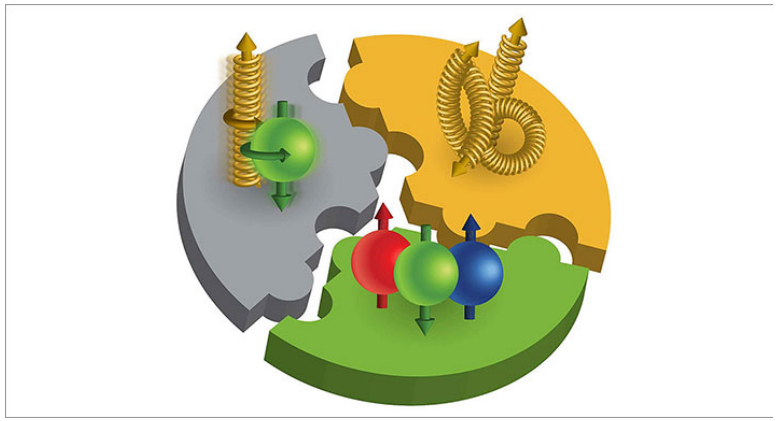
Sea Quark Surprise Reveals Deeper Complexity in Proton Spin Puzzle



Sea Quark Surprise Reveals Deeper Complexity in Proton Spin Puzzle

New results from STAR experiment show antiquarks' contribution to proton spin depends on "flavor"—and in a way that's opposite to those flavors' relative abundance

March 14, 2019



The proton spin puzzle: Scientists want to know how different constituents of the proton contribute to its spin, a fundamental property that plays a role in how these building blocks give rise to nearly all visible matter in the universe. Pieces of the puzzle include the orbital angular momentum of quarks and gluons (top left), gluon spin (top right) and quark and antiquark spin (bottom). The latest data from RHIC reveal that the antiquarks' contribution is more complex than previously thought.

UPTON, NY—New data from the STAR experiment at the **Relativistic Heavy Ion Collider** (RHIC) add detail—and complexity—to an intriguing puzzle that scientists have been seeking to solve: how the building blocks that make up a proton contribute to its spin. The results, just published as a rapid communication in the journal **Physical Review D,** reveal definitively for the first time that different "flavors" of antiquarks contribute differently to the proton's overall spin—and in a way that's opposite to those flavors' relative abundance.

"This measurement shows that the quark piece of the proton spin puzzle is made of several pieces," said James Drachenberg, a deputy spokesperson for STAR from Abilene Christian University. "It's not a boring puzzle; it's not evenly divided. There's a more complicated picture and this result is giving us the first glimpse of what that picture looks like."

Why study proton spin?

Spin is a fundamental property of particles, as essential to a particle's identity as its electric charge. Because particles have spin, they can act like tiny magnets with a particular polarity. Aligning and flipping the polarity of proton spin is the basis for

https://www.bnl.gov/newsroom/news.php?a=114331 1/5

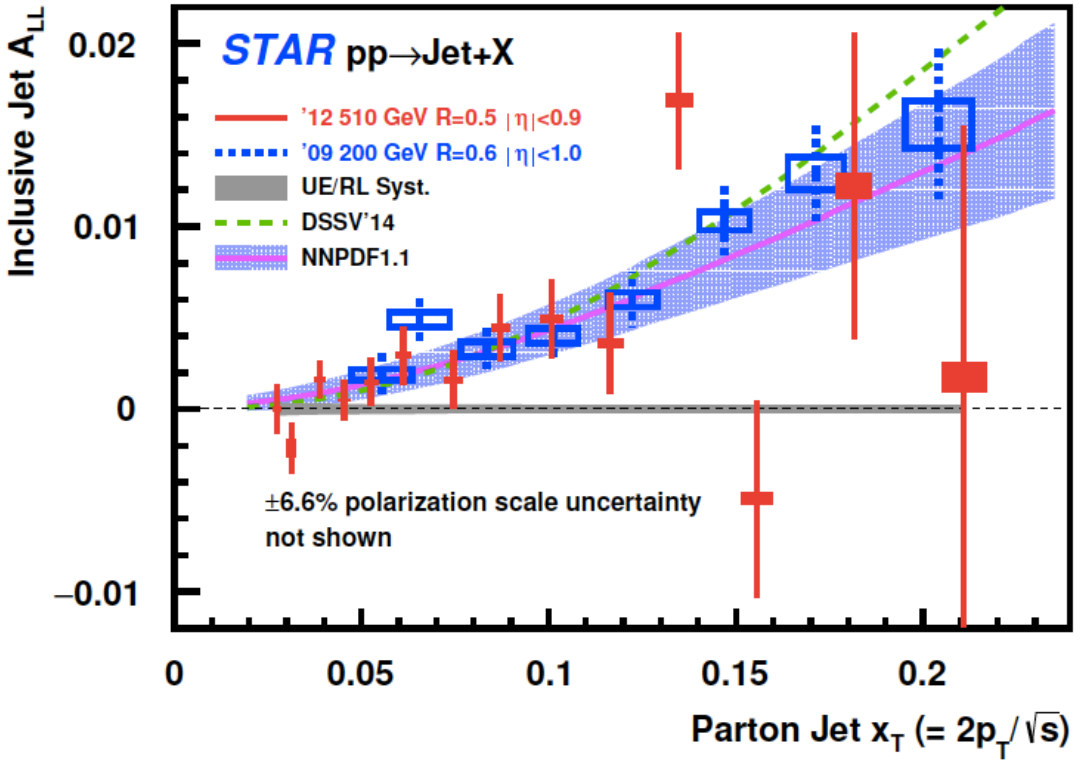
news Links

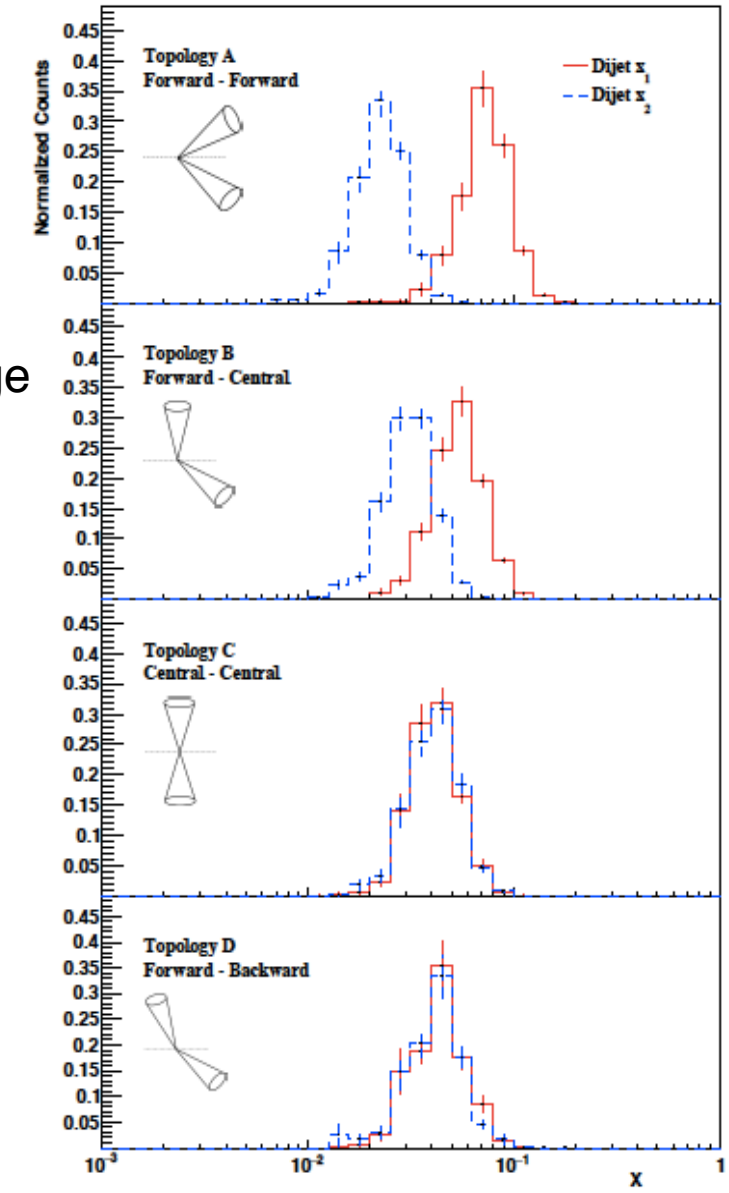
- Berkeley Lab news release
- Temple University news release
- Stony Brook University news story
- Shandong University news story
- Unique New Probe of Proton Spin Structure at RHIC
- Physicists Narrow Search for Solution to Proton Spin Puzzle

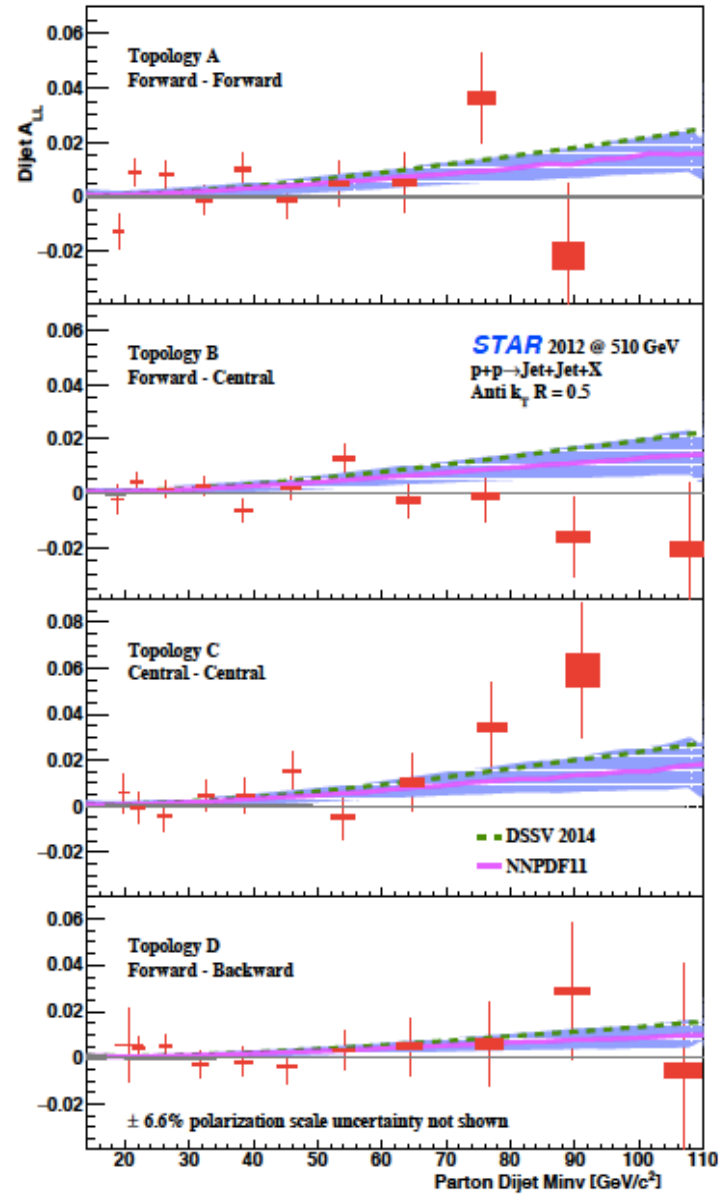
Jet and dijet probing gluon spin

arXiv: 1906.02740

- Excellent agreement with theoretical expectations
- Data-driven event-by-event UE subtraction developed for this result.
- Reach lower x_T ~0.025
- Dijet kinematics allow scan of different *x* range

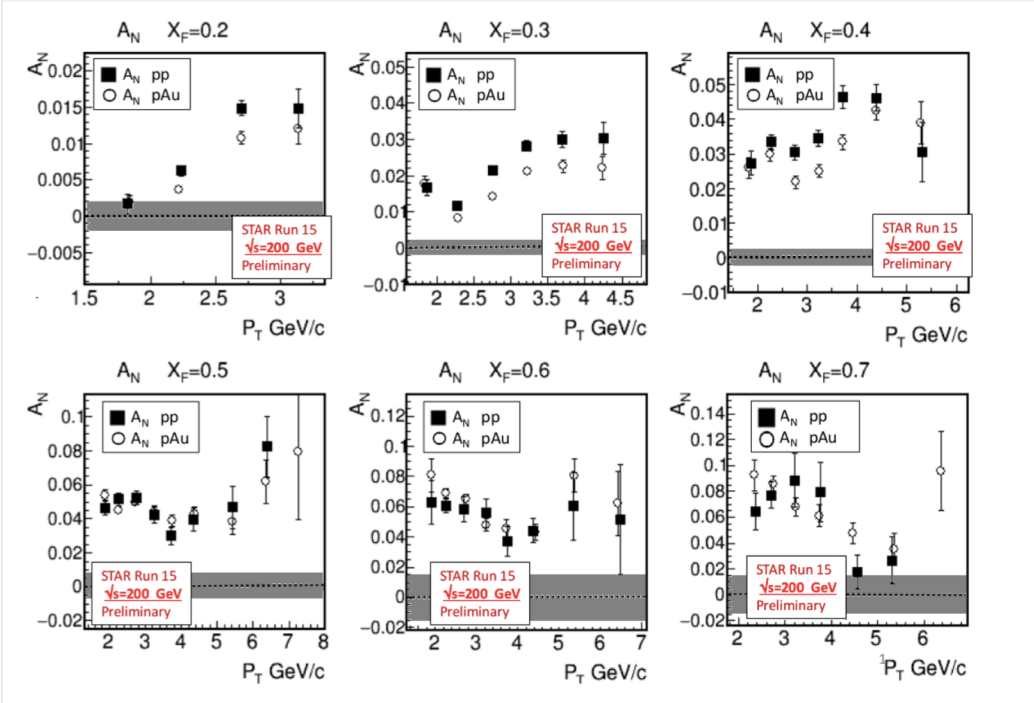




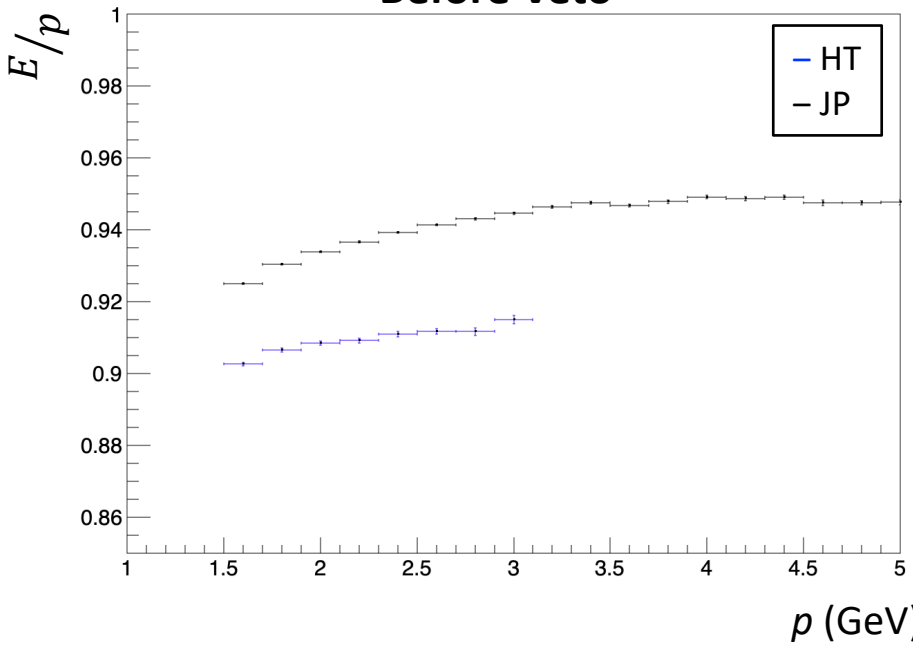


Run 2015 BEMC Calibration (nail syst.)

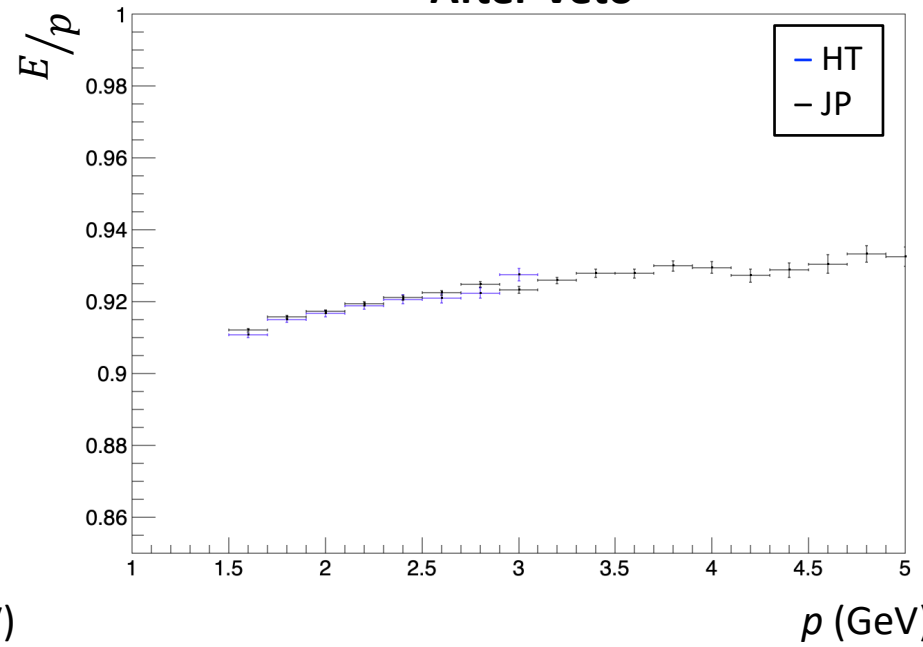
- Two types of triggers are used in the BEMC calibration: Jet Patch (JP) and Barrel High Tower (HT)
- Previous calibrations have shown that the E/p ratio for electron candidates has a ~2.5% discrepancy between JP triggered events and HT triggered events.
- A new veto was introduced that removes electron candidate tracks that do not pass at least 60˚ from at least one tower or jet patch that is above a trigger threshold.
- Now the disagreement between triggers has been completely eliminated

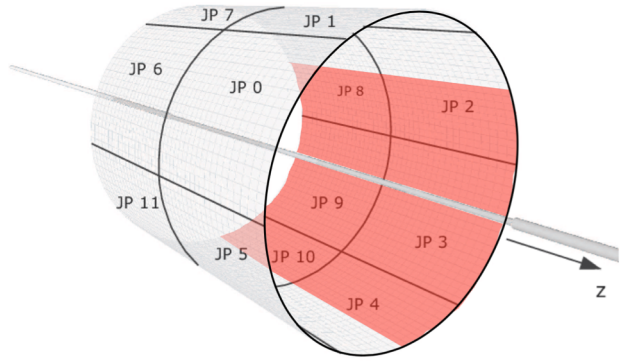


Before Veto



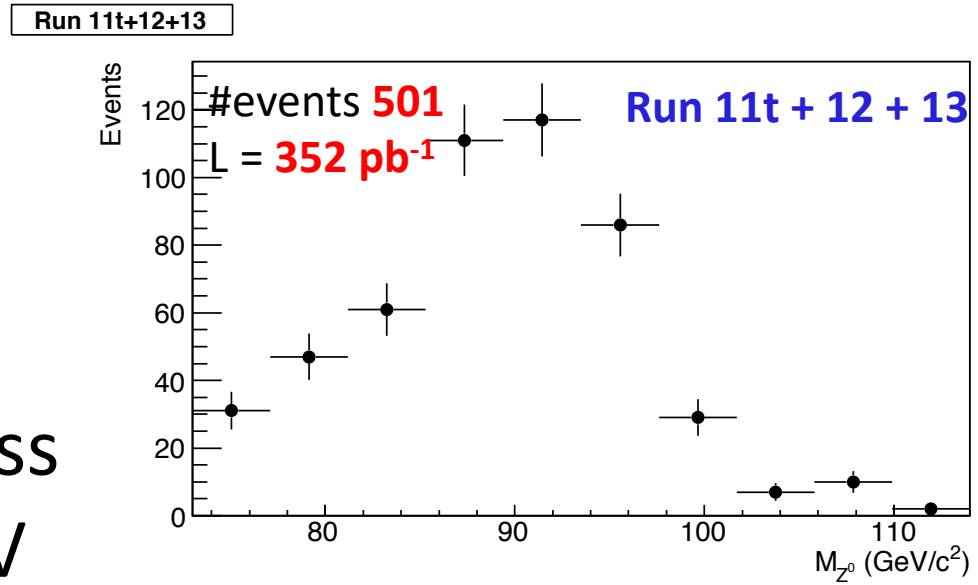
After Veto



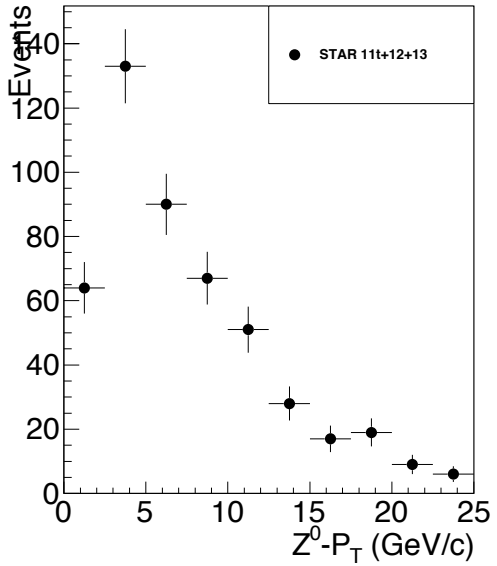


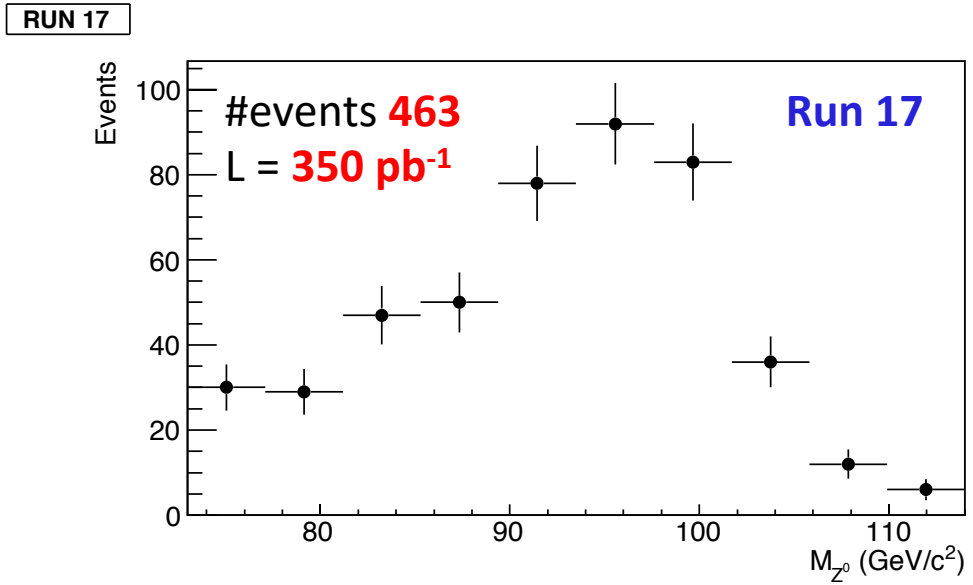
Run 17 Analysis progress: Z^0 boson kinematics

Z^0 mass 91GeV

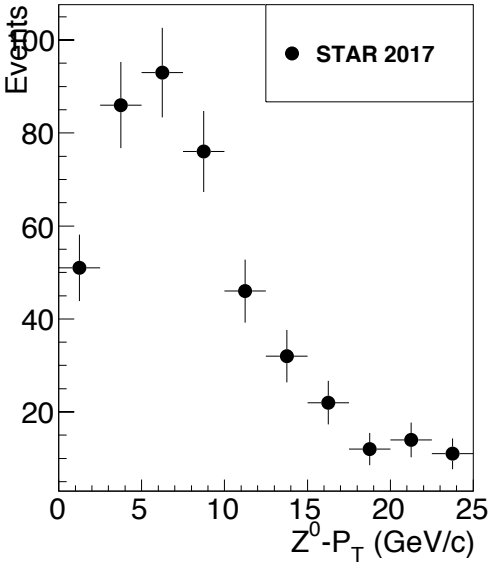


Mean	89.12
RMS	7.265
Underflow	0
Overflow	0
Integral	501





Mean	92.33
RMS	8.567
Underflow	0
Overflow	0
Integral	463



Summary

- 5 new institutions joined
- 17 PHD graduates
- 22 papers published,

  10 in journal review
- 28 paper committees in action

- Run 19 about to complete with successful upgrades
- the isobar production and analyses progressing
- BES-I data analyses toward completion
- Significant advance toward understanding systematics in run 15 FMS and BEMC data
- Progress toward run 17 W/Z and FMS A_N results
- Results and publications from run13-17 and earlier datasets presented

Another very productive year

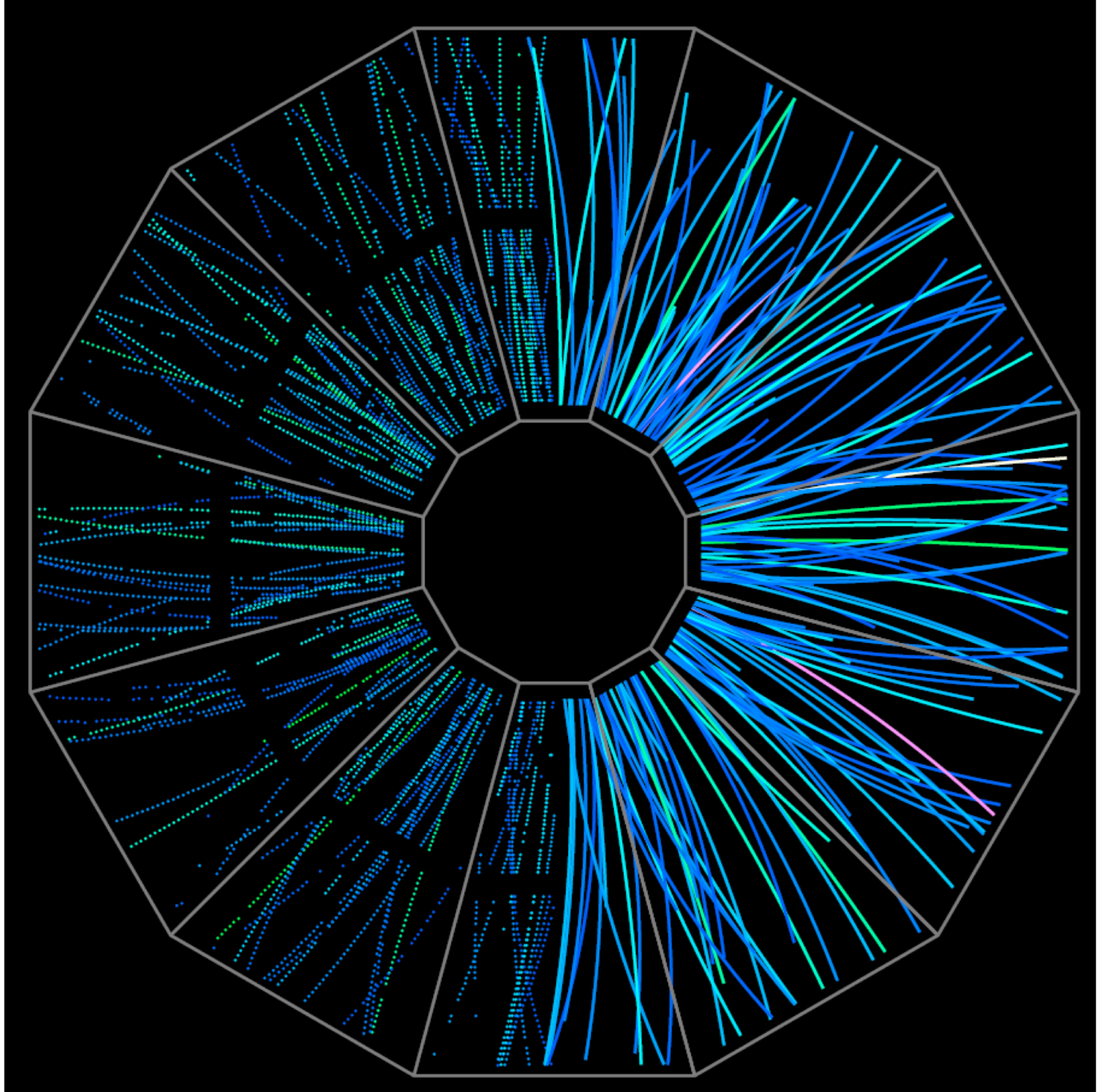
2017 DOE Secretary Achievement Award

Local Support group spares no effort in supporting the facility

Thank you!

DOE iTPC project
Closeout Review (05/02/19):
Panel:
Howard Fenker (Jlab)
Hendrik Schatz (MSU)
Richard Van Berg (UPenn)
Elizabeth Bartosz (DOE)

First-line comment:
“This is a success story!”



It has been an incredible 6-year run
ending on a happy note.

I wouldn’t trade for anything else.