BNL STAR Group Efforts

Biennial Science and Technology Review of RHIC

Lijuan Ruan, BNL

- Group composition and responsibilities
- Operation support
- Science highlights
- Upgrade involvement and leadership
- Research relevant to EIC science case
- Summary

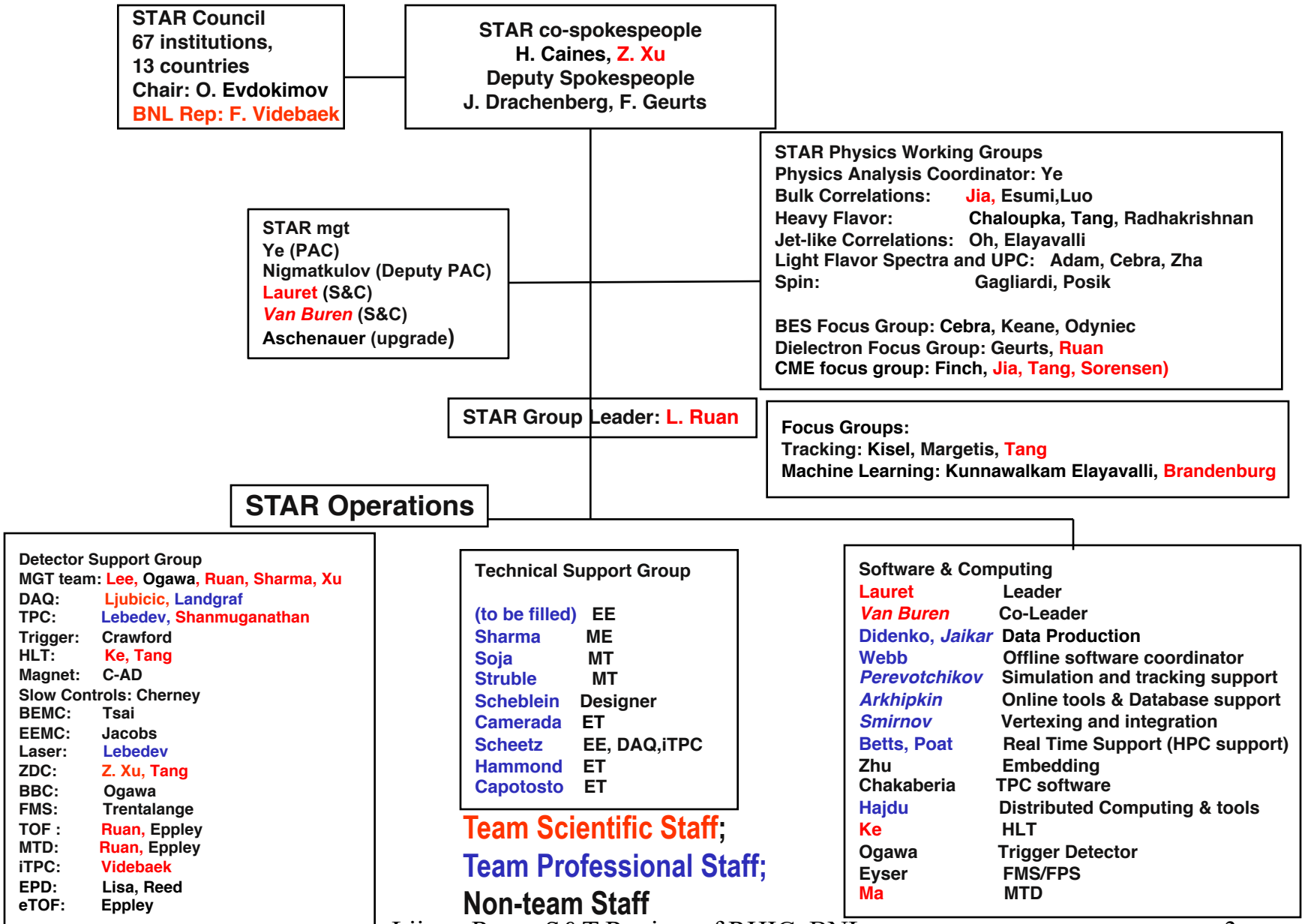
BNL STAR Heavy Ion Group

BNL STAR group dual mission:

- Support for the existing detector systems, operation, data taking and processing, along with development of new detector technology
- Ground-breaking scientific research to utilize these systems to their fullest potential, taking advantage of detailed expertise and knowledge of the detector capabilities
  - Ratio research : operations (8.95 FTE : 23.4 FTE)

BNL STAR group plays central and critical role to the success of the STAR experiment in all of these areas

The researchers and their roles at STAR



STAR Operations Group

- Key experimental support in STAR Technical support Group
  - Essential for maintenance and installation of new detectors

  Management team: Lee, Ogawa, Ruan, Sharma, Xu

  Mechanical Engineer Sharma

  Facility Manager Struble

  Mechanical Tech Soja, Struble

  Mechanical Designer for modification new detectors Scheblein

- Electronics development, support and repair for STAR sub systems

  Electronics Engineers Valentio (head, left in May 2019), Scheetz (phase retirement)

  Electronics Technicians: Camarda, Capotosto, Hammond.

Electronics Group Activities

2017:

* iTPC (1 sector)
  - FEE prototype production
  - RDO prototype production
  - Padplane production
  - Power supply

* EPD
  - Differential Receiver Board
  - Power Supply Box
  - Cable installation

* Trigger
  - QT-BOC fabrication
  - TDSMI fabrication
  - QT-8 (for PMTs)
  - QT-8 (for SiPM)
  - QT32C design/production

* Forward ECal
  - DEP16 prototype
  - Cable installation

* Gated Grid:
  - Driver & control boards

2018:

* iTPC (24 sectors)
  - FEE and RDO final revisions
  - FEE test/production/installation
  - RDO test/production/installation
  - Padplane design/fabrication
  - Gridleak board design/fabrication
  - Power supply replacement
  - Fiber runs to DAQ room
  - Installation of DAQ computers

* Trigger
  - QT32C install/setup
  - VME crate maintenance

* ETOF
  - East floor rack preparation
  - Cat6 & HV cable installation
  - Fiber runs to DAQ room
  - HV distribution boxes

* TPC air handler
  - debugging
  - remote controls

* sTGC
  - test setup R&D

2019-2020:

* Forward Ecal/Hcal
  - Design/produce custom crate configuration/w high speed backplane
  - Passive Patch Panel design/production
  - DEP32 design/production
  - Active Patch Panel design/production
  - DEPIO design/production
  - DEP cables/installation
  - LED maintenance system
  - Profile LED temperature and positioning

* sTGC
  - HV Protection Box

* Forward Silicon Tracker
  - Inner signal cable assembly

* Gated Grid
  - Driver & control board repair/test

* BEMC
  - Fuse modifications

* iTPC:
  - JTAG interface implementation

Software And Computing (S&C) Team Composition

Core team

- Leader: Lauret
  - Other core activities: Infrastructure, RACF liaison, Cyber Security, OSG
- Co-Leader: *Van Buren*
  - Other core activities: Calibration coordinator, NPPS liaison
- Offline software: Webb, *Perevoztchikov, Smirnov*
  - Tracking support: *Perevoztchikov*
  - Integration, sub-system support and vertexing: *Smirnov*
- Database activities, online MetaData: *Arkhipkin*
- Software librarian & Data production coordinators: Didenko, *Jaikar* (1/2)
- Distributed production, distributed computing technology and online tool support: Hajdu
- Real-time, Online and user support: Betts and Poat
  - Grid Operation point of contact: Betts
  - DOE/NP, HPC/Cori support: Poat (Lauret as PI)

People in italic are moved to the NPPS group.

Software And Computing (S&C) Responsibilities

- The S&C team is responsible for
  - The STAR specific infrastructure (online resources, online networking, Meta-Data archiving, …) in support of the data taking, run monitoring as well as STAR specific user support (real-time support)
  - The development of core framework components, tools and techniques in support of the scientific program. This includes framework development, simulation and modeling, global tracking, global calibration, efficient access to database, efficient retrieval of data from mass storage, …
  - The data reduction and production to physics usable quantities to sustain the experiment's Physics analysis (local and distributed data production)

- The Core team provides technical expertise critical for timely and correct physics results and to ensure data quality as it is recorded – it coordinates activities sustained by external workforce.

- We continue to
  - Seek toward automation of tasks, optimization of resources and environment/workflow preservation (via virtualization)
  - Focus on publishing our work (community benefit). The OSG/NP proposal aims at publishing the best practice and lesson learn for a wide NP community benefit (ALICE, Jlab, …)

- Due to increase workload (15 years datasets analyzed, more sub-systems including iTPC), workforce was refocused on software support as well as production and "early" QA.
  - The re-assignment of dedicated workforce to a new NPPS group (in Italic) is being closely followed (without their constant effort on STA, issues may arise)
  - As last year, with reduced staffing, the following activities are "best effort" basis only: Event Display and visualization, ROOT framework development, Grid activity overall coordination, EIC synergy
  - Machine Learning becoming relevant, a new Machine Learning focus group was created leveraging efforts across the collaboration's workforce (soft coordination)

S&C Highlights

- Transition of all workflows on the NERSC Cori/HPC system from PDSF (now retired)
  - Thanks to the agency for their support for an OSG/NP program of work, NP is resent on the OSG Executive Board: Side benefits: CVMFS supported in STAR for broad reach + VM based STAR environment available to STAR collaborators
- Designed new workflow for Isobar data (blinded production)
- Full 64 bits support for the framework (including Geant simulations)
- HFT embedding implemented (mis-alignments)
- picoDST (smaller / more compact format) now produced and added to STAR Data Management System
- Enhanced library validation and code QA - dashboard
- Team worked with the iTPC software team for code integration + eTOF code integration achieved - day 1 availability!
- Continuous support for operation and data productions - enhanced QA; FastOffline covered for 48% of the data (files)
- Supported calibration efforts - R&D on new TPC issues; coordination over many datasets

Group Hardware Operational Responsibilities

Operation Management Team: Lee, Ogawa, Ruan, Xu, Sharma

TPC Hardware: Lebedev, Shanmuganathan

DAQ: Ljubicic, Landgraf

ZDC: Z.Xu, Tang

TOF- MTD: Ruan

iTPC: Videbaek

HLT: Ke, Tang

HCAL pixelation R&D: Bland

Publication, Leadership & Awards

STAR had 11 publications in FY17, 18 in FY18, 13 in FY19 and 8 submitted.
The BNL group had 17 papers as co-PAs, and 19 papers as GPC members (including chairs).

Chair of RHIC/AGS users group: Ruan (July 2015 – June 2018)
Co- Chairing of EIC science task force: Ullrich

Awards

STAR team receives Secretary's Achievement Award in 2018.

Flemming Videbaek receives a Certificate of Appreciation from DOE in 2019 for the outstanding project management of the STAR iTPC.

Research Highlights

Tightly coupled responsibilities for hardware, software, and analysis provide the BNL STAR group a uniquely fertile ground for new uses of the STAR detector

Focus of local researchers

- Heavy flavor, exotics, and dileptons: Utilizing RHIC II luminosity and upgrades

  Brandenburg, Dunlop, Ma, Ruan, Tang, Ullrich, Videbaek, Xu, Yang
- Flow and correlations: utilizing RHIC flexibility
  - Energy and beam species to constrain system properties with flow phenomena
  - Chiral Magnetic Effect/Wave
  - Initial state fluctuations, viscosity, vorticity, equation of state

  Jia, Sorensen, Tang, Tribedy, Upsal

Extremely important for the collaboration:

Pool of local expertise for supervision of visiting students, post-docs

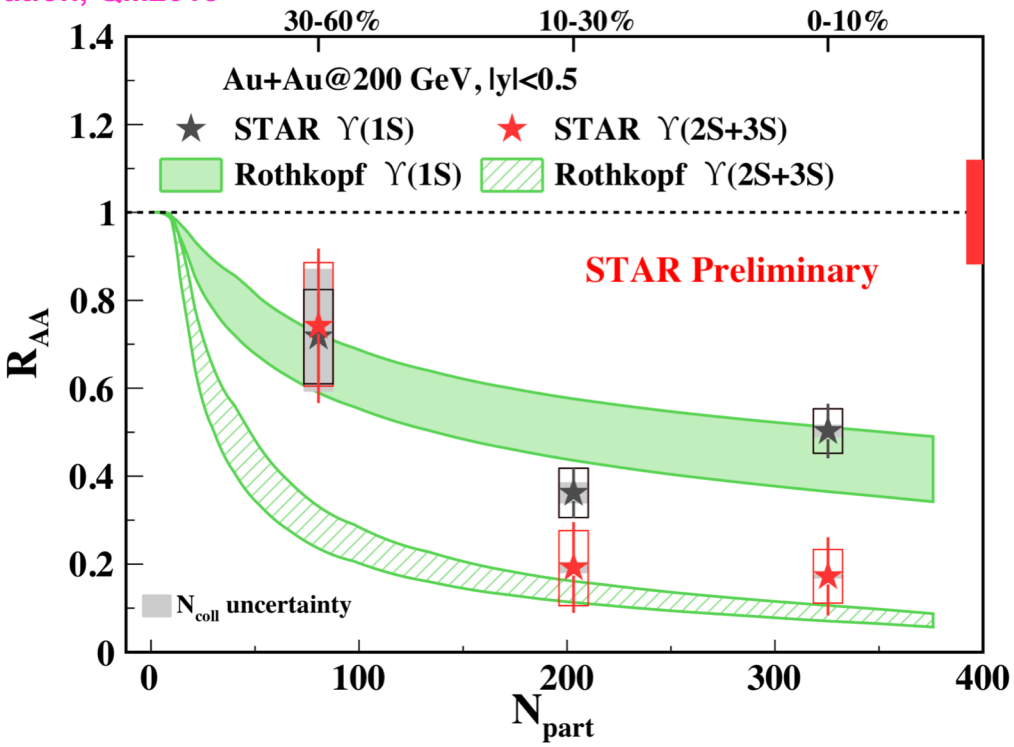
Highlights from the last two years

- Quarkonium: two MTD papers accepted for publication (Ma, Ruan).

  In pipeline: sequential suppression for Υ(1S), Υ(2S+3S), targeted for PRL, …
- Photo-nuclear and two photon processes: PRL2018, accepted by PRL (Ruan, Xu, Yang). In pipeline: UPC dielectron, targeted for Science, …
- Constrain η/s (T): 3 particle correlations, PLB2019 and PRC2018 (Tribedy and Sorensen).
- Off-diagonal cumulants: PRC2019 (Tribedy).
- Exotics: anti-hypertriton and hypertriton mass differences, submitted to Nature Physics (Xu).
- Thermal dielectron and photons, CME, CMW, vorticity: Ruan, Sorensen, Tang, Tribedy, Upsal.
- Push for a small-system scan: Jia.
- Published many a few author papers: 2 PRL, 4 PLB, 8 PRC, 2 PRD, 2 NIMA, …

Different ϒ states suppression

STAR Collaboration, QM2018



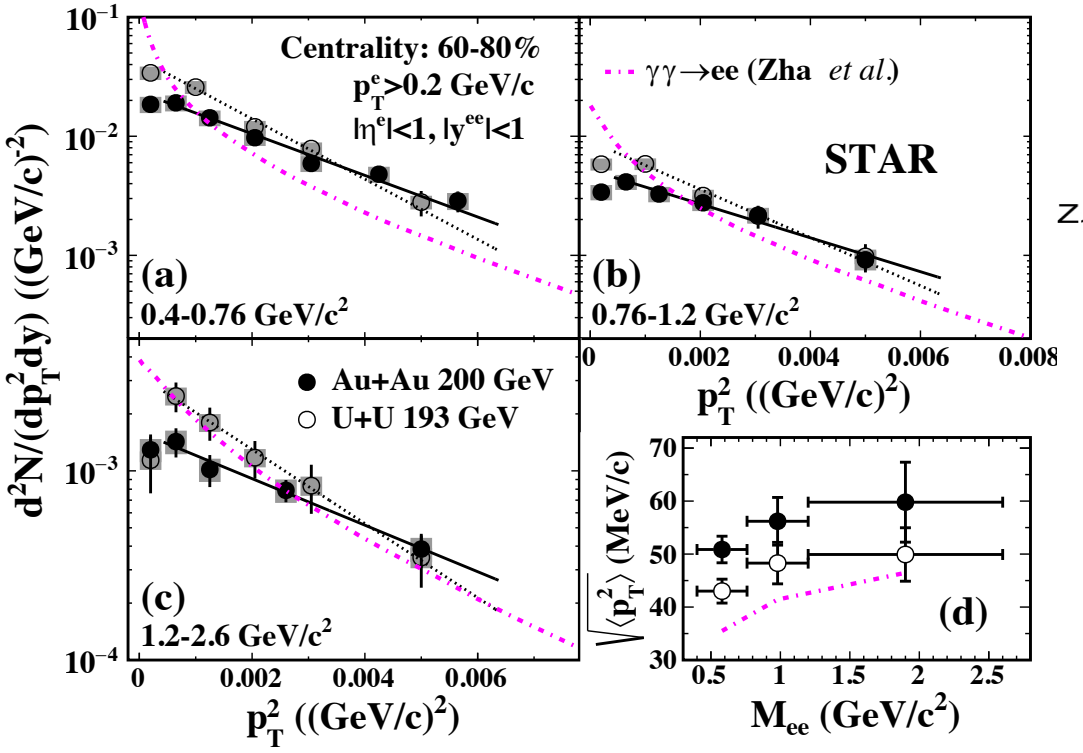
Ma, Ruan, Yang

0.28, 0.56, 0.78 fm for ϒ(1S), ϒ(2S), ϒ(3S).
Negligible contribution from b and bbar recombination at RHIC
A better probe to study color-screening feature of QGP.

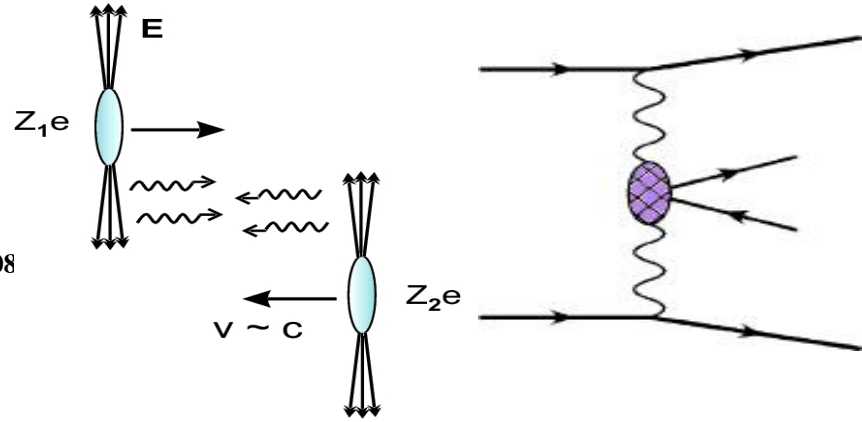
Sequential suppression at RHIC!

Very low p_T electron-positron excess

STAR: Phys. Rev. Lett. 121 (2018) 132301



Ruan, Xu, Yang



Coherent photon-photon interaction!!

p_T^2 distribution: more broadened than the STARlight calculation.
Detailed study of impact parameter dependence is underway.

BES three-particle mixed harmonic correlations

fig : Schenke et al
1605.07158

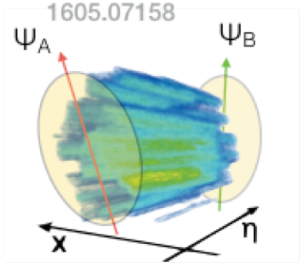
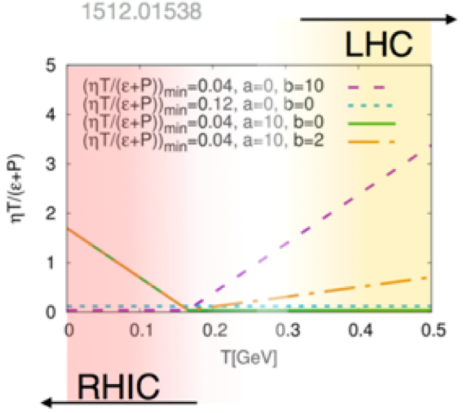
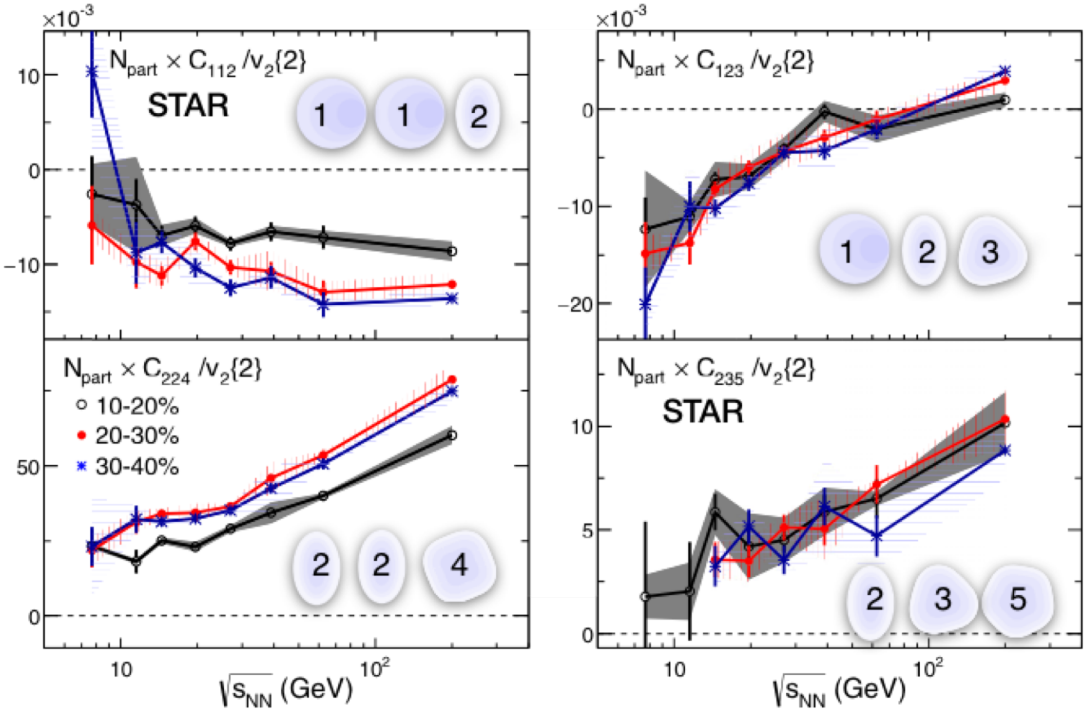


fig : Deincol et al
1512.01538



STAR Collaboration (L. Adamczyk et al.), Phys. Rev. C 98 (2018), 034918

$$C_{m,n,m+n} = \langle\langle \cos(m\phi_1 + n\phi_2 - (m+n)\phi_3) \rangle\rangle$$



First measurements of the beam energy dependence of mixed harmonic correlations that measures the correlation between different harmonic planes (Ψ_n) & flow coefficients (v_n)

New insights on 3D-initial state, non-linear hydro response and η/s (T)

Sorensen and Tribedy

High Level Trigger (HLT) development

1.HLT good event selection has become a default requirement of the STAR trigger setup. In all STAR heavy-ion experiments, HLT good event selection provide real-time QA, live feedback to CAD and provide a major metric to track the STAR data taking progress.

2.Completely refactor the HLT software with multithreading technology to fully release the computing power of Xeon Phi coprocessors (Landgraf and Ke)

3.Extended the HLT calibration server with automatic TPC space charge calibration

4.Parallelize the HLT QA server to increase the QA throughput and better utilize the hardware

5. Deployed a distributed storage system based on Ceph, using the existing disk slots of HLT cluster. The Ceph system provides a unified storage space of 30TB with up to 1GB/s write and 2GB/s read bandwidth. This storage system make the HLT express production possible. It can also be extended at anytime.

Tracking focus group (TFG) development

1. Together with experts from Ivan Kiesel's group (Frankfurt), improved CA tracker performance. CA tracker is now integrated into STAR reconstruction software.

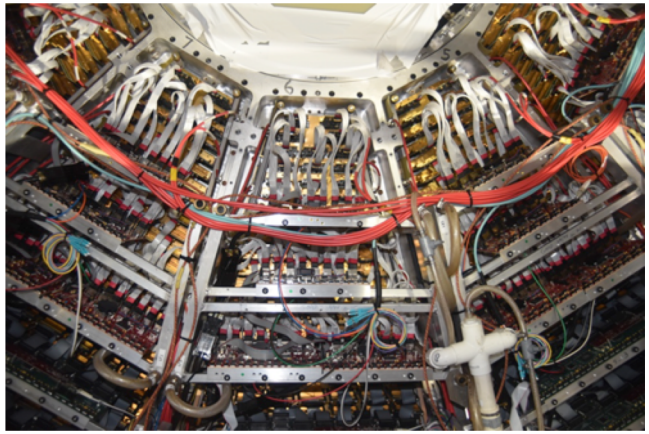
2. Together with experts from Frankfurt, demonstrated that KFParticle has considerable advantage over conventional vertex construction. Provided KFPartical package as PID option for STAR.

3. Developed an express data production framework, which uses the redundant HLT CPU resources to produce ~70% of the HLT good events within hours of data taking. The HLT express production enabled quick QA and express analysis. The prototype have already processed all the currently collected energies of BES-II.

STAR upgrades for BES-II (a)

iTPC

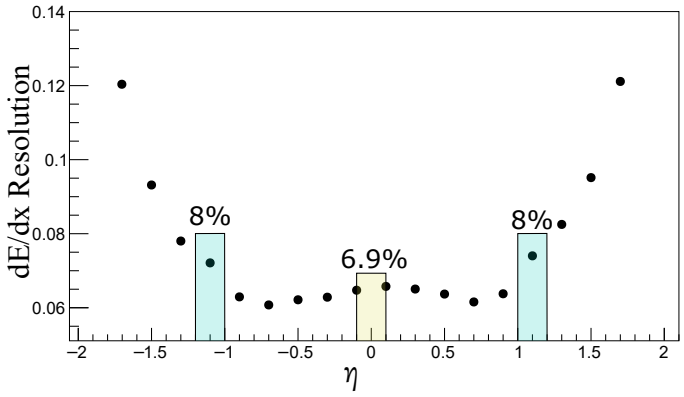
The iTPC project had a tight schedule, but was completed with installation of 24 new sectors and associated electronics



Data taking in Run-19 was successful

The group had leading roles in all phases of project

- Project manager: Videbaek
- Installation tooling, integration: Sharma, Lebedev, Shanmuganathan
- Electronics: Ljubicic Scheetz (retired) STSG
- Simulations, calibrations: Fisyak, vanBuren



Optimal performance parameters were demonstrated in May

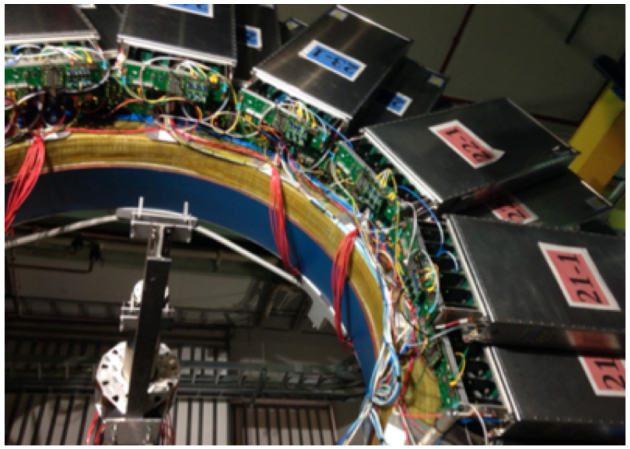
STAR upgrades for BES-II (b)

Event Plane Detector (EPD)

- Fully installed and operational for Run-18
  - Mechanical Integration Sharma, STSG

eTOF

- STAR CBM phase 0 collaboration
- Installed for Run-19
  - Mechanical Integration, gas system: Sharma, Lebedev STSG
  - DAQ trigger integration Ljubicic



STAR forward upgrade

- Proposal: sharpen the physics case for heavy ion collisions: Jia, Ruan, Sorensen, Tribedy, Xu. Simulation efforts from S&C core team members: Lauret, Ogawa, *Perev*, *Van Buren,* Webb.

After a successful cost and schedule review on Nov 18, 2018:

- The small-strip Thin Gap Chamber project manager: Ruan
- Forward Silicon Tracker deputy project manager: Videbaek
- Software coordinator: James Daniel Brandenburg
- DAQ, mechanical integration: Ljubicic, Rahul

People in italic are moved to the NPPS group.

EIC Science in STAR

- STAR group involved in EIC efforts since 2007
- Active group member: T. Ullrich, J.H. Lee, L. Ruan
- Key authors of major EIC papers (White Paper (Eur.Phys.J. A52 (2016)), Energy Assessement Paper (Rept.Prog.Phys. 82 (2019))
- Core member of BNL EIC Working Group are also member in STAR but funded through PD (see A. Desphande's talk)
- EIC Working Group at BNL chaired by T. Ullrich and J.H. Lee
- Generic EIC Detector R&D Program coordinated by T. Ullrich since 2014 (see A. Desphande's talk)
- Active participation in
  - EIC LDRD program (Ullrich, Ruan)
  - Joint BNL/SBU CFNS center
    - J.H. Lee is Scientific Coordinator on the BNL side
    - Lee and Ullrich are both member of the CFNS program steering committee
  - EIC User Group:
    - Ullrich is BNL's representative on the EIC User Group Steering Committee.
- Frequent EIC related talks, seminars & colloquiums. Various EIC related publications (Lee, Ullrich)

Summary

BNL STAR group dual mission:

- Support for the existing detector systems, operation, data taking and processing, along with development of new detector technology
- Ground-breaking scientific research to utilize these systems to their fullest potential, taking advantage of detailed expertise and knowledge of the detector capabilities

Pool of local expertise for supervision of long-term visiting students and post-docs (29 from16 institutions) and summer interns for the last 3 years

BNL STAR group plays central and critical role to the success of the STAR experiment in all of these areas.

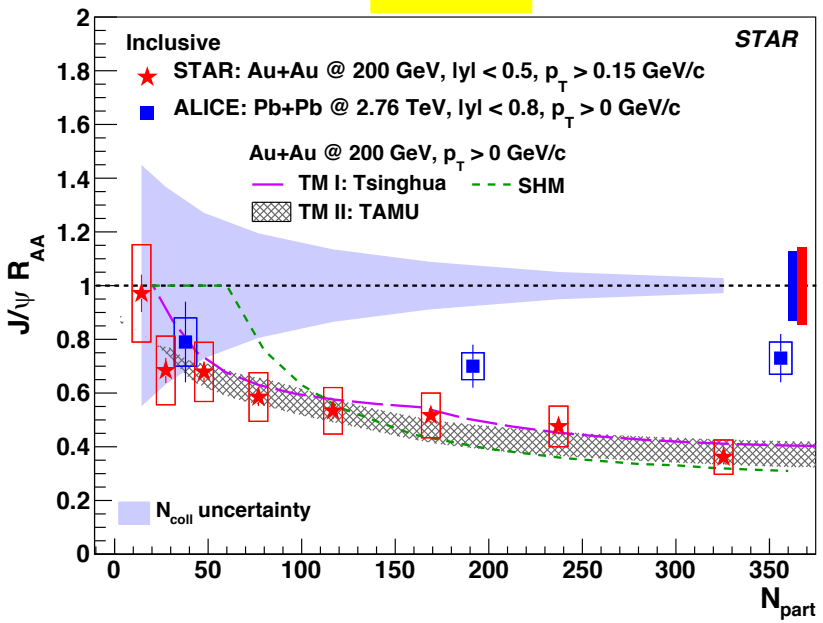
Backup

Au+Au @ 200 GeV: J/ψ R_{AA} vs. centrality

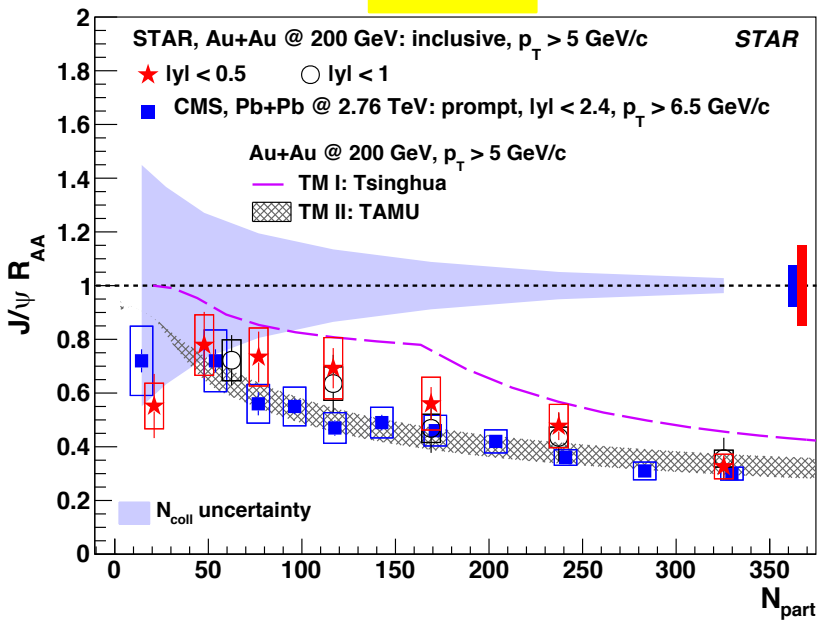
- Utilizing the Muon Telescope Detector at STAR

arXiv:1905.13669
PLB797(2019)134917

Low p_T



High p_T



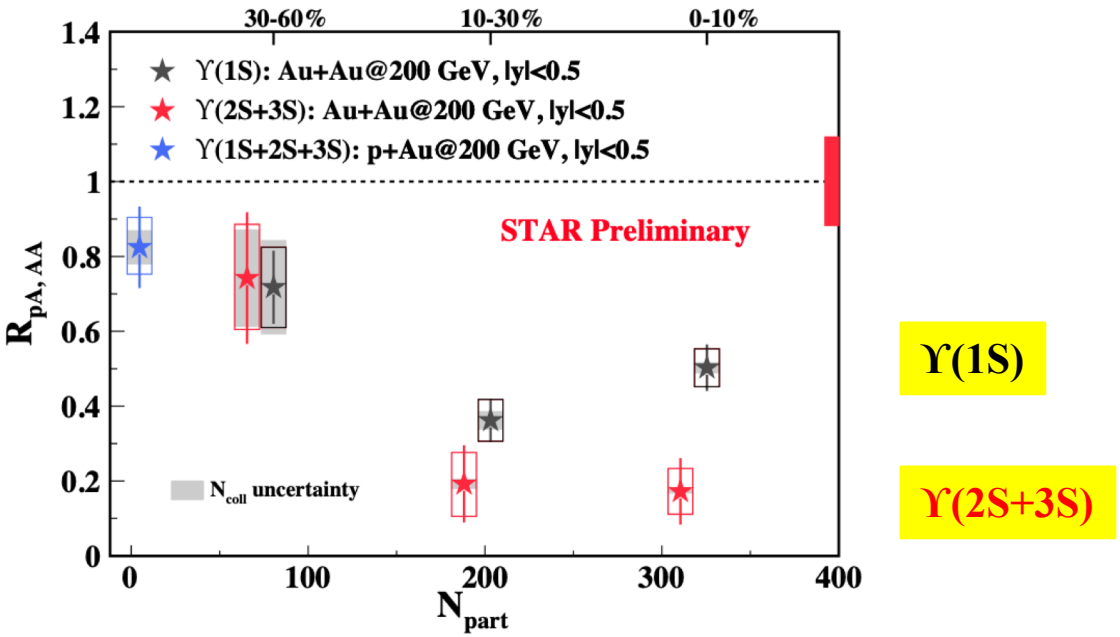
- Low p_T: significantly larger suppression at RHIC than LHC in central collisions
  - ➢ Less regeneration contribution at RHIC
- High p_T: indication of less suppression at RHIC
  - Lower medium temperature at RHIC
- Transport model calculations describe data well at low p_T, but have some difficulties at high p_T
  - Opportunity for further improvements

ALICE : PLB 734 (2014) 314
CMS: JHEP 05 (2012) 063

Tsinghua: PRC 89 (2014) 054911
TAMU: PRC 82 (2010) 064905
SHM: Nature 561 (7723) (2018) 321

Au+Au @ 200 GeV: Υ R_{AA} vs. centrality

- Combined dimuon and dielectron results

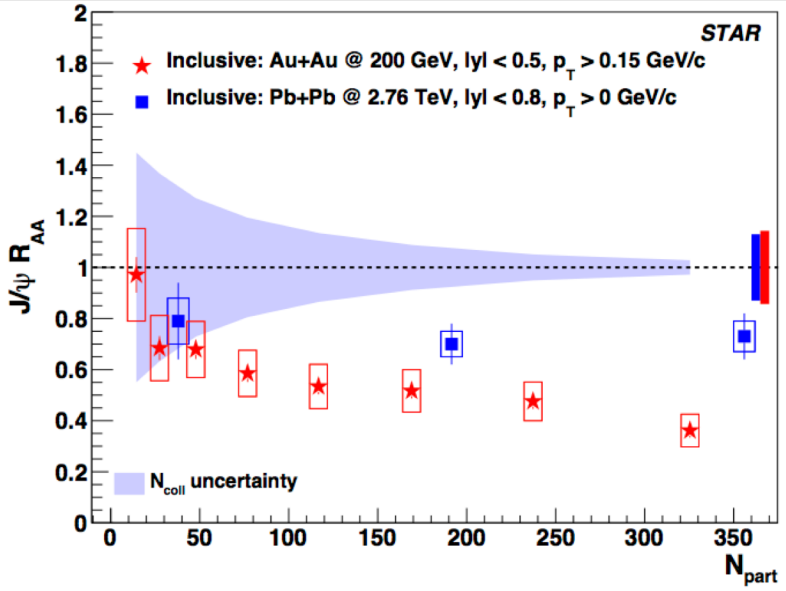


- Peripheral: suppression comparable to that measured in p+Au
- Peripheral → central: increasing suppression consistent with enhanced hot medium effects
- **Central: Υ(2S+3S) is more suppressed than Υ(1S), as expected from the "sequential melting" picture of the color screening effect**

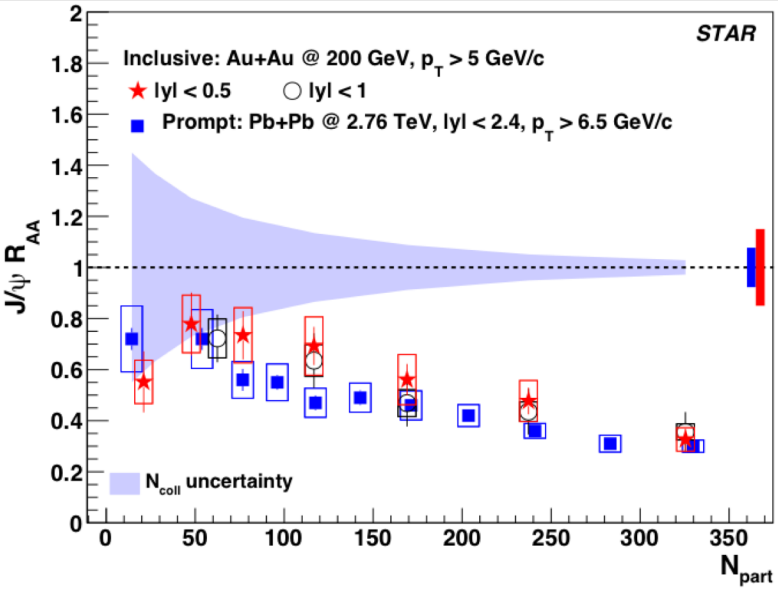
J/ψ suppression pattern

STAR Collaboration, arXiv: 1905.13669, PLB797(2019)134917

$p_T > 0.15$ GeV/c



$p_T > 5$ GeV/c



Ma, Ruan

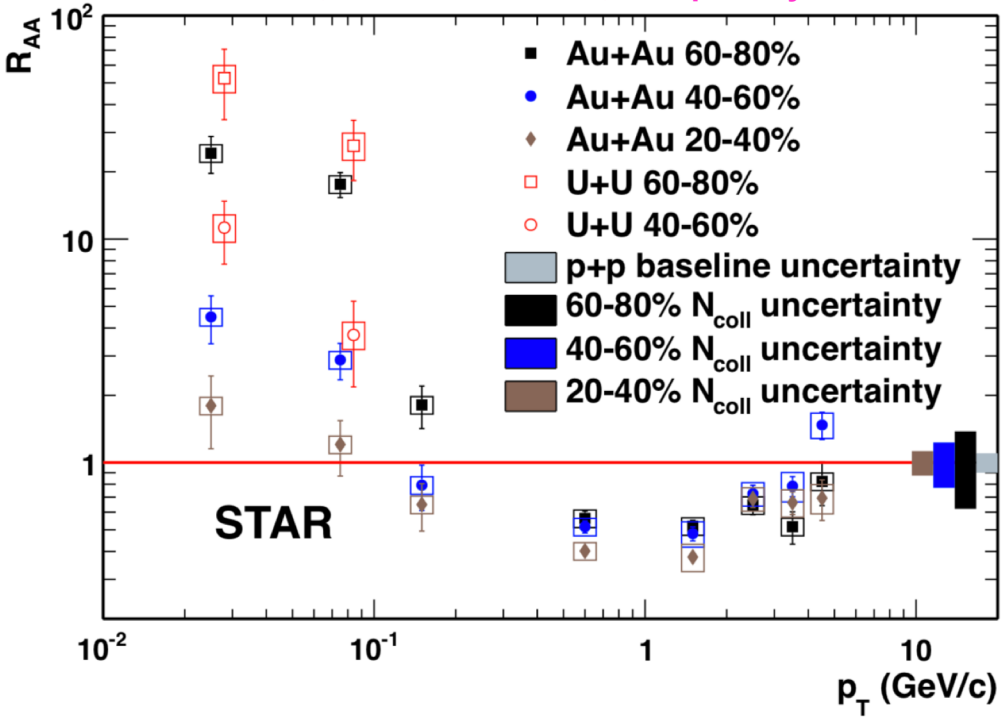
J/ψ through its dileptonic decay: indicator of deconfinement

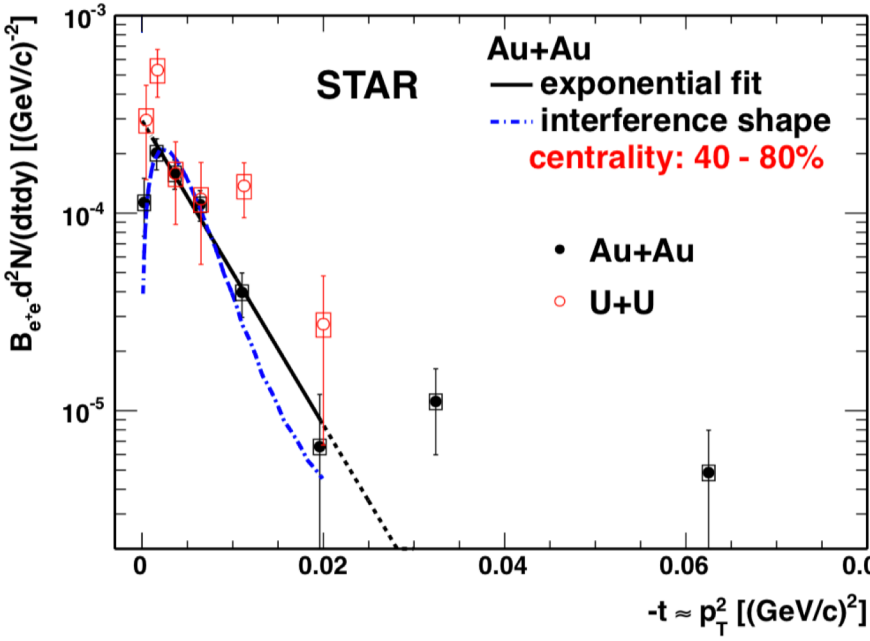
consistent with more significant contribution from ccbar recombination at LHC energies

Interplay between color screening and recombination: describe the J/ψ suppression pattern and flow measurements

Very low p_T J/ψ in heavy ion collisions

STAR Collaboration, arXiv: 1904.11658, accepted by PRL





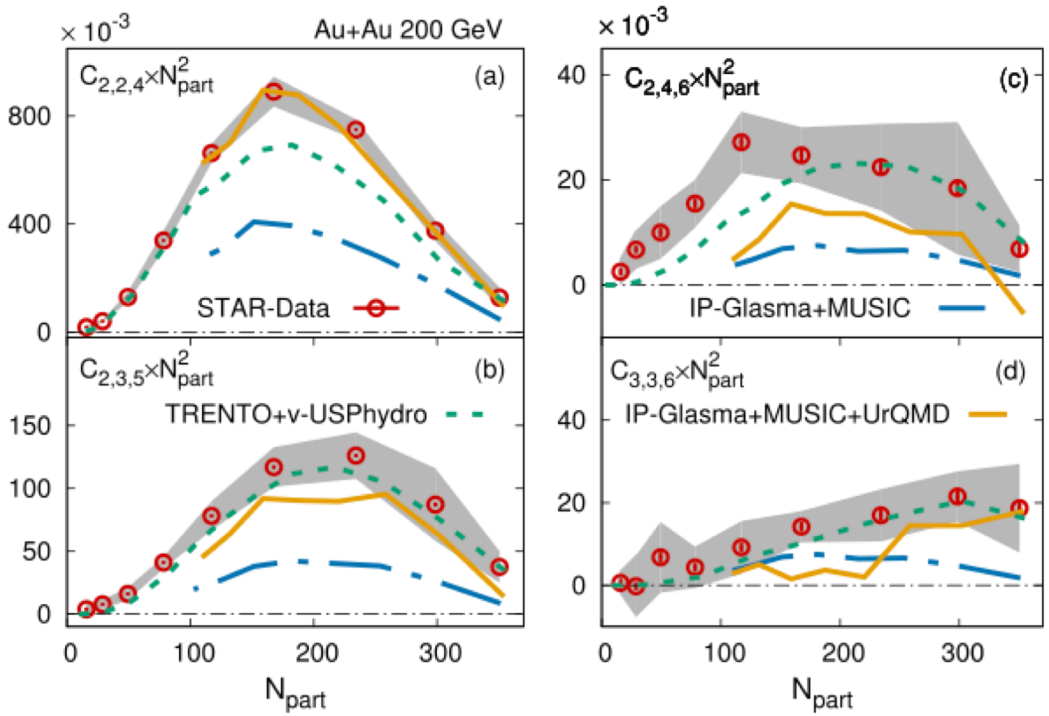
Ruan, Xu, Yang

Large enhancement of J/ψ yield observed in peripheral A+A collisions!

Slope parameter consistent with the size of the Au nucleus.
Interference structure observed. Coherent photon-nucleus interactions!

Three-particle mixed harmonic correlations

STAR Collaboration (L. Adamczyk et al.), Phys. Lett. B 790 (2019) 81-88
STAR Collaboration (L. Adamczyk et al.), Phys. Rev. C 98 (2018), 034918



First measurements of the charge inclusive three-particle azimuthal correlations → Insights on non-linear hydro response & temperature dependence of viscosity

Hydrodynamic model shows dominant contribution from the viscosity of hadronic phase to harmonic event-plane correlation at RHIC

Sorensen and Tribedy

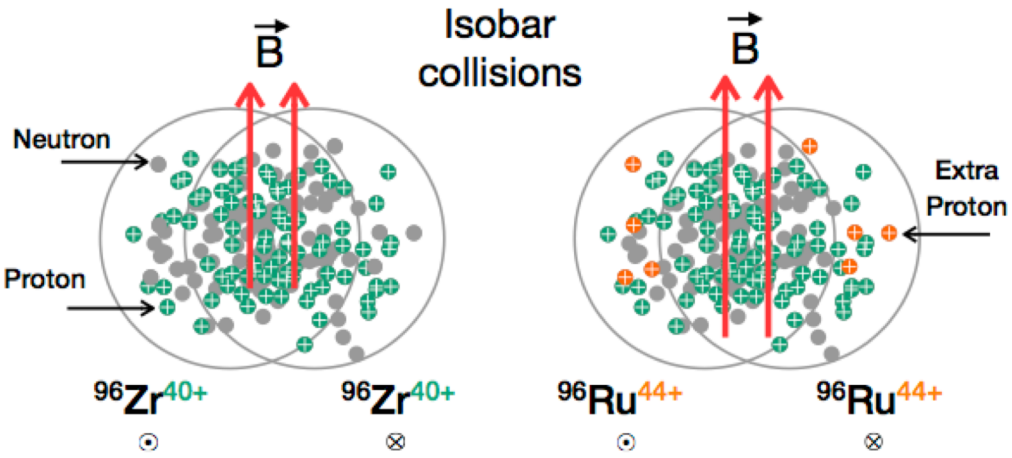
Decisive tests of CME using Isobar collisions

Voloshin, Phys.Rev.Lett. 105 (2010) 172301

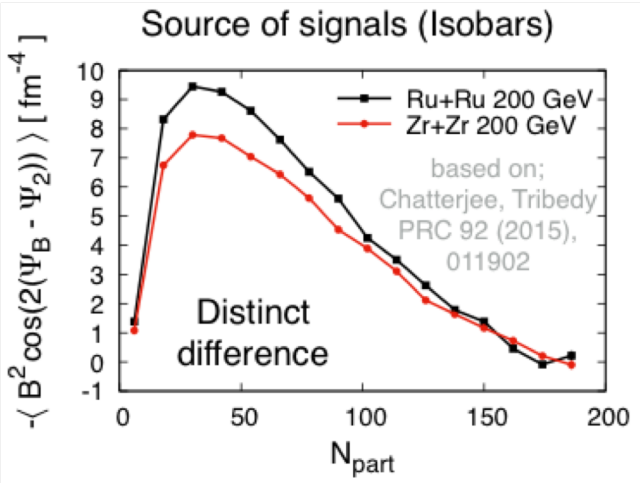
Testing the Chiral Magnetic Effect with Central $U+U$ collisions

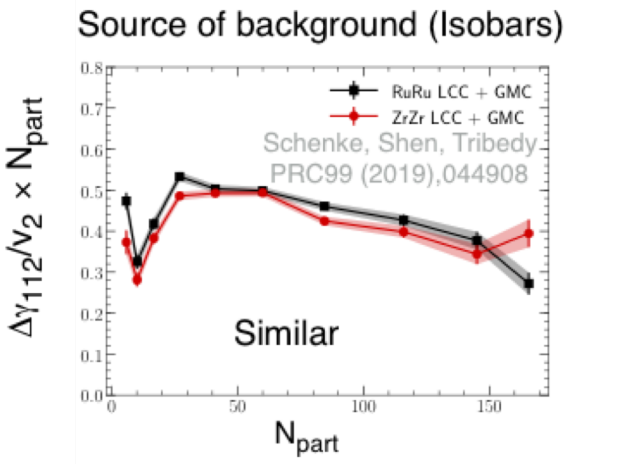
Sergei A. Voloshin
Wayne State University, Detroit, Michigan 48201, USA

The charge separation dependence on the strength of the magnetic field can be further studied with collision of isobaric nuclei, such as $^{96}_{44}Ru$ and $^{96}_{40}Zr$. These nuclei have the same mass number, but differ by the charge.

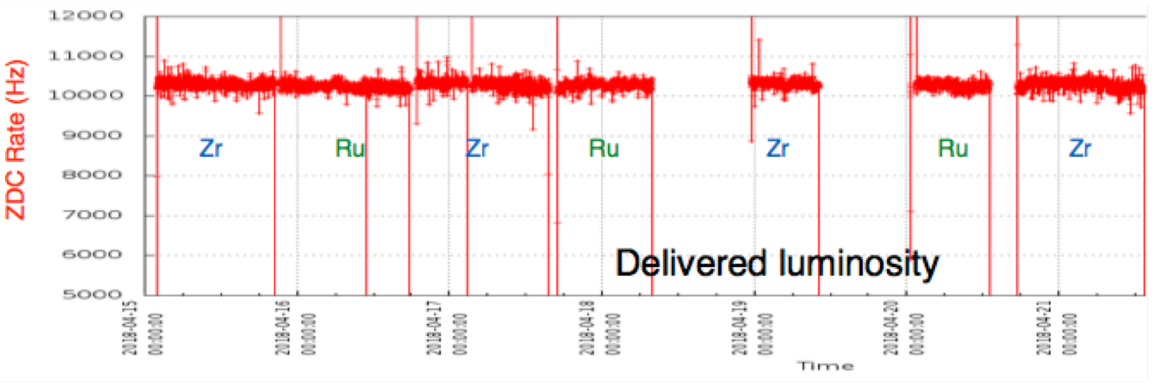


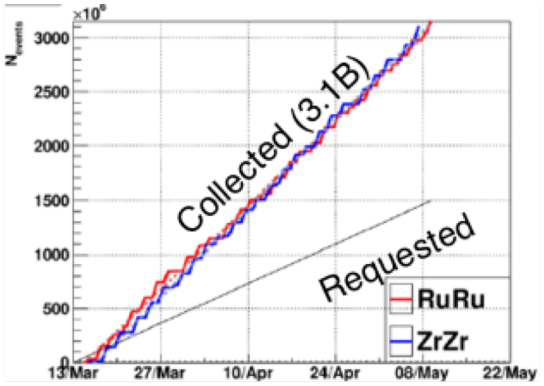
10% larger B-field in Ru+Ru but similar background as Zr+Zr makes Isobar collisions an ideal place to make a decisive test of CME





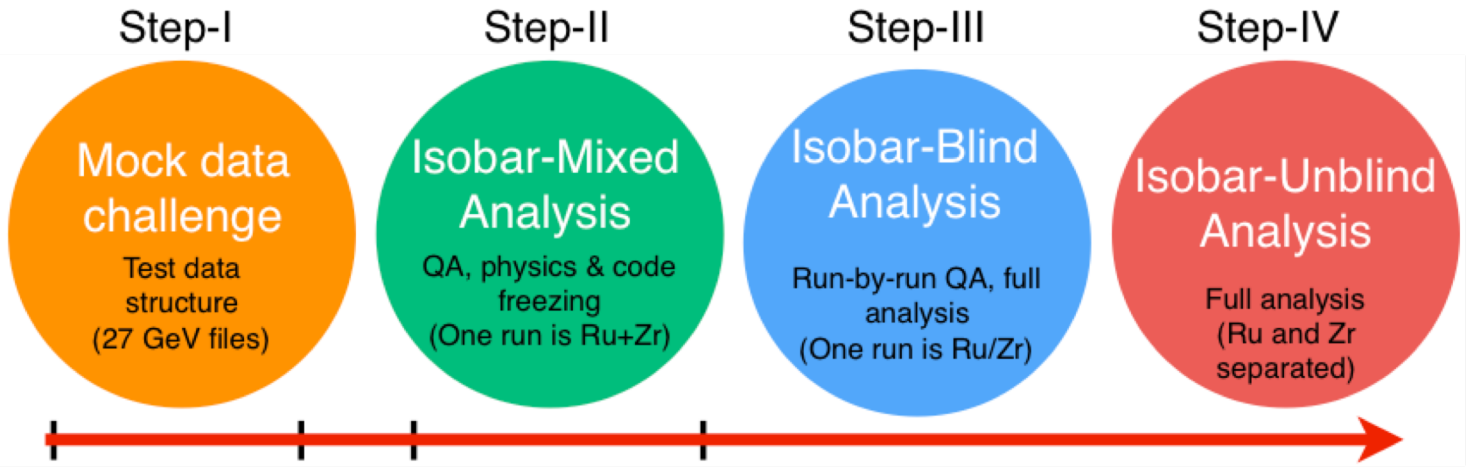
Isobar data collection and blind analysis





3.1B events for both Ru+Ru, Zr+Zr collected over 8 weeks

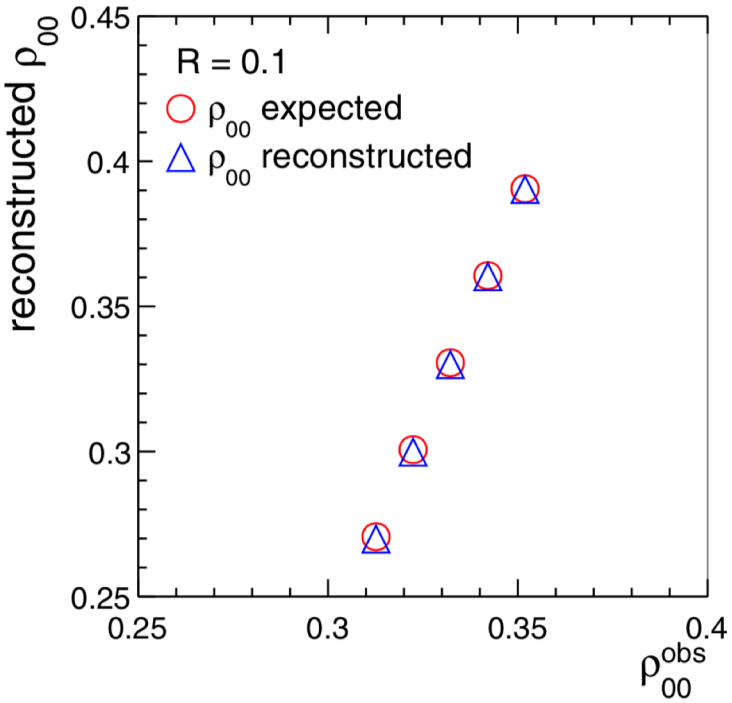
Blind analysis ongoing by four independent groups (**BNL-Fudan**,UIC-SBU,UCLA,Purdue)



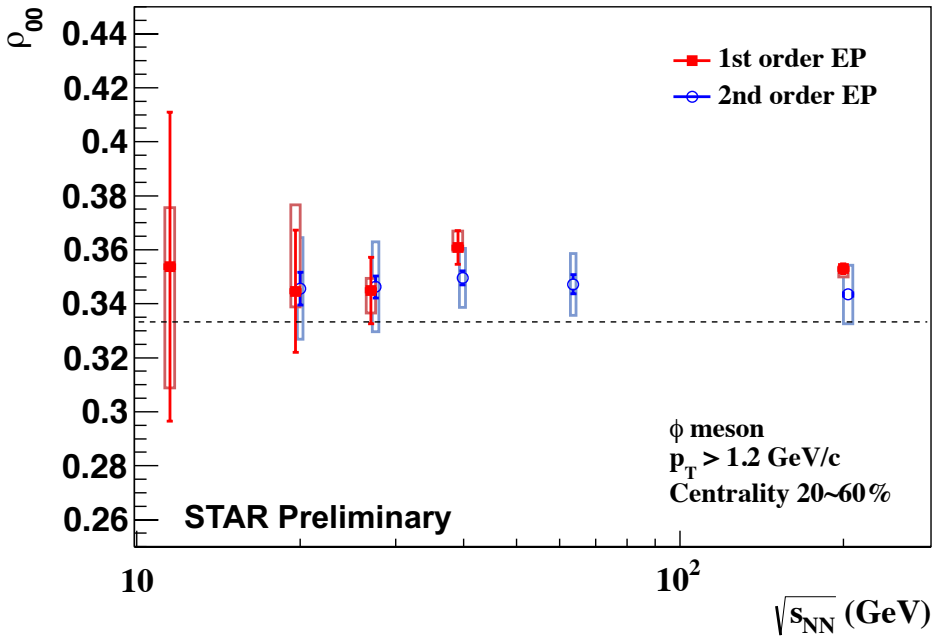
First blind analysis, new detector (EPD) many challenges, currently between Step-II & III

Tribedy

Global spin alignment measurement



Tang, Chirality workshop 2018

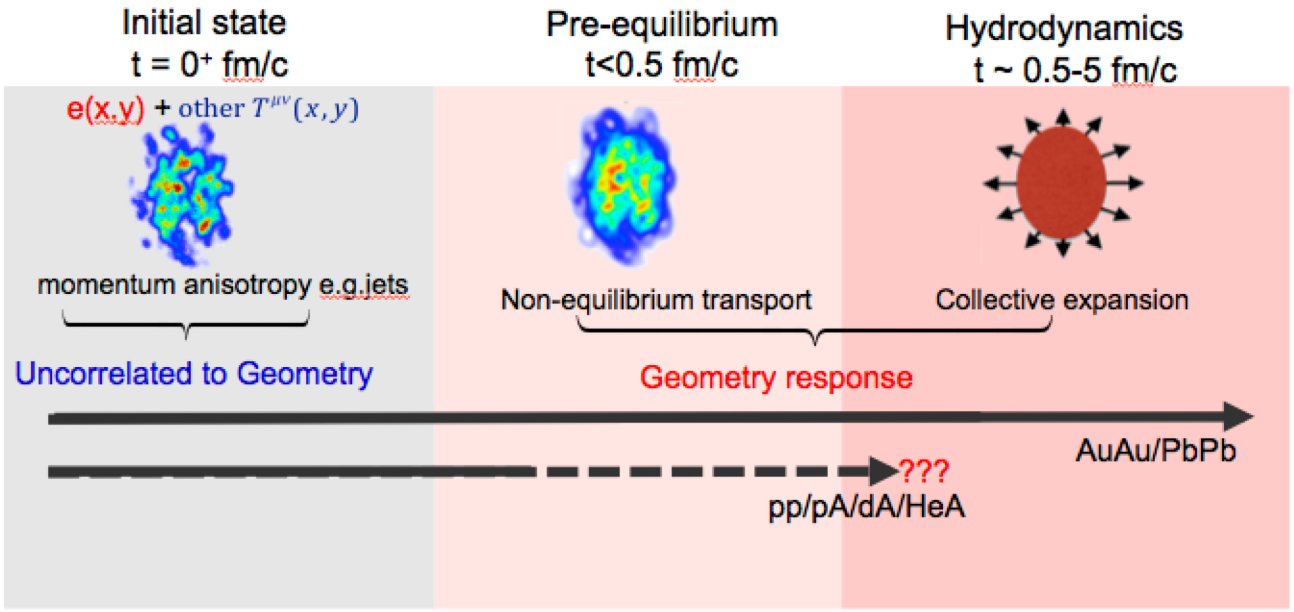


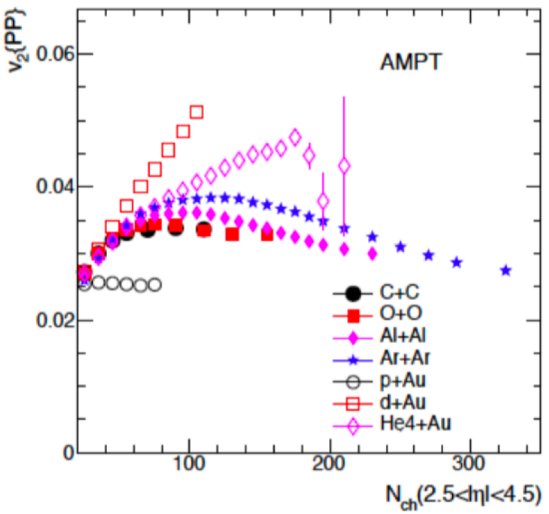
The procedure for measuring global spin alignment is thoroughly investigated with practical considerations (resolution, acceptance etc.)

Significant global spin alignment observed at 200 and 39 GeV.
Its implication is under discussion with theorists.

Tang

Pushing for a future small system scan





arXiv:1904.10415

Can we disentangle these three scenarios?

Drastically different geometry response between symmetric and asymmetric system

Extend the level-arm to disentangle contributions from three stages

- Where initial-stage interactions become sub-dominant?
- What is the role of pre-equilibrium vs. hydrodynamics?

Further system-size scan needed! Only RHIC can do this!

Jia