STAR Isobar Blind Analysis Method

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OUTLINE

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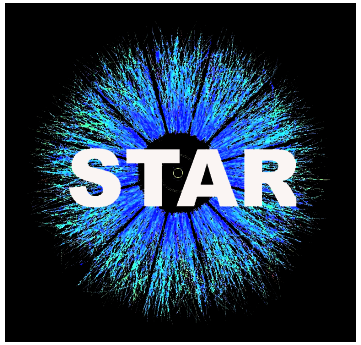


Important Considerations

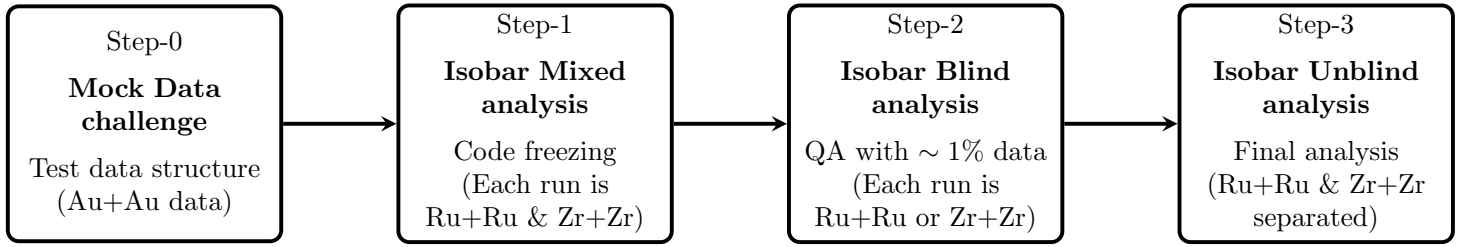
For STAR Chiral Magnetic Effect (CME) analyses:

- **Critical to account for**
  - ***Time-dependent*** detector fluctuations
  - Anomalies in the collection of 30-minute "runs" of the data acquisition system
- Do not randomize variables that may severely compromise analysis quality
  - *E.g., randomizing the sign of reconstructed charged-particle signals prevents charge-dependent efficiency corrections*
- 2018 data-taking used frequent switching of "isobar" species ($^{96}_{44}\mathrm{Ru} + {}^{96}_{44}\mathrm{Ru}$ and $^{96}_{40}\mathrm{Zr} + {}^{96}_{40}\mathrm{Zr}$)
  - Species expected to have comparable behavior, e.g., luminosity, trigger, energy, vertex distribution, occupancy of tracks
  - *Possible to blind species by interleaving or "mixing" events from two species*
- Certain non-analyst experts need access to un-blind data
  - E.g.. STAR detector experts during RHIC running or offline calibration experts
  - ***All*** *must recuse themselves from blind physics analysis*
- Selection of high quality runs for analyses must proceed prior to mixing of events

Vital Stats

- 2017 BNL NPP Program Advisory Committee recommended ***blind analyses*** of ***CME studies*** of Run-18 isobar data
- Published analysis blinding manuscript:

Methods for a blind analysis of isobar data collected by the STAR collaboration,
J. Adam et al. (STAR Collaboration), Nuclear Science and Techniques 32, 48 (2021).

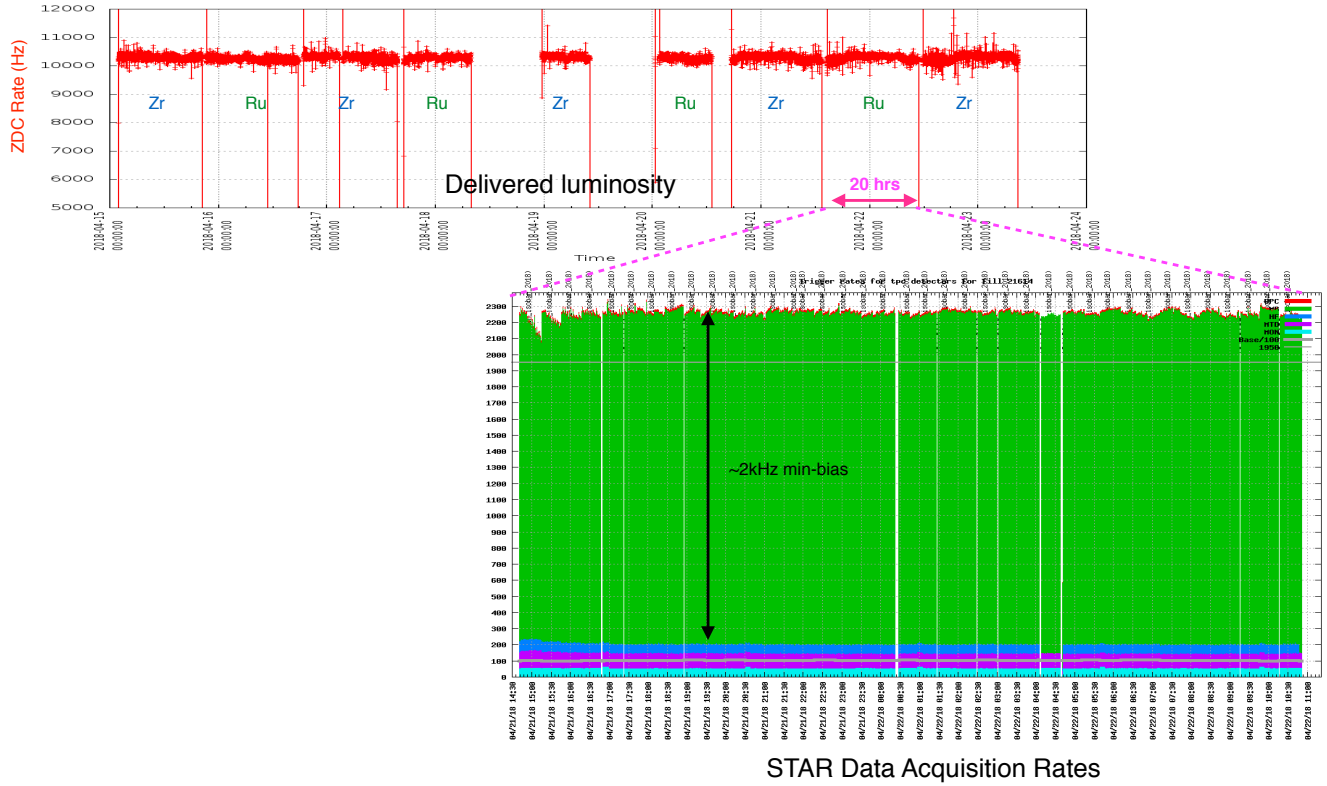


- **Methods developed and accepted by collaboration in January 2018, well before 2018 data-taking**
- **Step-0, Initial steps**
  - Calibrations and quality assurance (QA) of data acquisition "runs" by calibration experts
  - "Mock data challenge": *Sanity-check of feasibility and implementation*
- **Step-1, "The Reference"**
  - Provide output files composed of collision data from a ***mix*** of the two isobar species
  - As much as possible, order of collision "events" ***respects time-dependent changes in detector conditions***
  - **Analysis code** and **time-dependent QA** tuned and frozen
- **Step-2, "The run by run QA sample"**
  - Provide files that blind the isobar species but do not "mix" data from different data acquisition runs
  - Only allow "run-by-run" corrections and code alteration directly resulting from these corrections
- **Step-3, Full un-blinding**

Data-taking for Isobar Collisions

RHIC Running

- Switch isobar species each time beam is inserted into RHIC
- Stable luminosity (matched between species) with long (~20 hour) beam circulation time
- Adjust and level luminosity to optimize data collection rate while minimizing backgrounds and systematics
- Restrict species-related information to those necessary for successful data-taking
- Calibration experts (recused from CME analyses) evaluate data quality “in real time”

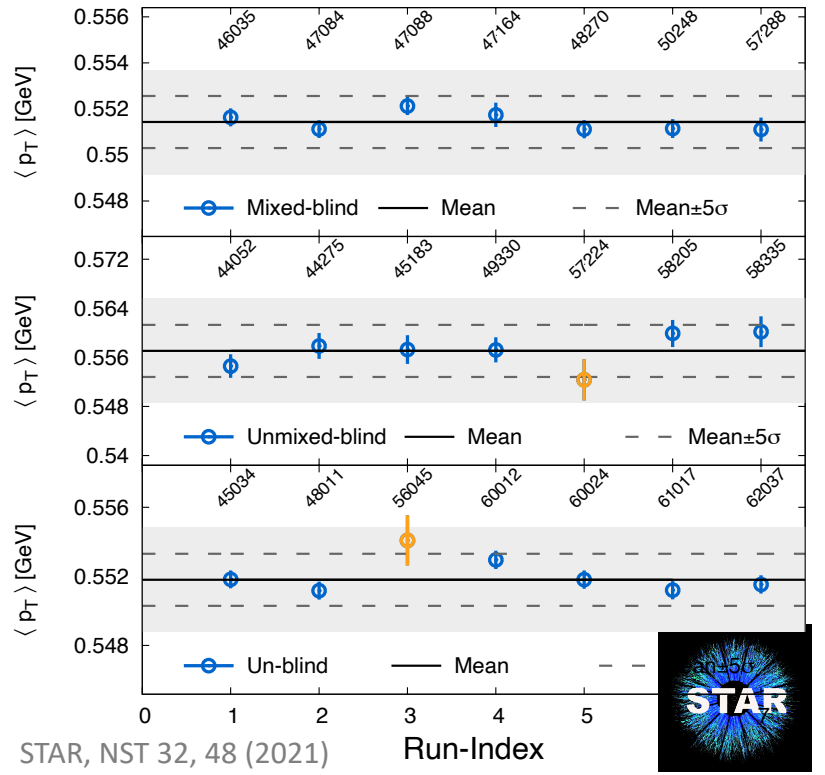


STAR Data Acquisition Rates

Step-0: Initial Steps

“The Tune-up”

- Calibrations and quality run selection by un-blind experts
- Develop software infrastructure to implement the blinding procedure
  - Event mixing procedure and run-numbers encrypted
  - Additional information obfuscated in data
    - *Event ID, run ID, event timestamp, collision species, hit/coincidence/background rates from certain detectors*
- “Mock data challenge”
  - *Sanity-check of feasibility and implementation*
  - Utilize blinding procedures on 2018 27 GeV Au+Au data
  - Analysts tune code on “mock data”
    - *Check that data blinding infrastructure works as intended*
    - *Verify the appropriate information is blinded as intended*
    - *Ensure appropriate information is accessible to analysts*
    - *Check that analysis codes run properly on “blind” data structures*
    - *Confirm “blind" and “unblind" results are the same*
      - *sanity check of procedures*



STAR, NST 32, 48 (2021)

Step-1: Isobar Blind and Mixed

"The Reference"

- Provide output files composed of events from a ***mix*** of the two isobar species
  - *Mixing procedure encrypted and known only by two computing experts (recused)*
- As much as possible, order of events ***respects time-dependent change in run conditions***
- **Analysis code** and **time-dependent QA** tuned
- Critical analysis needs enabled by this step:
  - Extraction of time-dependent spectra for quality assessment
  - Detection of time-dependent anomalies
  - Measurement of peak widths relevant to momentum resolution

Following completion of Step-1, analysis codes are frozen and committed to the repository
Before moving to Step-2, codes are documented and reviewed by the isobar paper review committee

Step-2: Isobar Blind

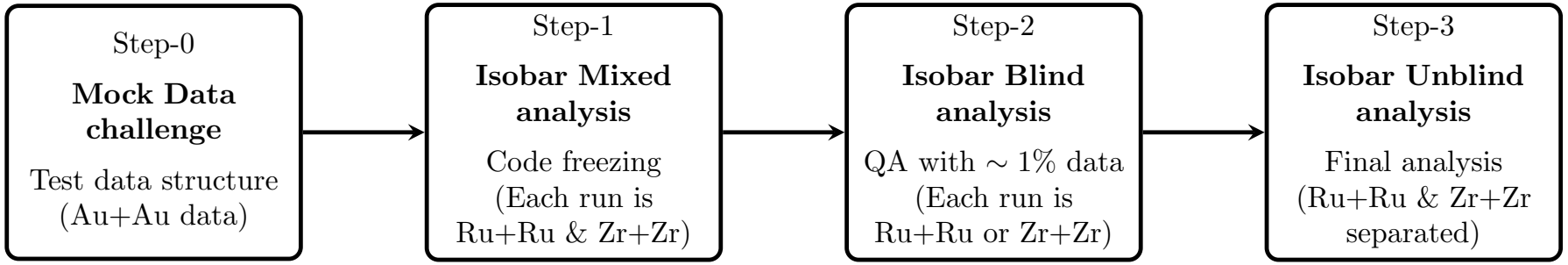
"The run by run QA sample"

- Provide data files that obscure the species but do ***not*** mix events across different runs
  - *Limit the number of events to prevent deciphering species by simple counting*
- ***Only run-by-run corrections and code alteration directly resulting from these corrections are allowed at this stage***
- Additional bad runs identified based on physics quantities and discarded
  - *Analysts perform run-by-run QA using a predefined and frozen algorithm*
- This step enables analysts to perform QA using quantities relevant to their specific analysis

Following completion of Step-2…

- ***Analysis codes are reviewed, frozen, and committed to the repository***
- ***Fully un-blind data are released and analyzed with the frozen codes***
- Only changes to correct "mistakes" are allowed after unblinding
  - Errors in arithmetic
  - Unintended departures from ***documented and approved*** procedures, cuts, corrections, and systematic uncertainty estimates

Summary



- STAR has developed a procedure for the CME isobar blind analyses
  - Step-0: Calibrations, run-QA, and mock data challenge
  - Step-1: Isobar blind and mixed (analysis codes tuning)
  - Step-2: Isobar blind and un-mixed (run-by-run QA and correction)
  - Step-3: Full un-blinding (physics analysis)
- Development and implementation has been a substantial, collective undertaking
  - Innovative RHIC running
  - New software and computing infrastructure
  - Cooperation across analysis groups, physics working groups, committees, etc.

Thank you to all who supported the effort!