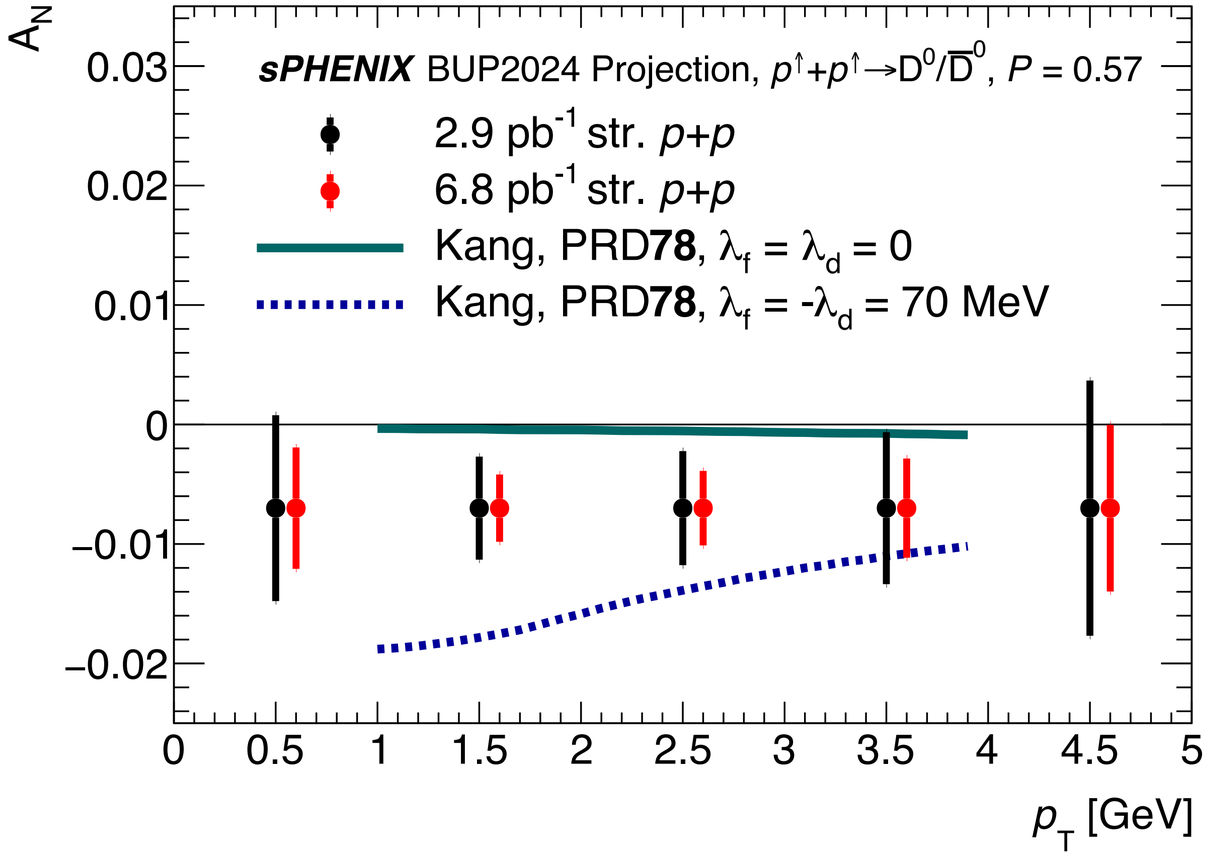
sPHENIX Response to PAC Homework



BNL NPP Physics Advisory Committee (PAC) Meeting

The two theory curves above bracket a range of possible parameters, which the D^0 A_N measurement will constrain

8 November 2024

sPHENIX PAC Meeting Presenters

Question 1

Q. What activities are planned for the shutdown and can sPHENIX start the run earlier than late March? How much earlier?

A primary activity of this shutdown is the replacement of the rack-mounted boxes of voltage dividers supplying HV to the TPC GEM foils with CAEN cascading power supplies. This work is expected to take until the end of CY'24.

We also plan a significant period of data taking with cosmic rays, in part to check the operation of the TPC with these new supplies and to further commission the laser calibration system of the TPC.

We could conceivably be ready for the start of Run-25 in early March. An abbreviated shutdown does entail significant risk; it shortchanges the testing we plan prior to start of operations, and there is very little schedule float to recover from problems we may encounter. Our experience with the abbreviated schedule leading to the start of Run-23 highlights the importance of allowing time for careful, systematic pre-operations testing.

There are 43 weeks and 5 days between March 1, 2025 and December 31, 2025. **The collaboration urges BNL to pursue an extension to the RHIC ASE** to ensure the successful completion of the RHIC science program should a technical, operational, or funding catastrophe curtail Run-25 short of its target duration.

Question 2

Q. The streaming readout has been a critical component to achieve the sPHENIX p+p data-taking goals for heavy quark meson measurements. Is there any data analysis results to show that the streaming readout is working well as expected? If not yet, when does the collaboration expect to have such results?

We have performed **low-level checks** of data integrity (e.g., synchronization between different readout elements on a subsystem) and reconstruction (e.g. cluster multiplicity, tracklet and vertex reconstruction, and ADC distributions) throughout the run. INTT cluster timing, and cluster and track crossing distributions, all looks as we expect given the current state of the reconstruction.

Higher level checks (e.g., dE/dx vs momentum, strange hadron mass peaks) are being performed right now and the results so far are consistent with the streaming readout working as expected.

We plan to have a **broad review of these results at the mid-December collaboration meeting** (and in working sessions organized prior to that meeting).

Question 3(a)

Q. Your priority list of additional running opportunities includes i) 8 weeks of p+p at 200 GeV to complete the physics baseline measurements for AuAu, ii) 5 weeks for p+Au and iii) 2 weeks of O+O. For each one of these three, please describe in the most compact and succinct way (few sentences each) the physics opportunities that are lost if these runs do not take place. …

p+p: The sPHENIX capability for a variety of flagship measurements, including jet+track correlations, open heavy flavor, and Upsilons, will be degraded due to the lack of a sufficient *p+p* reference. Unique *p+p* measurements, such as the D^0 A_{N} and studies of heavy flavor hadronization at RHIC energies would have a reduced scientific impact.

***p*+Au**: RHIC loses the opportunity to definitively address fundamental scientific questions in small, asymmetric collision systems, including the interplay of collective phenomena in the soft sector with the (apparent lack of) modifications of hard probes. Furthermore, there is a major missed opportunity in not combining the unique sPHENIX experimental capabilities with the world-unique RHIC capability of polarized *p*+Au collisions.

O+O: The international heavy-ion physics field would lose the **only** possibility to make apples-to-apples comparisons of hard probes of the identical nucleus-nucleus collision system at RHIC and the LHC, i.e. keeping the geometry fixed but greatly varying the collision energy and thus QGP properties. There is no other foreseeable species match between RHIC and LHC.

Question 3(b)

Q. … Please include an indication of the importance and timeliness of the expected results. …

For many of the flagship measurements, there is no comparable dataset at RHIC, and thus the measurements will be unique.

The expected timescale is comparable to the corresponding measurements made from data in the ongoing LHC Run 3 (which ends in 2026).

Question 3(c)

Q. … Can you outline the minimal meaningful running scenarios, under which these three additional programs remain in your view still physics motivated (for instance: x<8 weeks of pp, y<5 weeks of pAu or z<2 weeks of OO)? Can you comment on x, y, z and what sets these lower limits if any?

p+p: The proposed eight weeks results in a doubling of the full-system triggered dataset for jet+track, *b*-jet, and Upsilon physics and a x2.3 increase in the tracker-only streaming data (assuming 30% streaming readout). With this configuration, we feel that fewer weeks than this incurs a significant opportunity cost.

However, if the streaming readout fraction could be significantly increased (which is TBC in sPHENIX), as few as five weeks of additional *p+p* running would still confer a worthwhile benefit for the open heavy flavor program.

***p*+Au**: sPHENIX has no specific luminosity targets in this system, and thus running for three or four weeks is likely to still be impactful.

O+O: We feel that two weeks is the minimum viable time. For less running time than this, there is the possibility that machine downtime or other unexpected issue in changing species results in no significant integrated luminosity, and thus the risk/reward ratio is too low.

Question 4

Q. Please give the PAC the summary of your data preservation plans.

We will make use of the extensive RHIC experience and joint RHIC efforts

- ➡ sPHENIX members involved in PHENIX effort
- ➡ Using Invenio at BNL to track analysis documentation, comments and responses
- ➡ Rely on SDCC for continued access to raw data and DSTs
- ➡ Investigating additional approaches for preserving analysis schemes (RIVET, ReAna)
- ➡ Collaboration approved requirement to submit numerical values for all results to HEPdata

sPHENIX software framework design with data preservation and analysis reproducibility in mind

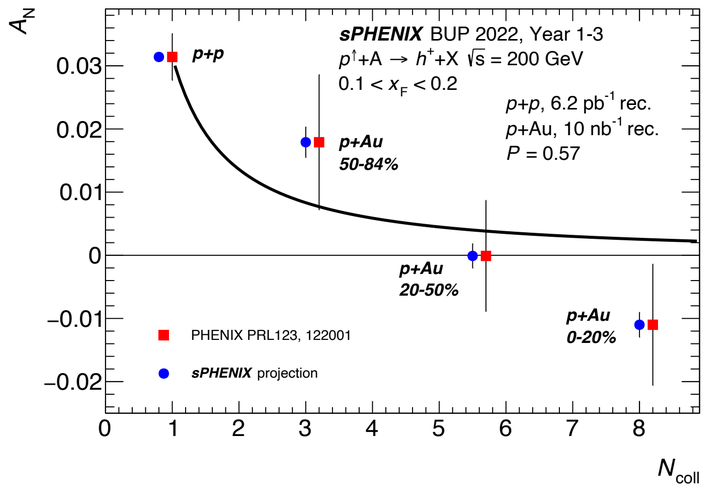
- ➡ Calibration/conditions DB is tagged to allow re-reconstruction and re-analysis
- ➡ Demonstrated in PHENIX and sPHENIX MDC that tagged builds (+stored RN) allow reproduction w/ identical results
- ➡ Analyses will use centralized mechanism (“Analysis taxi”) where code and macros are archived (PHENIX model)
- ➡ Schema evolution will ensure continued access to prior DST versions (demonstrated in PHENIX going back to 2003)

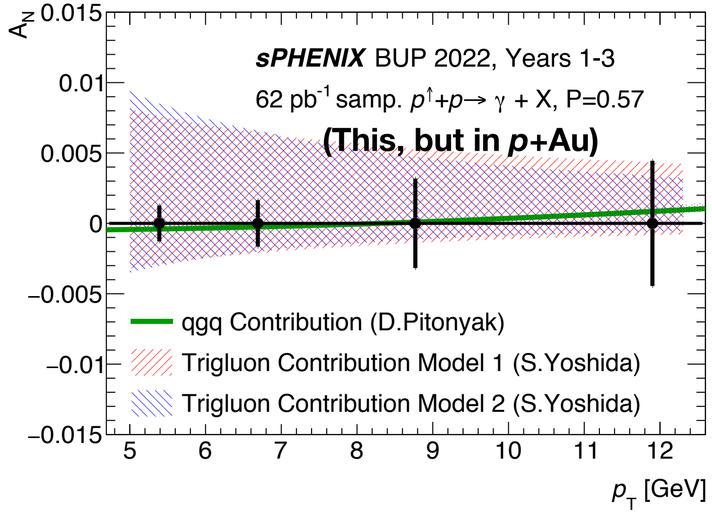
Question 5

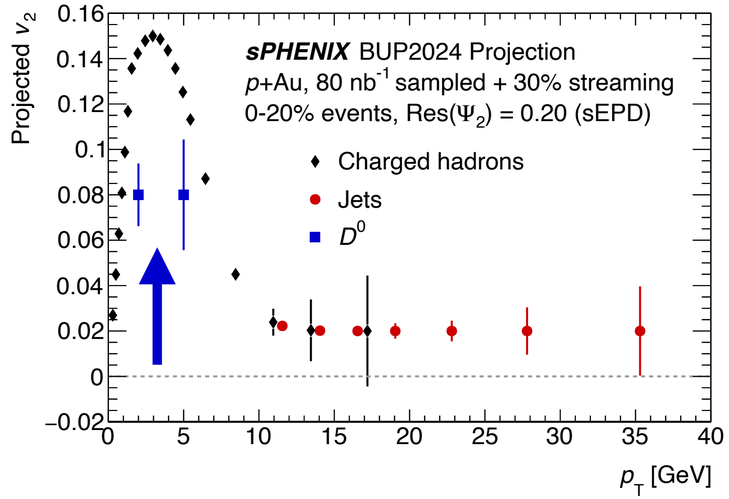
Q. What are the most compelling measurements that sPHENIX plans, which will take advantage of POLARIZED pAu collisions?

We give a number of potential measurements:

- ➡ Understand nuclear dependence of hadron A_N, differentially in p_T and x_F
- ➡ Photon A_N and D^0 A_N (similar uncertainties to D^0 v_2 projection)
- ➡ Nuclear transverse momentum dependent PDFs (TMDs), spin-dependent k_T broadening with dijets, etc.







Question 6

Q. Can you give us a rough estimate of the dominant systematic uncertainties in the projection plots for your flagship hard probes measurements? This would be helpful in assessing the impact of additional pp statistics.

p+p statistics are particularly important for providing *in situ* constraints on the calorimeter performance in data.

We can estimate the dominant uncertainty sources from experience with similar measurement techniques at RHIC and LHC. For selected flagship measurements:

Photon+jet p_{T} ratio: absolute jet / HCal energy scale uncertainty

Jet sub-structure quantities: this depends on the measurement and technique, but could be: energy scale (e.g. for z_g), angular resolution (e.g. for R_g), unfolding-related uncertainties, etc.

Non-prompt D^0 yields: data-MC agreement of DCA templates for prompt/non-prompt separation, tracking efficiency

Upsilon yields: electron selection and signal/background modeling

Question 7

Q. If, after the completion of the Au+Au collisions, there are an additional 2 or 3 or 4 or 5 weeks available, what would be your priority in such cases?

Our priorities in the following scenarios would be (in all cases contingent on reaching the 7 nb^{-1} Au+Au goal):

5 weeks: If the streaming fraction in *p*+*p* collisions can be increased to 50% or higher, the priority would be *p*+*p* running. Otherwise, *p*+Au running.

4 weeks: *p*+Au running

3 weeks: *p*+Au running

2 weeks: O+O running

Fewer than two weeks: sPHENIX feels that the reward-to-risk ratio of switching running species is low, and would opt to continue with the current collision species.

Question 8

Q. You mentioned in the oral presentation today that in pA, the handling of splash events would be more difficult. If it turns out that splash events will still affect the MVTX in Run 25, what are the handles for working in streaming mode in pA?

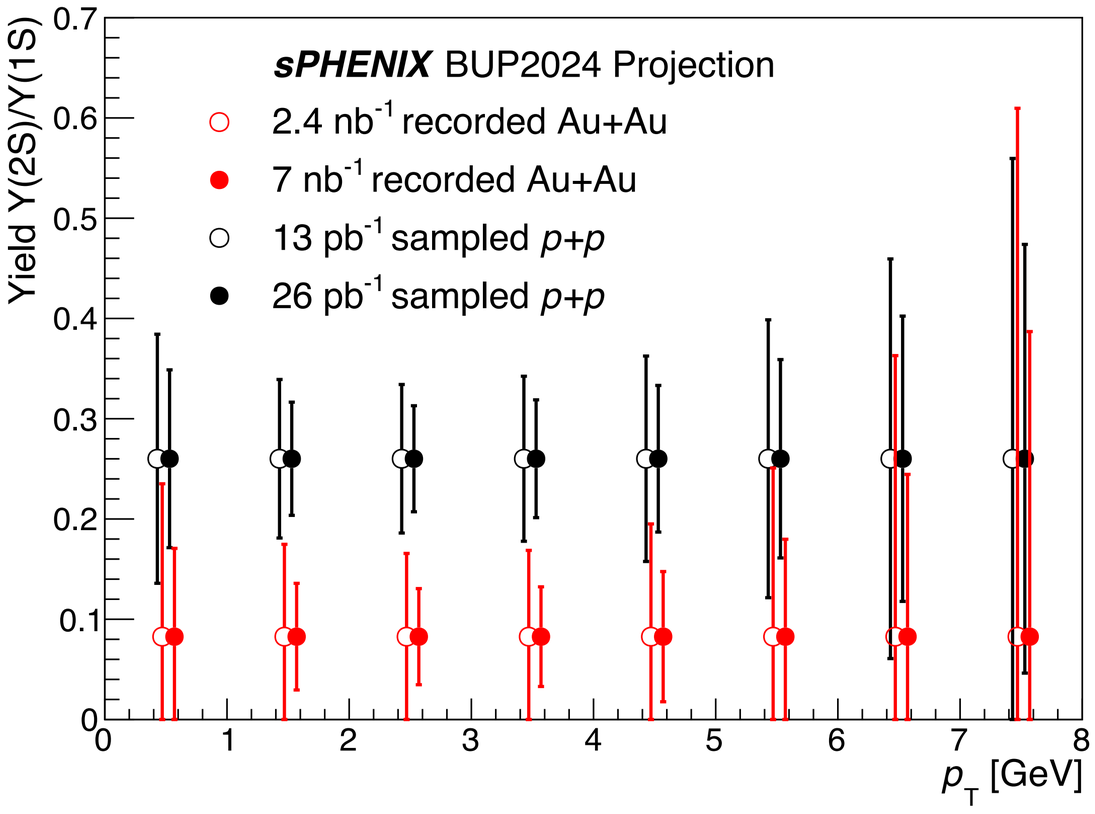
The **higher *p*+Au collision rate** compared to Au+Au will negate the improvement in autorecovery (AR) rates that the triggered readout provides compared to streaming readout.

MVTX experts will use the shutdown period to implement **further optimizations to the MVTX firmware and software** based on observations made during the 3 week Au+Au run. Part of the upgrades involve implementing changes made to the ITS-2 detector at ALICE from their experience of beam-induced autorecoveries, lowering the AR rate for a given rate of splash events, and **experts from the collaboration are part of the C-AD taskforce** to optimize RHIC optics further.

It is important to note that the AR rate is strongly phi-dependent (concentrated in the horizontal plane), leading to **significant partial, but not total, acceptance loss** with the AR rates observed after beam optimization at the end of Run 24. We have a simulation framework to estimate the loss of effective single-particle and HF decay acceptance as function of AR rates, but have not yet performed simulations for the plausible range of *p*+Au scenarios.

Question 9

Q. On slide 10, could you indicate on the plot the values of the Y2S/Y1S for pp and AA from existing measurements and/or theoretical estimates?



The Upsilon 2S/1S ratio in ***p+p*** is taken from the CDF measurement in $p + \bar{p}$ (averaged over all p_{T}): PRL 88 (2002) 161802

The Upsilon 2S/1S ratio in **Au+Au** is taken by applying the R_{AA} for each state from a theoretical calculation for RHIC energies by Strickland and Bazow: NPA 879 (2012) 25

Question 10

Q. [Question to sPHENIX and BNL management]

Last year we recommended BNL and sPHENIX collaboration to procure the necessary computing resources for data processing of Run 24 and 25. Can you update us on the steps that have been done and on what still needs to be achieved?

It is our understanding that the needed computing resources will be available on the required time scales.

The detailed plan for these major procurements will be summarized by Jamie Dunlop.

Question 11

Q. If funding for 40+ cryoweeks in CY'25 were available, would you be able to use it effectively?

sPHENIX is prepared to make every effort to fully utilize all cryoweeks available in the remainder of RHIC running.

Still, the experiment **depends heavily on a limited number of experts** for its operation. Running continuously from March to December is difficult due to the continued demand on those people. Efficiently utilizing a long run would be more manageable if a break without beam of at least one month were inserted into the overall run plan.

In this case, we would urge to start the run early (see question 1) and to **prepare for an extension of the RHIC ASE, should running in CY 26 be necessary to complete the RHIC science mission**.