PHENIX Beam Use Proposal for RHIC Run-7 and Beyond

The PHENIX Collaboration

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Abstract

A multi-year program to further elucidate the nature of nuclear matter at the highest temperatures and densities, and to increase our understanding of the spin structure of the proton is proposed. Key new instrumentation will be deployed to provide unique insights into the nature of strongly interacting matter formed in Au+Au collisions. Information on the current status of the experiment, on the data sets recorded to date, and on the program of proposed upgrades is also provided.

Executive Summary

The PHENIX Collaboration proposes a continued scientific program of increased precision based on the development of the highest possible luminosities in ion-ion, "proton"-nucleus and polarized proton collisions. Building on the successes of Runs 1-6, the requested running conditions for heavy ions are designed to extend the discovery potential at RHIC via measurement of penetrating probes and hard processes in the heaviest colliding system at the highest energy combined with corresponding baseline measurement in d+Au and p+p collisions. The deployment of new detector sub-systems significantly extends the physics reach of PHENIX, and opens new and important channels for detailed investigation. The baseline measurements in p+p collisions will result from the extended running requested in the polarized proton program, where improvements in luminosity and polarization will continue to provide advances beyond the current results. For both programs, the emphasis in Runs 7-10 is on achieving maximum physics sensitivity via accumulation of data-sets with an order-of-magnitude increase in integrated luminosity over current values. An intensive program of luminosity and polarization development is requested for polarized protons, including timely development of 500 GeV operations, leading to quality measurements of ΔG in various production channels.

1 Introduction

The goals of the PHENIX Collaboration for future RHIC running have been clearly delineated in our previous Beam Use Proposals and in presentations to the Program Advisory Committee[1, 2, 3, 4, 5, 6, 7, 8]. The consistent theme that emerges is the need to develop the highest possible integrated luminosities (and polarizations in the case of p+p running) to explore fully the range of fundamental phenomena in the nucleus+nucleus, "proton"+nucleus and proton+proton collisions at RHIC energies. The requested program has been designed to provide incisive measurements necessary to understand the spin structure of the proton and the nature of nuclear matter at the extremes of temperature and density, while performing the necessary baseline measurements for both the spin and the heavy ion programs. Every effort has been made to insure that PHENIX's triggering, data acquisition and archiving abilities meet or exceed those necessary to sample fully the delivered luminosity. A similar effort has been made to provide timely analysis of these data-sets using not only the RHIC Computing Facility (RCF), but also the very significant computing resources from PHENIX institutions in the United States (LLNL, New Mexico, ORNL, Vanderbilt), Japan ("CC-J") and France ("CC-F").

In this Beam Use Proposal we refine our previous request[8] in response to the unforseen budget issues which resulted in only proton+proton running Run-6, and in light of the availability of significant upgrades to the PHENIX apparatus. The proposed program will provide the first definitive measurement of the low-mass dilepton spectrum at RHIC energies, will greatly extend our understanding of flow phenomena for rare probes, up to and including the J/ψ, and will continue our systematic attack on both single and double spin asymmetries in polarized proton collisions.

2 Status of the PHENIX Experiment

The PHENIX detector has evolved from a partial implementation of only the central arms in Run-1 to a completed installation of the baseline + AEE (Additional Experimental Equipment) systems for Run-3 to a significantly enhanced detector for Runs 4, 5 and 6. A program of strategic upgrades will continue and indeed accelerate this continuing extension of PHENIX's capabilities into Run-7 and beyond.

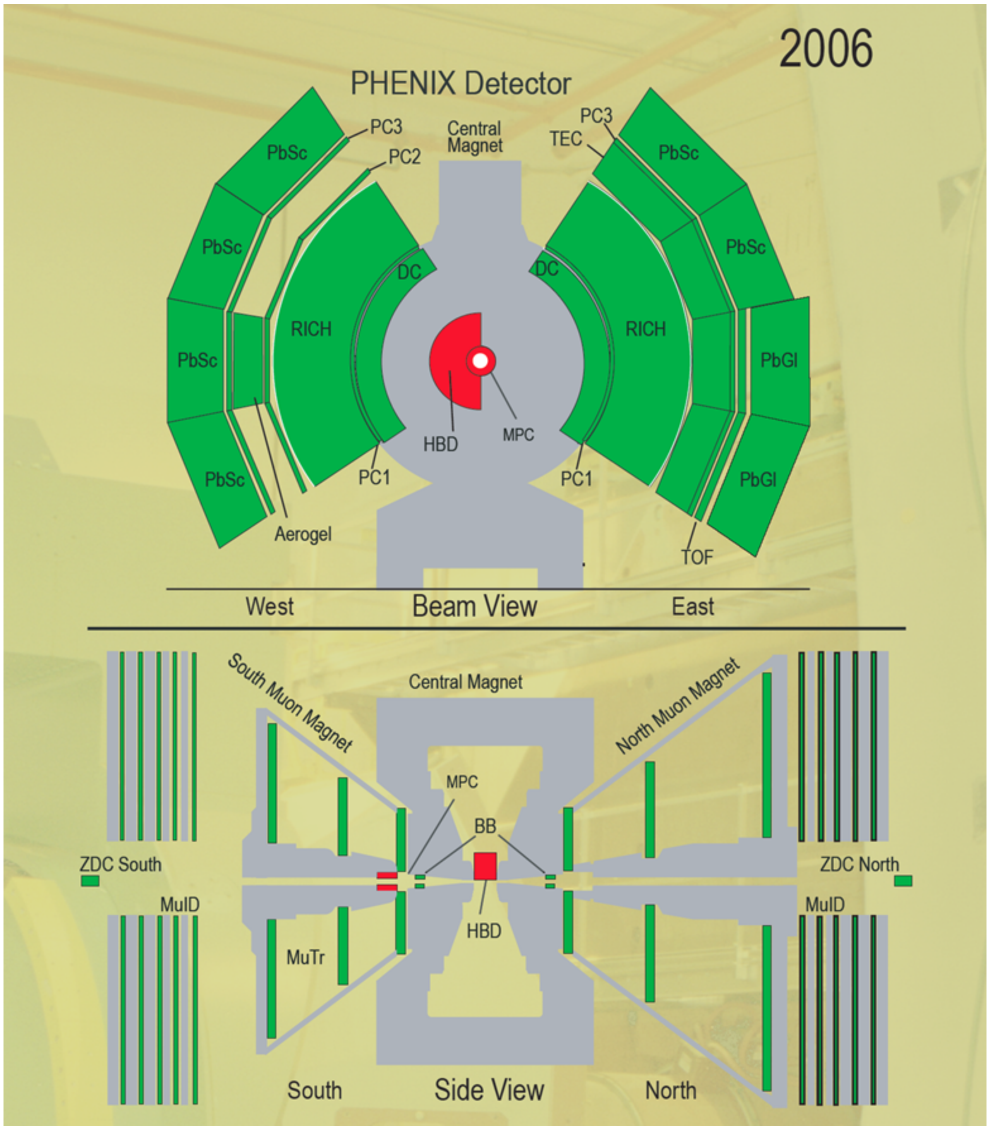


Figure 1: Configuration of PHENIX in Run-6, showing the location of the Hadron Blind Detector (HBD) Prototype and the Muon Piston Calorimeter (MPC).

2.1 Run-6 Additions to PHENIX

Specific improvements to PHENIX in Run-6 included

- A prototype for the Hadron Blind Detector was installed and tested in the PHENIX central aperture (Figure 2).
- The South Muon Piston Calorimeter was installed, commissioned and operated.

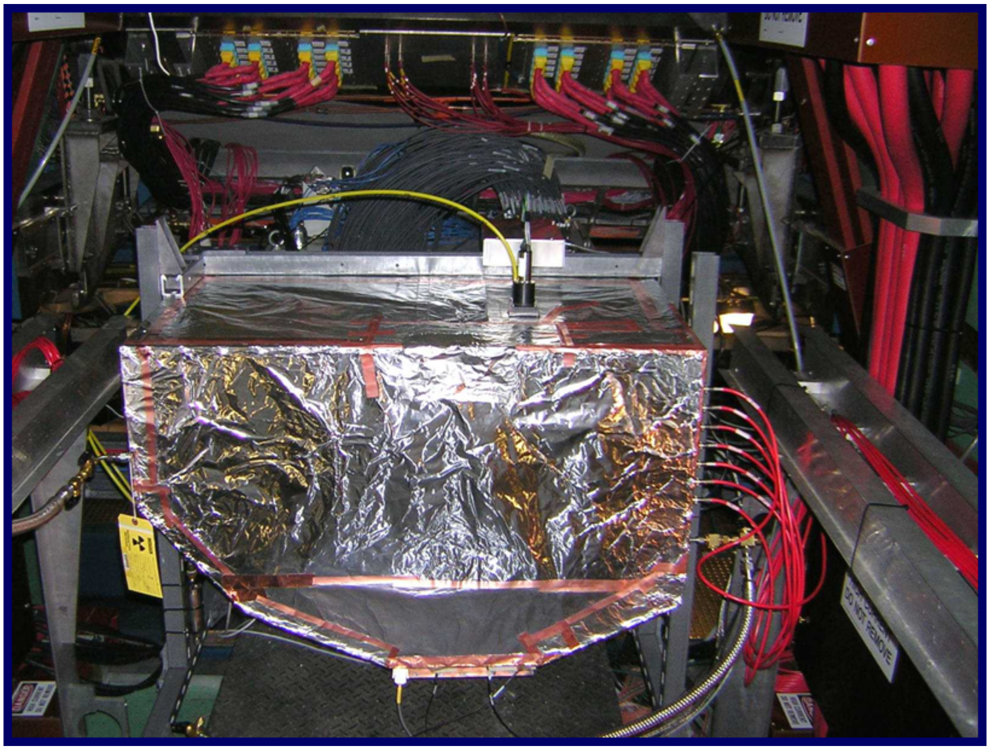


Figure 2: A prototype for the PHENIX Hadron Blind Detector as configured and tested in Run-6.

Clear π^0 peaks were seen, along with an asymmetry in the large x_F region in transversely polarized collisions (Figure 3).

- On-line filtering of Level-2 tags generated during data acquisition to provide events for fast-track analysis streams dedicated to rare probes (Figure 4).

2.2 Run-6 Achievements

In Run-6 PHENIX continued to demonstrate its ability to acquire data at event rates in excess of 5000 events/s while remaining at a livetime of greater than 90%. The dramatic improvement in integrated luminosity and Figure Of Merit over previous polarized proton runs is shown in Figure 5. A detailed accounting is provided in Table 1, which shows the statistics on the total number of events, total archived data volumes, and integrated luminosities achieved by PHENIX in Runs 1 through 6.

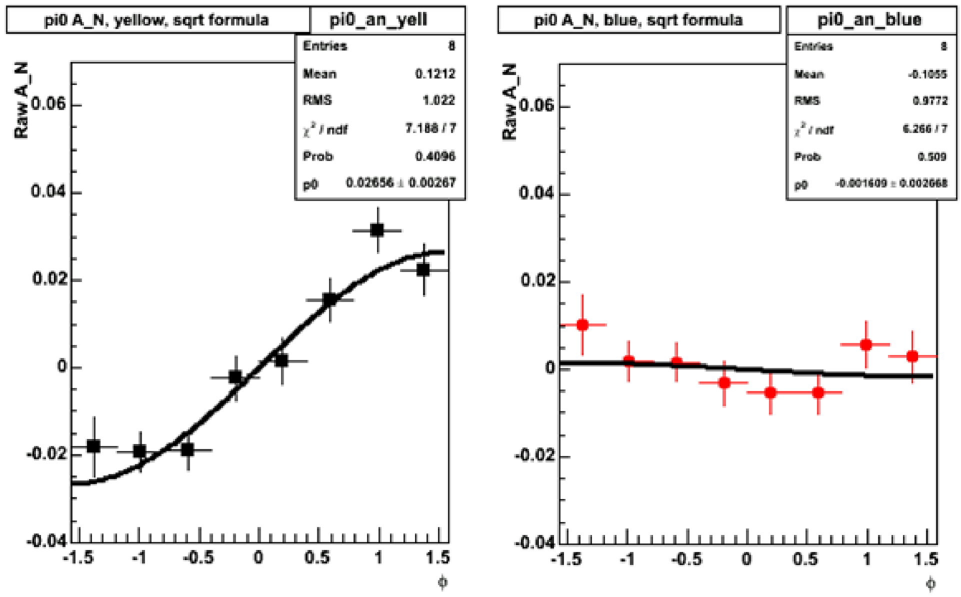


Figure 3: The raw Φ asymmetry observed in the South Muon Piston Calorimeter for transversely polarized collisions in the Yellow beam (left) and the Blue beam (right). Pions incident upon the South MPC corresponds to large positive (negative) x_F for polarization in the Yellow (Blue) beam.

The following should be noted regarding the values shown in Table 1: For each data-set the "*proton+proton equivalent*" "*recorded*" integrated luminosity is given by the corresponding column of the table. For an $A+B$ collision the *proton+proton equivalent* integrated luminosity is given by

$$\int \mathcal{L}\ dt|_{p+pequivalent} \equiv A \cdot B \int \mathcal{L}\ dt|_{A+B} \quad ,$$

which corresponds to the integrated parton+parton luminosity, without taking into account any nuclear enhancement or suppression effects. The *recorded* integrated luminosity is the number of collisions actually examined by PHENIX, as distinguished from the larger value delivered by the RHIC accelerator. For this discussion we focus on the recorded[1] values, in that it is directly proportional to the number of events examined for physics content (the number of equivalent minimum bias events is also listed in Table 1).

[1]Note that in the case of minimum bias data sets, "recorded" is strictly accurate, while for triggered data "sampled" more accurately describes the process. We use "recorded" as shorthand for either case to refer to the number of events examined by PHENIX for a given physics observable.

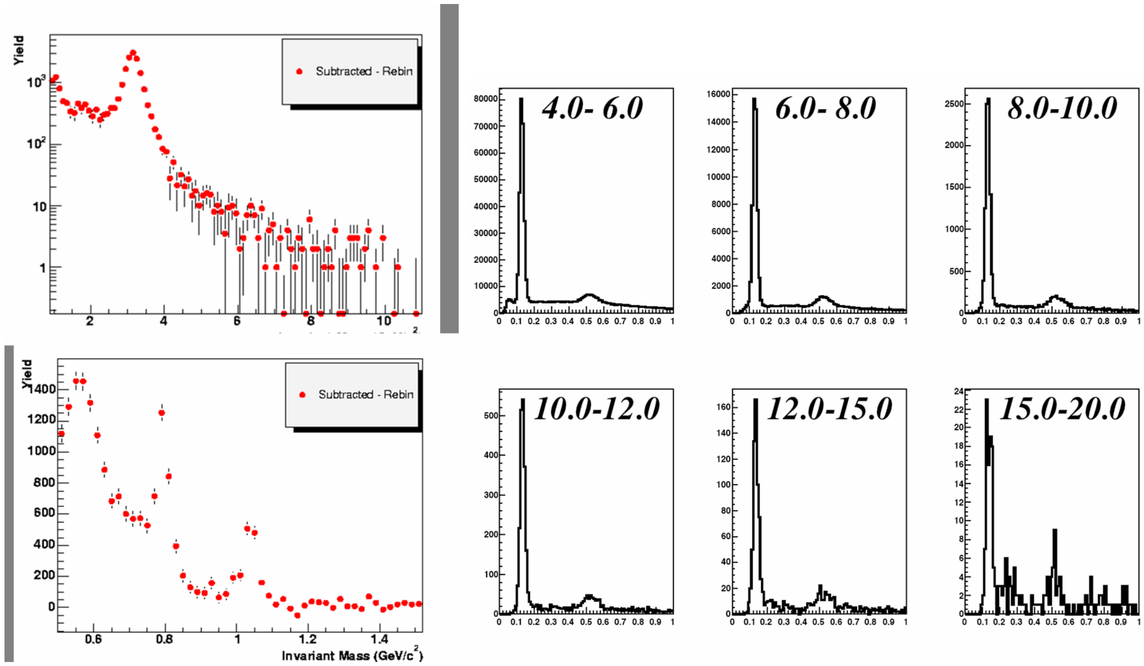


Figure 4: Results from Level-2 filtered data produced in quasi-real time by PHENIX during Run-6. Left Top: Invariant mass spectrum of $\mu^+\mu^-$ pairs in the South Muon Arm. Left Bottom: Invariant mass spectrum of e^+e^- pairs in the Central Arms. Right: Invariant mass spectra of $\gamma\gamma$ pairs for various p_T bins (in-plot label, in GeV/c) in the Central Arms.

2.3 Upgrades in Run-7 and beyond

This Beam Use Proposal is predicated upon the continued systematic implementation of the PHENIX upgrade plan shown in Figure 6. Of particular importance for Run-7 are several major items which will greatly extend PHENIX's capabilities. The following sub-sections discuss each of these in turn.

2.3.1 The Hadron-Blind Detector (HBD)

The HBD is a proximity focused Cerenkov detector insensitive to the vast majority of charged hadrons created in the central rapidity region. In contrast, essentially all electrons from external and internal conversions are detected, which in turn leads to rejection of the majority of pairs that form the combinatoric background in analyses of low-mass e^+e^- pairs. Reduction of this background is of crucial importance in this sector in which

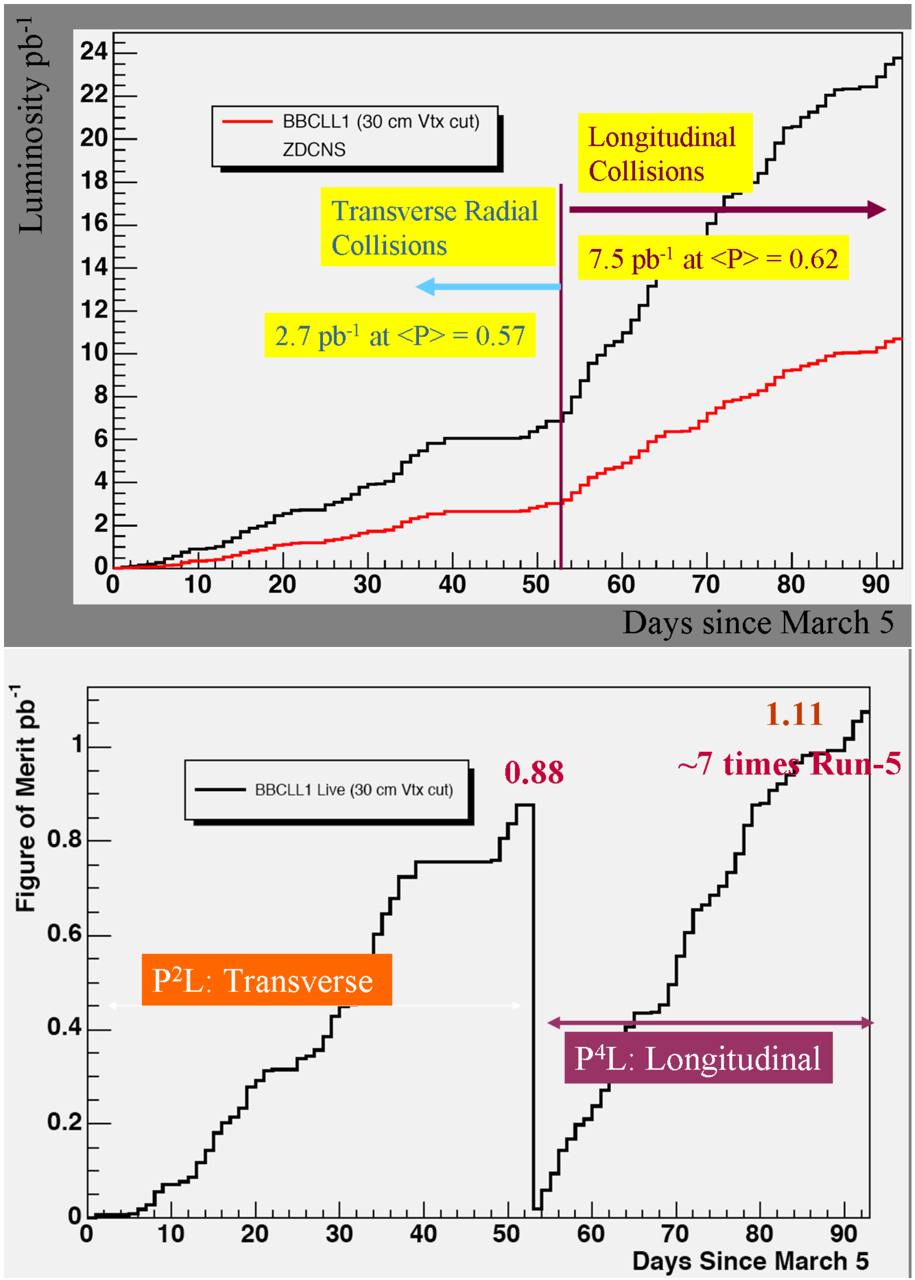


Figure 5: Integrated luminosity versus time recorded by PHENIX in Run-6 (top) and the corresponding Figures Of Merit (bottom).

the signal pairs are sensitive probes of thermal radiation, chiral symmetry restoration and medium modifications to hadron properties. The present result (Figure 7), even when using most of the Run-4 Au+Au data-set, is severely limited by the low signal-to-

Run	Year	Species	$\sqrt{s_{NN}}$ (GeV)	$\int L\ dt$	N_{Tot}	p+p Equivalent	Data Size
01	2000	Au+Au	130	1 μb^{-1}	10M	0.04 pb^{-1}	3 TB
02	2001/2002	Au+Au	200	24 μb^{-1}	170M	1.0 pb^{-1}	10 TB
		p+p	200	0.15 pb^{-1}	3.7G	0.15 pb^{-1}	20 TB
03	2002/2003	d+Au	200	2.74 nb^{-1}	5.5G	1.1 pb^{-1}	46 TB
		p+p	200	0.35 pb^{-1}	6.6G	0.35 pb^{-1}	35 TB
04	2004/2004	Au+Au	200	241 μb^{-1}	1.5G	10.0 pb^{-1}	270 TB
		Au+Au	62.4	9 μb^{-1}	58M	0.36 pb^{-1}	10 TB
		p+p	200	0.35 pb^{-1}	6.6G	0.35 pb^{-1}	35 TB
05	2004/2005	Cu+Cu	200	3 nb^{-1}	8.6G	11.9 pb^{-1}	173 TB
		Cu+Cu	62.4	0.19 nb^{-1}	0.4G	0.8 pb^{-1}	48 TB
		Cu+Cu	22.5	2.7 μb^{-1}	9M	0.01 pb^{-1}	1 TB
		p+p	200	3.8 pb^{-1}	85G	3.8 pb^{-1}	262 TB
06	2006	p+p	200	10.7 pb^{-1}	230G	10.7 pb^{-1}	310 TB
		p+p	62.4	0.1 pb^{-1}	28G	0.1 pb^{-1}	25 TB

Table 1: Summary of the PHENIX data sets acquired in RHIC Runs 1 though 6. All integrated luminosities listed are *recorded* values.

background (S/B) ratio[2]. The HBD will improve this by a factor of ~ 100, which, when combined with the significantly larger size of the requested Run-7 Au+Au sample, will produce a qualitatively new result in this important sector.

2.3.2 The Muon Piston Calorimeter (MPC)

In Run-6, the South MPC was installed; its North Arm counterpart will be installed for Run-7. The two MPC's are slightly different due to geometric constaints: the South MPC consists of 192 PbWO_4 crystals, the North 220 crystals, each read out with avalanche photodiodes and PHENIX EmCal electronics. The MPC's provide high quality calorimetry

[2]Note that the large systematic errors shown in Figure 7 are due to imperfect knowledge of the normalization for the combinatorial background, which in turn results from the small S/B ratio.

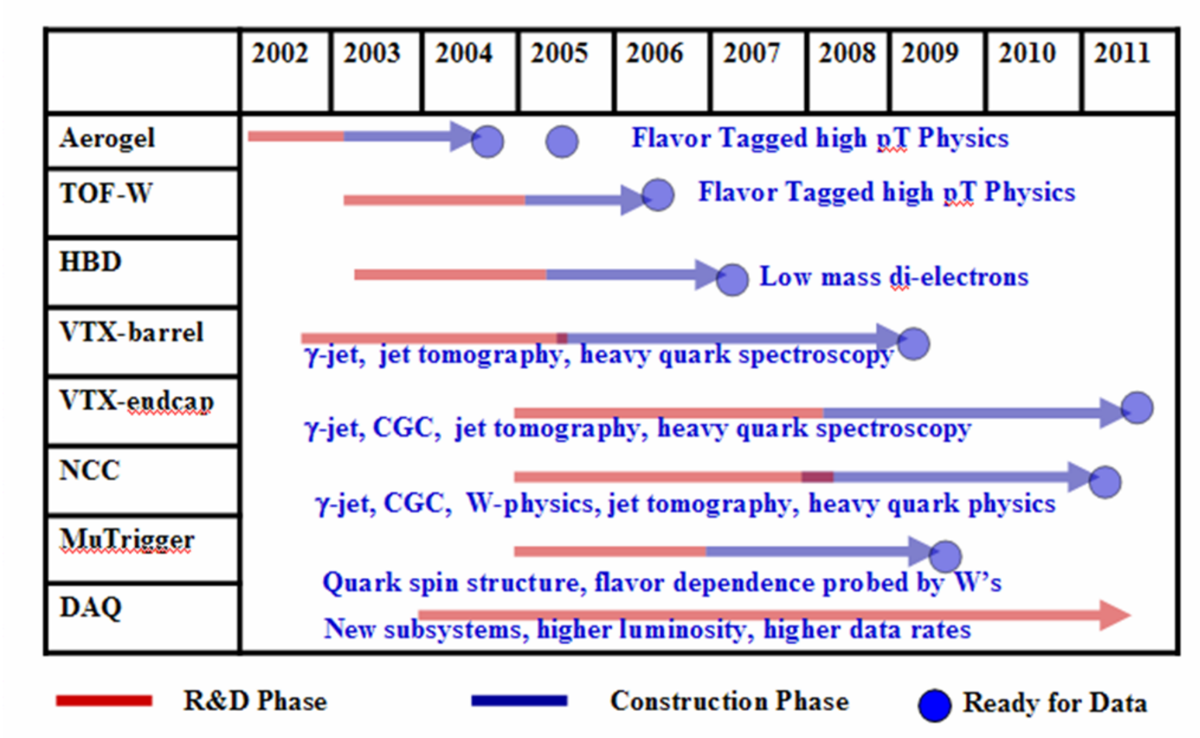


Figure 6: The technically-driven schedule for planned PHENIX upgrades together with physics extensions provided by same.

in the region $3.1 < |\eta| <\sim 3.7$. Figure 8 shows the MPC South as installed in Run-6 and results from an ongoing analysis of MPC data.

2.3.3 The Reaction Plane Detector (RXNP)

In the course of ongoing Run-4 and Run-5 analyses of the reaction-plane dependence of various rare[3] probes, it became clear that the (lack of) reaction plane resolution was a major obstacle. A small group of PHENIX physicists accepted the challenge to develop a subsystem that would overcome these difficulties by measuring the angular dependence of multiplicity in the pseudorapidity region $1 < |\eta| < 3$. The RXNP detector that emerged from that effort is now ready for installation in the PHENIX aperture for Run-7. It consists of 48 scintillators with Pb converters, read out with wavelength-shifting fibers and phototubes into EmCal electronics. Monte Carlo studies indicate that it will improve

[3] This is not the case for particles with abundances sufficient to permit a pair-based correlation function approach to azimuthal flow.

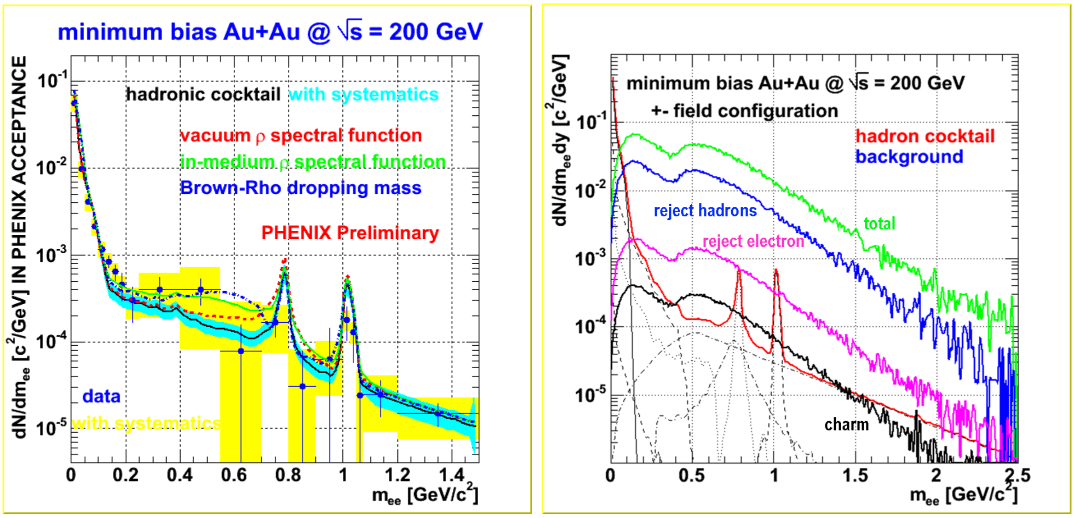


Figure 7: Left-hand plot: The invariant mass spectrum of e^+e^- pairs measured by PHENIX from the Run-4 data-set for Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. Also shown are theoretical calculations[9, 10] using a ρ spectral function without (red) and with (blue and green) in-medium modifications. Right-hand plot: The expected background rejection from the HBD. The background is shown in green, the reduction from "rejection" (blindness" to hadrons is shown in blue, the spectrum after rejection of background electrons and hadrons in shown in magenta. The hadronic "cocktail" of known sources is shown is red; the black line shows the combinatoric background from semileptonic charm decays.

the reaction plane resolution by a factor of two relative to that supplied by the Beam-Beam Counters (see Figure 9), which will provide the same statistical precision with 1/4 the required integrated luminosity.

The rapidity region spanned by the RXNP also makes it very attractive as a trigger counter during low-energy runs, where the reduced width of the pseudorapidity distribution creates inefficiencies for the current trigger based on the Beam-Beam Counters. The possibility of incorporating the RXNP into the Level-1 trigger is under active investigation.

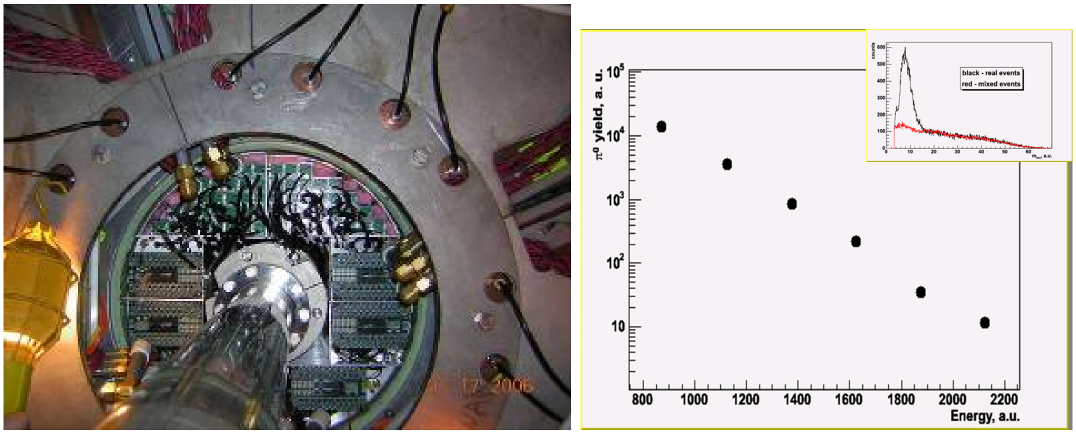


Figure 8: Left-hand figure: The MPC as installed for Run-6 in the “piston” of the South Muon Magnet. Right-hand plot: An energy spectrum (arbitrary units) from the MPC South in Run-6. The inset shows the π^0 invariant mass peak obtained from the MPC.

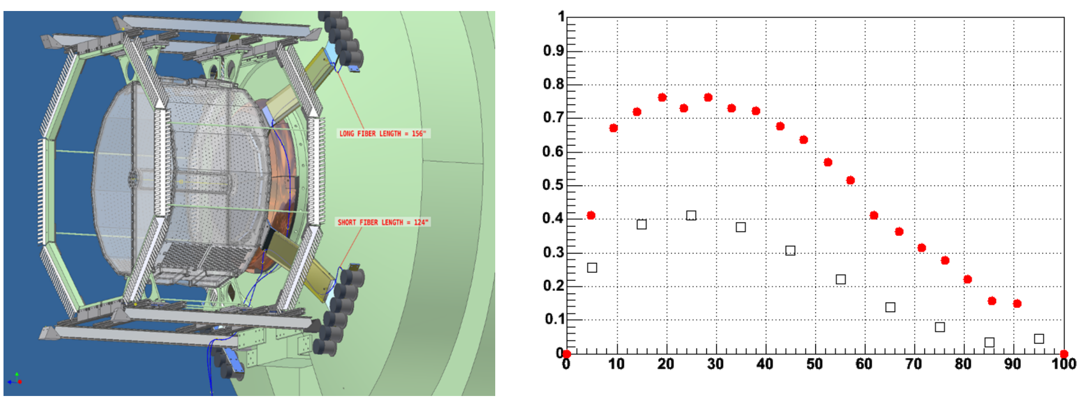


Figure 9: Left-hand figure: The RXNP as located between the HBD and PHENIX Central Magnet pole tip. Right-hand plot: The expected improvement in reaction plane resolution as a function of centrality for the RXNP as compared to the present Beam-Beam Counters.

2.3.4 The Time Of Flight West (TOF-W) detector

The TOF-W is a highly segmented time-of-flight detector using multi-gap resistive plate chambers (MRPC's) and read out with a modification of PHENIX TOF electronics. In conjunction with the Aerogel-based Cerenkov detector already installed, it will provide complete π/K/p separation for p_T up to 10 GeV/c. Of particular interest will be particle identification in the region of the displaced peak observed in the away-side jets in Au+Au collisions[11]. Results from a prototype installed and tested in PHENIX demonstrate

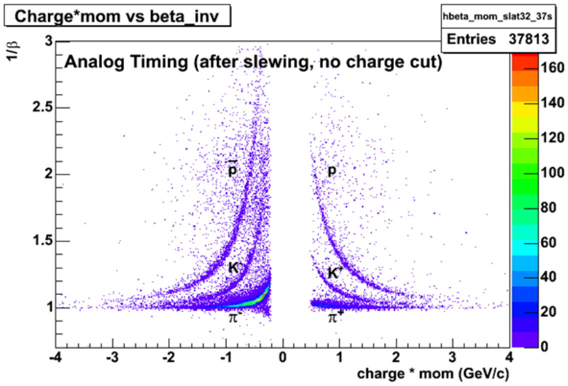


Figure 10: Left-hand figure: The time-of-flight versus charge times momentum as measured by a TOF-W prototype by PHENIX in Run-5. Right-hand photo: Installation of the TOF-W into PHENIX in July, 2006.

that the required timing performance has been met (Figure 10). The system has been mechanically installed in the PHENIX West arm is undergoing cabling and testing in preparation for Run-7.

2.4 Future Upgrades

These recently or soon-to-be installed subsystems are crucial elements of a coordinated, continuing series of planned upgrades to the PHENIX detector designed to improve its sensitivity and to greatly extend its physics reach for both heavy ion and spin physics[12]. As shown in Figure 6, this program also includes

- **VTX**, an inner silicon pixel and strip detector in the central region of PHENIX.
- **FVTX**, a silicon mini-strip detector to cover the muon-arm apertures (prototype funded as a LANL LDRD).
- **Nose-Cone Calorimeter (NCC)**, a Si-W calorimeter replaces the current PHENIX "nose-cones" in the region $0.9 < |\eta| < 3.0$.
- **MuTrigger**, a set of RPC stations that will provide a clean trigger on the highest p_T muons from W decays, and improve the pattern recognition capabilities of the muon spectrometers.

- **DAQ**, a program of ongoing improvements to the PHENIX Data Acquisition system.

The VTX appears in the President's budget for FY07. Both the FVTX and the NCC have been favorably reviewed in BNL-convened outside reviews and declared ready for construction starts in FY08. The MuTrigger has been approved and funded for $1.98M as an MRI by the National Science Foundation. Recently, a proposal for additional improvements to this trigger system to cope with RHIC II luminosities has been approved for JSPS funding to being in JFY07.

2.5 Timing of Near-Term Upgrades

The entire structure of Beam Use Proposal is guided by the carefully structured, ongoing program of upgrades delineated above. In particular, the request is predicated on making all necessary measurements in Au+Au with the HBD in Runs 7, 8 and 9. Following that, the HBD will be removed from its data-taking position (along with the RXNP) in order to install the VTX detector, together with mechanical infrastructure to support the FVTX. Accordingly, we have requested Au+Au, d+Au and p+p collisions at 200 GeV in proportions designed to give roughly equivalent proton+proton luminosities, thereby assuring appropriate baseline and cold nuclear matter measurements for the HBD physics program.

3 Run Planning Assumptions and Methodology

3.1 Input from the Associate Laboratory Director for HENP

The call for Beam Use Proposals from the Interim Associate Laboratory Directory for Nuclear and High Energy Physics requested updates of the previously submitted Beam Use Proposals, in light of the unusual developments surrounding Run-6, and the expanded running time proposed in the President's Budget for FY07. For our planning purposes, we have assumed 25 weeks of *physics running* per year. Naively, this would correspond to 34 cryo weeks per year in the case of two-mode operation, which in principle is consistent with the President's Budget. However, we very much hope that the ever-increasing understanding of RHIC performance can lead to decreased start-up times and further increases in operational efficiency, such that 25 physics weeks per year may be possible in future years in (say) a 31 or 32 cryo week scenario. In particular, we expect this to be the case when species and energies that have previously been run are revisited, as is in the case in much of our request.

3.2 C-A D input

Detailed guidance provided by the Collider-Accelerator Department (C-A D) describes the projected year-by-year luminosities for various species, along with the expected time-development of luminosity in a given running period[13]. Here we briefly summarize the parameters most relevant to our planning process:

3.2.1 Overheads

- **Cool-down**: 1.5 weeks
- **Warm-up**: 0.5 weeks
- **Set-up**:
  - 1.5 weeks $\equiv$ time required to set-up machine for a given species.
  - 0.5-1.0 additional weeks in the case of polarized protons

- **Ramp-up**:
  - 1 weeks ≡ time required to achieve stable operations with useful (initial) luminosities.
  - 1 week required in the case of a second mode in same run-year
- **Condition Changes**:
  - 2-3 days required to achieve stable operations at a lower energy for a given species.
  - 1-2 days required to change polarization orientation

Then, as detailed in the supplied guidance[13], 30 weeks of cryogenic operations translates into 22.5 weeks of physics running in the case of two modes, one of them polarized protons.

For PHENIX planning purposes, we have assumed sufficient cryo weeks in FY07-FY09 to supply 25 weeks of physics running each year. Nominally, this translates into 32.5 weeks of cryogenic operation, albeit with somewhat generous set-up times, i.e., we believe these are conservative estimates for translating cryo weeks into physics weeks.

3.2.2 Luminosity Development

Perhaps the single most important piece of guidance from C-A D regarding luminosity development is their emphatic statement *"To reach the luminosities projected in the Research Plan for Spin Physics at RHIC[14] it is necessary to have a long polarized proton run in every year."* While we did consider in some detail alternative plans that did not incorporate a yearly run with polarized protons, we could not demonstrate with reasonable confidence that our ambitious goals for spin observables could be met without the annual opportunity to further develop luminosity and polarization.

The now rather extensive experience with operating RHIC in a variety of modes and in understanding luminosity limitations provides some confidence in the projected minimum luminosities, which are based on either actual experience or achieving the same charge per bunch as for Au beams. Maximum projected luminosities were also provided, based on current understanding of the accelerator limits. The dynamic range between minimum and maximum values is considerably smaller than in past years, due to increased experience with actual operating parameters and increased understanding of intrinsic limits. In either case, a “4 week linear growth” model was applied to model the time development of the initial luminosity value achieved at the end of “ramp-up” to the final value. Guidance was also provided for anticipated year-by-year growth of the maximum luminosity which would result from various planned improvements in accelerator operations.

The specific assumptions regarding the luminosity for a given species will be detailed in the individual subsections of Section 4 that follow. In general, we will adhere to our previous methodology of using the geometric mean of the minimum and maximum projected luminosities, except in those cases where we believe (based on documented C-AD performance) that this results in an overly conservative estimate. A specific instance where a different methodology is used is in estimating the delivered luminosity for polarized protons. Here we have adopted the assumption of 70% of the C-AD maximum, in order to be consistent with the projections found in the Spin Research Plan[14] that was submitted to DOE in February, 2005. In either case, delivered luminosities are converted to PHENIX-recorded luminosity assuming a PHENIX integrated live-time from all sources of 60%, and that 70% of the delivered luminosity will satisfy our vertex requirement of $|z| < 30$ cm.

4 Beam Use Proposal for Runs 7 and Beyond

4.1 General Considerations

Some general considerations concerning the RHIC program guided the development of our request. Chief among these is the desire to maintain the program of discovery physics that has attracted world-wide attention to the RHIC heavy ion program, *while maintaining* the progress in both polarized proton performance and in the spin physics program. Therefore we assume that, absent compelling arguments for investigating new systems and species, resources are best utilized by

- Continued enrichment of existing data sets that are statistically sparse in essential physics channels (accepting that this may in fact require accumulation of data over multi-year periods)
- Continued development of luminosity and polarization to stay on schedule for development of the same necessary for decisive measurements with polarized protons.
- **Completing** surveys by securing requisite baseline data in a timely fashion, so that comparison data sets are obtained with essentially the same detector configuration.

Table 2: The PHENIX Beam Use Proposal for Runs 7-10.

RUN	**SPECIES**	$\sqrt{s_{NN}}$ **(GeV)**	**PHYSICS WEEKS**	$\int \mathcal{L}dt$ **(recorded)**	**p+p Equivalent**
7	Au+Au	200	15	1.1 nb^{-1}	44 pb^{-1}
	p+p	200	10	32 pb^{-1}	32 pb^{-1}
8	d+Au	200	15	58 nb^{-1}	23 pb^{-1}
	p+p	200	10	52 pb^{-1}	52 pb^{-1}
9	Au+Au	TBD	25-M		
	p+p	500	M		
10	A+A?	200	25-N		
	p+p	500	N		
11	U+U?	200	25-X		
	p+p	500	X		

4.2 Executive Summary

Table 2 summarizes the current PHENIX Beam Use Proposal. This plan incorporates the major features from our previous request[8]:

- Au+Au running at $\sqrt{s_{NN}} = 200$ GeV to significantly advance the statistical precision and physics reach of our existing Run-4 data set.
- A period of polarized proton running with transverse (radial) polarization, to perform a measurement of the gluon Sivers function.
- Continued development of polarized proton luminosity and polarization leading to a sensitive measurement of the gluon polarization of the proton via 200 (and 500) GeV p+p collisions.
- A d+Au run, again to take advantage of significant advances in luminosity and data acquisition throughput to refine our knowledge of this essential baseline system by more than an order-of-magnitude in integrated luminosity.

In particular, we emphasize the request returns to the system that was deferred from Run-6 due to the unusual scheduling and budgetary exigencies: high statistics Au+Au at 200 GeV. The identical arguments for the importance of this measurement that were made in the previous Beam Use Proposal continue to apply, now augmented by two important additions to the PHENIX apparatus:

1. The Reaction Plane detector, which improves our resolution on the reaction plane by a factor of two, thereby making possible critical new measurements (e.g., the flow of J/ψ 's)
2. The Hadron Blind Detector, which permits high sensitivity measurements of low-mass dileptons with a precision greatly exceeding our previous background-limited results.

4.3 Discussion

The proposed plan emphasizes increasing the statistical reach of existing data-sets by one (Au+Au) to two (polarized protons) orders-of-magnitude, through the year-by-year accumulation of data, coupled with (ongoing) advances in accelerator performance and (existing) improvements to the PHENIX triggering and data acquisition systems. In particular, it should be noted that PHENIX's ability to archive Au+Au events has been increased by a factor of 3-5 from its already impressive capabilities demonstrated in Run-4.

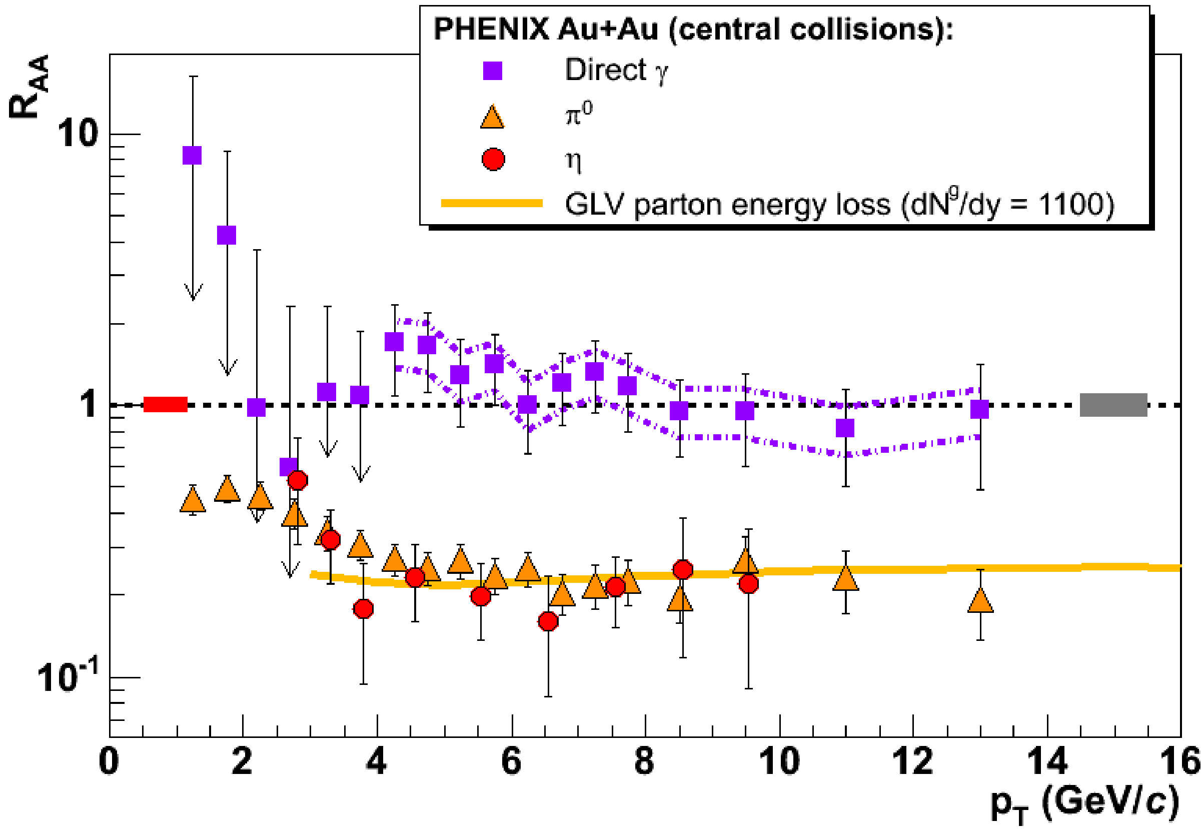


Figure 11: The nuclear suppression factor R_{AA} measured in $\sqrt{s_{NN}} = 200$ GeV central Au+Au collisions for π^0's, η's and direct photons[15]. The red and gray bands at $R_{AA} = 1$ represent the systematic error on the number of binary collisions and on the p+p reference spectrum, respectively.

That such a strategy is warranted for the heavy ion program may be seen by examining the PHENIX published data[15] on the nuclear modification factors for direct photons, π^0's and η's shown in Figure 11 or our preliminary result on heavy flavor flow (Figure 12). While these results are derived using the full Run-4 data set for full energy Au+Au collisions, over substantial regions of interest the statistical errors substantially exceed the systematic errors. Correspondingly, the ability to address fundamental questions (e.g., does the flow extend to bottom quarks?) is limited by the statistical reach of the existing data sets. Additional crucial rare event physics that we have yet to address

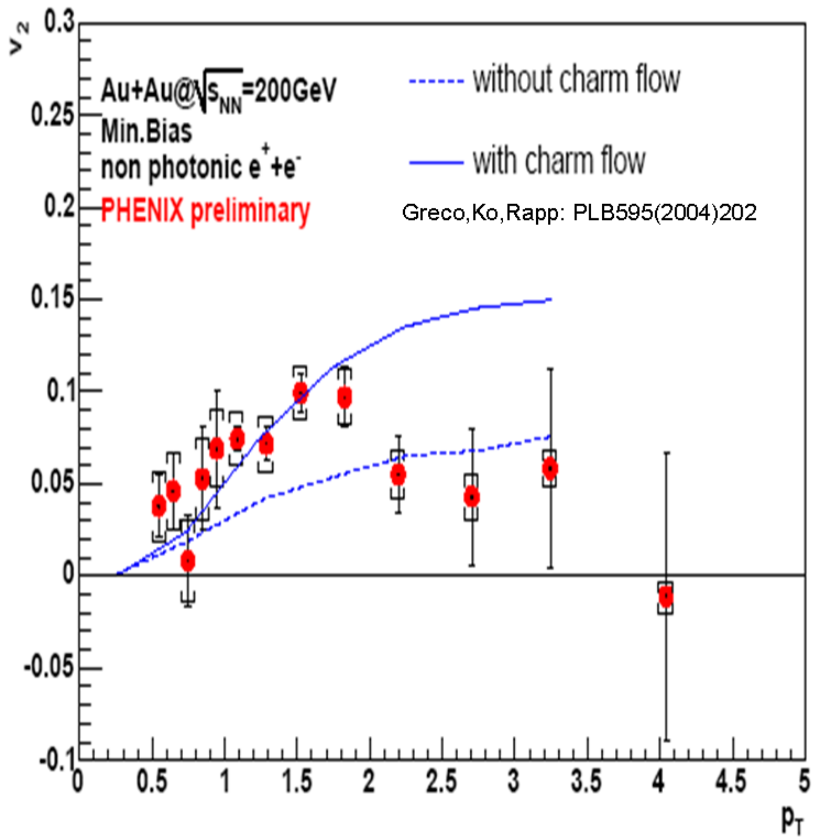


Figure 12: Preliminary results on the elliptic flow coefficient v_2 for single electrons as a function of transverse momentum from central Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Systematic errors are represented by the square brackets on each point.

include the flow of J/ψ 's (perhaps a critical test of regeneration mechanisms), photon+jet measurements, direct photon flow (again, which may be a critical test for QGP-induced bremsstrahlung and/or conversion mechanisms) and 3-particle jet correlations.

While there is great value to be derived from the multi-year planning process, we are also aware of the intrinsic limitations when such plans are confronted with ongoing discovery physics. Accordingly, we have left the energy for the Au+Au segment of Run-9 in Table 2 as "TBD" (To Be Determined). It is expected that this some fraction of this running will be at lower energies, with the precise allocation depending on results from our analysis of the Run-7 data set and on C-A D progress in establishing collisions at low-energy. As always, the decision will be made by the standard PHENIX practice of discussion in the Executive Council, based on input from the Physics Working Groups.

The particular sequence of Au+Au in Run-7, d+Au in Run-8 and Au+Au in Run-9 is motivated by and coordinated with the program of upgrades delineated in Figure 6. In particular, this three-year segment will provide robust data-sets in Au+Au, d+Au and p+p collisions for the low-mass dilepton physics made possible by the HBD. It was worth noting that upon completion of the 200 GeV polarized proton, this plan will achieve comparable sensitivity in terms of the p+p equivalent integrated luminosity for Au+Au, d+Au and p+p collisions, thereby assuring adequate baseline data for the heavy ion program as well as achieving our goals for spin measurements at this energy.

5 Detailed Remarks

This section provides specific remarks for the various components of our plan.

5.1 Run-7

In this section we present the PHENIX Beam Use Proposal for Run-7.

5.1.1 15 weeks Au+Au at $\sqrt{s_{NN}}$=200 GeV

The geometric mean of the minimum and maximum C-AD guidance for Au+Au running at $\sqrt{s_{NN}} = 200$ GeV corresponds to 215 μb^{-1} per week of delivered luminosity. Allowing for a 4 week ramp to this value, 15 weeks of running corresponds to 2800 μb^{-1} delivered, and 1200 μb^{-1} recorded, which represents a factor of 4-5 increase over our Run-4 data set for this system.

Trigger Strategy: PHENIX has developed the ability to process and archive data at a rate of 5 kHz. We estimate that at the luminosity projected by C-A D for Run-7 this will allow, averaged over a store, ∼75-80% of all Au+Au collisions to be archived as minimum bias events. This is extremely important to our physics program, because it leads to very large yields of crucial signals that are essentially impossible to trigger on in Au+Au collisions, at almost no cost to the rare probes measurements.

Examples of measurements that benefit greatly from this ability are:

- Single muons
- Light vector mesons decaying to either di-electrons or hadrons.
- Low mass di-electron (or di-muon) continuum physics.
- Low and intermediate p_T photons.
- Charged hadrons with particle identification (particularly important when performing jet correlations).

The value of this strategy is already apparent from our Run-4 Au+Au data-set, in that we have presented preliminary results for observables in all of these channels. Very importantly, in Run-7 the low mass di-electron measurements enabled by the new HBD detector will be able to use essentially the full luminosity available to PHENIX.

Representative Measurements

Here we present some indications of the additional physics reach expected from this data set in conjunction with the upgraded PHENIX apparatus.

Suppression Studies: While the ultimate insights into transport phenomena in the nuclear medium will be derived from "tomographic" studies (e.g., $R_{AA}^{\pi^0}(p_T)$ as a function of angle with respect to the reaction plane, greatly improved via the new RXNP), the added physics reach of the requested data set is valuable even for "traditional" studies of the nuclear suppression factor. For example, Horowitz and co-workers[16] argue that considerable sensitivity can be derived through more careful theoretical treatment of the nuclear geometry and its fluctuations. As demonstrated in Figure 13, factor of two variations in the initial gluon density can be resolved through improved experiment precision in the region $p_T > 15$ GeV/c. That this is possible is shown in Figure 14, which illustrates the improvement in p_T reach and statistical precision expected from the requested Run-7 Au+Au sample.

Flow Studies: As mentioned above, detailed tomography will result from the combined effects of the additional statistics from Run-7 together with the improved reaction plane resolution. This is shown in Figure 15, showing the significant extension in p_T reach for such studies. A particular benefactor from the improved resolution on the reaction plane

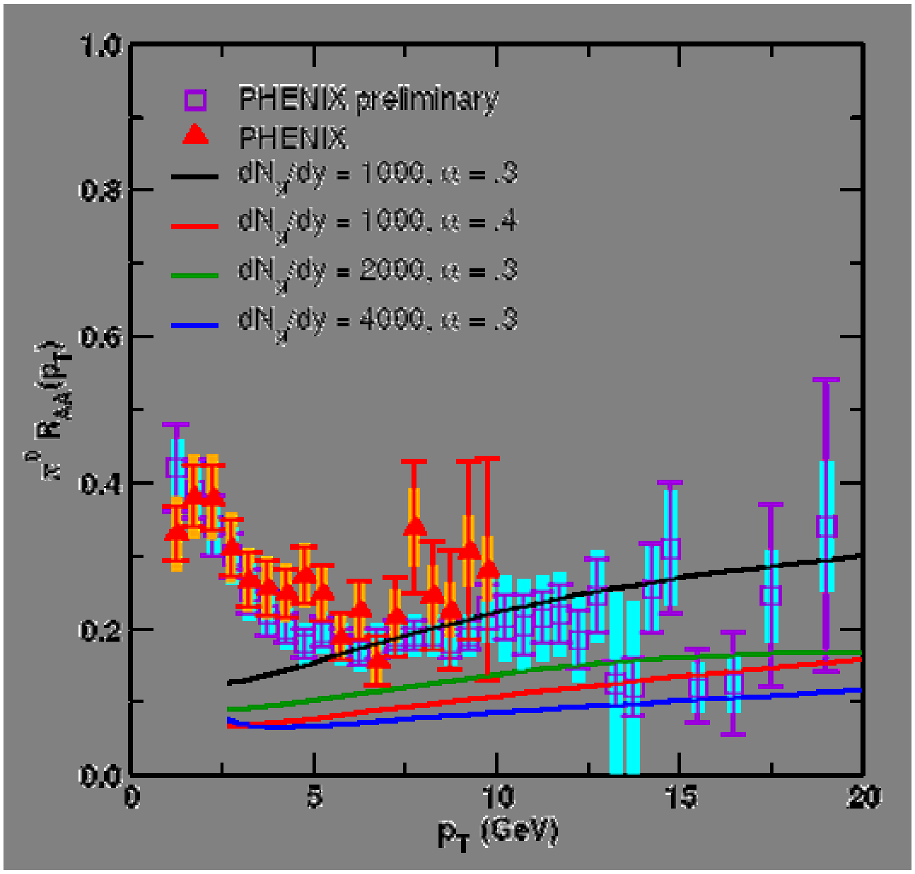
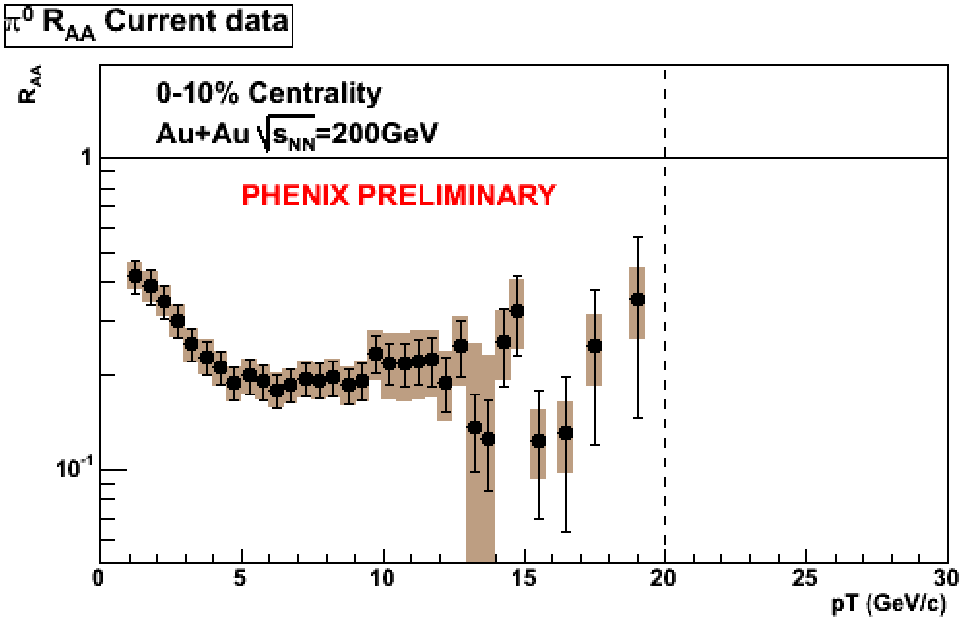


Figure 13: The nuclear suppression factor $R^{\pi^0}_{AA}(p_T)$ from PHENIX published[17] and preliminary data is compared with calculations[16] of same for varying values of the initial gluon density dN_g/dy and the QCD coupling constant α.

is the study of J/ψ flow. Current internal studies in PHENIX using the Run-4 data set do not allow determination of the sign of v_2, even when integrated over large p_T intervals. The expected factor of two improvement on reaction plane resolution, coupled with the factor of four or more in integrated luminosity should suffice to overcome these current limitations.

5.1.2 10 weeks polarized p+p at 200 GeV

Based on the Collider-Accelerator Department guidance for Run-7 luminosity[13], we assume the following figures on luminosity and polarization for the above request.



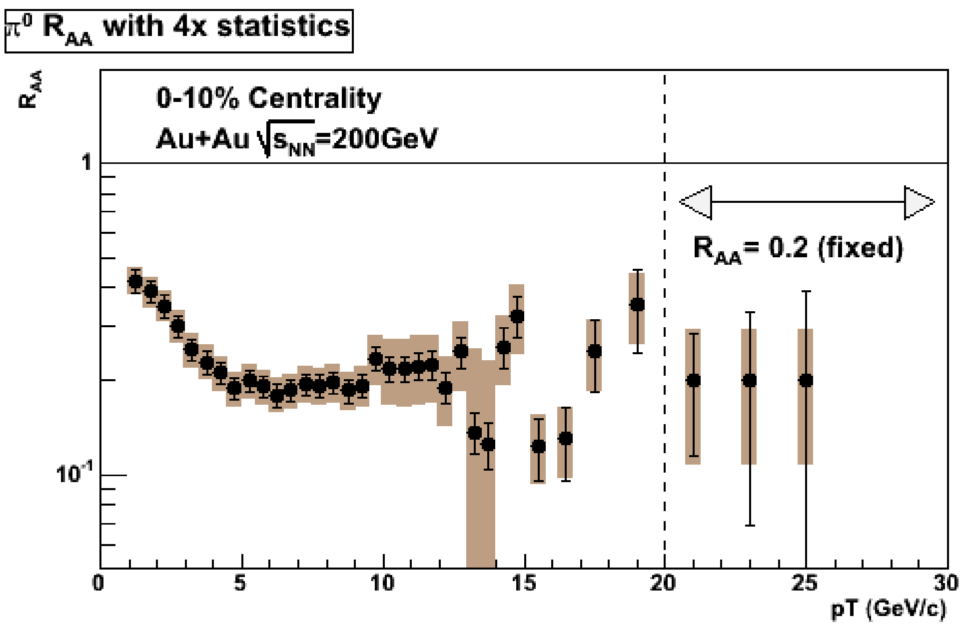


Figure 14: The PHENIX Preliminary nuclear suppression factor $R_{AA}^{\pi^0}(p_T)$ from Run-4 (top plot) is compared to the improved precision and p_T reach made possible by the requested Run-7 Au+Au run (bottom plot).

- The estimate for the delivered (integrated) luminosity ranges from 40 pb^{-1} to 100 pb^{-1} for 10 weeks. We use 80 pb^{-1} in this proposal. This is consistent with the "70% of maximum" methodology used in the RHIC spin plan applied to the maximum estimate of 14 pb^{-1} per week.

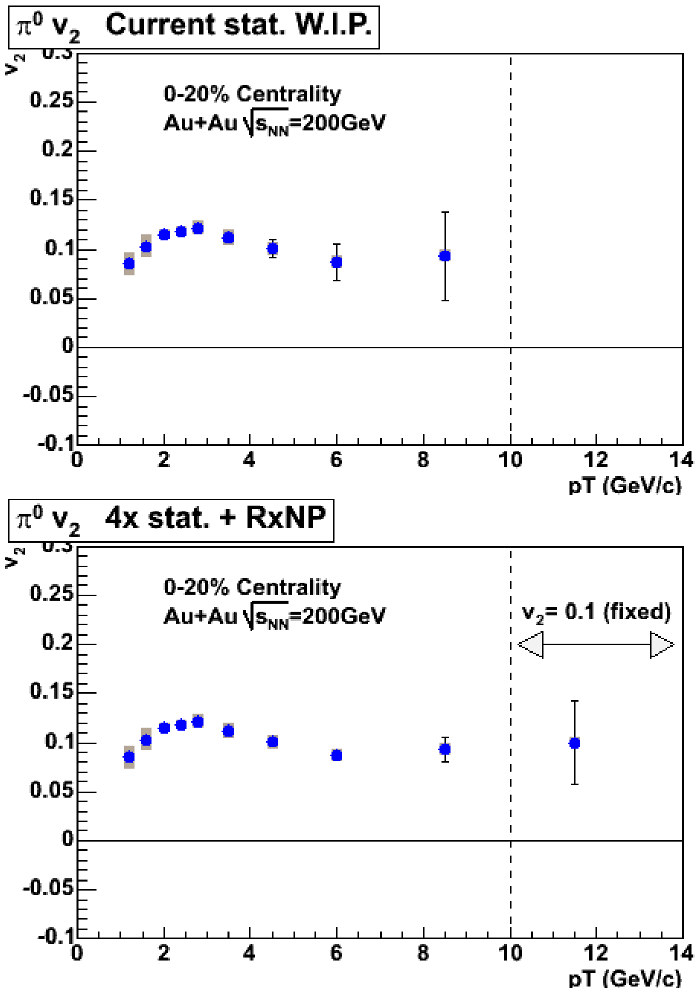


Figure 15: The PHENIX "Work In Progress" result for the elliptic flow coefficient $v_2(p_T)$ for π^0's measured in $\sqrt{s_{NN}} = 200$ GeV Au+Au collisions (top plot) compared to the improvements from the RxNP and increased data sample from the requested Run-7 Au+Au run.

- Applying the standard factors for data-taking efficiency and vertex cuts leads to 32 pb^{-1} recorded.
- The proposed breakdown of Run-7 32 pb^{-1} is: ~ 6 pb^{-1} transverse and ~ 26 pb^{-1} longitudinal. The ratio of these two is somewhat different from that of the running time due to the assumed ramp-up from the initial luminosity. To be conservative, most of the physics projections supplied below use 20 pb^{-1} and 5 pb^{-1} for the transverse and longitudinal segments, respectively.
- We assume 65% polarization, again as per the supplied guidance.

2.5 Weeks of Transverse Polarization

Transverse spin physics is an integral part of the RHIC spin program. With transverse polarization in RHIC we aim to measure transversity distributions and the Sivers function in a short but dedicated times taken out of the spin operations time. The cleanest channels for these two measurements are:

- A_T for interference fragmentation function
- A_N for back to back di-hadrons produced in p+p collisions

The quark transversity distribution function is the last leading twist distribution function in the nucleon. As it is chiral-odd it has not been measured so far. In p+p transversity can be accessed in combination with either the Collins fragmentation function or the interference fragmentation function. The access over the Collins function requires a good jet reconstruction and will only be available after further upgrades. The transversity measurement over the interference function is already feasible with Run-7 for PHENIX since it only requires the detection of two pions of different charge. The Belle experiment has measured the Collins function[18] and measurements for the Interference fragmentation function can be expected in time for the Run-7 measurements. The HERMES measurements already suggest a sizeable Interference fragmentation function[19].

Another fascinating aspect of transverse spin physics has resulted from increased theoretical understanding[20] of single spin asymmetries in deep inelastic scattering measurements, and by the discovery by STAR of their persistence at RHIC energies[21]. Boer and Vogelsang have proposed that a sensitive measurement of the gluon Sivers function could be obtained via azimuthal correlations of jets produced in collisions of transversely polarized protons with unpolarized protons[22]. The effect, which would manifest itself as a non-zero value of A_N for such correlations, is proportional to the T-odd quantity $\vec{S}_T \cdot (\vec{P} \times \vec{k}_T)$, which naively was thought to vanish prior to the discovery by Brodsky, Hwang and Schmidt[20] of the essential role of final-state interactions from gluon exchange between the outgoing quark and the spectators. This quantity is at the center of intense theoretical debate focusing on transverse spin phenomena in QCD and on related questions of factorization and the universality of distribution and fragmentation functions in hard-scattering processes. Sivers distributions play a key role in gaining first insight in the origin of transverse spin phenomena in QCD processes.

As in the case of ΔG, the transverse spin measurements are multi-year measurements when the luminosities are low, but the recently finished Run-6 and the anticipated 6 pb^{-1} from Run-7 would be sufficient to provide a high impact statement from PHENIX in the field of transverse physics.

We took in Run-6 a limited amount of data for the back-to-back di-pion correlations, which has direct connections to the Sivers distribution function in transverse spin dynamics of the partons. While this was the first exploratory measurement, additional transverse spin data recorded in Run-7 for transversity measurements would also automatically improve up this measurement due to the Muon Piston Calorimeters. With these detectors the need to run radial transverse for the Sivers function measurement so as to maximize the di-pion acceptance into PHENIX's central East and West spectrometer is no longer necessary. As such the A_T for transversity and A_N for Sivers can be performed simultaneously.

Our sensitivity for neutral pion A_N in the central arm from Run-7 is shown in Figure 16. The Run-5 data sample which we already have on tape will put a significant constraint on the gluon Sivers function in the central rapidity. But this will be *further* improved by Run-6 and 7 data. In Run-7 the two MPC's will be fully functional and operational in the range $3.1 < |\eta| <\sim 3.7$. This detector has recently shown its first asymmetries using the inclusive neutral pions (see Figure 3). Detailed calibration of the energy scale and understanding of the detector operations is in progress. In Run-7 the MPC promises to be a very significant detector for all transverse spin measurements.

It is pointed out by Boer and Vogelsang that gluon Sivers function can be measured by observing back-to-back jets[22]. In PHENIX we measure A_N of back-to-back two hadrons instead of jets. We have enough sensitivity to observe a non-zero A_N if the Sivers function is large, as shown in Fig.17. This will be a significant increment in our statistical errors expected from Run-6.

7.5 Weeks with Longitudinal Polarization

Determination of polarized gluon distribution is of paramount importance to the RHIC spin program. The DOE milestone for this goal is 2008[4]. PHENIX plans to accomplish

[4]While it is not explicit as to what it means to achieve this milestone, the proposed operations schedule in the RHIC Spin Research Plan[14] will certainly accomplish this as will be discussed later in this document and shown in Figure 19. Considering the data production and analysis times, only the data from Run-7, and not from Run-8 or 9 would be available for achieving the DOE milestone.

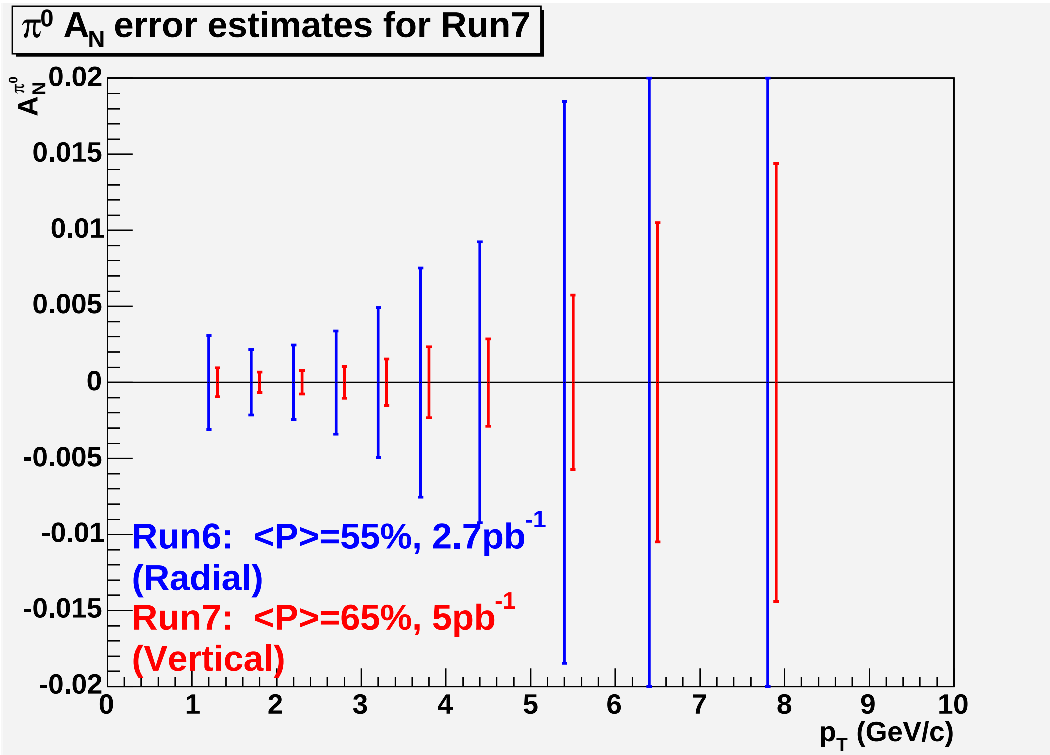


Figure 16: Projected $A_N^{\pi^0}$ measurement in Run-6 and 7 in the central rapidity assuming our known analysis cut losses and beam polarization direction. Run-6 was estimated for radial transverse operation, while the Run-7 are shown assuming vertical transverse collisions at PHENIX.

this using two main physics channels:

- $\vec{p} + \vec{p} \to \pi^0 + X$ and
- $\vec{p} + \vec{p} \to \gamma + X$

PHENIX has already published the Run-3 and Run-4 results[23, 24] for $A_{LL}(\pi^0)$, and has an order-of-magnitude large data set in the final stages of analysis from Run-5. However, all spin observables to date are luminosity-starved. This is illustrated in Figure 18 which shows the Run-5, 6, (5+6) and possible Run-7 statistical uncertainties plotted for the range of p_T values published by PHENIX to date. The Run-5 and Run-6 uncertainties correspond to the full statistical samples including the known analysis cut

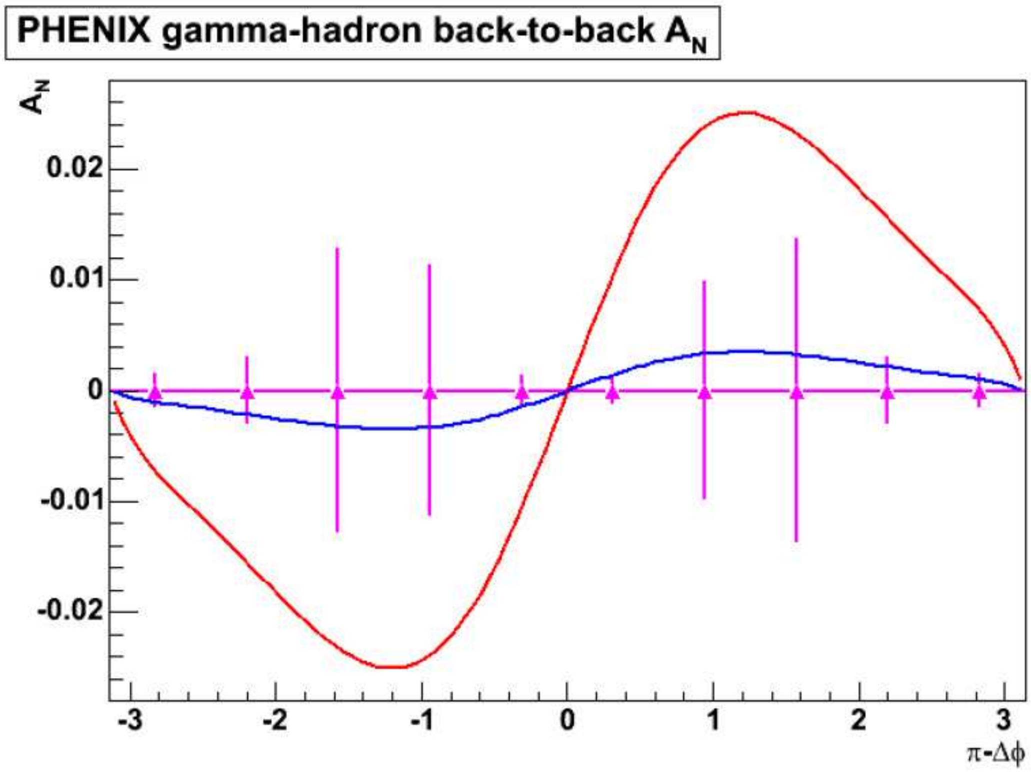


Figure 17: Expected sensitivity of A_N of back-to-back π^0-hadron pairs in the central arm. The theory lines are the maximal (red) and minimal (blue) A_N cited in Ref. [22], corresponding to estimates where the magnitude of the gluon Sivers function is equal to a parametrization of the d-quark Sivers distribution from E704 A_N or to a case where the gluon Sivers function is identically zero, respectively.

efficiencies (as determined from Run-5 data analysis experience). Also shown are various theoretical curves for A_{LL} vs. p_T calculated from the best fit (GRVS-std) at Next-to-Leadg-Order (NLO) to the Deep Inelastic Scattering (DIS) data available in 2004 and a set of model dependent assumptions (extreme scenarios) for the value of Δg at input scales (GRVX-max, Δg = 0 and Δg = -g) [26]. The best fit in this exercise corresponds to $\Delta g = 0.4$ at a $Q^2 = 1$ GeV^2.

Figure 19 shows the possible error bars for 3, 2 and 1 σ (blue, red and black, respectively) defined in a χ^2 sense, achievable in Run-5, 6, 7 and Run-8, respectively. This plot is a summary of several χ^2 vs. Δg plots made using theoretical calculations (see explana-

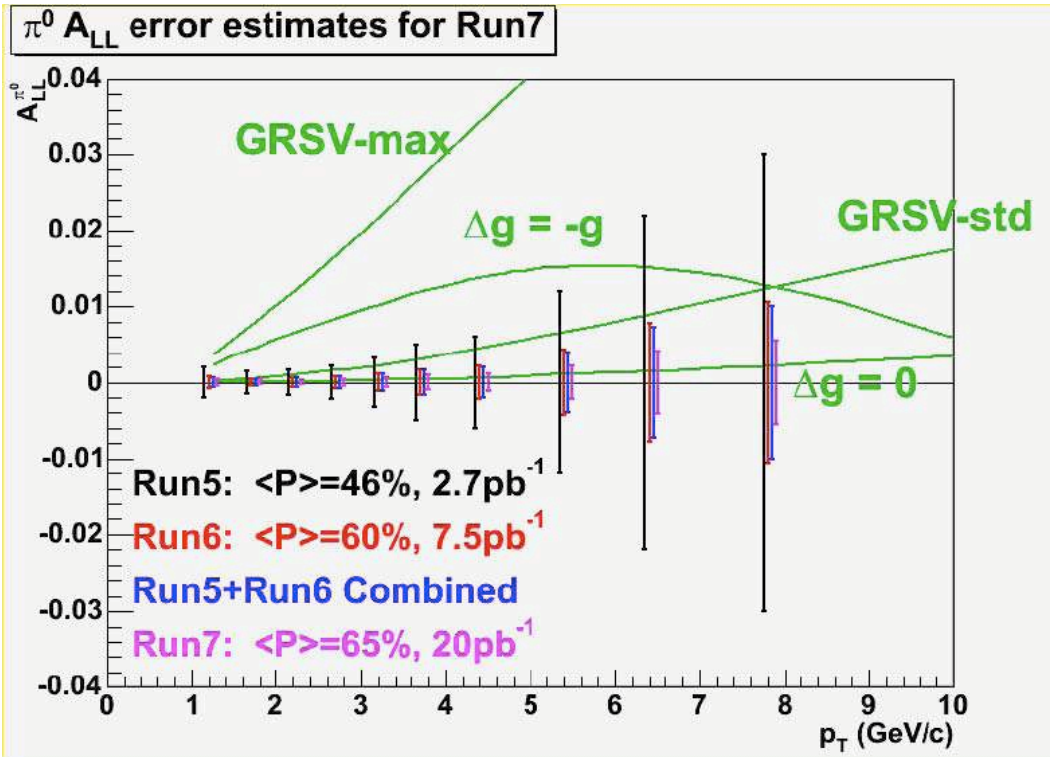


Figure 18: Projected $A_{LL}^{\pi^0}$ measurement in Run-7. For comparison, estimations for previous measurements, including the recently finished Run-6 and the analyzed data set from Run-5 have been shown. The reduction of about 15% statistical sample due to analysis cuts has been applied to the Run-7 data set based on our knowledge of these from Run-5. Various scenarios of ΔG based on GRSV fits[25] and their assumptions[26] are shown in green.

tion below) and statistical uncertainty estimates corresponding to Run-5, 6, 7 and Run-8. These uncertainty bars (corresponding to the 1,2 & 3-σ χ^2 uncertainty were calculated using the following method: On our request W. Vogelsang and M. Stratmann, provided us with a set of curves which were re-fits to the DIS data, each with a fixed value of Δg in the range $\Delta g = -g$ to $\Delta g = g$ (max). The PHENIX Run-5 results were then compared to these set of different theoretical curves to evaluate the χ^2 and thus determine a $\chi^2_{\min}$ and a corresponding Δg and the corresponding 3, 2 and 1-σ statistical uncertainties from a χ^2 vs. Δg plot. Keeping the central value of Δg the same, the exercise was repeated for Run-6, 7 and 8. The statistical uncertainties obtained from this exercise are plotted in the Fig. 19 at positions $\sigma_{A_{LL}}(Run5)/\sigma_{A_{LL}} = 2$, 4 and 10.

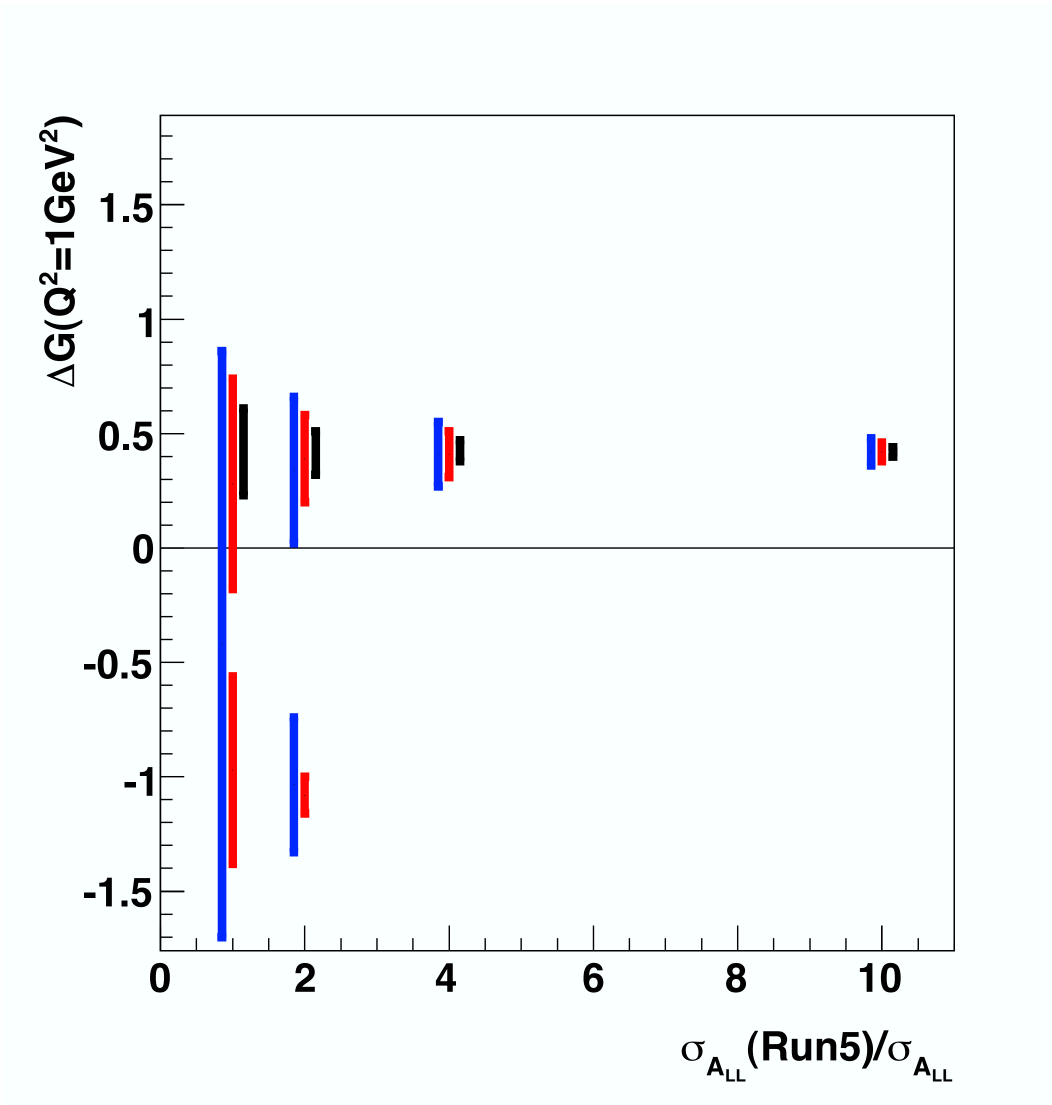


Figure 19: Statistical uncertainties on Δg based on our results of $A_{LL}^{\pi^0}$ measurement from Runs-5, 6,7 and 8 assuming the central value of $A_{LL}^{\pi^0}$ remains on the GRSV-std line, which corresponds to $\Delta G \sim 0.4$ at $Q^2 = 1$ GeV^2. The left-most error bars are for Run-5 (known), the next two being for Run-6 and Run-7 and on the right is shown the result including Run-8, the last 200 GeV operations data. The horizontal axis indicates how many times more precisely the $A_{LL}^{\pi^0}$ is measured in each Run, compared to Run-5; e.g., in Run-8, 10-times smaller errors than Run-5 are expected. The different colors (blue, red, and black) indicate the 3, 2 and 1 σ error bars for ΔG on a χ^2 plot.

The fact that we can not decisively distinguish between positive and negative value of Δg from our Run-5 data is apparent in the set of blue, red & black uncertainty estimates in the left-most set of bars. Our data are consistent with the present best-fit value of GRSV-std curve, but because the determining power of our analysis presently comes from a region of rather low-p_T where the gg process dominates in the neutral pion production, we have limited power in ruling out the negative minima in the χ^2 vs. Δg plots. This is reflected in the 3 and 2-σ error bars being large enough to cover this possibility in the Run-5 analysis. As the luminosity increases, our statistical uncertainties improve beyond the differences in the Δg scenarios, mentioned earlier, and we explore higher p_T regions, a combined effect of which is the gradual but definite improvement in our ability to determine the value of Δg.

It is also clear from this exercise that our effectiveness to determine the Δg remains high, as indicated in the above scenario, if the value of Δg itself is large or non-zero. If the value of Δg is lower or close to zero, then a whole different sets of parameters come in to this picture, and the physics of nucleon spin become even more fascinating making the Run-7 result equally if not more exciting.

With Run-7 statistics, assuming that the value of ΔG value remains consistent with our best fit from Run-5 and the DIS result, we will be able to clearly distinguish between the $\Delta G = 0$ and GRSV-std $\Delta G = 0.4$ scenario even purely based on inclusive π^0 asymmetries[5]. **Over all we believe that our sensitivity will reach to the level of accuracy such that the result will have a huge impact on the understanding of gluon spin component in the proton spin.** This could then become one of the earliest and the strongest *definitive* statement coming out of RHIC Spin on the topic of nucleon spin, and could be considered as having achieved the NSAC performance milestone for 2008.

Also at that time, due to increasing statistical samples accumulated by other physics channels, we would have multiple handles on this determination of polarized gluon distribution. In the case of inclusive neutral pion asymmetries, the resolving power between the various polarized gluon scenarios is strongest in the low p_T region. However, this is also the kinematic region in which the partonic interaction for neutral pion production is mostly gluon-gluon scattering, and as such does not give a unequivocal handle on the

[5]As a general comment and a caveat on the method of determining Δg from inclusive π^0 double spin asymmetries, one should remember that that the x region in which PHENIX makes measurements is between 0.05 and 0.22 and all statements made in this document presently ignore the uncertainties associated with parton distributions and their extrapolations outside of this measured region.

sign of the polarized gluon distribution. There are several options, namely,

1. Measure neutral pion A_{LL} at $p_T > 6$ GeV/c, where the qg subprocess dominates, with good accuracy.

2. Measure charged pion double longitudinal asymmetry in this kinematic region, where the values of $A_{LL}^{\pi^\pm}$ are more or less than the other depending on the sign of the polarized gluon distribution. To achieve that we need significantly larger data samples than those achieved so far.

In fact, a full array of channels will be available at this juncture, including but not limited to, η's, single electrons, and single muons.

Eventually, when the whole statistical data sample at 200 GeV is collected by 2009, the direct photon measurement will give an independent determination of ΔG. In the prompt photon production process, gluon compton process ($qg \rightarrow q\gamma$) is the dominant process and is devoid of sign or fragmentation ambiguities theoretically possible in the inclusive pion production processes. Run-7 data will give the first result of A_{LL} of direct photon, as shown in Figure 20, and will be a crucial first step moving towards a significant result.

It is also our opinion, that eventually the polarized gluon distribution will be determined by a global analysis of the world's available data set including RHIC data and the deep inelastic scattering data. Having an early data set on direct photon events which influences the sign of the polarized gluon distribution will allow us to over come the sign ambiguities arising from the inclusive neutral pion measurements, especially if the value of the gluon distribution's first moment is small.

5.1.3 p+p development at 500 GeV

This item is a placeholder to endorse potential C-A D requests for further development of 500 GeV polarized proton running. It is not clear if collisions and stable physics running will be achieved; if so, PHENIX will be prepared to perform initial measurements at this new energy. We are also interested in measuring backgrounds and trigger performance at 500 GeV.

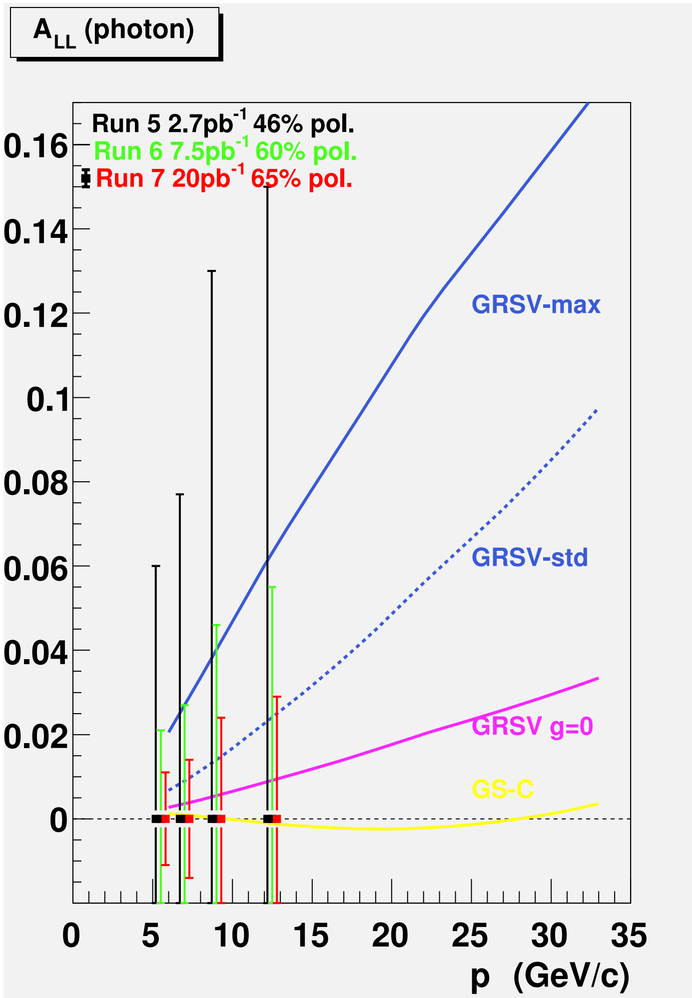


Figure 20: Projected A_{LL}^{γ} measurement in Run-5, 6 and 7 assuming our known data taking efficiencies and analysis cut losses based on run-3 and preliminary run-5 analyses.

5.2 Run-8

5.2.1 15 weeks d+Au at $\sqrt{s_{NN}}$ = 200 GeV

As noted in Section 4.2, we can develop an integrated luminosity in this period that exceeds our Run-3 d+Au value of 2.7 nb^{-1} by more than an order-of-magnitude. Given the significant increase now made available by our Run-5 p+p data-set of 3.8 pb^{-1} ,

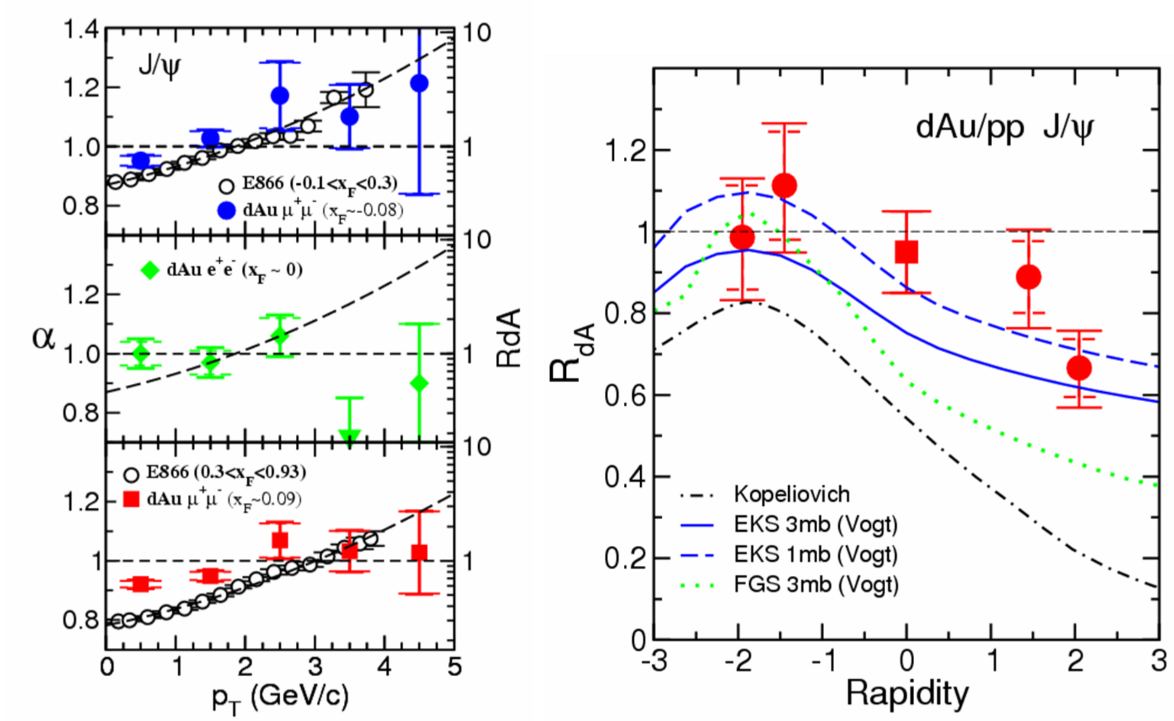


Figure 21: PHENIX Run-3 results[27] from $\sqrt{s_{NN}} = 200$ GeV d+Au collisions for (left) J/ψ yields parameterized as A^{α} as a function of transverse momentum compared to results from E866/NuSea[28] and (right) the nuclear suppression factor R_{dAu} as a function of rapidity, compared to various models of initial-state shadowing and final-state absorption[29, 30, 31].

and the additional 10.7 pb^{-1} Run-6, the Run-3 d+Au data-set is now very much the limiting factor in our ability to make precision measurements of the relatively small but crucial nuclear modifications that occur in cold nuclear matter. This is demonstrated in Figure 21, which shows the data from our publication of the Run-3 data on J/ψ production[27], compared to both previous fixed-target data[28] and to models of initial and final state nuclear modifications[29, 30, 31]. It is clear that additional resolving power is needed to make rigorous distinctions between the various models.

A 15 week run of d+Au collisions, assuming the geometric mean of the minimum (4.5 nb^{-1} per week) and maximum (15 nb^{-1} per week) C-A D guidance will result in a recorded sample of 58 nb^{-1} , i.e., an factor of 20 increase over the existing d+Au data-set. This will provide much greater precision in determining the absorption cross section in cold nuclear matter, which is of critical importance to a quantitative understanding of

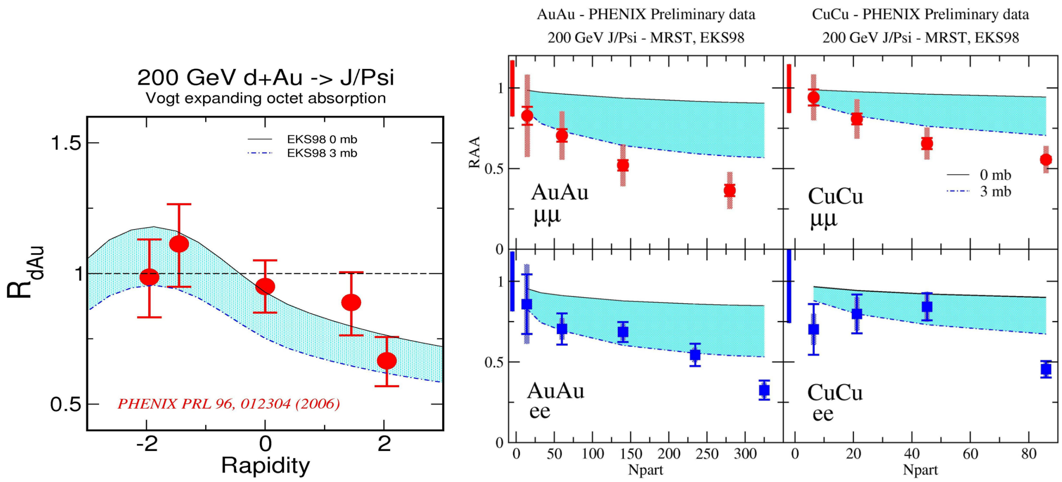


Figure 22: PHENIX Run-3 results[27] from $\sqrt{s_{NN}}$ = 200 GeV d+Au collisions for (left) the nuclear suppression factor R_{dAu} as a function of rapidity, compared to models incorporating various values of the absorption cross section and (right) the range of suppression factors allowed by the uncertainty in the absorption cross section, as compared to PHENIX Preliminary data from Au+Au and Cu+Cu collisions.

J/ψ yields in Au+Au collisions at RHIC energies. This is illustrated in Figure 22, which shows how the allowed range for the value of the absorption cross section σ_{abs} from the Run-3 d+Au data translates into a major uncertainty in understanding the A+A data. Very different physics conclusions follow from $\sigma_{abs} = 3$ mb as compared to $\sigma_{abs} = 0$ mb, differences which will be resolved with the new precision from the requested Run-8 d+Au data-set.

Two additional points are worth noting here. First, due to extensive studies conducted by PHENIX, we were able to identify sources of background in the muon arms and develop a shielding plan that has greatly improved the Signal/Background since Run-3[6]. Therefore, the improvement in our understanding of the d+Au data in the muon channels will exceed the simple factor of 20 in integrated luminosities. Second, we have argued that greater precision is required for understanding the role of absorption in cold nuclear matter. This of course is the simplest such model of nuclear effects. Quantitative investigation and incisive tests of other effects such as Sudakov suppression[32], gluon saturation[33], etc. can be made only with the substantially increased data set we are requesting in Run-8.

[6]We would like to take this opportunity to thank C-A D for their interest in and support for installing this essential shielding.

5.2.2 10 weeks p+p Longitudinal Polarization at 200 GeV

The projected luminosity increases lead to a substantially higher recorded integrated luminosity for Run-8 than Run-7 (52 pb^{-1} as compared to 32 pb^{-1}). If the entire period is devoted to longitudinal running (plausible, but a decision to be taken based on physics learned from Run-7), the increase for the longitudinal data-set becomes a factor of two for Run-8 as compared to Run-7, leading to a cumulative longitudinal data-set from Runs 6-8 of 85 pb^{-1} , all with polarization of (at least) 60-65%. The physics reach of such a data set has already been discussed in Section 5.1.2, so here we will simply note that it will allow determination of A_{LL} in a variety of channels (charged and neutral pions, η's, J/ψ 's, single electrons, direct photons, Λ's and $\bar{\Lambda}$'s, etc. As such, it is likely to represent a logical endpoint for our initial investigation of polarized proton collisions at 200 GeV. As always, we would continue to support C-A D requests for machine studies and development in support of 500 GeV running with polarized protons, especially as that will form the basis for the next major effort in our spin program.

5.3 Run-9

5.3.1 25-M weeks Au+Au

With the anticipated recording of an additional 1.1 nb^{-1} of Au+Au data at $\sqrt{s_{NN}}$ = 200 GeV, PHENIX will have reached several important goals. First, we will have extended our Run-4 Au+Au data-set by at least a factor of four, with upgraded detectors leading to an order-of-magnitude improvement in sensitivity, thereby accessing the many observables listed above (Sections 4.2 and 5.1.1) that remain statistics-limited. Second, we will have used the HBD to make the first precision measurements at RHIC of the spectrum of low-mass di-electrons. It is entirely possible that, driven by discoveries made with the HBD in the Run-7 Au+Au data set at $\sqrt{s_{NN}} = 200$ GeV that we would request further running at this energy. However, we are also aware of the substantial potential of RHIC for low-energy running, and the great physics interest in same. As Run-9 would be the last year for HBD running before insertion of the VTX detector, we wish to leave open the possibility of using a significant fraction of Run-9 for running Au+Au at lower energies.

5.3.2 M weeks p+p at 500 GeV

As noted in the previous section, we prefer to specify the precise length of the Run-9 Au+Au segment and its energy (energies) when the physics from Runs 7 and 8 is in hand. This of course impacts in turn our ability to specify the length of the polarized proton segment, hence the algebraic nomenclature. However, we wish to emphasize the crucial aspect of having a 500 GeV polarized proton segment in Run-9. This is necessary both as per the C-A D guidance, and to commission and take data with the Muon Trigger, the first half of which will be installed prior to Run-9. This is an essential step in PHENIX's progress towards W physics in the next decade.

5.4 Run-10

5.4.1 25-N weeks "heavy ion" running at $\sqrt{s_{NN}} = 200$ GeV

As we have noted in previous Beam Use Proposals, the resolution on assumed heavy ion species more than three years from the time of writing is quite limited. Nonetheless, we have left this item as placeholder, to indicate continued interest in this aspect of the program as the various upgrades continue to extend PHENIX's ability to make incisive measurements. Of particular interest will be the first opportunity in Run-10 to perform physics measurements using the Si-VTX tracker, which would provide intrinsically new results from either Au+Au or d+Au collisions on displaced vertices from heavy flavor decays to provide qualitatively new data on the production, energy loss and flow of charm and beauty.

5.4.2 N weeks p+p longitudinal polarization at 500 GeV

The complete Muon Trigger will be available for Run-10, and we anticipate a major data-taking run for W physics at this time.

5.5 Run-11

5.5.1 25-X weeks "heavy ion" running at $\sqrt{s_{NN}} = 200$ GeV

Once again cautioning about the difficulty with long-baseline projections, we nonetheless note that completion of the EBIS project in this period will provide the unprecedented opportunity to study U+U collisions. The static quadrupole deformation of the uranium nucleus will lead to collisions (in some orientations) with significantly greater initial densities than those found in Au+Au collisions, presenting new challenges to both theory and experiment to extract and understand the influence of the initial geometry on the subsequent dynamics.

5.5.2 X weeks p+p longitudinal polarization at 500 GeV

As in the 200 GeV polarized proton program, we project steady accumulation of integrated luminosity at this new energy over a multi-year period. The Nose Cone Calorimeter and the Forward Vertex detectors could also be available at this time, once again extending the PHENIX physics reach.

5.6 Discussion Summary

It is appropriate to augment the specific discussion of the previous section with some general observations derived from this multi-year planning process. We provide some of these below in itemized form:

- *The first, most obvious and most urgent point is the need to provide steady progress in both the heavy ion and the polarized proton program by continuing the impressive program of improvements in luminosity, polarization and reliability of operations demonstrated in RHIC Runs 1-6.* The Collider-Accelerator Department has made special note of the need for annual operations with polarized protons in order to reach the luminosities necessary for success in that program, and we endorse that request.
- We note that even in the extended scope of this proposal, it is not possible to

accommodate the entire spectrum of additional measurements (e.g., Si+Au, Si+Si, d+Cu) that could be of interest. As previously noted, absent *compelling* arguments for investigating these systems, we believe great scientific value is obtained through significant extensions in the physics reach of the heaviest colliding system, coupled with corresponding additions to the d+Au and p+p baseline measurements.

- To maximize the discovery potential so evident in the first years of RHIC operations, it is advantageous to pursue each running mode to the limit of available luminosity, and whenever possible to balance the integrated luminosities between modes to develop equivalent parton-parton flux (and thus p_T reach) in all comparison data sets.

The plan proposed here incorporates these observations, and is intended to continue the program of discovery and precision physics that has become the definition of RHIC physics.

References

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