PHENIX Status

W.A. Zajc

for the PHENIX Collaboration

(this talk available at
http://www.phenix.bnl.gov/phenix/WWW/publish/zajc/sp/presentations/DOEReviewJul05/)

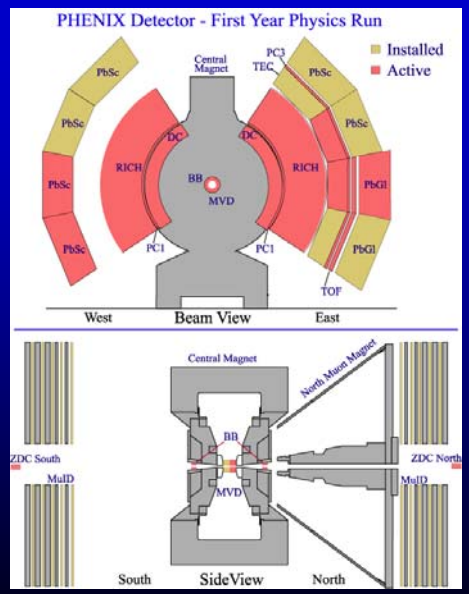
Outline

- Past- what made PHENIX PHENIX?
  - Experiment growth
  - Data set(s) growth
  - Collaboration growth
  - Accomplishments
- Present- what is PHENIX doing?
  - Current status
  - Run-5 achievements
- Future- quo vadis PHENIX?
  - Physics goals
  - Upgrade plans

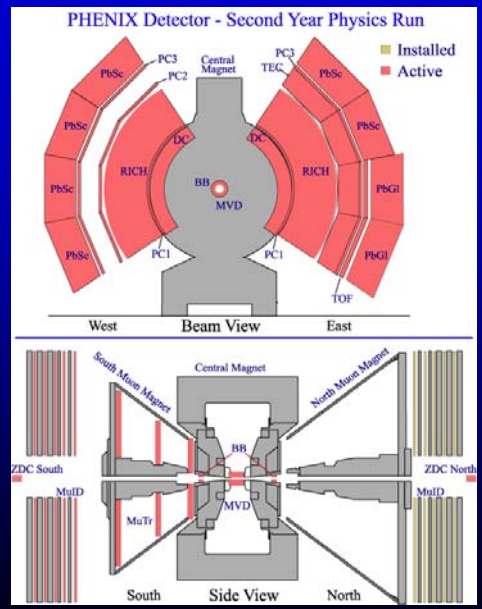
Run-1 to Run-3 Capsule History

Run	Year	Species	$s^{1/2}$ [GeV]	∫Ldt	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

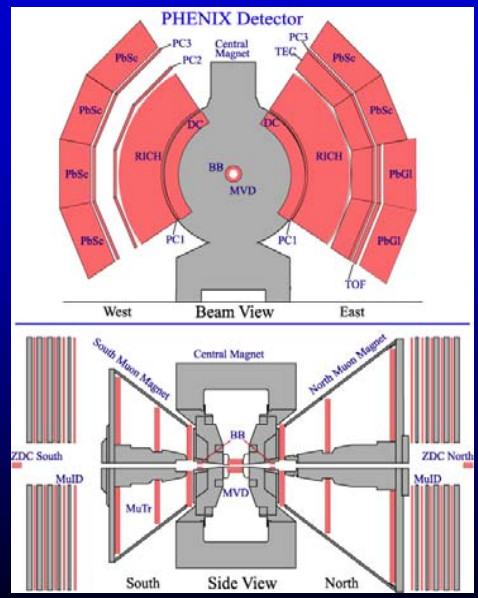
Run-1



Run-2

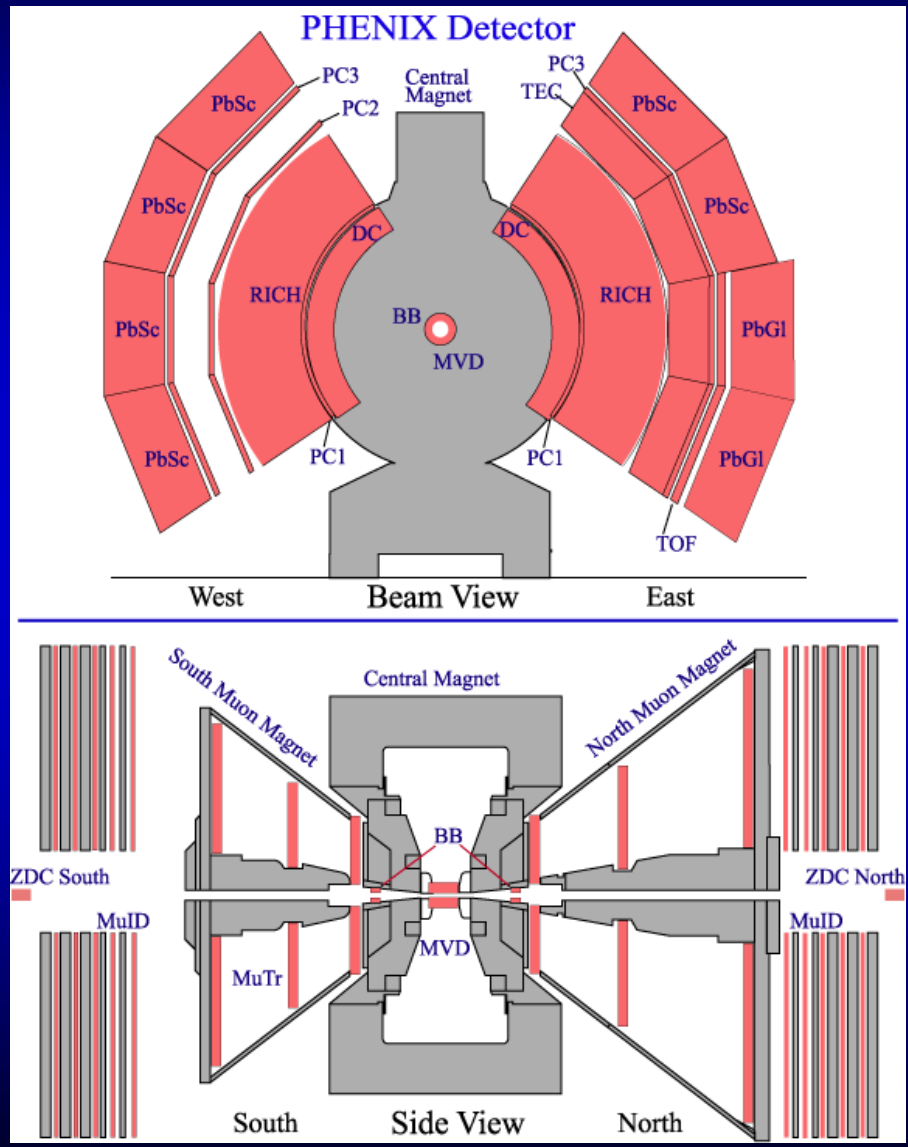


Run-3

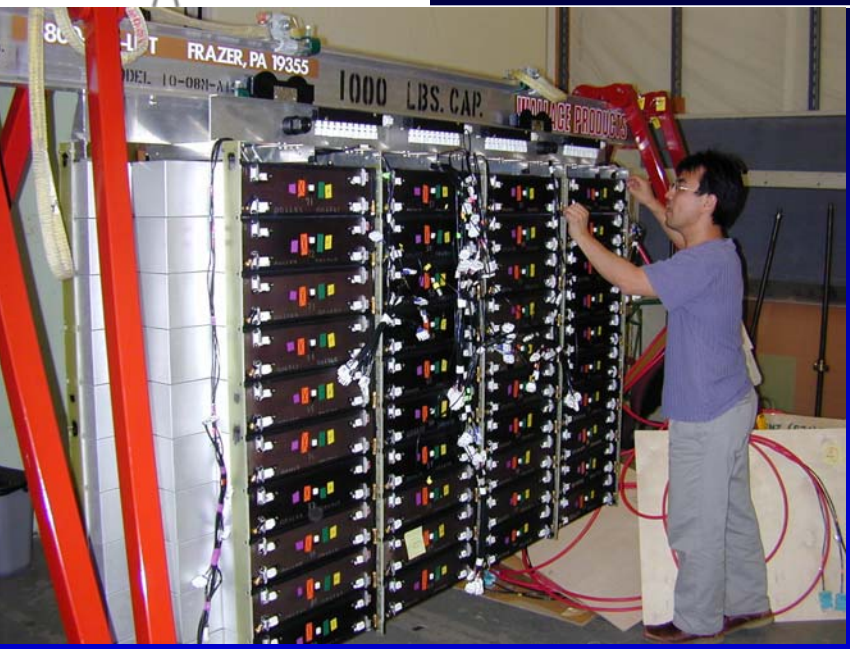


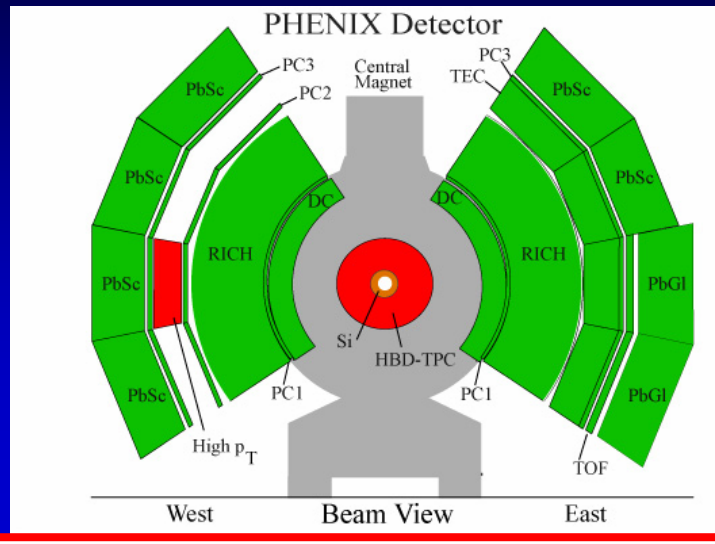
Run-3: Design Configuration!

- **Central Arm Tracking**
  - Drift Chamber
  - Pad Chambers
  - Time Expansion Chamber
- **Muon Arm Tracking**
  - Muon Tracker: North Muon Tracker
- **Calorimetry**
  - PbGl
  - PbSc
- **Particle Id**
  - Muon Identifier: North Muon Identifier
  - RICH
  - TOF
  - TEC
- **Global Detectors**
  - BBC
  - ZDC/SMD Local Polarimeter
  - Forward Hadron Calorimeters
  - NTC
  - MVD
- **Online Calibration and Production**

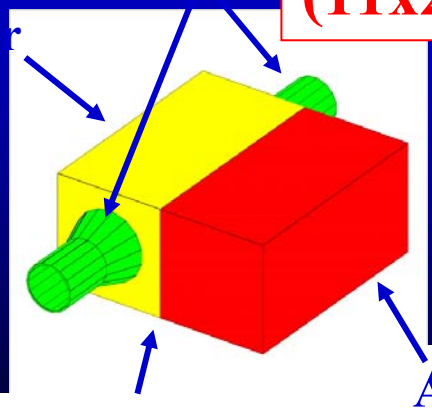


Run-4 Additions





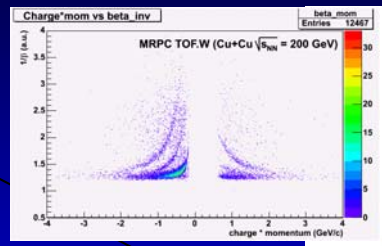
Aerogel Cell (11x22x11 cm^3)



- The Aerogel detector is a threshold Cerenkov counter
- Aerogel is a very low density, SiO_2 – based solid
- Aerogel has index of refr. between gases & liquids.
- Ident. charged particles in a range inaccessible with other technologies.

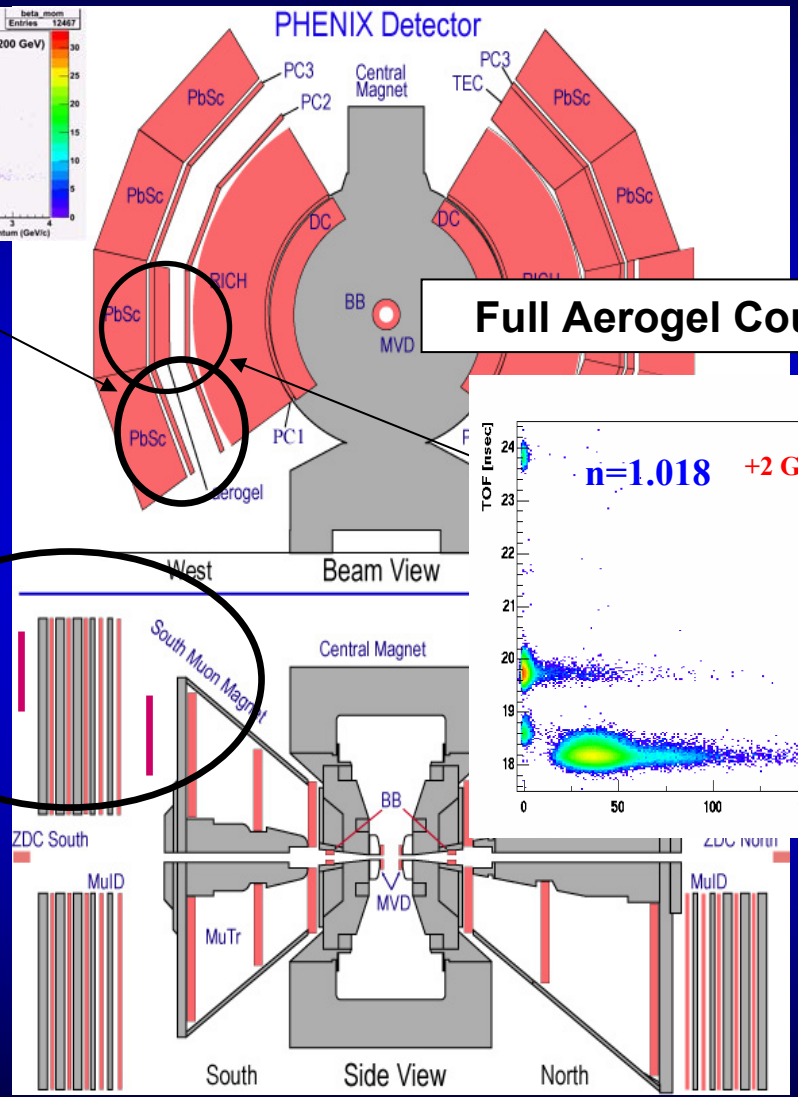
PHENIX Configuration in Run-5

TOF-West RPC prototype installed and tested in CuCu running.



Prototype RPC muon trigger chambers.

NSF $1.98M
Approved!



Full Aerogel Counter

***ALSO*:**
New LVL1 Triggers (MuID and ERT)
Improved DAQ (>5kHz)
Multi-Event Buffering (95% live)
OnCal calibrations
LVL2 Filtering rare events

Run-1 to Run-5 Capsule History

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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	2003/2004	Au+Au	200	241 μb^{-1}	1.5G	10.0 pb^{-1}	270 TB
		Au+Au	62	9 μb^{-1}	58M	0.36 pb^{-1}	10 TB
05	2004/2005	Cu+Cu	200	3 nb^{-1}	8.6G	11.9 pb^{-1}	173 TB
		Cu+Cu	62	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}	85B	3.8 pb^{-1}	262 TB

Collaboration Status

- Healthy
  - Wide-ranging participation in
    - Data analysis
    - Shift support (309 individuals in Run-5 !)
    - Upgrades program

- Continued growth:

Year	Institutions	Nations	Participants
2001	53	11	420
2003	57	12	460
2005	62	13	550

PHENIX Collaboration, 2005

- University of São Paulo, São Paulo, Brazil
- Academia Sinica, Taipei 11529, China
- China Institute of Atomic Energy (CIAE), Beijing, P. R. China
- Peking University, Beijing, P. R. China
- Charles University, Faculty of Mathematics and Physics, Ke Karlovu 3, 12116 Prague, Czech Republic
- Czech Technical University, Faculty of Nuclear Sciences and Physical Engineering, Brehova 7, 11519 Prague, Czech Republic
- Institute of Physics, Academy of Sciences of the Czech Republic, Na Slovance 2, 182 21 Prague, Czech Republic
- Laboratoire de Physique Corpusculaire (LPC), Universite de Clermont-Ferrand, 63 170 Aubiere, Clermont-Ferrand, France
- Dapnia, CEA Saclay, Bat. 703, F-91191 Gif-sur-Yvette, France
- IPN-Orsay, Universite Paris Sud, CNRS-IN2P3, BP1, F-91406 Orsay, France
- Laboratoire Leprince-Ringuet, Ecole Polytechnique, CNRS-IN2P3, Route de Saclay, F-91128 Palaiseau, France
- SUBATECH, Ecòle des Mines at Nantes, F-44307 Nantes France
- University of Muenster, Muenster, Germany
- KFKI Research Institute for Particle and Nuclear Physics at the Hungarian Academy of Sciences (MTA KFKI RMKI), Budapest, Hungary
- Debrecen University, Debrecen, Hungary
- Eövös Loránd University (ELTE), Budapest, Hungary
- Banaras Hindu University, Banaras, India
- Bhabha Atomic Research Centre (BARC), Bombay, India
- Weizmann Institute, Rehovot, 76100, Israel
- Center for Nuclear Study (CNS-Tokyo), University of Tokyo, Tanashi, Tokyo 188, Japan
- Hiroshima University, Higashi-Hiroshima 739, Japan
- KEK - High Energy Accelerator Research Organization, 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan
- Kyoto University, Kyoto, Japan
- Nagasaki Institute of Applied Science, Nagasaki-shi, Nagasaki, Japan
- RIKEN, The Institute of Physical and Chemical Research, Wako, Saitama 35 0198, Japan
- RIKEN – BNL Research Center, Japan, located at BNL
- Physics Department, Rikkyo University, 3-34-1 Nishi-Ikebukuro, Toshima, Tokyo 171-8501, Japan
- Tokyo Institute of Technology, Oh-okayama, Meguro, Tokyo 152-8551, Japa
- University of Tsukuba, 1-1-1 Tennodai, Tsukuba-shi Ibaraki-ken 305-8577, Japan
- Waseda University, Tokyo, Japan
- Cyclotron Application Laboratory, KAERI, Seoul, South Korea
- Kangnung National University, Kangnung 210-702, South Korea
- Korea University, Seoul, 136-701, Korea
- Myong Ji University, Yongin City 449-728, Korea
- System Electronics Laboratory, Seoul National University, Seoul, South Korea
- Yonsei University, Seoul 120-749, Korea
- IHEP (Protvino), State Research Center of Russian Federation "Institute fo High Energy Physics", Protvino 142281, Russia
- Joint Institute for Nuclear Research (JINR-Dubna), Dubna, Russia
- Kurchatov Institute, Moscow, Russia
- PNPI, Petersburg Nuclear Physics Institute, Gatchina, Leningrad region, 188300, Russia
- Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Vorob'evy Gory, Moscow 119992, Russia
- Saint-Petersburg State Polytechnical Univiversity, Politechnicheskayastr, 2

13 Countries; 62 Institutions; 550 Participants*

- Lund University, Lund, Sweden
- Abilene Christian University, Abilene, Texas, USA
- Brookhaven National Laboratory (BNL), Upton, NY 11973, USA
- University of California - Riverside (UCR), Riverside, CA 92521, USA
- University of Colorado, Boulder, CO, USA
- Columbia University, Nevis Laboratories, Irvington, NY 10533, USA
- Florida Institute of Technology, Melbourne, FL 32901, USA
- Florida State University (FSU), Tallahassee, FL 32306, USA
- Georgia State University (GSU), Atlanta, GA, 30303, USA
- University of Illinois Urbana-Champaign, Urbana-Champaign, IL, USA
- Iowa State University (ISU) and Ames Laboratory, Ames, IA 50011, USA
- Los Alamos National Laboratory (LANL), Los Alamos, NM 87545, USA
- Lawrence Livermore National Laboratory (LLNL), Livermore, CA 94550, USA
- University of New Mexico, Albuquerque, New Mexico, USA
- New Mexico State University, Las Cruces, New Mexico, USA
- Department of Chemistry, State University of New York at Stony Brook (USB), Stony Brook, NY 11794, USA
- Department of Physics and Astronomy, State University of New York at Stony Brook (USB), Stony Brook, NY 11794, USA
- Oak Ridge National Laboratory (ORNL), Oak Ridge, TN 37831, USA
- University of Tennessee (UT), Knoxville, TN 37996, USA
- Vanderbilt University, Nashville, TN 37235, USA

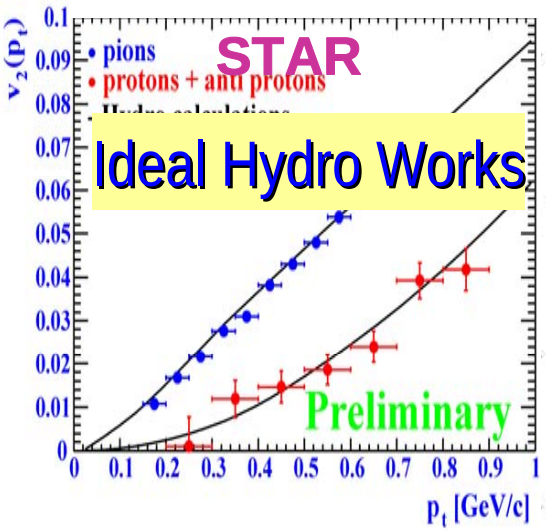
(Partial Listing) of Awards

- PECASE
  - V. Cianciolo (ORNL)
  - S. Mioduszewski (BNL)
- OJI
  - J. Nagle (Colorado)
  - J. Velkovska (Vanderbilt)
- Sloan
  - J. Nagle (Colorado)
- RHIC/AGS Thesis Award
  - J. Burward-Hoy (Stony Brook)
  - H. Sato (Kyoto)
  - C. Klein-Boesing (Muenster)
- Sambamurti Award
  - J. Mitchell (BNL)
  - S. Mioduszewski (BNL)
- Gertrude Goldhaber Memorial Award
  - A. Sickles (Stony Brook)
- Luise Meyer-Schutzmeister Memorial Award
  - C. Aidala (Columbia)

PHENIX Scientific Impact

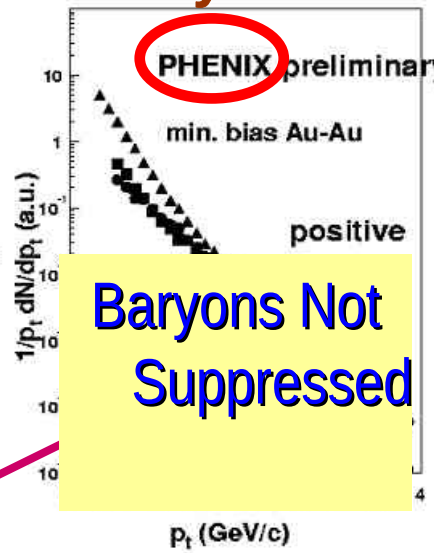
Four major "day 1" discoveries

Collective Flow



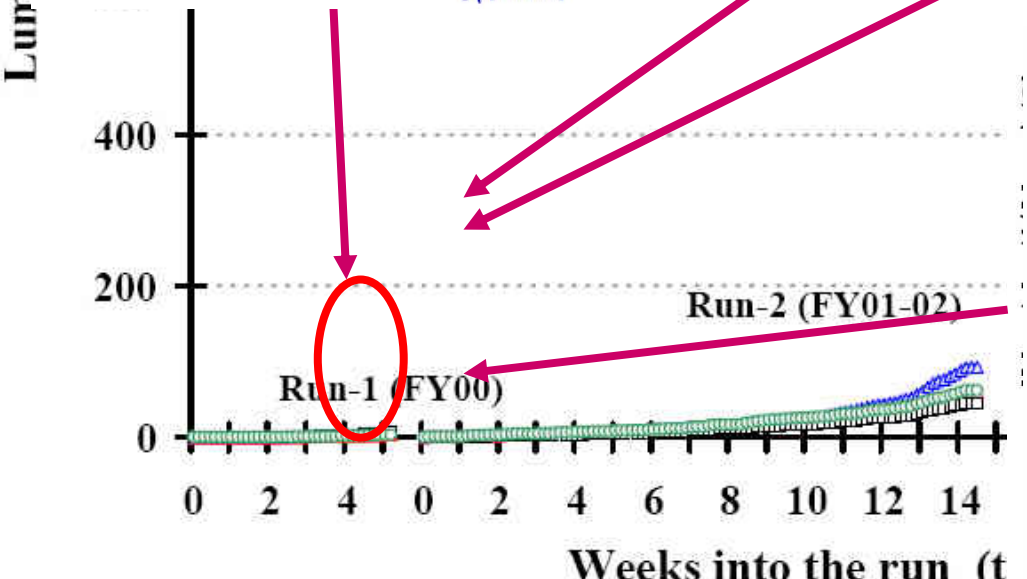
Jet Quenching

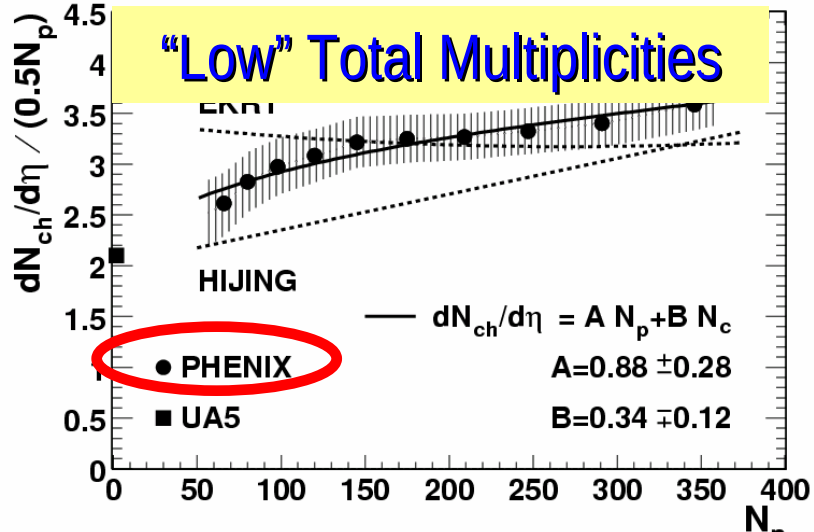
Baryon anomaly



As presented by M. Gyulassy in June, 2004 to Nuclear Science Advisory Committee

CGC Saturation



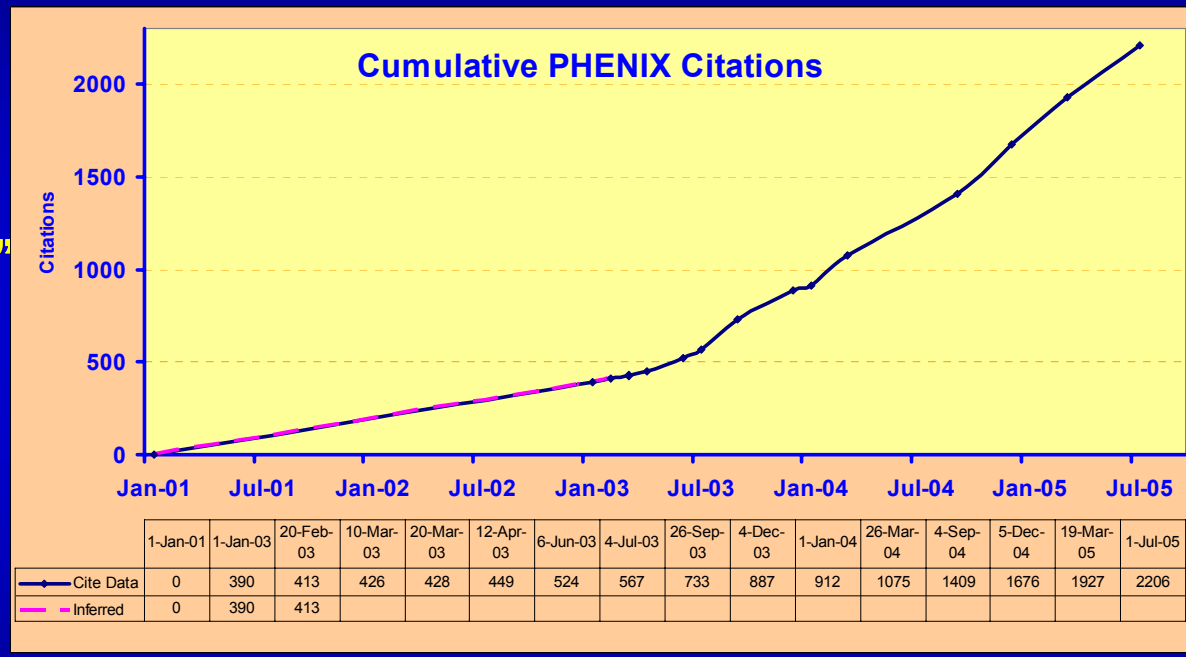


Accomplishments and Discoveries

- First measurement of the dependence of the charged particle pseudo-rapidity density and the transverse energy on the number of participants in Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV; systamatic study of same versus energy.
- Discovery of high p_T suppression in π^0 and charged particle production in Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV and a systematic study of the scaling properties of the suppression; extension of these results to much higher transverse momenta in Au+Au collisions at $\sqrt{s_{NN}}$ =200 GeV
- (Co)-Discovery of absence of high p_T suppression in d+Au collisions at $\sqrt{s_{NN}}$ =200 GeV.
- Discovery of the anomalously large proton and anti-proton yields at high transverse momentum in Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV through the systematic study of $\pi^{\pm}$, $K^{\pm}$, $p^{\pm}$ spectra; measurement of Λ and anti-Λ in Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV ; study of the scaling properties of the proton and anti-proton yields , of Φ production and d and dbar production n Au+Au collisions at $\sqrt{s_{NN}}$ =200 GeV.
- Measurement of HBT correlations in $\pi^+\pi^+$ and $\pi^-\pi^-$ pairs in Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV , establishing the ``HBT puzzle" of $R_{OUT} \sim R_{SIDE}$ extends to high pair momentum; extension of these results to $\sqrt{s_{NN}}$ = 200 GeV
- First measurement of single electron spectra in Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV, suggesting that charm production scales with the number of binary collisions.
- Sensitive measures of charge fluctuations and fluctuations in mean p_T and transverse energy per particle in Au+Au collisions at at $\sqrt{s_{NN}}$ =130~GeV; role of jets in p_T fluctuations at 200 GeV
- Measurements of elliptic flow for charged particles from Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV and identified charged hadrons from Au+Au collisions at $\sqrt{s_{NN}}$ =200 GeV along with study of the saturation of the azimuthal flow.
- Extensive study of hydrodynamic flow, particle yields, ratios and spectra from Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV and 200 GeV.
- First observation of J/Ψ production in Au+Au collisions at $\sqrt{s_{NN}}$ =200 GeV.
- Measurement of crucial baseline data on π^0 spectra , J/ Ψ production and direct photon production in p+p collisions at $\sqrt{s_{NN}}$ =200~GeV.
- First measurement of direct photon production in Au+Au collisions at $\sqrt{s_{NN}}$ =200 GeV, demonstrating that photon yields scaleswith the number of binary collisions.
- First observation of heavy flavor flow in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV
- First measurement of $A_{LL}(\pi^o)$ in p+p collisions at $\sqrt{s_{NN}}$ =200 GeV
- First study of jet structure of baryon excess in Au+Au collisions at $\sqrt{s_{NN}}$ =200 GeV
- First study of nuclear modification factor in d+Au collisions in forward *and* backward region at $\sqrt{s_{NN}}$ =200 GeV

Publication Summary

- Run-1
  - 12 publications
  - 9 are SPIRES "TopCites"
    - 5 of these are "famous"
  - One "archival" summary
- Run-2
  - 16 publications to date
  - 6 are SPIRES "TopCites"
    - 4 of these are "famous"
  - One "archival" summary
- Run-3
  - 3 publications to date
  - 1 is a SPIRES "TopCite"
    - In fact, it is "famous"



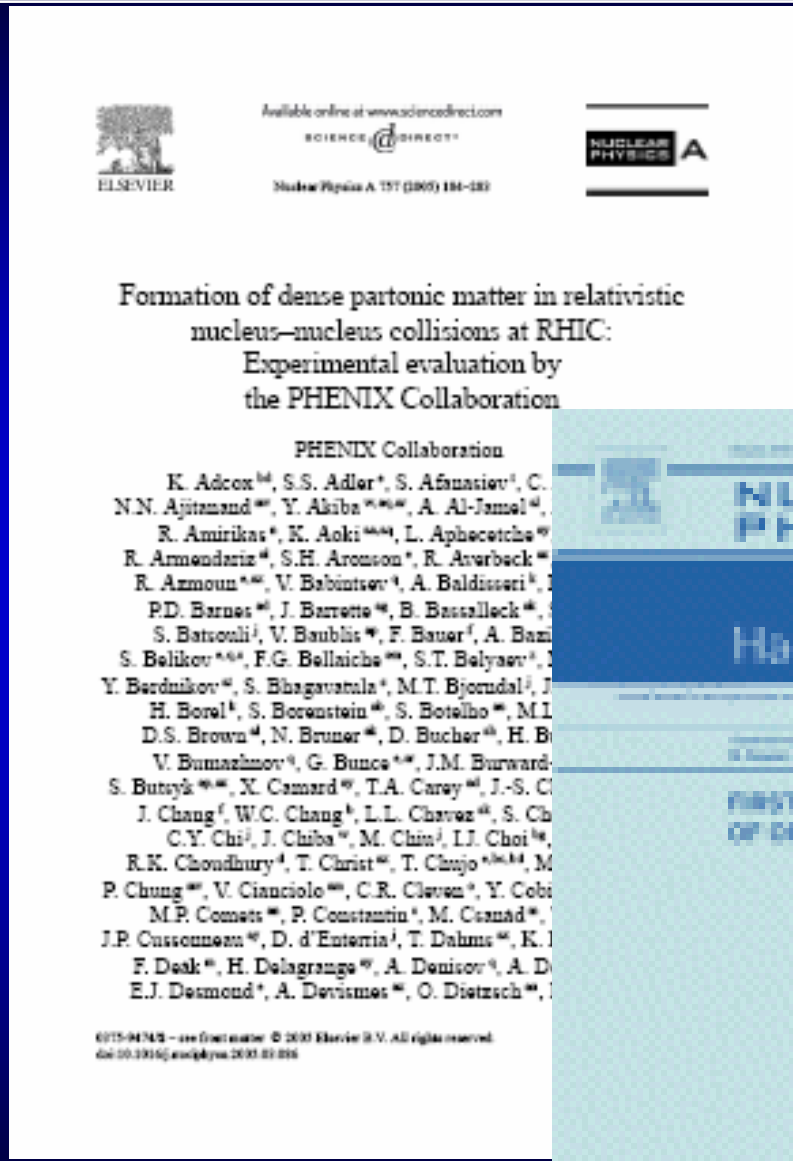
	1-Jan-01	1-Jan-03	20-Feb-03	10-Mar-03	20-Mar-03	12-Apr-03	6-Jun-03	4-Jul-03	26-Sep-03	4-Dec-03	1-Jan-04	26-Mar-04	4-Sep-04	5-Dec-04	19-Mar-05	1-Jul-05
Cite Data	0	390	413	426	428	449	524	567	733	887	912	1075	1409	1676	1927	2206
Inferred	0	390	413													

- 4 papers on various Run 1+2+3+4 combinations
- Total: 35 papers to date, 16 TopCites, 10 "Famous" papers

- Run-4: > x 10 *data-size compared to Run-2 Au+Au*

PHENIX "White Paper"

- Summary of PHENIX results from RHIC Runs 1-3
  - 126 pages
  - 56 figures
  - 267 references
- Part of "First Three Years of Experiments at RHIC" special volume in Nuclear Physics A.
- PHENIX paper has already received 46 citations



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Nuclear Physics A 757 (2005) 184–283

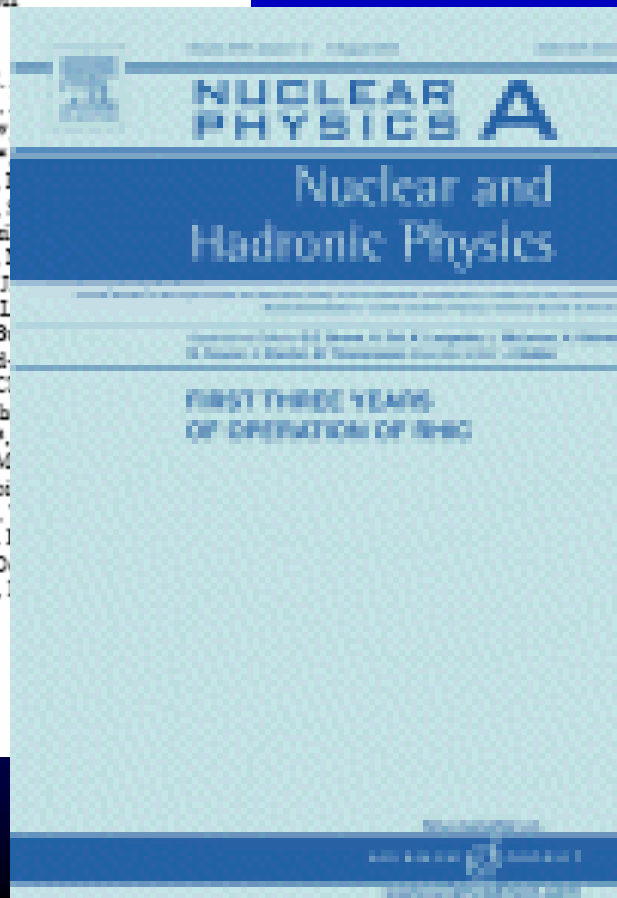
NUCLEAR PHYSICS A

Formation of dense partonic matter in relativistic nucleus–nucleus collisions at RHIC: Experimental evaluation by the PHENIX Collaboration

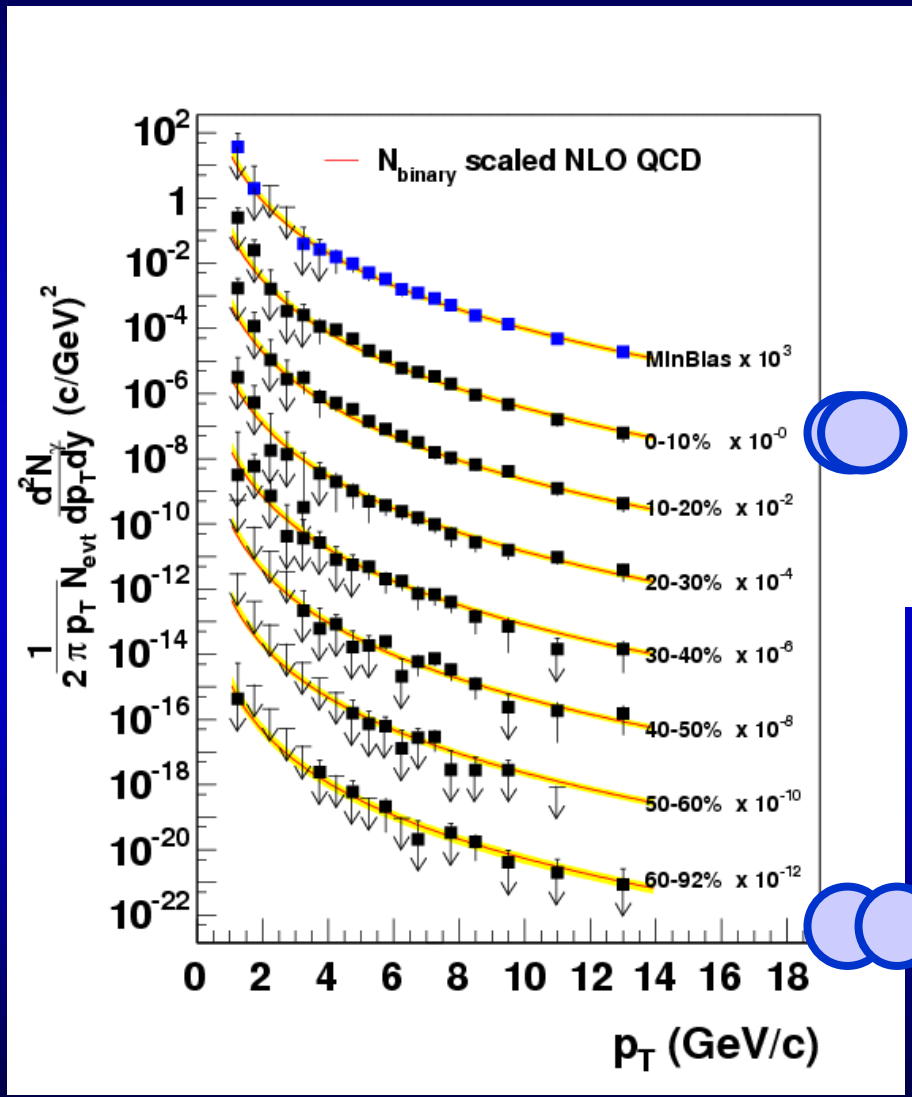
PHENIX Collaboration

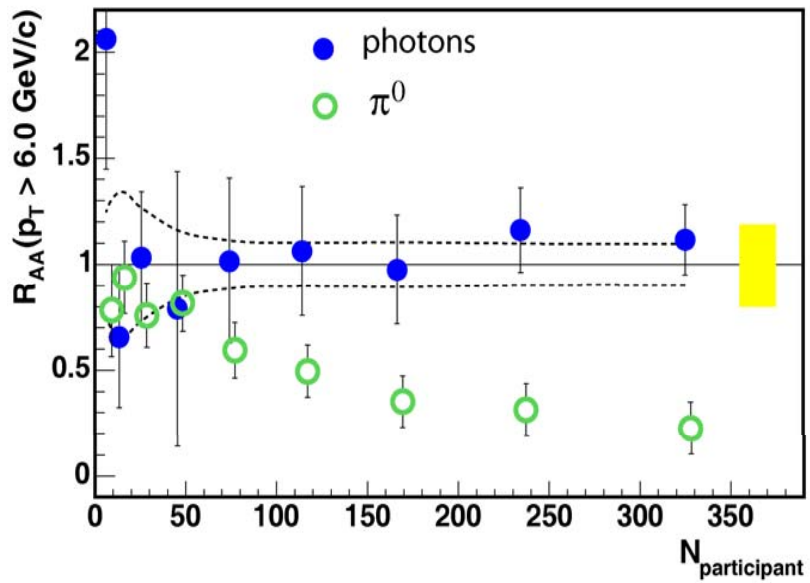
K. Adcox[bd], S.S. Adler[a], S. Afanasiev[t], C.
N.N. Ajitanand[ae], Y. Akiba[ac,ag], A. Al-Jamel[ad],
R. Amirikas[x], K. Aoki[ag,ah], L. Aphecetche[af],
R. Armendariz[ad], S.H. Aronson[a], R. Averbeck[ae],
R. Azmoun[a,ae], V. Babintsev[s], A. Baldisseri[k],
P.D. Barnes[ai], J. Barrette[ag], B. Bassalleck[ad],
S. Batsouli[j], V. Baublis[ar], F. Bauer[f], A. Bazi
S. Belikov[a,t,u], F.G. Bellaiche[ap], S.T. Belyaev[v],
Y. Berdnikov[av], S. Bhagavatula[x], M.T. Bjorndal[j],
H. Borel[k], S. Borenstein[ab], S. Botelho[au], M.L.
D.S. Brown[ad], N. Bruner[ad], D. Bucher[ah], H. Bu
V. Bumazhnov[s], G. Bunce[a,ag], J.M. Burward-
S. Butsyk[ae,ao], X. Camard[af], T.A. Carey[ai], J.-S. C
J. Chang[f], W.C. Chang[b], L.L. Chavez[ad], S. Ch
C.Y. Chi[j], J. Chiba[w], M. Chiu[j], I.J. Choi[ba],
R.K. Choudhury[d], T. Christ[ae], T. Chujo[a,ac,bd], M
P. Chung[ae], V. Cianciolo[ar], C.R. Cleven[y], Y. Cobi
M.P. Comets[au], P. Constantin[t], M. Csanad[n],
J.P. Cussonneau[af], D. d'Enterria[j], T. Dahms[ae], K.
F. Deak[n], H. Delagrange[af], A. Denisov[t], A. D
E.J. Desmond[a], A. Devismes[ae], O. Dietzsch[at],

doi:10.1016/j.nuclphysa.2005.03.086



Recent Paper

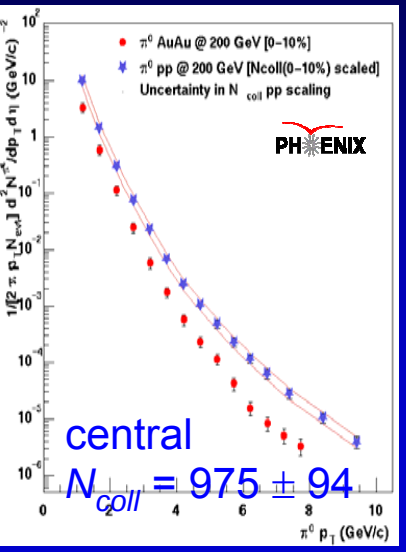




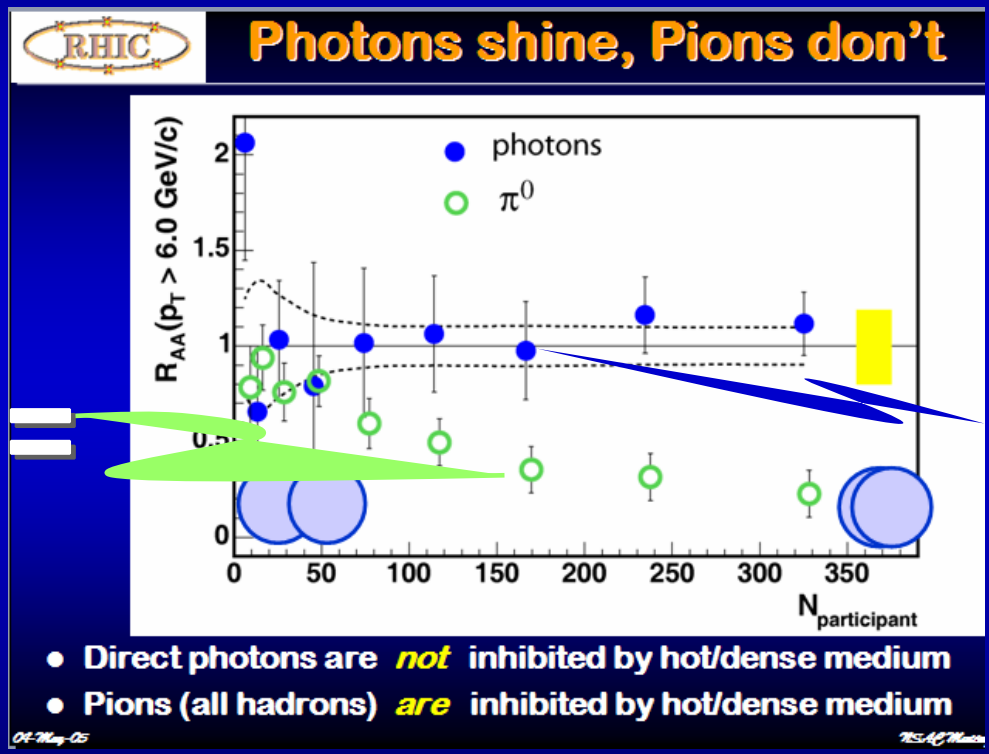
It's "easy" to measure the direct photons because the π^0's are heavily suppressed.

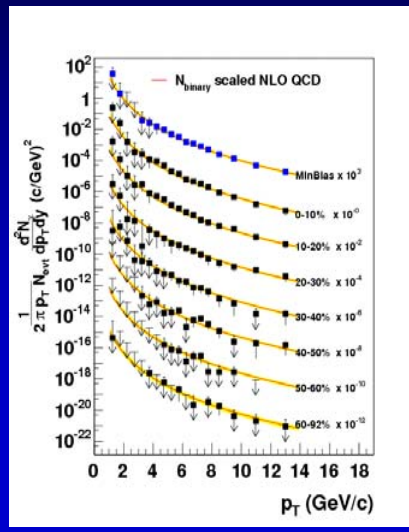
Comparison with pQCD calculation agrees with measured multiplicity – we understand the initial state.

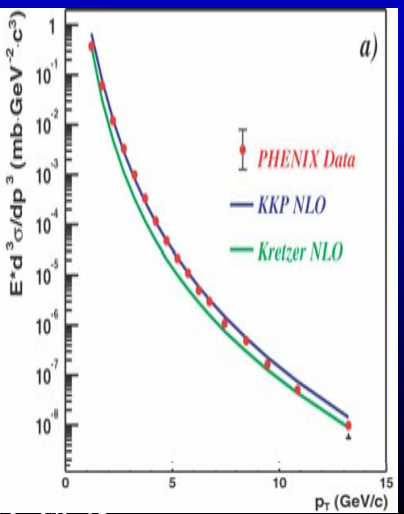
Scientific Precision



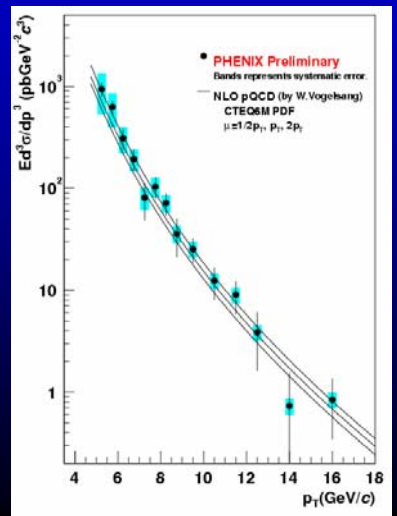
- This one figure encodes rigorous control of systematics





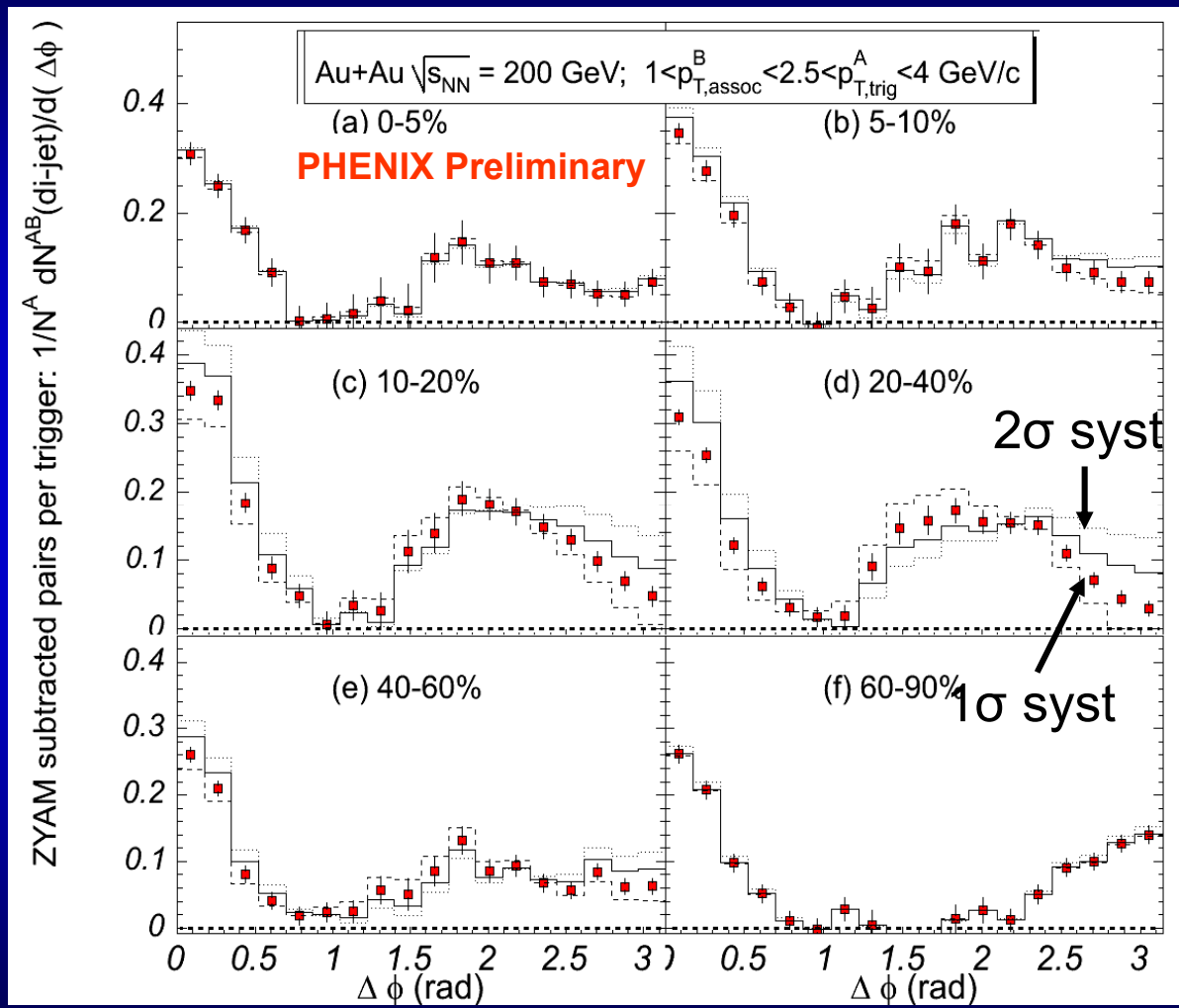


- in four different measurements over many orders of magnitude

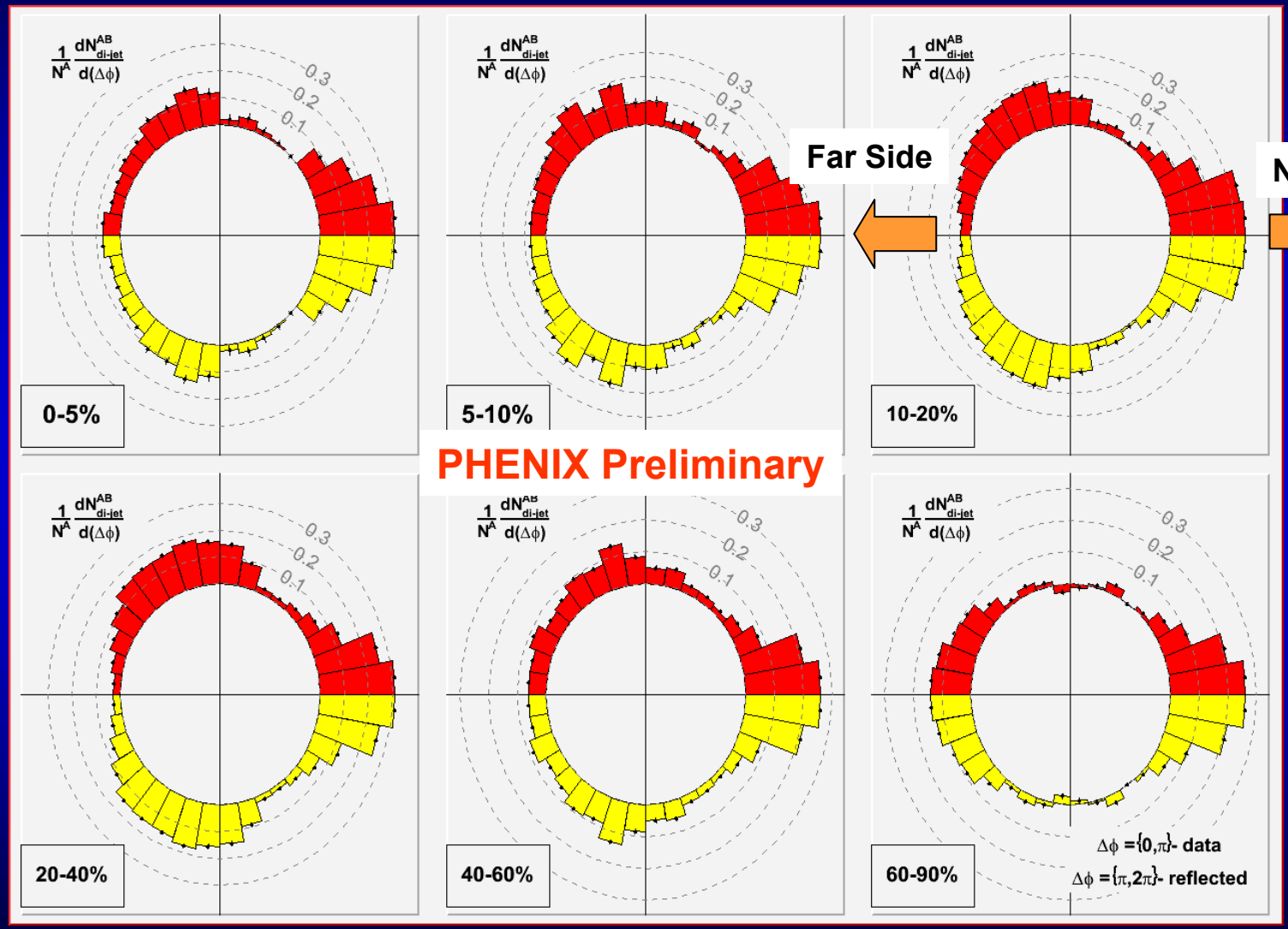


New Paper

- **Back-angle correlations in Au+Au display unusual shape!**
  - **Indication of shock wave?**
    - **hep-ph/0411315**
    - **nucl-th/0506013**
  - **If so, measure the speed of sound in the medium ?**
  - **Run-4,5 needed to push to higher p_T**
    - **Easier to deal with v_2**
    - **Narrowing correlation peaks**

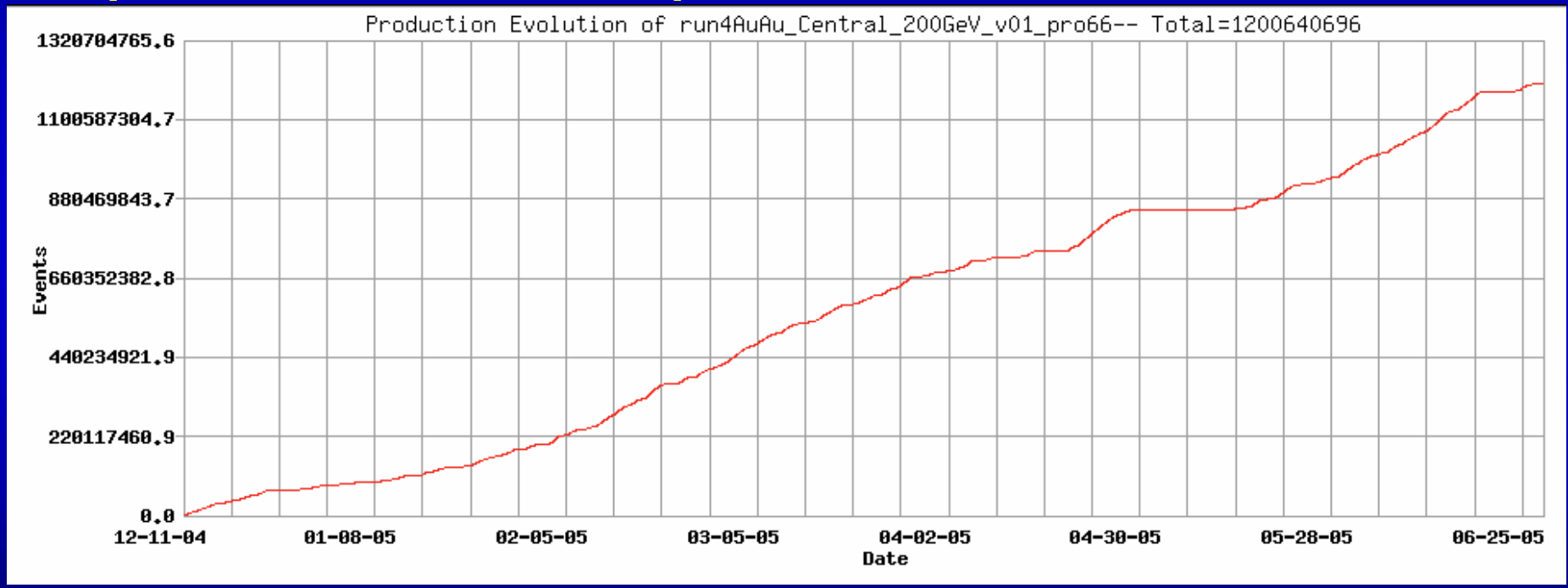


Another View...



Towards More Papers

- **Tremendous effort to process entire Run-4 Au+Au data-set prior to upcoming Quark Matter**
  - **Required extensive optimization of RCF machines, HPSS, etc (details in D. Morrison talk)**



Number of reconstructed events vs time, for Central Arm Run4 production

Will finish before you read this slide…

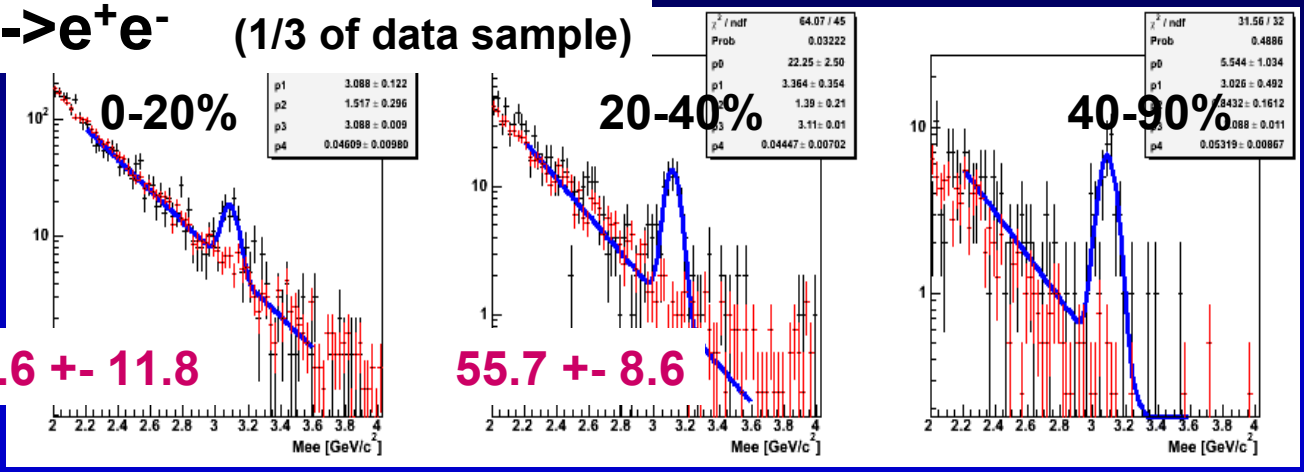
2 week plateau in April-May corresponds to farm downtime + Single Muon test production (30M events)

PHENIX Data Production

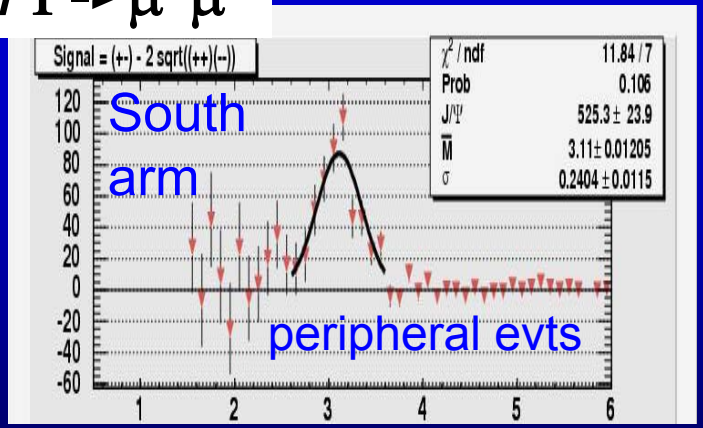
- **PHENIX is making use of collaboration resources to stay ahead of the incoming data:**
  - **Run-4 AuAu Data Production at RCF**
    - **Preliminary results from full dataset for QM05**
  - **Run-4 Muon Production at Computing Center - France (CC-F)**
    - **LVL2 filtered production underway**
  - **Run-4 pp Production at Computing Center - Japan (CC-J)**
  - **Run-5 CuCu 200 GeV/62.4 GeV (ORNL farm)**
    - **LVL2 filtered analysis will yield QM05 preliminary results**
    - **100 M minbias events produced in counting house (200 GeV)**
    - **150 M minbias events poduced in counting house (62.4 GeV)**
    - **Full production at RCF this summer (after Run-4 complete)**
  - **Run-5 CuCu 22.5 GeV**
    - **All events produced on VA farm in PHENIX Counting House**
  - **Run-5 pp production at CC-J**
    - **LVL2 filtered analysis**
    - **All pp data shipped via network to CC-J during run**
  - **Simulation at Vanderbilt, LLNL, New Mexico (all results archived at RCF)**

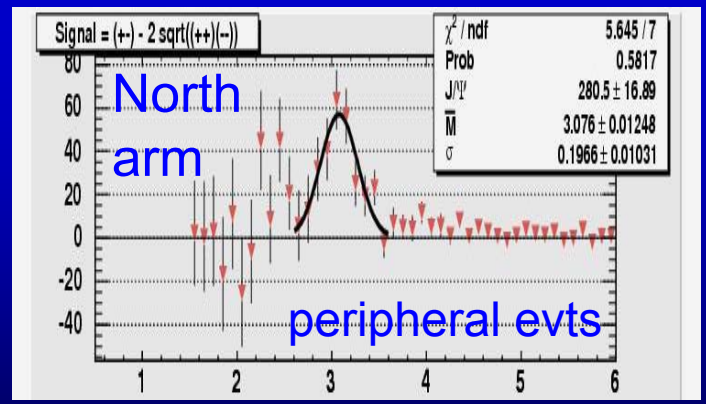
J/Ψ in Run-4 Au+Au

J/Ψ->e^+e^- (1/3 of data sample)



J/Ψ->$\mu^+\mu^-$



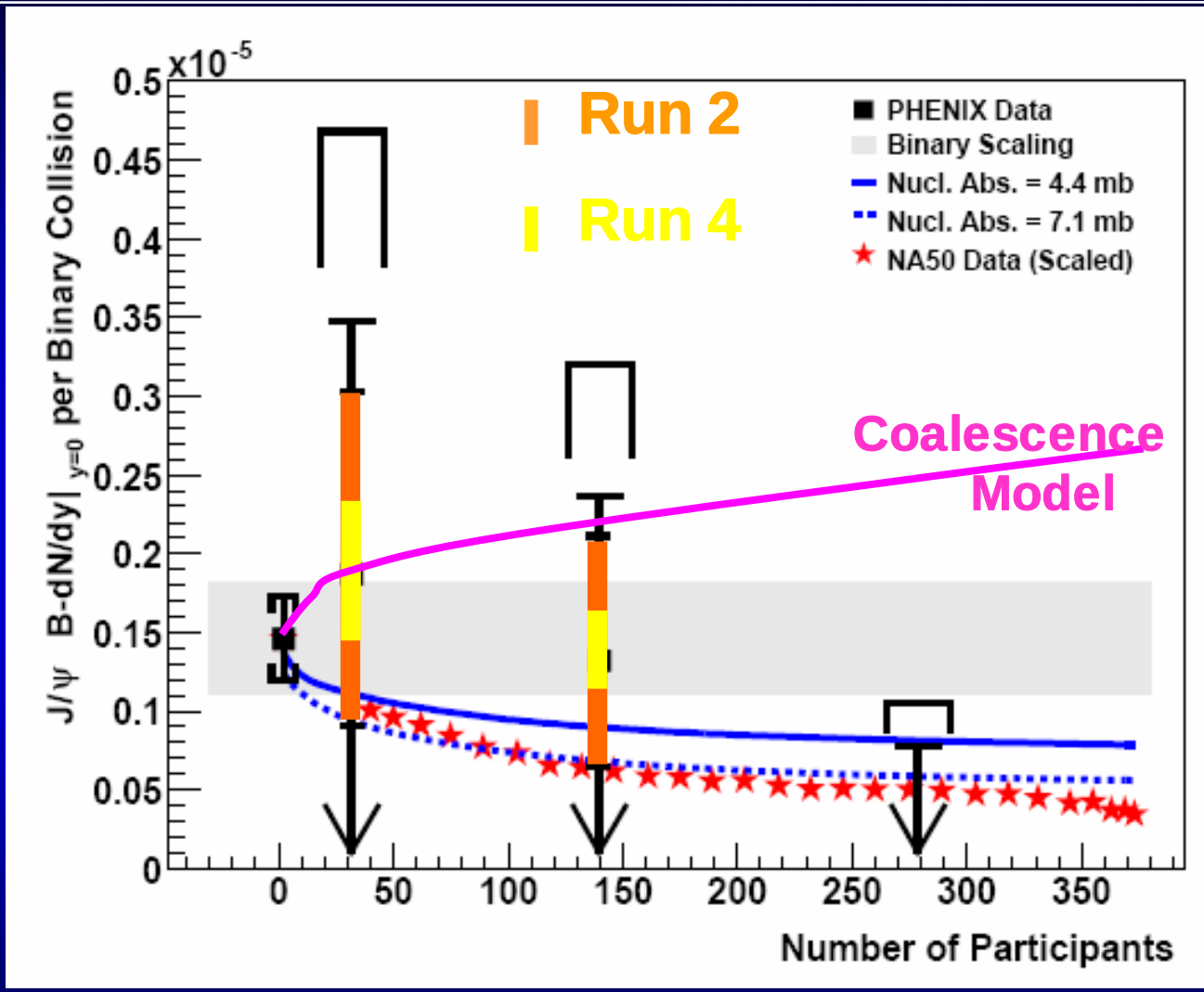


Data production and analysis underway – see you at QM05!

Current and Projected Status

- Existing Run-2 data set barely discriminates between *enhanced* and *suppressed* J/Ψ production

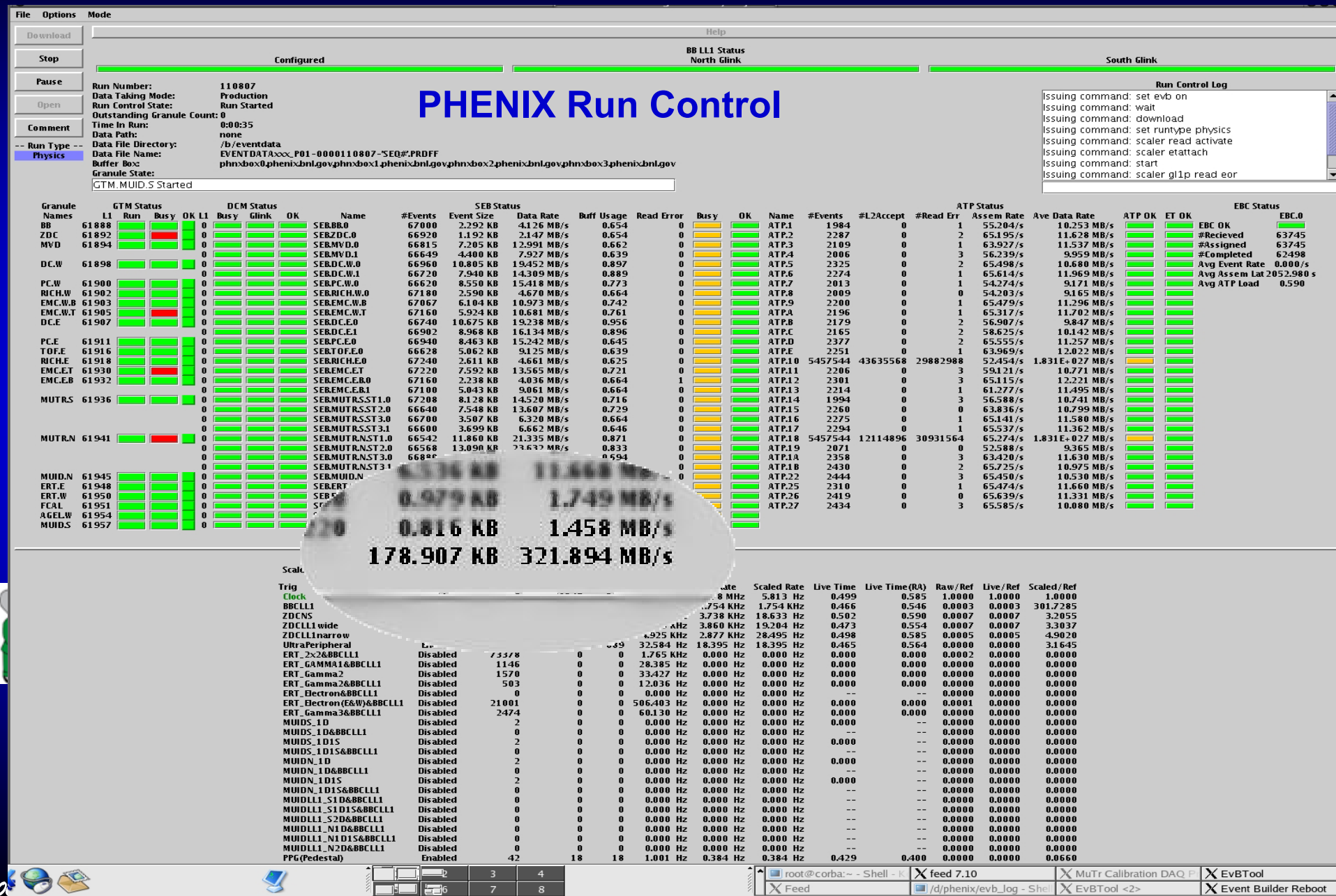
- Run-4 analysis will distinguish between *'ordinary'* and *'anamolous'* suppression



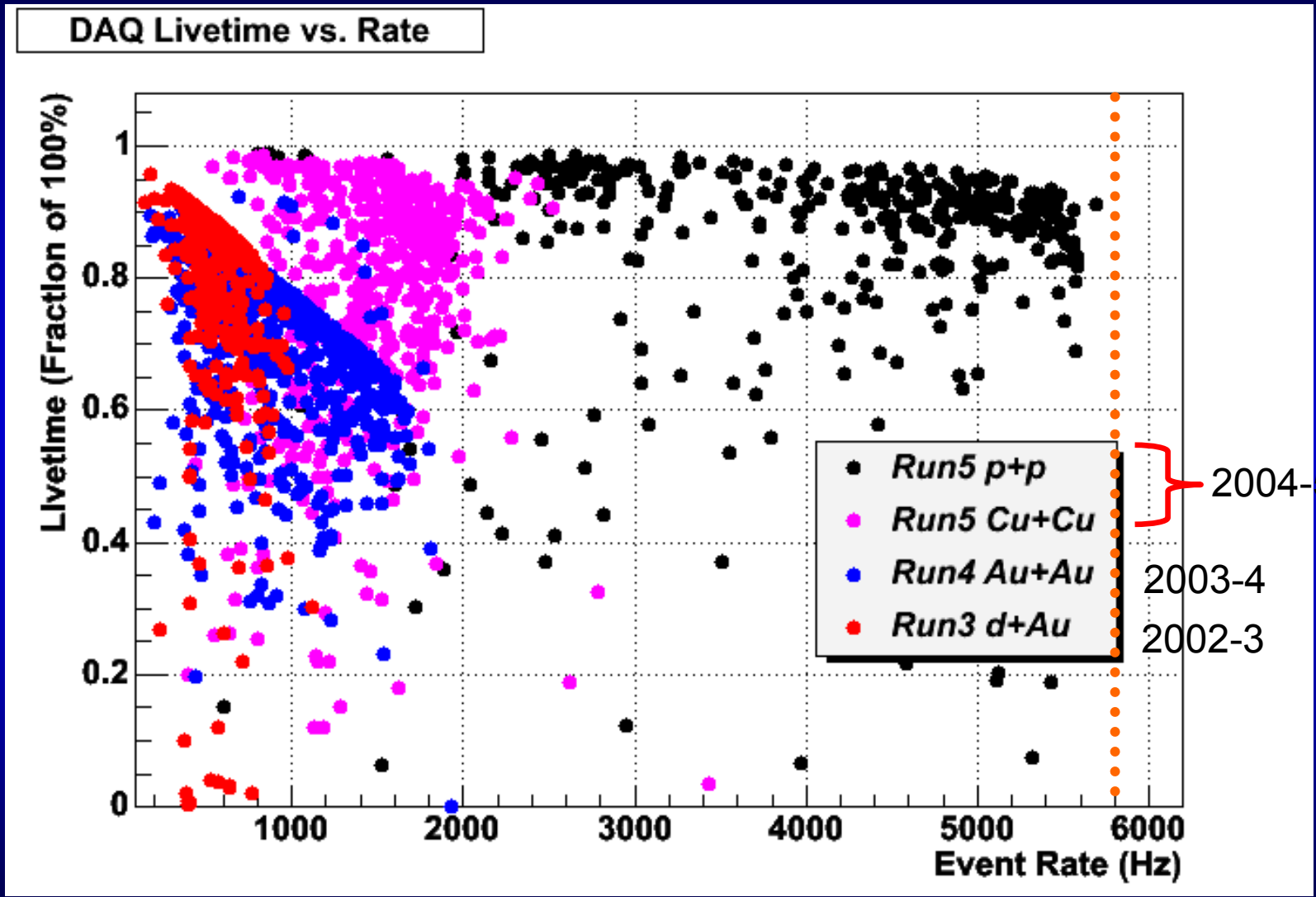
Coming Soon…

- **Eighteen parallel talks at QM05:**
  - PHENIX Measurement of Particle Yields at High pT with Respect to Reaction Plane in Au+Au collisions at sqrt(s) = 200 GeV, **David Winter**
  - High pT pi0, eta, identified charged hadron and inclusive charged hadron spectra from PHENIX, **Maya Shimomura**
  - Probing Cold and Hot, Dense Nuclear Media via High p_T Jets with Di-hadron and gamma-hadron Correlations with PHENIX, **Nathan Grau**
  - Flavor Dependence of jet-correlations in Au+Au collisions at sqrt(s_NN) =200GeV with the PHENIX Detector, **Wolf Holzmann**
  - Measurement of Direct Photons in sqrt(s_NN) = 200 GeV p+p, d+Au, and Au+Au Collisions with the PHENIX Experiment at RHIC, **Stefan Bathe**
  - Evidence for a long-range pion emission source in Au+Au Collisions at sqrt(s_NN)=200GeV in PHENIX, **Paul Chung**
  - Systematic study of identified particle production in PHENIX, **Masahiro Konno**
  - Anisotropic Flow in sqrt(s_NN) = 200 GeV Cu+Cu and Au+Au collisions at RHIC - PHENIX, **Hiroshi Masui**
  - Nuclear modifications and elliptic flow measurements for phi mesons at sqrt(s_NN) = 200 GeV dAu and AuAu collisions by PHENIX, **Dipali Pal**
  - Measurement of event-by-event fluctuations and order parameters in PHENIX, **Tomoaki Nakamura**
  - PHENIX results on J/ψ production in Au+Au and Cu+Cu collisions at sqrt(s_NN)=200 GeV, **Hugo Pereira**
  - Study of J/ψ Production in $p+p$ and $d+Au$ Collisions at sqrt(s_NN) = 200 GeV by the PHENIX Experiment, **Sasha Lebedev**
  - Heavy flavor production in p+p and d+Au collisions at sqrt(s_NN)=200 GeV, from single leptons over a wide kinematic range, **Youngil Kwon**
  - PHENIX results on Open Heavy flavor production in Au+Au collisions at sqrt(s_NN) = 200 GeV, **Sergei Butsyk**
  - Comparison of Phi properties as seen in dielectron and hadronic decay channels in Au+Au collisions by PHENIX at RHIC, **Sasha Kozlov**
  - First measurement of omega-meson production with the PHENIX Experiment at RHIC, **Viktor Riabov**
  - Measurement of low mass dielectron continuum in sqrt(s_NN)=200 GeV Au-Au collisions in the PHENIX Experiment at RHIC, **Alberica Toia**
  - Analysis of three-particle correlations in sqrt(s_NN) = 200 GeV Au+Au collisions at PHENIX, **Mate Csanad**

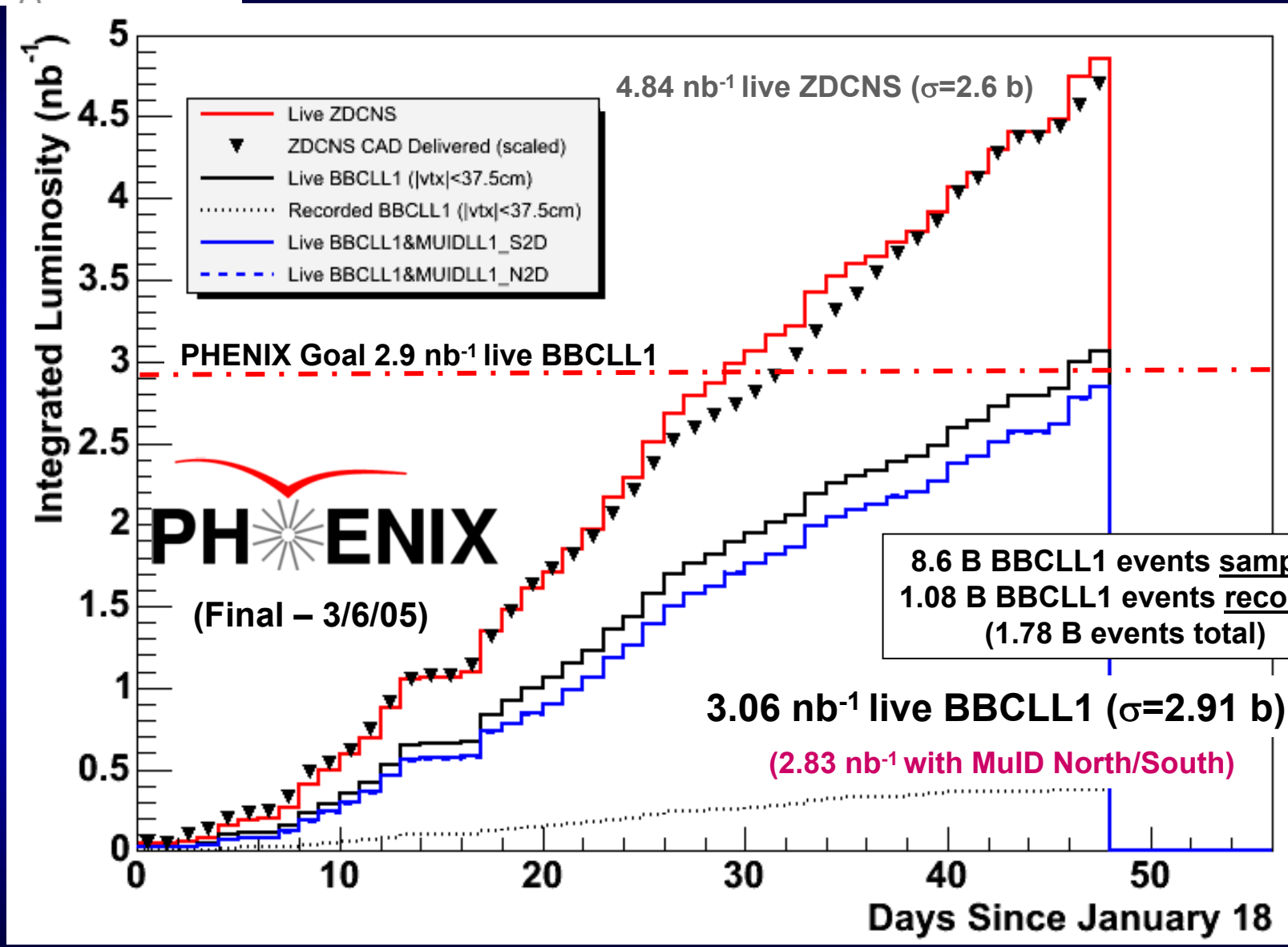
Comparable Data Archiving Rates



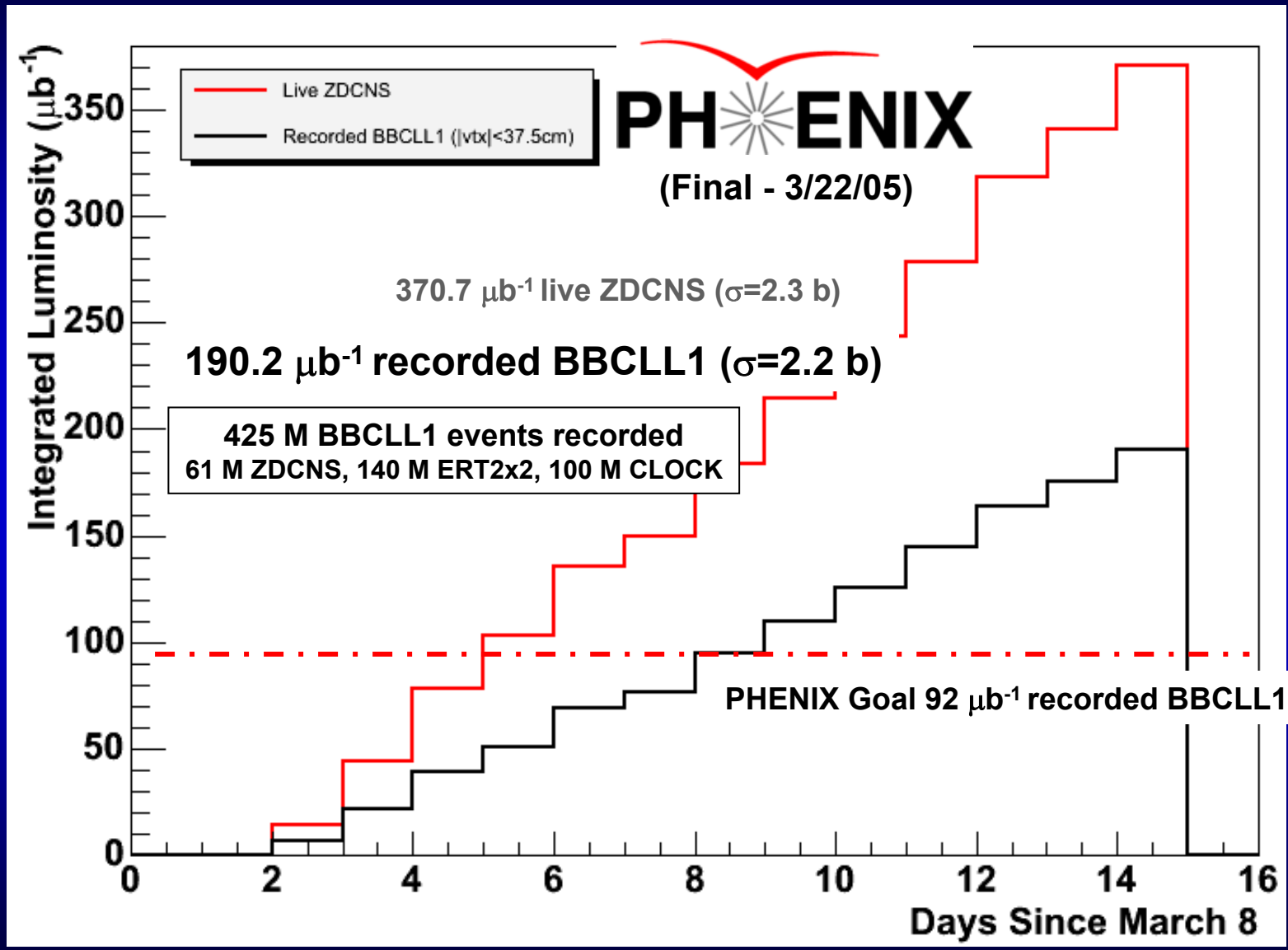
PHENIX DAQ Performance



200 GeV Cu+Cu Integrated Luminosity



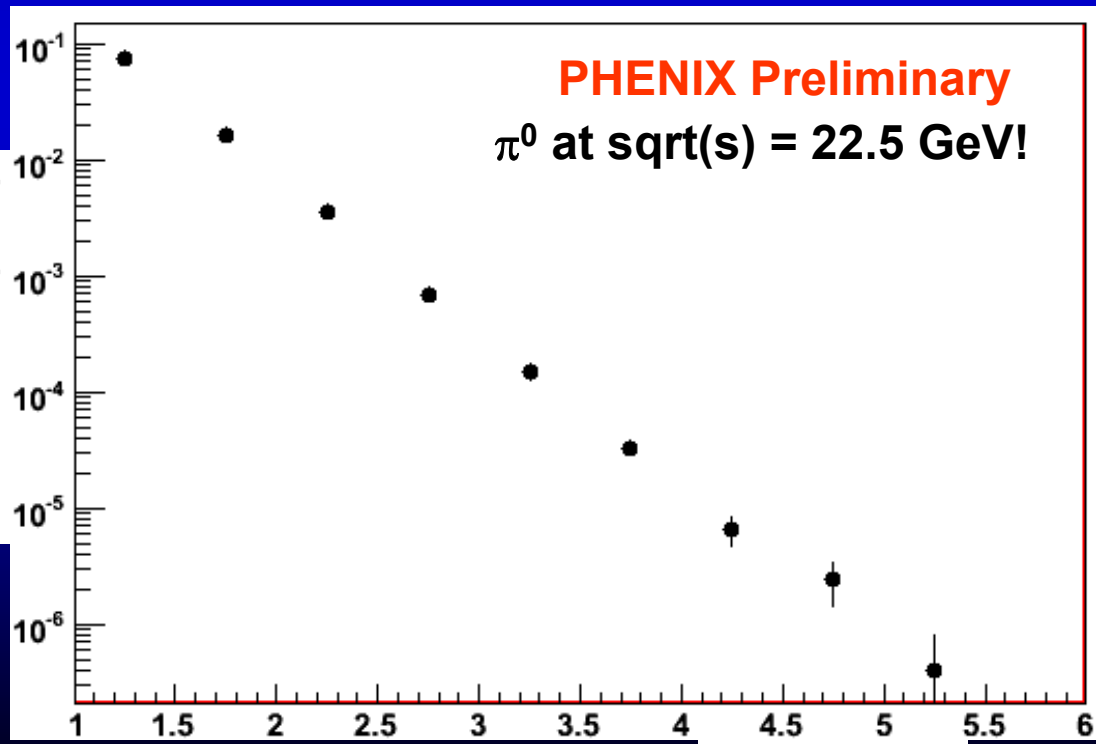
62.4 GeV Cu+Cu Integrated Luminosity



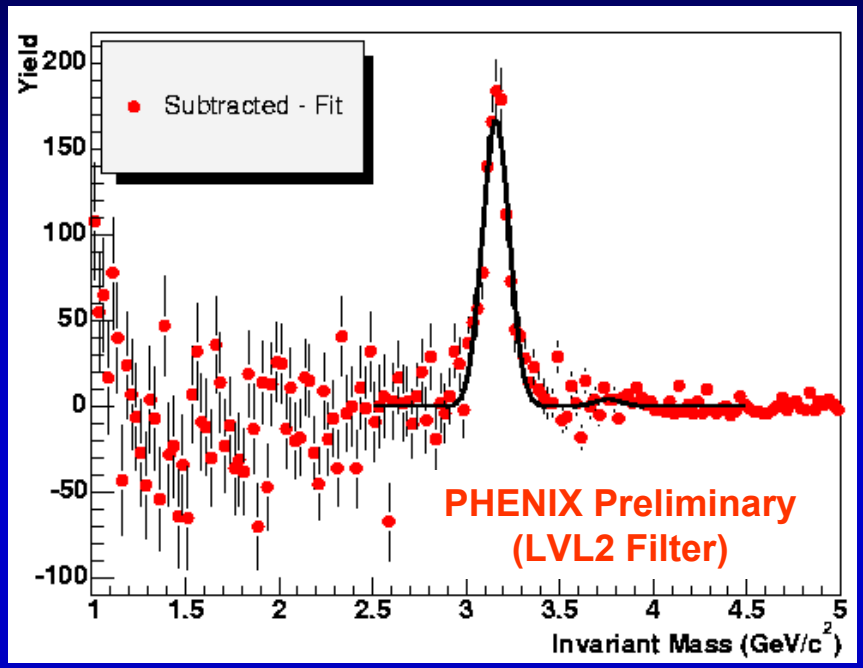
Cu+Cu at 22.5 GeV

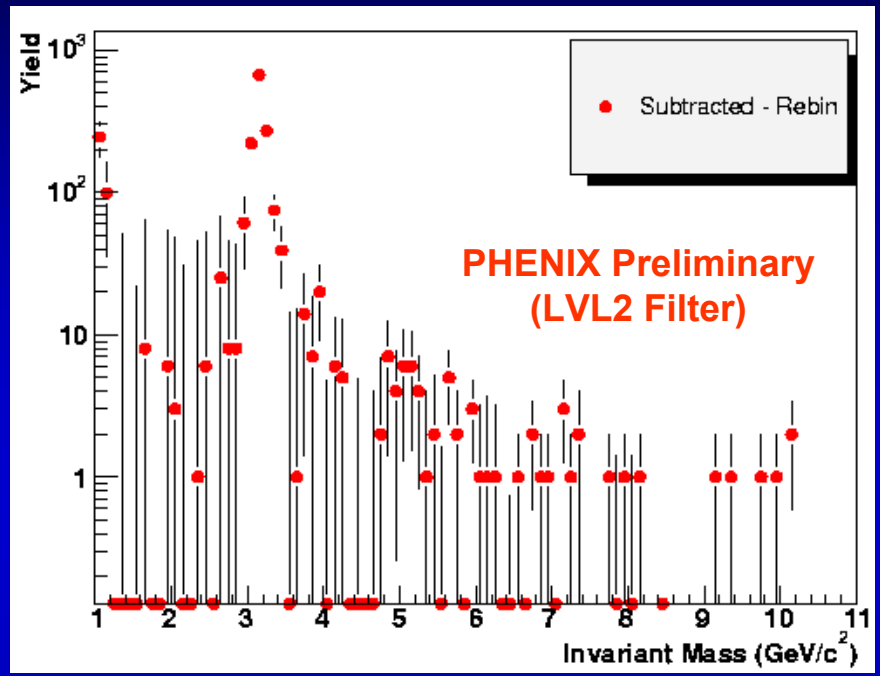
- **The injection energy run for CuCu opens additional exciting opportunities:**
  - **Collected 9.3M BBCLL1 events**
  - **R_{AA} for π^0 at 22.5 GeV?**
    - **p_T ~ 5 GeV is** $x_T = 2p_T/\sqrt{s} \sim 0.4$ **!**

Fraction of available n-n CMS energy carried by a particle in the final state



J/Ψ'e+e- in Cu+Cu 200 GeV





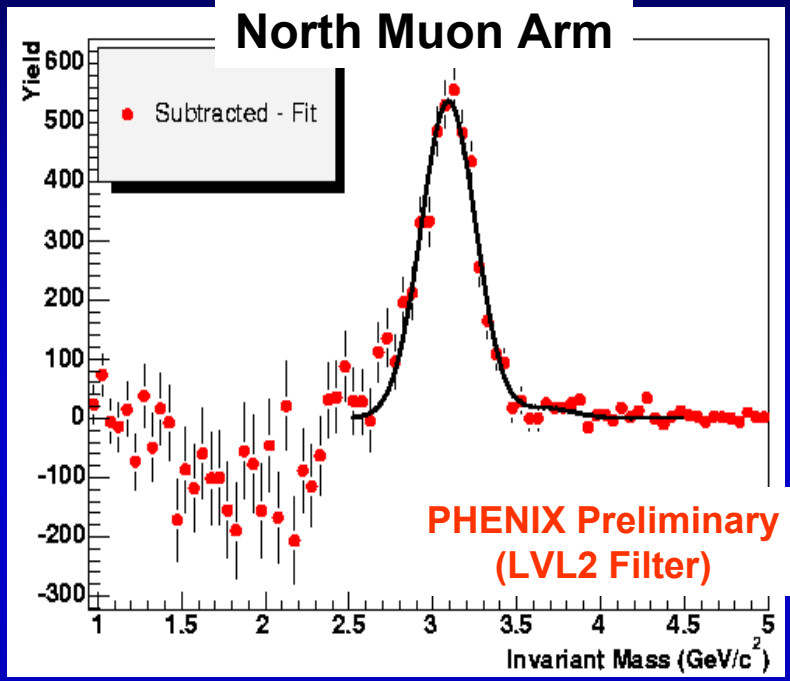
1249+/-61 J/Ψ

Handful of counts in upsilon mass region!

- **Results from LVL2 fast analysis and preliminary calibrations (semi real-time)**
- **No corrections have been applied to the data**
- **Full analysis underway….**

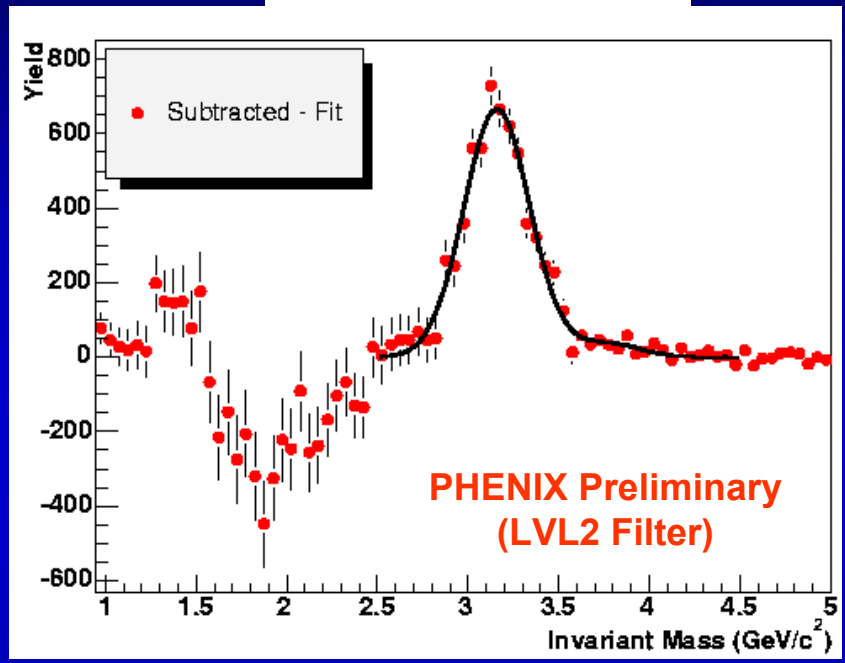
J/Ψ'μ⁺μ⁻ in CuCu 200 GeV

North Muon Arm



4690+/-162 J/Ψ

South Muon Arm

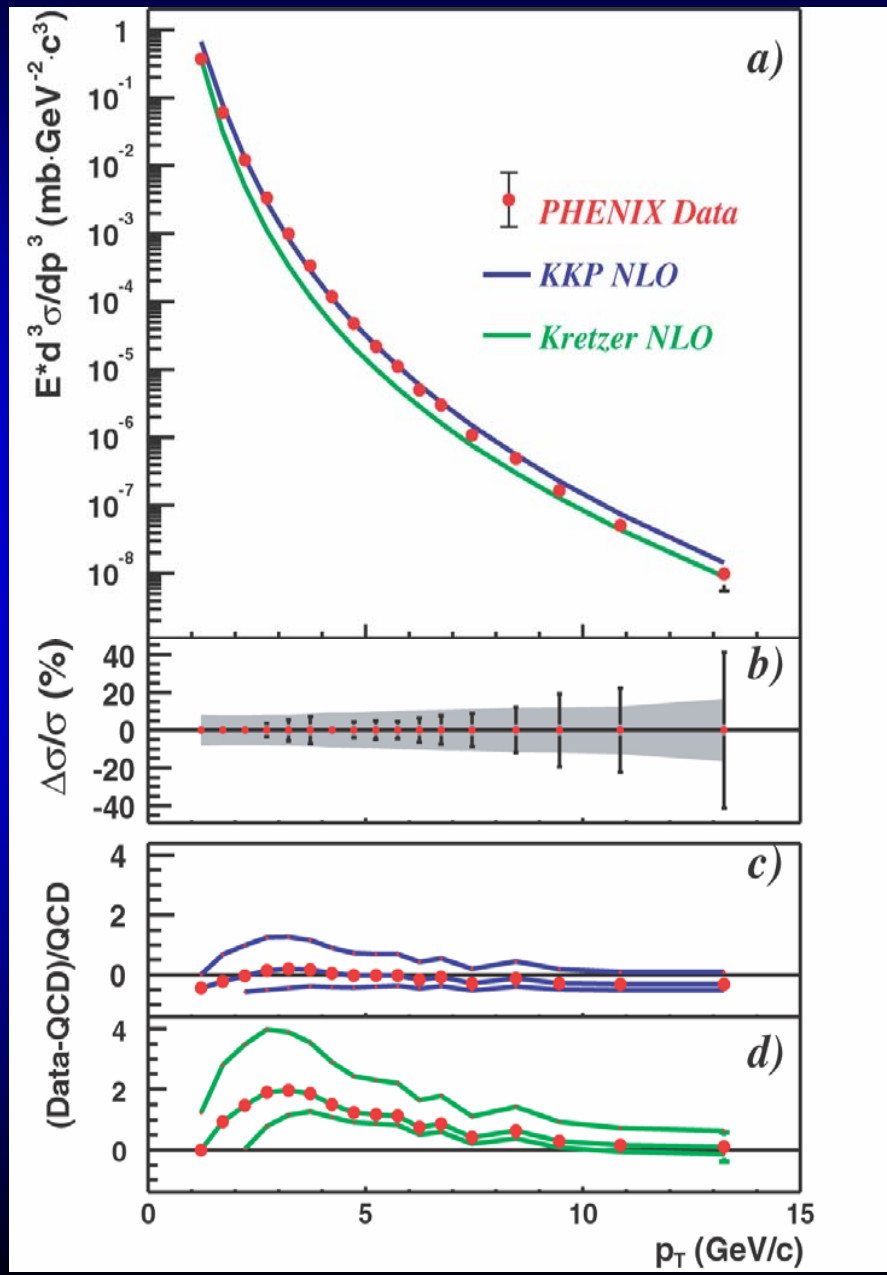


6567+/-201 J/Ψ

- Results from LVL2 fast analysis and preliminary calibrations (semi real-time)
- No corrections have been applied to the data
- Full analysis underway….

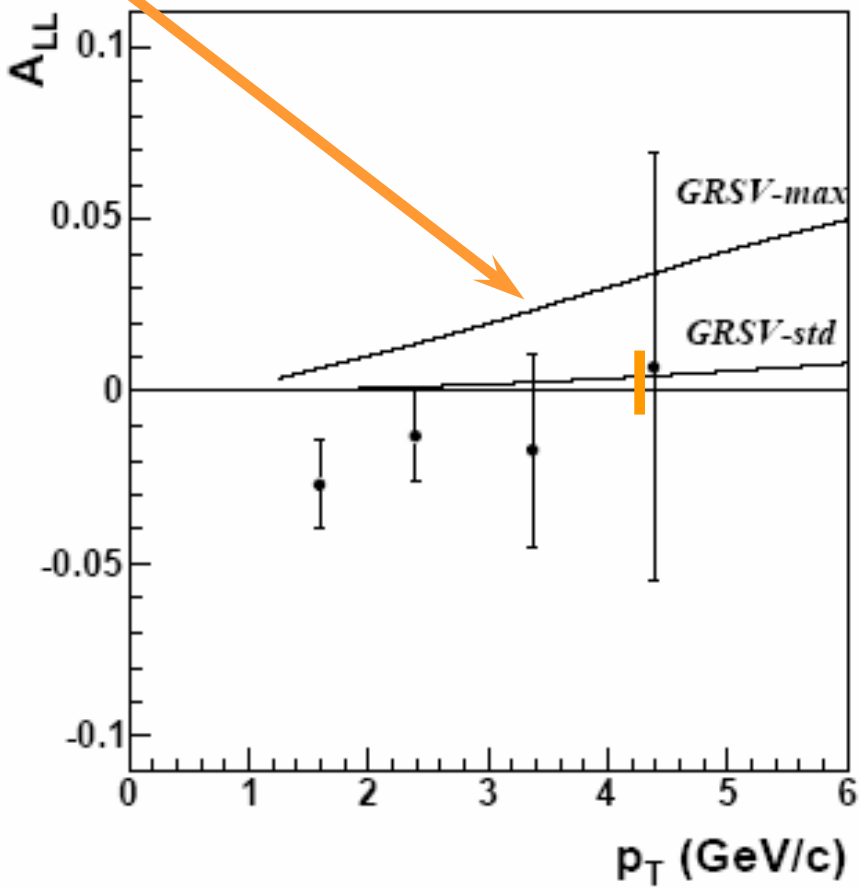
Our First "Spin" Publication

- "Midrapidity Neutral Pion Production in Proton-Proton Collisions at $\sqrt{s}$ = 200 GeV", accepted for publication in PRL on 19 September 2003, hep-ex/0304038
  - ☞ *Important confirmation of of theoretical foundations for spin program*
    - Results consistent with pQCD calculation
    - Favors a larger gluon-to-pion FF (KKP)
    - *Provides confidence for proceeding with spin measurements via hadronic channels*
- Run3 results reproduce Run2 results
  - Confirm the Run-3 data reliability and consistency
  - Run3 data reaches even higher p_T's; results will be finalized soon

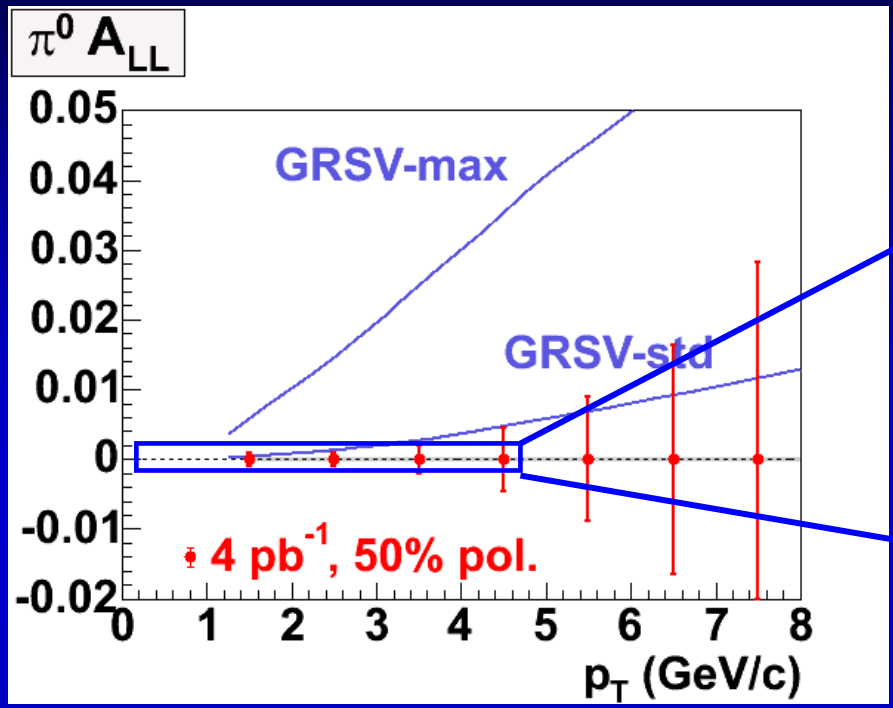


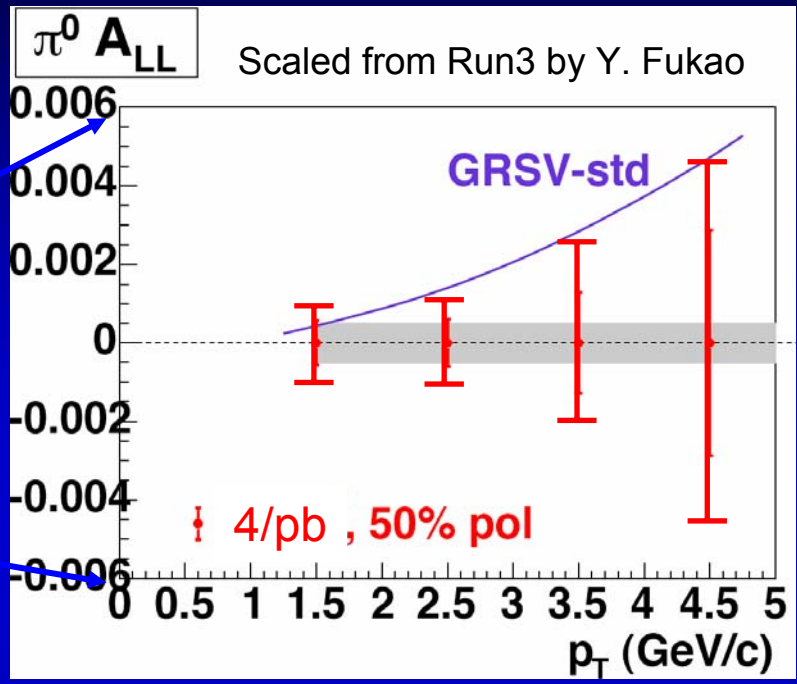
Near-Term Spin Prospects

- Run-3 published result "Double Helicity Asymmetry in Inclusive Mid-Rapidity neutral pion Production for Polarized p+p Collisions at sqrt(s)=200 GeV "
  Phys. Rev. Lett. 93, 202002 (2004)
- Extensive study of systematics
  - Bunch shuffling, background studies, A_L checks, ...
  - Relative luminosity precision ~ 2.5×10^{-4}
  - ➡ Contribution to A_{LL} < 0.2%
  - ➡ Dominated by statistical errors from 0.22 pb^{-1} sample
- Based on
  - <P> = 27%
  - 0.35 pb^{-1} recorded
  - Compared to calculations by
    - B.Jäger *et al.*, PRD67, 054005 (2003)
    - M. Glück *et al.*, PRD63, 094005 (2001)
  - Consistent with GRSV-std (C.L. ~ 16-20%)
- *A very important proof-of-principle for spin program!*



π^0 A_{LL} Expectations from Run-5





Run-3+Run-4 distinguished between GRSV-max and GRSV-std

Run-5 will distinguish between GRSV-std and $\Delta G = 0$ (or GRSV-min).

Planning

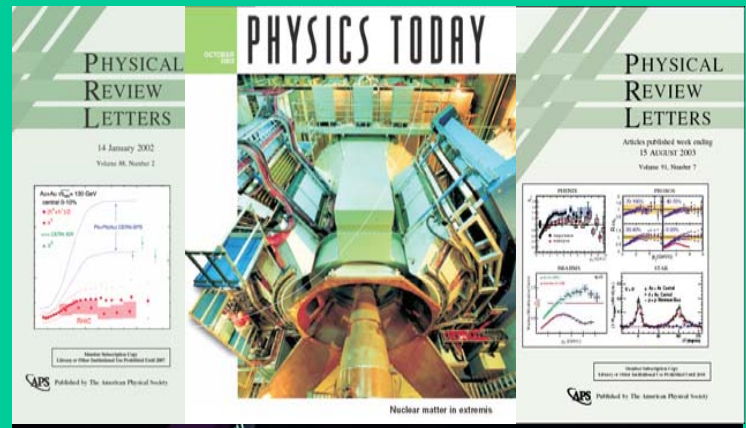
- Extensive set of recent planning and review exercises:
  - NSAC subcommittee on Heavy Ion Physics (P. Barnes, chair)
  - PHENIX Decadal Plan
  - BNL 20-year Facility Plan
  - Spin Decadal Plan
  - Multi-year Beam Use Proposal

The Immediate "Problem"

- How to fit
  - 150+ pages
  - 60+ figures
  - 10+ tables
  - 160+ references

  into one 30 minute talk?

- Not to mention PHENIX Beam Use Proposal
  - 30+ pages
  - Explicit run requests for RHIC Run-5 to Run-10
- Not to mention the problem of planning discovery physics for next 10 years…



Decadal Plan: Executive Summary (1)

- The PHENIX Collaboration has developed a plan for the detailed investigation of quantum chromodynamics in the next decade. The [redacted] of the PHENIX experiment to [redacted] in combination with RHIC's unparalleled flexibility as a hadronic collider, provides a physics program of extraordinary breadth and depth. A superlative set of measurements to [redacted] has been identified. The components of this plan include
  - Definitive measurements that will establish the nature of the matter created in nucleus+nucleus collisions, that will determine if the description of such matter as a quark-gluon plasma is appropriate, and that will quantify both the equilibrium and non-equilibrium features of the produced medium.
  - Precision measurements of the gluon structure of the proton, and of the spin structure of the gluon and sea-quark distributions of the proton via polarized proton+proton collisions.
  - Determination of the gluon distribution in cold nuclear matter using proton+nucleus collisions.

Decadal Plan: Executive Summary (2)

- Each of these fundamental fields of investigation will be addressed through a program of correlated measurements in some or all of the following channels:
  - Particle production at high transverse momentum, studied via single particle inclusive measurements of identified charged and neutral hadrons, multi-particle correlations and jet production.
  - Direct photon, photon+jet and virtual photon production.
  - Light and heavy vector mesons.
  - Heavy flavor production.

Spin Physics

- **Executive Summary: "Precision measurements of the gluon structure of the proton, and of the spin structure of the gluon and sea-quark distributions of the proton via polarized proton+proton collisions."**
- **An integral part of our program, our collaboration, our experiment, our future**
- **Original desiderata:**
  - **$\sqrt{s}$ = 200 GeV: 320 pb^{-1}, <P> = 70%**
  - **$\sqrt{s}$ = 500 GeV: 800 pb^{-1}, <P> = 70%**
- **Exponential progress:**
  - **Run-3: $\sqrt{s}$ = 200 GeV: 0.35 pb^{-1}, <P> = 27%**
  - **Run-4: $\sqrt{s}$ = 200 GeV: 0.35 pb^{-1}, <P> = 40%**
  - **Run-5: $\sqrt{s}$ = 200 GeV: 3.10 pb^{-1}, <P> = 50%**
  - **Figure of merit for double-spin asymmetries is $P^4 L$**

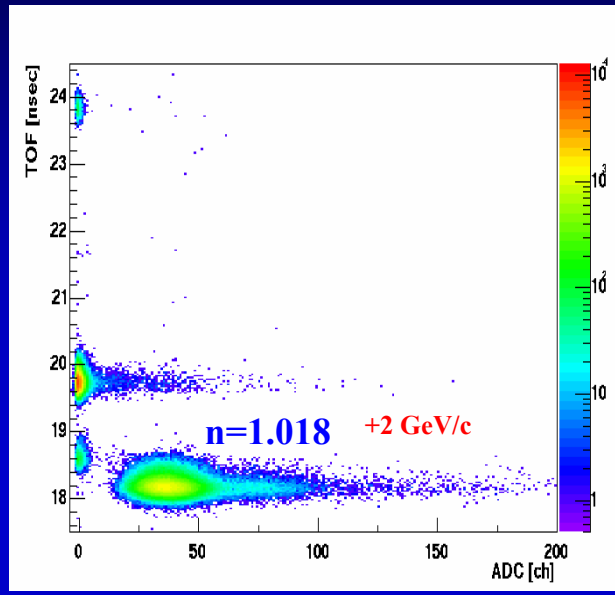
Decadal Plan: Executive Summary (3)

- A portion of this program is achievable using the present capabilities of PHENIX experimental apparatus, but the physics reach is considerably extended and the program made even more compelling by a proposed set of upgrades which include
  - An aerogel and time-of-flight system to provide complete π/K/p separation for momenta up to ~10 GeV/c.
  - A vertex detector to detect displaced vertices from the decay of mesons containing charm or bottom quarks.
  - A hadron-blind detector to detect and track electrons near the vertex.
  - A muon trigger upgrade to preserve sensitivity at the highest projected RHIC luminosities.
  - A forward calorimeter to provide photon+jet studies over a wide kinematic range.

AGEL + TOF-W

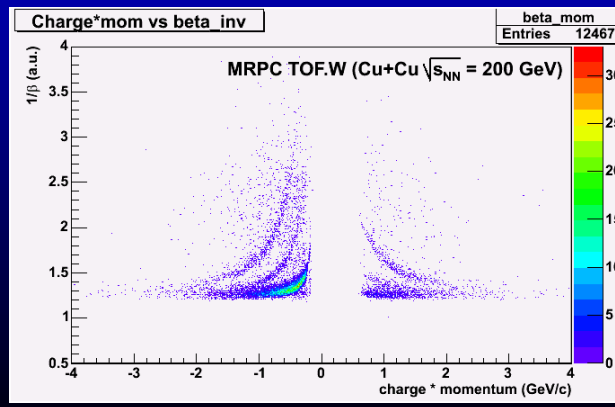
- "An aerogel and time-of-flight system to provide complete π/K/p separation for momenta up to ~10 GeV/c."

- Project well underway



  - Aerogel completely installed (first physics results to be presented at QM05)

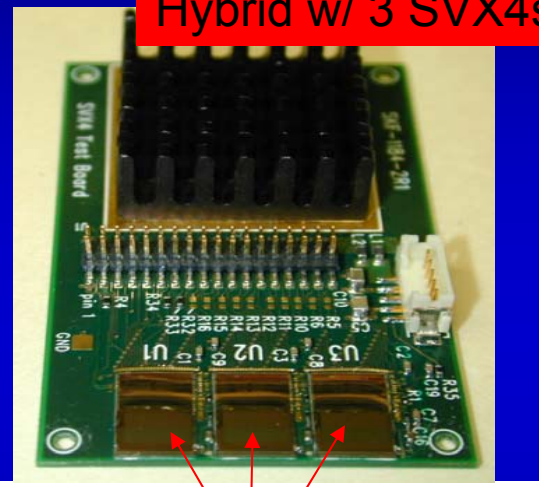
  - TOF-W ('Time-Of-Flight-West')
    - Partial funding: J. Velkovska (Vanderbilt) OJI
    - Prototypes tested in Run-5
    - System to be installed in Run-6

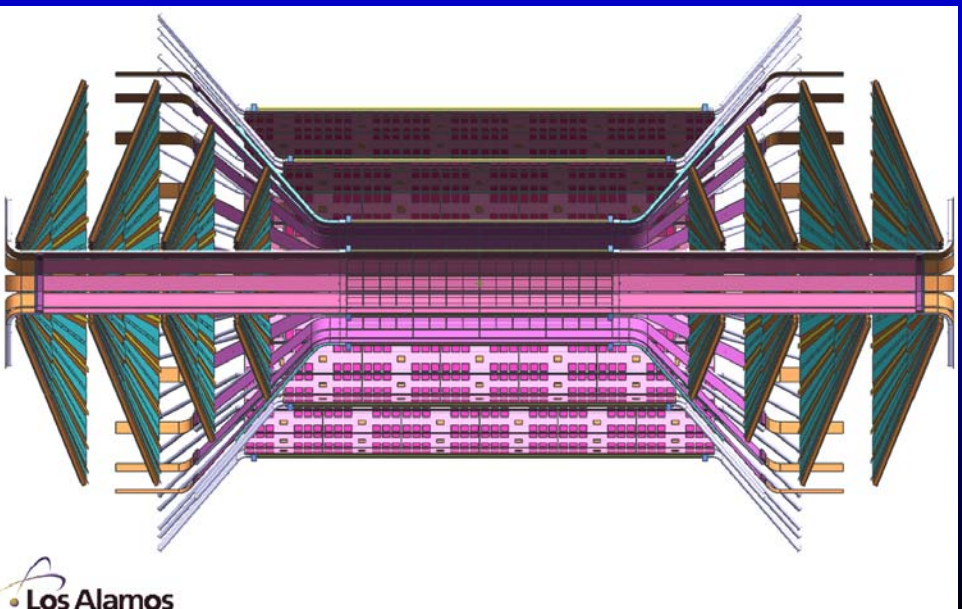


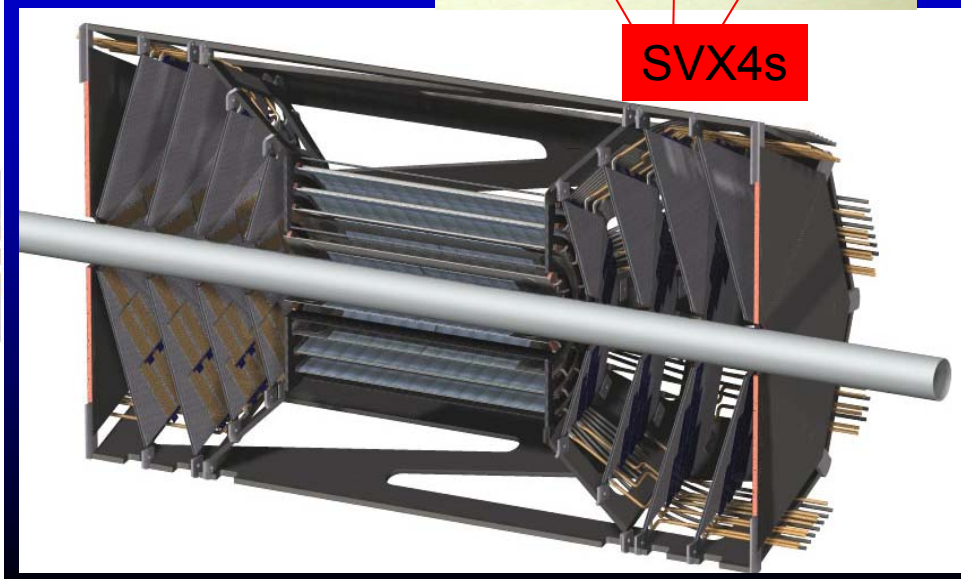
PHENIX

Silicon Tracker

- "A vertex detector to detect displaced vertices from the decay of mesons containing charm or bottom quarks."
  - ~$3M committed by RIKEN
  - MIE proposal submitted to DOE Aug-04:
    - "Project Readiness" review 19-20 January, 2005
    - Total Project Cost = $4.4M
    - Hoping for a FY07 start
    - Very active ongoing R&D program

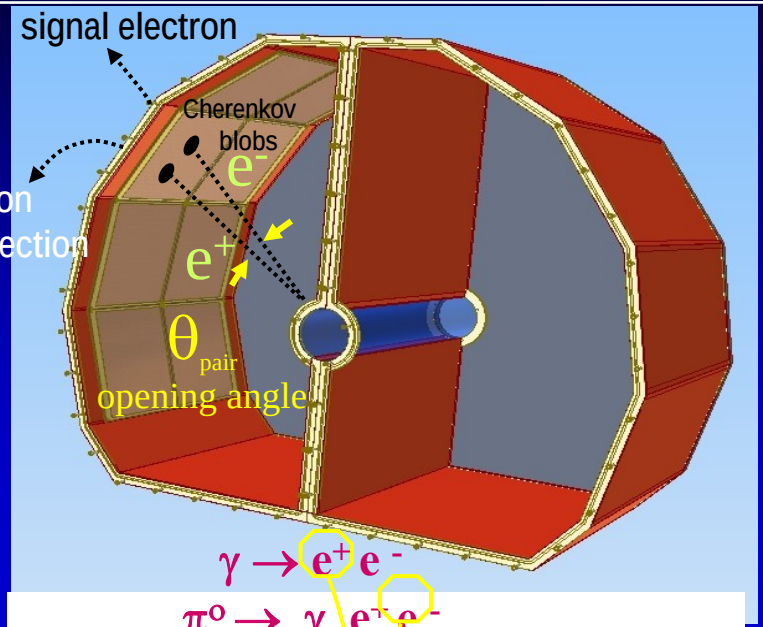


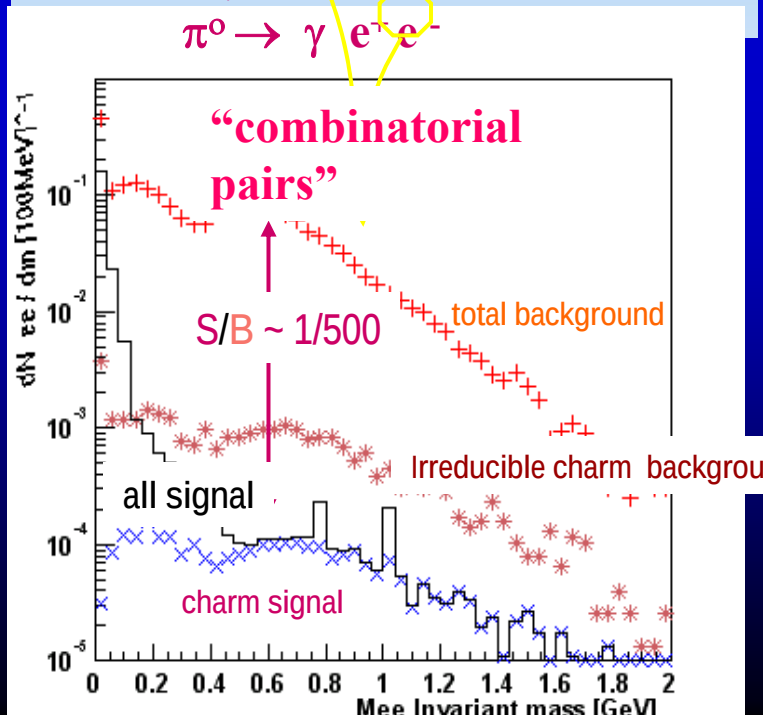




Hadron-Blind Detector (HBD)

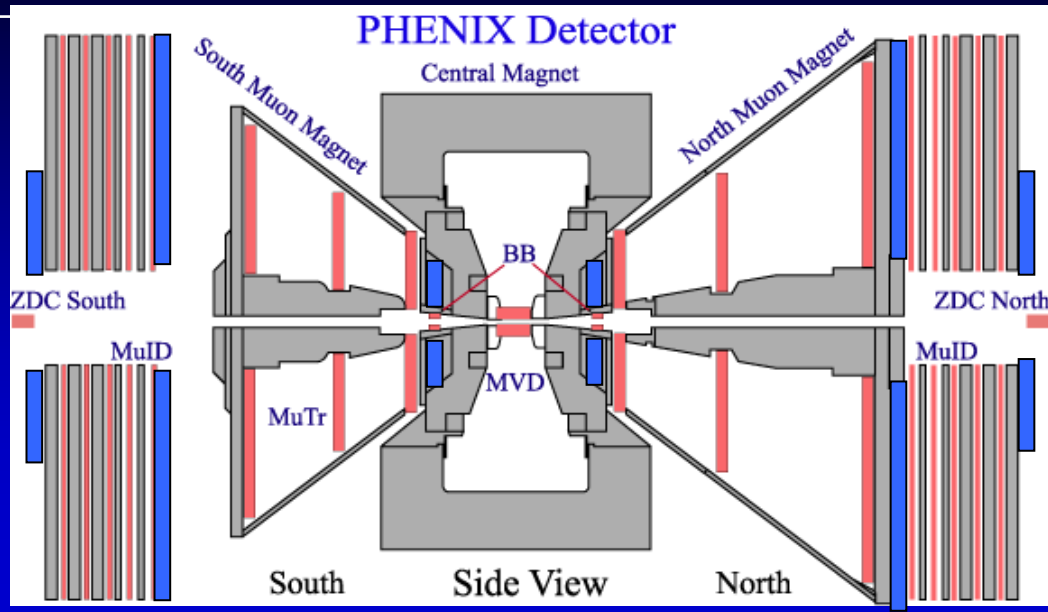
- "A hadron-blind detector to detect and track electrons near the vertex."
- Dalitz rejection via opening angle
  - Identify electrons in field free region
  - Veto signal electrons with partner
- HBD: a novel detector concept:
  - windowless CF4 Cherenkov detector
  - 50 cm radiator length
  - CsI reflective photocathode
  - Triple GEM with pad readout
- Construction/installation 2005/2006 (R&D completed)
- Breaking news: NSF will fund $250K (+ $57K from SUNY-SB)

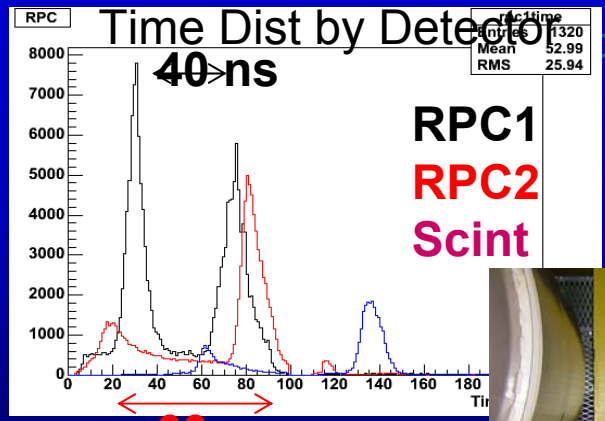


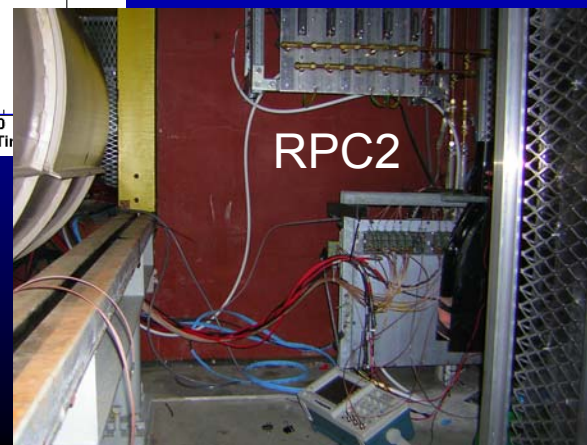


Muon Trigger Upgrade

- "A muon trigger upgrade to preserve sensitivity at the highest projected RHIC luminosities."
- Resistive Plate Chamber technology chosen by PHENIX
  - Cheap – wide coverage possible
  - Can leverage existing RPC R&D from CMS
  - Timing information
    - reject beam backgrounds
    - track association with correct bunch
  - 3-dim space point for enhanced pattern recognition
- Two small prototypes successfully tested in Run05
- Breaking news: Will be funded as NSF MRI for $1.98M
  - $100K UIUC
  - $100K UCR
  - $50K ISU
  - $30K RBRC

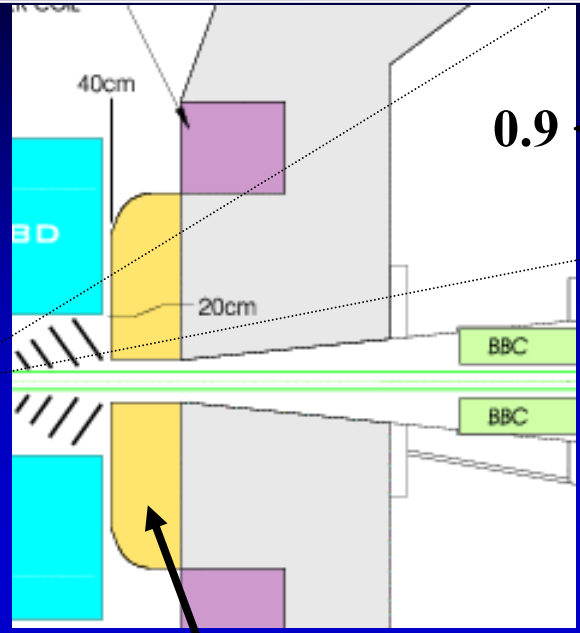


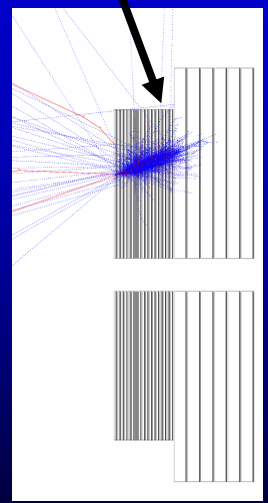




Nosecone Calorimeter (NCC)

- "A forward calorimeter to provide photon+jet studies over a wide kinematic range."
- Forward physics with PHENIX
  - Large acceptance calorimeter
  - EM calorimeter ~40 X/X_0
  - hadronic section (1.6 λ/λ_0)
  - Tungsten with Silicon readout
- Extended physics reach with NCC
  - Extended A-A program
    - high p_T phenomena: π^0 and γ-jet
    - $\chi_c \rightarrow J/\psi + \gamma$
  - Small *x*-physics in p-A
- Scope
  - Recently proposed to PHENIX collaboration
  - New expert groups join R&D (Moscow State, Czech groups)
  - Construction FY08 – FY09

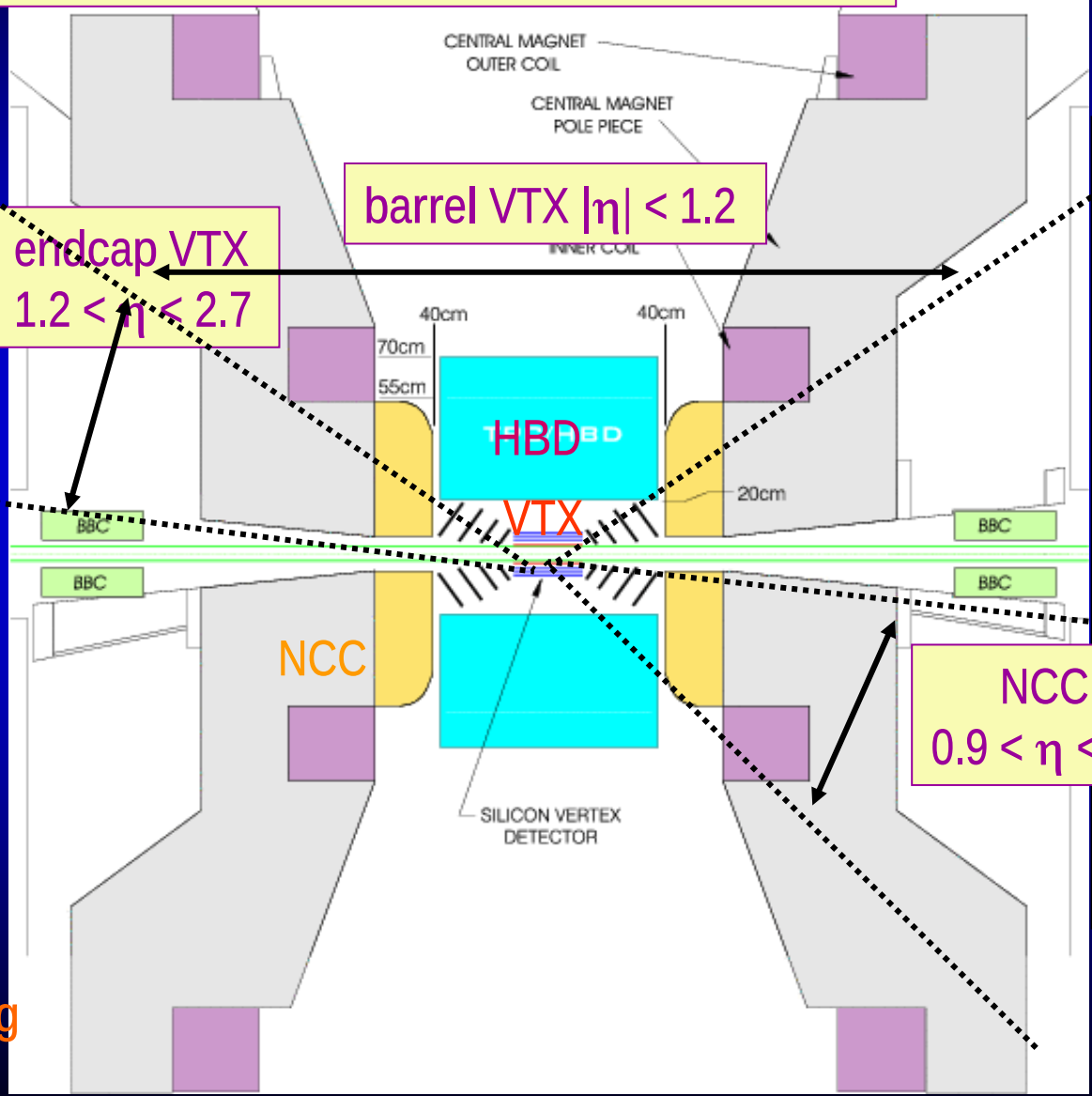




W-silicon sampling calorimeter

PHENIX Upgrade Projects

Provides displaced vertex & jet measurement over 2π



Displaced vertex:
VTX: silicon tracker

Jet measurement:
NCC: nose cone calorimeter

Other detectors:
HBD: hadron blind detector
Muon trigger
PID in west arm

PHENIX view of RHIC Upgrade Plans

Near term: Base line

Medium term: first upgrades

Long term: full detector and RHIC upgrades

2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

Analysis of data on tape

Near term detector upgrades of PHENIX
TOF-W, HBD, VTX , μTrig

Commissioning

40x design luminosity for Au-Au via electron cooling

PHENIX upgrades

Long term upgrades
FVTX, TPC/GEM, NCC

RHIC luminosity upgrade

RHIC baseline program

Au-Au ~ 250 μb^{-1} at 200 GeV
Species scan at 200 GeV
Au-Au energy scan
Polarized protons ≥ 150 nb^{-1}

Extended program with 1st detector upgrades:

Au-Au ~ 1.5 nb^{-1} at 200 GeV
Polarized p at 500 GeV
(start p-A program)

Full utilization of RHIC opportunities:

Studies of QGP with rare probes:
jet tomography, open flavor,
J/ψ, ψ', χc, ϒ(1s), ϒ(2s), ϒ(3s)

Complete spin physics program
p-A physics

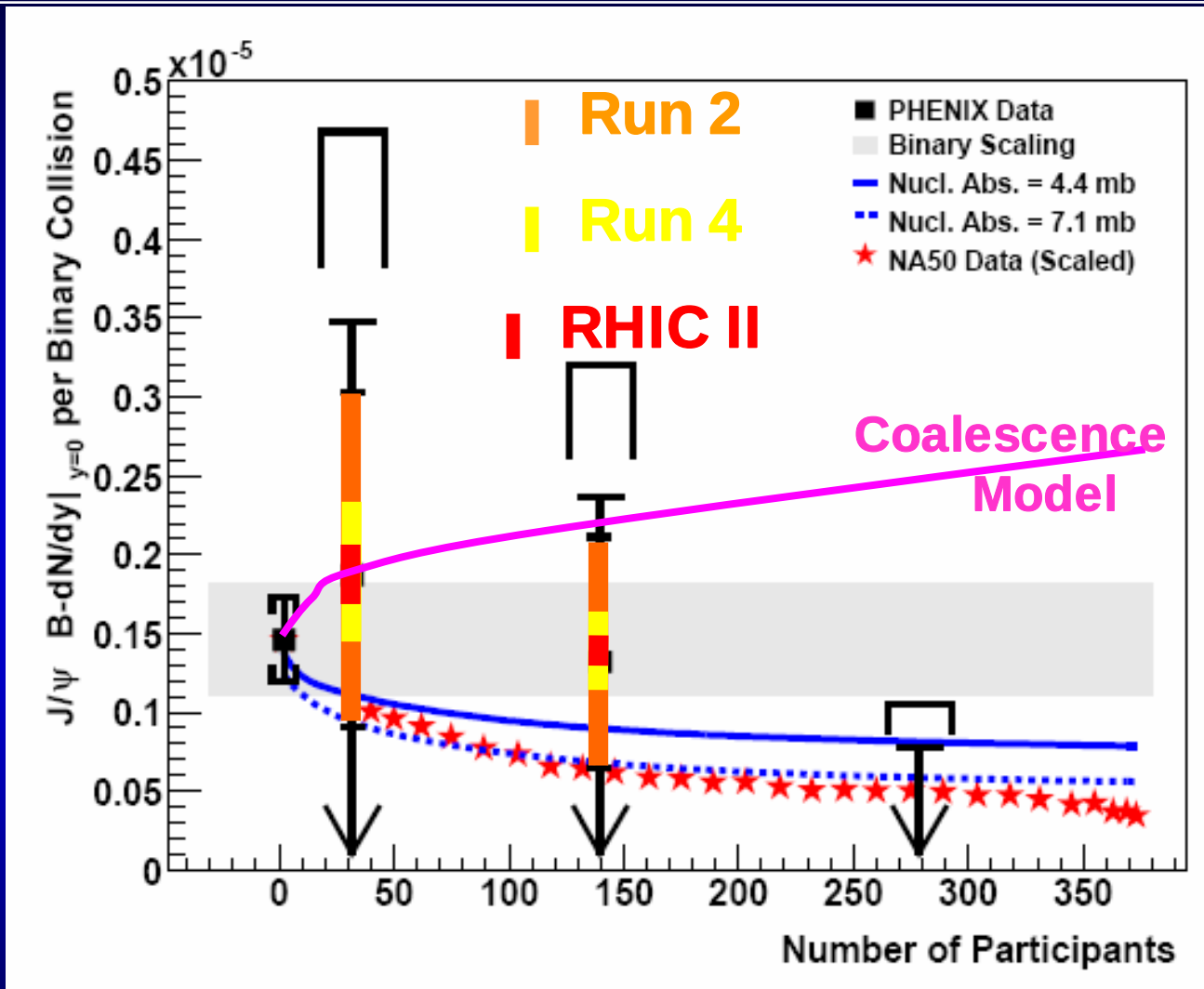
06-Jul-05

Beyond Run-7

- For Run-8 and beyond, various PHENIX upgrades become (or are already) available:
  - Si-Vertex
  - Hadron Blind Detector
  - Inner tracker
  - Muon trigger
  - Nose Cone Calorimeter
- These greatly extend our physics reach, and make re-visiting various canonical systems very attractive
- Precise strategy of course depends on time sequence of availability
- NSAC (preliminary) guidance:
  "Invest in near-term detector upgrades of the two large experiments, PHENIX and STAR, to take full advantage of the existing accelerator capabilities."

Current and Projected Status

- Existing Run-2 data set barely discriminates between *enhanced* and *suppressed* J/Ψ production
- Run-4 analysis will barely suffice to distinguish between *'ordinary'* and *'anamolous'* suppression



- Full sensitivity to screening physics using J/Ψ and Ψ ' will require *much greater* integrated luminosities, such as those provided by x10 luminosity upgrade to RHIC

Summary

- PHENIX successes in Runs 1-5 have paralleled those of the accelerator
- Ongoing, productive enterprise engaged in timely publication of an extraordinarily broad spectrum of results (Au+Au, p+p, d+Au)
- Proposed upgrades will
  - Open new channels for investigation
  - Extend investigation of rare processes to address fundamental questions in heavy ion physics
  - Extend demonstrated spin physics capabilities to higher p_T and to new channels
- Proposed program depends critically on
  - (demonstrated success of) timely development of luminosity and polarization through extended periods of beam development and steady running
  - Funding for upgrades, accelerator running, computing
- Plans provide for a program of continued discovery and extended precision for the next decade

PHENIX

Back-up

PHENIX Chronology

- Following slides assembled with assistance of Ed O'Brien (PHENIX Operations Manager)

- PHENIX has an excellent track record of

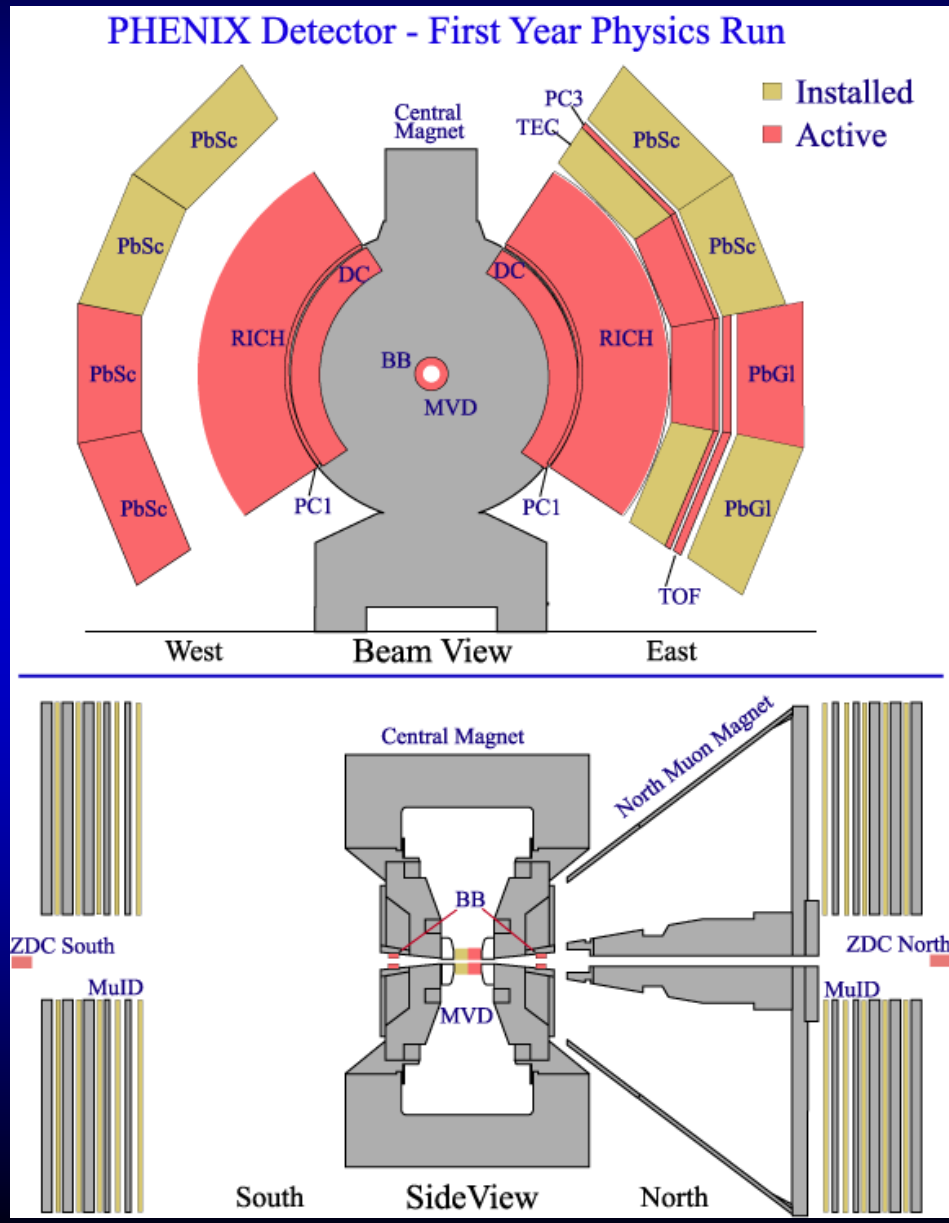
  - Performing major installations and/or upgrades in each shutdown

  while

  - Maintaining scientific productivity

Run-1 Configuration

- Two central arms
  - Mechanically ~complete
  - Roughly half of aperture instrumented
- Global detectors
  - Zero-degree Calorimeters (ZDCs)
  - Beam-Beam Counters (BBCs)
  - Multiplicity and Vertex Detector (MVD, engineering run)

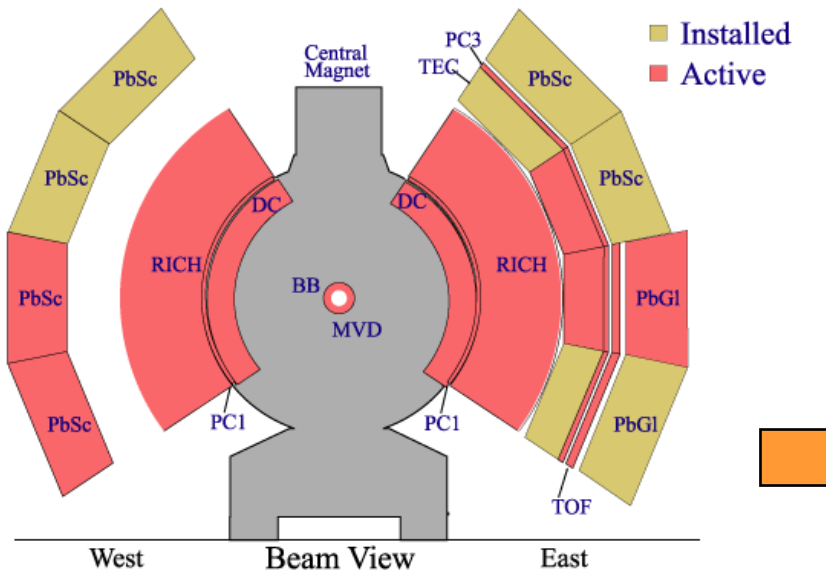


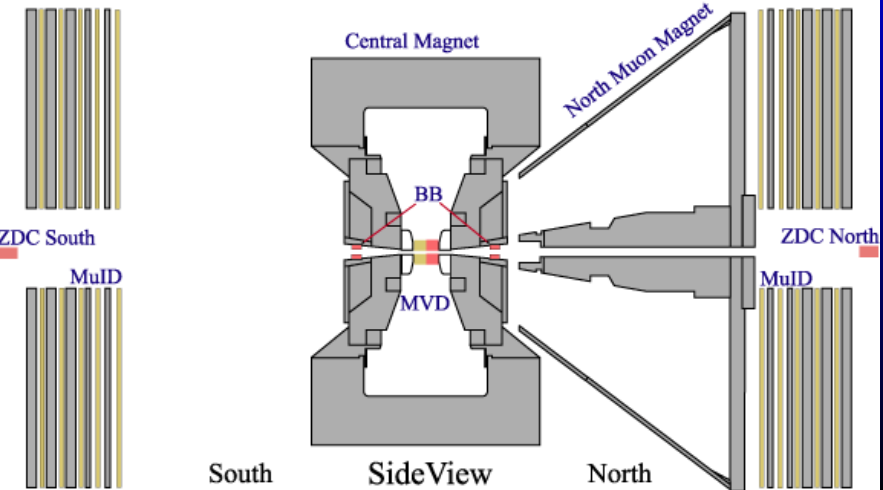
Run-1 Publications

- "Centrality dependence of charged particle multiplicity in Au-Au collisions at $\sqrt{s_{NN}}$ = 130 GeV", PRL 86 (2001) 3500
- "Measurement of the midrapidity transverse energy distribution from $\sqrt{s_{NN}}$ = 130 GeV Au-Au collisions at RHIC", PRL 87 (2001) 052301
- "Suppression of hadrons with large transverse momentum in central Au-Au collisions at $\sqrt{s_{NN}}$ = 130 GeV", PRL 88, 022301 (2002).
- "Centrality dependence of $\pi^{+/-}$, $K^{+/-}$, p and pbar production at RHIC," PRL 88, 242301 (2002).
- "Transverse mass dependence of the two-pion correlation for Au+Au collisions at $\sqrt{s_{NN}}$ = 130 GeV", PRL 88, 192302 (2002)
- "Measurement of single electrons and implications for charm production in Au+Au collisions at $\sqrt{s_{NN}}$ = 130 GeV", PRL 88, 192303 (2002)
- "Net Charge Fluctuations in Au+Au Interactions at $\sqrt{s_{NN}}$ = 130 GeV," PRL. 89, 082301 (2002)
- "Event-by event fluctuations in Mean p_T and mean e_T in sqrt(s_NN) = 130GeV Au+Au Collisions" Phys. Rev. C66, 024901 (2002)
- "Flow Measurements via Two-particle Azimuthal Correlations in Au + Au Collisions at $\sqrt{s_{NN}}$ = 130 GeV" , PRL 89, 212301 (2002)
- "Measurement of the lambda and lambda^bar particles in Au+Au Collisions at $\sqrt{s_{NN}}$ =130 GeV", PRL 89, 092302 (2002)
- "Centrality Dependence of the High pT Charged Hadron Suppression in Au+Au collisions at $\sqrt{s_{NN}}$ = 130 GeV", Phys. Lett. B561, 82 (2003)
- "Single Identified Hadron Spectra from $\sqrt{s_{NN}}$ = 130 GeV Au+Au Collisions", to appear in Physical Review C, nucl-ex/0307010

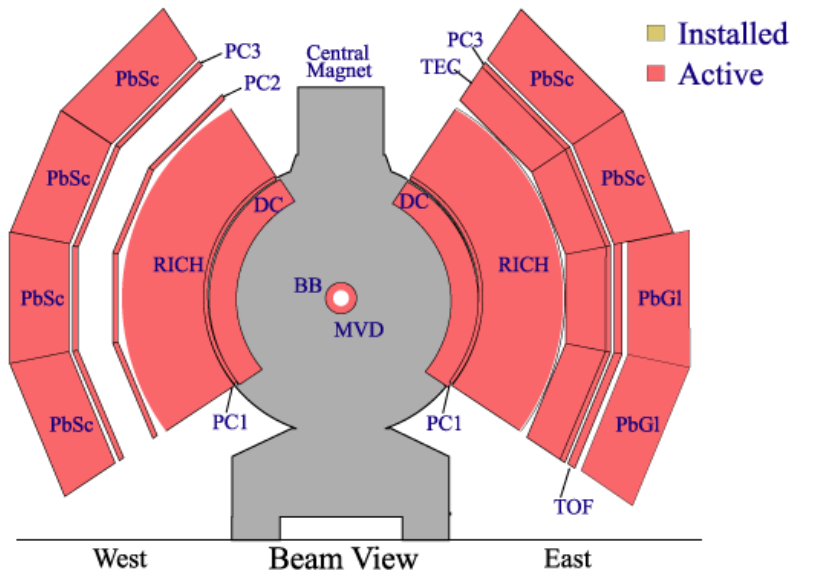
From Run-1 to Run-2

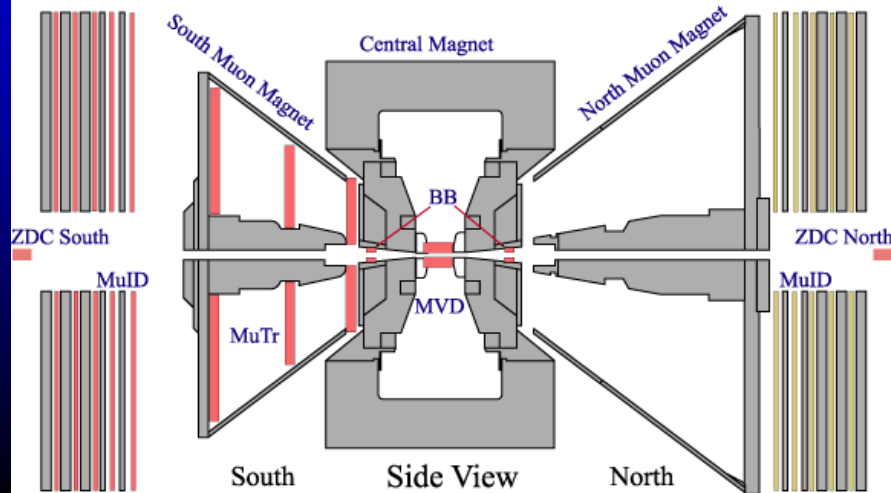
Run-1 (2000)





Run-2 (2001-2)

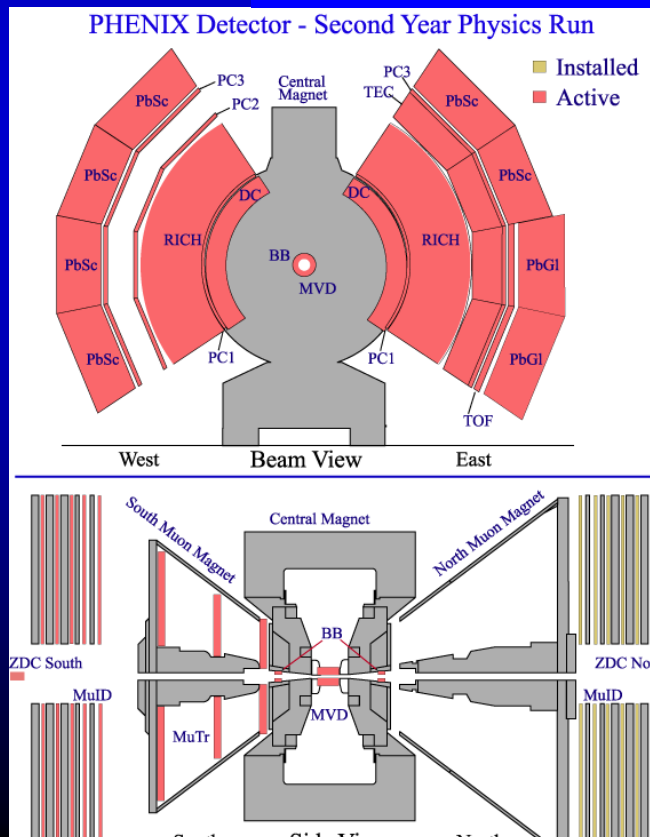




Work in 2001 Shutdown

- Construction, installation and commissioning of South Muon Spectrometer
- Install and commission PC2, PC3 in West carriage
- Install and commission 5 sectors EMCal electronics
- Install and commission 2 sectors TEC electronics
- Commissioning and operation of MVD (Silicon Vertex)
- Commissioning and operation of PHENIX Event Builder
- Commissioning and operation of PHENIX Level2 Trigger
- Completion of RICH electronics
- Major servicing of Drift Chamber East

Run-2 PHENIX



Run-2 Publications

- "Suppressed π^0 Production at Large Transverse Momentum in Central Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV" , Phys. Rev. Lett. 91, 072301 (2003)
- "Scaling Properties of Proton and Anti-proton Production in $\sqrt{s_{NN}}$ = 200 GeV Au+Au Collisions“, Phys. Rev. Lett 91, 172301 (2003).
- "J/Ψ Production in Au-Au Collisions at $\sqrt{s_{NN}}$ =200 GeV at the Relativistic Heavy Ion Collider", Phys. Rev. C 69, 014901 (2004).
- "Elliptic Flow of Identified Hadrons in Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV" , Phys.Rev.Lett. 91 (2003) 182301
- "Midrapidity Neutral Pion Production in Proton-Proton Collisions at $\sqrt{s}$ = 200 GeV“, Phys. Rev. Lett. 91, 241803 (2003)
- "Identified Charged Particle Spectra and Yields in Au-Au Collisions at $\sqrt{s_{NN}}$= 200 GeV", Phys. Rev. C 69, 034909 (2004)
- "J/Ψ production from proton-proton collisions at $\sqrt{s}$ = 200 GeV“, Phys. Rev. Lett. 92, 051802 (2004)
- "High-pt Charged Hadron Suppression in Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 Gev”, Phys. Rev. C 69, 034910 (2004)
- "Measurement of Non-Random Event-by-Event Average Transverse Momentum Fluctuations in $\sqrt{s_{NN}}$ =200 GeV Au+Au Collisions" , S.S. Adler et al., Phys. Rev. Lett. 93, 092301 (2004),
- "Bose-Einstein Correlations of Charged Pion Pairs in Au+Au Collisions at $\sqrt{s_{NN}}$ =200 GeV" to appear in PRL, nucl-ex/0401003
- "Deuteron and anti-deuteron production in Au+Au collisions at \sqrt{s} = 200 GeV" , submitted to PRL June 1, 2004, Preprint: nucl-ex/0406004
- "Identified Leading Particle Correlations in Au+Au and d+Au collisions at $\sqrt{s_{NN}}$ =200 GeV" , submitted to PRL Aug. 7, 2004, nucl-ex/0408007

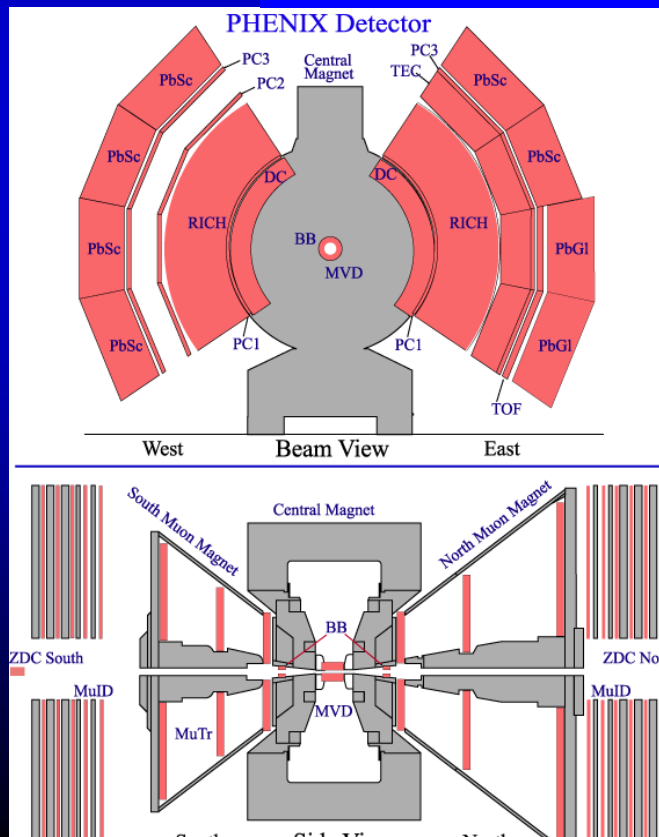
Also contains Run-3 d+Au data

Work in 2002 Shutdown

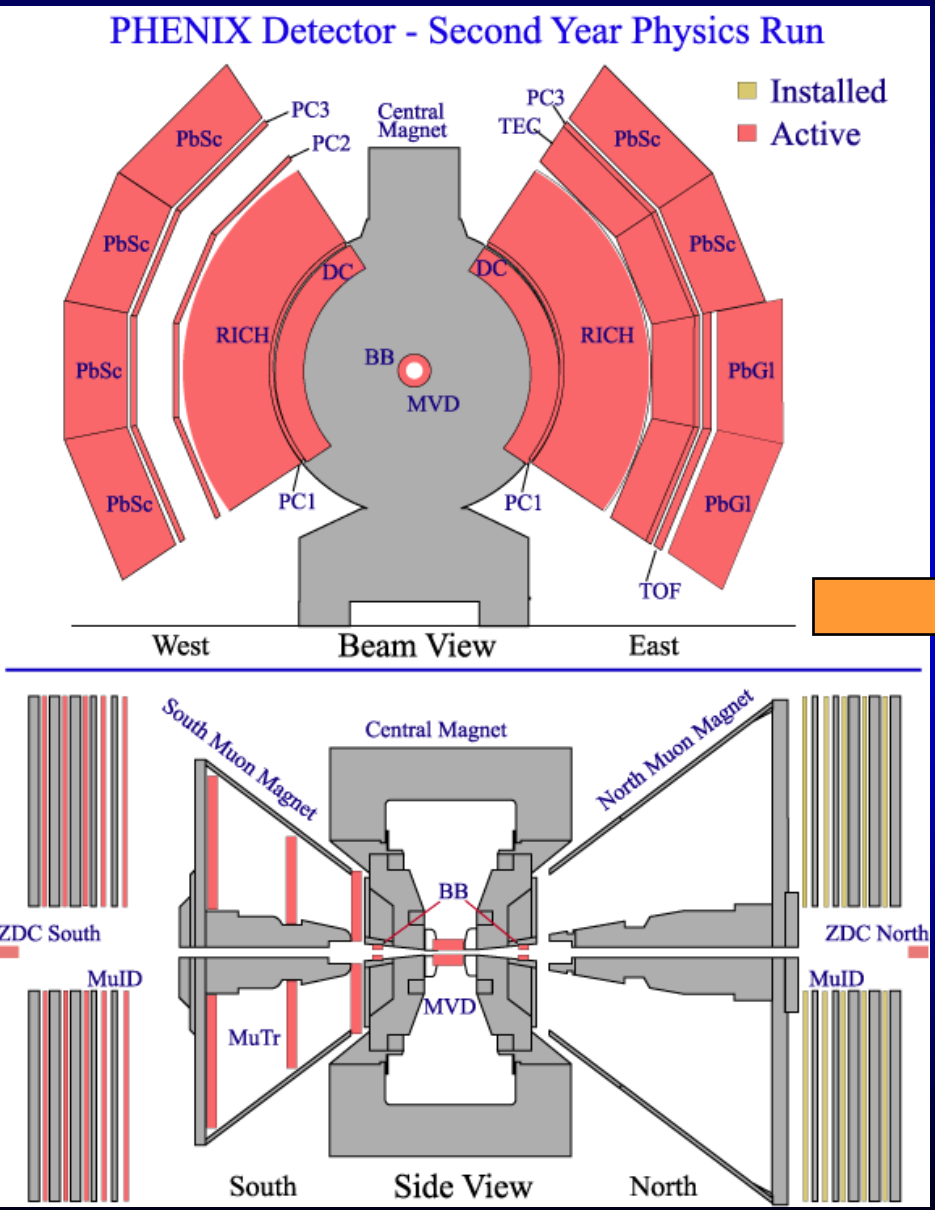
- MuTrk South Spectrometer removal, service and reinstallation
- MuTrk North Spectrometer prep, installation & commissioning
- MuID shielding installation in MuID cutout N&S
- Installation of TRD radiator packs in Time Expansion Chamber
- Install Central Magnet inner coils
- Replace temporary access scaffold with permanent access system
- Modify Central Magnet nosecones
- Install new BBC rack. Move electronics and recable
- Addition of Two Forward Calorimeter for d-A running
- Upgrade to PHENIX safety systems
- Installation of all electronics for Muon North spectrometer arm muTracking + MuID
- Installation of 2 additional planes of electronics for Time Expansion Chamber
- Upgrades to LVL1 Trigger system (NTC, ZDC, EMCal/RICH, MuID)

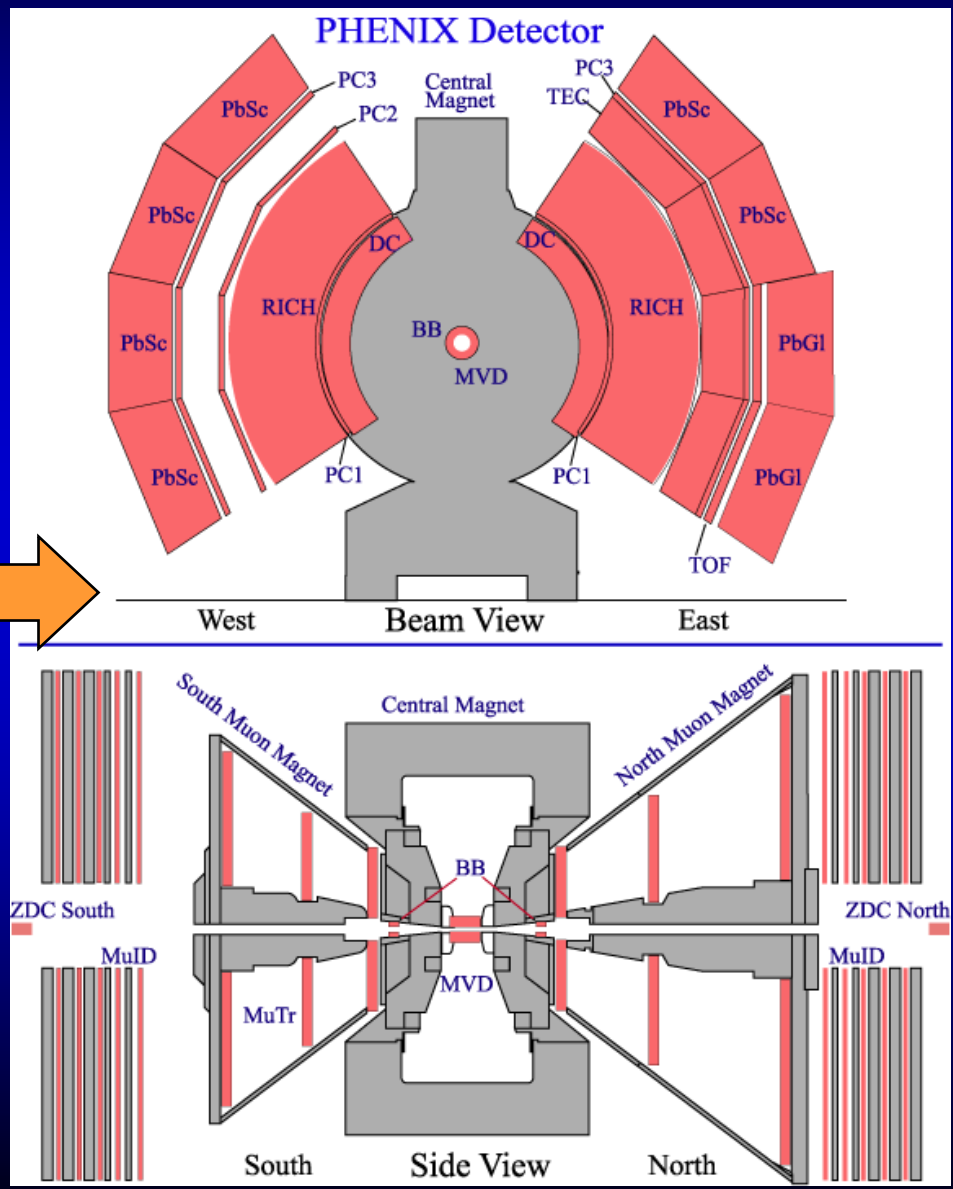
PHENIX baseline detector was declared COMPLETE at the beginning of Run-3

Run-3 PHENIX



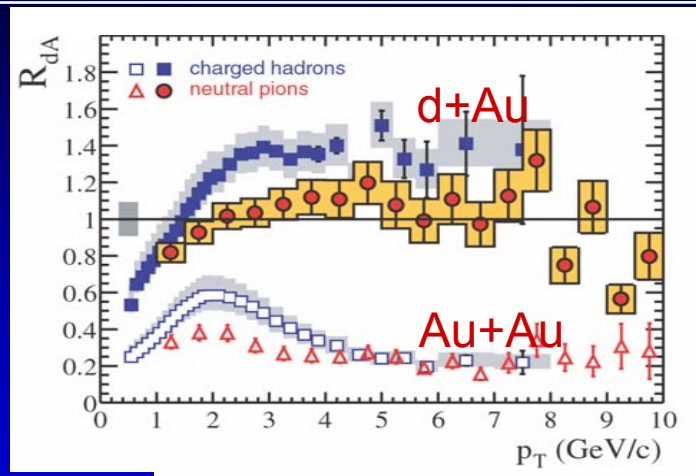
Run-3 and Beyond



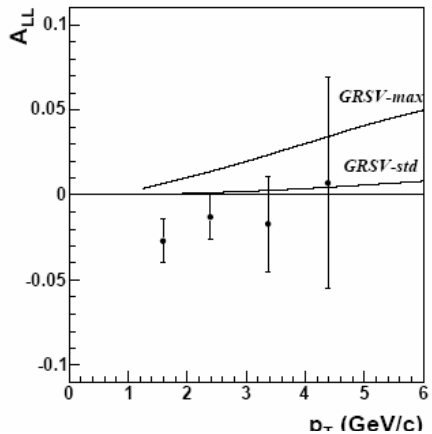


Run-3 Publications

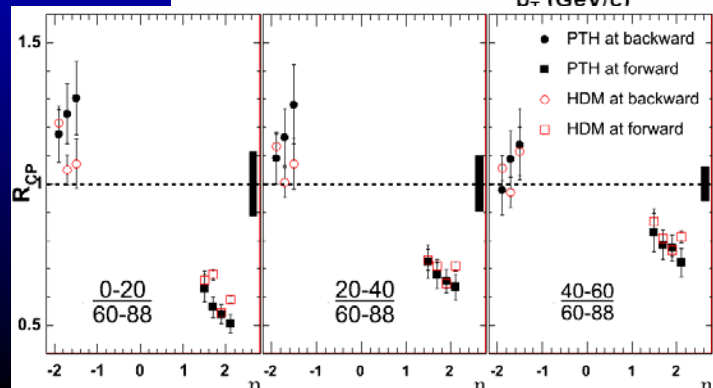
- "Absence of Suppression in Particle Production at Large Transverse Momentum in $\sqrt{s_{NN}}$ = 200 GeV d+Au Collisions",
  PRL 91, 072303 (2003)
  - ☞ PID-ed particles (π^0's) out to the highest p_T's PHENIX's unique contribution to June '03 "press event"



- "Double Helicity Asymmetry in Inclusive Mid-Rapidity neutral pion Production for Polarized p+p Collisions at sqrt(s)=200 GeV "
  Phys. Rev. Lett. 93, 202002 (2004)
  - ☞ First measurement of A_{LL} at RHIC.



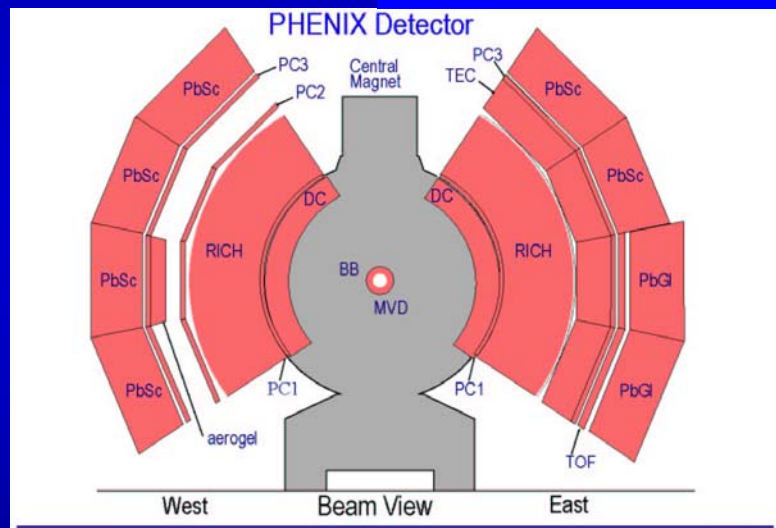
- "Nuclear Modification Factors for Hadrons At Forward and Backward Rapidities in Deuteron-Gold Collisions at √sNN = 200 GeV"
  Phys. Rev. Lett. 94, 082302
  - ☞ Clever extension of PHENIX hadron capabilities to the muon arms

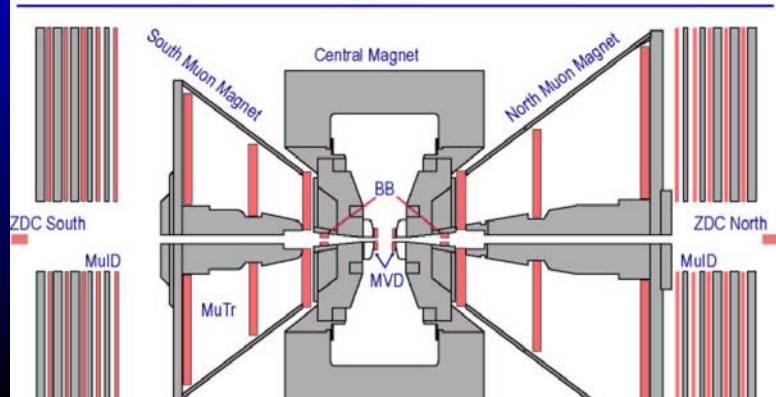


Work in 2003 Shutdown

- Reinstall Photon Shields
- Muon N&S Servicing
- Complete and commission TRD Xenon system
- West Carriage platforms for Aerogel
- Installation of Aerogel ½ sector
- Complete Inner Coil buswork
- Magnet mapping with Inner Coil
- New MuTracking Gas System
- New IR air conditioning
- Improve IR Rack cooling water
- Improve shielding in the tunnel for Muon Arms
- General Detector Maintenance
- Electronics Maintenance
- Improve TEC LV situation
- Replace Drift Chamber East dc/dc converters
- Fab MuID N LL1 boards
- Finish configuration of gigabit Ethernet EvB switch
- More LVL2 code development
- Fix Pad Chamber Multi-event buffering
- Change Databases (Objy to PostgreSQL)
- Complete installation of TEC/TRD electronics
- Complete ERT/MuID S LL1
- Fab Smart Partitioner Modules for MuTracking

Run-4 PHENIX





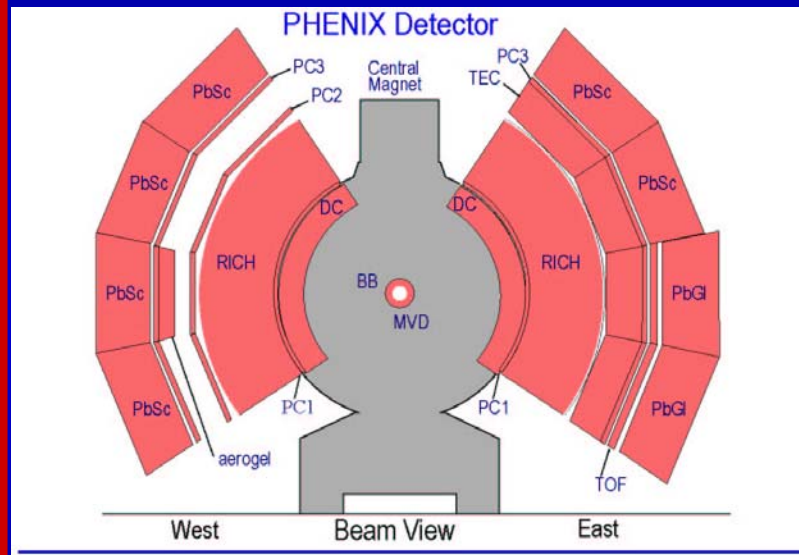
PHENIX Work Completed in 2004 Shutdown

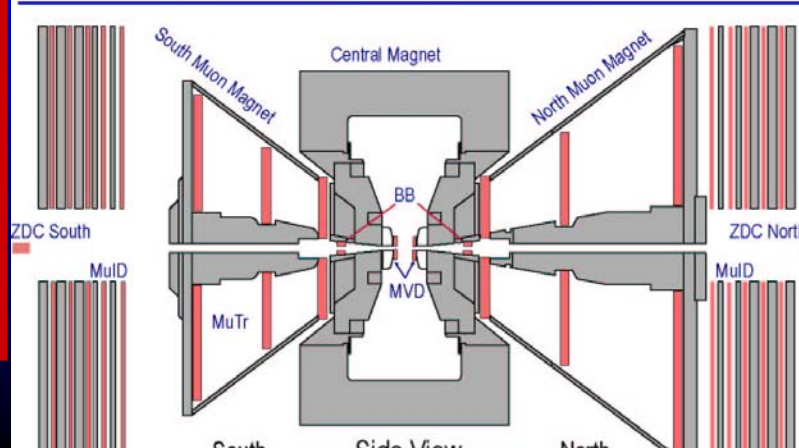
- ✔ General maintenance on PHENIX subsystems
- ✔ 2nd ½ of Aerogel Sector completed and installed
- ✔ Drift Chamber E Window repair
- ✔ DC W dc-dc converter replacement
- ✔ Magnet mapping
- ✔ Lots of Gas system work
- ✔ Extra Tunnel Shielding for Muon Arms
- ✔ Fix Multi-event buffering (MuTracker, EMCal)
- ✔ Improve FEM Data Formatting (MuTracking, EMCal)
- ✔ LL1 trigger work (MuID, ERT)
- ✔ EvB improvements (convert to LINUX)
- ✔ Implement 4X data buffering capability in 1008 (32 TB)
- ✔ TOF-W prototype installed in West Arm
- ✔ New Scalers for pp running
- New Rack Platforms for PHENIX Upgrade Detectors

Built, install Summer 05

What is New for Run-5

- New Aerogel ½-sector completed and installed
- Multi-event buffering for MuTracking, EMCal implemented
- Event Builder converted to Linux , plus other improvements.
- With DAQ & EvB improvements expect 5+ kHz event recording rate (Data rate max 1 GB/s uncompressed).
- 32 TB additional buffering capacity in 1008.
  - Increase bufferboxes from 4 to 6
- New maps of the magnetic field
- Tests of TOF-West prototype
- Gas system improvements for MuID, TRD
- Additional tunnel shielding for Muon Arms
- LL1 working for MuID and ERT
- Improvements to PHENIX Safety system
- New Scalers available for pp run





Current Run Request

- An extensive program of luminosity and polarization development for p+p,
  with the goal of the earliest practicable measurement of ΔG
- Light-ion running,
  to investigate dependence on system size
- A reduced energy run,
  again with emphasis on obtaining highest possible integrated luminosity
- High integrated luminosities achieved via minimal variations in species and energies,
  as per CAD guidance
- ➡ In particular, now provide for several consecutive years of p+p development

Table 2: The PHENIX Beam Use Proposal for 31 cryo weeks in Run-5, and 27 cryo weeks in latter years.

RUN	SPECIES	$\sqrt{s_{NN}}$ (GeV)	PHYSICS WEEKS	$\int \mathcal{L}dt$ (delivered)	p+p Equivalent
5	Cu+Cu	200	10	7.0 nb^{-1}	27.6 pb^{-1}
	p+p	200	11	13.1 pb^{-1}	13.1 pb^{-1}
6	Au+Au	62.4	9	111 μb^{-1}	4.3 pb^{-1}
	p+p	200	8	15.0 pb^{-1}	15.0 pb^{-1}
7	p+p	200	20	122 pb^{-1}	122 pb^{-1}
8	Au+Au	200	20	4140 μb^{-1}	161 pb^{-1}
9	p+p	500	20	359 pb^{-1}	359 pb^{-1}
10	d+Au	200	20	91.6 nb^{-1}	36 pb^{-1}

62.4 GeV Limitations

- The resolving power of R_{AA} from Au+Au 62.4 GeV data is limited by ***world's reference data*** for identified particle production at this energy:
- The resolving power of R_{AA} from Au+Au 62.4 GeV data is limited by ***the statistical reach*** of this too-short first look at 62.4 GeV:
- Hence our Run-6 request for A+A : Au+Au at 62.4 GeV

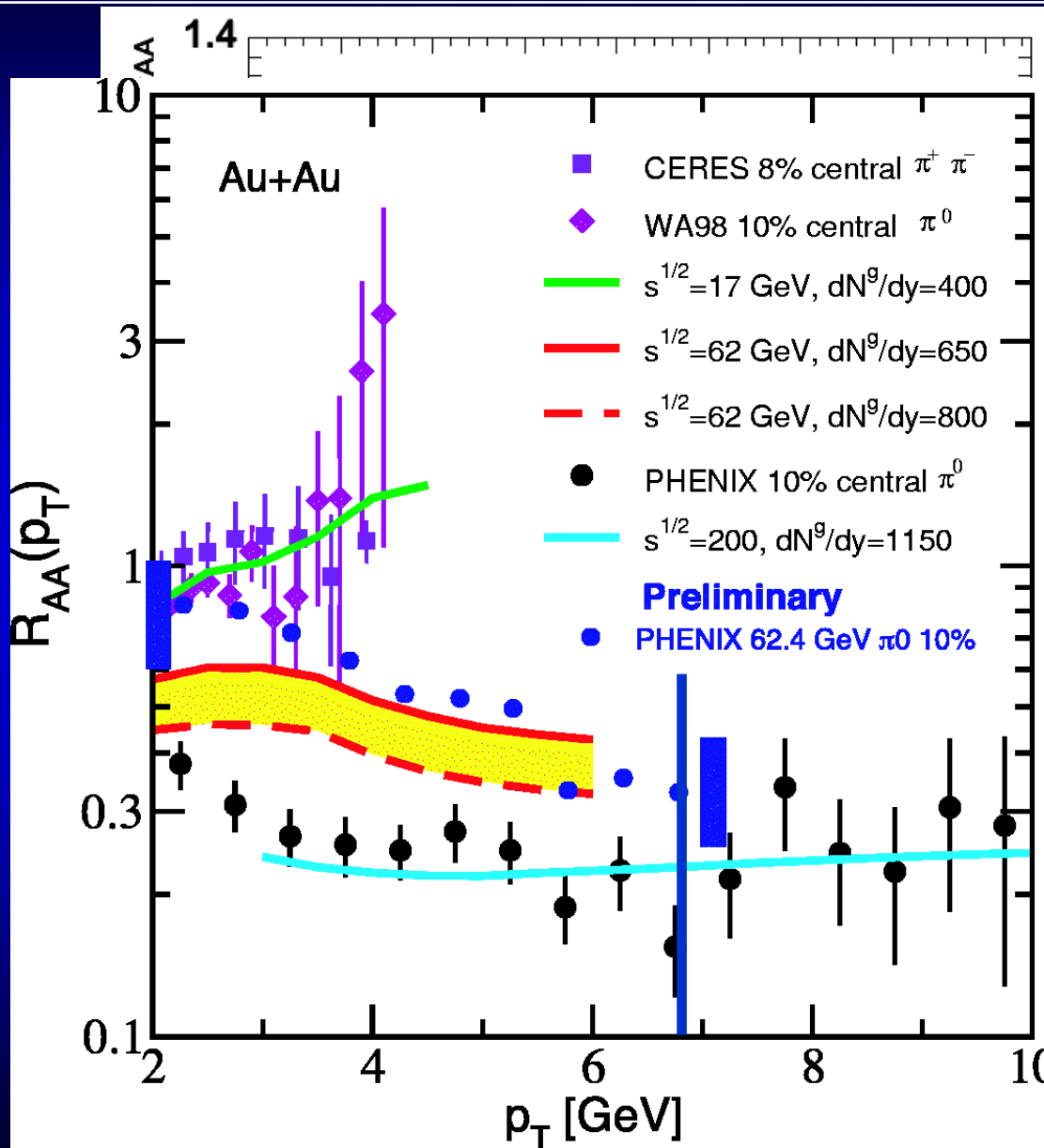
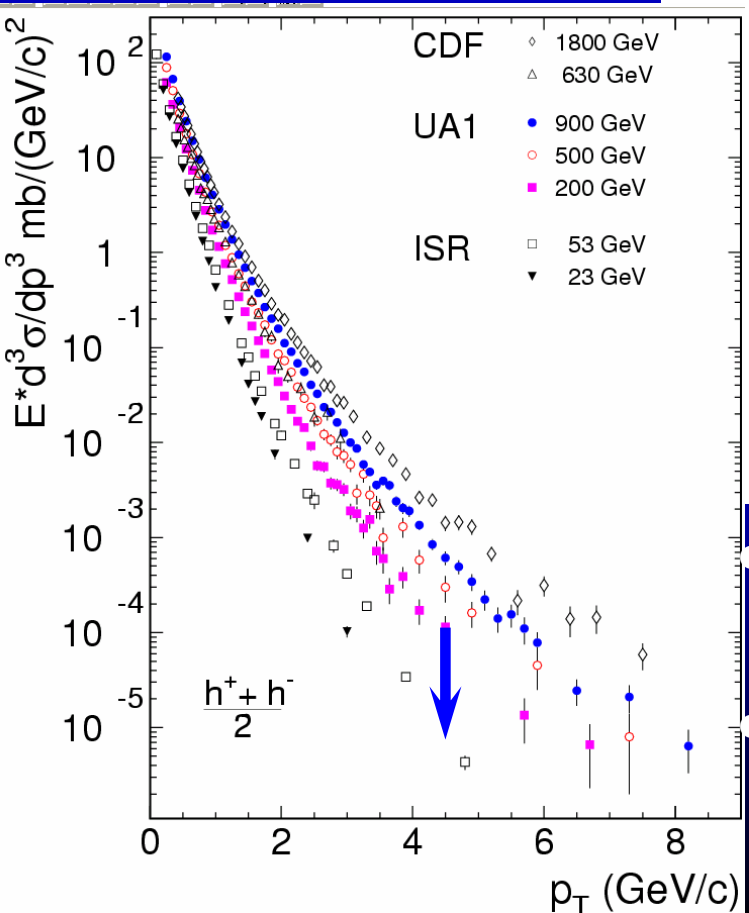
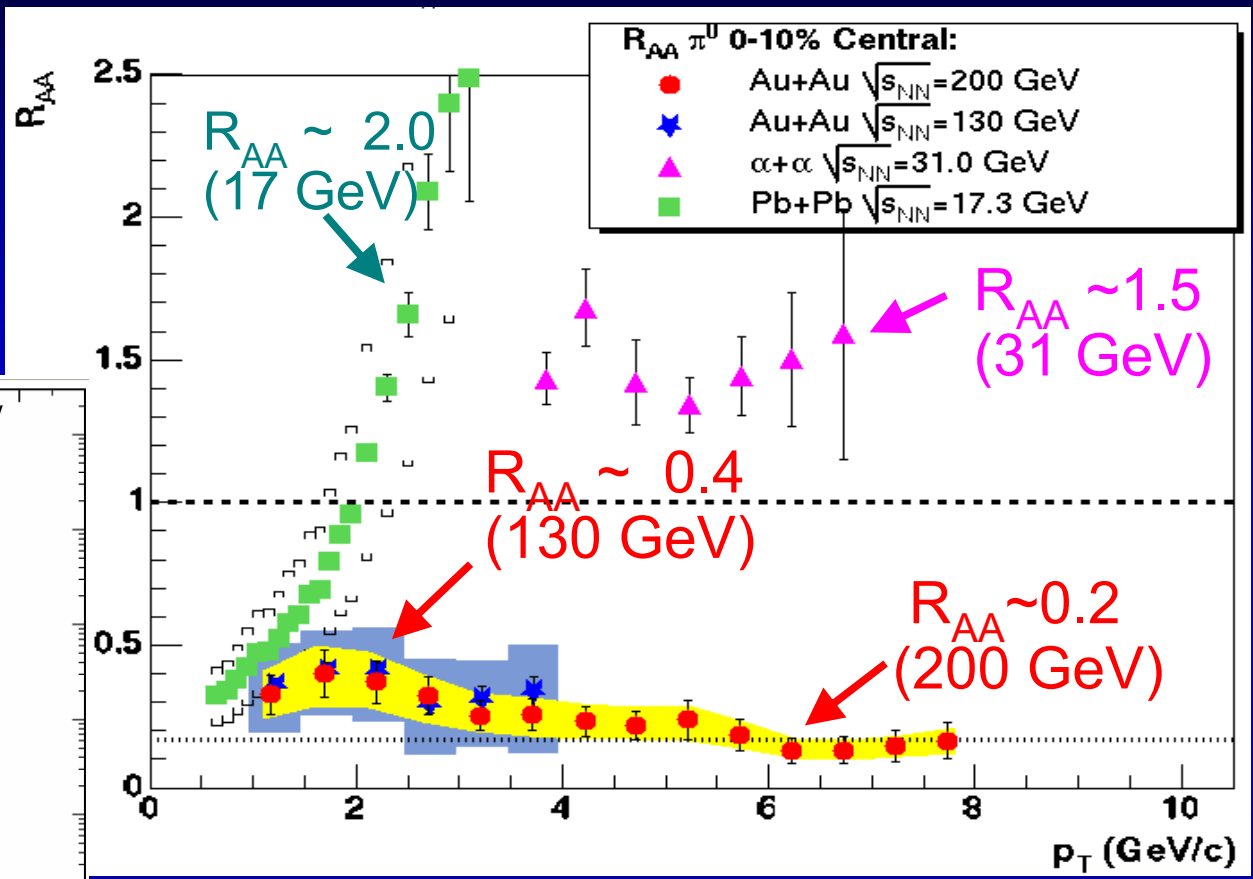


Figure 11: Left: World's data for $p+p \rightarrow \pi^0 + X$ at $\sqrt{s}$=62.4 GeV. Right: The ratio of the individual data sets to a global fit.

Why 62.4 GeV?

- **Select an energy to make the suppression go away**





- ***At a √s that still allows "full" coverage in p_T.***
- **Nota Bene:**
  - **RHIC luminosity scales as *s* (i.e., E^2)**
  - **ISR p+p comparison data**