PHENIX Overview And Physics

W.A. Zajc
for the PHENIX Collaboration

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

Outline

- Who is PHENIX ?
- Why is PHENIX ?
- What is PHENIX ?
  - Past- what made PHENIX PHENIX?
    - Collaboration growth
    - Experiment growth
    - Data set(s) growth
    - Accomplishments
  - Present- what is PHENIX doing?
    - Current status
    - Run-6 status
  - Future- quo vadis PHENIX?
    - Physics goals
    - Upgrade plans

Who ?

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

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

Management Structure

PHENIX

Collaboration

Institutional Board

PHENIX Management

Spokesperson -	William Zajc	Columbia U
Dpty Spokesperson-	Yasuyuki Akiba	RIKEN
Dpty Spokesperson	Matthias Grosse-Perdekamp	UIUC
Operations Manager	Edward O'Brien	BNL
Upgrade Manager-	Axel Drees	Stony Brook U

Executive Council

Detector Council

Physics Working Groups

- Members of PHENIX propose upgrade to PM
- EC/DC approve
  - Design
  - Construction
- PM & DC manage project to completion
- Large projects require BNL & DOE approval

Coordinators

Chief Engineer	DAQ Coor.	Computing Coor.	Analysis Coord.	Trigger Coor.	Run Coord.	PHENIX Admin
D. Lynch BNL	J. Haggerty BNL	D. Morrison BNL	R. Averbeck Stony Brook	J. Nagle UColorado	A Deshpande Stony Brook	B. Johnson BNL

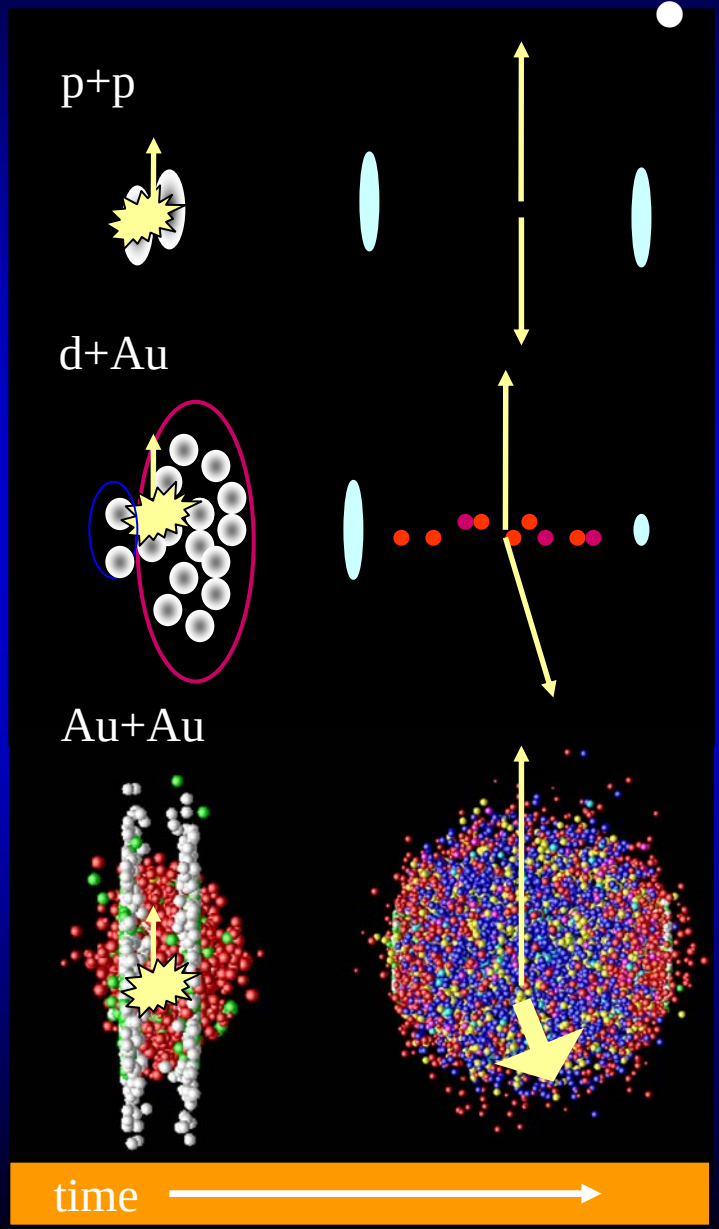
What is PHENIX?

- **P**ioneering **H**igh **E**nergy **N**uclear **I**nteraction e**X**periment

- Goals:
  - Broadest possible study of A+A, p+A, p+p collisions to
    - Study nuclear matter under extreme conditions
    - Using a wide variety of probes sensitive to all timescales
    - Study systematic variations with species and energy
  - Measure spin structure of the nucleon

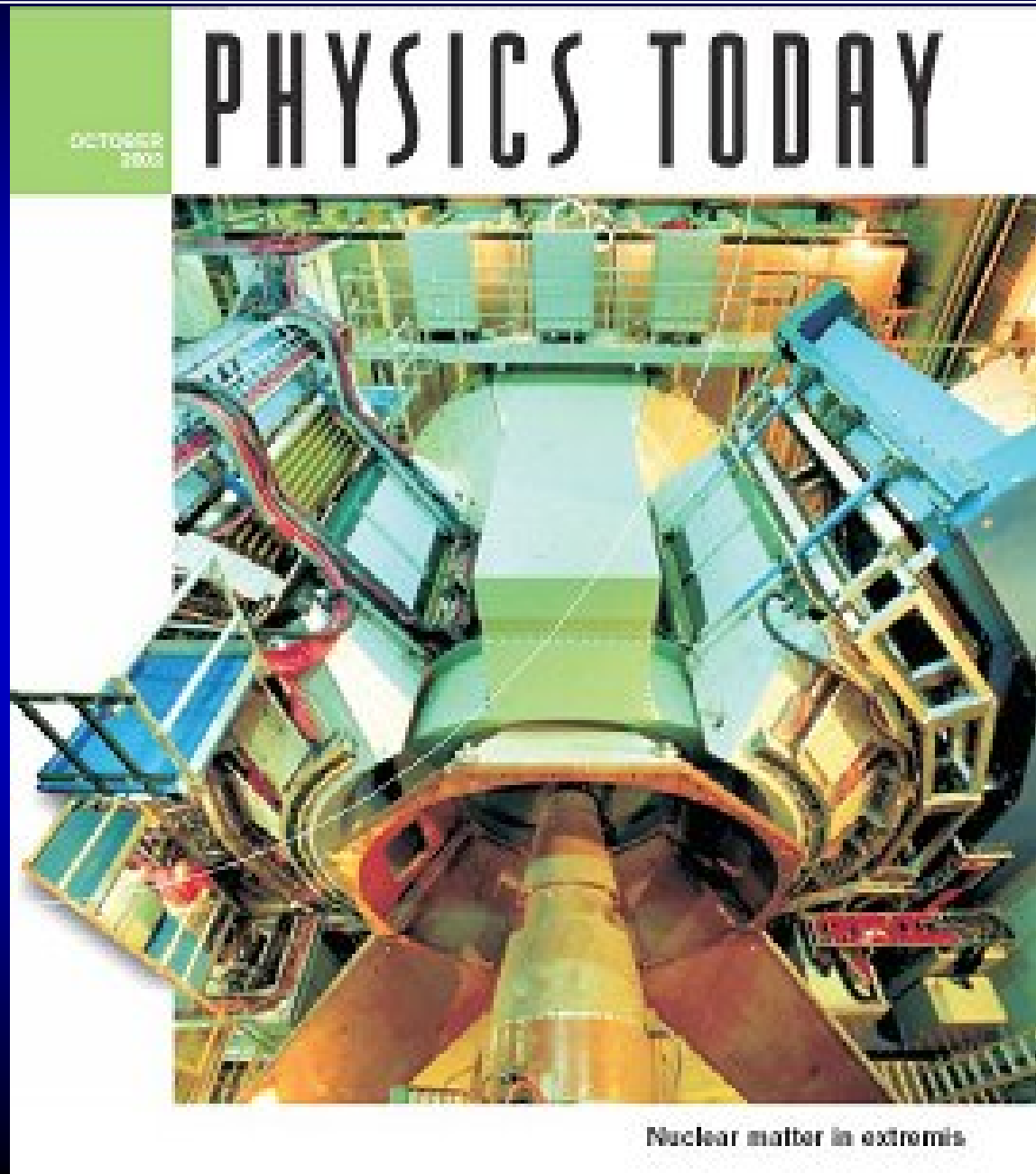
➔These two programs have produced a detector with unparalleled capabilities

PHENIX Physics



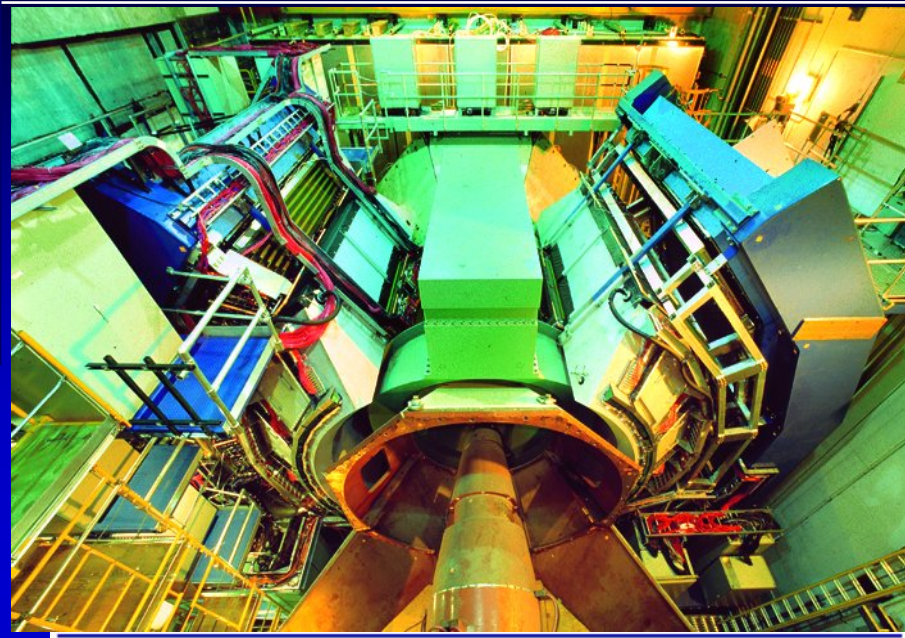
- **Systematic approach essential:**
  - **p+p: BASELINE**
    - Establish applicability of pQCD
    - First measurement of A_{LL} ~ gluon polarization
  - **d+Au: CONTROL**
    - No suppression in cold nuclear matter
  - **Au+Au: NEW EFFECTS**
    - *Strong* suppression in hot nuclear matter
    - Hydrodynamic flow of ~ perfect fluid

A Poster Child for RHIC



The PHENIX Detector

- Detector Redundancy
- Fine Granularity, Mass Resolution
- High Data Rate
- Good Particle ID
- Limited Acceptance



Charged Particle Tracking:

- Drift Chamber
- Pad Chamber
- Time Expansion Chamber/TRD
- Cathode Strip Chambers(Mu Tracking)

Particle ID:

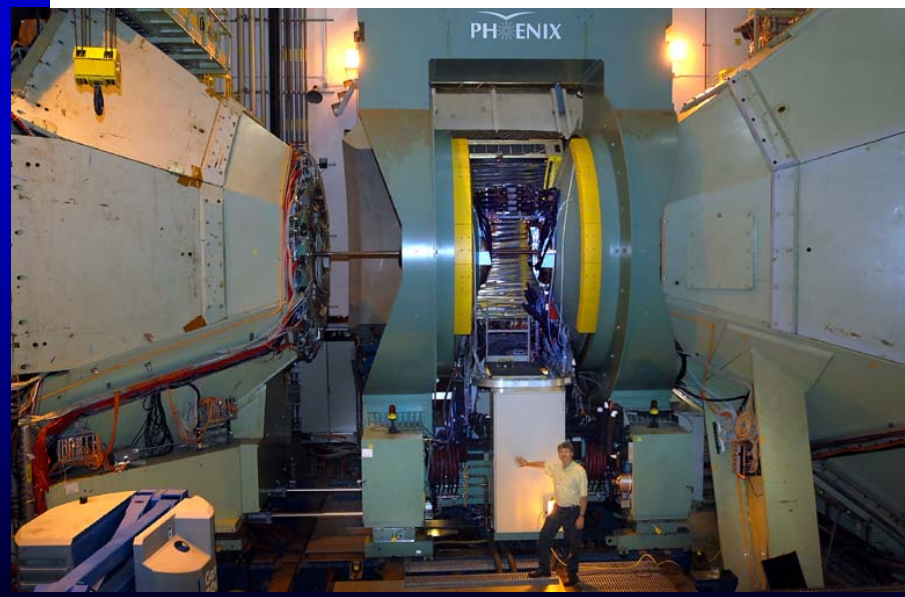
- Time of Flight
- Ring Imaging Cerenkov Counter
- TEC/TRD
- Muon ID (PDT's)
- Aerogel Cerenkov Counter

Calorimetry:

- Pb Scintillator
- Pb Glass

Event Characterization:

- Multiplicity Vertex Detector (Si Strip,Pad)
- Beam-Beam Counter
- Zero Degree Calorimeter/Shower Max Detector
- Forward Calorimeter



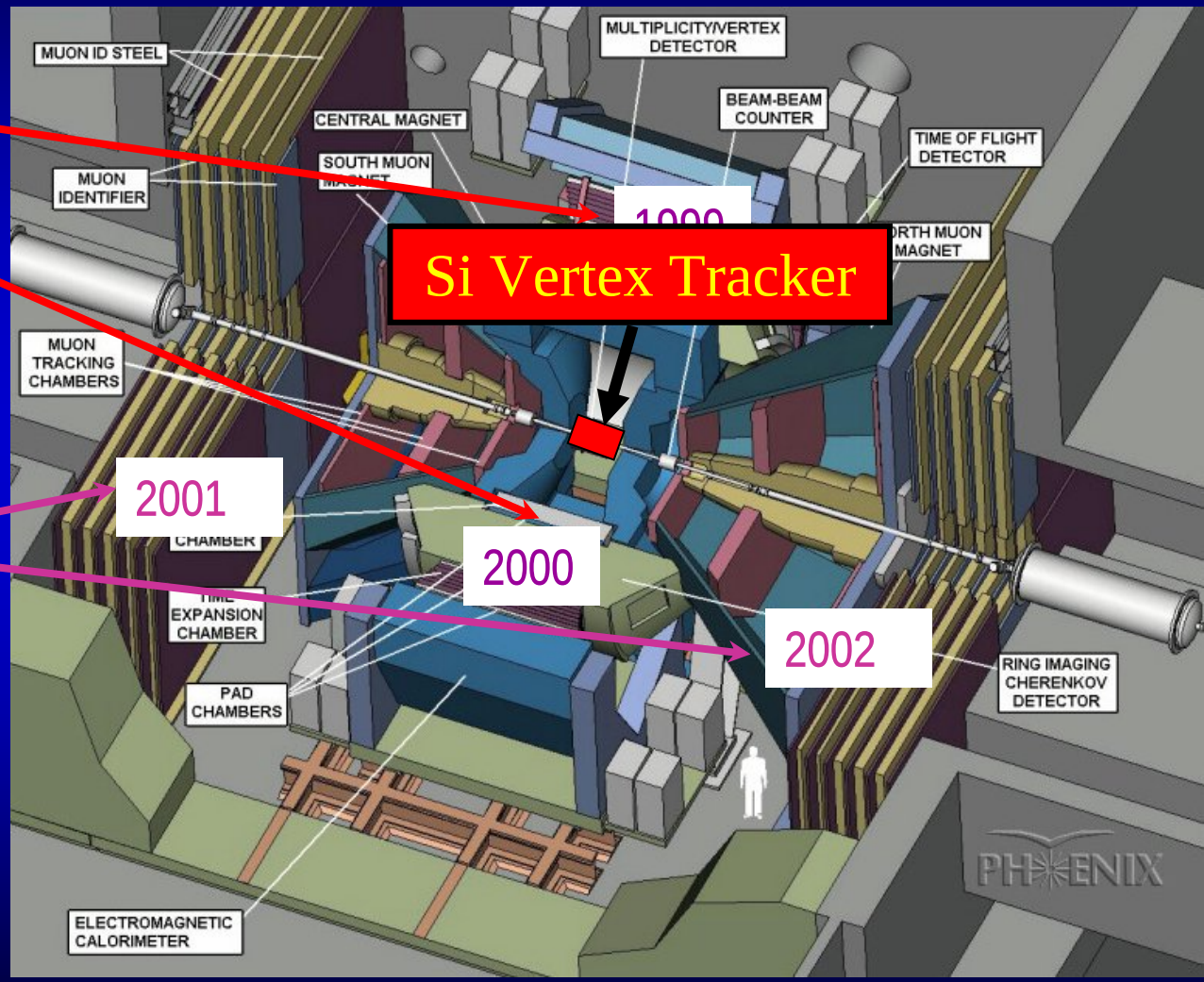
PHENIX Chronology

- PHENIX has an excellent track record of
  - Performing major installations and/or upgrades in each shutdown

  while
  - Maintaining scientific productivity
- See Back-up slides for complete chronology
  - (Most material there provided courtesy of Ed O'Brien, PHENIX Operations Manager)

Schedule

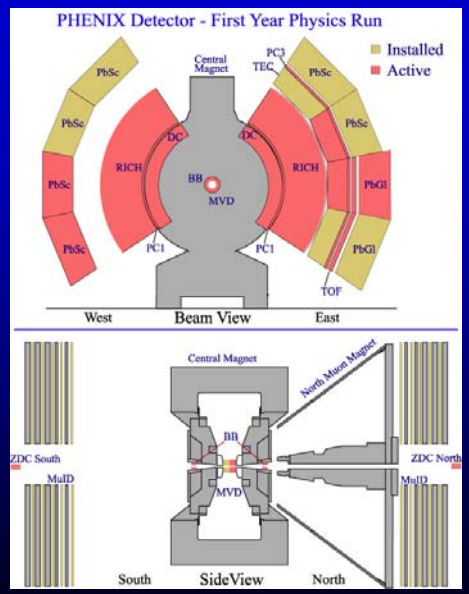
- 2 central spectrometers
- 2 forward spectrometers
- Forward detectors
  - Triggering
  - Centrality
  - Local polarimetry
  - Luminosity monitoring



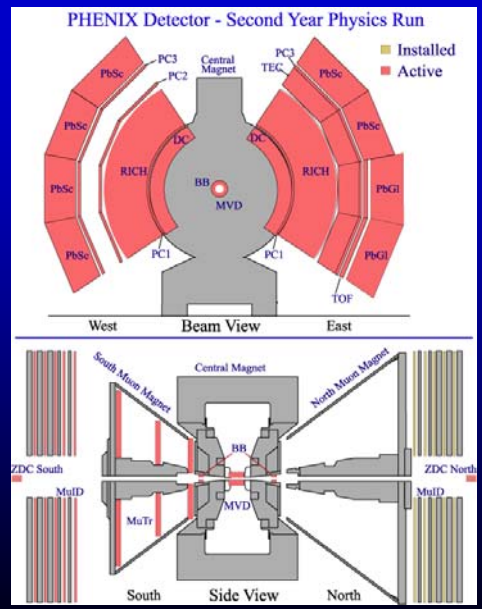
Run-1 to Run-3 Capsule History

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

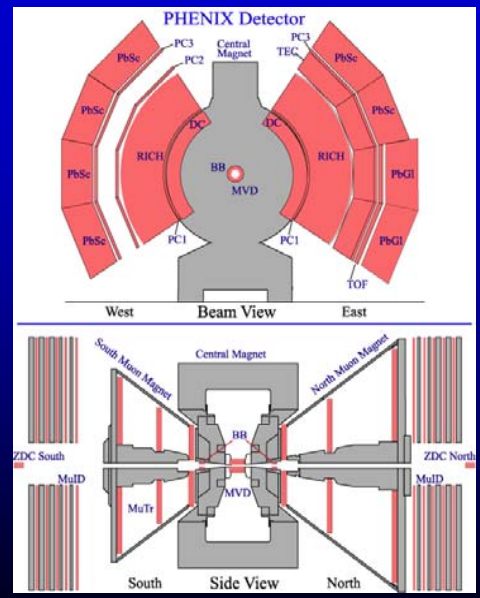
Run-1



Run-2

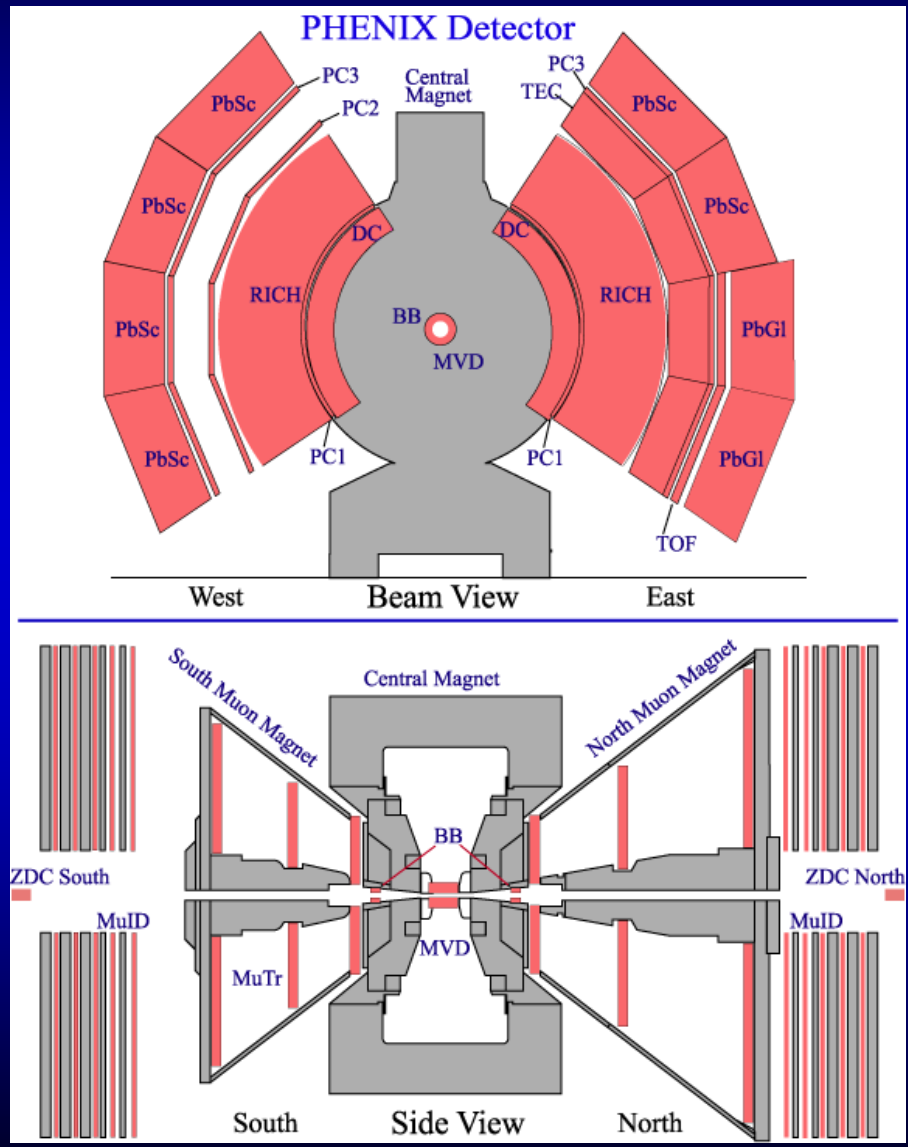


Run-3

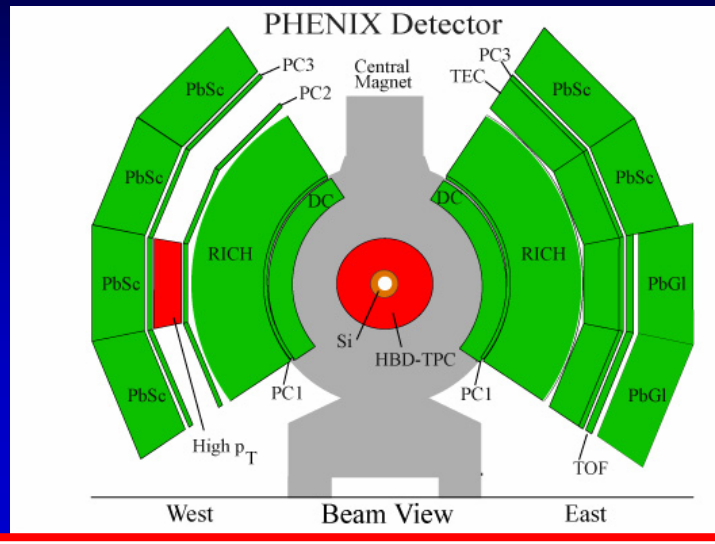


Run-3: Design Configuration!

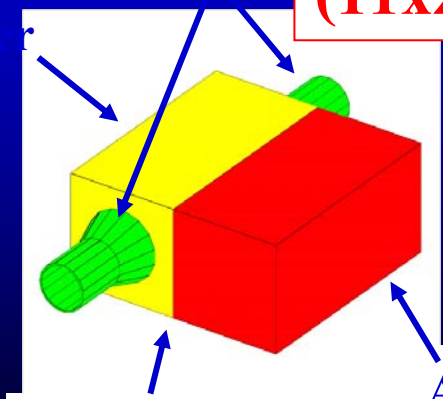
- **Central Arm Tracking**
  - Drift Chamber
  - Pad Chambers
  - Time Expansion Chamber
- **Muon Arm Tracking**
  - Muon Tracker: North Muon Tracker
- **Calorimetry**
  - PbGl
  - PbSc
- **Particle Id**
  - Muon Identifier: North Muon Identifier
  - RICH
  - TOF
  - TEC
- **Global Detectors**
  - BBC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



Run-4 Additions



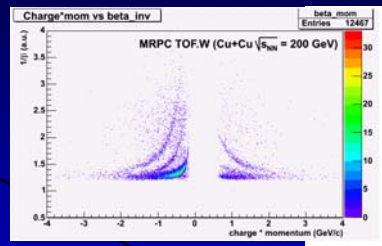
Aerogel Cell (11x22x11 cm^3)

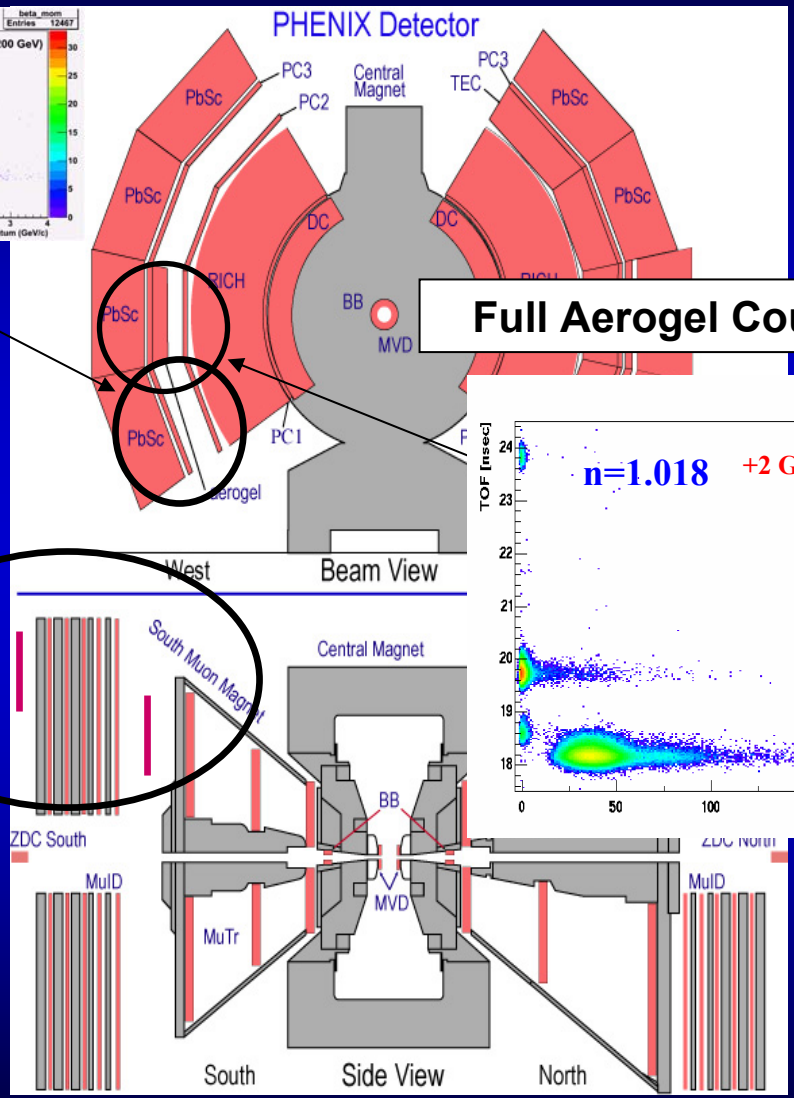


- The Aerogel detector is a threshold Cerenkov counter
- Aerogel is a very low density, SiO_2 – based solid
- Aerogel has index of refr. between gases & liquids.
- Ident. charged particles in a range inaccessible with other technologies.

PHENIX Configuration in Run-5

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





Full Aerogel Counter

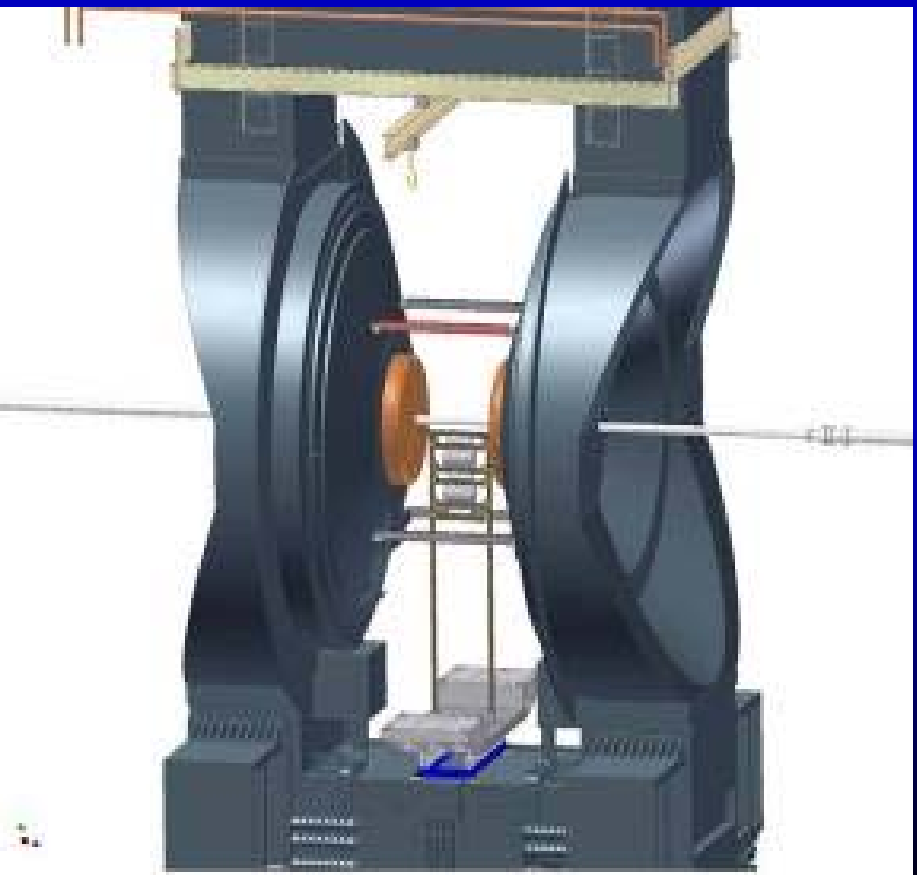
Prototype RPC muon trigger chambers.

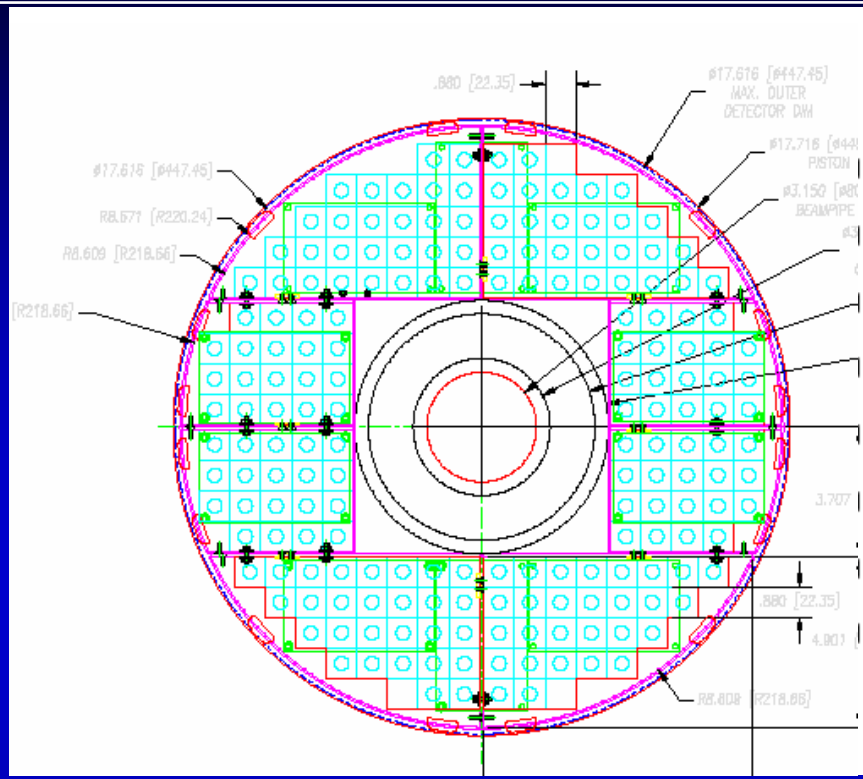
NSF $1.98M
Approved!

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

New Additions for Run-6

- Radiation tests of strip-pixel samples (see talk by S. Batsouli)





- Muon Piston Calorimeter (MPC)
  - 192 $PbW0_4$ crystals
  - APD read out w. EmCal FEM's

Run-1 to Run-5 Capsule History

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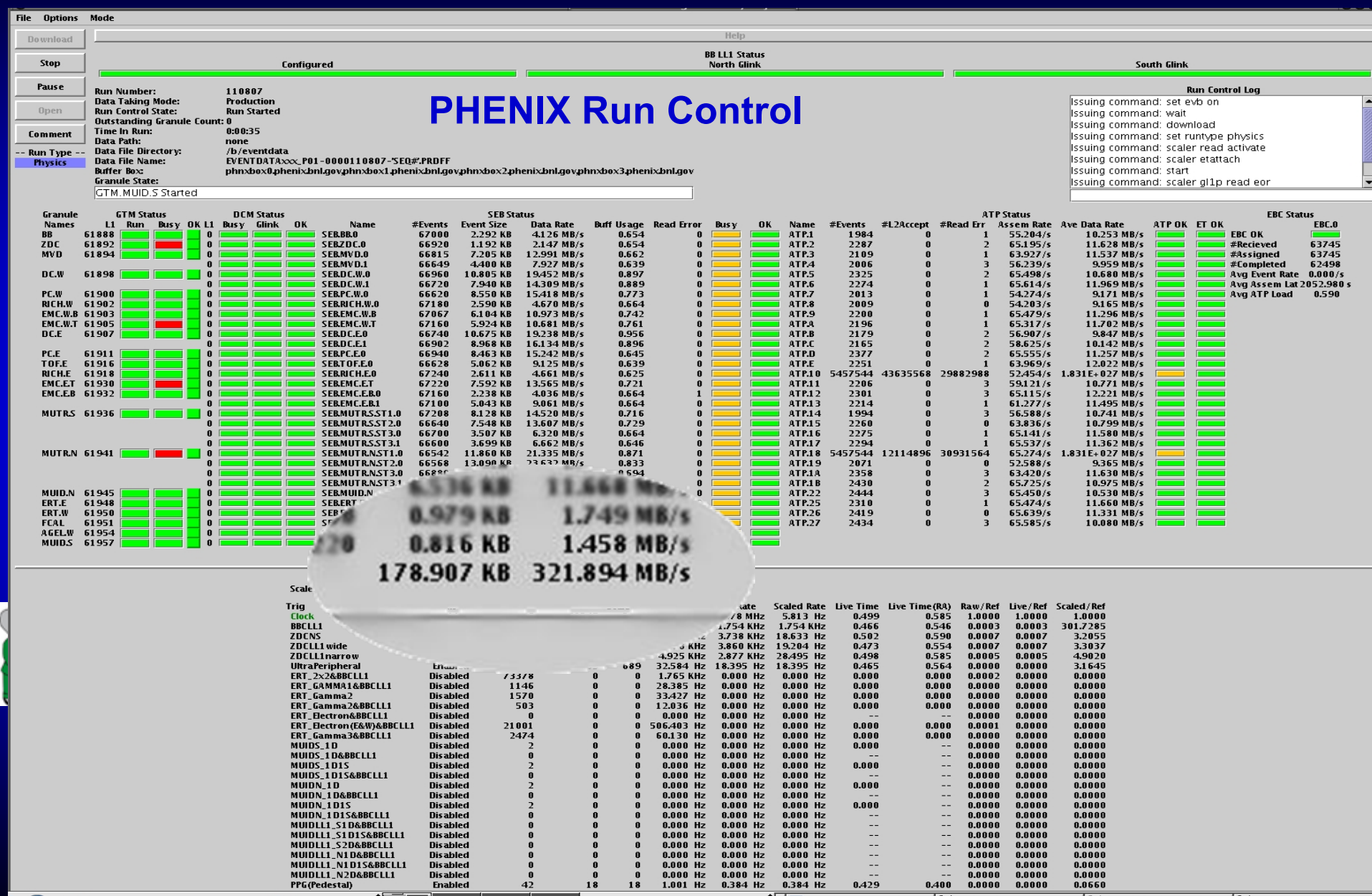
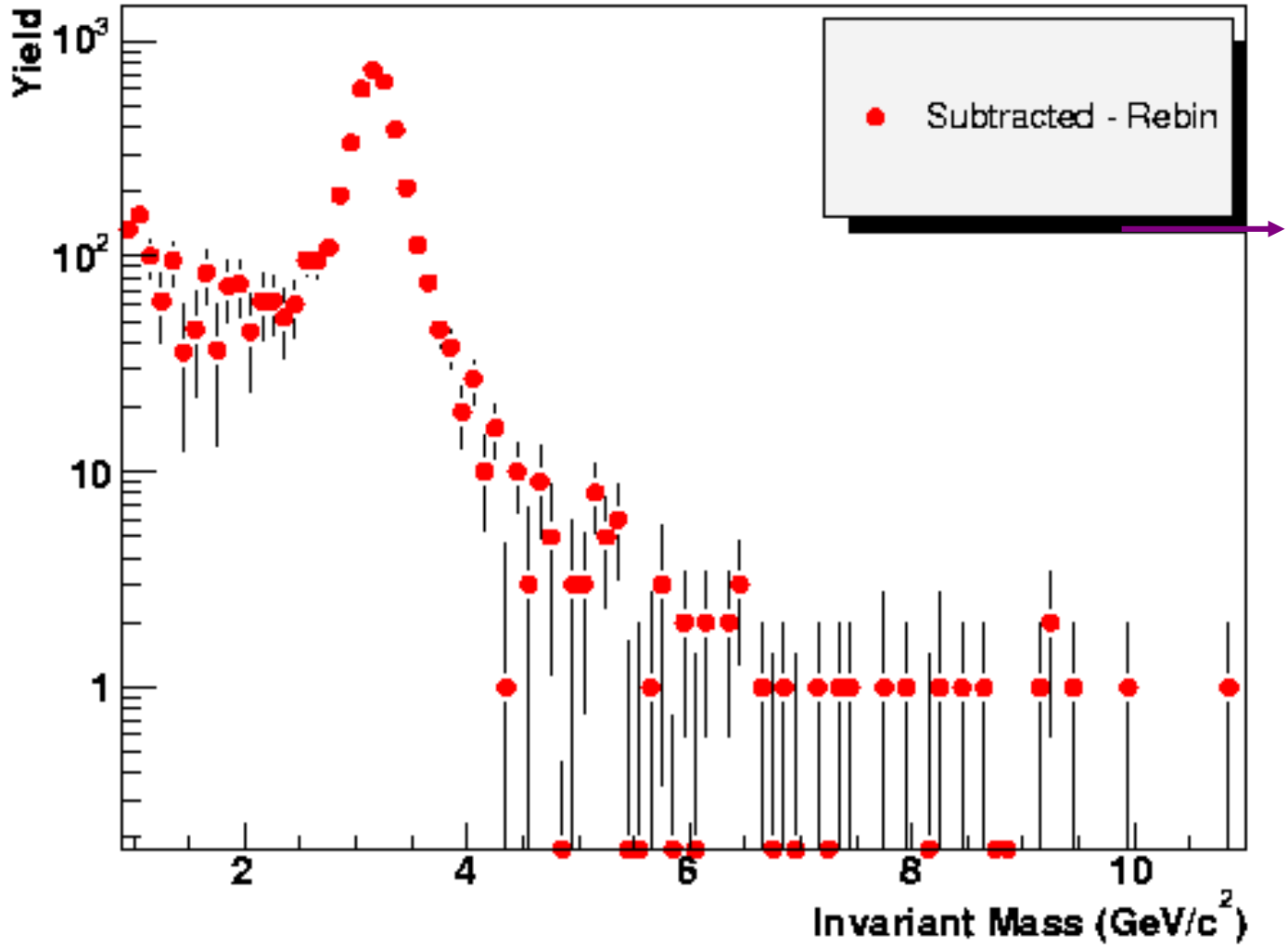
		p+p	200	0.35 pb^{-1}	6.6G	0.35 pb^{-1}	35 TB
04	2003/2004	Au+Au	200	241 μb^{-1}	1.5G	10.0 pb^{-1}	270 TB
		Au+Au	62	9 μb^{-1}	58M	0.36 pb^{-1}	10 TB
05	2004/2005	Cu+Cu	200	3 nb^{-1}	8.6G	11.9 pb^{-1}	173 TB
		Cu+Cu	62	0.19 nb^{-1}	0.4G	0.8 pb^{-1}	48 TB
		Cu+Cu	22.5	2.7 μb^{-1}	9M	0.01 pb^{-1}	1 TB
		p+p	200	3.8 pb^{-1}	85B	3.8 pb^{-1}	262 TB

Comparable Data Archiving Rates

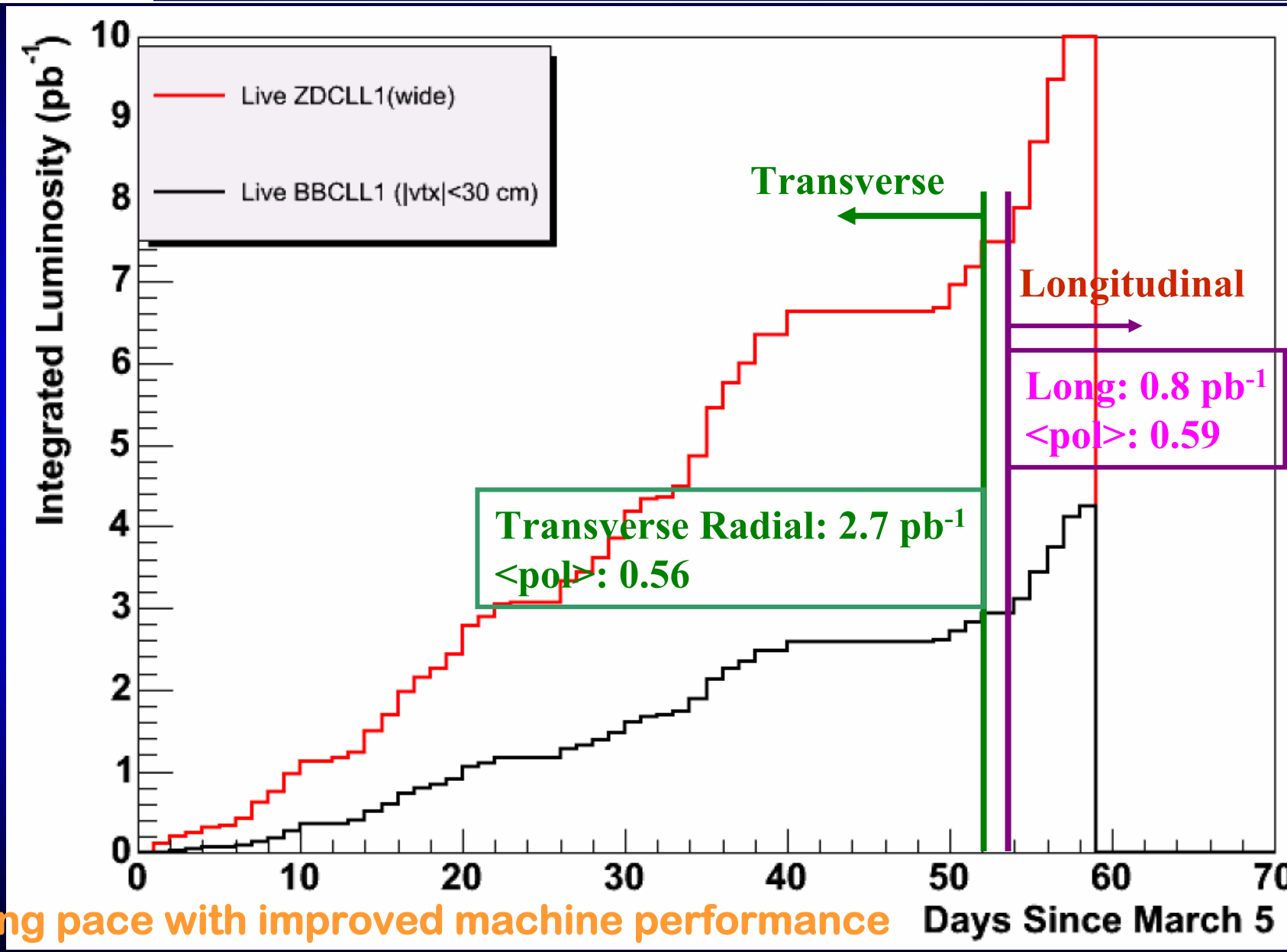


Run-6 Progress (I)

Quasi real-time production of J/Ψ data



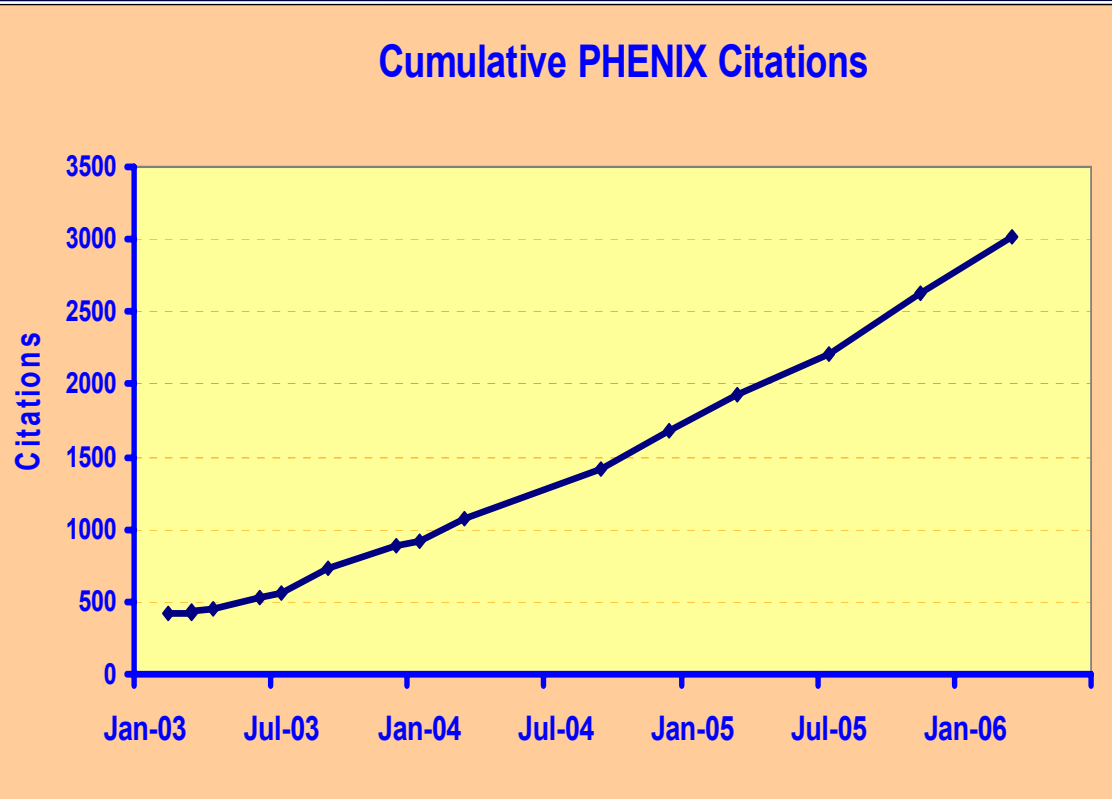
Run-6 Progress (II)



- Keeping pace with improved machine performance

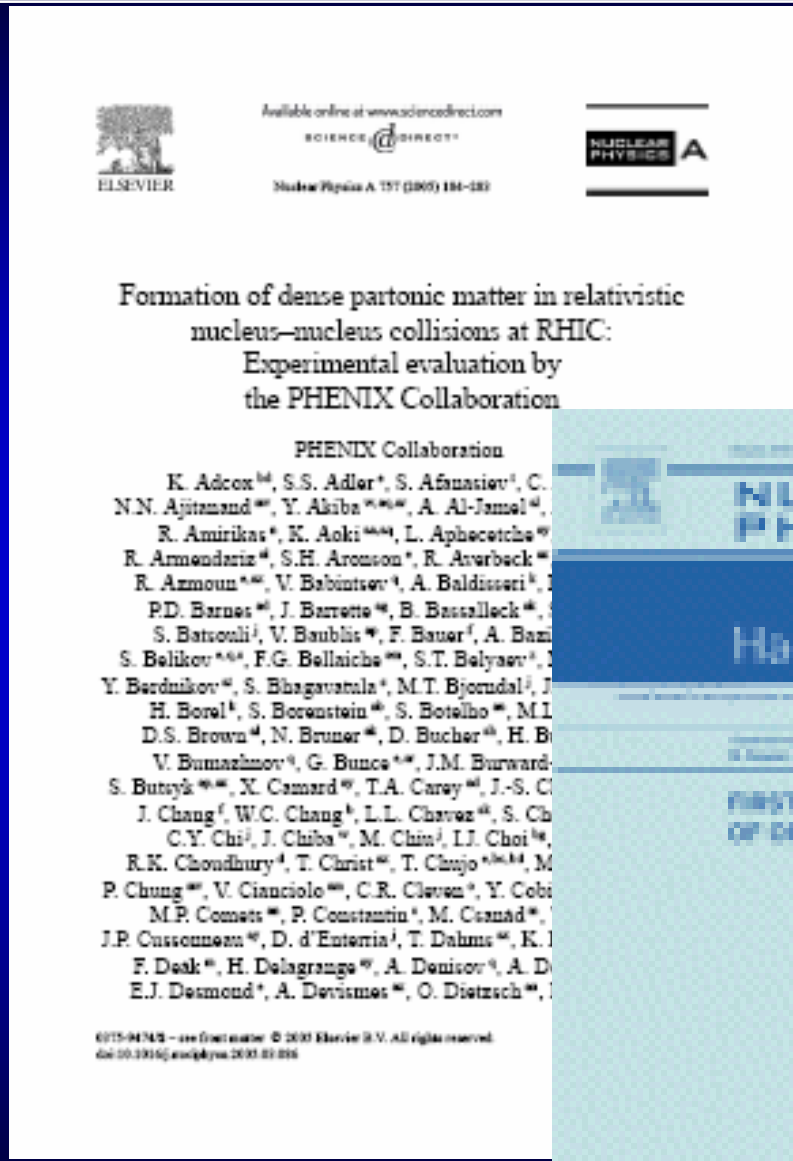
Publication Summary

- Since 2001:
  - 28 PRL's
  - 9 Phys. Rev. C's
  - 1 Phys. Rev. D
  - 1 Phys. Lett. B
  - 1 Nucl. Phys. A (White Paper)
- > 3000 citations
- Most-cited paper from RHIC:
  - "*Suppression of hadrons with large transverse momentum in central Au+Au collisions at* $\sqrt{s_{NN}}$ *= 130 GeV*", K. Adcox *et al.* , Phys.Rev.Lett. 88:022301 (2002), nucl-ex/0109003
  - 12 other papers with > 100 citations



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 150 citations

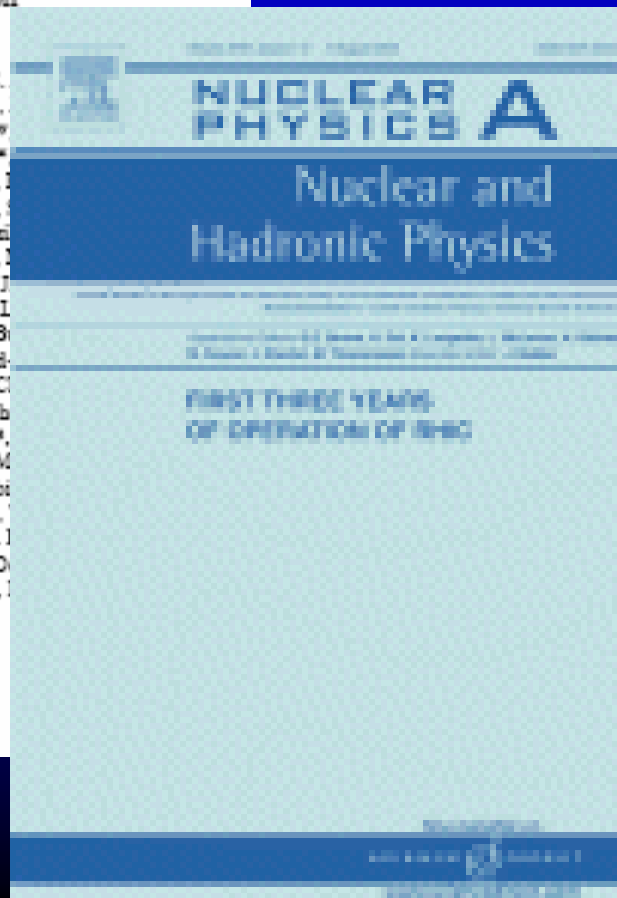

ELSEVIER
Available online at www.sciencedirect.com
SCIENCE DIRECT
NUCLEAR PHYSICS A

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

PHENIX Collaboration

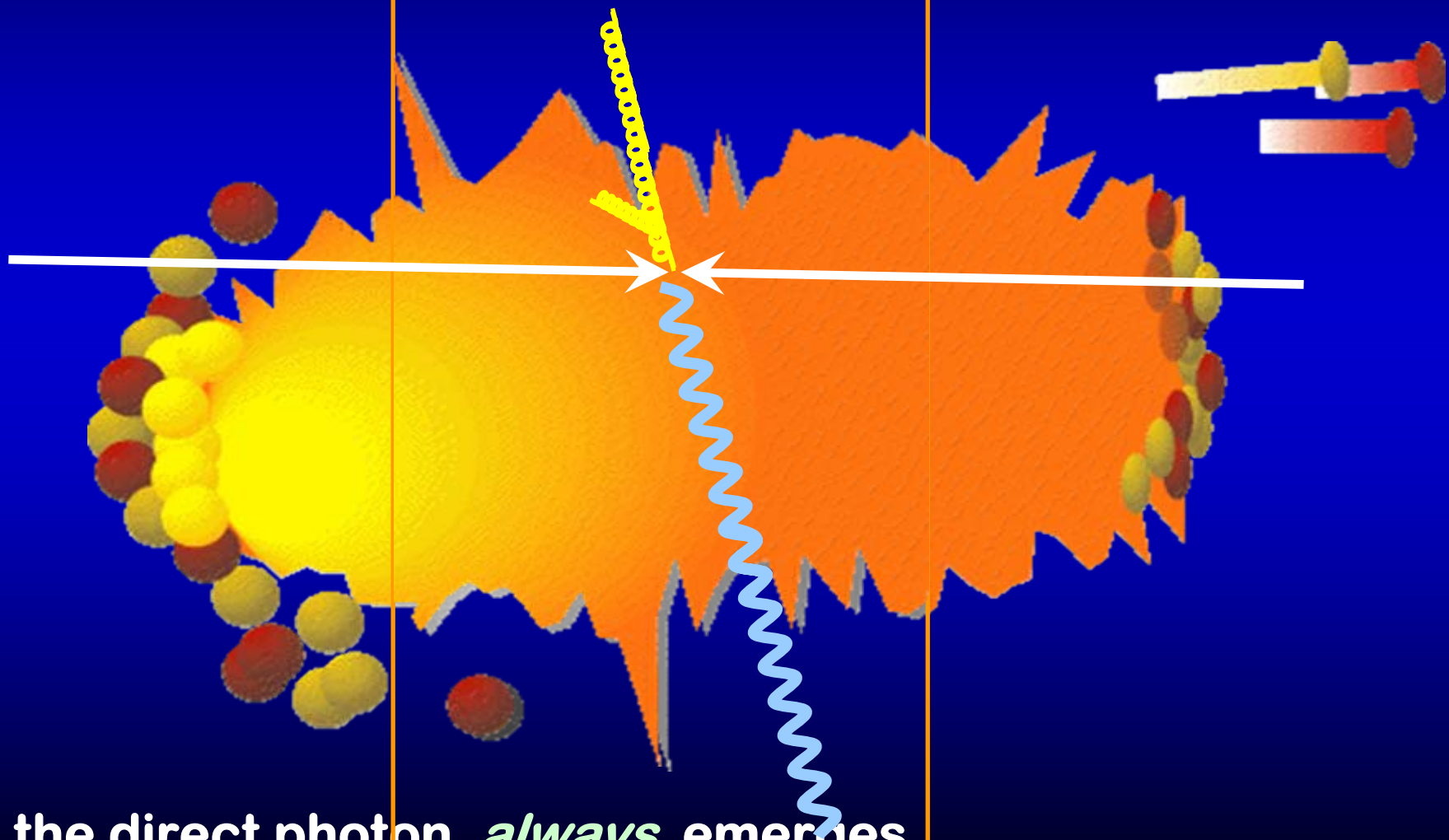
K. Adcox, S.S. Adler, S. Afanasiev, C.
N.N. Ajitanand, Y. Akiba, A. Al-Jamel,
R. Amirikas, K. Aoki, L. Aphecetche,
R. Armendariz, S.H. Aronson, R. Averbeck,
R. Averoun, V. Babintsev, A. Baldisseri,
P.D. Barnes, J. Barrette, B. Bassalleck,
S. Batsouli, V. Baublis, F. Bauer, A. Bazi
S. Belikov, F.G. Bellaiche, S.T. Belyaev,
Y. Berdnikov, S. Bhagavatula, M.T. Bjorndal,
H. Borel, S. Borenstein, S. Botelho, M.L.
D.S. Brown, N. Bruner, D. Bucher, H. Bu
V. Bumazhnov, G. Bunce, J.M. Burward-
S. Butsyk, X. Camard, T.A. Carey, J.-S. C
J. Chang, W.C. Chang, L.L. Chavez, S. Ch
C.Y. Chi, J. Chiba, M. Chiu, I.J. Choi,
R.K. Choudhury, T. Christ, T. Chujo,
P. Chung, V. Cianciolo, C.R. Cleven, Y. Cobi
M.P. Comets, P. Constantin, M. Csanad,
J.P. Cussonneau, D. d'Enterria, T. Dahms, K.
F. Deak, H. Delagrange, A. Denisov, A. D
E.J. Desmond, A. Devismes, O. Dietzsch,

doi:10.1016/j.nuclphysa.2005.03.086



Schematically (Photons)

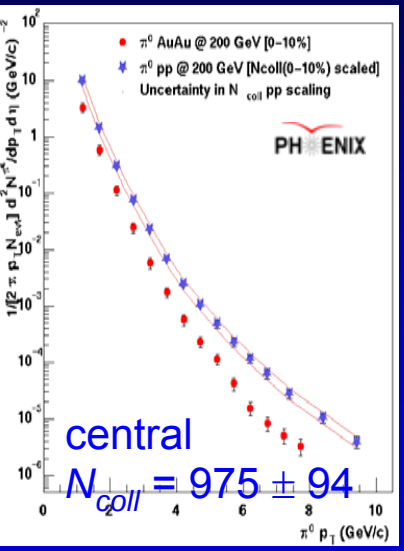
Scattered partons on the "near side" *lose energy*, but emerge;

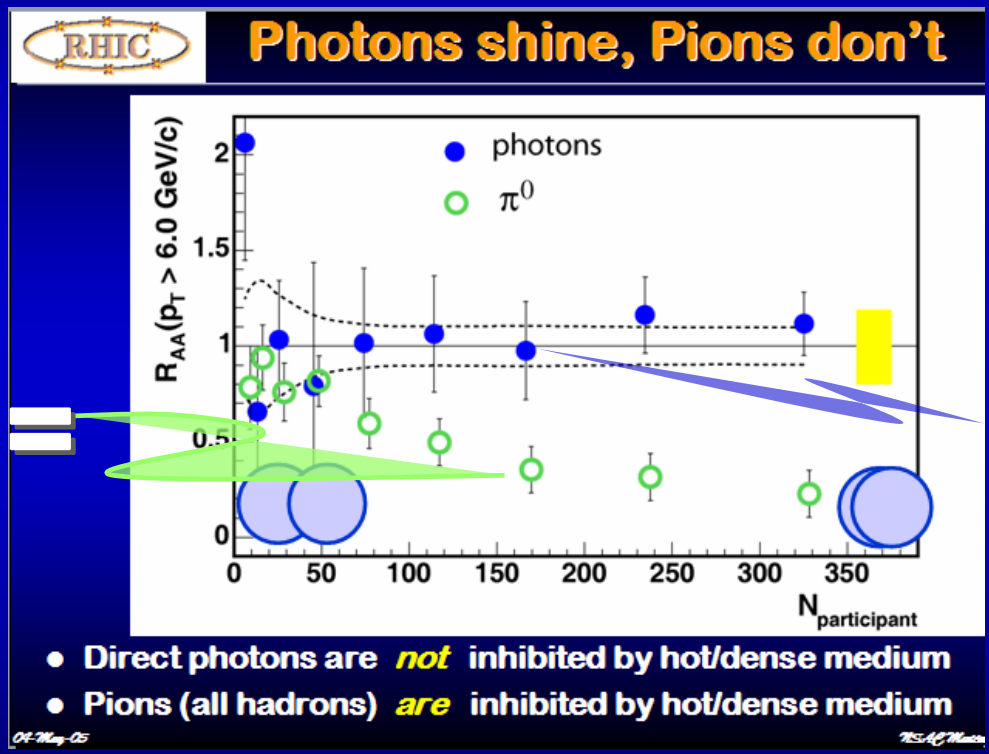


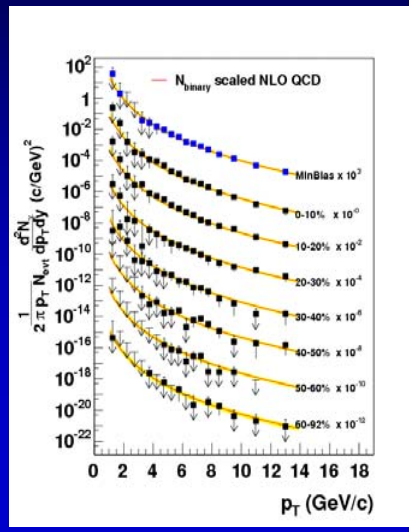
the direct photon *always* emerges

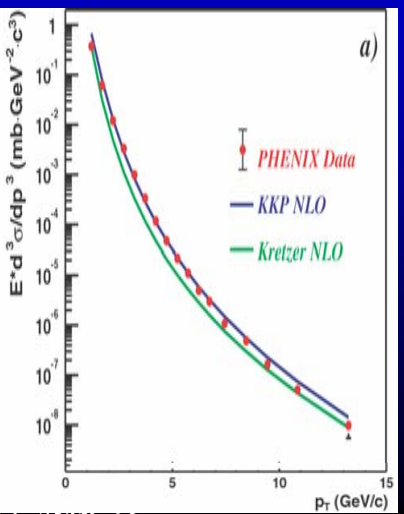
Scientific Precision

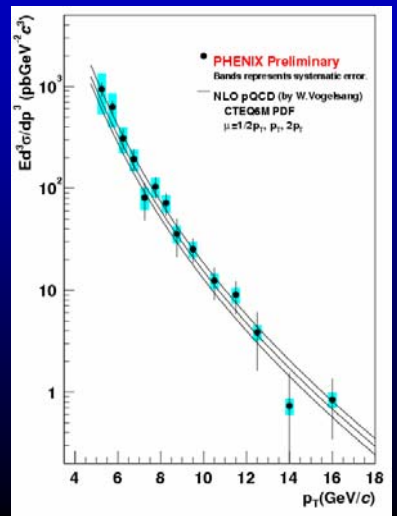
- This one figure encodes rigorous control of systematics











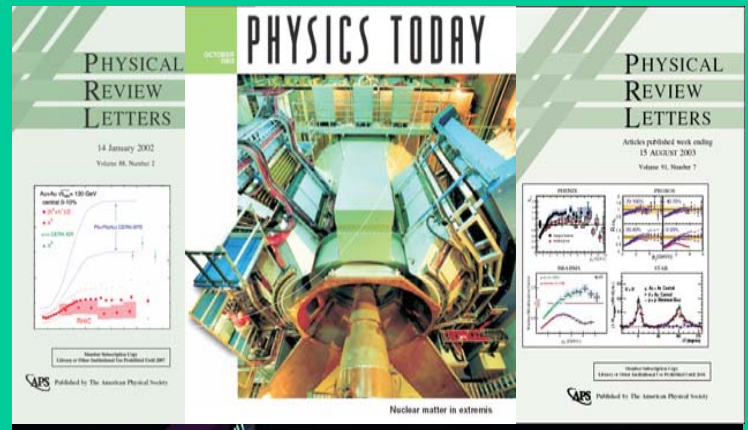
- in four different measurements over many orders of magnitude

PHENIX Decadal Plan

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

  into remainder of this talk?

- Will tour portions of Executive Summary relevant to upgrade plans.



Decadal Plan: Executive Summary (1)

- The PHENIX Collaboration has developed a plan for the detailed investigation of quantum chromodynamics in the next decade. The demonstrated capabilities of the PHENIX experiment to measure rare processes in hadronic, leptonic and photonic channels, 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 elucidate the states of both hot and cold nuclear matter, and to measure the spin structure of the proton 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.

PHENIX

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.

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.

The Upgraded PHENIX Detector

Charged Particle Tracking:

- Drift Chamber
- Pad Chamber
- Time Expansion Chamber/TRD
- Cathode Strip Chambers(Mu Tracking)
- Forward Muon Trigger Detector
- ☞ *Si Vertex Tracking Detector- Barrel (Pixel + Strips)*
- Si Vertex Endcap (mini-strips)

Particle ID:

- Time of Flight
- Ring Imaging Cerenkov Counter
- TEC/TRD
- Muon ID (PDT's)
- Aerogel Cerenkov Counter
- Multi-Resistive Plate Chamber Time of Flight
- Hadron Blind Detector

Calorimetry:

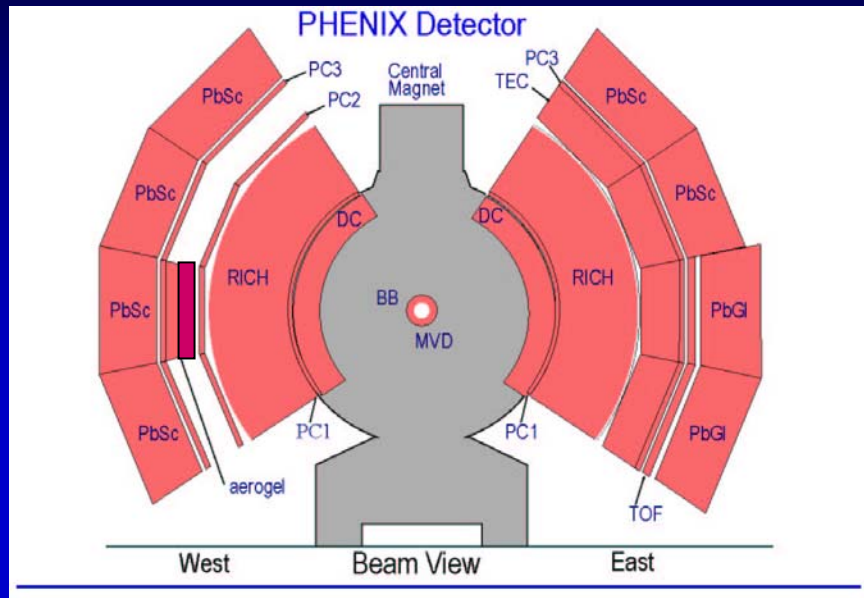
- Pb Scintillator
- Pb Glass
- Nose Cone Calorimeter

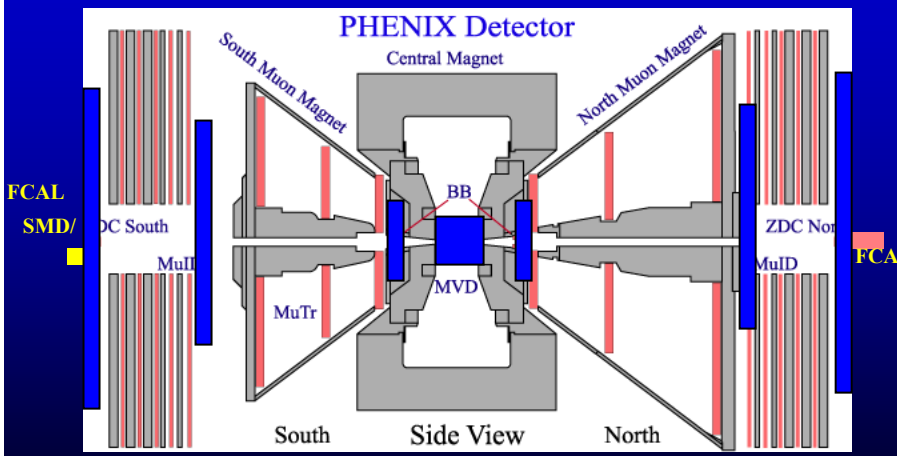
Event Characterization:

- Beam-Beam Counter
- Zero Degree Calorimeter/Shower Max Detector
- Forward Calorimeter

Data Acquisition:

- DAQ Upgrade

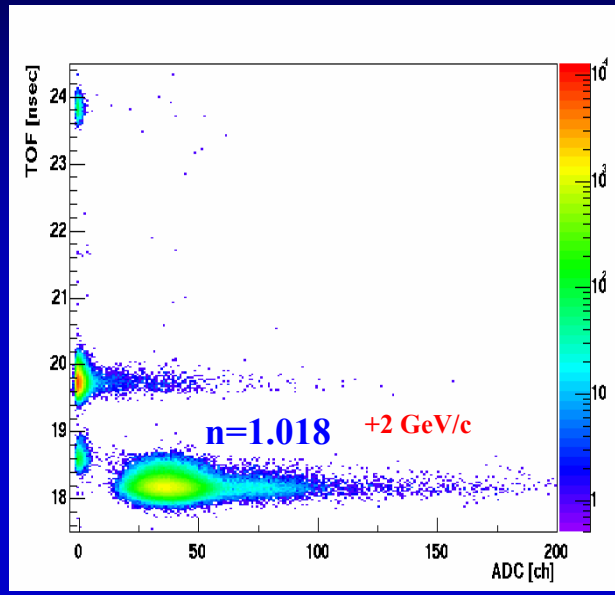




AGEL + TOF-W

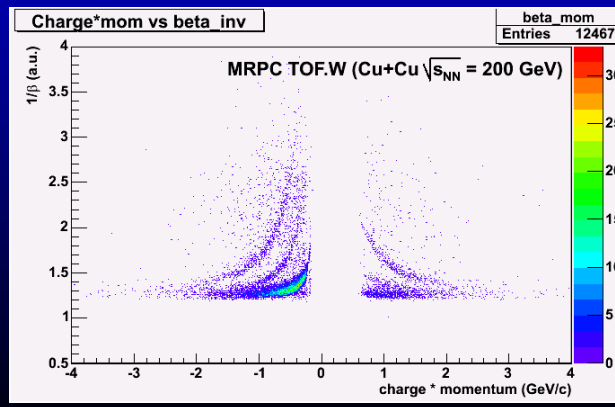
- "An aerogel and time-of-flight system to provide complete π/K/p separation for momenta up to ~10 GeV/c."

- Project well underway



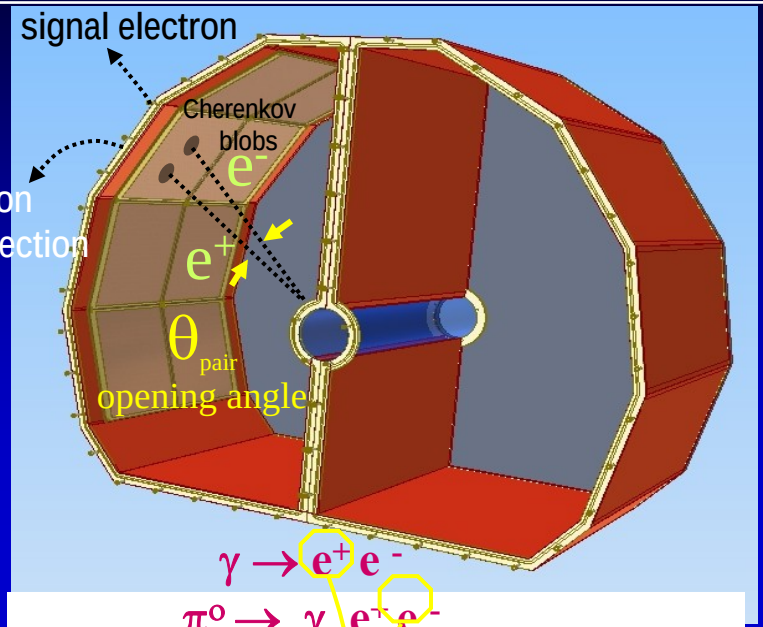
  - Aerogel completely installed (first physics results now available)

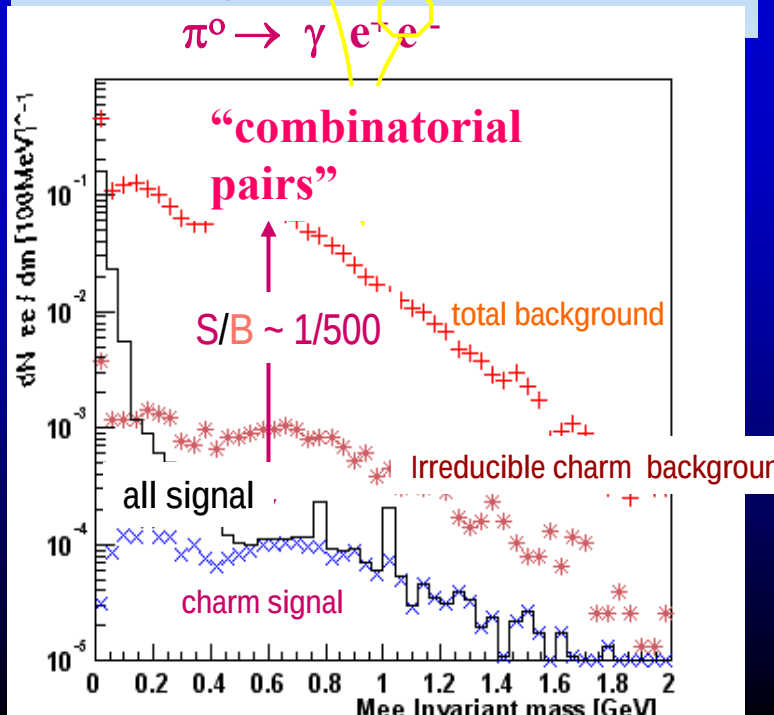
  - TOF-W ('Time-Of-Flight-West')
    - Partial funding: J. Velkovska (Vanderbilt) OJI
    - Prototypes tested in Run-5
    - System to be installed in next shutdown



Hadron-Blind Detector (HBD)

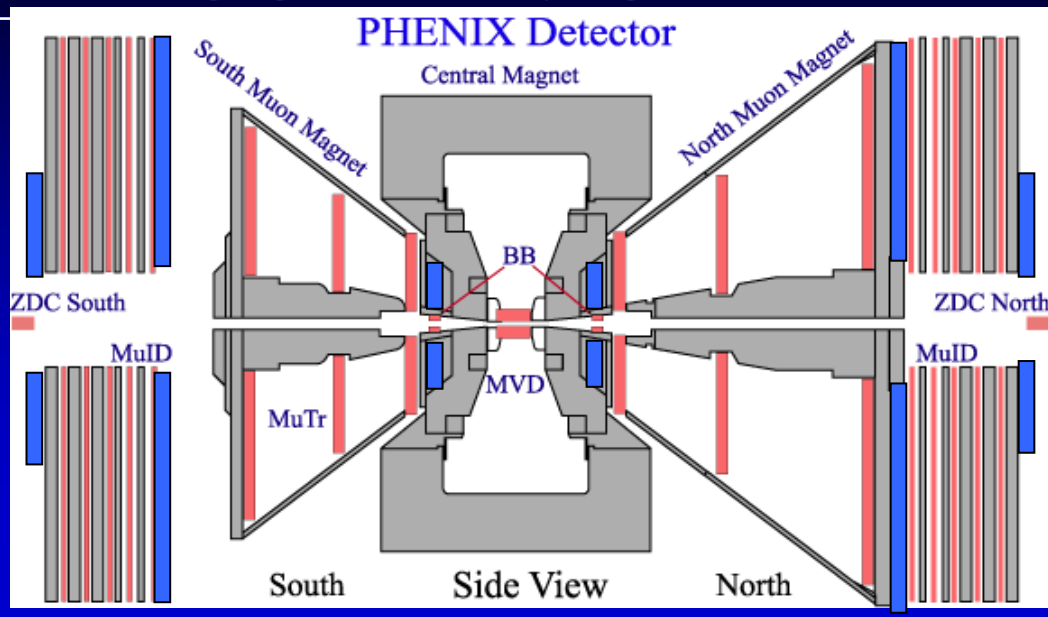
- "A hadron-blind detector to detect and track electrons near the vertex."
- Dalitz rejection via opening angle
  - Identify electrons in field free region
  - Veto signal electrons with partner
- HBD: a novel detector concept:
  - windowless CF4 Cherenkov detector
  - 50 cm radiator length
  - CsI reflective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

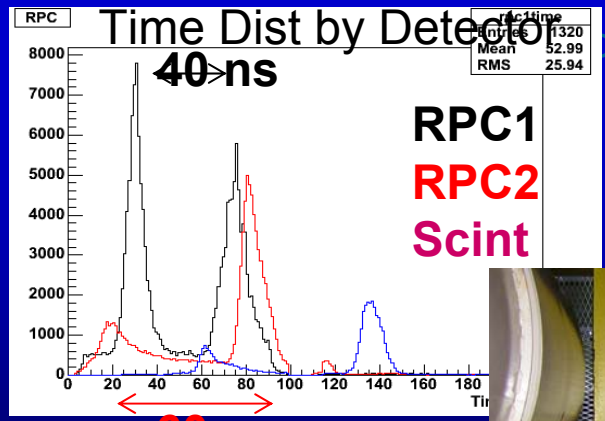


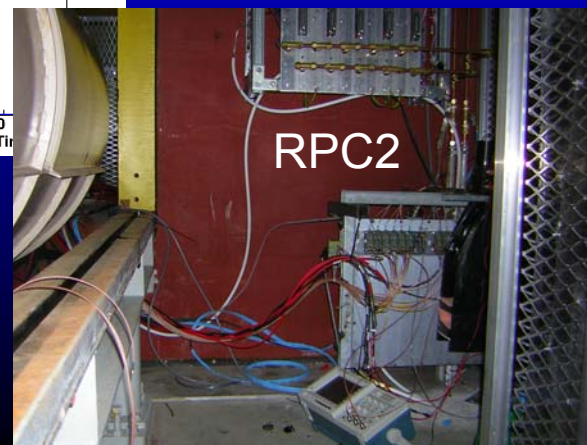


Muon Trigger Upgrade

- "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
- Funded as NSF MRI for $1.98M
  - $100K UIUC
  - $100K UCR
  - $50K ISU
  - $30K RBRC
- Breaking news: JSPS funding $1.5-2.0M for MuTr trigger (JFY07 start)

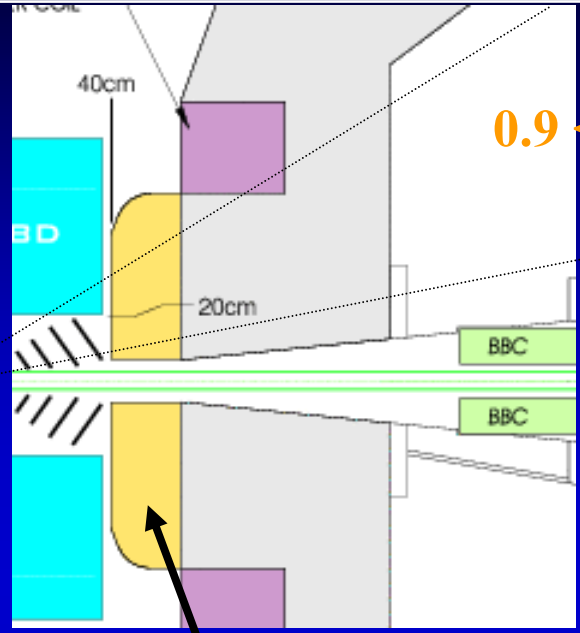




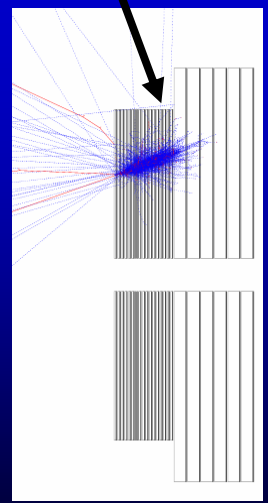


Nosecone Calorimeter (NCC)

- "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_o
  - 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 favorably reviewed for FY08 start
  - New expert groups join R&D (Moscow State, Czech groups)
  - Construction FY08 – FY10



$0.9 < \eta < 3.0$

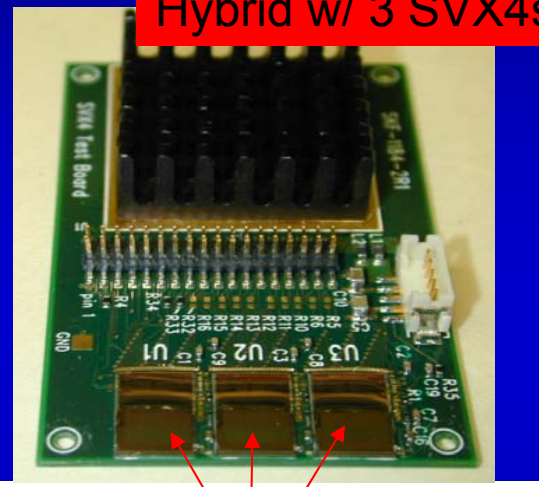


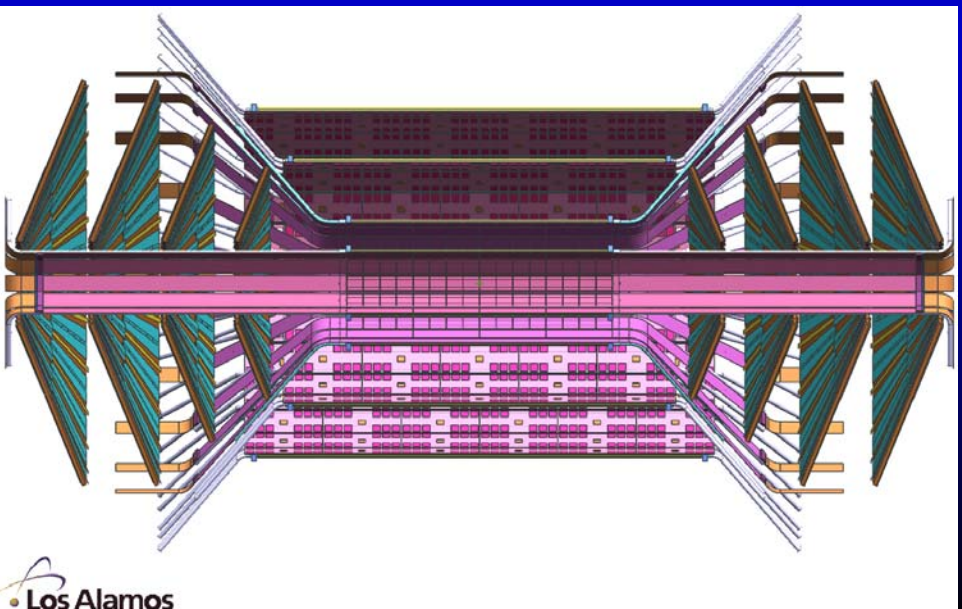
W-silicon sampling calorimeter

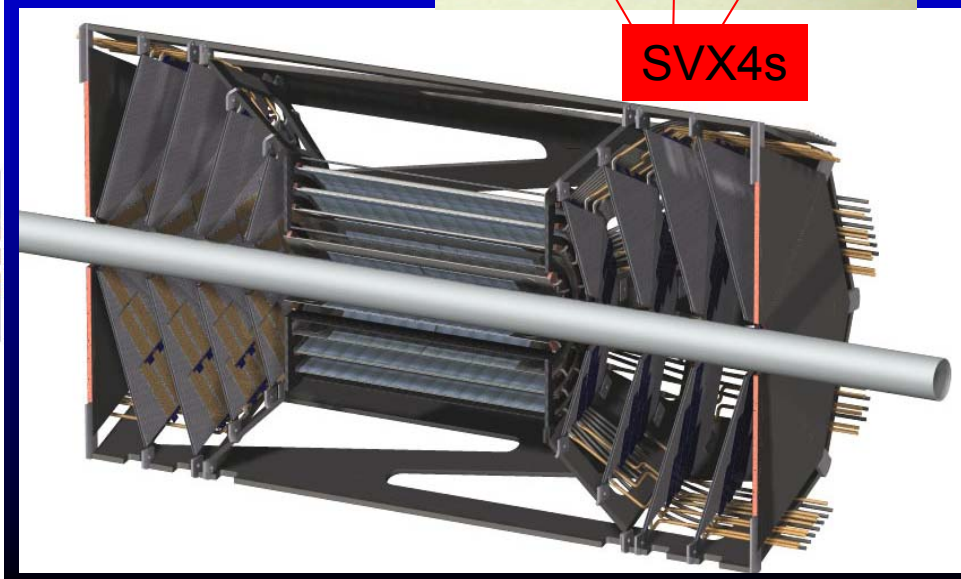
20 cm

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 = $4.6M
    - In President's Budget for FY07
    - Very active ongoing R&D program

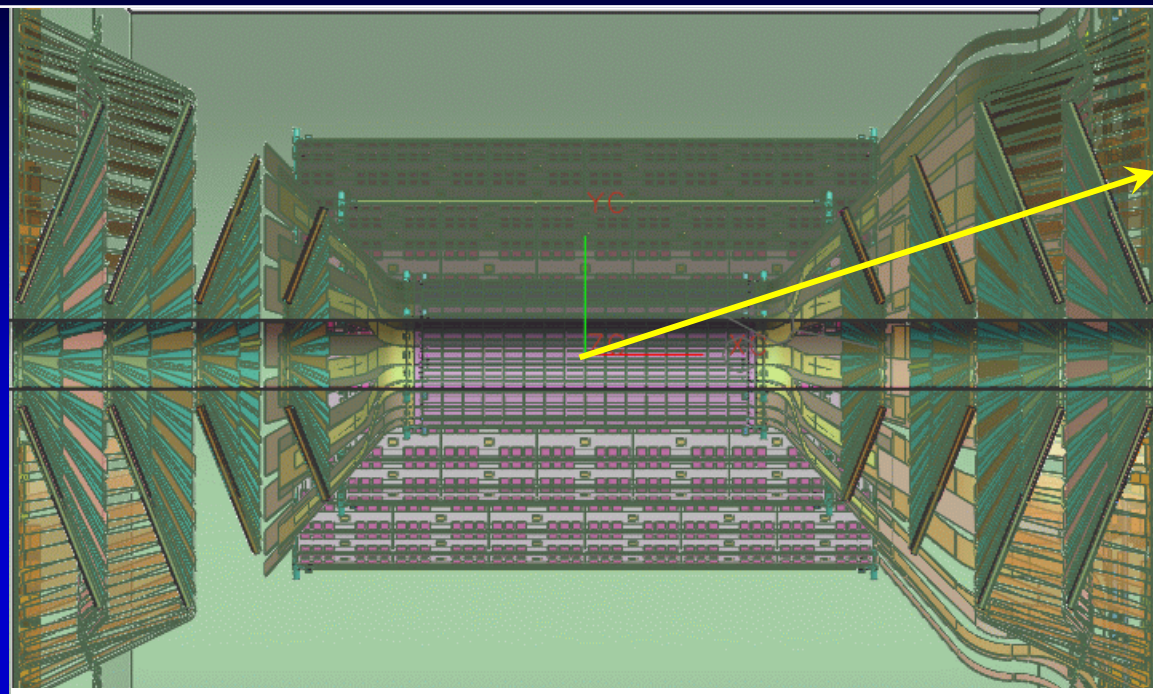


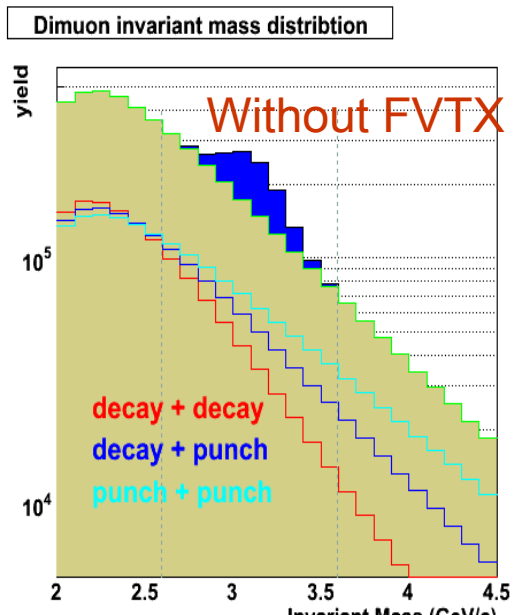


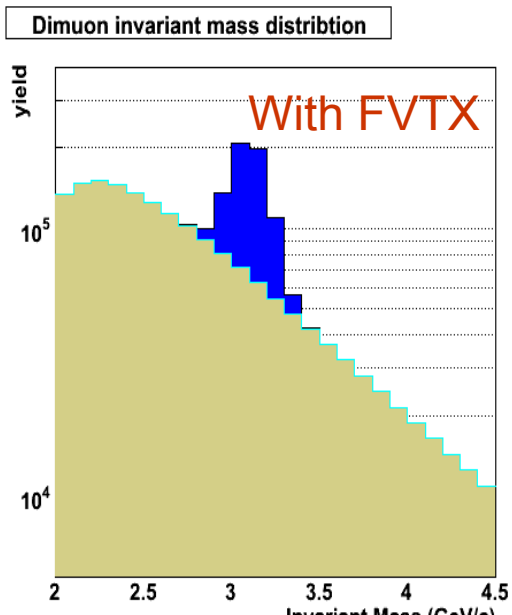


Forward Vertexing

- Baseline:
  - 4 layers
  - Tilted to make tracks ~normal-incidence
  - 50 mm radial pitch, 7.5° phi segmentation (2 – 13 mm)
  - Maximize z and r extent to give good resolution and ≥3 hits/track as much as possible
  - 2*0.86M channels
- Scope
  - Recently favorably reviewed for FY08 start
  - Bootstrapped by LANL LDRD funds to construct one octant prototype

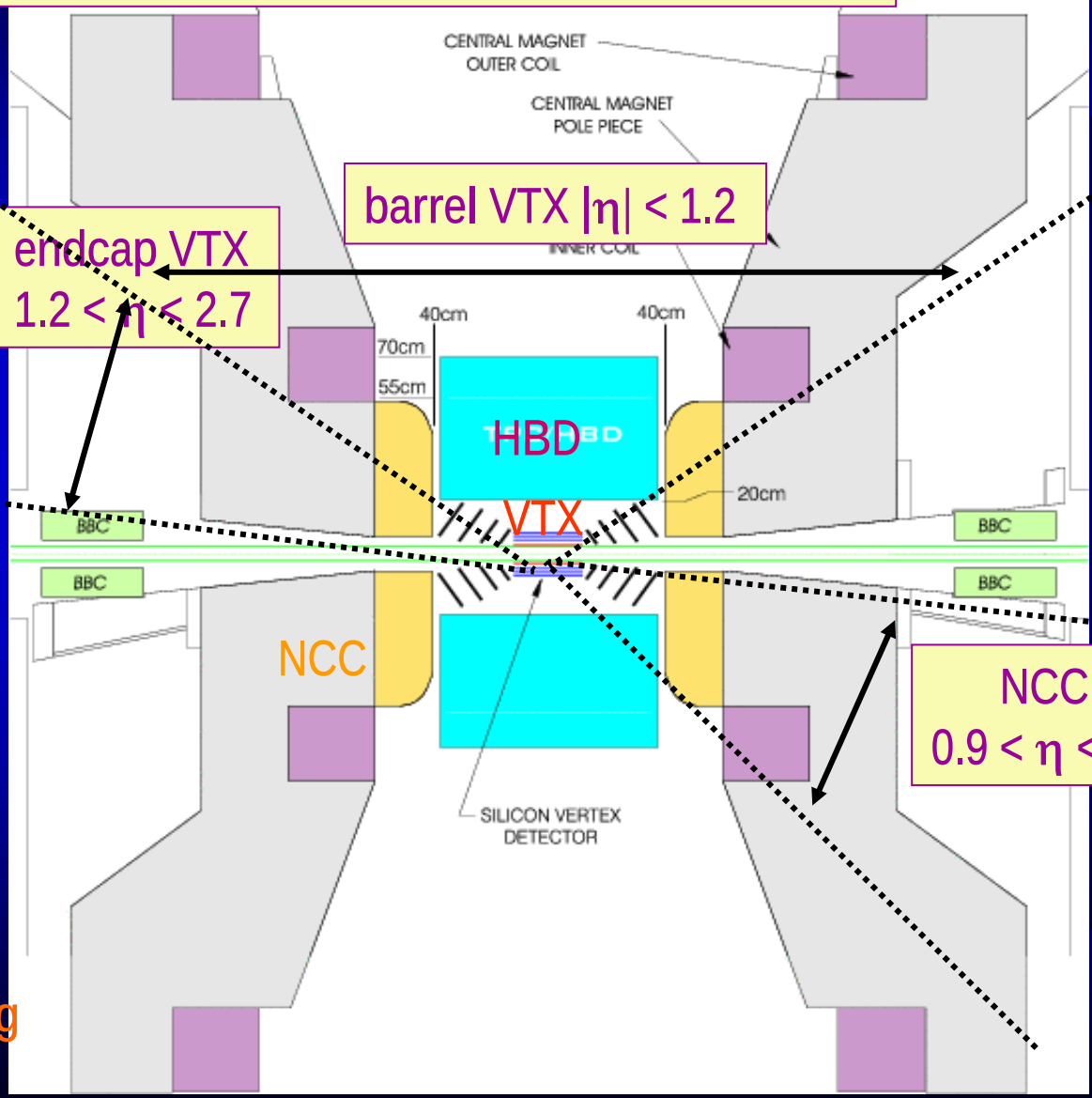






PHENIX Upgrade Projects

Provides displaced vertex & jet measurement over 2π



Displaced vertex:
VTX: silicon tracker
FVTX: forward Si

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, 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

Looking Ahead

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

PHENIX

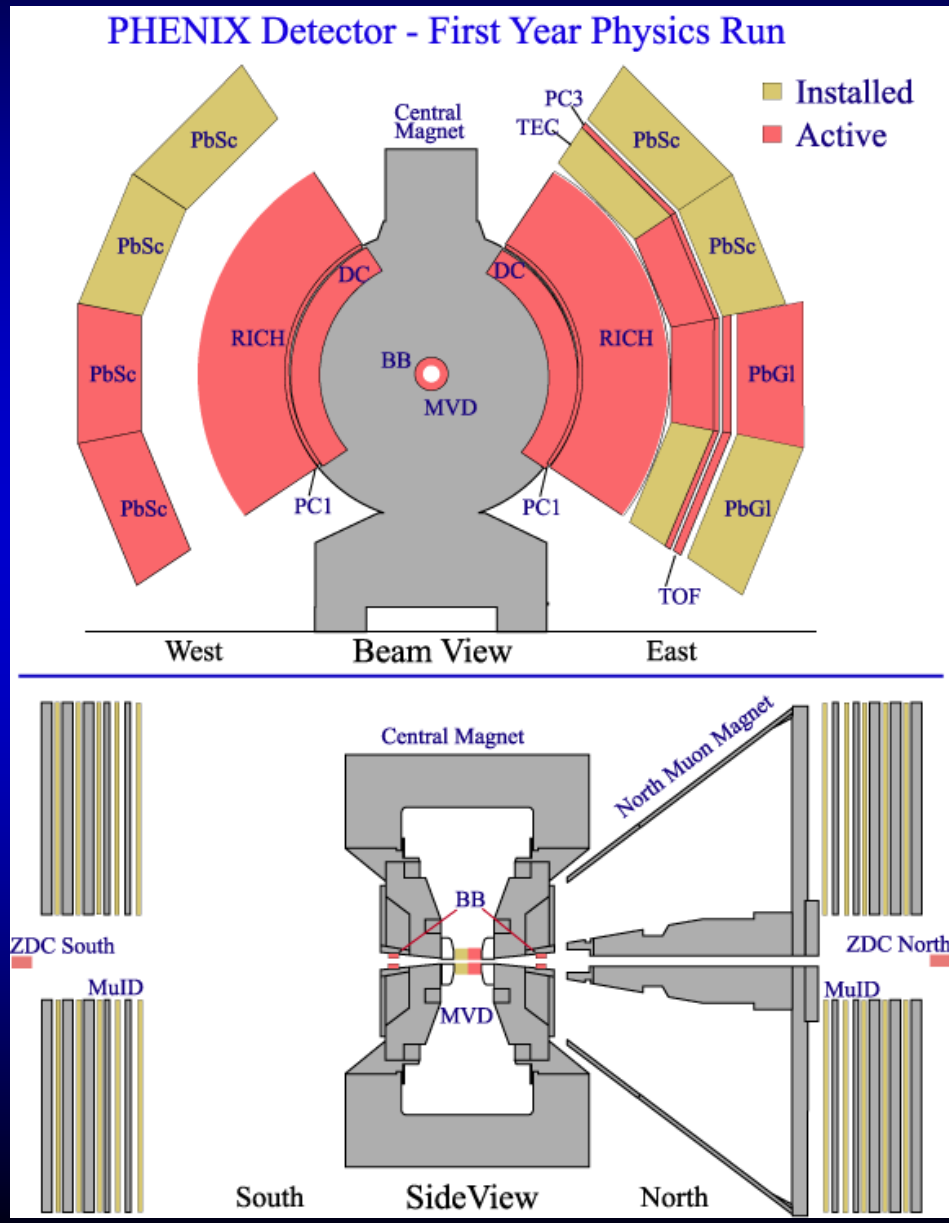
Summary

- PHENIX successes in Runs 1-6 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 (*especially VTX!*) 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
- Plans provide for a program of continued discovery and extended precision for the next decade

Back-up

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)

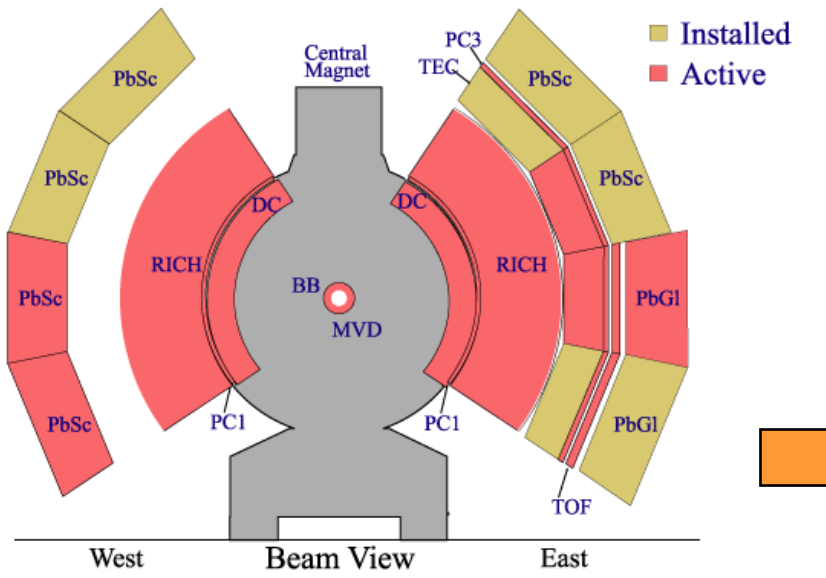


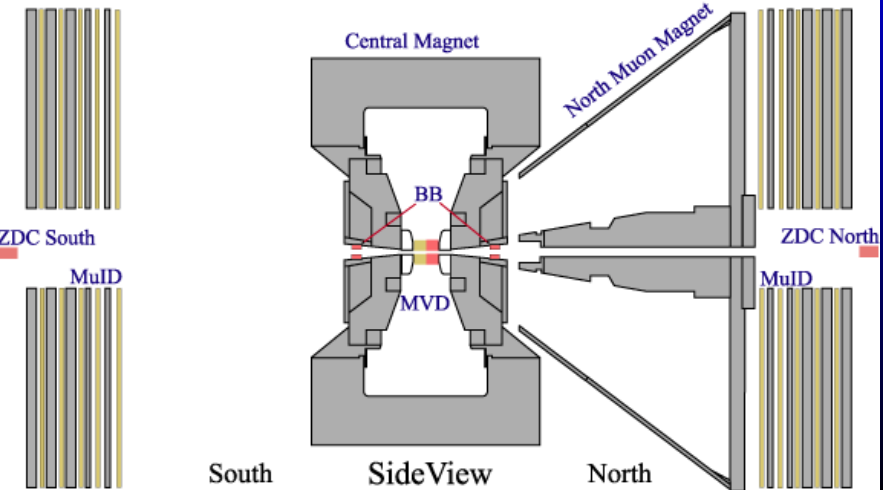
Run-1 Publications

- "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

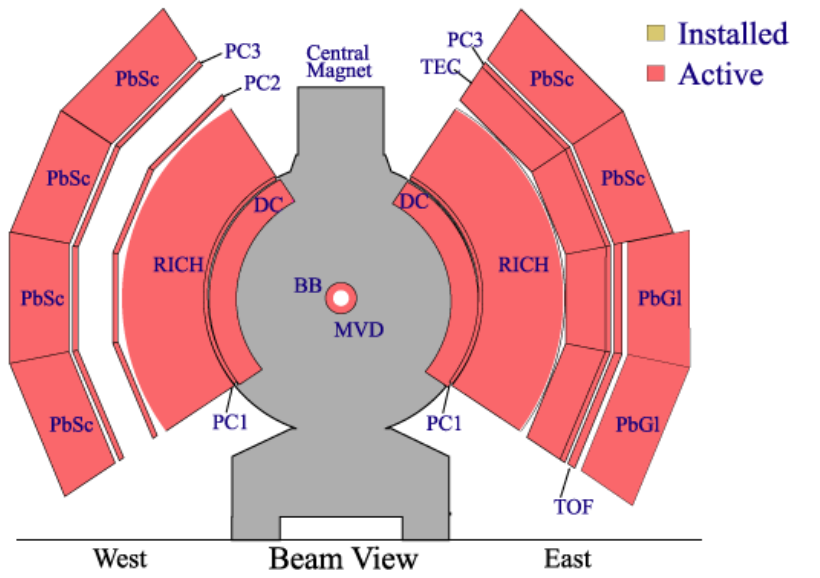
From Run-1 to Run-2

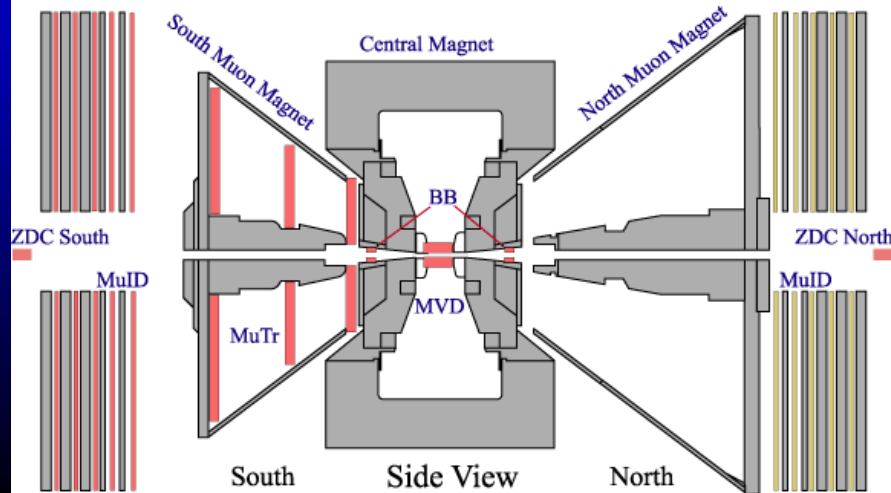
Run-1 (2000)





Run-2 (2001-2)

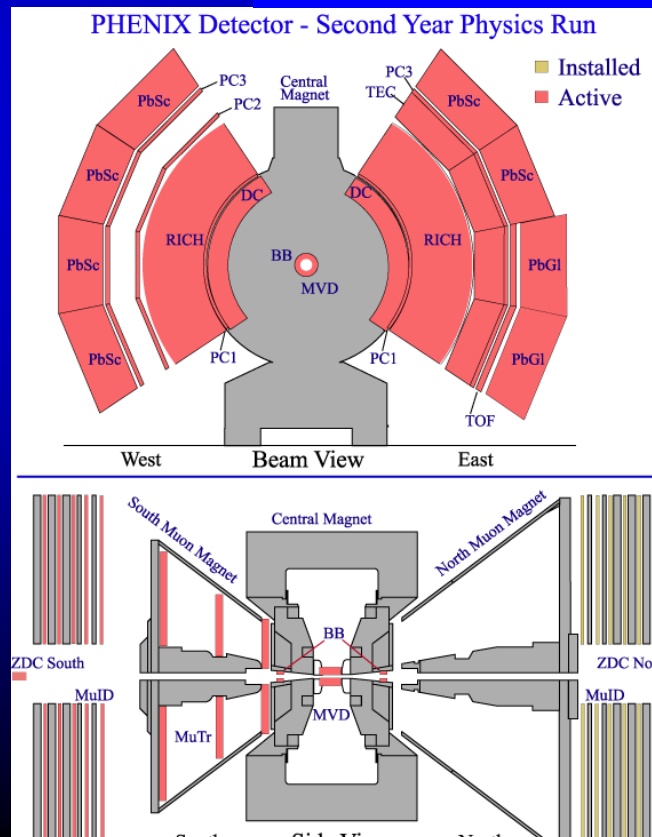




Work in 2001 Shutdown

- 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



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

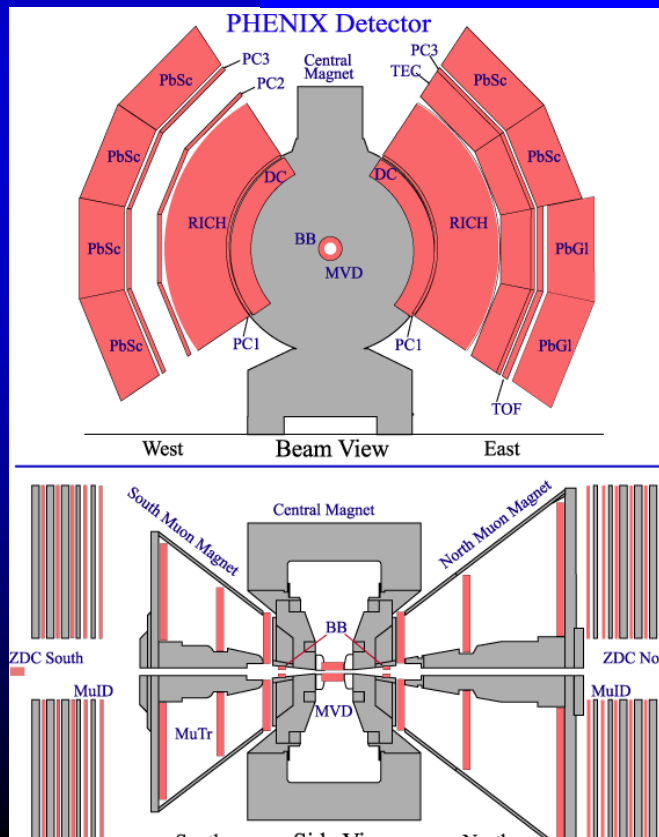
Also contains Run-3 d+Au data

Work in 2002 Shutdown

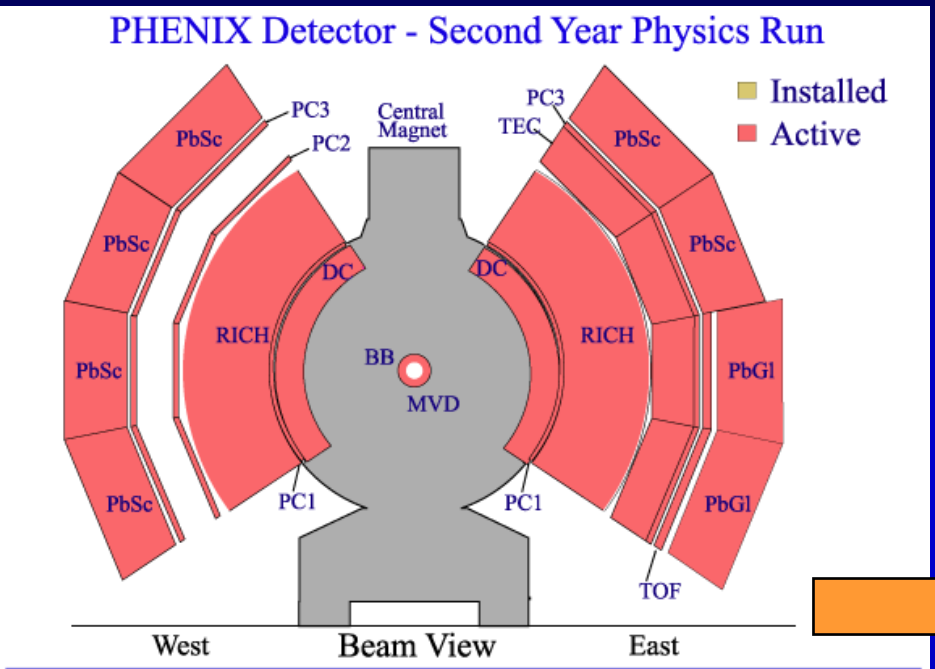
- MuTrk South Spectrometer removal, service and reinstallation
- MuTrk North Spectrometer prep, installation & commissioning
- MuID shielding installation in MuID cutout N&S
- Installation of TRD radiator packs in Time Expansion Chamber
- Install Central Magnet inner coils
- Replace temporary access 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)

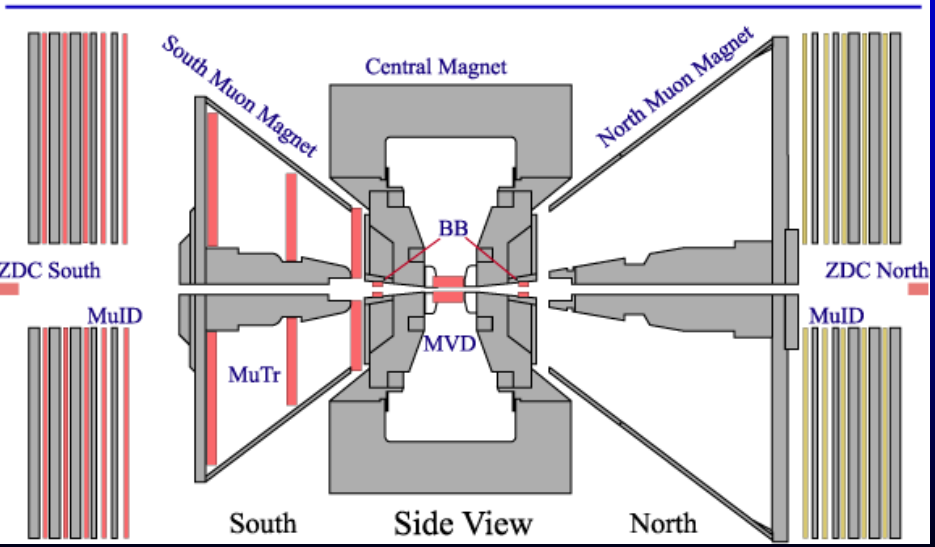
PHENIX baseline detector was declared COMPLETE at the beginning of Run-3

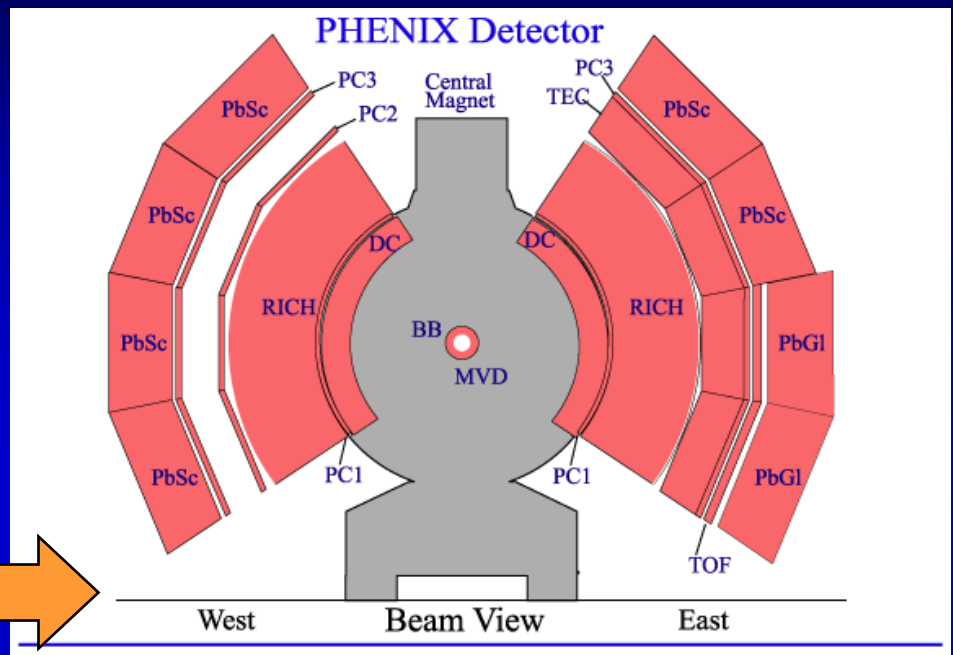
Run-3 PHENIX

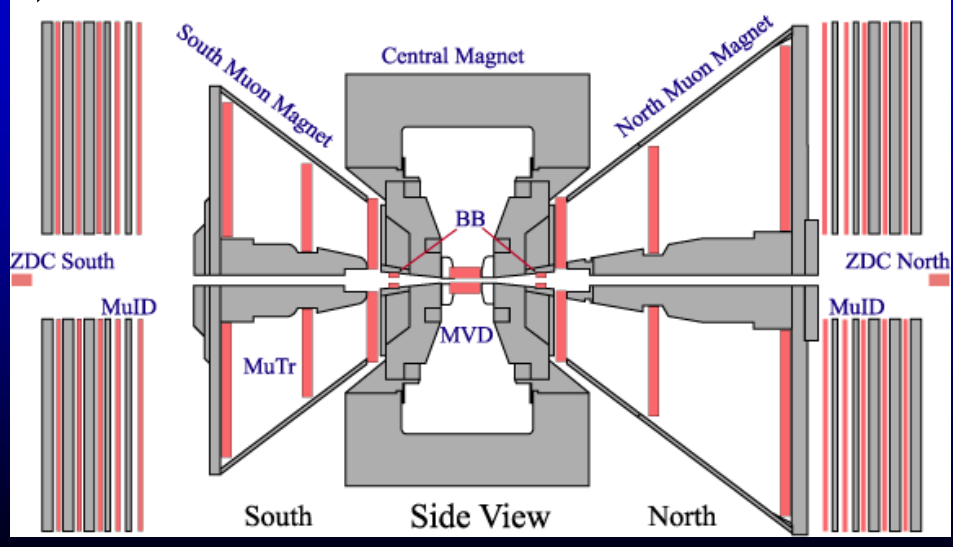


Run-3 and Beyond



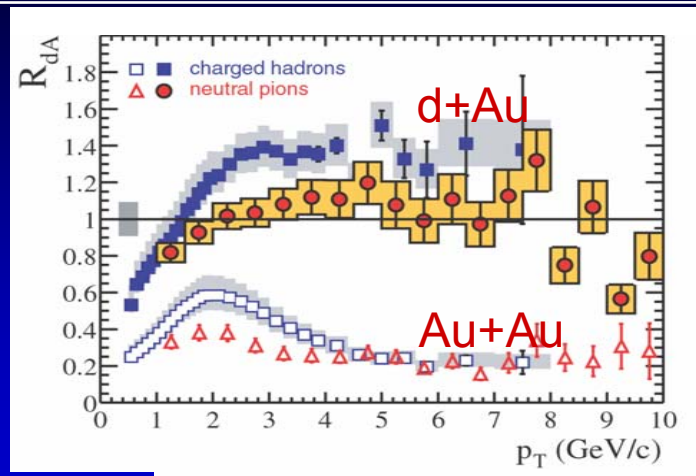




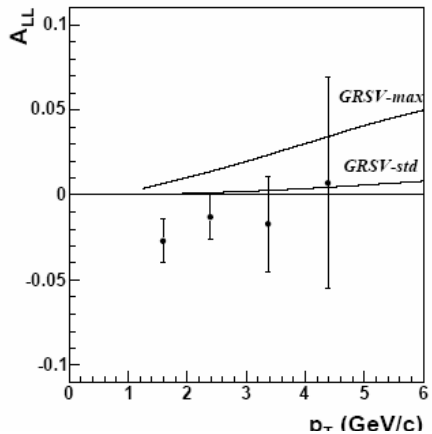


Run-3 Publications

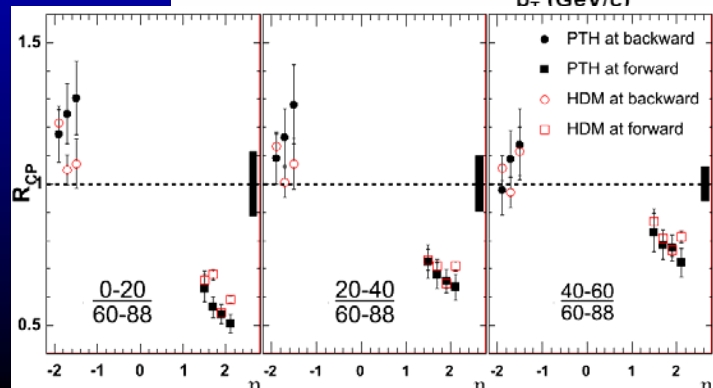
- "Absence of Suppression in Particle Production at Large Transverse Momentum in $\sqrt{s_{NN}}$ = 200 GeV d+Au Collisions",
  PRL 91, 072303 (2003)
  - ☞ PID-ed particles (π^0's) out to the highest p_T's PHENIX's unique contribution to June '03 "press event"



- "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.



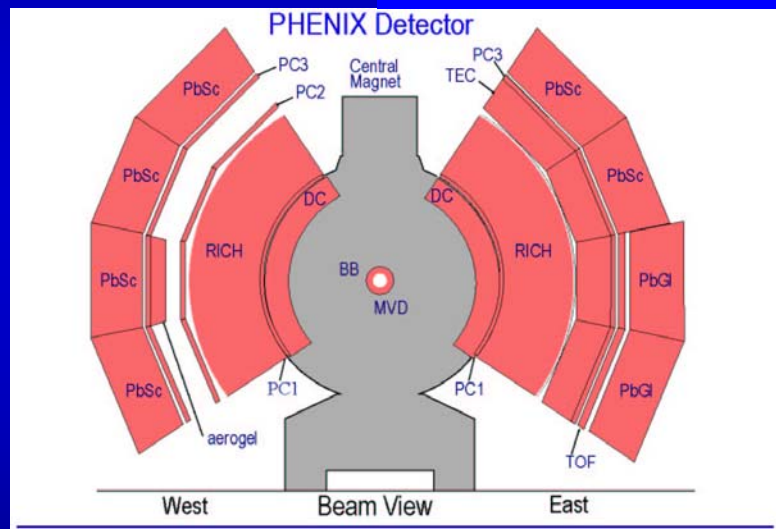
- "Nuclear Modification Factors for Hadrons At Forward and Backward Rapidities in Deuteron-Gold Collisions at √sNN = 200 GeV"
  Phys. Rev. Lett. 94, 082302
  - ☞ Clever extension of PHENIX hadron capabilities to the muon arms

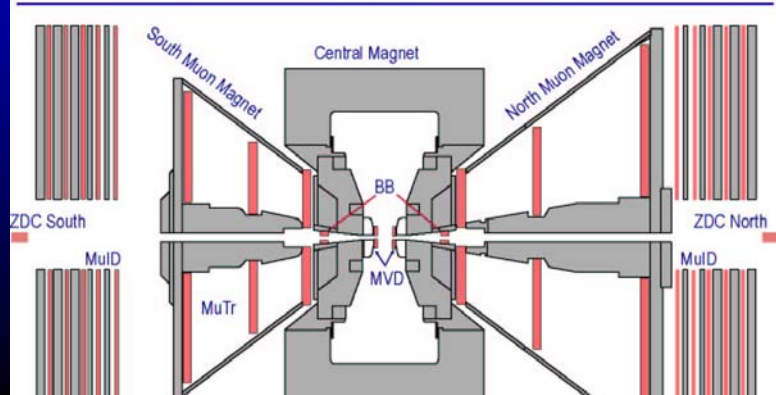


Work in 2003 Shutdown

- 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





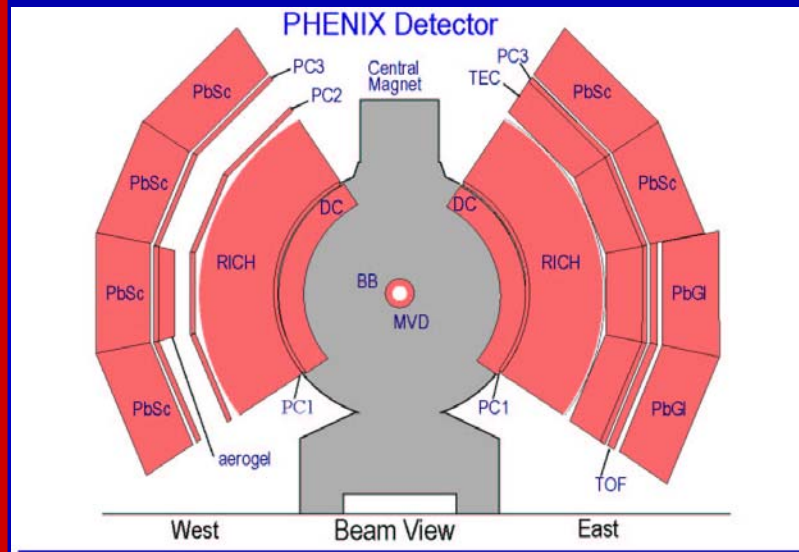
Work in 2004 Shutdown

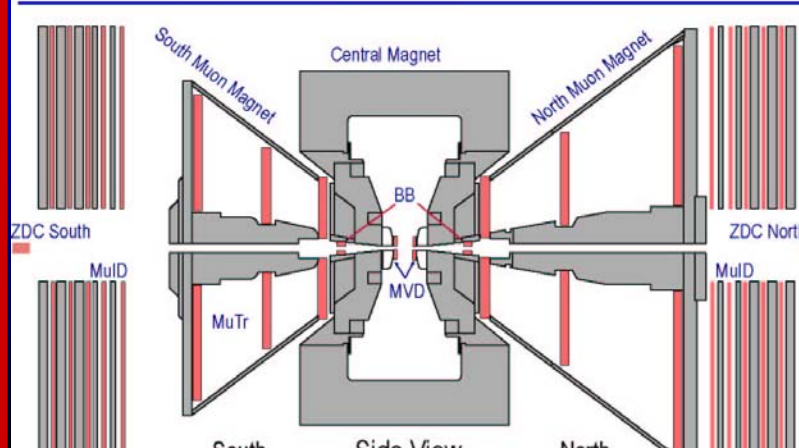
- General maintenance on PHENIX subsystems
- 2nd ½ of Aerogel Sector completed and installed
- Drift Chamber E Window repair
- DC W dc-dc converter replacement
- Magnet mapping
- Lots of Gas system work
- Extra Tunnel Shielding for Muon Arms
- Fix Multi-event buffering (MuTracker, EMCal)
- Improve FEM 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

Built, install Summer 05

Work in 2005 Shutdown

- 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

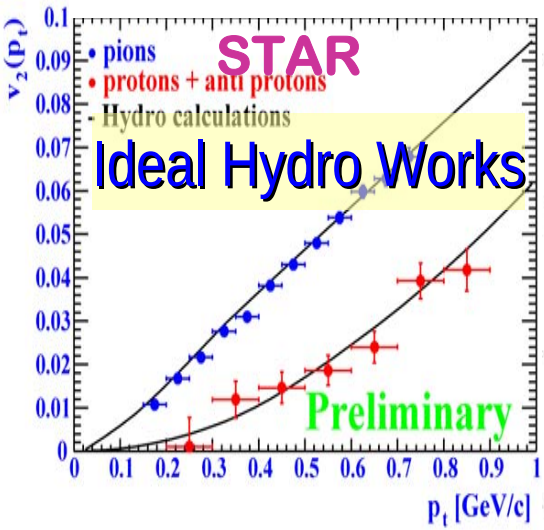




PHENIX Scientific Impact

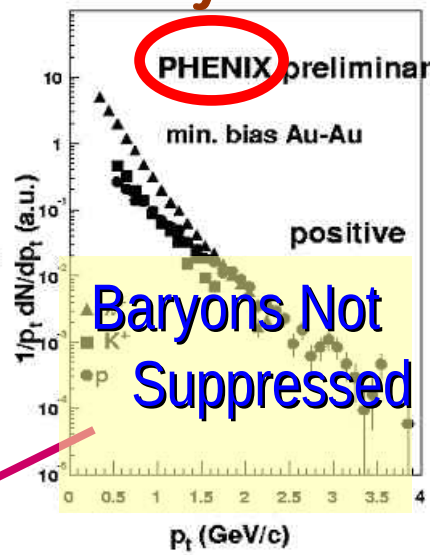
Four major "day 1" discoveries

Collective Flow



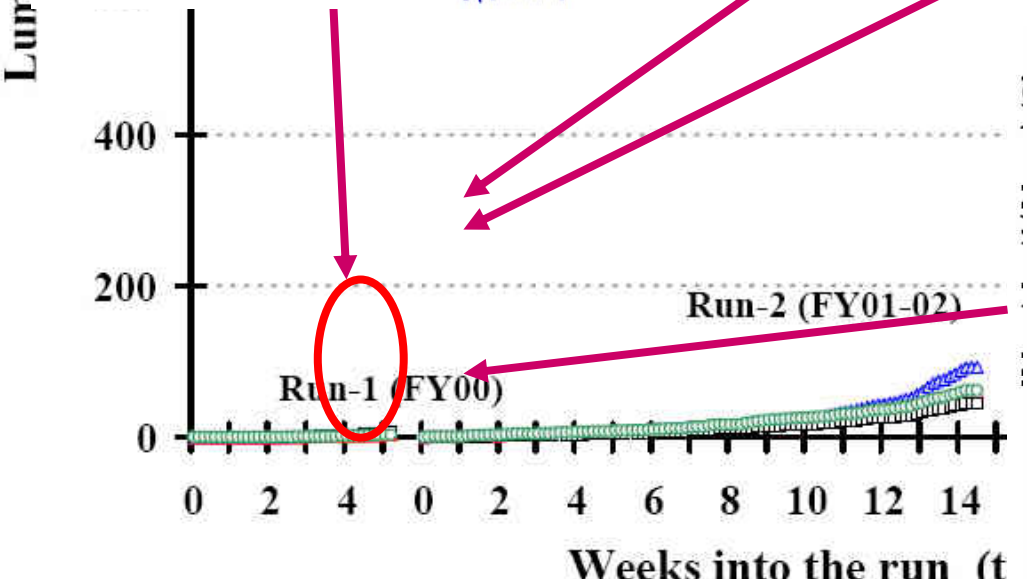
Jet Quenching

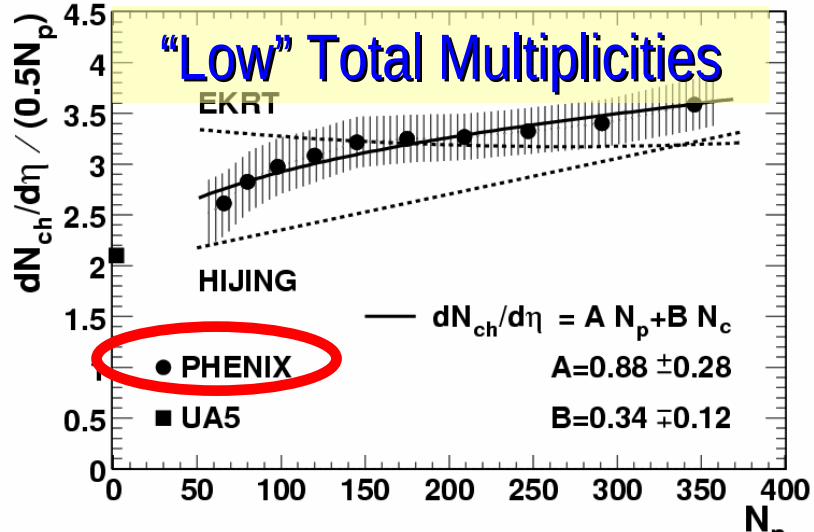
Baryon anomaly



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

CGC Saturation





PHENIX

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