PHENIX

PHENIX:

Accomplishments, Status, Perspectives and Issues

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for the PHENIX Collaboration

(this talk available at http://www.phenix.bnl.gov/phenix/WWW/publish/zajc/sp/presentations/DOEReviewJul06/)

Outline

- Accomplishments
  - Past- what made PHENIX PHENIX?
  - Collaboration growth
  - Experiment growth
  - Data set(s) growth
  - PHYSICS IMPACT
- Status
  - Present- what is PHENIX doing?
  - Run-6 achievements
- Perspectives
  - Quo vadis PHENIX?
  - Physics goals
  - Upgrade plans
- Issues

What is PHENIX?

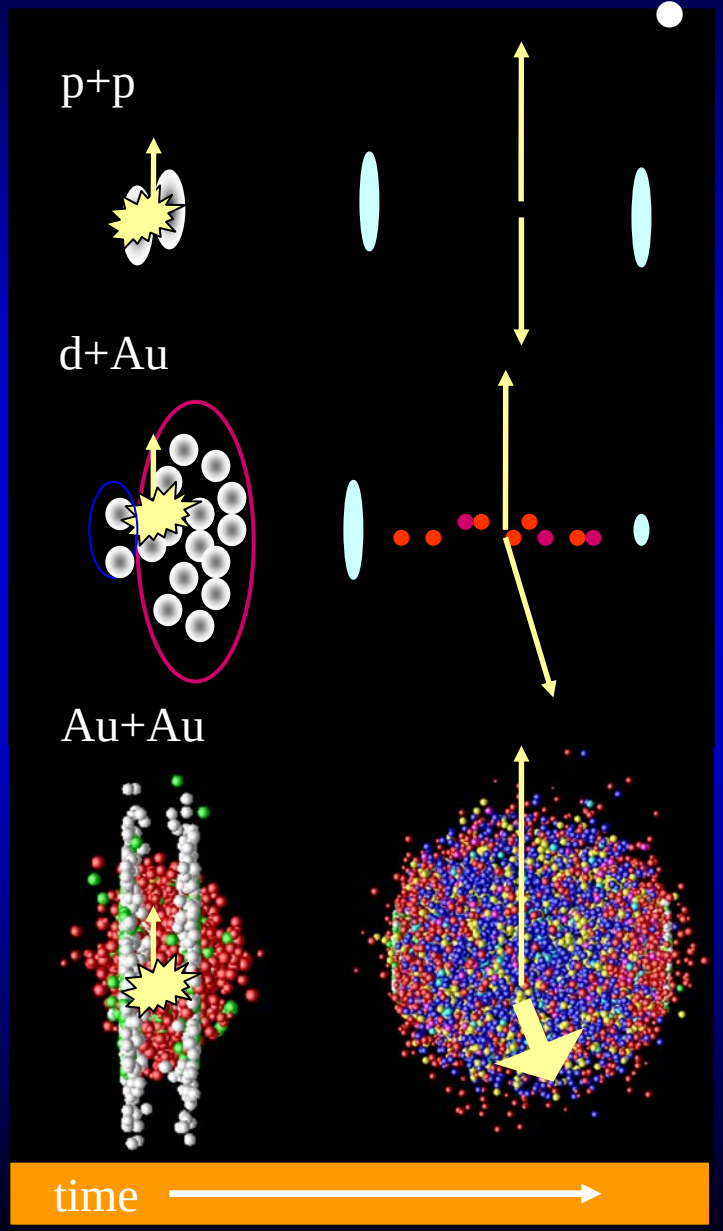
- **P**ioneering **H**igh **E**nergy **N**uclear **I**nteraction e**X**periment

- **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

Accomplishments

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

PHENIX Chronology

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

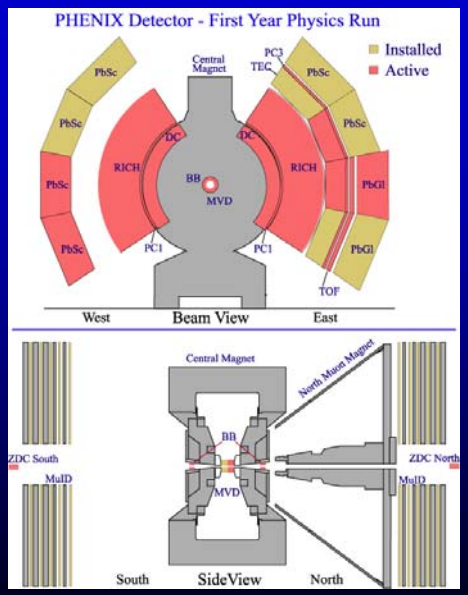
while

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

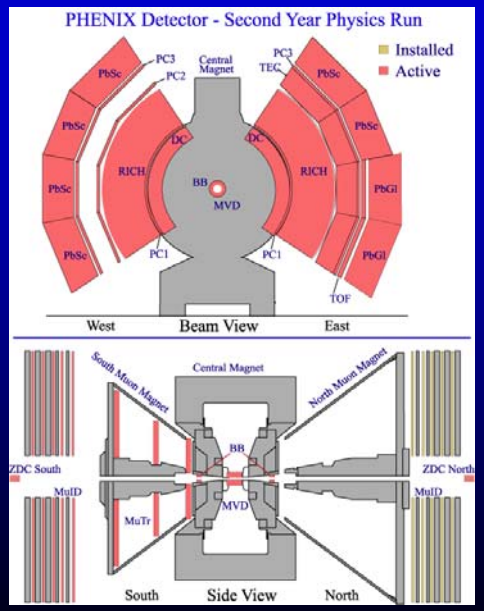
Run-1 to Run-3 Capsule History

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

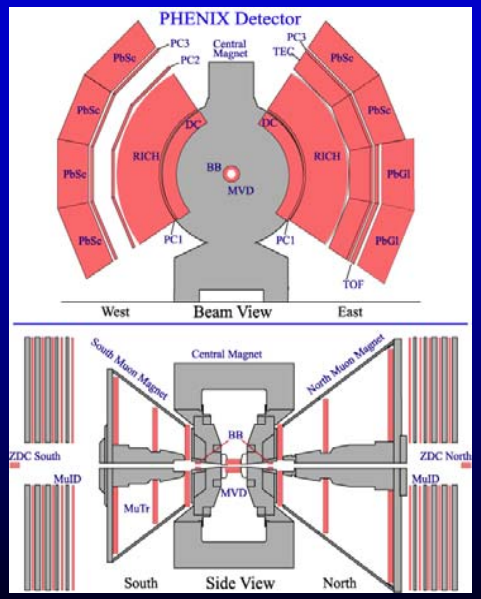
Run-1



Run-2

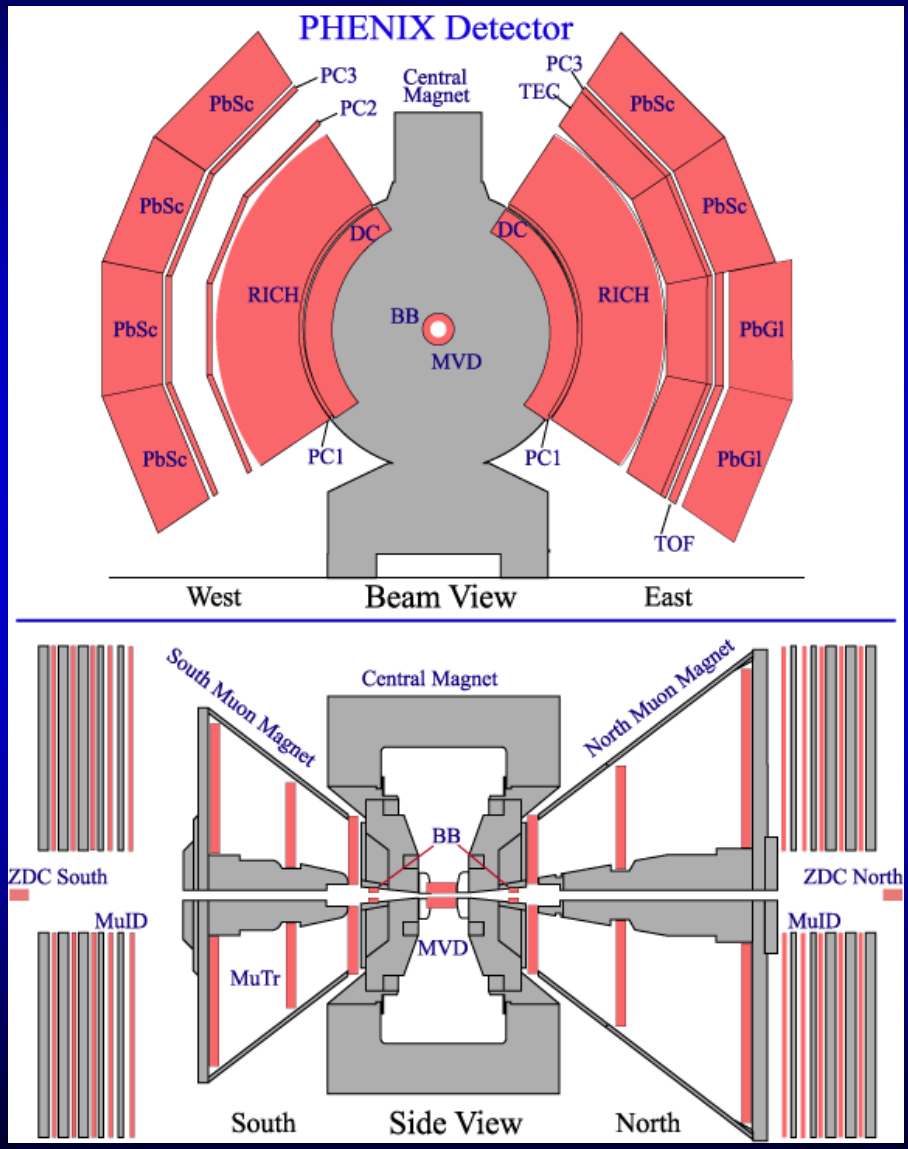


Run-3

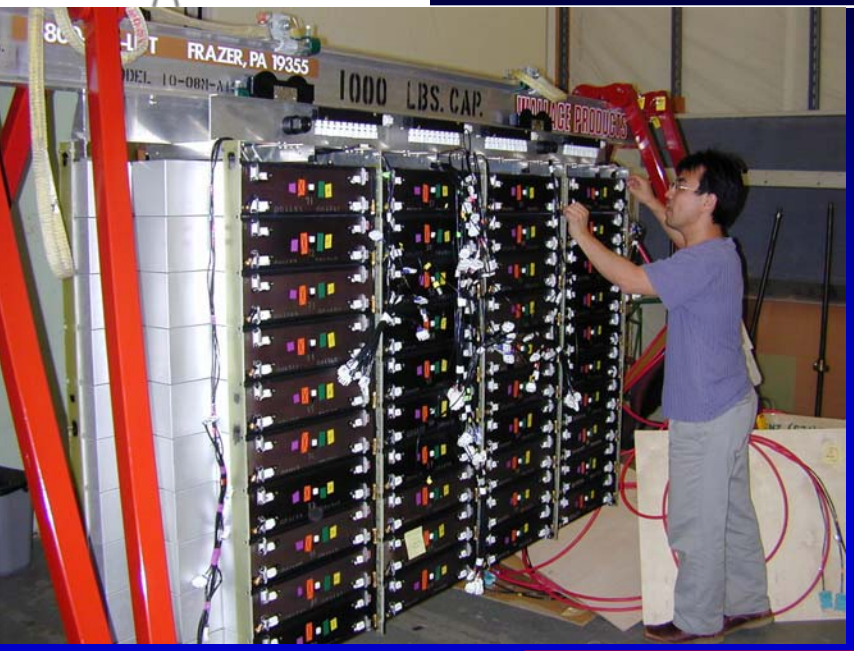


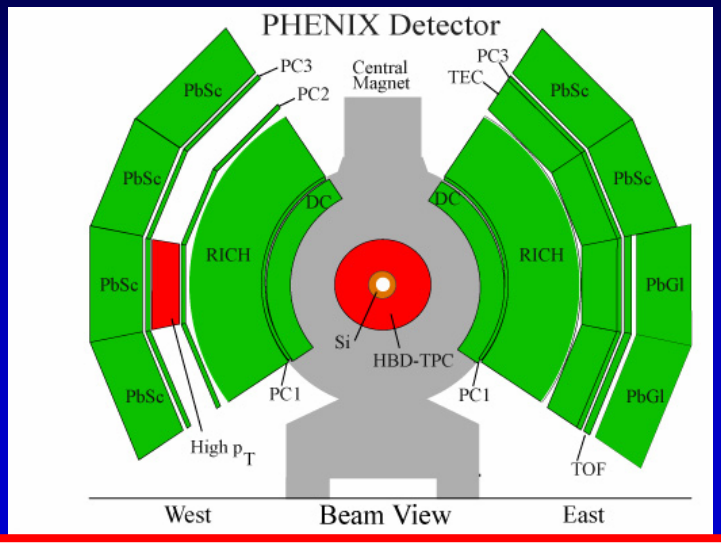
Run-3: Design Configuration!

- **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**

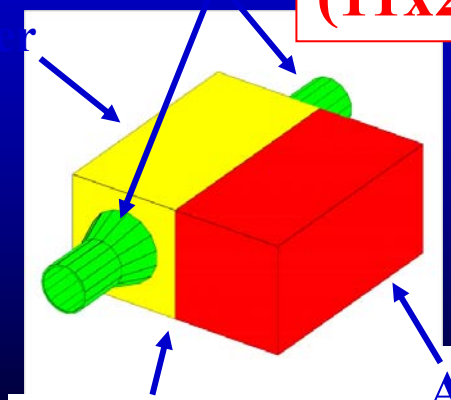


Run-4 Additions





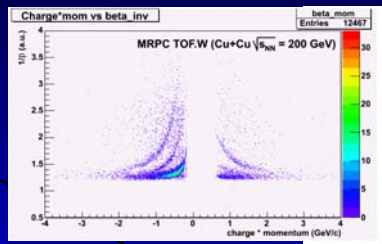
Aerogel Cell (11x22x11 cm^3)

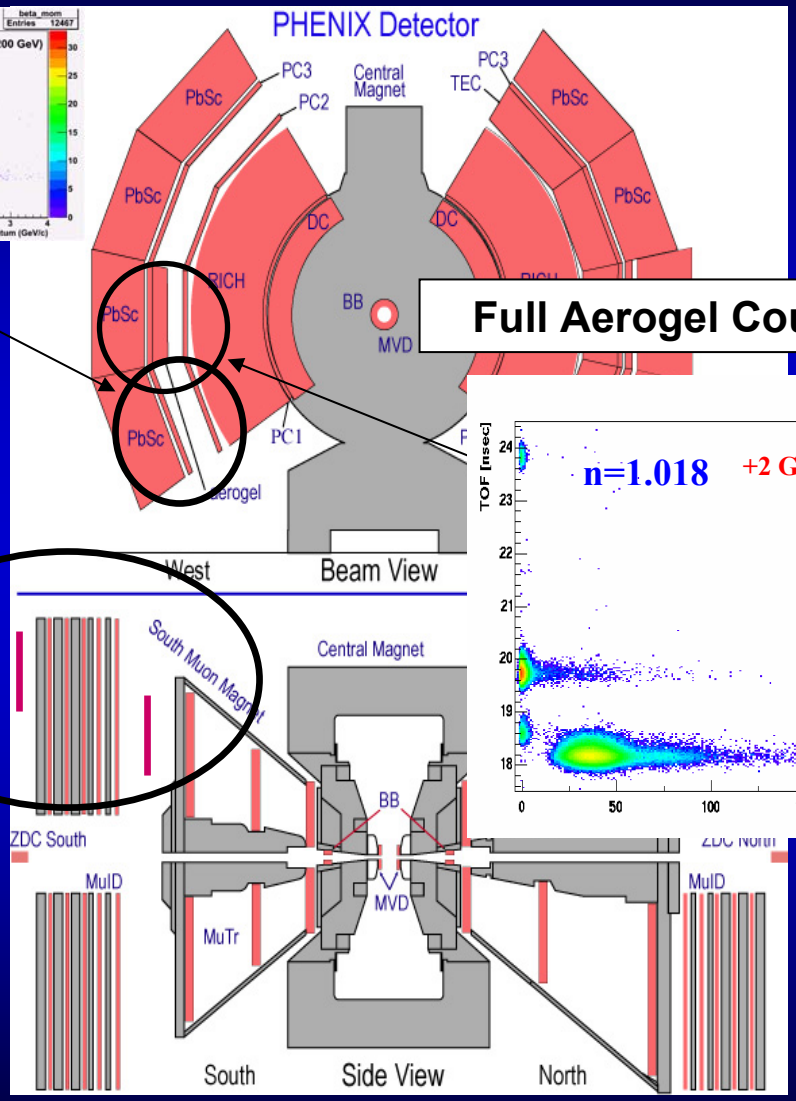


- The Aerogel detector is a threshold Cerenkov counter
- Aerogel is a very low density, SiO_2 – based solid
- Aerogel has index of refr. between gases & liquids.
- Ident. charged particles in a range inaccessible with other technologies.

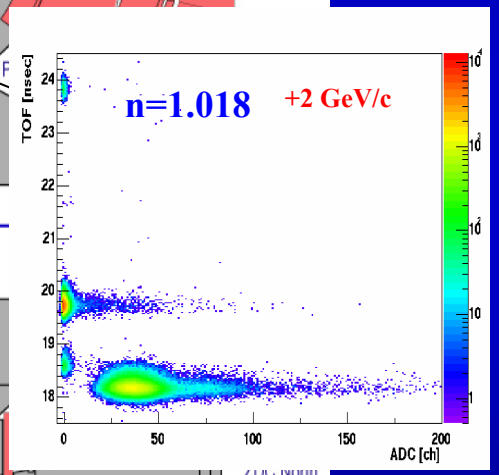
PHENIX Configuration in Run-5

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





Full Aerogel Counter



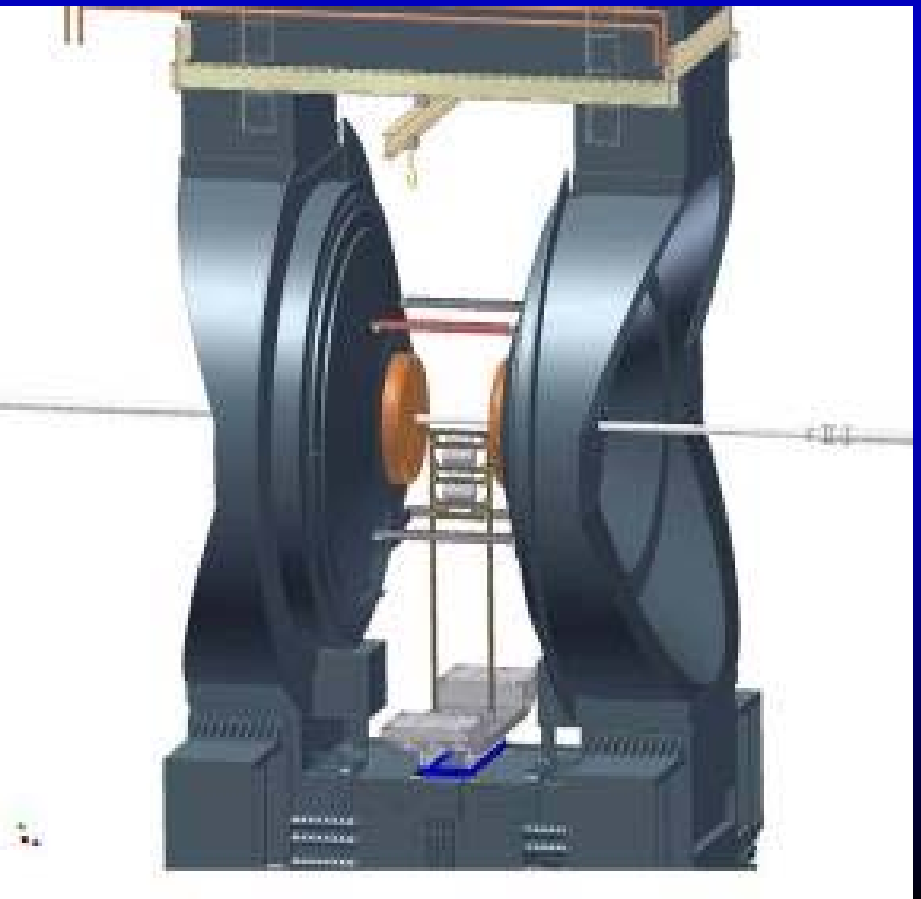
Prototype RPC muon trigger chambers.

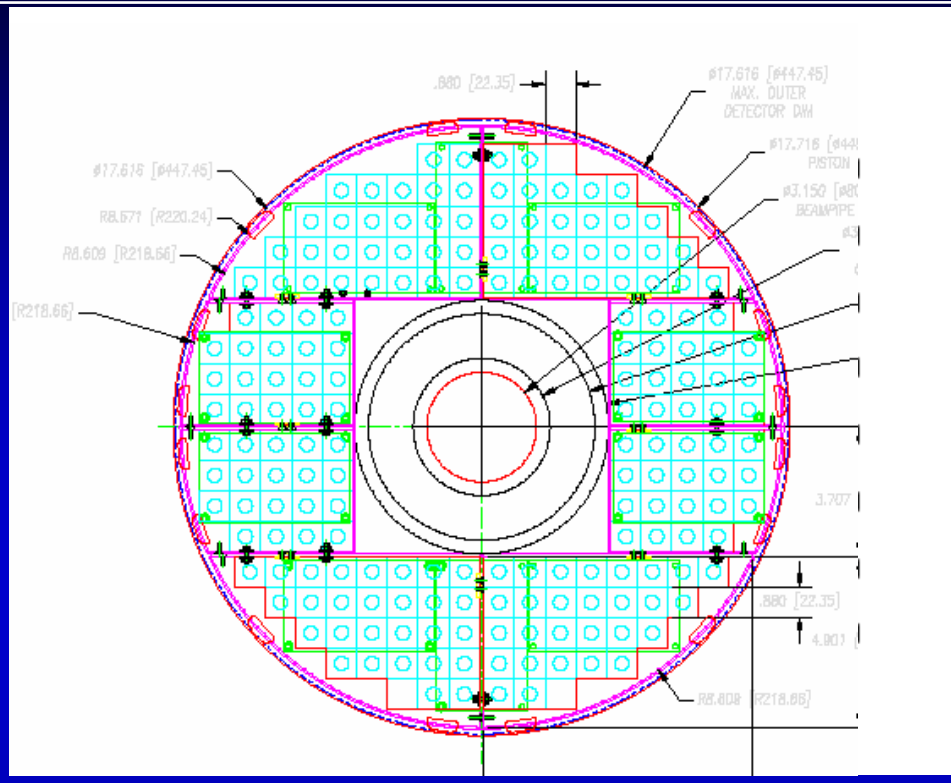
NSF $1.98M
Approved!

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





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

Status

Run-1 to Run-6 Capsule History

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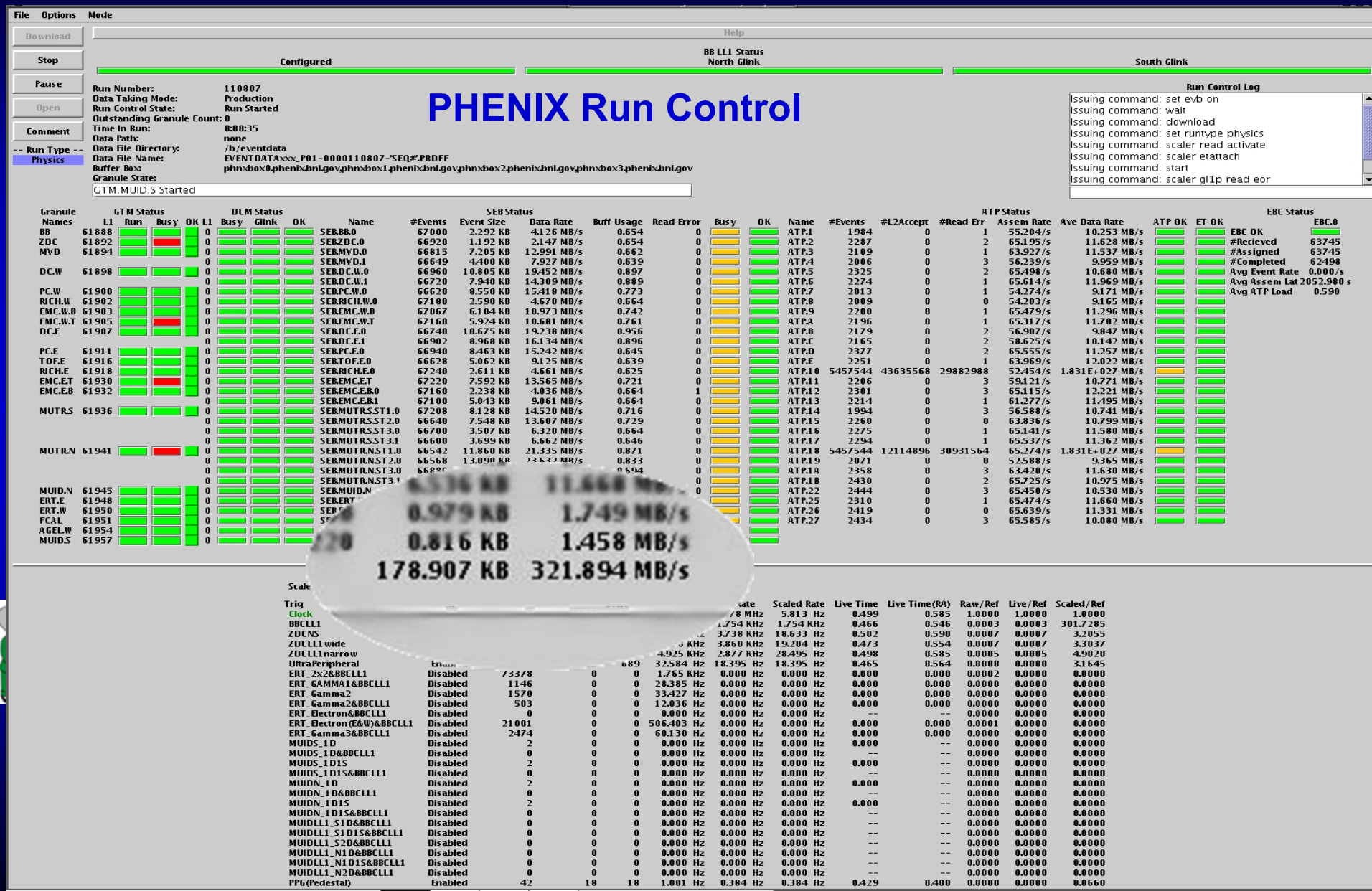
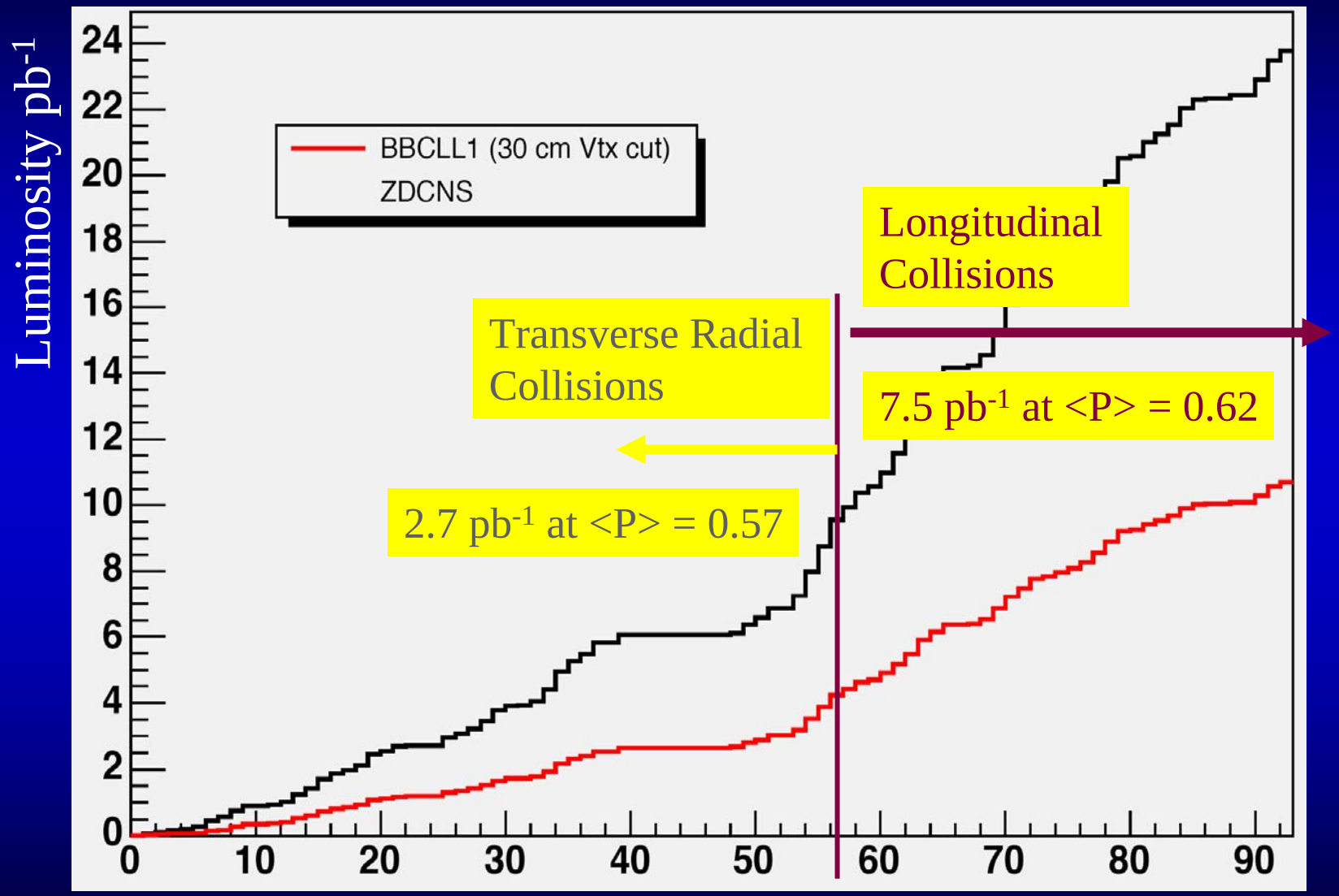
		p+p	200	0.35 pb^{-1}	6.6G	0.35 pb^{-1}	35 TB
04	2003/2004	Au+Au	200	241 μb^{-1}	1.5G	10.0 pb^{-1}	270 TB
		Au+Au	62	9 μb^{-1}	58M	0.36 pb^{-1}	10 TB
05	2004/2005	Cu+Cu	200	3 nb^{-1}	8.6G	11.9 pb^{-1}	173 TB
		Cu+Cu	62	0.19 nb^{-1}	0.4G	0.8 pb^{-1}	48 TB
		Cu+Cu	22.5	2.7 μb^{-1}	9M	0.01 pb^{-1}	1 TB
		p+p	200	3.8 pb^{-1}	85B	3.8 pb^{-1}	262 TB
06	2006	p+p	200	10.7 pb^{-1}	230B	10.7 pb^{-1}	310 TB
		p+p	62	0.1 pb^{-1}	28B	0.1 pb^{-1}	25 TB

Comparable Data Archiving Rates

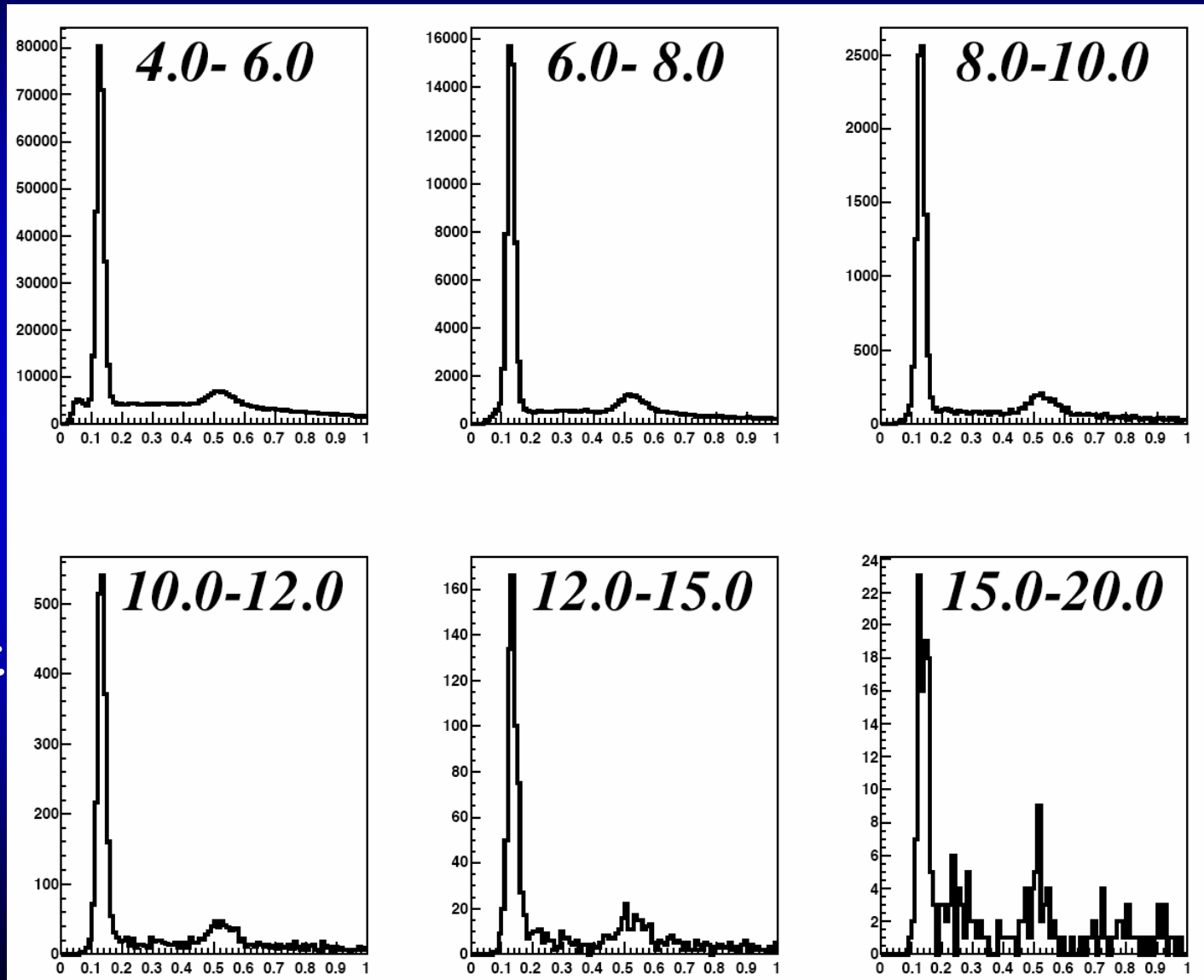


Run-6 Accumulations



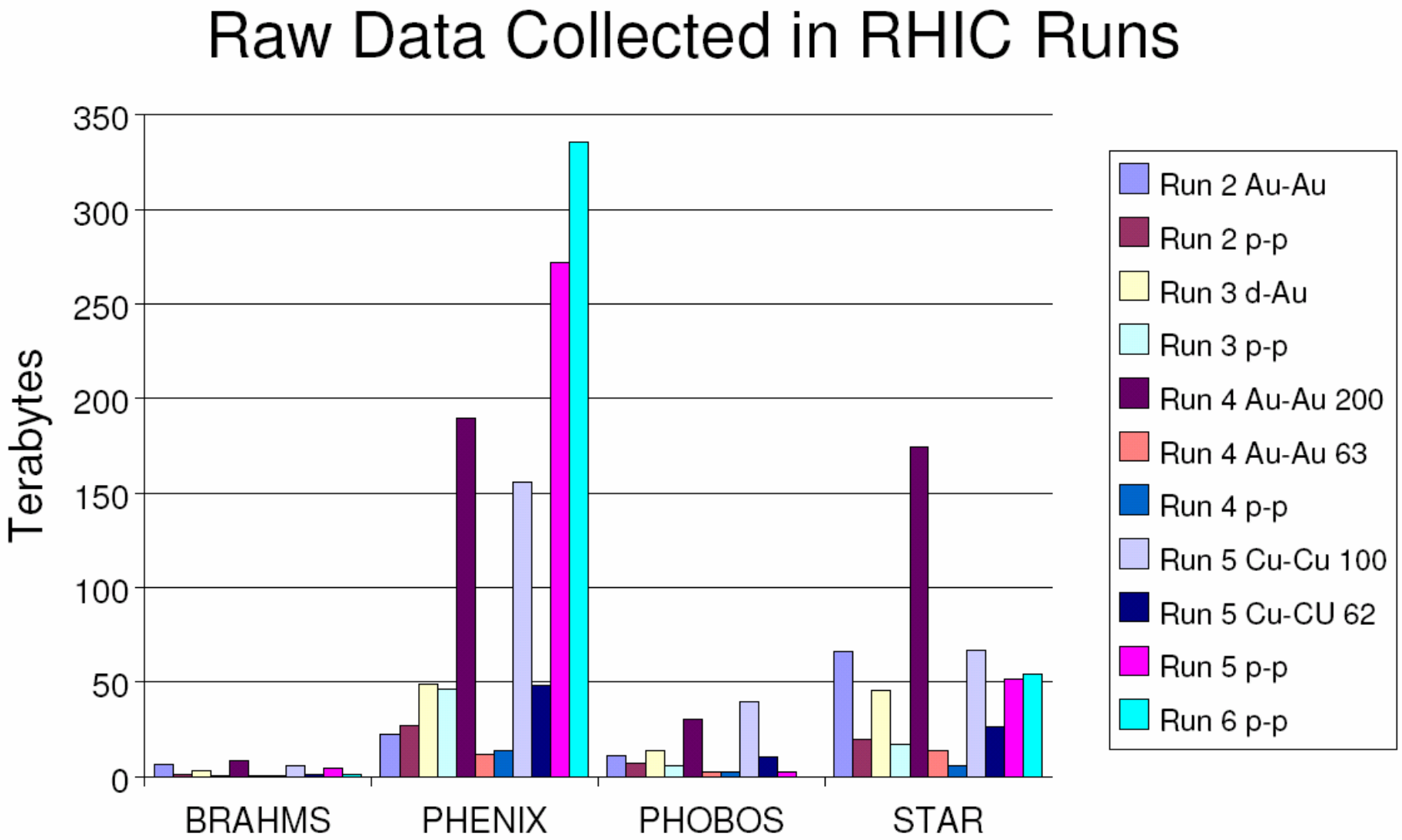
Run-6 Data Quality

- Level 2 filter:
  - $\pi^0 \rightarrow \gamma\gamma$,
  - $\eta^0 \rightarrow \gamma\gamma$
- Clear η peak seen out to ~20 GeV/c
- Obtained in quasi real-time production on Vanderbilt farm



Total Data Volumes

- Plot courtesy of Tom Throwe (RCF)



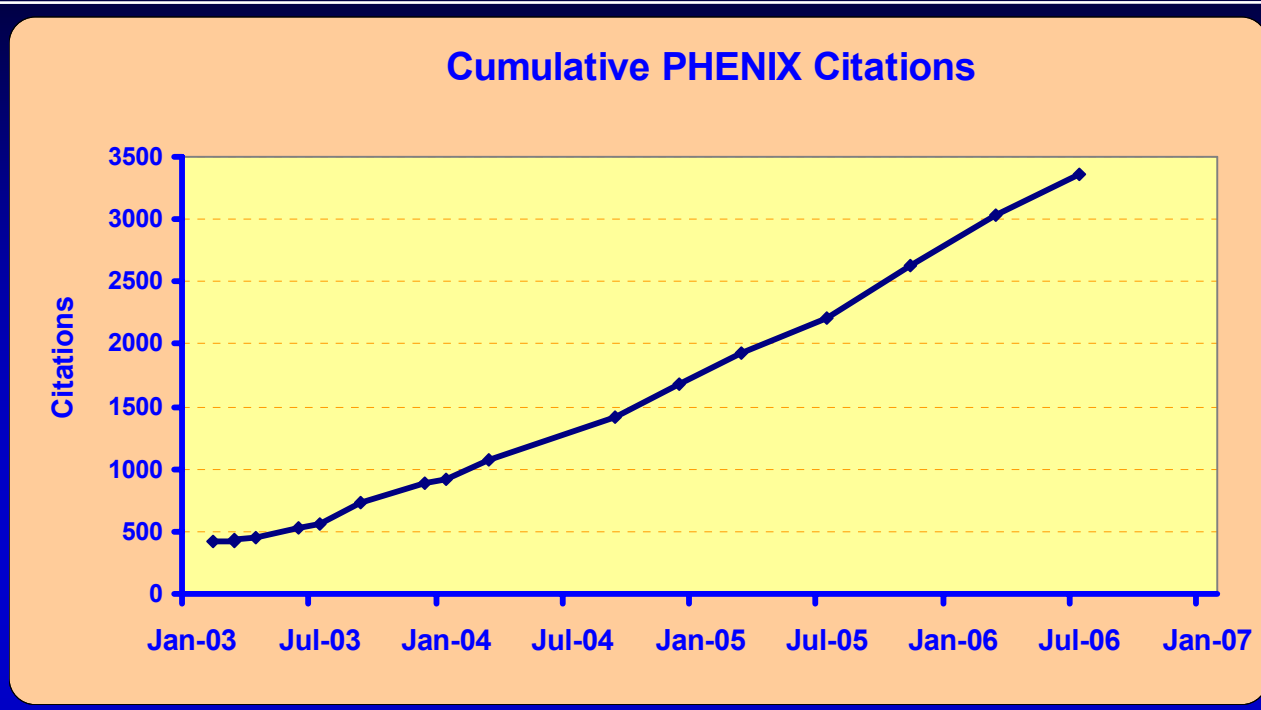
PHENIX Data Production

- 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
  - Run-4 pp Production at Computing Center - Japan (CC-J)
  - Run-5 CuCu 200 GeV/62.4 GeV (ORNL farm)
    - LVL2 filtered analysis provided 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
  - 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 (270 TB) shipped via network to CC-J during Run-5
  - Run-6 pp production at CC-J
    - LVL2 filtered data run at Vanderbilt
  - Simulation at Vanderbilt, LLNL, New Mexico (all results archived at RCF)

☞ Production for all PHENIX data-sets achieved by start of Run-7

Publication Summary

- Since 2001:
  - 30 PRL's
  - 10 Phys. Rev. C's
  - 3 Phys. Rev. D
  - 1 Phys. Lett. B
  - 1 Nucl. Phys. A (White Paper)
- > 3300 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 185 citations

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Nuclear Physics A 757 (2005) 184–283

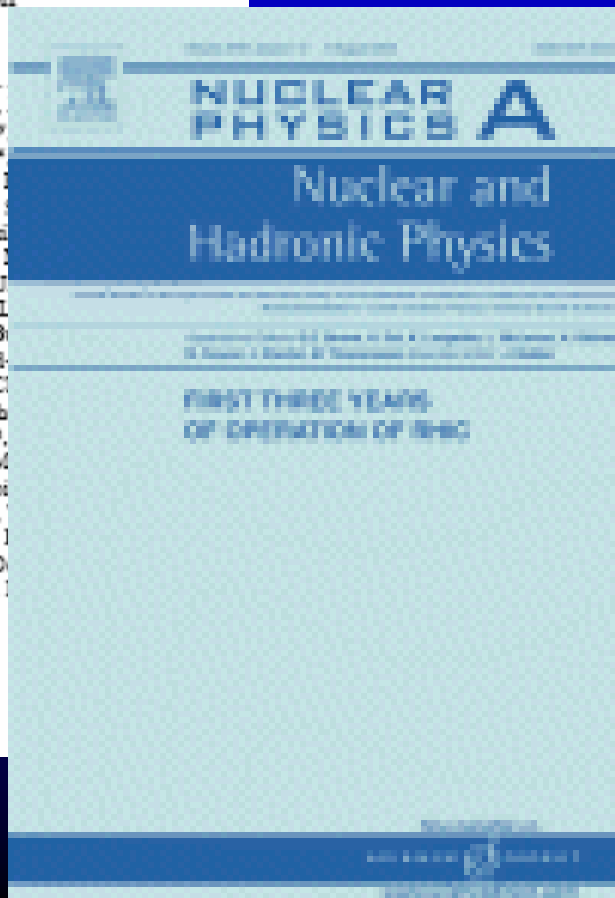
NUCLEAR PHYSICS A

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

PHENIX Collaboration

K. Adcox, 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. Averbeck, 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. B
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, M
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,

0375-9474/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.nuclphysa.2005.03.086



NUCLEAR PHYSICS A

Nuclear and Hadronic Physics

FIRST THREE YEARS OF OPERATION OF RHIC

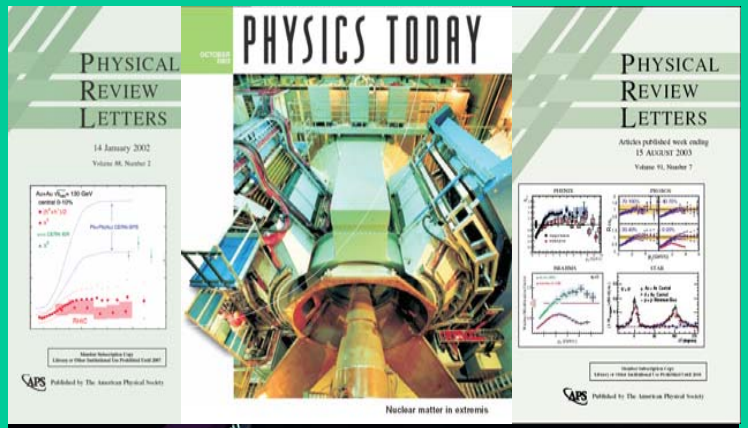
Perspectives

Past→Present → Planned Physics

- 48 PHENIX physics papers to date either published or submitted to scientific journals
- Topics in those papers cover a broad range
  - J/Ψ production in HI collisons
  - High pT suppression and energy loss
  - Observation of direct photons
  - Elliptic flow including flow of heavy quarks
  - Jet behavior
  - Charge fluctuations
  - Anomalous Baryon/meson ratios →
  - Double spin asymmetry A_{LL} in polarized proton collision
  - Single spin asymmetry A_N
  - Nuclear modification factors in d-Au collisions.....
- Future topics and the motivation for detector upgrades
  - Flavor-tagged high pT physics (Energy loss, baryon/meson anomaly)
  - Low mass electron pair continuum (Thermal radiation, chiral symmetry)
  - Heavy quark behavior (c, b quark characteristics in dense medium)
  - charmonium spectroscopy (J/ψ, ψ' , χ_c and ϒ(1s),ϒ(2s),ϒ(3s))
  - gluon spin structure (ΔG/G) through g-jet correlations
  - quark spin structure (Δq/q) through W-production
  - Transversity
  - A-, p_T-, x-dependence of the parton structure of nuclei
  - gluon saturation and the color glass condensate at low x

PHENIX Decadal Plan

- Outlined in
  - 150+ pages
  - 60+ figures
  - 10+ tables
  - 160+ references
- Will tour portions of Executive Summary relevant to upgrade plans
- Clearly a synopsis of a synopsis of a . . .



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

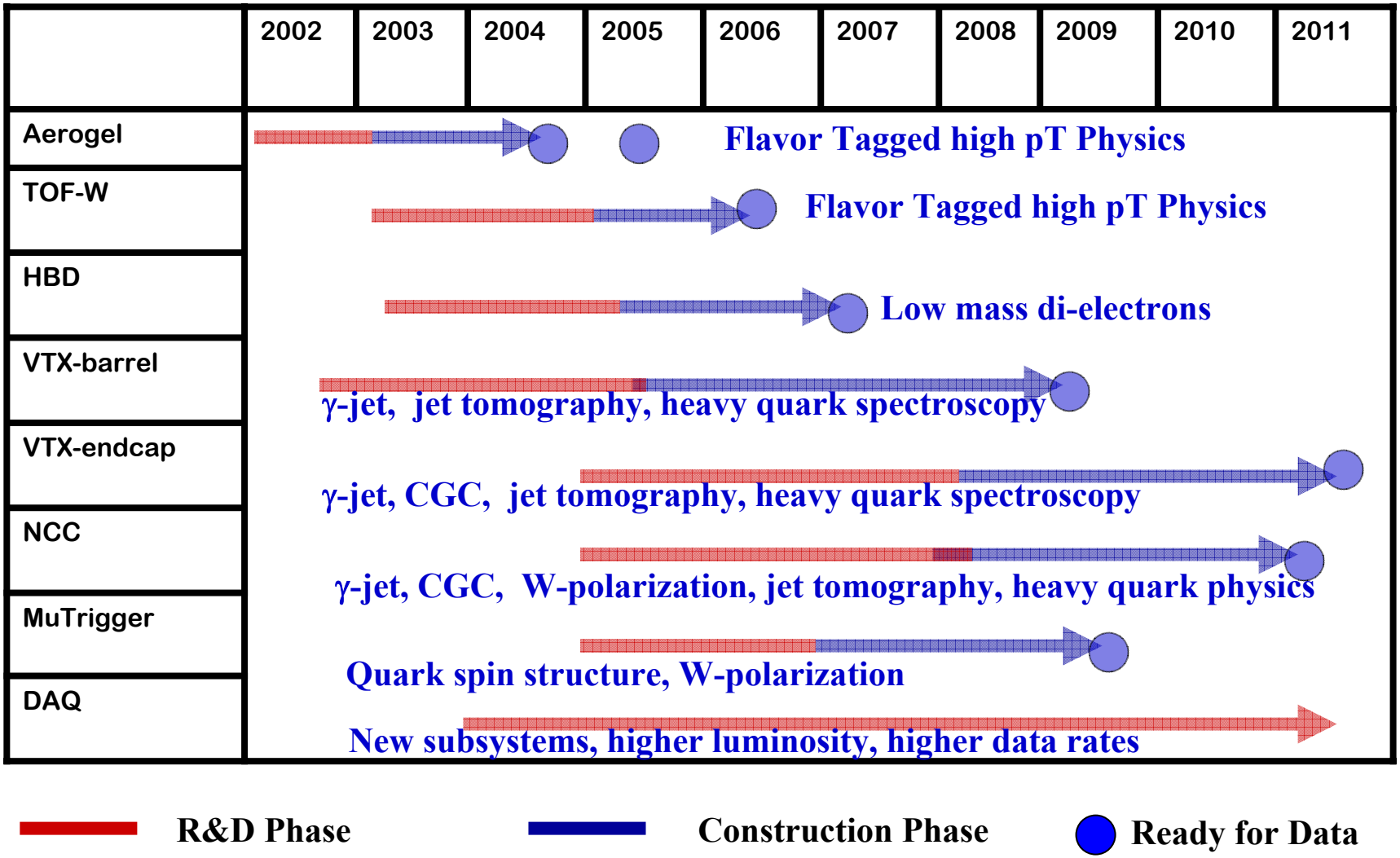
Decadal Plan: Executive Summary (2)

- 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.

Future (Compelling) Physics



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:

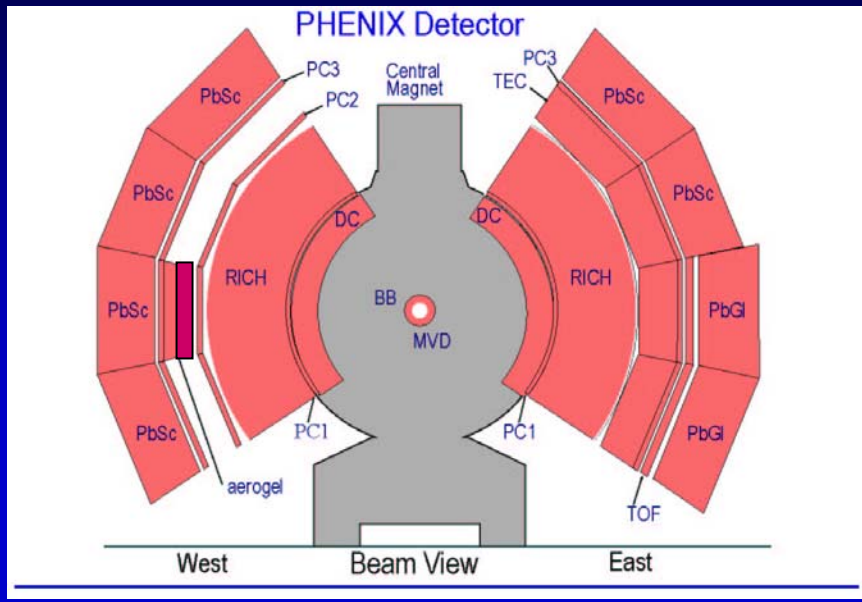
- Pb Scintillator
- Pb Glass
- Nose Cone Calorimeter

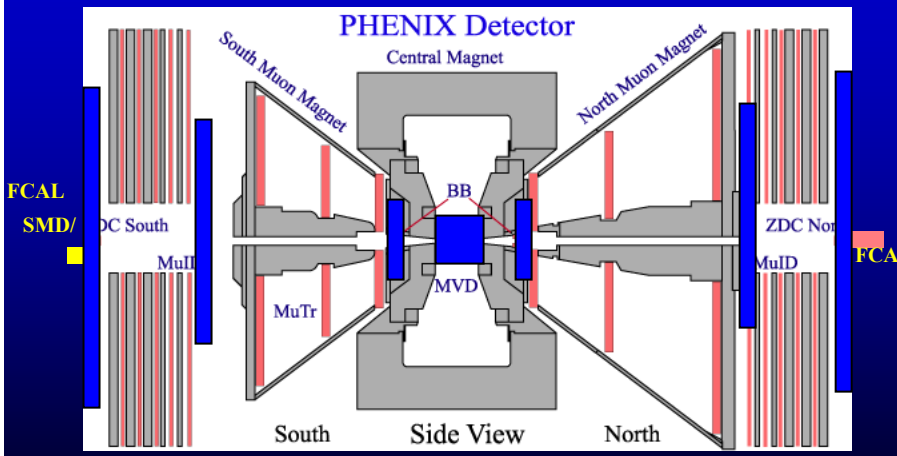
Event Characterization:

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

Data Acquisition:

- DAQ Upgrade

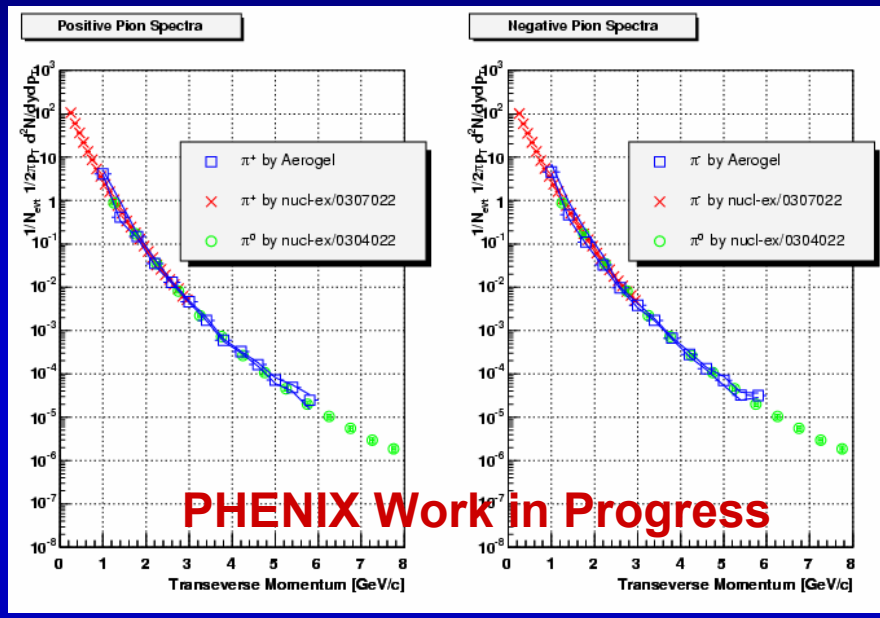




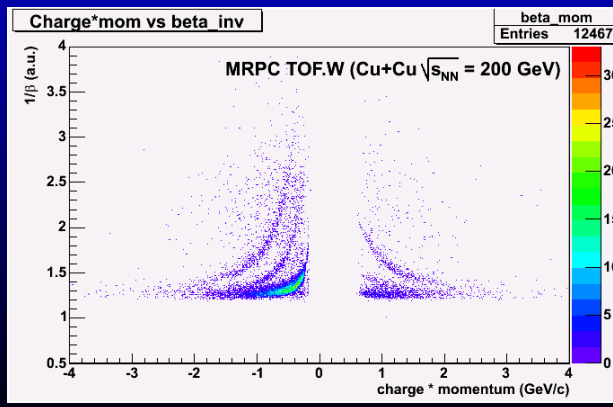
AGEL + TOF-W

- "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

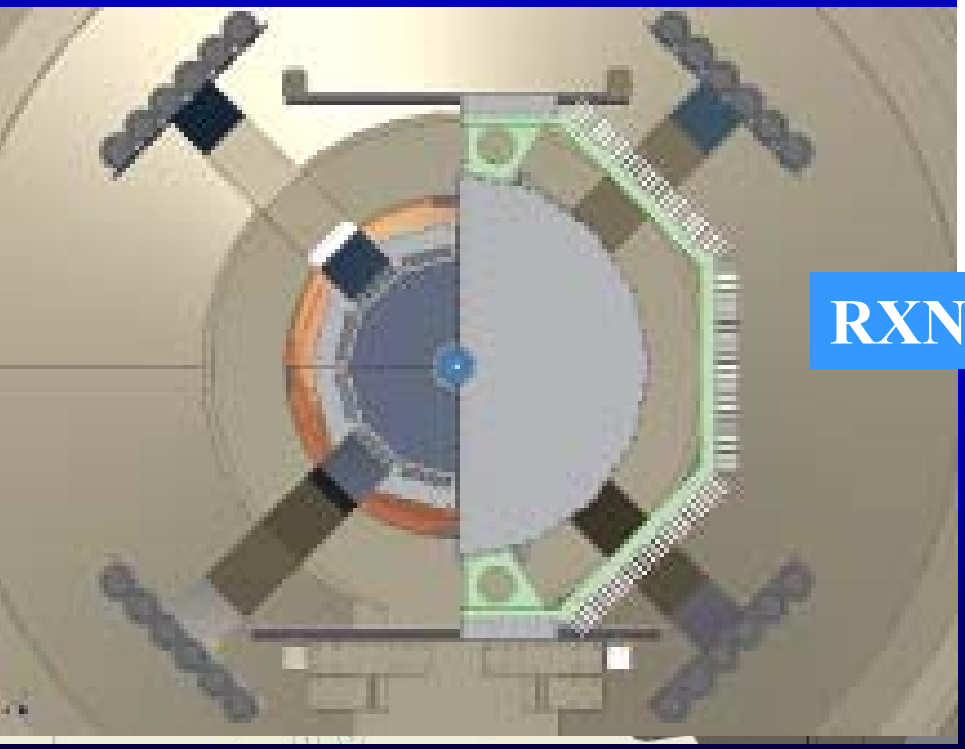


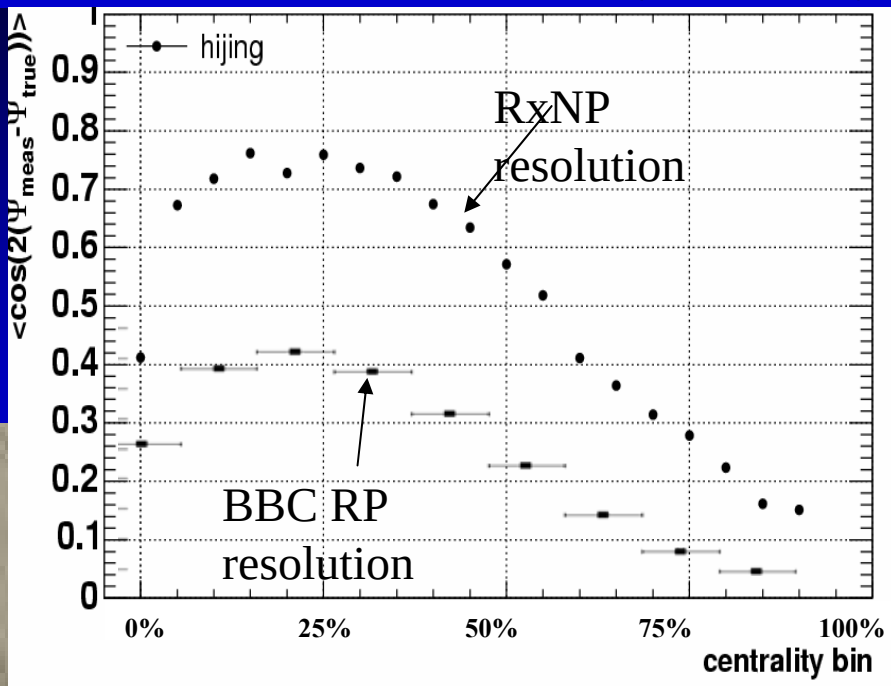
  - TOF-W ('Time-Of-Flight-West')
    - Partial funding: J. Velkovska (Vanderbilt) OJI
    - Prototypes tested in Run-5
    - System will be installed in current shutdown



Reaction Plane Detector (RXNP)

- 48 Scintillator paddles with lead converter at $1<|\eta|<3$ for reaction plane measurement
  - Resolution improves by ~ factor 2
  - Trigger counter for low energy running, where η is reduced from beam energy

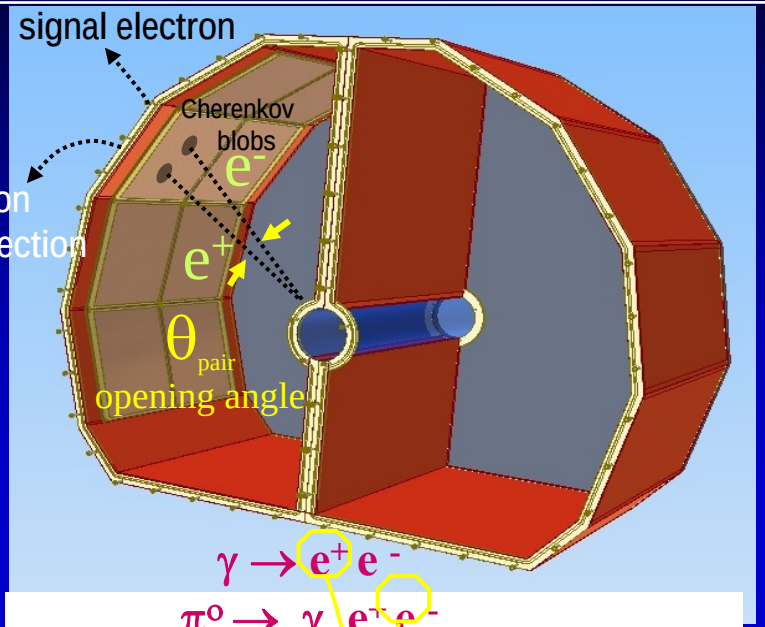




RXNP Installation starts in 2 weeks

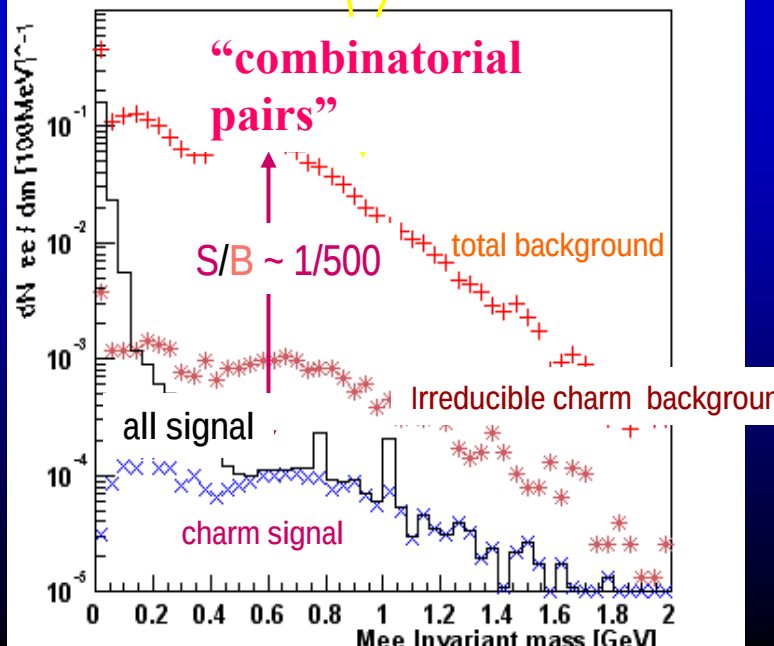
Hadron-Blind Detector (HBD)

- "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
- Funding: DOE + $250K (NSF) + $100K (Weizmann) + $57K (SUNY-SB)



$\gamma \rightarrow e^+ e^-$

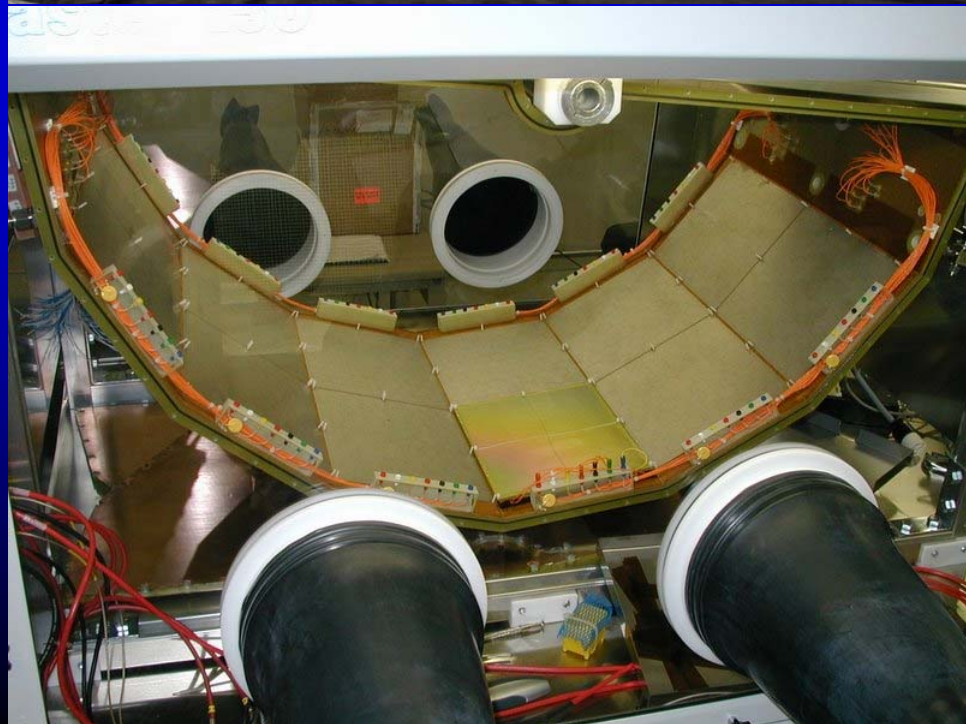
$\pi^o \rightarrow \gamma\ e^+ e^-$



The HBD Becomes Real

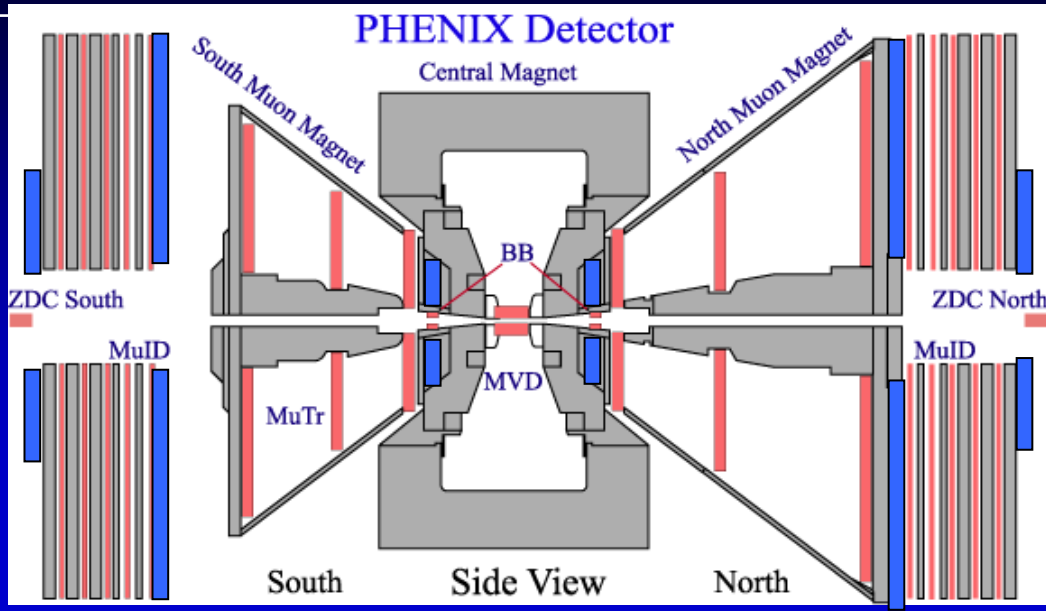
- Construction completed at the Weizmann

- In the glove box at Stony Brook

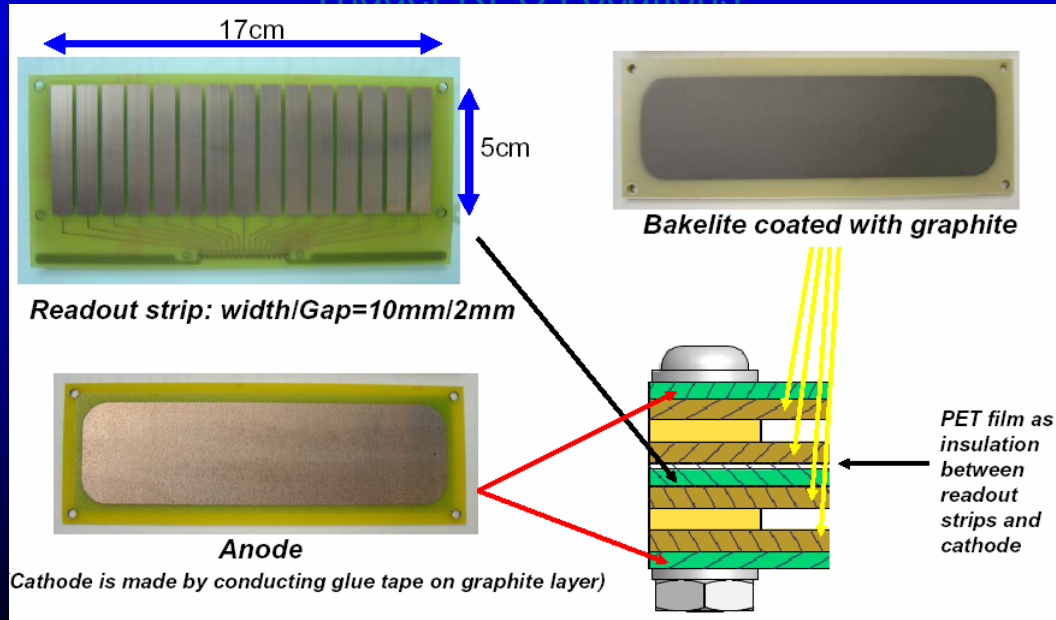


Muon Trigger Upgrade

- "A muon trigger upgrade to preserve sensitivity at the highest projected RHIC luminosities."
- RHIC I Luminosities (2009-12):
  - Resistive Plate Chamber technology chosen by PHENIX
    - Cheap – wide coverage possible
    - Can leverage existing RPC R&D from CMS
    - 3-dim space point enhances pattern recognition
  - Two small prototypes successfully tested in Run05
  - Funded as NSF MRI for $1.98M
    - $100K UIUC
    - $100K UCR
    - $50K ISU
    - $30K RBRC
- RHIC II Luminosities (2012+):
  - Fast read-out of muTr FEE
  - JSPS funding $1.5-2.0M for MuTr trigger (JFY07 start)

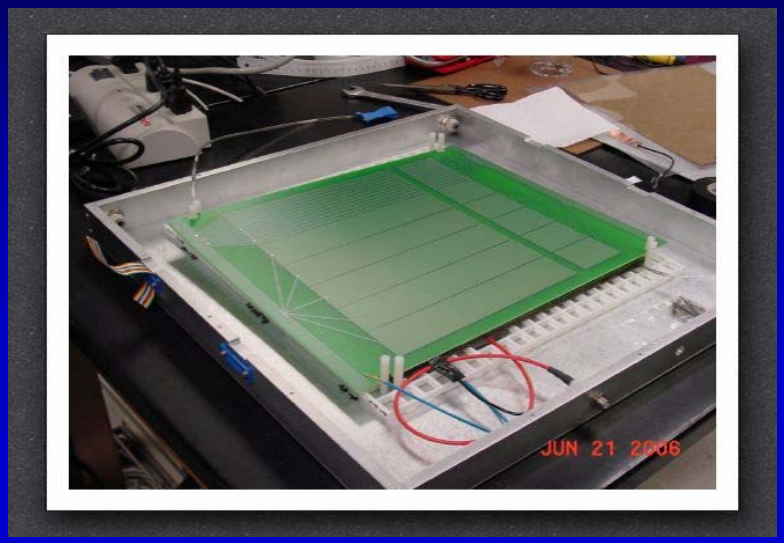


Trigger RPC Locations



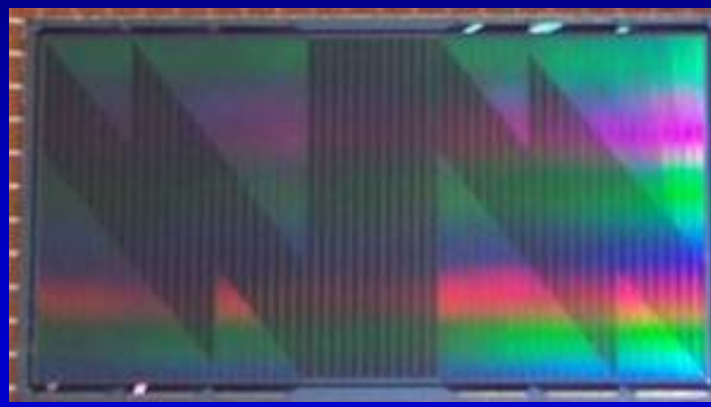
2nd Generation Prototypes (GSU)

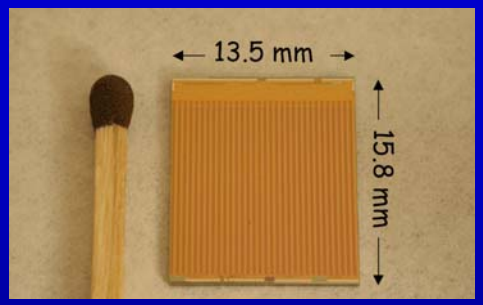
Detector R&D at GSU, Nevis, Colorado and UIUC.



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 Jan-05
    - Total Project Cost = $4.6M
    - In President's Budget for FY07
    - Very active ongoing R→D program
  - Favorable DOE Review May 4-5, 2006
  - Goal: Ready for data-taking in Run-10

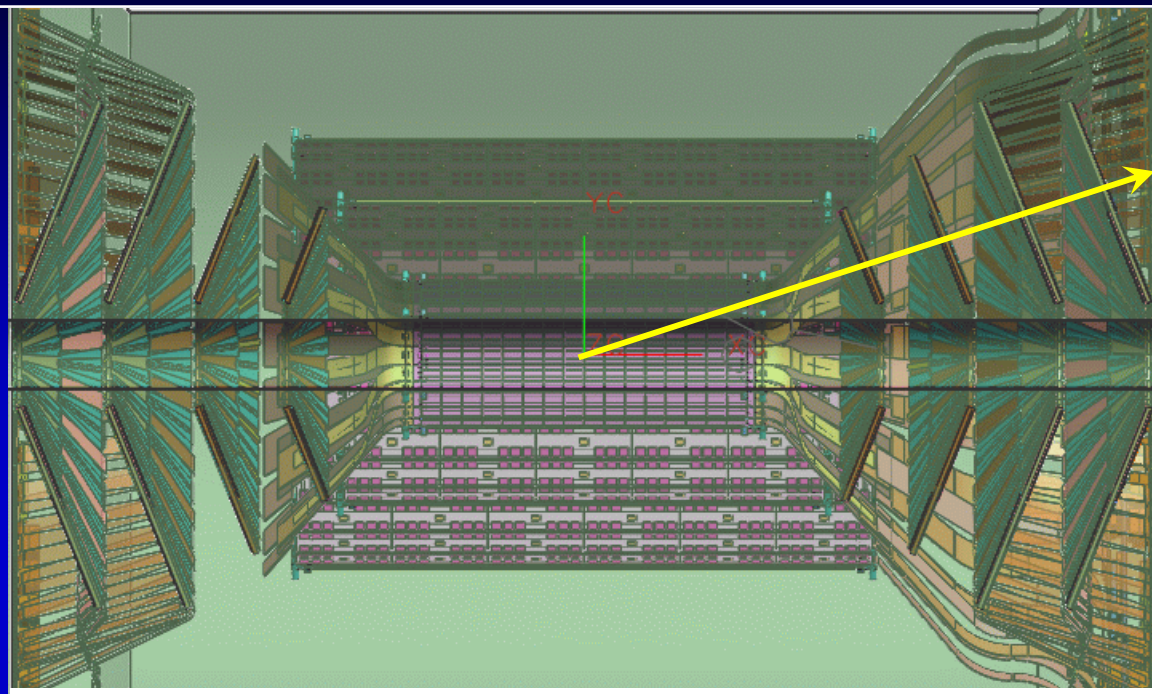


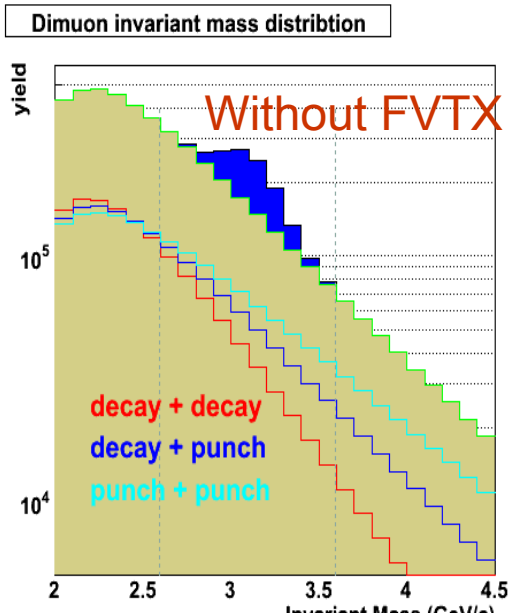


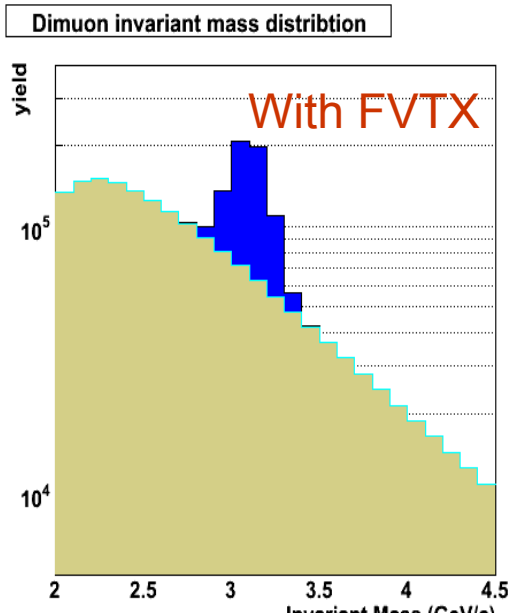
- Pixels: active area
  - $\Delta r\ \Phi$: 1.28 cm = 50μm x 256
  - Δz : 1.36 cm = 425μm x 32

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

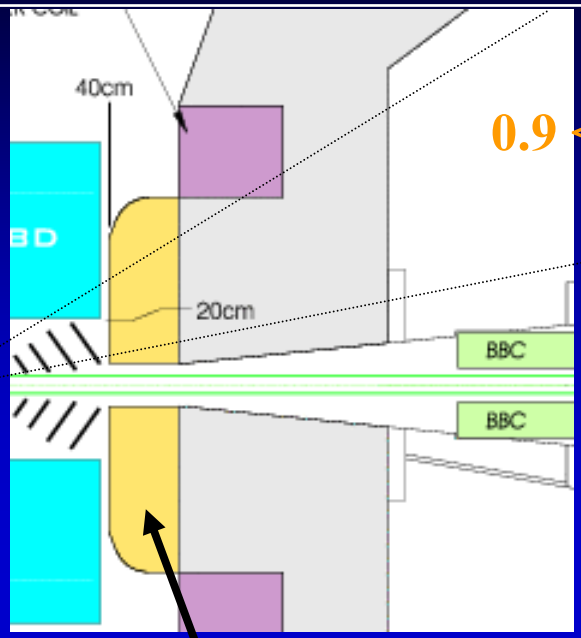




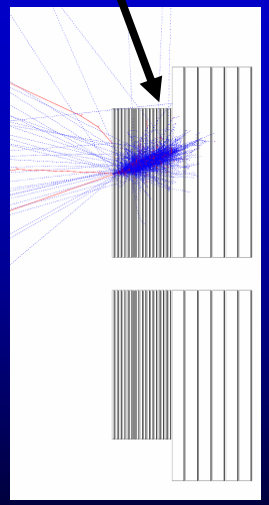


Nosecone Calorimeter (NCC)

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



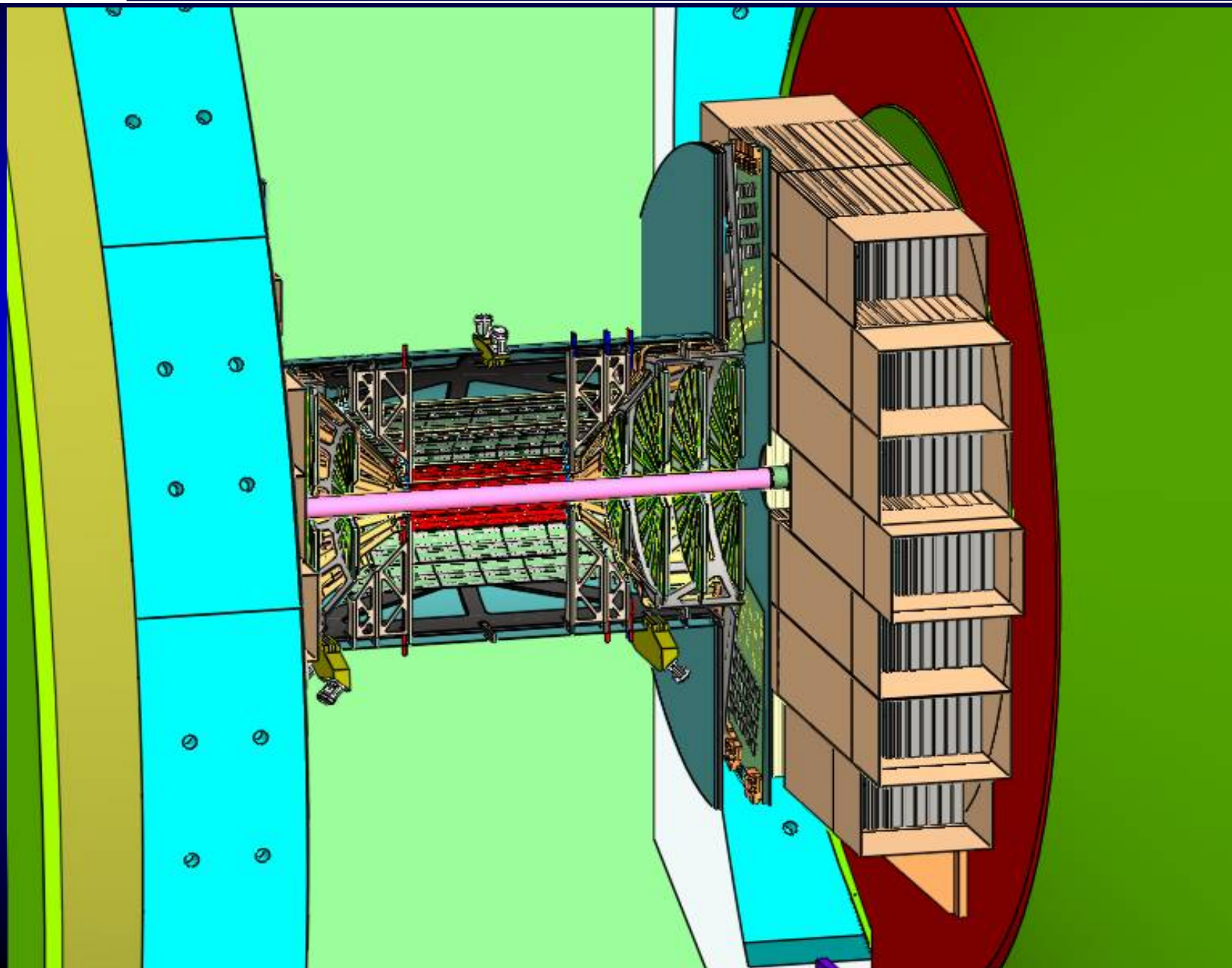
$0.9 < \eta < 3.0$



W-silicon sampling calorimeter

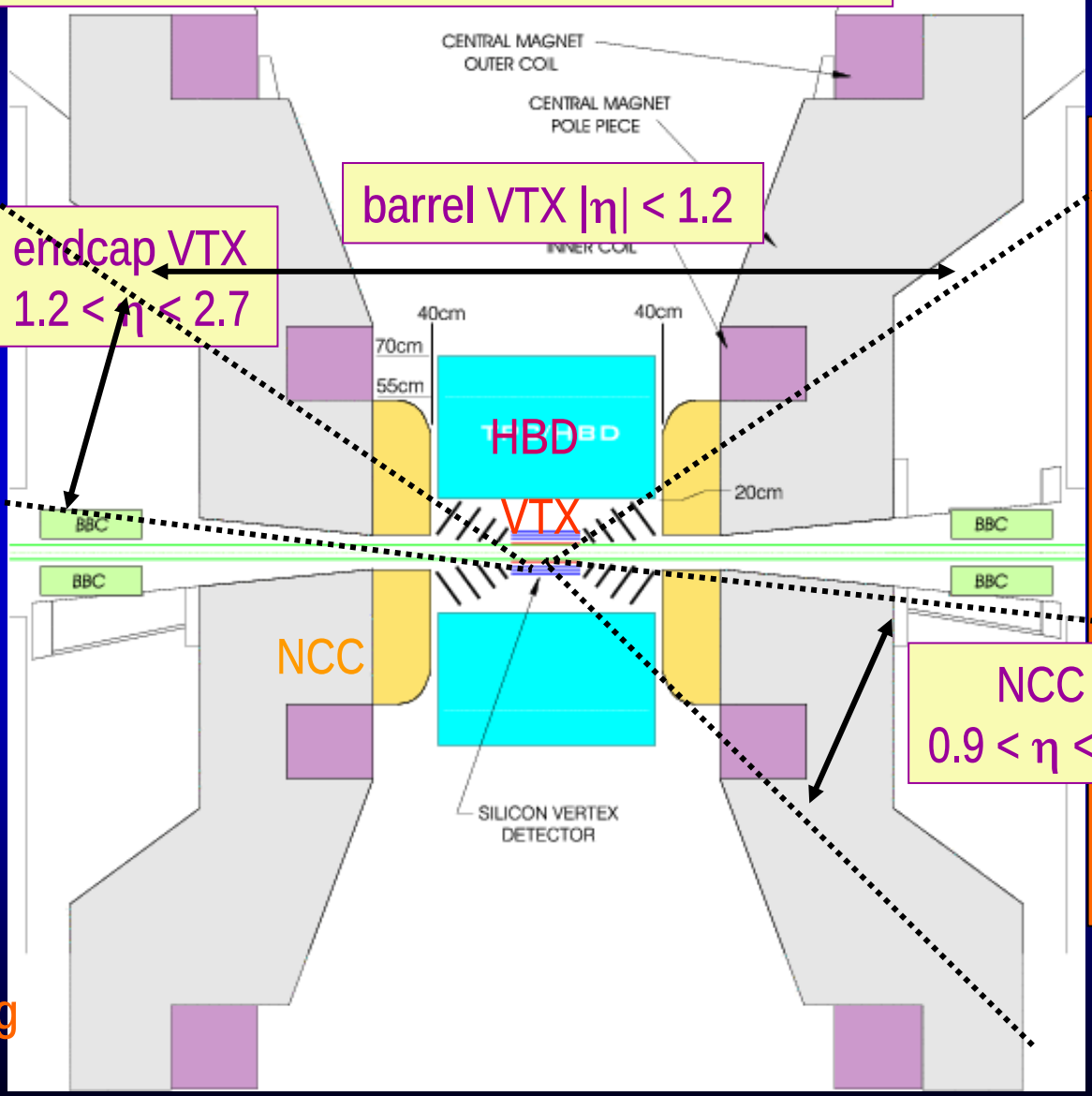
20 cm

VTX + FVTX +NCC



PHENIX Upgrade Projects

Provides displaced vertex & jet measurement over 2π

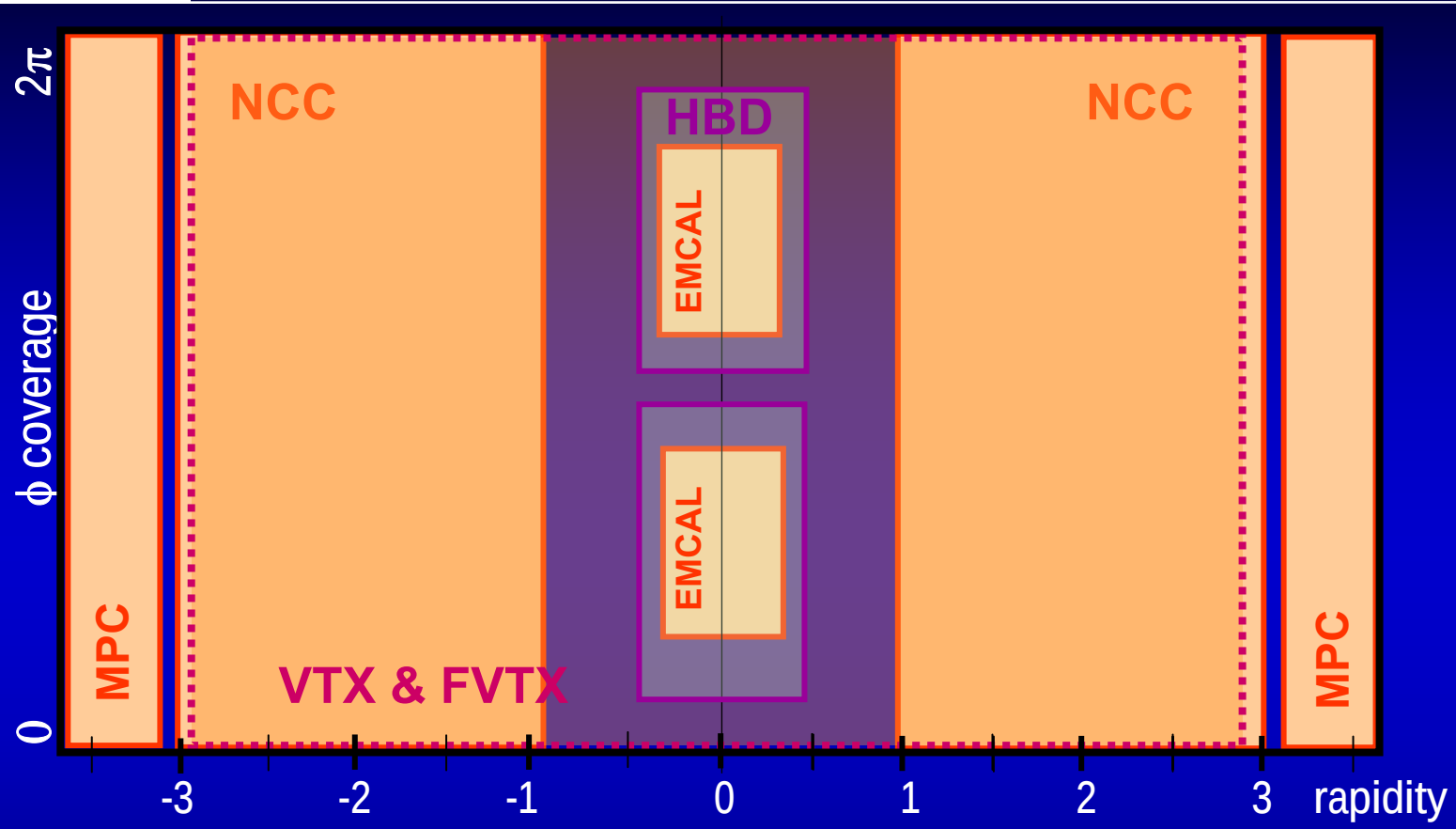


Displaced vertex:
VTX: silicon tracker
FVTX: forward Si

Jet measurement:
NCC: nose cone calorimeter

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

Future Acceptance for Hard Probes

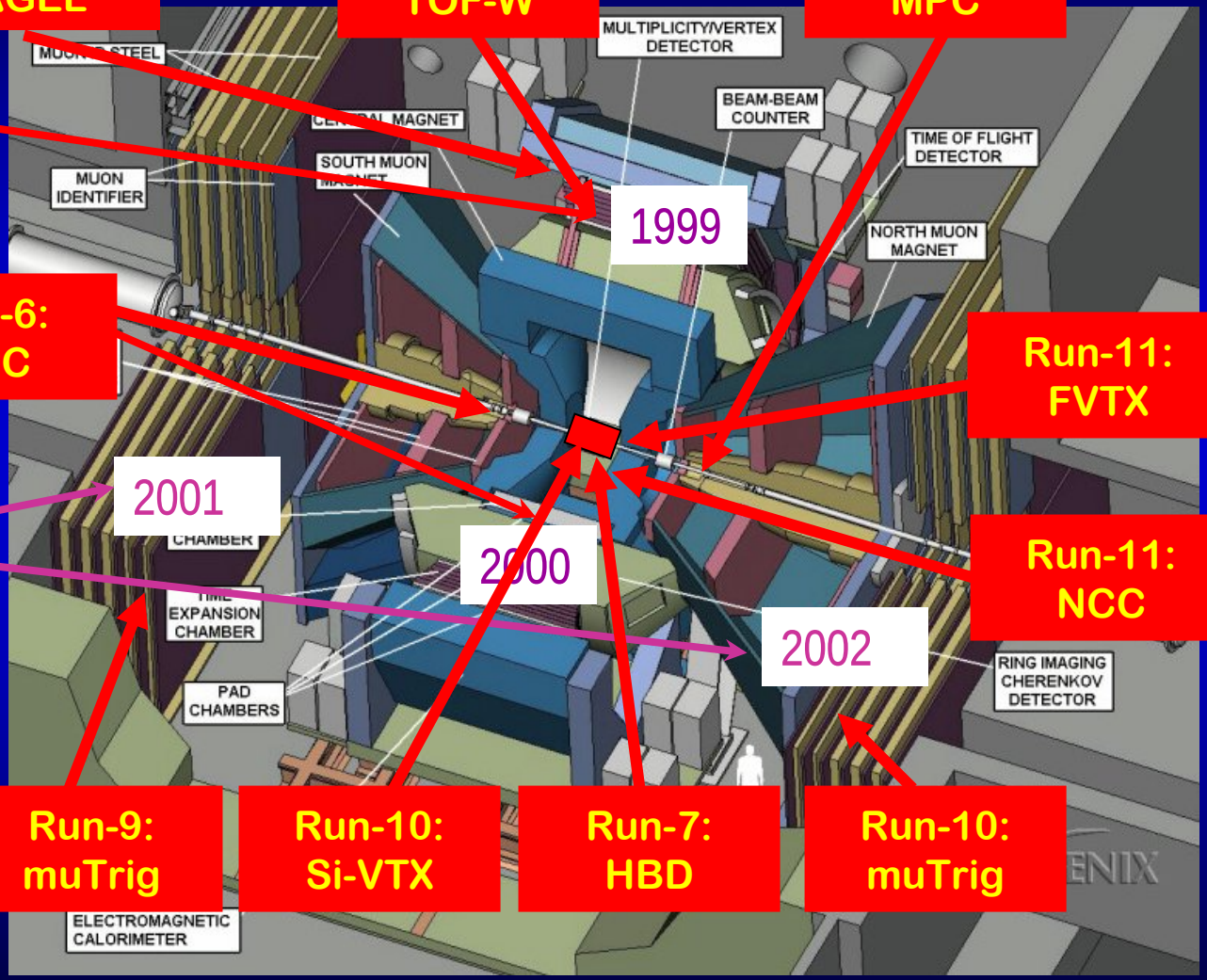


(i) π^0 and direct γ with combination of all electromagnetic calorimeters
(ii) heavy flavor with precision vertex tracking with silicon detectors
combine (i)&(ii) for jet tomography with γ-jet

(iii) low mass dilepton measurements with HBD + PHENIX central arms

Schedule

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



Runs 4-5: AGEL

Run-7: TOF-W

Run-7: MPC

Run-6: MPC

Run-11: FVTX

Run-11: NCC

Run-9: muTrig

Run-10: Si-VTX

Run-7: HBD

Run-10: muTrig

Management Structure

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	J. Haggerty	D. Morrison	R. Averbeck	J. Nagle	A Deshpande	B. Johnson
BNL	BNL	BNL	Stony Brook	UColorado	Stony Brook	BNL

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:

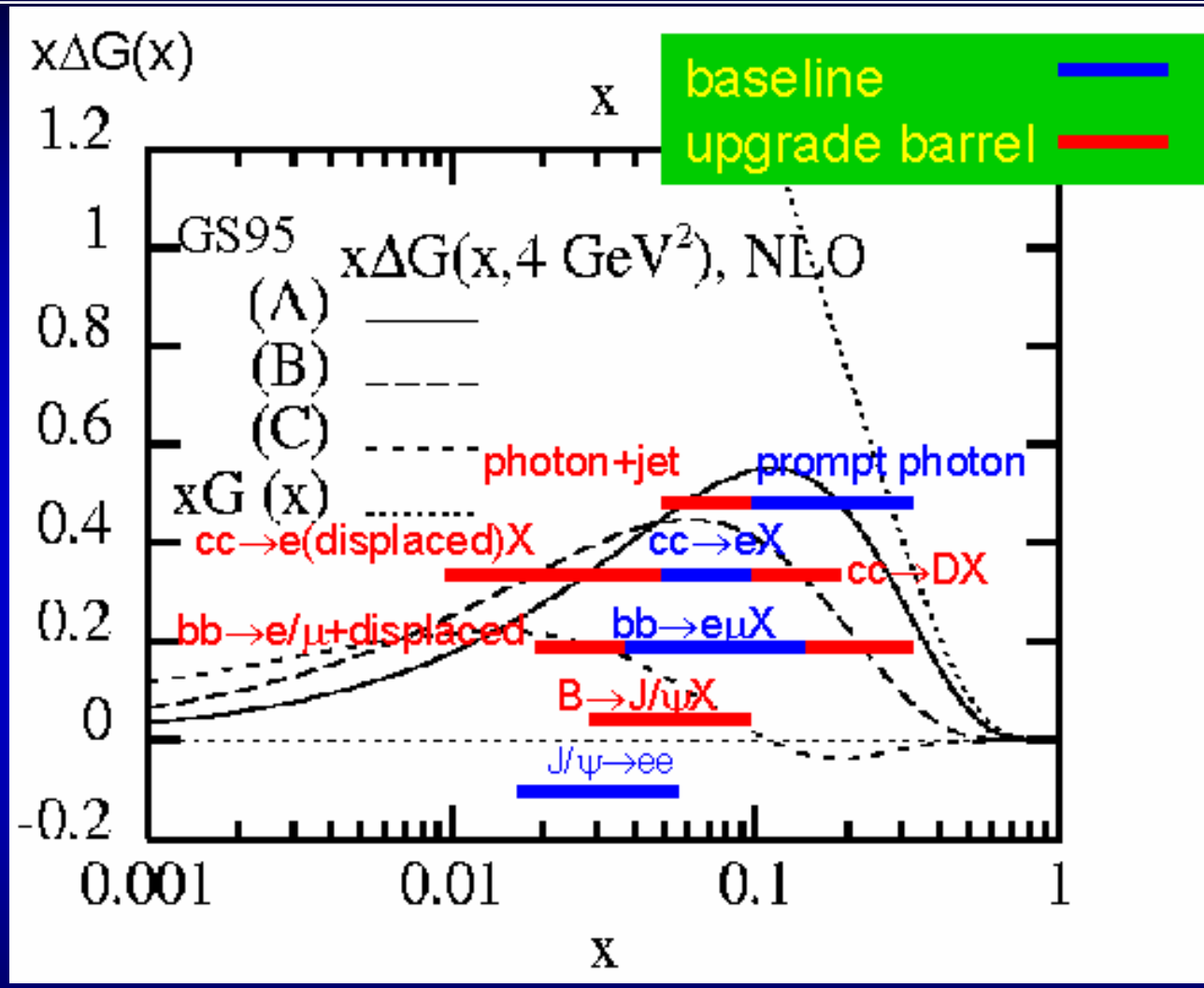
Studies of QGP with rare probes:
jet tomography, open flavor,
J/ψ, ψ', χc, $\Upsilon(1s)$, $\Upsilon(2s)$, $\Upsilon(3s)$

Complete spin physics program
p+A physics

Physics Goals: Gluon polarization ΔG(x)

Gluon polarization can be measured by double-spin asymmetry A_{LL} of direct photon and heavy quark production in polarized pp collisions

Jet + direct γ → constraint on x_g



- charm and bottom identification by displaced vertices
- Jet identification with larger acceptance

Complementary Overlaps

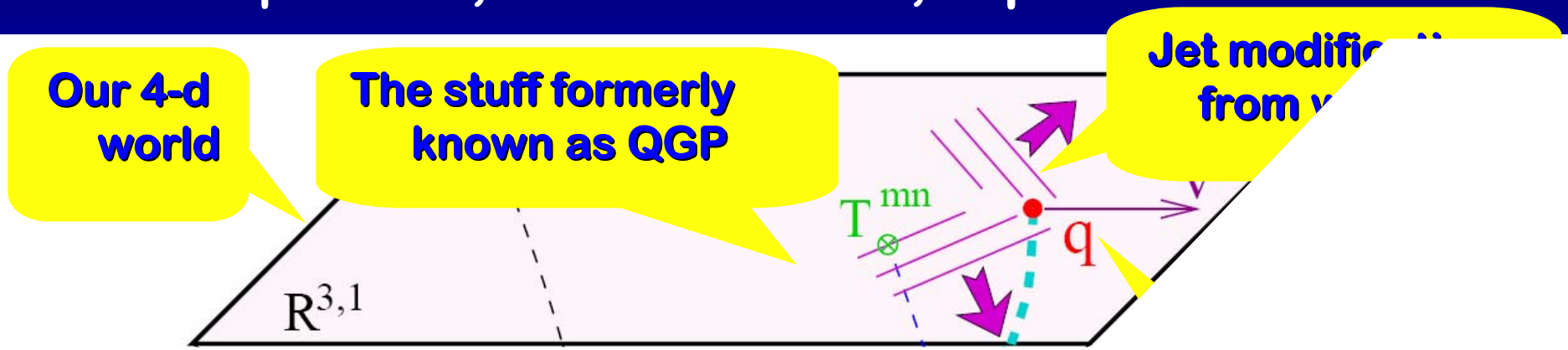
- Synergetic overlaps in upgrades greatly improve physics reach

- Example #1:
  Muon Trigger Upgrade
  - Primary motivation: Improve trigger rejection for W physics in 500 GeV p+p running
  - Collateral benefit: Space-points will greatly enhance pattern recognition in highest mulitplicity A+A collisions

- Example #2: NCC + VTX
  - Primary(?) motivation: Allow complete kinematic reconstruction (x_1 and x_2) in p+p high Q^2 events
  - Collateral benefit: A powerful combination for studying wake-fields associated with tagged heavy flavor jets

New Dimensions in RHIC Physics?

- "The stress tensor of a quark moving through $\mathcal{N}$=4 thermal plasma", J.J. Friess *et al.*, hep-th/0607022



Who ?

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 (~300 individuals in Run-6 !)
    - Upgrades program
- Continued growth:

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

- Recent Additions
  - Jyvaskyla University (Finland)
  - University of Maryland
  - Ehwa Women's University (Korea)
  - Muhlenberg College

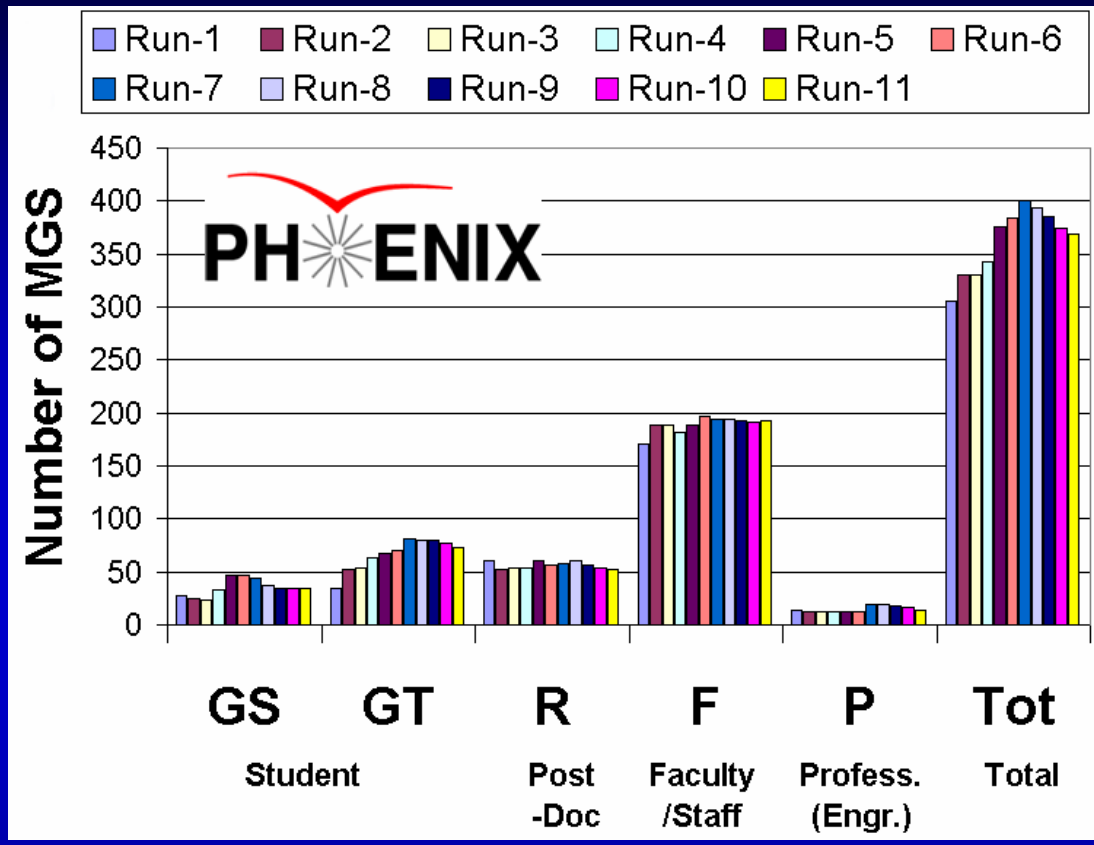
(Partial) Listing of Awards

- Presidential Early Career Awards for Scientists and Engineers
  - V. Cianciolo (ORNL)
  - S. Mioduszewski (BNL)
- Outstanding Junior Investigator (DOE)
  - J. Nagle (Colorado)
  - J. Velkovska (Vanderbilt)
- Sloan Fellowship
  - J. Nagle (Colorado)
- RHIC/AGS Thesis Award
  - J. Burward-Hoy (Stony Brook)
  - H. Sato (Kyoto)
  - C. Klein-Boesing (Muenster)
  - A. Sickles (Stony Brook)
- Sambamurti Award
  - J. Mitchell (BNL)
  - S. Mioduszewski (BNL)
- Gertrude Goldhaber Memorial Award
  - A. Sickles (SUNY-Stony Brook)
- Luise Meyer-Schutzmeister Memorial Award
  - C. Aidala (Columbia)
- "Best Young Researcher", Westfaelische Wilhelms-University of Muenster
  - K. Reygers (Muenster)
- Intel Science Talent Finalist
  - B. Huang (Longwood High School; Advisor: Prof. T. Hemmick, SUNY-Stony Brook)

Issues

Collaboration Projections

- Recently completed survey of projected "Members in Good Standing" (≡ qualifying authors) shows decline in out-years
- Partially expected as European groups emphasize LHC
- Exacerbating factors
  - ☞ *Perception of funding uncertainties for RHIC*
- Ameliorating factors
  - Upgrades program
  - Low-energy program at RHIC
  - (near-future) Reality of LHC schedule
  - (out-years) Reality of LHC priorities(?)



Great prospects here!

Issues

- We are still dealing with the impact of past budget uncertainties
  - *Perception* of no long-term future for RHIC
  - Will take time (and stable budgets!) to correct
- The upgrade program provides clear opportunities for new collaborators
  - Again, clear prospects for stable funding necessary for timely progress
- Participation by the European DIS community in RHIC spin is hindered by funding agencies
  - Negotiation at DOE level may be necessary

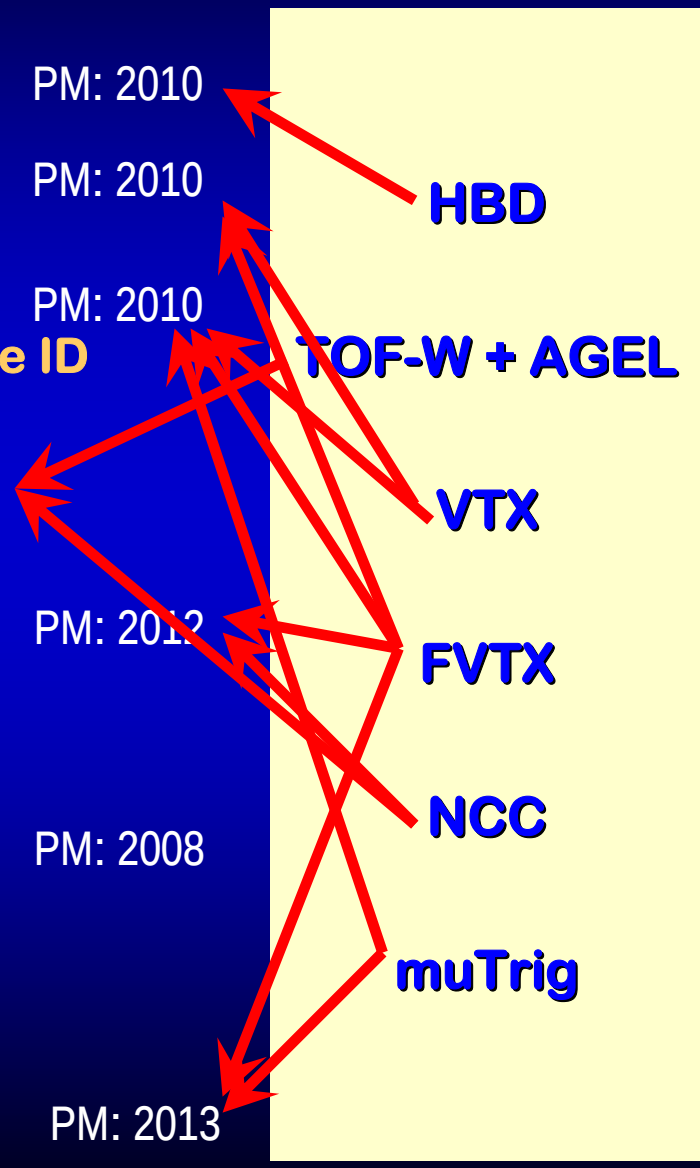
Looking Ahead

- For Run-7 and beyond, various PHENIX upgrades become (or are already) available:
  - Hadron Blind Detector
  - Si-VTX
  - Muon trigger
  - Nose Cone Calorimeter
  - FVTX

- 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."

NSAC Performance Measures

- Heavy Ion:
  - e-pair mass spectrum
    - "Hadron Blind" Dalitz pair rejection — PM: 2010
  - Open charm measurements in AA
    - High Resolution vertex detection — PM: 2010
  - Charmonium Spectroscopy
    - High luminosity; precision vertex, particle ID — PM: 2010
  - Jet Tomography
    - High luminosity; increased acceptance; enhanced particle ID
  - Gluon shadowing; low-x in d-Au
    - particle detection at forward rapidity — PM: 2012
- Spin:
  - Complete initial ΔG/G measurement
    - No upgrades needed — PM: 2008
  - Transverse spin measurements
    - Forward particle measurement
  - W measurements at 500 GeV
    - Forward tracking/triggering in PHENIX — PM: 2013



*DOE performance milestones set by NSAC

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 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

PHENIX Students (I)

Given Name	Family Name	Thesis Topic	Completion Date	Institution	Adviser	Second Adviser	Other Institution	PWG
Andrew	Adare	Jet Physics in 200 GeV Cu+Cu Collisions		University of Colorado	Nagle			Photon/Hard
Christine	Aidala	Measurement of A_N and A_{LL} through Neutral and Charged Pions	2005	Columbia University	Cole			Spin
Hisham	Albataineh	Measurment of A_N for transverse single-spin from 62.4GeV and 200GeV		New Mexico State University	Papavassiliou	Liu		Spin
Ahmed	Al-Jamel	J/psi production properties from polarized proton-proton collisions at 200 GeV	2004	New Mexico State University	Papavassiliou			Spin
Raul	Armendariz	Run-4 Au-Au		New Mexico State University	Pate			Heavy/Light
Stefan	Bathe	Momentum Fluctuations and Production of Neutral Mesons in Ultra-Relativistic Heavy Ion Collisions	2002	University of Muenster	Santo			Photon/Hard
Robert	Bennett	Longitudinal Double spin asymmetry of Photon Production in Polarized Protons at 200 GeV		SUNY-Stony Brook (Physics)	Deshpande			Spin
Kieran	Boyle	Longitudinal Double Spin Asymmetry of pi0 Production in Polarized Protons at 200 GeV		SUNY-Stony Brook (Physics)	Deshpande			Spin
Henner	Buesching	Azimuthal Photon Correlations in Ultra-relativistic p+A, Pb+Pb and Au+Au Reactions	2002	University of Muenster	Santo			Photon/Hard
Jane	Burward-Hoy	Transverse Momentum Distributions of Hadrons Produced in Au+Au Collisions at 130 GeV Measured by the PHENIX experiment at RHIC BNL	2001	SUNY-Stony Brook (Physics)	Jacak			Global/Hadron
Sergey	Butsyk	Charm production in 200-GeV p+p collisions	2005	SUNY-Stony Brook (Physics)				
Sarah	Campbell	Low mass di-electrons from Cu+Cu Collisions		SUNY-Stony Brook (Physics)	Hemmick			Heavy/Light
Xavier	Camard			SUBATECH				
Mickey	Chiu	Angular Correlations in High p_T Particle Production in Au-Au Collisons at RHIC	2004	Columbia University	Zajc	Nagle	Colorado	Photon/Hard
Christopher	Cleven	Heavy Flavor Production and the Reaction Plane in Heavy Ion Collisions at RHIC		Georgia State University	He			Heavy/Light
Yann	Cobigo	Production de J/Psi dans les collisions proton-proton et deuton-or à 200 GeV dans le centre de masse nucléon-nucléon	2004	Dapnia/Saclay	Gosset			Heavy/Light
Paul	Constantin	Extraction of jet properties from two-particle azimuthal correlations in pp and AuAu collisions at $\sqrt{s_{NN}}$ = 200 GeV	2004	Iowa State University	Lajoie			Photon/Hard
Kushal	Das	J/Psi Production Measured via e+e- decays in Au-Au Collisions at RHIC		Florida State University	Frawley			Heavy/Light
Cesar Luiz	da Silva	Study of Vector Mesons with the PHENIX Detector		University of Sao Paulo	Dietzsch	Rosati	Iowa State	Heavy/Light
Torsten	Dahms	Measurement of Photons via Conversion Pairs with the PHENIX Experiment at RHIC	2005	SUNY-Stony Brook (Physics)	Drees			(Master's Thesis)
Alan	Dion	Heavy Flavor Production (via e-mu?)		SUNY-Stony Brook (Physics)	Averbeck			Heavy/Light
Lesley	D'Orazio			University of Maryland	Mignery			
Rickard	du Rietz	Deuteron and anti-deuteron production in $\sqrt{s_{NN}}$=200 GeV AuAu Collisions at RHIC	2002	Lund University	Gustafsson			Heavy/Light
Karim	El Chenawi	A High Resolution Tracking System for High Energy Heavy-Ion Experiments	1998	Lund University	Gustafsson			(Master's Thesis)
Jamil	Egdemir	Nuclear Modification Factor in Semi-leptonic Heavy Flavor decays in 200 GeV Au+Au Collisions		SUNY-Stony Brook (Physics)	Averbeck			Heavy/Light
Tatia	Engelmore			Columbia University	Cole			Photon/Hard
Akitomo	Enokizono	Space-time evolution of hot and dense matter probed by Bose-Einstein correlation in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV	2004	Hiroshima University	Sugitate			Global/Hadron
Tahsina	Ferdousi	Measurement of Charged Particle Multiplicity with the Multiplicity and Vertex Detector at the PHENIX Detector at RHIC	2002	UC-Riverside	Seto			(Master's Thesis)
Justin	Frantz	Direct Photon Shine: Direct Photon and π^0 Production in $\sqrt{s_{NN}}$ = 200 GeV Au-Au Collisions	2004	Columbia University	Cole	Nagle	Colorado	Photon/Hard
Yoshi	Fukao	Double spin asymmetry in pi0 production in p+p collisions		Kyoto University	Saito			Spin
Sebastien	Gadrat	Etude de la production de charme ouvert et de Drell-Yan dans les collisions p+p avec PHENIX à RHIC	2005	Clermont-Ferrand	Roche			Heavy/Light
Irakli	Garishvili	Open Charm in Cu+Cu at 200 GeV		University of Tennessee	Read	Sorensen		Heavy/Light
Andrew	Glenn	Single Muon Production and Implications for Charm in $\sqrt{s}$NN = 200 GeV Au+Au Collisions	2005	University of Tennessee	Sorensen	Read		
Nathan	Grau	Jet correlations from p+p, d+Au and Au+Au collisions	2005	Iowa State University	Ogilvie			Photon/Hard
Taku	Gunji	J/psi -> e+e- measurements in Au-Au Collisions at RHIC-PHENIX		CNS-Tokyo	Hamagaki			Heavy/Light
Takashi	Hachiya			Hiroshima University	Sugitate			
Ahmed	Hadj Henni	Direct Photons in p+p Collisions at 200 GeV		SUBATECH	Delagrange			Photon/Hard
Ali	Hanks			Columbia University	Cole			Photon/Hard
Eva	Haslum	Event-by-event fluctuations in relativistic heavy-ion collisions		Lund University	Gustafsson	Oskarsson		Global/Hadron
Robert	Hobbs	Measuring the Partonic Orbital Angular Momentum in the Proton from Two Particle Azimuthal Correlations at PHENIX in Run3pp	2006	University of New Mexico	Fields			Spin
Wolf	Holzmann		2006	SUNY-Stony Brook (Chemistry)	Lacey			Photon/Hard
Andrew	Hoover	The PHENIX Muon Spectrometer and J/psi Production in $\sqrt{s}$=200 GeV proton-proton collisions at RHIC	2003	New Mexico State University	Pate			Heavy/Light
Takuma	Horaguchi	Direct photon production in polarized proton-proton collisions at PHENIX		Tokyo Institute of Technology	Shibata			Spin
Donald	Hornback	Open Charm in p+p Collisions at 200 GeV		University of Tennessee	Read	Sorensen		Heavy/Light
TadaAki	Isobe	Direct Photon and pi0 Production in 200 GeV Au+Au Collisions		CNS-Tokyo	Hamagaki			Photon/Hard
Michael	Issah			SUNY-Stony Brook (Chemistry)	Lacey			Photon/Hard
Wooyoung	Jang			University of Korea				
Jiangyong	Jia	High-pT Charged Hadron Suppression in Au-Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV	2003	SUNY-Stony Brook (Physics)	Drees			Photon/Hard
Jiamin	Jin	Direct photon Jet Physics in 200GeV/c Au+Au Collisions		Columbia University	Cole			Photon/Hard
Soichiro	Kametani	Measurement of J/Psi Production in the e+e- Channel in d+Au collisions at $\sqrt{s_{NN}}$ = 200GeV		CNS-Tokyo	Hamagaki			Heavy/Light
Nobuyuki	Kamihara	J/Psi formation and decay in polarized proton-proton collisions at PHENIX		Tokyo Institute of Technology	Shibata			Spin

PHENIX Students (II)

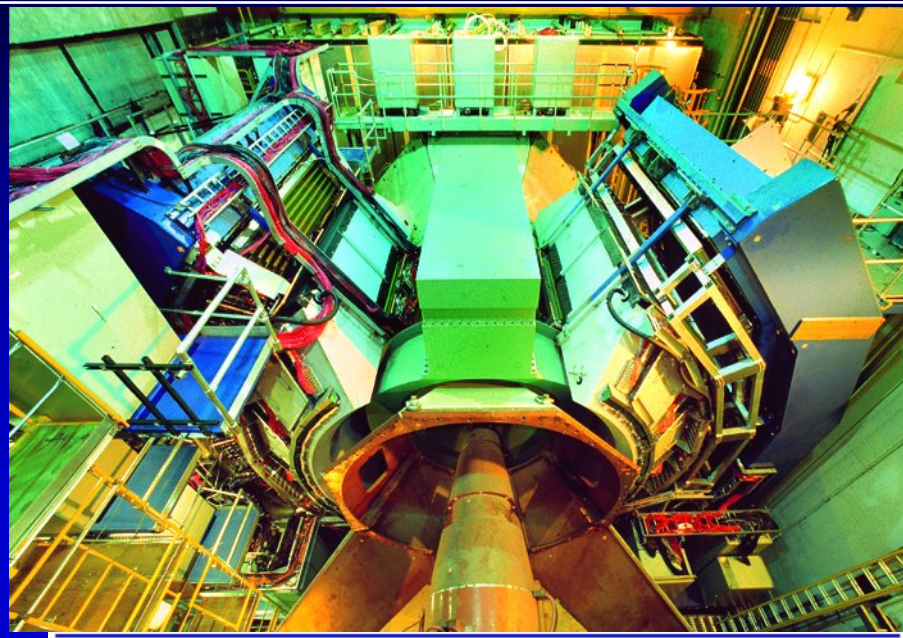
Given Name	Family Name	Thesis Topic	Completion Date	Institution	Adviser	Second Adviser	Other Institution	PWG
Young Gook	Kim	PHENIX Event Characterization Using Charged Particle Multiplicities measured with the MVD		Yonsei University	Kang			Global/Hadron
Dong Jo	Kim	J/Ψ Production in d+Au and p+p Collisions as √s=200 GeV	2004	Yonsei University	Kang			Heavy/Light
Akio	Kiyomichi	Study of Identified Hadron Spectra and Yields at Mid-rapidity in $\sqrt{s_{NN}}$ = 200 GeV Au+Au Collisions	2005	University of Tsukuba	Miake			Global/Hadron
Christian	Klein-Bösing	Production of Neutral Pions and Direct Photons in Ultra-Relativistic Au+Au Collisions	2005	University of Muenster	Santo			Photon/Hard
Ryota	Kohara	J/psi Suppression Mechanism		Hiroshima University	Sugitate			Heavy/Light
Dmitri	Kotchetgov	Study of chiral symmetry restoration in relativistic heavy-ion collisions at RHIC		UC-Riverside	Seto			
Alexander	Kozlov	(Electron Pairs)		Weizmann Institute	Tserruya			Heavy/Light
MinJung	Kweon	J/Psi Production in Au+Au Collision at RHIC	2005	Korea University	Hong			Heavy/Light
Yue Shi	Lai			Columbia University	Cole			Photon/Hard
KwangBok	Lee			Korea University	Hong			Heavy/Light
Hiroshi	Masui	Elliptic Flow of Identified Hadrons in Au+Au and Cu+Cu Collisions at RHIC		University of Tsukuba	Miake	Esumi		Global/Hadron
Felice	Matathias	Identified Particle Production in p+p and d+Au Collisions at RHIC Energies	2004	SUNY-Stony Brook (Physics)	Hemmick			
Takashi	Matsumoto	Measurements of production cross section of J/psi in $\sqrt{s_{NN}}$ = 200 GeV Au+Au reactions at RHIC		CNS-Tokyo	Hamagaki			Heavy/Light
Alexander	Milov	Particle production in heavy ion collisions at RHIC energies	2002	Weizmann Institute	Tserruya			Global/Hadron
Astrid	Morreale	Measurement of Longitudinal Double Spin Asymmetry through Charged Pions		UC-Riverside	Barish			Spin
Mohammed	Muniruzzman	> Asymmetry through Charged Pions	2003	UC-Riverside	Seto			Heavy/Light
Tomoaki	Nakamura			Hiroshima University	Sugitate			
Jason	Newby	J/Psi Production in Heavy Ions at RHIC using PHENIX muon arms	2003	University of Tennessee	Sorensen	Read		Heavy/Light
Paul	Nilsson	Experimental studies of particle production in ultra-relativistic heavy ion collisions	2001	Lund University	Oskarsson	Gustafsson		Global/Hadron
Susumu	Oda	Measurement of Vector Mesons in the e+e- Channel in Cu+Cu Collisions		CNS-Tokyo	Hamagaki			Heavy/Light
Ken	Oyama	Pizero production in Au+Au Collisions at $\sqrt{s_{NN}}$ = 130 GeV	2002	CNS-Tokyo	Hamagaki			Photon/Hard
WooJin	Park	Open Charm Production in Au-Au Collisions at RHIC		University of Korea	Hong			Heavy/Light
Hua	Pei			Iowa State University	Ogilvie			Photon/Hard
Hai	Qu	Quarkonium Polarization Measurement at RHIC		Georgia State University	He			Heavy/Light
Anuj	Purwar	Study of Initial and Final State Effects in Ultrarelativistic Heavy Ion Collisions Using Hadronic Probes	2004	SUNY-Stony Brook (Physics)	Hemmick			Global/Hadron
Andry	Rakotozafindrabe	J/Ψ Production in Cu+Cu Collisions		Laboratoire **L**eprince-**R**inguet	Fleuret			Heavy/Light
Yuriy	Riabov	Measurement of the spectral shape of light mesons produced in relativistic ion collisions through hadron decay modes		PNPI	Samsonov	Milov	SUNY-Stony Brook (Physics)	Heavy/Light
Eric	Richardson			University of Maryland	Mignery			
Sarah	Rosendahl	Resonance studies in Heavy Ion collisions at RHIC		Lund University	Nystrand	Stenlund		Global/Hadron
Sang Su	Ryu	Fluctuations in the Charged Particle Multiplicity Distributions		Yonsei University	Kang			Heavy/Light
Shingo	Sakai	Azimuthal anisotropy of heavy flavor electrons in Au+Au collisions at 200 GeV		University of Tsukuba	Miake	Esumi		Heavy/Light
Hiroki	Sato	J/psi Production in p+p Collisions at sqrt(s) = 200 GeV	2003	Kyoto University	Imai			Heavy/Light
Baldo	Sahlmueller	Spectra of pi0's, eta's and direct photons in 200 GeV Au+Au Collisions		University of Muenster	Wessels			Photon/Hard
Joeseph	Seele	Cross section and A_{LL} for η production in polarized p+p collisions at 200 GeV		University of Colorado	Kinney	Nagle		Spin
Anne	Sickles	Azimuthal Correlation and Conditional Yield Measurements in √sNN=200GeV in Au+Au, d+Au and p+p Collisions at RHIC	2005	SUNY-Stony Brook (Physics)	Jacak			Photon/Hard
David	Silvermyr	Aspects of Hadron Production in High-Energy Heavy-Ion Collisions	2001	Lund University	Stenlund	Gustafsson		Global/Hadron
Catherine	Silvestre	J/Psi Production in Au+Au Collision at RHIC		Saclay (CEA)	Pereira	Gonin		Heavy/Light
Steven	Skutnik	A scalable analytic model for single event upsets in radiation-hardened field programmable gate arrays in the PHENIX interaction region	2005	Iowa State University	Lajoie			(Master's Thesis)
Mikhail	Stepanov	Charm production in 200-GeV polarized p-p collisions		New Mexico State University	Papavassiliou			Spin
Peter	Tarjan			Debrecen University	David			Photon/Hard
Manabu	Togawa	Single Transverse-spin asymmetry in forward neutron production in p+p collisions at 200 GeV and 410 GeV		Kyoto University	Saito			Spin
Hisayuki	Torii	Midrapidity Neutral-Pion Production in Proton-Proton Collisions at √s = 200GeV	2003	Kyoto University	Imai			Photon/Hard
Vi-Nham	Tram	Etude de la production du J/psi dans les collisions or-or à 200 GeV par paire de nucléons dans l'expérience PHENIX	2006	Laboratoire **L**eprince-**R**inguet	Drapier	Fleuret		Heavy/Light
Yuji	Tsuchimoto			Hiroshima University	Sugitate	Homma		
Thomas	Svensson	Tracking Chambers with 2-Dimensional Readout for the PHENIX Experiment at RHIC	1999	Lund University	Oskarsson	Stenlund		
Henrik	Tydesjo	Net charge fluctuations in AuAu collisions at RHIC	2004	Lund University	Oskarsson			Global/Hadron
Eric	Vazquez			Columbia University	Cole			Photon/Hard
Matthew	Wysocki	Quarkonia in Au+Au and Cu+Cu Collisions at 200 GeV		University of Colorado	Nagle			Heavy/Light
Oliver	Zaudtke	Pi0- and direct photon spectra from 200 GeV Au-Au and pp-data		University of Muenster	Wessels	Reygers		Photon/Hard
Chun	Zhang	Nuclear Modification Factor for Hadrons at Forward and Backward Rapidities in Deuteron+Gold Collisions at √sNN = 200 GeV	2004	Columbia University	Zajc	Nagle	Colorado	Heavy/Light
Xiaopeng	Zong			Iowa State University	Rosati			Heavy/Light

NSAC Performance Measures

- RHIC program of sufficient breadth that it encompasses two broad categories in the NSAC Performance Measures :
  - Physics of High Density and Hot Hadronic Matter:
    - ✓2005 Measure J/ψ production in Au+Au at $\sqrt{s_{NN}}$ = 200 GeV.
    - ✓2005 Measure flow and spectra of multiply-strange baryons in Au+Au at $\sqrt{s_{NN}}$ = 200 GeV.
    - ✓2007 Measure high transverse momentum jet systematics vs. $\sqrt{s_{NN}}$ up to 200 GeV and vs. system size up to Au+Au.
    - 2009 Perform realistic three-dimensional numerical simulations to describe the medium and the conditions required by the collective flow measured at RHIC
    - ✓2010 Measure the energy and system size dependence of J/ψ production over the range of ions and energies available at RHIC.
    - ✓2010 Measure e^+e^- production in the mass range $500 \leq m_{e+e-} \leq 1000$ MeV/c^2 in $\sqrt{s_{NN}}$= 200 GeV collisions.
    - 2010 Complete realistic calculations of jet production in a high density medium for comparison with experiment.
    - ✓2012 Determine gluon densities at low x in cold nuclei via p+Au or d+Au collisions
  - Hadronic Physics
    - ✓2008 Make measurements of spin carried by the glue in the proton with polarized proton-proton collisions at center of mass energy $\sqrt{s}$ = 200 GeV.
    - ✓2013 Measure flavor-identified q and q contributions to the spin of the proton via the longitudinal-spin asymmetry of W production.
- Conclusion: ***All of the experimental measures listed above are achievable via the proposed program of detector and accelerator upgrades***

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:

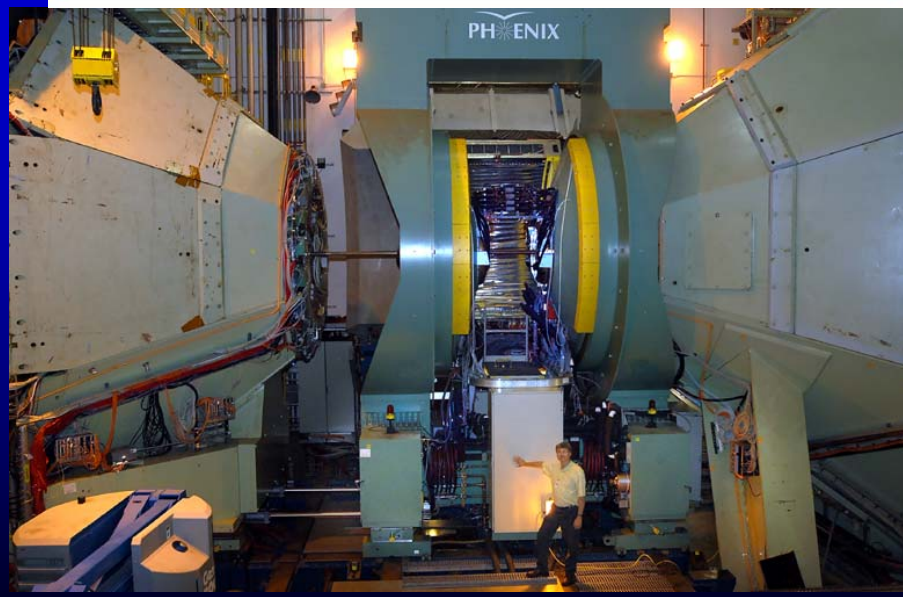
- Time of Flight
- Ring Imaging Cerenkov Counter
- TEC/TRD
- Muon ID (PDT's)
- Aerogel Cerenkov Counter

Calorimetry:

- Pb Scintillator
- Pb Glass

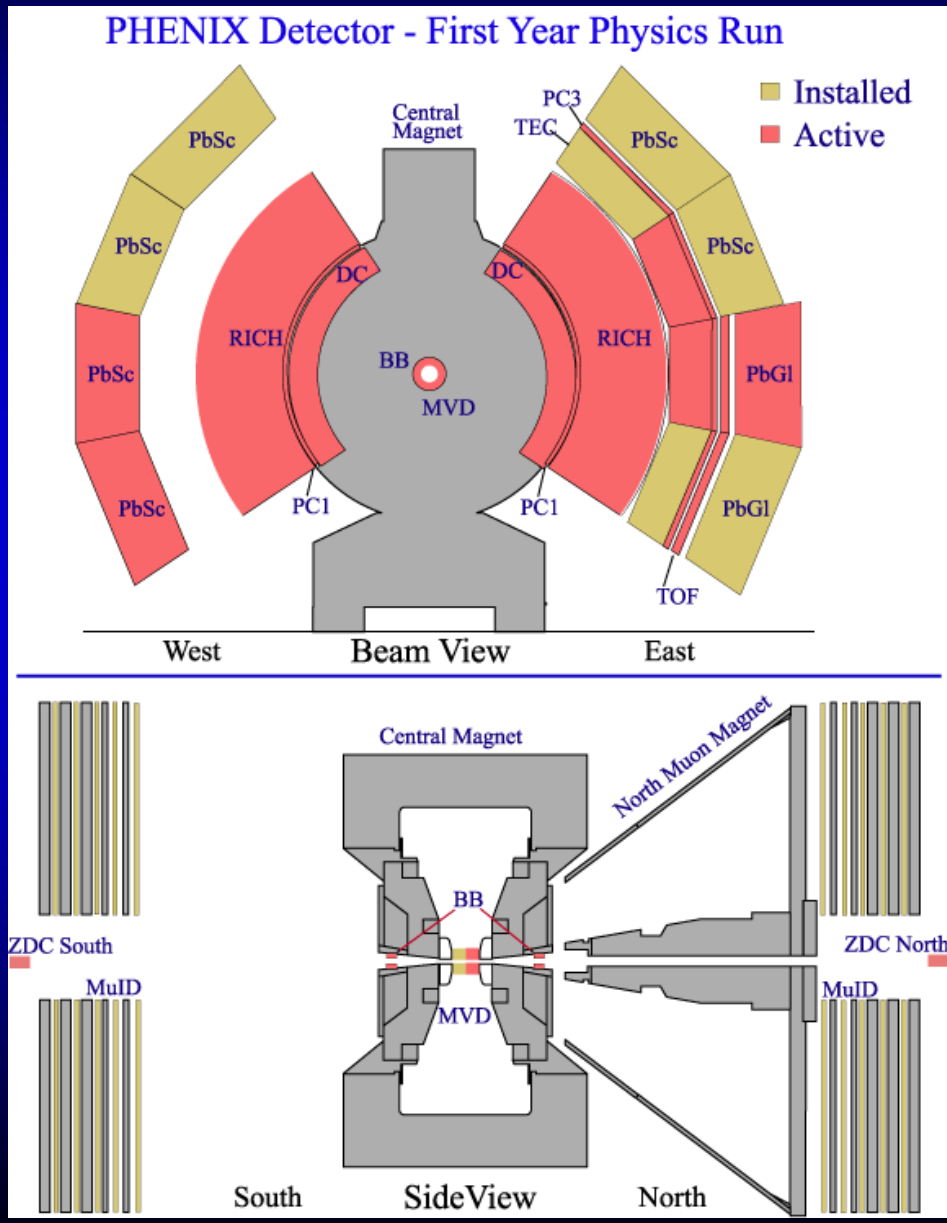
Event Characterization:

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



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)

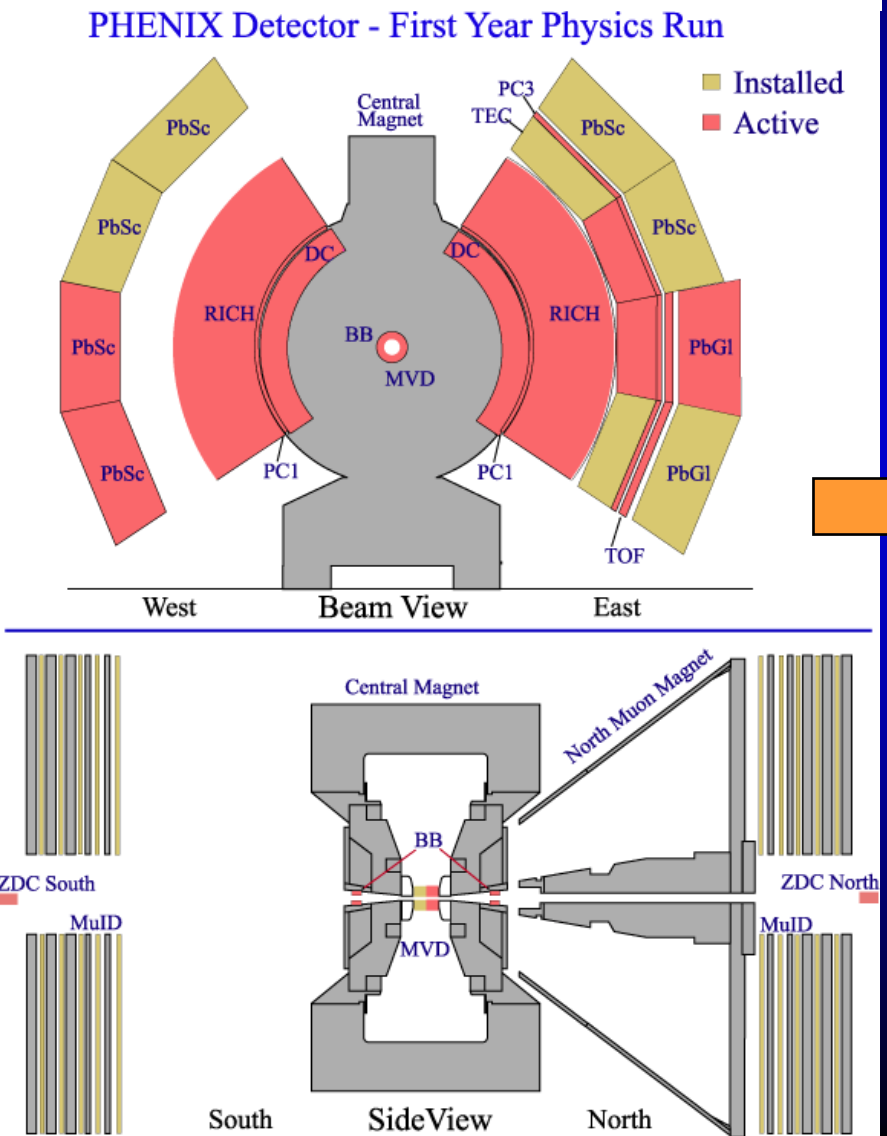


Run-1 Publications

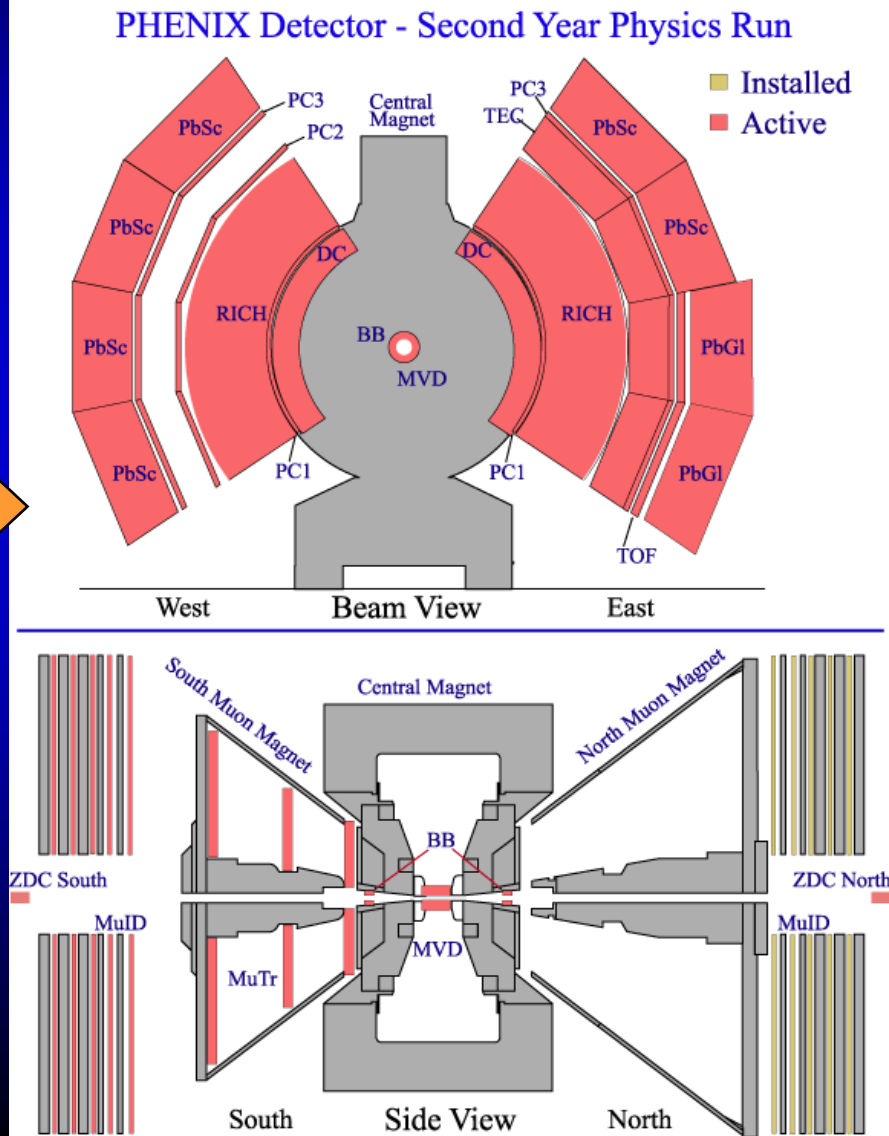
- "Centrality dependence of charged particle multiplicity in Au-Au collisions at $\sqrt{s_{NN}}$ = 130 GeV", PRL 86 (2001) 3500
- "Measurement of the midrapidity transverse energy distribution from $\sqrt{s_{NN}}$ = 130 GeV Au-Au collisions at RHIC", PRL 87 (2001) 052301
- "Suppression of hadrons with 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)



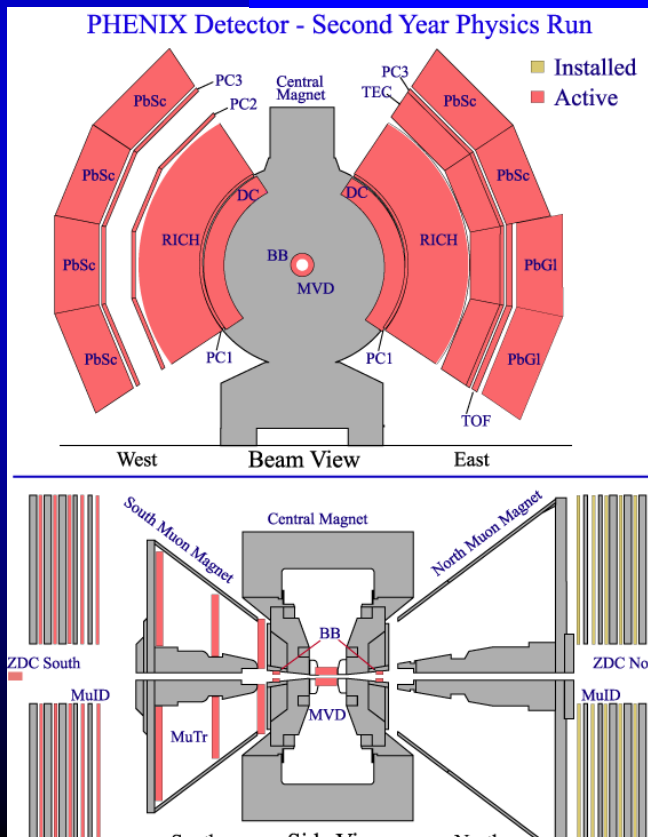
Run-2 (2001-2)



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

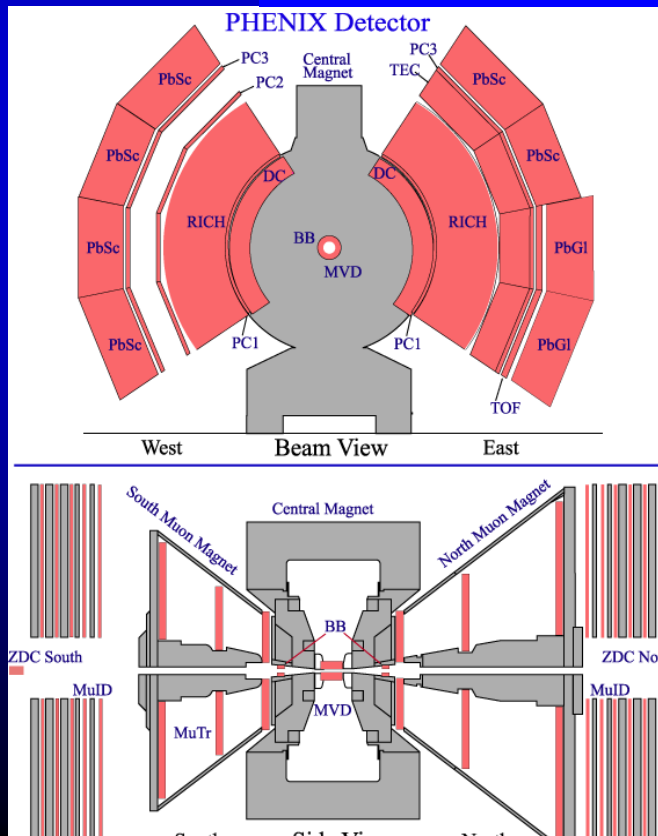
- "Suppressed π^0 Production at Large Transverse Momentum in Central Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV" , Phys. Rev. Lett. 91, 072301 (2003)
- "Scaling Properties of Proton and Anti-proton Production in $\sqrt{s_{NN}}$ = 200 GeV Au+Au Collisions", Phys. Rev. Lett 91, 172301 (2003).
- "J/Ψ 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

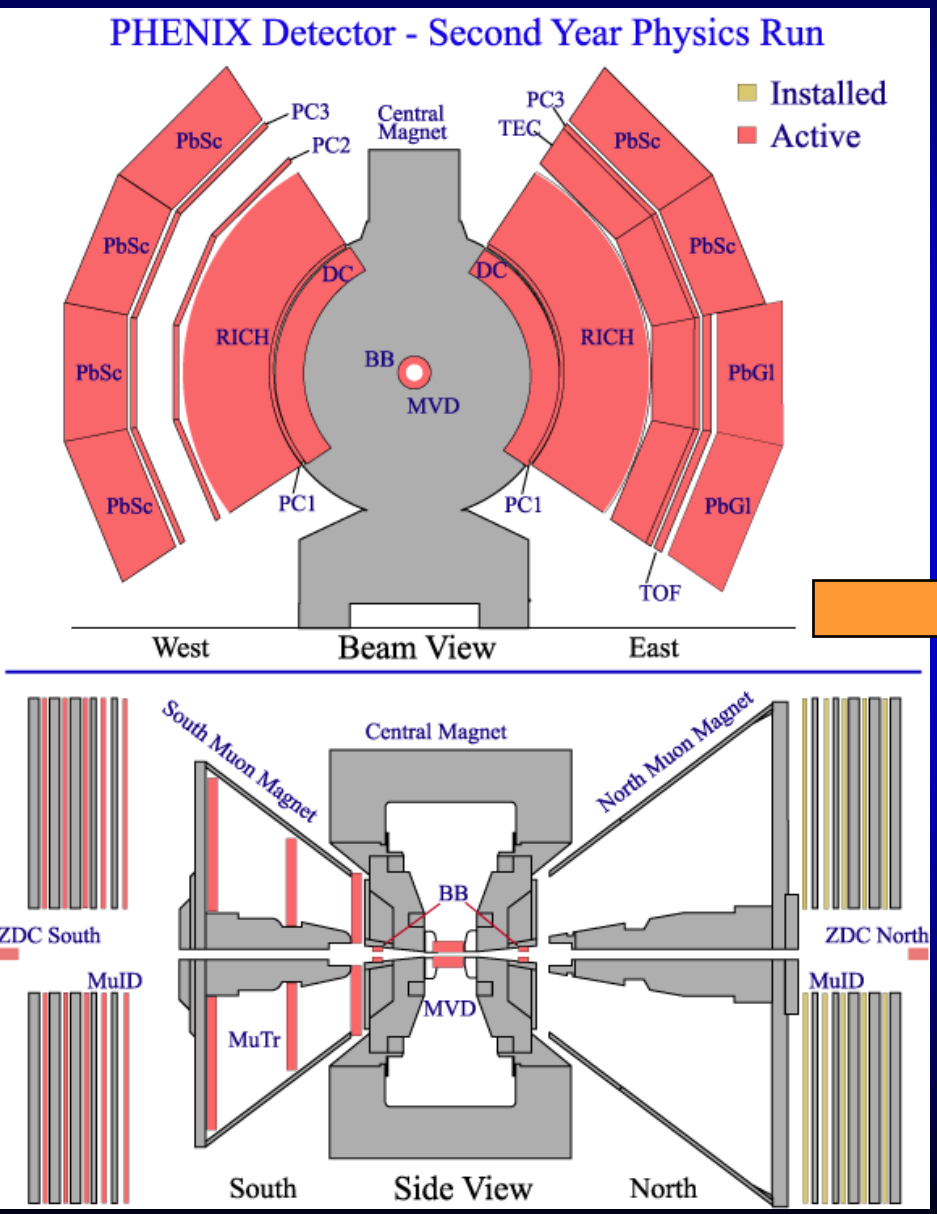
- MuTrk South Spectrometer removal, service and reinstallation
- MuTrk North Spectrometer prep, installation & commissioning
- MuID shielding installation in MuID cutout N&S
- Installation of TRD radiator packs in Time Expansion Chamber
- Install Central Magnet inner coils
- Replace temporary access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

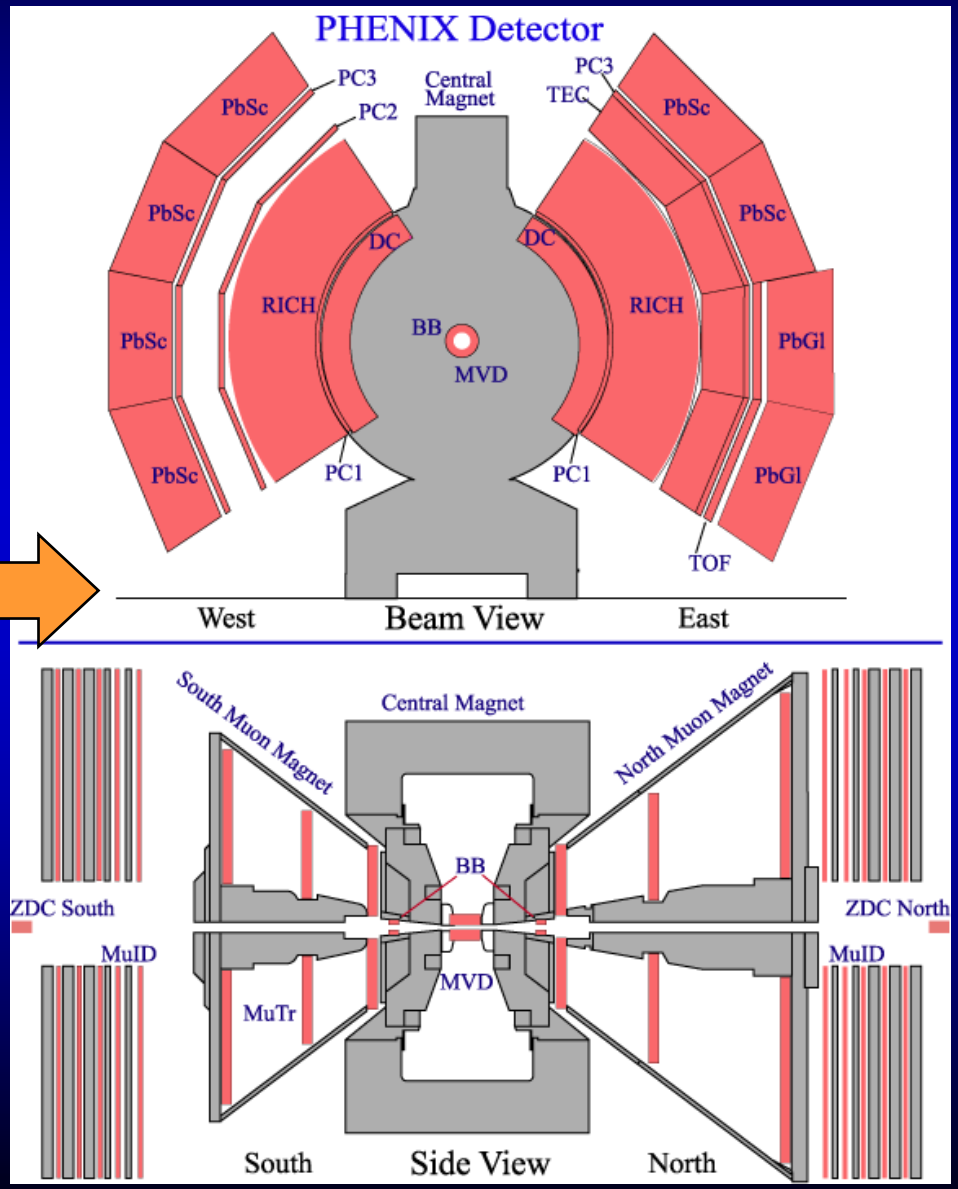
Run-3 PHENIX



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

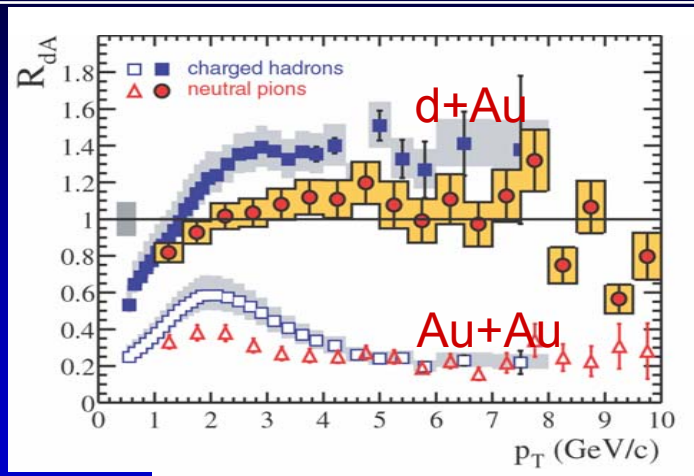
Run-3 and Beyond



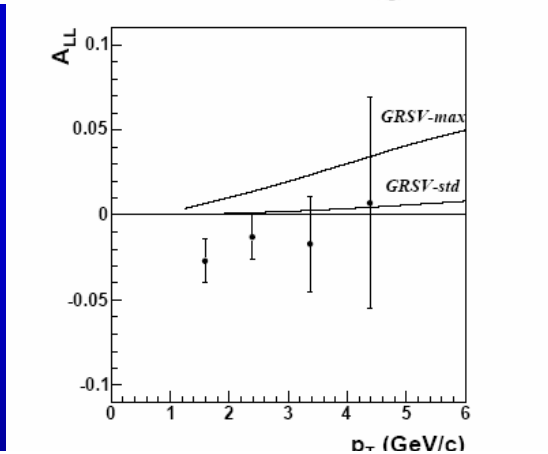


Run-3 Publications

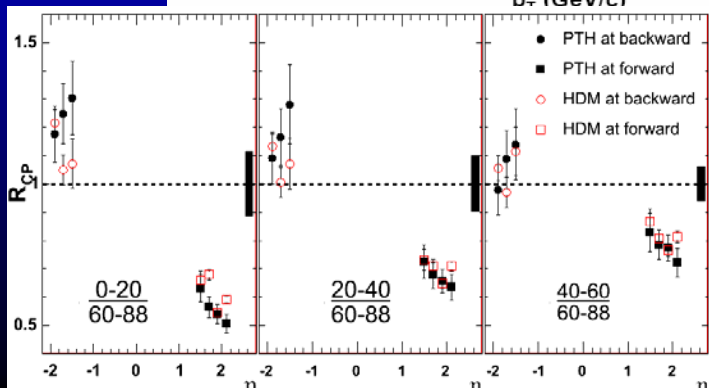
- "Absence of Suppression in Particle Production at Large Transverse Momentum in $\sqrt{s_{NN}}$ = 200 GeV d+Au Collisions",
  PRL 91, 072303 (2003)
  - ☞ PID-ed particles (π^0's) out to the highest p_T's PHENIX's unique contribution to June '03 "press event"



- "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.



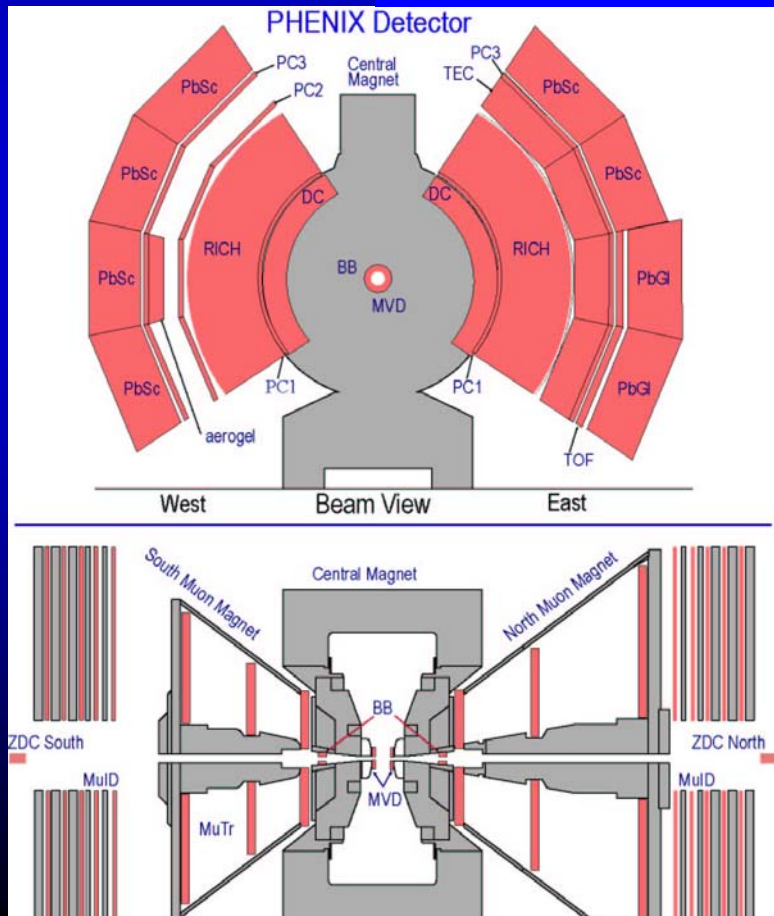
- "Nuclear Modification Factors for Hadrons At Forward and Backward Rapidities in Deuteron-Gold Collisions at √sNN = 200 GeV"
  Phys. Rev. Lett. 94, 082302
  - ☞ Clever extension of PHENIX hadron capabilities to the muon arms



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



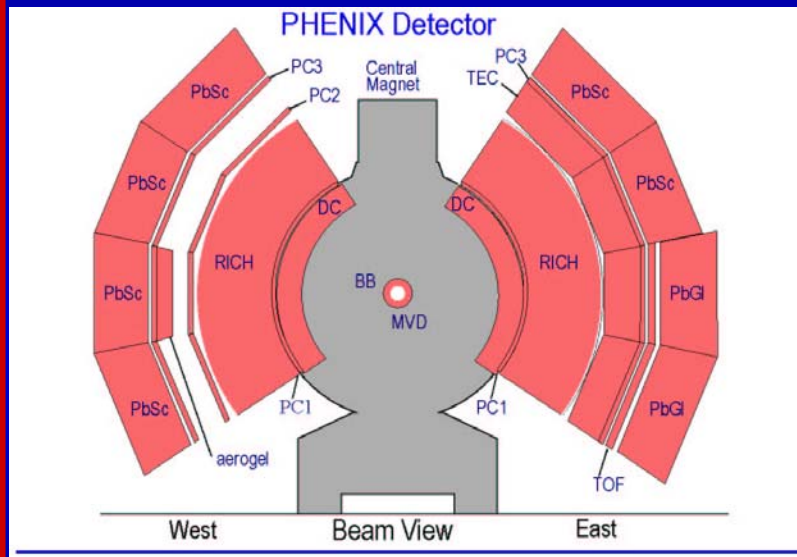
Work in 2004 Shutdown

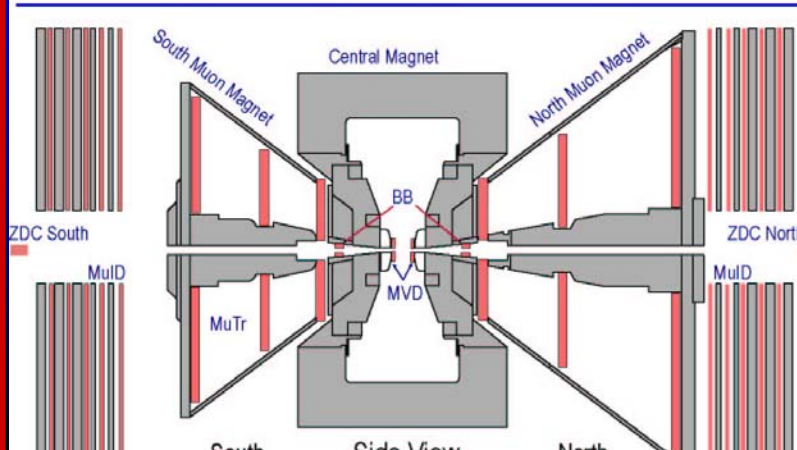
- General maintenance on PHENIX subsystems
- 2nd ½ of Aerogel Sector completed and installed
- Drift Chamber E Window repair
- DC W dc-dc converter replacement
- Magnet mapping
- Lots of Gas system work
- Extra Tunnel Shielding for Muon Arms
- Fix Multi-event buffering (MuTracker, EMCal)
- Improve FEM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

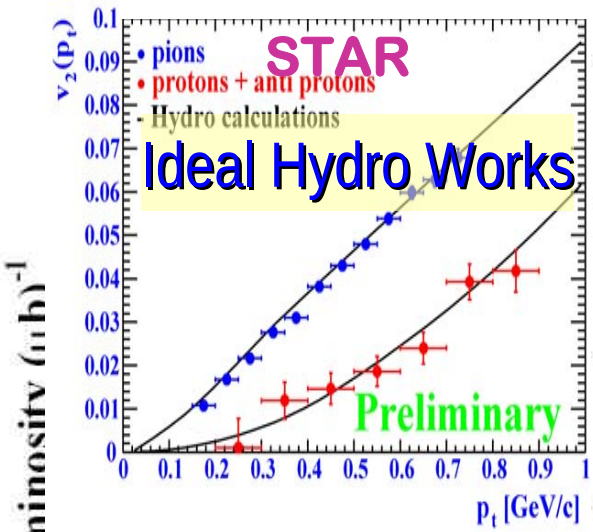
- New Aerogel ½-sector completed and installed
- Multi-event buffering for MuTracking, EMCal implemented
- Event Builder converted to Linux , plus other improvements.
- With DAQ & EvB improvements expect 5+ kHz event recording rate (Data rate max 1 GB/s uncompressed).
- 32 TB additional buffering capacity 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





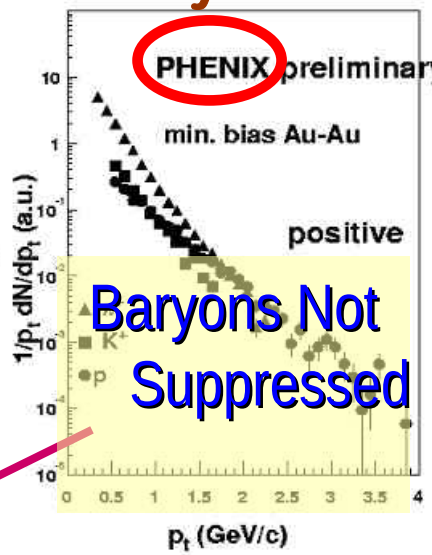
Four major "day 1" discoveries

Collective Flow



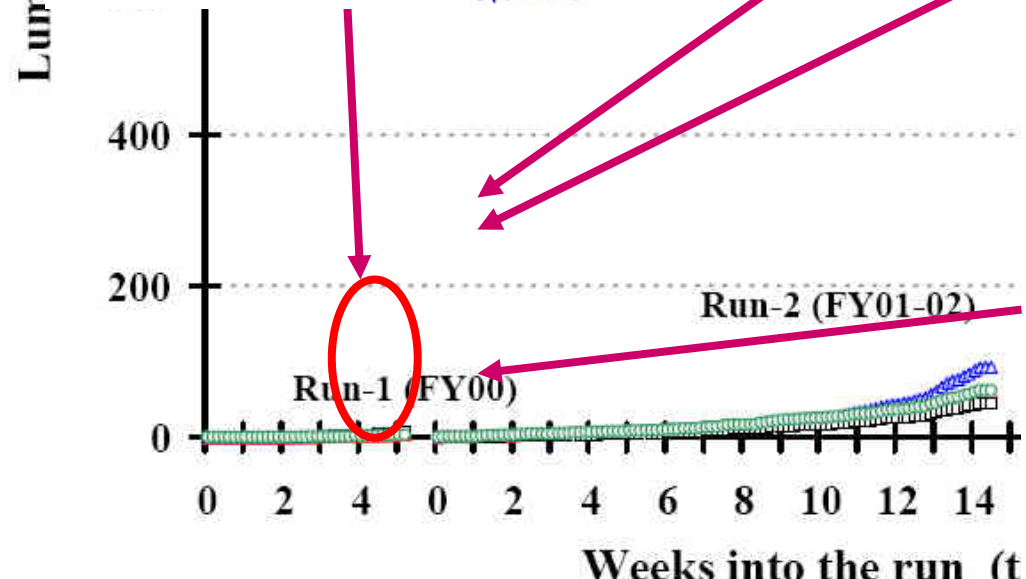
Jet Quenching

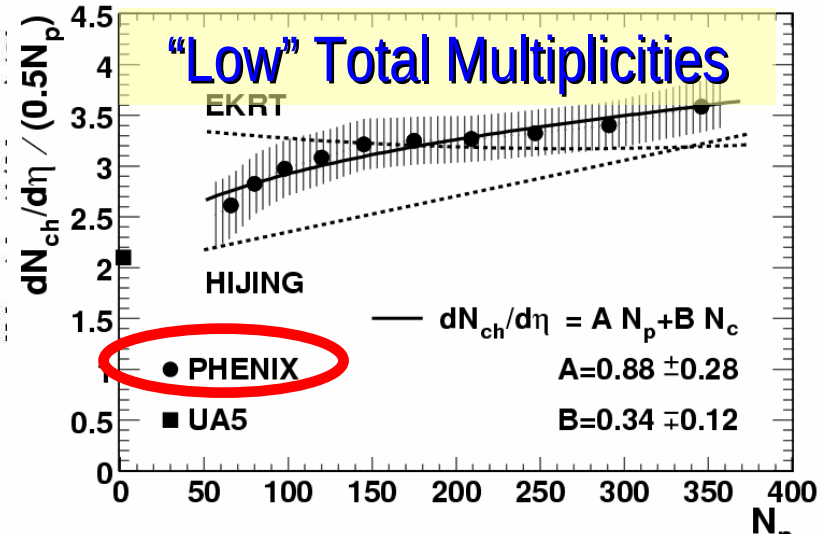
Baryon anomaly



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

CGC Saturation



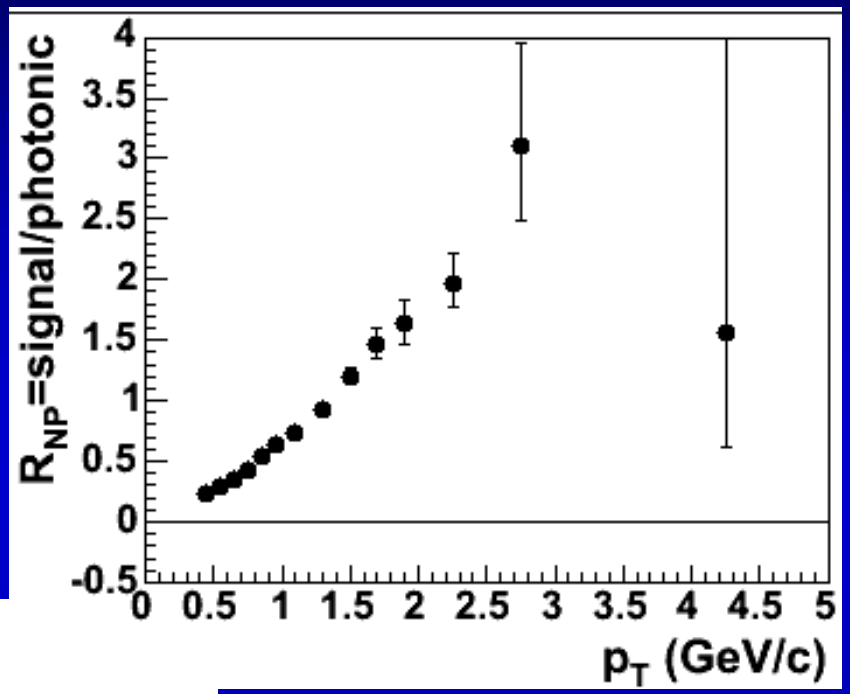


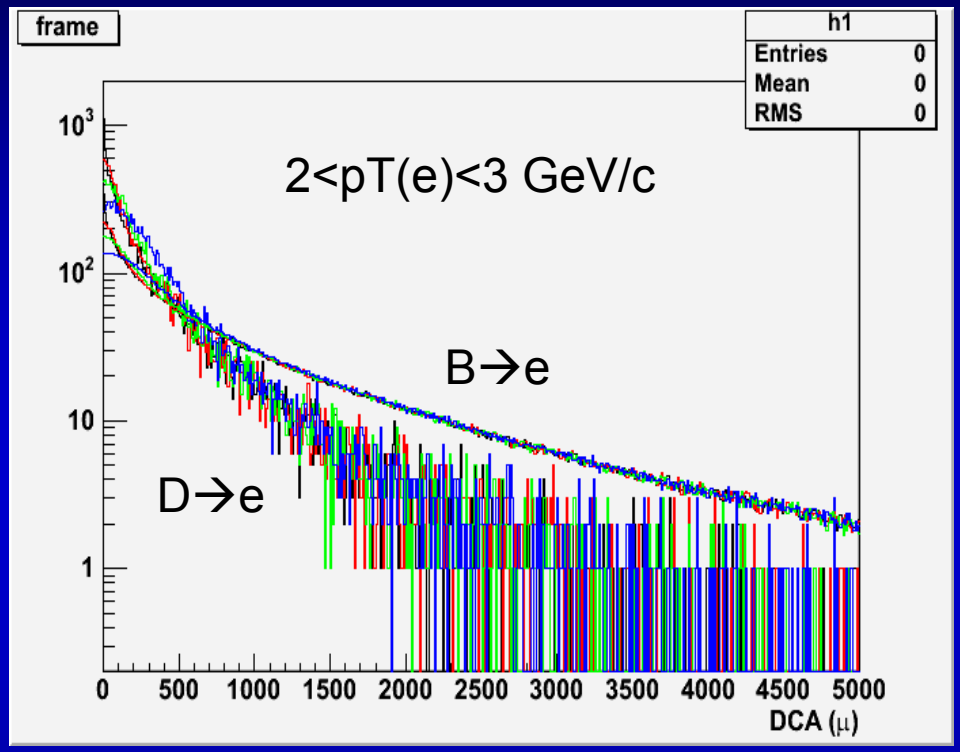
PHENIX

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

b/c Separation by DCA distribution





- PHENIX has already achieve quite clean single electron measurement from c or b decay. (S/B ~ 2 at pT~2 GeV/c) (left figure)
- The main purpose of VTX is to separate c→e and b→e component. This can be achieved by relatively modest DCA resolution. The right plot shows a PYTHIA simulation of DCA distribution of B→e and D→e. The different color corresponds to different DCA resolution (black:0, red: 50μ, green:100μ, and blue: 150μ).
- DCA resolution of 150 micron does not make much difference to DCA cuts of 700 micron or larger, where we have clear separation of B and D component.