Prospects of the gluon polarization measurement at PHENIX

SPIN 2002 at BNL

September 11, 2002

Yuji Goto (RIKEN/RBRC)

for the PHENIX collaboration

PHENIX

University of São Paulo, São Paulo, Brazil
Academia Sinica, Taipei 11529, China
China Institute of Atomic Energy (CIAE), Beijing, P. R. China
Laboratoire de Physique Corpusculaire (LPC), Universite de Clermont-Ferrand, 63170 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
LPNHE-Palaiseau, Ecole Polytechnique, CNRS-IN2P3, Route de Saclay, F-91128, Palaiseau, France
SUBATECH, Ecole des Mines at Nantes, F-44307 Nantes, France
University of Muenster, Muenster, Germany
Banaras Hindu University,Banaras, India
Bhabha Atomic Research Centre (BARC),Bombay, India
Weizmann Institute, Rehovot, Israel
Center for Nuclear Study (CNS-Tokyo), University of Tokyo, Tanashi, Tokyo 188, Japan
Hiroshima University, Higashi-Hiroshima 739, Japan
KEK, Institute for High Energy Physics,Tsukuba, Japan
Kyoto University, Kyoto, Japan
Nagasaki Institute of Applied Science, Nagasaki-shi, Nagasaki, Japan
RIKEN, Institute for Physical and Chemical Research, Hirosawa, Wako, Japan
University of Tokyo, Bunkyo-ku, Tokyo 113, Japan
Tokyo Institute of Technology, Ohokayama, Meguro, Tokyo, Japan
University of Tsukuba, Tsukuba, 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
Institute of High Energy Physics (IHEP-Protvino or Serpukhov), Protovino, Russia
Joint Institute for Nuclear Research (JINR-Dubna), Dubna, Russia
Kurchatov Institute, Moscow, Russia
PNPI: St. Petersburg Nuclear Physics Institute, Gatchina, Leningrad, Russia
Lund University, Lund, Sweden
Abilene Christian University, Abilene, Texas, USA
Brookhaven National Laboratory (BNL), Upton, NY 11973
University of California - Riverside (UCR), Riverside, CA 92521, USA
Columbia University, Nevis Laboratories, Irvington, NY 10533, USA
Florida State University (FSU), Tallahassee, FL 32306, USA
Georgia State University (GSU), Atlanta, GA, 30303, USA
Iowa State University (ISU) and Ames Laboratory, Ames, IA 50011, USA
LANL: Los Alamos National Laboratory, Los Alamos, NM 87545, USA
LLNL: Lawrence Livermore National Laboratory, 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

Spin program at PHENIX

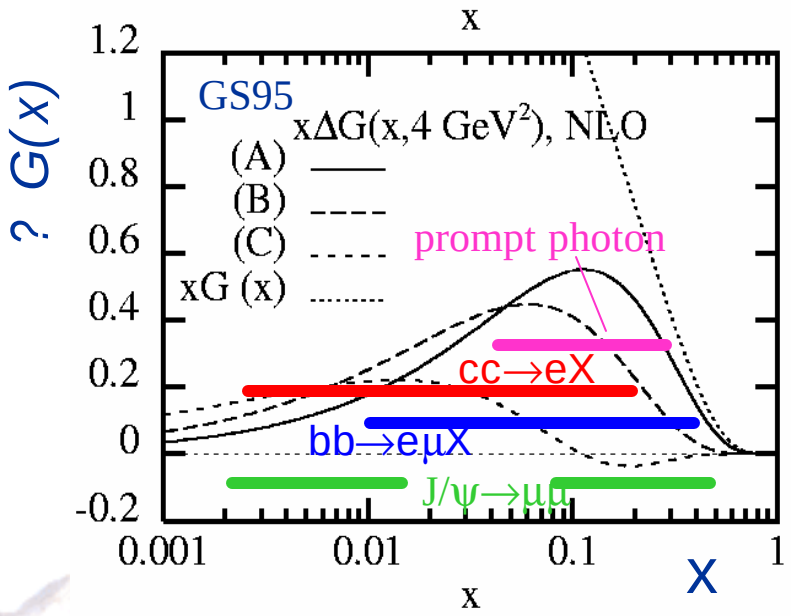
- Quark polarization – flavor decomposition
  - parity violating $W^{\pm}$ — Nicki Burner's talk (Tuesday)
- Transversity
- Search for new physics with parity violation
- Gluon polarization
  - open heavy flavor with e, eμ — Ken Barish's talk (Monday)
  - J/ψ — Hiroki Sato's talk (Monday)
- Single transverse-spin asymmetry
  - π^0 — Brendan Fox's talk (Tuesday)
  - charged hadron — Kensuke Okada's talk (Tuesday)
  - single muon — Atsushi Taketani's talk (Tuesday)
- at IP12
  - neutron, photon, π^0 — Yoshinori Fukao (Tuesday)

Outline

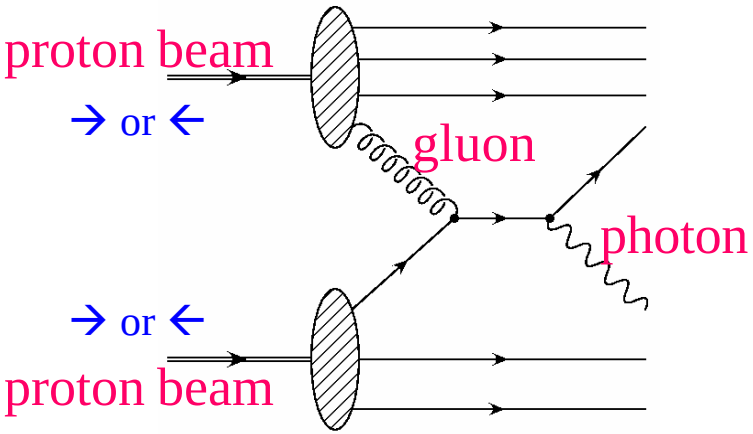
- Introduction
  - gluon polarization measurement
    - prompt photon
    - heavy flavor
    - p^0 and charged hadrons
- PHENIX 2001-2002 run
  - analysis status
  - for gluon polarization measurement in next runs
    - p^0, J/ψ
    - relative luminosity
    - local polarimeter
- PHENIX upgrade plan
  - for full luminosity run …
- Summary

Gluon polarization measurement

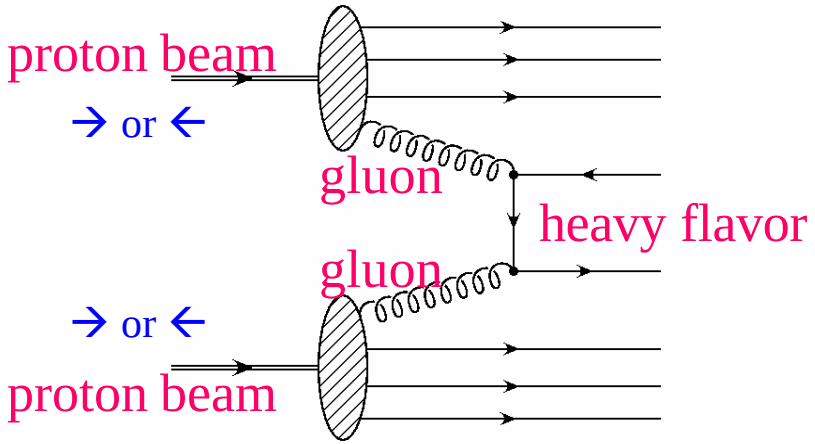
- Covering wide x_g region by measuring:
  - photon
  - muon
  - electron
  - charged hadrons …



prompt photon – gluon Compton



heavy flavor – gluon fusion

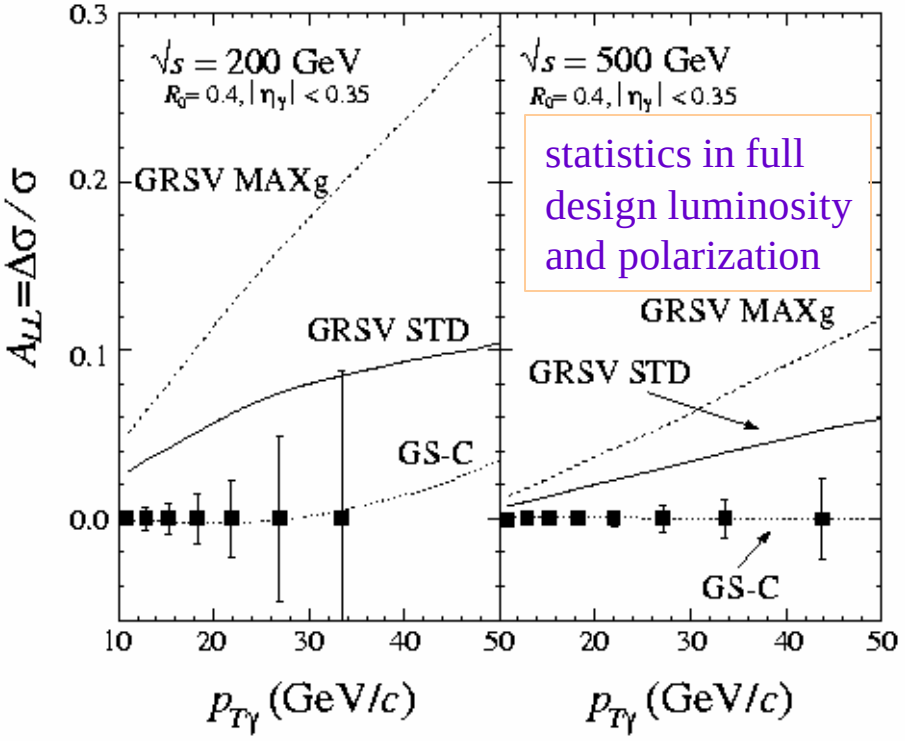


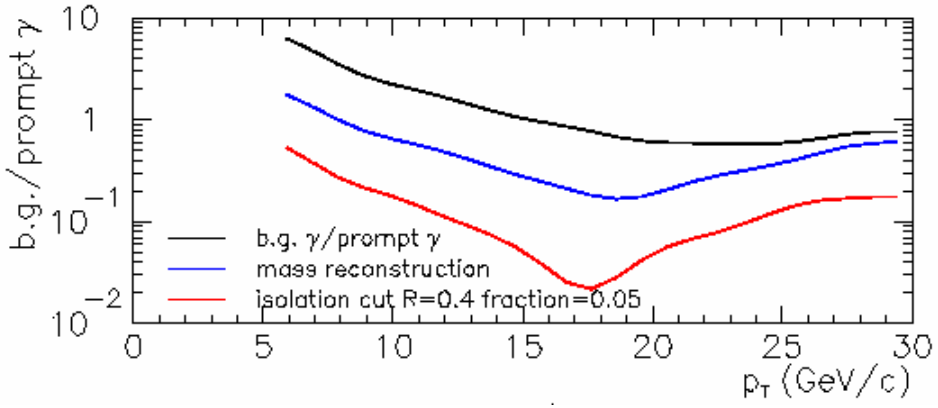
Gluon polarization measurement

- Prompt photon
  - clear interpretation
    - gluon Compton process dominant
  - experimentally challenging
    - good background reduction with high performance EMCal at PHENIX

$$A_{LL}(p_T) = \frac{\Delta g(x_g, Q^2)}{g(x_g, Q^2)} \cdot A_1^{\,p}(x_q, Q^2) \cdot a_{LL}(\cos\theta^*)$$

➔ $x_g = 0.04 - 0.3$



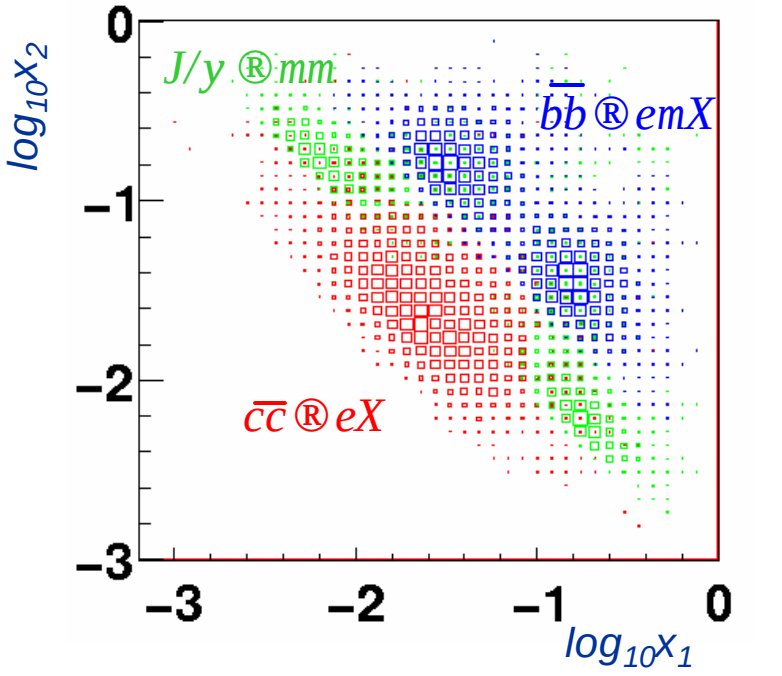


Gluon polarization measurement

- Heavy flavor
  - $x_g \rightarrow 0.01$ and smaller
    - J/ψ production
    - open heavy flavor production
  - uncertainties
    - J/ψ production mechanism
    - prompt J/ψ or decay
    - background
    - charm and bottom
    - ...

heavy flavor : gluon fusion

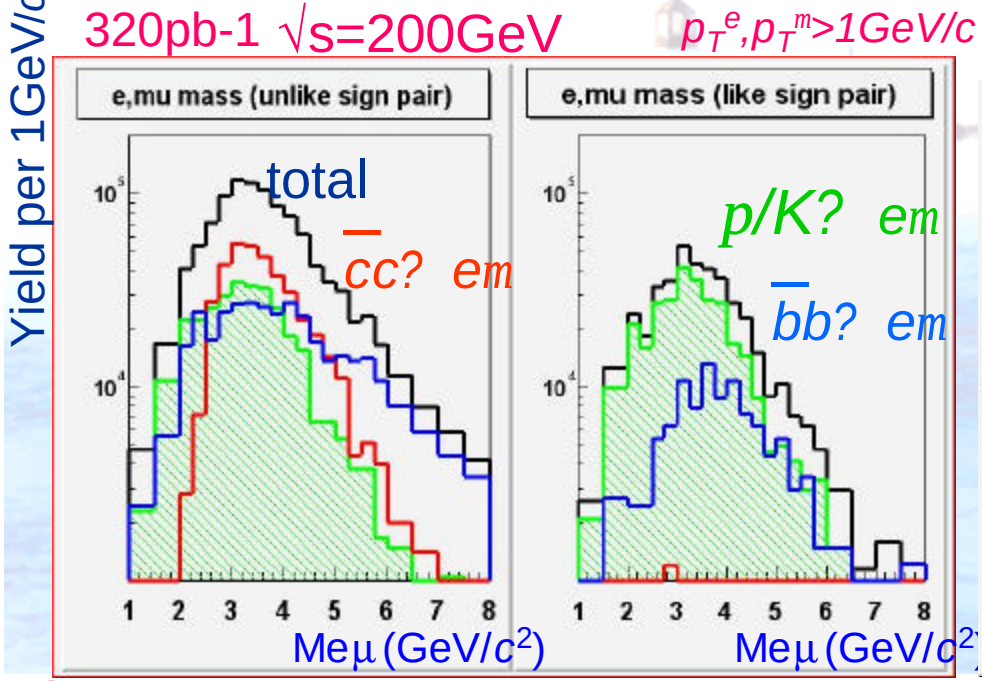
$gg \rightarrow c\bar{c}, b\bar{b}$

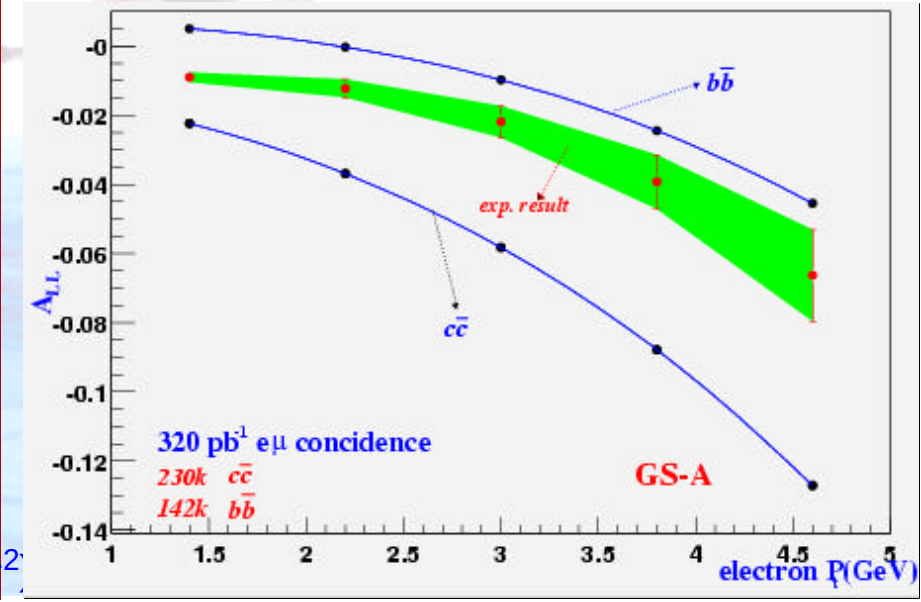


Gluon polarization measurement

- Heavy flavor
  - e-μ coincidence
    - clean: bottom-only at high mass
    - background evaluation with like-sign pairs

➔ These measurements will be done in 2004-2005 and beyond …
➔ They will be discussed later again.
➔ What is the plan in next runs ?





H. Sato / W. Xie

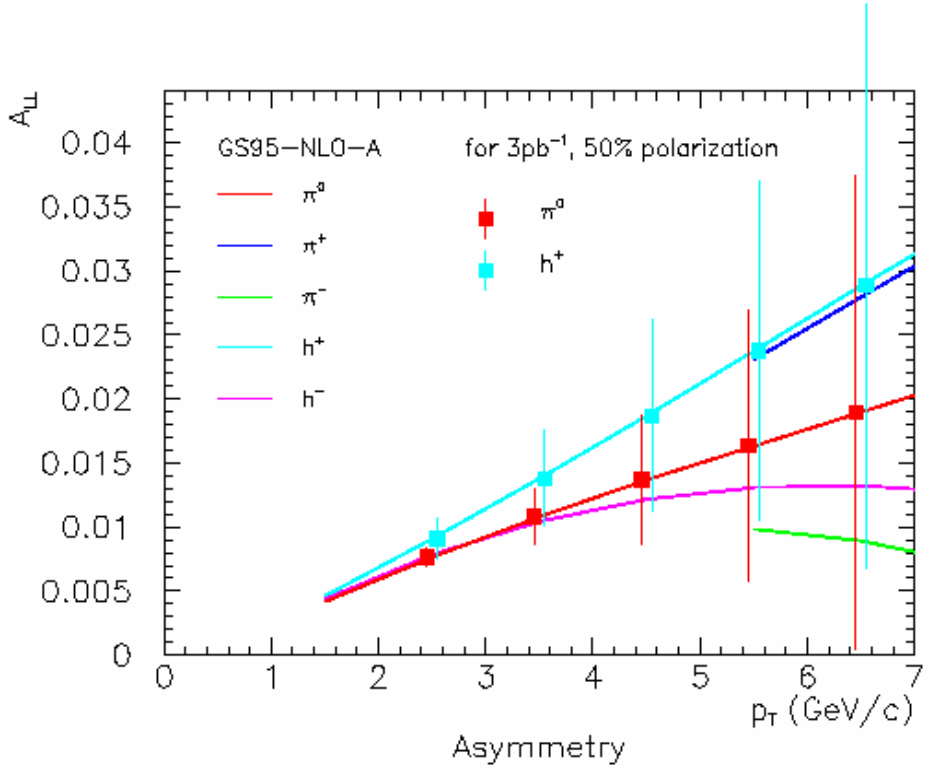
Gluon polarization measurement

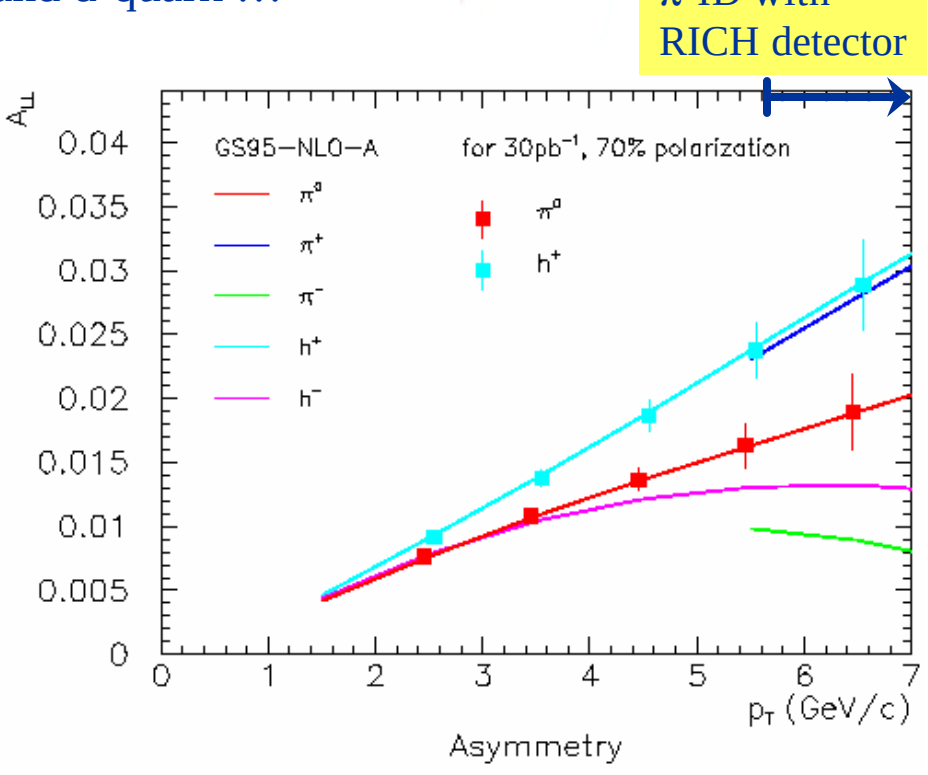
- 2001-2002 run (run-2)
  - study systematics
    - p^0, J/ψ cross section measurement (with transversely polarized beam)
    - luminosity measurement, local polarimeter, …
- 2002-2003 run (run-3)
  - ~3pb^{-1} at $\sqrt{s}$=200GeV
  - 50% polarization
  - A_{LL} of p^0 and charged hadrons
- 2003-2004 run (run-4)
  - ~30pb^{-1} at $\sqrt{s}$=200GeV
  - 70% polarization if AGS snake can start operation …
  - A_{LL} of heavy flavor
    - J/?
    - single-electron
    - start e-μ coincidence
  - start A_{LL} of direct photon

Gluon polarization measurement

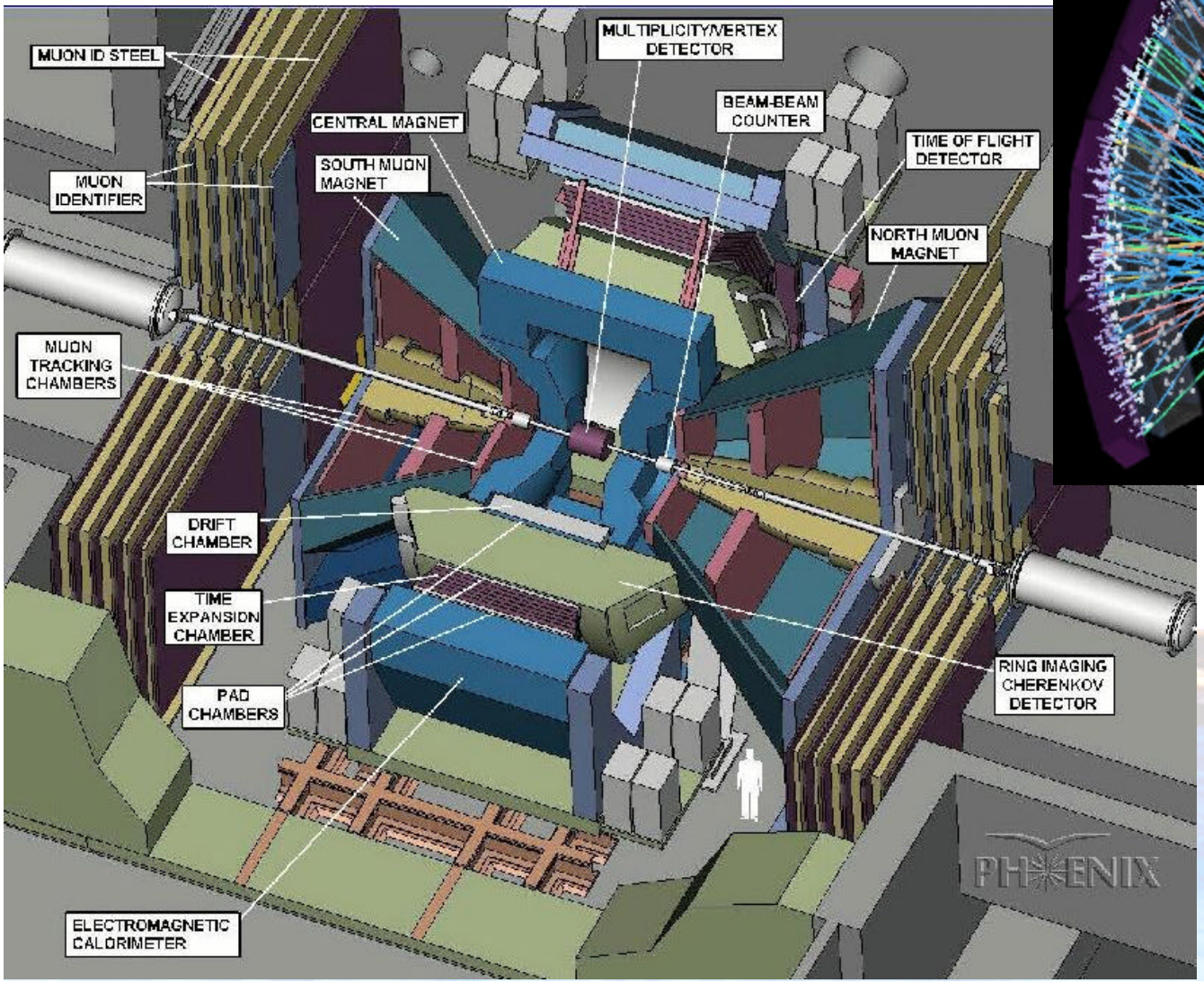
- p^0 and charged hadrons
  - alternative to jet measurement in the small acceptance
    - all channels are combined for the gluon polarization analysis
  - quark polarization – flavor decomposition
    - p^+ from u-quark, p^0/p^- from u- and d-quark …

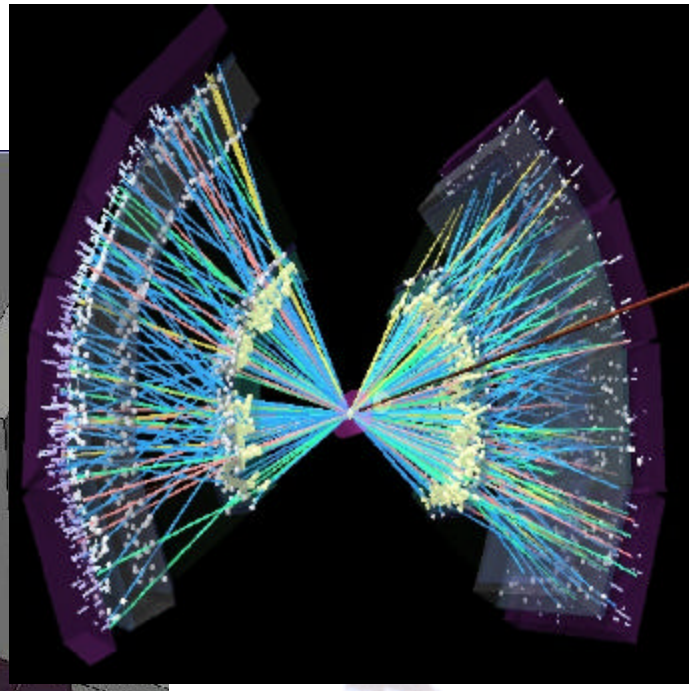
π-ID with RICH detector





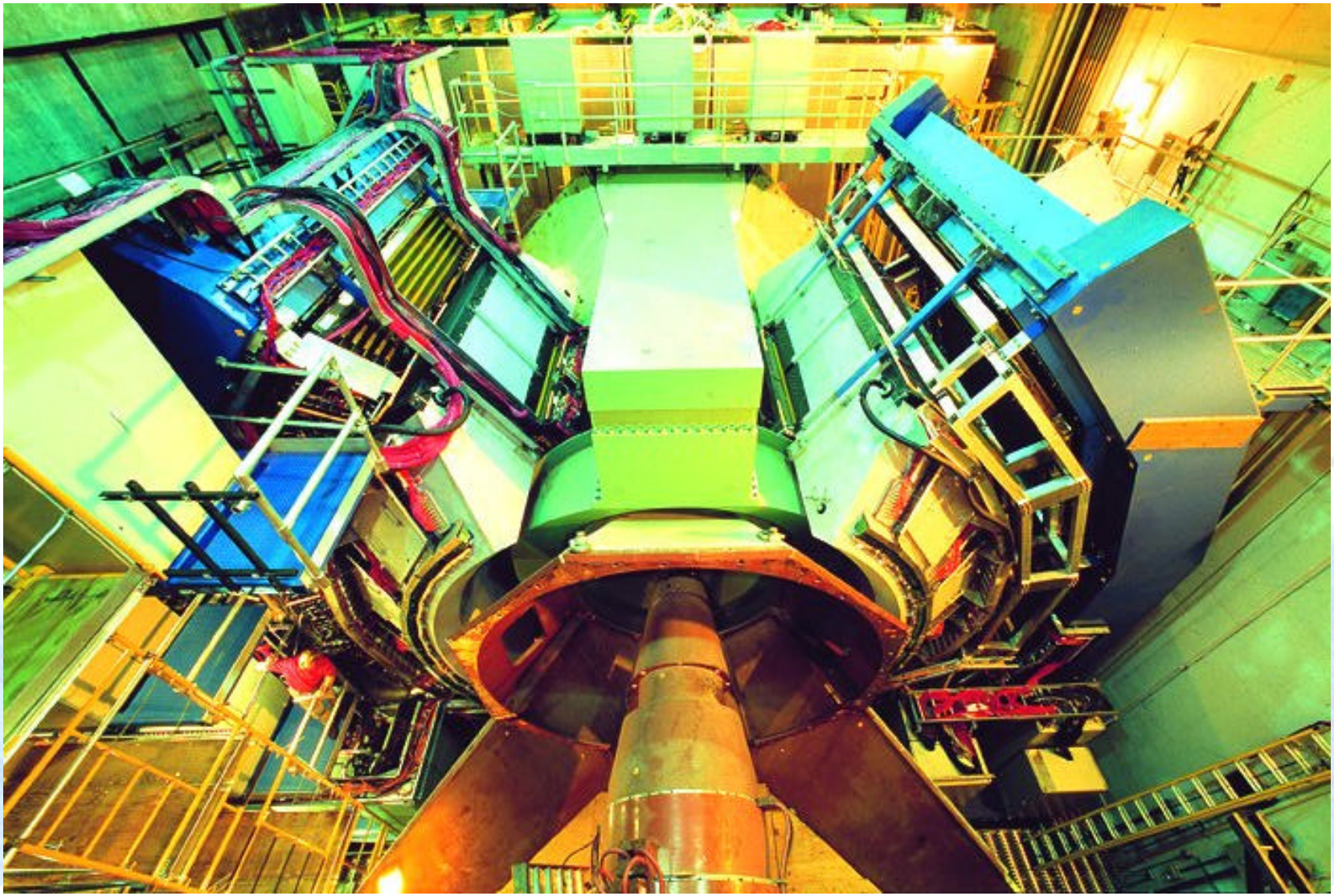
PHENIX



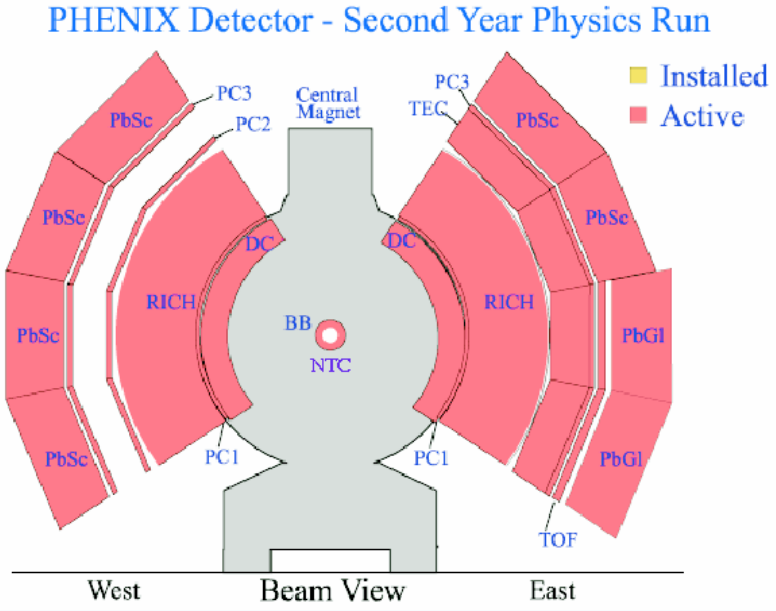


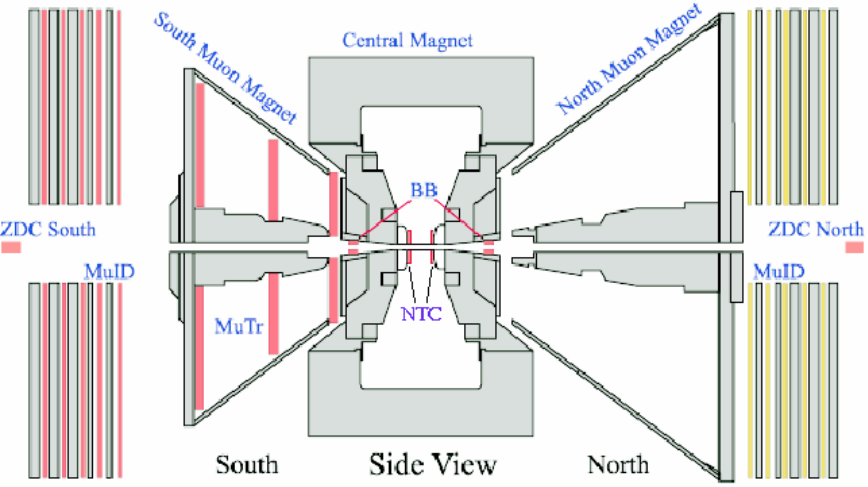
Au-Au collision
$\sqrt{s_{NN}}$ = 200 GeV

PHENIX in 2001-2002 run



PHENIX in 2001-2002 run



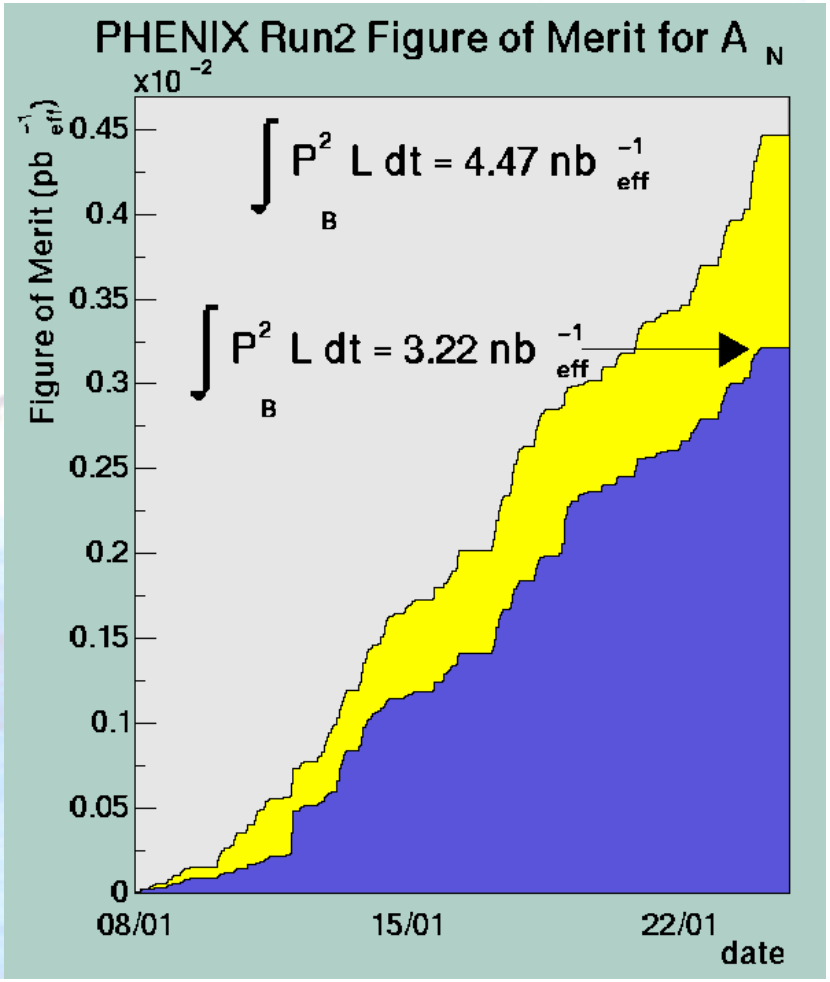


- Full central arms
- South muon arm
- 1st-level trigger system
  - high-p_T EMCal trigger
  - μ-ID trigger
- DAQ
  - 1kHz & 70MB/sec

➔ Muon north arm will start operation in 2002-2003 run
  - detectors are all installed and being commissioned now

2001-2002 run

- Luminosity
  - integrated luminosity 0.15 pb^{-1}
  - $L = 1.5 \times 10^{30}$ $cm^{-1}sec^{-1}$ at maximum
- Polarization – transverse
  - $<P_{yellow}>=17$ %
  - $<P_{blue}>=14$ %
  - 25 % at maximum
  - result of using the backup motor generator with lower ramping rate for the AGS



2001-2002 run

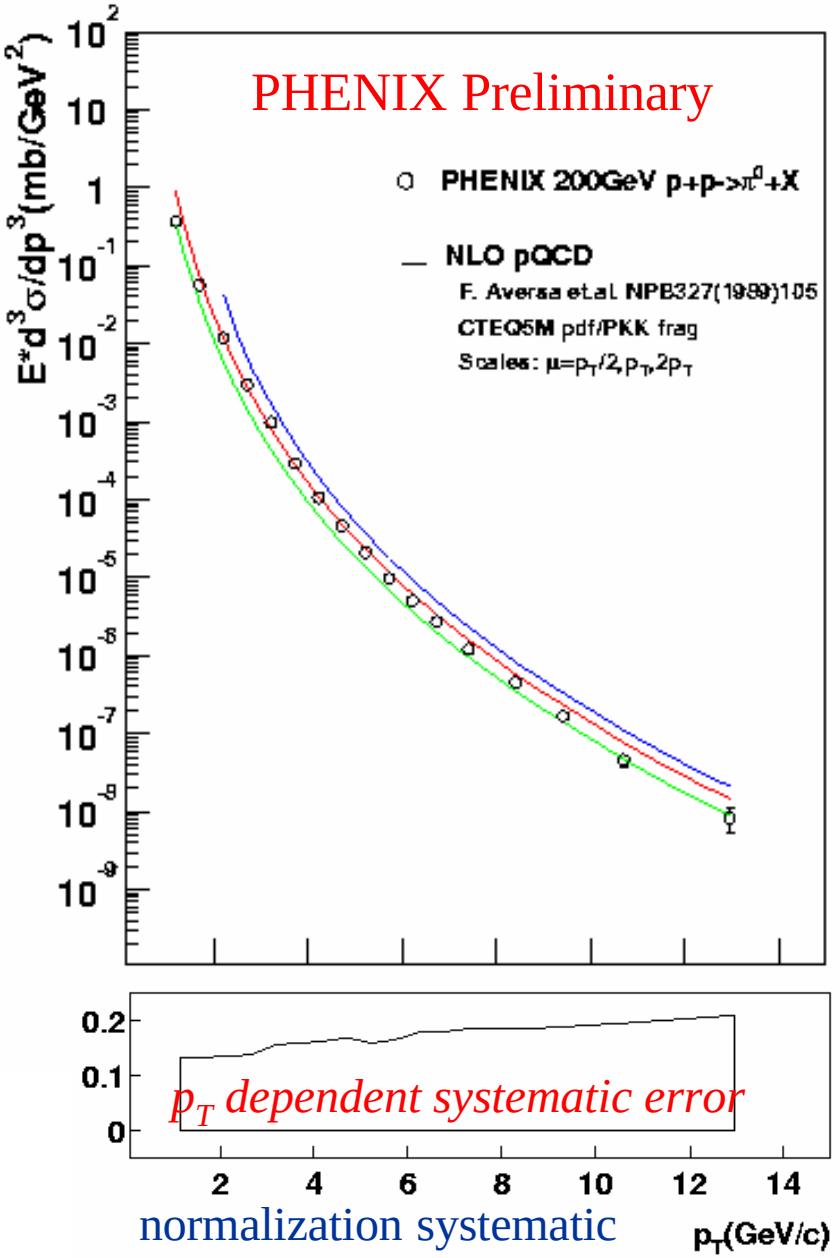
- A_N measurement
  - analysis ongoing …
  - central arm
    - mid-rapidity, $x_F \sim 0$
    - p^0, charged hadrons, J/ψ, …
  - muon arm
    - forward-rapidity, $1.2 < h < 2.4$
    - single-μ, J/ψ, …
- Cross section measurement
  - p^0, J/ψ, …
- Systematic studies
  - relative luminosity study
  - local polarimeter development at IP12
    - A_N measurement of neutron, photon, π^0 at very forward-rapidity

2001-2002 run

- π^0 cross section
  - data covers over 8 orders of magnitude
    - p_T = 1 – 13 GeV/c
    - by combining minimum bias trigger and EMCal trigger data
  - NLO pQCD calculation is consistent with our data
    - CTEQ5M PDF + PKK FF
    - within the scale $\mu = p_T/2 - 2p_T$

➔ some confidence in understanding subprocesses

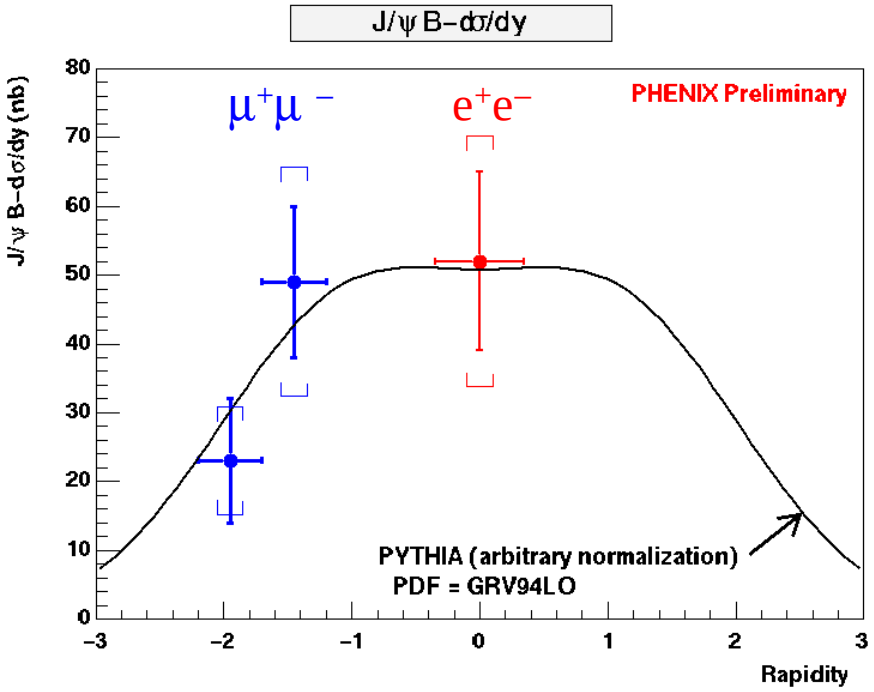
B. Fox / H. Torii



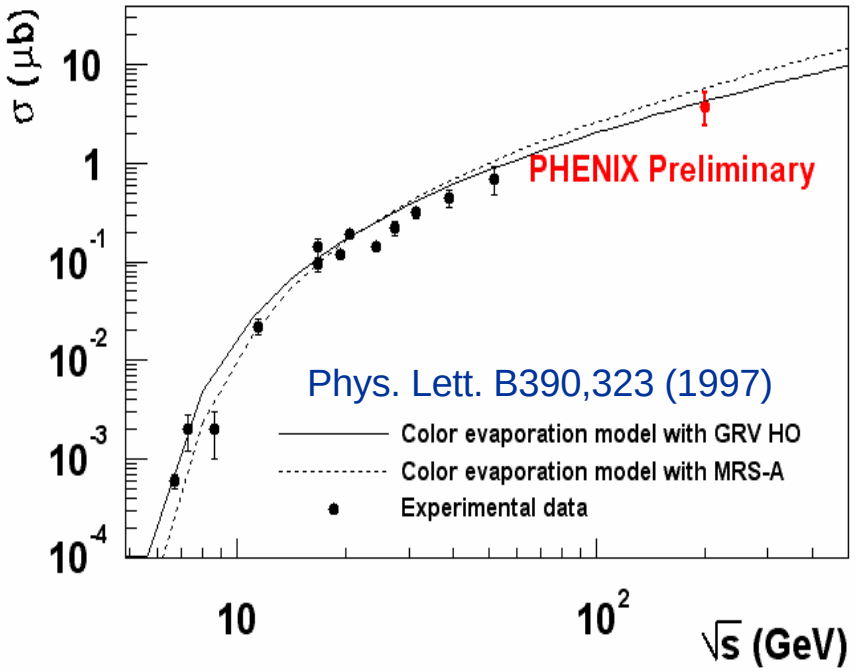
normalization systematic error 30% is not included

2001-2002 run

- $J/\psi \rightarrow \mu^+\mu^-$, e^+e^-
  - $Br(J/\psi \rightarrow l^+l^-)\ \sigma(p+p \rightarrow J/\psi X) = 226 \pm 36\ (stat.) \pm 79\ (syst.)$ nb
  - $\sigma(p+p \rightarrow J/\psi X) = 3.8 \pm 0.6\ (stat.) \pm 1.3\ (syst.)$ μb



H. Sato



2001-2002 run

- Relative luminosity measurement

T. Kawabata

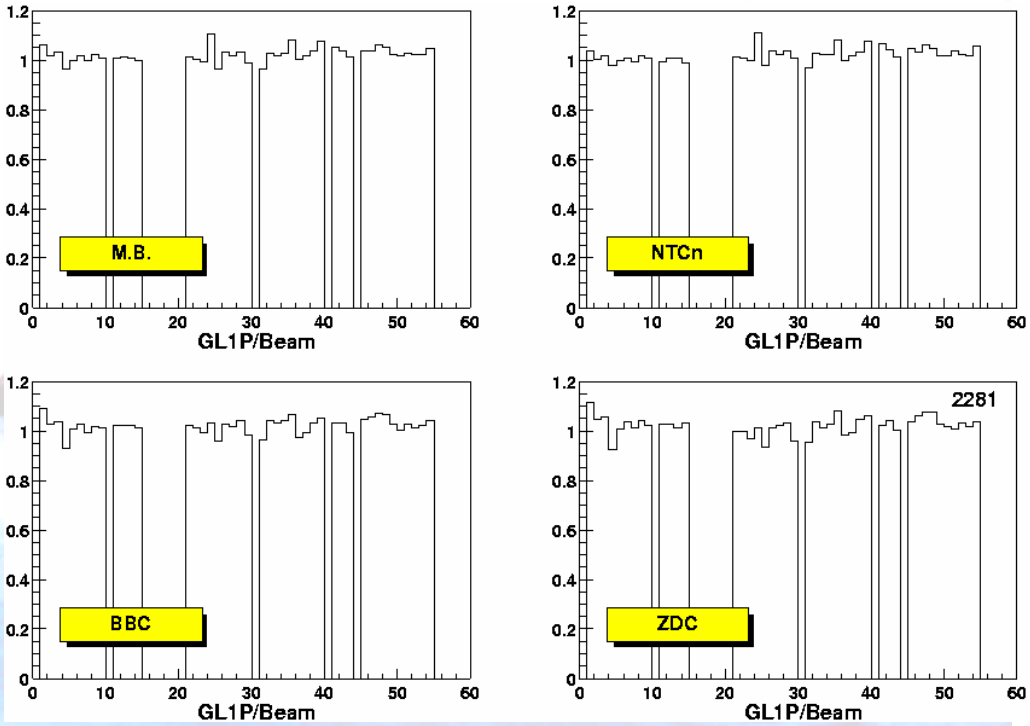
$$A_{LL} = \frac{1}{P^2} \cdot \frac{N_{++} - R \cdot N_{+-}}{N_{++} + R \cdot N_{+-}}$$

$$R = \frac{L_{++}}{L_{+-}}$$

– $DA_{LL} < 0.3\%$ measurement in 2002-2003 run requires $DR < 0.1\%$ measurement

➔ Crossing-sorted scalers

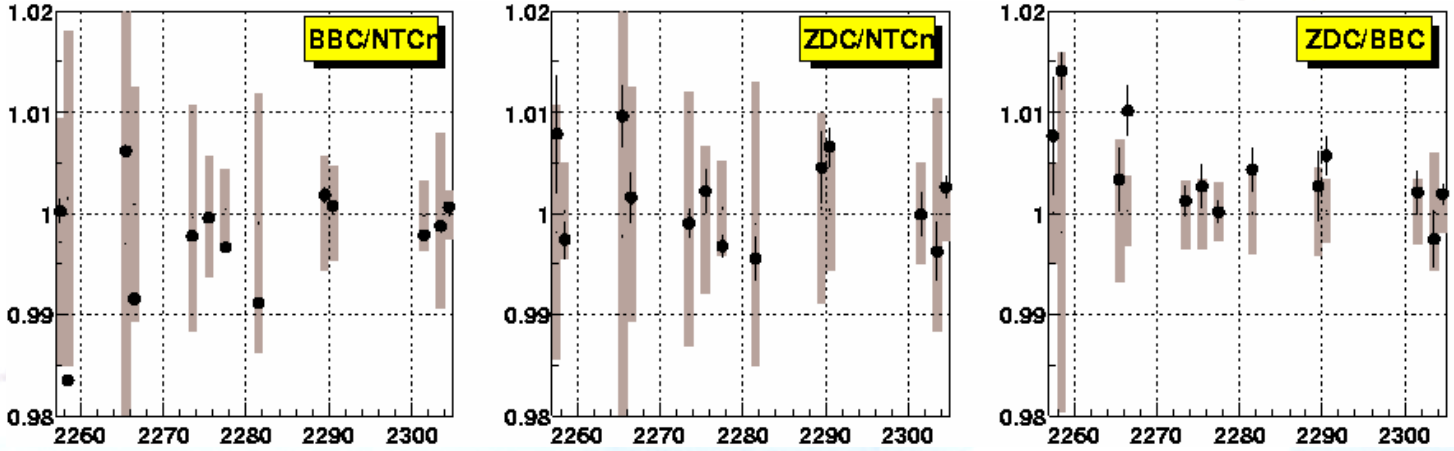
– 4 scalers × 120 crossings
  - Min.Bias = BBC ⊕ NTC
  - BBC
  - NTC
  - ZDC



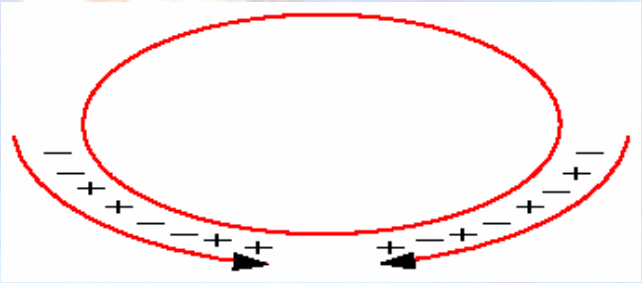
crossing-sorted specific luminosity
= scaler / WCM blue / WCM yellow
(WCM: wall current monitor)

2001-2002 run

- Crossing-sorted scalers
  - *DR* = 0.3% achieved in good fills (preliminary)
  - 0.2% in total run by averaging effect



  - bunch-by-bunch characteristics make this systematic uncertainty
  - relation with accelerator parameters ??



- 2002-2003 run
  - additional luminosity telescope
  - recogging / spin flip

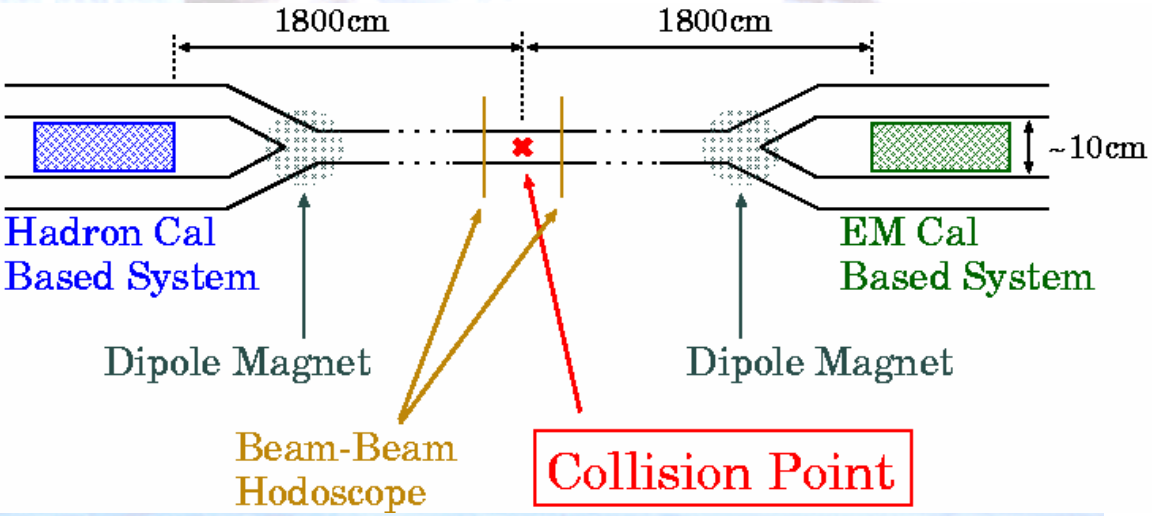
➔ ~10-times better relative luminosity measurement expected

2001-2002 run

- Local polarimeter
  - for the operation with spin rotators in 2002-2003 run
    - to confirm spin dynamics in RHIC ring
    - spin dynamics between spin rotators is completely transparent to the rest of accelerator by design
  - development of a new polarimeter to be installed at PHENIX

➔ A_N measurement at IP12

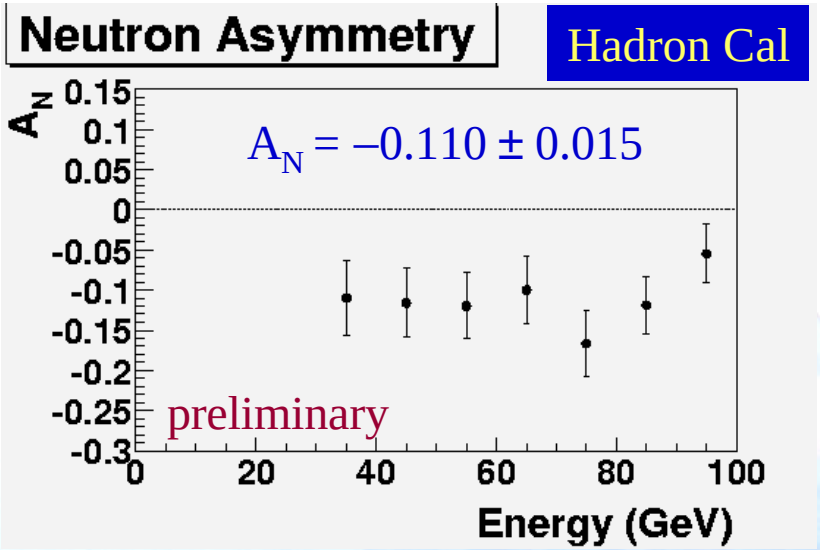
- neutron, photon, and π^0
- very forward region
- $p_T < 0.3$ GeV/c, $x_F > 0.2$

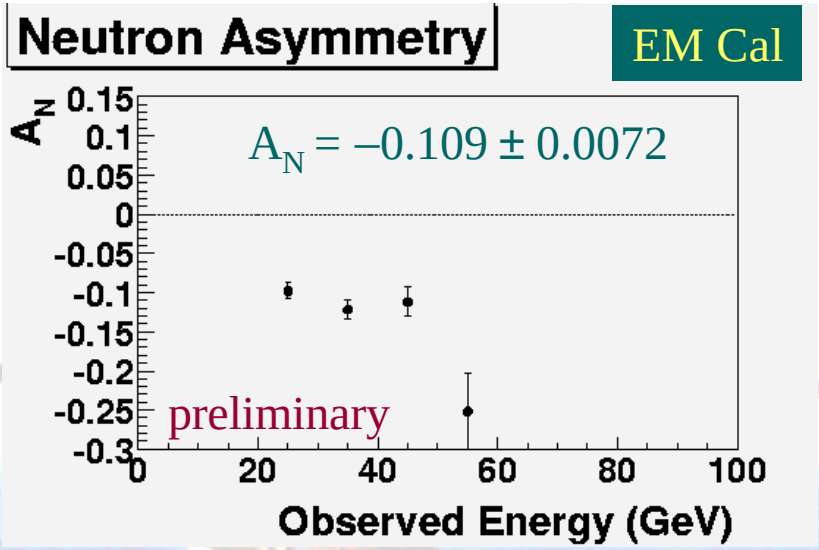


2001-2002 run

- A_N measurement at IP12
  - large neutron A_N was discovered

Y. Fukao



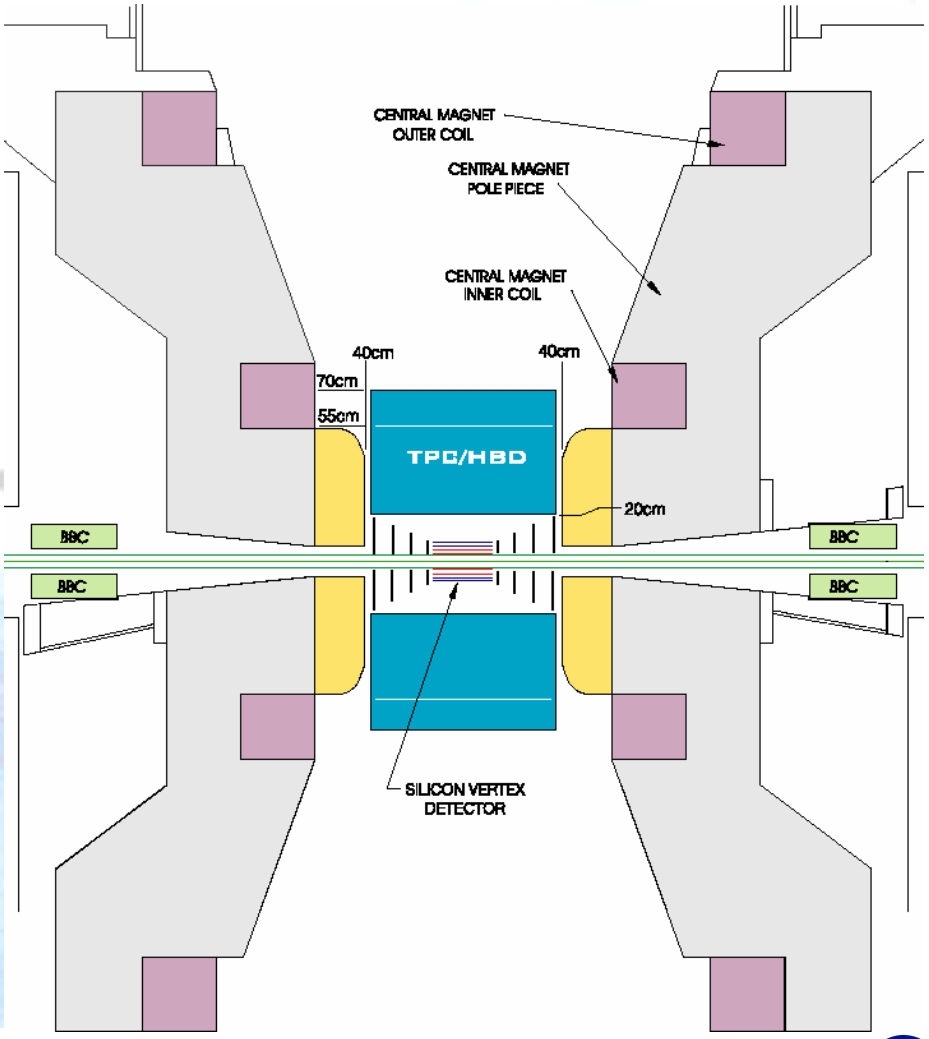


➔ Local polarimeter at PHENIX

- ZDC + position sensitive counters to measure the neutron A_N
- 8-ch hodoscopes for both X- and Y-directions at the shower maximum position of the ZDC (between 1st and 2nd modules)

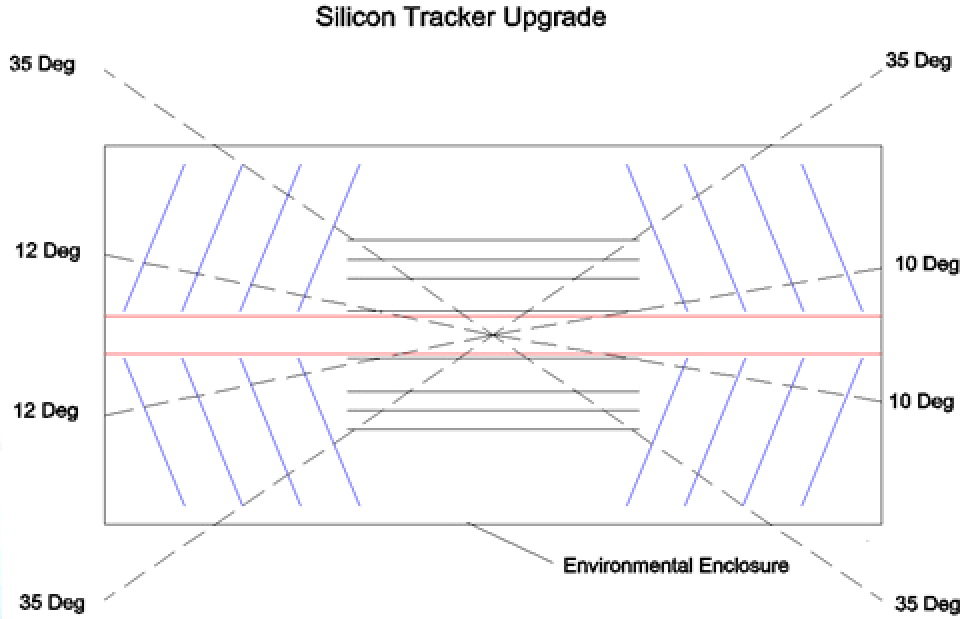
PHENIX upgrade plan

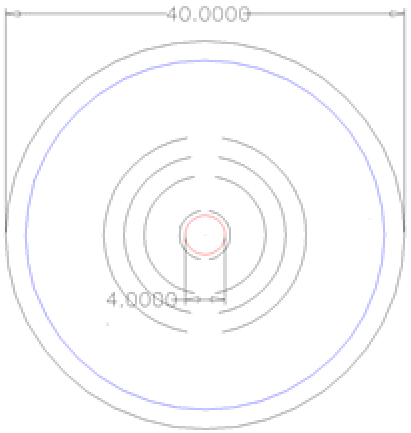
- 2004-2005 and beyond …
  - full luminosity
    - 800pb^{-1} at $\sqrt{s}$=500GeV
    - 320pb^{-1} at $\sqrt{s}$=200GeV
  - A_{LL} of direct photon
  - A_{LL} of heavy flavor
- Upgrades
  - silicon vertex tracker
  - W-trigger
  - TPC/HBD for low mass electron-pair measurement
  - aerogel Cherenkov detector
  - DAQ upgrade



PHENIX upgrade plan

- Silicon vertex tracker
  - straw-man design





  - barrel: 4 layers
    - $|h| < 1$ & $\Delta\phi \sim 2\pi$
    - 1 pixel layer + 3 strip layers (or 2 pixel layer + 2 strip layers)
  - endcap: 4 layers
    - to match with muon arms

PHENIX upgrade plan

- Heavy flavor
  - identifying displaced vertex
  - open charm in the endcap

$$D \rightarrow m + X$$

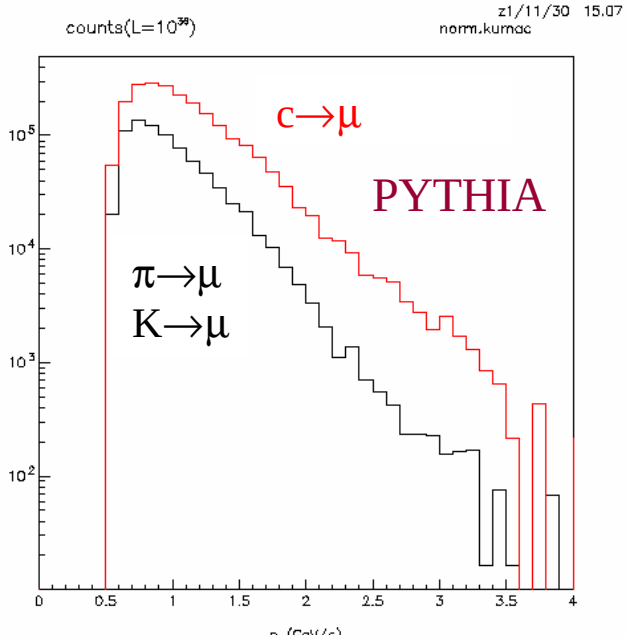
    - muon displaced vertex: $\sigma_z \sim 100\ \mu m$
  - open bottom in the endcap

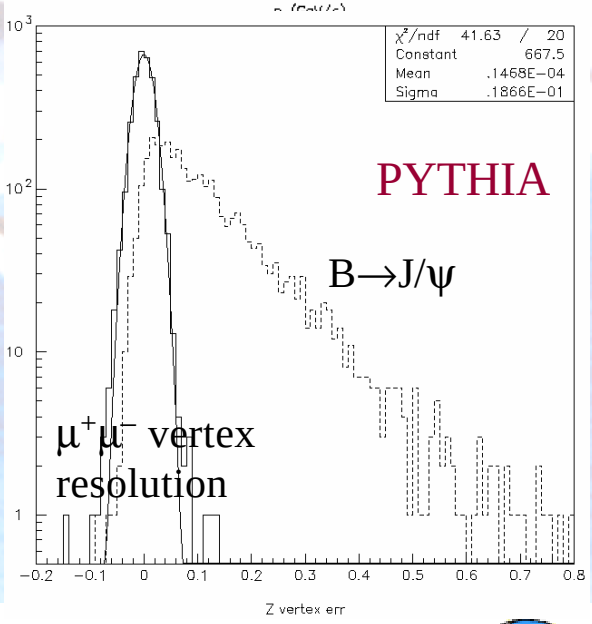
$$B \rightarrow J/y \rightarrow m^+ m^-$$

  - open bottom in the barrel

$$B \rightarrow J/y \rightarrow e^+ e^-$$

    - electron displaced vertex: $\sigma_{DCA} < 50\ \mu m$ (DCA: distance of the closest approach) at $p_T > 1$ GeV/c

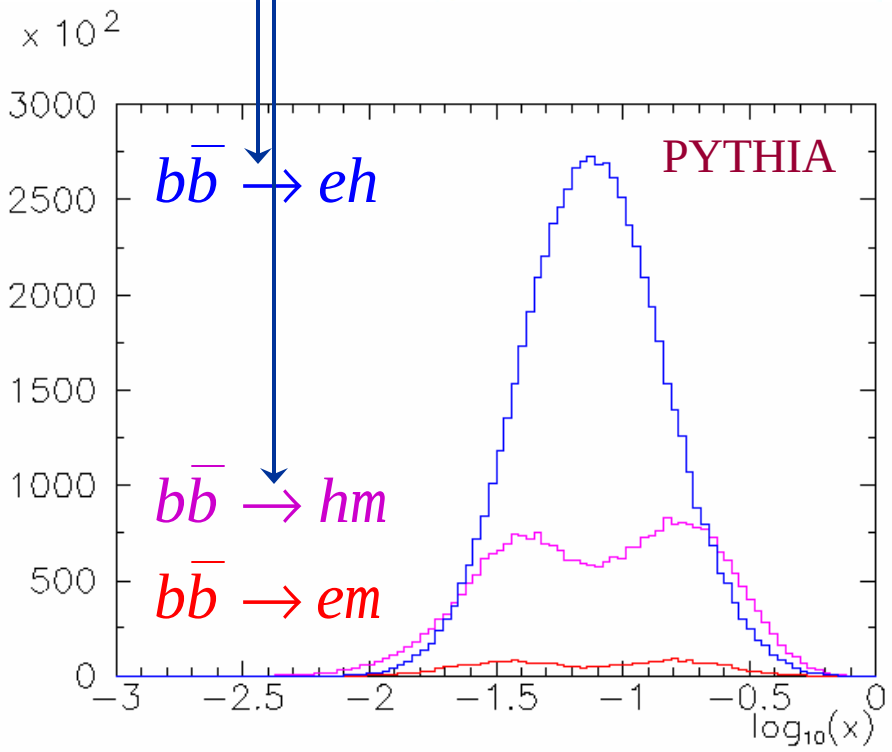




PHENIX upgrade plan

- Heavy flavor
  - bottom-pair measurement
  - extension of e-μ coincidence
    - μ + displaced vertex
      - statistics: × 30 ??
        - » branching: × 10
        - » acceptance: × 6
        - » efficiency: × 0.5
    - e + displaced vertex
  - higher statistics
  - cleaner channel

× displaced vertex cut efficiency should be applied (× 0.5 ?)



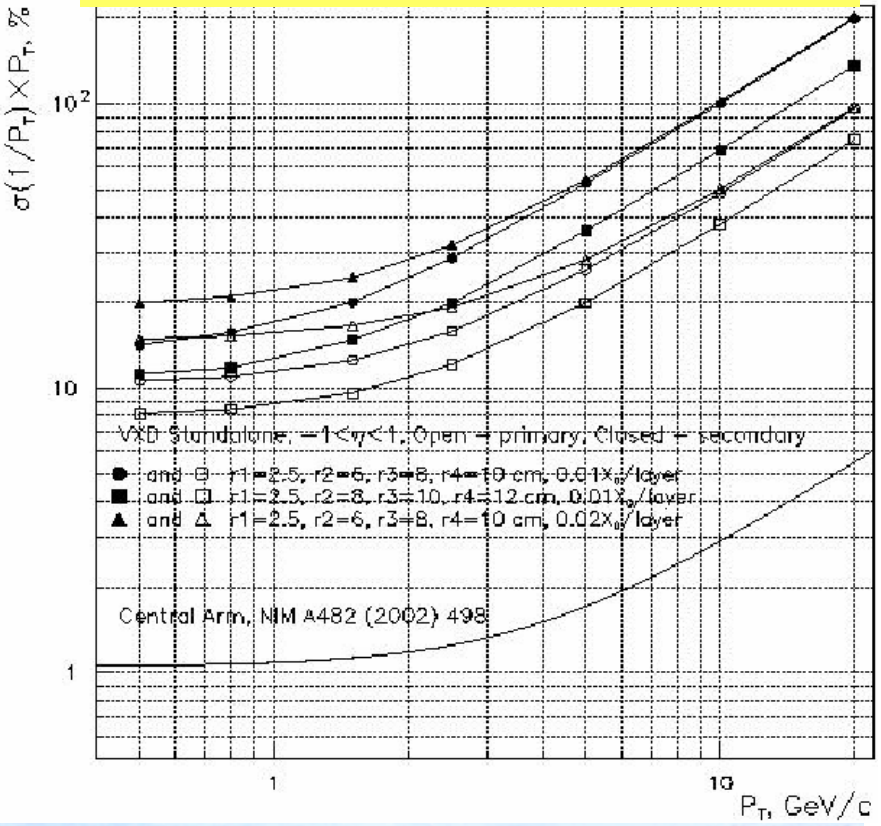
PHENIX upgrade plan

- Photon+jet
  - photon detected by EMCal: $|h| < 0.35$
  - jet detected by silicon tracker
    - $|h| < 1$ with barrel only

    ➔ wider with endcap, too …
  - momentum resolution
    - ~10- 20 % at p_T = 0.5 – 1 GeV/c
    - ~50-100% at p_T = 10 GeV/c

    ➔ improves with TPC …
  - optimizing to find jet axis well enough …

momentum resolution at B = 9 kGauss



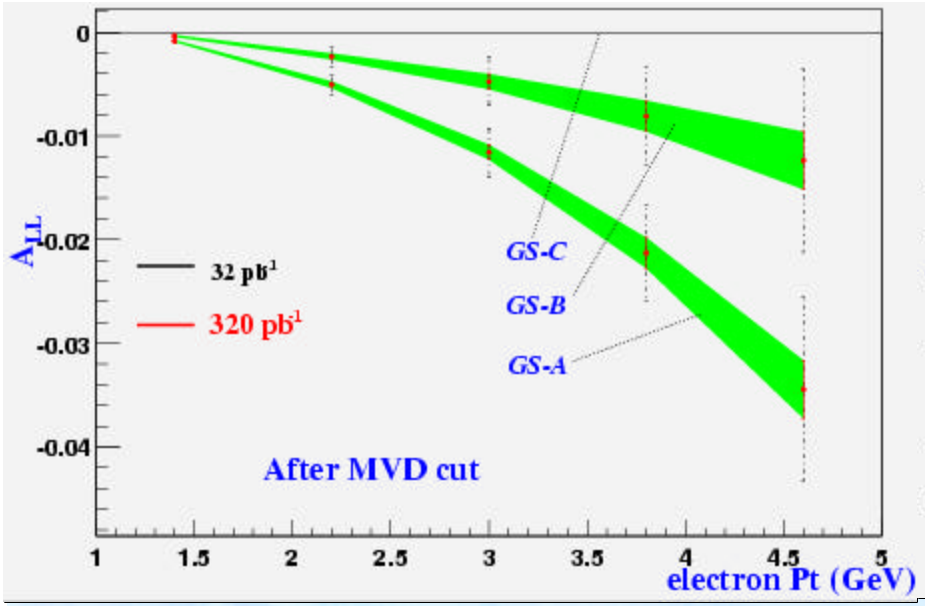
Summary

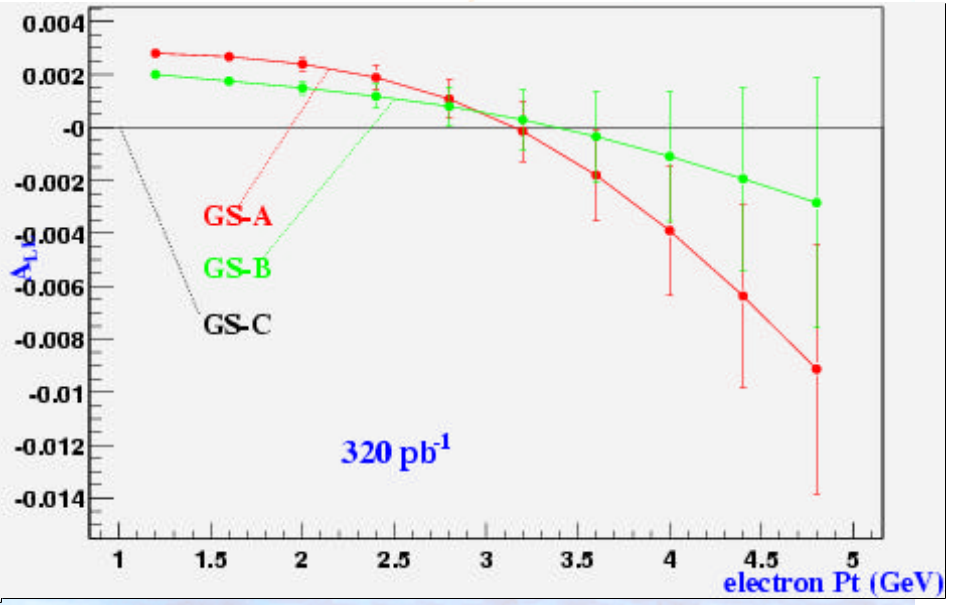
- Very successfully in 2001-2002
  - highly selective trigger for spin physics
  - p_T spectrum of π^0 described well by pQCD
- Analysis of many A_N measurements are ongoing
  - p^0, J/ψ, charged hadrons, single muon, …
- Preparation for the gluon polarization measurements is going very steadily
  - development of relative luminosity monitor, local polarimeter, …
  - for next runs
- Further upgrade plans are also going …
  - for full luminosity runs …

Gluon polarization measurement

- Heavy flavor
  - single-electron
    - background from conversion and p^0 Dalitz decay

K. Barish / W. Xie





background rejection with MVD
(multiplicity vertex detector)

background selection with MVD
to study jet asymmetry

2001-2002 run

- A_N measurement at IP12