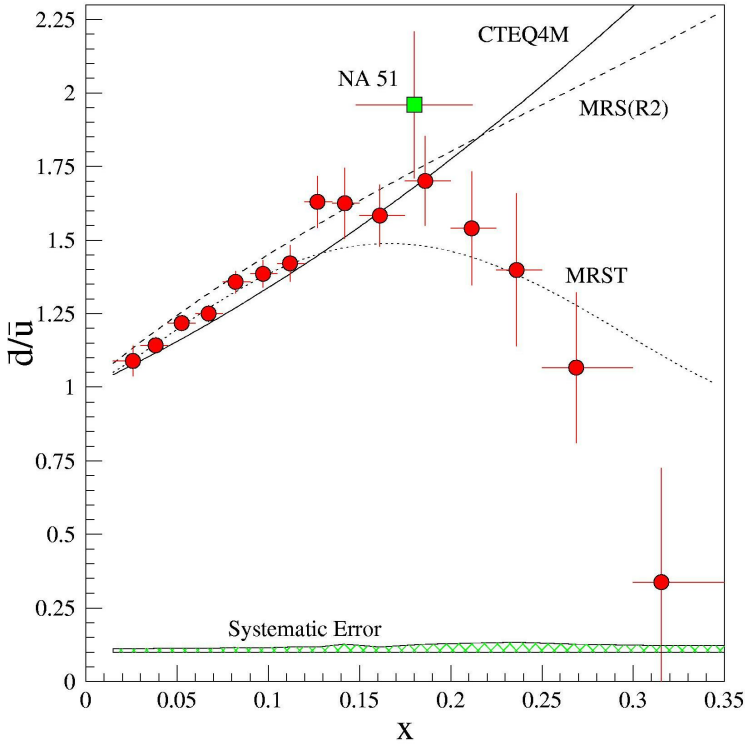
RHIC/HENP Physics Program at LANL

Parton structure, modification in nuclei, spin-dependence and the Quark Gluon Plasma(QGP):

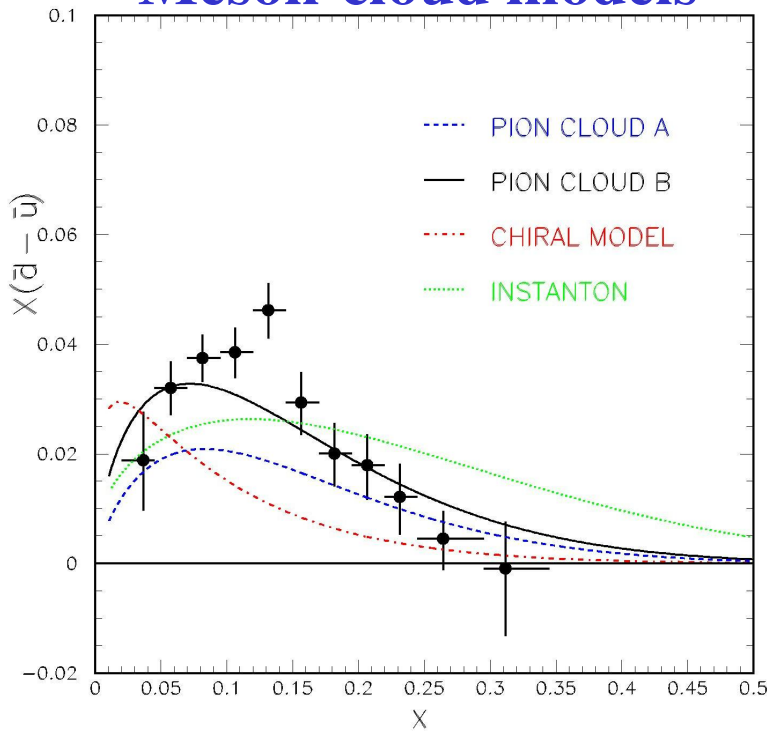
- Flavor asymmetry of the nucleon sea and its spin-dependence; origins from meson-cloud of the nucleon
- Gluon structure functions, their shadowing in nuclei and spin-dependence
- Energy loss & fragmentation of partons (light & heavy) in nuclei to elucidate the parton dynamics of these processes. Contrast with same in hot/high-density matter.
- Heavy-quark (open and closed-c,b) production and suppression in cold nuclei & in QGP.
- Characteristics of heavy-ion collisions through charged particle multiplicities, reaction plane measurements, etc.

Flavor Asymmetry of the Nucleon Sea

FNAL E866/NuSea



Meson-cloud models



Also FNAL E906 – extension of flavor asymmetry measurement to x > 0.2 with high precision

From Draft NSAC Long Range Plan :
"The Structure of the Nuclear Building Blocks"

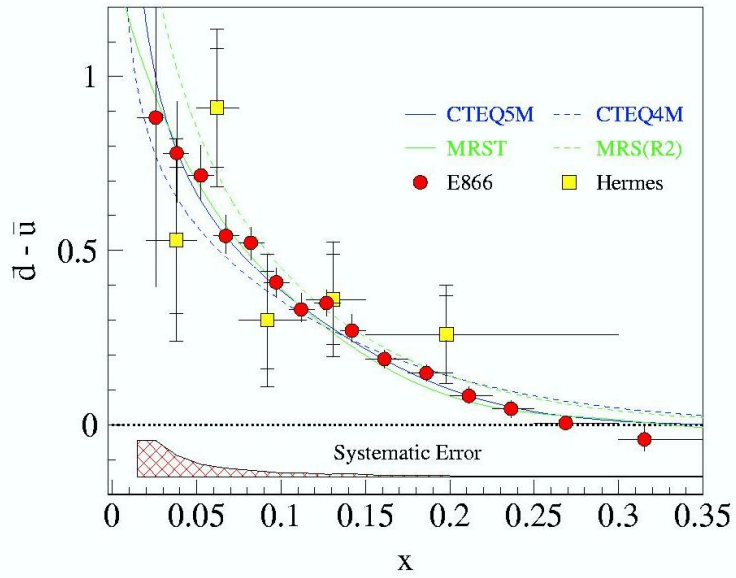


Figure 5: $\bar{d}(x) - \bar{u}(x)$ from E866 and HERMES are shown versus x. Parameterizations from various parton distribution functions are also shown.

Considerable new insight has been obtained into the quark structure of the proton. One of the most dramatic results came from a measurement carried out by nuclear physicists at the FNAL proton accelerator; it showed (see Fig. 5) that the distribution of up-antiquarks ($\bar{u}$) differs from the distribution of down-antiquarks ($\bar{d}$). Since the perturbative gluon radiation mechanism produces equal numbers of $\bar{u}$ and $\bar{d}$ quarks, it was often assumed that these distributions were identical. This result demonstrates that the proton cannot simply be thought of as a collection of three valence quarks and glue at any scale. The non-perturbative nature of QCD is essential in understanding the antiquark distributions, and the results are most easily interpreted at the hadronic level, where a proton spends part of its time as a fluctuation into a neutron and a π^+, which contains an extra $\bar{d}$ quark. These experiments have a direct bearing on other studies of the sea of quark-antiquark pairs, for example the sea of strange quarks that are studied in parity-violating electron scattering.

J.C.Peng, LANL

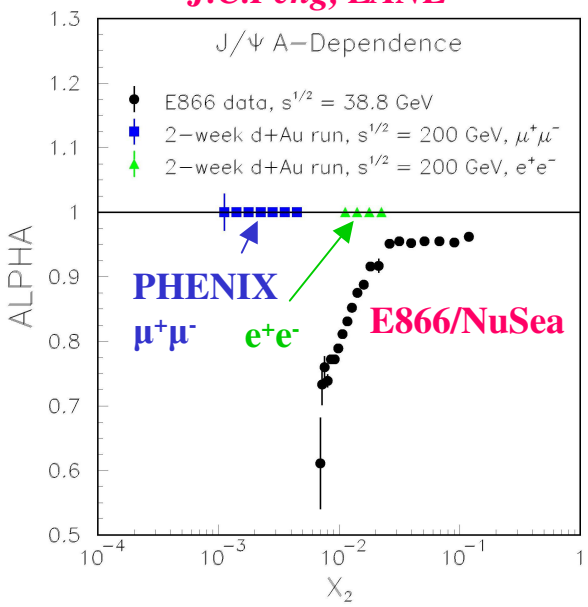
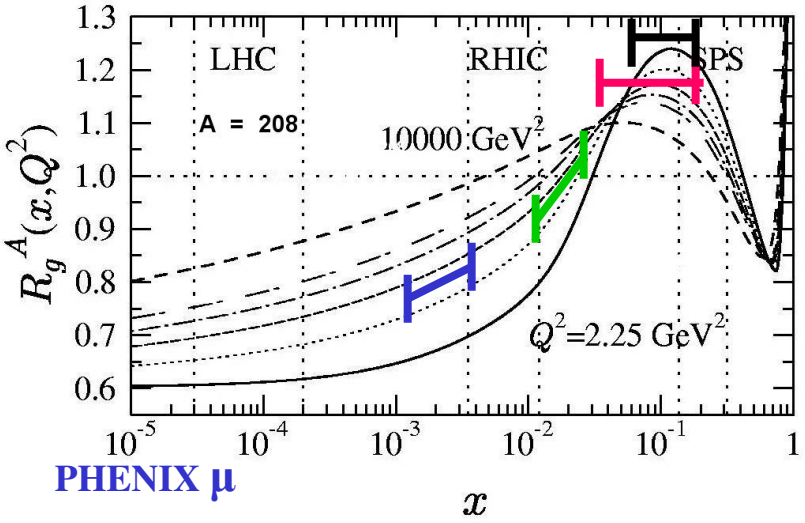


Figure 7: Expected statistical accuracy for measuring the nuclear dependence parameter α from a two-week d+Au run at PHENIX. Data from a fixed-target experiment [6] at $s^{1/2}$ = 38.8 GeV are also shown.

Eskola, Kolhinen, Vogt hep-ph/0104124



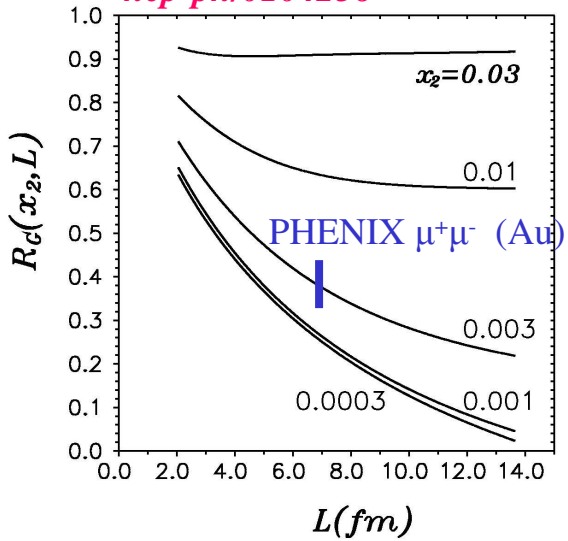
PHENIX μ

PHENIX e

E866 (mid-rapidity)

NA50

Kopeliovich, Tarasov, & Hufner hep-ph/0104256



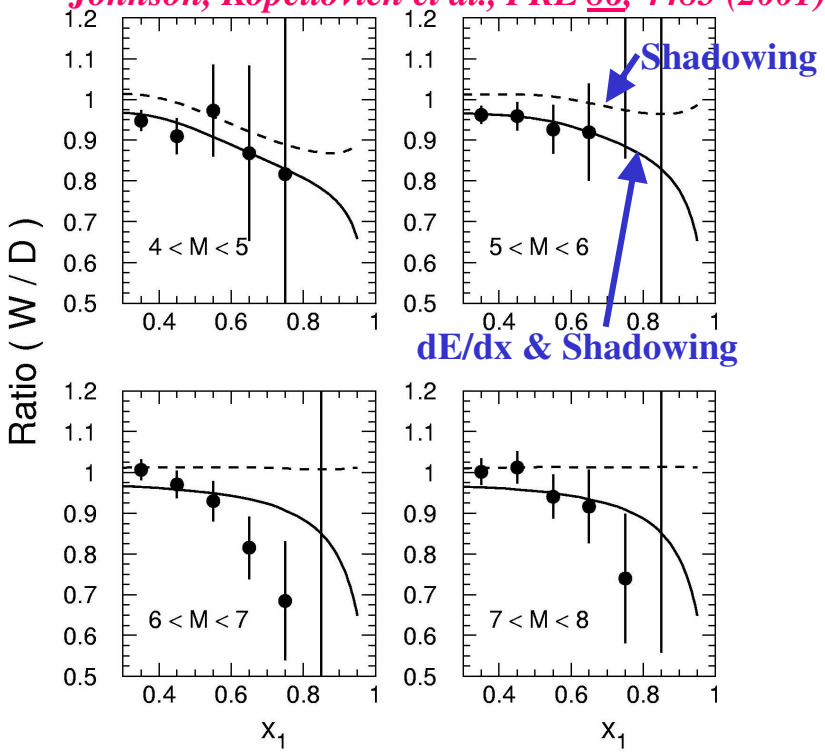
Gluon Structure Functions

Shadowing for J/Ψ's in PHENIX μ acceptance for Au-Au collisions?

•Large uncertainty: *Eskola…* : ~ 0.8 vrs *Kopeliovich…* : ~ 0.4 -> must be measured

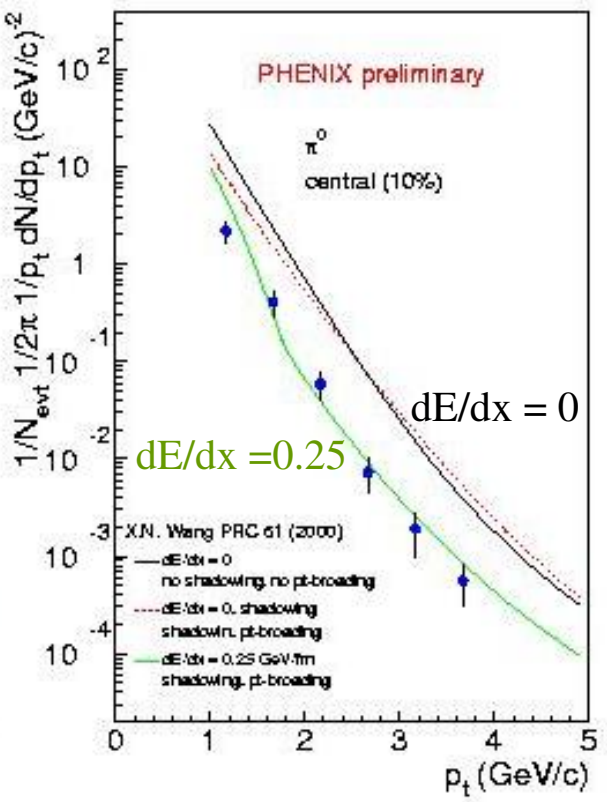
Quark energy loss in nuclear matter

Johnson, Kopeliovich et al., PRL 86, 4483 (2001)



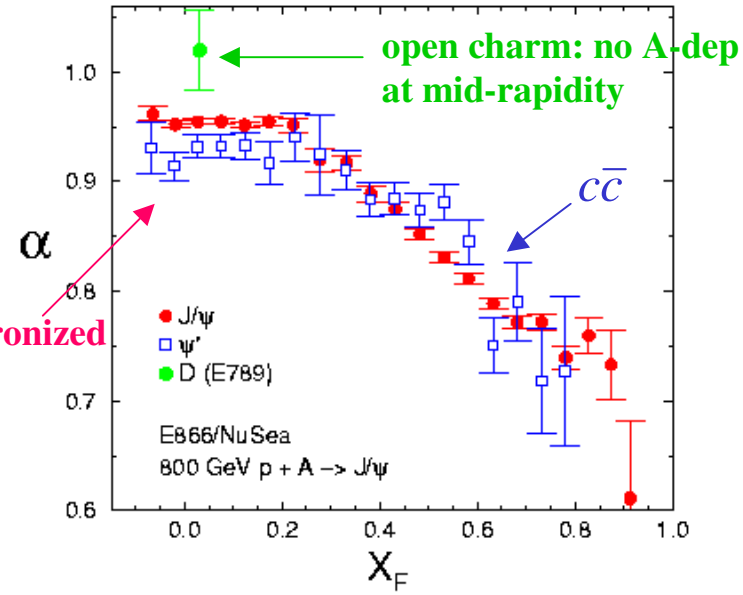
Analysis of our p-A Drell-Yan data (*E772 - PRL 64, 2479 (1990)* using the Kopeliovich model. Dashed lines with shadowing only; solid lines with parton energy loss of,

dE/dz = 2.32 ± 0.52 ± 0.5 GeV/fm



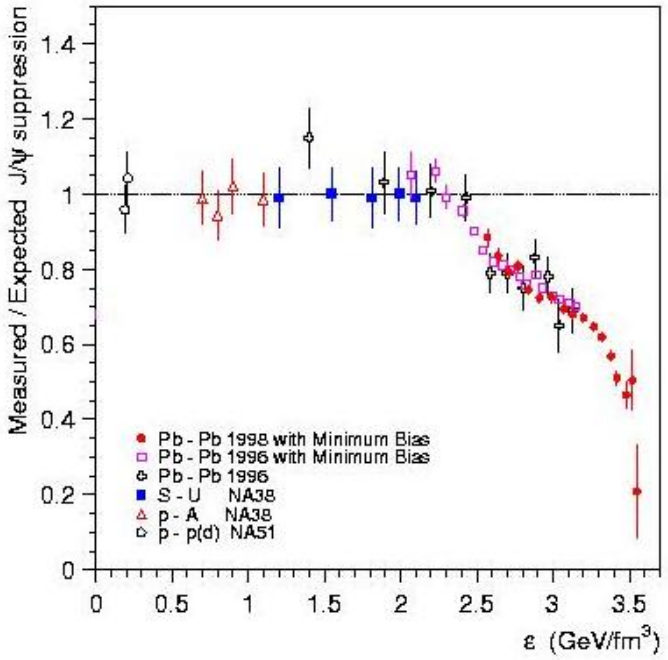
Charged hadron and π^0 production at PHENIX versus p_T for central collisions which, when compared to pQCD models that work well for peripheral collisions, suggests that jet-quenching or energy-loss may be present.

Nuclear Dependence of Charm Production: E866/NuSea



- **J/Ψ and Ψ' similar at large x_F where they both correspond to a $c\bar{c}$ traversing the nucleus**
- **but Ψ' absorbed more strongly than J/Ψ near mid-rapidity (x_F ~ 0) where the resonances are beginning to be hadronized in nucleus.**

NA50 -- Anomalous J/Ψ suppression. Evidence for QGP??

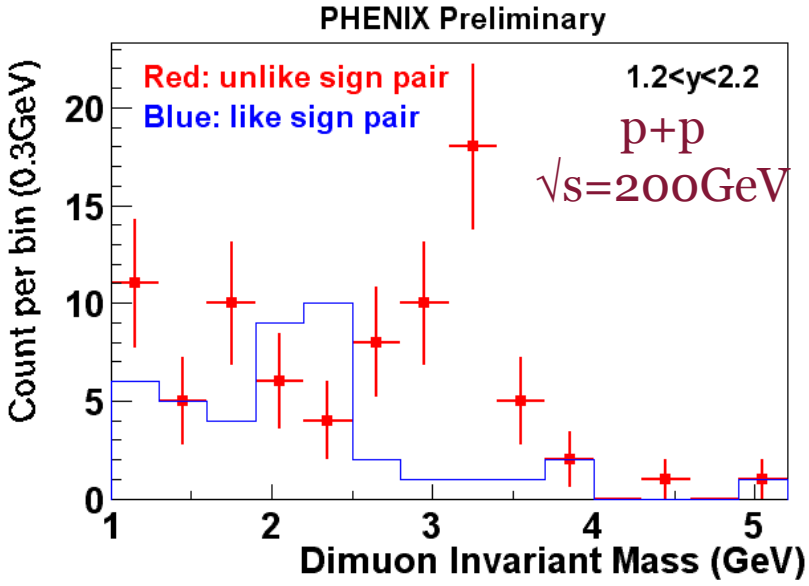


- **We need a comprehensive understanding of charmonium production in nuclei**
- **Competing effects may be identified in p-A collisions by their strong kinematic dependencies, together with complementary studies of Drell-Yan scattering and open-charm production**

$p+p \rightarrow J/\psi \rightarrow \mu^+\mu^-$

$$B_r \left.\frac{d\sigma_{J/\psi}}{dy}\right|_{y=1.7} = \frac{N_{J/\psi}}{A_{cc}\varepsilon_{reco}\varepsilon_{BBC}^{J/\psi} L\Delta y}$$

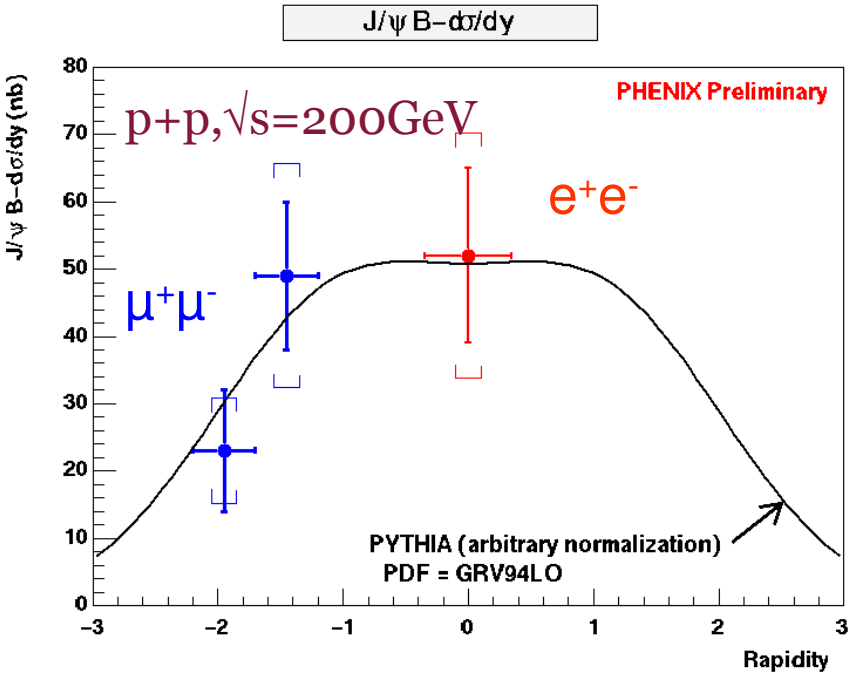
- $N_{J/\psi} = 36 \pm 7$ (stat.) ± 4 (syst
- $A_{cc}\varepsilon_{reco} = 0.0163 \pm 0.031$
- $\varepsilon_{BBC}^{J/\psi} L = 0.60 \pm 0.12$ nb^{-1}
- Δy: rapidity coverage = 1.0

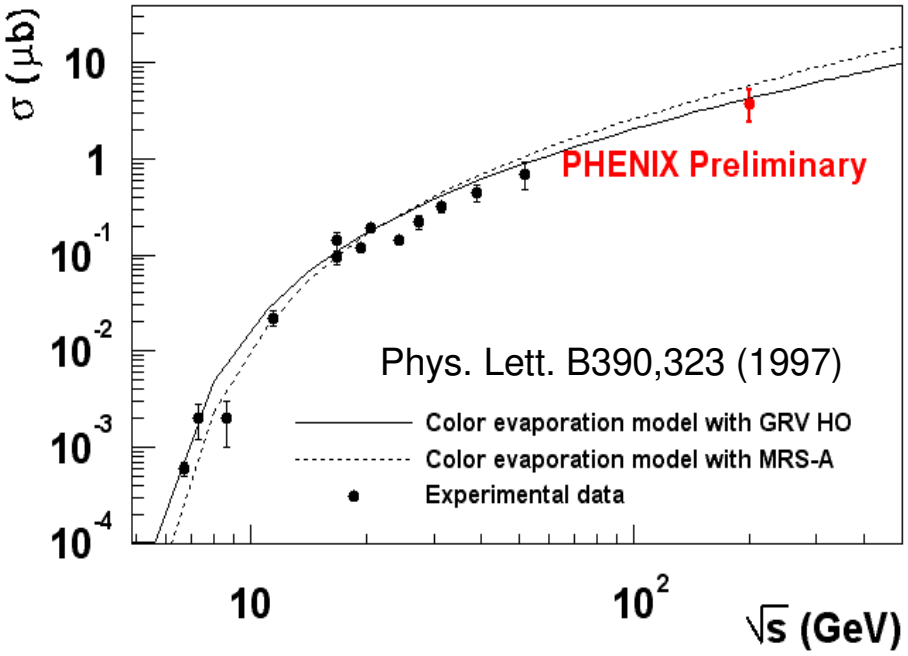


Br $(J/\psi \rightarrow \mu^+\mu^-)$ $d\sigma_{J/\psi}/dy|_{y=1.7.} = 37 \pm 7$ (stat.) ± 11 (syst.) nb

PHENIX Preliminary

$\sigma(p+p \rightarrow J/\psi X)$

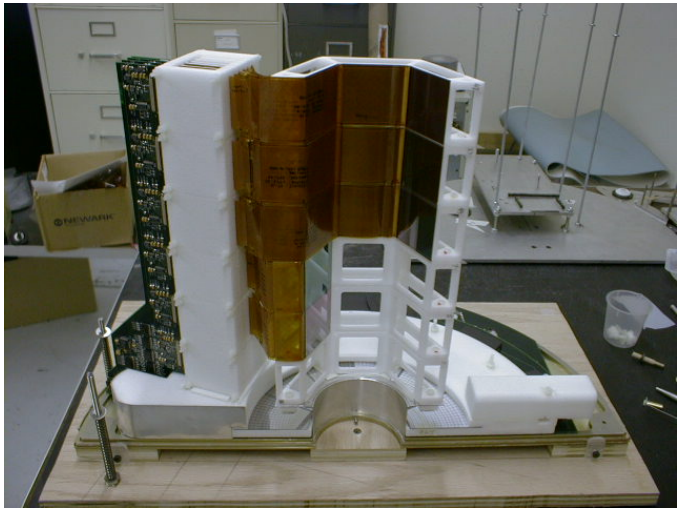




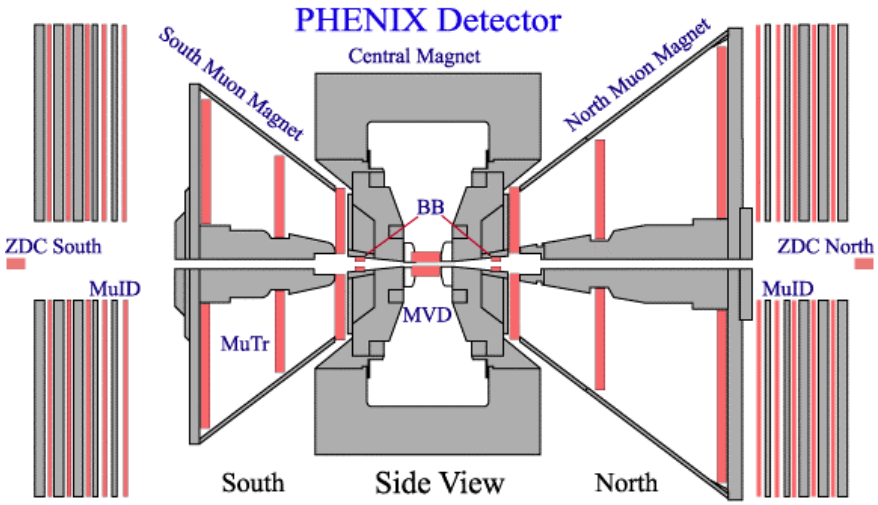
Rapidity Fit gives

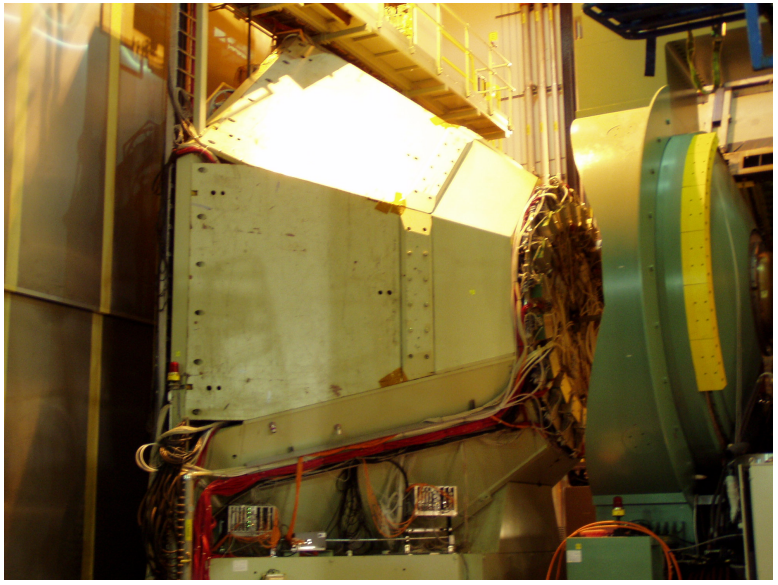
Br ($J/\psi \rightarrow l^+l^-$) σ ($p+p \rightarrow J/\psi X$)
= 226 ± 36 (stat.) ± 79 (syst.) nb
σ ($p+p \rightarrow J/\psi X$)
= 3.8 ± 0.6 (stat.) ± 1.3 (syst.) μb

- Our result is consistent with $\sqrt{s}$ scaling from lower energy results

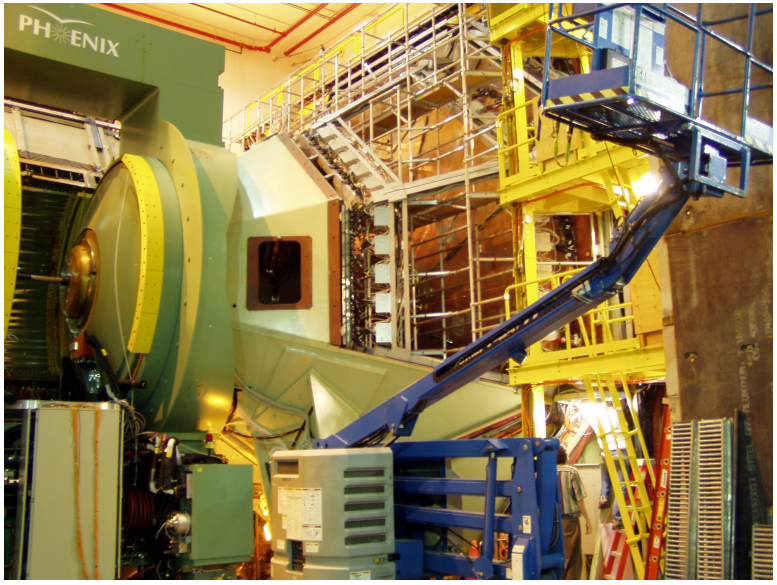


MVD





South Muon Arm



North Muon Arm

LANL Contributions to PHENIX & Obligations

- Defined much of the physics program for PHENIX muons and spin & major contributors to PHENIX CDR
- Led in getting the muon arms into PHENIX & conceived the spin program including bringing the Japanese (RIKEN) group into RHIC.
- Physics-based design & construction of Muon spectrometers & MVD in PHENIX
- Continuing Obligations:
  - Finish construction & commissioning (MVD & Muon Arms) (2002-3)
  - Shifts, physics leadership and analysis; talks, EC, DC, PWG's.
  - Analysis tools
  - Maintenance
    - with strong French contribution for muon electronics
    - For MVD; lifetime limited by plans for silicon vertex detector (<= 2005?)
  - Other upgrades, e.g. de-multiplexing muon electronics, scintillator additions to muon spectrometers to allow higher-rate triggering, …?
- Future silicon vertex upgrade still under exploration

Current Activities

- Completing construction of North muon arm and MVD
  - **North muon arm close-up ~ Oct. 23**
  - **MVD installation ~ Nov. 11**
- Commissioning of above and data taking
  - **Run-III: d-Au ~ Jan. 1 (11 wks); p-p ~ Apr. 7 (3 wks)**
  - **Shifts, sub-system experts on call (MVD, MuTr), period coordinators, …**
  - **Luminosity targets are sufficient to get, e.g. ~ 10k (d-Au) J/Ψ's**
- Planning for Run-III, e.g. triggering
- Continuing development of analysis tools & analysis of data to physics
- Detector Council reps (MVD & MuTr); PHENIX Executive Council (MJL); Muon software lead, Physics Working Groups (PWG's), …
- Silicon vertex upgrade design & construction (LDRD seeded, R&D funding requested); focus on conceptual/engineering design & in next year.

Resources in RHIC/HENP Program

- ~7.3 FTE effort (1 of this open-charm LDRD) + 1 PD + Engineering (.35)
  - Brooks(.9), Lee, Leitch, Liu, McGaughey, Sullivan(.75), VanHecke
  - Barnes(.4), Moss(.25); Silvermyr (PD)
  - Sondheim(.25), Boissevain(.1) (Engineers)
- Program sub-critical because of loss of Peng, Moss, Garvey, Jacak, Simon-Gillo, Kapustinsky, most of engineering; & only have 1 postdoc. Replaced with only 1.5 FTE (Liu & Barnes) – need to add high-level physics leadership and couple postdocs!!
- Budget ~ $3.06M DOE ($2.2M HI + $.86M HENP) + $240k LDRD
- Flat budget - May be able to add high-level physics leader (TSM) and 2 postdocs on a flat budget (probably ~$150k short to do this?)
- -15% (~$.45M) – lose ability to shore-up sub-critical physics leadership & will lead to death of the program. Jeopardizes our ability to get physics payoff from ~10 years of construction
- +15% - Would assure vigorous future program by adding staff & postdocs at least at the level shown above

Issues & Concerns

- Finally emerging from construction & need to assure a strong leadership in physics. Need good people to do this – e.g. new high-level staff and more postdocs are critical!
- Not visible enough to the community & our sponsors in terms of physics leadership
- Balance with another construction project if silicon-vertex upgrade project takes off?
- Possible implications on the program scope of a new high-level hire?

Backup Slides:

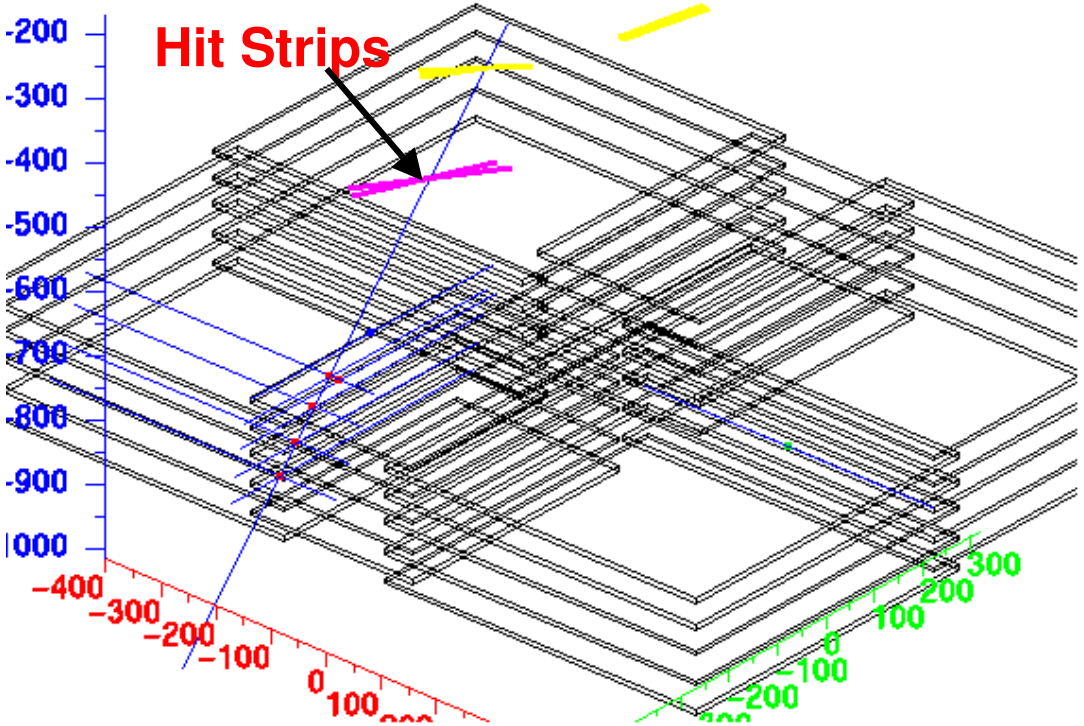
Muon Tracker Responsibilities This Year

- South arm commissioning through this year's run
- Analysis Software oversight and development
- North Arm station 2 and 3 chambers and all associated mechanical structures
- North Chamber Installation
- North FEE (many components not covered by French)
- Support of North FEE Installation
- MuTr Management until Jan '02
- Continued MuTr Mechanics management
- Integration

North arm to be installed this year

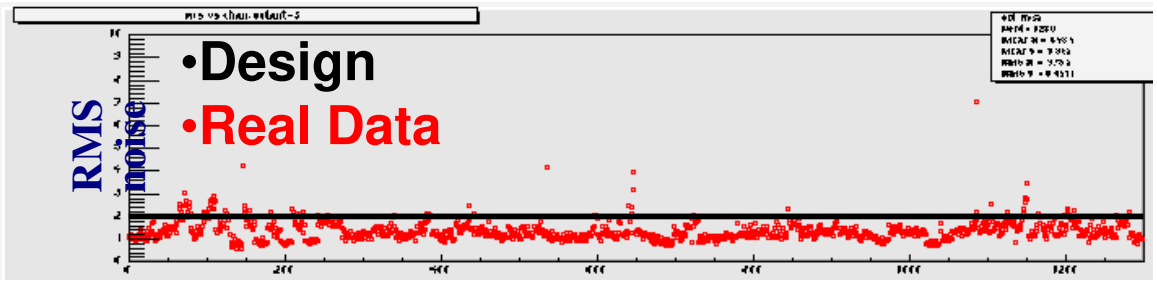
South arm installed last year

South Arm Commissioning and Performance

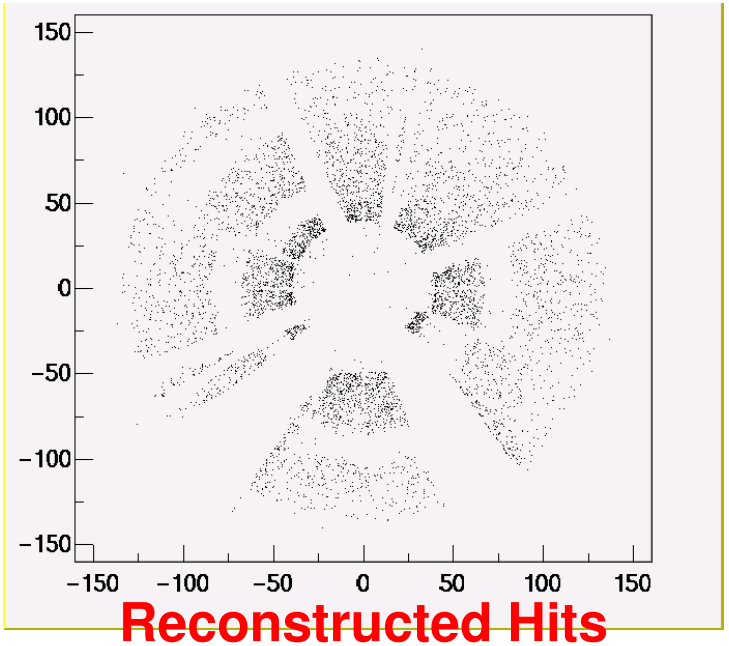


Cosmic event in muon system

- Readout working and cosmic track events seen even prior to collisions
- Design specs for noise largely met (needed to achieve physics design goals)
- Reconstruction at chamber level working well
- Chamber resolution required for first physics analyses achieved
- Full track reconstruction working



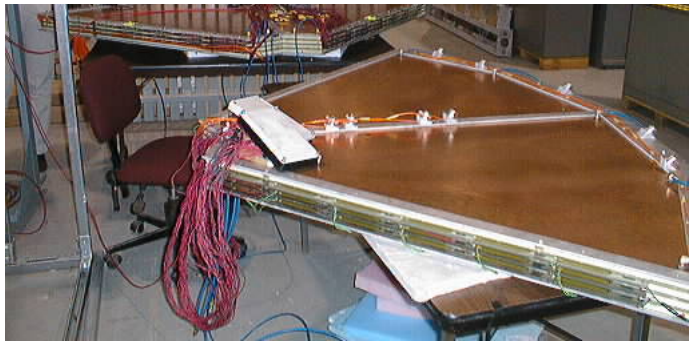
Station 1 Noise levels



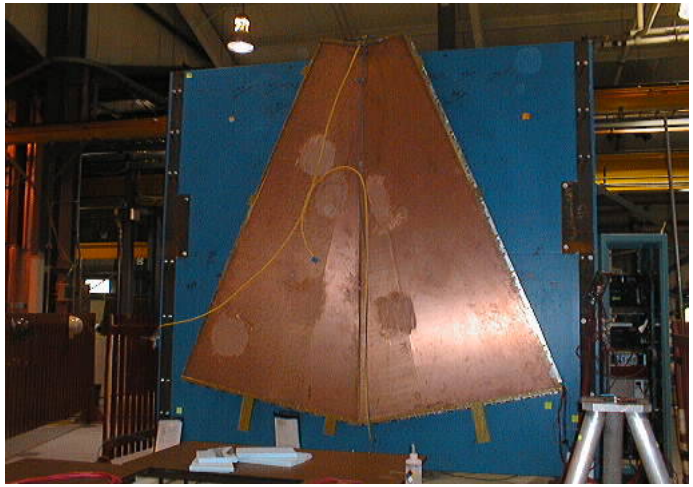
Reconstructed Hits

North Chambers and Mechanics

•Station 2 and 3 chambers built and undergoing final testing and commissioning at BNL
•Chamber support structures in progress
•Installation to begin in April



Station 1 Quadrant at BNL



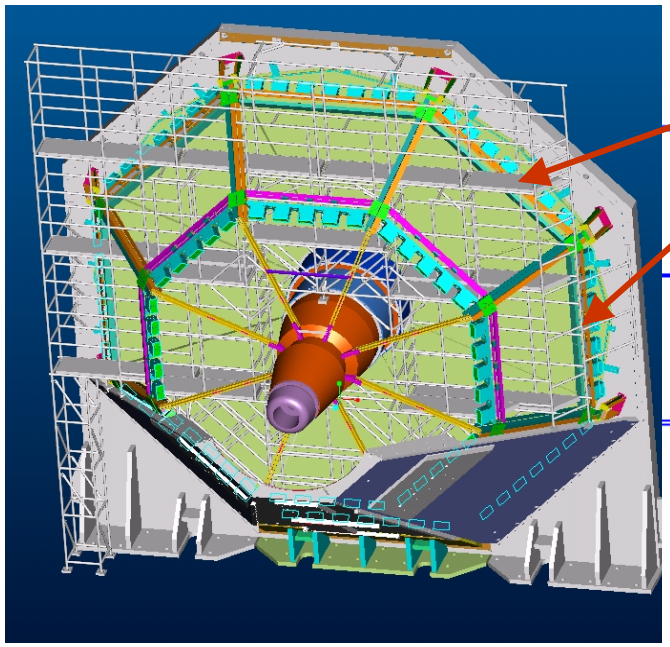
Station 3 Octant at BNL

Station 2 Octant at BNL

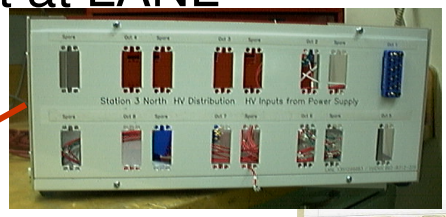
Station 2 Support Structure

North Arm FEE Contributions

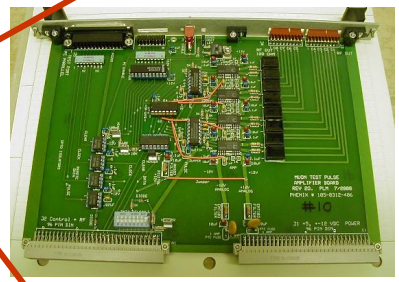
- Mechanical support designed and overseen at LANL, built at NMSU and delivered to BNL
- Calibration system completed and delivered to BNL
- Optical Fiber<-->Copper electronics system completed and delivered to BNL
- HV Distribution system designed and being built at LANL
- Rack and cable layout completed at LANL

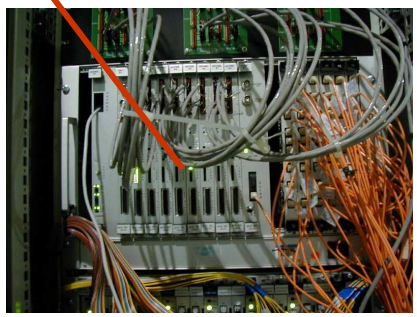


North Magnet Layout and FEE Support Structures

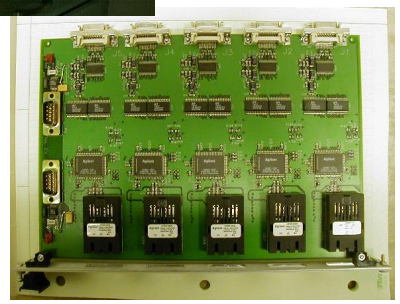


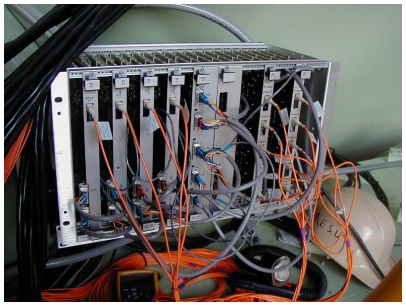
HV dist.





Calibration System





1/10 of Optical ↔ Copper Translation System