PHENIX:
Current Results and Future Capabilities for Heavy Flavor Production in Relativistic Heavy Ion Collisions

Vince Cianciolo (Oak Ridge National Lab),
for the PHENIX Collaboration

ECT* Charm Workshop
17-22 June, 2002

Alternative Title

PHENIX: A Charming Experiment With Beautiful Possibilities

Vince Cianciolo (Oak Ridge National Lab),
for the PHENIX Collaboration

Outline

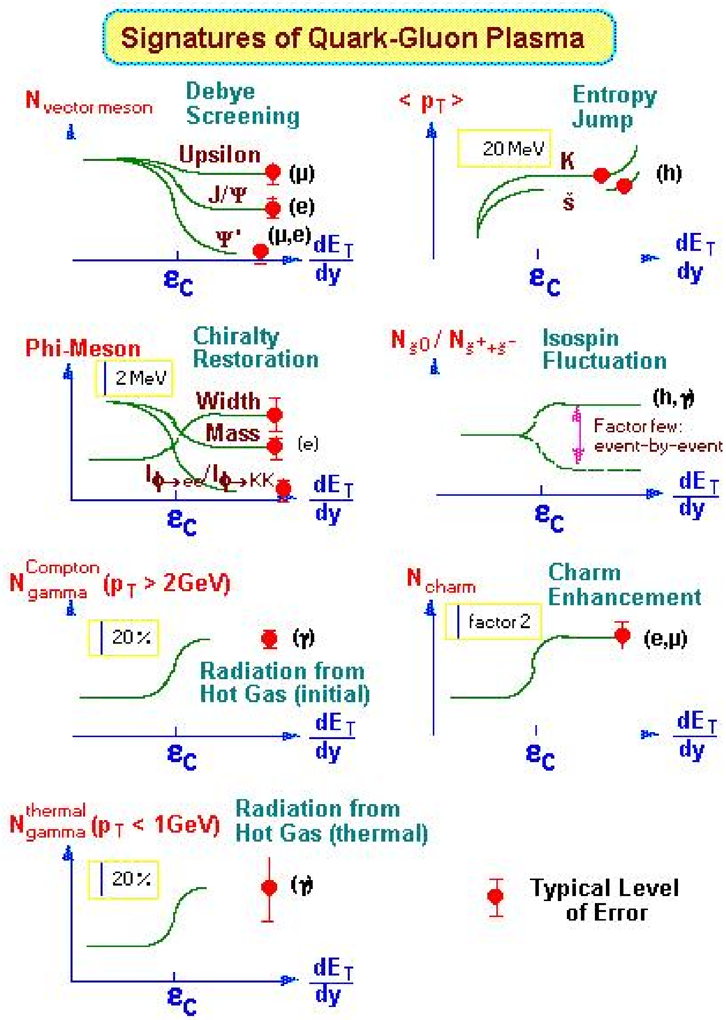
- Why heavy flavor?
- An introduction to PHENIX
- Results from Run-1
- What to expect from Run-2
- Long-term strategy

What's in a Name?

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

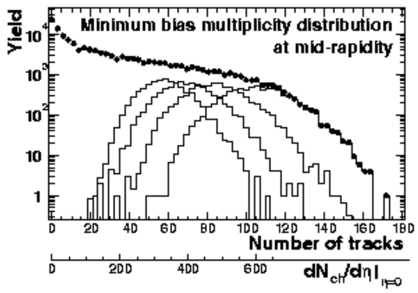
P hotons
H adrons
E lectrons (and Muons)
N uclear
I nteraction
e X periment

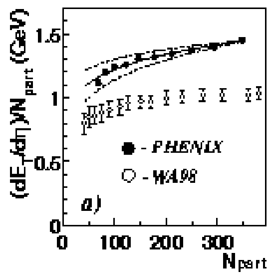
How To Hunt For The QGP?

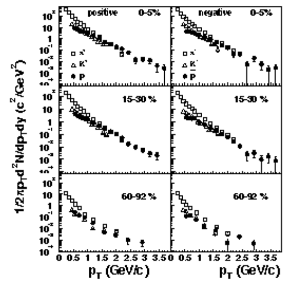


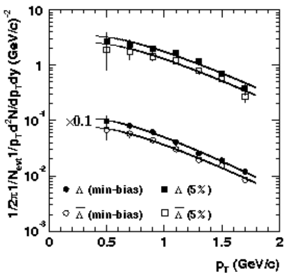
- PHENIX Goal: Measure as many signatures as possible simultaneously vs. several independent variables.

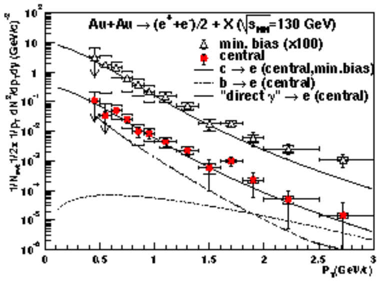
Status Of The Hunt

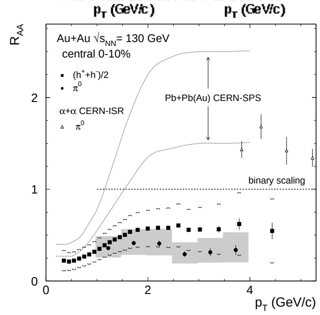


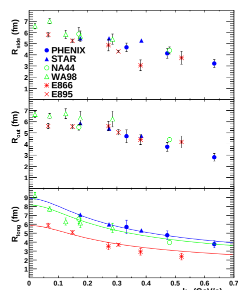


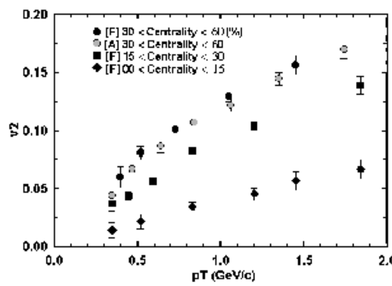




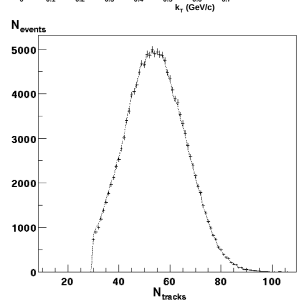


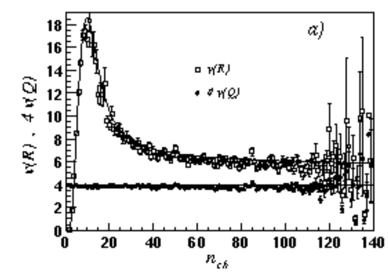






PRL 86 (2001) 3500
PRL 87 (2001) 052301
PRL 88 (2002) 242301
nucl-ex 0204007
PRL 88 (2002) 192303
PRL 88 (2002) 022301
PRL 88 (2002) 192302
nucl-ex/0204005
nucl-ex/0203015
nucl-ex/0203014

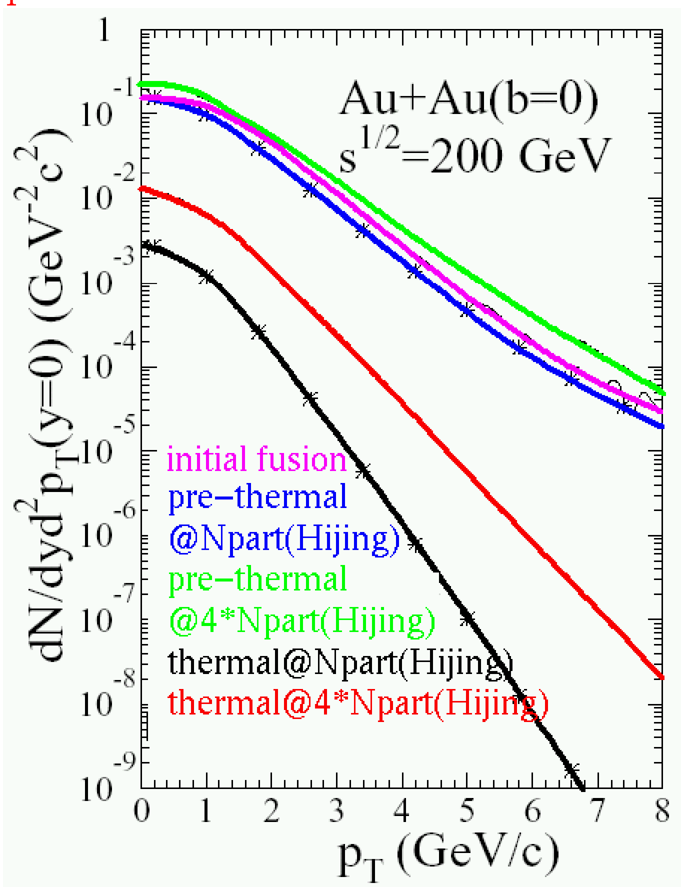




Vince Cianciolo (Oak Ridge National Lab),
for the PHENIX Collaboration
ECT Charm Workshop*
17-22 June, 2002

Why Is Heavy Flavor Interesting?

- Heavy quarks are heavy — so they are reliable probes of early, hard-scattering stages in a collision.
- Pre-equilibrium heavy flavor production probes initial parton densities and equilibration time.



Levai, Muller, Wang PRC 51 (1995) 3326.

Why Is Heavy Flavor Interesting?

- Heavy quarks are heavy - so, they are predicted to have different energy loss characteristics in a QGP.
- This would manifest itself as different quenching behavior *vs.* p_T for heavy and light quarks.

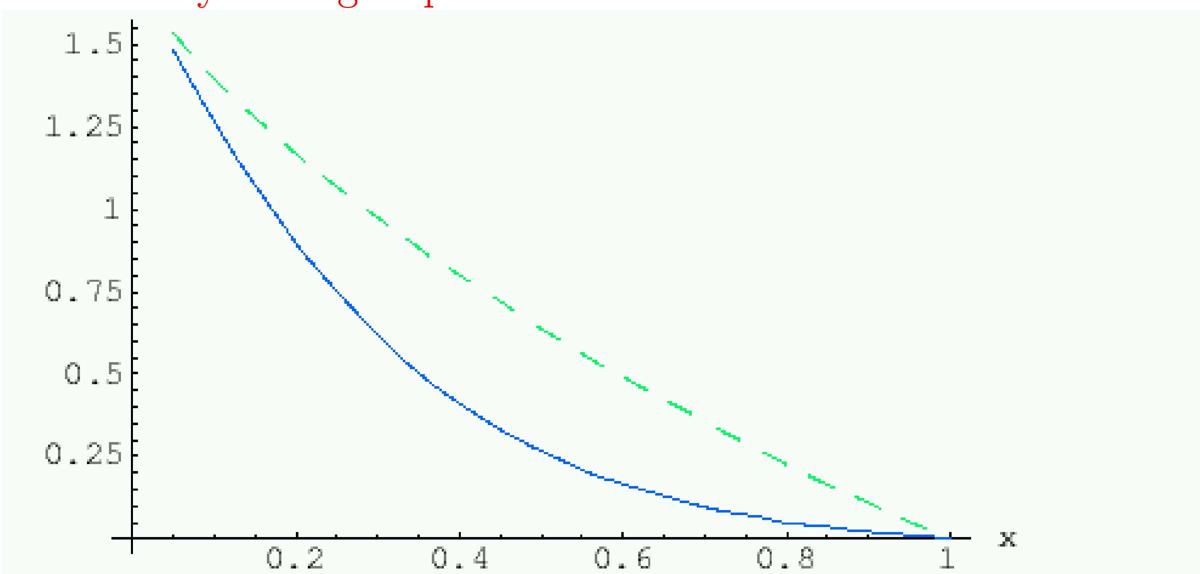
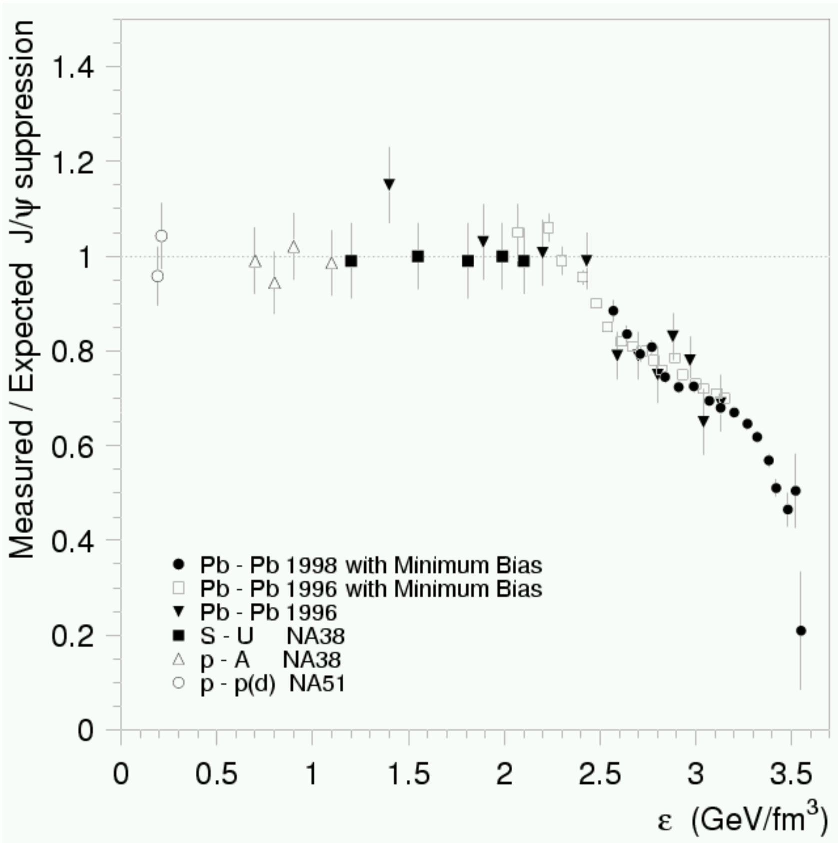


Figure 2: Comparison of energy distributions $\sqrt{x}I(x)$ of gluons radiated off charm (solid line) and light (dashed line) quarks in hot matter with $\hat{q} = 0.2\,\mathrm{GeV}^3$ ($p_\perp = 10\,\mathrm{GeV}$, $L = 5\,\mathrm{fm}$).

Dokshitzer and Kharzeev, Phys. Lett. B519 (2001) 199-206.

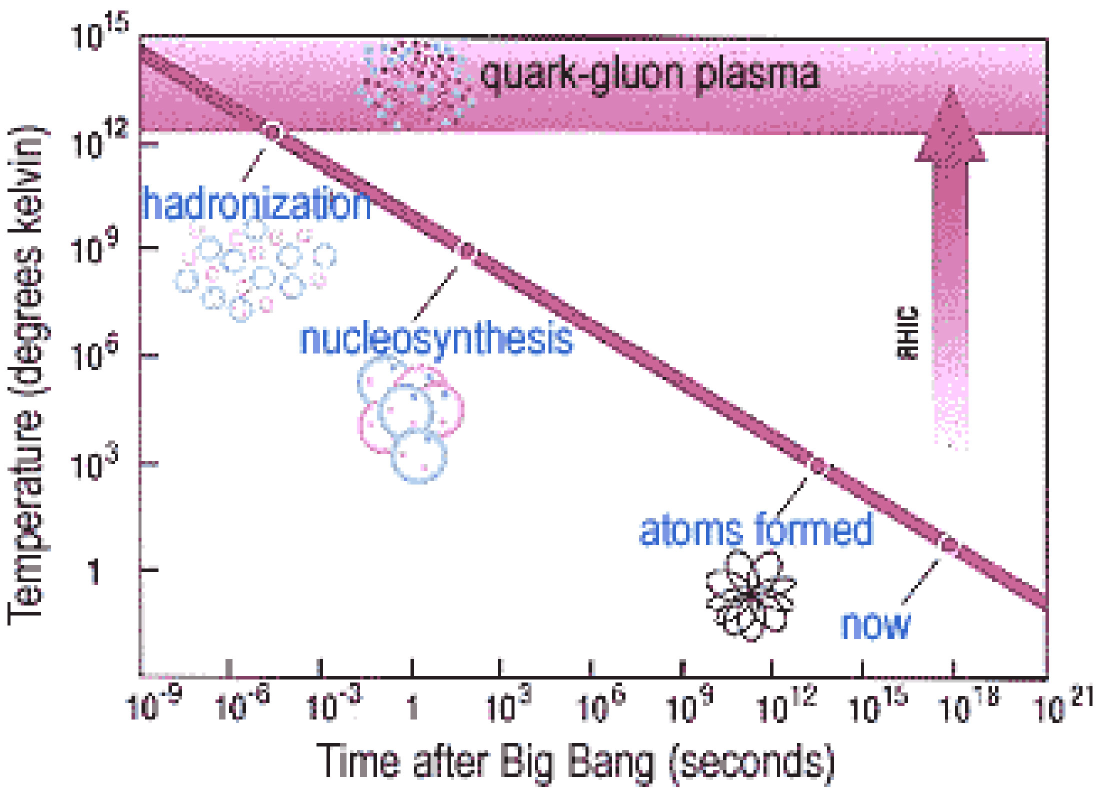
Why Is Heavy Flavor Interesting?



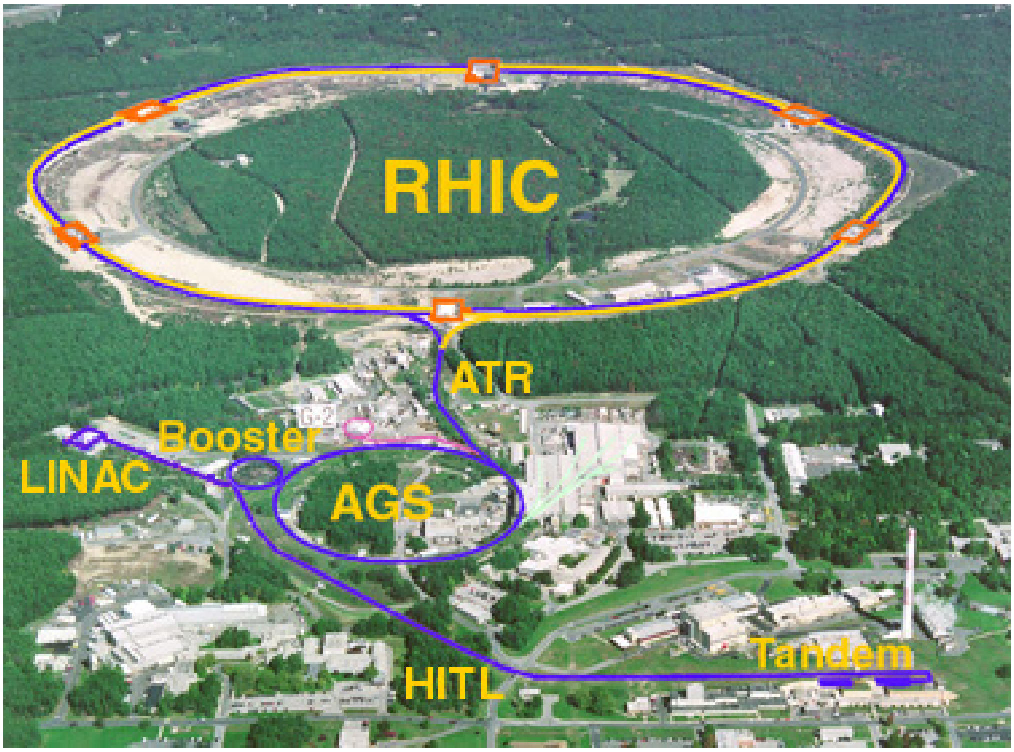
NA50, Phys. Lett. B477 (2000) 28.

- Heavy flavor is needed to form "onia" — one of the marquis signatures of QGP formation.
- Charmonia have been explored at the SPS. At RHIC we will observe production in a wide range of systems and also explore bottomonia production - an important control.

We Need A Time Machine



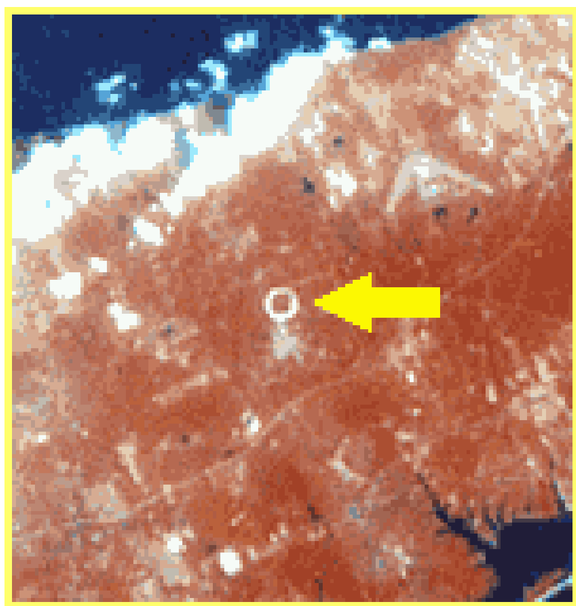
RHIC Is That Time Machine



RHIC designed to take a full systematic measurement set:

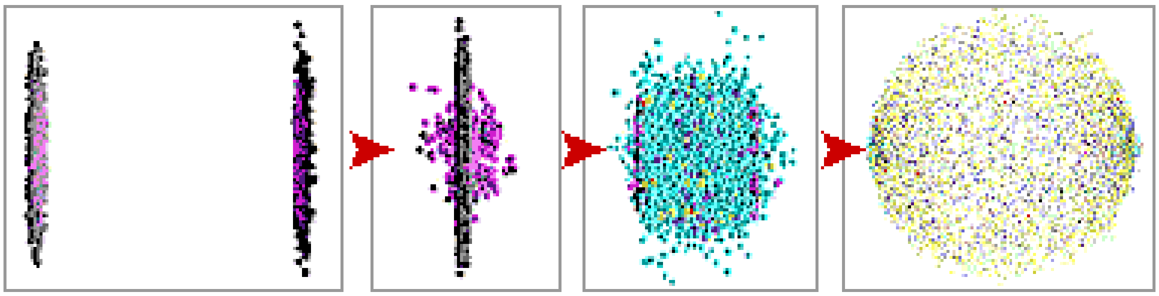
- Capable of pp, pA, AA, where $A \leq 197$.
- $\approx 20 < \sqrt{s_{NN}}\,(\mathrm{GeV}) < 200$ (500 GeV for pp).
- $\mathcal{L}_{AuAu}^{design} = 2 \times 10^{26}\,\mathrm{cm}^{-2}\mathrm{sec}^{-1}$ ($\mathcal{L}_{AuAu}^{RHIC-II} = 7 \times 10^{27}\,\mathrm{cm}^{-2}\mathrm{sec}^{-1}$)
- $\mathcal{L}_{pp}^{design} = 5.6 \times 10^{30}\,\mathrm{cm}^{-2}\mathrm{sec}^{-1}$ ($\mathcal{L}_{pp}^{RHIC-II(200GeV)} = 1.6 \times 10^{32}\,\mathrm{cm}^{-2}\mathrm{sec}^{-1}$)

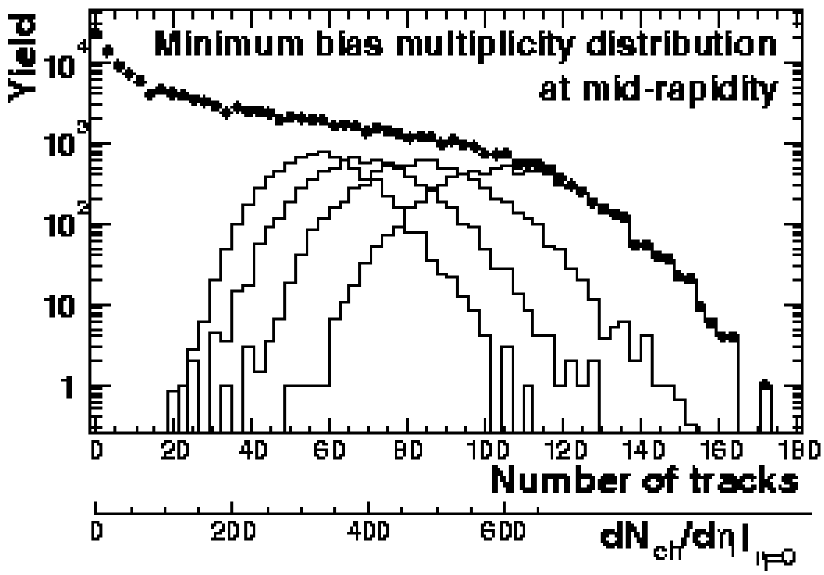
RHIC Is BIG



Vince Cianciolo (Oak Ridge National Lab),
for the PHENIX Collaboration

Needles In A Haystack

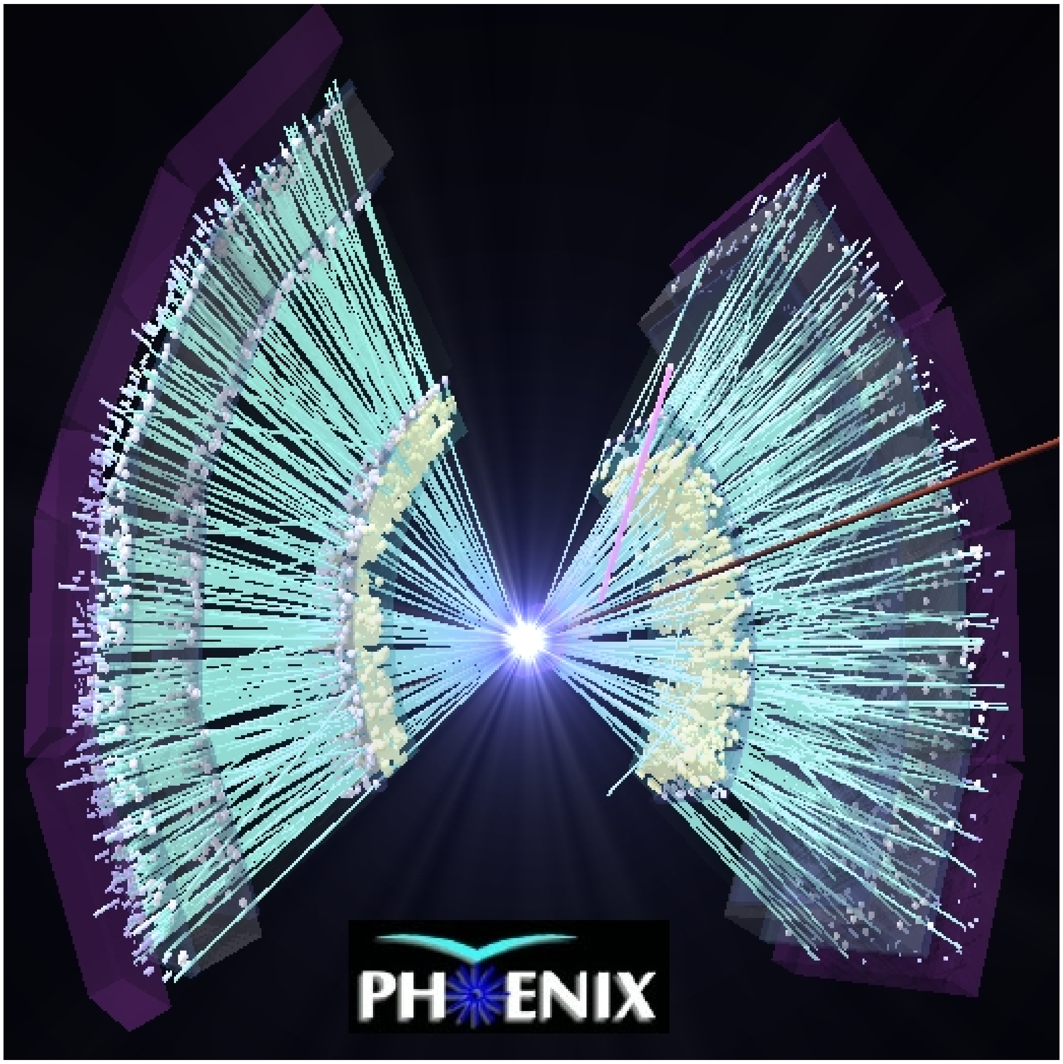




PRL 86 (2001) 3500

- That's 160 tracks into half ($\delta\phi = \pi/2$, $|\eta| < 0.35$) of the PHENIX acceptance!

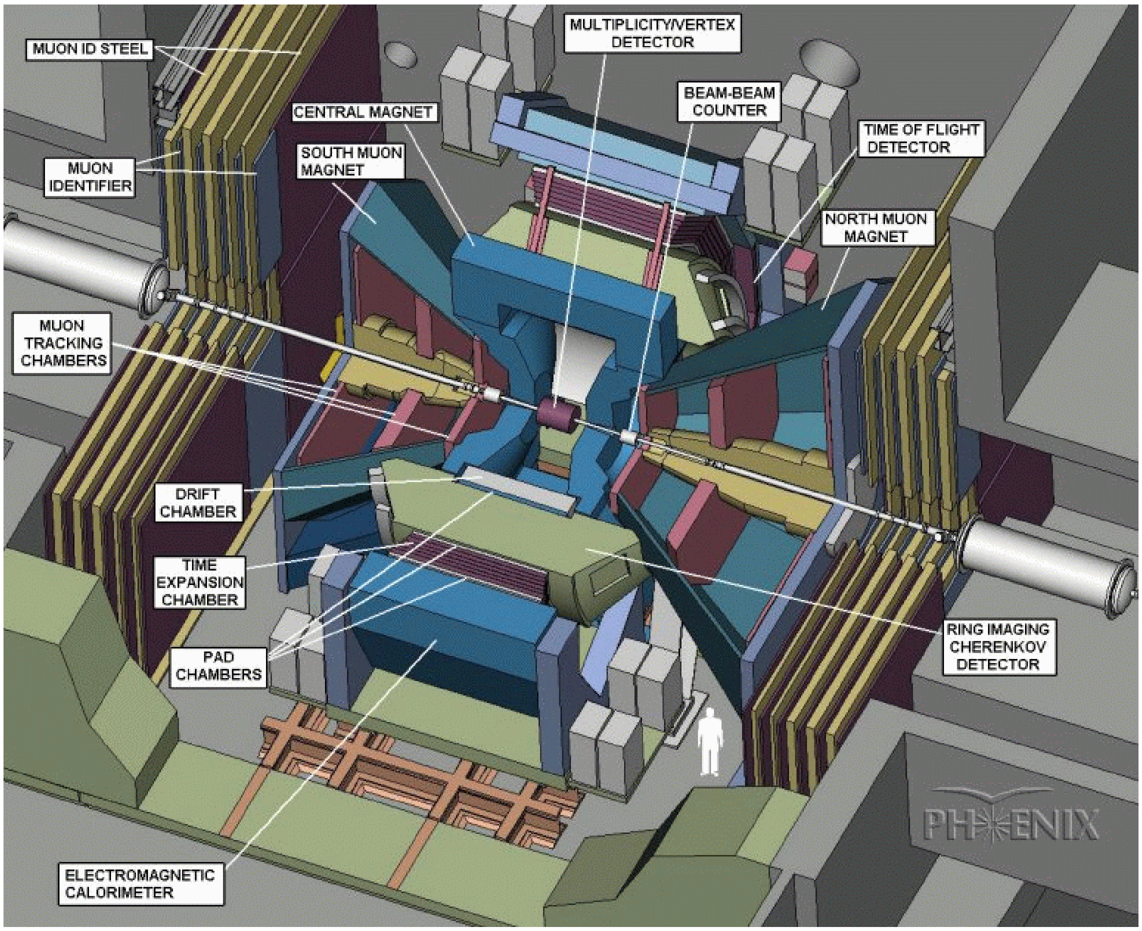
PHENIX Rising



Vince Cianciolo (Oak Ridge National Lab),
for the PHENIX Collaboration
ECT Charm Workshop*
17-22 June, 2002

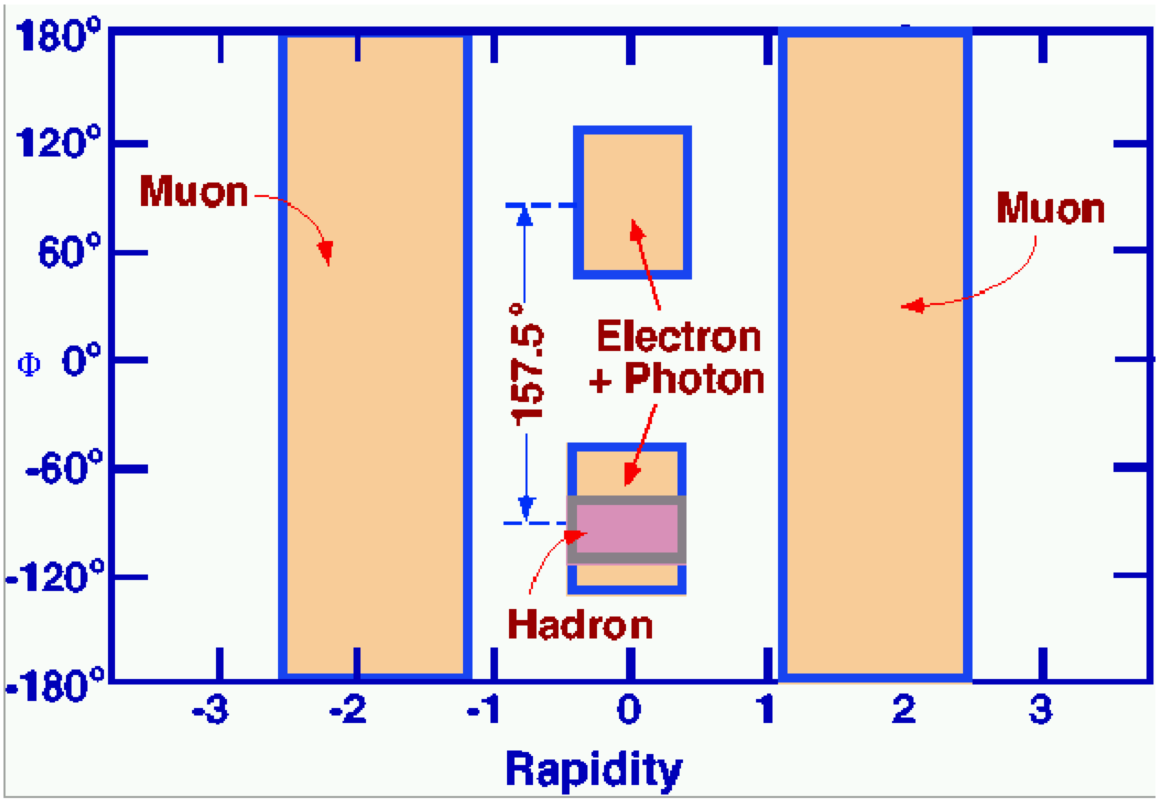
PHENIX

PHENIX — An Artist's Conception



- Global detectors (Multiplicity/Vertex Detector, Beam-Beam Counters, Zero-Degree Calorimeters) to measure vertex, centrality.
- Two $y = 0$ spectrometers to measure photons, electrons, hadrons.
- Two forward-rapidity muon spectrometers.

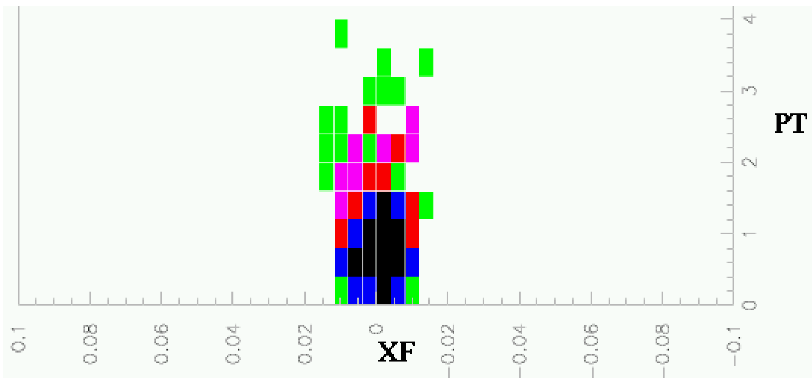
PHENIX — Acceptance



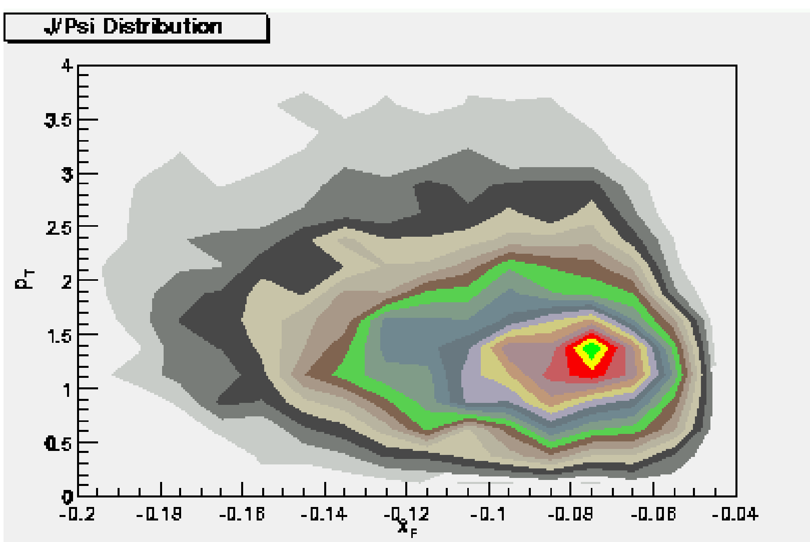
	Central *(Electron)* Arms	Forward *(Muon)* Arms
J/Ψ Acceptance	0.8% $B_{ee}\sigma$	8.6% $B_{\mu\mu}\sigma$
Υ Acceptance	1.7% $B_{ee}\sigma$	6.0% $B_{\mu\mu}\sigma$
J/Ψ resolution	20 MeV	105 MeV
Υ resolution	160 MeV	180 MeV

"You can measure all of the particles some of the time (STAR), or some of the particles all of the time (PHENIX)."

PHENIX — Di-lepton Relative Yields



Central Arms

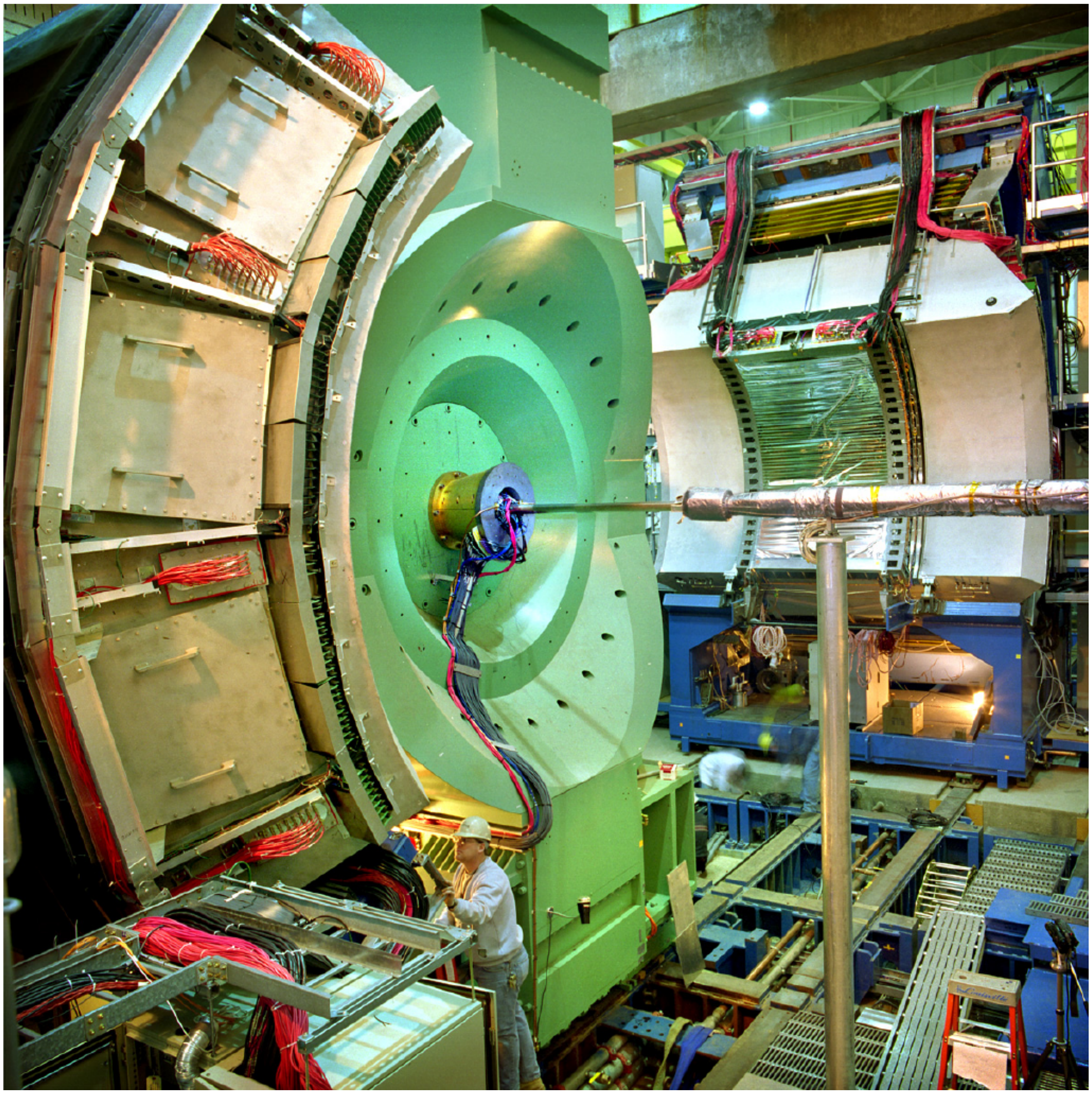


Muon Arms

Vince Cianciolo (Oak Ridge National Lab),
for the PHENIX Collaboration
ECT Charm Workshop*
17-22 June, 2002

PHENIX — Skeleton

PHENIX — Flesh and Muscle

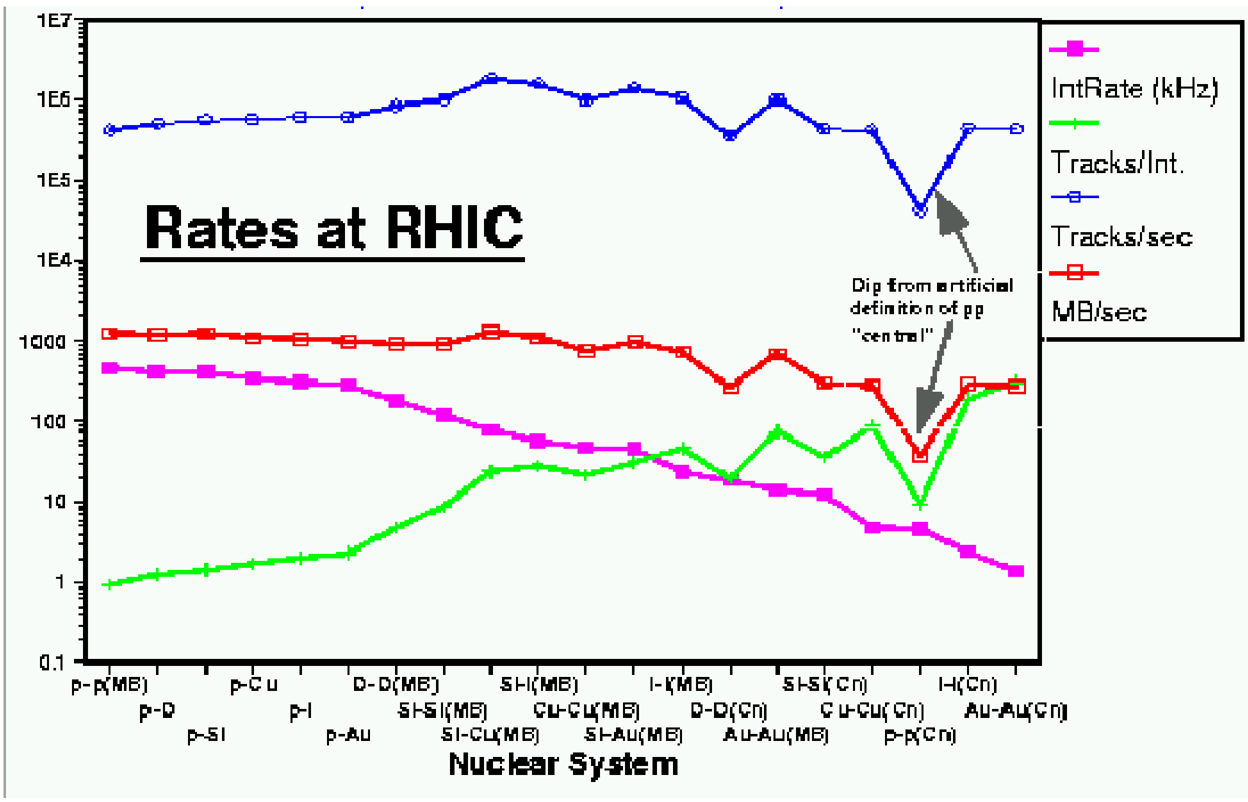


Vince Cianciolo (Oak Ridge National Lab),
for the PHENIX Collaboration
ECT Charm Workshop*
17-22 June, 2002

PHENIX — Muon Muscles

Vince Cianciolo (Oak Ridge National Lab),
for the PHENIX Collaboration

RHIC's Flexibility — A DAQ Challenge



- Interaction rates and event sizes vary over $\times 1000$ from pp to $AuAu$.
- In order to take full advantage of available luminosity for all species multiple levels of event selection (triggering) are required.

Needed: Flexible, Intelligent Triggering

- Bottom Line
  - PHENIX is designed to be a high-rate experiment. We can digitize and store an event every 80 μsec, and we store data at a rate of 35 MB/sec (integrates to 1 Petabyte per year).
  - Still, RHIC makes *many* more collisions then we can possibly write to tape or analyze $\rightarrow$ we pick the good ones (triggering).

- Level-1
  - Goal – make very fast (4 μsec) decision that event is interesting, reducing event rate below 12.5 kHz.
  - Uses only a subset of the detector.
  - Typical algorithm — search for EMCAL cluster/RICH ring match.
  - Especially important for pp with the highest event rates.

- Level-2
  - Goal — Make fast decision (80μsec $\times$ N_{CPU}) decision that event is interesting, reducing data rate below 35 MB/sec.
  - Can use data from entire detector.
  - Typical algorithm — Select di-leptons with $J/\Psi M_{inv}$ mass cut.
  - Especially important for $AuAu$ due to large event size.
  - Note — also critical to reduce event size $\rightarrow$ 0-suppression, online calibrations required.

PHENIX — A Worldwide Collaboration

11 Countries; 52 Institutions; 430 Participants*

Brazil — University of São Paulo, São Paulo

China — Academia Sinica, Taipei, Taiwan
China Institute of Atomic Energy, Beijing
Peking University, Beijing

France — LPC, University de Clermont-Ferrand, Clermont-Ferrand
Dapnia, CEA Saclay, Gif-sur-Yvette
IPN-Orsay, Universite Paris Sud, CNRS-IN2P3, Orsay
LLR, Ecòle Polytechnique, CNRS-IN2P3, Palaiseau
SUBATECH, Ecòle des Mines at Nantes, Nantes

Germany — University of Münster, Münster

India — Banaras Hindu University, Banaras
Bhabha Atomic Research Centre, Bombay

Israel — Weizmann Institute, Rehovot

Japan — Center for Nuclear Study, University of Tokyo, Tokyo
Hiroshima University, Higashi-Hiroshima
KEK, Institute for High Energy Physics, Tsukuba
Kyoto University, Kyoto
Nagasaki Institute of Applied Science, Nagasaki
RIKEN, Institute for Physical and Chemical Research, Wako
RIKEN-BNL Research Center, Upton, NY
University of Tokyo, Bunkyo-ku, Tokyo
Tokyo Institute of Technology, Tokyo
University of Tsukuba, Tsukuba
Waseda University, Tokyo

S. Korea — Cyclotron Application Laboratory, KAERI, Seoul
Kangnung National University, Kangnung
Korea University, Seoul
Myong Ji University, Yongin City
System Electronics Laboratory, Seoul Nat. University, Seoul
Yonsei University, Seoul

Russia — Institute of High Energy Physics, Protovino
Joint Institute for Nuclear Research, Dubna
Kurchatov Institute, Moscow
PNPI, St. Petersburg Nuclear Physics Institute, St. Petersburg
St. Petersburg State Technical University, St. Petersburg

Sweden — Lund University, Lund

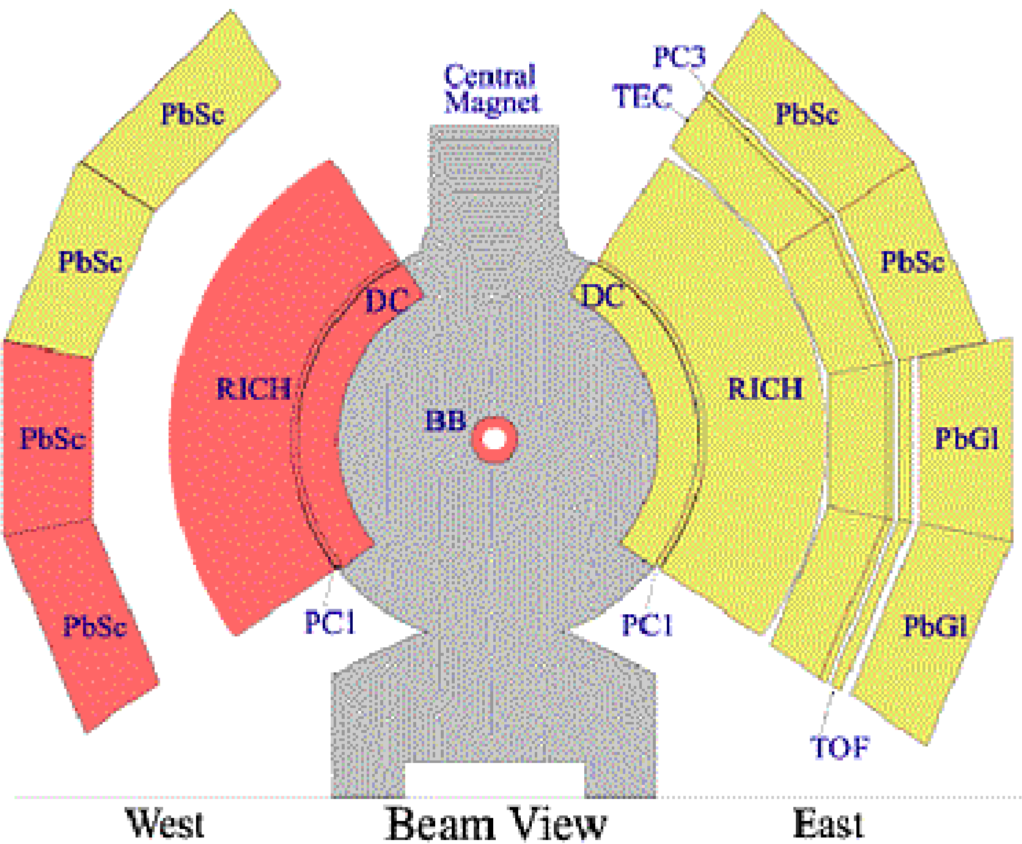
USA — Abilene Christian University, Abilene, TX
Brookhaven National Laboratory, Upton, NY
University of California - Riverside, Riverside, CA
Columbia University, Nevis Laboratories, Irvington, NY
Florida State University, Tallahassee, FL
Georgia State University, Atlanta, GA
Iowa State University and Ames Laboratory, Ames, IA
Los Alamos National Laboratory, Los Alamos, NM
Lawrence Livermore National Laboratory, Livermore, CA
University of New Mexico, Albuquerque, NM
New Mexico State University, Las Cruces, NM
Dept. of Chemistry, Stony Brook Univ., Stony Brook, NY
Dept. Phys. and Astronomy, Stony Brook Univ., Stony Brook, NY
Oak Ridge National Laboratory, Oak Ridge, TN
University of Tennessee, Knoxville, TN
Vanderbilt University, Nashville, TN

*as of January 2002

Look At All Those Smiling Faces!!

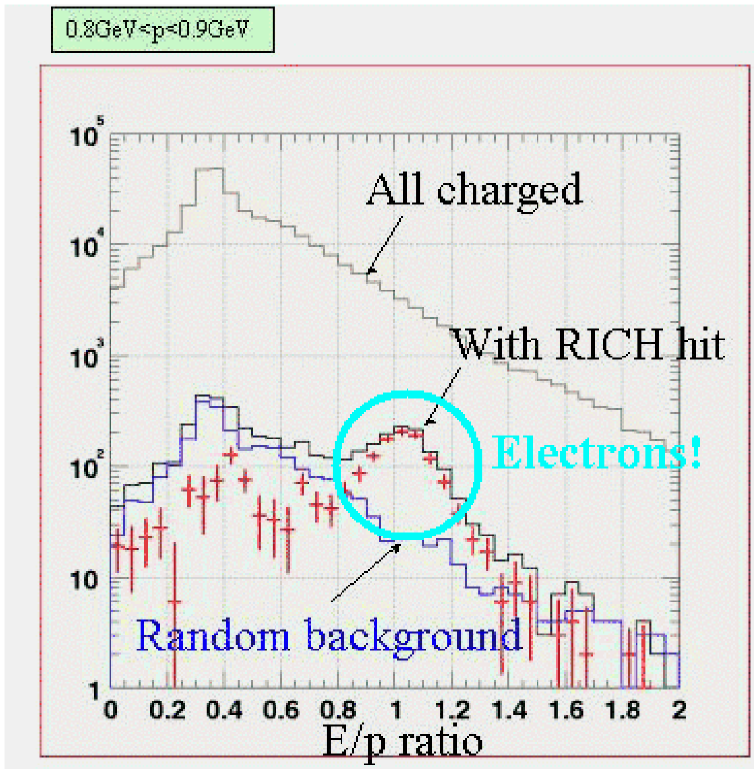
Vince Cianciolo (Oak Ridge National Lab),
for the PHENIX Collaboration
ECT Charm Workshop*
17-22 June, 2002

Run-1 Electron Measurement



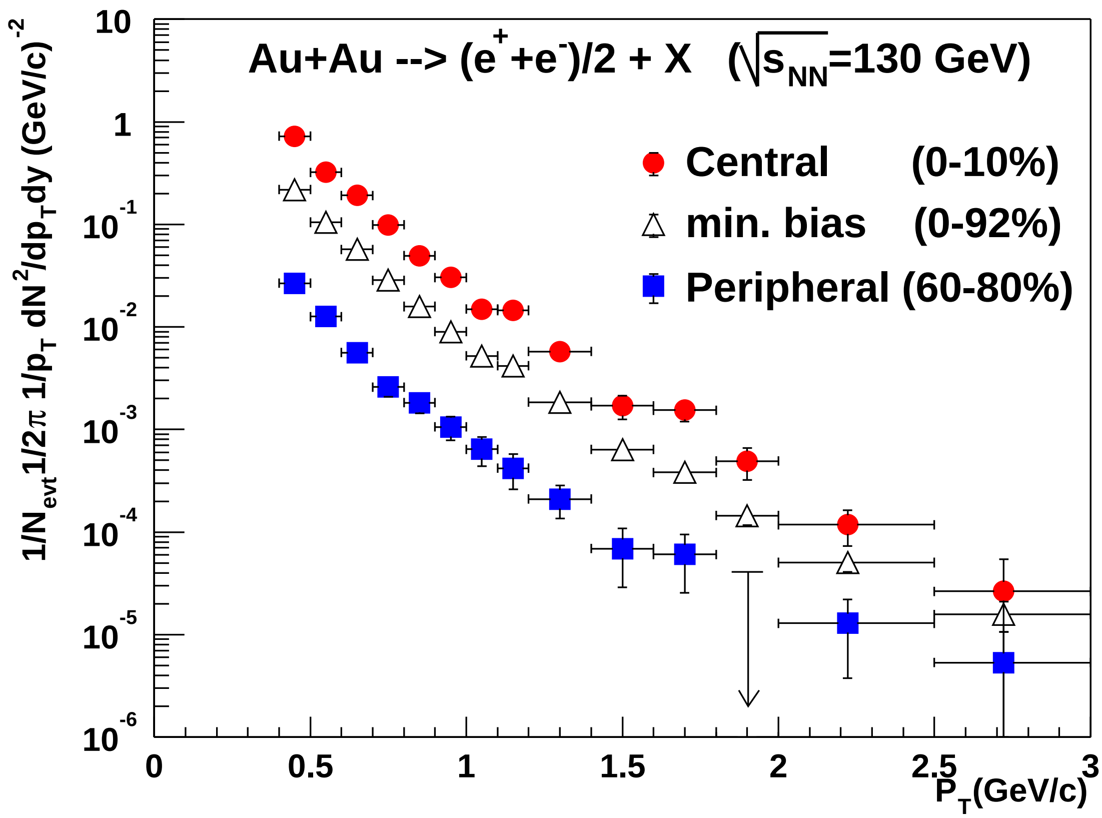
- Run-1 (Year 2000) single-electron dataset is comprised of 1.23 M $AuAu$ collisions ($\sqrt{s_{NN}} = 130\,\mathrm{GeV}$, $z_{vertex} < 30\,\mathrm{cm}$).
- z_{vertex} cut assures that interaction occured within magnet nosecones.
- Note: $\mathcal{L}^{int}_{AuAu} = 0.17\mu\mathrm{b}^{-1}$ (14 minutes at $\mathcal{L}^{design}_{AuAu}$).

Electron Identification



- The challenge - electron/hadron separation at a level of 10^{-4}
- The answer - a multi-pronged attack.
  - PC (3D hits $\rightarrow$ pattern recognition)
  - DC (High precision projective (2D) position information $\rightarrow$ tracking, momentum determination)
  - RICH ($p_{min}(\pi) = 4\,\mathrm{GeV/c} \rightarrow$ electron ID)
  - EMCAL (Energy measurement, vertex electron ($E/p \approx 1$) ID)

Raw Electron Spectrum

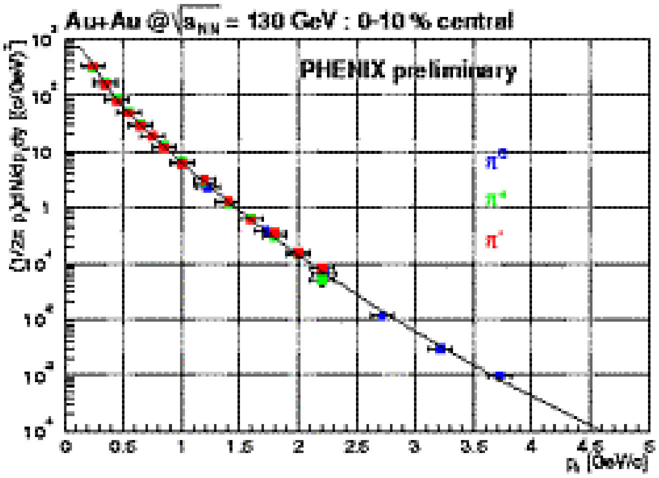


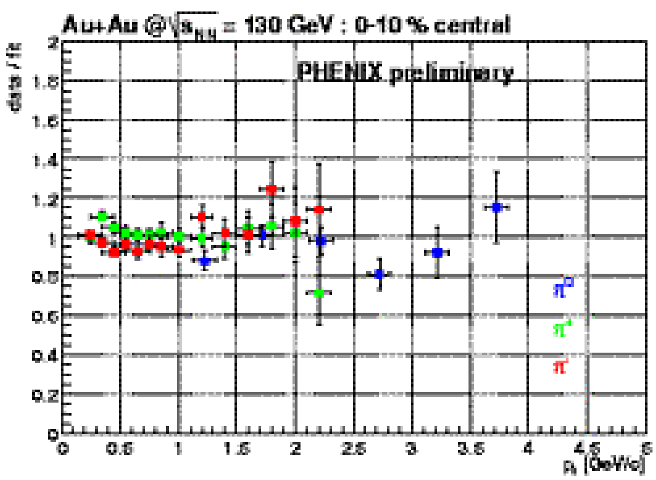
PRL 88 (2002) 192303

Electron Sources

- "Background"
  - $\pi^0 \rightarrow e^+e^-\gamma$ (Dalitz) and
    $\pi^0 \rightarrow \gamma\gamma \rightarrow e^+e^-\gamma$ (external conversion).
    * $\approx$ 80% of background.
    * Proportional to pions (well-measured by PHENIX).
    * Conversion $\approx 1.9 \times$ Dalitz in PHENIX.
  - $\eta \rightarrow e^+e^-\gamma$ (Dalitz) and
    $\eta \rightarrow \gamma\gamma \rightarrow e^+e^-\gamma$ (external conversion).
    * $\approx$ 20% of π^0 contribution at high p_T.
  - Other small contributors:
    * Dalitz decays of η', ω, ϕ.
    * Di-electron decays of ρ, ω, ϕ.
    * Kaon decays.
- "Signal"
  - Decay of charm mesons.
  - Decay of bottom mesons.
  - Thermal di-leptons.
  - Conversion of direct photons.

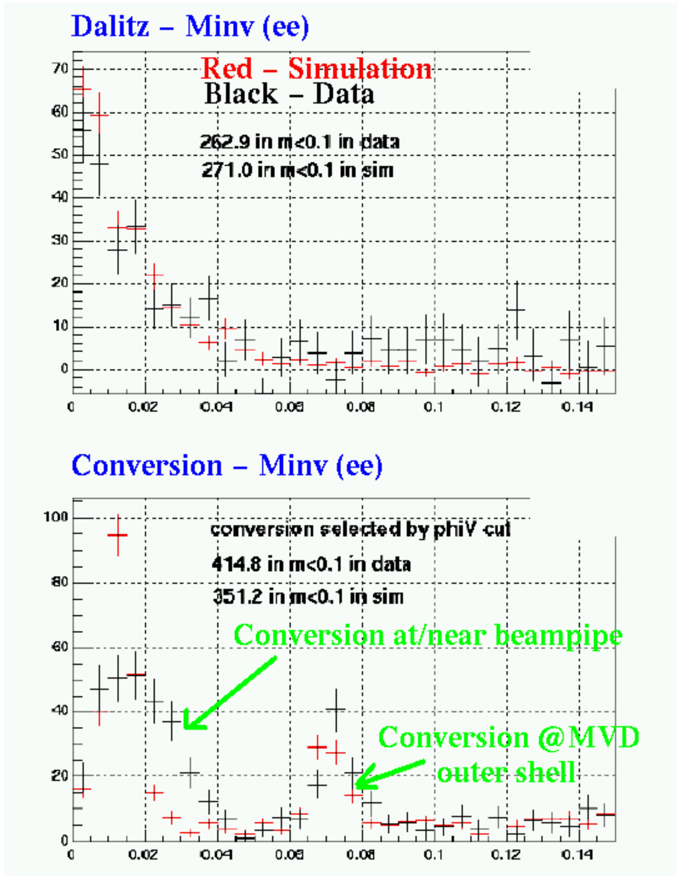
Hadronic Backgrounds





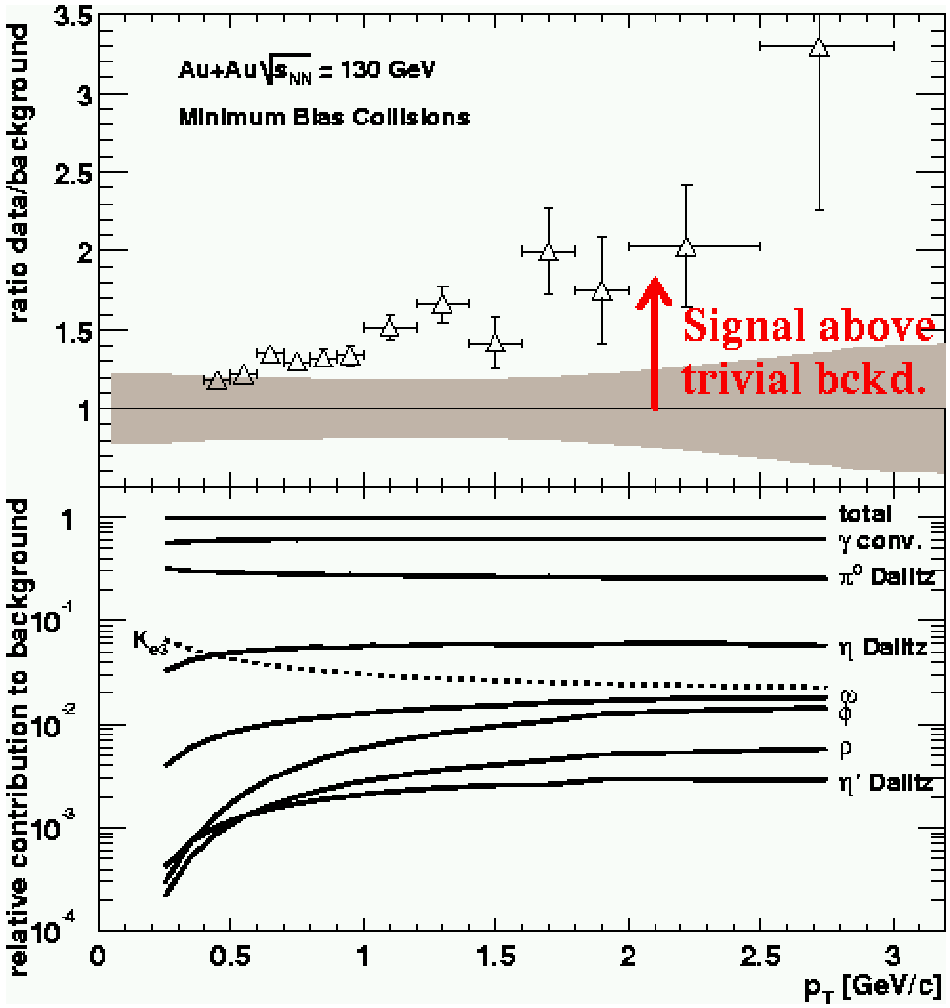
- "Trivial" background dominated (80%) by π^0.
- Backgrounds calculated with a hadronic decay generator.
- Input π p_T spectrum is tuned to PHENIX $\pi^{\pm,0}$ measurement.
- Other hadron (h) input spectra obtained via $p_T \to \sqrt{p_T^2 + m_h^2 - m_\pi^2}$.
- $K^\pm$ and $p^\pm$ spectra agree with this scaling to w/i 20%.

Conversion Electrons



- Identify conversion electrons through orientation of pair decay angle relative to B-field.
- Conversion at $r \neq 0$ gives false mass $\rightarrow$ good check that we understand non-direct sources of $e^{\pm}$.
- MC and Data agree fairly well in distribution and magnitude.

Contribution Above "Background" Sources



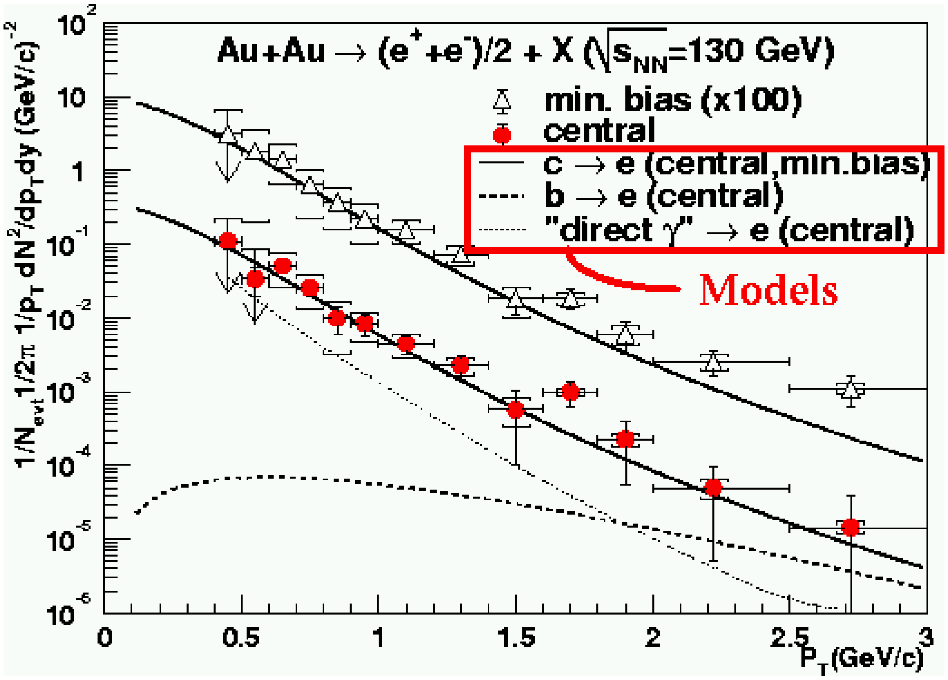
PRL 88 (2002) 192303

- Sum of fractional "background" sources in bottom panel = 1.
- These summed contributions form unit-level in top panel.

PYTHIA and Charm

- PYTHIA parameters tuned to reproduce fixed target charm and single electron cross-sections and p_T distributions.
  - PYTHIA 6.152+CTEQ5L
  - $m_c = 1.25\,\mathrm{GeV/c}$
  - $K = 3.5$
  - $< k_T >= 1.5\,\mathrm{GeV/c}$
- With these parameters, $\sigma(pp \rightarrow c\bar{c}) = 330\,\mu\mathrm{b}$.

Electron Yield Minus "Background" - The Charm Hypothesis



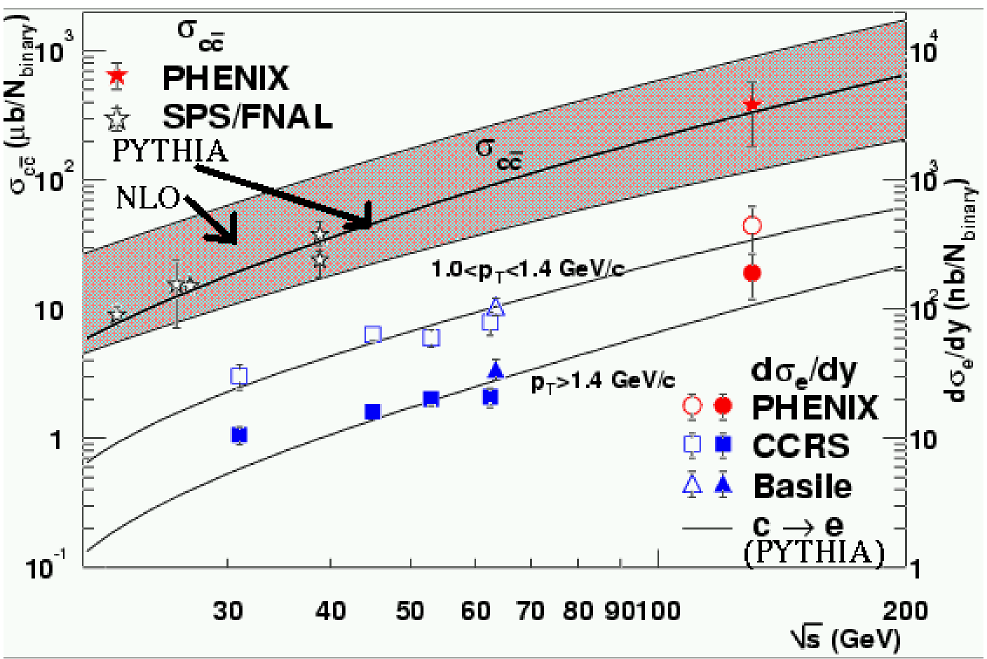
PRL 88 (2002) 192303

- Charm contribution shown: $EdN_e/dp^3 = T_{AA}Ed\sigma/dp^3$ — *Not a fit!*
- T_{AA} nuclear overlap integral; $Ed\sigma/dp^3$ PYTHIA charm-decay $e^{\pm}$.
- Also shown are the bottom contribution from an analagous calculation and a calculation for direct photons. Both are relatively small and are ignored in a fit of $\sigma_{c\bar{c}}$ to the minimum bias and central datasets.

$\sigma_{c\bar{c}}$ *Scaling With* N_{binary}

Charm cross section per NN collision derived from the single electron data for central (0-10%) and minimum bias (0-92%) collisions. The first and second errors are statistical and systematic, respectively.

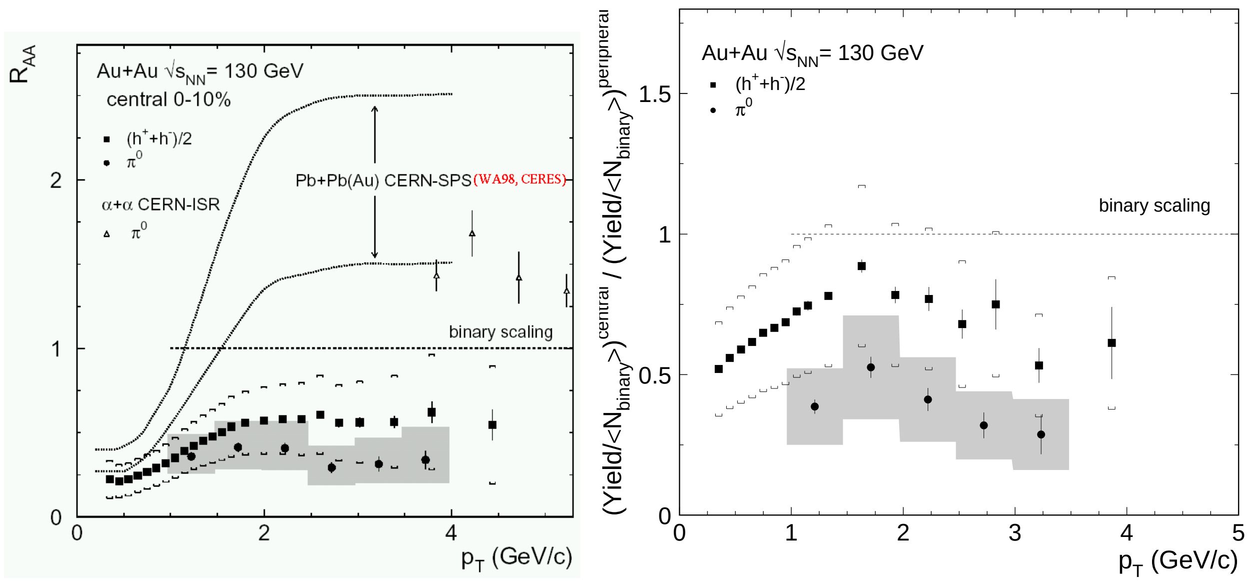
Centrality	$T_{AA}(\text{mb}^{-1})$	$d\sigma_{c\bar{c}}/dy\|_{y=0}(\mu\text{b})$	$\sigma_{c\bar{c}}(\mu\text{b})$
0-10%	22.6 ± 1.6(sys.)	$97 \pm 13 \pm 49$	$380 \pm 60 \pm 200$
0-92%	6.2 ± 0.4(sys.)	$107 \pm 8 \pm 63$	$420 \pm 33 \pm 250$



PRL 88 (2002) 192303

- Central and minimum bias are consistent with each other and with *pp* if we assume that N_{binary} is OK.

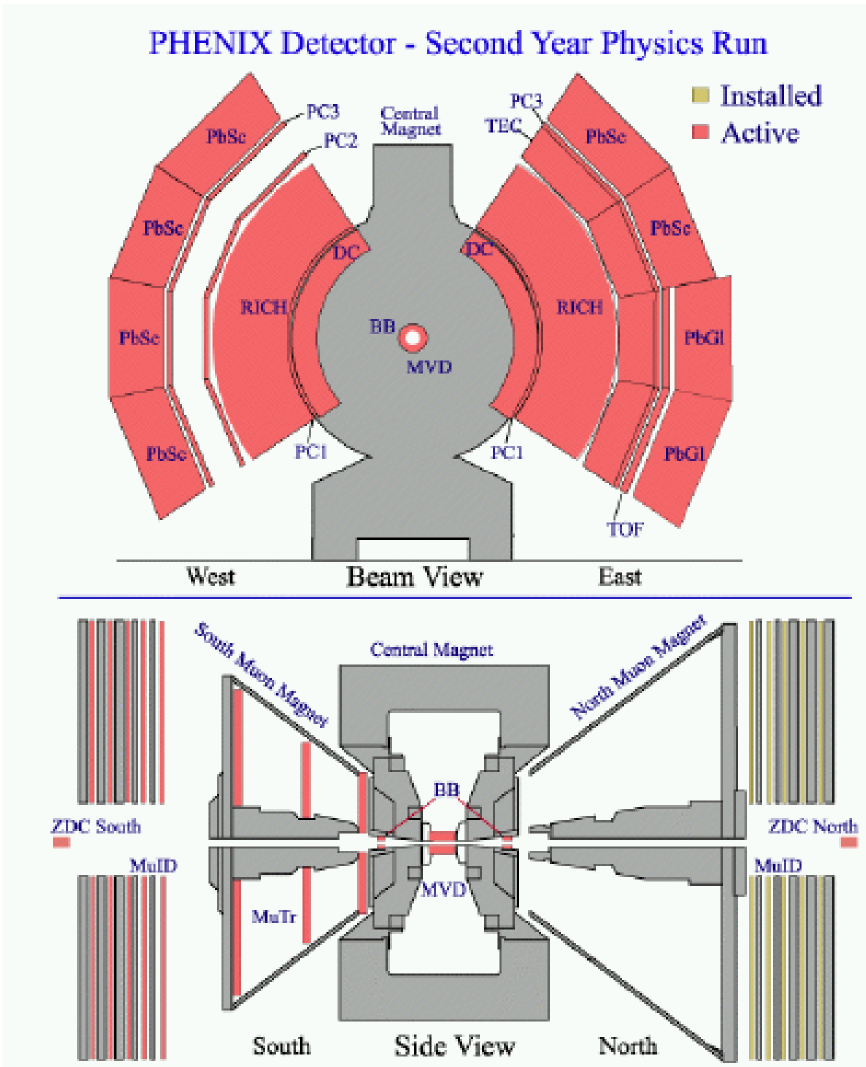
High-p_T Hadrons (Not) Scaling With N_{binary}



PRL 88 (2002) 022301

- Hadrons w/ $p_T > 2\,\mathrm{GeV/c}$ (nominal hard-scattering scale from pp) are not only not enhanced above N_{binary} sccaling by Cronin effect; they are significantly suppressed.

Run-2 Configuration



- For Run-2 (Year 2001) both central arms were fully operational.
- Also, the south muon arm was commissioned.

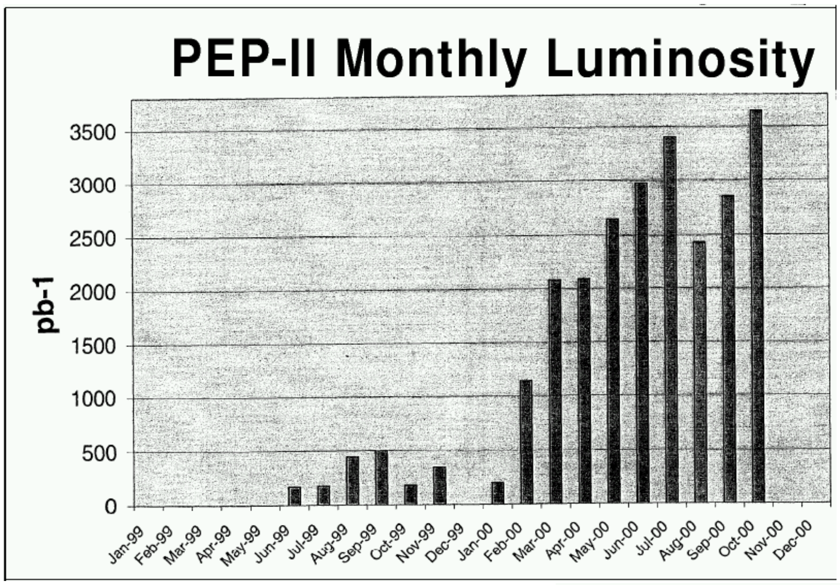
Run-2 Dataset

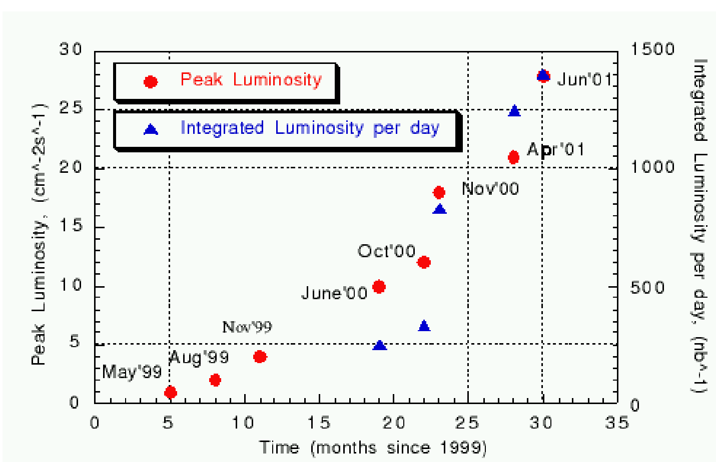
- Improvement in statistical errors will extend charm measurement to much higher p_T values ($\approx 4 - 5\,\mathrm{GeV/c}$), allowing more direct comparison to the observed high-p_T hadron suppression:
  - $\approx \times 150$ more collisions sampled.
  - Detector improvements increase acceptance by $> \times 2$.
- Improvement in systematic errors will allow a much more precise measurement:
  - pp comparison dataset, so that $\sigma(pp \to c\bar{c})$ is known.
  - Special runs with γ converter installed near the beam pipe will allow a direct measurement of the γ-conversion background.
  - Higher precision π^0 measurement also important.

Run-2 Dataset, cont.

- Extensions of the detector will allow us to measure previously unexplored regions of phase space and will allow us to take full advantage of RHIC luminosity improvements:
  - South muon arm commissioned.
  - High-level triggers commissioned.
- Even with significantly improved luminosity, Run-2 represents only ≈ 3 days $\mathcal{L}_{AuAu}^{design}$ and ≈ 1 day $\mathcal{L}_{pp}^{design}$.
  So, we expect:
  - $pp \rightarrow J/\Psi \rightarrow e^{\pm} \approx 200$
  - $AuAu \rightarrow J/\Psi \rightarrow e^{\pm} \approx 150$
  - $pp \rightarrow J/\Psi \rightarrow \mu^{\pm} \approx 60$
  - $AuAu \rightarrow J/\Psi \rightarrow \mu^{\pm} \approx 300$
- Note, large uncertainties in both production and efficiency.

Collider Luminosity — A Reality Check





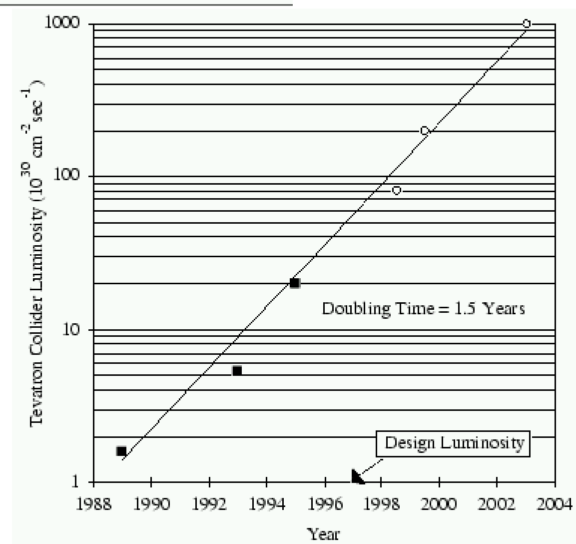
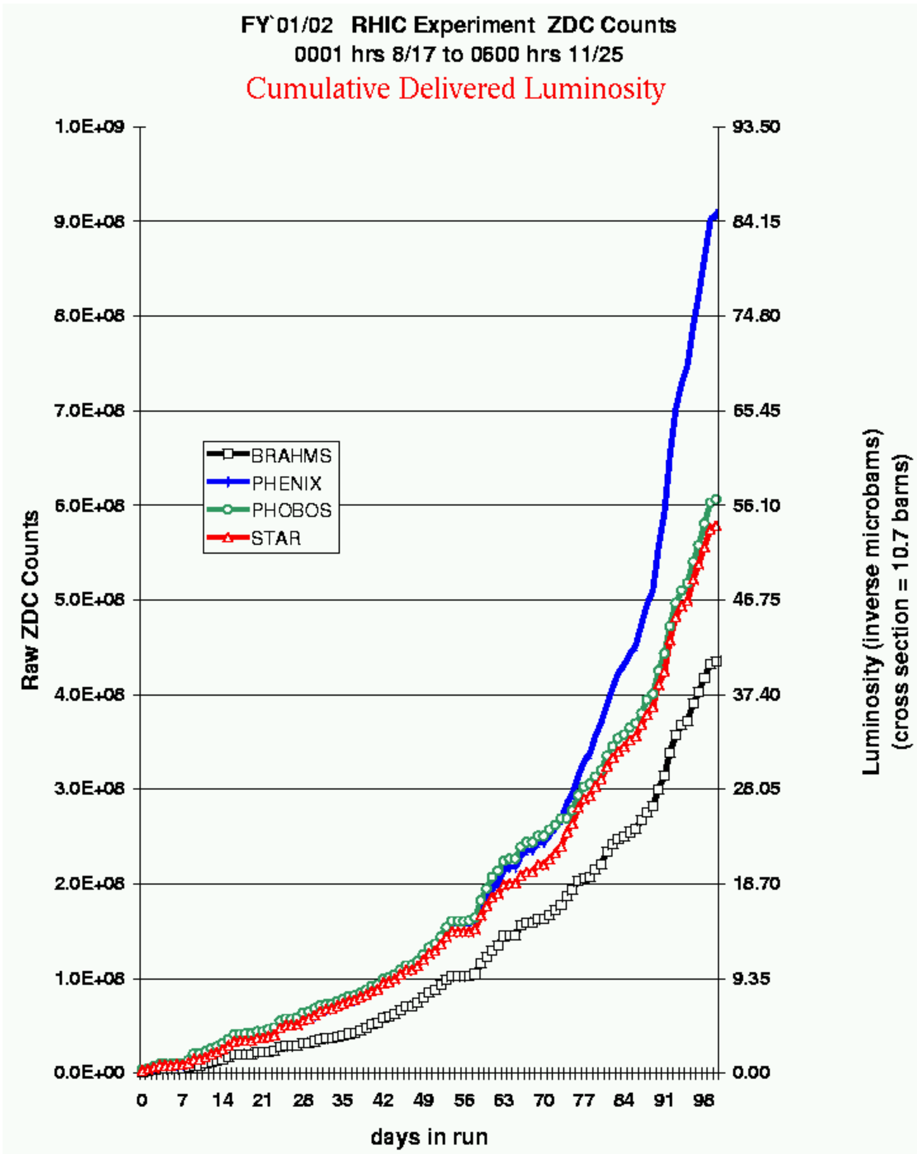


Figure 1.1: Tevatron Collider luminosity as a function of time. The filled circles are measured "best typical" peak luminosities, the line is an exponential fit to the data, and the open points represent goals for the future.

RHIC Luminosity Growth



- Peak luminosity reached $\mathcal{L}_{AuAu}^{design}$ by the end of Run-2!

Luminosity — Think Strike Zone

What do you mean — “What’s a strike zone?!?”

Vince Cianciolo (Oak Ridge National Lab),
for the PHENIX Collaboration

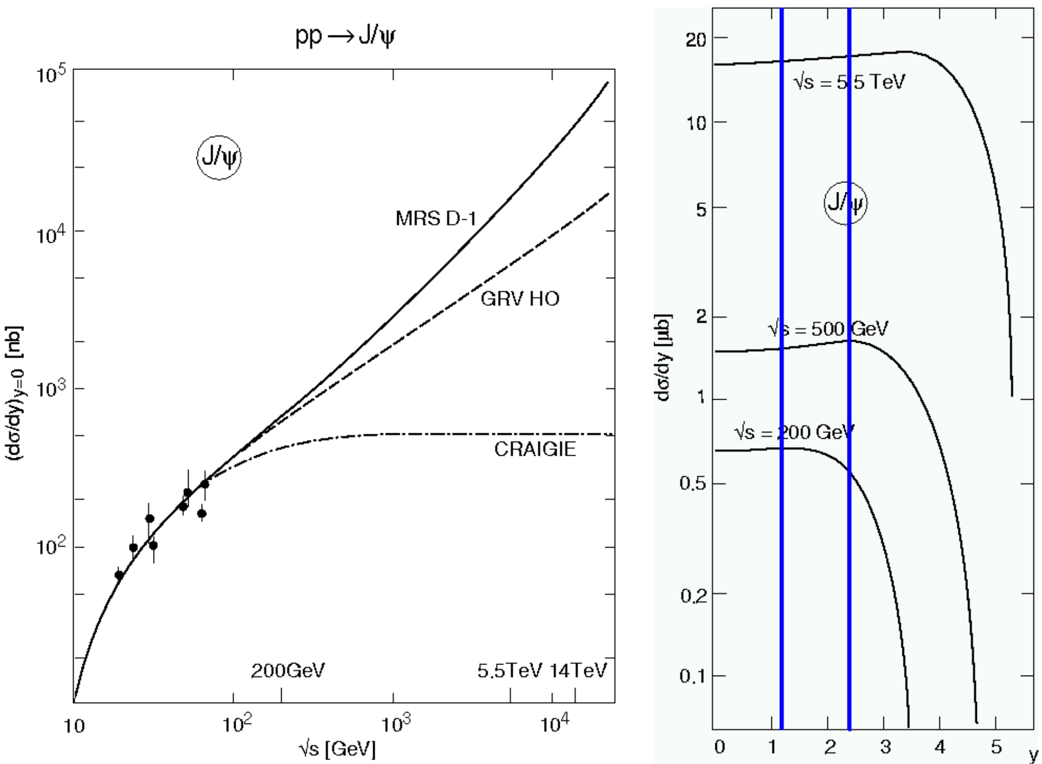
OK, Luminosity — Think World Cup Goal

- At a fixed-target machine achieving high luminosity is hard enough.
- But, since targets are large relative to the beam the standard luminosity formula reduces from $\mathcal{L} = f_{rev} B N_B \frac{N_B}{4\pi r^2_{beam}}$ to $f_{rev} B N_B \frac{\rho t N_A}{A}$.
- Therefore, it is sufficient to simply achieve a large number of projectile particles. One chooses a target thickness balancing collision rate against multiple scattering.
- In analogy with a goalie turning away shots, many projectile particles will pass through a typical target. For a 1 mm Pb target (chosen to be thin to minimize multiple scattering) only $\frac{\rho t N_A}{A}\sigma =$ 1.6% of shots will score — pretty good goalie!

Collider Luminosity —
Think You Scoring vs. Italian National Team

- At a collider the target is *much* smaller — $r_{rms} \approx 0.2\,\text{mm}$ typically.
- In addition, the targets are often not there — $30\,\text{cm bunch}/(\text{c} * 106\,\text{ns}) \approx 1\%$.
- And, all projectiles that miss must go around the ring, arriving at the correct time and location to try again.
  And they must do this repeatedly for many hours.
- Finally, the target is *much* thinner. For typical values, only $\frac{N_B}{4\pi r_{beam}^2}\sigma = 1.4 \times 10^{-10}\%$ of shots will score — amazingly good goalie!
- Another analogy (Glenn Young) is that a collider really makes vacuum/vacuum collisions: $\rho_{bunch}^{RHIC} = 1 \times 10^{-10}\,\text{g/cm}^3$!

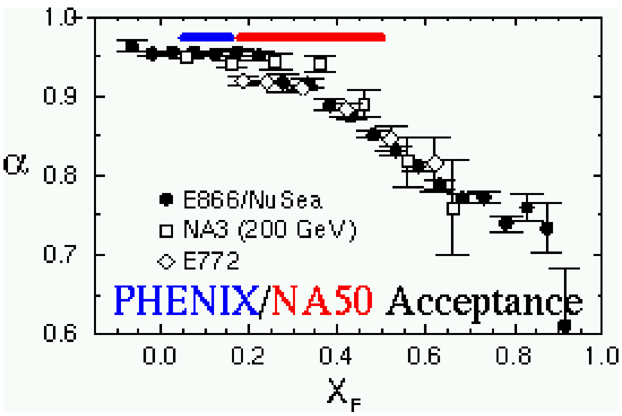
Significant Uncertainty in $pp \to J/\Psi$ Yield

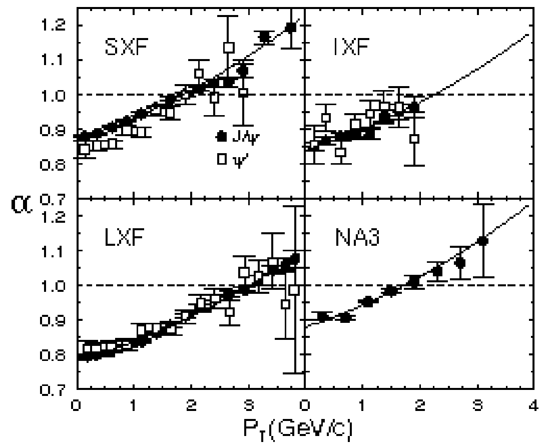


Gavai *et al.*, Int. J. Mod. Phys A10 (1995) 3043.

- Yield at $y = 0$ is subject to significant uncertainty at $\sqrt{s_{NN}}$.
- Rapid fall-off in rapidity distribution is near the high-rapidity edge of the muon arm acceptance ($1.2 < y < 2.4$). Even more true for lower energies.
- Same-energy *pp* comparison dataset *required*.

Significant Shadowing Effects





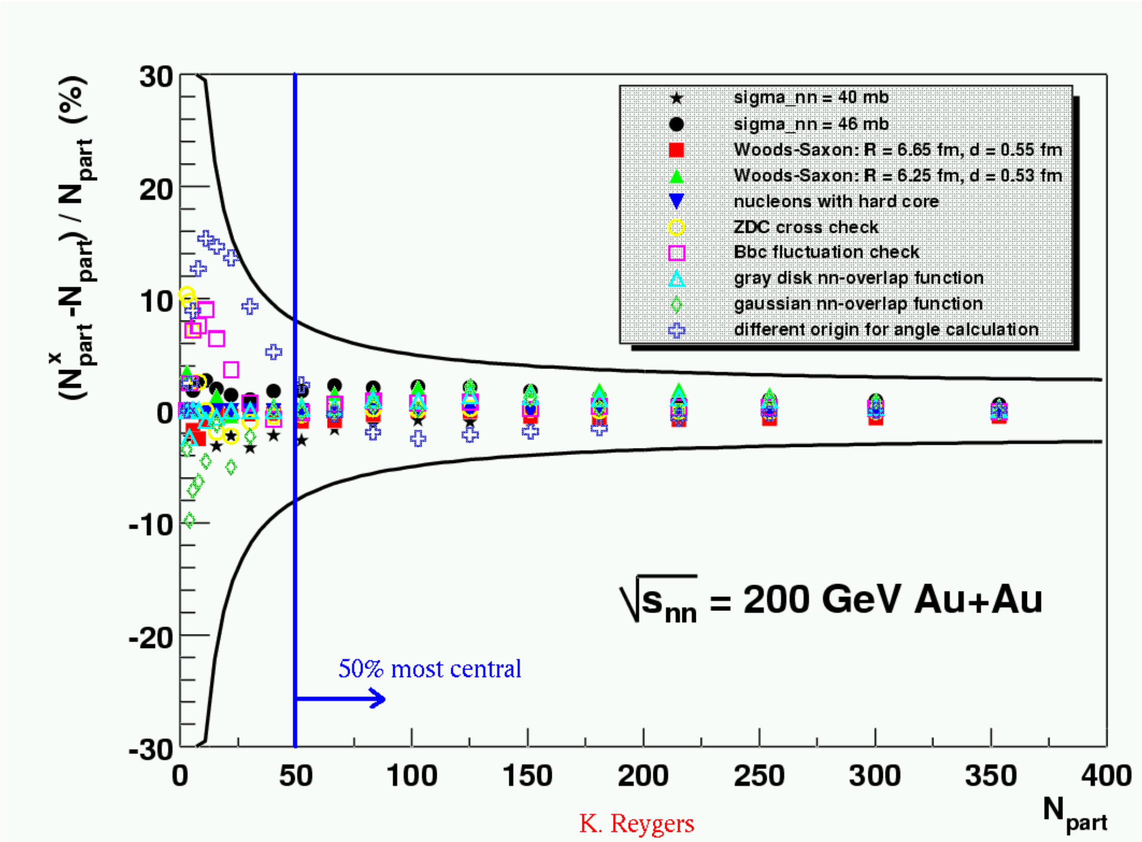
E866, PRL 84 (2000) 3256.

- E866 (FNAL) sees significant shadowing effects in pA collisions in relevant regions of phase space.
- Can use dA collisions to study this effect at RHIC energies in PHENIX acceptance.

Vince Cianciolo (Oak Ridge National Lab),
for the PHENIX Collaboration
ECT Charm Workshop*
17-22 June, 2002

$aa^* \to J/\Psi + X$ — *Centrality Control*

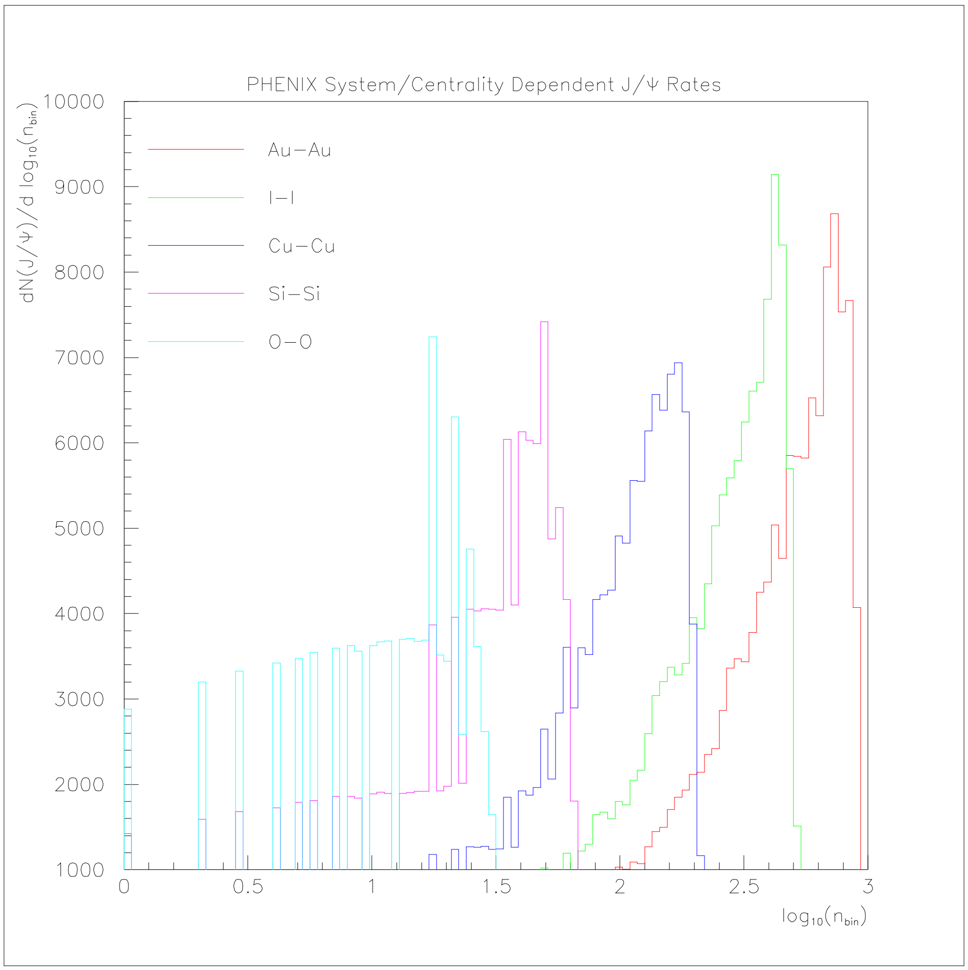
* — light ion collisions.



- Systematic uncertainty in N_{part} (or N_{binary}) is large for peripheral collisions.
- Only for central collisions can we control geometry and $N_{binary} \to$ we need to systematically study light ion (aa) collisions, where $a = O, Si, Cu, I, ...$.

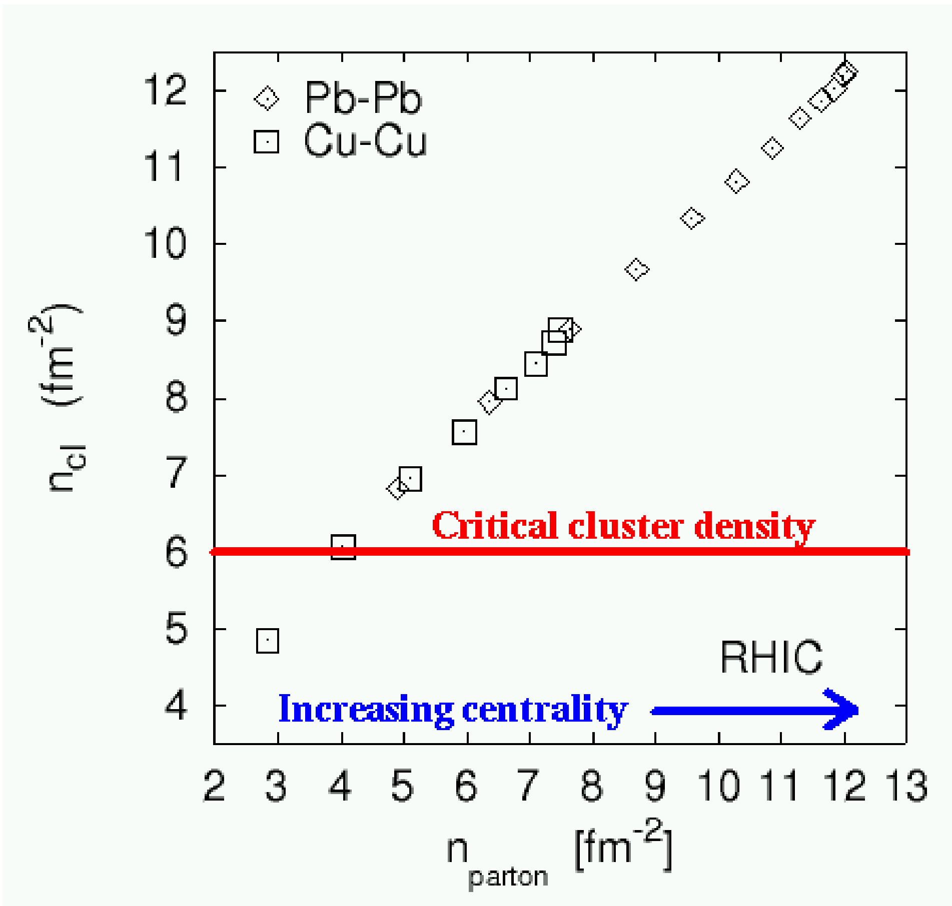
$aa \rightarrow J/\Psi + X$ — *More Efficient*

- For lighter ions RHIC can deliver higher luminosity.
- So, we can most efficiently explore the range of N_{binary} by scanning a series of light-ion species.



$aa \to J/\Psi + X$ — *We'd Like To See Some* J/Ψ*'s!*

- There's at least one prediction that there won't be *any* surviving J/Ψ's in $AuAu$ collisions at RHIC energies.



$aa \to J/\Psi + X$ — *Rate Estimates*

Species	$\mathcal{L}_{200}^{design}$	$t^{100k\,*}(J/\Psi)$	$N^{\Psi'}(t^{100k})^{\dagger}$	$N^{\Upsilon}(t^{100k})^{\ddagger}$	$N^{\Upsilon'+\Upsilon''}(t^{100k})^{\odot}$
AuAu	2.0×10^{26}	12	1800	120	45
II	2.6×10^{27}	2	1800	120	45
CuCu	8.3×10^{27}	2.5	1800	110	45
SiSi	3.5×10^{28}	2.5	1800	100	45
OO	7.7×10^{28}	3	1800	95	45
pp	5.6×10^{30}	7	1800	70	45

* Time to obtain 100k J/Ψ's assuming $\sigma(pp \to J/\Psi) = 3.3\,\mu$b, $A^{1.84}$ scaling.

† Number of Ψ' obtained in t^{100k} assuming $\sigma(pp \to \Psi') = 0.46\,\mu$b, $A^{1.84}$ scaling.

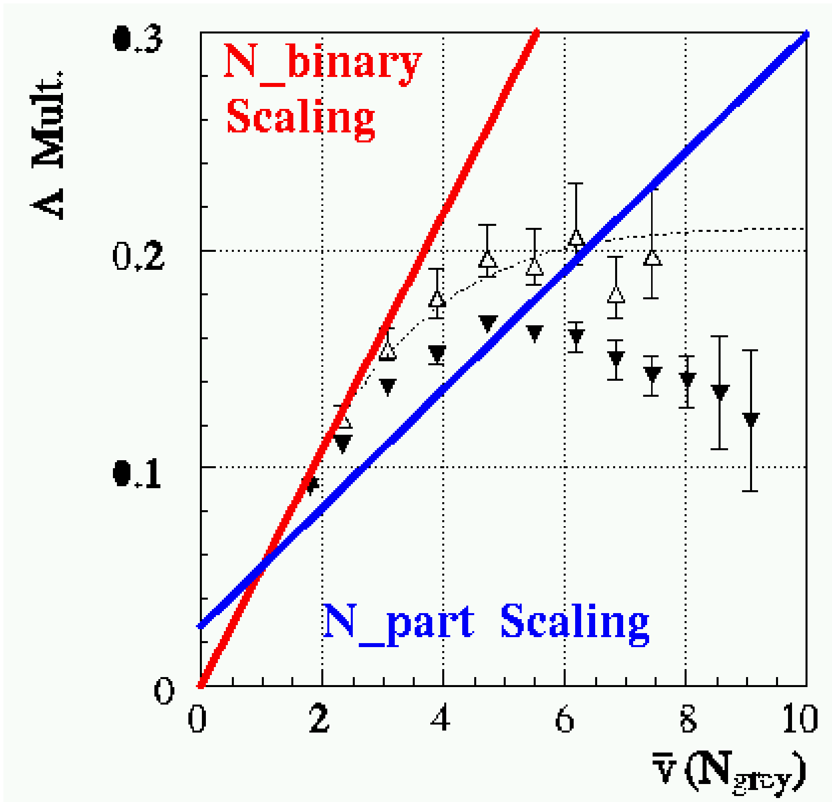
‡ Number of Υ obtained in t^{100k} assuming $\sigma(pp \to \Upsilon) = 0.29\,$nb, $A^{1.94}$ scaling.

$^\odot$ Number of $\Upsilon' + \Upsilon''$ obtained in t^{100k} assuming $\sigma(pp \to \Upsilon' + \Upsilon'') = 0.19\,$nb, $A^{1.84}$ scaling.

- All estimates assume 50%/50% RHIC/PHENIX uptime.
- All estimates assume sufficient trigger selectivity to sample all minimum bias events.
- Estimates are for weeks at design luminosity. This does not include machine overhead for, *e.g.*, cool-down, warm-up and luminosity development.

- Note - although an energy scan is also desireable it is much less feasible for rare processes since $\mathcal{L}$ drops with $\sqrt{s}$ as does J/Ψ production.
- Ultimately Υ family measurements are expected to supply a control point. This will be greatly assisted by RHIC-II ($\times 40$ luminosity increase)

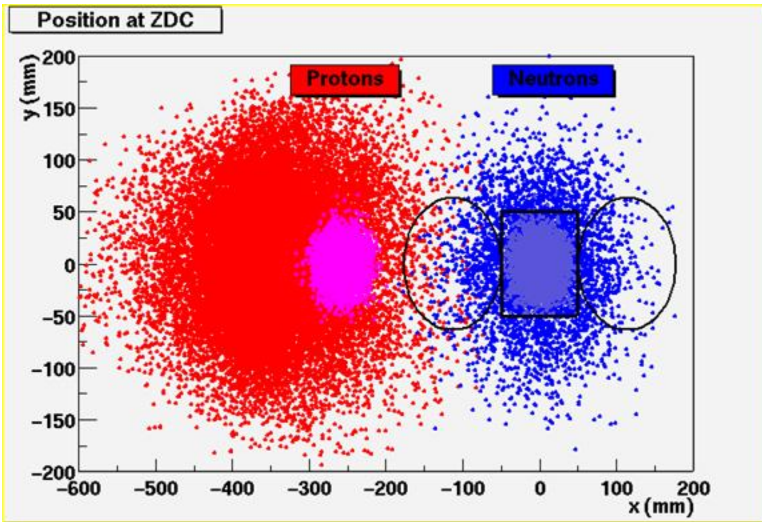
Not All NN Collisions Are Created Equal



E910, PRL 85 (2000) 4868-4871.

- Emulsion experiments showed that in pA collisions the number of projectile collisions (ν) is related to the number of "grey" tracks ($50 < p_T\,(\mathrm{MeV/c}) < 100$).
- E910 (AGS) made high-statistics PID measurements in pA collisions vs. $\bar{\nu}(N_{grey})$ and showed that not all collisions are created equal. Λ production goes like $\bar{\nu}$ for $\bar{\nu} \le 3$ and then saturates.
- This effect is washed out when integrating over pA centralities.

Measuring pA, dA Centrality at RHIC

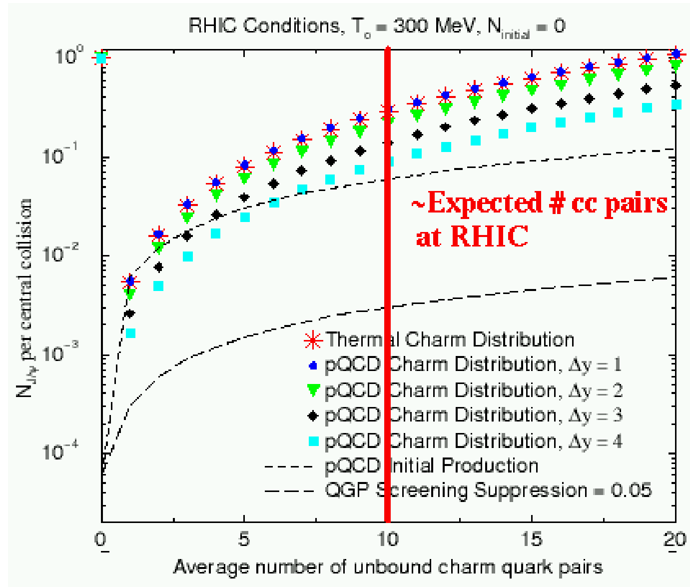


- PHENIX will study this effect at RHIC using "new" forward calorimeters which determine the centrality of pA, dA collisions through the forward energy deposited in the "A" direction.

- E864 (AGS) calorimeter in the detector graveyard.

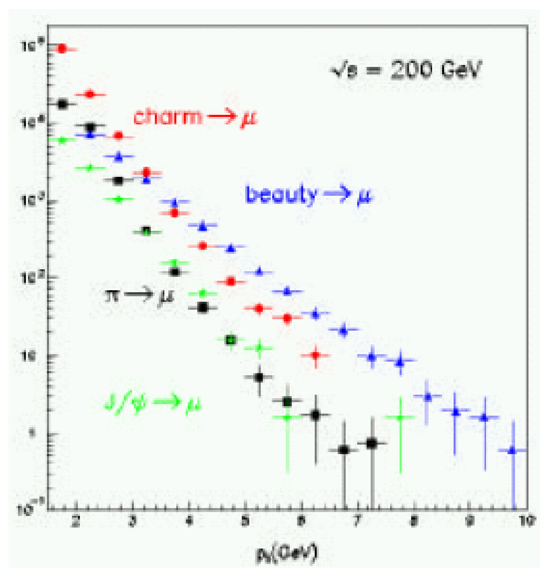
Charm Production - An Important Control

- Enhanced charm production in AA collisions discussed many places in the literature.
- Proposed in thermal recombination models that J/Ψ production will be enhanced.



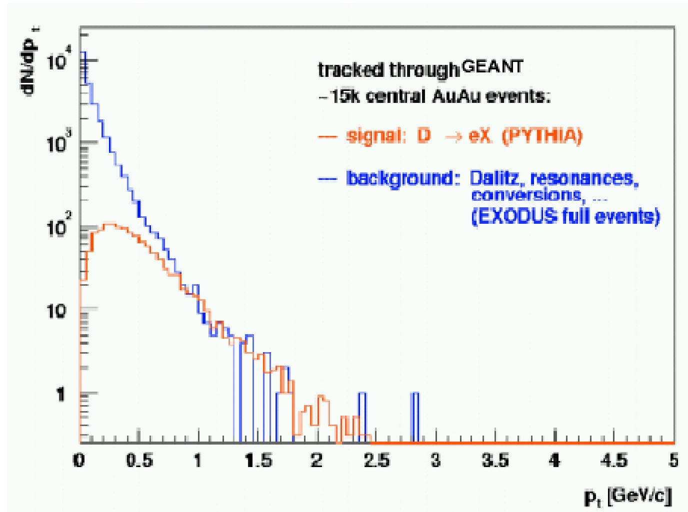
Thews and Rafelski, Nucl. Phys. A698 (2002) 575

- PHENIX will make a muon-channel charm measurement analagous to the electron-channel measurement detailed above. We will also eventually explore $e - \mu$ coincidences.

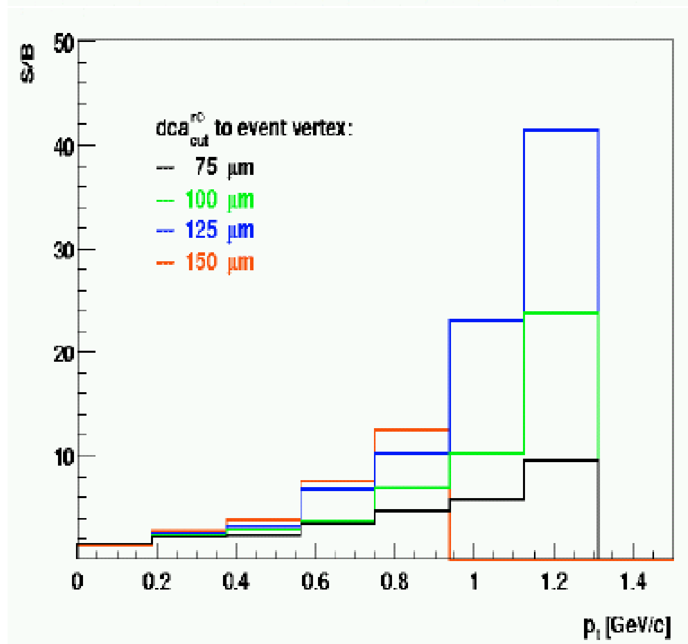


Measuring Displaced Vertices

- $S/B \approx 1$ for $p_T > 1\,\mathrm{GeV/c}$. Not shown is "background" from open bottom mesons which becomes significant for $p_T > 2.5\,\mathrm{GeV/c}$.

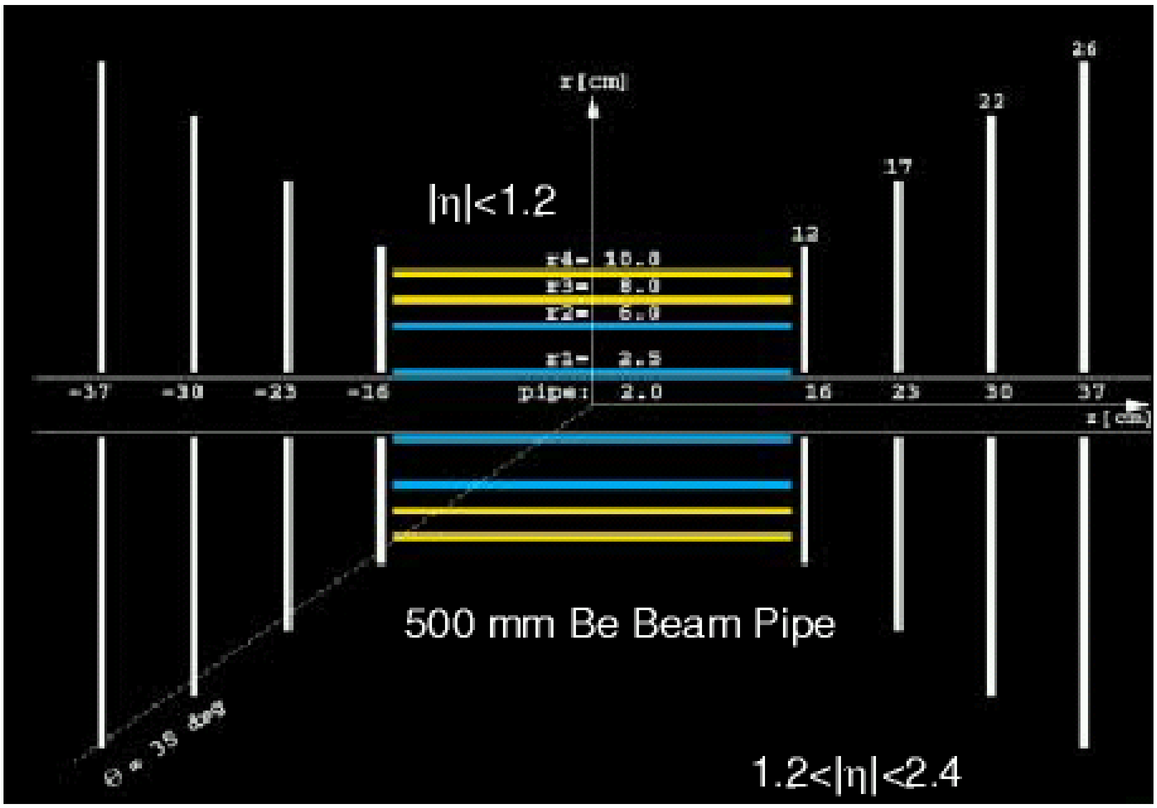


- Signal-to-background greatly improved by measuring displaced vertices.
- Distinguishes open charm from open bottom.



PHENIX

Silicon Vertex Detector Upgrade



- Silicon Vertex detector conceptual development well underway.
- Significant challenge in terms of data volume, electronics development, radiation length minimization.

Conclusions

- Heavy-flavor era at RHIC has begun.
- From a modest dataset from RHIC Run-1 PHENIX has measured $c\bar{c}$ production and found that it scales (within large error bars) with N_{binary}.
- This is in apparent contradiction with our observation of a suppression of high-p_T hadron production relative to N_{binary}.
- The dataset from RHIC Run-2 is more than $\times 100$ larger, plus the PHENIX central arm acceptance was significantly larger. This will allow us to significantly extend the p_T reach of our charm measurements.
- The collection of a pp comparison set and runs with known converter thicknesses will significantly improve our systematic errors.
- One of the muon arms was commissioned, significantly increasing our phase-space coverage for heavy-flavor measurements.
- High level triggers were commissioned, a vital component in our goal to examine every collision for the possibility of interesting Physics.

Conclusions, cont.

- Heavy-flavor production (open-flavor and "onia") in heavy ion collisions is complicated:
  - pp - production (magnitude, phase-space, mechanism).
  - pA - shadowing, energy loss, scaling vs. pA centrality?
  - AA- Screening, recombination, ...
- Runs 3,4 (2002-3) will provide substantially improved datasets (significant increases in luminosity, plus second muon arm) for 4(?) different collision types $(AuAu, dAu, pp, aa(SiSi?))$ — a first systematic study of nearly all production aspects at RHIC energies:
  - The heaviest system.
  - pp comparison set.
  - Shadowing, cold-nuclear matter suppression, energy loss.
  - N_{binary} scaling in lighter a system.
- PHENIX has a long-term measurement and upgrade strategy designed to make the systematic measurements required to truly understand it.