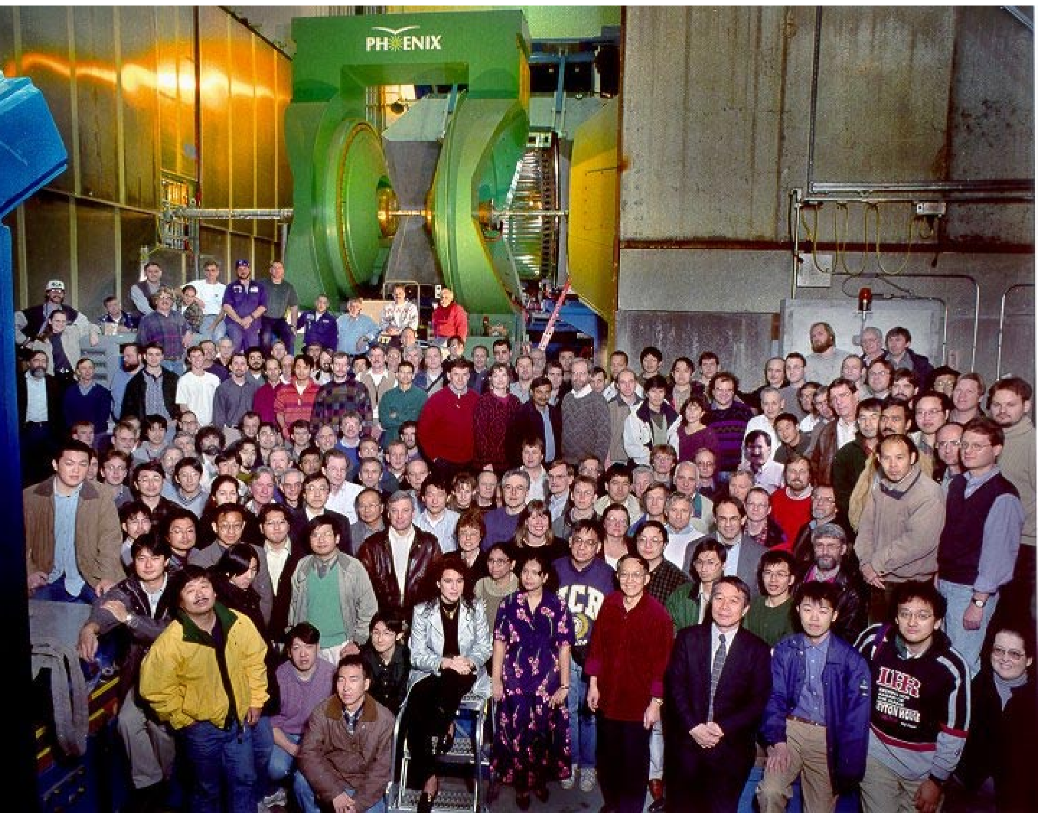
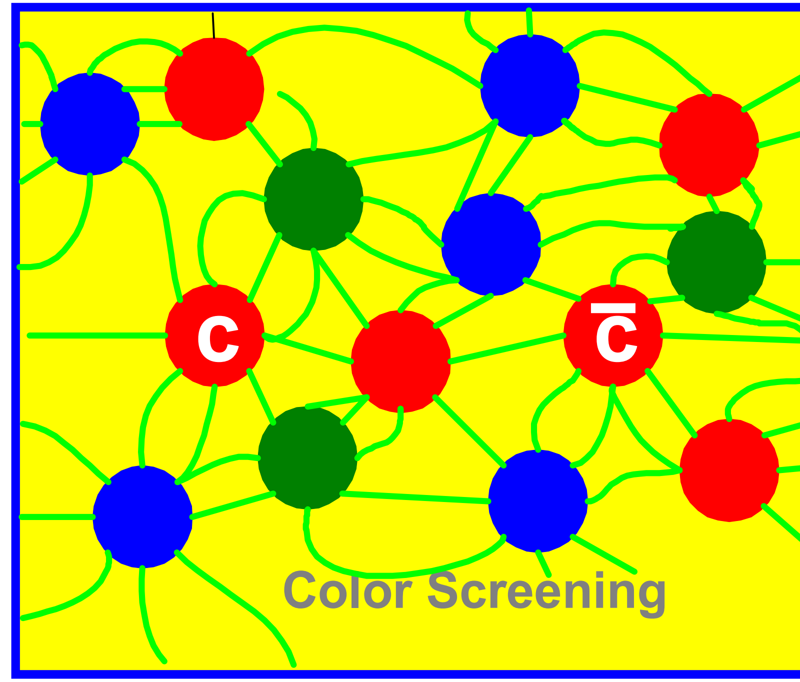
Heavy Flavor Physics in PHENIX





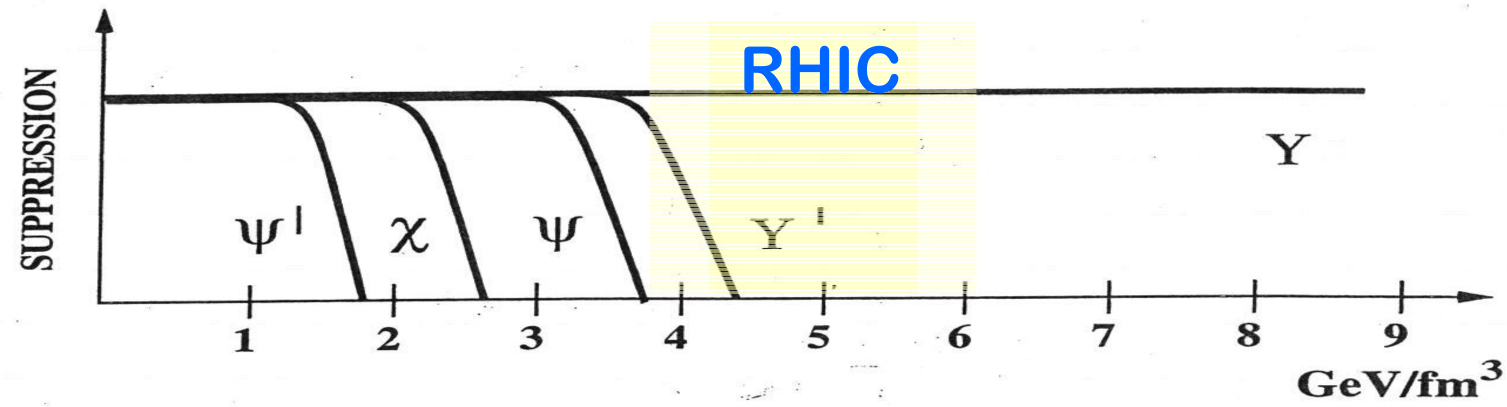
Kenneth N. Barish
UC Riverside
Nassau, Bahamas
Jan. 24, 2002

Quarkonium in deconfined media

In deconfined media

» QCD potential modified

- From screening of $Q\bar{Q}$ pairs in a deconfined plasma we may expect a suppression of J/ψ and other quarkonium states.



» Gluons are hardened

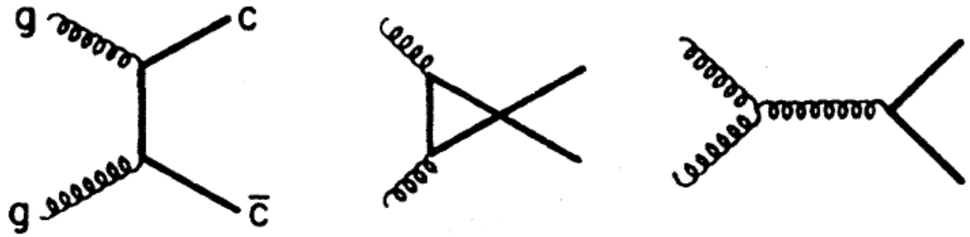
☞ **They are distributed thermally:** $\langle P_g \rangle_{deconf} = 3T$ (T=200MeV, $\langle Pg \rangle_{deconf}$ = 0.6 GeV)

In confined media gluons are thermally distributed in π's:

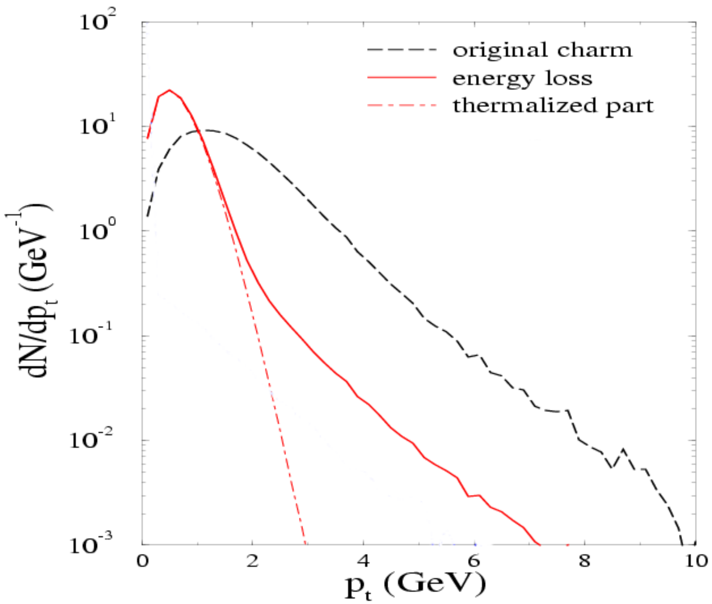
☞ $\langle P_g \rangle = 1/5 \langle P_\pi \rangle = 3/5\ T$
(For T=200MeV, $\langle P_g \rangle$ = 0.1 GeV)

Charm production in heavy ions

- ✓ The measurement of charm production is necessary as a normalization for the quarkonium result.
- ✓ A charm measurement is also intrinsically interesting
  - » Charm is produced in the earliest part of HI collisions via gg fusion and is sensitive to the initial gluon density



  - » Charm quarks may suffer energy loss through gluon radiation in a dense plasma. This would result in softening the D spectra.
    - – Although loss could be suppressed due to “dead cone” effect.
  - » Charm can be thermally produced at very high temperatures.

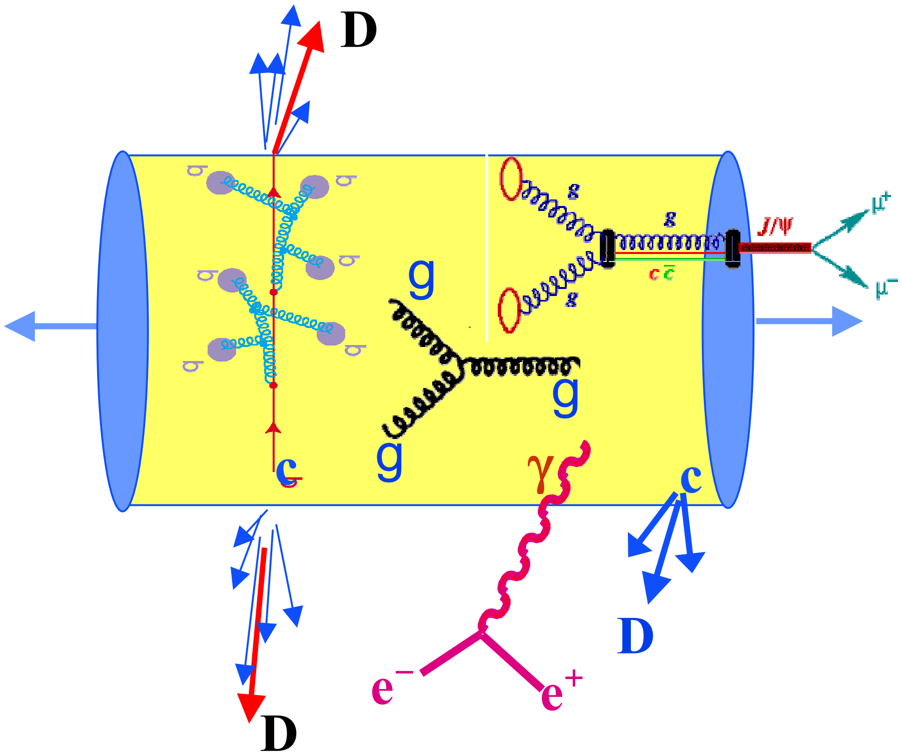


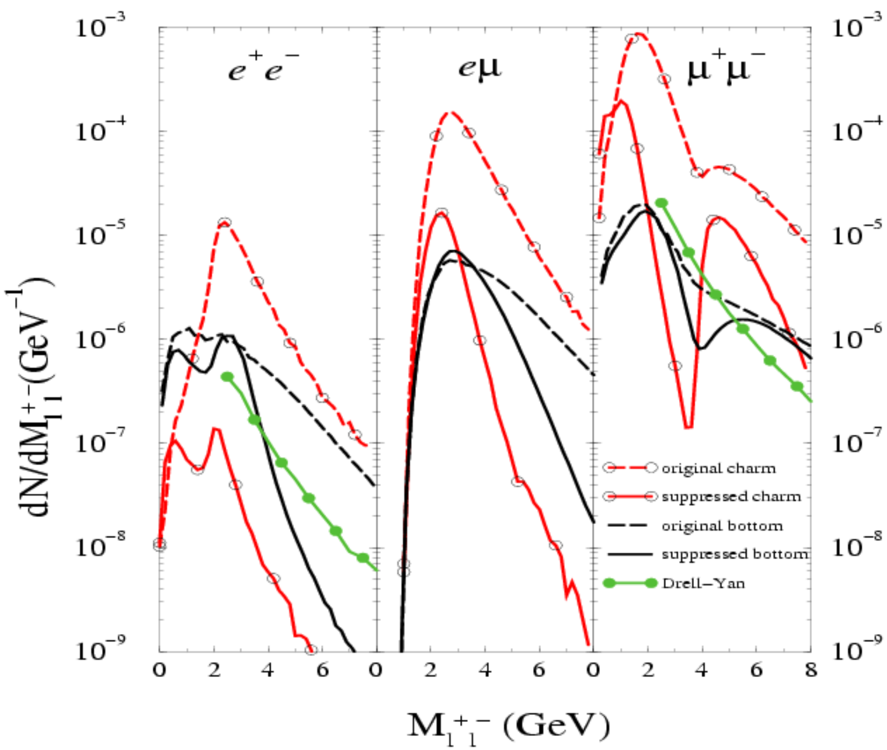
Z.Lin, R. Vogt, X-N. Wang PRC 57 (1998)

K. Barish
UC Riverside

Charm program at PHENIX

Need to measure heavy quarks in pp, pA, and AA to in ee, eμ, and μμ to help untangle channel rich in physics.



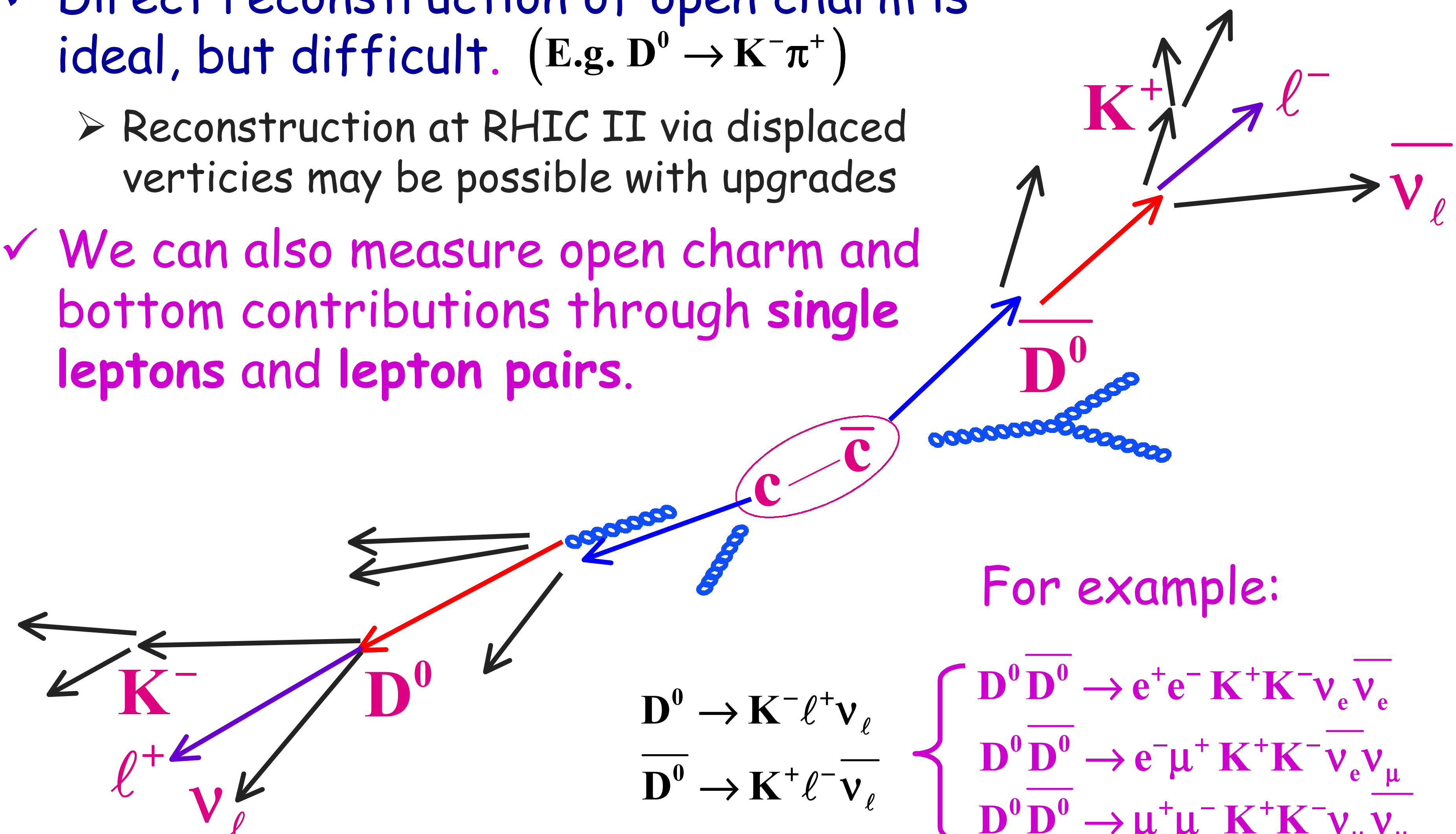


Z.Lin, R. Vogt, X-N. Wang PRC 57 (1998)

K. Barish
UC Riverside

Charm decays

- ✓ Direct reconstruction of open charm is ideal, but difficult. (E.g. $D^0 \rightarrow K^- \pi^+$)
  - ➢ Reconstruction at RHIC II via displaced verticies may be possible with upgrades
- ✓ We can also measure open charm and bottom contributions through **single leptons** and **lepton pairs**.



$D^0 \rightarrow K^- \ell^+ \nu_\ell$

$\overline{D^0} \rightarrow K^+ \ell^- \overline{\nu}_\ell$

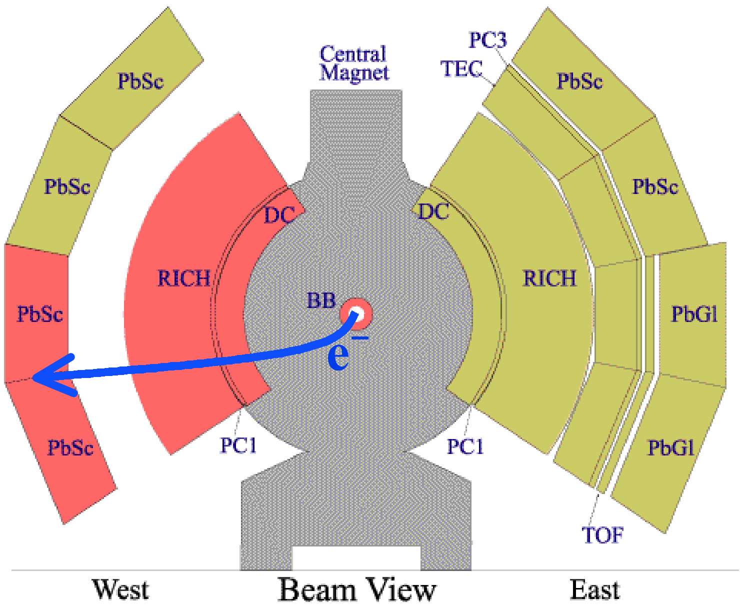
For example:

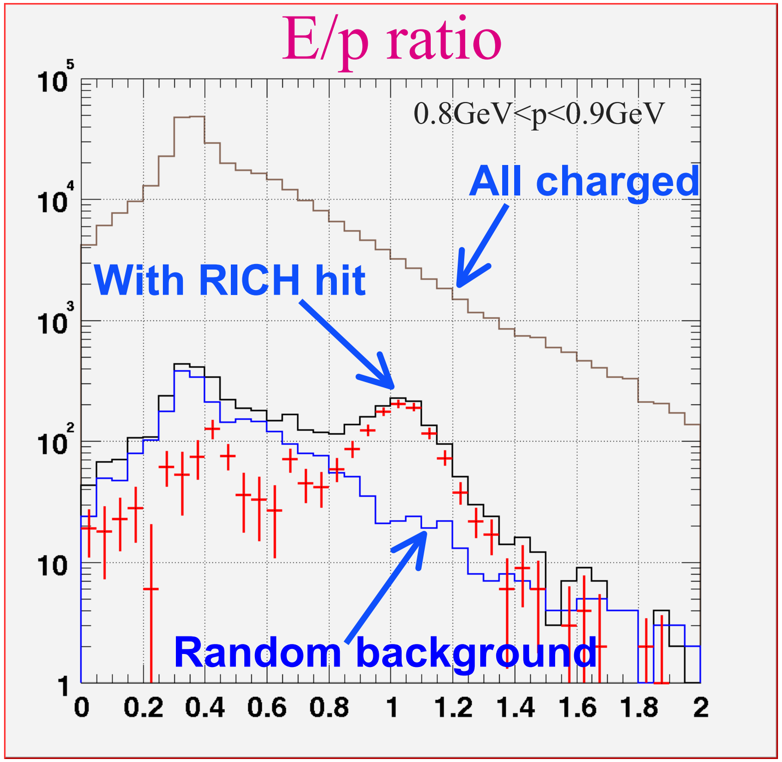
$$\left\{ \begin{array}{l} D^0 \overline{D^0} \rightarrow e^+ e^- K^+ K^- \nu_e \overline{\nu_e} \\ D^0 \overline{D^0} \rightarrow e^- \mu^+ K^+ K^- \overline{\nu_e} \nu_\mu \\ D^0 \overline{D^0} \rightarrow \mu^+ \mu^- K^+ K^- \nu_\mu \overline{\nu_\mu} \end{array} \right.$$

K. Barish
UC Riverside

Electron ID in year-1

- Electrons are identified by RICH and EMCAL

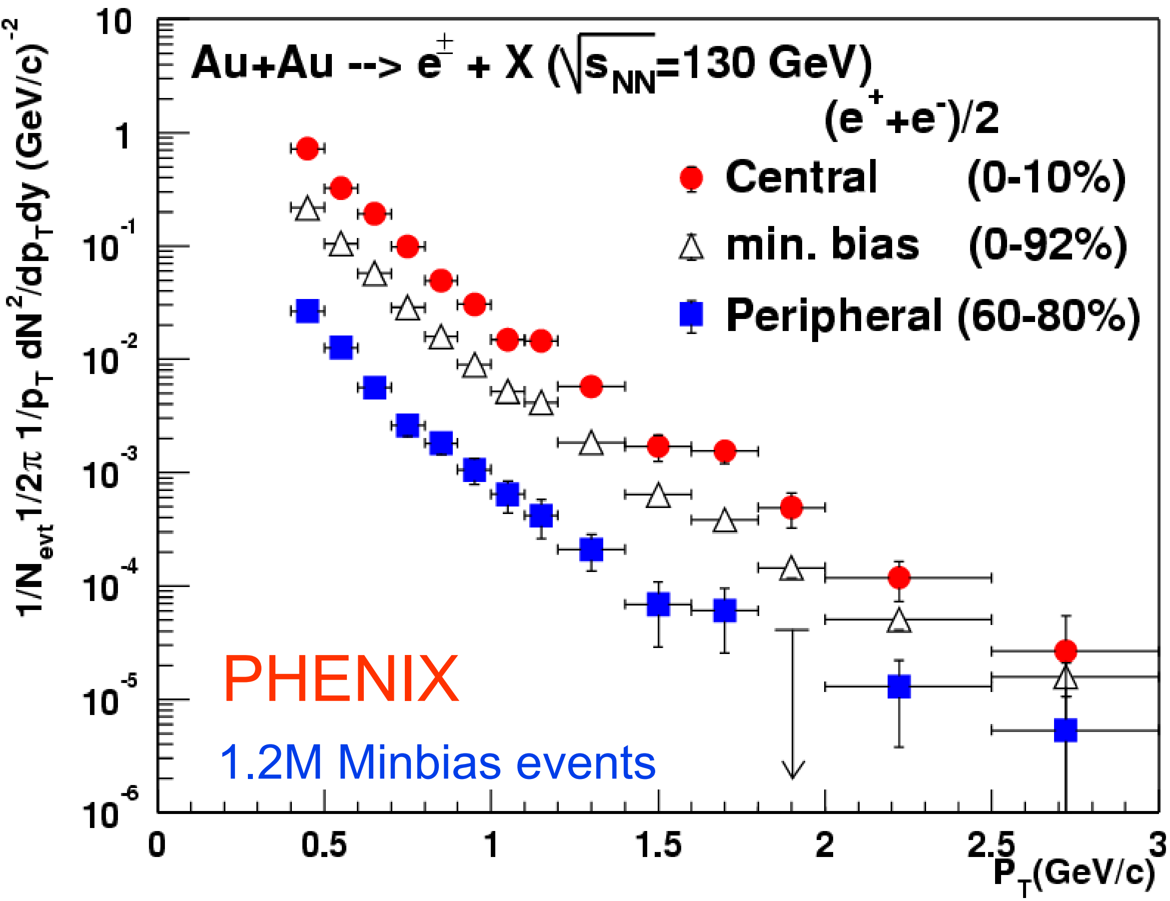




- A clear peak in the energy/momentum (E/p) ratio is seen at 1.0 after RICH hit is required
- EMCAL E/p cut cleans up the background.
- Random background is also subtracted by an event mixing method

K. Barish
UC Riverside

Single electron spectra

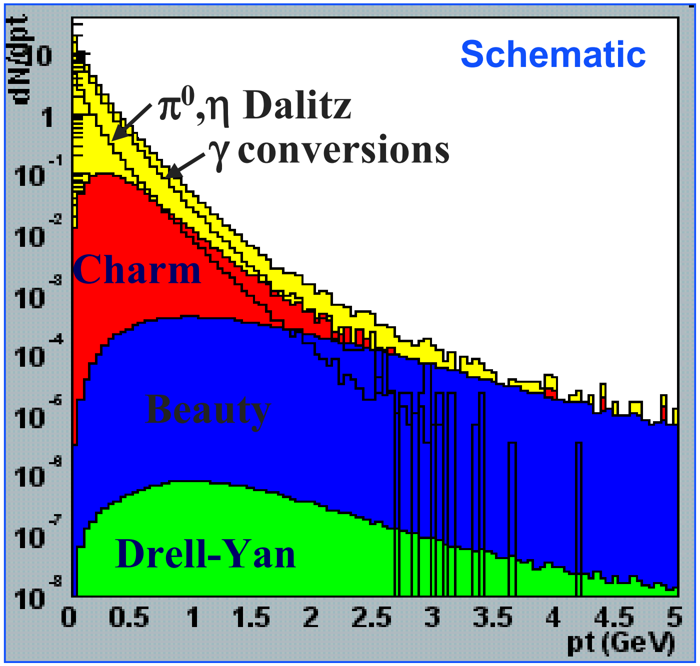


Spectra includes:

- Light hadron decays
- γ conversions

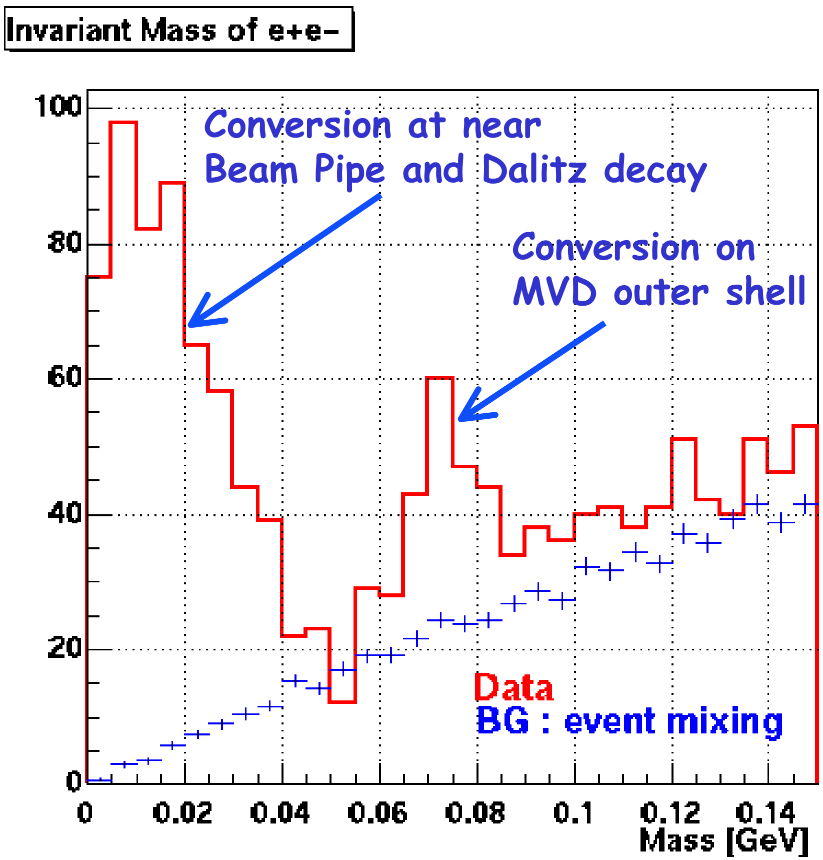
Remaining signal:

- charm and bottom
- thermal production
- new physics



K. Barish
UC Riverside

Dalitz and conversion contribution



Dominant contributions

$\pi^0 \rightarrow e^+e^- \gamma$ $\quad$ $\eta \rightarrow e^+e^- \gamma$

$\pi^0 \rightarrow \gamma\gamma$ $\quad$ $\eta \rightarrow \gamma\gamma$

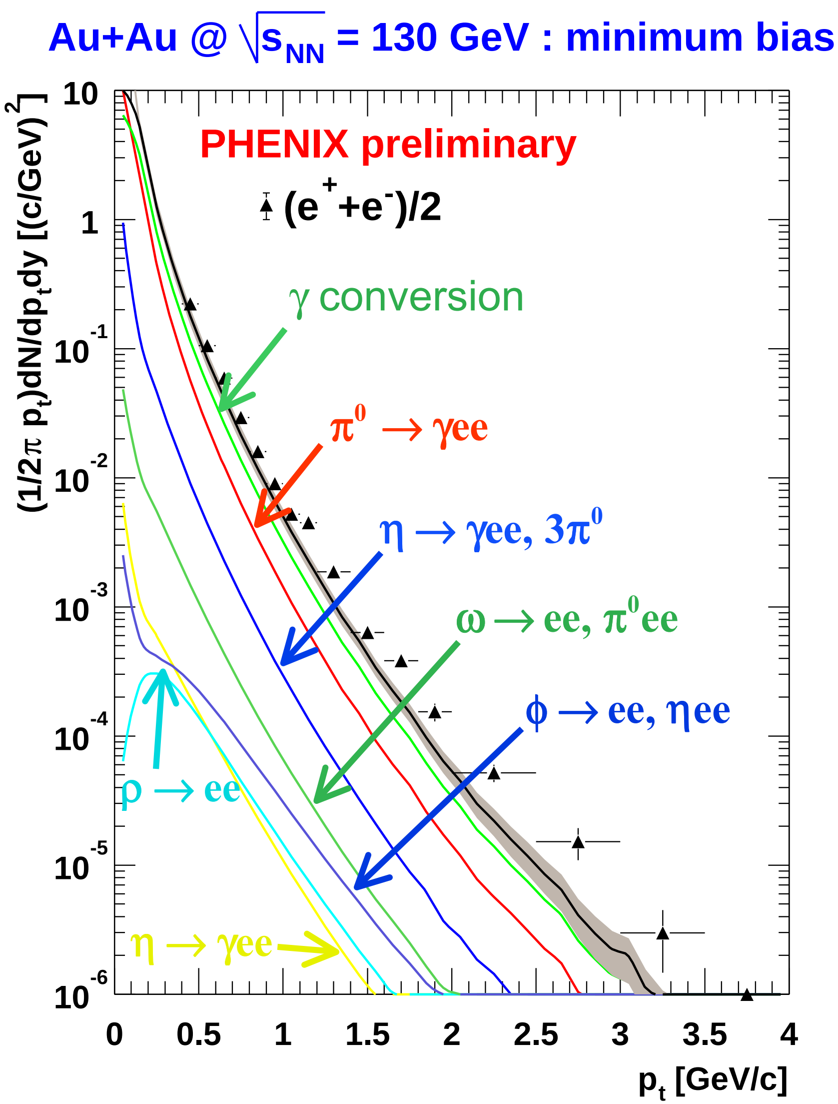
$\quad\quad \hookrightarrow e^+e^-$ $\quad\quad \hookrightarrow e^+e^-$

- ✓ The electrons from light hadron decays are estimated from a cocktail calculation that is constrained by PHENIX's pion measurement.

- ✓ The simulation is cross checked by comparing the relative yield of Dalitz pairs and conversion pairs in the real data and in the simulation.

K. Barish
UC Riverside

Light hadron cocktail calculation



Coctail Input:

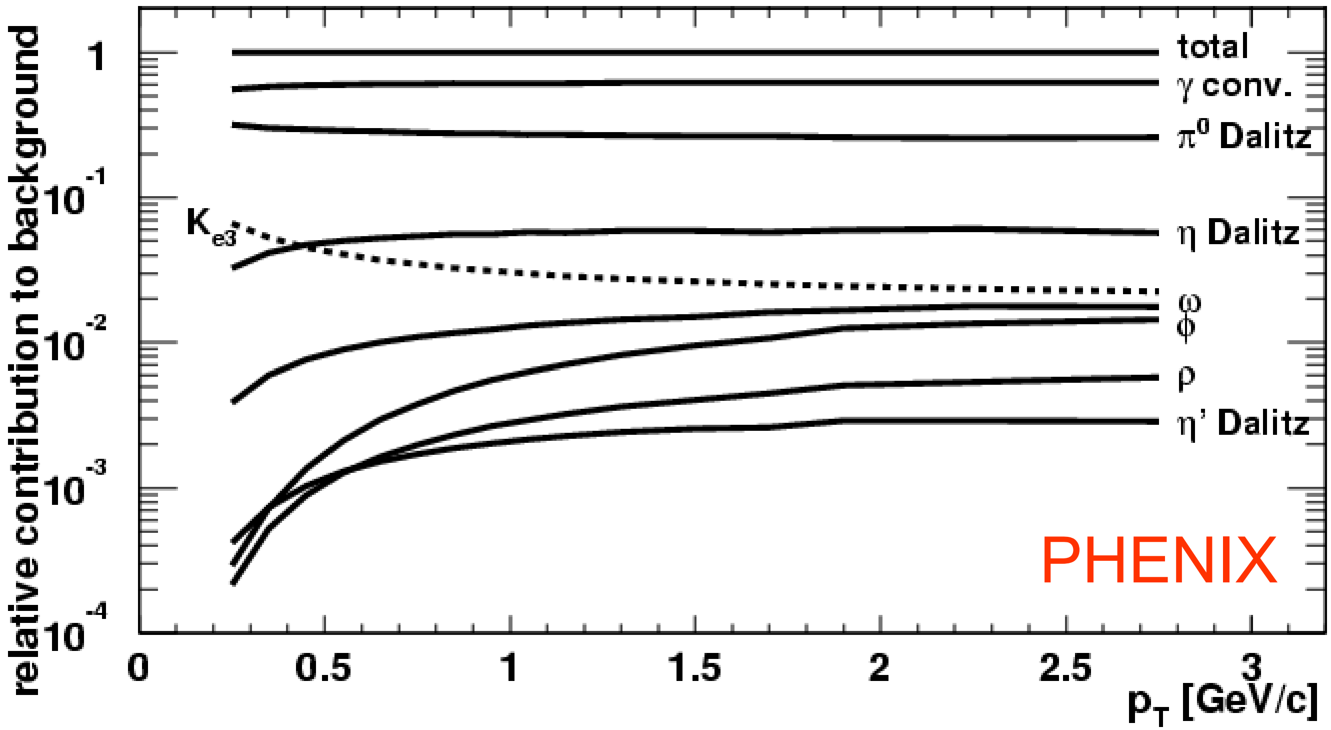
- » Pions (dominant source e^- at low p_t)
  - Take rapidity flat around y=0
  - Take π spectra from PHENIX data
    - Assume charge symmetry ($\pi^0 = \pi^+ = \pi^-$)
- » Use M_T scaling for other hadrons

$$p_t \rightarrow \sqrt{p_t^2 + m_h^2 - m_\pi^2}$$

  - Spectra shapes of PHENIX's $p^\pm$, $K^\pm$ data agree with this scaling within 20%
  - At high p_t take:
    - ✓ $\eta/\pi = 0.55$, $\eta'/\pi = 0.25$, $\rho/\pi = \omega/\pi = 1.0$ [Based on p data from SPS, FNAL and SPS]
    - ✓ $\phi/\pi = 0.4$ [Agrees with STAR ϕ/h^- inclusive measurement of .02]
    - ✓ Assign 50% systematic error to the ratios

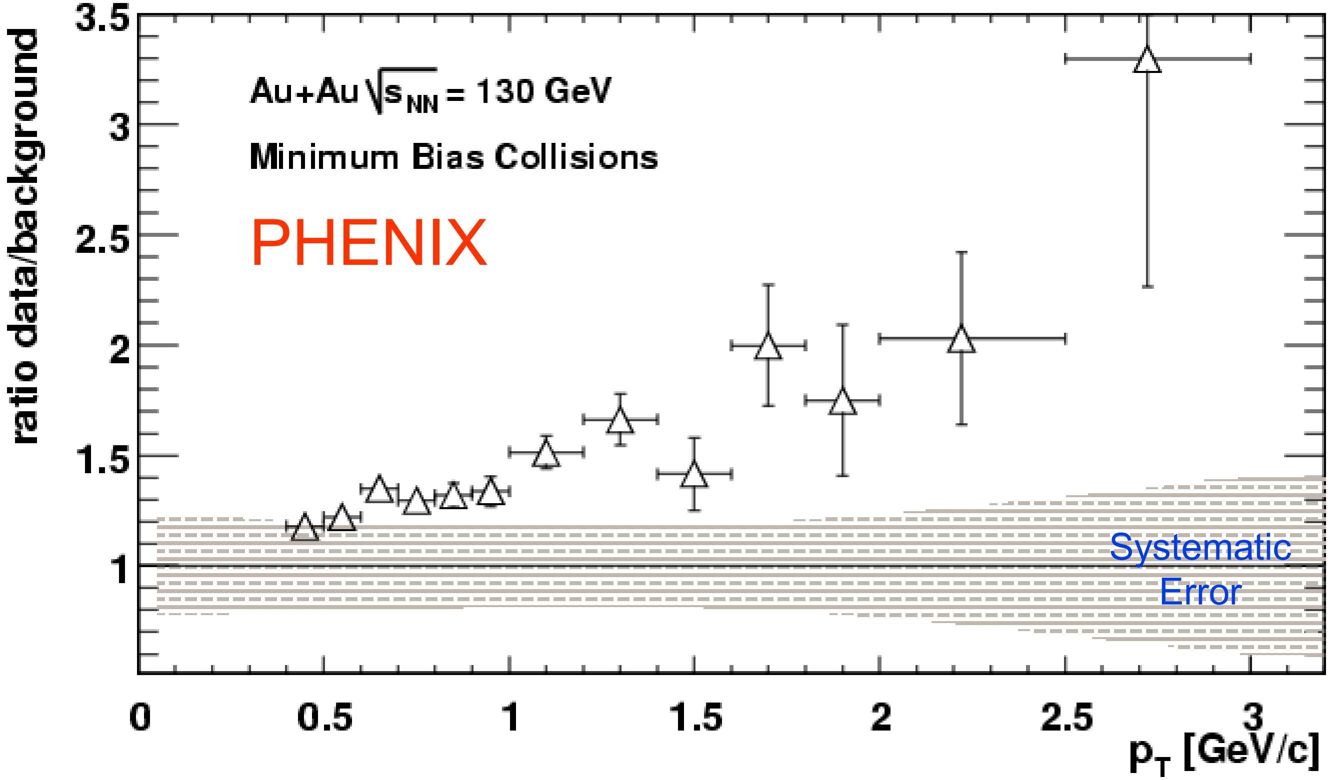
K. Barish
UC Riverside

Contributions to light hadron cocktail



~80% of background from π^0 (either directly from Dalitz decays or indirectly through γ conversion)

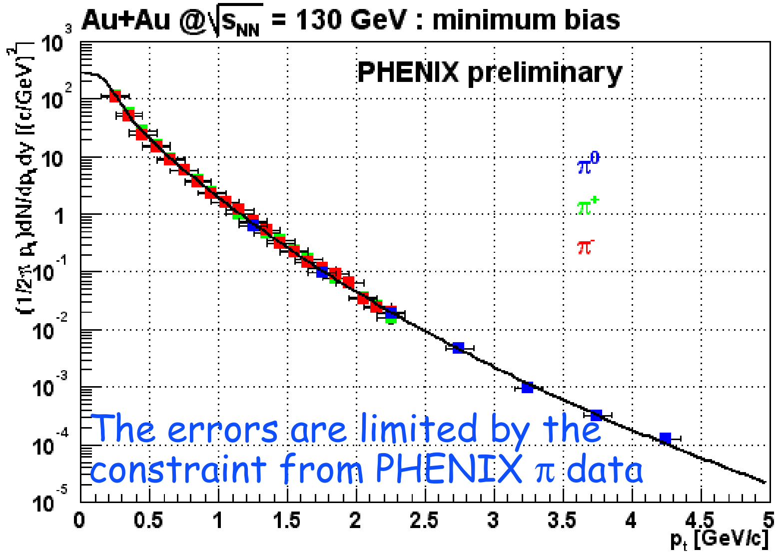
Data / cocktail



- ✓ A clear excess above light hadron cocktail seen for $p_T > 0.6$ GeV/c
- ✓ Central data also shows similar excess, while peripheral data does not have enough statistics
- ✓ Excess increases as a function of p_T, as is expected from charm.

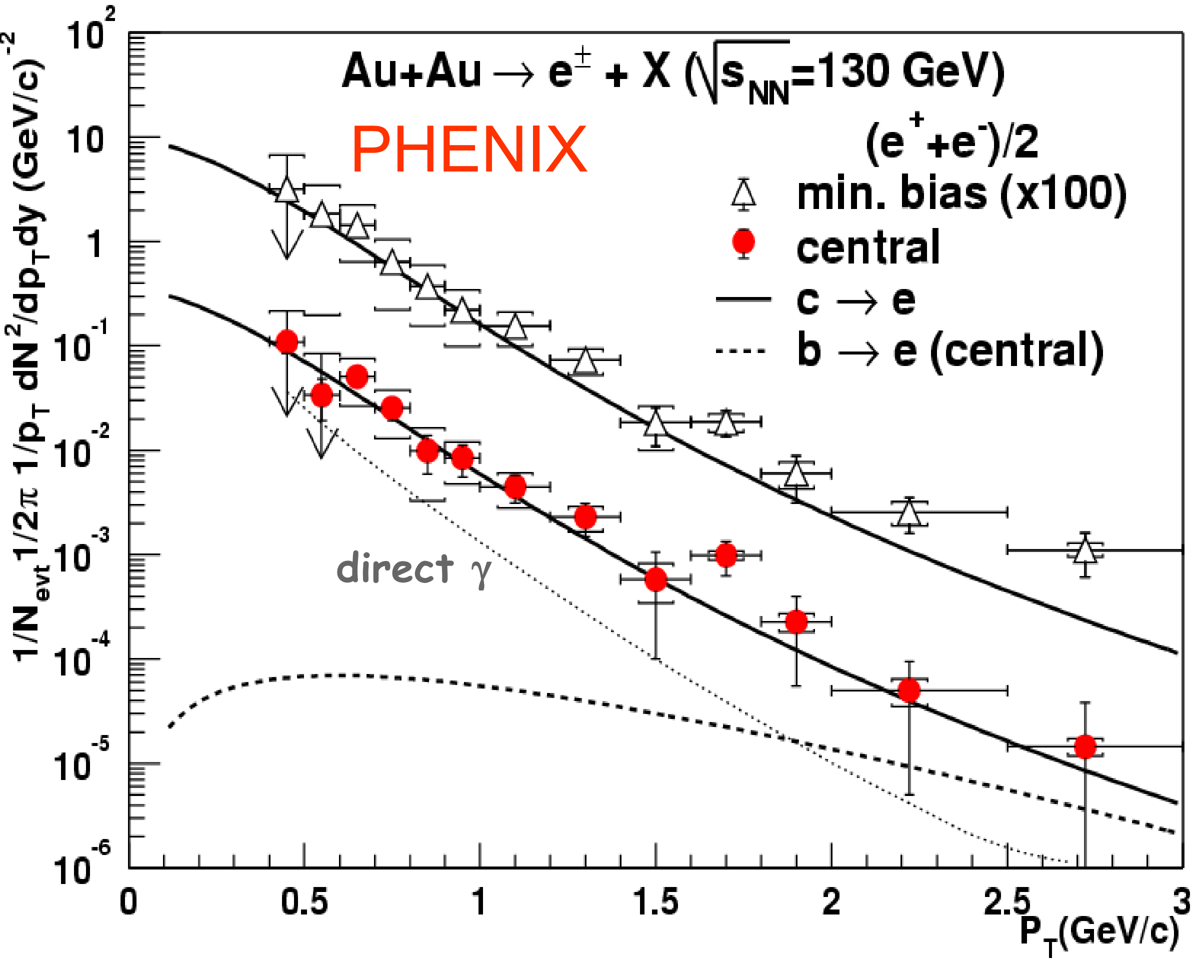
Systematic errors

- The systematic errors in the data and cocktail are roughly equal.
- The dominant sources systematic error in the light hadron cocktail come from uncertainties in:
  - the normalization and shape of input π^0 spectrum
  - the h/π^0 ratios
  - the conversion/Dalitz ratio



- The dominant sources systematic error in the data come from uncertainties in:
  - the detector efficiency
  - RICH ID and E/p cut efficiencies
  - the subtraction of hadron background
  - the EMCal/RICH association

Background subtracted electron spectra



- ✓ Excess consistent with semi-leptonic decay from charm (c → eX)
- ✓ PYTHIA calculation:
  - ➢ Input that fits SPS, FNAL, and ISR single electron data
    - o Version: 6.152
    - o CTEQ5L PDFs
    - o M_c=1.25Gev/c^2
    - o K=3.5, $\langle k_t \rangle$=1.5
  - ➢ In pp gives

$$\sigma_{c\bar{c}} = 330\mu b$$

- ✓ Data is a bit higher than this PYTHIA parameterization.

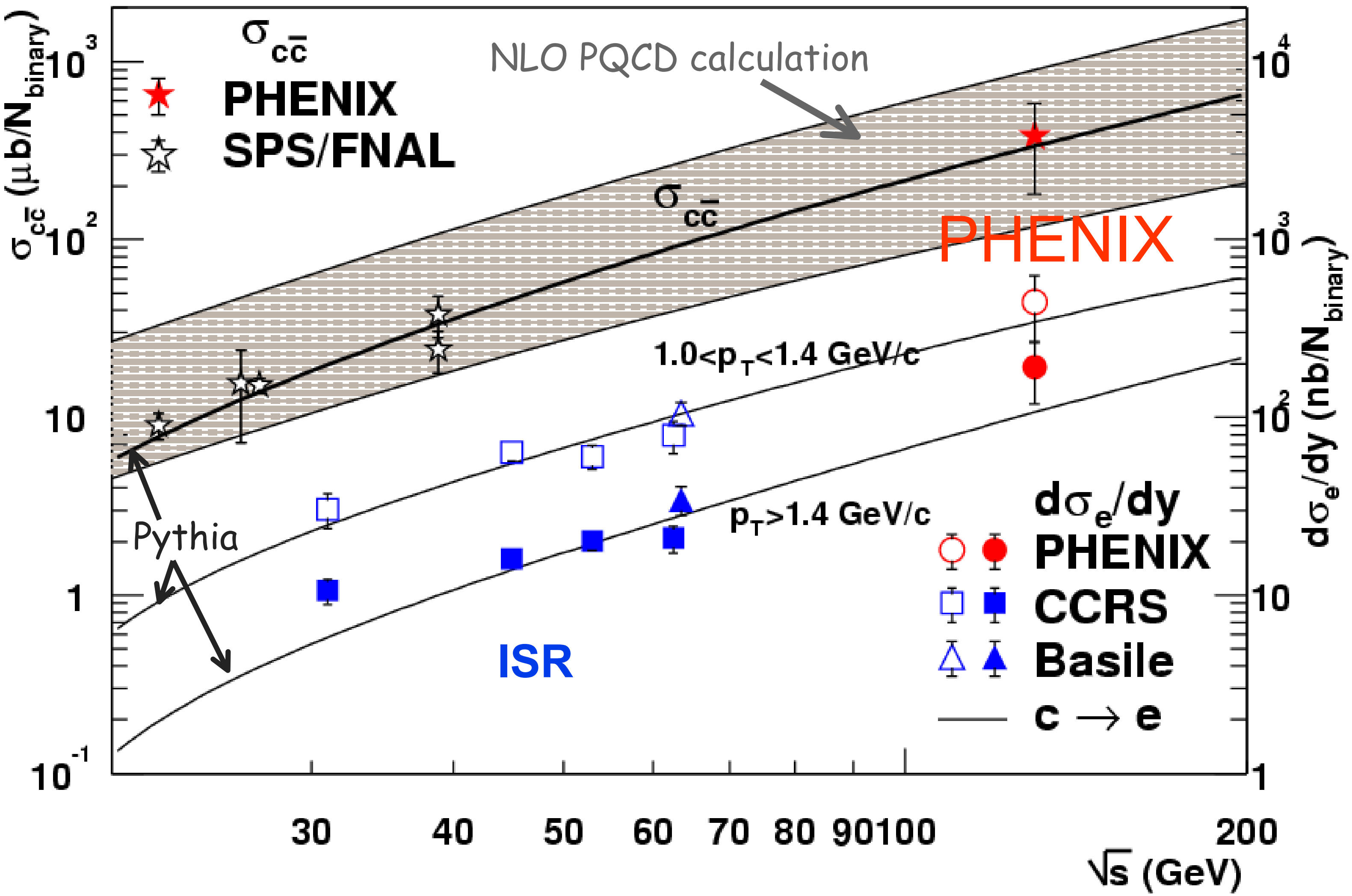
Charm yield

- We can estimate the charm yield by assuming that all single electrons above the background are from charm
  - Neglect other possible sources such as thermal γ and di-leptons
  - This may be overestimating the charm yield
- By fitting the PYTHIA calculation to the data for p_T>0.8GeV/c, we obtain charm cross sections per binary NN collision:

$$\sigma_{c\bar{c}}^{0-10\%} = 380 \pm 60 \pm 200 \mu b \text{ and } \sigma_{c\bar{c}}^{0-92\%} = 420 \pm 33 \pm 250 \mu b$$

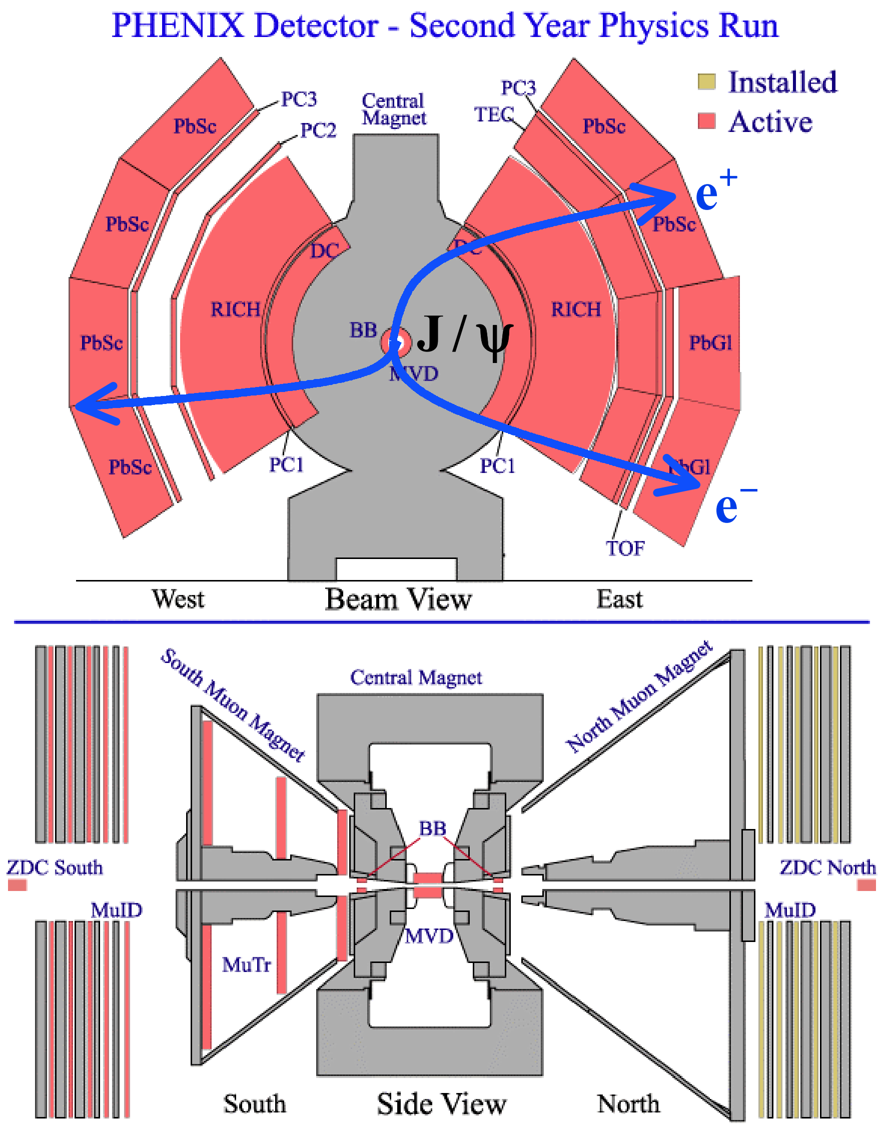
- The data is consistent with binary scaling (i.e. no nuclear or medium effects), but with large uncertainties.

Comparison with lower energies



K. Barish
UC Riverside

Year-2 detector

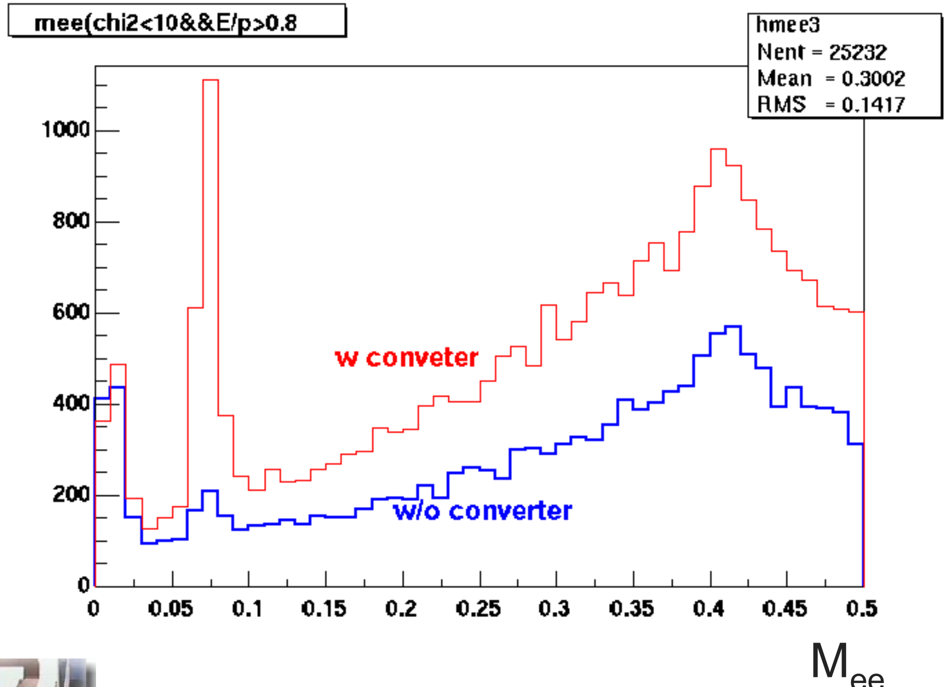


- ✓ **Central arms fully instrumented**
  - » Level-2 trigger uses BB, RICH, EMCal, & PC.
    - For single electrons: make p_T cut (E threshold)
    - For J/ψ and ee pairs: make rough invariant mass selection
- ✓ **South muon arm installed**
  - » Level-2 trigger uses road-finder (next year Level-1)
    - For single muons: require 1 deep road in muID
    - For μμ: require 1 deep & 1 shallow roads in muID

K. Barish
UC Riverside

Year-2 improvements for charm

- ✓ Much higher statistics
  - o 170M events sampled (92M minbias)
- ✓ Special "converter" run with heavy-ions to directly measure background from photon conversion.
- ✓ Charm and η/π measurement in pp run

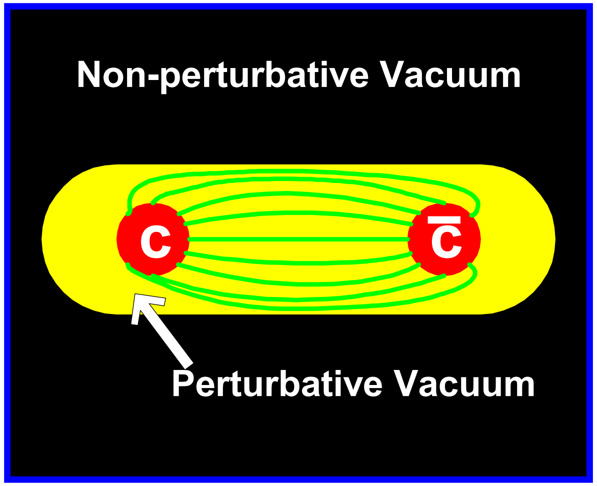


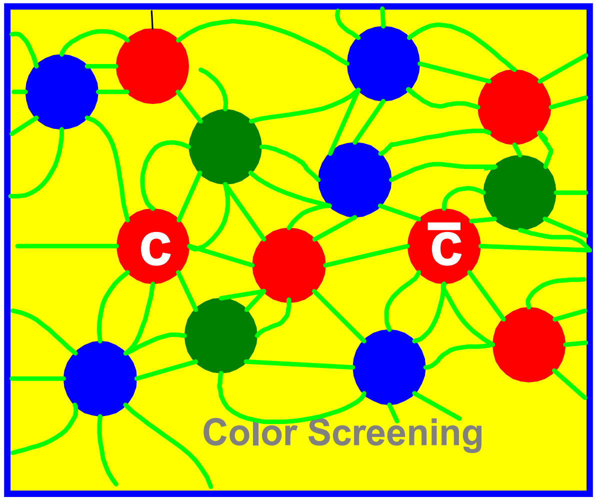
K. Barish
UC Riverside

J/ψ in year-2

- ✓ **170M events sampled (minbias + triggered)**
- ✓ In the absence of anomalous suppression or additional thermal production at RHIC, and assuming $\sigma(pp \rightarrow J/\psi) = 3.3\times10^{-6}$ b we will reconstruct of order:
  - ➢ ~100 $J/\psi \rightarrow ee$
  - ➢ ~500 $J/\psi \rightarrow \mu\mu$

Note: there is a large uncertainty (both in production and reconstruction) in this estimate





K. Barish
UC Riverside

PHENIX

Conclusion and outlook

The PHENIX heavy flavor program has begun!

✓ An excess of single electrons above the expected light hadron contribution is seen in Year-1 data.

✓ Neglecting other possible contributions, the excess translates into $\sigma_{c\bar{c}}^{0-10\%} = 380 \pm 60 \pm 200 \mu b$

Year-2 data will yield:

- First look at $J/\psi \rightarrow e^+e^-, \mu^+\mu^-$
- Improved single electron spectra with special converter run to directly measure Dalitz/Converter contribution
- Charm and J/ψ pp data