Heavy Flavor Production in PHENIX

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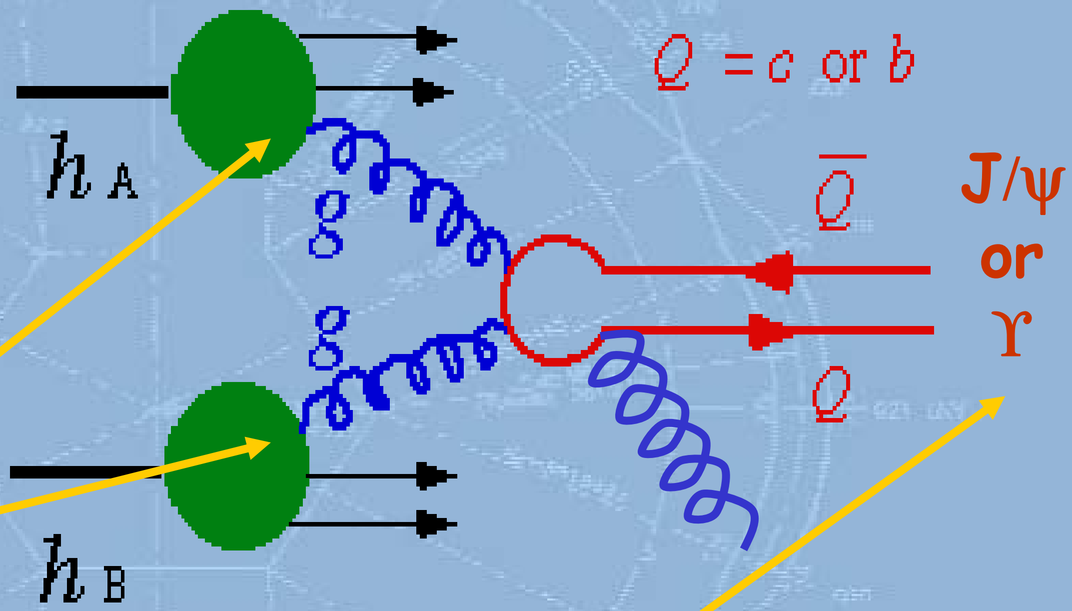
Heavy flavor production

- ✓ "Onia" production
  - ✓ Leading order at low x = "gluon fusion"
- ✓ Sensitive to:

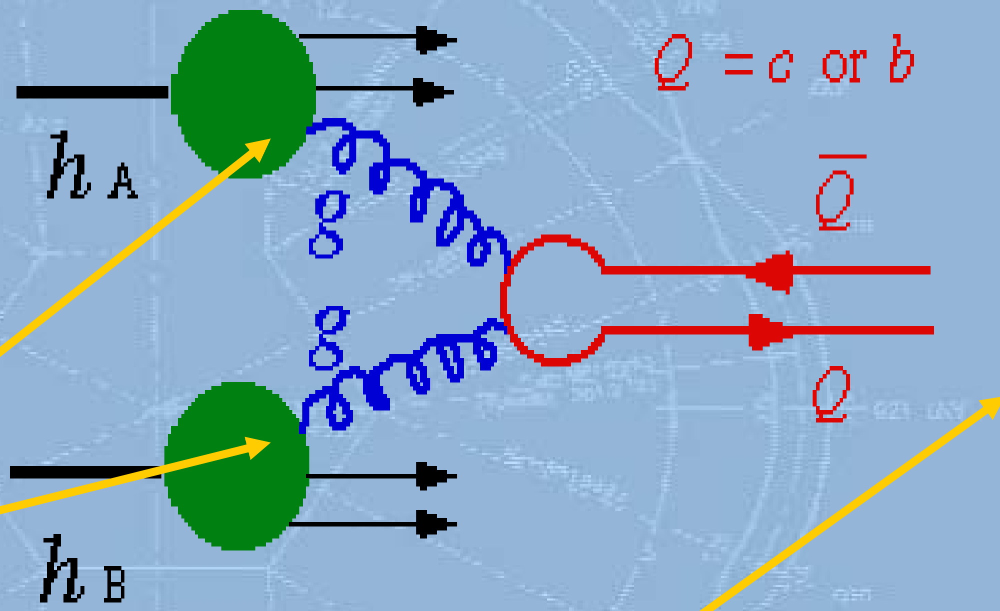


- ✓ Initial state
  - ✓ Parton distribution functions
  - ✓ p_T broadening
  - ✓ Parton energy loss in the initial state ?
  - ✓ Polarization ?
- ✓ Final state
  - ✓ Parton energy loss in the hot & dense medium ?
  - ✓ Thermal enhancement ?
  - ✓ Flow ?

+ feed-down (e.g. B or χ_c-> J/ψ)

Heavy flavor production

- Open charm (or beauty) production
  - Leading order at low x = "gluon fusion"



- Sensitive to:
  - Initial state
    - Parton distribution functions
    - p_T broadening
    - Parton energy loss in the initial state ?
    - Polarization ?
  - Final state
    - Parton energy loss in the hot & dense medium ?
    - Thermal enhancement ?
    - Flow ?

Physics Motivations

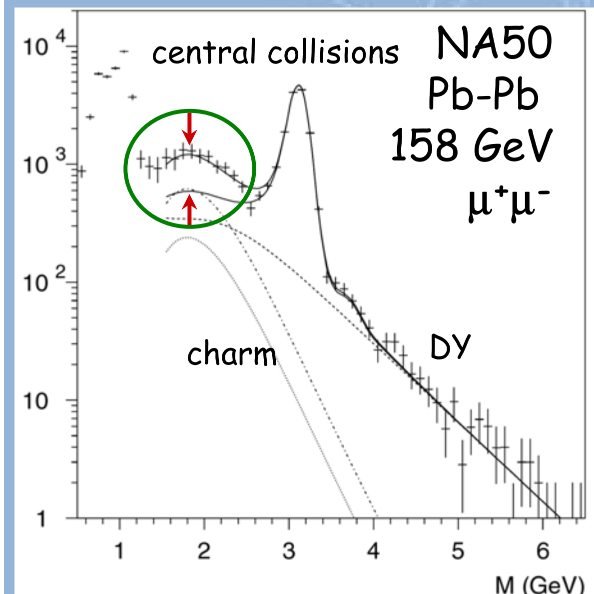
- Open flavors are interesting *per se* :

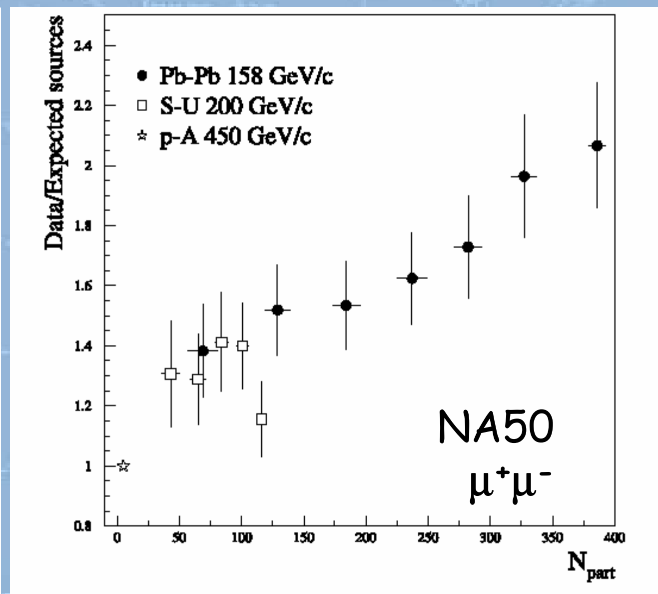
- Do heavy quark suffer « quenching », as light flavors do ?
  - Higher quark mass -> less gluon radiation ("dead cone effect")
  - D/π modified at moderate p_T due to different quenching
    - Y. L. Dokshitzer & D.E. Kharzeev, Phys.Lett.B519(2001)199-206

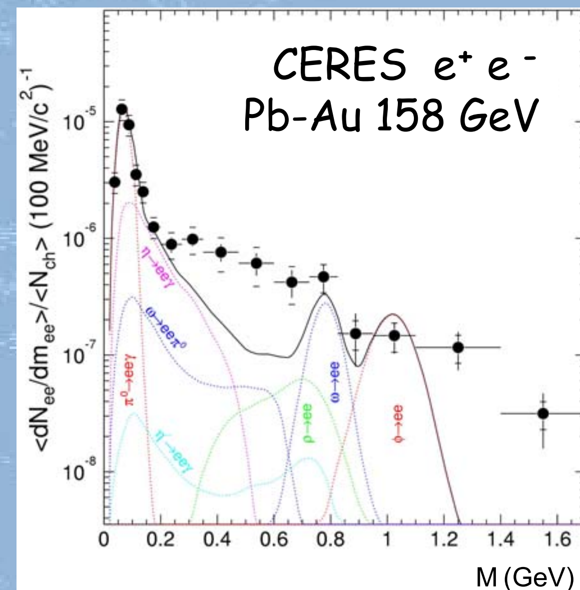
- Do heavy quark flow ?
  - Early creation in hard process -> they should not
  - Additional creation, enhancement, "in medium" effects -> they could
  - In any case, OPEN = they're detected once bound to light quarks
    - Influence of light quark flow
    - Influence of decay if detected in semi-leptonic decay channels

Physics Motivations

- ✓ Possible charm enhancement in Heavy Ion collisions ?
  - ✓ "unexpected sources" of dileptons observed at SPS
  - ✓ This contribution doesn't scale as the number of collisions







  - ✓ Is there an enhancement of charm production ?
  - ✓ Ideally, open charm should be used as a reference for J/ψ production, as color screening prevents charmonia bound states

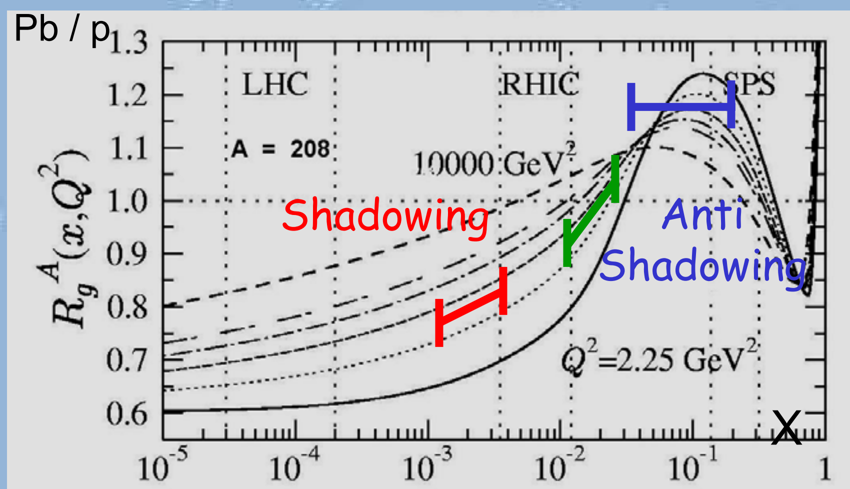
color screening ⇔ bound charmonia / open charm

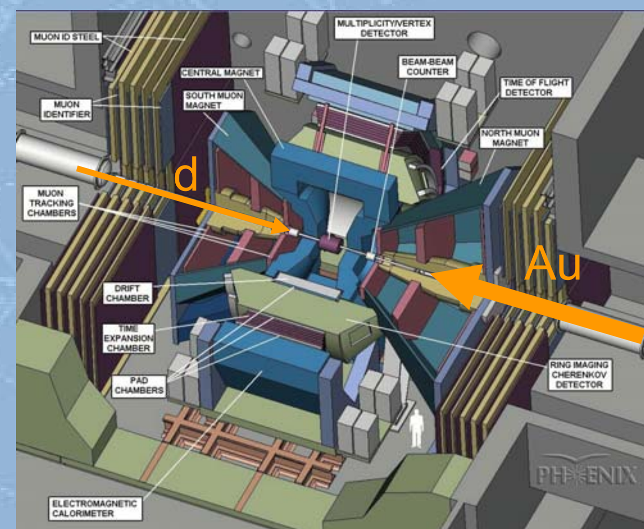
Physics Motivations

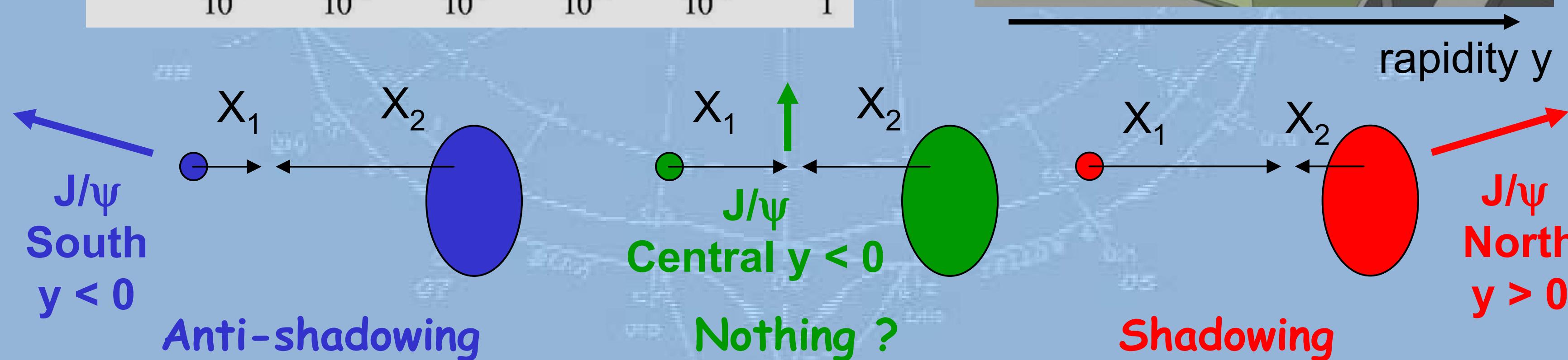
- Heavy flavor = probe for « cold » nuclear effects
  - Parton distribution functions are modified in nuclei

color screening ⇔ bound charmonia / open charm

  - e.g. in d-Au collisions :

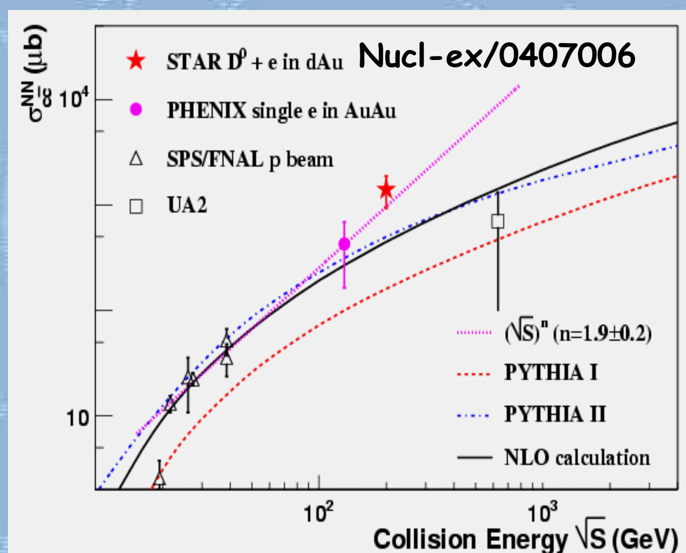


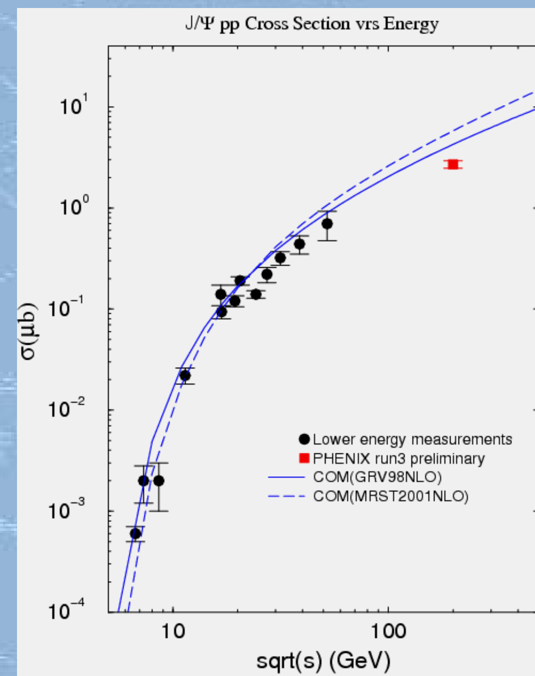




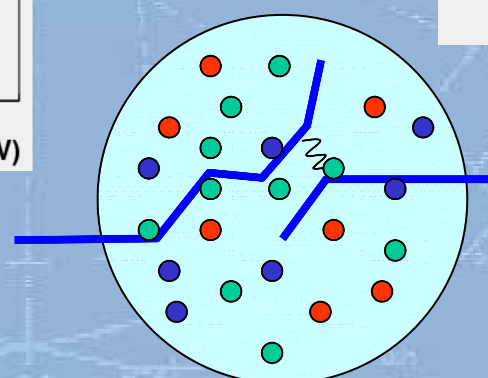
Physics Motivations

- ✓ Charm production is sensitive to incident energy of partons
  - ✓ Possible energy loss in the initial state may affect charmonium production
    - ✓ Holds both for charmonia and open charm, so could be checked with open charm





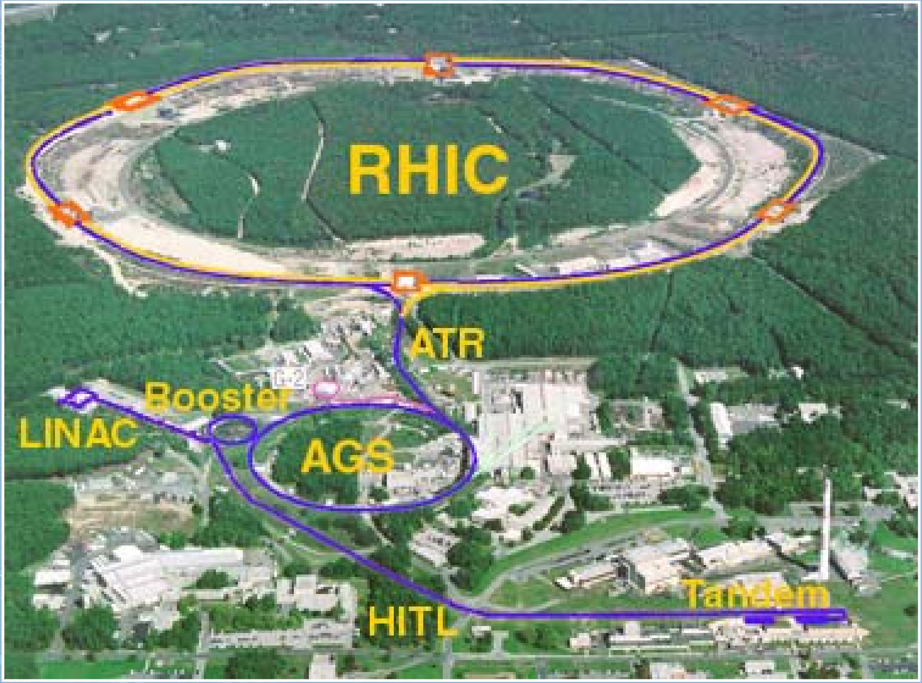
- ✓ Sensitive p_T broadening (e.g.: gluon-nucleon scattering)



color screening ⇔ bound charmonia / open charm

RHIC

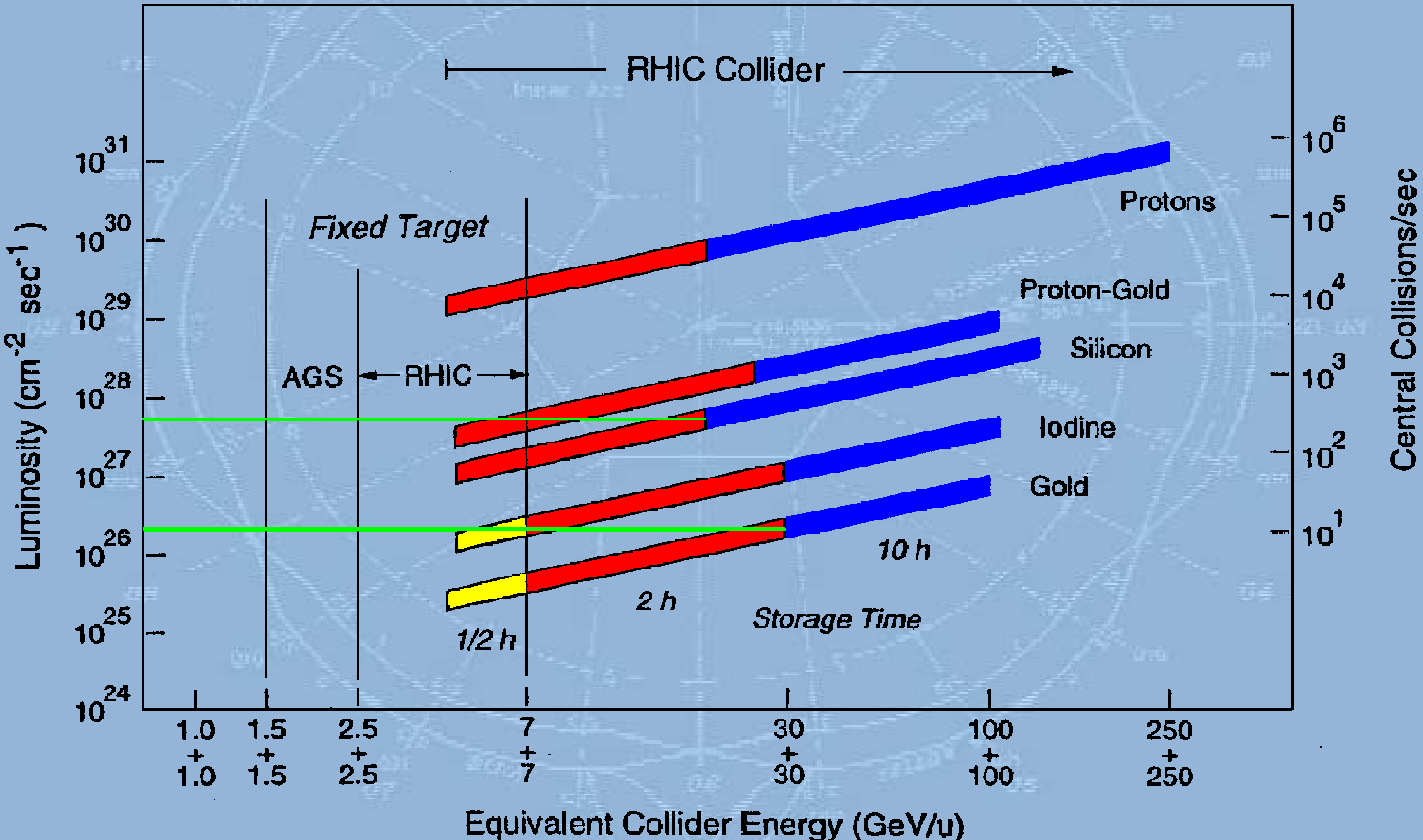
- ✓ RHIC (Relativistic Heavy Ion Collider)
  - ✓ Long Island, not so far from Manhattan ;-)
  - ✓ Dedicated to heavy ion physics & spin studies
  - ✓ 4 experiments
  - ✓ 100+100 GeV/A
  - ✓ Variable incident energy
  - ✓ p-p up to 500 GeV



PHENIX

RHIC

- ✓ Vast incident energy range
- ✓ Various ion species from p to Au

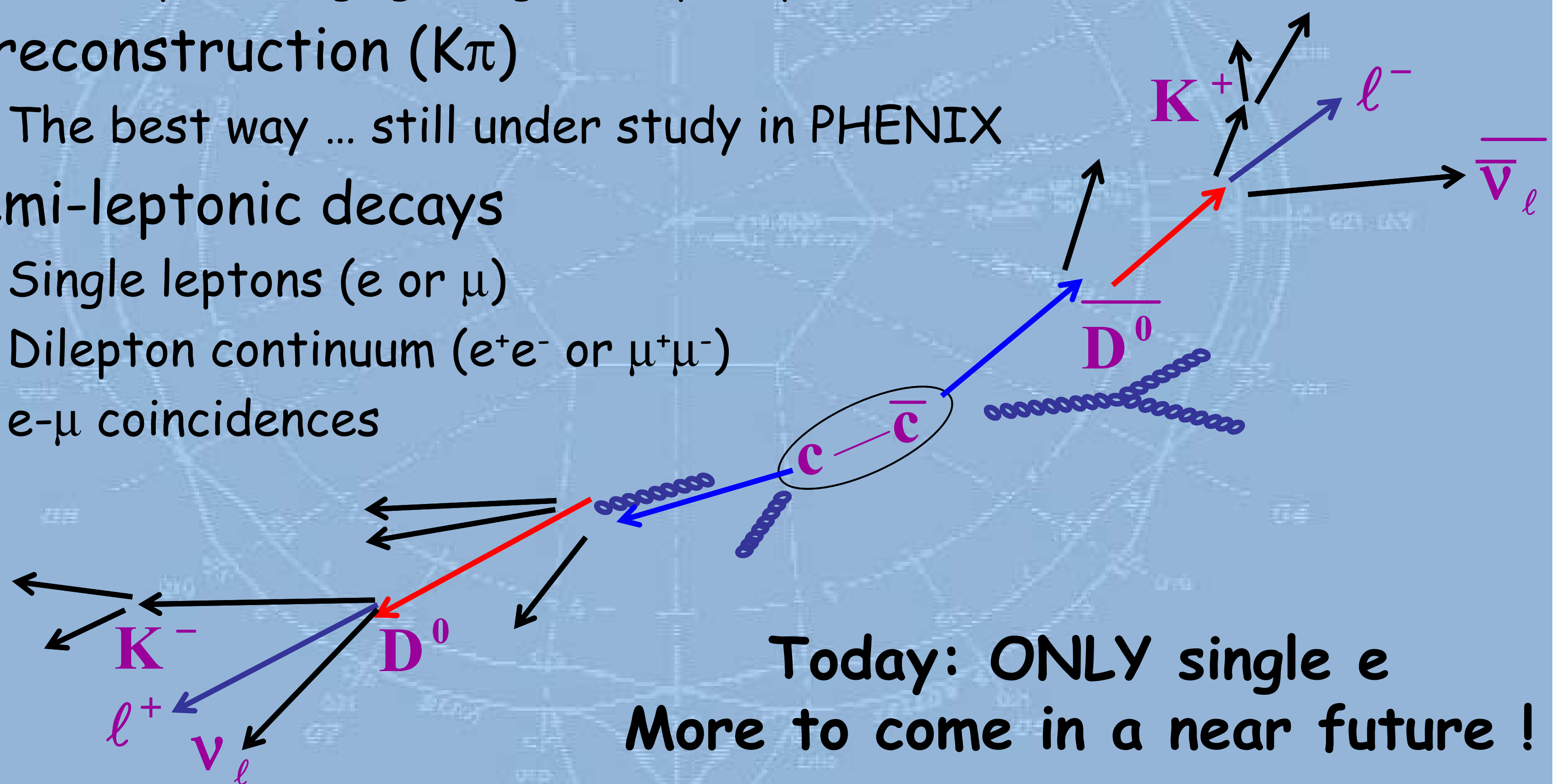


PHENIX

- ✓ Electrons in EM-Cal + RICH
- ✓ Muons in MuTr + MuId

Heavy flavors

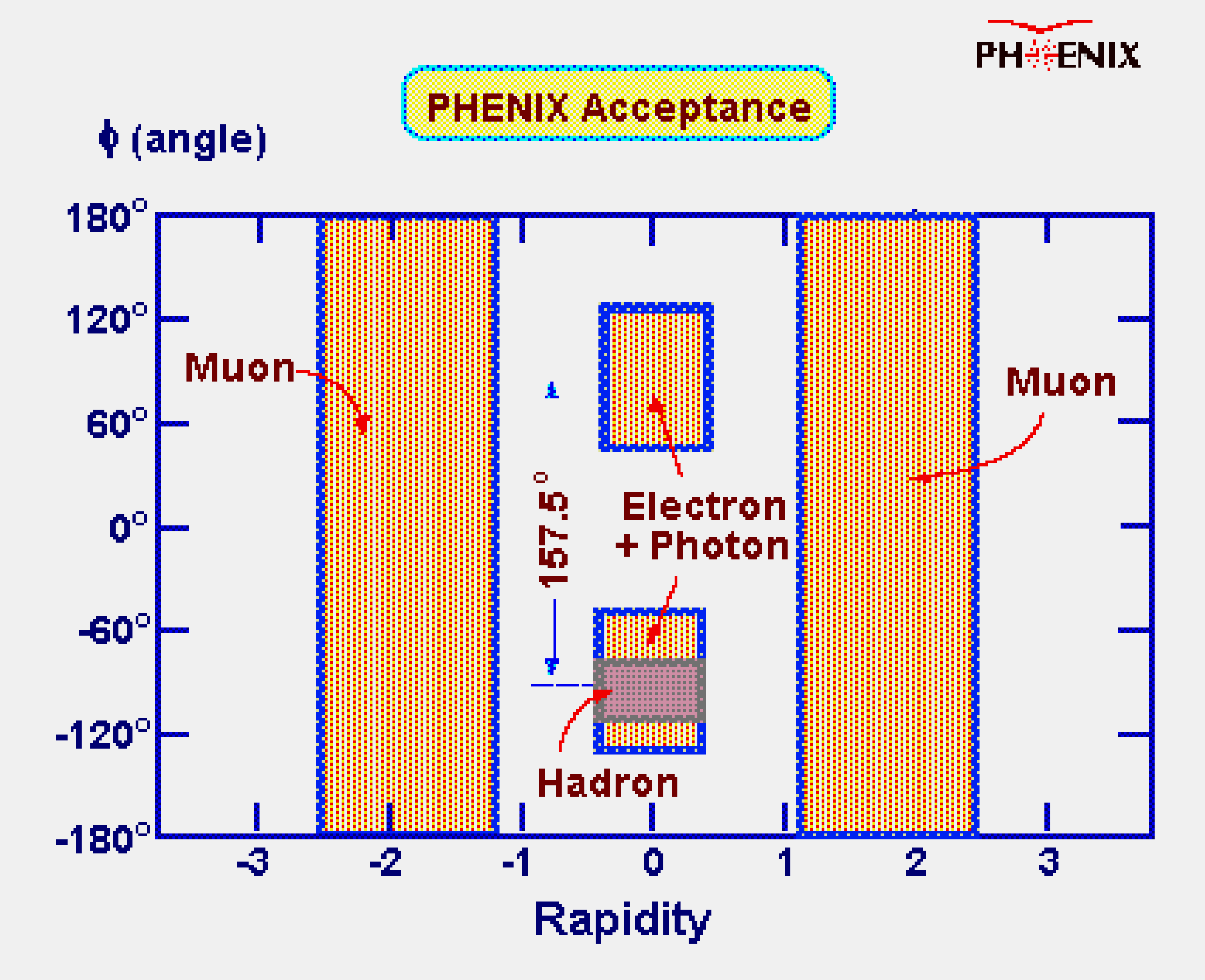
- ✓ Secondary decay vertex … long term future ?
  - ✓ Needs precise tracking close to IP to see displaced vertex …
    - ✓ we have no detector to do this
    - ✓ Very challenging in high multiplicity & radiation environment
- ✓ D reconstruction (Kπ)
  - ✓ The best way … still under study in PHENIX
- ✓ Semi-leptonic decays
  - ✓ Single leptons (e or μ)
  - ✓ Dilepton continuum (e^+e^- or $\mu^+\mu^-$)
  - ✓ e-μ coincidences



Today: ONLY single e
More to come in a near future !

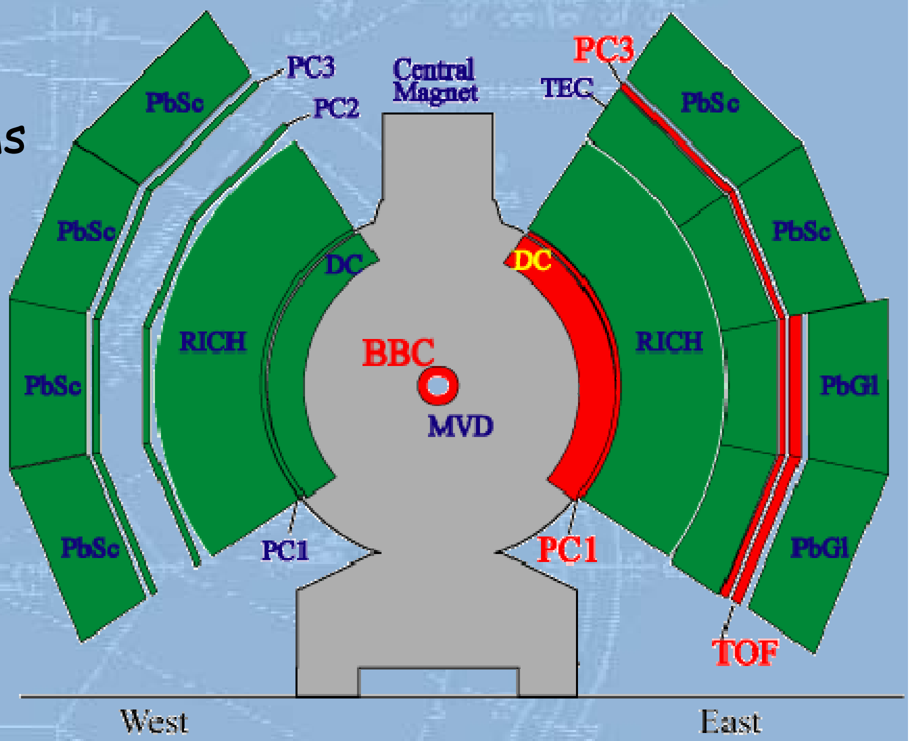
PHENIX

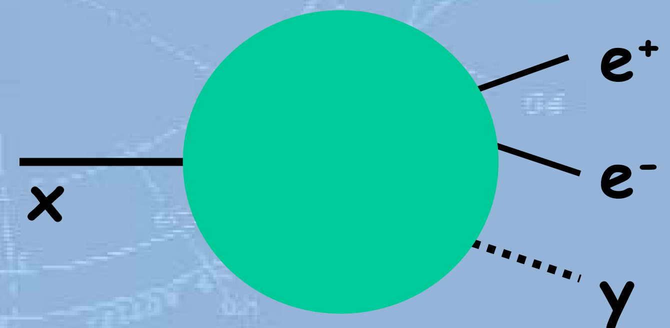
✓ Different acceptance domains



Open charm in PHENIX

- For now:
  - Only single electrons in central arms
  - Only open charm
- Electrons
  - $|\eta| < 0.35$ $\Delta\phi = \pi / 4$
  - Tracks reconstructed with Drift Chamber & PC1
  - EM-Cal matching hit
  - RICH hits + ring shape
  - Timing (EMC or TOF)
- "Photonic" electrons
  - γ conversion
  - π^0 and η/η' Dalitz decay: $\to \gamma ee$
  - light vector meson decay:
    - $\omega, \varphi \to (\pi^0,\eta)ee$



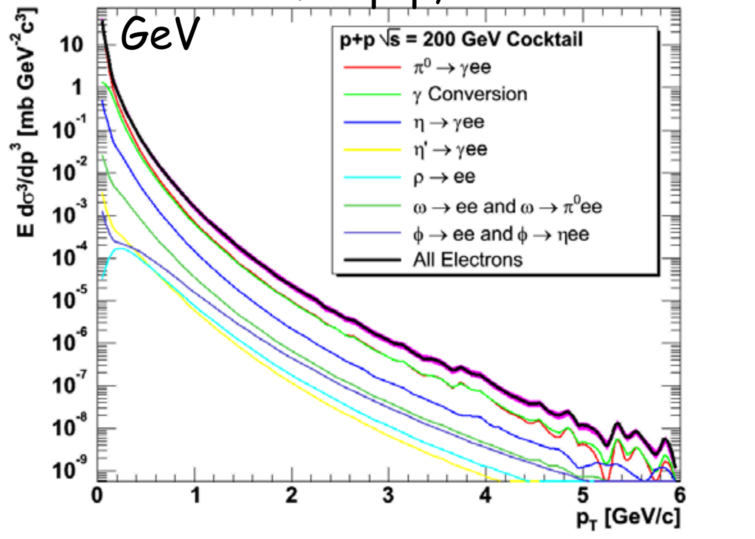


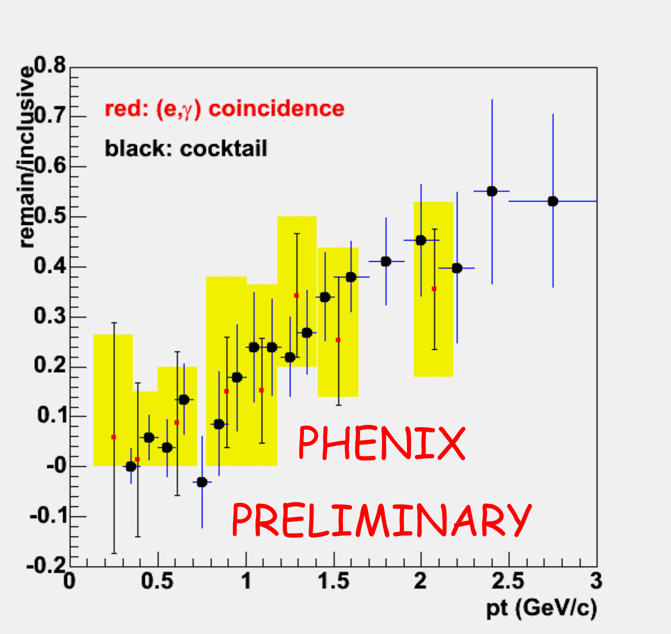
Yield proportional to real γ

Open charm in PHENIX

- NON-photonic electrons = ALL – PHOTONIC
  - K decay
  - ρ, ω, φ → ee
  - c → e (dominant)
  - b → e
- Subtract background by:
  - Cocktail method
  - Converter method
  - Direct measurement of γ e coincidences + event mixing
- Correct for acceptances and efficiencies
- Non-photonic contribution increases with p_T
  - Good agreement between cocktail method and γ e coincidence method

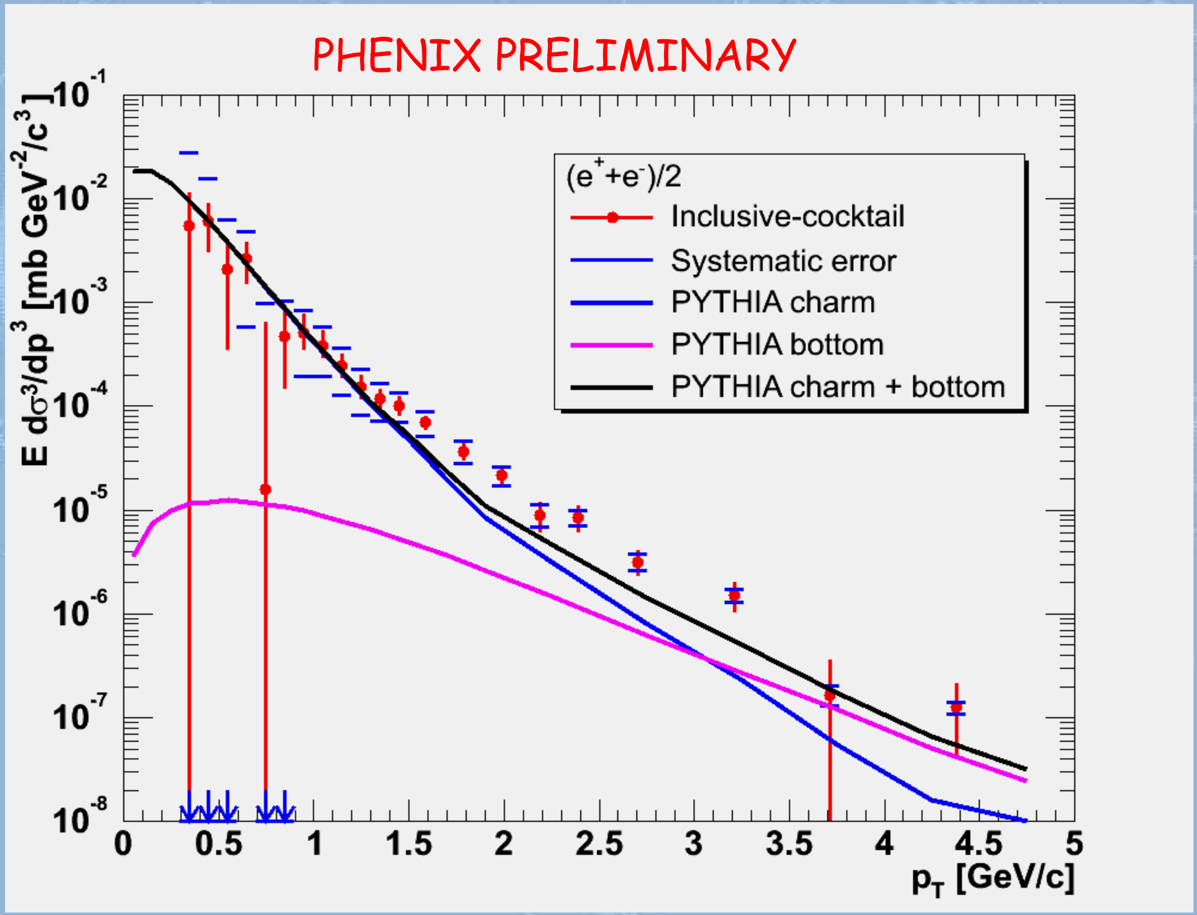
Cocktail for p-p, √s = 200 GeV





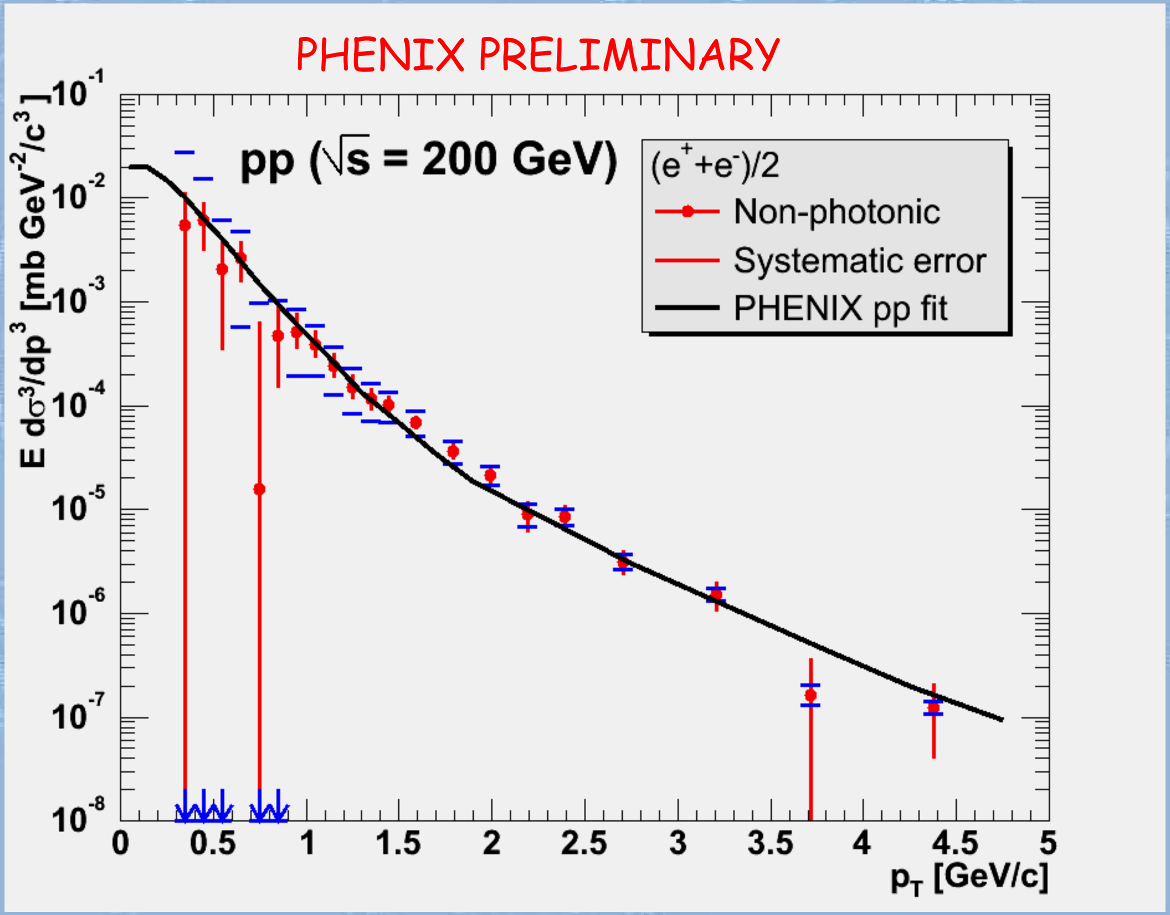
p-p ($\sqrt{s}$ = 200 GeV)

- ✓ Non-photonic electrons in p-p as compared to Pythia:
  - ✓ Reasonable agreement
    - ✓ Charm alone not sufficient at high p_T
    - ✓ Bottom -> not enough statistics



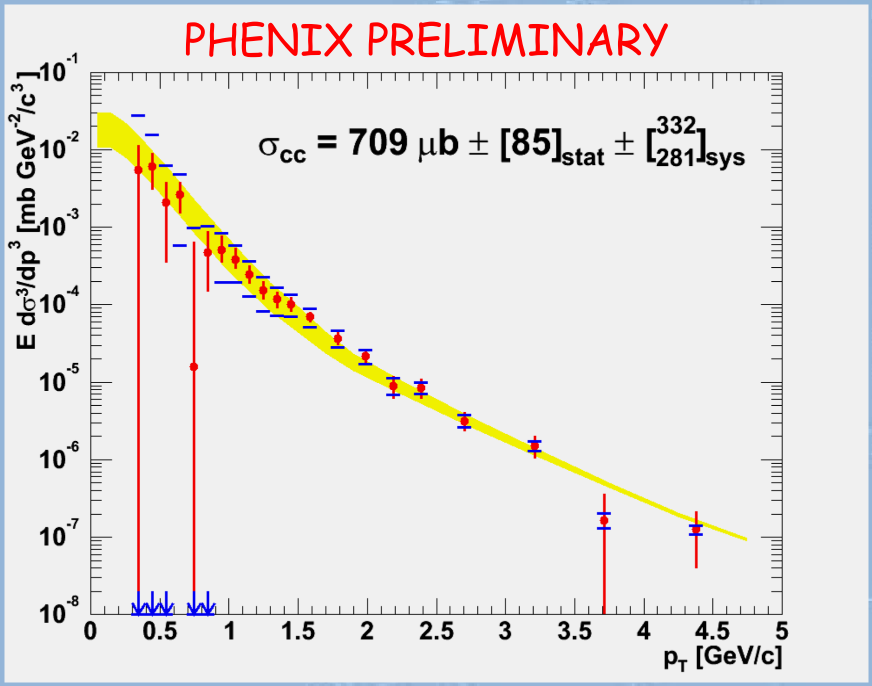
p-p ($\sqrt{s}$ = 200 GeV)

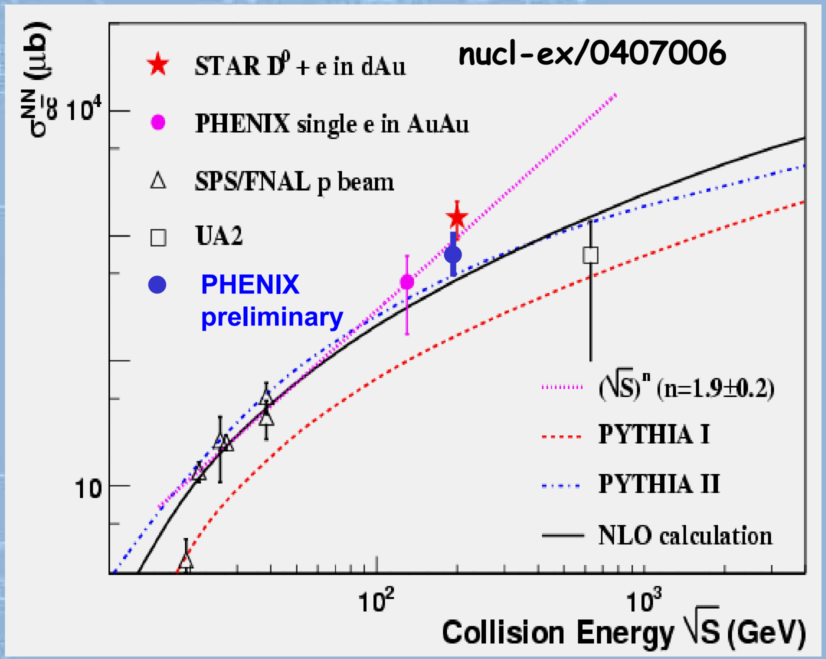
- ✓ Phenomenological fit
  - ✓ To compare with d-Au and Au-Au …



p-p ($\sqrt{s}$ = 200 GeV)

✓ … and to extract charm cross section

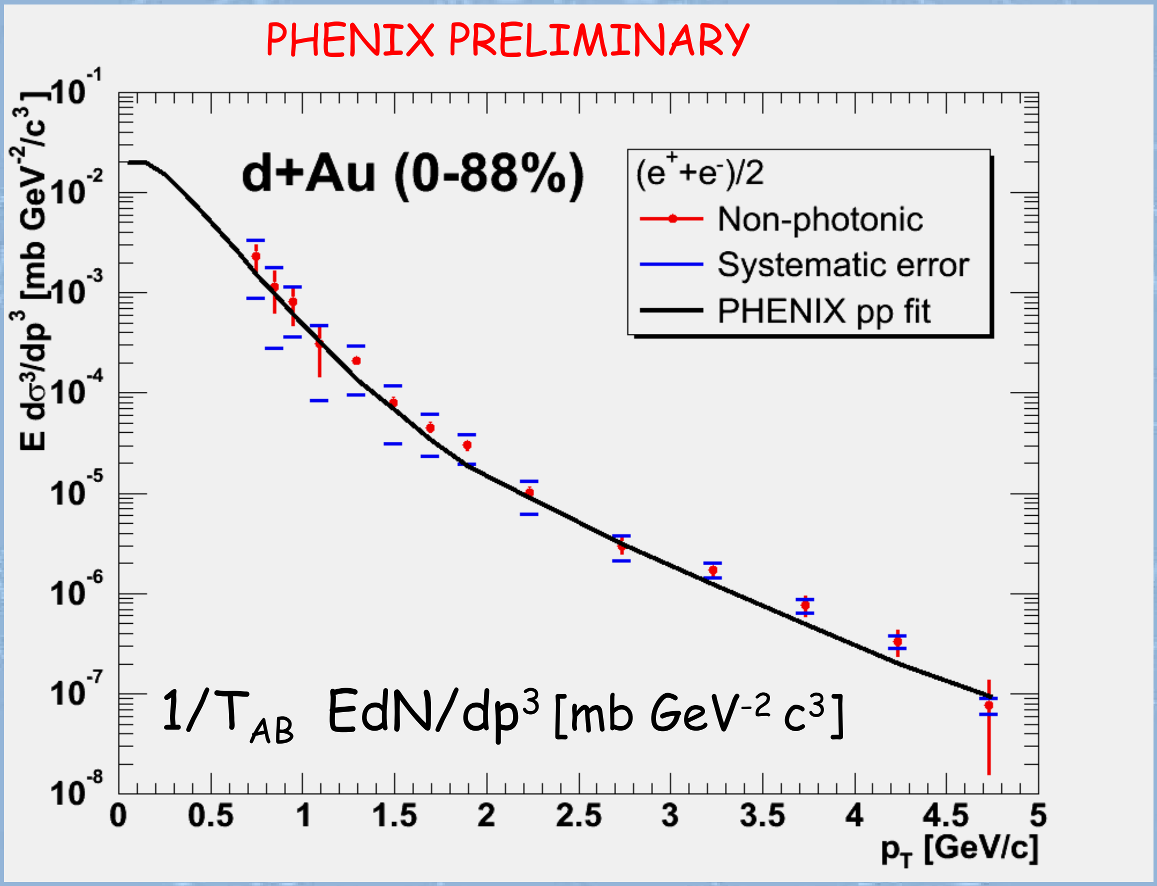




σ_{cc}=709μb ± 85(stat)$^{+332}_{-281}$(syst)

d-Au ($\sqrt{s}$ = 200 GeV)

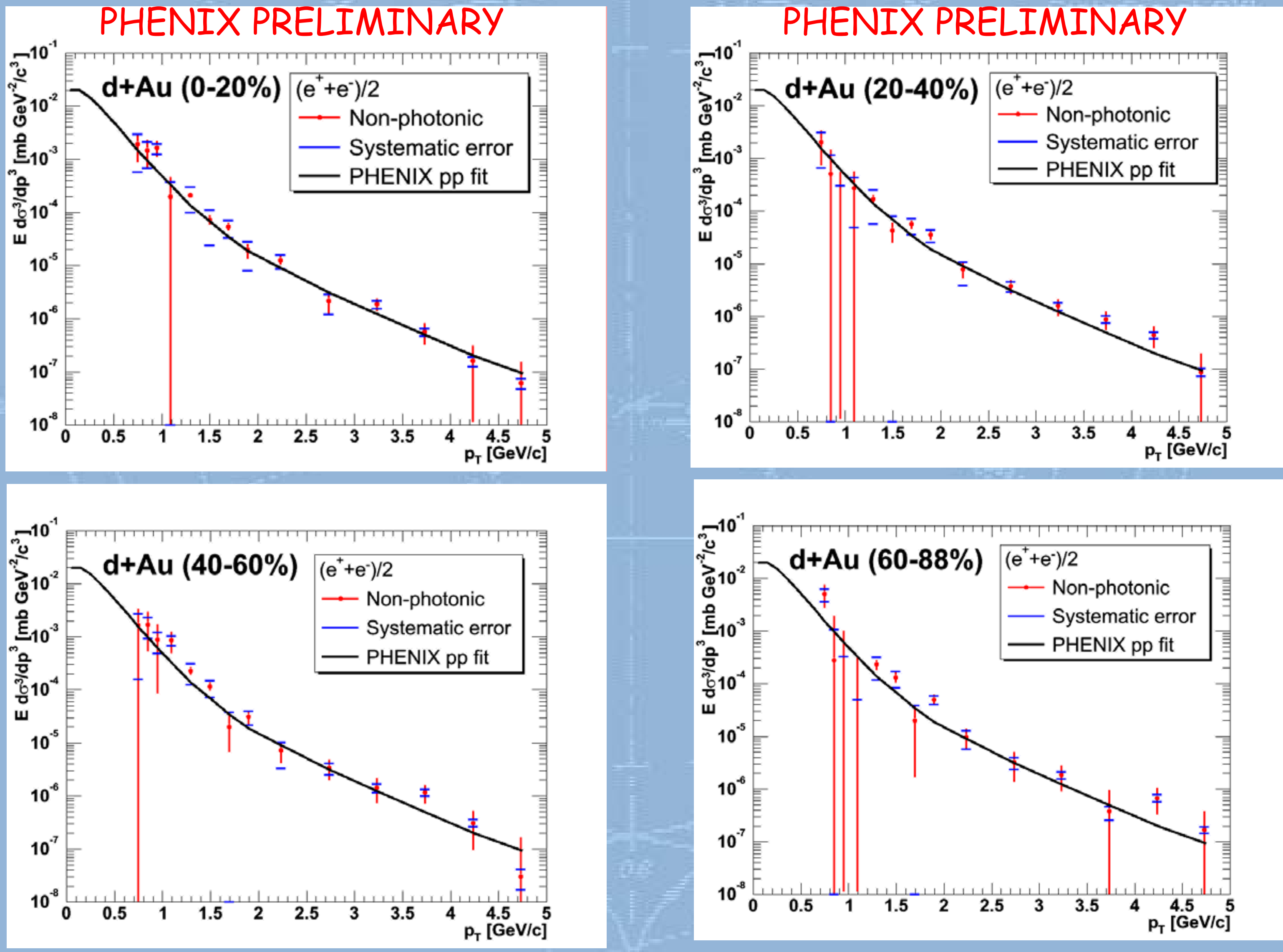
✓ d-Au collisions: minimum bias result (binary scaled)



✓ COMPATIBLE WITH BINARY SCALING

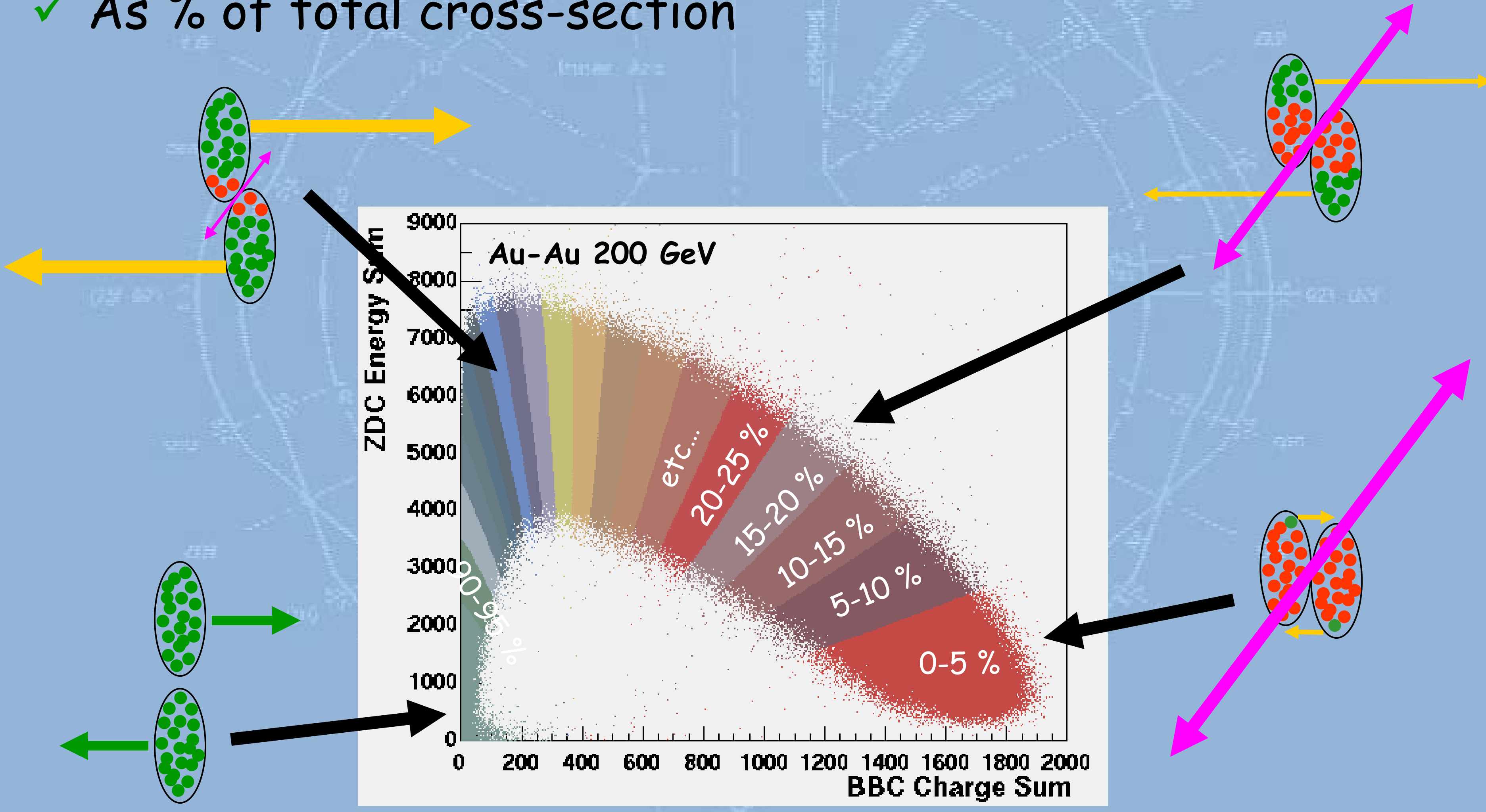
d-Au ($\sqrt{s}$ = 200 GeV)

✓ d-Au: binary scaling also holds for different centralities

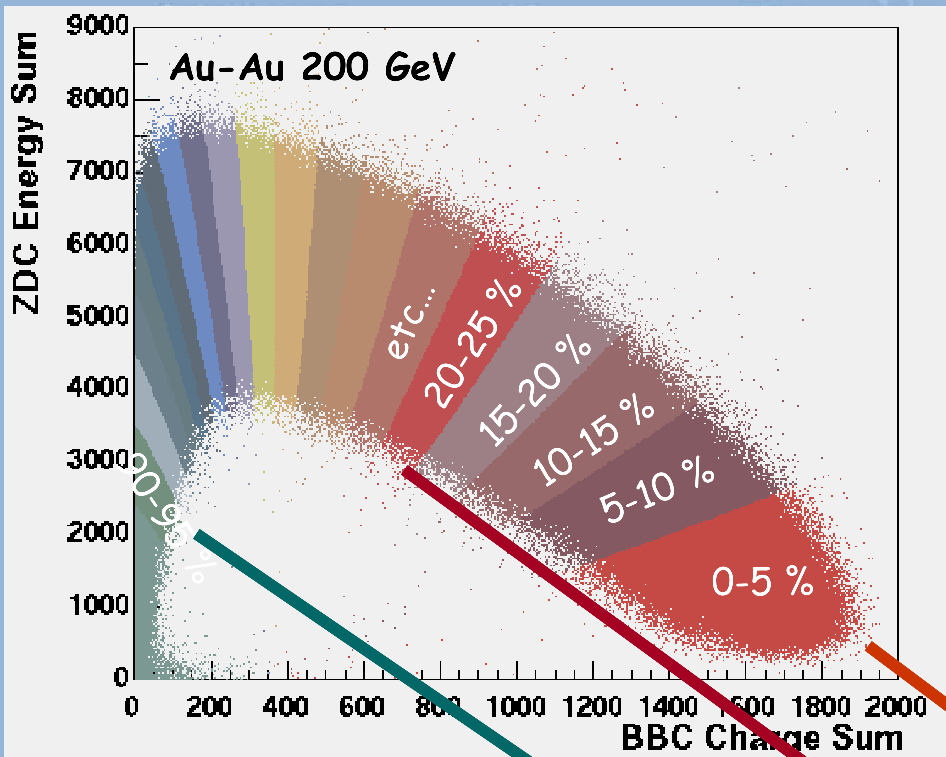


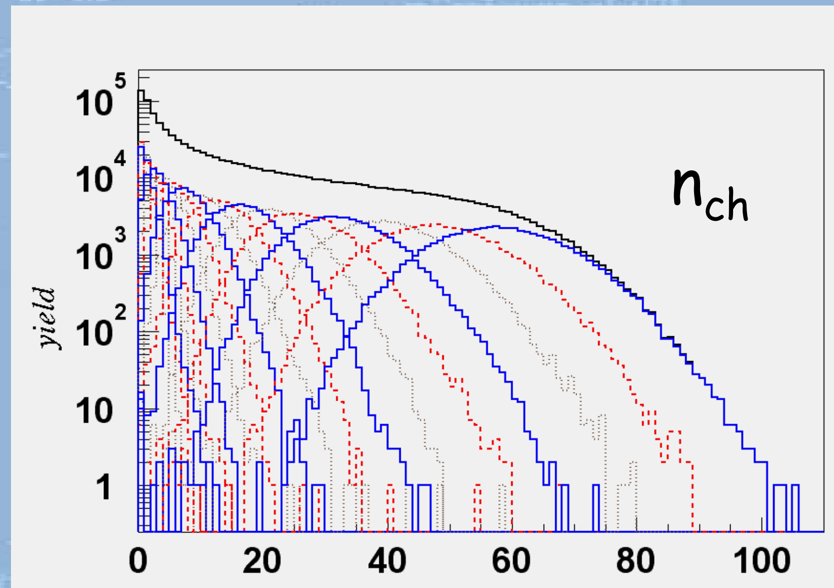
Collision centrality: Au-Au

- ✓ E_{ZDC} (spectators) / BBC (secondary particles) correlation
  - ✓ "zero degree calorimeter" + "beam-beam counter"
- ✓ As % of total cross-section



Collision centrality: Au-Au





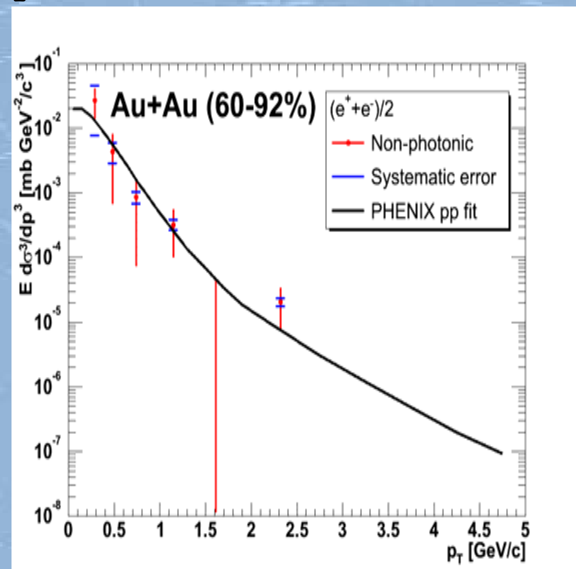
B (fm)	N_{part}	N_{coll}
2,3 ± 0,9	353 ± 19	1091 ± 102
7,1 ± 0,5	181 ± 16	422 ± 65
14,5 ± 0,3	4.1 ± 2.5	2.8 ± 2.2

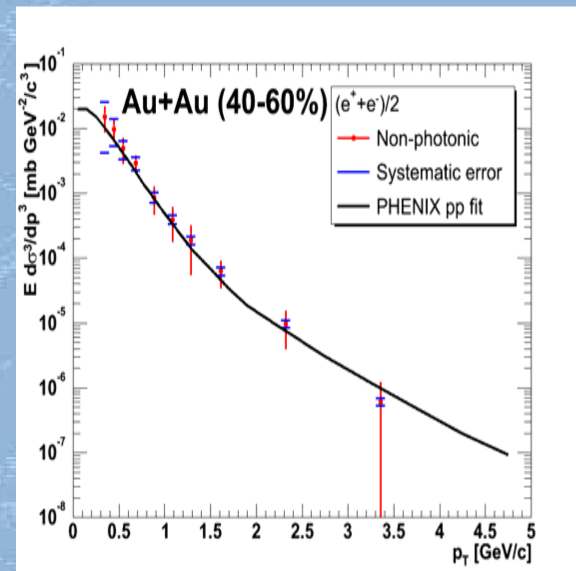
- ✓ Glauber model
  - ✓ Nuclear density profile
  - ✓ Geometry
  - ✓ N-N cross-section

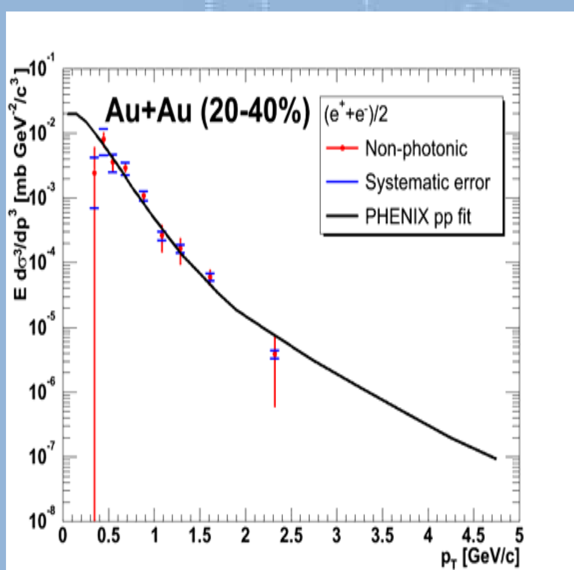
Au-Au ($\sqrt{s}$ = 200 GeV)

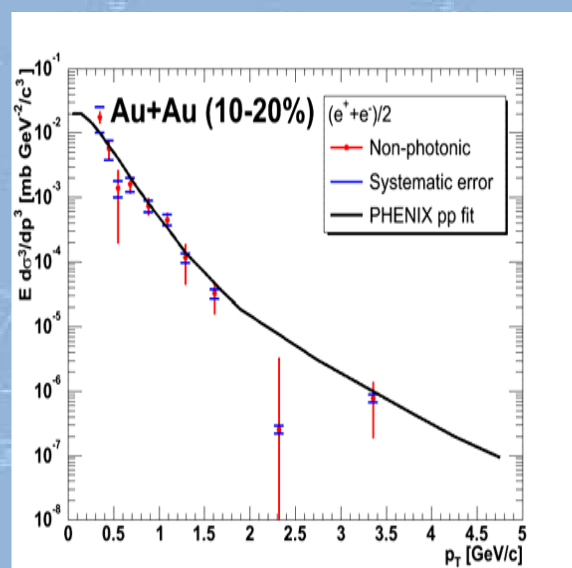
$1/T_{AB}$ EdN/dp^3 [mb GeV^{-2} c^3]

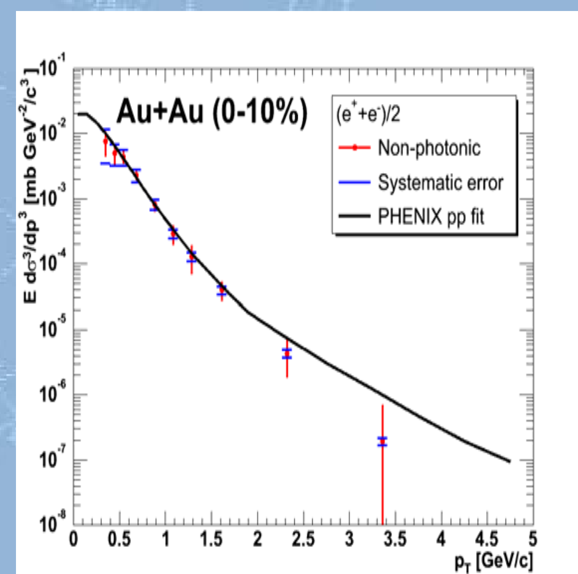
- ✓ Au-Au as a function of centrality
- ✓ Compatible with binary scaling
  - ✓ Need more stat. at high p_T !!!





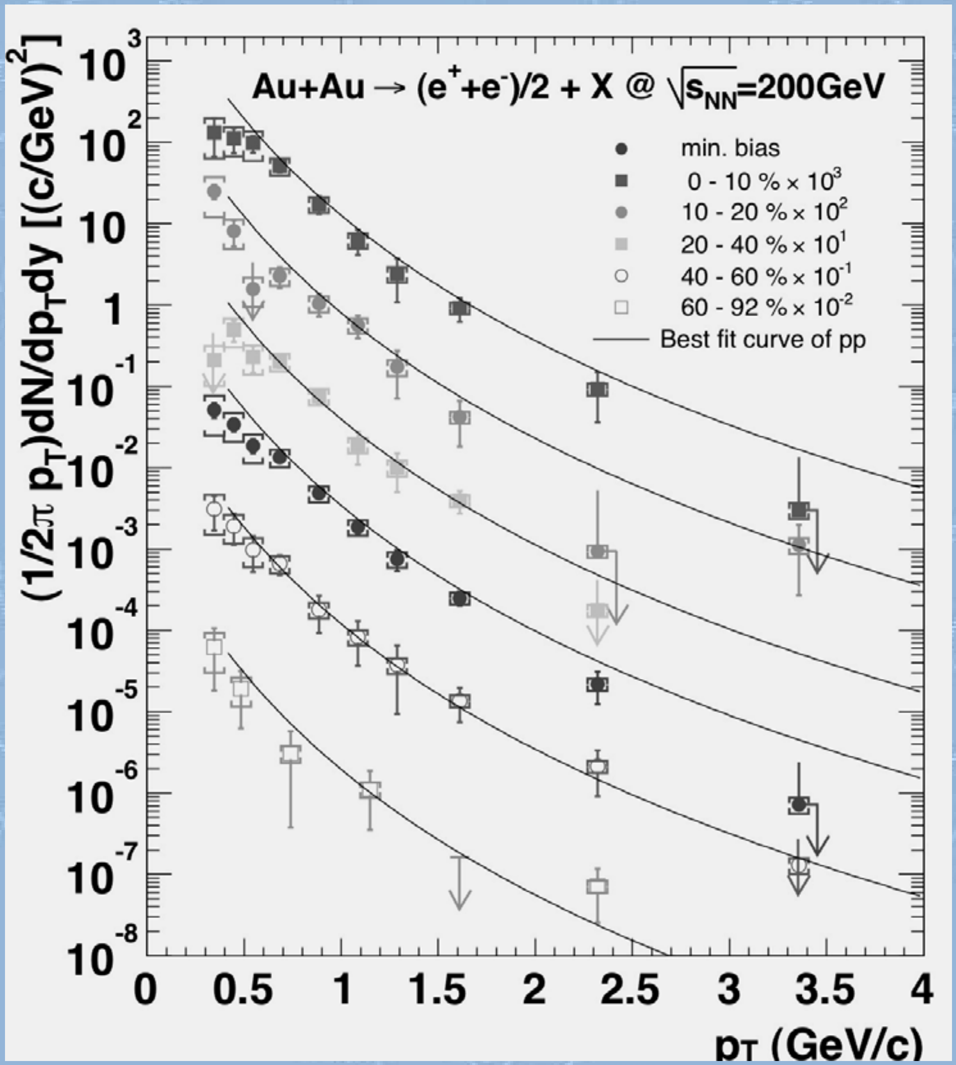






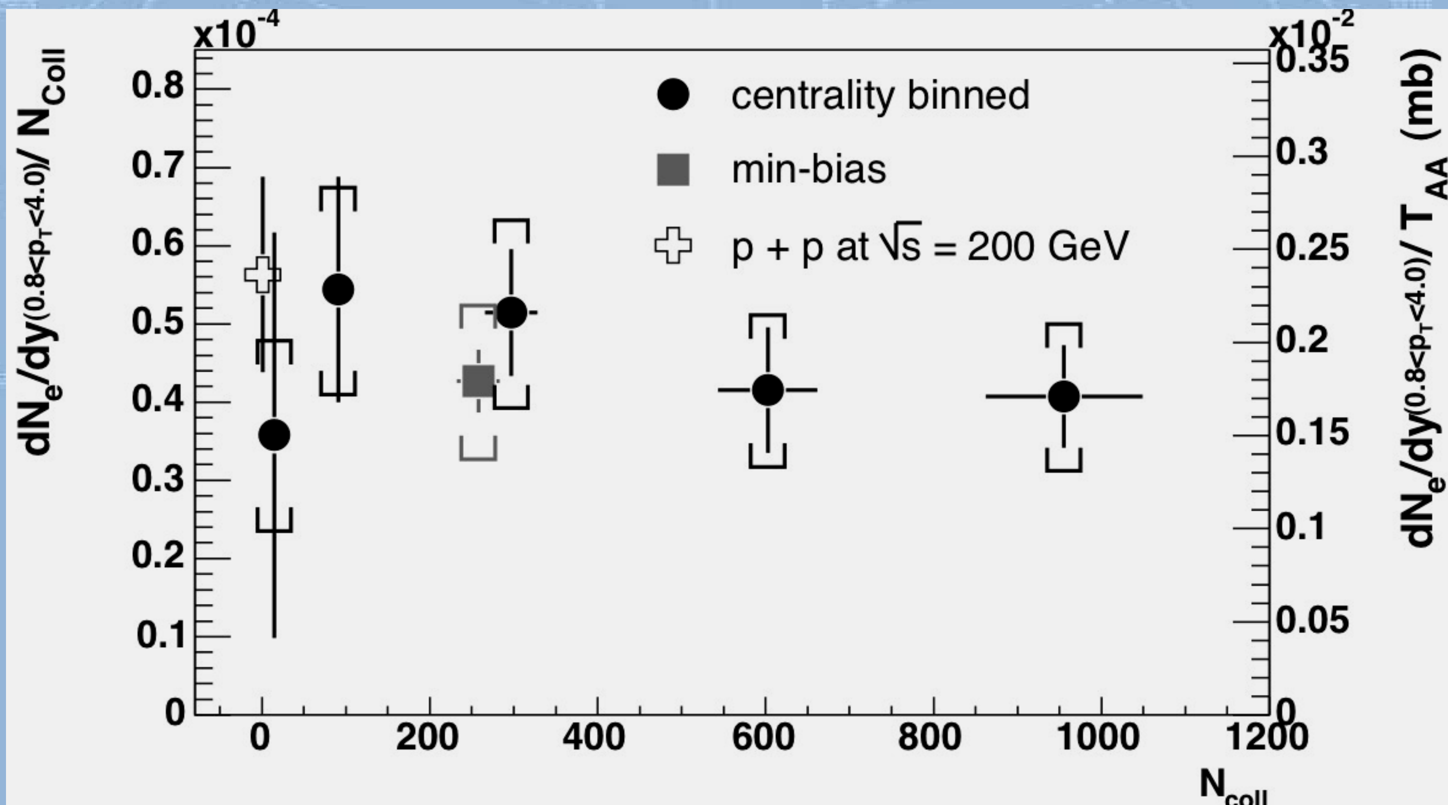
Au-Au ($\sqrt{s}$ = 200 GeV)

✓ Au-Au as a function of centrality: summary plot



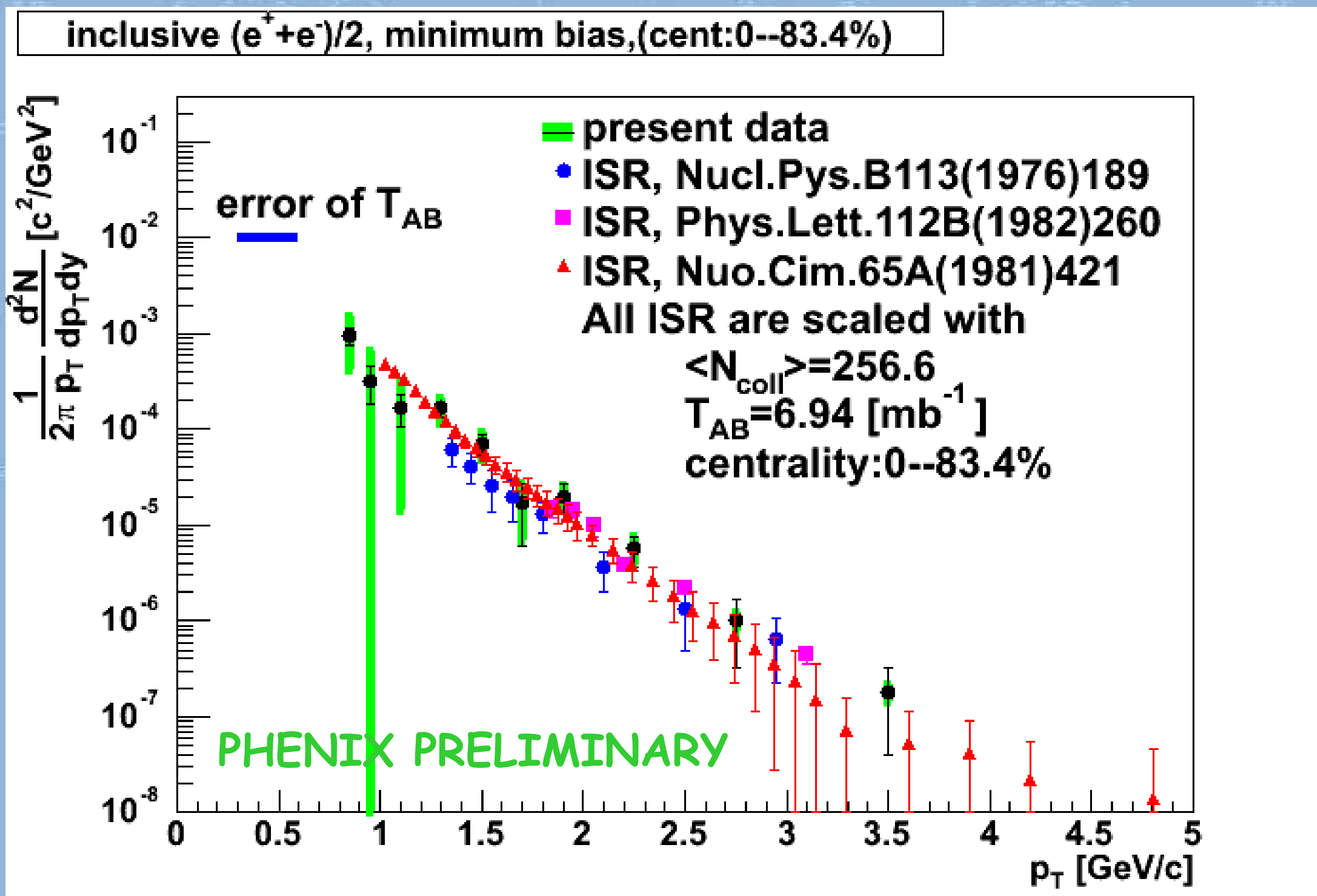
Au-Au ($\sqrt{s}$ = 200 GeV)

- Open charm in Au-Au : consistent with Ncoll scaling
  - 0.8 < pT < 4.0
  - α = 0.938 ± 0.075 (stat) ± 0.018 (syst)
  - Together with p-p: α = 0.958 ± 0.035 (stat)



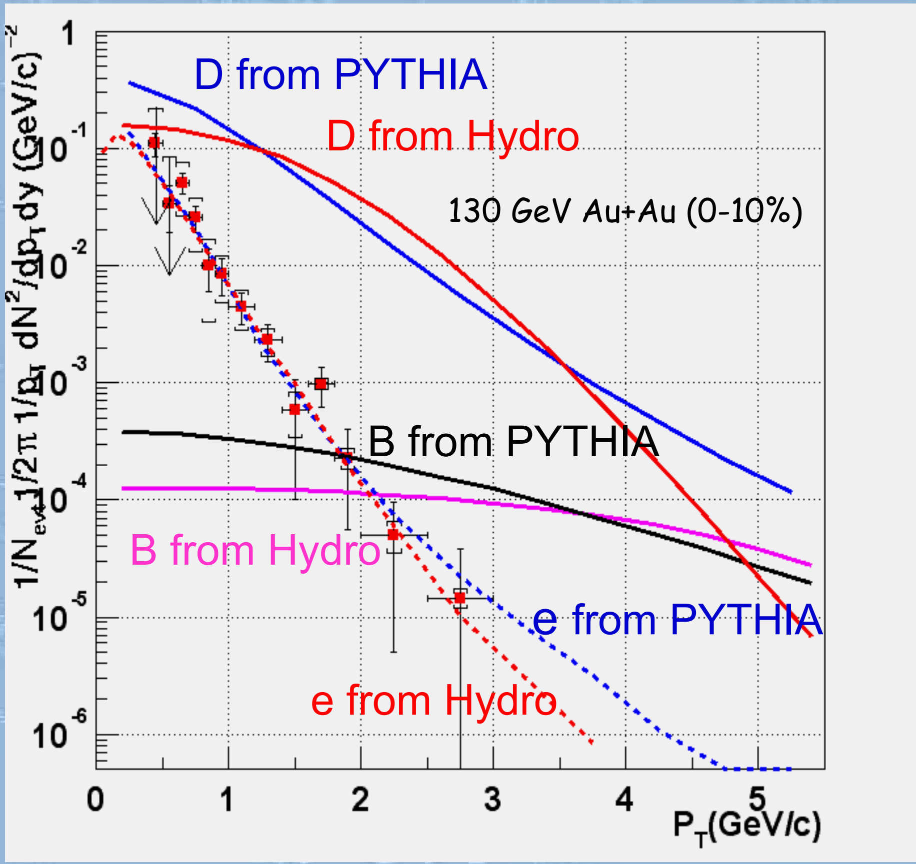
Au-Au ($\sqrt{s}$ = 62.4 GeV)

- Open charm in Au-Au @ 62.4 GeV, as compared to ISR p-p data at the same incident energy
  - Also compatible with ‹Ncoll› scaling



Flow ?

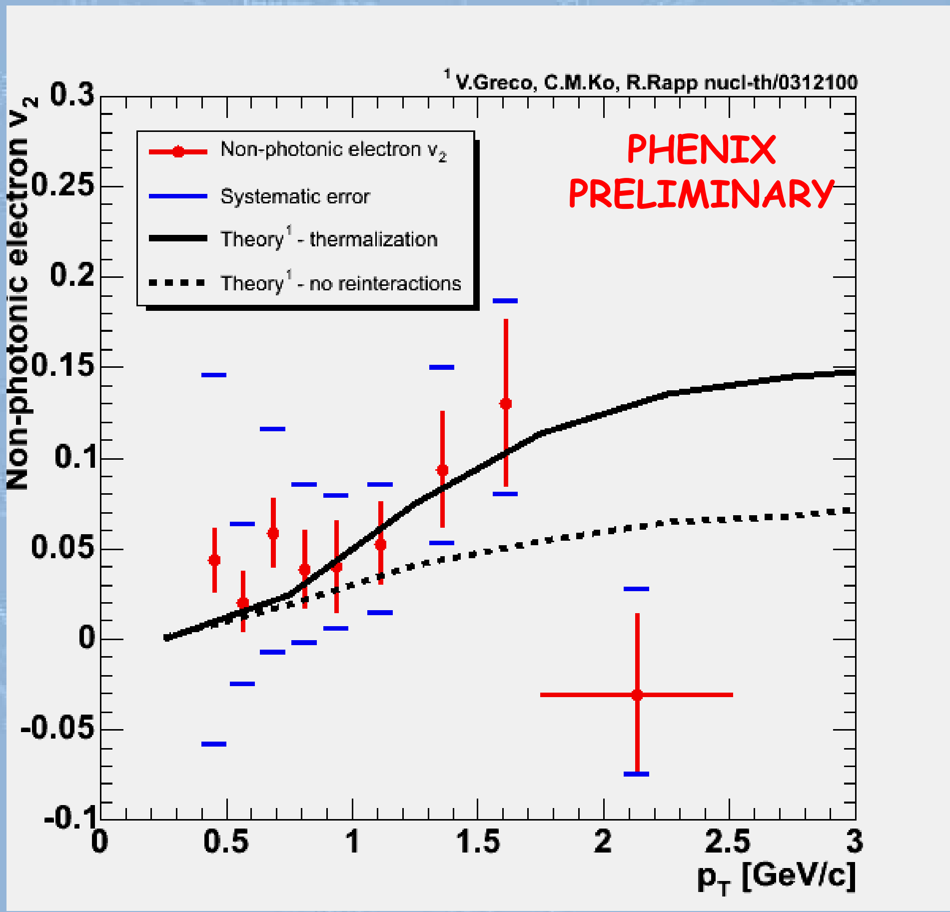
- Undistinguishable scenarios from p_T distributions
  - Would require high statistics at high p_T
  - Difference smoothed by decay



S. Batsouli, S.Kelly, M.Gyulassy, J.Nagle
Phys.Lett. B557 (2003) 26-32

Flow: Au-Au

- What about direct flow measurement … V_2 ?
  - V_2 of non photonic electrons in 200 GeV/A Au-Au (run 2)
    - Need more statistics (run 4)



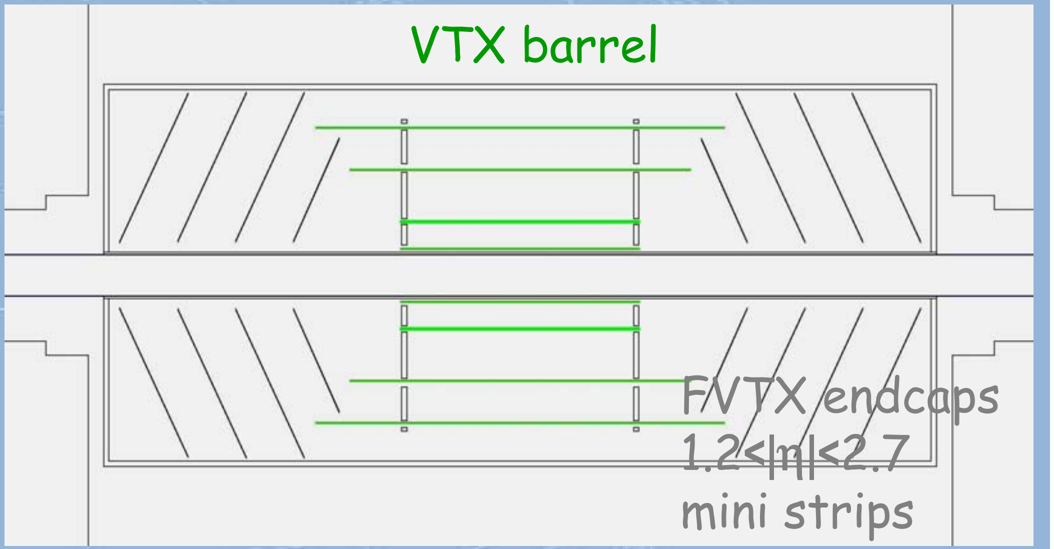
Conclusion

- ✓ PHENIX measures open charm with single electrons
- ✓ Proton-proton : reasonable agreement with PYTHIA
  - ✓ Charm + bottom
  - ✓ σ somewhat lower than reported by STAR
- ✓ d-Au: good agreement with Ncoll scaling for the 4 centrality bins
- ✓ Au-Au : good agreement with Ncoll scaling for the 5 centrality bins: $\alpha = 0.938 \pm 0.075$ (stat) ± 0.018 (syst)
  - ✓ Together with p-p: $\alpha = 0.958 \pm 0.035$ (stat)
- ✓ NO DEVIATION FROM BINARY SCALING OBSERVED SO FAR IN OPEN CHARM PRODUCTION

Outlook

- ✓ Near future: Run4 = much more statistics to come !
  - ✓ + Single muons
  - ✓ + Dilepton continuum
    - ✓ needs high stat + good control of combinatorial background
  - ✓ + Electron-muon coincidences ?

- ✓ PHENIX upgrades:
  - ✓ Barrel VTX
    - ✓ Pixel + strips
  - ✓ Forward VTX
    - ✓ strips



Future heavy flavor detection in PHENIX:

- Beauty and low p_T charm via displaced e and/or μ $-2.7<\eta<-1.2$, $|\eta|<0.35$, $2.7<\eta<1.2$
- Beauty through displaced $J/\psi \rightarrow ee\ (\mu\mu)$ $-2.7<\eta<-1.2$, $|\eta|<0.35$, $2.7<\eta<1.2$
- High p_T charm through $D \rightarrow \pi K$ $|\eta|<0.35$

Thank you !

PHENIX

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*as of January 2004