J/Ψ and open charm measurements at RHIC/PHENIX

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Outline

Physics with Open Charm and Charmonium

- for p-p, d-Au and Au-Au at RHIC

Open Charm Measurements

- via single electron spectra: at 130 and 200 GeV.

J/Ψ Production Measurements

- J/Ψ->$\mu^+\mu^-$, e^+e^- for p-p, Au-Au (and d-Au) at 200 GeV

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Charm Physics

p-p

- Comparison with pQCD calculation
- Measurement of gluon density G(x)
- Base line for charm physics in pA and AA

p(d)-A

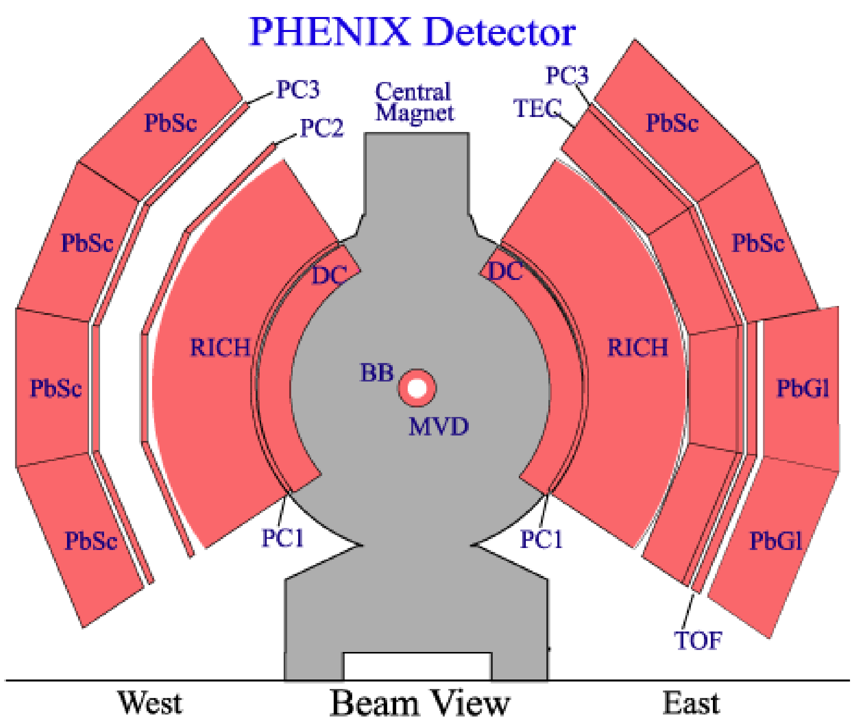
- Gluon shadowing
- Energy loss of gluons in cold nuclear matter
- Base line (normal nuclear effect) for charm physics in AA

A-A

- Gluon shadowing
- Energy loss of charm in high density matter
- Thermal production of charm in high temperature QGP

Single lepton spectra at high p_T is a useful way to study charm/heavy-quark production.

PHENIX Central Arms & Electron Measurements



- High resolution tracking and momentum measurement from Drift Chamber. Matching with Pad Chambers.
- Good electron identification from Ring Imaging Cherenkov detector and Electromagnetic Calorimeter.
- High performance Level-1/Level-2 trigger.

Centrality selection with Beam -Beam Counters and Zero-Degree Calorimeters.

Measure electron between

$|\eta|<=0.35$ and $p>=0.2$GeV

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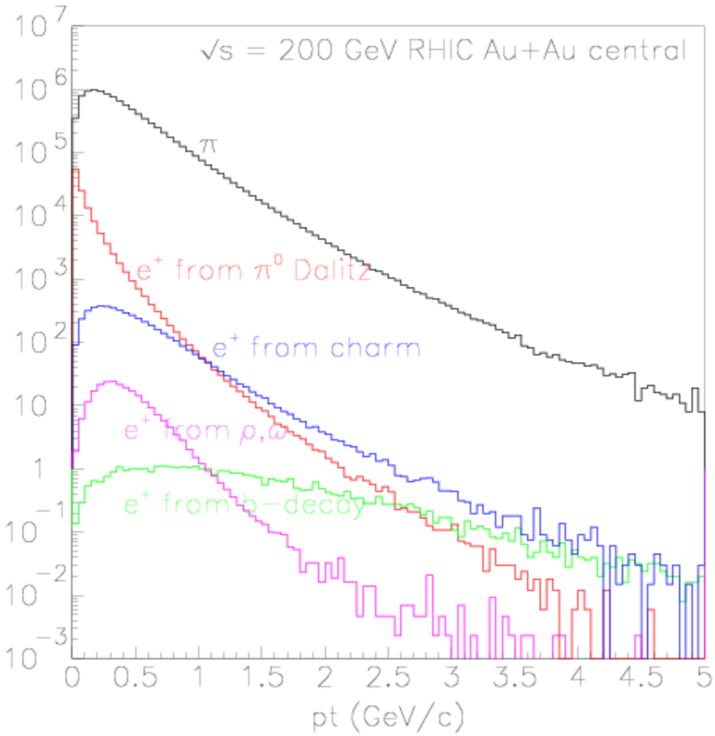
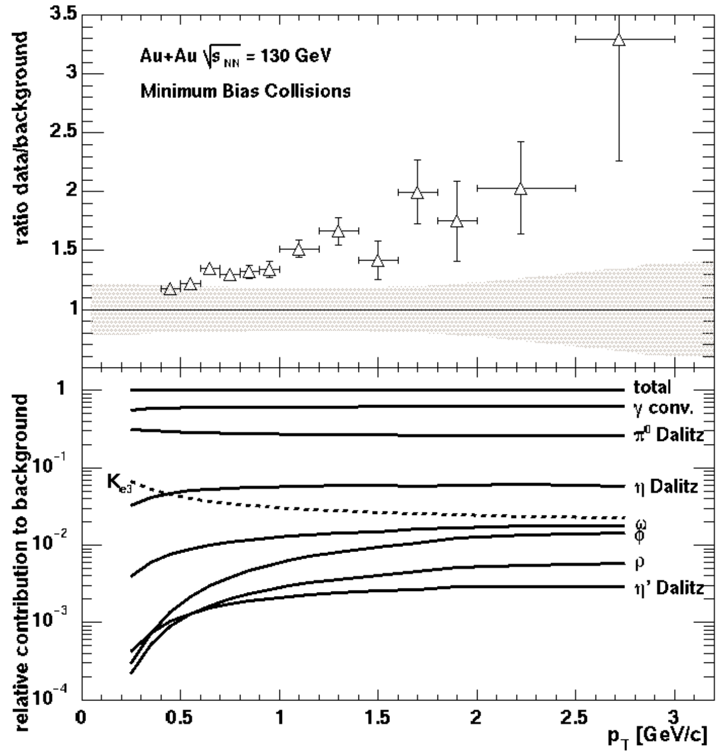
Charm and Single Electrons at RHIC

Simulation before RHIC



PHENIX data (PRL88)



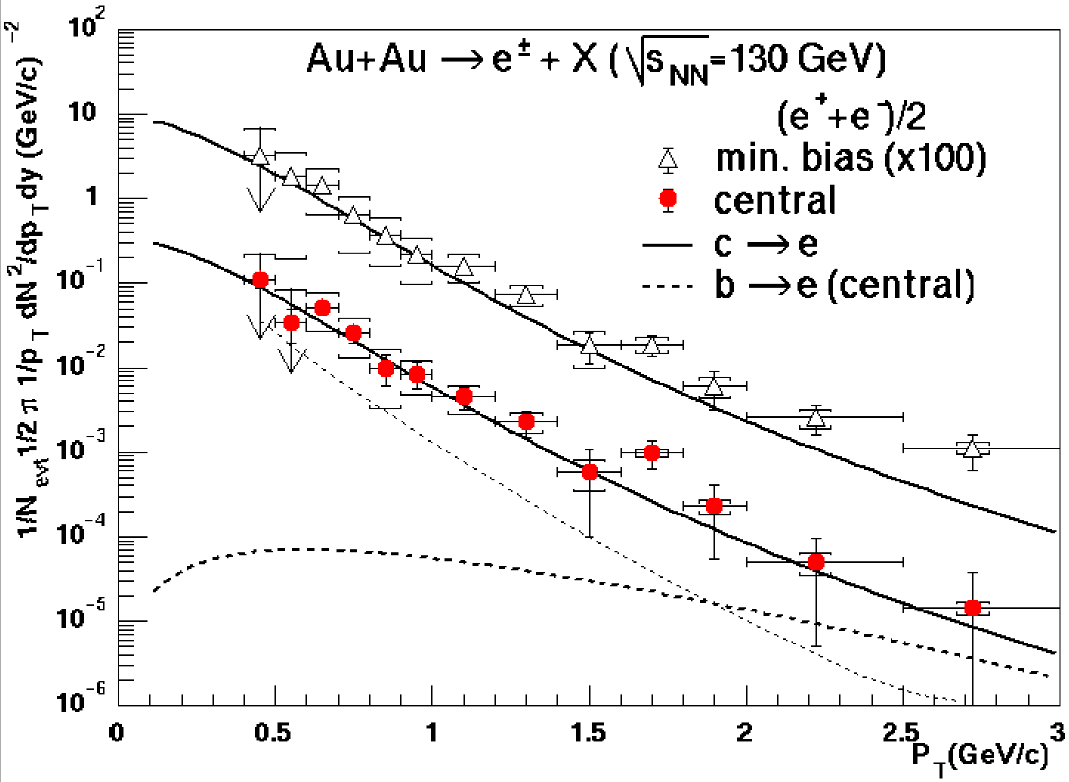
Expected at RHIC that charm decay can be the dominant component of single electron in $p_T > 1.5$ GeV/c

Large production cross section of charm (300-600 μb)

- Production of high pt pions strongly suppressed relative to binary collision scaling
- Production of charm quark roughly scale with binary collisions.

PHENIX observed excess in single electron yield over expectation from light meson decays and photon conversions => charm signal at RHIC

Open Charm in PHENIX: Run-1 AuAu Single Electron data



Compared single electron signal with the expected charm contribution

$EdN_e/dp^3 = T_{AA} Ed\sigma/dp^3$

T_{AA}: nuclear overlap integral

$Ed\sigma/dp^3$: electron spectrum from charm decay calculated using PYTHIA

=> Reasonable agreement

Assuming that all single electron signal is from charm decay and with binary collision scaling, charm cross section at 130 GeV is obtained as:

$\sigma_{cc}^{0\text{-}10\%}$ **= 380 ± 60 (stat) ± 200 (sys) μb,**

$\sigma_{cc}^{0\text{-}92\%}$ **= 420 ± 33 (stat) ± 250 (sys) μb**

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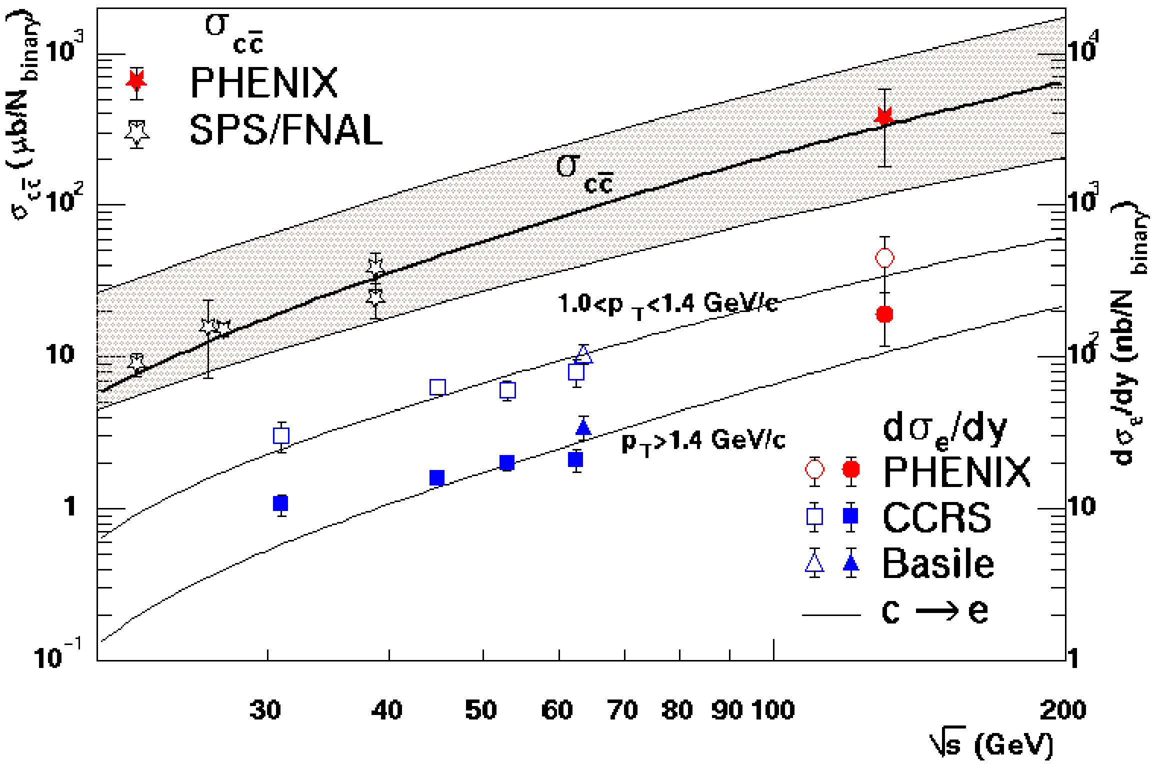
Comparison with other Experiments



Single electron cross sections and charm cross sections are compared with

Solid curves: PYTHIA

Shaded band: NLO QCD

Assuming binary collision scaling, PHENIX data are consistent with √s systematics (within large uncertainties)!

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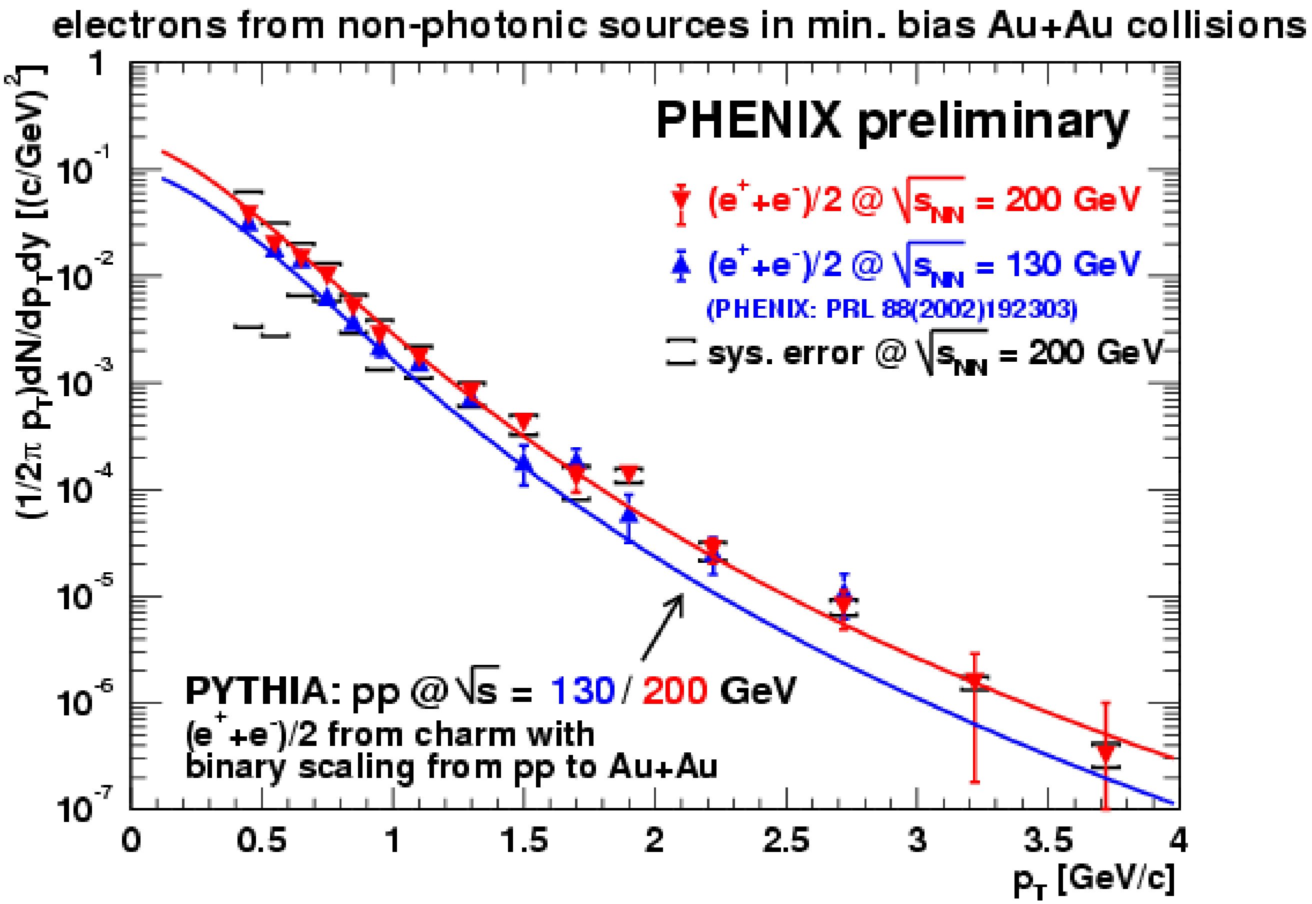
Run-2 AuAu Single Electron Result

Run-2: extra handle on systematics;

Comparing runs with and without installed extra photon converter



The yield of non-photonic electron at 200 GeV is higher than 130 GeV

The increase is consistent with PYTHIA charm calculation

(σ_{cc} (130 GeV) = 330 μb, σ_{cc} (200 GeV) = 650 μb)

Large systematic uncertainty due to material thickness without converter.

The error will be reduced in the final result.

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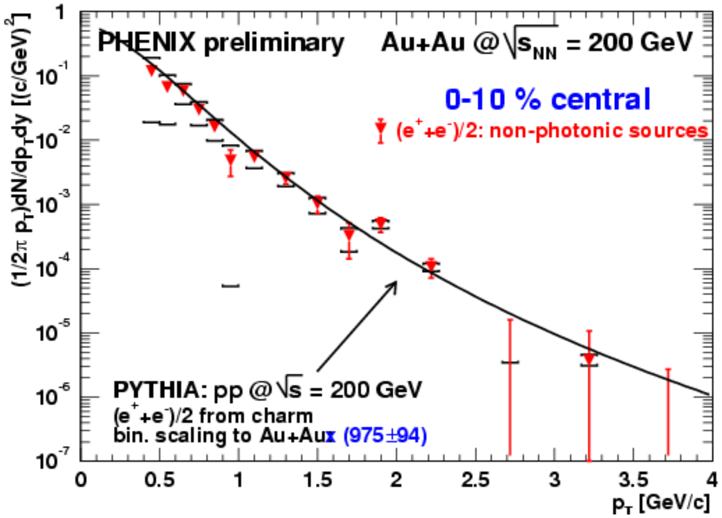
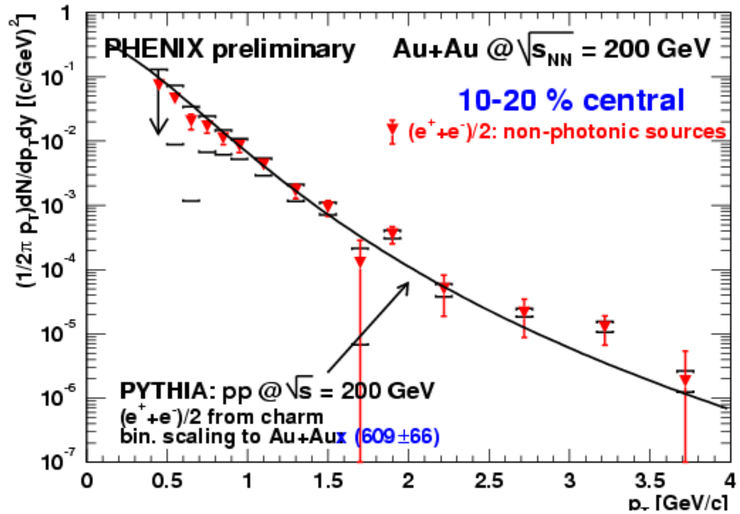
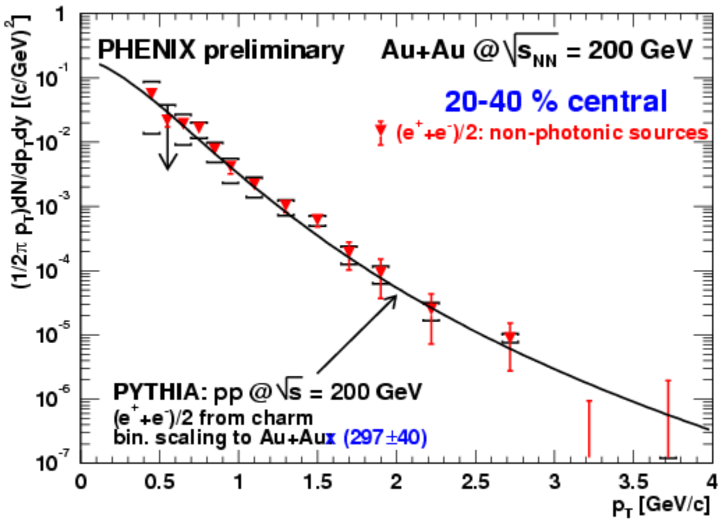
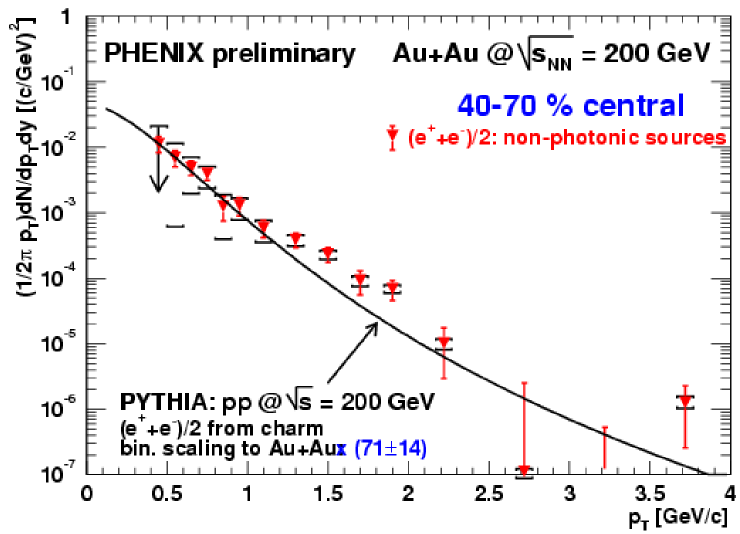
Centrality Dependence









PHENIX data consistent with the PYTHIA charm spectrum scaled by number of binary collisions in all centrality bins!

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J/Ψ Production

p-p : study of production mechanism and cross sections

Color evaporation model, Color singlet model, Color octet model

Polarization, Rapidity dependence (electron and muon channels)

Production of J/Ψ, Ψ',.. states

Base line for pA and AA

p(d)-A : study of "normal nuclear effect": shadowing and energy loss

Nuclear dependence of σ(J/Ψ): A^{α} or σ_{abs} (nuclear absorption)

Base line for AA

A-A : study of "medium effect" in high density matter

J/Ψ suppression : signature of QGP (Matsui/Satz)

J/Ψ formation by c quark coalescence at RHIC/LHC ?

Comparisons between various collision species are very important.

Studies done via both dielectron and dimuon channels in PHENIX.

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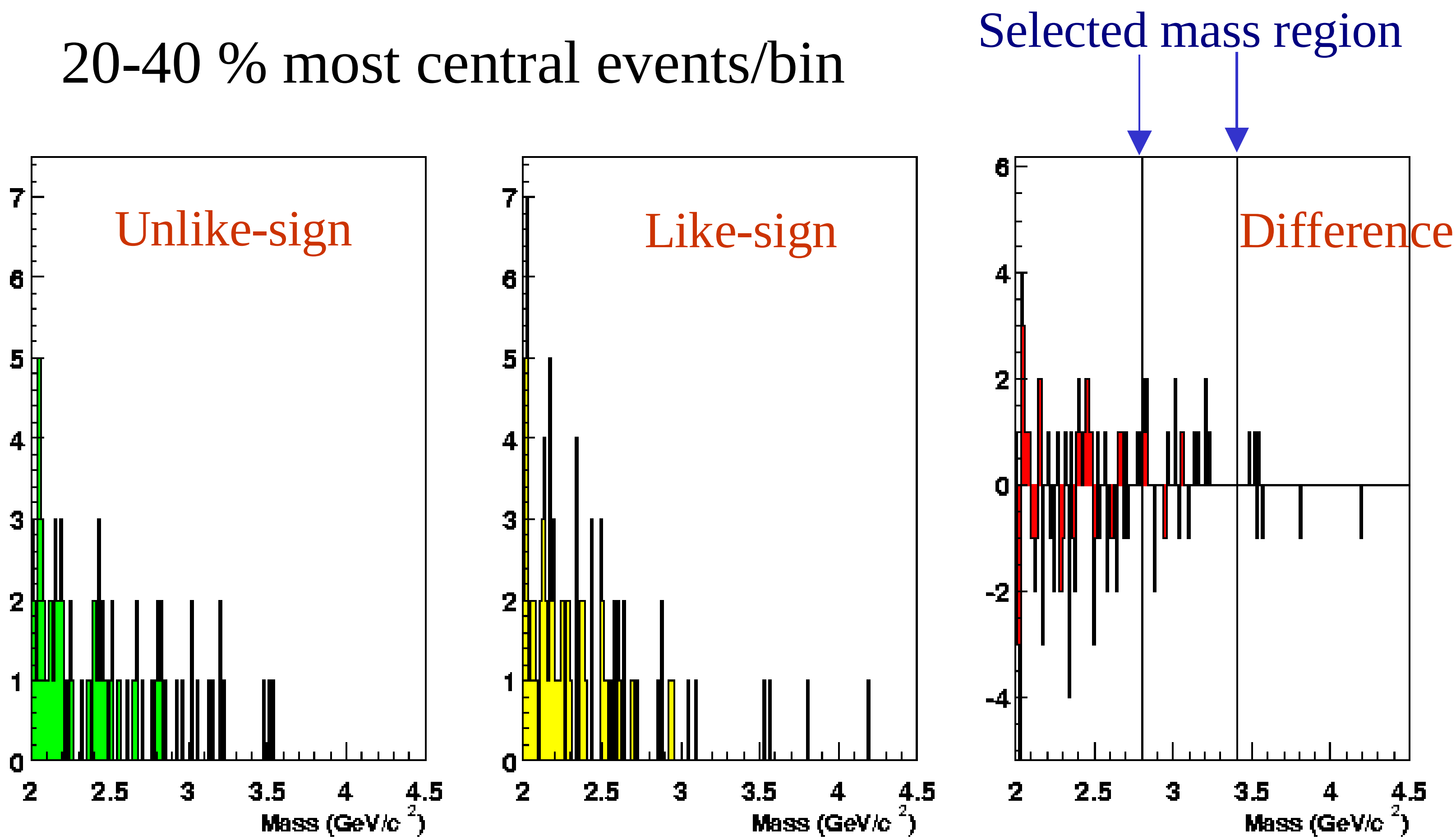
Run-2 AuAu Dielectrons



Analysis limited by statistics. 3 centrality bins are used:
0-20%, 20-40%, 40-90%.

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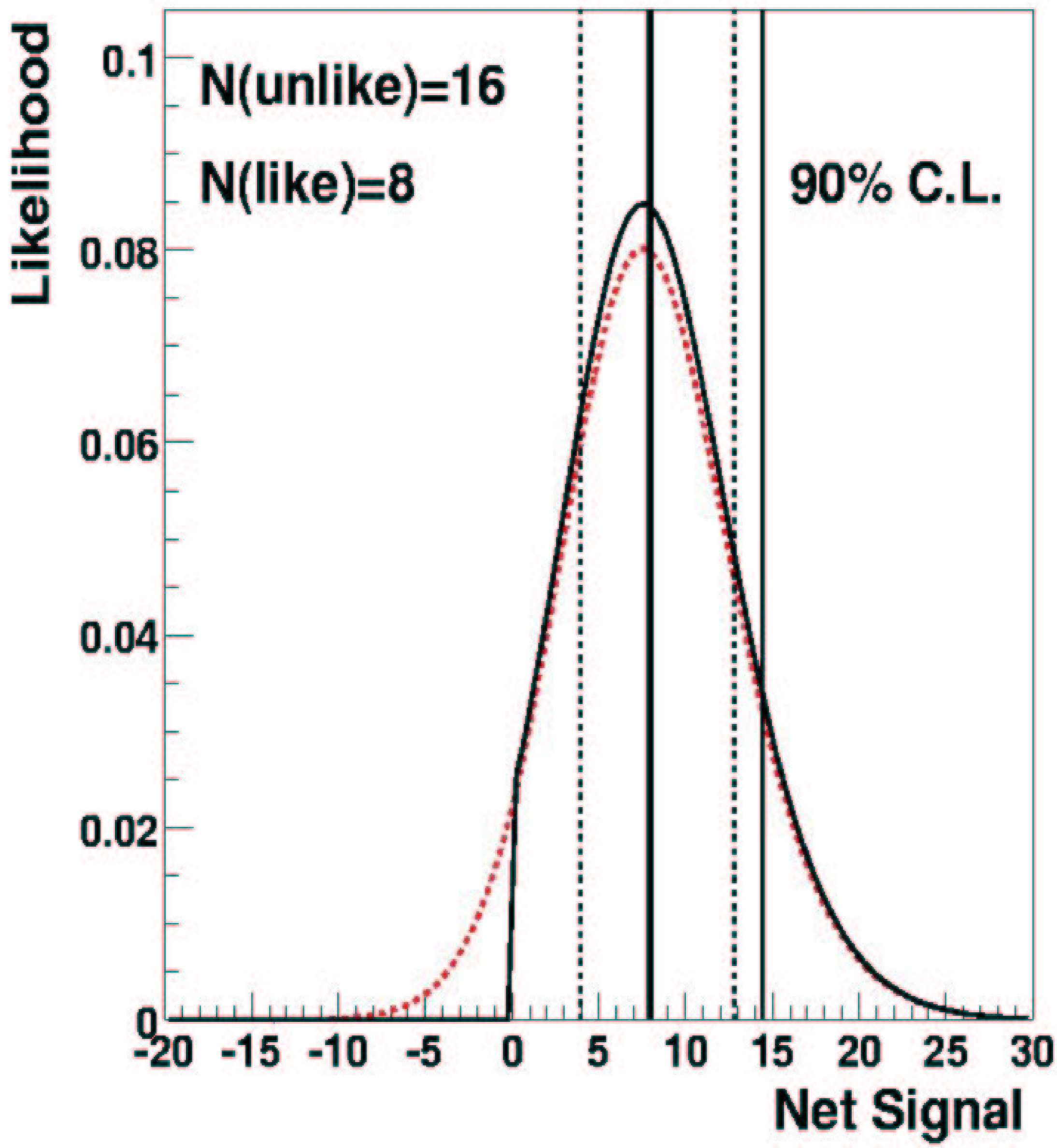
Statistics

20-40 % most central bin

Based on unlike and like-sign counts, the most probable signal and the associated 90 % confidence limits are calculated.



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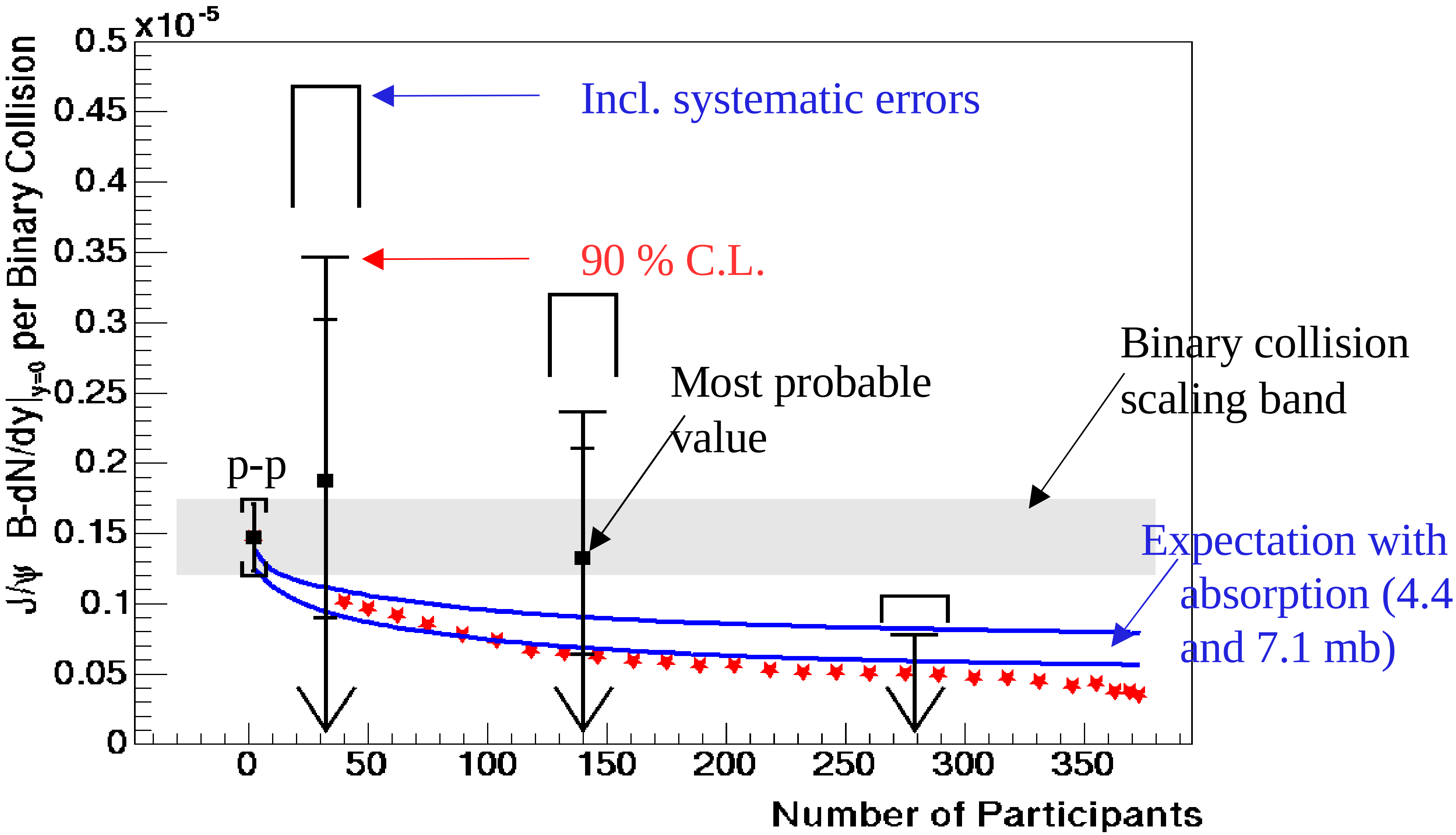
Centrality dependence



NA50 points normalized to pp point (described shortly..)

- for shape comparisons only.

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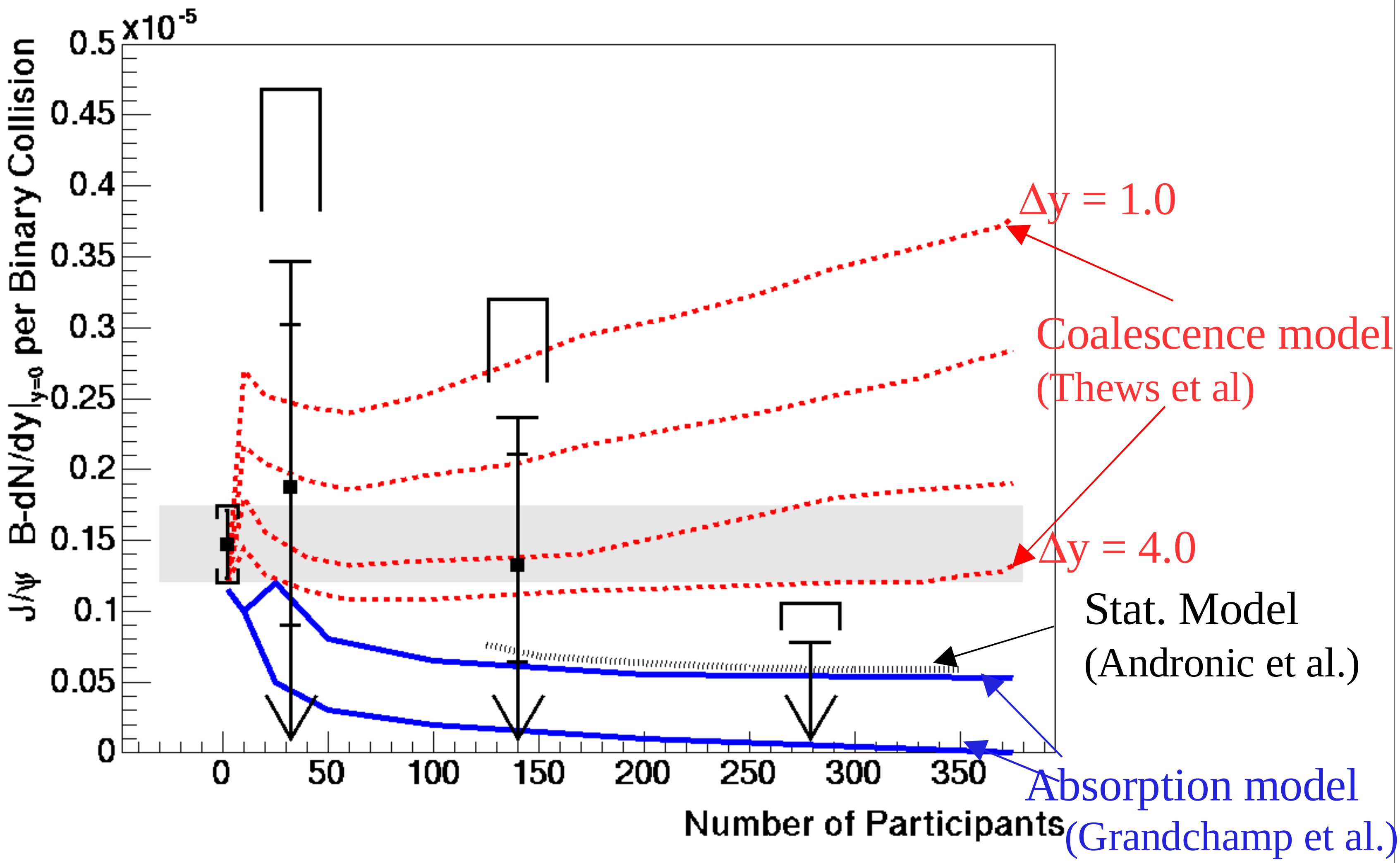
Model Comparisons



Disfavor models with enhancement relative to binary collision scaling.
Cannot discriminate between models that lead to suppression relative to binary collision scaling.

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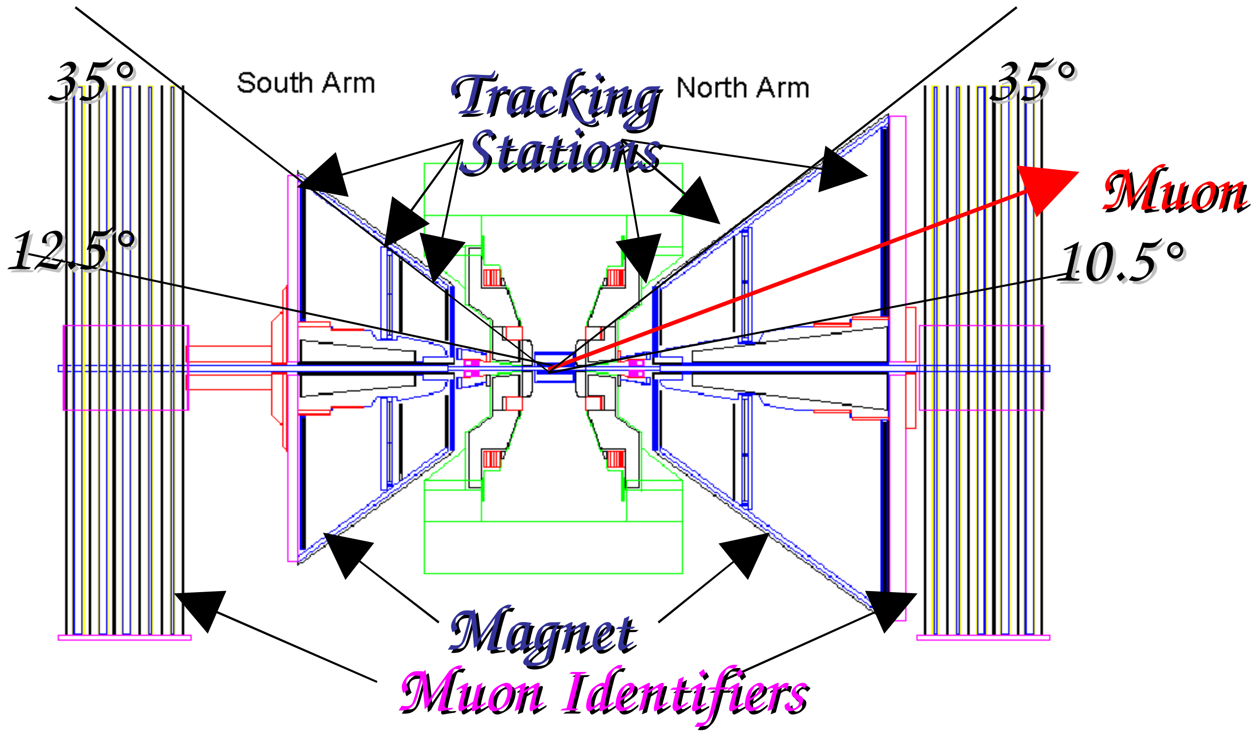
PHENIX Muon Arms

(Run-2 p-p and onwards: Electrons are still detected in the central arms..)

2 Muon Trackers =
2x3 stations

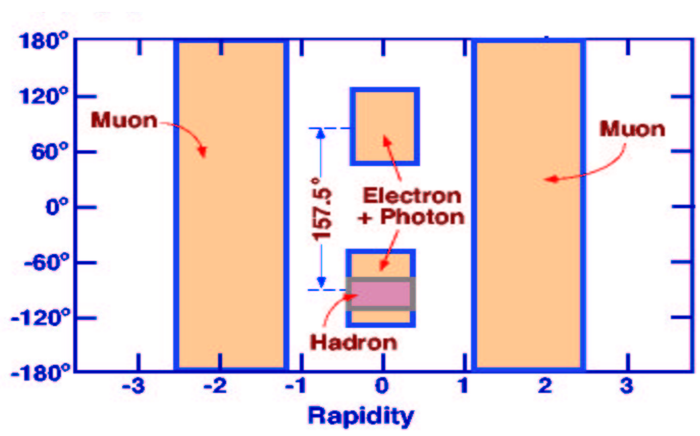
2 Muon Identifiers
= 2x5 planes



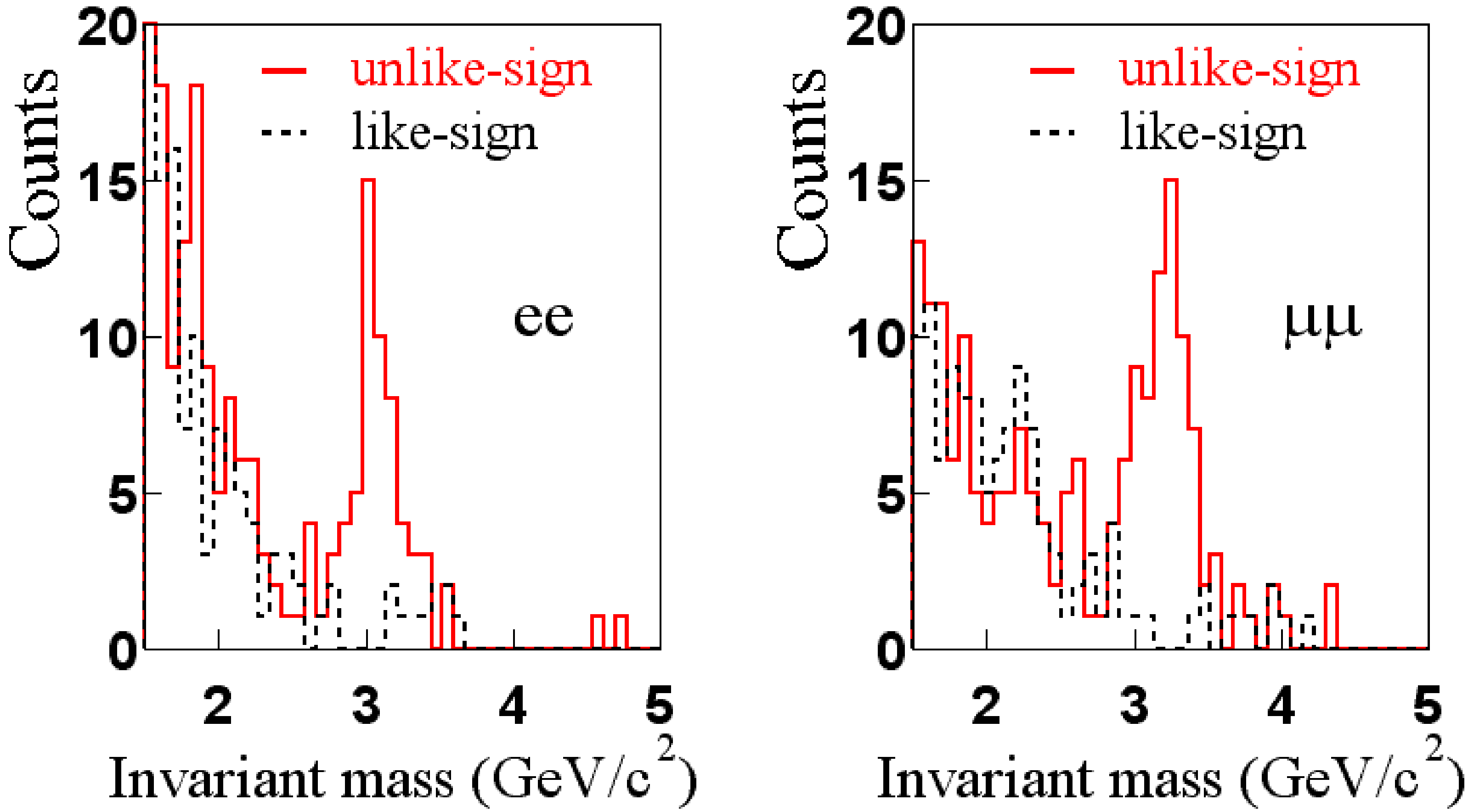
South Arm:
Began operations
in 2001: Run-2.

North Arm:
Installed in 2002.

Acceptance : $1.2 < |\eta| < 2.4$
$\Delta\Phi = 2\pi$
Muon minimum momentum ~ 2 GeV/c



Run-2 pp Results



Clear J/Ψ signals seen in both central and muon arms.
Resolutions in agreement with expectations.

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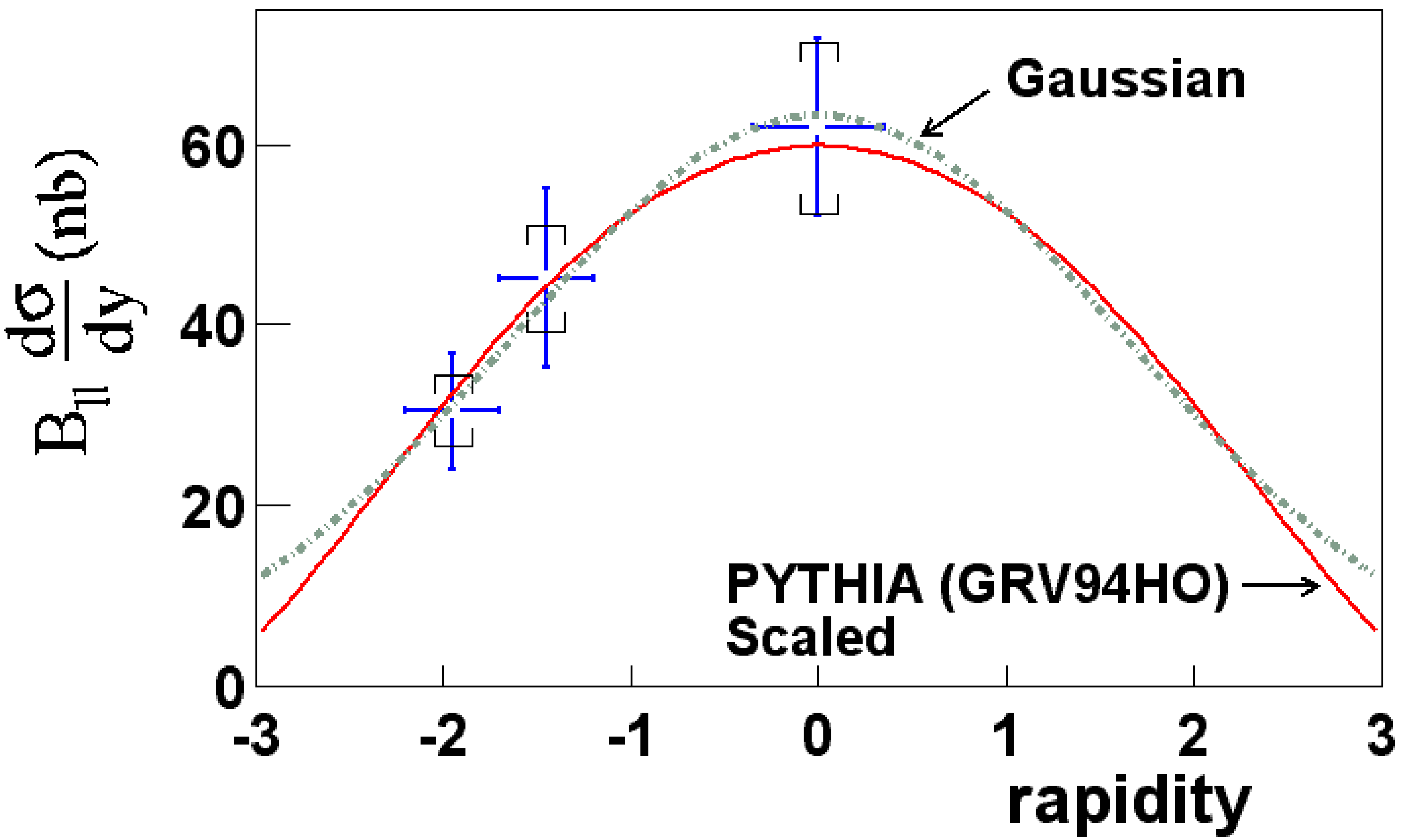
Rapidity Distribution



Integrated cross-section : 3.98 ± 0.62 (stat) ± 0.56 (sys) ± 0.41(abs) μb

Estimated B decay feed down contribution : < 4% (@ 200 GeV)

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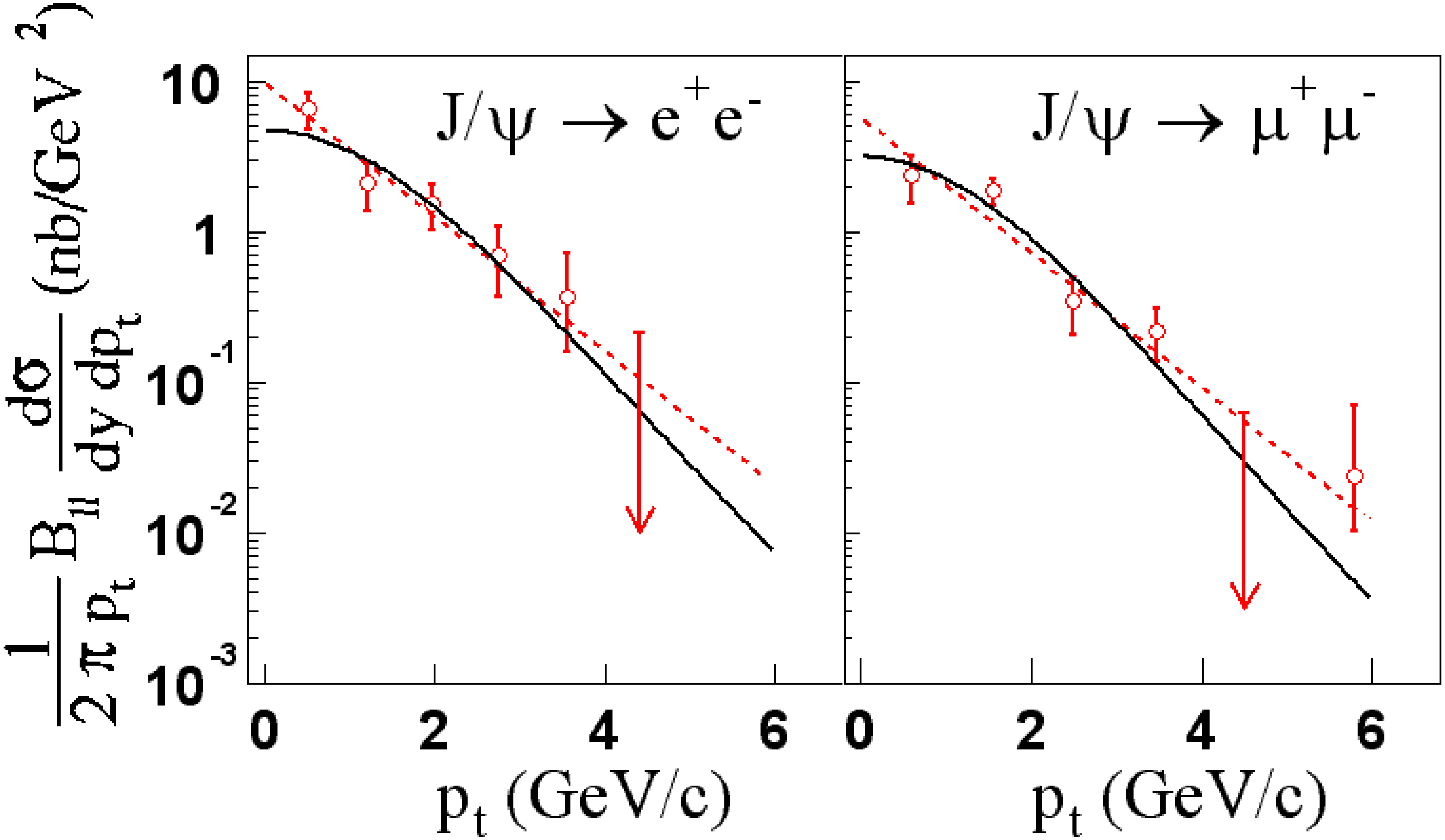
p-p : J/Ψ p_T distribution



Combination of electron and muon results and phenomenological and exponential fits gives:

$\langle p_T \rangle$ = 1.80 ± 0.23 (stat) ± 0.16 (sys) GeV/c

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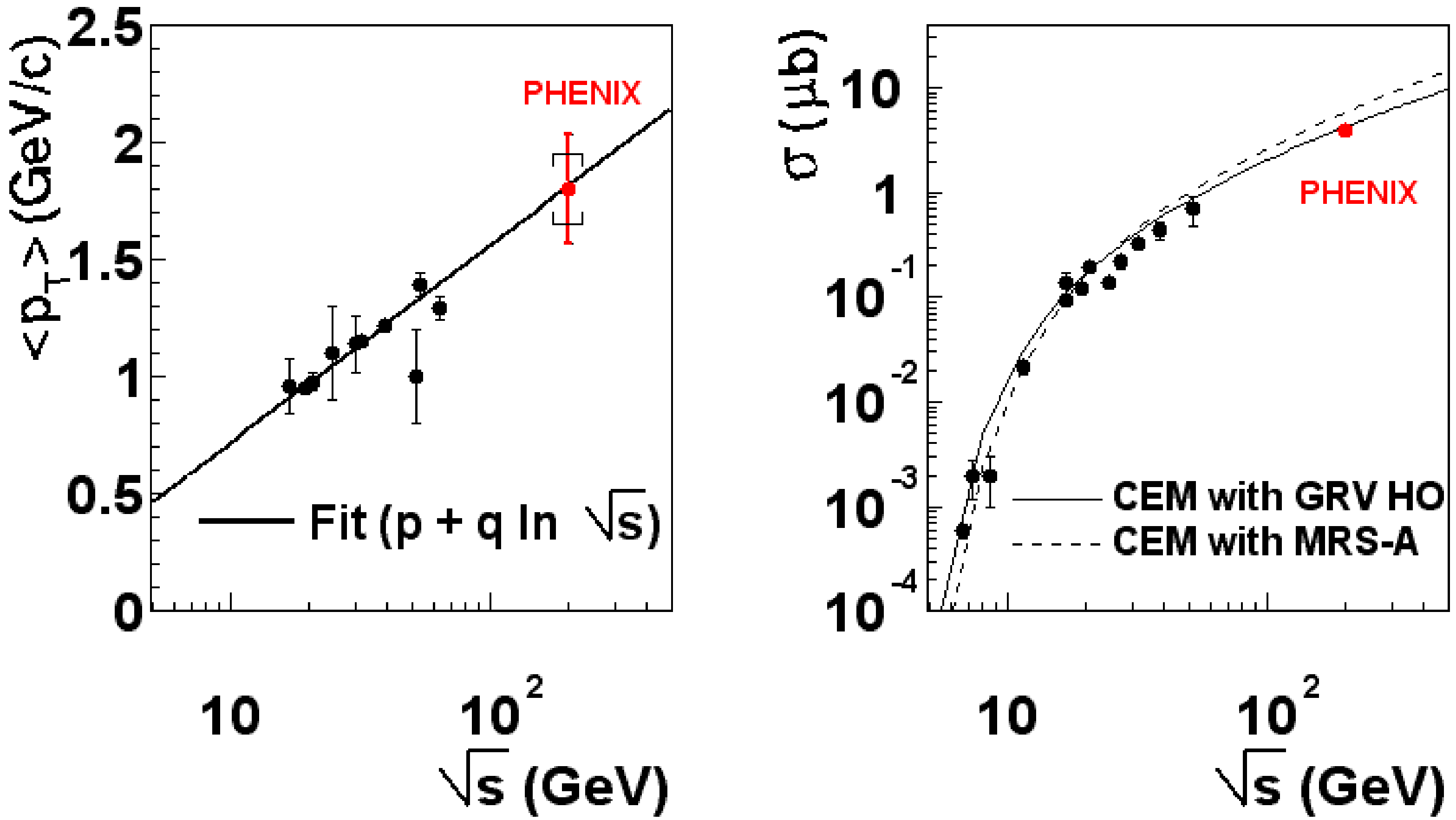
Comparisons with other Experiments



Phenomenological fit for average p_T; p = 0.531, q= 0.188

Cross-section well described by Color Evaporation Model.

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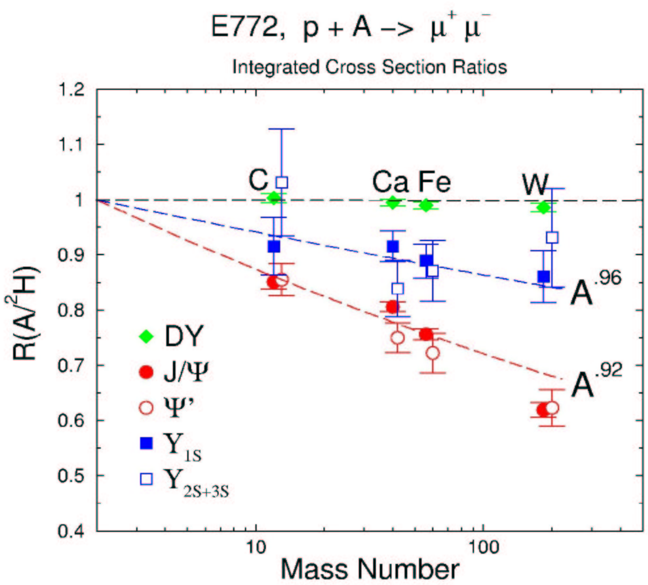
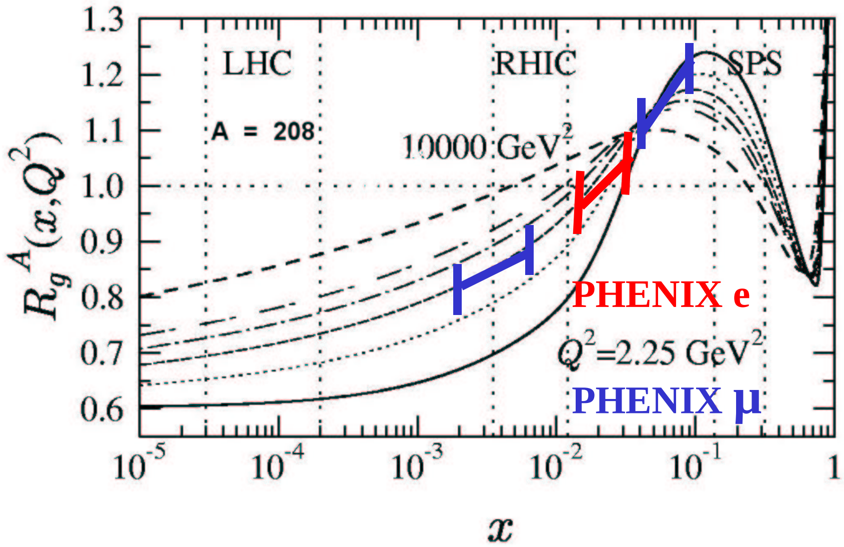
J/Ψ Suppression / Gluon Shadowing



Eskola, Kolhinen, Vogt hep-ph/0104124



J/Ψ suppression : an effective signature of Quark-Gluon Plasma (QGP) formation?

Color screening in a QGP would destroy $c\bar{c}$ pairs before they can hadronize into charmonium

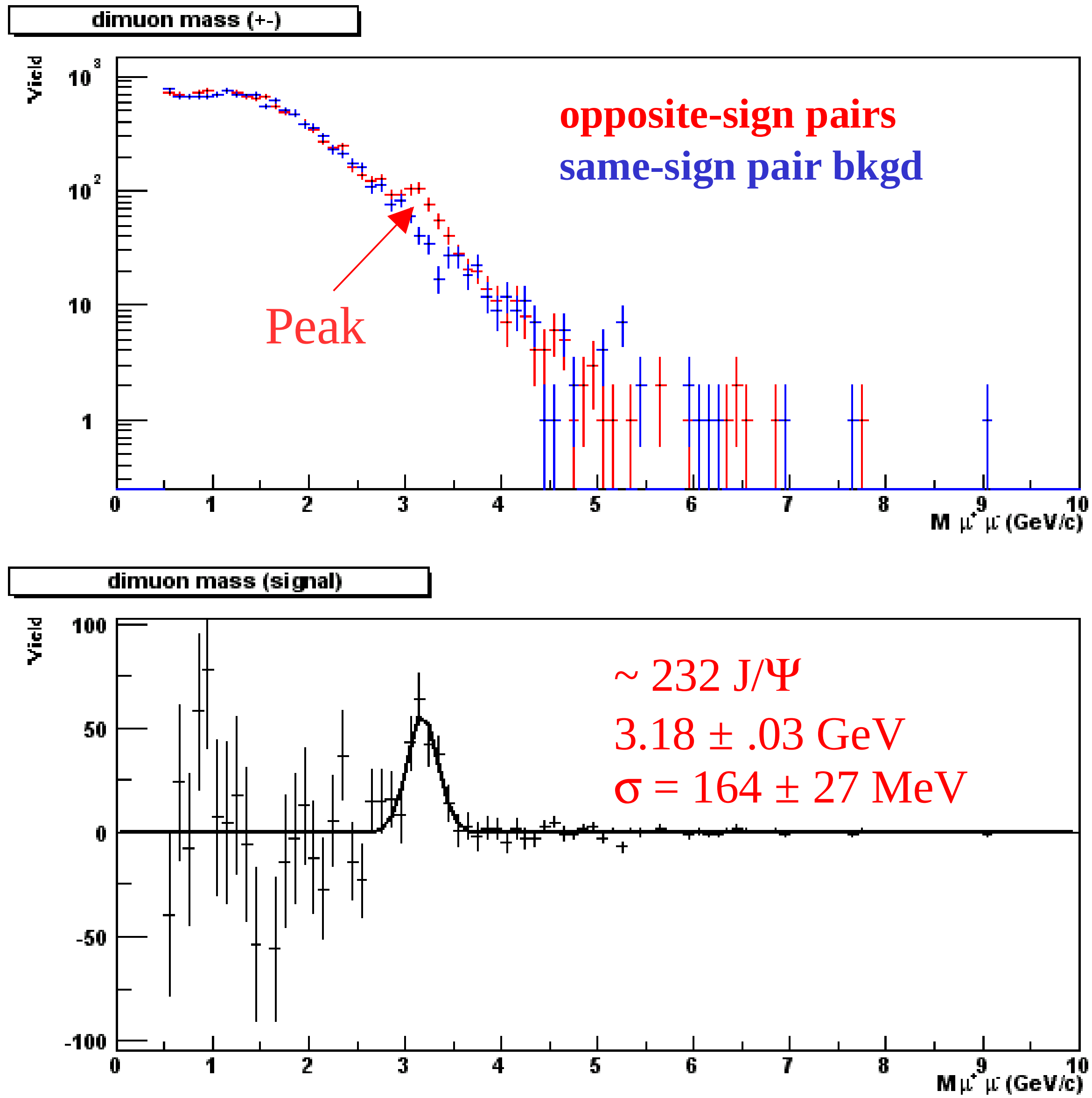
Ordinary nuclear effects, like gluon shadowing, can also affect J/Ψ's. These can be studied in e.g. d-Au collisions.

Gluon shadowing effects for nuclei, for the relevant x and Q^2 regions for PHENIX, have large uncertainties (e.g. Eskola vs Kopeliovich)

Run-3 dAu : South muon arm

Analyzed a subset of the data.

Expect of the order of a factor of four improvement of the statistics when the whole d-Au run is included.



$M_{\mu+\mu-}$ (GeV/c^2)

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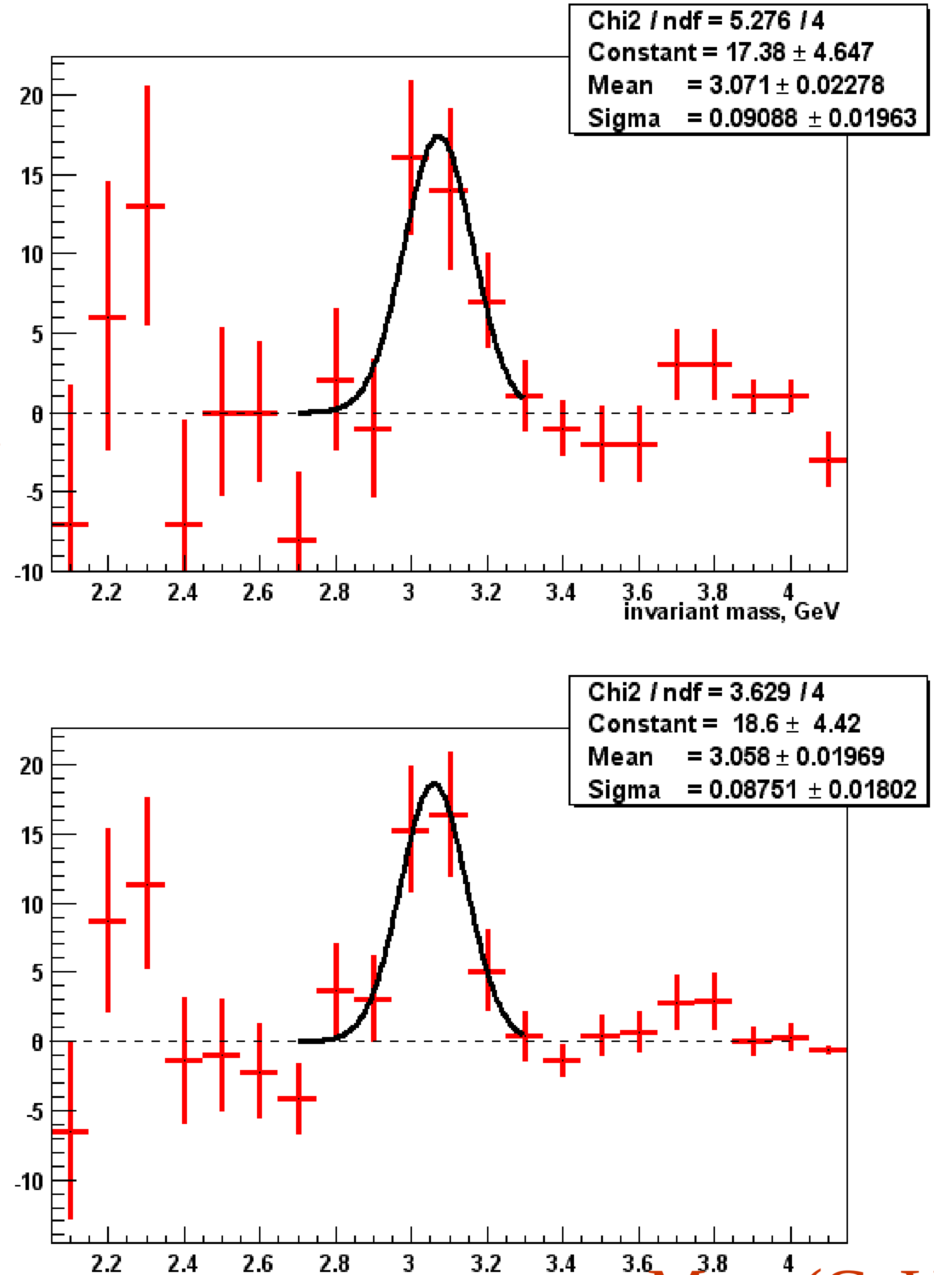
Run-3 dAu : Central arms

(Analyzed another subset of the data)

Top plot shows subtracted difference using like-sign as background estimate, bottom is with using mixed events.



M_{e+e-} (GeV/c^2)

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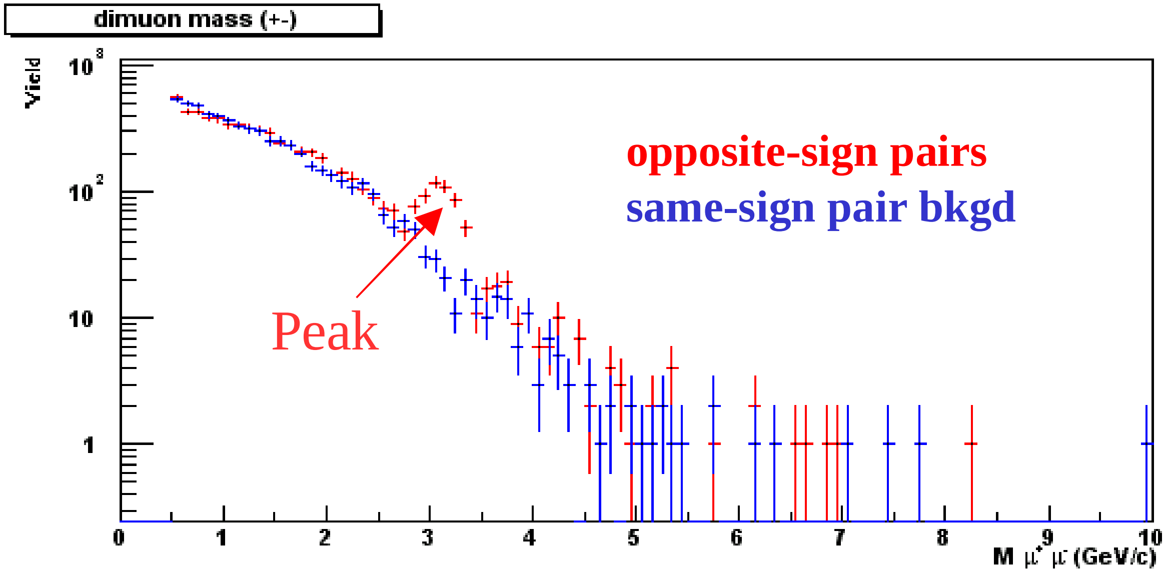
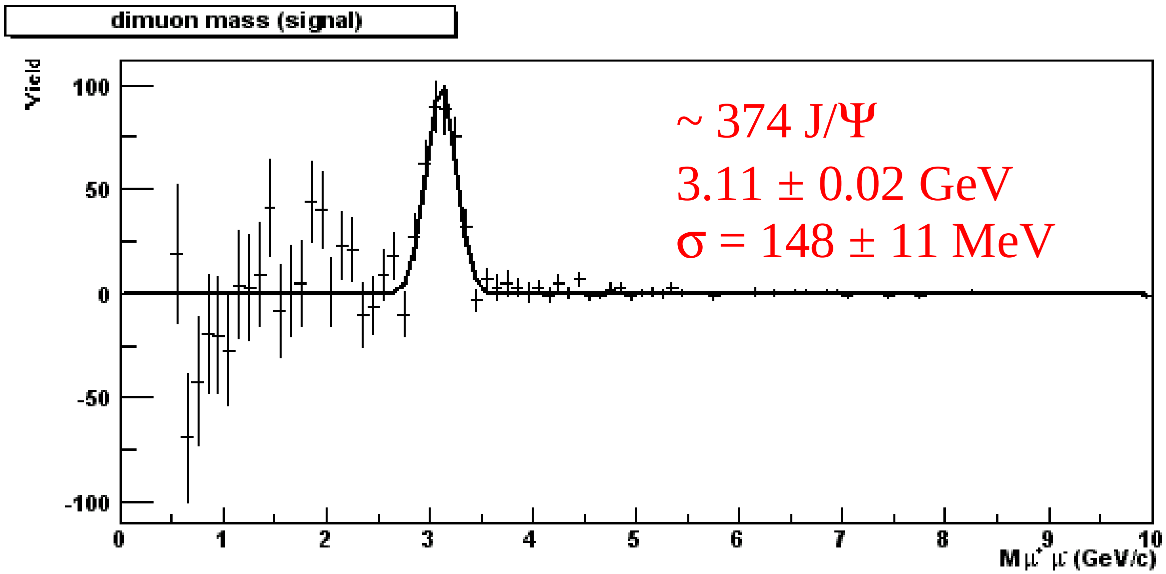
Run-3 dAu : North muon arm

Note: yet another different data sample, no corrections for detector & trigger eff. or acceptance.



Direct comparisons between the yield in the arms are thus meaningless for now.

But hopefully not for too long..



$M_{\mu+\mu-}$ (GeV/c^2)

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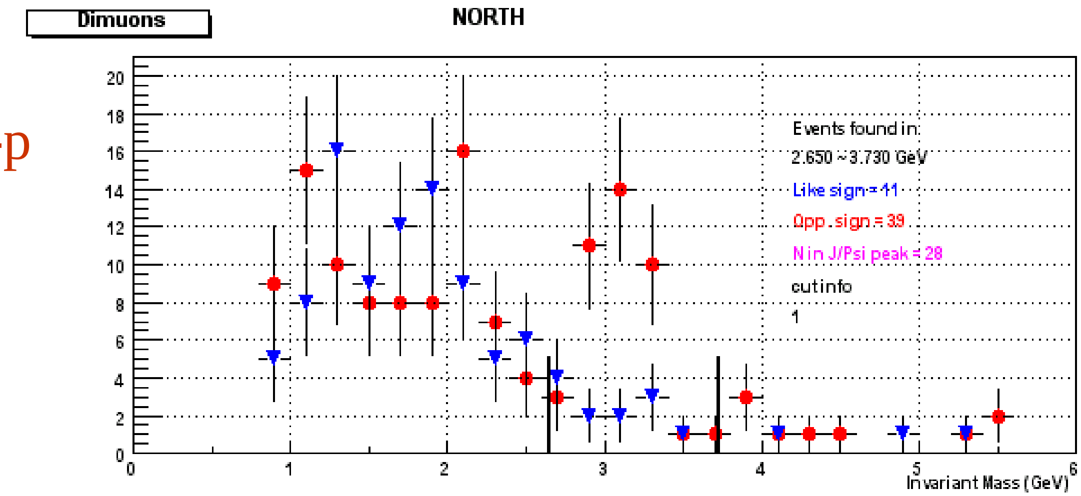
Run-3 p-p : North muon arm

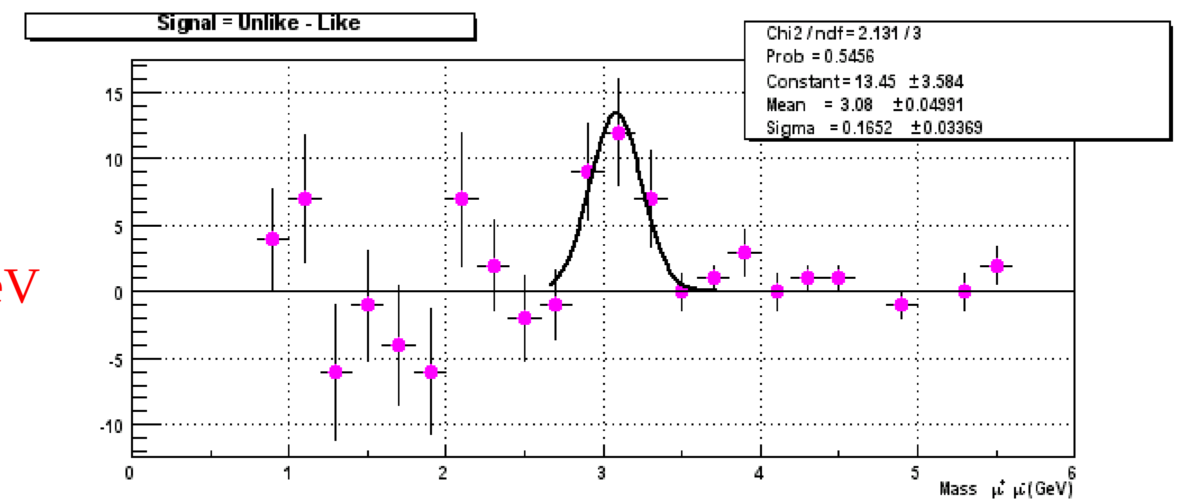
A first look at a Run-3 p-p data subset



~ 28 J/Ψ's

3.08 ± 0.06 GeV

σ = 165 ± 34 MeV



$M_{\mu+\mu-}$ (GeV/c^2)

Summary

Charm production measured by single electron spectra

- consistent with binary collision scaling

The first J/Ψ's in p-p and Au-Au interactions at RHIC have been obtained

- p-p cross section in agreement with color evaporation model
- Au-Au centrality dependence disfavors enhancement models

First d-Au run recently completed. More substantial yields were obtained.

- Should give us more understanding about e.g. gluon shadowing
- Baseline for comparisons with the upcoming high statistics Au-Au run

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Outlook

There are quite a few results and work-in-progress, that were not covered here, e.g.:

- Single muon (high pT) spectra
- Au-Au J/Ψ dimuon analysis
- e-μ coincidences (alt. charm measurement)

The p-p part of Run-3 is ongoing and should result in a significantly improved p-p data sample.

In the near future, a high luminosity Au-Au run is expected.

For the longer term, a Si-Vertex upgrade is being worked on.

- would enable direct measurements of open charm via secondary vertices.

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A lot more to look forward to!

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China Institute of Atomic Energy, Beijing
Peking University, Beijing

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*as of July 2002

Luminosity summary

Run	Year	Species	$s^{1/2}$ [GeV]	$\int Ldt$	N_{tot}
01	2000	Au-Au	130	1 μb^{-1}	10M
02	2001/2002	Au-Au	200	24 μb^{-1}	170M
		p-p	200	0.15 pb^{-1}	3.7G
03	2002/2003	d-Au	200	2.74 nb^{-1}	5.5G
		p-p	200	ongoing	

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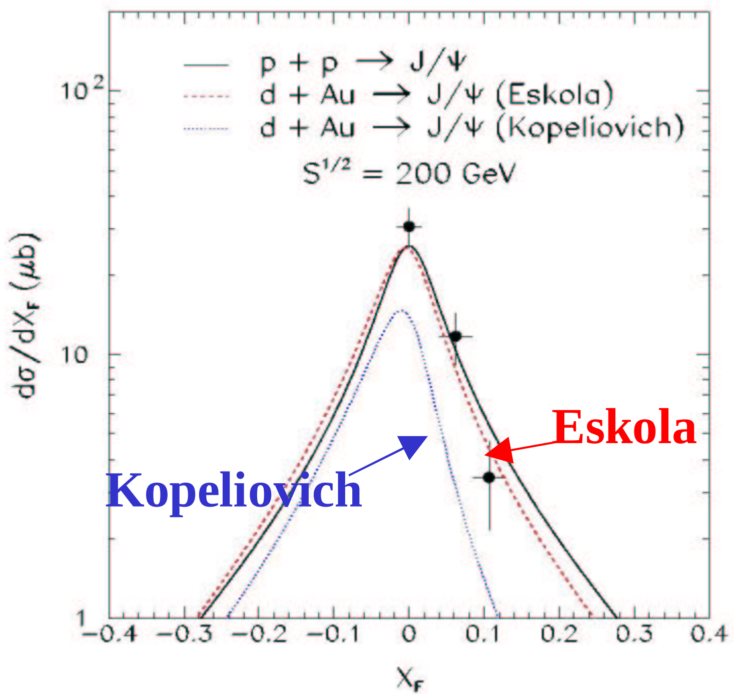
Kinematics

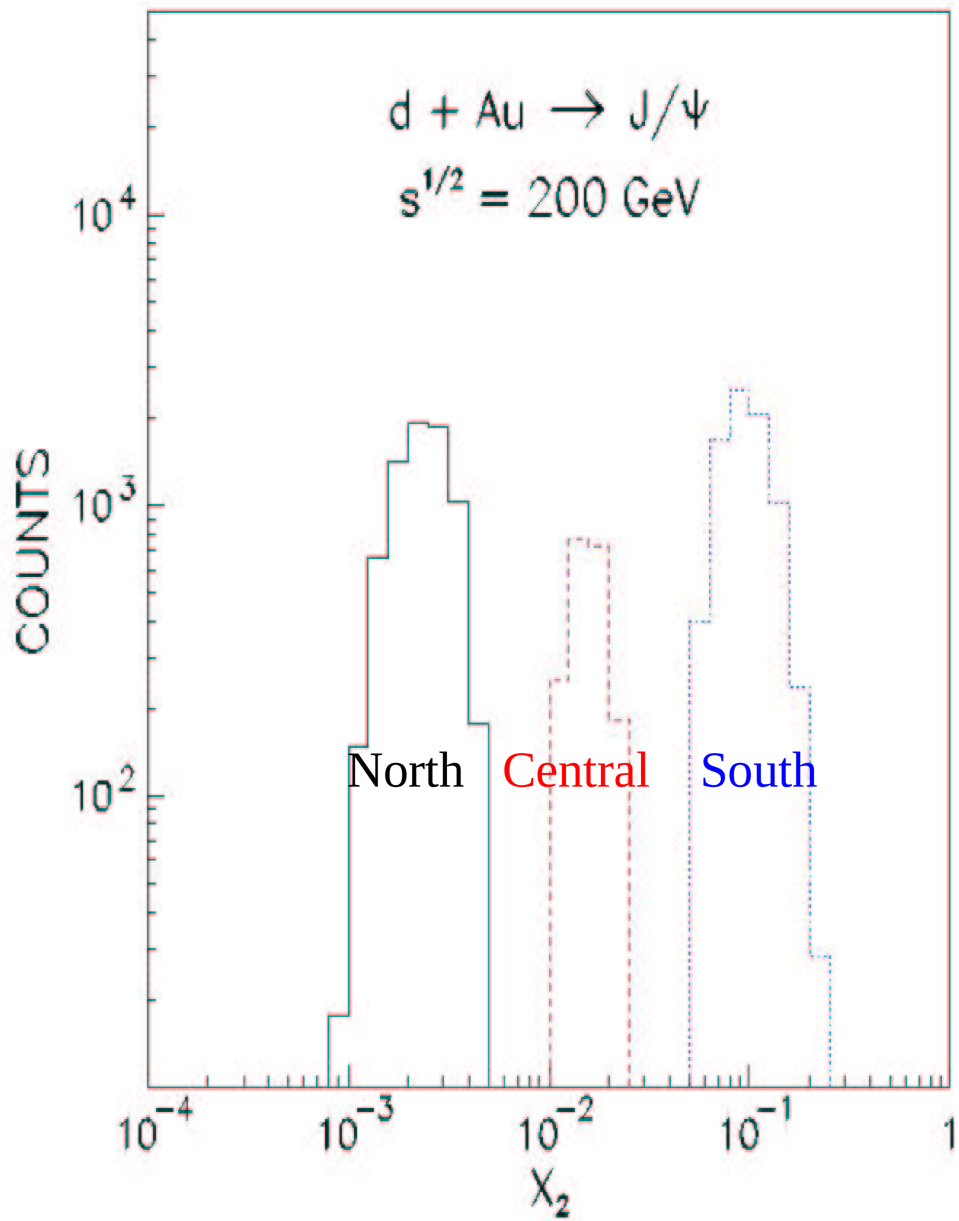
$x_F = 2*p_z/sqrt(s)$.

$\tau = m^2/s$,

$x_1 = 1/2*(x_F+sqrt(x_F^2+4*\tau))$;

$x_2 = x_1 - x_F$





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