Υ Measurements by the PHENIX Collaboration

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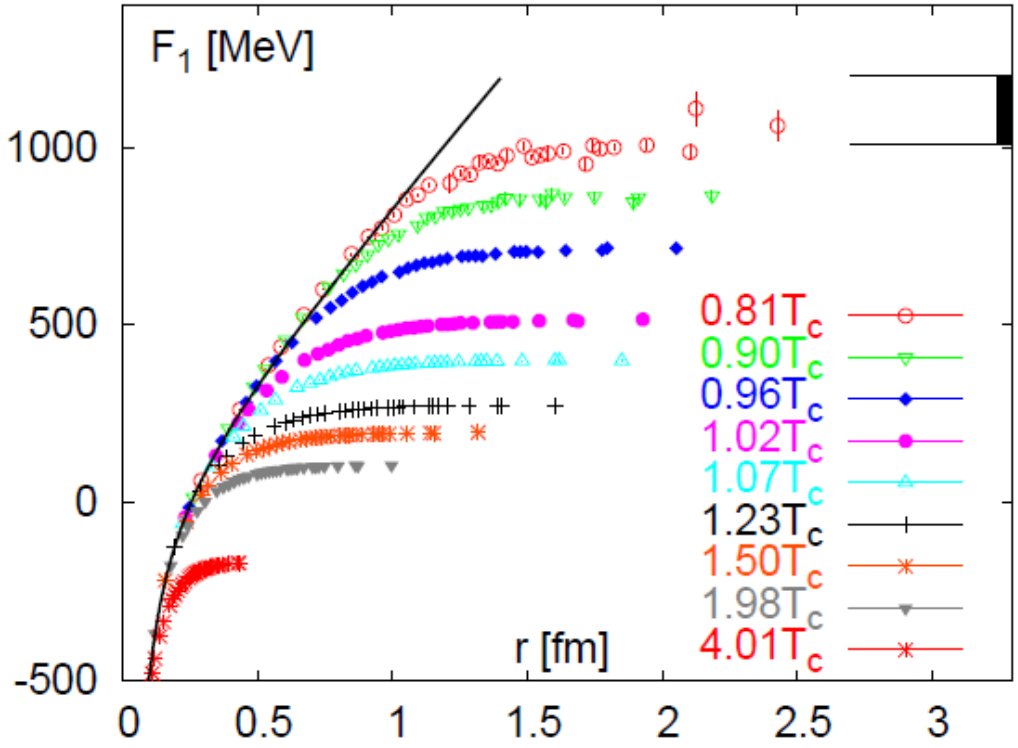
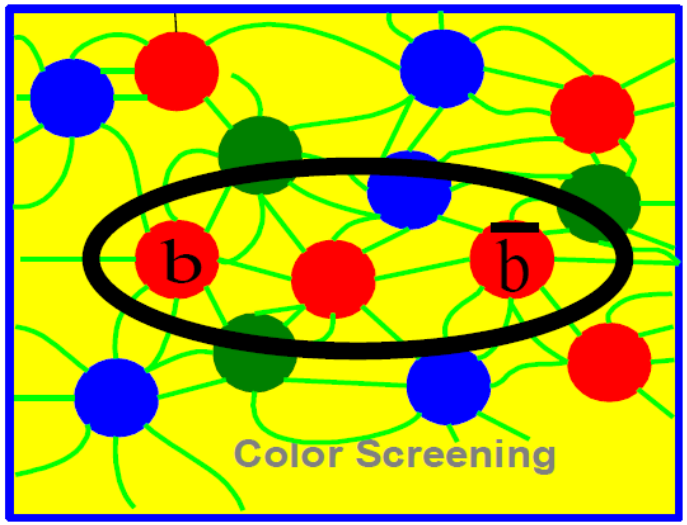
For the PHENIX Collaboration

Hard Probes 2012

Color Screening

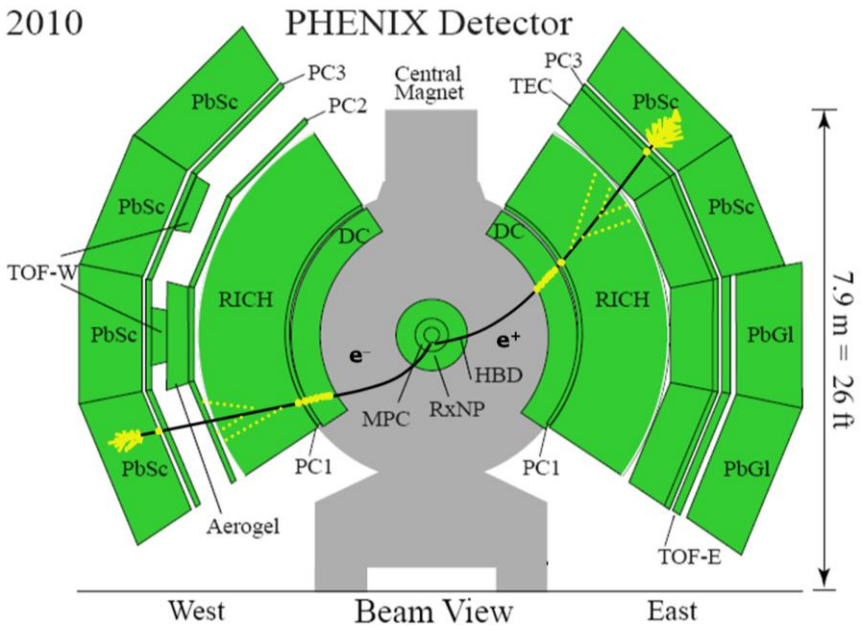


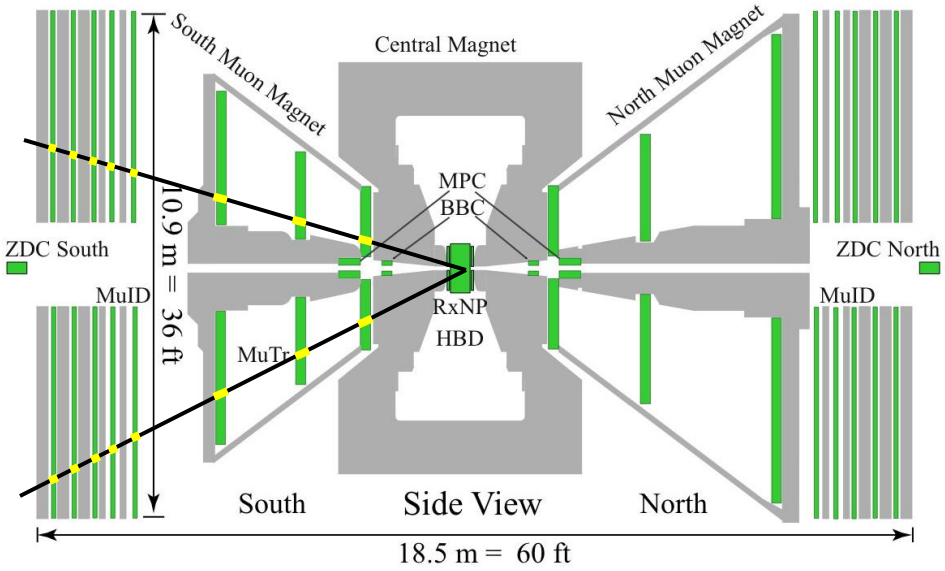


By looking at the suppression of various states we can measure color screening in the QGP

state	Υ(1S)	Υ(2S)	Υ(3S)
Mass(GeV)	9.46	10.0	10.36
ΔE (GeV)	1.10	0.54	0.20
r_o(fm)	0.28	0.56	0.78

The PHENIX Detector





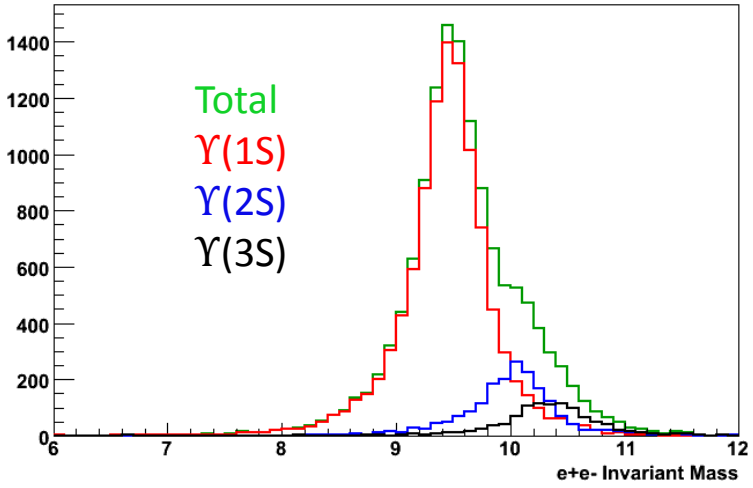
Mid rapidity: $\Upsilon \rightarrow e^+e^-$

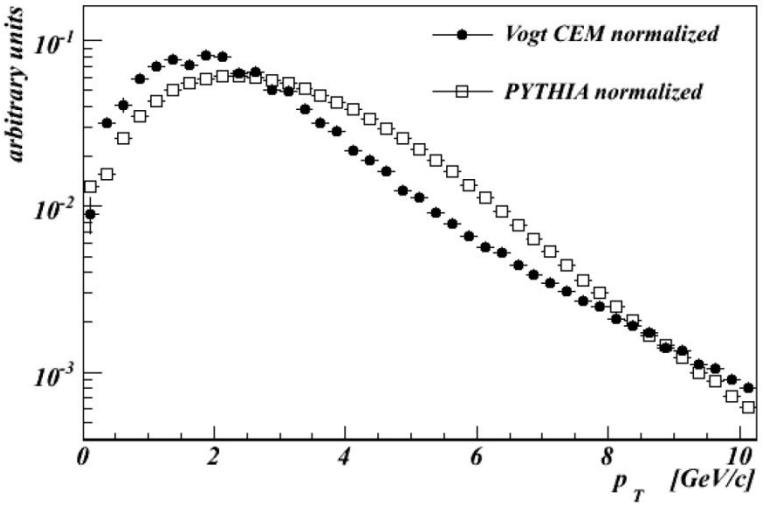
$|\eta|<0.35$, $\Delta\Phi = 2 \times \pi/2$, $p>0.2$ GeV/c

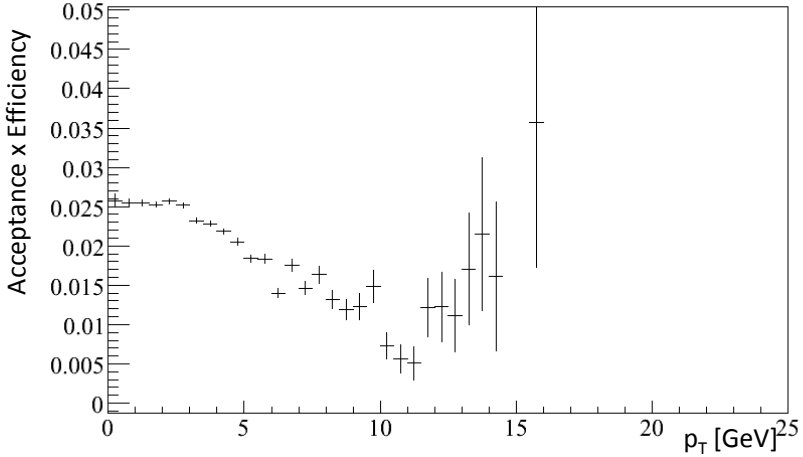
Forward rapidity: $\Upsilon \rightarrow \mu^+\mu^-$

$1.2<|\eta|<2.2$, $\Delta\Phi = 2\pi$, $p>2$ GeV/c

Detector Acceptance: Central Arms



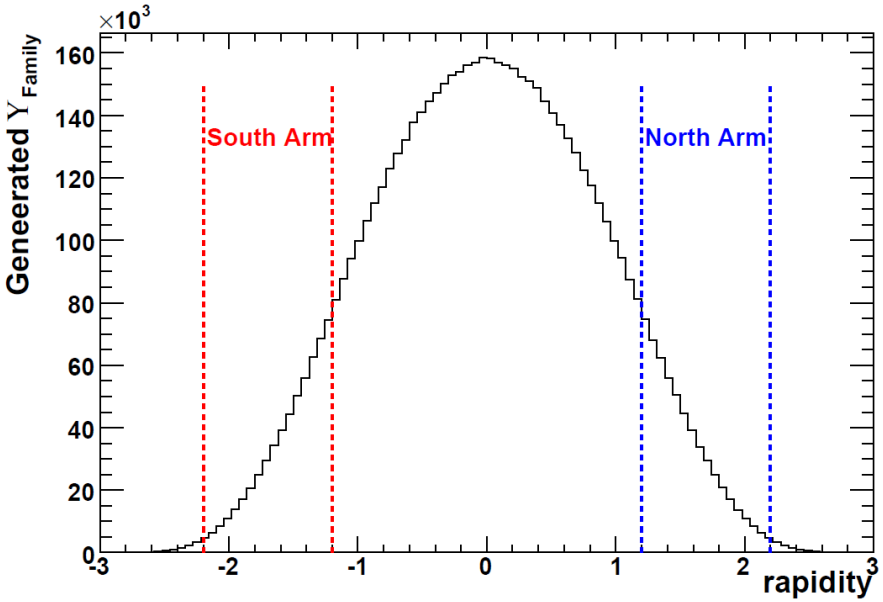


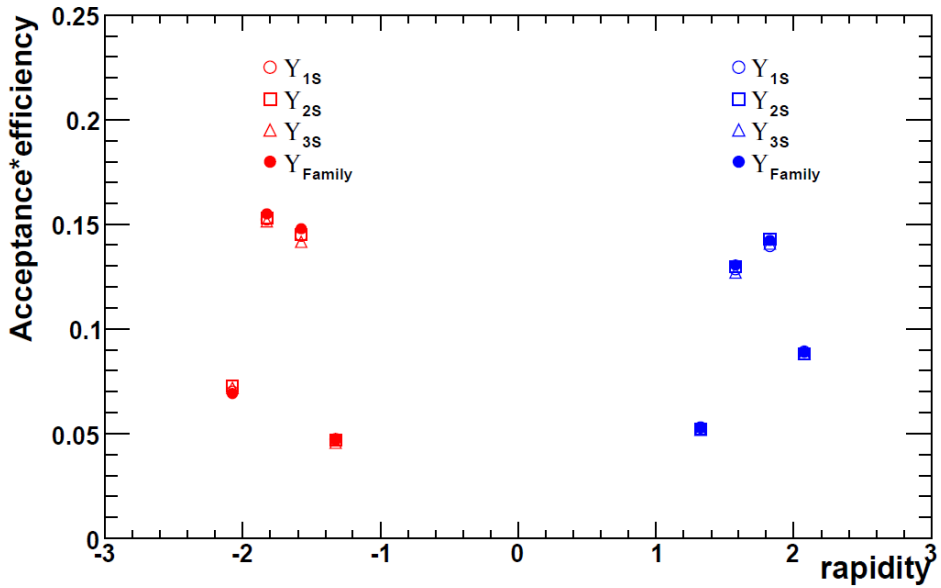


- Υ states simulated
- Various p_T models
- Calculated Acceptance

$$A \times \varepsilon_{eID}(\Upsilon) = 2.33 \pm 0.17(\text{sys. acceptance}) \pm 0.01(\text{sys. eID})\%$$

Detector Acceptance: Muon Arms





South Acc = 0.0989 ± 0.0004
North Acc = 0.0950 ± 0.0004

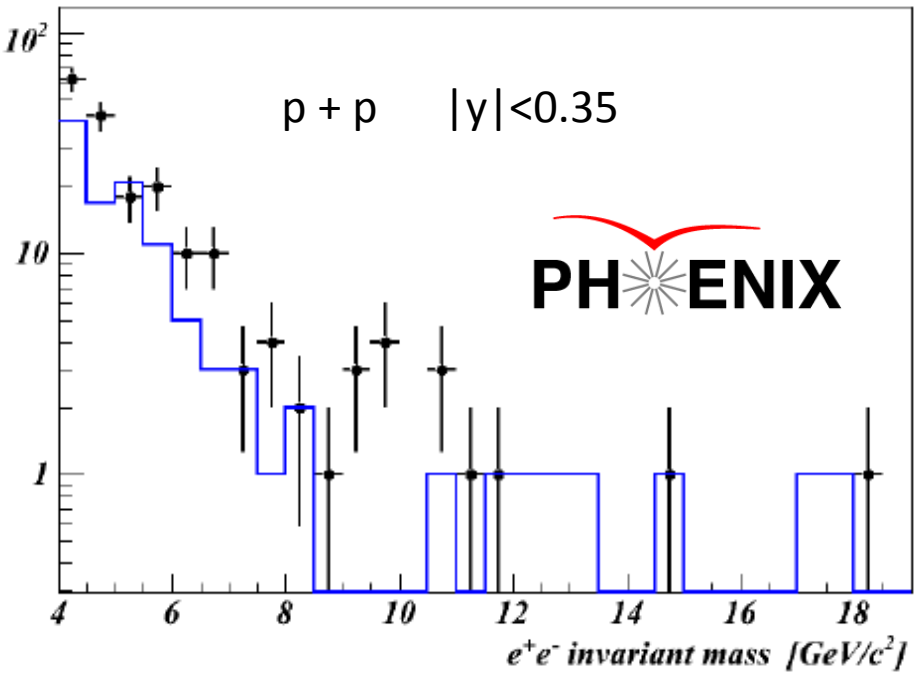
- Υ(1S+2S+3S) simulated
- Acceptance x Efficiency values calculated
- Integrated acceptance corrections used

The Process

- The invariant mass spectra of e^+e^- and $\mu^+\mu^-$ pairs are created.
- Υ candidates are selected by taking pairs with an invariant mass between 8.5 and 11.5 GeV
- The Υ yields are estimated from these candidates after removing the background contributions
  - Combinatorial background from random e^+e^- or $\mu^+\mu^-$ pairs
  - Correlated continuum background from Drell-Yan, open bottom and open charm (semi-leptonic decays)

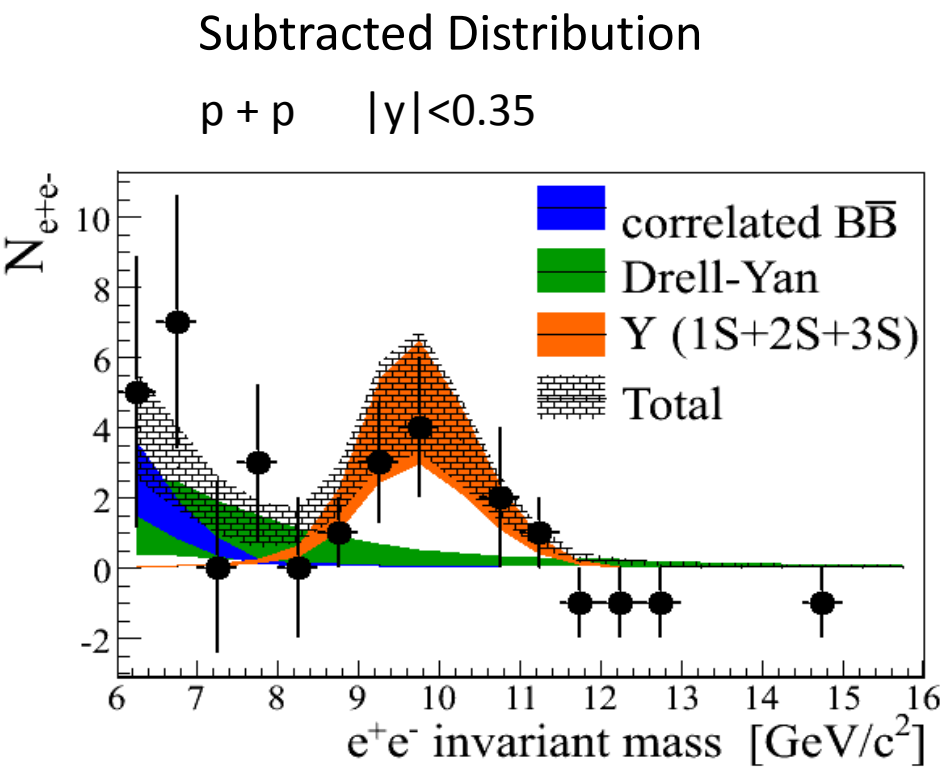
Combinatorial Background

Black Points: Opposite Sign Pairs
Blue Points: Same Sign Pairs



- Mass spectra for like sign and opposite signed lepton pairs were created.
- Like sign mass spectra used to determine the distribution of randomly associated leptons.
- Like sign distribution is subtracted from unlike sign to determine the mass distribution of pairs from physical processes.

Combinatorial Background



- Mass spectra for like sign and opposite signed lepton pairs were created.
- Like sign mass spectra used to determine the distribution of randomly associated leptons.
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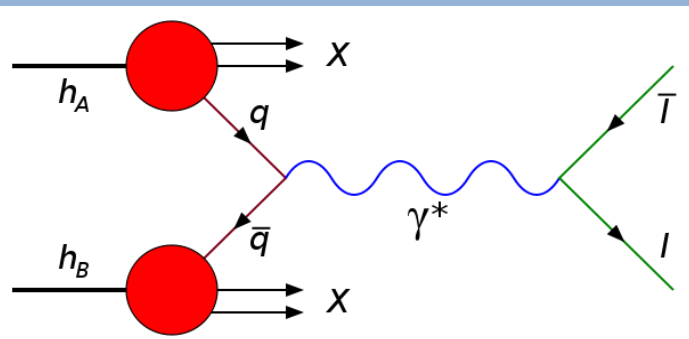
Correlated Backgrounds

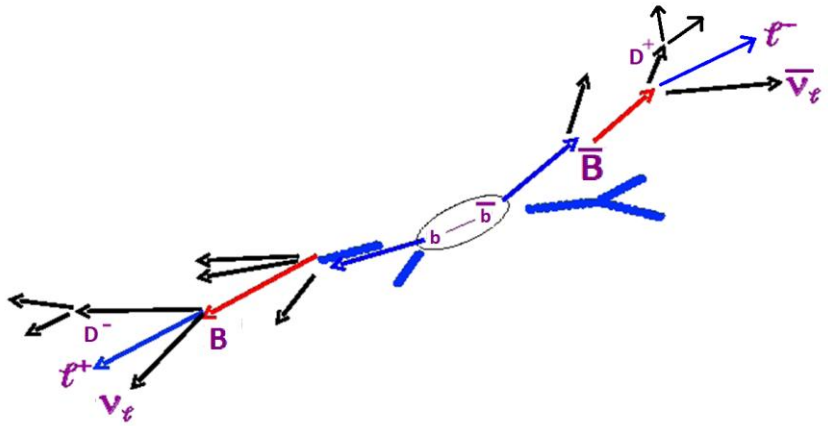
Drell-Yan



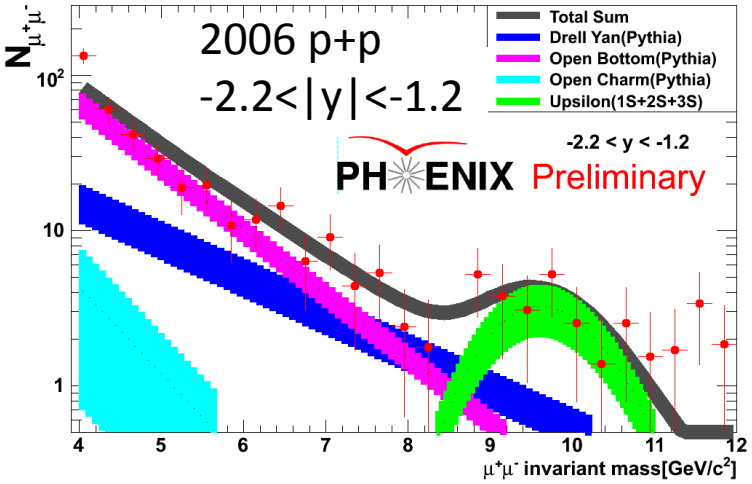
Backgrounds from physical processes which can produce e^+e^- and $\mu^+\mu^-$ pairs in the Υ mass region.

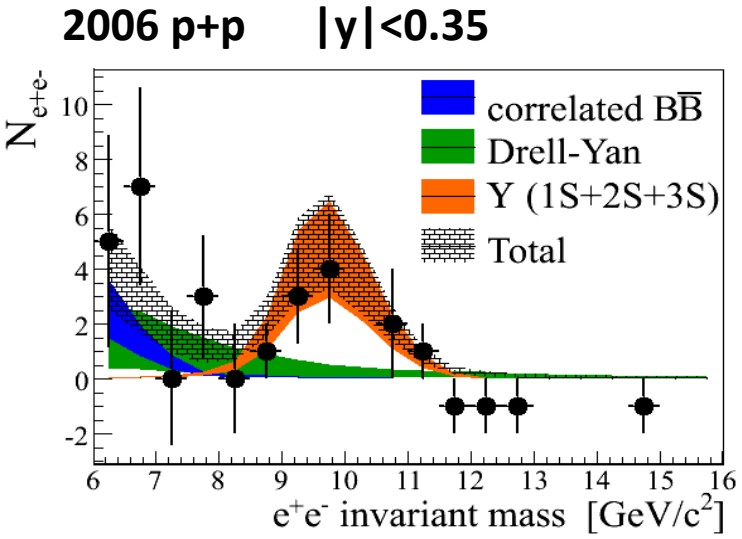
Pythia and GEANT simulations were used to determine the shape of the di-lepton mass spectra for these processes.

Open Heavy Flavor



Determining Yields



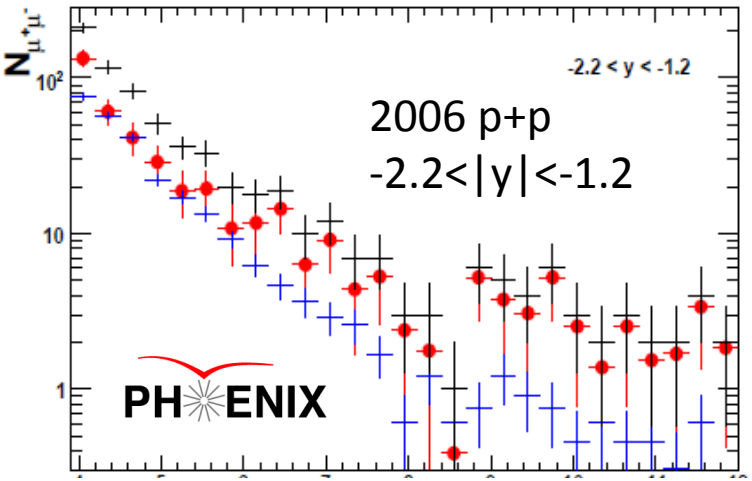


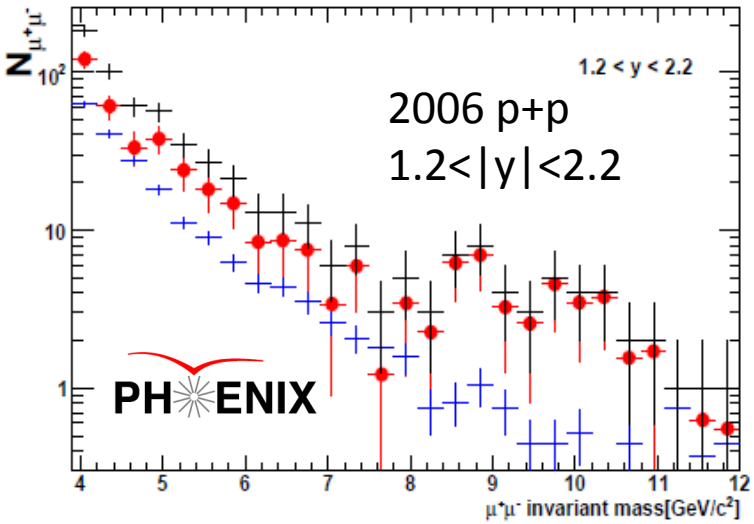
- Combinatorial background subtracted.
- Correlated background was fitted to the data outside of the Υ mass region.
- Count pairs between 8.5 and 11.5 GeV and subtract the integral of the background fit.

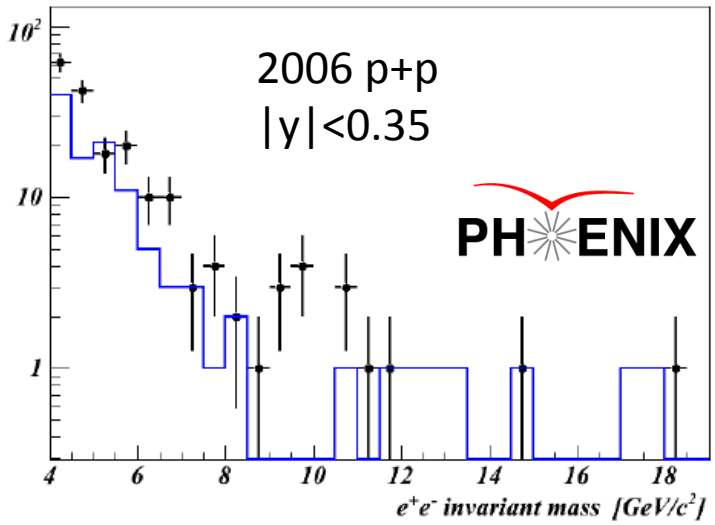
2006 p+p Measurements

- Mid-rapidity in the di-electron channel
- Forward and backward rapidity in the di-muon channel

2006 p+p Signals





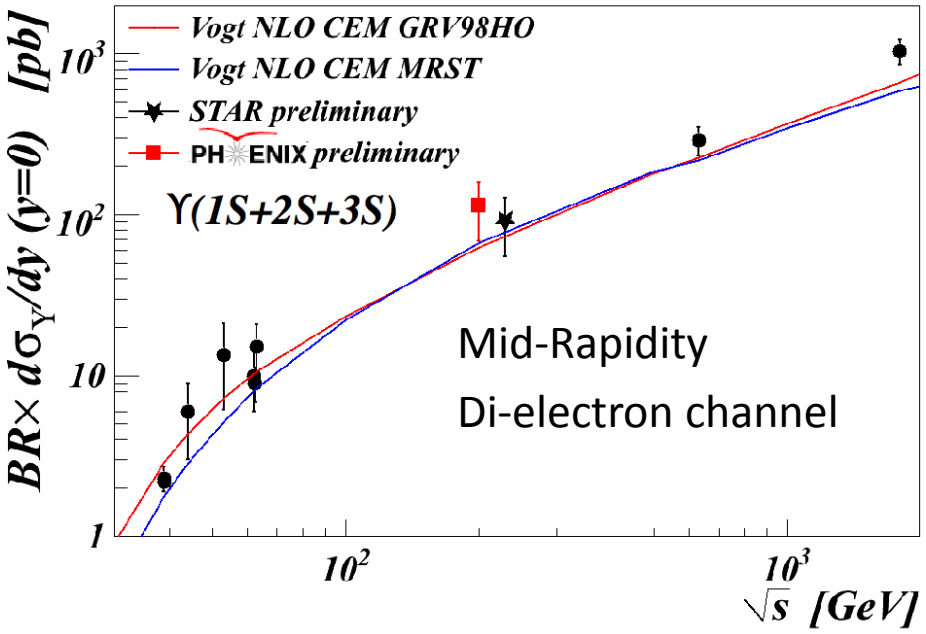


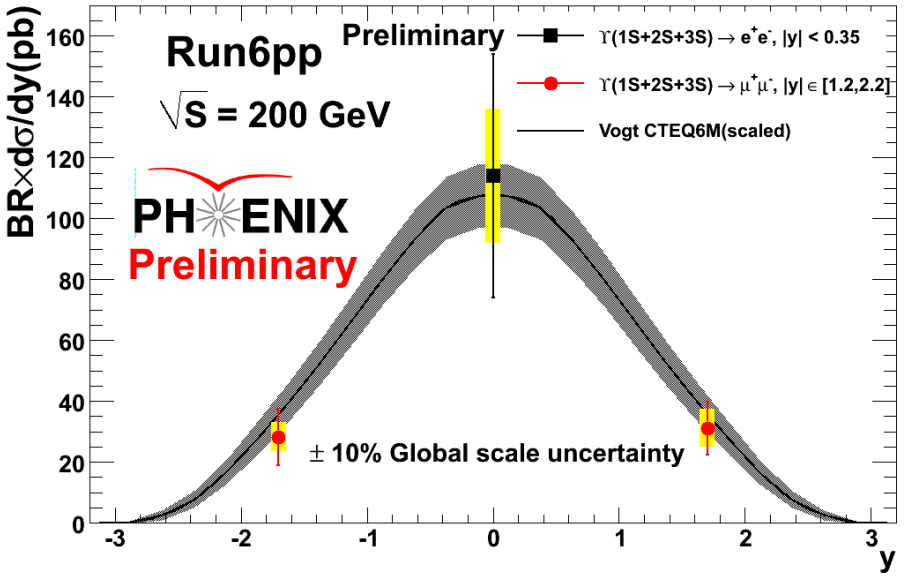
Black Points: Opposite Sign Pairs

Blue Points: Same Sign Pairs

Red Points: Black - Blue

2006 p+p Results





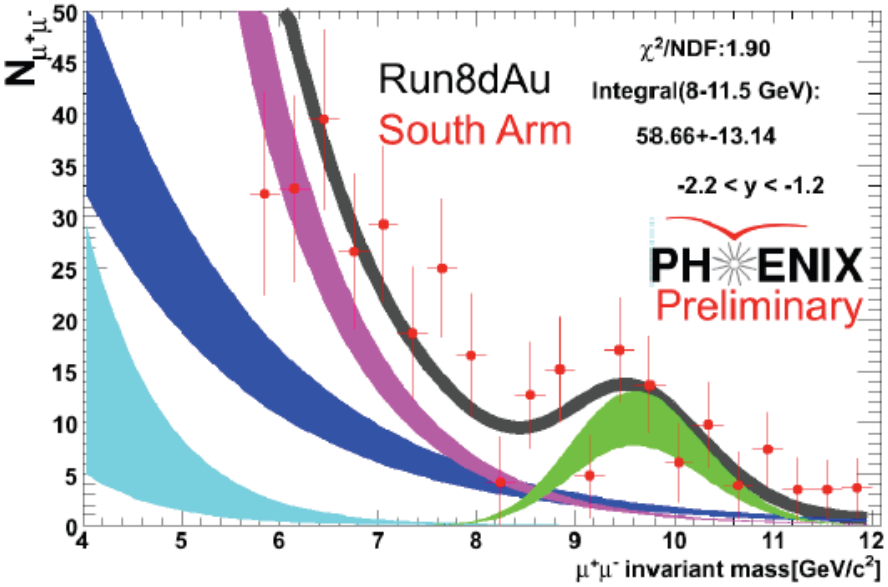
$$\left.\frac{dN}{dy}\right|_{y=0} = \frac{1}{\Delta y} \times \frac{N_\Upsilon}{N_{BBC}} \times \frac{(1 - f_{cont})}{\varepsilon^\Upsilon_{BBC} \varepsilon_{ERT\_E} A \varepsilon_{eID} \varepsilon_{mass\ cut}}$$

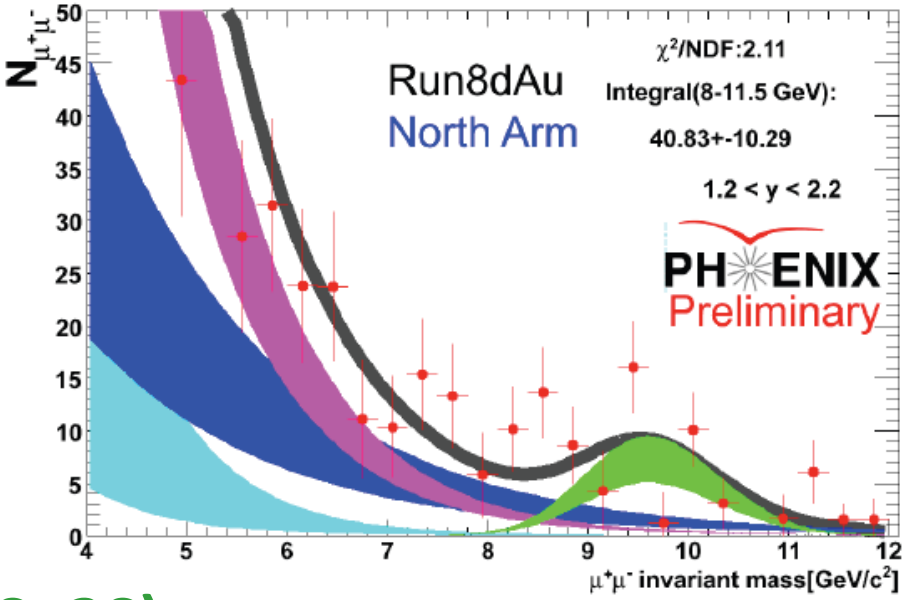
$$B\sigma_\Upsilon|_{y=0} = B\frac{dN}{dy} \times \sigma_{pp} \times \varepsilon_{BBCLL1}$$

2008 d+Au Measurements

- Use PHENIX p+p data as baseline
- Compare to calculated cross section from 2008 d+Au to determine R_{dA}
  - Currently have result at forward and backward rapidity
  - Work is being done on a mid-rapidity measurement in the Central Arms

2008 d+Au Signals





-2.2 < y < -1.2

ϒ(1S+2S+3S)

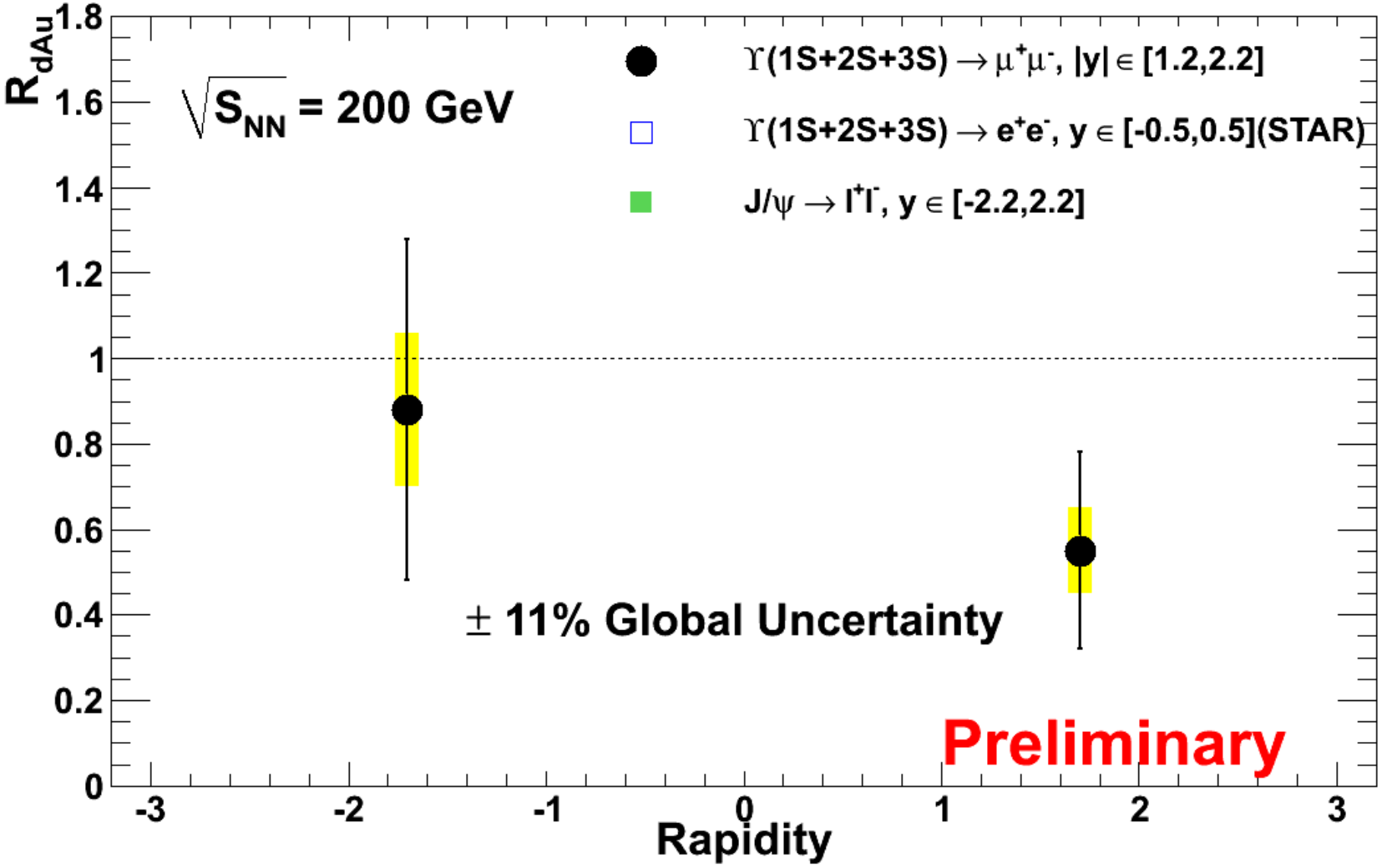
Drell-Yan

Open Bottom

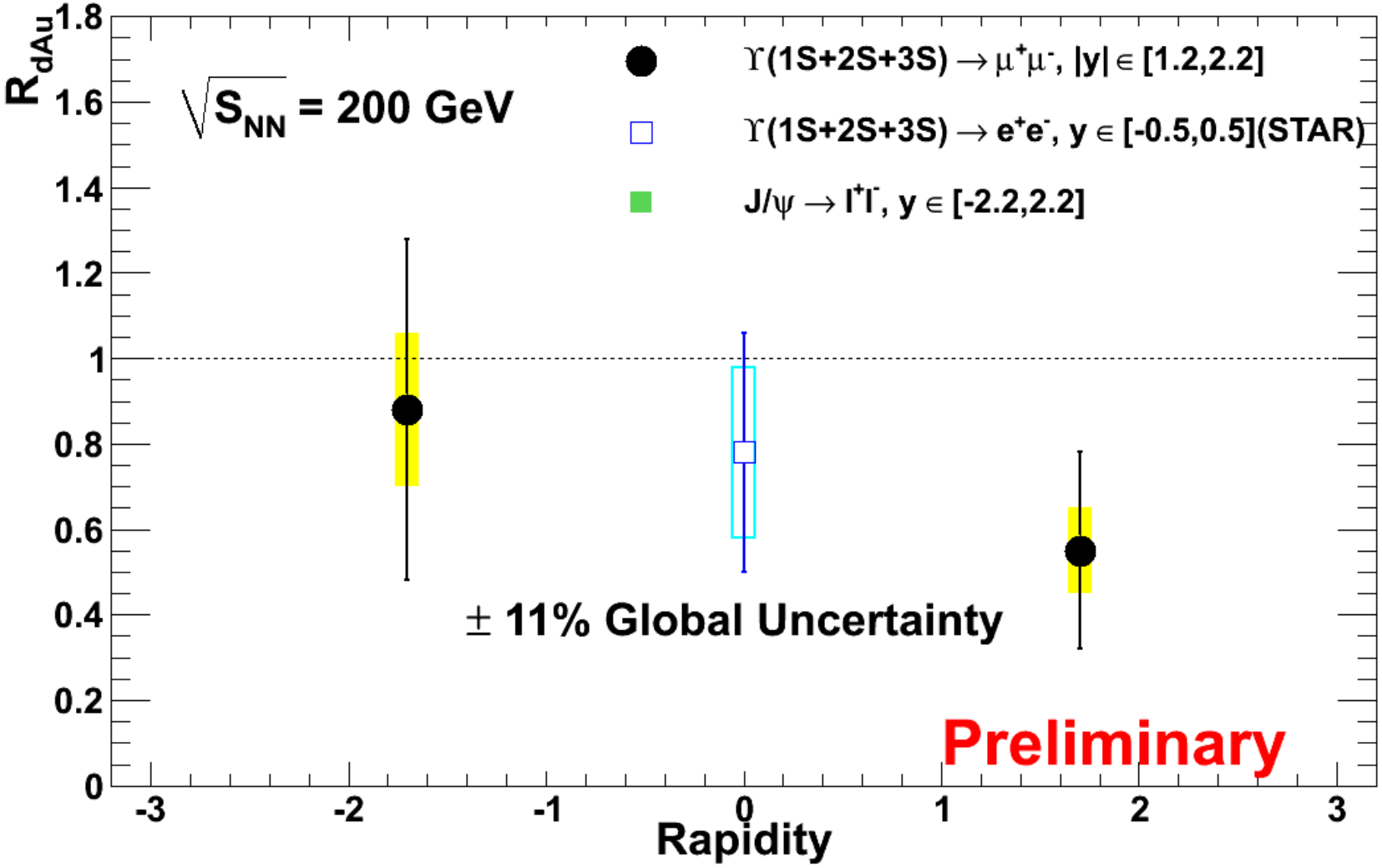
Open Charm

1.2 < y < 2.2

R_{dA} Results


R_dAu
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
√S_NN = 200 GeV
Υ(1S+2S+3S) → μ⁺μ⁻, |y| ∈ [1.2,2.2]
Υ(1S+2S+3S) → e⁺e⁻, y ∈ [-0.5,0.5](STAR)
J/ψ → l⁺l⁻, y ∈ [-2.2,2.2]
± 11% Global Uncertainty
Preliminary
-3
-2
-1
0
1
2
3
Rapidity

R_{dA} Results


R_dAu
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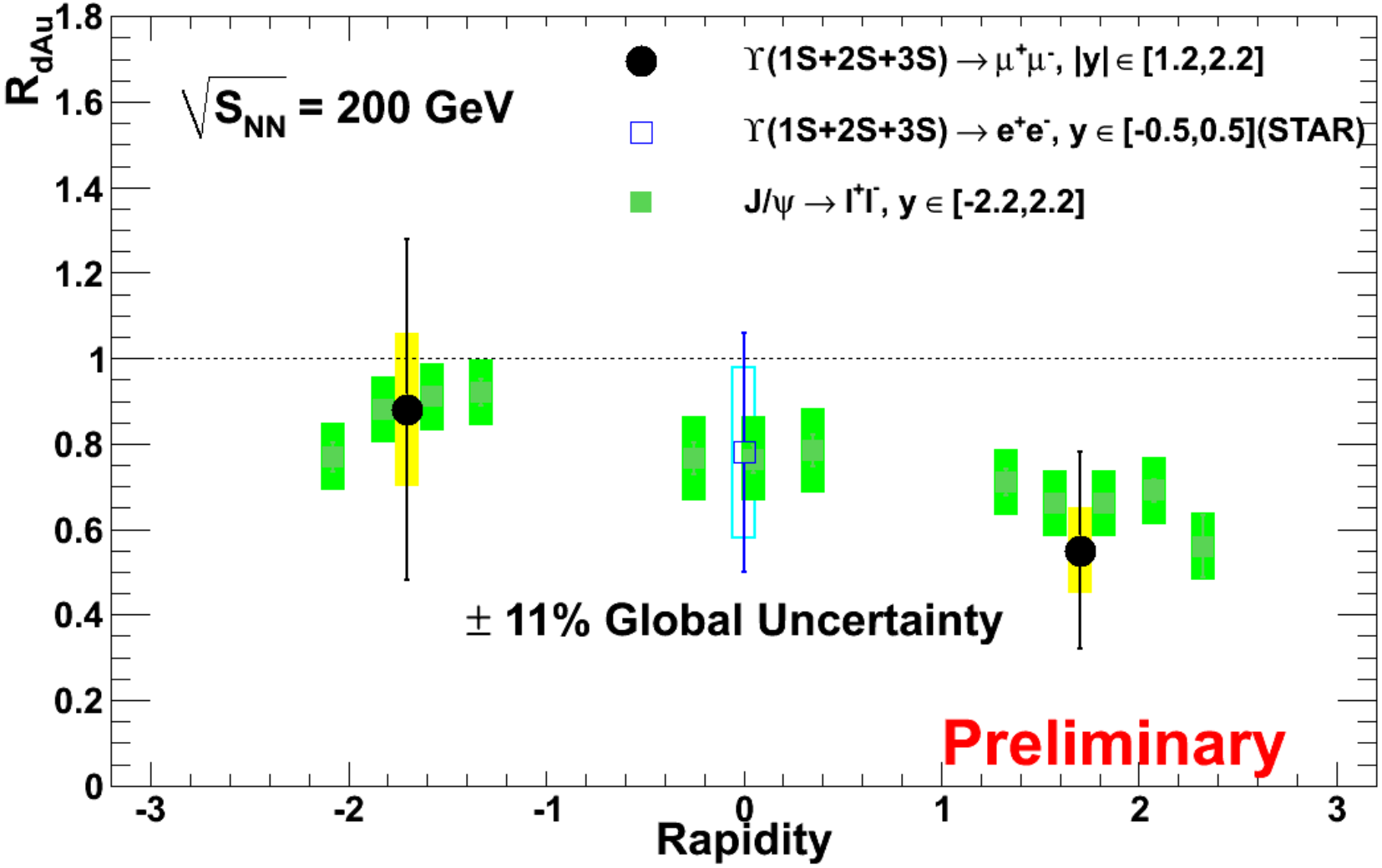
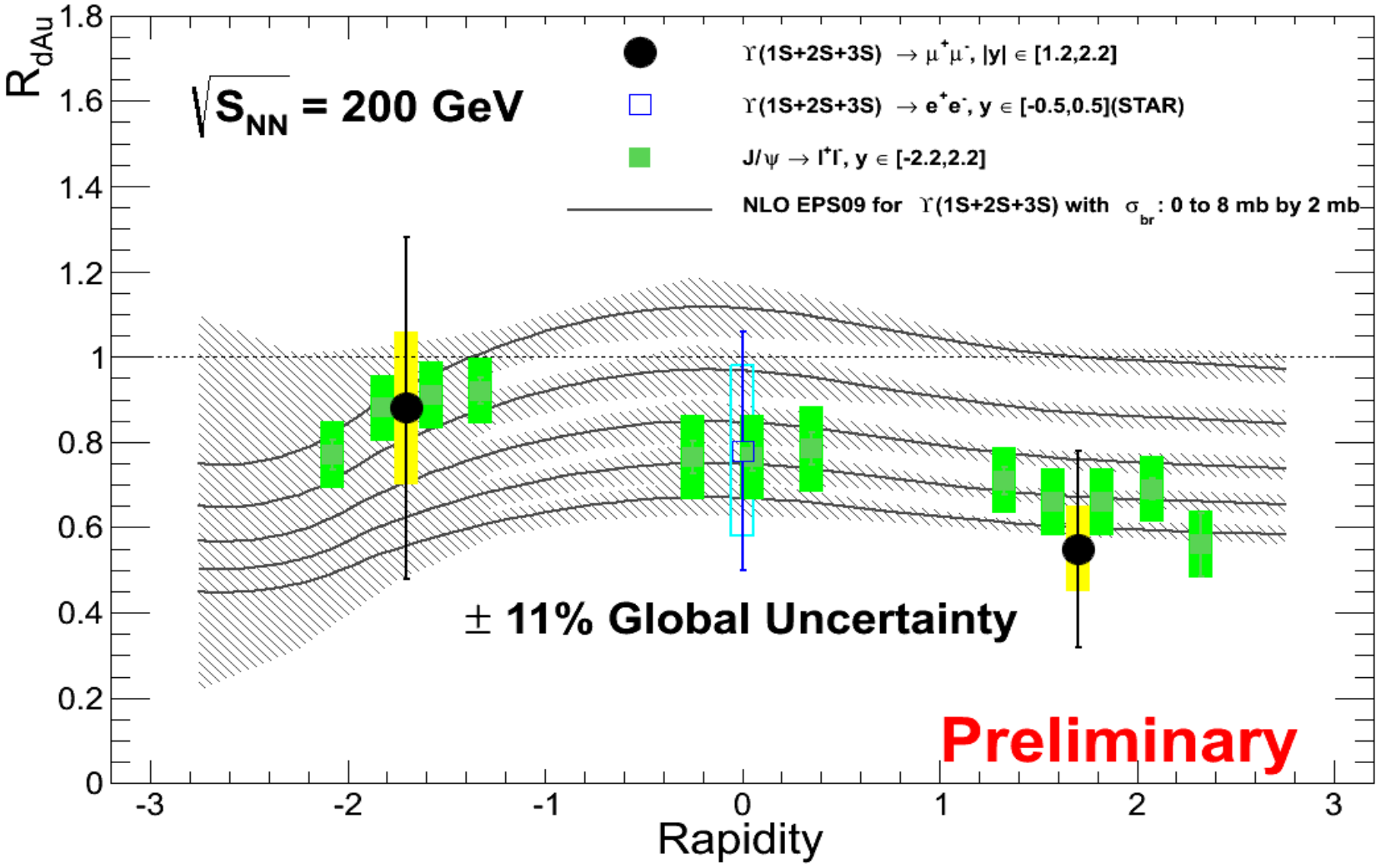
J/ψ → l⁺l⁻, y ∈ [-2.2,2.2]
± 11% Global Uncertainty
Preliminary
Rapidity
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-3
-2
-1
0
1
2
3

R_{dA} Results


R_{dAu}
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
$\sqrt{S_{NN}}$ = 200 GeV
$\Upsilon(1S+2S+3S) \rightarrow \mu^+\mu^-$, $|y| \in [1.2,2.2]$
$\Upsilon(1S+2S+3S) \rightarrow e^+e^-$, $y \in [-0.5,0.5]$(STAR)
$J/\psi \rightarrow l^+l^-$, $y \in [-2.2,2.2]$
$\pm$ 11% Global Uncertainty
Preliminary
-3
-2
-1
0
1
2
3
Rapidity

R_{dA} Results


R_{dAu}
$\sqrt{S_{NN}}$ = 200 GeV
Υ(1S+2S+3S) $\rightarrow \mu^+\mu^-$, |y| $\in$ [1.2,2.2]
Υ(1S+2S+3S) $\rightarrow e^+e^-$, y $\in$ [-0.5,0.5](STAR)
$J/\psi \rightarrow l^+l^-$, y $\in$ [-2.2,2.2]
NLO EPS09 for Υ(1S+2S+3S) with σ_{br} : 0 to 8 mb by 2 mb
± 11% Global Uncertainty
Preliminary
Rapidity

2010 Au+Au Measurements

- Use PHENIX p+p data as baseline
- Leverage previous PHENIX J/ψ results to reduce systematics

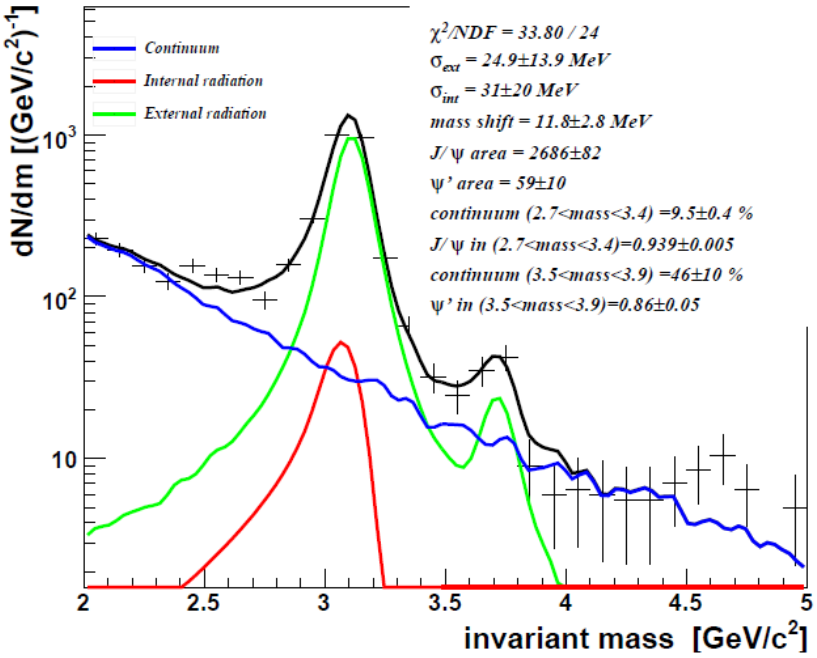
Υ R_{AA} Calculation Relative to J/ψ

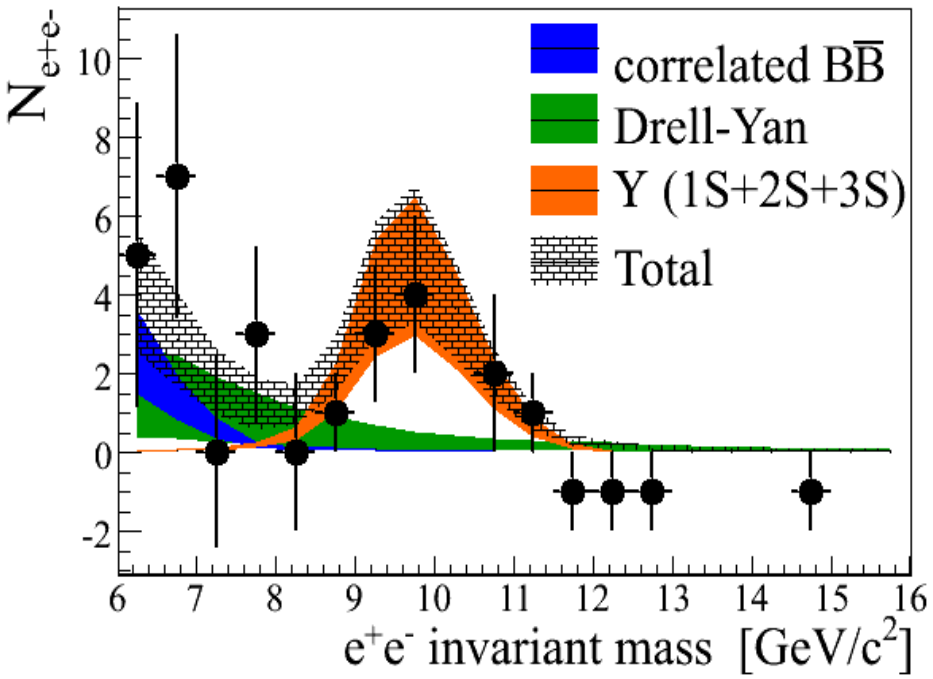
Particle yield ratios(preliminary result) – compare the Υ yields to J/ψ yields in p+p and in Au+Au. Suppression can be determined by renormalizing the J/ψ yield by previously calculated R_{AA}

$$R_{AA}(\Upsilon) = \frac{[N(\Upsilon)/N(J/\psi)]_{AA}}{[N(\Upsilon)/N(J/\psi)]_{pp}} \times \varepsilon_{rel} \times R_{AA}(J/\psi)$$

This method is appealing because it largely cancels any detector performance caused systematics and we already have J/ψ results from the 2004 Au+Au data set that we can use to leverage our understanding.

Previous J/ψ and ϒ in p+p at |y|<0.35



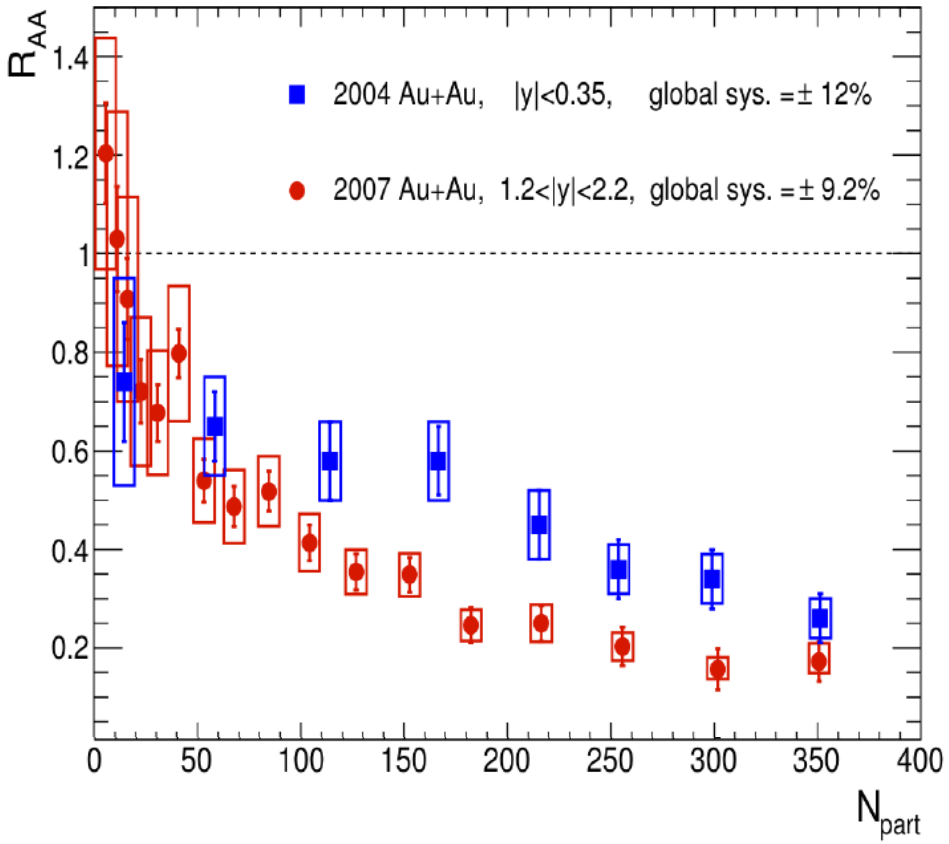


N[J/ψ] = 2686 ± 82

N[ϒ] = 10.5 ± 3.7

$$[N(\Upsilon)/N(J/\psi)]_{pp} = (3.96 \pm 1.40 \pm 0.92) \times 10^{-3}$$

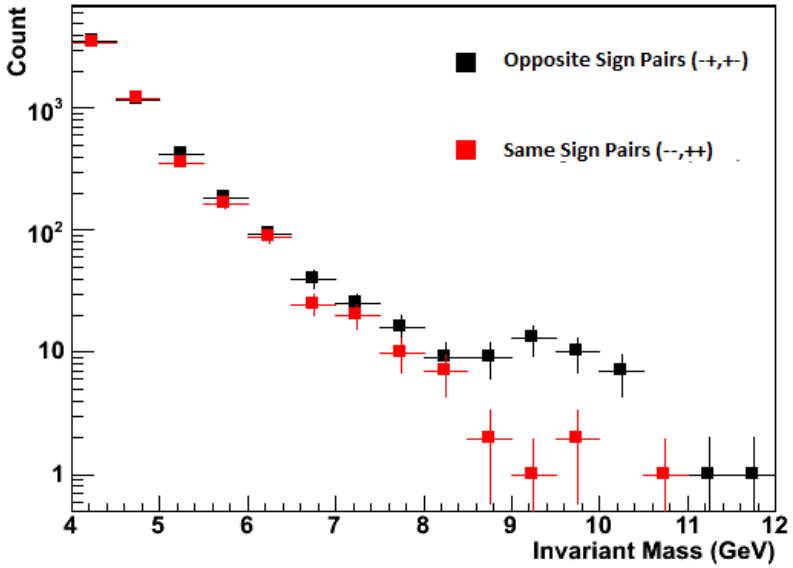
Previous J/ψ Measurement

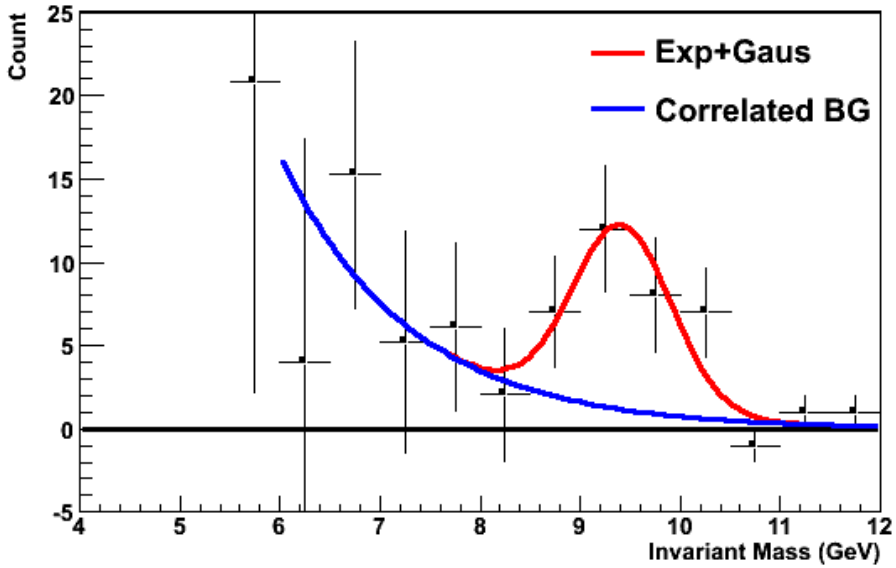


2004 Au+Au data analysis provides a significant J/ψ result. Used a weighted average of the blue data points to get a min-bias R_{AA}(J/ψ).

$$R_{AA}^{MB}(J/\psi) = 0.425 \pm 0.025(stat) \pm 0.051(sys) \pm 0.051(global)$$

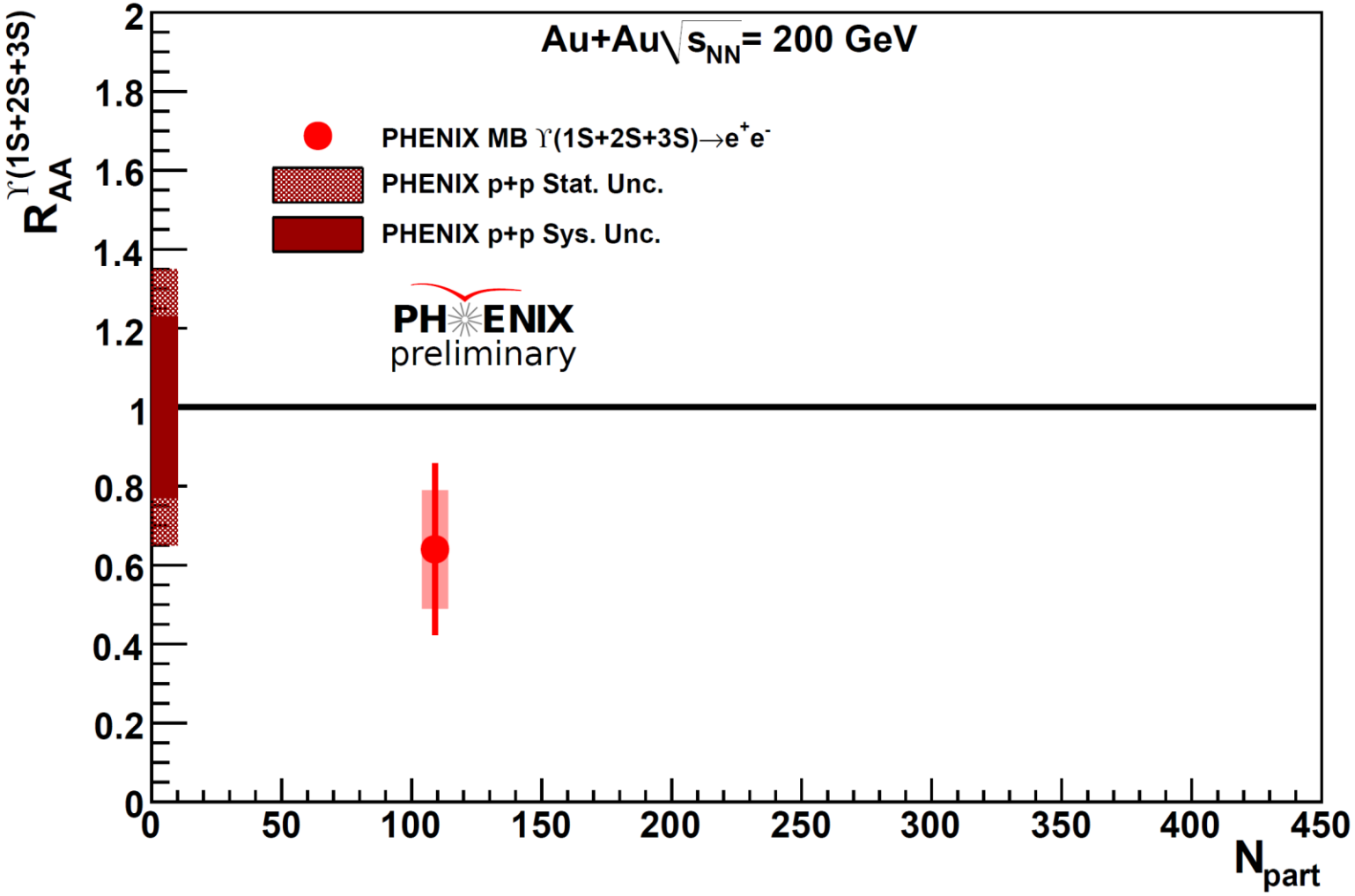
$\Upsilon \rightarrow e^+e^-$ in Au+Au at $|y|<0.35$



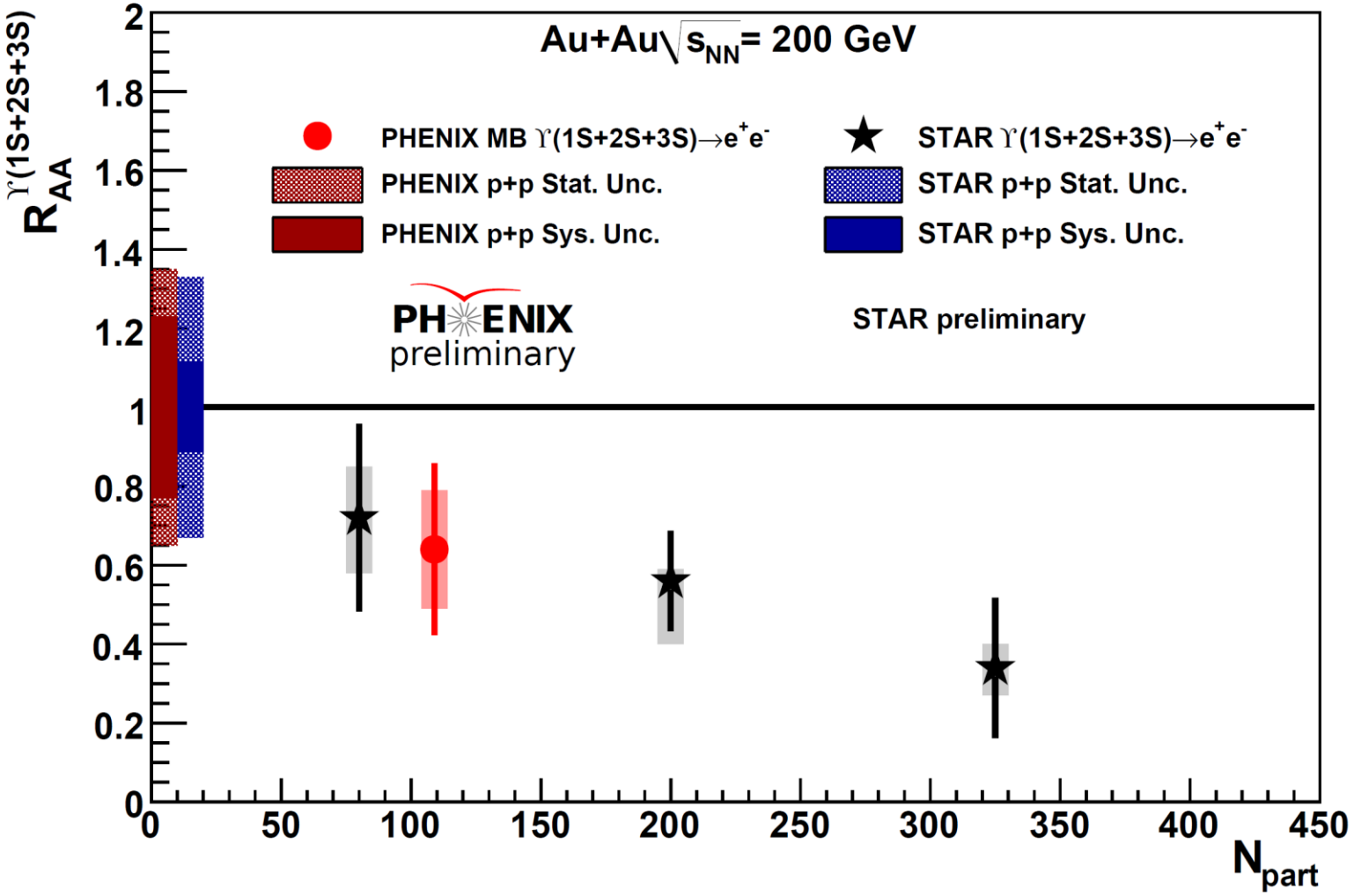


The same sign combinatoric background is subtracted in the same way the p+p and d+Au were shown previously. The resulting distribution it then fit with an exponential + Gaussian function. Entries between 8.5 and 11.5 GeV are counted and the area under the exponential portion of the fit are subtracted to find the Υ yields.

Preliminary Result



Comparison to STAR

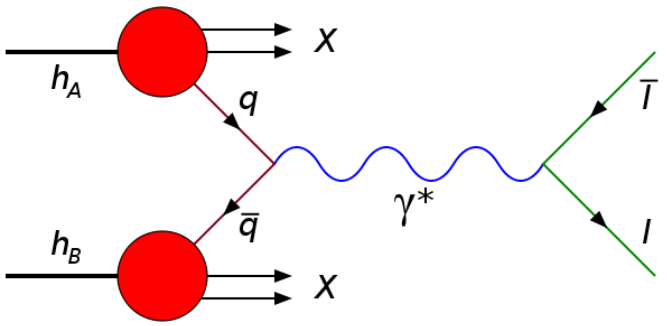


Conclusion

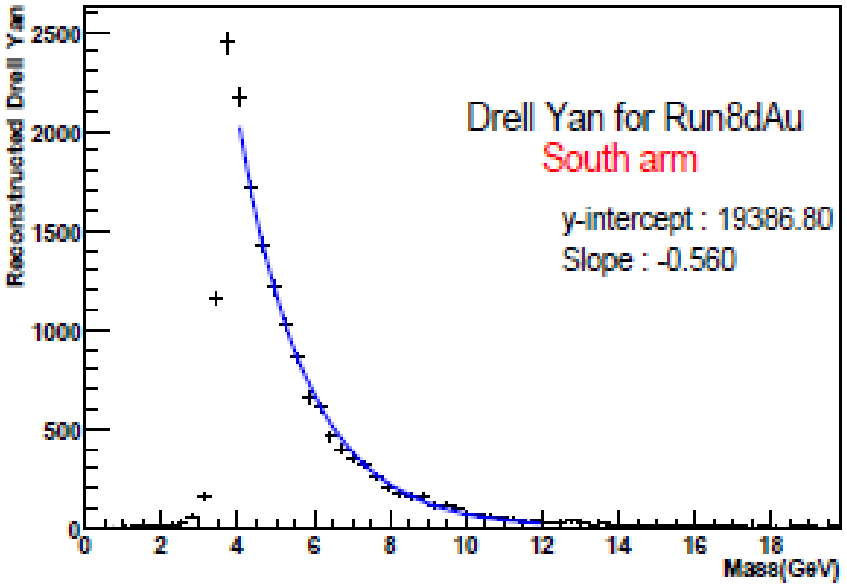
- Beginning of a rich Υ program at PHENIX
  - Complementing the extensive J/ψ measurements already made by PHENIX
- Exciting results still coming
  - Improved d+Au measurement
  - New Au+Au measurement at forward rapidity

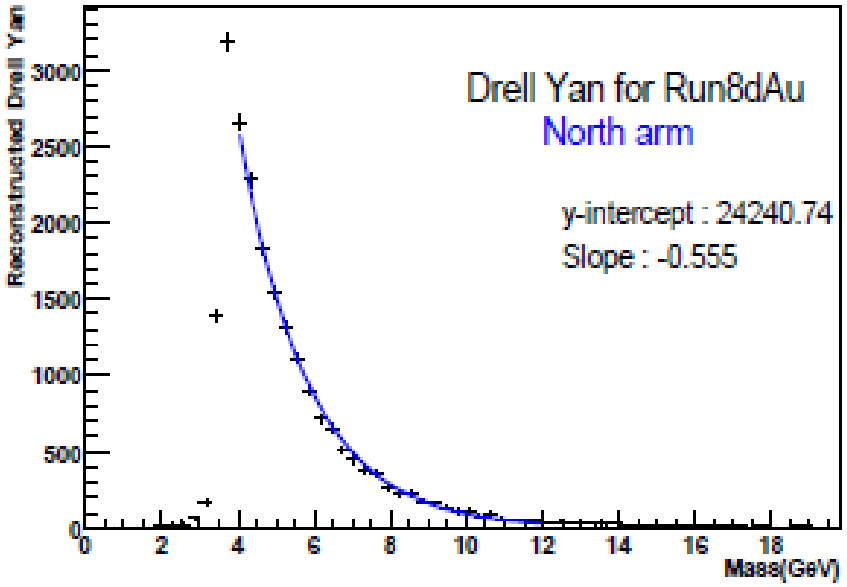
BACKUP

Drell Yan

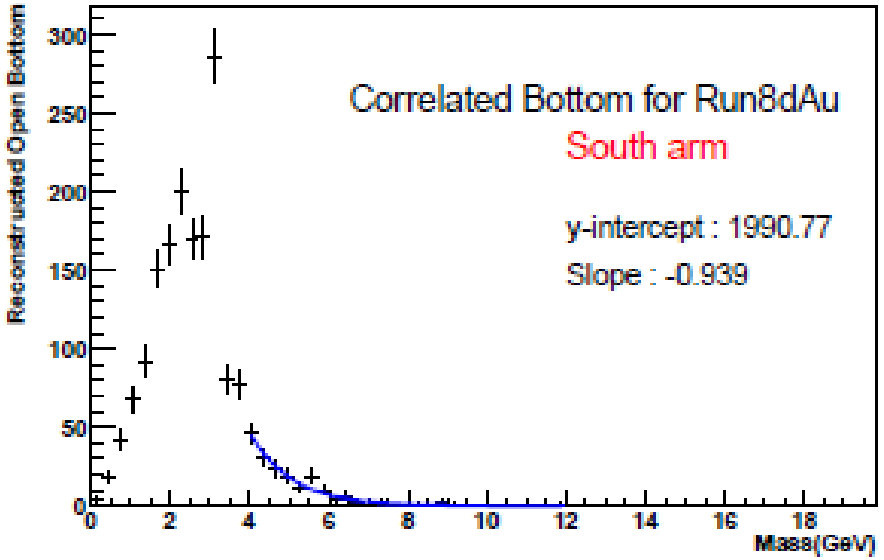


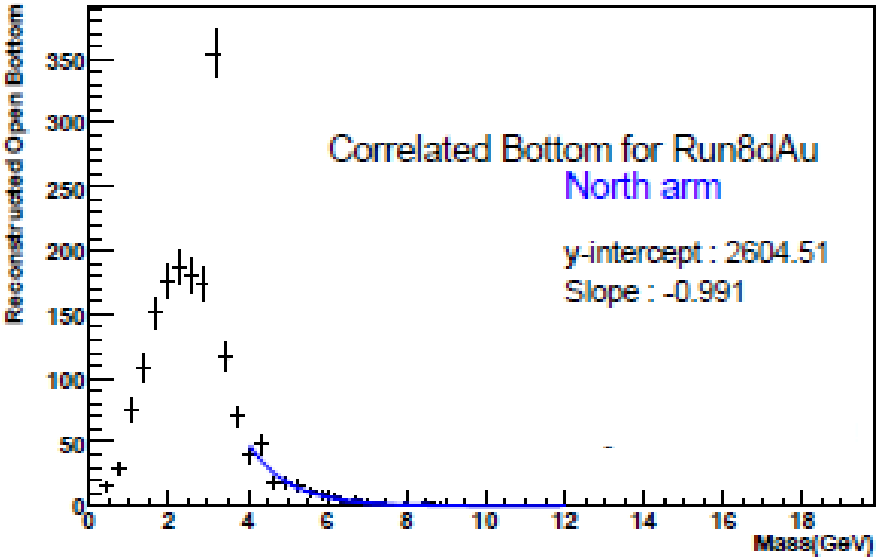
Parameters	Index	Setting	Meaning
msel		11	Single W/Z production
ckin	1	3.5	set minimum mass value as 3.5 GeV
parp parp	91 31	1.5 1.1	set k_T value = 1.5 set k factor = 1.1
mstp mstp mstp	32 33 51	4 1 7	set Q_2 scale = 4 use k factor select PDF of CTEQ5L



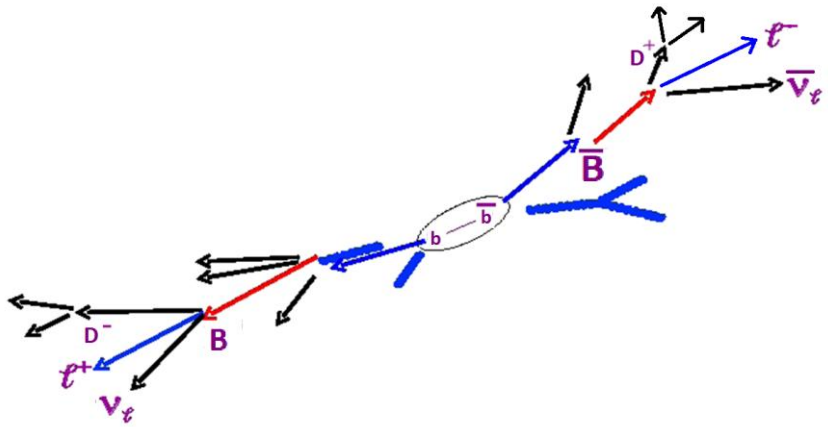


Open Bottom

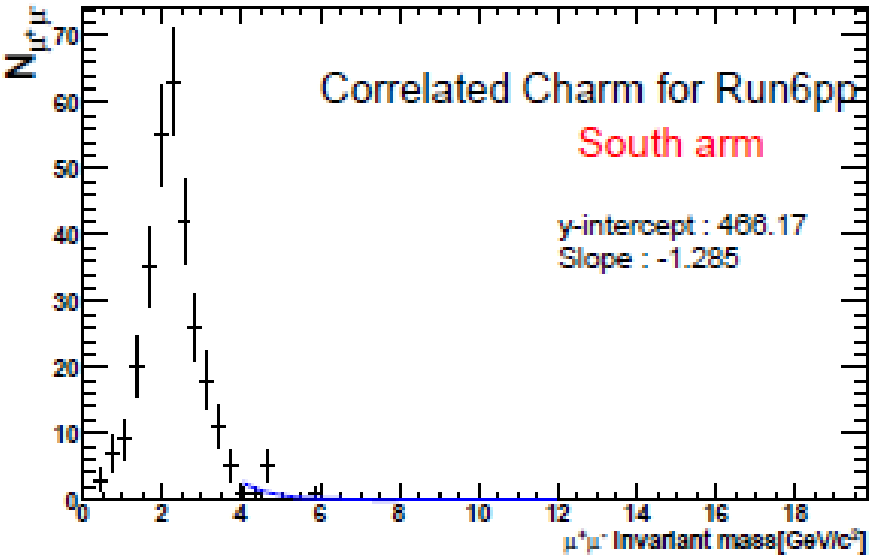


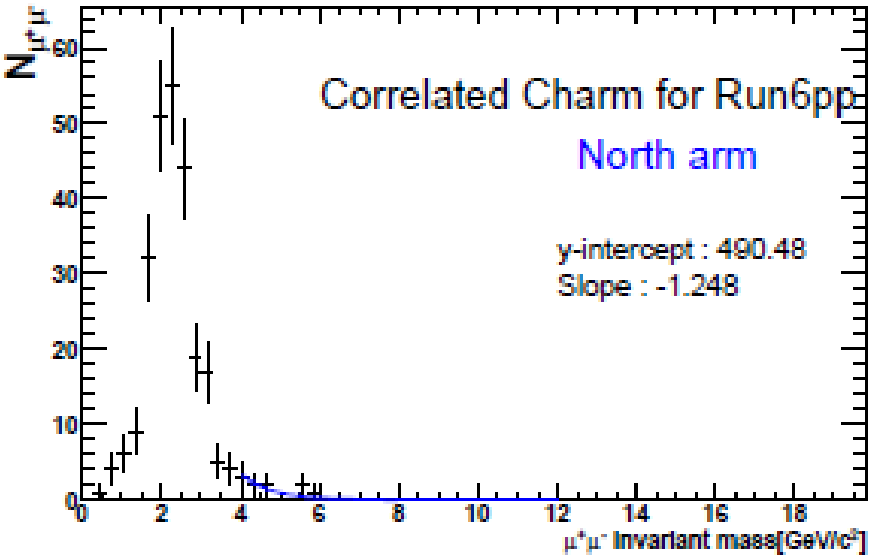


Parameters	Index1	Index2	Setting	Meaning
msel			5	turn on bottom production of heavy flavor.
pmas	5	1	4.1	make bottom quark mass as 4.1 GeV
parp	91		1.5	set k_T value = 1.5
parp	31		3.4	set k factor = 3.4
mstp	32		4	set Q_2 scale = 4
mstp	33		1	use k factor
mstp	51		7	select PDF of CTEQ5L



Open Charm





PHPYTHIA Settings

msel 4 (turns on charm production)

pmas 4 1 1.25 (sets charm quark mass to 1.25 GeV)