J/ψ from dAu (nuclear effects)

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Santa Fe Muon Fest

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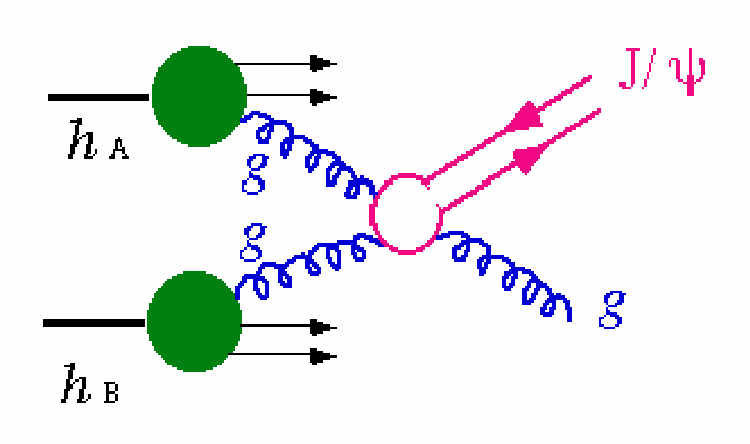
* David Silvermyr enjoying the soccer cup in Europe

Physics motivations for dAu

1. Get the reference for Au+Au collisions (and QGP)
2. Disentangle various " cold " nuclear effects
   - In nuclei modification of parton distribution functions
     - Antishadowing & Shadowing (gluon saturation ? Color Glass Cond ?)
   - Energy loss of initial partons
     - Can kill the J/ψ !
   - Multiple scattering of initial partons
     - p_T broadening (Cronin effect)
   - J/ψ absorption
     - Or other final state effects ?...

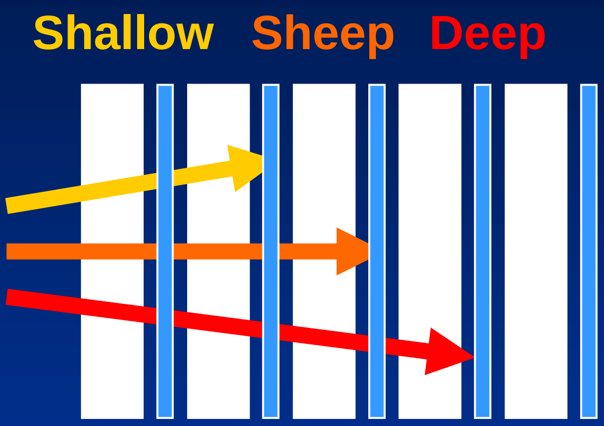


- The tools :
  - Look over broad ranges of p_T, rapidity, centrality...

Outline

1. Some technicalities about our dAu run
2. Quark Matter 2004 reminder
   - The preliminary result
3. A word about interpretations
4. Expectation for Au-Au
5. Progress towards the final result
   - A kind of report from the PPG038

1. Our dAu run (online)



- Luminosity : 2.74 nb^{-1}
- Trigger : LVL1 trigger with
  - ~ Half with 1Deep 1Shallow

    (eq. to 1.57 south and 1.71 north MinBias Gevents)
  - ~ Half with 2Deeps

    (eq. to 1.18 south and 1.55 north MinBias Gevents)

  (recabling of LVL1 trigger wrt run 2 : deep means 4th gap* – back to nominal for run 4)

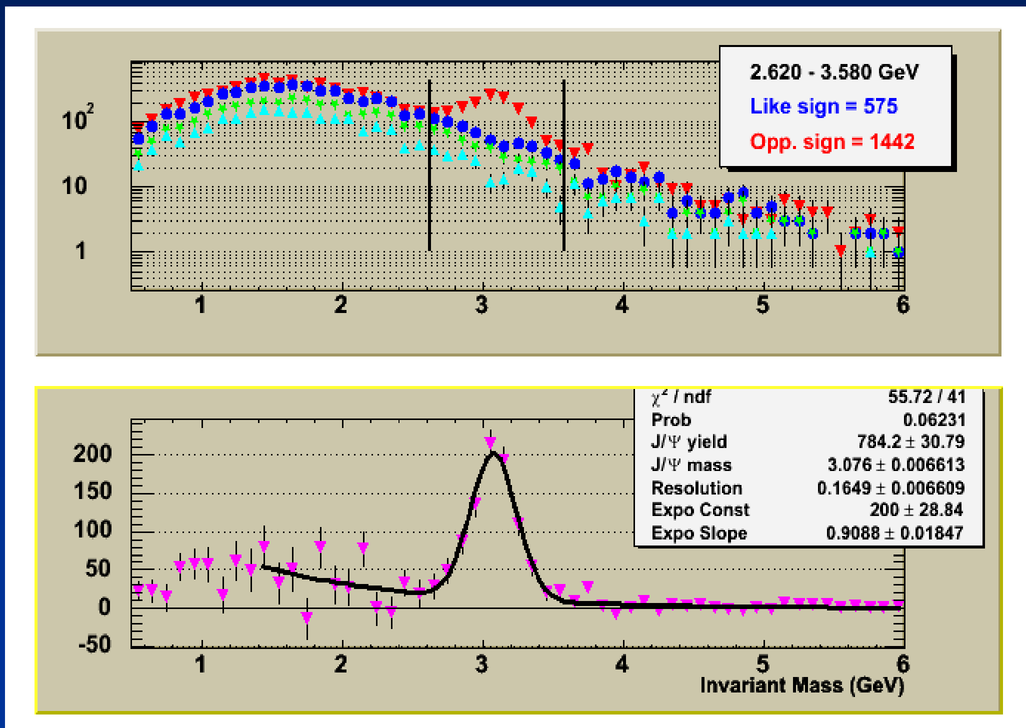
* Starting to count at 1

Our dAu run (offline)

- Reconstruction code first looked for muon reaching the 3rd gap* (thus missing some triggered 1D1S events)
  - So is pro43 (CCF) thus the QM04 result
  - So was the later "official" pro45 (RCF)
  - (MUTOO was running successfully without MuId matching allowing to notice this "mistake")
  - Fixed for pro48 (dAu) and pro50 (pp) CCF production (being used for final result)

* Starting to count at 1

2. QM04 reminders

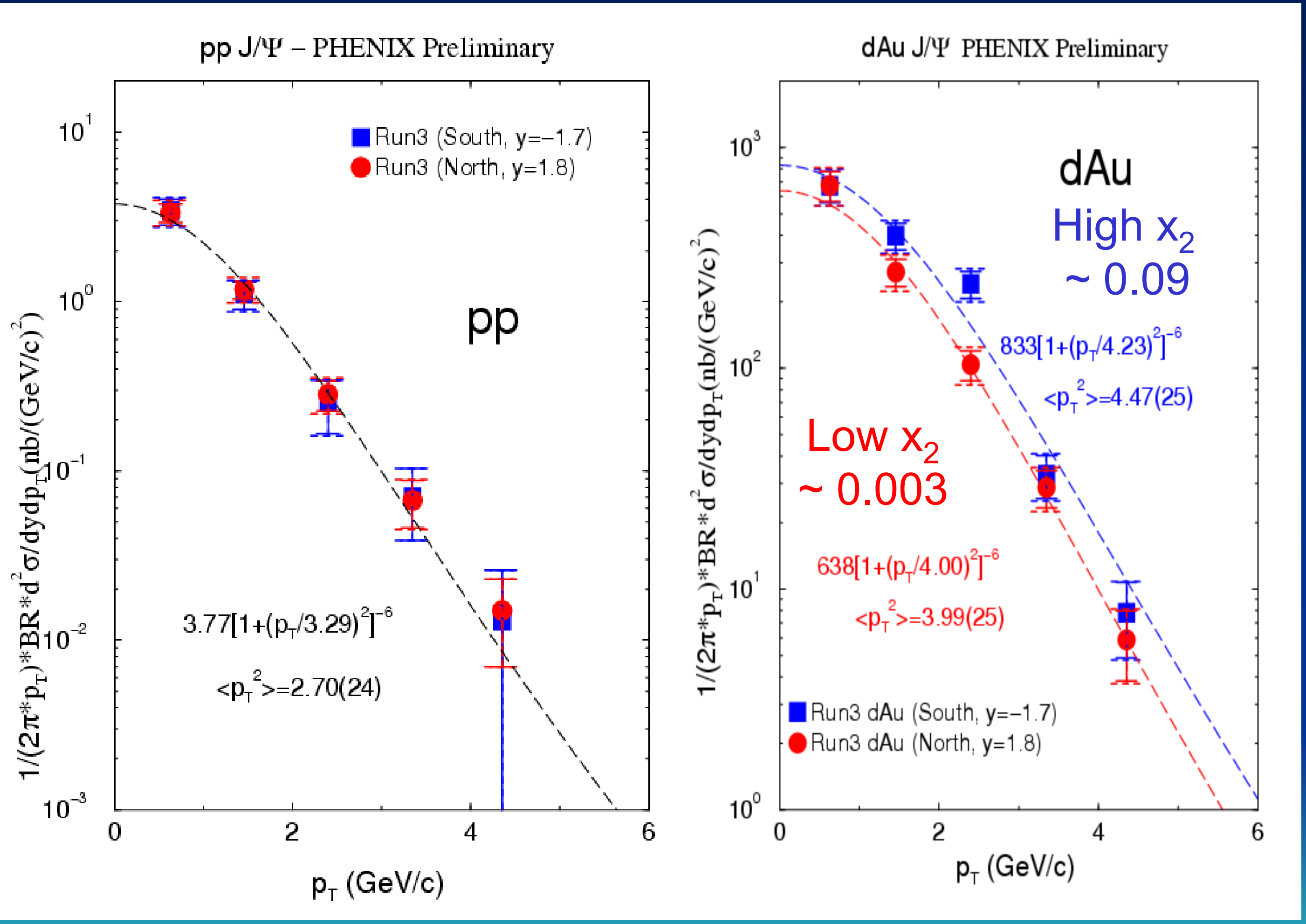


μμ analysis done on
600 + 800 J/ψ from dAu
120 + 300 J/ψ from pp
(south + north)

ee analysis done on
300 J/ψ from dAu
100 J/ψ from pp

See the analysis note 255 for $\mu^+\mu^-$
See the analysis note 258 for e^+e^-
QM04 proceedings nucl-ex/0403030

p_T broadening in dAu



$\Delta\langle p_T^2\rangle =$

$\langle p_T^2\rangle_{dAu} - \langle p_T^2\rangle_{pp}$

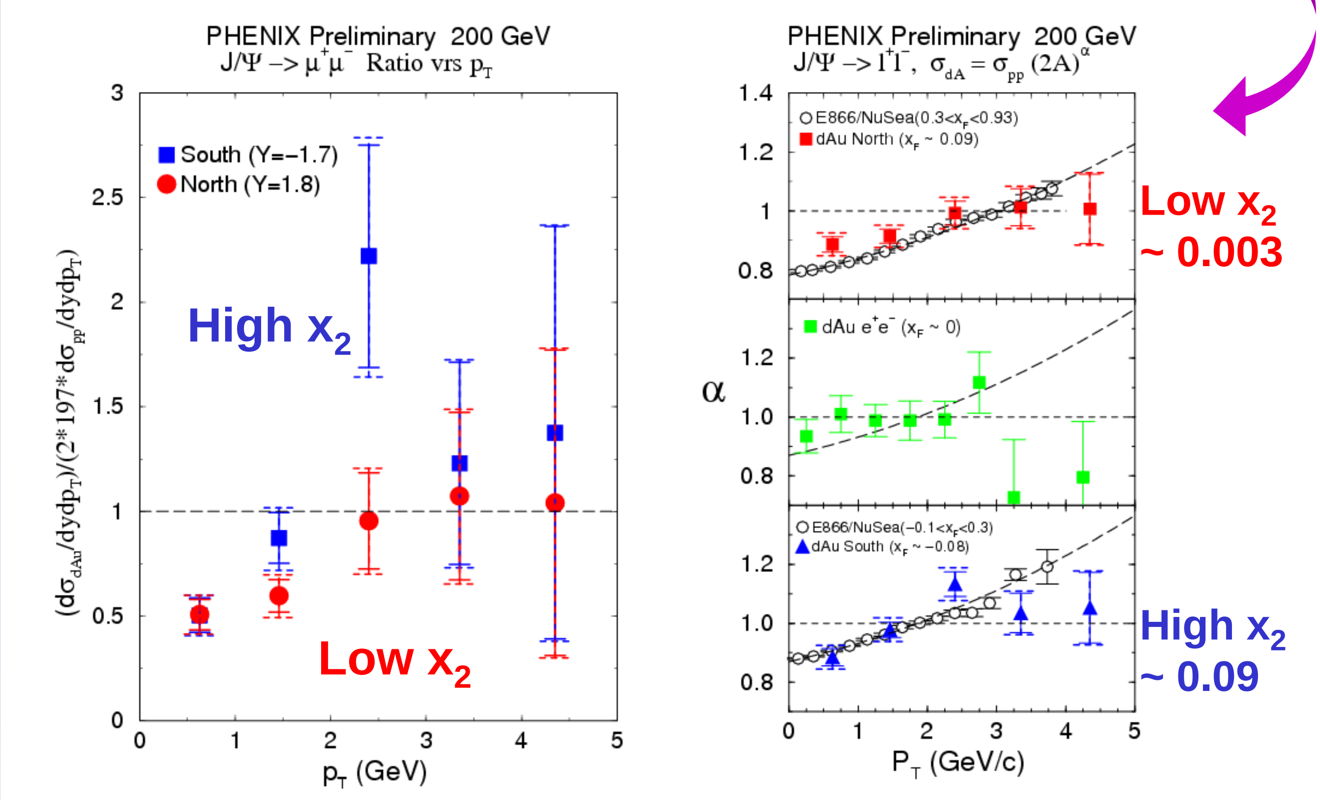
$1.77 \pm 0.35\ GeV^2$

$1.29 \pm 0.35\ GeV^2$

(preliminary)

dAu/pp versus p_T

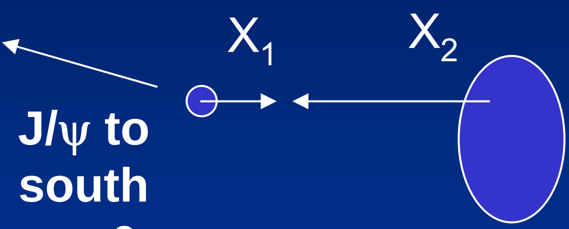
$$R_{dA} = \sigma_{dA} / 2 \times 197 \times \sigma_{pp} \qquad \sigma_{dA} = \sigma_{pp} (2 \times 197)^{\alpha}$$



"broadening" comparable to lower energies ($\sqrt{s}$ = 39 GeV in E866)

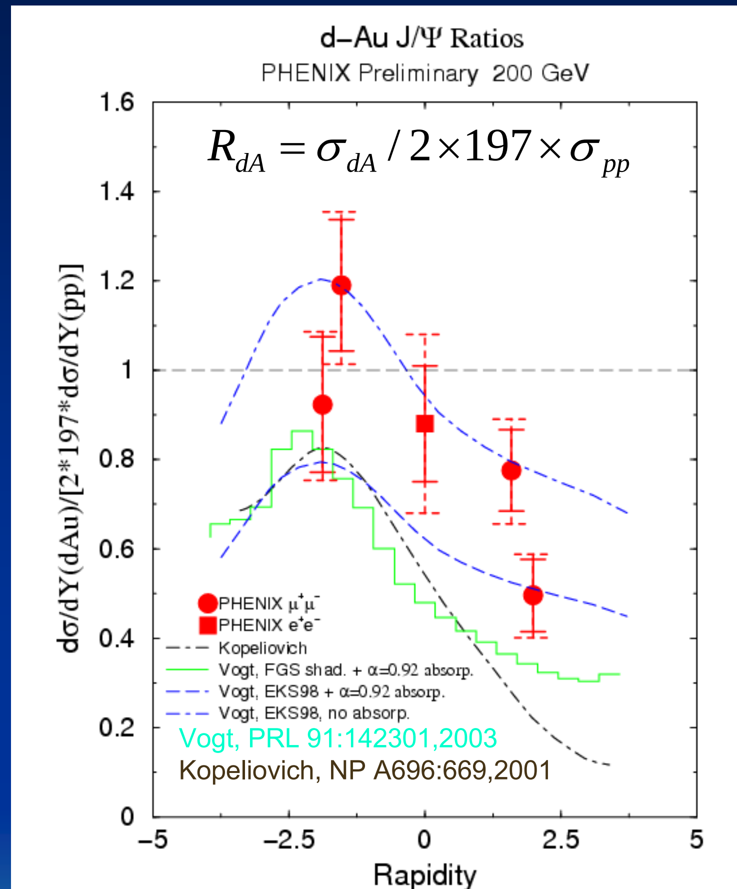
dAu/pp vs rapidity

Backward

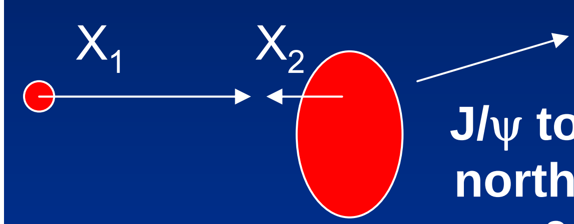


J/ψ to south y < 0

High X_2 ~ 0.09
Antishadowing expected



Forward



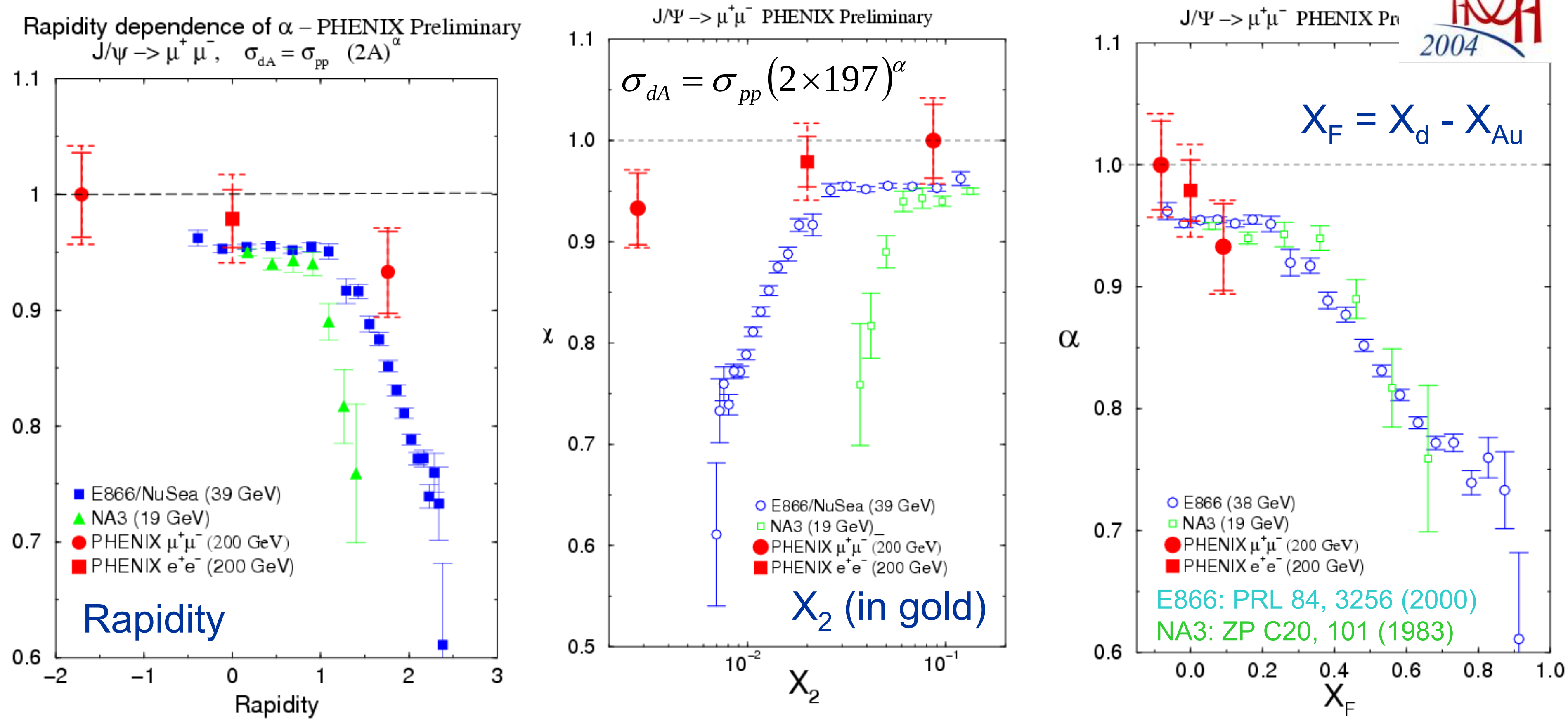
J/ψ to north y > 0

Low X_2 ~ 0.003
Shadowing expected

Data favour (some) shadowing + (weak) absorption (α > 0.92)

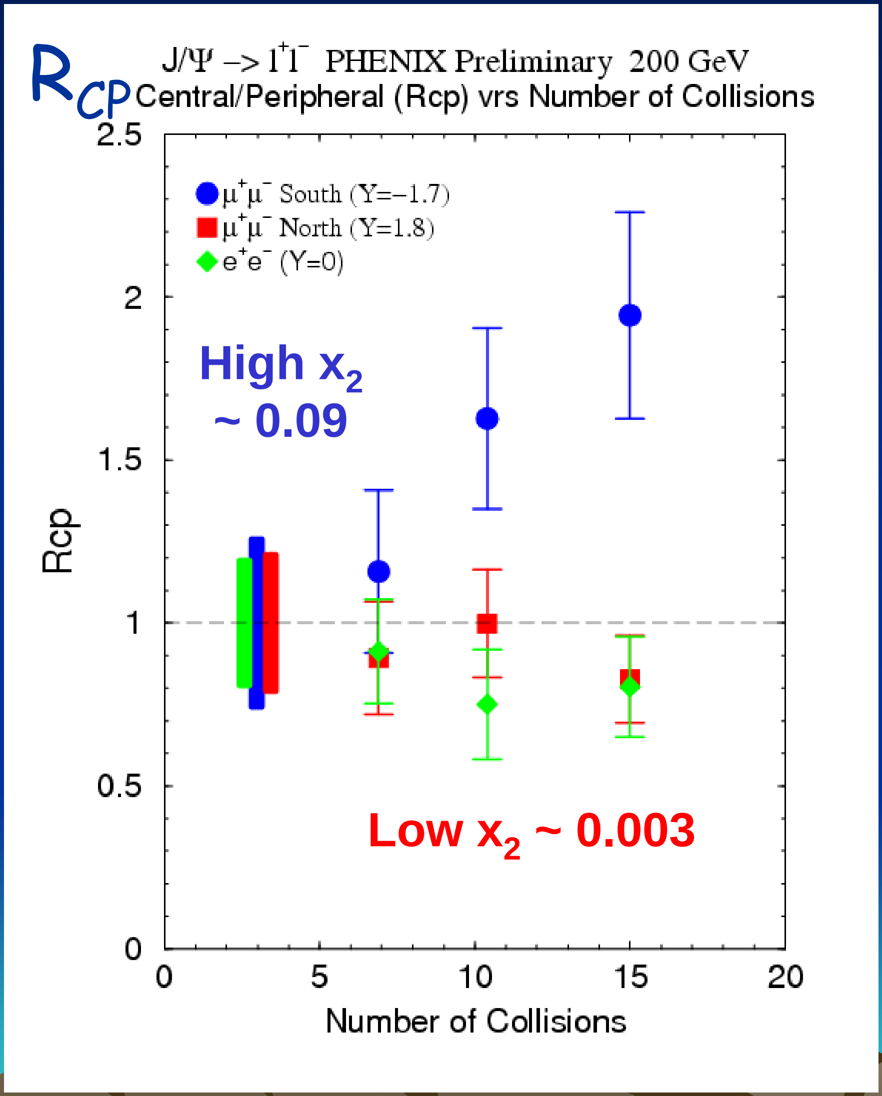
With limited statistics difficult to disentangle nuclear effects

α compared to lower $\sqrt{s}$



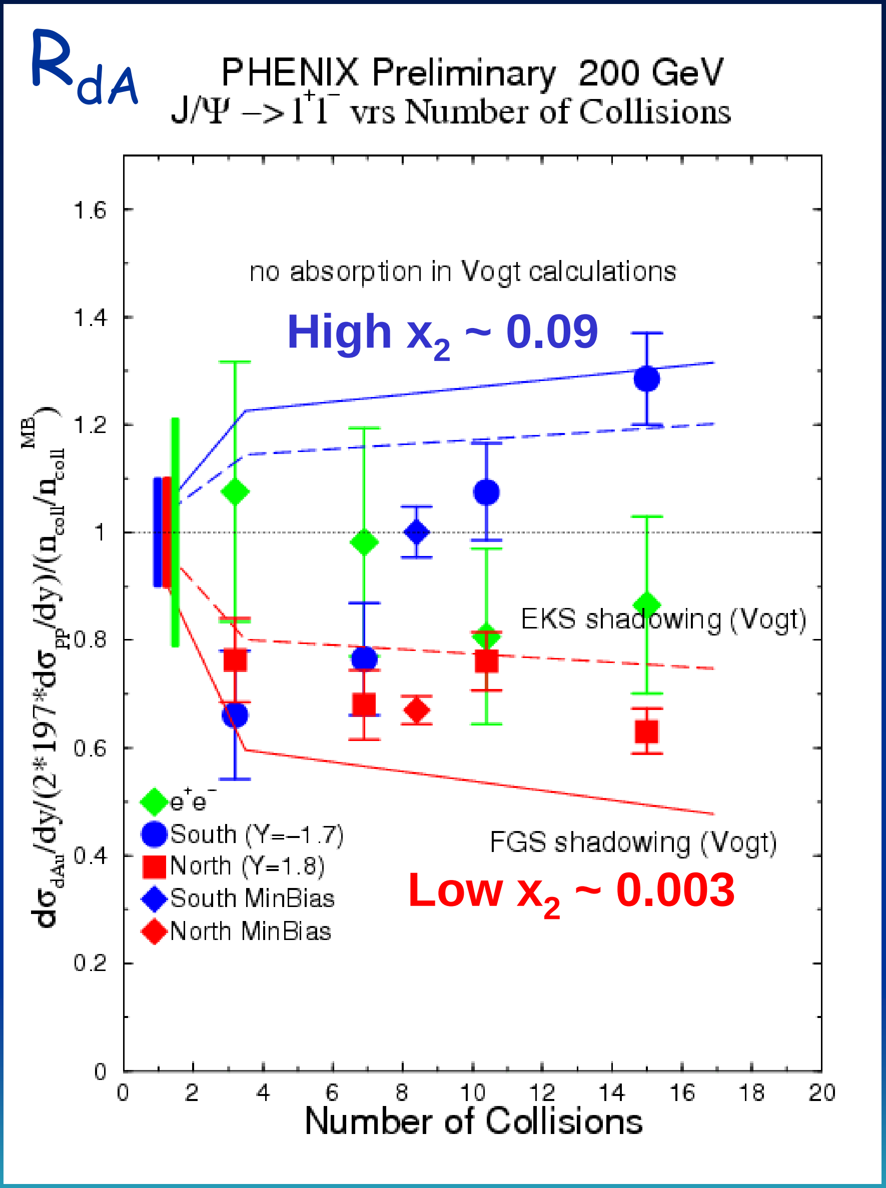
- Not universal versus X_2 : shadowing is not the whole story (at low $\sqrt{s}$)
- Same versus X_F for diff $\sqrt{s}$. Incident parton energy loss ? (high X_d = high X_F)
- Energy loss expected to be weak at RHIC energy.

Central/peripheral vs N_{coll}



$$R_{cp}(N_{coll}) = \frac{N_{J\psi}^{cent} \times < N_{coll}^{perif} >}{N_{J\psi}^{perif} \times < N_{coll}^{cent} >}$$

- Low variations at low et mid x_2 :
  - Weak net nuclear effects
  - Small shadowing centrality dependence…
- At High x_2 surprising steep rising shape with centrality !
  - Can antishadowing be that violent ?



dAu / pp vs N_{coll}

$$R = \frac{\sigma_{dA} \times < N_{coll}^{MB} >}{2 \times 197 \times \sigma_{pp} \times < N_{coll} >}$$

- Low x_2 consistant with inhomogeneous shadowing…
- High x_2 steeper than corresponding antishadowing !
  - What can it be ?
  - Something about being closer to the gold rest frame ?
  - No clear understanding yet…
    - Theorists at work…

3. A word about interpretations

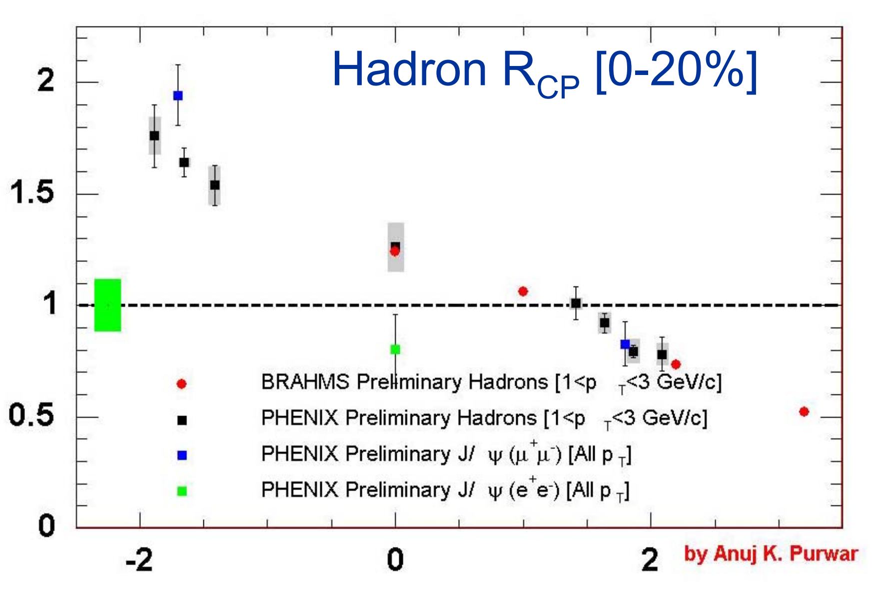
- The steep rising shape makes the J/ψ look like lighter hadrons… No fundamental reasons for that…
  - Different processes (gluon fusion for J/ψ, still q+g for hadrons)
  - Different pT ranges ! (J/ψ = all p_T)
  - Hard versus soft ??? (create the J/ψ mass first)

- Open charm could help !
  - No J/ψ effects…
- See tomorrow's talks !

(Ming, Chun, Ken, Kazuya…)

- Some theorists at work

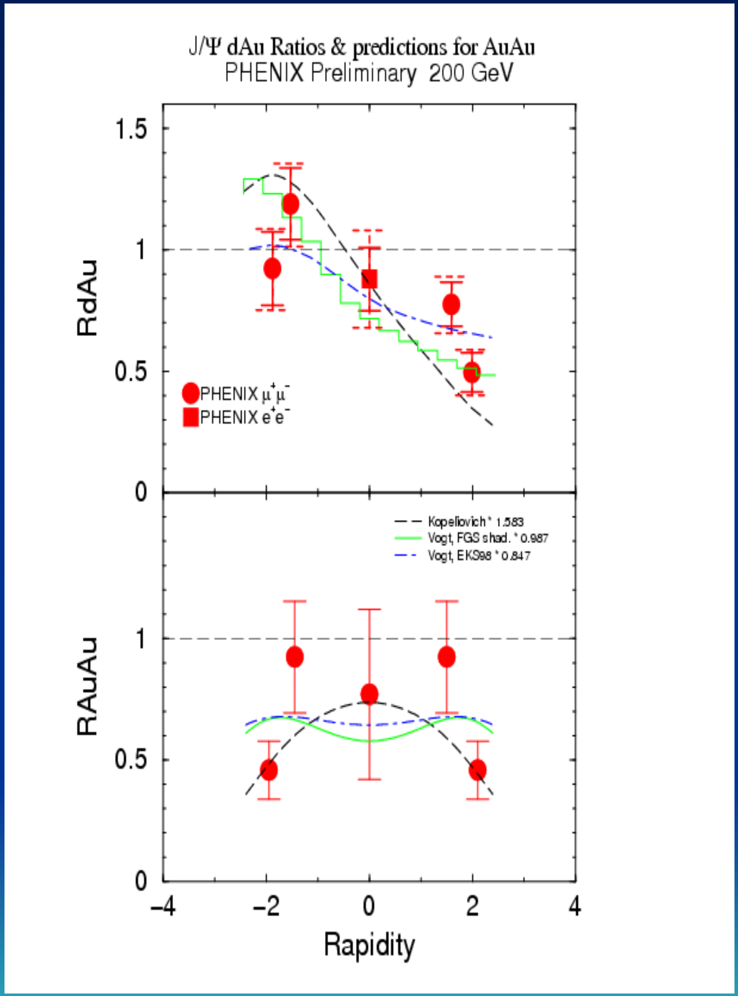
(Kharzeev & Tuchin, Kopeliovich, Thews…) not published yet



4. Expectation for Au-Au

- backward x forward rapidity
  - With data points
  - With arbitrary scaled theoretical curves
- As much as a factor of 2 suppression due to… shadowing ?

(for Hugo's talk today, for MinJung, ViNham and ? theses tomorrow)



5. Progress towards final results

- PPG038 is formed
- Title : " *J/Psi Production and Nuclear Effects for d+Au and p+p Collisions at RHIC* "
- Intended : Physical Review Letters
- Chair : Mike Leitch
- Members : Yasuyuki Akiba, Jane Burward-Hoy, Raphael Granier de Cassagnac, Soichiro Kametani, DongJo Kim, Sasha Lebedev, David Silvermyr, Wei Xie.

\+ other contributors working as well…

Dominant μμ uncertainties

Systematic error	pp South	pp North	dAu South	dAu North	Ratio South	Ratio North
Fitting	±7.1%	±4.7%	±10.3%	±11.9%	±3.7%	±2.8%
Ghosts	−1.5%	−1.5%	−1.5%	−1.5%	−1.5%	−1.5%
Combinatorial Background	±5%	±5%	±5%	±5%	±5%	±5%
Point-to-point	+8.7% −8.8%	+6.9% −7.0%	+11.4% −11.5%	+12.9% −13.0%	+6.4% −6.4%	+5.9% −5.9%
MuID Tube Efficiency	+6 − 9%	+6 − 9%	+6 − 9%	+6 − 9%	+3 − 6%	+3 − 6%
MuTr Chamber Efficiency	+6.5%	+9.5%	+6.5%	+9.5%	+3.3%	+4.8%
MuTr Attenuated Strips	0.0%	±5%	0.0%	±5%	0.0%	±5%
Event Mixing Error	±3%	±3%	±3%	±3%	±3%	±3%
MuTr HV state	±3%	±3%	±3%	±3%	±3%	±3%
Arm-to-Arm	+9.8% −9.9%	+13.0% −11.1%	+9.8% −9.9%	+13.0% −11.1%	+6.2% −8.1%	+8.7% −10.1%
MuTr MC Represent.	±5%	±5%	±5%	±5%	0.0%	0.0%
Rapidity Distr.	±3%	±3%	±3%	±3%	0.0%	0.0%
Global	+5.8% −5.8%	+5.8% −5.8%	+5.8% −5.8%	+5.8% −5.8%	0.0% 0.0%	0.0% 0.0%
SUM	+14.3% −14.5%	+15.8% −14.4%	+16.2% −16.3%	+19.2% −18.1%	+8.9% −10.3%	+10.5% −11.7%

Table 19: Summary of systematic errors. All errors listed are fractional errors in %. Top box are for errors to be applied independently to each point. In the middle box, are errors which depend on the arm we consider but should be the same for all points within this arm. The bottom box is for errors that are independent of any selection.

(from AN255)

Typical statistical errors are (splitting in 2 rapidity bins)
~ 7% from dAu
~ 13% from pp
(merged S+N)

Should improve !
- Higher efficiency with shallower roadfinding
- Better under-standing of MuTr efficiencies (Xiaorong's work)

Where are we trying to gain ?

- Need more pp statistics !
  - (for RdA, pp yields and cross sections…)
  - What can we hope from run 4 ?
- Need more dAu statistics !
  - (mostly for Rcp)
- Need to work on background subtraction !
  - Combinatorial background (reduce stat. error)
  - Physical background (for dAu yields, Rcp…)
- Detector inefficiencies knowledge may stay as the dominant systematics…

Getting more (shallower) muons

- More J/ψ but more comb. background
- Is it worth it ?
- Look at the signal/background ratio

or rough estimate of error :

$$\%ERR = \frac{\sqrt{N_{+-} + N_{++} + N_{--}}}{N_{+-} - (N_{++} + N_{--})}$$

	pro43		pro48/50		Trend
	Signal	%ERR	Signal	%ERR	
dAuN2D	371	7.4%	402	7.4%	stable
dAuNDS	496	7.2%	568	8.0%	worse
dAuS2D	169	17.3%	255	15.7%	better
dAuSDS	417	10.7%	489	14.8%	worse
ppN	302	7.1%	356	7.2%	stable
ppS	119	11.2%	169	11.1%	stable

Staying with QM04 "standard cuts"

Adding cuts to optimize S/B

Signal Gain	pro43		pro48/50		Cuts
	Signal	%ERR	Signal	%ERR	
dAuN2D	371	7.4%	402	7.4%	std
1.05	361	7.4%	404	6.9%	std & 2D
			390	7.0%	std & 2D & DG0 &DS3ctp
dAuNDS	496	7.2%	568	8.0%	std
1.15	494	7.2%	588	7.0%	std & DS
			572	6.8%	std & DS & DG0 &DS3ctp
dAuS2D	169	17.3%	255	15.7%	std
1.34	173	15.8%	240	13.9%	std & 2D
			226	13.0%	std & 2D & DG0 &DS3ctp
dAuSDS	417	10.7%	489	14.8%	std
1.20	415	10.7%	543	12.1%	std & DS
			501	10.9%	std & DS & DG0 &DS3ctp
ppN	302	7.1%	356	7.2%	std
1.10	301	7.1%	344	6.9%	std & DS
			333	6.9%	std & DS & DG0 &DS3ctp
ppS	119	11.2%	169	11.1%	std
1.37	119	11.2%	167	10.6%	std & DS
			163	10.1%	std & DS & DG0 &DS3ctp

New cuts to get better S/B

For instance :

- Mimic offline the trigger condition (1D1S or 2D)
- DG0 maximum
  - 15 for north arm
  - 30 for south arm
- DS3ctp maximum
  - 15 for north arm
  - 25 for south arm

(study done by Ermias Tujuba an undergrad student at LLR)

→ It is decided to work with the shallower roads. Cuts may be further defined.

A useless statistical error…

- Part of our error is due to comb. bg. through :
  $\#J/\psi = (+-) - 2\sqrt{(++)(--)}$
- Carries a statistical error
- Using rough formula and

previous cuts, we can hope :

sample	S/B	~ error (incl bg)	~ error (no bg)
dAuN2D	2,23	7,0%	6,1%
dAUNDS	1,20	6,8%	5,7%
dAuS2D	0,71	13,0%	10,3%
dAuSDS	0,40	10,9%	8,4%
ppN	3,33	6,9%	6,2%
ppS	3,02	10,1%	9,0%

- And thus hope a gain a bit everywhere
  - (yields, RdA, Rcp)

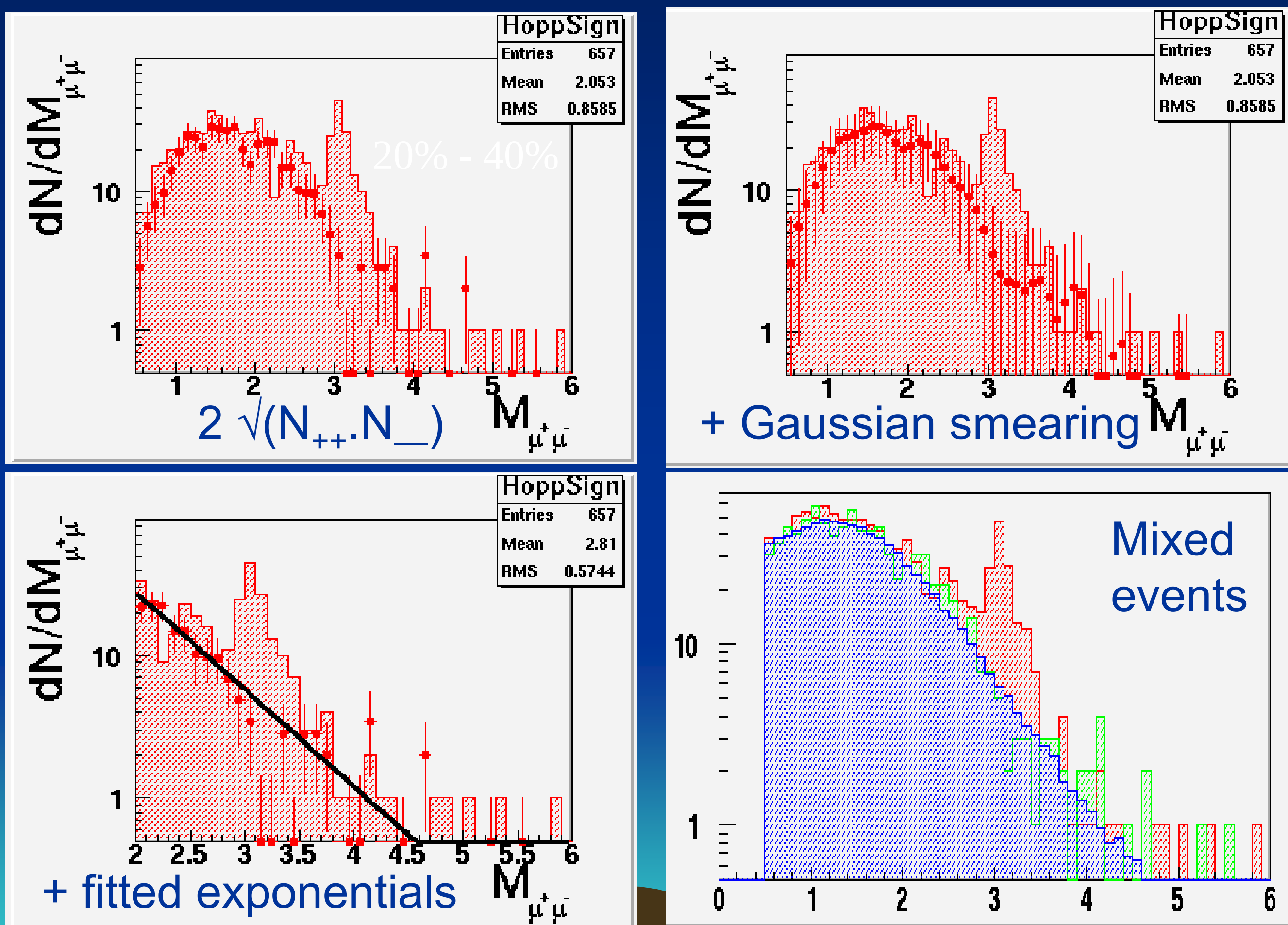
To get rid of the comb. errors

Various ideas (from the easier to the tougher)

1. Redistribute the bg events of a bin in the nearby bins (acc. to gaussian) (Mike)
   - Reduce fluctuations but shouldn't change errors
2. Fit the (++) and (--) (Fred/Ermias)
   - Reduce fluctuations and errors
   - Difficult to fit small samples (high p_T)
3. Mixing events ! (Fred)
   - Should <u>eradicate</u> errors and fluctuations

As an example of the progress…

The 4 methods on one centrality bin of the dAu north 2 deeps sample.



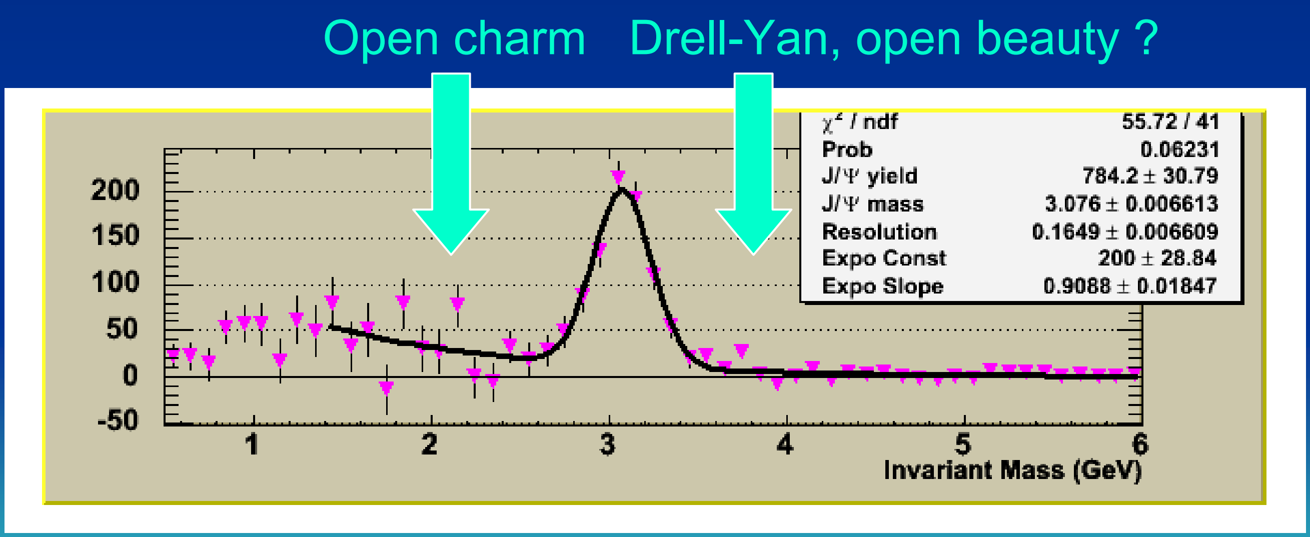
Remarks :

- 1 and 2 can be used together…
- What are the systematics assoc. to each methods ?
- Will be probably interesting for AuAu too…

(thanks to Fred and Andry, his PhD student)

Need to work on physical bg too

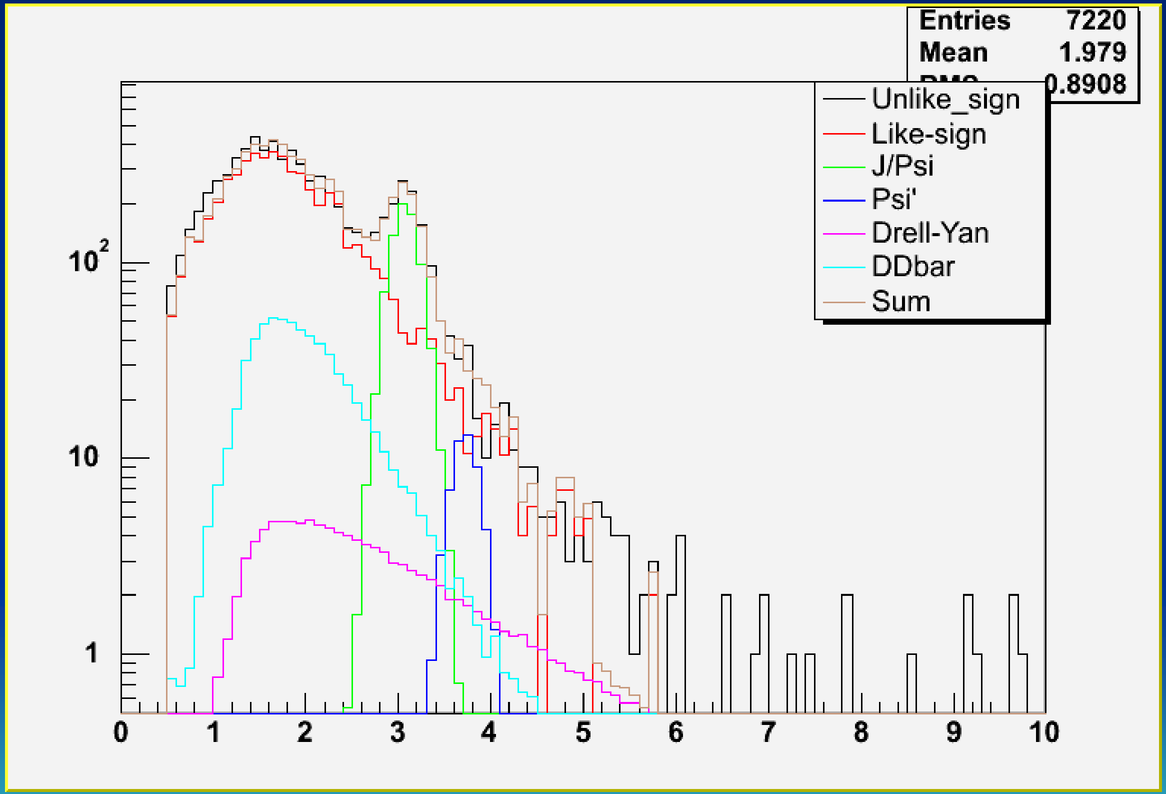
- Syst error = allow any value between no background (exp) and twice the measured background with (exp+gauss)
- Check that various shapes give consistent results…
- Can we assume a smaller uncertainty ?
- Need more knowledge about open charm and DY…



See Sebastien's this afternoon

Need to work on physical bg

- Maybe, one day, we'll be able to use this kind of fit…
- (with a low systematic error associated)

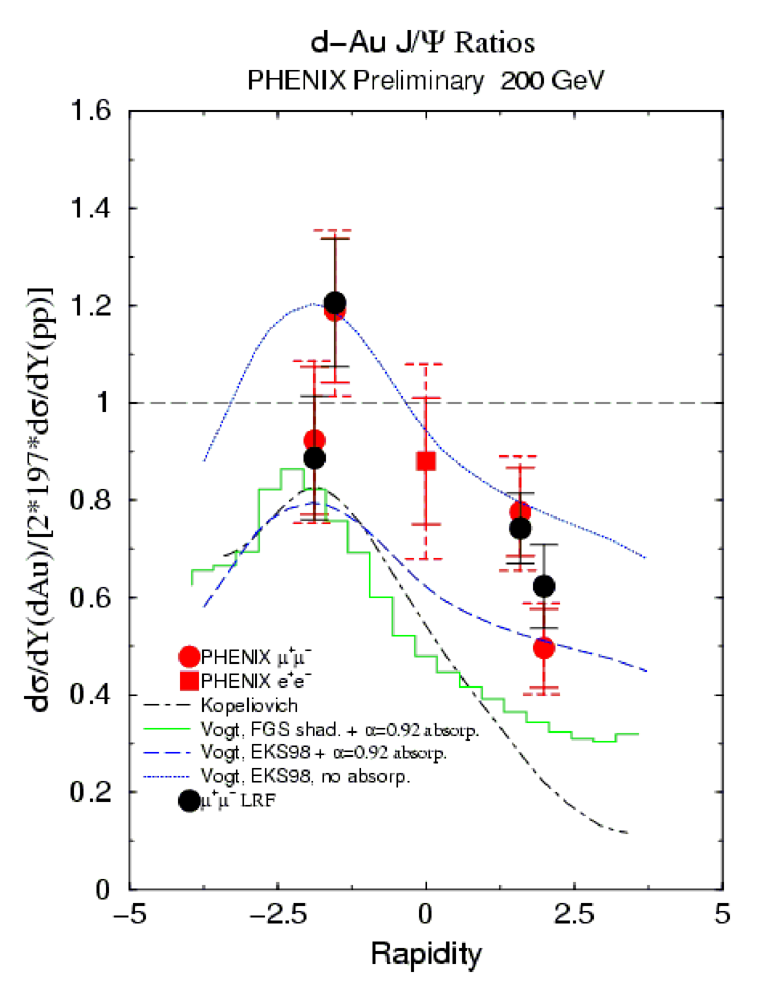


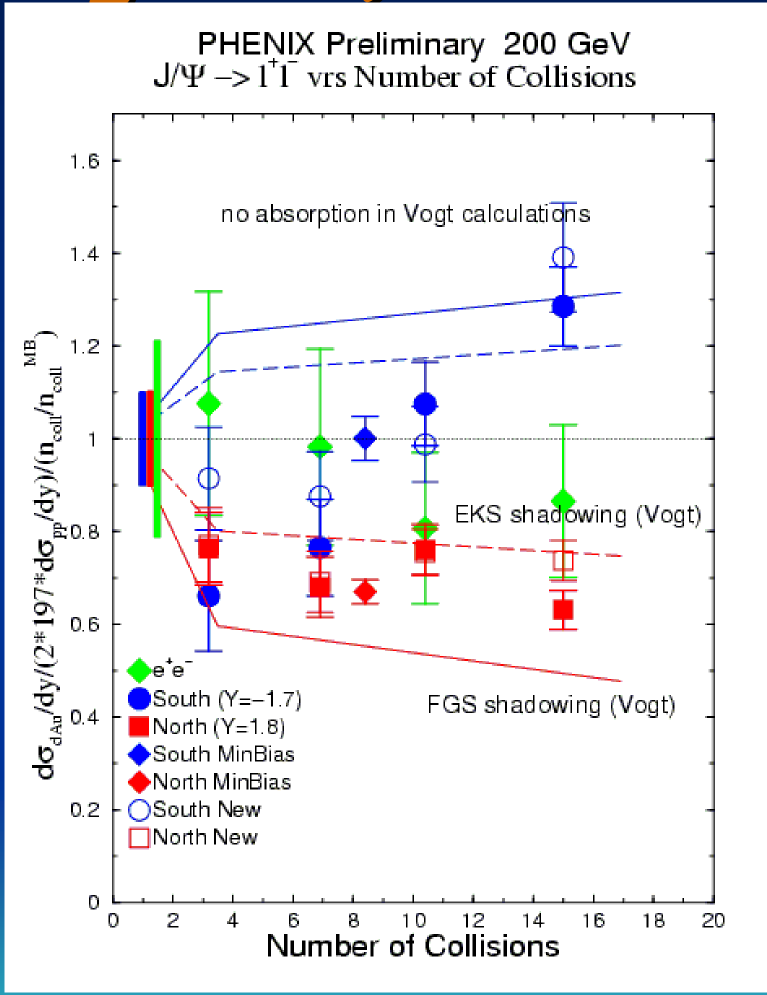
To be done…

- More doubling of the analysis wrt QM04
  - Mike + DongJo's efficiencies
  - Raphael & Ermias efficiencies
  - Cuts, background techniques may vary between us for crosscheck.

- We're a bit late… Finalization should occur during July…

Insight on new plots (work in progress)





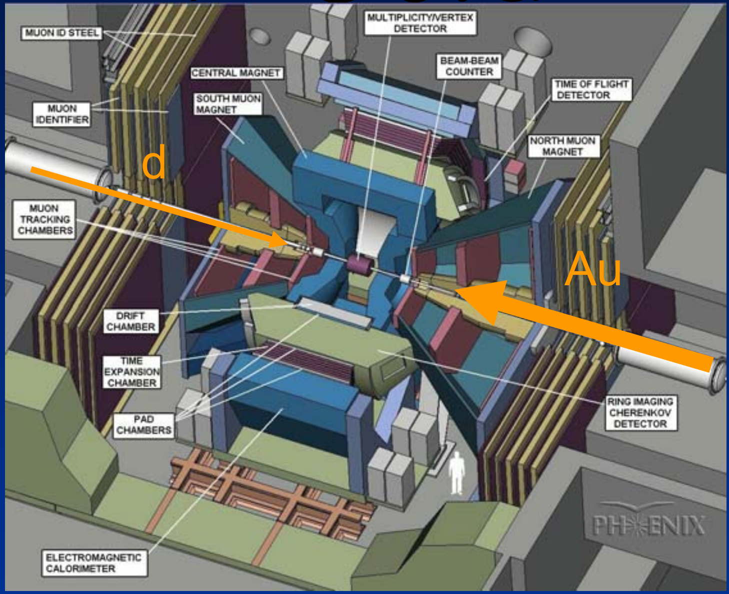
Conclusions

- We have seen (small) nuclear effects !
  - Some shadowing
  - Smaller absorption than expected (α > 0.92)
  - p_T broadening similar to lower energies
  - Something above antishadowing ?
    - Rising RdA versus centrality at high x_2 ($y < -1.2$)
- Reanalysis is in progress… More news in July
  - Hope for a slightly lower uncertainties
- Still difficult to disentangle the effects
- The relevance do Au-Au comparison will depend on the magnitude of Au-Au effect !
  - We still need more luminosity !

Back up slides

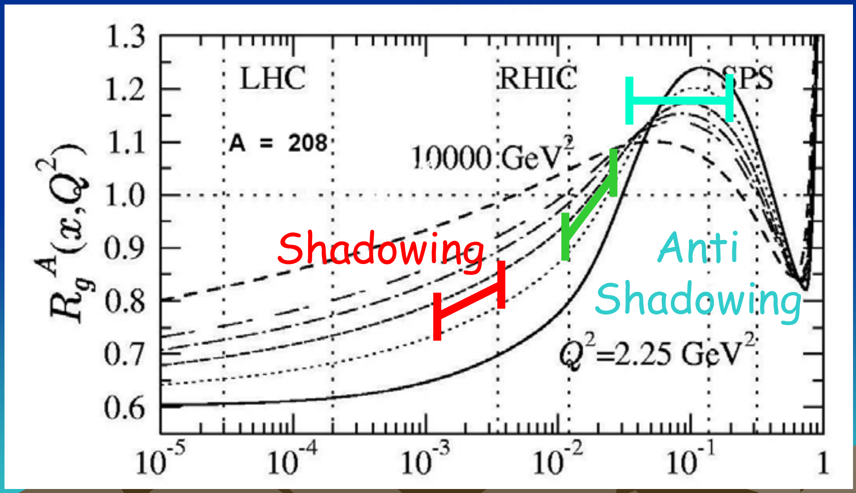
Deuteron → ← Gold

- In PHENIX, J/ψ mostly produced by gluon fusion, and thus sensitive to gluon pdf.
- Three rapidity ranges probe different momentum fraction of Au partons.
  - South ($y < -1.2$) : large X_2 (in gold) ~ 0.090
  - Central ($y \sim 0$) : intermediate X_2 ~ 0.020
  - North ($y > 1.2$) : small X_2 (in gold) ~ 0.003



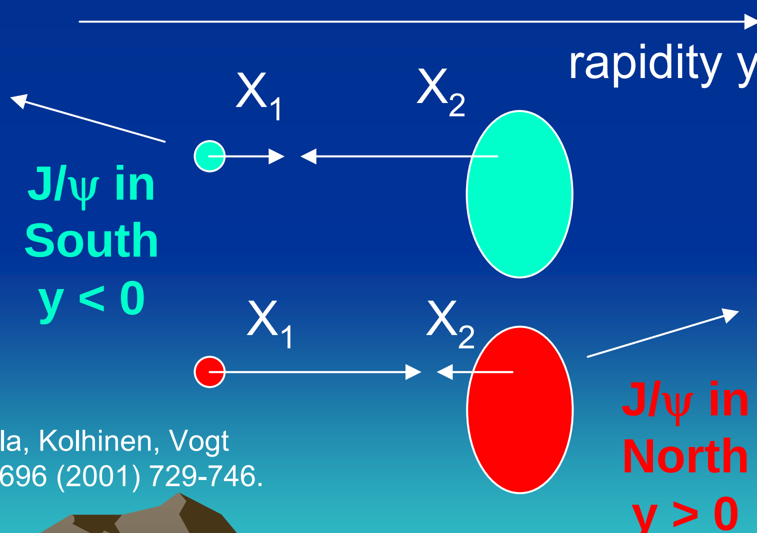
Example of predicted gluon shadowing in d+Au

gluons in Pb / gluons in p

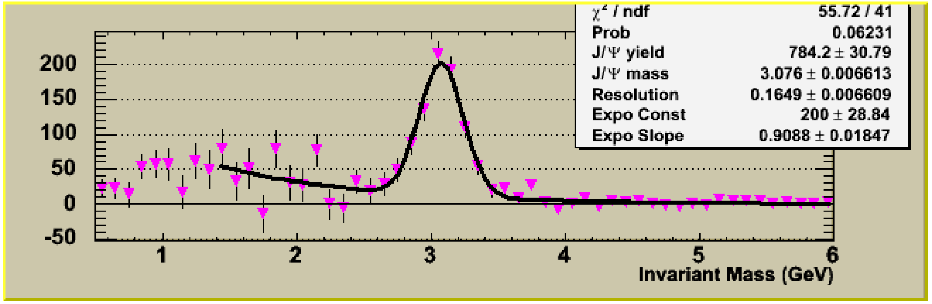


X

From Eskola, Kolhinen, Vogt Nucl. Phys. A696 (2001) 729-746.

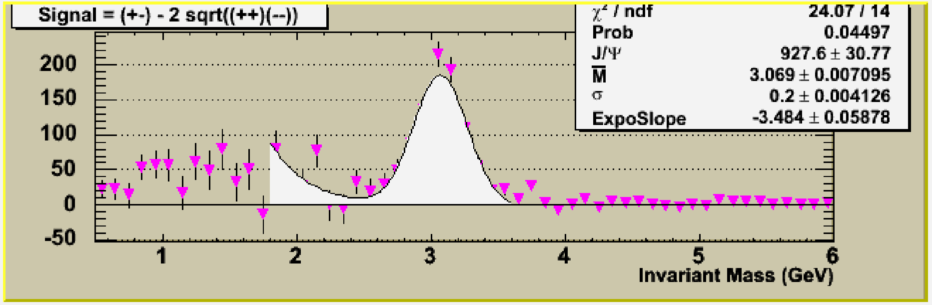


Systematics due to physical bg

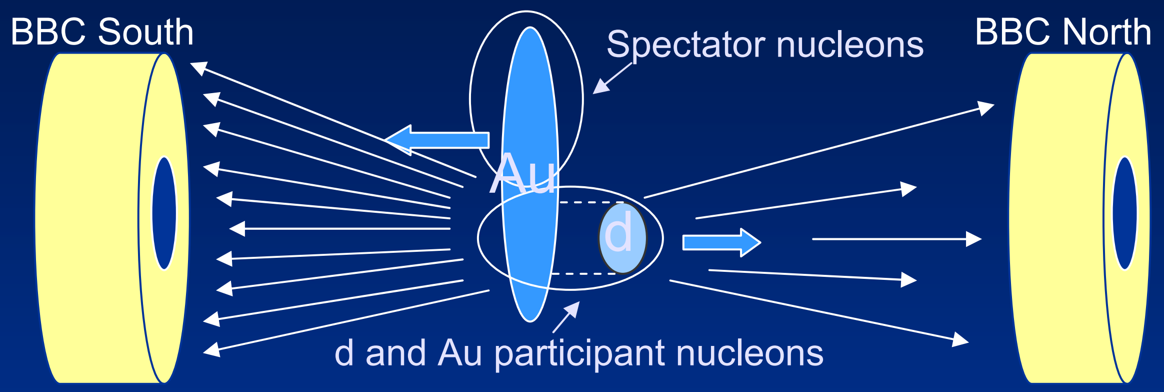


system	arm	1. e+g	2. e+g	3. q+g	4. e+2g	5. 2e+2g	6. gaus	7. e+g	error
dAu	N	784(32)	772(32)	742(31)	766(31)	828(32)	925(31)	928(31)	10.34%
dAu	S	578(27)	559(28)	522(27)	565(33)	553(27)	697(27)	710(27)	11.88%
pp	N	290(19)	270(19)	286(13)	292(19)	292(19)	326(18)	332(18)	7.12%
pp	S	118(12)	115(13)	109(13)	111(12)	111(12)	128(11)	132(12)	4.69%
dAu/pp	S	4.88	4.87	4.78	5.10	4.99	5.45	5.40	3.7%
dAu/pp	N	2.70	2.86	2.60	2.62	2.83	2.83	2.79	2.8%

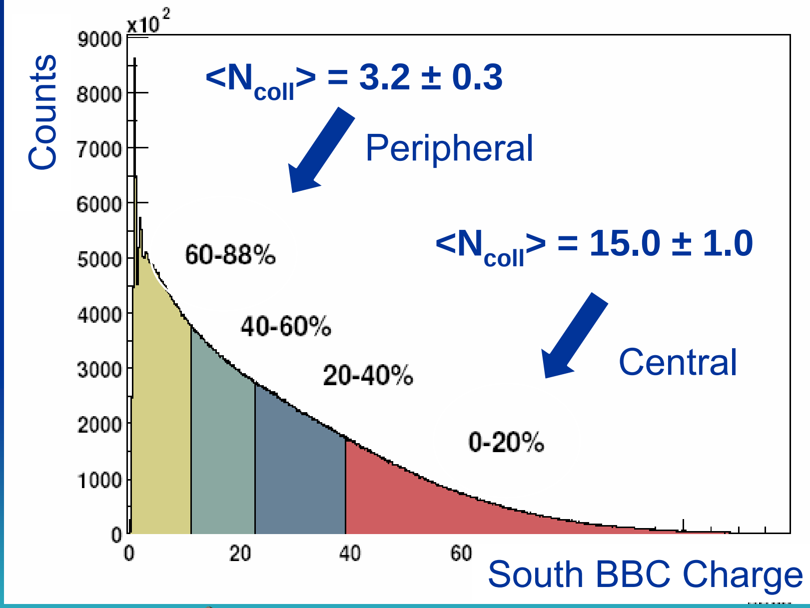
Table 11: Systematic uncertainties associated with the shapes and background descriptions used for fitting the mass spectra and extracting the J/ψ yields. The last column is the systematic errors derive from this comparison.



Centrality in d+Au



- Au breaks up in our south BBC
- Define 4 centrality classes
- Relate centrality to $\langle N_{coll} \rangle$ through Glauber calculations
- $\langle N_{coll}^{MB} \rangle = 8.4 \pm 0.7$



Number of MB events

Sample	In RC	In MWG	MWG/RC	BBC live	$\lvert z_{vtx}\rvert < 38$	N_{MB}
S2D	2 412 354	2 217 582	91.93%	1 335 801 768	$\sim$ 96.4%	1.184×10^9
S1D1S	31 820 276	27 886 566	87.64%	1 875 636 515	$\sim$ 94.5%	1.566×10^9
N2D	1 061 717	1 022 462	96.30%	1 701 932 446	$\sim$ 95.2%	1.553×10^9
N1D1S	3 051 636	2 847 592	93.31%	1 971 994 519	$\sim$ 94.7%	1.711×10^9
SPP	1 164 526	1 164 244	99.98%	4 639 768 393	$\sim$ 97.7%	4.531×10^9
NPP	4 062 648	4 057 461	99.87%	4 108 647 407	$\sim$ 98.0%	4.021×10^9

Table 9: Number of processed triggers found in the run control and in the nanodst. The number of corresponding minimum bias events N_{MB} is equal to the number of lived BBC triggers $\times$ the MWG/RC ratio $\times$ the fraction of these events passing our $|z_{vtx}| < 38$ vertex cut estimated on scaled recorded BBC triggers. This numbers were computed on a run by run basis and sum up to the number in the last column.