Fixed target charmonium production with proton and lead beams at LHC

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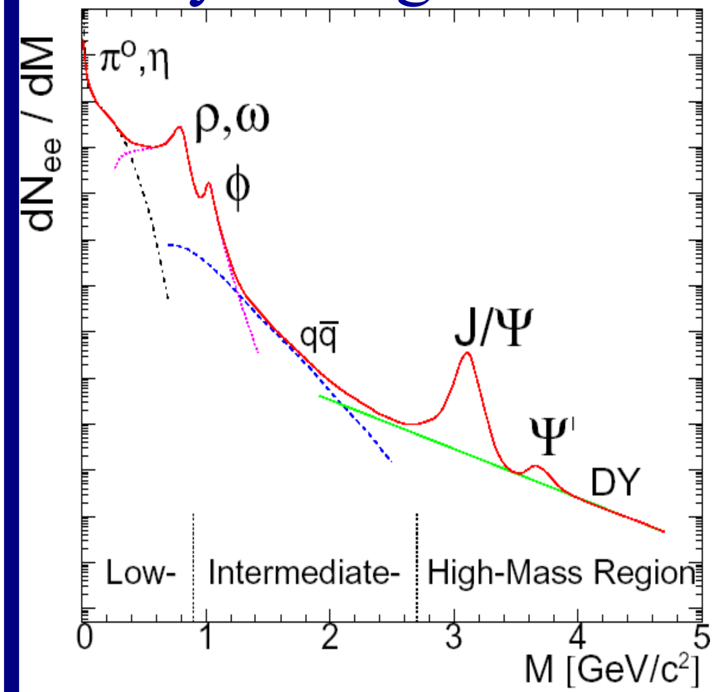
1. Physics motivation.
2. Geometrical acceptances for J/ψ measurement at ALICE for PbPb interactions at √s= 5.5 TeV and pp interaction at √s = 14 TeV.
3. Evaluation of geometrical acceptances for PbPb and p-A fixed target J/ψ measurement by dimuon spectrometer of ALICE.
5. Luminosity and counting rate estimation.
6. Conclusions.

Charmonium

- 35 years ago: discovery of J/ψ, 23 years ago: Matsui & Satz



colour screening in deconfined matter
→ J/ψ suppression
→ possible signature of QGP formation

Experimental and theoretical investigations
→ situation is much more complicated

cold nuclear matter / initial state effects (CNM)

- **“normal” nuclear absorption**
- **(anti)shadowin**
- **saturation, color glass condensate**

suppression via comovers
feed down from χ_c, ψ’
sequential screening (first: χ_c, ψ’, J/ψ only well above T_c)
regeneration via statistical hadronization or charm coalescence

important for “large” charm yield, i.e. RHIC and LHC ?

Fixed-target data (SPS, FNAL, HERA)

AA collisions
SU, PbPb, InIn

SPS:	NA38,	NA50, NA60
√s(GeV)	19.4	17.3

pA collisions

	HERA-B,	E866,	NA50/51,	NA38/3,	NA60
√s(GeV)	41.6	38.8	29.1/27.4	19.4	27.4/17.3

Colliders (RHIC,LHC)

AA collisions

RHIC CuCu, AuAu √s =200 GeV
LHC PbPb √s = 5.5 TeV

pA collisions

RHIC pp, dAu √s =200 GeV
LHC pp, pA √s = 14 TeV

Fixed-target (LHC) – new opportunity – energy between SPS and RHIC

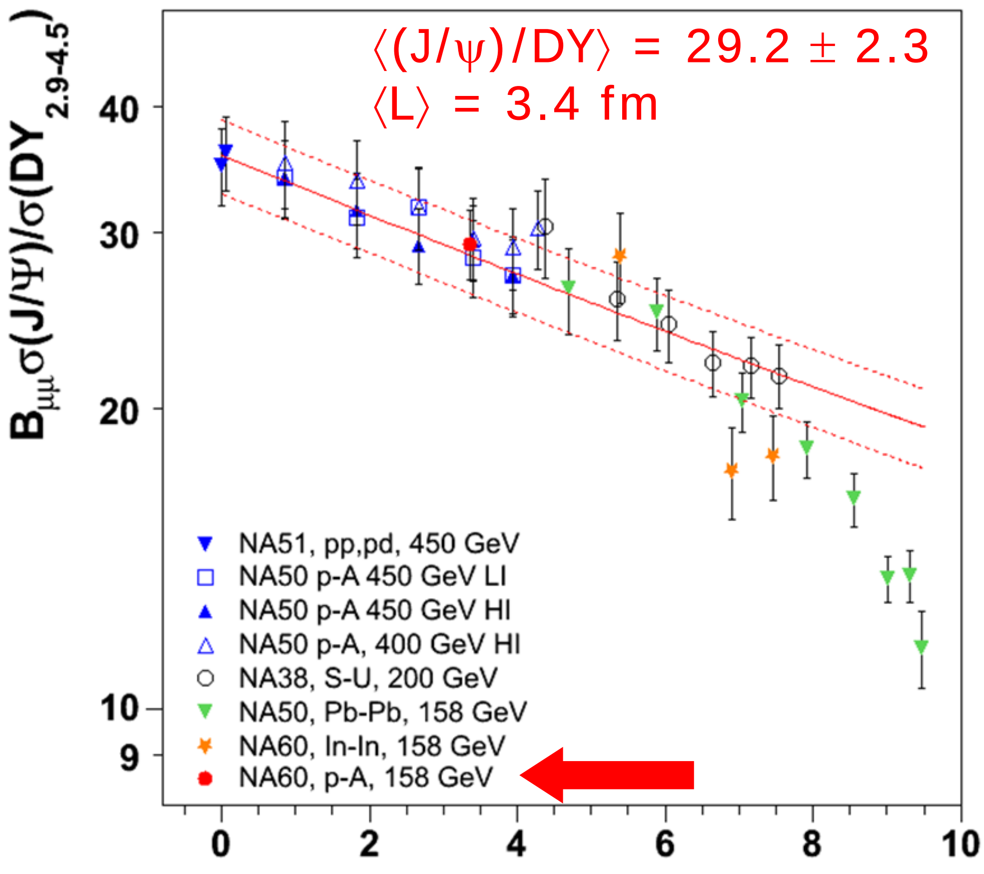
AA collisions

Pb-Pb 2750 GeV/nucleon, √s = 71.8 GeV

pA collisions

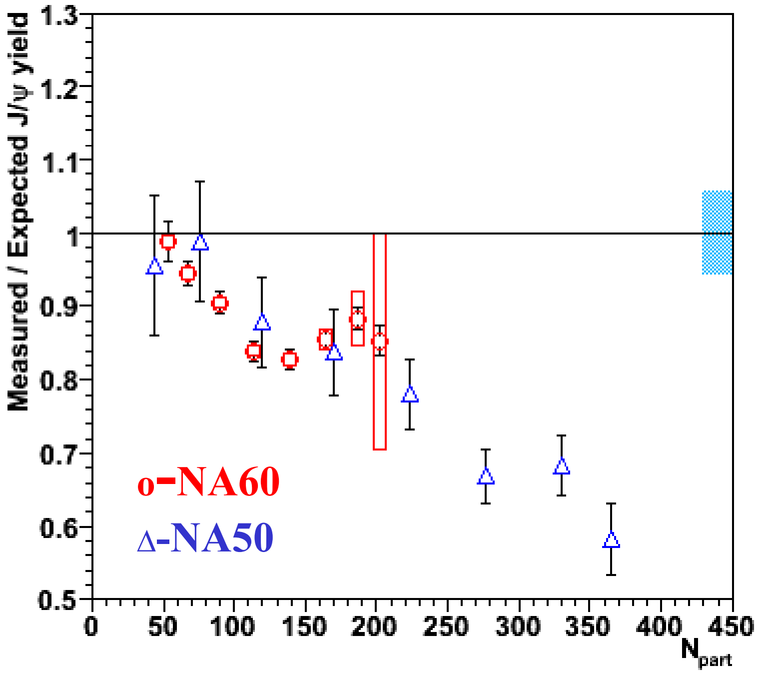
p-A 7000 GeV , √s = 114.6 GeV
2750 GeV, √s = 71.8 GeV

Comparison of J/ψ/DY (NA38, NA50, NA60)



$\sigma_{abs}(J/\psi) = 4.2\pm0.5$ mb

NA60 published results



R. Arnaldi et al., PRL99 (2007) 132302

- NA50 results- an "anomalous suppression" in PbPb.
  Preliminary NA60- "anomalous suppression" presented already in In-In.
  p-A at 158 GeV showed that rescaling from 400 and 450 GeV to 158 GeV is correct. σ_{abs} does not have strong energy dependence.

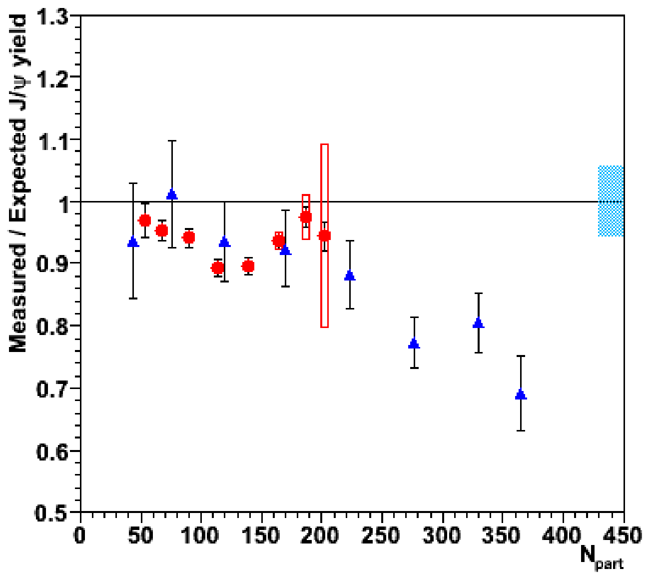
New results from NA60

R.Arnaldi, E.Scomparin, QM09

σ_{abs} is energy and kinematic domain dependent

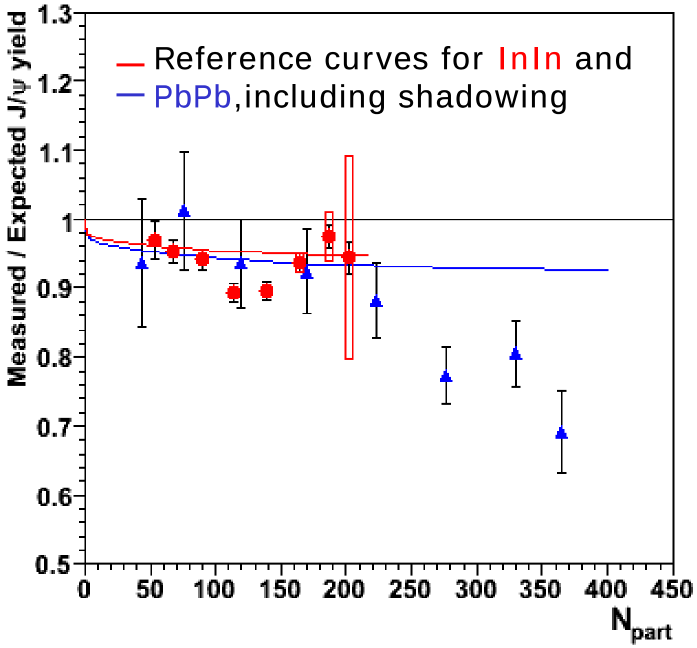
$\sigma_{abs}^{J/\psi}$ (158 GeV) = 7.6 ± 0.7 ± 0.6 mb
$\sigma_{abs}^{J/\psi}$ (400 GeV) = 4.3 ± 0.8 ± 0.6 mb

QM09 new reference



Anomalous suppression in In-In ≤ 10%
Anomalous suppression in Pb-Pb up to 30%

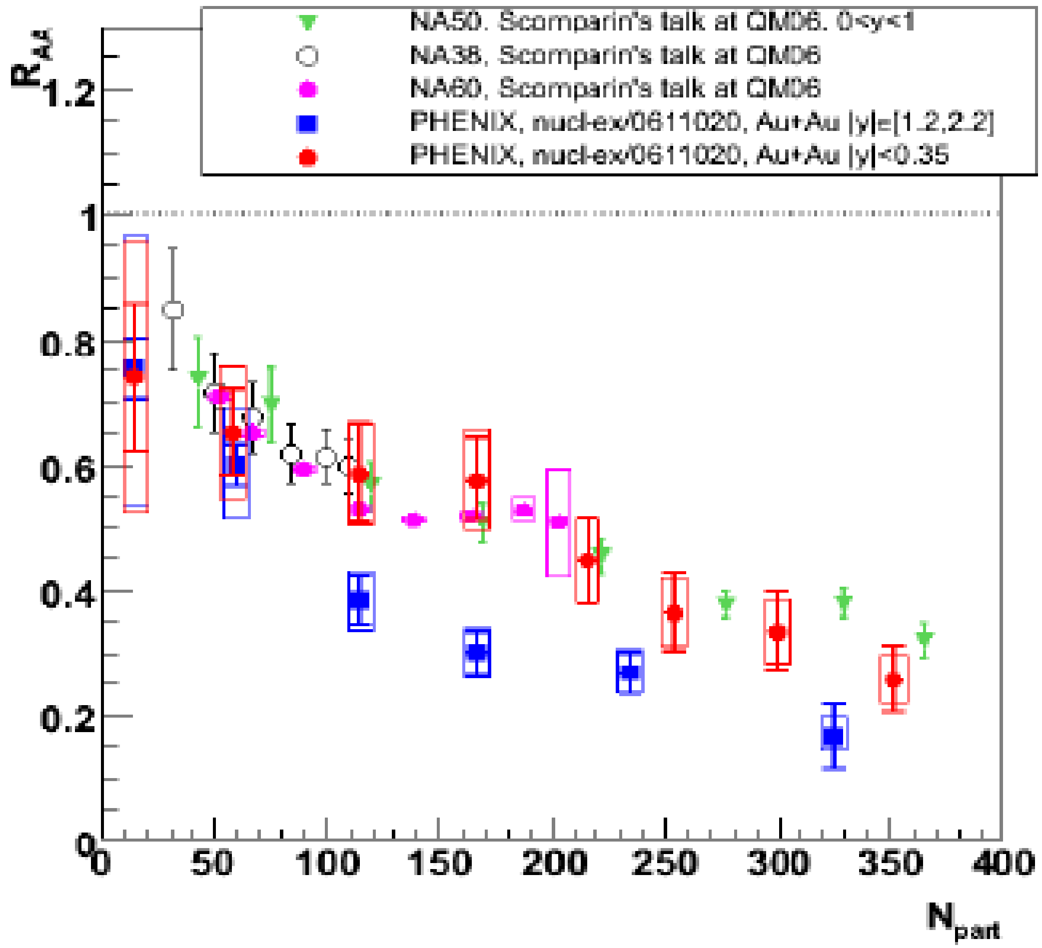
If anti-shadowing is taken in account (but very model dependent!)



with anti-shadowing (EKS)
σ_{abs}= 9.3± 0.7± 0.7 mb

Central Pb-Pb: still anomalously suppressed
In-In: almost no anomalous suppression?

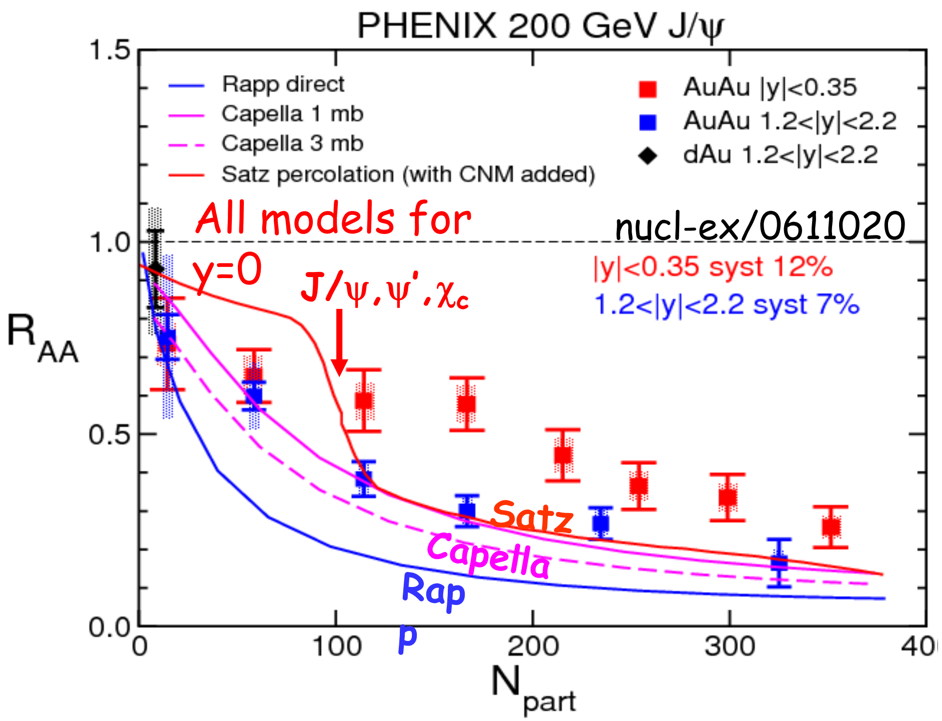
Comparison SPS and RHIC data

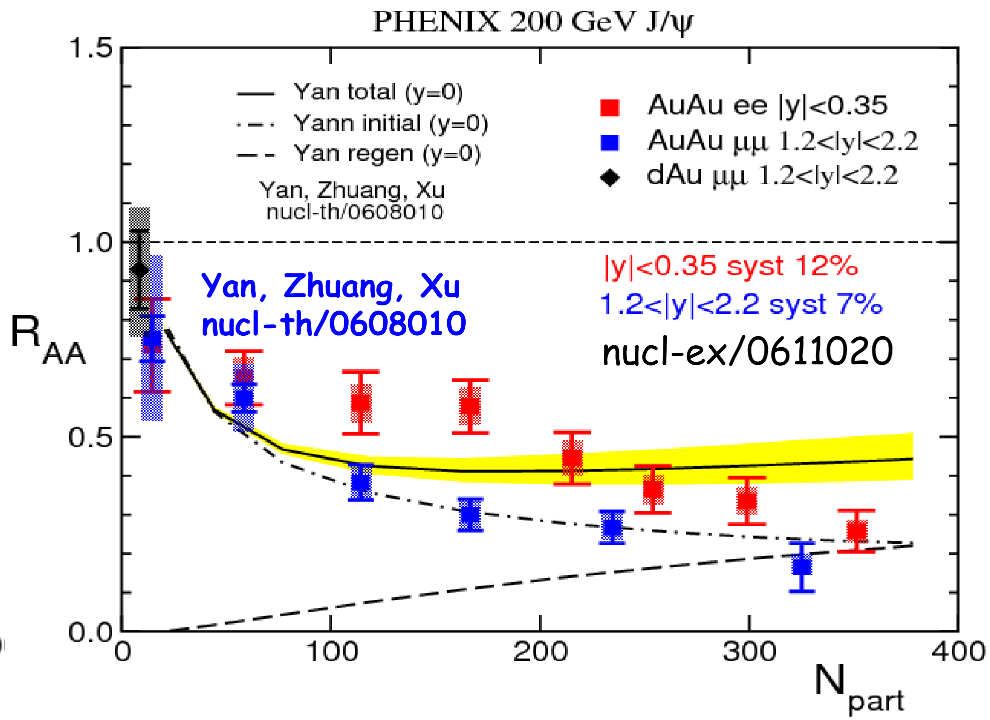


No energy dependence, but rapidity dependence

Suppression R_{AA} vs N_{part} at RHIC.

PHENIX Au-Au data



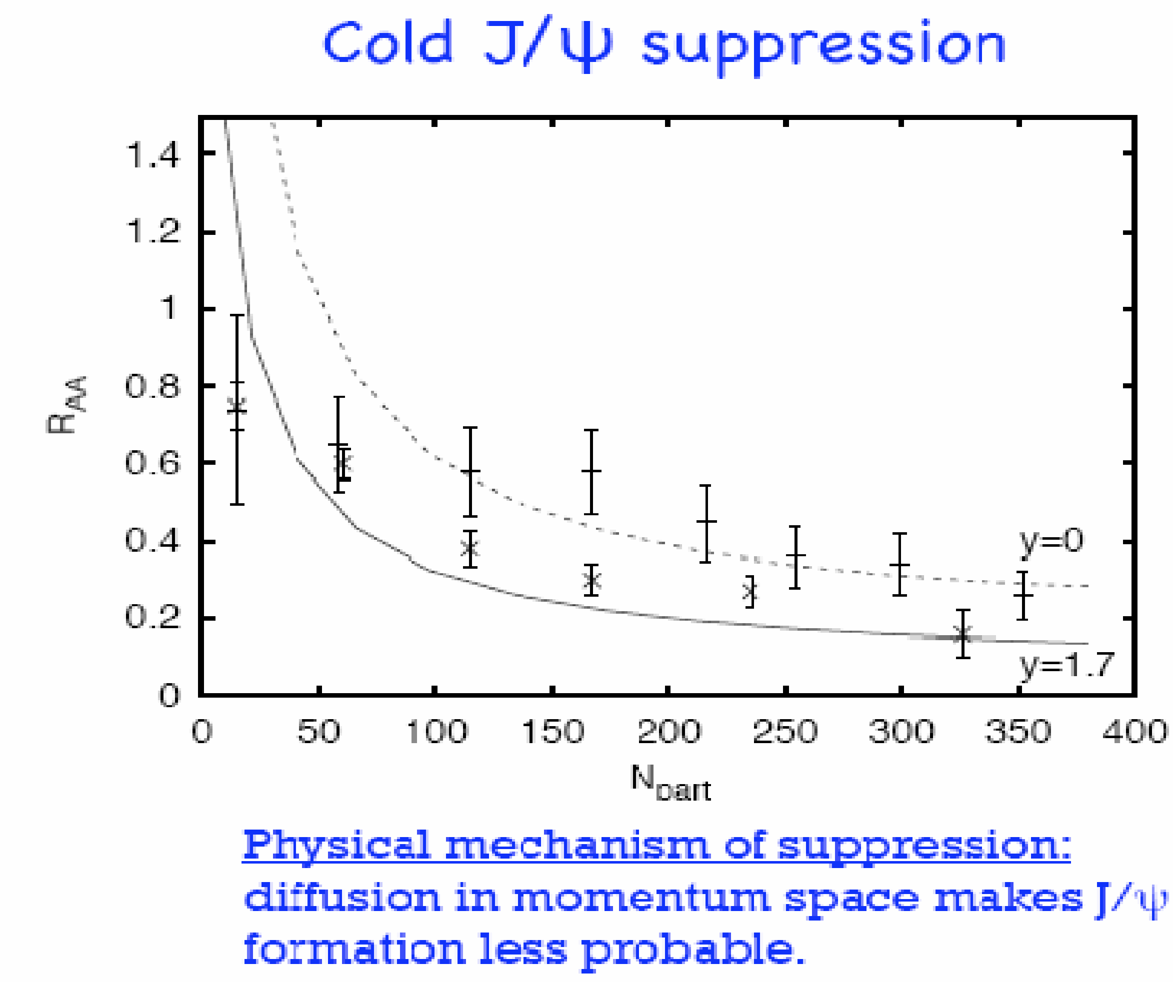


Models for mid-rapidity Au-Au data

Without regeneration

With regeneration

Gluon saturation model for J/ψ production



Without regeneration

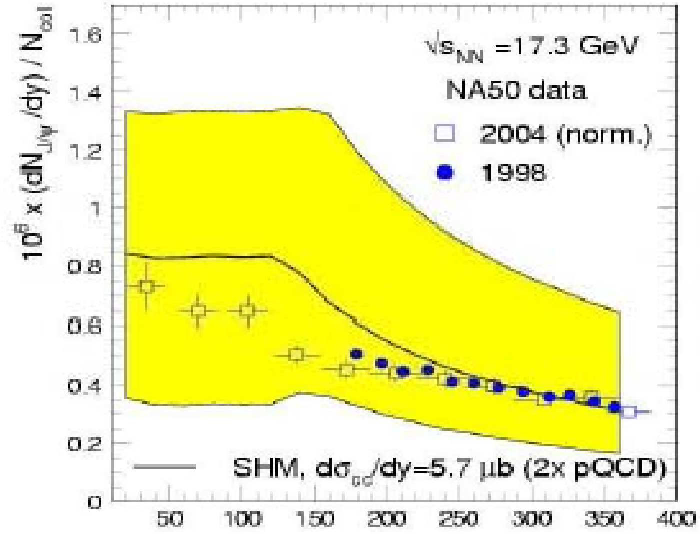
Prediction- strong overall supression at LHC energy

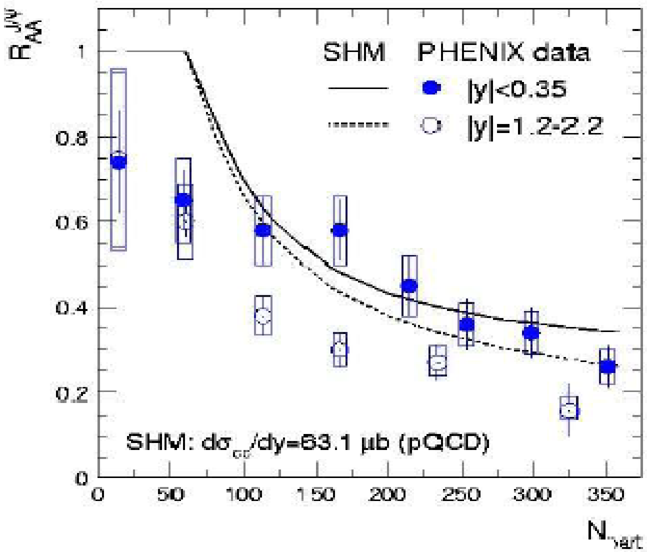
Kharzeev, Levin, Nardi, Tuchin, arXiv:0809.2933

Statistical hadronization model

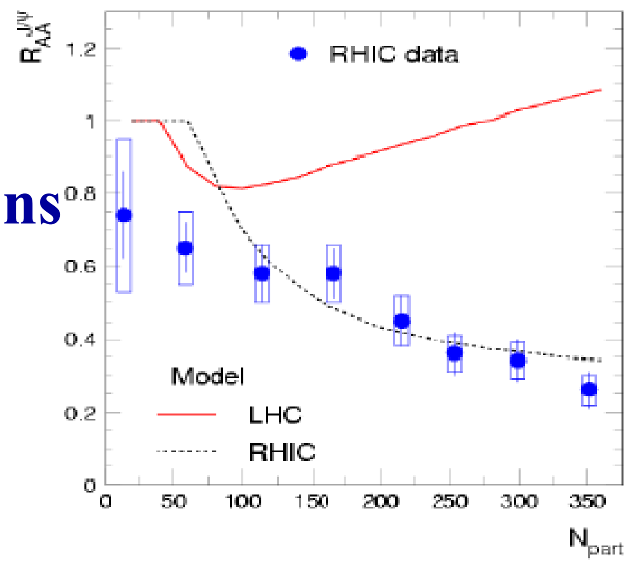
With regeneration

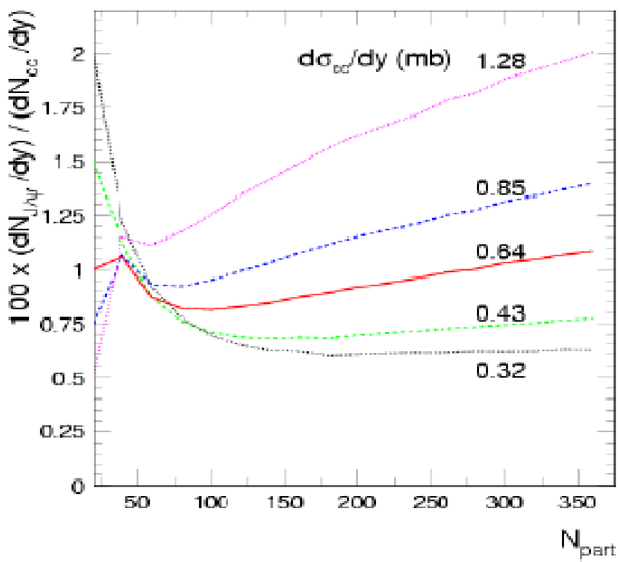
Original: P.Brawn-Munzingen, J.Stachel, PL B490 (2000) 196





Predictions for LHC





No theoretical model that could reproduce all data.

Fixed target experiment at LHC for charmonium production at the energy range between SPS and RHIC in p-A and A-A collisions with planning proton beam at T=7 TeV ($\sqrt{s}$ = 114.6 GeV) and Pb beam at 2.75 TeV ($\sqrt{s}$ = 71.8 GeV) is possibility to clarify the mechanism of charmonium production, to separate two possibilities:

i): hard production and suppression in QGP and/or hadronic dissociation or

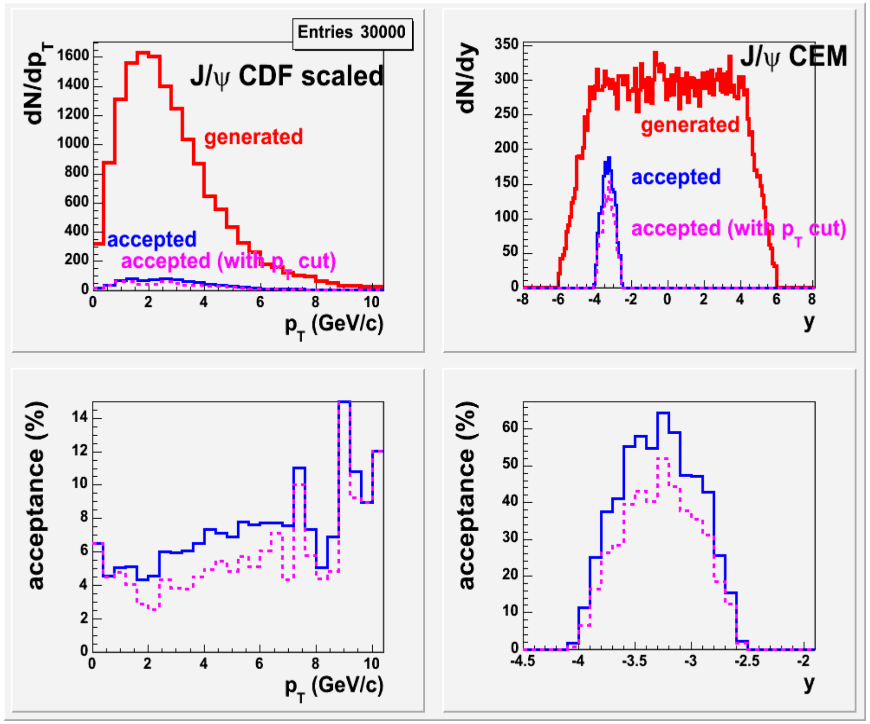
ii): hard production and secondary statistical production with recombination, since the probability of recombination decrease with decreasing energy of collision in thermal model.

Geometrical acceptances for J/ψ at ALICE

Pb-Pb, √s=5.5 TeV

J/ψ are generated using CEM y-spectra and CDF scaled p_T-spectra and including shadowing for Pb-Pb.

I_{acc} = Integrated acceptance = $N_{accepted}/N^{total}_{generated}$



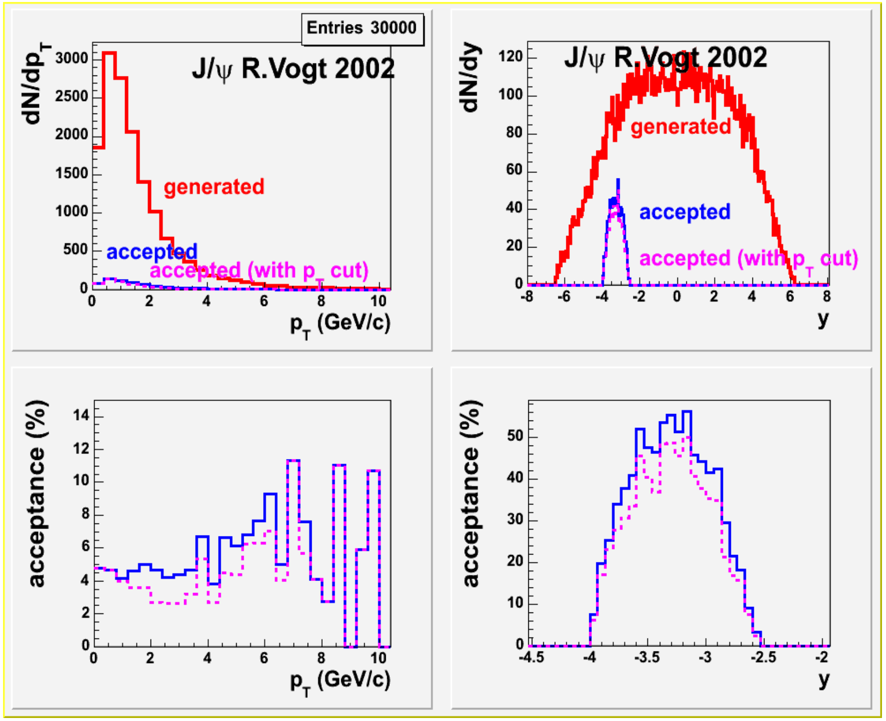
I_{acc}= **5.76%**-w/o p_T cut

4.26%- with cut p_T >1 GeV/c

pp, √s=14 TeV

J/ψ are generated according R.Vogt 2002 approximation for p_T -spectra and y - distribution.

$N_{gen}(J/\psi)$=30000



I_{acc}= **4.71%**-w/o p_T cut

4.01%- with cut p_T >1 GeV/c

Fixed target experiment

Pb-Pb, T=2750 GeV, $\sqrt{s}$=71.8 GeV.

J/ψ are generated at z=0 and outside of ITS at z=+50 cm.

J/ψ are generated using p_T-spectra with HERA and PHENIX form, consistent with COM model, but parameters are energy scaled: $dN/dp_T \sim p_T[1+(35\pi \cdot p_T/256 \cdot \langle p_T \rangle)^2]^{-6}$ with $\langle p_T \rangle = 1.4$, and using y-spectra as Gaussian with mean value $y_{cm}=0$ and $\sigma=1.1$

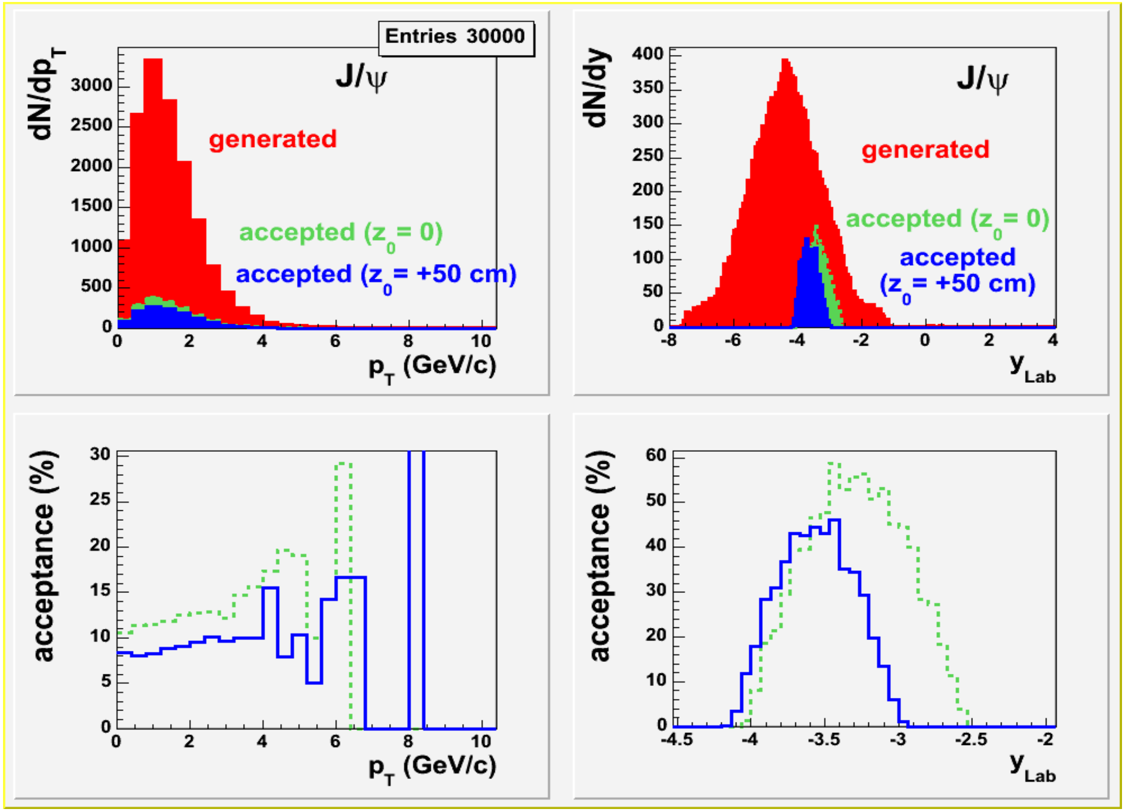
J/ψ are accepted in the rapidity range $-2.5<\eta<-4.0$ ($-2.98<\eta<-4.14$), and each of 2 muons in the degree range $171^0<\theta<178^0$ ($174.2^0<\theta<178.2^0$) for generation J/ψ at z=0 (z=+50 cm).

z=0

$I_{acc} = 12.0\%$

z=+50 cm

$I_{acc} = 8.79\%$

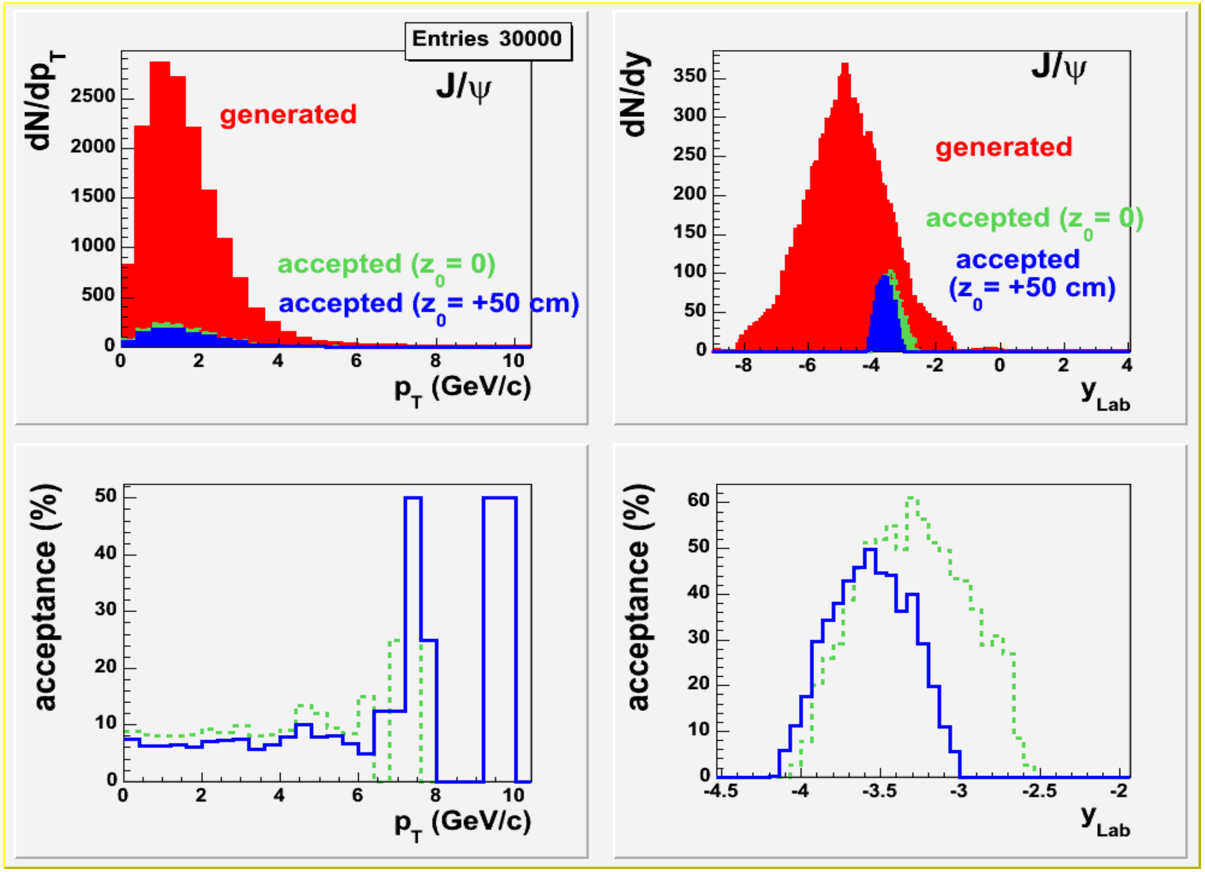


Fixed target experiment

pA, T=7000 GeV, √s=114.6 GeV.

J/ψ are generated at z=0 and outside ITS at z=+50 cm.

J/ψ are generated using p_T-spectra with the same parametrization with energy scaled parameter: $dN/dp_T \sim p_T[1+(35\pi \cdot p_T/256 \cdot \langle p_T \rangle)^2]^{-6}$ where $\langle p_T \rangle = 1.6$, and using y-spectra as Gaussian with mean value $y_{cm}=0$ and $\sigma=1.25$.



z=0

I_{acc} = 8.54%

z=+50 cm

I_{acc} = 5.98%

Geometrical acceptances

System pPb_{fixed}

pt cut	√s (TeV)	z = 0	z = +50 cm	z = -50 cm	z = +350 cm
no cut	0.1146	8.54	5.98	5.07	0.21
pt > 1 GeV/c	0.1146	6.77	4.89	4.11	0.19
no cut	0.0718	12.0	7.97	7.44	0.33
pt > 1 GeV/c	0.0718	9.79	6.62	6.20	0.26
η range		-4.0 ↔ - 2.5	-4.09 ↔ -2.97	-3.76 ↔ -2.5	-4.3 ↔ -4.10

As it was already used for the experiment on collider with a fixed target at HERA-B K.Ehret, Nucl. Instr. Meth. A 446 (2000) 190, the target in the form of thin ribbon could be placed around the main orbit of LHC. The life time of the beam is determined by the beam-beam and beam-gas interactions. Therefore after some time the particles will leave the main orbit and interact with the target ribbon. So for fixed target measurements only halo of the beam will be used. Therefore no deterioration of the main beam will be introduced. The experiments at different interaction points will not feel any presence of the fixed target at the IP of ALICE.

Luminocity, cross sections($x_F>0$) , counting rates

System	$\sqrt{s}$ (TeV)	σ_{nn} (μb)	$\sigma_{pA}=\sigma_{nn}\cdot A^{0.92}$ (μb)	ε (%)	$\varepsilon\cdot B\cdot\sigma_{pA}$ (μb)	L ($cm^{-2}s^{-1}$)	Rate ($hour^{-1}$)
pp	14	32.9	32.9	4.7	0.091	$3\cdot10^{30}$	982
pp_{RHIC}	0.200	2.7	2.7	3.59	0.0057	$2\cdot10^{31}$	410
pPb_{fixed}	0.1146	0.65	88.2	5.98	0.310	$1.5\cdot10^{29}$(*)	168
pPb_{fixed}	0.0718	0.55	74.6	7.97	0.349	$1.5\cdot10^{29}$	189
pPb_{NA50}	0.0274	0.19	25.8	14.0	0.212	$7\cdot10^{29}$(**)	535
$PbPb_{fixed}$	0.0718	0.55	10130	7.97	47.5	$3.2\cdot10^{27}$(***)	547

(*) pPb_{fixed}, 500 μ wire, 10^{12} protons/60 min, z=+50 cm

(**) pPb_{NA50}, $3\cdot10^{7}$ protons/s, Eur. Phys. J. C33(2004) 31

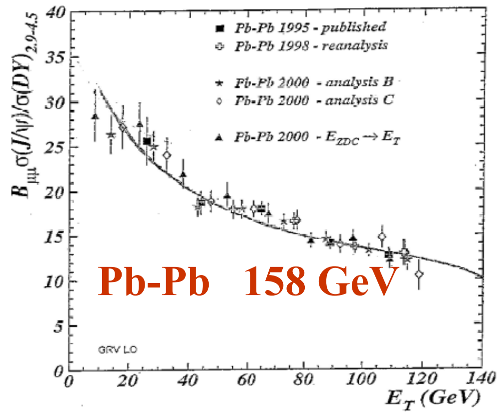
(***) **PbPb cross section, $6.8\cdot10^{8}$ ions/60 min**

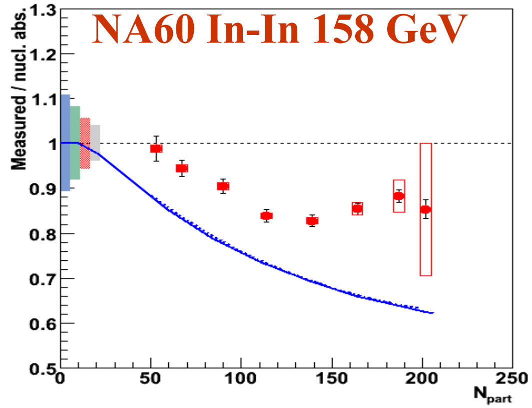
Conclusions

1. The integrated geometrical acceptances for charmonium measurement by dimuon spectrometer of ALICE are 5.76% for $\sqrt{s}$=5.5 TeV Pb-Pb and 4.71% for $\sqrt{s}$=14 TeV pp collisions.
2. For fixed target charmonium measurement by ALICE spectrometer the geometrical acceptances are of the same order , and even larger: 7.97% for $\sqrt{s}$=71.8 GeV Pb-Pb and 5.98% for $\sqrt{s}$=114.6 GeV pA at z=+50 cm. The acceptances are compartible with the acceptances from other experiments, except HERA.
3. The energy range for fixed target experiment between SPS and RHIC gives important additional information.

BACKUP

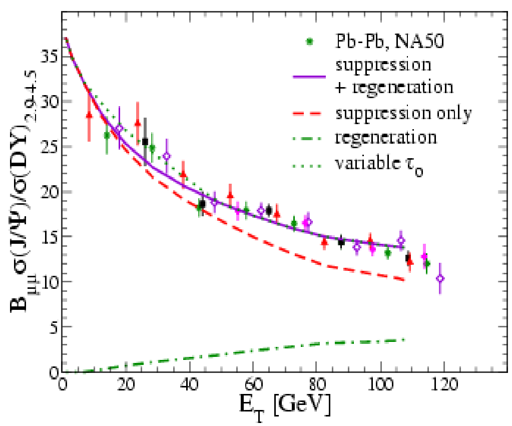
Theoretical models could not reproduce simultaneously NA50 and NA60

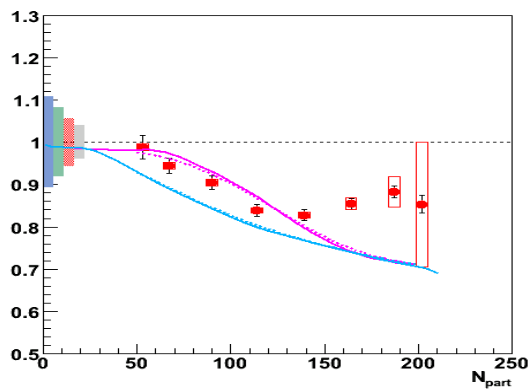




Suppression by produced hadrons ("comovers")

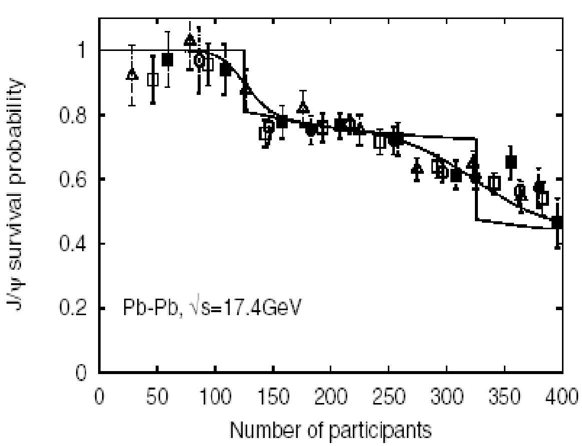
Capella-Ferreiro EPJ C42(2005) 419

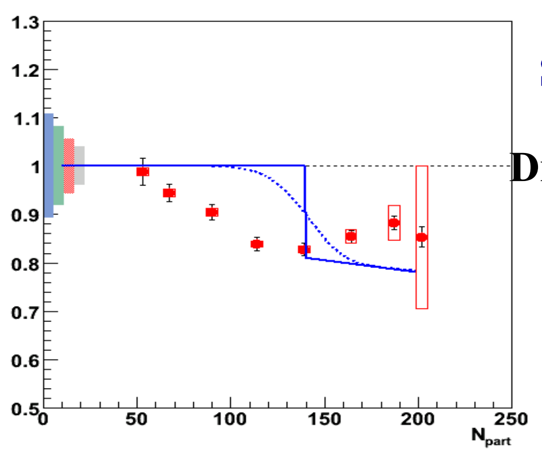




QGP + hadrons + regeneration + in-medium effects

Grandchamp, Rapp, Brown EPJ C43 (2005) 91



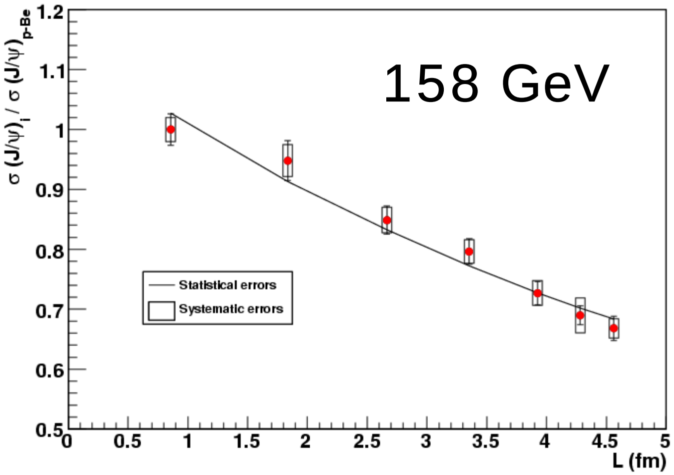


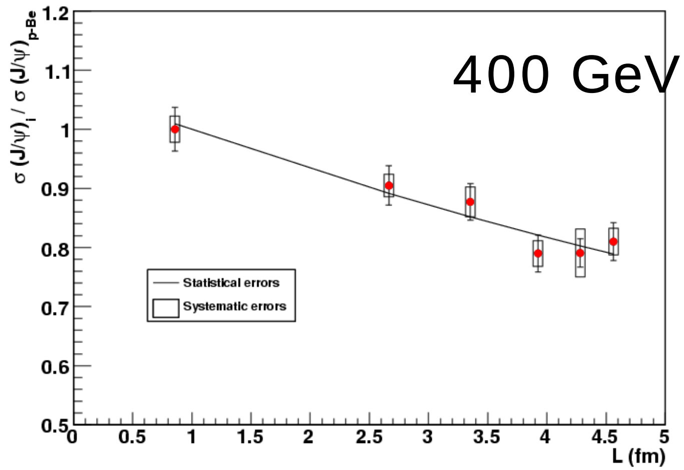
Suppression due to a percolation phase transition

Digal-Fortunato-Satz Eur.Phys.J.C32 (2004) 547

New results from NA60

R.Arnaldi, E.Scomparin, QM09

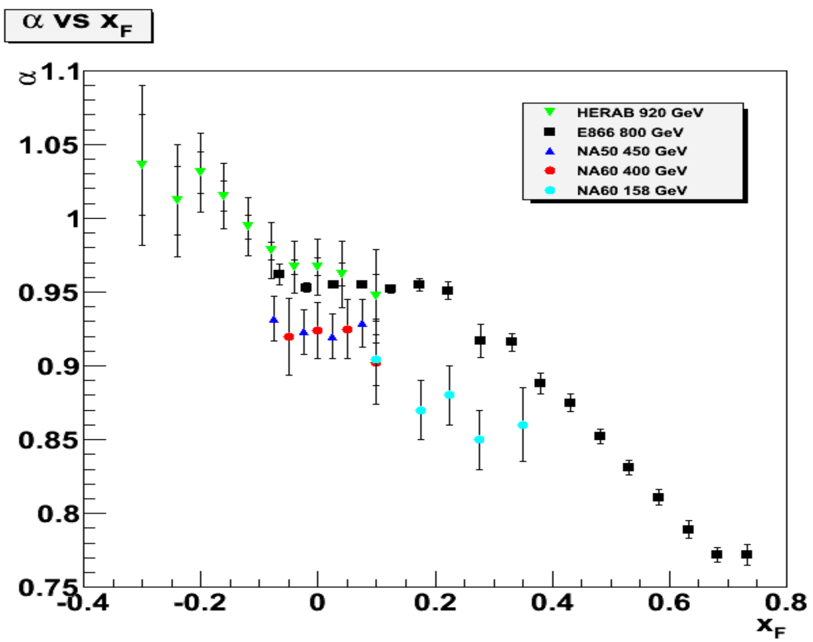




σ_{abs} is energy and kinematic domain dependent

→ $\sigma(J/\psi) \sim \exp(-\rho\sigma_{abs} L)$

$\sigma_{abs}^{J/\psi}$ (158 GeV) = 7.6 ± 0.7 ± 0.6 mb
$\sigma_{abs}^{J/\psi}$ (400 GeV) = 4.3 ± 0.8 ± 0.6 mb



→ Using $\sigma_{pA}=\sigma_{pp} A^{\alpha}$

α (158 GeV) = 0.882 ± 0.009 ± 0.008
α (400 GeV) = 0.927 ± 0.013 ± 0.009

The luminosity estimate is shown in the Table . This number we obtain from the LHC proton parameters for the Commissioning Version 3(*)
http://bruening.home.cern.ch/bruening/lcc/WWW-pages/commissioning_parameter.htm

It gives $1.15 \cdot 10^{11}$ protons per bunch, 44 bunches and life time 15.4 hours. From these parameters we get particle loss of $3.2 \cdot 10^{11}$ during one hour and luminosity about $1.5 \cdot 10^{29}$ for 500 micron lead ribbon.