C H I C

Charm in Heavy Ion Collisions @ SPS

1. J/Ψ – Suppression in A+A
2. CHIC – Physics motivations
3. CHIC – Experimental aspects

J/Ψ – Suppression in A+A

- **SPS (17 GeV) .vs. RHIC (200 GeV)**
  - Compare
    - 0<y<1 at SPS **(NA50/NA60)**
    - |y|<0.35 at RHIC **(PHENIX)**

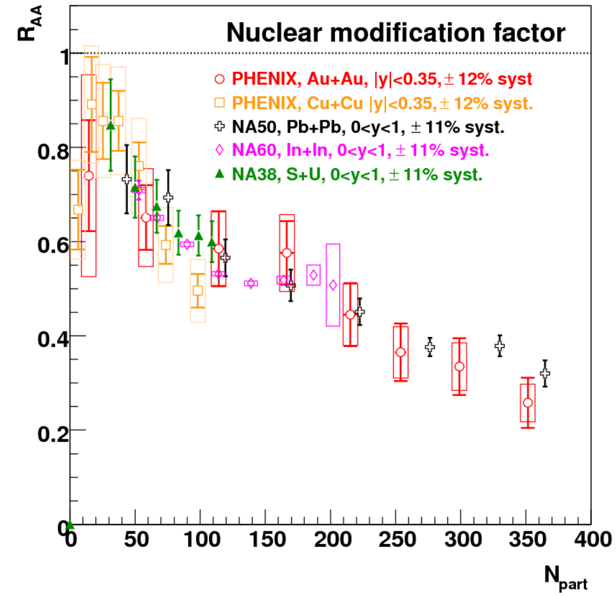
      ➔ ~ same *y* (~same x_F)
  - SIMILAR SUPPRESSION at SPS.vs.RHIC
  - Assuming CNM effects amplitude are the same (possible within large RHIC uncertainties), two hypothesis :

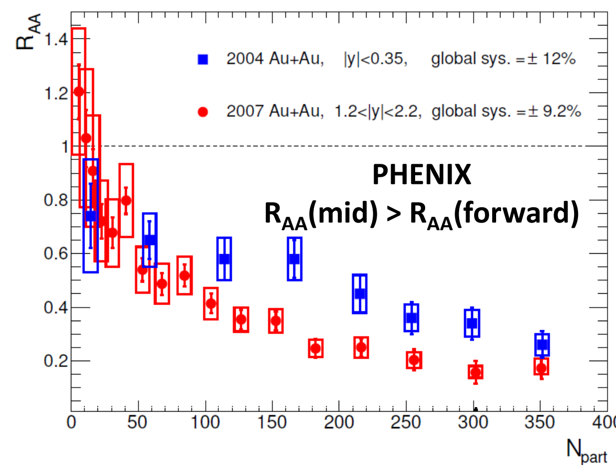
    1. Due to recombination process which **exactly** compensates a larger suppression expected at RHIC energies

    2. Due to χ_c suppression (and Ψ') only *

       ➔ SEQUENTIAL SUPPRESSION

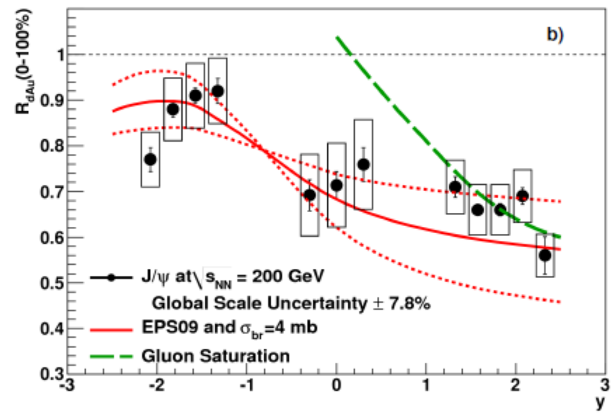
* **direct J/Ψ not suppressed**

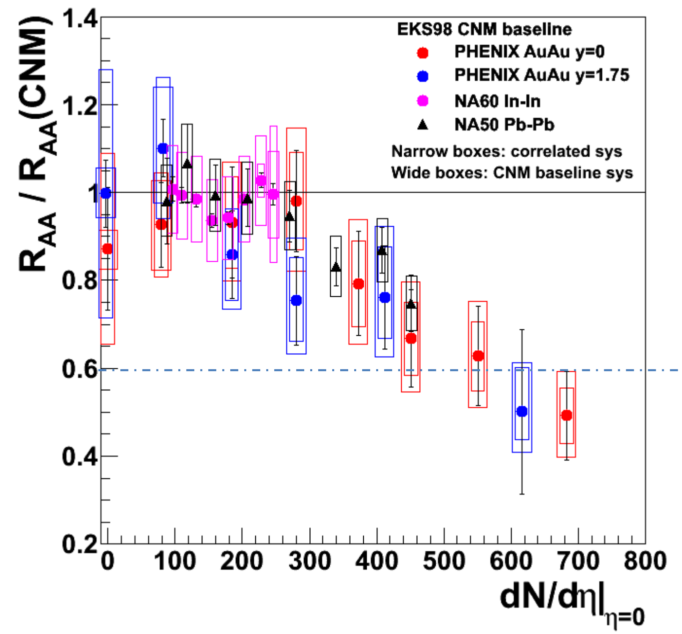




J/Ψ – Suppression in A+A

- **SPS (17 GeV) .vs. RHIC (200 GeV)**
  - Compare
    - 0<y<1 at SPS **(NA50/NA60)**
    - |y|<0.35 at RHIC **(PHENIX)**
    - 1.2 < |y| < 2.2 at RHIC **(PHENIX)**
  - ***After CNM effects correction:***
    - **SIMILAR SUPPRESSION** at SPS .vs. RHIC
    - If recombination at RHIC, must be small
    - Hint for **sequential suppression ?** **(χ_c and Ψ' melting ?)**
    - But ***LARGE*** CNM effects ***uncertainties*** ➔ not clear yet

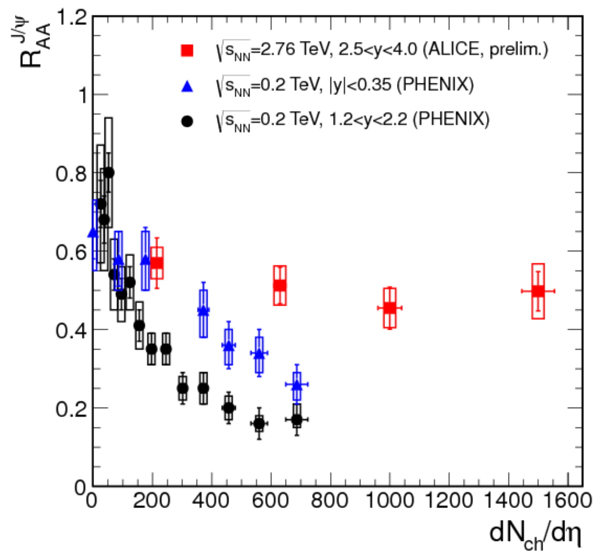


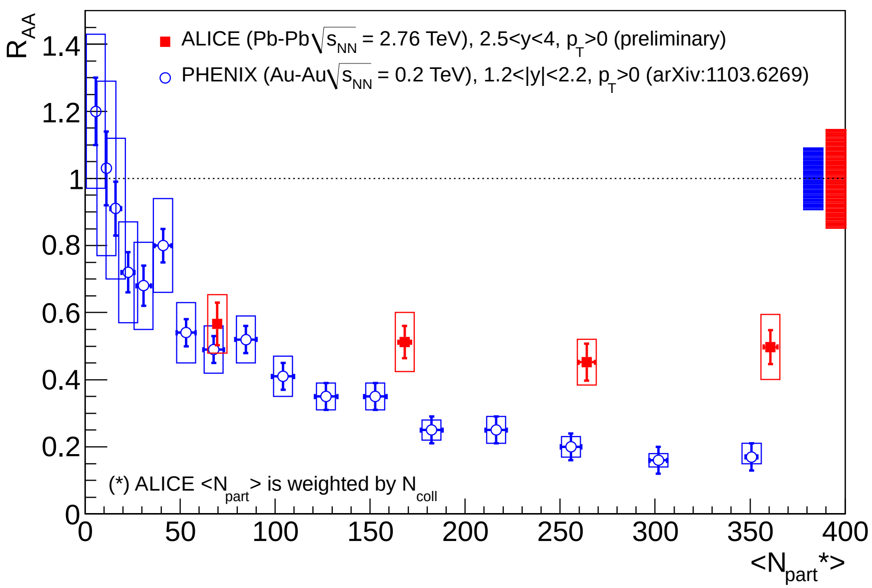


J/Ψ – Suppression in A+A

- **RHIC (200 GeV) .vs. LHC (2.76 TeV)**
  - Compare
    - 1.2 < |*y*| < 2.2 at RHIC **(PHENIX)**
    - 2.5 < *y* < 4 at LHC **(ALICE)**
  - **LESS SUPPRESSION** at LHC .vs. RHIC
  - Assuming CNM effects amplitude are the same (or larger at LHC) :
  - Could be due to **recombination** effects

Caution : Needs CNM effects comparison

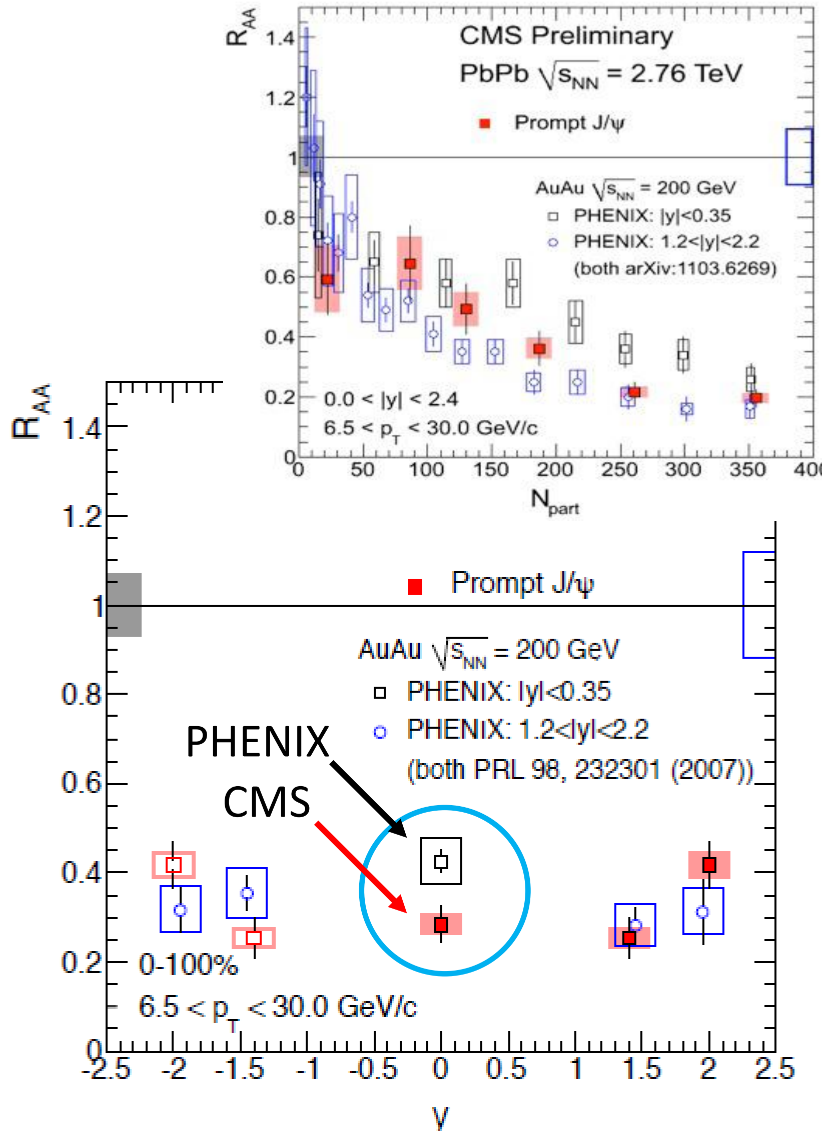




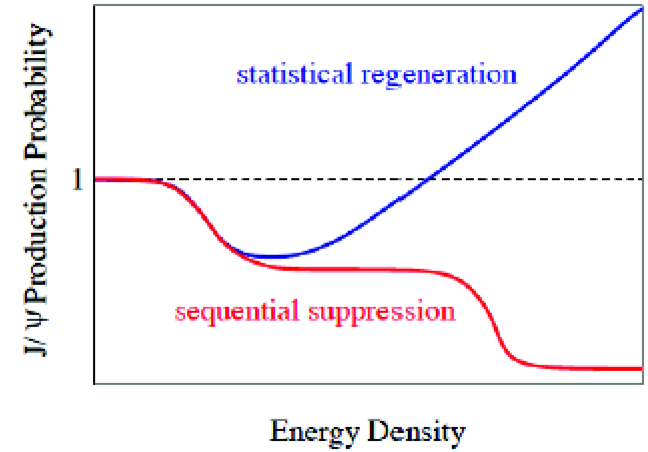
J/Ψ – Suppression in A+A

- **RHIC (200 GeV) .vs. LHC (2.76 TeV)**
  - Compare
    - |y|<0.35 at RHIC **(PHENIX)**
    - |y|<1 at LHC **(CMS)**
  - **MORE SUPPRESSION** at LHC .vs. RHIC
  - Assuming CNM effects amplitude are the same (or smaller at LHC) :
    - p_T>6.5 GeV/c → no recombination applies
    - larger suppression due to **HDM effects ?**
    - Hint for **sequential suppression ? (J/Ψ melting)**

Caution : Needs CNM effects comparison



J/Ψ – Suppression in A+A



- **Similar suppression at SPS.vs.RHIC**
  - After CNM effects correction
- **Larger suppression at LHC outside recombination regime**
  - CMS results (assuming CNM effects are the same or smaller)
- **Smaller suppression at LHC inside recombination regime**
  - ALICE results (assuming CNM effects are the same of larger)
- **Large uncertainties due to CNM effects**
- **Need to measure χ_c to (dis)prove sequential suppression → CHIC experiment**

CHIC – Physics motivations

1. Measure χ_c in A+A at SPS

How χ_c is suppressed relative to J/Ψ ?

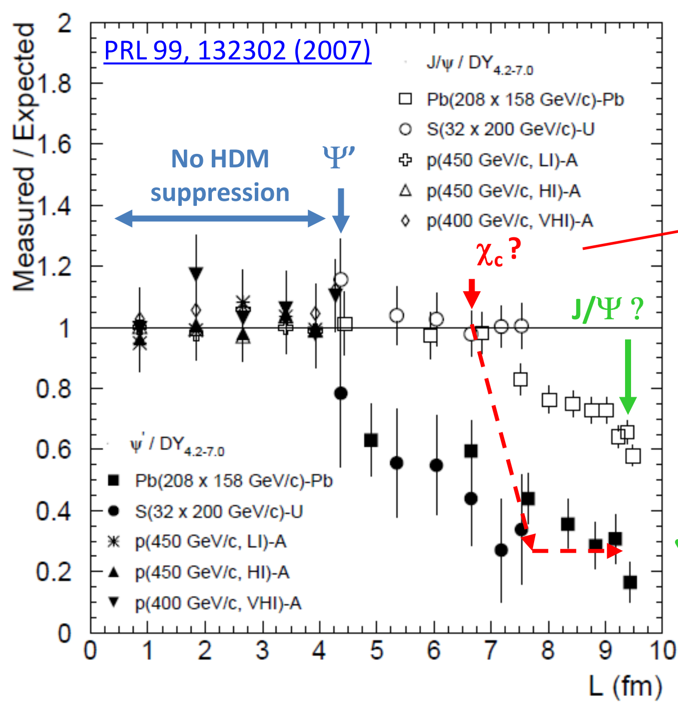
What is the dependence with y, p_T, centrality,… ?

Mandatory to draw the whole picture (SPS .vs. RHIC .vs. LHC)

Why SPS ?

1 **SPS best place to see full Sequential suppression**

2 **No recombination at SPS**



Need to be measured

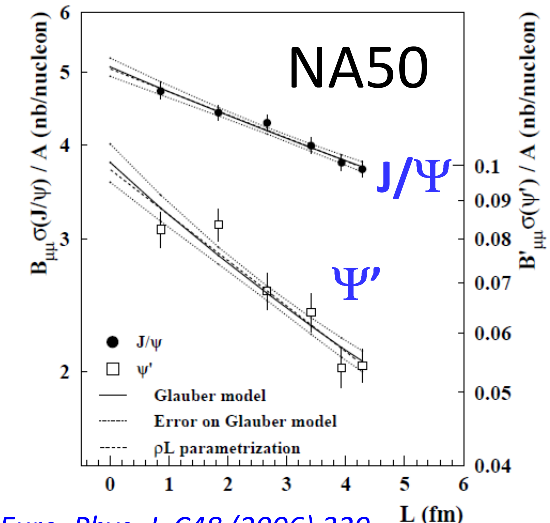
χ_c measurement will answer this

Most central RHIC ? LHC ?

CHIC – Physics motivations

2. Measure charmonium in p+A at SPS

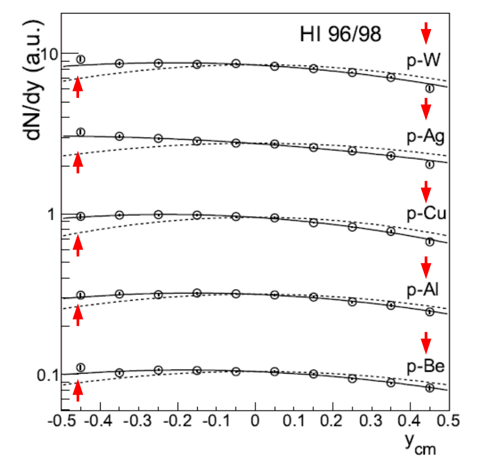
J/Ψ and Ψ' **suppression** in p+A collisions as a function of L



Euro. Phys. J. C48 (2006) 329.

➔ **Measuring different charmonium states gives key information on nuclear « absorption » and production mechanism.**

J/Ψ **rapidity distribution** in p+A collisions (asymetry wrt y_{cm}=0)



➔ **Measuring charmonium in a wide x_F range is important to identify possible (anti)shadowing effects**

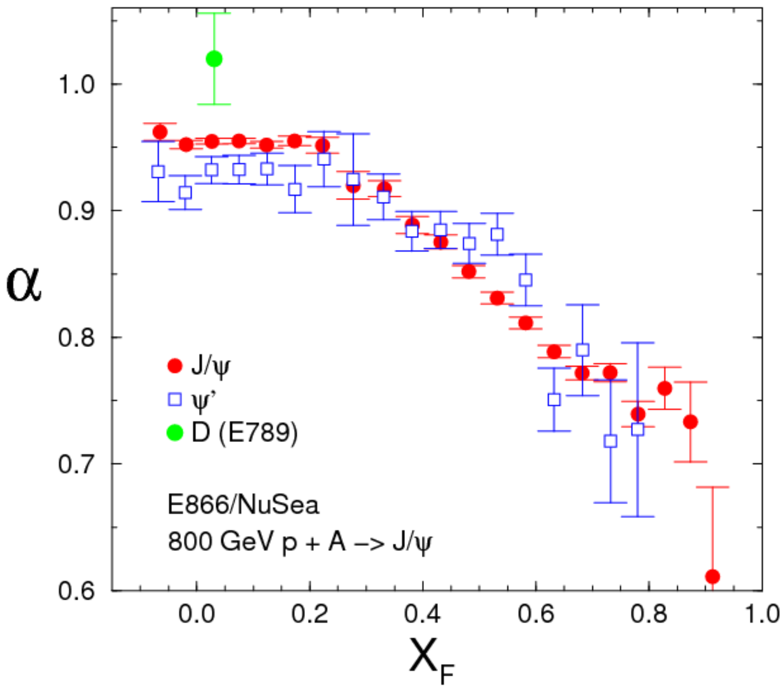
CHIC – Physics motivations

2. Measure charmonium in p+A at SPS

➔ **Measuring charmonium in a wide x_F range is important to identify possible (anti)shadowing effects**

$$\sigma_A = \sigma_p * A^\alpha$$

E866, Phys. Rev. Lett. 84, 3256-3260 (2000)



$$x_F = \frac{2M}{\sqrt{s}} \sinh \; y_{CMS}$$

With M=3.1 GeV/c² and √**s=17.2 GeV** (158 GeV)
$x_F = 1$ ➔ $y_{CMS} = 1.7$

With M=3.1 GeV/c² and √**s=29.1 GeV** (450 GeV)
$x_F = 1$ ➔ $y_{CMS} = 2.2$
$Y_{CMS}=2$ ➔ $x_F = 0.8$

Possible to access large x_F if measuring charmonia at rapidity up to y_{CMS}~2

CHIC – Physics motivations

1. Measure χ_c production in A+A

How χ_c is suppressed relative to J/Ψ ? What is the dependence with y, p_T, N_{part},… ?

Mandatory to draw the whole picture (SPS .vs. RHIC .vs. LHC)

Benchmark 1 : Measure χ_c production within $y_{CMS} \in$ [-0.5, 0.5]

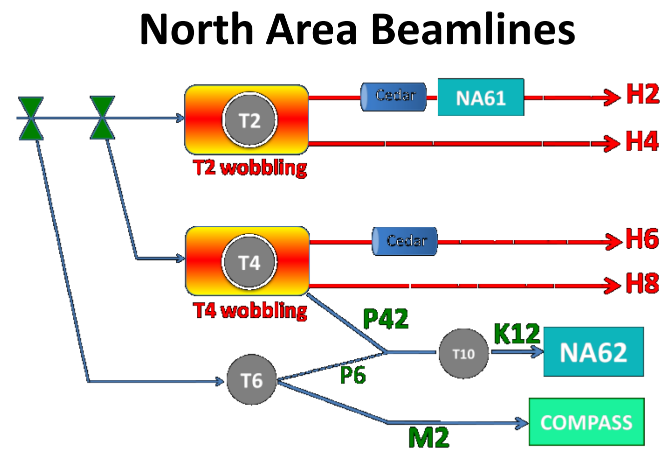
2. Measure charmonia production in p+A

what is the dependence of charmonia suppression with rapidity ?

Crucial to understand effects due to cold nuclear matter

Benchmark 2 : Measure charmonium states within $y_{CMS} \in$ [-0.5, 2]

CHIC – Expected yields



- **Need high intensity p and Pb beams (~ 10^7 Pb/sec)**
  - NA50/NA60 beam line not available (NA62)
  - H2 beam line occupied by NA61
  - H4 and H8 available but need shielding for HI

- **NA50: European Physical Journal C39 (2005) 335**
  - *New measurement of J/ψ suppression in Pb+Pb at 158 GeV/nucleon*
  - 35 days of data taking in 2000
  - ~1.10^7Pb/s over 5s bursts every 20s
  - 4 mm thick Pb target (10%λ_I)
  - ~ 100 000 $J/\Psi \rightarrow \mu^+\mu^-$ within $y^* \in [0,1]$ (on tape)

- **Expect fair amount of χ_c: $N_{J/\Psi}$ ~ 60% direct + ~30% from χ_c + ~10% from Ψ'**
  - Same conditions as NA50 setup → **~20 000 χ_c expected within $y_{CMS} \in [-0.5,0.5]$**
  - Expect more with thicker target (1cm for instance)

CHIC – Detector design

- **Primary goals :**
  - $\chi_c \rightarrow J/\Psi + \gamma \rightarrow \mu^+ \mu^- \gamma$ at $y_{CMS} = 0$
  - $J/\Psi \rightarrow \mu^+ \mu^-$ in large y_{CMS} range
- **Detector features : very compact**

1. **Spectrometer**

   - Measure tracks before absorber ➔ σ_M~20 MeV/c²

   - Covers y_{CMS} [-0.5, 2] ➔ need high segmentation

   ➔ Silicon technologies

2. **Calorimeter**

   - Measuring γ in high π^0 multiplicity environment

   ➔ ultra-granular EMCal (Calice)

3. **Absorber/trigger**

   - Using 4.5 m thick Fe to absorb π/K and low P $\mu^{+/-}$

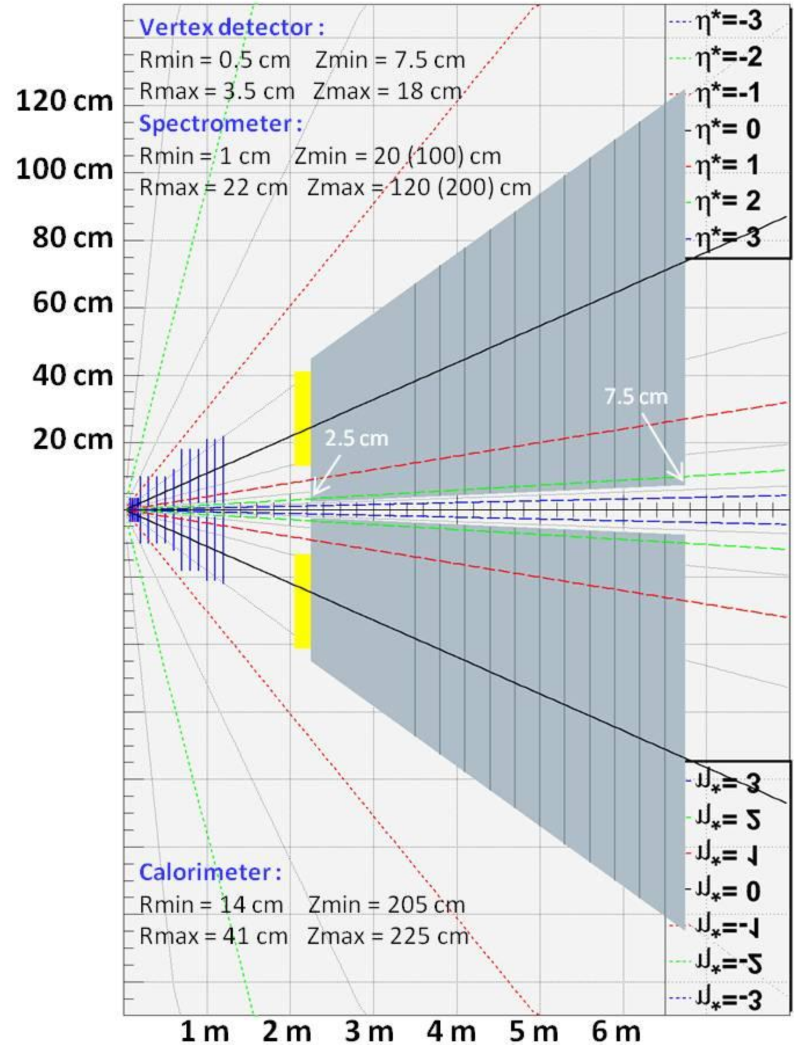
   - Can use smaller absorber if Fe magnetized

   - Trigger to be defined (expected rate = 0.3 kHz)

- **Expected performances**

1. **tracking :** $\frac{\Delta P}{P} \sim 1\%$ within 1m long 2.5T $\vec{B}$

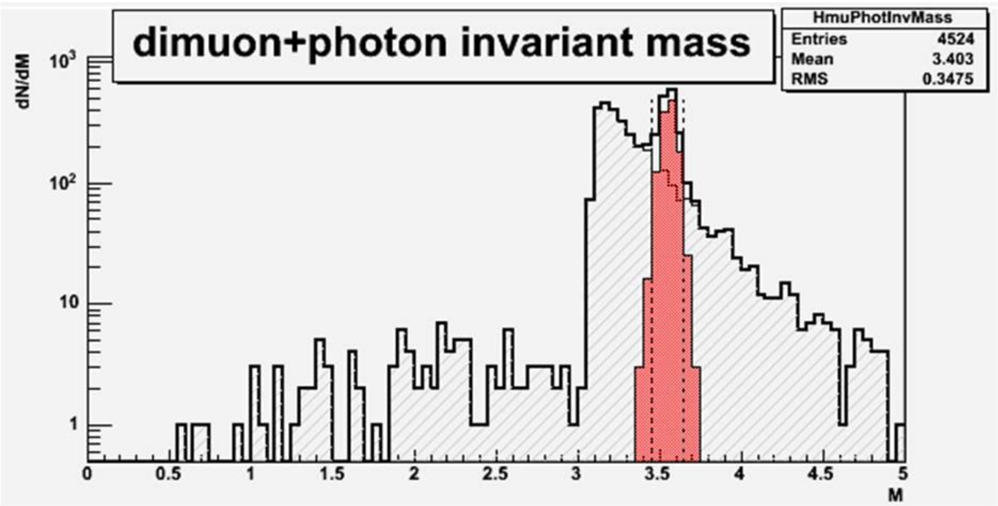
2. **Calorimetry :** $\frac{\Delta E}{E} \sim \frac{20\ \%}{\sqrt{E}}$

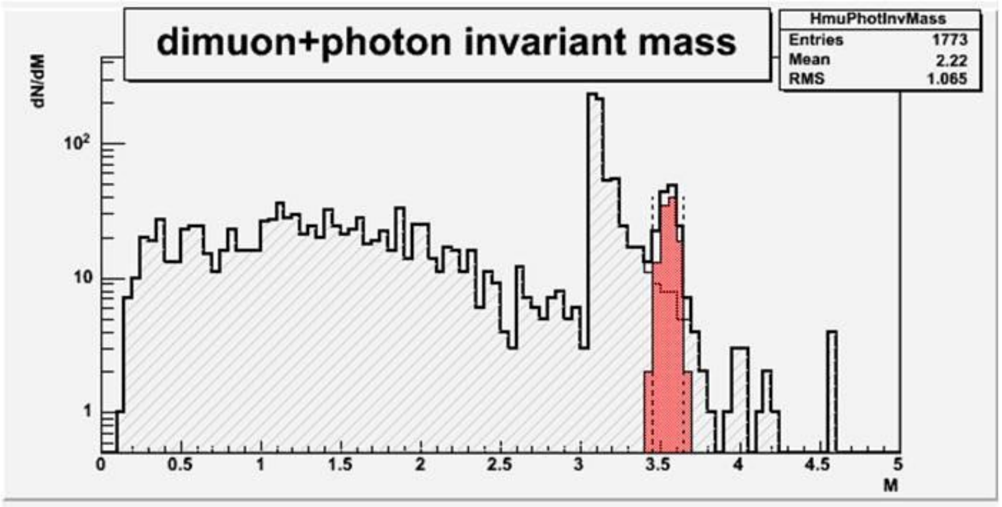


CHIC – Performances

- χ_{c2} **in p+p collisions at √s=17.8 GeV**
  - **Sample:**
    - 20 000 events with Pythia 6.421
    - 1 $\chi_{c2} \rightarrow J/\Psi\ \gamma \rightarrow \mu^+ \mu^- \gamma$ per event
    - Smearing $\Delta P_\mu / P_\mu$ = 1%
    - Smearing $\Delta E_\gamma / E_\gamma = 20\% / \sqrt{E_\gamma}$
  - **Selections :**
    - Keep muons w/ $-0.5 < y_{cms} < 0.5$
    - Keep muons w/ $P_z > 7$ GeV
    - Keep muons w/ $z_{vertex} < 215$ cm
    - Keep photons w/ $-0.5 < y_{cms} < 0.5$
    - Reject photons w/ $M_{\gamma\gamma} \in [100, 160]$ MeV/c²
  - **Results** : signal/bkg = 2.8

- χ_{c2} **in Pb+Pb at √s=17.8 GeV**
  - **Sample:**
    - 10 000 events minbias with Epos 1.6
    - 1 pythia χ_{c2} embedded in each event
    - Same selections as in p+p
    - Reject γ if not in the same emisphere as J/Ψ
  - **Results** : signal/bkg = 3.6





Conclusion

- Many data on J/Ψ at various energies, more to come.
- Still difficult to understand:
  - Is there sequential screening ?
  - When does recombination applies ?
- χ_c is a key measurement to (dis)prove sequential screening.
- Because of its energy, SPS is the best place to start with.
- Thanks to new technologies (tracking, calorimetry), it is FEASIBLE.
- **Let's do it !**

Letter of Intent

CHIC: Charm in Heavy Ion Collisions

Study of charm production with proton and heavy ion beams at the CERN SPS

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uu UU, S

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October 11, 2011

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A Technical summary and commitments

This technical summary is based on the tentative design presented in this letter. All numbers presented here as well as anticipated technologies have not been fully optimized yet and are thus prone to modifications.

Detector	measurement goals	anticipated technology	rapidity range	tentative design location/length/inner/outer radius	contact person
active target	–	??	–	?	?
vertex	event vertex centrality of the collision	6 silicon planes	[-0.5,0.5]	7.5/10.5/0.5/7.5 cm	?
tracker	charged tracks	11 silicon planes + 1m 2.5 T magnet	[-0.5,1] [0.5,2]	20/100/1/22 cm 100/200/1/22 cm	?
calorimeter	photons	tungsten/silicon	[-0.5,0.5]	205/20/14/41 cm	F. Fleuret
absorber	–	Fe	[-0.5,2]	225/450/2.5/120 cm	?
trigger	muons	? magnetic field ?	[-0.5,2]	225/450/2.5/120 cm	?

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backup

Experimental landscape

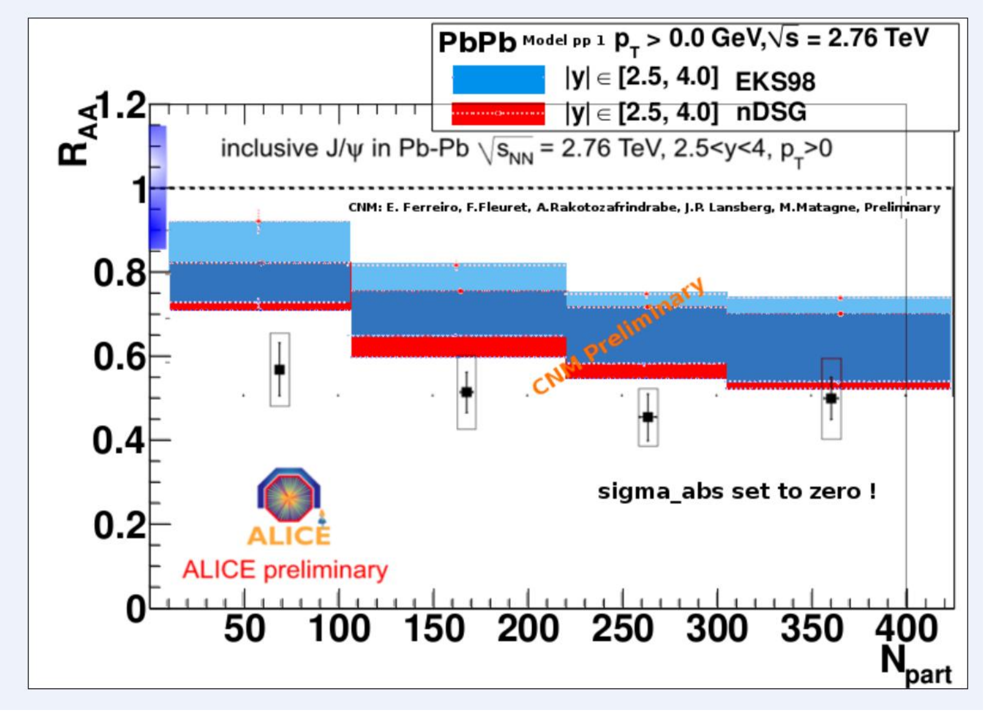
- **Current landscape**
  - **Fixed target : SPS/CERN NA38/50/60 experiments – $\sqrt{s_{NN}}$ = 17 – 30 GeV**
    - **Statistics :100 000's J/ψ**
    - **Data sets : p+A w/ A=p, d, Be, Al, Cu, Ag, W, Pb; S+U, In+In, Pb+Pb**
    - **Small rapidity coverage (typically y $\in$ [0,1])**
  - **Collider : RHIC/BNL Phenix, Star experiments – $\sqrt{s_{NN}}$ = 200 GeV**
    - **Statistics : 1000's J/ψ (10000's since 2007)**
    - **Data sets : p+p, d+Au, Cu+Cu, Au+Au**
    - **Large rapidity coverage (y $\in$ [-0.5,0.5], y $\in$ [-2.2,-1.2] and y $\in$ [1.2,2.2])**
  - **Collider : LHC/CERN Alice, CMS, Atlas experiments ($\sqrt{s_{NN}}$ = 5,5 TeV)**
    - **Statistics : 100000's J/ψ**
    - **Data sets : p+p, Pb+Pb, p+Pb**
    - **Large rapidity coverage (|y|<2.5 ATLAS/CMS, |y|<0.9 and -4.0 < y < -2.5 ALICE)**

- **Feedback : 4 key points**

1. **High statistics**→draw clear suppression pattern in **Hot Nuclear Matter** and **Cold Nuclear Matter**
2. **Large data set** → draw clear suppression pattern in **Cold Nuclear Matter**
3. **Large x_F (rapidity) coverage** → understand suppression mechanism in **Cold Nuclear Matter**
4. **As large sample of quarkonium states as possible** → understand suppression mechanism in **Hot Nuclear Matter** and **Cold Nuclear Matter**

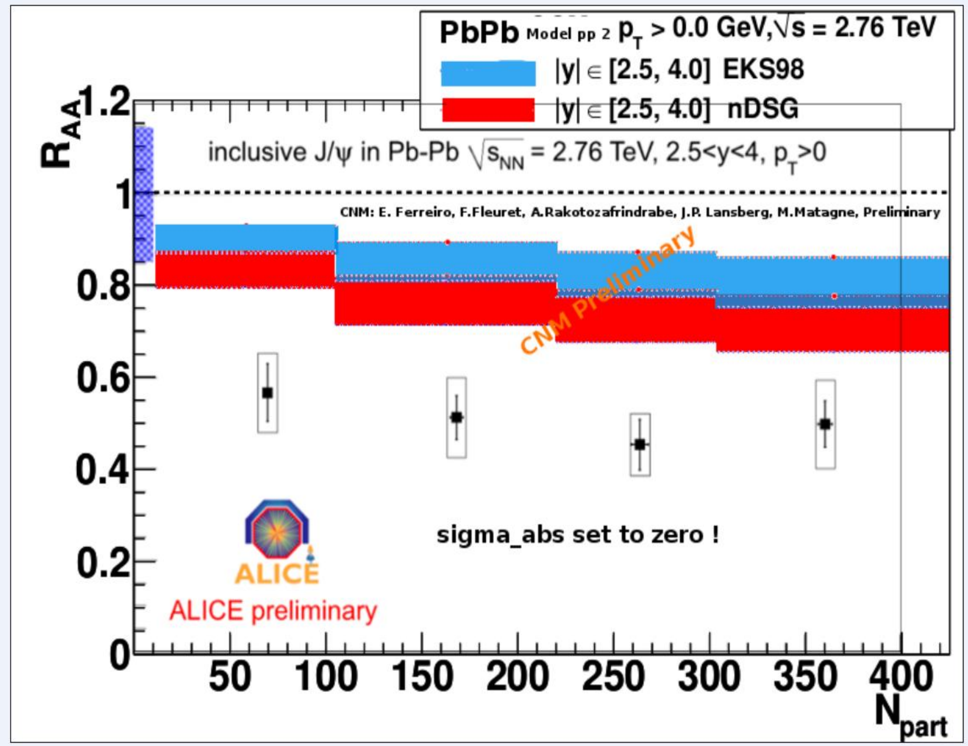
ALICE .vs. FFLMR/2→2+k_T smearing

- **2 → 2 + k_T smearing**
  - x_1/x_2 computed w/ 2→2 before k_T smearing



ALICE .vs. FFLMR/2→2

- **2 → 2**
  - x_1/x_2 computed w/ 2→2
  - No k_T smearing



ALICE .vs. FFLMR/2→2

- **2 → 2**
  - x_1/x_2 computed w/ 2→2
  - No k_T smearing