CHIC, Charme et QGP

– quarkonia suppression in A+A –

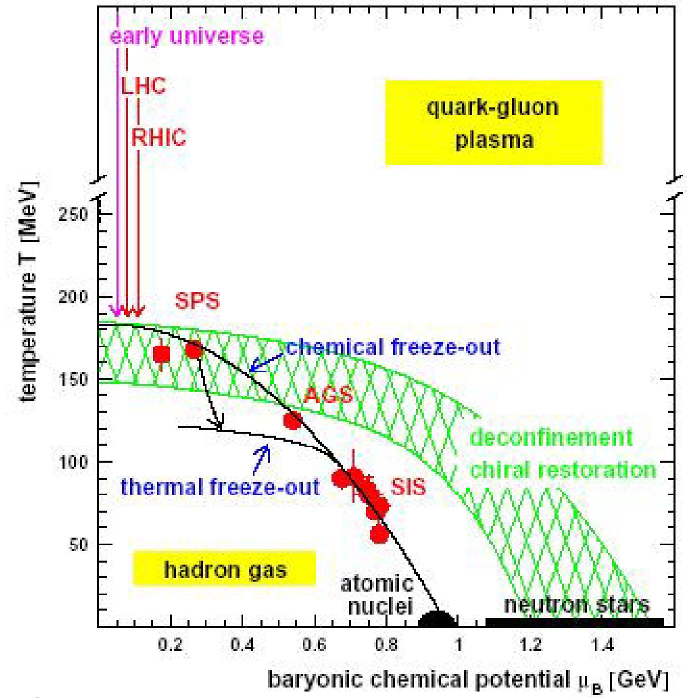
– J/Ψ experimental highlights –

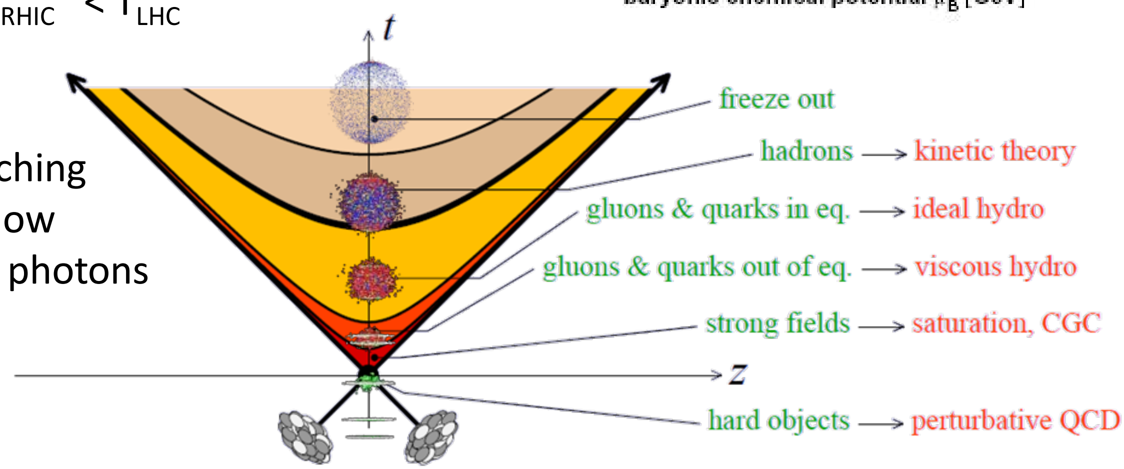
– CHIC physics motivations –

– CHIC experimental aspects –

Quark Gluon Plasma

- **Deconfined matter**
  - **In the universe**
    - **Big bang**: from plasma to confined matter
      - High temperature : 10^{12} K
      - 10^{-6} s
    - **Neutron stars**: from confined matter to plasma
      - Star collapse
      - High density of matter
        (5 to 10 times standard nuclear density)
  - **In the lab: heavy ion collisions**
    - CMS energy: $\sqrt{s}_{SPS} < \sqrt{s}_{RHIC} < \sqrt{s}_{LHC}$
    - Energy density: $\varepsilon_{SPS} < \varepsilon_{RHIC} < \varepsilon_{LHC}$
    - Temperature: $T_{SPS} < T_{RHIC} < T_{LHC}$
  - **QGP features**
    - Very high density : jet quenching
    - Collective motion : elliptic flow
    - High temperature : thermal photons
    - Color screening : **quarkonia**
    - ➔ **finding transition to QGP**





quarkonia suppression in A+A collisions

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J/ψ SUPPRESSION BY QUARK–GLUON PLASMA FORMATION ☆

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If high energy heavy ion collisions lead to the formation of a hot quark–gluon plasma, then colour screening prevents $c\bar{c}$ binding in the deconfined interior of the interaction region. To study this effect, the temperature dependence of the screening radius, as obtained from lattice QCD, is compared with the J/ψ radius calculated in charmonium models. The feasibility to detect this effect clearly in the dilepton mass spectrum is examined. It is concluded that J/ψ suppression in nuclear collisions should provide an unambiguous signature of quark–gluon plasma formation.

quarkonia suppression in A+A collisions

- **Motivations**
  - Quarkonia suppression is a prediction of lattice QCD calculations, for instance :

state	$J/\psi(1S)$	$\chi_c(1P)$	$\psi'(2S)$	$\Upsilon(1S)$	$\chi_b(1P)$	$\Upsilon(2S)$	$\chi_b(2P)$	$\Upsilon(3S)$
T_d/T_c	2.10	1.16	1.12	> 4.0	1.76	1.60	1.19	1.17

H. Satz, J. Phys. G 32 (2006)

- **Experimental setups**

SPS/CERN – NA38, NA50, NA60 ($\sqrt{s_{NN}}$ = 17 – 30 GeV): fixed target experiments

- **Statistic** :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 ∈ [0,1])

RHIC/BNL Phenix experiment ($\sqrt{s_{NN}}$ = 200 GeV): collider experiments

- Statistic : 1000's J/ψ (10000's since 2007)
- Data sets : p+p, d+Au, Cu+Cu, Au+Au
- **Large rapidity coverage** (y ∈ [-0.5,0.5], y ∈ [-2.2,-1.2] and y ∈ [1.2,2.2])

LHC/CERN experiments ($\sqrt{s_{NN}}$ = 5,5 TeV): collider experiments

- Collider experiments
- **Statistic** : 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)

quarkonia suppression in A+A collisions

- **Sequential suppression in a QGP**

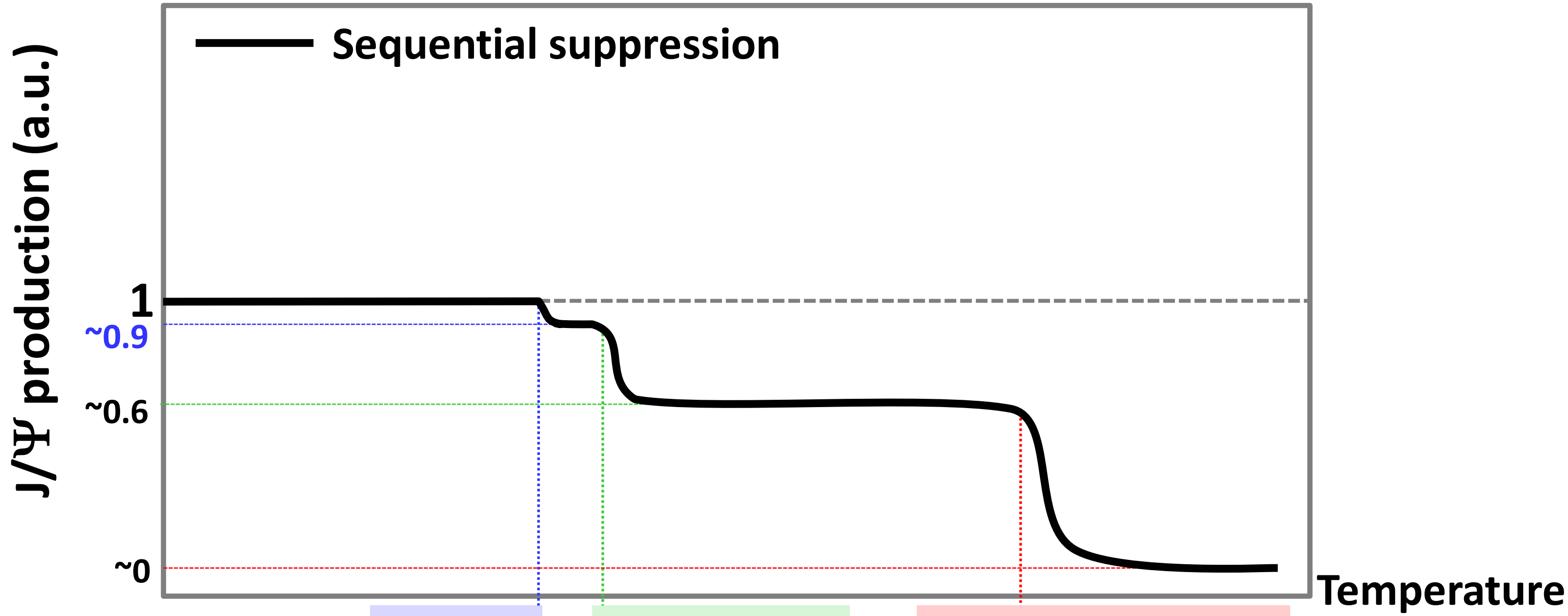
inclusive J/Ψ yield ~ 60% direct J/Ψ + 30% $\chi_c \rightarrow J/\Psi + \gamma$ + 10% Ψ' → J/Ψ + X

Charmonium temperatures of dissociation

state	$J/\psi(1S)$	$\chi_c(1P)$	$\psi'(2S)$
T_d/T_c	2.10	1.16	1.12

H. Satz, J. Phys. G 32 (2006)

$T_{LHC\text{-}CERN} > T_{RHIC\text{-}BNL} > T_{SPS\text{-}CERN}$

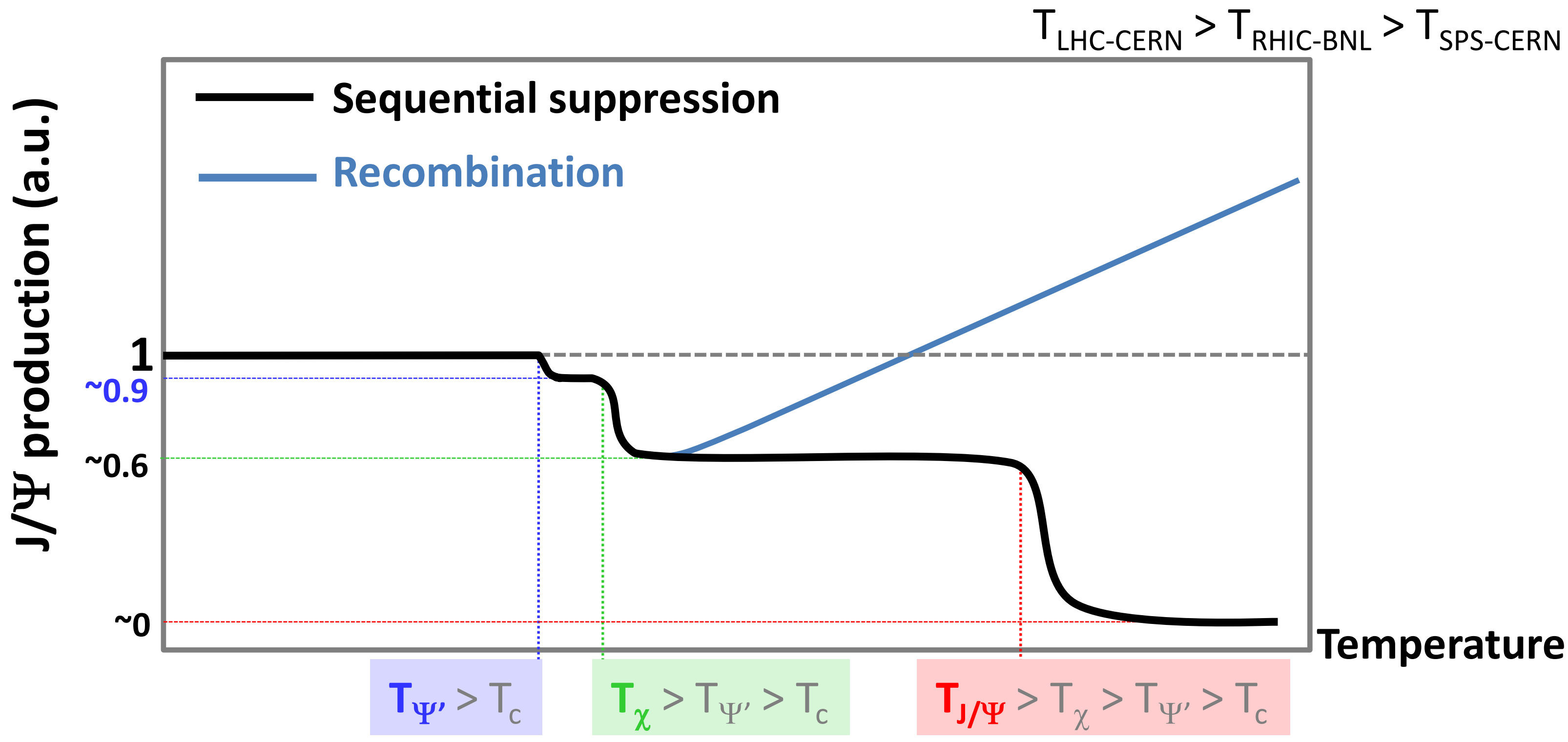


$T_{\Psi'} > T_c$ $T_\chi > T_{\Psi'} > T_c$ $T_{J/\Psi} > T_\chi > T_{\Psi'} > T_c$

quarkonia suppression in A+A collisions

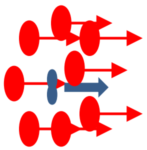
- **Recombination in a QGP**

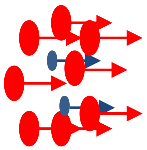
If QGP at work ➔ c and $\bar{c}$ quarks can combine to form a J/Ψ
(require a large number of $c\bar{c}$ pairs → RHIC ? LHC ?)



quarkonia suppression in A+A collisions

- **Suppression by comovers (Alternative scenario)**
  - Suppression by comovers: (Eur.Phys.J.C58:437-444,2008)
    - quarkonia can be broken by interaction with comoving hadrons

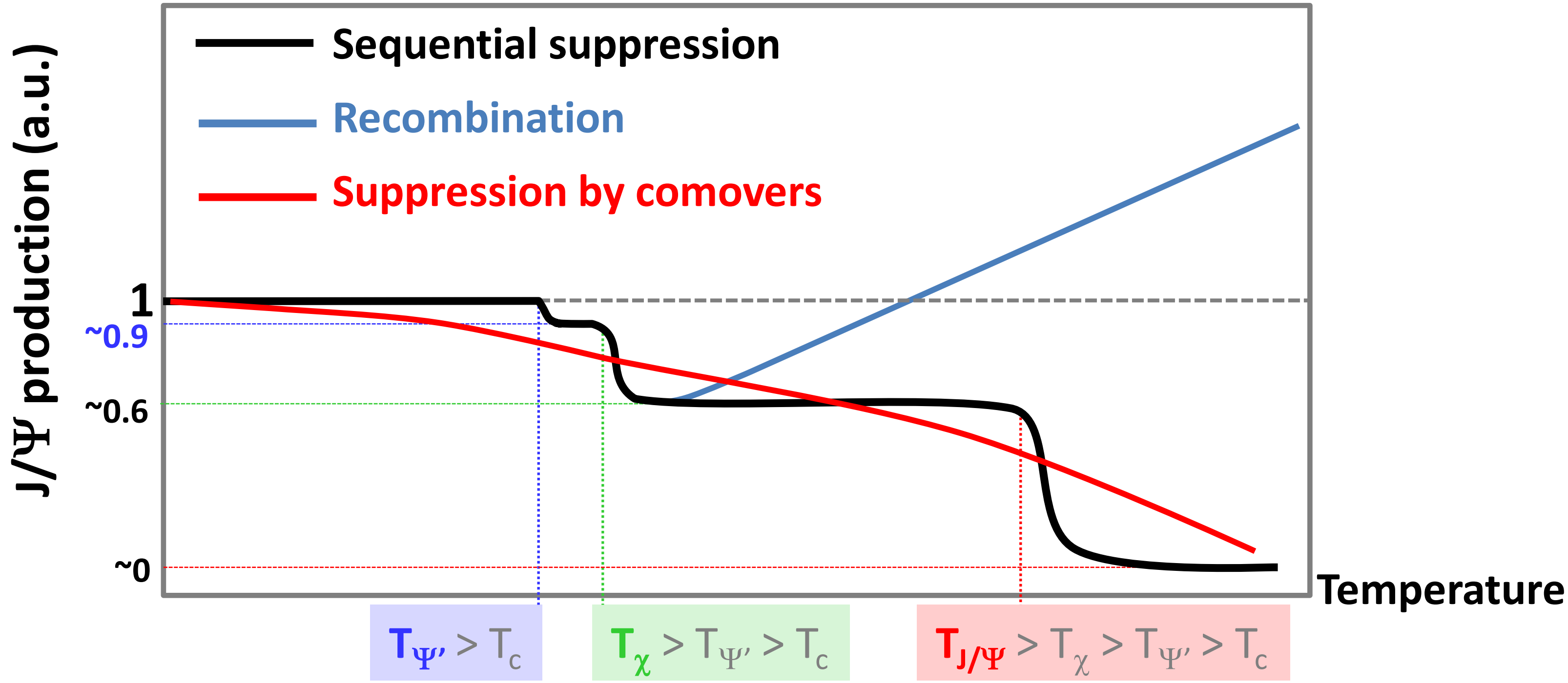




Two parameters

Interaction cross section σ_{co} Hadron density N^{co}

$$\tau \frac{\mathrm{d}N_{J/\psi}}{\mathrm{d}\tau}(b,s,y) = -\sigma_{co} N^{co}(b,s,y) N_{J/\psi}(b,s,y)$$



quarkonia suppression in A+A collisions

- **Observable : Nuclear modification factor R_{AA}**

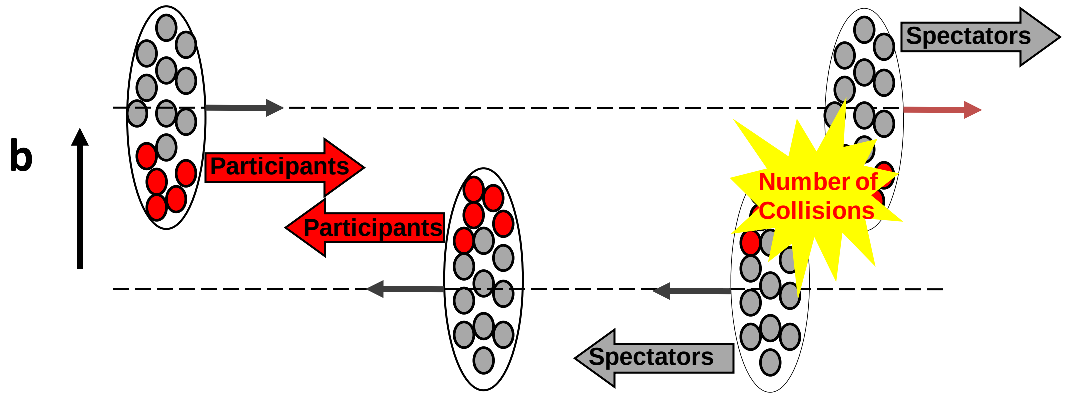
$$R_{AA} = \frac{dN_{AA}}{<N_{coll}> \times dN_{pp}}$$

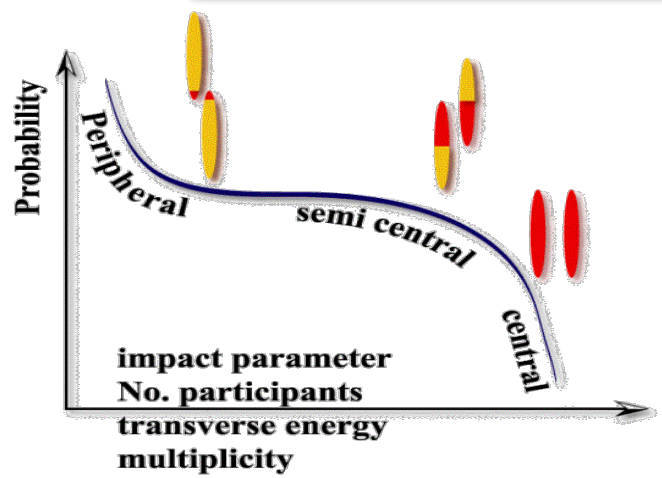
If no nuclear effet, $R_{AA} = 1$

  - dN_{AA} = yield in A+A collisions
  - $<N_{coll}>$ = average number of nucleon-nucleon collisions in A+A collisions
  - dN_{PP} = yield in p+p collisions ≡ yield in one nucleon-nucleon collision

- **Centrality of the nucleus-nucleus collision**
  - N_{part}= number of participant nucleons ≡ interacting nucleons
  - N_{coll} (L)= number of binary collisions ≡ nucleon-nucleon collisions
  - dN_{ch}/dy= produced charged particles density ≡ energy density

Centrality	b (fm)	N_{part}	N_{coll}
0 – 5 %	2.3 ± 0.9	353 ± 19	1091 ± 102
20 – 25 %	7.1 ± 0.5	181 ± 16	422 ± 65
90 – 95%	14.5 ± 0.3	4.1 ± 2.5	2.8 ±2.2





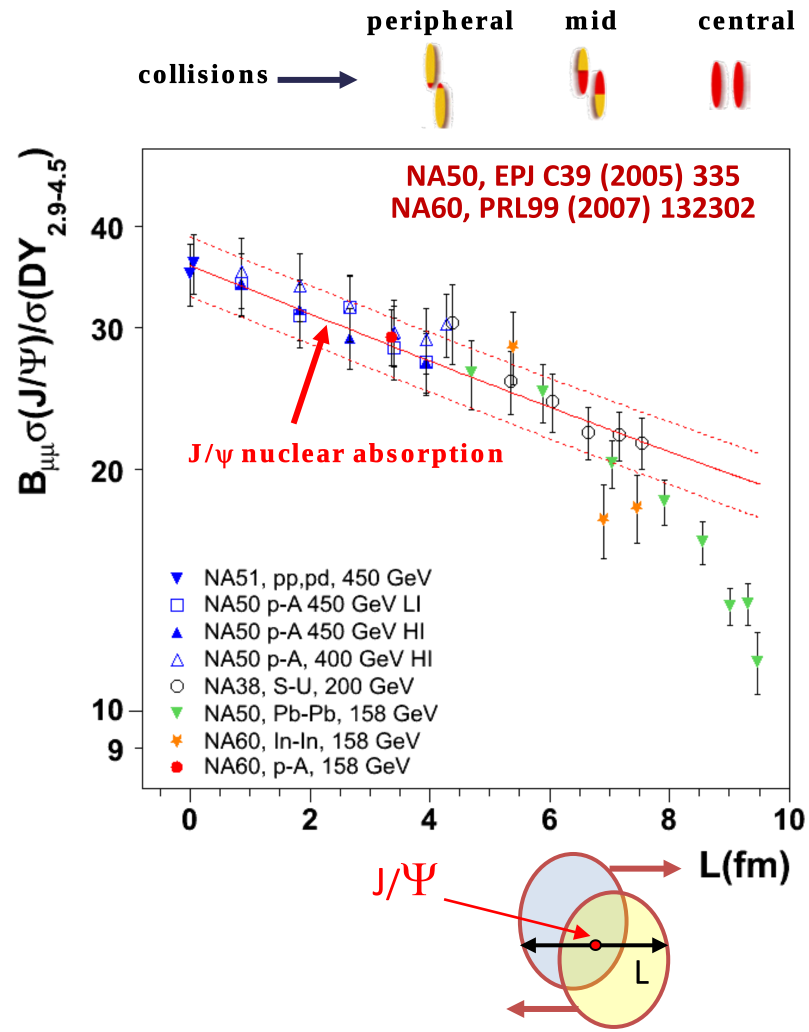
J/Ψ experimental highlights

- **SPS (17 GeV): NA38, NA51, NA50, NA60**

Two major results :

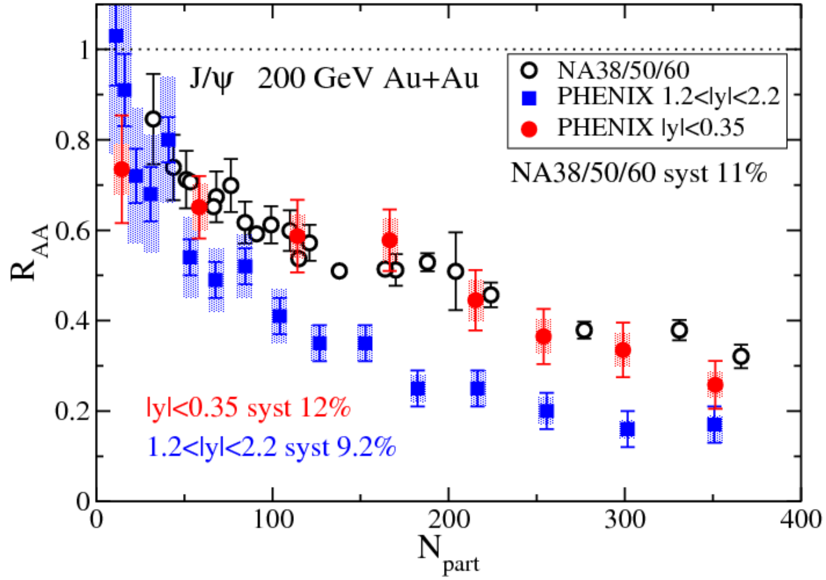
1. Observation of **Cold Nuclear Matter effects :** Absorption by nuclear matter
   - Suppression observed from p+p to peripheral Pb+Pb
   - J/ψ survival probability : $S(J/\Psi) \propto e^{-\rho\sigma_{abs}L}$
   - Fit to data: **σ_{abs}=4.18 ±0.35 mb**

2. Observation of **Anomalous suppression** in Pb+Pb (NA50) central collisions when compared with Cold Nuclear Matter effects.

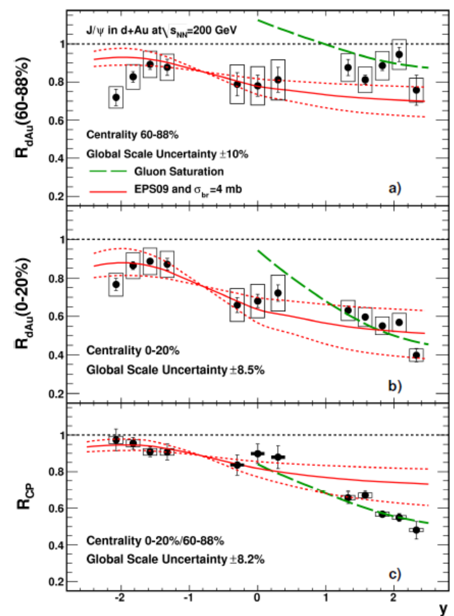


J/Ψ experimental highlights

- **RHIC (200 GeV) .vs. SPS (17 GeV)**
  1. Hot and dense matter effects
     - Measure J/Ψ in Au+Au (RHIC) Pb+Pb (SPS)
     - Compare at same rapidity (same y ~ same x_F)
       - 0<y<1 at SPS **(NA50/NA60)**
       - |y|<0.35 at RHIC **(PHENIX)**
     - Expected larger suppression at RHIC due to larger energy density
     - observe **SIMILAR SUPPRESSION at mid rapidity**
     - Observe **LARGER SUPPRESSION at forward rapidity**

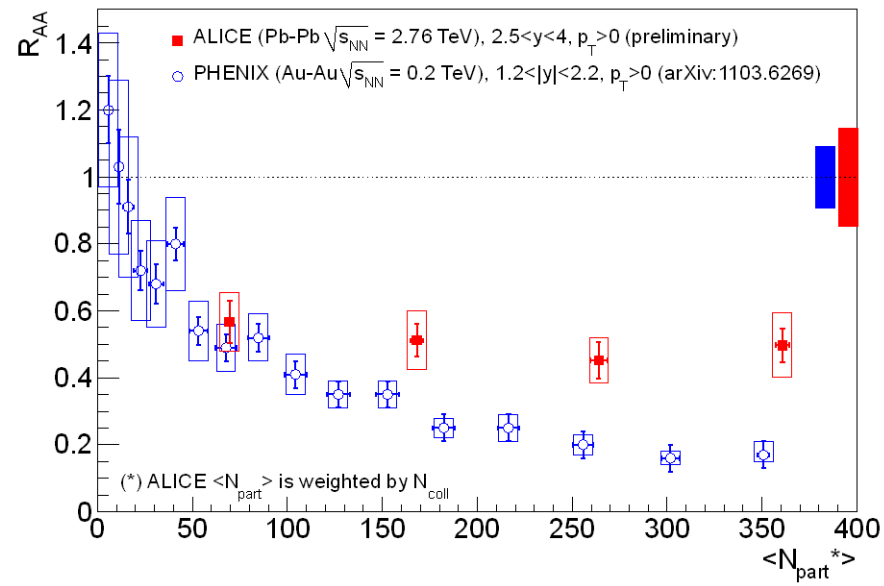


  2. Cold Nuclear Matter effects at RHIC
     - Measure J/Ψ production in d+Au collisions
     - Observe **LARGER SUPPRESSION at forward rapidity (small x_2)**
     - Pattern still not fully understood
     - Difference forward.vs.mid rapidity may explain larger suppression observed in forward Au+Au

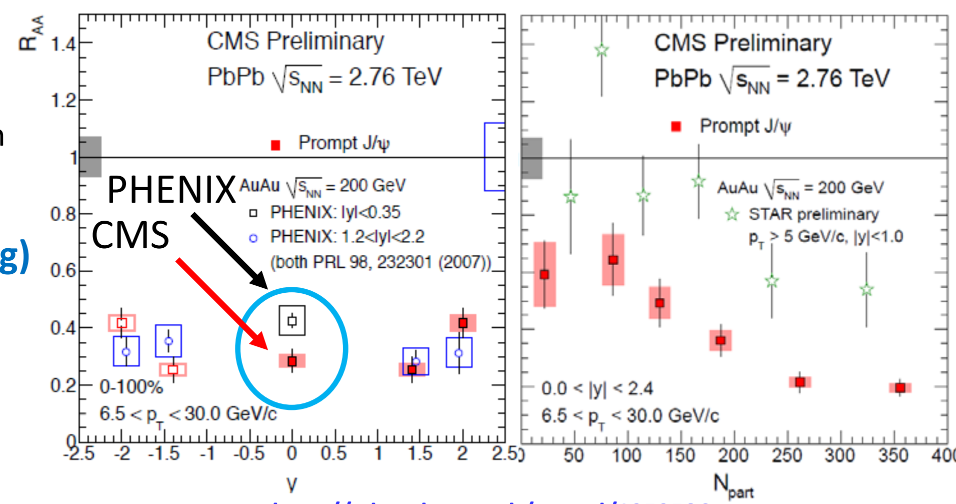


J/Ψ experimental highlights

- **RHIC (200 GeV) .vs. LHC (2.76 TeV) at forward rapidity**
  - Compare PHENIX vs ALICE
    - 1.2 < |*y*| < 2.2 at RHIC/**PHENIX**
    - 2.5 < *y* < 4 at LHC/**ALICE**
  - **LESS SUPPRESSION** at LHC .vs. RHIC
  - Could be due to **recombination** effects



- **RHIC (200 GeV) .vs. LHC (2.76 TeV) at mid-rapidity**
  - Compare PHENIX, STAR vs CMS
    - |y|<0.35 at RHIC/**PHENIX**
    - |y|<1 at RHIC/**STAR**
    - |y|<1 at LHC/**CMS**
  - **MORE SUPPRESSION** at LHC .vs. RHIC
    - p_T>6.5 GeV/c ➔ in principle no recombination applies
    - larger suppression due to **QGP effects ?**
  - Hint of **sequential suppression ? (J/Ψ melting)**



Caution : Need CNM effects comparison

http://cdsweb.cern.ch/record/1353586

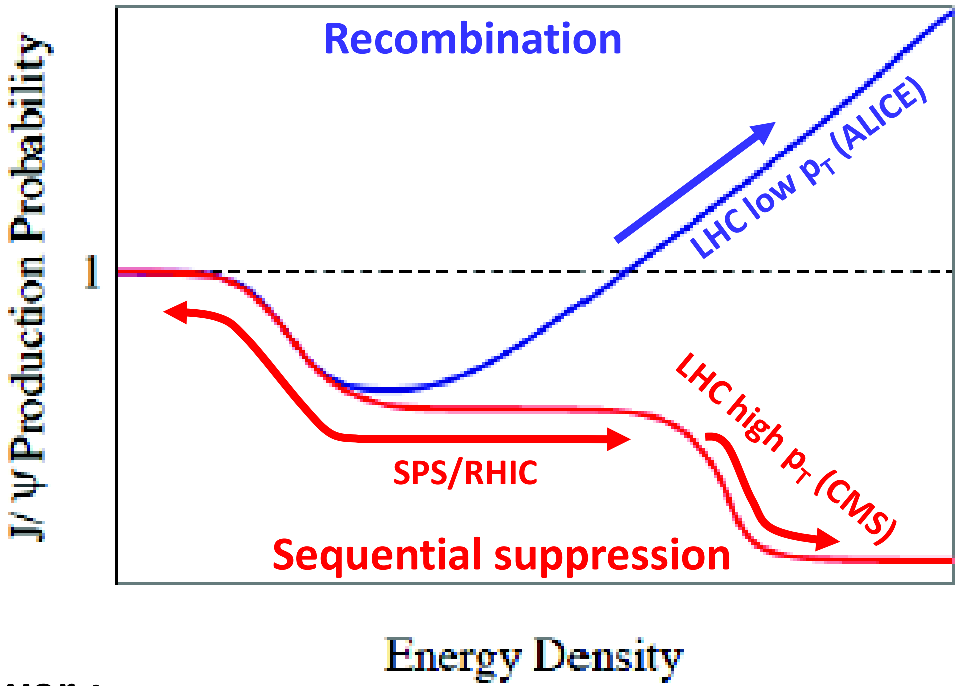
quarkonia suppression in A+A

- **Overall possible J/Ψ (simplified) picture**

1. ***Similar suppression* at SPS.vs.RHIC**

2. ***Larger suppression* at LHC outside recombination regime**
   CMS results
   Hint of sequential suppression ?
   (assuming CNM effects are the same or smaller)

3. ***Smaller suppression* at LHC inside recombination regime**
   ALICE results
   Hint of recombination?
   (assuming CNM effects are the same of larger)



- **Next fondamental questions to answer :**
  – ***Are CNM effects playing an important role at LHC ?*** p+Pb run
  – ***Is recombination mechanism at work ?*** J/Ψ at mid-rapidity at low p_T
  – ***Is sequential suppression at work ?*** measure χ_c in A+A→ not accessible → **CHIC**

CHIC – Physics motivations

- **Benchmark 1: Measure χ_c in A+A at SPS**

Physics goal : <u>test charmonium sequential suppression scenario</u>

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 at SPS ?

➡ **Lowest energy density where anomalous suppression has been seen.**

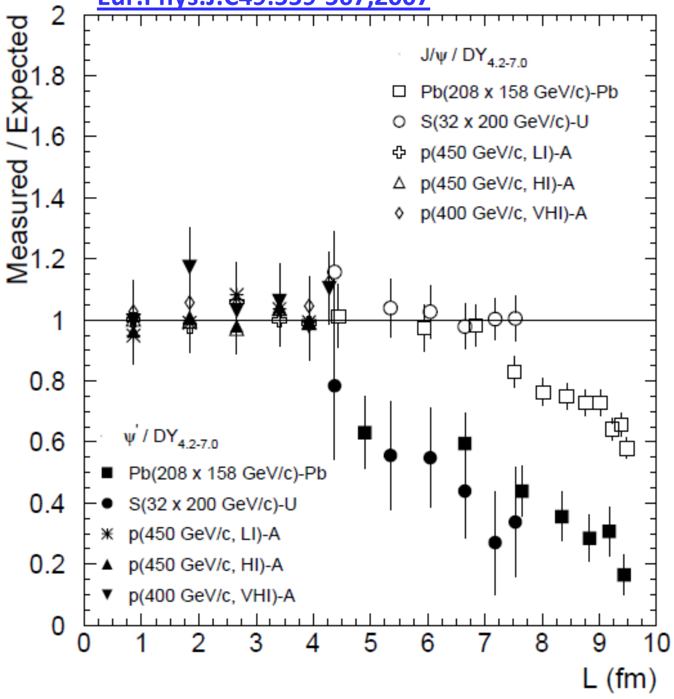
➡ **Appropriate range of energy density to investigate full sequential suppression : Ψ', χ_c and J/Ψ**

➡ **No recombination at SPS**

Why a fixed target experiment ?

➡ **Precise control of normal suppression (CNM effects)**

Eur.Phys.J.C49:559-567,2007



CHIC – Physics motivations

- **Quarkonia suppression**

At SPS

60% direct J/Ψ
+ 30% $\chi_c \rightarrow J/\Psi + \gamma$
+ 10% $\Psi' \rightarrow J/\Psi + X$

Inclusive J/Ψ yield

Two possible scenarios:

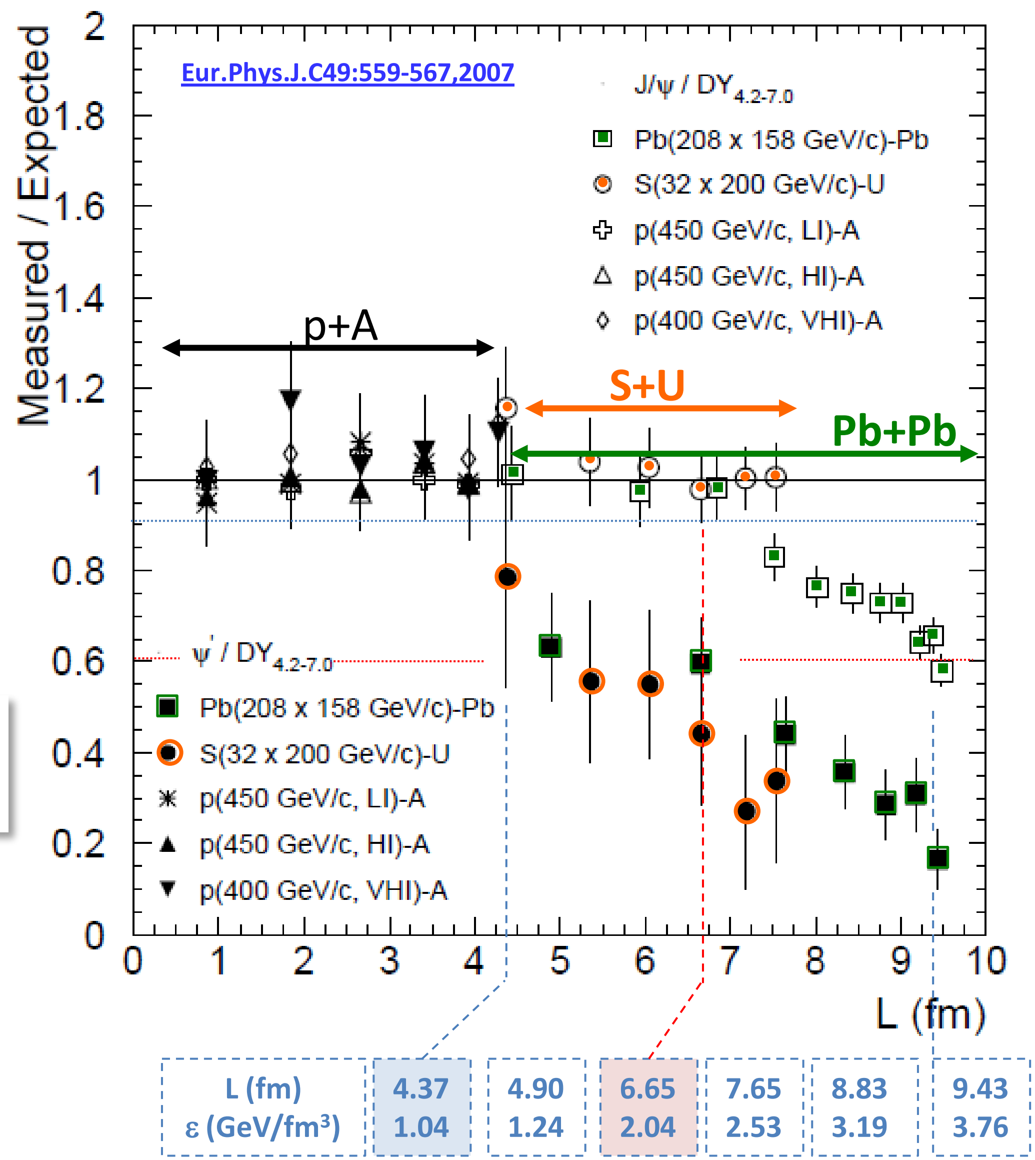
- **sequential suppression (QGP)**
- **comovers (no QGP)**

Temperature of dissociation

state	$J/\psi(1S)$	$\chi_c(1P)$	$\psi'(2S)$	$\Upsilon(1S)$	$\chi_b(1P)$	$\Upsilon(2S)$	$\chi_b(2P)$	$\Upsilon(3S)$
T_d/T_c	2.10	1.16	1.12	> 4.0	1.76	1.60	1.19	1.17

Binding energy

state	η_c	J/ψ	χ_{c0}	χ_{c1}	χ_{c2}	ψ'
mass [GeV]	2.98	3.10	3.42	3.51	3.56	3.69
ΔE [GeV]	0.75	0.64	0.32	0.22	0.18	0.05



CHIC – Physics motivations

- **Two possible scenarios**

1. QGP (sequential suppression)

state	η_c	J/ψ	χ_{c0}	χ_{c1}	χ_{c2}	ψ'
mass [GeV]	2.98	3.10	3.42	3.51	3.56	3.69
ΔE [GeV]	0.75	0.64	0.32	0.22	0.18	0.05

Because ΔE (Ψ') ~50 MeV

- **Ψ' easily suppressed by comovers**

Because $\Delta E(\chi_c)$~200 MeV and $\Delta E(J/\Psi)$~600 MeV

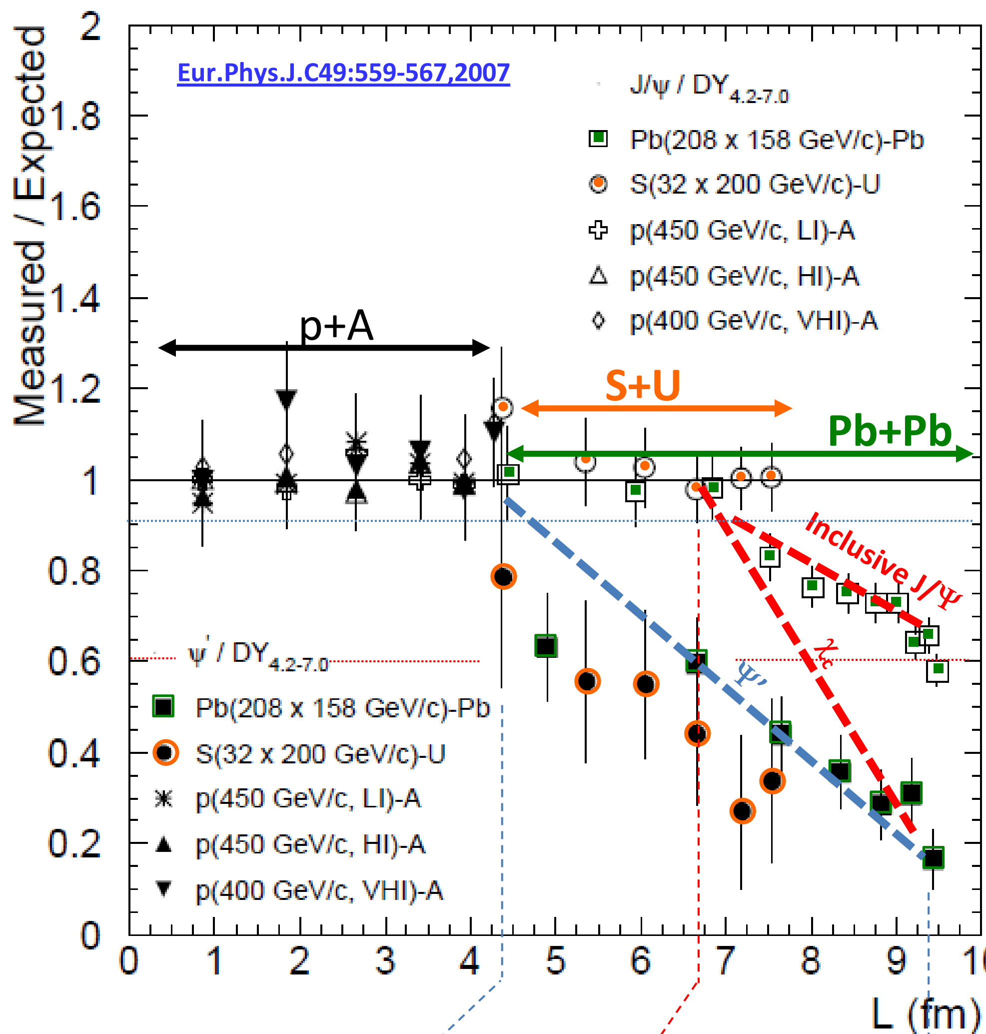
- **χ_c and J/Ψ hardly suppressed by comovers**

If χ_c suppressed by **QGP**,

- **χ_c slope strongly steeper than J/Ψ and Ψ'**

Measuring

χ_c suppression pattern
will (in)validate this



L (fm)	4.37	4.90	6.65	7.65	8.83	9.43
ε (GeV/fm³)	1.04	1.24	2.04	2.53	3.19	3.76

Note that direct J/Ψ can be experimentally estimated

$$\text{Yield}_{\text{incl.}J/\Psi} - \text{Yield}_{\chi c \to J/\Psi+\gamma} - \text{Yield}_{\Psi'} \sim \text{Yield}_{\text{direct } J/\Psi}$$

CHIC – Physics motivations

- **Two possible scenarios**

2. No QGP (full comovers)

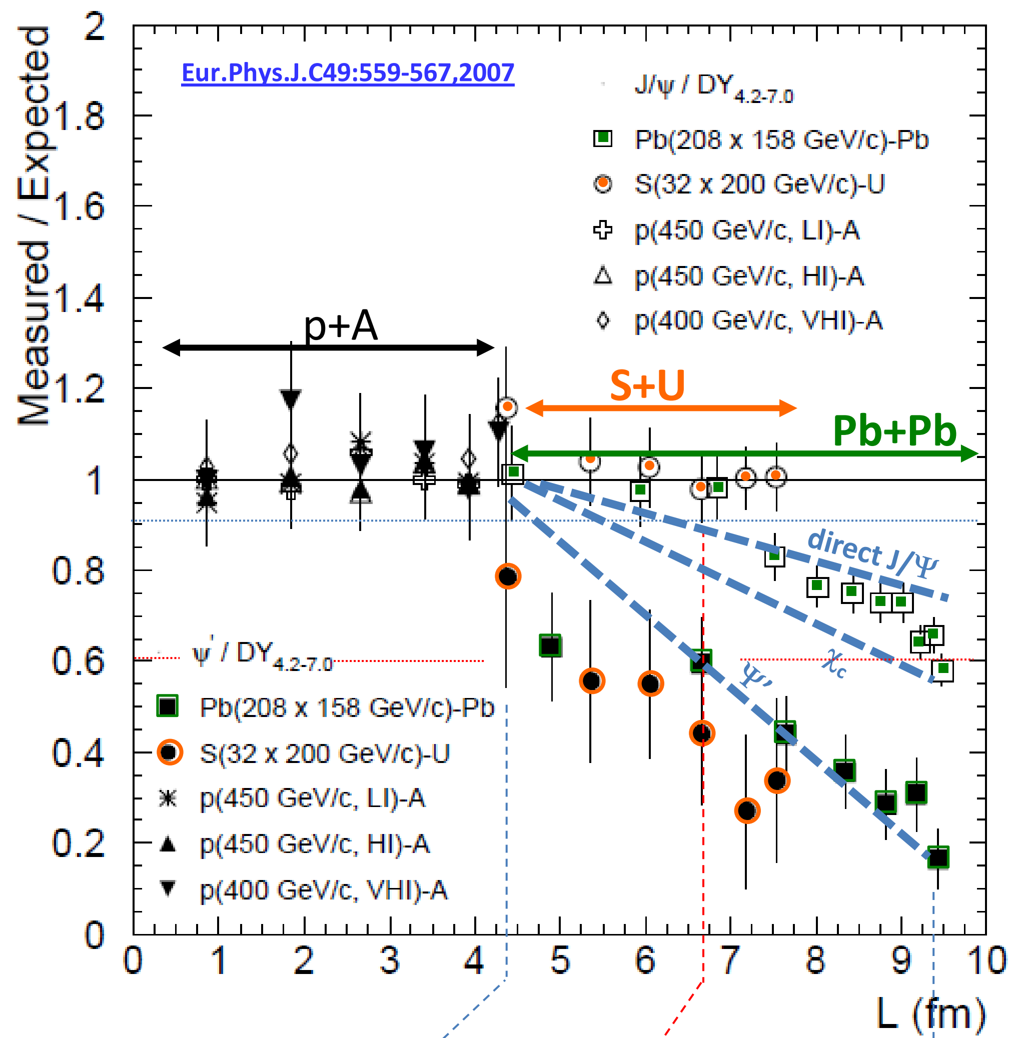
state	η_c	J/ψ	χ_{c0}	χ_{c1}	χ_{c2}	ψ'
mass [GeV]	2.98	3.10	3.42	3.51	3.56	3.69
ΔE [GeV]	0.75	0.64	0.32	0.22	0.18	0.05

Because $\sigma_{J/\Psi\text{-co}} \leq \sigma_{\chi c\text{-co}} \leq \sigma_{\Psi'\text{-co}}$

- Ψ' slope slightly steeper than χ_c
- χ_c slope slightly steeper than J/Ψ

Measuring

χ_c suppression pattern will (in)validate this



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$\text{Yield}_{\text{incl.}J/\Psi} - \text{Yield}_{\chi c \to J/\Psi+\gamma} - \text{Yield}_{\Psi'} \sim \text{Yield}_{\text{direct } J/\Psi}$

CHIC – Physics motivations

- **Conclusion : measure χ_c in A+A at SPS**

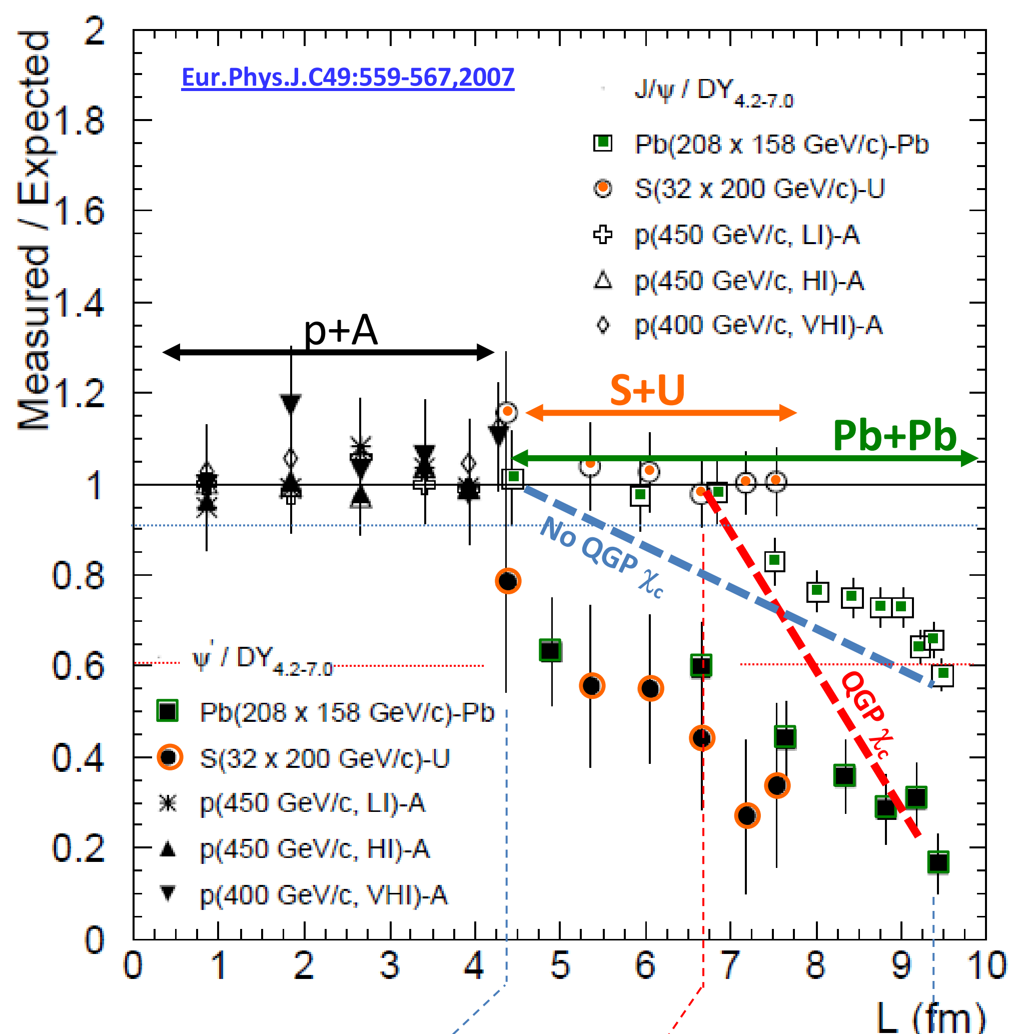
measuring

Ψ', J/Ψ and χ_c suppression pattern

will answer the question

------ QGP

------ no QGP



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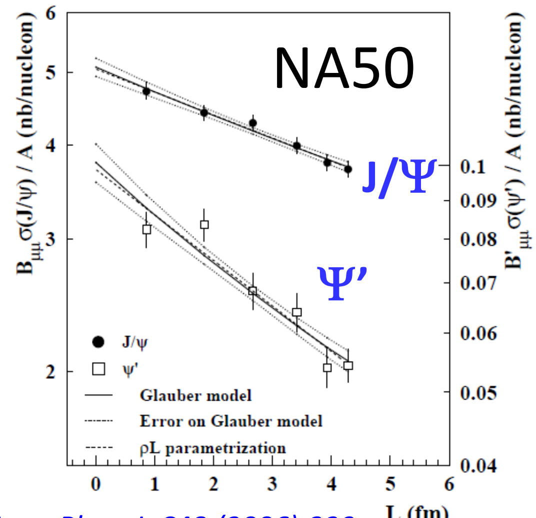
CHIC – Physics motivations

- **Benchmark 2: Measure charmonium in p+A at SPS**

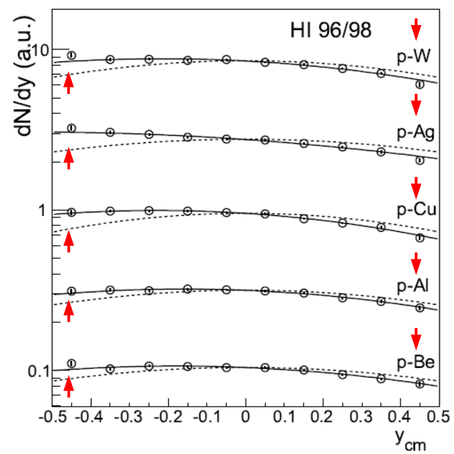
J/Ψ and Ψ’ **suppression** in p+A collisions as a function of L



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

➔ Measuring different charmonium states gives key information on Cold Nuclear Matter 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

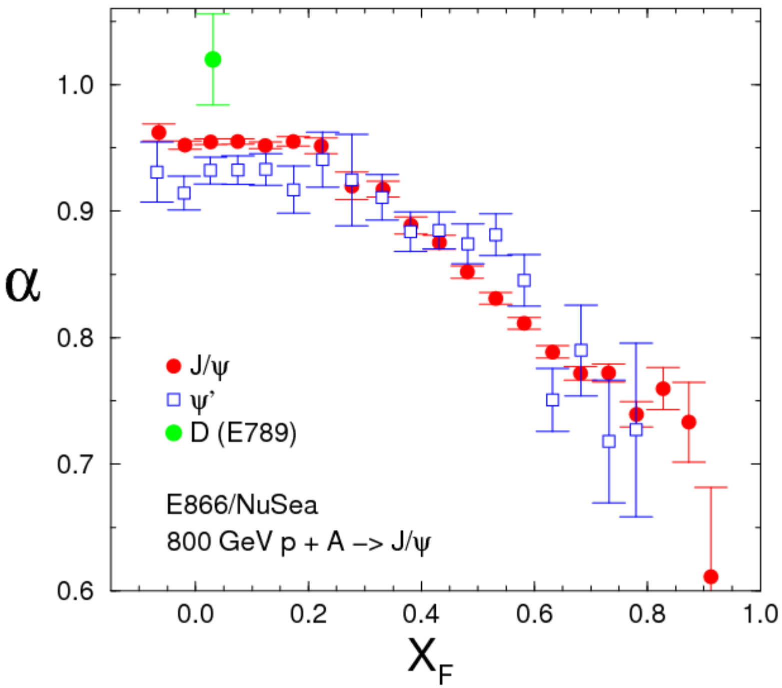
CHIC – Physics motivations

- **Measure charmonium in p+A at SPS**

➔ Measuring charmonium in a wide x_F range is important to estimate 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

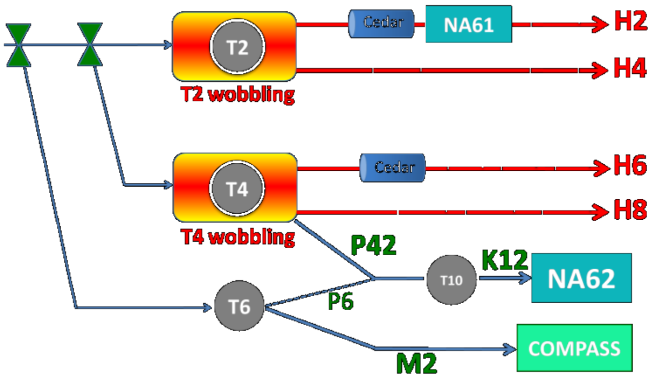
Benchmark 2 : Measure charmonium states within $y_{CMS} \in [-0.5, 2]$

3. Other physics subjects

Open charm, low mass resonances, Drell-Yan,…

CHIC – Expected yields

North Area Beamlines



- **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

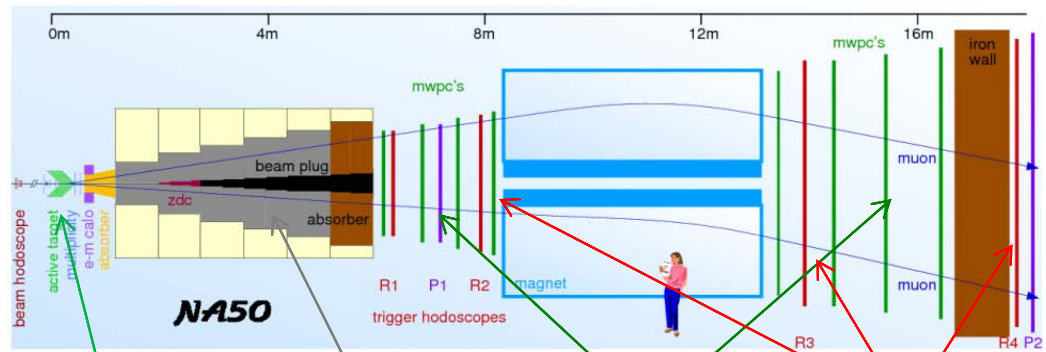
- **NA50: European Physical Journal C39 (2005) 335**
  - *New measurement of J/ψ suppression in Pb+Pb at 158 GeV/nucleon*
  - 35 days of data taking in 2000
  - ~1.10^7Pb/s over 5s bursts every 20s
  - 4 mm thick Pb target ($10\%\lambda_I$)
  - ~ 100 000 $J/\Psi \rightarrow \mu^+\mu^-$ within $y_{CMS}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

- **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

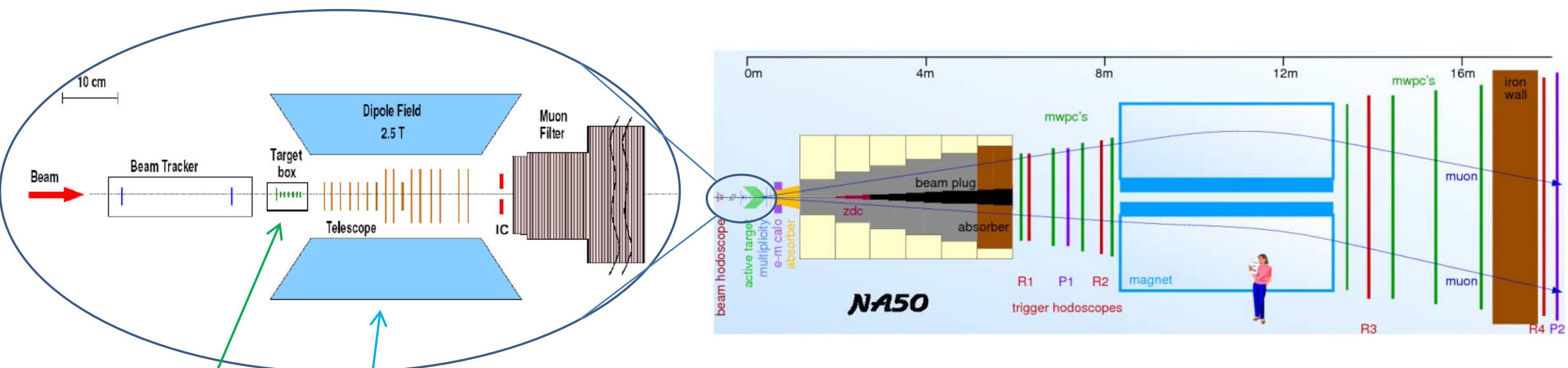
- **Past experiments**

1st generation: NA38,NA50,NA51
Measure dimuons



Target → absorber → spectrometer → muID

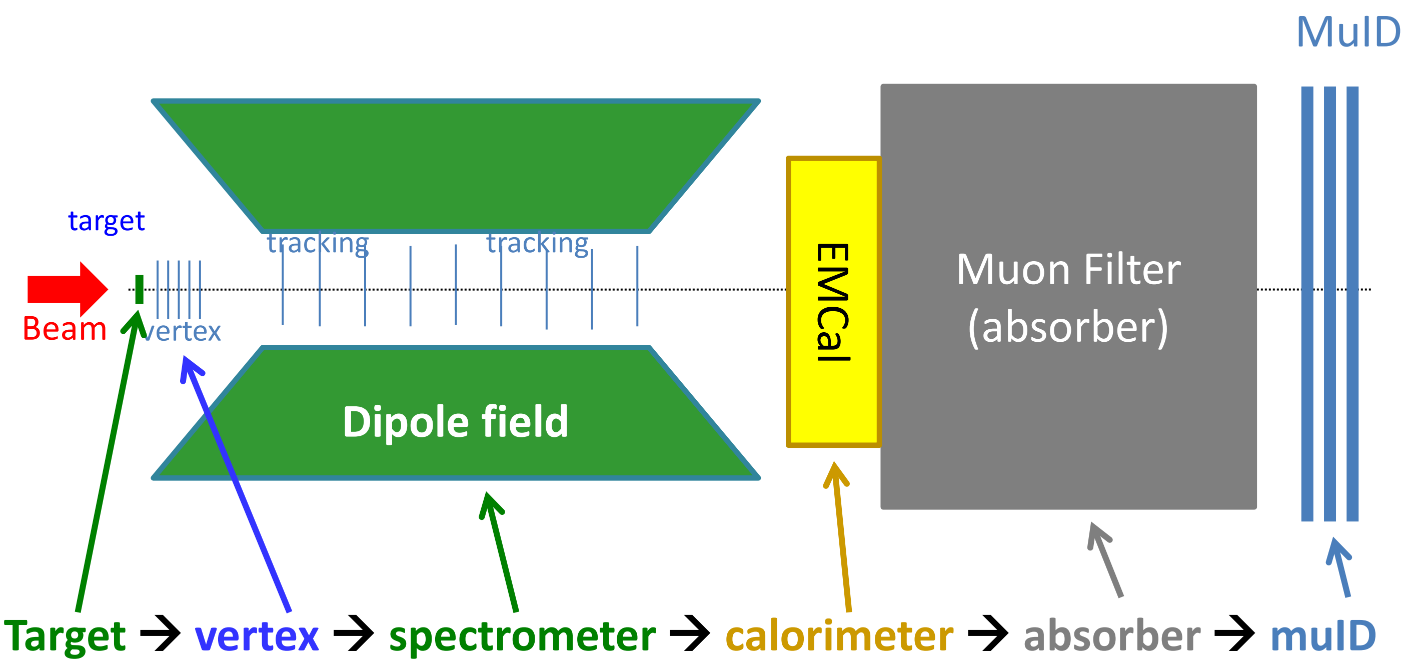
2nd generation: NA60
Measure dimuons and open charm vertex



Target → telescope

CHIC – detector design

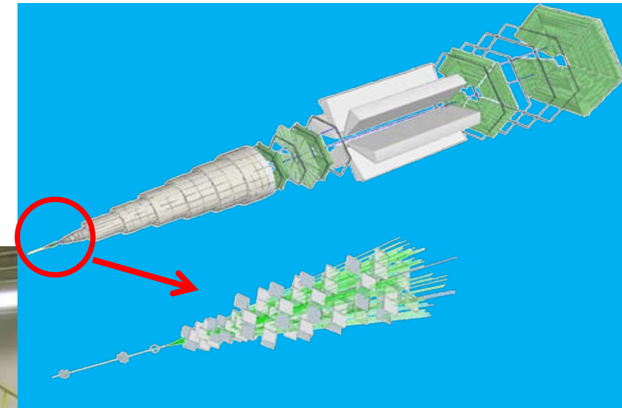
- **3rd generation: CHIC**
  - Measure dimuons and **photons**
    - Must place the **calorimeter in front of the absorber**
    - Must separate photon/electron ➔ **tracking in front of the calorimeter.**

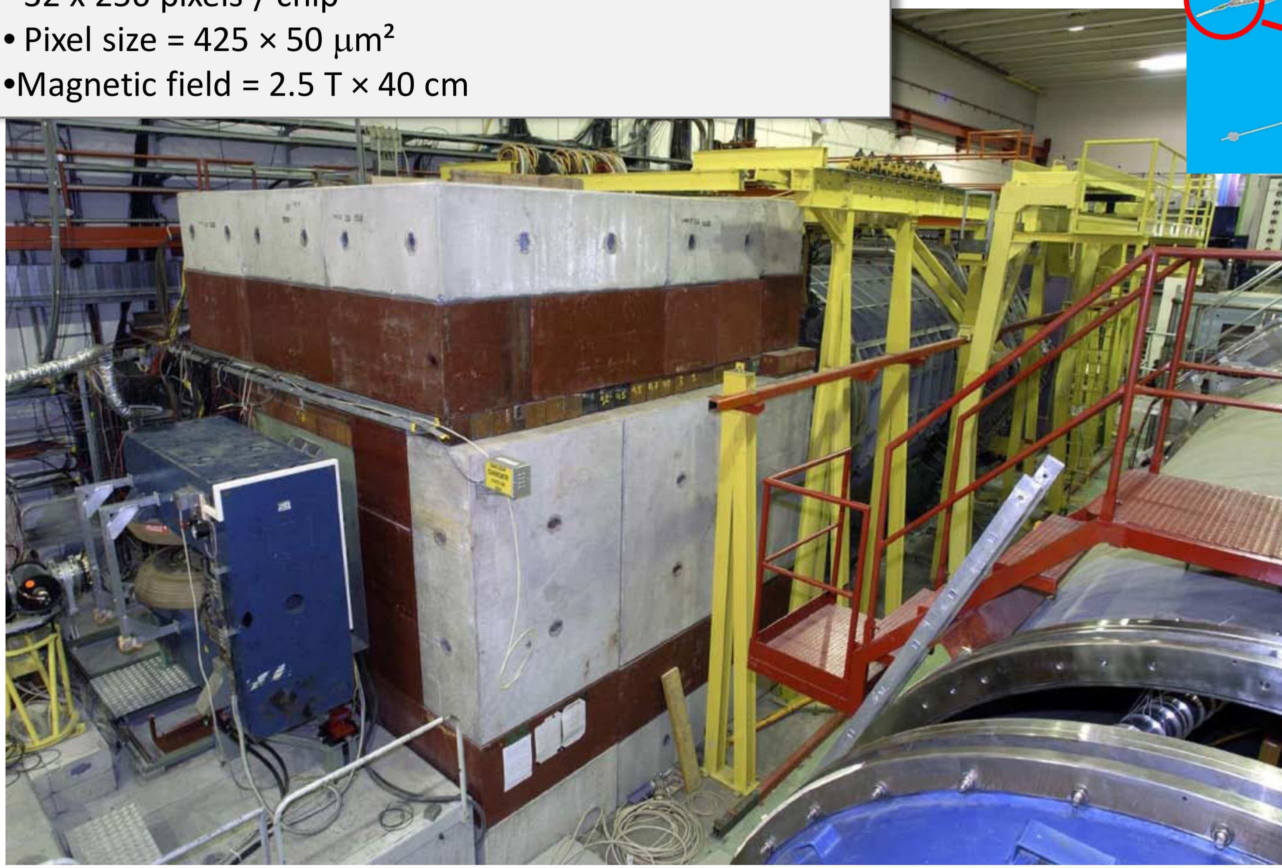


CHIC – tracking

- **The NA60 example**

Pixel detector
- 16 planes – 96 chips total
- 32 x 256 pixels / chip
- Pixel size = 425 × 50 μm²
- Magnetic field = 2.5 T × 40 cm





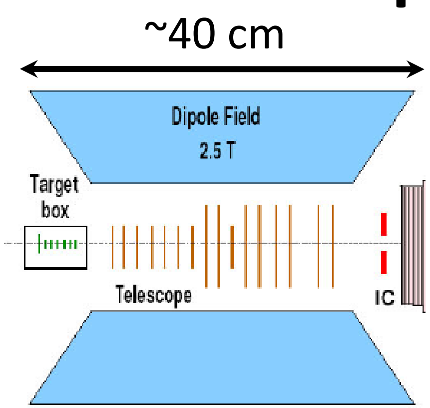
Momentum resolution
@J/Ψ mass
(typical p_μ ~ 15 GeV/c)

$$\frac{\Delta P}{P} \sim 6\%$$

(R. S. priv. Comm.)

CHIC – tracking

- **The NA60 pixel detector**



$$\boxed{\frac{\Delta P}{P} = 6\%} \Rightarrow \frac{\Delta M}{M} = \frac{\Delta P}{\sqrt{2}P} = 4.2\% \Rightarrow \boxed{\Delta M_{J/\Psi} \sim 130\text{ MeV}}$$

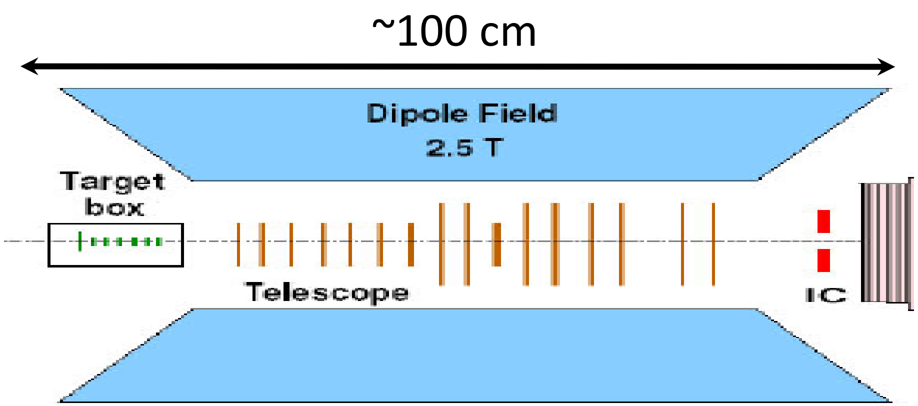
***L* = 0.4 m**

$$\boxed{\frac{\Delta P}{P} \propto \frac{1}{BL^2} P}$$

***L* = 1 m**

$$\boxed{\frac{\Delta P}{P} = 1\% \Rightarrow \Delta M_{J/\Psi} \sim 20\text{ MeV}}$$

- **The CHIC pixel detector**



CHIC – tracking

- **Size, position, resolution : tentative design – toy**

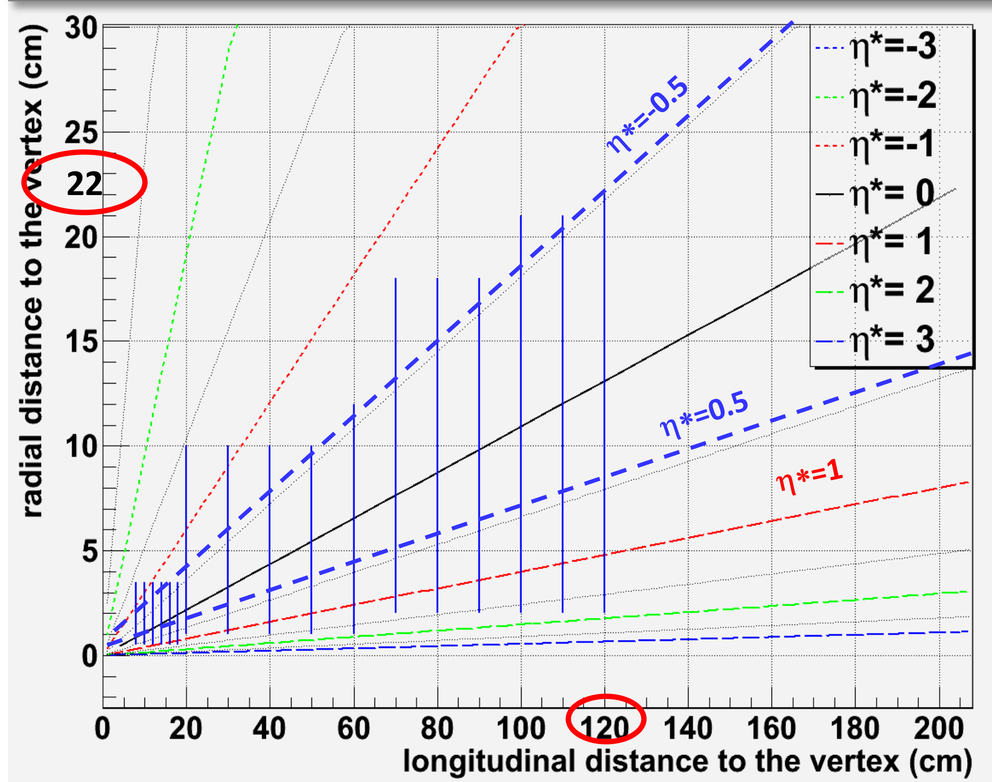
B (T)	L (cm)	ΔP/P (%)	ΔM (MeV)
2.5	40	~ 6	~120
2.5	60	~ 2.7	~60
2.5	80	~ 1.5	~30
2.5	**100**	**~1**	**~20**

← NA60 (row 1)
← CHIC (row 4)

11 plane spectrometer

@ z_{max} = 120 cm → $r_{max}(\eta^*=-0.5)$~22 cm

11 planes from z=20 cm to z = 120 cm

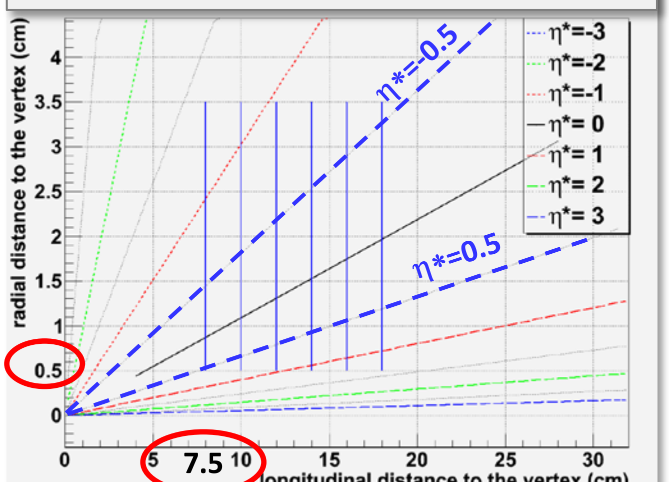


Track particles within $\eta^* \in [-0.5 ; 1]$

6 plane vertex

@ r_{min} = 0.5 cm → $z_{min}(\eta^*=0.5)$~7.5 cm

6 planes from z=8 cm to z=18 cm



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B (T)	L (cm)	ΔP/P (%)	ΔM (MeV)
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2.5	**100**	**~1**	**~20**

← NA60 (row 1)

← CHIC (row 4)

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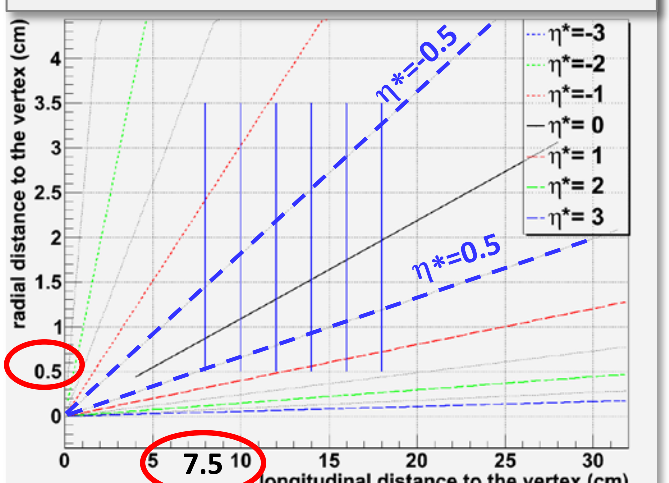
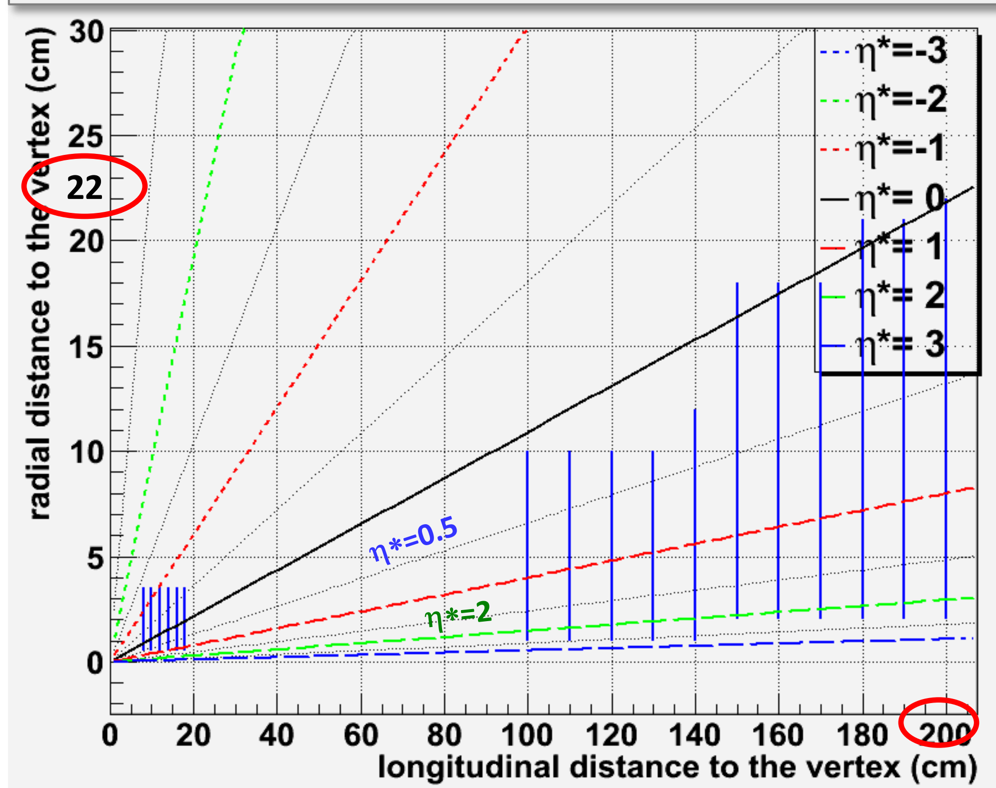


11 plane spectrometer

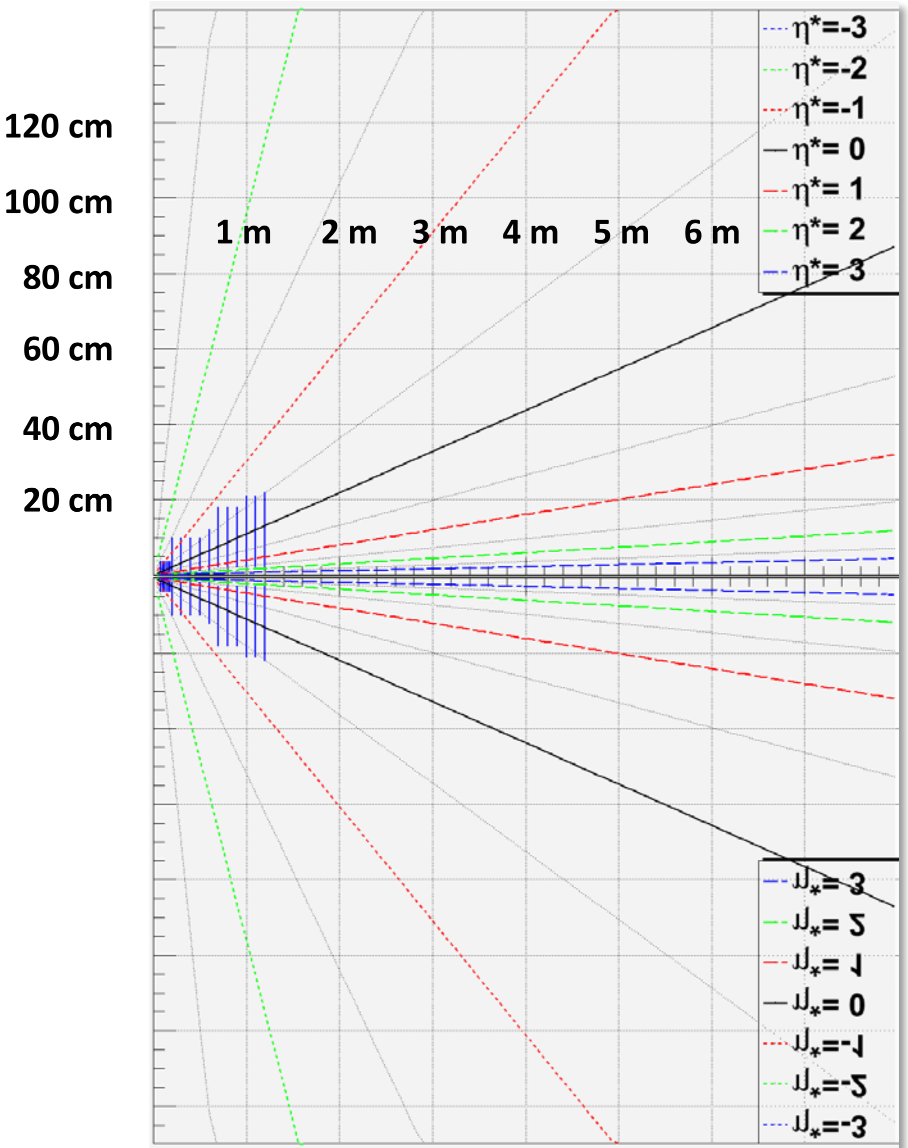
@ z_{max} = 120 cm ➔ $r_{max}(\eta^*=-0.5)$~22 cm

11 planes from z=100 cm to z = 200 cm



Track particles within $\eta^* \in [0.5 ; 2]$

CHIC – tentative design



Vertex detector :

R_{min} = 0.5 cm Z_{min} = 7.5 cm

R_{max} = 3.5 cm Z_{max} = 18 cm

Spectrometer :

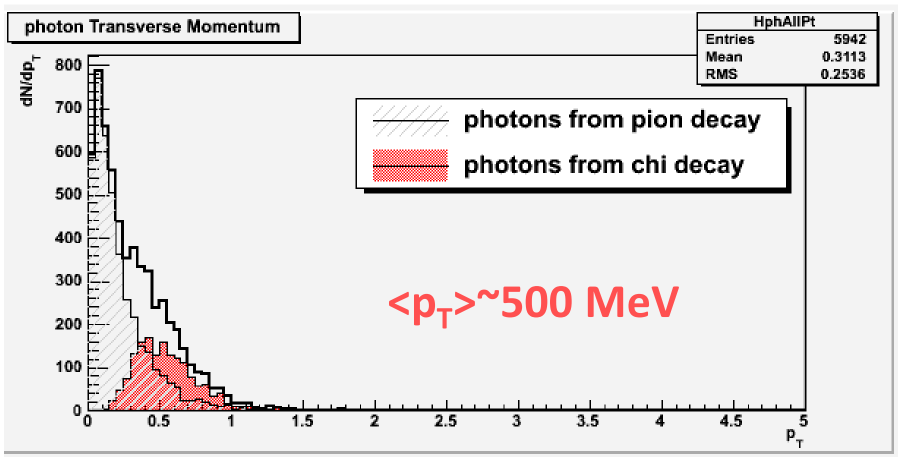
R_{min} = 1 cm Z_{min} = 20 (100) cm

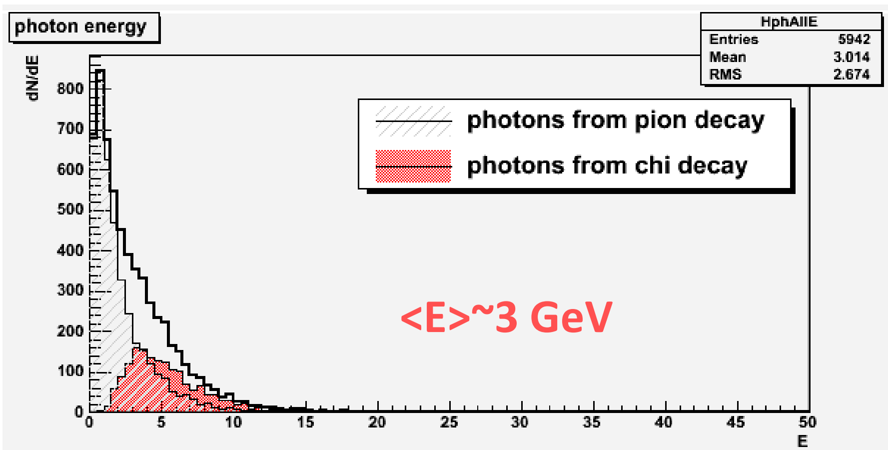
R_{max} = 22 cm Z_{max} = 120 (200) cm

CHIC – calorimetry

- **Goal : measure $\chi_c \rightarrow J/\Psi + \gamma$**
- **Issues**
  1. Low energy photon (similar to $\pi^0 \rightarrow \gamma\gamma$)
  2. High multiplicity of photon from $\pi^0 / \eta \rightarrow \gamma\gamma$
  3. High multiplicity of charged particles ($\pi^{+/-}$)

Pythia 6.421 - p+p - $\sqrt{s}$ = 17.2 GeV





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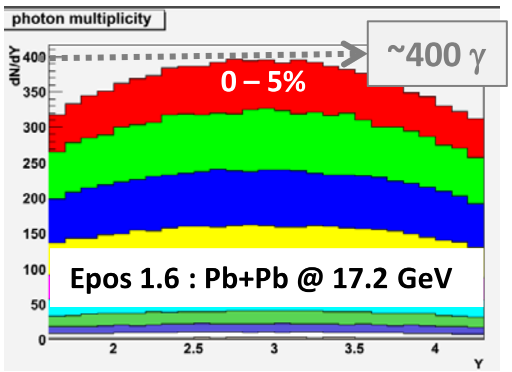
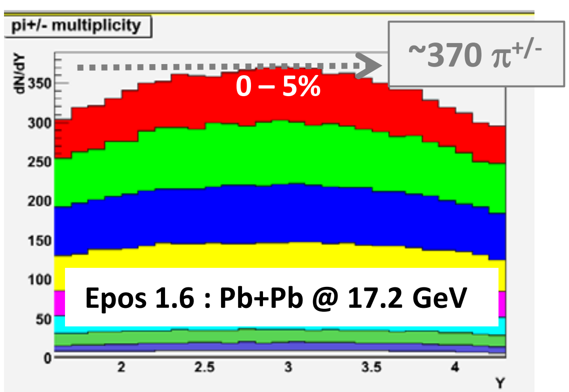
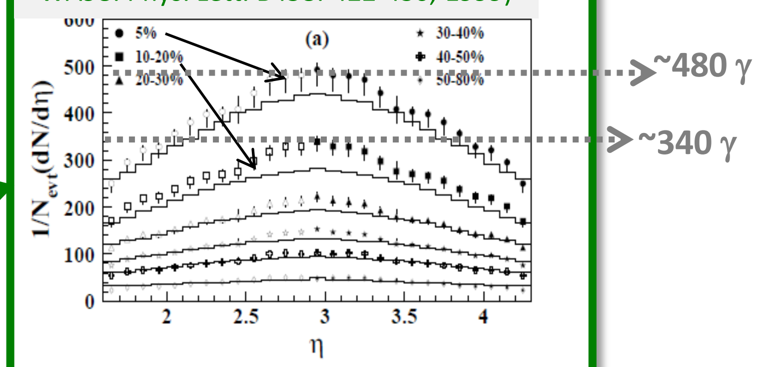
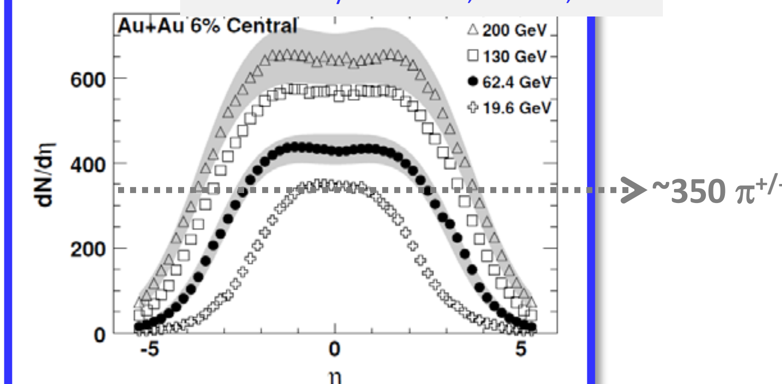




WA98: Phys. Lett. B458: 422-430, 1999)



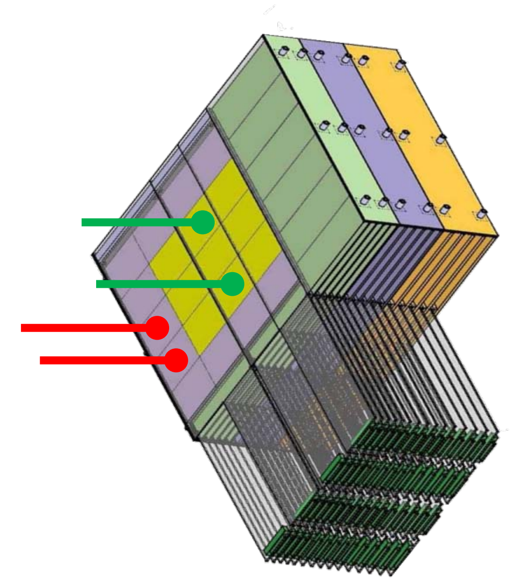
Phobos: Phys. Rev. C74, 021901, 2006



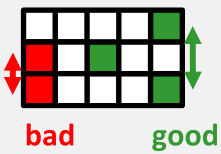
0 – 5% Pb+Pb most central → ~450 γ + 350 $\pi^{+/-}$

CHIC – calorimetry

- **Need very high segmentation**
  - to separate two electromagnetic showers
  - To isolate photons from $\pi^{+/-}$ contamination
- **W + Si calorimeter à la Calice**
  - 30 layers
  - 0.5 x 0.5 cm^2 pads
  - 24 X_0 in 20 cm
- **W+Si : two relevant quantities**



1st relevant quantity : distance between two incoming particles



→Min. distance between 2 particles at impact
= 1 free pad = 1 cm (for 0.5×0.5 cm^2)

→distance between two incoming particles must be > 1 cm

→N photons ➔ N/2 neutrals (π^0 + η)➔ N $\pi^{+/-}$
➔ N γ + N $\pi^{+/-}$ = 2N particles

→ distance between two photons must be > 2 cm (1cm×2N/N)

2nd relevant quantity : EM shower transverse size
→Moliere Radius R_M : 90% of the shower energy

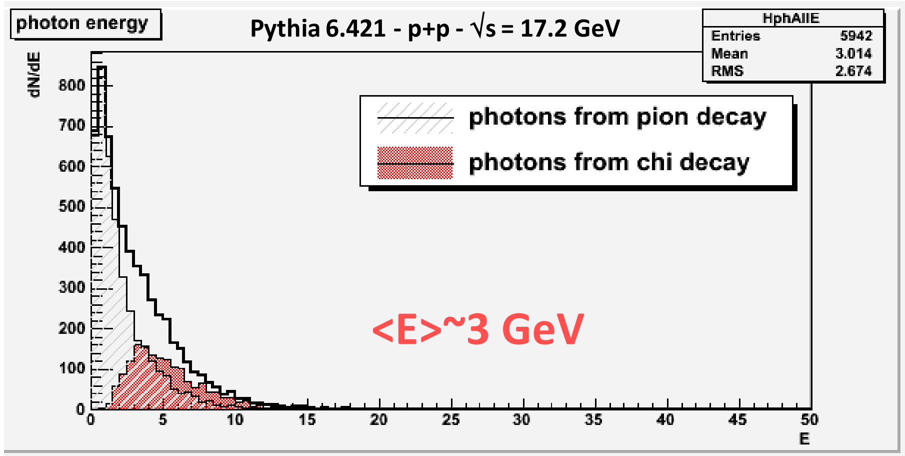
$$\begin{cases} R_M = X_0 \dfrac{21\,\mathrm{MeV}}{610\,\mathrm{MeV}/(Z+1.24)} \\ X_0 = \dfrac{716.4 \times A\ \mathrm{g.cm^{-2}}}{Z(Z+1)\ln\left(287/\sqrt{Z}\right)} \end{cases} \Rightarrow R_M(W) = \frac{17.6\,\mathrm{g.cm^{-2}}}{19.25\,\mathrm{g.cm^{-3}}} \approx 0.9\,\mathrm{cm}$$

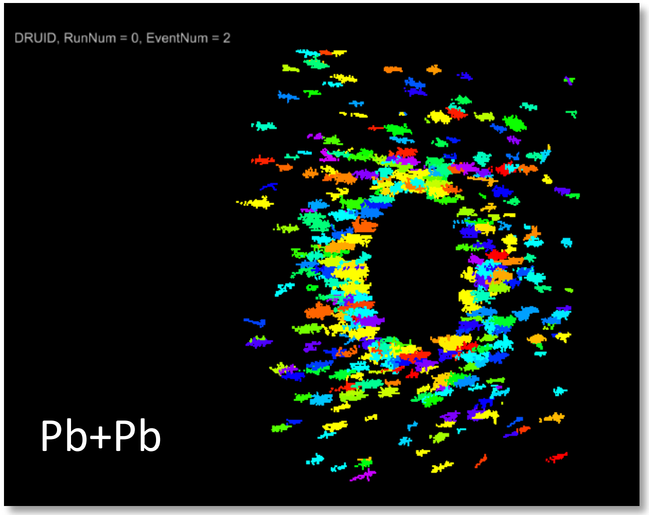
→Distance between two photons must be > 2 cm (2 R_M)

Geometrical condition: in principle $\Delta\gamma$ > 2cm

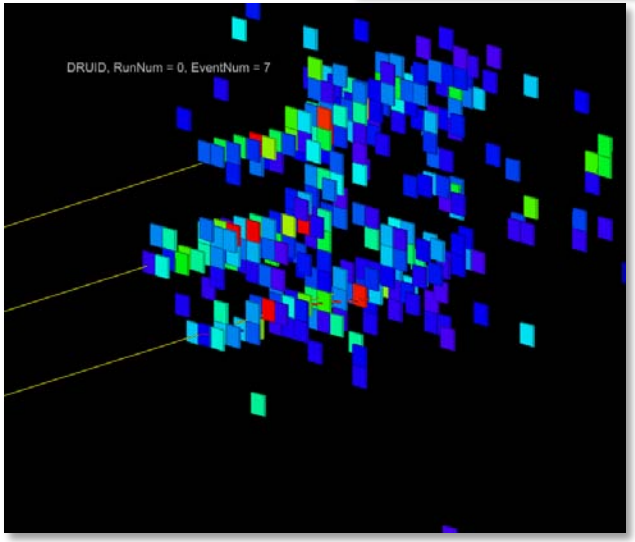
CHIC – calorimetry

- **Full simulation performed with the Calice Ecal proto**





3 photons with E~2 GeV
distance between each photon~ 2 cm

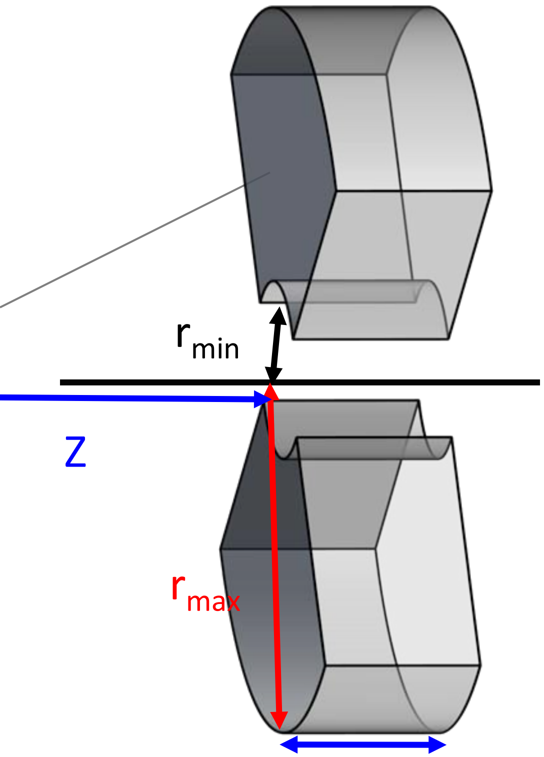


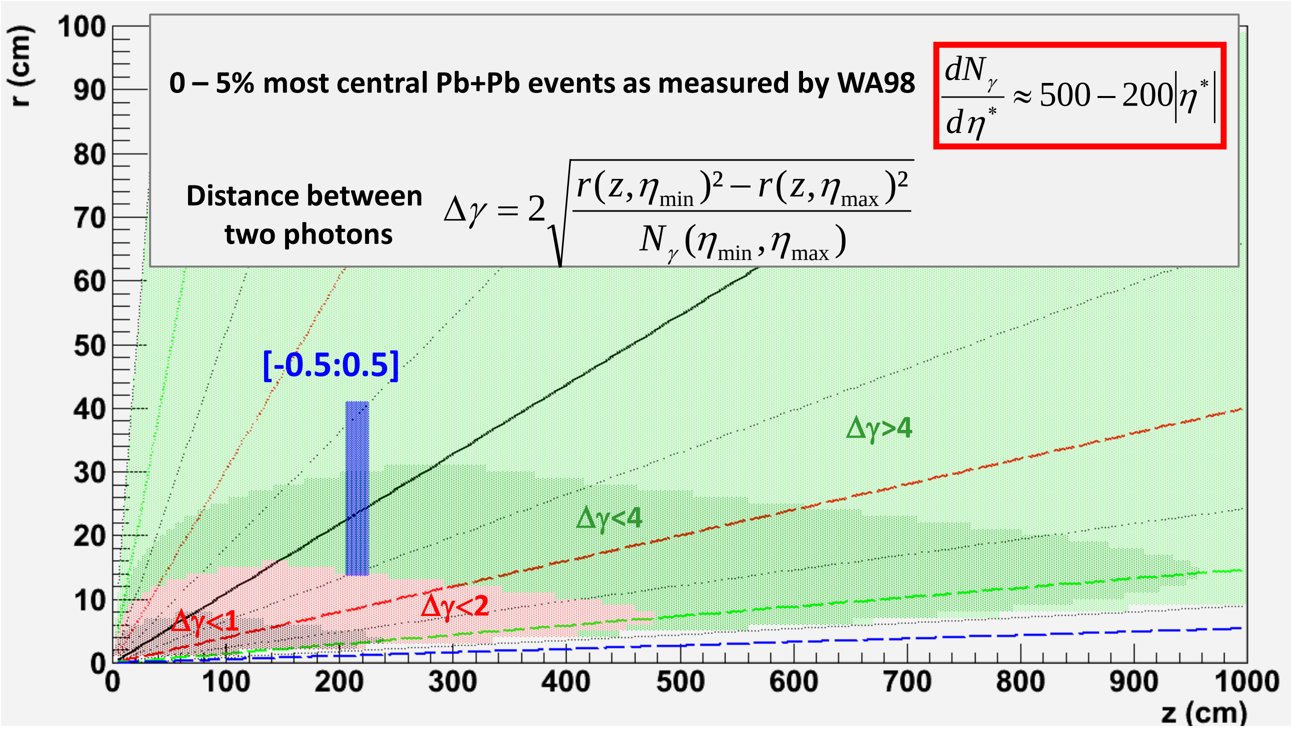
0.5 x 0.5 cm² pads

(full simu made by D. Jeans - LLR - Calice collab.)

CHIC – calorimetry

- **Size and position : tentative design**

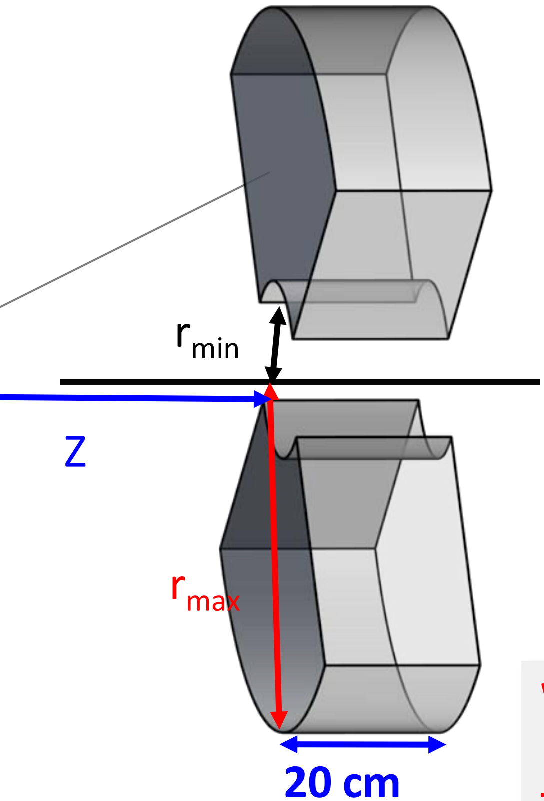


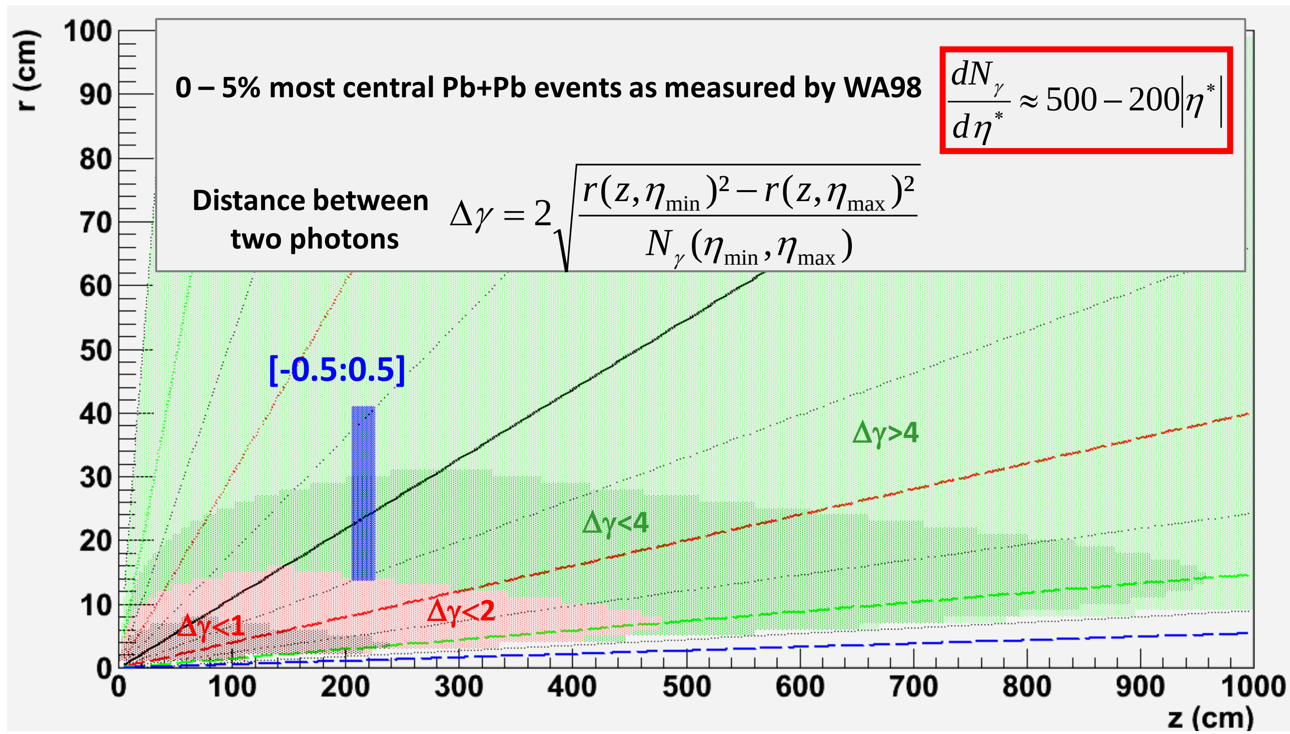


Closer position to the target w/ Δγ>2cm:
➔Z = 205 cm [-0.5:0.5]
➔R_{min} = 13.6 cm
➔R_{max} = 40.9 cm
Using 0.5 x 0.5 cm² pads

CHIC – calorimetry

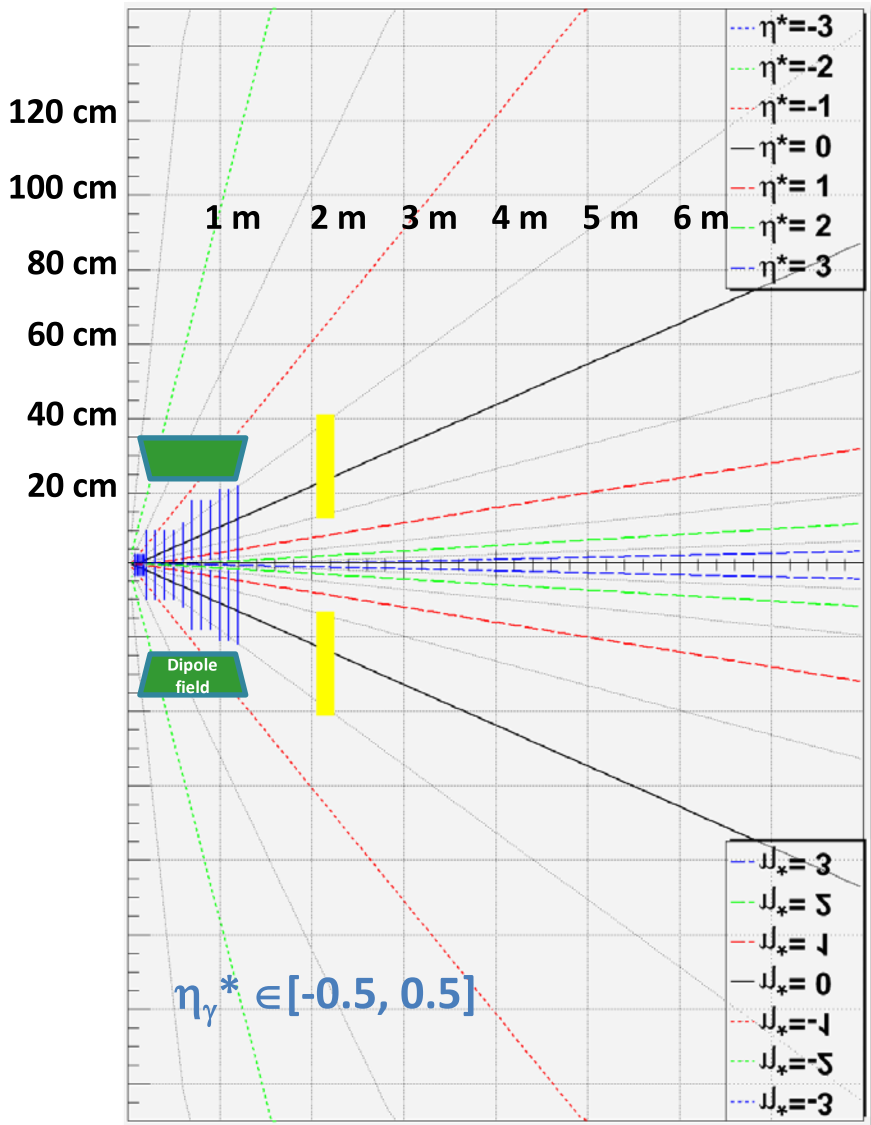
- **Size and position : tentative design**





Warning : not clear that Δγ>2 cm is large enough.
May need to investigate alternative design, for instance:
taking Δγ>4cm with z = 205 cm ➔ $R_{min/max}$=30/55 cm ➔ **η* ∈[-0.8, -0.3]**
taking Δγ>4cm with η* ∈[-0.5, 0.5] ➔ **z ~400 cm**
Must check with full simulation what is optimum Δγ !

CHIC – tentative design



Vertex detector :

R_{min} = 0.5 cm Z_{min} = 7.5 cm

R_{max} = 3.5 cm Z_{max} = 18 cm

Spectrometer :

R_{min} = 1 cm Z_{min} = 20 (100) cm

R_{max} = 22 cm Z_{max} = 120 (200) cm

Calorimeter $\Delta\gamma$>2 cm:

Rmin = 14 cm Zmin = 205 cm

Rmax = 41 cm Zmax = 225 cm

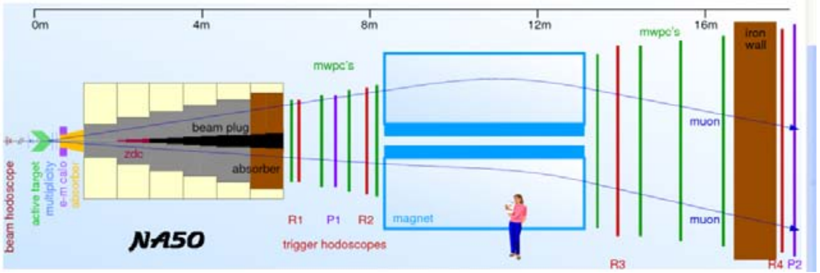
CHIC – absorber

- **Absorber type**

NA50/NA60 : measure muon momentum **after** the absorber

➔ **must minimize multiple scattering**

- Must use low Z material: best = BeO (but expensive)
- **NA50 : 0.6 m BeO + 4 m C + 0.6 m Fe = 5.2 m**

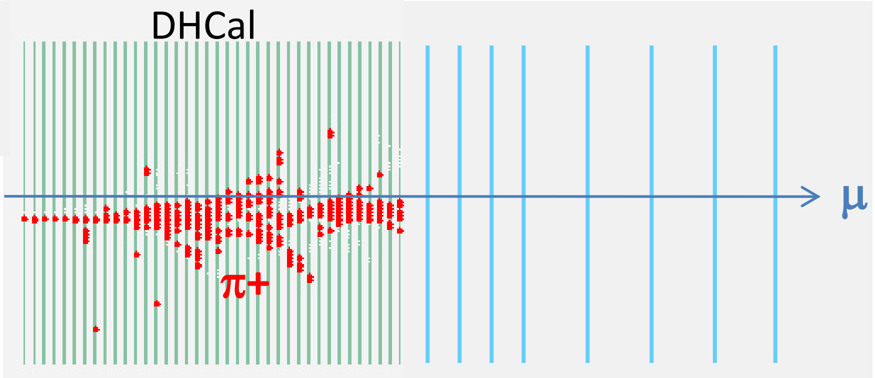


CHIC : measure muon momentum before the absorber

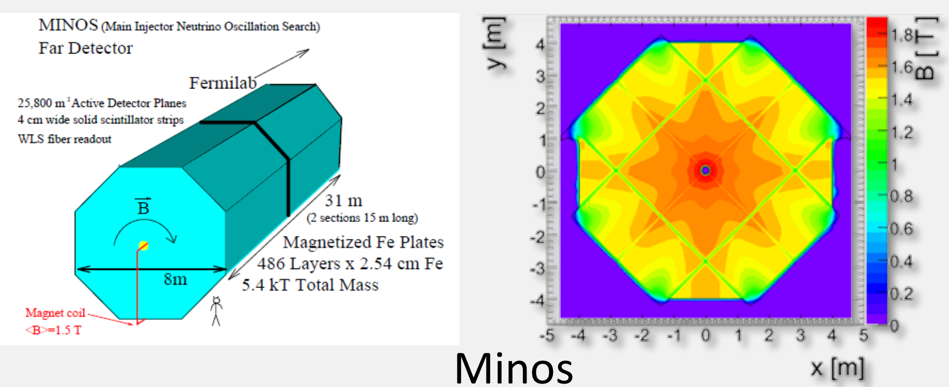
➔ minimization of multiple scattering less crucial

➔ **can use Fe material to absorb $\pi^{+/-}$**

➔ need to **match muon track position** between spectrometer and trigger : **Use an instrumented Fe absorber**



http://newsline.linearcollider.org/archive/2010/20101104.html

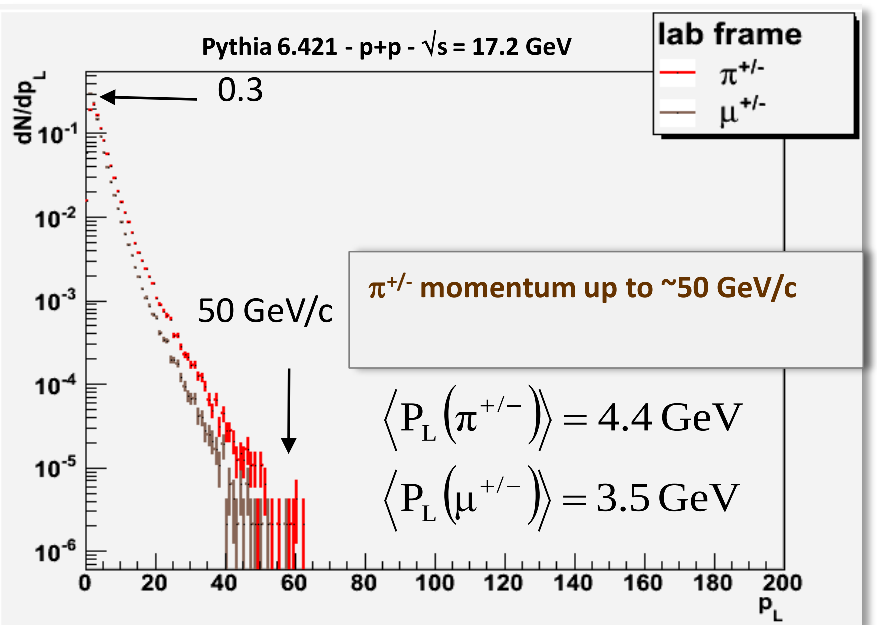


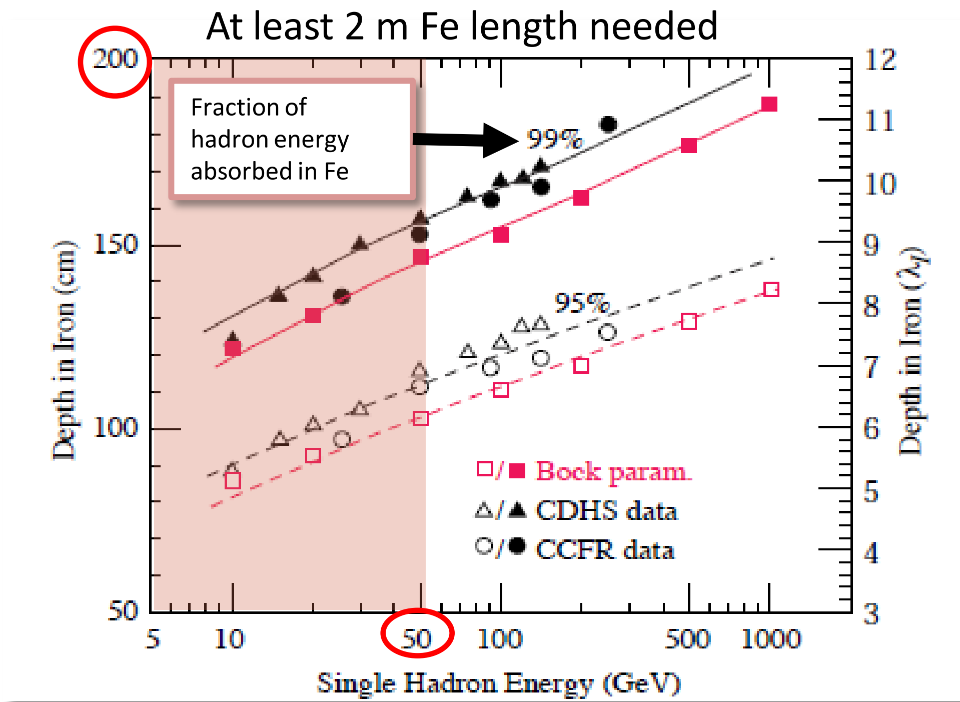
Minos

➔ can match muon track momentum between spectrometer and trigger : **Use magnetized Fe absorber ?**

CHIC – absorber

- **Absorber size and hadron energy loss**





Particle Data Group: J. Phys. G 37, 075021 (2010)

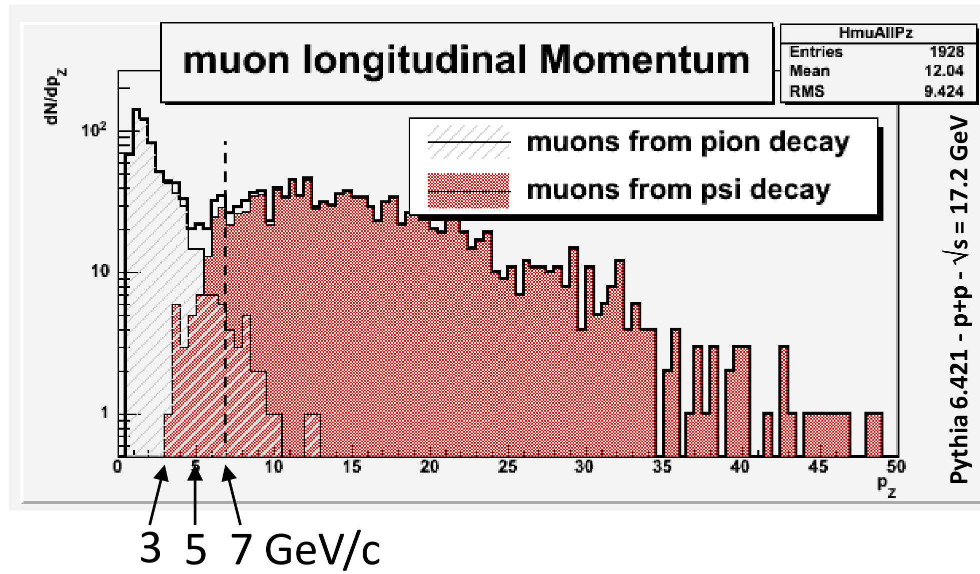
➔ **all $\pi^{+/-}$ stopped with a 2.0 m Fe absorber**

CHIC – absorber

- **Absorber size and muon energy loss**

All $\pi^{+/-}$ stopped with a 2.0 m Fe absorber

➔ but need more Fe to stop muons from pion decay



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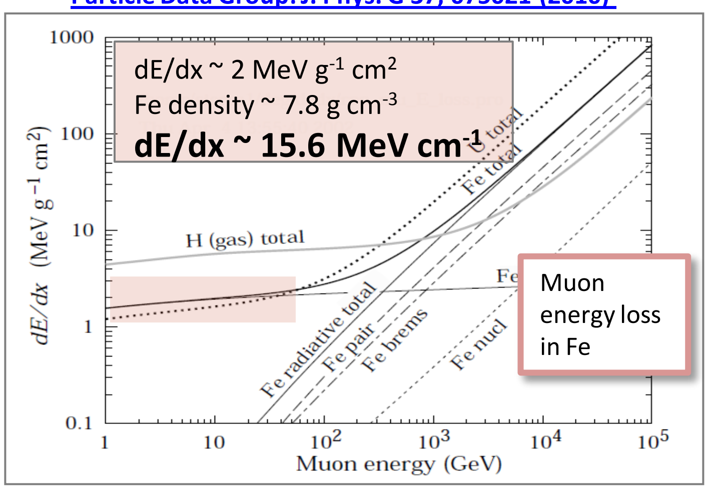


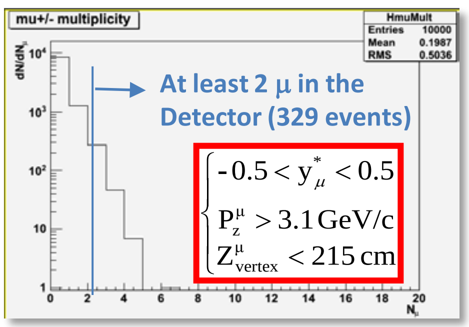
➔ 2.0 m Fe ➔ $\Delta E/\Delta x$ ~ 15.6 x 200 ~ 3 GeV ➔ $\mathcal{A}_{J/\Psi}$ ~ 18.4 %
➔ 3.2 m Fe ➔ $\Delta E/\Delta x$ ~ 15.6 x 320 ~ 5 GeV ➔ $\mathcal{A}_{J/\Psi}$ ~ 18.0 %
➔ 3.8 m Fe ➔ $\Delta E/\Delta x$ ~ 15.6 x 380 ~ 6 GeV ➔ $\mathcal{A}_{J/\Psi}$ ~ 17.3 %
➔ 4.5 m Fe ➔ $\Delta E/\Delta x$ ~ 15.6 x 450 ~ 7 GeV ➔ $\mathcal{A}_{J/\Psi}$ ~ 16.1 %

CHIC – trigger rate in Pb+Pb

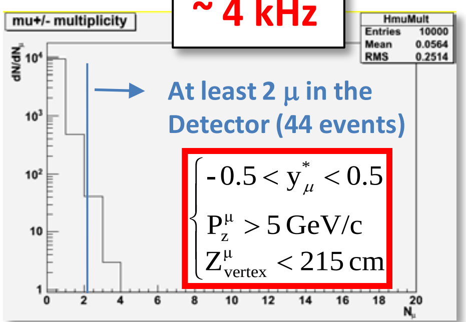
- **Pb Beam intensity**
  - NA50 → 5.10^7 ions/bunch → 10^7 ions/sec (with a bunch time length ~ 5 sec)
  - **Luminosity : $\mathcal{L}$ =** $N_b x N_T = N_b$ x (ρ x e x $\mathcal{N}_A$)/A = 10^7x(11.35 x 0.4 x 6.02 10^{23})/207.19=**0.12μb^{-1}s^{-1}**
- **Number of min bias events (for Pb+Pb)**
  - σ_I=68.8 x ($A^{1/3}{}_{proj}$ + $B^{1/3}{}_{targ}$ – 1.32)^2 → $\sigma^{PbPb}_{minbias}$=68.8 x ($208^{1/3}$ + $207.19^{1/3}$ – 1.32)^2=**7.62 barn**
  - **Nevents/sec** ~ 0.12 10^6 x 7.62 **~ 0.9 MHz**
- **Event rejection :**

Absorber starts @ 205 cm
$\pi^{+/-}$ stop decaying after ~1 λ_I in tungsten (λ_I~10cm)
→ **$\pi^{+/-}$ stop decaying @ 2.15 m**

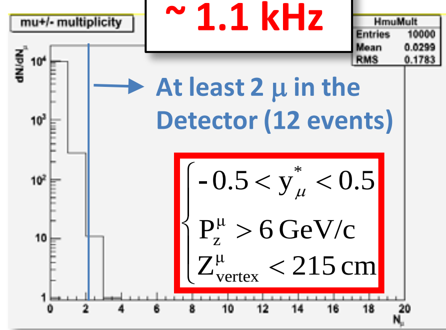
10 000 Pb+Pb minbias events generated with EPOS 1.6



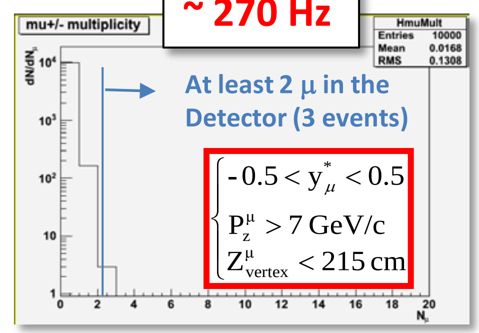
~ 4 kHz



~ 1.1 kHz



~ 270 Hz



3.2m Fe abs.: P_z>5 GeV/c: Trigger accepts 44/10000 events→ **N_{events}/sec** ~ 0.9 MHz x 4.4 10^{-3} **~ 4 kHz**
3.8m Fe abs.: P_z>6 GeV/c: Trigger accepts 12/10000 events → **N_{events}/sec** ~ 0.9 MHz x 1.2 10^{-3} **~ 1.1 kHz**
4.5m Fe abs.: P_z>7 GeV/c: Trigger accepts 3/10000 events → **N_{events}/sec** ~ 0.9 MHz x 3 10^{-4} **~ 270 Hz**

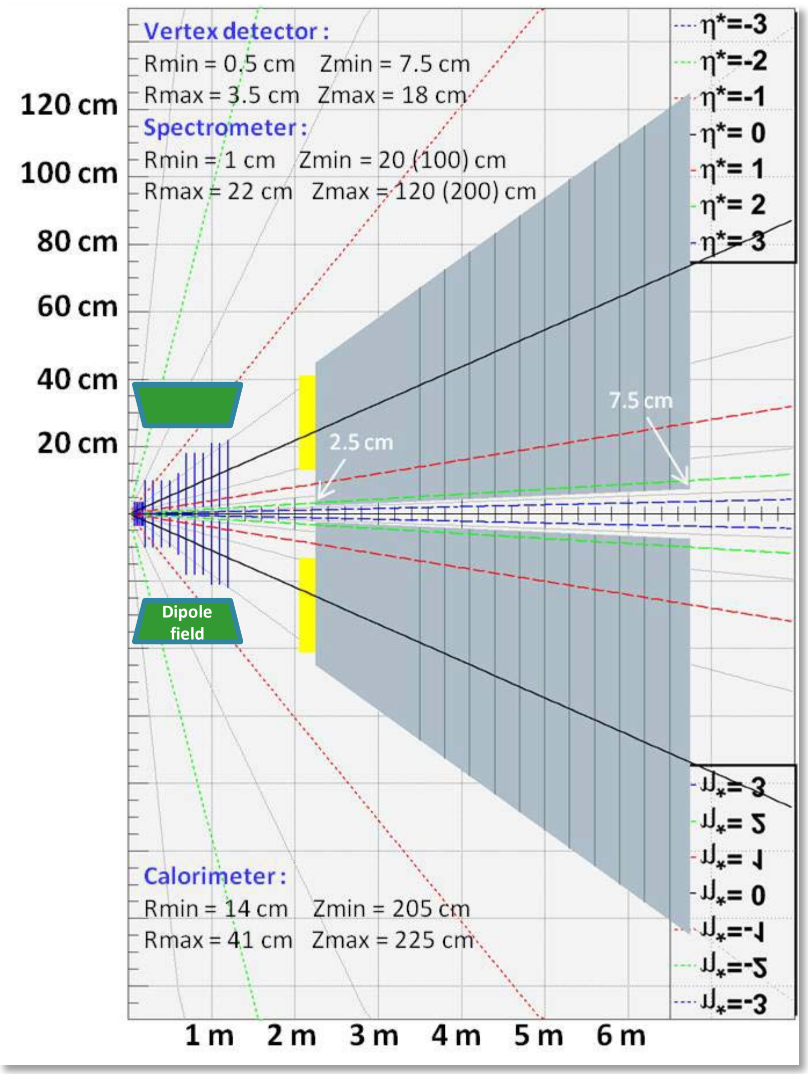
CHIC – Detector design

- **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)

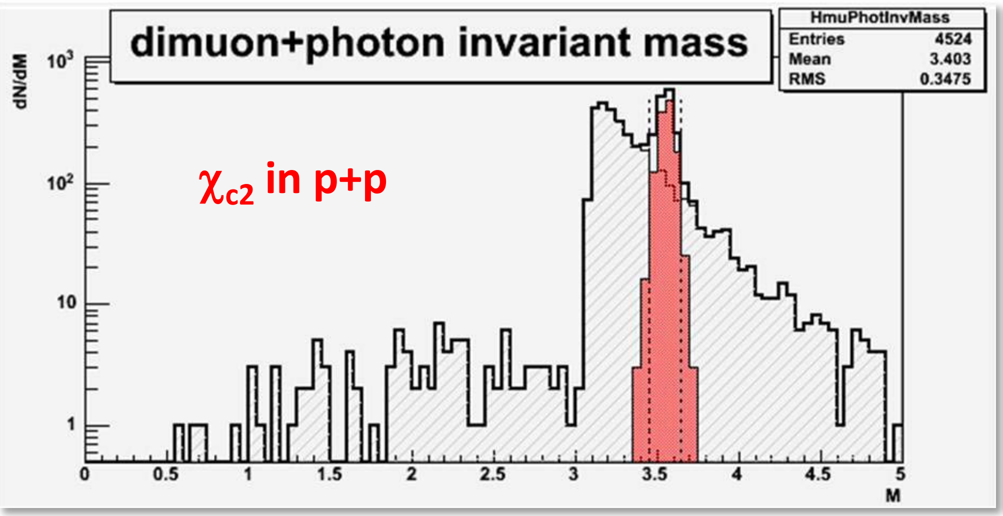
- **Expected performances**

1. **tracking :**
$$\frac{\Delta P}{P} \sim 1\% \text{ within } 1\text{m long } 2.5\text{T } \vec{B}$$
2. **Calorimetry :**
$$\frac{\Delta E}{E} \sim \frac{20\%}{\sqrt{E}}$$

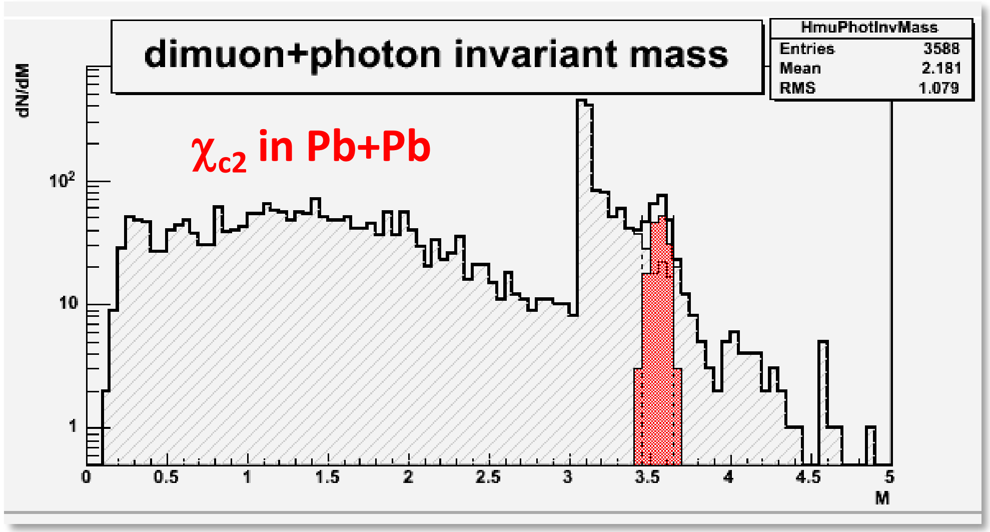


CHIC – Performances

- 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
  - **Selections**
    - Same selections as in p+p
  - **Results** : signal/bkg = 1.7



Conclusion

- Already many data on J/Ψ production at different energies, more to come
- Still difficult to fully understand:
  - Did we see sequential suppression ?
  - Did we see recombination ?
- The measurement of χ_c is a crucial step
- SPS is the best place to start
- It is today feasible
- **Search for partners**

Expression of Interest

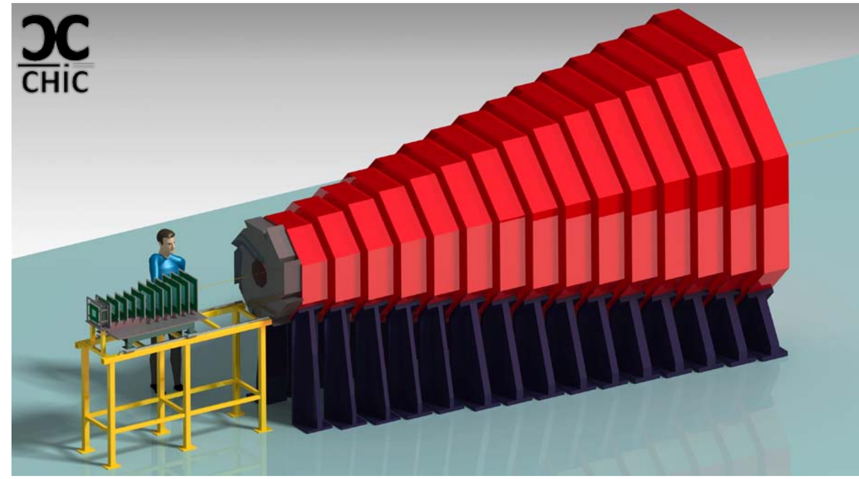
CHIC: Charm in Heavy Ion Collisions

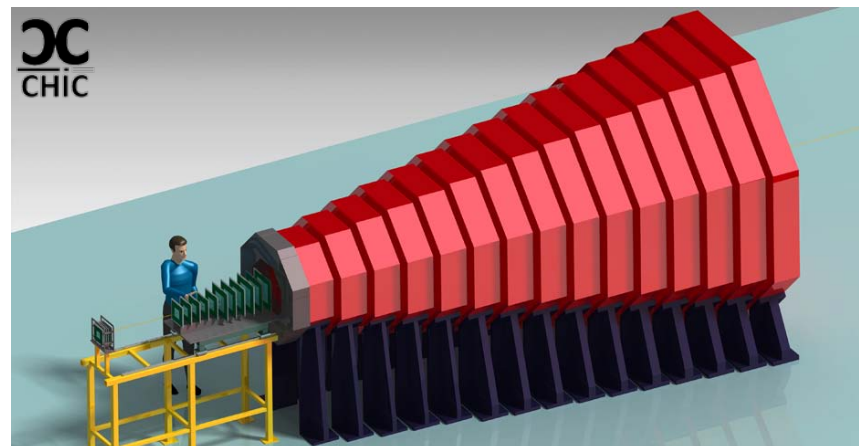
Study of charm production with proton and heavy ion beams at the CERN SPS

E. G. Ferreiro, Universidad de Santiago de Compostela, Spain
F. Fleuret, LLR-École polytechnique, CNRS/IN2P3, Palaiseau, France

Abstract

We propose a third generation experiment devoted to the measurement of open and hidden charm production in heavy ion collisions. The specific purpose of this experiment is to measure $\chi_c \to J/\psi + \gamma$ in the very busy environment produced in Pb+Pb collisions. This will lead to the first observation of charmonium sequential suppression in a Quark Gluon Plasma.





Dessins produits par Oscar Ferreira – LLR