Color screening in Quark Gluon Plasma (QGP): A new experiment to measure charm production in PbPb collisions at the CERN SPS

CHIC: Charm in Heavy Ion Collisions

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Heavy quarks

• Heavy quarks and Quark Gluon Plasma (QGP)

*Heavy quarks are “special” QGP probes:* $m_Q \gg QGP$ critical temperature $T_c (~170 \text{ MeV})$,

$\rightarrow$ Heavy quarks should be produced in initial hard nucleon-nucleon collisions only, the QGP phase shouldn’t modify the overall heavy quark yields,

$\rightarrow$ QGP phase should modify relative heavy quark (open/hidden) bound state yields

Heavy quark hadronization ($c\bar{c}$ example):

• $\sim 90\%$ of $c\bar{c}$ pairs $\rightarrow$ open charm
• $\sim 10\%$ of $c\bar{c}$ pairs $\rightarrow$ hidden charm (charmonia)

Since most of the produced $c\bar{c}$ pairs hadronize into open charm ($\sim 90\%$), open charm production reflects the original charm quark yield.

PHENIX Au+Au collisions @ $\sqrt{s_{NN}} = 200$ GeV

Blue = open charm
Red = hidden charm

• no (little) modification of open charm yield
• modification of $J/\Psi$ ($c\bar{c}$ bound state) yield
Heavy quarks

Heavy quarks and Quark Gluon Plasma

*Heavy quarks are “special” QGP probes*: $m_Q \gg$ QGP critical temperature $T_C (~170$ MeV),

- Heavy quarks should be produced in initial hard nucleon-nucleon collisions only, the 
  QGP phase shouldn’t modify the overall heavy quark yields,
- QGP phase should modify relative heavy quark (open/hidden) bound state yields

- Possible QGP effects on quarkonium:
  - **Color screening**: $Q\bar{Q}$ bound states suppression
    - Color screening in a QGP decreases quarkonium binding
    - Color screening should lead to a suppression of quarkonium production yields
  - **Recombination**: $Q\bar{Q}$ bound states enhancement
    - at sufficiently high $\sqrt{s_{NN}}$, heavy quarks are abondantly produced.
    - After thermalisation, statistical combination can lead to an enhancement of quarkonium production yields
Charm quarks

The Physics case

• Experimentally, charmonium is a privileged probe
  – Charmonium production in A+A collisions studied at:
    • CERN-SPS (\(\sqrt{s}=17\) GeV) NA38, NA50, NA60 experiments
    • BNL-RHIC (\(\sqrt{s}=200\) GeV) PHENIX, STAR experiments
    • CERN-LHC (\(\sqrt{s}=2.76\) TeV) ALICE, CMS experiments

  – Short summary for J/\(\Psi\):
    • NA50 (PbPb@SPS) observed an anomalous J/\(\Psi\) suppression
    • PHENIX (AuAu@RHIC) observed a similar suppression (than NA50)
    • ALICE (PbPb@LHC) observed a smaller suppression (than PHENIX)

  ➔ Possible Color screening starting at SPS
  ➔ Possible recombination occurring at LHC

  – Within the SPS+RHIC+LHC energy range, charm seems to be the adequate probe to investigate both screening and recombination.
What next to be done with charmonium

To confirm (and study) charmonium color screening and enhancement, one must compare charmonium and open charm production in A+A collisions

- Since most of the produced $c\bar{c}$ pairs hadronize into open charm ($\sim 90\%$), open charm production reflects the original $c\bar{c}$ pair production
- Open charm is therefore an (the?) appropriate reference to calibrate charmonium screening/recombination studies.

Study charmonium recombination
- Both $J/\Psi$ and open charm will be measured in PbPb at large energy densities at LHC
  
  LHC is the best place to study charmonium recombination

Study charmonium color screening
- At SPS energies, in Pb+Pb collisions, $J/\Psi$ suppression occurs in the middle of the accessible energy density range
  
  SPS is the best place to study color screening
- Need measurement of open charm yields
- Need precise measurements of several $c\bar{c}$ states to test if color screening leads indeed to a sequential suppression

Charmonium production probability vs Energy Density

- $c\bar{c}$ screening
- $c\bar{c}$ recombination
- SPS
- LHC

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Sequential suppression

- Quarkonium sequential suppression
  - Quarkonium sequential suppression in a Quark Gluon Plasma is a prediction of lattice QCD, 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          |

- Because of feed-downs and different $T_d$, sequential suppression should show up.

  - Feed-downs contributing to $J/\Psi$ inclusive yield
    - 60% direct $J/\Psi$
    - + 30% $\chi_c \rightarrow J/\Psi + \gamma$
    - + 10% $\Psi' \rightarrow J/\Psi + X$
    - Inclusive $J/\Psi$ yield

According to lattice calculations,

$T_d (\Psi') < T_d (\chi_c) < T_d (J/\Psi)$

⇒ One should observe a step-like suppression pattern

Charmonia in A+A

• Anomalous suppression at SPS


$L = \text{length of nuclear matter seen by quarkonium state}$

Expected = measured yields in p+A extrapolated to large $L$

$\rightarrow \text{Need of a larger feed-down fraction}$

$\rightarrow \text{Need of a stronger bound state}$

$\rightarrow \text{Need to measure } \chi_c \text{ yield !}$

NA50 measured $J/\Psi$ and $\Psi'$, but,
- too small $\Psi' \rightarrow J/\Psi$ feed-down
- too fragile $\Psi'$

to answer the question

Color screening ?

$0.9 = \text{length of nuclear matter seen by quarkonium state}$
Charmonia in A+A

Suppression patterns

• Anomalous suppression at SPS

  Color screening?

  Take advantage of large $\chi_c \rightarrow J/\Psi$ feed-down fraction

Measuring $J/\Psi$, $\Psi'$ and $\chi_c$ suppression patterns will give the answer

• Alternative (no QGP) scenario:
  suppression by comoving hadrons
  – Smooth suppression
  – Same suppression-starting point
  – Slopes related to binding energy: $S_{\Psi'} > S_{\chi_c} > S_{J/\Psi}$


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Experimental design

• **Must measure:**
  - Charmonia: $J/\Psi$, $\Psi'$, $\chi_c$
  - open charm (for reference)

• **Beam: fixed-target experiment**
  - high-intensity 158 GeV/c Pb beam
  - high-intensity 158/450 GeV/c $p$ beam

• **Experimental constraints**
  - Measure muons from charmonia and open charm decays
  - Measure photon from $\chi_c$ decay ($\chi_c \rightarrow J/\Psi + \gamma$)

• **Detector main components**:
  1. **Vertex detector + Spectrometer**
     • Measures tracks before absorber ⇒ very good mass resolution
     • Measure muon vertex offset ⇒ open charm
  2. **Ultra-granular calorimeter**
     • Measure $\gamma$ in high $\pi^0$ multiplicity environment
  3. **Absorber/ muon trigger**
     • Absorb $\pi/K$
     • Minimize fake triggers from $\pi/K$ decays

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A new experiment @ SPS

**Apparatus artist view**

**Instrumented Absorber:**
- 4.5 m thick Fe absorber
- Dimuon trigger rate $\sim 0.3$ kHz
- Could be magnetized to measure muon momentum

**Calorimeter:**
- Ultra-granular EMCal
- W + Si layers à la CALICE
  - 30 layers
  - 0.5 x 0.5 cm$^2$ pads
  - 24 $X_0$ in 20 cm
- $\Delta E/E \sim 15\% / \sqrt{E}$

**Magnet:**
- 1m long 2.5 T dipole

**Silicon Spectrometer**
- Covers 1.5 rapidity unit
- $\Delta p/p = 1\% \Rightarrow J/\Psi$ mass resolution $\sim 20$ MeV/$c^2$
**Apparatus**

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**Silicon spectrometer**

**• The NA60 example**

**Pixel detector**
- 16 planes – 96 chips total
- 32 x 256 pixels / chip
- Pixel size = 425 x 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.)
**Apparatus**

- **The NA60 pixel detector**
  
  \[ \frac{\Delta P}{P} = 6\% \Rightarrow \frac{\Delta M}{M} = \frac{\Delta P}{\sqrt{2P}} = 4.2\% \Rightarrow \Delta M_{J/\Psi} \sim 130 \text{ MeV} \]

- **The CHIC pixel detector**

  \( \frac{\Delta P}{P} \propto \frac{1}{BL^2} \frac{P}{P} \)

  \[ \Delta P = 1\% \Rightarrow \Delta M_{J/\Psi} \sim 20 \text{ MeV} \]
Apparatus

• Need to measure low energy photon (~3 GeV in lab) in high $\pi^0$ multiplicity environment $\rightarrow$ need very high segmentation
  • To separate 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

Calorimetry

3 photons with $E\sim2$ GeV
distance between photons~ 2 cm

(full simu made by D. Jeans - LLR - Calice collab.)
• Absorber size and muon energy loss

All $\pi^{+/0}$ stopped with a 2.0 m Fe

⇒ but need more Fe to stop muons from pion decay

Muon energy loss in Fe

dE/dx $\sim$ 2 MeV g$^{-1}$ cm$^2$
Fe density $\sim$ 7.8 g cm$^{-3}$
dE/dx $\sim$ 15.6 MeV cm$^{-1}$

$\Delta E/\Delta x$ $\sim$ 15.6 x 200 $\sim$ 3 GeV
$\Rightarrow$ 2.0 m Fe

$\Rightarrow$ 3.2 m Fe $\Rightarrow$ $\Delta E/\Delta x$ $\sim$ 15.6 x 320 $\sim$ 5 GeV

$\Rightarrow$ 3.8 m Fe $\Rightarrow$ $\Delta E/\Delta x$ $\sim$ 15.6 x 380 $\sim$ 6 GeV

$\Rightarrow$ 4.5 m Fe $\Rightarrow$ $\Delta E/\Delta x$ $\sim$ 15.6 x 450 $\sim$ 7 GeV

Expected performances

**Typical mass plots (~1 week data taking w/ a 10% $\lambda_1$ Pb target)**

- 200 000 $J/\Psi$ embedded in Pb+Pb Minbias events produced w/ EPOS
  - 140 000 direct $J/\Psi \rightarrow \mu^+\mu^-$ (70%)
  - 60 000 $\chi_c \rightarrow J/\Psi \gamma \rightarrow \mu^+\mu^-\gamma$ (30%)

![Graph showing dimuon invariant mass distribution]

**Signal extraction**

After acceptance/selection cuts within $y_{CMS} \in [-0.5;0.5]$

- 35 000 $J/\Psi \rightarrow \mu^+\mu^-$
  $\Rightarrow$ acc x eff = 17.4%

- Including 1700 $\chi_c \rightarrow J/\Psi \gamma \rightarrow \mu^+\mu^-\gamma$
  $\Rightarrow$ acc x eff = 2.8%
Expected number of events

- Typical 40-day Pb+Pb run ($10^7 \text{s}^{-1}$ Pb beam $\rightarrow$ 10% $\lambda_1$ Pb target)
  - $\sim 180 000 \ J/\Psi \rightarrow \mu^+\mu^-$ recorded
  - 2 extreme numerical scenarios:
    - If $\chi_c$ suppressed as $J/\Psi$  
      \[
      \frac{\chi_c \text{ yield}}{J/\Psi \text{ yield}} \sim 4\%
      \]
      \[
      \left( \frac{\chi_c \text{ yield}}{\text{most periph.}} \right) = 16942 \times 4\% = 677
      \]
    - If $\chi_c$ suppressed as $\Psi'$  
      \[
      \frac{\chi_c \text{ yield}}{\Psi' \text{ yield}} = 2.18
      \]
      \[
      \left( \frac{\chi_c \text{ yield}}{\text{most periph.}} \right) = 16942 \times 4\% \times 0.6 = 406
      \]

Statistics

Possible $\chi_c$ suppression pattern

- $\sim 180 000 \ J/\Psi$
- $\sim 1300 \ \Psi'$
- $\sim 3000 \ \chi_c$

<table>
<thead>
<tr>
<th>$E_T$ range (GeV)</th>
<th>$\psi'$</th>
<th>$J/\psi$</th>
<th>$\chi_c$ as $\psi'$</th>
<th>$\chi_c$ as $J/\psi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3–20</td>
<td>186 ± 25</td>
<td>16942 ± 146</td>
<td>406</td>
<td>677</td>
</tr>
<tr>
<td>20–35</td>
<td>243 ± 31</td>
<td>25229 ± 181</td>
<td>530</td>
<td>1010</td>
</tr>
<tr>
<td>35–50</td>
<td>227 ± 35</td>
<td>27276 ± 192</td>
<td>495</td>
<td>1094</td>
</tr>
<tr>
<td>50–65</td>
<td>193 ± 36</td>
<td>27681 ± 196</td>
<td>421</td>
<td>1107</td>
</tr>
<tr>
<td>65–80</td>
<td>154 ± 36</td>
<td>27315 ± 200</td>
<td>336</td>
<td>1093</td>
</tr>
<tr>
<td>80–95</td>
<td>159 ± 37</td>
<td>25111 ± 193</td>
<td>647</td>
<td>1004</td>
</tr>
<tr>
<td>95–150</td>
<td>110 ± 40</td>
<td>28570 ± 209</td>
<td>240</td>
<td>1143</td>
</tr>
<tr>
<td></td>
<td></td>
<td>240</td>
<td>1143</td>
<td>3075</td>
</tr>
</tbody>
</table>

NA50 data
Open charm

Measuring muon offset

- Use same Strategy as NA60: measure muon vertex

  - Open charm decay length:
    \[
    \begin{align*}
    D^+/ -: c\tau &= 311.8 \mu m \\
    D^0 &: c\tau &= 122.9 \mu m
    \end{align*}
    \]

- NA60 has separated prompt (red) from charm (blue) contribution in In+In
- NA60 has found an excess of prompt dimuons in Intermediate Mass Region
- NA60 has measured open charm cross-section: compatible with p+A results

CHIC: Vertex detector located 7.5 cm downstream of the target (7 cm for NA60)

- CHIC is able to measure open charm yields.
- Detailed simulations needed to estimate performances
A thorough p+A program is mandatory to study Cold Nuclear Matter effects as a reference to study Hot Nuclear Matter effects

- Must control (understand):
  - charmonium absorption by cold nuclear matter \( \Rightarrow \) A dependence
  - Shadowing/anti-shadowing \( (x_2 \text{ scaling}) \)
  - Energy loss, formation time \( (x_F \text{ scaling}) \)

\[ \text{Mid-rapidity : } y_{CMS} \in [-0.5 ; 1] \]

\[ \text{Forward-rapidity : } y_{CMS} \in [0.5 ; 2] \]
**A thorough p+A program**

**Detector capabilities**

- **Large rapidity range**
  - Significantly larger rapidity range for CHIC ($y_{CMS} \in [-0.5; 2]$) vs. NA50 ($y_{CMS} \in [0; 1]$)

- **Precise $A$ dependence** (thanks to fixed-target mode)
  - NA50 samples: $p+$Be, $p+$Al, $p+$Cu, $p+$Ag, $p+W$, $p+Pb$

- **Large amount of data** (thanks to fixed-target mode)
  - Large statistics required to study $J/\Psi$, $\Psi'$, $\chi_c$ and open charm differential yields as a function of $y$, $p_T$.
  - Current SPS operation: Delivering proton beam to the LHC several months per year
  - Significantly larger (than NA50) amount of data available for CHIC.

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Typical 1 week/target NA50 data taking

(EPJ C33 (2004) 31-40)

<table>
<thead>
<tr>
<th>Target</th>
<th>size ($\lambda_f$)</th>
<th>$&lt;I_{protons}&gt;$ ($\times10^8$)</th>
<th>Total $N_{protons}$ ($\times10^{12}$)</th>
<th>$N_{\mu\mu}^+$ (2.7 - 3.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Be</td>
<td>60 %</td>
<td>21.7</td>
<td>50.7</td>
<td>368 000</td>
</tr>
<tr>
<td>Al</td>
<td>52 %</td>
<td>23.0</td>
<td>63.4</td>
<td>602 000</td>
</tr>
<tr>
<td>Cu</td>
<td>28 %</td>
<td>27.0</td>
<td>45.5</td>
<td>762 000</td>
</tr>
<tr>
<td>Ag</td>
<td>30 %</td>
<td>24.8</td>
<td>43.8</td>
<td>821 000</td>
</tr>
<tr>
<td>W</td>
<td>19 %</td>
<td>23.5</td>
<td>28.5</td>
<td>524 000</td>
</tr>
</tbody>
</table>
• EoI submitted to the SPS Committee (oct. 2012)

The SPSC has received an expression of interest to study charm production with proton and heavy ion beams. The SPSC recognizes the strong physics motivation of a study that addresses central open questions about the color screening of charmonium in heavy ion collisions and about cold nuclear matter effects. For a comprehensive investigation, an extension including open charm production would be desirable.

For further review, the SPSC would require a letter of intent with information about the experimental implementation and the collaboration pursuing it.
Towards a Letter of Intent

• Green light from CERN SPSC
  – EoI submitted to SPSC in oct. 2012: CERN-SPSC-2012-031
  – Positive feed-back from SPSC in jan. 2013: CERN-SPSC-2013-008

• Current think tank
  – F. Arleo, E.G. Ferreiro, F. Fleuret, P.-B. Gossiaux, S. Peigné
  – Many opportunities for experimentalists

• apparatus
  – Tracking
    • Needs low detector occupancy ➔ silicon technology
    • Welcomes group with expertise!
  – Calorimetry
    • Need ultragranular calorimetry à la CALICE
    • Expertise at LLR - Ecole polytechnique (France)
  – Trigger
    • Instrumented (magnetized) Fe Absorber
    • Welcomes group with expertise!

• Expected timeline
  – From T₀ (3 labs involved): ~ 5 Years for full simulation and final design (2 years), construction and installation (2 years), commissionning (1 year)
Conclusion

• Measuring $J/\Psi$, $\Psi'$, $\chi_c$ and open charm in A+A collisions at SPS will (dis)prove sequential suppression scenario.

• Measuring $J/\Psi$, $\Psi'$, $\chi_c$ and open charm in p+A collisions with several targets will give a thorough control of Cold Nuclear Matter effects

• The apparatus is well suited to explore other important physics subjects such as low mass lepton pairs production in heavy ion collisions.

• Many opportunities to contribute to the project

• Testing sequential suppression scenario at SPS is crucial to fully understand RHIC and LHC results.
Results from CMS

“Observation of Sequential $\Upsilon$ Suppression in PbPb collisions”
(at LHC)

*PRL109, 222301 (2012)*

Testing sequential suppression scenario at SPS is crucial to fully understand RHIC and LHC results.
Testing sequential suppression scenario at SPS is crucial to fully understand RHIC and LHC results.
backup
• How to Test sequential suppression with charmonia?
  – must measure $J/\Psi$, $\Psi'$, $\chi_c$
  – ~30% (resp. ~10%) of inclusive $J/\Psi$ comes from $\chi_c$ (resp. $\Psi'$) decay.
  – According to lattice calculations, $T_d (\Psi') < T_d (\chi_c) < T_d (J/\Psi)$
  – If screening, one should observe a step-like suppression patterns

• Alternative (no QGP) scenario: suppression by comoving hadrons
  – Smooth suppression
  – Same suppression-starting point
  – Slopes related to binding energy:
    $S_{\Psi'} > S_{\chi_c} > S_{J/\Psi}$
Comovers

- Anomalous suppression at SPS

Expectations in comovers scenario

<table>
<thead>
<tr>
<th>Binding energy</th>
<th>state</th>
<th>$\eta_c$</th>
<th>$J/\psi$</th>
<th>$\chi_0$</th>
<th>$\chi_1$</th>
<th>$\chi_2$</th>
<th>$\psi'$</th>
</tr>
</thead>
<tbody>
<tr>
<td>mass [GeV]</td>
<td>2.98</td>
<td>3.10</td>
<td>3.42</td>
<td>3.51</td>
<td>3.56</td>
<td>3.69</td>
<td></td>
</tr>
<tr>
<td>$\Delta E$ [GeV]</td>
<td>0.75</td>
<td>0.64</td>
<td>0.32</td>
<td>0.22</td>
<td>0.18</td>
<td>0.05</td>
<td></td>
</tr>
</tbody>
</table>

Taking breakup cross-sections:
- **comovers-direct $J/\Psi = 0.2$ mb**
- **comovers – $\chi_c = 1.0$ mb**
- **comovers – $\Psi'' = 2.0$ mb**

and considering feed-downs

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

Inclusive $J/\Psi$ yield

Testing sequential suppression scenario at SPS is crucial to fully understand RHIC and LHC results.
Energy scan

- Spectrometer acceptance: two detector configurations

Depending on the beam energy, different rapidity ranges accessible

<table>
<thead>
<tr>
<th>$P_{\text{beam}}$ (GeV/c)</th>
<th>$\sqrt{s}$ (GeV)</th>
<th>Rapidity of Center-of-mass</th>
<th>Mid-rapidity</th>
<th>Forward-rapidity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>$y_{\text{CMS min}}$</td>
<td>$y_{\text{CMS max}}$</td>
</tr>
<tr>
<td>158</td>
<td>17.2</td>
<td>2.91</td>
<td>-0.5</td>
<td>1</td>
</tr>
<tr>
<td>120</td>
<td>15.1</td>
<td>2.77</td>
<td>-0.36</td>
<td>1.14</td>
</tr>
<tr>
<td>80</td>
<td>12.3</td>
<td>2.57</td>
<td>-0.16</td>
<td>1.34</td>
</tr>
<tr>
<td>60</td>
<td>10.7</td>
<td>2.43</td>
<td>-0.02</td>
<td>1.48</td>
</tr>
</tbody>
</table>

Common coverage: $y_{\text{CMS}} \in [0;2]$ (NA50/NA60 coverage = [0;1])
Rapidity coverage

- A thorough p+A program
  - mandatory as reference for hot nuclear matter effects

\[ J/\Psi, \Psi', \chi_c \text{ in a large } y_{\text{CMS}} \text{ range} \]
  \[ \rightarrow \text{Large coverage in } x_2 \]
  \[ \rightarrow \text{Large coverage in } x_F \]

<table>
<thead>
<tr>
<th>( E_{\text{beam}} (\sqrt{s}) )</th>
<th>Exp.</th>
<th>( Y_{\text{CMS}} )</th>
<th>( x_2 )</th>
<th>( x_F )</th>
</tr>
</thead>
<tbody>
<tr>
<td>158 GeV (~17 GeV)</td>
<td>NA50</td>
<td>[0;1]</td>
<td>[0.07;0.18]</td>
<td>[0;0.42]</td>
</tr>
<tr>
<td>CHIC</td>
<td>[-0.5;2]</td>
<td>[0.02;0.30]</td>
<td>[-0.19;1]</td>
<td></td>
</tr>
<tr>
<td>450 GeV (~29 GeV)</td>
<td>NA50</td>
<td>[-0.4;0.6]</td>
<td>[0.06;0.16]</td>
<td>[-0.09;0.14]</td>
</tr>
<tr>
<td>CHIC</td>
<td>[-0.9;1.6]</td>
<td>[0.02;0.26]</td>
<td>[-0.22;0.51]</td>
<td></td>
</tr>
</tbody>
</table>

\[ Q^2 = 10 \text{ GeV}^2 \]

\[ x = x_2 = \frac{M}{\sqrt{s}} e^{-y_{\text{CMS}}} \]

\[ x_F = \frac{2M}{\sqrt{s}} \sinh y_{\text{CMS}} \]

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Mass resolution

- **CHIC expected performances for low mass dileptons**
  - Tracking performed upstream to the absorber
    - no multiple scattering due to absorber
    - momentum resolution affected by magnetic field only:
      \[ \frac{\Delta P}{P} \propto \frac{1}{BL^2} P \]
  - Momentum resolution
    - With a 1m long 2.5T dipolar magnetic field
      - \[ \frac{\Delta P_\mu}{P_\mu} = 1\% \] for typical muon from J/Ψ (<\(P_\mu\)> ~10 GeV/c)
      - \[ \frac{\Delta P_\mu}{P_\mu} = 0.7\% \] for typical muon from \(\omega\) (<\(P_\mu\)> ~7 GeV/c)
  - Expected mass resolution:
    - J/Ψ: \[ \frac{\Delta P_\mu}{P_\mu} = 1\% \] \[ \Rightarrow \frac{\Delta P_\mu}{\sqrt{2P_\mu}} = \frac{\Delta M_{\mu\mu}}{M_{\mu\mu}} = 0.7\% \]
    - \(\omega\): \[ \frac{\Delta P_\mu}{P_\mu} = 0.7\% \] \[ \Rightarrow \frac{\Delta P_\mu}{\sqrt{2P_\mu}} = \frac{\Delta M_{\mu\mu}}{M_{\mu\mu}} = 0.5\% \]

- \(\Delta M_{J/\Psi} \approx 3.097 \text{ GeV}/c^2 \times 0.7\% \approx 20 \text{ MeV}/c^2\)
  - NA50: \(\Delta M_{J/\Psi} \approx 90 \text{ MeV}/c^2\)
- \(\Delta M_{\omega} \approx 782.7 \text{ MeV}/c^2 \times 0.5\% \approx 4 \text{ MeV}/c^2\)
  - NA60: \(\Delta M_{\omega} \approx 20 \text{ MeV}/c^2\)
“...The town meeting also observed that the CERN SPS would be well-positioned to contribute decisively and at a competitive time scale to central open physics issues at large baryon density. In particular, the CERN SPS will remain also in the future the only machine capable of delivering, heavy ion beams with energies exceeding 30 GeV/nucleon, and the potential of investigating rare penetrating probes at this machine is attractive.”
J/ψ@SPS vs. Ψ@LHC color screening?

Les-Houches - 2014

Charmonia @ SPS

bottomonia @ LHC

On the same axis