Thermal charm production and Charmonium production at FCC

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THU

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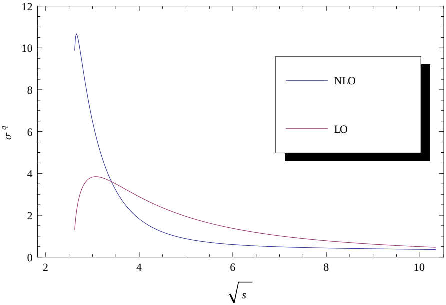
Overview

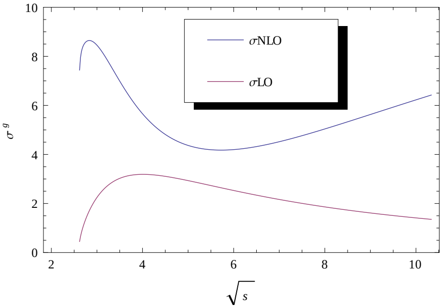
Important role of HF production at higher collision energy

- Due to the much more stronger suppression, almost all the initial produced charmonium could be eaten up by the hotter fireball, then regeneration/recombination will be dominant.
- Along with increasing collision energy, the medium will be hotter and denser: hotter means the partons in the medium could be more energetic(functiones as $\sqrt{s}$), denser means the number of partons will be much more(functiones as PDF).
  $\rightarrow$ higher in-medium production rate for charm quark pairs.
- The regeneration/recombination yields quatratically depends on number of charm pairs in the medium.
- Be carefull of the shadowing effect(spatial dependent) when drawing the conclusion.

charm pair production processes

- Leading Order: $g + g \to c + \bar{c}$ $\quad q + \bar{q} \to c + \bar{c}$
- Next-Leading Order: $g + g \to c + \bar{c} + g$ $\quad q + \bar{q} \to c + \bar{c} + g$

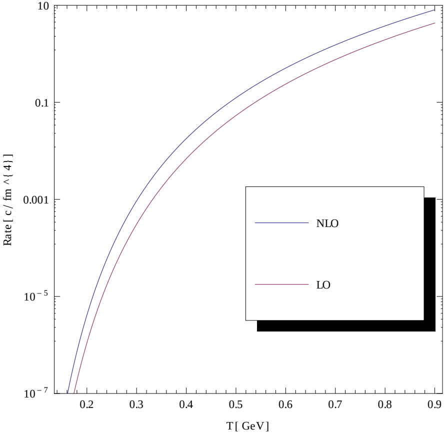




P. Nason, S. Dawson R.K. Ellis, NPB 303, 607 (1988)

charm pair production rate

$$R_{12} = \frac{dN_{reaction}}{d^4x} = \frac{1}{\nu}\int \frac{d^3\vec{p_1}}{(2\pi)^3 2E_1}\frac{d^3\vec{p_2}}{(2\pi)^3 2E_2} 4F_{12}\sigma_{12} f_1 f_2 \qquad (1)$$



Rate equation for charm production

$$\partial_\mu(n_{c\bar{c}}^{LR} u^\mu) = R_{gain} - R_{loss} \tag{2}$$

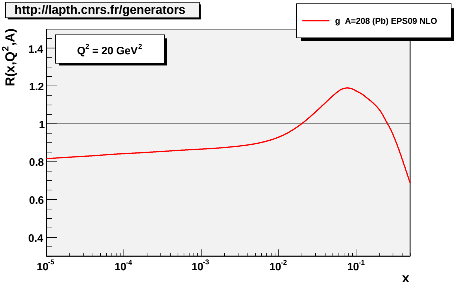
$n_{c\bar{c}}^{LR}$: charm pair density in local rest frame
$u^\mu = \gamma(1, \vec{v})$: 4-velocity of fluid cell in Hydro medium
Considering boost invariant initial condition in mid-rapidity:

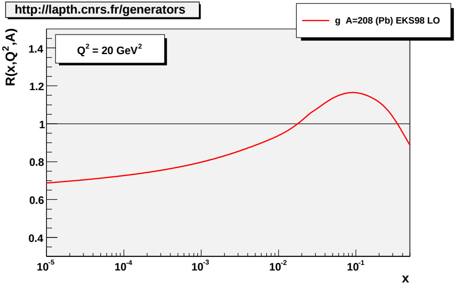
$$\partial_\tau(n_{c\bar{c}}) + \nabla_T(n_{c\bar{c}}\vec{v}_T) + \frac{n_{c\bar{c}}}{\tau} = R_{gain} - R_{loss} \tag{3}$$

$n_{c\bar{c}}$: charm pair density in lab frame
Initial condition: $n_{c\bar{c}}(\vec{x}_T, \tau_0) = \frac{1}{\tau_0}\frac{d\sigma_{c\bar{c}}^{pp}}{d\eta}|_{\eta=0} T_{AB}(\vec{x}_T)$
$\times[1 + A(R_g(\bar{x}, \bar{\mu}_F) - 1)\frac{T_A(\vec{x}_T)}{T_{AB}(\vec{0})}][1 + A(R_g(\bar{x}, \bar{\mu}_F) - 1)\frac{T_B(\vec{x}_T)}{T_{AB}(\vec{0})}]$

Charm production 1

- 2.76TeV, shadowing will reduce the charm production, thermal production is negligible
- 5.5TeV, thermal production can just compensate the shadowing induced reduction

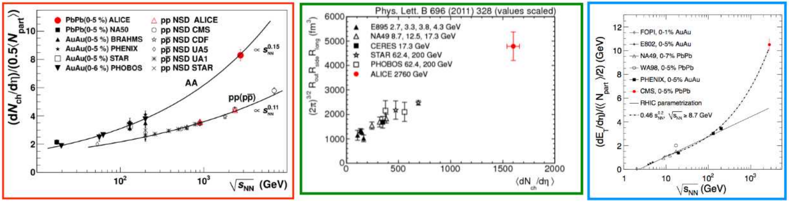




fit from existed measurements:

21 (第 21 页，共 49 页) 适合页宽 开始演示 离开全屏

$dN_{ch}/d\eta$ x 1.8	Volume x1.8	$dE_T/d\eta$ x2.2



Quantity	Pb–Pb 2.76 TeV	Pb–Pb 5.5 TeV	Pb–Pb 39 TeV
$dN_{ch}/d\eta$ at $\eta = 0$	1600	2000	3600
Total N_{ch}	17000	23000	50000
$dE_T/d\eta$ at $\eta = 0$	2 TeV	2.6 TeV	5.8 TeV
BE homogeneity volume	5000 fm^3	6200 fm^3	11000 fm^3
BE decoupling time	10 fm/c	11 fm/c	13 fm/c

Kick-off, Geneva, 21

talk by Andrea Dainese

$$s_0(\vec{x}_T,\tau_0) = s_{max}\frac{\rho_{sr}(\vec{x}_T)}{\rho_{sr}(\vec{0})}dN_{ch}/d\eta \quad (4)$$

$$\rho_{sr}(\vec{x}_T) = \frac{1-\alpha}{2}n_{part}(\vec{x}_T) + \alpha n_{coll}(\vec{x}_T) \quad (5)$$

Shadowing also need to be included in the hard contribution for bulk medium: $n_{coll}(\vec{x}_T) \rightarrow \bar{n}_{coll}(\vec{x}_T) =$
$T_{AB}(\vec{x}_T)[1 + A(R_g(\bar{x},\bar{\mu}_F) - 1)\frac{T_A(\vec{x}_T)}{T_{AB}(\vec{0})}][1 + A(R_g(\bar{x},\bar{\mu}_F) - 1)\frac{T_B(\vec{x}_T)}{T_{AB}(\vec{0})}]$(6)

coll.energy	$\tau_0(fm/c)$	$T_{max}(MeV)$	α
2.76 TeV	0.6	484	0.14
5.5 TeV	0.6	580	0.16
39 TeV	0.3	860	0.2

2+1d Hydro + Charm Rate Eq.

$$\partial_\tau E + \nabla M = -(E+p)/\tau \tag{7}$$

$$\partial_\tau M_x + \nabla(M_x \mathbf{v}) = -\mathbf{M_x}/\tau - \partial_\mathbf{x}\mathbf{p} \tag{8}$$

$$\partial_\tau M_y + \nabla(M_y \mathbf{v}) = -\mathbf{M_y}/\tau - \partial_\mathbf{y}\mathbf{p} \tag{9}$$

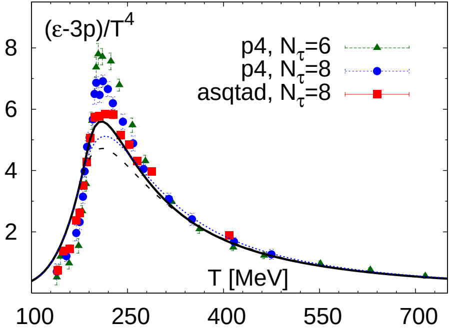
$$\partial_\tau(n_{c\bar{c}}) + \nabla_T(n_{c\bar{c}}\vec{v}_T) + \frac{n_{c\bar{c}}}{\tau} = R_{gain} - R_{loss} \tag{10}$$

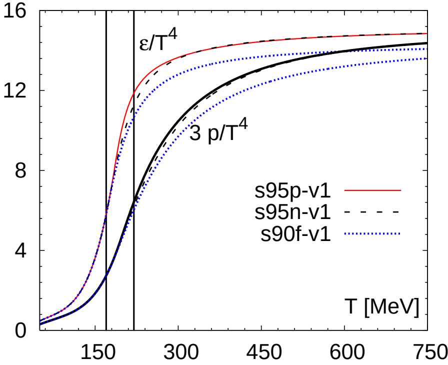
estimate charm cross section from FONLL together with existed data:

coll.energy	$d\sigma^{pp}_{c\bar{c}}/d\eta_{\eta=0}(mb)$	$\sigma^{inelastic}_{pp}(mb)$
2.76 TeV	0.65	62
5.5 TeV	1.0	72
39 TeV	2.5	100

Equation of State

fit lattice EOS: s95p





Bazavov et al, Phys.Rev.D80:014504,2009

Pasi Huovinen and Peter Petreczky, Nucl.Phys.A837:26-53,2010

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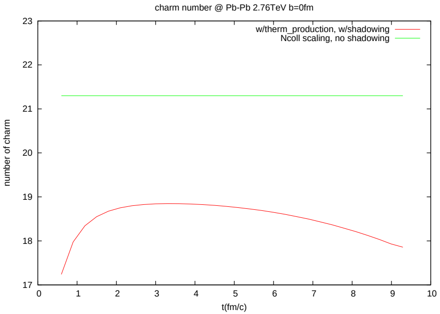
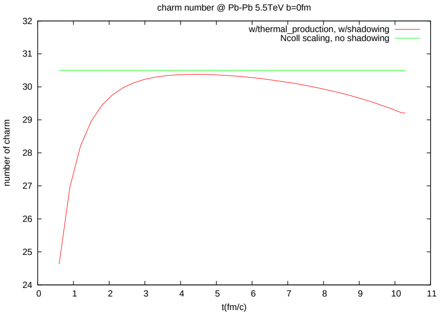
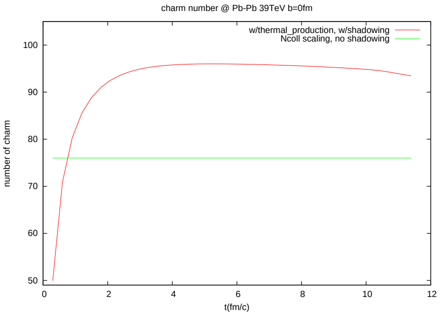
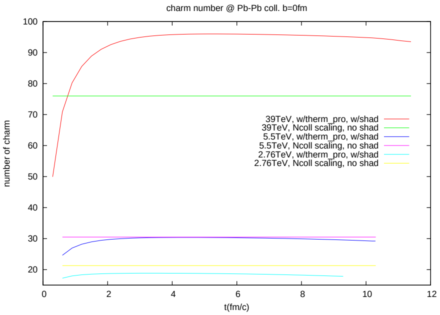




Charm production 2

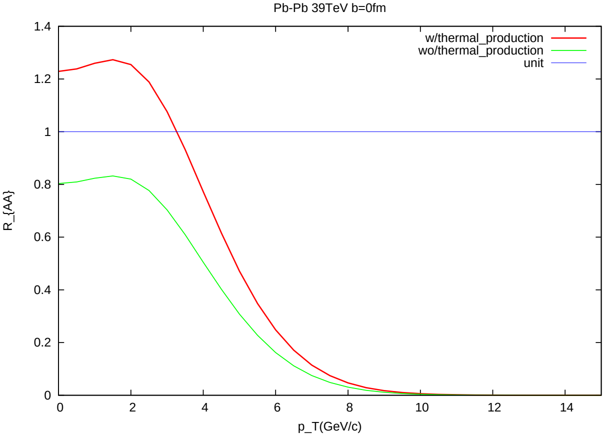
- 39TeV, thermal production can overcome the shaodwong and finally leads to 22% enhancement
- along with increasing coll.energy, thermal charm production becomes more important.





Charmonium production

- thermal charm production leads to $R_{AA}^{J/\Psi} > 1$ at low p_T.



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