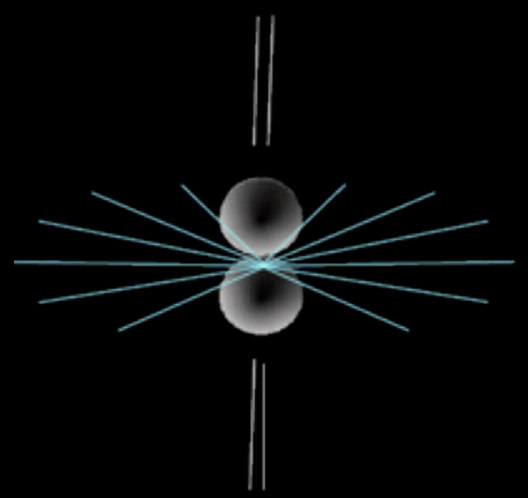
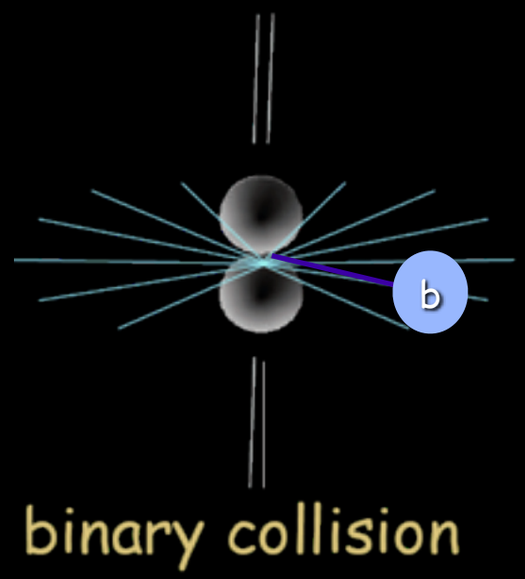
Recent Heavy Flavor Results from PHENIX

Cesar Luiz da Silva
Los Alamos National Lab
for the PHENIX Collaboration

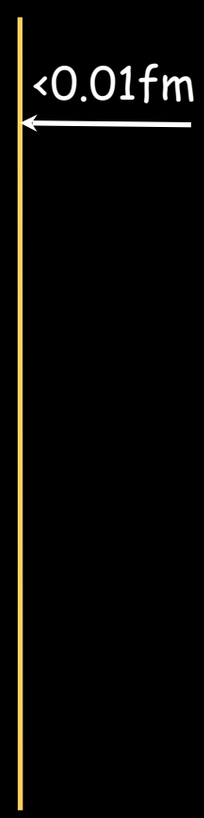
EMMI 2013 - LBNL - Heavy Flavor and QCD Phase Structure in High Energy Collisions

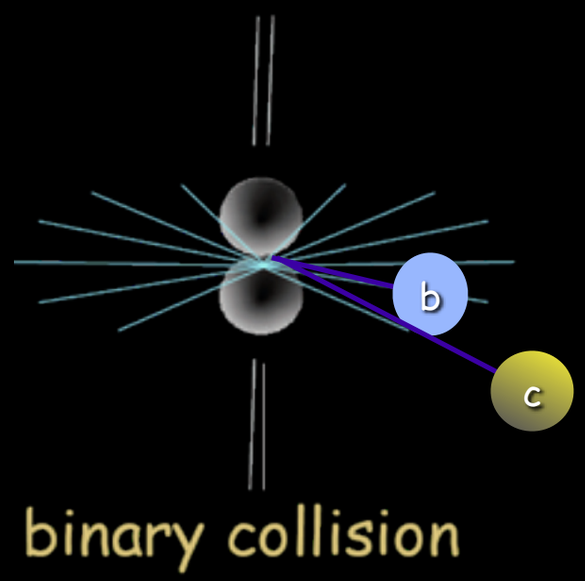


binary collision



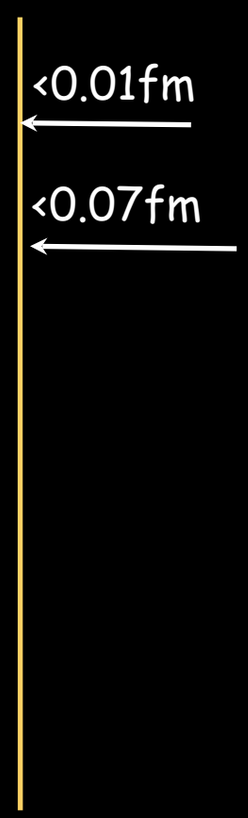
b bottom quark

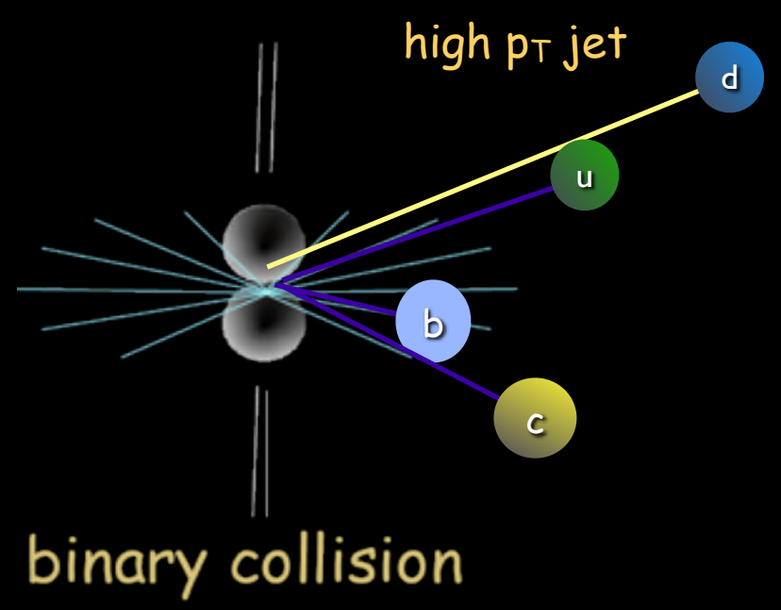


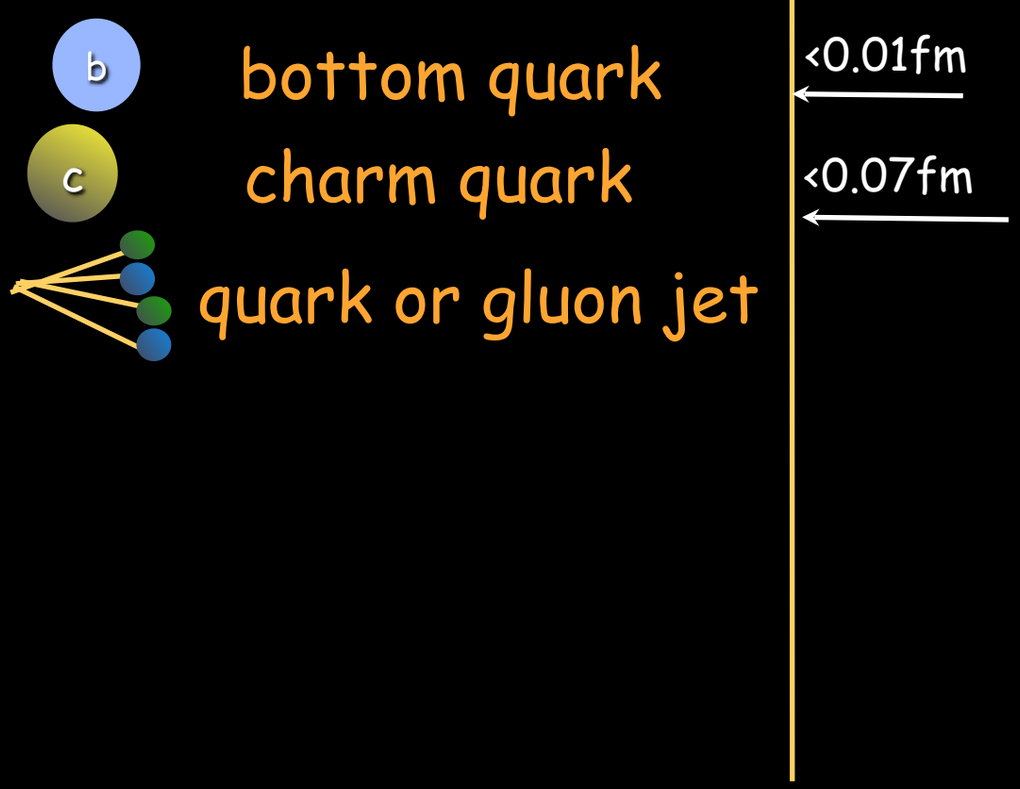


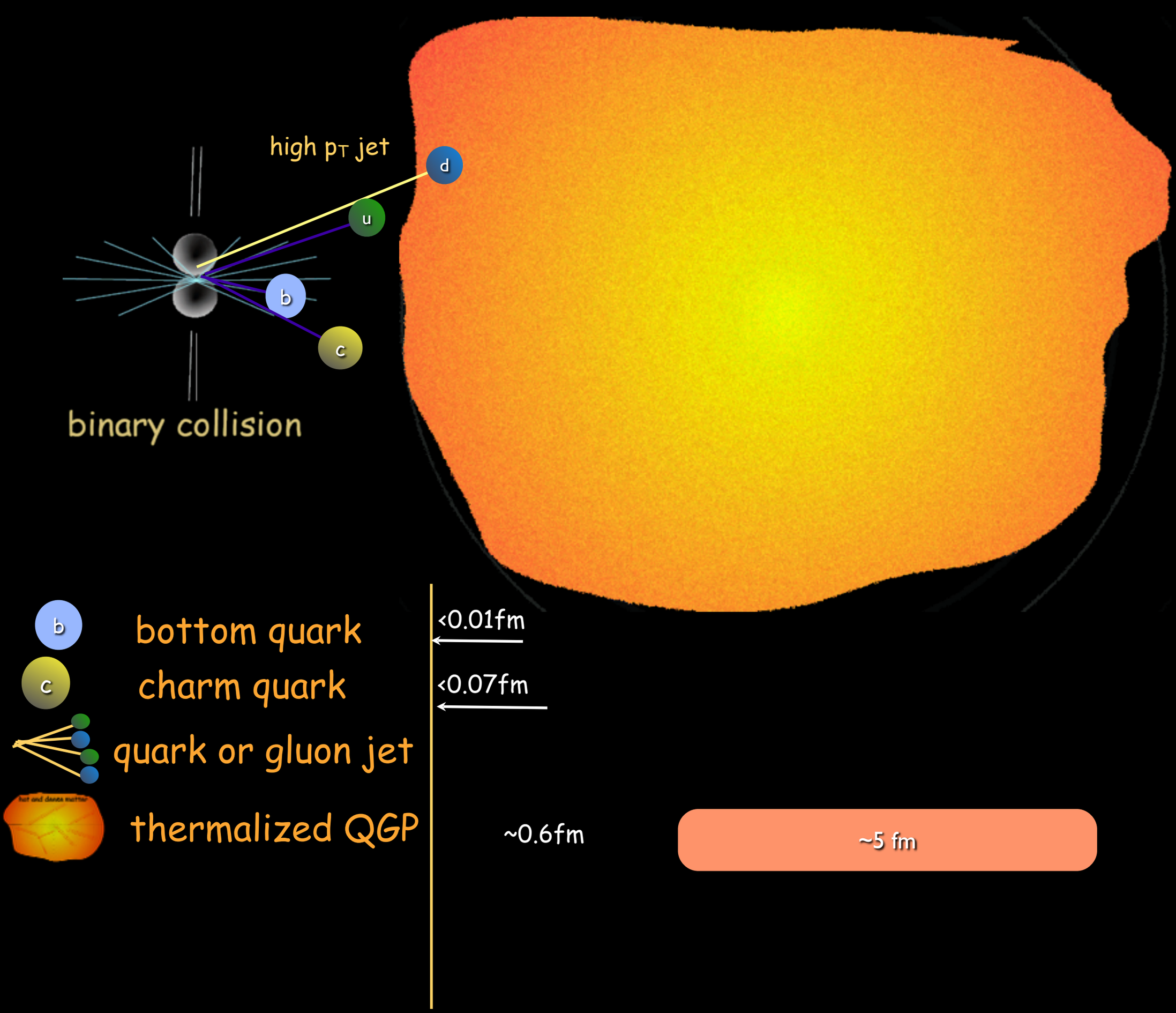
b bottom quark

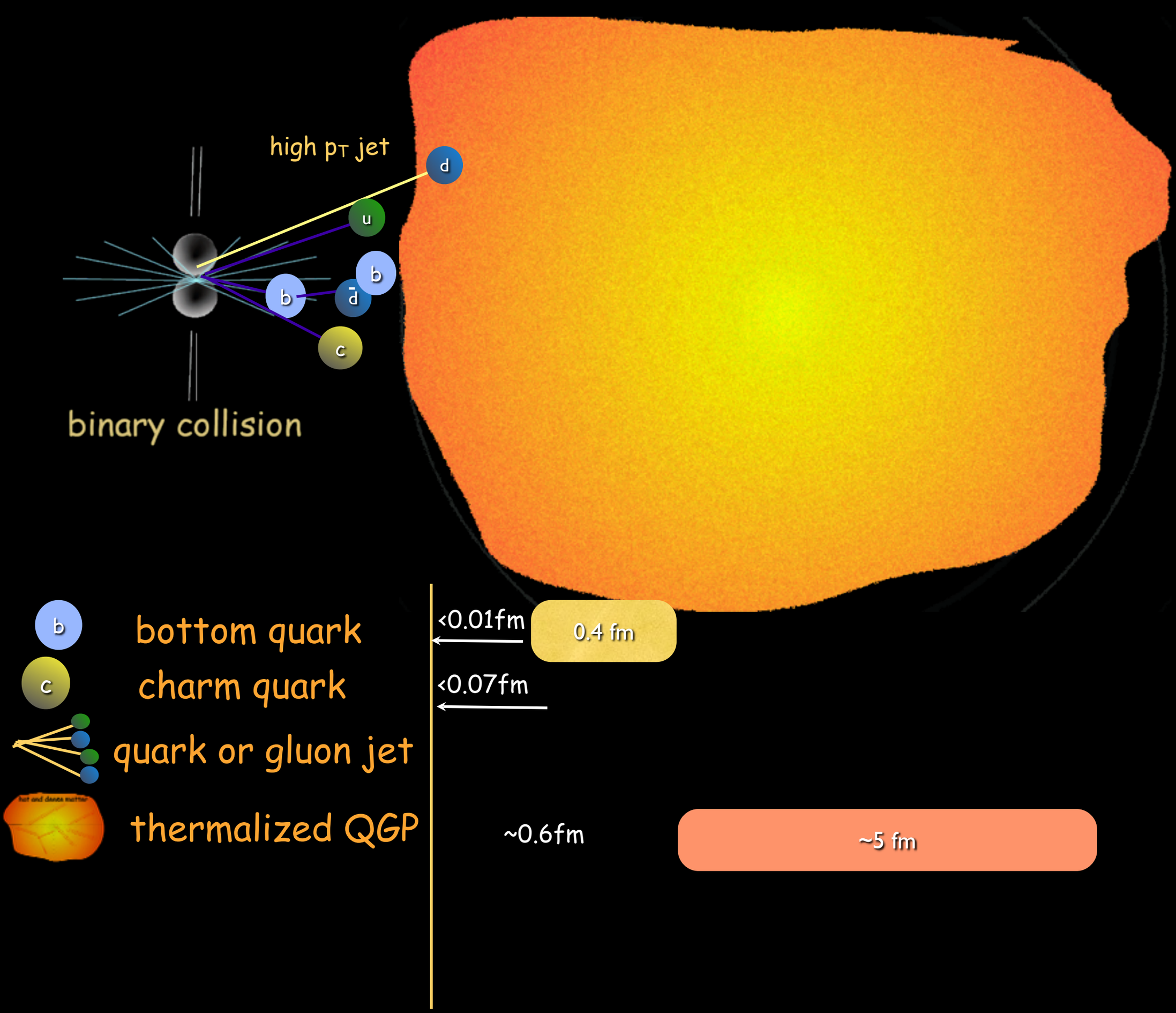
c charm quark

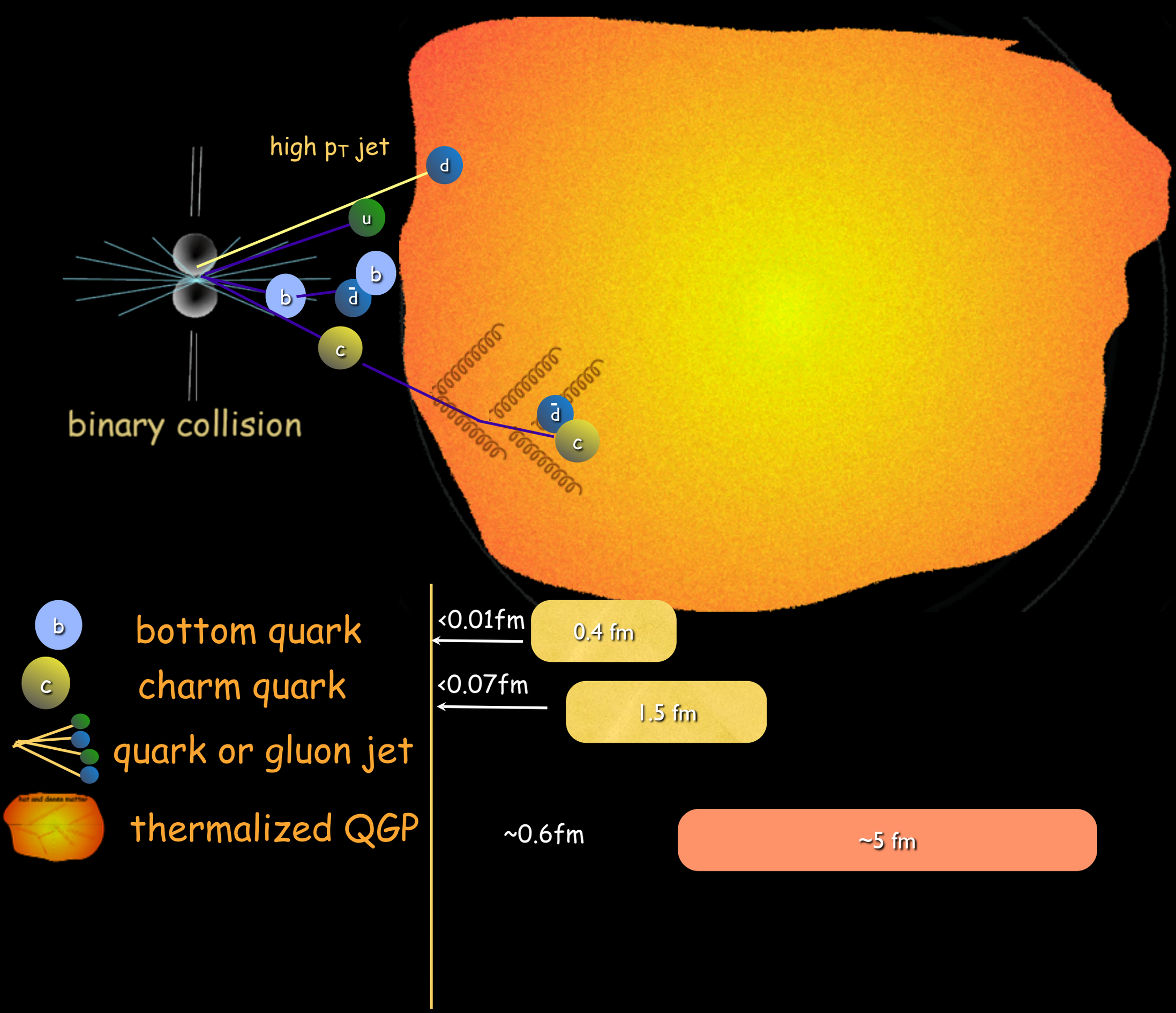


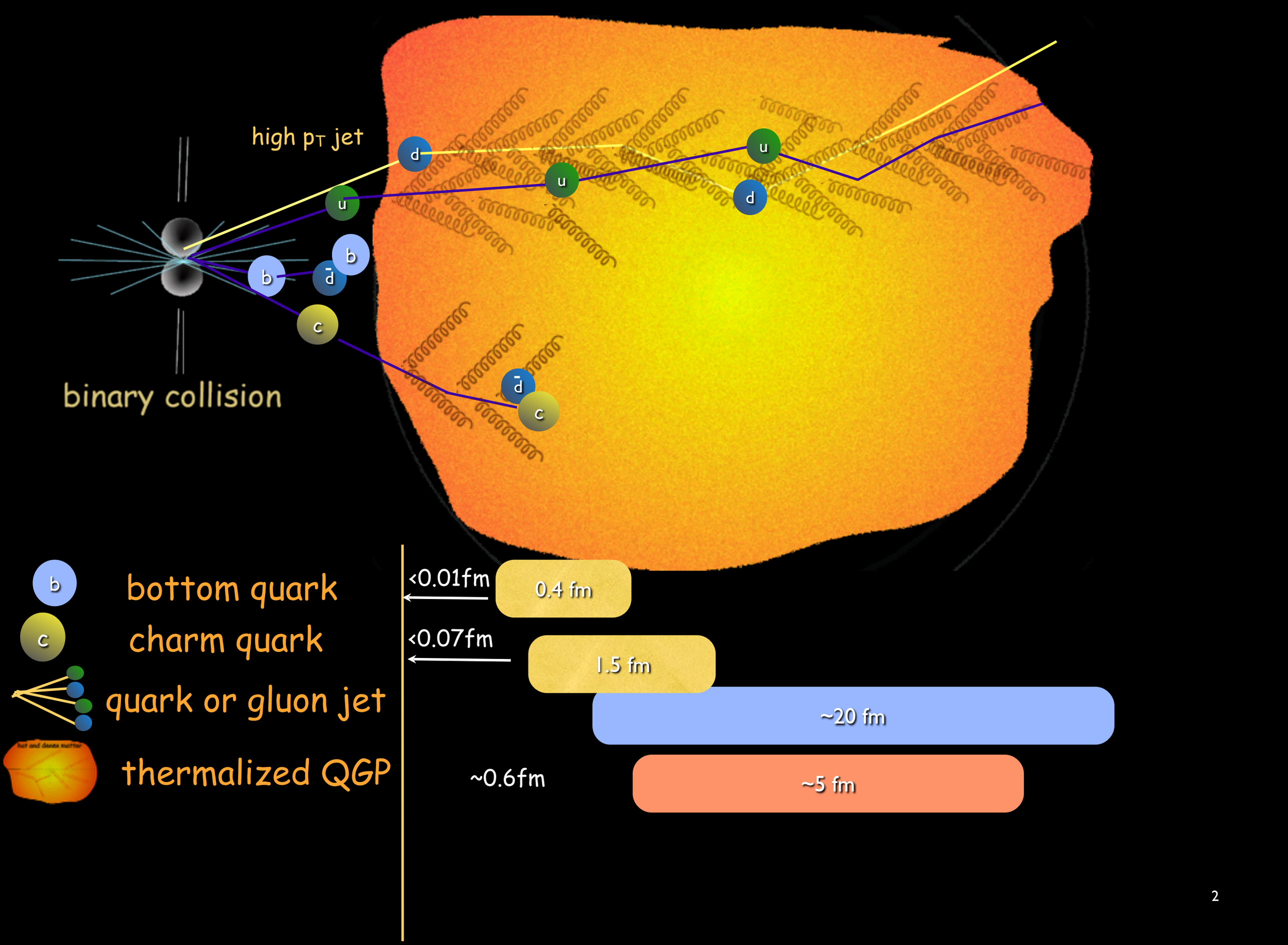

high p_T jet
d
u
b
c
binary collision

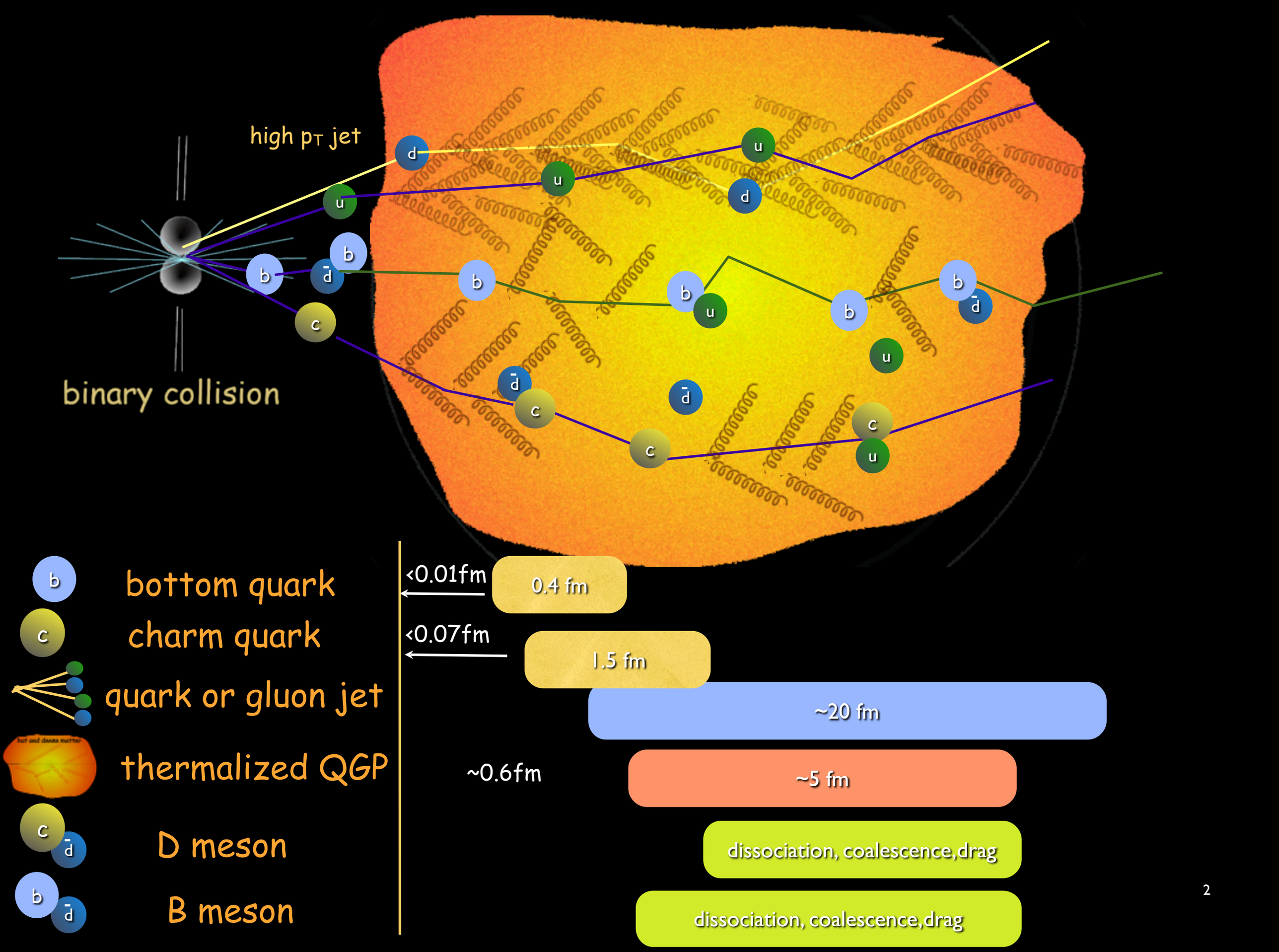

b
bottom quark
c
charm quark
quark or gluon jet
<0.01fm
<0.07fm

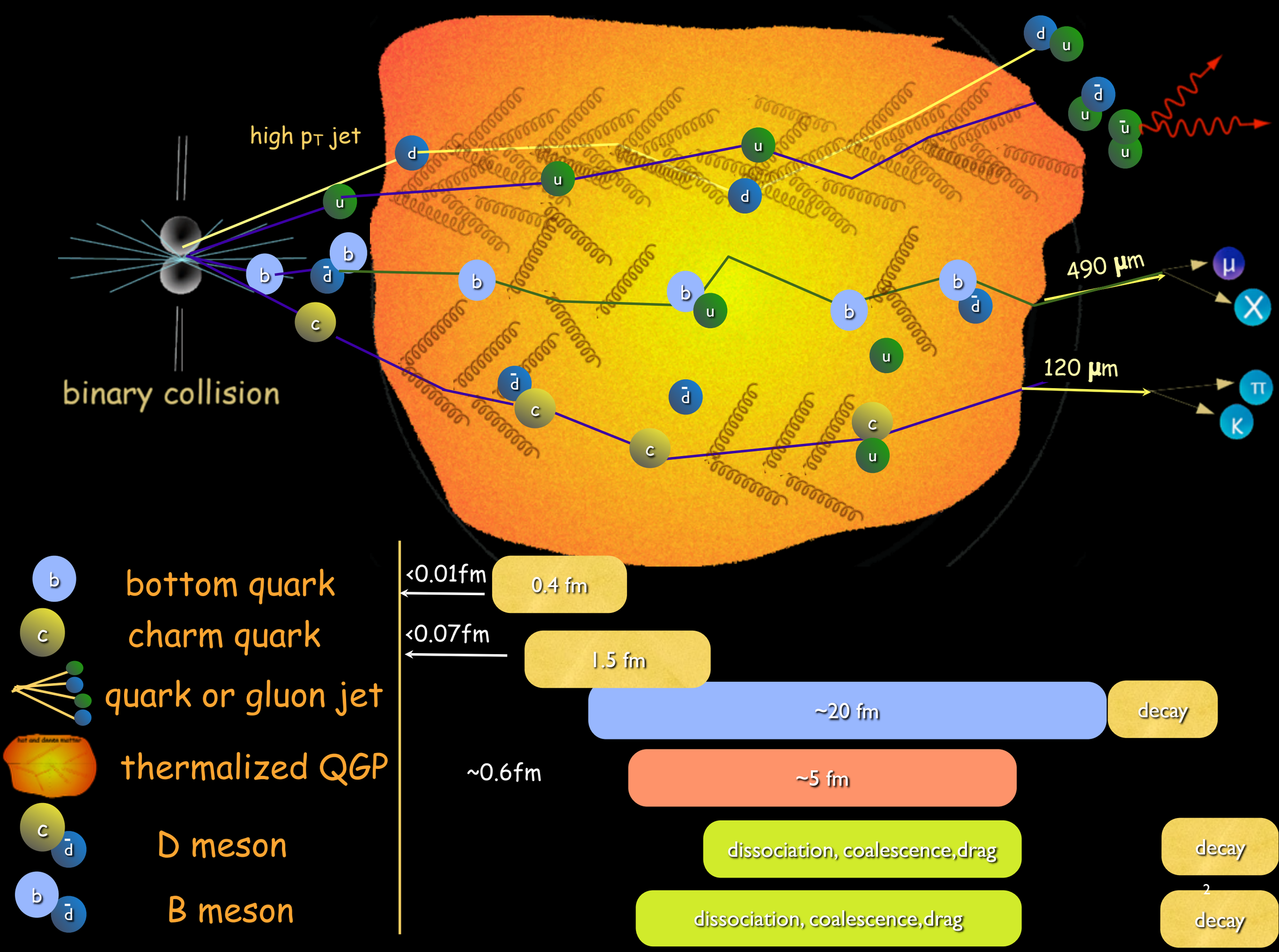

high p_T jet
d
u
b
c
binary collision
b
bottom quark
c
charm quark
quark or gluon jet
thermalized QGP
<0.01fm
<0.07fm
~0.6fm
~5 fm

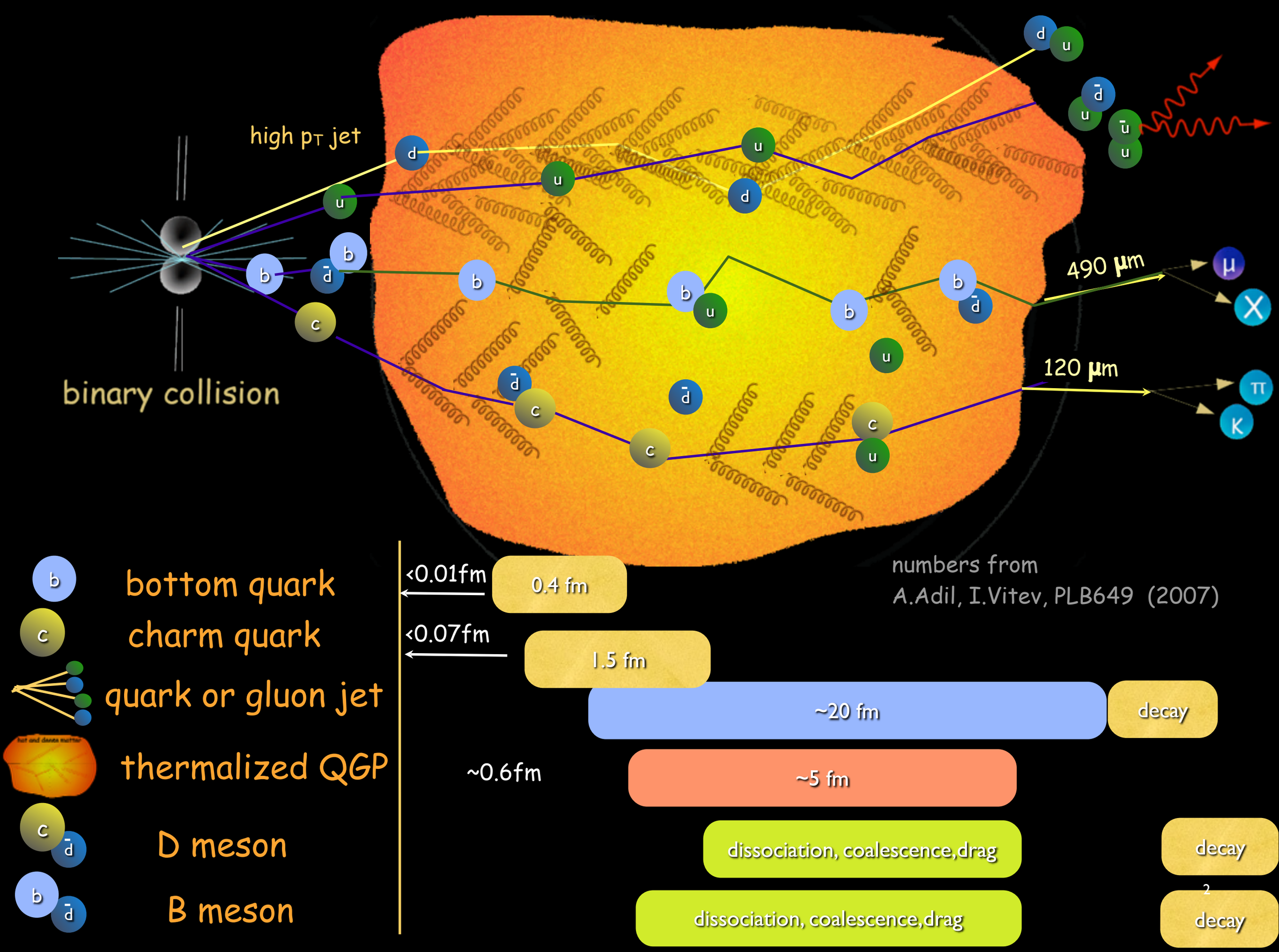

high p_T jet
d
u
b
b
$\bar{d}$
c
binary collision
b
bottom quark
c
charm quark
quark or gluon jet
thermalized QGP
<0.01fm
0.4 fm
<0.07fm
~0.6fm
~5 fm


high p_T jet
d
u
b
b
$\bar{d}$
c
$\bar{d}$
c
binary collision
b
bottom quark
c
charm quark
quark or gluon jet
thermalized QGP
<0.01fm
0.4 fm
<0.07fm
1.5 fm
~0.6fm
~5 fm


high p_T jet
binary collision
d
u
u
b
b
$\bar{d}$
c
u
d
$\bar{d}$
c
b
bottom quark
c
charm quark
quark or gluon jet
thermalized QGP
<0.01fm
0.4 fm
<0.07fm
1.5 fm
~20 fm
~0.6fm
~5 fm


high p_T jet
binary collision
b
c
quark or gluon jet
thermalized QGP
D meson
B meson
bottom quark
charm quark
<0.01fm
0.4 fm
<0.07fm
1.5 fm
~20 fm
~0.6fm
~5 fm
dissociation, coalescence,drag
dissociation, coalescence,drag


high p_T jet
binary collision
490 μm
120 μm
μ
X
π
K
b bottom quark
c charm quark
quark or gluon jet
thermalized QGP
c d̄ D meson
b d̄ B meson
<0.01fm
0.4 fm
<0.07fm
1.5 fm
~20 fm
decay
~0.6fm
~5 fm
dissociation, coalescence,drag
decay
dissociation, coalescence,drag
decay


high p_T jet
binary collision
490 μm
120 μm
μ
X
π
K
b bottom quark
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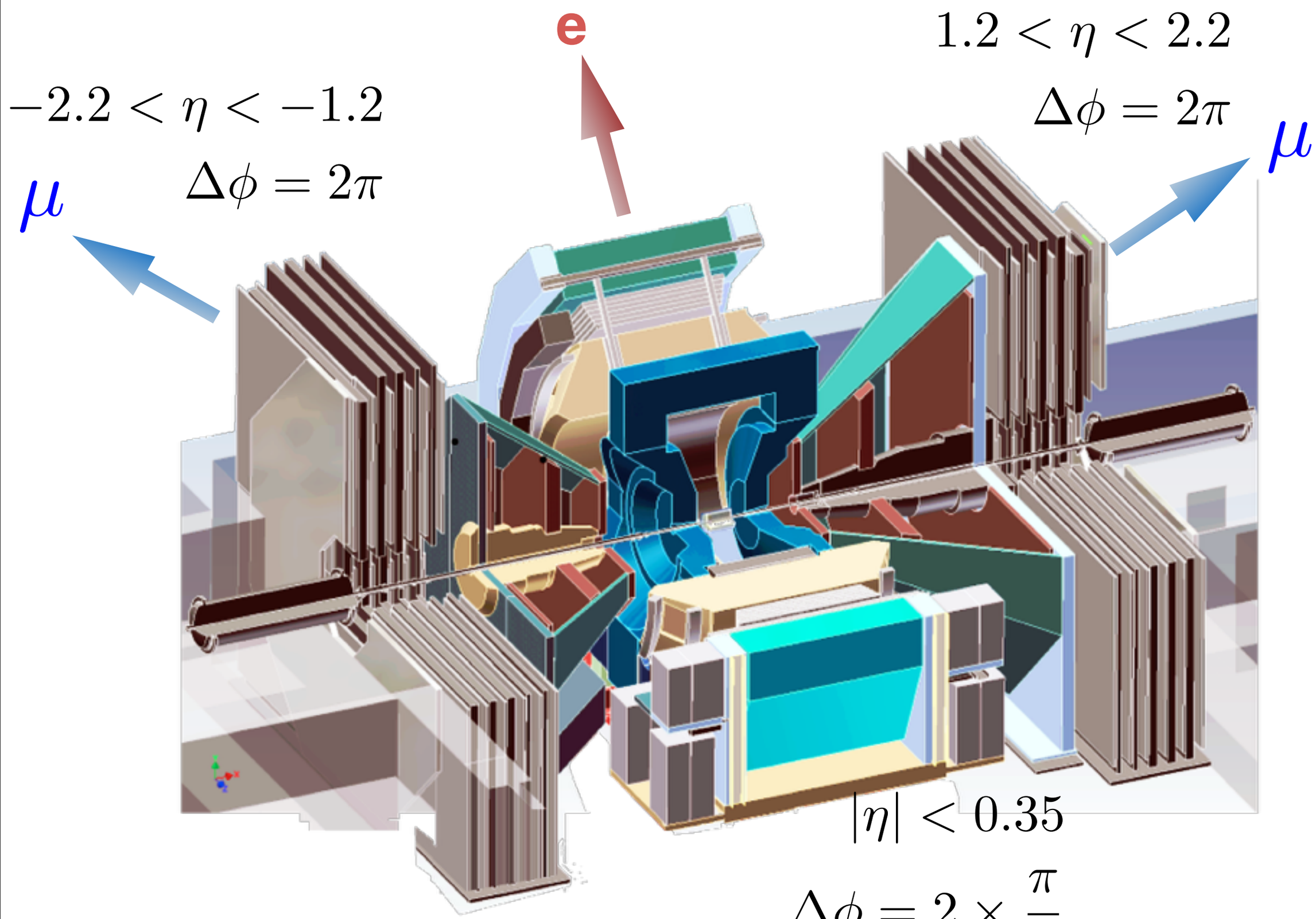
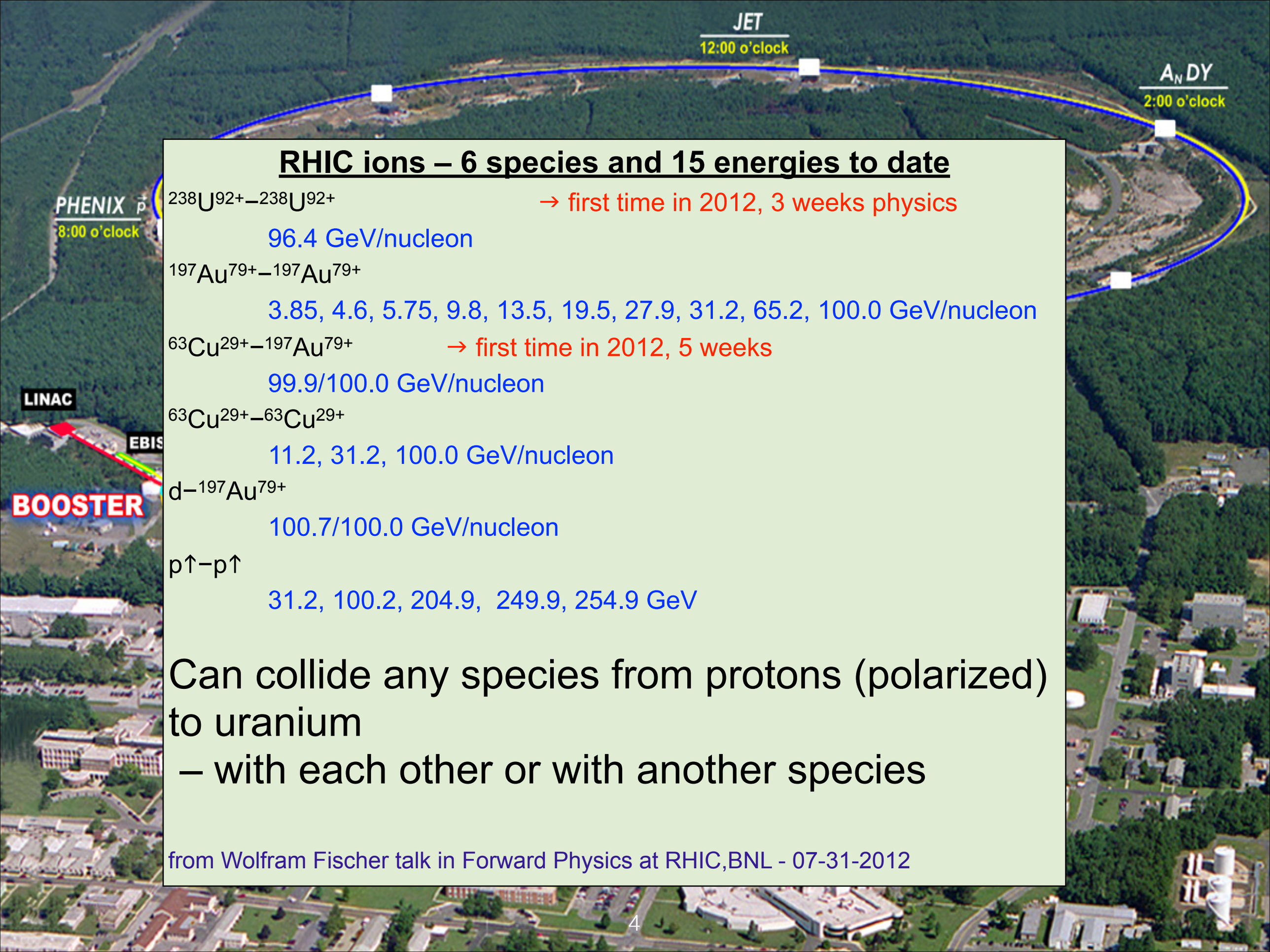
quark or gluon jet
thermalized QGP
c d̄ D meson
b d̄ B meson
<0.01fm
0.4 fm
<0.07fm
1.5 fm
~20 fm
decay
~0.6fm
~5 fm
dissociation, coalescence,drag
decay
dissociation, coalescence,drag
decay
numbers from
A.Adil, I.Vitev, PLB649 (2007)

LEPTONS iN PHENIX DETECTOR





RHIC ions – 6 species and 15 energies to date

$^{238}U^{92+}$–$^{238}U^{92+}$ → first time in 2012, 3 weeks physics

96.4 GeV/nucleon

$^{197}Au^{79+}$–$^{197}Au^{79+}$

3.85, 4.6, 5.75, 9.8, 13.5, 19.5, 27.9, 31.2, 65.2, 100.0 GeV/nucleon

$^{63}Cu^{29+}$–$^{197}Au^{79+}$ → first time in 2012, 5 weeks

99.9/100.0 GeV/nucleon

$^{63}Cu^{29+}$–$^{63}Cu^{29+}$

11.2, 31.2, 100.0 GeV/nucleon

d–$^{197}Au^{79+}$

100.7/100.0 GeV/nucleon

p↑–p↑

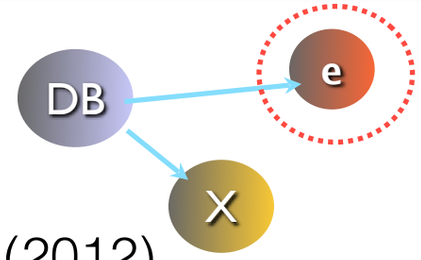
31.2, 100.2, 204.9, 249.9, 254.9 GeV

Can collide any species from protons (polarized) to uranium
– with each other or with another species

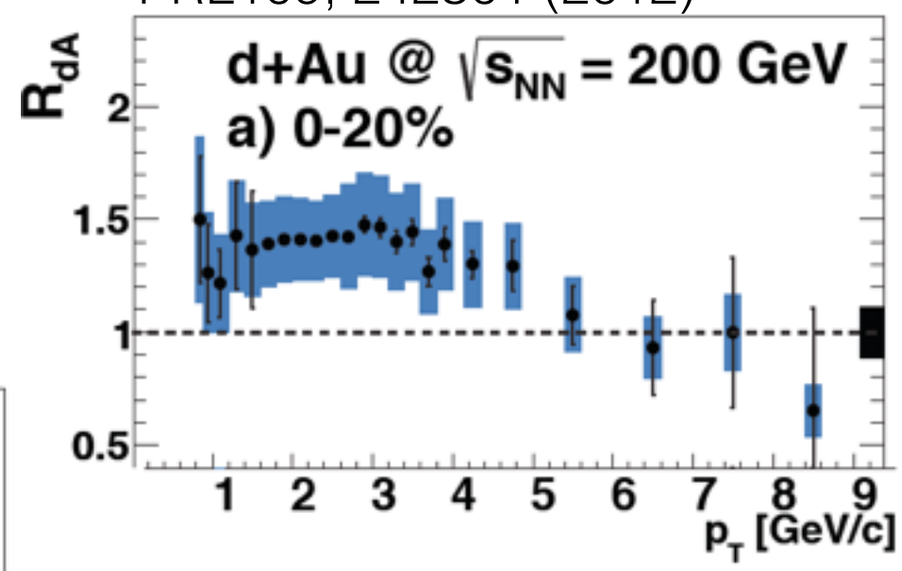
from Wolfram Fischer talk in Forward Physics at RHIC,BNL - 07-31-2012

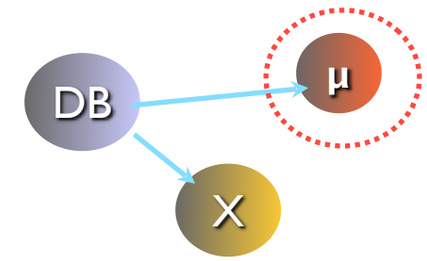
Heavy ion runs
Integrated nucleon-pair luminosity L_{NN} [pb^{-1}]
Weeks in physics
0
20
40
60
80
100
120
140
160
180
200
0
2
4
6
8
10
12
14
16
18
20
2011 Au-Au
2010 Au-Au
2012 Cu-Au
2007 Au-Au
2008 d-Au
2012 U-U
2005 Cu-Cu
2004 Au-Au
2000 Au-Au
2003 d-Au
2001 Au-Au

d+Au Heavy Flavor Results

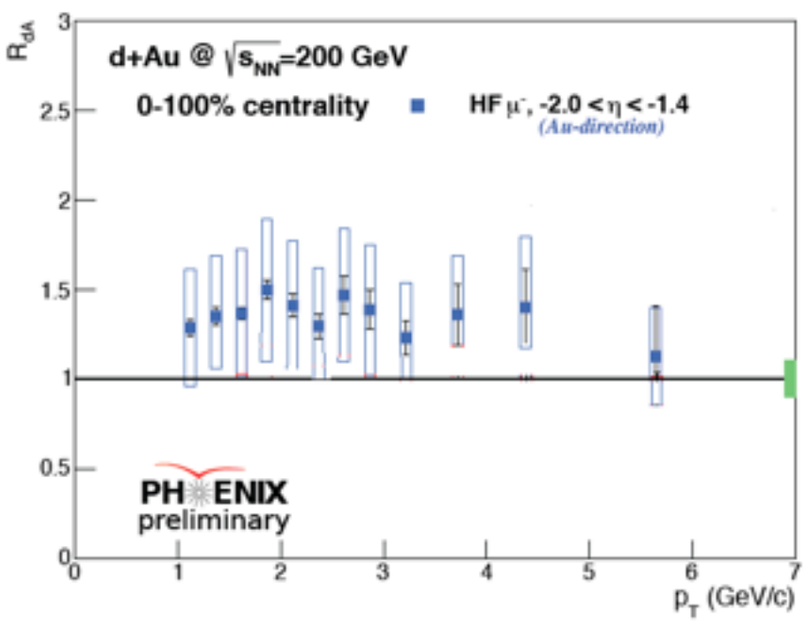


PRL109, 242301 (2012)





arXiv:1310.1005



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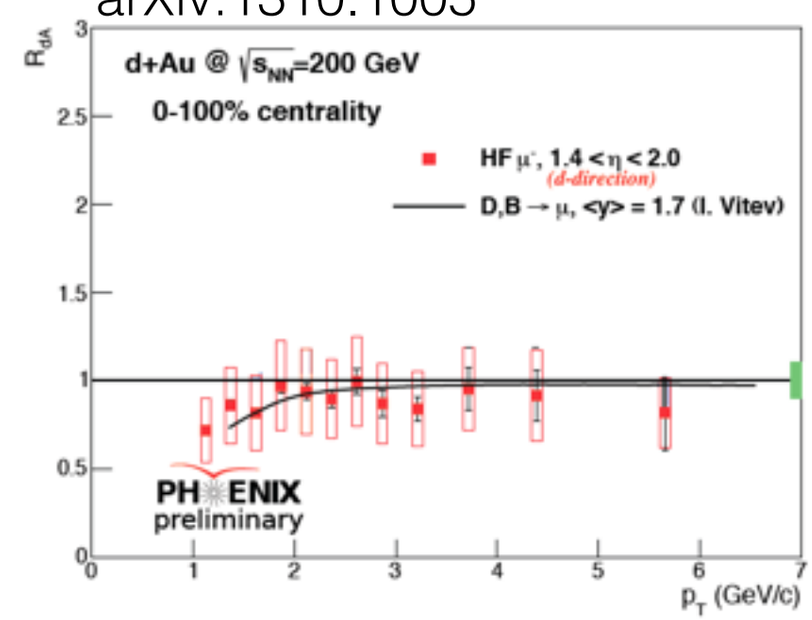
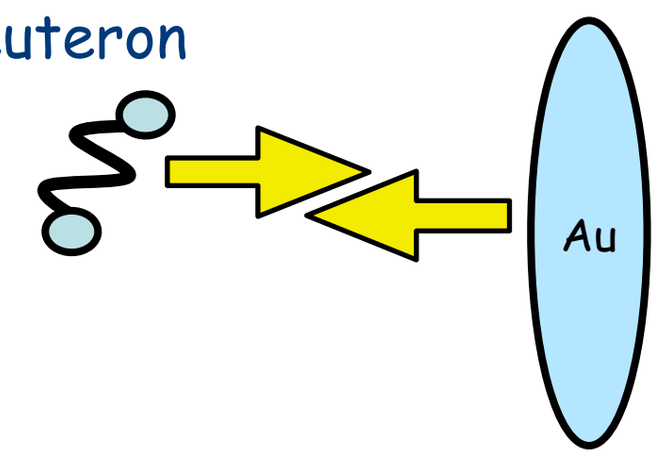
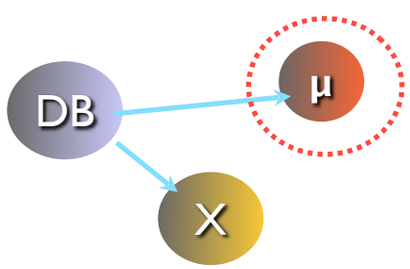
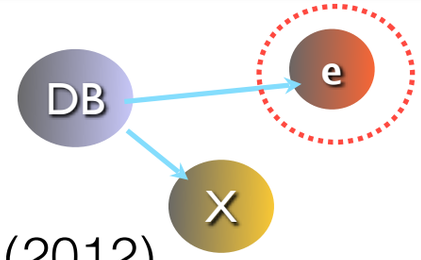


deuteron

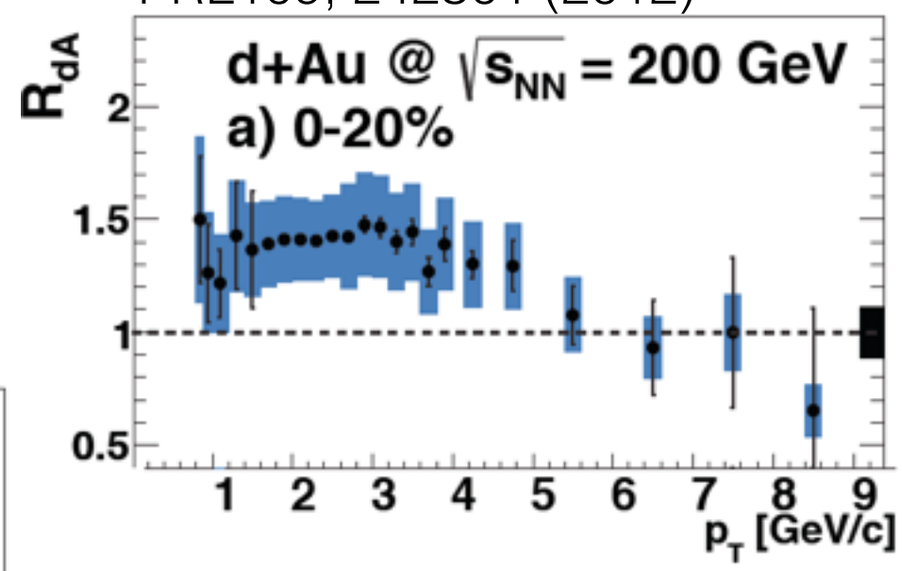


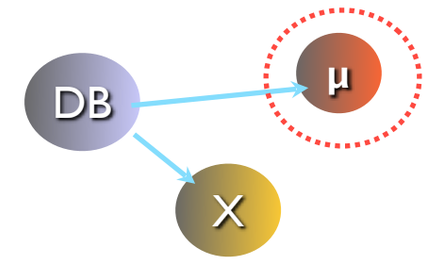


d+Au Heavy Flavor Results



PRL109, 242301 (2012)





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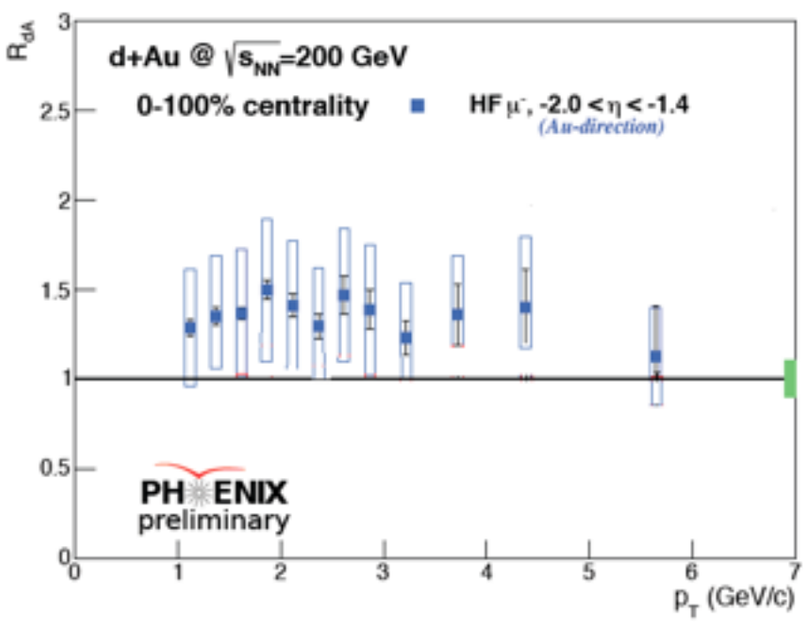
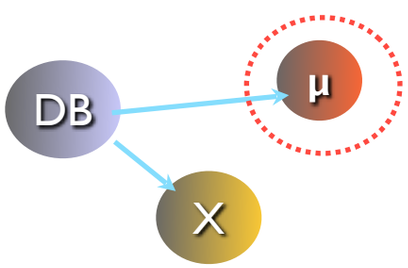
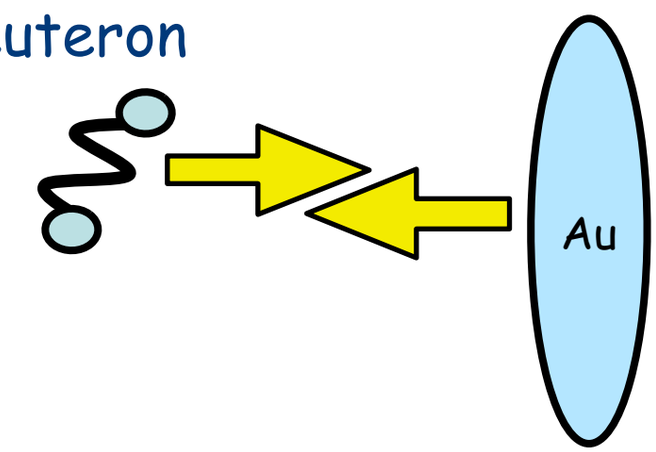




deuteron



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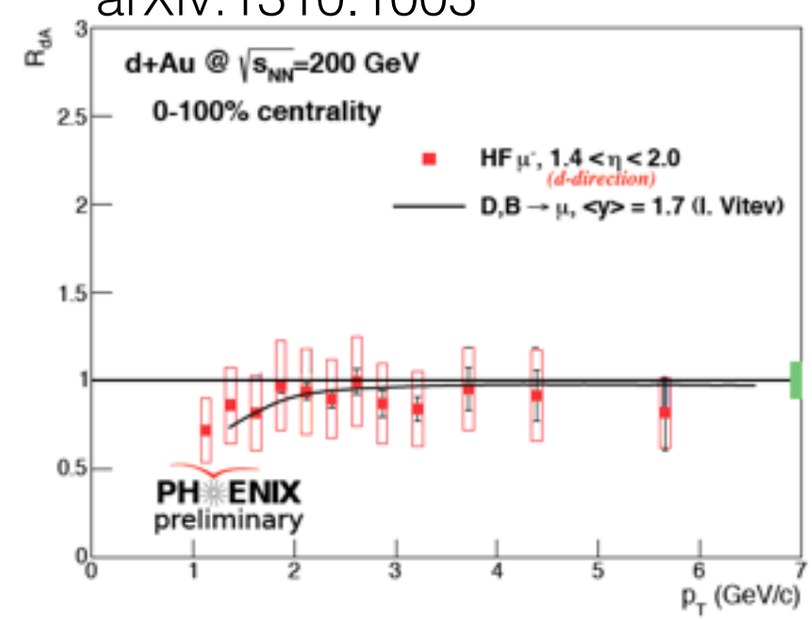
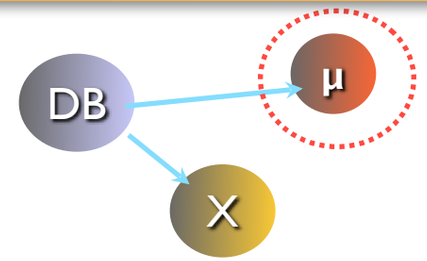
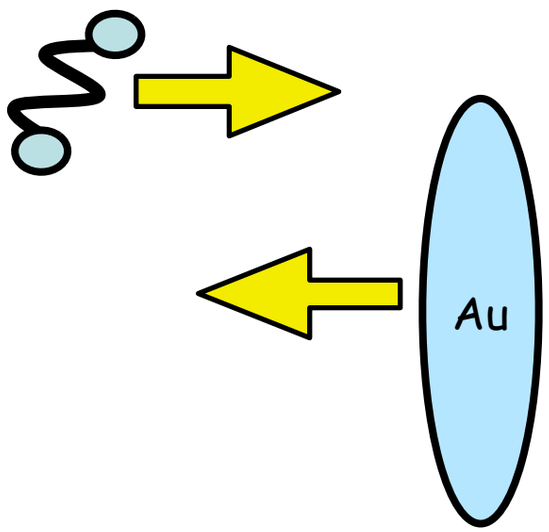
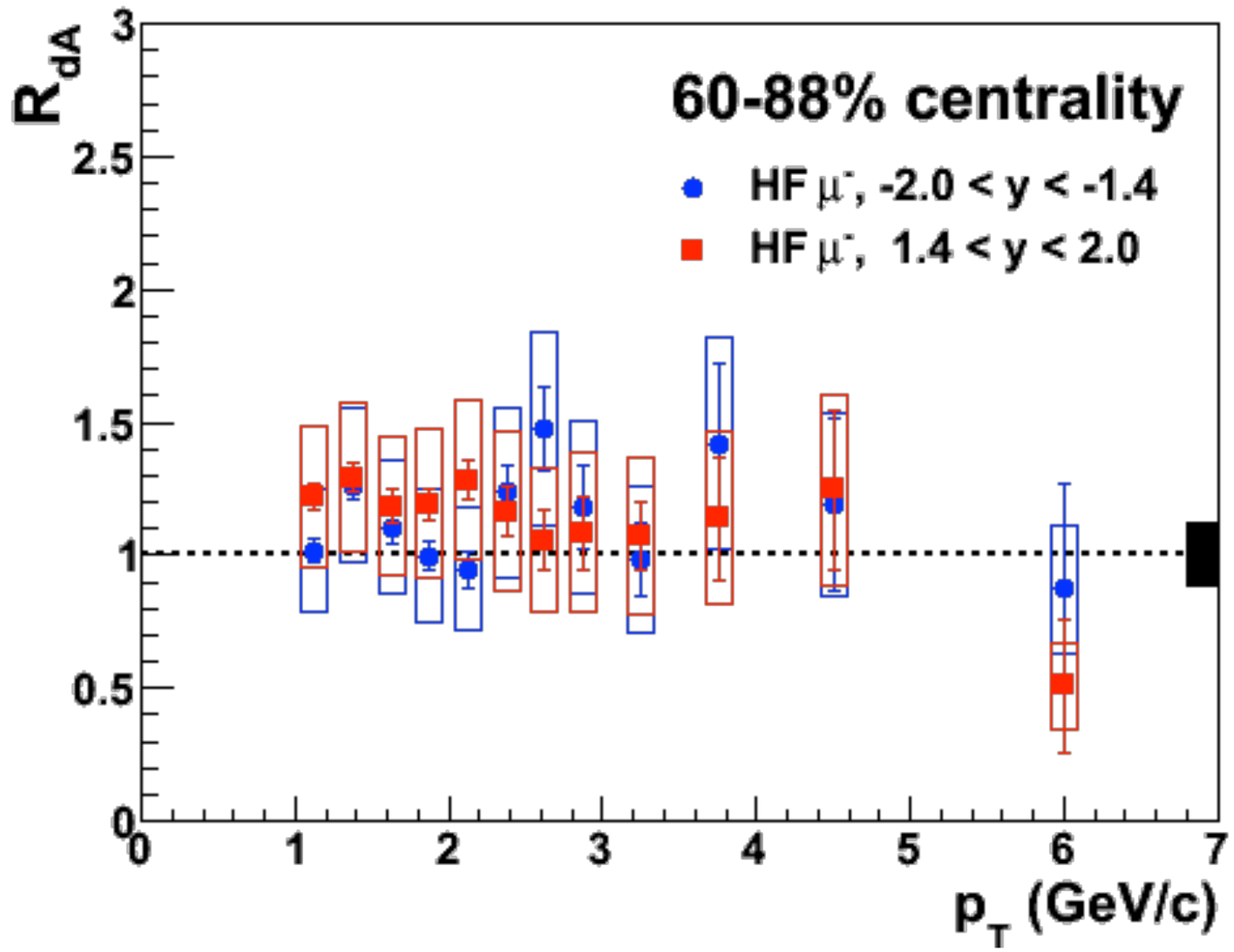


Vitev: coherent effect+Croning

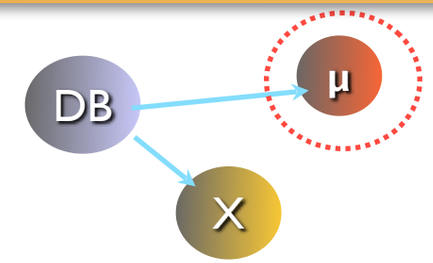
d+Au Heavy Flavor Results

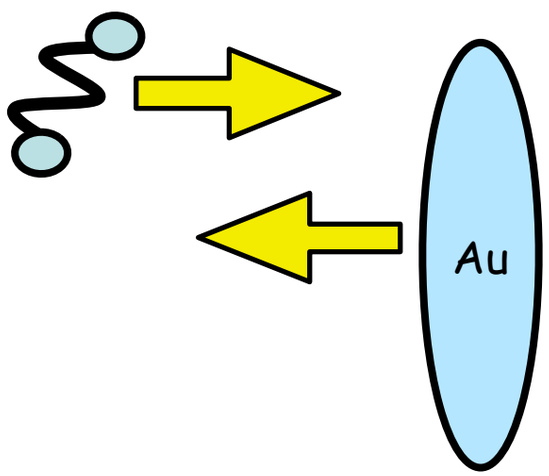


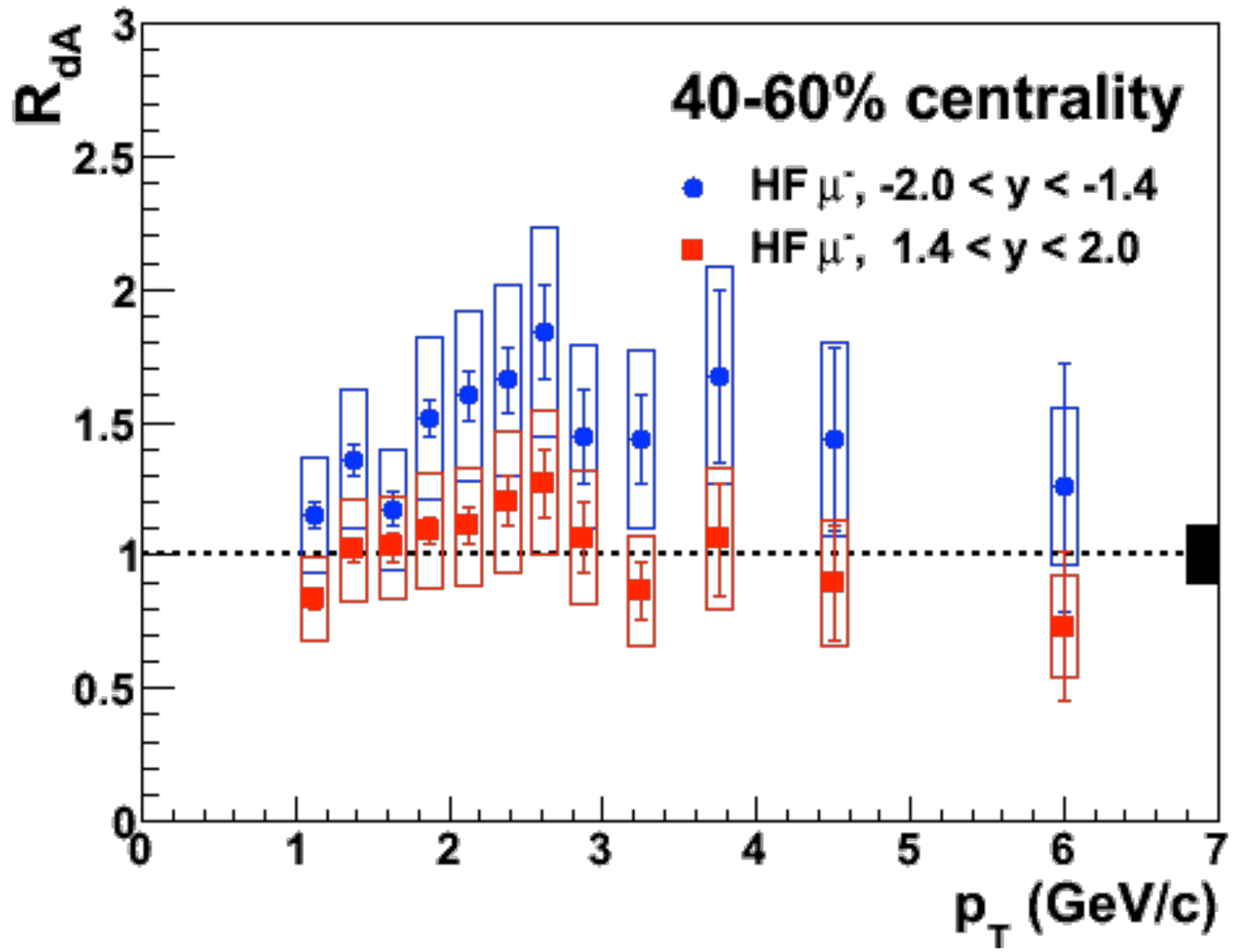




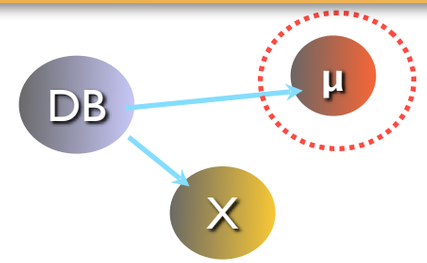
d+Au Heavy Flavor Results

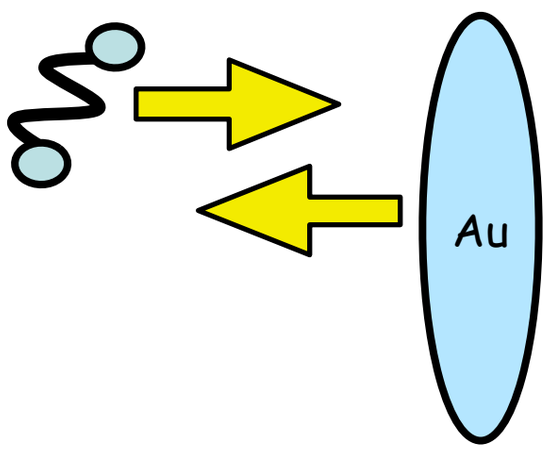


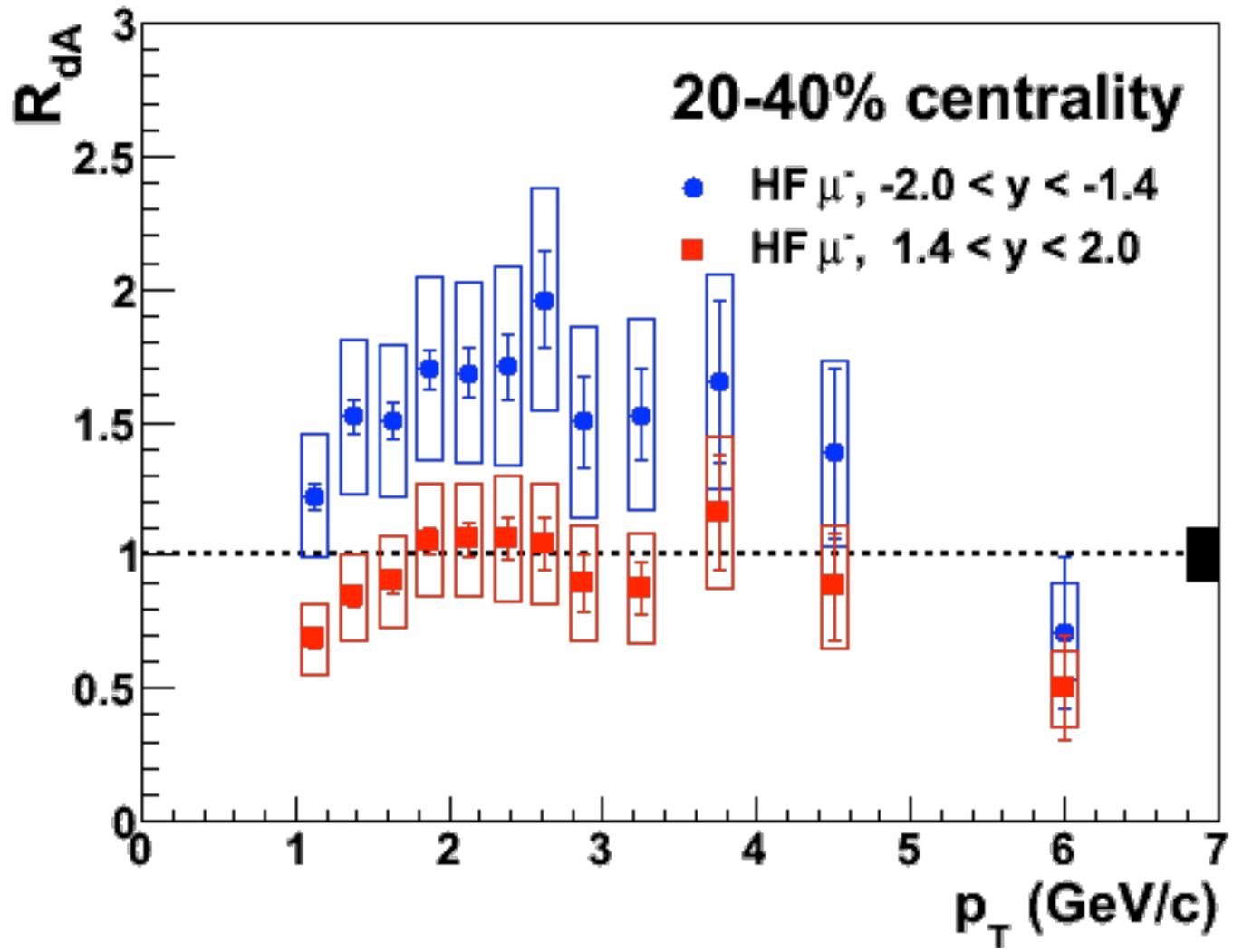




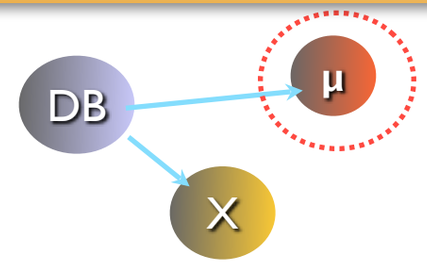
d+Au Heavy Flavor Results

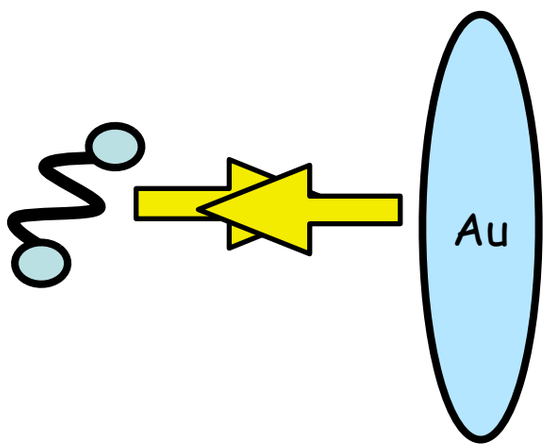


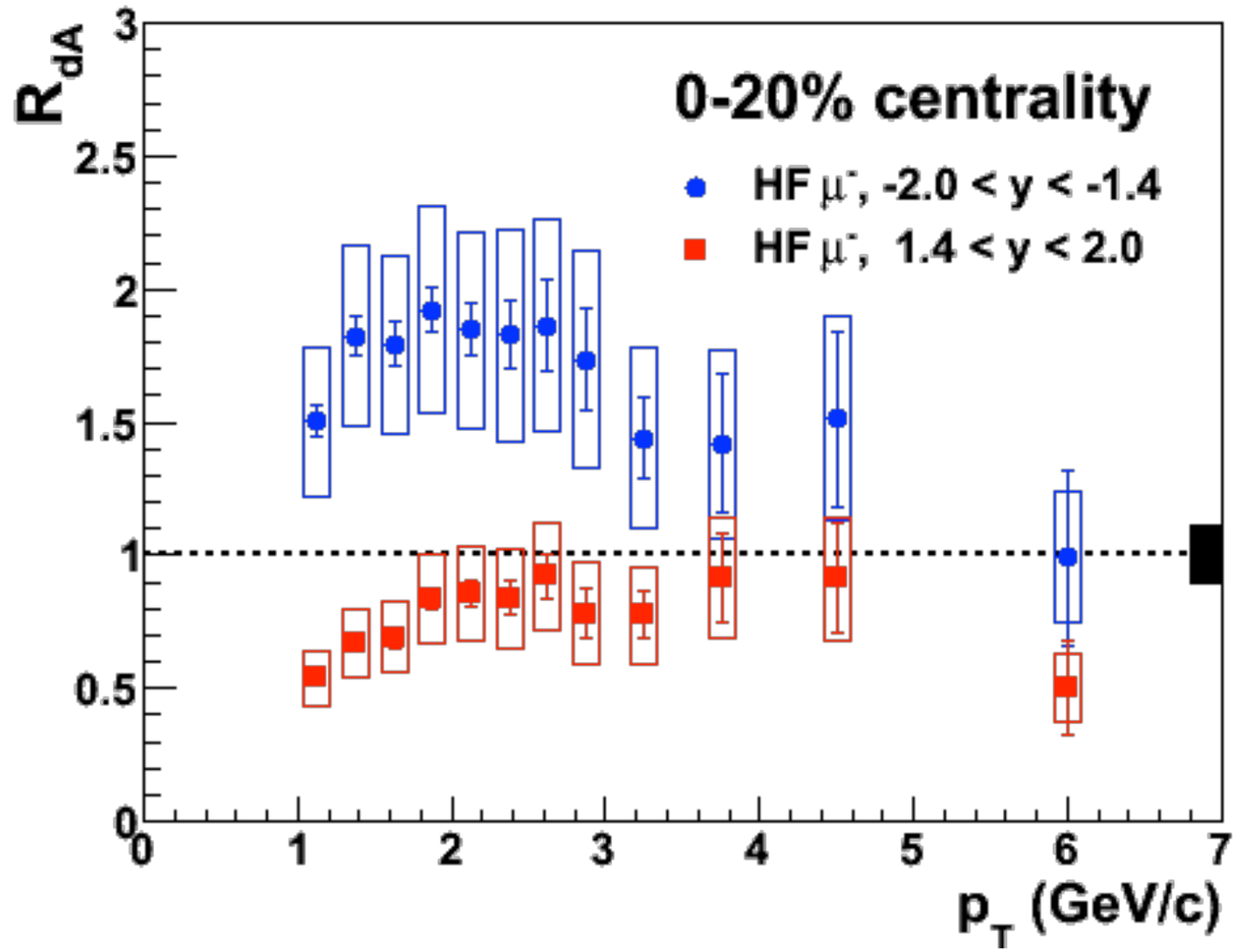




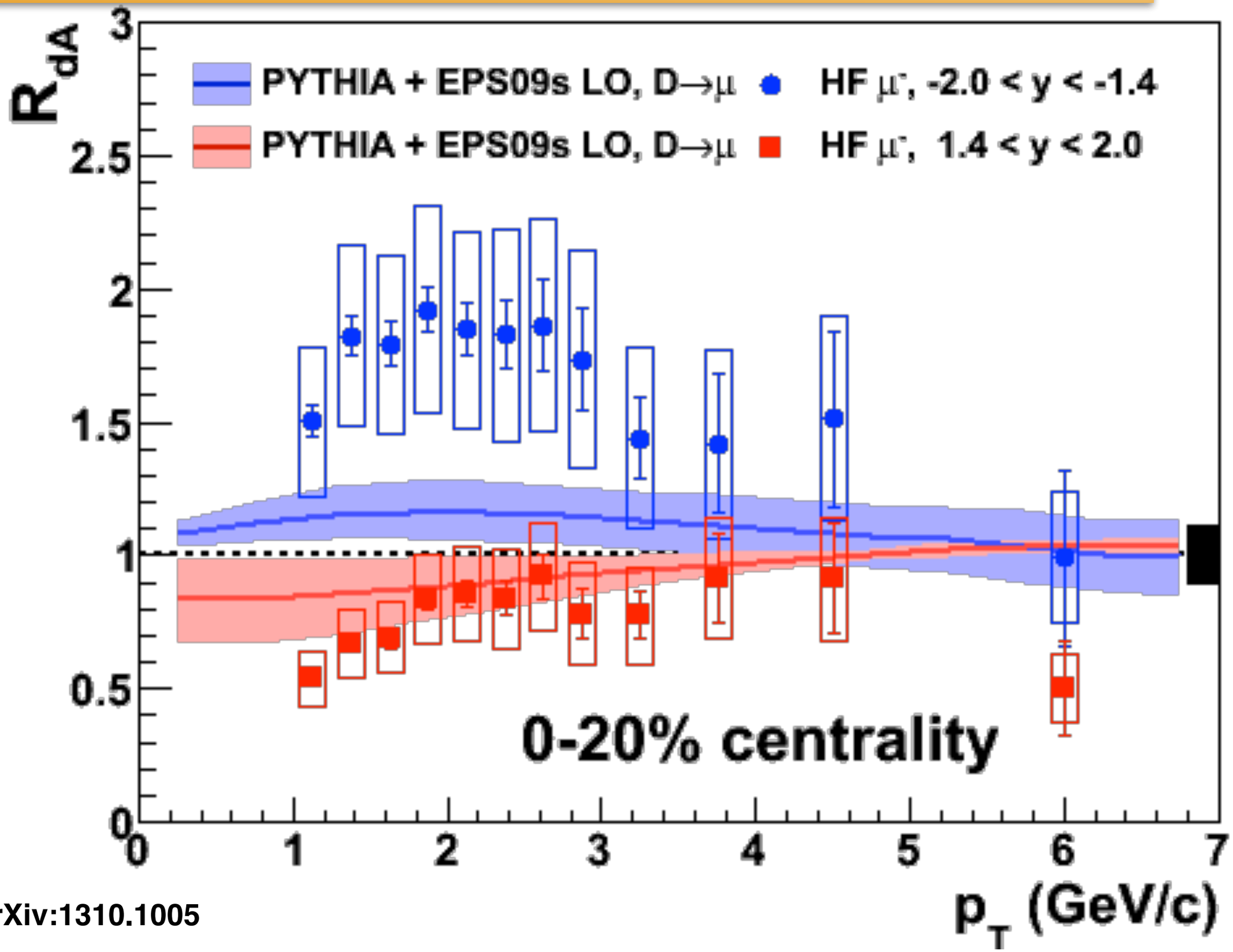
d+Au Heavy Flavor Results





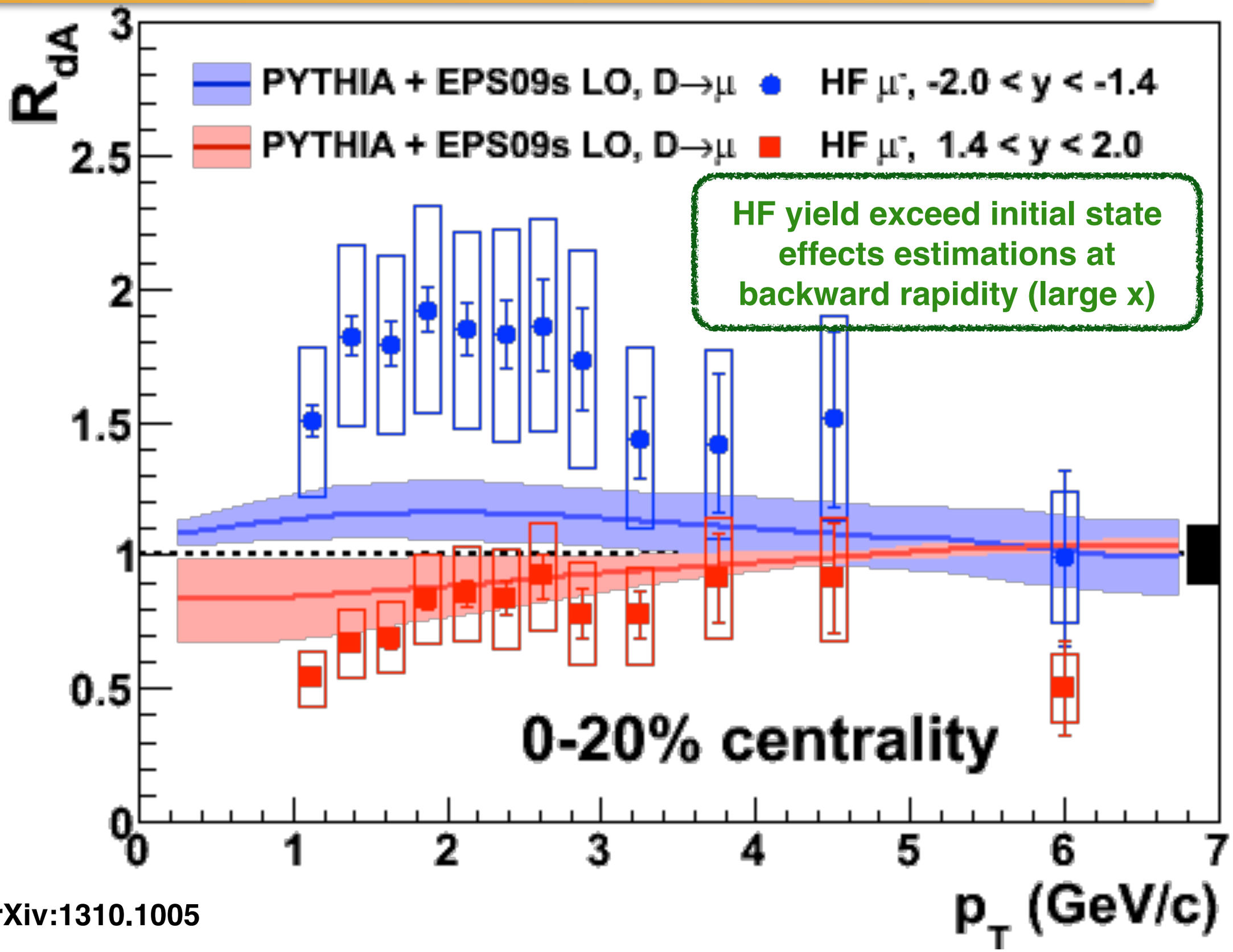


d+Au Heavy Flavor Comparison with EPS09s



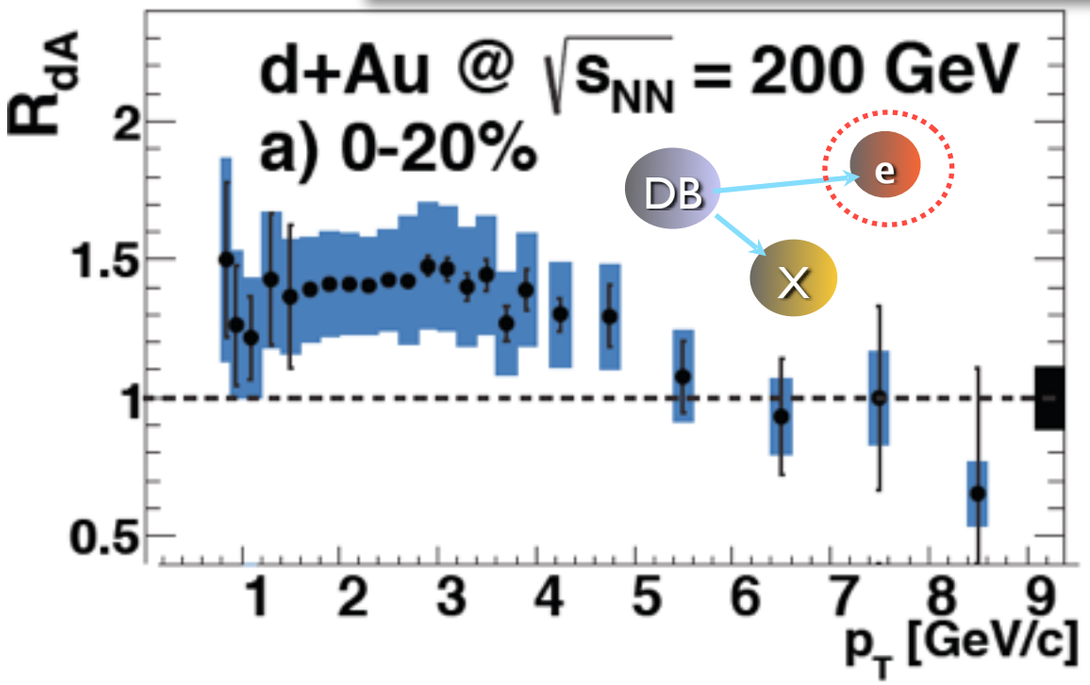
arXiv:1310.1005

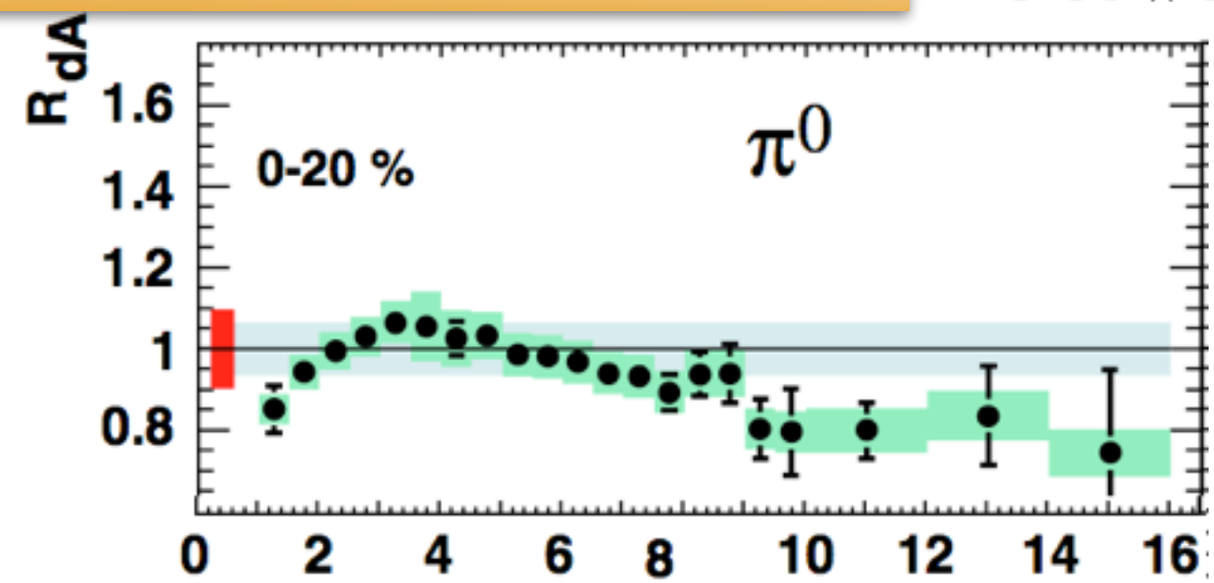
d+Au Heavy Flavor Comparison with EPS09s



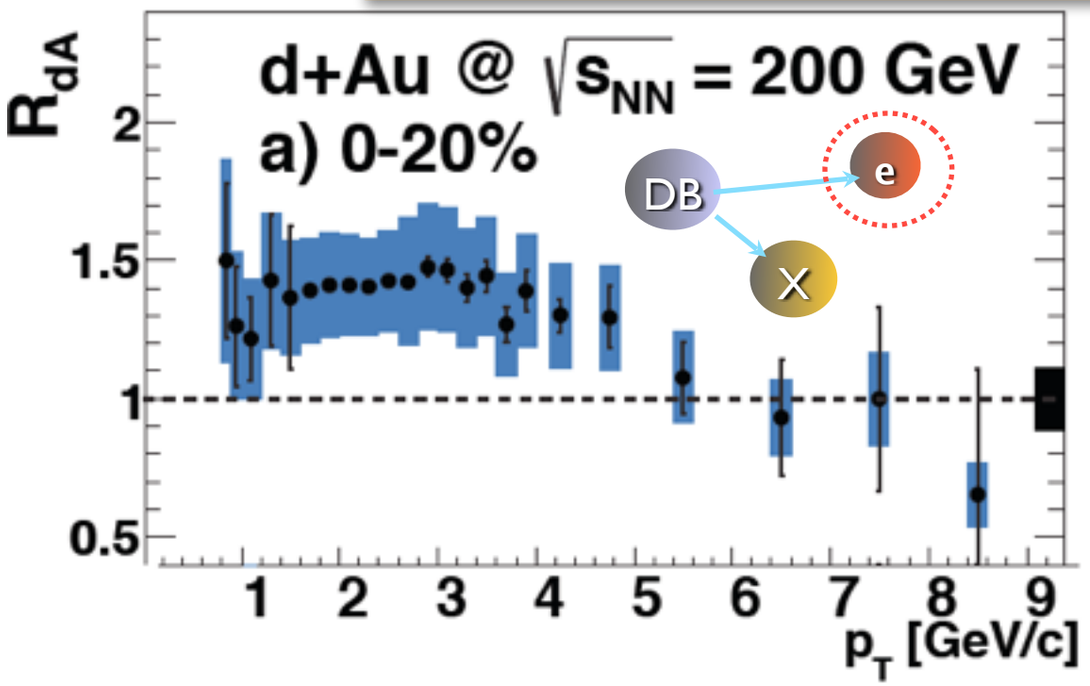
arXiv:1310.1005

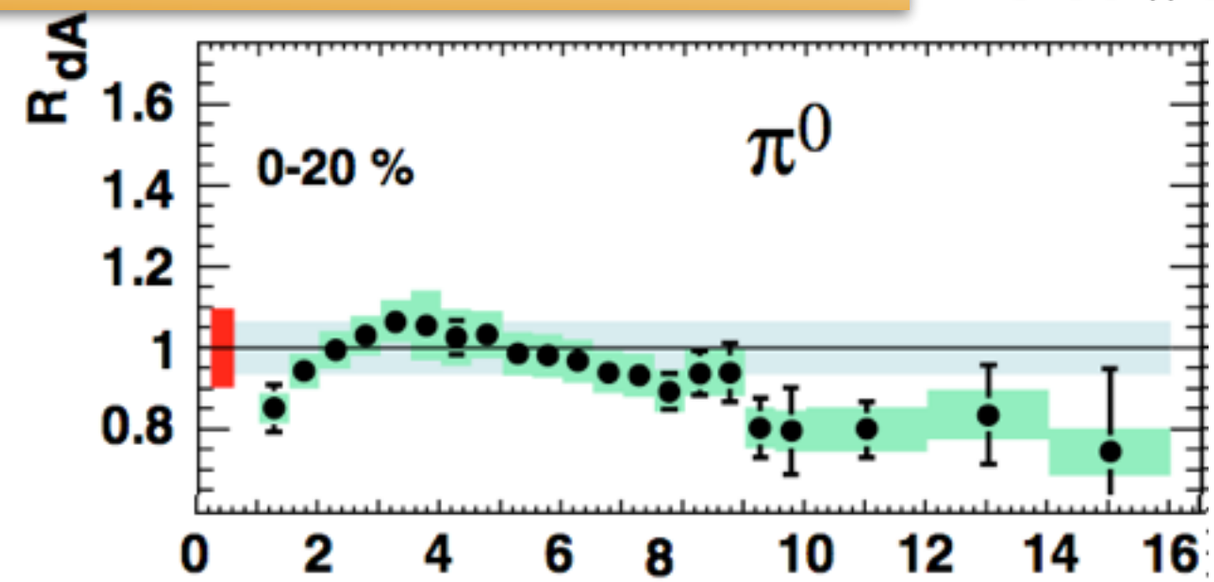
Light/Heavy quark comparison

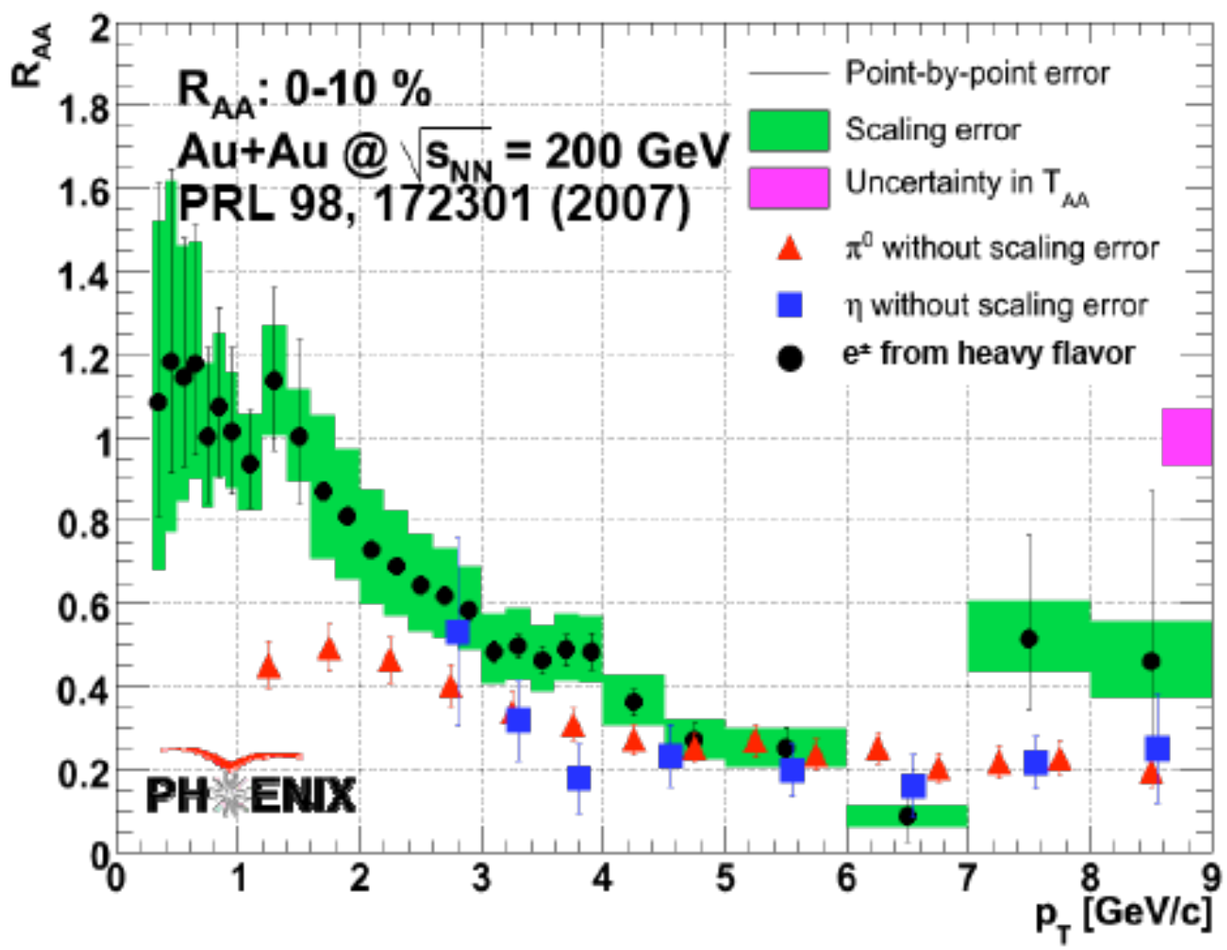




Light/Heavy quark comparison







Light/Heavy quark comparison

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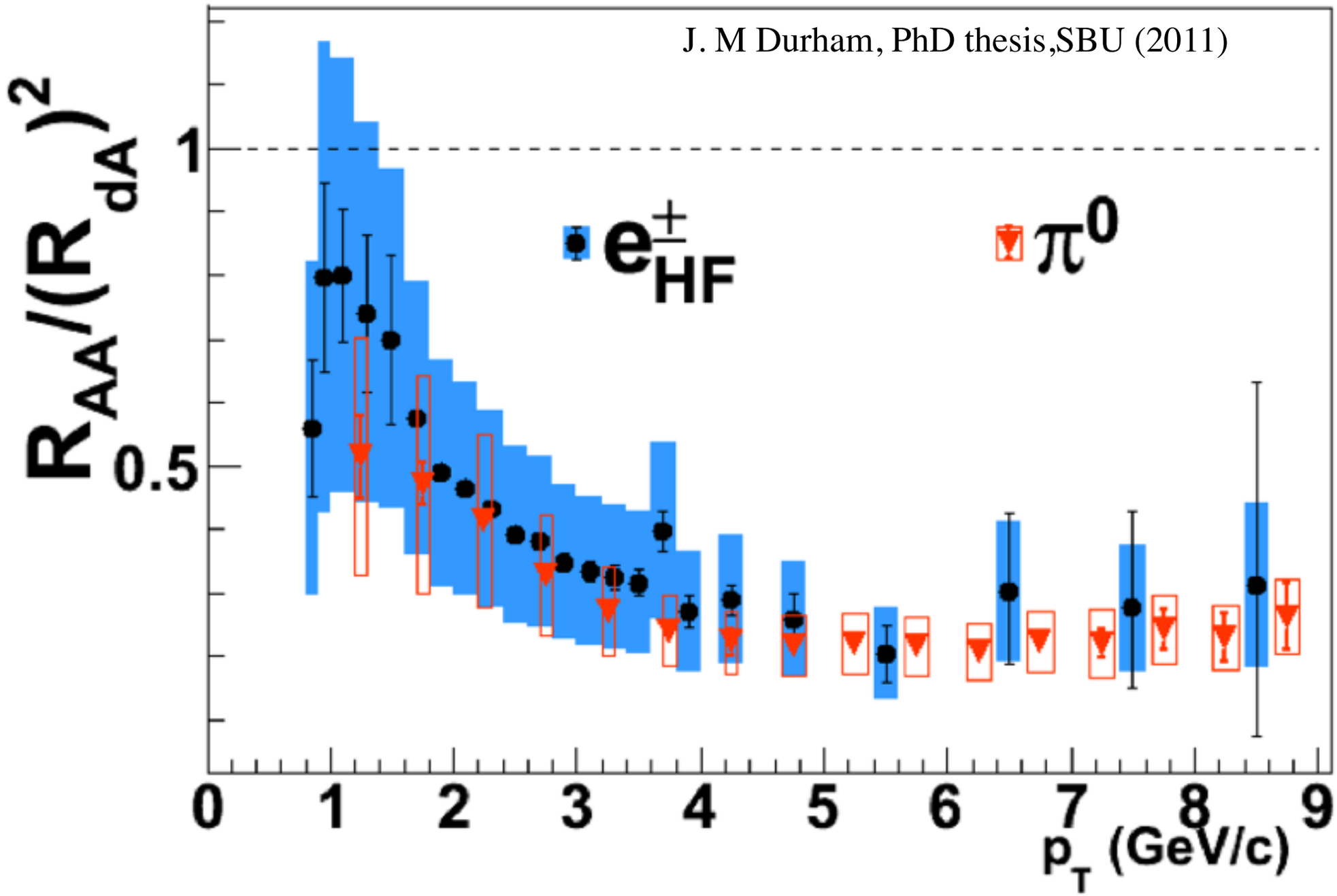
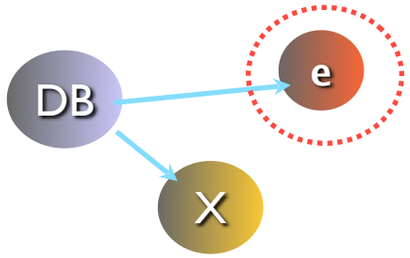


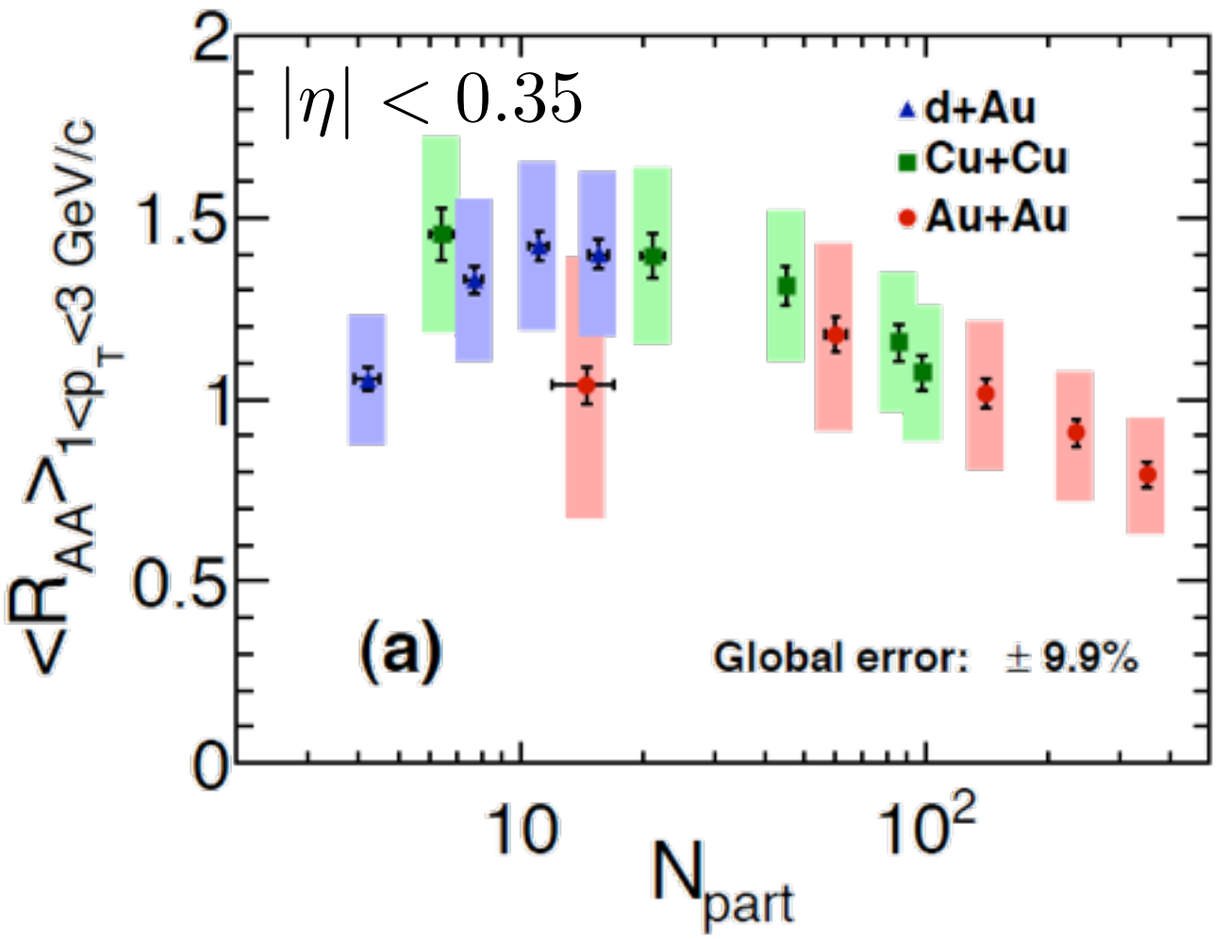
Same final state modification of **light** and **heavy** quarks at ALL p_T.

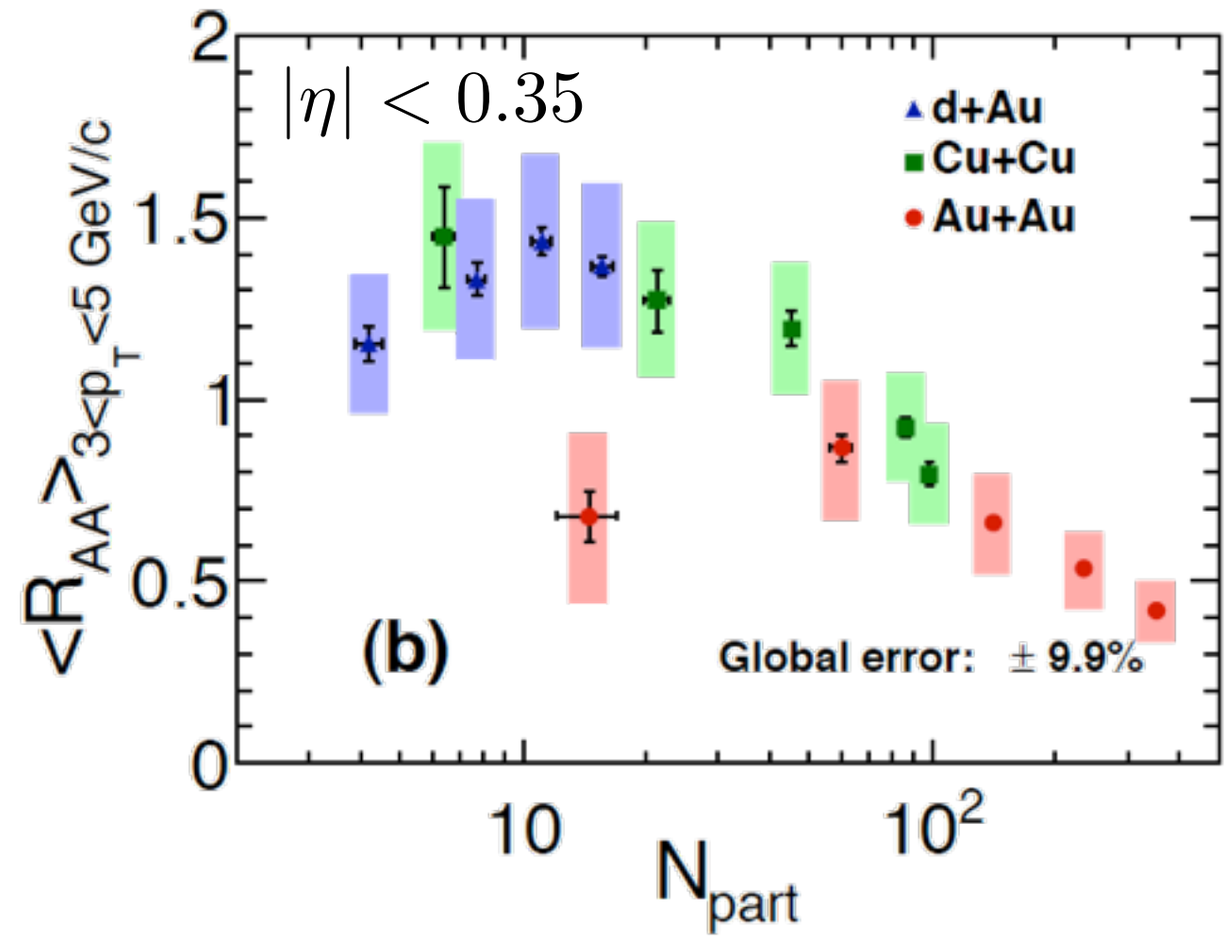
R_{AA} vs. pT vs. N_{part} vs. system size



New Cu+Cu result

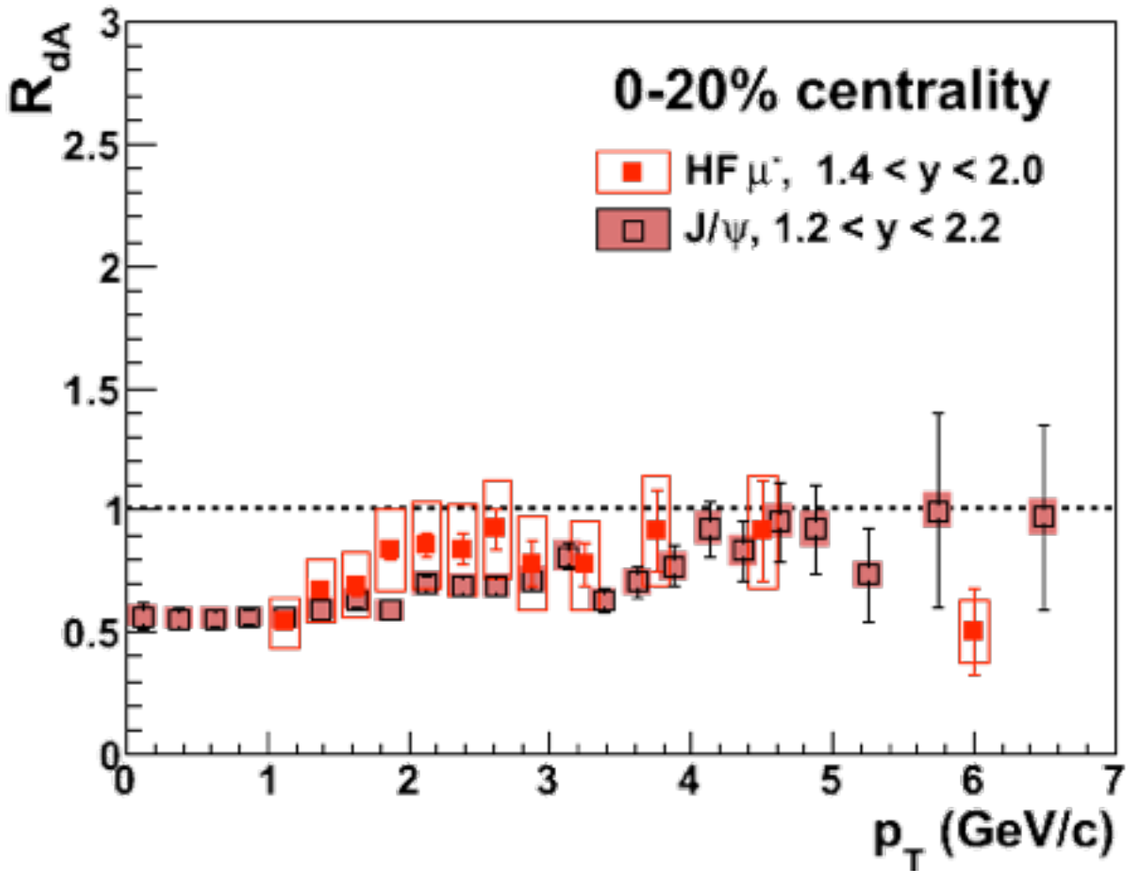
arXiv:1310.8286





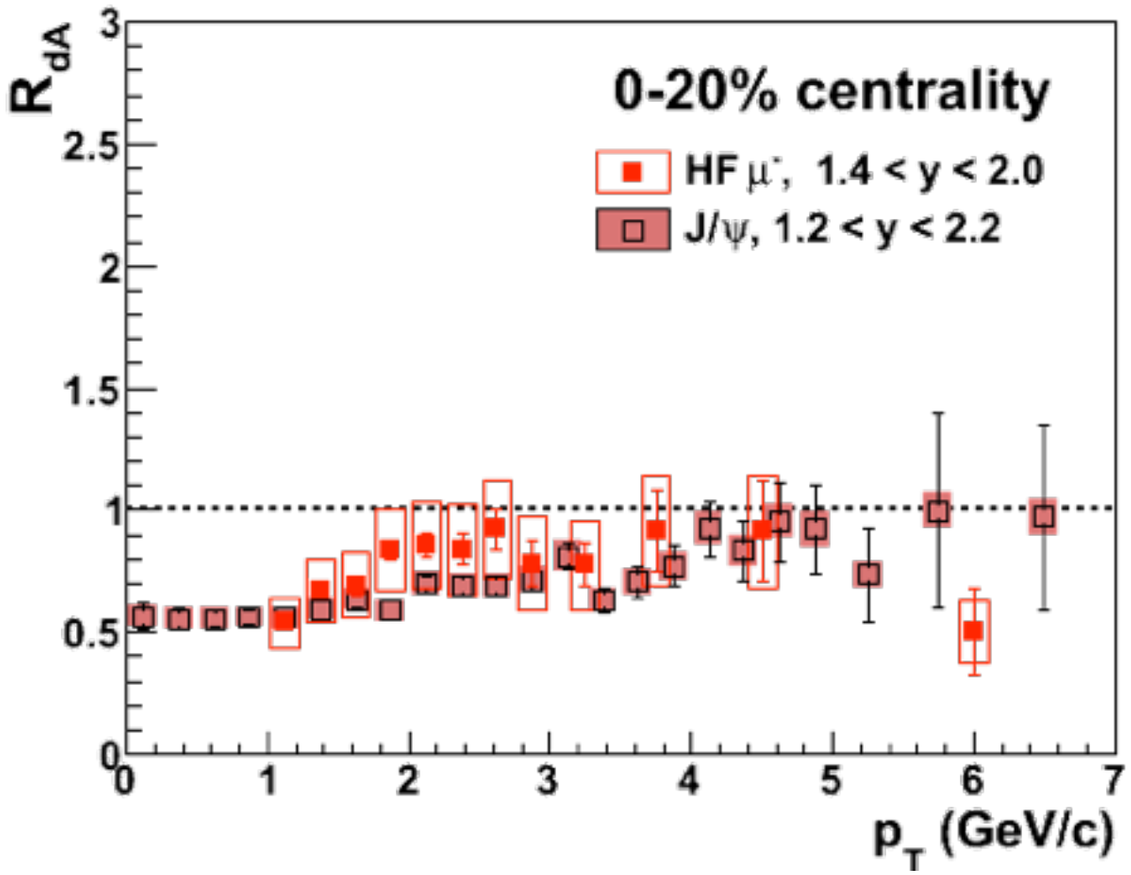
Modification in Cu+Cu is an interplay between d+Au and Au+Au results

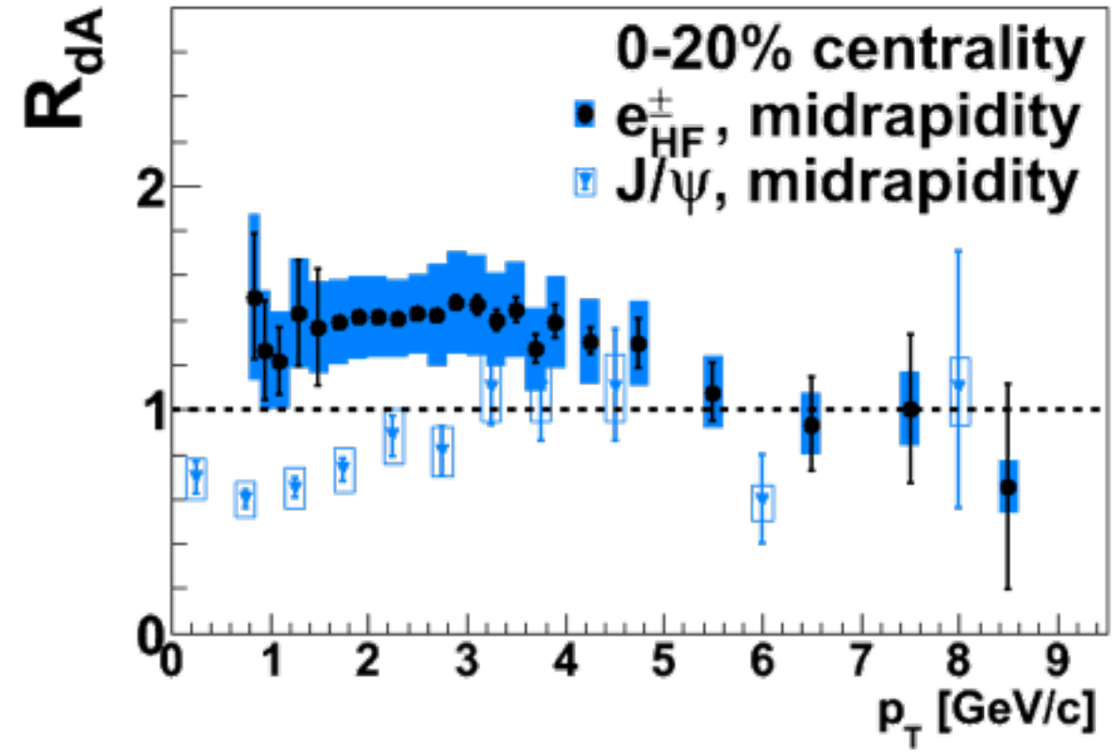
Open and bound $c\bar{c}$ modifications

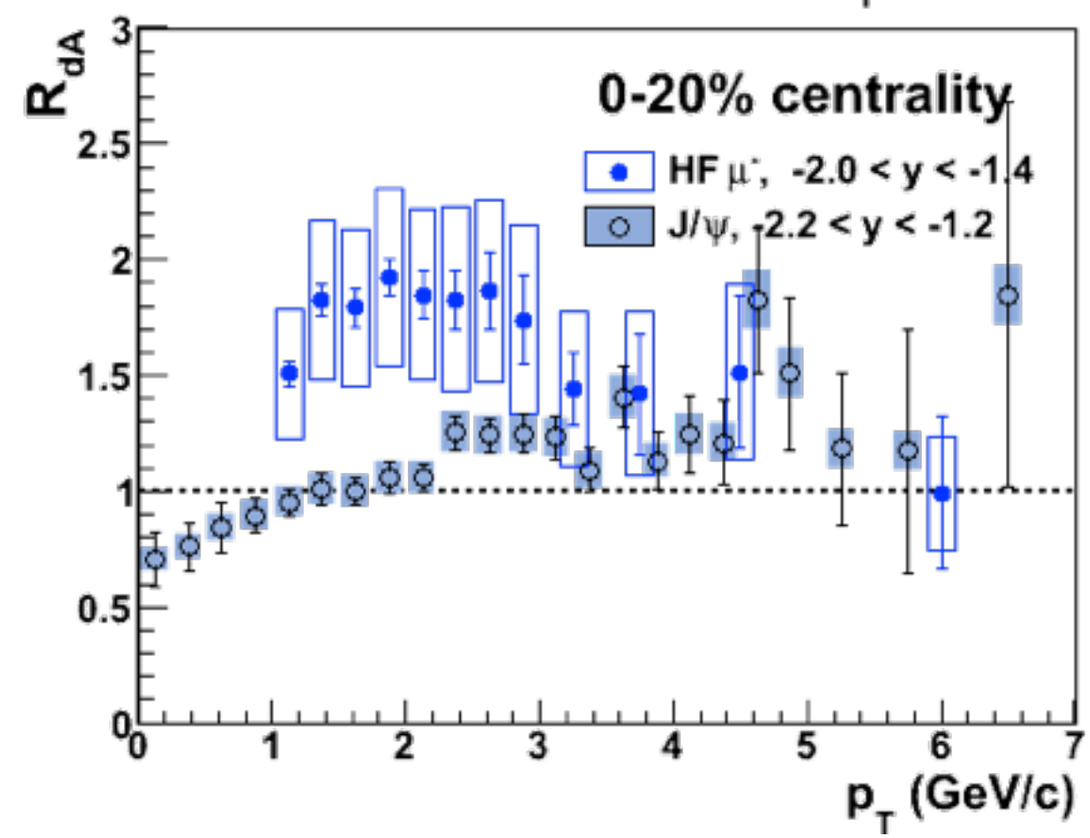


- J/ψ and open charm have same p_T dependence at forward direction
- Small final state effects.

Open and bound $c\bar{c}$ modifications



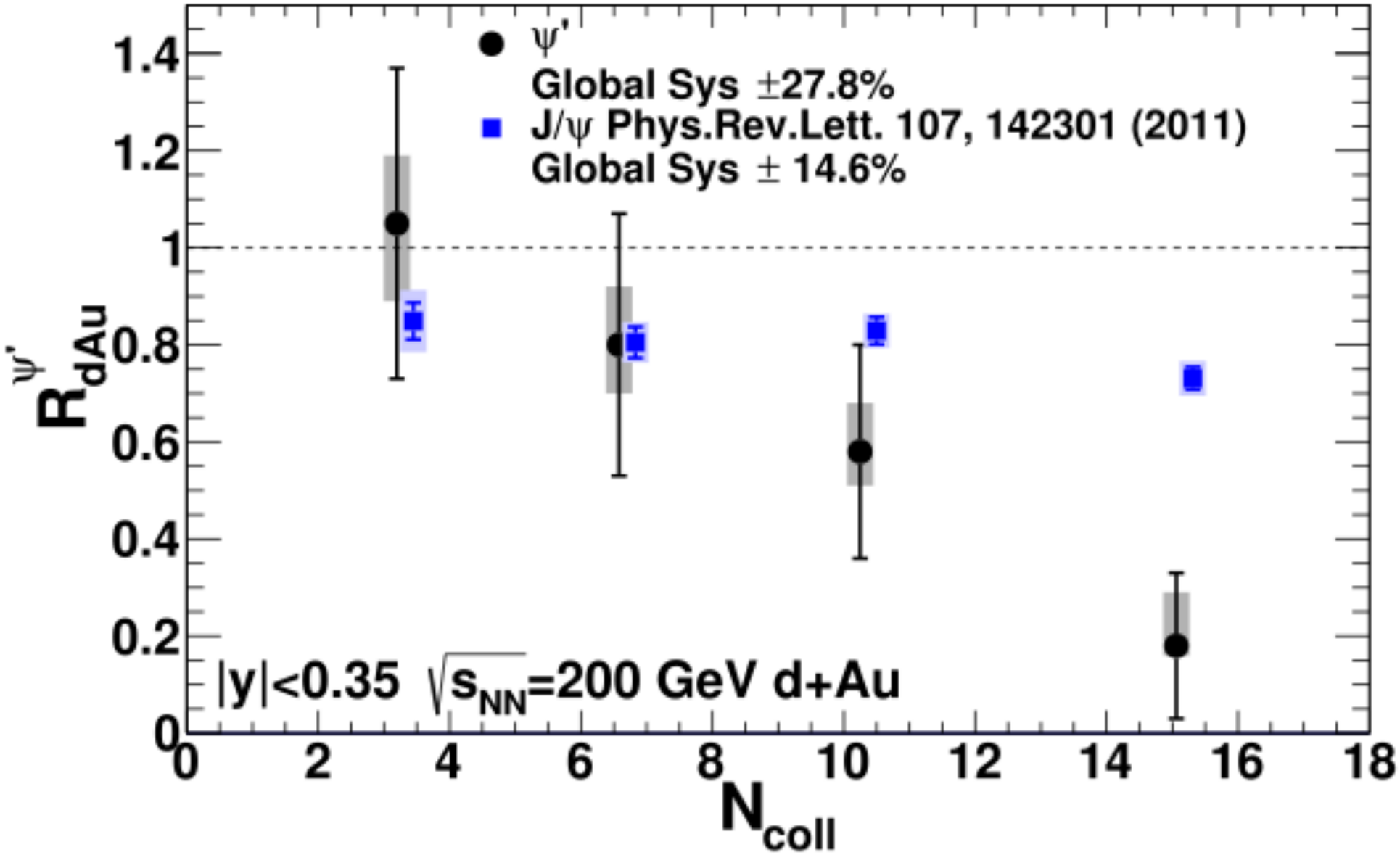




- J/ψ and open charm have same p_T dependence at forward direction
- Small final state effects.
- significant final state effects at low p_T mid- and backward rapidities

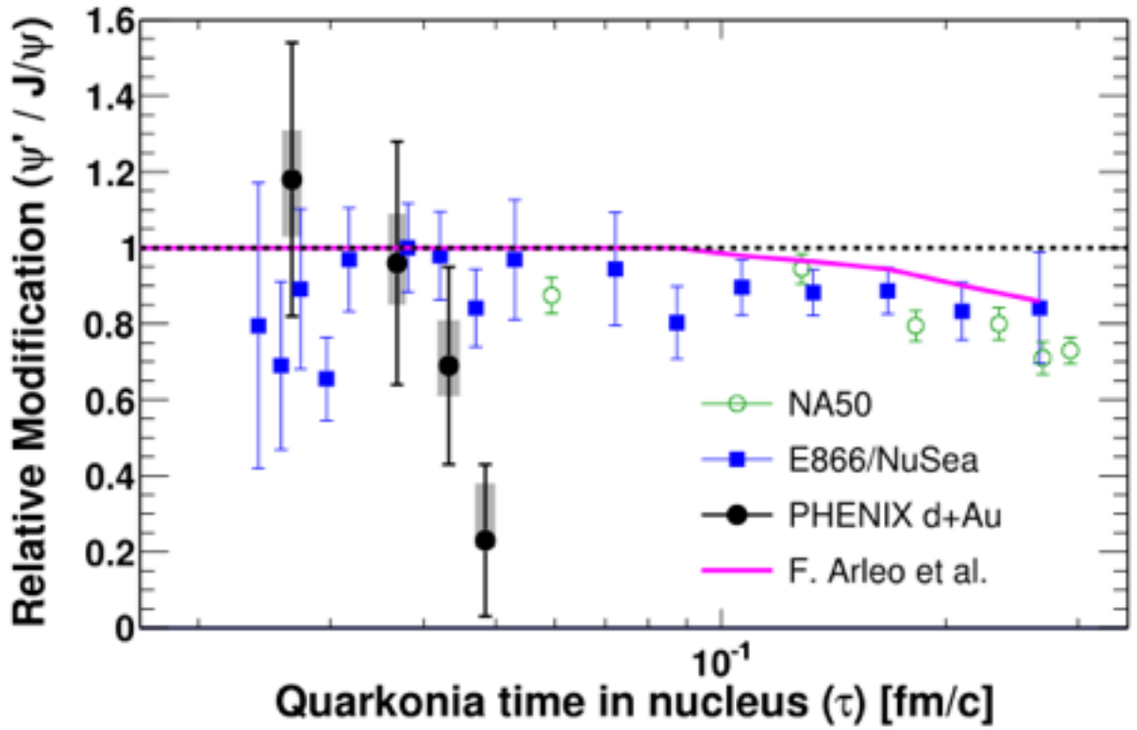
Charmonia suppression in d+Au

PRL111, 202301 (2013)

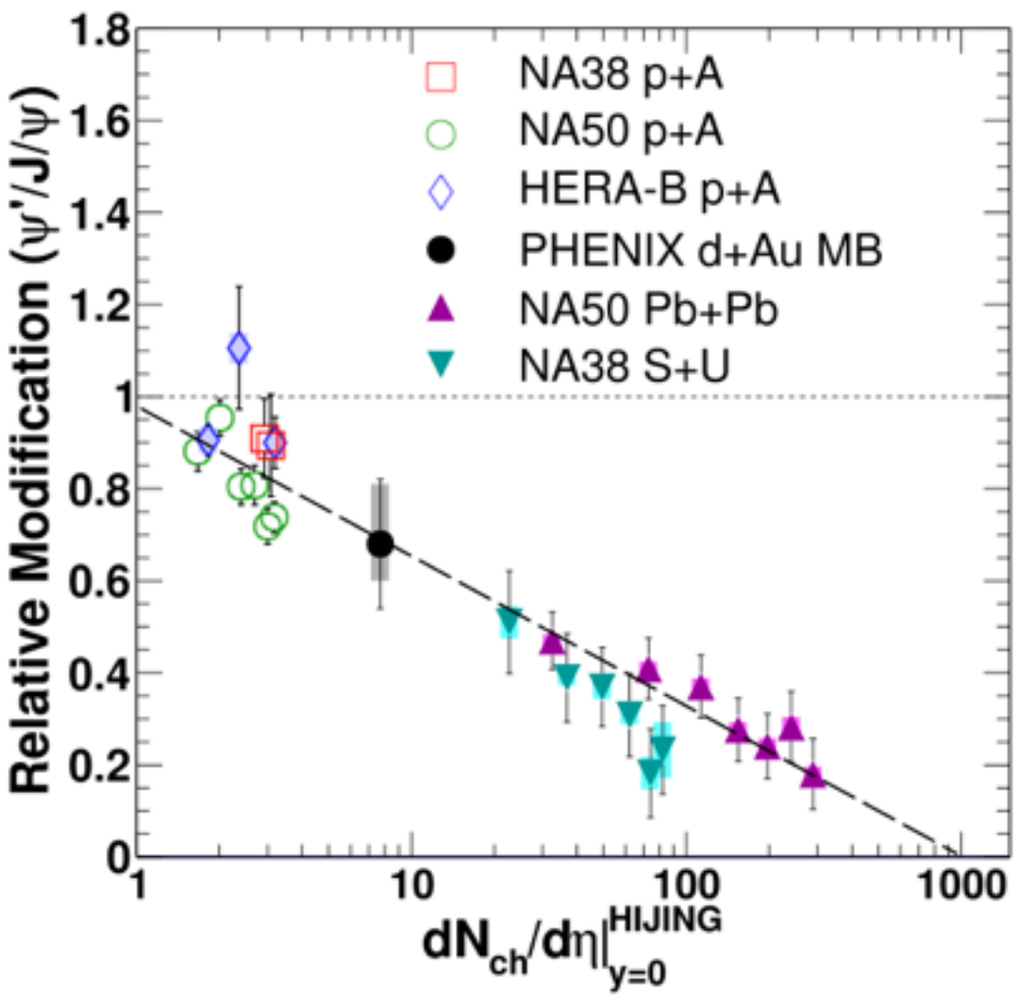


- ψ' has a binding energy 12× smaller than J/ψ
- data confirms ψ' is more sensitive to final state effects
- excellent tool to study charmonium nuclear absorption

PRL111, 202301 (2013)

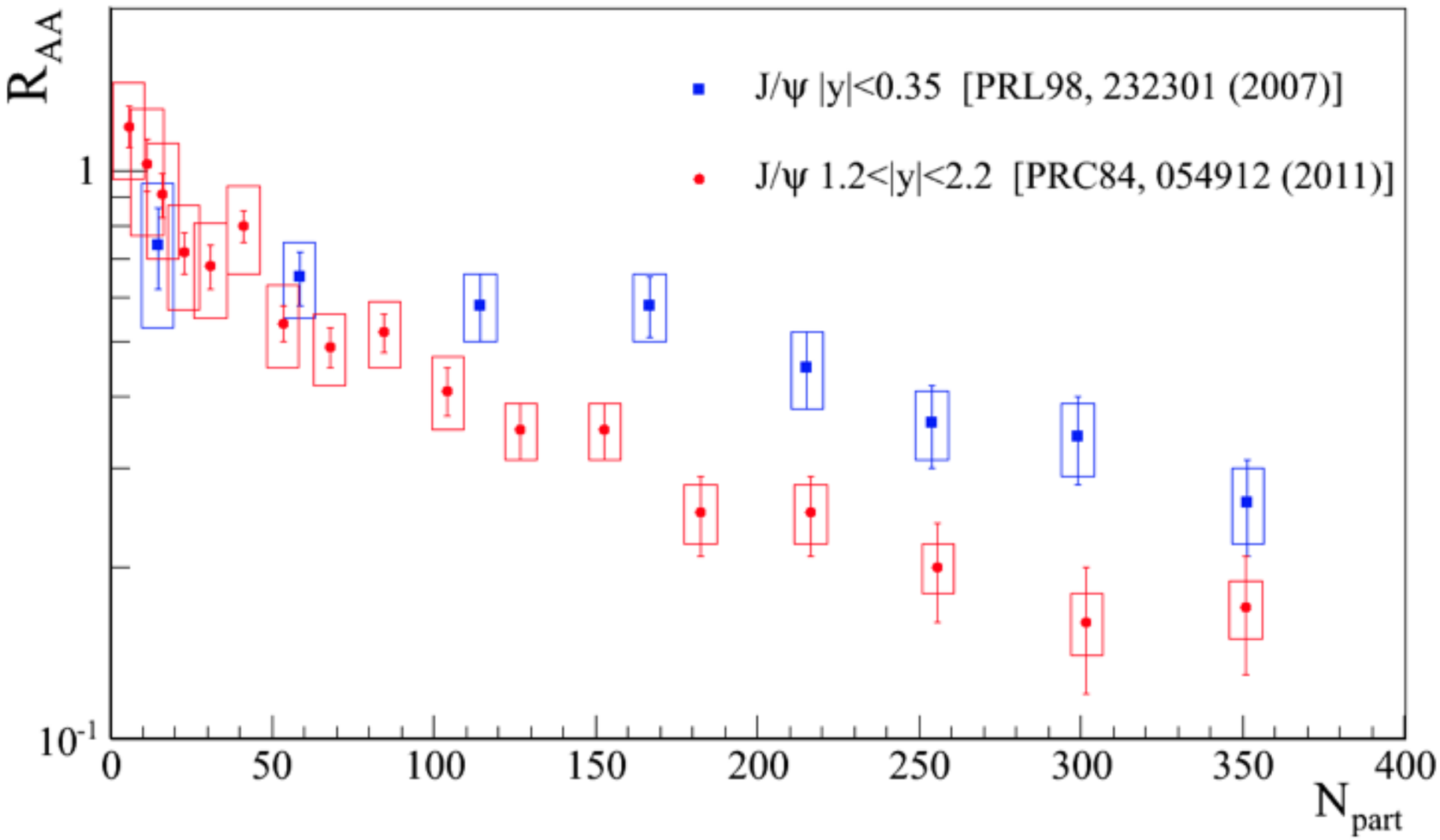


- bound $c\bar{c}$ may cross the nucleus as a pre-resonant state
- J/ψ and ψ' should have the same suppression
- data indicates something different



- particle activity can change the relative suppression of ψ'
- CMS sees the same behavior for Υ states
- comovers ?

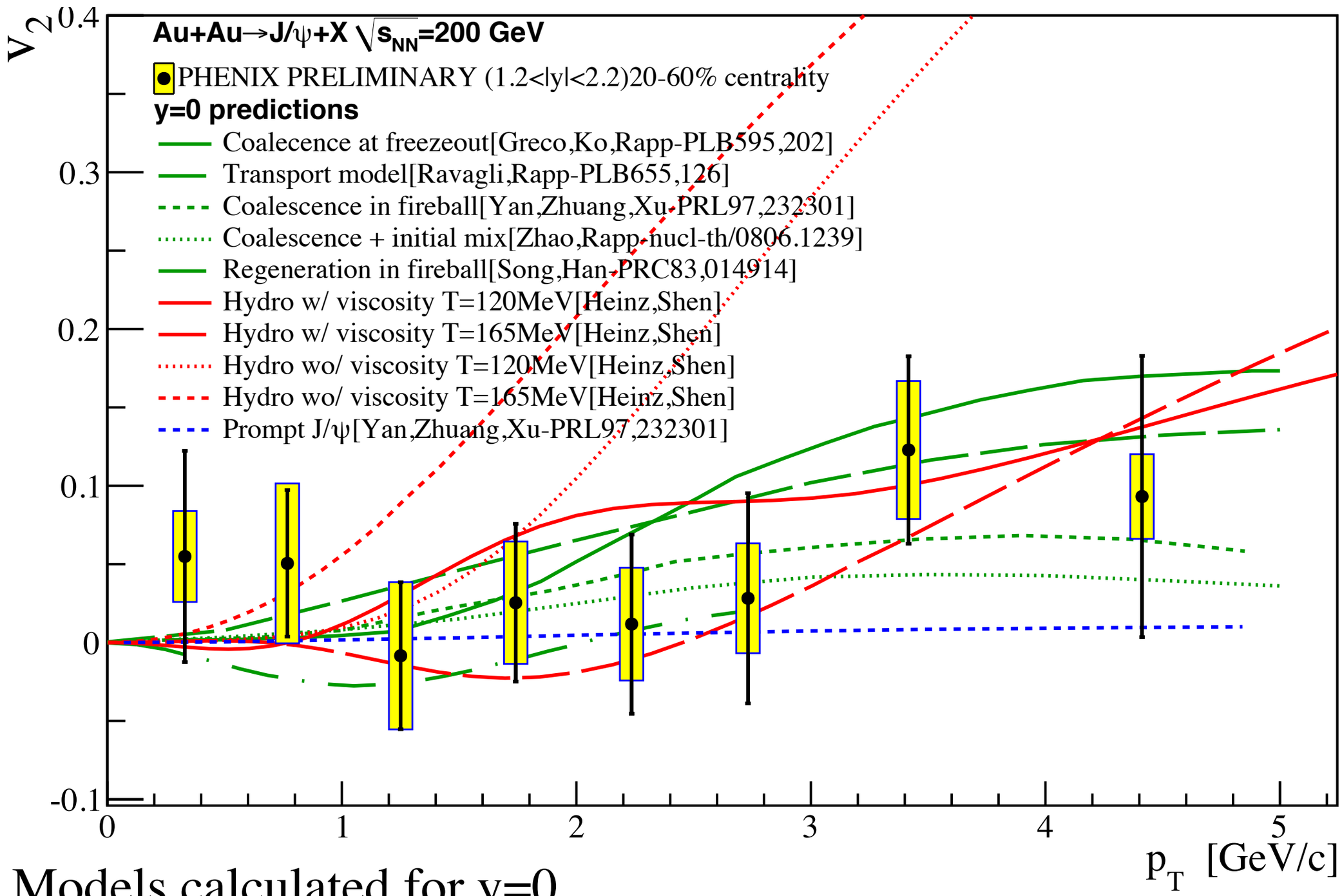
Mid- and large rapidity J/Psi R_{AA}



Same initial state effect (shadowing and anti-shadowing cancel at large rapidity)

Larger RAA at mid-rapidity indicates another source of J/Psi (regeneration?)

J/Psi azimuthal anisotropy at 1.2<|y|<2.2

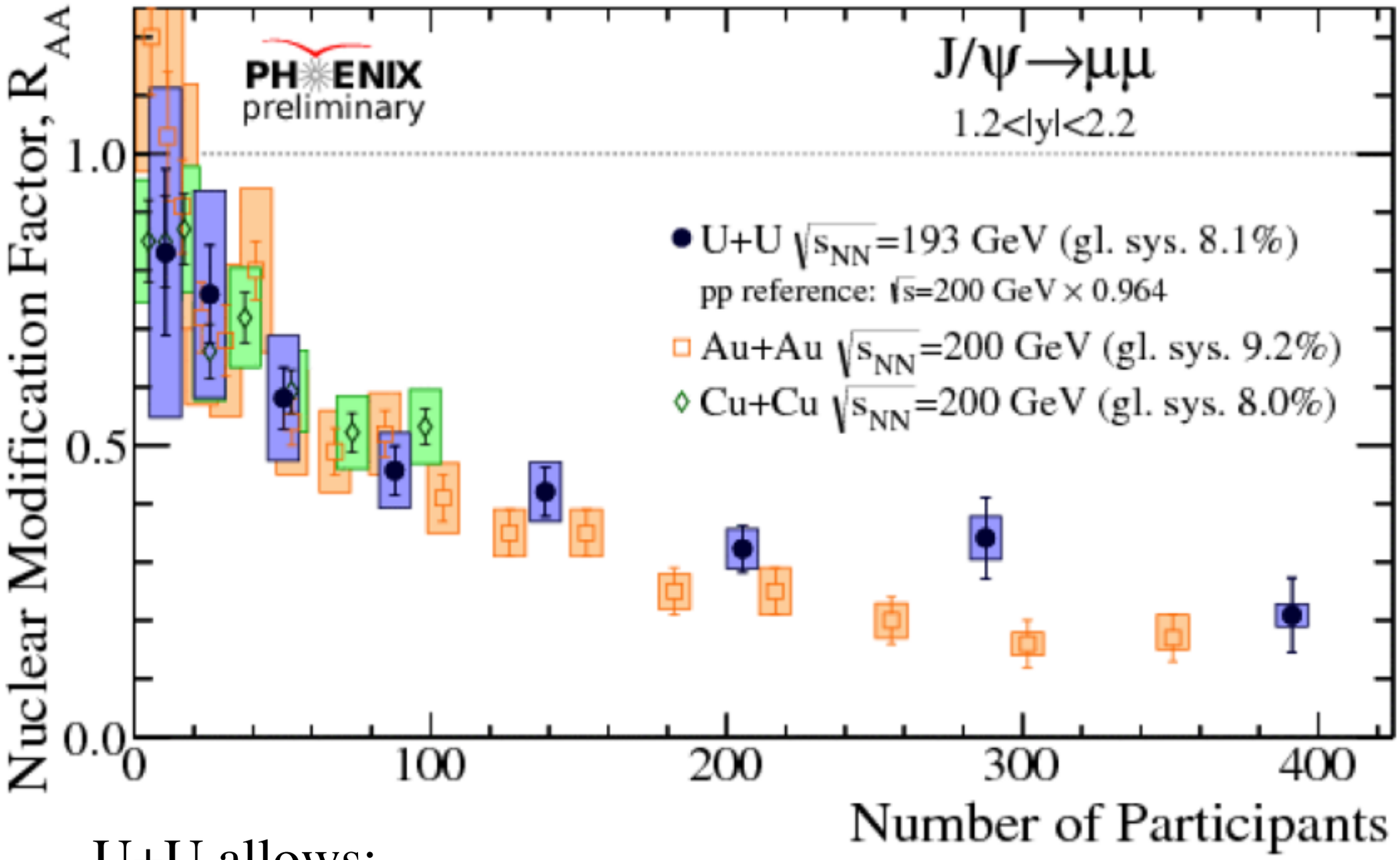


Models calculated for y=0

Data don't rule out most of coalescence/regeneration models.

Trend for increasing v_2 at high p_T ?

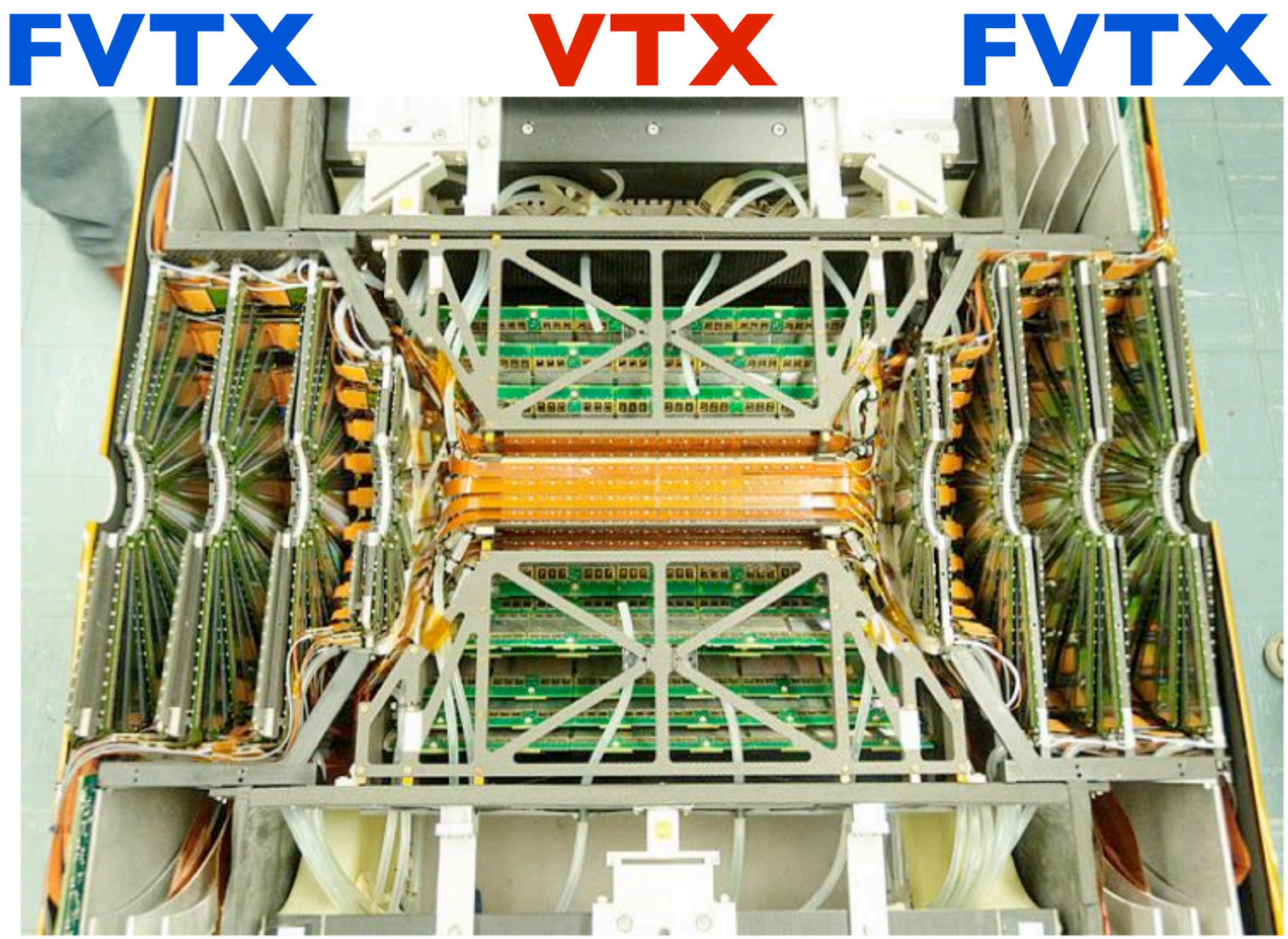
J/Psi R_{AA} in U+U collisions



U+U allows:

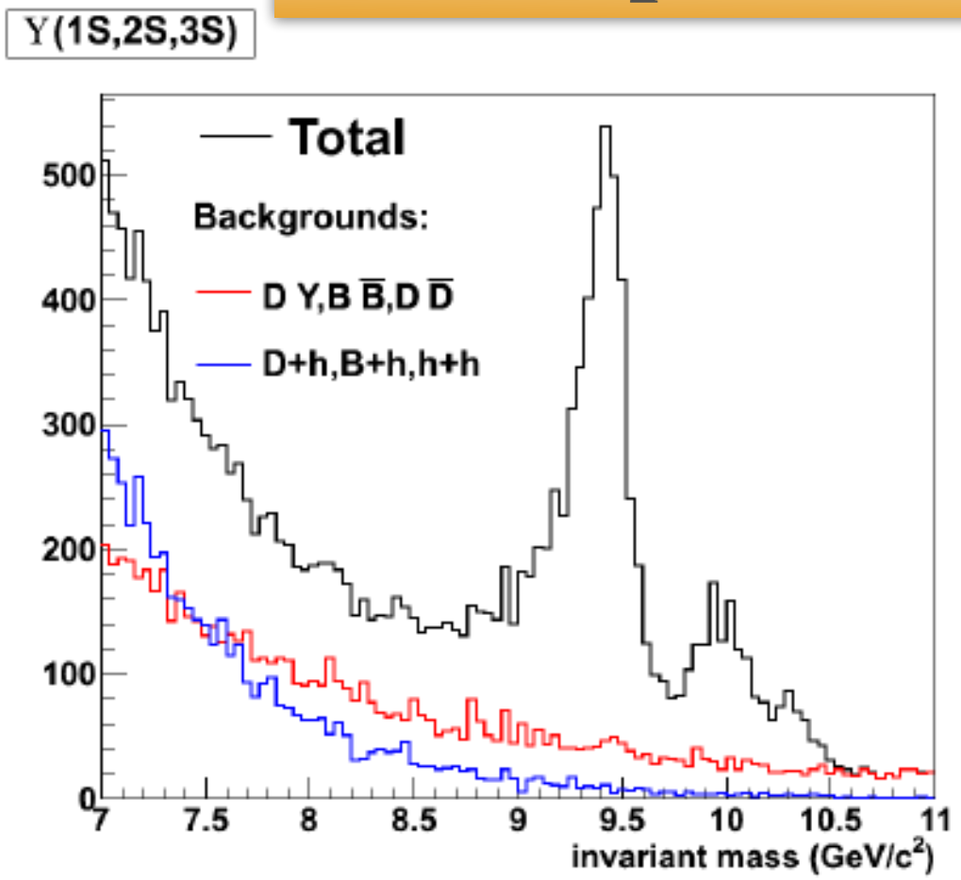
- higher energy density
- more room for recombination
- different geometry

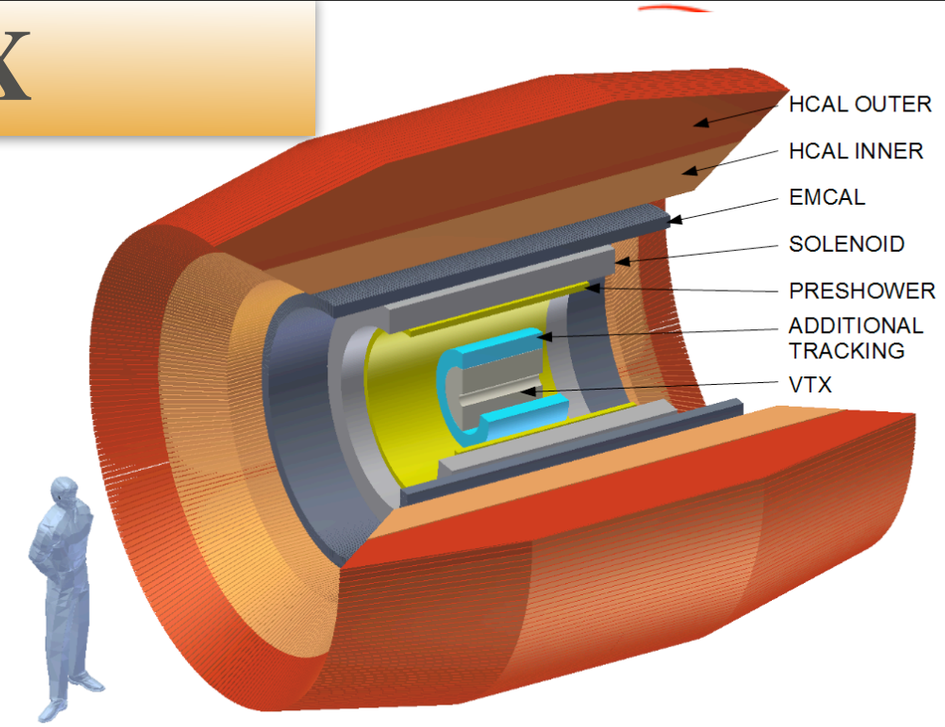
Near Future Results



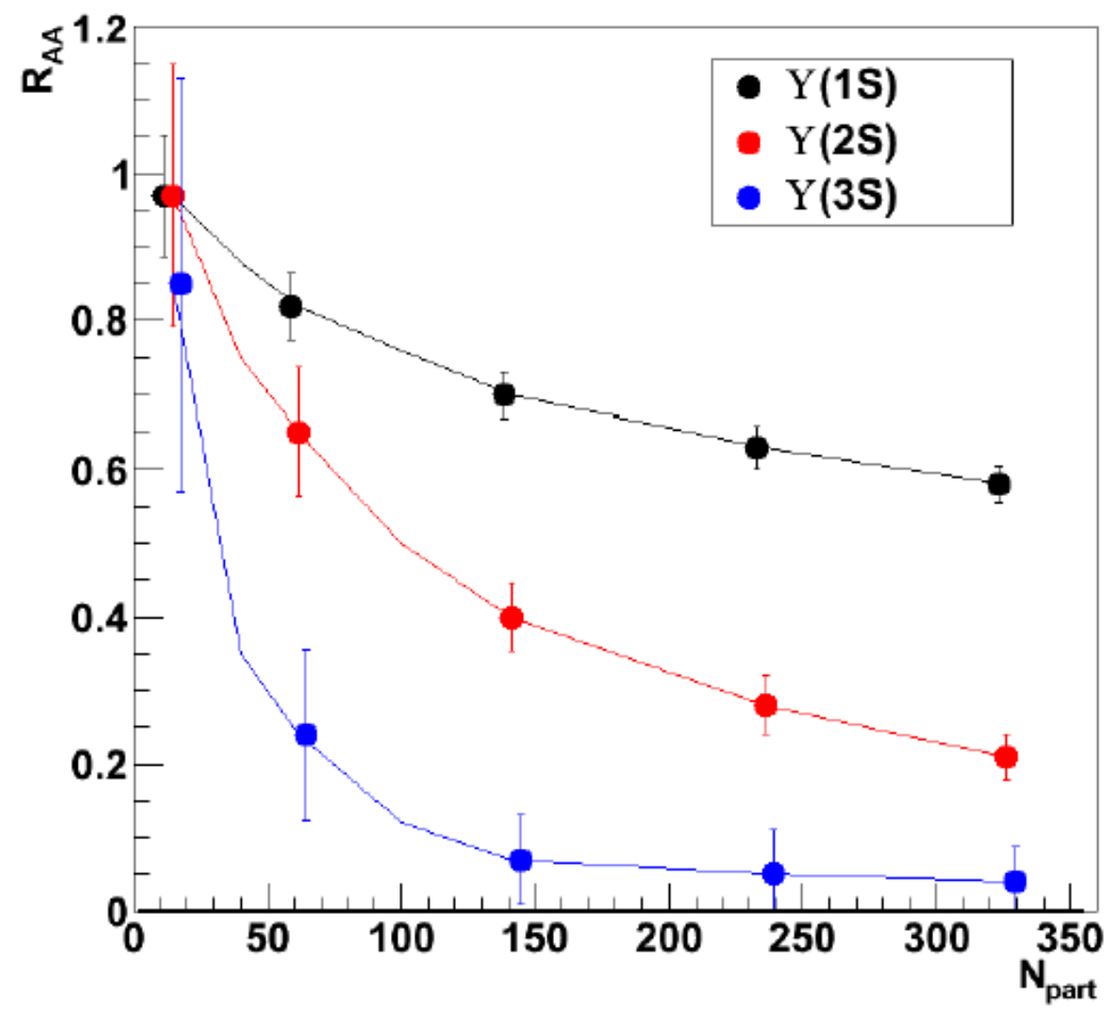
- charm and bottom nuclear modification factors at mid and forward rapidity
- ψ' measurement at forward rapididy
- heavy flavor v_2
- and much more ...

Upsilons in sPHENIX





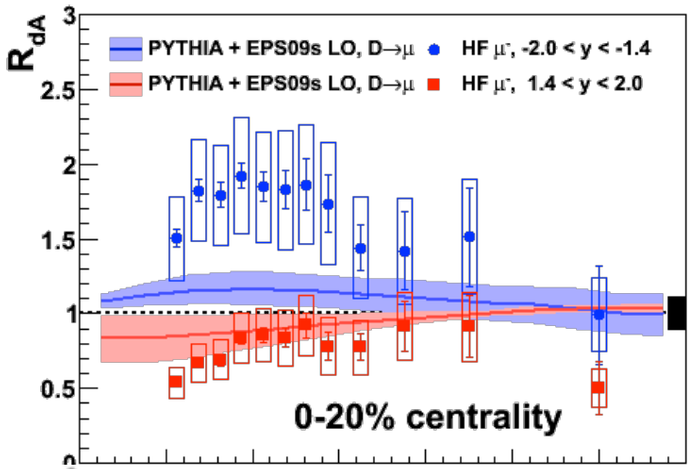
Species	$\int L\,dt$	Events	$\langle N_{coll} \rangle$	Υ(1S)	Υ(2S)	Υ(3S)
$p+p$	18 pb^{-1}	756 B	1	805	202	106
Au+Au (MB)		50 B	240.4	12794	3217	1687
Au+Au (0–10%)		5 B	962	5121	1288	675

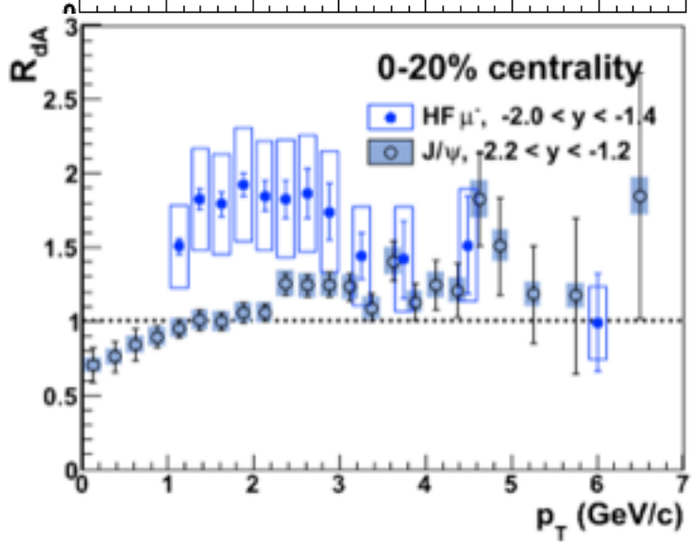


Clear separation of the three states
Large acceptance
Similar statistics to LHC

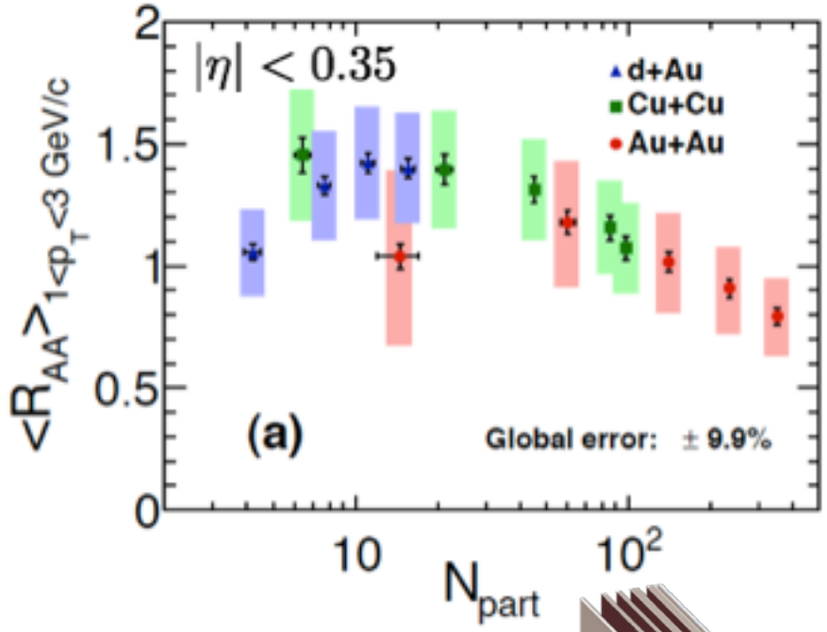
Scale of the HF R_{AA} with N_{part}.

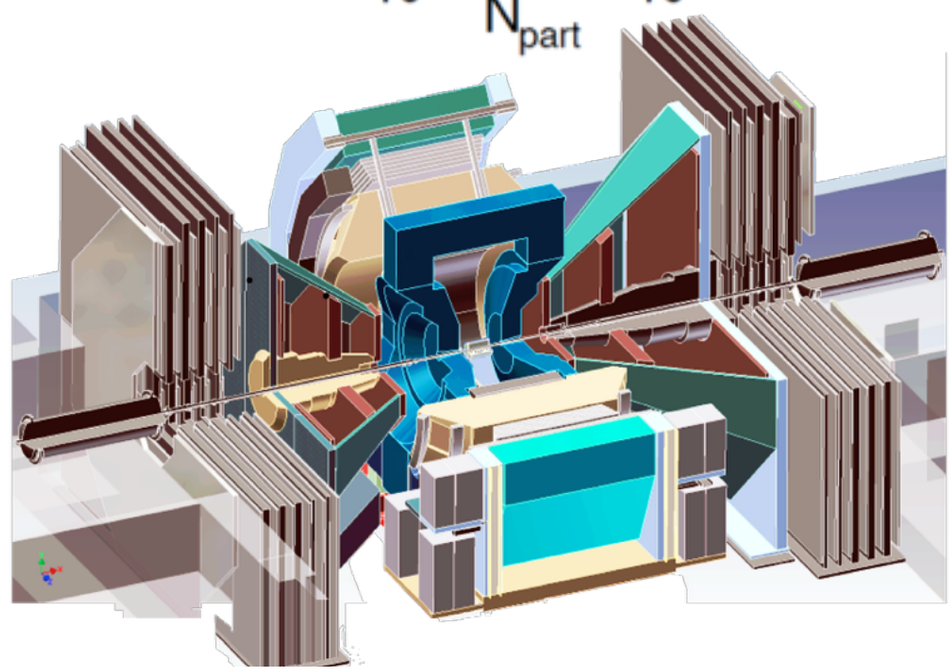
HF larger than EPS09 at backward direction

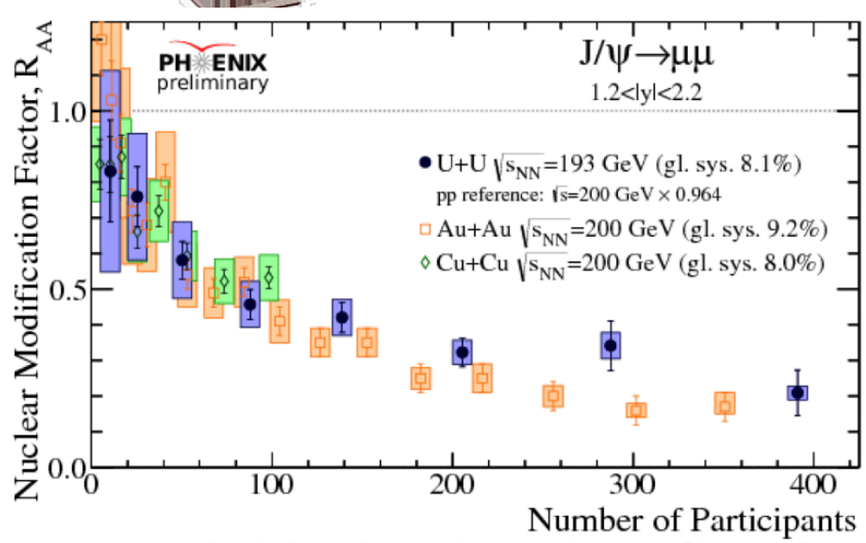




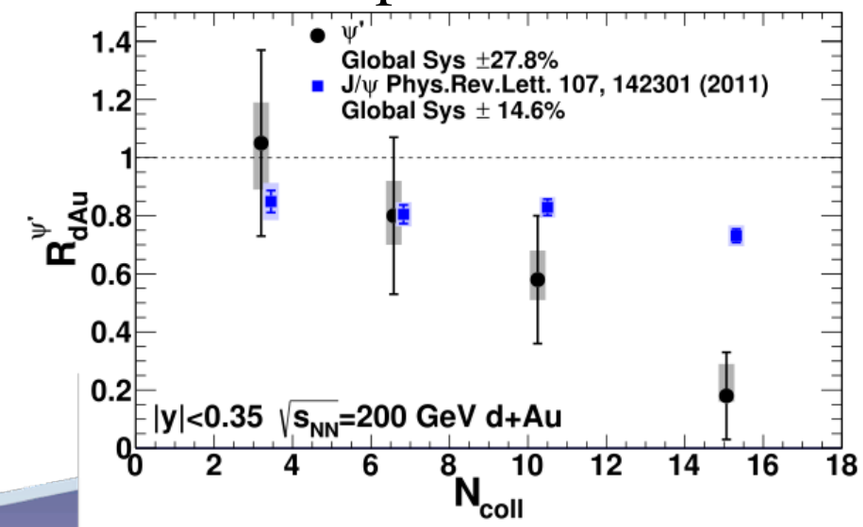
J/ψ more suppressed than HF at mid- and backward.
Hint for final state effect.

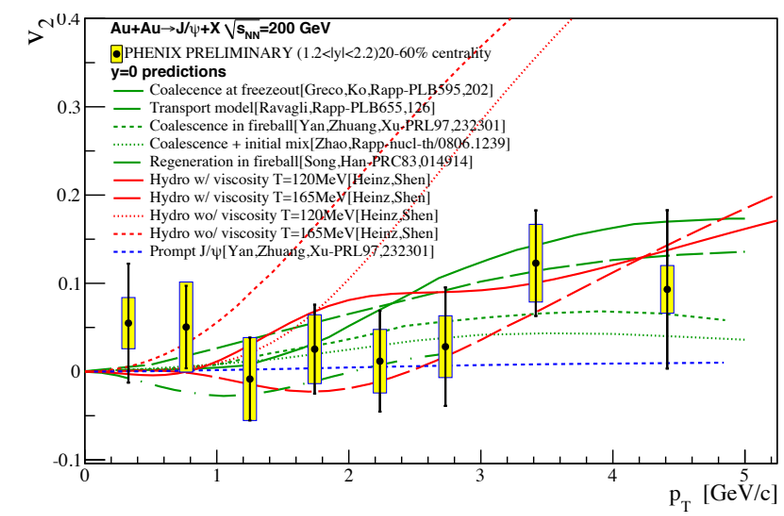






ψ' relative suppression suggests nuclear absorption from comover.





J/ψ v_2 still consistent with many charm coalescence scenarios.

J/ψ R_{AA} now available for Au+Au, Cu+Cu, U+U, d+Au