Experimental Overview of Open Heavy Flavor

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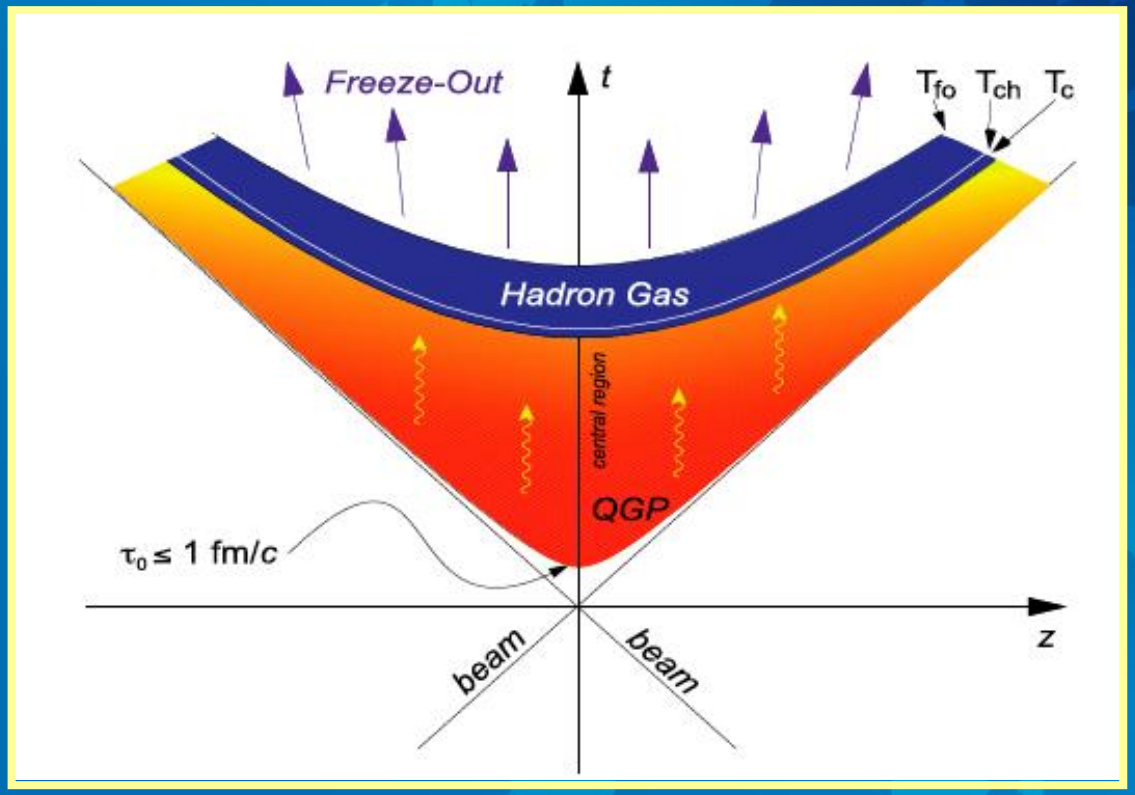
GSI Darmstadt

Thanks to organizers !

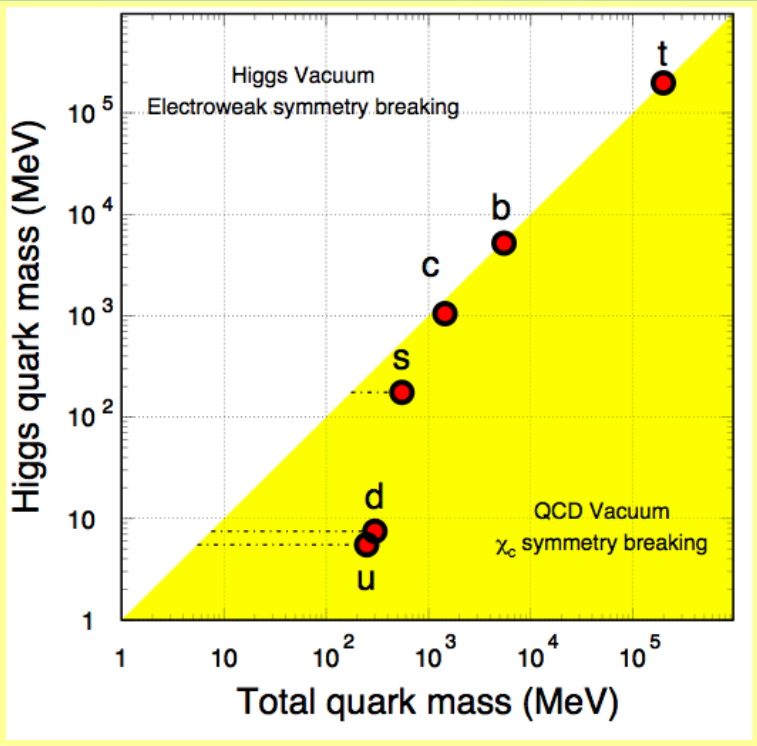
Time Scales



Plot: courtesy of R. Stock.

- **QGP life time**
  10 fm/c ≈ $3 \cdot 10^{-23}$ s
- **thermalization time**
  0.2 fm/c ≈ $7 \cdot 10^{-25}$ s
- **formation time**
  (e.g. charm quark):
  $1/2m_c$ = 0.08 fm/c
  ≈ $3 \cdot 10^{-25}$ s
- **collision time**
  $2R/\gamma$ = 0.005 fm/c
  ≈ $2 \cdot 10^{-26}$ s

Heavy - flavor: a unique probe



X. Zhu, M. Bleicher, S.L. Huang, ks, H. Stöcker, N. Xu, and P. Zhuang, PLB 647 (2007) 366.

$m_{c,b} \gg \Lambda_{QCD}, T_{QGP}$: new scale

$m_{c,b} \approx$ const., $m_{u,d,s} \neq$ const.

Q^2

time

initial conditions:

$S_{c\bar{c}}, S_{b\bar{b}}$

test pQCD

probe gluon distribution

early partonic stage:

diffusion (γ), drag (α)

flow, jets, correlations

probe thermalization

hadronization:

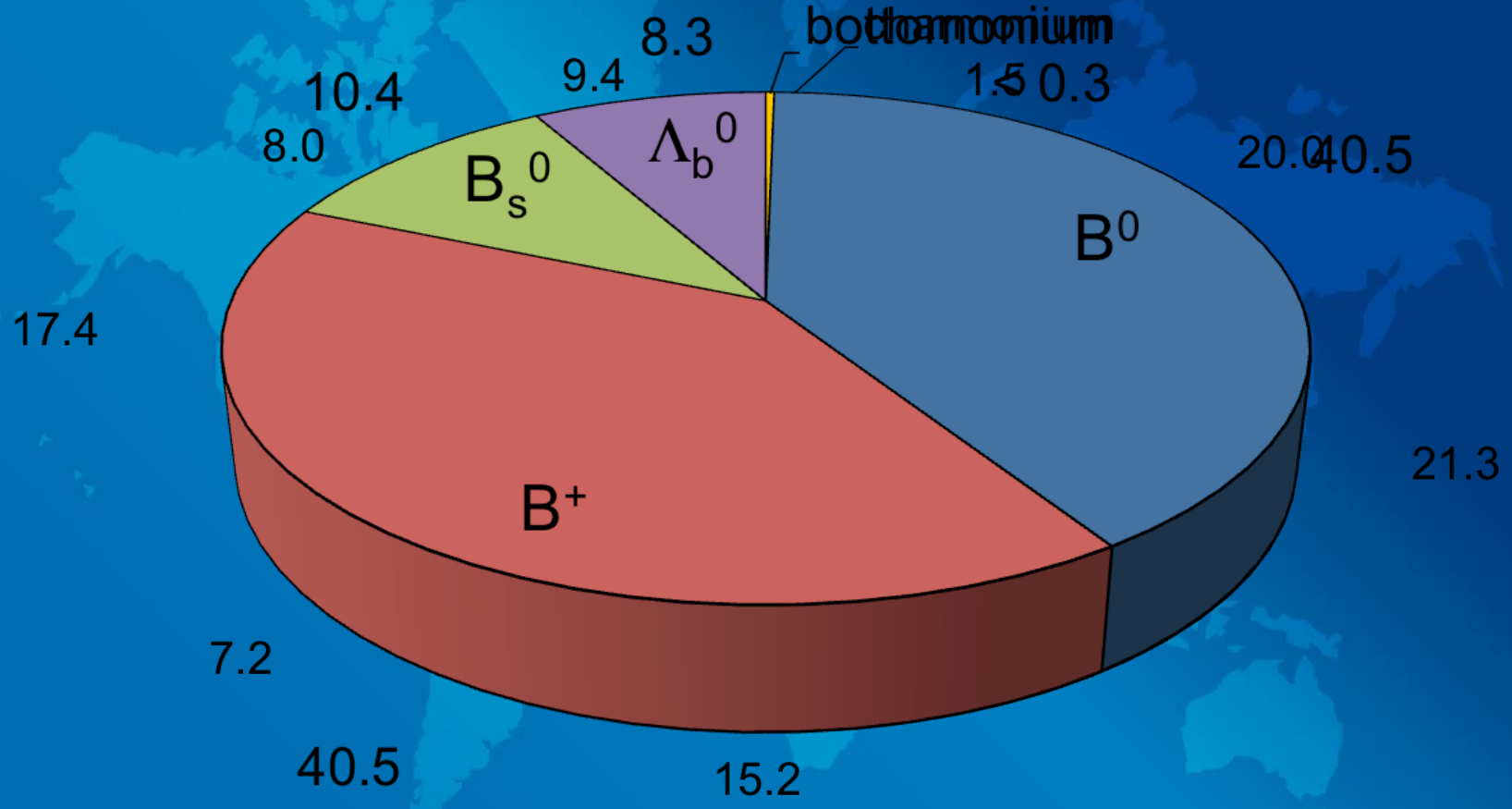
chiral symmetry restoration

confinement

statistical coalescence

J/ψ enhancement / suppression

Where does all the heavy flavor go ?



Heavy-quark detection

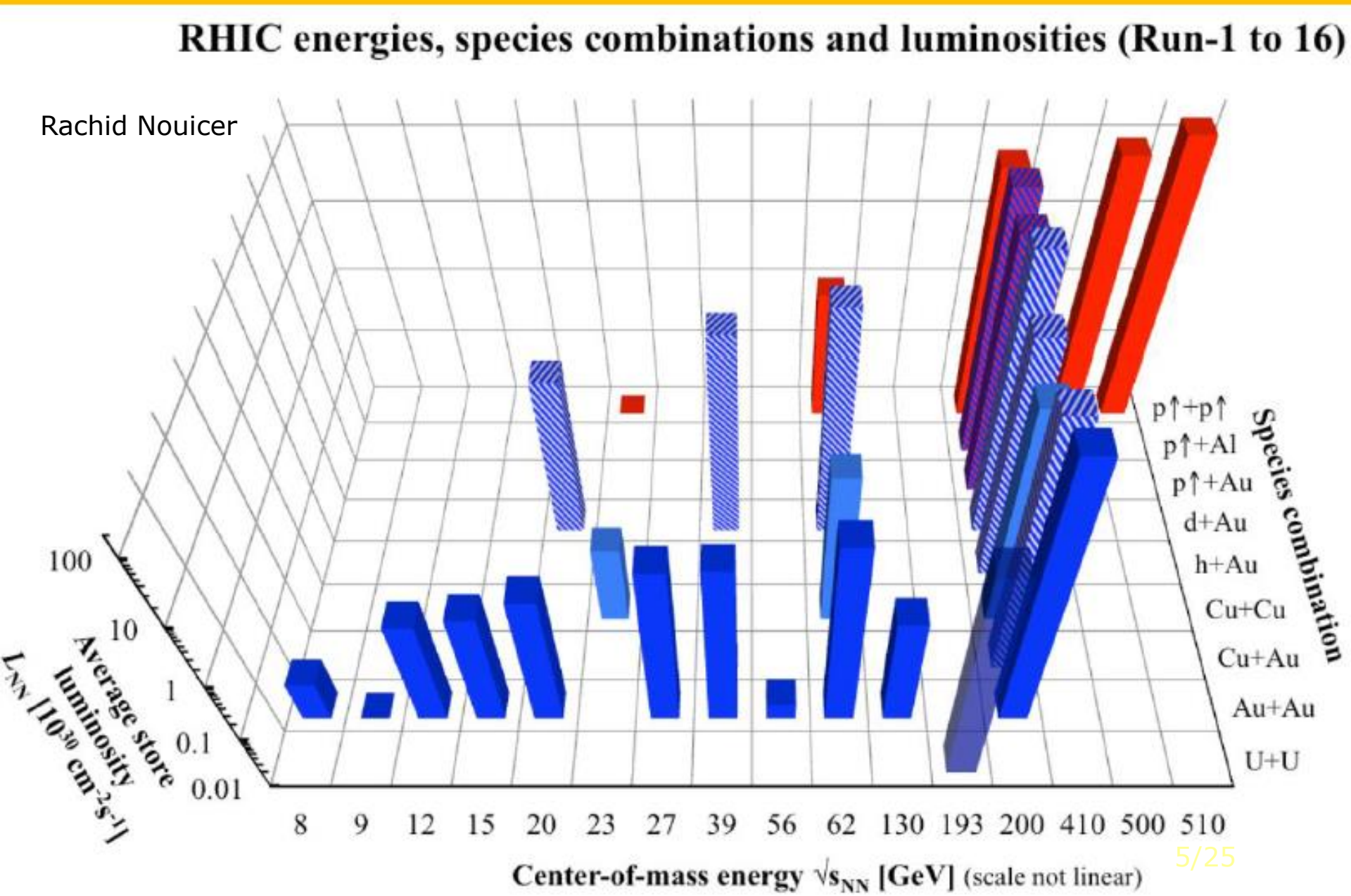
plot: courtesy of D. Tlusty.

- e.g., $D^0 \rightarrow K^- + \pi^+$,

  $c\tau = 123\ \mu m$

- **displaced** decay **vertex** is **signature** of **heavy-quark decay**

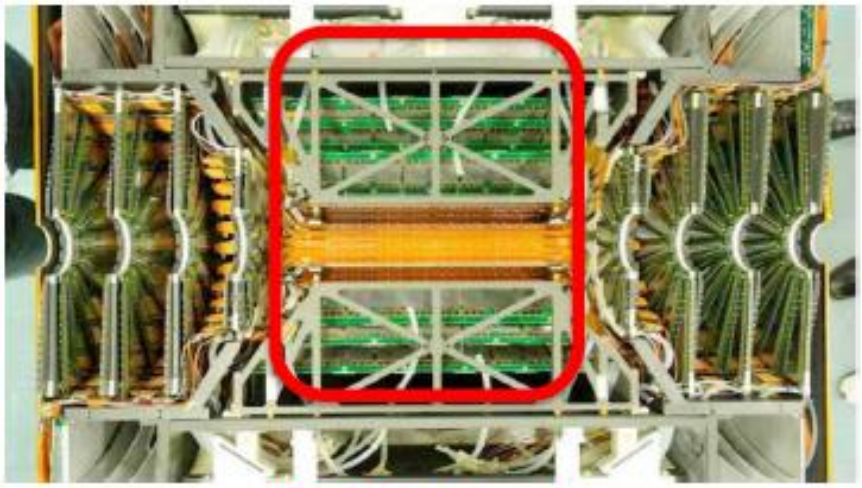
RHIC Amazing QCD Machine: Many Species and Many Energies!



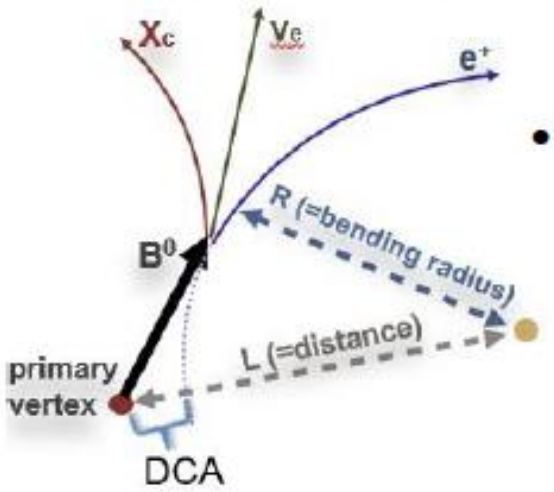
What NEW on Open Heavy Flavor?

NEW!

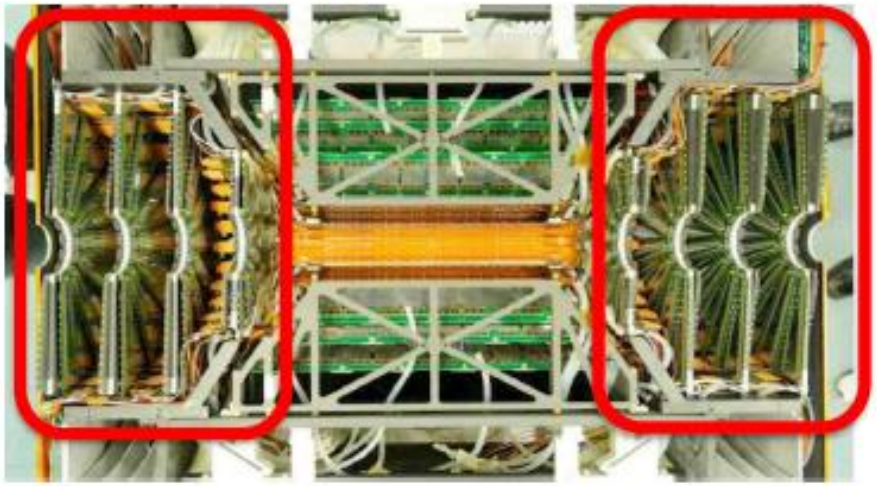
c/b separation by secondary vertex



VTX detector

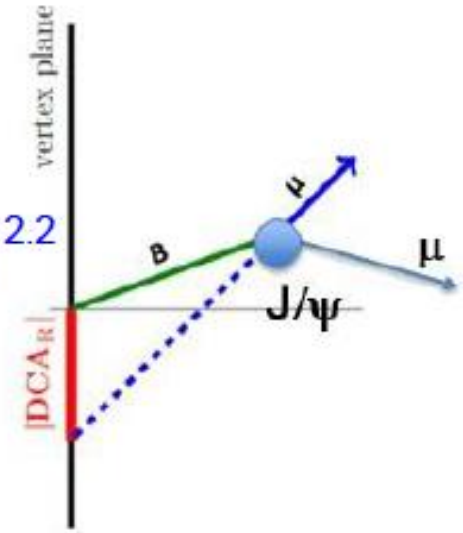


- VTX (2011):
  - Midrapidity: $|\eta| < 1.2$
  - AuAu 200 GeV:
    - ~ 60 μm DCAT resolution



FVTX detector

- FVTX (2012):
  - Forward rapidity - $1.2 < |\eta| < 2.2$
  - Improved muon momentum resolution & precise tracking



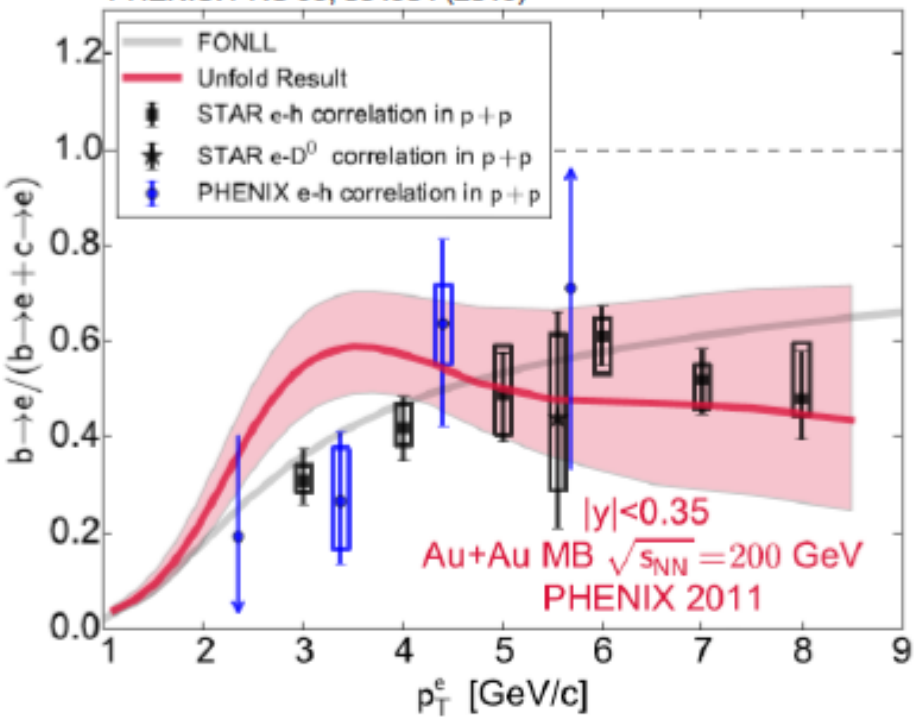
What NEW on Open Heavy Flavor?

NEW!

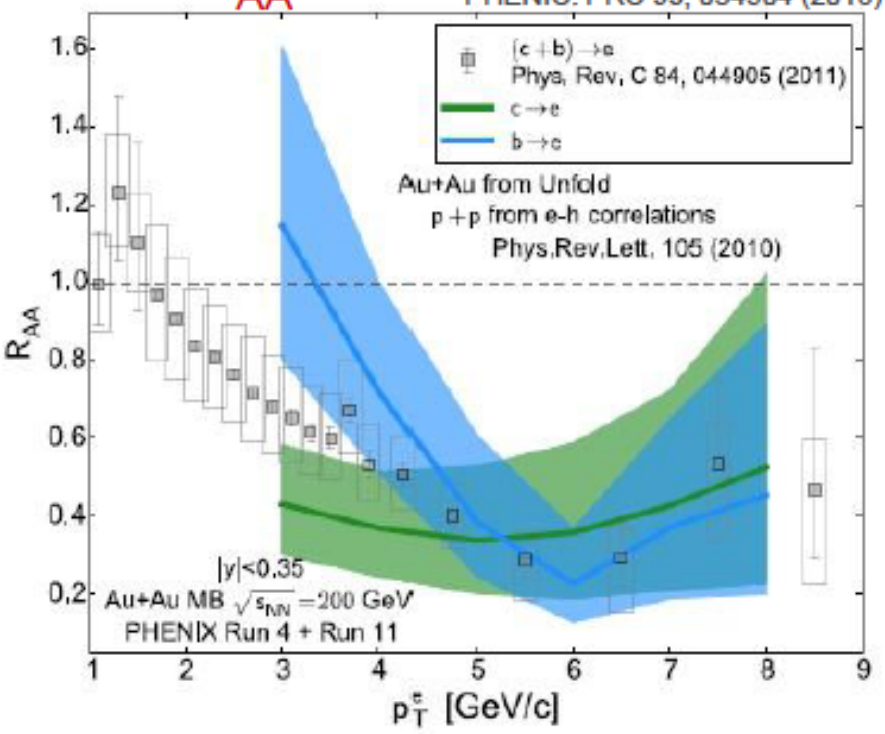
First Results from PHENIX VTX: b/c separation

Bottom and Charm R_{AA}

PHENIC: PRC 93, 034904 (2016)



PHENIC: PRC 93, 034904 (2016)



$$R_{AA}^{c\to e} = \frac{(1-F_{\mathrm{AuAu}})}{(1-F_{pp})} R_{AA}^{\mathrm{HF}}$$

$$R_{AA}^{b\to e} = \frac{F_{\mathrm{AuAu}}}{F_{pp}} R_{AA}^{\mathrm{HF}},$$

We see that around $p_T < 4$ GeV the electrons from bottom experience much less suppression than electrons from charm.

Stay Tuned:

- 2014 data set x10 better statistics than 2011
  - Decrease uncertainties
  - Increase p_T reach
  - Centrality separation
- Good 2015 p+p and p+Au data sets

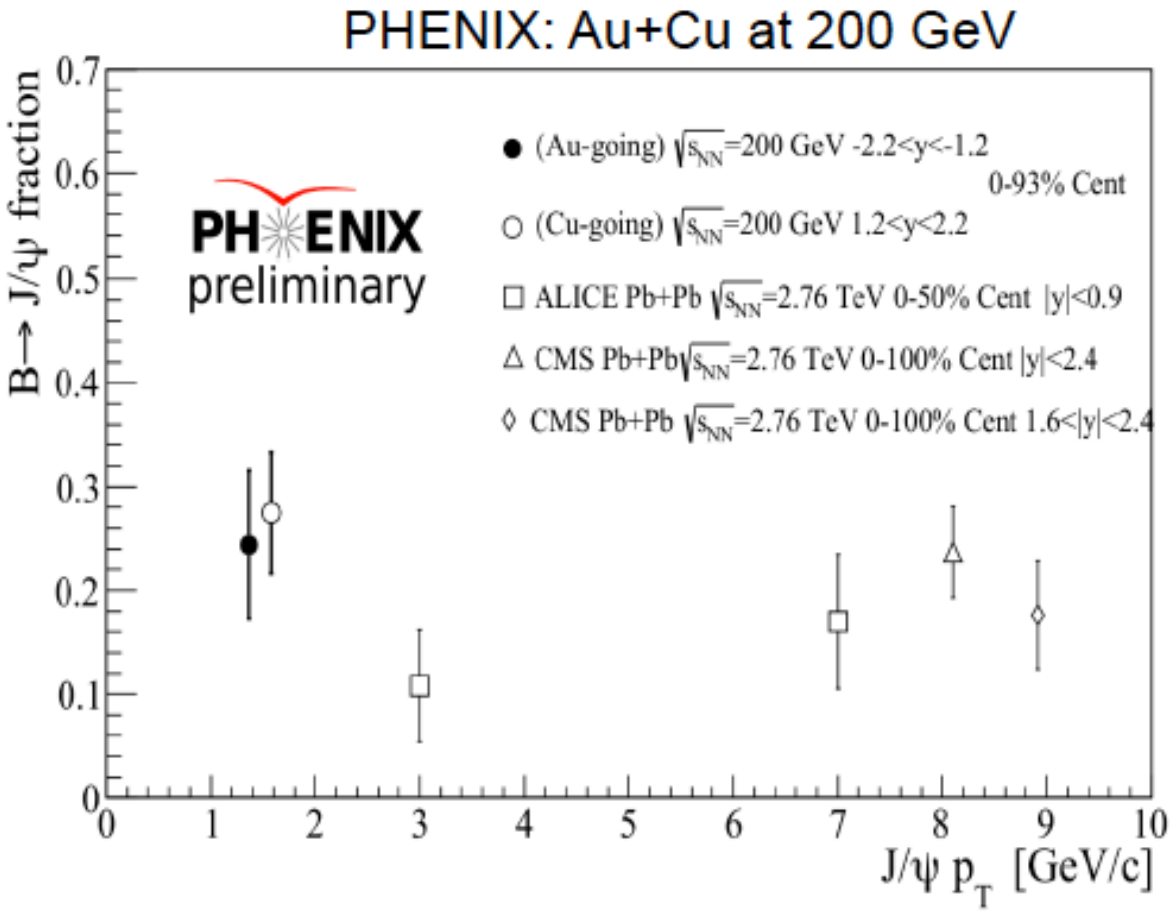
7/25

What NEW on Open Heavy Flavor?

First Results from the PHENIX FVTX: B → J/ψ

B->J/ψ fraction

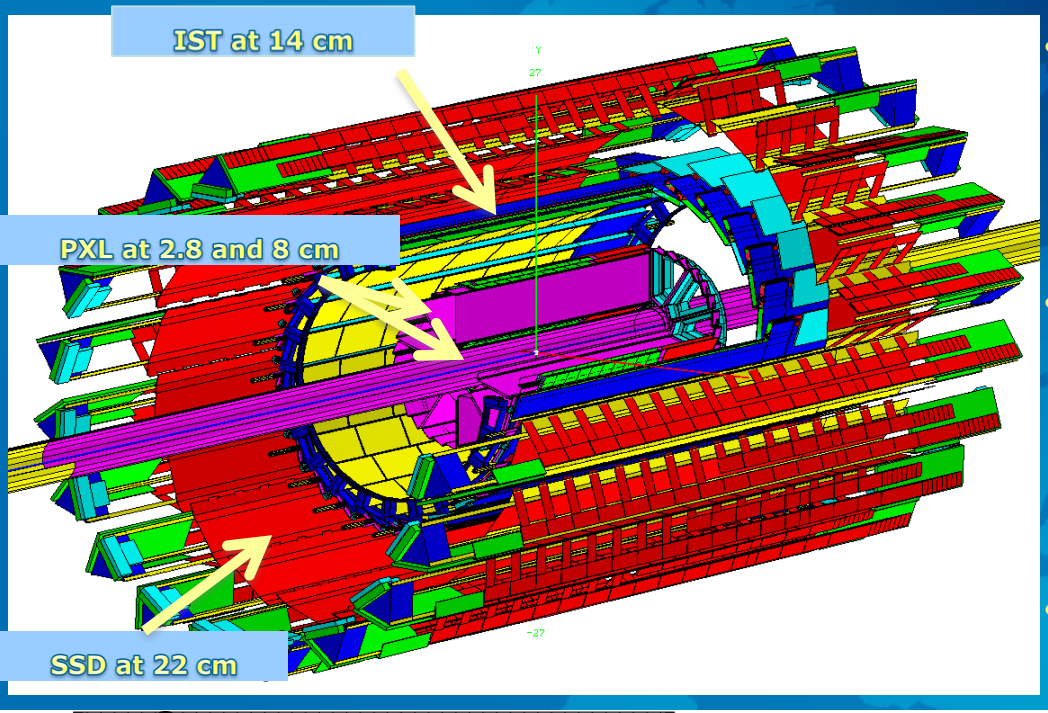
- $F_{B\to J/\psi}$ was determined for both the gold and copper going directions.
- Difference is attributed to a smaller suppression of B mesons relative to inclusive J/ψ at RHIC energies



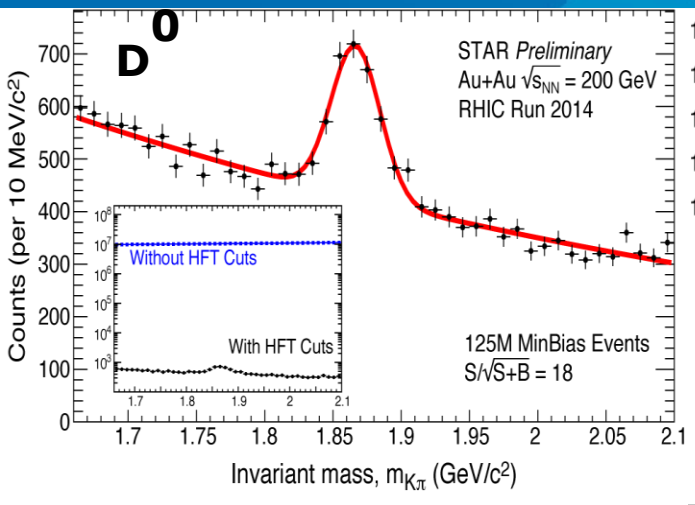
Xuan Li, Tu. 9:40

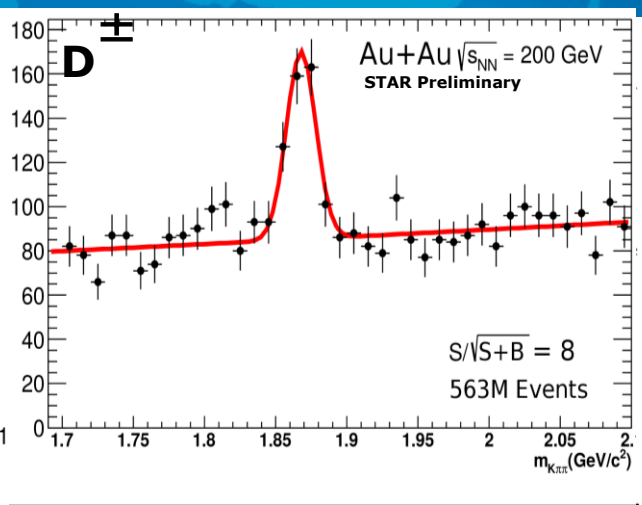
STAR Heavy Flavor Tracker

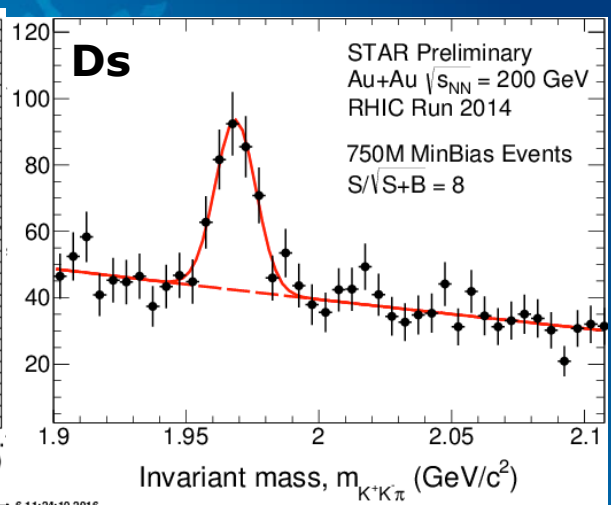
Yezhen Yu
Long Xu
Michael Lomnitz
Wei Li



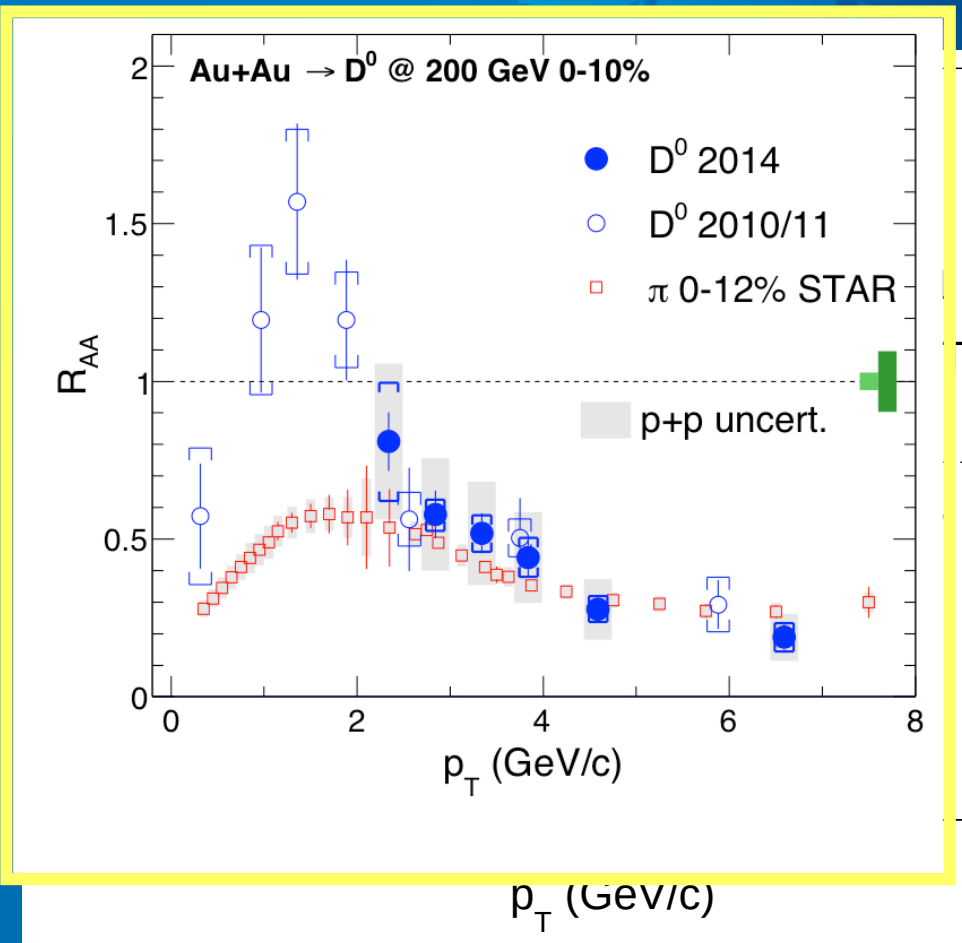
- First application of Monolithic Active Pixel Sensor technology in collider experiments. DCA resolution <50 μm for pT=750 MeV/c Kaon
- Recorded about 3B Minimum Bias 200 GeV Au+Au events for D0, D±, Ds, Λc, and 1 nb-1 high pT electron and dimuon samples for D/B➔e and B➔ J/ψ studies in 2014 and 2016.
- Results presented today are based on partial 2014 MB data

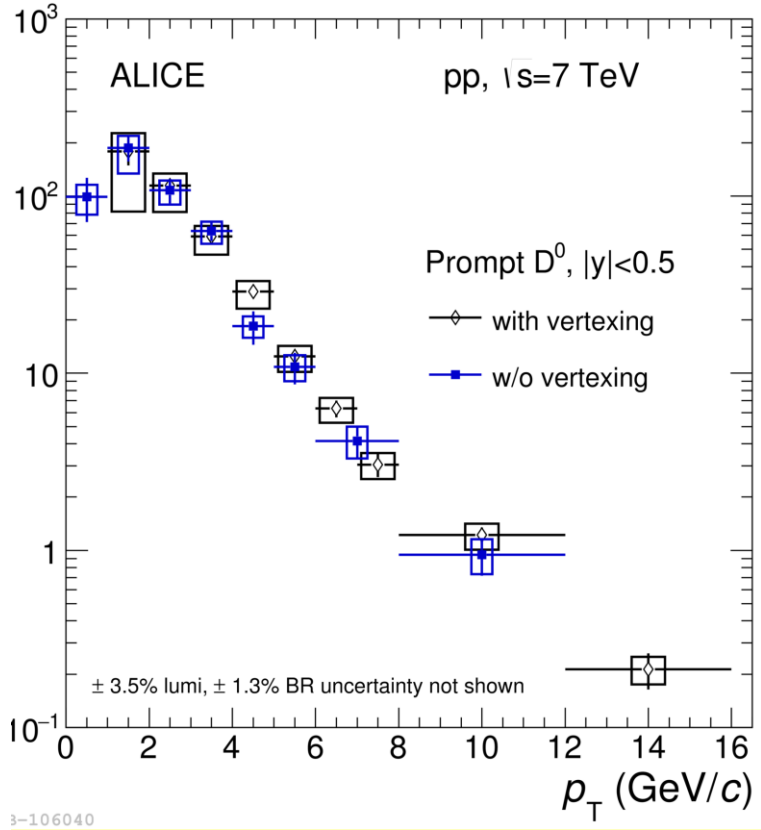






D^0 Nuclear modification Factor R_{AA}

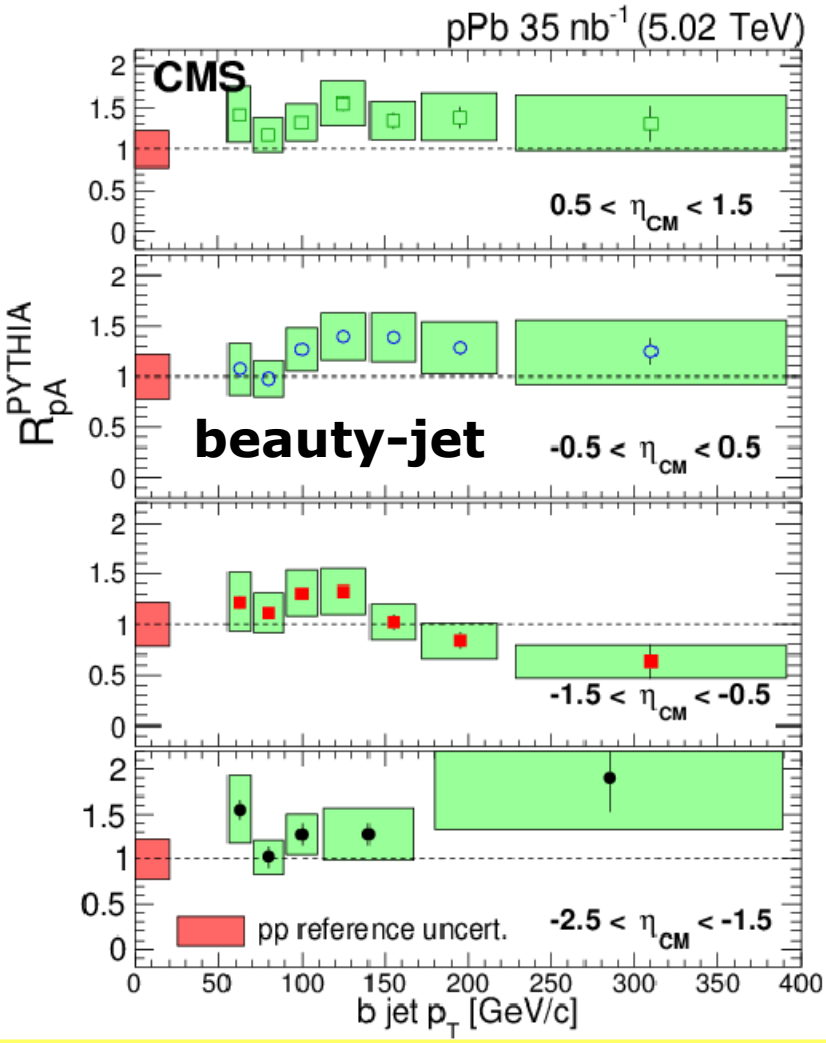


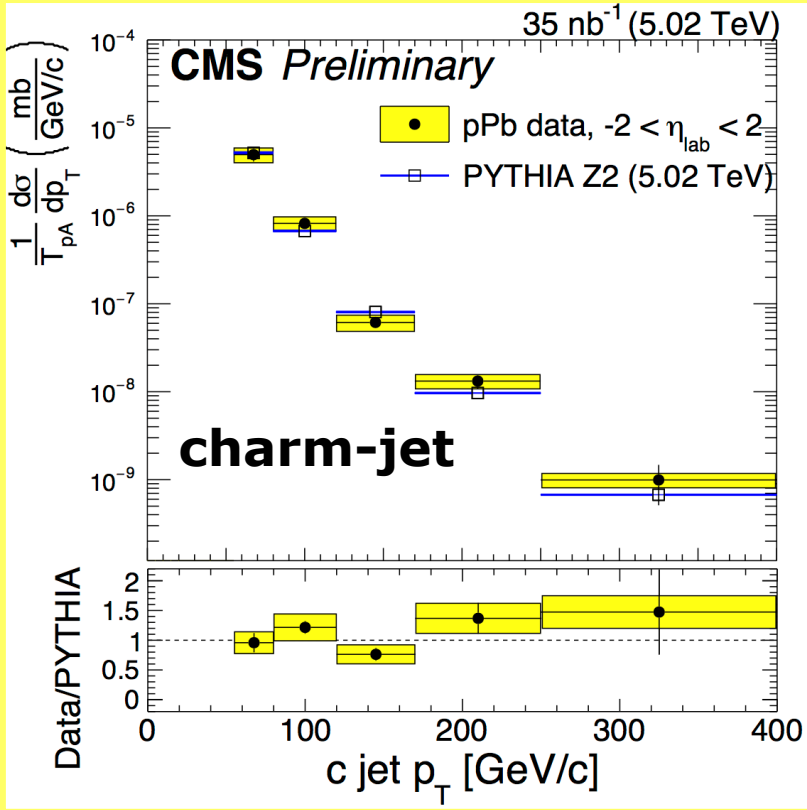


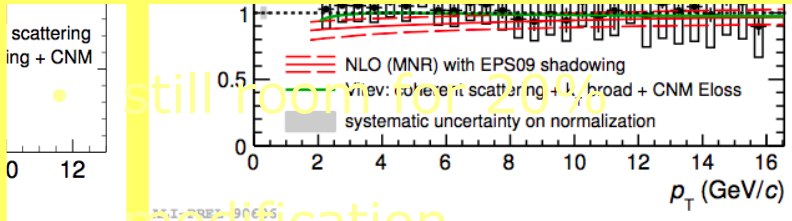
w/o topological selection

- At RHIC $R_{AA} > 1$, at LHC not → shadowing (?) C. Terrevoli, Tu. 14:40

Nuclear modificatin of parton distributions – p-Pb Collisions

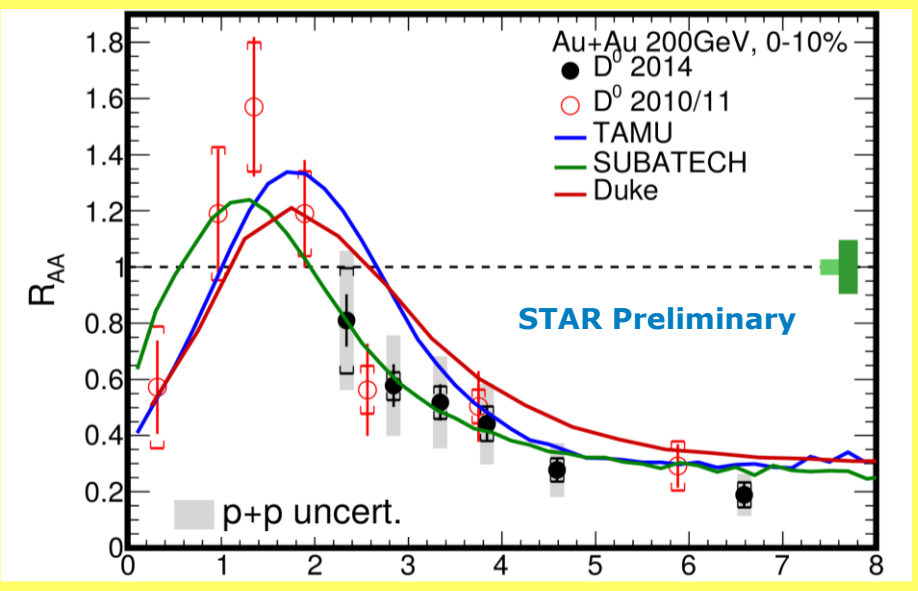


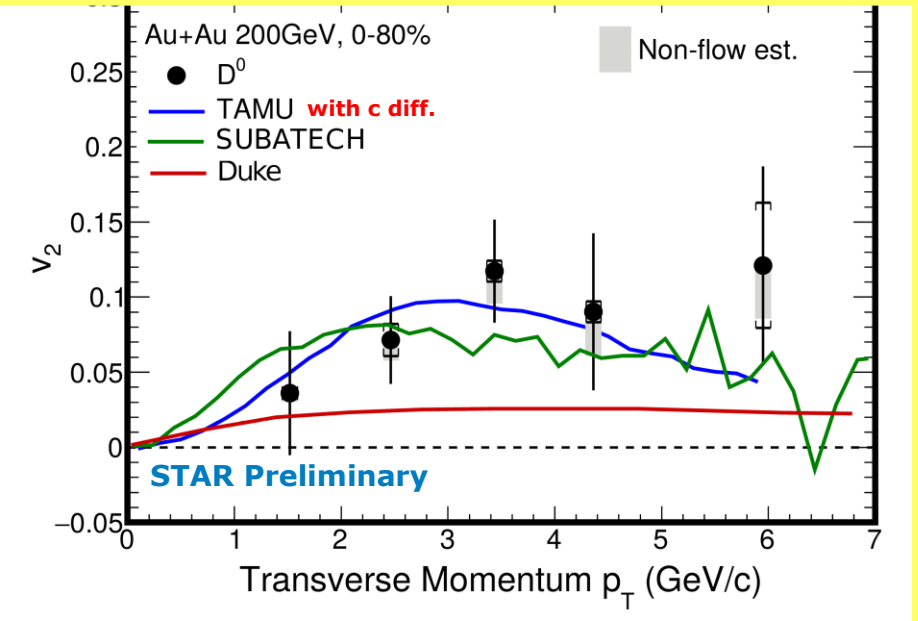


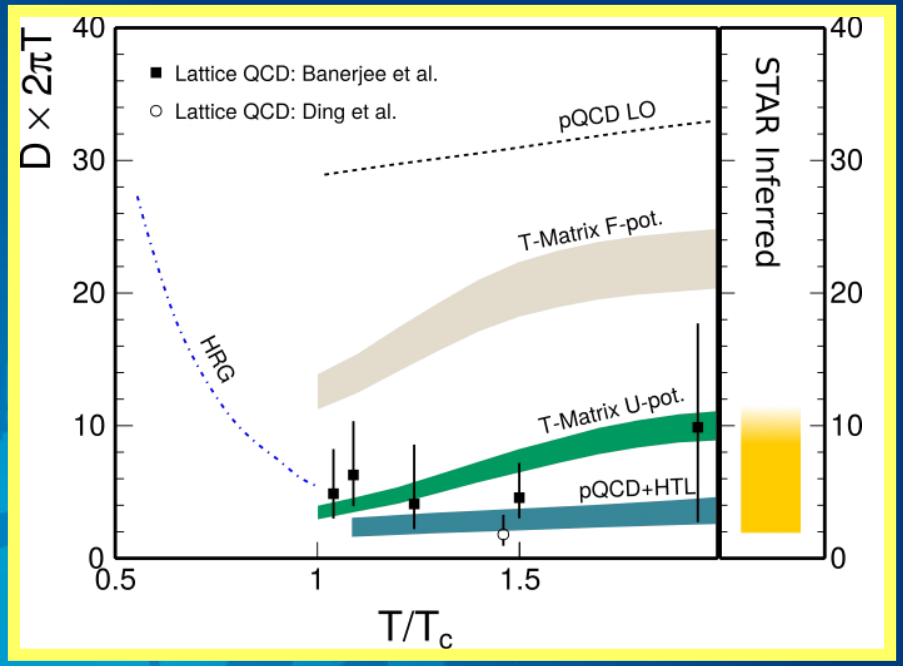


- still room for 20% modification

Comparison with Theory

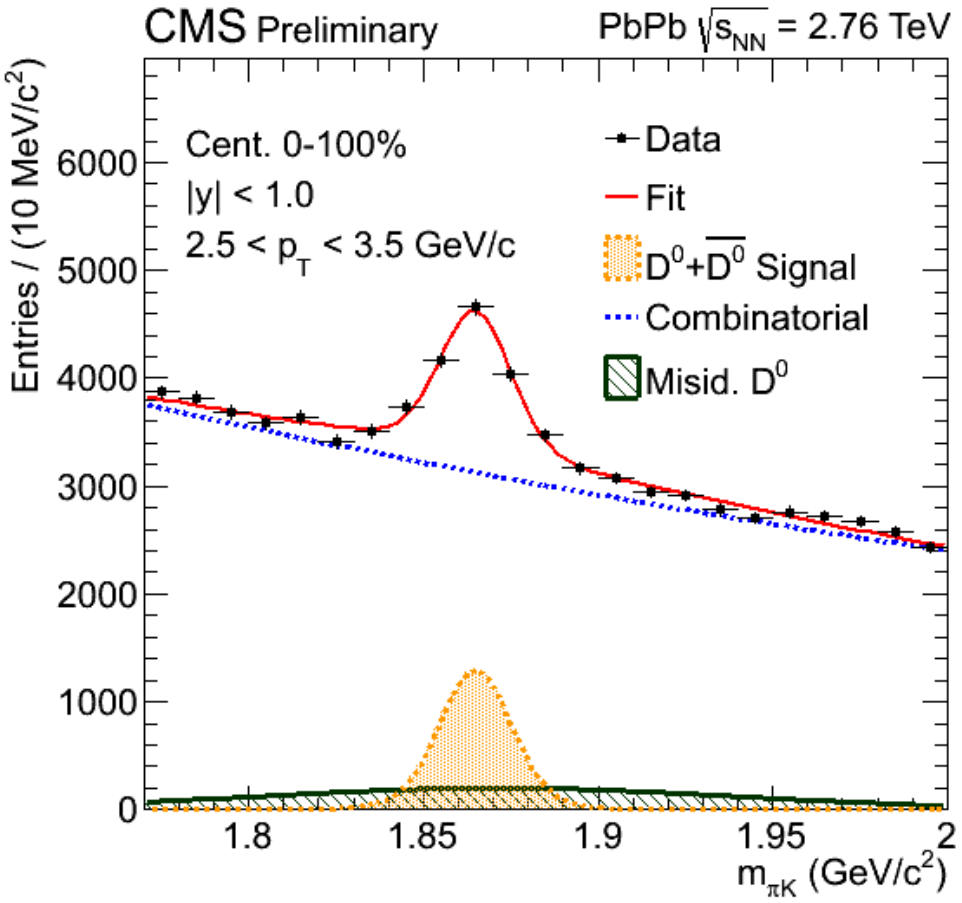






Models with charm diffusion coefficient of 2-11 describe STAR D^0 R_{AA} and v_2 results. Lattice calculations are consistent with these values inferred from data.

Kinematic reflections



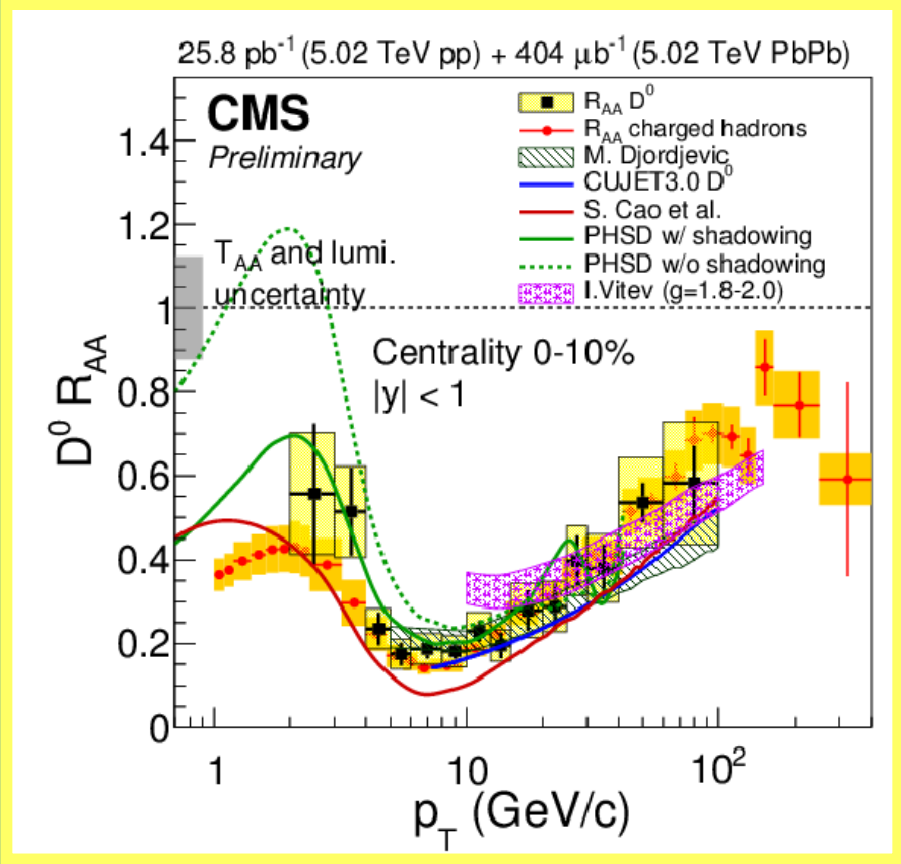
$D^0 \rightarrow K^- + \pi^+$

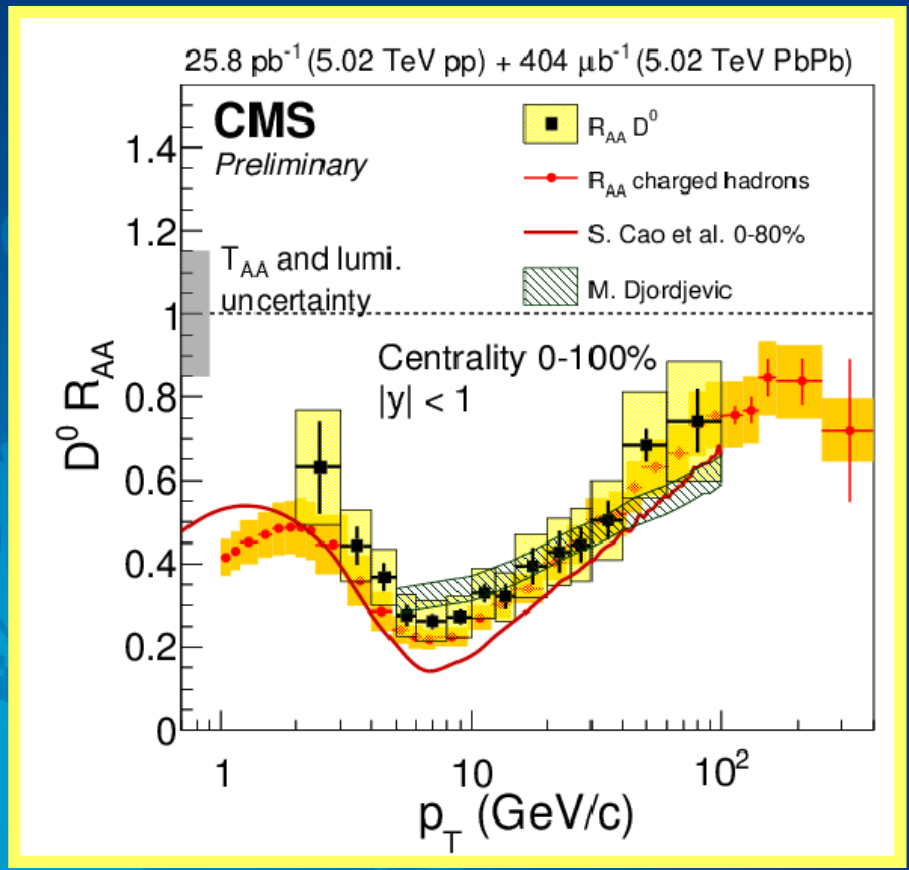
anti-$D^0 \rightarrow K^+ + \pi^-$

in absence of particle identification, particle gets reconstructed as anti-particle under wrong mass assumption

→ Correlated background

Neutral D mesons from CMS, muons from ATLAS





D up to 100 GeV/c (!)

n.b. D mesons at central bin make up 40% of all min.bias D mesons (N_{binary}- scaling)

Centrality dependence oberved by ALICE

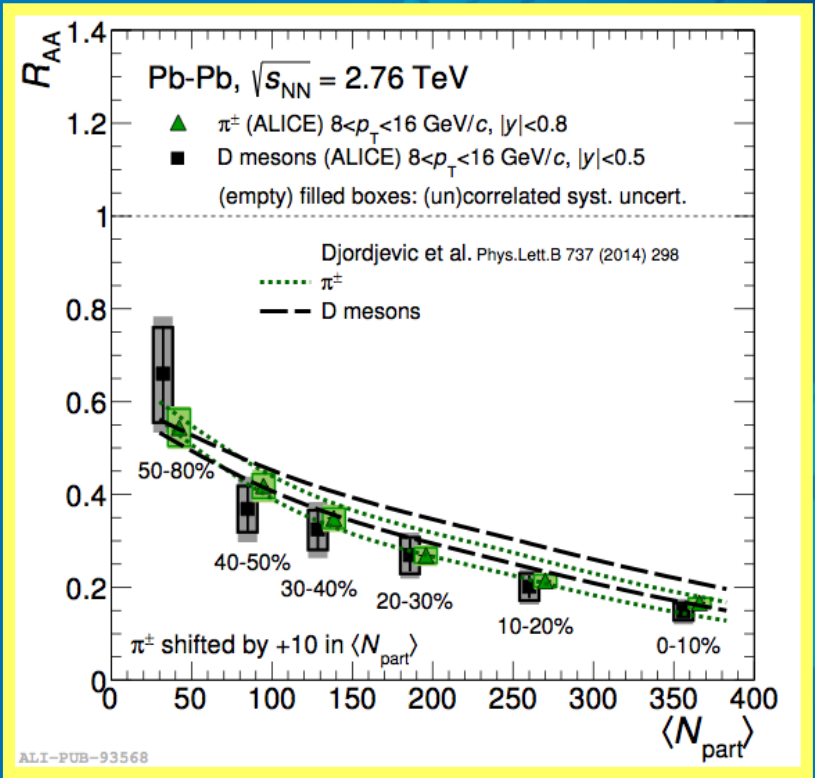
pp reference corresponds to more than 1000 x 1 billion collisions, taken within 3 days

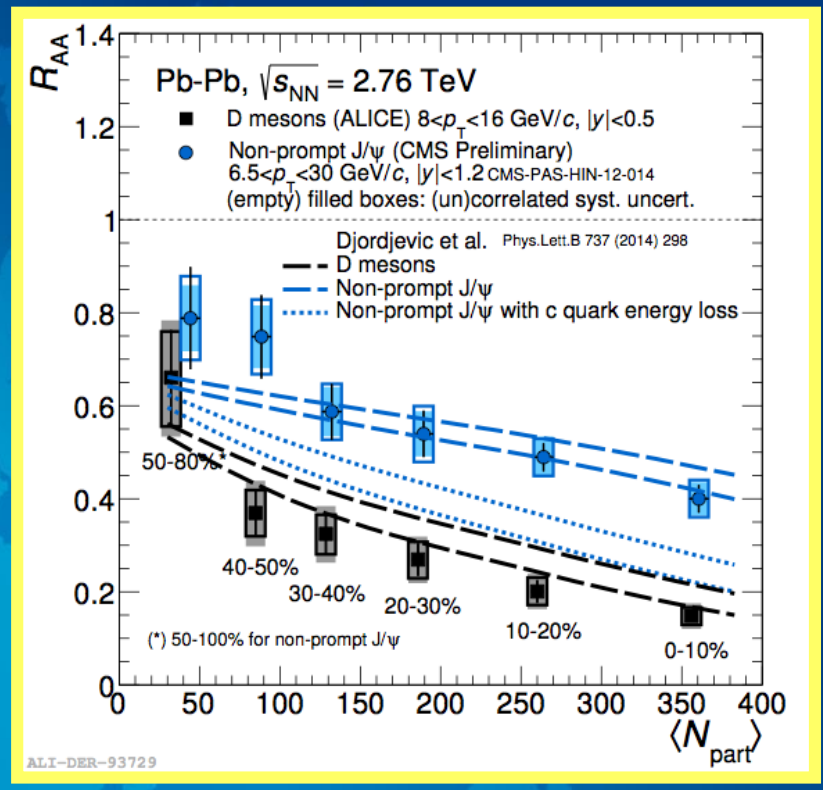
In muons fromHF decay, momentum dependence washed out

Qipeng Hu
K. Jung, Thu. 9:00
J. Wang Tu. 15:20,

Mass dependence on R_{AA}

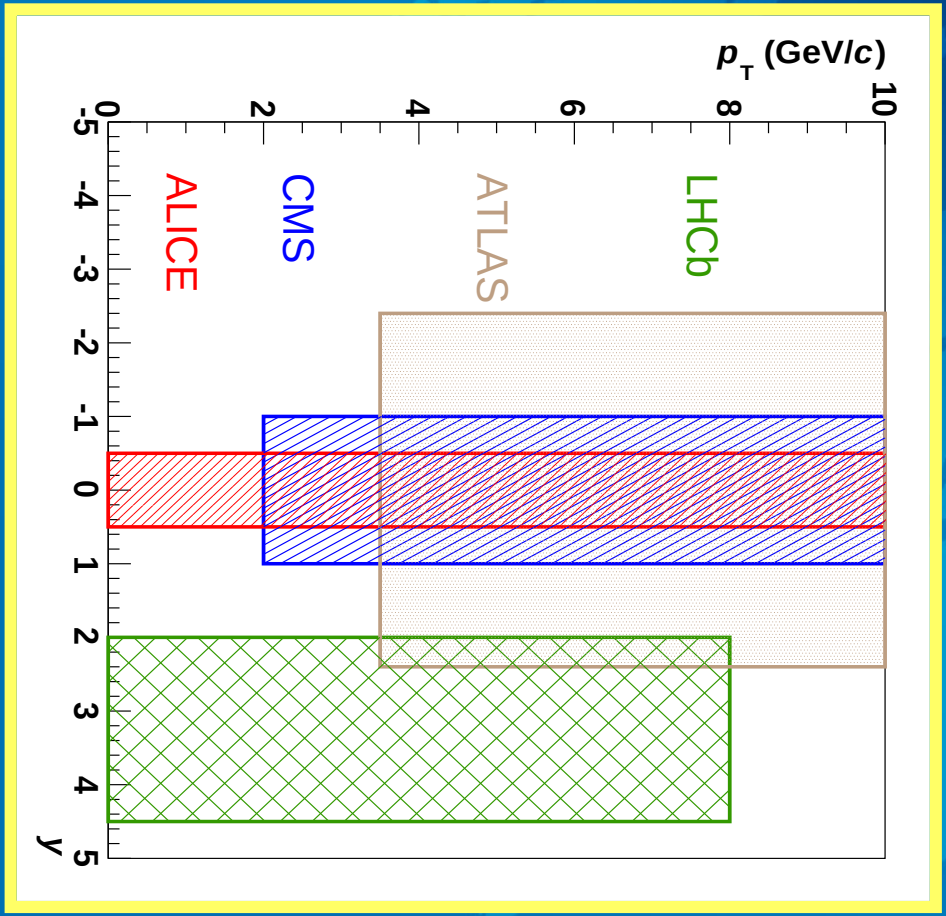
Yezhen Yu
Long Xu
Michael Lomnitz
Wei Li





$R_{AA}(D) < R_{AA}(B \rightarrow J/\psi)$
hint for mass hierarchy of the RAA
described by model including mass-dependent radiative and collisional energy loss

D meson acceptance at LHC*



- Rapidity dependence (!)
- Full coverage in p_T,
- Below 2 GeV/c at $y \approx 0$

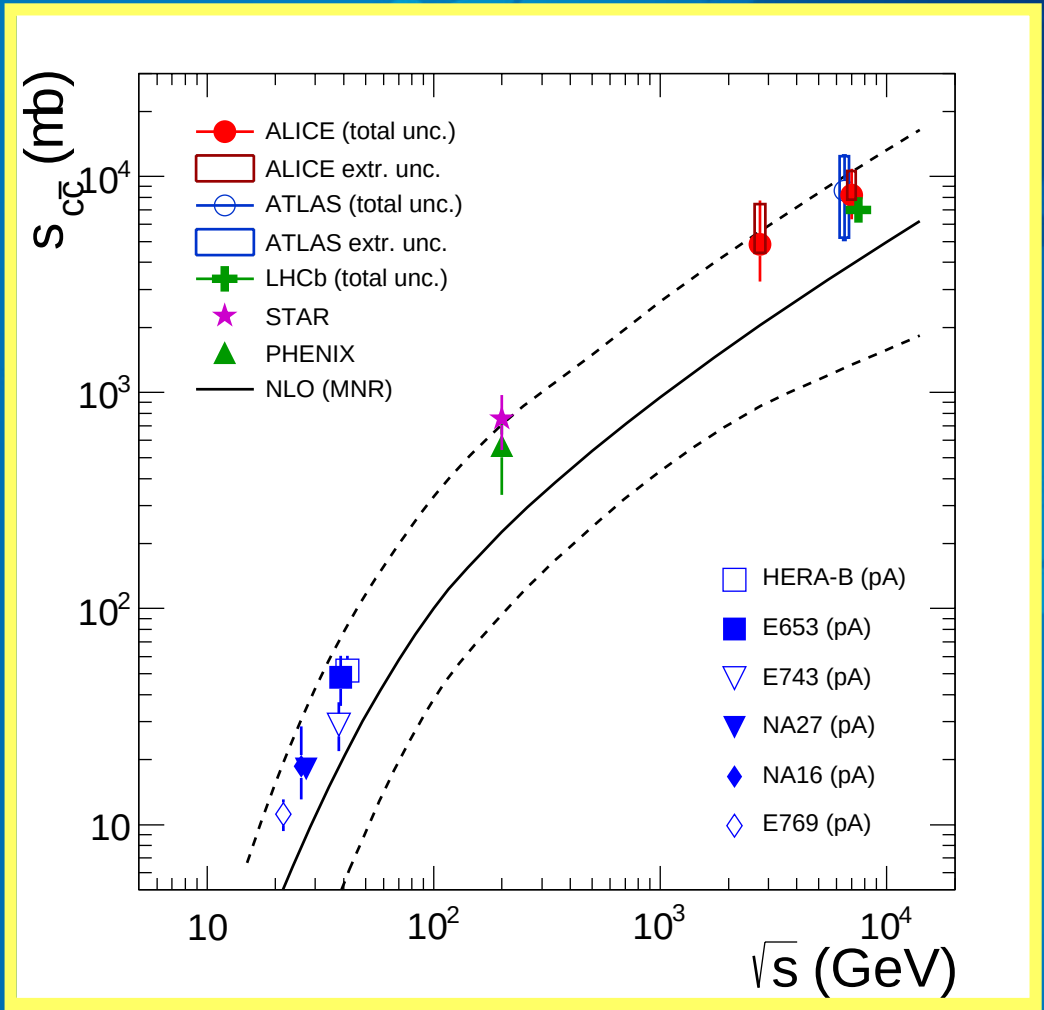
→ w/o topological selection

→ PID is key

Also for Λ_c → p K π

STAR at RHIC: $|y| < 1$, $p_T > 0$
*LHCb in collider mode

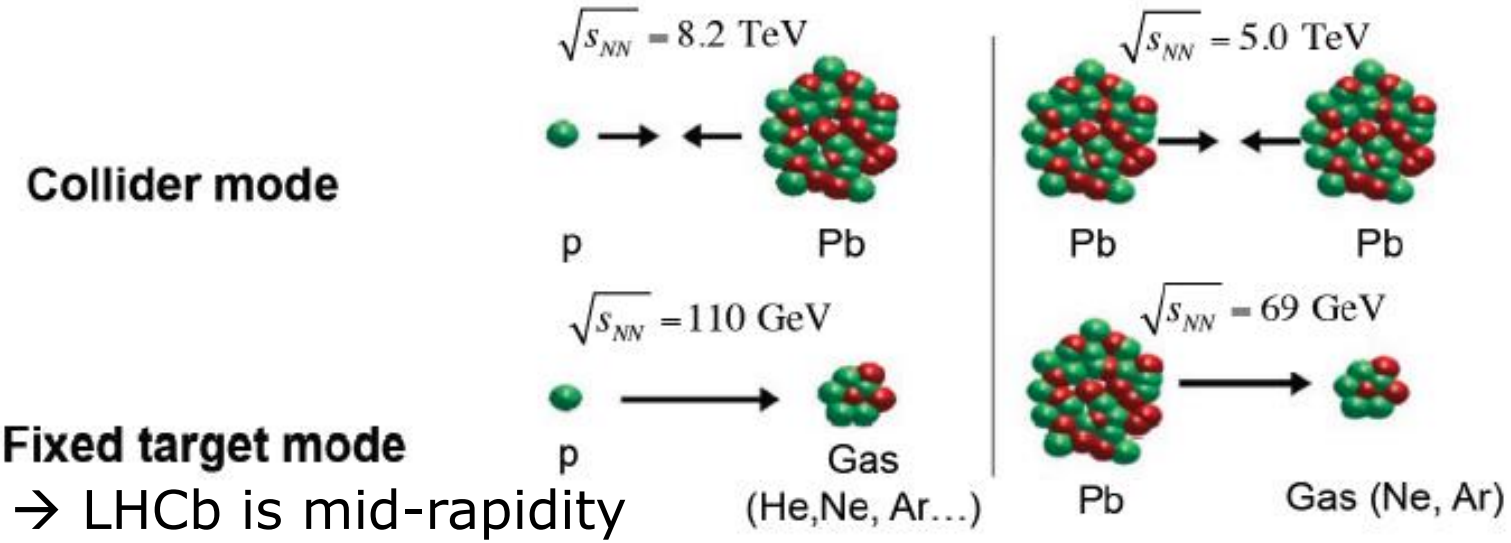
Open-charm cross section



- STAR, pp@200GeV updated from run 12
- ALICE p_T range extended to 0 GeV/c
- experimental data sits in the upper theory band
- hints at lower charm mass

Experimental approach

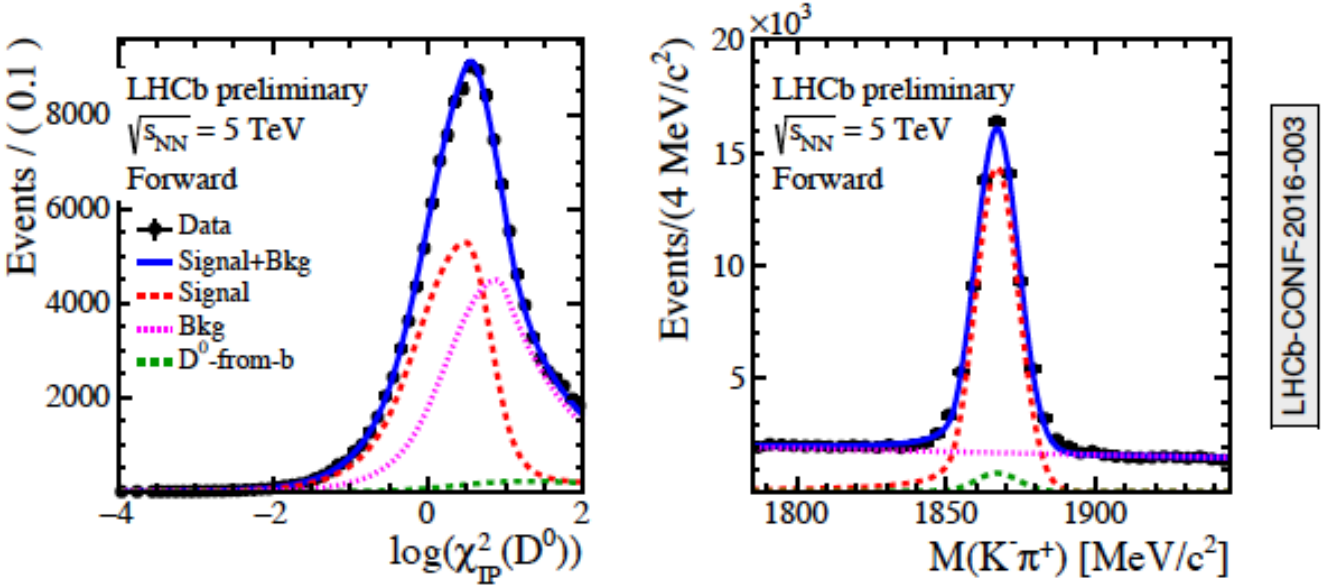
- *study hadronic collisions*
  - as a function of the centre-of-mass energy
  - for different beam-target combinations
  - reference given by pp collisons



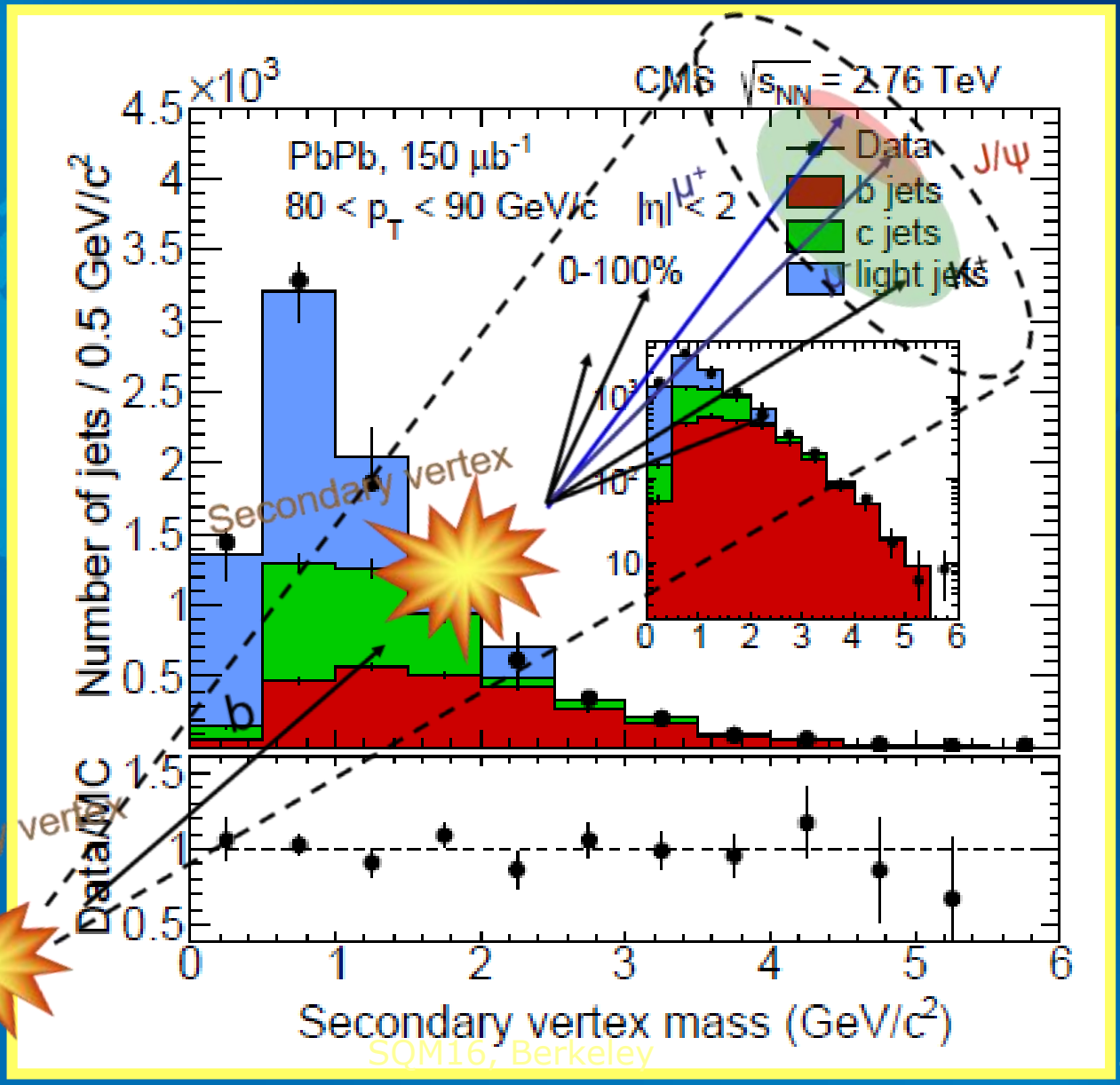
→ LHCb is mid-rapidity detector, -3 < y < 1

D^0 production in pPb collisions

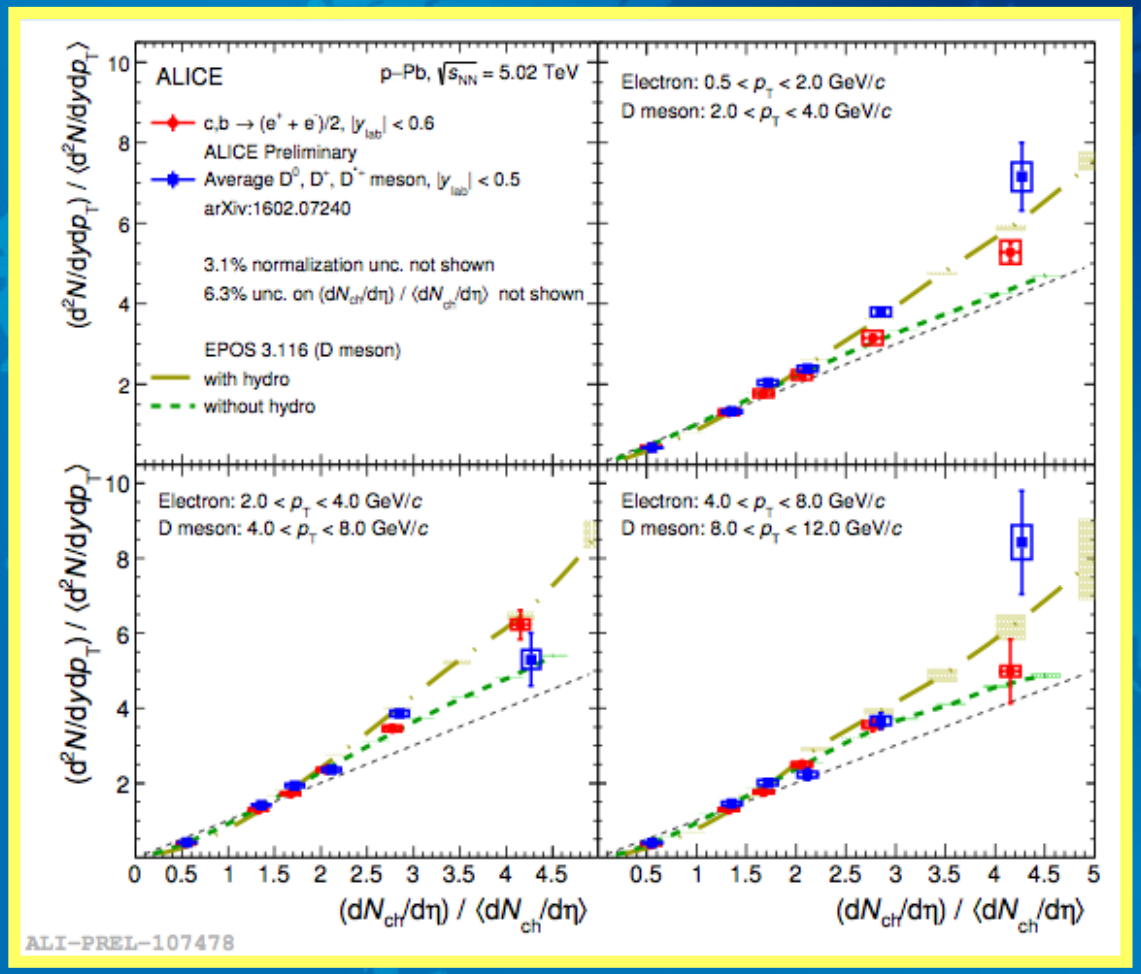
- *forward production of open charm in pA collisions*
  - reconstruction in $D^0 \to K^-\pi^+$ decays
  - $L = 0.11\,\text{nb}^{-1}$ (forward) and $L = 0.05\,\text{nb}^{-1}$ (backward)
  - $p_T < 8\,\text{GeV}/c$, $1.5 < y^* < 4.0$ (forward), $-5.0 < y^* < -2.5$ (backward)
  - simultaneous 2D fit of invariant mass and impact parameter
    - different method than for $J/\psi, \psi(2S)$ since the D^0 has a finite lifetime
    - extraction of prompt yields down to $p_T \to 0$



Open heavy flavor jet reconstruction

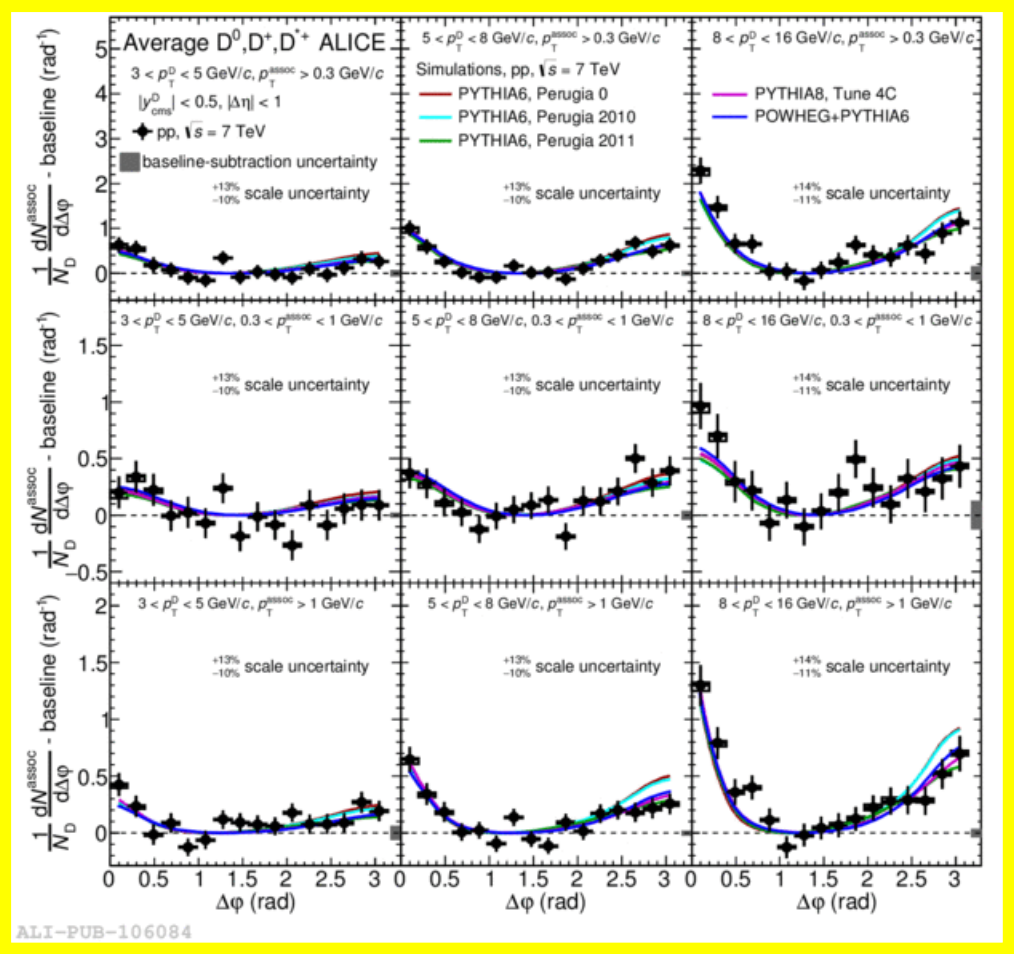


Multiplicity dependence



J. Wagner, Tu. 17:40

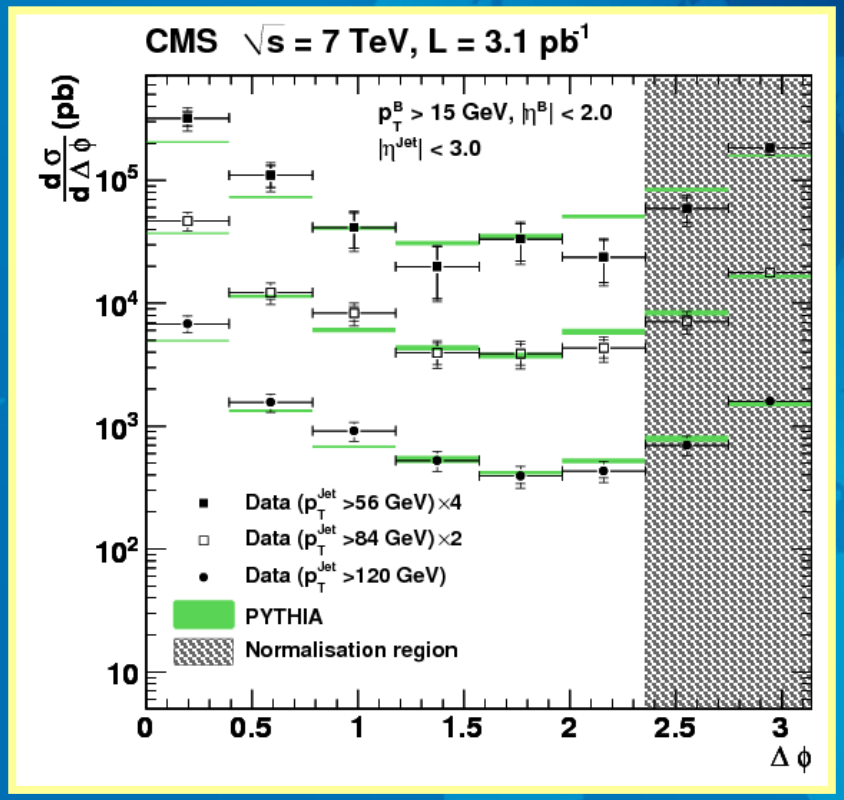
D meson correlations



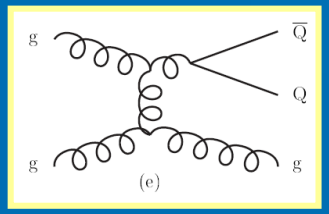
- D meson correlated with all other charged particles
- 'Baseline' subtracted, assuming no yield at minimum of distribution

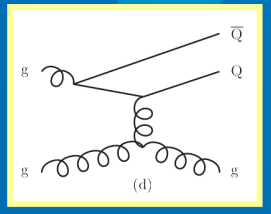
F. Colomaria, Tu. 16:00

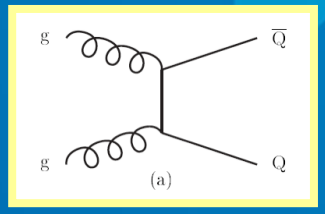
Heavy – quark Correlations*



- CMS trigger: inspected 200 x 10^9 p+p collisions
- B–Bbar
- Gluon splitting underestimated in PYTHIA
- Lower charm mass would increase gluon-splitting rate





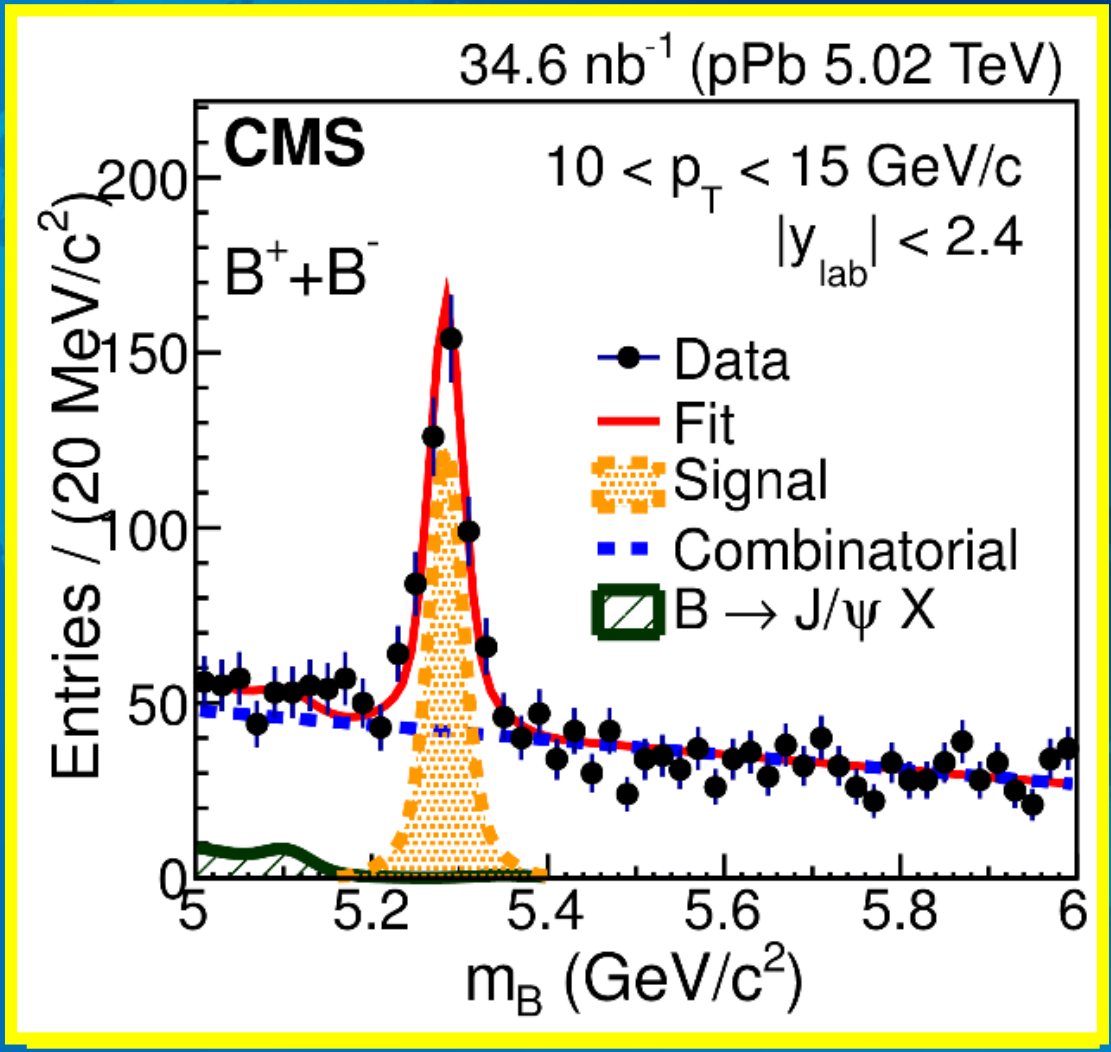


*CMS collaboration:JHEP 1102 (2011) 136; arXiv:1192.3194v2 [hep-ex].

H1: m_c =1.26 GeV/c^2, arXiv:1211.1182;

D0: Z boson + c jet, arXiv:1308.4384;
D0:photon + c jet, arXiv:1210.5033;
CDF, photon + c,b jet, arXiv:1303.6136;
CMS: W + charm, CMS-PAS-SMP-12-002.

B mesons from CMS and ALICE



D. Silvermyer,
Fri. 9:00

Conclusions

QM 2004, Oakland
first sight of open charm
No secondary vertexing

SQM 2016
electrons, muons from heavy-flavor decays
System size and energy scan
Fully reconstructed D, B mesons, diplayed J/ψ
Charm jets, beauty jets
correlations, …

RHIC experiments still pushing the limits
All 4 large-scale at LHC participate in HI program
→ **Looking forward** to SQM2017 !