4th Heavy Ion Jet Workshop, École Polytechnique, 25-27 July 2016

Future Heavy Flavour Measurements: LHC Upgrades and Outlook to FCC

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Outline

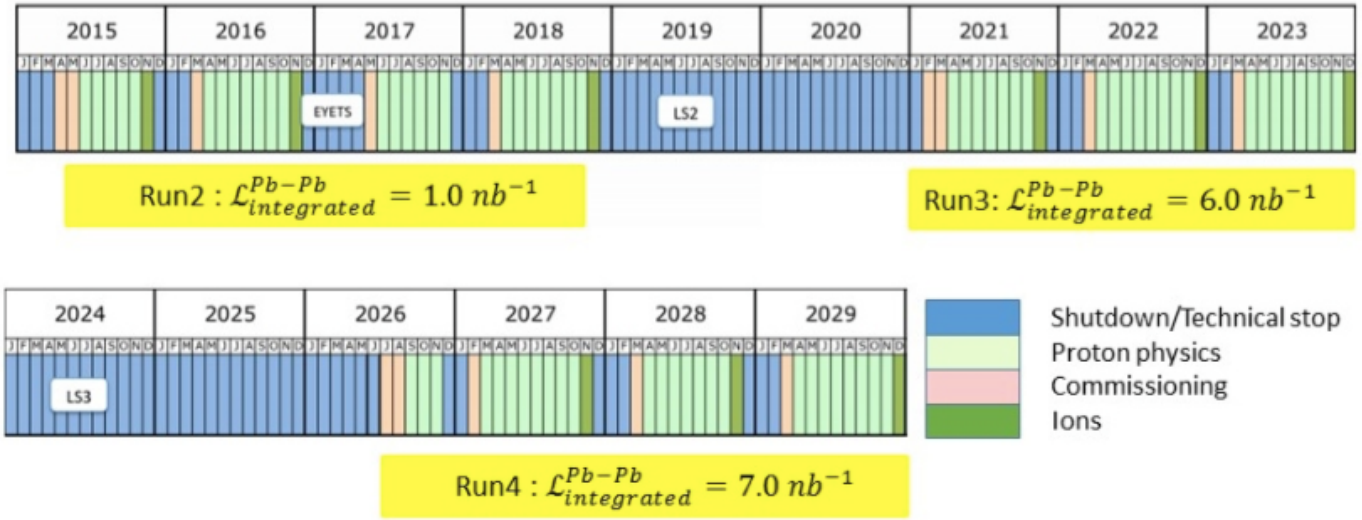
Part I:

- Future HI programme at LHC
- Detector upgrades
- Projected performance for HF measurements

Part II:

- Introduction to the FCC Study
- Example of novel QGP observables at FCC: thermal charm and boosted tops

Timeline of future HI running at the LHC



- Run 2:
  - Pb-Pb: few/nb (0.7/nb in 2015), at $\sqrt{s_{NN}}$ = 5 TeV
  - p-Pb at 5 and 8 TeV (increased luminosity)
  - pp reference at Pb-Pb energy (5 TeV)
- LS2:
  - LHC injector upgrades; bunch spacing (likely) reduced to 25 ns; Pb-Pb interaction rate may exceed 50 kHz (now <10 kHz)
  - Experiments upgrades (LS2 and LS3)
- Runs 3+4:
  - Experiments request for **Pb-Pb: >10/nb** (ALICE: 10/nb at 0.5T + 3/nb at 0.2T)
  - In line with latest projections by the machine group

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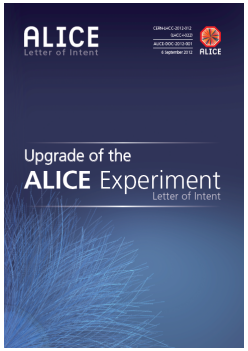
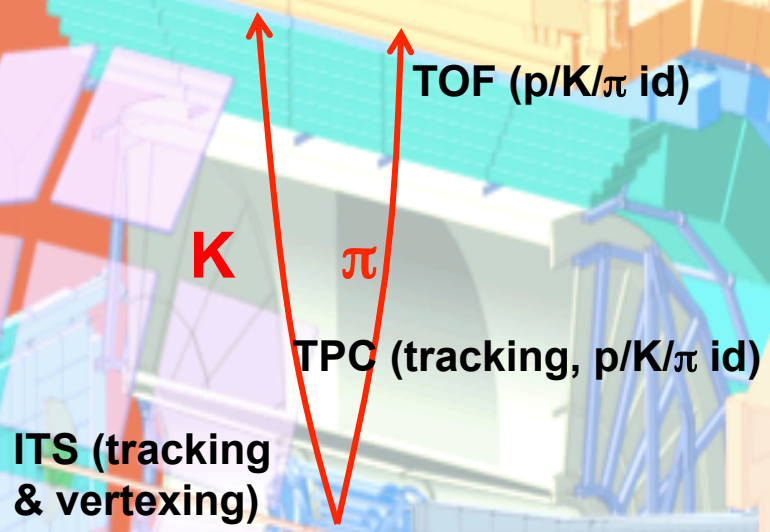
ALICE Upgrade: (selected) physics questions & observables

1. **Characterise mechanisms of quark-medium interaction**
   → **Heavy flavour dynamics and hadronisation at low p_T**
2. **Charmonia regeneration as tool to study deconfinement**
   → **Charmonia down to zero p_T**
3. **Chiral symmetry and QGP temperature at LHC**
   → **Vector mesons and virtual thermal photons via di-leptons**



http://cdsweb.cern.ch/record/1475243
http://cdsweb.cern.ch/record/1592659

ALICE Upgrade: Heavy Flavour requirements



Currently, in Pb-Pb:

$D^0 \rightarrow K\pi$

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

$D^* \rightarrow D^0\pi$

$D_s \rightarrow KK\pi$ (limited)

$HF \rightarrow e/\mu + X$

$B \rightarrow e / J/\psi + X$ (limited)

Goals for upgrade:

Precision! $p_T \rightarrow 0$!

$B \rightarrow D^0 + X$

$B \rightarrow J/\psi + X$

$B \rightarrow e/\mu + X$

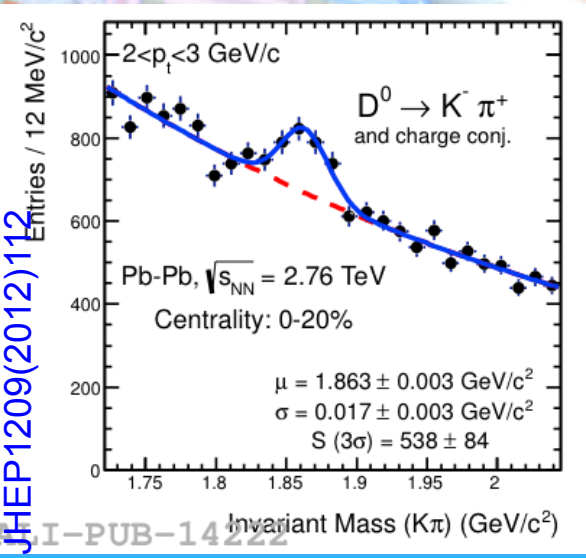
$\Lambda_c \rightarrow pK\pi$

$\Lambda_b \rightarrow \Lambda_c\pi$

General features:

Decay at few 100 μm from interaction point

Large combinatorial background → low signal/background → no dedicated trigger



JHEP1209(2012)112

CERN-PUBLI-14222

Requirements:

- **Vertexing resolution**
- **Preserve particle identification**
- **Large statistics (no dedicated trigger)**

ALICE Upgrade Strategy

- Main observables:
  - Low-p_T heavy flavour
  - Low-p_T charmonia
  - (Very) low-p_T and low-mass di-leptons
- Mostly "untriggerable" because of extremely low S/B

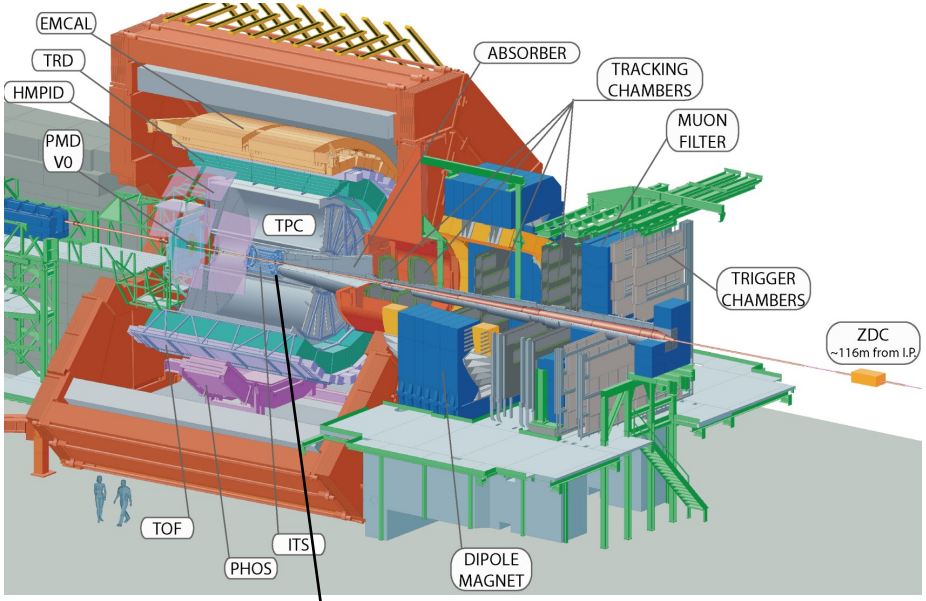
→ Trigger approach: write all interactions at 50 kHz in Pb-Pb (currently 1 kHz)

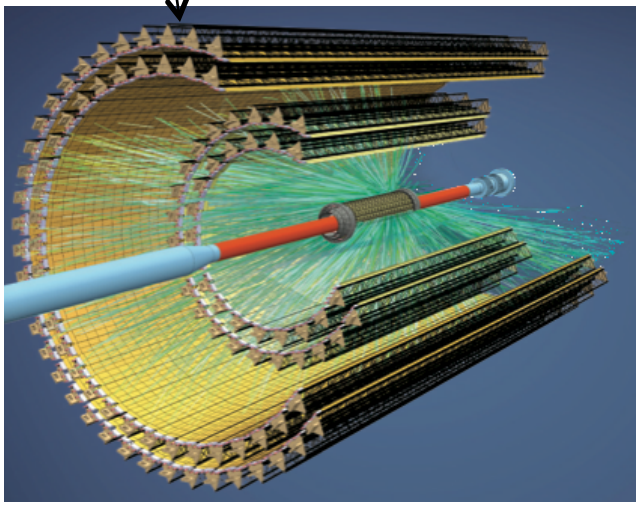
~1 TB/s → **O^2 facility at ALICE site: integrated online-offline system for calibration, reconstruction and data compression** → **~90 GB/s**

→ Run3-4: increase of MB sample **x100** wrt Run 2,
10/nb ~ 100 billion MB events

ALICE Detector Upgrade

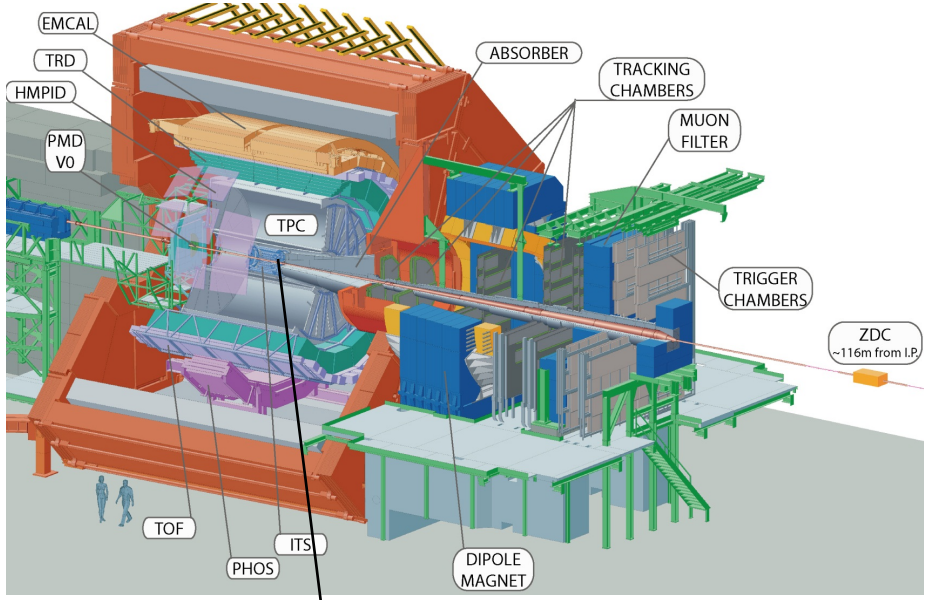
- New Inner Tracking System (ITS)
  - Improved resolution, less material, faster readout

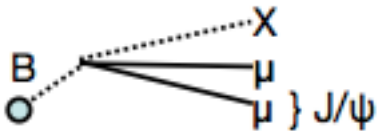


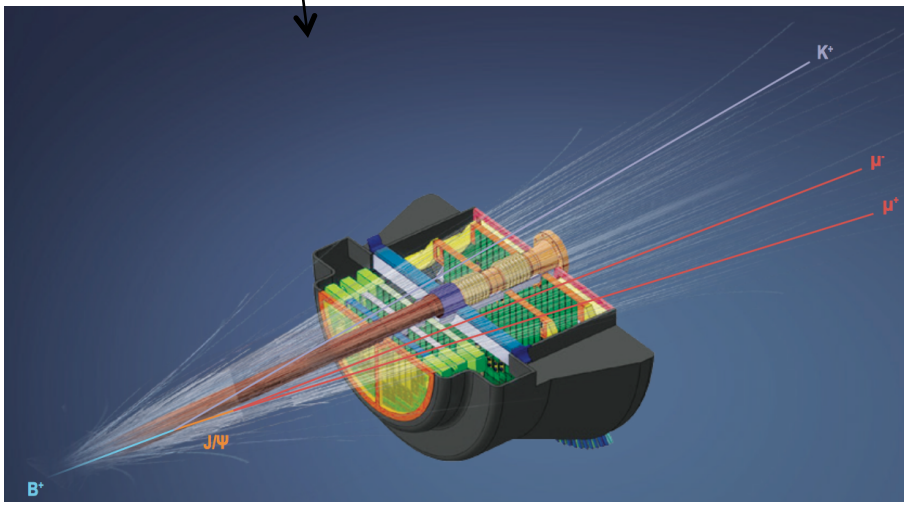


ALICE Detector Upgrade

- New Inner Tracking System (ITS)
  - Improved resolution, less material, faster readout
- New Forward Muon Tracker (MFT)
  - HF vertices also at forward rapidity

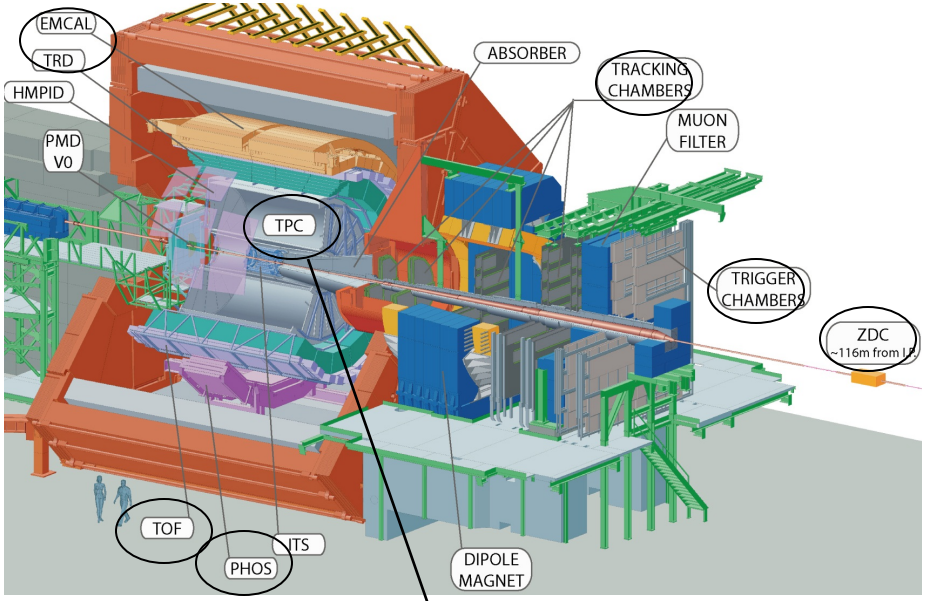


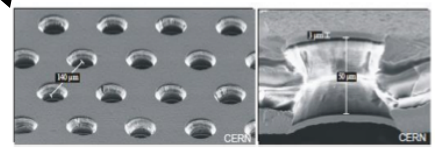




ALICE Detector Upgrade

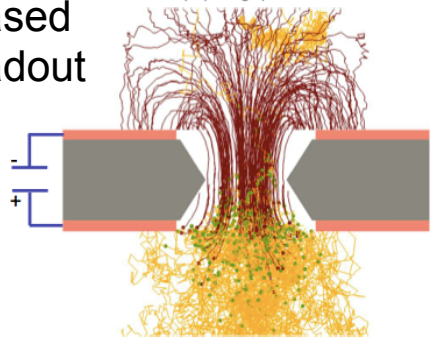
- New Inner Tracking System (ITS)
  - Improved resolution, less material, faster readout
- New Forward Muon Tracker (MFT)
  - HF vertices also at forward rapidity
- Upgraded read-out for TPC, TOF, TRD, MUON, ZDC, EMCal, PHOS, new trigger detector (FIT), integrated Online-Offline system (O^2)
  - Record Pb-Pb data at 50 kHz





Electron microscope photograph of a GEM foil

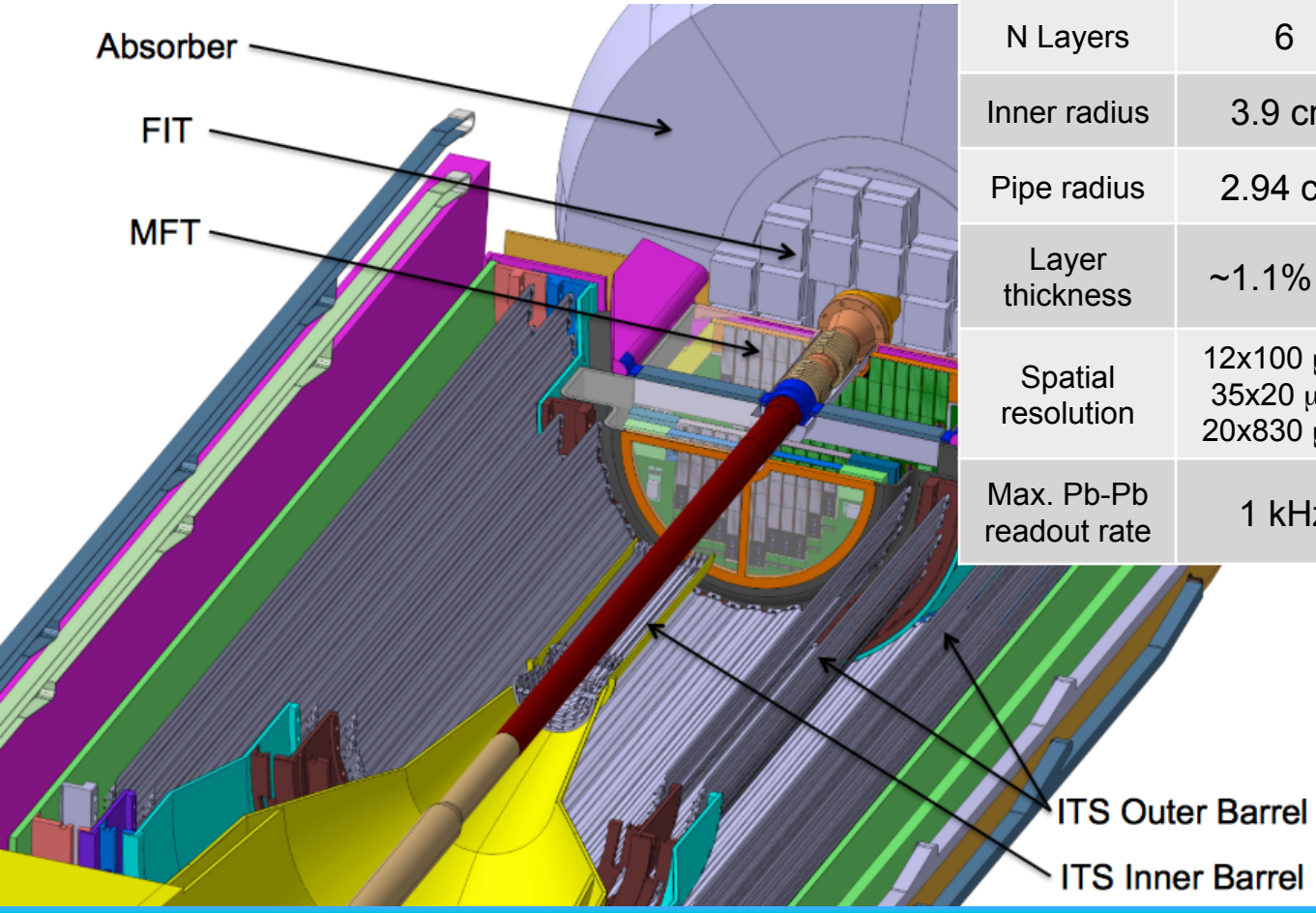
GEM-based TPC readout



New ALICE all-pixel trackers: ITS and MFT

- Both trackers fully based on Monolithic Active Pixel Sensors (MAPS)

	Pres. ITS	New ITS	MFT
Acceptance	$\|\eta\|<0.9$	$\|\eta\|<1.5$	$-3.6<\eta<-2.3$
N Layers	6	7	5
Inner radius	3.9 cm	2.3 cm	/
Pipe radius	2.94 cm	1.86 cm	/
Layer thickness	~1.1% X_0	0.3-0.8% X_0	0.6% X_0
Spatial resolution	12x100 μm^2 35x20 μm^2 20x830 μm^2	~5x5 μm^2	~5x5 μm^2
Max. Pb-Pb readout rate	1 kHz	100 kHz	100 kHz

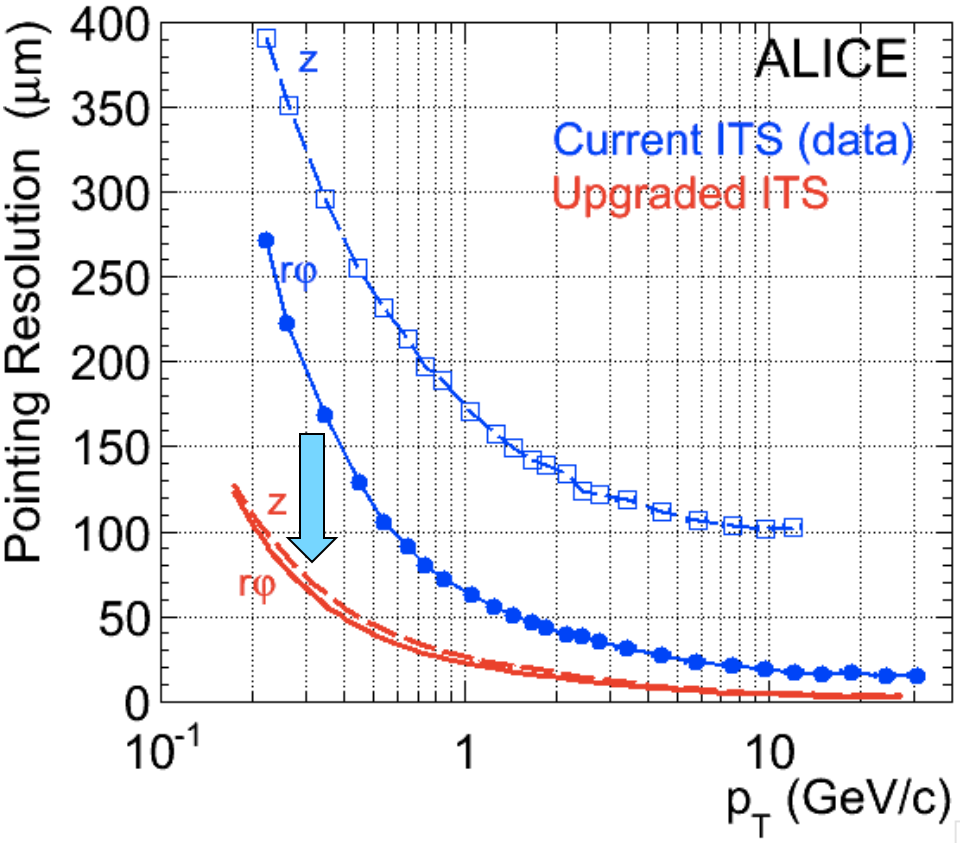


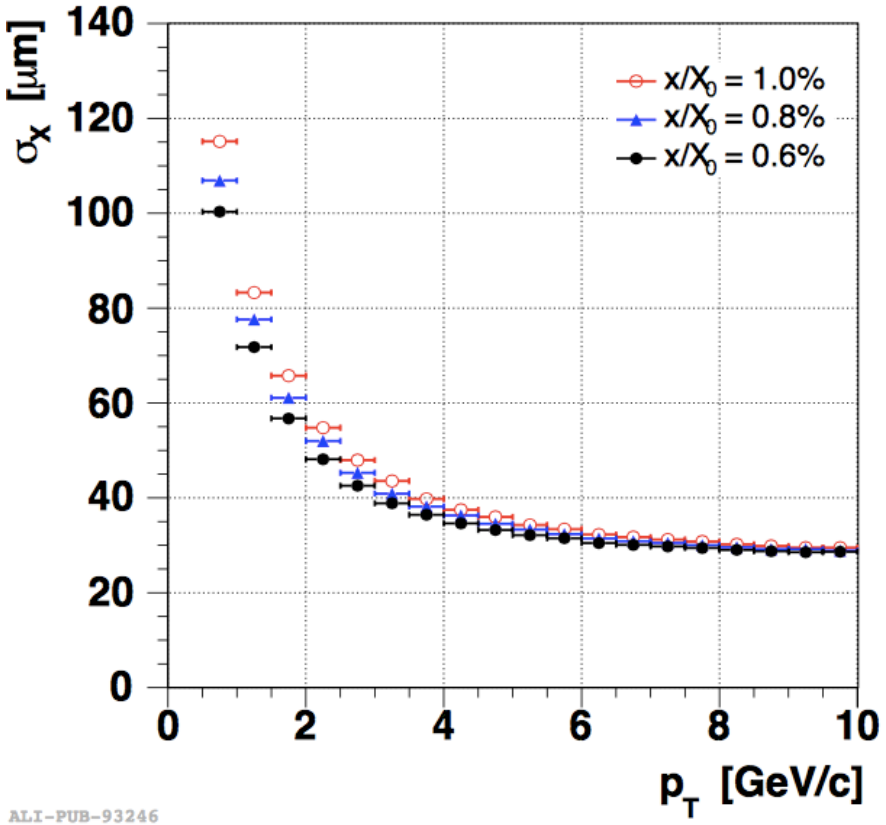
ITS: CERN-LHCC-2013-024
MFT: CERN-LHCC-2015-001

ALICE Upgrade tracking precision

ITS: pointing resolution x3 better in transverse plane (x6 along beam)

MFT: pointing resolution better than 100 μm for p_T > 1 GeV/c





Adapted from CERN-LHCC-2013-024

CERN-LHCC-2015-001

Focus on ATLAS and CMS

- Main observables:
  - Differential studies of jets at very high p_T
  - D and B mesons, HF-jets
  - Differential studies of quarkonium states
- Exploit detector specificities (strengthened with the upgrades):
  - muon ID
  - precise trackers
  - calorimetry
- Mostly based on muon, jet, displaced track triggers

→ Trigger/DAQ approach: strong event rate reduction

50 kHz → **L1** → **~ few kHz** → **HLT** → **~ 100 Hz**

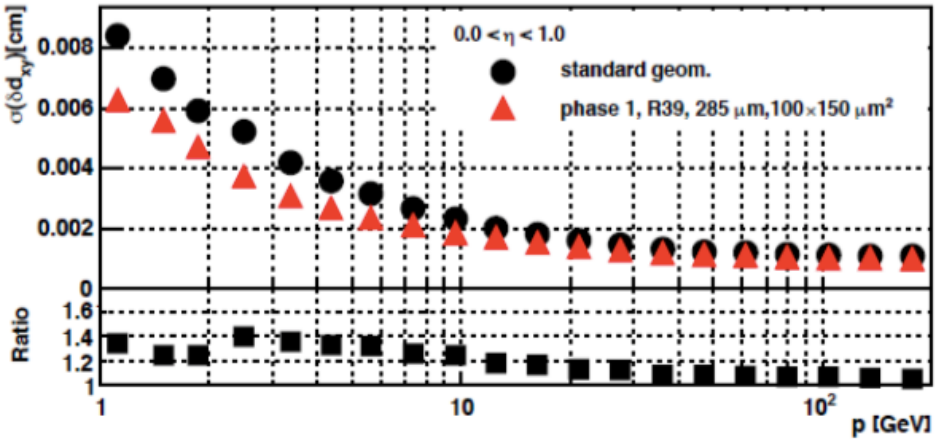
→ Run 3-4: 10/nb → increase of sample **x10** wrt Run 2

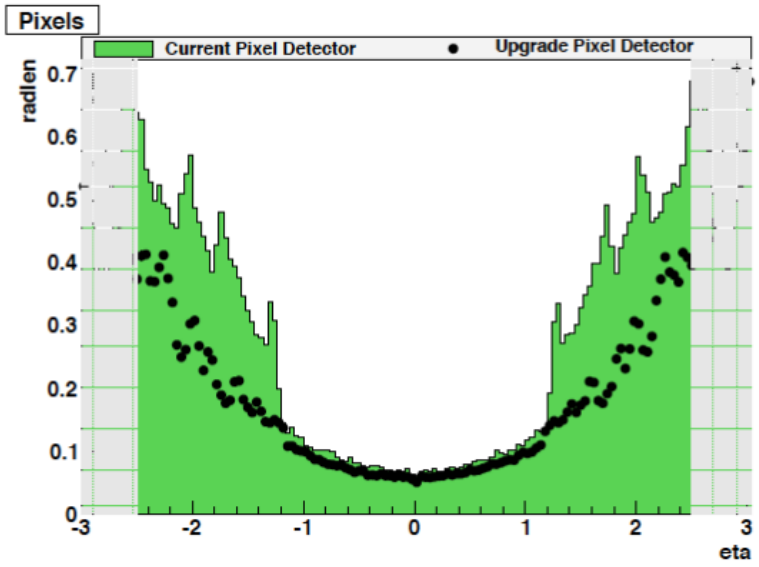
ATLAS and CMS: upgrades most relevant to HI

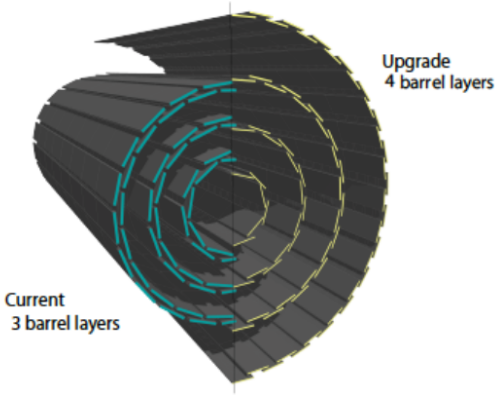
- ATLAS
  - Additional pixel layer (LS1), then new tracker (LS3): tracking and b-tag
  - Fast tracking trigger (LS2): high-multiplicity tracking
  - Calorimeter and muon upgrades (LS2): electron, γ, muon triggers
- CMS
  - Upgrade of trigger and DAQ, L1 calorimeter trigger (LS1): enables L1 rejection at 95%, e.g. (after LS2) from 50 kHz to <3 kHz (HLT input)
  - New pixel tracker (YETS16-17), then new tracker (LS3): tracking and b-tagging
  - Extension of forward muon system (LS3): muon acceptance
  - Upgrade forward calorimeter (LS3): forward jets in HI

New CMS pixel tracker

- To be installed during 2016-17 year-end tech. stop
  - Reduced material budget
  - Improved IP resolution



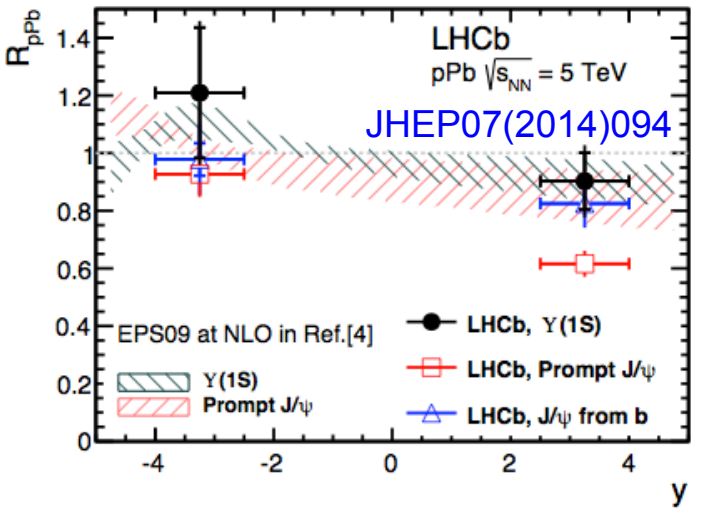


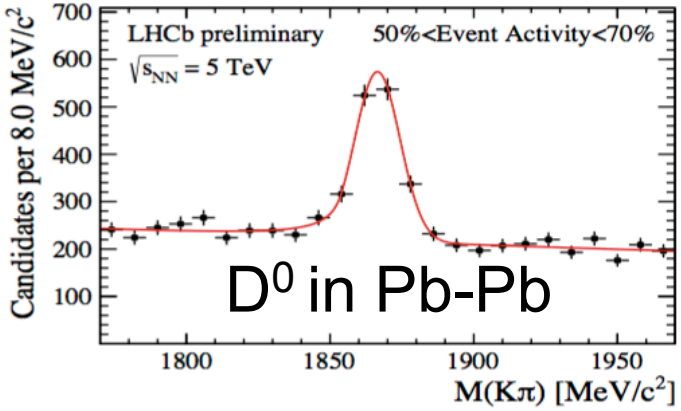


- Will have strong impact, also in Pb-Pb, on:
  - Extension of η acceptance
  - Non-prompt J/ψ
  - b-tagged jets
  - Full reconstruction of D and B meson decays

Focus on LHCb

- Joined recent p-Pb and Pb-Pb runs
- Strong impact of LHCb unique features: forward and low-p_T acceptance, vertexing, PID
  - Cold nuclear matter effects on D mesons, prompt and non-prompt J/ψ, Υ(1S)
  - First observation of Z production in p-Pb
- Pb-Pb: large potential, performance in central collisions not yet assessed
- Interest in future HI runs, also after LS2
- Upgrades (LS2) most relevant to HI:
  - New trackers (pixel, strip, scintillating fiber)
  - Readout upgrade: up 40 MHz (pp)
    → exploit full delivered HI rate





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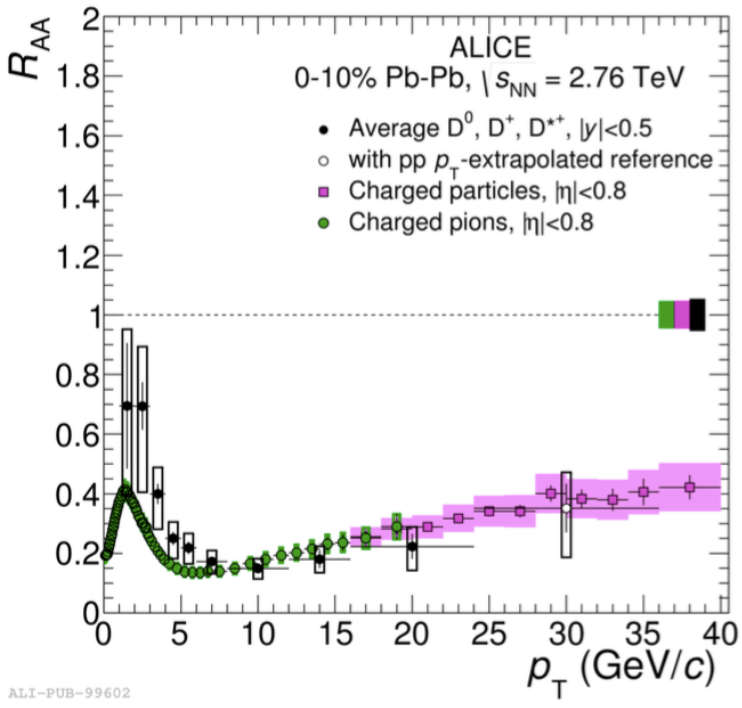
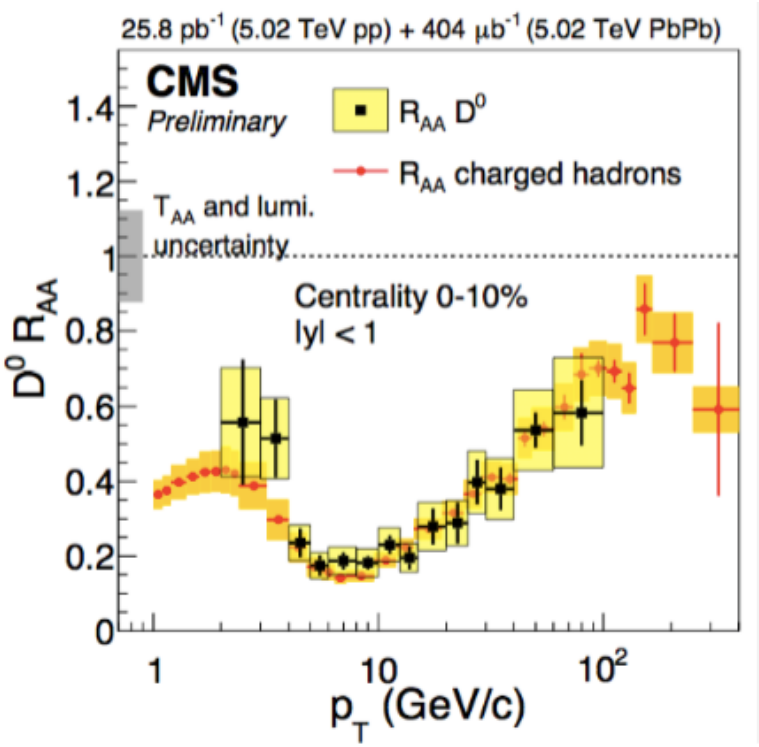
Heavy flavour R_{AA} at LHC: present status

- D R_{AA} consistent with pions and charged hadrons within uncertainties at 2.76 (ALICE and CMS) and 5.02 TeV (CMS)



ALICE, JHEP1603 (2016) 081



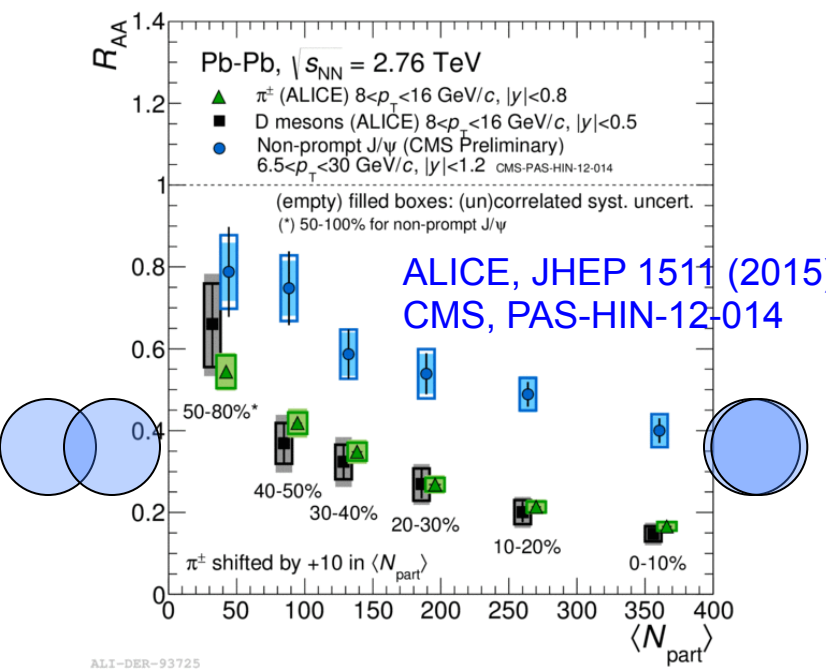
CMS-PAS-HIN-16-001, CMS-PAS-HIN-15-015

Need to improve precision and accuracy to conclude on D vs π and assess colour-charge dependence of energy loss

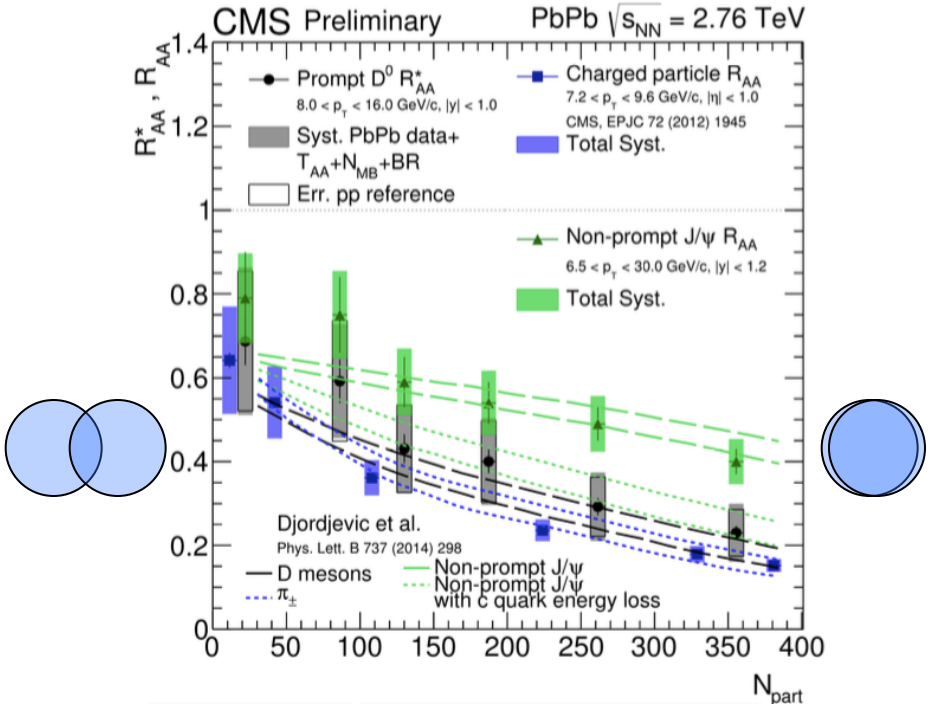
Heavy flavour R_{AA} at LHC: present status

- First indication of mass dependence of energy loss:

$$R_{AA}^{B}\ (\text{CMS}) > R_{AA}^{D}\ (\text{ALICE, CMS})$$

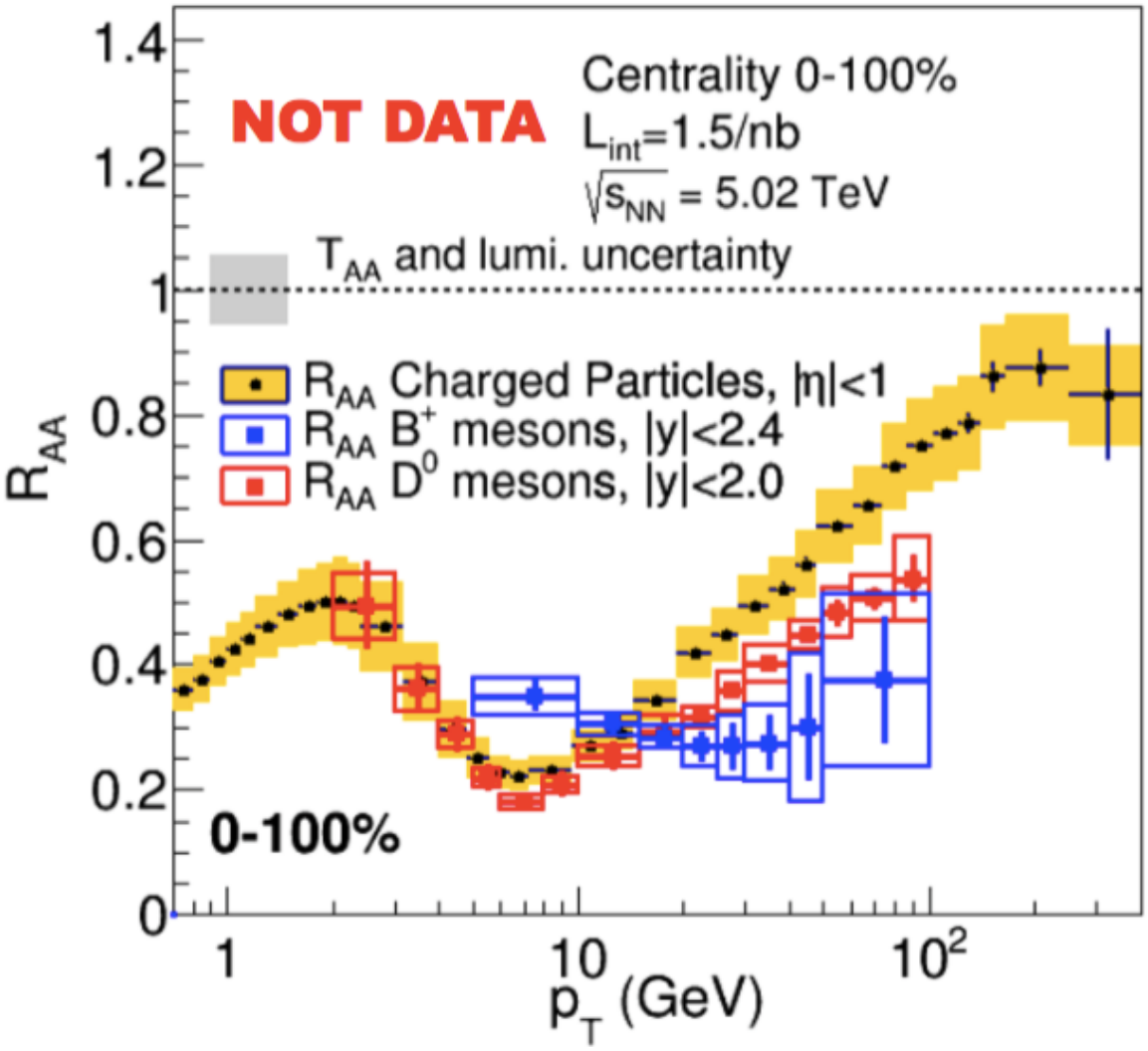


ALICE, JHEP 1511 (2015) 205
CMS, PAS-HIN-12-014



Limited to high p_T (~10 GeV) and large uncertainties in centrality dependence

Heavy flavour R_{AA}: CMS Run-2 projection



L_{int}=1.5/nb (Pb-Pb 2018)

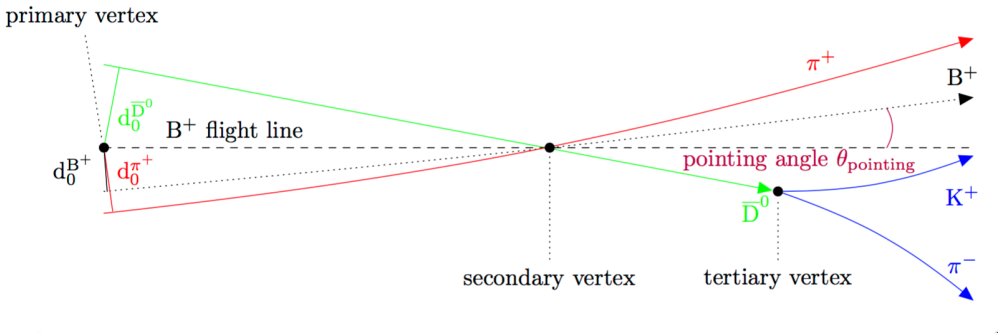
D: p_T>2 GeV, stat ~15%
B: p_T>5 GeV, stat ~10%

shown last week by Y.-J. Lee

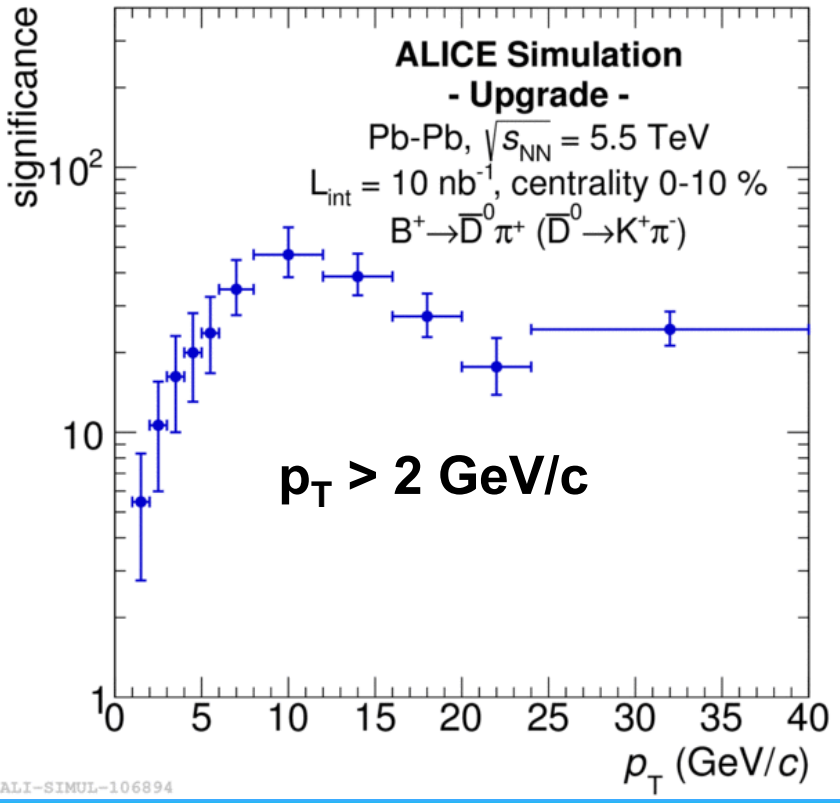
Beauty with ALICE Upgrade: recent studies

- New studies on B reconstruction using exclusive decays:

$$B^+ \rightarrow D^0(\rightarrow K\pi)\pi^+$$



Significance = 1/(relative stat. error)

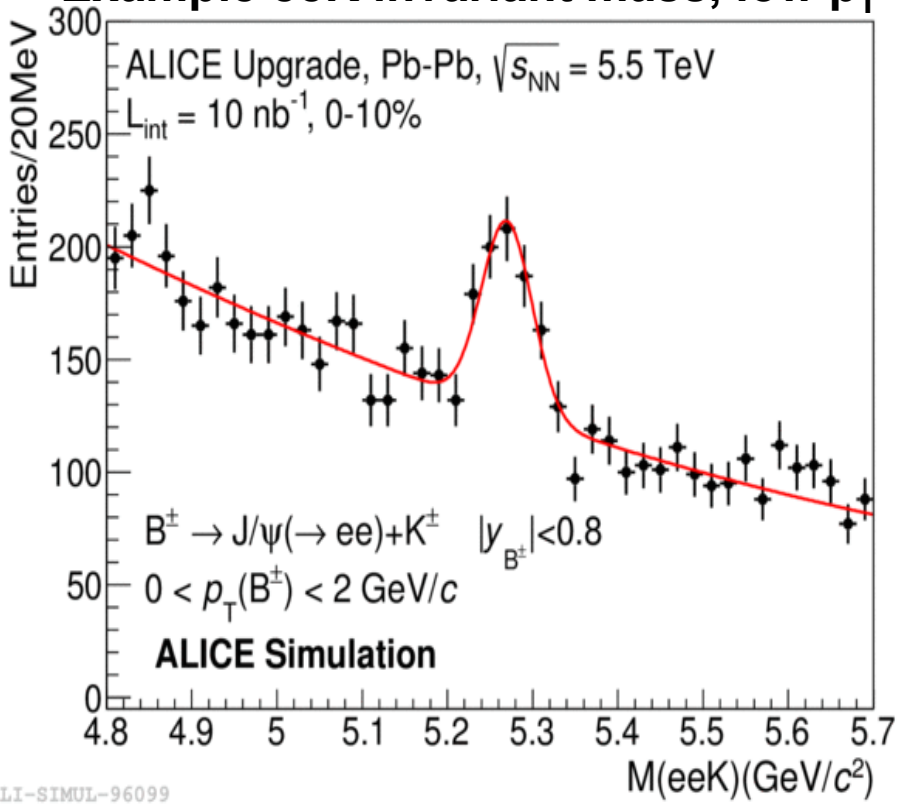


Beauty with ALICE Upgrade: recent studies

- New studies on B reconstruction using exclusive decays:

$B^+ \rightarrow J/\psi(\rightarrow ee)K^+$

Example eeK invariant mass, low p_T



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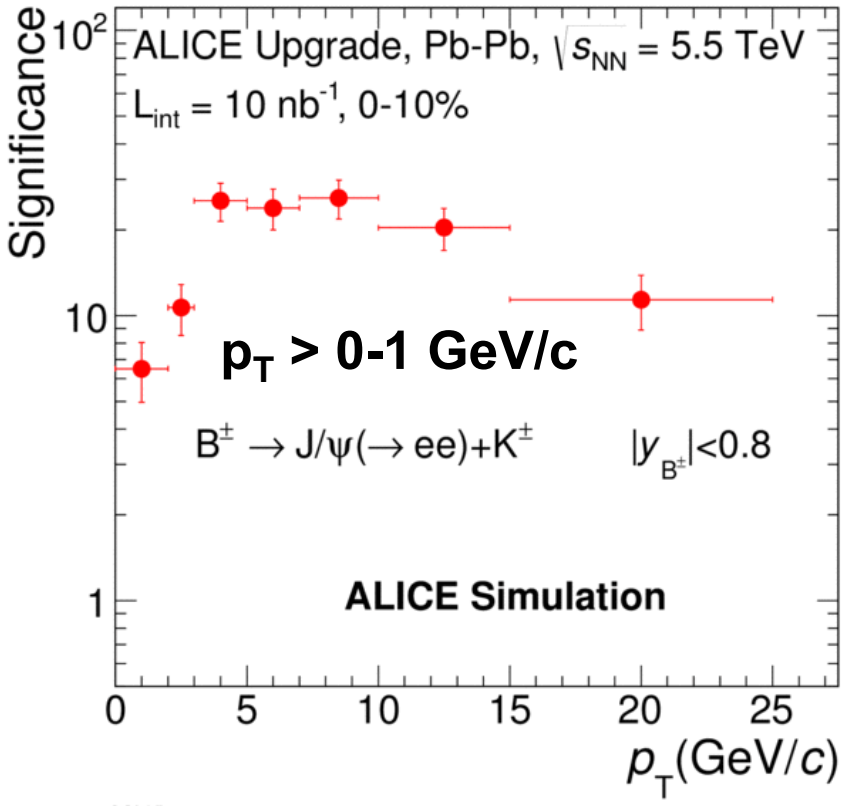
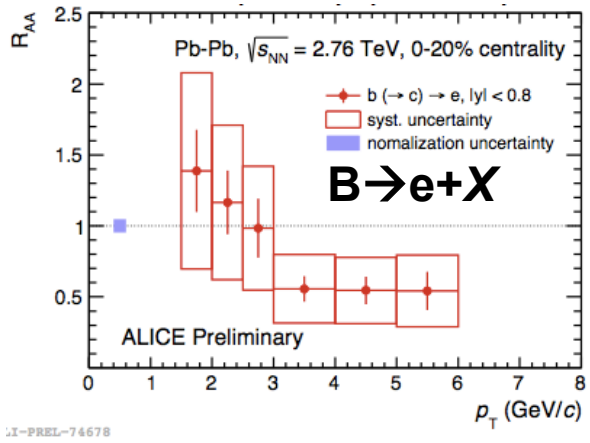
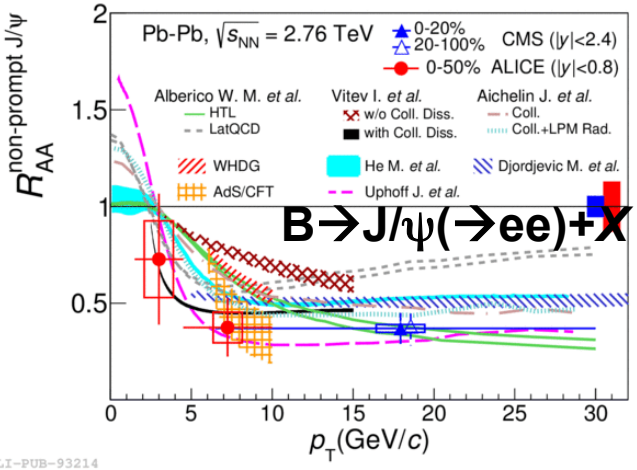


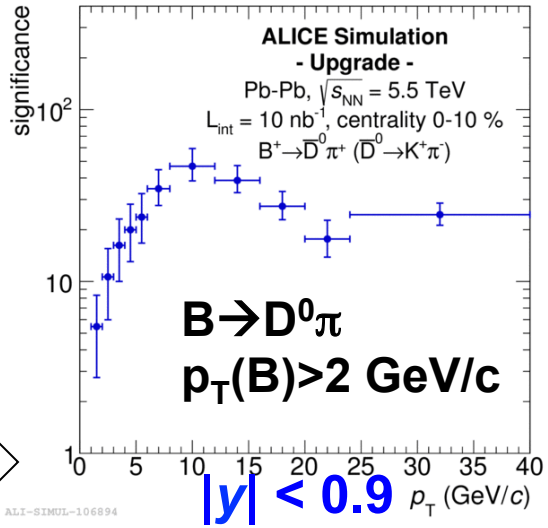
Beauty with ALICE Upgrade: summary

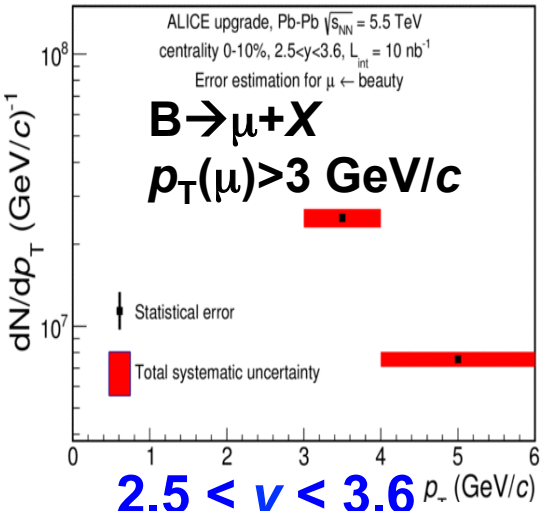


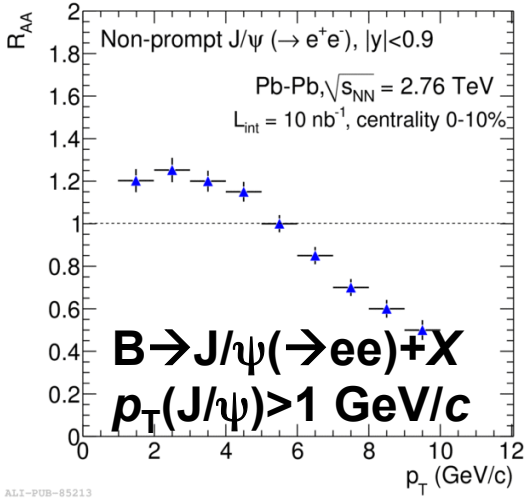
Run-1

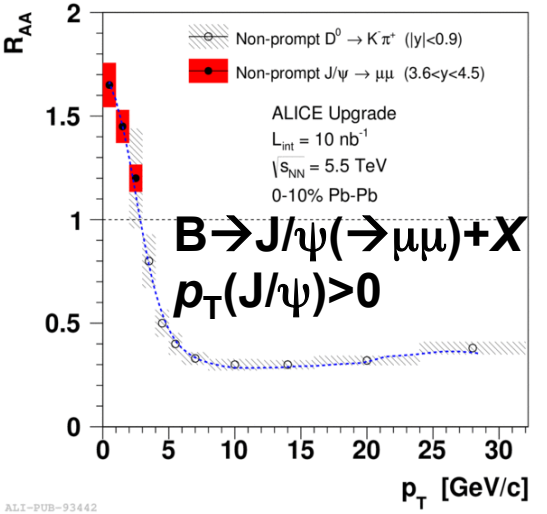


ALICE, arXiv:1504.07151





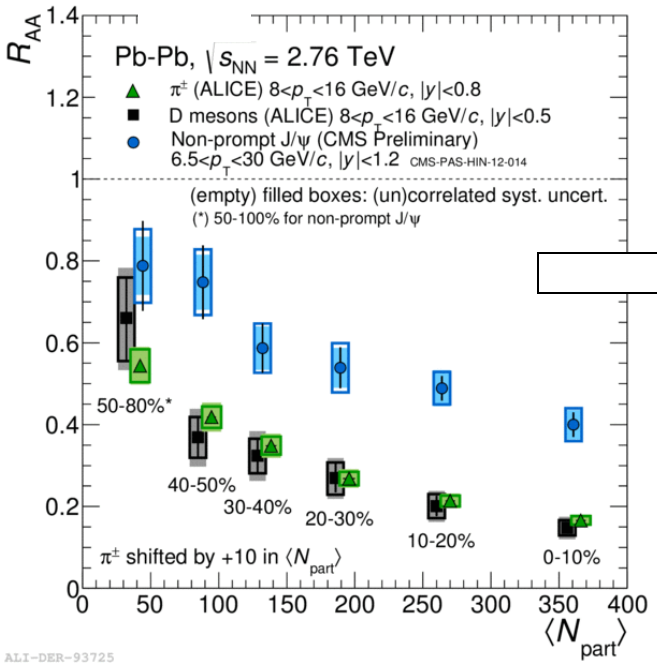




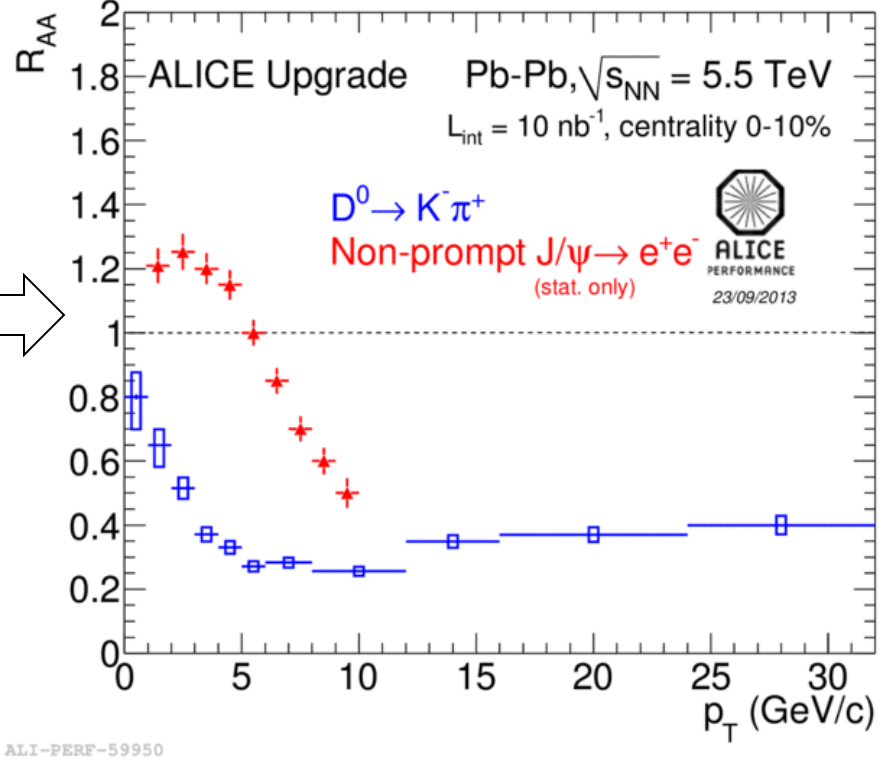
ALICE, CERN-LHCC-2013-024, CERN-LHCC-2015-001

Heavy flavour R_{AA}: ALICE Upgrade

Present data: Charm and beauty R_{AA} at p_T~10 GeV



Upgrade: Charm and beauty R_{AA} down to p_T~0 using D^0 and B-decay J/ψ

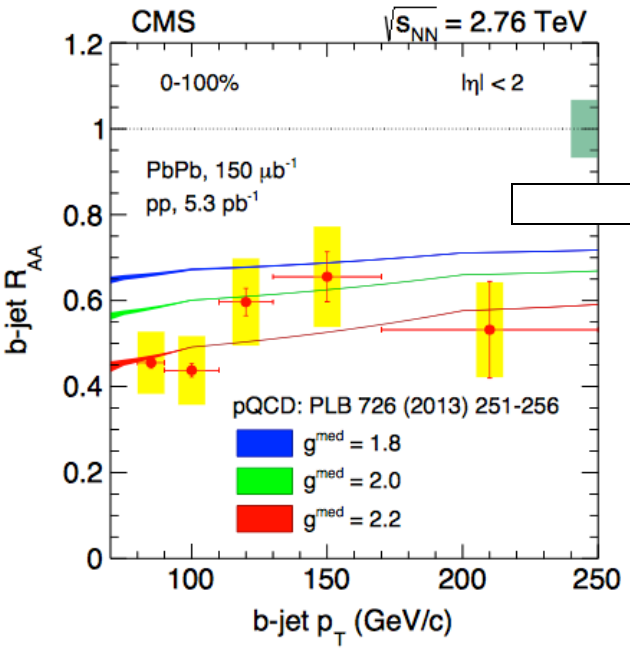


ALICE, CERN-LHCC-2013-024

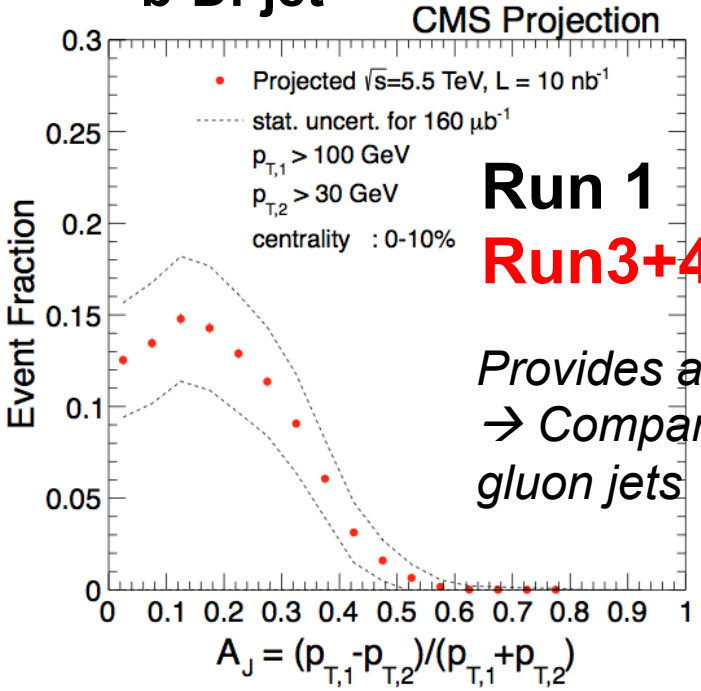
b-tagged jets: CMS performance

- First measurement of b-jet R_{AA} in heavy ion collisions (0.15/nb)
- CMS projections for 10/nb (Run3+Run4)
  - 140k b-jets with p_T > 120 GeV/c
  - High-precision measurement of $b\bar{b}$ Di-jet momentum imbalance

b-jet RAA Run-1:



b-Di-jet



Run 1

Run3+4

Provides a tag for quark jets
→ Compare A_J for quark and gluon jets

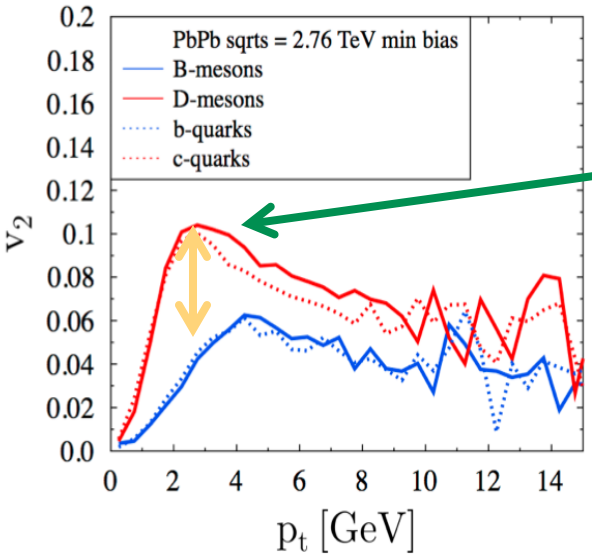
CMS, PRL 113 (2014) 13, 132301

CMS, PAS-FTR-13-025

Heavy Flavour Flow

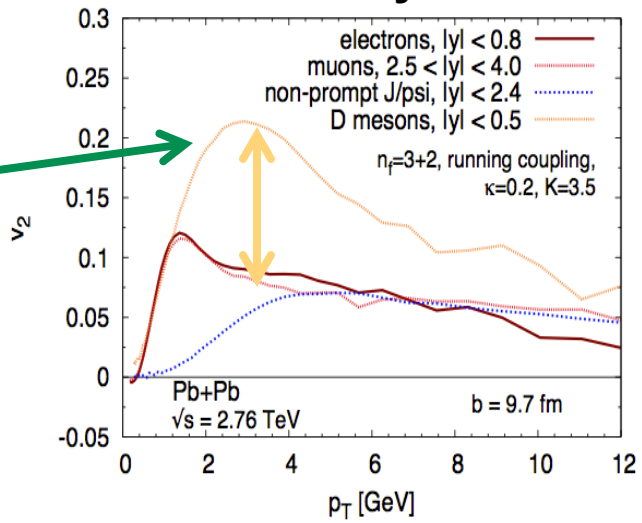
- Do HQs take part in the "collectivity"? → look for radial and elliptic flow
- Information on QGP transport coefficient, role of E loss mechanisms, and hadronization mechanisms
  - Due to their large mass, HQs need frequent interactions with large coupling to build flow (a clear expectation: $v_2^b < v_2^c$) ↔
  - Collisional energy loss gives larger v_2 than radiative ↔
  - Coalescence increases radial and elliptic flow at intermediate p_T ↔

Coll+Rad



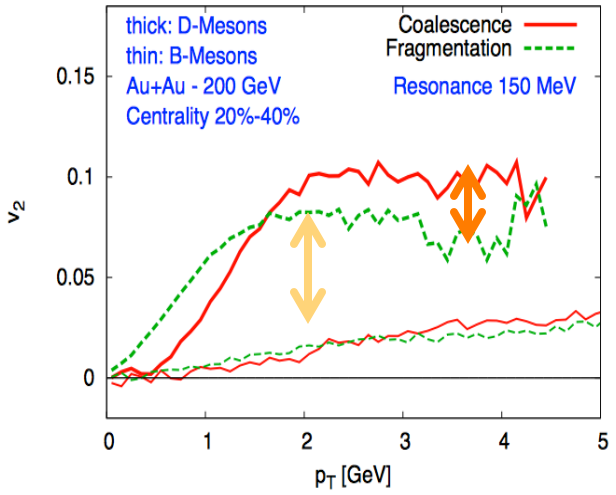
J. Aichelin et al., arXiv:1201.4192

Coll only



J. Uphoff et al., arXiv:1205.4945

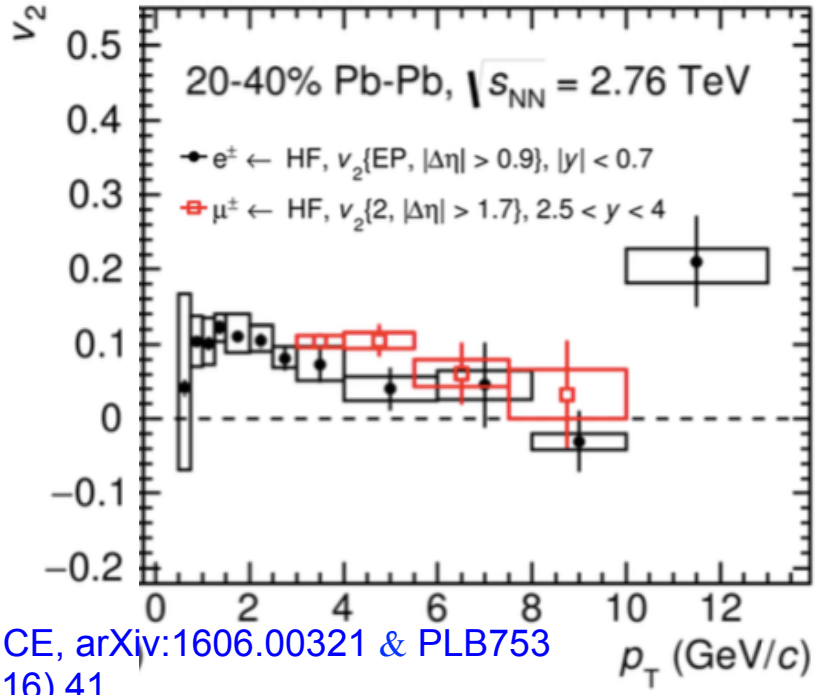
Coll (via resonance)



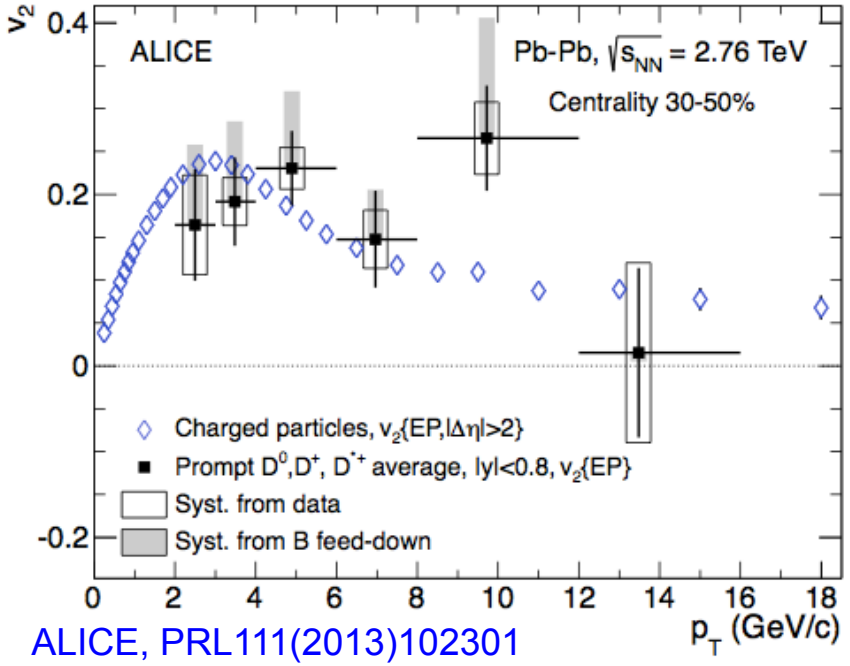
T. Lang et al., arXiv:1211.6912

Heavy flavour v_2: current status

- Charm hadrons have v_2>0, comparable to light hadrons
- HF-decay leptons (inclusive) also have v_2>0
- Heavy quark collective flow? Role of hadronization?



ALICE, arXiv:1606.00321 & PLB753 (2016) 41

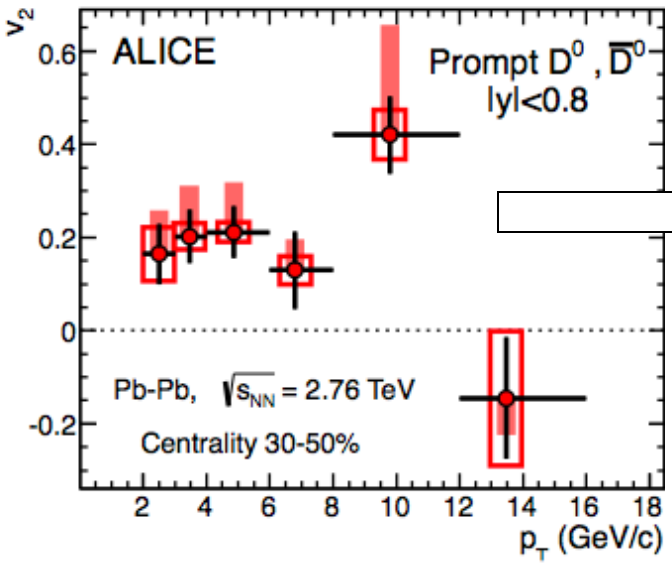


ALICE, PRL111(2013)102301

Still quite qualitative, sizeable uncertainties for charm and no separate measurement for beauty

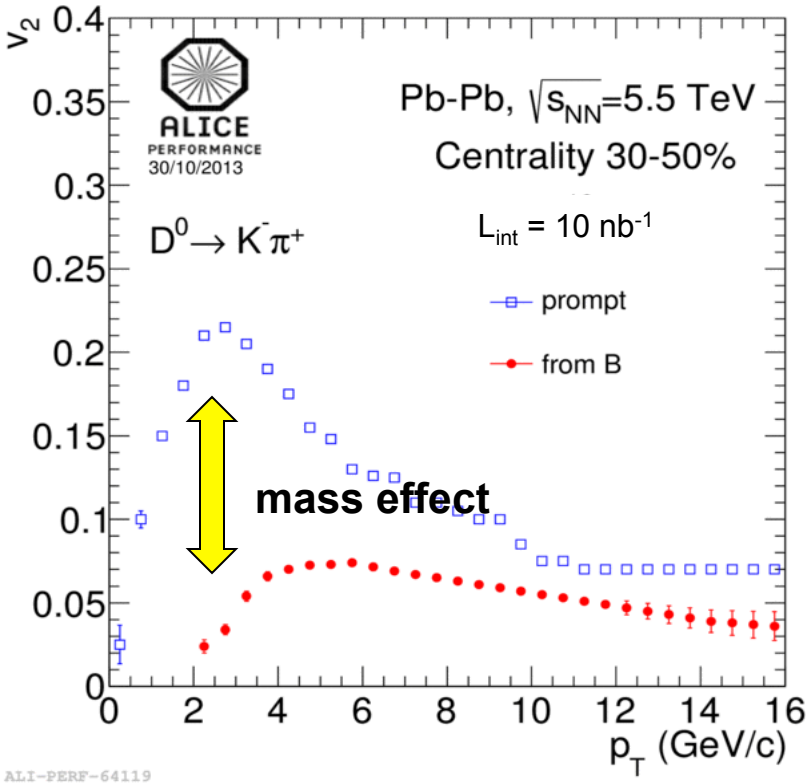
Heavy flavour v_2: ALICE Upgrade

Present data on charm v_2



ALICE, PRL 111 (2013) 102301

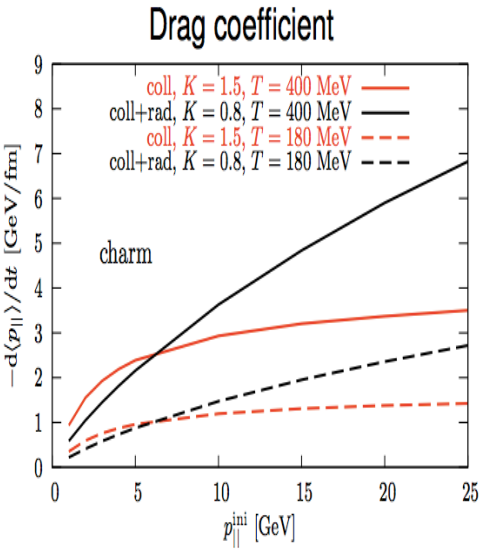
Upgrade: Charm and beauty v_2 down to p_T~0 using prompt and B-decay D^0

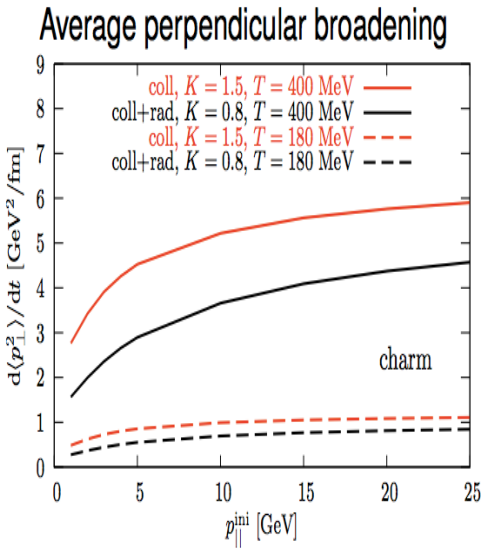


ALICE, CERN-LHCC-2013-024

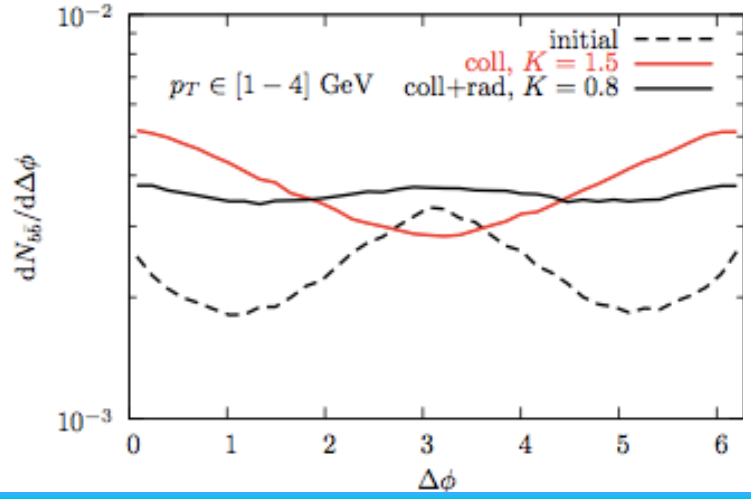
Input values from BAMPS model:
C. Greiner et al. arXiv:1205.4945

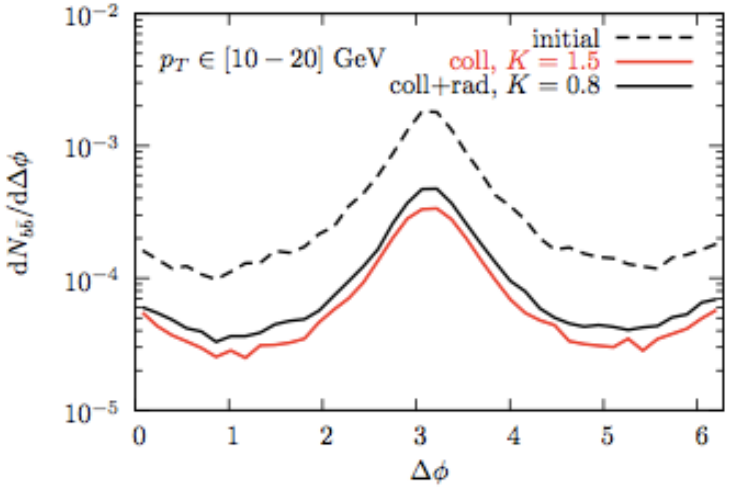
Assessing energy loss mechanisms with HF correlations





- Drag coeff (~ Energy loss):
  - Drives momentum loss (→R_{AA})
  - Sensitive to **radiative** at $p_{T,c}$>15 GeV
- Broadening:
  - Drives elliptic flow
  - Mostly given by collisional
- HQ correlations predicted to be sensitive, but only at low p_T

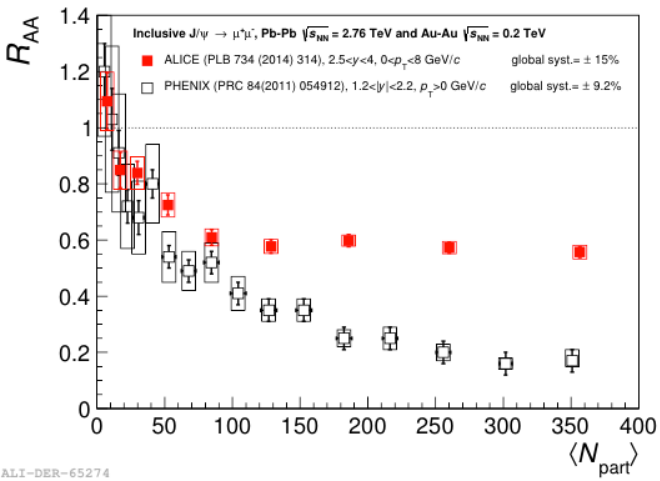




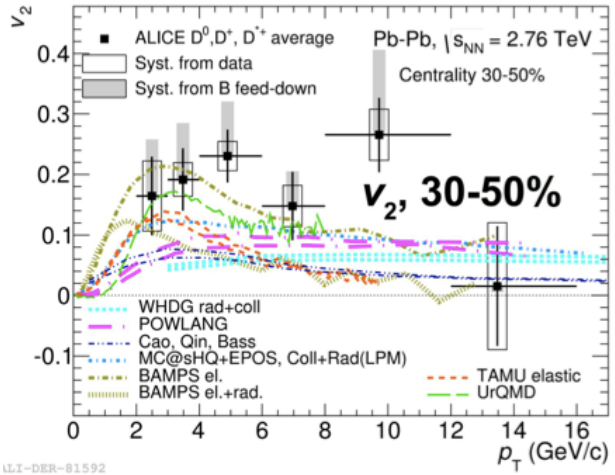
Nahrgang et al.

In-medium heavy flavour hadronization?

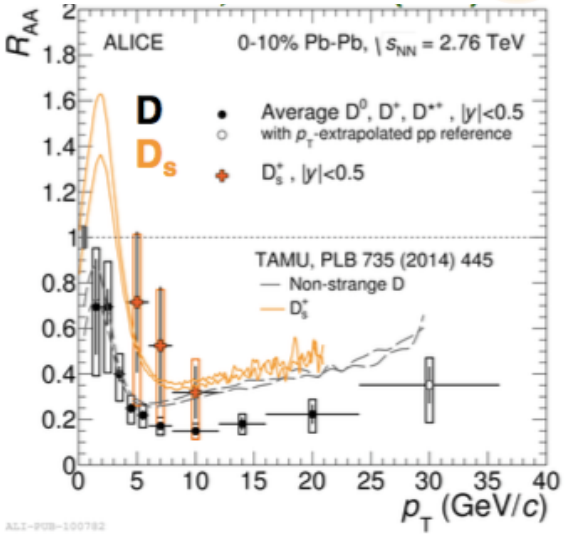
- From LHC Run-1 data, some indications that charm quarks could recombine in the QGP:
  - J/ψ R_{AA} (and v_2) at low p_T
  - D meson v_2 better described by models with recombination
  - D_s R_{AA} (central value) larger than D R_{AA}?



ALICE, PLB734 (2014) 314



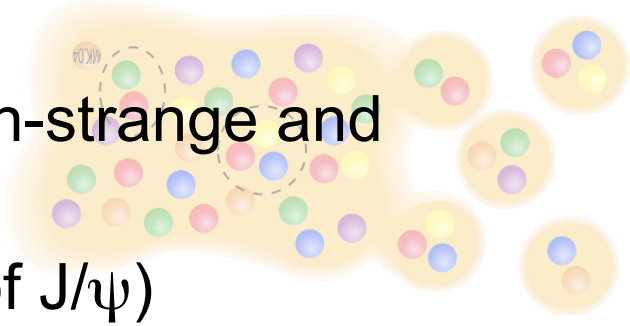
ALICE, PRC90 (2014) 034904



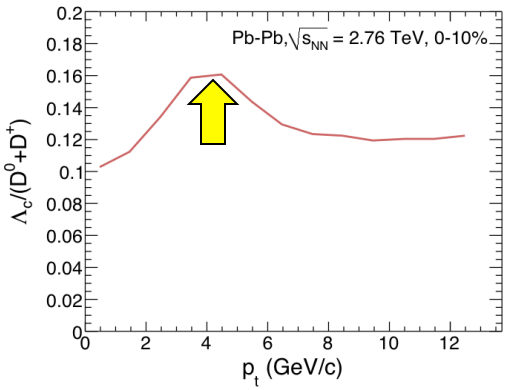
ALICE, JHEP1603 (2016) 082

In-medium heavy flavour hadronization?

- From LHC Run-1 data, some indications that charm quarks could recombine in the QGP:
- → Precise measurements of HF mesons (non-strange and strange) and baryons
- → Precise measurements of their v_2 (+ that of J/ψ)

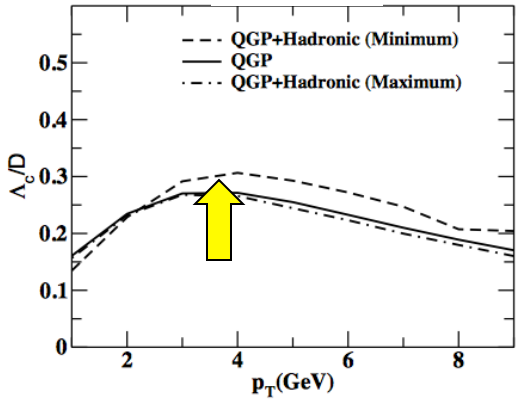


Λ_c/D



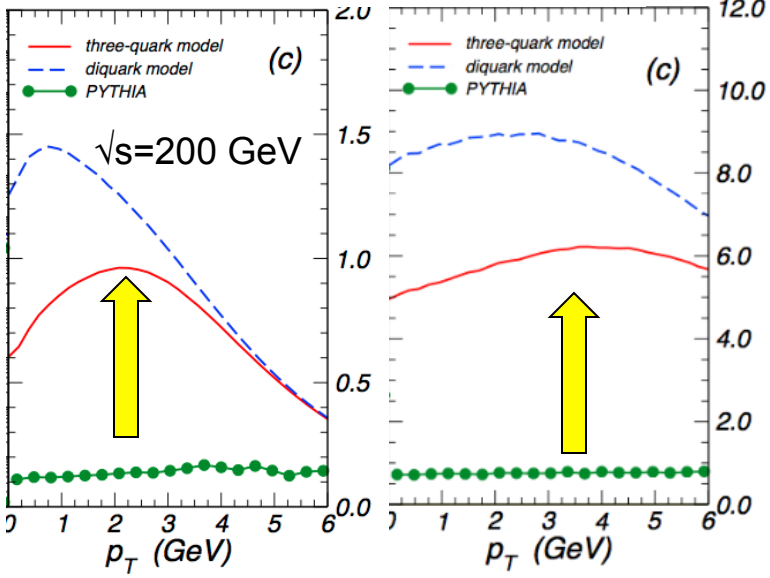
Rapp et al., based on PRL110 (2013)

Λ_c/D



Greco et al. PRD90 (2014)

Λ_c/D and Λ_b/B

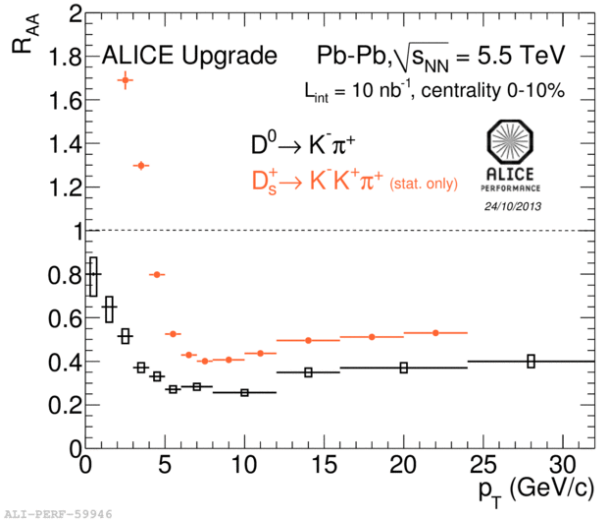


Ko et al. PRC79 (2008)

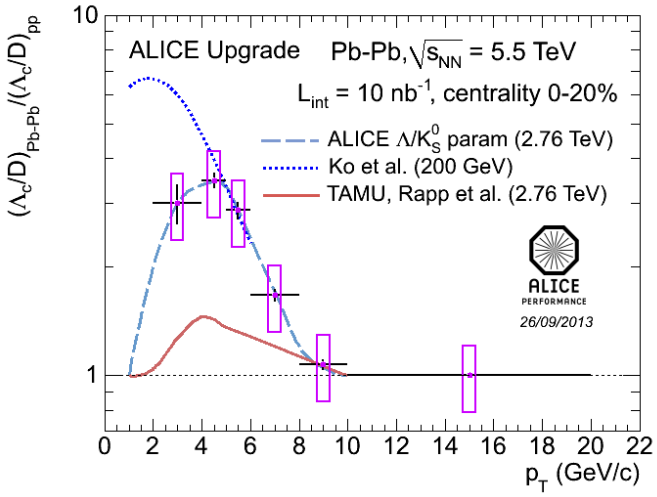
HF "hadrochemistry" with ALICE Upgrade

- $\Lambda_c \rightarrow pK\pi$ and $D_s \rightarrow KK\pi$ ($c\tau$=60 and 150 μm) with good precision for p_T>2 GeV/c
- $\Lambda_b \rightarrow \Lambda_c\pi$ ($c\tau$=450 μm) accessible for p_T>7 GeV/c

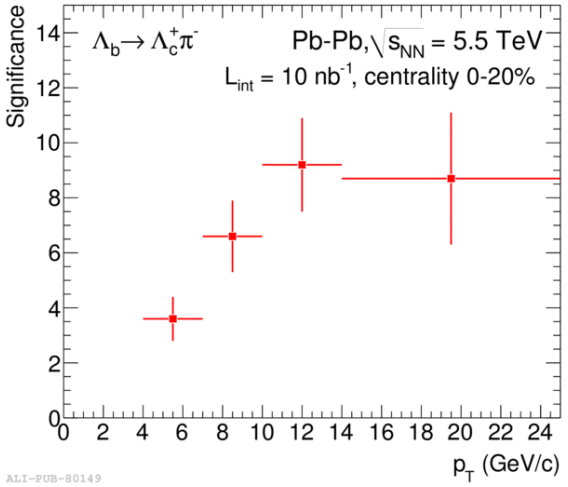
D^0 and D_s R_{AA}



Λ_c/D "enhancement"



Λ_b significance



ALICE, CERN-LHCC-2013-024

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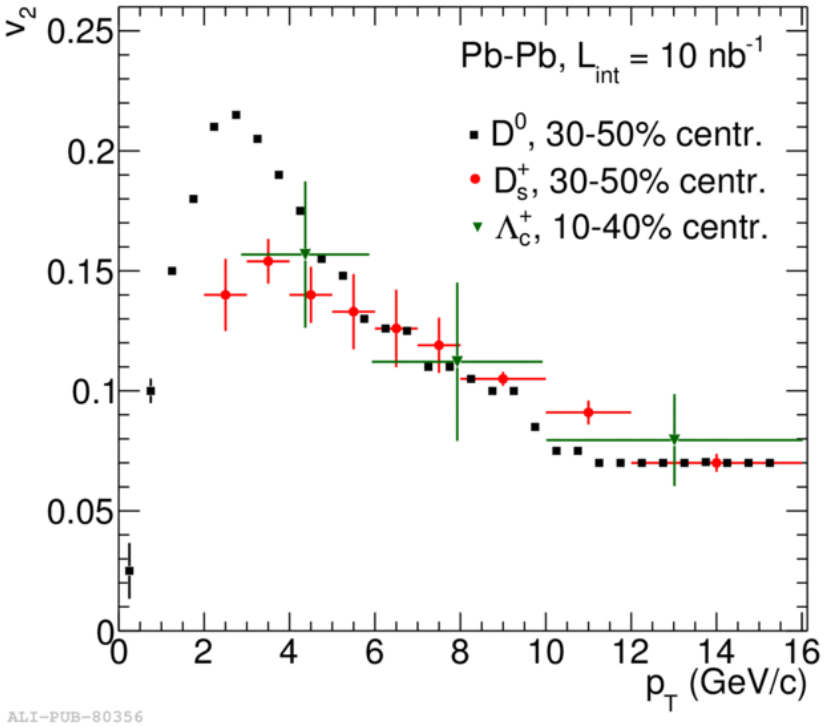
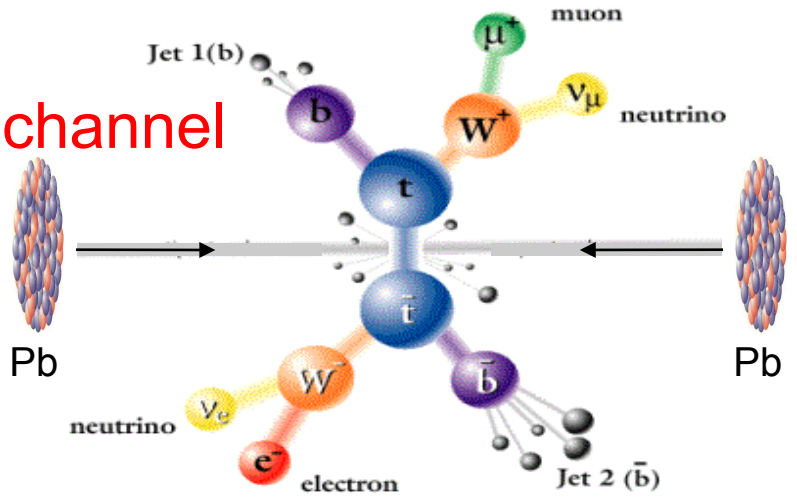
D^0, D_s, Λ_c v_2



ALICE, CERN-LHCC-2013-024

… and the heaviest of all: top in Pb-Pb

- $t\bar{t}$ decay channels:
  - 10% $b\bar{b} + \ell\ell + \not{E}_T$ observation channel
  - 44% $b\bar{b} + \ell + 2\,jets + \not{E}_T$
  - 46% $b\bar{b} + 4\,jets$



- Estimate for observation channel in CMS (CMS PAS-FTR-2013-025)
- → **~500 events for 10 nb^{-1} Pb-Pb 5.5 TeV**

- → Most top quarks decay before the QGP formation (the b quarks will cross the medium and broaden/shift the reconstructed top mass)
- → But boosted top quarks decay in the QGP, which brings me to the FCC part of the talk

Outline

Part I:

- Future HI programme at LHC
- Detector upgrades
- Projected performance for HF measurements

Part II:

- Introduction to the FCC Study
- Example of novel QGP observables at FCC: thermal charm and boosted tops

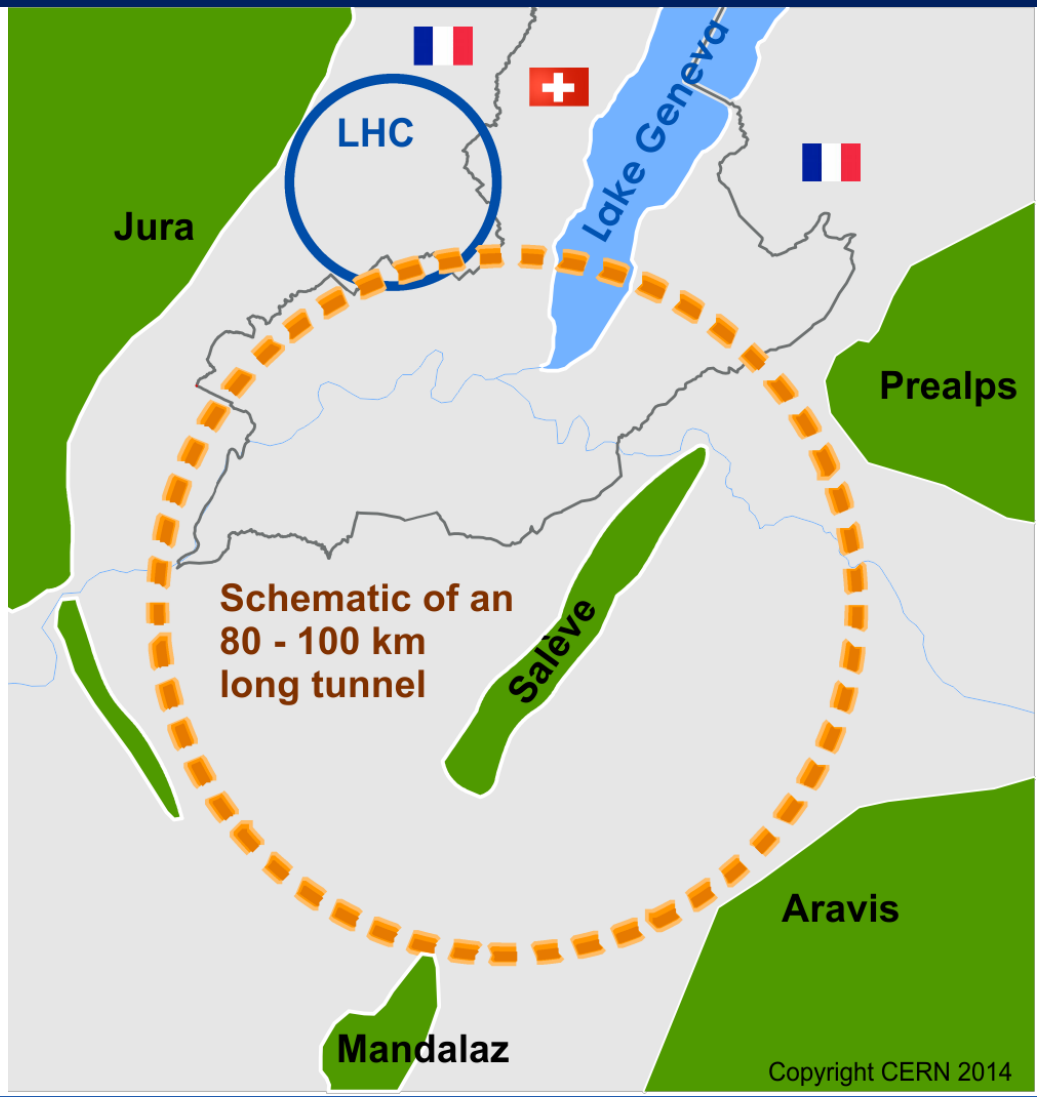
Future Circular Collider Study - SCOPE
CDR and cost review for the next ESU (2018)

Forming an international collaboration to study:

- ***pp*-collider (*FCC-hh*)**
  → defining infrastructure requirements

~16 T ⇒ 100 TeV *pp* in 100 km
~20 T ⇒ 100 TeV *pp* in 80 km

- ***e*⁺*e*⁻ collider (*FCC-ee*)** as potential intermediate step
- ***p-e* (*FCC-he*) option**
- **80-100 km infrastructure** in Geneva area



HI Organization and Report 2016

- Ions at FCC-hh Working Group:
  - Coord: A.D., S. Masciocchi, C. Salgado, U. Wiedemann
  - Sub-group of “FCC-h Physics, Experiments, Detectors”
  - Participation of CERN Beams dep. (J. Jowett, M. Schaumann)
  - Contact with HI theory group of CEPC-SppC
  - Twiki https://twiki.cern.ch/twiki/bin/view/LHCPhysics/HeavyIons
- 6 workshops/meetings 2013-15
  - https://indico.cern.ch/event/331669/ and links therein
- “Report2016” is online: **arXiv:1605.01389**
  - 40 pages, about 50 authors
  - Section editors: N. Armesto, A. Dainese, D. d’Enterria, J. Jowett, J.P.Lansberg, G. Milhano, C. Salgado, M. Schaumann, M. van Leeuwen, U. Wiedemann

Energy and luminosity

- Centre-of-mass energy per nucleon-nucleon collision:

$$\sqrt{s_{NN}} = \sqrt{\frac{Z_1 Z_2}{A_1 A_2}}\sqrt{s_{pp}} \quad \Rightarrow \quad \sqrt{s_{PbPb}} = 39\ TeV \quad \sqrt{s_{pPb}} = 63\ TeV \quad \text{for} \quad \sqrt{s_{pp}} = 100\ TeV$$

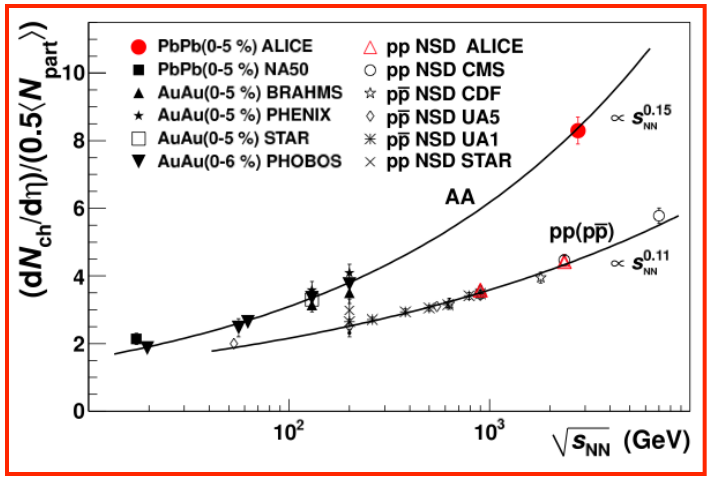
- Projected L_{int} /month: 33/nb for Pb-Pb and 8/pb for p-Pb
  - e.g. in three 1-month Pb-Pb runs: 100/nb ~ 10x full LHC programme

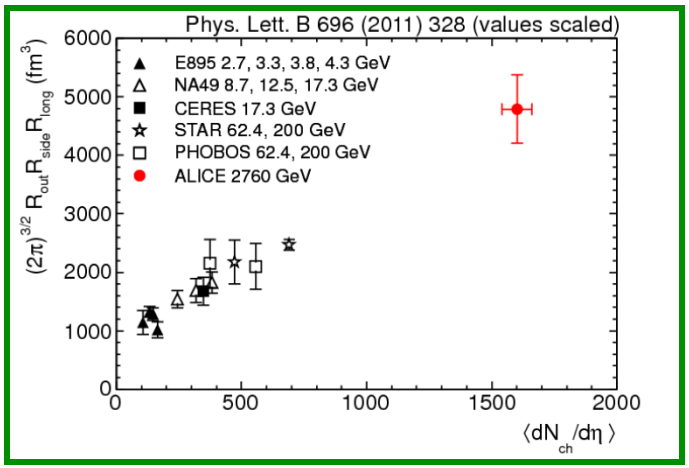
M.Schaumann, J.Jowett, in arXiv:1605.01389

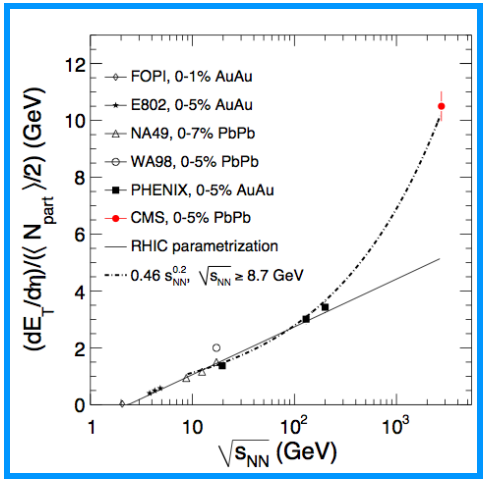
QGP "fireball": global properties

- Extrapolation to 39 TeV: increase wrt LHC 5.5 TeV

$dN_{ch}/d\eta$ x 1.8 **Volume x1.8** **$dE_T/d\eta$ (& ε) 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 $\eta = 0$	1.8–2.0 TeV	2.3–2.6 TeV	5.2–5.8 TeV
Homogeneity volume	5000 fm^3	6200 fm^3	11000 fm^3
Decoupling time	10 fm/c	11 fm/c	13 fm/c
ε at $\tau = 1$ fm/c	12–13 GeV/fm^3	16–17 GeV/fm^3	35–40 GeV/fm^3

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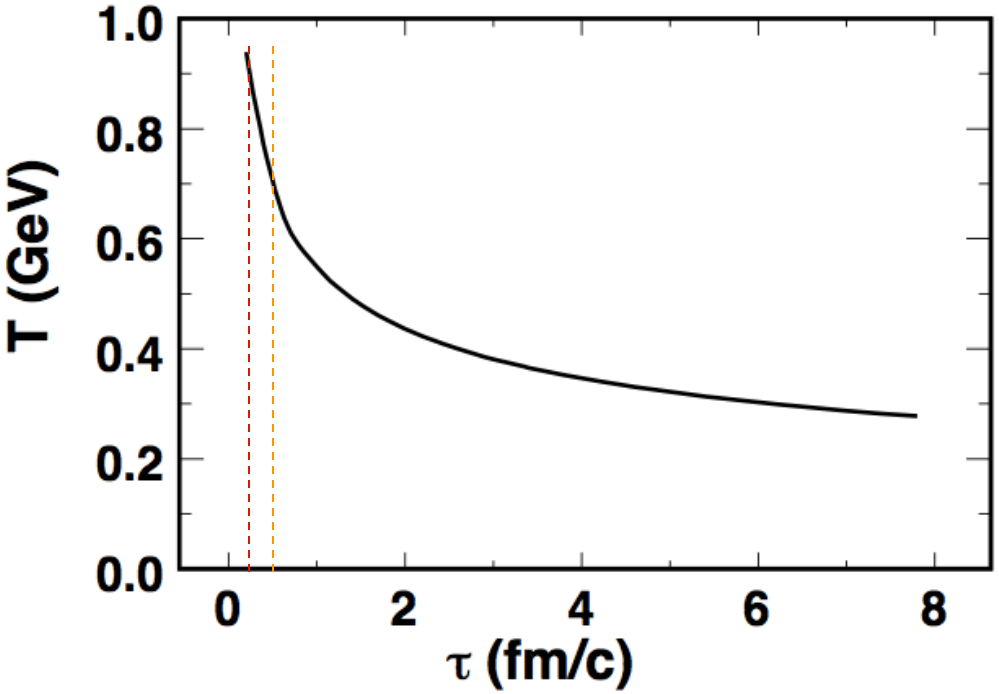
Higher QGP temperature

- Larger c.m.s. energy → larger fireball temperature
- From hydrodynamic simulation:



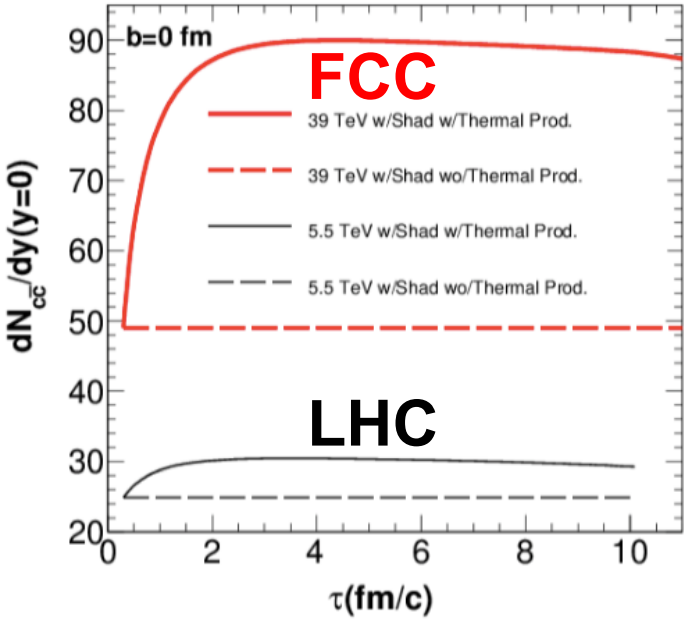
- 900 MeV at τ = 0.2 fm/c
- 650 MeV at τ = 0.5 fm/c

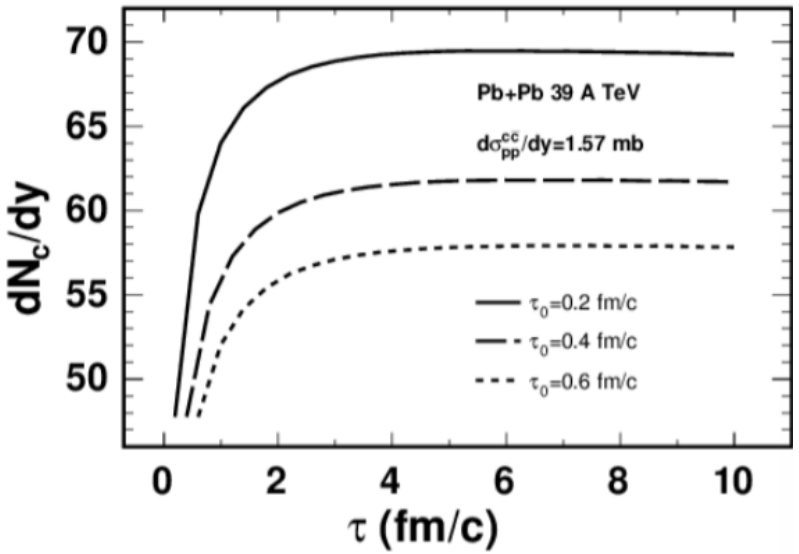
Note that a QGP with temperature T ~ 1 GeV has energy density ε ~ 2 TeV/fm^3 !

C.M. Ko, Y. Liu, arXiv:1604.01207

Large "thermal" charm production?

- Expect abundant secondary production of $c\bar{c}$ pairs in the medium from $gg \rightarrow c\bar{c}$, $q\bar{q} \rightarrow c\bar{c}$ + NLO …





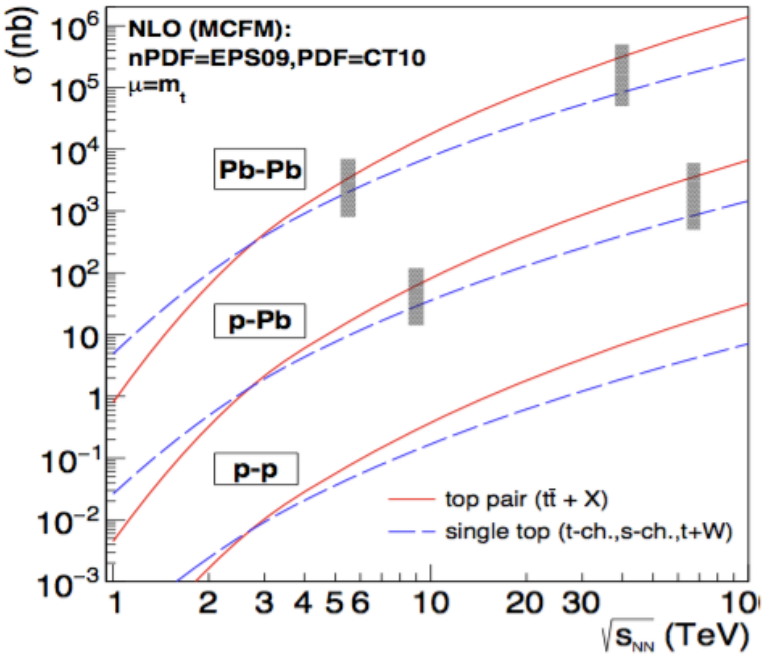
- Up to 50-100% "enhancement" wrt primary charm
- Should be visible above (shadowing-corrected) binary scaling
- Sensitive to QGP properties: T vs τ, and τ_0

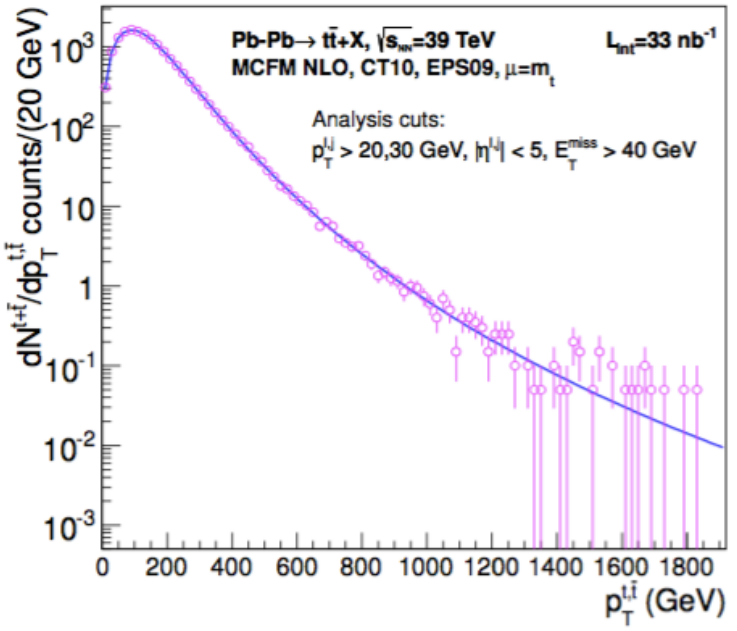
K. Zhou et al., arXiv:1602.01667

C.M. Ko, Y. Liu, arXiv:1604.01207

Top production at FCC energy

- The increased energy and luminosity at FCC would make of t-tbar events a very abundant probe



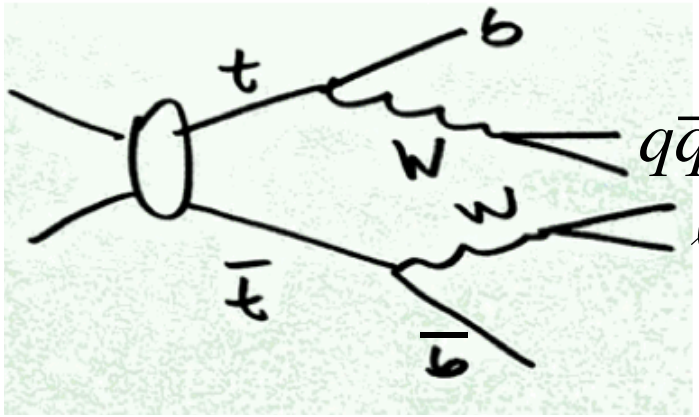


- Top cross section increases by x80 from 5.5 TeV to 39 TeV
- Kinematic simulation study: 3x10^5 $t\bar{t} \to b\bar{b}\,\ell\ell\,\nu\nu$ per run (33/nb)
- Top p_T distribution up to ~1.2 TeV/c

D. d'Enterria, et al. Phys. Lett. B746 (2015) 64–72, arXiv:1501.05879 [hep-ph]

An interesting physics case for top: boosted color singlets in the QGP

- Boosted (i.e. high p_T) top events: $t\bar{t} \rightarrow b\bar{b} + q\bar{q} + \ell + \nu$



This $q\bar{q}$ is produced as a color singlet and it "sees" the QGP with a time delay given by the boost of the t and of the W

The rest of the final state

$$2\ b-jets + \ell + \not{E}_T$$

is used to tag the event topology

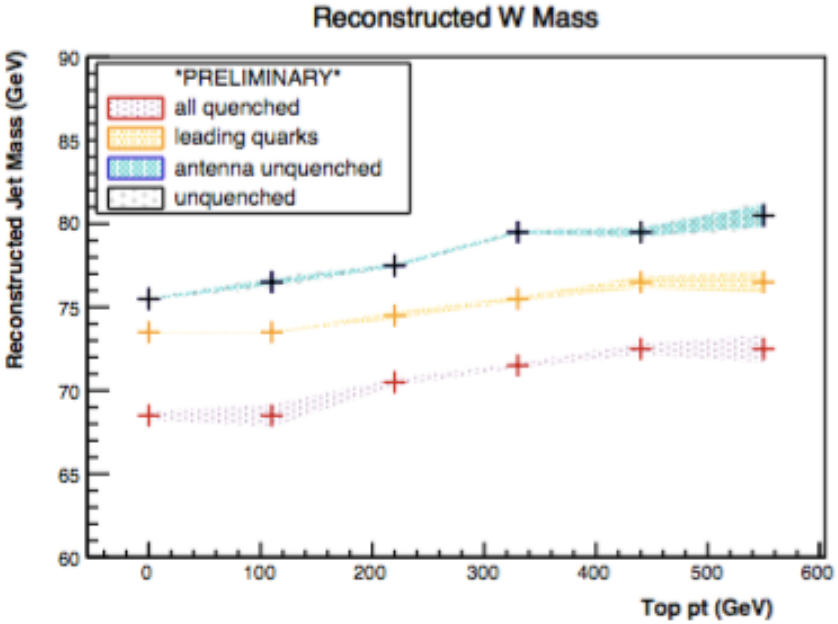
- Boosted-top events can therefore be used to address two novel studies in the sector of parton energy loss:
  1. Time-evolution of QGP opacity, because of the boost
  2. Role of color coherence in parton energy loss, because the pair is initially a color singlet

Will be discussed tomorrow by L.Apolinario

An interesting physics case for top: boosted color singlets in the QGP

- Energy loss of the $q\bar{q}$ pair results in a shift of the W mass reconstructed from the $q\bar{q}$ jet(s)
- Observables:
  1. The shift of the W mass discriminates scenarios on the role of color coherence (small shift in case coherence plays a role)
  2. The shift vs top p_T probes the time-evolution of the QGP density

Kinematic simulation study with Pb-Pb 39 TeV (100/nb)

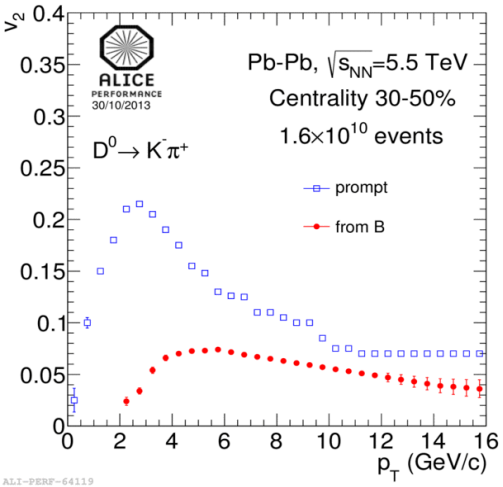


More on this and updated results tomorrow by L.Apolinario

Apolinario, Milhano, Salam, Salgado, in arXiv:1605.01389

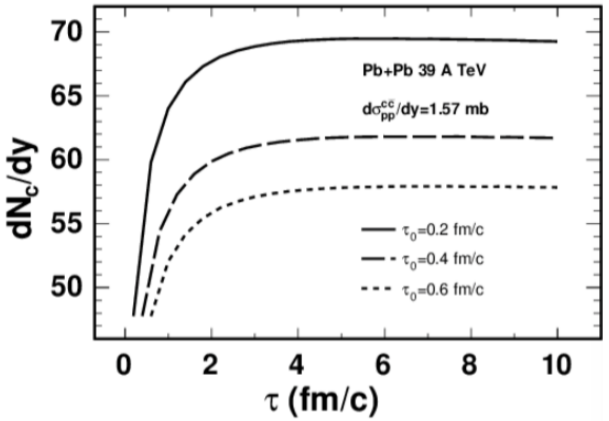
Summary

LHC 2020s: precision in HF sector!

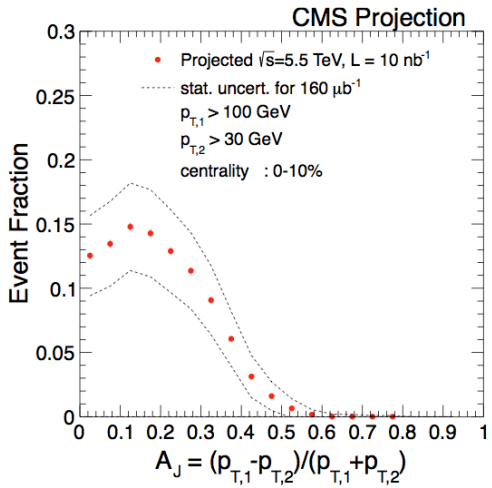


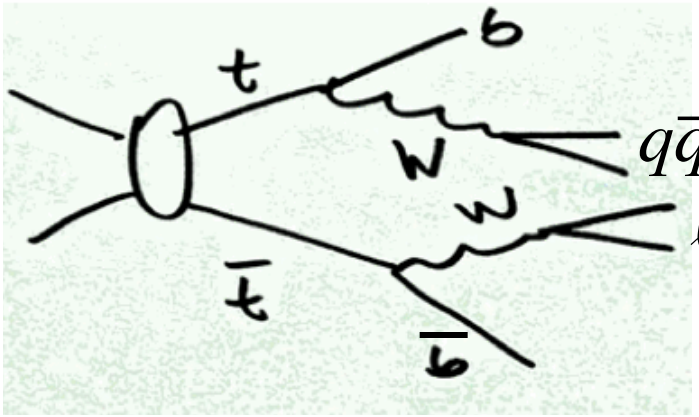
FCC 2040s (?): novel opportunities with HF!

from very low p_T



… to very high p_T





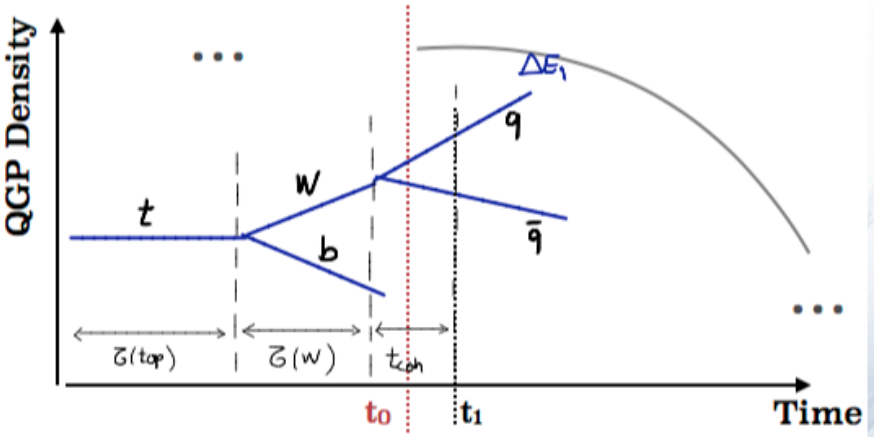
EXTRA SLIDES

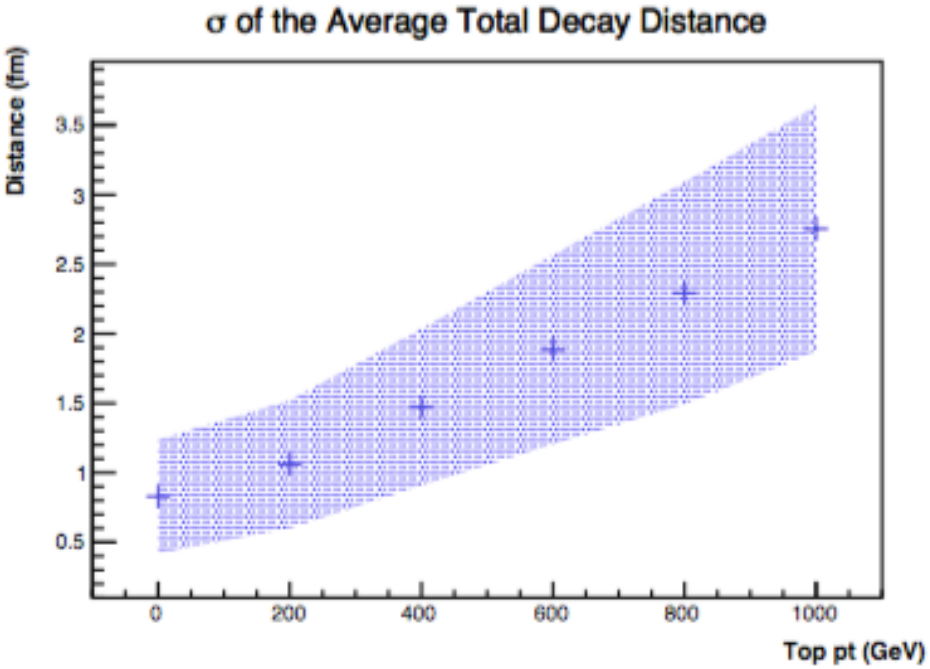
Available Documents

- ALICE Upgrade LOI: CERN-LHCC-2012-012
  - Addendum (Muon Forward Tracker): CERN-LHCC-2013-014
- ALICE inner tracker upgrade TDR: CERN-LHCC-2013-024
- CMS HI HL-LHC projections: CMS-PAS-FTR-13-025
- Presentations at the Heavy Ion Town Meeting (June 2012):
  - http://indico.cern.ch/event/HItownmeeting
- Inputs by ALICE, ATLAS, CMS to the ESPG meeting Cracow (Sep 2012)
  - http://indico.cern.ch/confId=182232
  - HI community presentation (H. Appelshaeueser) http://indico.cern.ch/getFile.py/access?contribId=16&sessionId=2&resId=0&materialId=slides&confId=182232

An interesting physics case for top: boosted color singlets in the QGP

1) Testing the time evolution of the QGP density

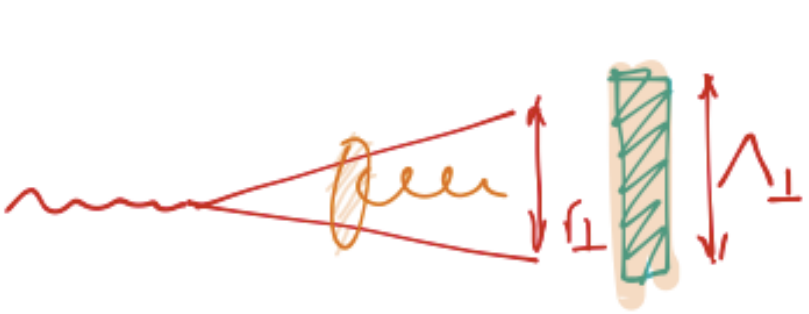




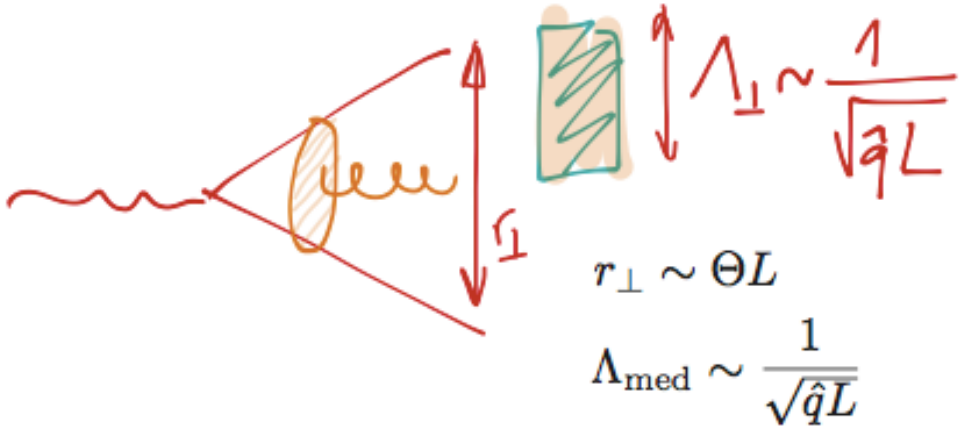
Estimate of the "start time" of energy loss: reaches 2-3 fm/c for top p_T~0.5-1 TeV/c

An interesting physics case for top: boosted color singlets in the QGP

2) Testing the role of color coherence



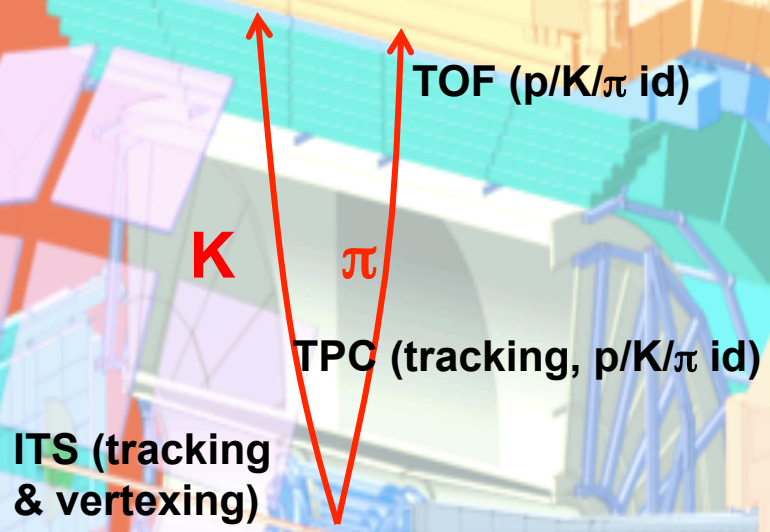
q-qbar with small opening angle; seen as color-singlet by the medium, **no interaction expected**



Medium induces decoherence, opening angle increases → **energy loss of color-octet's in the medium**

Armesto, Casalderrey, Iancu, Ma, Mehtar-Tani, Salgado, Tywoniuk 2010-2014

Heavy flavour: requirements



Currently, in Pb-Pb:

$D^0 \rightarrow K\pi$

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

$D^* \rightarrow D^0\pi$

$D_s \rightarrow KK\pi$

Goals for upgrade:

$B \rightarrow D^0+X$

$B \rightarrow J/\psi+X$

$B \rightarrow D^0\pi$

$B \rightarrow e/\mu +X$

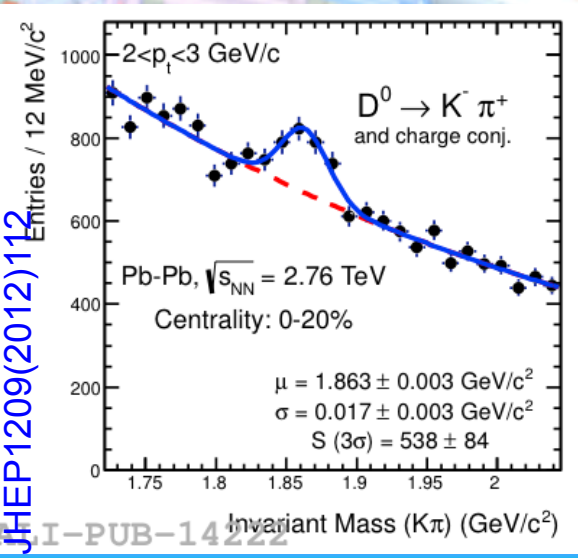
$\Lambda_c \rightarrow pK\pi$

$\Lambda_b \rightarrow \Lambda_c\pi$

General features:

Decay at few 100 μm from interaction point

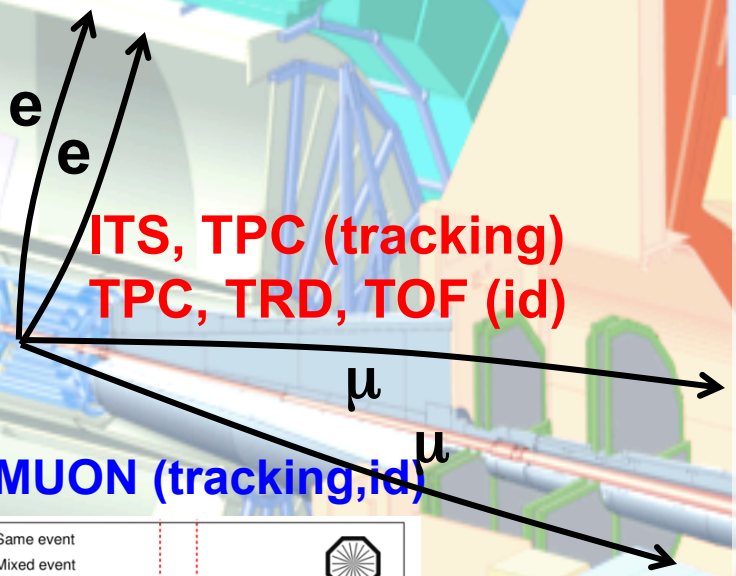
Large combinatorial background → low signal/background → no dedicated trigger



Requirements:

- **Vertexing resolution**
- **Preserve particle identification**
- **Large statistics (no dedicated trigger)**

Charmonium: requirements

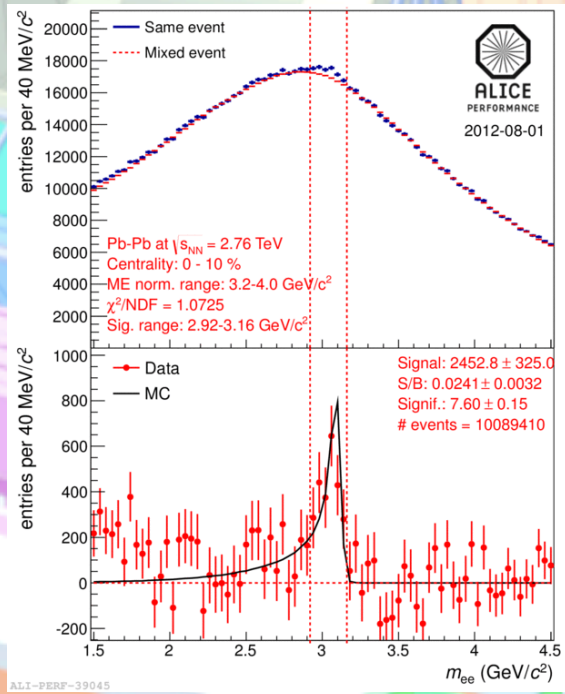


Currently, in Pb-Pb:
Incl. J/ψ → μμ
Incl. J/ψ → ee
ψ' → μμ
Goals for upgrade:
ψ' → ee
Direct J/ψ
B → J/ψ+X

General features:

B decay few 100 μm from interaction point

Large combinatorial background in ee channel → low signal/background → no dedicated trigger



Requirements:

- **Vertexing resolution**
- **Preserve particle identification**
- **Large statistics (no dedicated trigger)**