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Prospects for heavy-flavour measurements in Pb–Pb collisions at the LHC with the new ALICE inner tracker

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ALICE



Outline

Introduction

The ALICE upgrade

Simulation studies

- Heavy-flavour mesons

- Hadronization of heavy quarks

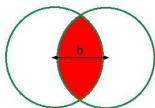
Conclusions

Heavy flavours as probes of the QGP

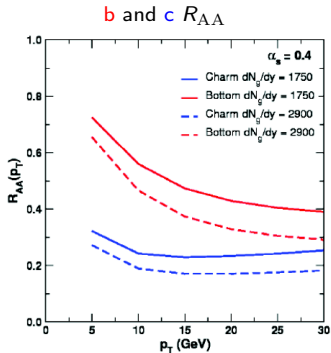
- ▶ Heavy quarks (= **charm and beauty**, in this talk) are mainly produced in the first hard scattering processes
- ▶ They interact with the medium and bring to the final state information on the deconfined phase
- ▶ The nuclear modification factor probes the **in-medium energy loss**
 $(\langle T_{AA} \rangle \propto N_{\text{coll}} / \sigma_{NN}^{\text{inel}})$

$$R_{AA} = \frac{dN^{\text{Pb-Pb}}/dp_T}{\langle T_{AA} \rangle \times d\sigma^{\text{pp}}/dp_T}$$

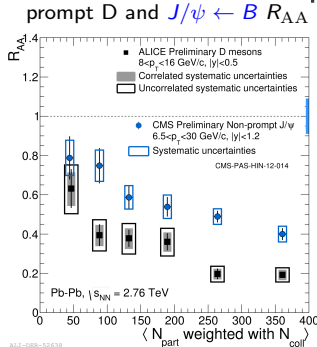
- ▶ **Collective behaviour** of the medium: in semi-central collisions study azimuthal anisotropy of particle production (e.g. elliptic flow – v_2)



Mass and colour charge dependence of energy loss



S.Wicks et al., Nucl.Phys. A783, 493 (2007)



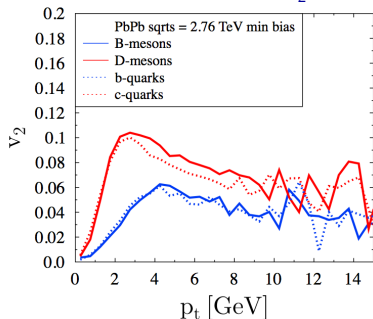
- ▶ Gluons and light quarks are expected to lose more energy wrt heavy quarks (mass and colour charge dependence)
- ▶ Expected hierarchy: $R_{AA}(B) > R_{AA}(D) > R_{AA}(\text{light hadrons})$

underbrace $R_{AA}(B)$ underbrace $R_{AA}(D)$ underbrace $R_{AA}(\text{light hadrons})$
beauty charm u, d, s

- ▶ Comparison with $J/\psi \leftarrow B$ from CMS limited at high p_{\perp}
- ▶ Hierarchy seems there, but rather large uncertainties

Collective behaviour of heavy quarks in the medium

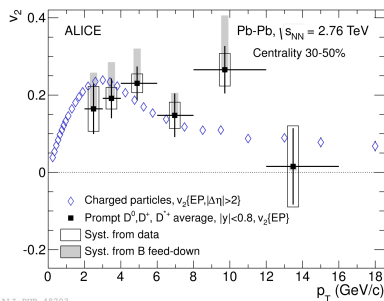
Prediction of B and D v_2



J. Aichelin et al., arXiv:1201.4192

- ▶ Coll. + rad. energy loss + QGP hydro expansion
- ▶ Limited precision, low- p_T reach at 2 GeV/c
- ▶ Does the heavier B meson flow?

D meson v_2 , semi-central collisions



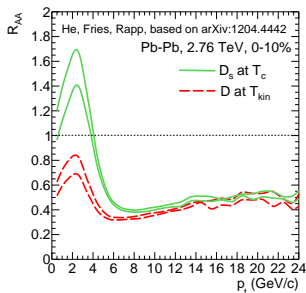
ALI-PUB-48703

ALICE Coll., arXiv:1305.2707

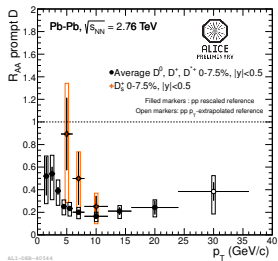
- ▶ Prompt D meson v_2 of the same magnitude as charged hadrons

Strangeness enhancement and heavy q hadronization

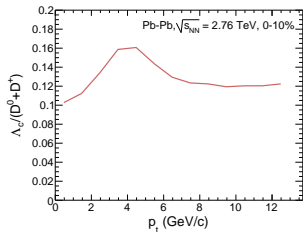
Prediction $R_{AA}(D_s)$



D_s R_{AA} in central collisions



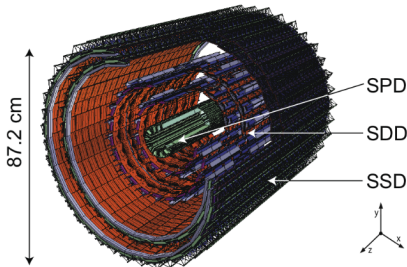
Prediction $\Lambda_c/(D^0 + D^+)$



- ▶ Hadronization via coalescence? D_s R_{AA} and baryon-over-meson ratio enhancement at low-intermediate p_T
- ▶ Hint of larger R_{AA} for D_s ?
- ▶ Λ_c signal extracted in pp collisions so far ($c\tau = 60 \mu\text{m}$)

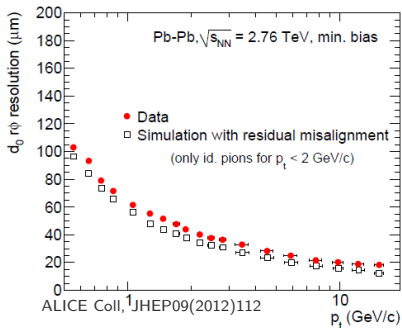
Current Inner Tracking System (ITS)

ALICE Inner Tracking System (ITS)



- ▶ Six layers with 3 technologies (pixels, drift, strips)
- ▶ Innermost layer at 3.9 cm from the beam axis

Impact parameter resolution

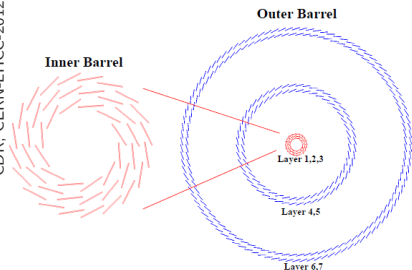


- ▶ $d_0(r\phi)$ resolution $\sim 60 \mu\text{m}$ at 1 GeV/c in Pb-Pb collisions

The ITS upgrade within the ALICE upgrade strategy

- ▶ **Better impact parameter resolution** to select heavy-flavour signals
 - ▶ Inner layer as close as 2.2 cm from the beam axis (7 layers in total)
 - ▶ Low material budget (e.g. 0.3% x/X_0 per layer with monolithic pixel technology)
- ▶ **Larger statistics**
 - ▶ Fast readout to cope with interaction rates of few 100 kHz for pp and 50 kHz for Pb–Pb collisions
 - ▶ New GEM based TPC readout which provide continuous readout
 - ▶ Integrated Online-Offline framework (O^2 project)

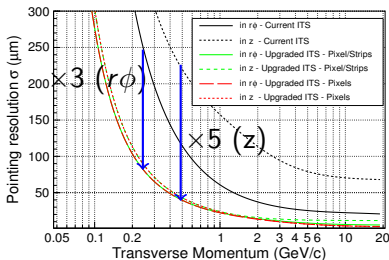
CDR, CERN-LHCC-2012-13 Lol, CERN-LHCC-2012-12



- ▶ Expected integrated luminosity: 10 nb^{-1} (corresponding to $\sim 8 \times 10^9$ events in 0-10% central) in Pb–Pb
- ▶ Upgrade foreseen for the LHC long shut down of 2017-18

Performance of the new ITS

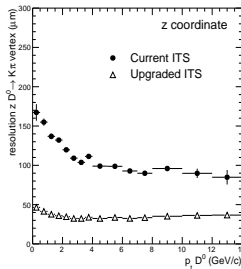
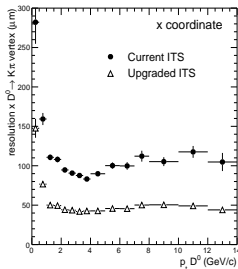
ITS standalone d_0 resolution



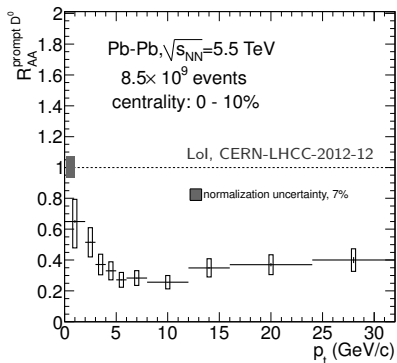
For the studies presented: 7 pixel layers, 0.3%

X/X_0 per layer, intrinsic reso $4 \mu\text{m}$

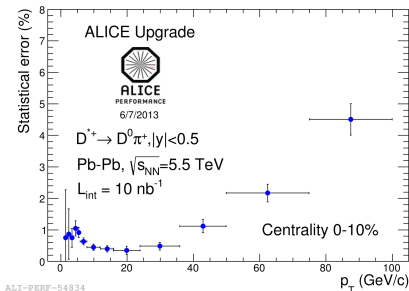
D^0 secondary vtx resolution (x, z)



D meson performance with the upgrade



- ▶ Improved impact parameter resolution
- ▶ Larger integrated luminosity
- ▶ Conservative syst. err. based on current data

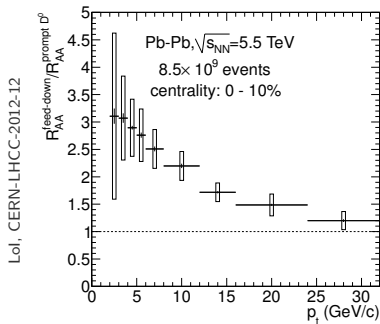


- ▶ Perspective: increase the p_T reach of the R_{AA}
- ▶ D^{*+} performance shows that the range $1 < p_T < 100$ GeV/c is accessible thanks to large increase in integrated luminosity

Beauty measurements

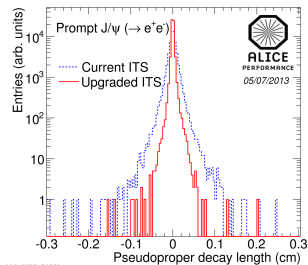
- ▶ Currently B measurement (limited to pp so far) in ALICE performed via displaced electrons (impact parameter method)
- ▶ **Direct B measurement** possible with the upgrade via:

- ▶ **Displaced D mesons** (exploiting different impact parameter distributions of D and B)

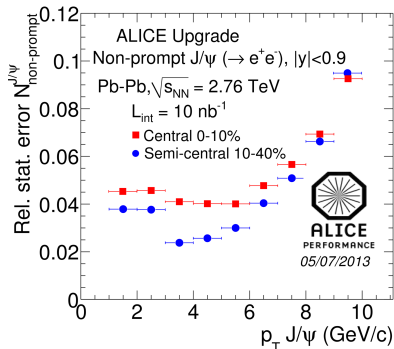
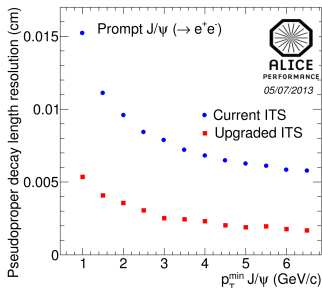


- ▶ Reconstruction $B \rightarrow J/\psi (\rightarrow e^+e^-)$ (pseudoproper decay length)
- ▶ Under study:
 fully reconstructed decays $B^+ \rightarrow \bar{D}^0 \pi^+$ and $B^0 \rightarrow D^{*-} \pi^+$

Non-prompt J/ψ measurement with the upgrade



\propto transverse decay length

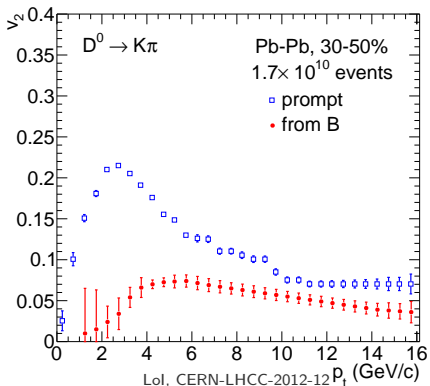


- ▶ B meson measurement
- ▶ Sensitive to mass dependence in heavy quarks energy loss

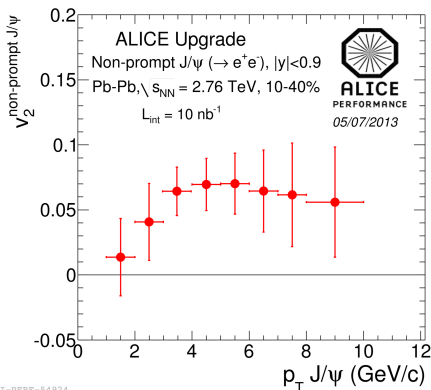
Azimuthal anisotropy of heavy quarks

- Separation of charm and beauty v_2 with the high integrated luminosity

Prompt and displaced D meson v_2

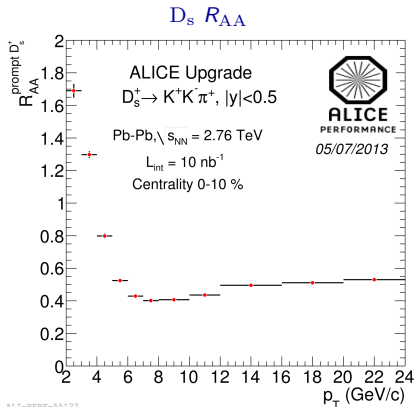


Non-prompt J/ψ v_2

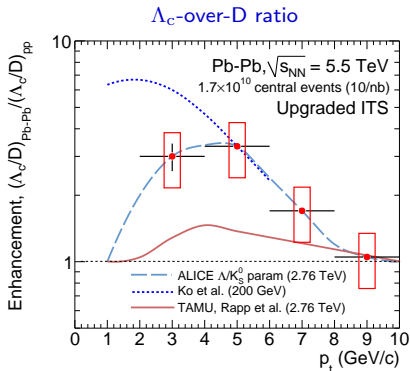


Hadronization of heavy-flavours: the D_s meson and the Λ_c baryon

- ▶ Hadronization via coalescence at low- p_T : enhancement of
 - ▶ $D_s R_{AA}$
 - ▶ Λ_c -over-D ratio



ALI-PERF-55122

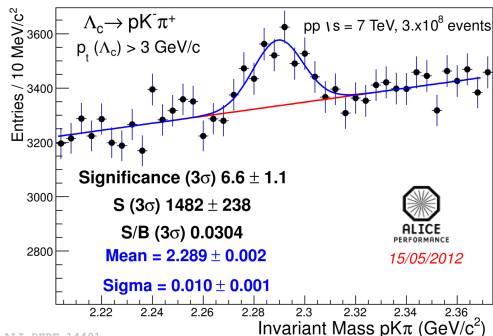


Summary and conclusions

- ▶ The results shown prove ALICE capability of studying heavy quarks as probe of the hot medium
- ▶ Heavy flavours are one of the main items in the upgrade programme
- ▶ Major upgrade now defined and scheduled for 2017-18:
 - ▶ New ITS
 - ▶ New high rate readout for TPC and other detectors
 - ▶ O^2 project
- ▶ The ALICE upgrade allows for a large set of new measurements, for different heavy-flavour hadron species, especially in the low momentum region

Λ_c in pp collisions

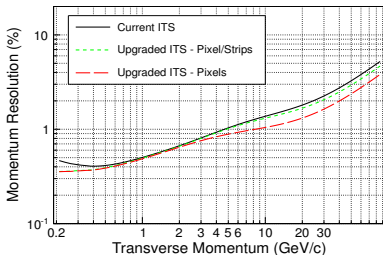
Λ_c signal in pp collisions



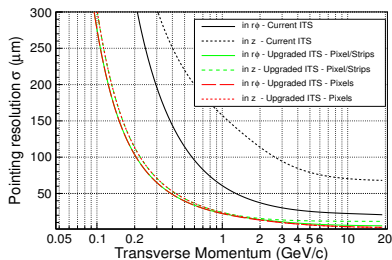
- ▶ Very challenging to separate Λ_c secondary vertex ($c\tau = 60 \mu\text{m}$ only!)
- ▶ Need larger statistics and better impact parameter resolution

Performance of the new ITS

ITS+TPC p_T resolution

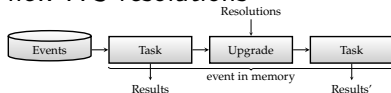


ITS standalone d_0 resolution

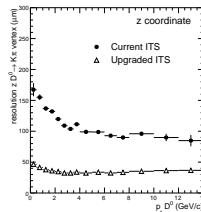
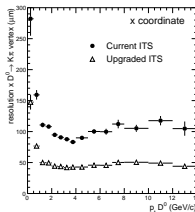


The hybrid approach

- Use existing MC productions, recalculate momenta and coordinates according to the new ITS resolutions



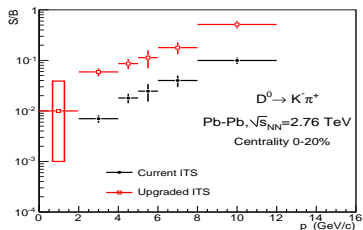
For the studies presented: 7 pixel layers, 0.3% X/X_0 per layer, intrinsic reso 4 μm



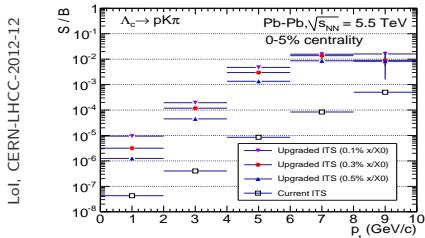
Charm mesons and baryons with the upgrade

- ▶ Improved performance of the D^0
- ▶ Λ_c measurement in Pb–Pb collisions down to 2 GeV/c

D^0 performance



Λ_c performance



LoI, CERN-LHCC-2012-12