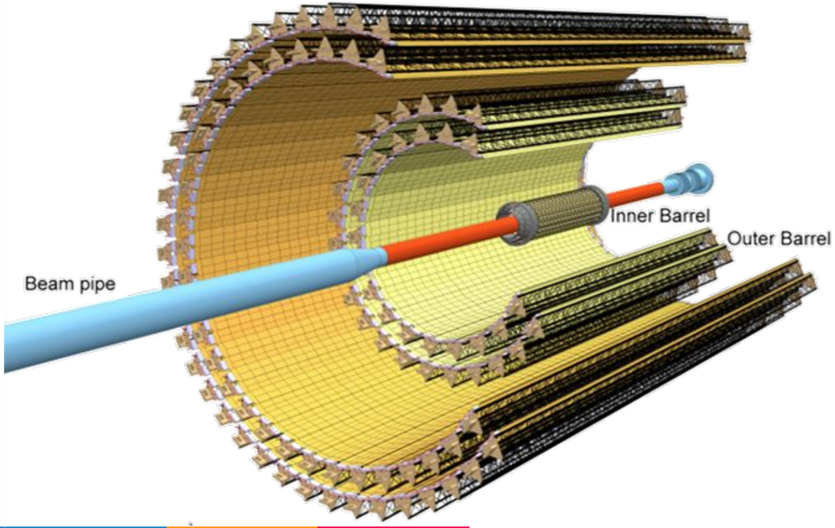
Heavy Flavour at ALICE: Status and Prospects



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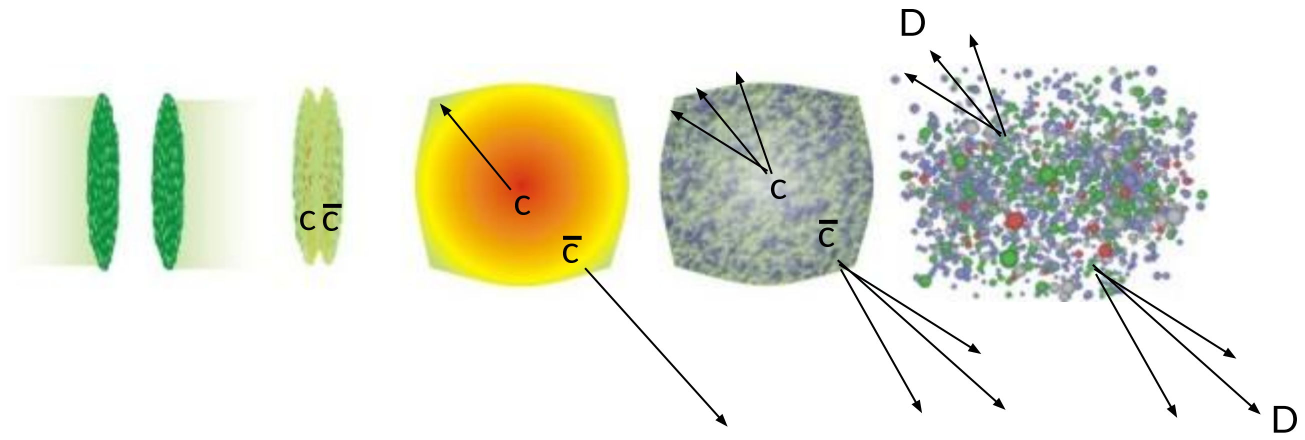
University of Tennessee - Knoxville

RHIC & AGS Annual Users' Meeting 2021

Jun 09, 2021

Heavy quarks



Heavy quarks are produced in the hard scattering

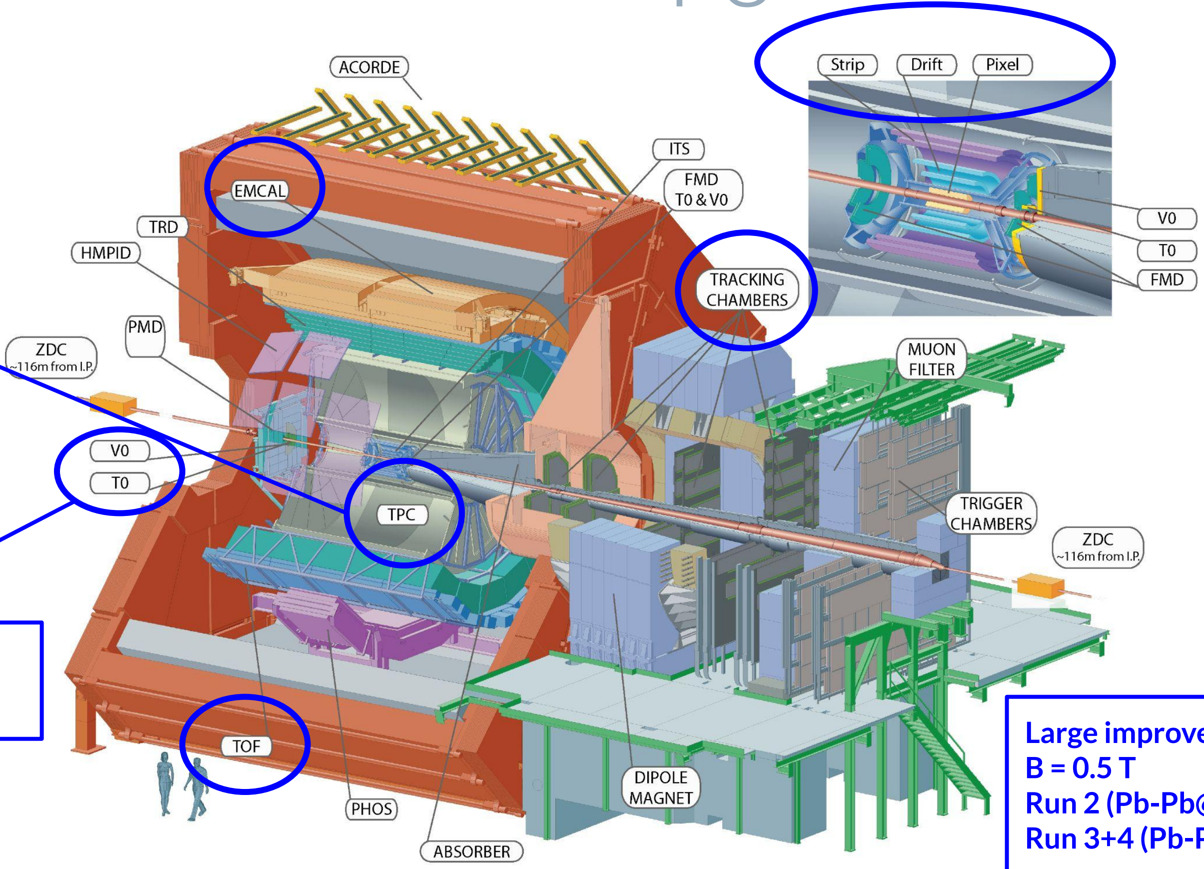
Present during the whole evolution of the system

Large mass $\rightarrow$ production can be calculated by p-QCD

ALICE detector and Upgrade

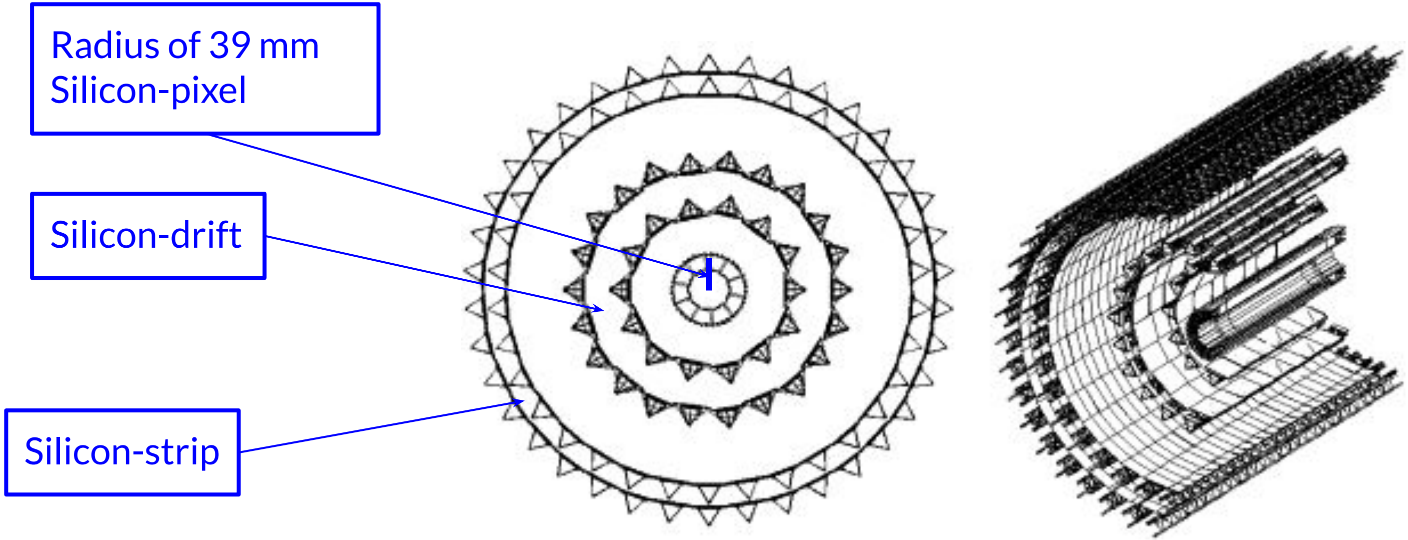
Readout based on Gas Electron Multiplier (GEM)
50 kHz continuous interaction rate

Replaced by the Fast Interaction Trigger (FIT)



Large improve in statistics
B = 0.5 T
Run 2 (Pb-Pb@5.02 Tev): 1 nb^{-1}
Run 3+4 (Pb-Pb@5.5 TeV): 10 nb^{-1}

Inner Tracking System (Run 1 and 2)



Reconstruction of primary vertex with a resolution better than 100 μm

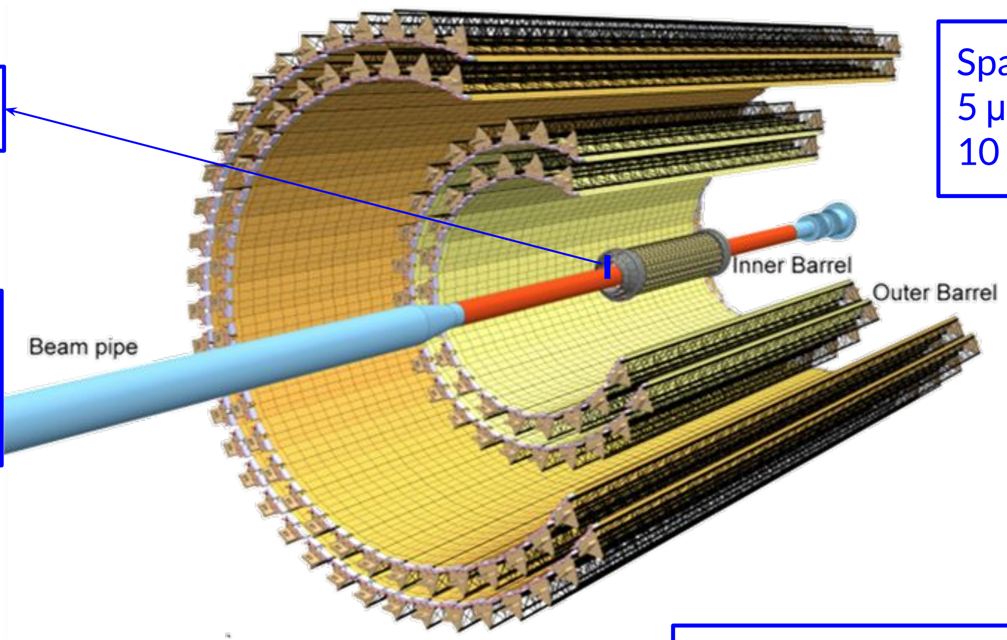
Tracking of particles with p_T < 100 MeV/*c*

Improves tracking of particles reconstructed with the Time-Projection Chamber (TPC)

Inner Tracking System Upgrade

Radius of 23 mm

Spatial resolution
5 μm (inner barrel)
10 μm (outer barrel)

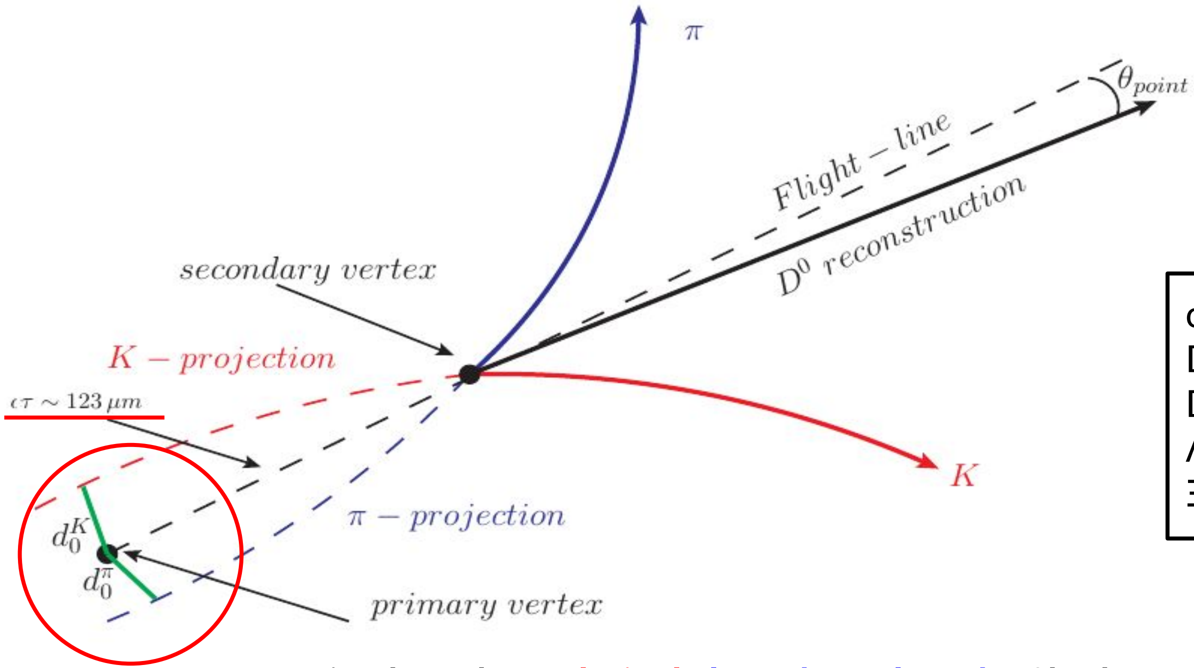


Reduced material budget
Innermost layers
$1.1 \rightarrow 0.3\ X/X_0$

All 7 layers → Monolithic Active Pixel Sensors (MAPS)
Improved readout: 1kHz → 50kHz (continuous)

References
https://cds.cern.ch/record/2661798
http://iopscience.iop.org/0954-3899/41/8/087002

Experimental strategy



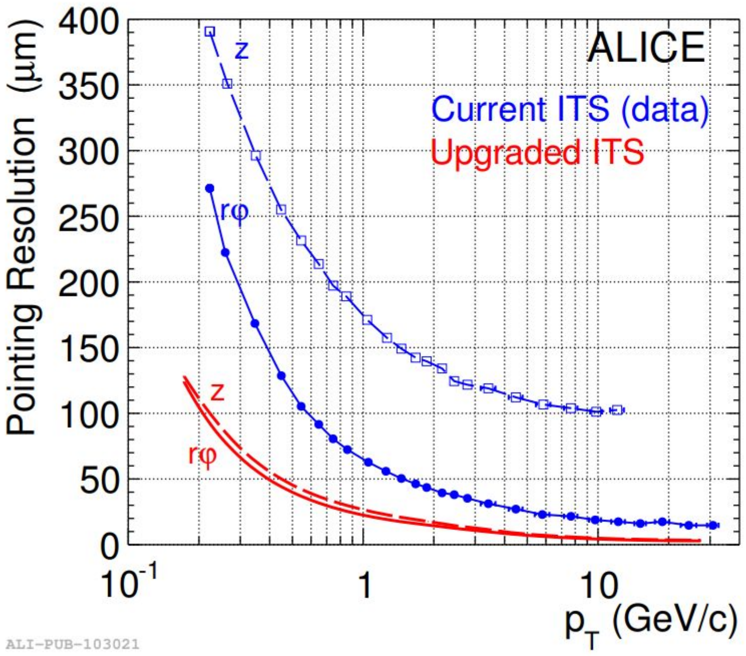
$c\boldsymbol{\tau}$
$D^0 \sim 123\ \mu m$
$D_s \sim 150\ \mu m$
$\Lambda^+_c \sim 60\ \mu m$
$\Xi^+_c \sim 132.6\ \mu m$

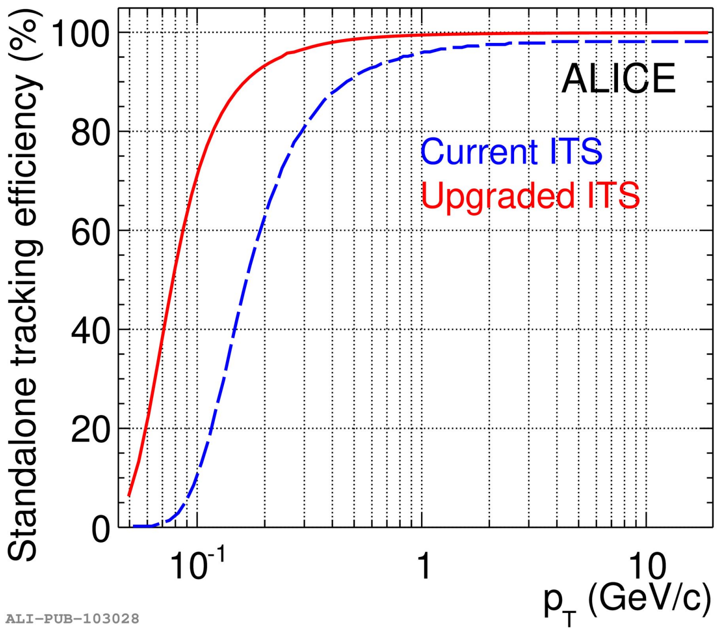
Reconstruction based on relatively long decay length of hadrons from heavy quarks

All hadrons reconstructed via hadronic decay channels follow a similar strategy

Good impact parameter resolution is a critical feature of the detector

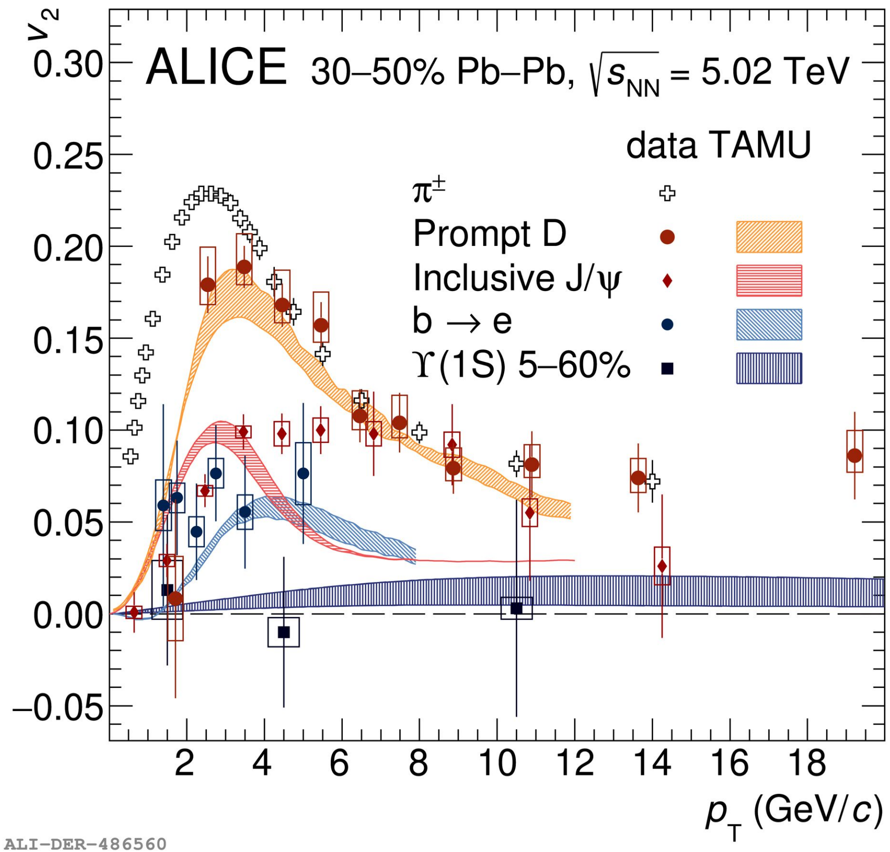
Inner Tracking System Upgrade





Improved impact parameter resolution (factor ~3 in rφ and ~5 in z)
Improved track reconstruction efficiency

Azimuthal Anisotropy



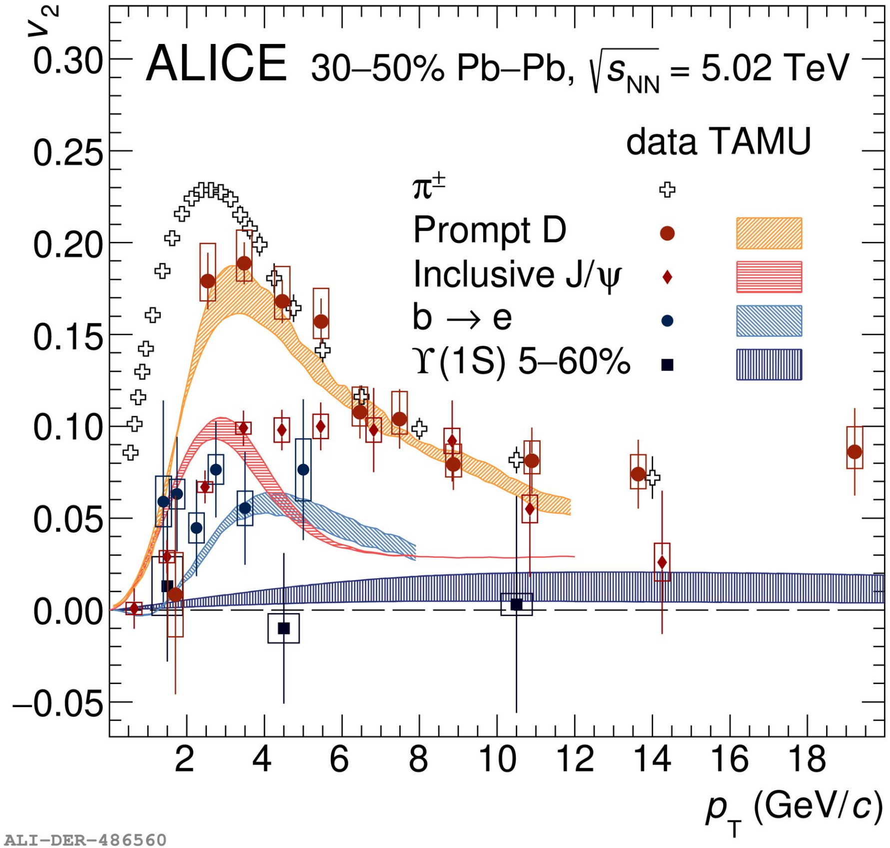
ALI-DER-486560

Elliptic flow (v_2) and triangular flow (v_3) heavy-flavour hadrons

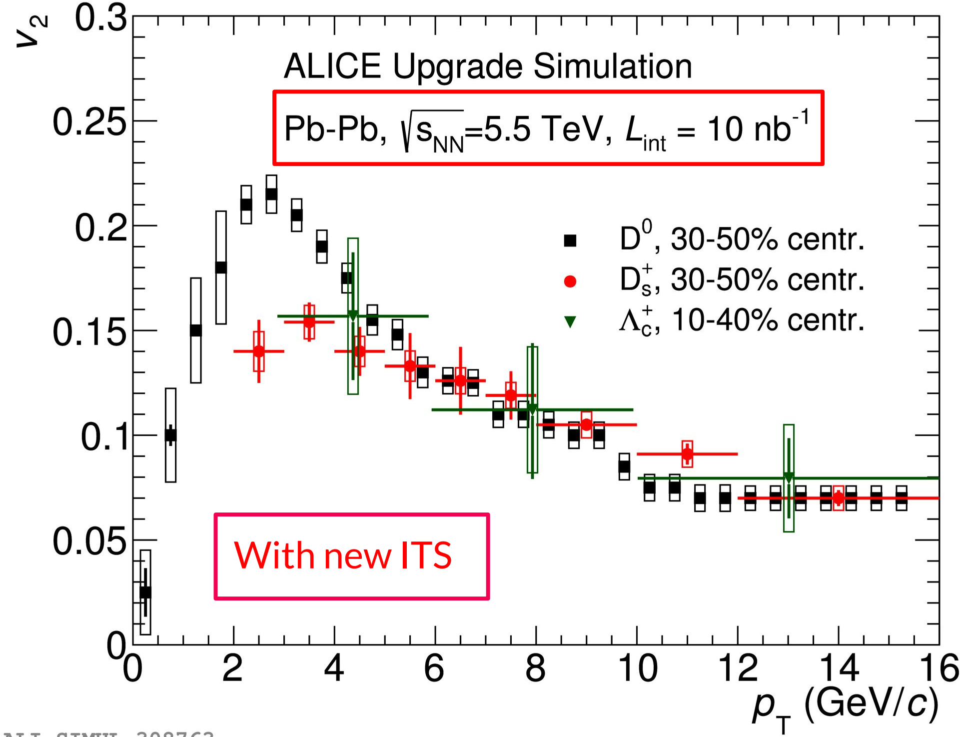
Participation of the heavy quarks in the collective expansion

Increase of elliptic flow from central to semi-central Pb-Pb collisions

Azimuthal Anisotropy - ITS Upgrade



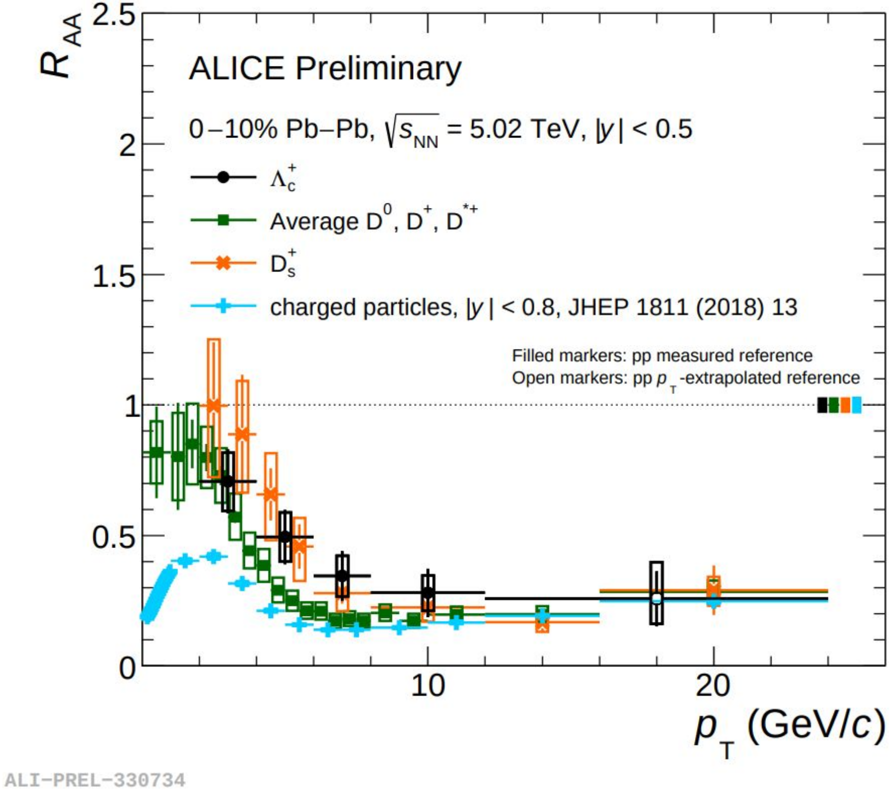
ALI-DER-486560



ALI-SIMUL-308763

Possibility of measurement of Λ^+_c elliptic flow
Better precision for D-meson v_2 down to 0 GeV/c

Nuclear modification factor



Strong suppression of hadrons from charm quarks in central Pb-Pb collisions

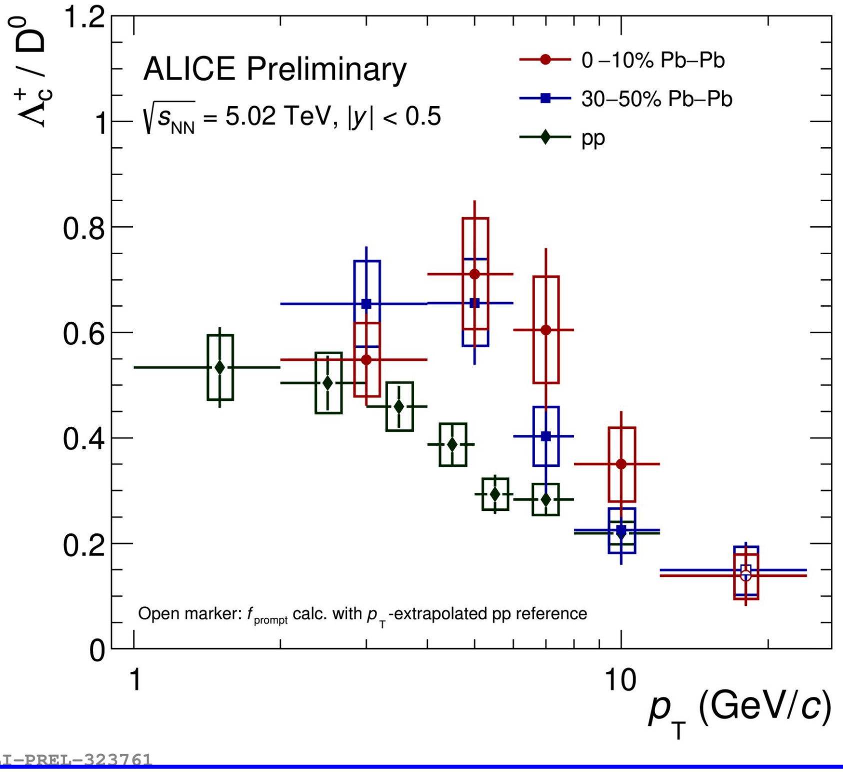
D^+_s and non strange D meson R_{AA} compatible for p_T > 8 GeV/c

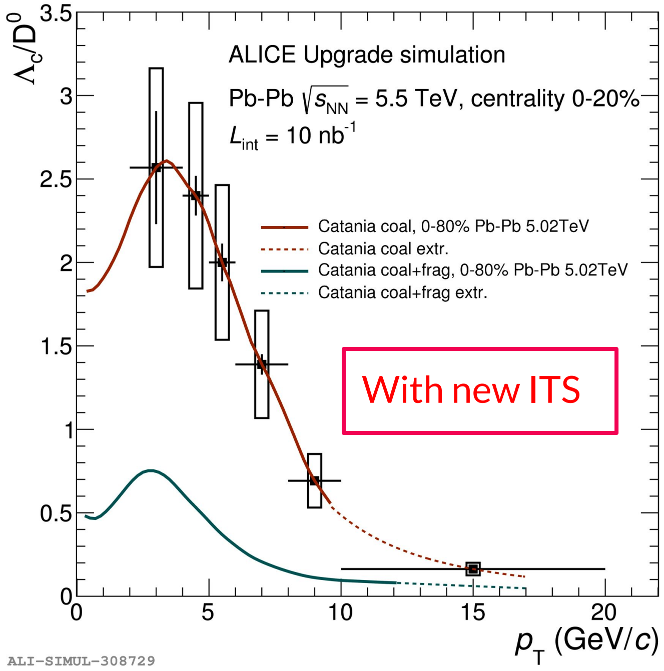
D^+_s R_{AA} systematically higher for p_T < 8 GeV/c

Λ^+_c R_{AA} systematically higher for p_T < 12 GeV/c

- Consistent with coalescence of charm quarks in the QGP

Λ_c and Λ_b - ITS Upgrade

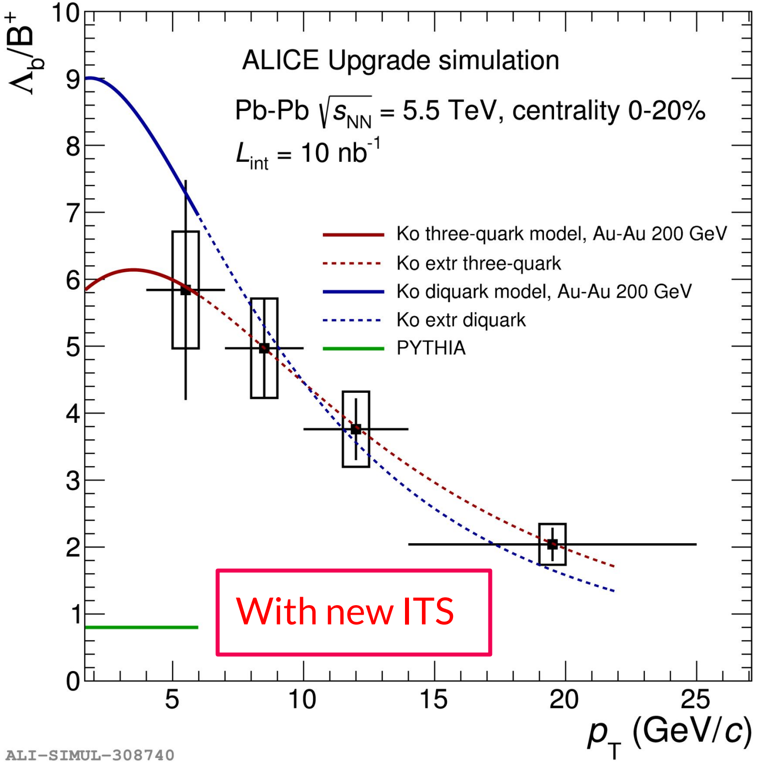




Statistical uncertainties greatly reduced

Enhancement of Λ_c production in Pb-Pb collisions in comparison to pp collisions. Recombination? Radial flow?

Λ_c and Λ_b - ITS Upgrade



ALI-SIMUL-308740

Measurement of Λ_b for the first time in ALICE

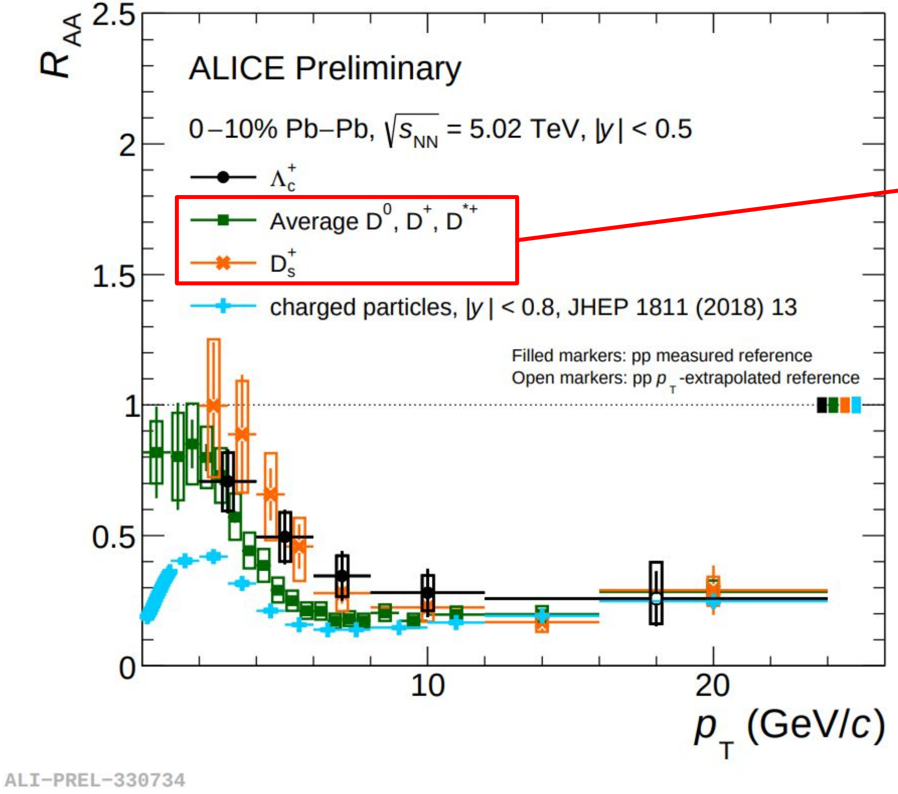
Reconstruction via hadronic decay channel

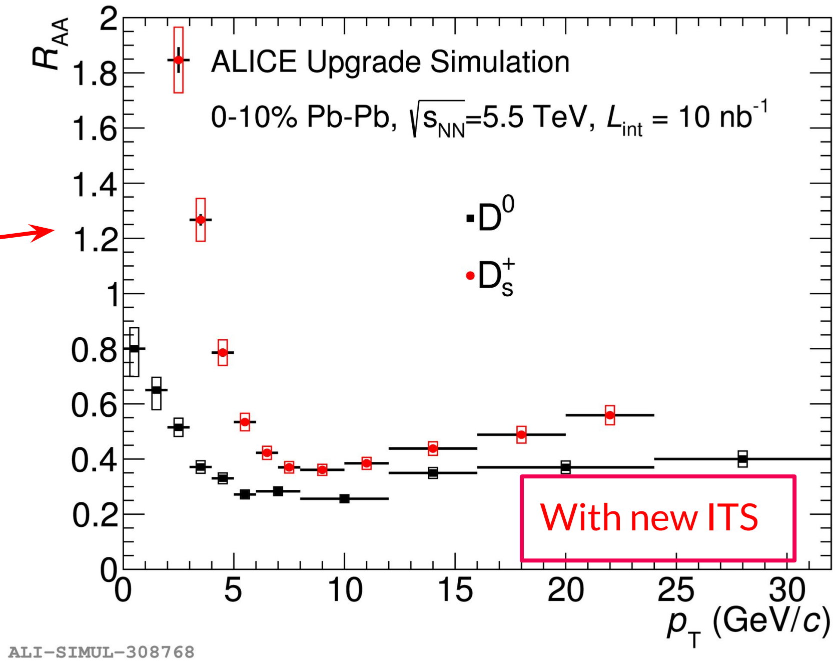
$\Lambda^0_b \rightarrow \Lambda^+_c \pi^-$ with $\Lambda^+_c \rightarrow pK^-\pi^+$

Λ_b statistical uncertainties ~30%
Λ_b systematic uncertainties ~15%

Allows for a deeper insight on bottom baryon production in heavy-ion collisions

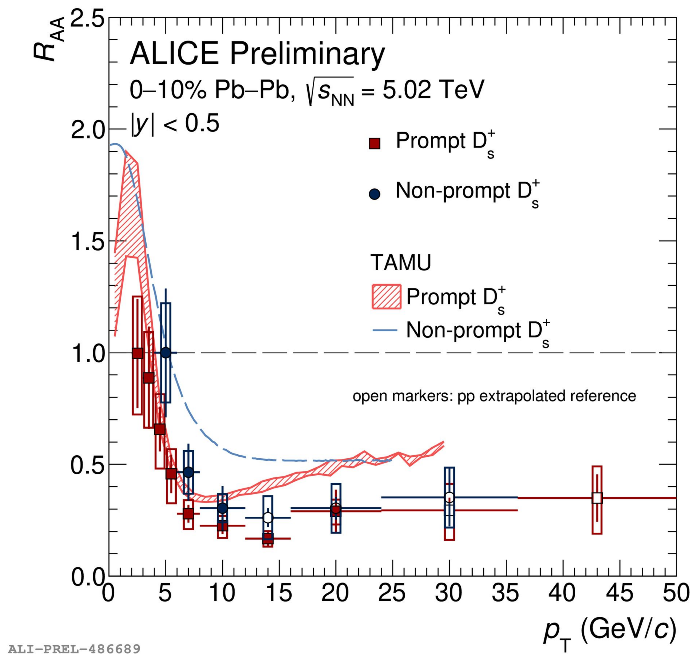
Nuclear modification factor - ITS Upgrade

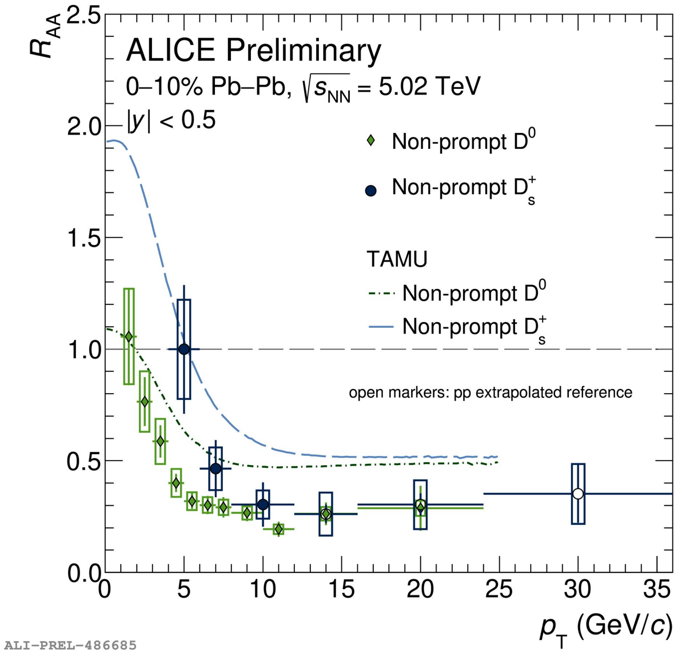




Higher precision for D meson measurements

Prompt and non-prompt D_s - R_{AA}

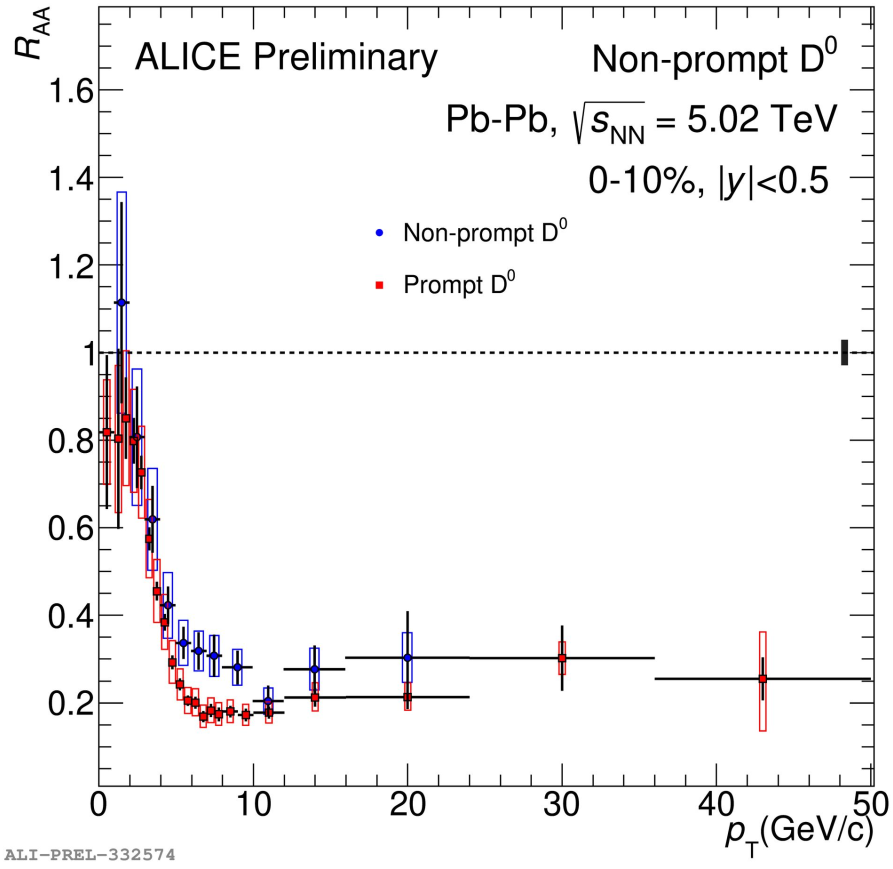




New results presented during sQM

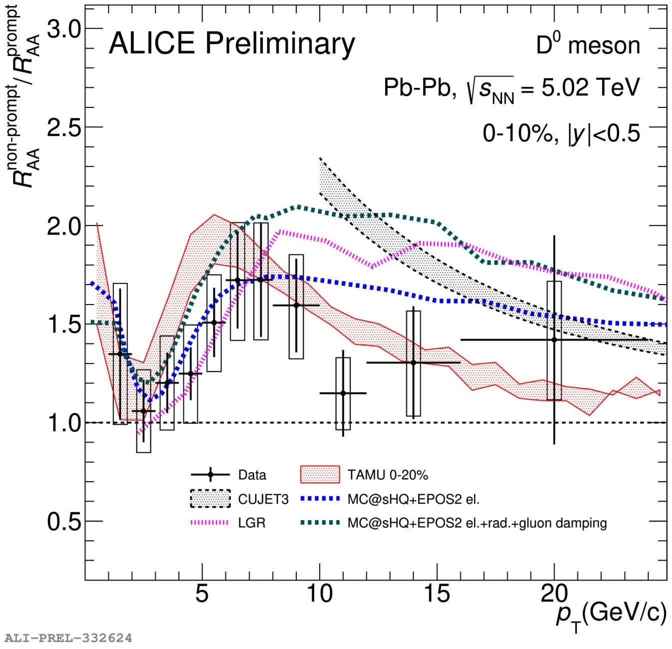
First measurement of non-prompt D^+_s
Hint of less suppressed non-prompt D^+_s production in central Pb-Pb collisions in comparison to prompt D^+_s and non-prompt D^0

Prompt and non-prompt D^0 - R_{AA}

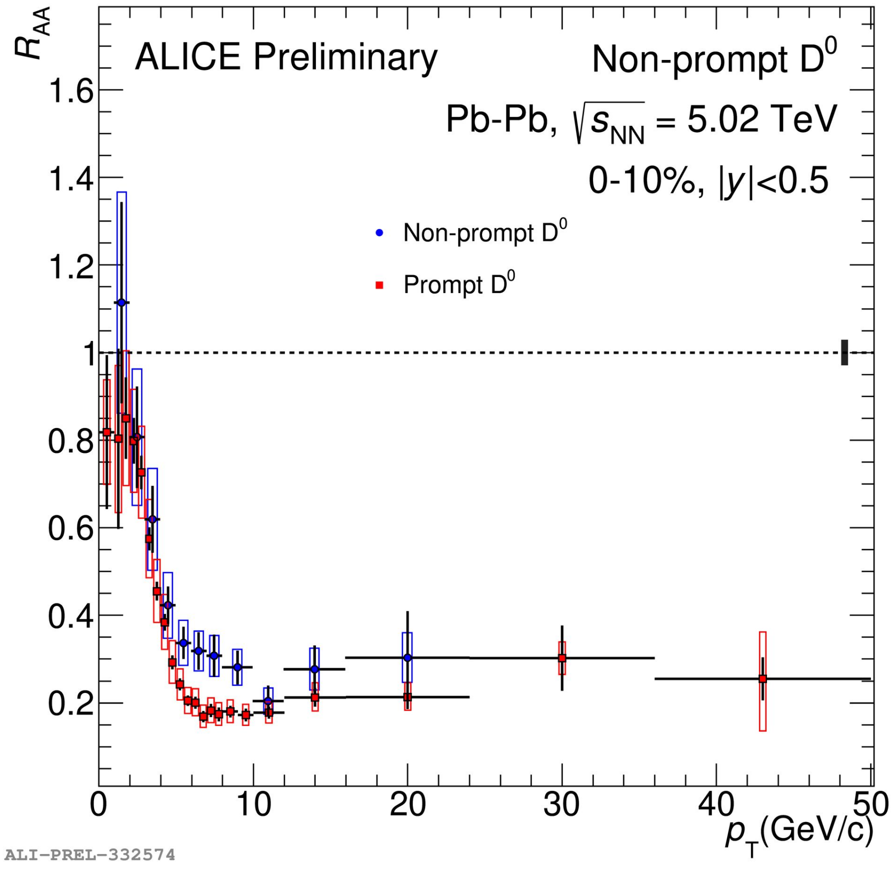


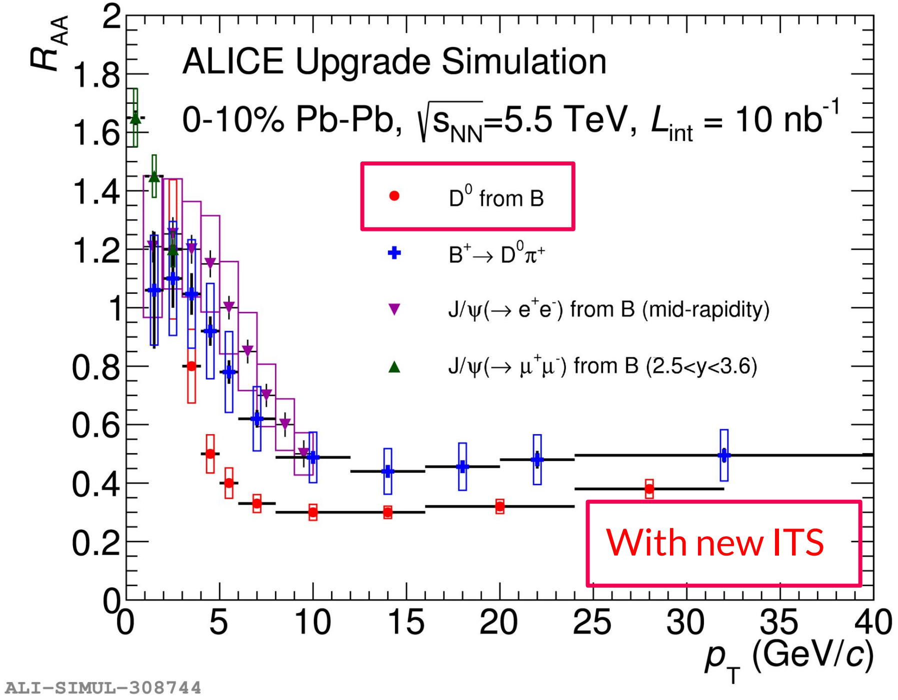
Hint of larger non-prompt D^0 R_{AA} in comparison to prompt

- Interplay of charm and bottom energy loss and recombination in the medium



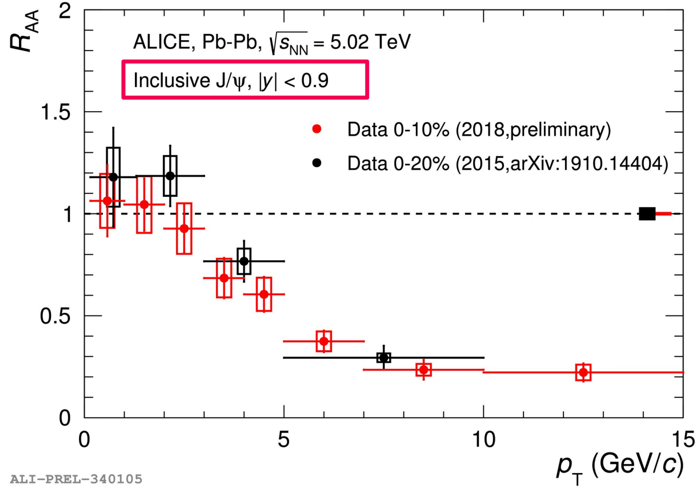
Prompt and non-prompt D^0 - ITS Upgrade

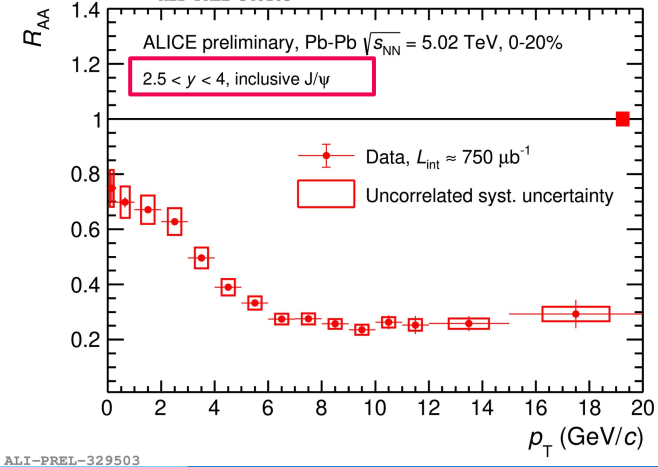


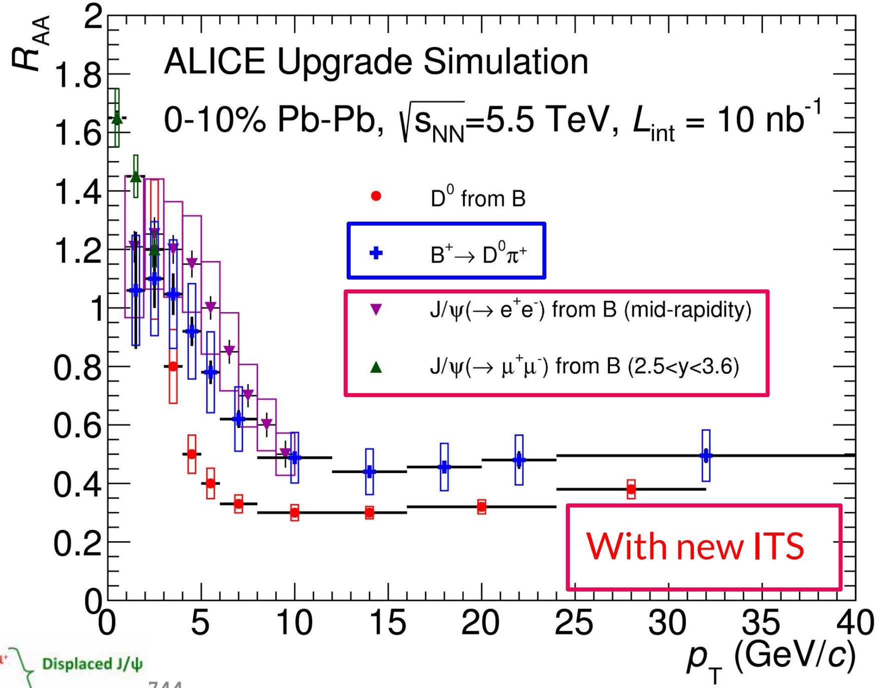


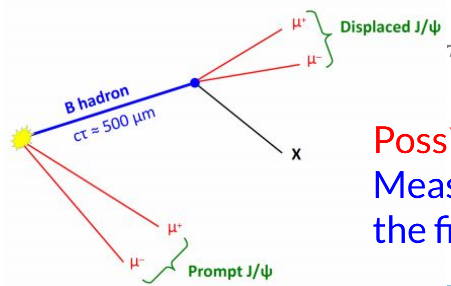
Extended measurement range and smaller uncertainties

Prompt and non-prompt J/ψ - ITS Upgrade









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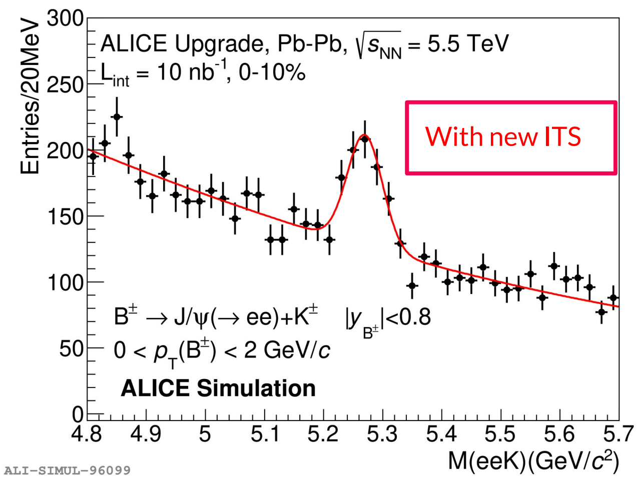
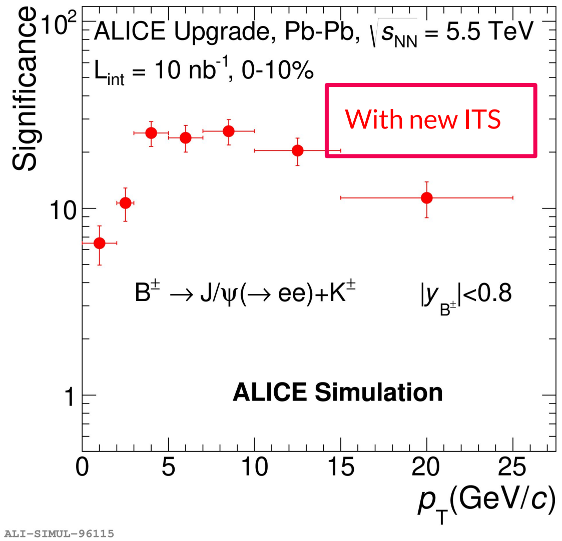
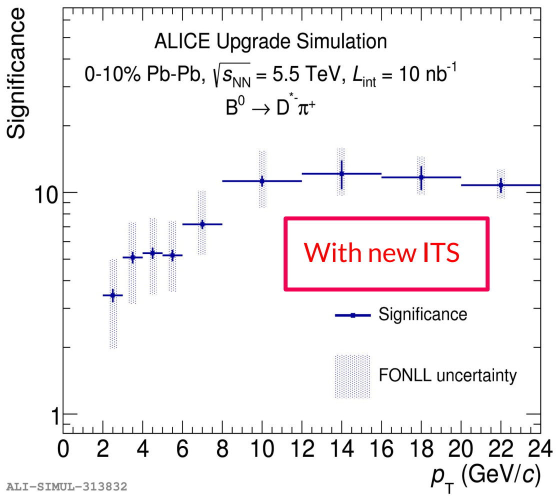
Possibility of measuring non prompt J/$\boldsymbol{\psi}$

Measurement of B mesons in ALICE for the first time

Measurement of $B^{\pm}$ and B^0 - ITS Upgrade





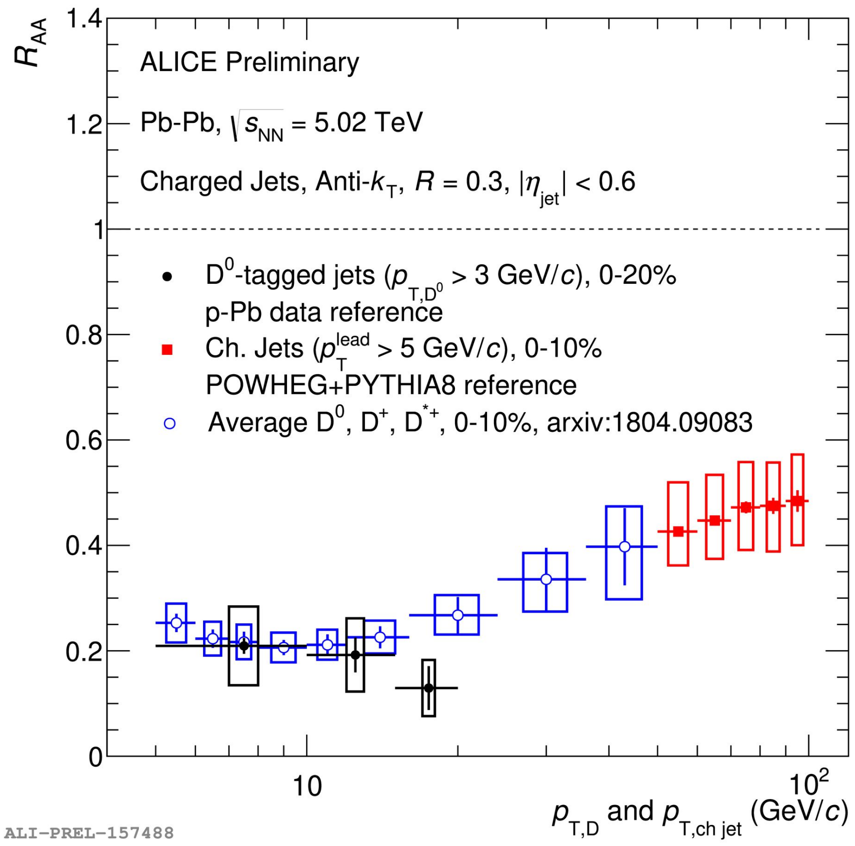


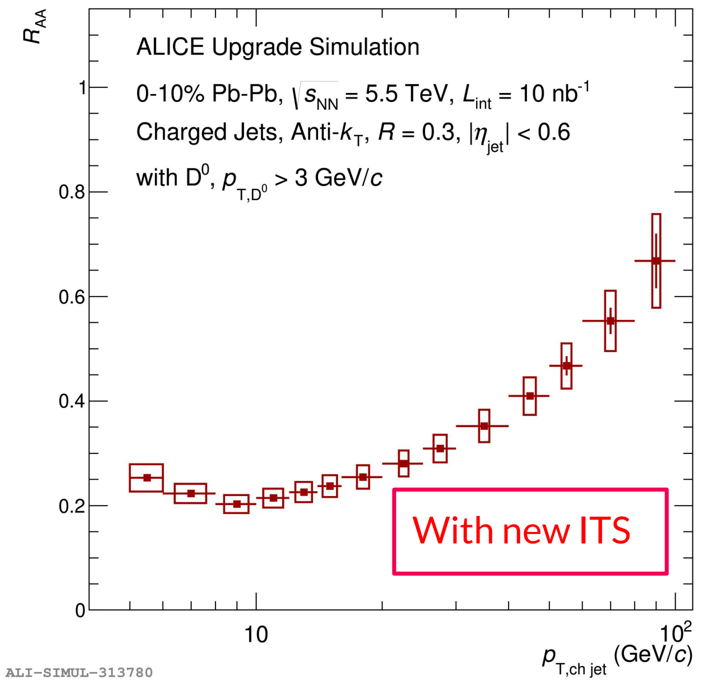
Possibility of measuring B^+ down to p_T = 0 GeV/c

Good significance up to 25 GeV/c

Estimated systematic uncertainties ~14%

D-tagged jets - ITS Upgrade





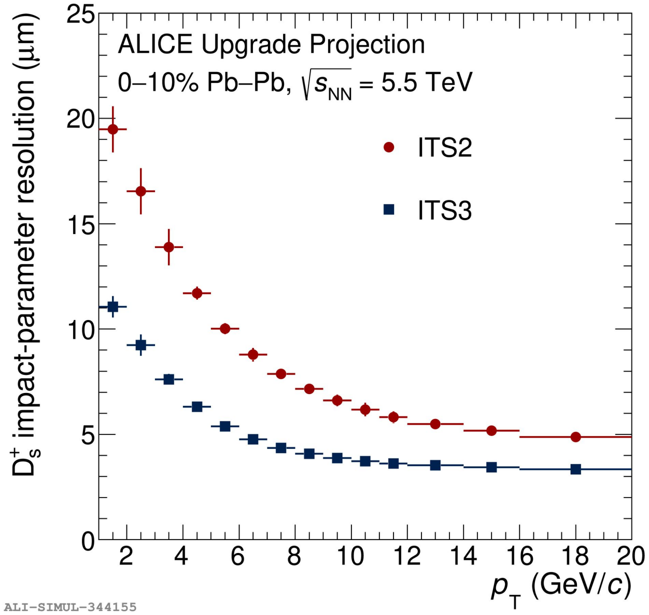
Improvement in range and precision
Overlap with inclusive jets

Run 4 ITS upgrade (ITS3)

- Further improvements for the ITS in Run 4 (2027-2030) are in preparation

- New ITS inner barrel
  - New three fully cylindrical layers with reduced material budget
  - Innermost layer closer to the beam-pipe
  - Beam-pipe thinner and with smaller outer radius

- Measurements possibilities with the ITS3
  - B^0_s, Λ_b and Ξ_c at low transverse momenta
  - Precise measurement of D_s R_{AA} and v_2
  - First observation of the c-deuteron could be in reach

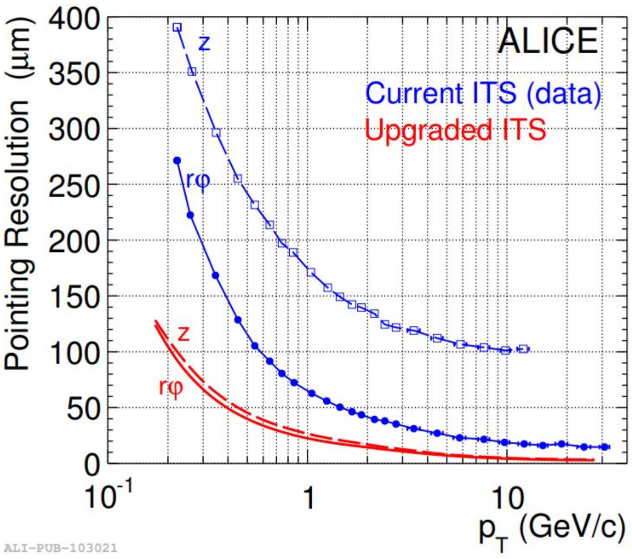


Conclusions

- The ITS upgrade is a fundamental part of the ALICE Run 3 and 4 physics program, in specific for heavy-flavour high precision measurements

- A collection of recent ALICE results on heavy-flavour measurements was presented

- Prospects of measurements on heavy-flavour hadrons using the upgraded ITS were presented
    - Measures with higher precision and larger kinematic ranges
    - Possibility of measuring B, Λ_b and non-prompt J/ψ in ALICE for the first time



Thank you!

Backup

Models

- The Catania model assumes that a QGP is formed in both pp and Pb–Pb collisions. In Pb–Pb collisions heavy-quark transport is implemented via the Boltzmann equation, and in both pp and Pb–Pb collisions hadronisation occurs either via coalescence, implemented through the Wigner formalism, or via fragmentation.

- The TAMU model describes charm-quark transport in a hydrodynamically expanding medium with the Langevin equation and hadronisation proceeds primarily via coalescence, implemented with a Resonance Recombination Model (RRM). Left-over charm quarks not undergoing coalescence are hadronised via fragmentation.
- In the TAMU model, the interactions are described by elastic collisions only

- The LGR, MC@sHQ+EPOS2 and CUJET3.1 models include both radiative and collisional energy loss processes. The contribution of hadronisation via quark recombination, in addition to independent fragmentation, is considered in MC@sHQ+EPOS2 and LGR models