Heavy-Flavour Studies with the new ALICE Pixel Trackers in Runs 3 and 4

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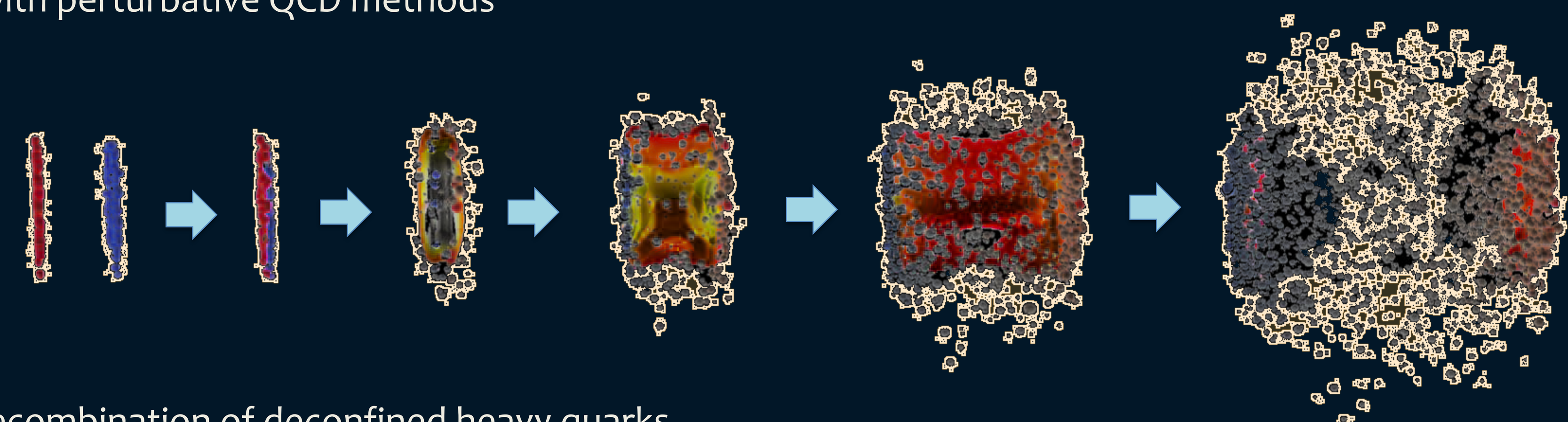
in memory of Andre Mischke

PHYSICS MOTIVATIONS

Heavy quarks (c, b) are important probes of the hot, dense and deconfined QCD medium, the Quark–Gluon Plasma (QGP) created in ultra-relativistic heavy-ion collisions

- Heavy-quark pair production is a perturbative process: production cross sections can be calculated with perturbative QCD methods
- Heavy quarks are produced early in the collisions, and they experience the full system evolution
- Heavy-quark number is conserved throughout the QGP lifetime
- Heavy quarks will traverse the surrounding medium:
  - They can loose energy by collisional or radiative processes
  - Charm could possibly reach (partial) thermalization in the QGP
- A fraction of heavy-quark pairs will bind (non-perturbatively) to form quarkonium states
  - Quarkonium can be sequentially suppressed by the QGP, and also be formed in the medium by recombination of deconfined heavy quarks

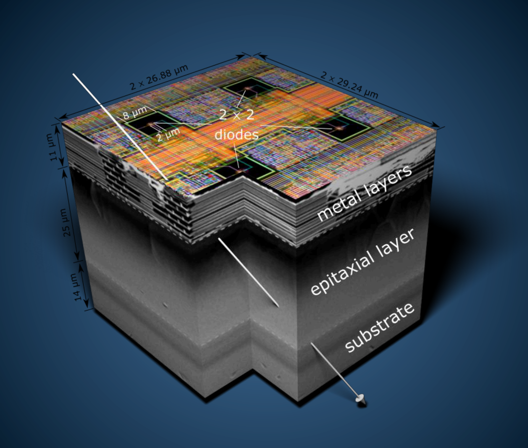


Heavy quarks are also a useful probe to study complex behaviors in smaller hadronic systems like pp and p-A (multi-parton interactions, collectivity)

DETECTOR TECHNOLOGY

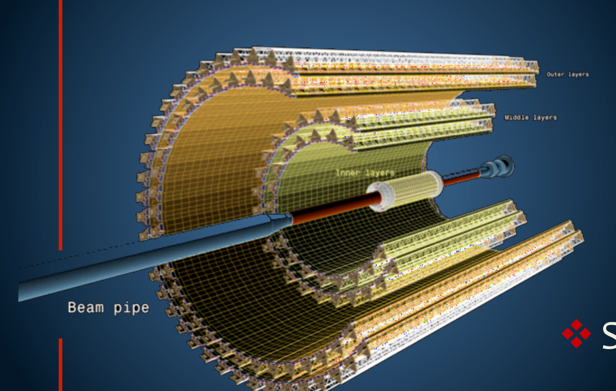
CERN-LHCC-2013-024, CERN-LHCC-2015-001

The ALPIDE chip: CMOS MAPS TowerJazz 0.18 μm technology

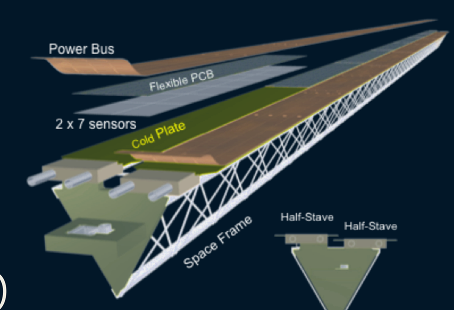


- **Sensor size:** 15 mm x 30 mm
- **Pixel size:** 29 μm x 27 μm
- **Detection efficiency:** > 99%
- **Event time resolution:** < 4 μs
- **Space resolution:** 5 μm
- **Radiation dose (Run3+Run4):** < 300 krad, < 2.0 × 10^{12} 1MeV n_{eq}/cm^2

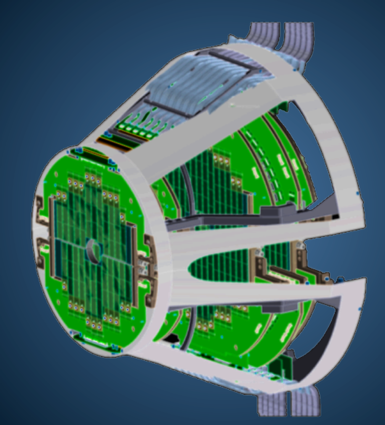
The new Inner Tracking System (ITS), improving tracking performance at mid-rapidity, namely at low p_T



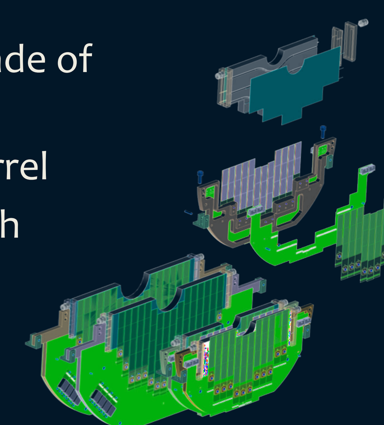
- 7 layers from R = 22 mm to R = 400 mm
- 24 000 ALPIDE chips, 12.5 Gigapixels (binary readout)
- Large area (10 m²) silicon pixel (MAPS) sensor tracker ($|\eta| < 1.22$)
- 0.3% x/X_0 for each of the 3 innermost layers (light mechanical structure)
- Spatial resolution of ≈ 5 μm, first layer closer to IP (smaller beam pipe radius)



The Muon Forward Tracker (MFT), a vertex tracker for the Muon Spectrometer



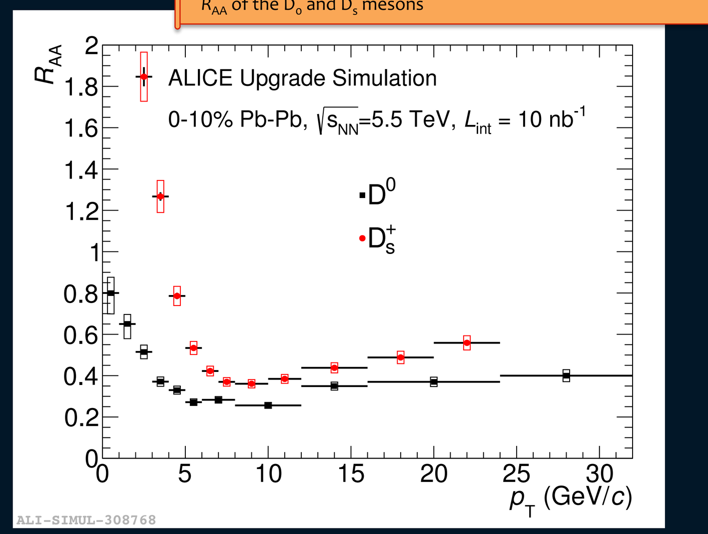
- 920 ALPIDE chips (0.4 m²) in 280 ladders made of 2 to 5 sensors each
- 5% of the ITS surface, twice the ITS inner barrel
- 5 disks, 0.7% x/X_0 and 2 detection planes each
- Inner radius limited by the beam pipe → Nominal acceptance: $2.5 < \eta < 3.6$, full azimuth



PHYSICS PERFORMANCE STUDIES

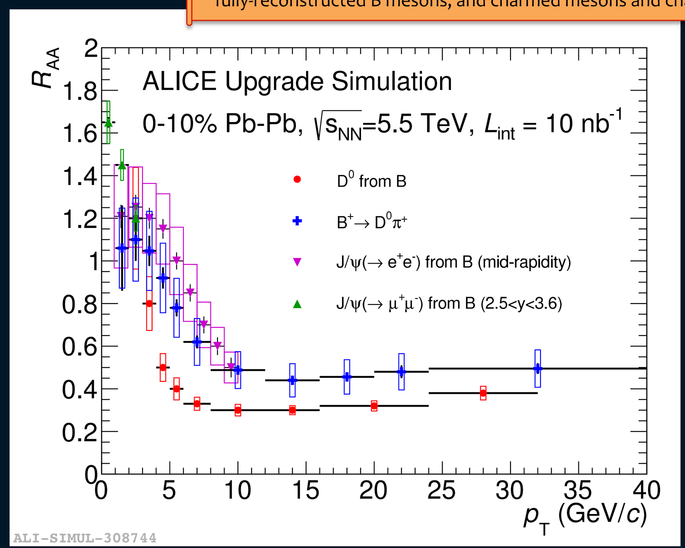
L_{int} **target:** 10 nb⁻¹ + 3 nb⁻¹ (low B-field) in Pb-Pb; 0.5 pb⁻¹ in p-Pb. Continuous readout mode (with upgraded readout and online-offline systems) to take Pb-Pb collisions at 50 kHz

Expected performance for the measurement of the nuclear modification factor R_{AA} of the D_s and D_s mesons



- **D⁰: standard candle for charm measurements.** Total uncertainties with the new ITS, down to zero p_T, are below 10% thanks to:
  - **Improved signal extraction** (background reduced by a factor 5-10)
  - **Precise isolation of prompt component**
- **D_s also accessible down to low p_T:** comparison of different D mesons reveals the hadronization mechanisms of charm quarks in the QGP

Expected performance for the measurement of the nuclear modification factor R_{AA} of fully-reconstructed B mesons, and charmed mesons and charmonium from b-decays



- **ALICE upgrade strategy foresees a combination of beauty measurements at mid- and forward-rapidity** to better constrain theoretical models
  - Fully-reconstructed B mesons and displaced D⁰ mesons at mid-rapidity
  - Displaced J/ψ both at mid- and forward rapidity
- Goal: transverse momentum, flavour and mass dependence of heavy-quark energy loss

- **Heavy-quark v_2** gives insight into the interactions with the light quarks of the medium and the hadronisation processes. The simultaneous description of R_{AA} and v_2 for heavy-flavour hadrons is still challenging for most of the theoretical models
- **Elliptic-flow measurements** will be addressed within the ALICE upgrade strategy both at mid- and forward-rapidity, for both charm and beauty sectors:
  - **Central barrel:** prompt charm mesons/baryons; D mesons and J/ψ from B
  - **Muon arm:** single muons from D mesons; J/ψ from B; single muons from B

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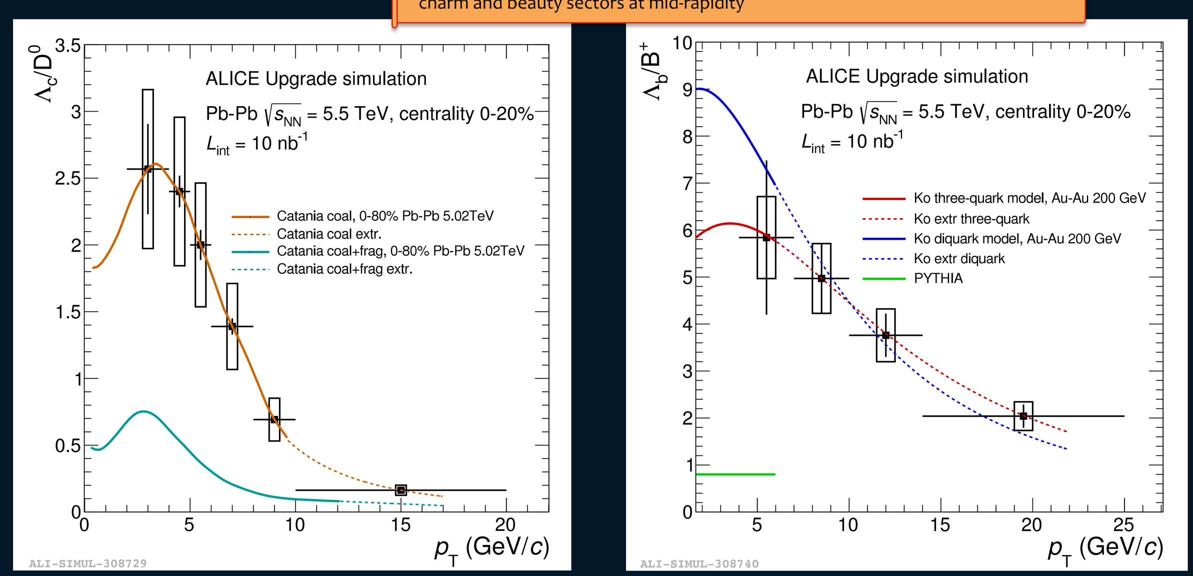
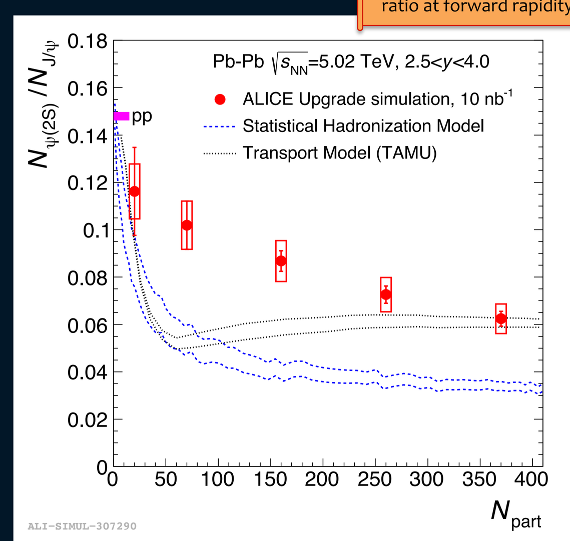
Expected performance for the measurement of the baryon/meson ratio in the charm and beauty sectors at mid-rapidity



Baryon/meson ratio for charm and beauty thanks to the cleaner vertex resolution for Λ_c and Λ_b baryons

- Insight into the hadronisation mechanisms of heavy quarks in the QGP

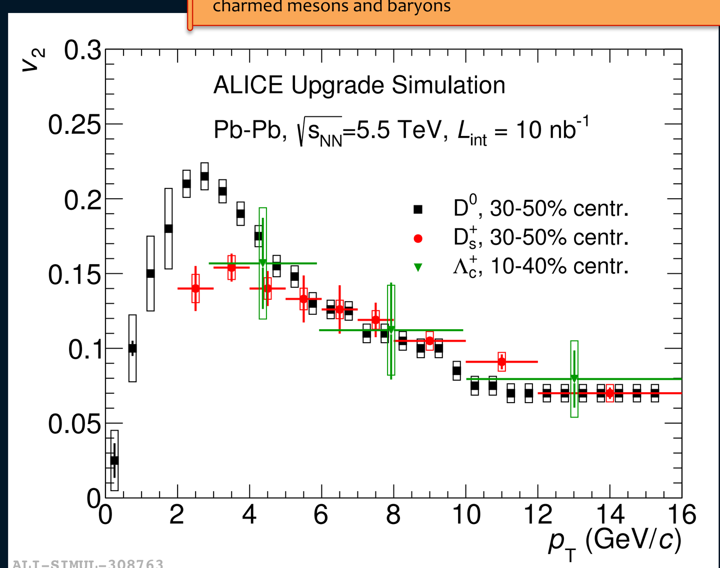
Expected performance for the measurement of the ψ(2S)/J/ψ ratio at forward rapidity



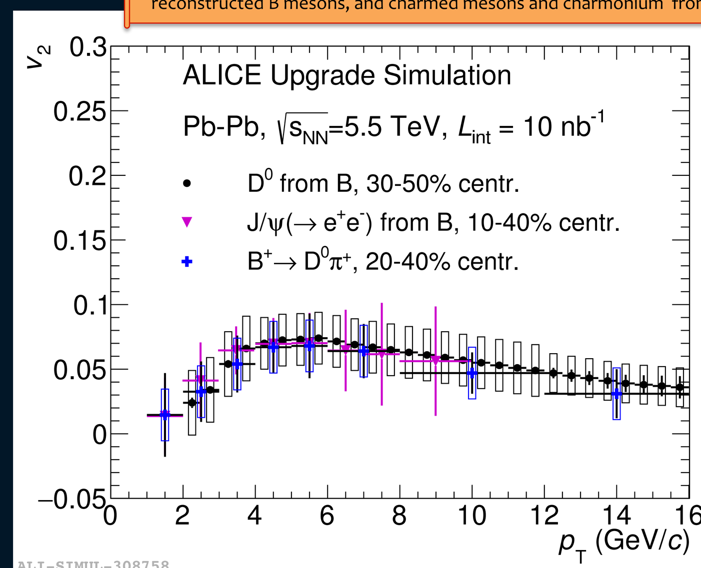
Improved precision on quarkonia measurements

- **Prompt J/ψ separation** achievable at forward rapidity
- Improved signal/background for **ψ(2S)**: test for charmonium production and recombination models
- Precise comparison of charmonium and bottomonium states: **mass/flavour dependence of heavy-quark flow**
- Precise centrality dependence of **bottomonium R_{AA}** at forward rapidity

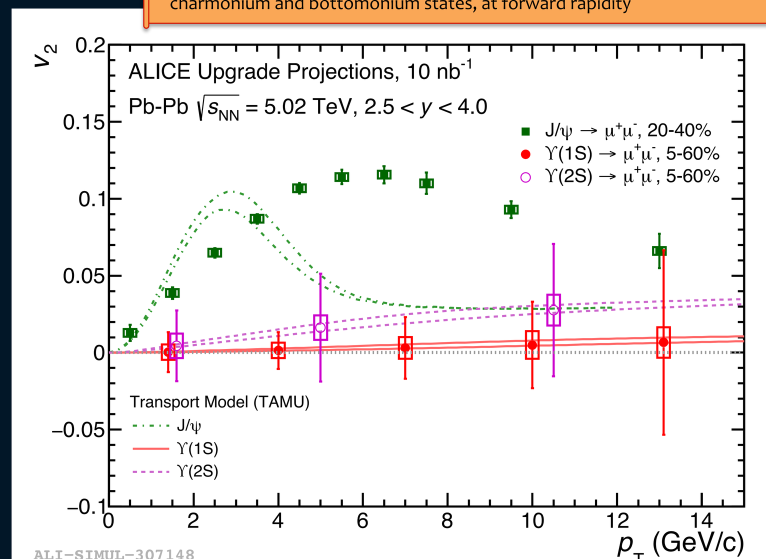
Expected performance for the measurement of the v_2 parameter for charmed mesons and baryons



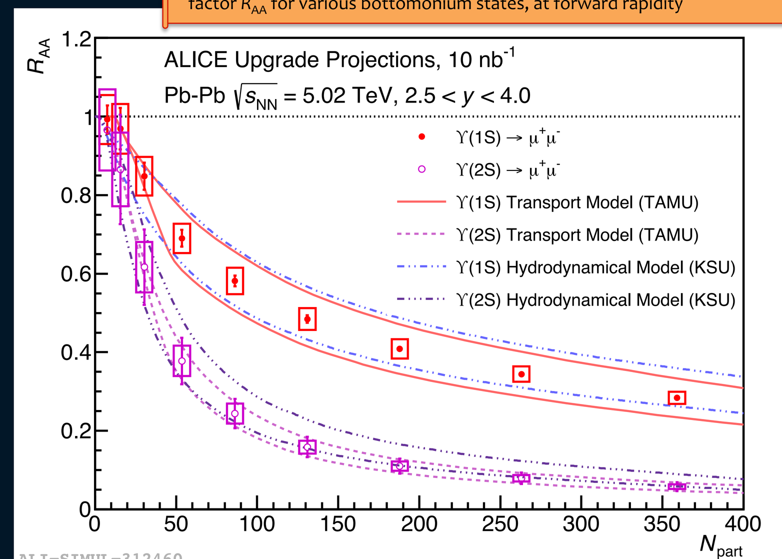
Expected performance for the measurement of the v_2 parameter for fully-reconstructed B mesons, and charmed mesons and charmonium from b-decays



Expected performance for the measurement of the v_2 parameter for various charmonium and bottomonium states, at forward rapidity



Expected performance for the measurement of the nuclear modification factor R_{AA} for various bottomonium states, at forward rapidity



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