Prospects for heavy flavour measurements with the ALICE inner and forward tracker upgrade

F. Fionda[(1)],
On behalf of the ALICE Collaboration

[(1)]University & INFN, Cagliari, Italy

Strangeness in Quark Matter
Dubna 6-11 July 2015

Outline

- ✔ Introduction
- ✔ Goals of future ALICE HF program
- ✔ The ALICE Upgrade strategy
- ✔ The upgraded Inner Tracking System and the new Muon Forward Tracker
  - ✔ Detector layouts
  - ✔ Physics Performance
- ✔ Conclusions

Heavy flavours as probes of the QGP

- The study of heavy-flavour particles (i.e. containing charm and beauty quarks) is important in A-A since they are produced at the early stage of the collisions
  → **sensitive to the full evolution of the hot and dense strongly-interacting medium (QGP)**

  - Partonic energy loss (radiative + collisional) different for gluons, light / heavy quarks. Hierarchy expected in the HF sector

$$\Delta E_c > \Delta E_b \Longrightarrow R_{AA}(D) < R_{AA}(B)$$

  - initial space anisotropy transferred to the momentum space → quantified by the second term of the Fourier expansion: elliptic flow (v_2)

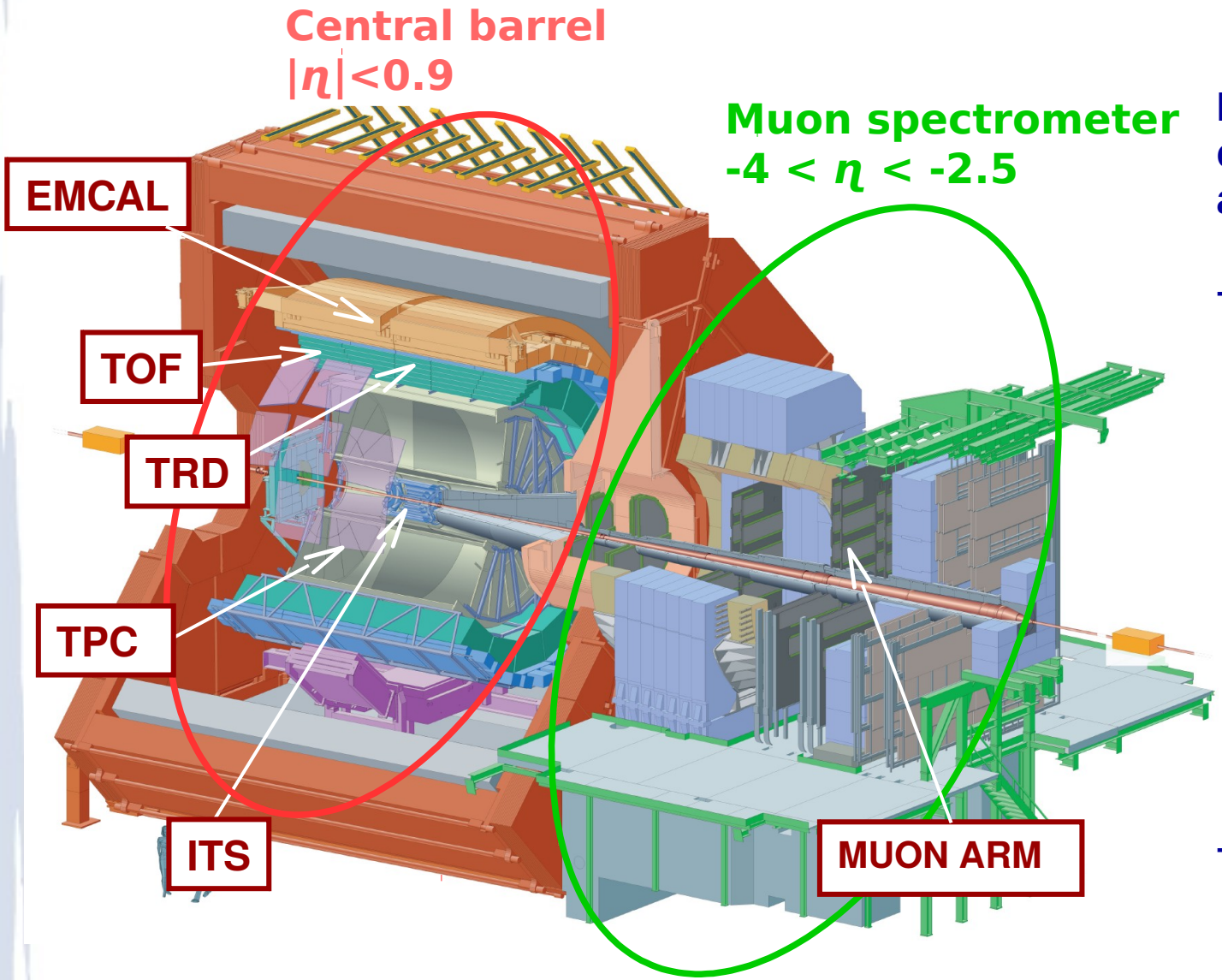
    - $v_2>0$ for HF hadrons → collectivity of heavy quarks in the QGP (low p_T)

  - Recombination mechanism (at low p_T):

    - predicts that the strange/non-strange (D_s/D) and baryon/meson (Λ_c/D, Λ_b/B) ratios are enhanced w.r.t. pp

- Complementary studies at central / forward rapidity → unique tool to study QGP with different densities at LHC

HF measurements in ALICE



Heavy-flavour decay channels currently addressed in ALICE:

– Central barrel:

$D^0 \rightarrow K^-\pi^+$
$D^+ \rightarrow K^-\pi^+\pi^+$
$D_s^+ \rightarrow K^-K^+\pi^+$
$D^{*+} \rightarrow D^0\pi^+$
$\Lambda_c^+ \rightarrow pK^-\pi^+$ (pp,pPb only)
$\Lambda_c^+ \rightarrow p\,K_s^0$ (pp,pPb only)
$B \rightarrow J/\psi+X$
$D/B \rightarrow e+X$
$B \rightarrow e+X$

– Muon spectrometer:

$D/B \rightarrow \mu+X$

Plenary talk by R. Bailhache
Parallel talks by: A. M. Barbano, F. Bossù, A. Festanti, C. Terrevoli

Objectives of the future HF program in ALICE

- Interesting results obtained from the Run1 data, but there are still open points → goals of the future HF program:

- Central rapidity:
  - **D mesons**: high-precision measurement down to very **low-p_T**
  - Exclusive reconstruction of the **charm baryon Λ_c**
    (proper decay length, $c\tau$, only 60 μm)
  - Exclusive reconstruction of **beauty mesons and baryons**

- Forward rapidity:
  - Precise determination of the muon production point →
    - **charm/beauty separation** in single muons
    - Beauty measurement via **non-prompt J/ψ**
  - **Reduce background from π/K decays** and the corresponding systematic uncertainties induced by background subtraction for HF-decay muon measurements at low p_T

The ALICE Upgrade strategy

Plenary talk by A. Dainese

- **Physics goal:** high precision measurements of rare probes at low p_T which cannot be selected with a dedicated trigger (very low signal/background)

- **Requirements:**
  - Very high statistics minimum bias sample: target $L_{int} = 10 nb^{-1}$ → x100 w.r.t. Run2 minimum-bias
  - Improve spatial precision on track and vertex position

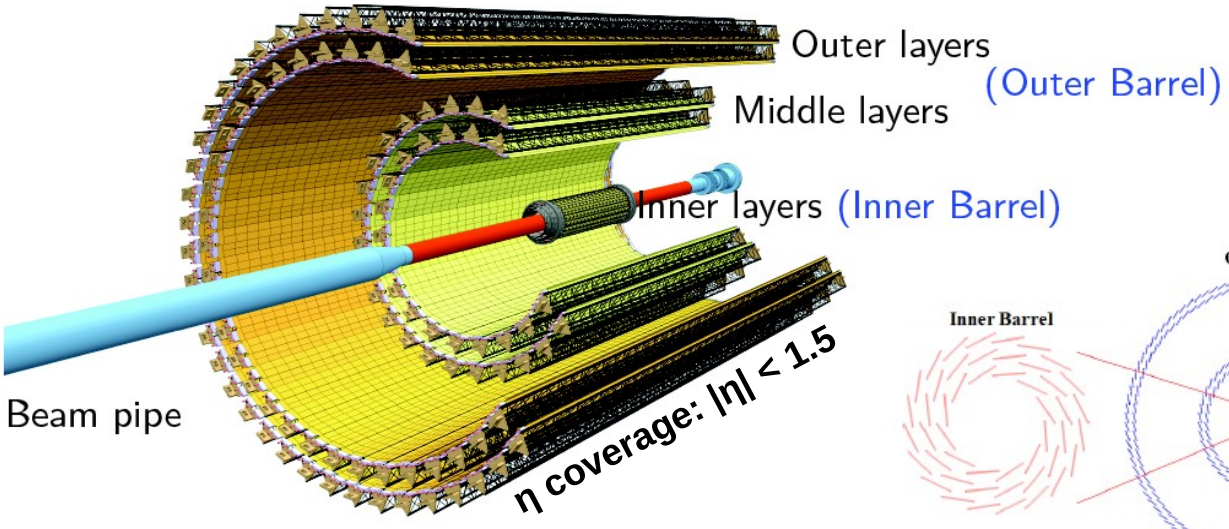
- **Strategy:**
  - Upgrade read-out (for several detectors) and new online-offline system → read out all Pb-Pb interactions at a maximum rate of 50 kHz with a minimum bias trigger
    - Upgrade of the Time Projection Chamber (TPC) (replacing MWPCs with micro-pattern gaseous detectors)
  - New Silicon Trackers:
    - Upgraded ITS at mid rapidity
    - New Muon Forward Tracker (MFT) at forward rapidity

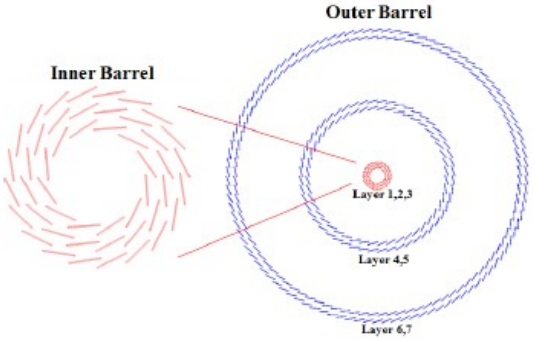
[Upgrade of the ALICE Experiment, Letter of Intent: CERN-LHCC-2012-012]
[Addendum to the Letter of Intent, The Muon Forward Tracker: CERN-LHCC-2013-014]

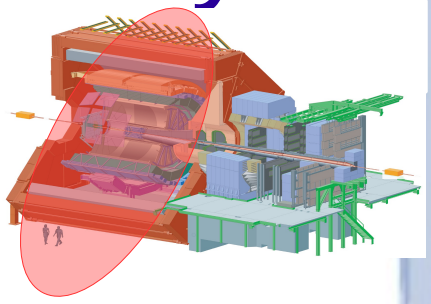
Layout and detector performance for ITS and MFT

The upgraded ITS at mid rapidity

[Upgrade of the Inner Tracking System, ALICE-TDR-017]





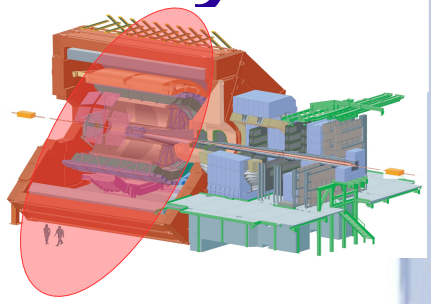


New ITS layout → 7 cylindrical layers of Monolithic Active Pixel Sensors (MAPS)

Design goals of the new ITS:

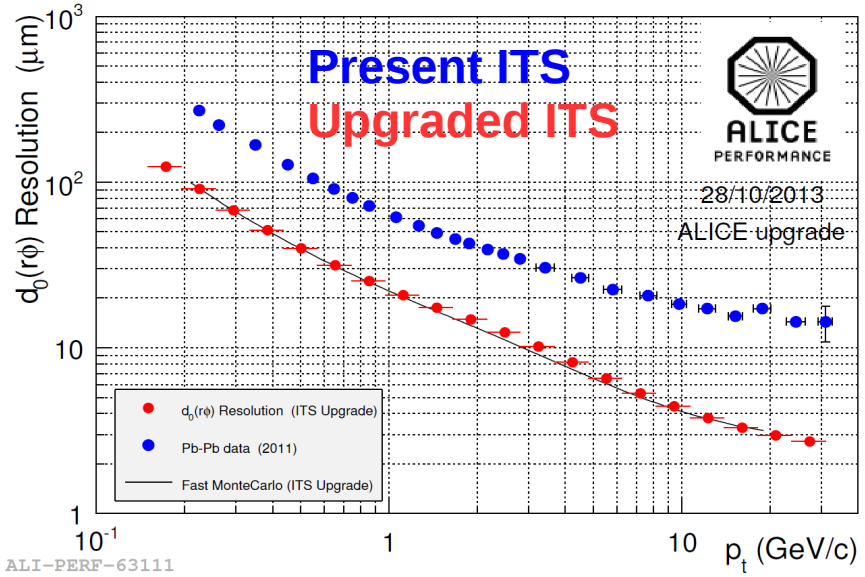
- ✔ Improve impact parameter resolution by a factor ~3 (6) in rφ (z)
  - ✔ get closer to the IP: first layer at r_0 = 23 mm (currently 39 mm) and beam pipe radius r_{bp}=18.6 mm (currently 29.4 mm)
  - ✔ material budget: 0.3% X_0 per layer for the three innermost layers (currently 1.1% X_0)
  - ✔ smaller pixel size: o(30μm × 30μm) (currently 50μm × 425μm)
- ✔ Improve tracking efficiency and p_T resolution especially at low p_T: increase number of layers to 7 (currently 6 layers) and granularity
- ✔ Fast readout: up to 100 kHz in Pb-Pb, up to 400 kHz in pp (currently 1 kHz in Pb-Pb)

The upgraded ITS at mid rapidity



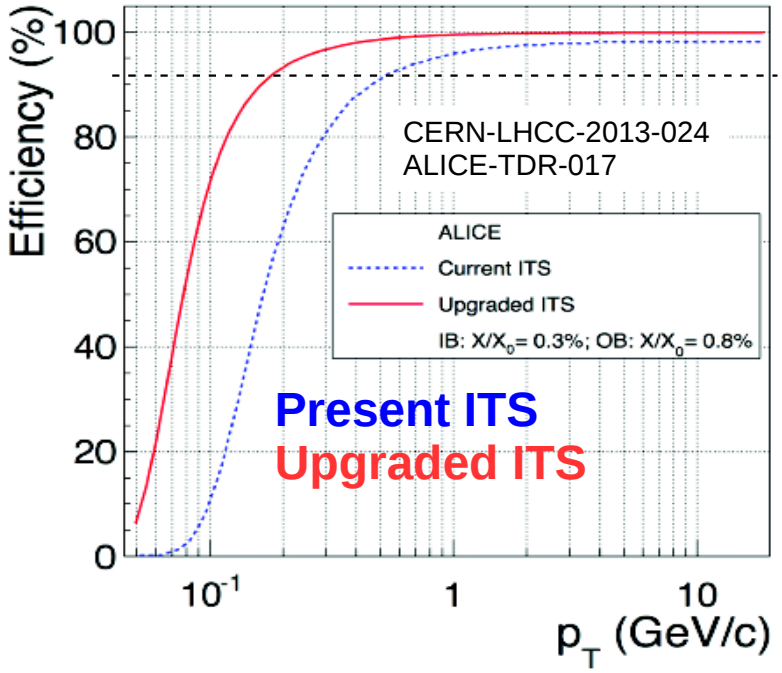
✔ **Detector performance studies:**
performed with simulations with realistic and complete detector geometry and material budget description

Impact parameter resolution



✔ Impact parameter resolution in rφ improved by a factor ~3

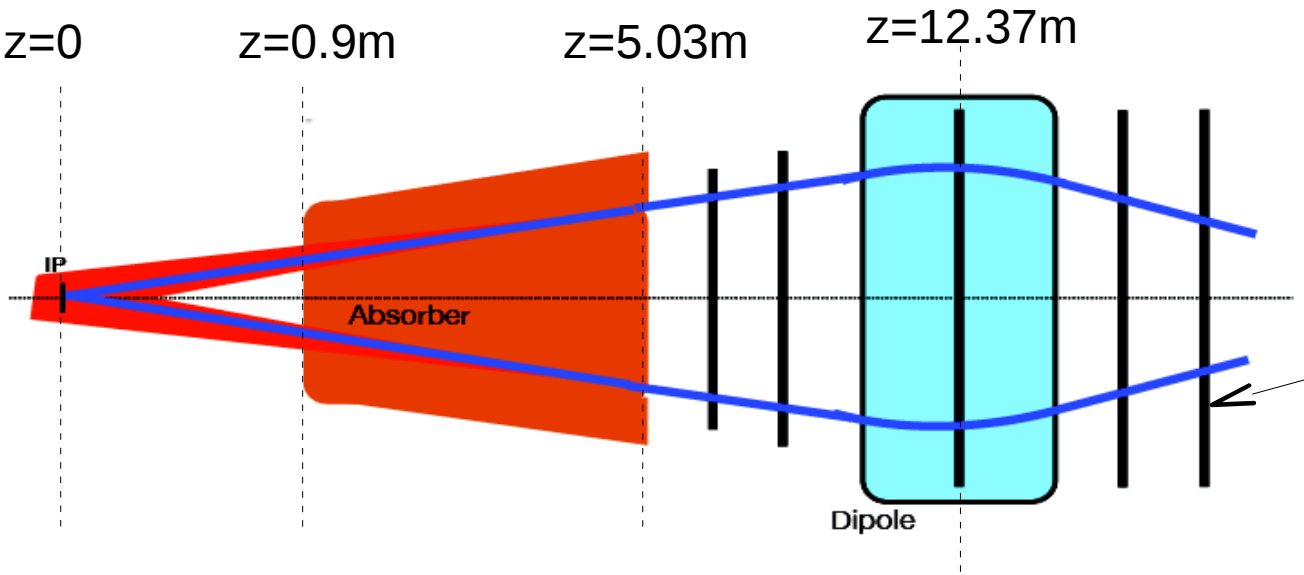
Track reconstruction efficiency

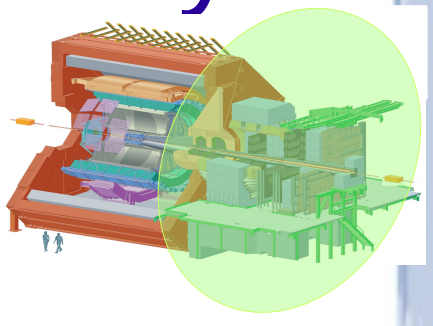


✔ Track reconstruction efficiency ~90% at p_T=0.1-0.2 GeV/c

The new MFT at forward rapidity

Simplified sketch of the present muon spectrometer





Tracking stations (cathode pad chambers)

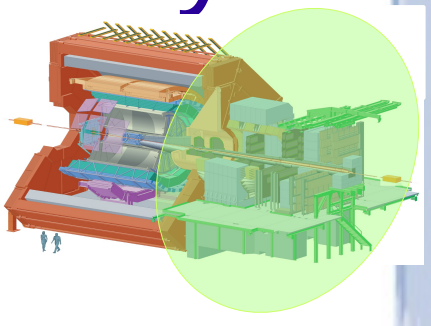
The extrapolation of the muon track candidates to the interaction region is affected by the presence of the absorber (large multiple scattering)

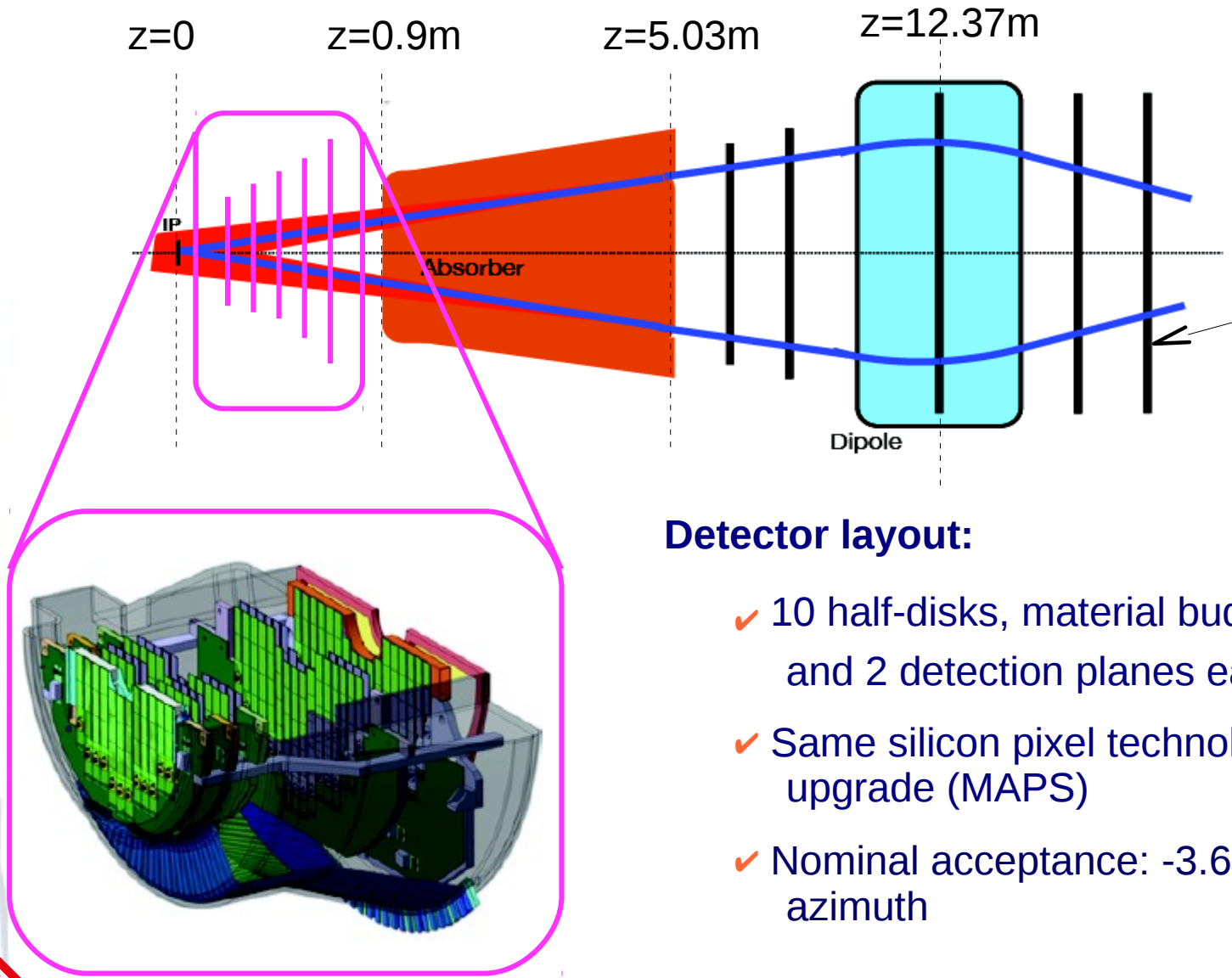
→ no constraints in the region of primary vertex are available with the present muon spectrometer !

The new MFT at forward rapidity

Simplified sketch of the present muon spectrometer **+ MFT**

[Muon Forward Tracker, ALICE-TDR-018]





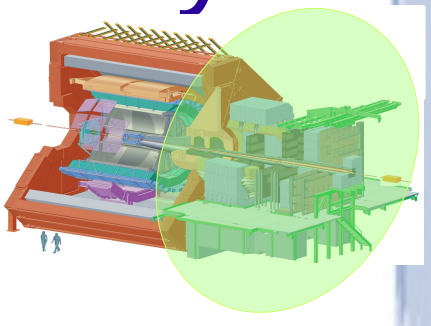
Detector layout:

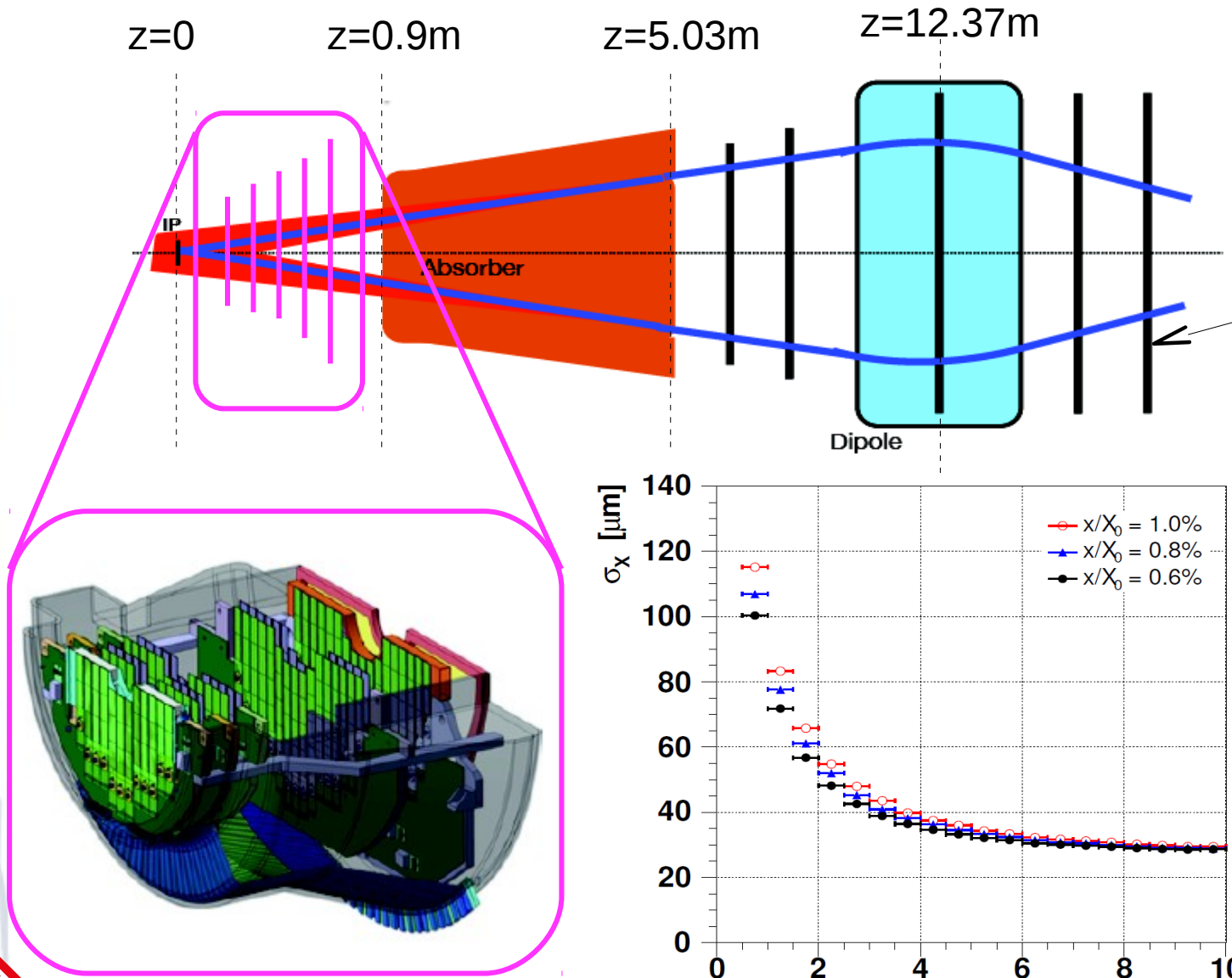
- ✔ 10 half-disks, material budget of about 0.6% X_0 and 2 detection planes each
- ✔ Same silicon pixel technology as the ITS upgrade (MAPS)
- ✔ Nominal acceptance: $-3.6 < \eta < -2.3$, full azimuth

The new MFT at forward rapidity

Simplified sketch of the present muon spectrometer **+ MFT**

[Muon Forward Tracker, ALICE-TDR-018]





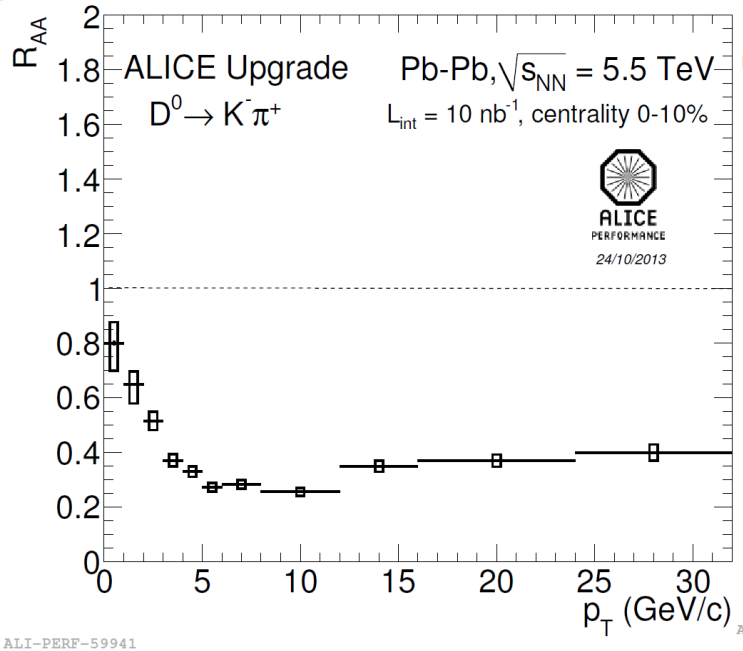
Tracking stations (cathode pad chambers)

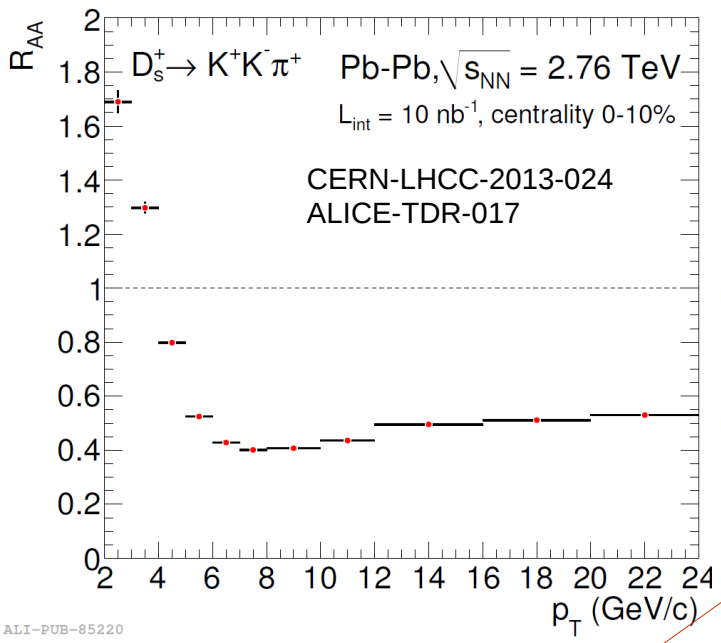
- ✔ Design thickness of 0.6% allows us to achieve <100 μm resolution above 1 GeV/*c*

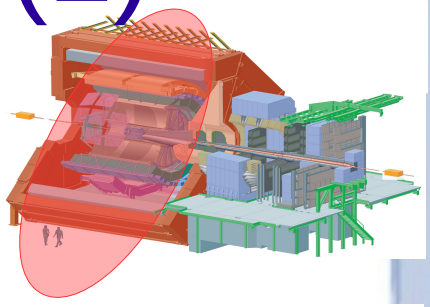
ALI-PUB-93

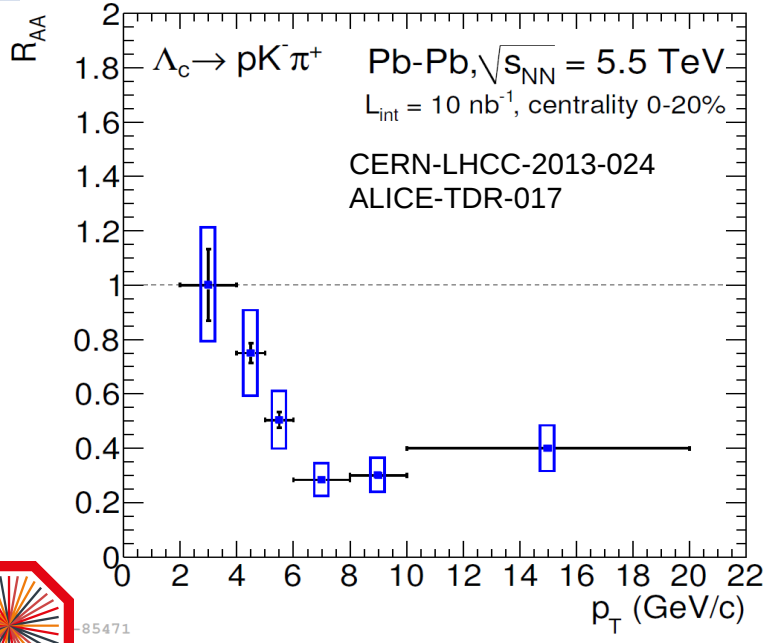
Heavy Flavour Physics performance (selected highlights)

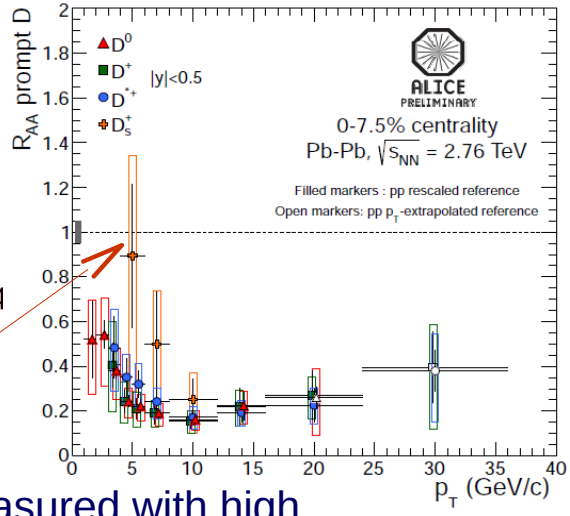
Open charm at mid-rapidity (1)







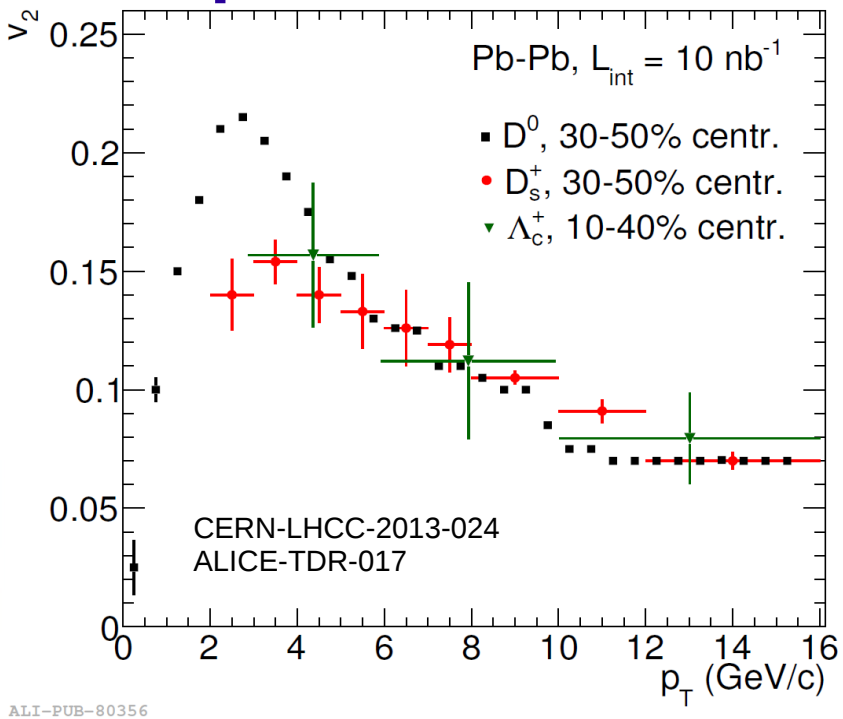


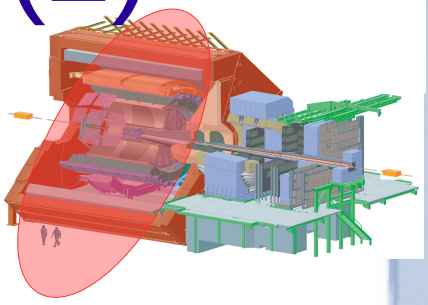


Current $R_{AA}(D_s)$ measurements

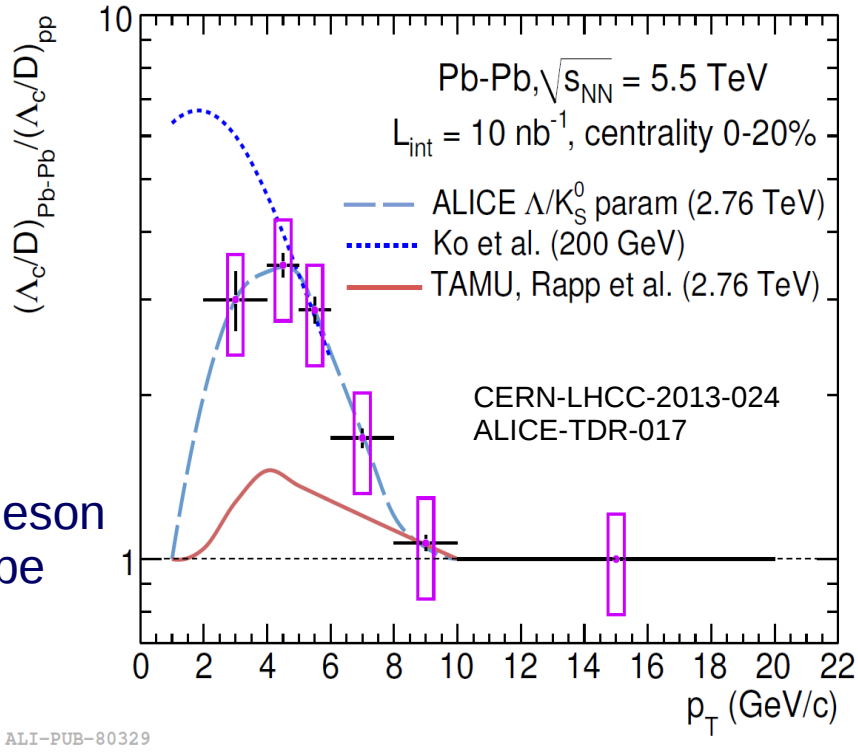
- Prompt D meson R_{AA} will be measured with high accuracy down to $p_T = 0$
  - Search for "strangeness enhancement" in the HF sector accessible with high precision
- Λ_c measurements will be available for the first time in Pb-Pb collision
  - Require excellent spatial resolution ($c\tau \approx 60$ μm) and PID capabilities
  - significant measurement expected for $p_T > 2$ GeV/c

Open charm at mid-rapidity (2)





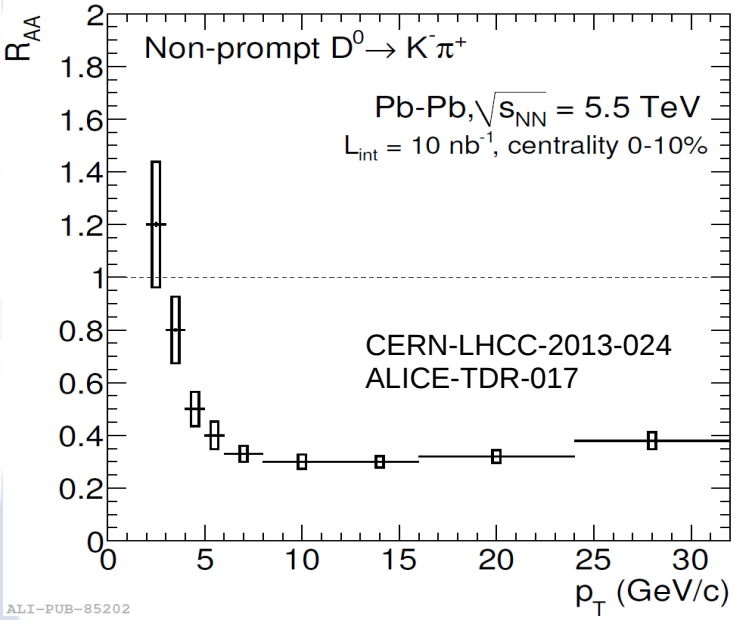
- v_2 measurements available for charm mesons and baryons down to very low p_T



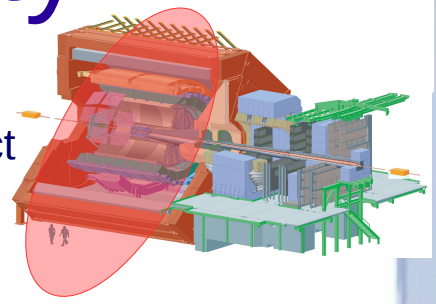
- the ratio baryon / meson for charm Λ_c/D will be measured in Pb-Pb

R_{AA} and v_2 measurements simultaneously available for several charm hadrons → powerful tool to constrain models !

Open beauty at mid-rapidity

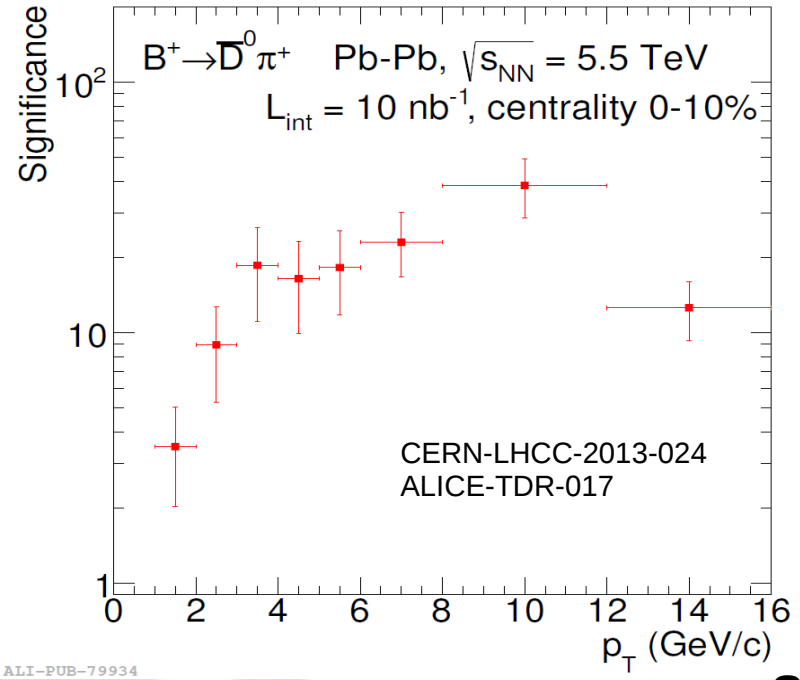


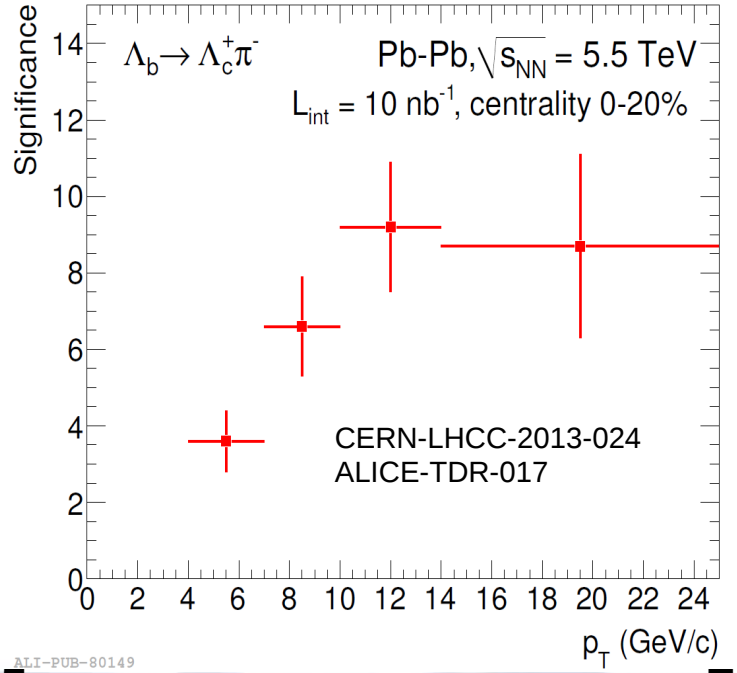
- Inclusive beauty hadron production:
  - via displaced D^0 → by exploiting impact parameter distributions
  - via displaced J/ψ (→ see next slide)
- Full kinematic reconstruction for beauty mesons and baryons by studying their specific decay topologies



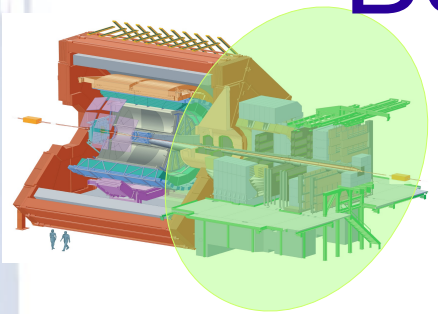
$B^+ \rightarrow \overline{D^0}\pi^+ (\overline{D^0} \rightarrow K^+\pi^-)$ $\quad$ $\Lambda_b \rightarrow \Lambda_c^+\pi^- (\Lambda_c^+ \rightarrow pK^-\pi^+)$

⇒ New measurements available at very low p_T !

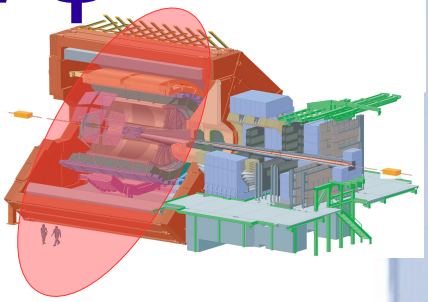




Beauty via non-prompt J/ψ



- ✔ Significantly improved w.r.t. Run1/Run2 at mid-rapidity
- ✔ Available for the first time at forward rapidity



$B \to J/\psi(\to \mu\mu)+X$ at forward rapidity ⟵ Studied decay channels ⟶ **$B \to J/\psi(\to ee)+X$ at mid-rapidity**

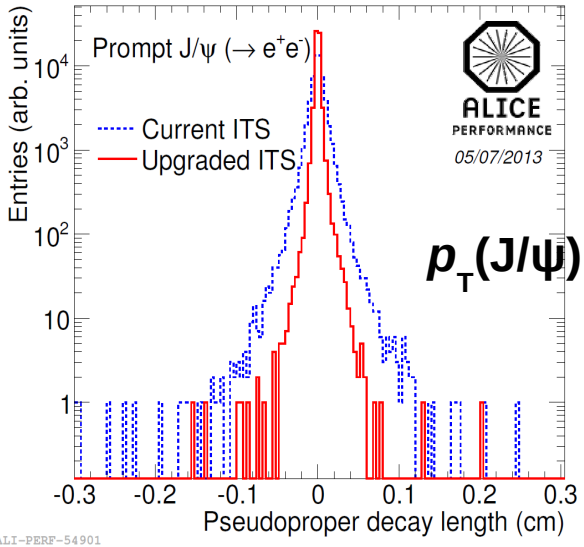
- ✔ Strategy: double (simultaneous) fit of the invariant mass of the pair and the "pseudo-proper" decay length:

$$l_z = L_z(J/\psi)\frac{M(J/\psi)}{p_z(J/\psi)}$$

Pseudo-proper decay length to separate prompt/displaced J/ψ properly defined

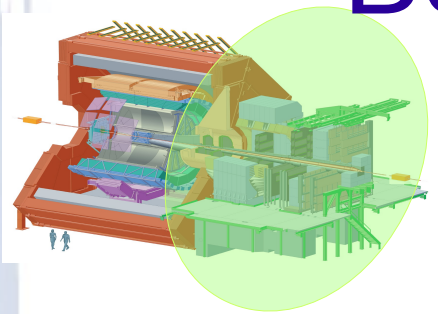
$$l_x = L_{xy}(J/\psi)\frac{M(J/\psi)}{p_T(J/\psi)}$$

- ✔ Pseudo-proper decay length resolution at mid-rapidity improved by a factor ~3 w.r.t. the current one

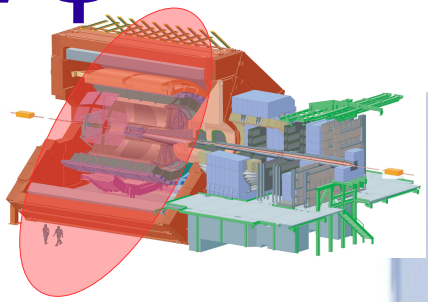


$p_T(J/\psi) > 1.3$ GeV/c

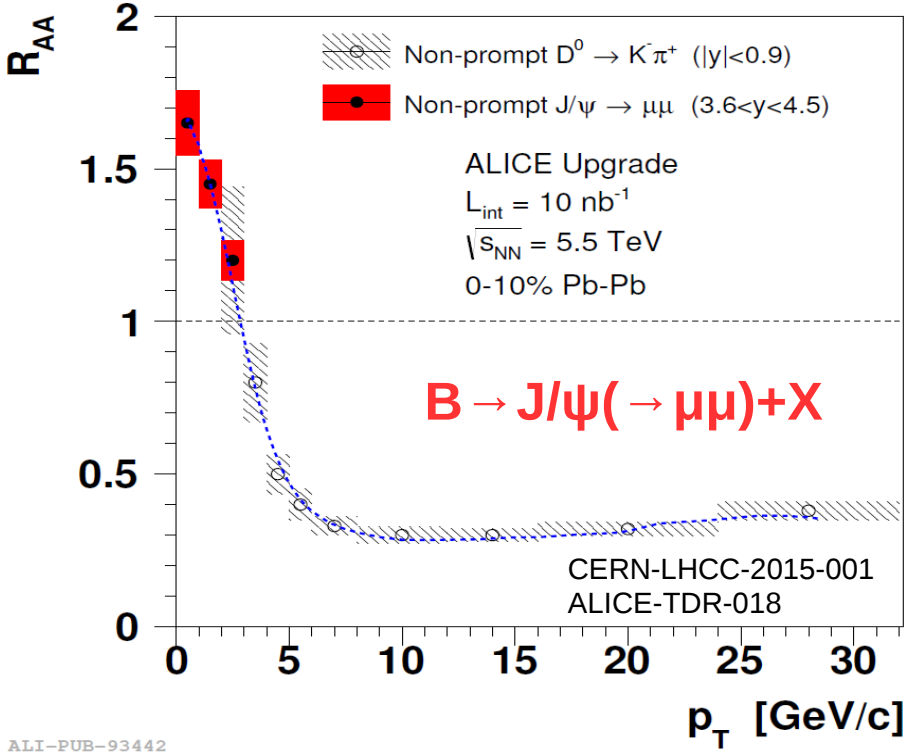
Beauty via non-prompt J/ψ

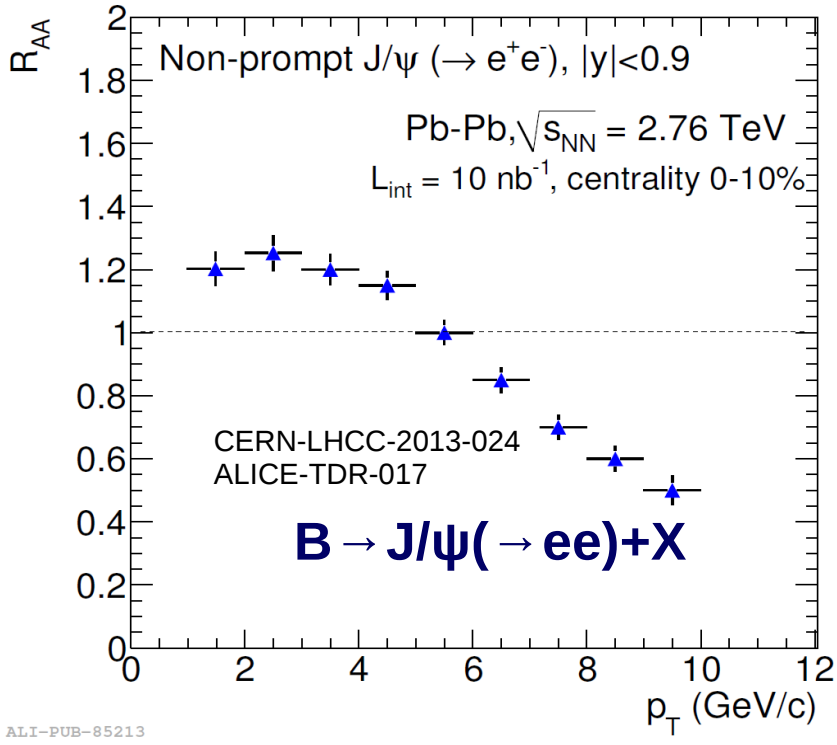


- ✔ Significantly improved w.r.t. Run1/Run2 at mid-rapidity
- ✔ Available for the first time at forward rapidity



$B \rightarrow J/\psi(\rightarrow \mu\mu)+X$ at forward rapidity ⟵ Studied decay channels ⟶ **$B \rightarrow J/\psi(\rightarrow ee)+X$ at mid-rapidity**

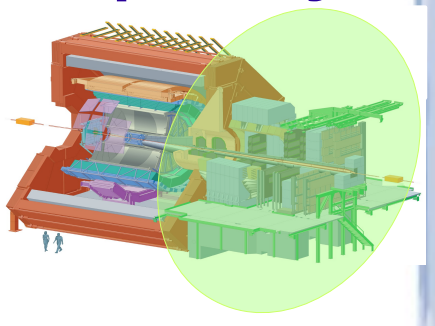


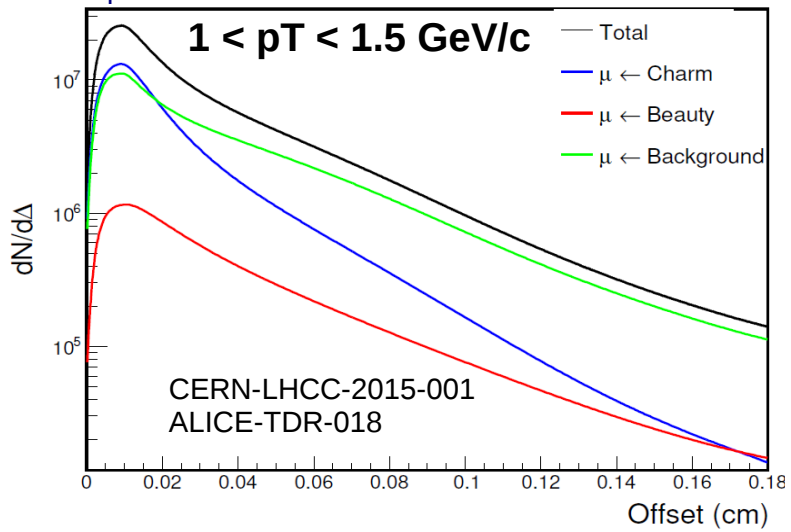


⟹ Non-prompt J/ψ (i.e. beauty) R_{AA} measurements available in a large rapidity window with high accuracy and down to very low p_T!

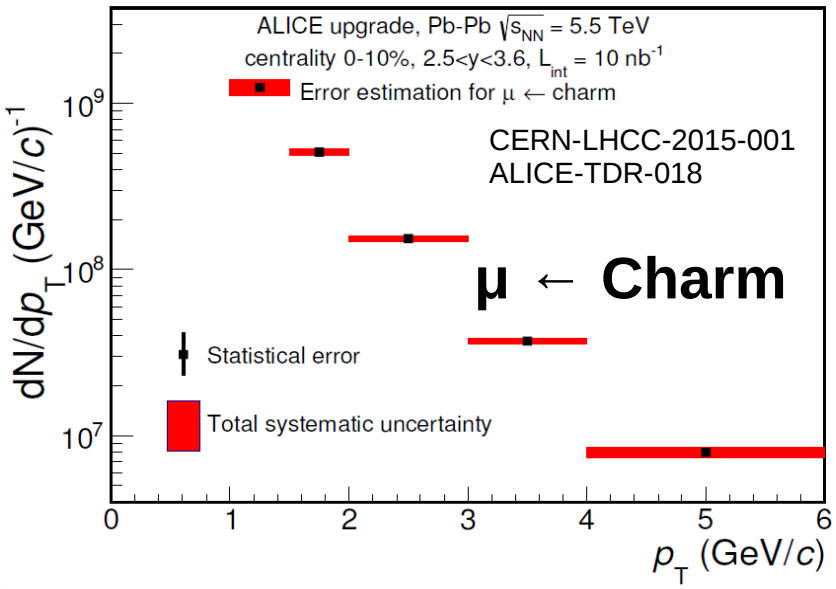
HF via single muons at forward rapidity

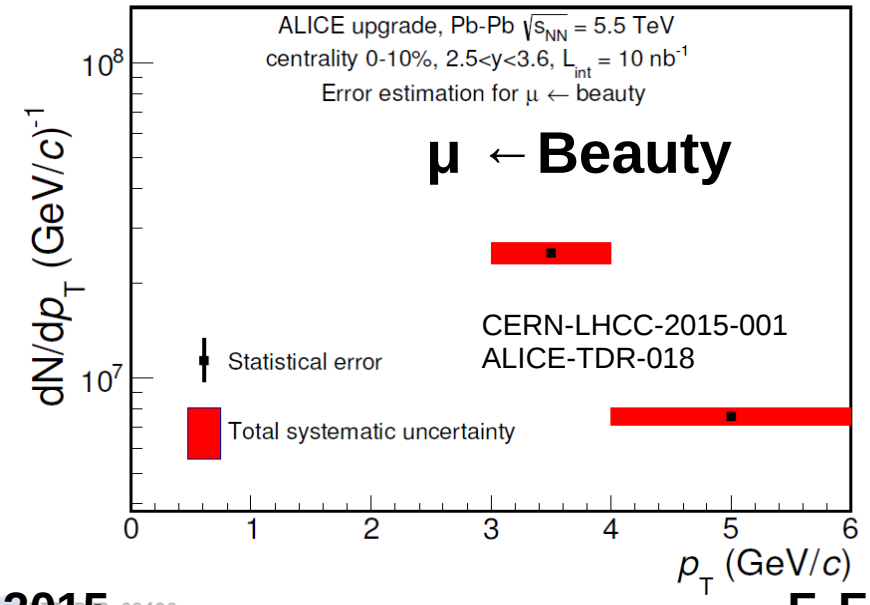
- ✔ Goal: measure separately c-decay / b-decay muon production (flow)
- ✔ Strategy: template fit of track-to-vertex offset (in xy) distribution in narrow p_T intervals





- ✔ Statistical uncertainty very small (~0.1%) assuming $10 nb^{-1}$
- ✔ Charm and beauty yields accessible from $p_T(\mu)$=1 and 3 GeV/c respectively
- ✔ Important baseline for charmonium measurements



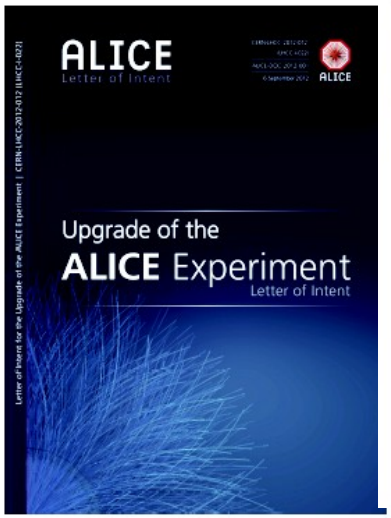


Conclusions

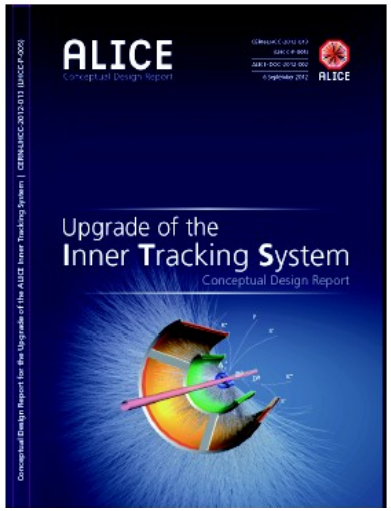
- ✔ New detectors will be installed during the Long Shutdown 2 and will be ready for the Run3 of LHC foreseen from 2020
- ✔ The installation of the new pixel trackers, ITS and MFT, will significantly extend the ALICE physics reach in the HF sector in a large rapidity window:
  - ✔ Improved precision for existing measurements down to p_T=0
  - ✔ New and unique measurements in both charm and beauty sectors

Charm and beauty era of the QGP!

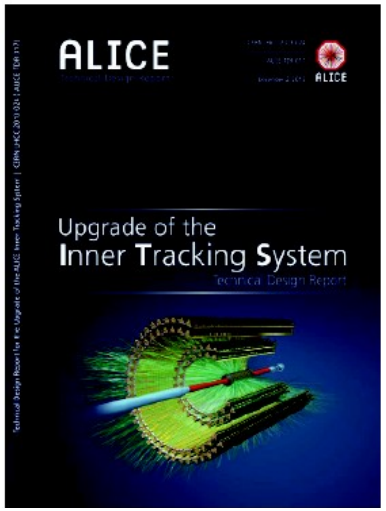
Find much more in:



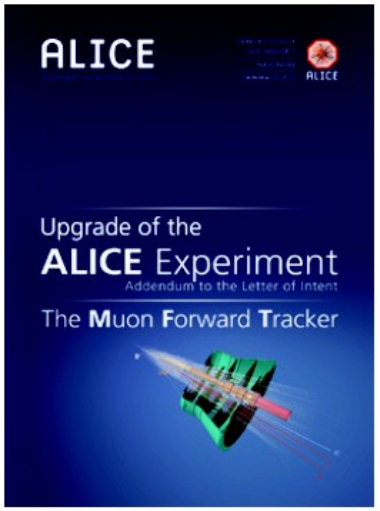
CERN-LHCC-2012-012
LHCC-I-022, 2012.



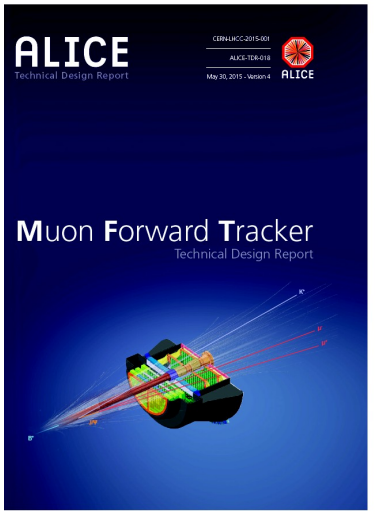
CERN-LHCC-2012-005
LHCC-G-159,2012.



CERN-LHCC-2013-024
ALICE-TDR-017



CERN-LHCC-2013-014
LHCC-I-022-ADD-1



CERN-LHCC-2015-001
ALICE-TDR-018