Prospects for heavy flavour measurements with the ALICE inner tracker upgrade

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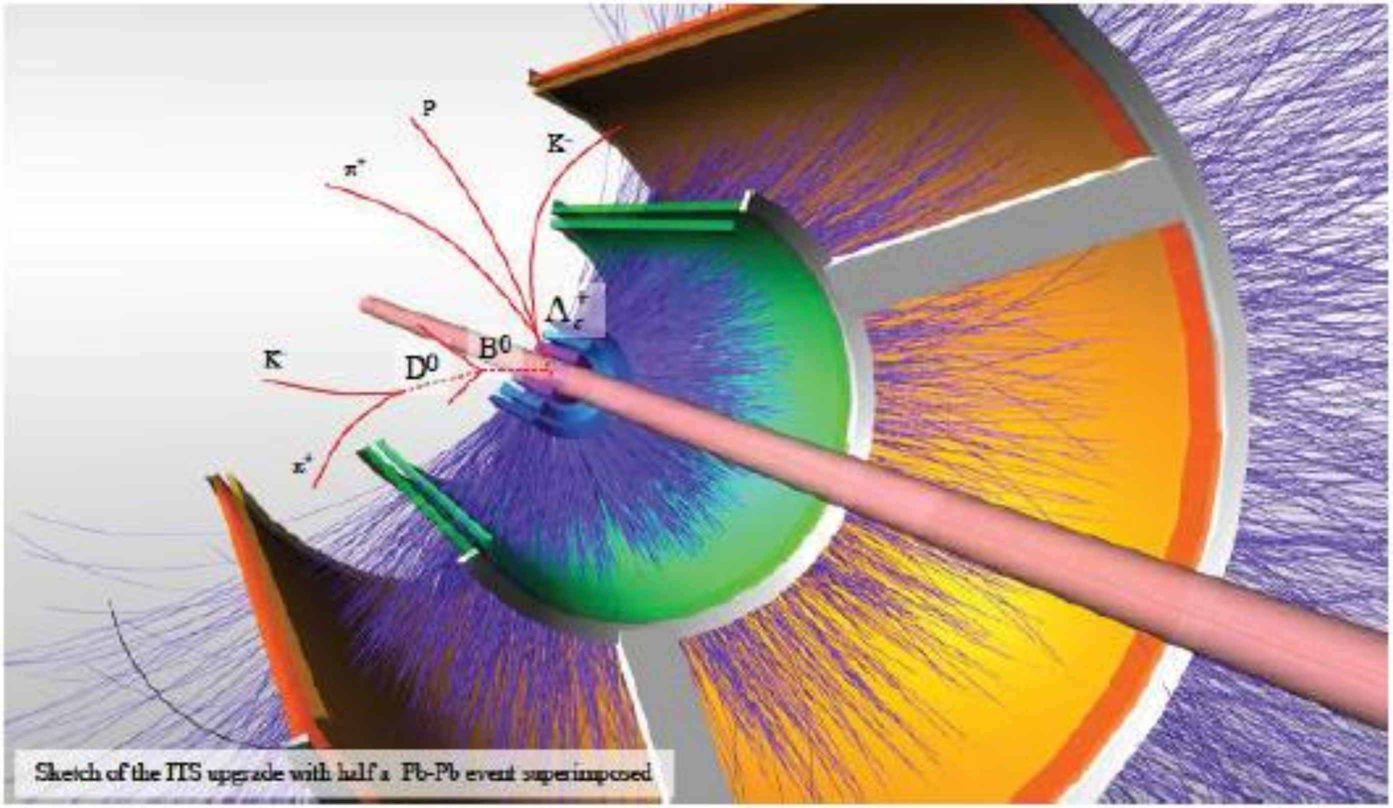

BIRMINGHAM
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SQM 2013

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Birmingham, United Kingdom

Outline

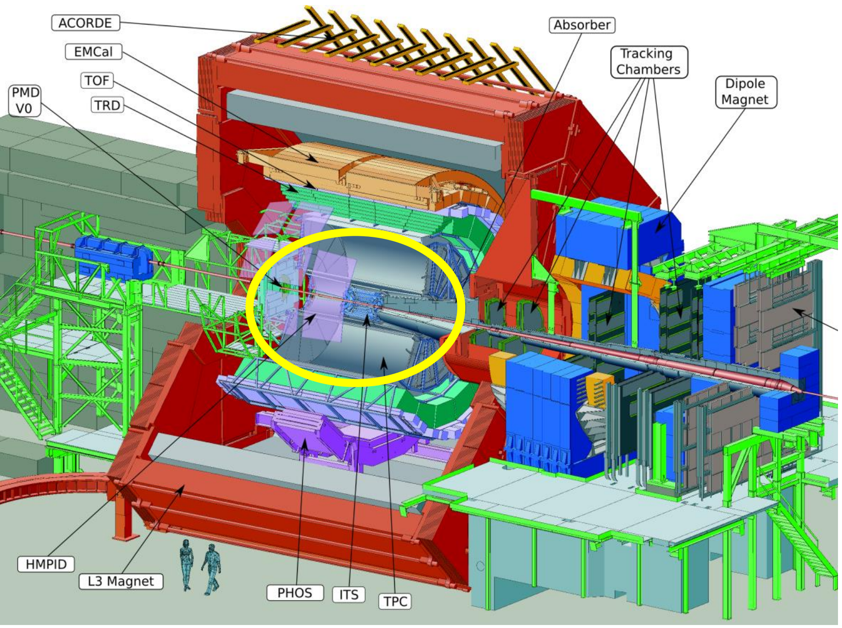
- ALICE Upgrade physics program
- Inner Tracking System (ITS)
- Heavy Flavour Performance in ALICE with the current ITS
- How to Upgrade?
- Physics performances with the ITS Upgrade
- Conclusion

ALICE
Inner Tracking System
Upgrade Physics program

ALICE is the general purpose Heavy-ion detector at the CERN LHC

Investigate properties of strongly interacting matter under extreme conditions of compression and temperature in Pb-Pb collisions - Characterization of the Quark-Gluon Plasma (QGP)

The upgrade of the ALICE inner tracker detector targets physics topics in which ALICE can bring a unique contribution in QGP characterization, among others, via heavy flavour probes

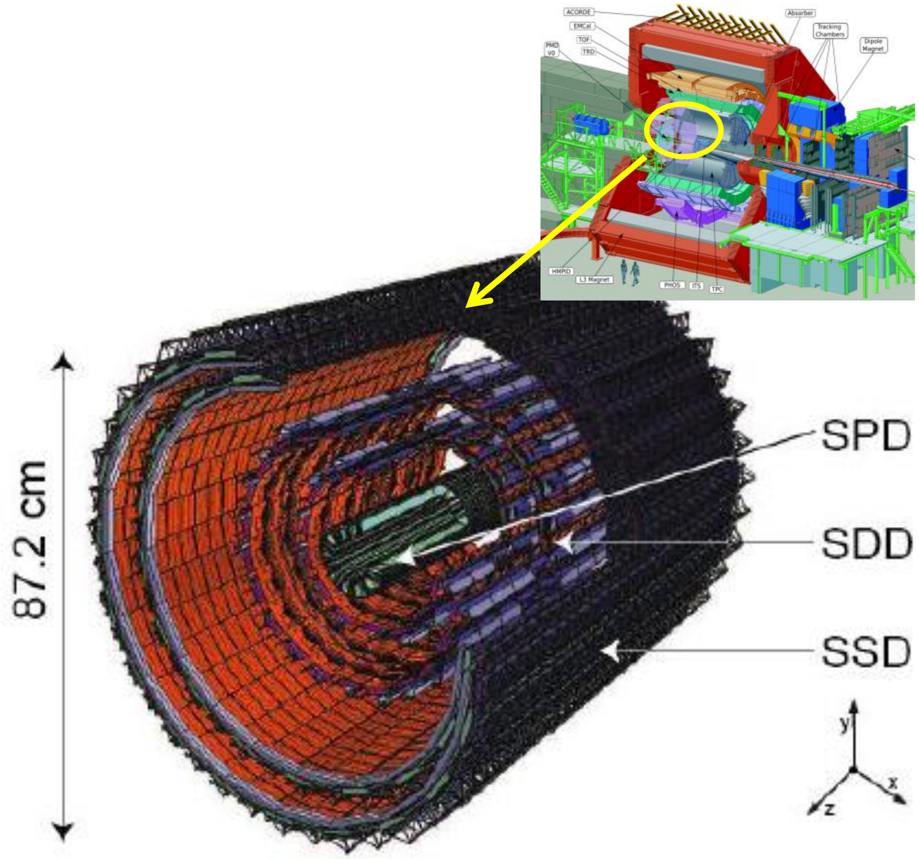


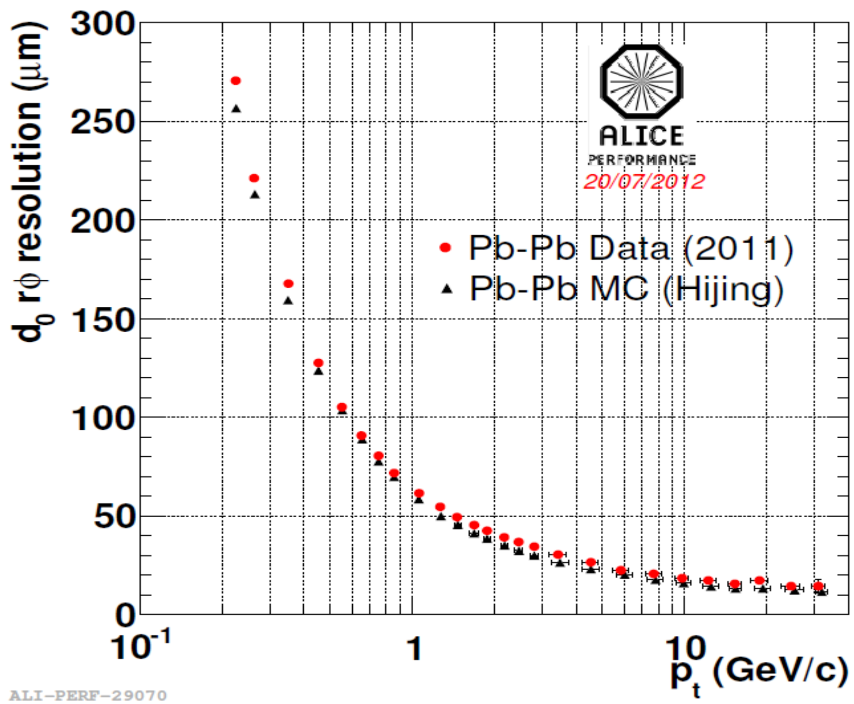
- Measurements of heavy flavour transport parameters in QGP via the probe-medium interaction
  - Heavy flavour azimuthal anisotropy and R_{AA}
  - Heavy Flavour baryon-to-mesons ratio
  - Mass dependence of energy loss
    → heavy flavour R_{AA} down to low p_T

Current Inner Tracking System

Capability to separate primary and secondary vertex of heavy flavour hadrons is provided by **Inner Tracking System**

- 6 layers of silicon detectors (pixels, drift, strips)
- PID (drift and strips)
- Low material budget: 7.2% X_0 for whole ITS





Limit: resolution not sufficient for Λ_c (cτ= 60μm)
d_0 resolution>60 μm for p_t<1GeV/c
Impossible in Pb-Pb

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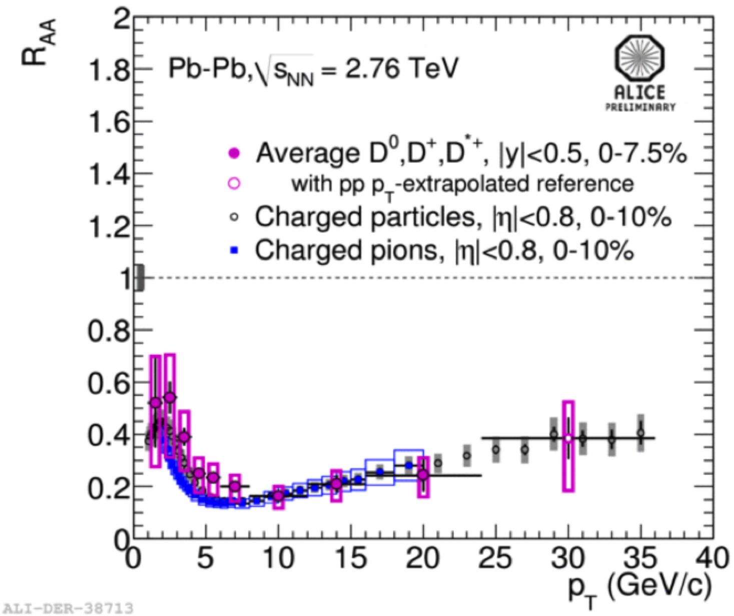
ALICE Performance
Characterization of QGP via Heavy Flavour
Mass dependence of Energy Loss

Theoretical predictions: $\Delta E_g > \Delta E_c > \Delta E_b$

- R_{AA} ratio between the particle yields per binary collision in Pb-Pb and pp, vs p_T

Expectations: $R_{AA}^{\pi} < R_{AA}^{D} < R_{AA}^{B}$ **(Y.L.Dokshitzer et al. Phys. Lett. B 519 (2001) 199.)**



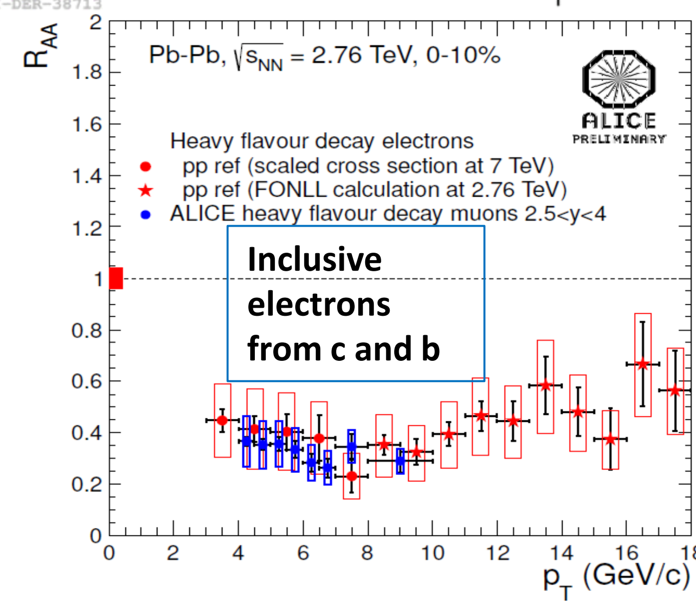
ALICE performance

D mesons R_{AA}

- High systematic uncertainties: the R_{AA} comparison is not conclusive
- *Upgrade: allow to reach p_T down to 0; improved tracking resolution and efficiency, and higher statistics will improve signal extraction providing higher significance*

B mesons R_{AA} → no measurements

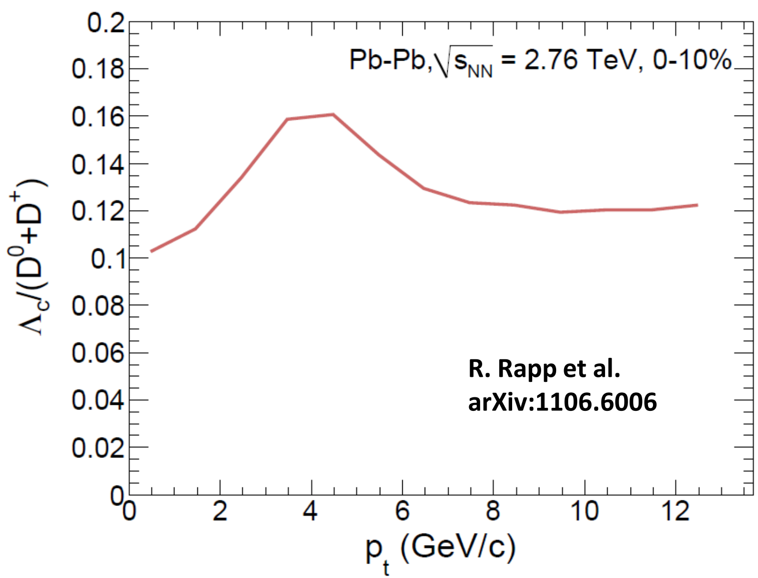
- B only via e+X and non-prompt J/ψ in pp;
- *Upgrade*: *open the way to the study of other channels (D^0 and J/ψ from B) allowed by improved performance and higher statistics*



ALICE Performance
Characterization of QGP via Heavy Flavour
In Medium hadronization

- Coalescence models predict an increase of baryon-to-meson ratio for light flavour and strange hadrons **(S.H.Lee Phys. Rev. Lett. 100, 222301 (2008))**
  - ✓ Observed for p/π and Λ/K ratio at intermediate p_T
- Prediction also for heavy flavour
  - Λ_c, Λ_b not accessible in Pb-Pb with current detector due to limited precision and statistics
- If coalescence contributes to charm hadronization
  - → D_s production is expected to be enhanced w.r.t other D at low p_T

❖*Upgrade: aim at measuring Λ_c/D and Λ_b/B ratios and D_S production improving tracking precision, statistics and extend the measurement to low p_T*



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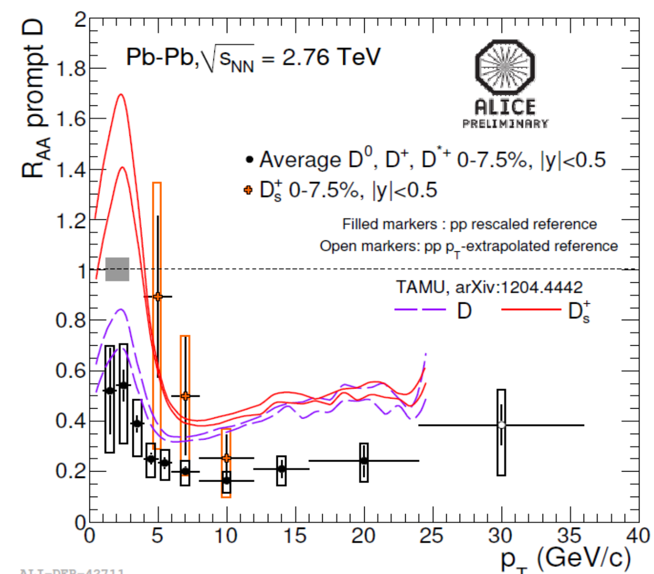


ALICE Performance
Characterization of QGP via Heavy Flavour Anisotropy

Elliptic flow v_2 sensitive to the thermalization of c and b in QGP

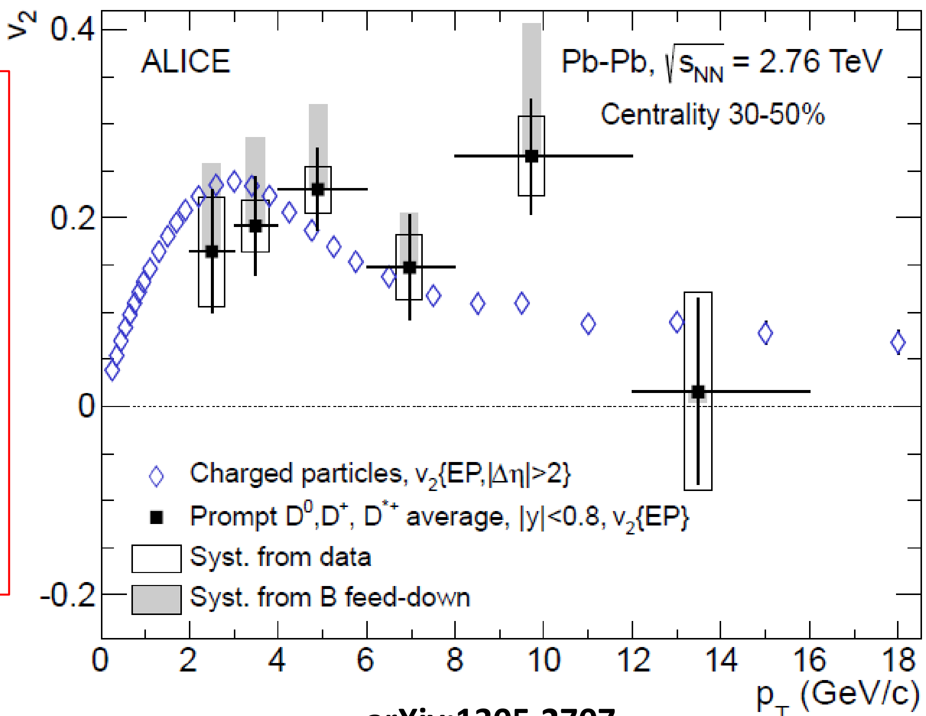
Models predicts **(S.A. Voloshin arXiv:0809.2949 [nucl-ex], J.Aichelin arXiv:1201.4192)**:

- large D mesons v_2 at low momentum
- Mass dependence of $v_2(B)<v_2(D)$

ALICE performance

- v_2 for D mesons down to 2 GeV/c
- Limited precision for D meson and measurement not possible for beauty v_2

❖ *Upgrade: down to 0 p_T for D meson v_2 ; also B v_2 will be accessible for the first time*



arXiv:1305.2707

ALICE

How To Upgrade the ITS

❑ Improve impact parameter resolution by a factor of ~3

- Get closer to IP
  - ✓ Beam pipe outer radius: r=17.2 mm (presently 29.8 mm)
  - ✓ First layer at 22 mm (presently 39 mm)
- Reduce material budget
  - ✓ 0.3% X_0 per pixel layer (presently 1.1%)
- Reduce pixel size
  - ✓ Pixel size (rϕ, *z*): 20-30, 20-50 μm (presently: 50 x 425 μm)

❑ High standalone tracking efficiency and p_T resolution

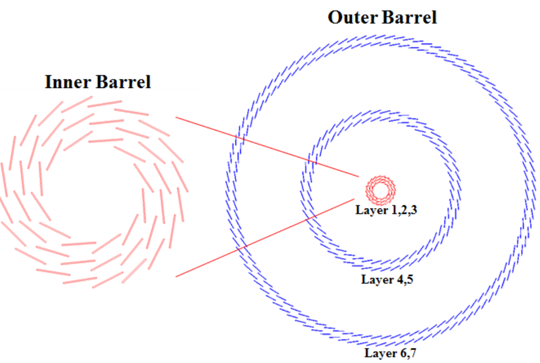
- Increase granularity pixels resolution 4 or 6 μm
- Increase number of layers 7 instead of 6

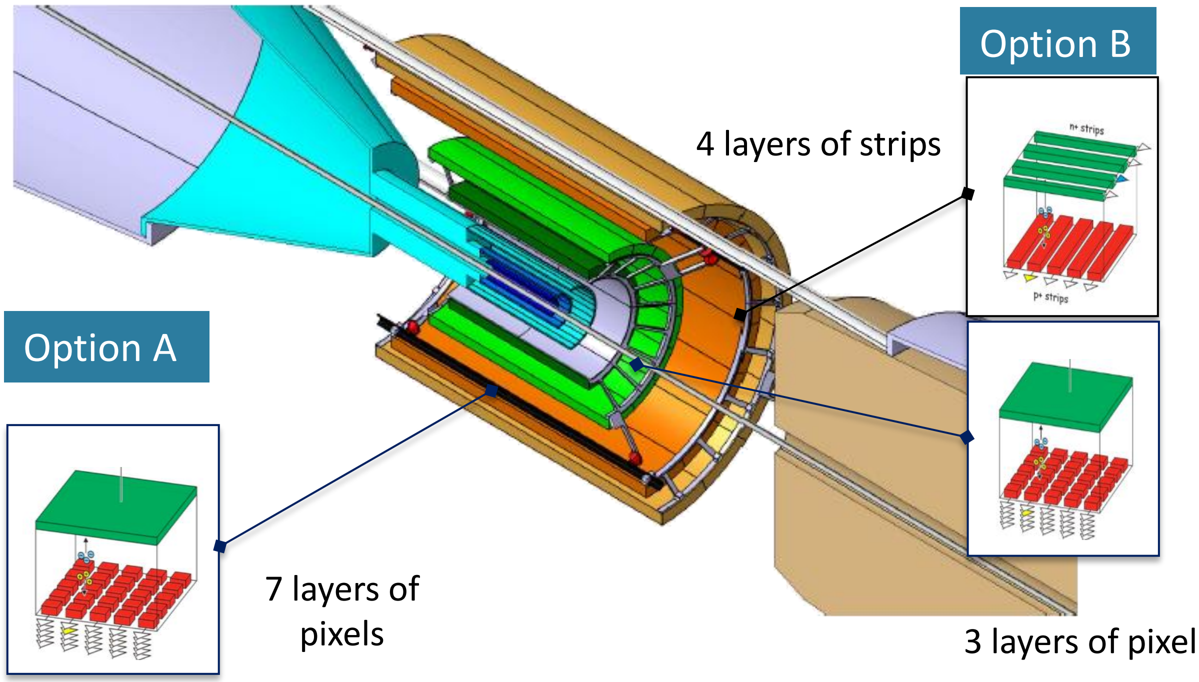
❑ Fast readout

- continuous readout of Pb-Pb interactions at > 50 kHz in order to exploit the upgrade LHC luminosity (>10 nb^{-1} in Pb-Pb that correspond to ~10^{10} central events)

➢ The global Upgrade ALICE program concerns also the upgrade of the other main central barrel detectors, including the Time Projection Chamber (TPC)

ITS Upgrade design options



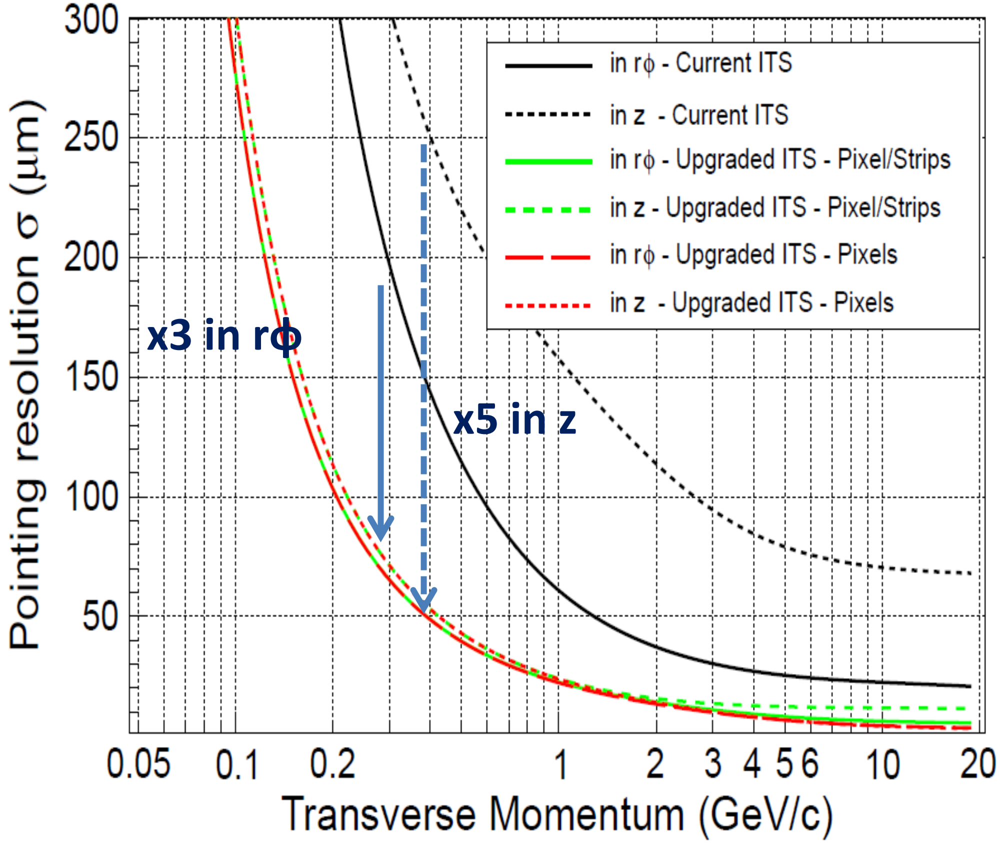


The upgrade is targeted for the second long shutdown (2017-2018).

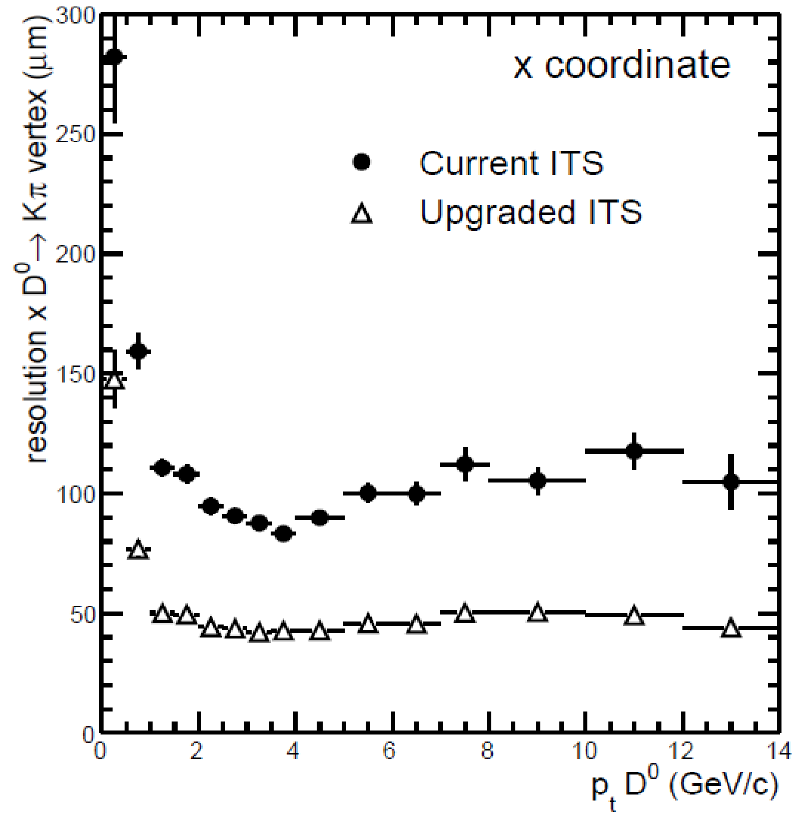
ITS Upgrade Conceptual Design Report:CERN-LHCC-2012-013
https:://aliceinfo.cern.ch/system/files/alice_upgrade/LHCC-P-005.pdf
Technical Design Report in preparation

ITS Upgrade Performance

Tracking resolution

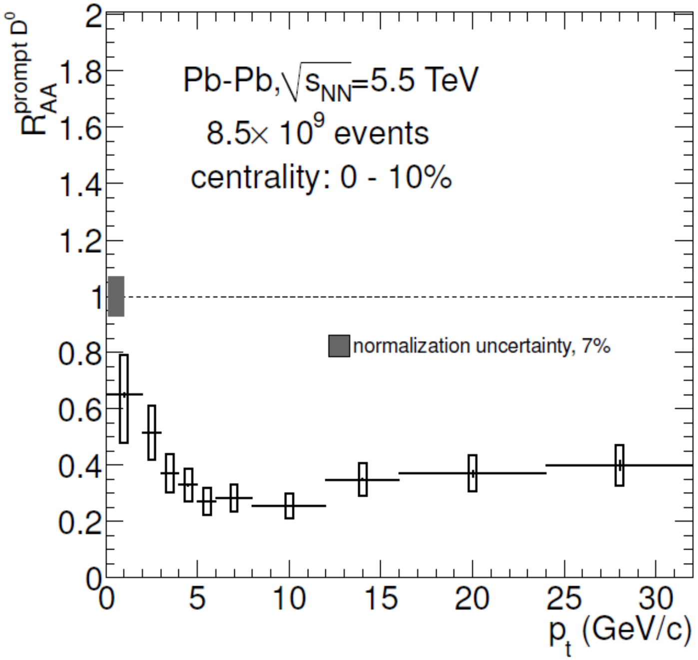


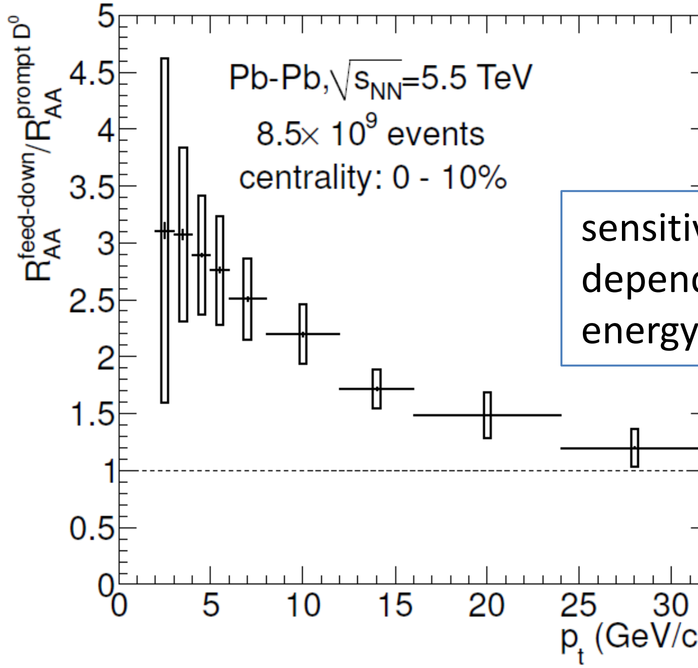
$D^0 \to K\pi$ secondary vertex resolution



- **tracking efficiency >90% down to 0.1- 0.2 GeV/c**
- **ITS stand-alone p_T resolution: improved by a factor ~2**

$D^0 \rightarrow K^-\pi^+$, D^0 from B, $D^{*+} \rightarrow K^-\pi^+\pi^+$



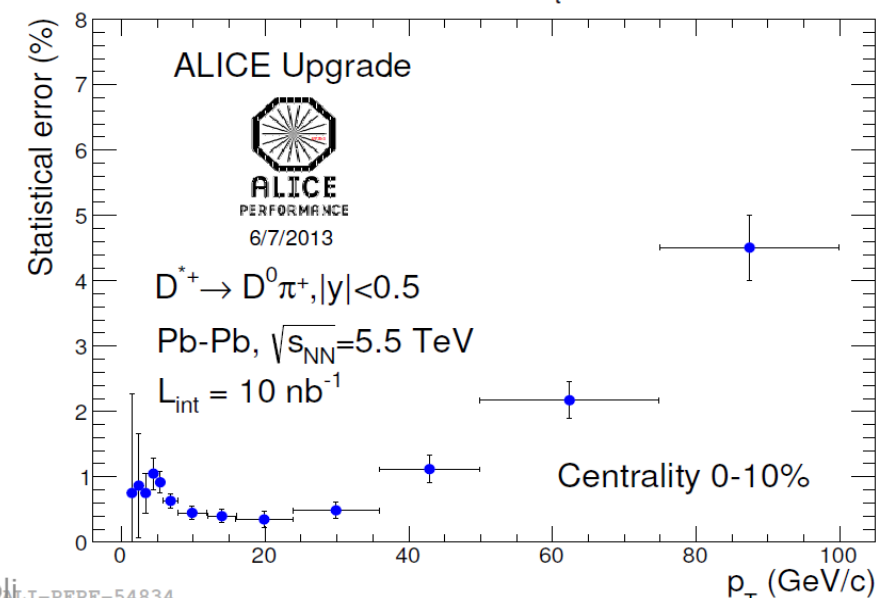


sensitive to mass dependence of energy loss

- ❖ D^0measurement down to $p_T \rightarrow 0$
  - conservative estimate of syst. errors based on current data
- ❖ Non-prompt D^0 to prompt D^0 ratio accessible

- ❖ D* analysis can be carried out in a wider p_T range (1-100 GeV/c) with high significance (20-100).

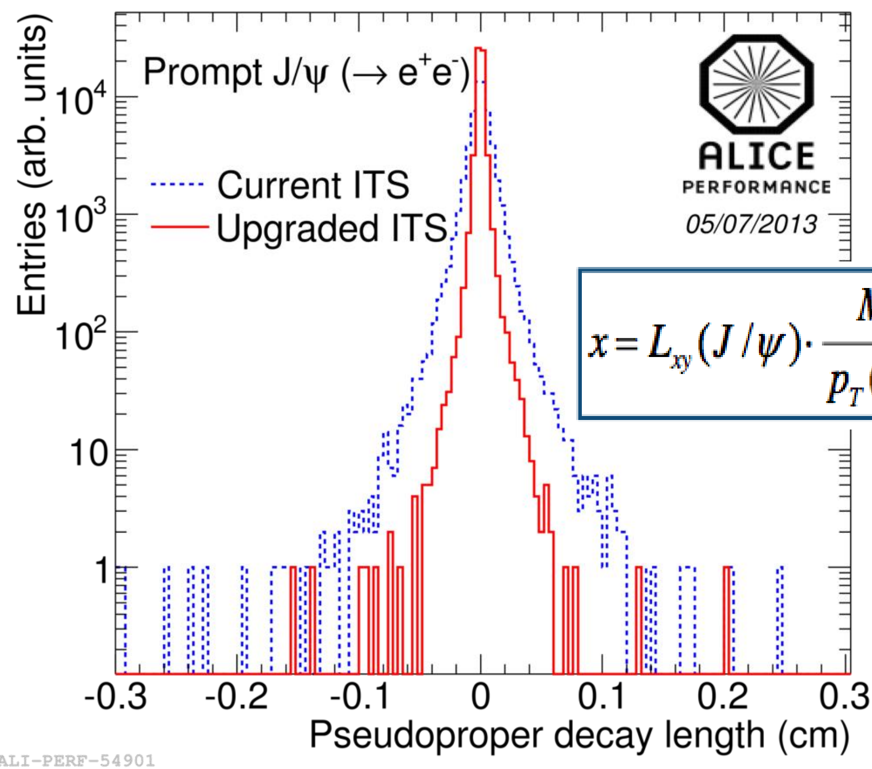
In data: performed in p_T range [3, 36] GeV/c significance 3-7



Beauty via displaced J/ψ→*ee*

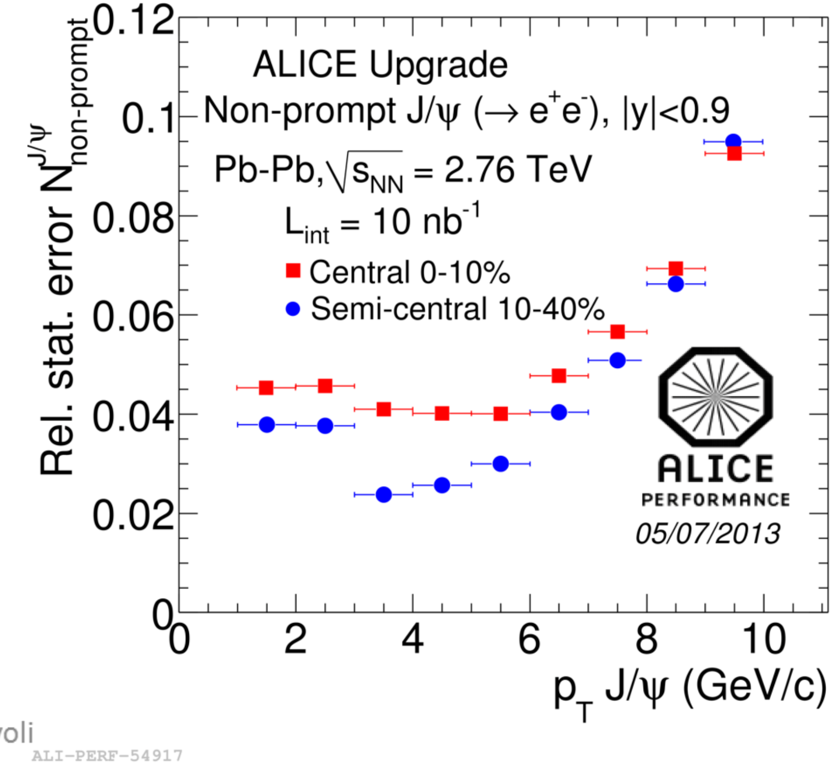
Direct measurement of beauty (via D^0 and J/ψ displaced) opens the possibility to measure with high precision the beauty energy loss (i.e. R_{AA}) and thermalization (i.e. v_2) covering a unique kinematic range (down to p_T ~1 GeV/c) at LHC

To separate prompt and secondary J/ψ (←B) the pseudo-proper decay length **x** is used



$$x = L_{xy}(J/\psi) \cdot \frac{M_{J/\psi}}{p_T(J/\psi)}$$

Precise measurement of non-prompt J/ψ R_{AA} from p_T=1 GeV/c



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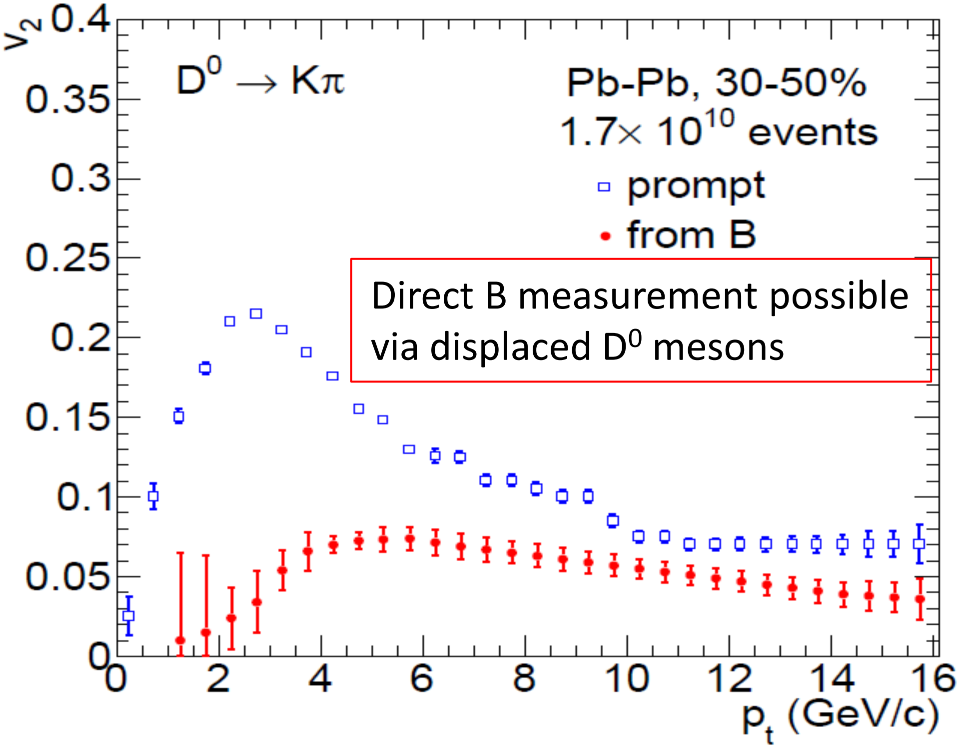
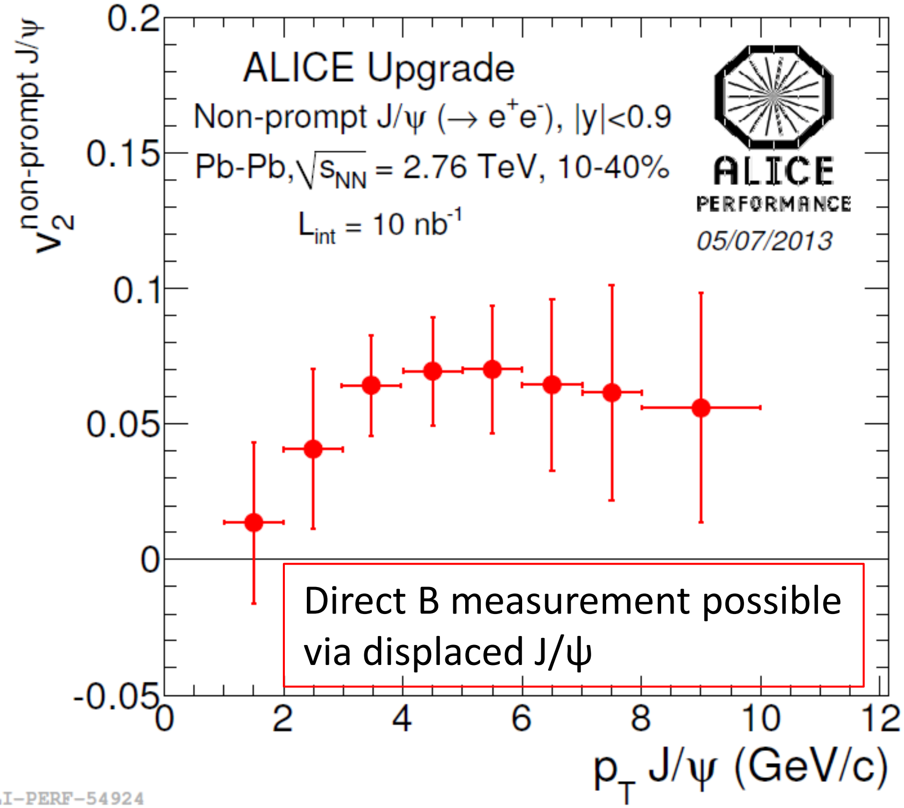
Beauty via displaced D^0 and J/ψ : v_2





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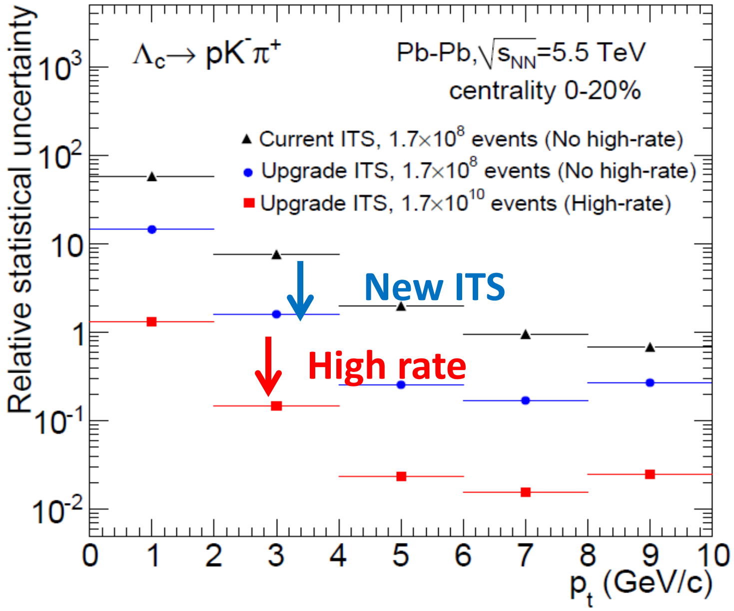
Upgrade:

- *precise v_2 measurement of prompt D and D from B*
- *positive elliptic flow for non-prompt J/ψ would be observed in 3<pT<8 GeV/c*

Charmed baryons: Λ_c



$\Lambda_c \to pK\pi$

not accessible with the current ITS in Pb-Pb

❖ Upgrade

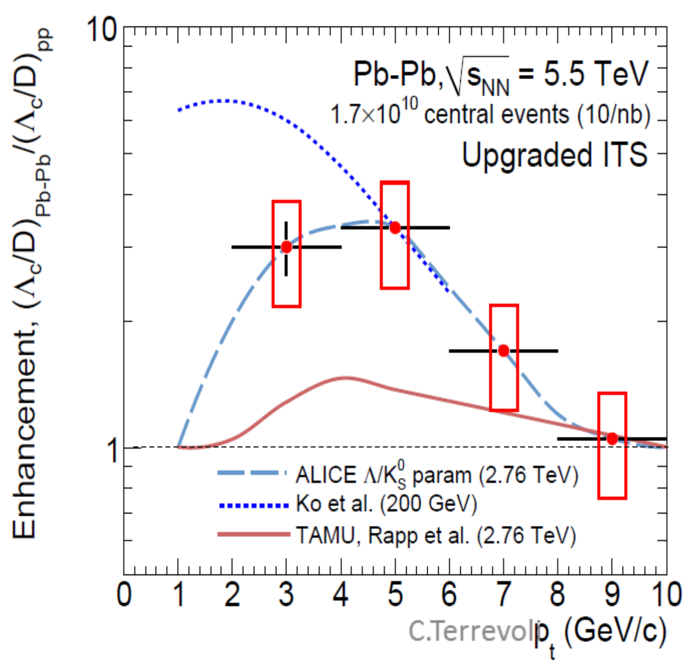
Improvement in resolution allows for cleaner vertex separation

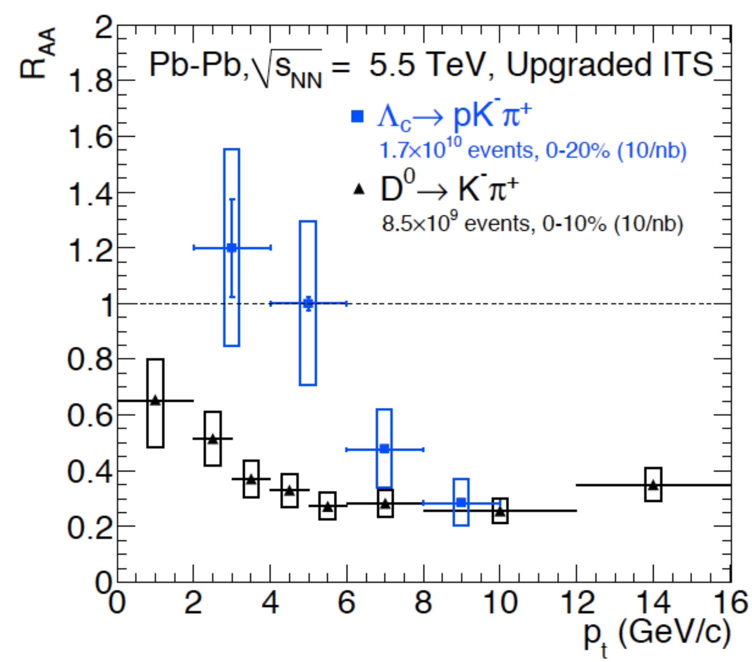
Λ_c production measurable down to 2 GeV/c with good precision

measurement of

❖ Λ_c/D ratio in Pb-Pb

❖ Λ_c R_{AA} down to p_T=2 GeV/c



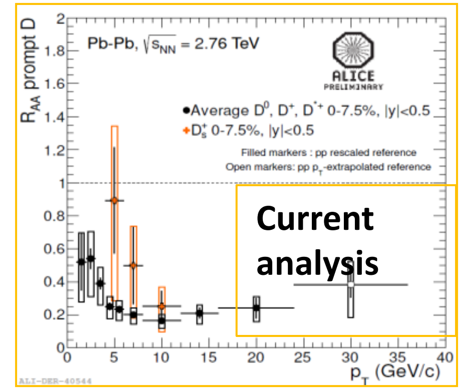


D_s: R_{AA} and v_2

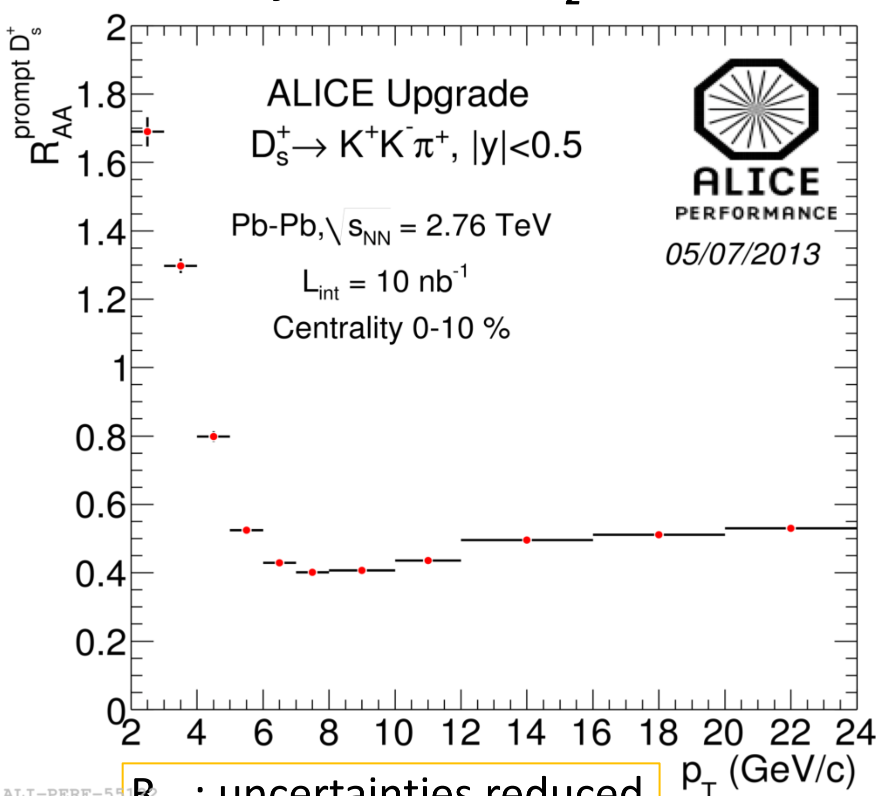
✓ R_{AA} of D_s larger than the R_{AA} of non-strange D mesons: seems to be larger at lower p_T but not possible to conclude within the present uncertainties !

❖ Upgrade: ***Possibility to reduce strongly the uncertainties on the R_{AA} measurement and to extend the measurement in the low p_T region***

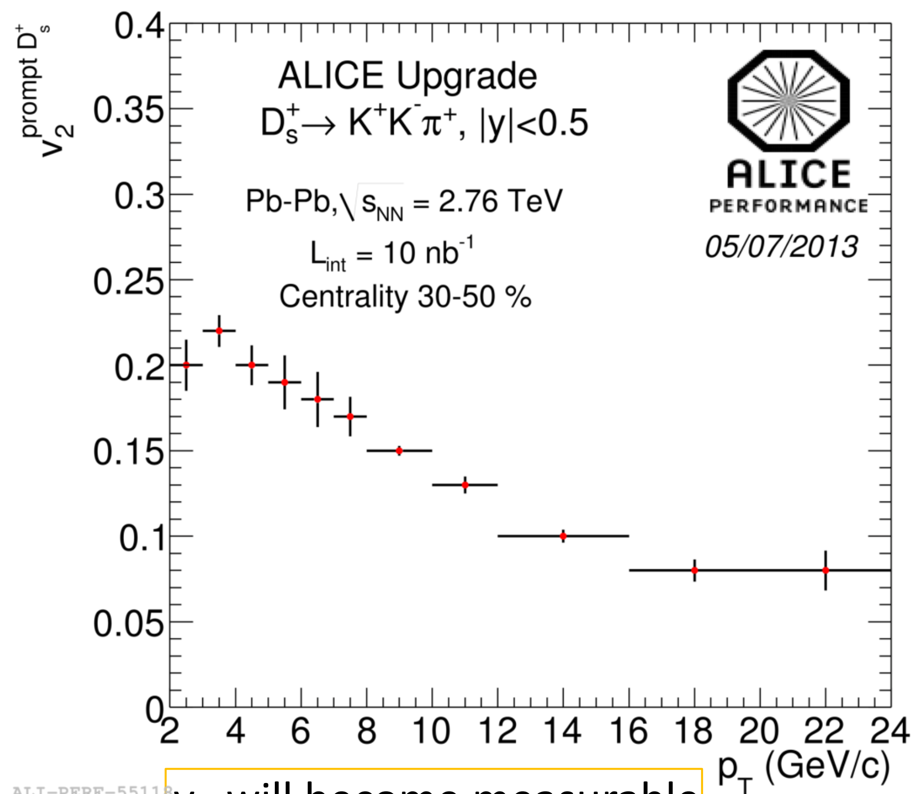
Possibility to evaluate v_2



Current analysis



R_{AA}: uncertainties reduced
extended p_T



v_2 will become measurable
for first time!

Conclusions

- **ALICE has a strong upgrade physics programme for precision QGP studies where Heavy flavour measurements play a central role**

Main requirements:

- Enhanced rate capabilities and new Inner Tracking System
  - Strong increase of the statistical precision in the measurements of yields and spectra of charmed mesons and baryons
  - A significant extension of the present physics programme with new measurements

ALICE is looking forward to the precision phase of Quark-Gluon Plasma measurements

BACKUP

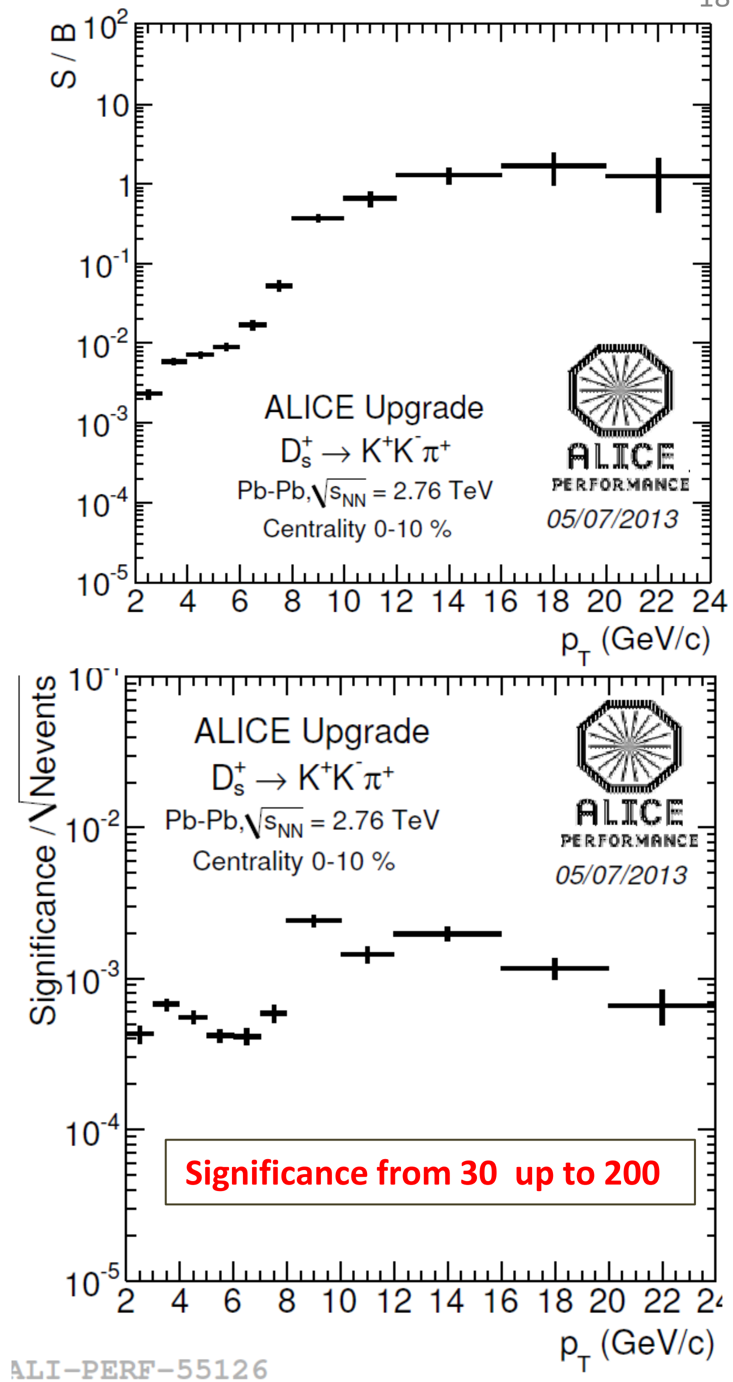
Strange D mesons: $D_s^+ \rightarrow K^- K^+ \pi^+$ with Upgrade

- ❑ Recombination: in QGP low p_T partons recombined each other to form higher p_T hadrons
- ❑ Enhancement of strange flavour in QGP

✓ The relative yield of D_s w.r.t non-strange D meson expected to be enhanced in Pb-Pb collisions at intermediate p_T if charm quarks hadronize via recombination in the medium

❖ Upgrade improve existing measurements:

- ✓ **Reduce strongly the background and improve S/B**
- ✓ **reduce uncertainties and extend p_T range**
  - ✓ current analysis in 3 p_T intervals from 4 to 12 GeV/c significance=3-4
  - **with upgrade** in 11 p_T intervals from 2 to 24 GeV/c



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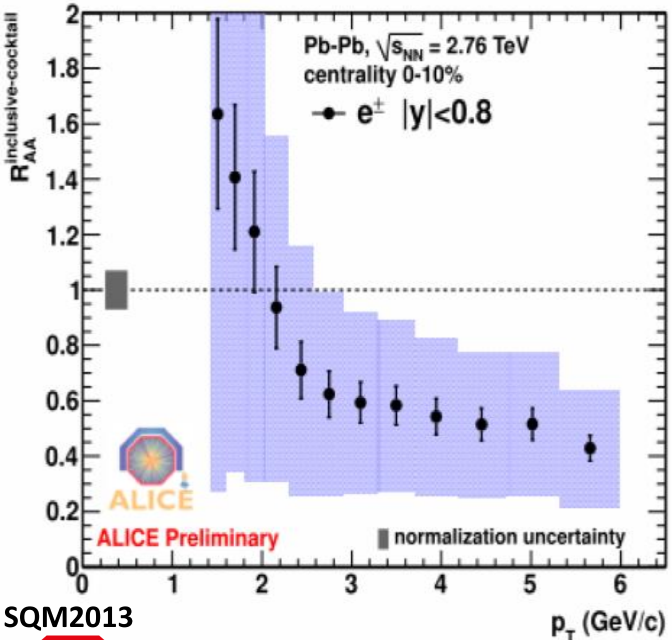
B→J/ψ

Current Analysis in central barrel:
only indirect measure of B via electrons



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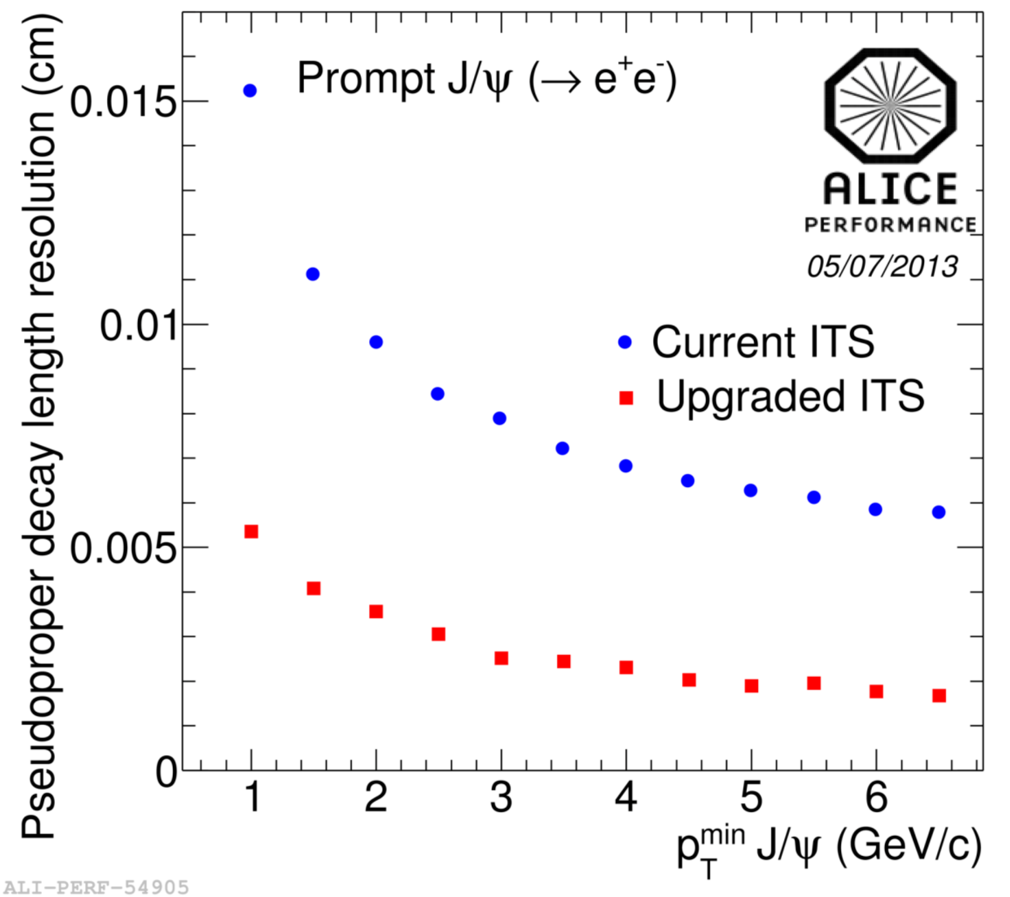
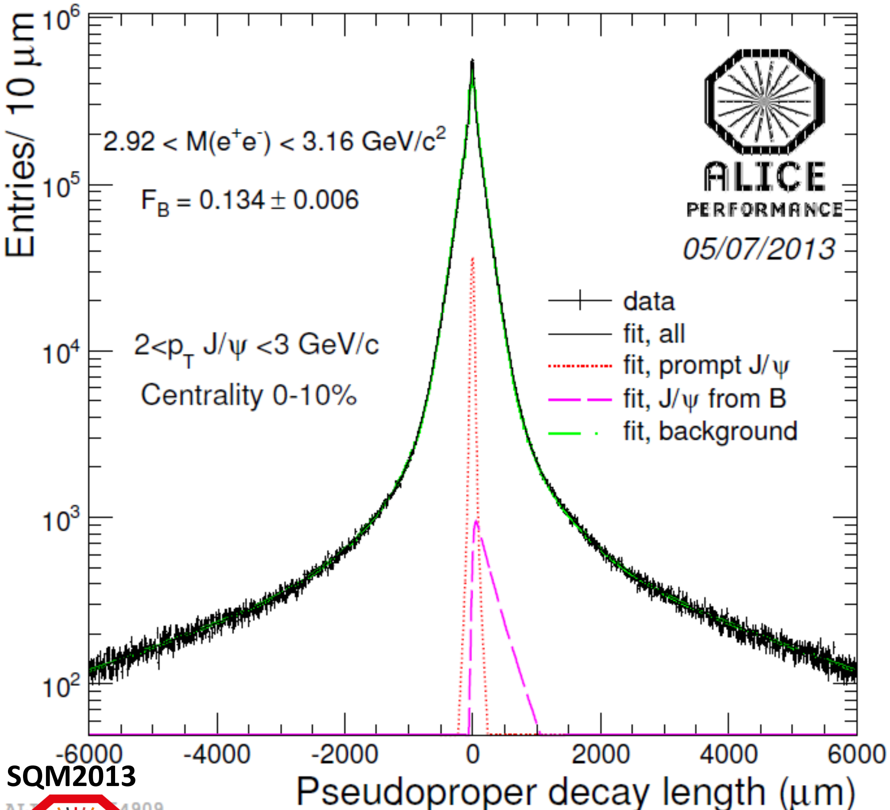
pseudo proper decay length resolution

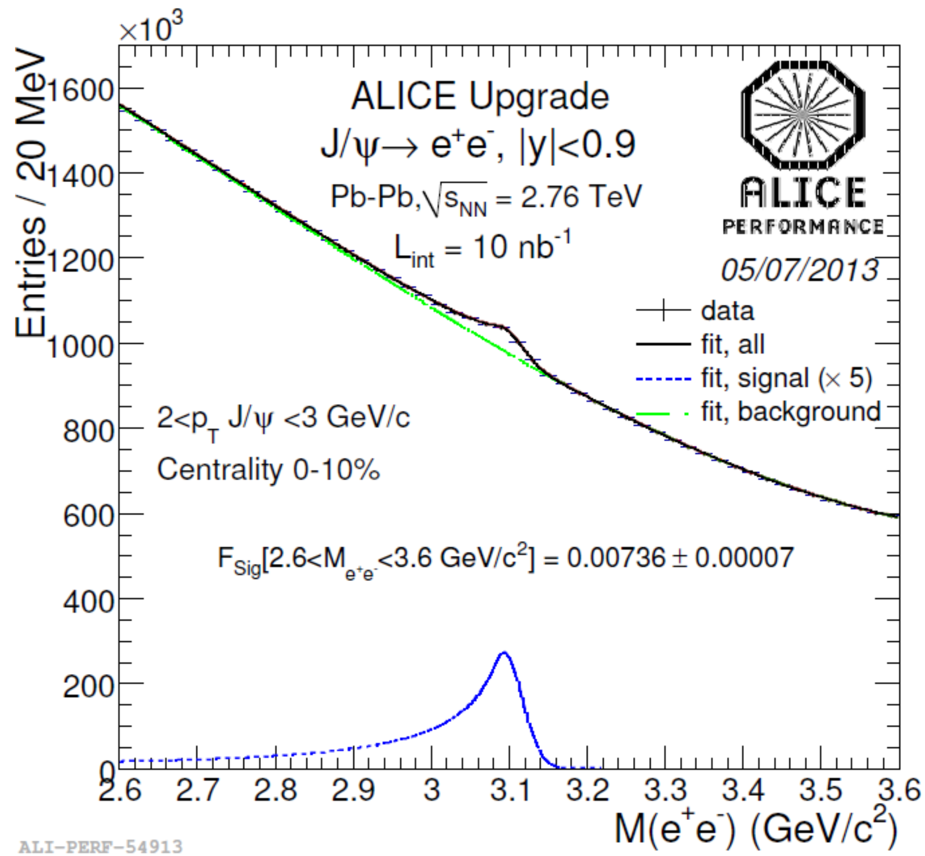
Improved resolution in prompt J/ψ due to new ITS detector
~ Factor 2



B→J/ψ

- Example of x and ee Invariant mass extraction in p_T bin 2-3 GeV/c with ITS Upgrade and high rate





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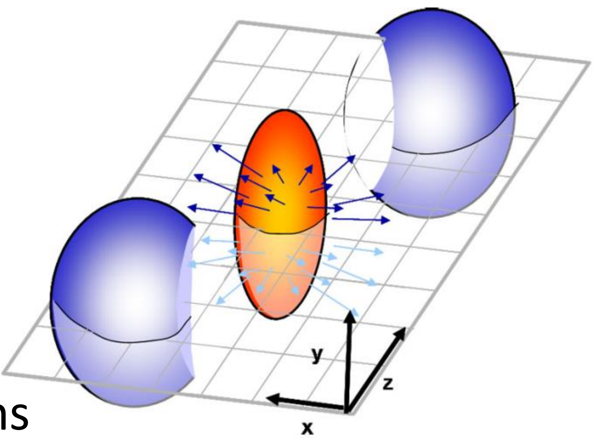
Collective Flow

- Anisotropic particle momentum distributions Ψ_{RP}
  - relative to the reaction plane:

$$\frac{dN}{d\phi} = \frac{N_0}{2\pi}\{1 + 2\nu_1 cos(\phi - \Psi_{RP}) + 2\nu_2 cos(2(\phi - \Psi_{RP}) + ...\}$$

- Angle of particle: ϕ
- Magnitude: $\nu_n(p_t, \eta) = \langle cos(n(\phi - \Psi_n))\rangle$



➔Valuable information on particle production mechanisms
- p_T < 2-3 GeV/c: flow pattern described by hydrodynamic models
  - Handle on equation-of-state of medium
- 3 < p_T < 6 GeV/c: flow larger for baryons than for mesons
- p_T > 8 GeV/c: high-energy parton fragmentation from initial hard scattering

PIXEL TECHNOLOGIES

Hybrid pixels

- ❑ Separate optimization of sensor and circuitry, complex in-pixel signal processing
- ❑ State-of-the-art detectors but are limited to inner layers due to their cost
- ❑ Charge collected by drift
- ❑ Proven radiation resistance to ALICE levels

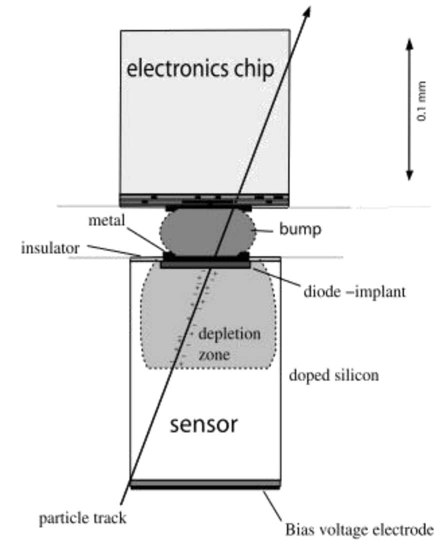
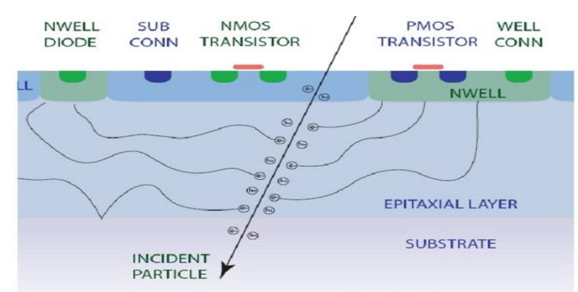


Figure - Rossi, L., Fischer, P., Rohe, T. & Wermes, N. (2006). Berlin: Springer.

Monolithic pixels

- ❑ Sensing layer is integrated into the CMOS chip
- ❑ Have shown significant progress in recent years and will soon be installed in STAR (HFT)
- ❑ Charge mainly collected by diffusion (though some new developments on the way)
- ❑ Radiation resistance needs to be proven



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