B-meson measurements with the upgrade of the ALICE Inner Tracking System

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Utrecht University

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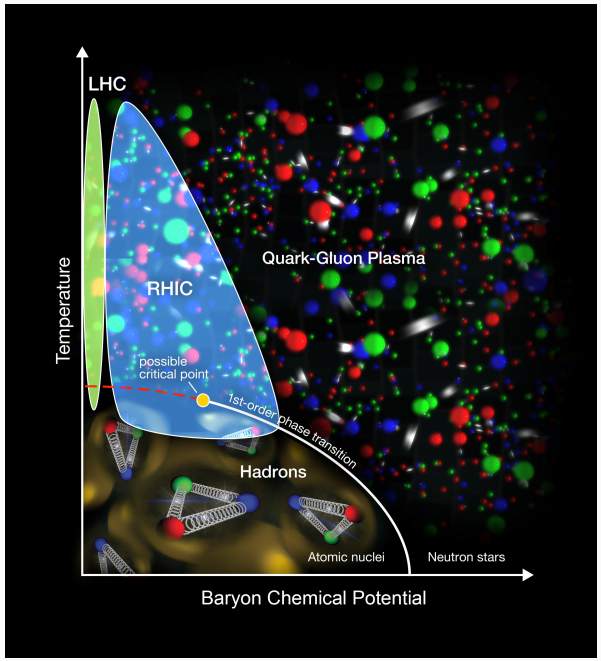
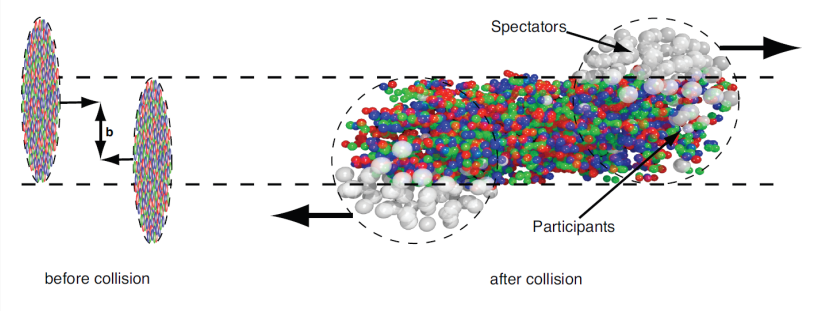
ALICE

Introduction and motivation

Quark-Gluon Plasma

- In ALICE, we study the properties of the **Quark-Gluon Plasma** (QGP), created in ultra relativistic heavy-ion collisions.
- The quarks and gluons are in a strongly-interacting deconfined state.
- This state of matter is predicted to exist in the early universe in the first microseconds after the Big Bang.





Heavy quarks

- Heavy quarks are generated early during the collision. The quark formation time is mass dependent:

$$\tau_q \propto \frac{1}{m_q}$$

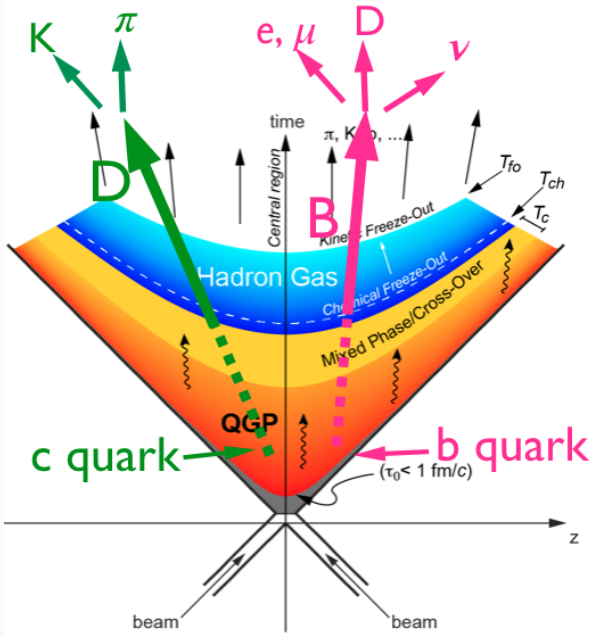
- Characteristic formation times are:

$$\tau_{\text{charm}} \sim 0.1 \text{ fm/c}$$

$$\tau_{\text{beauty}} \sim 0.04 \text{ fm/c}$$

$$\tau_{\text{QGP}}{}^{1} \sim 0.3 \text{ fm/c}$$

- The short formation times allow the heavy quarks to experience the full evolution of the medium.

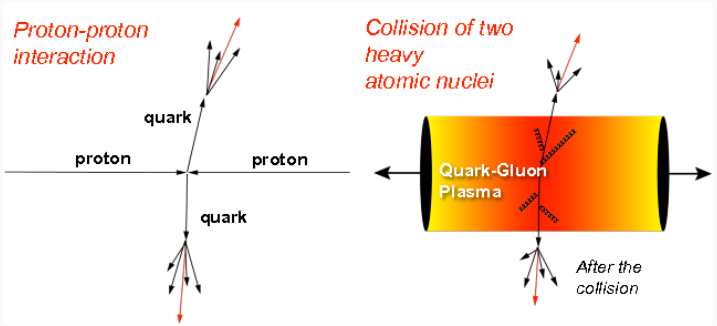


[1] F.M. Liu, S.X. Liu, Phys. Rev. C 89, 034906 (2014)

Heavy quarks

- The quarks lose energy when they move through the created medium through elastic collisions with other medium constituents and gluon radiation.
- This **energy loss is expected to depend on the parton type**. For example, radiative energy loss is suppressed for heavier particles through the deadcone effect.[2]

$$\Delta E_g > \Delta E_{u,d} > \Delta E_c > \Delta E_b$$



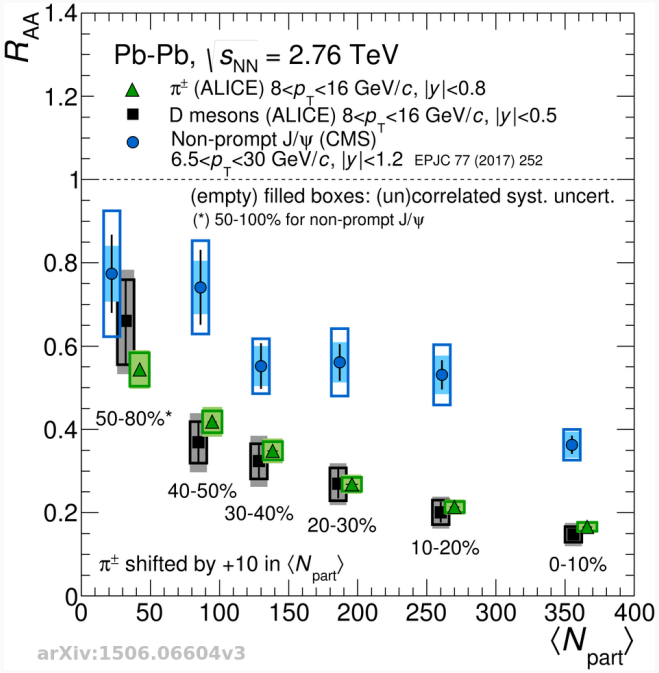
[2] arXiv:hep-ph/0106202v1

Heavy quarks

- To study the in-medium parton energy loss we measure the nuclear modification factor:

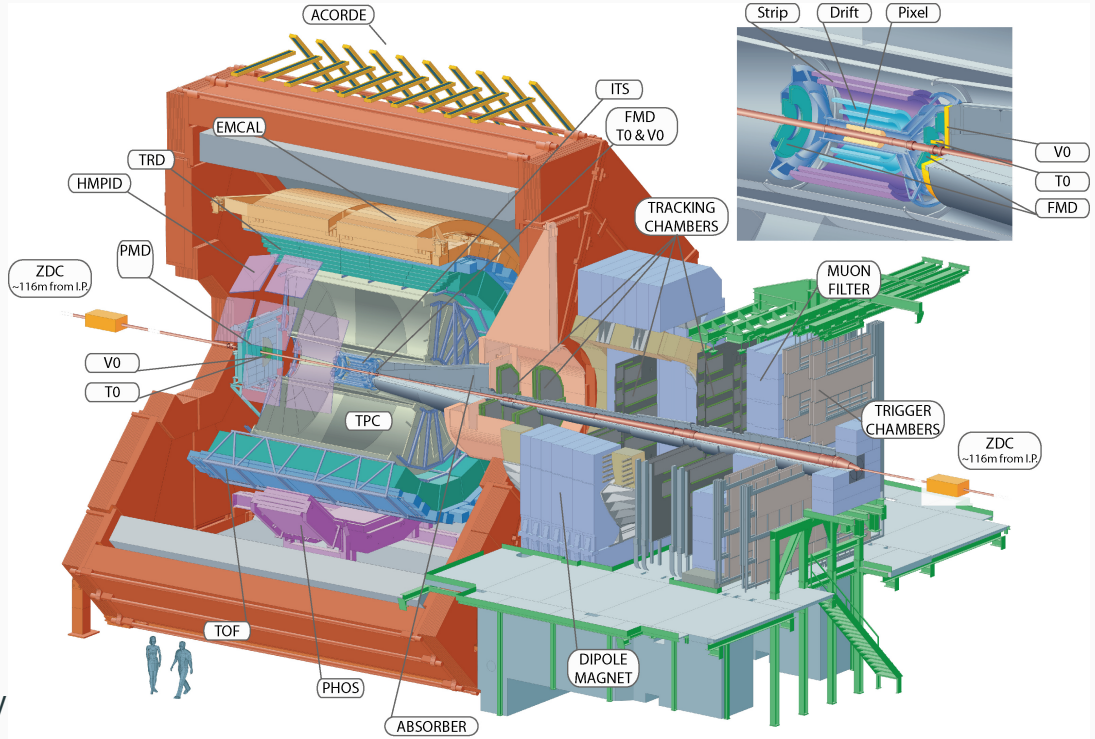
$$R_{AA}(p_T) = \frac{1}{\langle N_{coll} \rangle} \frac{dN_{AA}/dp_T}{dN_{pp}/dp_T}$$

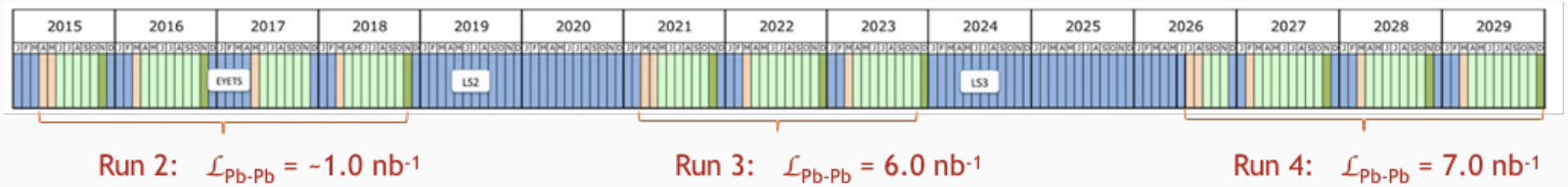
- High p_T: Indication of smaller energy loss for beauty than charm.
- **Need more precise measurement** from lower to higher p_T ($\sim$ 10 GeV/c) for a quantification of the effects.



ALICE

- ALICE is one of the four main experiments at the LHC.
- Full hadronic reconstruction of beauty mesons is currently out of reach.
- During the next LHC shutdown, **ALICE will be upgraded** for the Run 3 data taking to further explore the QGP properties. Heavy flavour gives access to the transport properties, such as the interaction strength and the diffusion of the deposited energy in the plasma.





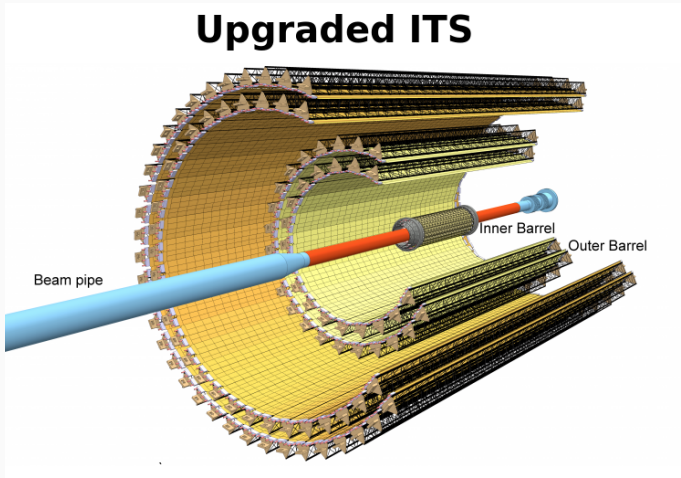
Inner Tracking System (ITS) upgrade

Inner Tracking System (ITS) upgrade

- The ITS is one of the main systems to be upgraded during the next shutdown.
- **This will significantly improve the physics performance of ALICE.**
- The ITS will be entirely composed of monolithic active pixel sensors.
- Detector will be accessible for maintenance during yearly shutdown.

Upgrade Letter of Intent J.Phys. G41 (2014) 087001

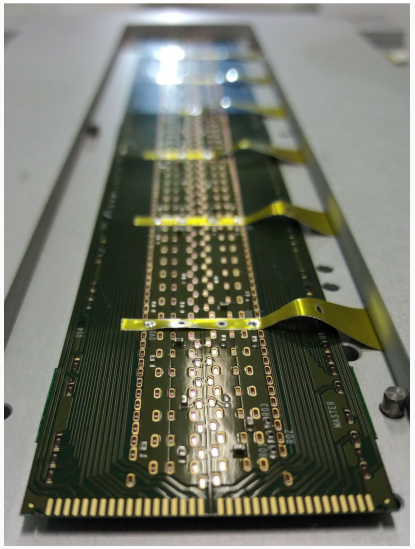
ALICE Upgrade Technical Design Report J.Phys. G41 (2014) 087002



	Current	Upgraded
Number of layers	6	7
Rapidity range	$\|\eta\| < 0.9$	$\|\eta\|$<1.5
Material budget per layer	$\sim 1.14\%$	$\sim 0.3\%$
Distance to interaction point	39mm	23mm
Pixel size	$50 \times 425\mu m^2$	$29 \times 29\mu m^2$
Spatial resolution	$12\mu m \times 100\mu m$*	$5\mu m \times 5\mu m$
Max. readout speed PbPb	1 kHz	50 kHz

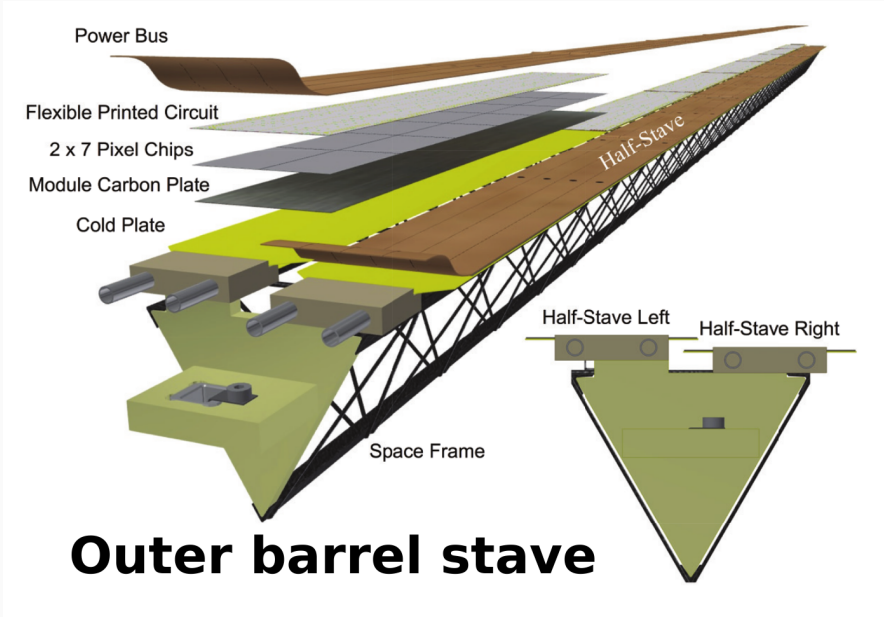
*: SPD

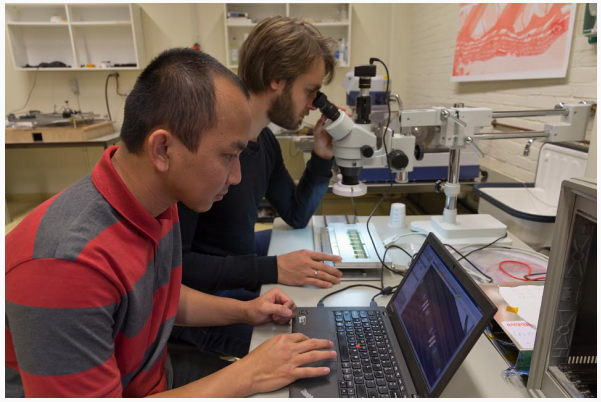
ITS module



Inner Tracking System (ITS) upgrade

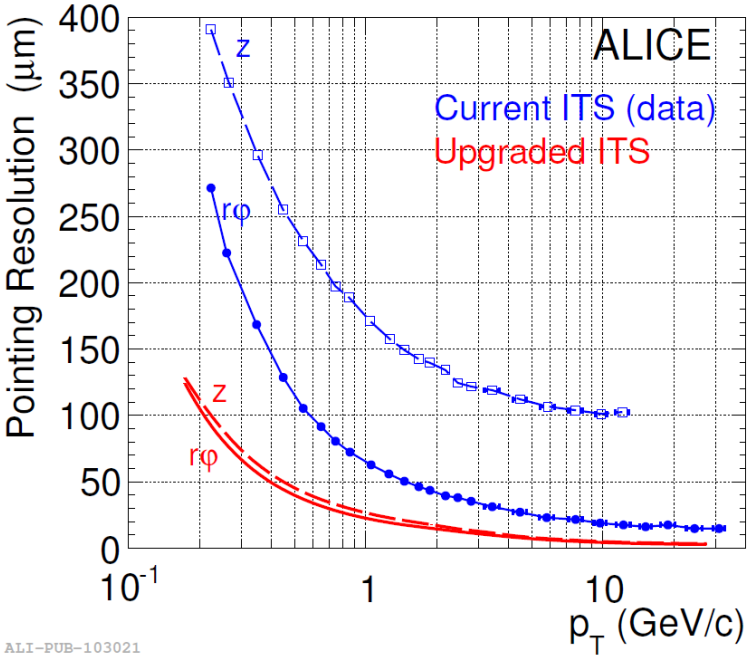
- The upgraded ITS is currently being built.
- Outer Barrel staves are being produced at Nikhef, Turin, Frascati, Berkeley, and Daresbury.
- PhD candidates of the heavy-flavour group of Utrecht University are involved in the production/assembly at Nikhef.



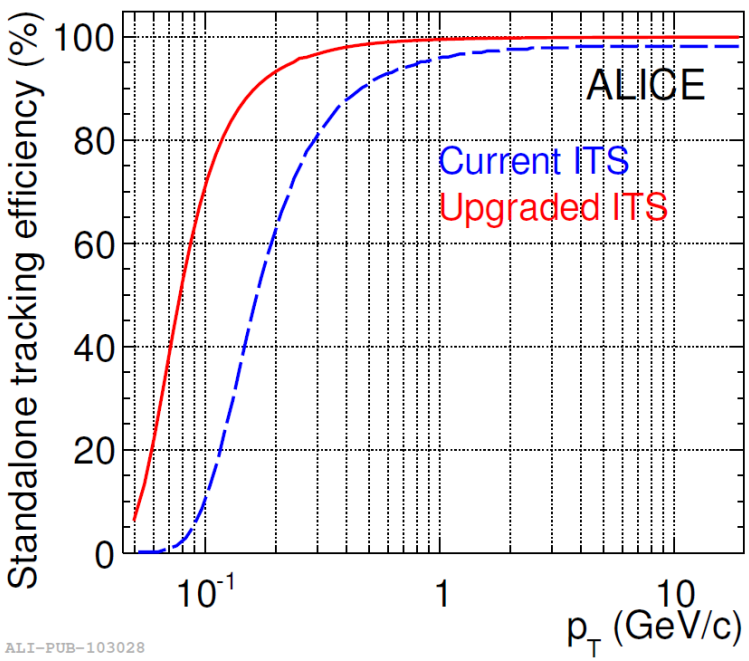


Inner Tracking System (ITS) upgrade

Pointing resolution



Tracking efficiency



- The new ITS will allow higher precision measurements at lower p_T thanks to:
  - the better pointing resolution (down to 25 μm at a p_T of 1 GeV/c),
  - the higher tracking efficiency,
  - and the improved read-out rate of the detector (resulting in $\sim$10$\times$ higher luminosity).
- **This will make open-beauty measurements accessible for ALICE.**

Full hadronic beauty reconstruction

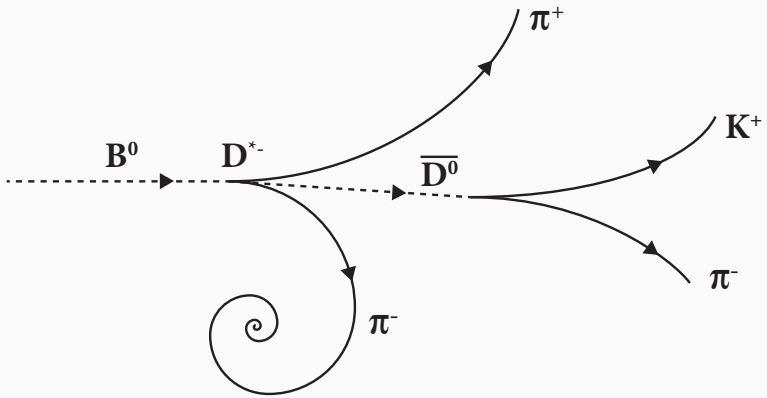
Full hadronic beauty reconstruction

- B mesons will be studied in several full hadronic decay channels:

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

$$B^+ \rightarrow \overline{D^0}\pi^+ \rightarrow K^+\pi^-\pi^+$$

- The reconstruction is performed using the identification of secondary vertices which have a distance of several hundred μm from the primary vertex.
- We remove background using PID at low p_T.

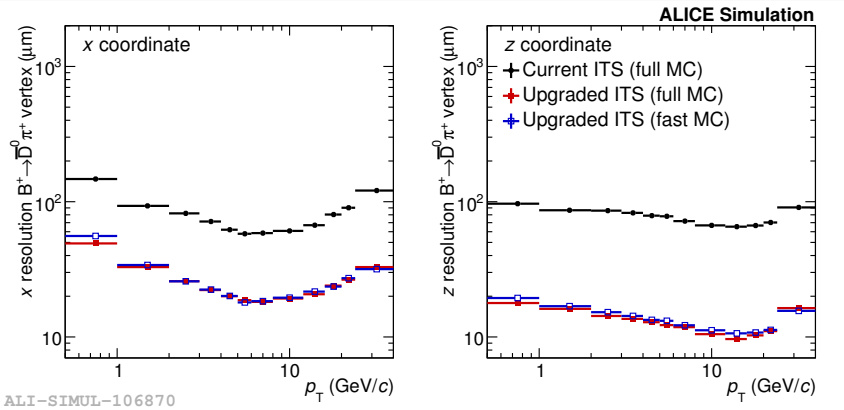


	Mean decay length	Branching ratio
$B^+ \rightarrow D^0\pi^+$	$\sim$491 μm	4.68×10^{-3}
$B^0 \rightarrow D^{*-}\pi^+$	$\sim$455 μm	2.74×10^{-3}
$D^{*-} \rightarrow \overline{D^0}\pi^-$	$\sim$2.4 fm	67.7×10^{-2}
$D^0 \rightarrow \pi^- K^+$	$\sim$120 μm	3.89×10^{-2}

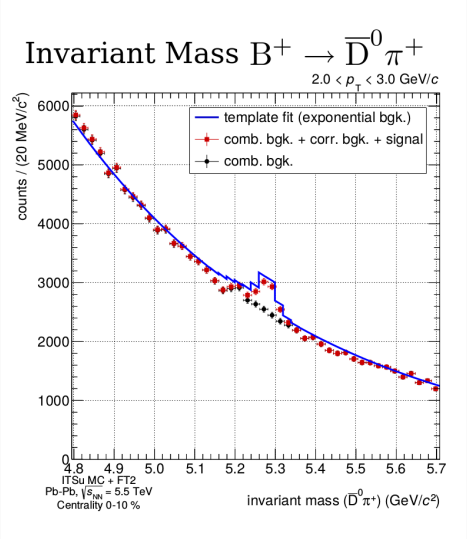
B^+ and B^0 PDG mass: 5.279 GeV/c^2

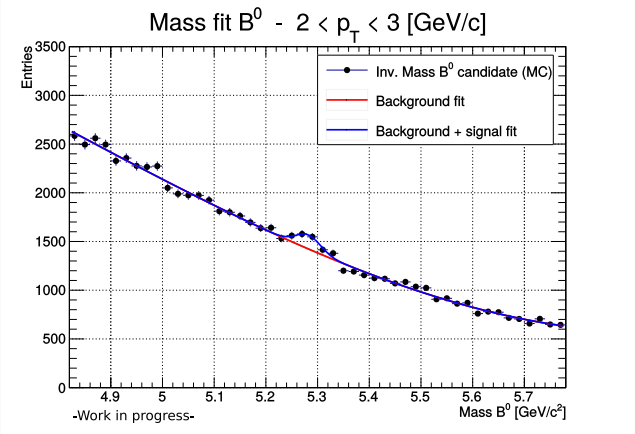
Full hadronic beauty reconstruction

- An excellent track and vertex resolution is needed for the reconstruction and background/signal separation.
- The new ITS provides this by significantly improving the vertex resolution:
  - $\sim 3\times$ in the x direction,
  - $\sim 5\times$ in the z direction.



- The beauty signal is extracted from the invariant mass distribution.

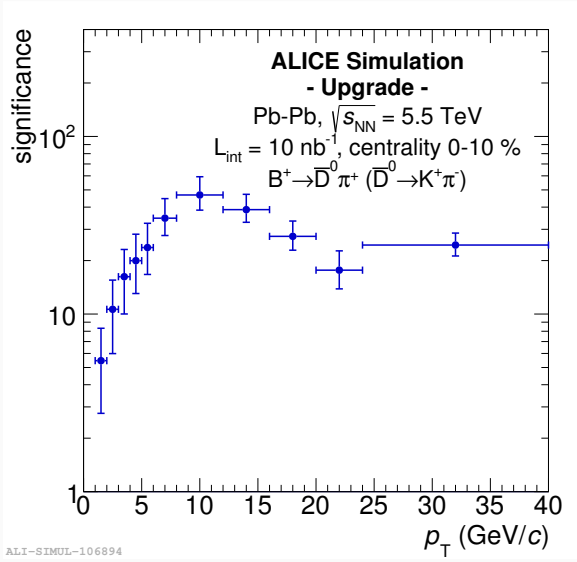


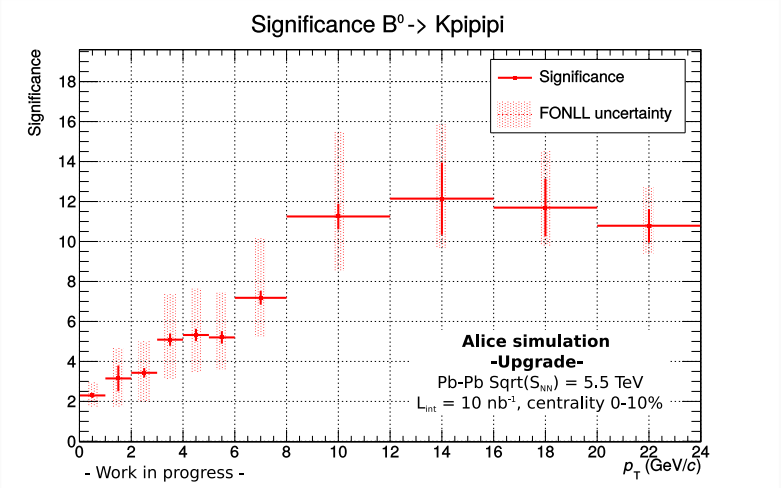


Physics performance of upgraded ITS

Physics performance of upgraded ITS

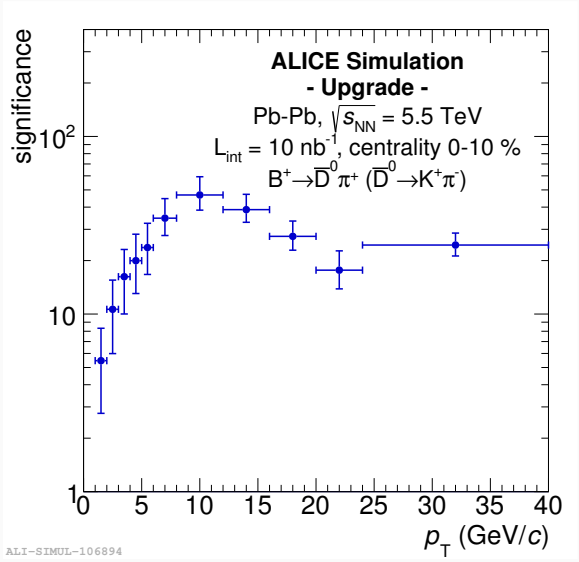
- Monte Carlo simulations show that we expect a clear signal over a wide p_T interval when measuring open-beauty after the upgrade.
- B-meson signal observation with a significance higher than 5 sigma for $p_T > 2$ GeV/c is expected.

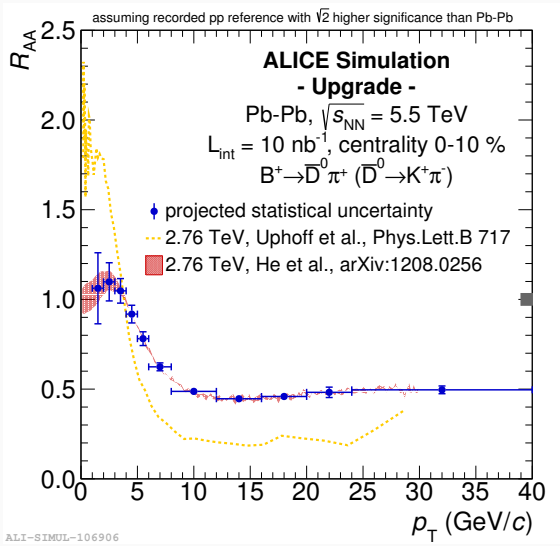


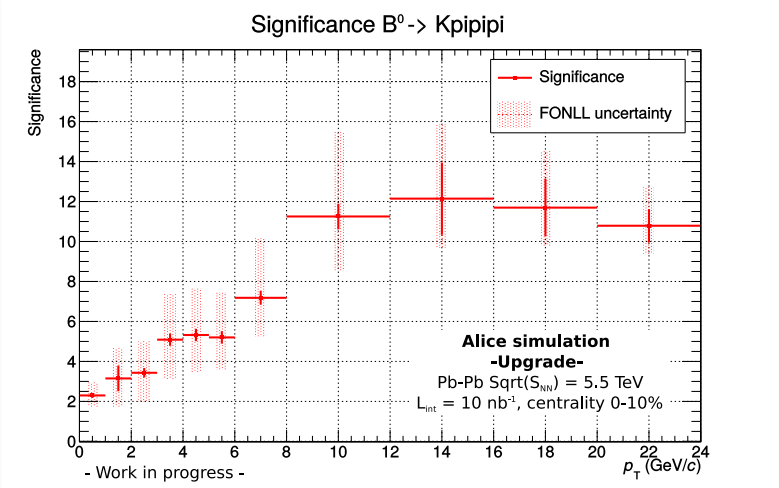


Physics performance of upgraded ITS

- Monte Carlo simulations show that we expect a clear signal over a wide p_T interval when measuring open-beauty after the upgrade.
- With the expected uncertainties we will be able to disentangle between different energy loss models

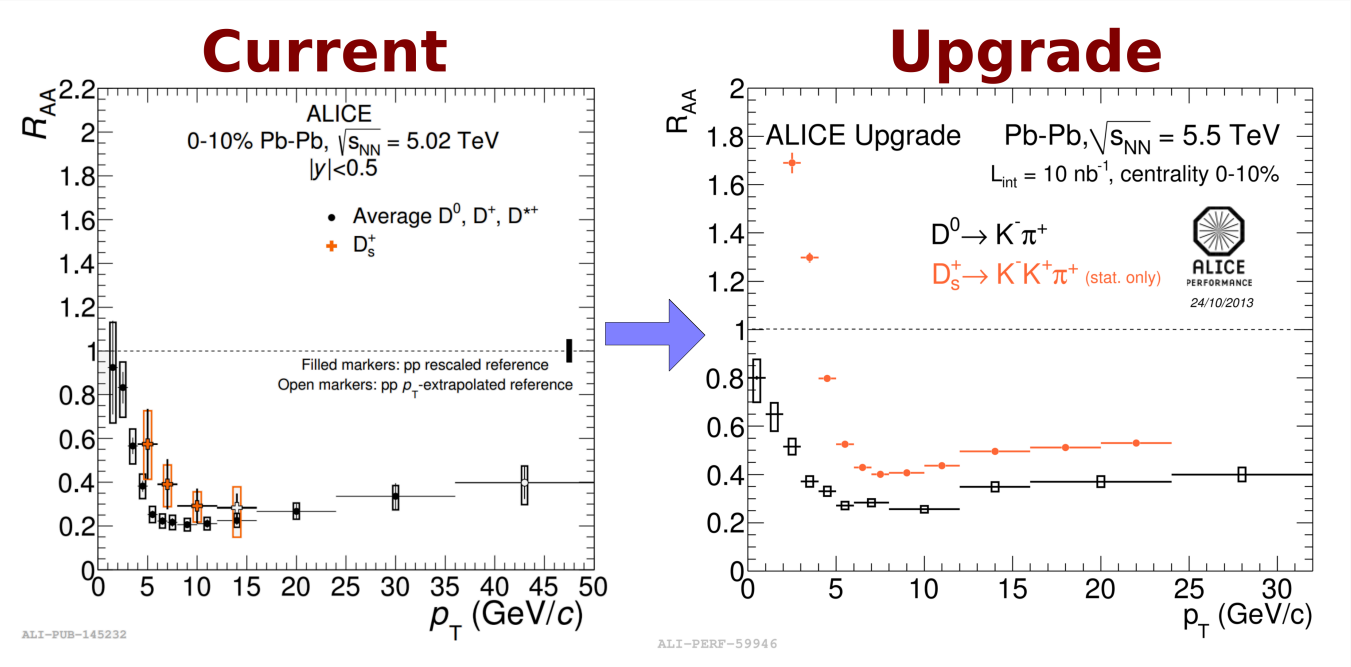






Physics performance of upgraded ITS

- The new ITS will also enable measurements with improved uncertainties at low and in a wider p_T range for prompt D mesons.
- Using results from charm and beauty measurements we will be able to study the mass dependence of energy loss in the QGP.



Conclusion and outlook

Conclusion and outlook

- ALICE will be upgraded during the next long shutdown of the LHC in 2019/2020.
- The new ITS, which is now being constructed, will be a major part of this upgrade.
- The new detector will enable high precision measurements and make open-beauty measurements in ALICE accessible.

Questions?

Backup slides

- The ITS upgrade will also allow us to study other beauty decays: