STUDIES FOR AN UPGRADE OF THE ALICE INNER TRACKING SYSTEM

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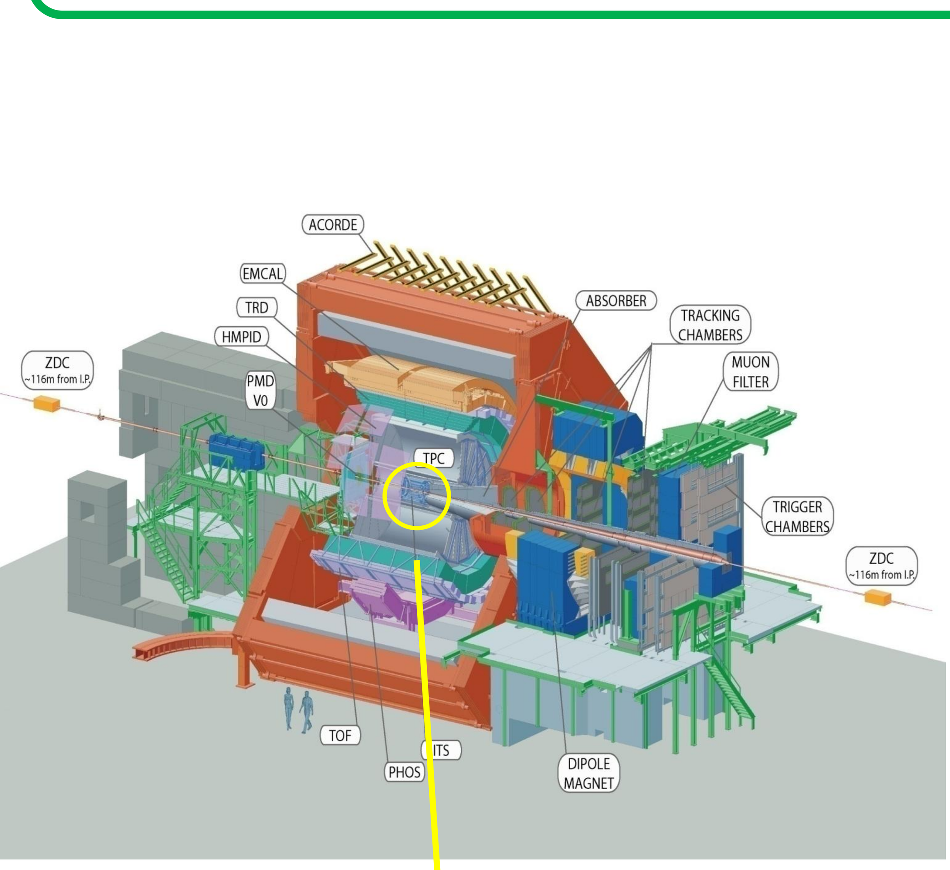
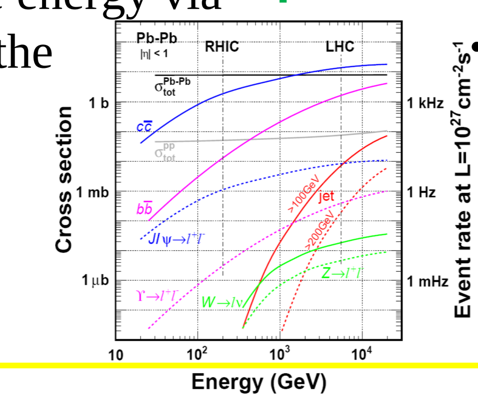
ALICE (A Large Ion Collider Experiment) is the general purpose heavy-ion detector at the CERN LHC. It has been designed to address the physics of strongly interacting matter and the quark-gluon plasma at extreme values of energy density and temperature in nucleus-nucleus collisions



Heavy quarks c and b are probes to investigate hot and dense QCD matter

- **produced in the early stage of the collision**
  - large Q → temporal and spatial scales ~1/Q: sufficiently small for the production to be unaffected by the properties of the medium
- **come out from the interaction region as hadrons carrying out information about the properties of the traversed medium**
  - while propagating through the medium they lose energy via QCD energy loss mechanisms which depend on the medium density, opacity and dimension
- **large cross section for cc and bb production:**
  - about 100 and 5 pairs respectively per central Pb-Pb collision at 5.5 TeV



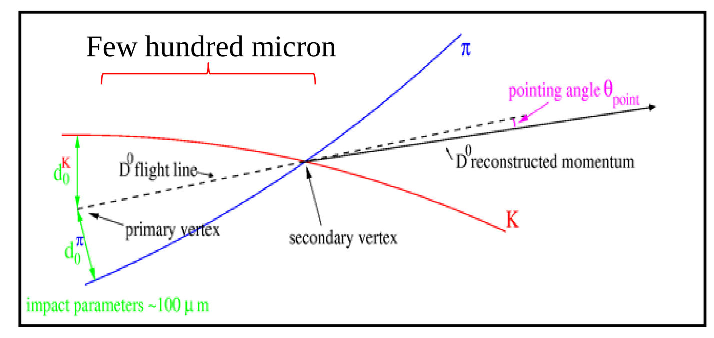
Open charm production measurements in ALICE through the exclusive reconstruction of decays into charged hadrons

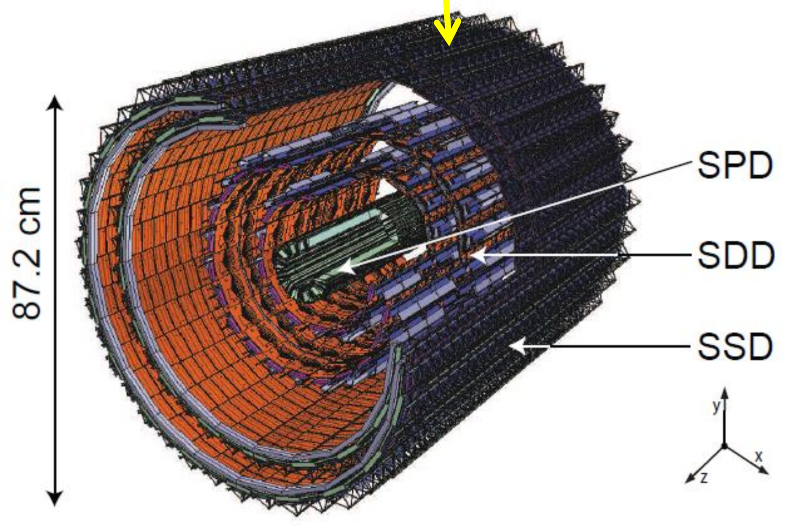
Ex: Open charm mesons under study

D^0 (cu) → $K^-\pi^+$ m ~ 1865 MeV cτ ~ 123 μm
D^+ (cd) → $K^-\pi^+\pi^+$ m ~ 1869 MeV cτ ~ 312 μm
D_s^+(cs) → $K^+K^-\pi^+$ m ~ 1968 MeV cτ ~ 150 μm
D^{*+}(cd) → $D^0\pi^+$ m ~ 2010 MeV

short lifetime
Identification relies on the possibility of resolving a decay vertex at distances of such order from the production one

- Analysis based on decay topology and invariant mass technique
- Fundamental selection cuts
  - impact parameter
  - distance of closest approach
  - pointing angle





The main tracking detectors of the ALICE set-up in the central barrel are the **Inner Tracking System** (ITS), the vertex detector, and the Time-Projection Chamber (TPC). The ITS consists of six cylindrical layers of silicon detectors located at radii between 4 and 43 cm from the beam axis and covering the pseudo-rapidity range |η|<0.9 for all vertices located within the interaction diamond.

ITS Main Goals are Primary and Secondary vertex recontstruction, Particle identification, Standalone reconstruction

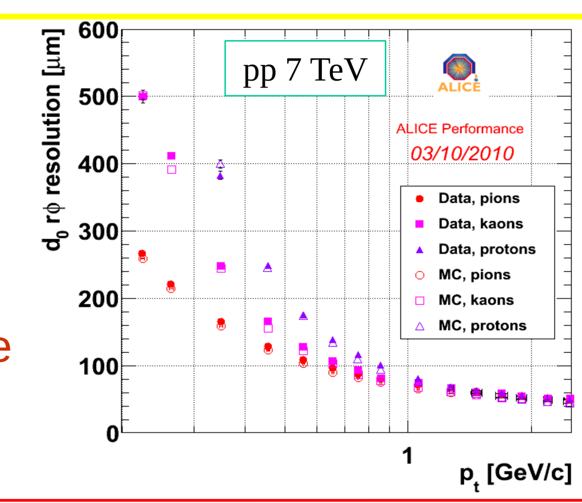
- Precise tracking to reconstruct and separate the secondary vertices of heavy-flavoured hadrons decays from the primary vertex.
  - Vertex resolution mainly determined by the two innermost layers
- Low momentum track reconstruction requires very low material budget
  X/X_0 ~ 7 % in total for the present ITS

Layer	Technology	Radius (cm)	±z (cm)	Spatial resolution (μm)	
				rϕ	z
1	Pixel	4.0	14.1	12	100
2	Pixel	7.2	14.1	12	100
3	Drift	15.0	22.2	38	28
4	Drift	23.9	29.7	38	28
5	Strip	38.5	43.2	20	830
6	Strip	43.6	48.9	20	830

provide dE/dx for particle identification (layers 3–6)

ITS performance

- ✓ High precision tracking: Impact parameter resolution better than 75 μm for p_T > 1 GeV/c
- ✓ Capabilities to measure open charm down to low pt in p-p (1 GeV/c) and PbPb (2 GeV/c)
- ✓ ITS as a standalone tracker down to p_T < 200 MeV/c
  - help for low momentum tracks which don't reach the TPC or pass trough its dead zone



ITS Upgrade Motivation

Extend ALICE's capability for the identification of short-lived particles containing heavy quarks through reconstruction and identification of the displaced vertex

- reconstruction of the exclusive Beauty decays
  - ✓ R_{AA}^B/R_{AA}^C → quark mass dependence of in-medium energy loss
- reconstruction of heavy flavour baryons (e.g. Λ_c and Λ_b)
  - ✓ Λ_c/D and Λ_b/B → heavy quark hadronization mechanism
- reconstruction of multi heavy flavoured hadrons
  - ✓ prediction of huge enhancement in Pb-Pb @LHC
- improvement of the physics reach for the particles which can be studied with the present ITS (e.g. v_2 of charm, extend coverage down to lower pT, etc.)

❑ Key performance aspects needed to achieve physics goals:

- major improvement obtained with
  - ✓ pixel layer closer to the beam line (owing to a new beam pipe with about 10 mm smaller radius)
  - ✓ reduction of the material budget (ex: factor 0.5 in the innermost layers w.r.t. the actual one)
  - ✓ reduction of intrinsic resolution in rφ and in z (would permit to make selection cuts in z too in order to reject combinatorial background)
- would permit:
  - ✓ improve pointing resolution by a factor 2 or 3 at central rapidity
  - ✓ improve momentum resolution

Access to new physics…

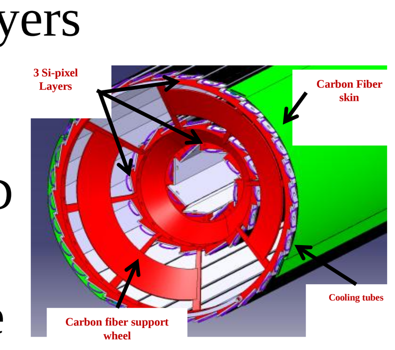
Timeline the full upgrade program targets the long shutdown in 2017/2018 but might require a two stage approach: partial upgrade in 2017/2018 and completion beyond 2020

New Layout and Technologies studies

A detector with a new layout and based on today's frontier technologies, enlarging the number of layers instrumented with silicon pixel detector, would offer new exciting possibilities within the physics scope described

Possible Upgrade Layout Options

❑ Replace the pixel detector with three new pixel layers
- current SDD and SSD remain → replace the SPD



❑ Replace the entire ITS with a new one
- Ex: 4 Pixels + 3 Strips layer

First two layers material budget goals:
- **Hybrid Silicon Pixel**
  - ❑ X/X_0 < 0.5% - 100 μm thick sensor + 50 μm thick electronics - pixel size 30 μm x100 μm
- **Monolithic Silicon Pixel**
  - ❑ X/X_0 < 0.3% - 50 μm thick ASIC – pixel size 20 μm x 20 μm

Silicon Strips Upgrade
- Cover a large area at r > 15 cm - Contribute to the tracking with good spatial resolution - Perform PID over a large dynamic range

R&D studies on going…

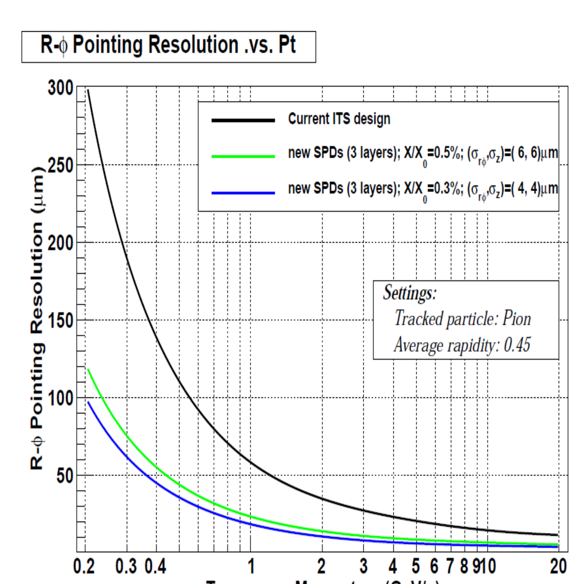
Simulation Studies

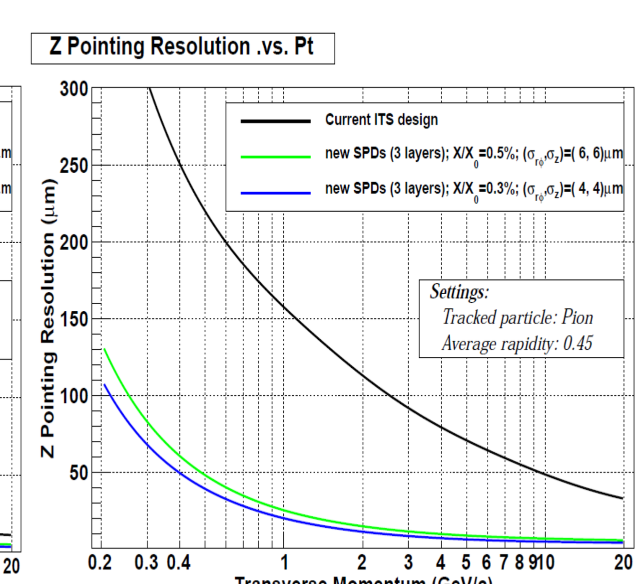
Analytical and Monte Carlo methods

- Define the detector specifications from physics requirements
- Simulate the detector performance based on the detector design
  - ✓ Number of layers, radii, segmentation, material budget evaluation:

factors of merit:
impact parameter & p_T resolution
& tracking efficiency & PID studies

Example of layout studies:
material budget & intrinsic resolutions

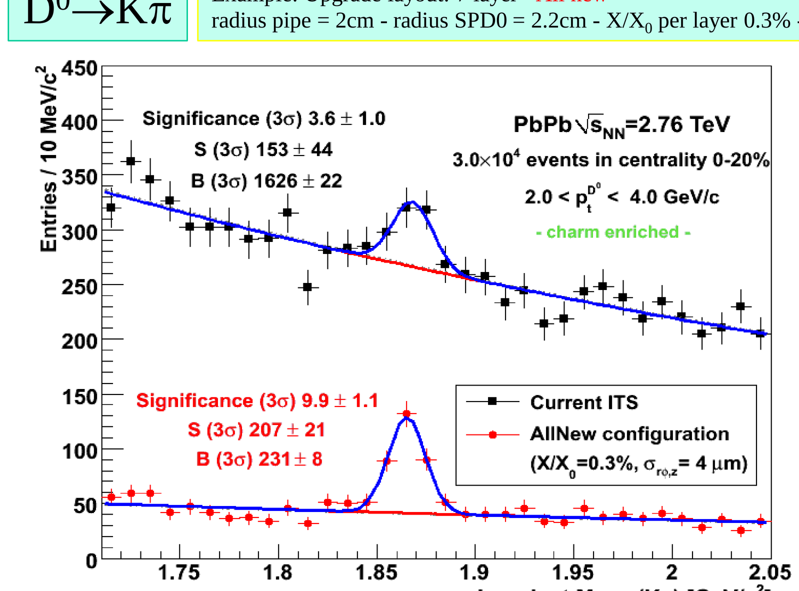




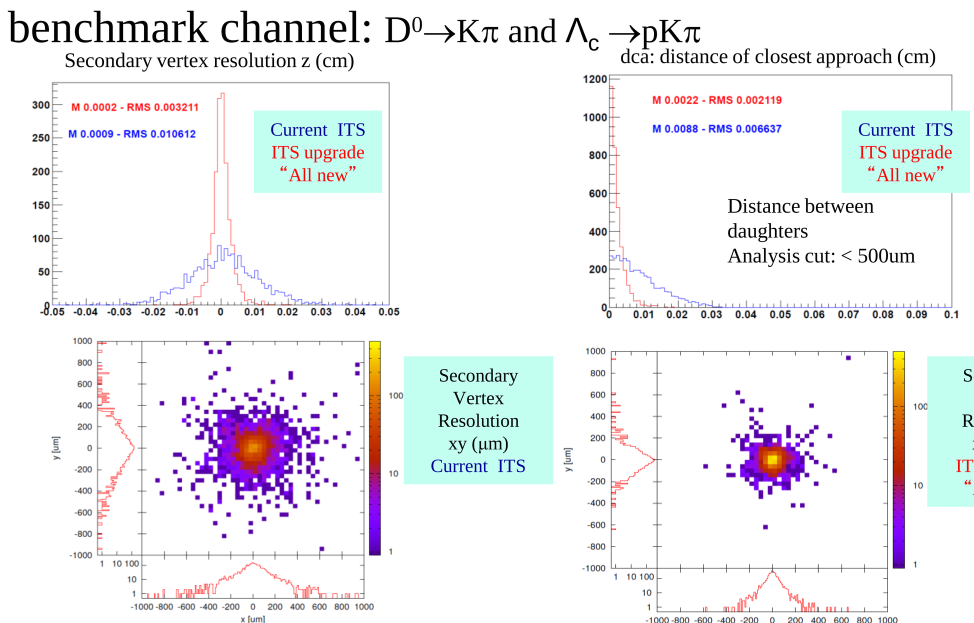
Preliminary performance studies with a new layout

(without any optimization of the analysis cuts) Analysis on benchmark channel: $D^0 \to K\pi$ and $\Lambda_c \to pK\pi$

$D^0 \to K\pi$ Example: Upgrade layout: 7 layer "All new" radius pipe = 2cm - radius SPD0 = 2.2cm - X/X_0 per layer 0.3% - spatial intrinsic resolution: 4 μm in rϕ and z

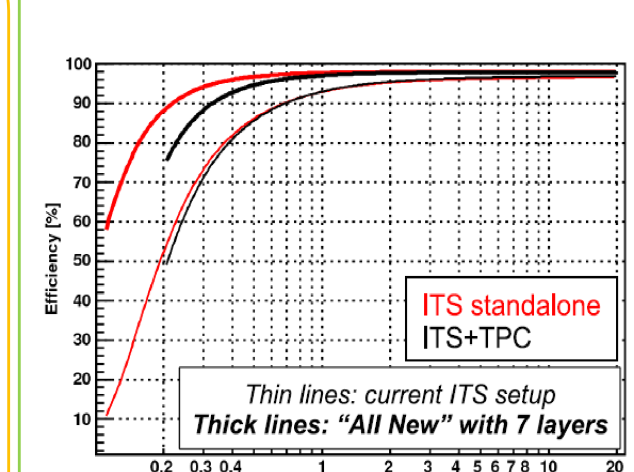


Background rejection a factor ~7 better using current analysis cuts not yet optimized for the improved resolutions obtained with the ITS Upgrade



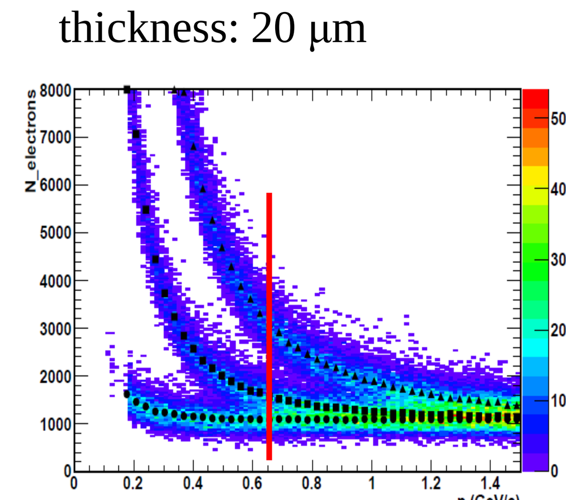
$\Lambda_c \to pK\pi$ 7 layer "All new": radius pipe = 2cm - radius SPD0 =2.2cm X/X_0 per layer 0.5% - spatial intrinsic resolution: 6 μm in rϕ and z

Tracking Efficiency (analytical estimate for having all clusters well associated to the track)



High standalone tracking efficiency would open the possibility to a level 2 (latency 100μs) trigger based on topological identification of open charm hadrons

Example of PID: ITS layout 7 SPD layers thickness: 20 μm



Good separation between K and p up to 650 MeV/c