Will ALICE be running during the HL-LHC era?

Hannes Wessels, LHC Performance Workshop, Chamonix 2012

- Executive summary:

YES

Long-term goals of the HI program

- Understanding QCD as a multi-particle theory
  - detailed characterization of the Quark-Gluon-Plasma
    - critical temperature, degrees of freedom, speed of sound, transport coefficients
    - precision measurements to address deconfinement and chiral symmetry restoration
- A lot has been achieved owing to the spectacular performance of the LHC with ions

What does it take?

- Progress on the nature of the QGP is made by studying multi-differential observables:
  - centrality
  - transverse momentum
  - event plane
  - flavour, …

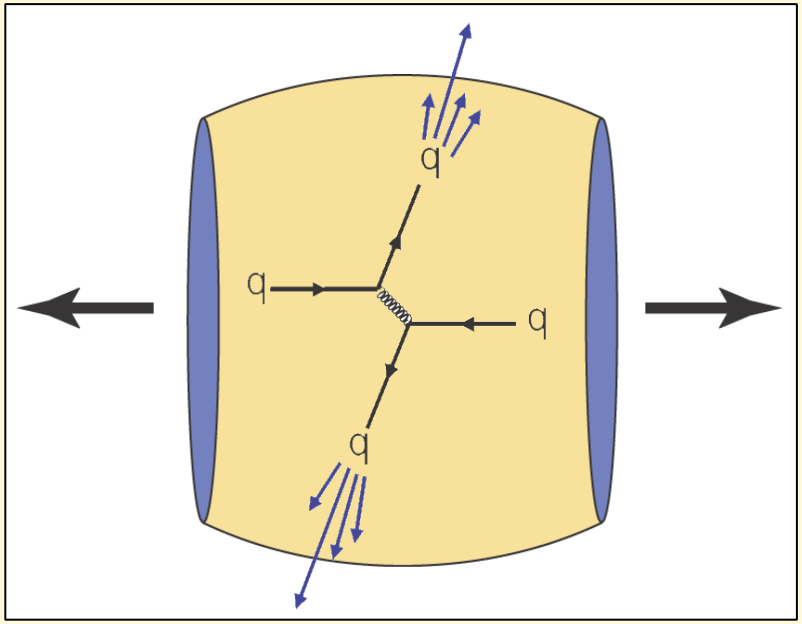
➔ This requires high statistics (luminosity)

- In order to understand the dynamics of the condensed phase of QCD access to specific physics channels is needed:
  - Charm and beauty from low to high p_t
  - Quarkonia
  - Jets and energy loss
  - Low mass lepton pairs

➔ This requires high precision measurements and statistics

One striking physics case (I)

- initial parton-parton scattering with large momentum transfer
  - calculable in pQCD
- particle jets follow direction of partons



➢ nucleus-nucleus collisions

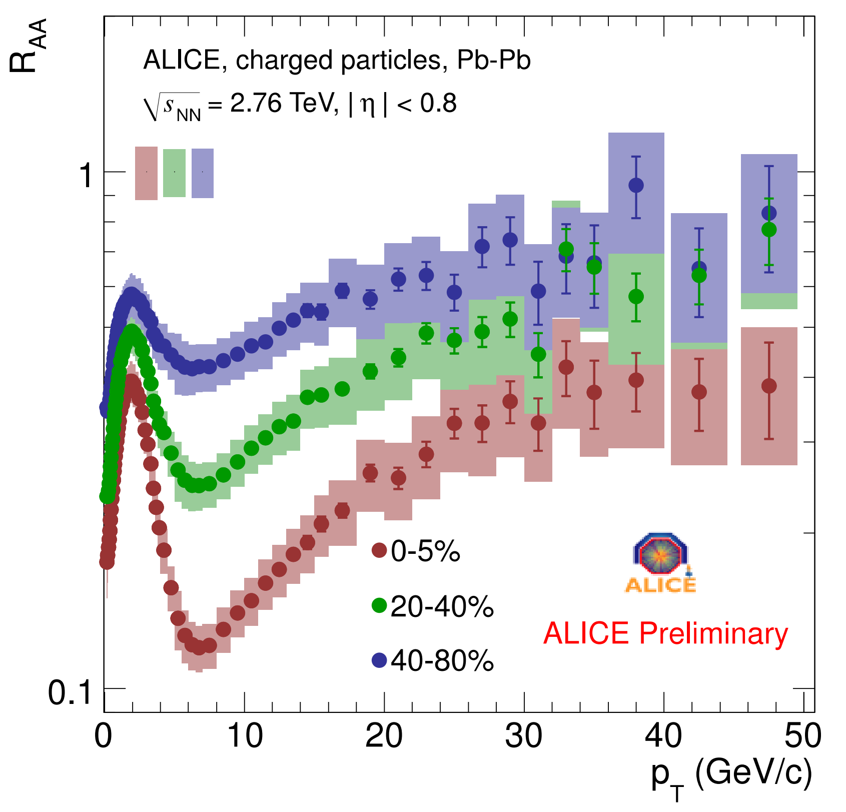
- hard initial scattering
- scattered partons probe traversed hot and dense medium
- 'jet tomography'

Medium modification quantified via nuclear modification factor R_{AA}

$$R_{AA}(p_T) = \frac{(1/N_{evt}^{AA})\, d^2N_{ch}^{AA}/d\eta dp_T}{\langle N_{coll}\rangle (1/N_{evt}^{pp})\, d^2N_{ch}^{pp}/d\eta dp_T}$$

One striking physics case (II)

Nuclear modification factor R_{AA} for charged particles as a function of centrality

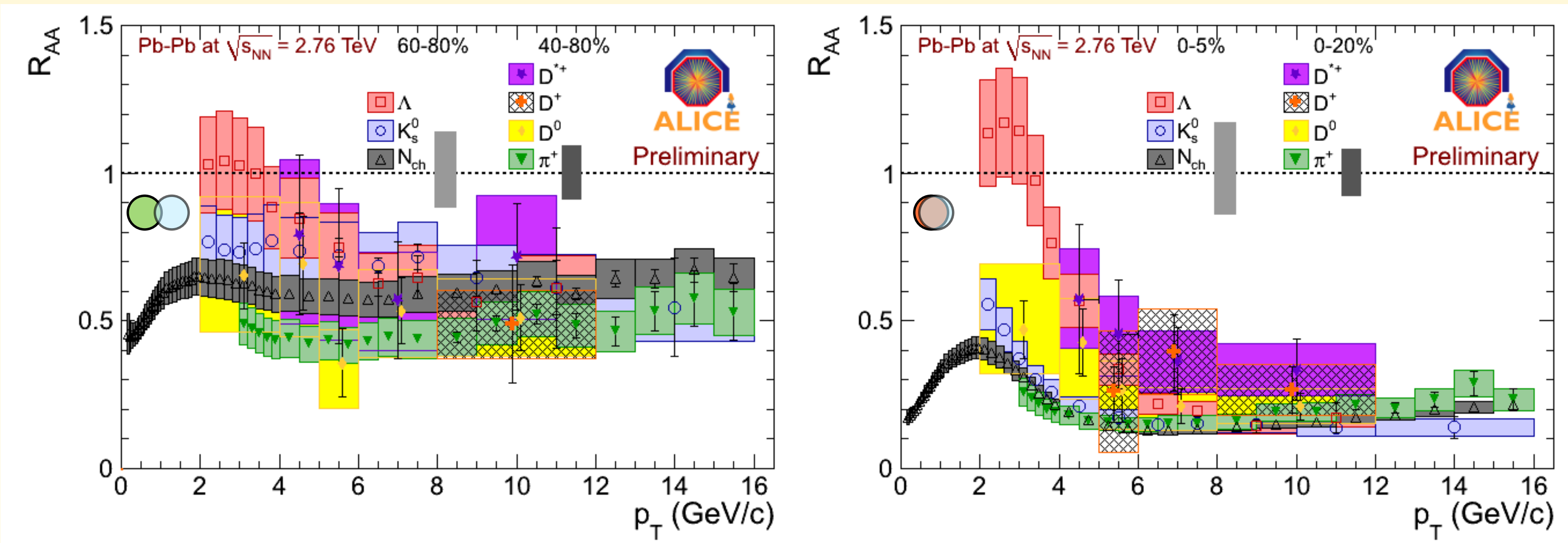


- in central collisions R_{AA} never reaches unity
- it is being debated whether perturbative methods can be used even at p_t>100 GeV/c

➔ need a detailed understanding of parton energy loss

One striking physics case (III)

Nuclear modification factor R_{AA} for identified particles



- **Significant charm suppression observed**, in contrast to predictions that it should be considerably less than for lighter hadrons
- thermalization is characterized by the emission pattern wrt event plane, i.e. elliptic flow (v_2)

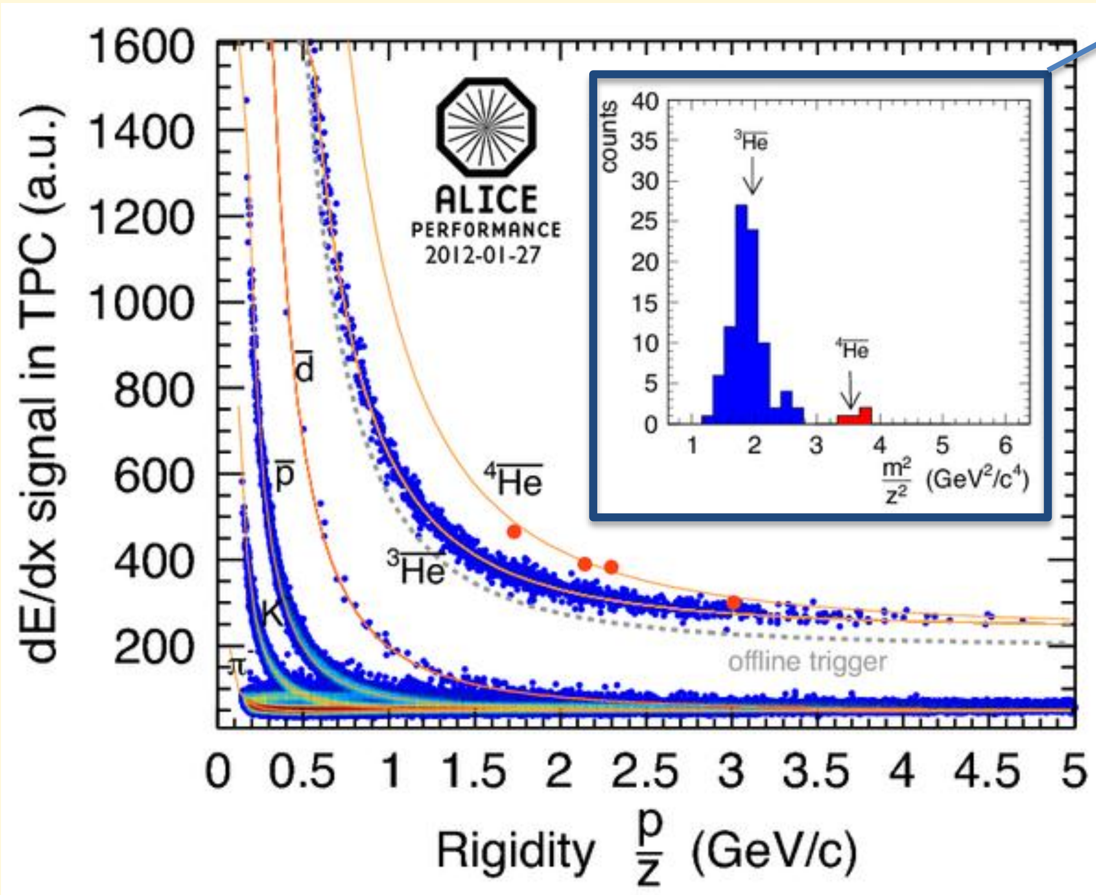
$$DE_g > DE_{c\approx q} > DE_b$$

$$R^{\pi}_{AA} < R^{D}_{AA} < R^{B}_{AA}?$$

$$v_{2,u/d} = v_{2,c} = v_{2,b}?$$

Relying on excellent particle ID

$$<\frac{dE}{dx}> = \frac{4\pi N e^4}{mc^2}\frac{z^2}{\beta^2}\left(\frac{1}{2}\ln\frac{2mc^2 E_{max}\beta^2\gamma^2}{I^2} - \frac{\beta^2}{2} - \frac{\delta(\beta)}{2}\right)$$



Time of flight (sensitive to m/z-ratio):

$$m = \frac{z \cdot R}{\sqrt{\gamma^2 - 1}}$$

ALICE upgrade plans

- ALICE has prepared an upgrade strategy document for the central barrel detectors and the muon arm

  ALICE @ High Rate

  endorsed by the collaboration,
  up for approval by the LHCC
- Upgrade strategy outlines physics case and measures to be taken in order to collect $10\ nb^{-1}$ PbPb collisions
- Extends particle identification capabilities and rate capabilities (up to 50 kHz PbPb. i.e. $L=6x10^{27}cm^{-2}s^{-1}$)

ALICE @ High Rate

- The upgrade entails building:
  - new beam pipe
  - new inner tracker (ITS) (scope and rate upgrade)
  - high-rate upgrade for the readout of the TPC, TRD, TOF, CALs, DAQ/HLT, Muons
- Furthermore, three major proposals are under consideration to extend the scope of ALICE: VHMPID, MFT, and FoCal
  - new high momentum PID capabilities
  - b-tagging for J/psi, low-mass di-muons
  - low-x physics with identified γ/π^{o}

Design goals ITS

1. Improve impact parameter resolution by a factor of ~3

- Identification of secondary vertices from decaying charm and beauty
- increase statistical accuracy of channels already measured by ALICE:
  - e.g. D^0, $B \rightarrow D_0$, $B \rightarrow J/\psi$, $B \rightarrow e$
- measurement of new channels not accessible with present ITS:
  - e.g. charmed baryon Λ_c , Λ_b

2. High standalone tracking efficiency and p_t resolution

- Online selection of event topologies with displaced vertices at L2 (~100 ms)
  - impact parameter of displaced tracks, distance between secondary and primary vertices, pointing angle
  - + PID
- reconstruct charm and beauty with ITS+TRD tracking and TOF PID

3. Fast readout

- readout of Pb-Pb interactions at > 50 kHz and pp interactions at > 2MHz

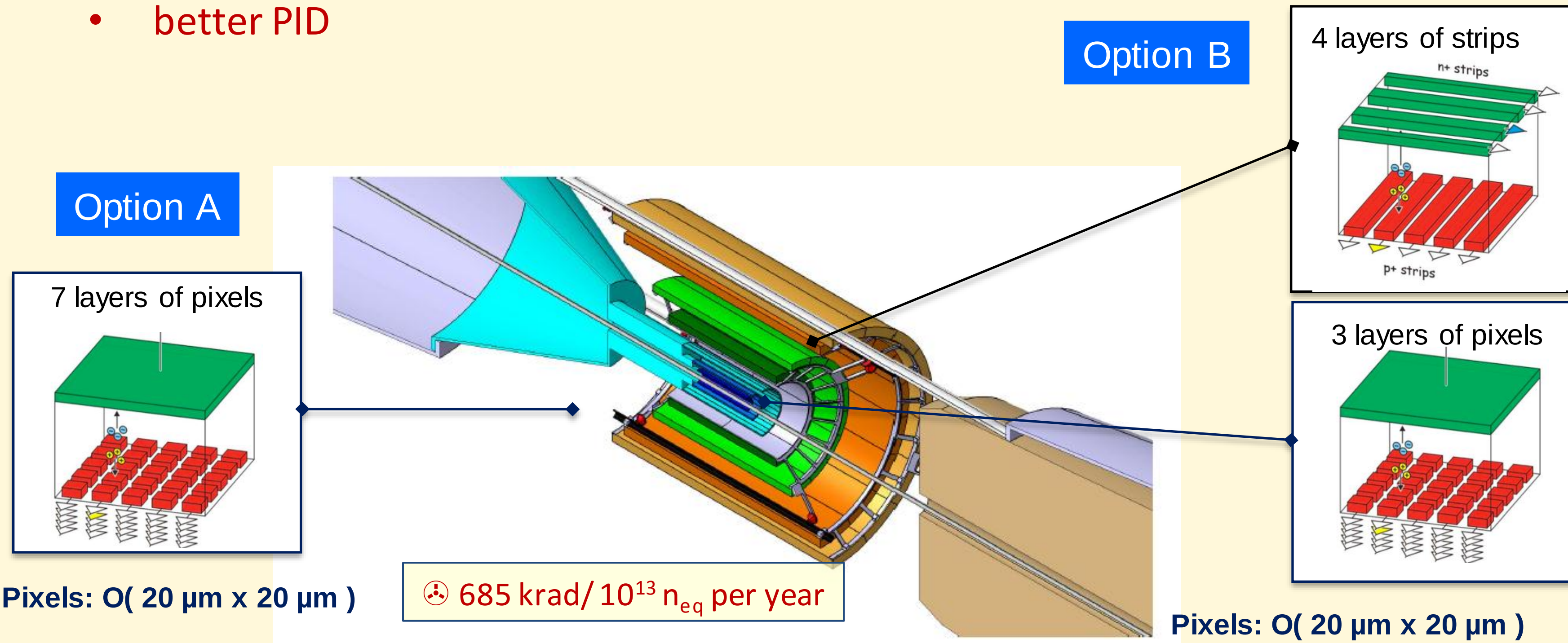
4. Fast insertion/removal for yearly maintenance

- possibility to replace non functioning detector modules during yearly winter shutdown

ITS upgrade options

A. 7 layers of pixel detectors
   - better standalone tracking efficiency and p_t resolution
   - worse PID (or no PID)

B. 3 innermost layers of pixel detectors and 4 outermost layers of strip detectors
   - worse standalone tracking efficiency and momentum resolution
   - better PID



Pixels: O(20 µm x 20 µm)

Pixels: O(20 µm x 20 µm)
Strips: 95 µm x 2 cm, double sided

Improving impact parameter resolution

1 - Get closer to the IP

present beam pipe: R_{OUT} = 29.8 mm, ΔR = 0.8 mm

⇩

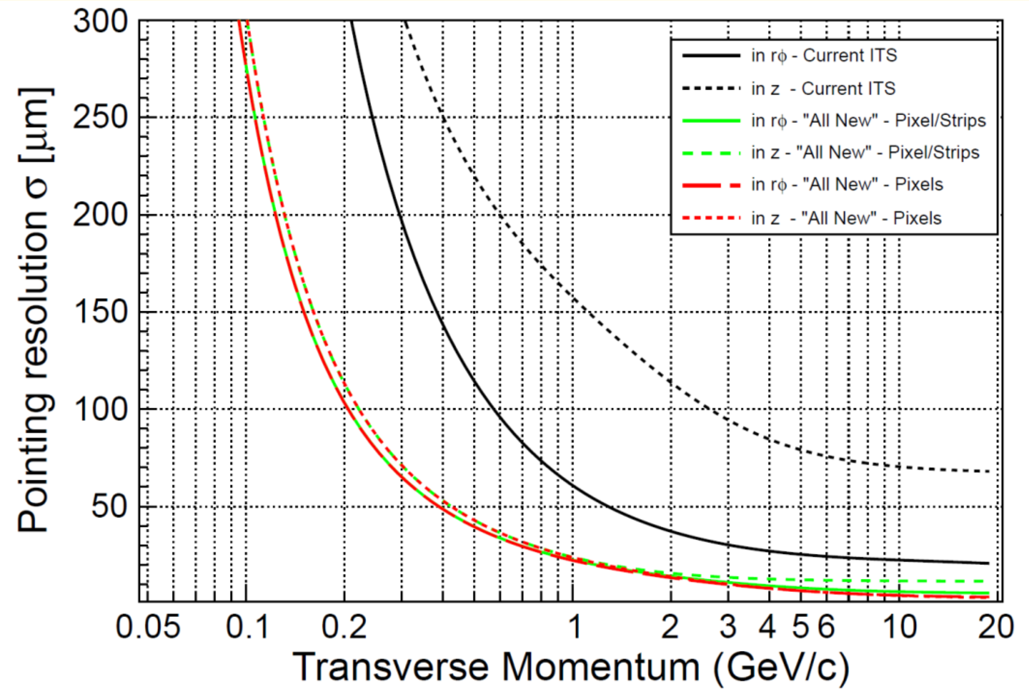
reduced beam pipe: R_{OUT} = 19.8 mm, ΔR = 0.8 mm

2 - Reduce material budget

present ITS: X/X_0 ~1.14% per layer

⇩

target for new ITS: X/X_0 ~0.3 – 0.5% per layer



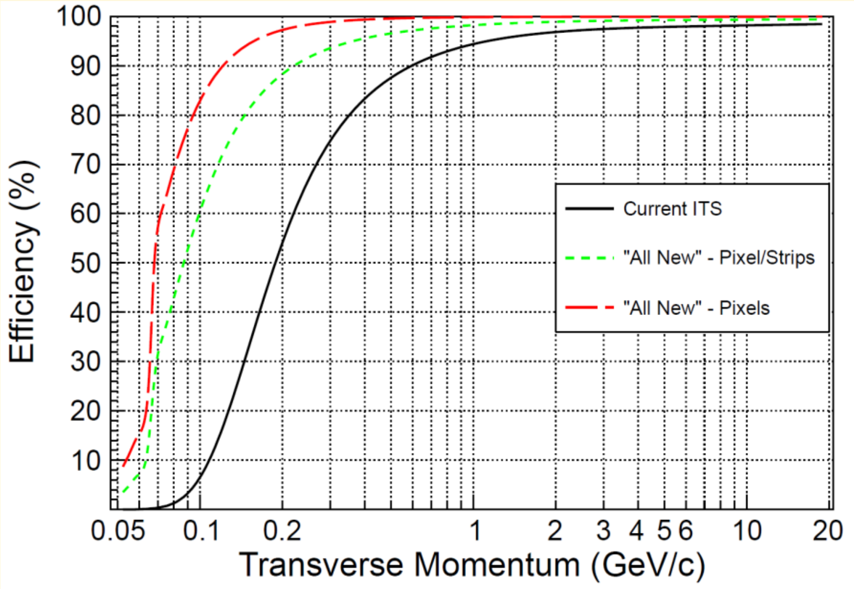
3 - Reduce pixel size

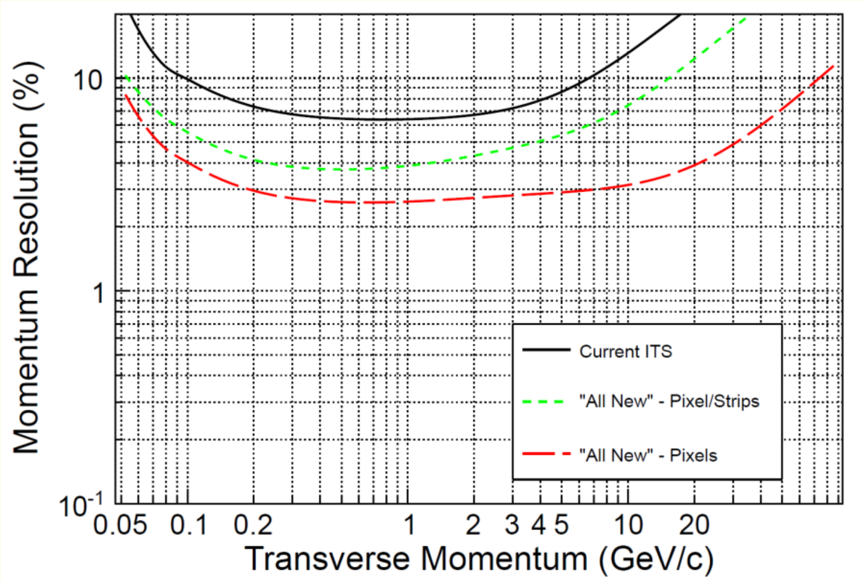
- currently 50μm x 425μm
  monolithic pixels ➡ O(20μm x 20μm)
  hybrid pixels ➡ O(30μm x 30μm)

Tracking efficiency and p_t resolution

Higher granularity and radial extension

- pixels 20μm x 20μm
- Combination of pixels (20μm, 20μm) and strips (90μm, 20mm)
- 6 layers -> 7 layers
- smaller inner (39->22mm) – larger outer (430->500mm) radius

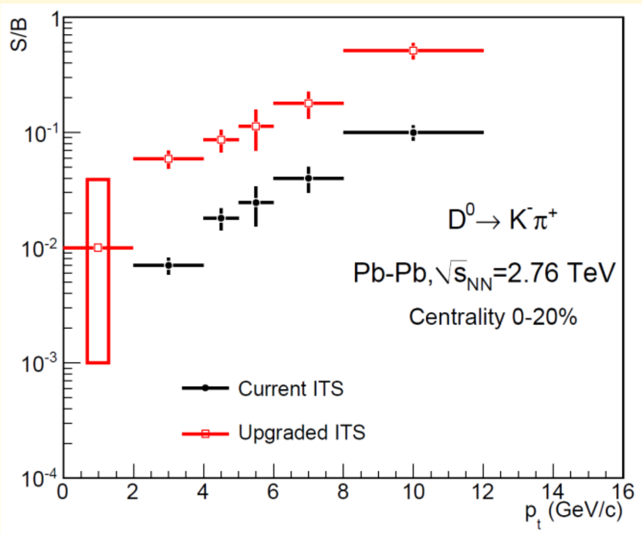


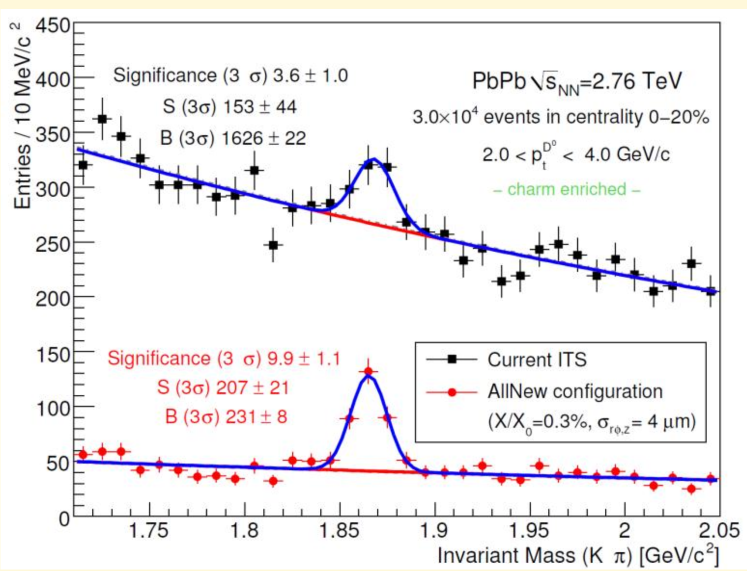


ITS standalone tracking: 430mm radius (500mm improves by another 10%)

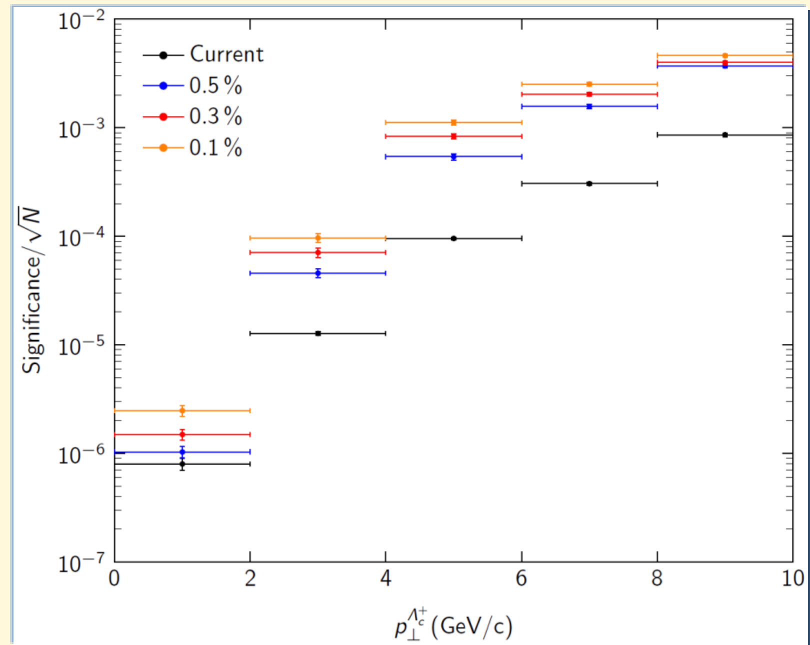
Benchmark channels D°, Λc

Benchmark channel at very low p_t: $D^0 \rightarrow K\pi$





$\Lambda_c \rightarrow pK\pi$ as benchmark channel in central (0-10%)Pb-Pb



Assuming ~ 10^{10} central events / year

0-2 Gev/c: significance (3σ) ~ 0.3

2-4 Gev/c: Significance (3σ) ~ 7

4-6 Gev/c: Significance (3σ) ~ 100

Heavy-ion program

adapted from J.M. Jowett

2013-14		Long shutdown LS1, increase *E*
2015-16	**Pb-Pb**	Design luminosity, ~ 250 μb^{-1}/year, Luminosity levelling?
2017	**p-Pb *or* Pb-Pb**	P-Pb to enhance 2015-16 data. Energy? Pb-Pb if μb^{-1} still needed
2018	**LS 2**	? install DS collimators to protect magnets ALICE upgrade for 6 × design luminosity
2019	**Pb-Pb**	Beyond design luminosity … as far as we can. Reduce bunch spacing?
2020	**p-Pb**	
2021	**Ar-Ar**	Intensity, to be seen from injector commissioning for SPS fixed target.
2022		LS3, upgrades ?? Stochastic cooling ??
>2022		PbPb luminosity production, pA, other ions (U??)

approved program: 1 nb^{-1} (2015-16 to 2019)

goal: 10 nb^{-1} (>2022)

an aside: Pb-p at high luminosity provides an unprecedented brilliant photon source

Ions in ATLAS and CMS in the HL-LHC era

- p-p collisions will continue to be the priority for ATLAS and CMS!
- interested in extending HI program into the HL-LHC period if heavy ions can be made available without impact on the p-p HL-LHC upgrade.
- HI running to remain limited to no more than ~10% of the yearly physics time.

Compatibility with LHeC

- Clearly ALICE will want exploit its upgrade program
  ➔HL ion running beyond LS3
  ➔also some pp
  ➔precludes the timely availability of IP2 as currently stated in the CDR of LHeC.

Will ALICE be running during the HL-LHC era?

YES

- Hopefully, you are convinced that there is a strong physics case that justifies the ambitious upgrade program

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