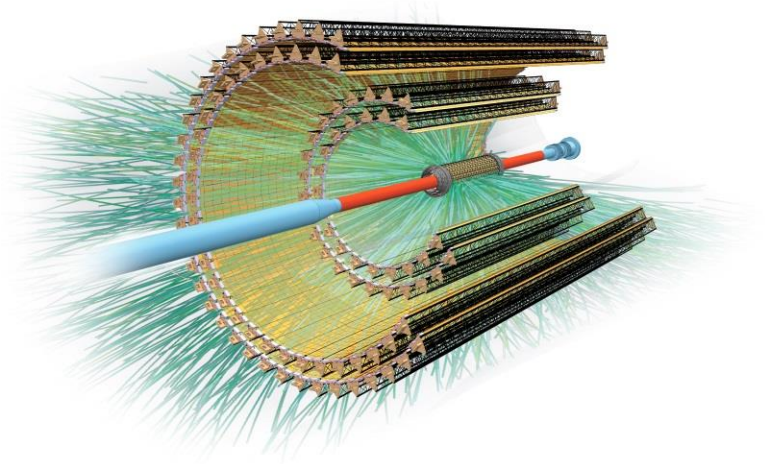
A Large Ion Collider Experiment

The Upgrade of the Inner Tracking System of ALICE



Sabyasachi Siddhanta
University and INFN, Cagliari, Italy

On behalf of the ALICE collaboration

XXIV QUARK MATTER
DARMSTADT 2014

ALICE upgrade strategy

Motivation

High precision measurements of rare probes at low p_T which cannot be selected with a trigger – require large event samples on tape.

Target

- Pb-Pb recorded luminosity ≥ 10 nb^{-1} plus pp and p-A data

Gain a factor of 100 in statistics for minimum bias trigger over the current programme

- Improve vertexing, tracking and read-out rate capabilities

Strategy (during LHC Long Shutdown 2 - 2018-19)

- Upgrade ALICE readout (for several detectors) and online systems
  - Read out all Pb-Pb interactions at a maximum rate of 50 kHz with a minimum bias trigger
  - Perform online data reduction
- New silicon trackers: Inner Tracking System (mid-rapidity), Muon Forward Tracker (forward rapidity)

ALICE Upgrades

New Silicon trackers

- A new beam pipe with smaller diameter
- A new, high-resolution, low-material Inner Tracking System (ITS)
- A new Muon Forward Tracker (MFT) - add vertexing capabilities to the current Muon Spectrometer

Posters: Antonio Uras (F-56) , Lizardo Palomo (M-29)

Detector readout and online systems upgrade

- Time Projection Chamber (TPC)- replacing MWPCs with micropattern gaseous detectors, new read-out electronics

Talk: Taku Gunji (170)

- Transition Radiation Detector (TRD), Time Of Flight detector (TOF), and Muon Spectrometer - upgrade of the read-out electronics
- Forward trigger detectors upgrade

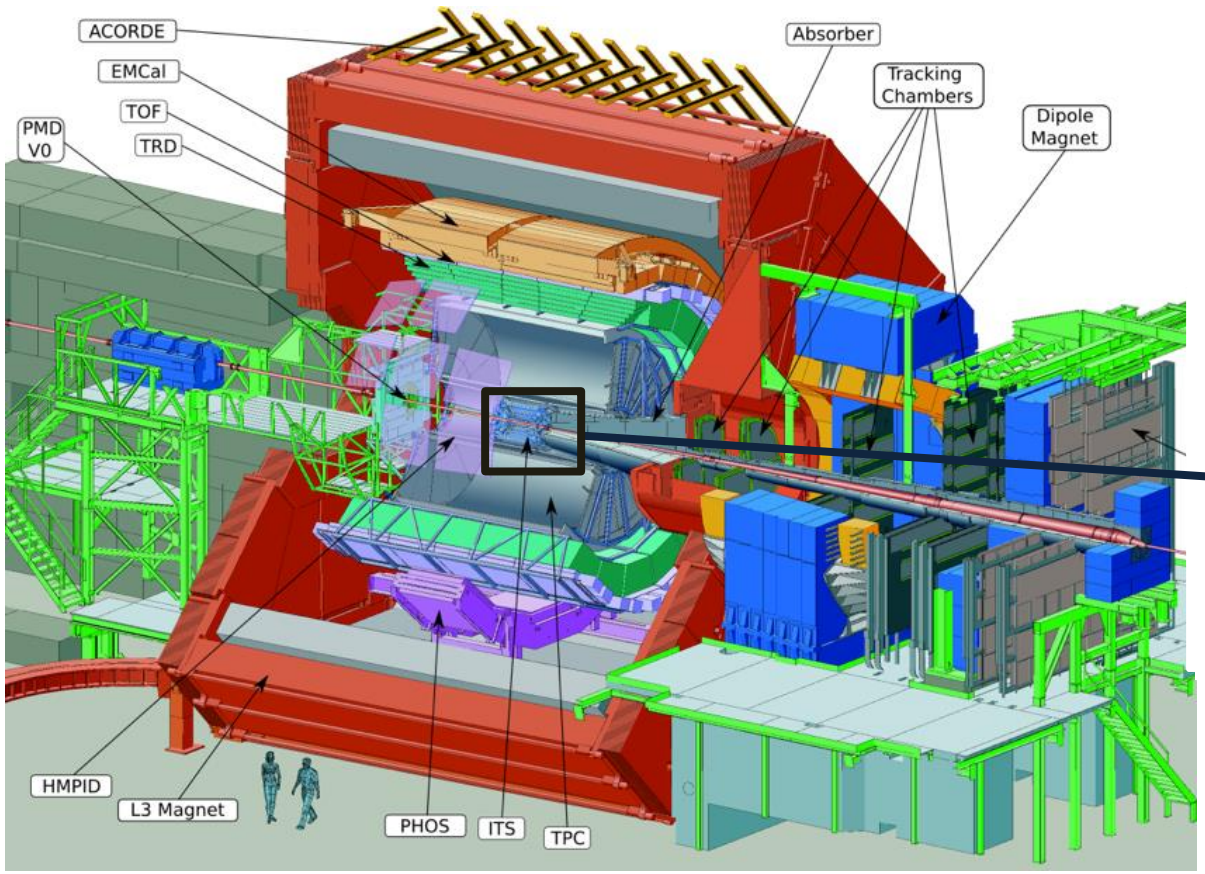
Poster: Wladyslaw Trzaska (M-28)

- A possible, new forward calorimeter

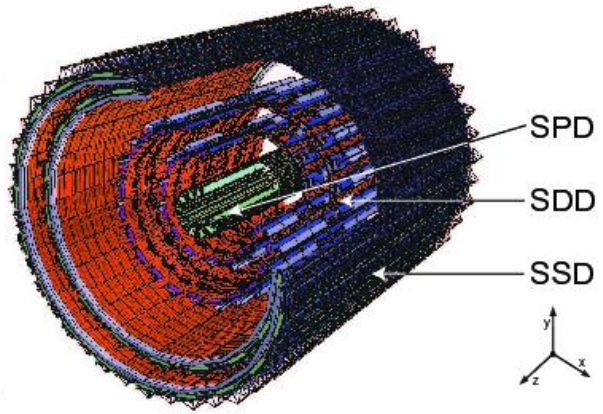
Poster: Thomas Peitzmann (M-22)

- Online systems and offline reconstruction and analysis framework upgrade (O^2)

ALICE – present ITS

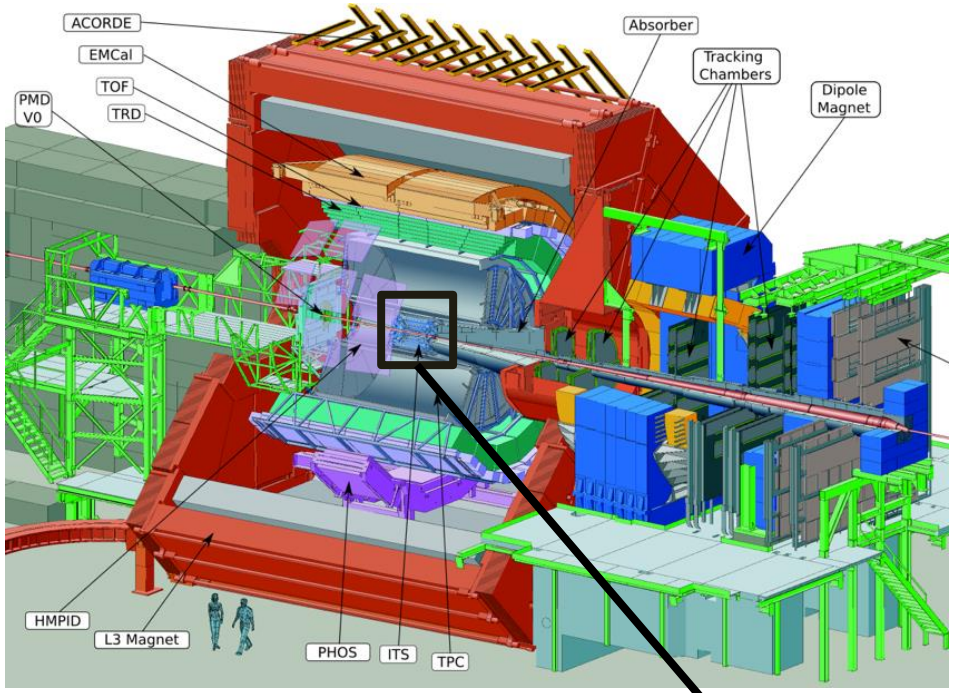


Present ITS

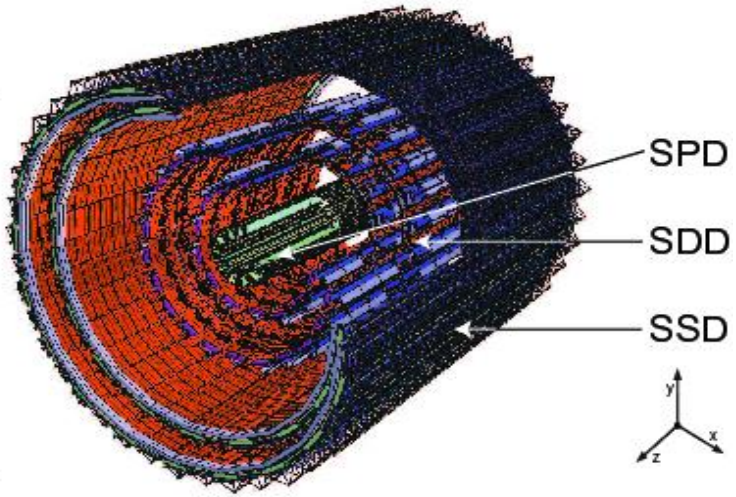


- Present ITS consists of 6 cylindrical layers of silicon detectors – 2 layers each of Silicon Pixel Detector (SPD), Silicon Drift Detector (SDD) and double sided Silicon microStrip Detector (SSD)

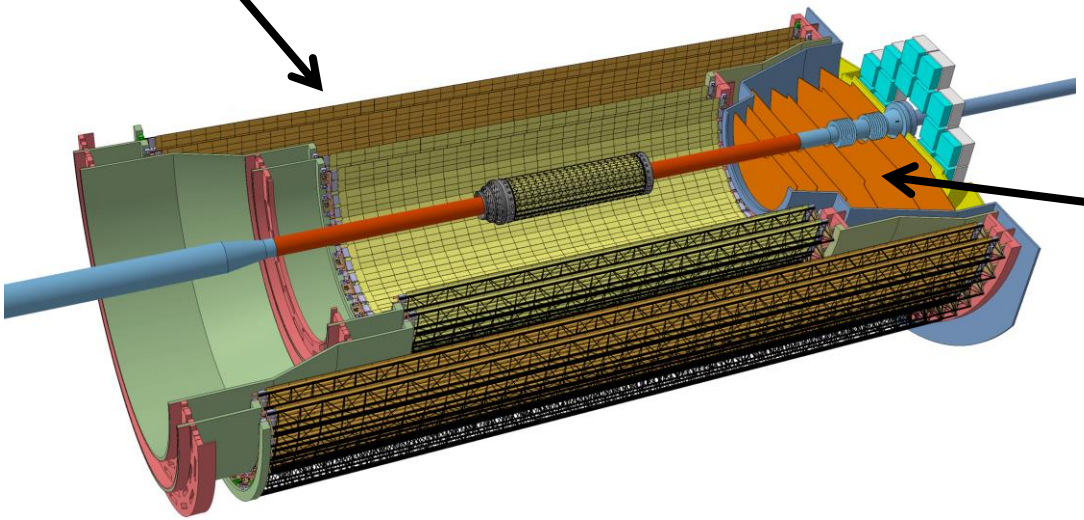
ALICE – new ITS



Present ITS



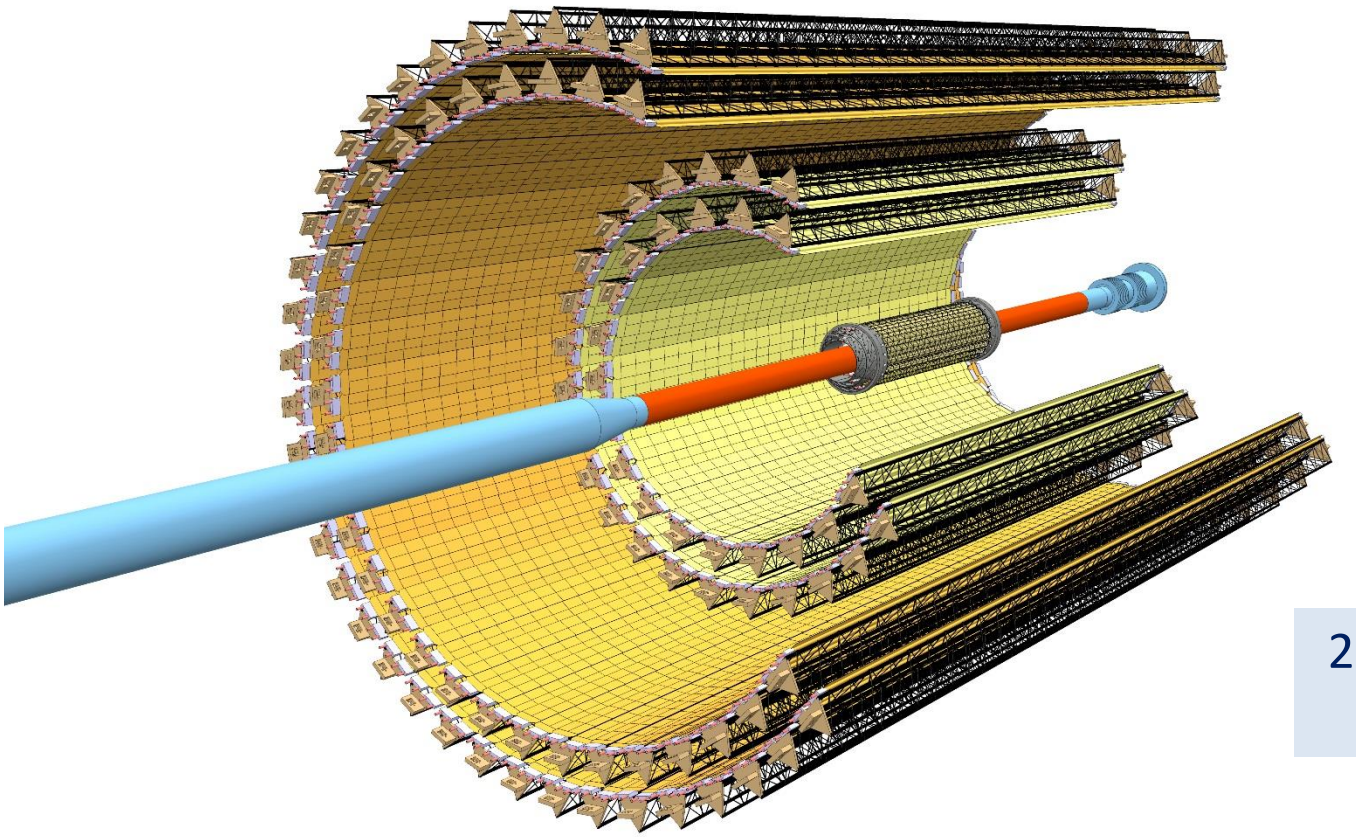
New ITS



ITS Upgrade Design Goals

- Improve impact parameter resolution (≈ factor of 3(5) in r-φ (z) at 500 MeV/c)
  - First layer closer to IP : r_0 = 39 mm→22 mm,
    smaller beam pipe: 29 mm →18.2 mm
  - Reduced material budget per layer, specially the inner layers :
    X/X_0 :1.14 % → 0.3 % for the first layer
  - Smaller pixel size: 50 µm x 425 µm → O (30 µm)
- Improve tracking efficiency and p_T resolution at low p_T
  - Increase number of layers (6→7)
  - Increase granularity
- Fast readout : 50 kHz in Pb-Pb, 200 kHz in pp (currently 1 kHz)
- Easier maintenance – allow insertion/removal of faulty detector components during the annual winter shutdown

New ITS Layout



25G pixels
~10 m²

New ITS layout

- 7- layer barrel geometry of MAPS
- Inner Barrel (3 layers)
- Outer Barrel (4 layers)

- **η coverage:** $|\eta| \leq 1.22$

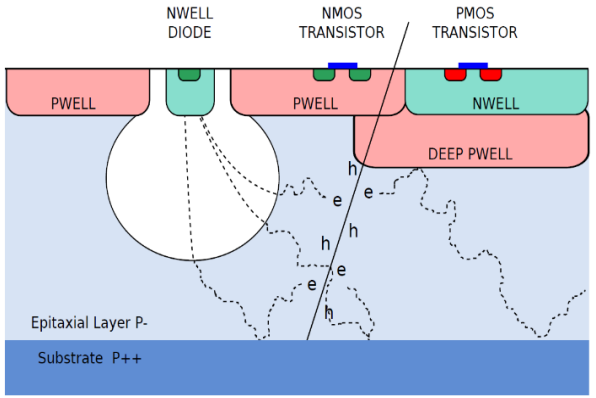
for tracks from 90 % most luminous region

- **r coverage:** 22 – 430 mm

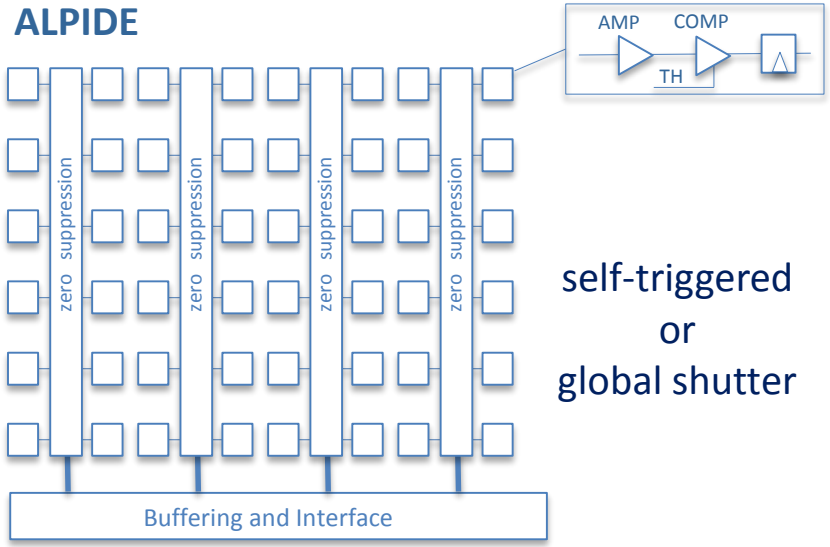
Pixel technology

Pixel choice: Monolithic Active Pixel Sensors (MAPS) using Tower Jazz 0.18 µm

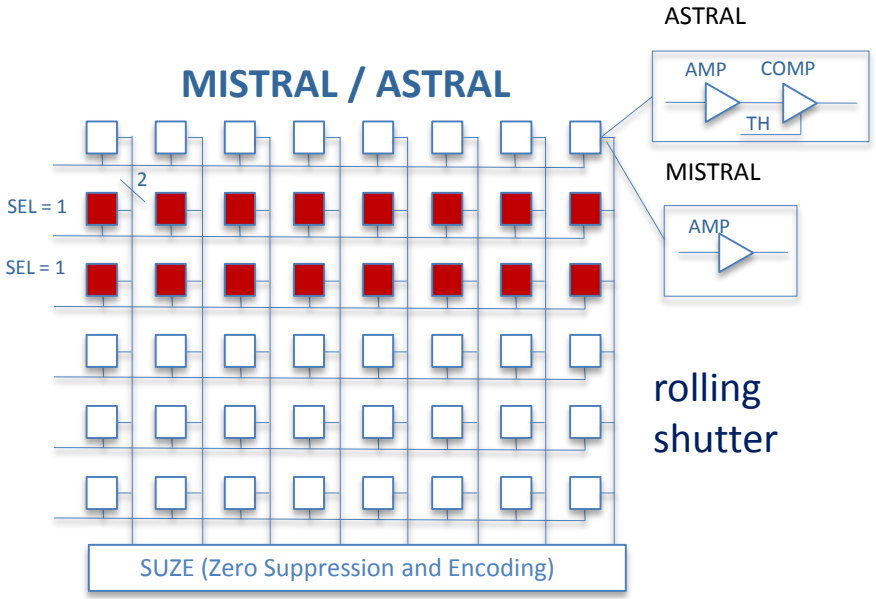
- Chip size: 15 mm x 30 mm
- Pixel pitch ~ 30 µm
- Si thickness: 50 µm
- Spatial resolution ~ 5 µm
- Power density < 100 mW/cm^2
- Integration time < 30 µs



Schematic cross section of a MAPS pixel



self-triggered
or
global shutter

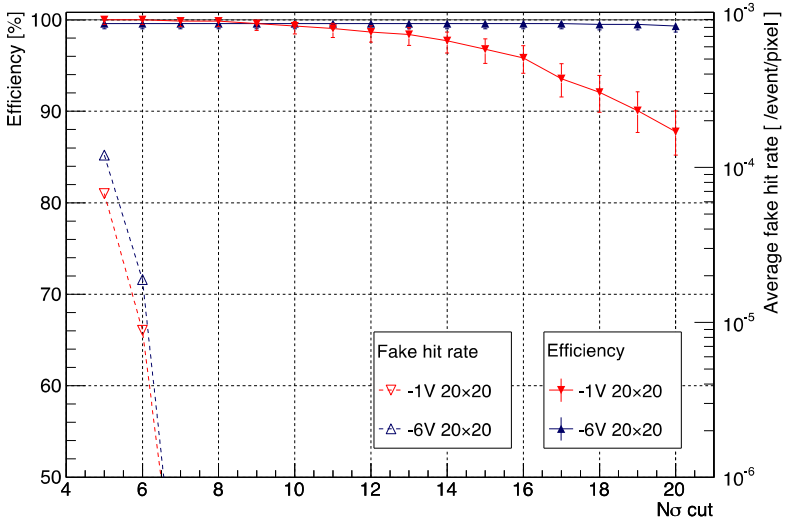


rolling
shutter

Pixel prototypes: Experimental results

ALPIDE

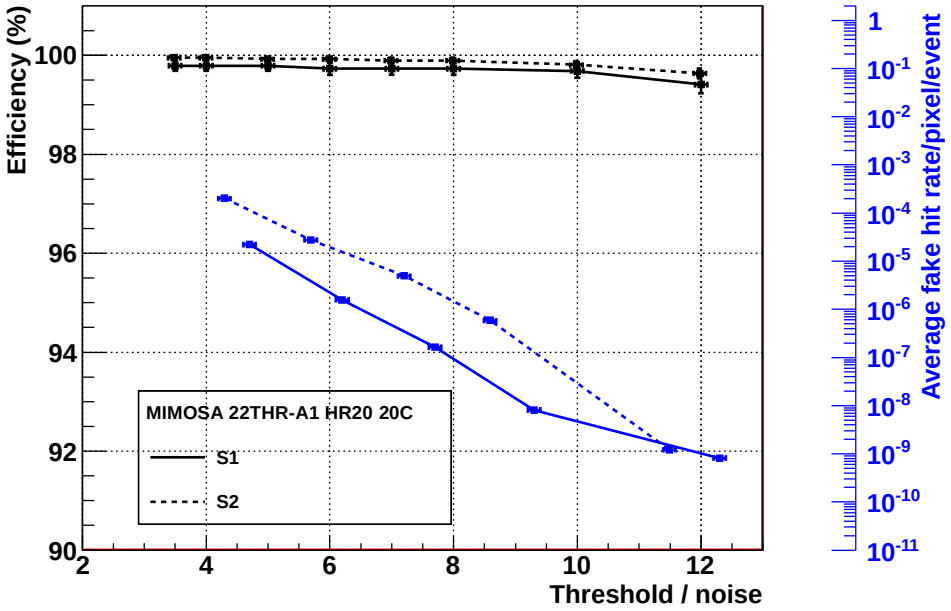
ALICE, CERN-LHCC-2013-024



Explorer: prototype with analogue output

MISTRAL/ ASTRAL

ALICE, CERN-LHCC-2013-024



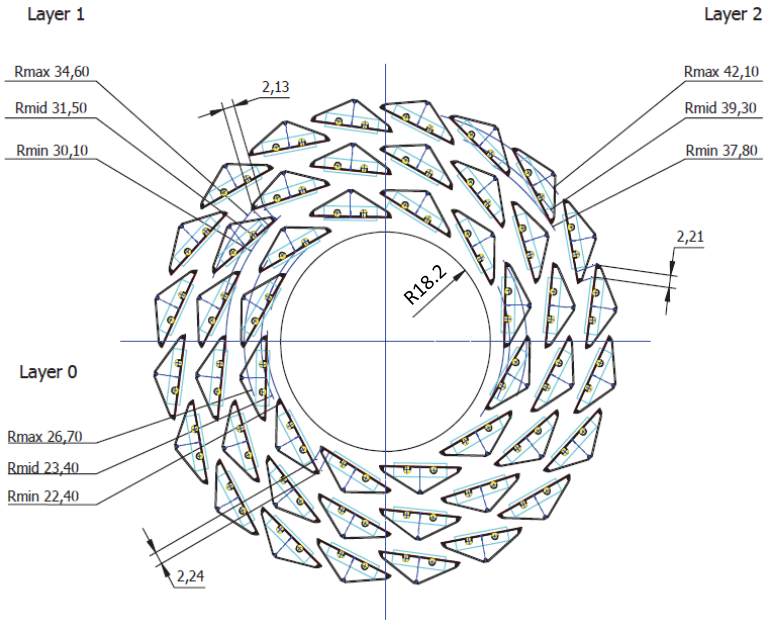
pALPIDE: sizeable prototype of final chip (digital output) , pixel size: 22 x 22 μm^2

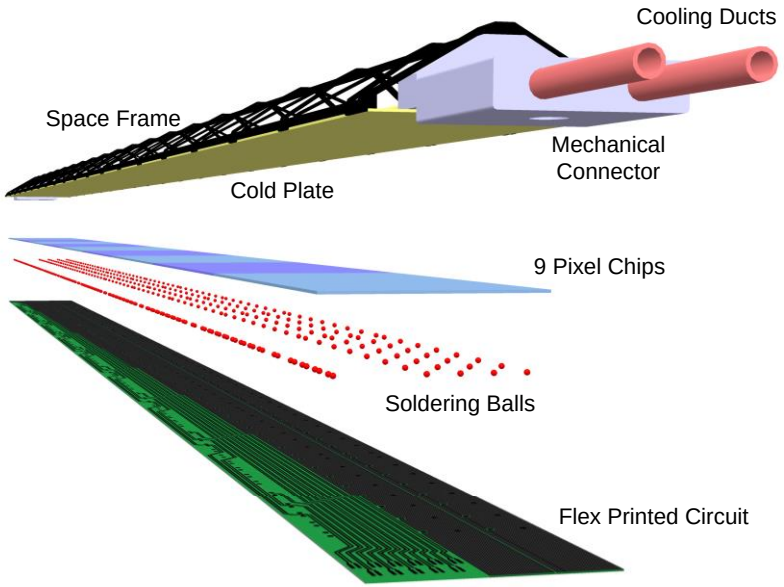
At Threshold / Noise: 20
Detection efficiency: 99.7 %
Fake hit rate < 10^{-8} pixel/event
Spatial resolution ~ 5 μm

MIMOSA-22-THR-A1 performance from digital output pixel size (22 x 33 μm^2) for two design options

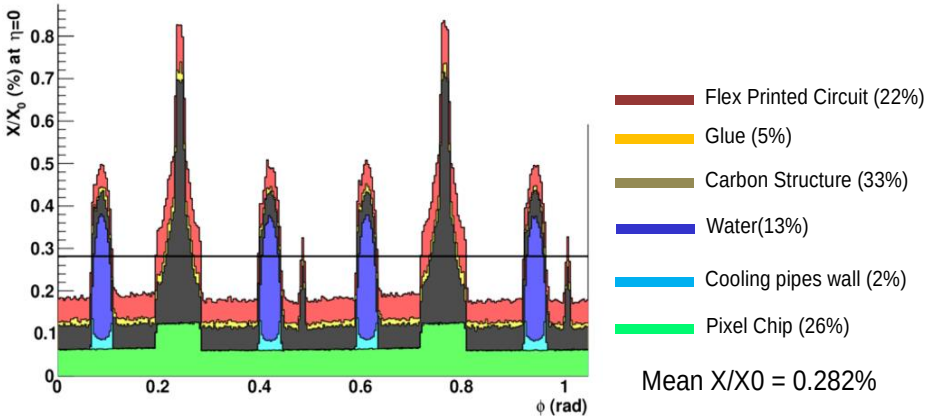
Measurements at DESY with 3-6 GeV/c electron and positron beam

Inner Barrel

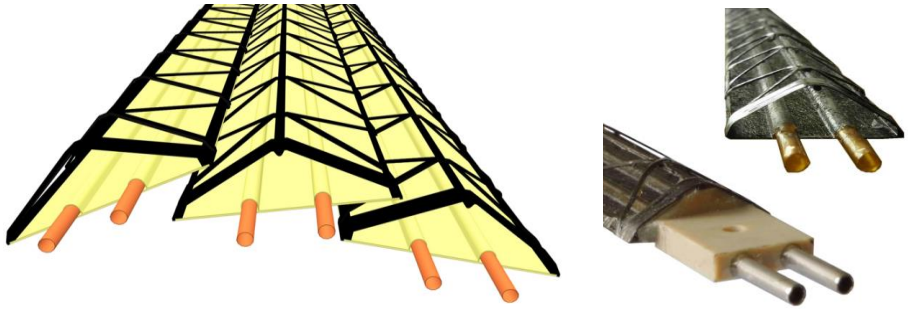




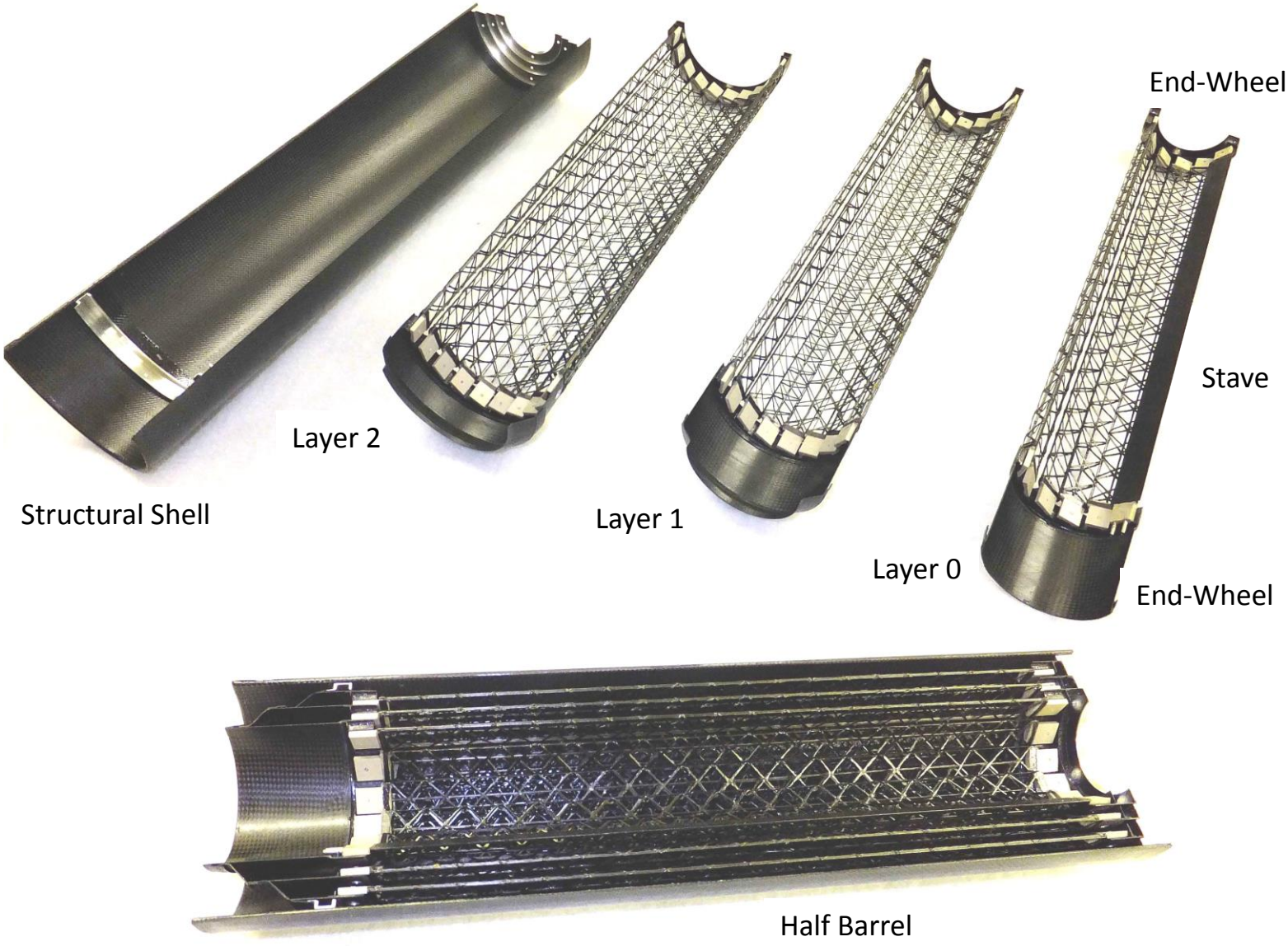
Material budget: ~ 0.3 % X_0 per layer



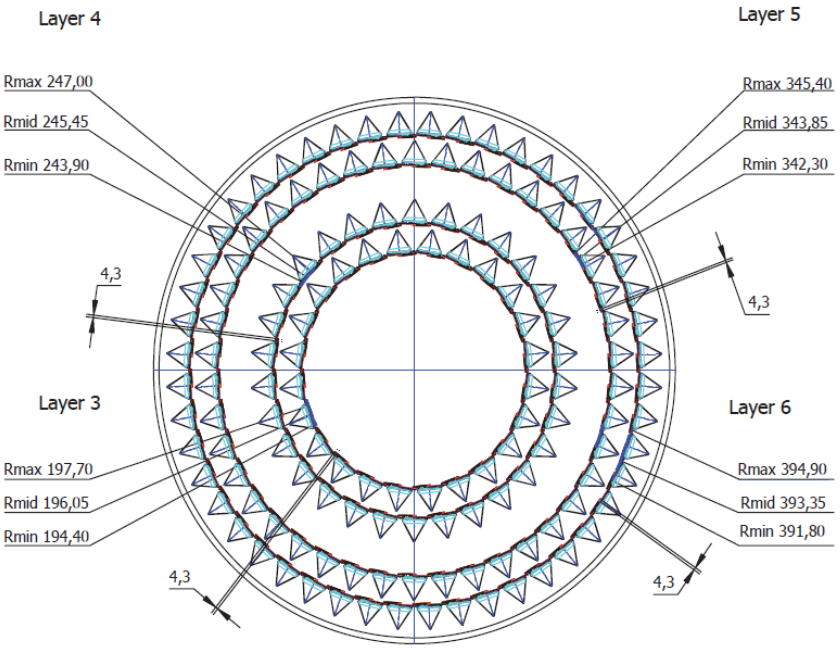
Inner Barrel Stave

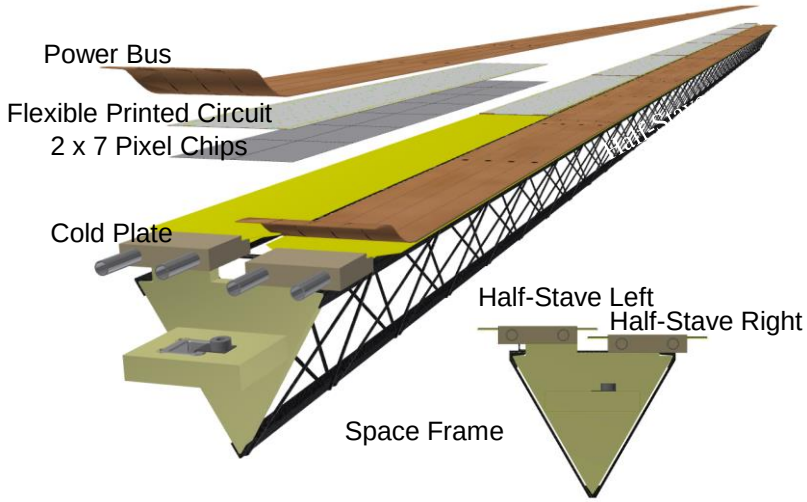


Inner Barrel prototype structures



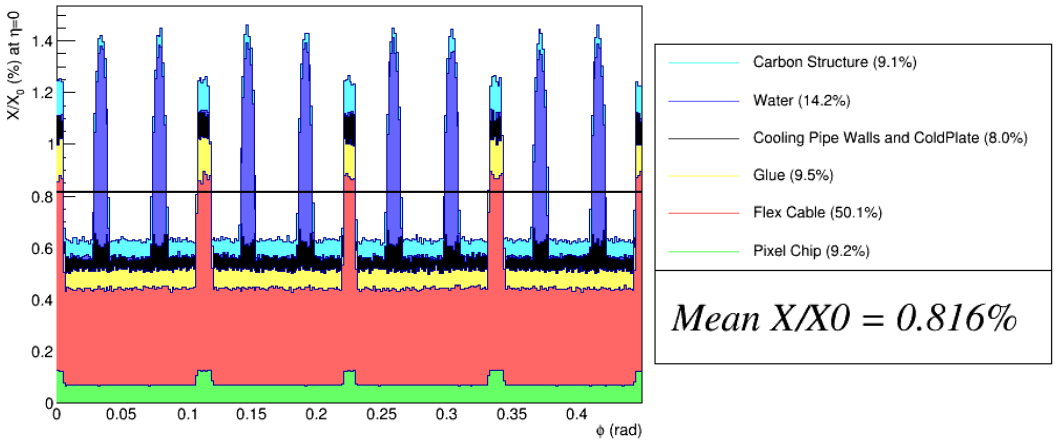
Outer Barrel

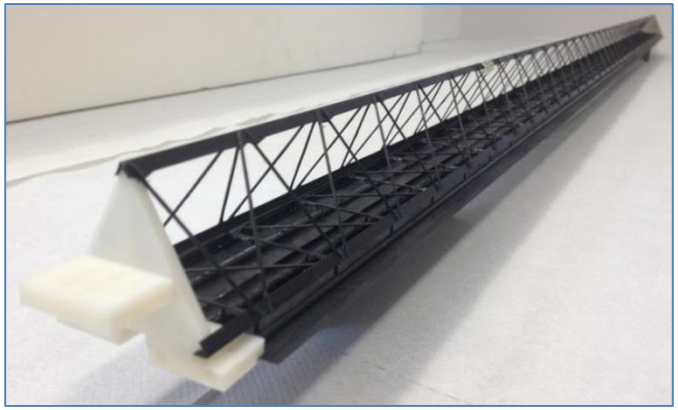




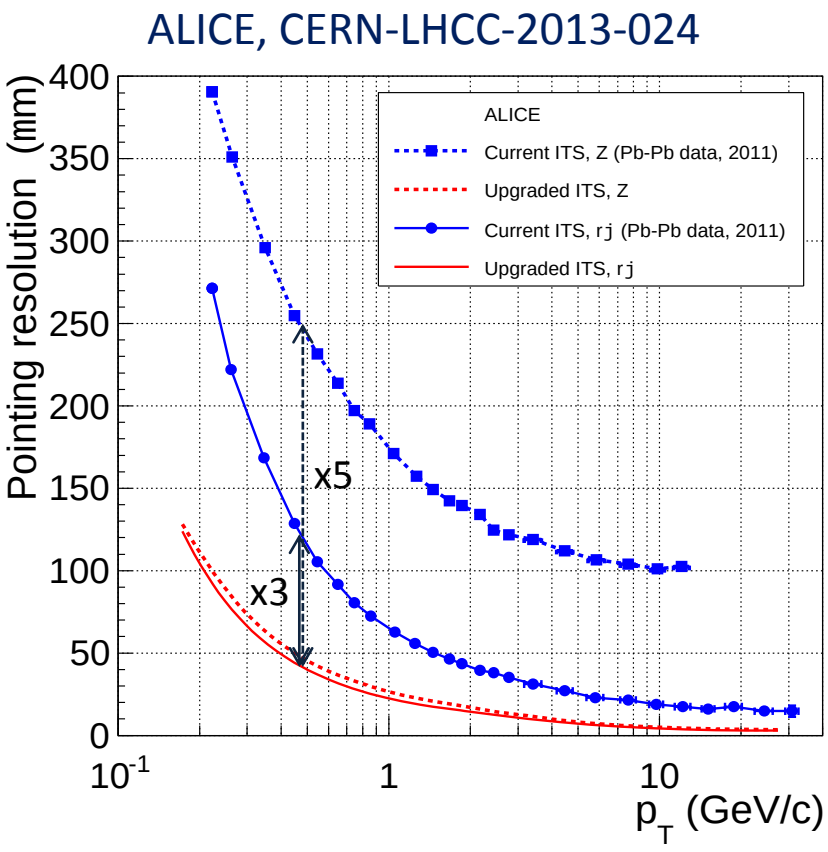
Outer Barrel Stave

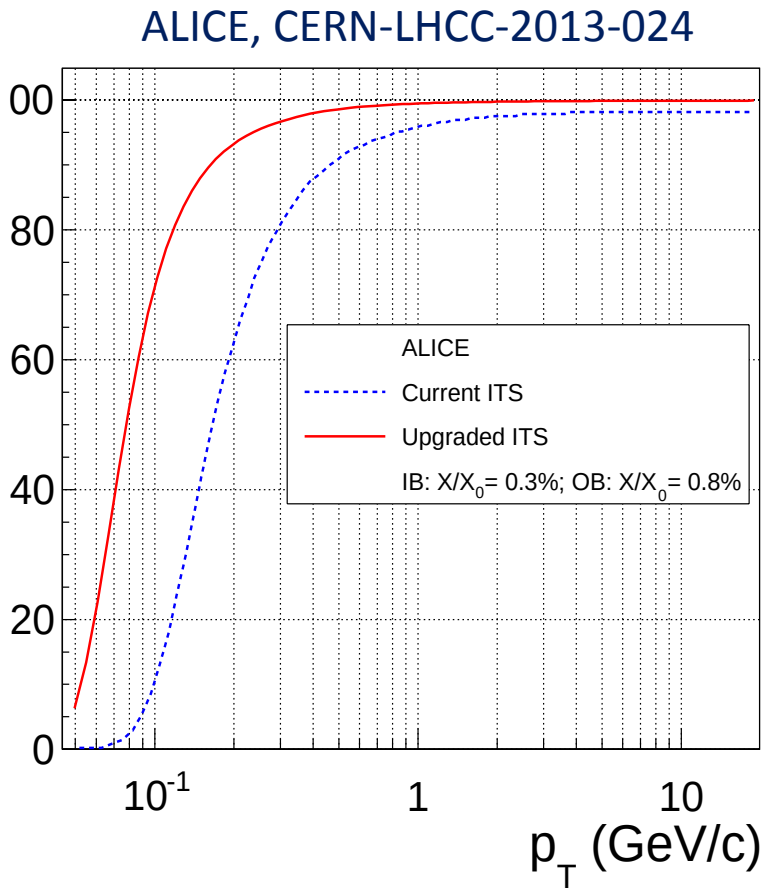
Material budget: ~ 0.8 % X_0 per layer





Detector performance studies

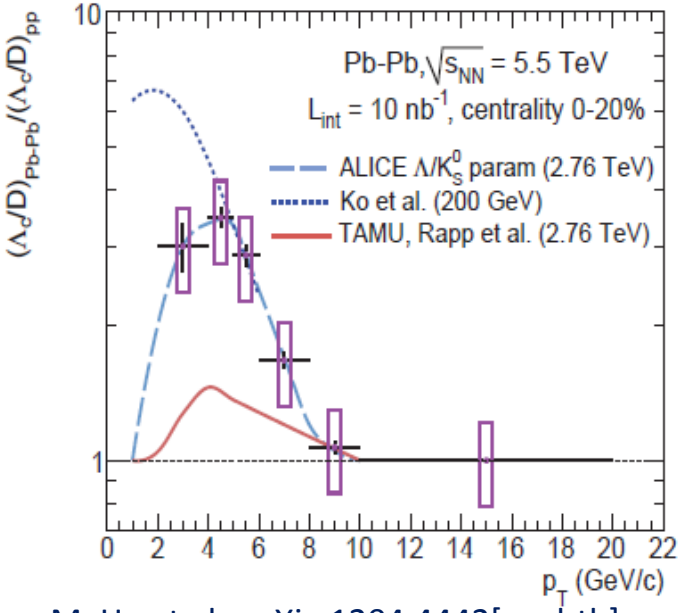




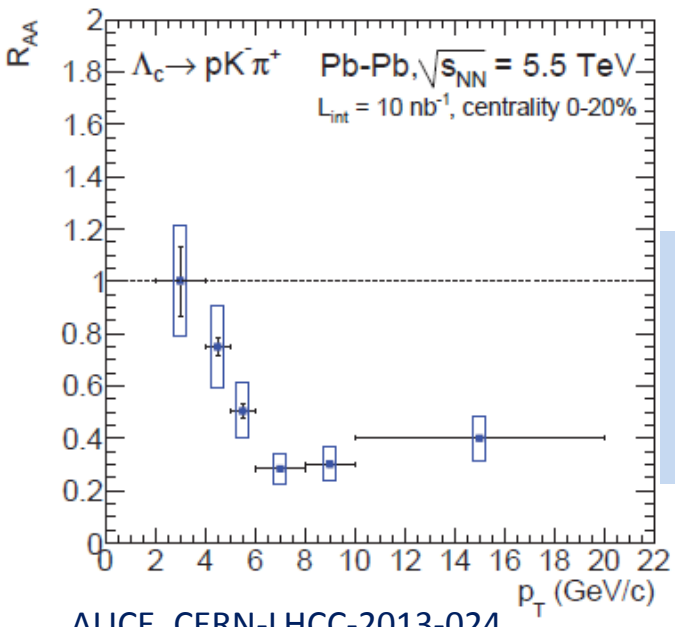
Expected improvement on pointing resolution (left) and tracking efficiency (right) for the new ITS over the present ITS

Physics performance studies - example

Λ_c has a decay length ($c\tau$ = 60 μm) smaller than the impact parameter resolution of the current ITS – currently inaccessible in Pb-Pb.



M. He et al., arXiv:1204.4442[nucl-th]
Y.Oh et al., Phys. Rev. C79, 044905(2009)



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Λ_c measurements in upgraded ALICE
Poster M-23: Rossella Romita

New ITS will allow Λ_c measurements for the first time in Pb-Pb collisions at the LHC.

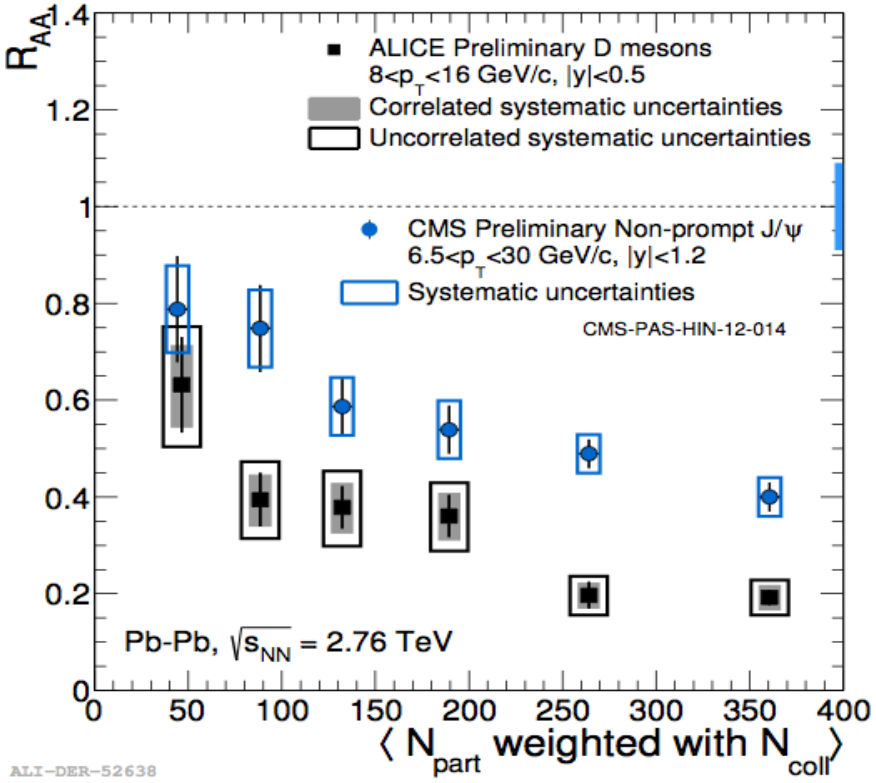
Ability to reconstruct Λ_c would also give insight to Λ_b measurements ($\Lambda_b \rightarrow \Lambda_c^+\pi^-$) for the first time in Pb-Pb collisions at the LHC.

Λ_b measurements in upgraded ALICE
Poster M-27 : Cristina Terrevoli

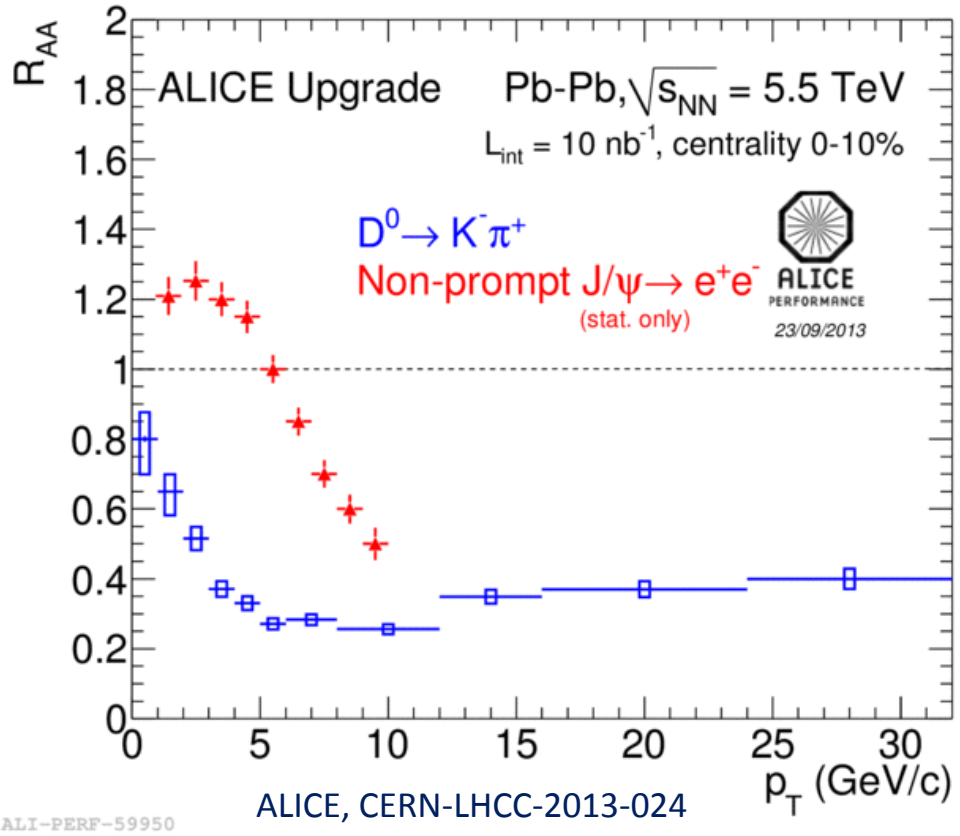
Physics performance studies - example

Heavy flavour - R_{AA}

Present



Upgrade



ALICE, CERN-LHCC-2013-024

Present results at p_T~10 GeV

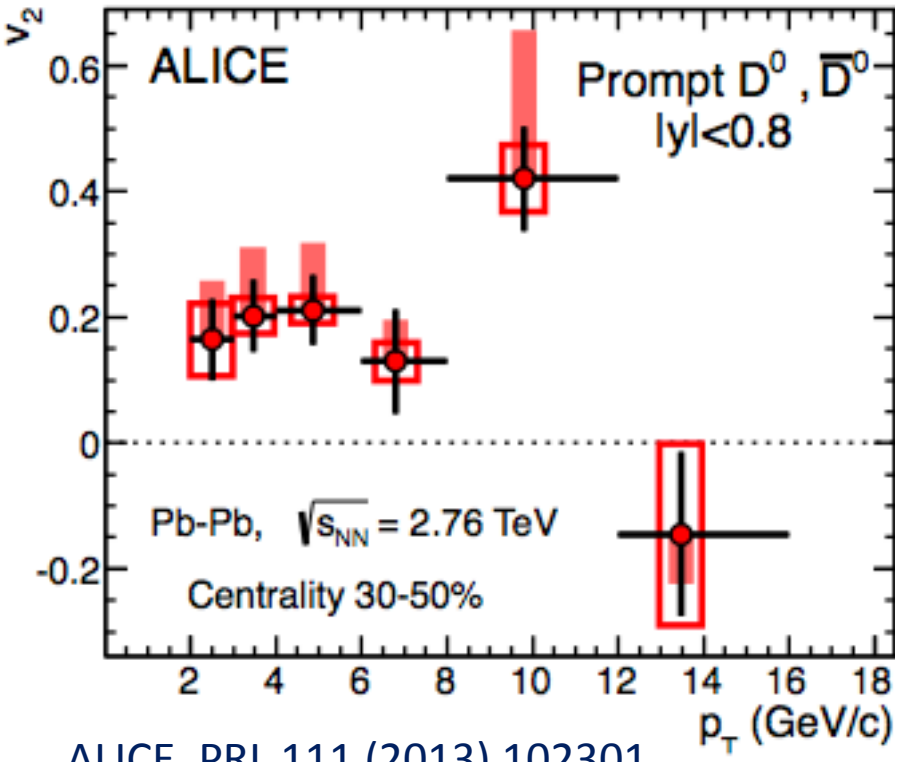
Talk: Andrea Festanti (94)

Charm and beauty R_{AA} down to p_T~0 using D^0 and B-decay J/ψ

Physics performance studies - example

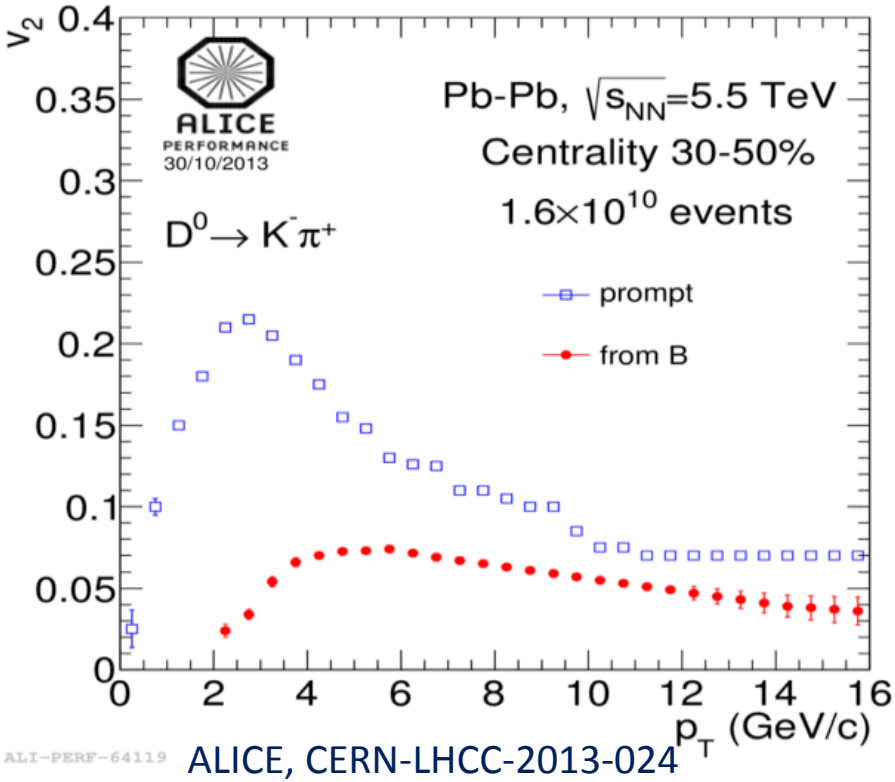
Heavy flavour - flow

Present



ALICE, PRL 111 (2013) 102301

Upgrade



ALICE, CERN-LHCC-2013-024

Input values from BAMPS model: C. Greiner et al. arXiv:1205.4945

Present results on charm v_2

Talk: Raphaelle Bailhache (122)

Charm v_2 down to p_T~0 using prompt and beauty v_2 down to B p_T~0 using B-decay D^0

Physics performance studies

Observable	Current, 0.1 nb^{-1}		Upgrade, 10 nb^{-1}	
	$p_{\mathrm{T}}^{\mathrm{min}}$ (GeV/c)	statistical uncertainty	$p_{\mathrm{T}}^{\mathrm{min}}$ (GeV/c)	statistical uncertainty
Heavy Flavour				
D meson R_{AA}	1	10 %	0	0.3 %
$\mathrm{D_s}$ meson R_{AA}	4	15 %	< 2	3 %
D meson from B R_{AA}	3	30 %	2	1 %
J/ψ from B R_{AA}	1.5	15 % (p_{T}-int.)	1	5 %
B^+ yield	not accessible		3	10 %
Λ_{c} R_{AA}	not accessible		2	15 %
$\Lambda_{\mathrm{c}}/\mathrm{D}^0$ ratio	not accessible		2	15 %
Λ_{b} yield	not accessible		7	20 %
D meson v_2 ($v_2 = 0.2$)	1	10 %	0	0.2 %
$\mathrm{D_s}$ meson v_2 ($v_2 = 0.2$)	not accessible		< 2	8 %
D from B v_2 ($v_2 = 0.05$)	not accessible		2	8 %
J/ψ from B v_2 ($v_2 = 0.05$)	not accessible		1	60 %
Λ_{c} v_2 ($v_2 = 0.15$)	not accessible		3	20 %
Dielectrons				
Temperature (intermediate mass)	not accessible			10 %
Elliptic flow ($v_2 = 0.1$)	not accessible			10 %
Low-mass spectral function	not accessible		0.3	20 %
Hypernuclei				
$^3_\Lambda\mathrm{H}$ yield	2	18 %	2	1.7 %

Posters

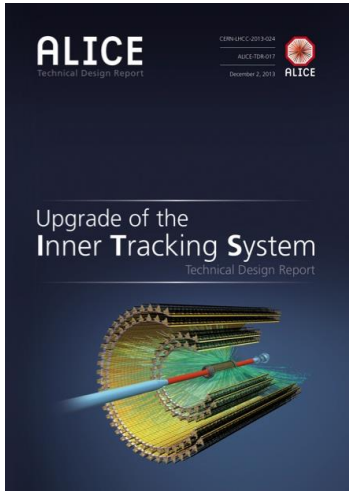
B^+: Johannes Stiller (M-26)

Λ_b: Cristina Terrevoli (M-27)

Λ_c: Rossella Romita (M-23)

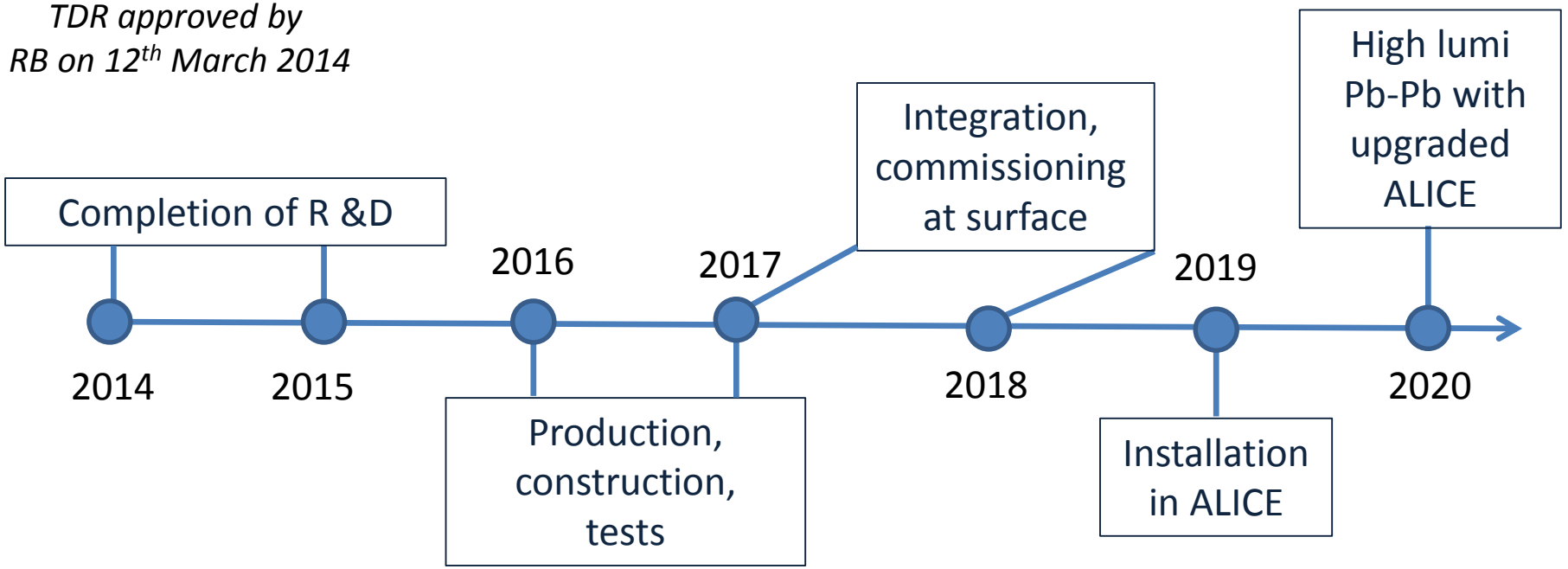
$^3_\Lambda H$: Stefania Bufalino (M-02)

Conclusion and Outlook



TDR approved by RB on 12th March 2014

- Detector layout and important technological aspects defined
- Integration and installation aspects studied in detail
- Detailed Monte Carlo simulations verified the detector and physics performances



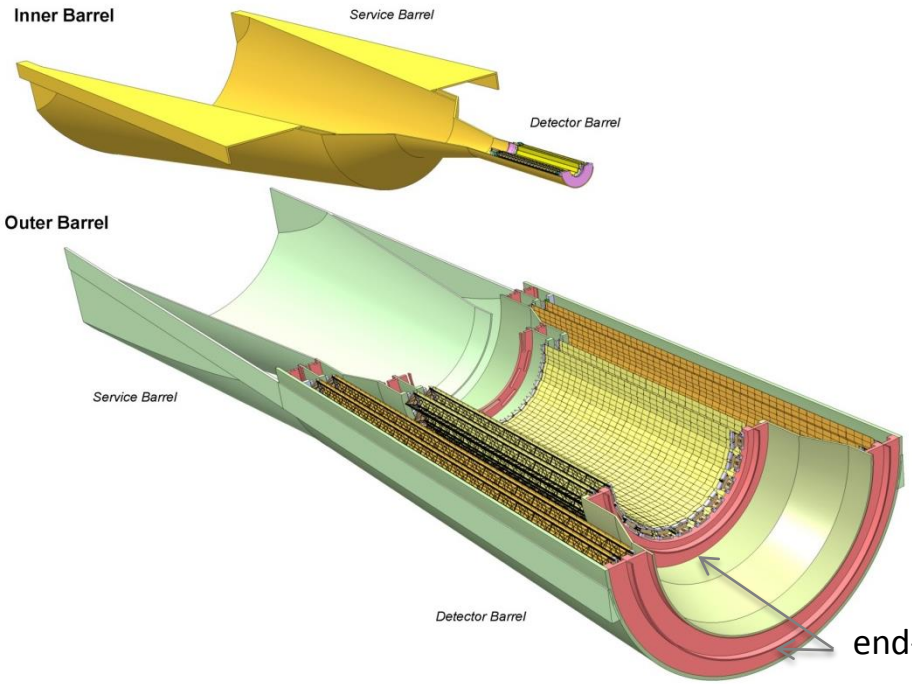
Spare Slides

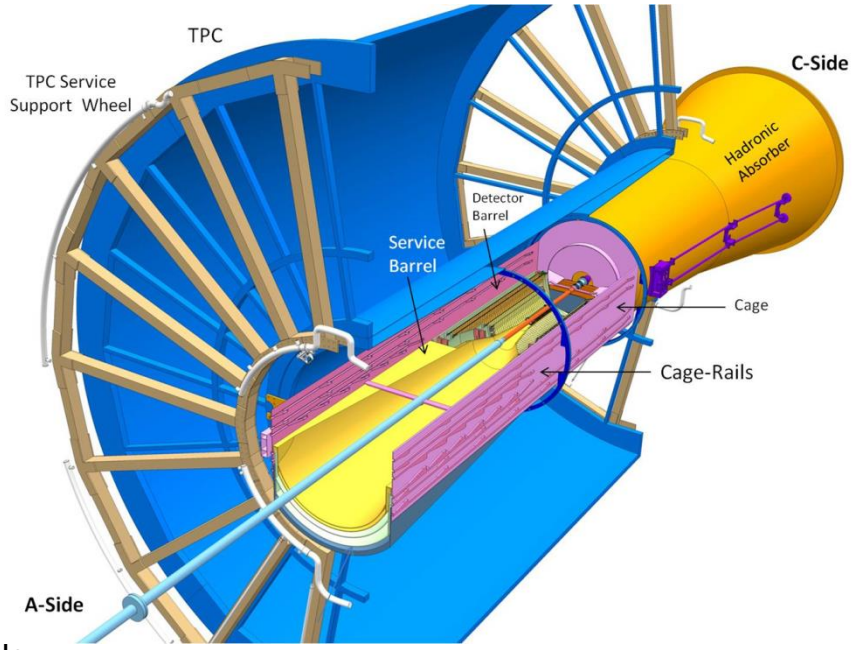
LHC schedule

LHC Long shutdown 2:

- Starts 2018 July
- 18 months + 3 months beam commissioning

Detector assembly and integration





end-wheels

- Cylindrical and Conical Structural Shells – services from one side only
- End-wheels: provide precise positioning of staves in a layer
- Fast installation, removal, maintenance