Status and prospects of the ALICE Inner Tracking System

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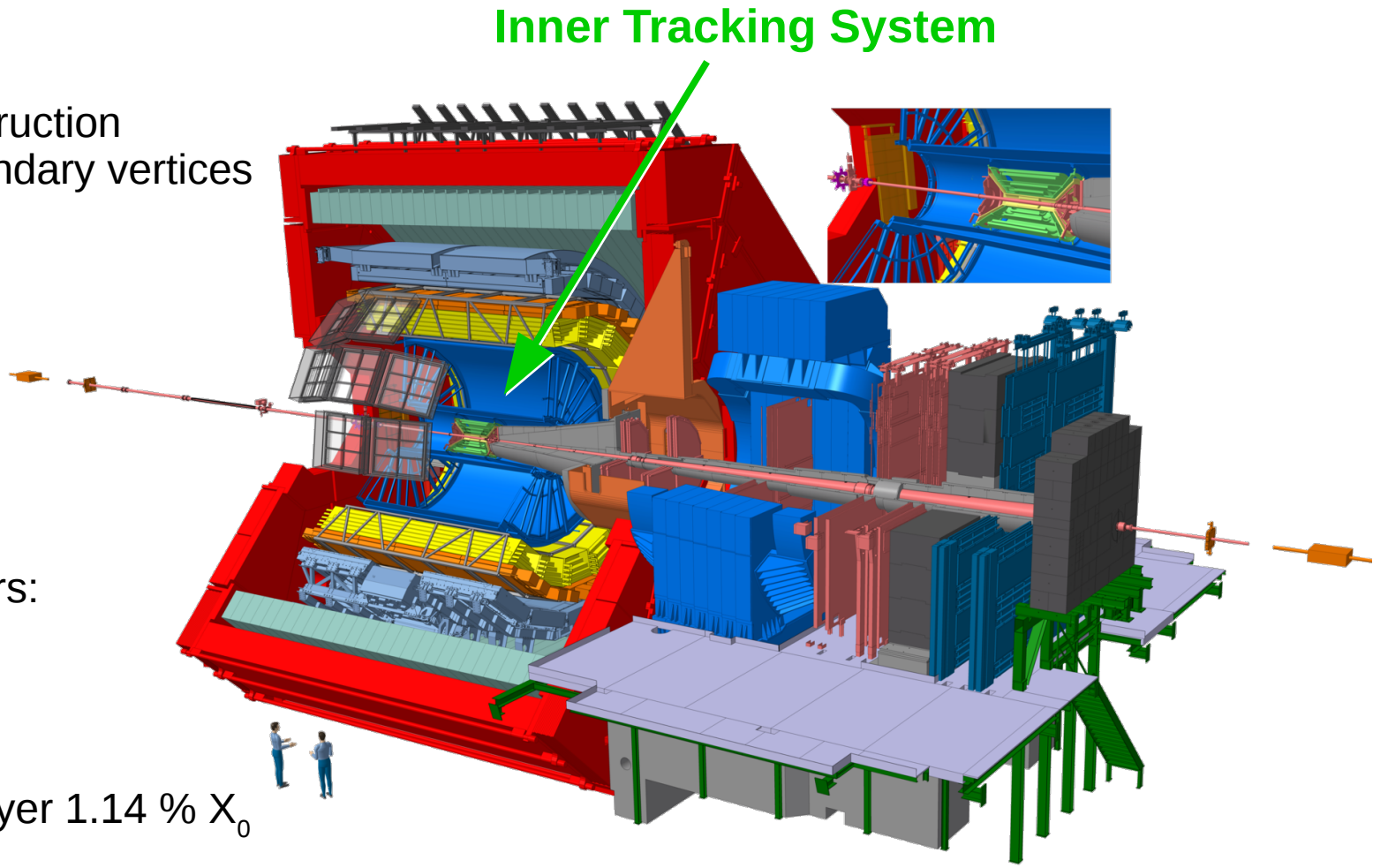
Inner Tracking System of the ALICE experiment

ITS is used in

1) primary vertex reconstruction
2) reconstruction of secondary vertices

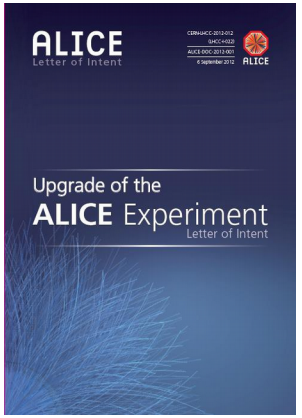


Old ITS1:

- 6 silicon detector layers:
  - 2 Silicon Pixel (**SPD**)
  - 2 Silicon Drift (**SDD**)
  - 2 Silicon Strip (**SSD**)
- Readout rate: ~1 kHz
- Material budget per layer 1.14 % X_0

Motivation for the ITS upgrade

ALICE physics goals for Run 3



J.Phys. G41 (2014) 087001

- vector mesons and low-mass di-leptons

chiral-symmetry restoration, virtual thermal photons from the quark-gluon plasma (**QGP**)

- open heavy flavor hadrons and quarkonia down to zero p_T

thermalization, hadronization, recombination, temperature evolution of the QGP

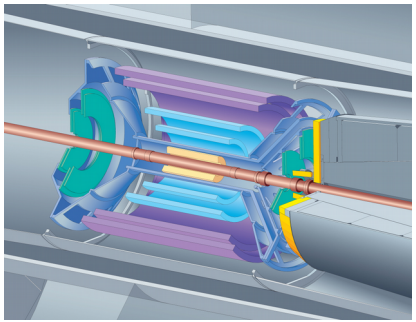
- high-precision measurement of light (anti-)nuclei and hypernuclei

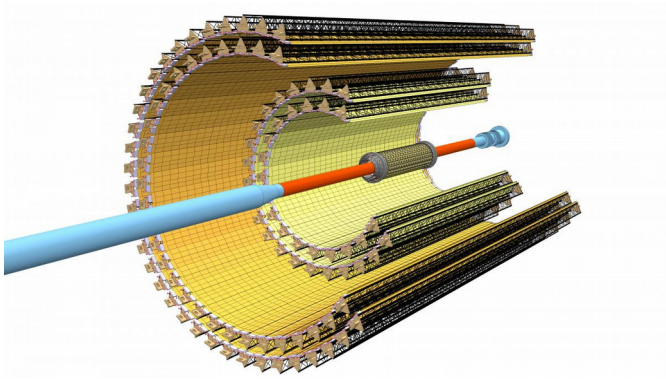
nucleosynthesis, exotics

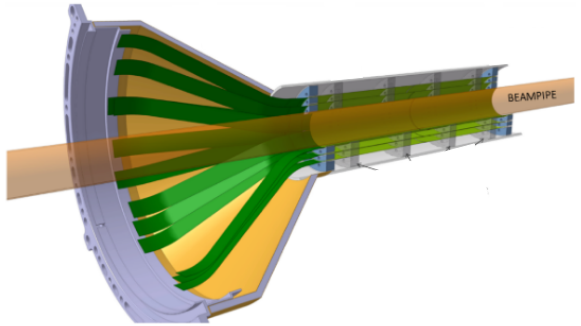
Main ITS2 upgrade requirements

- continuous read-out to fully exploit **50 kHz Pb-Pb interaction rate**
- improved tracking performance down to very low p_T

Evolution of the ITS

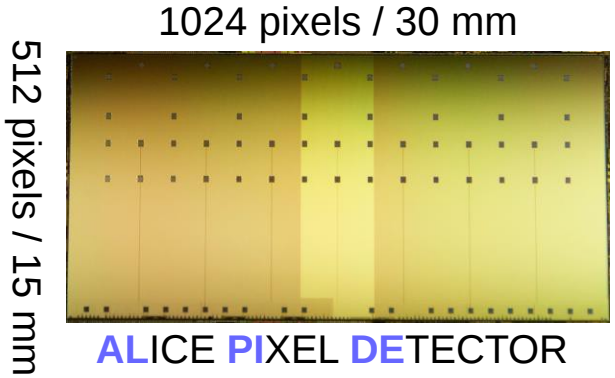


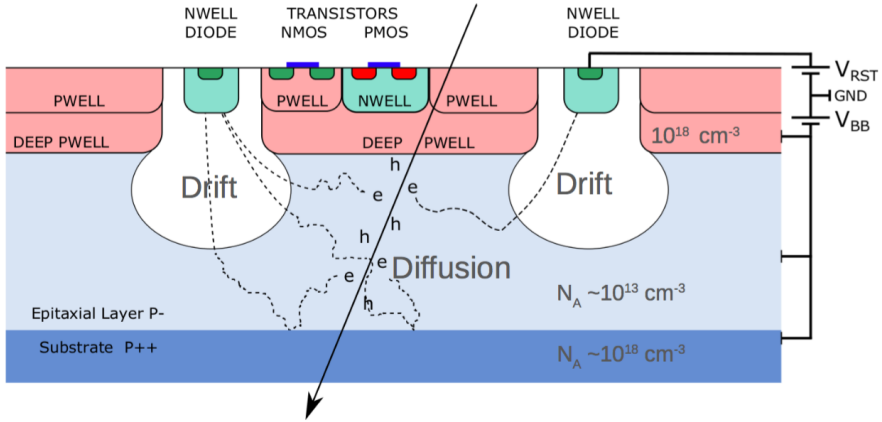




	ITS1	ITS2	ITS3
Design	6 layers SPD, SDD, SSP	7 layers of ALPIDE Monolithic Active Pixel Sensor (MAPS)	IB is replaced by a cylindrical structure from bent MAPS
Material budget per layer	1.14 % X_0	0.3 % X_0 Inner Barrel (IB), 1 % X_0 Outer Barrel (OB)	0.02 – 0.04 % X_0
Radial position of the first layer	39 mm	23 mm	18 mm
Period of operation	Till 2021 Run 1+2	2022 – 2030 Run 3+4	2027 – 2030 Run 4

ALPIDE pixel sensor





Monolitic Active Pixel Sensor ALPIDE

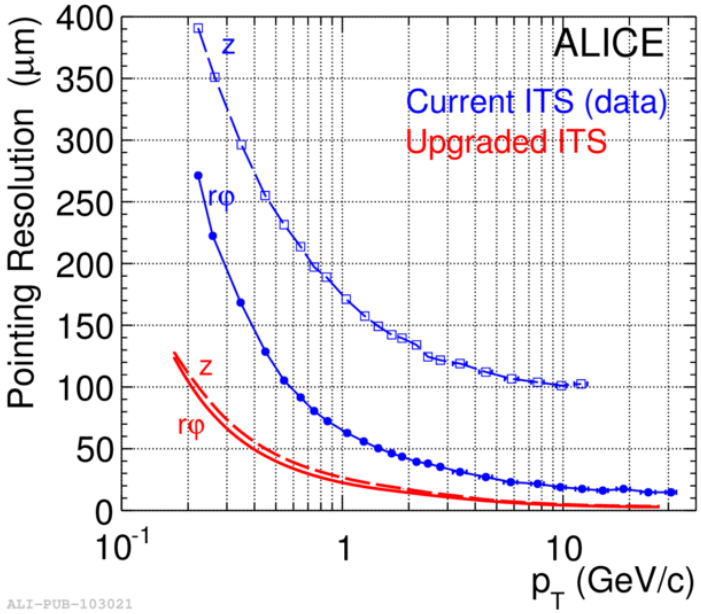
- 180 nm CMOS imaging process by TowerJazz
- Pixel pitch 29 μm × 27 μm
- Power consumption < 40 mW cm^{-2}
- Detection efficiency > **99 %**
- Fake-hit rate < **10^{-6}** /hits/cm^2
- Ability to mask pixels

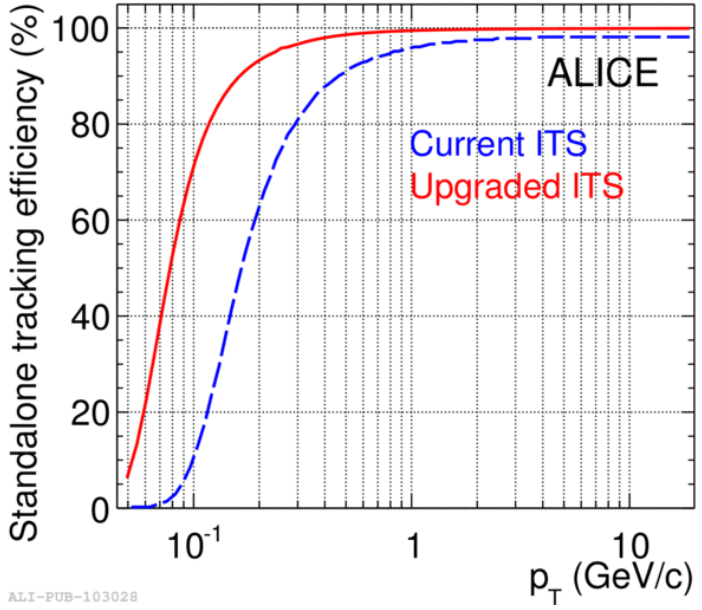
Radiation load for the Inner Barrel* (ALPIDE sensors required to sustain 10x larger radiation load)

- **T**otal **I**onizing **D**ose: 270 krad
- **N**on**I**onizing **E**nergy **L**osses ~ 1.7 10^{12} 1 MeV n_{eq} cm^{-2}

[*] J. Phys. G 41 (2014) 087002

Designed performance of ITS2





Position resolution will be improved by

- 6 times in *z* direction for $p_T < 1$ GeV/*c*
- 3 times in *rφ* direction for $p_T < 1$ GeV/*c*

ITS standalone tracking efficiency will be significanly increased below $p_T < 1$ GeV/*c*

General timeline of the upgrade

2011: Start of the ALPIDE sensor R&D

December 2016: Sensor and modules production started

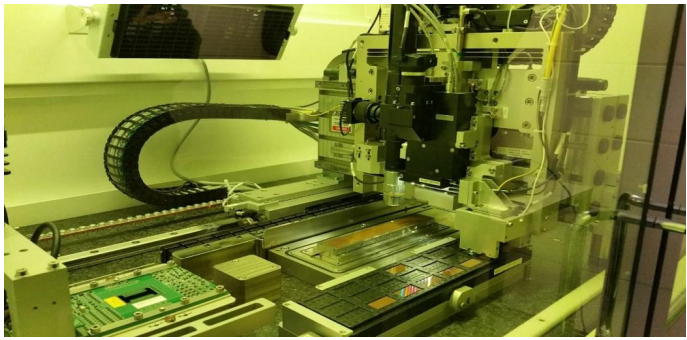
May 2019: Begining of the ITS commissioning in on-surface laboratory:

- Threshold scans
- Tests of noise performance
- Measurements of temperature and current
- Cosmic runs

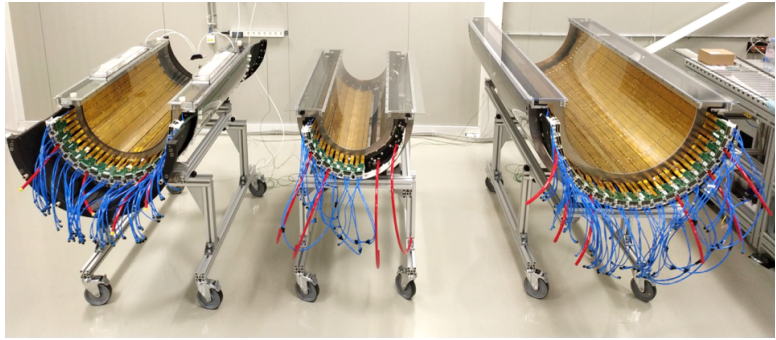
January 2021: Start of the ITS installation in the ALICE cavern

July 2021: Global commissioning

October 2021: Pilot beam test



Module Assembly Machine

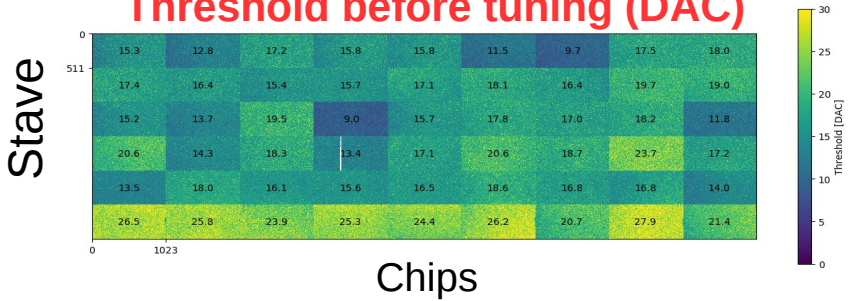


OB in the on-surface laboratory

ITS on-surface commissioning

- Uniform level of the threshold for all chips after choosing optimal working parameters

Threshold before tuning (DAC)



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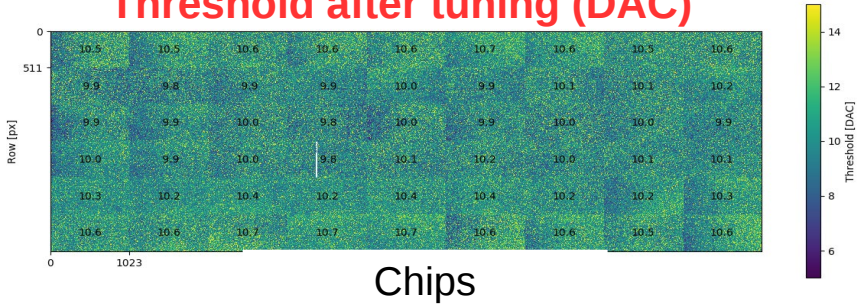
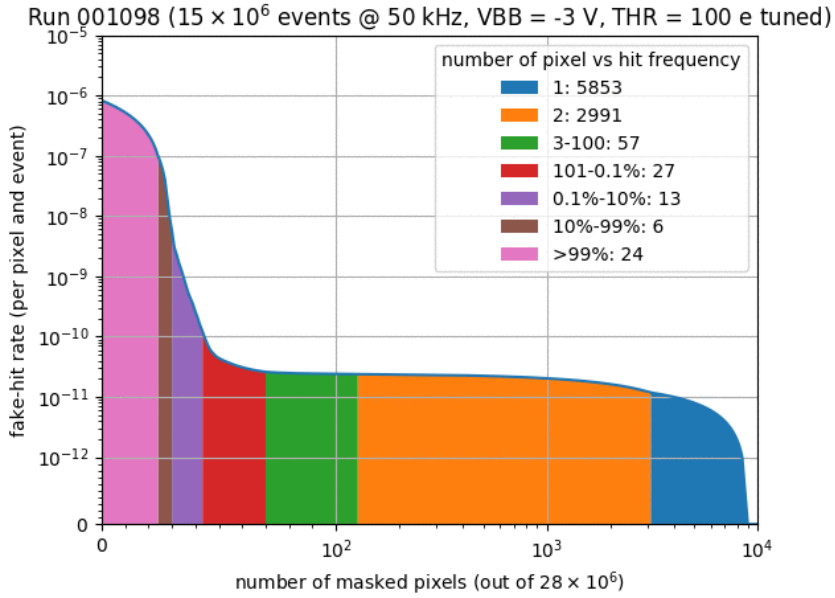
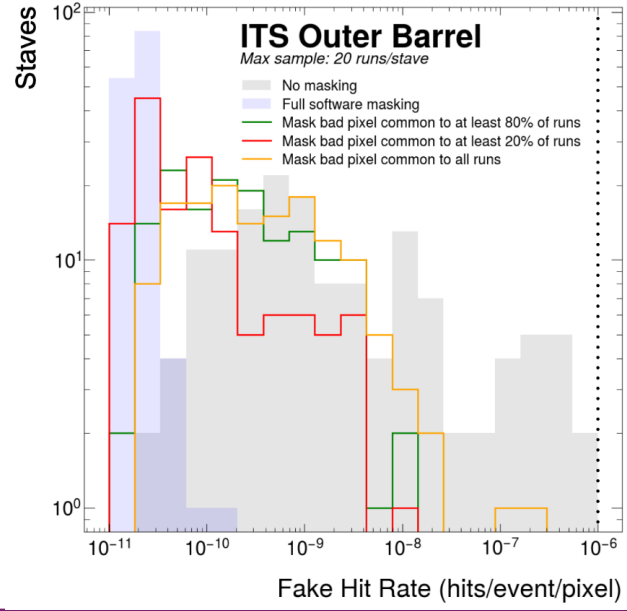
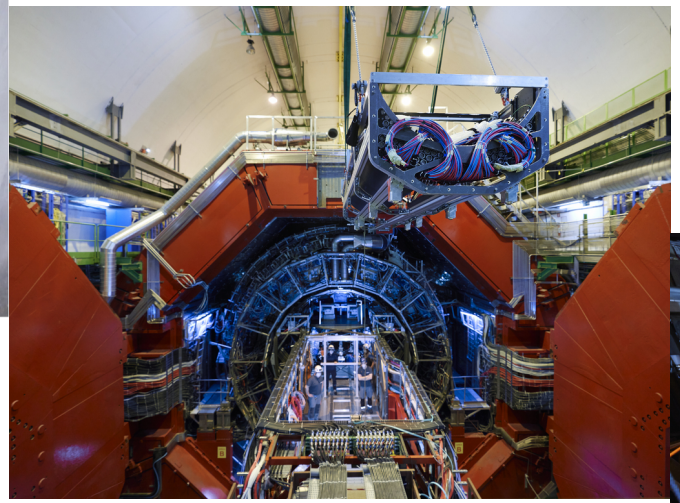


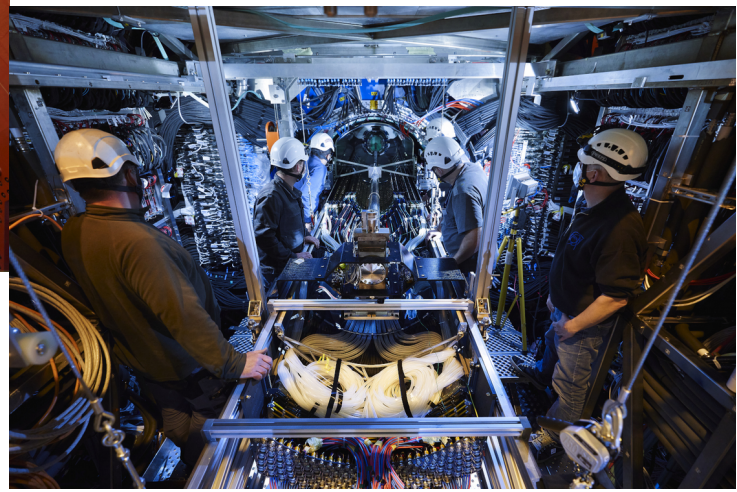
- Fake-hit rate ~ 10^{-10} /pixel /event after masking out noisy pixels **(Project goal is 10^{-6} /pixel /event)**





ITS installation in ALICE cavern





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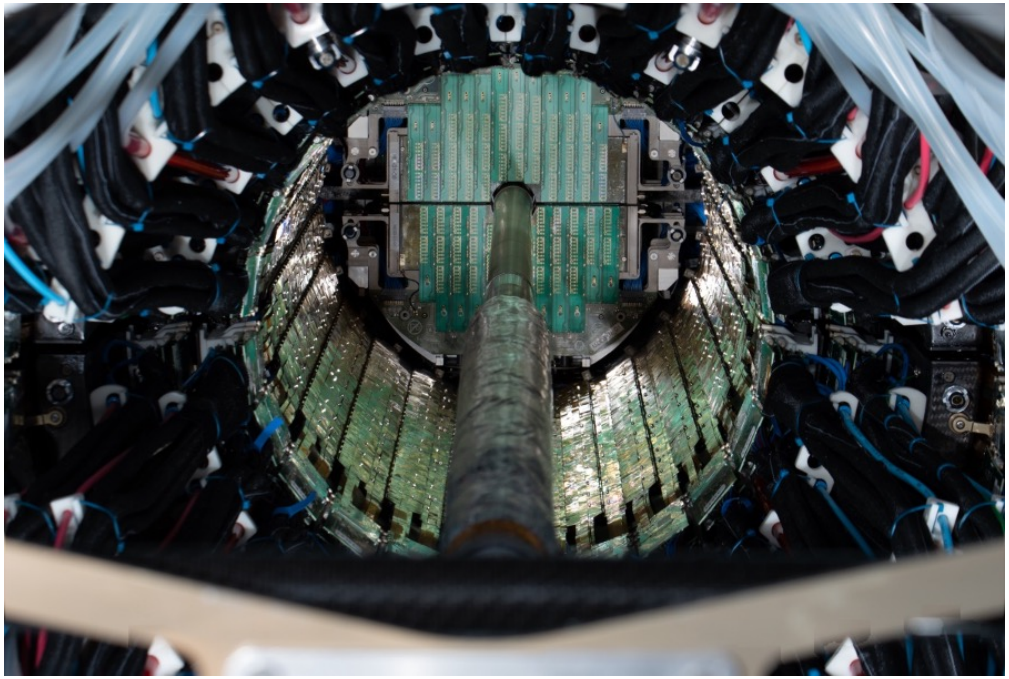
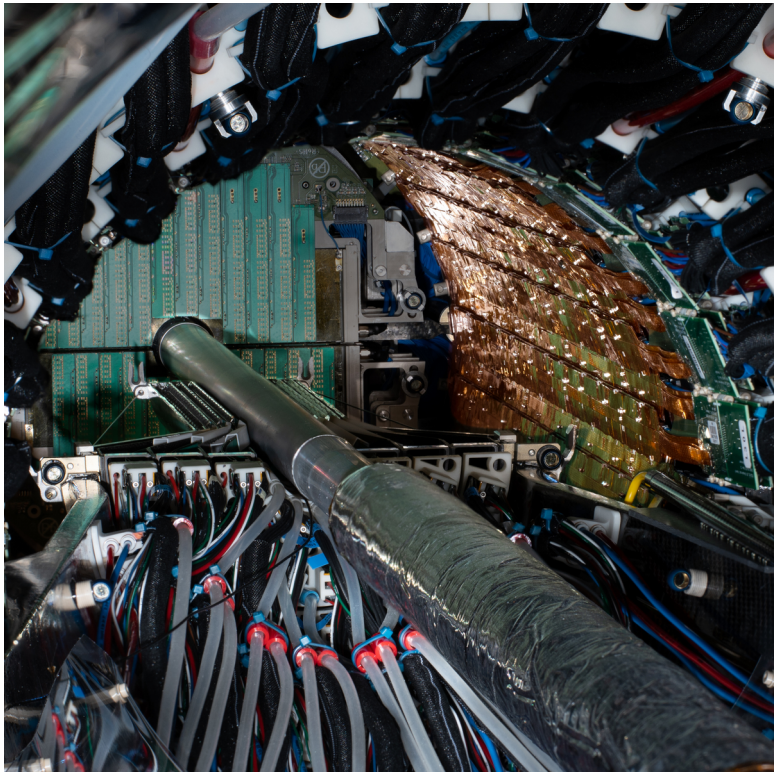


Installed OB

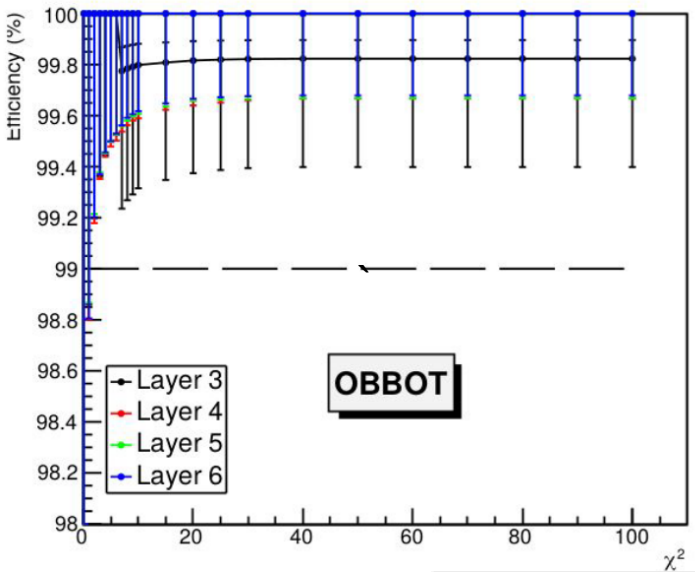


OB + bottom half-barrel of the IB

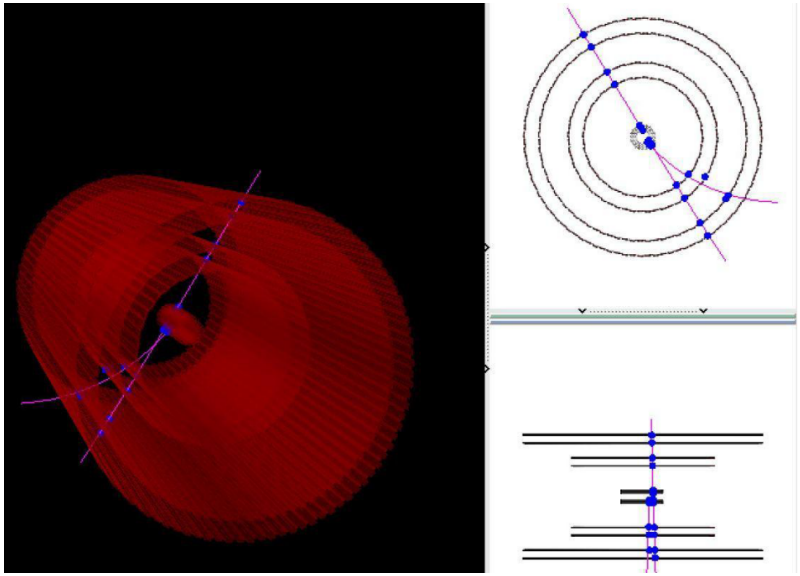
ITS Commissioning in the cavern

- Test of system connectivity and stability
- Test of Detector Control System and quality control
- First data taking with the complete detector
- Analysis of the first cosmic muon tracks

Tracking efficiency of comsic particles

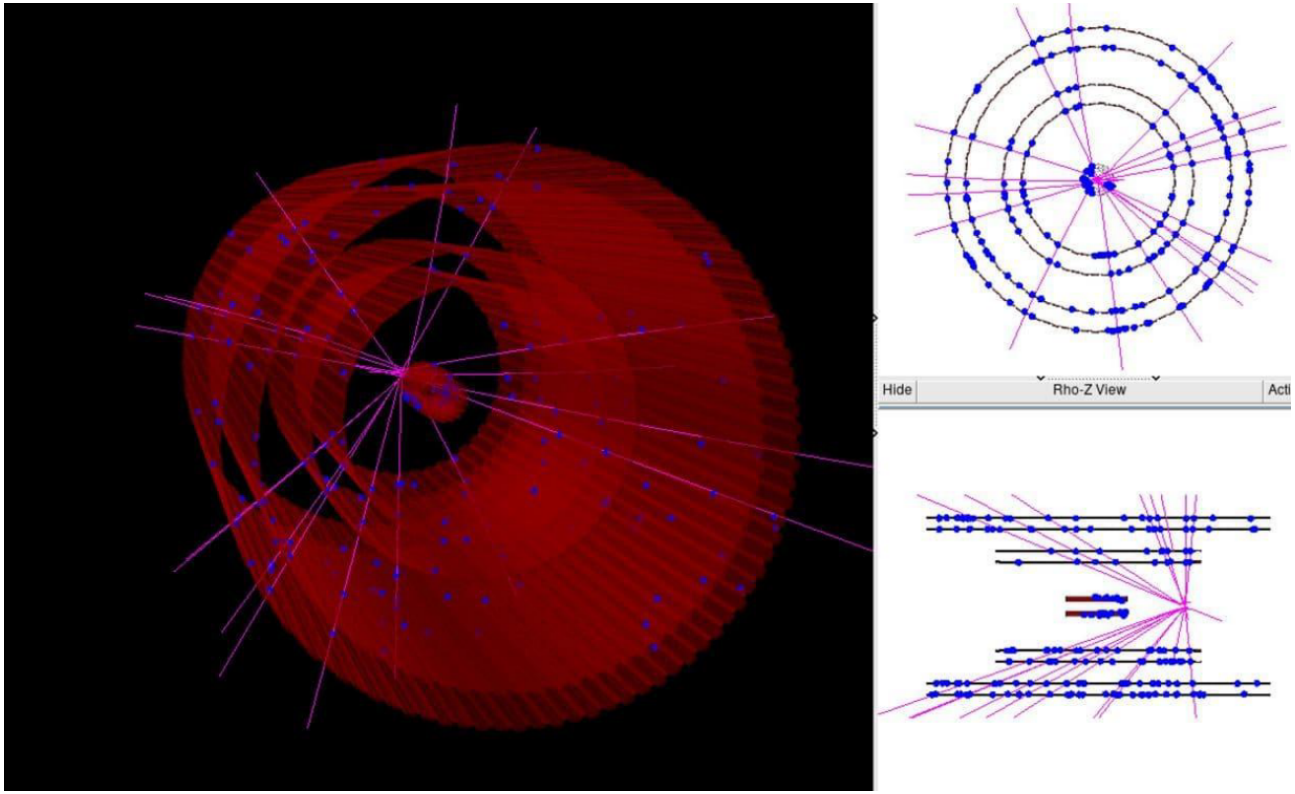


Example of a cosmic ray



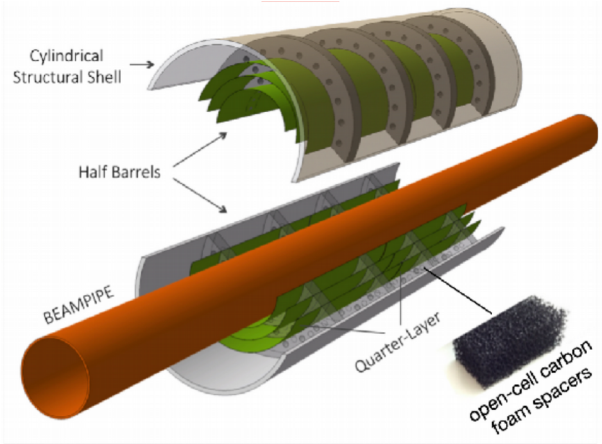
ITS pilot beam results

October pilot beam: pp collisions at $\sqrt{s}$ = 900 GeV, 0.2 T magnetic field



Detector and software successfully performed the first reconstruction of pp data

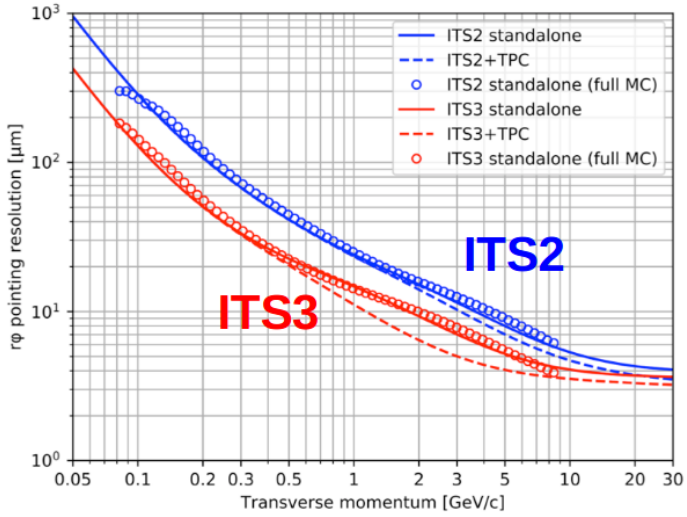
IB of the ITS3 vs ITS2

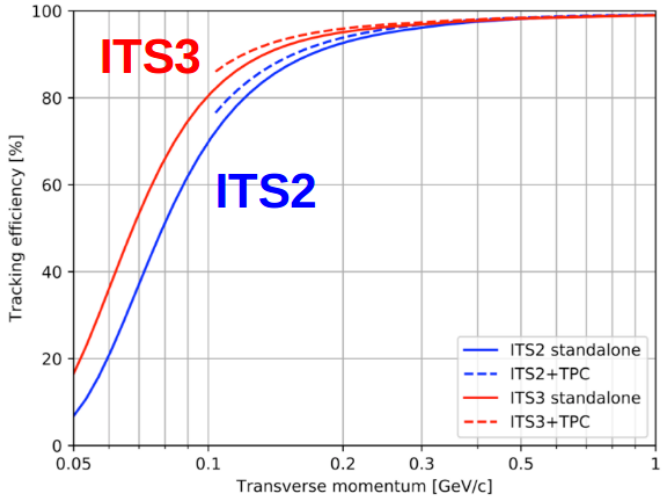


Changes with respect to the ITS2:

- Chip dimensions**:** 1.5 cm x 3 cm → 28 cm x 10 cm
- **Silicon thickness:** 50 μm → 20-40 μm
- **Power consumption:** 40 mW/cm^2 → 20 mW/cm^2
- Pixel size: 27 x 29 μm → 10 x 10 μm
- **Time resolution**: 1 μs → 100 ns
- NIEL radiation tolerance: 3 x 10^{13} → 3 x 10^{14} 1 MeV n_{eq}/cm^2
- TID radiation tolerance: 3 Mrad → 10 Mrad

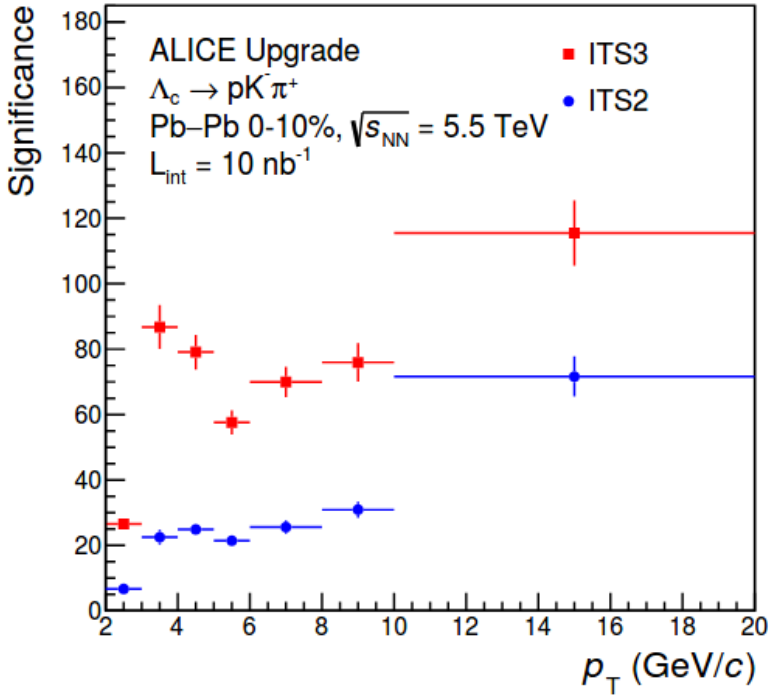
Result: **better tracking performance especially at low p_T**

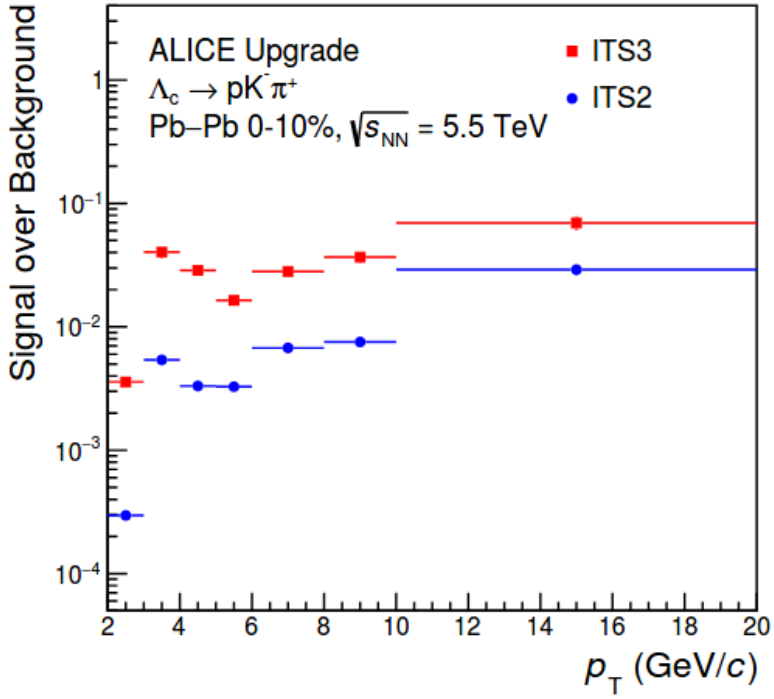




ITS3 performance

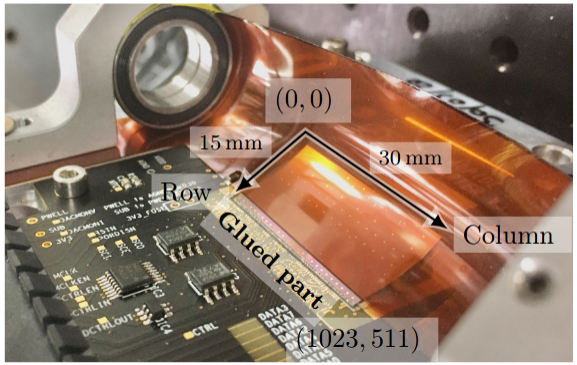
The improved impact parameter resolution and the reduced material budget of the ITS3 will significantly improve the performance of the heavy-flavour reconstruction [*]:

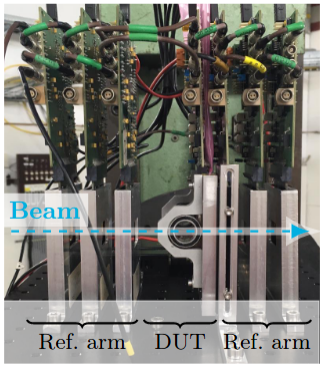


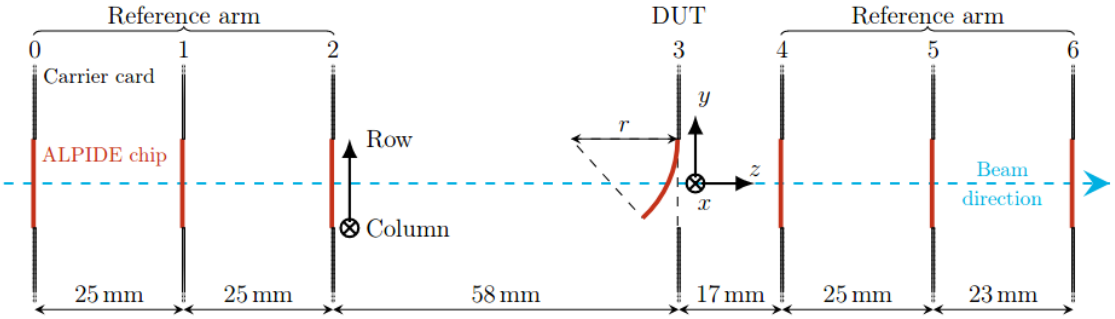


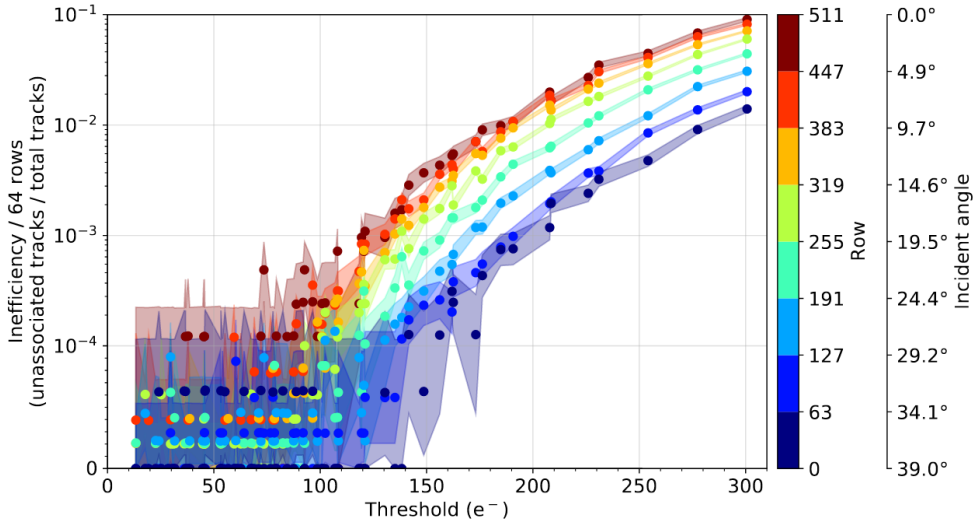
[*] Letter of Intent for an ALICE ITS Upgrade in LS3, CERN-LHCC-2019-018 ; LHCC-I-034

Test of the bent ALPIDE









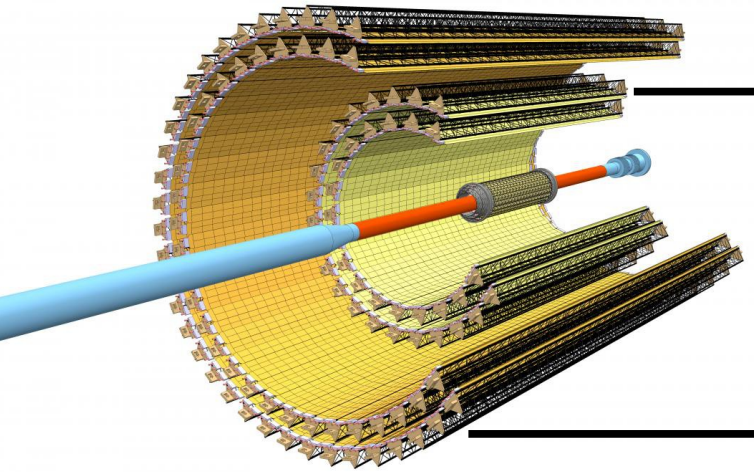
- Tested on 5.4 GeV electron beam
- Tracking done with ALPIDE telescope
- 99% trackig efficiency for default parameters

Summary

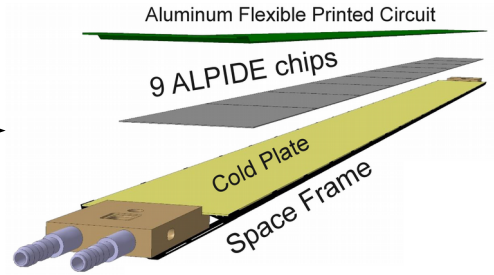
- On-surface ITS commissioning showed detector stability and confirmed compliance with the upgrade project goals.
- ITS2 was fully installed in the ALICE cavern.
- ITS2 performance was verified in pilot beams and global commissioning.
- ITS3 bent chip R&D is ongoing.

Backup

ITS2 layout

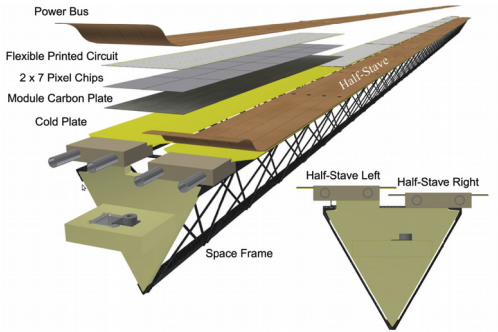


1 – 3 Layer: Inner Barrel Stave



- Length: 270 mm
- Sensor thickness: **50 µm**
- Material budget: ~ 0.3 % X_0
- Readout speed: 1200 Mbps

4 – 7 Layer: Outer Barrel Stave



- Split into two half staves
- Length: 844 mm (middle layer), 1475 mm (outer layer)
- Sensor thickness: **100 µm**
- Material budget: ~ 1 % X_0
- Readout speed: 400 Mbps

- 7 layers (inner/middle/outer): 3/2/2
- 192 staves (inner/middle/outer): 48/54/90
- 10 m^2 active silicon area
- 12.5×10^9 pixels