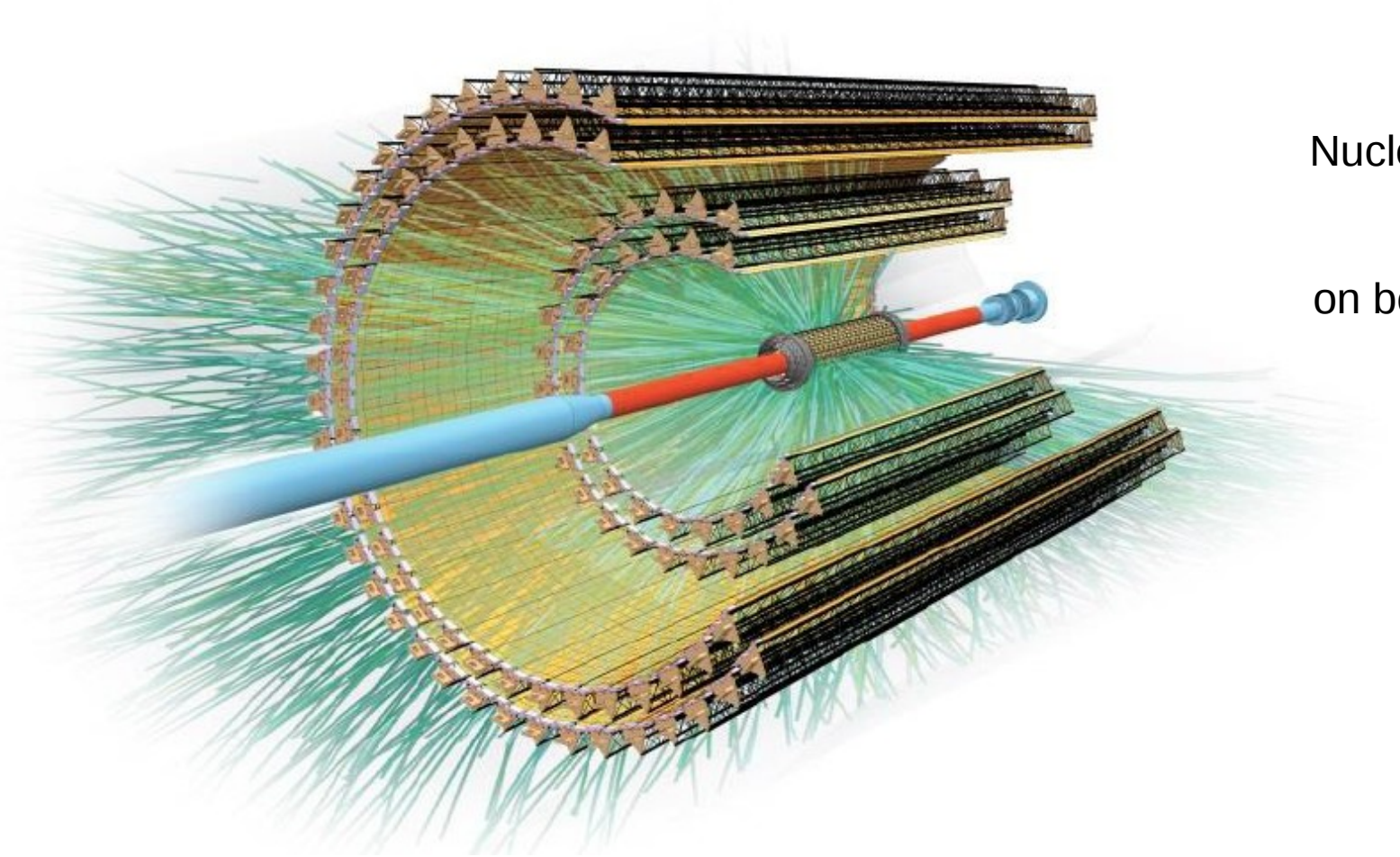
Commissioning of the upgraded ALICE

Inner Tracking System (ITS)

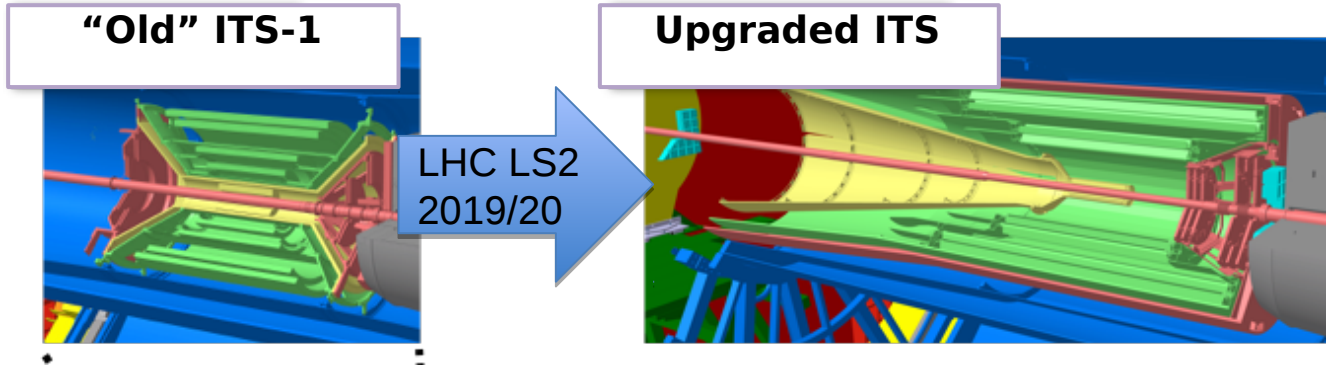


Svetlana Kushpil

Nuclear Physics Institute of the CAS
Řež, Czech Republic

on behalf of the ALICE Collaboration

Upgraded Inner Tracking System (ITS2)



	ITS 1	ITS2
layers	6	3 Inner Barrel (IB) 4 Outer Barrel (OB)
radius	39mm < r < 440mm	22mm < r < 400mm
η	$-1 \leq \eta \leq 1$	$-1.3 \leq \eta \leq 1.3$
X/X_0/layer	1.14%	0.35% (IB); 1% (OB)
rate capability	1kHz	100kHz (PbPb)

Motivations and goals

- Improved vertex and tracking precision
  first layer closer to IP, smaller pixels, less material
- Faster readout

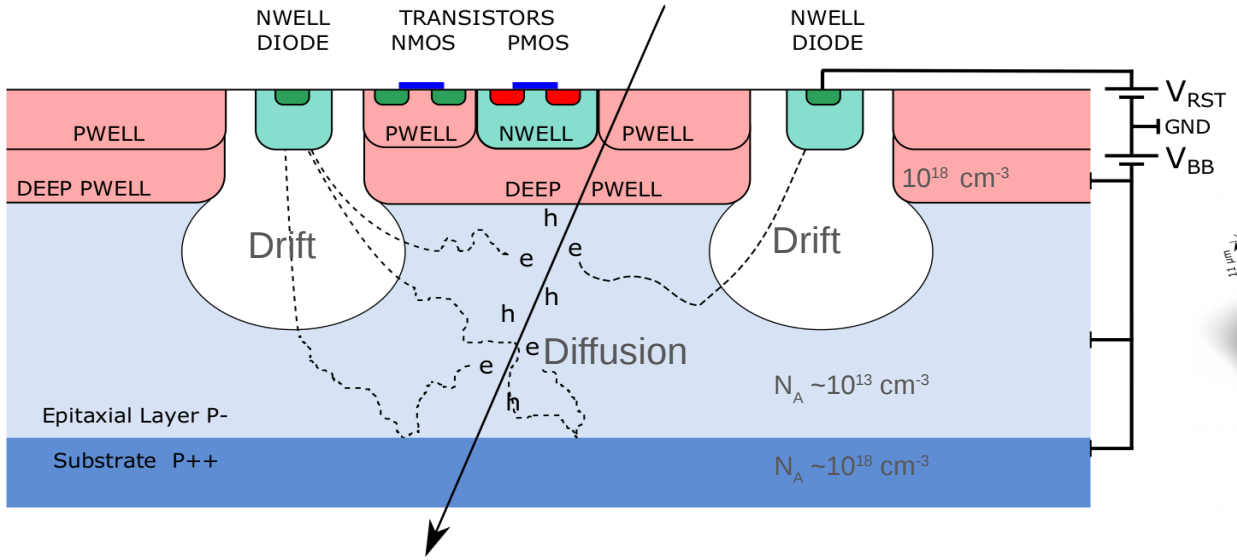
Based on MONOLITHIC ACTIVE PIXEL SENSOR (MAPS)
ALPIDE

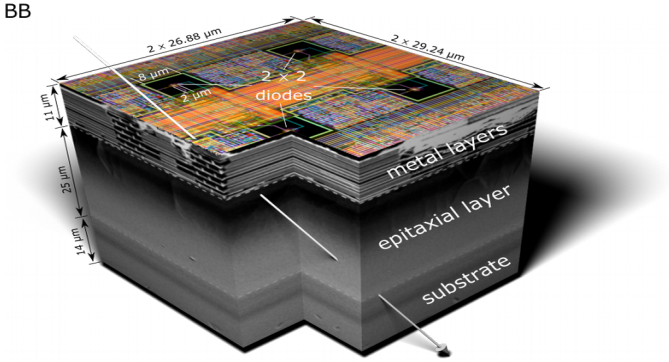
- 10 m^2 active silicon area (12.5 G-pixels)
- Spatial resolution ~5x5 μm^2 all layers
- Fake hit rate: $< 10^{-6}$ event $^{-1}$ pixel $^{-1}$
- Detection efficiency: > 99%

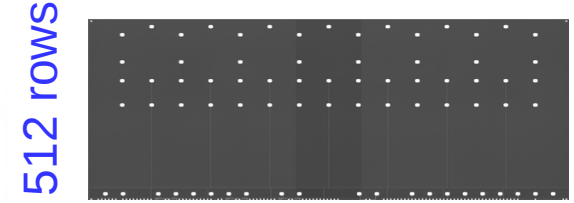
"Technical Design Report for the Upgrade of the ALICE Inner Tracking System"
ALICE Collaboration, J.Phys. G41 (2014) 087002, CERN-LHCC-2013-024

ALPIDE: MONOLITHIC ACTIVE PIXEL SENSOR

Pixel Sensor produced using TowerJazz 180 nm CMOS Imaging Process







Chip size: 30 mm x 15 mm
Pixel pitch: 29 µm x 27 µm
Chip thickness:
50 µm (IB - Inner Barrel)
100 µm (OB - Outer Barrel)
Length of stave:
844 mm (ML - Middle Layer)
1478 mm (OL - Outer Layer)

- Deep P-well allows in-pixel full CMOS (complex in-pixel circuitry without charge loss)
- Enables low-power read-out
- High granularity, low material budget
- Power: 40 mW/cm^2
- Resistivity (>1 kΩ·cm) p-type epitaxial layer (25 µm)
- Possibility of reverse biasing (up to -6 V)

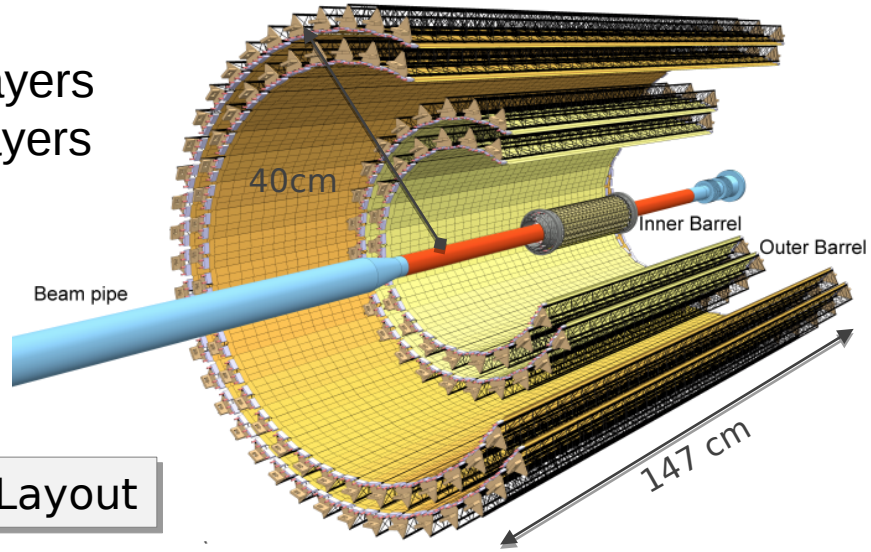
Expected radiation dose* : > 2700 krad Total Ionising Dose (TID),

> 1.7×10^{13} 1MeV n_{eq} cm^{-2} Non-Ionising Energy Loss (NIEL)

(* with safety factor)

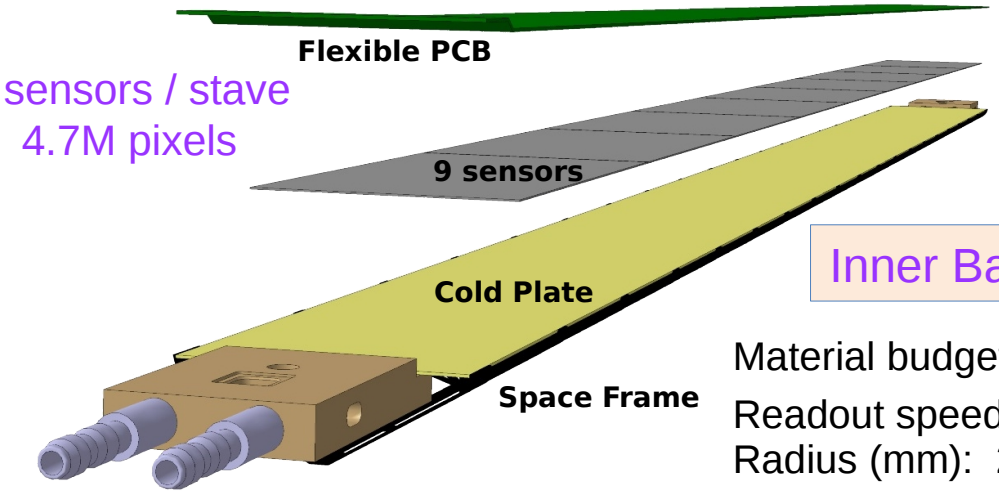
ITS2 in numbers

IB: 3 layers
OB: 4 layers



ITS Layout

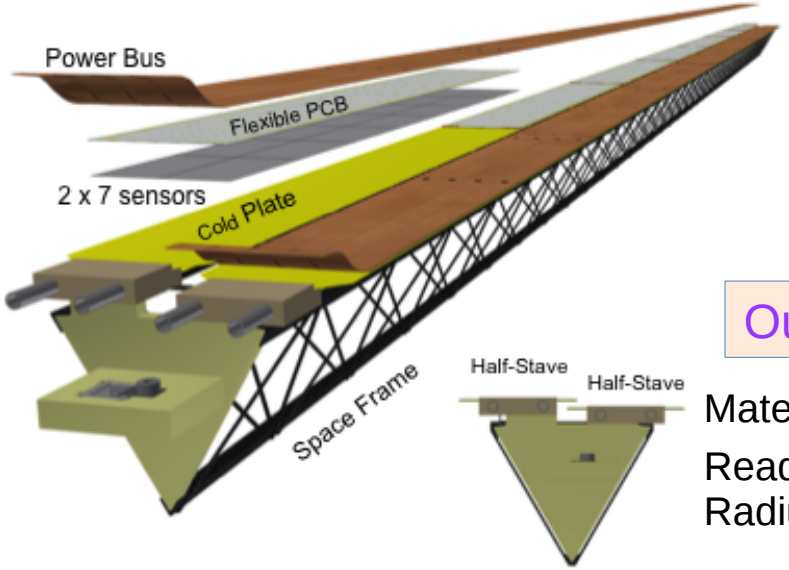
- Pixel sensor chip: ~ 24000 (including spares)
- IB staves: 48
- OB Hybrid Integrated Circuits: 1692
- OB Staves: 90 (Outer Layer), 54 (Middle Layer)
- Readout Units: 192
- Large carbon composite structures: 24



9 sensors / stave
4.7M pixels

Inner Barrel (IB)

Material budget: ~ 0.35% X_0
Readout speed: 1200 Mbps
Radius (mm): 22, 31, 39



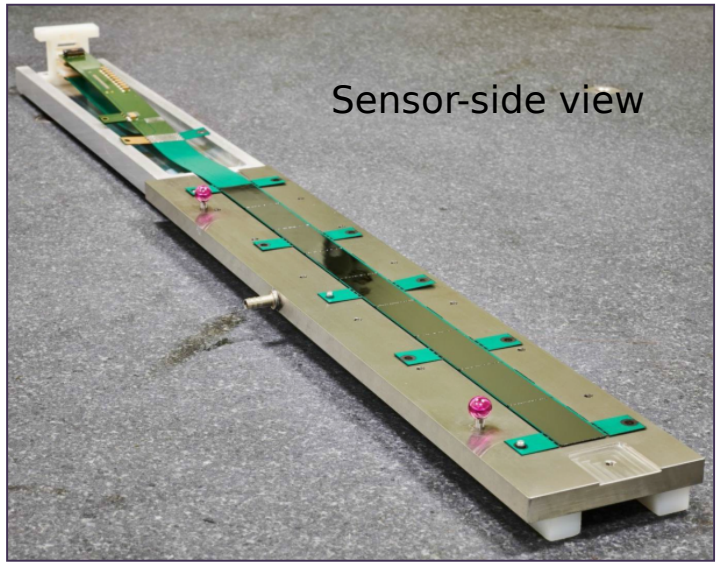
196 sensors / stave
103 M pixels

Outer Barrel (OB)

Material budget: ~ 1% X_0
Readout speed: 400 Mbps
Radius (mm): 194, 247, 353, 405

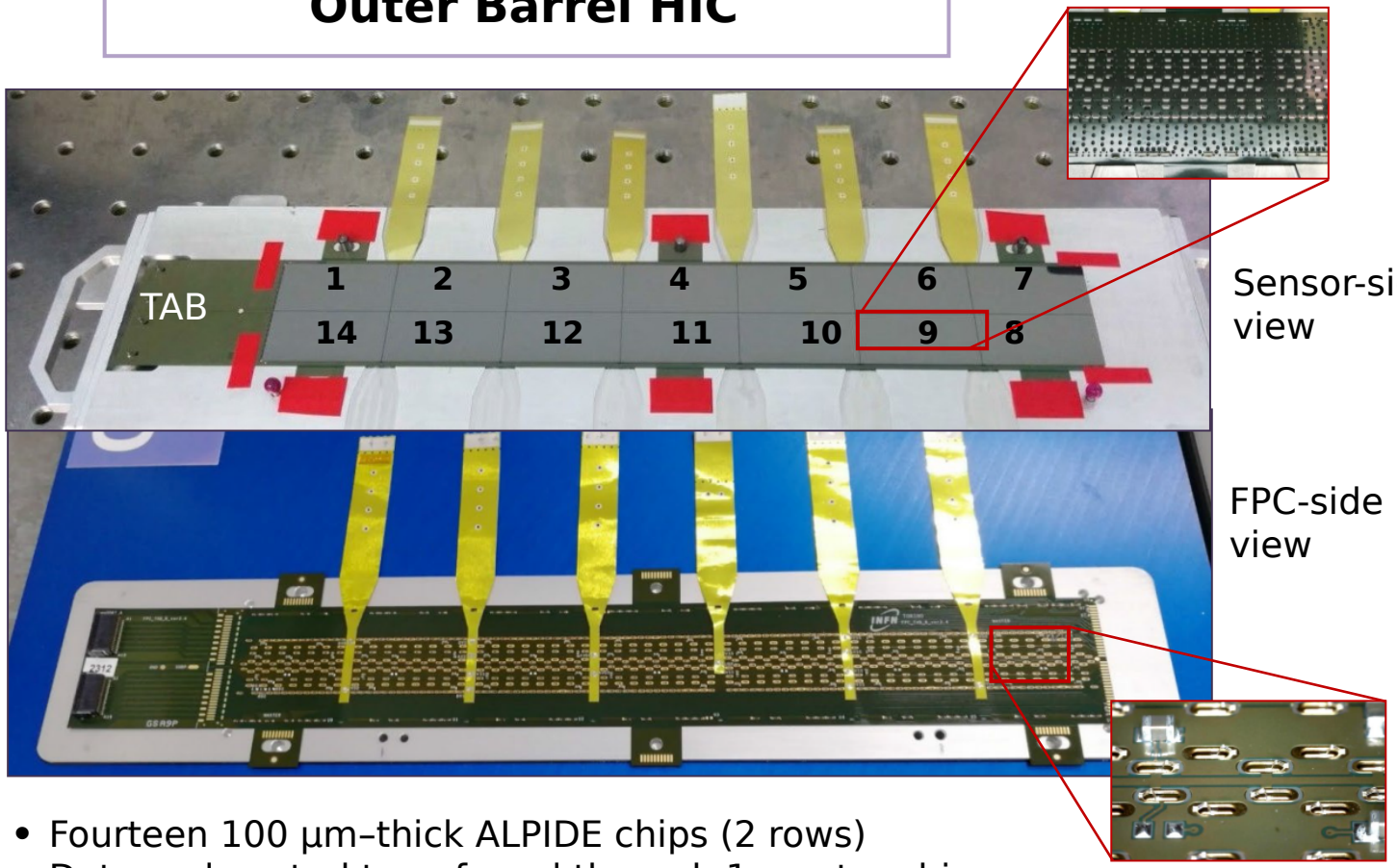
The Hybrid Integrated Circuit (HIC) modules

Inner Barrel HIC



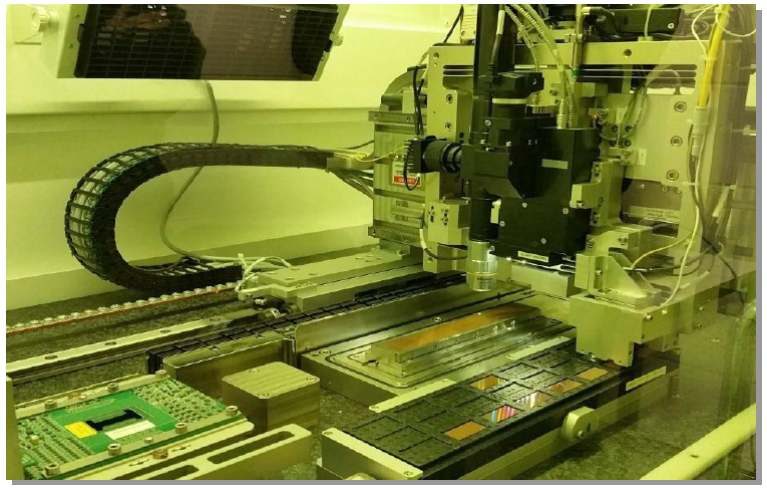
- Nine 50 µm-thick ALPIDE chips
- Aluminum Flexible Printed Circuit (FPC)
- Each chip read out separately
- Clock, control, data, power lines wire-bonded to FPC
- 27 cm length
- Hit density > 9.1 cm^{-2}

Outer Barrel HIC



- Fourteen 100 µm–thick ALPIDE chips (2 rows)
- Data and control transferred through 1 master chip per row
- Chips wire-bonded to copper FPC
- Power delivered via 6 cross-cables soldered to FPC
- Hit density < 2.8 cm^{-2}

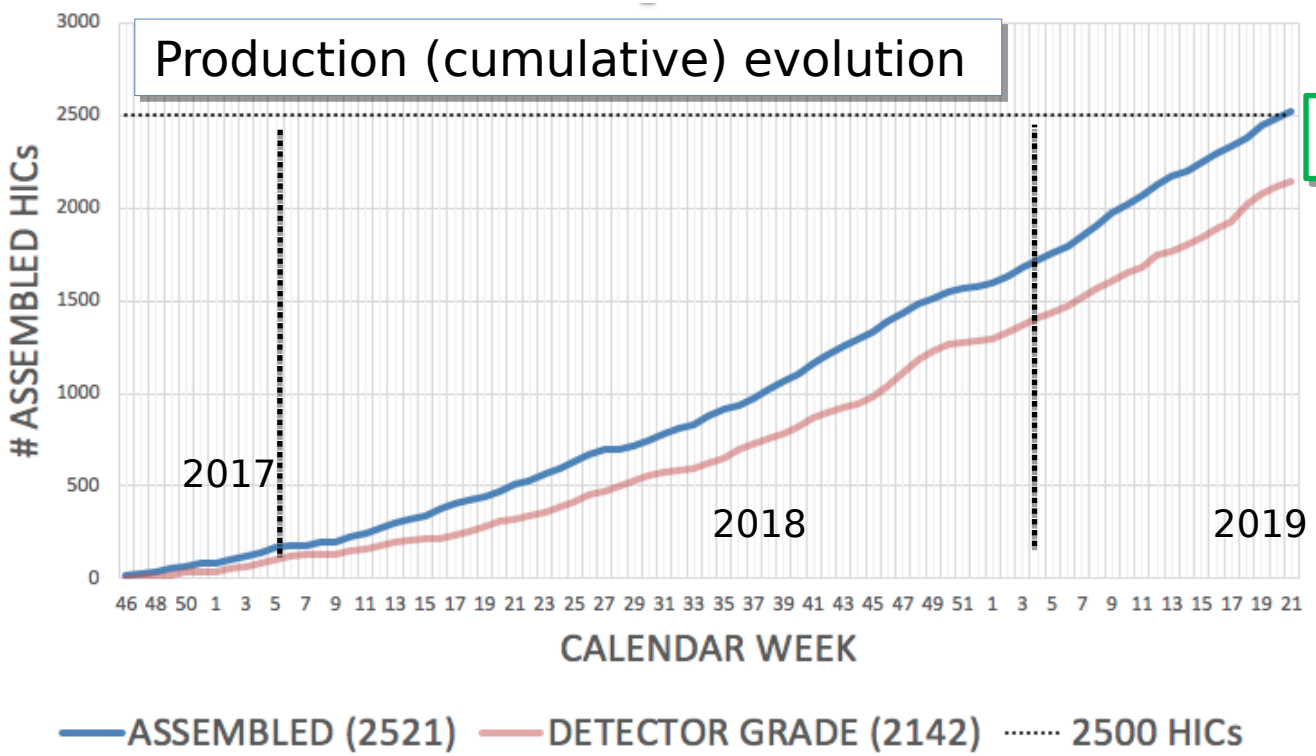
Outer Barrel HIC Production



Custom made Module
Assembly Machine (MAM)

Criteria for acceptance:

- < 1% dead pixels
- no low impedance paths
- electrical interfaces (HSlink + DCTRL) functioning with in specifications



Production completed!

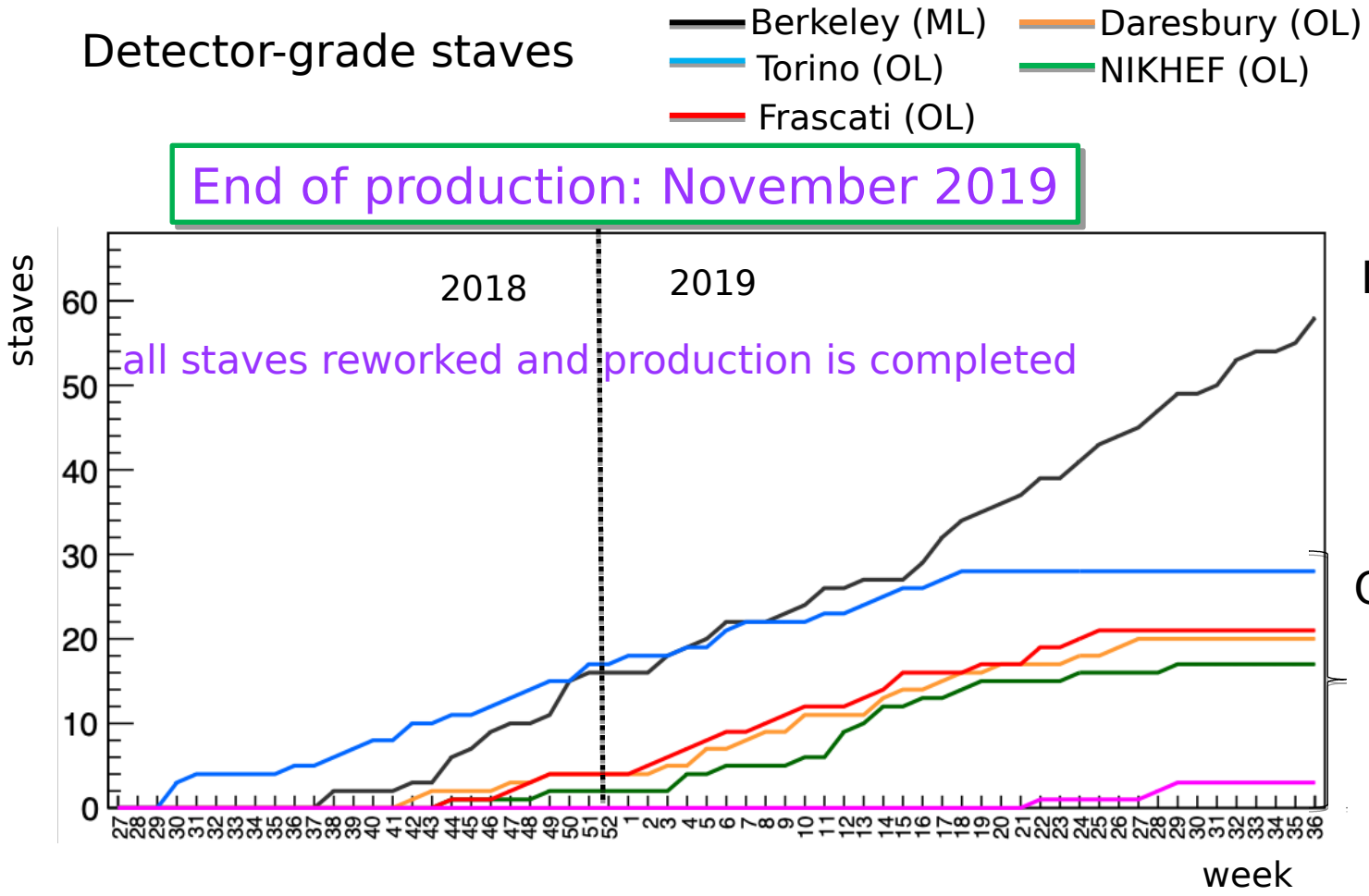
HIC production summary

- Total number: 2592
- Detector-grade: 2180
- Global yield: 84%
- Installed in OB: 1698

Outer Barrel Stave Production

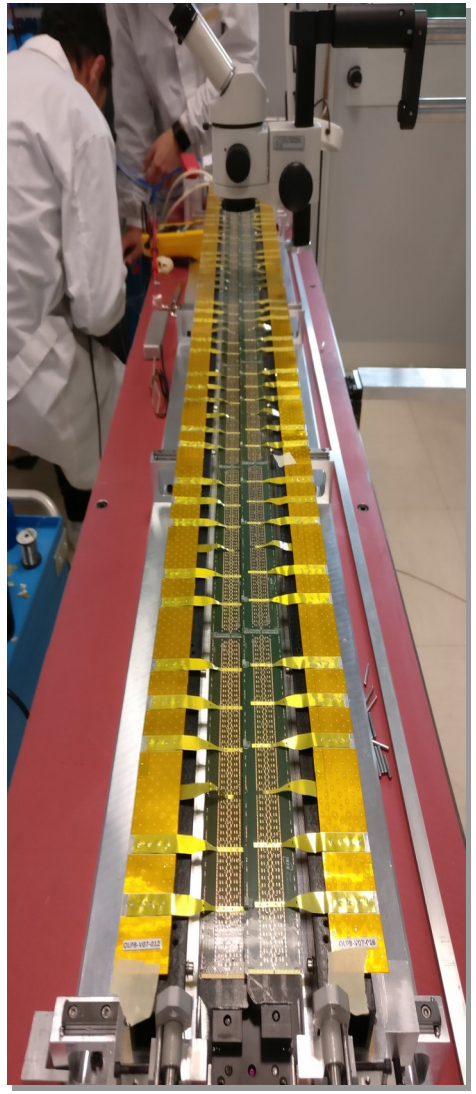
Target OB Staves: 90 + 10 (OL), 54 + 6 (ML) (including spares)

Detector-grade staves

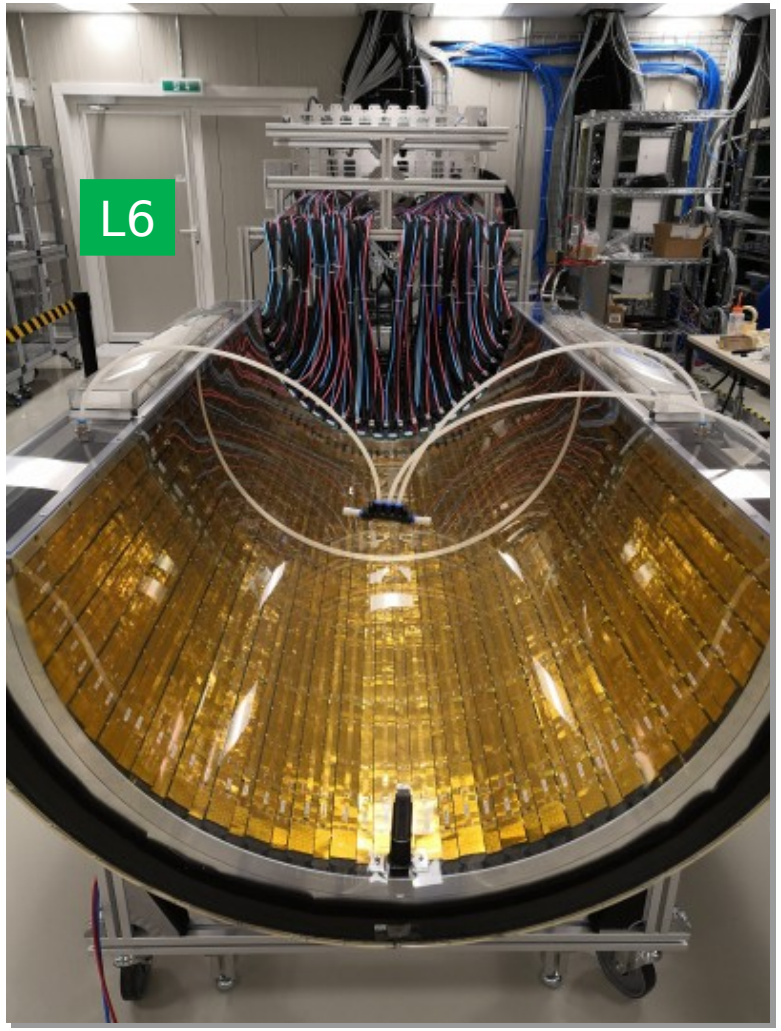


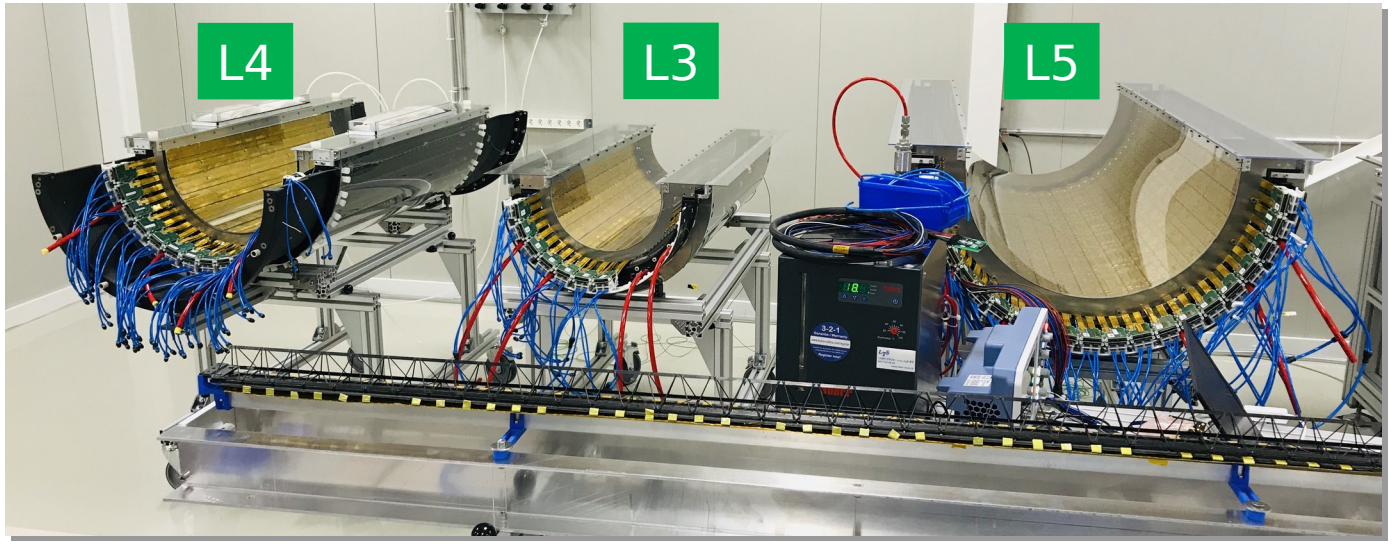
ML Staves Total: **64**

OL Staves Total: **101**



Outer Barrel – (half-) Layer Assembly





Half-Barrel Assembly (a hierarchical Russian doll like assembly)

All half-layers are first tested individually.

Layer and Barrel assembly

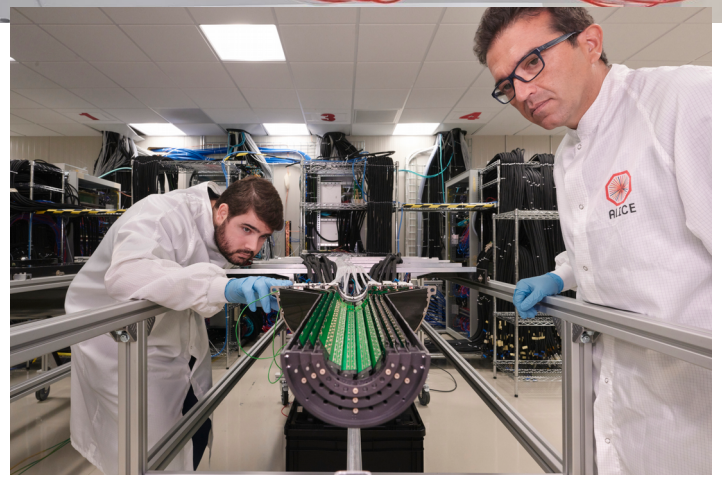
All components come to CERN

The staves are **tested** at reception

validated after installation or sent to **rework** in case of problems

Inner Barrel assembly completed: fully functional

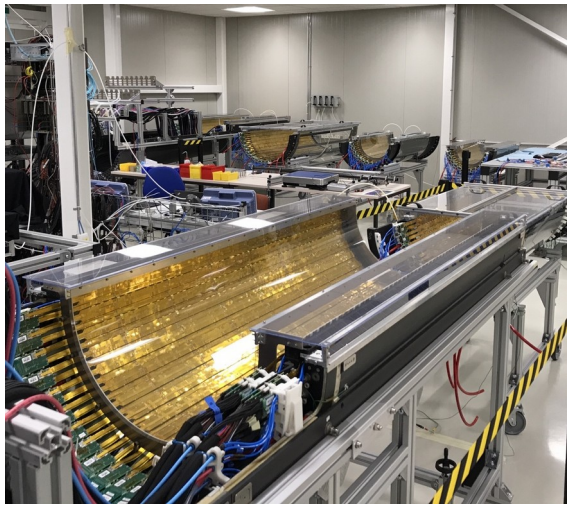
Inner half-layer



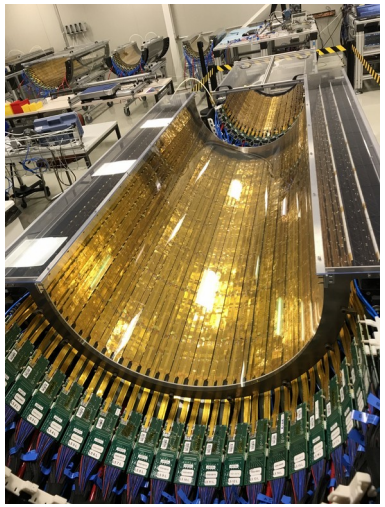
Outer half-barrel assembly completed

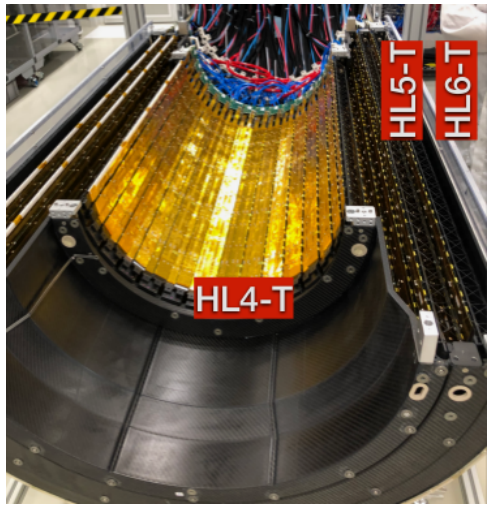
Maximum acceptable dead area per OB Stave: 1%

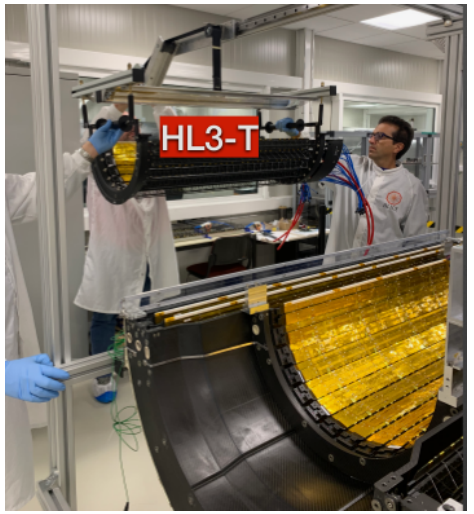
Middle half-layer



Outer half-layer

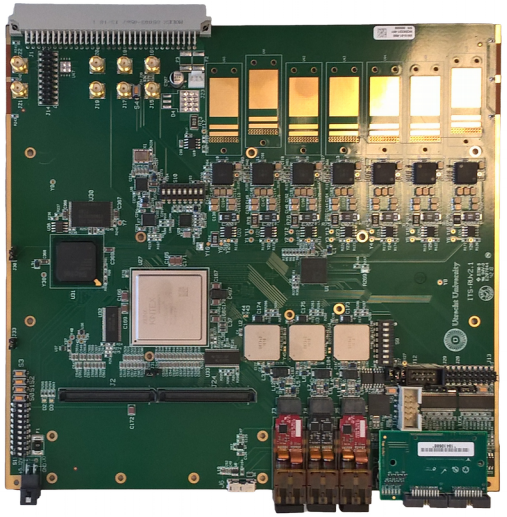






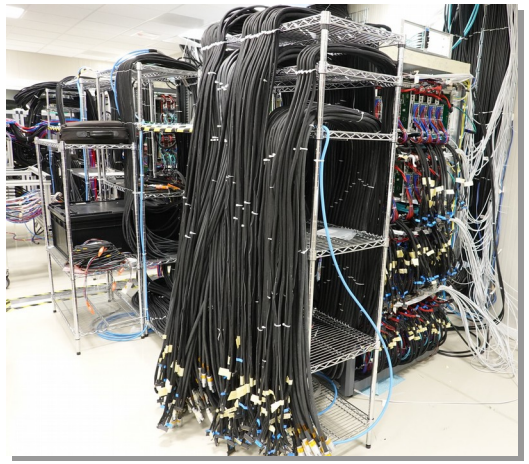
ITS upgrade - Component production status

Readout Unit (RU)



- 192 FPGA based RUs, operating in a mild radiation environment (< 10 krad TID & NIEL of 10^{11} 1 MeV n_{eq} cm^{-2})
- Board production completed

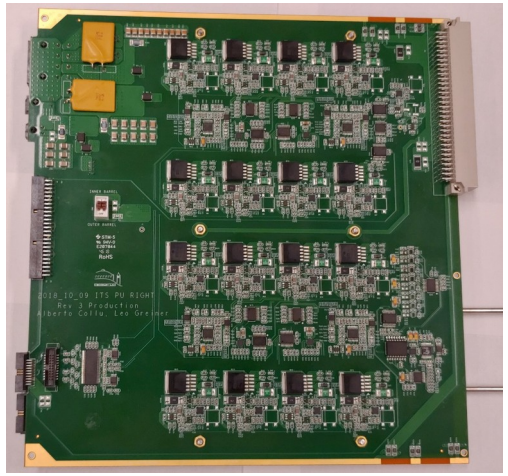
Power regulation&distribution



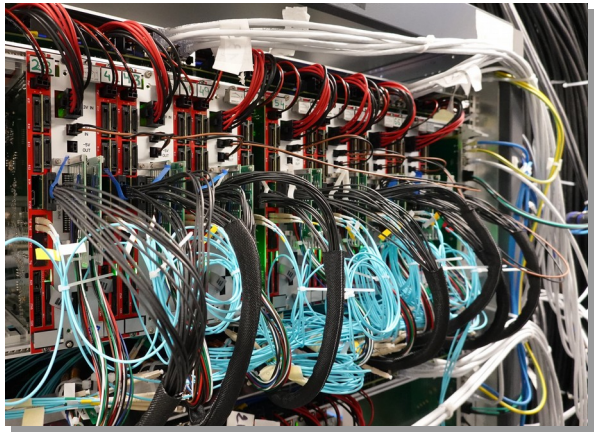
Production & Test completed !
Everything is installed and cabled!

- All cables installed in lab on surface
- All Power Boards installed
- Service installation finished
- Final installation will be in ALICE cavern

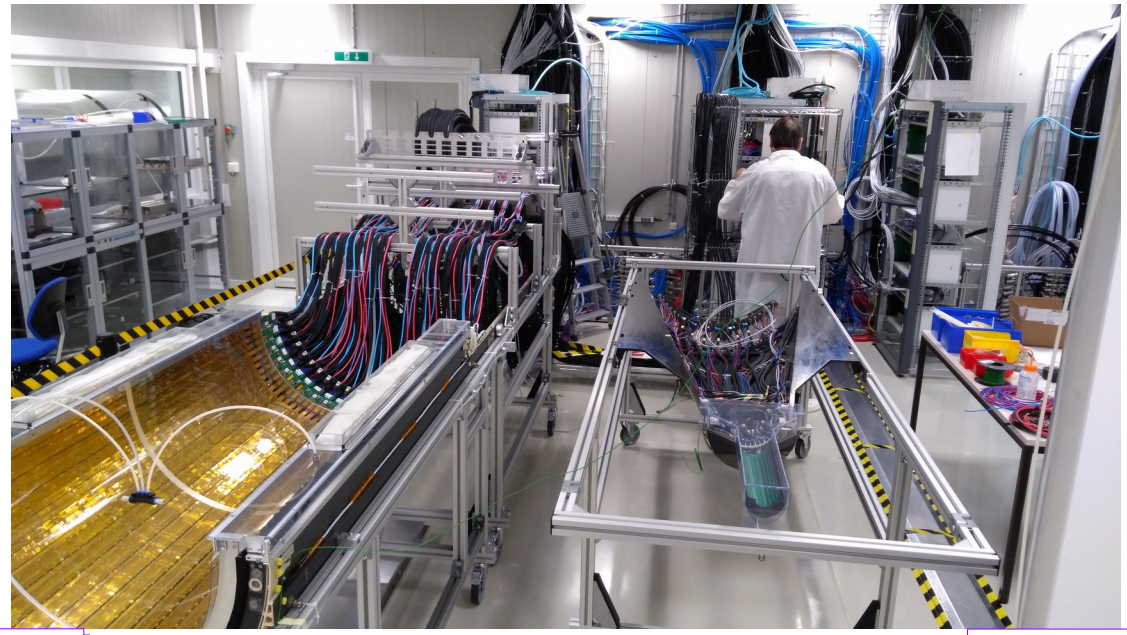
Power Boards



- CAEN powering modules available and in use in commissioning
- Services installed by the teams of Bari, Catania, CERN, COMSATS, Daresbury/Liverpool, Strasbourg



Commissioning shifts



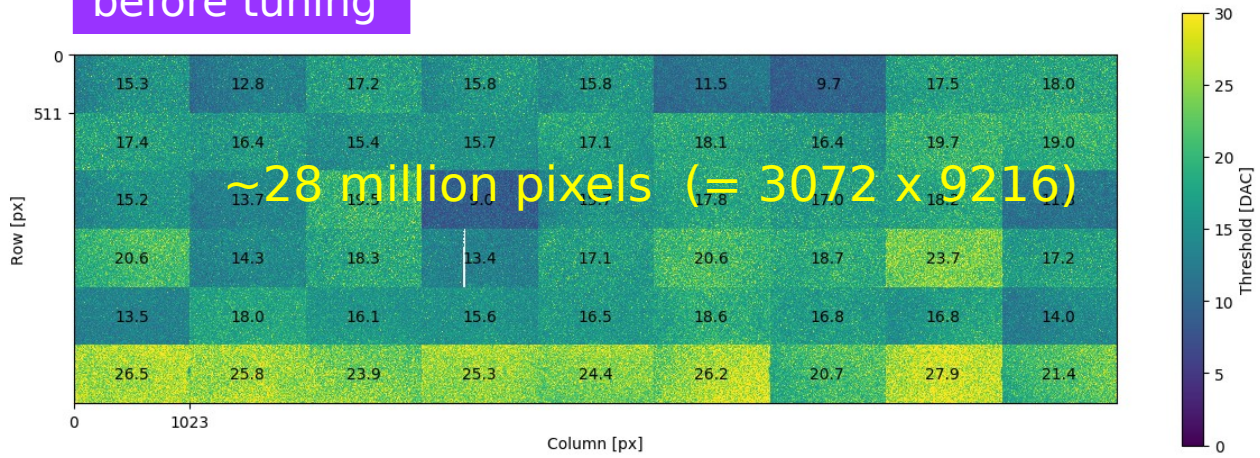
Clean room → Control room

- Full commissioning of the detector on surface including cosmic muon data taking
- Aim is to obtain the detector performance before installation inside the cavern
- Quality control of the main systems and components
- Commissioning shifts - 24/7
- Tests: threshold & the noise performance, long stability of parameters
- Monitoring: voltages / currents / temperatures

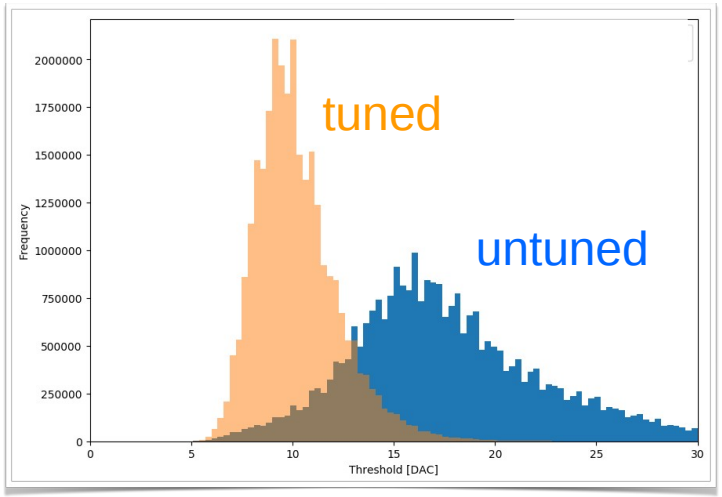
Inner Barrel Commissioning –Threshold Tuning

- Adjustment of front-end parameters to equilibrate the charge thresholds
- Achieving uniform response across the detector, verified on a spare IB half-layer
- Very satisfying threshold stability over time

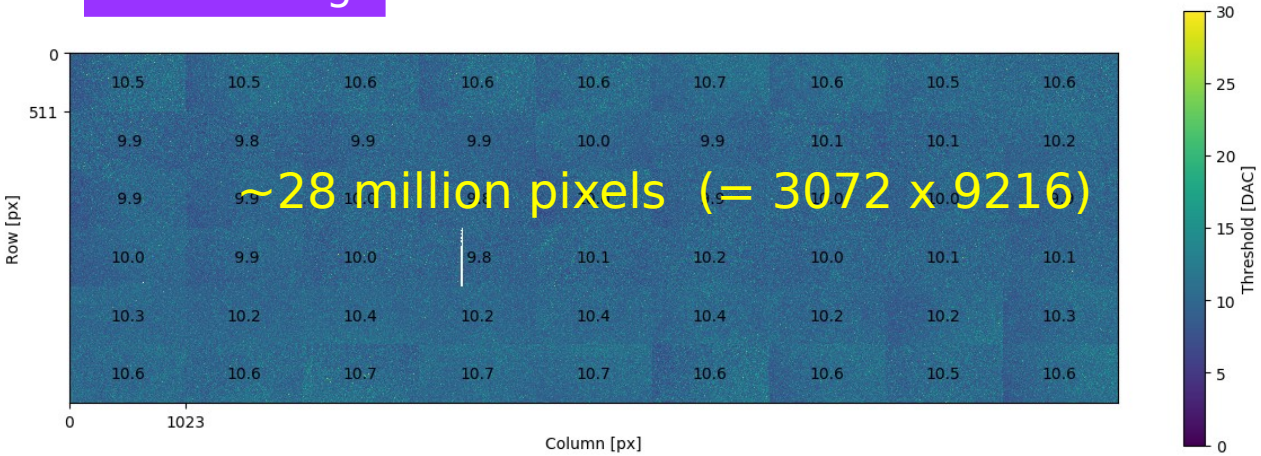
before tuning



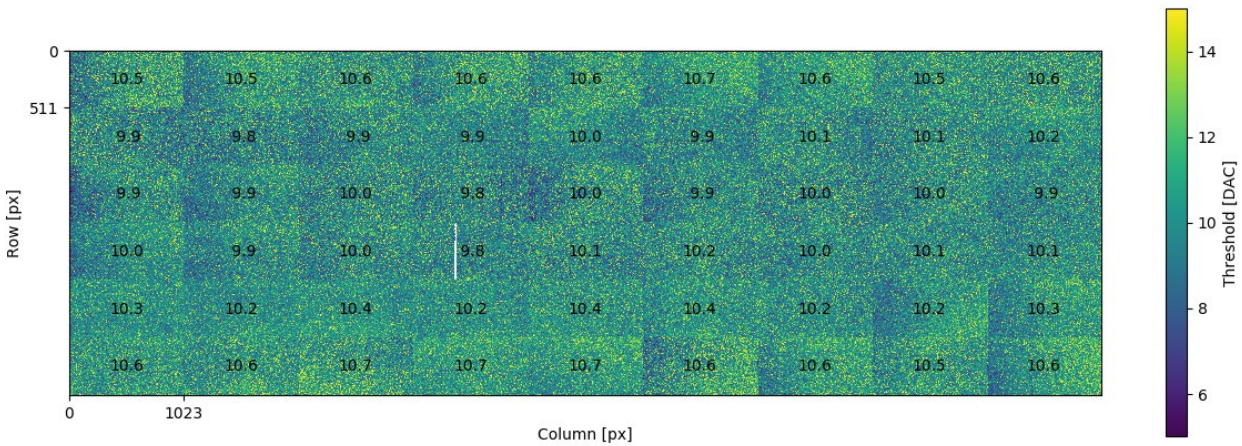
Test data from spare Inner-Barrel Half-layer #0



after tuning



after tuning (zoomed)

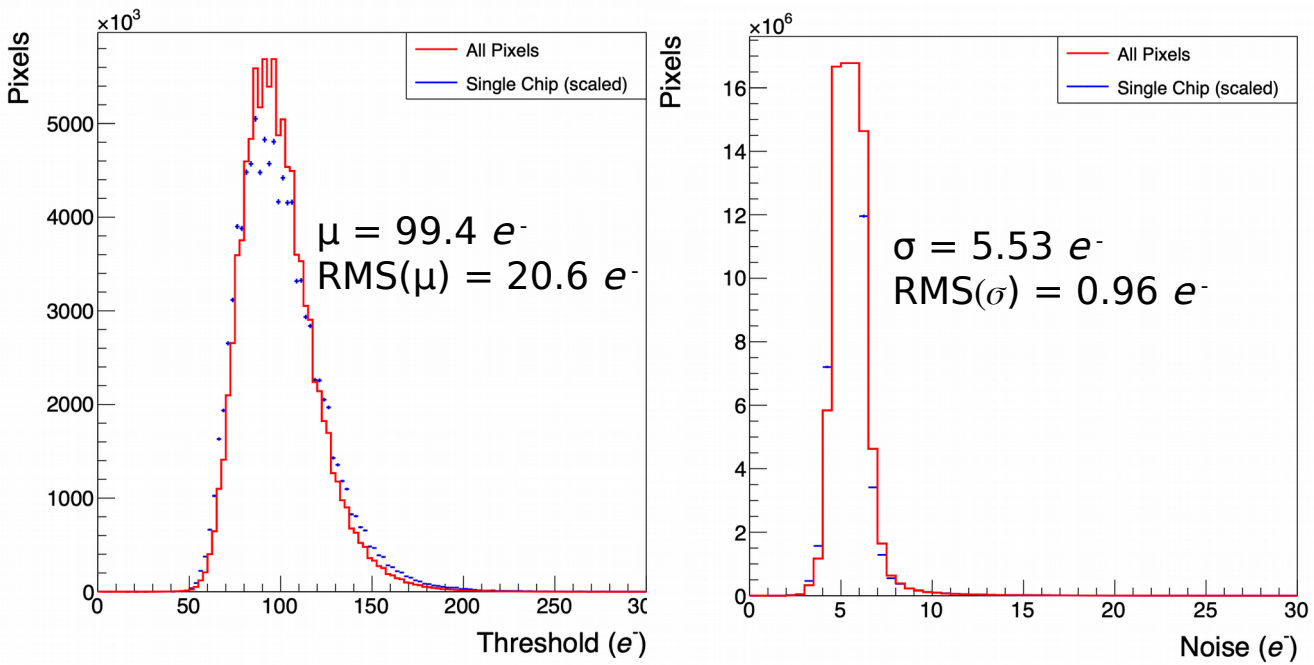


Inner Barrel Commissioning – Noise and Thresholds

Extremely quiet detector!

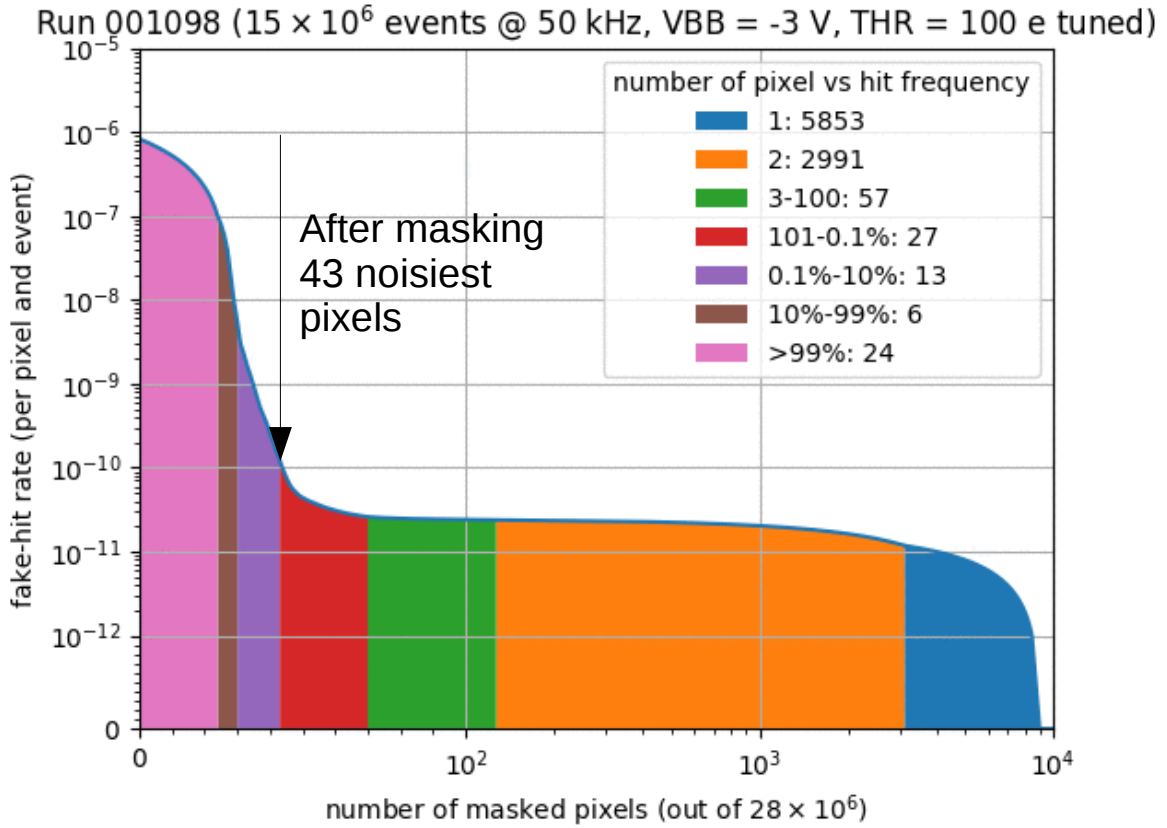
Threshold is a trade-off between:

- Detection efficiency :
  - Threshold < Charge Q_{MIP} (~225 e^-)
- Fake-hit rate :
  - Threshold >> Noise



Threshold and noise after tuning of an OL Stave (~100M pixels)

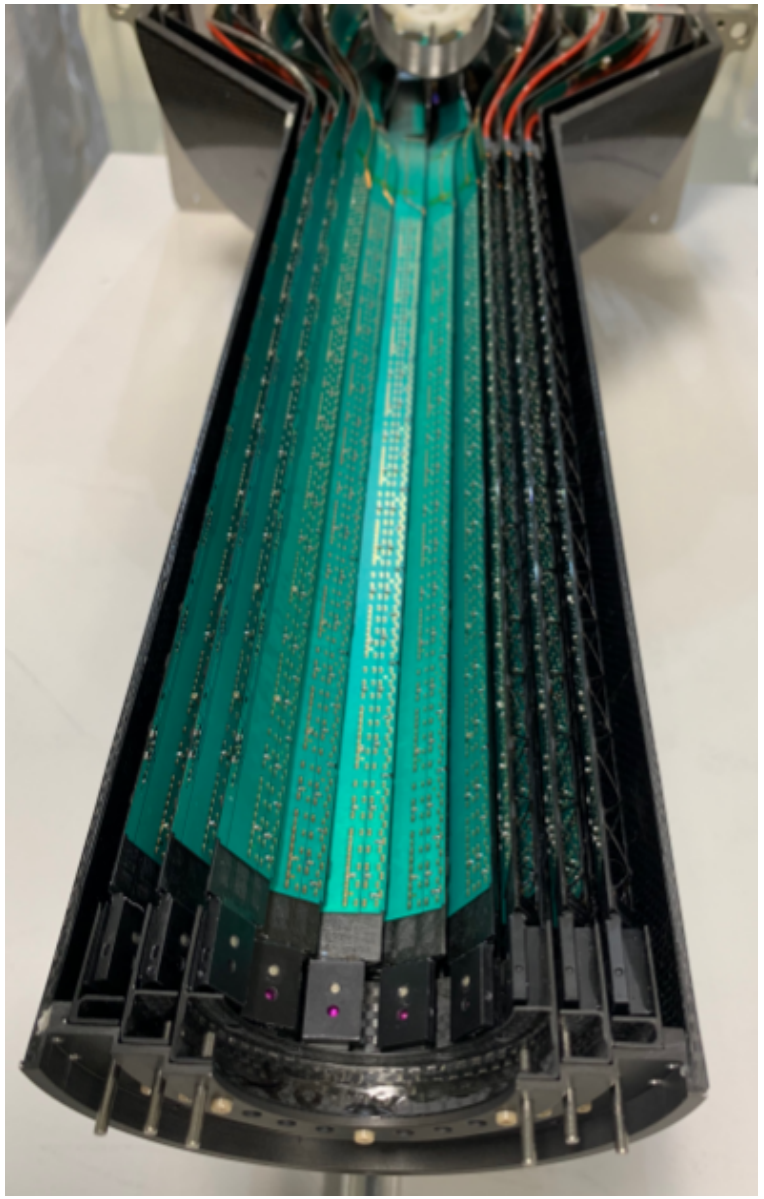
From tests performed on a spare IB layer, running the IB at fake-hit rates below 10^{-10}/pixel/event seems feasible

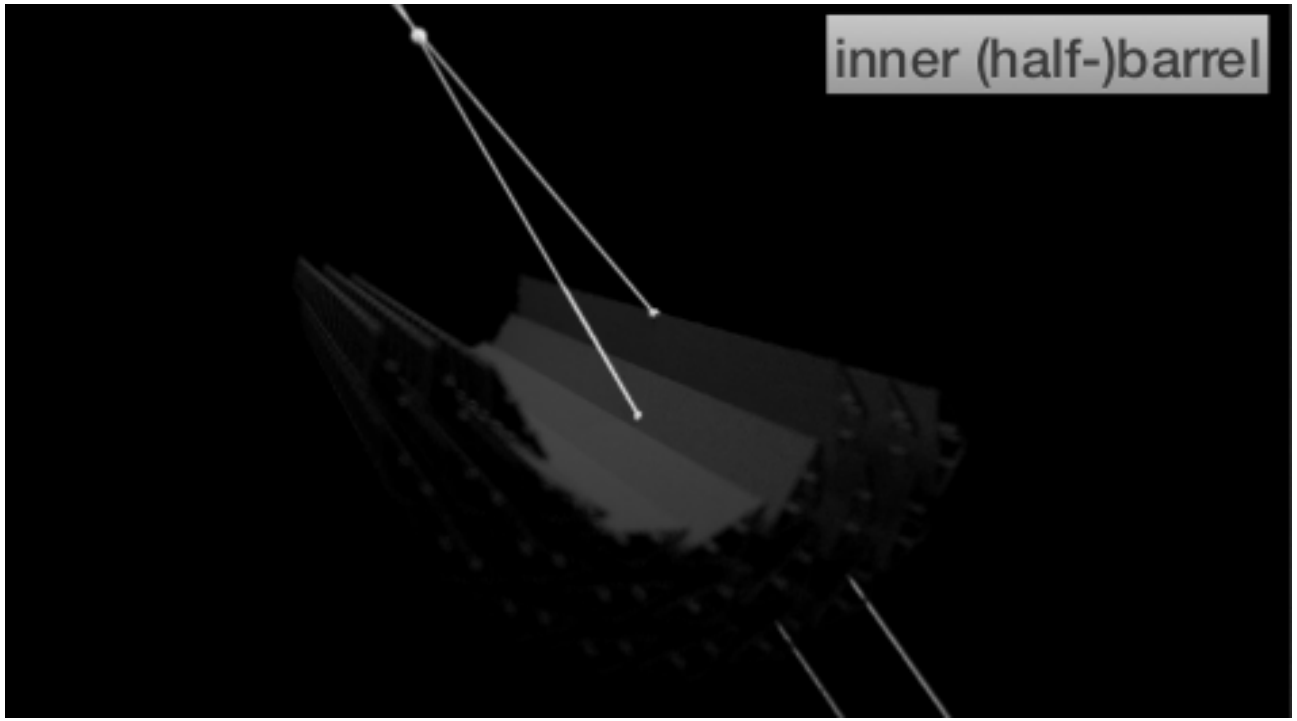


Inner Barrel Layer commissioning – Cosmics

- We get around 1 cosmic track per minute
- We started analyzing “real” data
- Goals: study track and cluster parameters, alignment

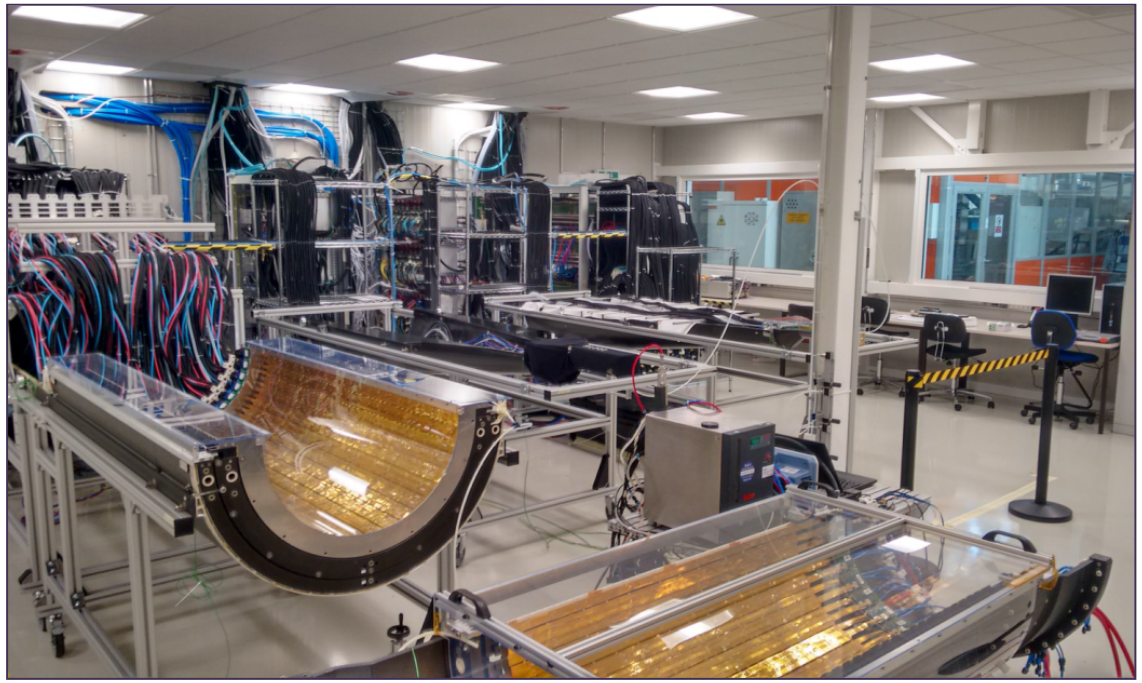
Full inner half-barrel commissioning – Cosmics

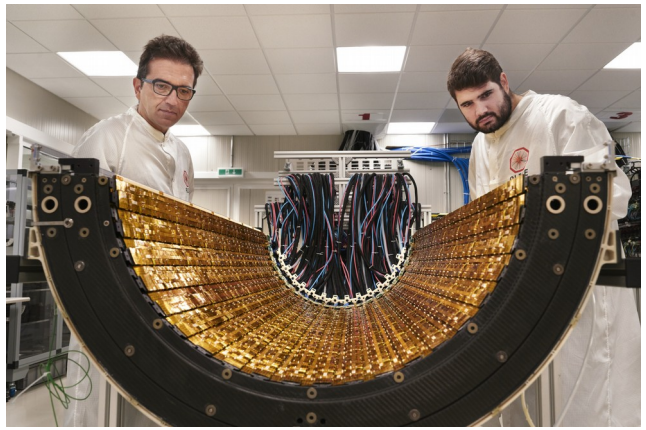




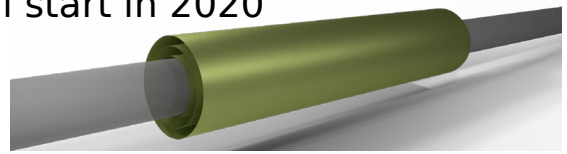
- We get around 3 cosmic tracks per minute

Summary





- ALICE ITS Upgrade (ITS-2) is based on MAPS technology
- It will improve the ALICE potential performance
- Detector component production, assembly and connection to the services is completed
- Commissioning at the surface is ongoing, will be completed by April 2020
- The detector will be transferred to P2 from May 2020 and installed in ALICE in July 2020
- Installation in ALICE will be followed by commissioning period
- We plan the data taking in 2021
- A further upgrade of the fully-cylindrical ITS Inner Barrel for the LHC Long Shutdown 3 has been proposed and the R&D activities will start in 2020



2025+ ALICE ITS-3

Innermost layer: at R = 18 mm

Thickness of each layer: 0.05% X_0

Back Up

Outline

① Overview

② Production of main components

- Outer Barrel HIC and Stave Production
- Readout Electronics
- Power Boards

③ Detector Assembly

④ Commissioning

ITS Upgrade: Construction Installation and Commissioning Timeline

ITS.13 May ‘19

ITS.18 Jun ‘19

ITS.14 Sep ‘19

ITS.15 Nov ‘19

ITS.28 July ‘20

Feb ‘21

Detector Construction and Assembly

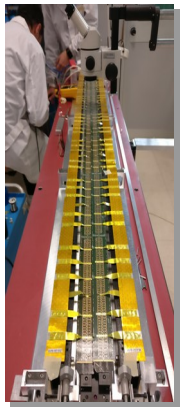
- Module production: completed!
- Stave production: done
- Electronics production: done!

Assembly and Commissioning

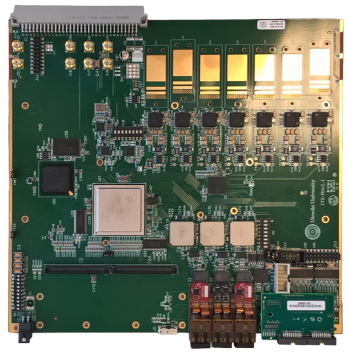
OB Stave Assembly End : done

Installation

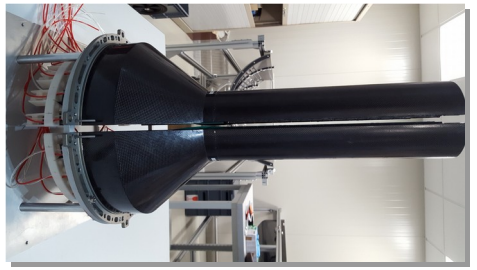
6-month Global Commissioning



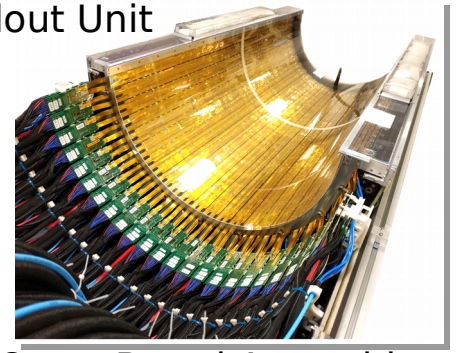
Stave



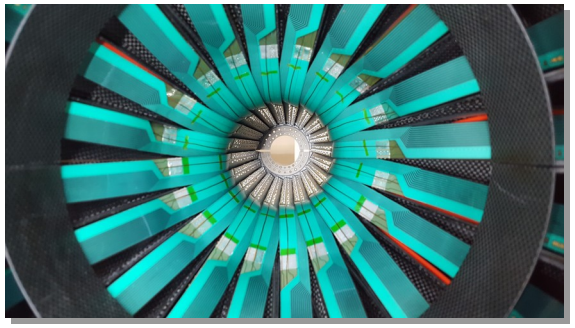
Readout Unit



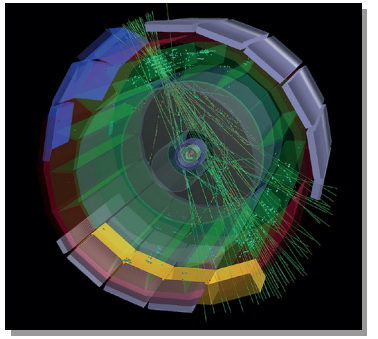
Inner Barrel Assembly



Outer Barrel Assembly



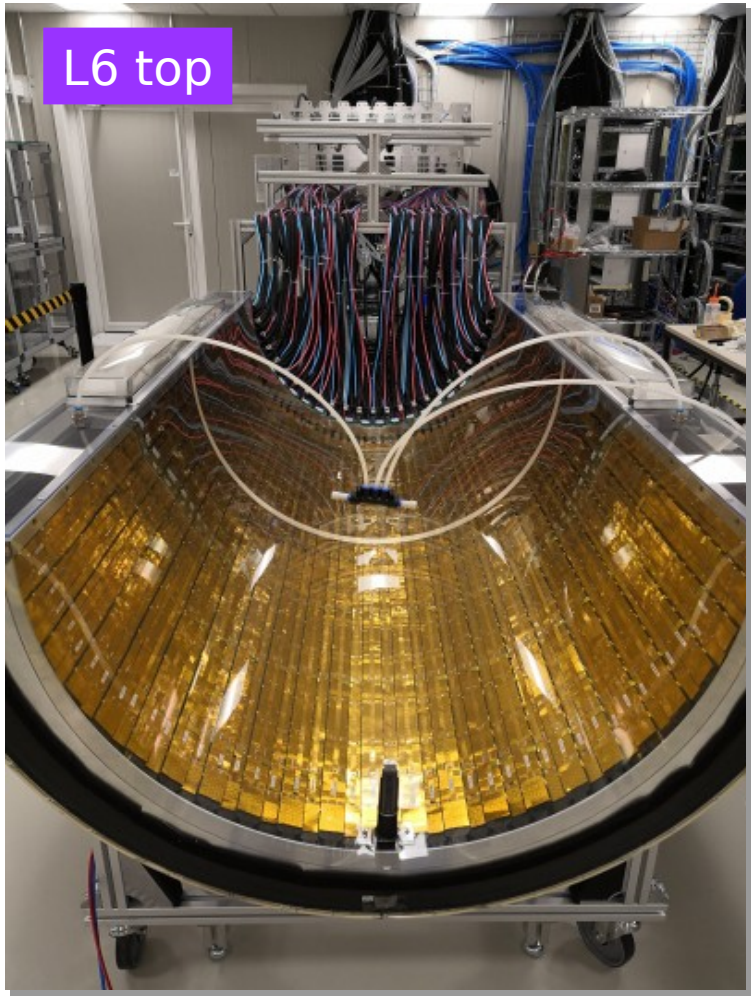
Installation

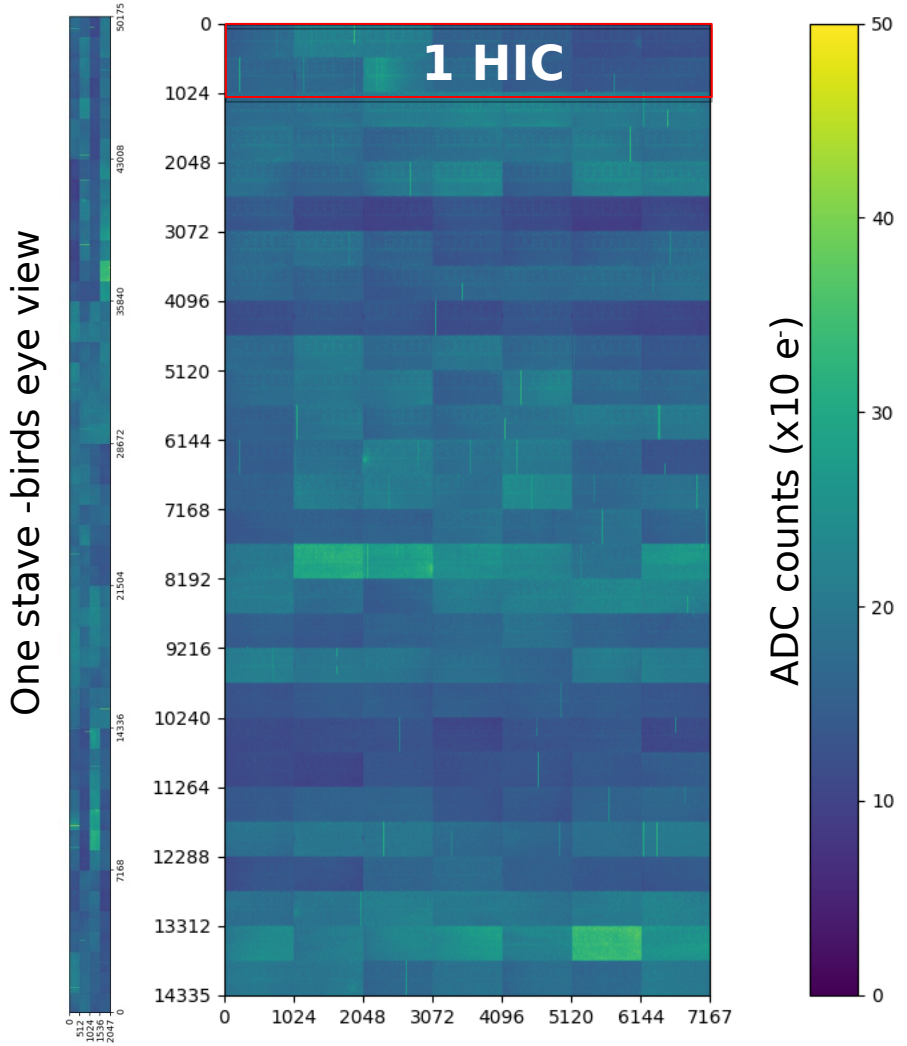


Global commissioning

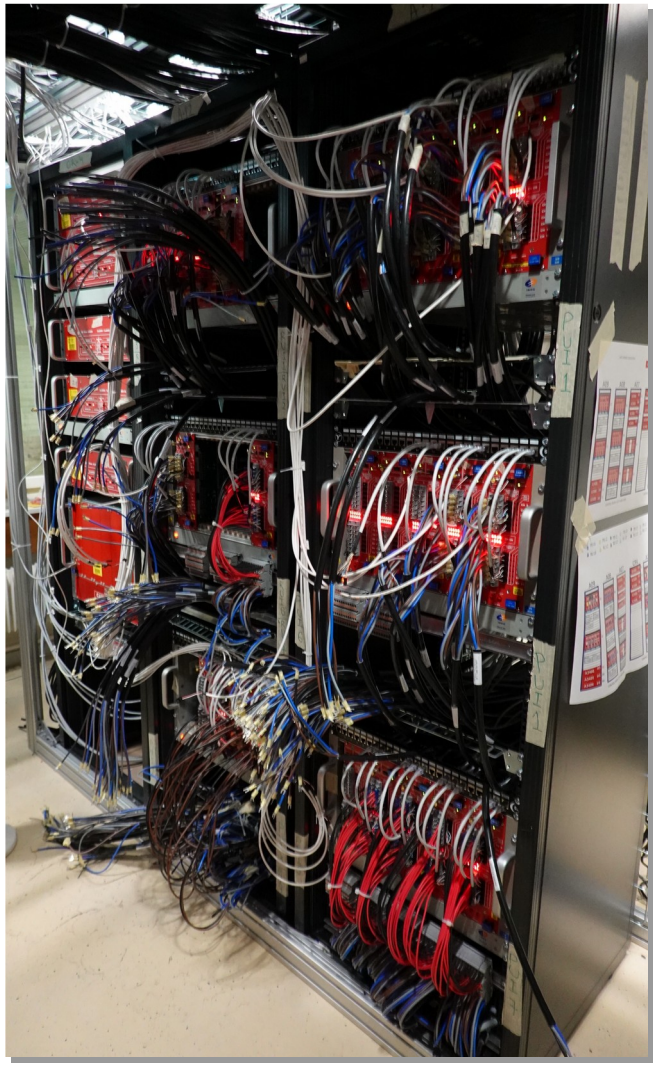
Outer Barrel Commissioning

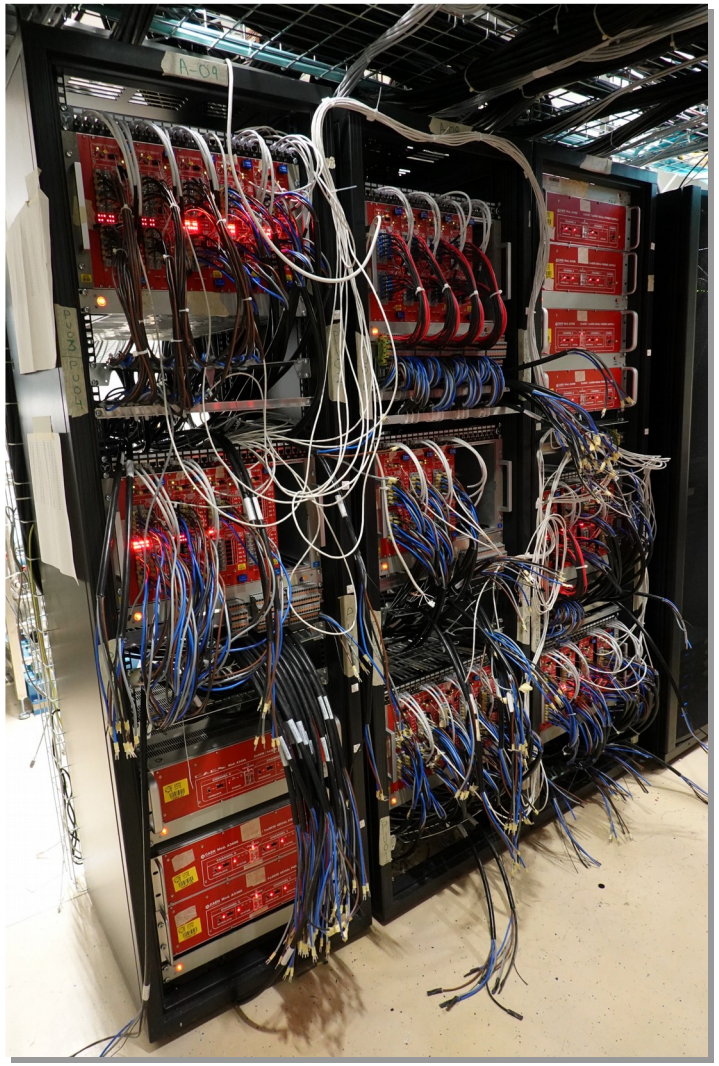
Example of threshold scan of one Outer Barrel Stave (~10^8 pixels)





Power Supplies for detector and readout electronics





- Completely cabled and tested