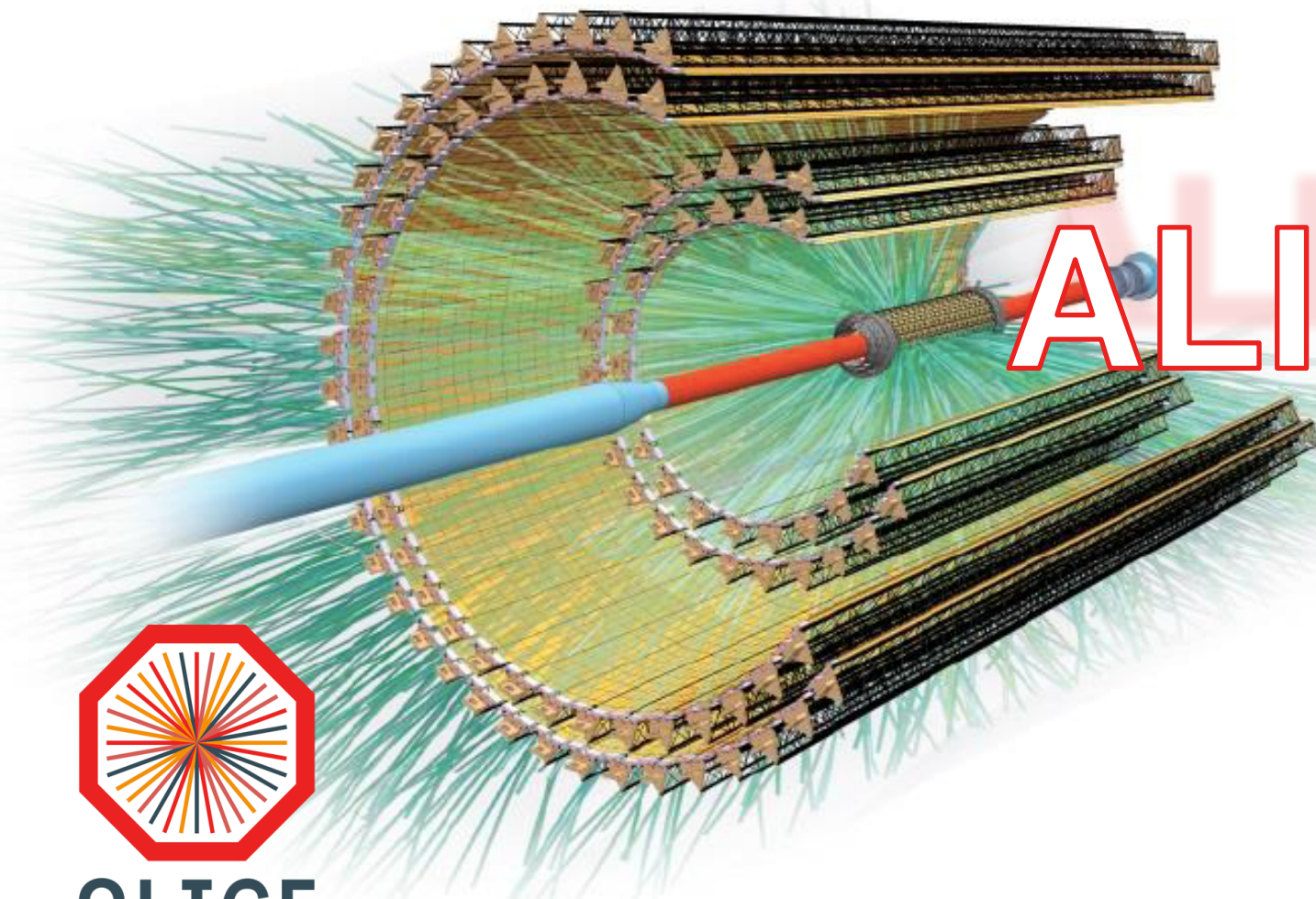
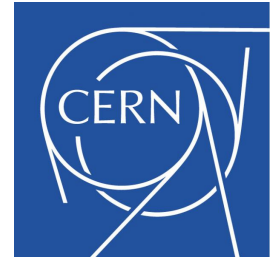




MUSEO  
STORICO DELLA FISICA  
E  
CENTRO  
STUDI E RICERCHE  
ENRICO FERMI



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# ALICE Status



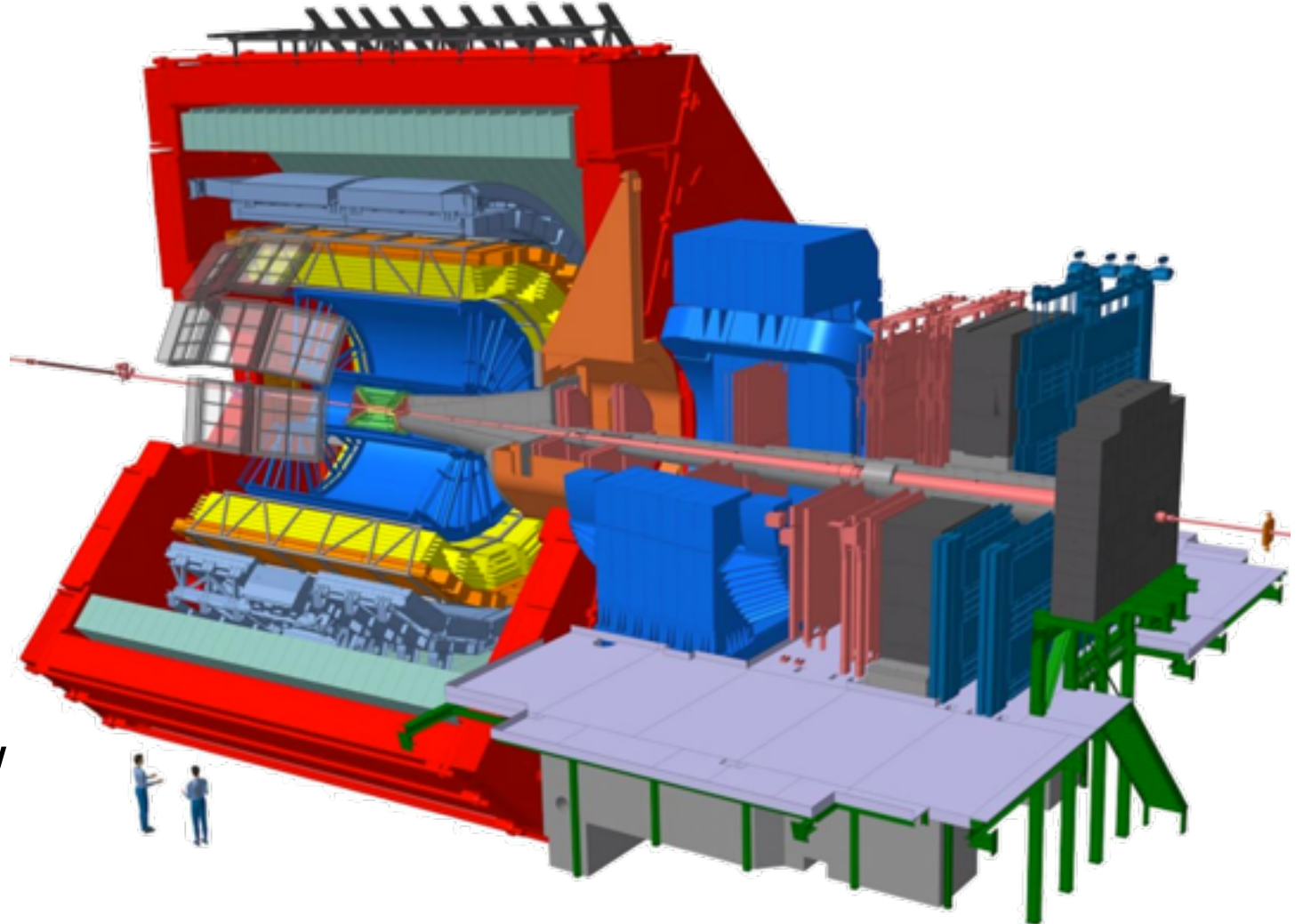
**ALICE**

***Federico Ronchetti***  
*INFN – Laboratori Nazionali di Frascati*  
*LNF Scientific Committee, November 13, 2017*



# Executive Summary

- **ALICE overview**
- ITS-Upgrade overview
- ALICE @ LNF
  - ITS Upgrade work
  - Data analysis work
- Outlook
  - Manpower and know-how
  - Conclusions

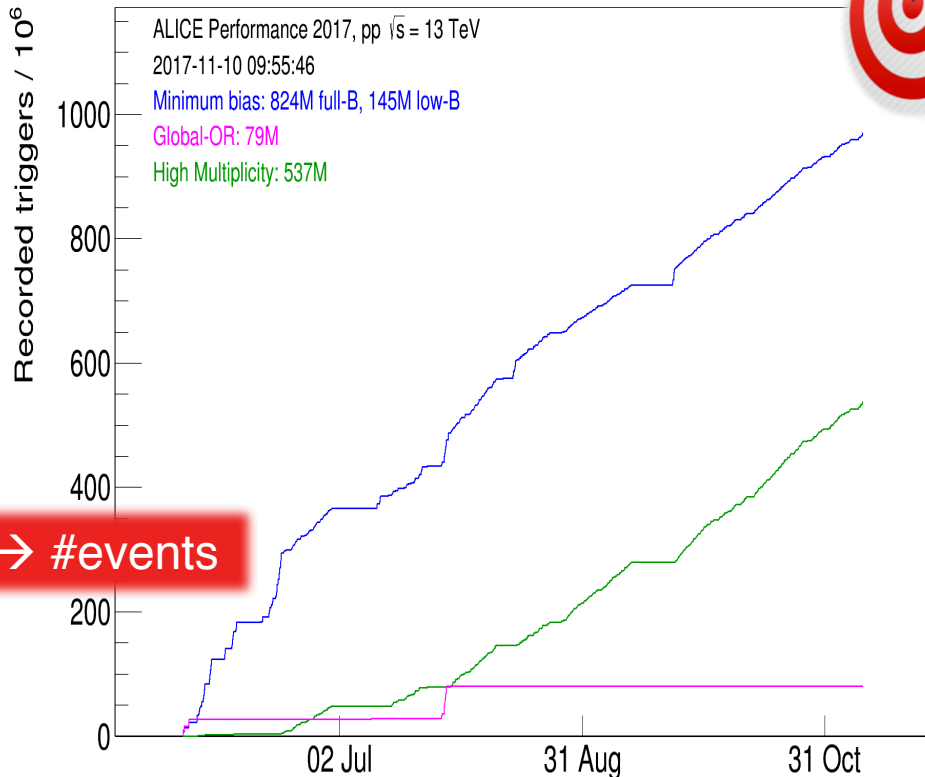
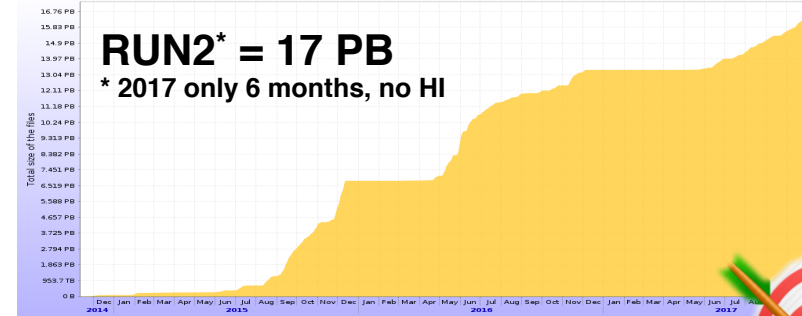




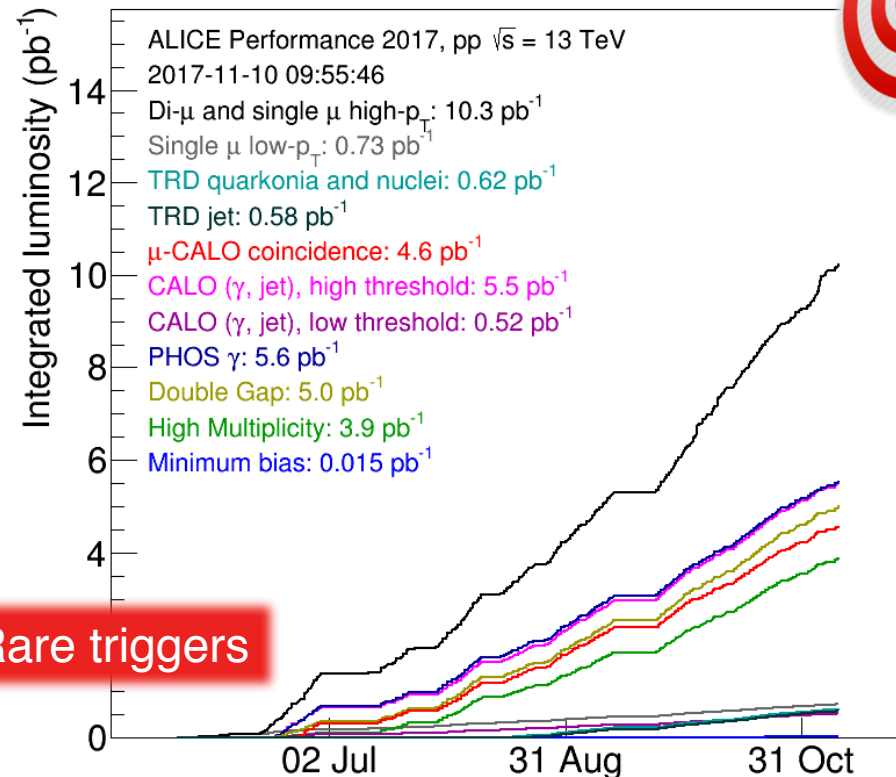
# ALICE Performance in 2017

## 2017: short pp run & XeXe pilot run

- **pp: 92%** running efficiency overall,  $>10 \text{ pb}^{-1}$  seen
- **XeXe: 1.7M MinBias** events



MinBias  $\rightarrow$  #events



Rare triggers



A Large Ion Collider Experiment

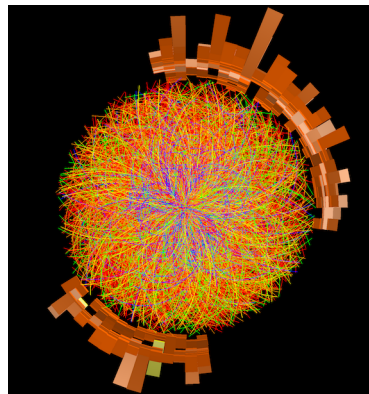
# ALICE Upgrade Motivations

## Physics goals → High-precision measurements of QGP properties

- Heavy Flavor and Quarkonia at very low  $p_T$ 
  - Thermalisation, recombination
- Vector mesons and low-mass di-leptons:
  - Chiral symmetry restoration, virtual thermal photons
- High-precision measurement of light nuclei and hyper-nuclei:
  - QGP nucleosynthesis, exotics

## Main detector requirements

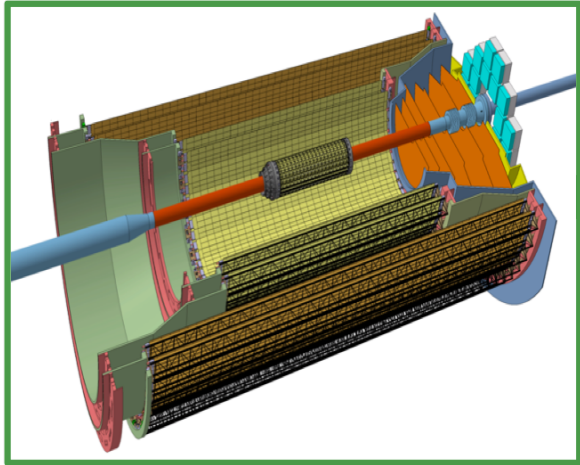
- High tracking efficiency and resolution at low  $p_T$ 
  - Increase granularity, reduce material thickness
- High-statistics, un-triggered data sample:
  - Increase readout rate, reduce data size (online data reduction)
- Preserve ALICE **UNIQUE particle ID capabilities at LHC**
  - Consolidate and “speed-up” PID detectors (i.e. TPC)



**ALICE UPGRADE**  
Targets LHC 2<sup>nd</sup> Long Shutdown (2019/20)

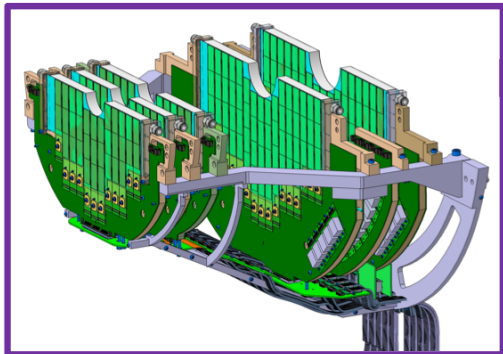


# ALICE Upgrade in LS2



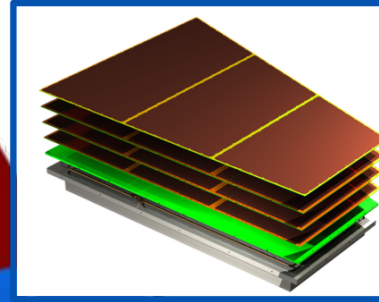
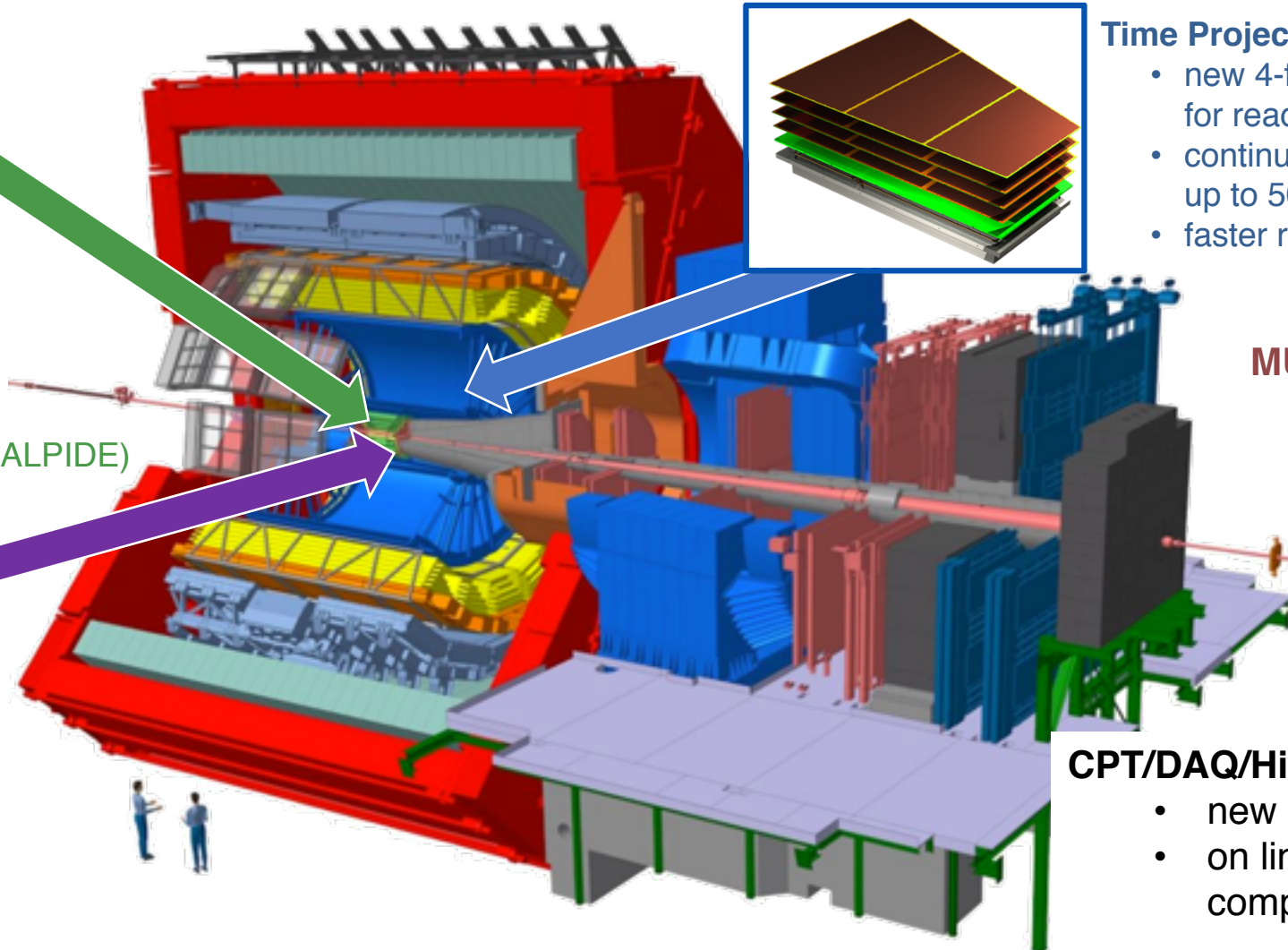
## New Inner Tracking System (ITS)

- 13 Gigapixels 0.18  $\mu\text{m}$  CMOS (ALPIDE)
- thinnest tracker at the LHC



## Muon Forward Tracker (MFT)

- new Si tracker (ALPIDE)
- Improved pointing precision



## Time Projection Chamber (TPC)

- new 4-fold GEM technology for readout chambers
- continuous readout up to 50 kHz
- faster readout electronics

## MUON ARM

- continuous readout electronics

## CPT/DAQ/High Level Trigger

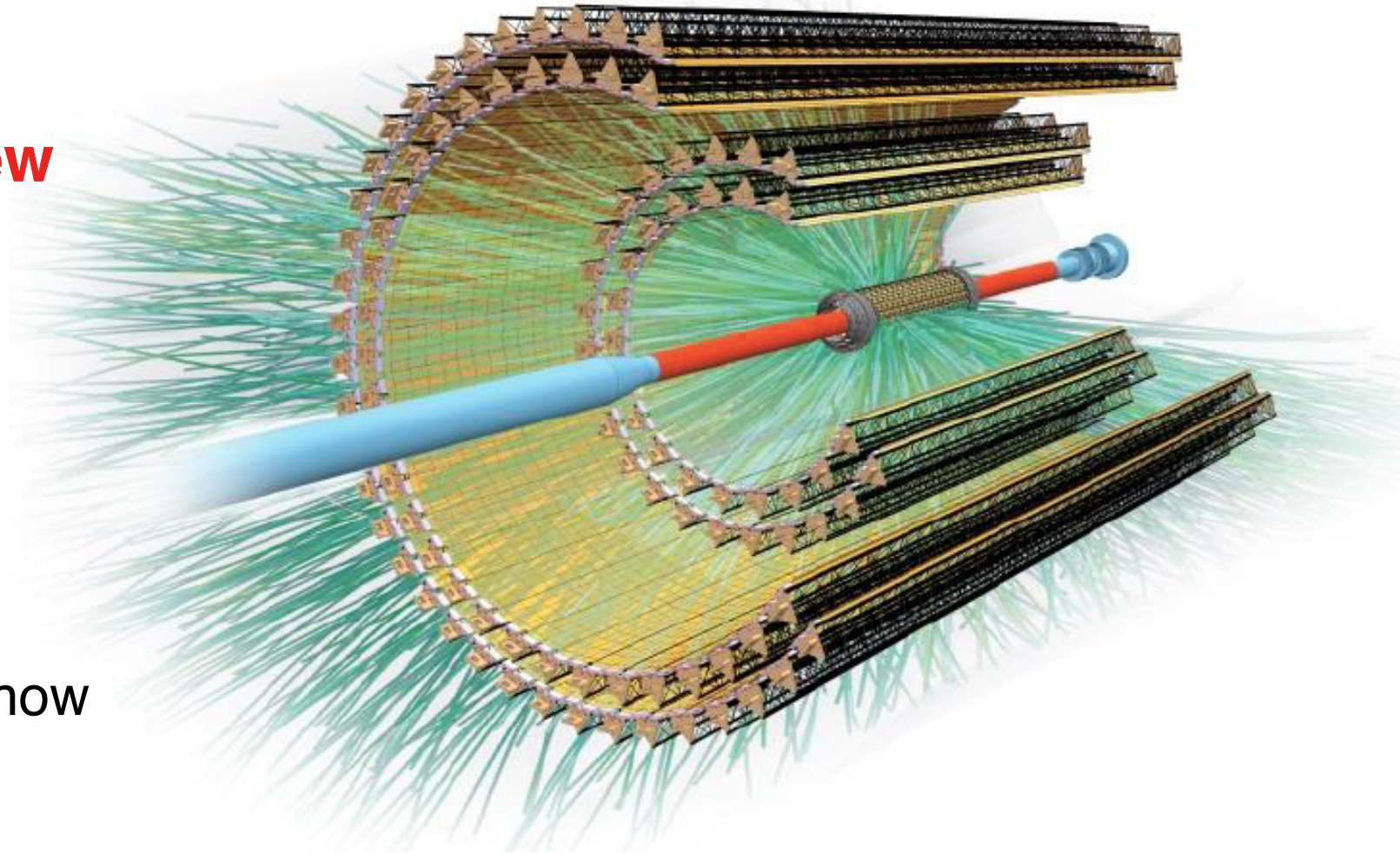
- new architecture
- on line tracking & data compression

CALO, TOF, TRD, ZDC: Faster readout



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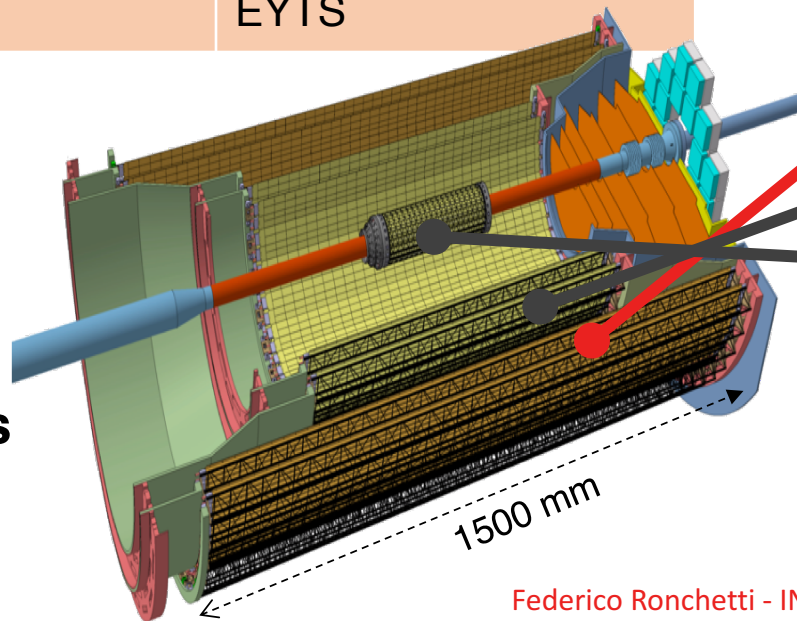




A Large Ion Collider Experiment

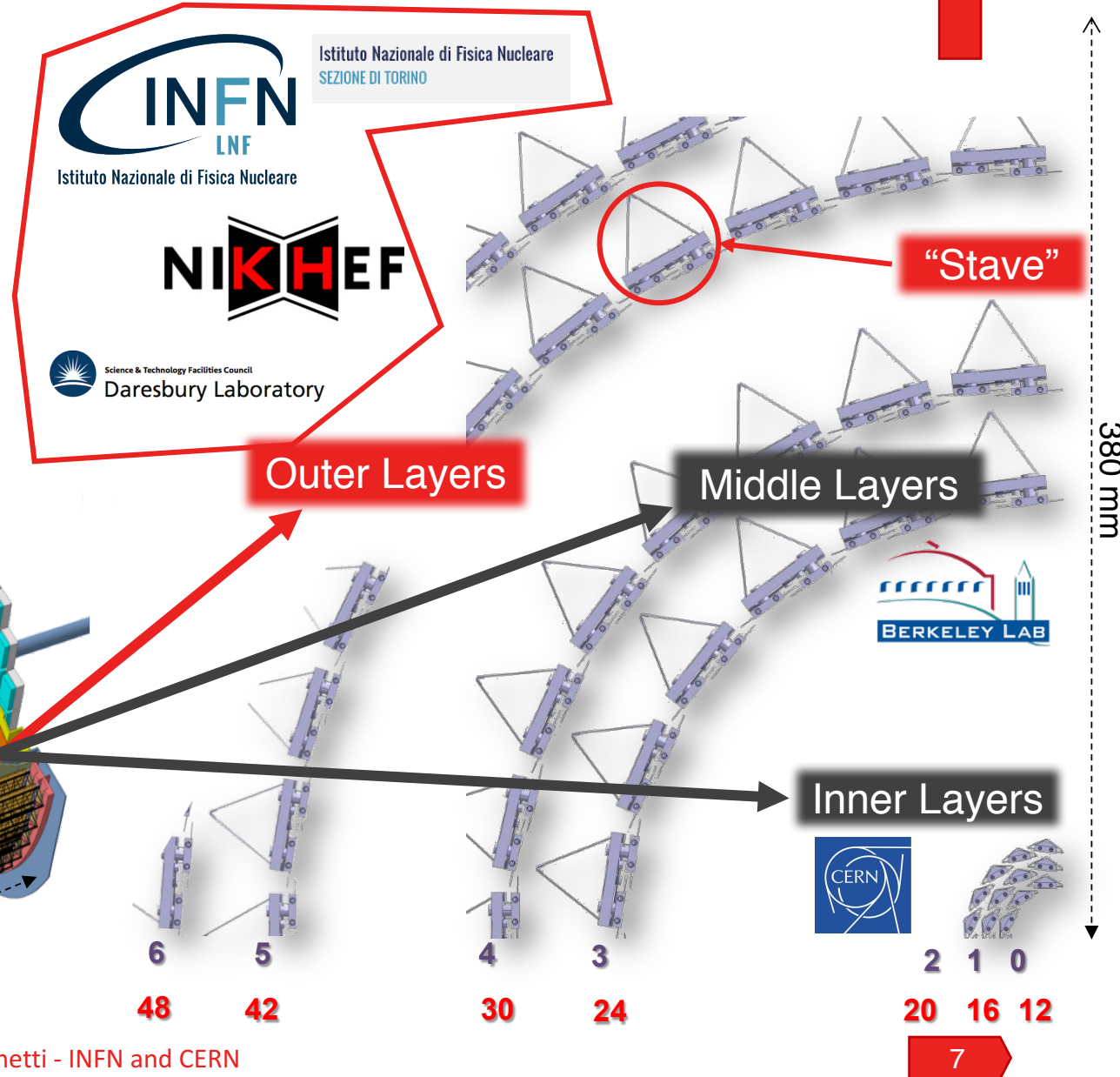
# ITS Structure

ITS	Before LS2	After LS2
Technology	Hybrid	MAPS: 180 nm CMOS
Rate	~ 1 kHz	100 kHz
Thickness	~1.14% $X_0$	0.3% $X_0$ (IB), 1% $X_0$ (OB)
Pixel size	425(xy) $\mu$ m x 50 $\mu$ m(z)	30 $\mu$ m(xy) x 15 $\mu$ m(z)
Si coverage	39 – 430 mm	22 – 400 mm
Layers	6 (only 2 of pixels)	7
Maintenance	LS	EYTS



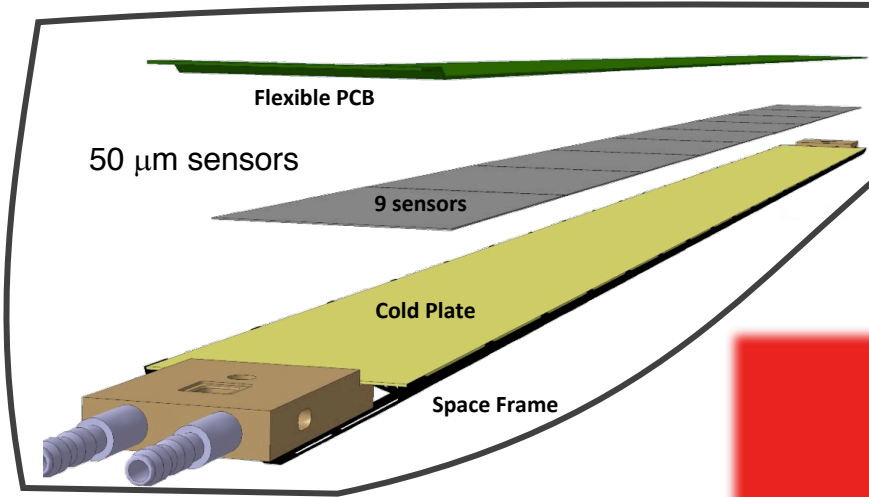
## 12,500 Megapixels!

192 staves + spares  
Area: ~ 10 m<sup>2</sup>



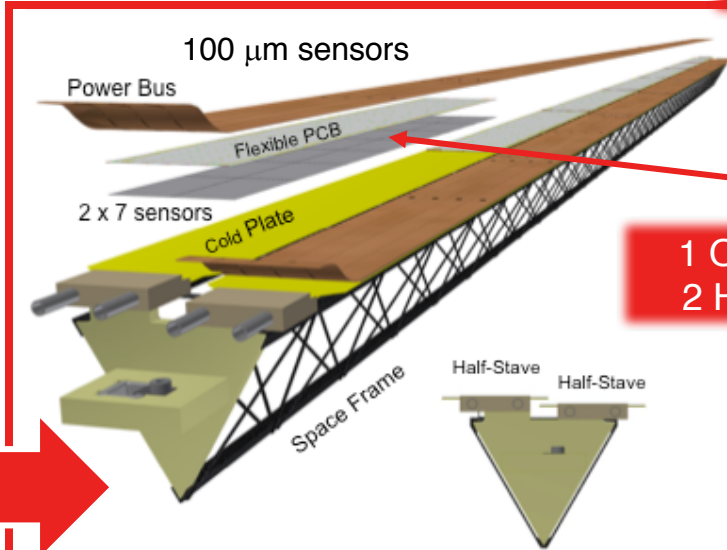
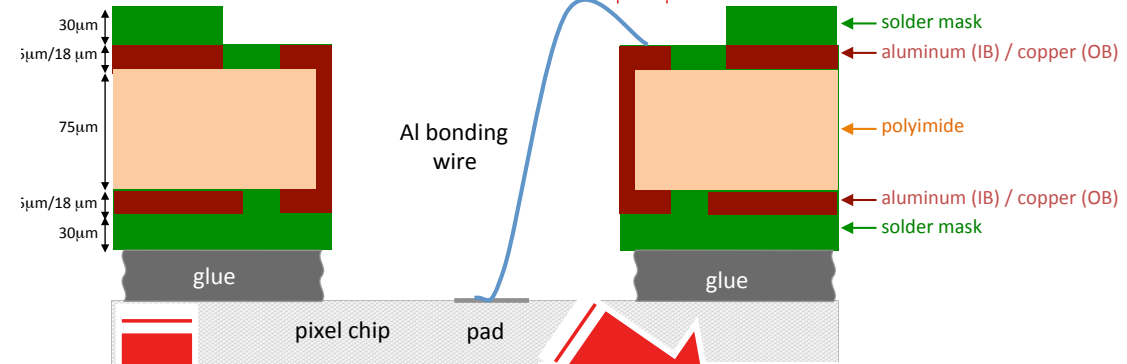


# Stave Structure



Inner Stave = 9 Sensors

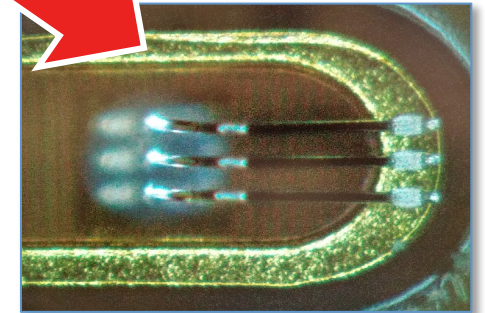
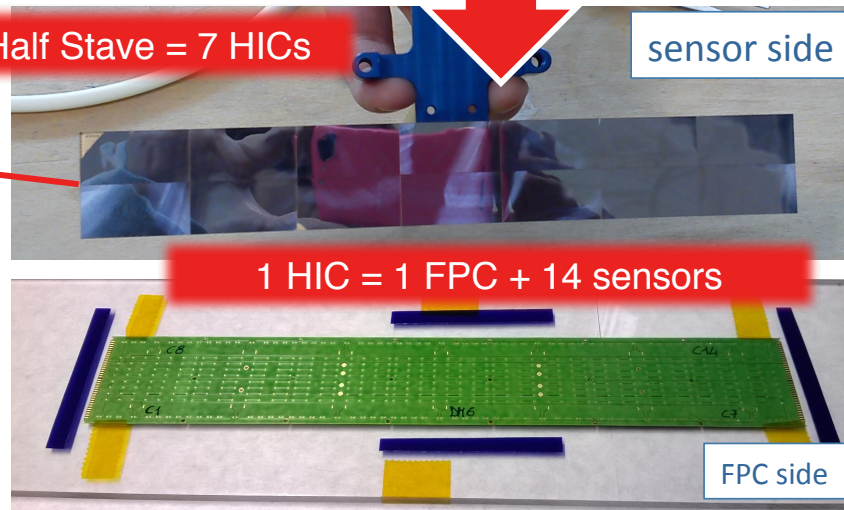
Outer Stave  
2x7 Sensors



1 Half Stave = 7 HICs

1 Outer Stave  
2 Half Staves

1 HIC = 1 FPC + 14 sensors



Al bonding





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# ALPIDE Sensor Technology

## TowerJazz-CERN 180 nm CMOS Imaging Process

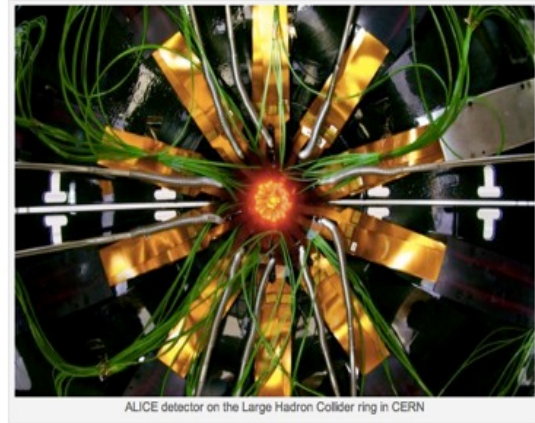
**TechTime** Electronics & Technology News

News | Business | Technology | Hebrew

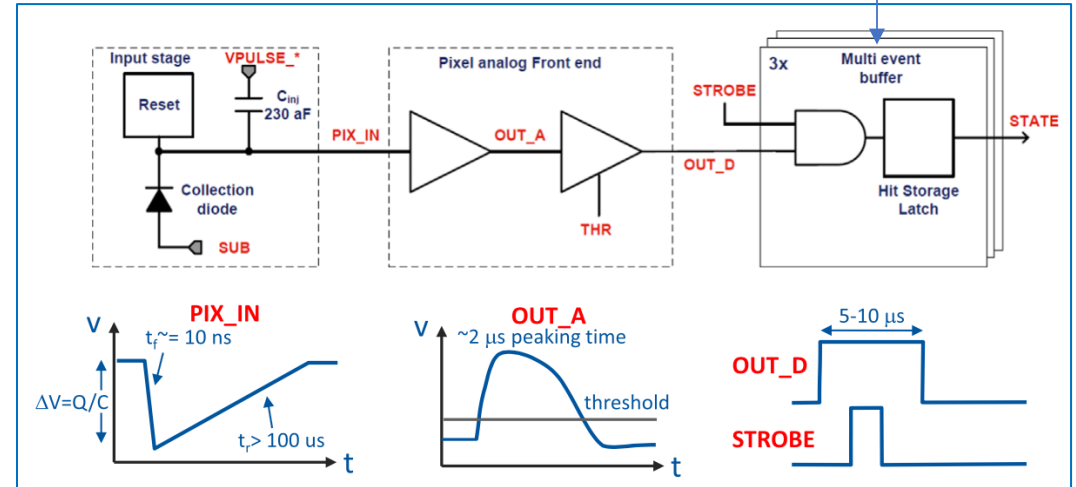
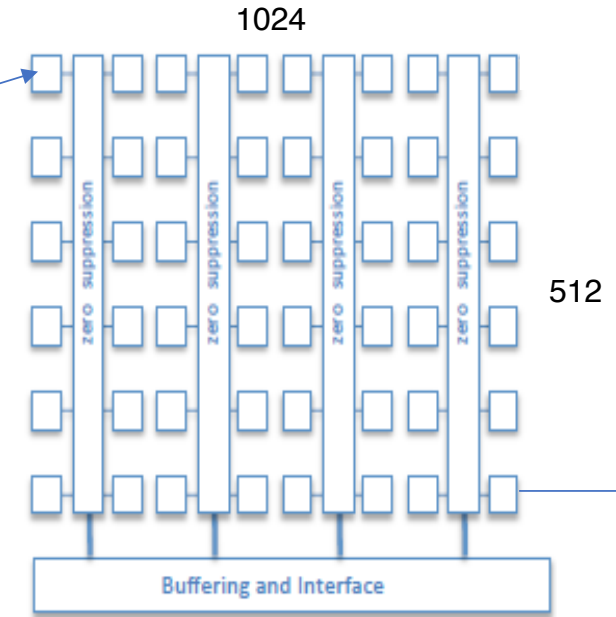
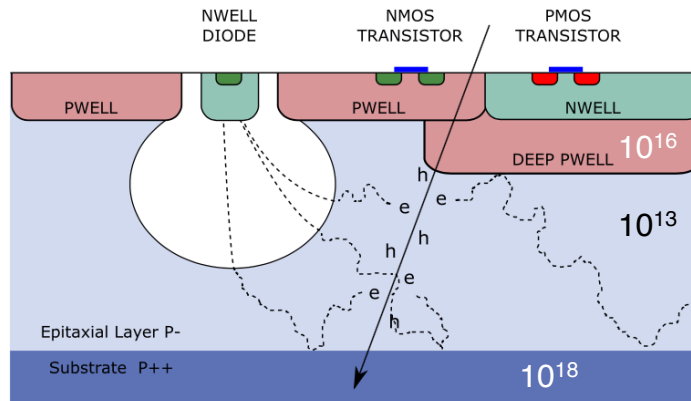
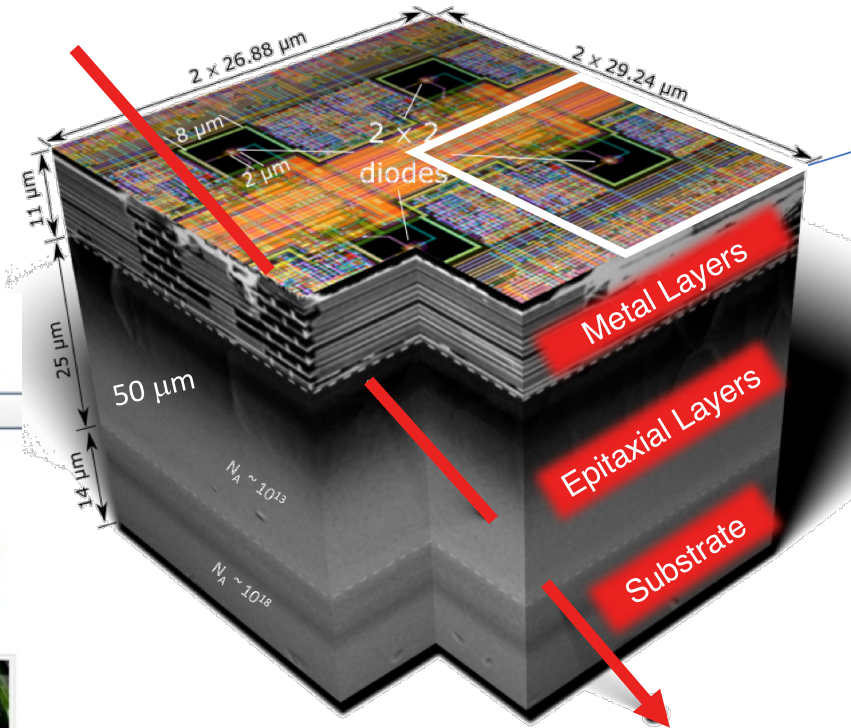
### TowerJazz will develop CERN's Image Sensor

Published 22 November 2013

The global specialty foundry TowerJazz, said it was chosen to provide the sensor for the upgrade of the Inner Tracking System (ITS) of the ALICE experiment at the European Organisation for Nuclear Research (CERN) in Geneva, Switzerland.



ALICE detector on the Large Hadron Collider ring in CERN

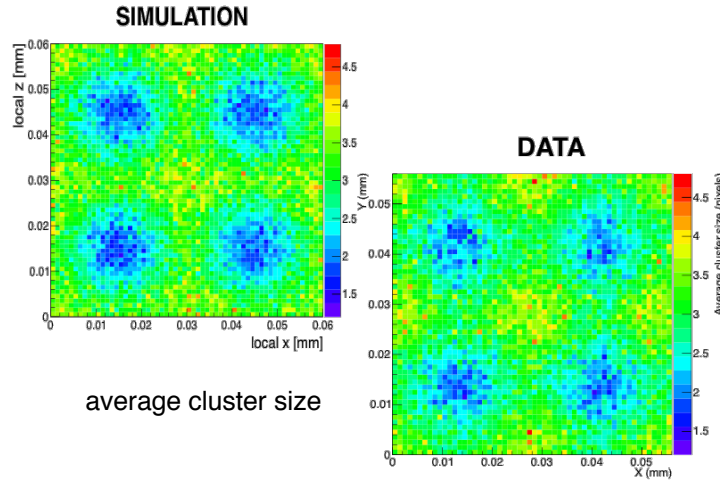




A Large Ion Collider Experiment

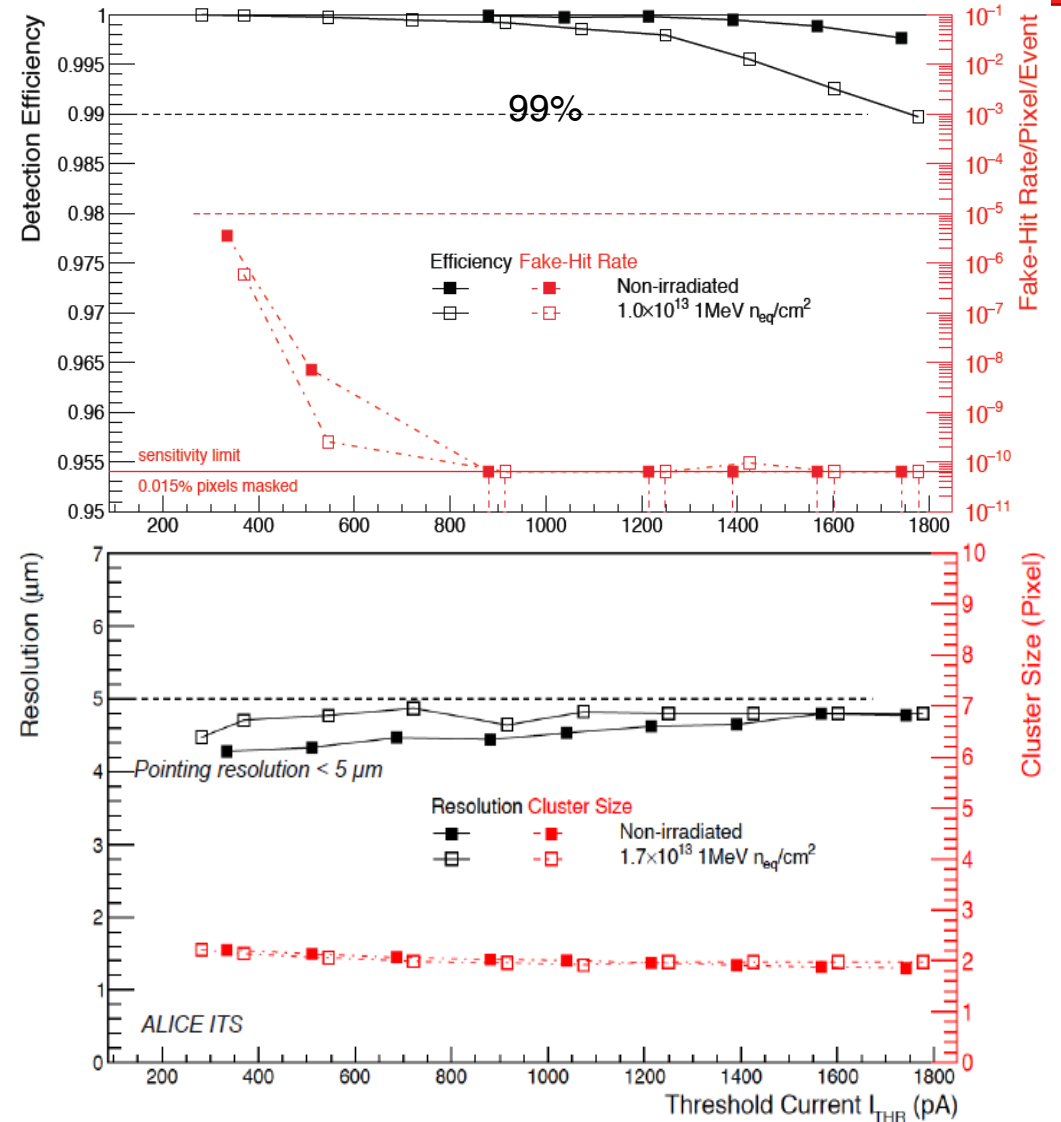
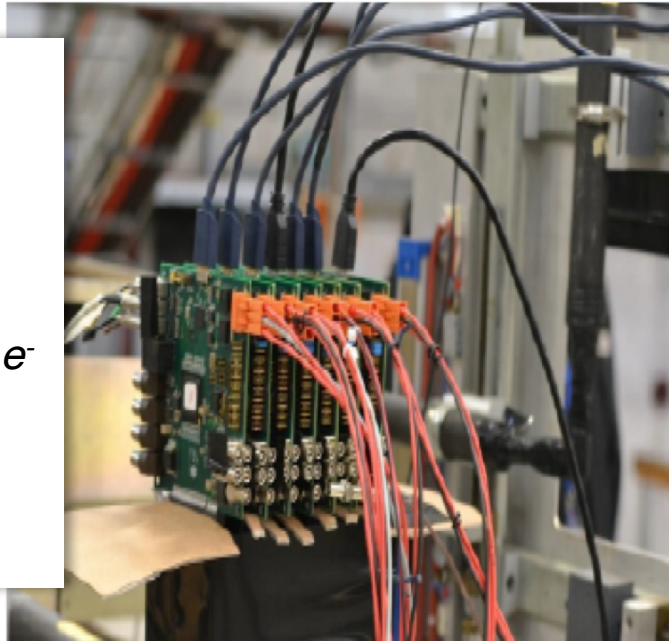
# ALPIDE Characterization

- MC Simulation with parametrized response model
- Cluster size and shape are modeled on test beam data



## Beam Test Facilities

- PS: 5-7 GeV  $\pi$
- SPS: 120 GeV  $\pi$
- PAL (S. Ko): 60 MeV  $e^-$
- LNF: 450 MeV  $e^-$
- DESY: 5.8 GeV  $e^-$



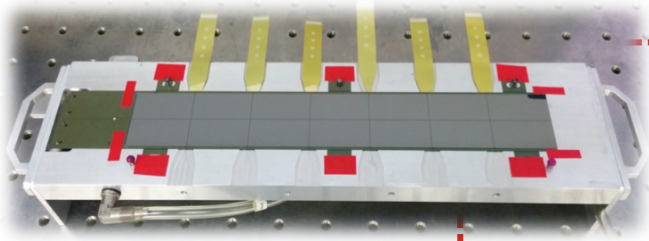


A Large Ion Collider Experiment

# The ITS Outer Layers

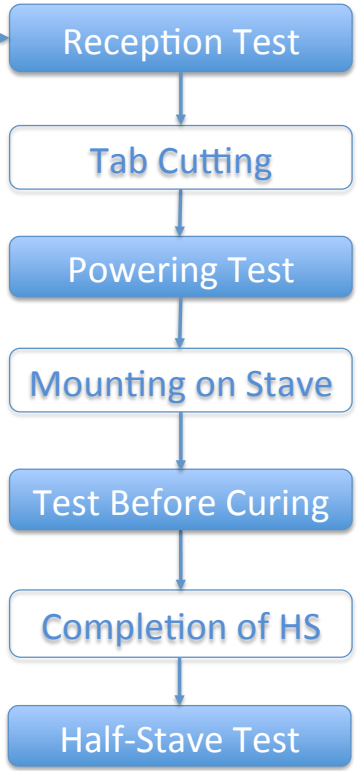
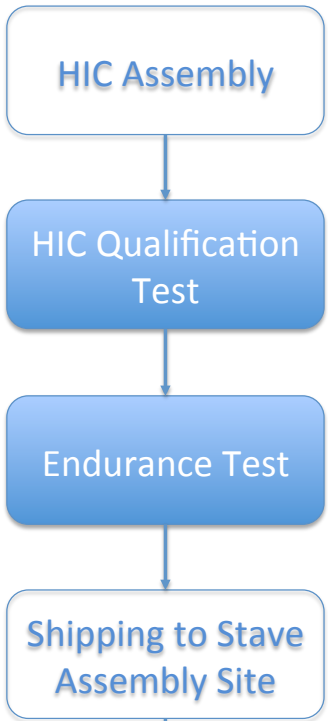
HIC Production: 2 HIC/day/site

Institute
Bari, Italy
Pusan, Korea
Wuhan, China
Strasbourg, France
Liverpool, UK
Saclay, France (MFT)



## Outer Layers

HIC Production Site



The map displays production sites across Europe, with red boxes highlighting key locations:

- Daresbury Laboratory** (UK)
- NIKHEF** (Netherlands)
- BERKELEY LAB ML** (USA)
- Istituto Nazionale di Fisica Nucleare SEZIONE DI TORINO** (Italy)
- INFN LNF** (Italy)

Technical specifications for the detector:

- 12,500 MP** (Megapixels)
- ~ 25 Staves/site**
- A 184 Megapixels detector in each site!**



A Large Ion Collider Experiment

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A Large Ion Collider Experiment

# ITS@LNF Infrastructure



## CMM Compressor

- Atlas Copco GA5FF 7bar, 15 l/s
- **Main Building Heat Pump**
- **New 27 kW unit in 2018**

## N-generator Refurbishing in 2017



## Vacuum Pumps Refurbished 2017



## 42 m<sup>2</sup> CI 10,000 **HIC Processing, Half Stave, and Stave assembly** Refurbished 2017

- Full workspace reorganization
- New larger and cleaner vestibule
- Improved tool vacuum distribution
- HIC cut table
- Welding table
- Network services (wire)
- Larger/duplicate CMM screen



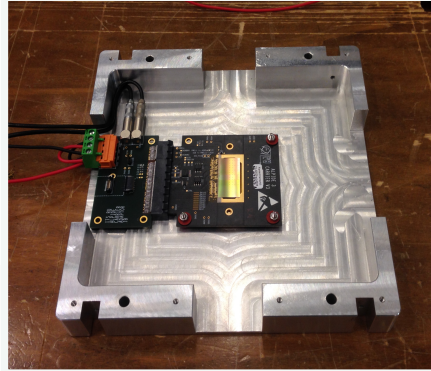
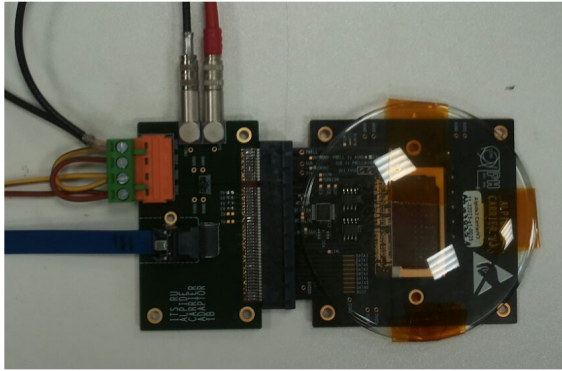
## 25 m<sup>2</sup> CI 100,000 **Stave powering and test / Storage area** Refurbished in 2017

- Vacuum line
- Cooling loop
- Stave power bus soldering and test table
- ESD cabinet for N bath HIC storage



A Large Ion Collider Experiment

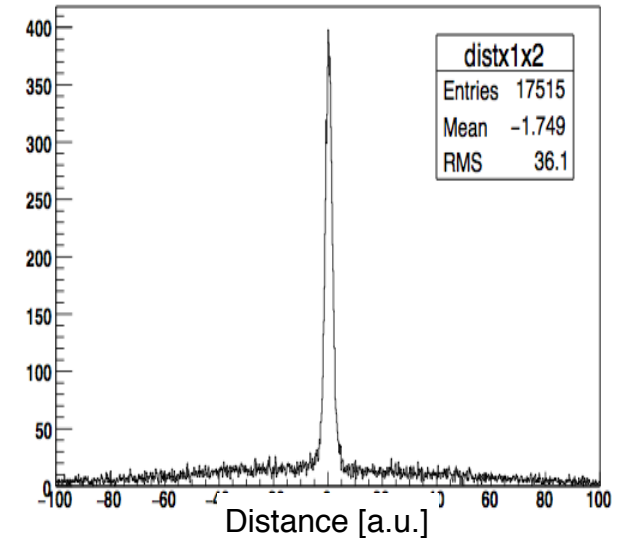
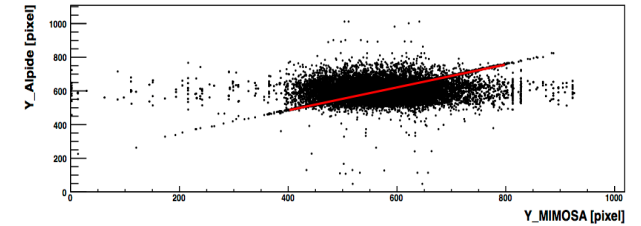
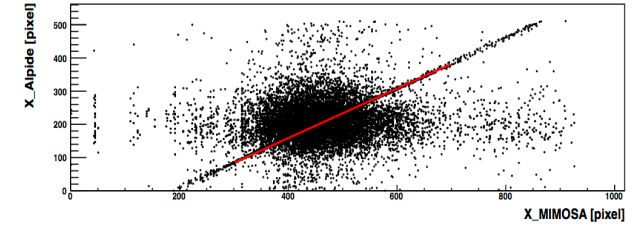
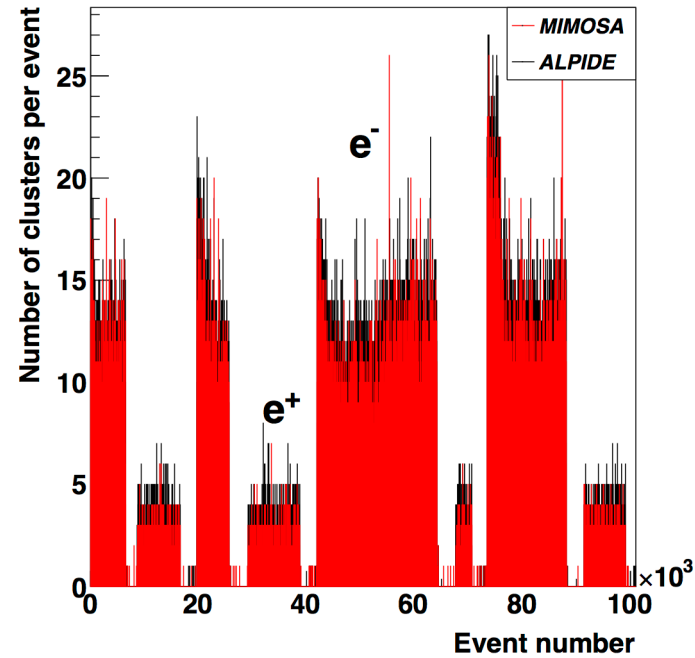
# ALPIDE Tests at LNF BTF



Under test:  
1x ALPIDE  
1x MIMOSA-28

ALPIDE sensor

MOSAIC  
readout board



LABORATORI NAZIONALI DI FRASCATI  
SIDS-Pubblicazioni

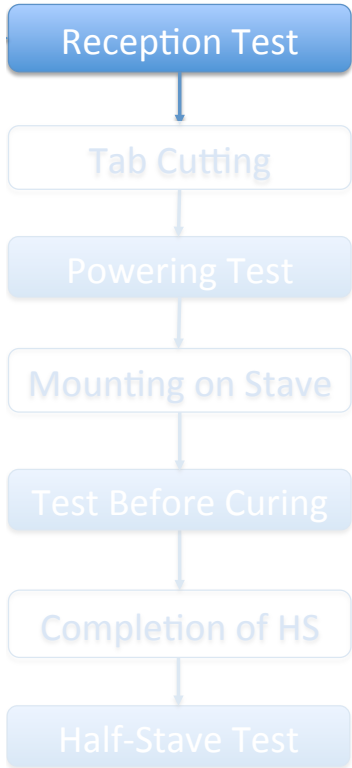
INFN-17-16/LNF  
May 6, 2017

## BEAM TEST OF ALPIDE SENSOR

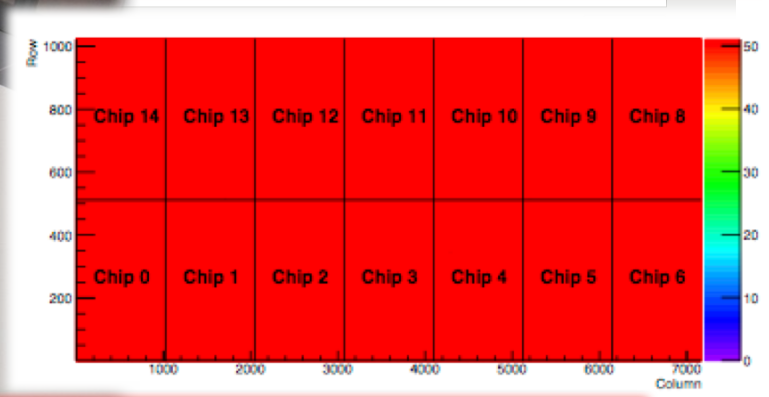
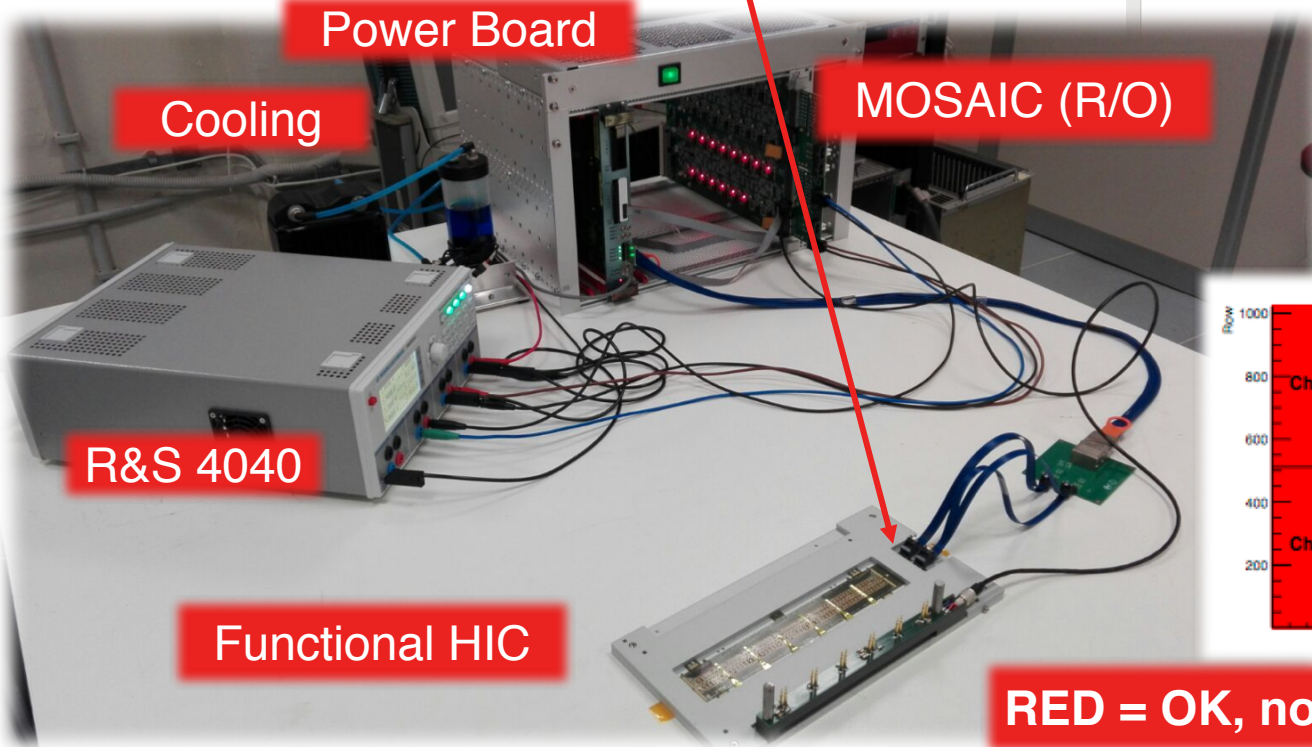
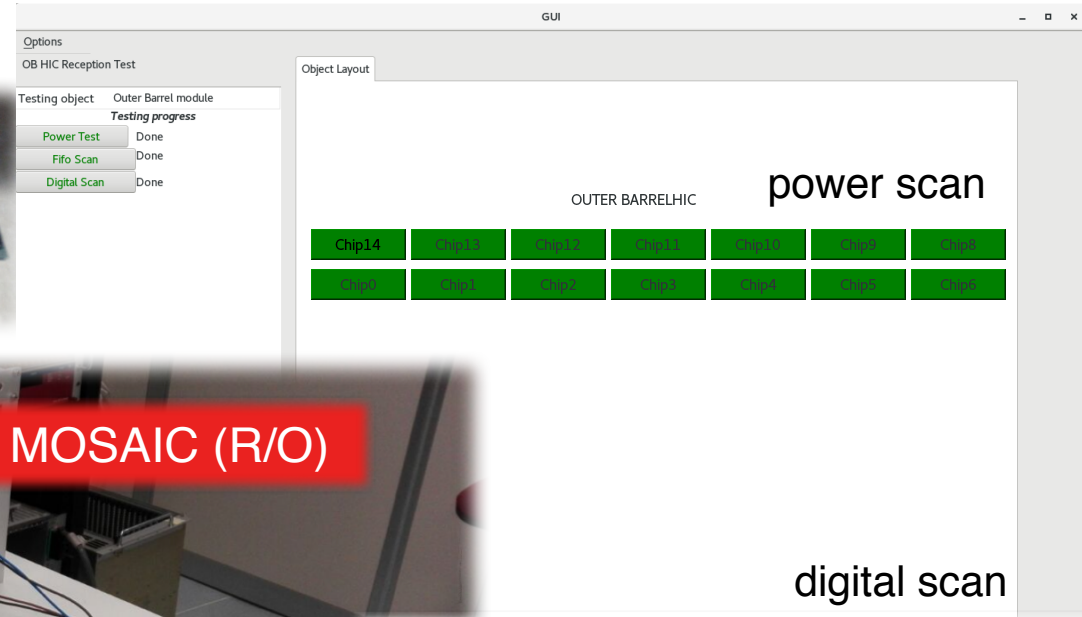
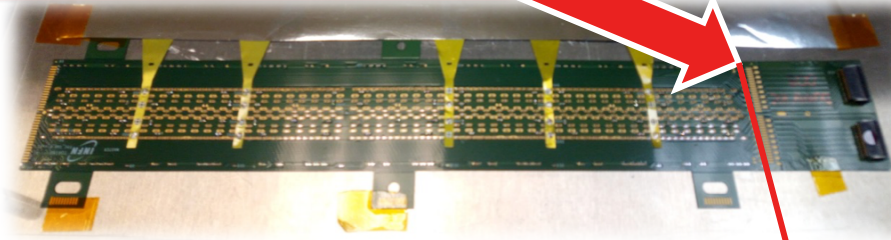
Alessandra Fantoni<sup>1</sup>, Paola Gianotti<sup>1</sup>, Pavel Larionov<sup>1</sup>,  
Paula F.T. Matuoka<sup>3</sup>, Valeria Muccifora<sup>1</sup>, Silvia Pisano<sup>1,2</sup>,  
Federico Ronchetti<sup>1</sup>, Eleuterio Spiriti<sup>1</sup>, Marco Toppi<sup>1</sup>



# Functional HIC Test



Tab = Readout Interface

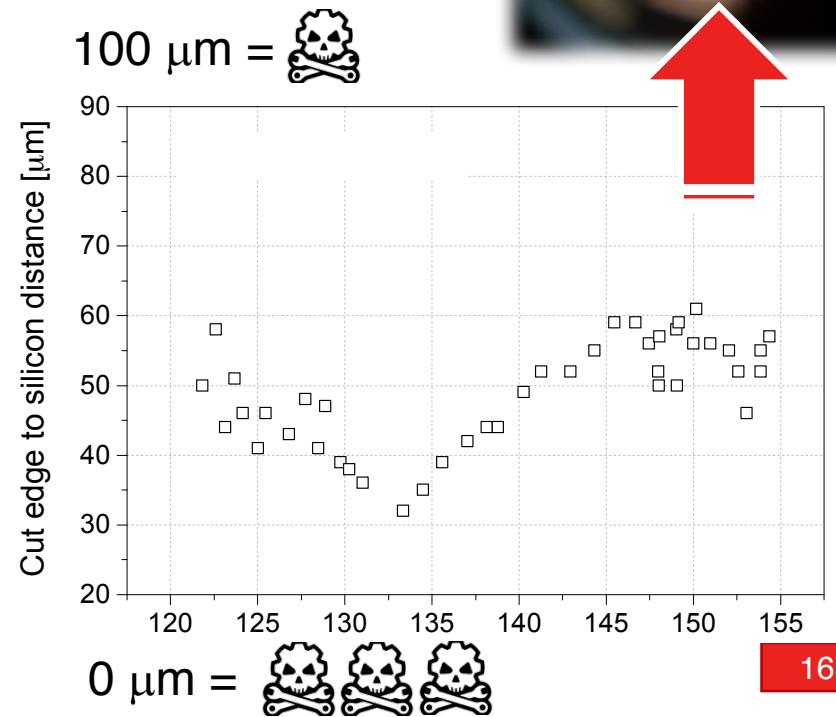
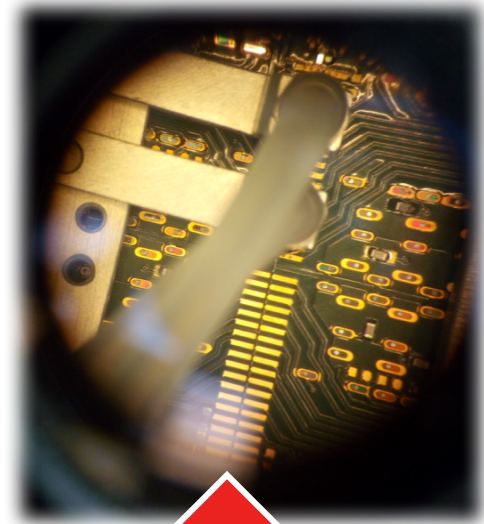
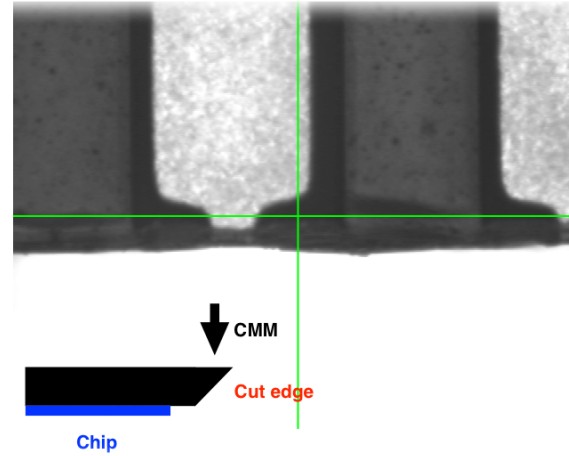
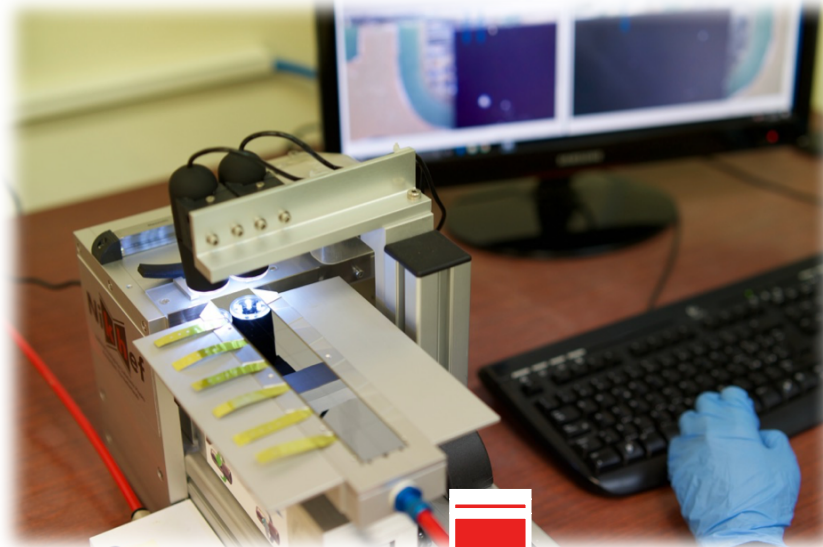
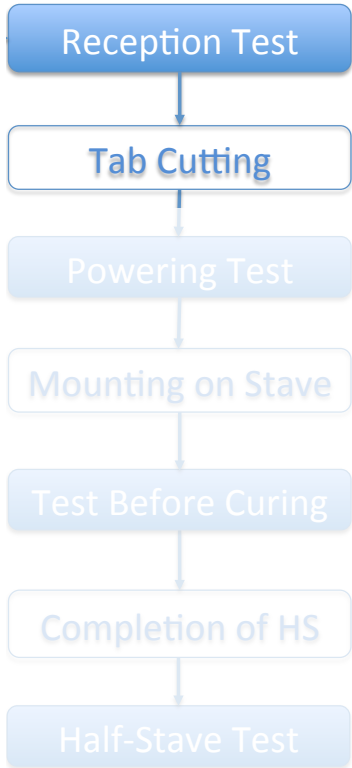


**RED = OK, non working pixels 0.2%**



A Large Ion Collider Experiment

# HIC Processing

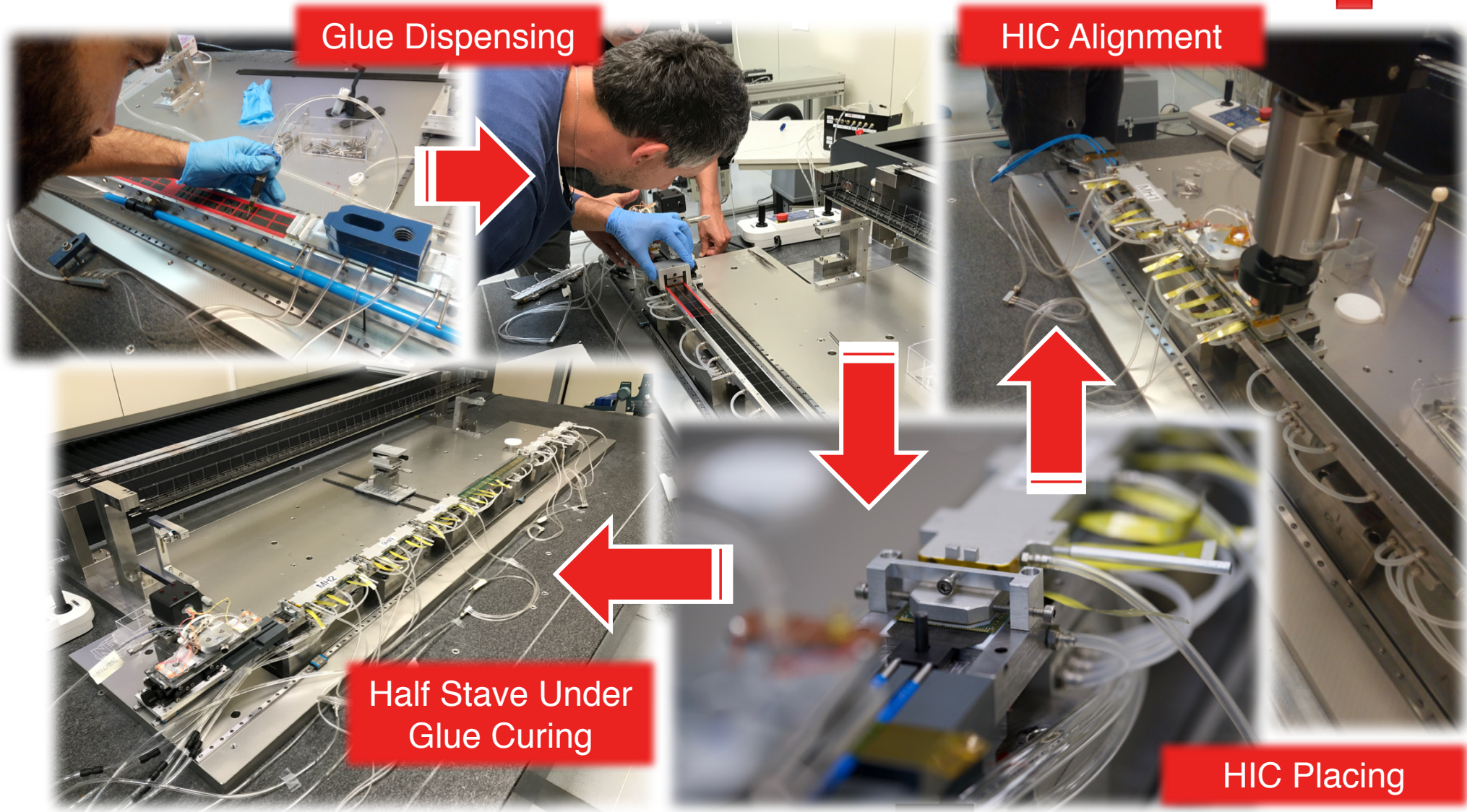
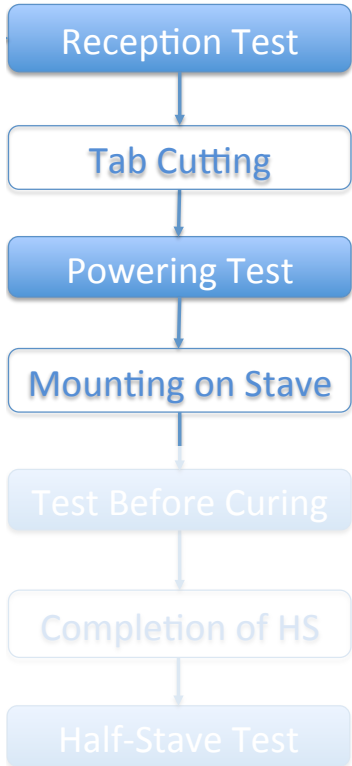






A Large Ion Collider Experiment

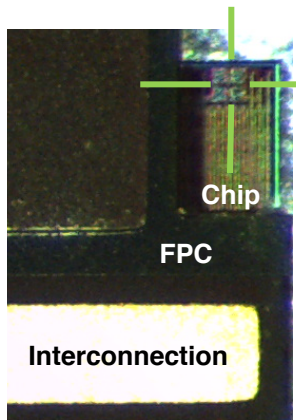
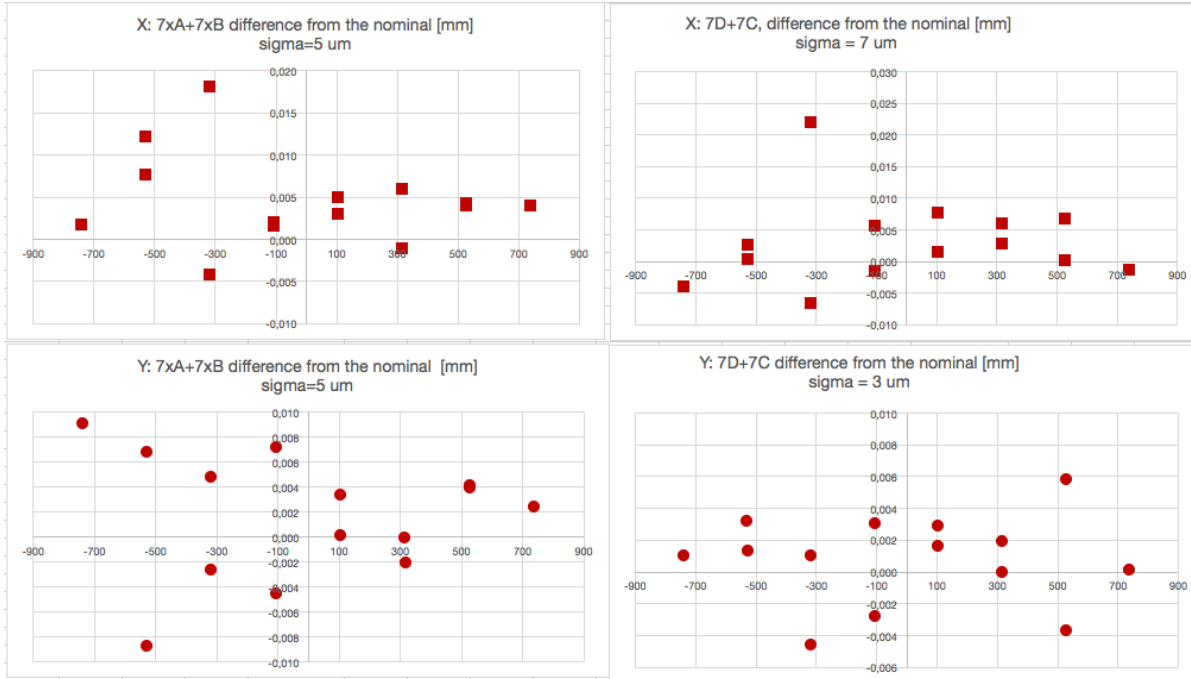
# Making the ITS Half Staves





A Large Ion Collider Experiment

# Alignment Quality at LNF



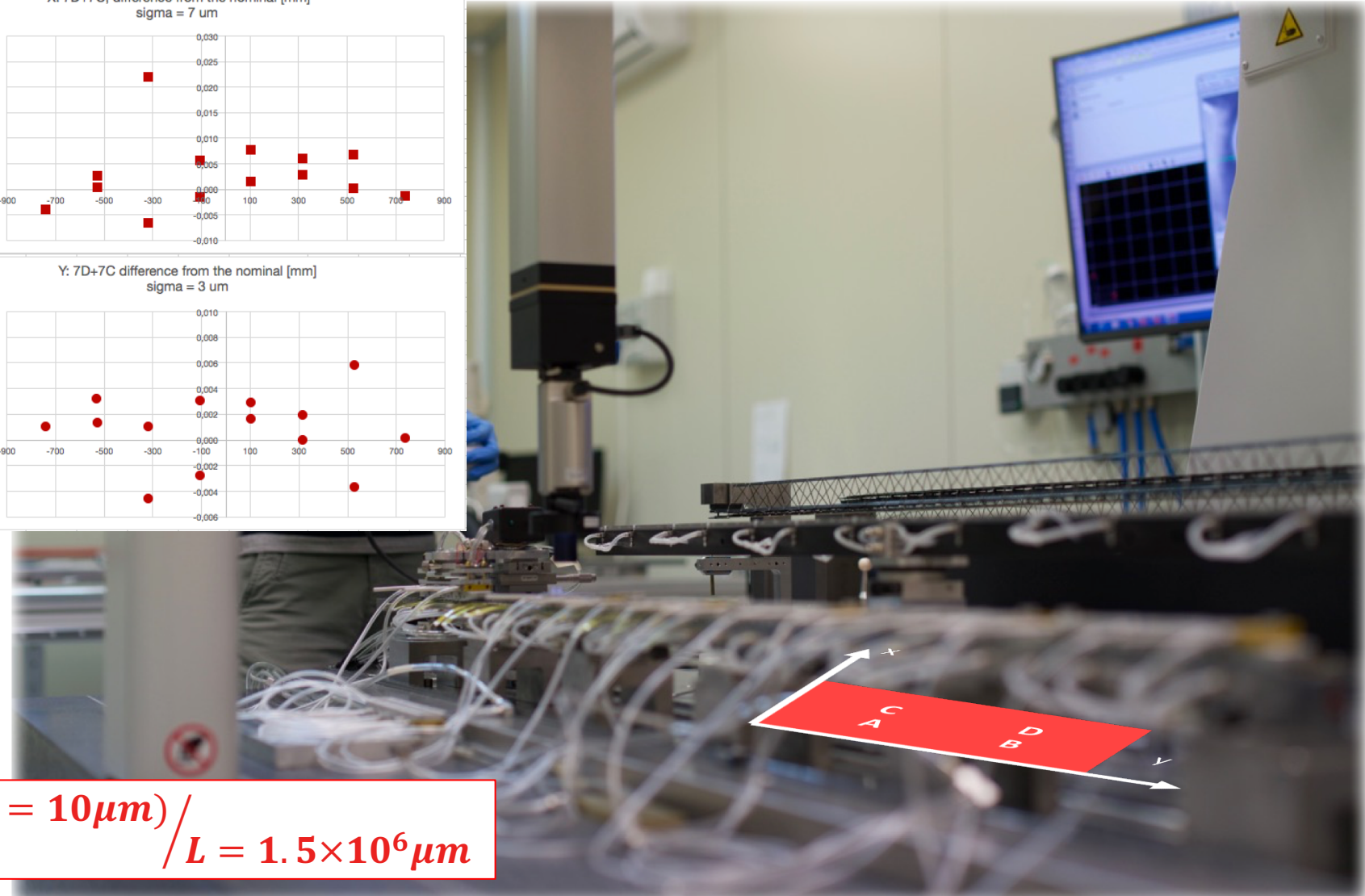
Marker  
Gap < 5 $\mu$ m

Chip

FPC

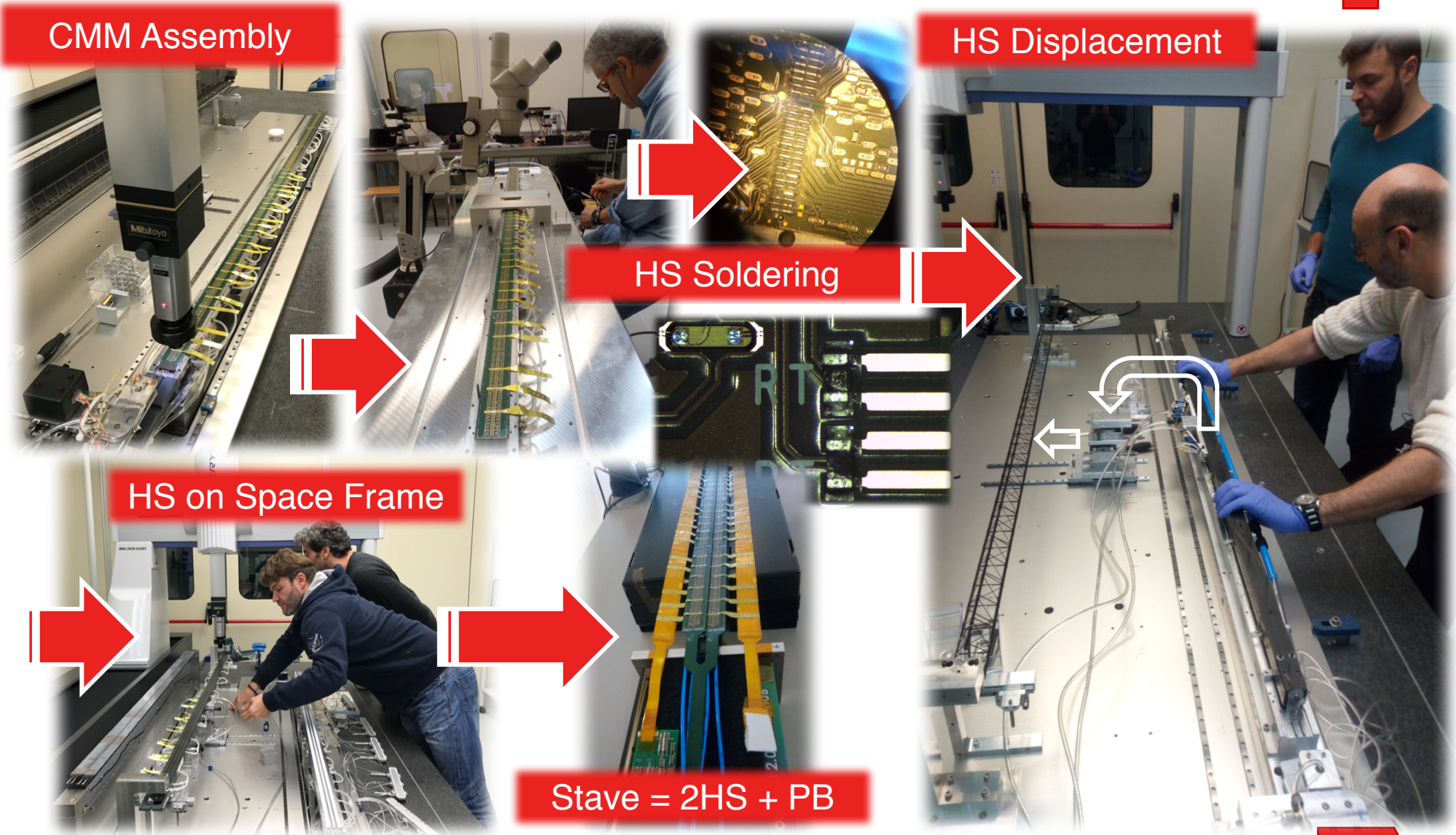
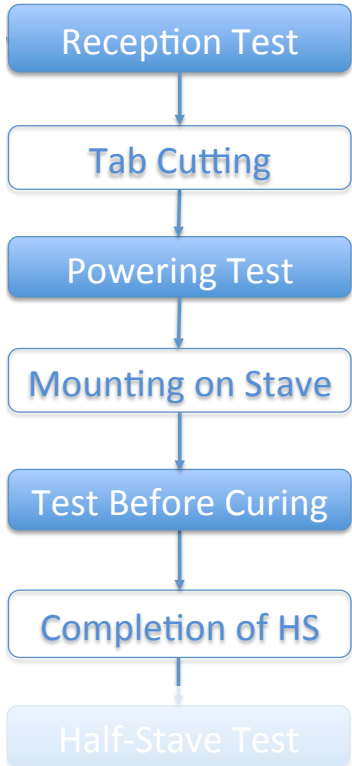
Interconnection

$$(RMS = 10\mu m) / L = 1.5 \times 10^6 \mu m$$



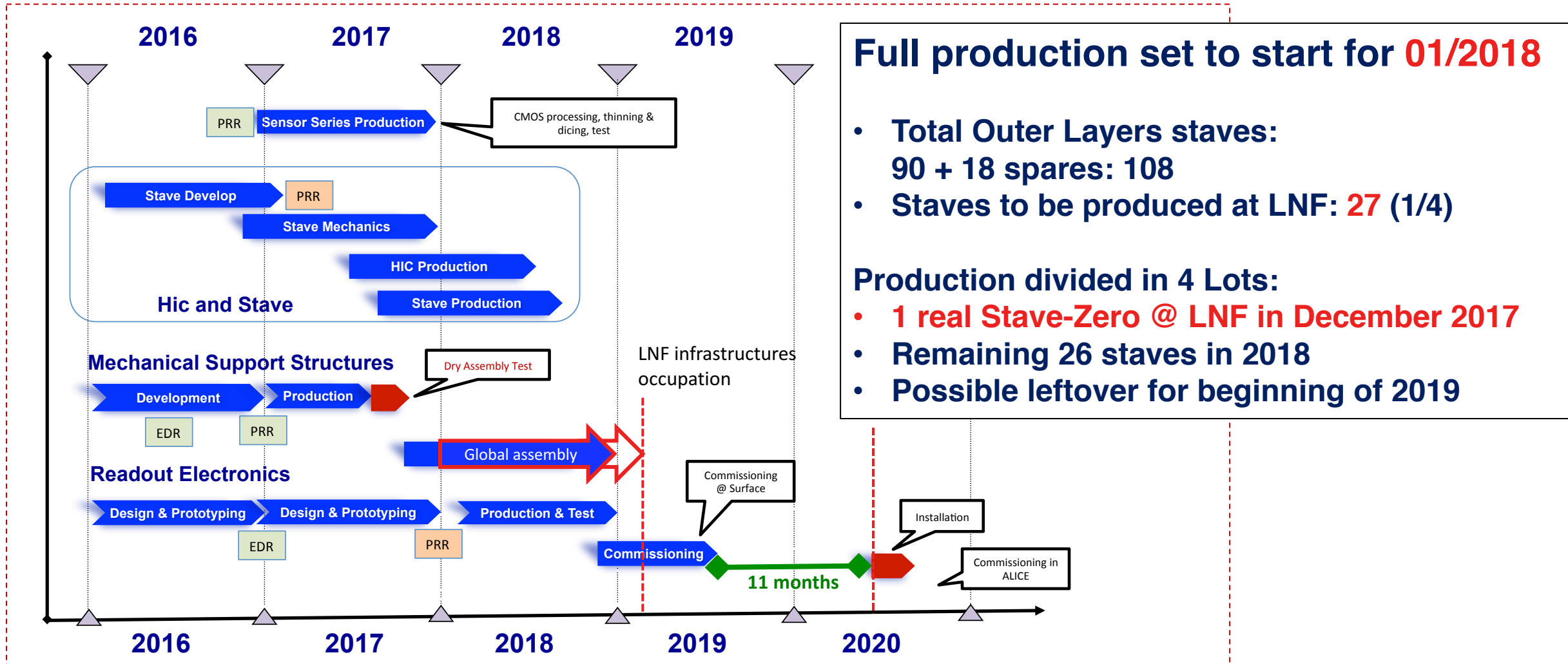


# Making the ITS Stave





# ITS Production Schedule

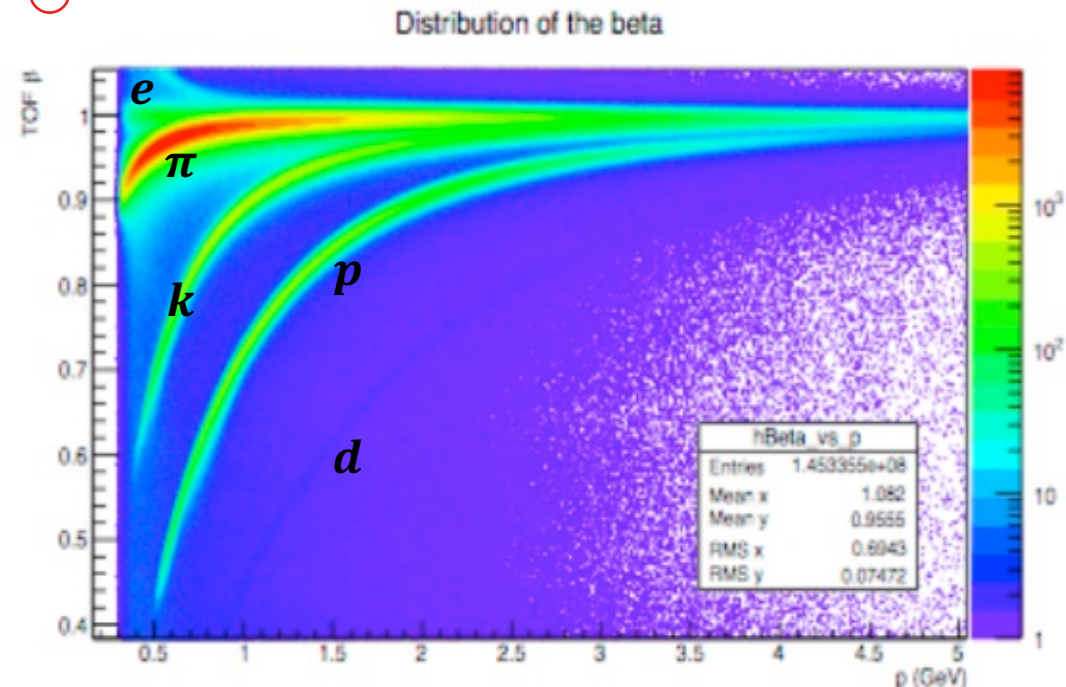




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*Measurement of the  $\pi, K, p$  spectra  
at  $\sqrt{s_{pPb}} = 8.16$  TeV*



Excellent PID from ALICE Time Of Flight signal



## **LNF Responsibility** (S. Pisano; P. F. Matuoka, P. Larionov, M. Toppi) for the ALICE Light Flavor (LF) Physics Working Group

- **Measurement of the  $\pi, K, p$  spectra at  $\sqrt{s_{pPb}} = 8.16$  TeV**
- **Essential reference for any LF analysis**
- **Analysis performed on the new  $pPb$  data collected in 2016.**
  - It will extend to the  $pPb$  case previous analyses on  $pp^*$  and  $PbPb^\diamond$ .

**Spectra are being extracted on a wide  $p_T$  range** ( $\sim 300$  MeV  $\div$   $\sim 10$  GeV)

- With limits varying with hadrons.

### **ALICE subsystems used in the analysis**

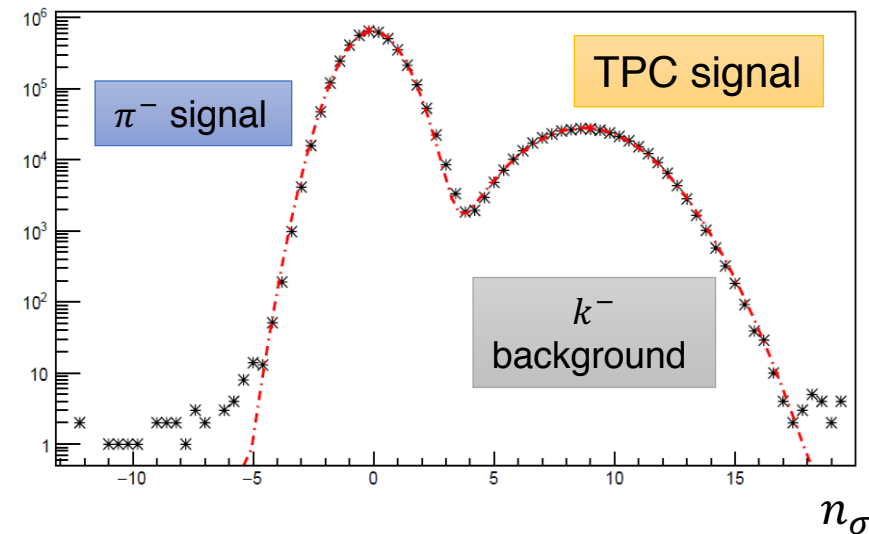
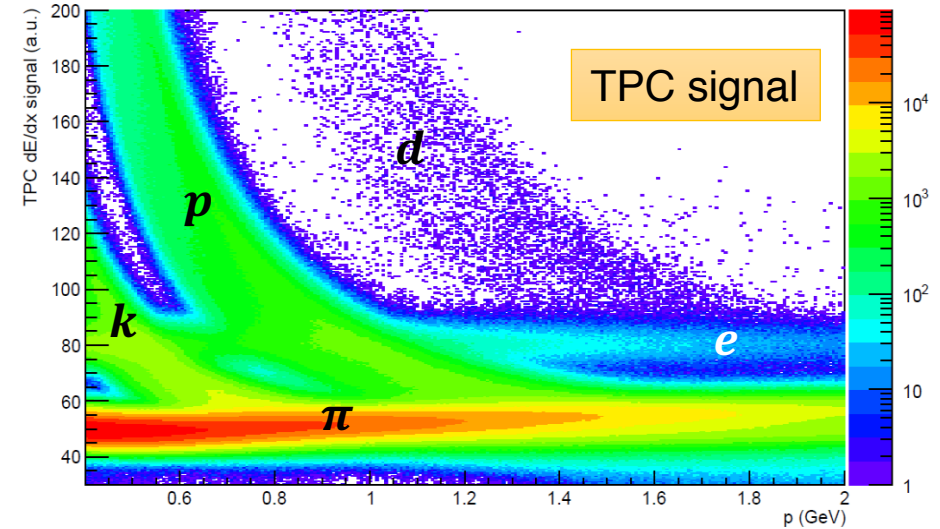
1. Inner Tracking System (ITS): low- $p_T$  tracking and PID through  $dE/dx$
2. Time-Projection Chamber (TPC): tracking and intermediate- $p_T$  PID through  $dE/dx$
3. Time-Of-Flight (TOF): intermediate- $p_T$  PID
4. TPC relativistic rise: high- $p_T$  PID

\* Production of Pions, Kaons and Protons in Pb-Pb Collisions at  $\sqrt{s_{NN}} = 5.02$  TeV, to be published  
◇ Production of Pions, Kaons and Protons in pp Collisions at  $\sqrt{s} = 13$  TeV, to be published



# ALICE Data Analysis @ LNF

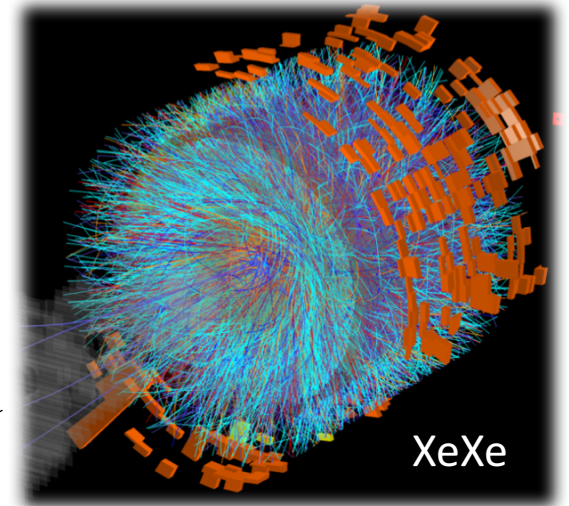
- Yields extracted in bins of  $p_T$  and rapidity
- Extraction strategies optimized in a dedicated way for the different detectors.
  - TOF  $\rightarrow \beta$  vs.  $p_T$
  - TPC  $\rightarrow$  *Bethe-Bloch* parametrization for a given particle hypothesis
- **Use ALICE excellent PID performances** and separation powers for the sub-detector involved in the considered ranges
- Results in preparation for Quark Matter 2018





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A Large Ion Collider Experiment



Istituto Nazionale di Fisica Nucleare



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FARNESINA



# + :Our Team

## Researchers / Technologists:

$\Delta^{2016/17} = 9.0 / 10.5$  FTE



**N. BIANCHI**  
100%



**P. F. MATUOKA**  
100%



**E. SPIRITI**  
40%



**E. DANE'**  
40%



**V. MUCCIFORA**  
100%



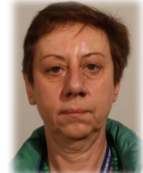
**M. TOPPI**  
100%



**A. FANTONI**  
100%



**S. PISANO**  
100%



**M. MAZZONI**  
U. SAPIENZA



**P. GIANOTTI**  
70%



**A. R. REOLON**  
100%



**F. MEDDI**  
U. SAPIENZA



**P. LARIONOV**  
100%



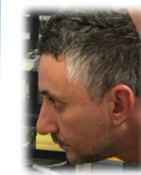
**F. RONCHETTI**  
100%



**S. DI LIBERTO**  
U. SAPIENZA



**A. ORLANDI**  
70%



**M. MATTEO**  
20%



**L. PASSAMONTI**  
50%



**E. PAOLETTI**  
40%



**D. PIERLUIGI**  
50%



**L. PASQUALI**  
10%



**A. RUSSO**  
40%



**A. VITICCHIE'**  
100%



**M. IANNONE**  
U. SAPIENZA

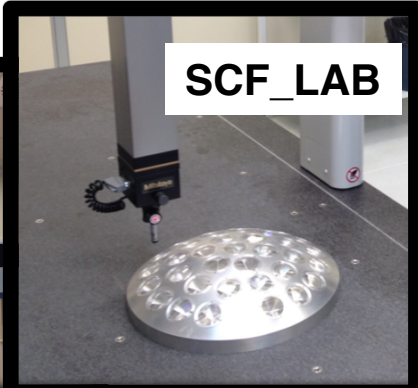




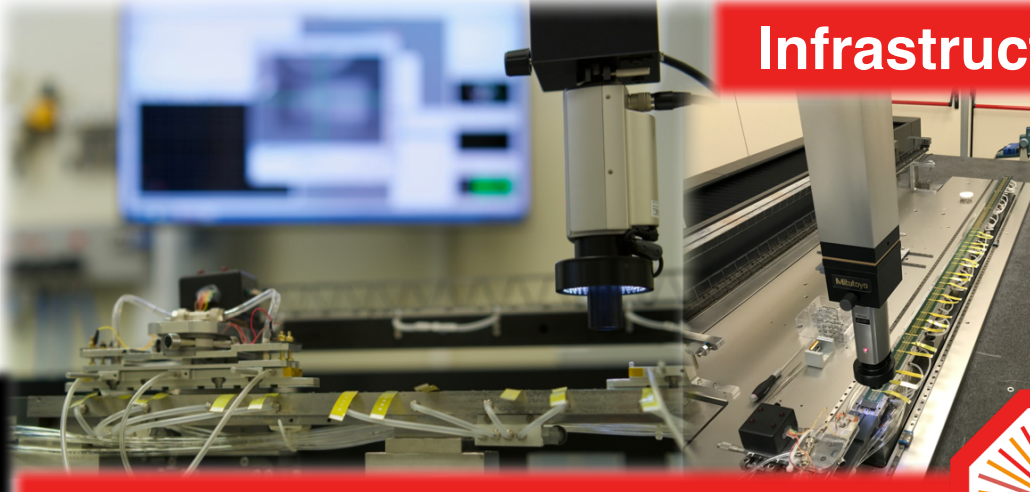
A Large Ion Collider Experiment

Mitutoyo

# Know-How Returns to LNF



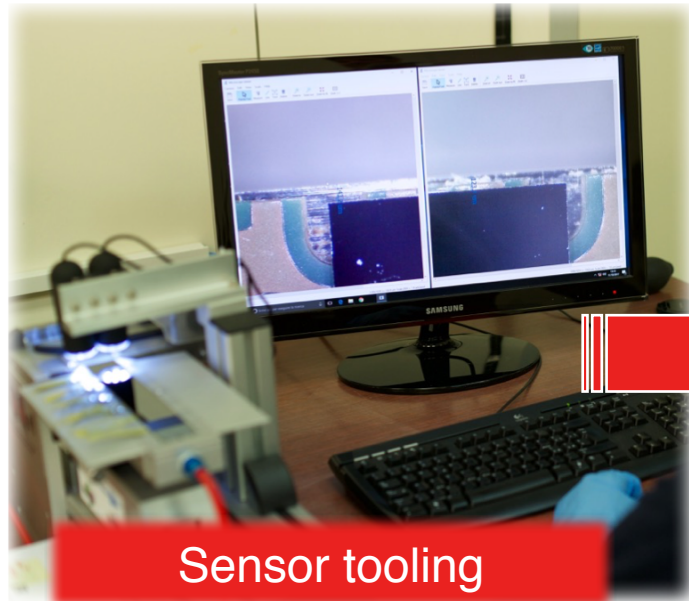
Flexible metrology available to LNF users



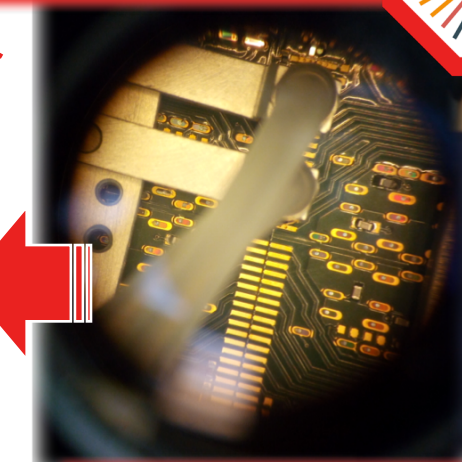
Infrastructure



High precision mechanics and metrology



Sensor tooling



Microelectronics



Silicon chips QA



In the last 10 years the LNF team has made **outstanding contributions** to the ALICE collaboration and to the ALICE apparatus

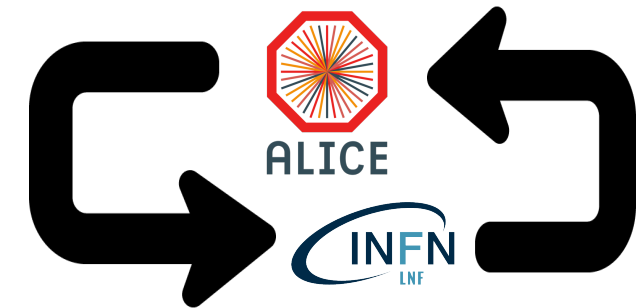
## Responsibilities

- EMCAL/DCAL **Technical Coordinator** for the assembly, construction, and installation @INFN (LNF+CT) (F. Ronchetti, 2007 → 2011)
- **Euro-Asian Coordinator** for the EMCAL/DCAL assembly, construction, and installation (A. Fantoni, 2007 → 2012)
- **EMCAL/DCAL Deputy Project Leader** (N. Bianchi, A. Fantoni, 2007 → present)
- **Coordinator for the EMCAL High Level Trigger** software development @CERN (F. Ronchetti, 2010 → 2011)
- **EMCAL System Run Coordinator** @CERN (F. Ronchetti, 2011 → 2013)
- **ALICE Technical Coordination for the LS1 consolidation** @CERN (F. Ronchetti, 2013 → 2014)
- **Period Run Coordinators** @CERN (F. Ronchetti, P. Di Nezza, A. Fantoni, 2014, 2015)
- **ALICE Run Coordinator** @CERN (F. Ronchetti, 2015/16)
- **ALICE Collaboration Board member** @CERN (N. Bianchi, V. Muccifora, 2007 → present)

## Activities

- **ITS Upgrade (Outer and middle layers workshop at LNF, May 2017)**
- **Physics Analysis** for Light Flavor PWG (S. Pisano, 2016 → present)
- **ALICE Physics Week at LNF in February 2018**, 200+ participants (LNF Team)
- Organizing Committee for Quark Matter 2018 in Venice (A. Fantoni, F. Ronchetti)

**Very significant  
return to LNF  
in terms of know-how**

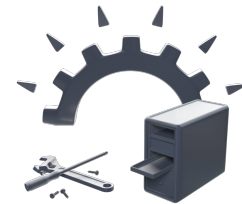


...to be  
continued...

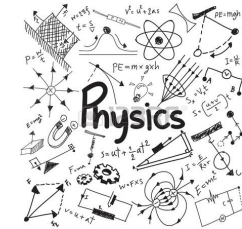
カヅク



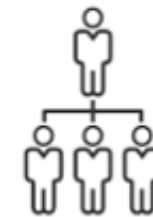
Thanks



**LNf Technical Division**



**LNf Research Division**



**LNf Directorate**



MUSEO  
STORICO DELLA FISICA  
E  
CENTRO  
STUDI E RICERCHE  
ENRICO FERMI





**Backup**

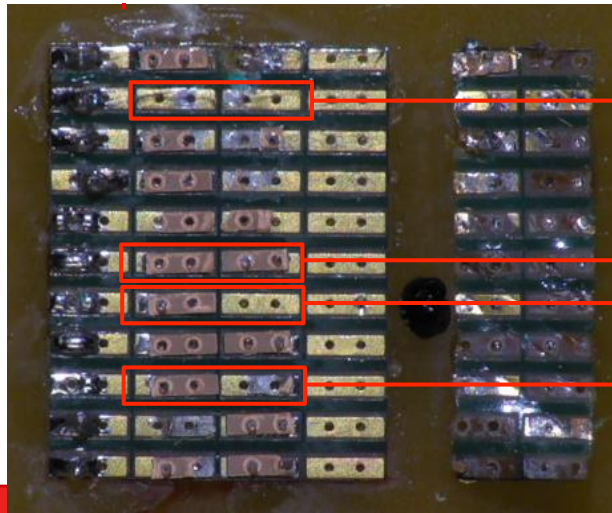
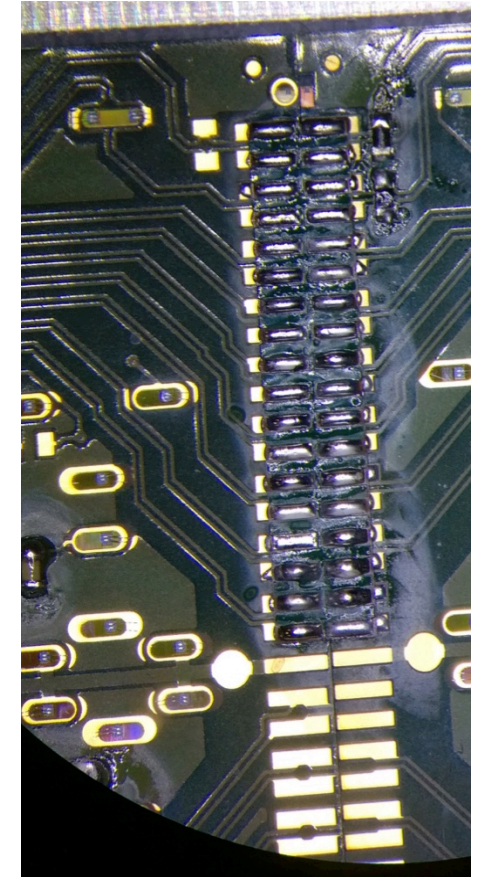
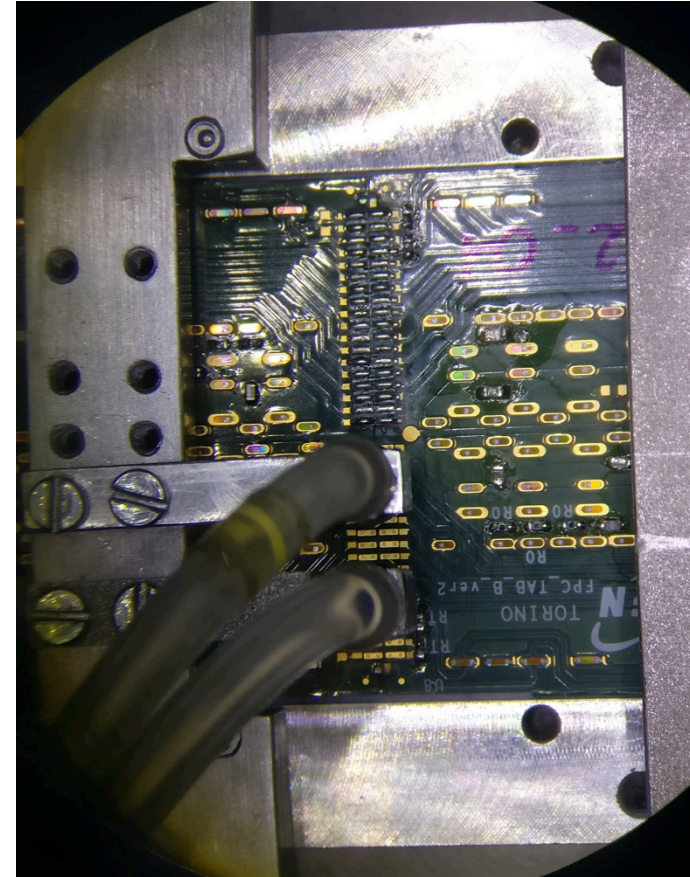
# Results: HIC-HIC Interconnections

A Large Ion Collider Experiment  
A Large Ion Collider Experiment



- HIC to HIC interconnections carry on CLK, CTRL and DATA lines are made by means of Flex Bridges n soldered to the corresponding pads on the FPCs
- Pads width: 400 $\mu$ m
- Pitch: 800  $\mu$ m  
36x2 solder points are present at each HIC-to-HIC interconnections

The Half Stave soldering station is used for: HIC-to-HIC interconnection and HS electric test



→ ET=good, MT=bad (2 fails)

→ ET=good, MT=good

→ ET=bad, MT=bad (1 fail)

→ ET=good, MT=bad (1 fail)

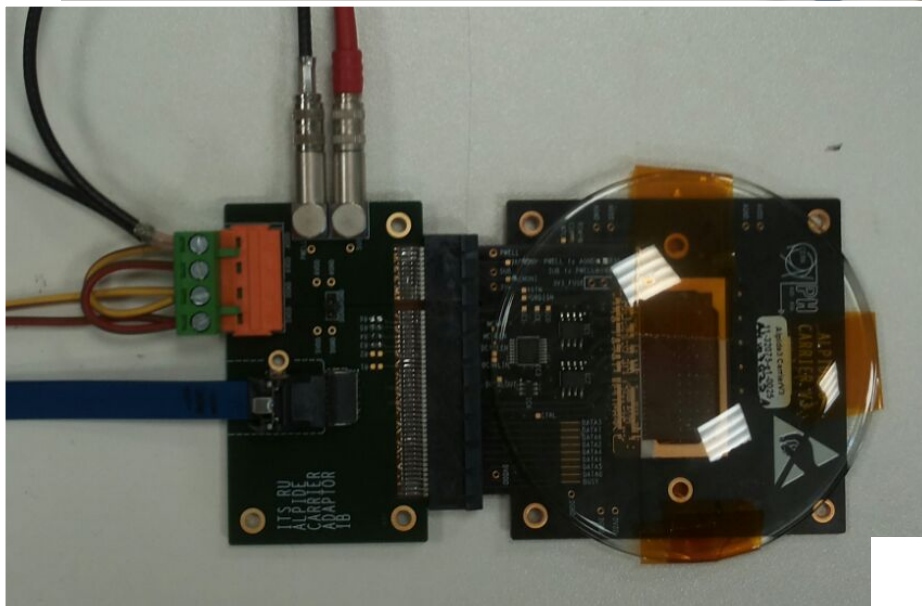
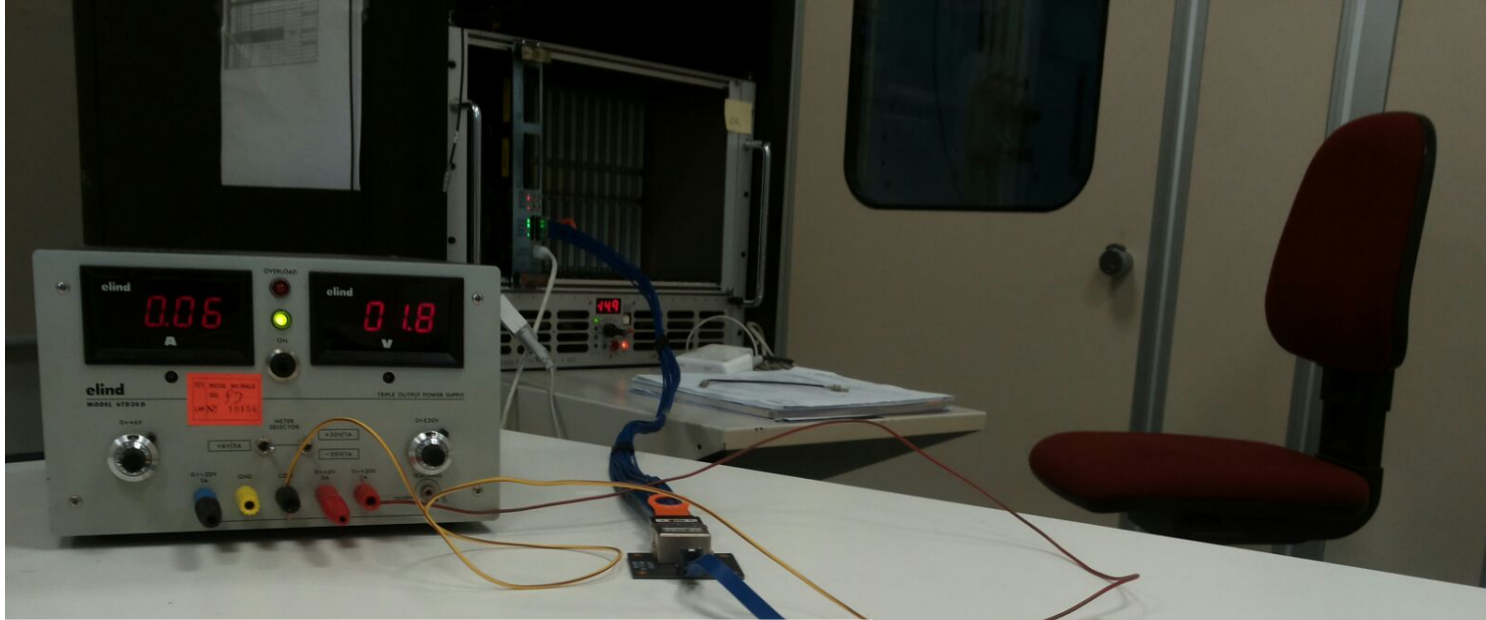
**100% Yield was obtained with:**

- Tip: UFTC-7CN02 ( $\phi=0.2$  mm) (Tip 02)
- Solder wire: EDSYN (Sn62Pb36Ag2  $\phi=0.35$  mm T= 183 $^{\circ}$ C)



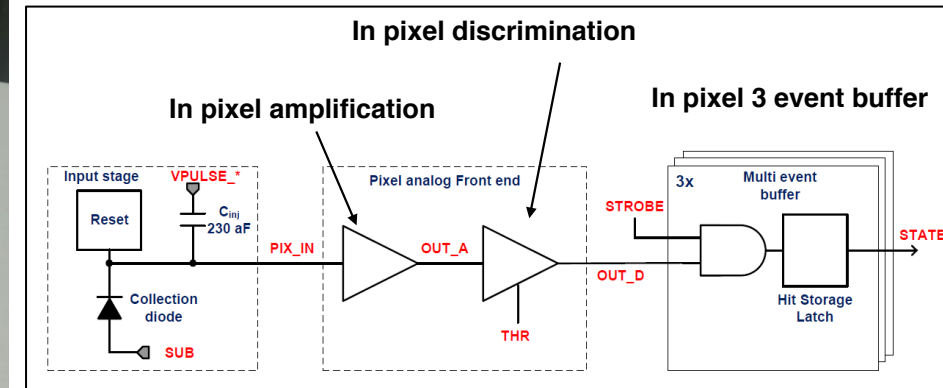
# Hands-on the ALPIDE Chip: First Setup in Grey Area

A Large Ion Collider Experiment  
A Large Ion Collider Experiment



## Single ALPIDE Pixel Chip carrier board at LNF

- Monolithic Active Pixel Sensor
- 180 nm CMOS imaging on high resistivity epitaxial layer substrate
- 1024x512 pixel per chip
- In pixel amplification, shaping, discrimination and multi event buffering



- Total # of pixels for the ITS: 12,500 M
- Tests in Frascati: signal injection, radioactive sources and beam test (BTF)



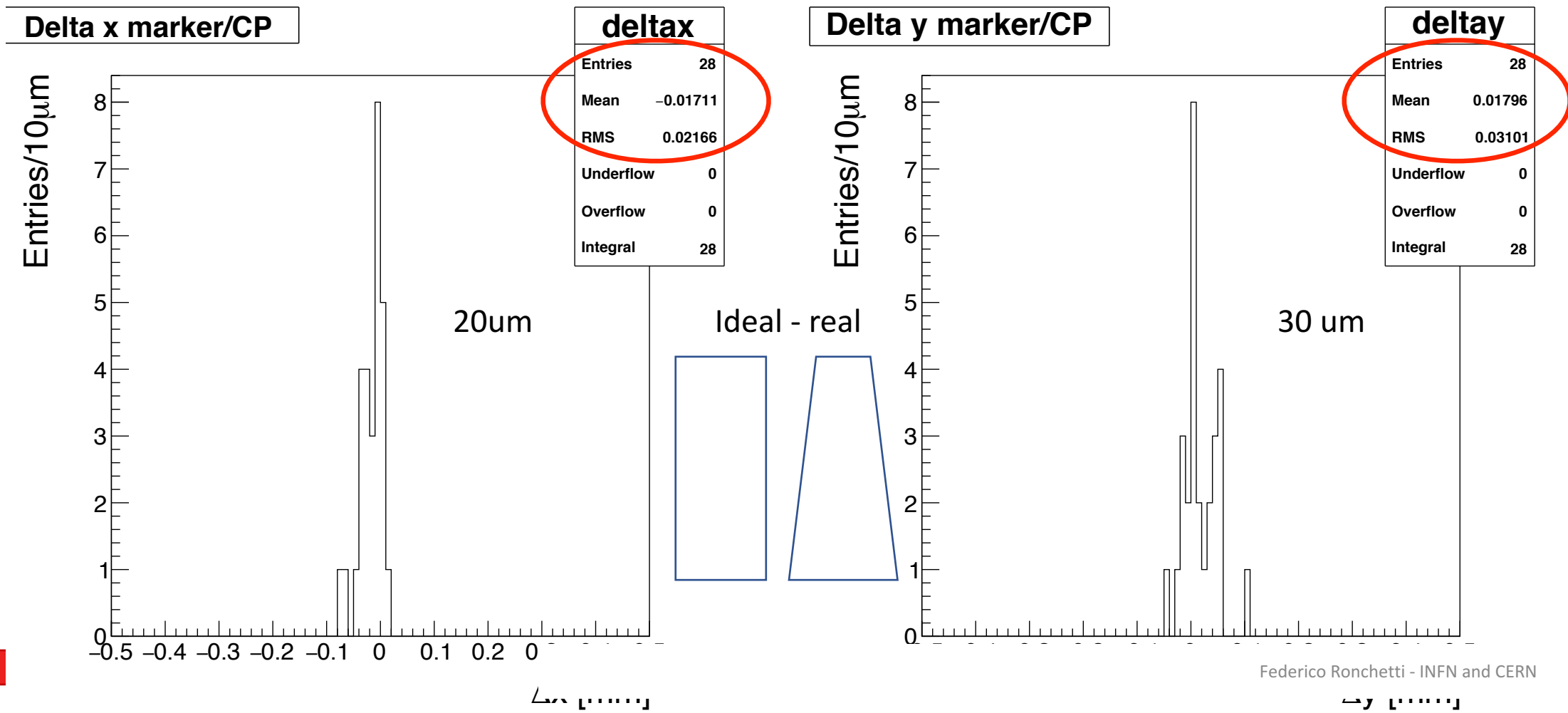
# Results: Half Stave Alignment using Dummy HICs



A Large Ion Collider Experiment  
A Large Ion Collider Experiment

## Caveat:

- **Dummy HICs are not as perfect** as real HICS in terms of marker positions
- **We used pre-production tools** (AI HS base, not final Handling Bar)

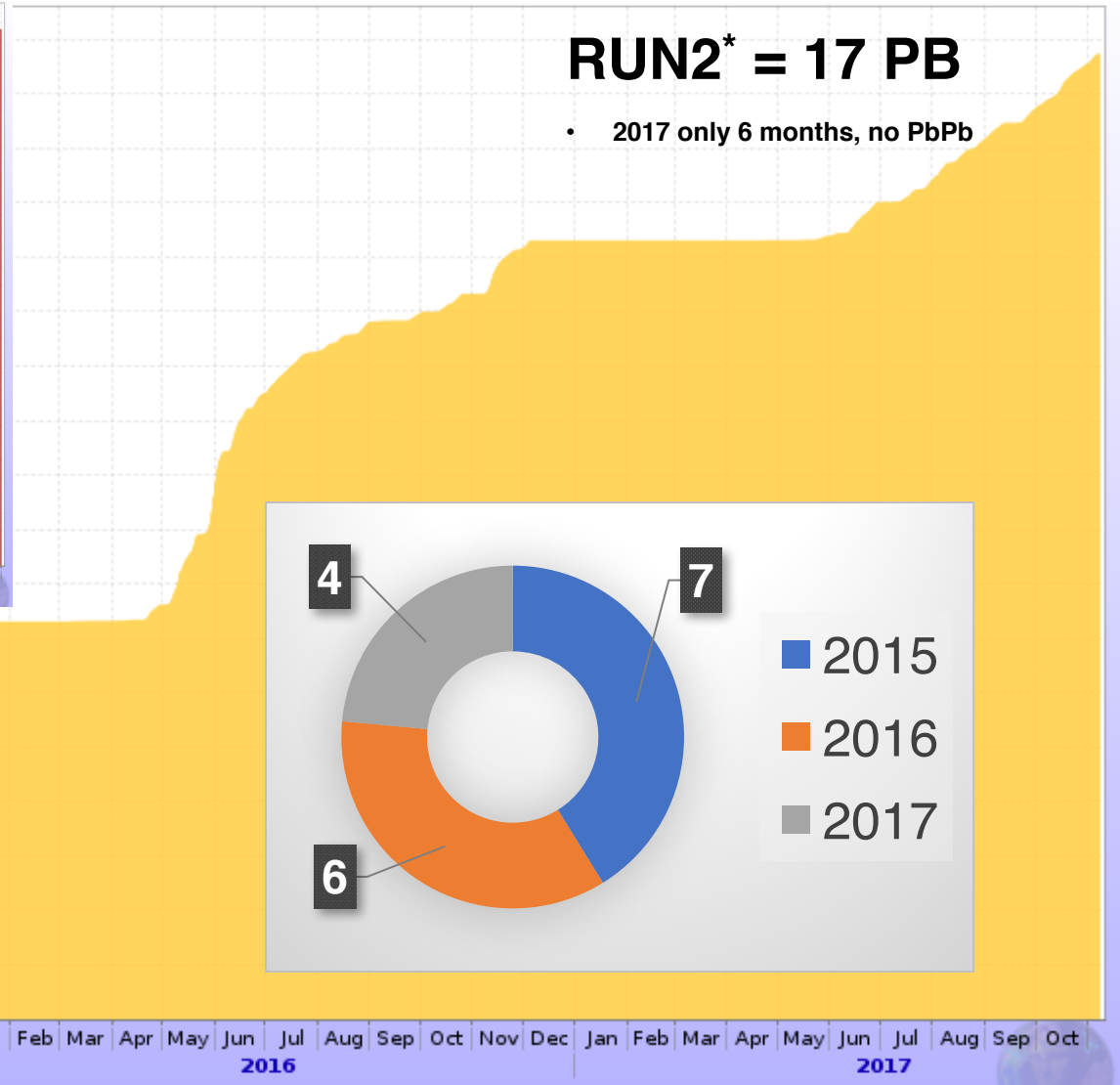
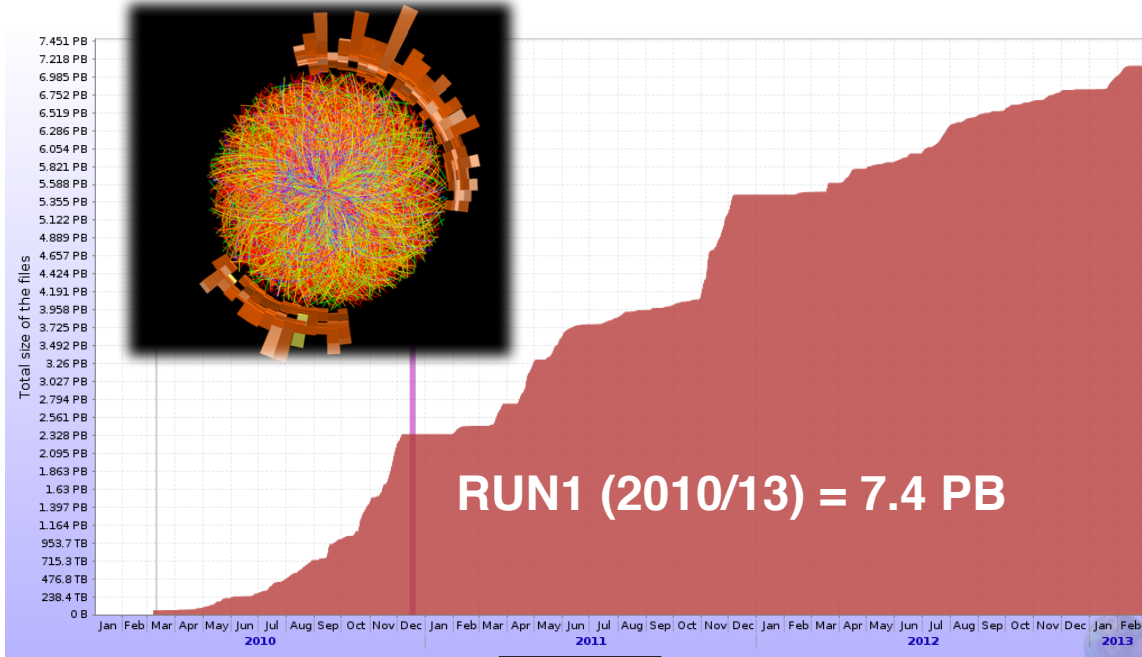






A Large Ion Collider Experiment

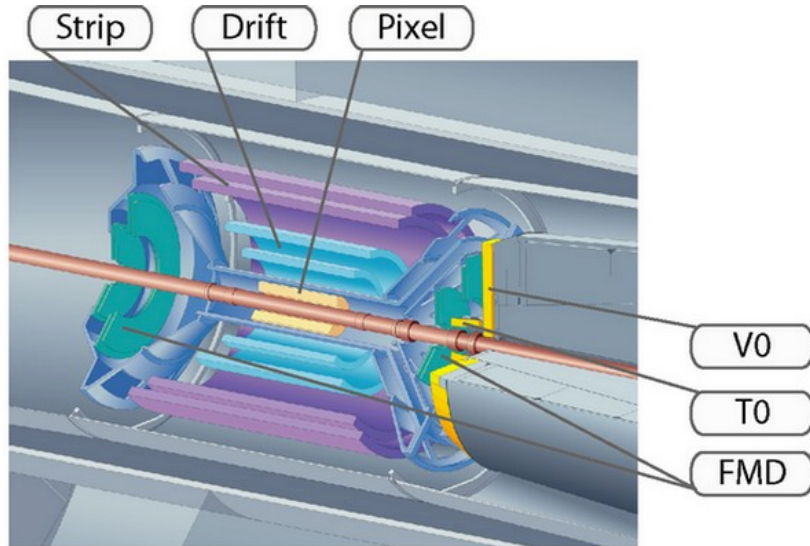
# Low Lumi, Big Data





# ITS Upgrade: Baseline

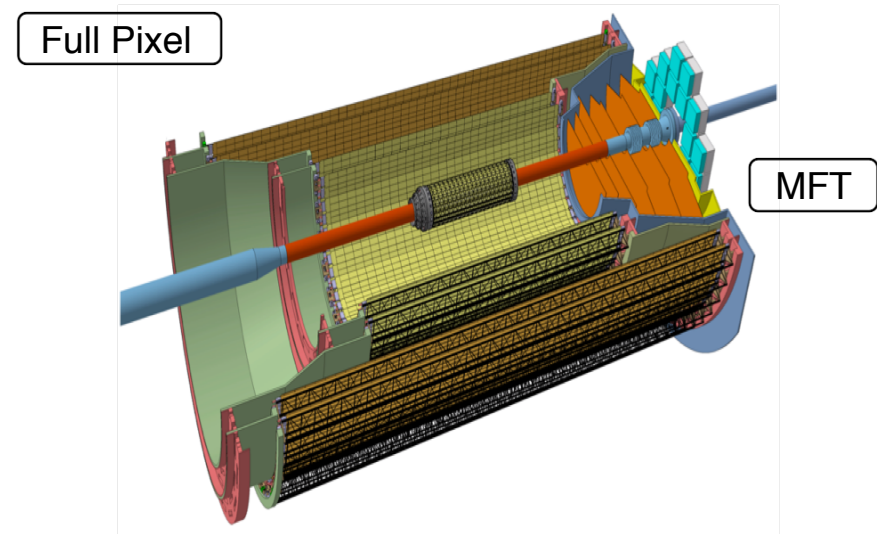
## Before LS2



### Performance (Pb-Pb)

- Hybrid
- $\sim 1$  kHz (due to SDD limitation)
- Layer thickness:  $\sim 1.14\% X_0$
- Pixel size:  $425(xy)\mu\text{m} \times 50\mu\text{m}(z)$
- Silicon volume coverage: 39 – 430 mm
- 6 layers (only 2 of pixel)

## After LS2



### Performance (Pb-Pb)

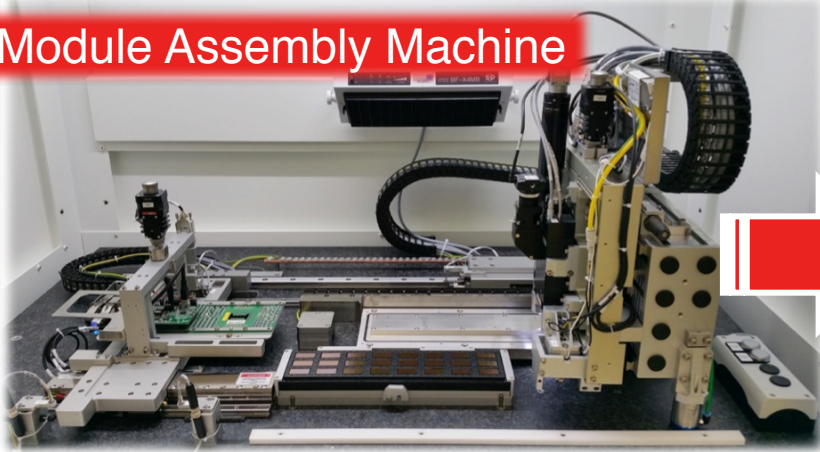
- **MAPS**: 180 nm CMOS Imaging Process
- ITS:  $\sim 100$  kHz
- Layer thickness:  $0.3\% X_0$  (IB),  $1\% X_0$  (OB)
- Pixel size:  $30\mu\text{m}(xy) \times 15\mu\text{m}(z)$
- Volume coverage :  $22 - 400$  mm
- 7 layers (3 inner + 4 outer), all pixels
- Fast insertion and removal during EYTS



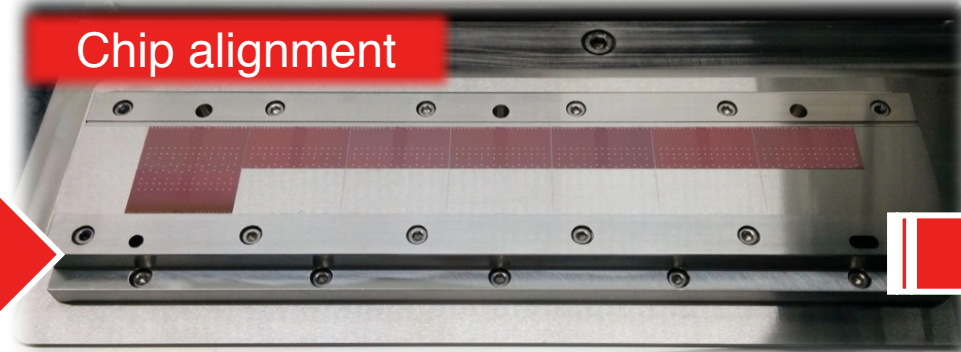
A Large Ion Collider Experiment

# OB HIC Assembly

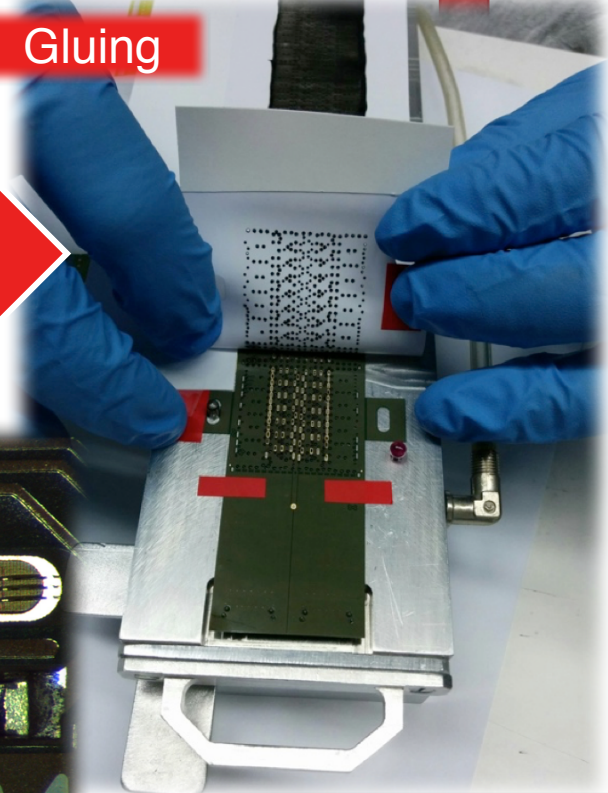
Module Assembly Machine



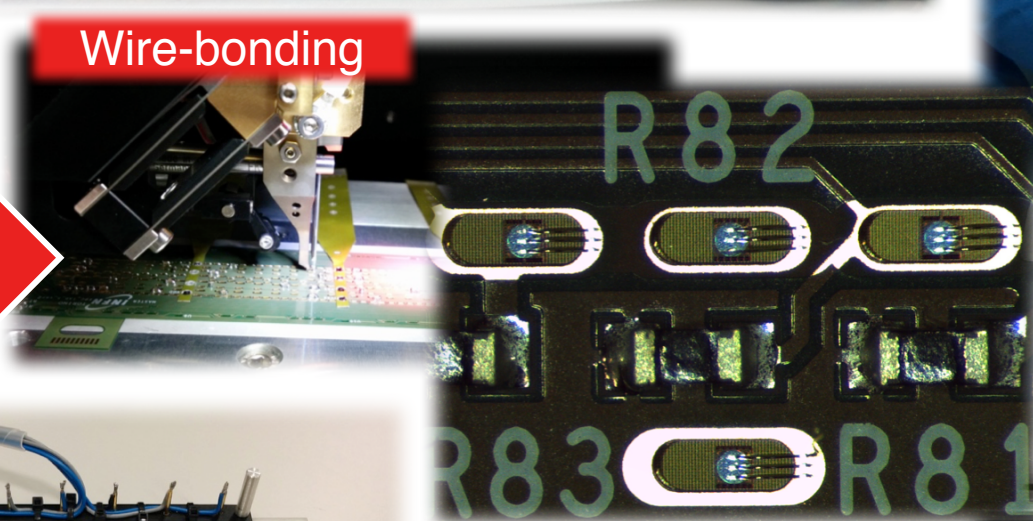
Chip alignment



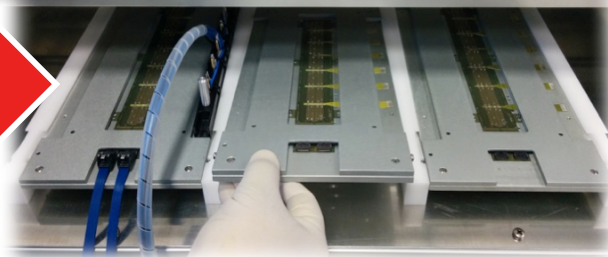
Gluing



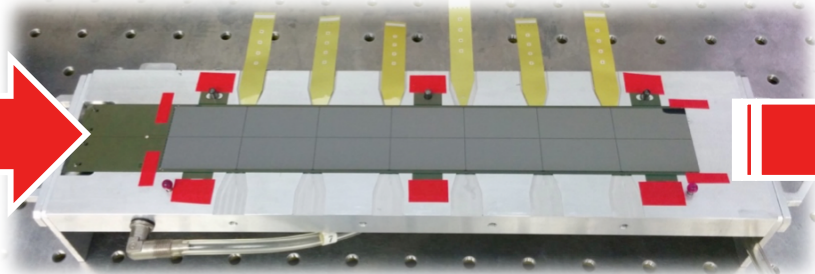
Wire-bonding



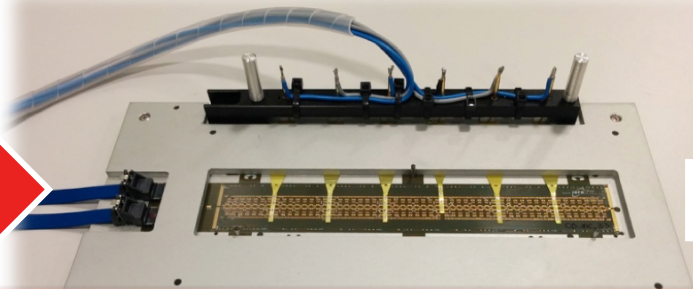
Endurance test



FPC-to-chips gluing



Transfer to carrier plate / characterization test

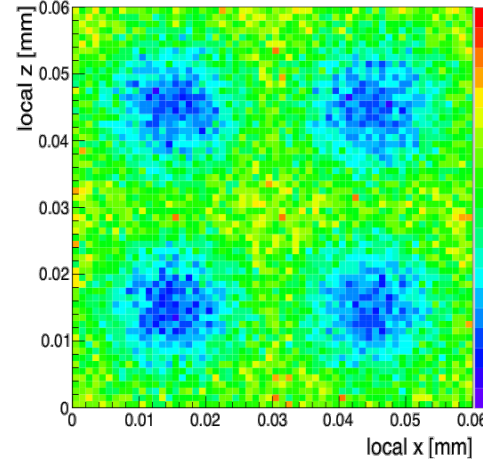




# ALPIDE Response

- Parametrized response model of the ALPIDE pixel chip is included in the ALICE MC Simulation
- Cluster size and shape are modeled on test beam data

SIMULATION



DATA

