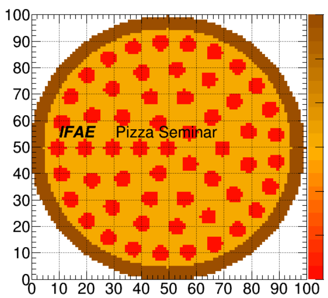
Overview of the ATLAS Forward Physics project

From the 3D pixel tracker perspective

Ivan Lopez

IFAE Pizza Seminar

May 6th, 2015



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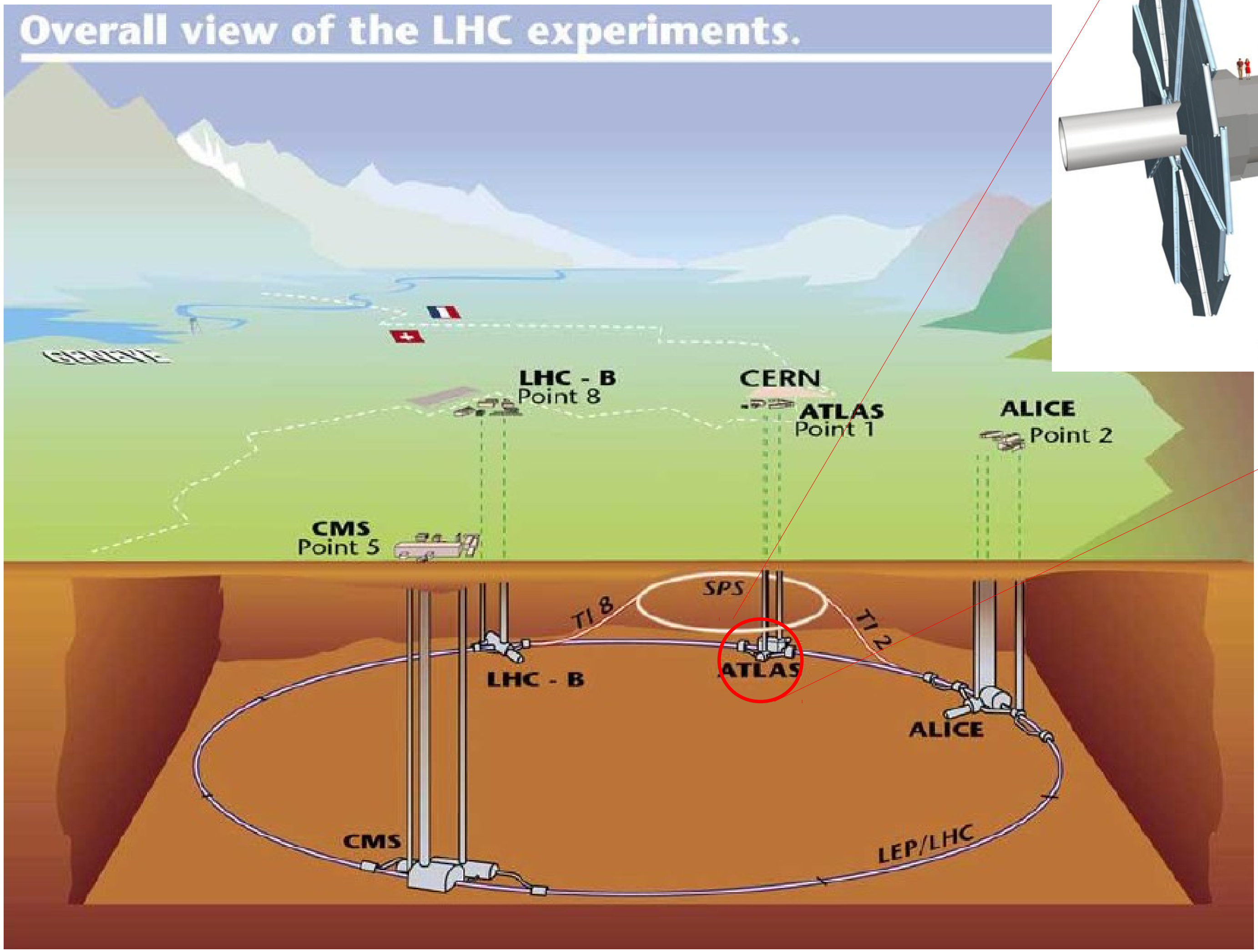
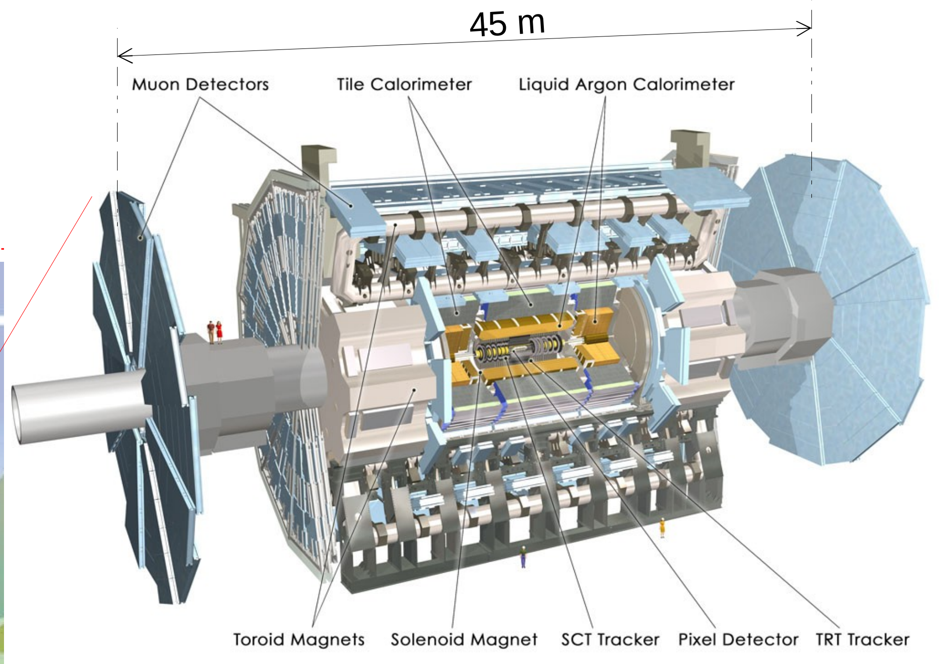
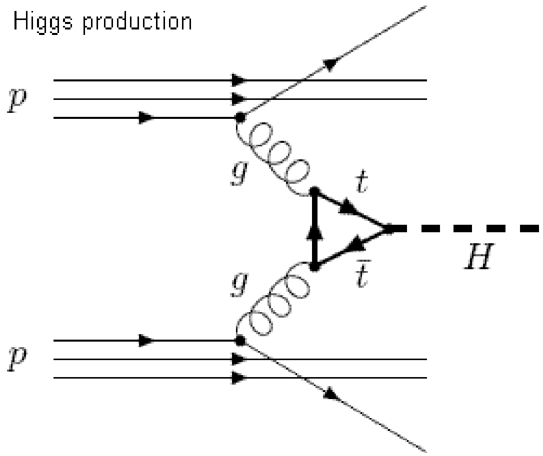
Universitat Autònoma de Barcelona

LHC and ATLAS







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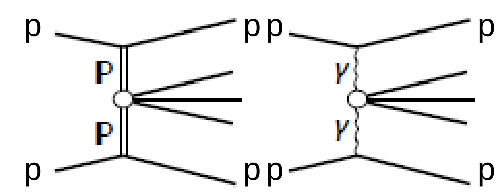
ATLAS Forward Physics (AFP)

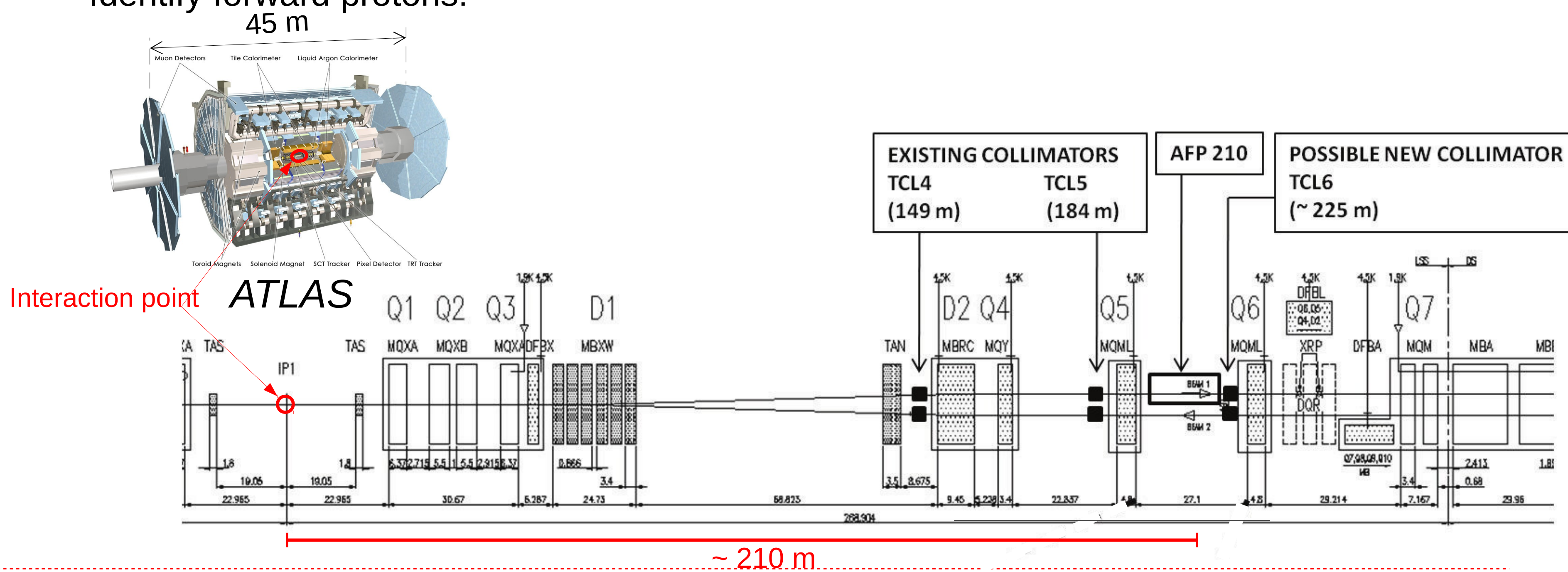
- Physics:
  - Look for processes with protons in the final state leaves **intact** the interaction point

    →Diffractive physics, eg.:

    - Double pomeron exchange: Pomeron structure
    - Double photon exchange: use LHC as a “photon collider”



  - Identify forward protons!



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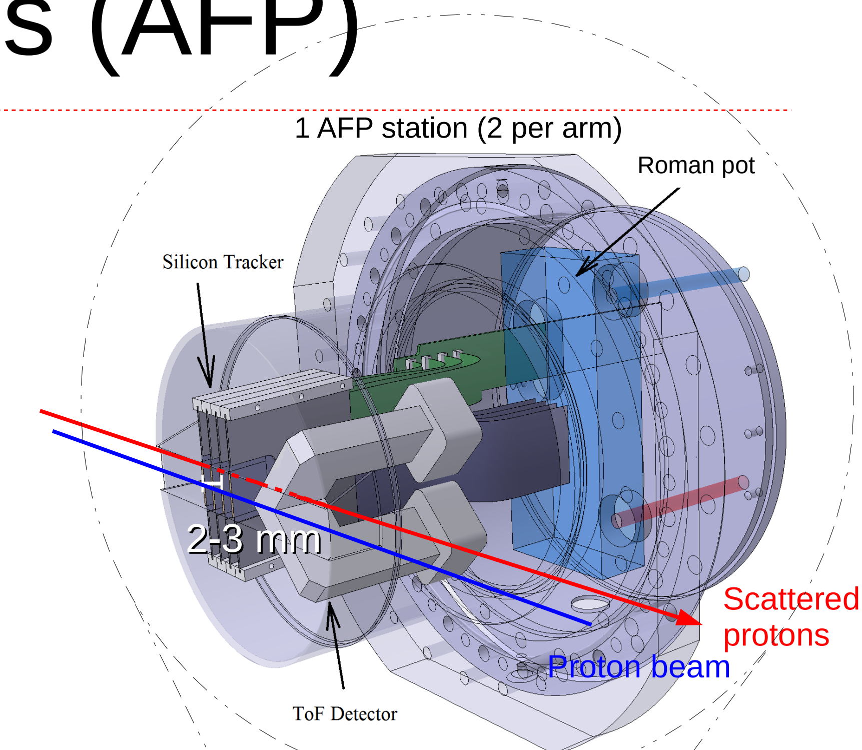
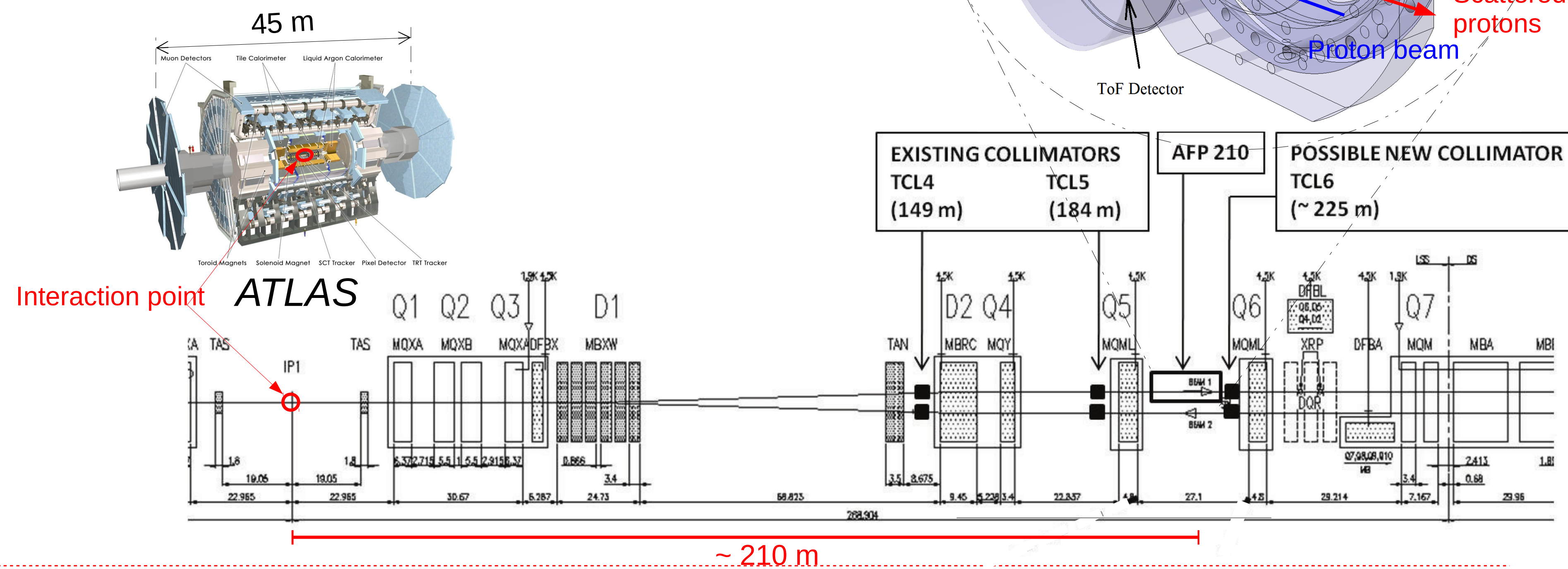
ATLAS Forward Physics (AFP)

- Detector:
  - **Tracker** + fast **Time of Flight** (ToF) detector

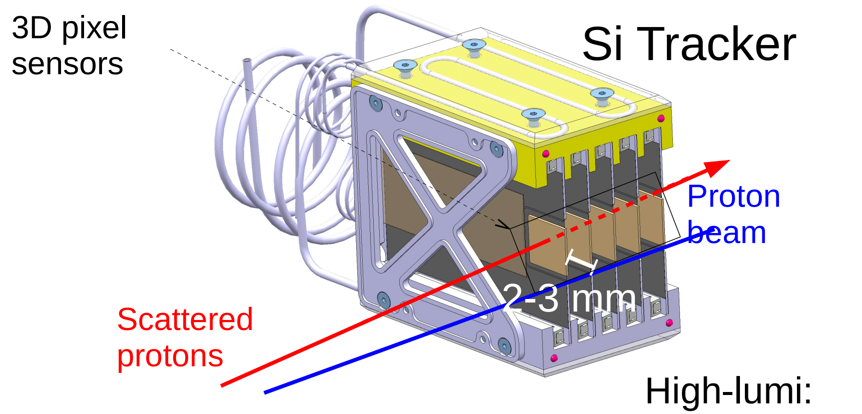
    → ~210 m from the ATLAS interaction point and 2-3 mm from the proton beam



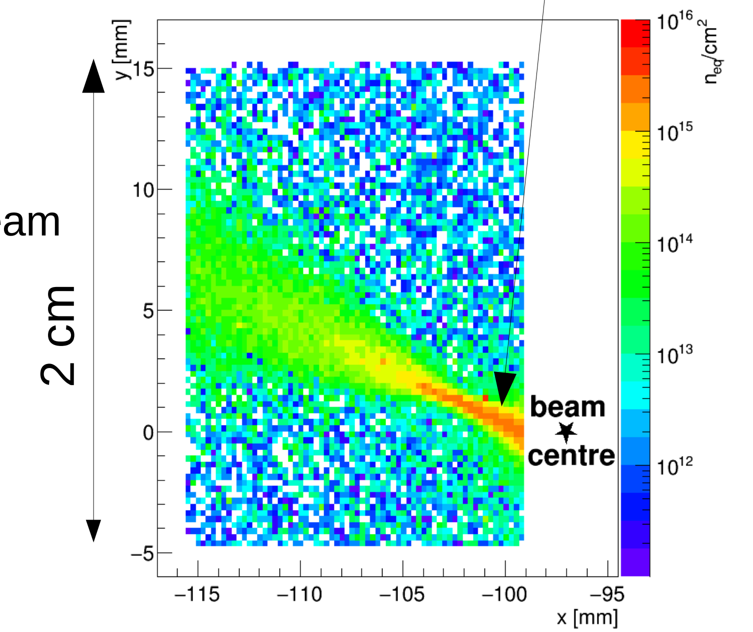


The Silicon Tracker

- Goal:
  - Measure position of scattered protons
    → Measurement of proton's relative energy loss
- Requirements:
  - Have a good position resolution $O(10\ \mu m)$
    → good energy loss resolution
  - Non-uniform beam profile
    → non-unif. radiation damage (fluence)
  - Have small dead area at the edges
    → we want the active area as close as possible to the beam



High-lumi:
~$3x10^{15}\ n_{eq}/cm^2$
(~$5x10^{15}\ p/cm^2$)



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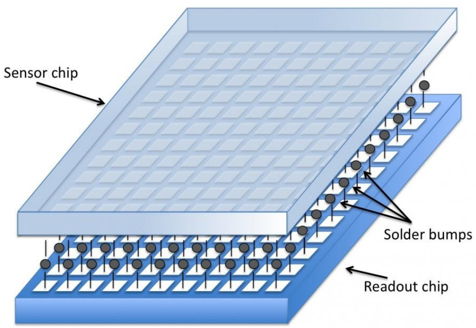
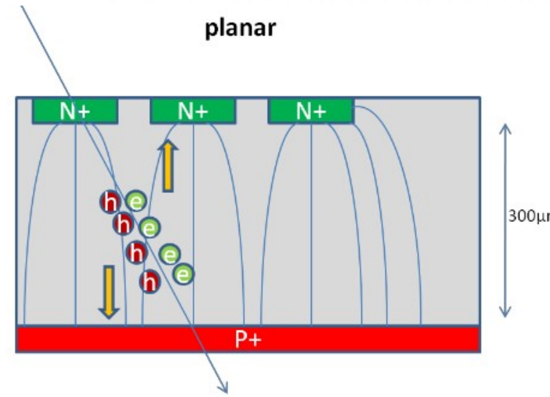
The Silicon Tracker

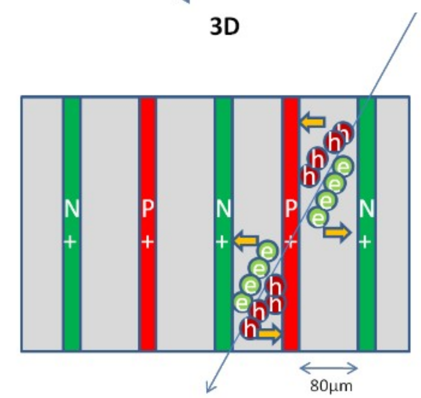
- Radiation hardness
  - → Silicon detectors: widely used in radiation hard environments
- Good position resolution
  - → Highly segmented/Pixelated detectors
- Sensor technology
  - Planar: electrodes on sensor surface
  - 3D: column-like electrodes
    - → Distance between electrodes decoupled from sensor thickness
    - → Lower voltages, shorter charge drift distances

Lower power disipation and more radiation hard

- IFAE has a large experience with 3D sensors:
  - ATLAS Insertable B-Layer (IBL) built with 3D sensors from IFAE-CNM







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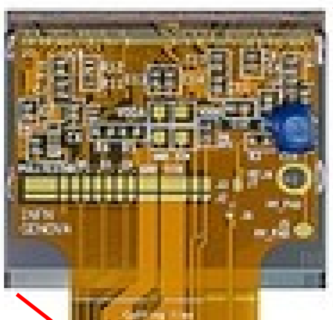
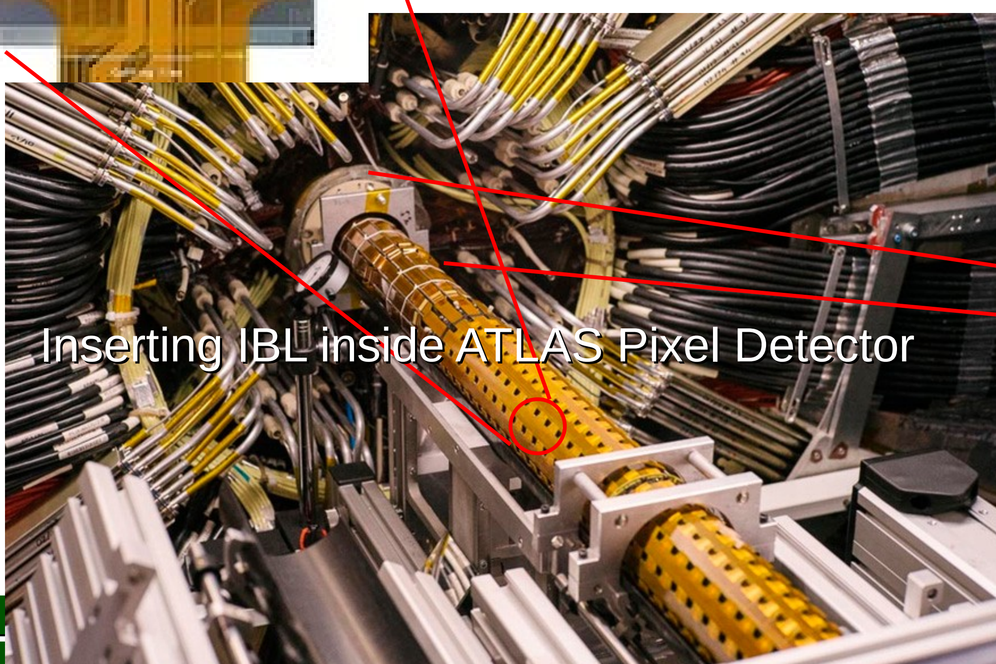
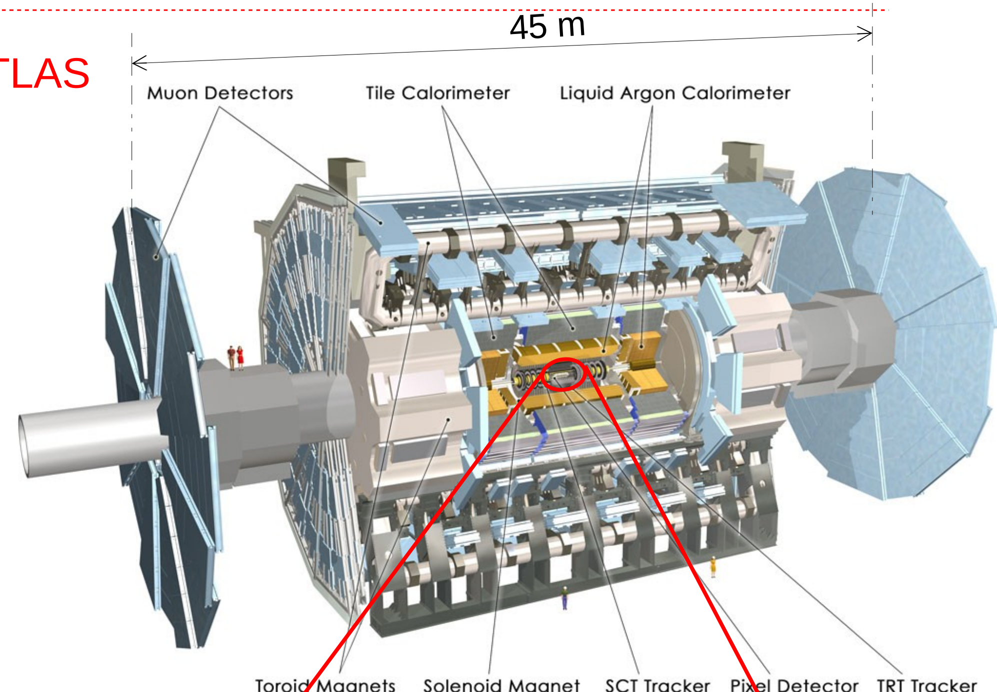
Experience in Insertable B-Layer (IBL)

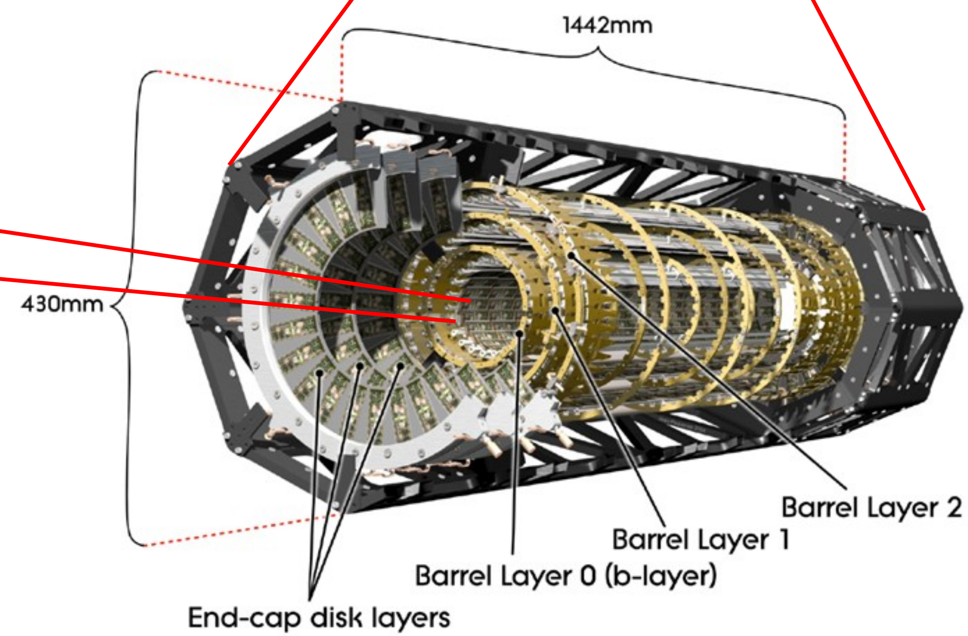
- IBL is a new layer of silicon tracker sensors in ATLAS Inner Detector
  - 3.3 cm from interaction point → Rad. hard
  - Inserted in 2014 → Ready for Run 2

1st use of 3D sensors in a HEP experiment



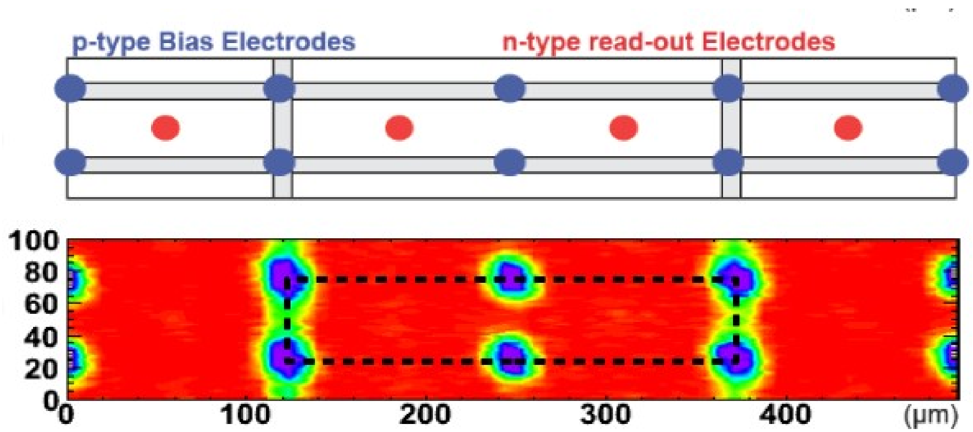


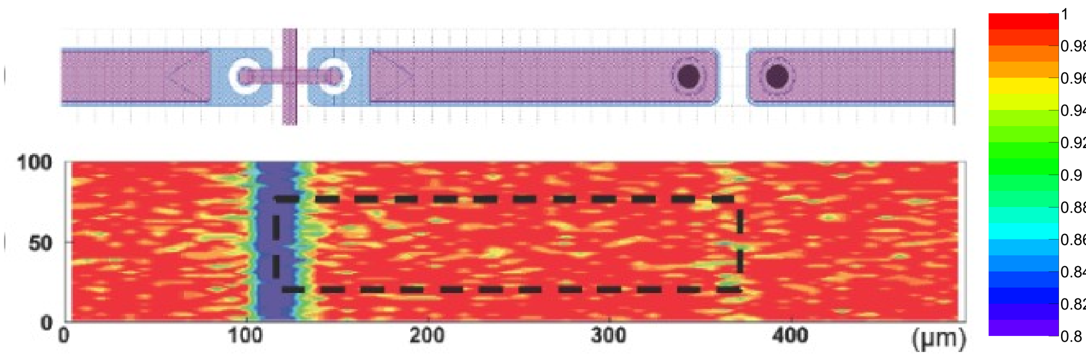




3D sensors in ATLAS IBL

- 3D silicon sensors
  - CNM (Barcelona) and FBK (Trento)
- Planar silicon sensors
  - CiS (Erfurt)





2012 JINST 7 P11010

CNM-3D, 5×10^{15} n_{eq}/cm^2, HV = 160V, **Eff.=97.5%**

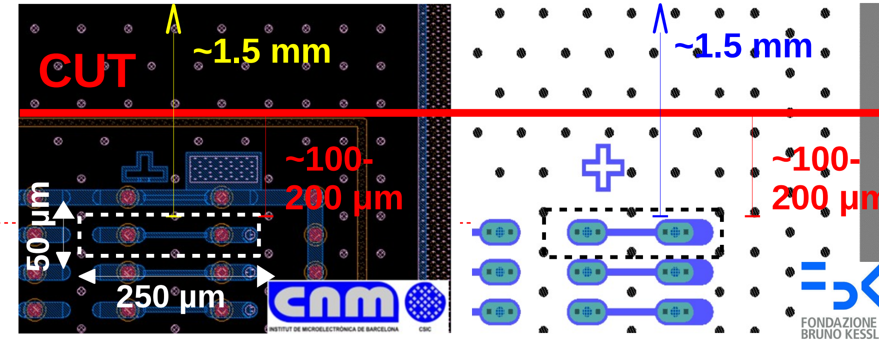
CiS-planar, 5×10^{15} n_{eq}/cm^2, HV = 1000V, **Eff.=96.9%**

3D needs less voltage to get the same efficiency → Radiation hard

IBL is 25% 3D and 75% planar

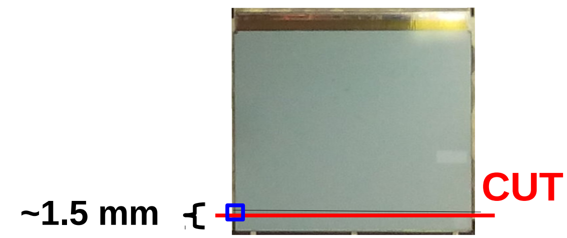
Use 3D also in AFP...

AFP prototypes



- FE-I4 3D pixel devices:
  - From ATLAS IBL design and front-end (FE-I4)
  - Two similar designs with different edge termination:
    - CNM: with 3D guard-ring
    - FBK: without 3D guard-ring
  - ~1.5 mm inactive edge on AFP-relevant side (opposite to wirebonds)

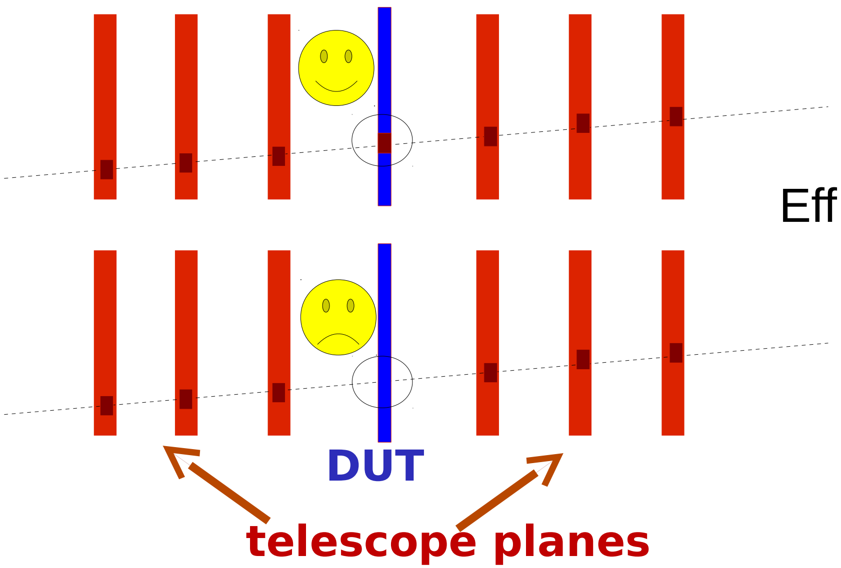
    → Slim-edge down to ~100-200 µm from the last pixel row

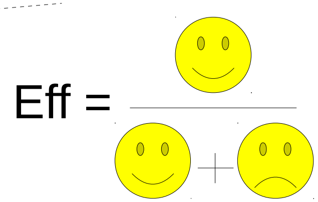


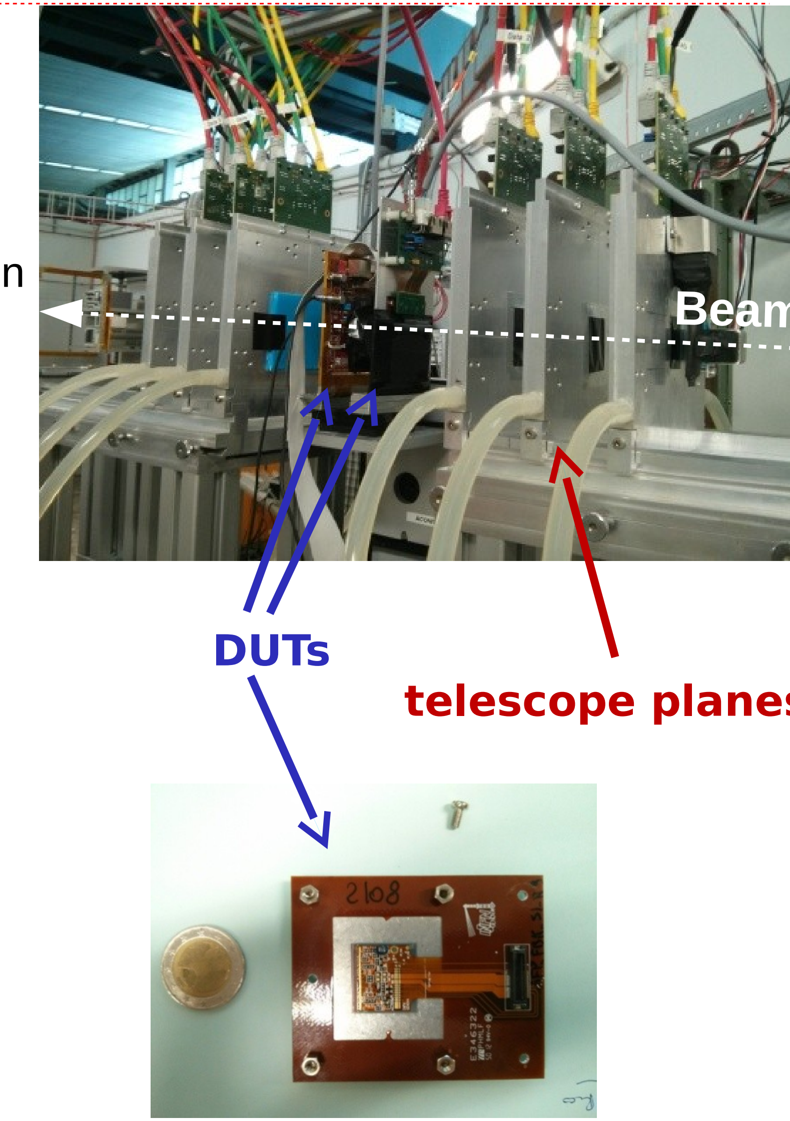
- Requirements:
  - Have a good position resolution
  - Cope with non-unif. radiation damage
  - Have small dead area at the edges
- Qualify modules with high energy particles: Testbeams
  - Measure efficiencies and resolutions

Testbeam campaings

- Hit efficiencies are studied in testbeams:
  - Particle's path reconstructed with high resolution telescope
  - Interpolated to the device under test (DUT) position
  - Are there hits around?

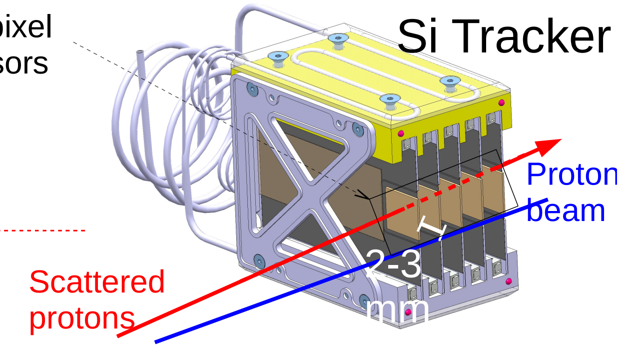




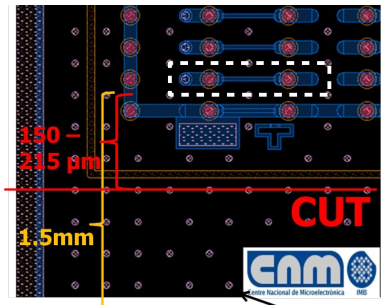


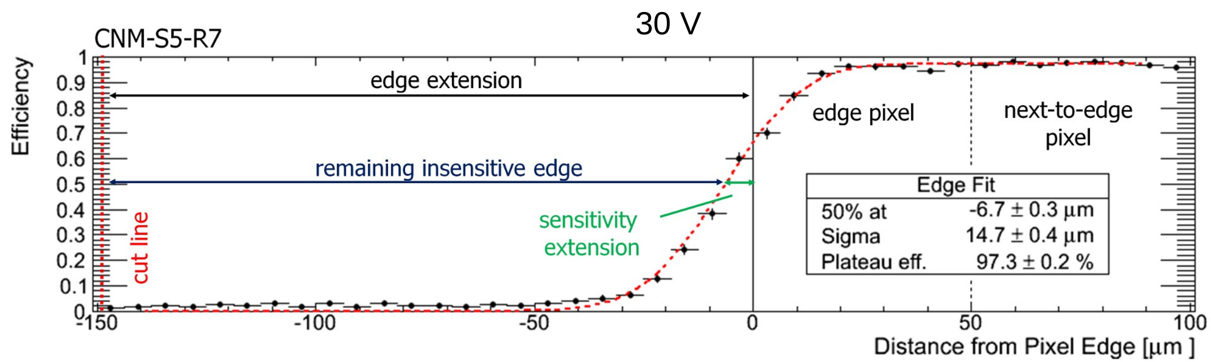
- Using the reconstructed tracks → also resolutions
- Testbeam facilities:
  - CERN SPS & DESY

Slim edges

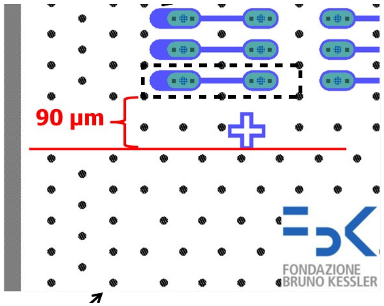


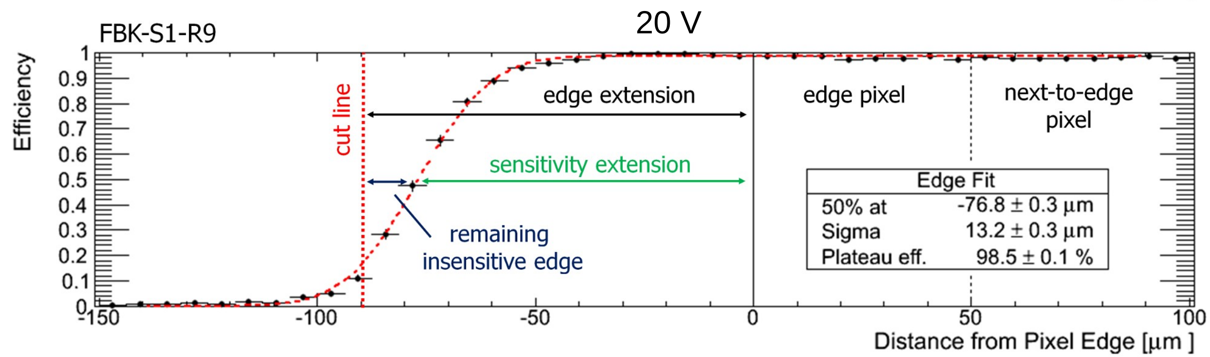
- Small inactive area:
  - Good efficiency after cutting (OK)





CNM design sensitive up to last pixel (3D guard-ring)





FBK design sensitive up to close to the cut line (no guard-ring)

- Requirements:
  1) **Small dead area at the edges**
  2) Cope with non-unif. radiation damage
  3) Good position resolution

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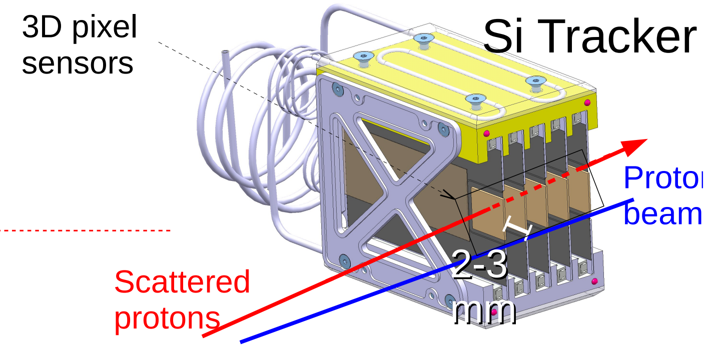
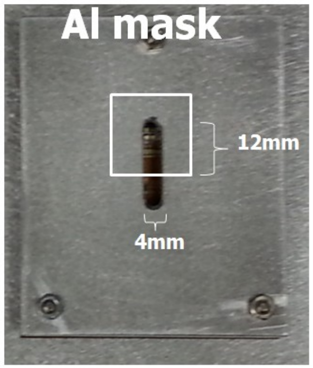
Efficiency after non-uniform irradiation

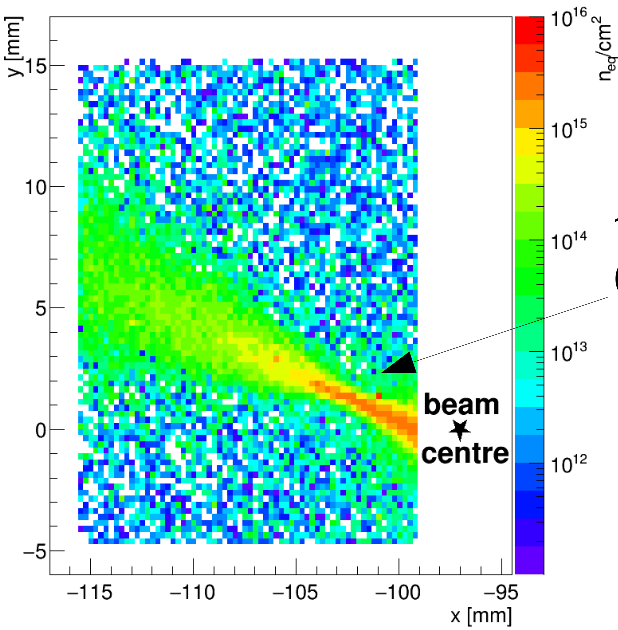


- Non-uniform irradiation campaigns
  - Irradiated sensors in non-uniform fluence up to fluences expected in the high-luminosity scenario

    → **CERN-PS and Karlsruhe**: ~2.6–4 x10^{15} n_{eq}/cm^2
  - Hit efficiency target **irrad** area within ~1-3 % of **non-irrad** part

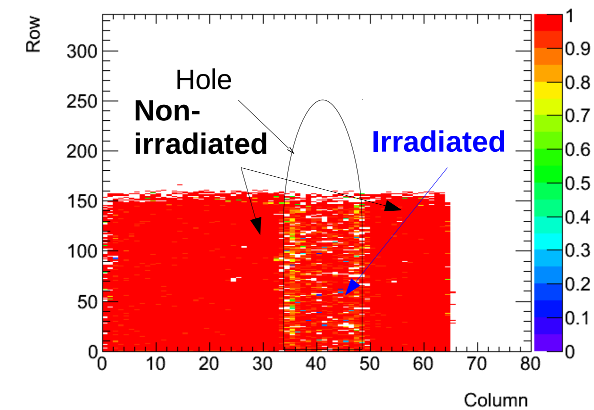
KIT Slit Hole





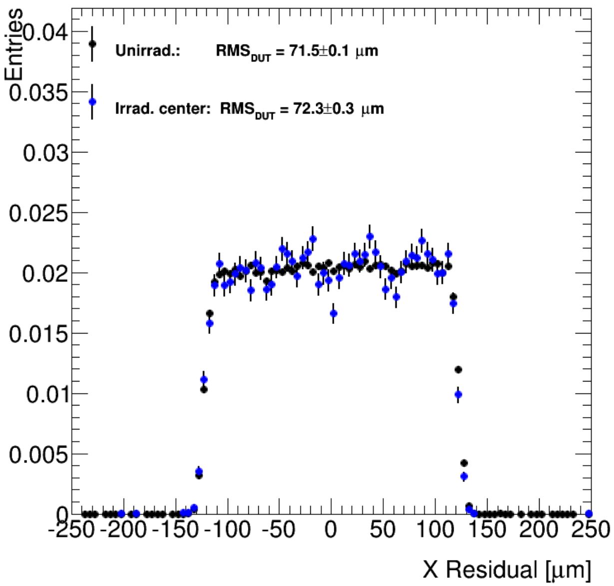
High-lumi:
~3x10^{15} n_{eq}/cm^2
(~5x10^{15} p/cm^2)

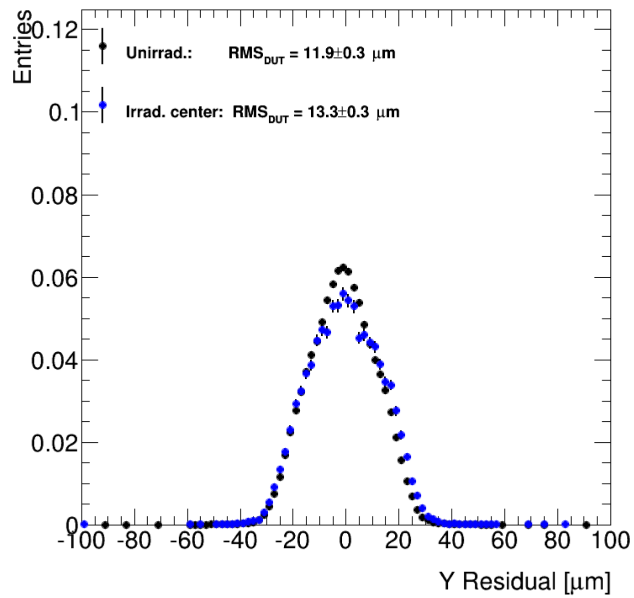
CNM-S5-R7, 80V

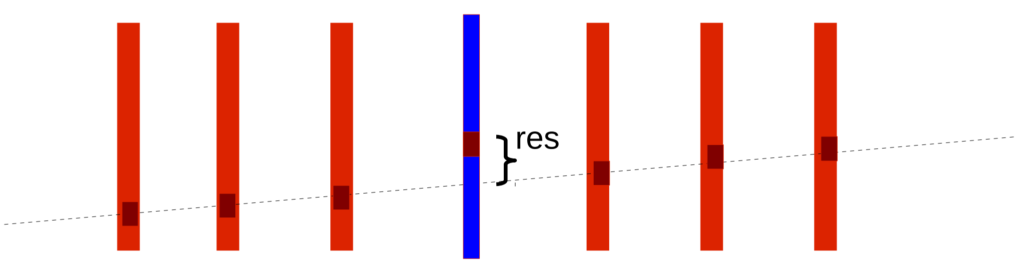


- Requirements:
  1) **Small dead area at the edges**
  2) **Cope with non-unif. radiation damage**
  3) Good position resolution

Position resolution







- Requirements:
  1) **Small dead area at the edges**
  2) **Cope with non-unif. radiation damage**
  3) **Good position resolution**

- Position resolution of a single plane: ~72 x 13 μm
  - Improvable by the use of more sofisticated cluster centre finding algorithms
- The resolution of a 4-plane tracker will improve over the single plane resolution

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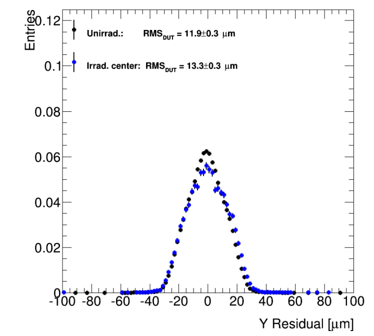
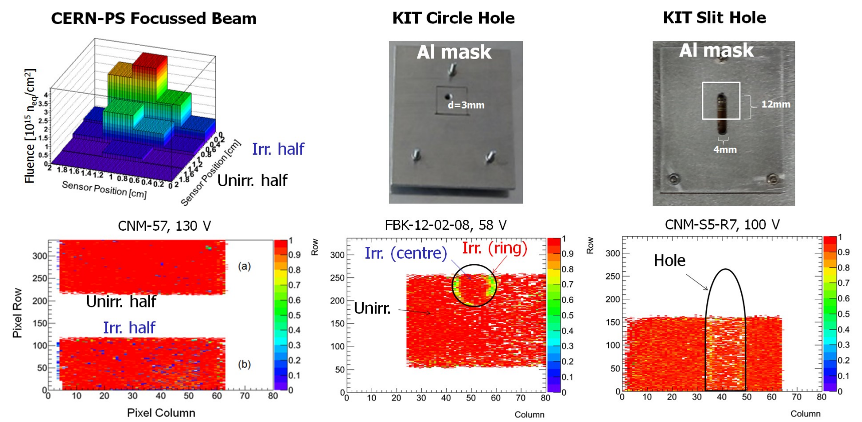
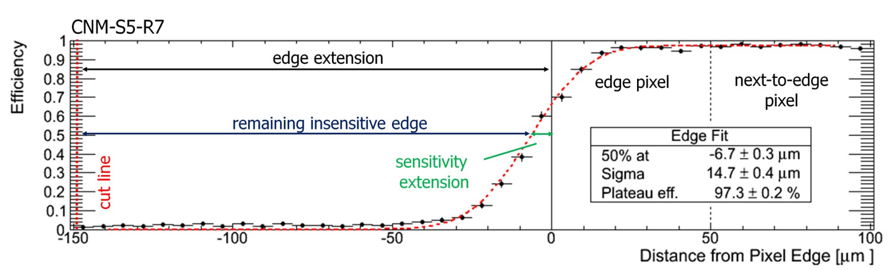
Summary (I)

- Tracker:
  - Has a good position resolution
  - Is able to cope with non-uniform radiation damage
  - Can be cut to have a small dead area at the edges





Approved Technical Review (April 2014)



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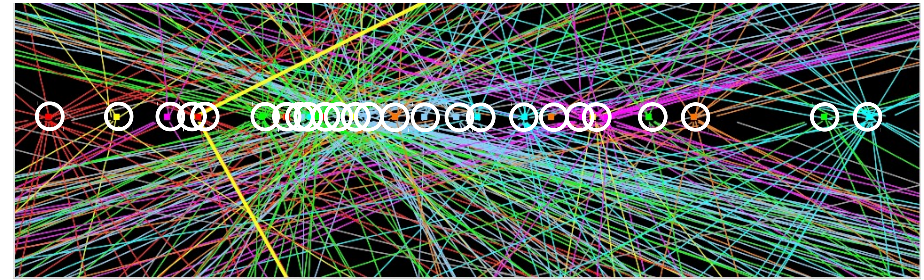
The Time of Flight detector

ToF detector

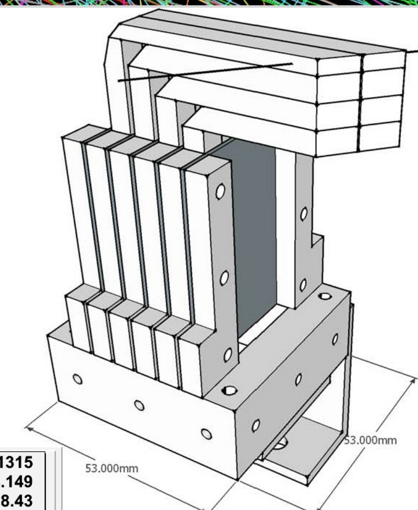
- Goal
  - Measure time of flight of scattered protons

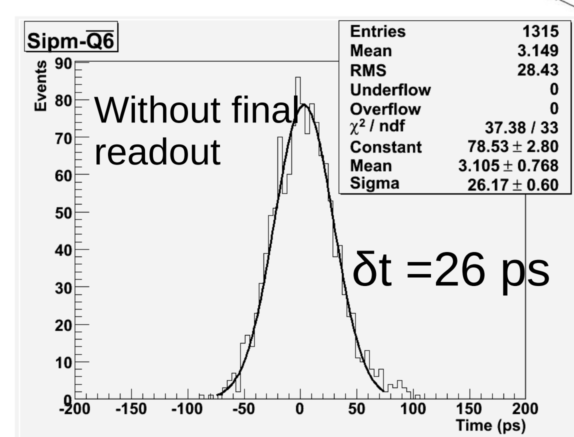
    → Identify primary vertex of diffractive interaction (reduce pile-up)
- Requirements
  - Good time resolution ~10 ps →~2 mm (for low-luminosity, ~30 ps)
- Quartz-bars
  - Cherenkov light is produced inside bars and guided to photomultiplier plate
- ToF also underwent its own qualification for AFP
- Tracker & ToF never tested with common readout

→ **Integration testbeam**



25 interactions in ~5 cm





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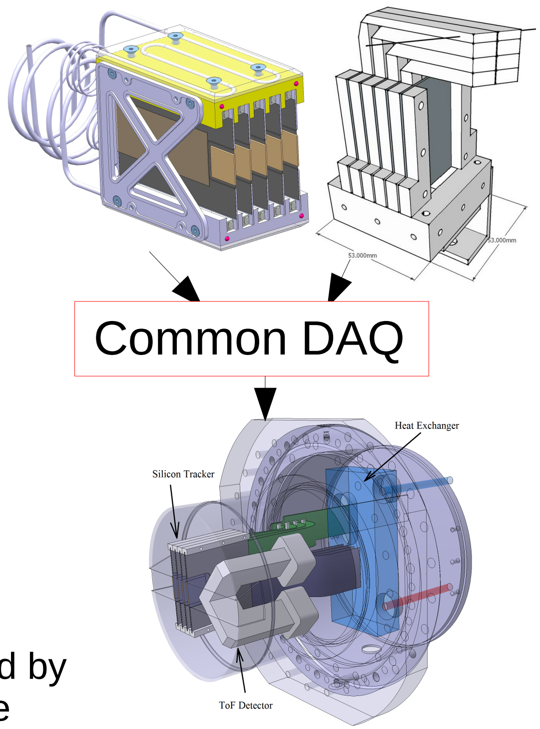
The AFP integration testbeam

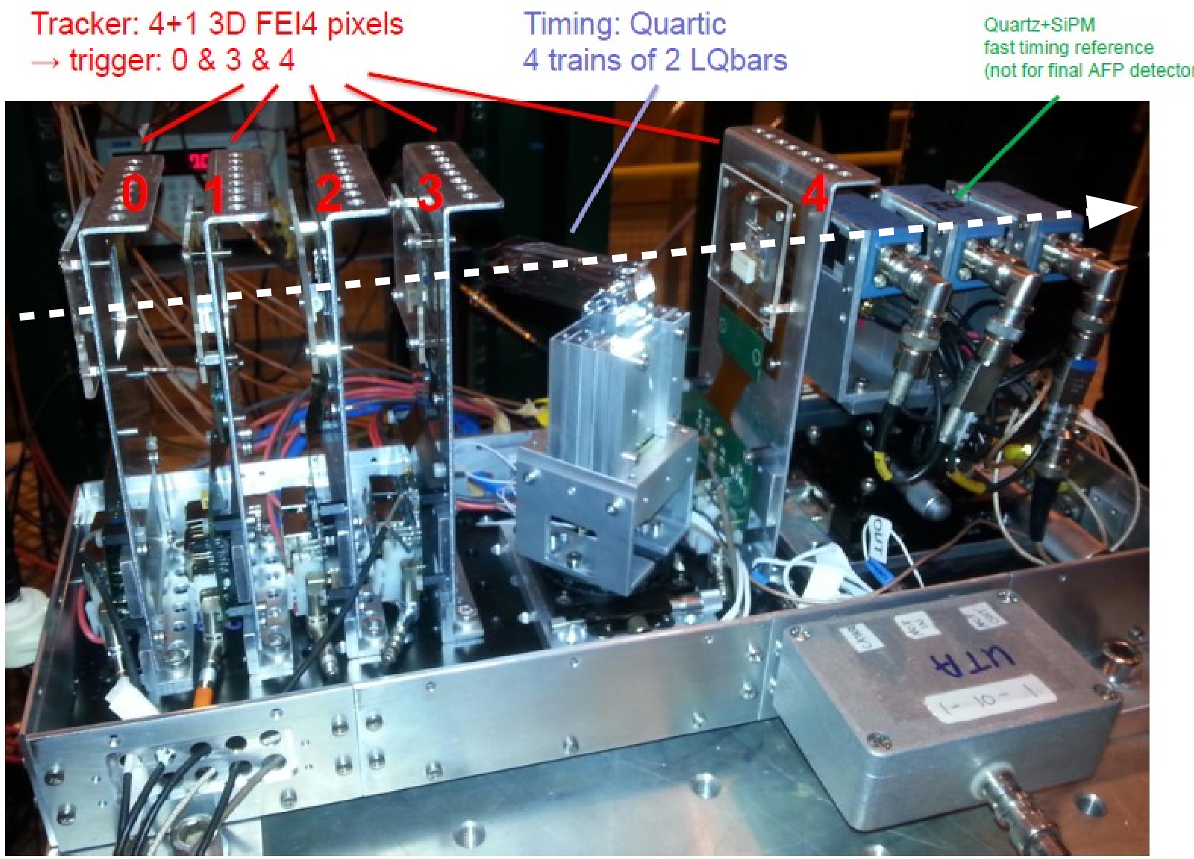
- Goal:
  - Take nice pictures
  - Run together tracker and ToF detector with a common DAQ
- CERN SPS testbeam Nov. 2014



Testbeam Coordinated by Jörn Lange (IFAE)

“We don't need it to work, we just need nice pictures”
– Anonymous, about the integration testbeam

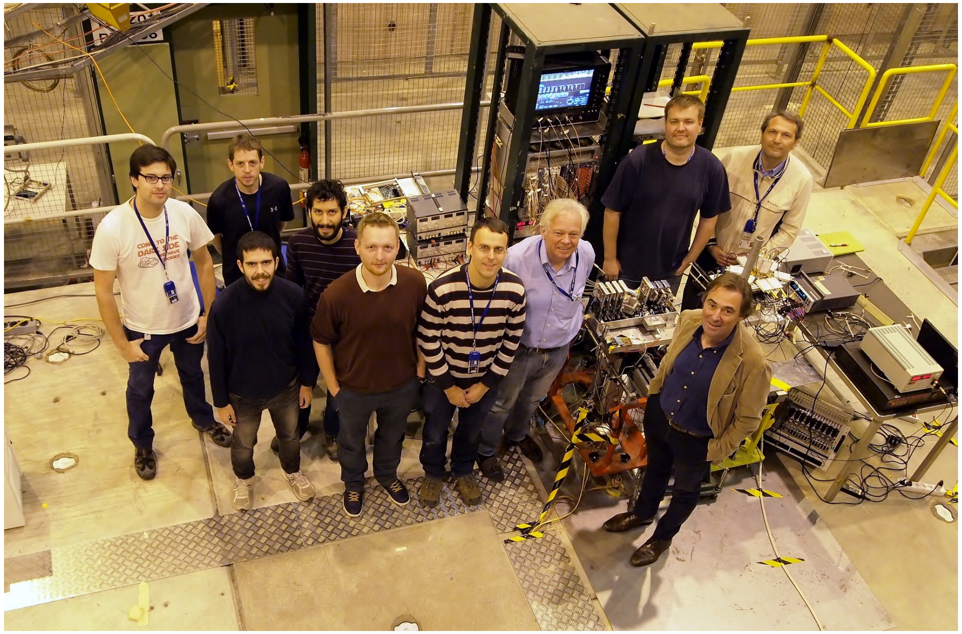
AFP Station Prototype for the testbeam



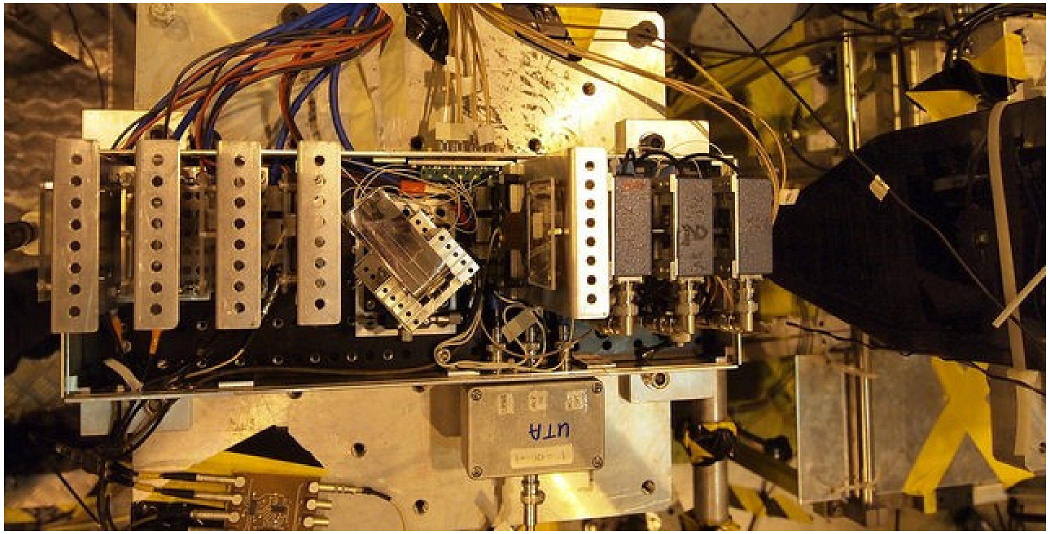
DAQ: Data AcQuisition system

The AFP integration testbeam: Results

- We took nice pictures



* Only half of the people



Pictures from Ladislav Chytka

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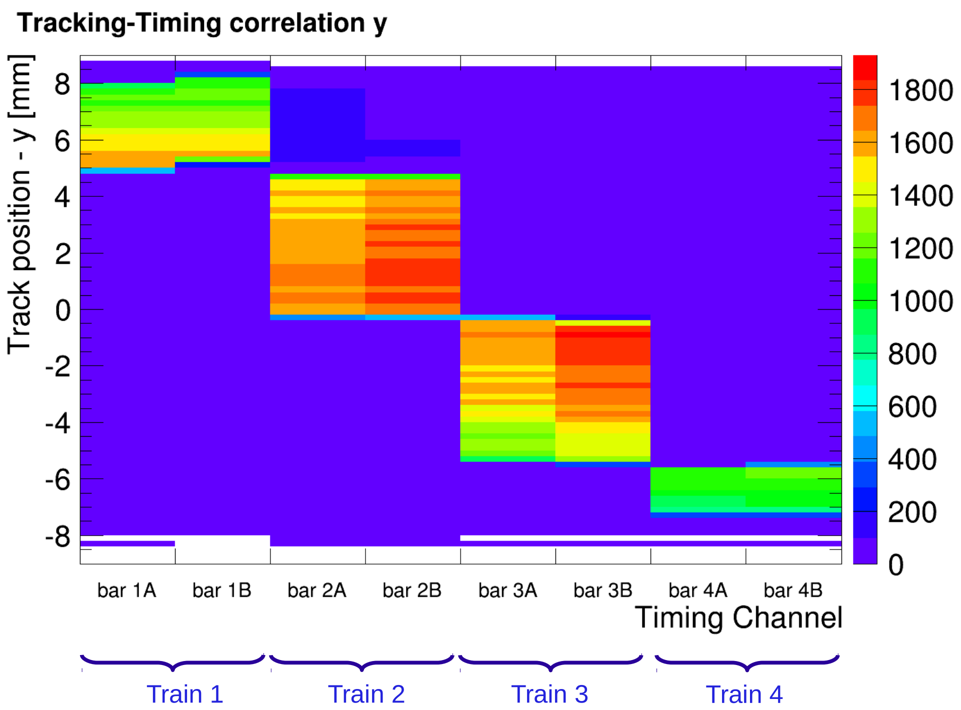
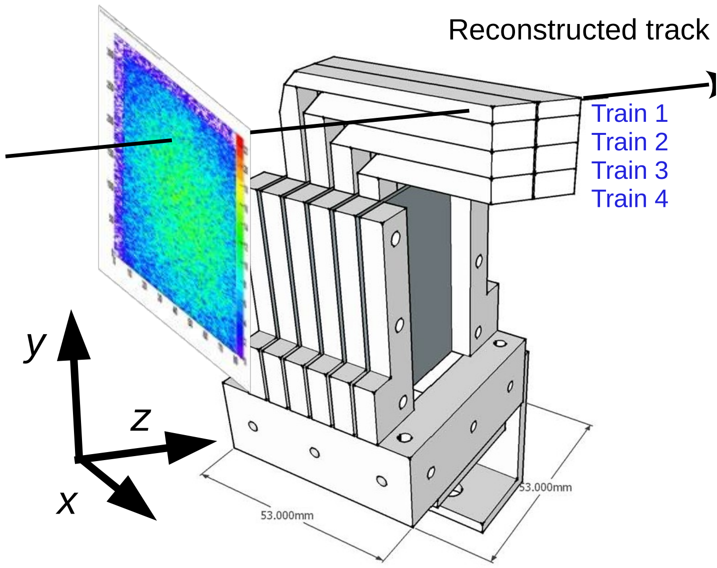
The AFP integration testbeam: Results

- Run together tracker and ToF detector
  - Correlation between tracking and timing information



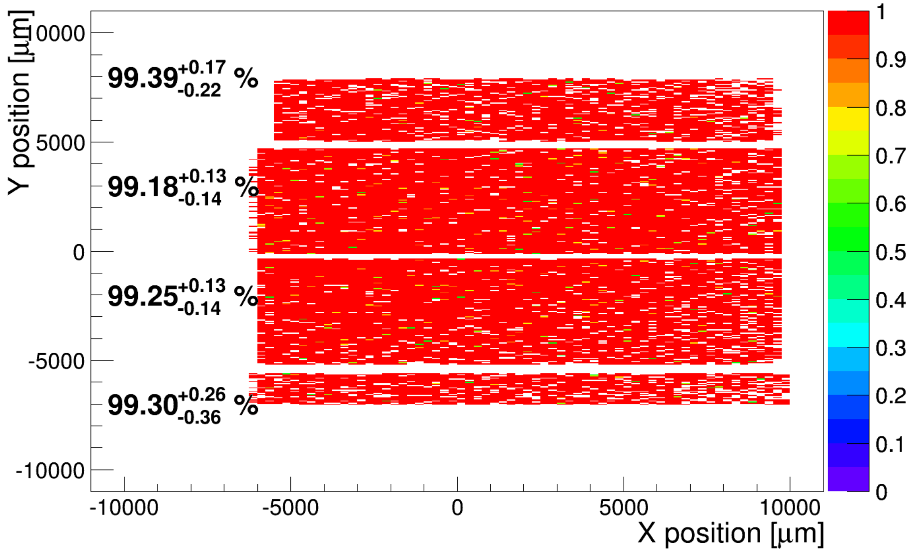


→ Tracking-timing integration works!
→ Main testbeam aim fulfilled!

The AFP integration testbeam: Results

- Run together tracker and ToF detector
  - Measured hit efficiency, crosstalk and noise of ToF with tracker information
  - Measured time resolution of ToF in the prototype set-up → δt = 35 ± 6 ps

Hit efficiency of four Qbars



Results presented by Jörn Lange (IFAE) in ATLAS Weekly 2.5 weeks after the testbeam

Later, AFP was approved by ATLAS

- Approved by ATLAS for dedicated low luminosity runs
  - Possible partial installation in the end of 2015
- Possible upgrade for high luminosity runs

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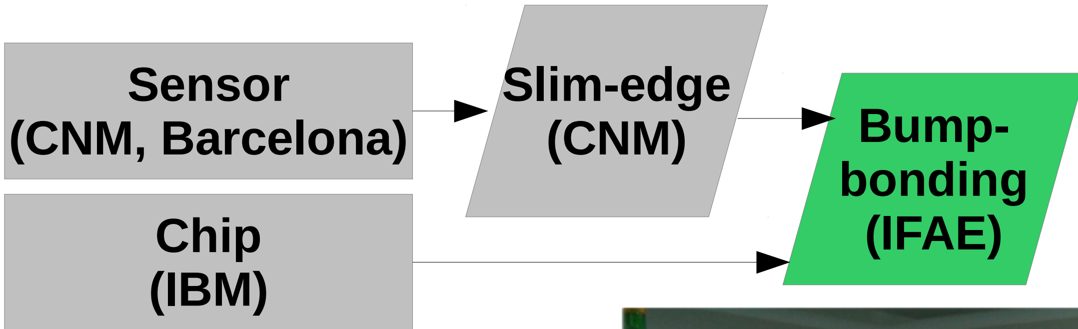
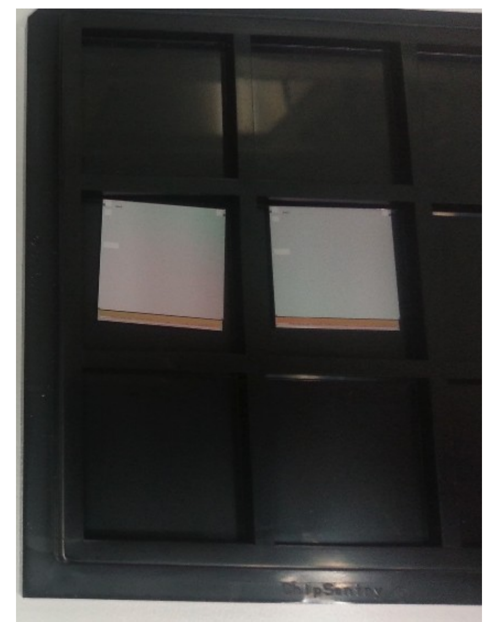
AFP module production

- IFAE is will assemble the AFP tracker module





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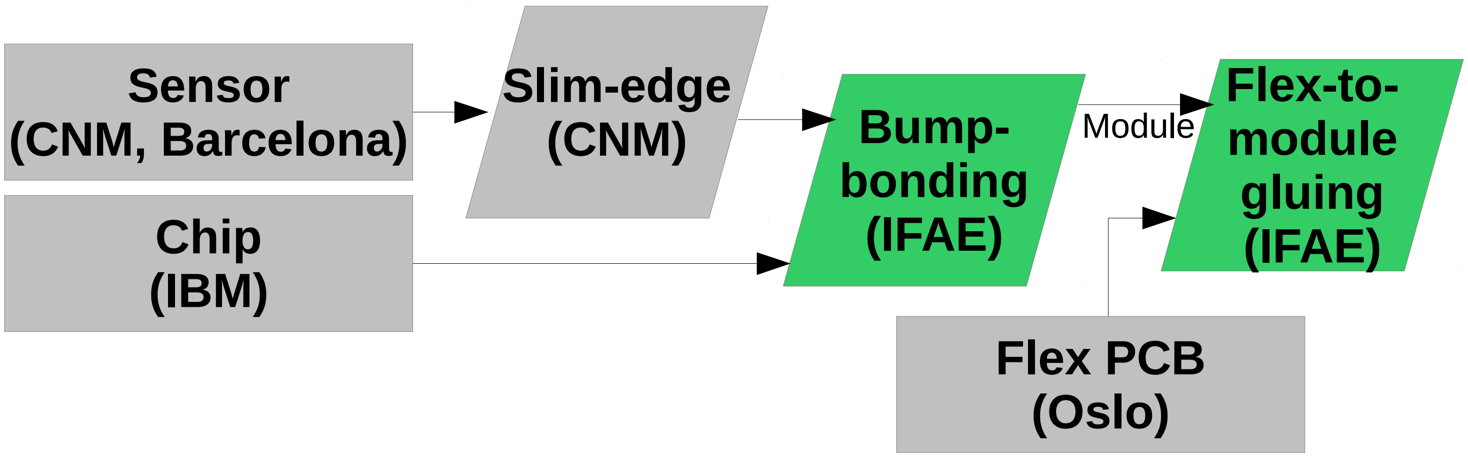

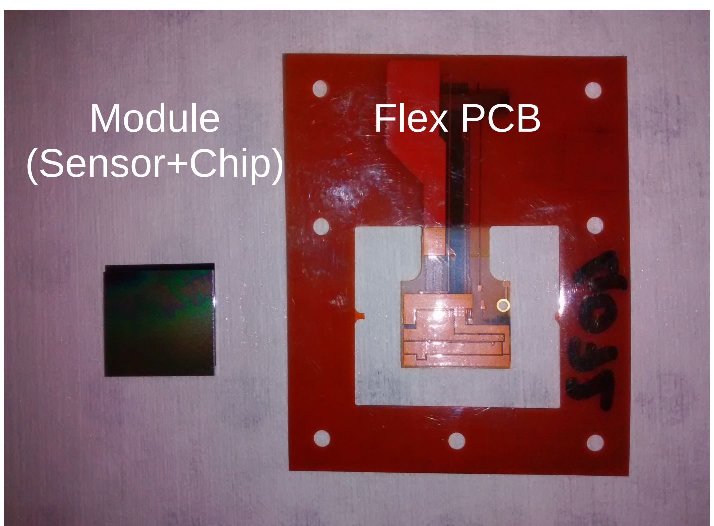

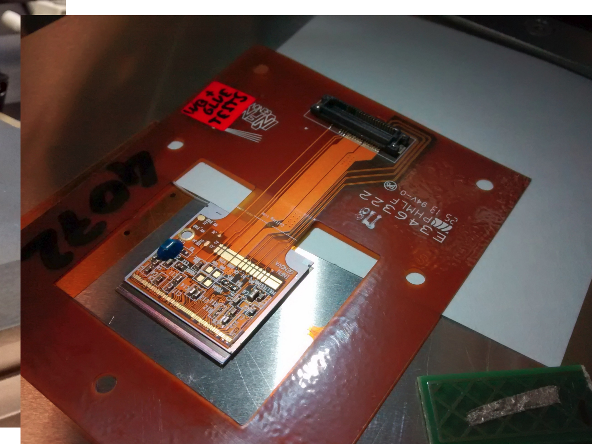

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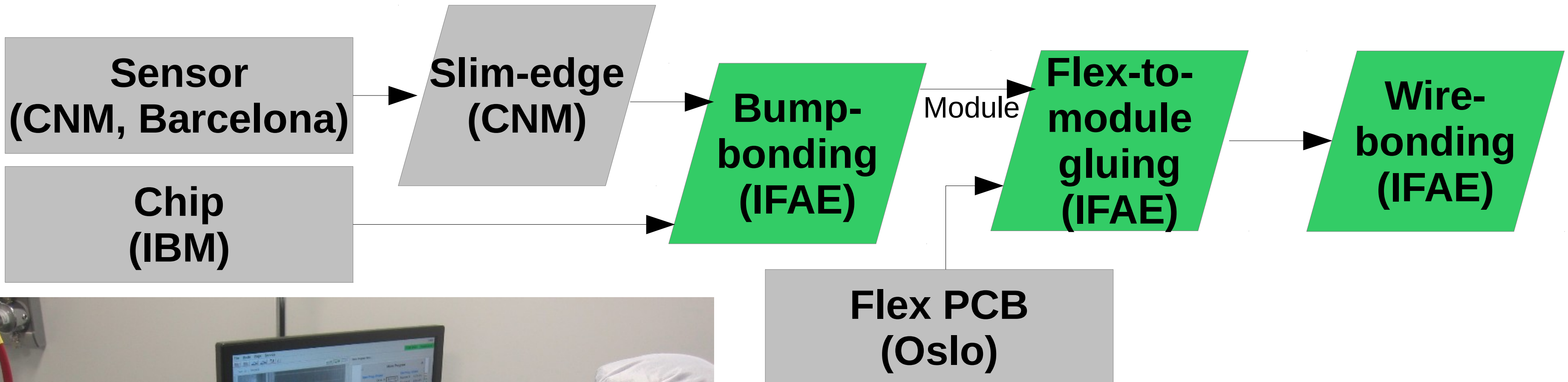
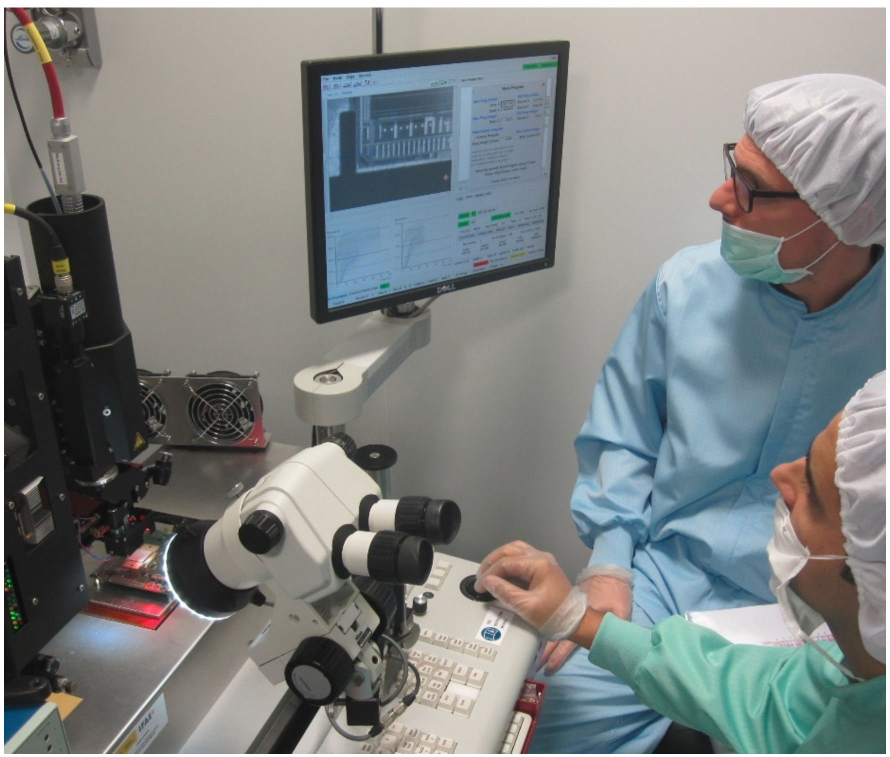
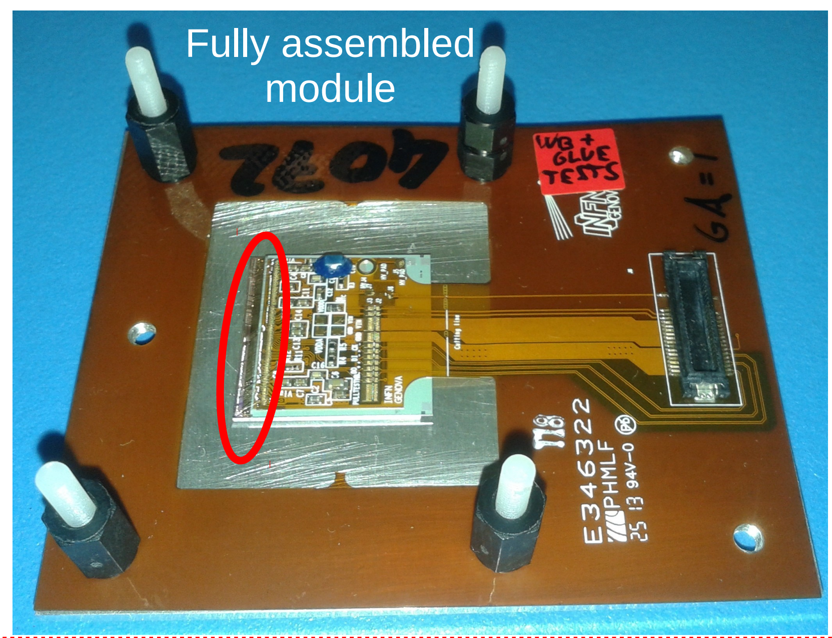
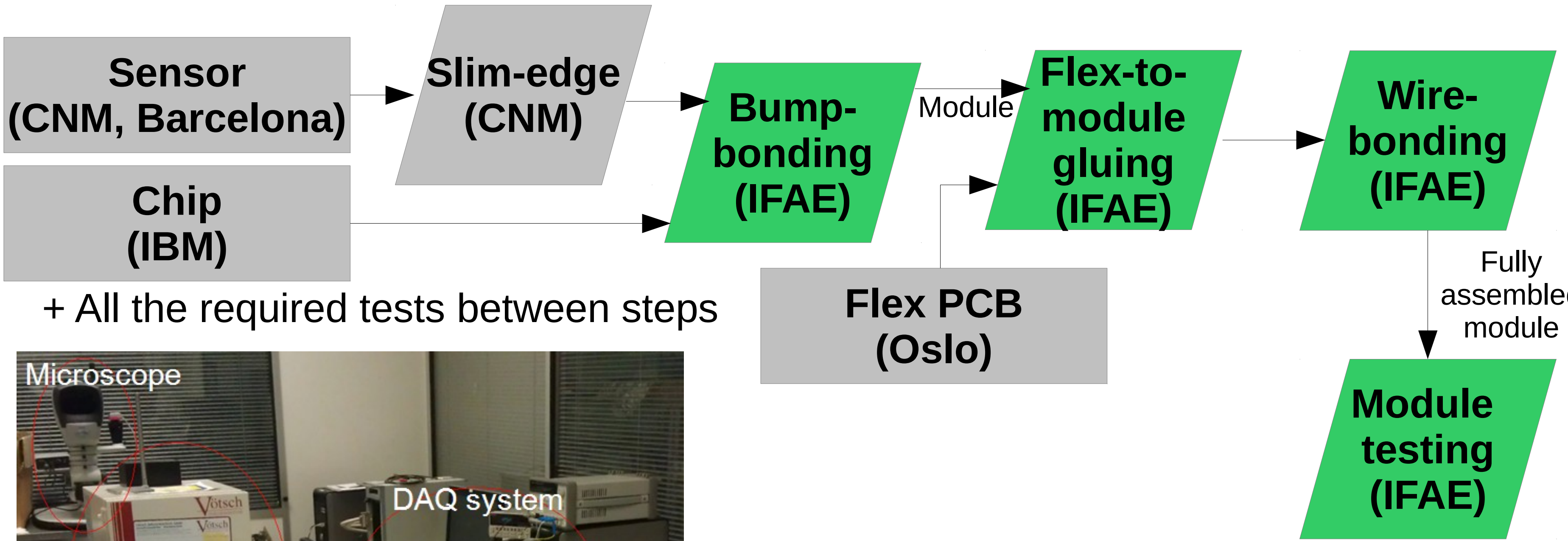




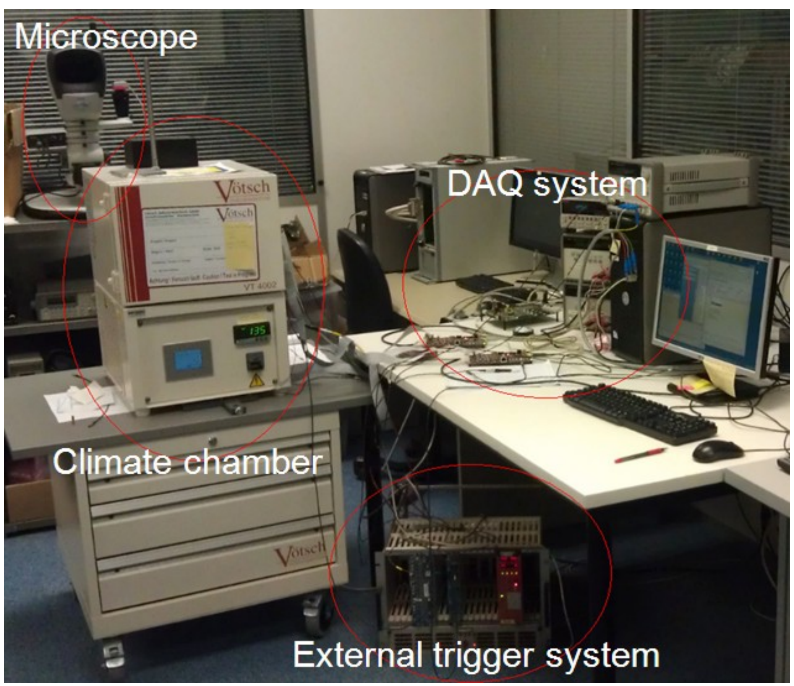


AFP module production

- IFAE is will assemble the AFP tracker module

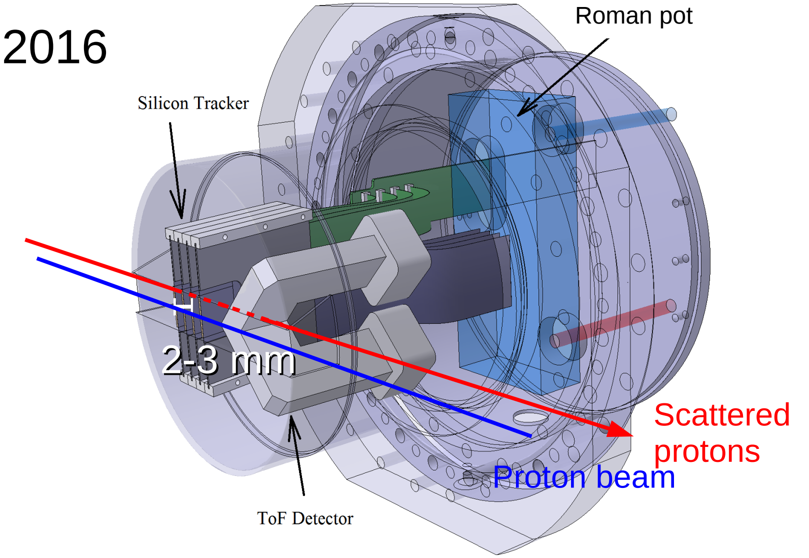


+ All the required tests between steps



Summary (II)

- AFP is a new detector at ~210 m from the ATLAS IP that will enable diffractive measurements
- 3D pixel modules have been successfully qualified for AFP
  - **Technical Review approval**
- Successfull integration testbeam campaign at CERN SPS on November 2014
  - **AFP approved by ATLAS for low luminosity runs**
- **IFAE played a key role in both milestones and will produce the tracker modules**
- AFP installation scheduled by end 2015 – beginning 2016



EXCELENCIA SEVERO OCHOA