Pixel Detectors and beam telescopes at CERN

From the largest machine on earth to its smallest components

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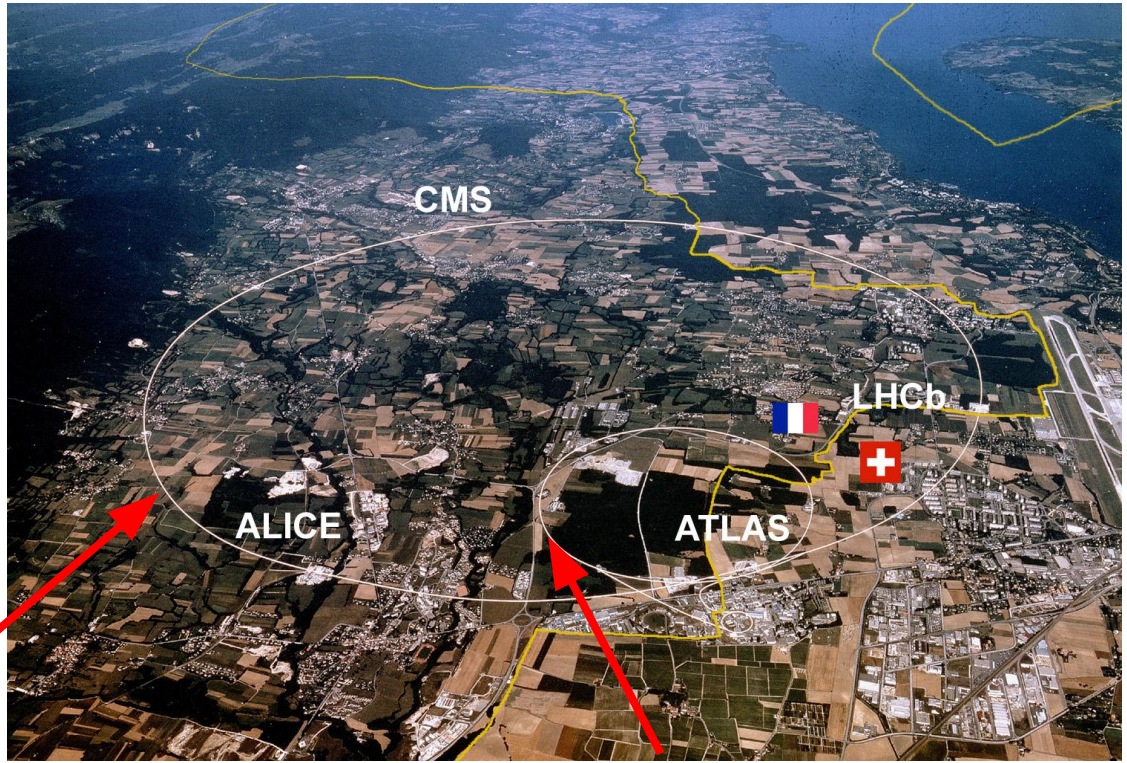
  - The LHC at CERN
  - The ATLAS experiment at the LHC
  - The ATLAS Tracker
  - Pixel detectors inside the Tracker
- Pixel particle detectors
  - Pixel detector principles
  - The MALTA detector
- Beam telescopes: A tiny tracker to test sensors
  - How it works
  - Some results

LHC & Co. at CERN

- The Large Hadron Collider (LHC) provides a very high energy particle beam for high energy physics experiments
- The Super Proton Synchrotron (SPS) provides a beam to the LHC and to test facilities for detector development

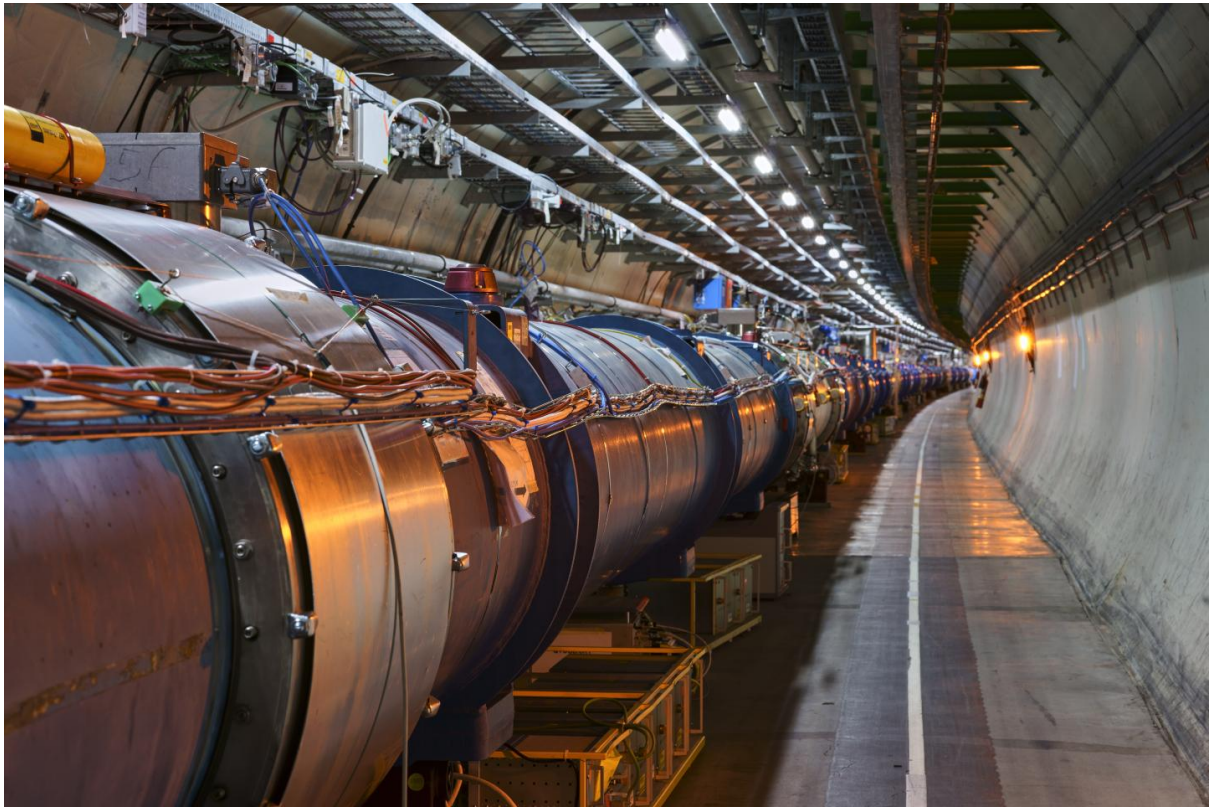


Large Hadron Collider

Super Proton Synchrotron

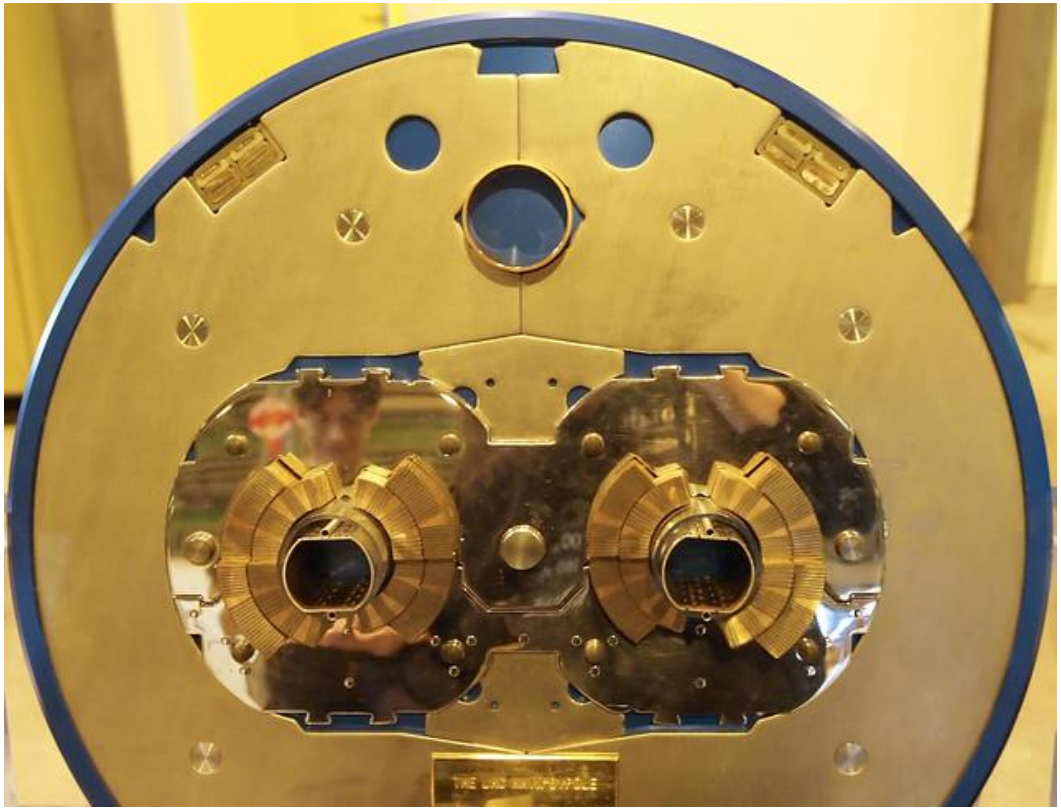
The LHC tunnel

- This tunnel keeps going for 27km
- Each magnet is 14.3m long and there are 1232 magnets in total
- Each magnet weights 35t



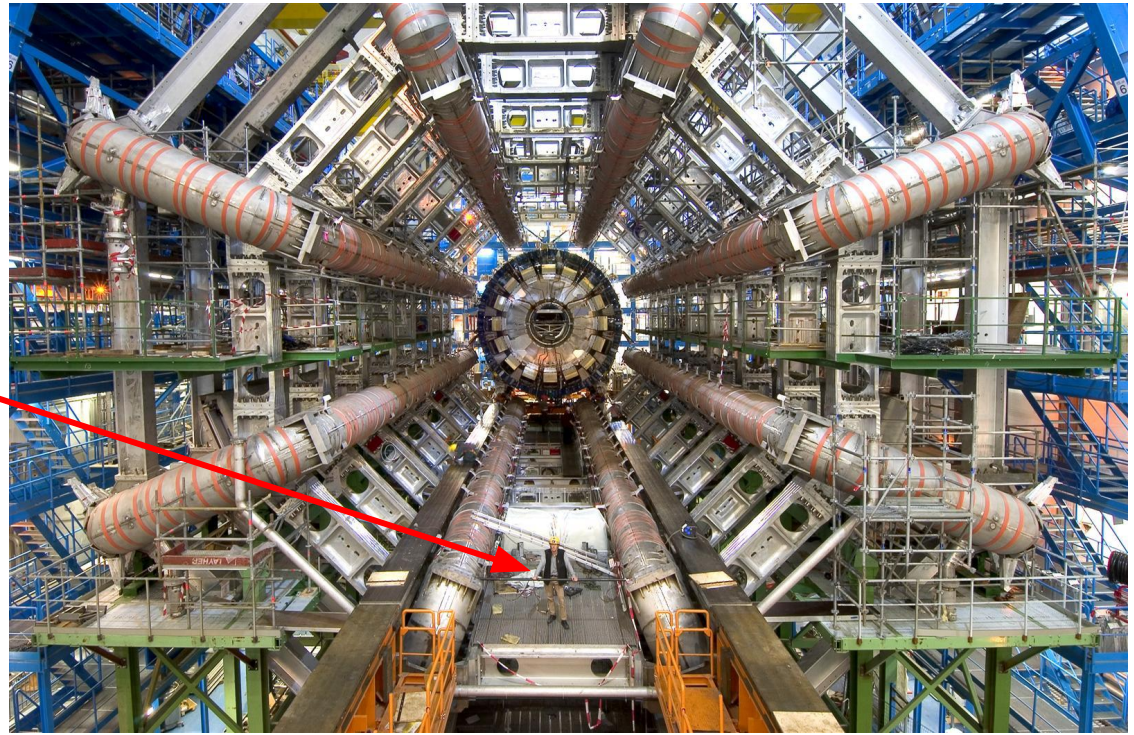
Inside an LHC magnet

- **There are 2 beams at once!**
- One beam moves clock-wise and one counter clock-wise.
- The beams cross in 4 places along the LHC: This is where collisions happen that experiments can measure.

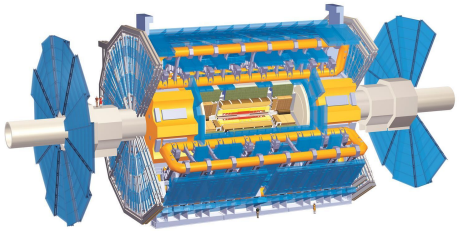


The ATLAS experiment

ATLAS cavern before the detector was installed

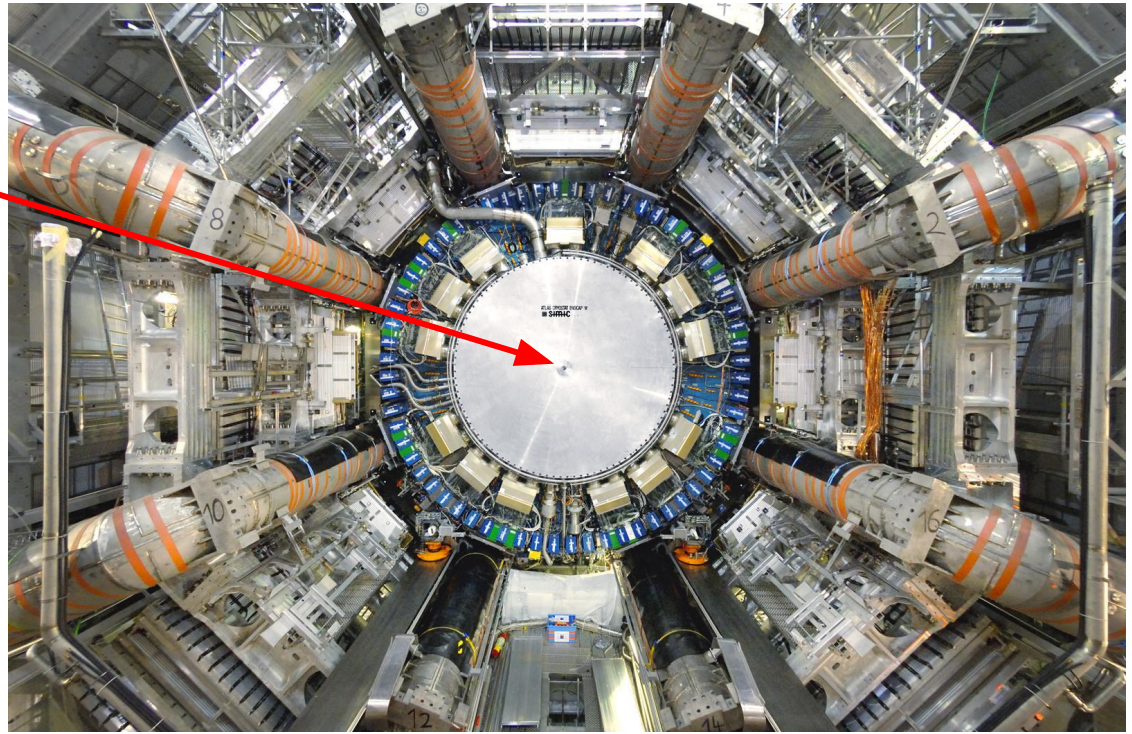


point of view



The ATLAS experiment

Inner Detector for tracking hidden in the center of this cylinder



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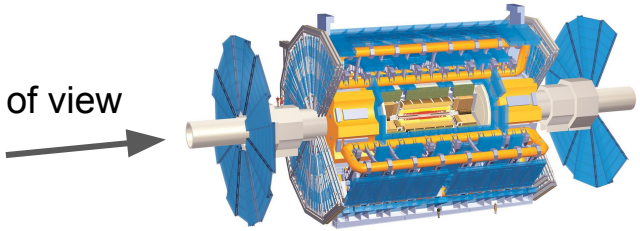
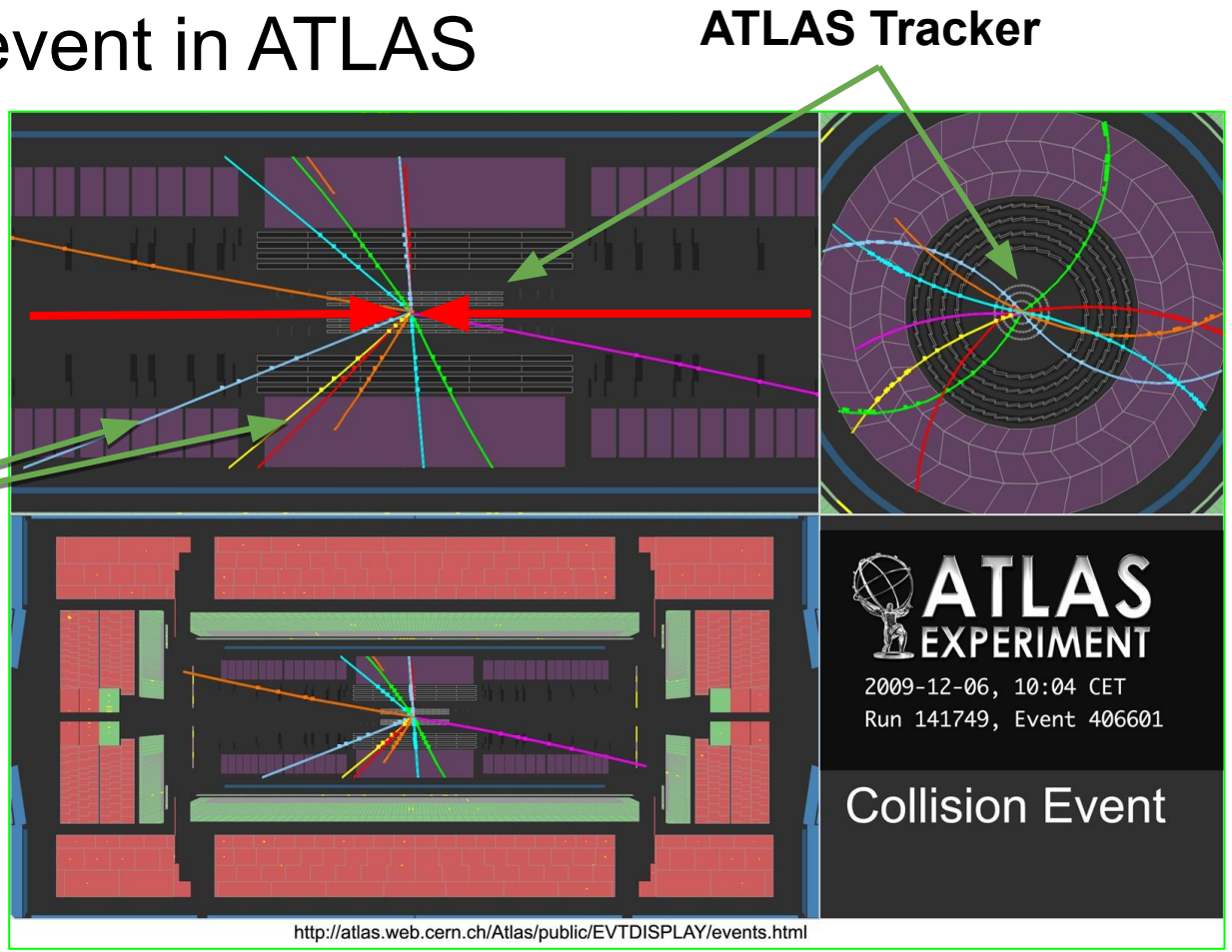
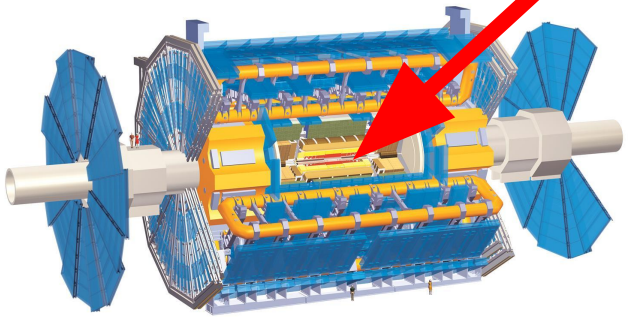


A collision event in ATLAS

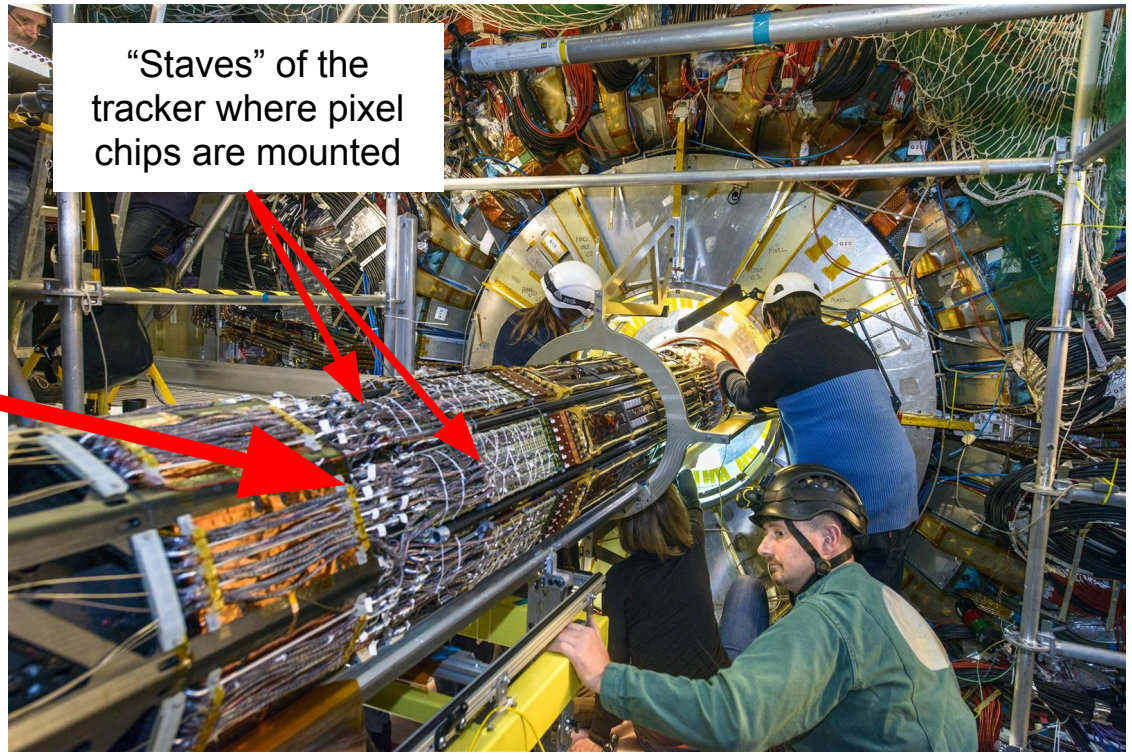


Inserting the ATLAS Tracker

- Here the ATLAS tracker is moved into the center of the ATLAS experiment
- The tracker will enclose the area where the beams of the LHC collide

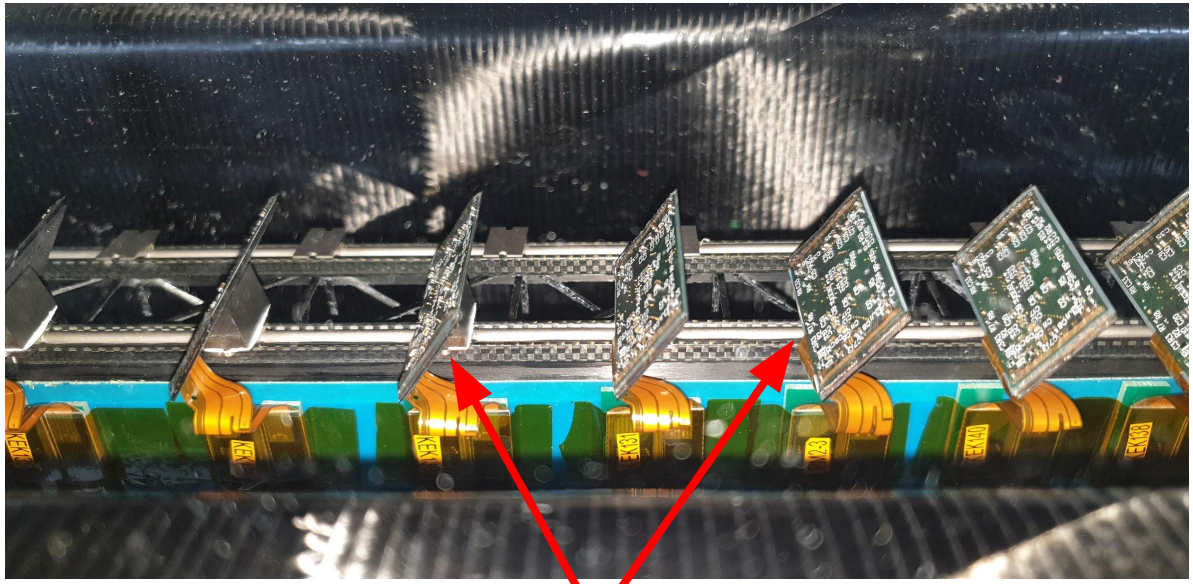


Tracker

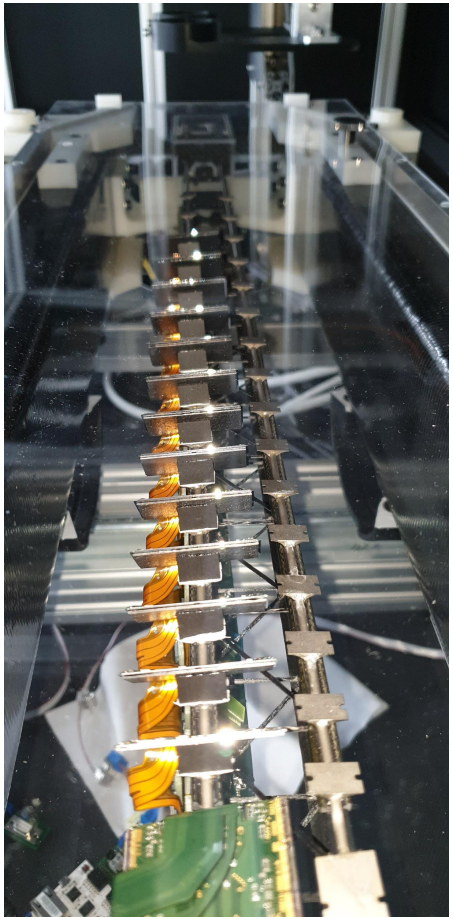


One test stave of the new tracker

-



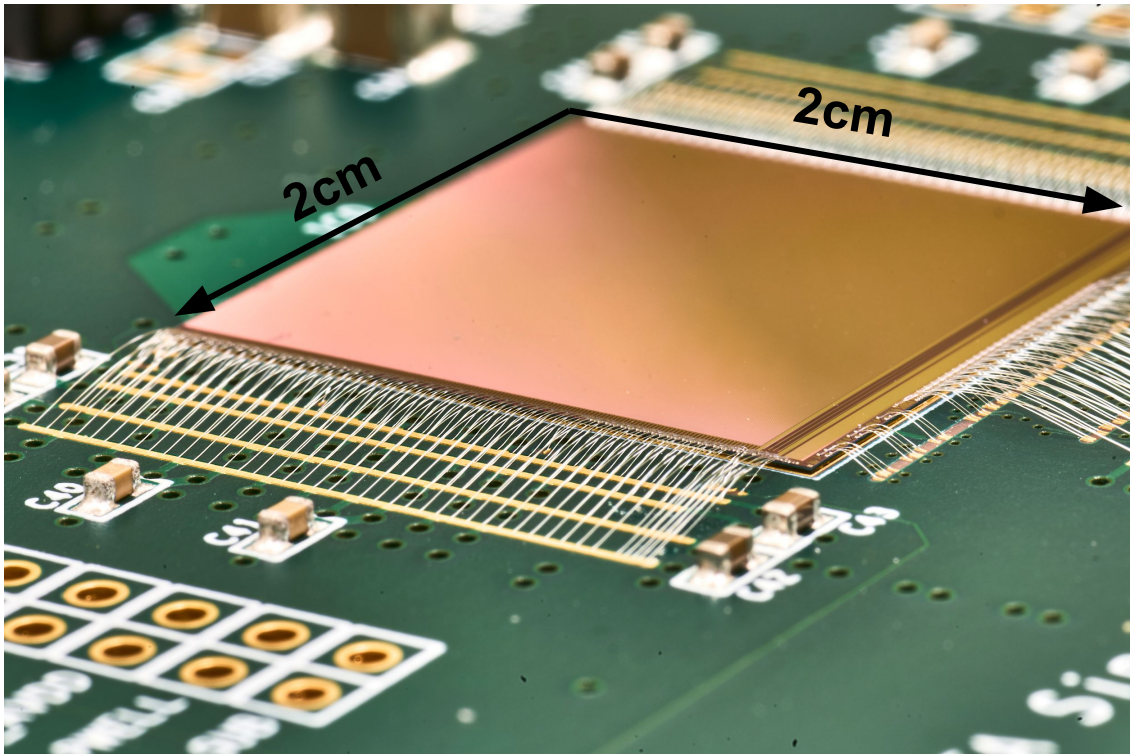
Individual pixel chips



Individual pixel chip on a test board: MALTA

- This is the MALTA chip (**M**onolithic from **AL**ice **T**o **A**tlas) which was initially designed for the new ATLAS Inner Tracker

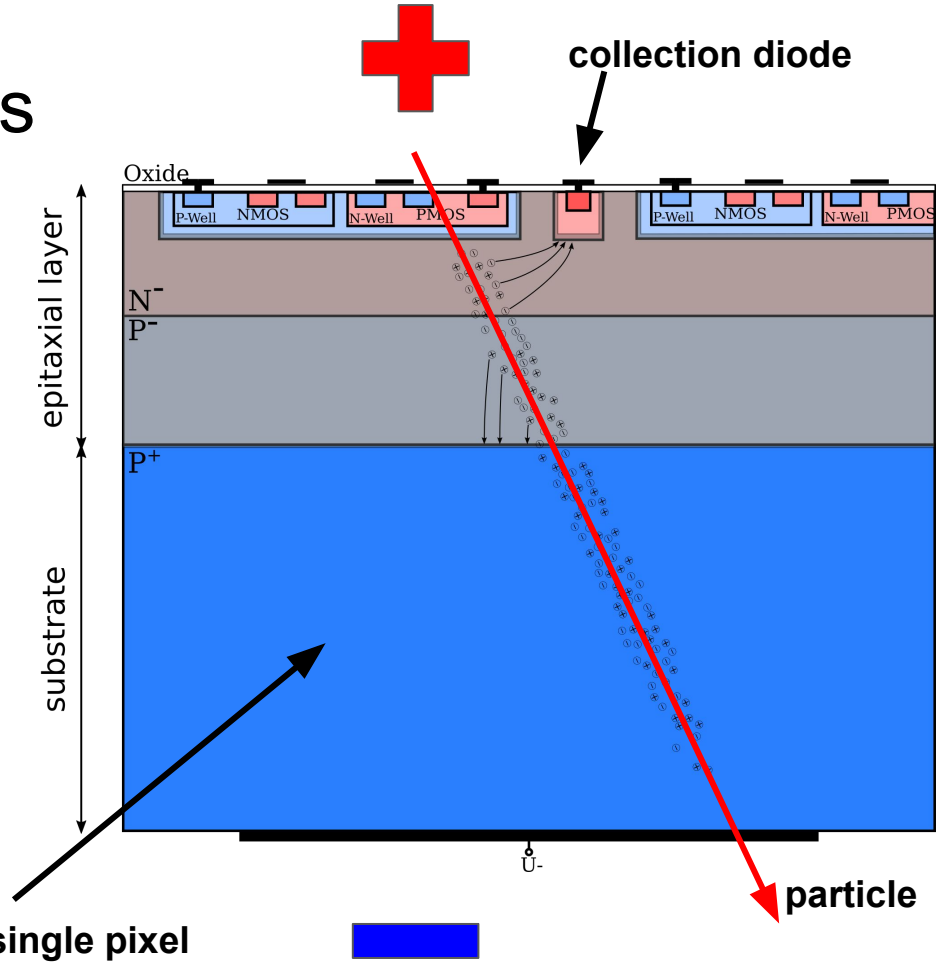
- 512x512 pixels
- 2x2cm large



Pixel detector principles

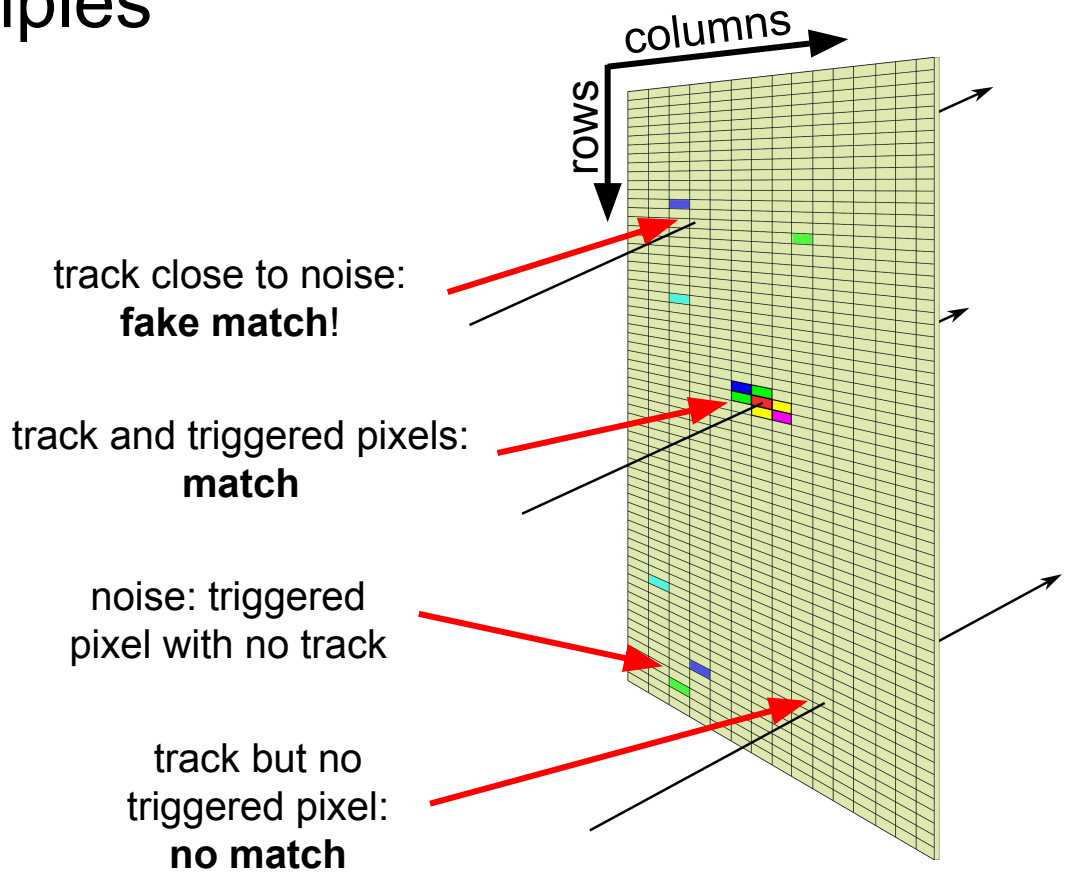
- passing particles leave trails of ionized electrons and electron “holes” (= place in the crystal lattice where an electron should be)
- **electrons** drift to the **positive pole**
- **holes** drift to the **negative pole**

collected electrons are the signal that triggers a pixel



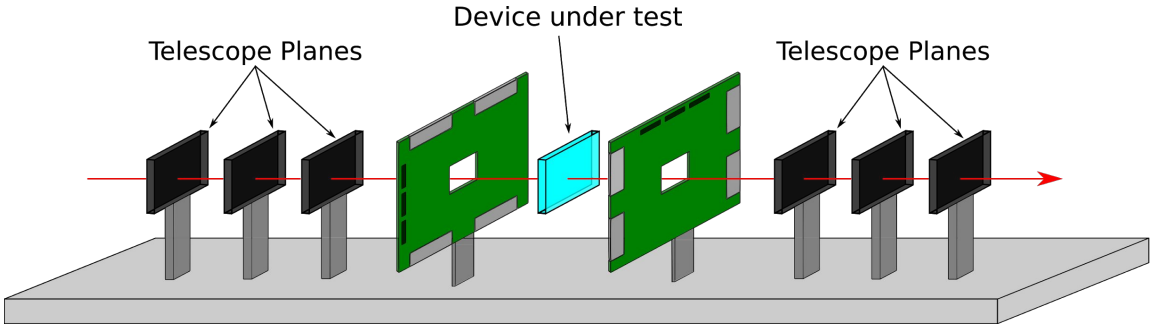
Pixel detector principles

- pixel detectors give **2D position information** about a passing particle
- this information is used to reconstruct the global trajectory of a particle
- most important:
  - **high efficiency**: don't miss particles!
  - **low noise**: no randomly triggered pixels



Beam telescope: A tiny tracker to test pixel detectors

- **use a test beam**
  - **provided by the SPS**
  - **various particles**
  - **various energies**



Beam telescope: A tiny tracker to test pixel detectors

- use a test beam
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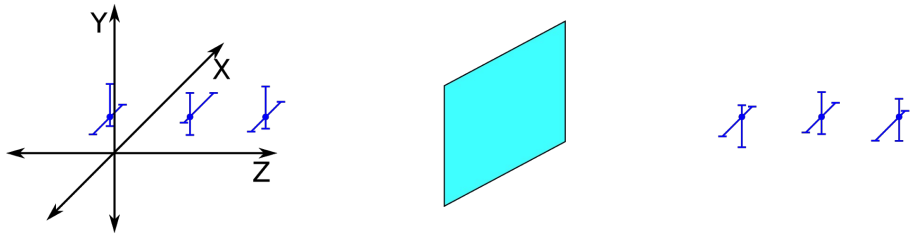
- **use proven pixel detectors to reconstruct particle tracks**



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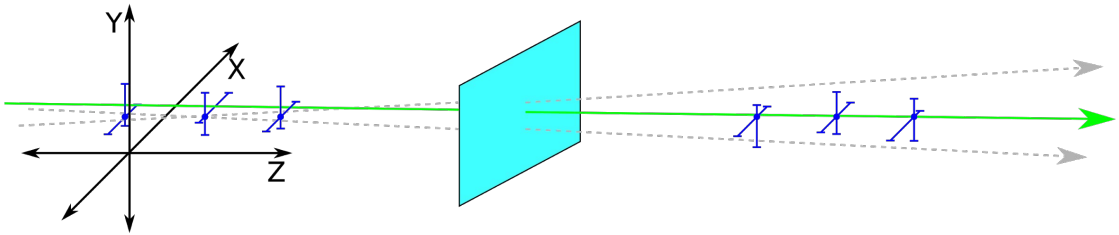

Beam telescope: A tiny tracker to test sensors

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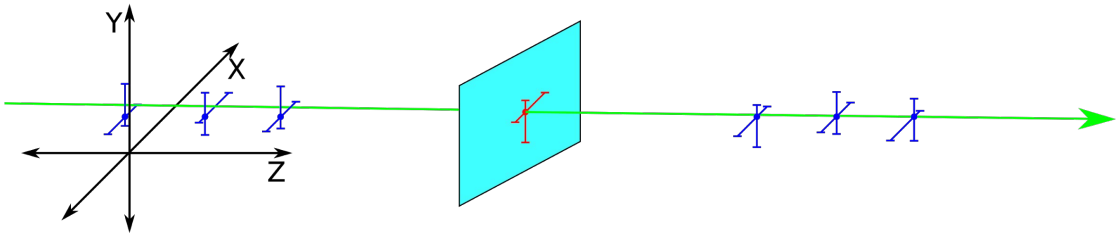
- use proven pixel detectors to reconstruct particle tracks
- **predict where the test sensor was hit**



Beam telescope: A tiny tracker to test sensors

- use a test beam
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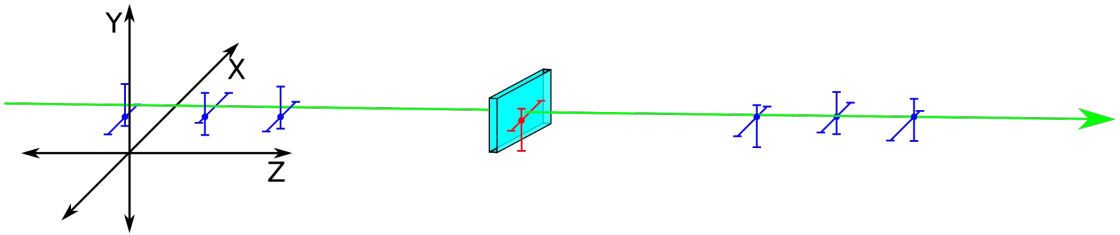
- use proven pixel detectors to reconstruct particle tracks
- predict where the test sensor was hit
- **compare the prediction to the response of the test detector**
  - **1 or more triggered pixels = cluster**



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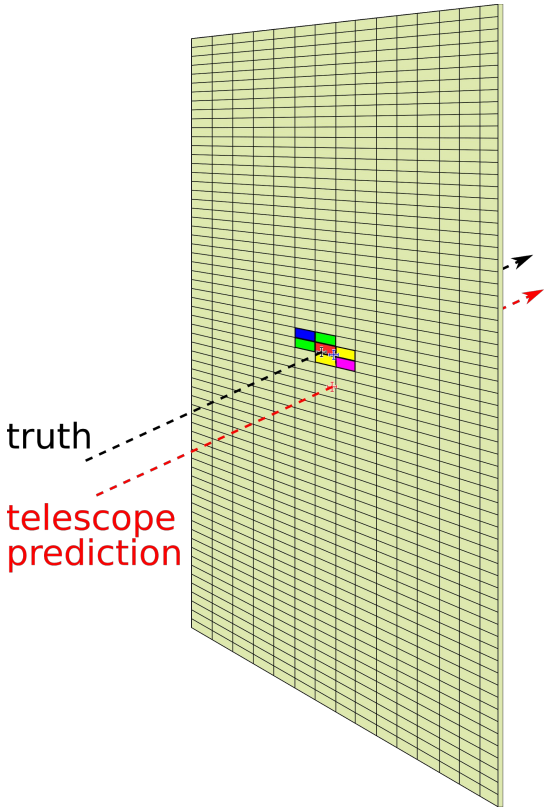
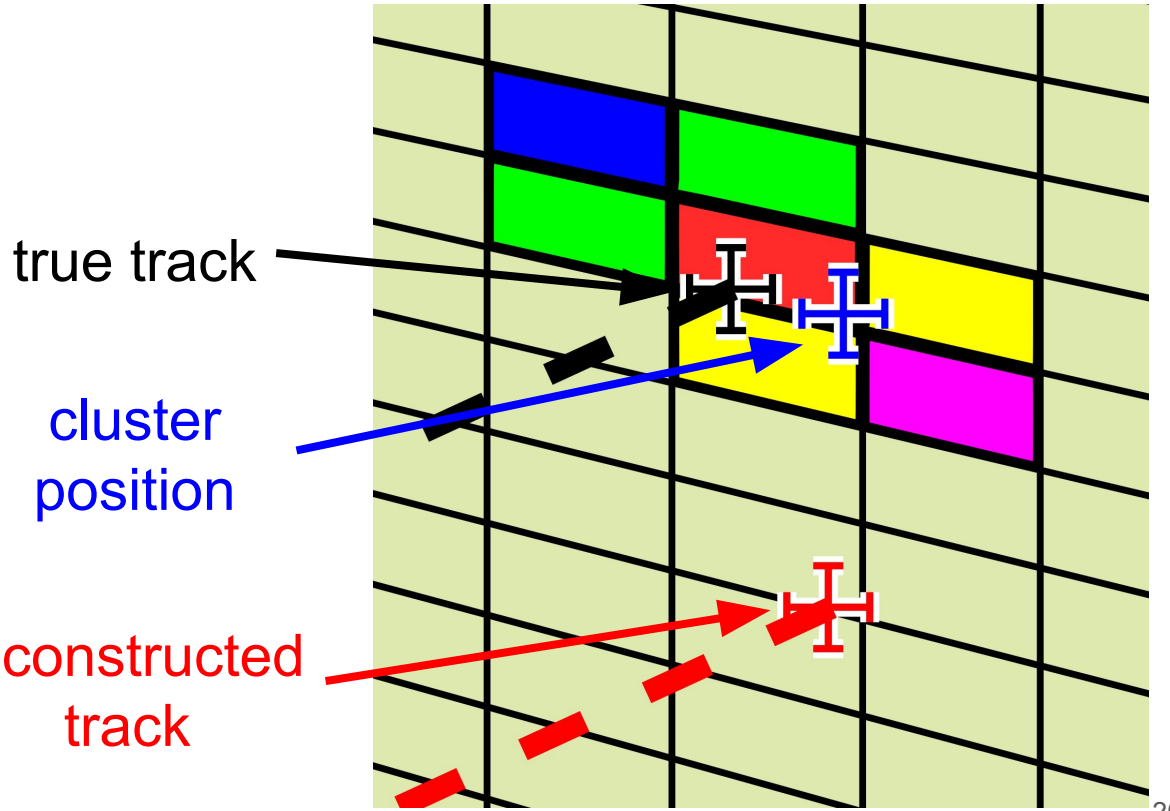


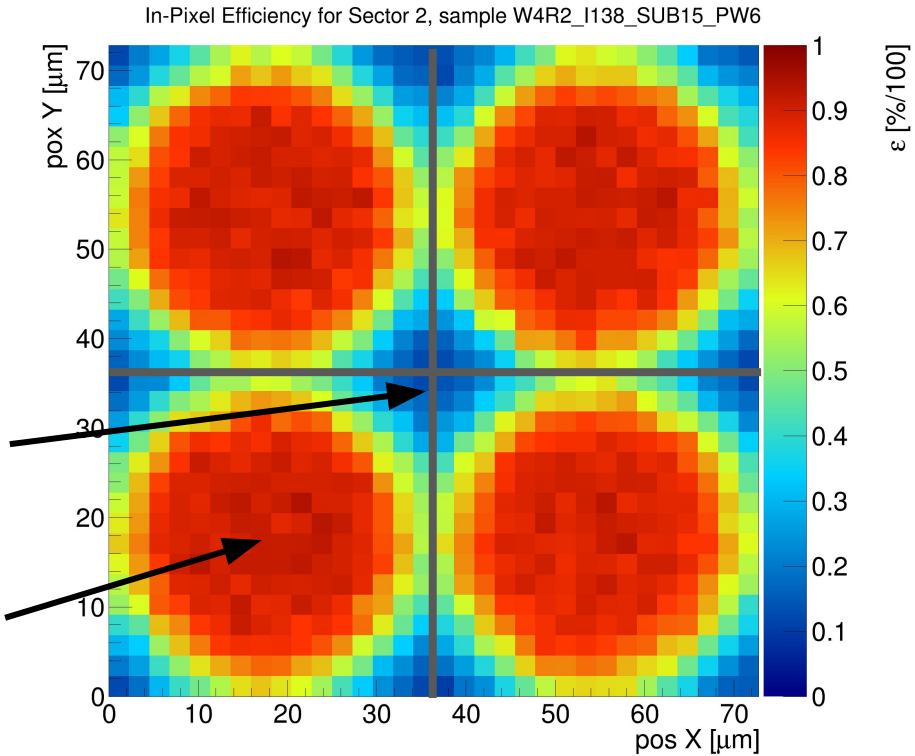
Results from beam tests

- **different colors indicate different amounts of energy** that was picked up by the pixel
- the reconstructed track is projected onto the test detector
- calculate the center positions for clusters on the test detector
- **reconstructed tracks close to a cluster are matched**



Results from beam tests

- shown are 2x2 pixels
- the pixels are only efficient at the center

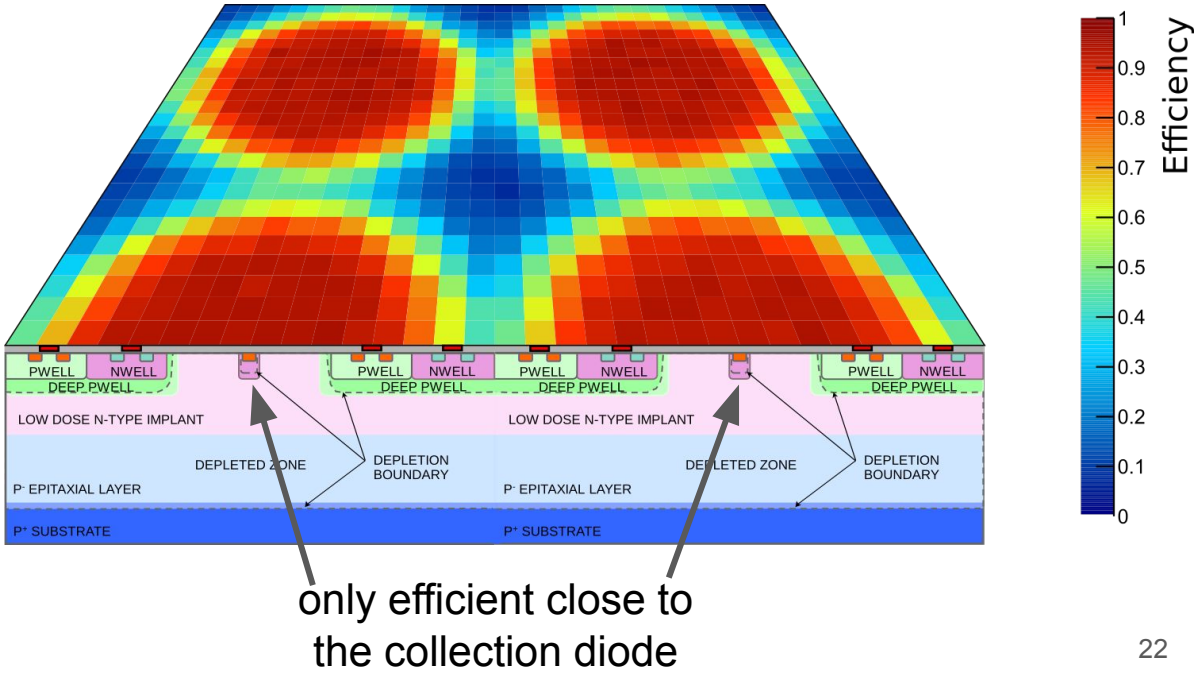


many **unmatched** tracks here = detector is **inefficient**

most tracks are **matched** here = detector is **efficient**

Results from beam tests

- compare the measured pattern to the pixel design
- study shows that the pixels are only efficient close to the collection diode
- **this issue was found with test beam measurements and is fixed in the new design!**



Conclusion

- Pixel detectors are among the smallest detector elements in any LHC experiment such as ATLAS
- New pixel detectors are necessary to deal with higher requirements as the LHC is constantly upgraded
- These new pixel detectors must be tested and their performance verified
- Tiny particle trackers called “beam telescopes” are used to do these tests
- The results drive the ongoing development of fully functioning pixel detectors of the next generation

All images are either created by the presenter or provided by the CERN public resources service.