Silicon detector Systems

EDIT 2020 DESY.

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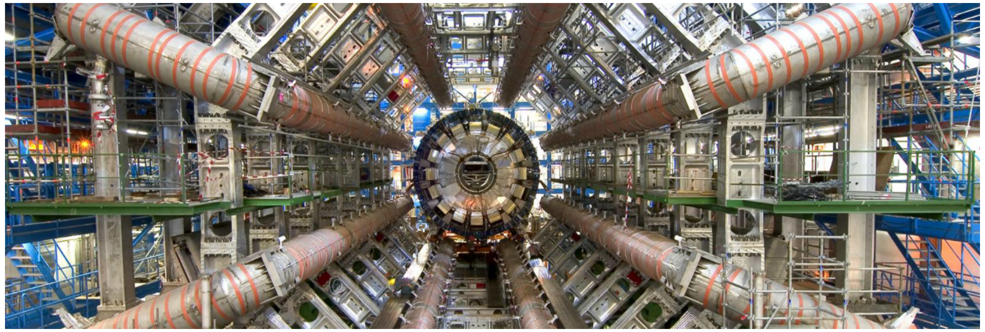
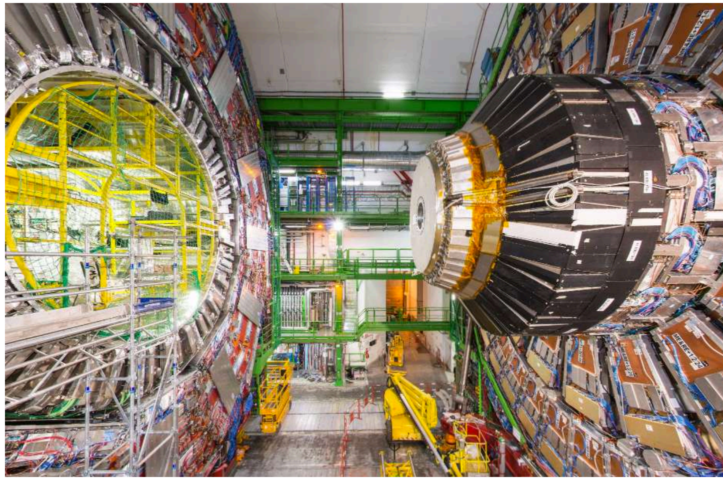
Silicon systems

Introduction





https://cms.cern/
https://atlas.cern/

Motivation

- Precise beam telescopes became an indispensable tool at test beams for the research & development of future particle detectors. They are essentially small tracking detectors with the same main element as for example a vertex pixel detector, but optimised for the use at a test beam.
- The DESY pixel telescopes are based on six pixel sensors used as reference particle tracking detector with an excellent pointing resolution (<5um), i.e. the position of the impinging particle is known this precise

Silicon systems

- In this track, students will work with the pixel beam telescopes learning about the trigger and DAQ system in the lab, learning how to align the telescope with respect to the particle beam at the DESY II test beam facility, investigating the charge sharing of a silicon pixel cells

Silicon systems

Tasks

5 TDAQ performance

- Location: eLAB (building 01c)

6 Spatial resolution simulation

- Allpix2
- Location: Seminarroom 3a (01b)
- Bring your laptop

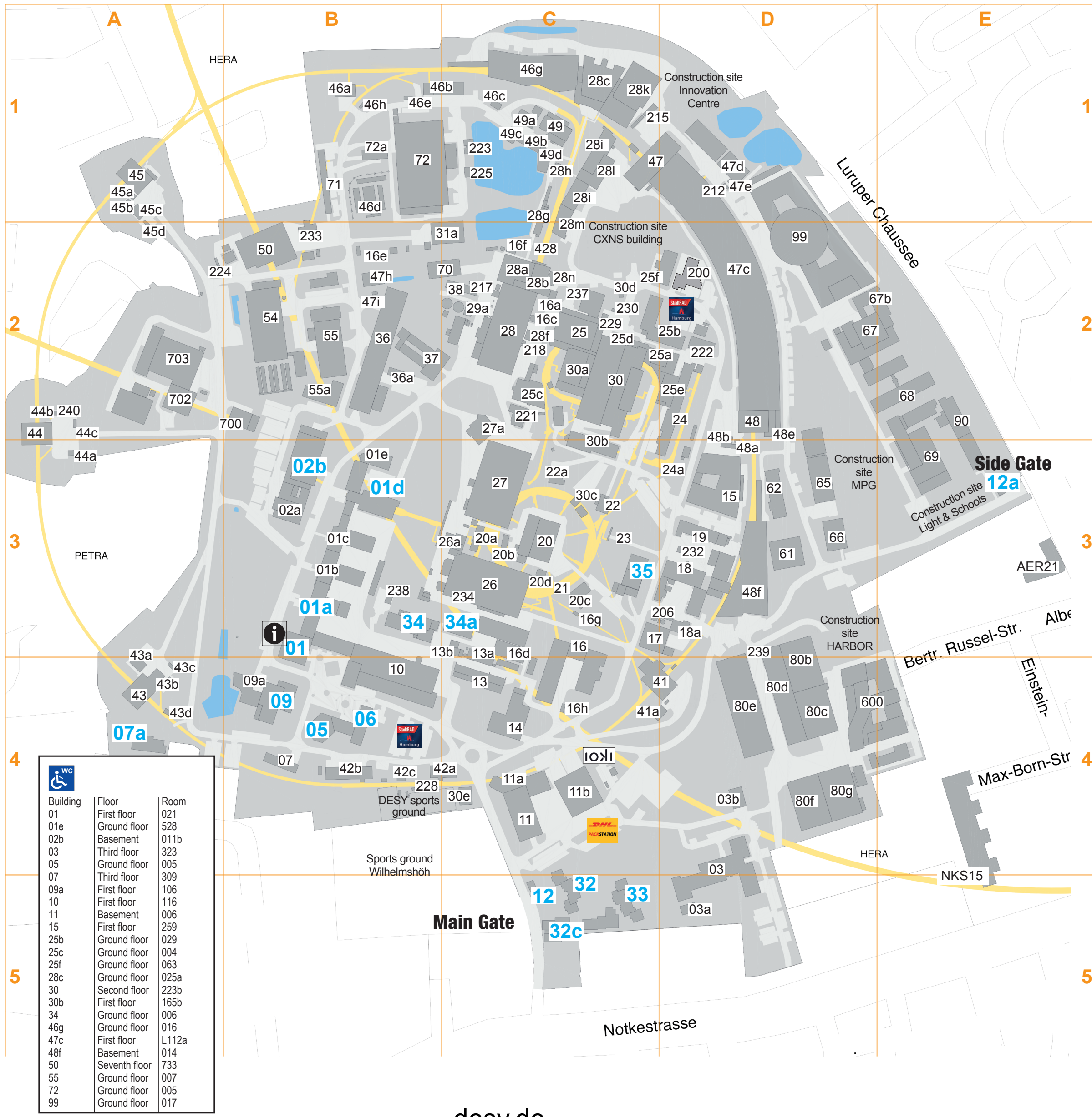
7 Telescope alignment

- Alignment of the telescope in the TB area
- Location: Test beam area 21 (building 27)

8 Multiple scattering

- Material budget imaging
- Location: Test beam area 21 (building 27)

Laboratory 1	01-01e	(B3)
Directorate	01	(B3)
Press and public relations	01	(B3)
Company medical officer	01a	(B3)
Seminar room 3-5	01b	(B3)
Library	01d	(B3)
Laboratory 2a, Theory	02a	(B3)
Computer centre, UCO	02b	(B3)
Radiation Protection D3	03	(D4)
Storage building	03b	(D4)
Auditorium (DESY), entrance building 6	05	(B4)
Administration building	06	(B4)
Post, Guest services	06	(B4)
Administration building	07	(B4)
Guest house 8	07a	(A4)
Canteen, cafeteria, bank	09, 09a	(B4)
Workshop	10	(B4)
Purchasing department	11	(C4)
Central warehouse	11a	(C4)
Social counselling / works council	11a	(C4)
Gate lodge Notkestraße (main gate)	12	(C5)
Gate lodge Luruper Chaussee (side gate)	12a	(E3)
Gas service	13a+b	(C3)
Vacuum laboratory	14	(C4)
CSSB	15	(D3)
MKK / Power station	16	(C3)
Heating plant	17	(C3)
Site service yard	18,18a	(D3)
Carpenters' building	19	(D3)
Synchrotron building	20	(C3)
Power house DESY	20c	(C3)
LAOLA	22	(C3)
Laboratory of the Universities of Hamburg and Lübeck	22a	(C3)
Accelerator development	23	(C3)
LINAC II	24	(D3)
PIA	24a	(D3)
FS experimental hall	25	(C2)
Office and laboratory building EMBL	25a	(C2)
FS office and laboratory 1	25b	(D2)
Detector laboratory	25c	(C2)
FS office and laboratory 4	25d	(C2)
FS office and laboratory 5+2	25e,f	(D2)
Experimental hall I / LINAC III	26	(C3)
DESY testbeam / experimental hall II	27	(C3)
Testing area	27a	(C2)
Experimental hall III	28,28a	(C2)
FLASH tunnel	428	(C1)
FLASH experimental hall „Albert Einstein“	28c	(C1)
FLASH experimental hall „Kai Siegbahn“	28k	(C1)
FLASH2 undulator building	28i	(C1)
FLASH laser hut	28g	(C1)
Water treatment plant	29a	(C2)
Accelerator control room (BKR) / SINBAD	30	(C2)
Supplying hall	30a	(C2)
Accelerator operation building	30b	(C3)
ARGUS detector	30e	(C4)
Accelerator components building	31a	(C2)
Guest house 2	32	(C5)
Kindergarten	32c	(C5)
Guest house 3	33	(C5)
Training area	34	(B3)
School lab physik.begreifen	34a	(C3)
Safety group / SAVE	35	(C3)
communication engeneering	35	



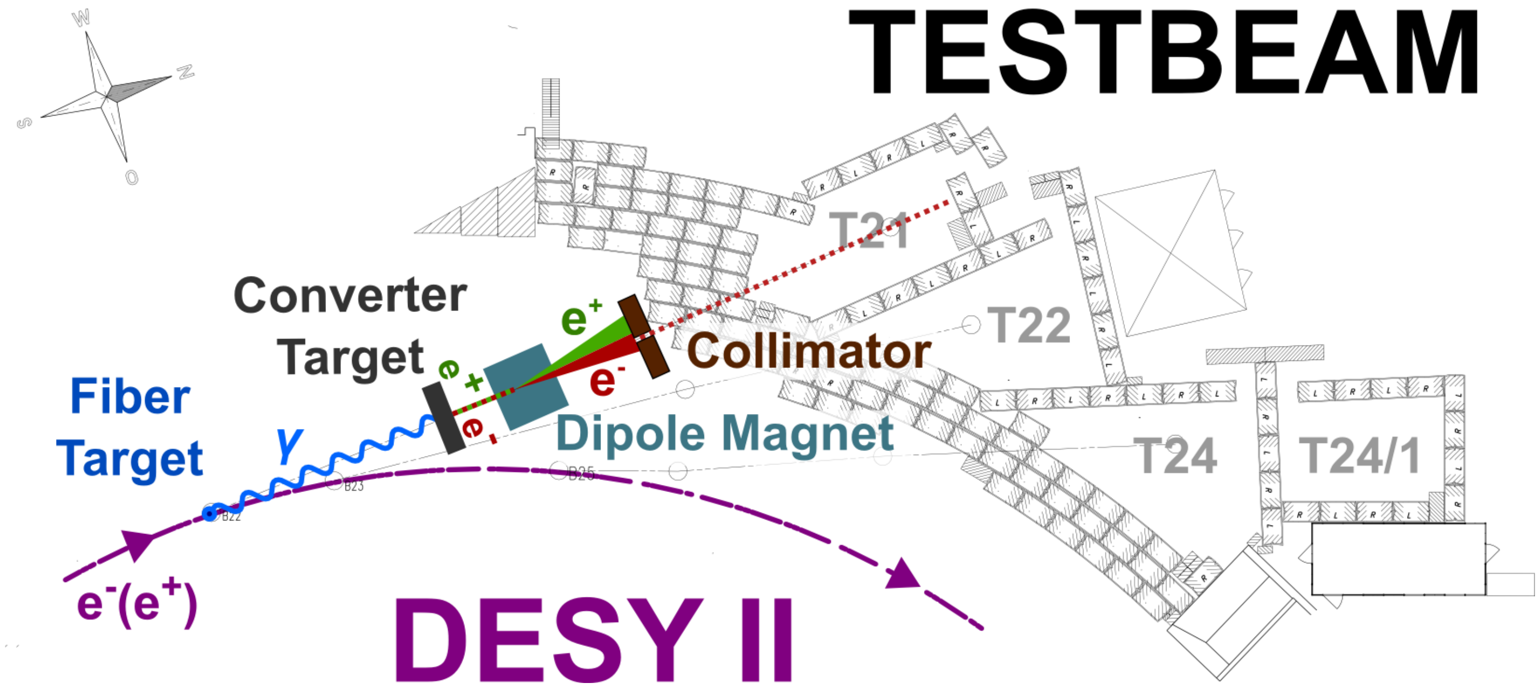
desy.de

DESY II testbeam area

DESY II is an electron positron synchrotron (292.8 m circumference), it is mainly an injector for DORIS and PETRA

Desy II testbeam area

- electron positron beam are converted to bremsstrahlung from carbon fibre targets. There are up to 1000 particles per cm² and energies from 1 to 6 GeV, an energy spread of ~5% and a divergence of ~1mrad.
- Three individual beam lines: user can control the area interlock, shutter, momentum and collimation



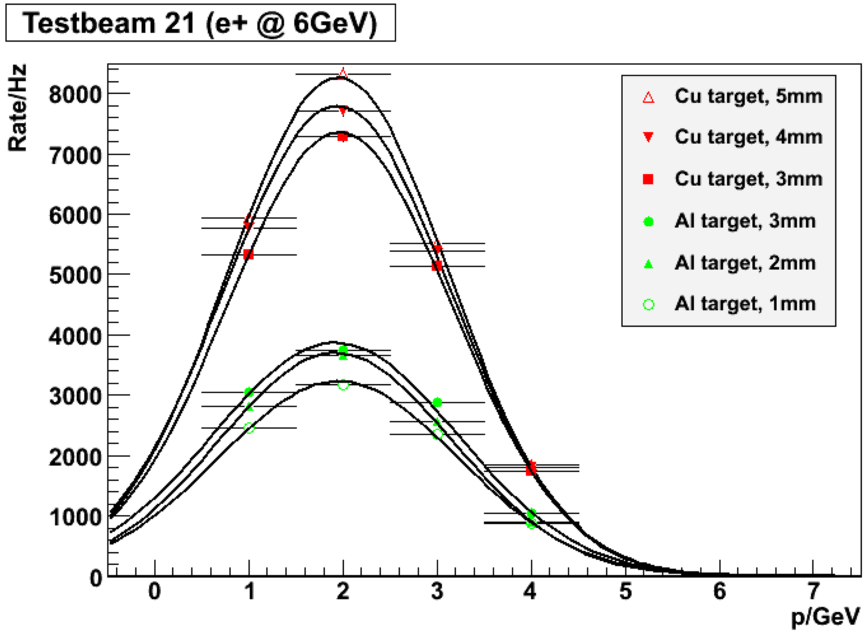
https://particle-physics.desy.de/test_beams_at_desy/beam_generation/index_ger.html

Test beam area

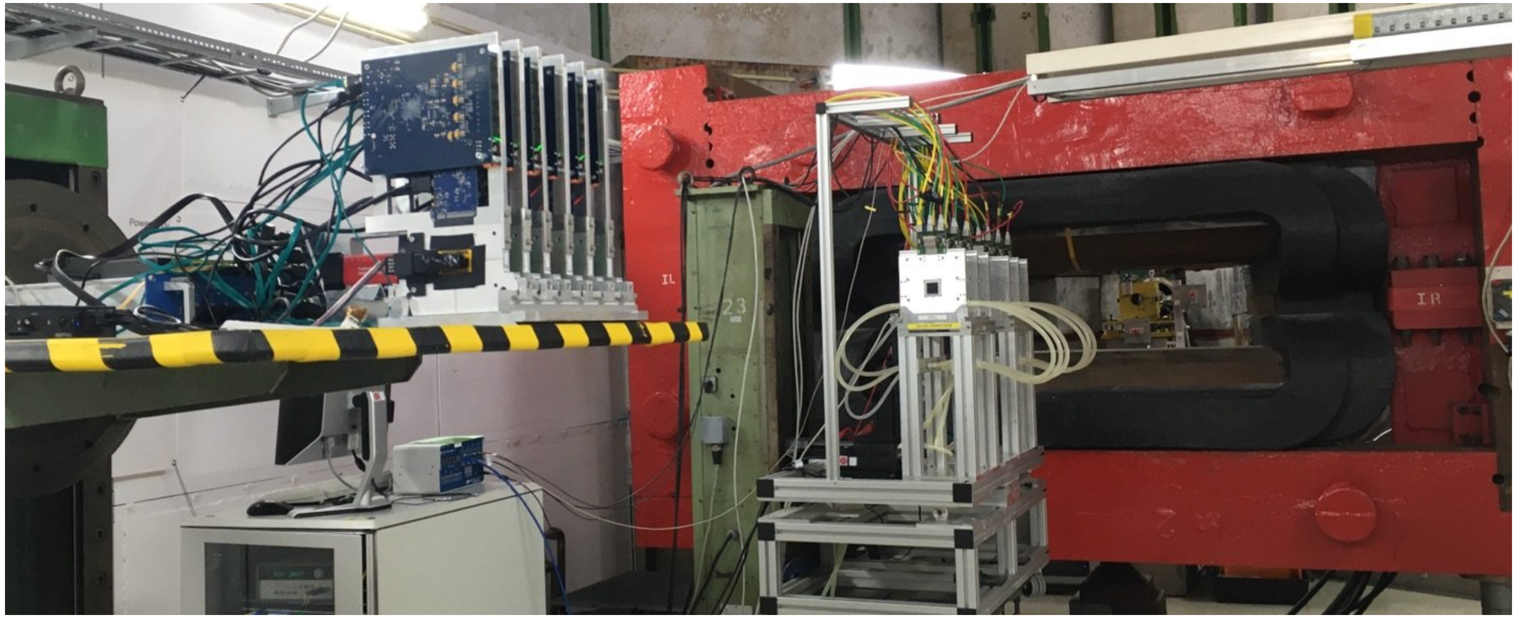
Test beam 21

Energy of the beam

- The beam by DESY II are electrons with energy ranging from 1 GeV to 6 GeV
- The particle rate increase or decrease with the energy of the beam
- Including a collimator will decrease the beam rate



https://particle-physics.desy.de/e252106/e252106/e252334

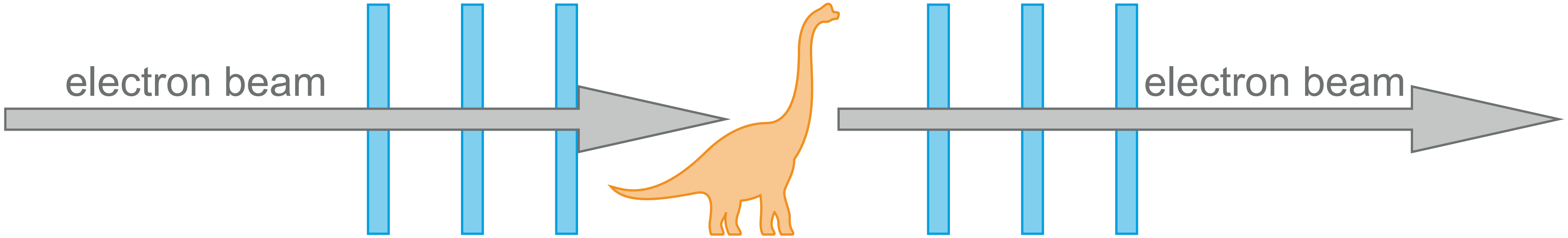


Telescopes: how to test the beam

TB21 is currently populated with two telescopes

Telescopes

- Technically they are not telescopes, but hodoscopes:
  - wikipedia: A **hodoscope** (from the Greek "hodos" for way or path, and "skopos" an observer) is an instrument used in particle detectors to detect passing charged particles and determine their trajectories. Hodoscopes are characterized by being made up of many segments; the combination of which segments record a detection is then used to infer where the particle passed through hodoscope.
  - We know we are wrong, we will call them telescopes anyway.
- Six silicon planes designed for tracking high energy particles and reconstruct their path. In the middle you put a device under test which you want to study its performance.
- scintillators and TLU (trigger logic unit) helps to perform the reconstruction of the beam path, and a software designed for this purpose (eudaq2).

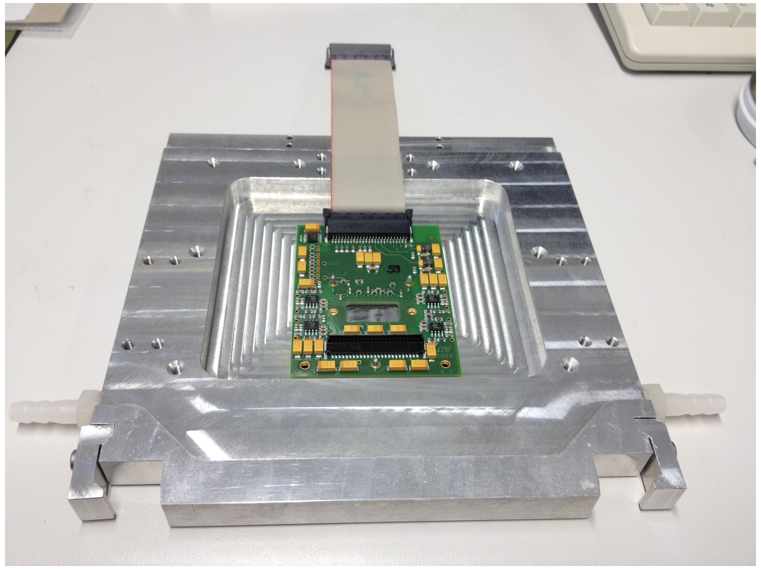


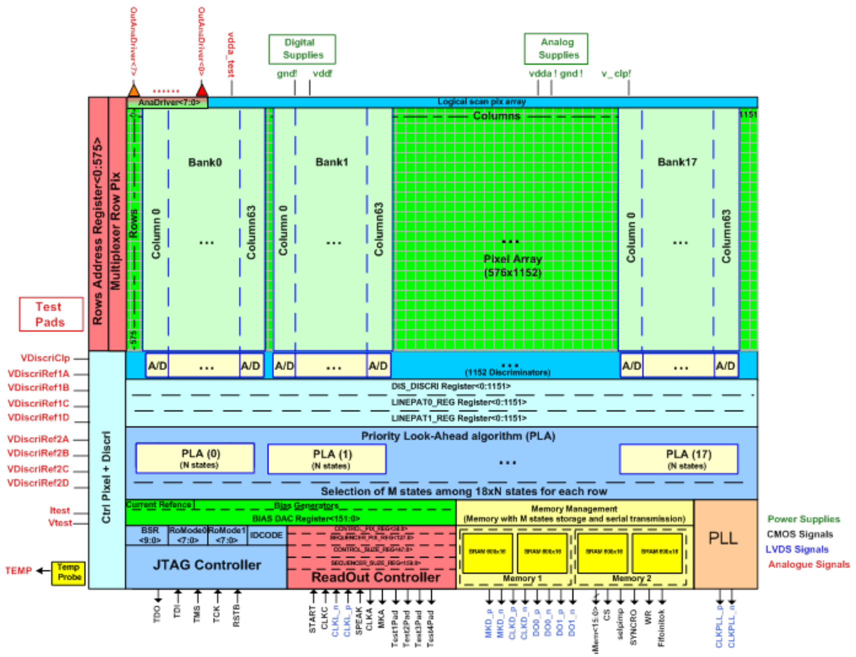
Sensors

Mimosa 26 sensors

Silicon sensor

- Mimosa is a Monolithic Active Pixel Sensor (MAPS) with fast binary readout.
- 576 by 1152 pixels, 18.5 μm pitch. Active area of 10.6 x 21.2 mm2. It can have active thicknesses between 10, 15 and 20 μm. Total thickness is reduced to 50 μm to diminish the impact on the material budget.
- The data stream of the binary pixel information is zero suppressed on the sensor chip. A sensor is read-out in a continuous rolling shutter mode, columns in parallel and row by row. One readout cycle takes 115.2 μs.
- They need to be powered at 8 V and JTAGing with the NI software.





http://www.iphc.cnrs.fr/IMG/pdf/M26_UserManual_light.pdf

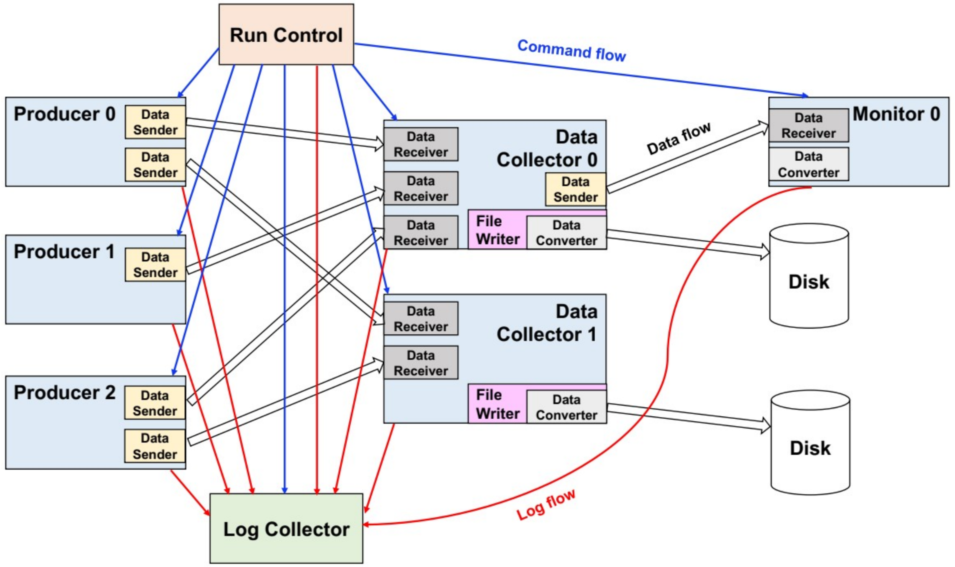
Software for data acquisition and reconstruction

Eudet, Eudaq2, EUtelescope, corryvreckan

Data acquisition

Eudaq2

- Run control of the telescope planes, TLU and DUT with a GUI (online monitoring) for checking the data



https://indico.cern.ch/event/813822/contributions/3652522/attachments/1977289/3291394/bttb8_tele_status.pdf

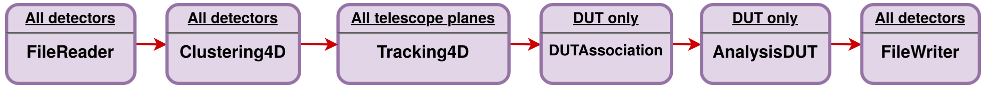
Reconstruction

EUTelescope

- GBL implemented
- All functionalities working

Corryvreckan

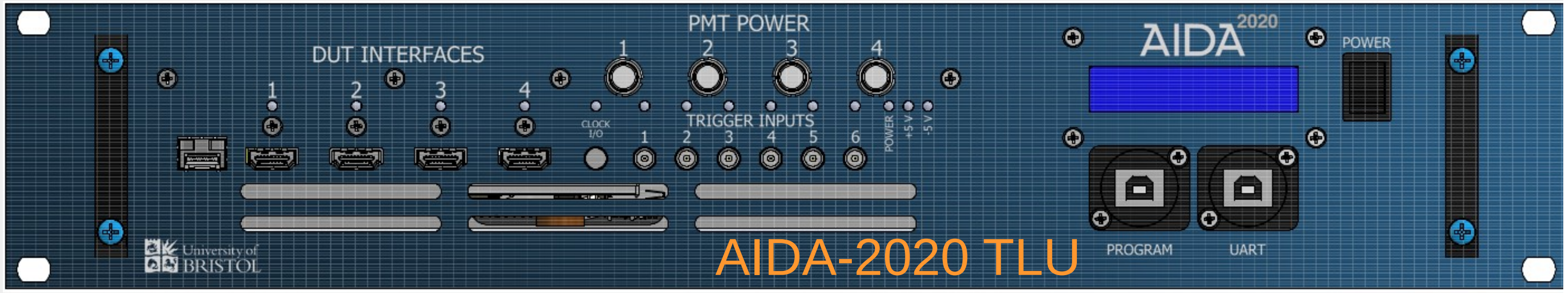
- Software in development to reconstruct
  - Preliminary GBL
  - on line monitoring
  - Has a modular approach



https://indico.cern.ch/event/813822/contributions/3648326/attachments/1974941/3289786/2020-01-28_BTTB8_Corryvreckan_Talk_JensKroeger.pdf

TLU (Trigger Logic Unit)

Why do we need a TLU while the sensors are autotriggered? (rolling shutter)



- 6 RJ-45 DUT interfaces
- 4 trigger inputs with manual threshold
- Supports EUDET modes
- USB connection
- Running out of spares

→

- 4 HDMI DUT interfaces
- 6 trigger inputs with threshold DAC
- Supports various modes
- Can be run in a network
- Allows for trigger rates of up to 1 MHz
- Available as table-top and rack version

https://indico.cern.ch/event/813822/contributions/3652522/attachments/1977289/3291394/bttb8_tele_status.pdf

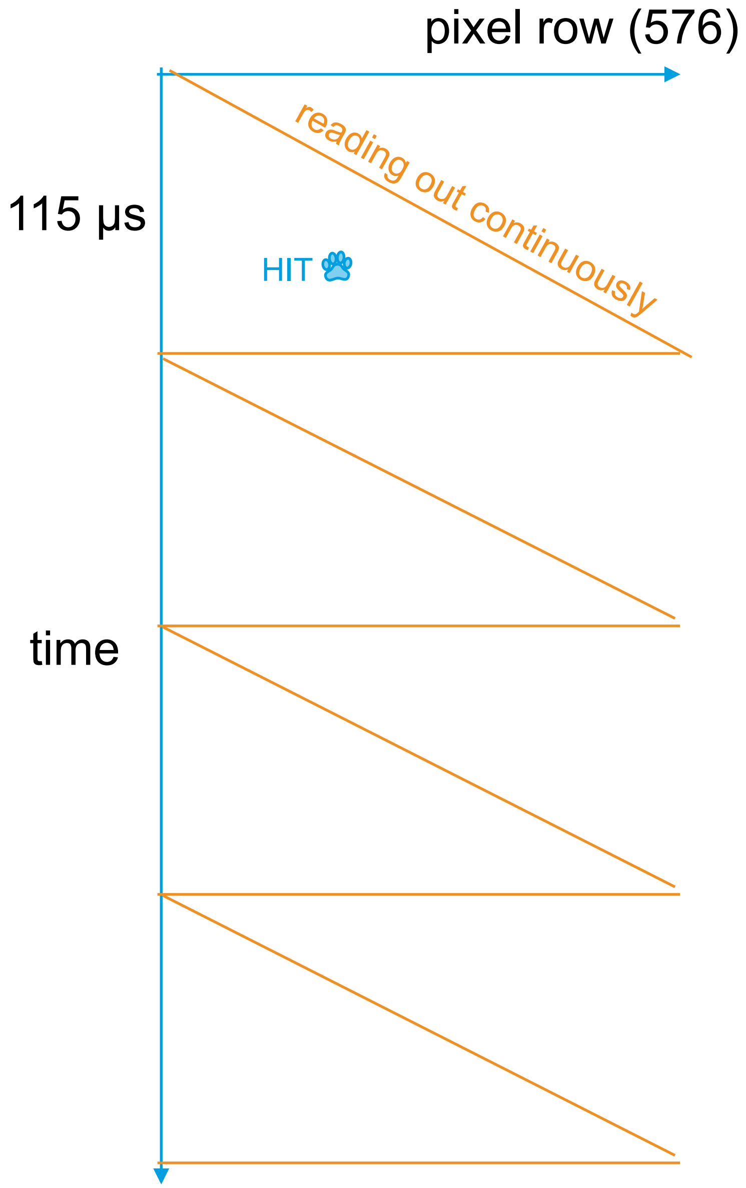
Tasks

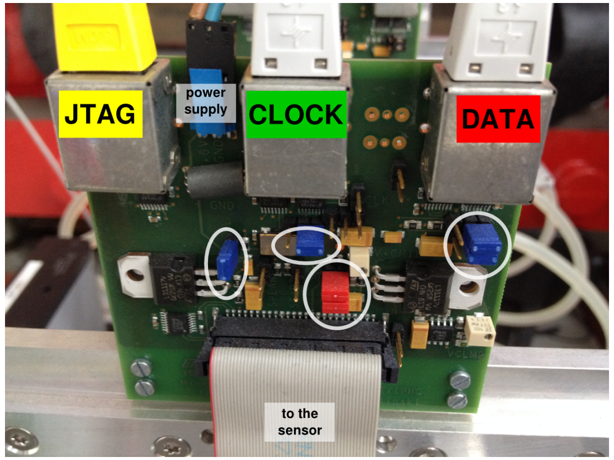
Task 5: TDAQ performance

eLAB4

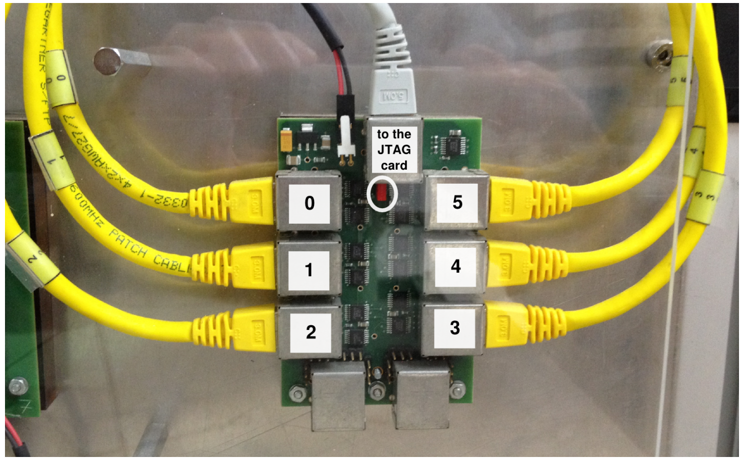
TDAQ (Trigger data acquisition) performance

- Telescopes here in DESY and in CERN (also FNAL and some other research centres) use Mimosa26 sensors.
- The tracking detectors have some similar behaviour, they are read out in continuous mode (rolling shutter)
- When the hit is after the shutter has passed, it will be taken into the next readout, thus that is the reason two consecutive clock cycles are taken





aux board



JTAG distribution board

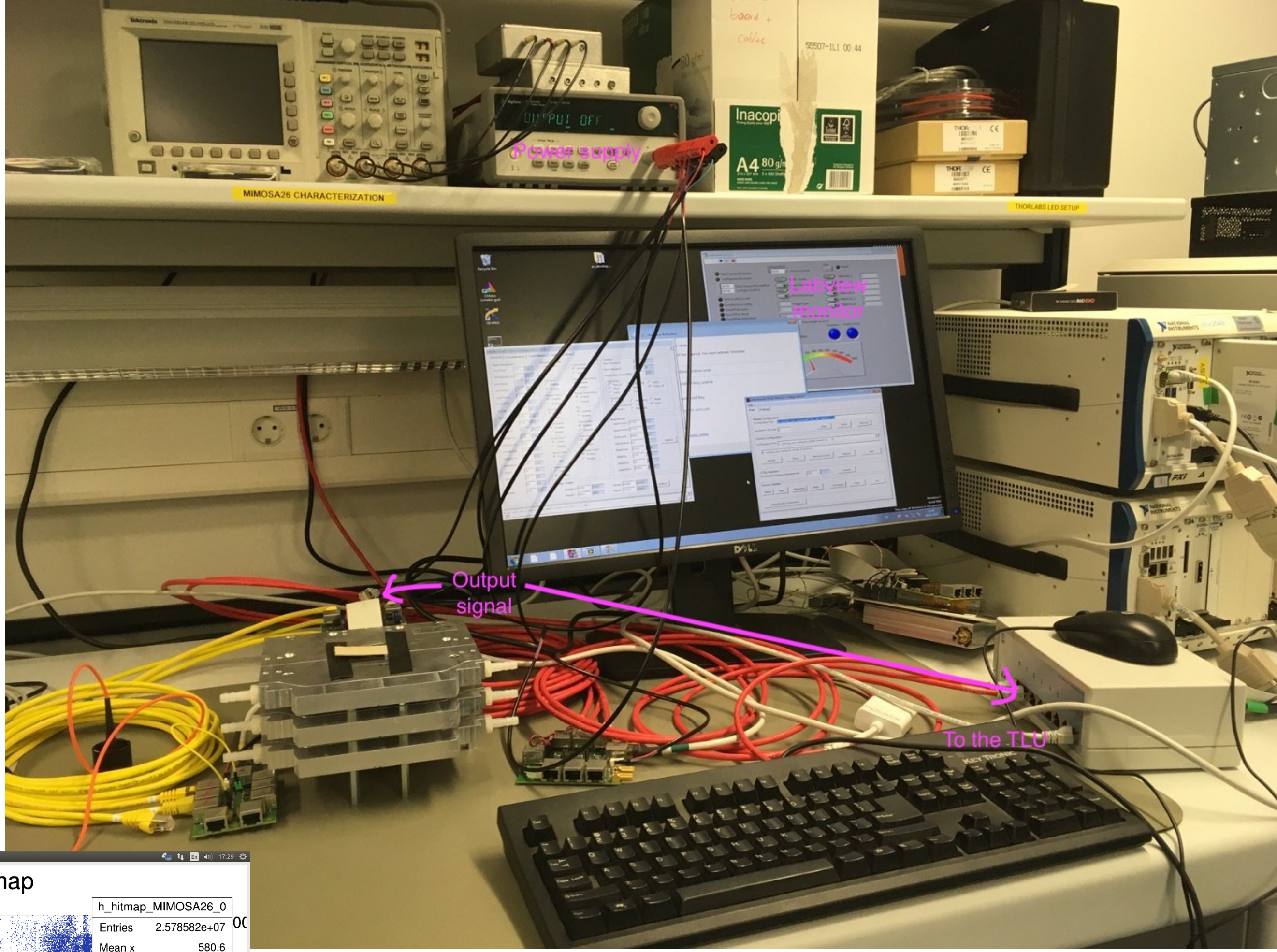
https://telescopes.desy.de/Hardware#Mimosa26_sensor

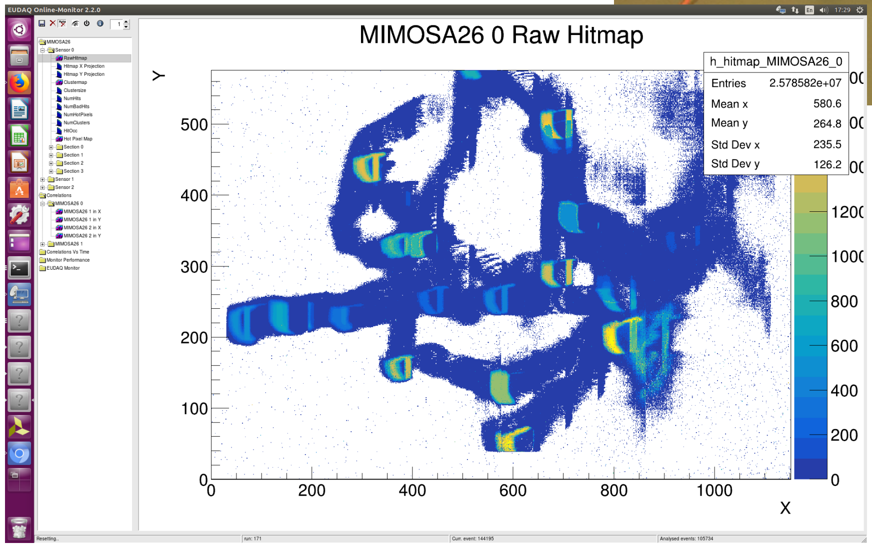
Task 5: TDAQ performance

eLAB4

TDAQ (Trigger data acquisition) performance

- In this task will study the Mimosa26 in detail
  - Starting in observing the signal it emit:
    - JTAGing and powering the sensor
    - observing it in an oscilloscope
  - Work in autotrigger and an external trigger
  - observe the signal created with a LASER

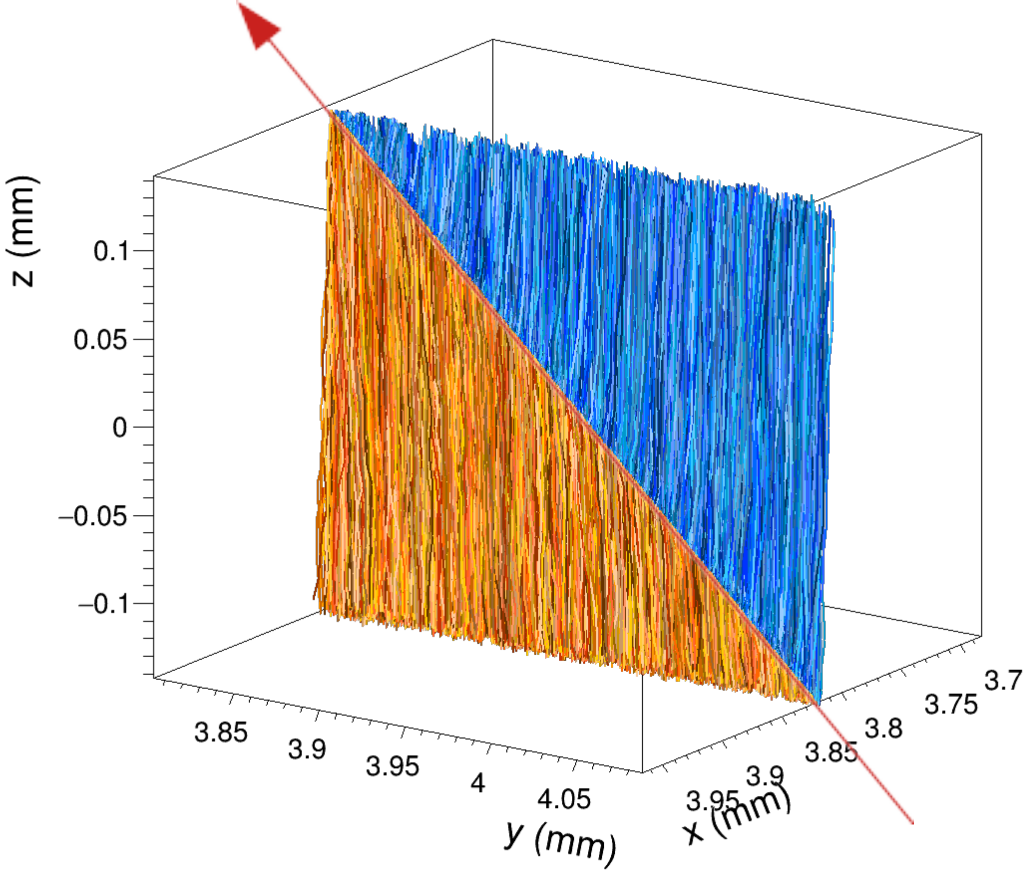




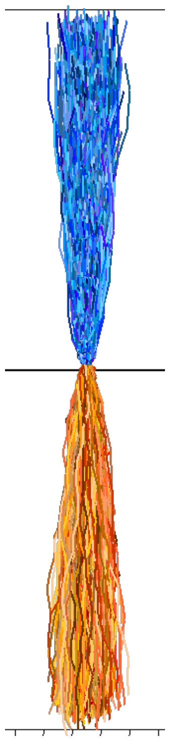
Task 6: Spatial resolution simulation

Allpix²

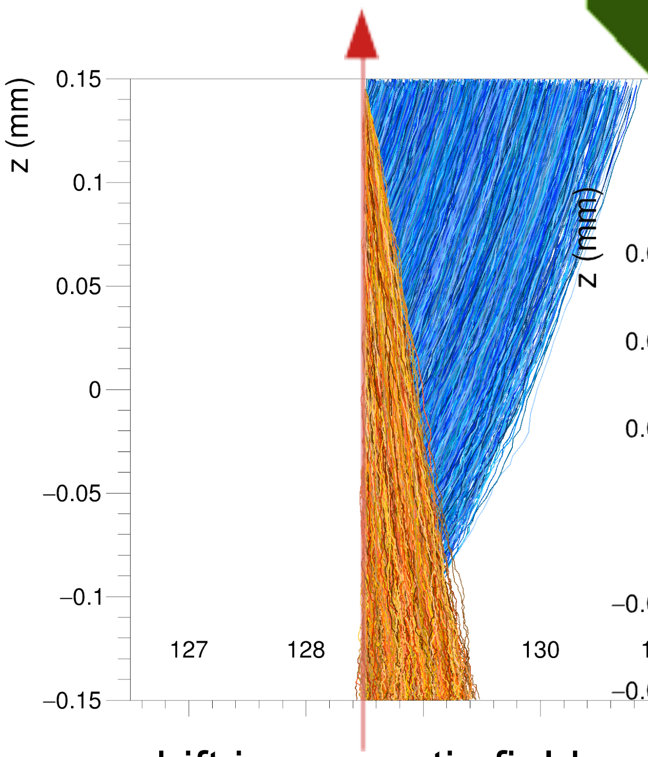
Silicon detector simulation



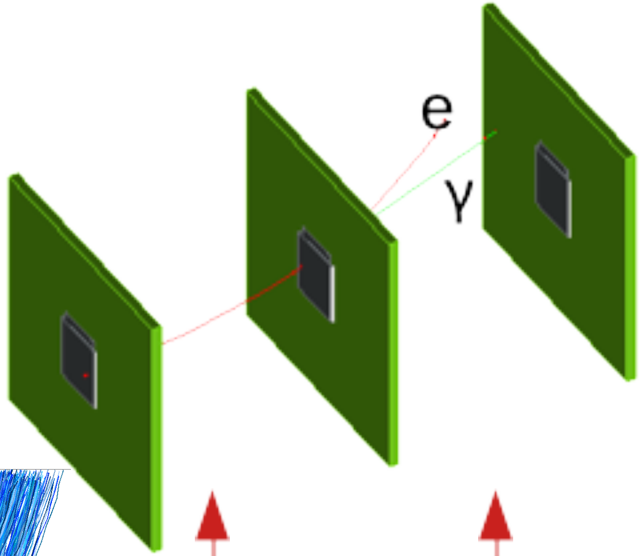
45° angle particle incidence

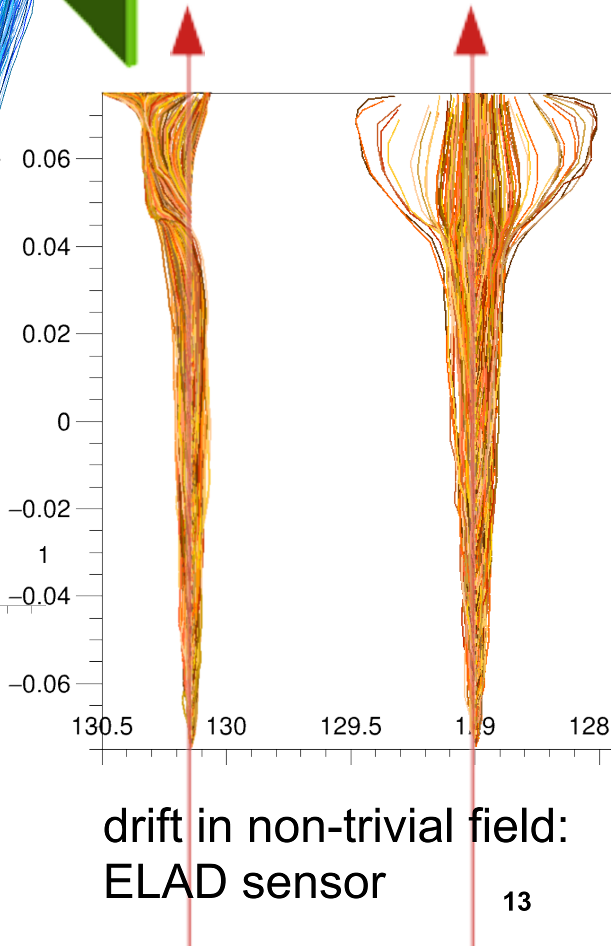


projection along trajectory



drift in magnetic field





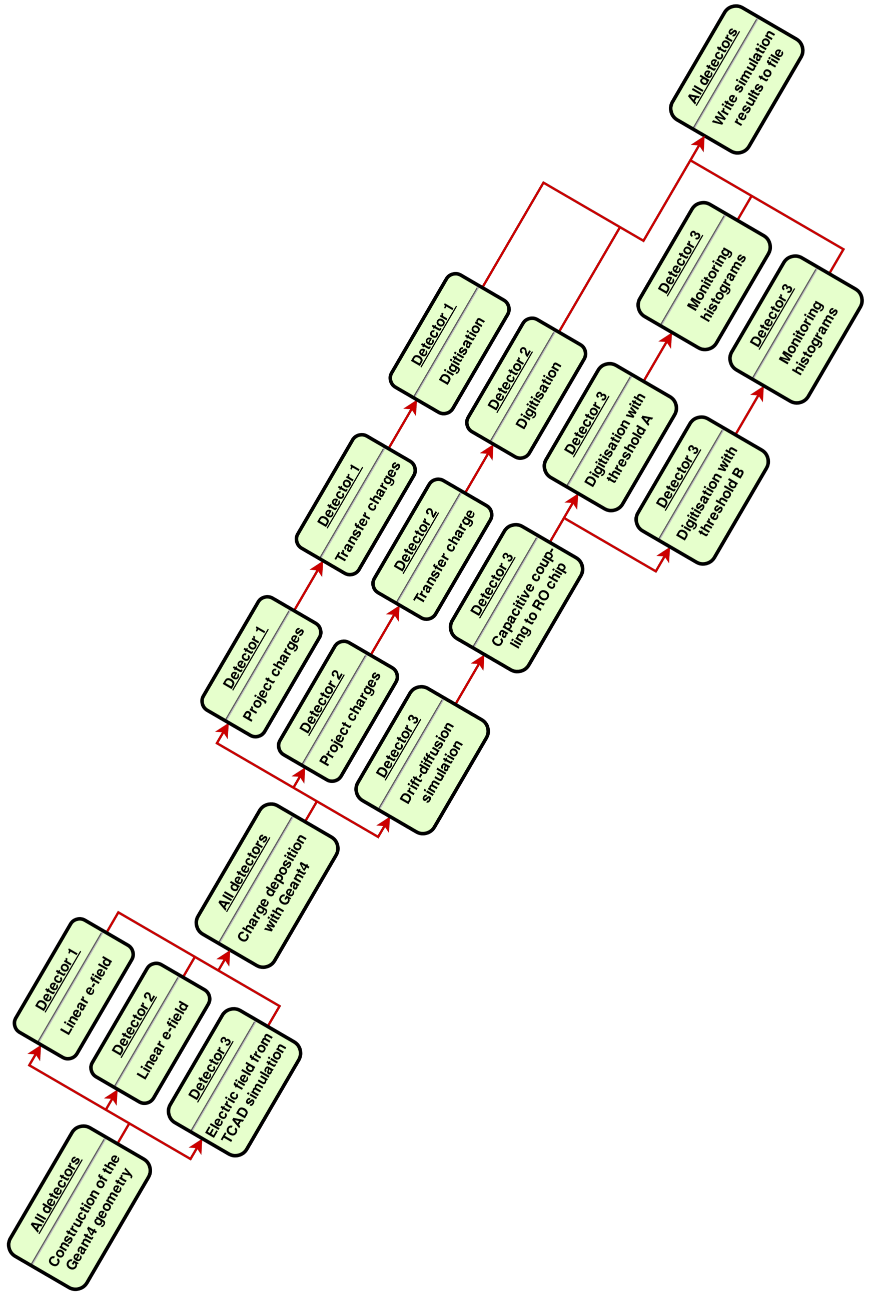
drift in non-trivial field:
ELAD sensor

Task 6: Spatial resolution simulation

Allpix2

Allpix2

- Your equipment:
  - Silicon pixel detector, 150 µm x 10 µm pixel pitch
  - Your own readout architecture
  - A particle beam and a magnet … well, in simulation
- Your task
  - Understand your detector
  - Get optimal spatial resolution!
- Bring your own laptop!!

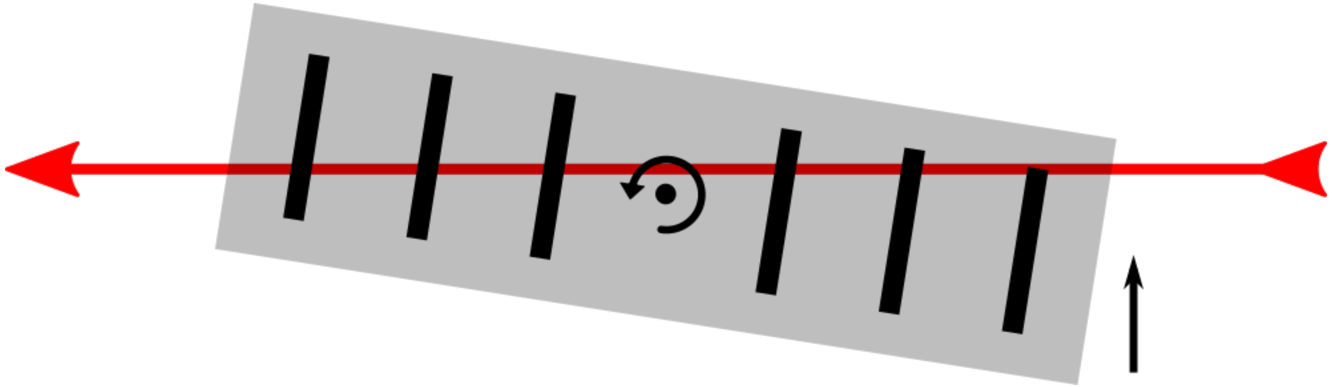


Task 7: Telescope alignment

Test beam area 21

Description

- The telescope is not always perfectly aligned for the measurements. In this tasks we will go through some of the basic steps to put the telescope through the beam without the minimum error.
- Telescope has to be in the beam position as also in the beam track, if it is out of track the software alignment can be very hard or impossible to do.

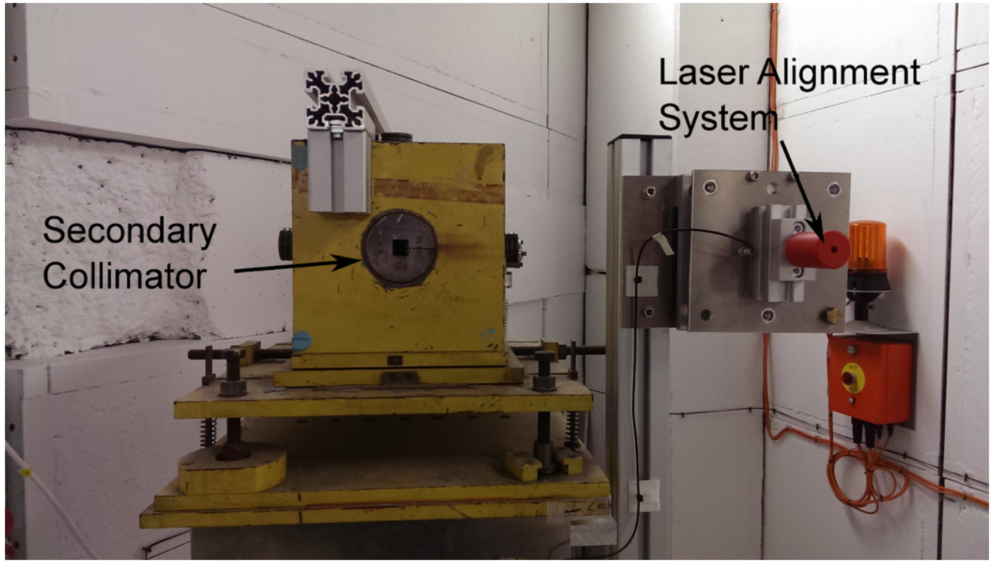


Task 7: Telescope alignment

Test beam area 21

Description

- You will use the mimosa telescope of the test beam area
  - align the stages with the alignment laser
  - observe the data on the online monitoring to see if the telescope is correctly aligned
  - Missalign the rotational axis of the stage, and align it again with the help of the online monitor. Try to convert the distance of the pixels with the rotation in order to access the area less times and disturb the other group task.
- Extra time:
  - Test the telescope with a DUT



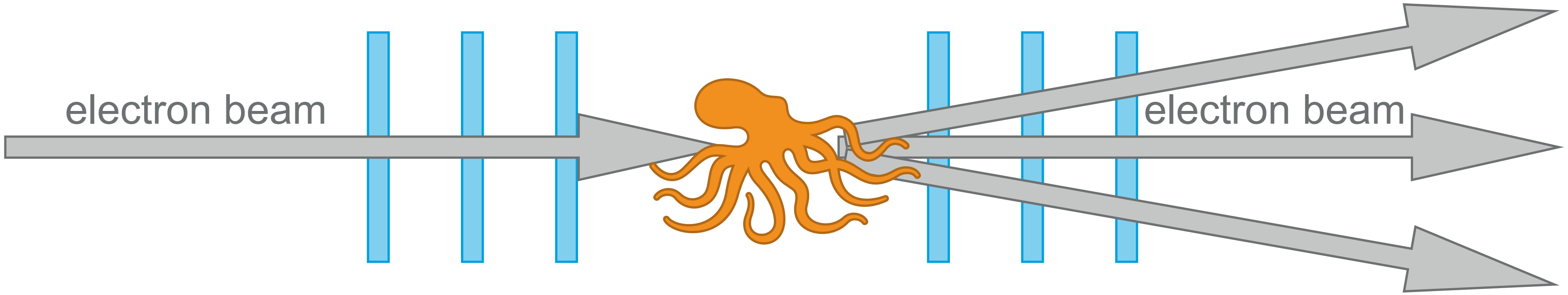
Task 8: Multiple scattering

Material budget Imaging

Highland formula

- A high energetic charged particle traversing matter is stochastically deflected by the atomic nuclei electric field. When it traverses large amount of material, it sum up to an effective deflection, called **Multiple Scattering.** It is described by the Highland formula

$$\Theta_0 = \frac{13.6MeV}{\beta cp} z \sqrt{\frac{l}{X_0}} \left[1 + 0.38 \ln \left(\frac{l}{X_0} \right) \right]$$

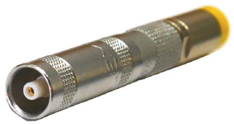


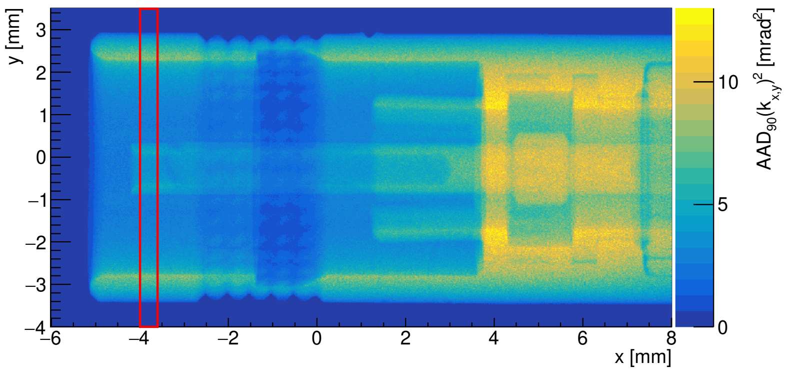
SUT (Sample Under Test) or in this case…. PUT (Pulpo Under Test)

Task 8: Multiple scattering

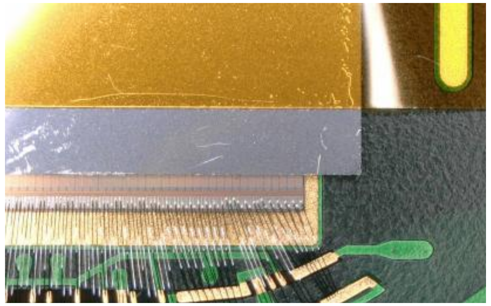
Material budget Imaging

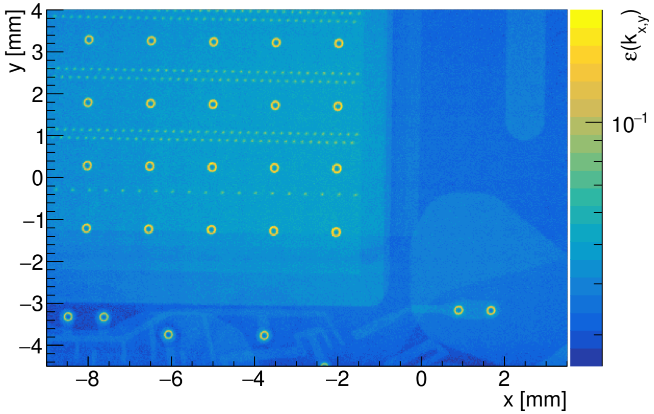
LEMO cable





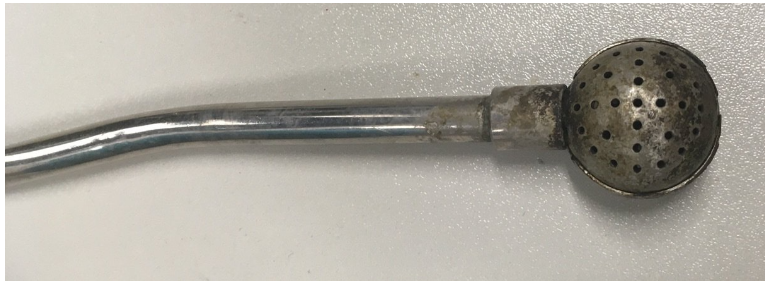
MacroPixel sub assembly detectors (MaPSA) for the PS modules (CMS Outer Tracker)

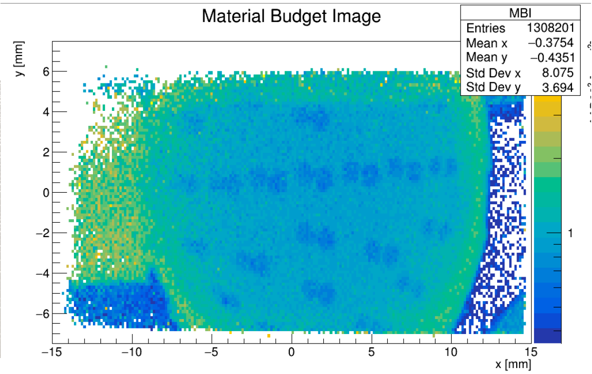


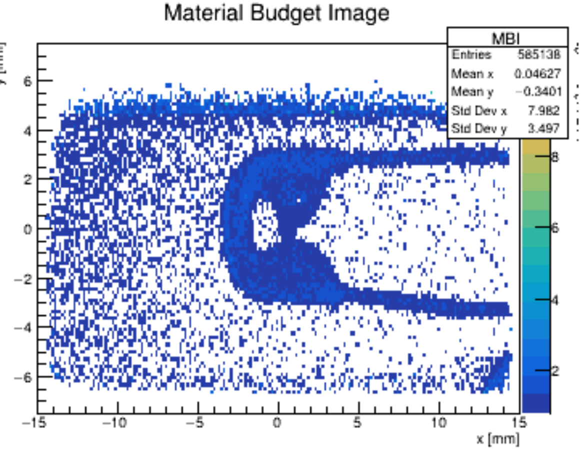


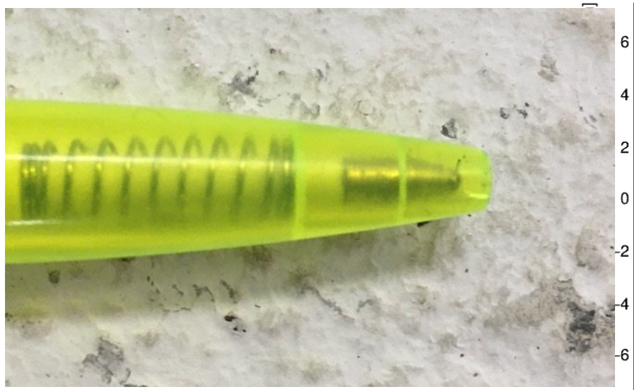
Cool pictures taken from Paul Schütze PhD thesis

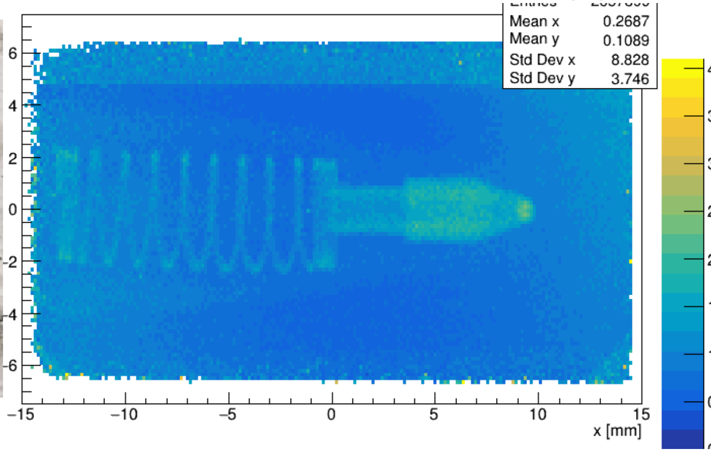
Images taken by other groups











Thank you

Remember to handle the equipment carefully and have fun