One Year Operation of the EUDET CMOS Pixel Telescope

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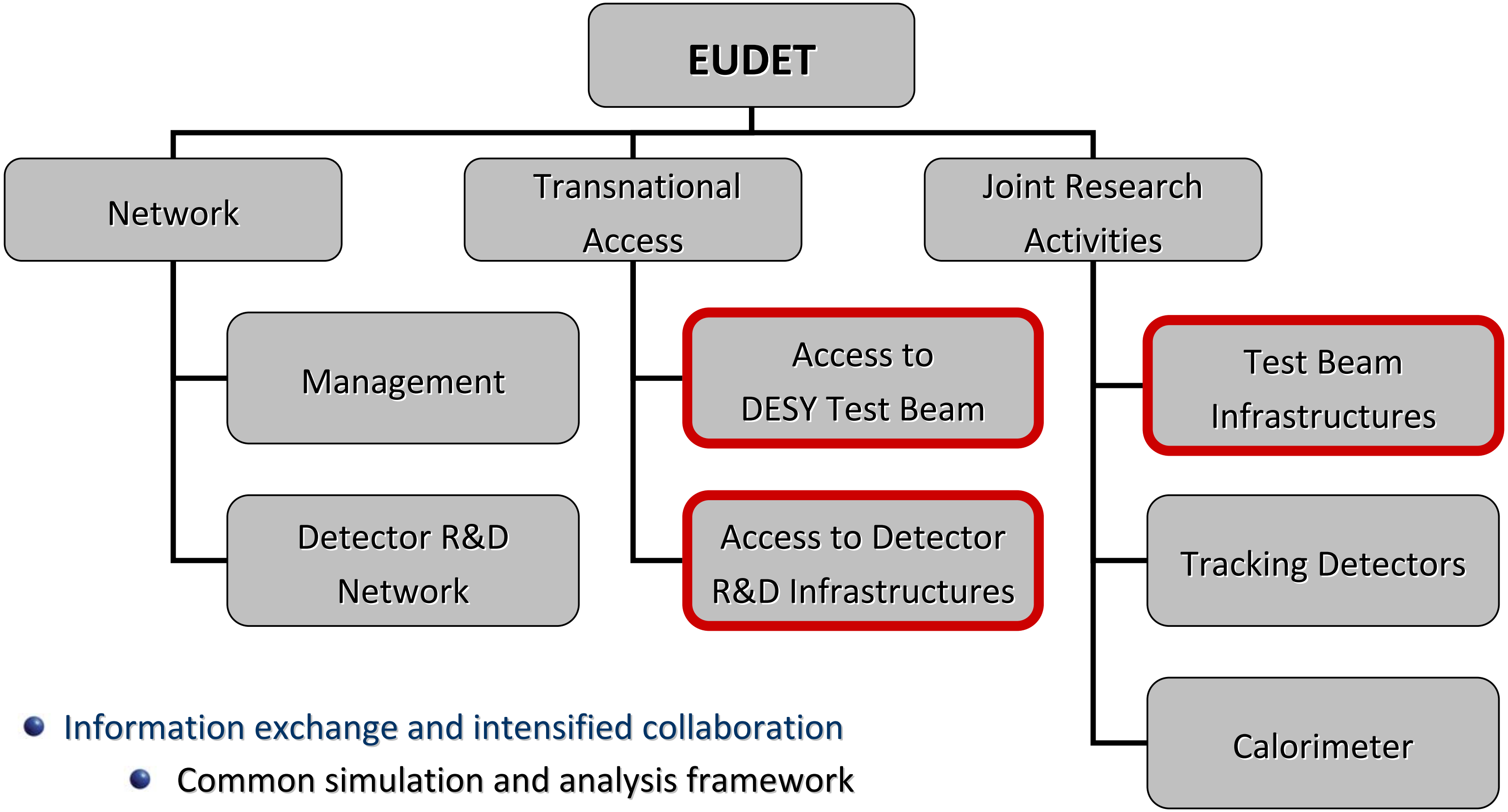
Outline

- The Telescope
- Performance
- Users
- Outlook

LCWS08
November 16-20, 2008
University of Illinois at Chicago

EUDET Structure



- Information exchange and intensified collaboration
  - Common simulation and analysis framework
  - Validation of simulation
  - Deep submicron radiation tolerant electronics

Telescope Requirements & Schedule

Generally applicable:

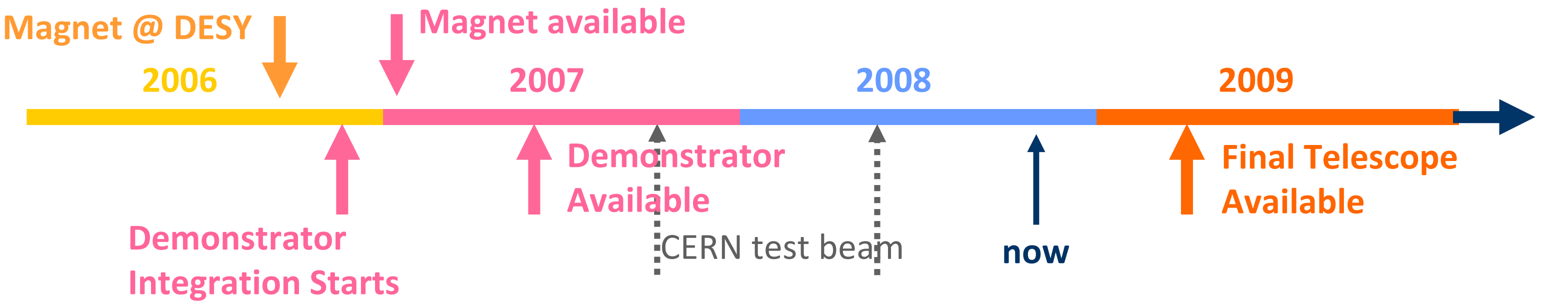
- Main use from small pixel sensors to larger volume tracking devices (TPC)
- Movement of device under test (DUT) to scan larger surface
- Large range of conditions: cooling, positioning, (magnetic field)
- Easy to use: well defined/described interface
- Very high precision: <3 µm precision even at smaller energies

Phase 1: "Demonstrator"

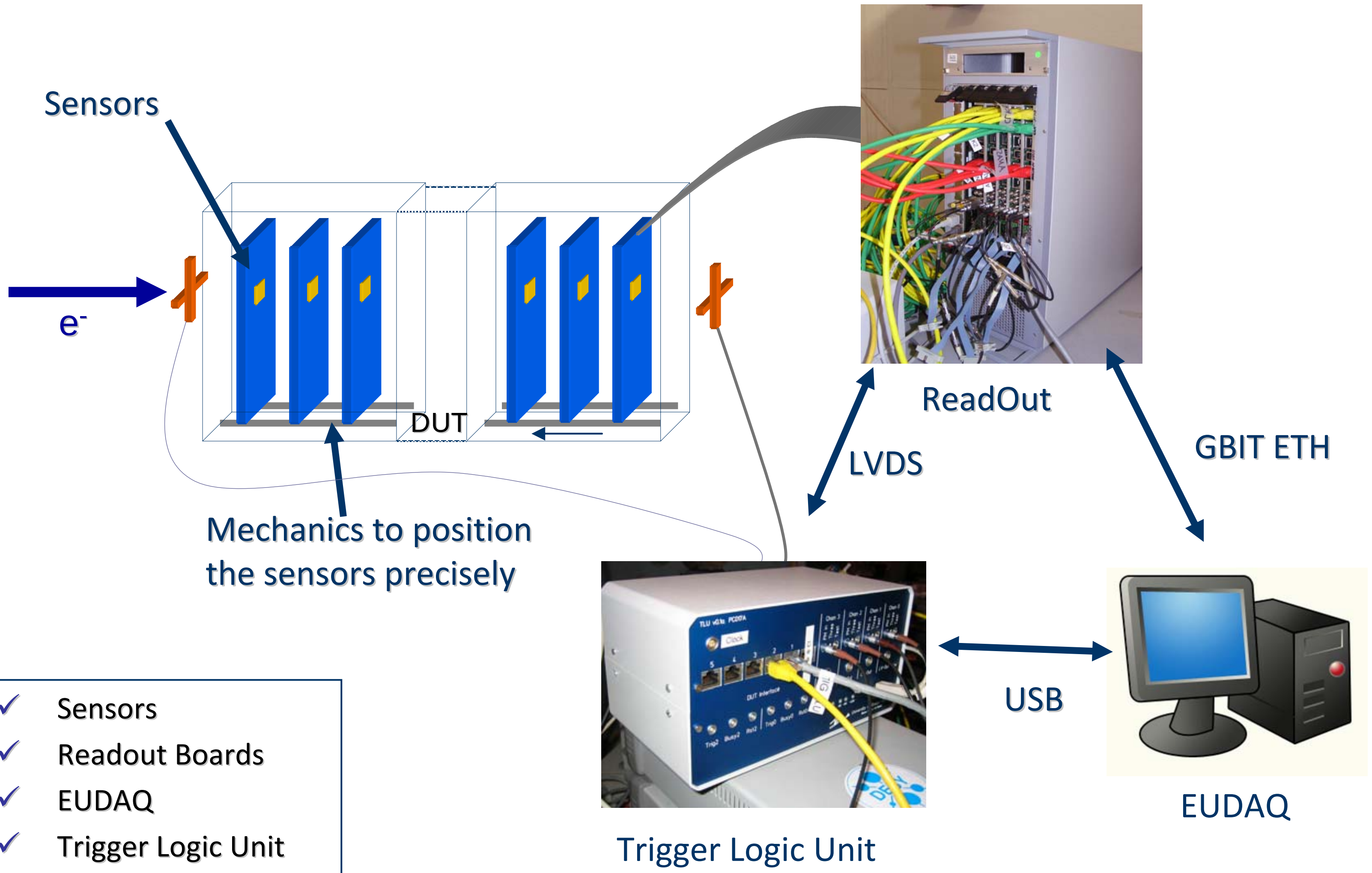
- First test facility will be available quickly for the groups developing pixels
- Use established pixel technology with analogue readout and no data reduction

Phase2: Final telescope

- Use pixel sensor with fully digital readout, integrated Correlated Double Sampling (CDS), and data sparsification
- The beam telescope will be ready early 2009



Telescope Ingredients



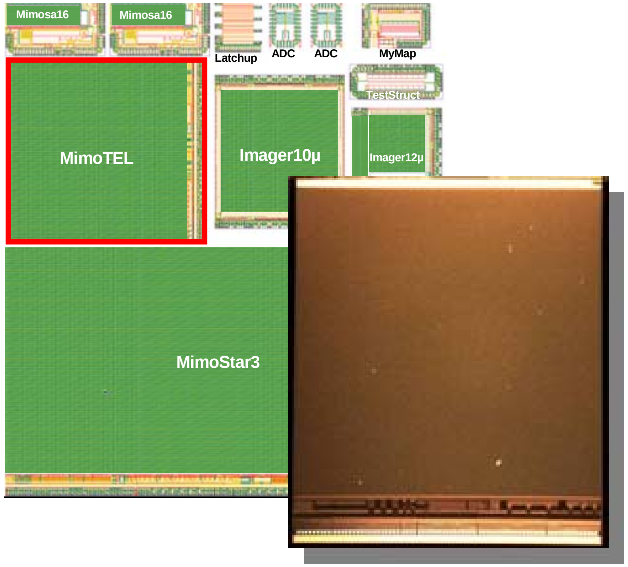
- ✓ Sensors
- ✓ Readout Boards
- ✓ EUDAQ
- ✓ Trigger Logic Unit
- ✓ Mechanics

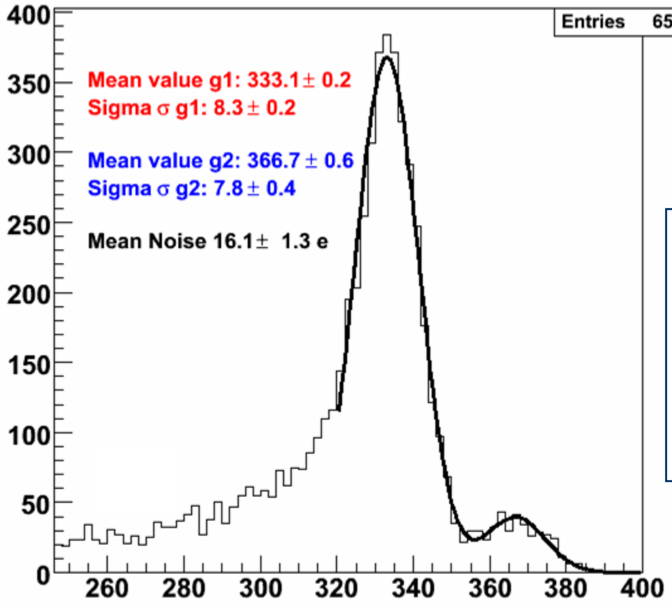
Reference Plane Sensors

IPHC Strasbourg

Demonstrator: MimoTel

- AMS 0.35 OPTO process with 14 and 20µm epitaxial layer
- 4 sub-arrays (64 × 256 pixel)
    - 30 × 30 µm² pitch: active area: 7.7 × 7.7 mm²
    - readout : 1.6 ms (4 analog output nodes at 10 MHz)
    - pixel designed to stand >1 MRad at room temperature
    - Available for community since February 2007





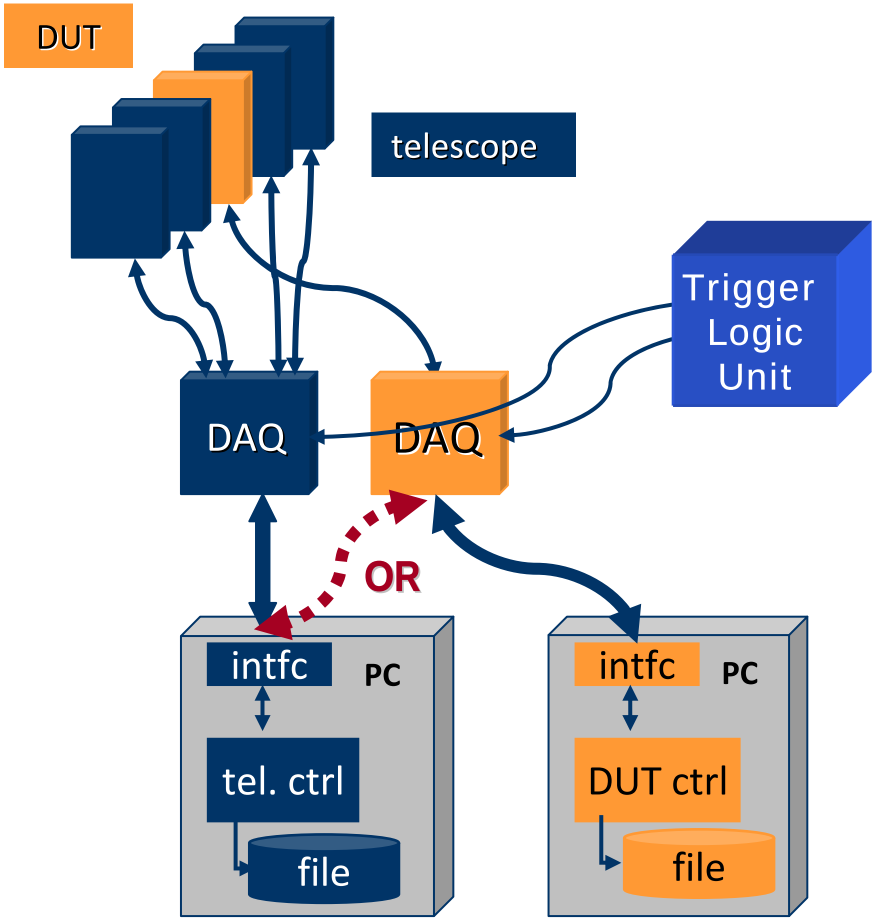
- Very good performances:
    - Noise: ENC ~ 15 electrons @room temperature
    - S/N (MPV) > 22
    - Efficiency ~ 99.9%

DAQ Integration Concept

- How to integrate the DUT hardware with the JRA1 beam telescope?
  - different groups with different detector technologies and different, pre-existing DAQ systems
- Use completely different hardware and DAQ for the DUT and the telescope
- Two levels of integration possible:
  - “easy” solution: at trigger level

  OR

  - **full integration on DAQ software level**



DAQ Hardware

EUDET Data Reduction Board

INFN Ferrara

Mother board built around an ALTERA CycloneII FPGA (clock: 80MHz) and hosting the core resources and Interfaces (VME64X slave, USB2.0, EUDET trigger bus)

NIOS II, 32 bit “soft” microcontr. (40Mz) implemented for

- on board diagnostics
- on-line calculation of pixel pedestal and noise
- remote configuration of the FPGA via RS-232, VME, USB2.0

Zero Suppressed readout to minimize the readout dead-time while in normal data taking.

Non Zero Suppressed readout of multiple frames for debugging or off-line pedestal and noise calculations

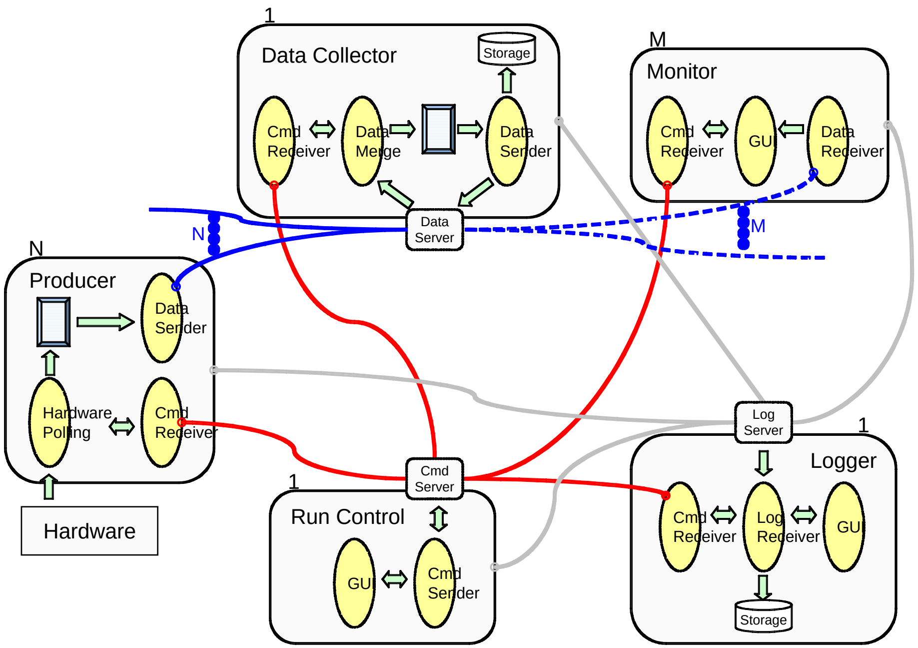
Trigger Logic Unit

Bristol Univ.

- Two handshake modes
  - Simple handshake
  - Trigger data handshake
- Timestamp and event-number via USB
- Available interfaces: LVDS via RJ45, NIM and TTL via Lemo
- Inputs for four trigger signals
- Internal trigger mode for testing
- Low voltage power supply for PMTs

And software-wise

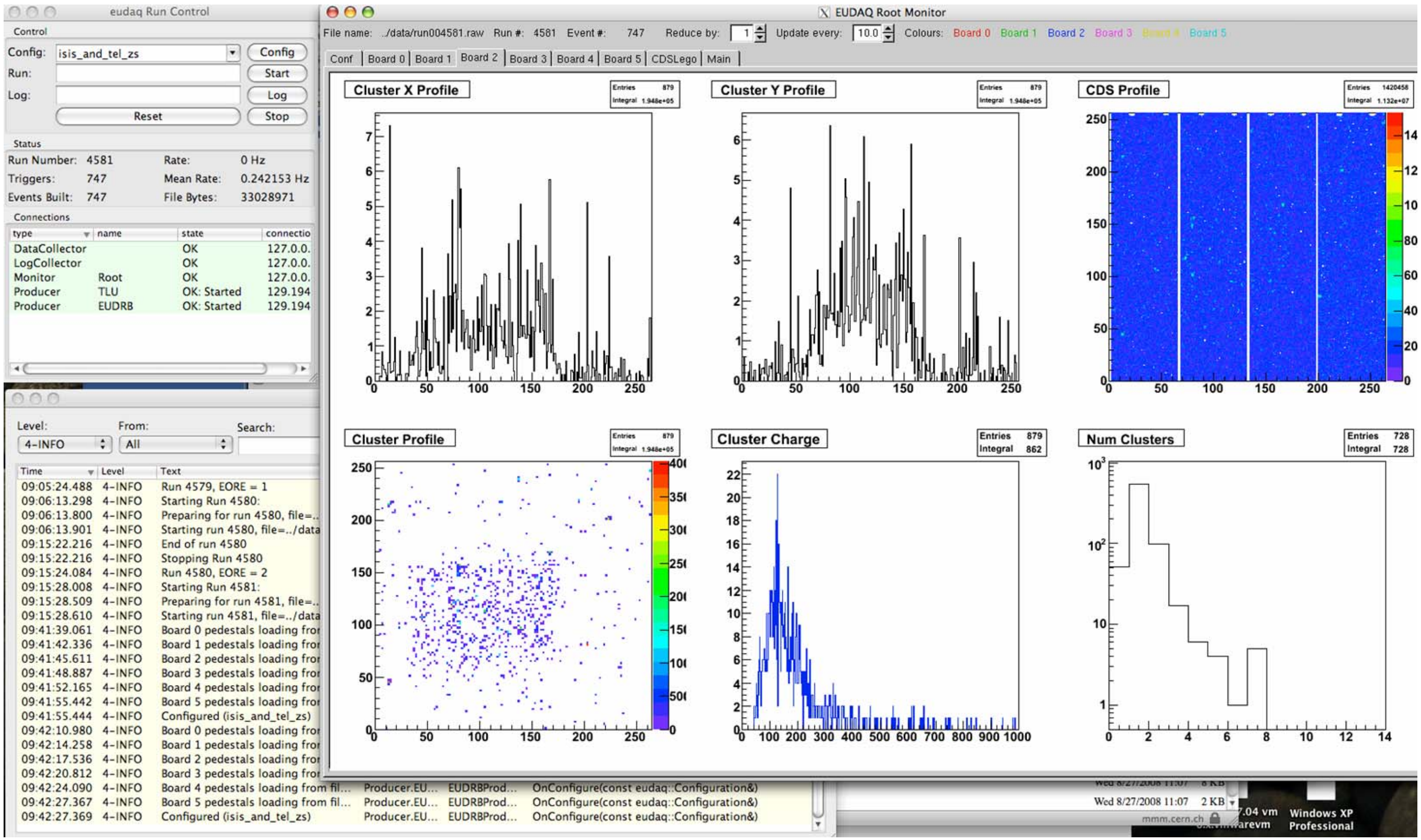
- Platform independant (MacOSX, Linux, Windows)
  - Object oriented, distributed and multithreaded
  - Highly modular, but light-weight
  - DAQ Software is divided into many
- parallel tasks:
  - **RunControl** to steer the task
  - several **Producer** tasks read the hardware
  - one **DataCollector** task bundles events, writes to file and sends
- subsets for monitoring
  - Several Online - Monitoring tasks
  - Logger task allows to see what is going on



HTTP://PROJECTS.HEPFORGE.ORG/EUDAQ/

We help you with the integration of your DAQ!

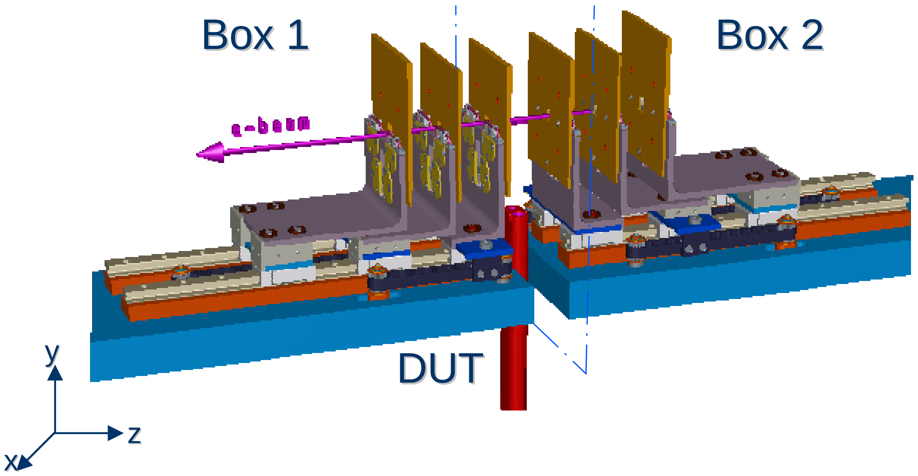
EUDAQ Run Control

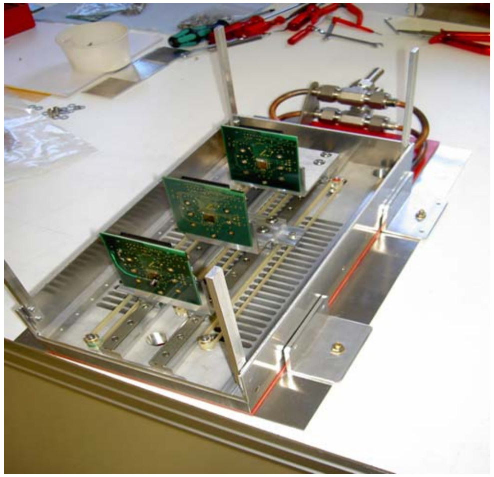


- Provides powerful online monitoring

Telescope Mechanics Concept

DESY Hamburg

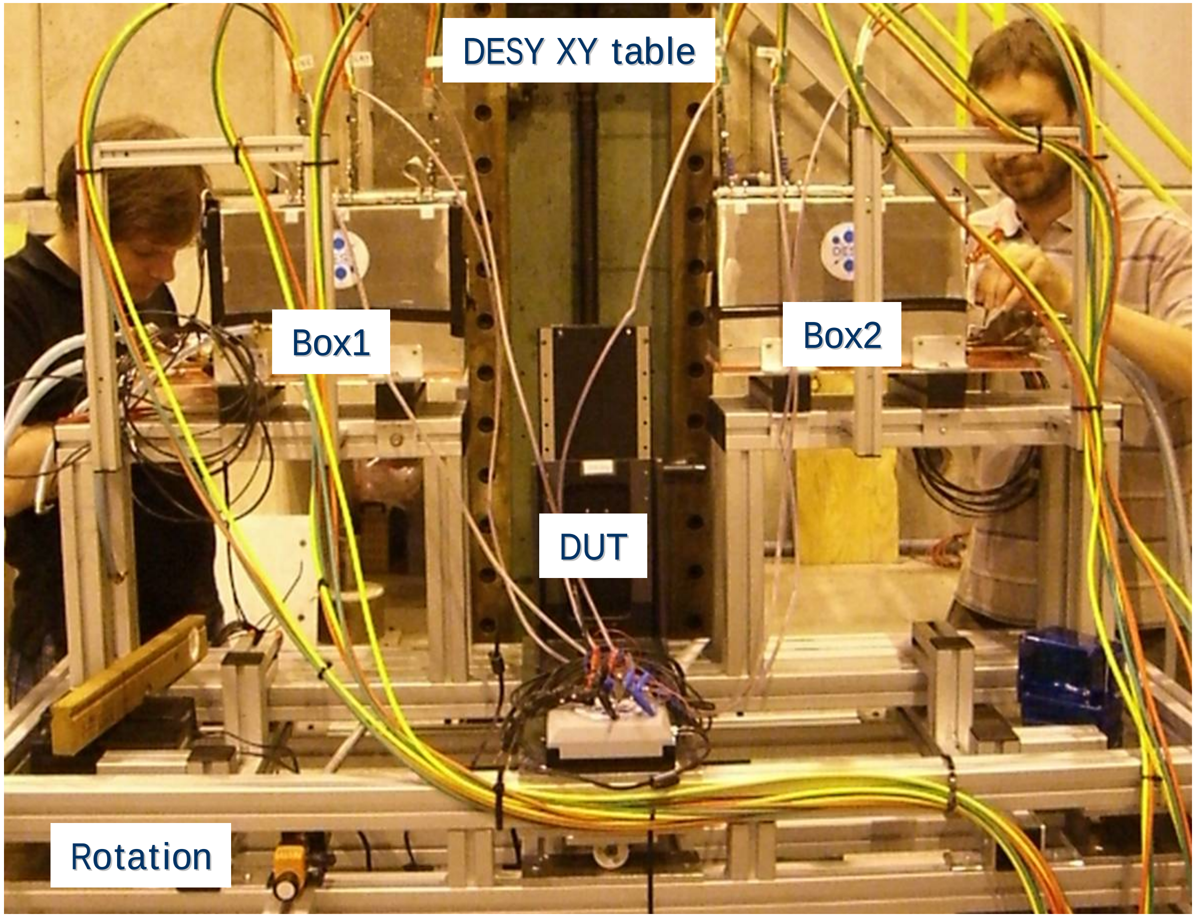




- Box 1 and 2:
  - movable in z-direction, optical bench for three reference planes
  - distances between planes are variable from 5 to 150 mm
- DUT position:
  - Gap between Box 1 and 2: variable in size from a few cm up to 50 cm
  - DUT positioned on XYϕ-table (optional)

- Optical benches inside box ease adjustment with respect to the beam

The real thing



- Overall mechanics now rather big as we allow the insertion of rather large DUTs (e.g CALICE) with a size of up to 50cm
- mechanical profiles give the system a good flexibility while keeping a stable mechanics

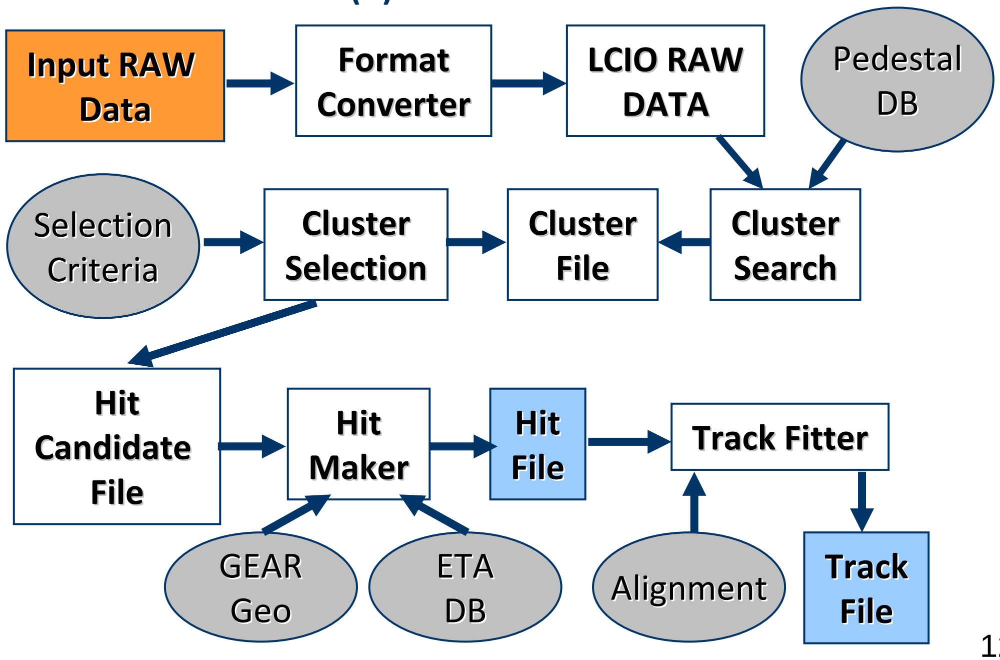
- Rotation of generell telescope plane versus the beam axis (few degrees) to ease the adjustment with respect to the beam

Analysis and reconstruction software

EUTelescope:

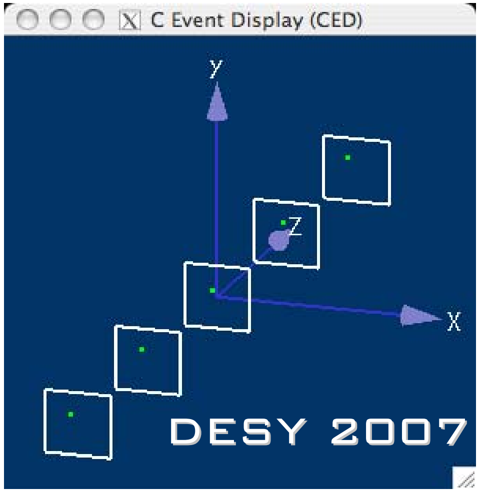
- Set of relevant high level objects (like tracks or space points) to characterise the DUT
- Histograms of important figures of merit.
- Based on available/tested software tools:
  - Single sensor analysis → **sucimaPix** (INFN)
  - Eta function correction → **MAF** (IPHC)
  - Track fitting → **Analytical track fitting** and straight line fitting
  - Alignment → **Millepede II**
  - Framework → ILC Core software = **Marlin + LCIO + GEAR + (R)AIDA + CED**

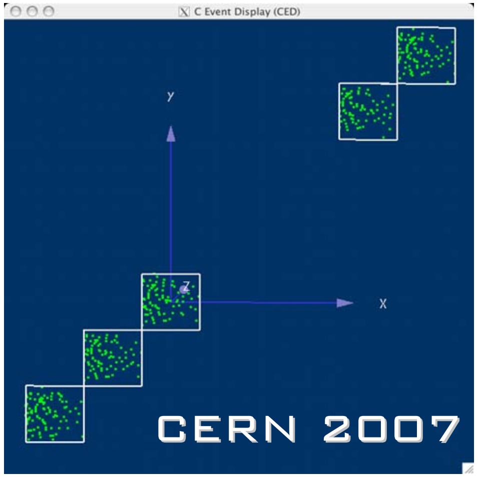
- Sticking to the ILC de-facto standard offers the possibility to easily use the GRID
- Each module is implemented in a Marlin processor
- execute all of them together, or stop after every single step



Test beam campaign

Date	Beam	Scope
06/07	DESY 6GeV e^-	First run with all components and integration in beam
08/07	DESY 6GeV e^-	detailed studies
09/07	CERN SPS	180 GeV hadrons, first user - DEPFET
12/07	DESY 6GeV e^-	User: BeamCal
05/08	CERN SPS	User: SiLC
07/08	CERN PS	User: CALICE
07/08	CERN PS	User: DEPFET
08/08	CERN SPS	User: MimoRoma
08/08	CERN SPS	User: DEPFET
08/08	CERN SPS	User: ISIS
09/08	CERN SPS	EUDET studies





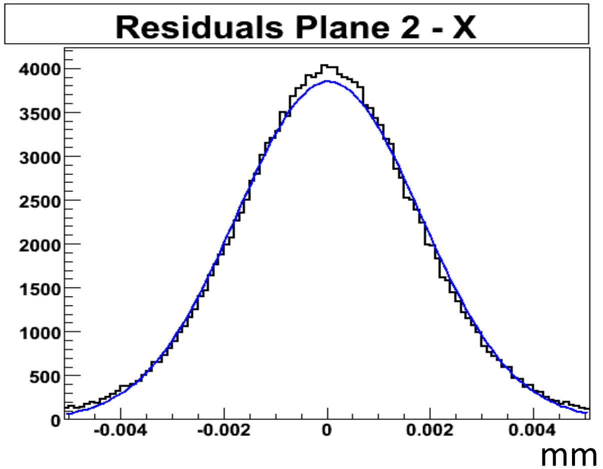
Performance of the telescope

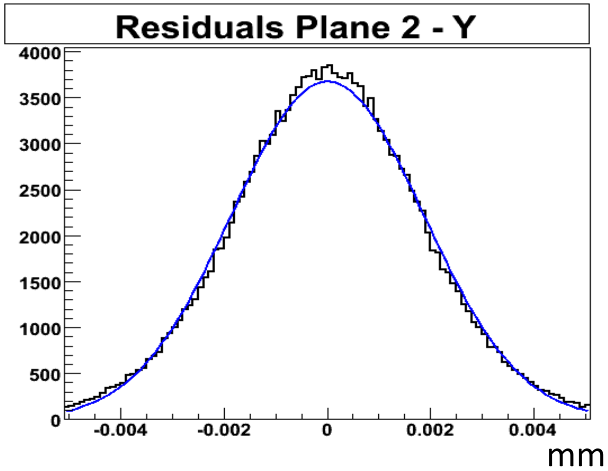
Alignment

- The alignment procedure based on Millepede II uses full tracks
- Typical values for the alignment constants
  - X and Y shifts: few 100µm
  - Rotation around beam axis: few mrad

Plane	Residuals X average value [µm]	Residuals Y average value [µm]
0	-0.003 ± 0,002	-0.023 ± 0,002
1	-0.015 ± 0.004	0.036 ± 0.005
2	0.032 ± 0.004	0.005 ± 0.005
3	-0.020 ± 0.004	-0.005 ± 0.005
4	0.001 ± 0.002	0.002 ± 0.002

(3 GeV electrons at DESY)





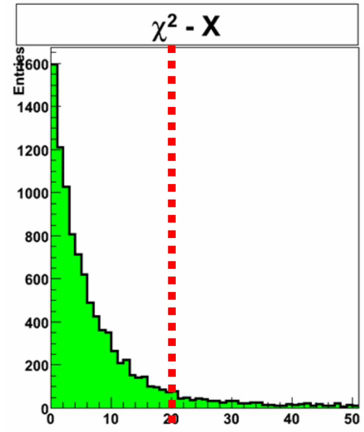
Precision of alignment better than 0.05 µm!

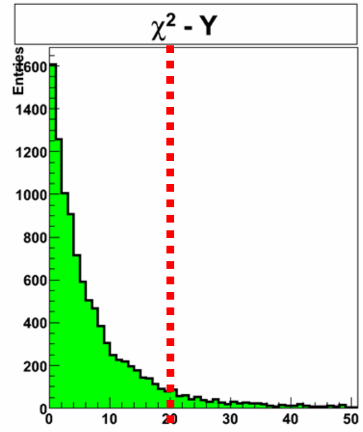
Performance of the telescope

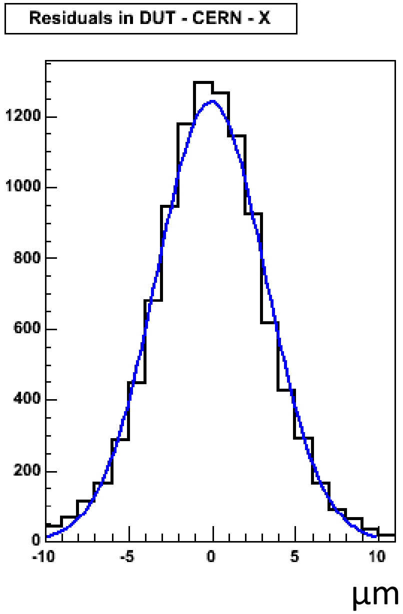
Resolution with Hadrons

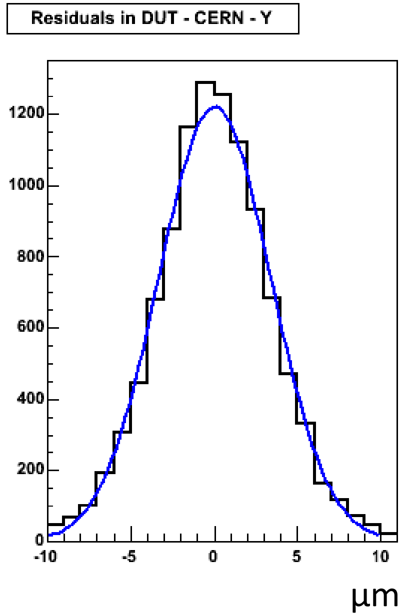
- With hadrons-> neglect multiple scattering
- Straight line fitting procedure using four planes only and extrapolating on the central one
- Fitting on x and y independently
- χ^2 cut < 20

$$\sigma^2 = \sigma^2_{\mathrm{DUT}} + \sigma^2_{\mathrm{Tel}} + \cancel{\sigma}^2_{\mathrm{MS}}$$







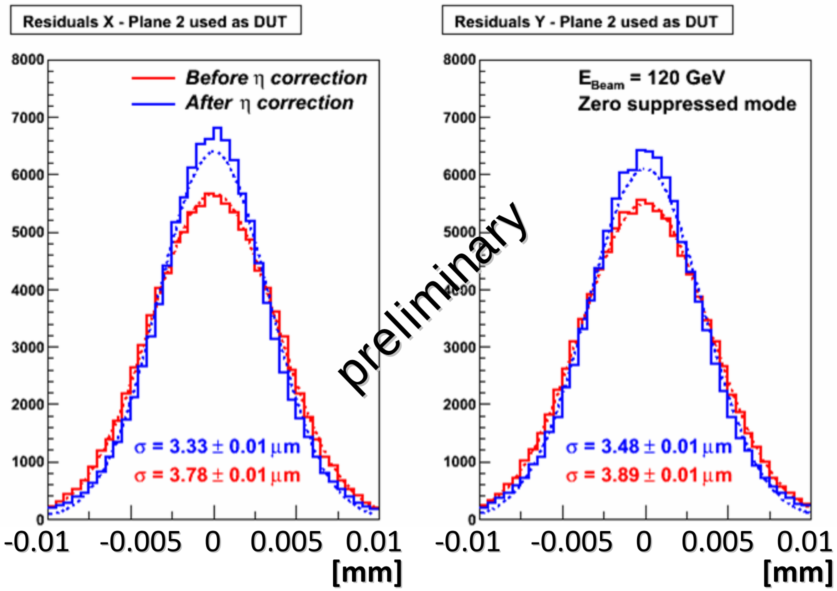


Observed width:
σ = 3.3 µm

Agrees with expectation:
$\sigma_{\mathrm{MimoTEL}}$ = 3.0 µm

(and analytical fitter)

Effect of Zero Suppression

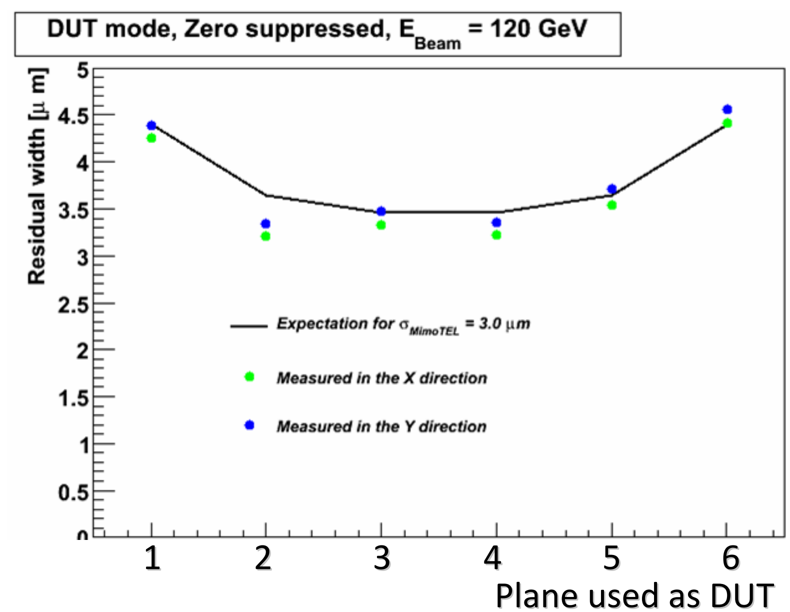


- Resolution (ZS) at hadron beam:
  - x: 3.33 μm + 0.01 μm
  - Y: 3.48 μm + 0.01 μm

  (both with η correction)
- RAW : 3.3 μm
- Too good to be true

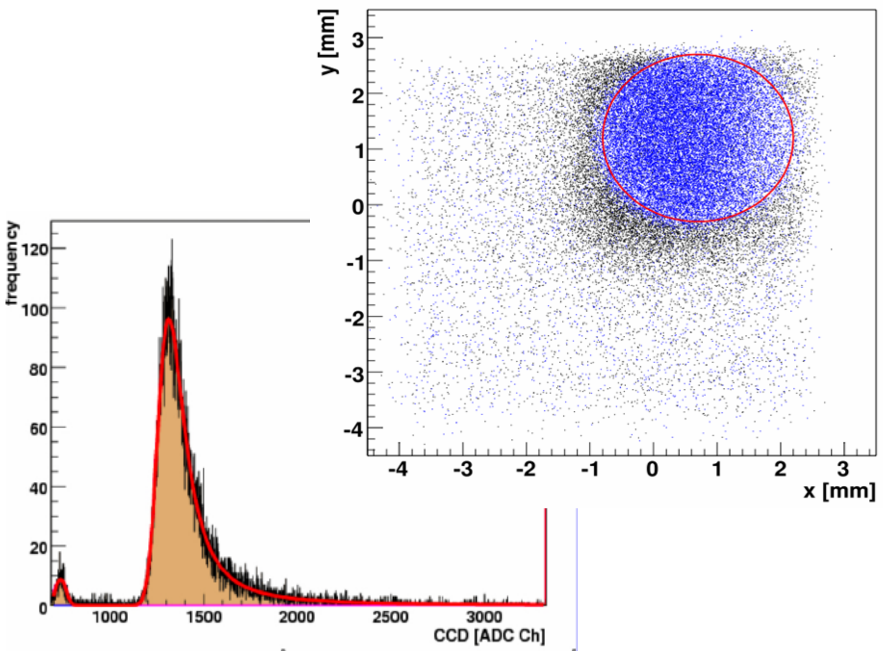
Possible explanation:

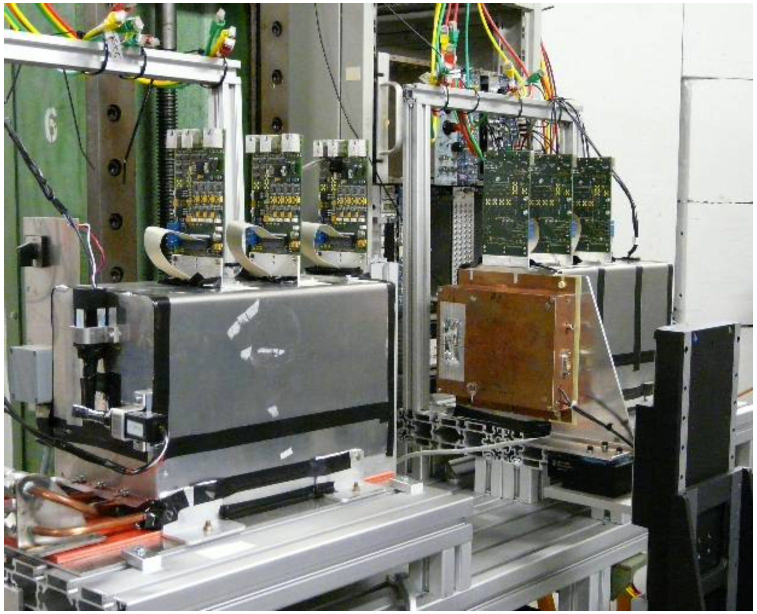
- RAW data from 2007
- ZS Data from 2008
- Noise improvement not taken into account
- RAW data 2008 currently being analysed



User: FCAL at DESY

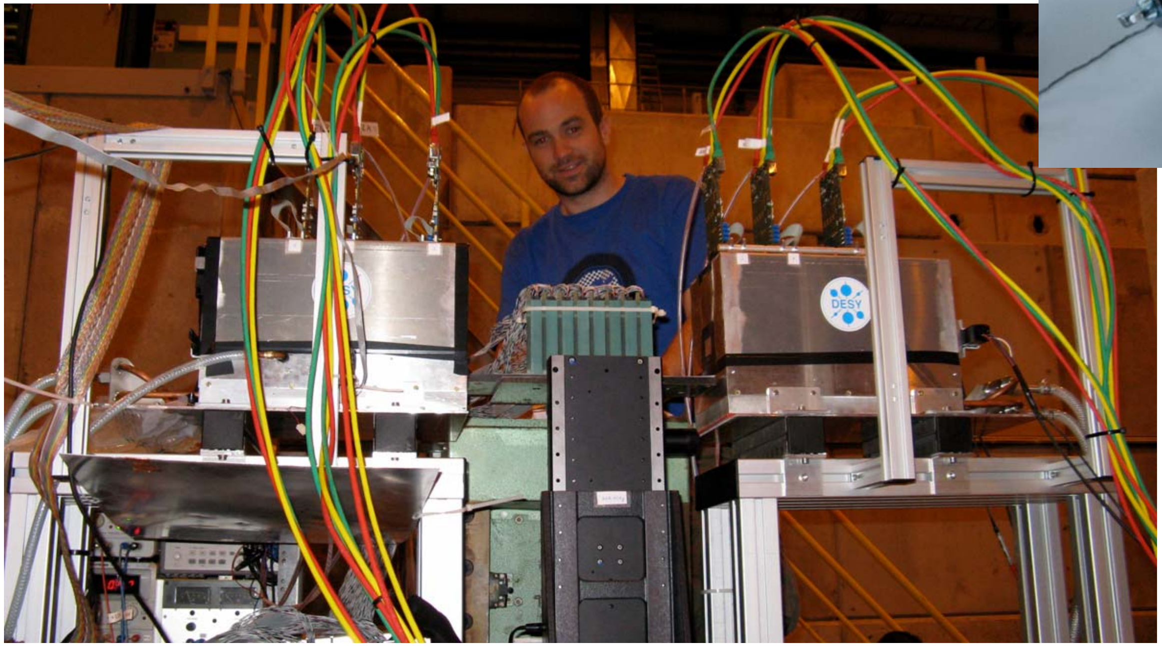
- Wanted to determine the charge collection efficiency of diamond detectors precisel
- The use of the EUDET telescope gave the possibility to define a fiducial area in the centre of the crystal to avoid edge effects





User: SiLC at SPS

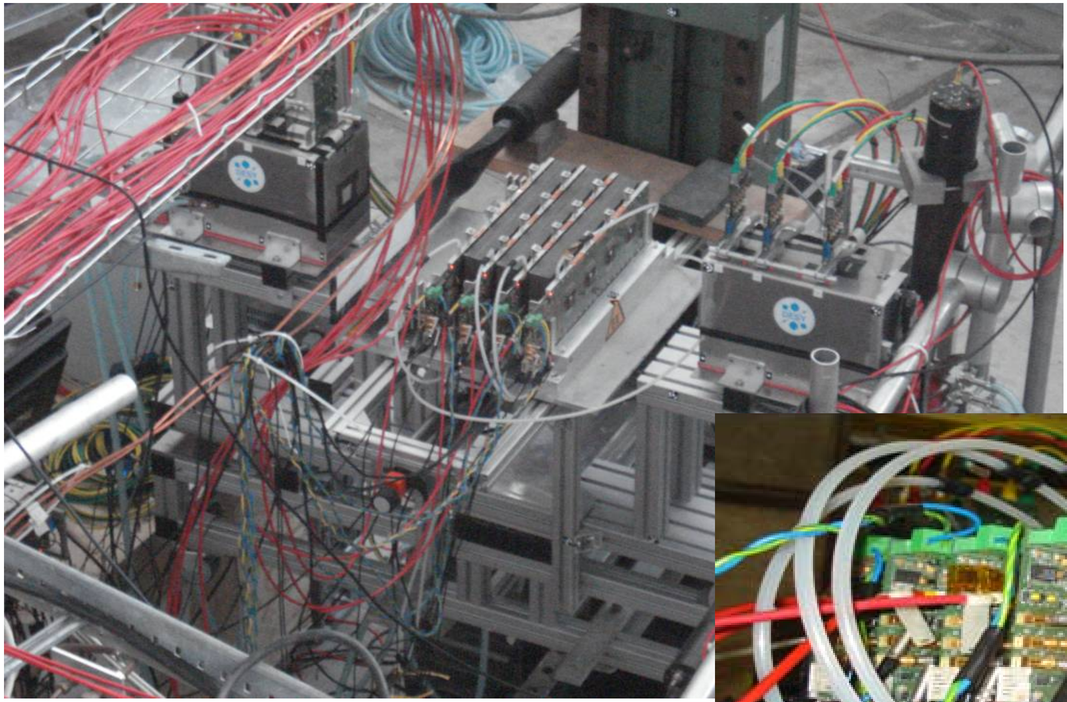
- Silicon strips for ILC
- Evaluate the best strip geometry of silicon strip sensors with 50 micron pitch to achieve the highest possible spatial resolution
- collected about 1.5M events in several configurations



- Analysis still under way
- Problems with synchronisation of DUT and EUDET telescope

User: CALICE – dHCAL at PS

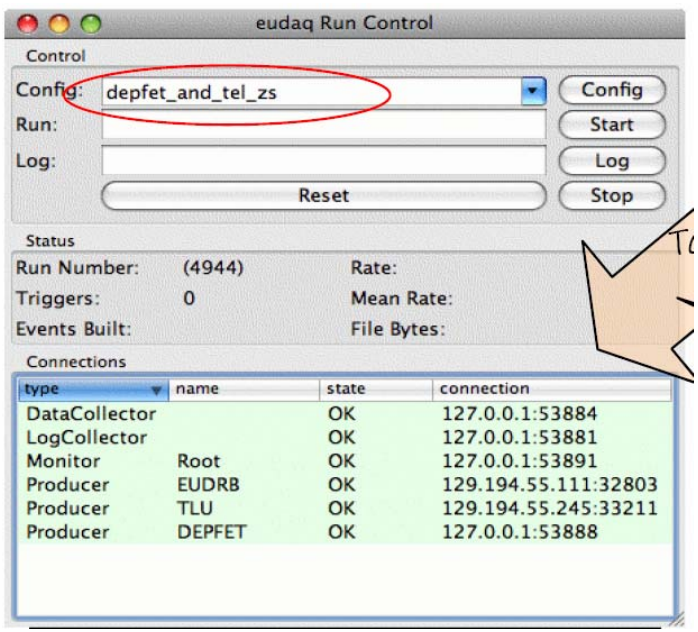
- to validate a new concept of a digital hadronic calorimeter for ILC
- sampling calorimeter constructed as a sequence of stainless steel absorbed plates and planes of gaseous detectors with high granularity and digital readout
- Gaseous detectors: GRPC and μMEGAs
- Readout: based on hardroc chip

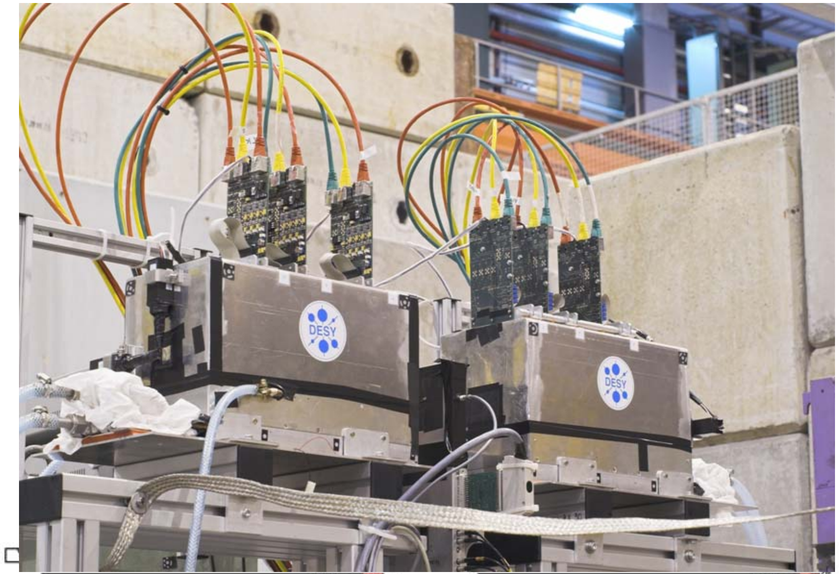


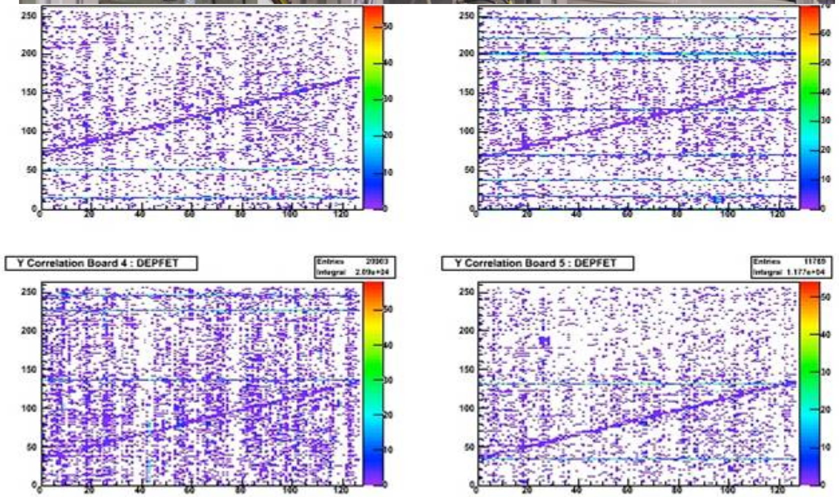
- study the efficiency and cross-talk in diff. beam conditions
- different gas mixtures and different high voltage values to optimise the detector response

User: DEPFET at PS and SPS

- At PS DEPFET efficiently worked on all little details for the user integration
- At SPS the main goal was measurements of efficiency, purity and intrinsic resolution
- DEPFET included on DAQ level -> own producer within EUDAQ -> one data stream
- 1 Million events as EUDET DUT !

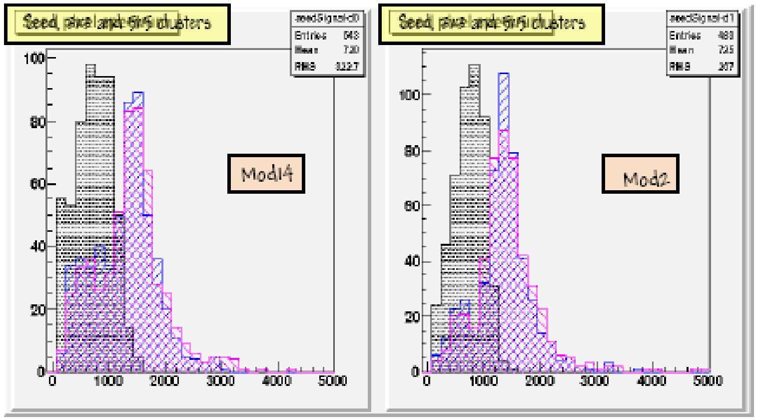


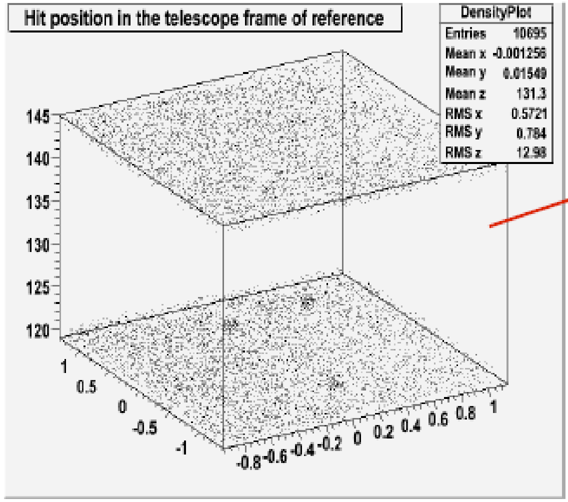


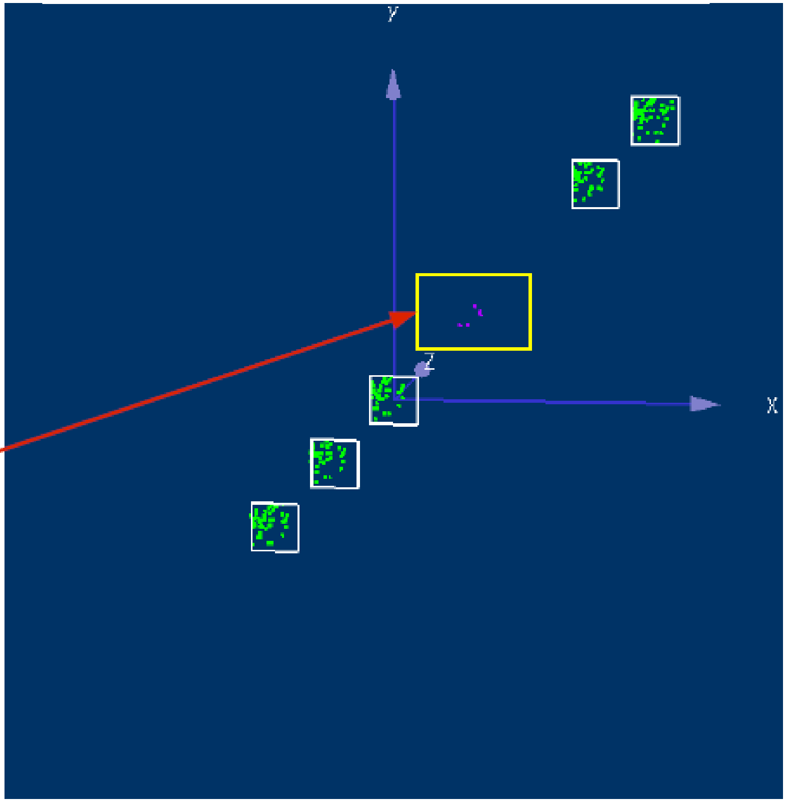


Correlation plots in EUDAQ Root Monitor

Depfet implemented in EUTelescope



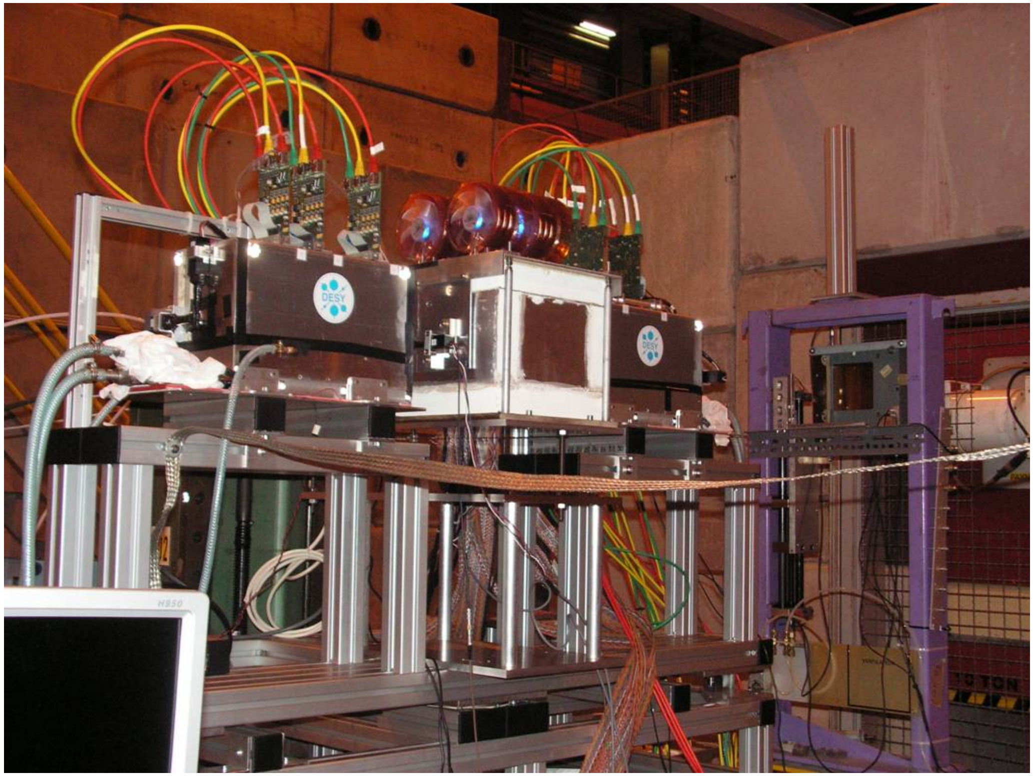




- DAQ integration to EUDET Telescope system (via RunControl, DQM, DATA merging on a DAQ and offline level) is done.

User: ISIS at SPS

- Self contained telescope @ DESY provided useful information
- Charge collection efficiency, charge sharing, hit-efficiency as function of position
- Standard and “p-well variant” of ISIS was tested

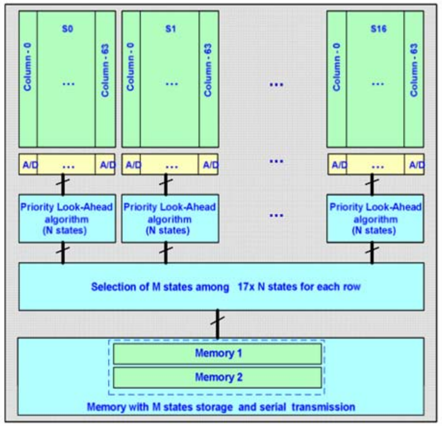


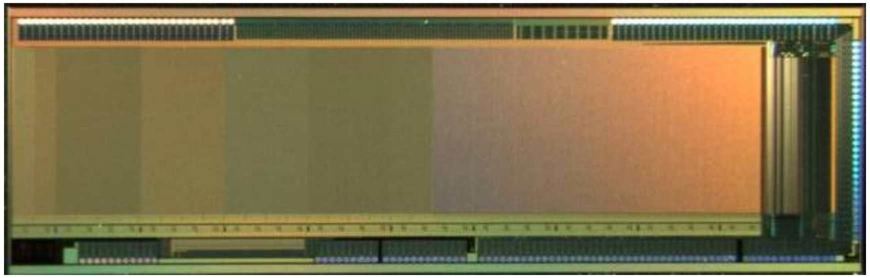
- Tracking and alignment sofware works
- Both standard and p-well ISIS performed okay
- Tracks in EUDET telescope and correlated hits in ISIS
- Alignment of ISIS sensor to telescope rather tricky (0.5 x 2mm)

Final Telescope Chip: Mimosa26

Autumn 2008 : fabrication of MIMOSA-26 = Final Sensor

- Mimosa-22 (binary outputs) complemented with zero-suppression (SUZE-01)
- best performing (rad. tol.) pixel architecture of MIMOSA-22
- Active surface : 1152 columns of 576 pixels (21.2 x 10.6 mm^2)
- Pixel pitch : 18.4 µm -> 0.7 million pixels -> σ_{sp} <3.5 µm => pointing resolution 2µm on DUT surface
- Integration time ~110 µs -> 10^4 frames / second
- Chip dimensions : ~21 x 12 mm^2
- Data throughput: 1 output at 80 Mbits/s or 2 outputs at 40 Mbits/s





Mimosa22

Outlook

- The demonstrator can be used at DESY until spring 2009
- Small changes planned in mechanics and cooling
- A high resolution plane (Mimosa18) was added for further improvement (data taking in December 2008)

- Spring 2009 the telescope will be upgraded to a full digital readout by introducing Mimosa26
- Then a faster well tested telescope will be available for the community
- Transport to CERN for the test beam season is planned for July 2009

What do we offer to users

- The two arm telescope with different geometries with the possibility to add one extra high resolution sensor plane.
  - The telescope comes with all the mechanics and the cooling system for the reference sensors.
  - Operating support: mainly remote but also local in some circumstances.
- The DAQ system; both hardware and software.
  - You can connect your device to our TLU, or (better) help is provided to integrate your R/O in our DAQ software.
- The analysis and reconstruction software.
  - As for the DAQ, you can rely on our output track file, or integrate your device in the main analysis stream.