The Demonstrator in 2008 and Telescope Outlook

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Outline

- The Demonstrator Telescope in 2008
  - Telescope Reference Plane Sensors
  - Data Acquisition System - EUDAQ
  - Mechanics and Infrastructure
  - Data Analysis Software – EUtelescope
  - Telescope Performance
- User Experience of 2008
- Towards the final digital telescope
- Two telescopes?
- Summary

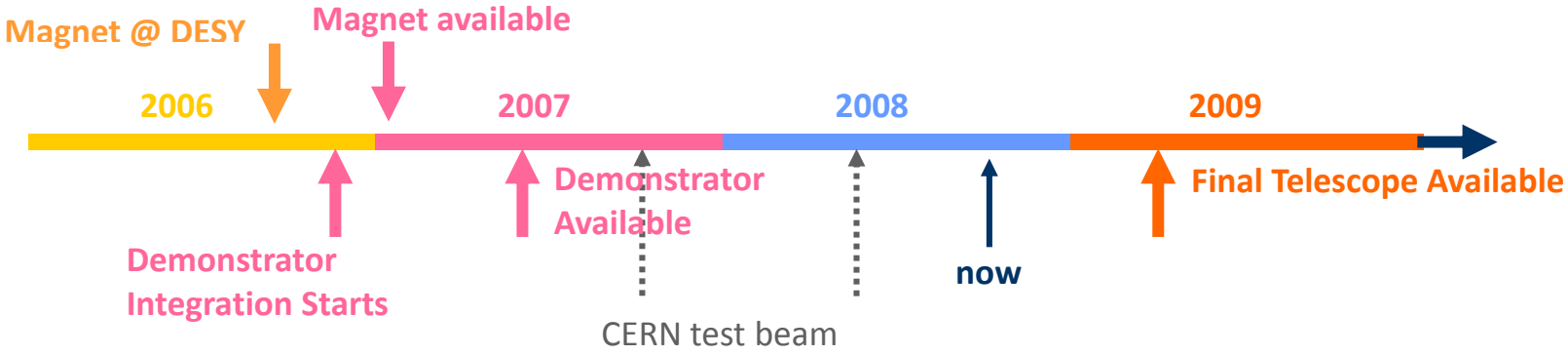
Telescope Schedule

Phase1: “Demonstrator”

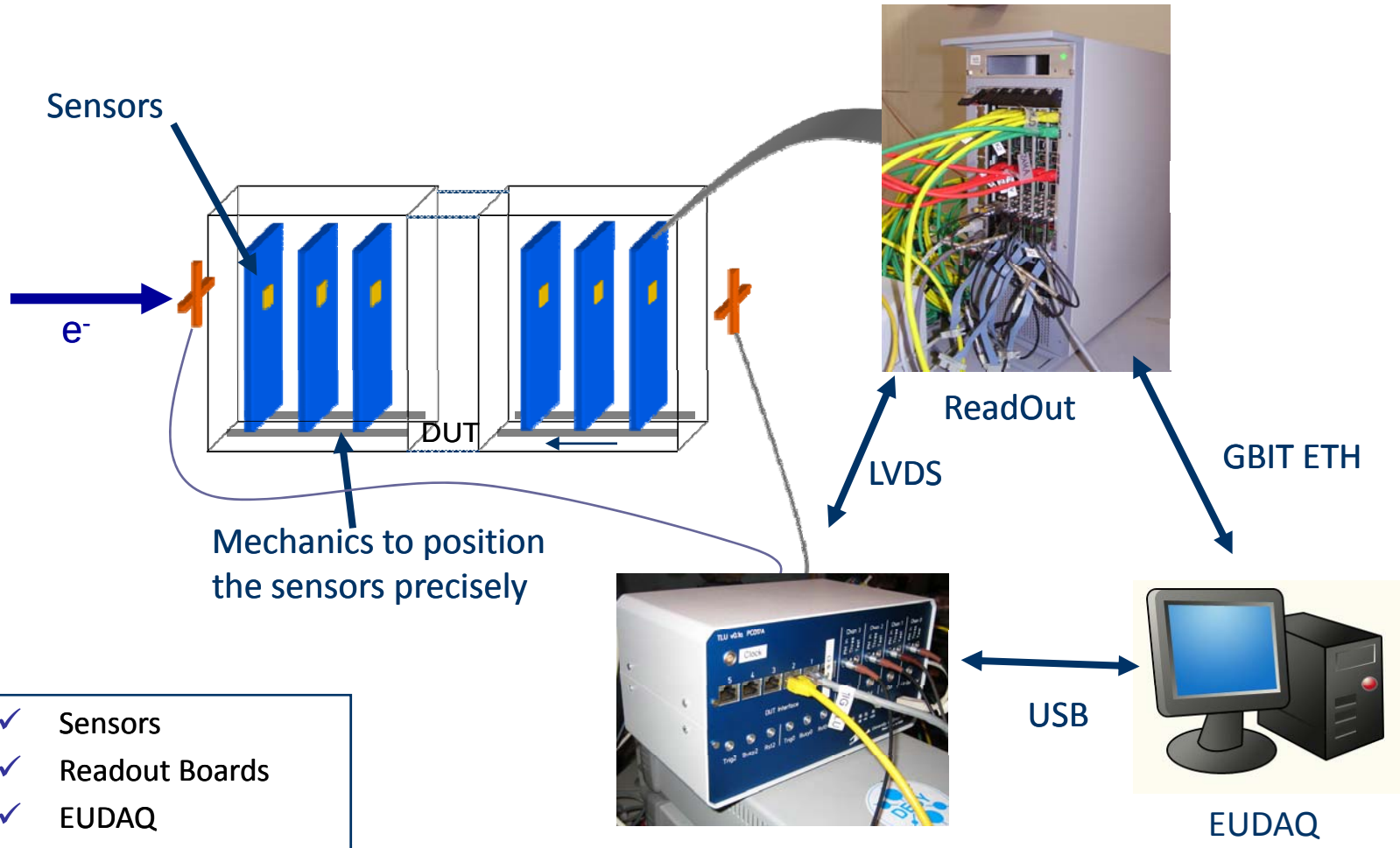
- First test facility will be available quickly for the groups developing pixels
- Use established pixel technology with analogue readout and no data reduction

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



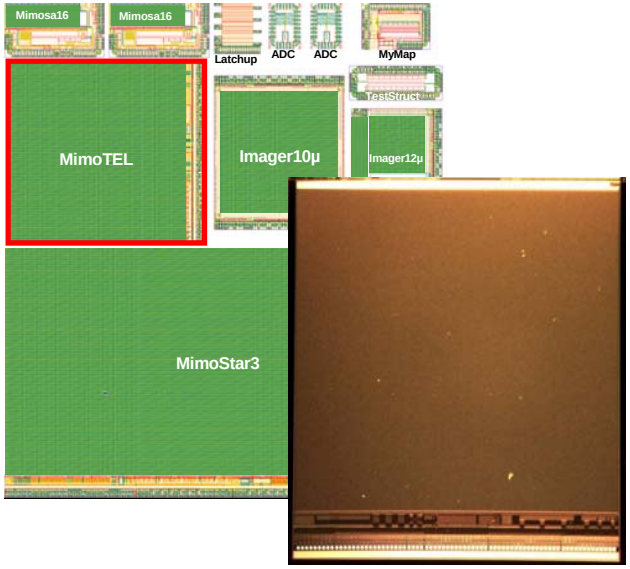
- ✓ Sensors
- ✓ Readout Boards
- ✓ EUDAQ
- ✓ Trigger Logic Unit
- ✓ Mechanics

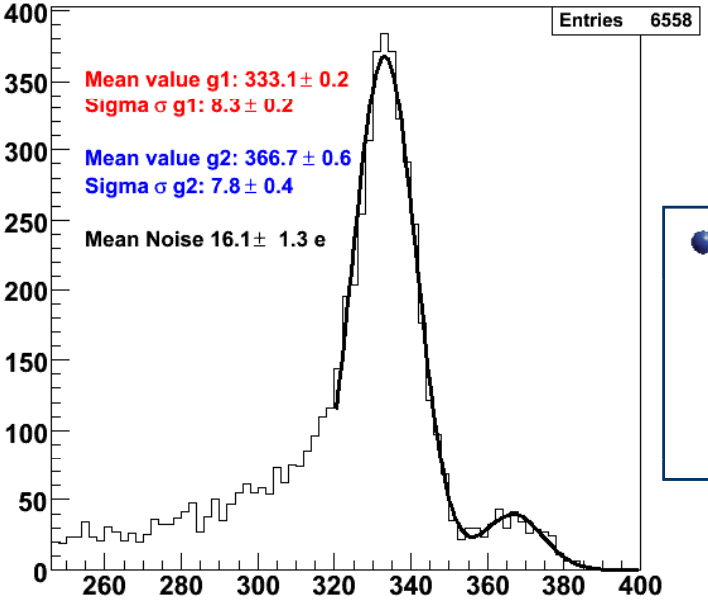
Reference Plane Sensors

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



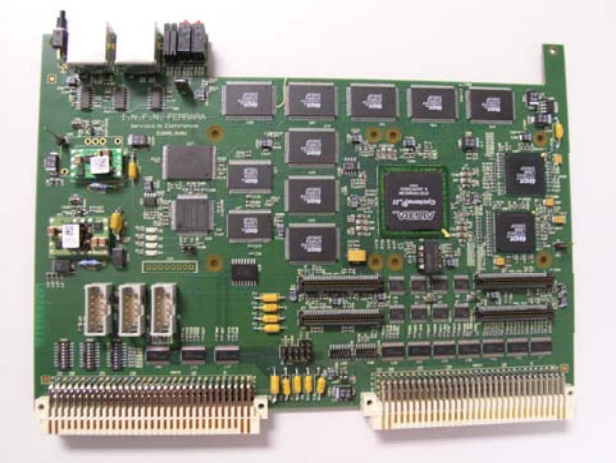


- Very good performances:
  - Noise: ENC ~ 15 electrons @room temperature
  - S/N (MPV) > 22
  - Efficiency ~ 99.9%

DAQ Hardware: EUDRB

INFN Ferrara

EUDET Data Reduction Board



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

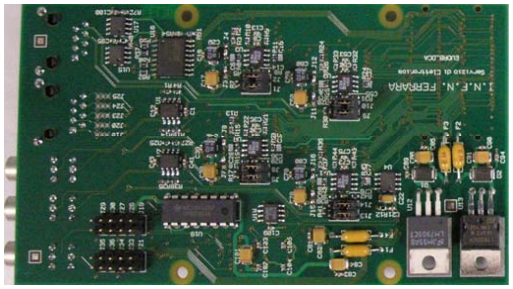
- on board diagnostics
- on-line calculation of pixel pedestal and noise
- remote configuration of the FPGA via RS-232, VME, USB2.0

Two readout modes:

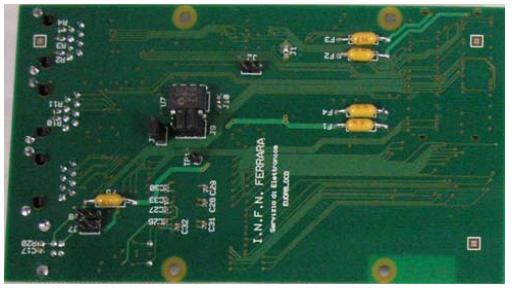
Zero Suppressed readout to minimize the readout dead-time while in normal data taking.

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

Analog Daughter card based on the successful LEPSI and SUCIMA designs clock rate up to 20 MHz

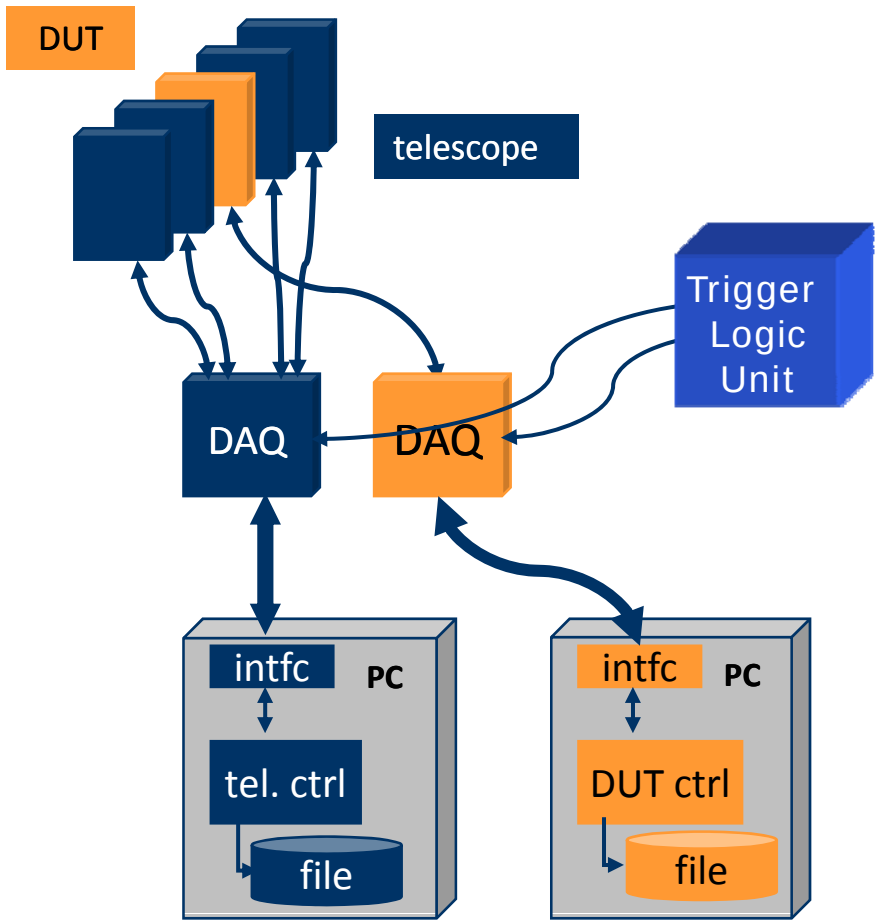


Digital daughter card drives/receives control signals for the detectors and features a USB 2.0 link



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
  - full integration on DAQ software level



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 AND, OR, NOR ….
- Internal trigger mode for testing
- Low voltage power supply for PMTs
- internal scalers
- TLU v0.1 extensively tested in 2007/2008
- Feedback to designer -> v0.2 developed

For more details see presentation from Scott Mandry/David Cussans

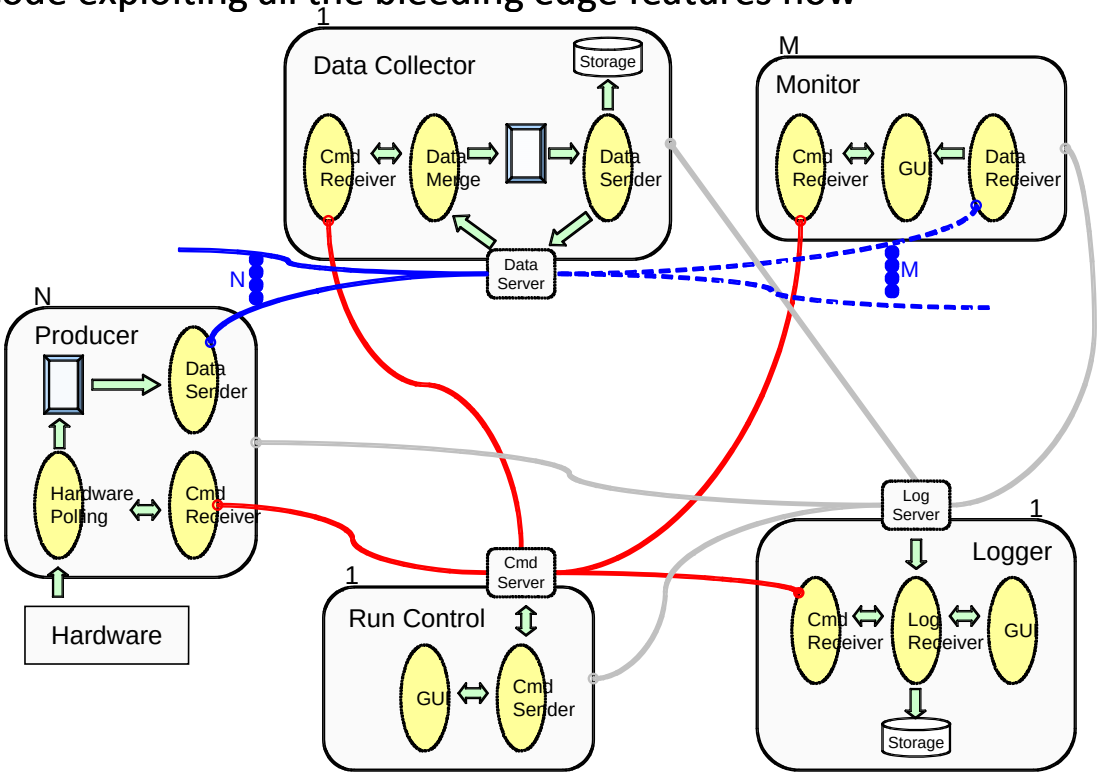
TLU v0.2

- Four sets of “Lemo” I/O connectors for DUT (increased from two)
- BUSY inputs can be switched between Lemo and RJ45 under s/ware control
- All outputs can be turned on/off under s/ware control
- I2C buses added for slow I/O – easily expandable.
- More LEDs for diagnostics
- now available

And software-wise - EUDAQ

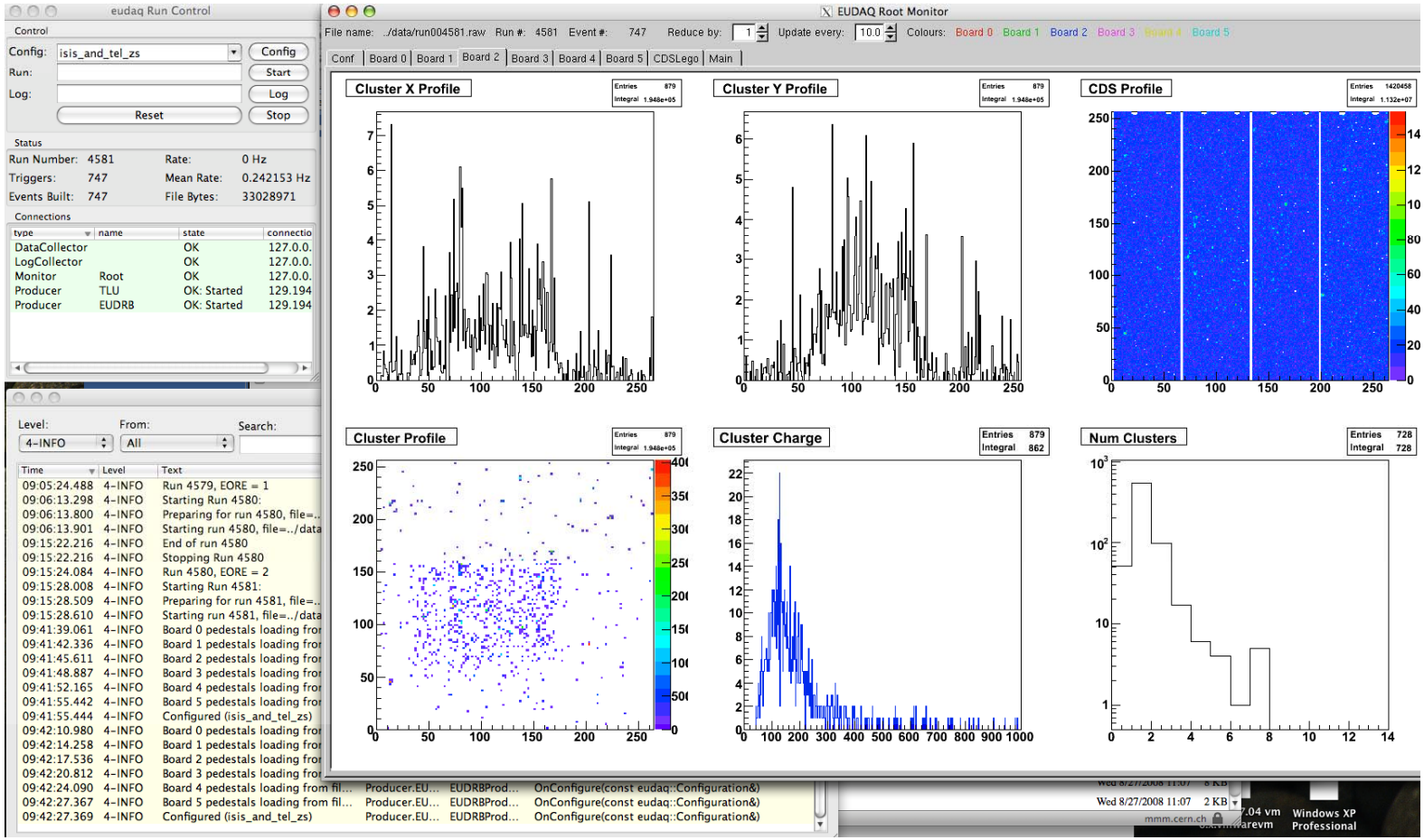
DPNC Geneva

- It's a very modern piece of code exploiting all the bleeding edge features now available:
  - Object Oriented C++
  - Multi-thread
  - Distributed (TCP/IP)
  - Highly modular
  - Runs on MacOS, Linux or Windows



- DAQ Software is divided into many parallel tasks:
  - several Producer tasks read the hardware
  - one FileWriter task bundles events, writes to file and sends subsets for monitoring
  - There can be several Online - Monitoring tasks
  - one Buffer Monitor task allows to see what is going on
  - a FileReader can re-inject data into the monitoring

EUDAQ Run Control



- Provides powerful online monitoring

http://projects.hepforge.org/eudaq/

Recent Improvements in EUDAQ

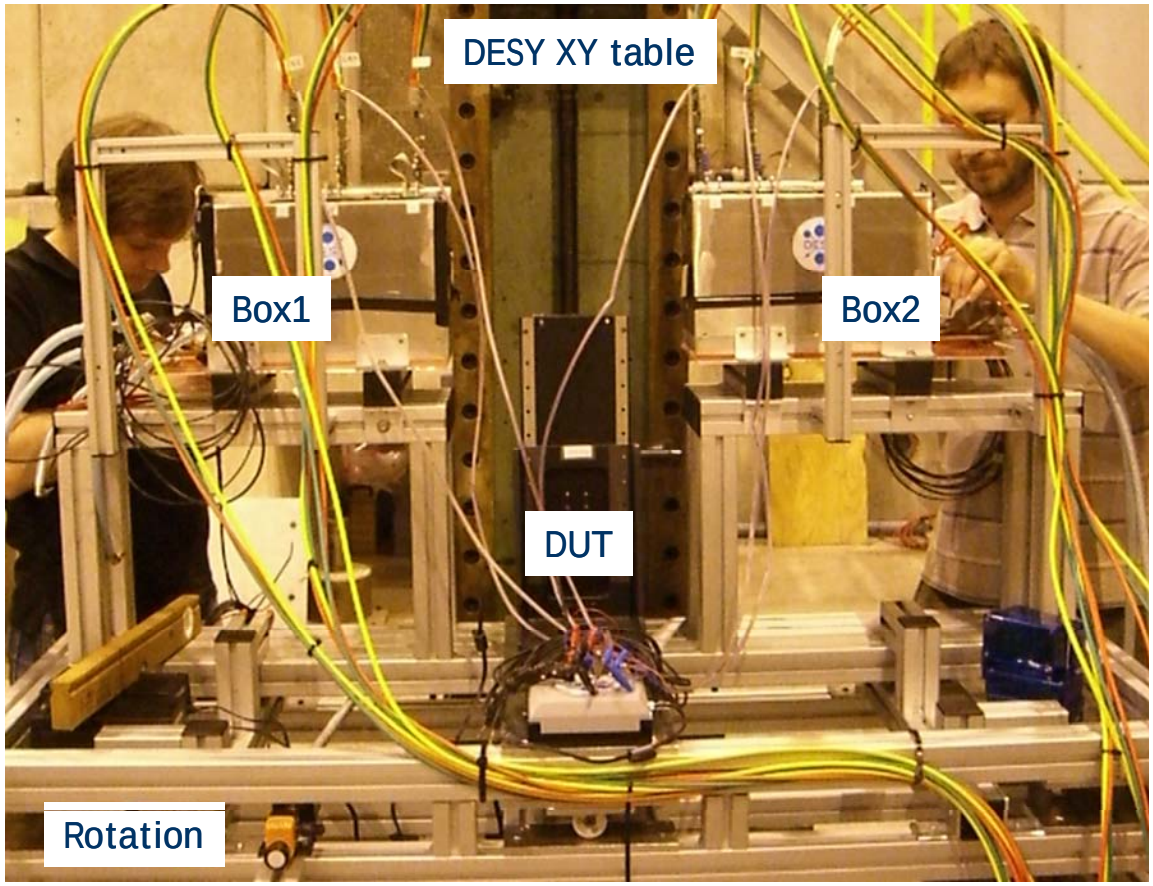
- Readout speed of EUDAQ rather slow (<50Hz during spill)
- Reason identified: switching between VME slots used 2ms for remapping of the VME address space -> VME driver problem
- Redefining „windows“ in address space solved the problem
- Readout rate of 400Hz for full demonstrator telescope expected (tbc)

- Other improvements on the way
  - DAQ stability (hopefully)
  - Easier integration of users (generic RawDataEvent)
  - Compatibility with 64-bit Linux
  - Support for new TLU

- Software ready for final telescope by end of year

For more details see presentations from Emlyn Corrin and Daniel Haas

The real thing



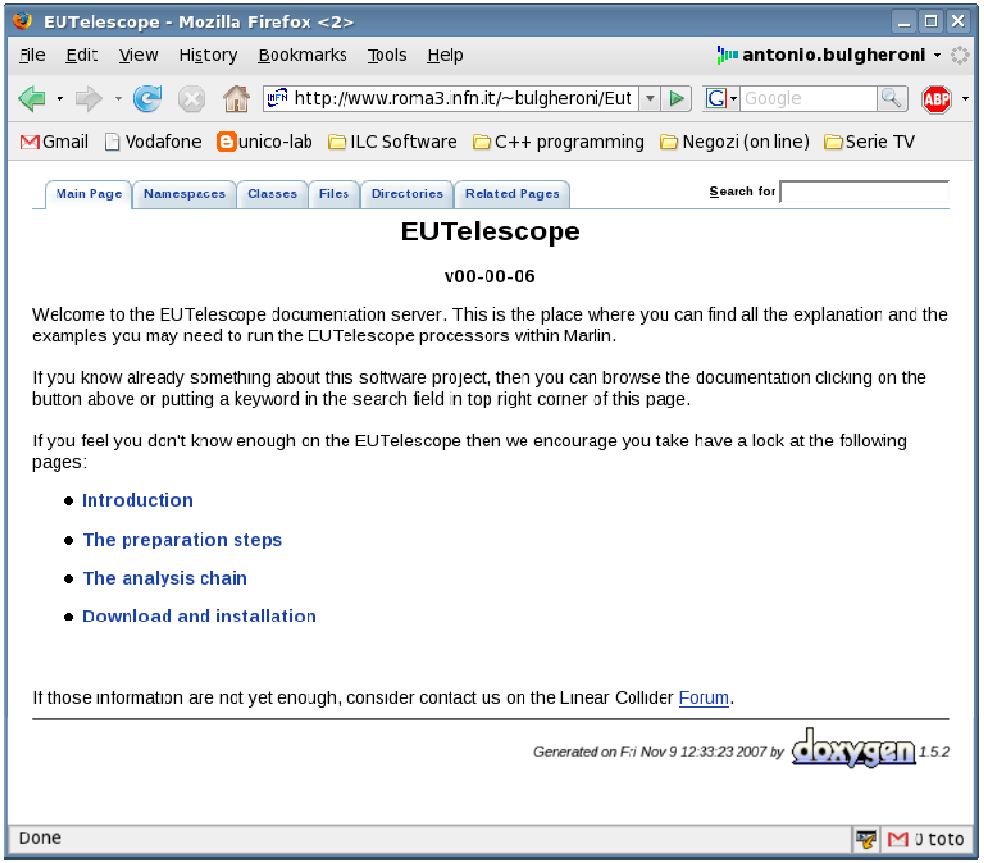
- Overall mechanics now rather big as we allow the insertion of rather large DUTs (e.g CALICE) with a size of up to 50cm
- "Rose&Krieger" mechanical profiles give the system a good flexibility while keeping a stable mechanics
- Rotation of generell telescope plane versus the beam axis (few degrees) to ease the adjustment with respect to the beam

- After extensive user time: list of improvements to done:
  - cooling
  - mechanical alignment of DUT with respect to the EUDET telescope

Analysis Software EUTelescope

- Providing the users a set of relevant high level objects (like tracks or space points) to characterize the DUT along with histograms of important figures of merit.
- Collaborating in the development of a common software framework in view of the future International Linear Collider experiment.

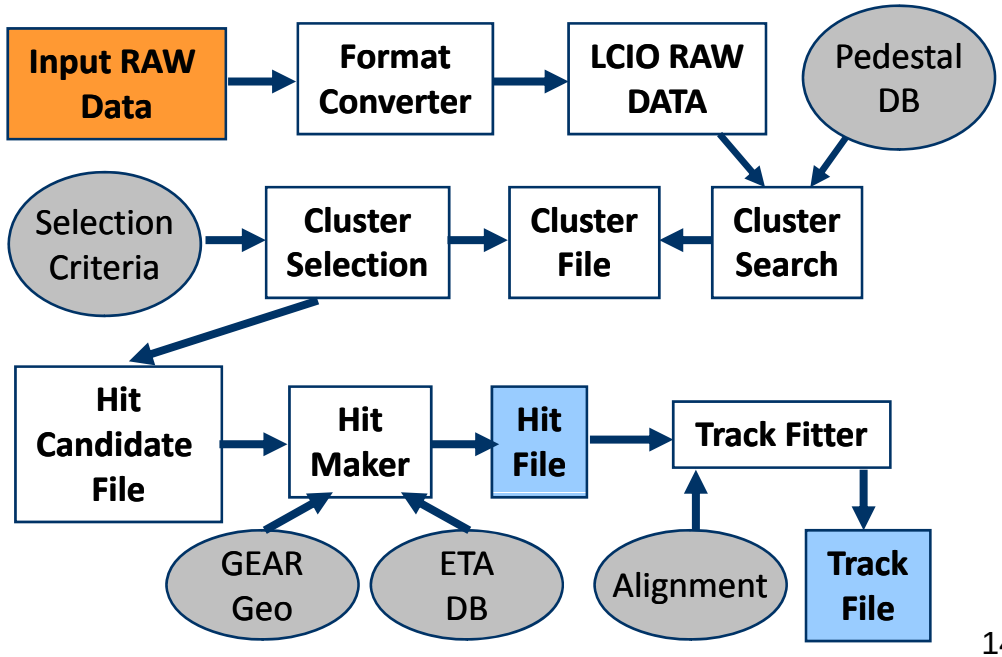
- Developed within the Software Networking activity, it is based on the official ILC framework: Marlin + LCIO
- EUTelescope is a set of Processors taking to care to handle the data stream from the DAQ to the reconstructed tracks
- Sticking to the ILC de-facto standard offers the possibility to easily use the GRID.



Analysis and reconstruction software

- Gain as much as possible from past experience and already available and 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 (+ LCCD).**

- Each module is implemented in a Marlin processor
- execute all of them together, or stop after every single step
- Advantages when debugging the system
- Can offer the user different level of information



Latest Developments in EUTelescope

- An increased number of detector R&D groups is adopting the EUTelescope package!
- Several issues have been adressed to ease the installation and usage of EUTelescope:
  - **Installation procedure**
  - **Keep documentation updated**
  - **A tutorial was held in May 2008** (availabe on the JRA1 webpage)
- New features (since Paris meeting)
  - Universal Reader -> Very general data reading and conversion processor
  - Correlator -> display correlations of hits and clusters in different telescope planes
  - Alignment -> Millipede II
  - Improved Event Viewer -> with tracks (before and after alignment)
- Tracking and alignment ready already now!

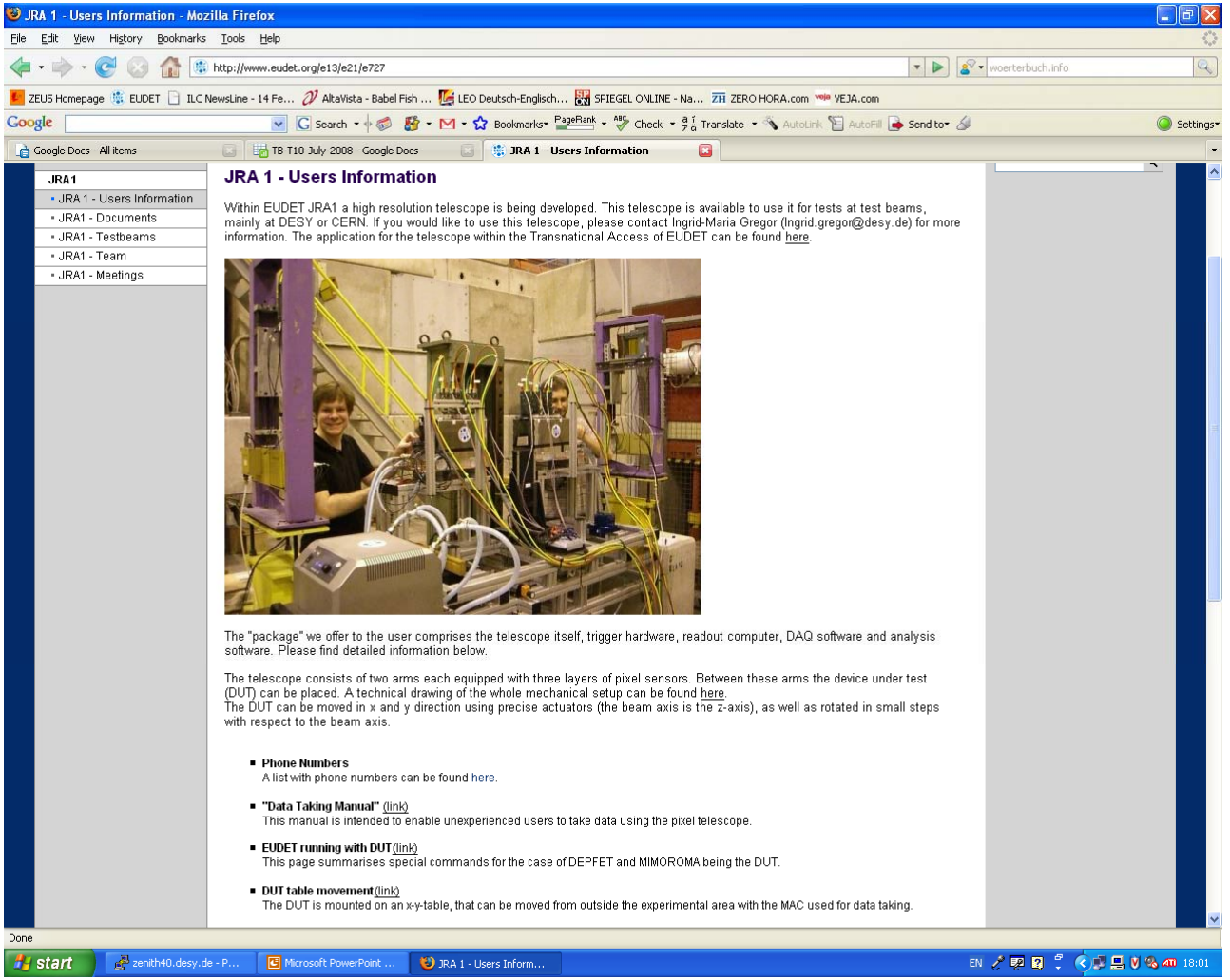
For more details see presentation from Philipp Roloff

All-Inclusive Package for 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.

Users Information Webpage

- **EUDET -> JRA1 -> Users Information**



Users Information Webpage

- Links with online help

- **Phone Numbers**
  A list with phone numbers can be found here.

- **"Data Taking Manual"** (link)
  This manual is intended to enable unexperienced users to take data using the pixel telescope.

- **EUDET running with DUT** (link)
  This page summarises special commands for the case of DEPFET and MIMOROMA being the DUT.

- **DUT table movement** (link)
  The DUT is mounted on an x-y-table, that can be moved from outside the experimental area with the MAC used for data taking.

- **Some Remarks for the DAQ PC** (link)
  This page summarises the necessary actions after the restart of the MAC for setting up a Parallels Desktop with Linux and correct network connections.

- **Boot setup for the MVME6100** (link)
  A description of the boot setup for the MVME6100.

- **"JRA1- Data Acquisition System"** (link)
  This memo describes the data acquisition system, giving an overview of actual hardware and software developments.

- **"EUDAQ Software"** (link)
  The DAQ software for the pixel telescope and some technical documentations can be found on the web page mentioned above.

- **"JRA1 Trigger Logic Unit"** (link)(link)
  These memos describe the JRA1 trigger logic unit.

Users Information Webpage

- Links for the analysis software

- **"EUTelescope Software"**
  - **"EUTelescope: Tracking Software"** (link)
    This memo describes the software tool performing all the off line procedures needed to extract from the data acquired DAQ the precise spatial information. The current status of the development of the tracking software tool named EUTele as well as foreseen future improvements are specified.
  - **"Software Tutorial"** (link)
    In this tutorial a short step-by-step analysis is described using a set of example steering, raw and lcio files. All files me in this tutorial are available here.
  - **"EUTelescope Software"** (link)
    On the EUTelescope documentation server explanations and examples that might be needed to run the EUTelescope processors within Marlin are given. The CVS repository can be found here.

- Whenever we see a gap in the documentation we add the information directly on the webpage
- Feedback from the users was very helpful !

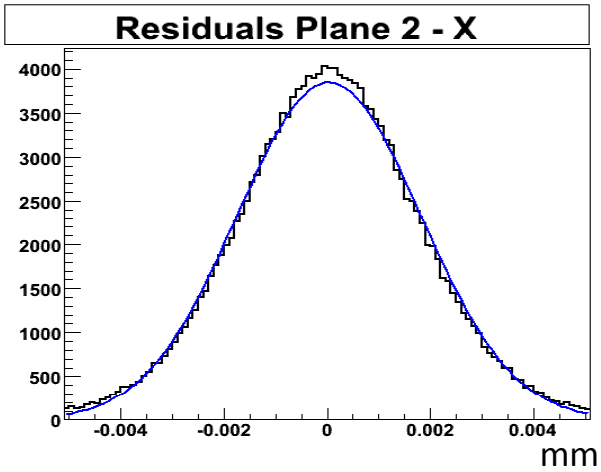
Performance of the telescope

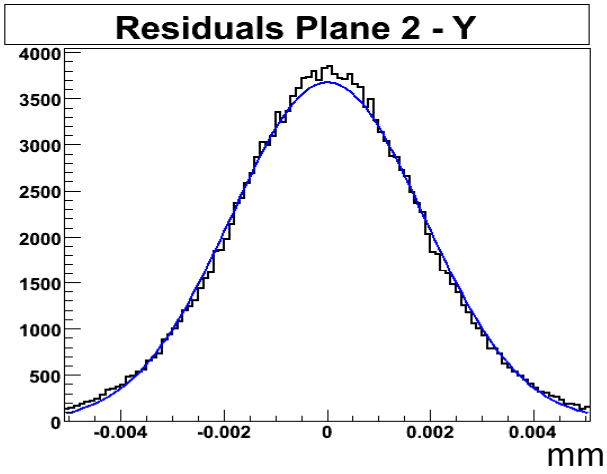
Alignment

- 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 K 0,002	-0.023 K 0,002
1	-0.012 K 0.004	0.036K 0.005
2	0.032 K 0.004	0.005K 0.005
3	-0.020K 0.004	-0.005K 0.005
4	0.001K 0.002	0.002K 0.002

(3 GeV electrons at DESY)





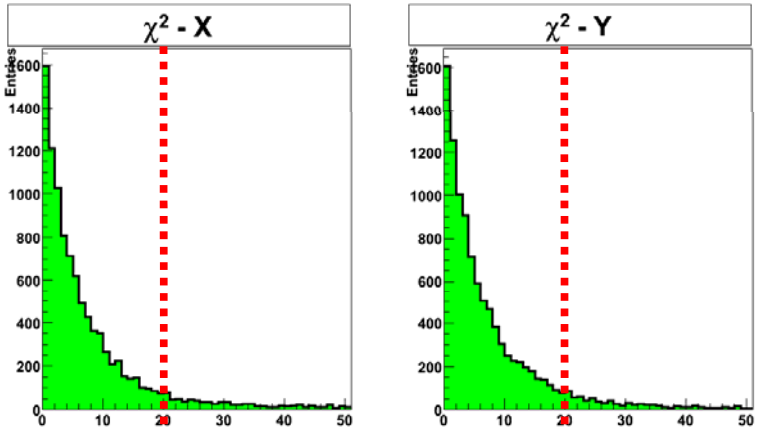
Precision of alignment better than 0.05 µm!

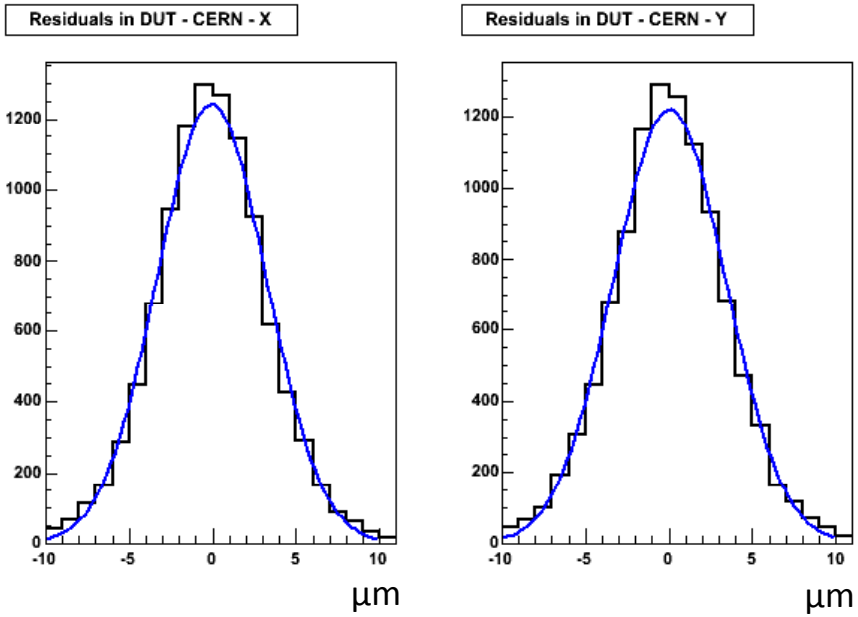
Performance of the telescope

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

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





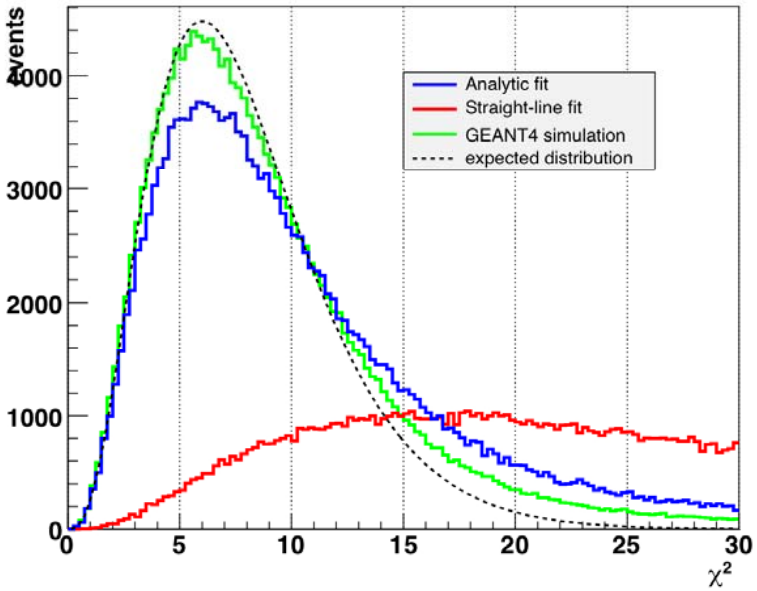
Observed width:
σ = 3.3 µm

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

(and analytical fitter)

Performance of the telescope

Resolution with Electrons



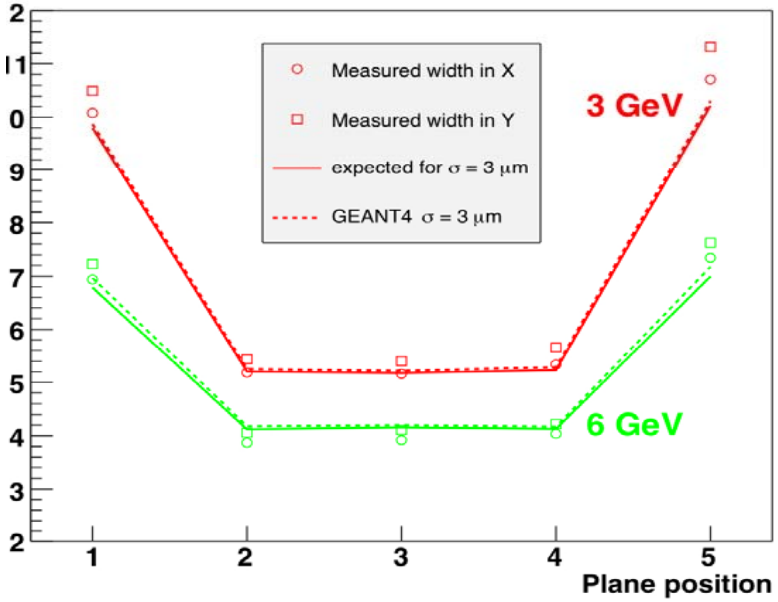
Good agreement between expectation and simulation!

For more details see presentation from Philipp Roloff

Analytical fit takes multiple scattering into account:

position measurement multiple scattering

$$\Delta\chi_i^2 = \left(\frac{y_i - p_i}{\sigma_i}\right)^2 + \left(\frac{\theta_i - \theta_{i-1}}{\Delta\theta_i}\right)^2$$



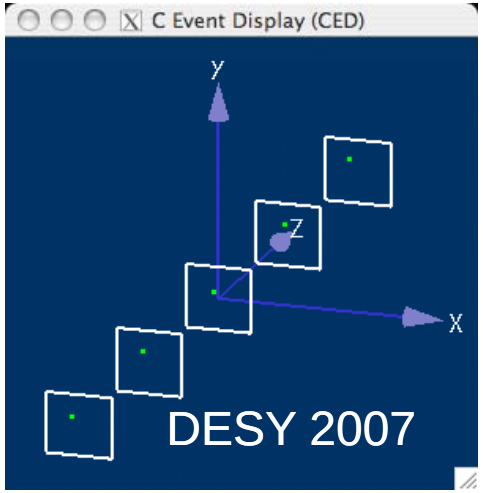
Test Beam Campaigns 2007 and 2008

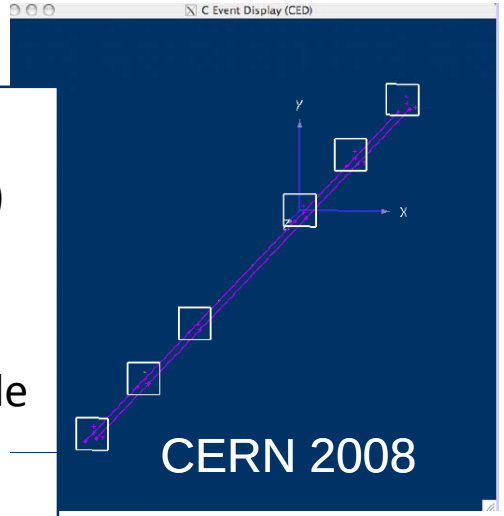
Test beam campaign

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		
07/08		
08/08		
08/08		
09/08		

Includes telescope characterisation:

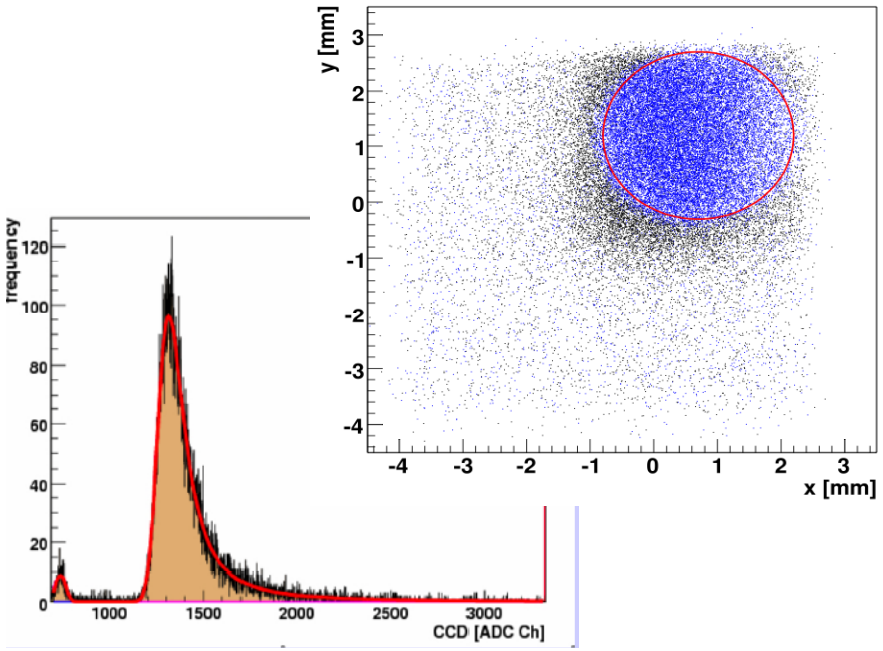
- Energy scan (E = 20, 40, 60, 80, 100, 120 GeV)
- Temperature scan: One sensor as DUT (T = 8, 12, 16 °C)
- Threshold scan: One sensor as DUT in ZS Mode (sigma = 2.0, 2.5, 3.0, 3.5, 4.0)
- Mimosa 18 as DUT in EUDET telescope

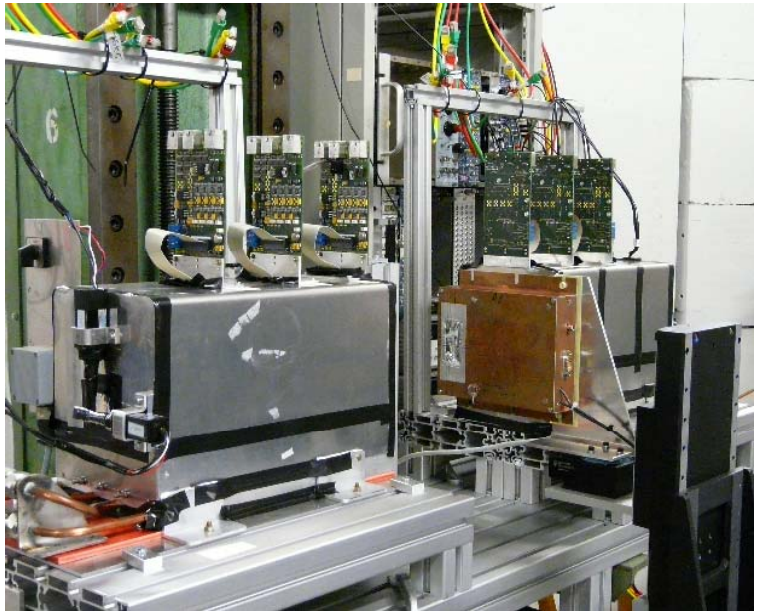




User: FCAL at DESY

- 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

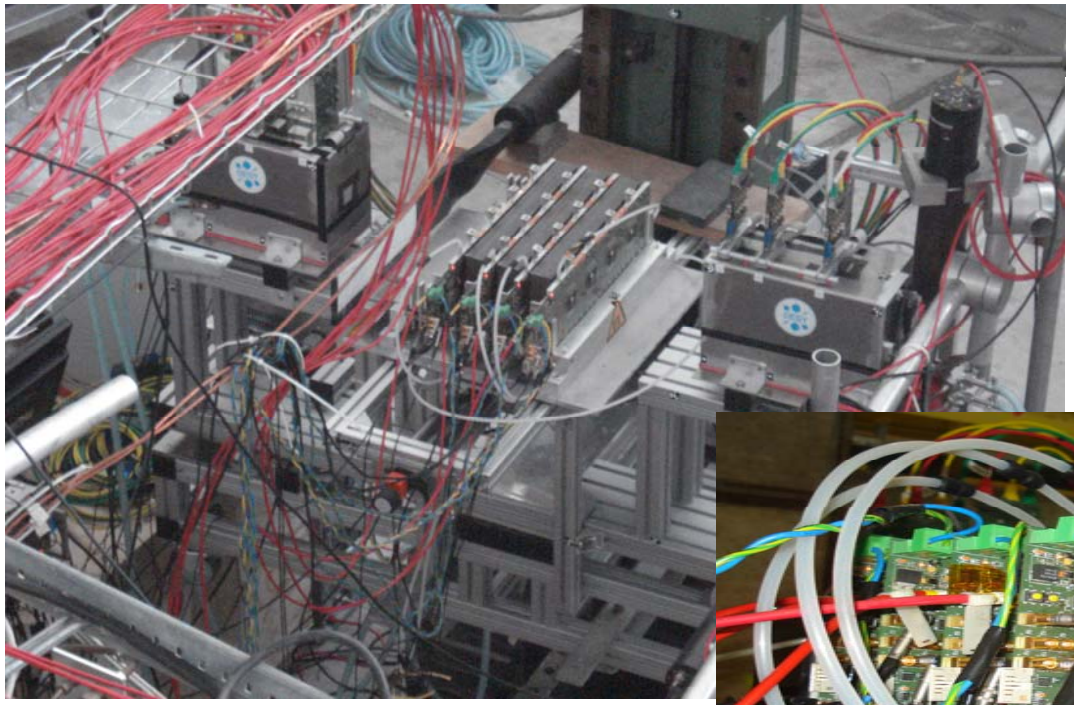

SiLC DUT

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

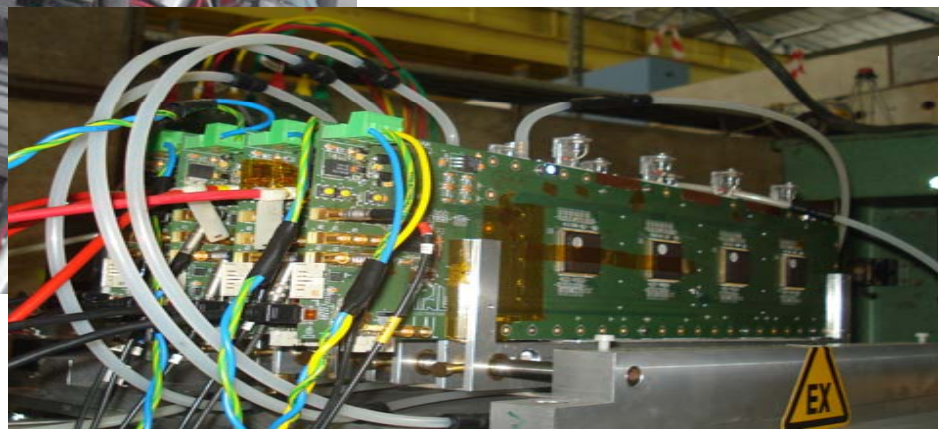
For more details see presentation from Thomas Bergauer

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



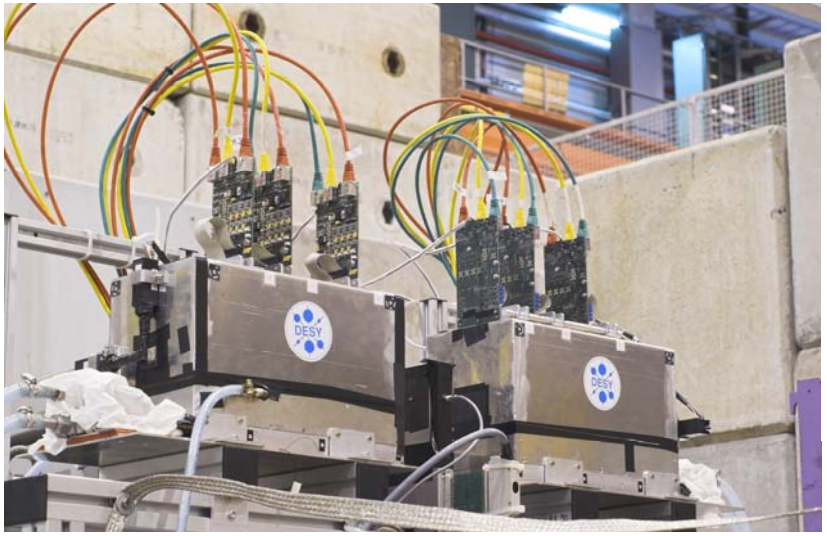
- study the efficiency and cross-talk in diff. beam conditions
- different gas mixtures and different high voltage values to optimise the detector response

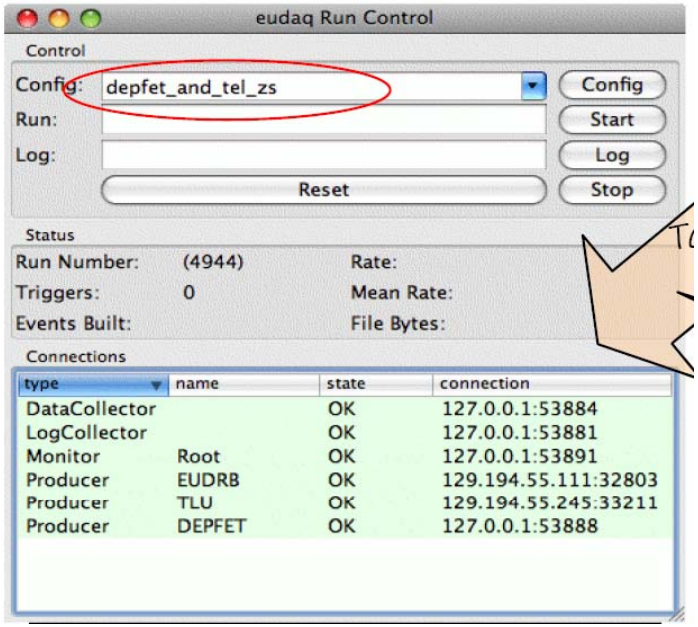


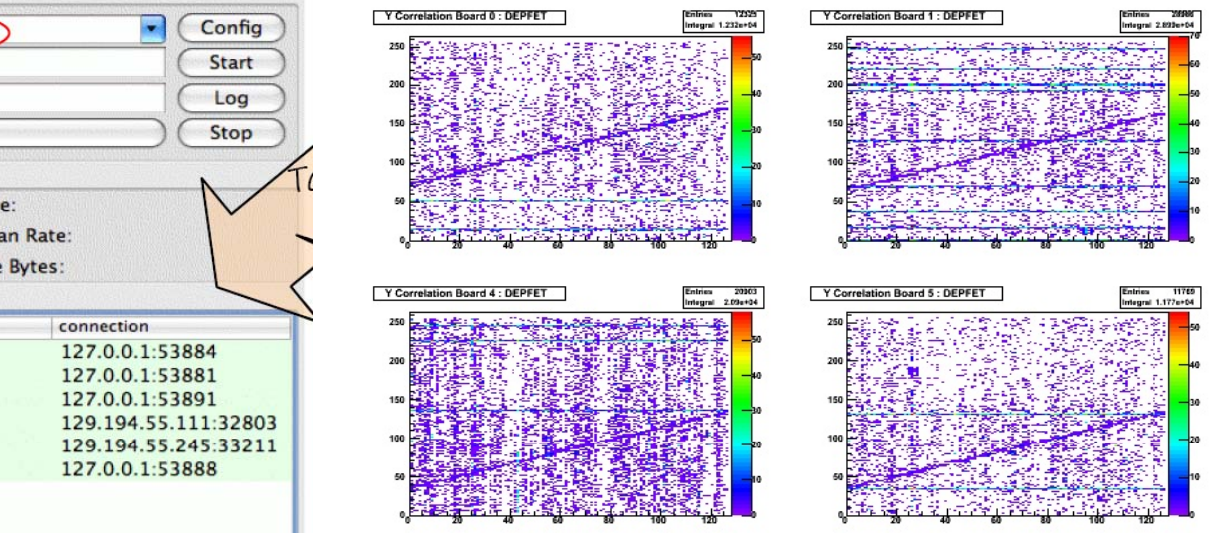
For more details see presentation from Imad Laktineh

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 !

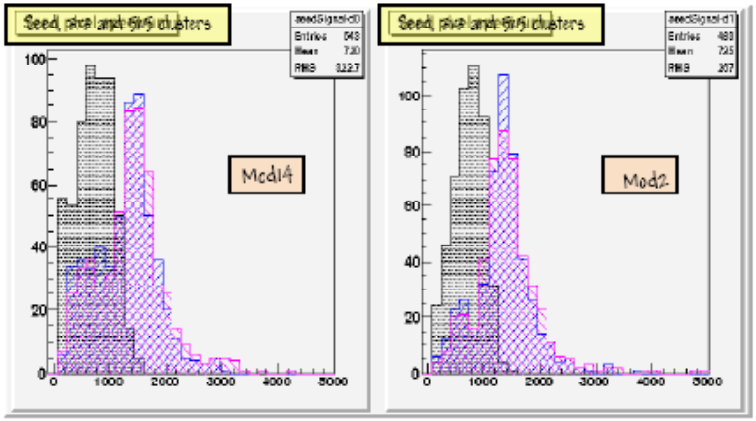


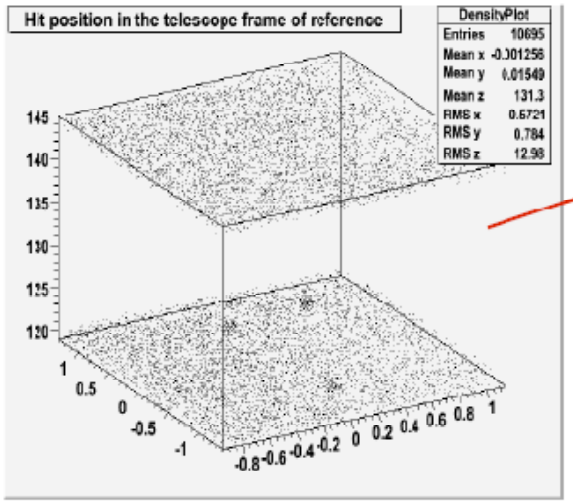




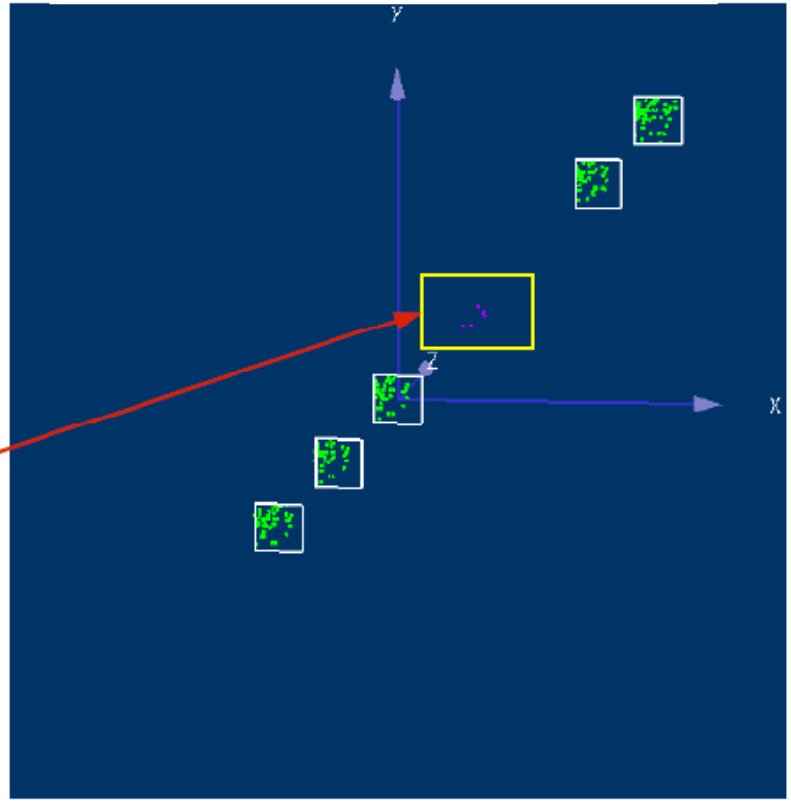
Correlation plots in EUDAQ Root Monitor

Depfet implemented in EUTelescope





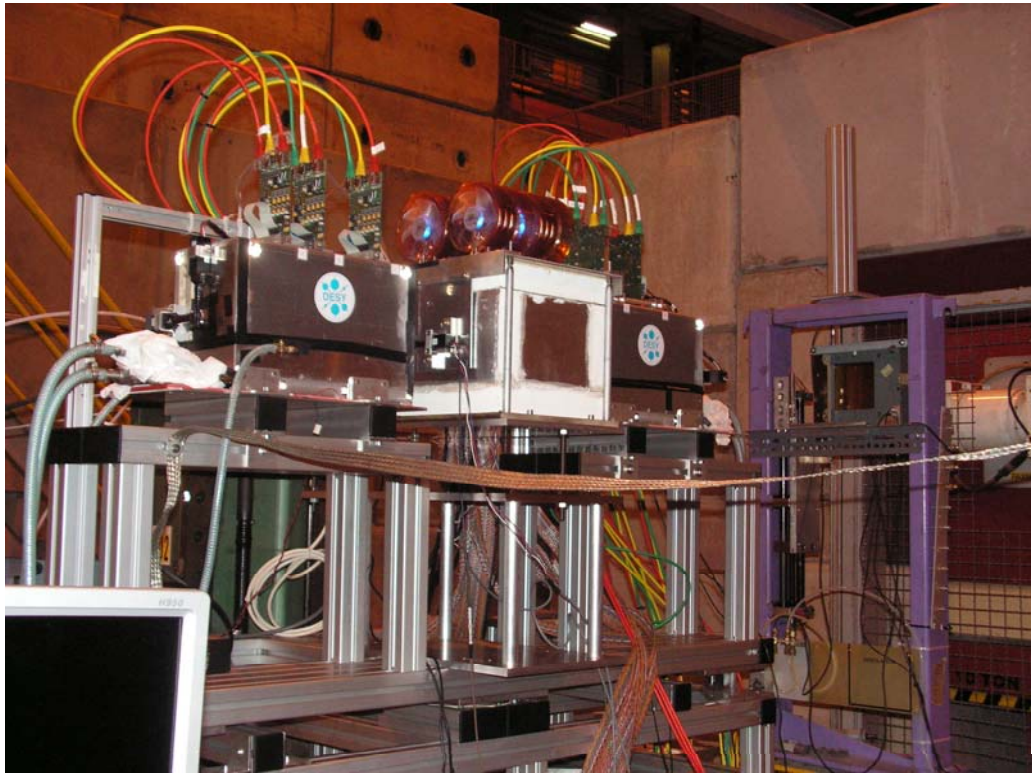
For more details see presentation from Julia Furletova



- 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)

For more details see presentation from Scott Mandry

What did we learn this summer

- The EUDET telescope was **16** weeks at CERN, **13** weeks taking data
  - >10 Million events, ~ 50 Million tracks and 887 Gbyte of data
- To make the telescope a true infrastructure for outsiders is a lot of work!

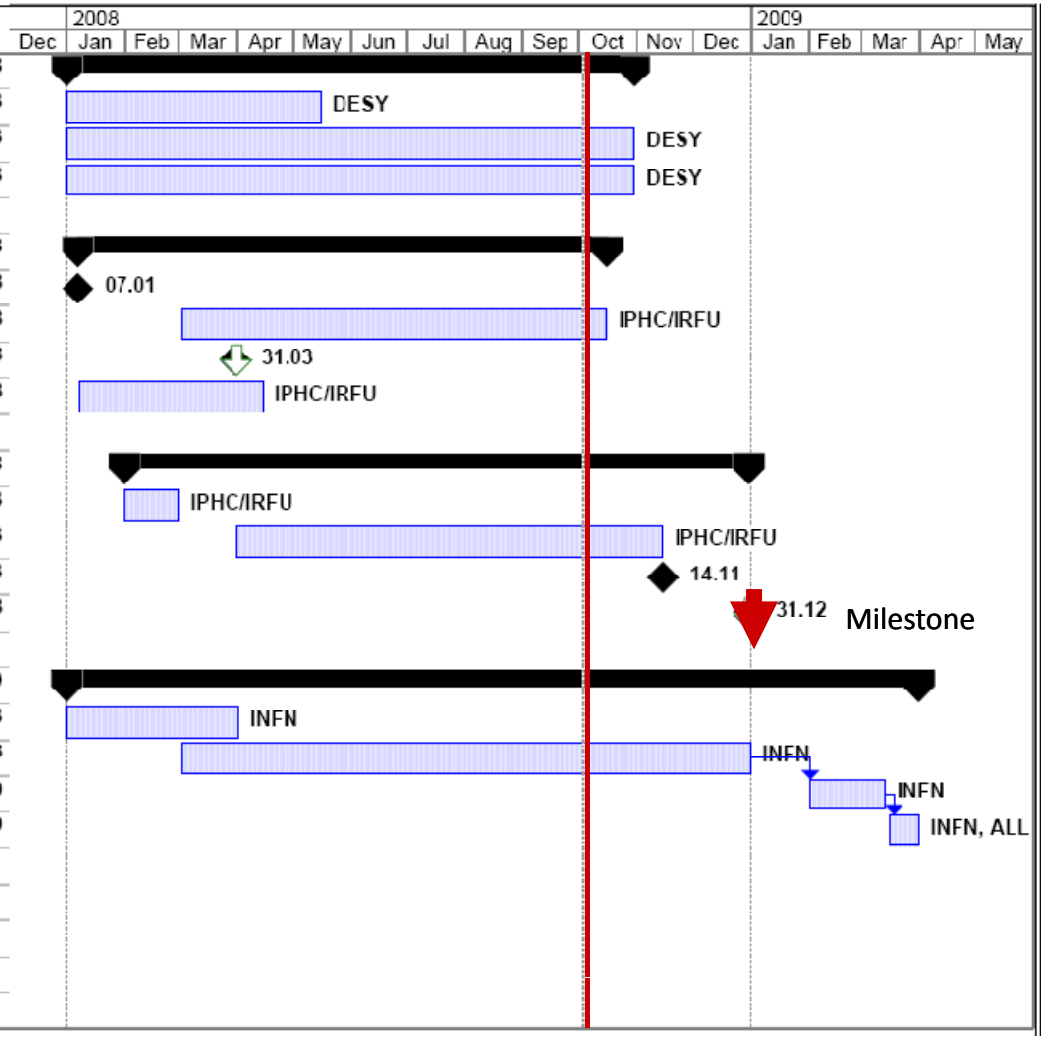
- Items we have to keep in mind for next user test beam campaign :
  - Certify EUDRB firmware (at DESY test beam)
  - When moving to different location (e.g. CERN) allocate some time with standalone data taking before users arrive (3 days)
  - Even better documentation for user integration -> users mostly have problems with the integration of the TLU signals in their system
  - Created to-do list to help the start up

User	**TB**	**#Runs**	**#Events**	**Data Size** [Gbyte]
Cadarache	SPS	64	5438957	2
SILC	SPS	230	1458173	157
Calice	PS	212	318437	9
Tapi	SPS	123	97598	149
Mimoroma	SPS	17	23985	20
ISIS	SPS	427	637866	27
DEPFET	SPS	355	2333133	346
EUTEL	SPS	148	342708	167
			10691178	**887**

Towards the Final Telescope

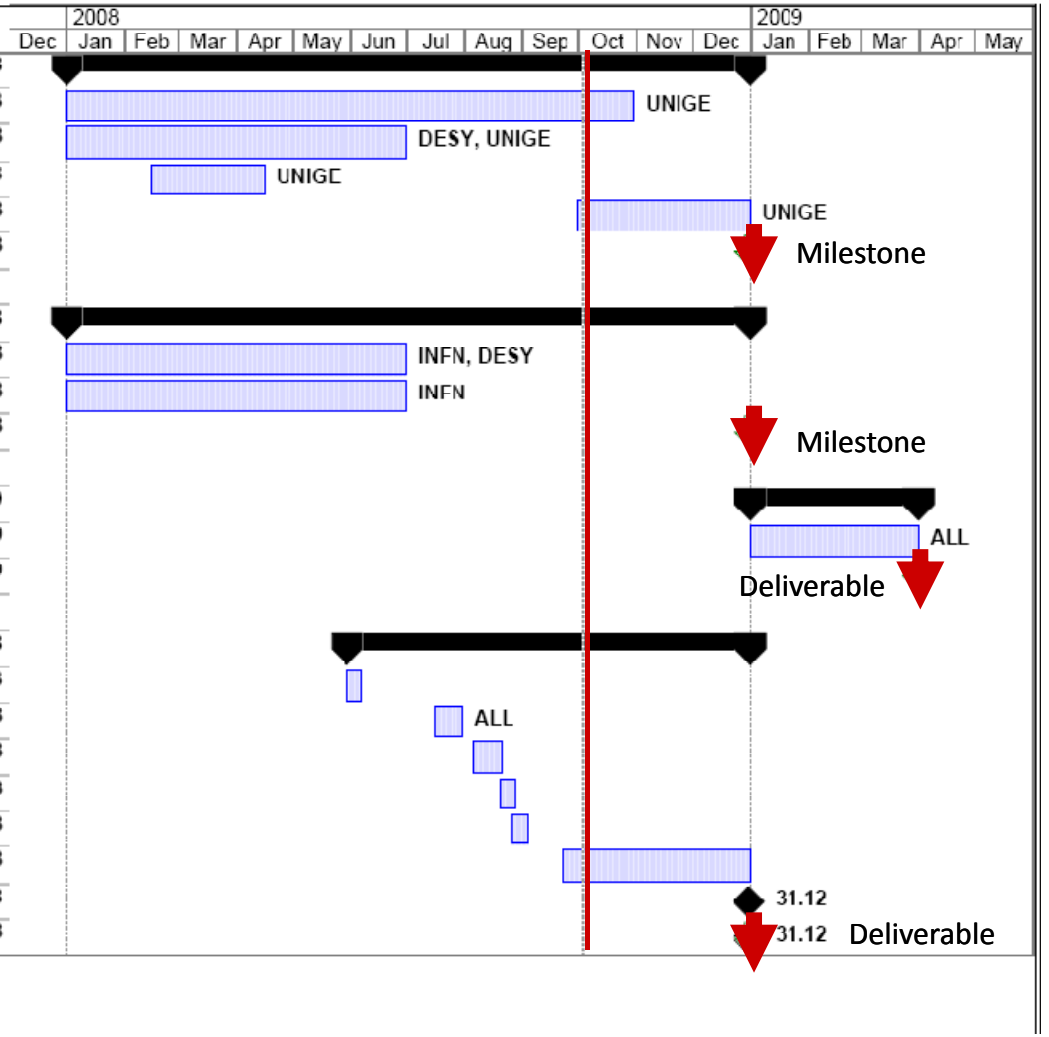
Timeline

ID	Task Name	Start	Finish
1	**Mechanics**	**Tue 01.01.08**	**Thu 30.10.08**
2	improve teles. alignment to be	Tue 01.01.08	Thu 15.05.08
3	sensor distance measure	Tue 01.01.08	Thu 30.10.08
4	improvement of cooling	Tue 01.01.08	Thu 30.10.08
5			
6	**Mimosa 22**	**Mon 07.01.08**	**Wed 15.10.08**
7	arrival of chip	Mon 07.01.08	Mon 07.01.08
8	test of Mimosa 22	Mon 03.03.08	Wed 15.10.08
9	Mimosa 22 (IDC) ready	Mon 31.03.08	Mon 31.03.08
10	PCB board production	Tue 08.01.08	Mon 14.04.08
11			
12	**Mimosa26**	**Fri 01.02.08**	**Wed 31.12.08**
13	Define specs and give to INFN	Fri 01.02.08	Fri 29.02.08
14	Mimos26 design	Tue 01.04.08	Fri 14.11.08
15	Mimosa 26 submission	Fri 14.11.08	Fri 14.11.08
16	Telescope chip (M26) ready	Wed 31.12.08	Wed 31.12.08
17			
18	EUDRB	**Tue 01.01.08**	**Tue 31.03.09**
19	new FPGA code for Mi18	Tue 01.01.08	Tue 01.04.08
20	preparation of EUDRB for M2	Mon 03.03.08	Wed 31.12.08
21	test of EUDRB with M26	Mon 02.02.09	Fri 13.03.09
22	integration in new telescope	Mon 16.03.09	Tue 31.03.09
23			
24			
25			
26			
27			



Timeline

ID	Task Name	Start	Finish
28	**EUDAQ**	**Tue 01.01.08**	**Wed 31.12.08**
29	improving VME drivers	Tue 01.01.08	Thu 30.10.08
30	improving online display	Tue 01.01.08	Mon 30.06.08
31	adjusted to Mimosa 18	Fri 15.02.08	Tue 15.04.08
32	update for Mimosa26	Wed 01.10.08	Wed 31.12.08
33	final readout ready	Wed 31.12.08	Wed 31.12.08
34			
35	**EUTelescope**	**Tue 01.01.08**	**Wed 31.12.08**
36	implement Milipede II	Tue 01.01.08	Mon 30.06.08
37	improve user interface	Tue 01.01.08	Mon 30.06.08
38	tracking software available	Wed 31.12.08	Wed 31.12.08
39			
40	**Final Telescope**	**Thu 01.01.09**	**Tue 31.03.09**
41	integration of M26 and EUDRI	Thu 01.01.09	Tue 31.03.09
42	new deadline	Tue 31.03.09	Tue 31.03.09
43			
44	**Testbeams**	**Fri 30.05.08**	**Wed 31.12.08**
45	SiLC at SPS/CERN	Fri 30.05.08	Fri 06.06.08
46	EUDET with DEPFET at PS	Wed 16.07.08	Wed 30.07.08
47	EUDET at H6/CERN	Wed 06.08.08	Wed 20.08.08
48	DEPFET at H6/CERN	Wed 20.08.08	Wed 27.08.08
49	ISIS at H6/CERN	Wed 27.08.08	Wed 03.09.08
50	EUDET at DESY testbeam	Mon 22.09.08	Wed 31.12.08
51	**Documentation**	**Wed 31.12.08**	**Wed 31.12.08**
52	Test report analog telescope	Wed 31.12.08	Wed 31.12.08



Upgrade of EUDRB to Mimosa26

Two options discussed:

Hardware Plan A:

- No need to build new daughter card
- Use the present J5 connector on current daughter card which provides 4 spare LVDS inputs (needs to be tested)
- Cost: 3kEUR
- Ready for field tests: end of February 2009

For more details see presentation from Livio Piemontese/Angelo Cotta Ramusino

Hardware Plan B:

- New daughter card approach
- Additional FPGA for de-serializing and data transfer
- Up to three Mimosa26 could be read by one board !
- Cost: 9kEUR
- Ready for field tests: end of April 2009

- Will follow hardware plan A to have DAQ hardware ready by end of year (milestone) and not to endanger our „big“ milestone at the end of month 39 (final telescope ready)

Two Telescopes ?

- Important question: what needs to be done to keep the demonstrator running while building the final telescope
- Planned: „upgrade“ demonstrator to final telescope
  - Replace MimoTel by Mimosa26
  - Change EUDRBs to digital readout
- Full Copy of Telescope costs ~100kEUR
- Keeping the demonstrator and building a more simple second telescope (using existing cooling, VME crate, power supplies etc.) might relax the price to ~40kEUR

Item	Full Copy [kEUR]
Chips (Mimosa26)	20
Sensor Boards	5
Readout Boards	20
Mechanics (simple)	10
VME CPU	3
VME crate 64bit	5
XY table	15
Cooling	5
Power Supplies	5
TOTAL	**88**

- Discussion during JRA1 meeting: feasible to have two telescopes in the end BUT give final telescope priority (keep milestones!)
- Manpower would also be needed to run two telescopes

Possible Users for 2009

- Previous users interested in additional tests
  - DEPFET, MimoRoma, CALICE, SiLC, ISIS, BeamCAL
- Interested groups contacted us for test beam season 2009 (DESY and CERN)
  - RD42 (Harris Kagan) – diamond pixel
  - RD51 (Matteo Alfonsi) – micro gas detectors
  - Medipix (Stanislav Pospisil) – Medipix sensor
  - ATLAS Planar Pixel (Claus Gössling) – new pixel sensors
  - CMS (Rutgers) – diamond pixel
  - CBM at Fair (Johann Heuser) – strip detectors for tracking

Outlook

- The telescope demonstrator is working according to specs!
- The demonstrator will be installed at DESY this fall and can be used until spring 2009
- Small changes planned in mechanics and cooling
- A high resolution plane will be added for further improvement

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