The EUDET Pixel Telescope Data Acquisition System

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on behalf of the EUDET Consortium

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Outline

- EUDET Overview
- The Pixel Telescope
- MAPS
- Telescope Data Acquisition
  - Philosopy
  - DAQ Hardware
  - DAQ Software
  - Analysis & Reconstruction
  - User Example
- Towards the final system
- Performance and Testbeams
- Conclusions

EUDET Overview

- EUDET is an "Integrated Infrastructure Initiative (I3)" within the EU funded "6th framework programme"
- Support improvement of infrastructure for detector R&D with larger prototypes
  - but not the R&D itself
- Not a collaboration
  - Other institutes can contribute and exploit the infrastructure
  - Infrastructure can be re-located
- Timeline 2006-2009 (prolongation till 2010)

Coordinator:
Prof. Joachim Mnich, DESY

EUDET Partner Institutes

Charles University Prague
IPASCR Prague

HIP Helsinki

LPC Clermont-Ferrand
LPSC Grenoble
LPHNE Paris
Ecole Polytechnique Palaiseau
LAL Orsay
IReS Strasbourg
CEA Saclay

DESY
Bonn University
Freiburg University
Hamburg University
Mannheim University
MPI Munich
Rostock University

Tel Aviv University

INFN Ferrara
INFN Milan
INFN Pavia
INFN Rome

NIKHEF Amsterdam

AGH Cracow
INPPAS Cracow

CSIC Santander

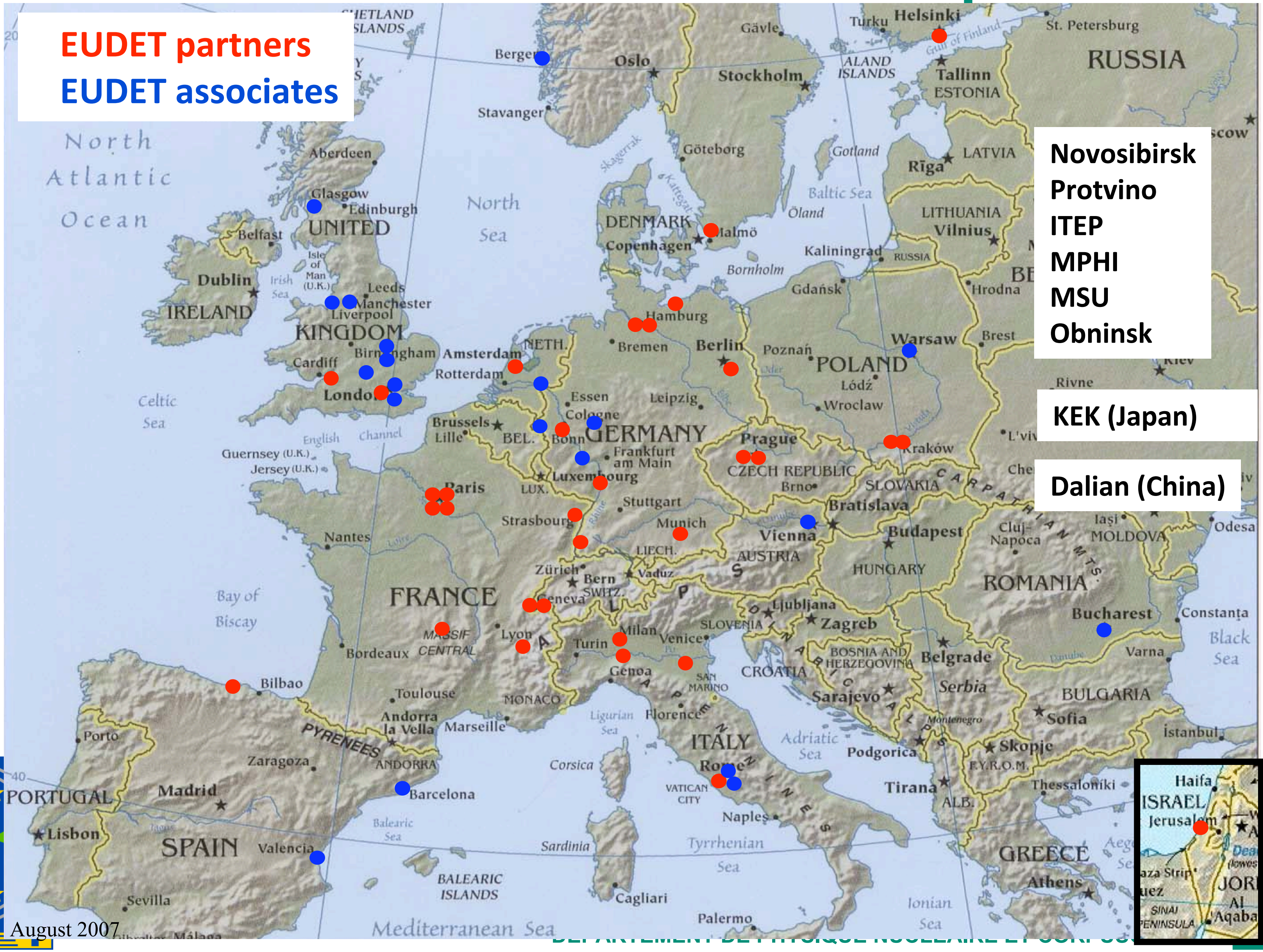
Lund University

CERN Geneva
Geneva University

Bristol University
UCL London

+ 22 associated institutes

The EUDET Map



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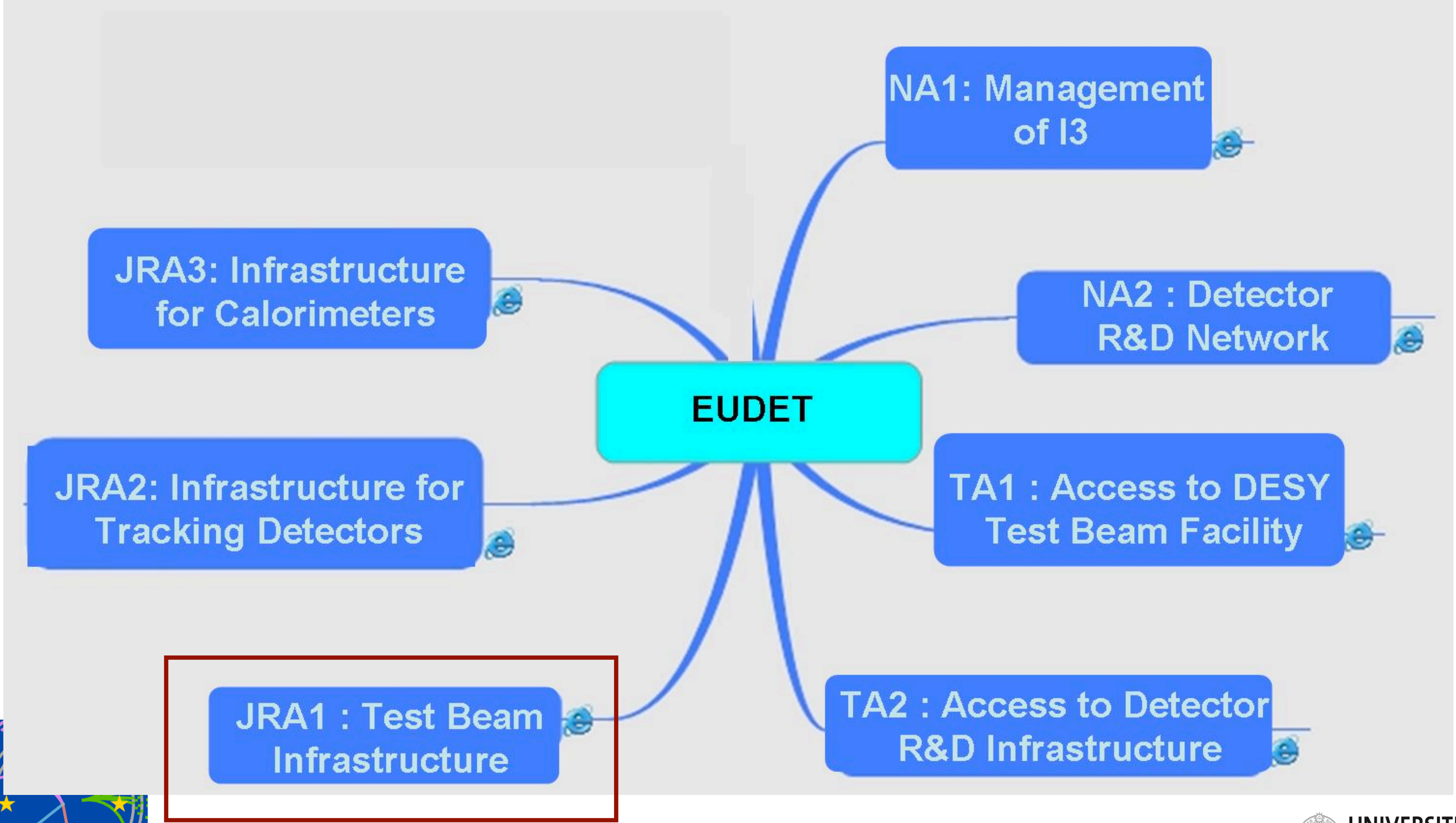
EUDET Activities



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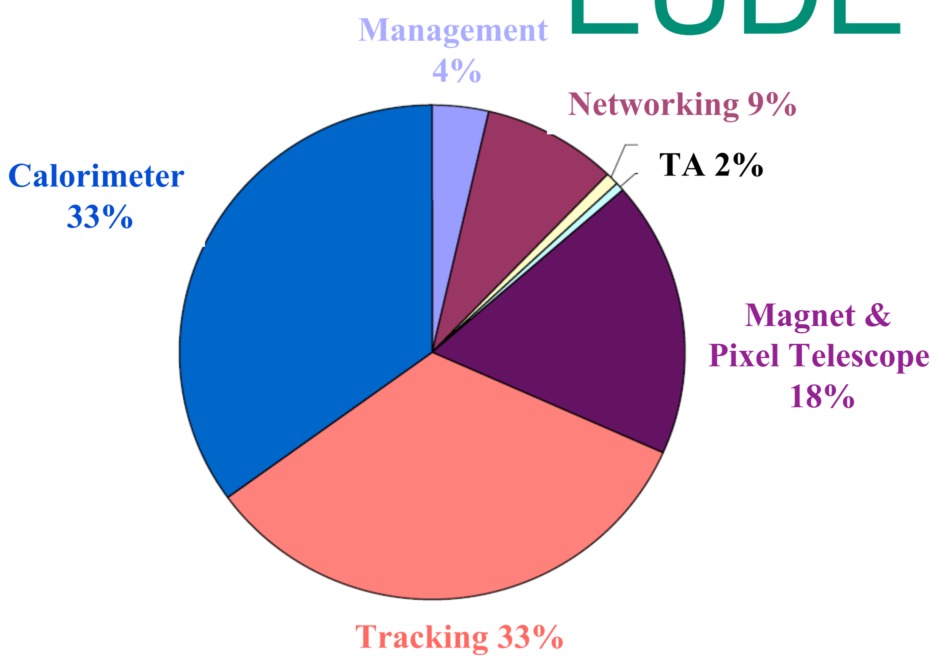
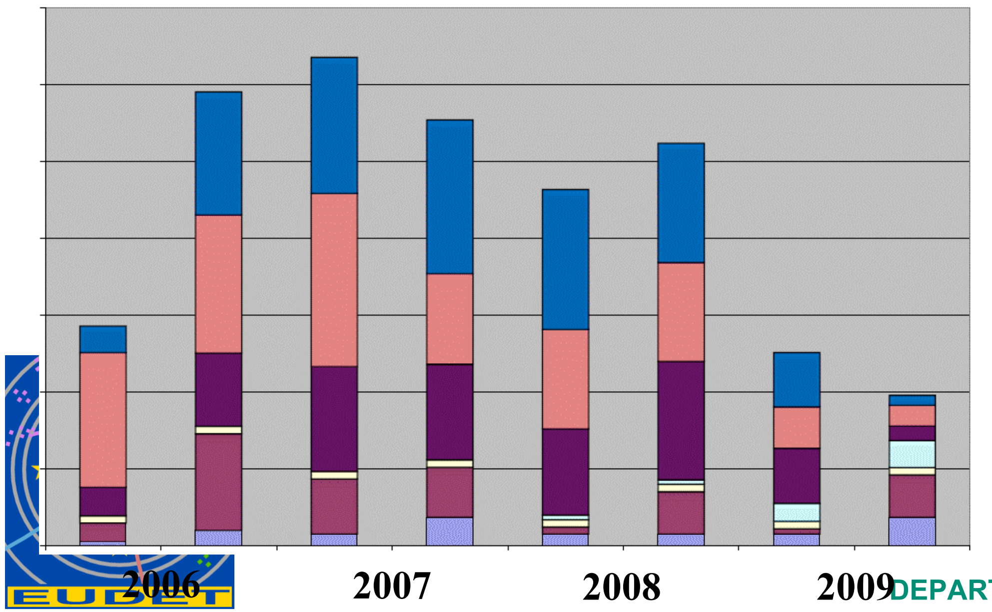
EUDET Budget





- most of the resources for the development of the infrastructures
- ramp-up first half 2006
- full swing activities for 2.5 years
- last year: phase-out and exploitation of infrastructures stretched till 2010 now
- Manpower:
  57 FTE (17 from EU)

Telescope Requirements & Schedule

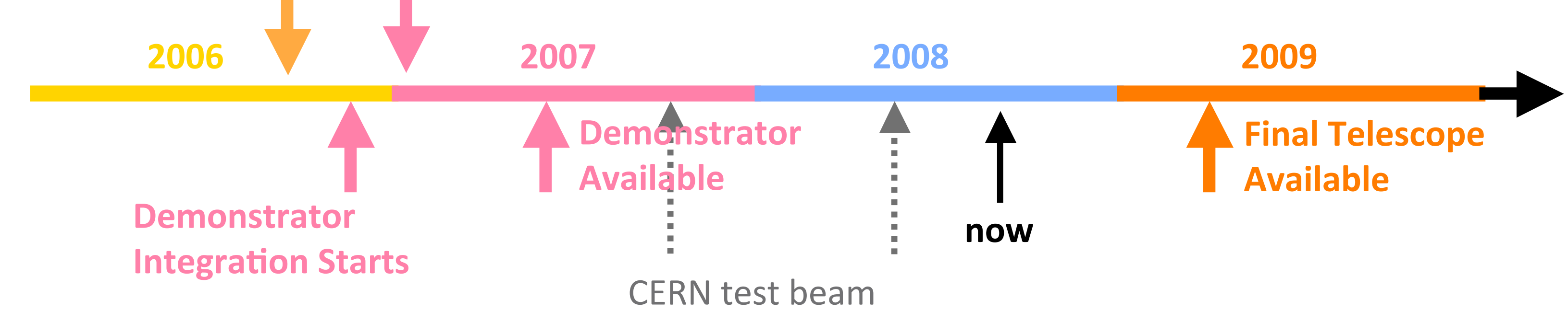
- General purpose telescope for different users:
  - small pixel sensors or larger volume tracking devices (TPC)
- Movement of device under test (DUT) to scan larger surface
- Adjustable cooling, positioning, (magnetic field)
- Easy to use: well defined/described interface
- Very high precision: <3 µm resolution even at smaller energies
- Use in different environments (DESY, CERN, ...)

Phase 1 (Demonstrator):

- Established pixel technology with analogue readout

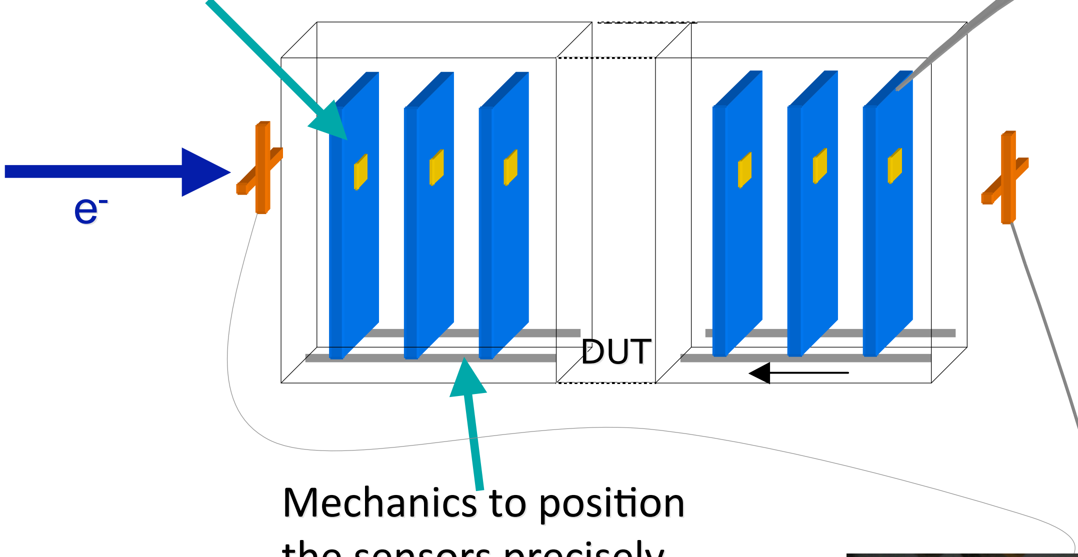
Phase 2 (Final Telescope):

- Sensor with fully digital readout, CDS and data sparsification
- Ready early 2009



Telescope Ingredients
(Demonstrator)

Sensors



Mechanics to position the sensors precisely

DESY Hamburg

ReadOut (EUDRB)

LVDS

GBIT ETH

Trigger Logic Unit (TLU)

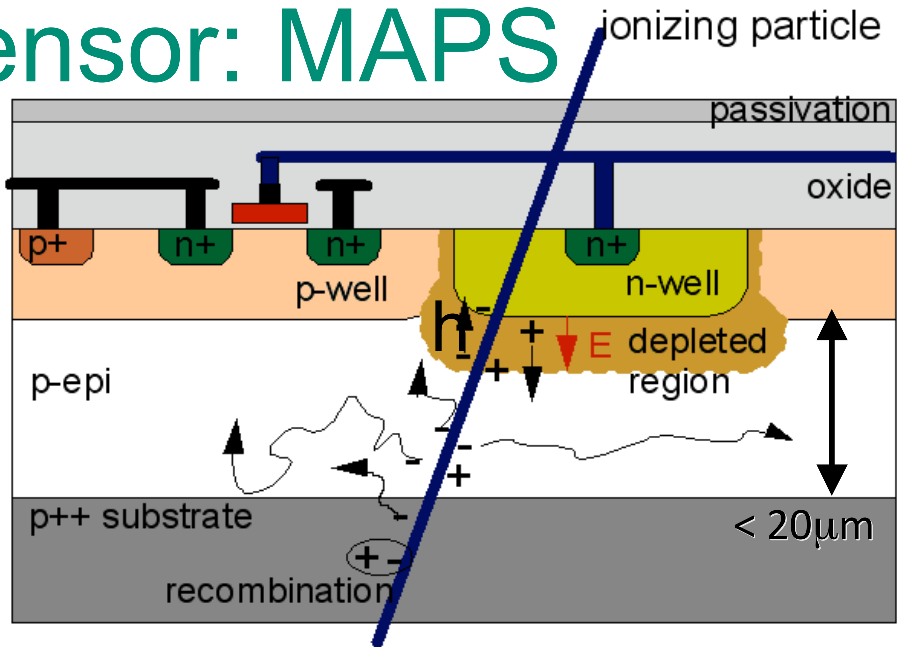
USB

EUDAQ

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

Choice of Pixel Sensor: MAPS

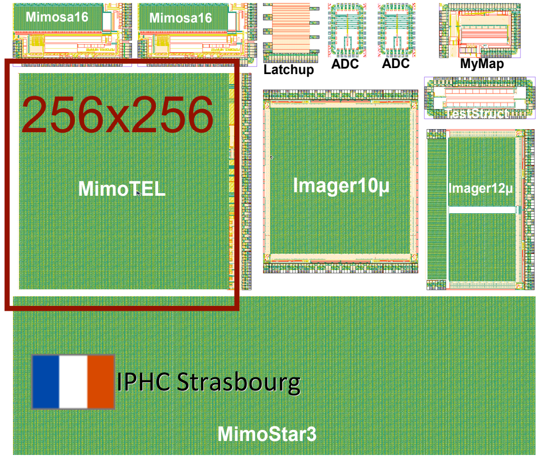
- At that time only ILC pixel technology with large enough arrays
- IRES/Strasbourg working on this since ~10 years
- Mimosa (Minimum Ionizing Particle MOS Active Pixel Sensor)
- Active area underneath the electronics (epi-layer <20µm thick) providing 100% fill-factor
- Charge generated by ionization in the epitaxial layer thermally diffuse toward low potential n-well region
- Standard, cost-effective CMOS process, no post-processing



Features of the MIMOSA – detectors:

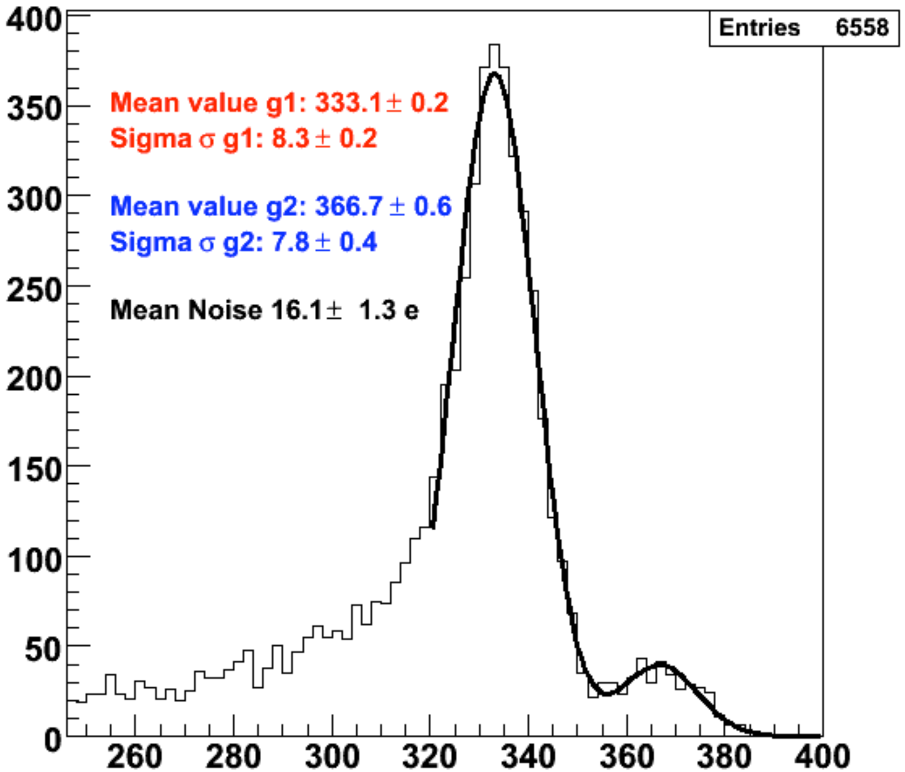
- Single point resolution 1 µm – 3 µm
- Pixel–pitch 10-40 µm
- Thinning achieved: 50 - 120µm
- S/N for MIPs 20 – 40
- Detection efficiency > 99%
- Radiation hard: 1MRad ; 2 x 10^{13} n_{eq}/cm^2
- Produced in various commercial CMOS-processes

Reference Plane Sensors



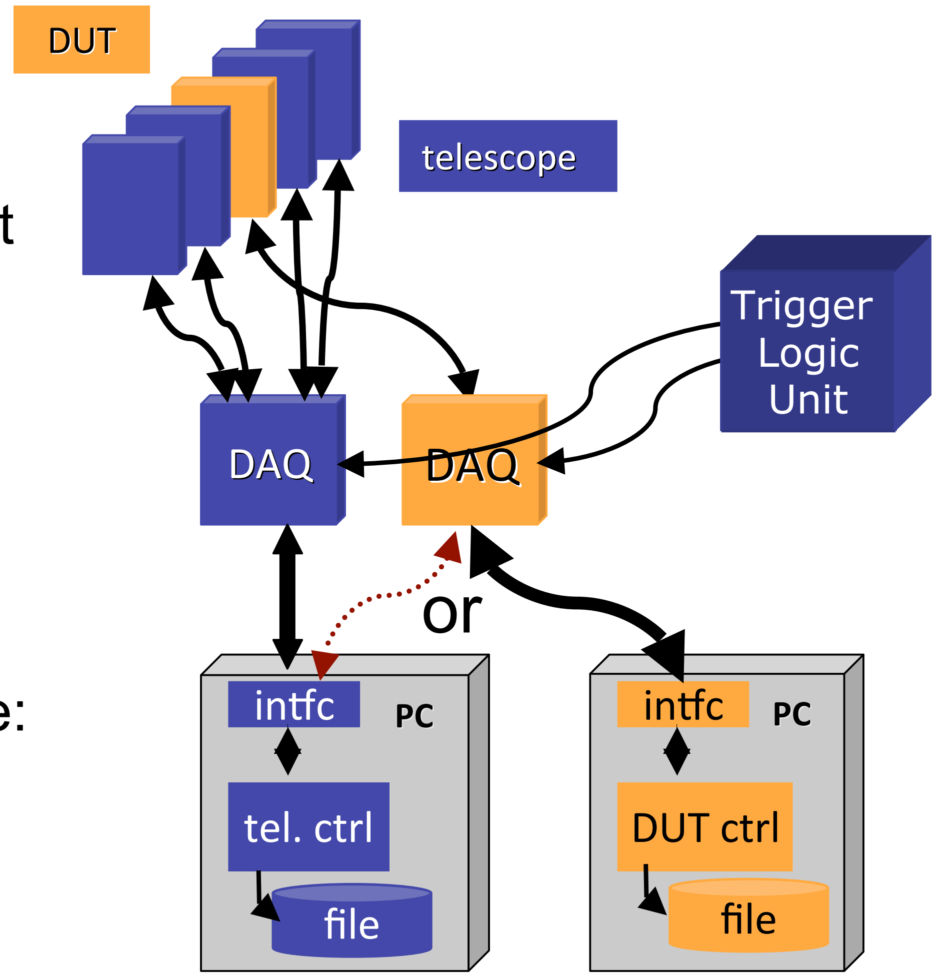
Demonstrator: MimoTel

- AMS 0.35 OPTO process with 14 and 20µm epitaxial layer
- 4 sub-arrays (64 × 256 pixel)
  - 30 × 30 µm^2 pitch
  - active area: 7.7 × 7.7 mm^2
  - readout : 1.6 ms (4 analog output nodes at 10 MHz)
  - pixel designed to stand >1 MRad
  - Used since February 2007
- Very good performances:
  - Noise: ENC ~ 15 electrons @room temperature
  - S/N (MPV) > 22
  - Efficiency ~ 99.9%

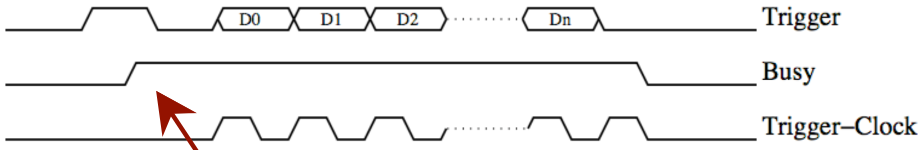


DAQ: Integration Concept

- How to integrate the DUT hardware with the EUDET 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



DAQ Hardware: TLU



Busy acknowledges the Trigger

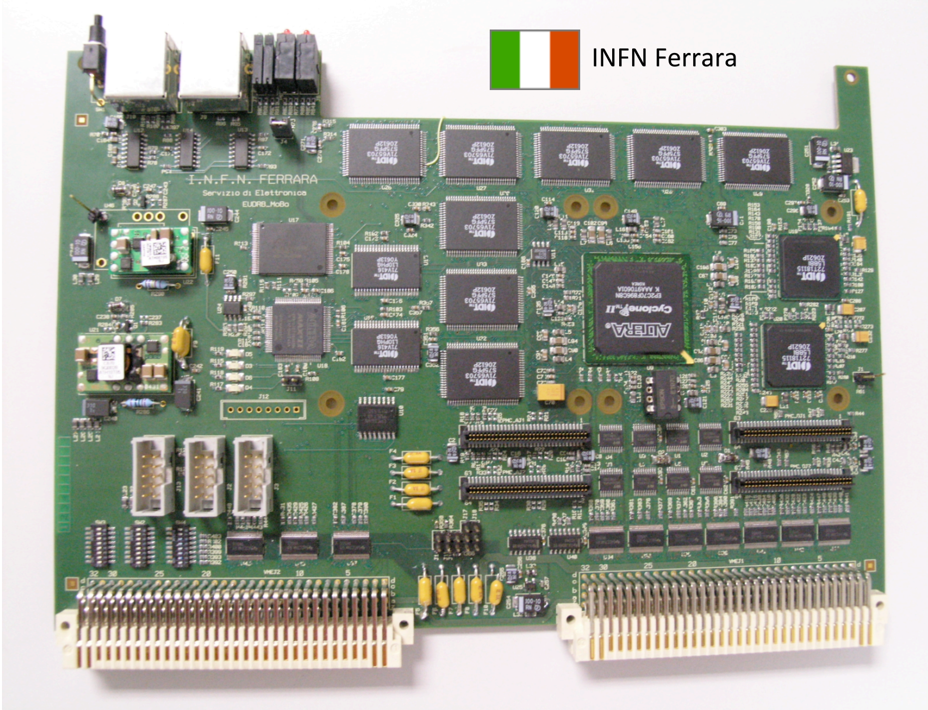
Trigger Logic Unit

- Two handshake modes
  - Simple handshake (Trigger/Busy/Reset)
  - Trigger data handshake incl. event number
- Timestamp and event-number via USB
- LVDS via RJ45, NIM and TTL via Lemo (Software-Selectable)
- Inputs for four trigger signals (ANDed, ORed, VETOed)
- Internal trigger mode and scalers for testing
- Low voltage power supply for PMTs
- Special needs for special demands:
  - Low Jitter mode (for TPCs etc.)
  - 'LHC'-users: increased timestamp resolution, central clocking

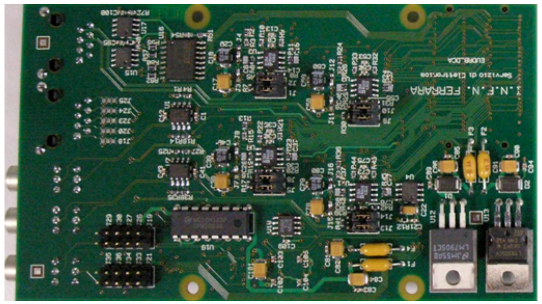
DAQ Hardware - EUDRB

EUDET Data Reduction Board:

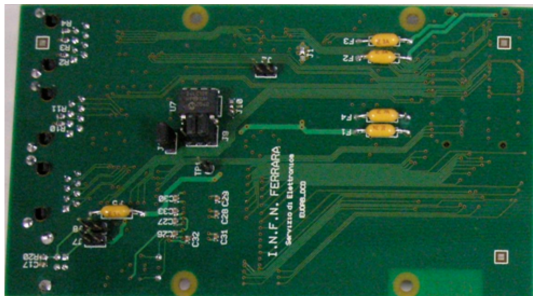
- Mother board with ALTERA CycloneII FPGA (clock: 80MHz) hosts core resources and Interfaces (VME64X slave, USB2.0, EUDET trigger bus)
- 2 Daughter cards (analog + digital)
- NIOS II, 32 bit "soft" microcontr. (40Mz) for diagnostitics, pedestal+noise calculation and remote configuration
- Two readout modes: Zero Suppressed for normal data taking, raw 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

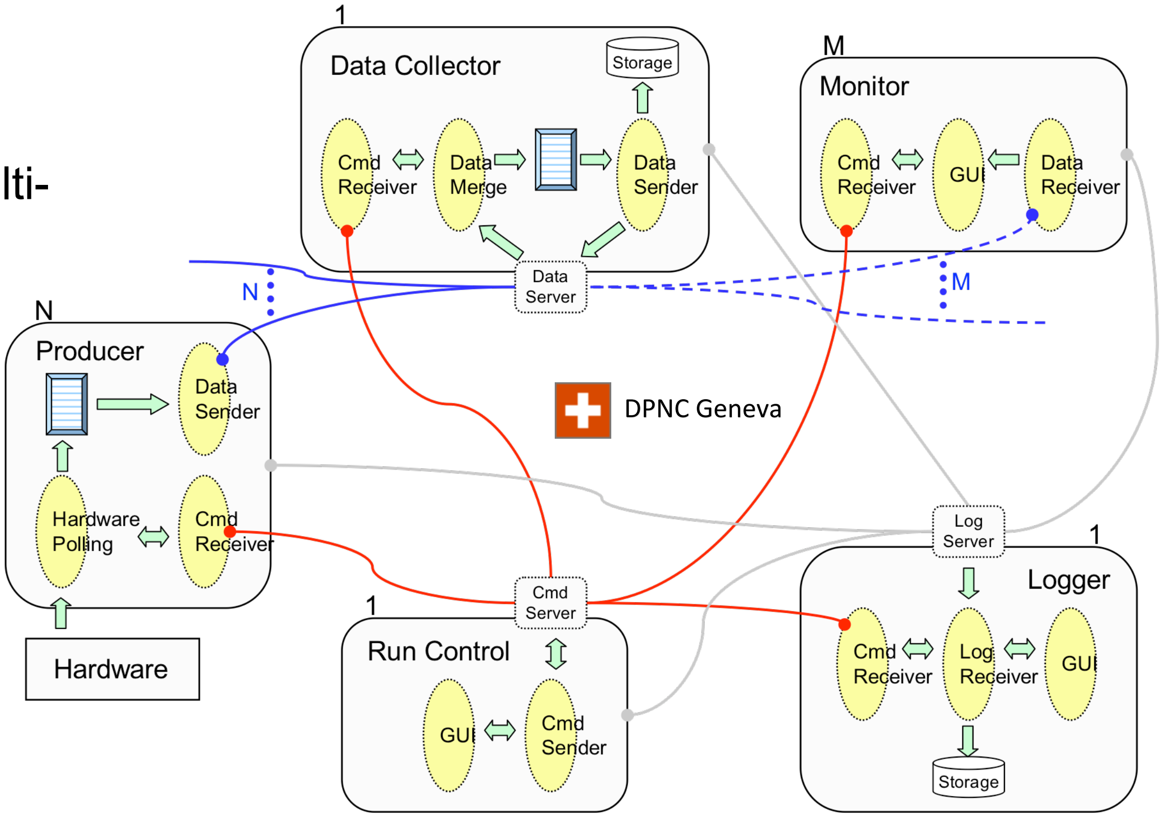


Digital daughter card drives/receives control signals for the detectors and features a USB 2.0 link



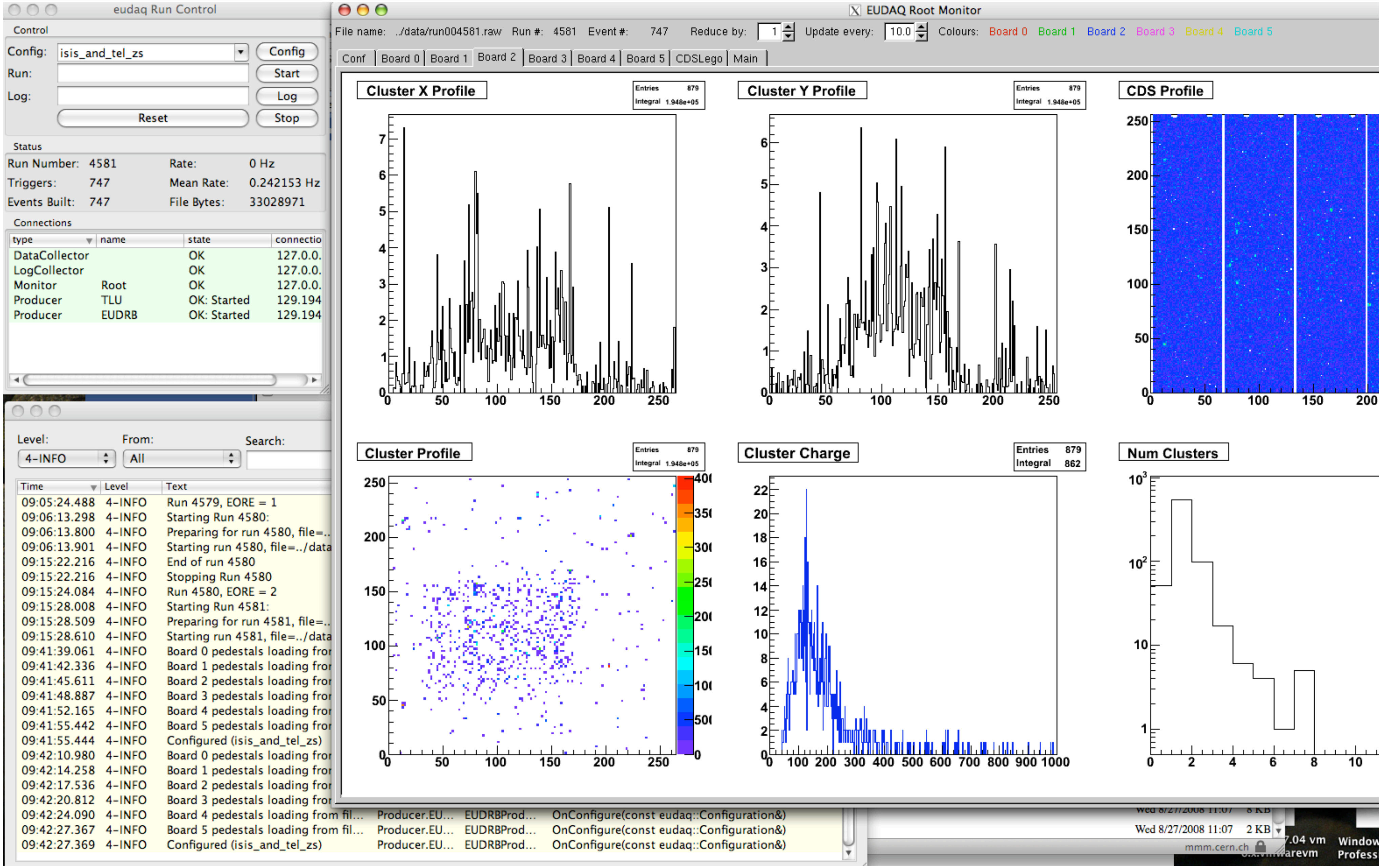
DAQ: Software

- Platform independant (MacOSX, Linux, Windows)
- Object oriented, distributed and multi-threaded
- 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



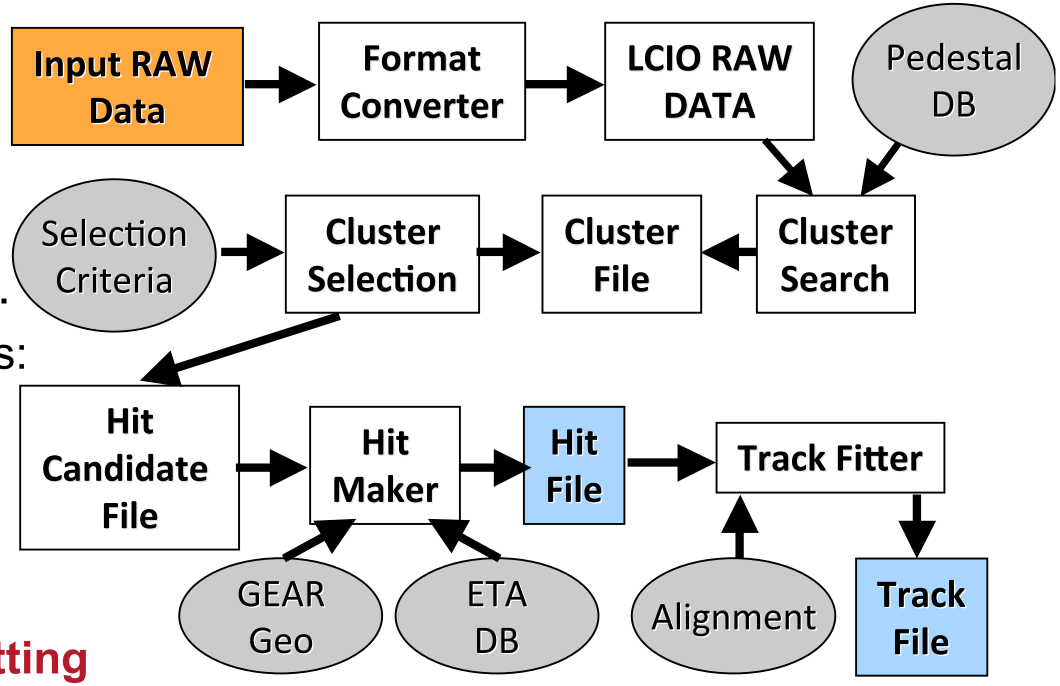
http://projects.hepforge.org/eudaq/

EUDAQ Run Control



Analysis & Reconstruction Software

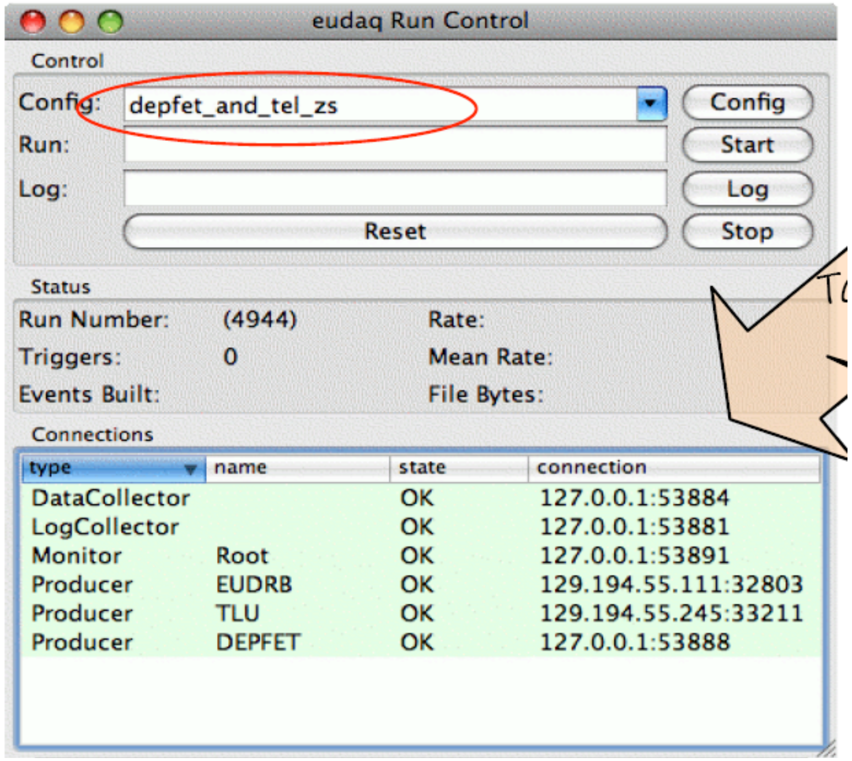
EUTelescope:

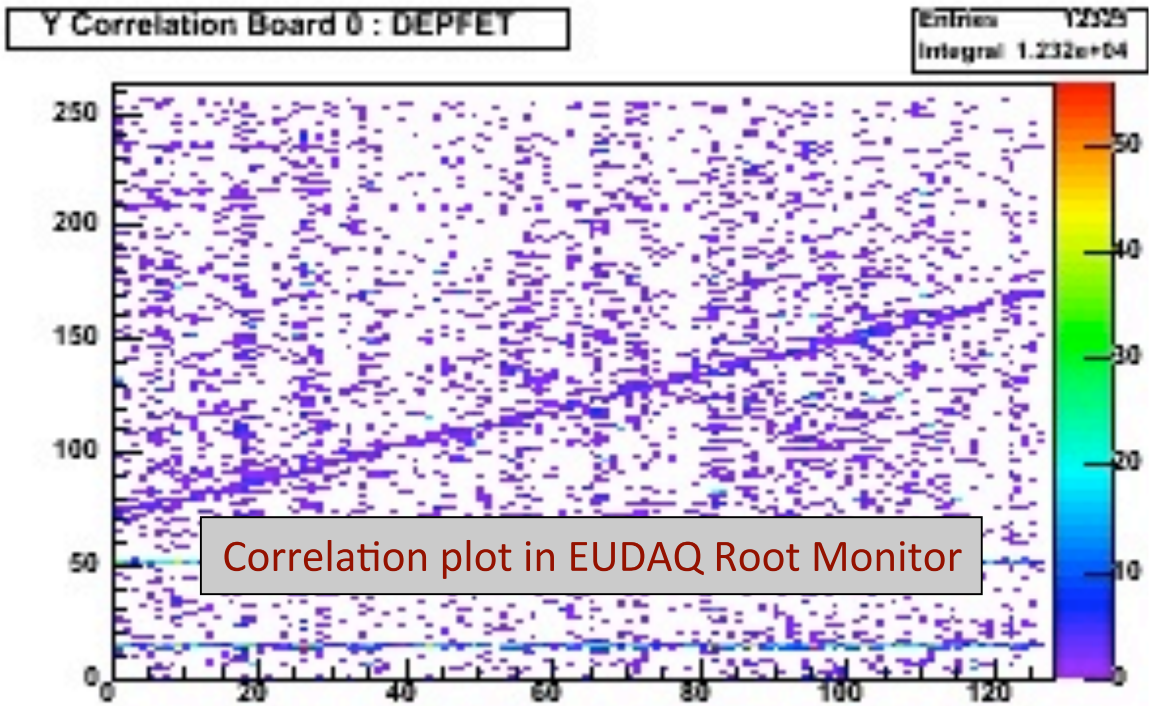


- Set of relevant high level objects (like tracks or space points) to characterize the DUT
- Histograms of important figures of merit.
- Based on available/tested software tools:
  - Single sensor analysis → **sucimaPix** (INFN)
  - Eta function correction → **MAF** (IPHC)
  - Track fitting → **Analytical 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

User Example: DEPFET

- DEPFET running at CERN PS and SPS within EUDET telescope
- Measurements of efficiency, purity and intrinsic resolution
- DEPFET fully included on DAQ level
  - own producer within EUDAQ
  - one data stream
- 1 Million events as EUDET DUT!





Correlation plot in EUDAQ Root Monitor

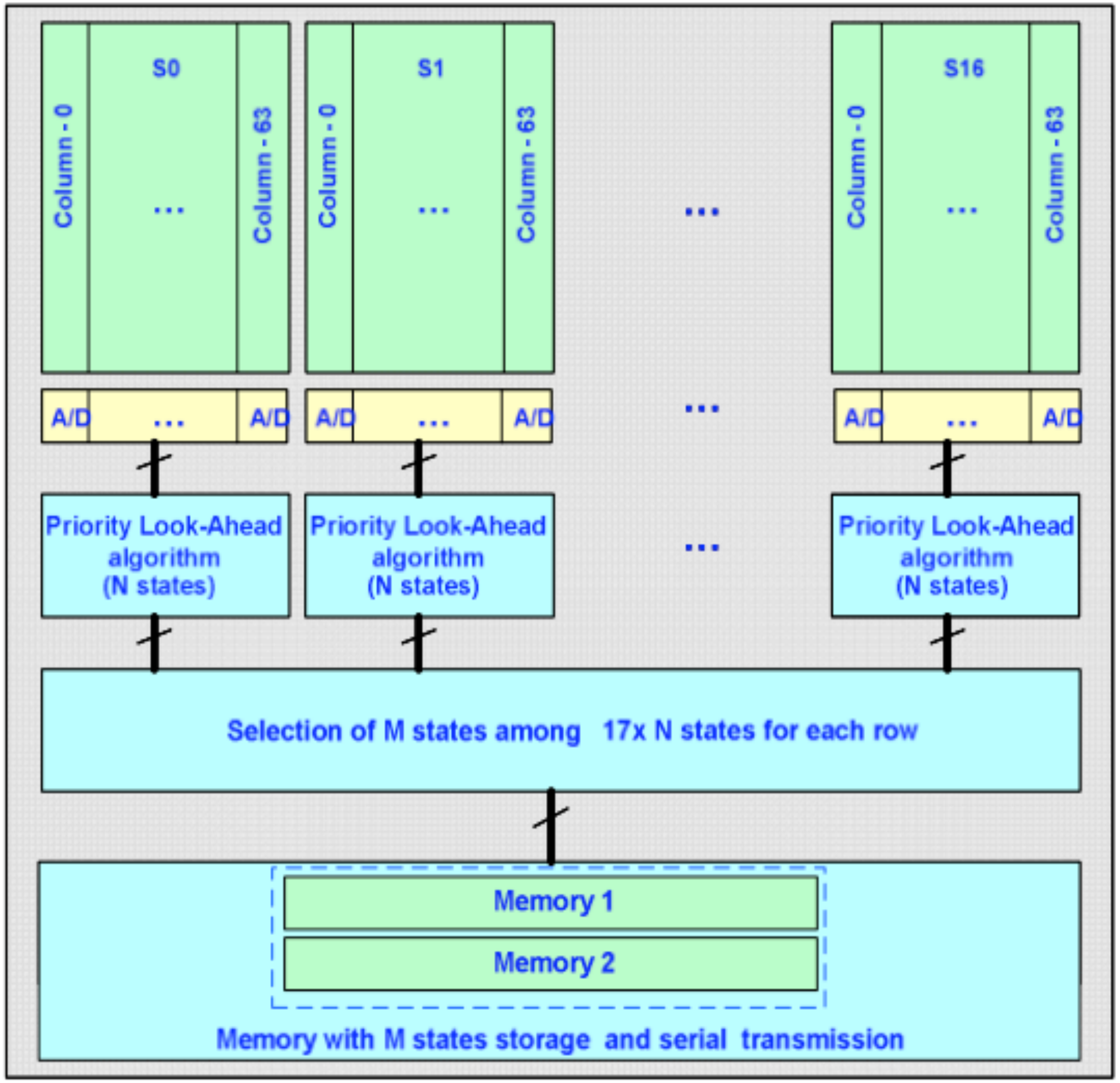
Step-by-Step EUDAQ Integration

- eudaq::Producer class handles communication with RunControl and Data Collector, and provides methods for the User.
- User writes a new class, inheriting from the Producer, and overrides various methods:
  - OnConfigure to configure their hardware.
  - OnStartRun provides RunNo: User must send a BoR Event
  - User reads his hardware, and calls SendEvent, which will take care of serializing the event and sending it to the DAQ.
  - OnStopRun gets called at the end of the run. The User should wait until all the data have been read out, then send an EoR Event.
- User writes a Converter Plugin, to convert his raw data
- User should Send an event for every trigger, even if empty, DataCollector expects this for combining data

Final Telescope Chip: TC/Mimosa 26

Submission in Nov 2008

- Mimosa-22 (binary outputs) complemented with zero-suppression (SUZE-01)
- Active surface : 1152 columns of 576 pixels (21.2×10.6 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
- Throughput: 1 output at 80 Mbits/s or 2 outputs at 40 Mbits/s
- Needs adoption of readout electronics (EUDRB)



TC/Mi26 available/under test since March 2009

DAQ Changes - EUDRB & EUDAQ

EUDRB evolves with new sensors

- was successfully adapted to sensor Mimosa 18 (4x more pixels) (still with on-board zero suppression)
- Changes to readout the final telescope chip:
  - All done in firmware, no hardware modification needed
  - embedded M26 simulator operating in mode 0 (two channels @ 90 MHz)
  - the M26 interface operates at up to 90MHz
  - overlapping INPUT (frame acq.) and OUTPUT (VME readout) operations
  - interrupt-driven event read-out
  - 2e-SST block transfer (> 100MB/s burst rate)
  - leading word count in the output event data block

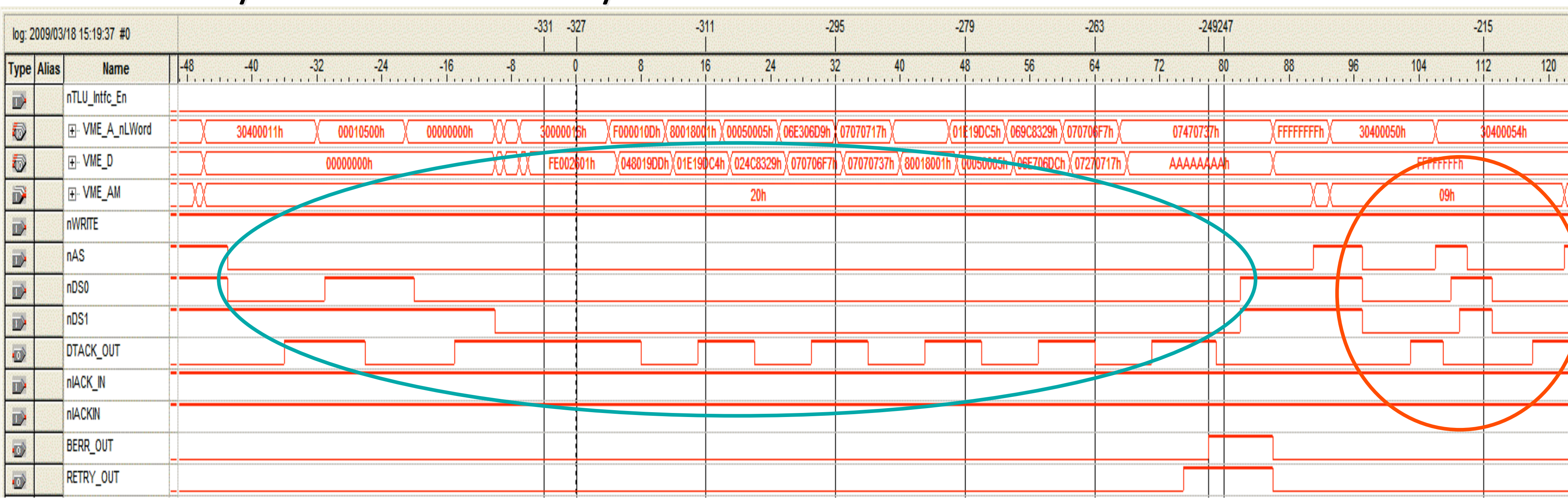
EUDAQ needs only minor changes

- modified EUDRBProducer to handle Mi-26 and 2eSST commands
- modified Converter to handle Mi-26
- small modifications to the RootMonitor

DAQ Changes - VME driver

2eSST transfer and Tsi148 driver 'features':

- CPU breaks 2eSST block transfer into many "atomic" transfers.
- atomic transfers allow 128 cycles (VME spec), but CPU never schedules more than 8 cycles thus making the transfer inefficient due to the overhead of the 3 address phases at the start of each "atomic" cycle.
- And worse: calling 2eSST block read within Tsi148 does not only provide block read!
- Example: Read 88 bytes, you get a block read of 80 bytes and 2 single cycle transfers of 4 bytes



DAQ Changes - VME driver speed

Performance (current Demonstrator, Mimotel)

- 6 EURDBs (~4kB each), no 2eSST, polling only, busy cleared by CPU: 200-300 Hz (2008: 50 Hz only)

Expected Performance (with Mi-26 simulator)

- Readout of one EUDRB, fixed event size of 2112 bytes,
  90 MHz: 4.88 kHz (theoretical limit 5 kHz)
- Readout of 3 EUDRBs, 4144 bytes: 1.1 kHz
  - fixed overhead for changing address space, and Tsi148 ‘features’
  - ‘real’ data will likely be smaller

Testbeams 2009

Run at CERN SPS from mid-July to mid-September (commissioning mid-June)

- 3 (experienced) Main Users:
  DEPFET, LCFI, SILC
- ‘Parasitic users’ from LHC upgrade programs (Atlas) etc.
- ‘own’ TC/Mi-26 will be tested as DUT,
  then become the ‘default’ telescope sensor in 2010
- Implementation of TC/Mi-26 will also address VME driver issues

Outlook & Conclusions

- The telescope demonstrator is working according to specs
- The demonstrator is at DESY test beam currently and will move to CERN afterwards (June - September)
- The final telescope chip TC/Mi-26 is under test
- DAQ performance has been increased for 2009 testbeams
- DAQ hardware and software is modified for TC/Mi-26
- final readout will achieve at least 1kHz
- Users can profit from a full analysis chain within the ILC software framework
- Everybody can join the fun and use the developed infrastructure to test their own devices

EUDET will run till end of 2010

What do we offer to users

- A two arm pixel telescope with variable geometries:
  - Mechanics and cooling system for the reference sensors is provided.
  - Operating support: mainly remote but also local in some circumstances.
- Possibility to add one extra high resolution (1 μm) sensor plane.
- The DAQ system; both hardware and software.
  - Trigger/Busy Handshake of full integration to our DAQ (help provided)
- The analysis and reconstruction software.
  - Rely on our output track file, or integrate in the main analysis stream.
- Possibility of travel money for users via FP6 Transnational Access

see http://www.eudet.org

Contact: Ingrid.Gregor@desy.de

All-inclusive Package for the Users