EUDET BEAM TELESCOPE

Marcin Jastrzab on behalf of Ingrid Gregor, Antonio Bulgheroni and JRA1 EUDET collaboration

Outline

- Introduction to EUDET
- Pixel beam telescope
  - Overall description
  - DAQ hardware / software
  - Analysis and reconstruction software
  - Summary of the test beam results
  - Future
- Conclusion

- **EU funded program supporting ILC detector R&D in Europe**
  - EUDET:
    - Is not a detector R&D programme in its narrower sense. It provides a framework for ILC detector R&D with larger prototypes
    - Does not cover all future needs (both financial and personnel). Additional resources required to exploit EUDET infrastructures.
    - Is not a closed club. Other institutes (European & non-European) are invited to contribute and exploit the developed infrastructures.

SIXTH FRAMEWORK PROGRAMME
Structuring the European Research Area Specific Programme
RESEARCH INFRASTRUCTURES ACTION

EUDET partners

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

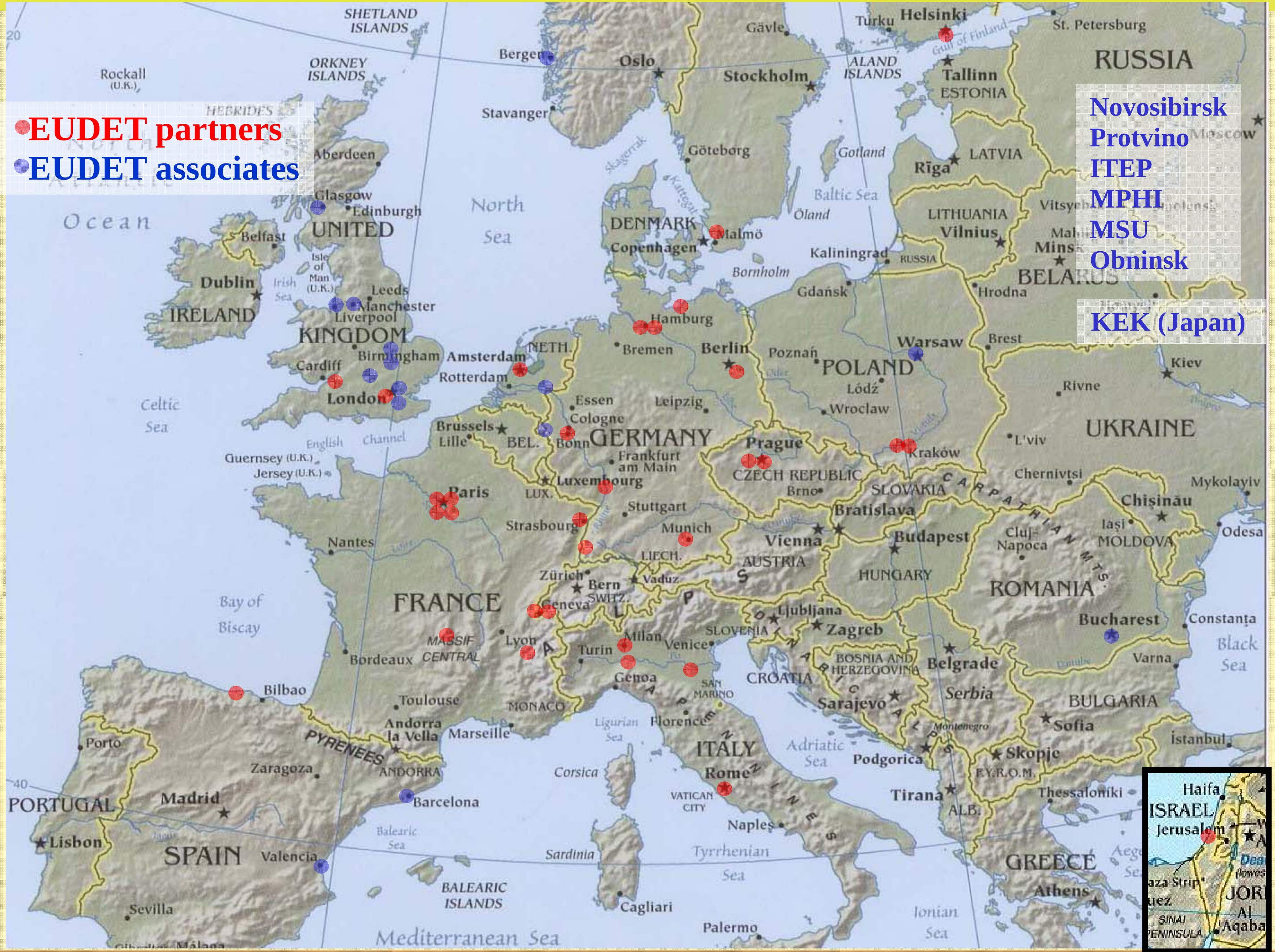
Lund University

CERN Geneva
Geneva University

Bristol University
UCL London

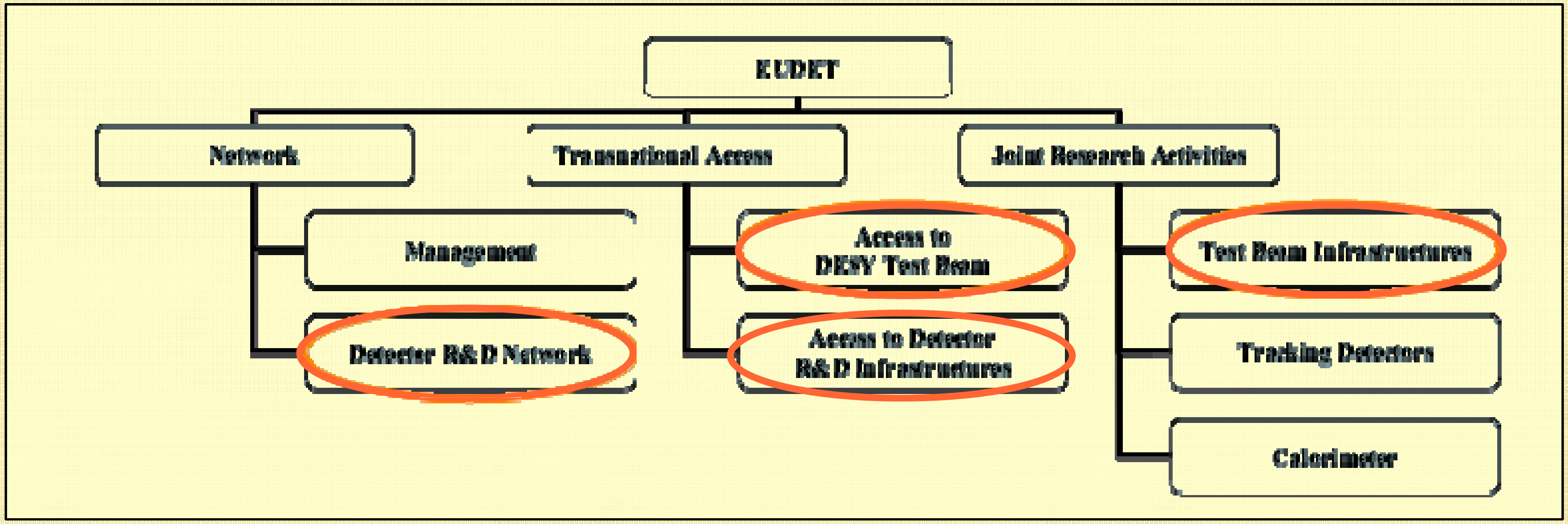
+ 22 associated institutes

EUDET map


EUDET partners
EUDET associates
Novosibirsk
Protvino
ITEP
MPHI
MSU
Obninsk
KEK (Japan)

EUDET pillars

- Three pillars: **Networking Activities, Transnational Access and Joint Research Activities**

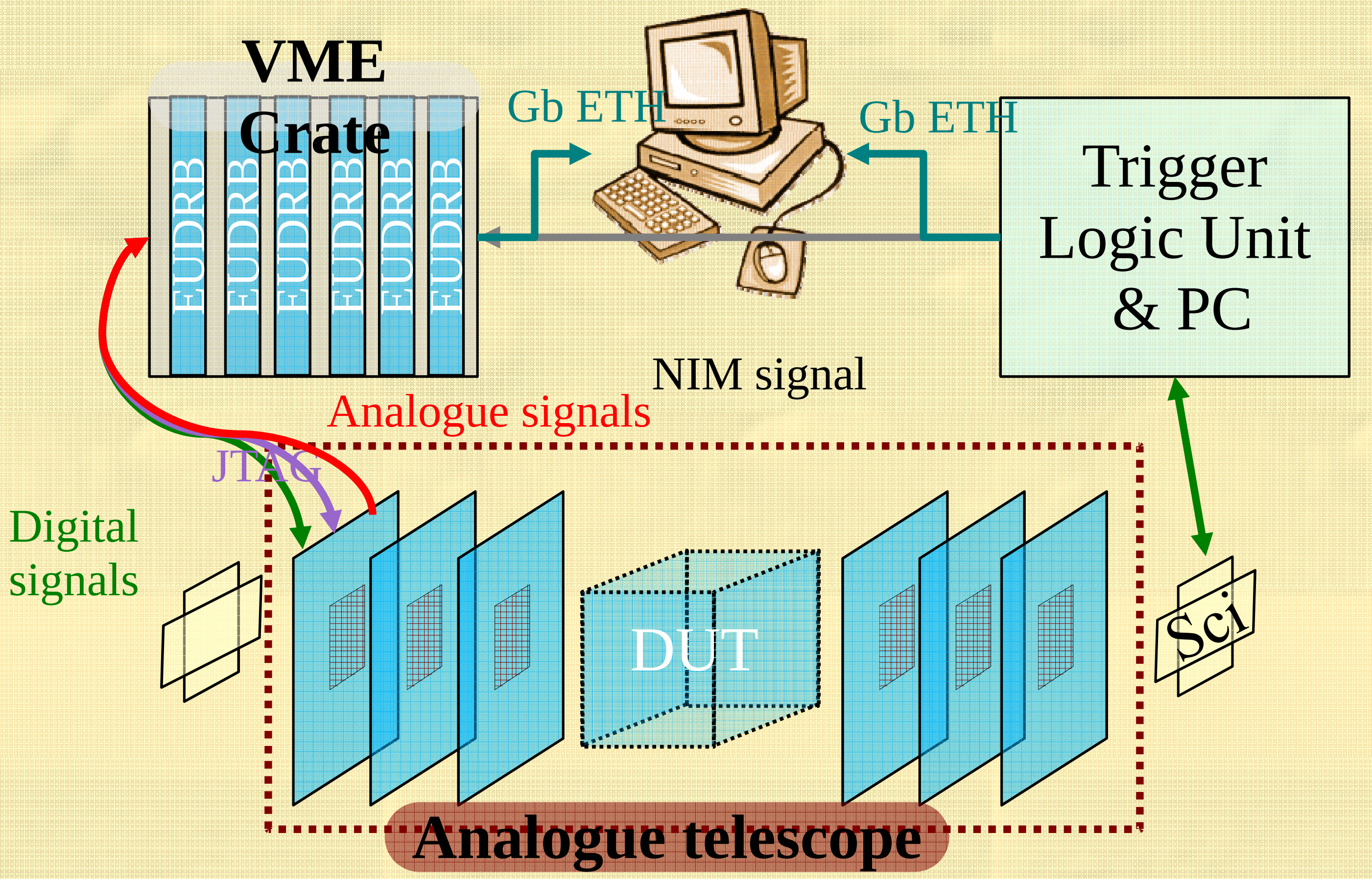


- **NA2: Common software framework** for TB and simulations, **Common DAQ**, deep-subμ electronics (CERN).
- **TA1: Using the DESY test beam area.**
- **TA2: Access to the EUDET infrastructures** (like the beam telescope)
- **JRA1:** Large bore magnet and **pixel beam telescope**

Pixel beam telescope

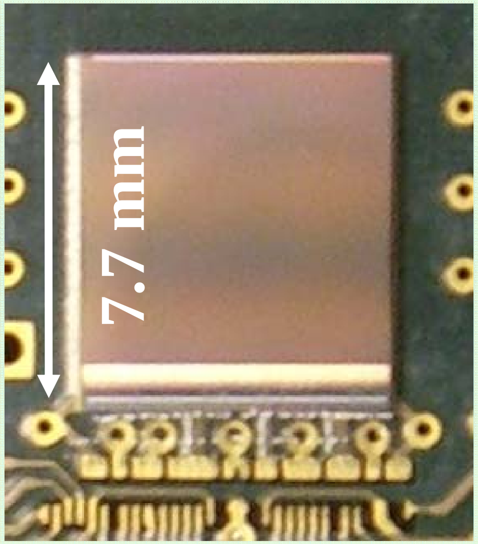
Two phases:

- 1st with analog sensors and sparsification @ the DAQ level (demonstrator)
- 2nd digital sensors with binary output and higher frame rate



Looking closer at the demonstrator

- MAPS sensor with SB structure
- 65k pixels with 30 um pitch
- Four parallel output channels
- Clock < 20 MHz



MimoTel

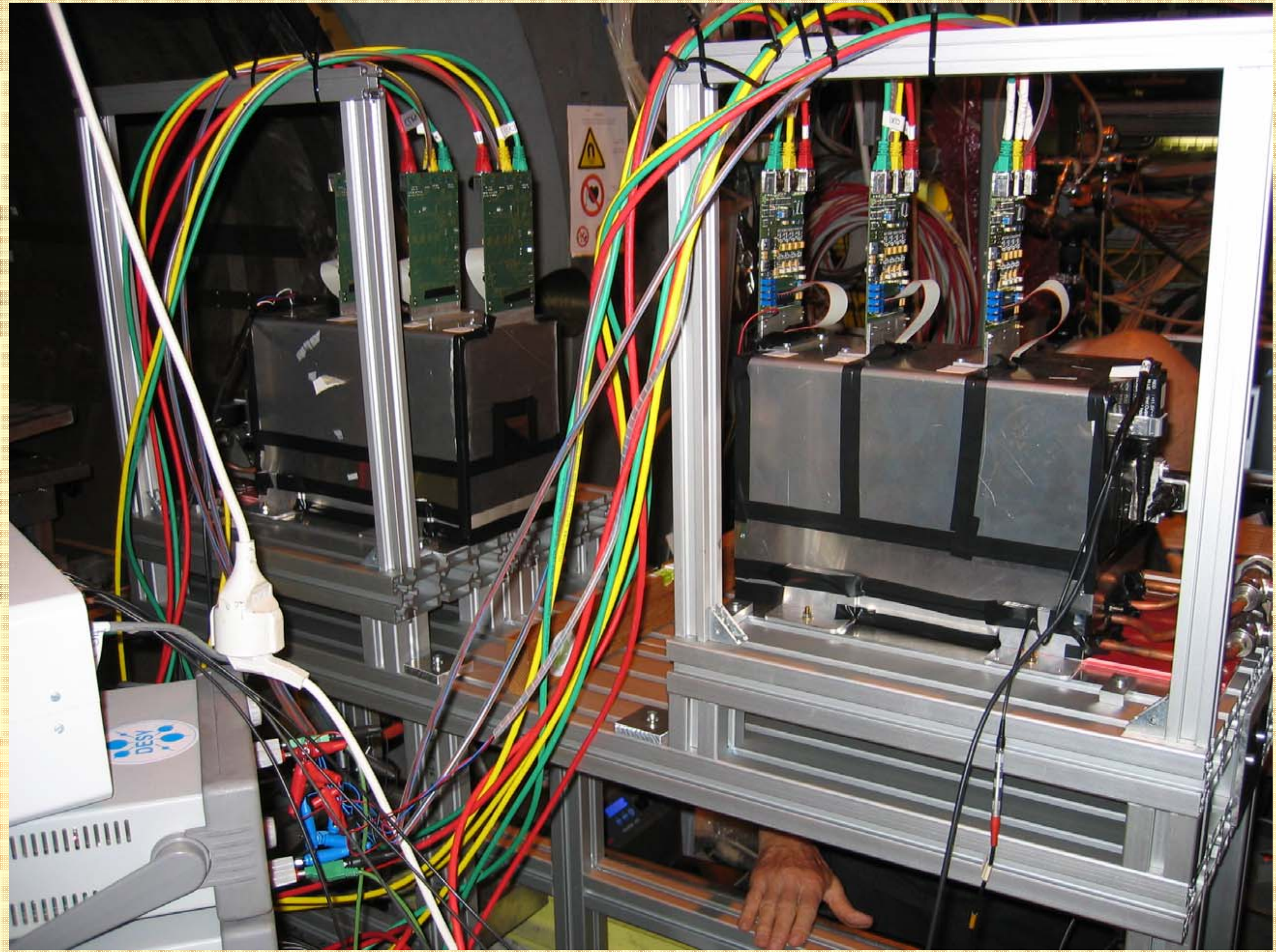
- VME 64x and USB2.0 DAQ board
- 1 board for each detector plane
- Two acquisition modalities:
  - RAW mode
  - **ZS mode**

EUDRB

- TLU used to synchronize all the telescope boards
- The DUT receive the trigger signal and the trigger number from the TLU
- Replacement of a NIM crate and modules!

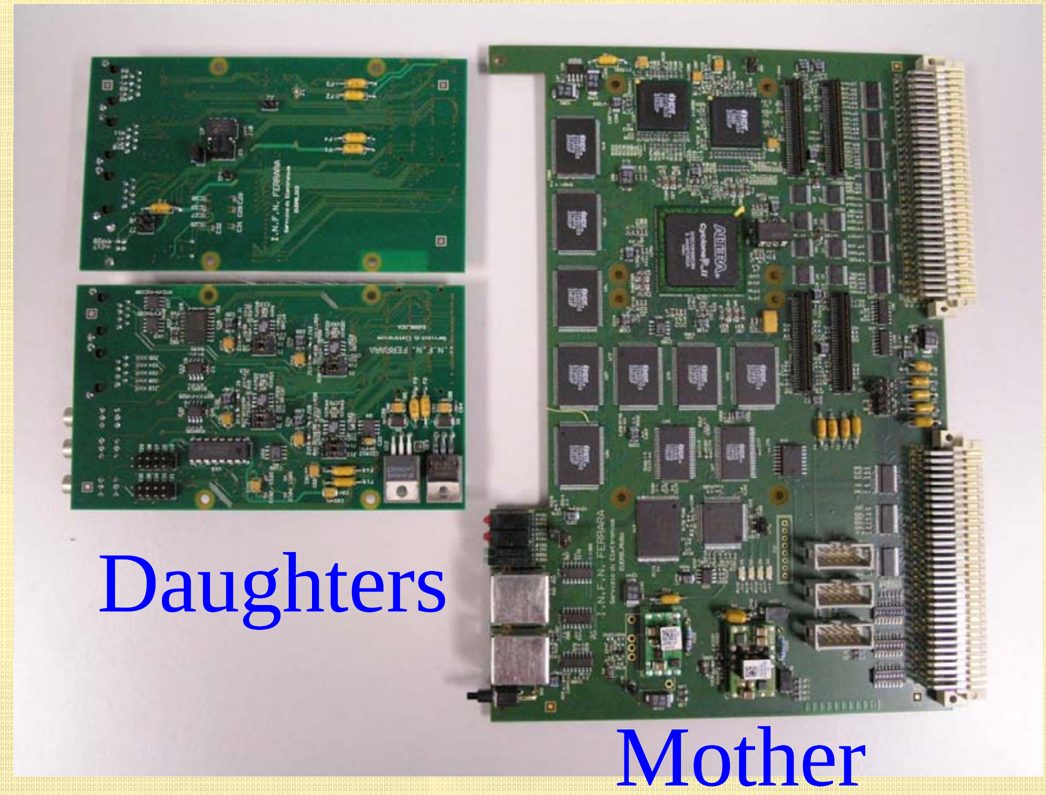
TLU

Alive and kicking!



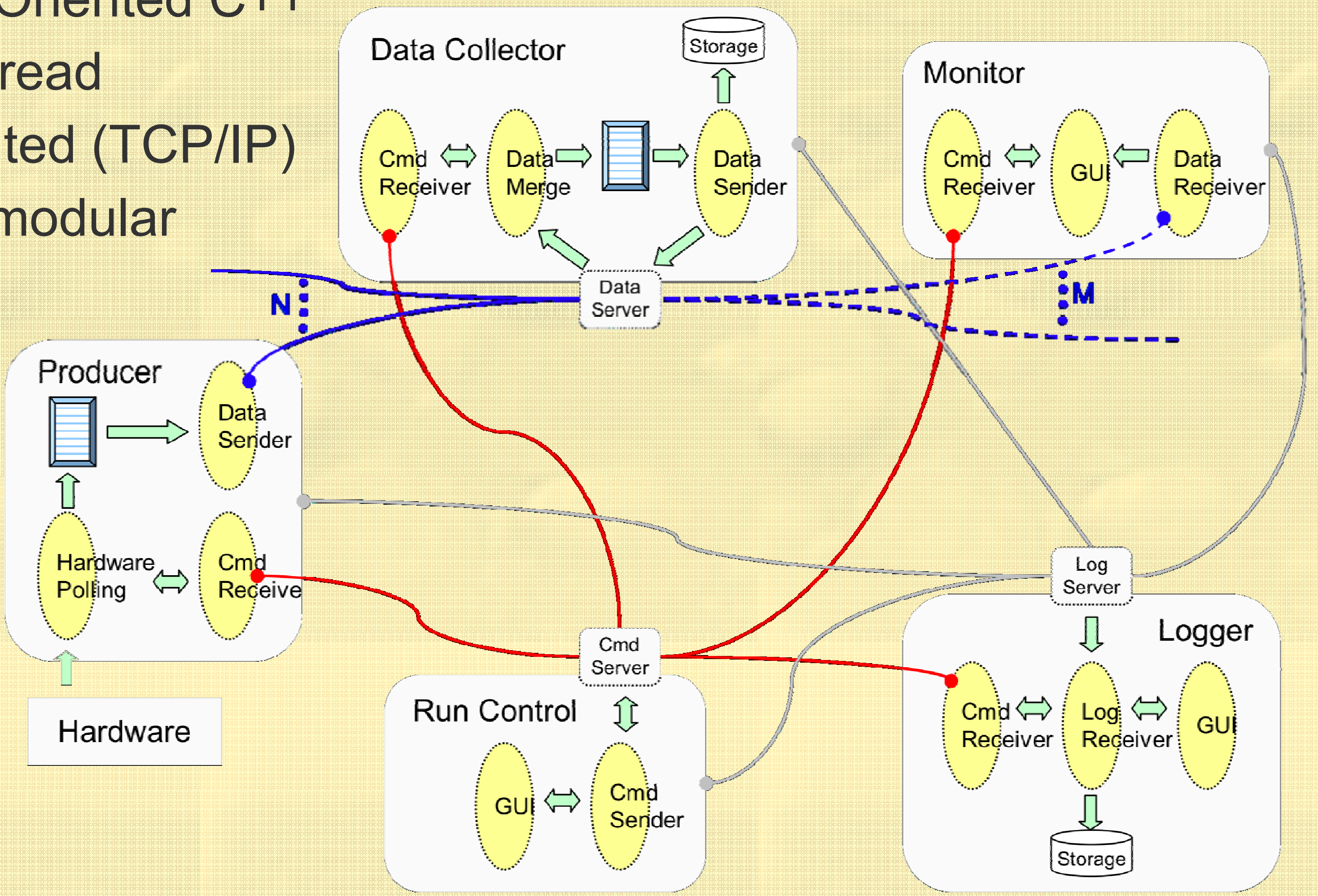
A closer look to the DAQ: hardware-wise

- EUDRB: EUDET Data Reduction Board, developed by INFN-Fe (see Angelo's talk)
  - Mother / Daughters approach:
    - Mother equipped with a powerful FPGA takes care of data handling, event building and data transmission.
    - Daughters are detector specific interface cards with eventually ADCs
- Two data transmission protocols:
  - VME 64x for test beam like setups and multiboard synchronization
  - USB2.0 for table top experiments and debug



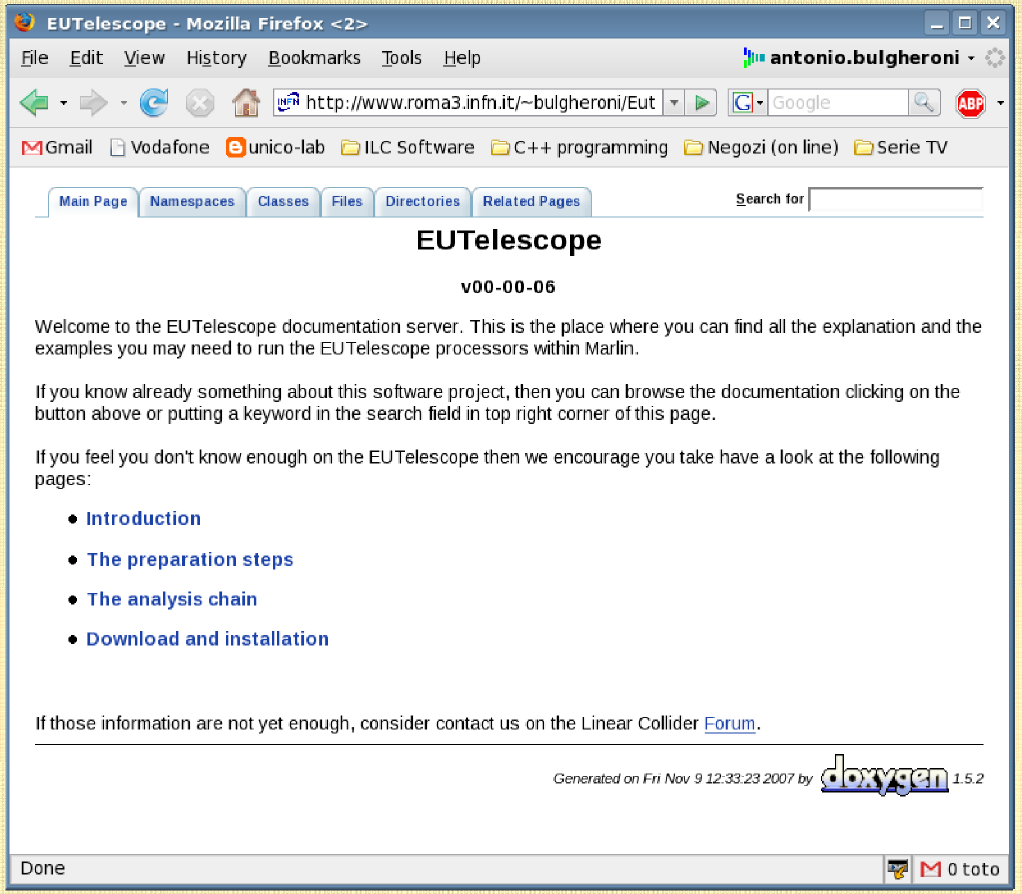
And software-wise

- 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

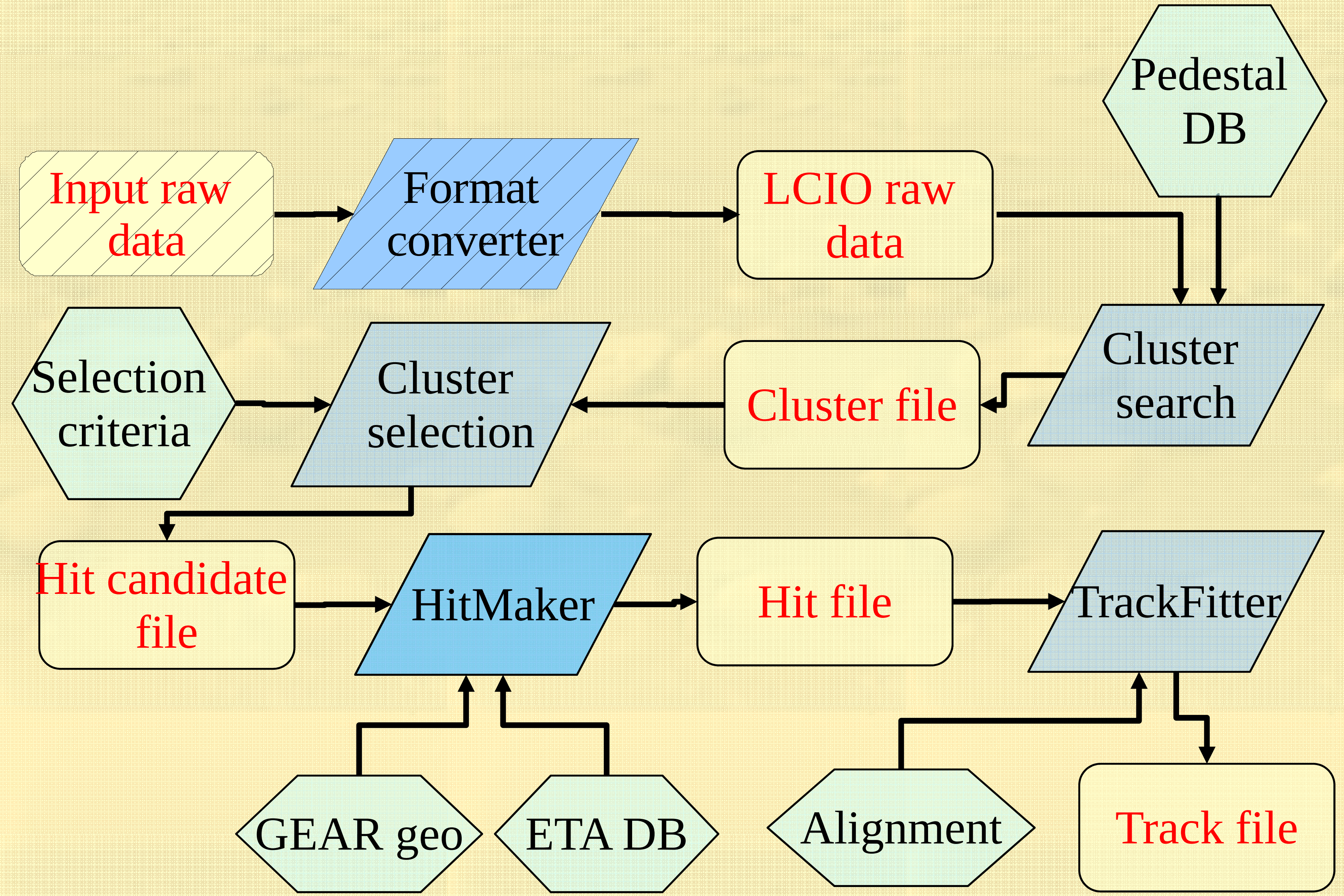


A world about the analysis software: EUTelescope

- 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.
  - Calice and our pixel telescope are the first two experiments in the world doing “real” analysis on the GRID



Analysis and reconstruction software diagram



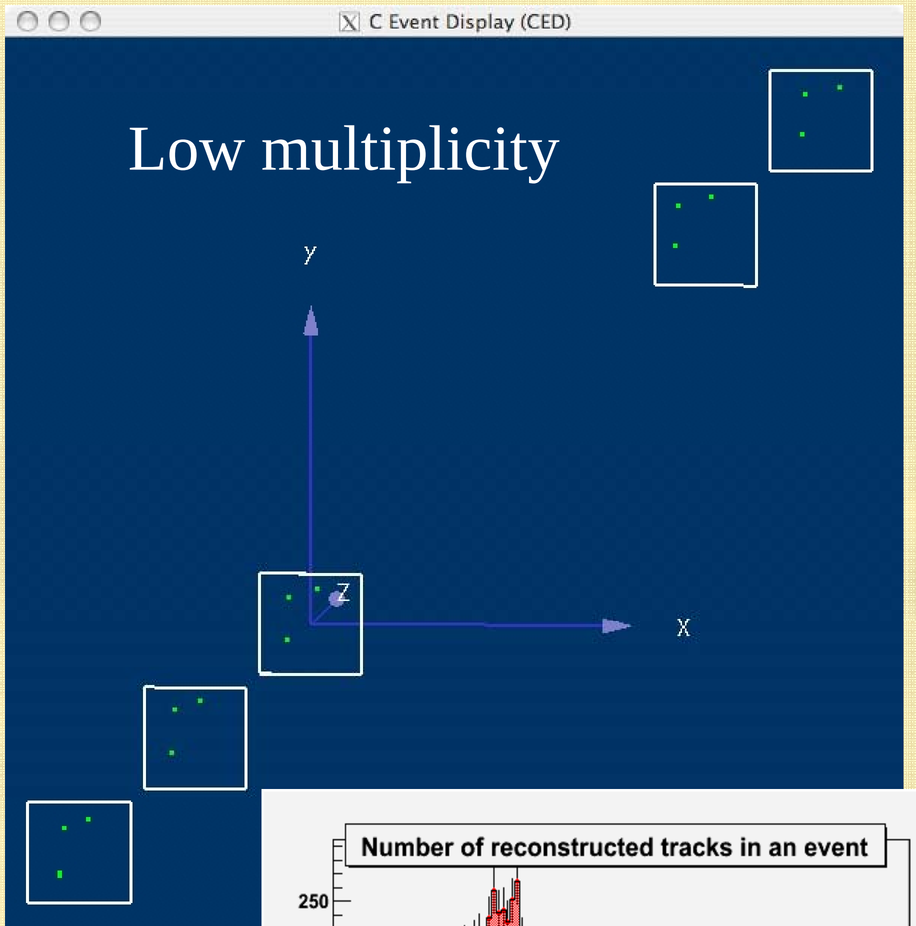
Test beam effort in 2007 and 2008

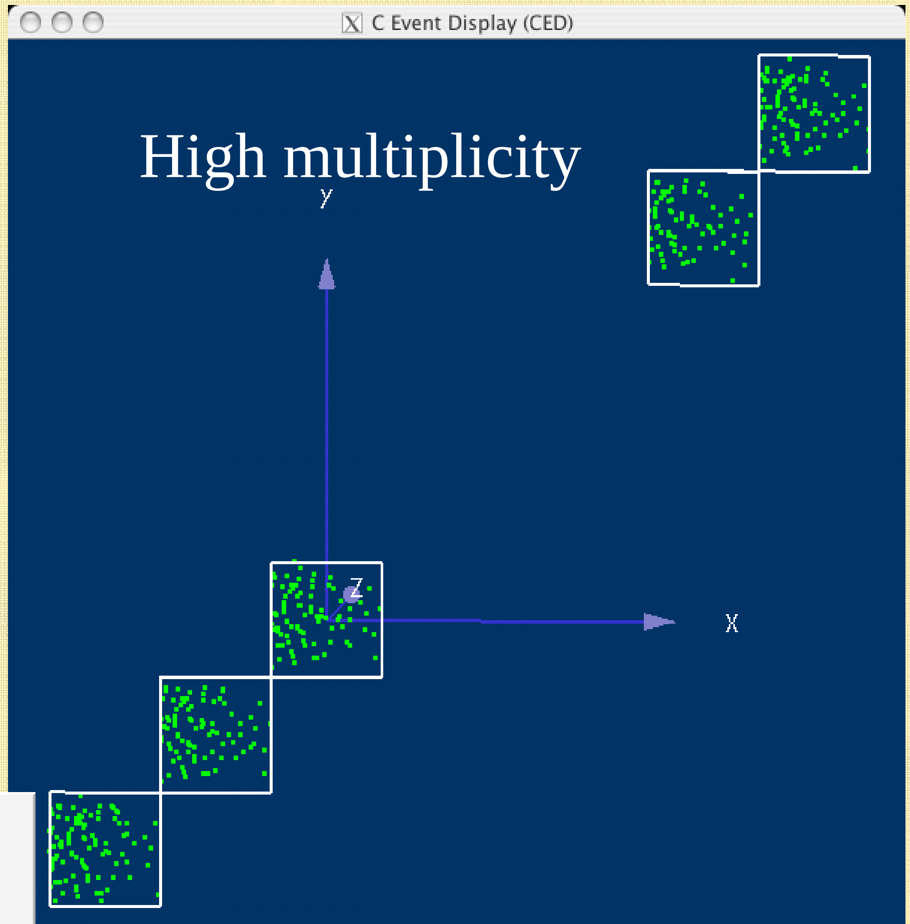
- The JRA1 group organized three tests on beam from June to September (2 at DESY and 1 at CERN) for a total of 6 weeks of data taking out of 12 working weeks... a real effort!
  - TB-DESY-JUNE (11 / 24 June 2007)
    - Integration (and smoke) test
  - TB-DESY-AUGUST (13 / 24 August 2007)
    - Testing the tester
  - TB-CERN-SEPTEMBER (17 / 27 September 2007)
    - First high energy test and first user: DEPFET
  - TB-CADARACHE-APRIL (see the talk of Daniel Husson)
    - Using the high resolution telescope to track nuclear reactor neutrons
  - TB-CERN-JUNE
    - Main user SiLC
  - TB-CERN-AUGUST
    - Several users: MimoRoma, DEPFET, LCFI

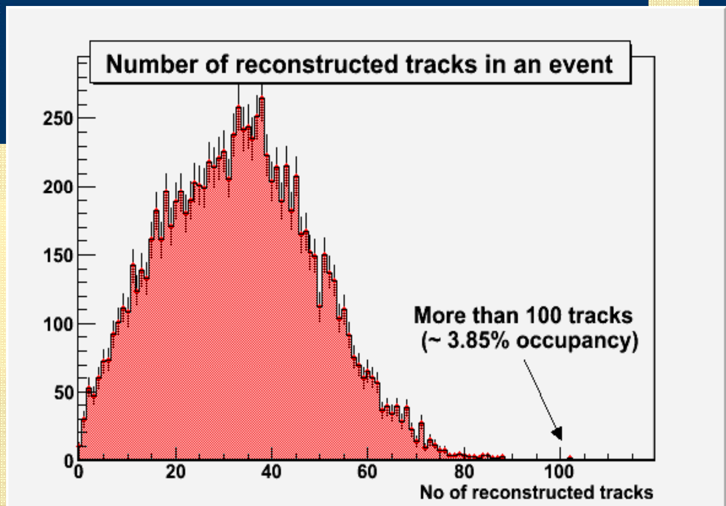
What do we offer to users

- All-inclusive package
  - 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.
    - 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.

Summary of the results: the event display







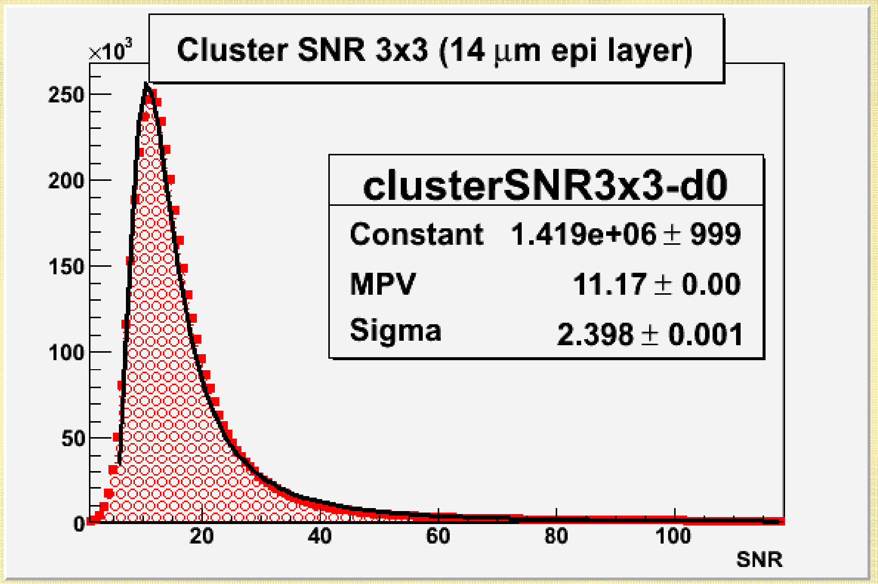
- OpenGL event display fully scalable and movable
- The same used for the ILD detector

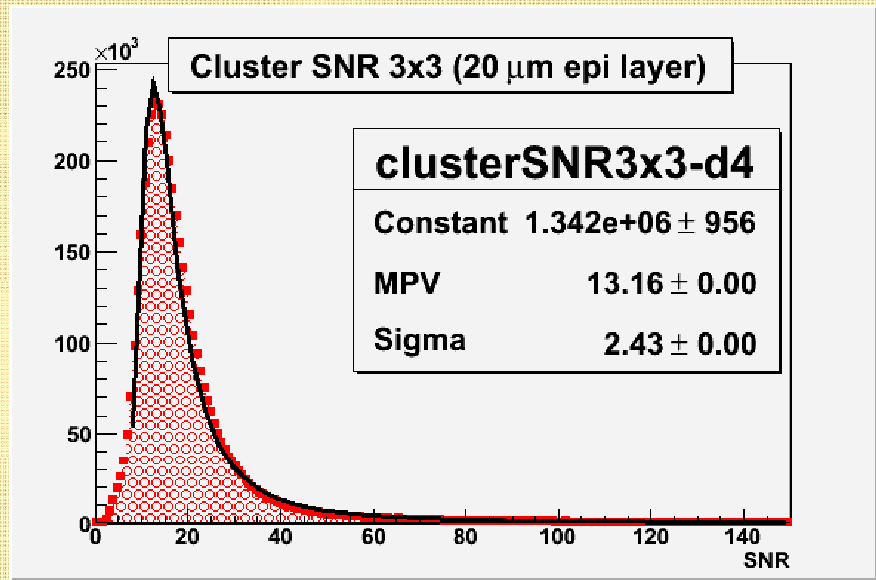
TB-CERN
SEPTEMBER

Sensor plane characterization

Detector #		SNR4	SNR3x3	Signal4 [ADC]	Signal3x3	SeedSNR
14 um epi	D0	14.0	11.2	104.4	131.0	12.5
	D1	13.6	10.9	103.0	129.0	12.2
	D2	14.3	11.3	105.0	130.3	12.8
20 um	D3	13.0	11.0	112.8	151.4	10.9
	D4	15.0	13.2	109.7	147.6	12.6

Landau MPV; T = 21 °C; Typical single pixel noise = 3.6 ADC (17 e-)





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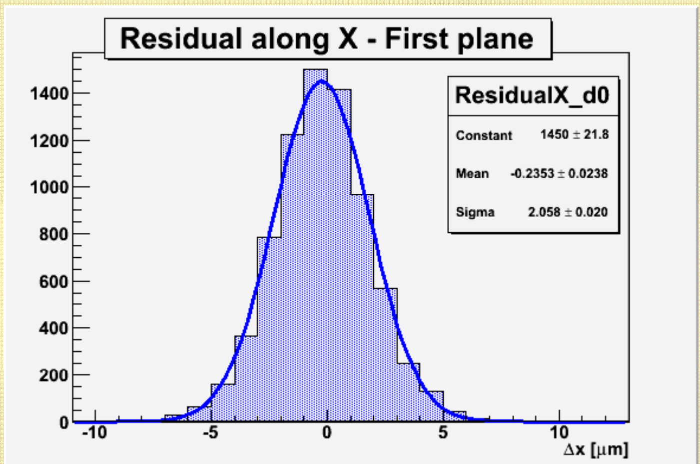
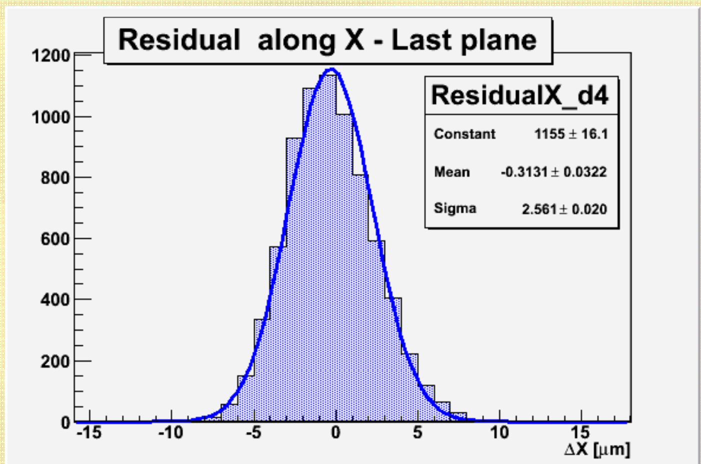
Telescope alignment

Detector #	Before alignment [um]		After alignment [um]	
	X	Y	X	Y
D0	REFERENCE			
D1	334.7	-395.3	0.26	0.68
D2	438.5	-345.9	-0.05	-0.26
D3	871.5	-547.4	0.38	-0.04
D4	54.7	-285.9	-0.31	0.01

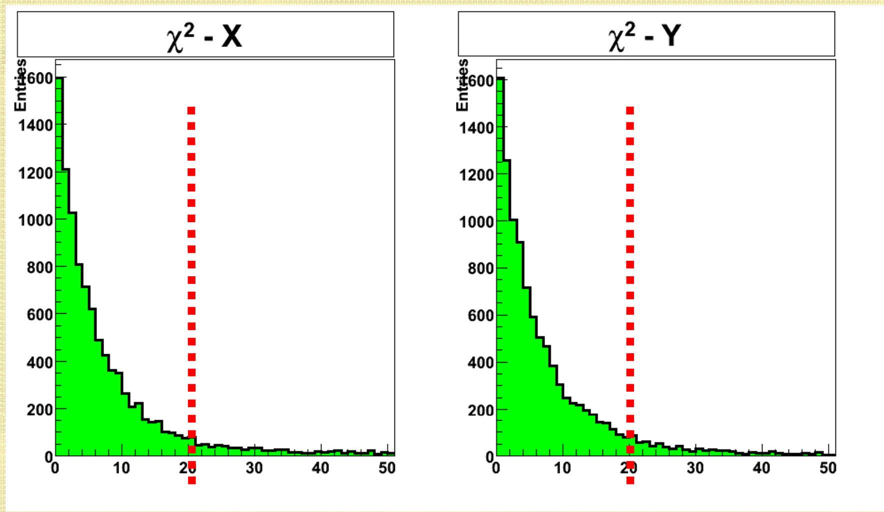


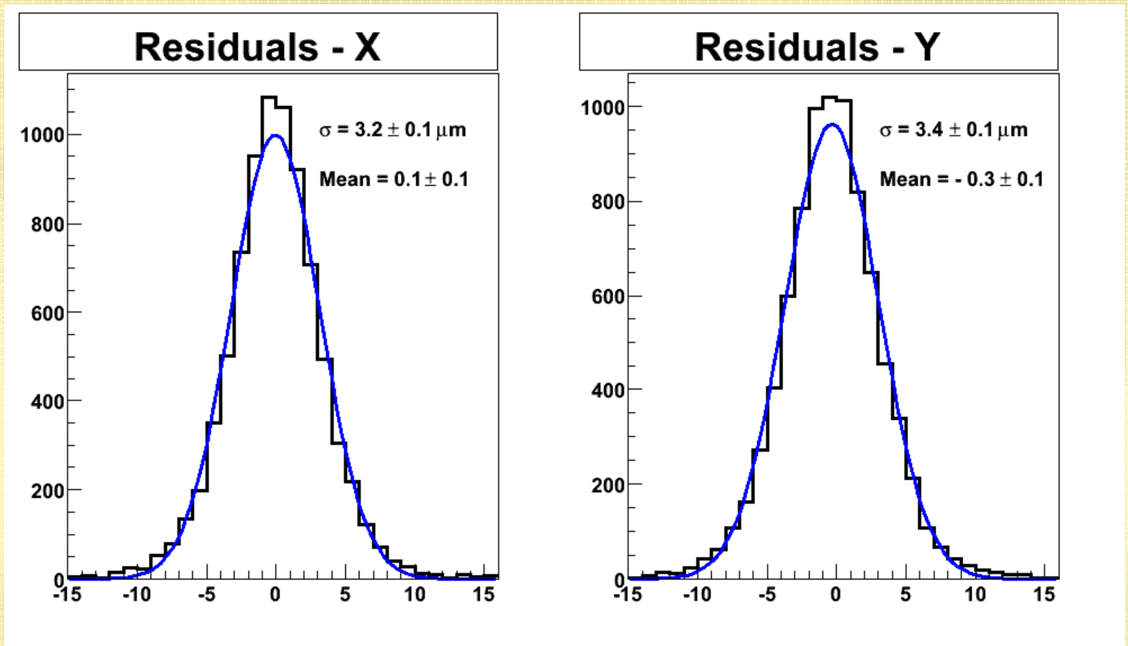


TB-CERN SEPTEMBER

Using one plane as a DUT

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





- Measured (intrinsic ⊕ telescope) resolution is **3.4** μm

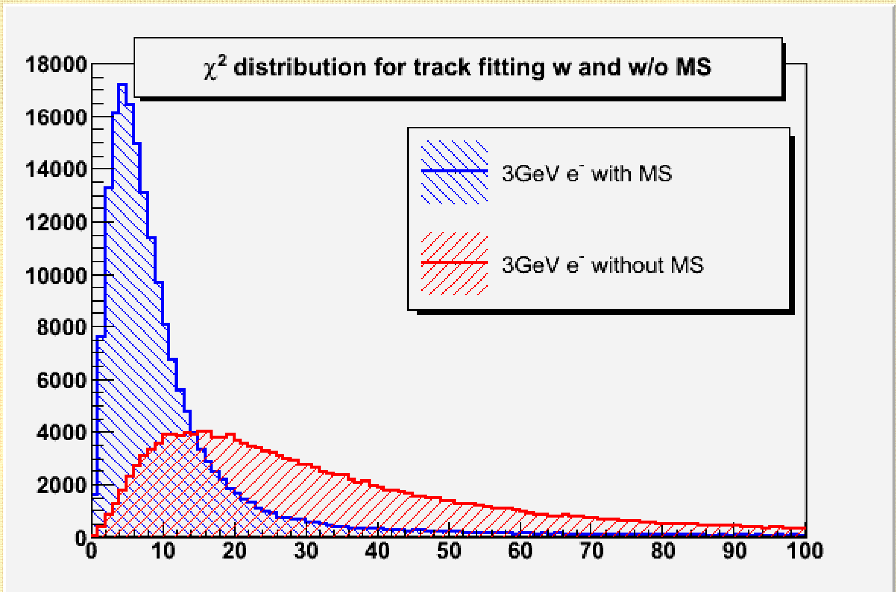
TB-CERN SEPTEMBER

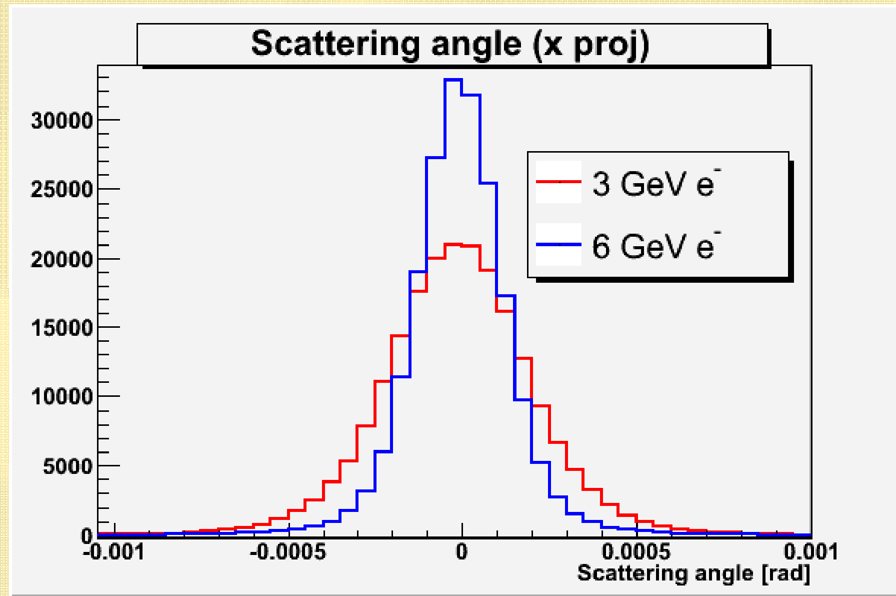
When the MS does matter

- When working with 3 and 6 GeV e^-, multiple scattering does play a role.
- Forget about straight lines and consider the multiple scattering angles.
- Contribution of plane *i* to χ^2

position measurement   multiple scattering

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



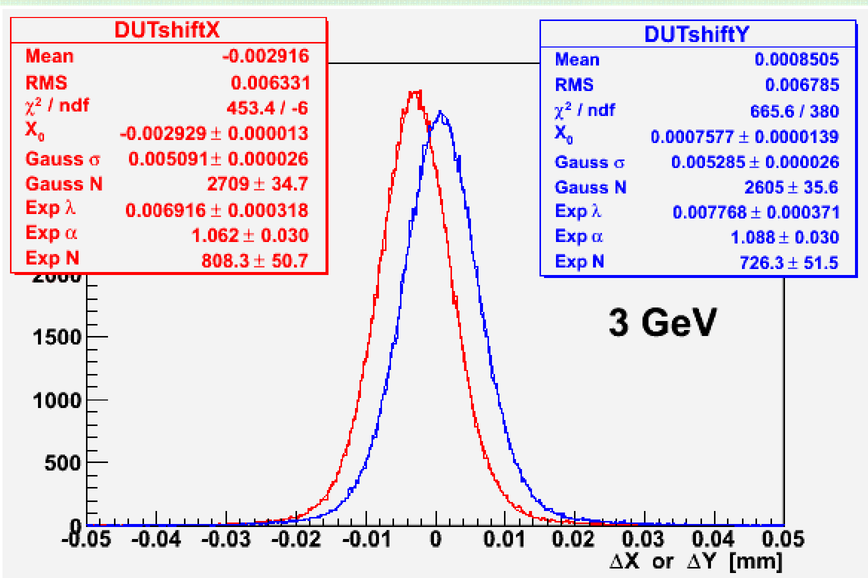


TB-DESY AUGUST

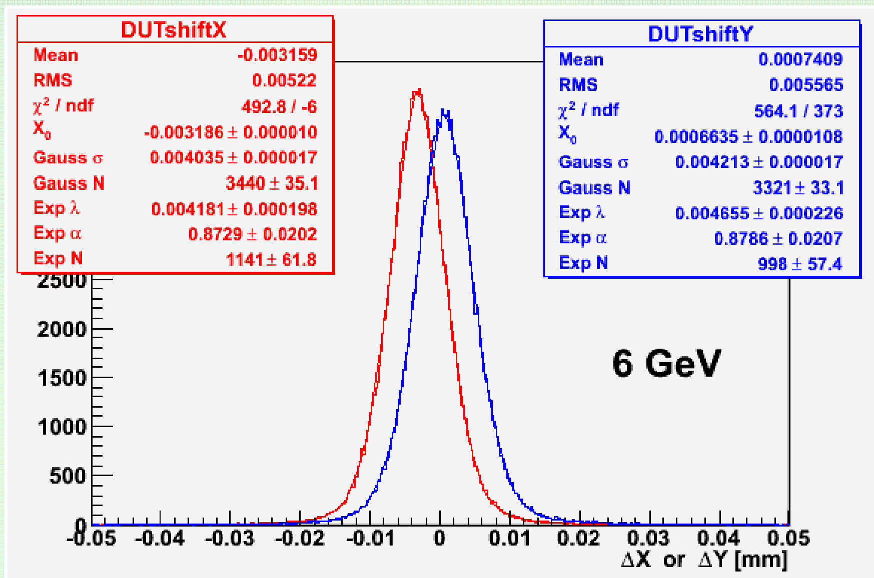
Resolution with e⁻

- Using the analytical fit, it is possible to take MS into account. Due to MS the telescope resolution is slightly worse at lower energies. But the observed widths are in very good agreement with expectations.

expected fit precision at DUT = 4.22 um
expected DUT width = 5.12 um
measured width = 5.09 um / 5.28 um



expected fit precision at DUT = 2.89 um
expected DUT width = 4.16 um
measured width = 4.03 um / 4.21 um



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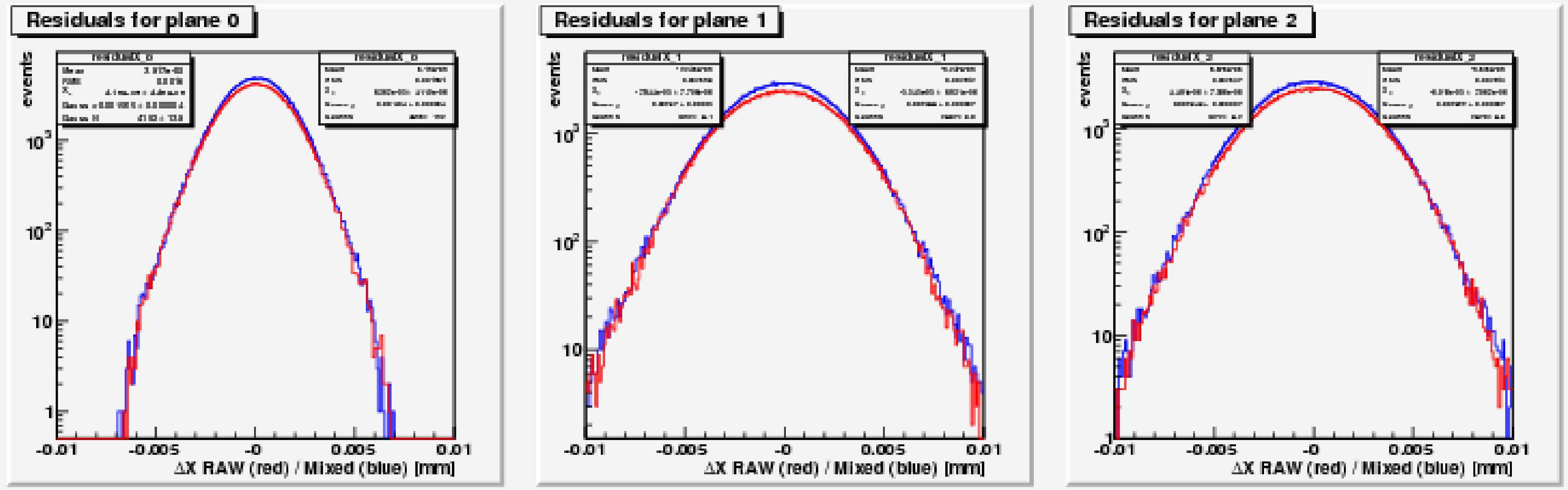
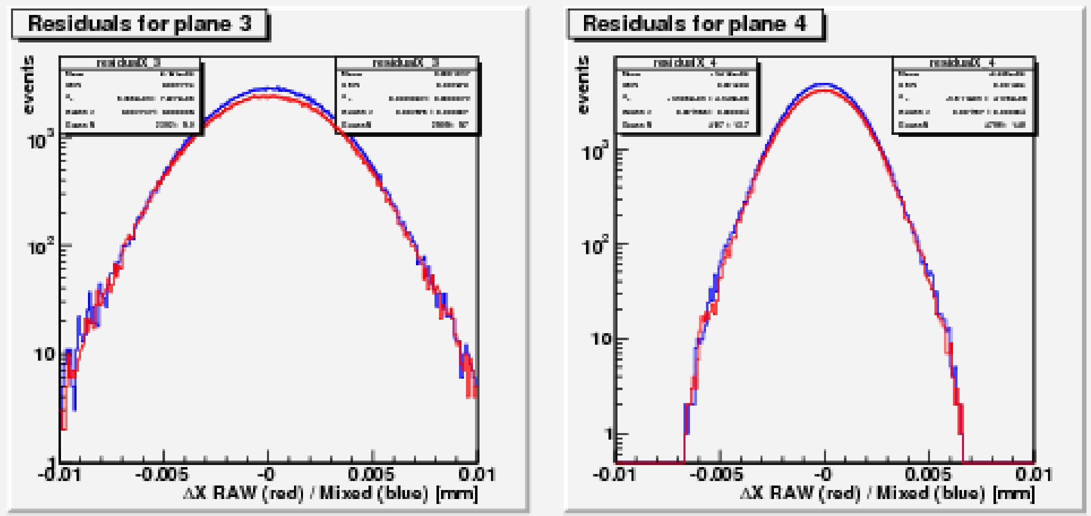
Is the ZS working?

- Telescope operated in MIXED mode (one every second sensor is readout in ZS mode)



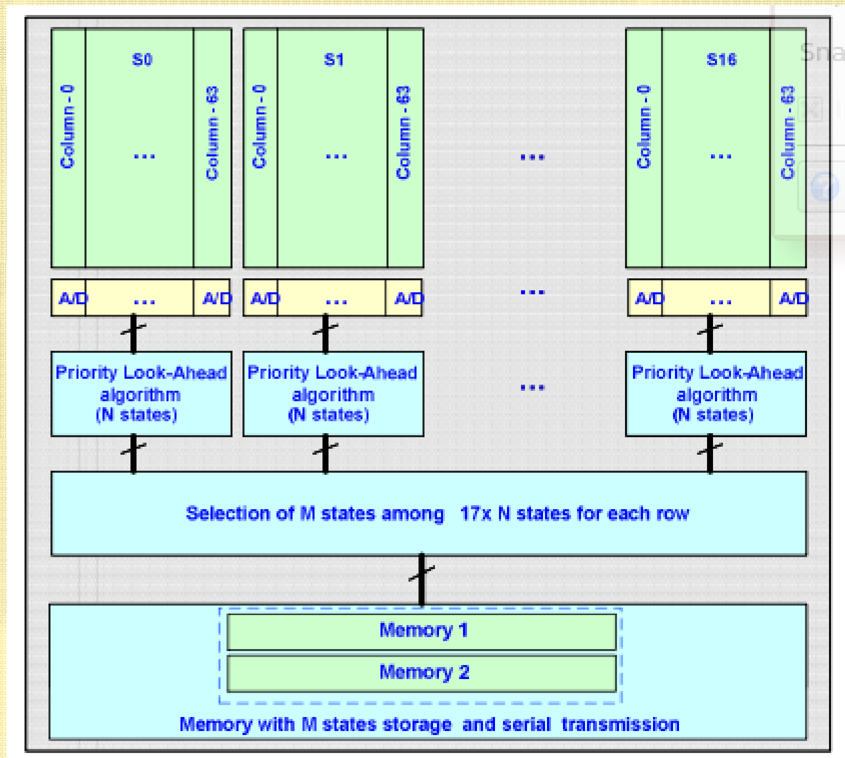


- Comparison between a MIXED and a RAW run

TB-DESY AUGUST

A glance in the future

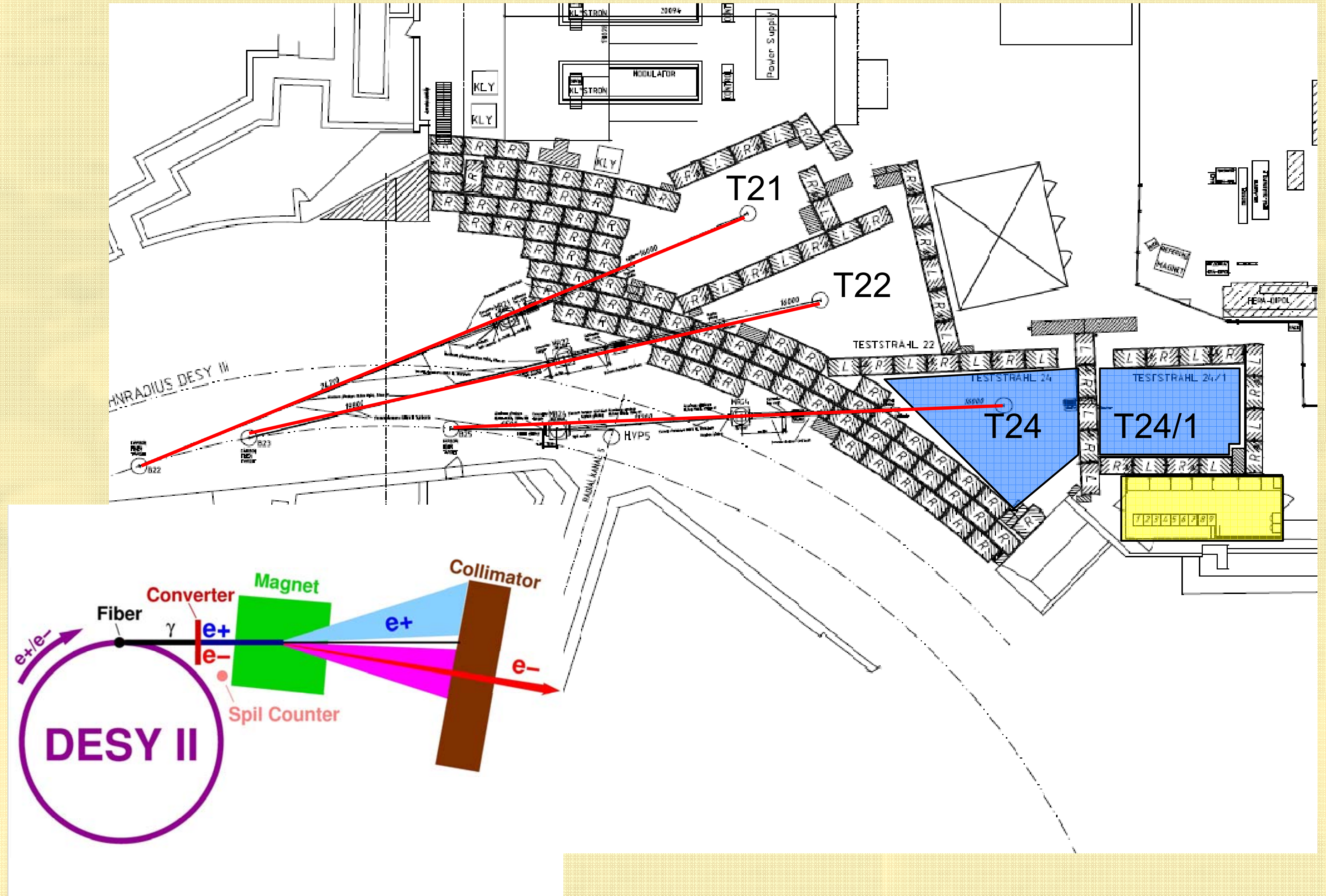
- M22+ = M22 + SUZE01
- 544 x 1088 pixels with 18.4 um pitch
- Hardware clustering algorithm with sparsified output



Conclusion

- EUDET is a great opportunity for team involved in detector R&D for the ILC
- Everybody can join the fun and use the developed infrastructure to test their own devices
- The telescope demonstrator is working according to specs but the final one is about to come.

Test beam area @ DESY



EUTelTestFitter

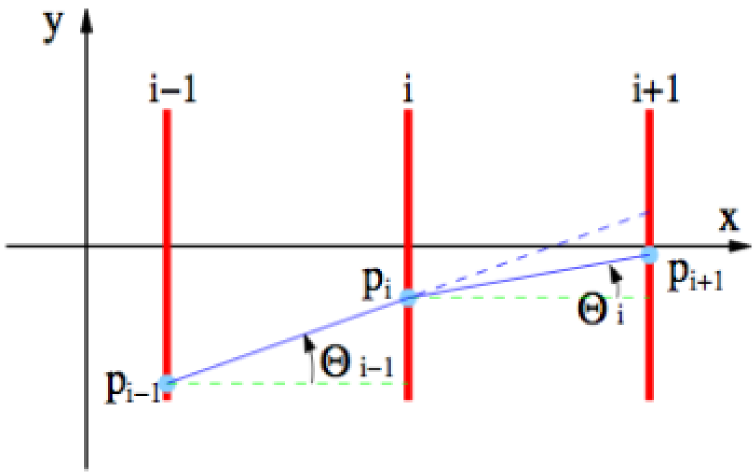
Results provided by A.F. Zarnecki

Analytical approach

We can determine track position in each plane (including DUT), i.e. N parameters (p_i, $i = 1 \dots N$), from $M < N$ measured positions in telescope planes.

We use constraints on multiple scattering!

Contribution of plane i to χ^2 of the fit



position measurement   multiple scattering

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

where: $$\Theta_i = \frac{p_{i+1} - p_i}{x_{i+1} - x_i}$$

Both terms present for planes $i \neq 1, i_{DUT}, N$,
first term missing for DUT, second for first and last plane

χ^2 minimum can be found by solving the matrix equation - fast!

Constraint from the beam direction can also be taken into account.