Very Busy Infrastructures - EUDET JRA1 from 2006 - 2010

Ingrid- Maria Gregor
on behalf of the JRA1 team

EUDET Annual Meeting
September 30th 2010
Hamburg

JRA1: Test Beam Infrastructure

Large bore magnet:

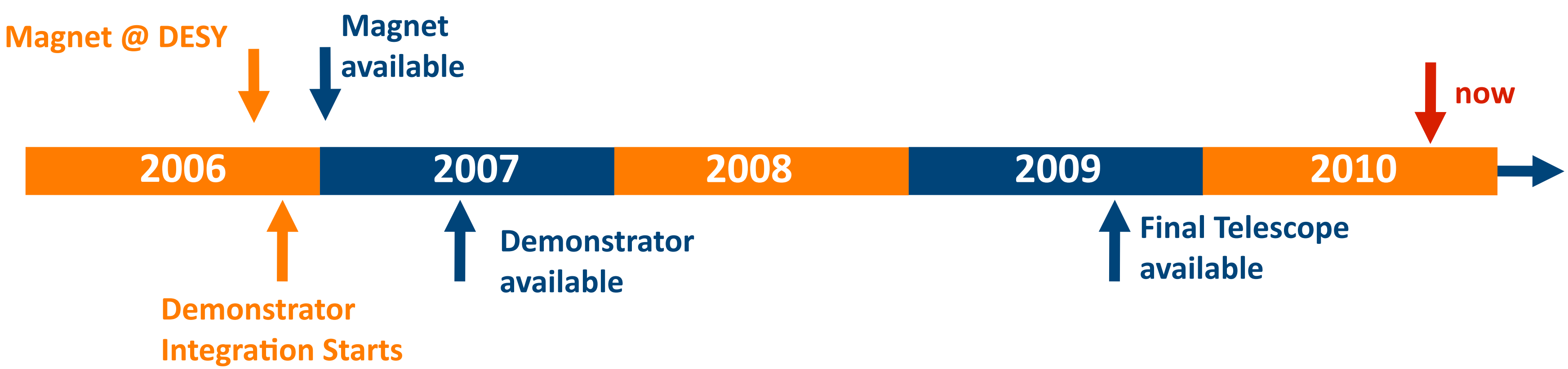
- 1Tesla, Ø≈85 cm, stand-alone He cooling, supplied by KEK
- Infrastructure (control, fieldmapping, etc.) through EUDET
- Magnet fully instrumented at DESY and ready for use

Pixel beam telescope:

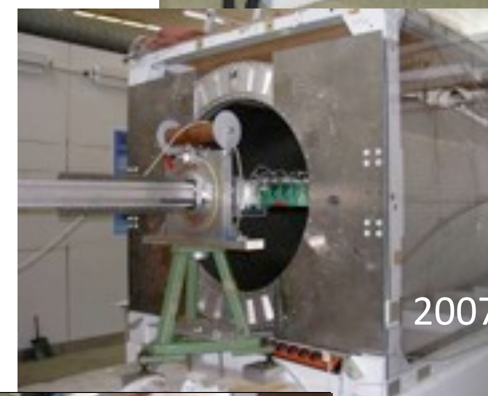
- 6 layers of Monolithic Active Pixel Sensor (MAPS) detectors
- DEPFET and ISIS pixel detectors for validation
- DAQ system
- Two staged approach

Tasks:

- A: Magnet
- B: Pixel Telescope Integration
- C: Pixel Telescope
- D: Data Acquisition and Evaluation Software
- E: Validation of Infrastructure



Evolution of Task A: Magnet



2006
- Lending details about magnet loan finalised
- Arrival of magnet at DESY in November
- First turn on of magnet December 10th

2007
- Field map measurement July
- Final field map available only in December -> analysis of data more challenging than expected

2008
- Transfer line for filling the liquid helium was improved and the existing procedure automated
- Installation of large TPC prototype

2009
- Completion of rotatable table

2010
- Regularily used by TPC group and users

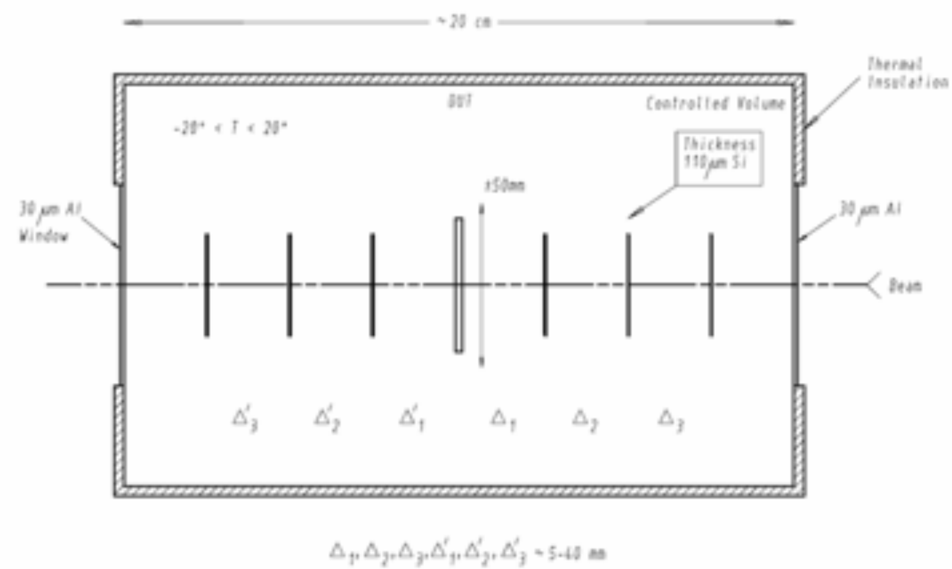
→ Details in JRA2 Session (Klaus Dehmelt)

Our Quest - Build a Beam Telescope

As defined during Kick-off Meeting February 2006

Generally applicable:

- DUTs: from small pixel sensors to larger detectors
- Movement of DUT to scan larger surface
- Large range of conditions: cooling, positioning, (B-Field)
- Easy to use: well defined/described interface
- Very high precision: <3 μm precision even at smaller energies
- Trigger rate ~ 1kHz
- Movable!

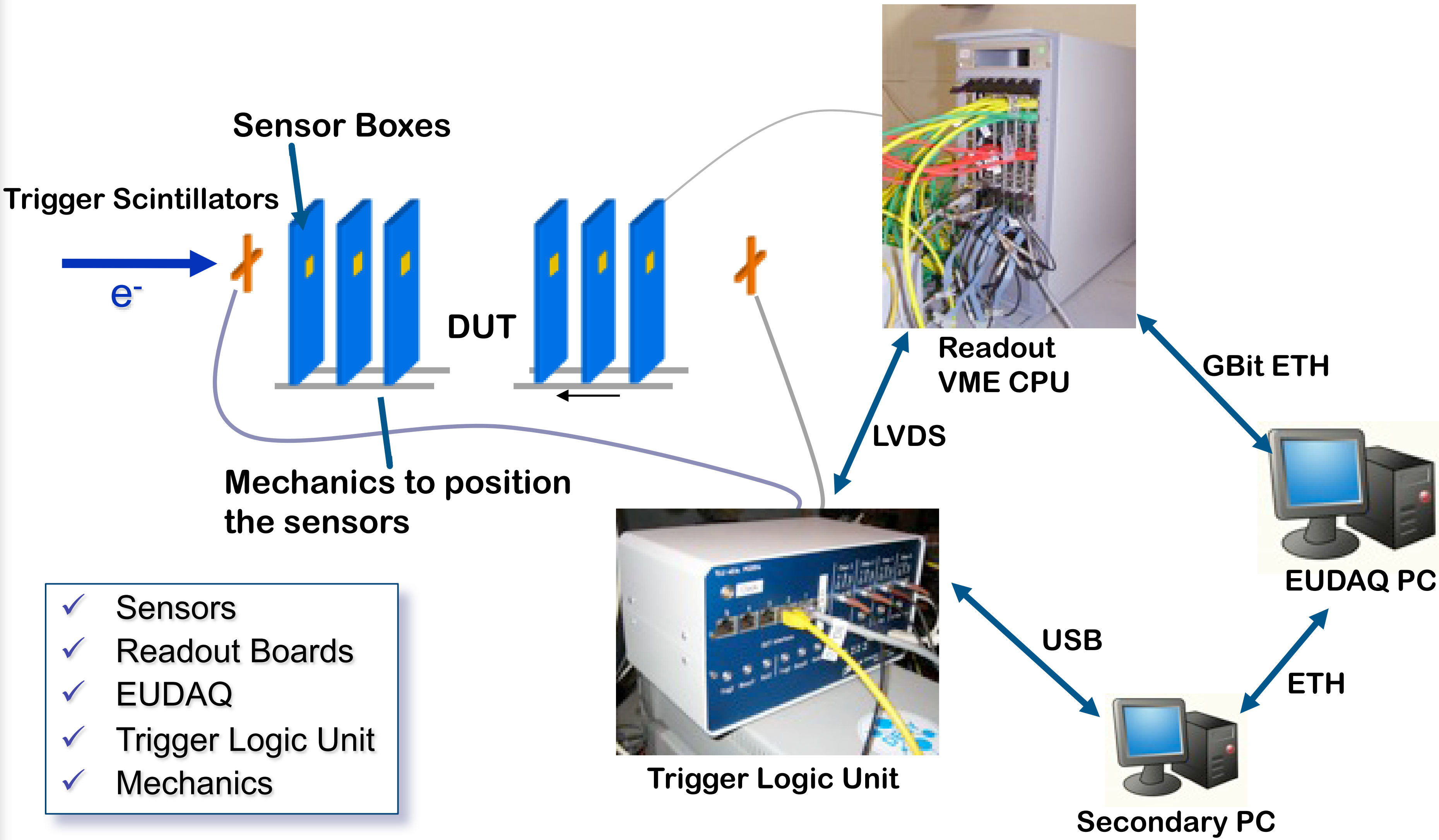


First sketch Kick-Off meeting 2006

Two staged approach

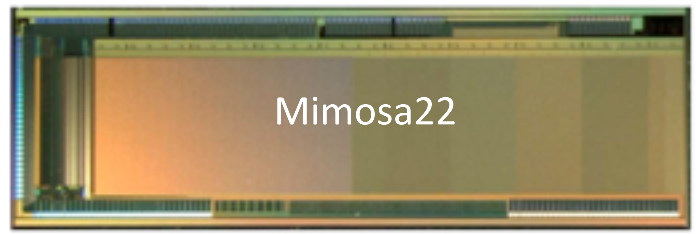
- Demonstrator telescope with analog sensors as soon as possible.
- Final Telescope with digital sensors, final resolution and high readout rate.

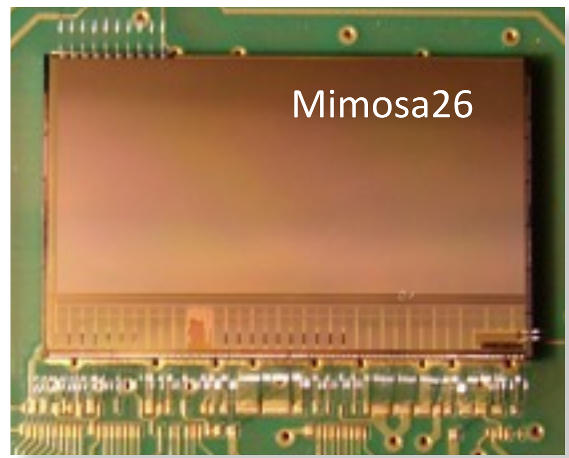
Telescope Ingredients



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

Evolution of Task: Telescope Sensors





2006
- SDC propotype 1 (MimoTel) planned and achieved for month 9
- High resolution plane Mimosa18 also available

2007
- SDC prototype 2 (SUZE01) available in month 15
- Intermediate chip (Mimosa22) submitted

2008
- SUZE01 fully tested
- Mimosa22 available month 27
- Telescope Chip Mimosa26 fully designed

2009
- Mimosa26 returned from foundry end of February, first results are available in March
- Available for telescope spring; implementation in telescope postponed to September on users request

→ Previous Talk (Jerome Baudot)

Evolution of Task: DAQ

Comprises DAQ hardware, DAQ software and Tracking/Reconstruction Software for evaluation

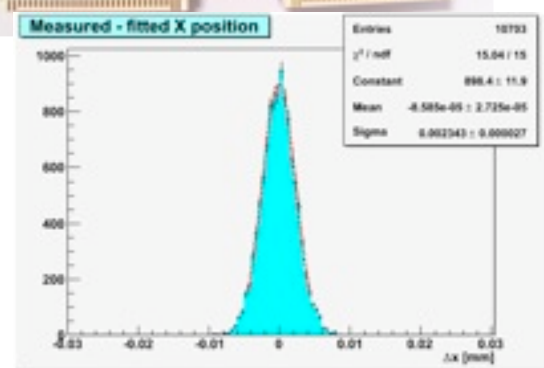
2006
- Decision on DAQ hardware and software concept
- First trigger logic unit (TLU) available

2007
- First EUDRB available (spring)
- DAQ software EUDAQ first version tested
- Full system tested at beams at DESY and CERN
- Analysis and reconstruction software tested

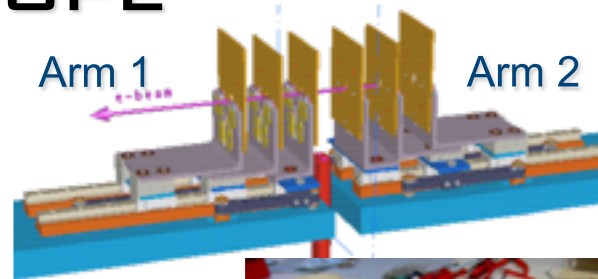
2008
- Updates in firmware of EUDRB and TLU
- Final version of EUDAQ available
- Reconstruction software finalised

2009
- Upgrade of EUDRB producer for the Final sensor (TC)
- Implementation of EUDRB firmware for (TC)

2010
- Mainly user support (DUT implementation in EUDAQ)



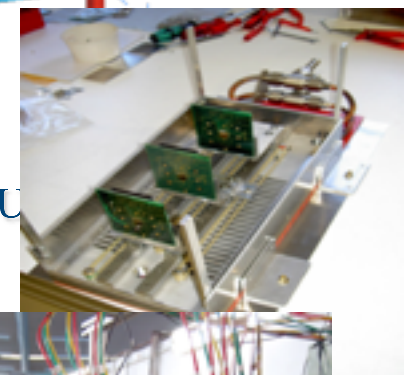
Evolution of Task: Telescope



Comprises mechanics, cooling and telescope infrastructure

2006
- Simulations on setup to define concept
- Design fixed: Flexible mechanics needed with two telescope arms and adjustable space for DUT

2007
- Finalisation and production of mechanics
- Procurement of additional infrastructure e.g. cooling, power and XY table
- June: **Demonstrator telescope available!**



2008
- Improvement of mechanical alignment and cooling
- Testbeam at CERN with many different users proved overall concept

2009
- Decision to delay “final telescope” until after summer -> users prefer known demonstrator over final telescope
- **Final telescope available!**

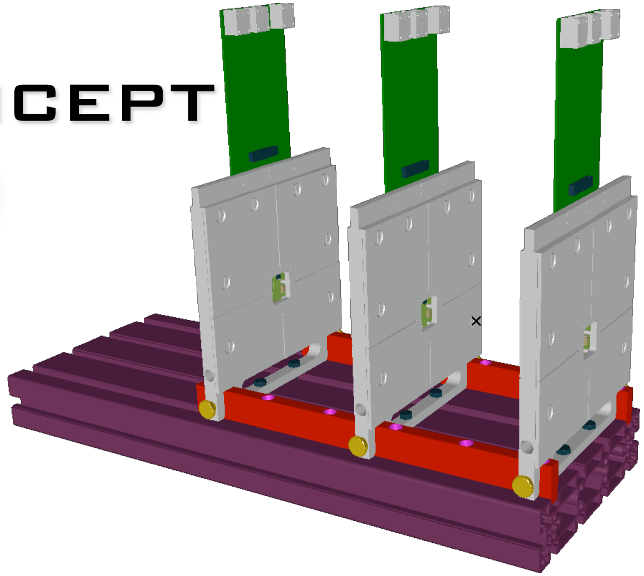
2010
- **Almost continuous user business!**

Telescope Mechanics Concept

- Plan: to develop a stable, flexible mechanics for small and also large DUTs.

Arm 1 and 2:

- Movable in z-direction, optical bench for three reference planes.
- Distances between planes are variable from 10 to 150 mm.
- Separate sensor boxes for each plane.

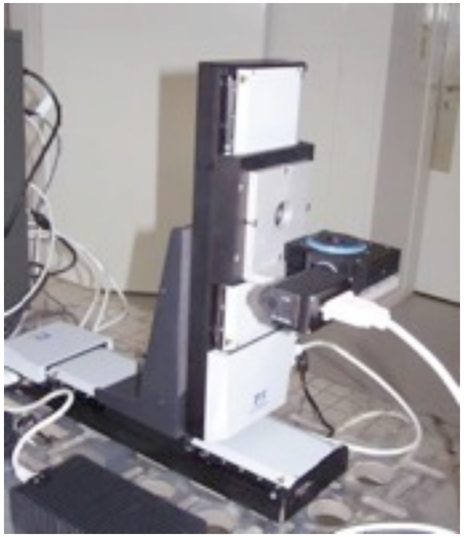


Sensor planes on mechanical support

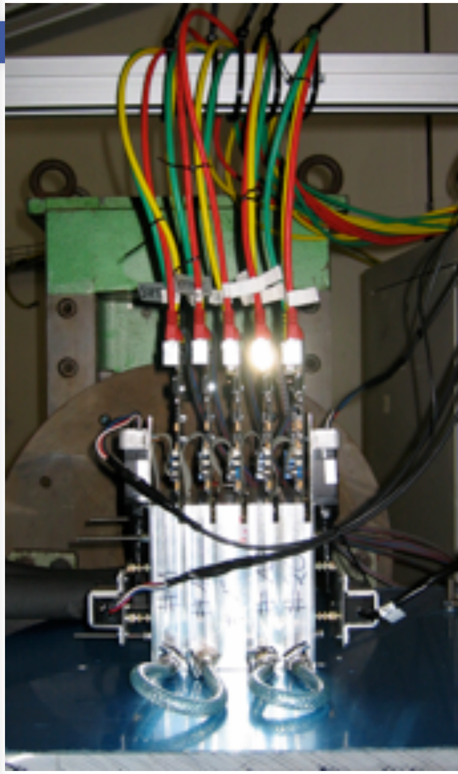
Mimosa26 positioned in sensor box (precisely machined; pins for positioning)

DUT position:

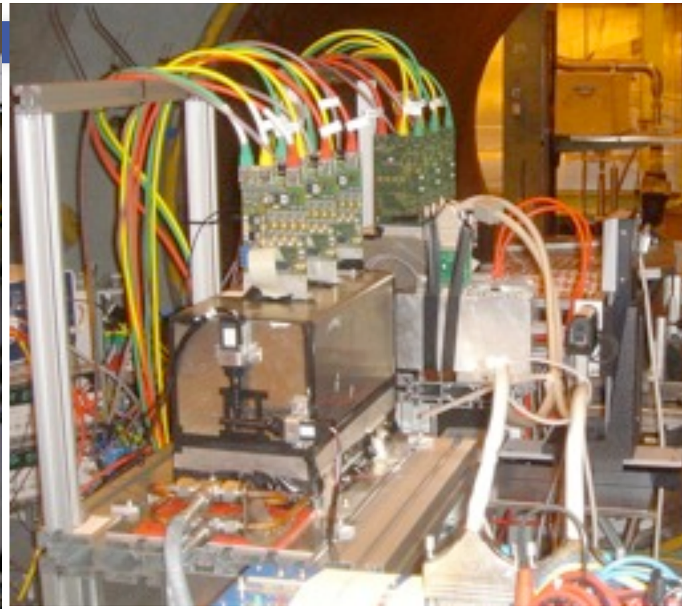
- Gap between arm 1 and 2: variable in size from a few cm up to 35 cm (on special request extendable)
- DUT positioned on XYφ-table (optional)



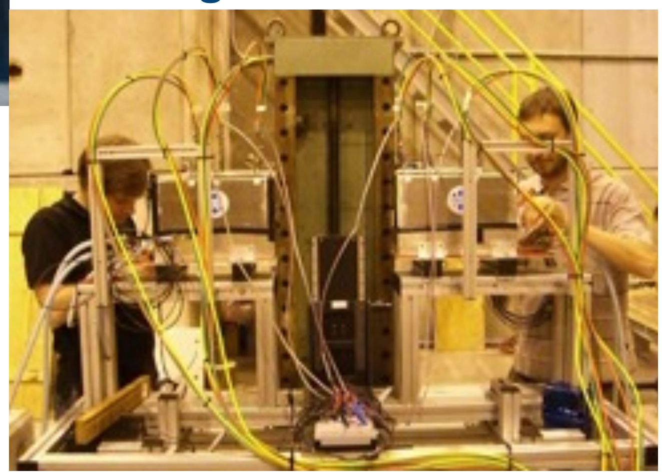
Metamorphosis



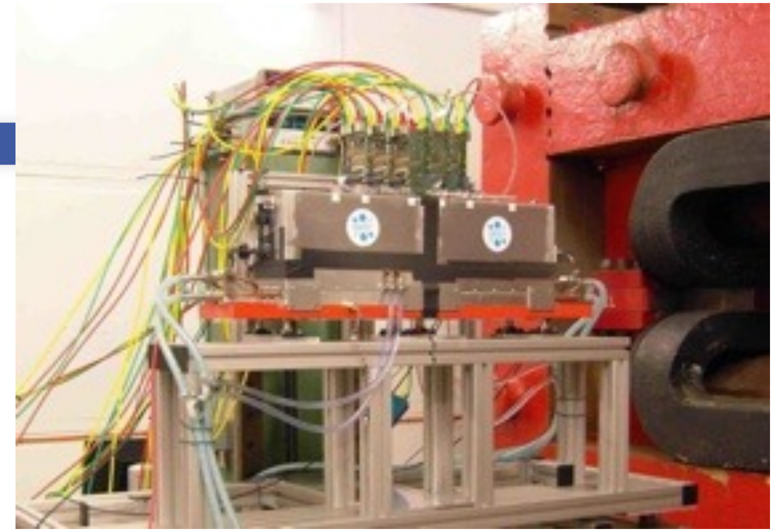
DESY June 2007



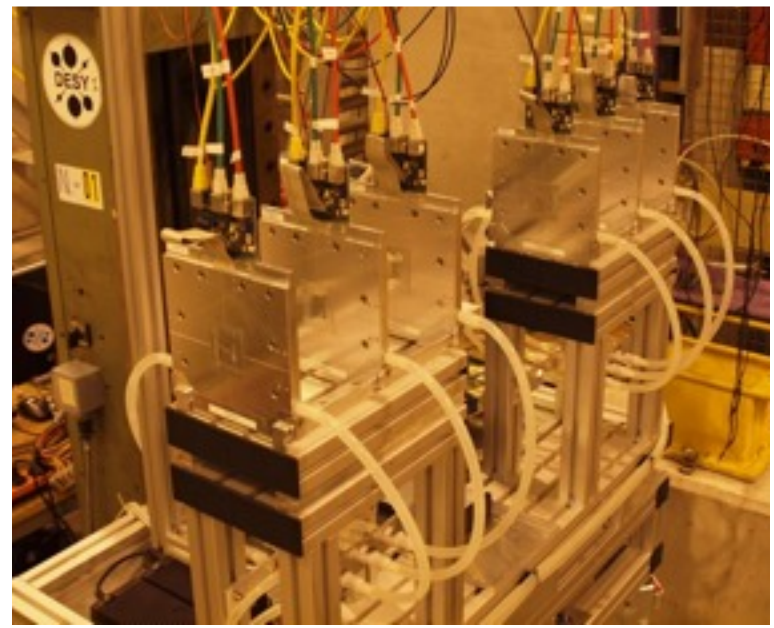
CERN August 2007



CERN 2008

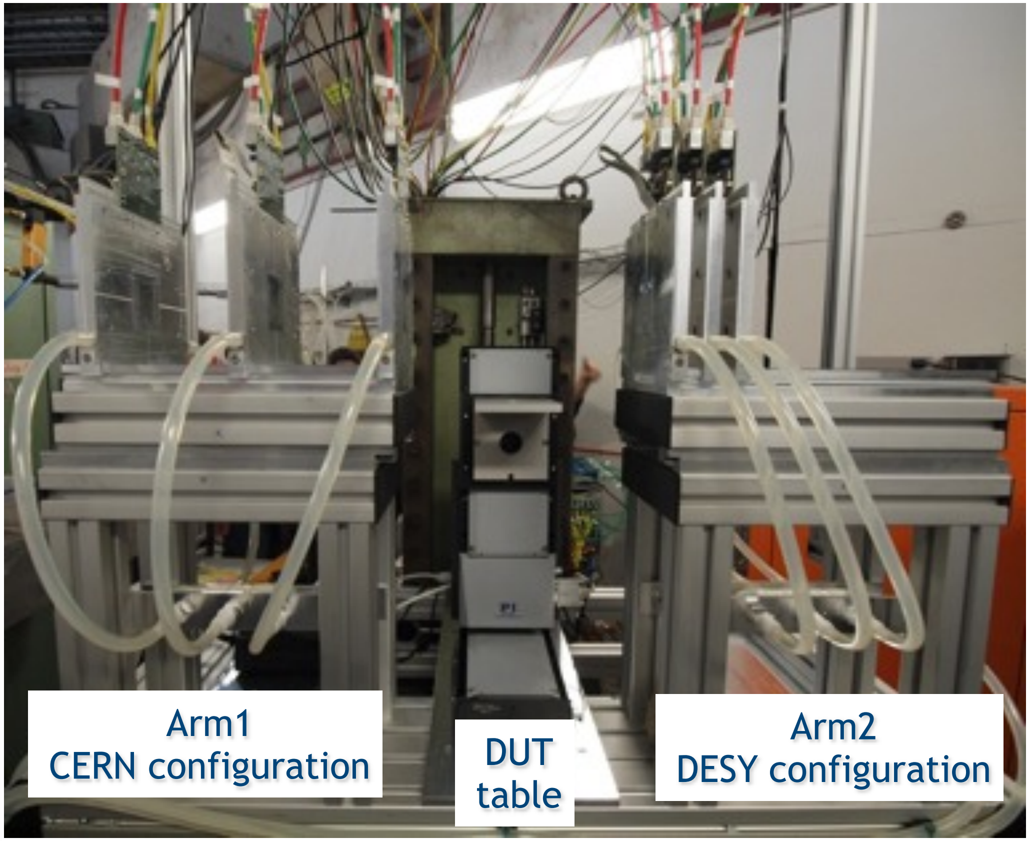


DESY 2009



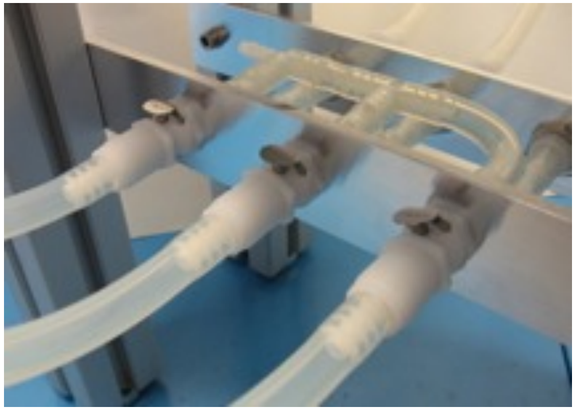
CERN 2010

The Final Mechanics



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

- Not magnetic material -> one arm fits into PCMAG!



Pluggable cooling hoses for easy installation

Infrastructure

- Infrastructure for JRA1 telescope is significant:
  - Mechanics
  - Cooling
  - Power supplies
  - Support XY table
  - DUT table
  - Computer for DUT positioner
  - Cables

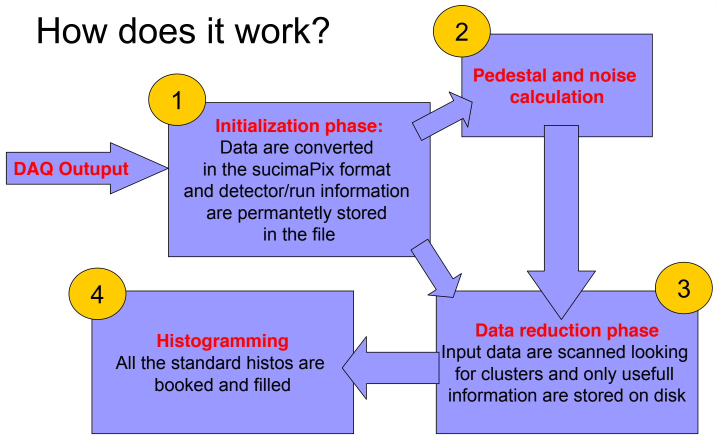
  - Webpages
  - Analysis Software

  - Postdocs, Students ;-) ….

Analysis and Reconstruction Software

Needed a Good Tool for users

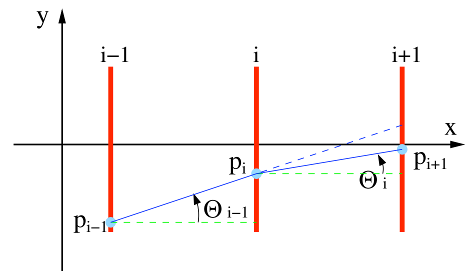
How does it work?



Antonio Bulgheroni, April 2006

TestFitter

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

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.

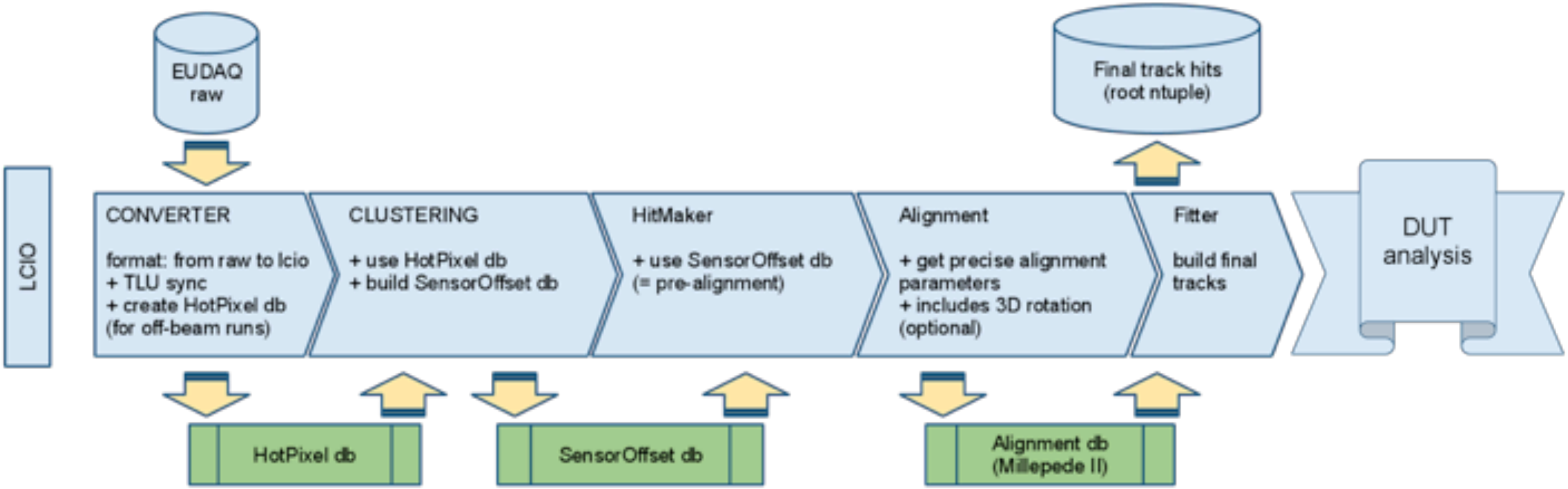
Filip Zarnecki, Spring 2007

- 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).**

Analysis and reconstruction software

- 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.

Status 2010



- In 2010 the main focus was on faster processing of data, full automatisation and better DUT analysis tools

EUTelescope Software

For details:
Igor Rubinskiy and
Slava Libov
(JRA1 Parallel Session)

EUTelescope release [Pro] Version v00-04-01

- in the last year
  - Python based submission scripts introduced
  - 8 intermediate releases
- The EUTelescope analysis framework is now final,
  - but there are always things to add or improve
- Significant performance improvements done
  - CPU time reduction
  - Memory usage reduction
  - human intervention reduced to minimum (almost none)
- documentation is kept up-to-date with every release

Optimised clustering
Hot pixel data base
Automated alignment (correlator)
DUT analysis improvements

- How to run the EUTelescope step by step with python scripts:
http://projects.hepforge.org/eudaq/Eutelescope/pythonScripts.html
- It is as easy to run analysis on GRID:
http://projects.hepforge.org/eudaq/Eutelescope/gridtools.html

Pointing Resolution

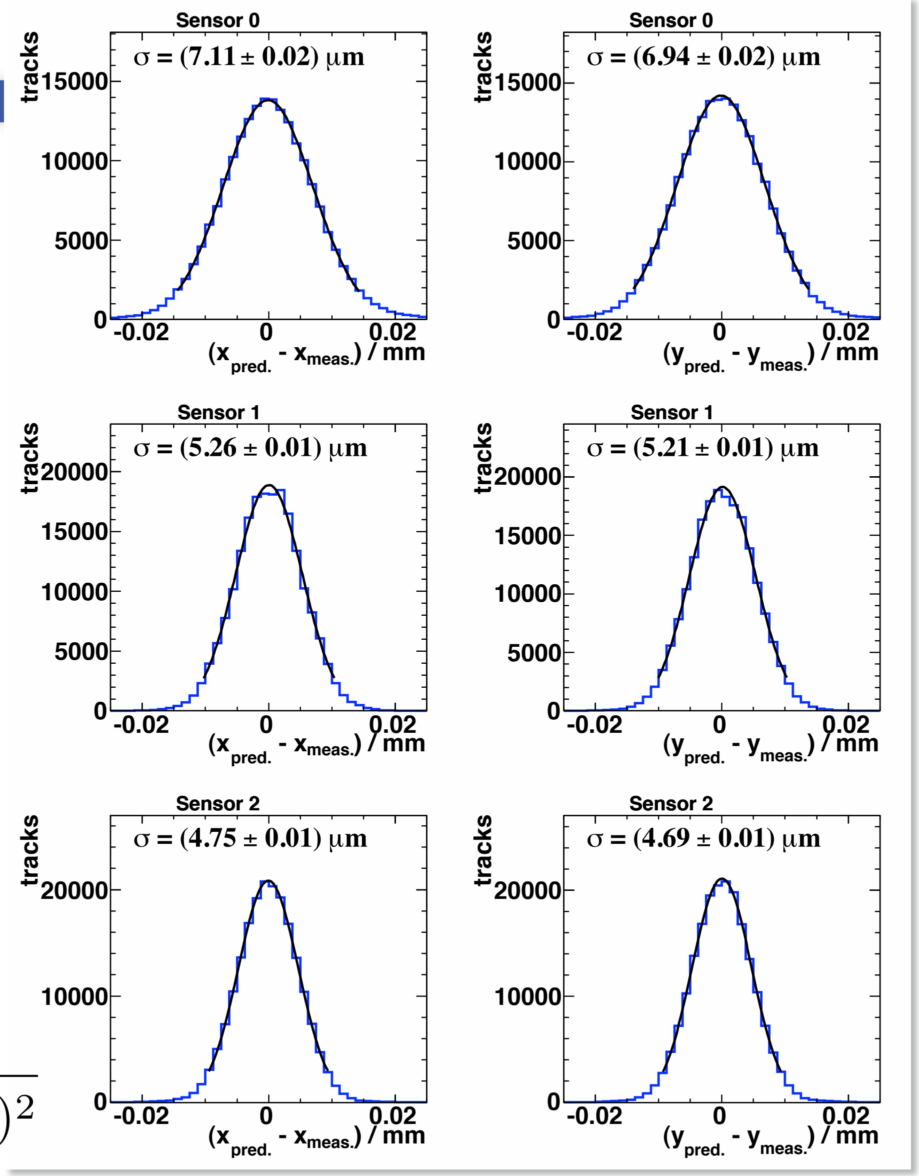
M26 as Ref. Planes

- Dedicated data to measure performance of telescope (120 GeV pions, SPS Sept. 2009)
- 5 planes with Mimosa26 (S/N = 10)
- Included 4 planes in track fit and treated 5th plane as DUT -> iterated for all planes
- Convolution of telescope resolution and DUT resolution

$$\sigma^2_{meas.} = \sigma^2_{tel} + \sigma^2_{M26} + \cancel{\sigma^2_{MS}}$$

$$\sigma^2_{tel} = k \cdot \sigma^2_{M26}$$

geometrical factor ($z_{DUT} = 0$) $k = \frac{\sum_i^N z_i^2}{N \sum_i^N z_i^2 - (\sum_i^N z_i)^2}$



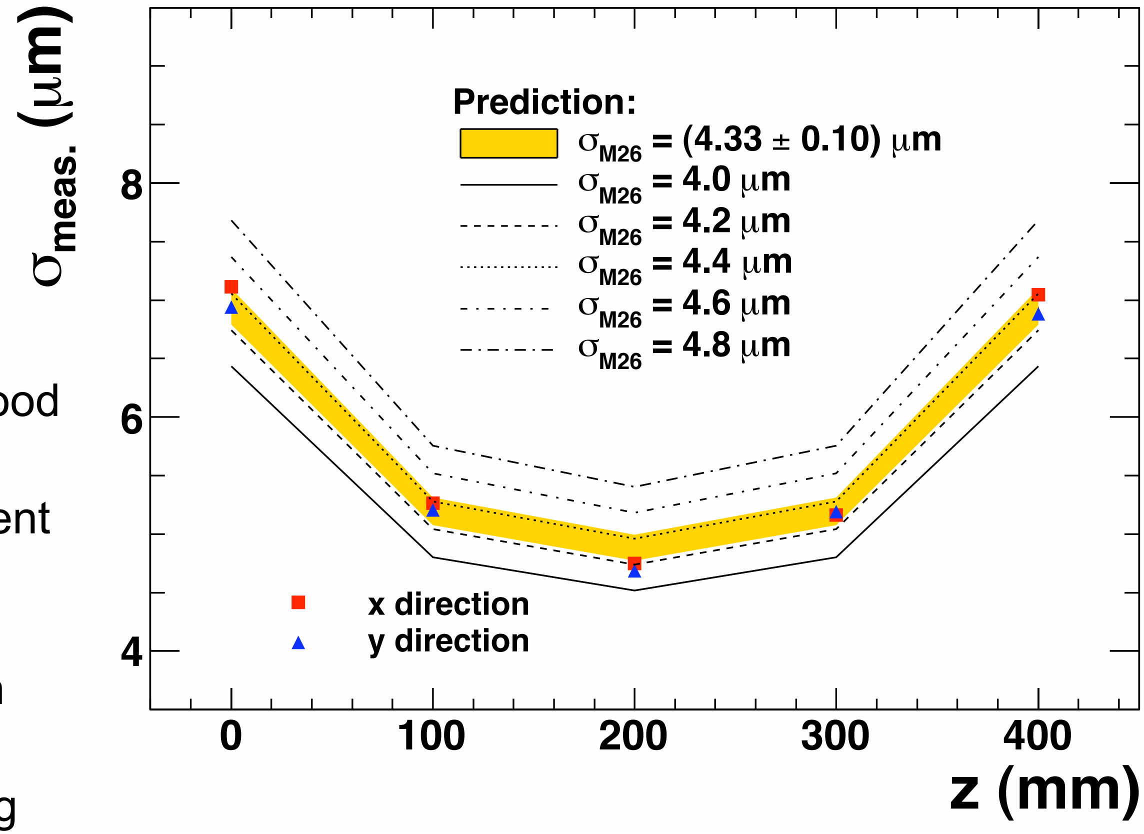
Plot: Joerg Behr (phd Thesis)

M26 as Ref. Planes

- Combined averaging for the extraction of σ_{M26}
- single-point resolution

=> $\sigma_{M26} \approx 4.33$

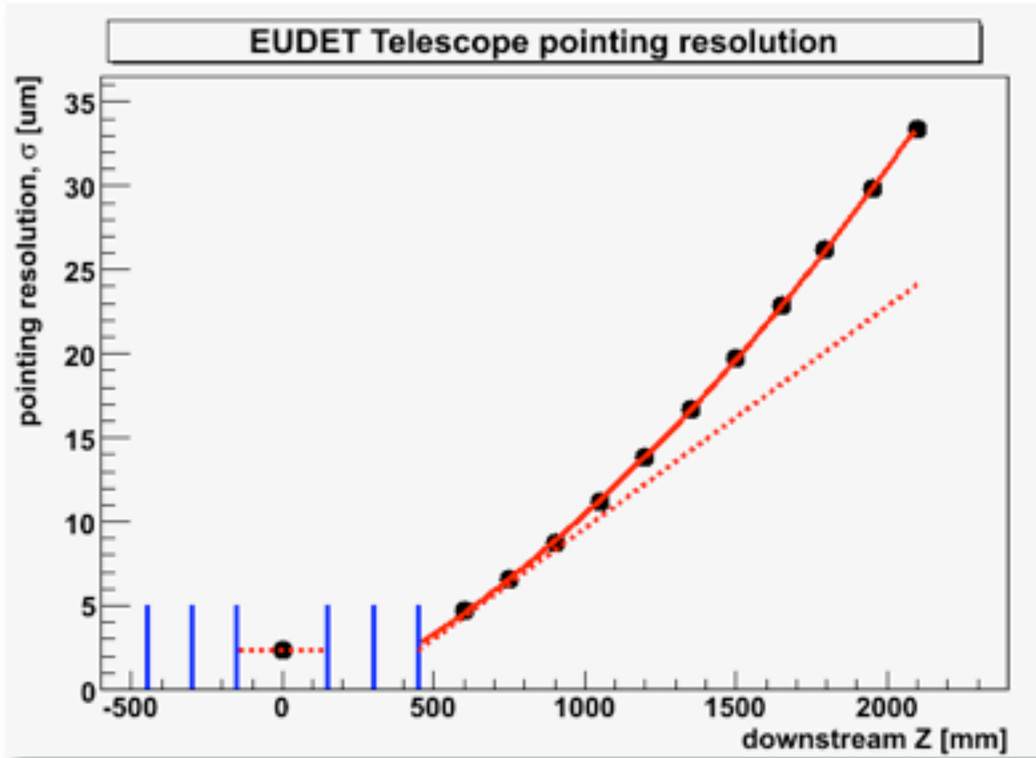
- Prediction for geo. scaling in good agreement with measurement.
- Within uncertainties in agreement with IPHC measurements (S/N =10)
- Measured of intrinsic resolution from IPHC: **3.5um**
- Telescope now ususally running with lower threshold
- Dedicated threshold scan planned for next week (finally time for our own studies)



Plot: Joerg Behr (phd Thesis)

Pointing Resolution

- Best position for DUT: centrally in the telescope.
- Best pointing resolution: <**2.0 µm** (six Mimosa26; intrinsic resol. <4.3µm (S/N<10)).
- Further improvement by adding Mimosa18s close to DUT (~1µm).



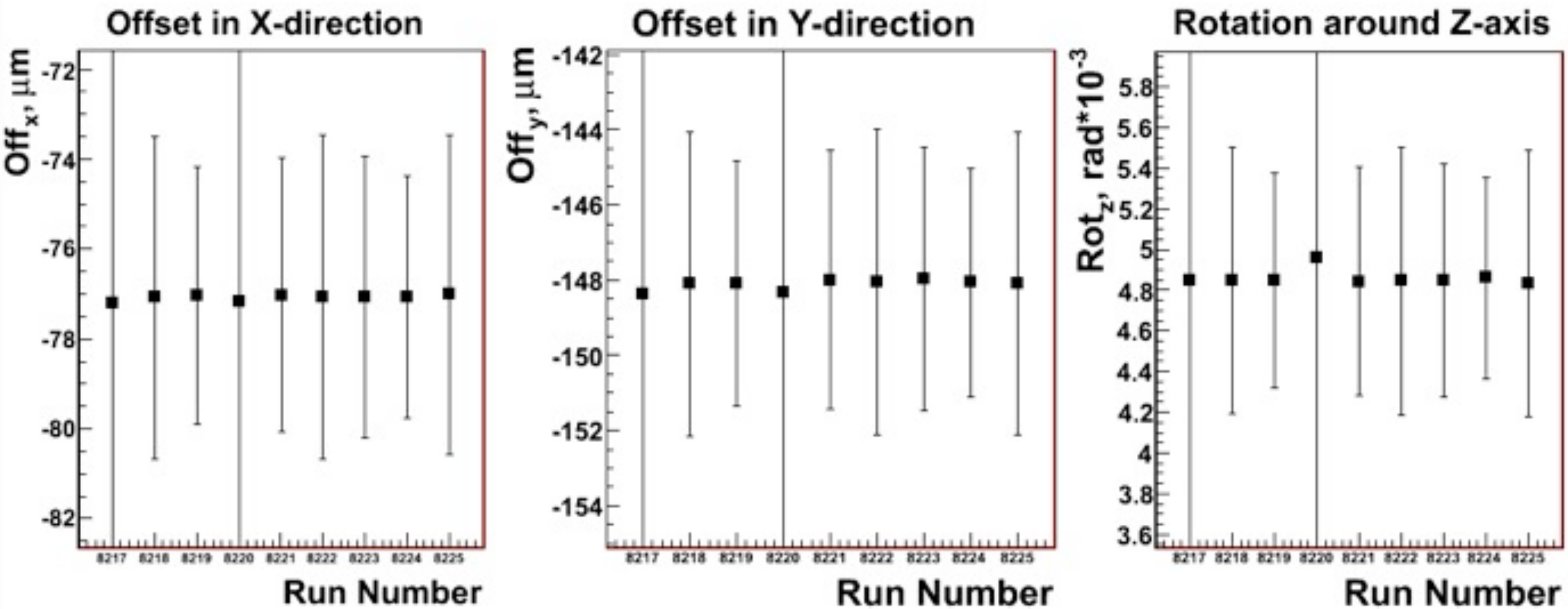
- Massive and larger detectors are better positioned behind telescope: pointing resolutions of < 5µm can be achieved by reducing the distance.
- Even in a distance of 1.5m behind the last plane a estimated pointing resolution of better than 25µm is possible (no further material between last active plane and DUT).

Plot: Igor Rubinsky

Alignment - Stability

- Alignment (MillepedeII) fully automatic (preselection with newly introduced correlator)
- Comparison of alignment constants for different runs
- Alignment constants very stable.

Run Number	Number of tracks used for alignment
8217	2006
8218	30194
8219	47162
8220	523
8221	41566
8222	29644
8223	39445
8224	53107
8225	30589



see https://www.wiki.terascale.de/index.php/Millepede_II

Plot: Slava Libov

The Use of the Infrastructure

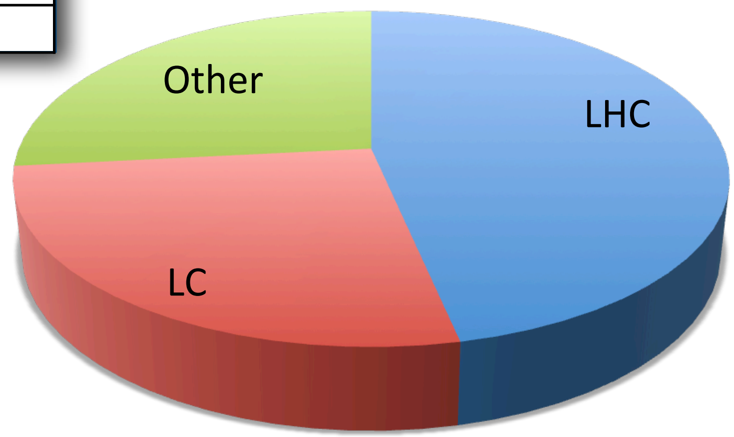
Users 2010

Dates	Beam line	User group	responsible
10.05.-15.05.	DESY	APIX(PPS)	Jens Weingarten
17.05.-20.05.	DESY	Timepix	Jan Timmermans
07.06.-14.06	CERN	RD42/SPIDER	Jens Weingarten
14.06.-21.06	CERN	ATLAS -3DSi	Philippe Grenier
21.06.-05.07	CERN	NA62	Tonino Sergi
05.07.-26.07	CERN	APIX (PPS)	Jens Weingarten
09.08-23.08	CERN	APIX-Diam.	Jens Weingarten
23.08.-20.09	CERN	ALFA	Karlheinz Hiller
20.09.-27.09	CERN	SPIDER	Jaap Velthuis
27.09.-11.10	CERN	SiLC/EUDET	Thomas Bergauer
11.10.-25.10	CERN	APIX (PPS)	Jens Weingarten
25.10.-08.11	CERN	APIX (IBL)	A.LaR, PG, JW
08.11.-15.11	CERN	SILCRD	David Cussans
15.11.-21.11	CERN	DEPFET	Julia Furletova

When preparing the schedule we always try to find time for every group independent of the community.

Requests from LHC community rising.

Current user

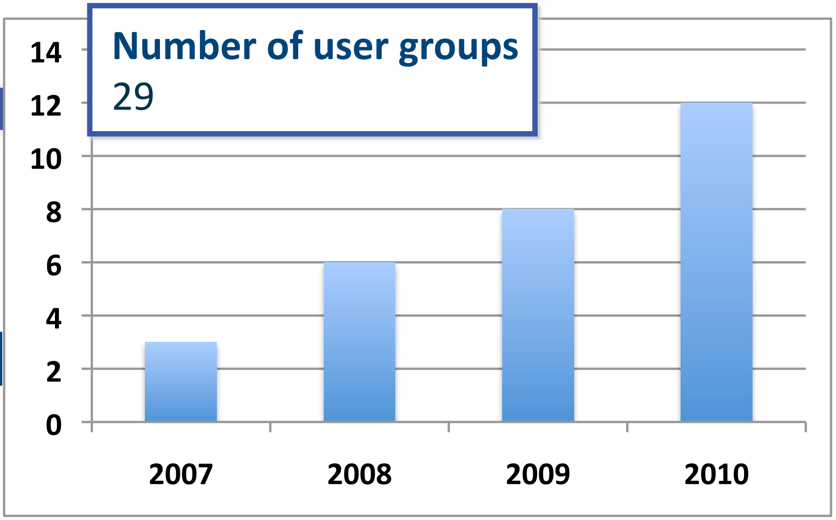


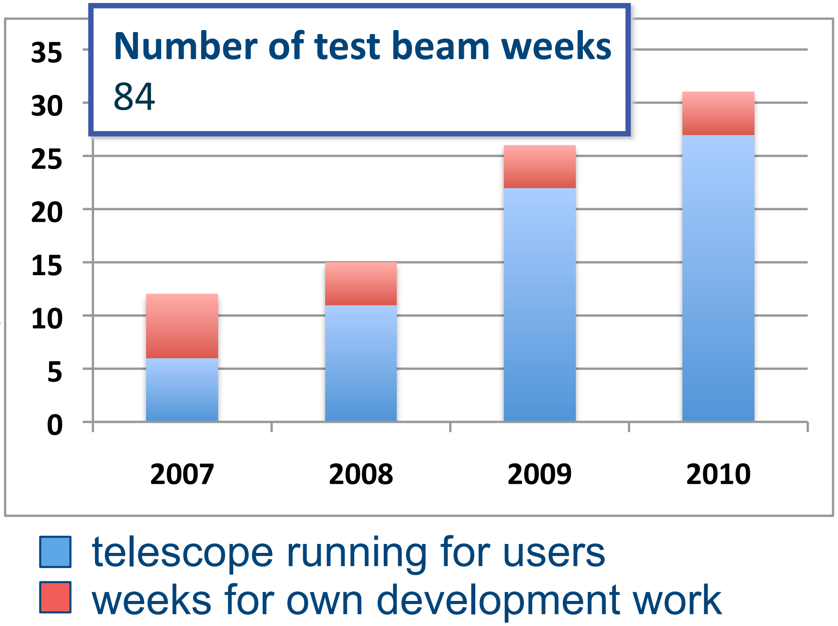
- Telescope will be moved back to DESY end of November
- First bookings for Februar, March and April 2010

User Statistic

Details for 2010

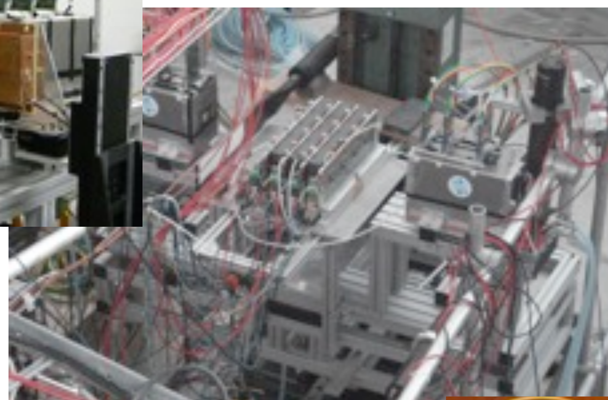
USER	Data size	#runs	# DUTs	BEAM	# events
FORTIS+TPAC	936	1523	1	DESY	~90 mio
TIMEPIX	-	-	-	“	-
APIX/RD42/SPIDER	534	942	1/1	CERN	~60 mio
NA62	15	288	0*	“	~15 mio
APIX (Diamond)	20	221	1-2	“	~10 mio
APIX (PPS)	85	908	8	“	~30 mio
ALFA	98	532	0*	“	~98 mio
SPIDER	8	72	...	“	~7 mio
SiLC	...	...	...	...	...
DEPFET	...	...	...	...	...
TOTAL					**~300 mio**





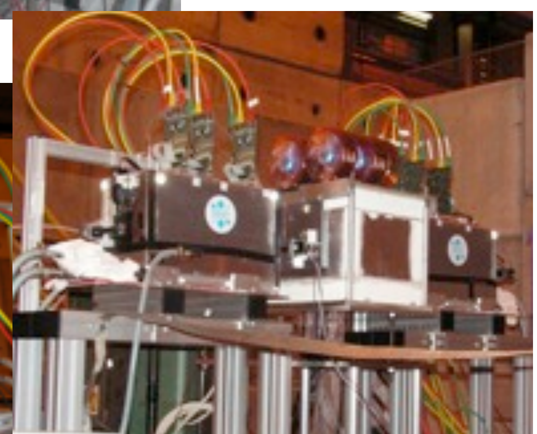
Telescope Users 2007-2010

FCAL@DESY



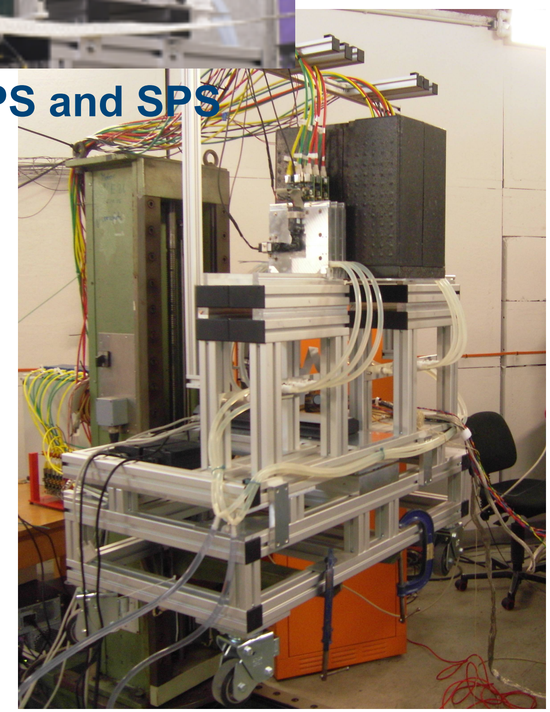
CALICE@CERN-PS

DEPFET@CERN-PS and SPS



ISIS@CERN-SPS

SiLC@CERN-SPS

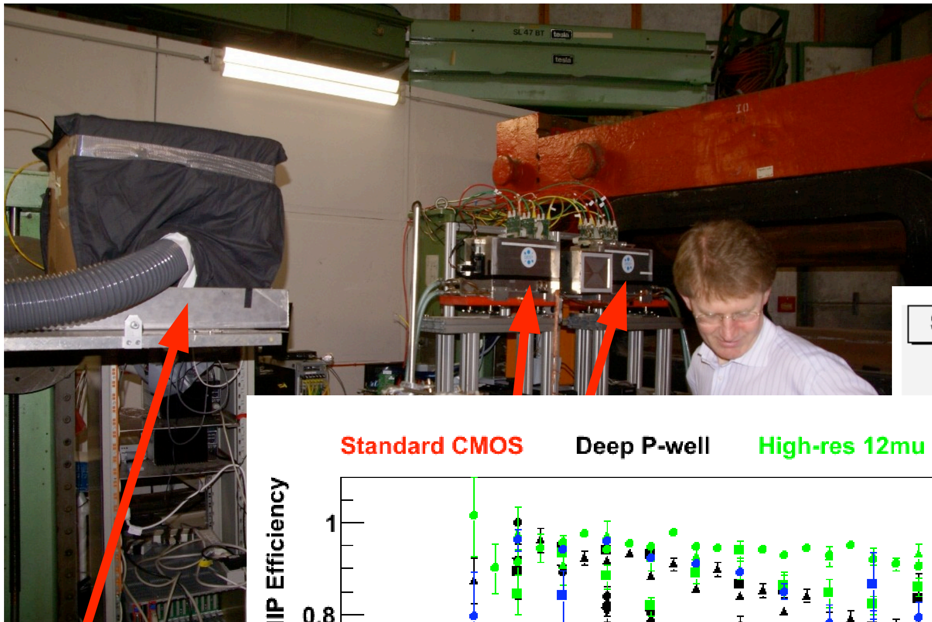


ATLAS-PIX@DESY

Latest User Results 2010

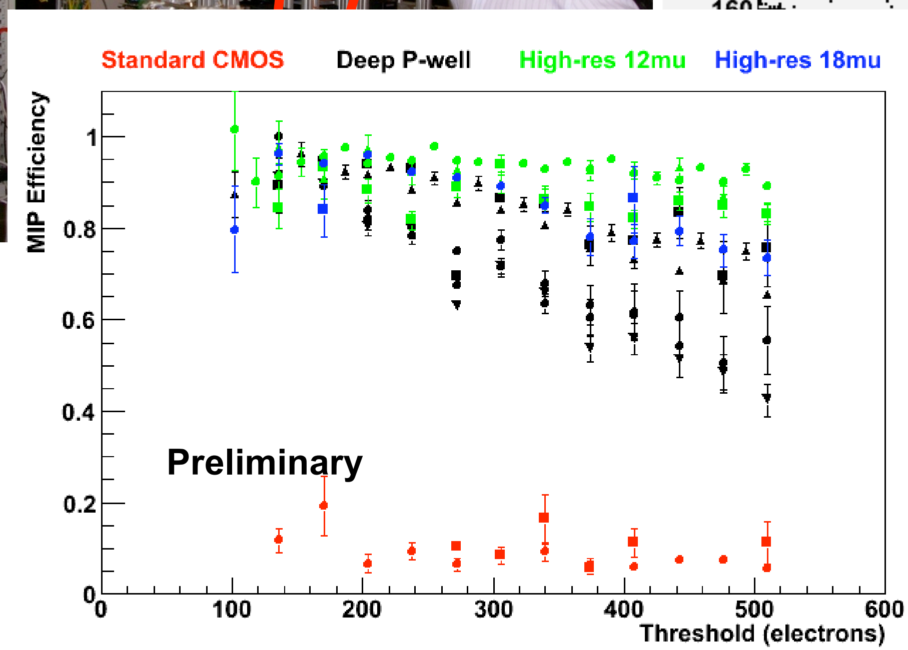
For details:
David Cussans
(JRA1 Parallel Session)

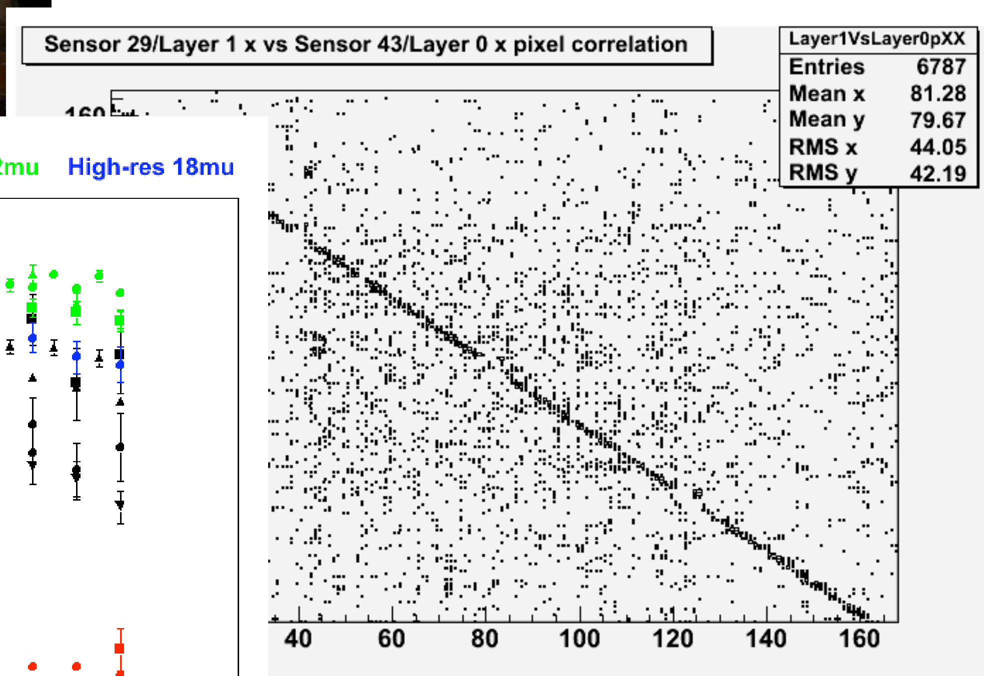
TPAC at DESY



TPAC

- Generic detector R&D for Silicon Pixel Detectors (SPiDER)
- TPAC -> developed for digital readout of the ECAL
- Successful test at DESY spring 2010



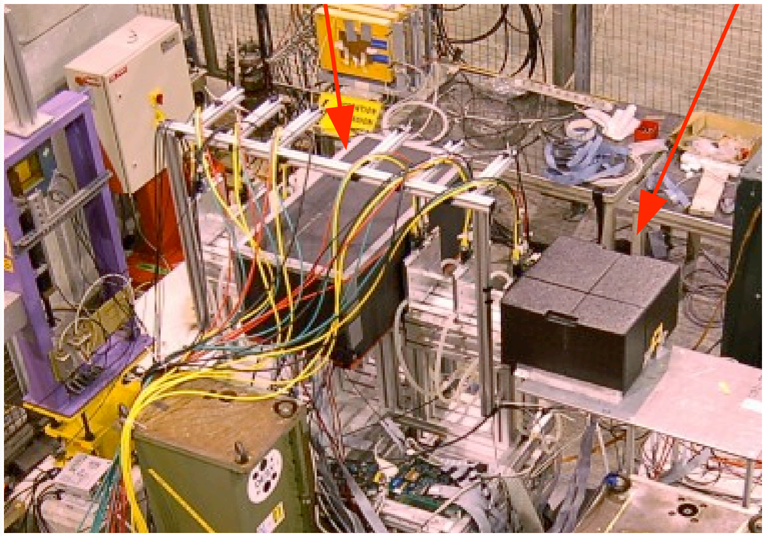


Latest User Results 2010

For details:
Slava Libov
(JRA1 Parallel Session)

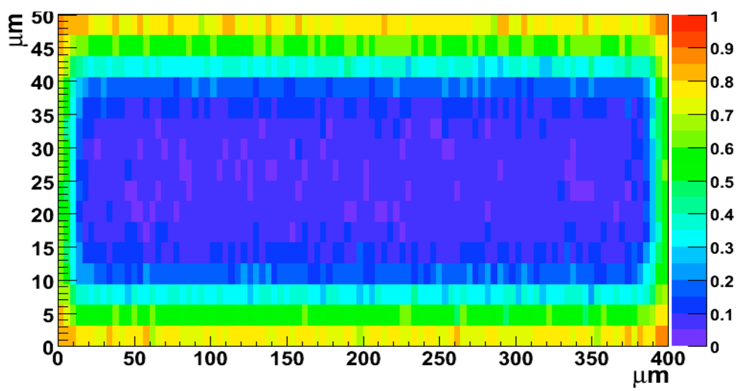
ATLAS-Pixel (PPS for IBL)

4 DUTs 4 DUTs

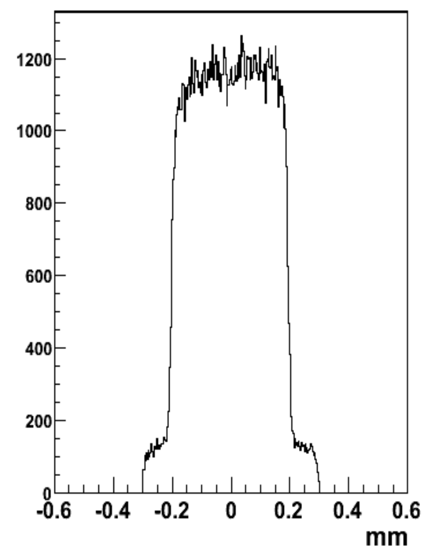


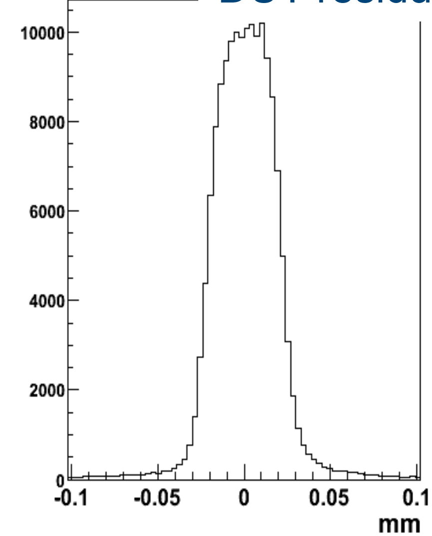
- Three different sensor technologies are under investigation for the ATLAS Insertable B-Layer (upgrade ~2016)
- All three collaborations used the EUDET telescope for independent test beams this summer
- Combined test beam planned for October
- All user EUTelescope for tracking and reconstruction
- DUT analysis also possible with EUTelescope frame work !!

Charge sharing probability versus position



DUT residuals

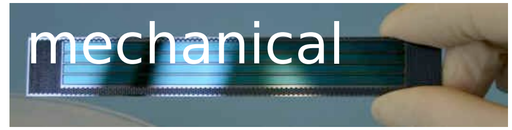


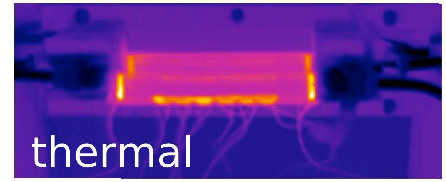


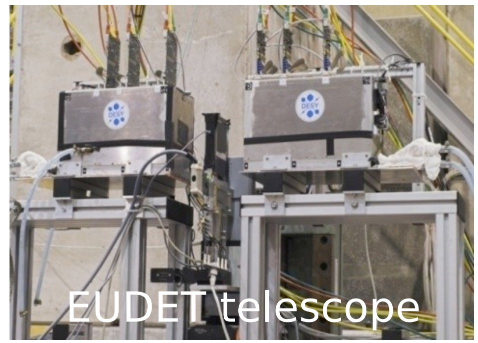
Outlook - PLUME and AIDA

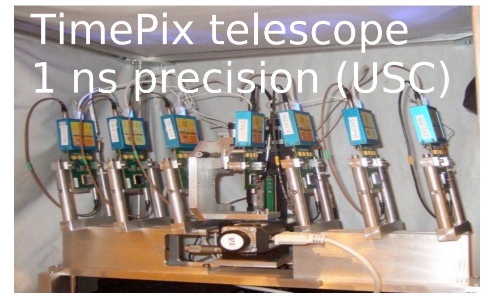
AIDA - WP 9.3 Pixel Detectors

- The main infrastructure is a beam telescope for characterization of prototypes
- Continuation of the EUDET telescope and surrounding infrastructure,
- Catering to sLHC needs (CO2 cooling plant, fast telescope arms)
- Infrastructure for thermo-mechanical characterization envisaged at DESY



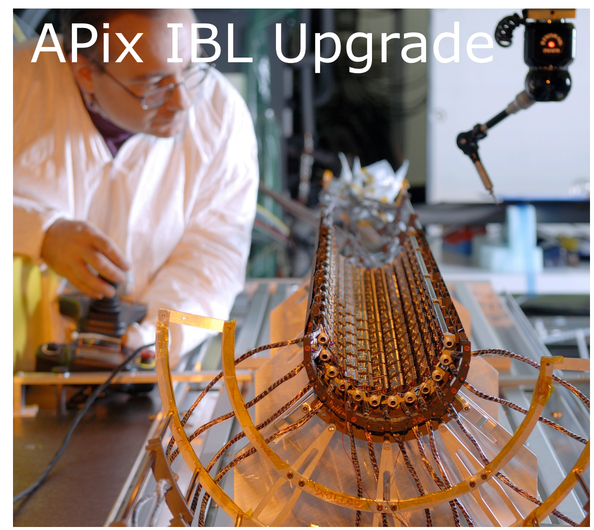






First ideas for next generation telescope

- Starting on the base of existing telescope
- User can choose from three different technologies:
  - ATLAS pix: LHC timing
  - Timepix: high precision timing and high resolution
  - Mimosa: large area (e.g. 4x4 cm^2) and high resolution
- Segmented trigger: easier tracking (Hodoscope)
- Possible further improvement: self triggered sensor
- New version of TLU: tagging



PLUME Pixelated Ladder with Ultra-low Material Embedding

Geometry for an ILD vertex detector, 2009-2012

Objectives :

- achieve a doublesided ladder prototype for an ILD vertex detector by 2012 (DBD)
- material budget : < 0.3% X_0 (final goal for 2012 prototype)
- quantify power pulsing and air-flow cooling effects on final sensor spatial resolution
- evaluate benefits of double-sided concept (mini-vectors)

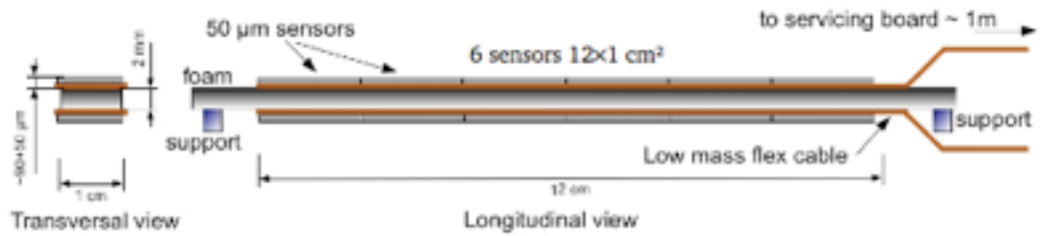
PLUME collaboration:
- Bristol University
- Oxford University
- DESY (Hamburg)
- IPHC (Strasbourg)

Baseline :

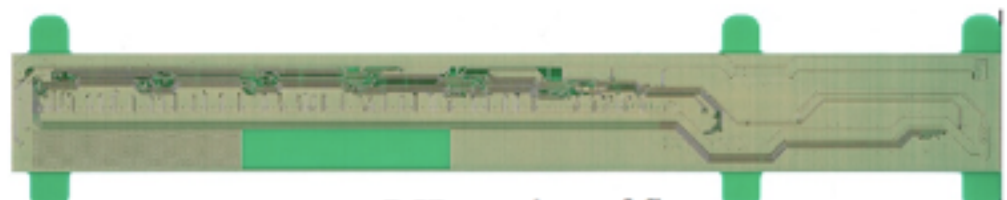
- MIMOSA-26 CMOS sensor (developed for EUDET-Telescope)
- Power pulsing (< 200ms period, ~1/50 duty cycle) and power dissipation (100mW/cm²)
- Air cooling

Current concept :

- 6 x MIMOSA-26 thinned down to 50µm
- Kapton-metal flex cable
- Silicon carbide foam (8% density) stiffener, 2mm thickness
- Wire bonding for flex - outer world connection
- Digital readout



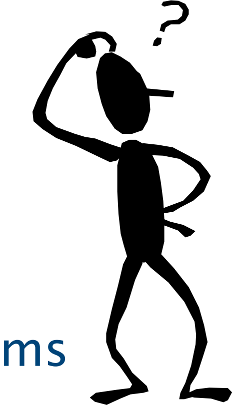
PLUME2010: to realize & test the first version of the full device with relaxed specifications



PCB version of flex

Material budget ~ 0.65 % X_0

What did we learn?



- All together the EUDET telescope was running **84** weeks in test beams
  - >1 Billion events and >10 Tbyte of data
- **To make the telescope a true infrastructure for users is a lot of work!**
  - What would we do differently?
    - Use (semi) commercial DAQ boards from the start.
    - Use stand-alone analysis software (Marlin is a difficult for non ILC users).
    - Segmented trigger.
    - Promise less support ;-)

Very important "side effect" (true for all JRAs):

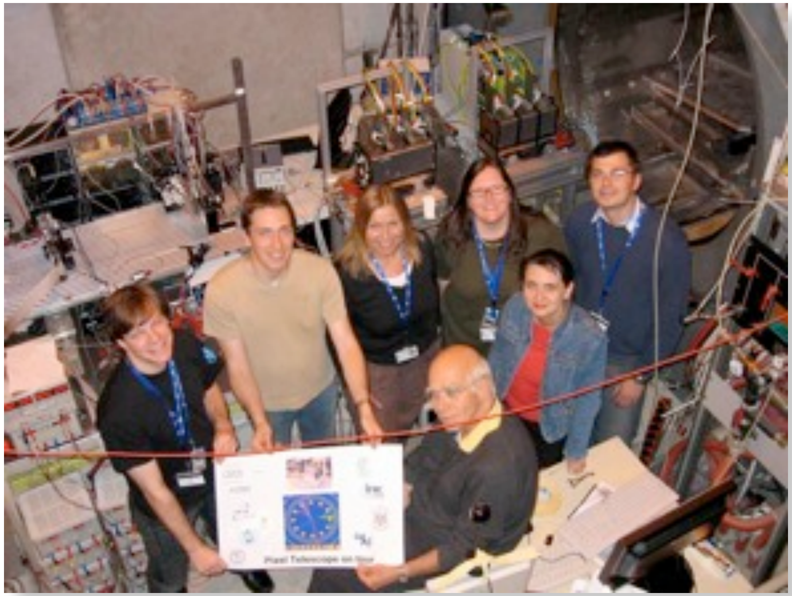
- Telescope has almost 4 million channels ~ HEP experiment of the 90s
- All aspects of a HEP experiment: data taking, triggering, data processing, alignment, analysis, interaction with matter, working in a team .....

- **Unique opportunity for students to get hands-on experience !!**

Conclusions

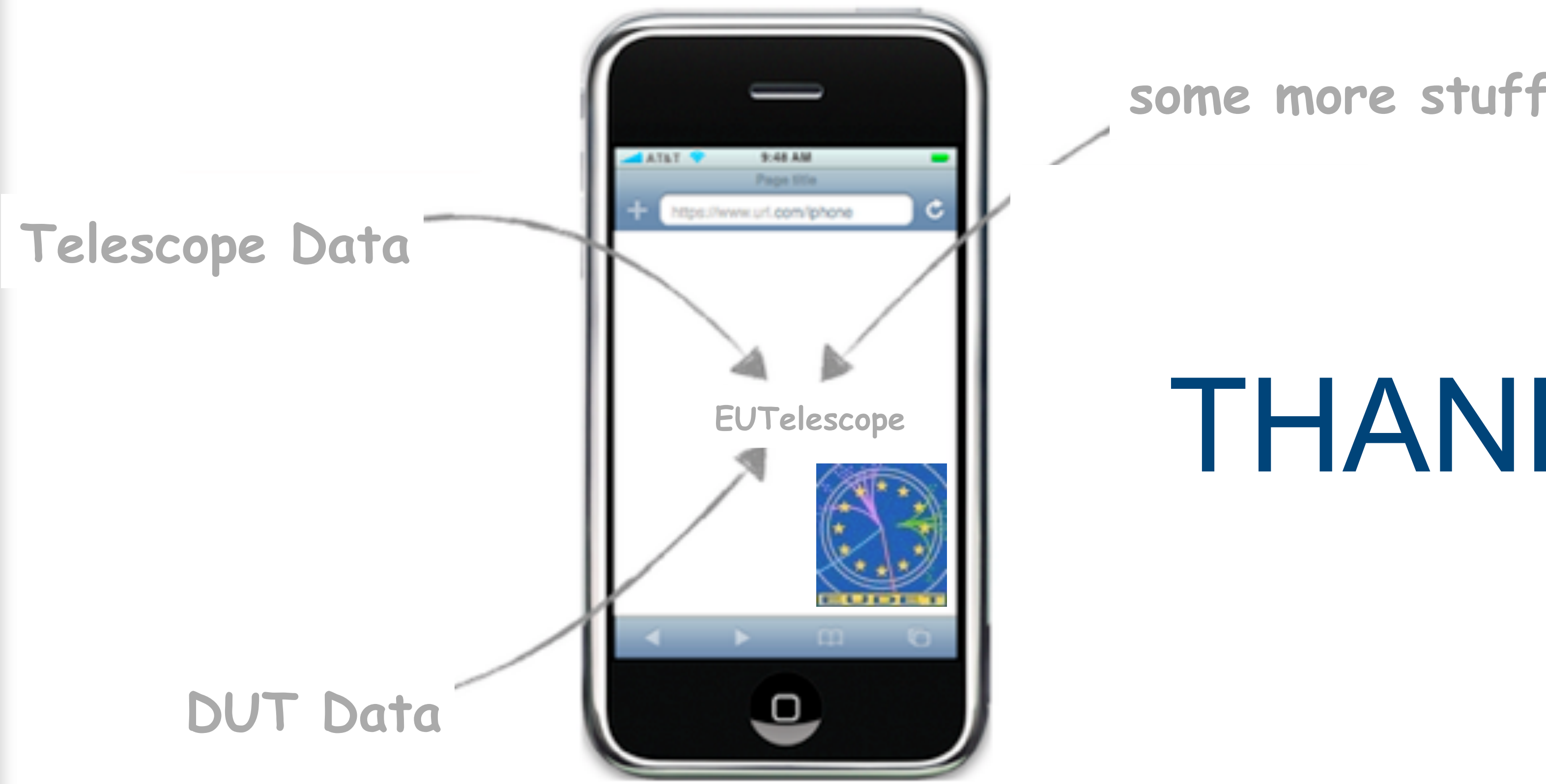
- EUDET is a great opportunity for teams involved in detector R&D.
- Everybody can join the fun and use the developed infrastructure to test their own devices (also non-ILC communities!)
- AIDA will hopefully continue this adventure

- The EUDET telescope is very successful since summer 2007 (demonstrator and now also the final version).
- Telescope Version 2010 is running at CERN SPS since June 1st and will stay the rest of the season. Afterwards back to DESY for more users.
- **The telescope is working very stably and according to specs:**
  - flexible
  - (usable in magnetic field)
  - easy DUT integration (incl. analysis)
  - trigger rate of ~1kHz
  - pointing resolution of <2um

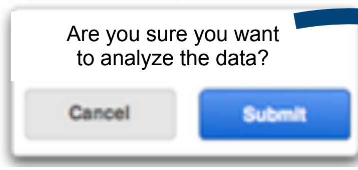


First CERN test beam in 2007

The Future yet to come ....



THANKS!!



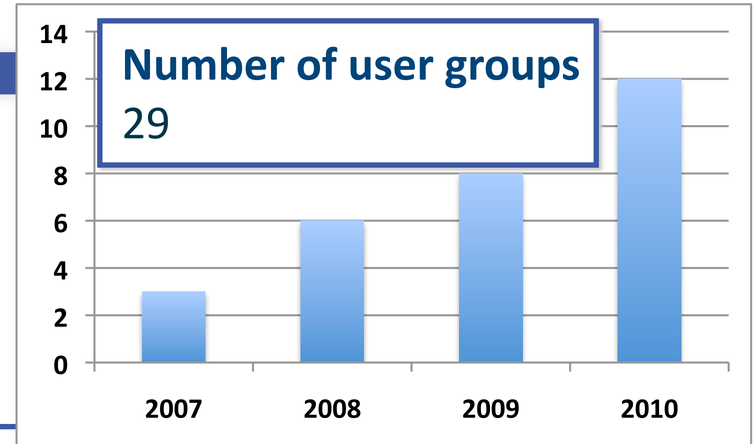
Paper
(to be submitted to a well known journal)

Some Statistics

Telescope
6 planes x 663552 pixels
= 4 Million channels

Evenings to debug the system
53

Number of user groups
29



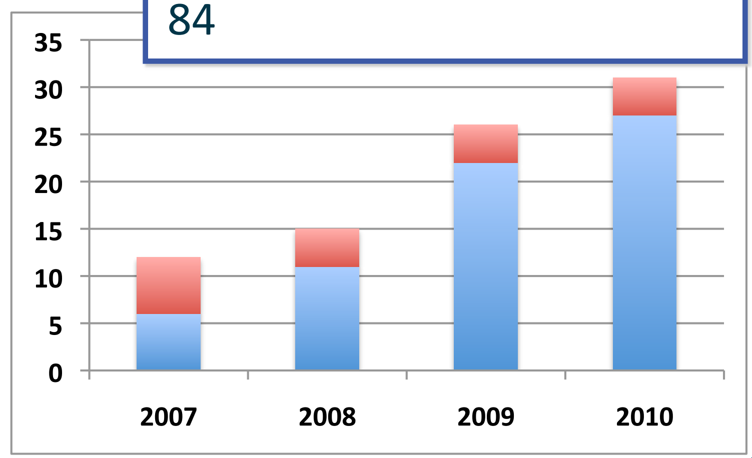
Readout speed
up to 1kHz

Pointing resolution
< 2um (Mimosa26 only)
~1um (usind HR plane)

Pixel pitch
MimoTel : 30um
Mimosa26: 18.4 um
Mimosa18: 10 um

TByte of data take
>10

Number of test beam weeks
84



Number of travelled km
8800

Dead hardware
1 VME power supply
2 MVME 6100 boards
1 VME back plane
1 TLU
3 postdocs