IWLC2010 International Workshop on Linear Colliders 2010

Conclusions from Detectors

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October 2010

Geneva

Outline

Disclaimer:

- **not a summary of all sessions and talks on LC detector R&D**
- **impossible to give justice to all the many results and developments presented here**

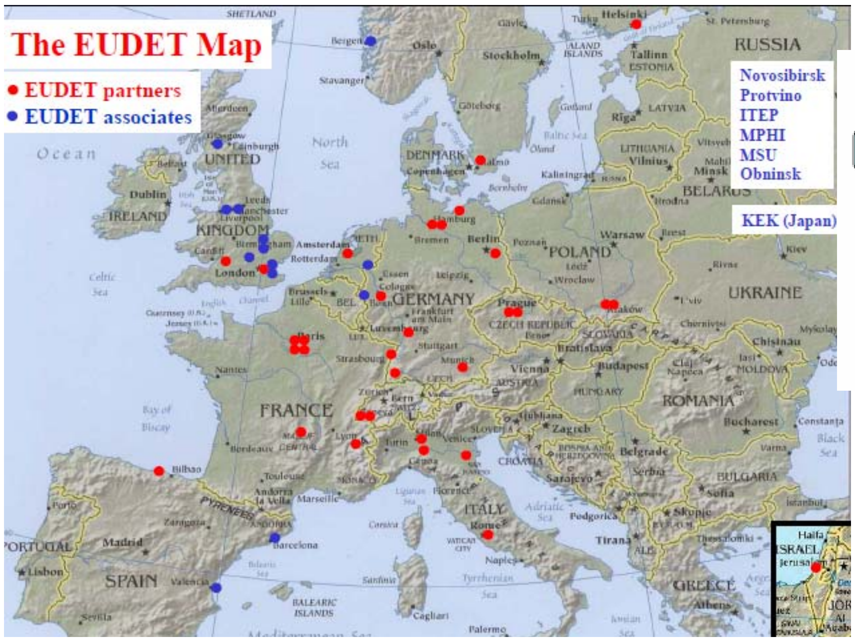
Instead:

- **pick a few highlights**
- **personal selection with a few personal remarks**
- **outlook**

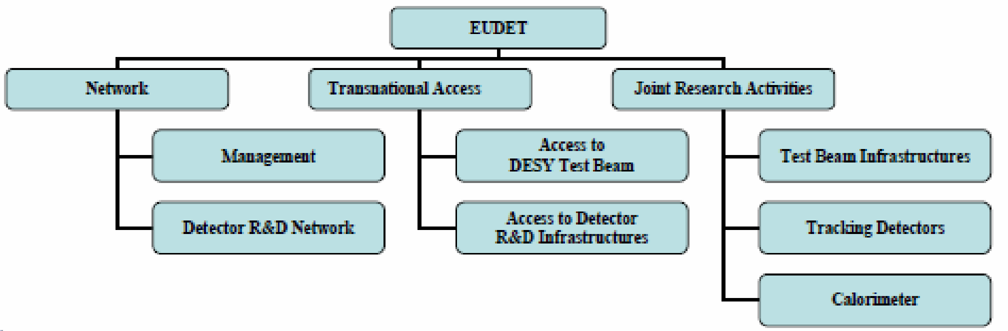
Looking back…

EUDET project 2006-2010:

- **collaboration in Europe & beyond**
  > 30 institutes



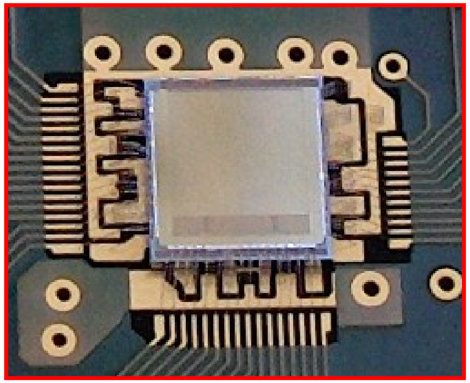
- **well defined structrue**

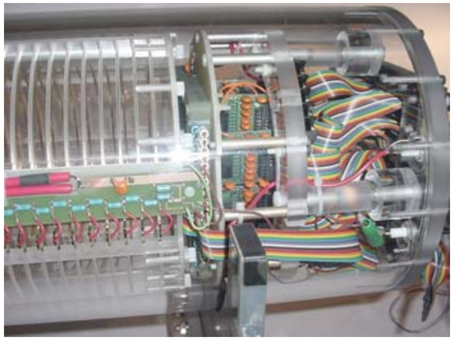


- **plus additional funds**
  7 M€ in total

Pre-EUDET (Vienna 2005)

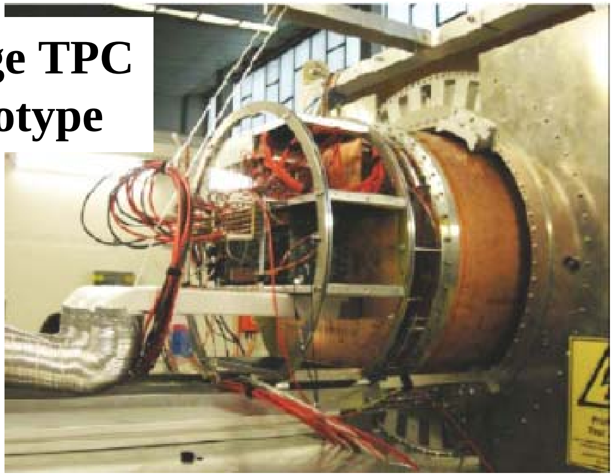
Today (Geneva 2010)





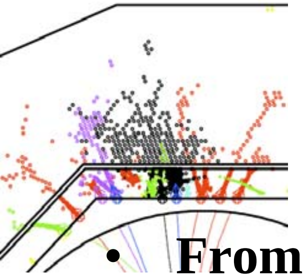
Small TPC prototypes

Large TPC prototype



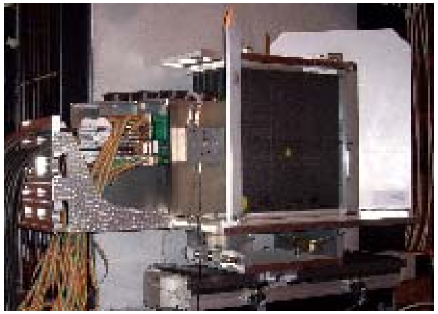
+ many other examples

Conclusion:
continue collaborative spirit → AIDA



EUDET - before / after

- From proof-of-principle to technology prototypes:
- compact mechanics, power-pulsed ASIC family, scalable DAQ
- ECAL



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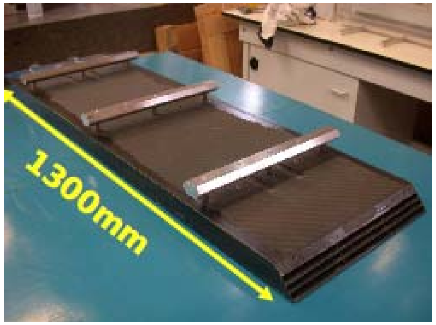
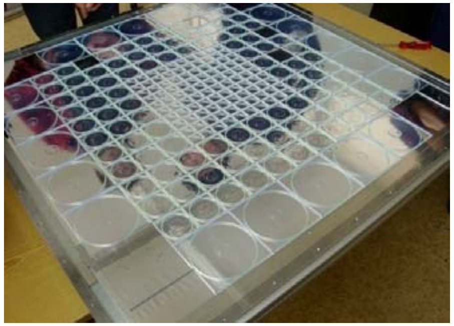


- aHCAL



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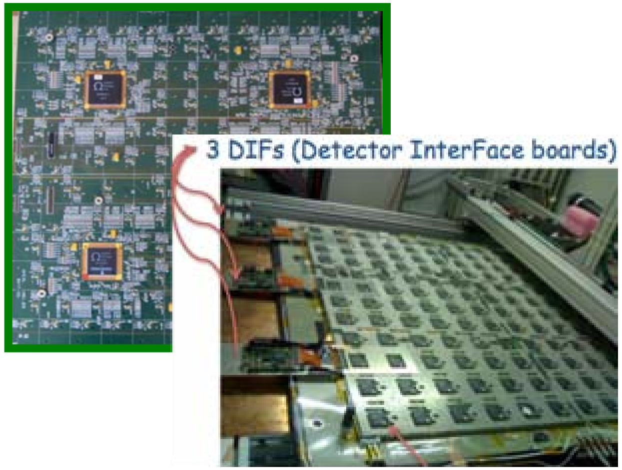


- dHCAL: (nothing) →

A few selected highlights…

LC Vertex Detector

Measure impact parameter, charge for every charged track in jets, and vertex mass.

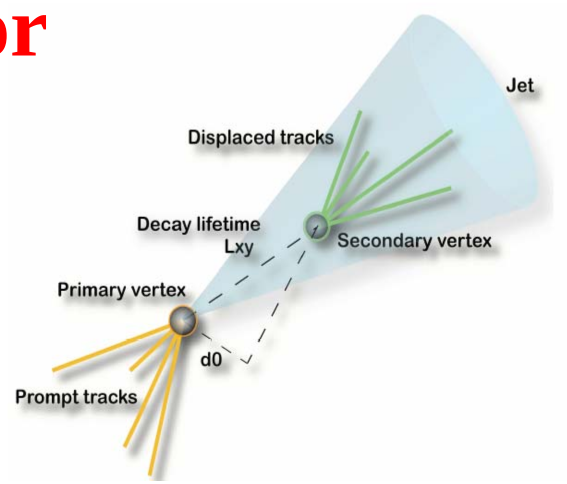


Figure of merit for the VXD:

Impact Parameter Resolution

$$\sigma_{r\phi} \approx \sigma_{rz} \approx a \oplus b/(p\sin^{3/2}\vartheta)$$

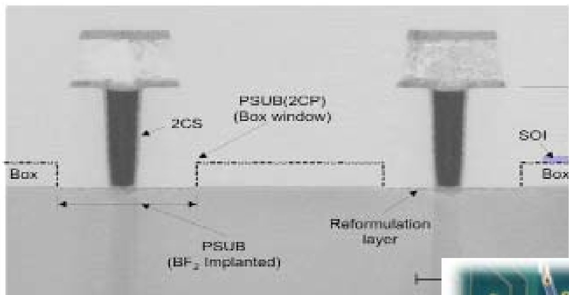
Need:

- Good angular coverage with many layers close to vertex.
- Efficient detector for very good impact parameter resolution
- Material ~ 0.1% X_0 per layer.
- Capable to cope with the LC beamstrahlung background (higher for CLIC)
- Single point resolution better than 3 µm.
- Small pixels, thin sensors, thin r/o electronics, low power (gas cooling).
- CLIC requires better timing resolution.

Accelerator	a (µm)	b (µm)
LEP	25	70
SLD	8	33
LHC	12	70
CLIC	**<5**	**<15**
ILC	**<5**	**<10**

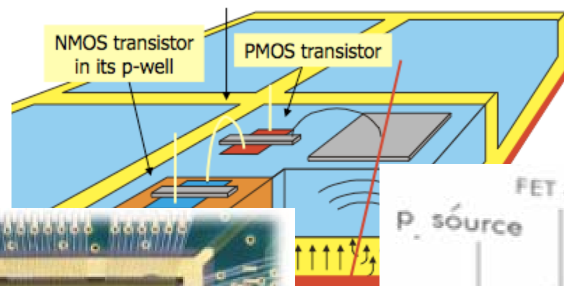
Technology Advances

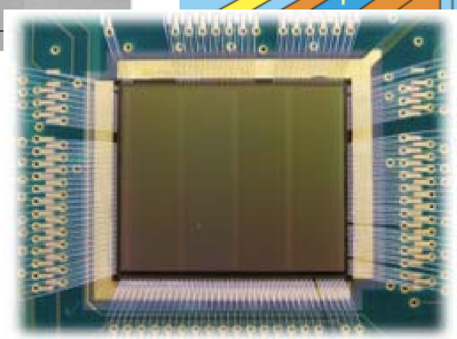
- **Diversified R&D on pixels continues**
- **substantial progress achieved on several fronts during the last year even if at reduced speed**
- **Great achievements partly because the relevant accessible industrial technologies have made sometimes striking progress**



SOI CMOS technology

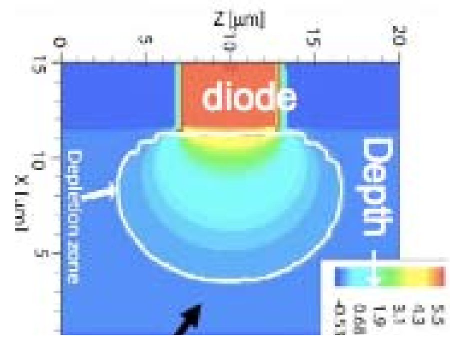
HV CMOS



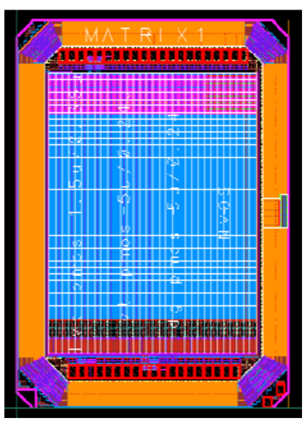


TPCA 1.2 from SPiDER

DEPFET



Mimosa26 w. high res.

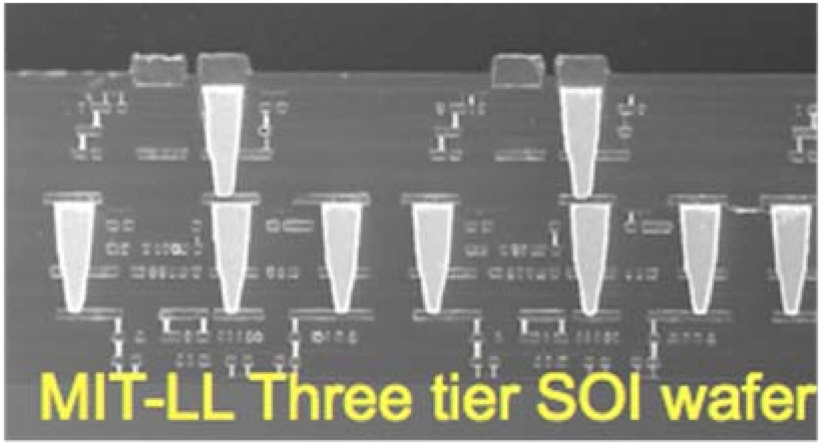


Matrix 1 of LePix

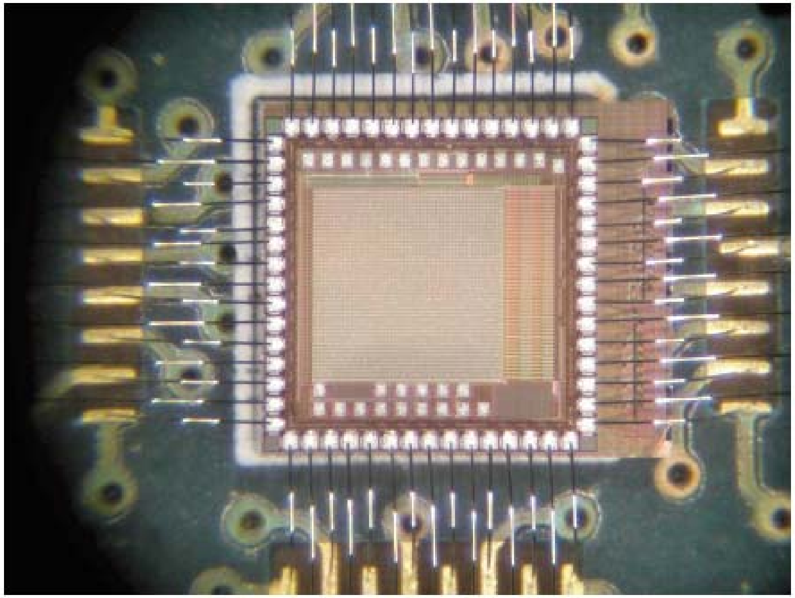
- **Some pixel technologies is now even at the level where it is expected to meat all ILD vertex detector specifications by 2011, i.e. within the DBD timeline**

3D Vertical Integration

Stacking of multiple layers of chips
- optimise pixel performance
- simplify integration
- possibility to develop novel monolithic pixel sensors
- Important for CLIC developments



Substantial number of teams contributing to this effort
- progress slower than expected
- but considerable progress recently

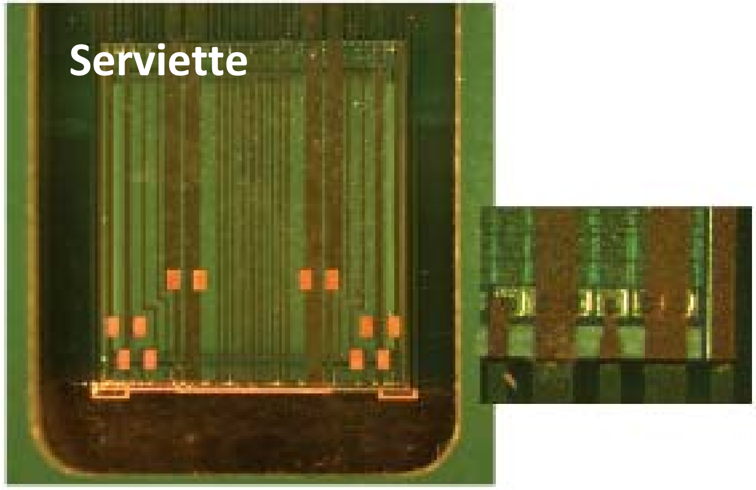


Vertically Integrated Pixel VIP2a (FNAL)

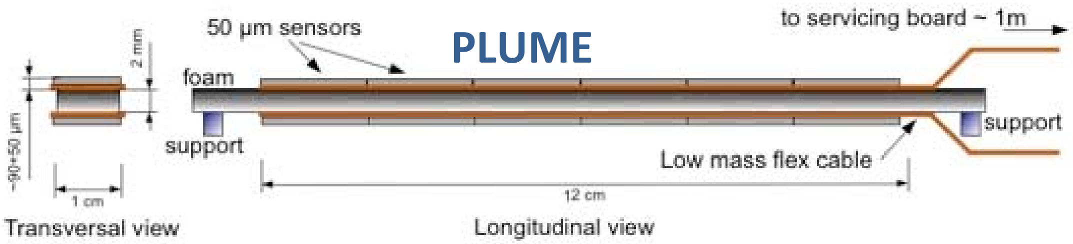
Integration Issues

- R&D on system integration issues have picked up speed
- Achieving ultra-light pixelated systems (like double-sided, or monolithic or unsupported ladders)

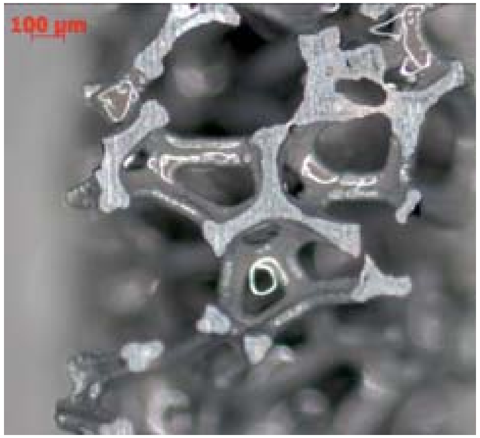
Thinned **DEPFET** sensor



Mimosa18 thinned to 30 um embedded in kapton
< 0.15% X_0



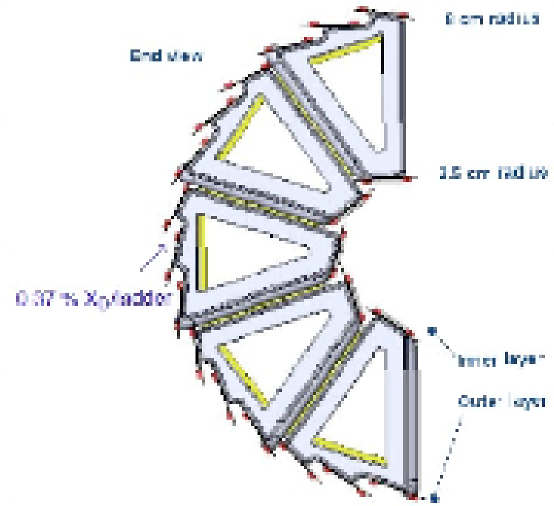
Fully equipped ladder with 50 µm sensors by 2012
~ 0.3% X_0



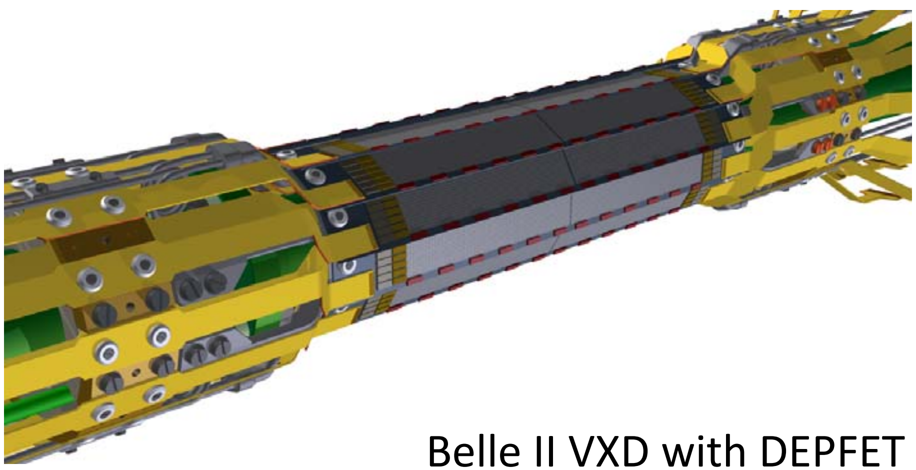
Silicon Carbide for novel mechanical vertex structures

LC technologies in real experiments

- Important: integration of sensors in real experiments
  - Smaller projects: beam telescopes (i.e. EUDET BT)
  - Real vertex detectors!
- Leads to concrete applications of > 10 years of R&D
- Allows to assess various emerging technologies in real experimental HEP conditions for the first time
- Even if they are not yet all pushed to the performances needed for the ILC.



STAR@RHIC with Mimosa (2012)



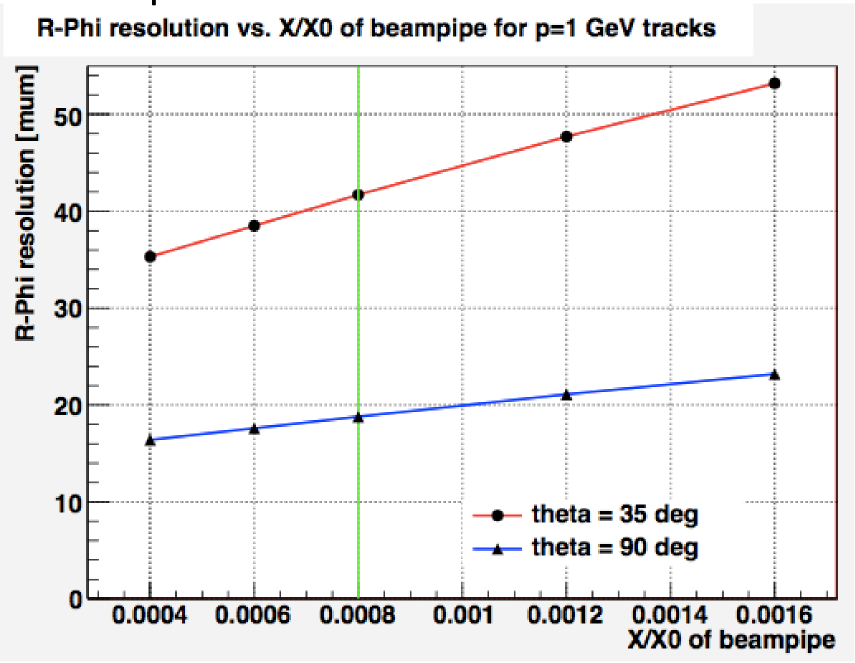
Belle II VXD with DEPFET (2014)

MC Simulation CLIC-VXD

- Layout optimisation for the vertex and forward tracking region started from validated ILC tracking-detector designs: ILD and SiD
- Adaptations for CLIC (background-) conditions: forward region, distances to IP
- Where applicable: complementary choices, to study influence on performance
- Fully implemented in Geant-4 simulation frameworks Mokka (ILD) and SLIC (SiD)

- Resulting designs CLIC_ILD_CDR and CLIC_SiD_CDR will be used for large-scale full-simulation MC studies towards a Conceptual Design Report (CDR), to be submitted in 2011

Example

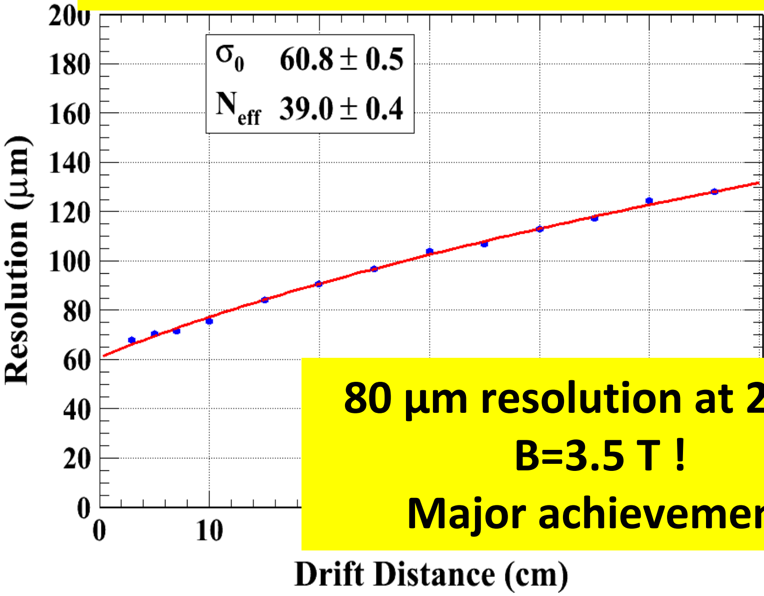


~20-30% worsening for x2 more material w.r.t. (optimistic) defaulT

Gaseous Tracking

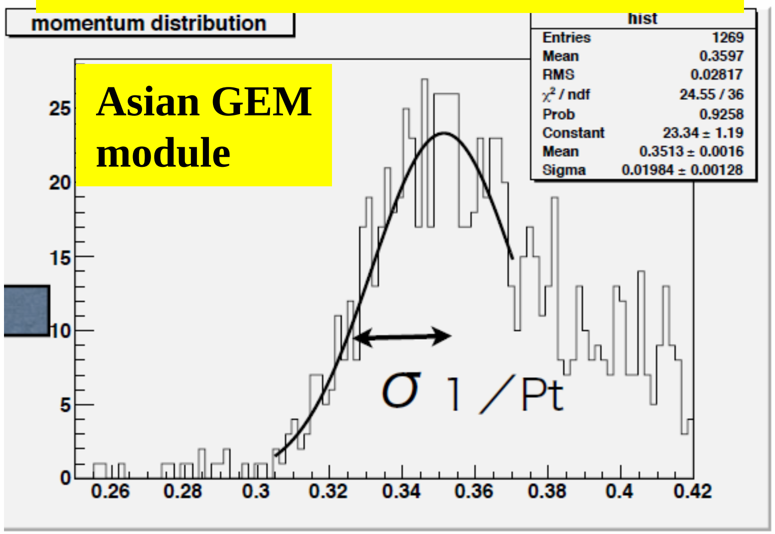
- TPC is main tracker for the ILC concept, as option under evaluation by CLIC
- Active R&D effort within the LC-TPC collaboration
- Focus of the past few years:
  - demonstrate feasibility and performance in prototypes
  - develop an realistic overall concept including integration in the ILD detector
  - major test beam effort by many groups using DESY beam

Micromegas based measurements



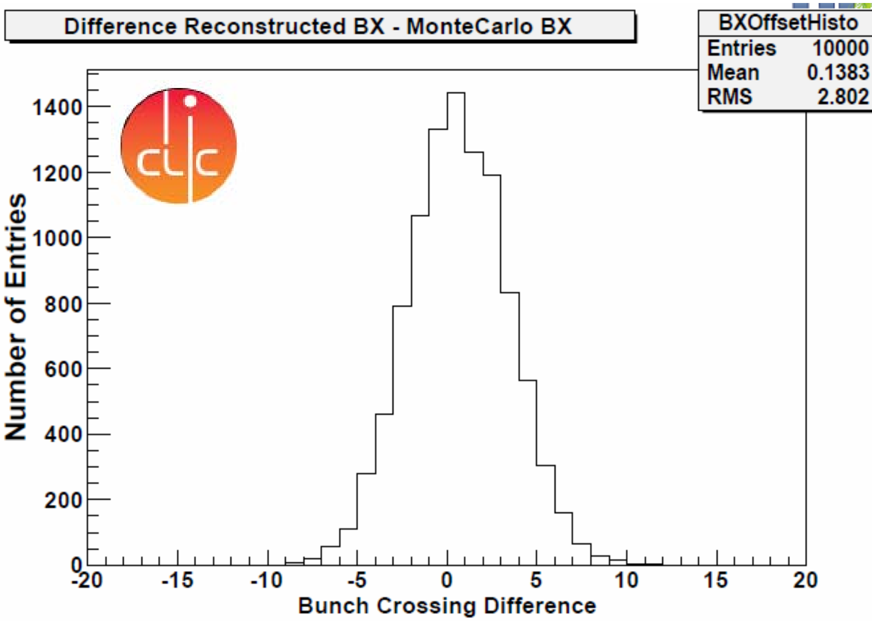
80 µm resolution at 2m in B=3.5 T !
Major achievement

First momentum measurement:
Only Factor 2 worse than required



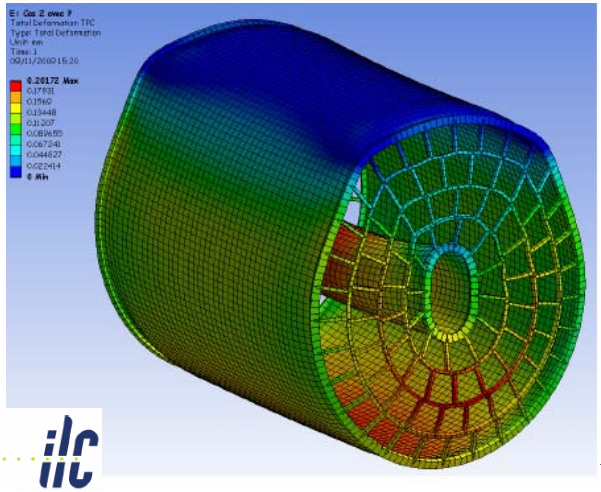
TPC at ILC & CLIC

- Requirements at ILC and CLIC are very different:
  - ILC: 369 ns vs CLIC: 0.5 ns (30 mm vs 40 µm)



Studies of detector integration have started

- Simulation: bunch crossing ID within +-5 CLIC bunches: TPC not immediately excluded



Studies of mechanics and integration into ILD have started

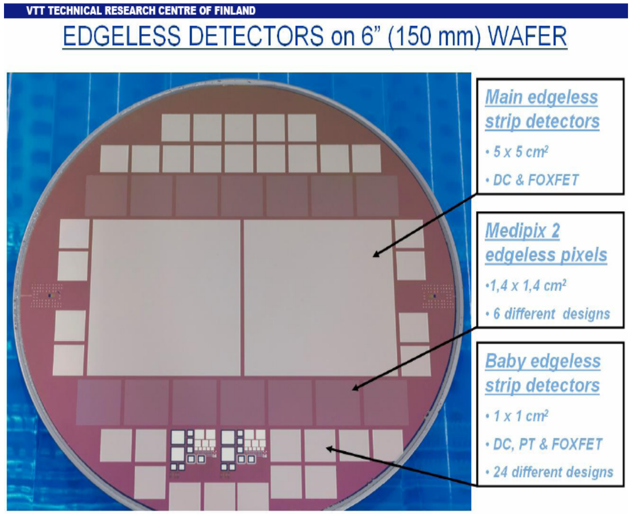
Silicon Tracking

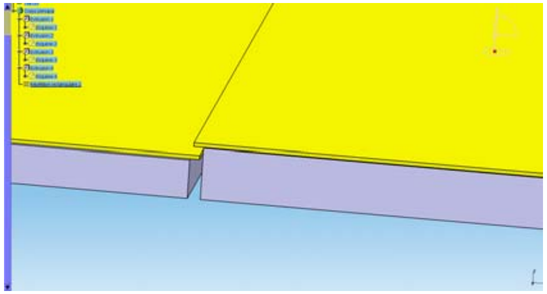
- Silicon tracking is central to both ILC and to CLIC concepts

- Main challenges:
  - material budget in sensors and support structures
  - level of integration of readout and services
  - power supply, power cycling
  - alignment methods

Topic has large synergy with other projects: sLHC, BELLEII, others

Example: edgeless sensors could simplify overall construction significantly and reduce material budget



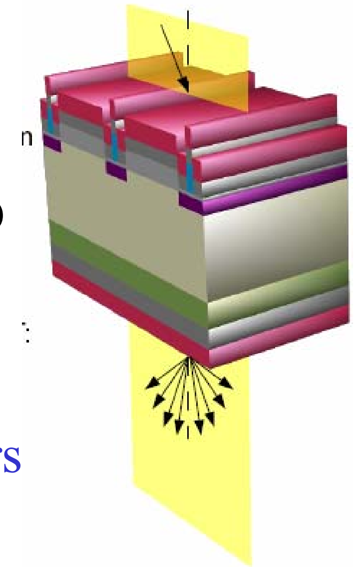


Test (edgeless) detectors on 6" wafer (SOI technology)

Silicon Tracking

Internal alignment is critical for success of tracking:

- True for any of the concepts
- Particular challenge for the large outer Silicon layer in ILD



Principle: shine laser beam through
Si-layer (a la CMS)
But: develop more transparent sensors
(20% → 60% transmission)

Readout: very wide field.

Development of mixed analogue- digital 128 channel ASCIC (SiTR chip)
Integrate the pitch adapter on the sensor
Sophisticated infrastructure and test benches developed
(in Europe within EUDET)

Mechanics:

Develop integrated concept for SI tracking integration into ILD and SiD

Main Challenges in Tracking

Technologies:

- Have at least one technology per system which fulfills all requirements
  Might well be different for ILC and CLIC
- Have a concept on how to get data from the sensor to the DAQ

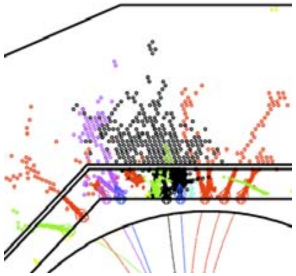
- **System aspects:**
  - Move from test to system aspects:
    - Large scale systems
    - System integration within sub-detector
    - System integration with other parts of the detector

TPC endplate design
TPC material budget
Si material budget

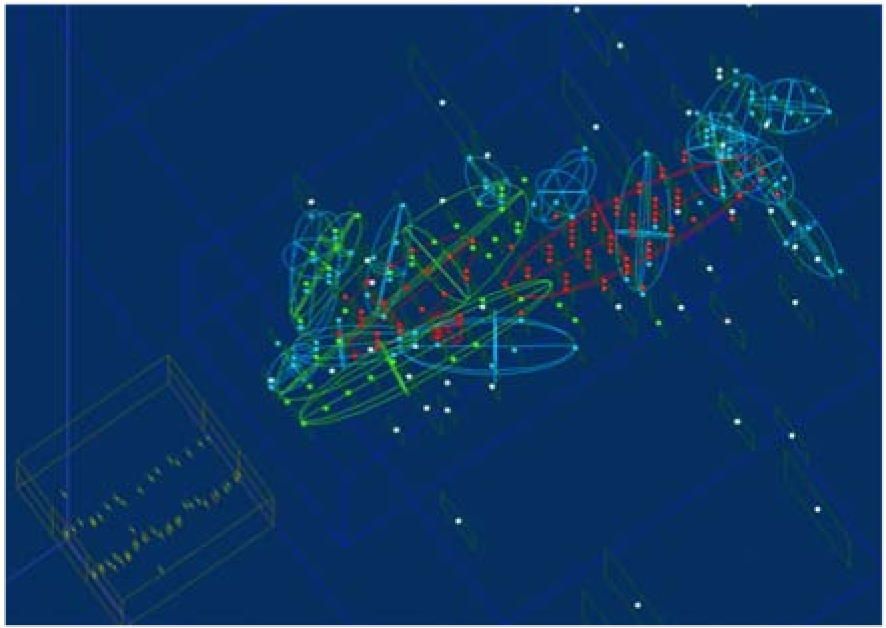
Engineering aspects:

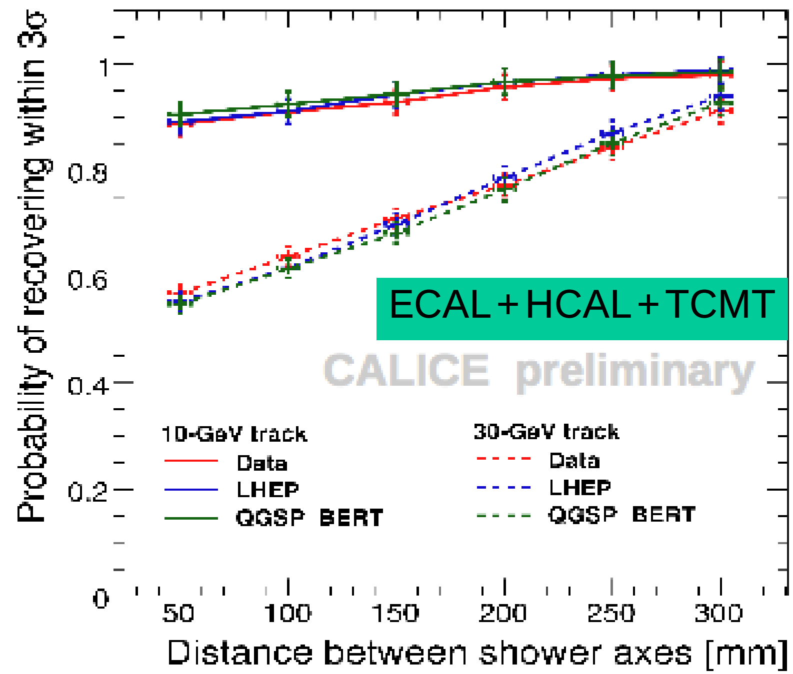
- Develop engineering concept for technology
- Develop powering and cooling concepts for system

Support structures
Power pulsing
Cabling, services



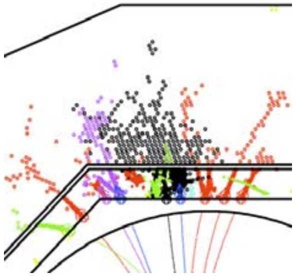
Calorimeter: PFLOW with test beam data





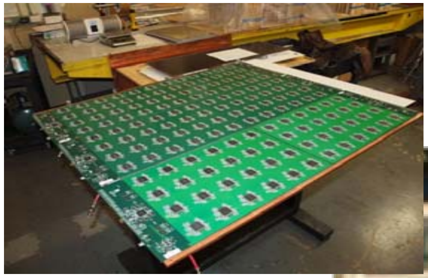
- The “double-track resolution” of an imaging calorimeter
- Small occupancy: use of event mixing technique possible
- Apply full **Pandora** clustering algorithm
- Important: agreement data - simulation
- Strong support for full detector simulations

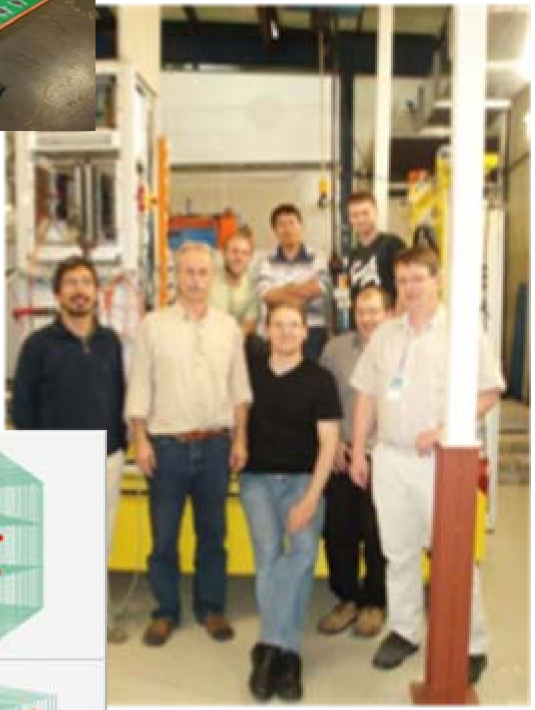
to be done with photons, too



DHCAL test beam started at FNAL

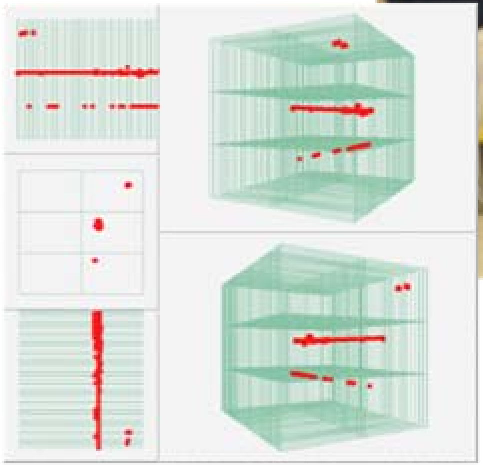
- cubic metre steel instrumented with RPCs
- Argonne led US effort in CALICE
- using existing Fe stack and infrastructure, DAQ, tail catcher





- first very clean muon events
- hadrons expected today

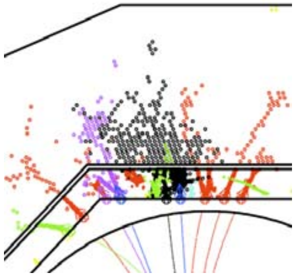
- combined run with SiW ECAL physics prototype in spring 2011



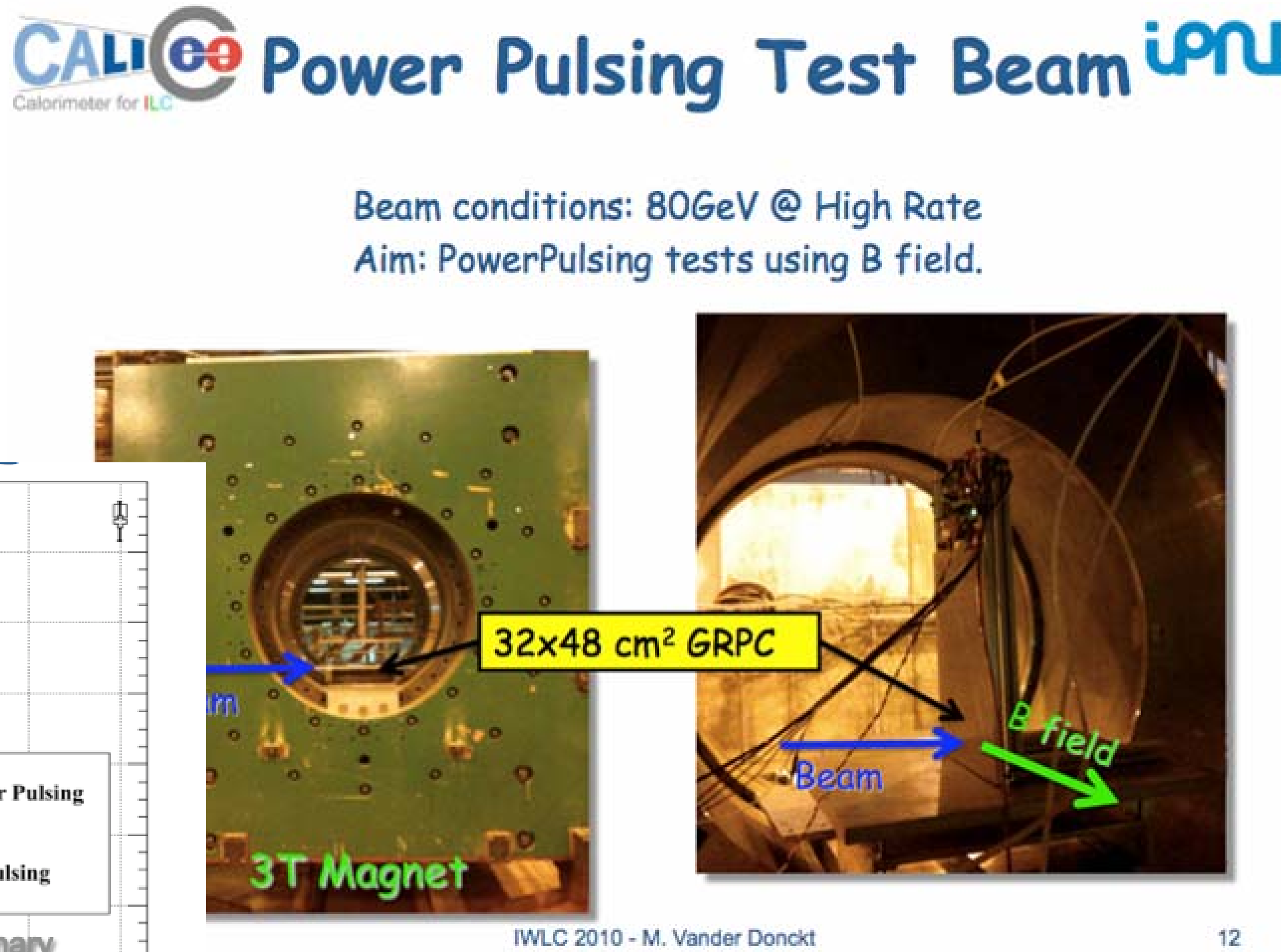
- possible continuation with W

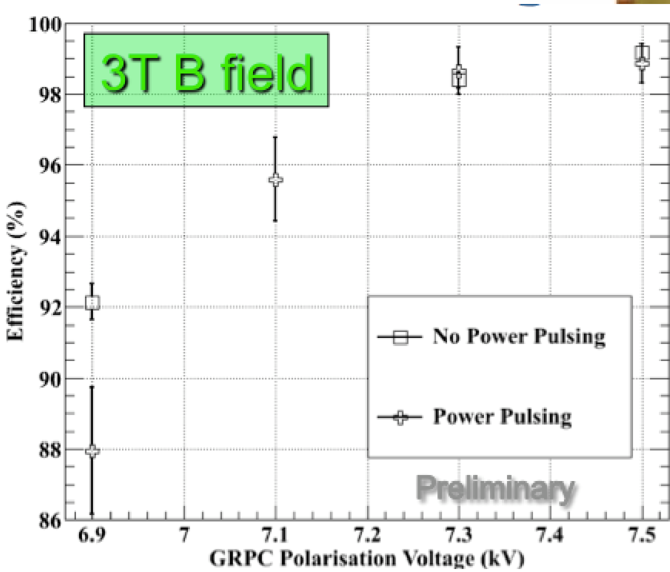
- Testbeam started this week

Power pulsing at 3 T

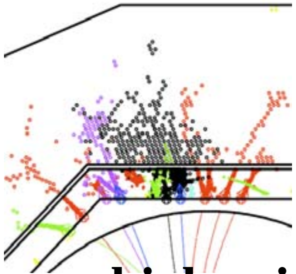


- sDHCAL technological prototype with integrated electronics and ASICs





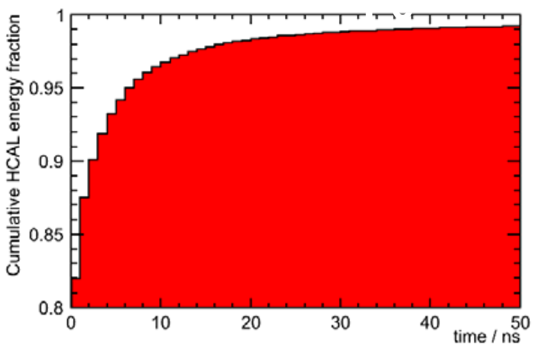
Calorimetry @ CLIC

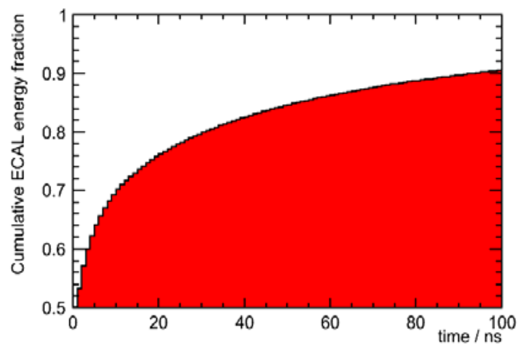


- higher jet energy - deeper HCAL
- tungsten is cost-competitive with a larger coil
- but slower (nuclear) response may be in conflict with time stamping needs

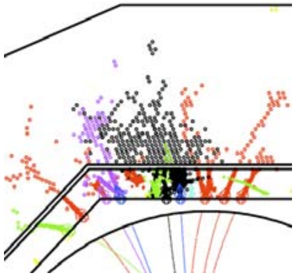
Pandora on ILD-CLIC

E_{JET}	RMS_{90}/E_J
45 GeV	3.6 %
100 GeV	2.9 %
250 GeV	2.8 %
500 GeV	3.0 %
1 TeV	3.2 %
1.5 TeV	3.2 %



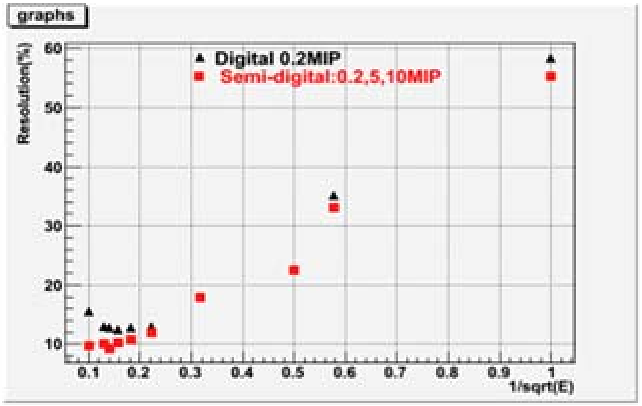


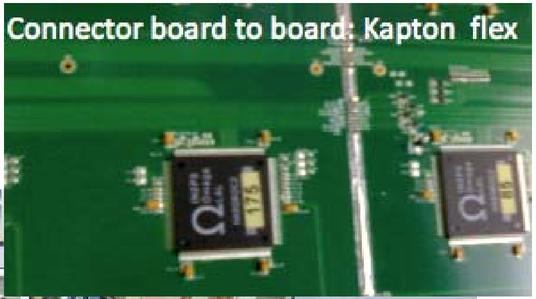
- CALICE test beam started @ CERN
  - first use existing scintillator aHCAL
  - later: gaseous dHCAL
  - and 2nd generation aHCAL with timing electronics

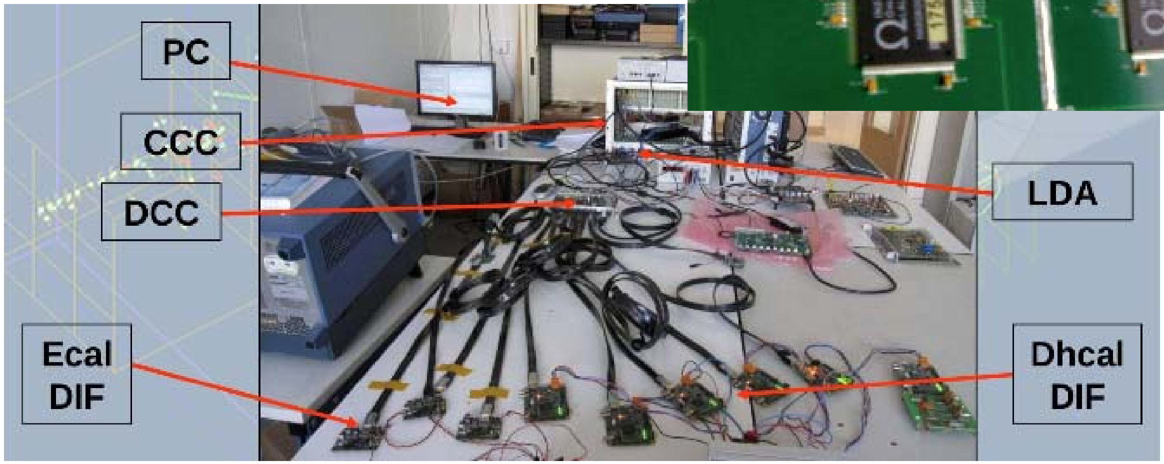


Calo: Towards DBD

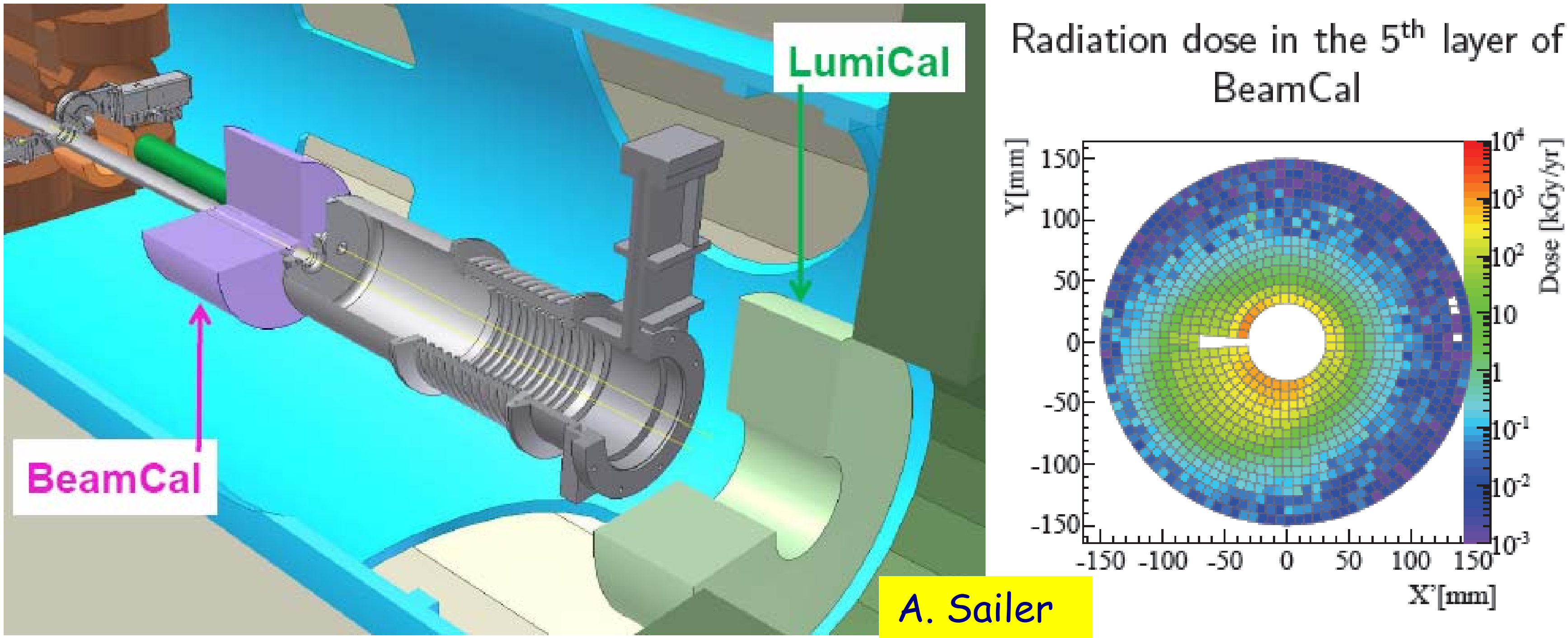
- **Physics with gaseous HCAL**
  - **understand operational stability uniformity, calibration, energy and topological resolution, use of amplitude information**
- **Electronics integration demonstrators with all candidate technologies**
- **System performance of a full size 2nd generation**
  - **sDHCAL module**
- **Make it work!**







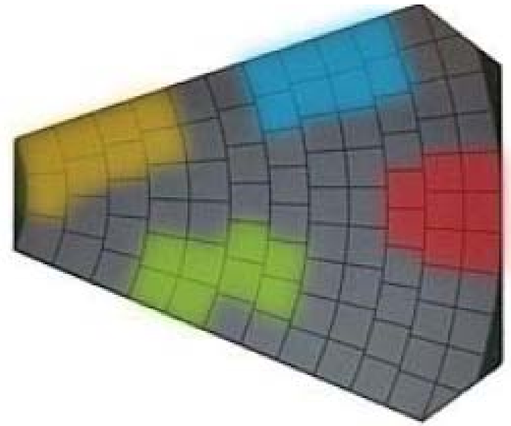
First Design of the Forward Region of a CLIC detector

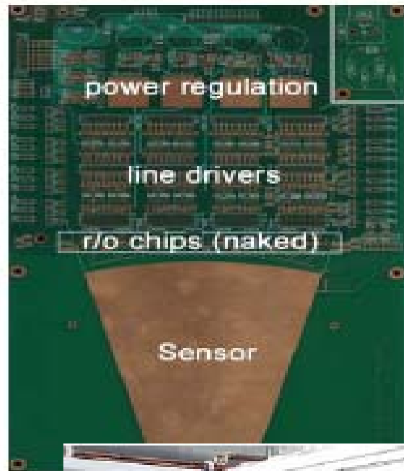


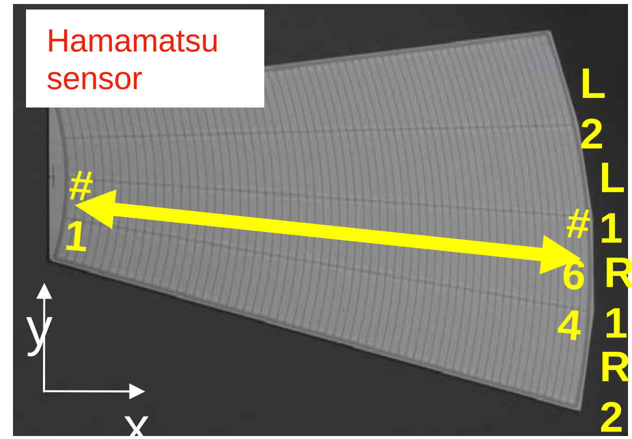
- **LumiCal is designed to measure the Luminosity with a precision of 10^{-2} at 3 TeV**
- **BeamCal feasible, improves hermeticity**

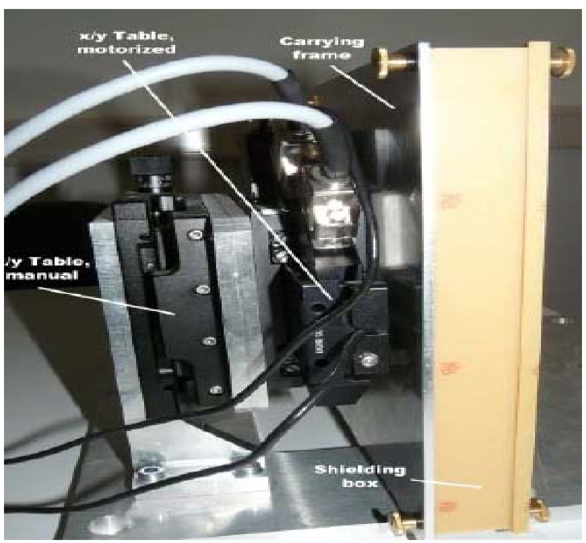
Succesful test-beam

Sensor plane Prototypes for LumiCal (Silicon) and BeamCal (GaAs) have been manufactured, connected to ASICs and studied in the 4 GeV electron beam at DESY (Most components supported by EUDET)









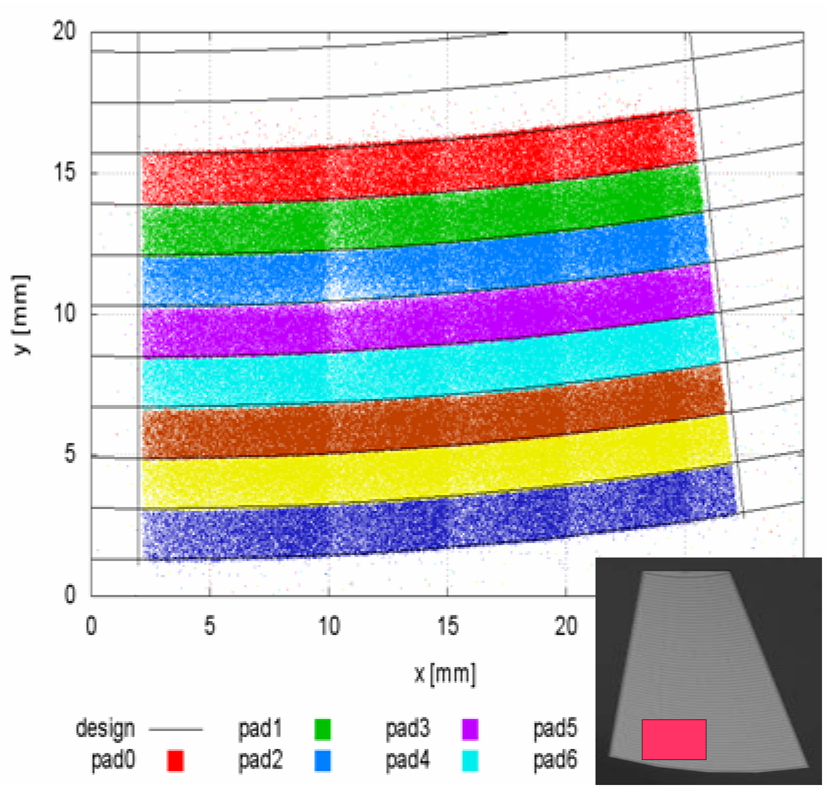
Aug 2010

Stand-by box   Device under test

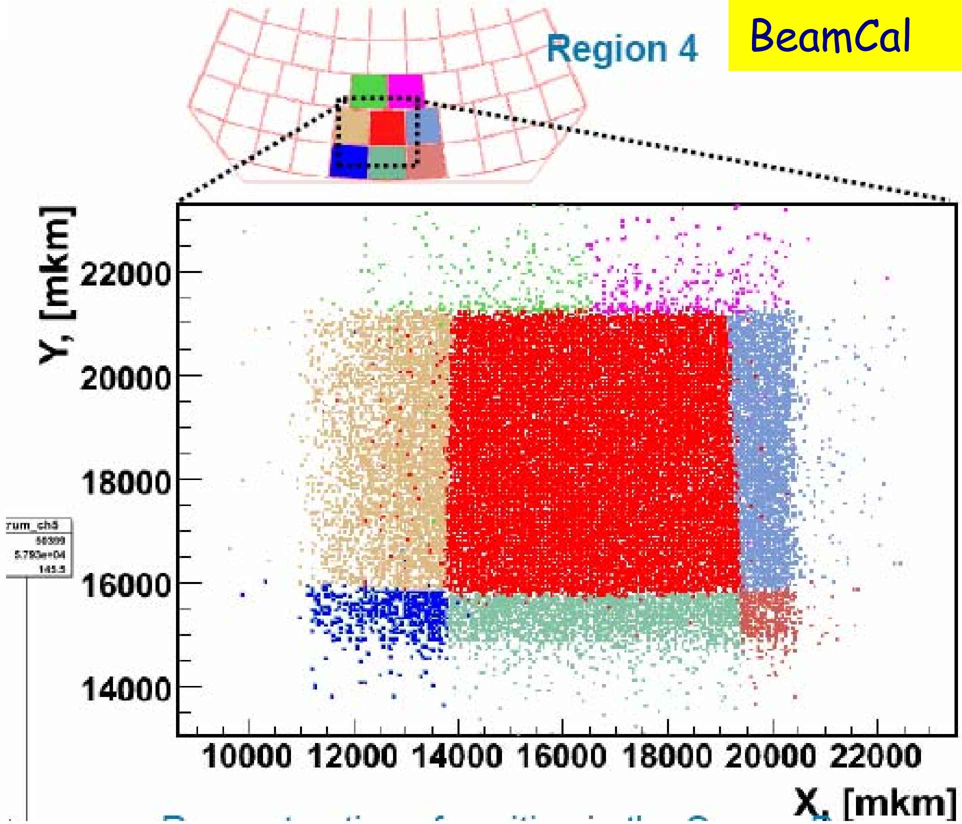
Succesful test-beam

- Several millions of trigger taken, Data analysis ongoing
- Preliminary results, impact point measured with the telescope correlated with the signal of a certain pad

LumiCal

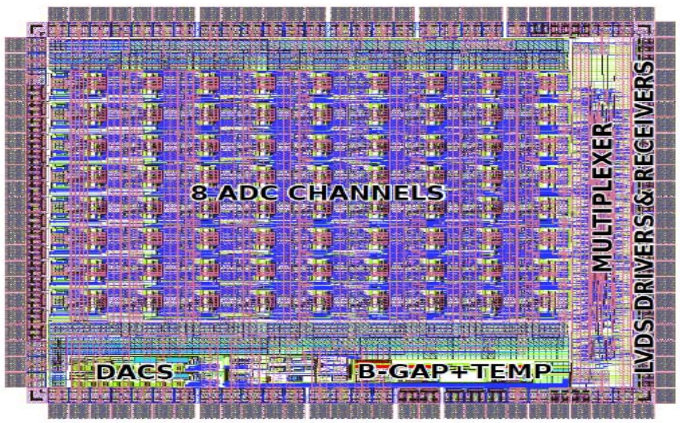


BeamCal



In Progress

8 Channel ASIC chips tested (UST Cracow)



Static and dynamic parameter as expected, working up to 50 MHz

Will be used in the next beam-test for a full system test

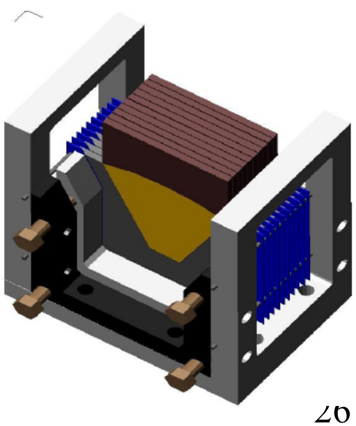
Power pulsing

FPGA based DAQ (UST Cracow, INP Cracow, Tel Aviv Univ.)

Xilinx Virtex5FXT FPGA with embedded PowerPC 440

2012: performance measurements of a fully assembled sensor plane

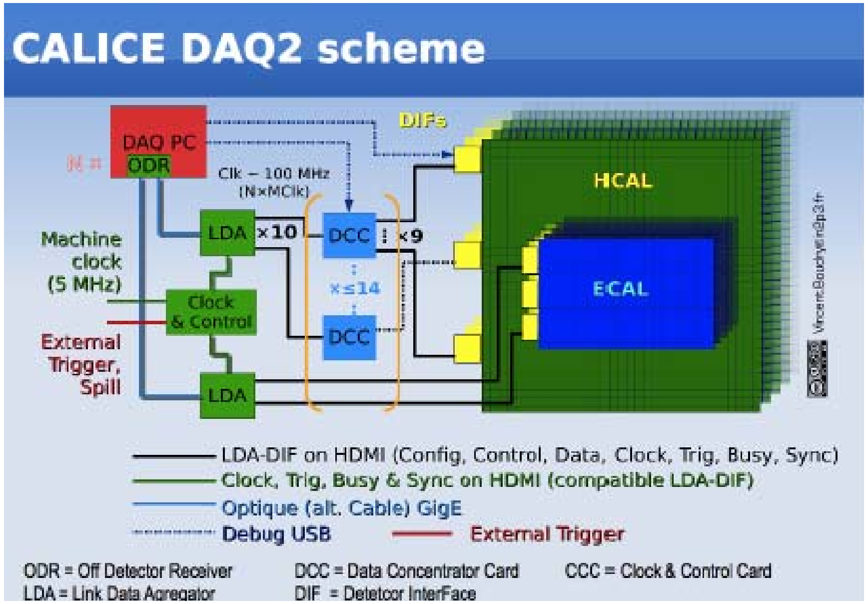
> 2012: towards a calorimeter prototype (AIDA supported)



DAQ and Software

DAQ:

- **Many efforts (test beam driven)**
  EUDET telescope, LCTPC, CALICE,…
- **Overall concept(s) needed**
- **Learn from LHC detectors**
  integrated concepts
  Result: DAQ efficiency > 90%



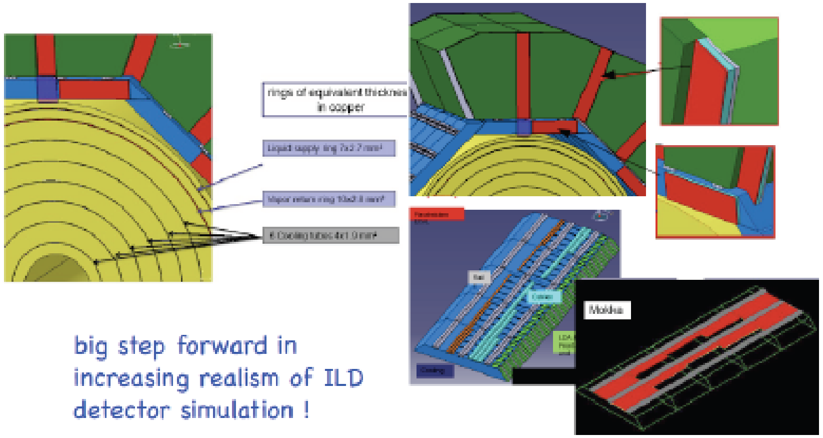
Software:

- **Common tools used by ILC & CLIC**
- **New models for DBD/CDR**

- **Simulation and reconstruction are making good progress towards optimisation**

new Mokka release – towards ILD_01

- added cabling and services for TPC, ECal & Hcal (C.Clerc, G.Musat)
- still missing: inner detector services (to be defined by R&D groups)



Summary

- Very rich detector R&D programme for a Linear Collider
- Very good progress in many projects
- Good collaboration ILC-CLIC

- LC detector R&D has impact on other projects, e.g.
    - LHC
    - B-factories
    - and beyond HEP

- Funding is critical

- Define plans until 2012 and beyond
    - Priorities
    - Integration & „low tech“ issues

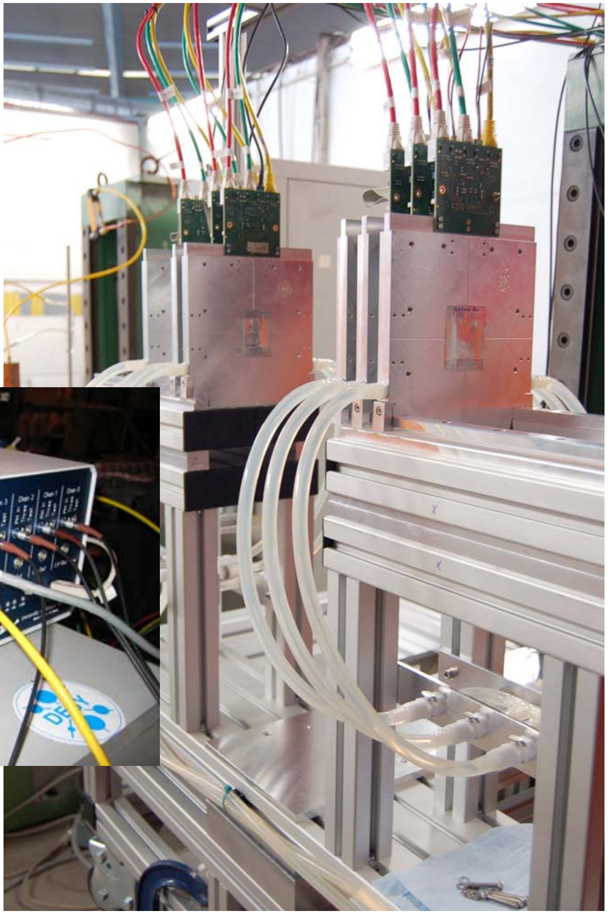
Backup slides

EUDET Telescope

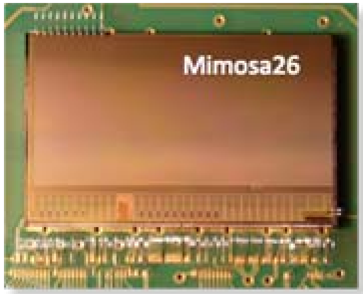
Generally applicable:

- Main use from small pixel sensors to larger volume tracking devices
- Movement of device under test (DUT) to scan larger surface
- **Easy to use:** well defined/described interface
- Very high precision: <3 µm precision even at smaller energies; < 2µm for high energy hadrons

Trigger Logic Unit



EUDET Telescope



- Mimosa26 sensor
- 663 kpixels with 18.4 um pitch
- column parallel binary readout

- Telescope is travelling back and forth between DESY and CERN since 2007 (84 test beam weeks so far)
- All together 29 user groups from LC and LHC (also combined running)