I.M. Gregor
J. Mnich
IEEE NSS Dresden

EUDET: Detector R&D Towards the International Linear Collider

- The EUDET initiative
- EUDET activities
  - Joint Research Activities
  - Networking
- Conclusions

Detector Challenges at ILC

Requirements for ILC

- Impact parameter resolution

$$\sigma_{r\phi} \approx \sigma_{rz} \approx 5 \oplus 10/(p \sin^{3/2} \vartheta)$$

- Momentum resolution

$$\sigma\left(\frac{1}{p_T}\right) = 5 \times 10^{-5} (GeV^{-1})$$

- Jet energy resolution

$$\frac{\sigma_E}{E} = \frac{30\%}{\sqrt{E}}$$

Compare to best performance to date

- Need factor three better than SLD

$$\sigma_{r\phi} \approx \sigma_{rz} \approx 7.7 \oplus 33/(p \sin^{3/2} \vartheta)$$

- Need factor 10 better than LEP

$$\sigma\left(\frac{1}{\mathrm{p_T}}\right) = 5 \times 10^{-4} (\mathrm{GeV}^{-1})$$

- Needs to be better than ZEUS

$$\frac{\sigma_E}{E} = \frac{55\%}{\sqrt{E}}$$

- Calorimeter granularity → Need factor ~200 better than LHC
- Pixel size → Need factor ~20 smaller than LHC
- Material budget, central → Need factor ~10 less than LHC
- Material budget, forward → Need factor ~1000 less than LHC

Adapted from M. Demarteau

EUDET

- 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
- EUDET is not a collaboration
  - Other institutes can contribute and exploit the infrastructure
  - Infrastructure can be re-located

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
Heidelberg 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

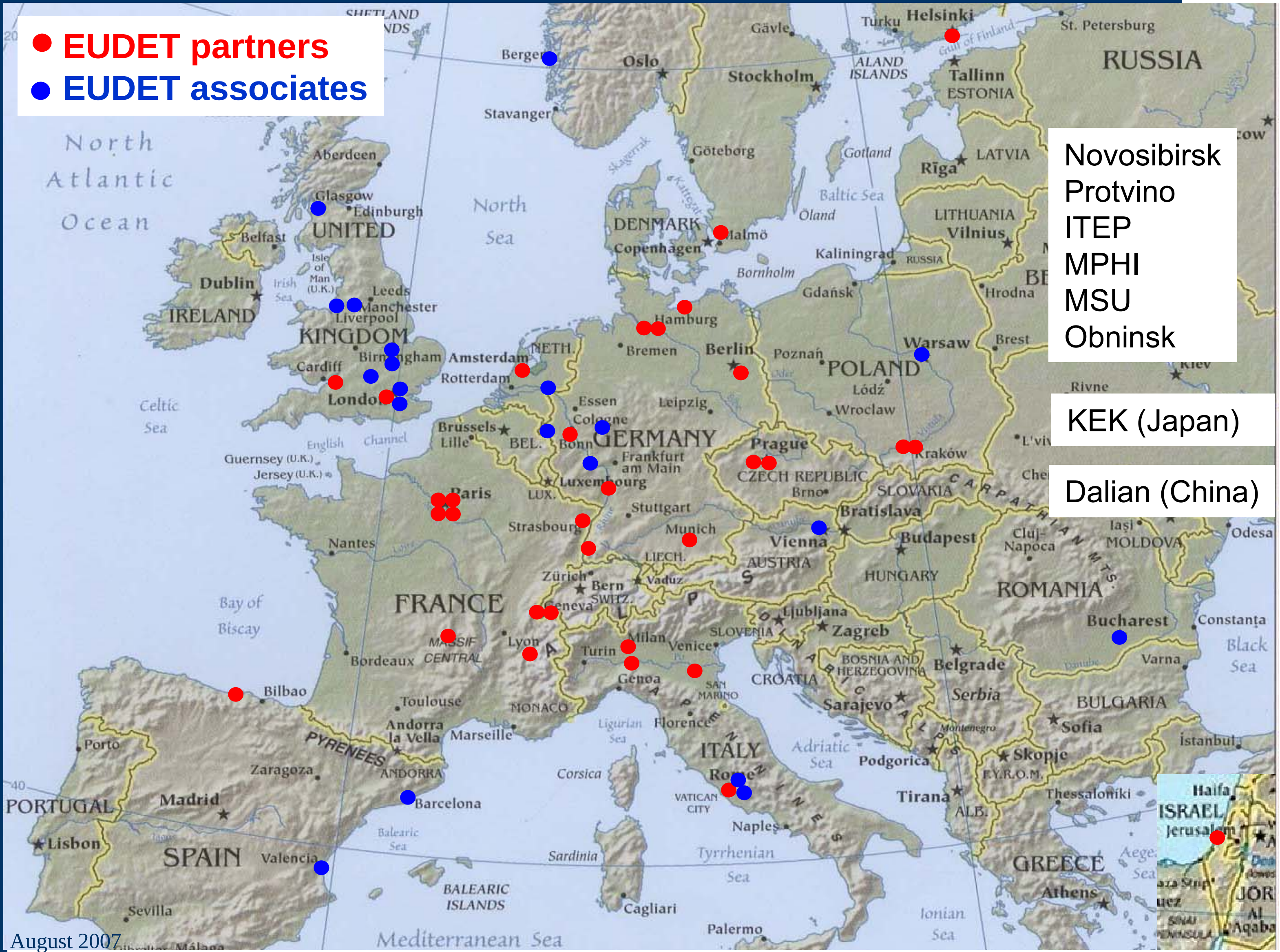
Lund University

CERN Geneva
Geneva University

Bristol University
UCL London

+ 27 associated institutes

The EUDET Map

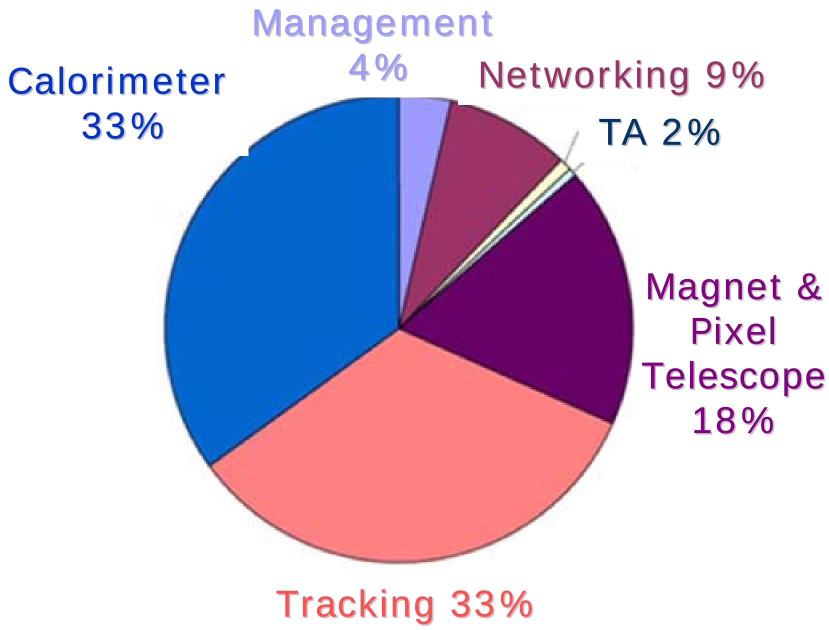


Novosibirsk
Protvino
ITEP
MPHI
MSU
Obninsk

KEK (Japan)

Dalian (China)

EUDET Budget



- Duration of 4 years
- Extension by 1 year until end 2010 to exploit infrastructures

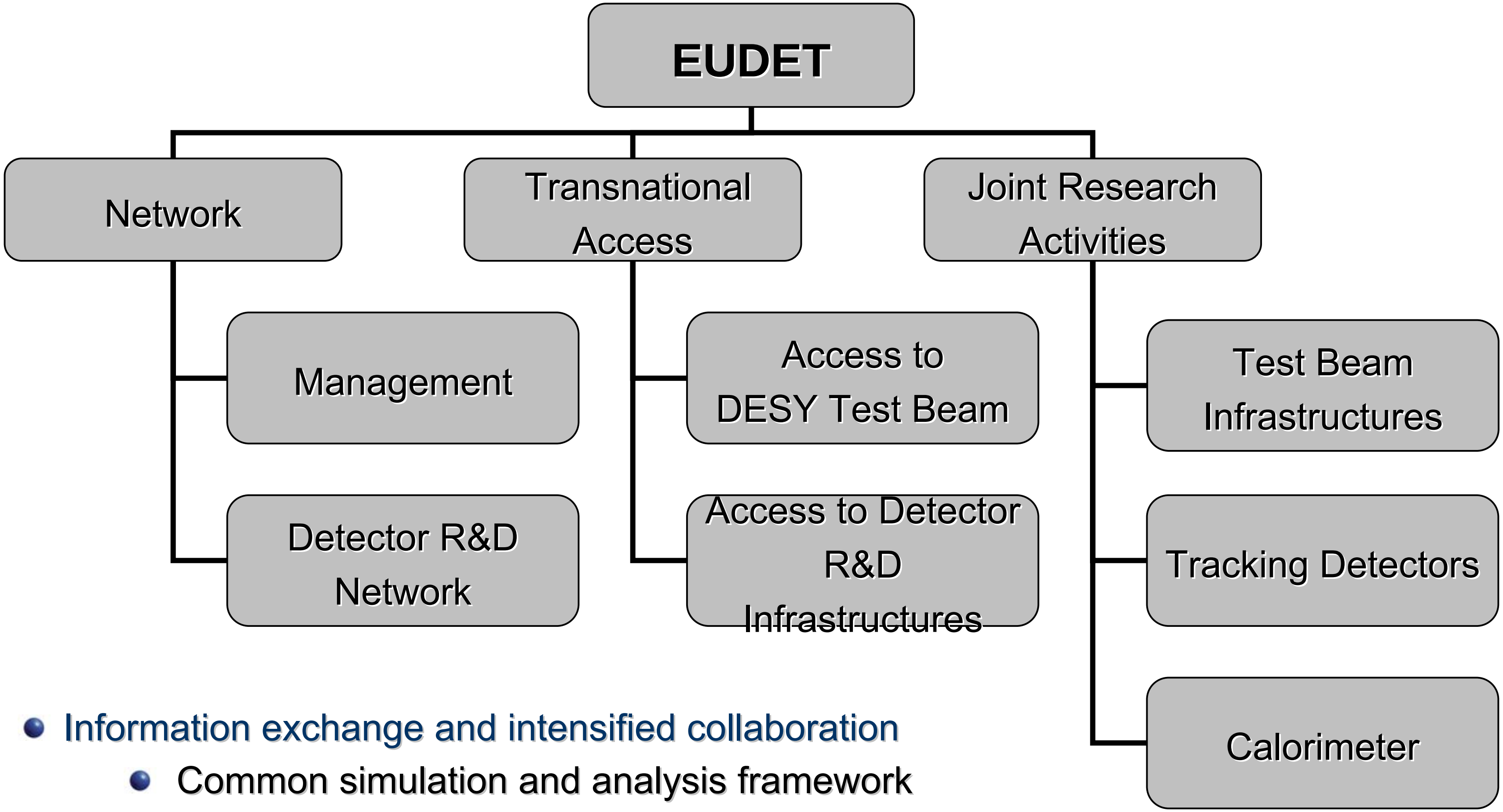
EU approval pending

- 21.5 million EUR total
- 7.0 million EU contribution

- Manpower
- ≈ 57 FTE total
- ≈ 17 FTE funded by EU

- most of the resources for the development of the infrastructures

EUDET Structure

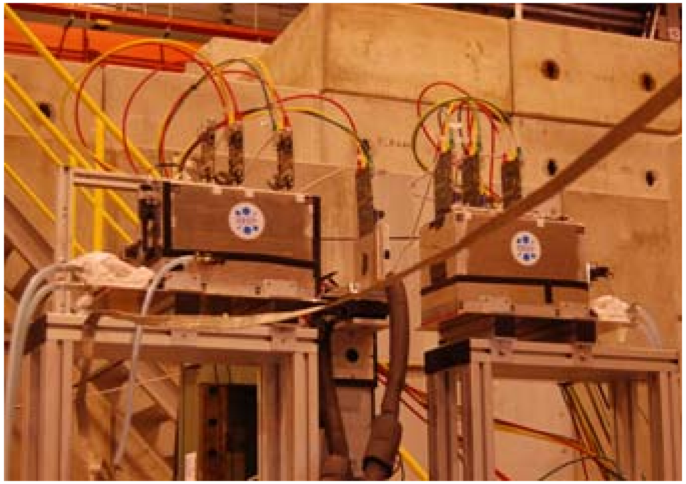


- Information exchange and intensified collaboration
  - Common simulation and analysis framework
  - Validation of simulation
  - Deep submicron radiation tolerant electronics

JRA1: PCMAG and Telescope

- 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
  - Demonstrator telescope in use since summer 2007



JRA1: Pixel Telescope

Phase 1: “Demonstrator”

- First test facility will be available quickly for the groups developing pixels
- Use established pixel technology with analogue readout and no data reduction
- Available since summer 2007
- So far used by about 10 different users
- 50 million tracks alone in summer 2008

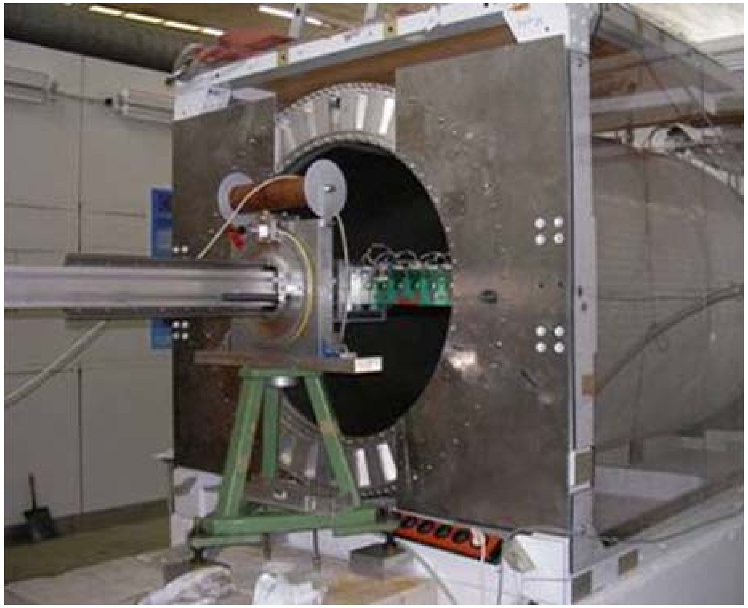
Phase 2: Final telescope

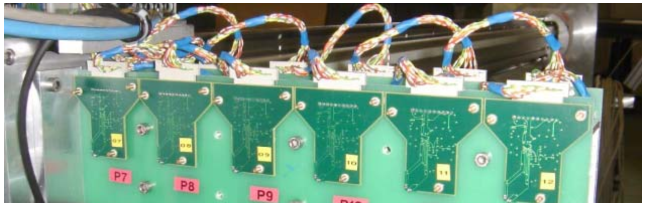
- Use pixel sensor with fully digital readout, integrated Correlated Double Sampling (CDS), and data sparsification
- The beam telescope will be ready early 2009

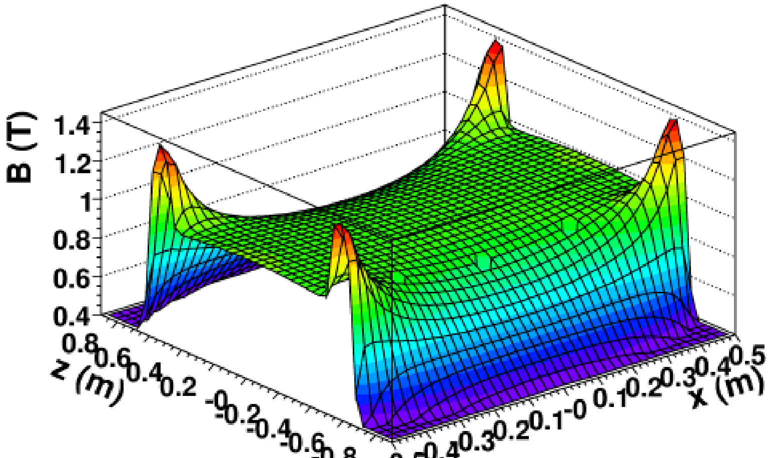
Daniel Haas, The EUDET Telescope, N58-3, this session

JRA1: Field Map of PCMAG

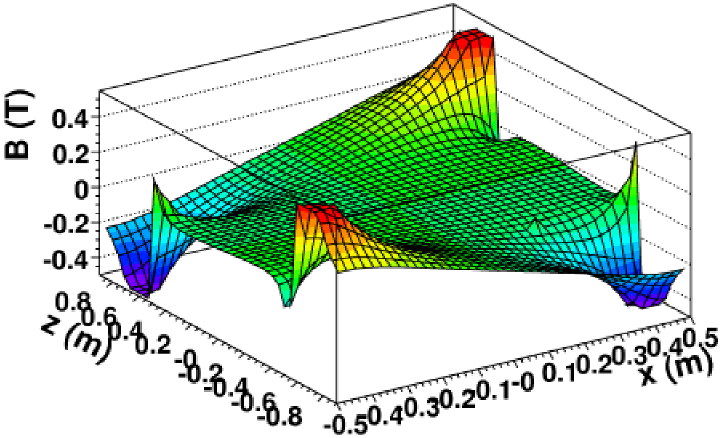
- Field mapping done at DESY by CERN-PH group
- Available in different forms, depending on the needed accuracy and speed
- Field map is accurate to a few Gauss, depending on region of the PCMAG







B_z



B_r

JRA2: Tracking Detectors

- Integrate the efforts of European institutions working on tracking detectors for the ILC

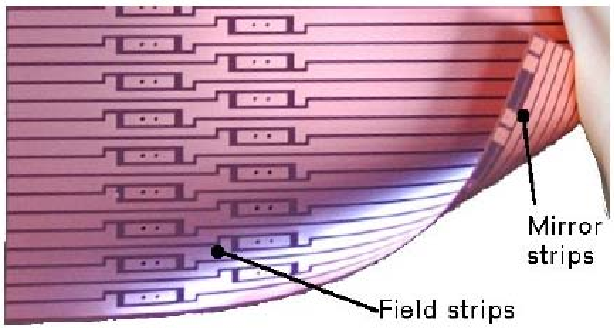
- Large TPC prototype:
  - Low mass field cage (for JRA1 magnet)
  - modular end plate system for large surface GEM & µMegas systems
  - development of prototype electronics for GEM & µMegas

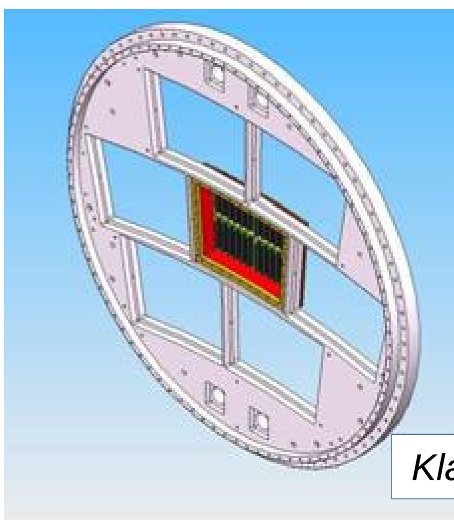
- Silicon TPC readout:
  - Development MediPix → TimePix
  - TPC diagnostic endplate module incl. DAQ

- Silicon tracking:
  - large & light mechanical structure for Si strip detectors
  - cooling& alignment system prototypes
  - multiplexed deep-submicron FE electronics

Large TPC Prototype

- a large field cage and prototype readout electronics
- developed to optimally use the magnet test facility
- field cage structure which combines light weight with excellent high voltage behaviour and mechanical stiffness





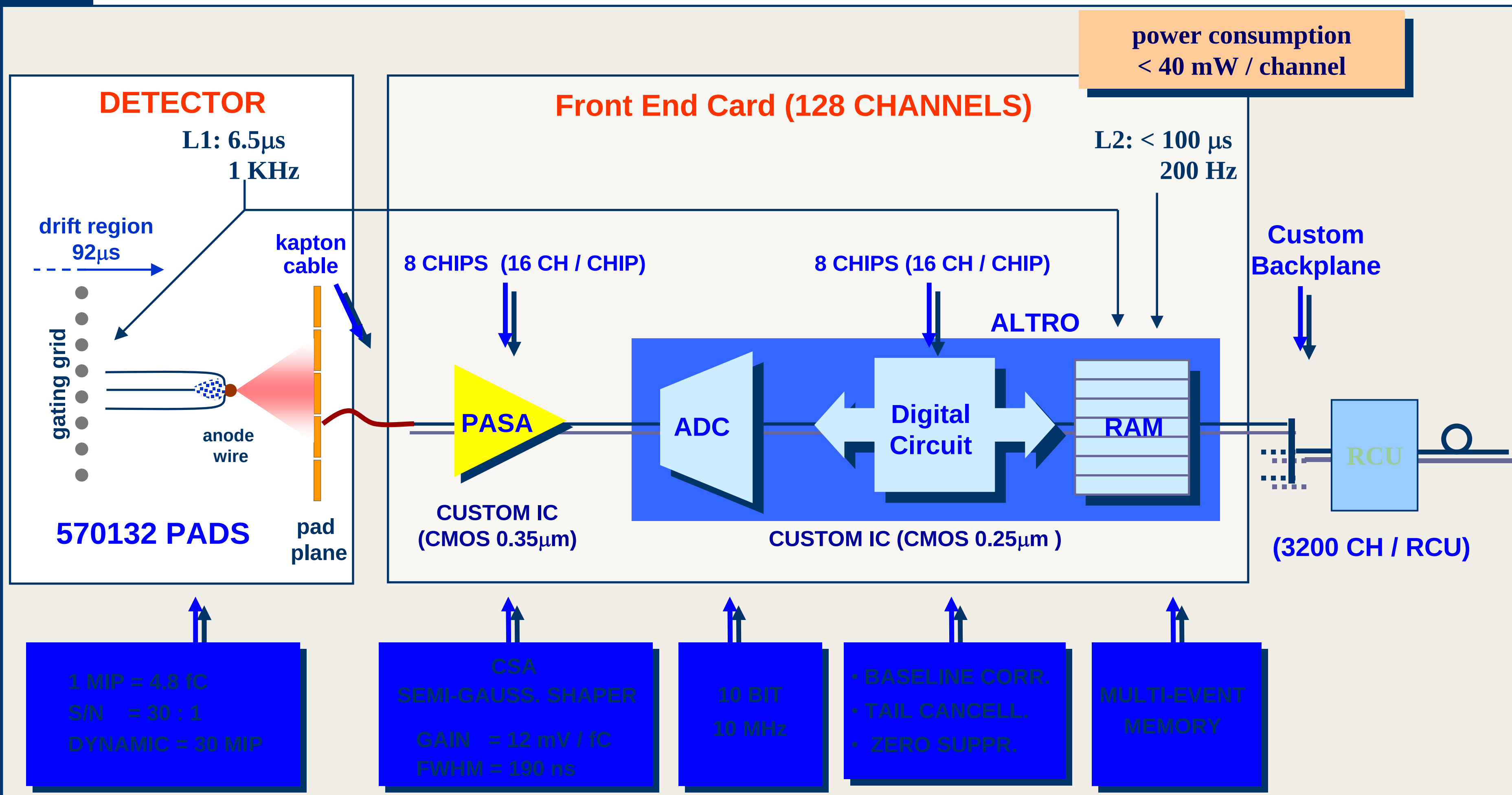
- field shaping strips developed
- field shaping system should guarantee field homogeneity of better than 1% throughout the active volume of the chamber

- readout electronics:
  - a programmable preamplifier – shaper ASIC
  - a digitization system based on a modified ALTRO chip (ALICE)

Klaus Dehmelt, The Large TPC Prototype for an ILC Detector , N62-4

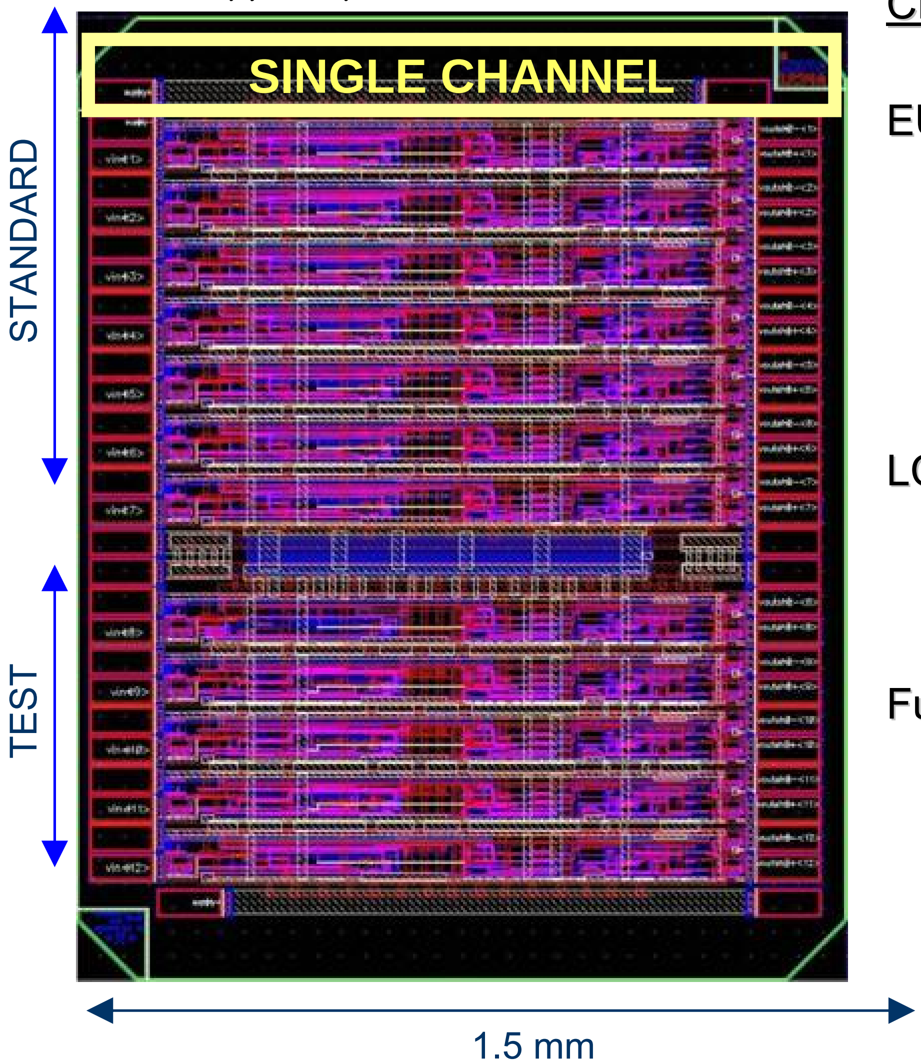
TPC Electronics

schematics TPC electronics
based on ALICE electronics



TPC Electronics

Prototype layout:



<u>CHIP Availability</u>

EUDET

- -PCA16, 160 tested for 2048ch system
- -ALTRO 25MHz 160 tested for 2048ch system
- -ALTRO 40MHz for high time resolution

LC-TPC project

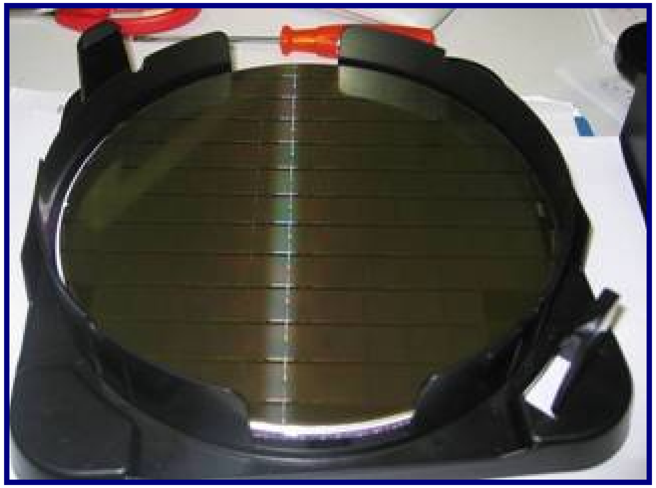
- -PCA16, 772 chips arrived .
- -25MHz ALTRO, 700 available

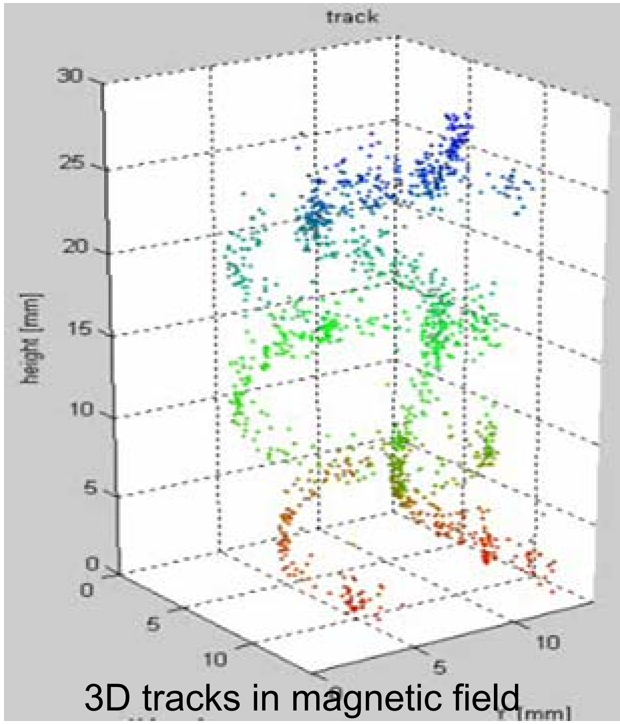
Full system available spring 2009

Si TPC Readout

- Digital TPC : The “Ultimate Resolution”
- Upgrade Medipix2 chip to get 3D information: timestamp enables TOT info = Timepix

- Timepix has been produced with a good yield and is working -> first test beam
- Timepix covered with 4μm of amourphous Silicon with a standard Micromegas in He/C4H10 (80/20)



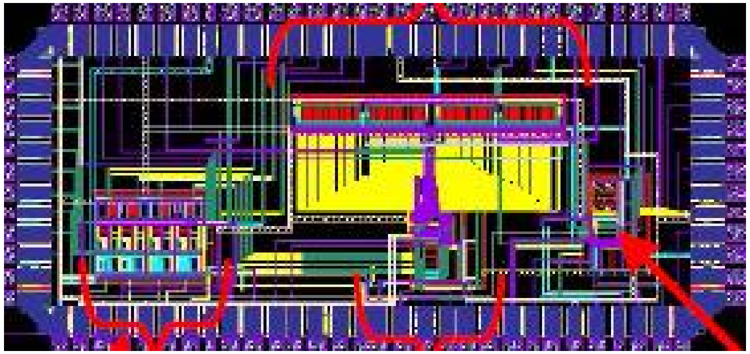


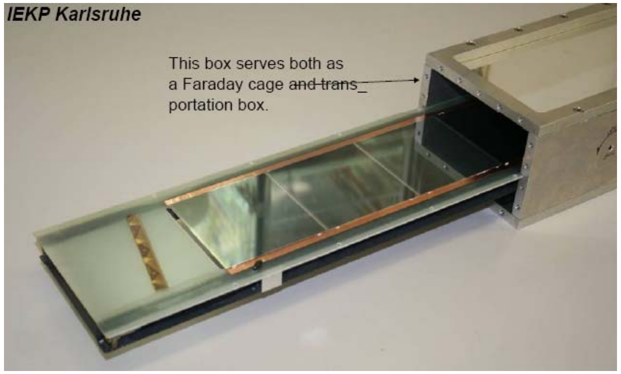
Sr90 tracks

Paul Colas, Electron Counting and Energy Resolution Study from X-Ray Conversion in Argon Mixtures with an InGrid-TimePix Detector , N31-5

Silicon Tracking

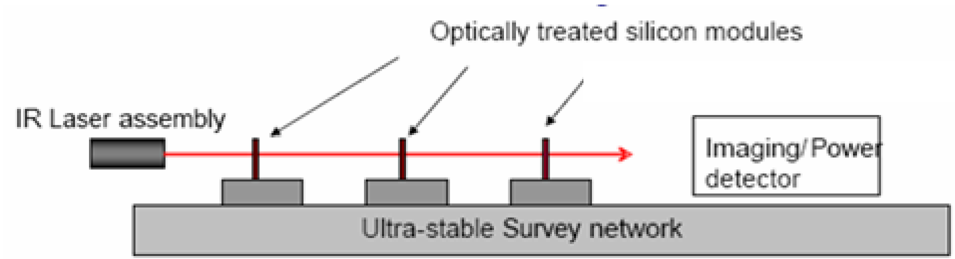
- enable groups to contribute to the development of long and thin Si-detector components
- providing common tools needed to test and simulate these sensors under real life conditions





- highly multiplexed, deep submicron front-end electronics
  - with low power consumption and the possibility for power cycling
  - DSM (130 nm)

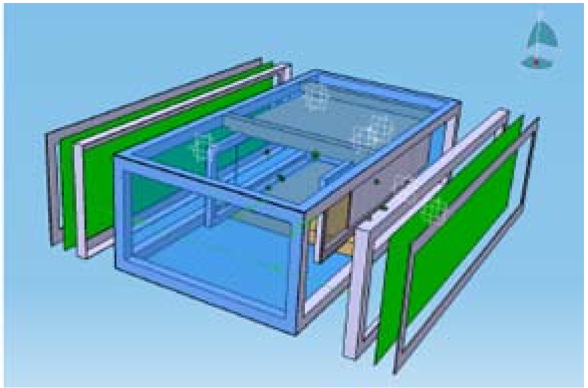
- prototype of the alignment system to work out
  - alignment challenges,
  - the distortions handling
  - calibrations for the overall tracking system



support for large sensor R&D

Mechanical Infrastructure

Convection Cooling System Prototype

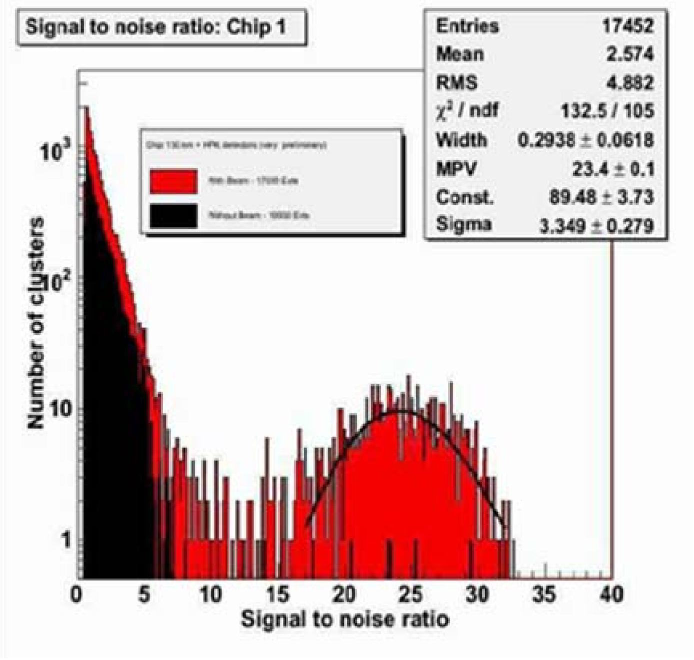


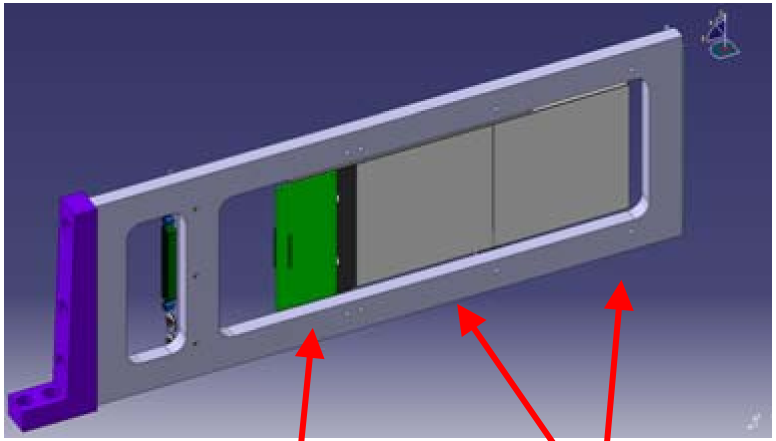
Motorized 3-D Table

- Suitable for testing Silicon sensors, pixel and microstrips in a beam test.
- Tested device can be moved and rotated with respect the beam line.
- Built in a modular way, so that it can arrange different types of DUT, with alignment telescopes or without.
- Remote controlled steering motors

Central tracker prototype

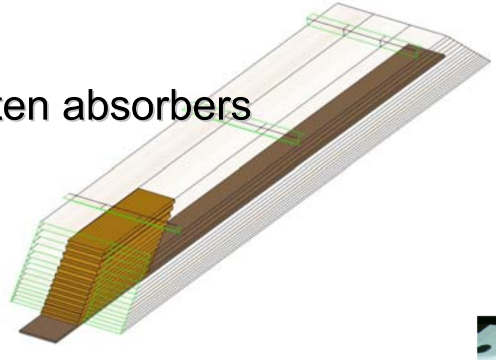
- Several detecting module prototypes have been assembled with sensors and electronics
- Tested at Lab test bench
- Beam test at DESY and CERN

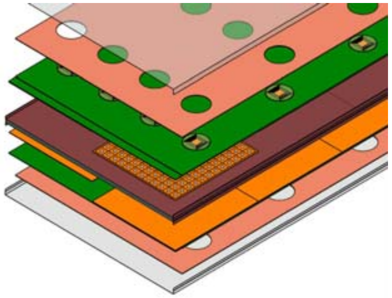




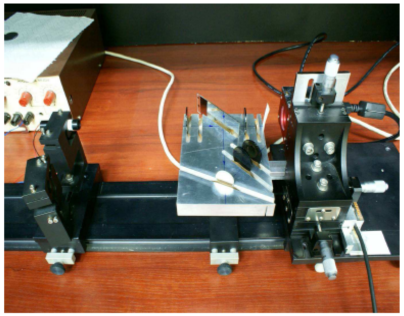
FE chip (130nm) 2 HPK 6’ sensors

JRA3: Calorimeters

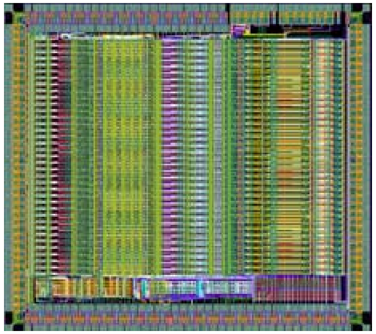




- **ECAL:**
  - Scalable prototype with tungsten absorbers
  - Si-sensors & readoutchips
- **HCAL:**
  - Scalable protoype
  - multi-purpose calibration system for various light sensing devices

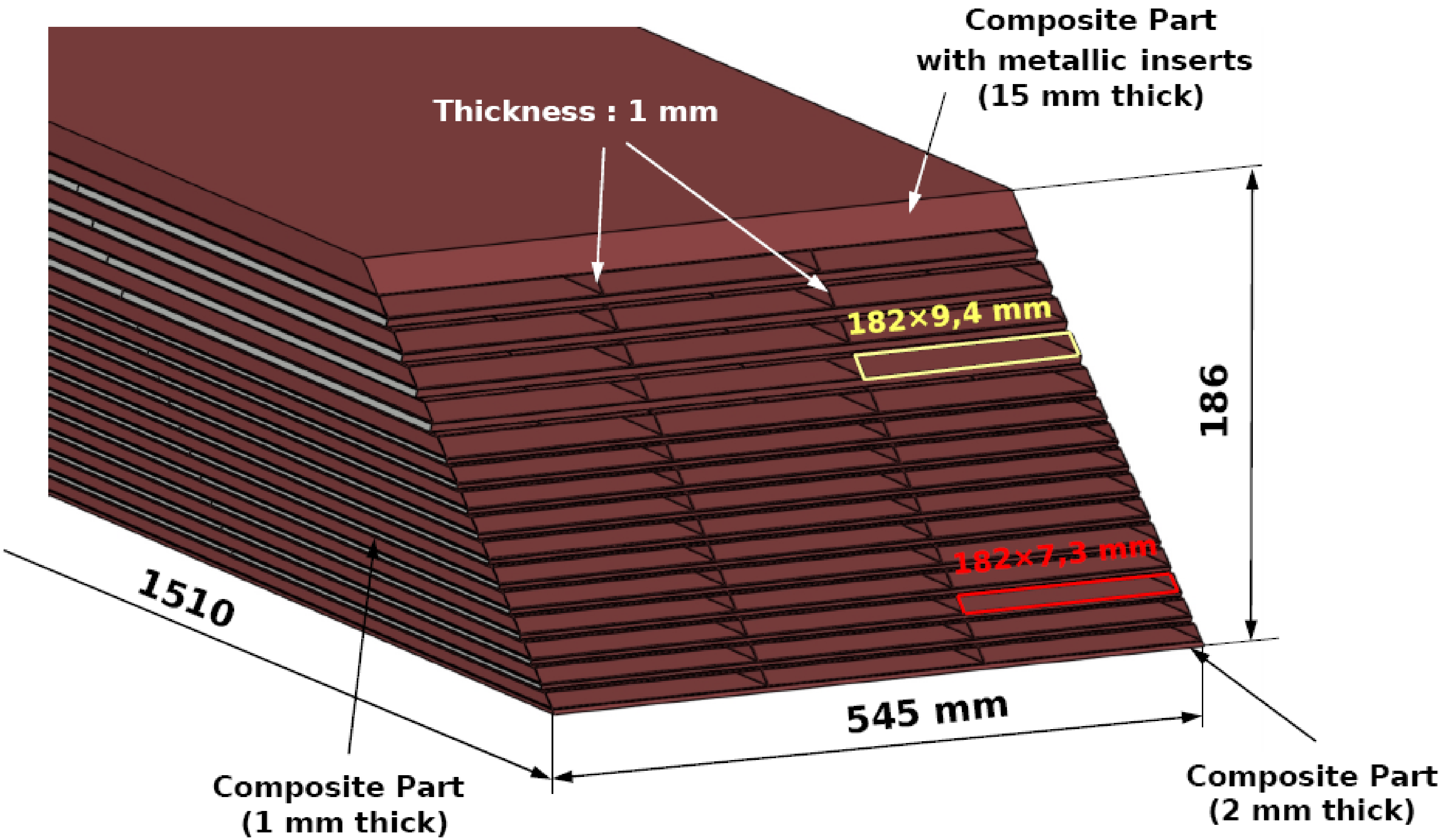


- **Very Forward Calorimeter:**
  - laser-based positioning system
  - Calibration system for silicon and diamond sensors
- FE Electronics and Data Acquisition System for the calorimeters

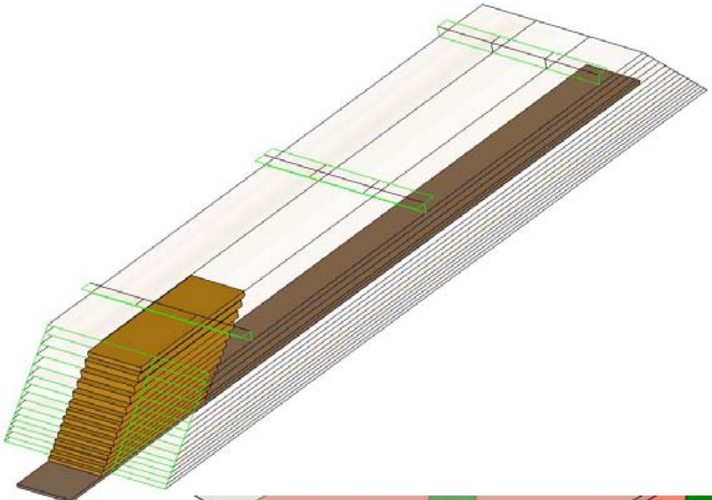


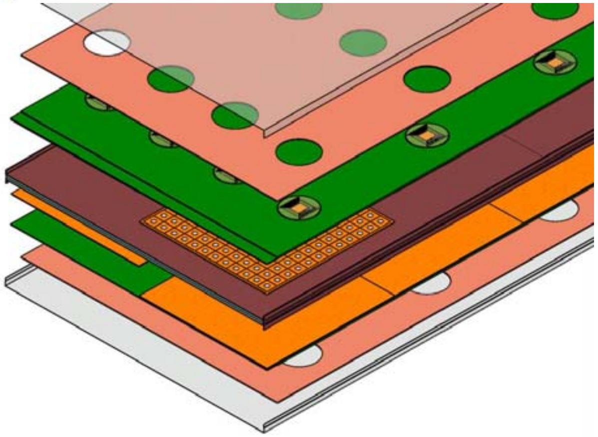
EUDET ECAL Prototype Module

- Construction of „real“ module pursued parallel to demonstrator studies



ECAL



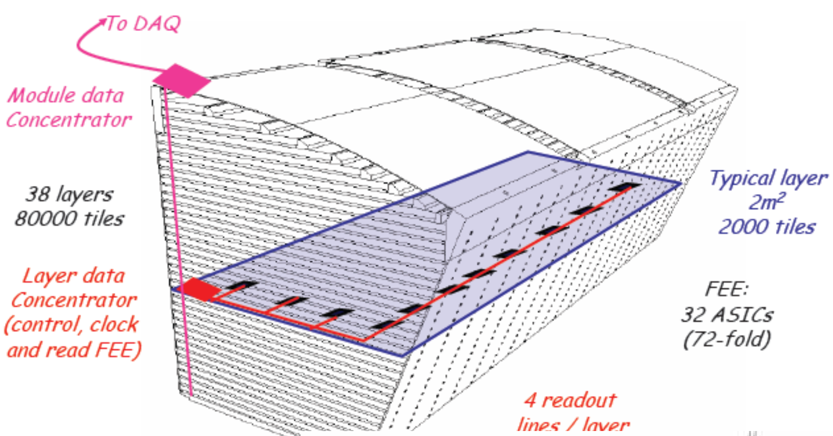


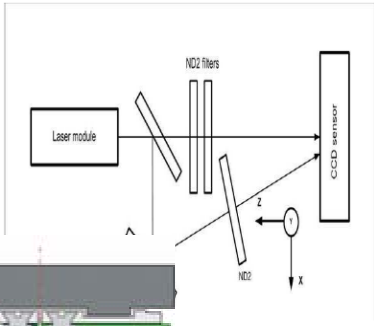
- The ECAL "EUDET module 0"
  - barrel module prototype
    - 0.4t tungsten, 1.8m long
    - ~1/6 instrumented (12k ch.)
  - One tower for e test beam
    - Embedded electronics
    - 1.5mm gap (PCB + wafer + ASICs)
    - Power pulsing
  - Test full scale mechanics, cooling, communication

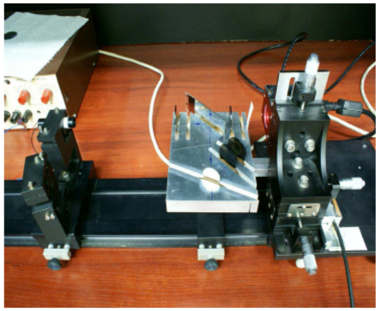
Roman Poeschl, Response of the CALICE Si-W ECAL Prototype to Electrons, N33-7

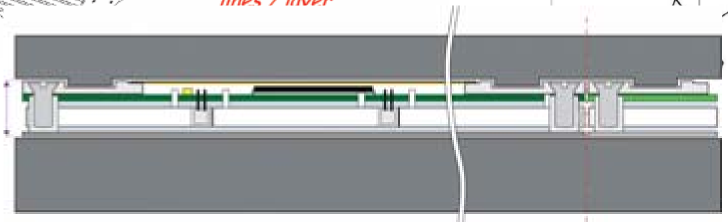
HCAL

- HCAL
  - Realistic structure
  - Integrated electronics
  - Readout architecture like ECAL
  - Calibration system, test stand





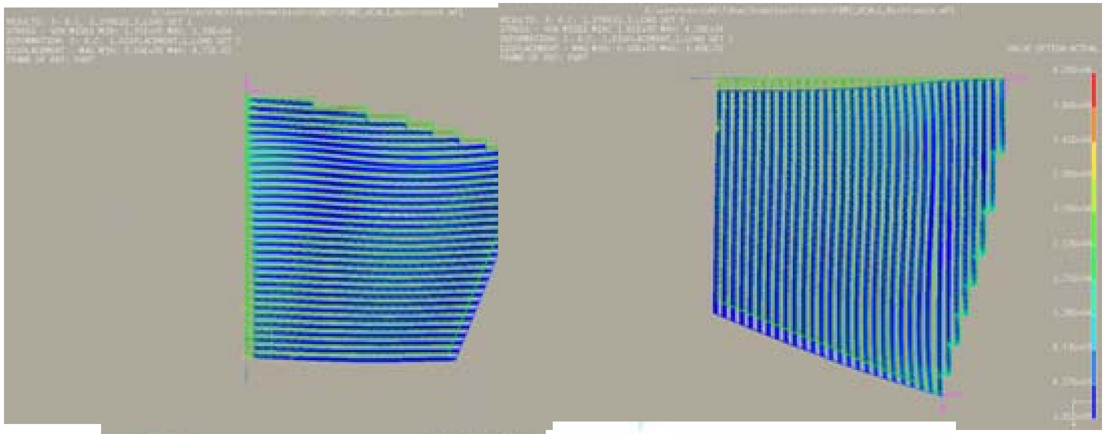




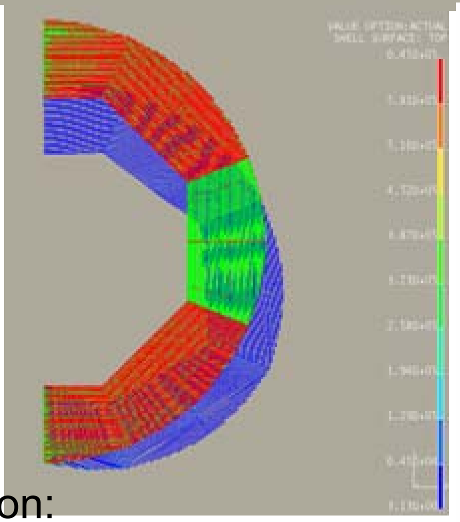
B. Lutz, Test beam results from the CALICE tile hadron calorimeter, N63-3

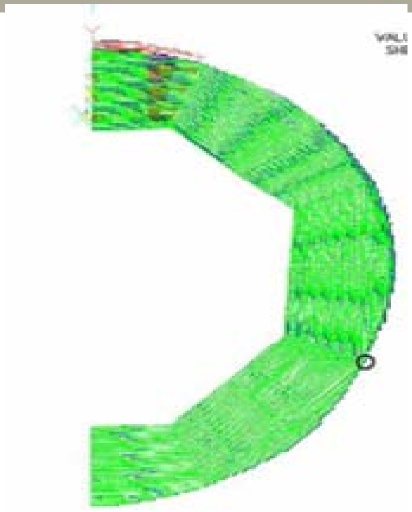
FEM calculations

FEM calculations for different geometrical configurations



Calculations for Whole Barrel





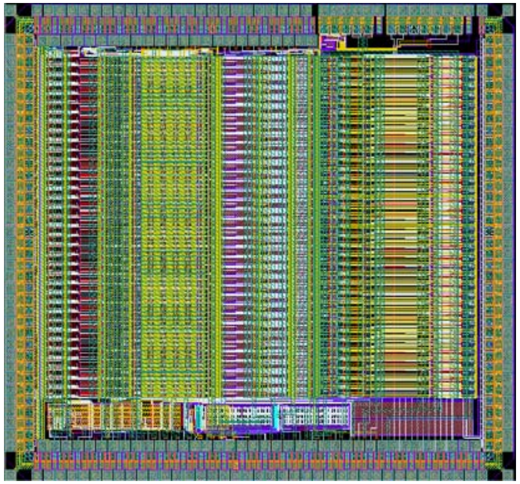
Maximum Deformation:

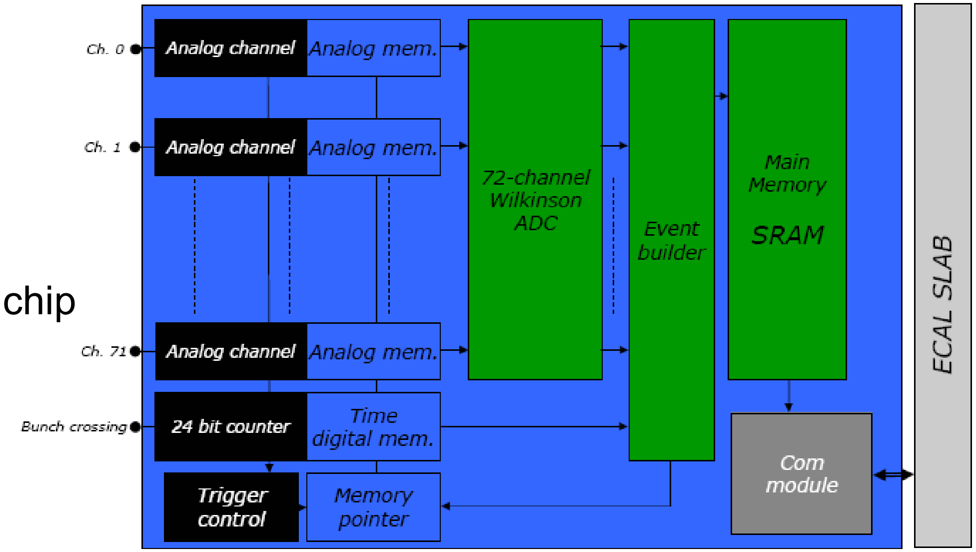
18.5 mm

Max. deformation: 2.9 mm

Calorimeter Electronics

- VFCAL
- Electronics
    - Integration is key
    - Digital part next to sensitive analogue FE
    - Power pulsing, stability
- HaRDROC
    - 64 ch digital HCAL chip
    - Under test
- SKIROC
    - 36ch ECAL chip
    - At foundry (0.35 AMS)
- SPIROC
    - 36ch analogue (SiPM) HCAL chip
    - Under design
- More versions in the pipeline

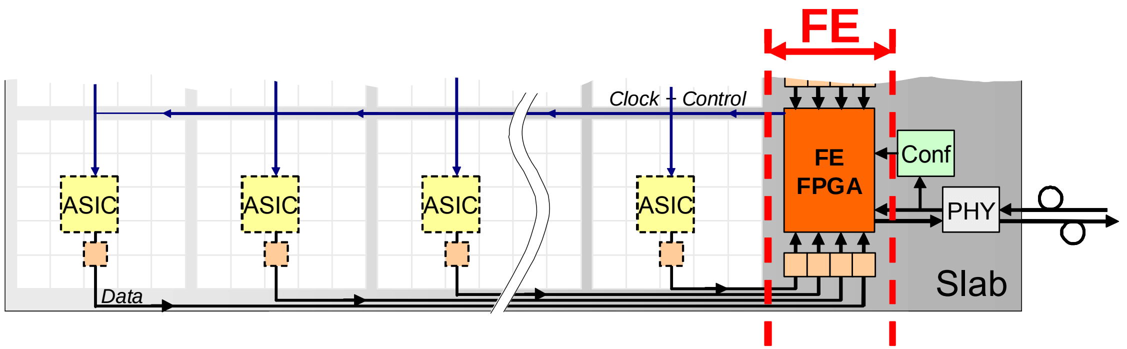


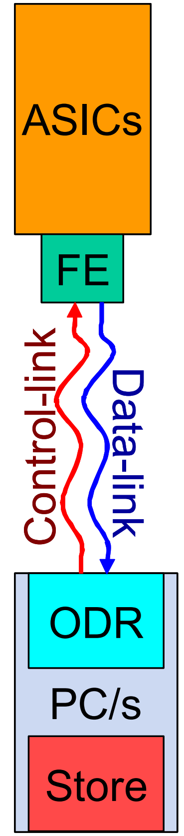


M. Reinecke, Integration Prototype of the CALICE Tile Hadron Calorimeter, N30-178

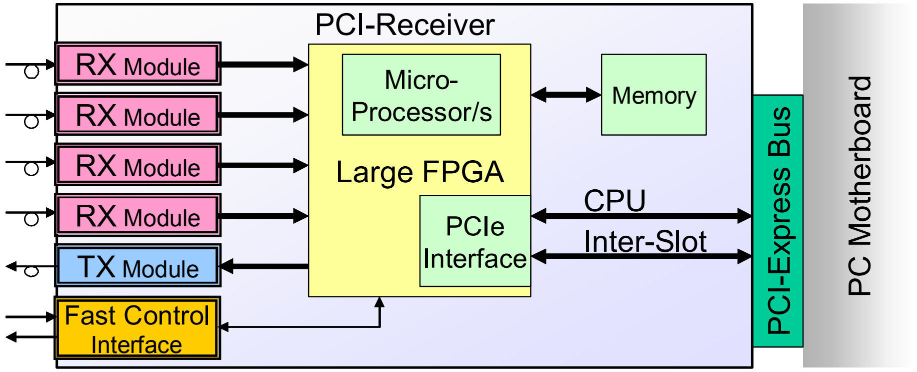
(Calorimeter) DAQ

- Scalable DAQ system
  - Commercial hardware where possible
  - Prototype for full detector ***and*** useable in test beam



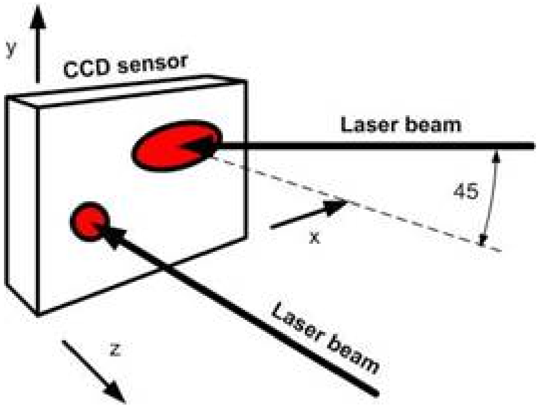


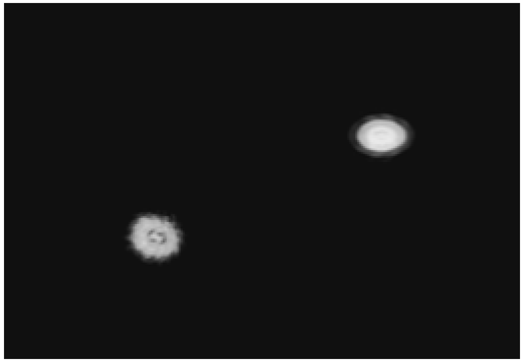
e.g. off-detector receiver: off-the-shelf



Forward Calorimeter

- VFCAL
    - Sensor test stands
    - Irradiation test beam infrastructure
    - Readout electronics
    - Laser alignment system
        - µm level precision





Over short distances accuracies reached:
Displacements in the x-y plane: +-0.5 µm
Displacements in z direction: +- 1.5 µm

S. Schuwalow, BeamCal for ILC Detectors , N63-8

EUDET Networking Activity

- Information exchange
  - www.eudet.org
  - Annual workshops (open to everyone)
- Computing and analysis
  - Grid based computer cluster
  - Common software for test beams and ILC simulations
  - embedded in ILC software & simulation effort, already used
- Shower simulation
  - Support from Geant4 team
  - Feedback of calorimeter testbeam results
- Deep sub-micron rad-hard electronics
  - Access through CERN contracts

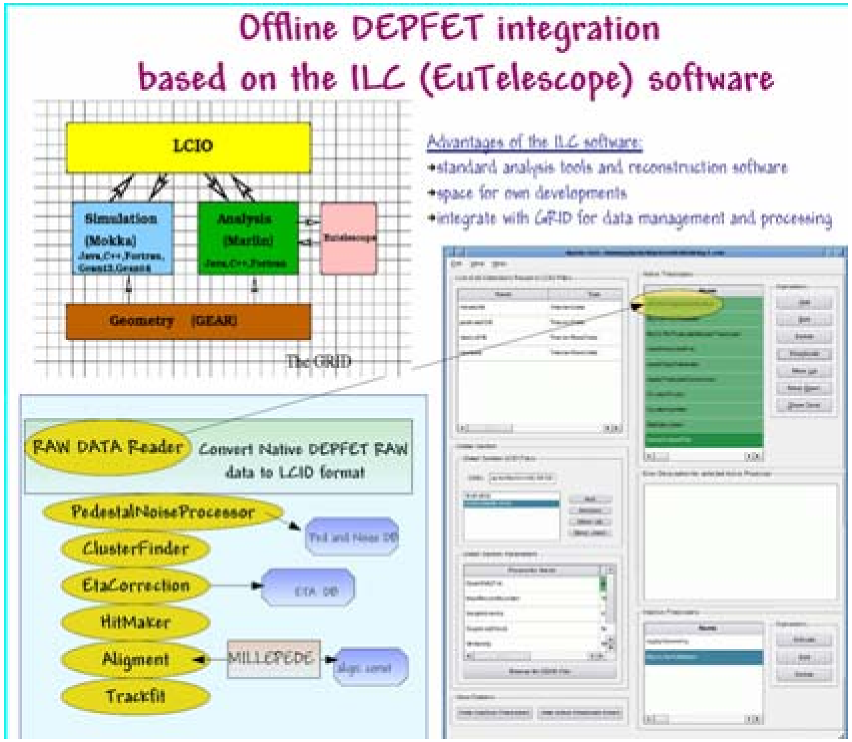
EUDET software ANALYS

- ANALYS: development of a common data analysis and simulation infrastructure
- development of a software framework for simulation,
- analysis and comparison of test beam experiments
- embedded into existing GRID infrastructure

Strategy

- the test beam software effort is tightly integrated with the overall common ILC/LDC software effort !
- **benefit from synergies where possible**
- same for grid: integrate with common ILC grid activities

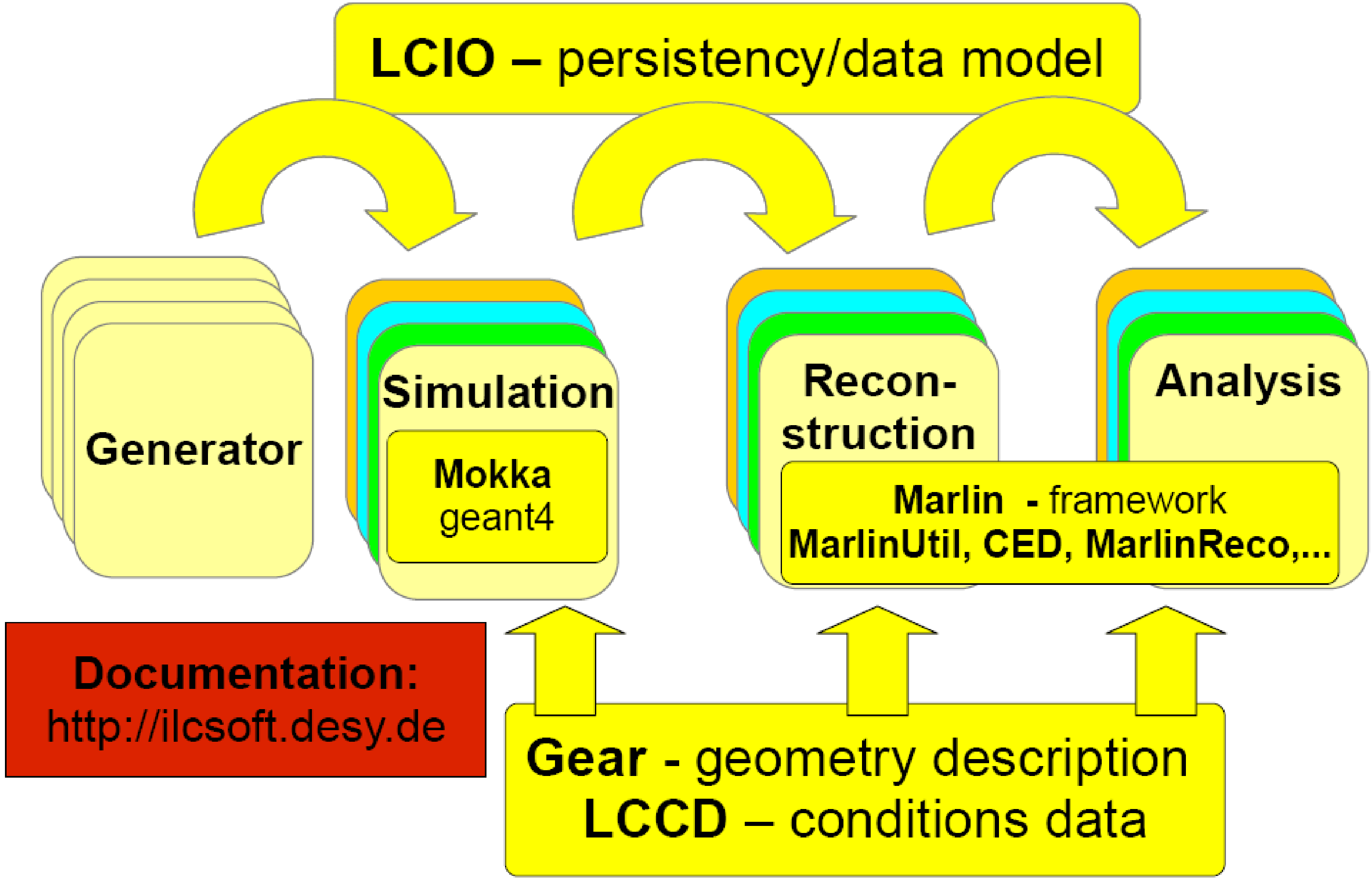
Example: integration of DEPFET analysis



M. Killenberg, A Common Software Framework for the TPC Development, N20-1

J. Furletova, The Integration of DEPFET in to the EUDET Telescope , N30-138

EUDET/LDC Software



Transnational Access

- Imposed by EU to foster trans-European access to research infrastructure
- Take advantage of it: apply for travel money!
  - For travel to DESY test beam
  - For travel to use any of the infrastructure created within the EUDET initiative
    - Magnet, beam telescope
    - Field cage, SiTPC, Si tracker
    - Calorimeter structure, readout, test stands
- Open to any European group
  - EUDET or not

Transnational Access

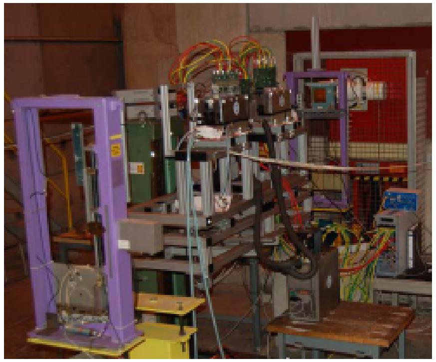
You can use it!

- Already available:
  - DESY electron testbeam
  - demonstrator pixel telescope
- All others will be ready in 2009
- www.eudet.org

EUDET provides in the framework of the Transnational Access scheme travel support for groups from the EU and countries associated to FP6 for using the following infrastructures:

TA1: DESY Test Beam

TA2: Experiments using infrastructure developed within the EUDET project



EUDET Telescope for test beam use.

As example… high precision beam telescope based on pixel sensors:

- The two arm high precision telescope with different geometries:
  - All the mechanics and the cooling system for the reference sensors.
  - Operating support: mainly remote but also local in some circumstances.
- The Data Acquisition system; hardware and software.
  - You can connect your device to our Trigger Logic Unit; help is provided to set up your DAQ in our system.
- The analysis and reconstruction software EUTelescope.

With this telescope a pointing resolution of up to better than 3um can be achieved.

WWW.EUDET.ORG

Apply for travel money through the **Transnational Access** and use the EUDET infrastructures

EUDET is an "Integrated Infrastructure Initiative" within the EU funded "6th framework programme". The project aims at creating a coordinated European effort towards research and development for the next generation of large-scale particle detectors.

Conclusions

- EUDET is an "Integrated Infrastructure Initiative (I3)" within the EU funded "6th framework programme"
  - an example of the high recognition of the ILC by the European Union
- Support improvement of infrastructure for detector R&D with larger prototypes
- Different Joint Research Activities (JRA)
  - encompassing all major ILC detector components
  - completion of most infrastructures early 2009
- Networking: large impact on structuring European ILC R&D efforts
- Transnational access: Infrastructure and support open to other detector R&D activities
- Future: develop EUDET towards overall detector integration and optimization

Backup Slides

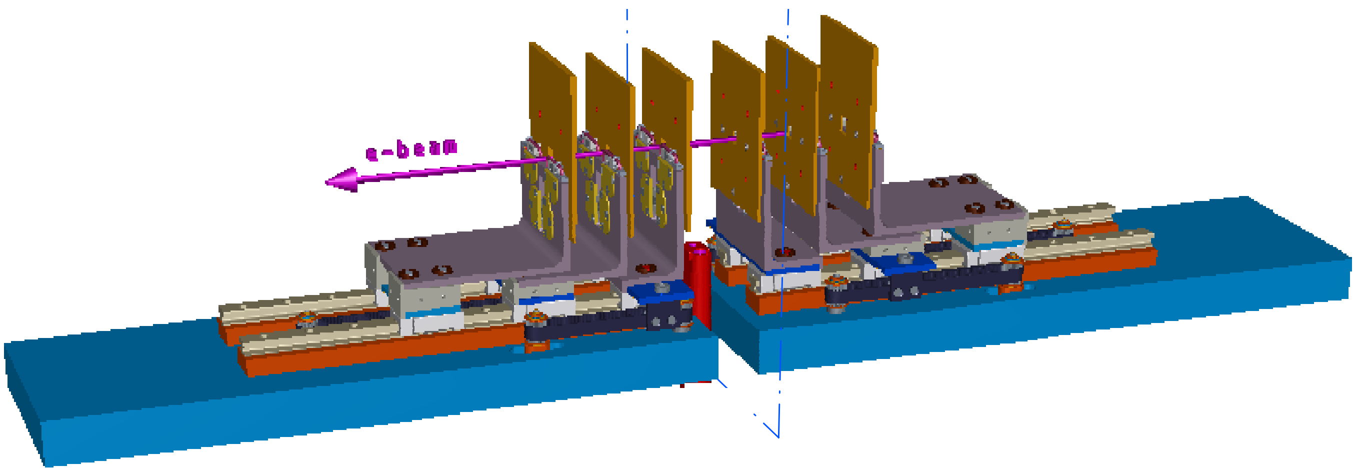
Important Links

www.eudet.org

- **You** can apply for travel money through the **Transnational Access** and use the EUDET infrastructure

testbeam.desy.de

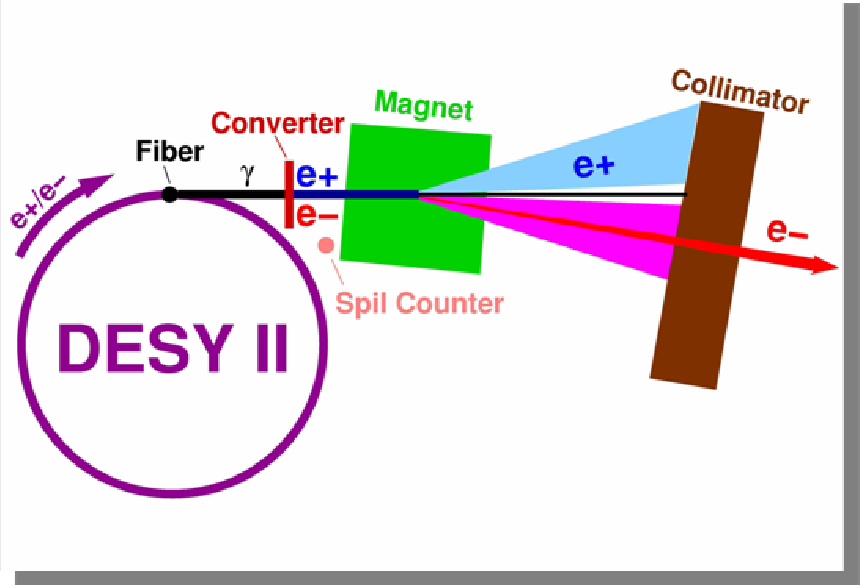
- You can apply for test beam time at DESY



DESY Test beam

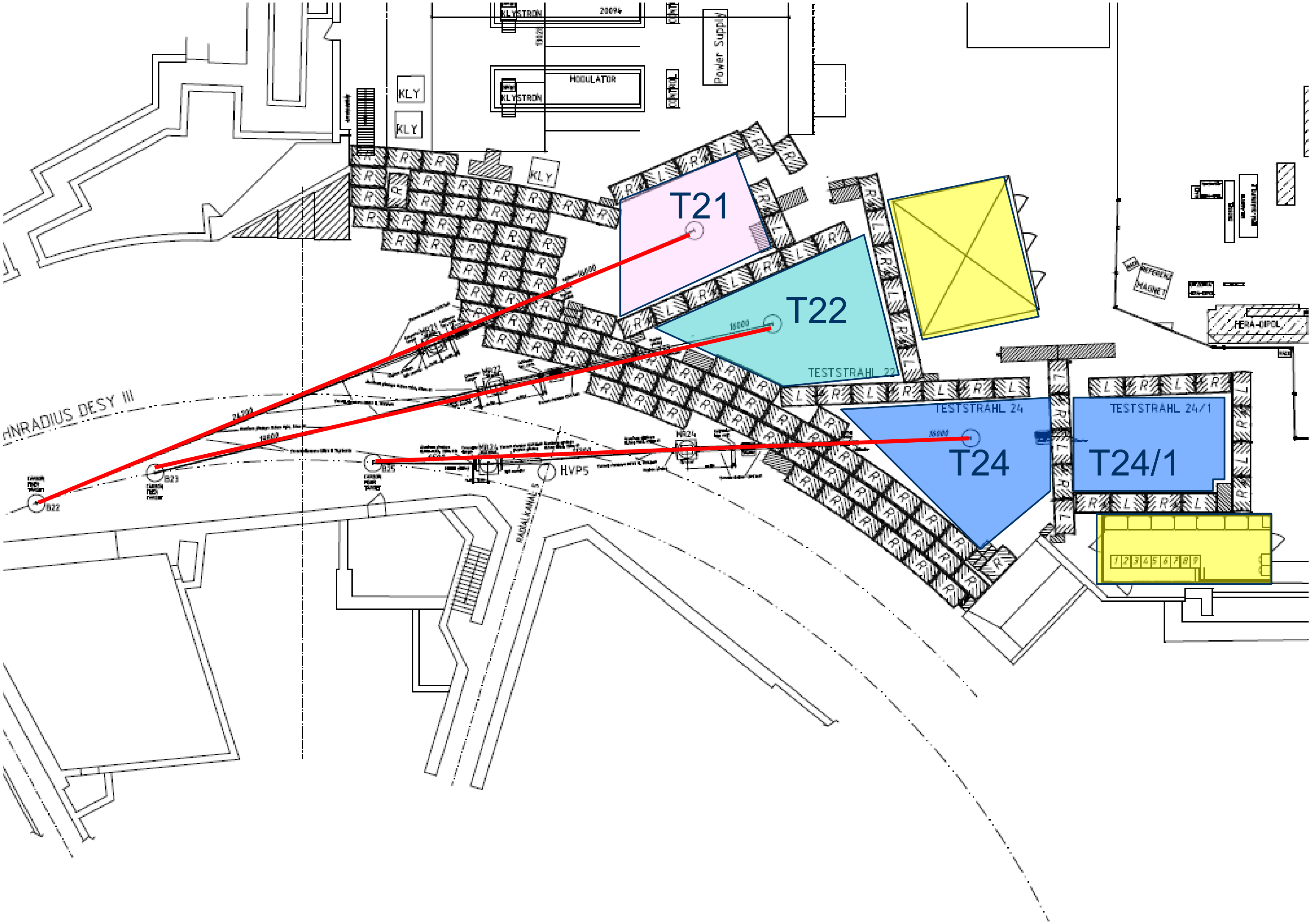
- Bremsstrahlungs/conversion beam with E_e up to 6 GeV.
- Beam momentum steered by magnet current by test beam user.
- Rates depending on beam line, energy, target material, collimator setting and operation.

Rates	Target	
Energy	3mm Cu	1mm Cu
1 GeV	~2.2 kHz	~ 0.5 kHz
2 GeV	~4.6 kHz	~1.1 kHz
3 GeV	~5.2 kHz	~1.3 kHz
4 GeV	~4.4 kHz	~1.1 kHz
5 GeV	~2.8 kHz	~0.5 kHz
6 GeV	~1.5 kHz	~0.2 kHz



In practice is the maximal event rate around 2 kHz.
(3 GeV, 3mm Cu convert, Collimator ca. 5mm x 5m

Testbeam Layout



Facilities for Test Beam User

- All three testbeam lines have
  - Interlock systems
  - Magnet control
  - Patch panels with preinstalled cable
  - Gas warning systems
  - Fast internet connection (DHCP)
- You can ask for:
  - Translation stages
  - Premixed gases
  - Superconducting Magnet (1T)
  - Beam Telescopes:
    - MVD Telescope
    - EUDET Telescope
- You have to bring:
  - Your Data Acquisition incl. computers
  - Trigger scintillators

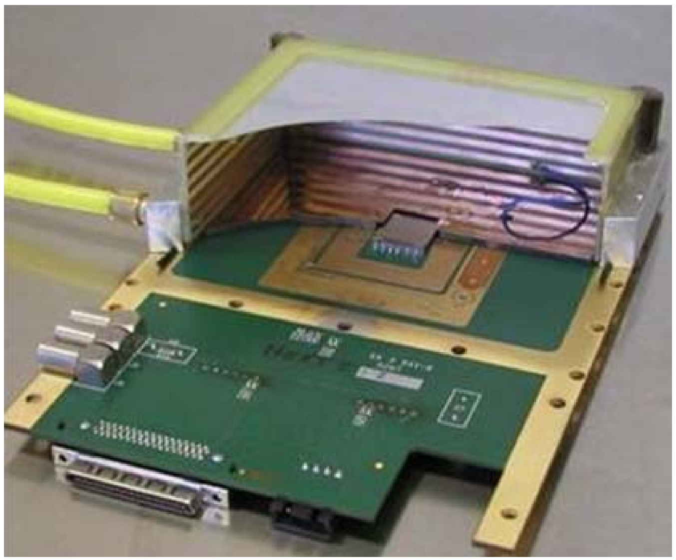
You can apply for test beam time at DESY

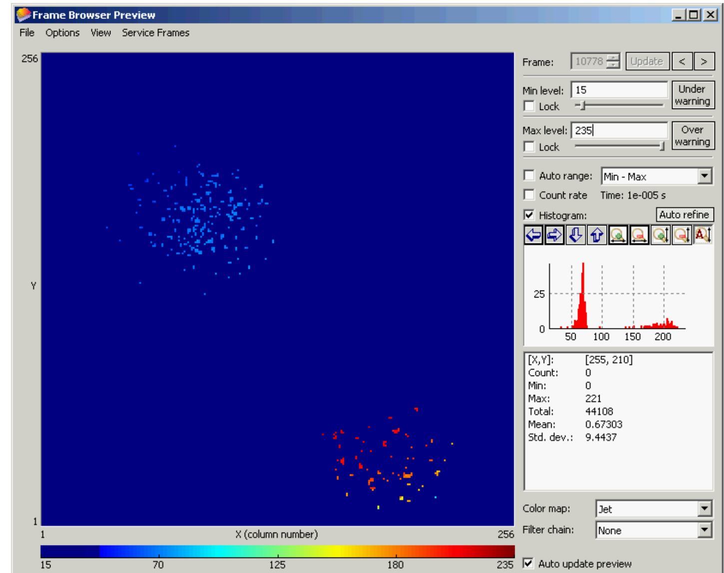
testbeam.desy.de

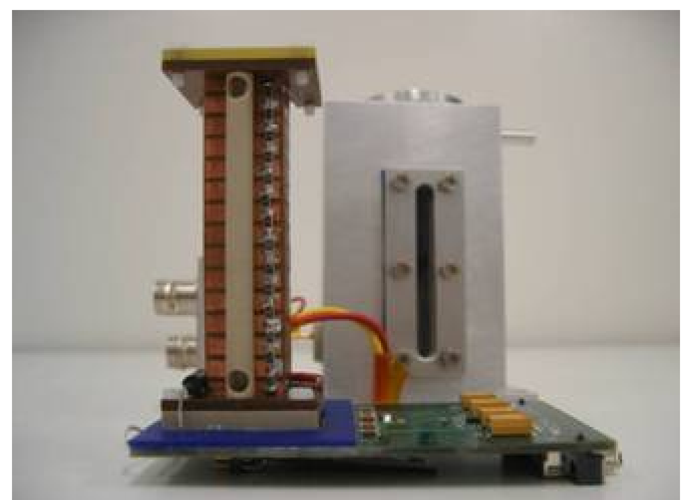
Or contact: testbeam-coor@desy.de

Si TPC Readout

See electrons from an X-ray conversion one by one and count them, study their fluctuation.

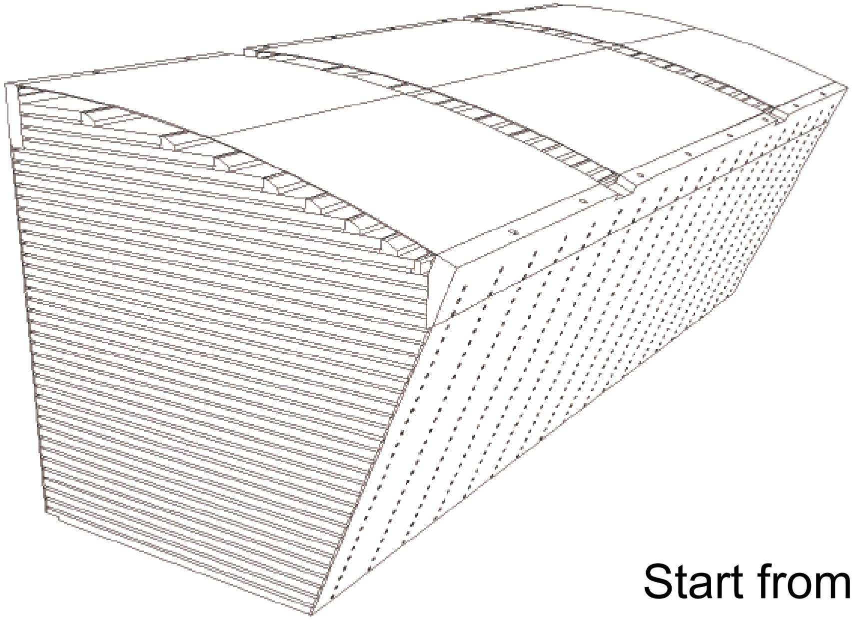






Calorimeter Module

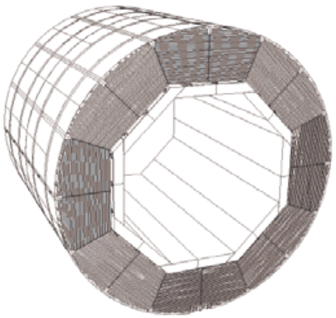
- 3 mm side panel
- ⇨ M6 screw size



Advantage
• Slim support structure

Disadvantages
• Uncertainties regarding stability
• High tolerance requirements (e.g.
• holes for screws, flatness of absorber
• plates)

Start from
TESLA design



HCAL

- Proof of principle -> reality