Detector R&D in particle physics at DESY

DESY is involved in a number of detector projects in particle physics

- LHC experiments
  - ATLAS
  - CMS
- BELLEII experiment at KEK-B (separate session)
- ILC project

- and a number of smaller projects: Olympus, ALPS

Connected to these projects fundamental R&D is done at DESY.

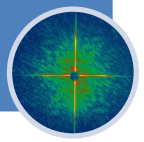
The following slides briefly summarize the detector development activities ongoing or planned at DESY's particle physics division.

Ties Behnke, DESY, based on contributions from
Ingrid Gregor (ATLAS, PLUME), Marcel Stanitzki (ATLAS), Guenter Eckerlin (CMS), Ralf Diener (TPC), Felix Sefkow (HCAL), Wolfgang Lohmann (FCAL), Jenny List (Polarisation)

DESY Organisation

- Detector Science FS-DS

Photon Science



- Linear Collider (FLC)
- ATLAS
- CMS
- BelleII

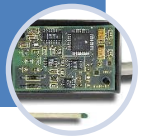
Particle Physics

- Machine instrumentation (FLA)

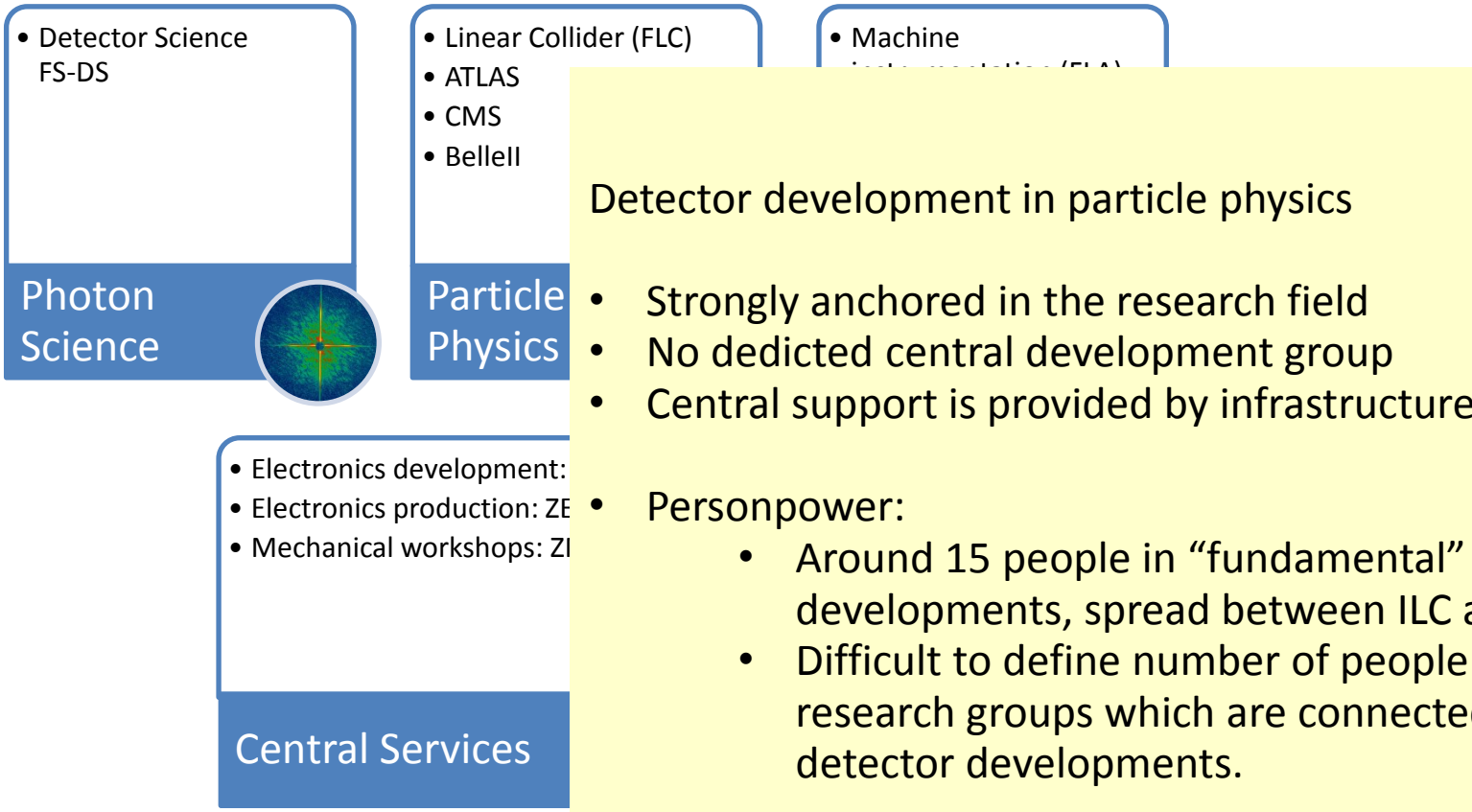
Accelerator Physics

- Electronics development: FE
- Electronics production: ZE
- Mechanical workshops: ZM

Central Services



DESY Organisation



Detector development in particle physics

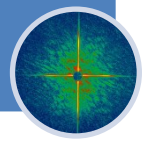
- Strongly anchored in the research field
- No dedicted central development group
- Central support is provided by infrastructure groups

- Personpower:
  - Around 15 people in “fundamental” developments, spread between ILC and LHC
  - Difficult to define number of people in the research groups which are connected to detector developments.

DESY Organisation

- Detector Science
  FS-DS

Photon Science



- Linear Collider (FLC)
- ATLAS
- CMS
- BelleII

Particle Physics

- Machine

- Electronics development:
- Electronics production: ZE
- Mechanical workshops: ZI

Central Services

Detector development in particle physics

- Str
- No
- Cer
- Per

Within new Helmholtz Structure:

- Stronger focus on fundamental developments
- Strong participation in Helmholtz program on detector development
- Increase and develop strong links to detector development in photon science on site

Structure of the proton | Explore the Terascale | Precision physics

LHC: flag-ship current program

key involvement by DESY in the detector upgrades:
intention to build and integrate a significant part of the upgraded Silicon trackers

strong Focus on Silicon Detectors (synergy with large expertise at Hamburg University and with program at the XFEL)

Instrumentation for Future Detectors

Electron positron colliders
ILC as future project
BelleII as near term (smaller) project

Development of high precision detectors, optimized with the particle flow paradigm in mind.

In addition to technologies DESY plays a central role in detector integration and overall systems design.

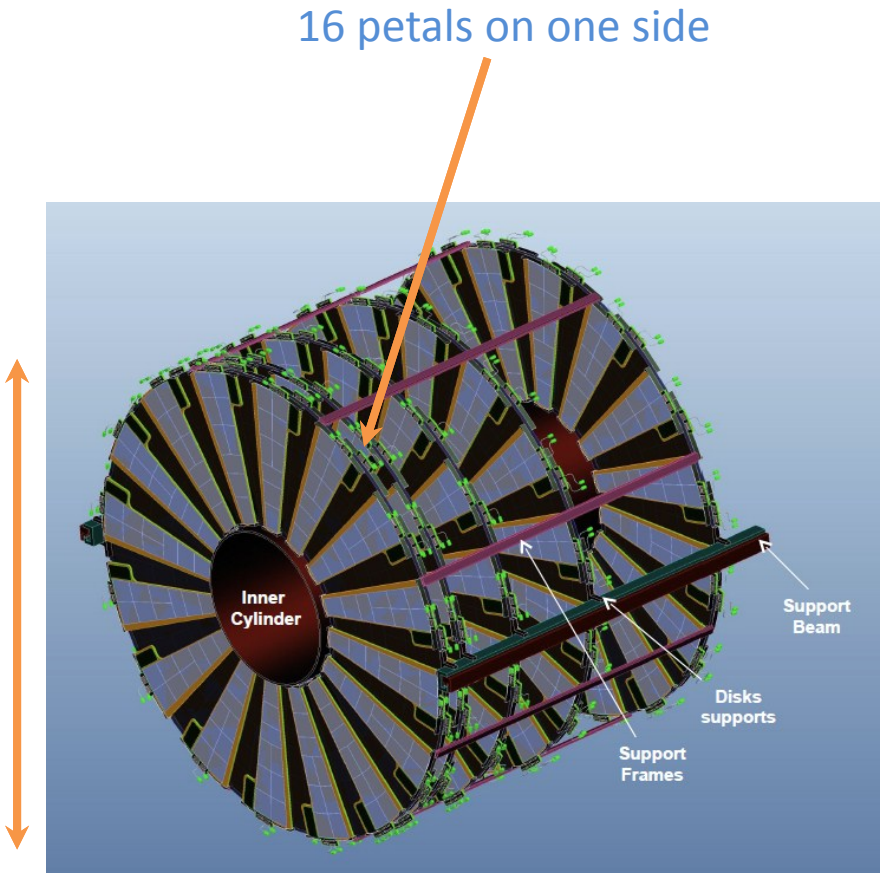
ATLAS

ATLAS Upgrade Activities

- Focusing on Silicon tracking
- Activities at DESY (Hamburg and Zeuthen)
  - ATLAS SCT Endcap Upgrade (2022)
  - Petal 2014 as R&D for the Endcap Upgrade
  - IBL (2013)
- Building on Infrastructure and Expertise available at DESY
- Good collaboration with CMS Upgrade Projects at DESY

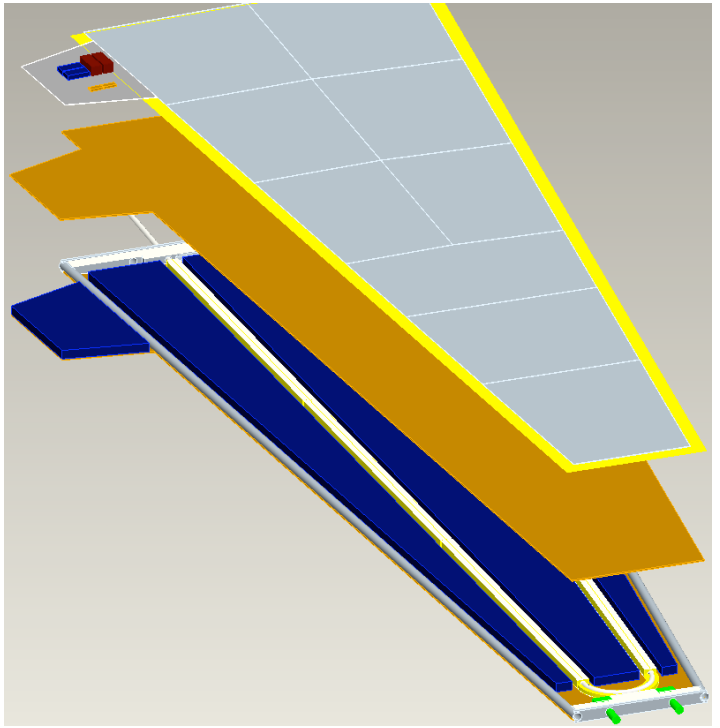
Upgrade of ATLAS SCT Endcap

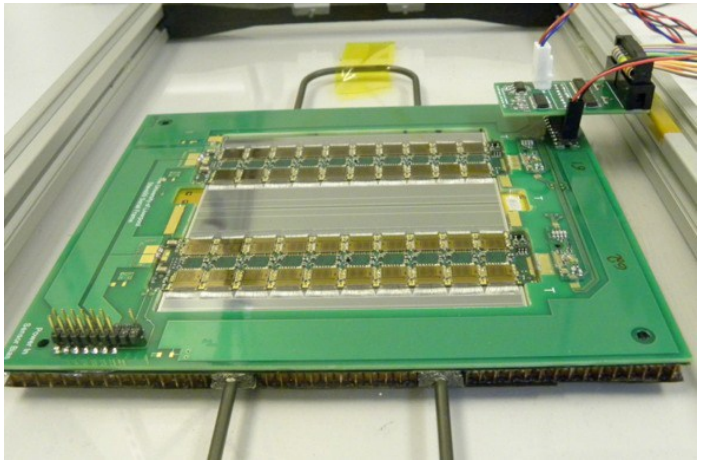
- Current SCT (Silicon Strip Tracker) will reach end-of-life in 2022
- Upgrade to handle higher event rates, pile-up and radiation levels from the High-Luminosity LHC
- Endcaps
  - 10 disks with 32 petals each
  - 9 modules per Petal
  - 50 m^2 Silicon



DESY activities

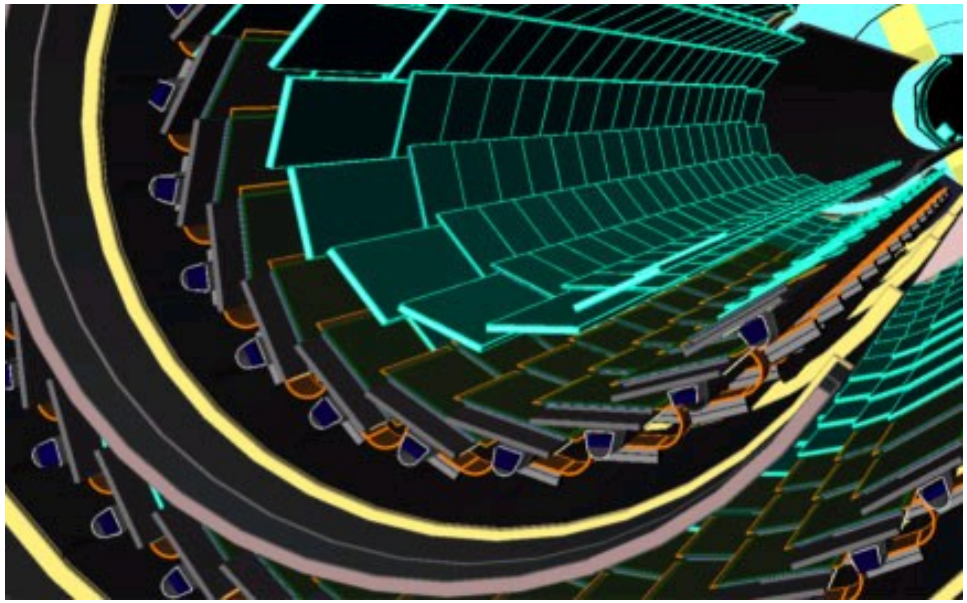
- ATLAS Stave
  - Sharing experience with SCT Barrel staves
- Petal 2014
  - Design of a prototype petal
- Petal activities focus on
  - Module production (bonding, gluing)
  - Mechanics & Cooling
  - End-of petal electronics
  - System integration
- Upgrade Simulation studies





Phase 0 upgrade: ATLAS IBL

- Mainly testbeam support
  - Telescope, Reconstruction…
  - Implementing Charge sharing models
- Optical fibers for the readout
  - Procurement and testing



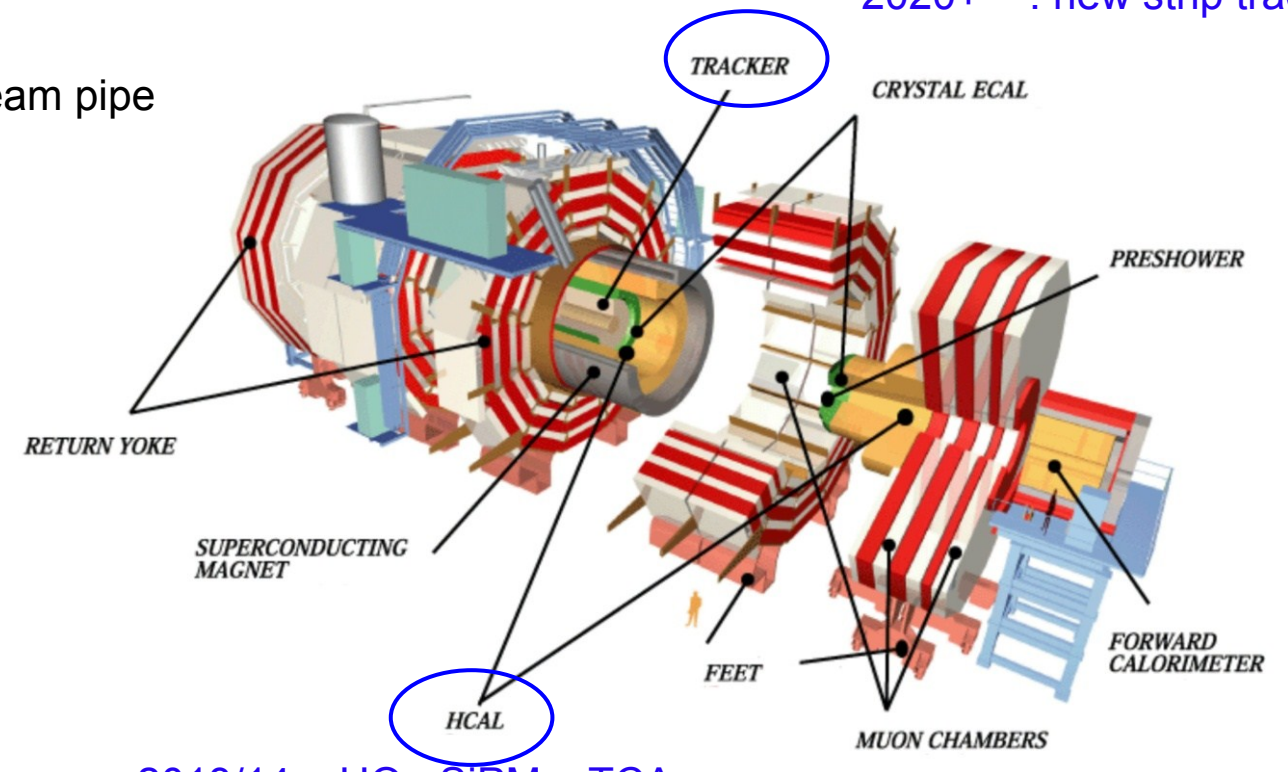
CMS

Detector R&D of the DESY-CMS Group

CMS Upgrade Activities phase I & phase II

2016/17 : new pixel detector
2020+ : new strip tracker / pixel

2013/14 : new beam pipe



2013/14 : HO : SiPM, uTCA
2017/18 : HB/HE : SiPM, uTCA

2013/14 ME 1/1 FE
2016/17 Endcaps (YE4)

DESY involvement

CMS upgrade activities

Silicon tracking:

Phase I: participate in the barrel upgrade

(DESY will construct the fourth layer of the new detector)

Phase II: envision a center at DESY for the construction of one complete endcap for CMS

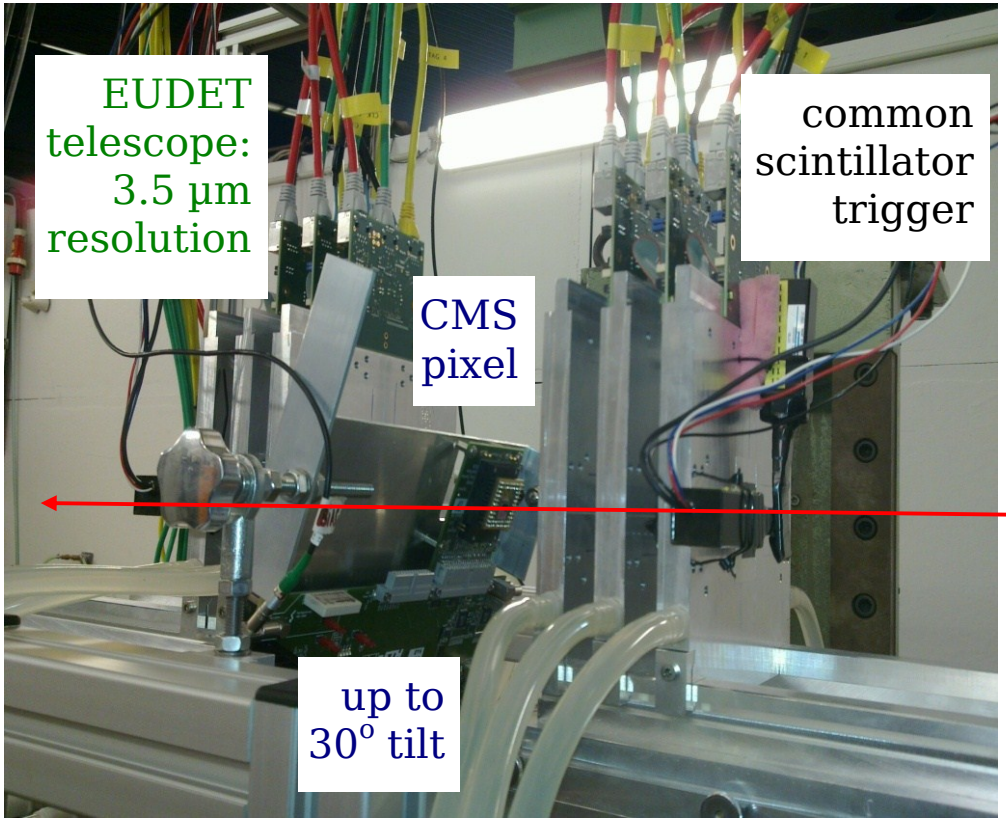
- Module Design und FE Analysis (thermal & mechanical) for the new Si-strip modules
- Building a temperature and deformation test stand to verify the calculations
- Building and testing of module prototypes, evaluating new materials
- Participating in the R&D for more radiation hard sensors (within the CMS sensor group) (characterization of different sensor materials and structures before and after irradiation)

Hadronic Calorimeter upgrade:

replace HPD's with SiPM for the HCAL barrel detector
(strong synergy with the ILC Calorimeter activities)

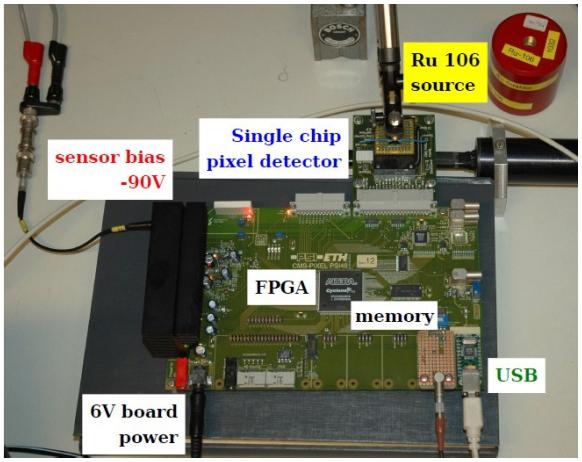
Beam conditions monitors
extremely radiation hard detectors

Testing CMS Pixel Module at DESY



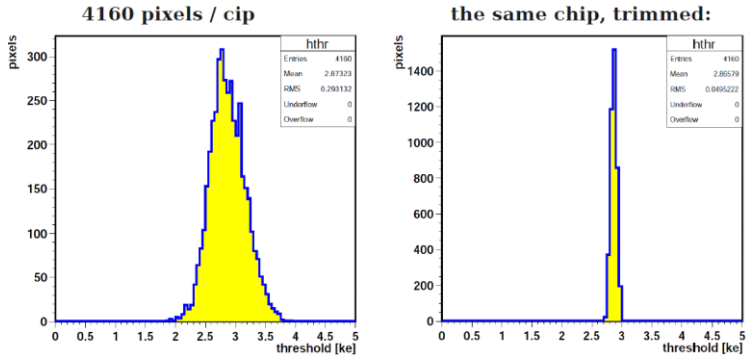
CMS pixel test board in the DESY 6GeV positron test beam

CMS pixel test board with Ru106 source



Calibration Example :
setting trim bits for uniform pixel output

Threshold variation

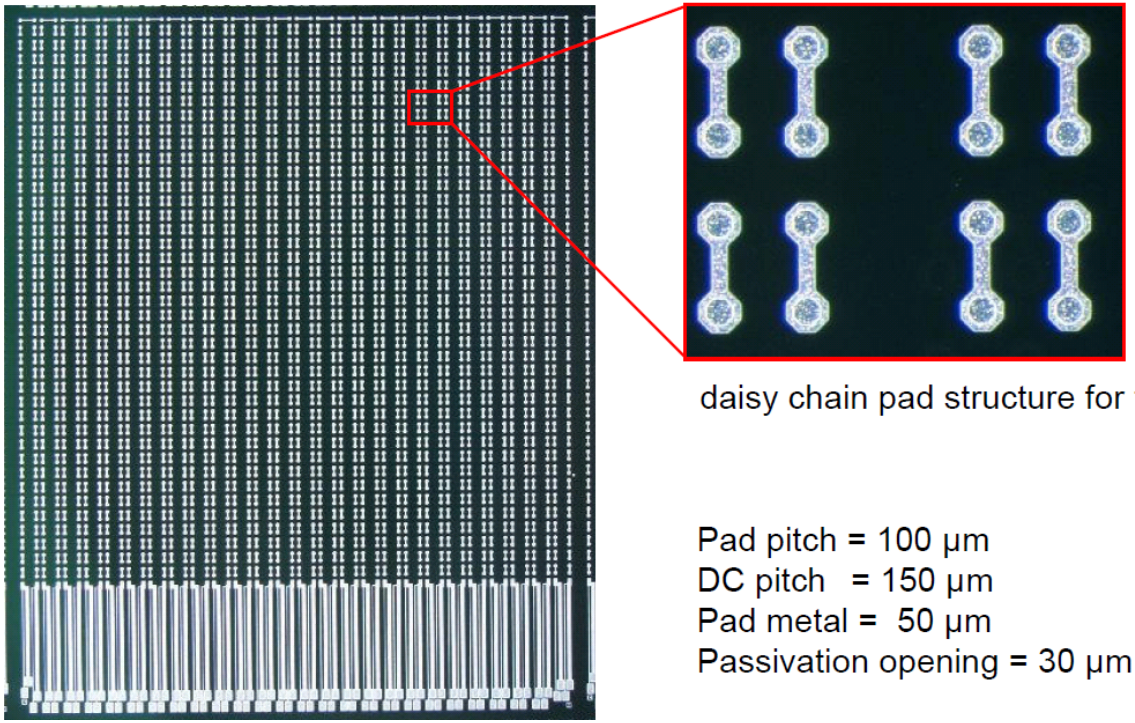


CMS transistor variations: threshold spread 290 e

4-bit DAC trimming: threshold spread 50 e

Bump bonding evaluation with test structures

MICROGRAPH OF WHOLE CHIP LAYOUT AND ZOOM TO DAISY CHAIN PADS

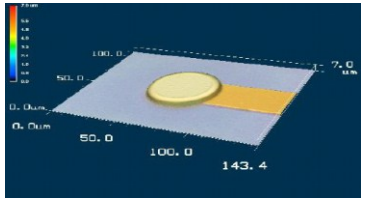


daisy chain pad structure for tests

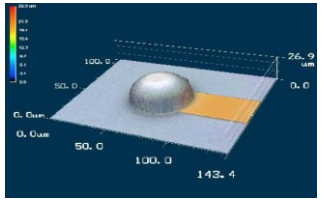
Pad pitch = 100 µm
DC pitch = 150 µm
Pad metal = 50 µm
Passivation opening = 30 µm

test and qualifying bump bonding processes from different companies/vendors

Example : Pac Tech



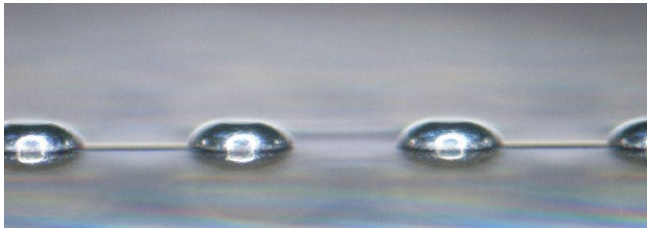
pad with UBM



pad with 40um solder ball

dummy ROC : 28 double columns with 80 pad per column building a daisy chain

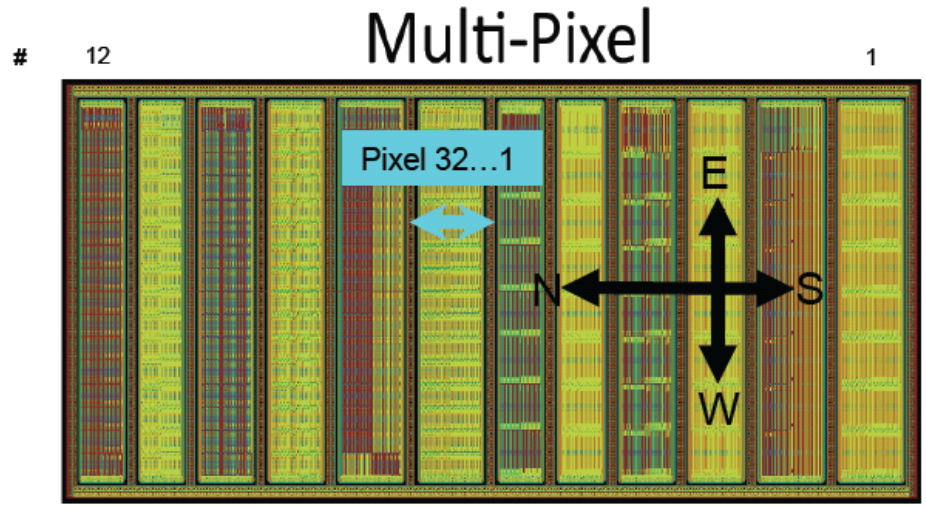
bump bonding the corresponding dummy sensor will allow to measure bonding efficiency



test structure with solder balls

Sensor R&D for radiation hard sensors (CEC)

Within the CEC measurement campaign DESY Zeuthen is characterizing multi-pixel test structures before and after irradiation

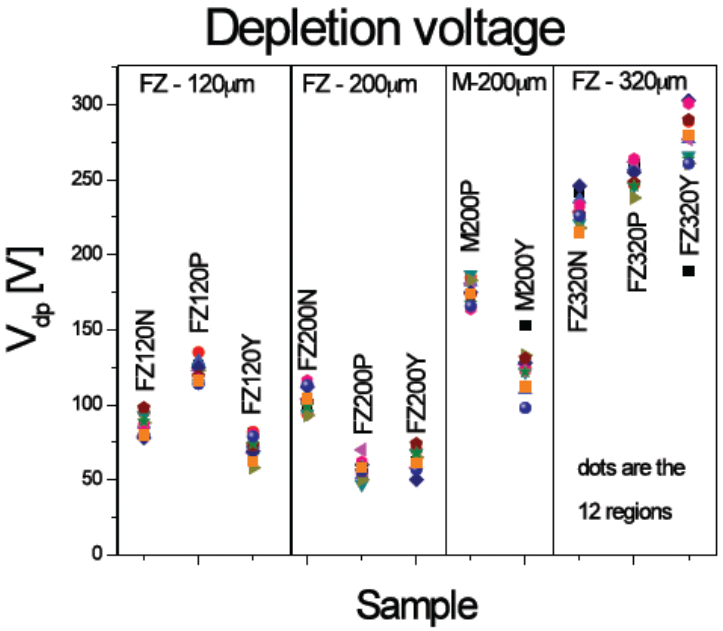


- 12 regions (3 ratios w/p, 2 diff. pixel lengths, 2 diff. Bias)

Multi pixel test structure with 12 different pixel configurations

measurements before irradiation in progress awaiting radiated samples

Example :
Depletion voltage for the different sensor materials



Phase II – Tracker Module R&D

detailed FEA simulation of modules

thermal and mechanical

essential input for module design

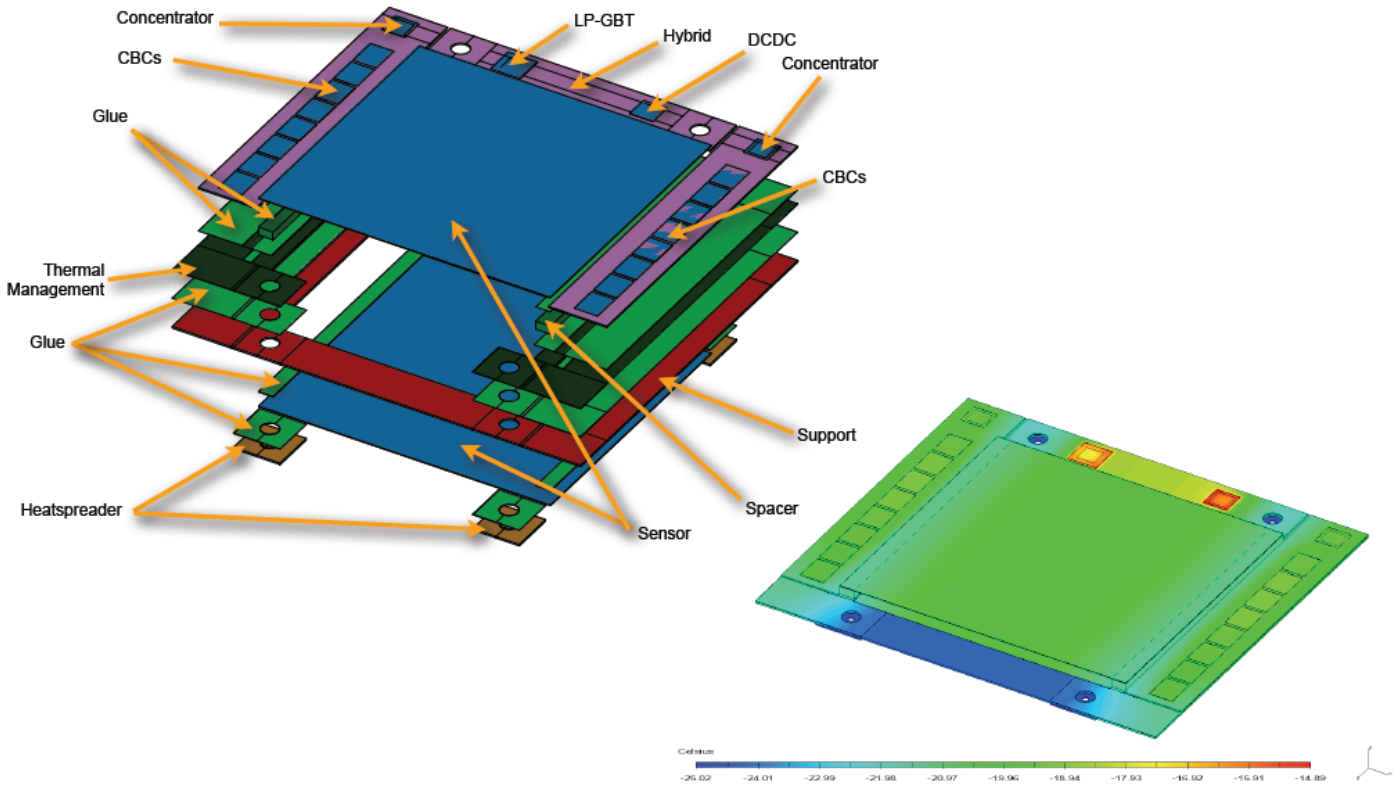
thermal and deformation tests
to validate results
(close collaboration with DESY-ATLAS group)

will characterize materials

plan to build and test prototypes at DESY in cooperation with FEC

……..

Design and FEA of the 2S Module

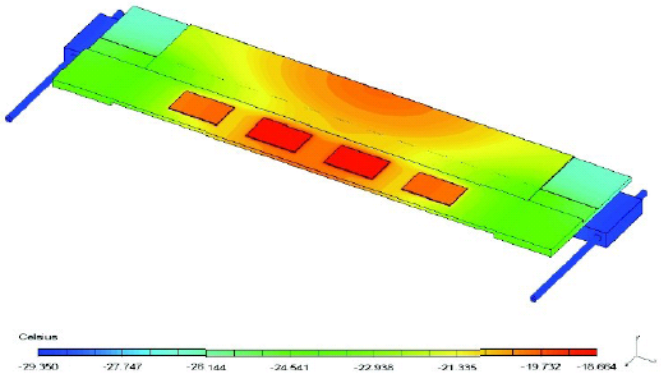


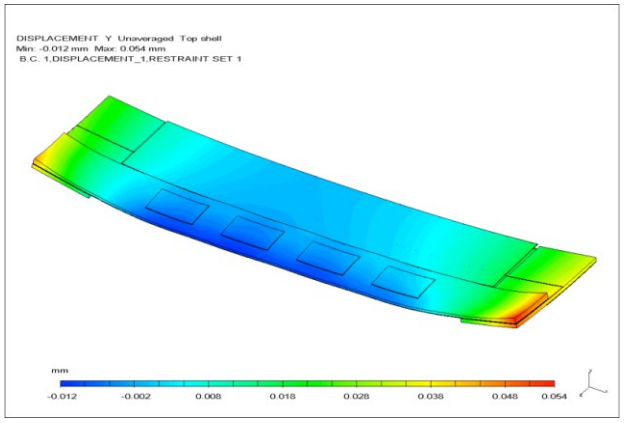
- 2 strip sensors with a spacing of 1mm - 4mm
  - Concentrator chip correlates signals from both sensors to form a Pt trigger
  - Trigger will be used in L1

- A prototype is going to be built by the end of this year

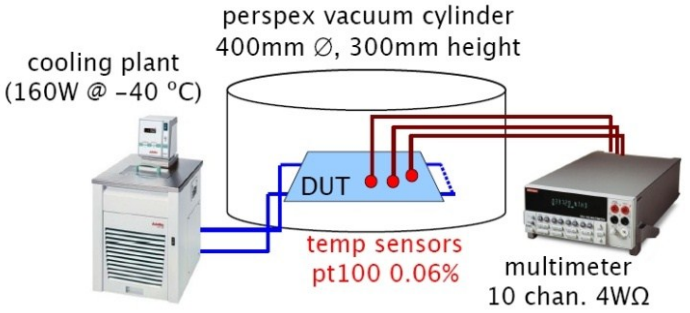
Phase II – module R&D

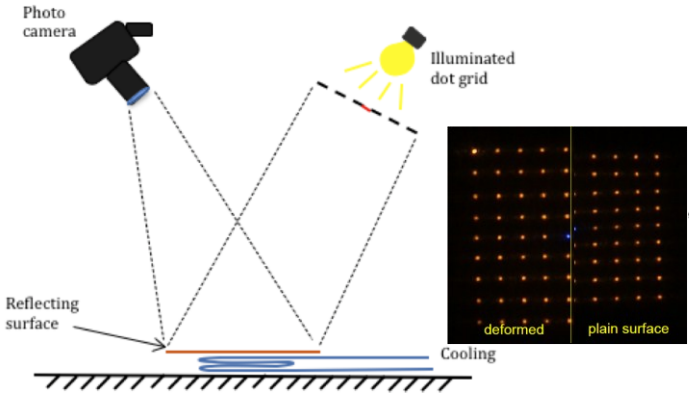
Finite Element calculations :
examples of thermal (top)
and mechanical calculations (bottom)





Crosscheck with measurements of test samples
and prototypes in a thermal test setup (top)
and a deformation test setup (bottom)

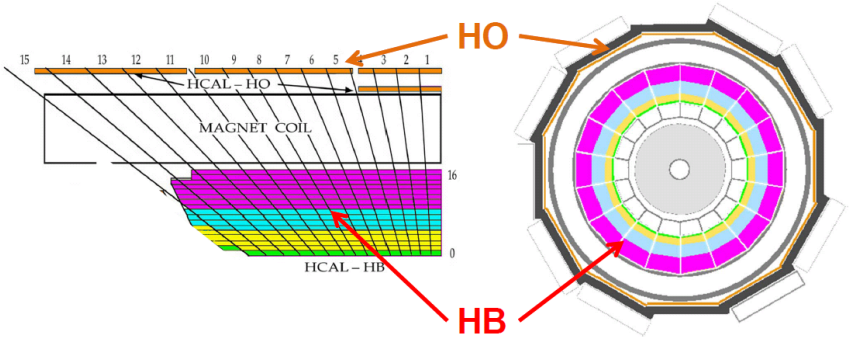




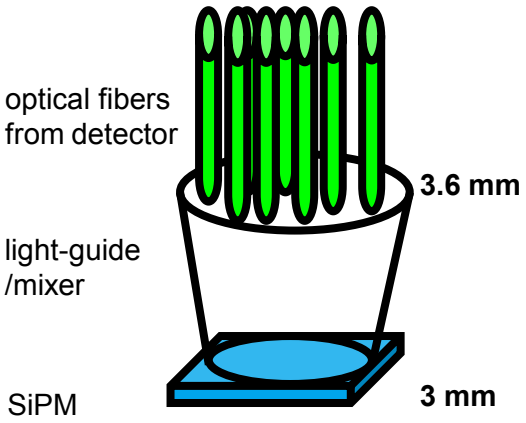
Both setup currently being commissioned
first tests with deformation mock-up sucessfull

SiPM Activities at DESY within CMS

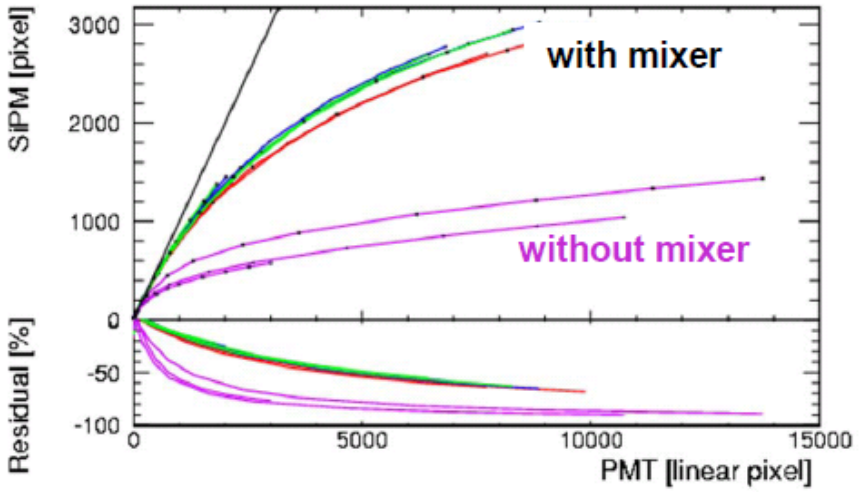
Replacement of HPD with SiPM



Optimization of light-guide and light-mixer for SiPM



Light-guide test setup at DESY

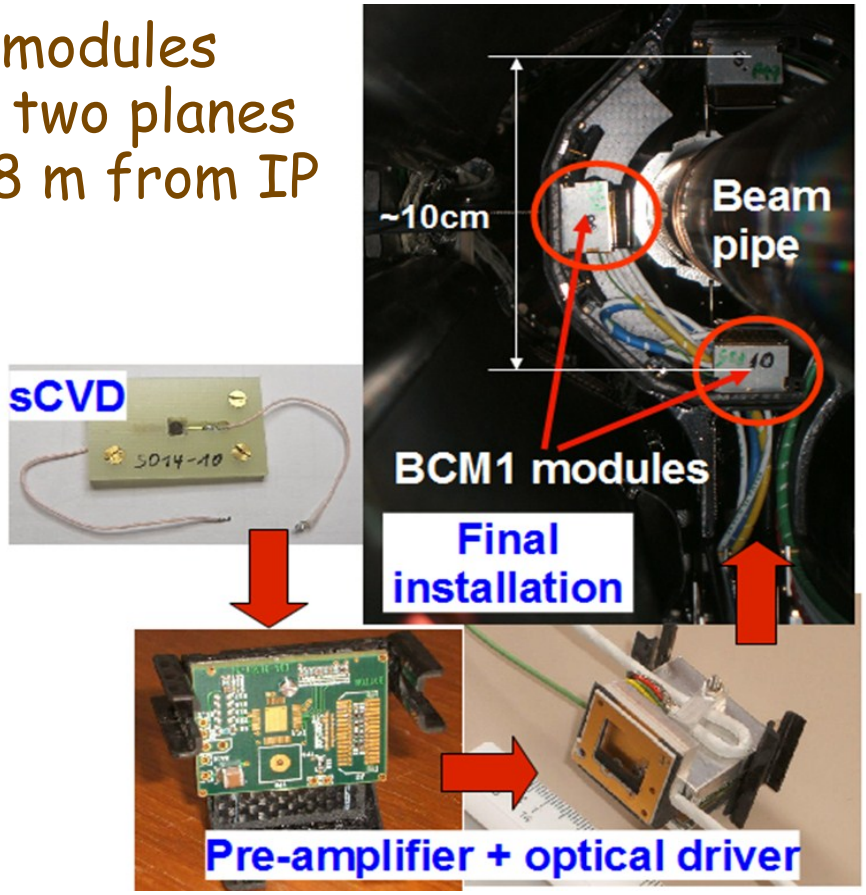


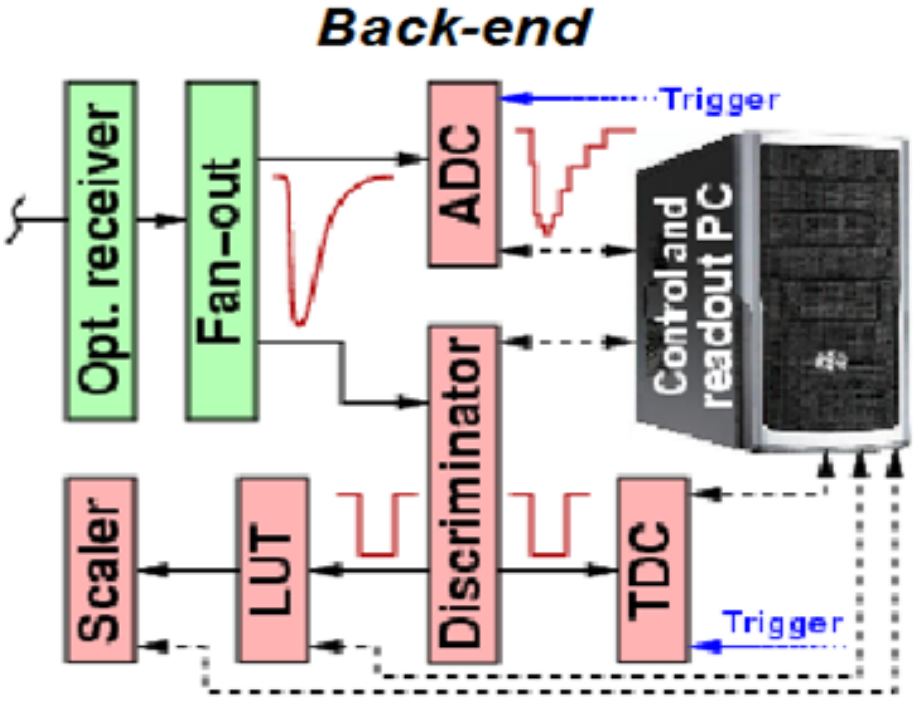
Saturation for different light mixers

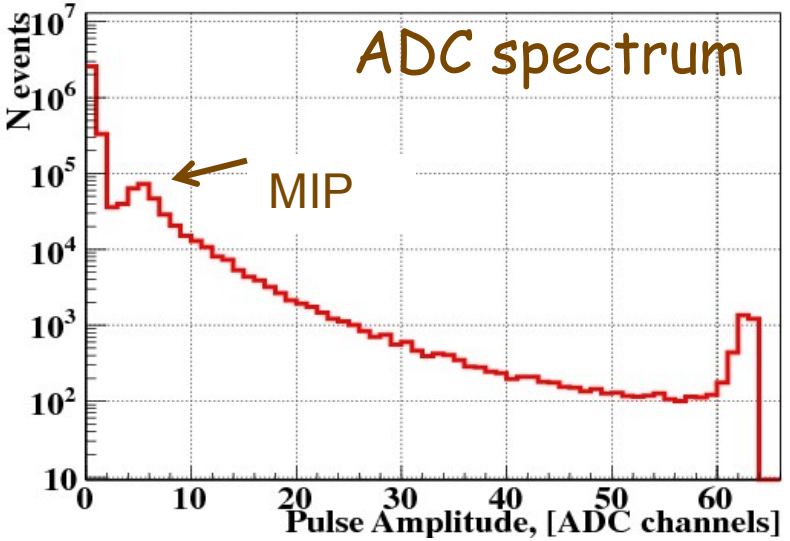
Strong synergies with the ILC effort at DESY

Fast Beam Conditions Monitor at CMS/LHC using Diamonds

4 modules
in two planes
1.8 m from IP



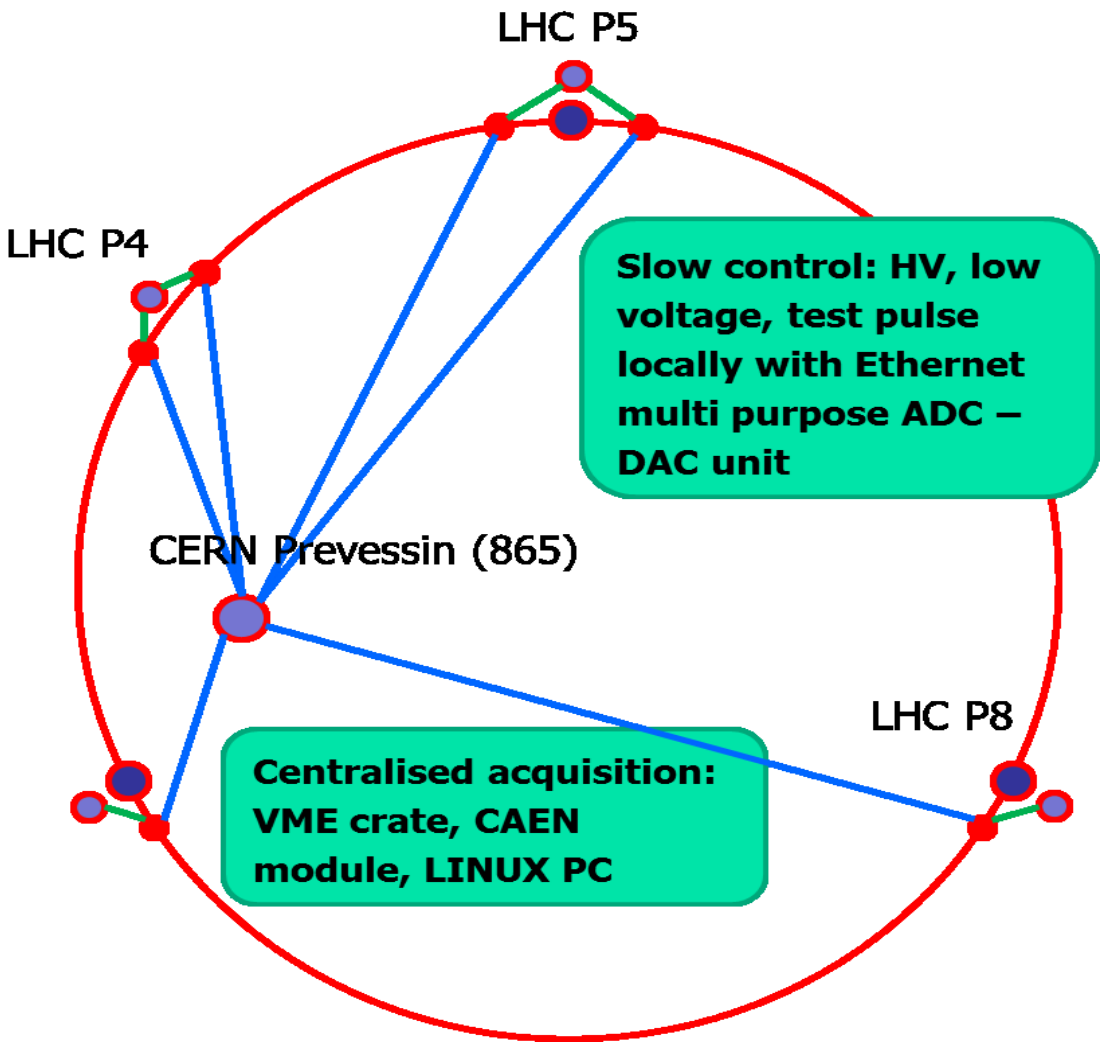




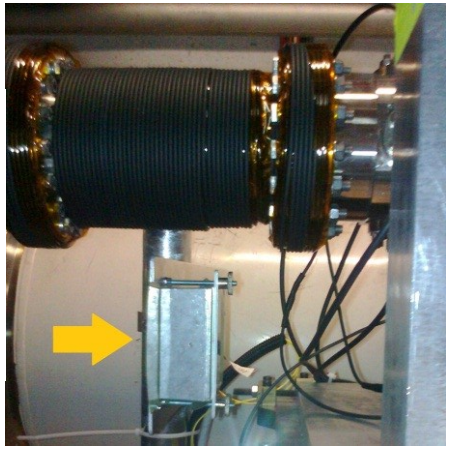
- radiation hard (sensors and ASICs)
- optical analog signal transmission
- robust and compact
- no slow control

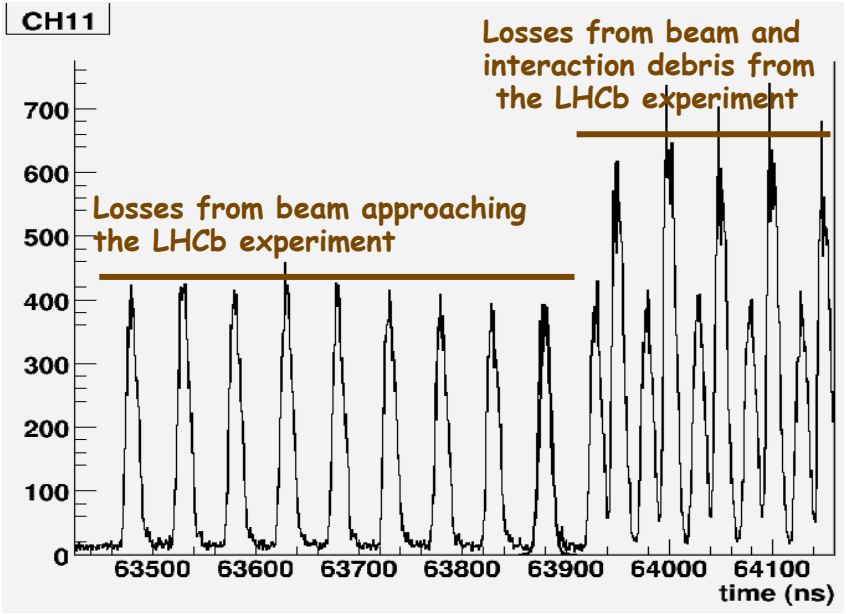
Installations and Results at LHC

Fast beam loss monitor based on the CMS concept collaboration CERN-CMS-DESY



A module installed below the LHC beam-pipe



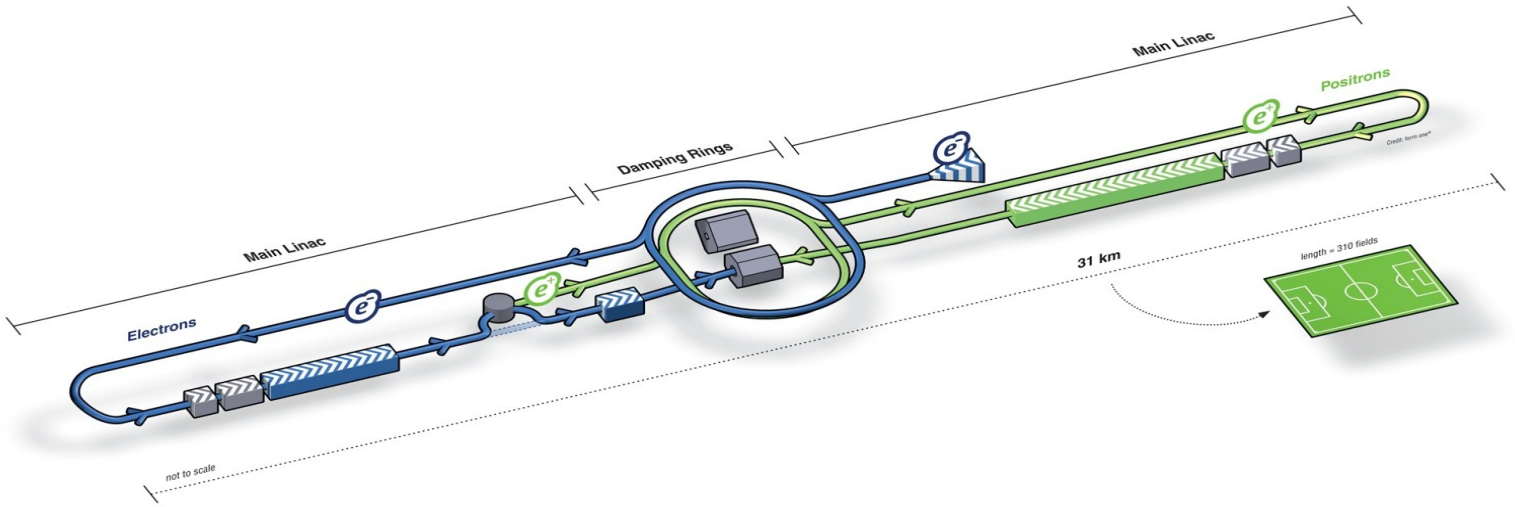


LINEAR COLLIDER

Detector Development towards a linear collider

Goal of the work:

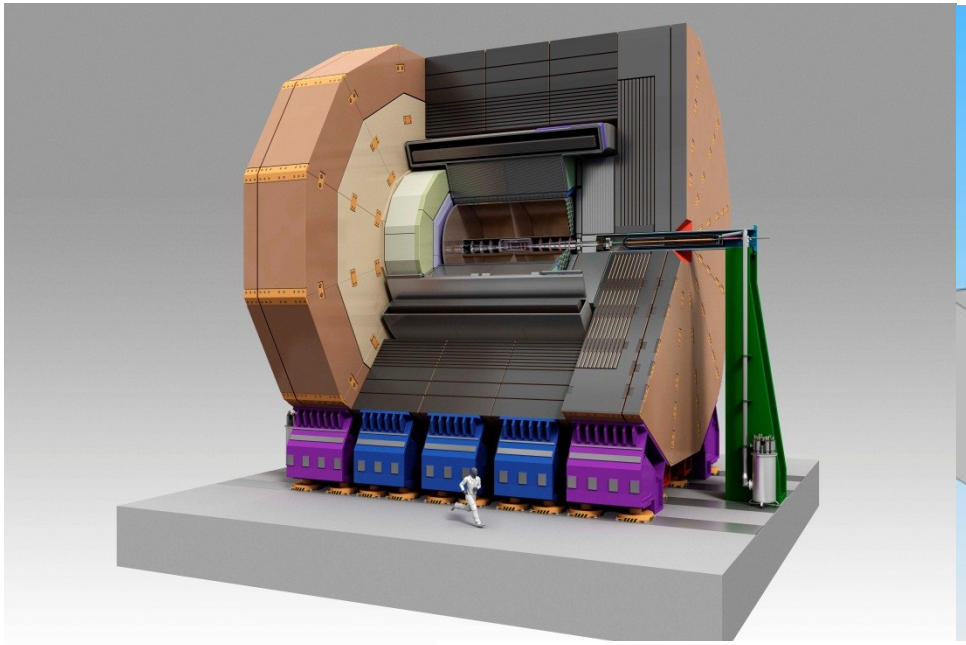
- Develop experimental techniques needed for a state-of-the art detector at a future linear collider like the ILC



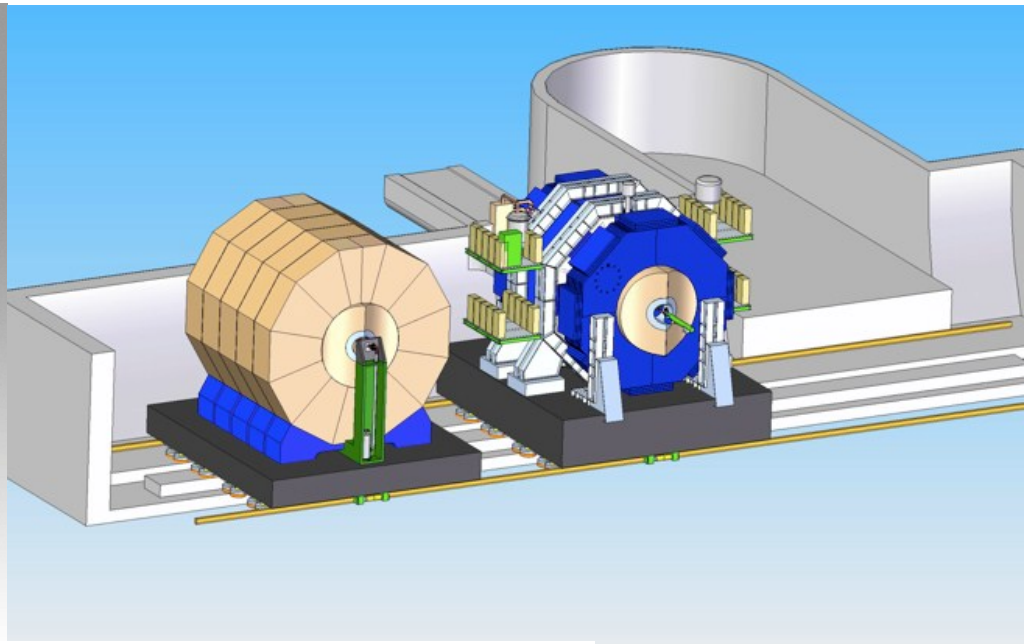
A linear collider is a major future facility following and complementing the LHC
Experimentation at such a collider is a major challenge and requires significant advances and new developments

Overall Detector

Detector concept for a linear collider (Proto Collaborations)



Detector Design



Detector Integration

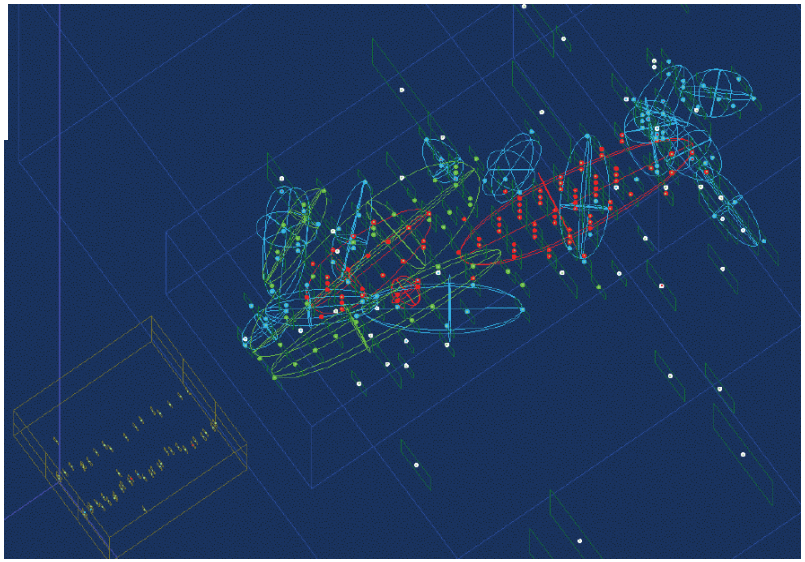
Developed in international collaboration (700+ members)

Strong leading roles by KEK and DESY
http://www.ilcild.org

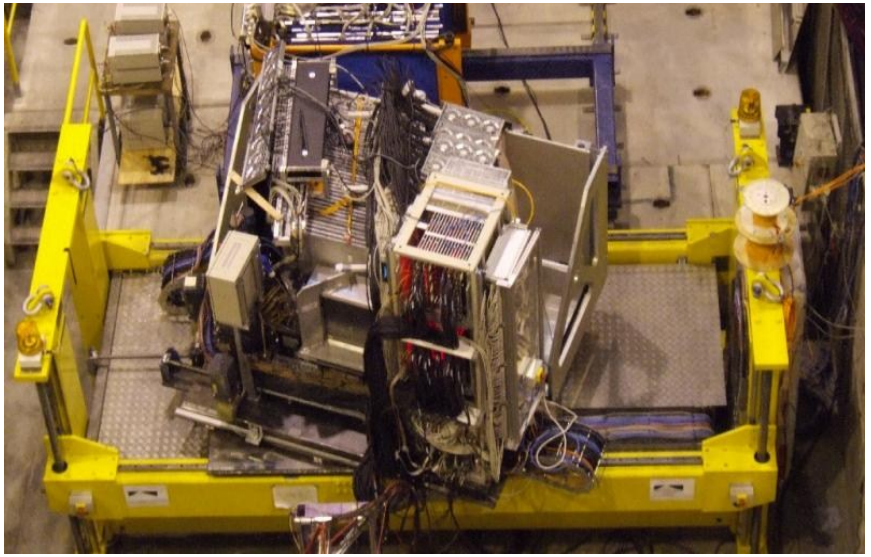
- Calorimeter (hadronic) developments
- Si-mu-Vertex detector
- Time projection chamber
- Forward instrumentation
- Beam instrumentation

Calorimeter Developments

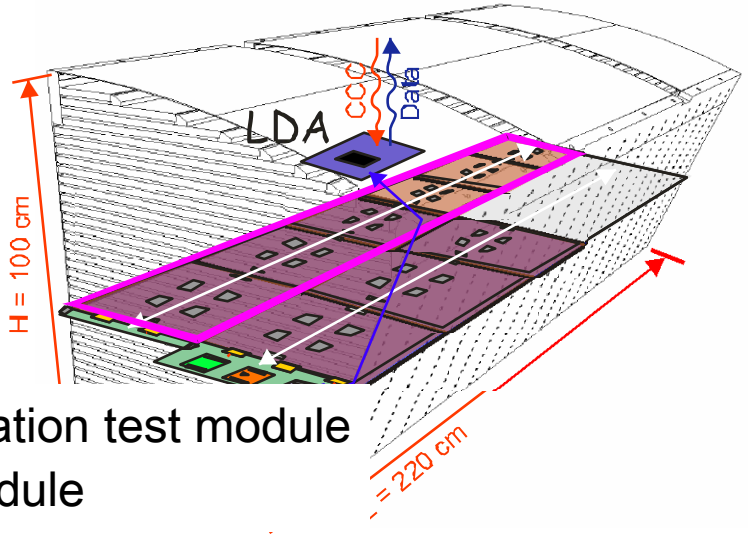
CALICE collaboration
F.Sefkow, spokesperson



- Development of novel technologies (SiPM)
- Development of new calorimeter concept (Pflow)
- Experimental precision investigation of hadronic calorimetry



Fermilab Test setup



Next generation test module
EUDET module

Calorimeter Developments

CALICE collaboration
F.Sefkow, spokesperson

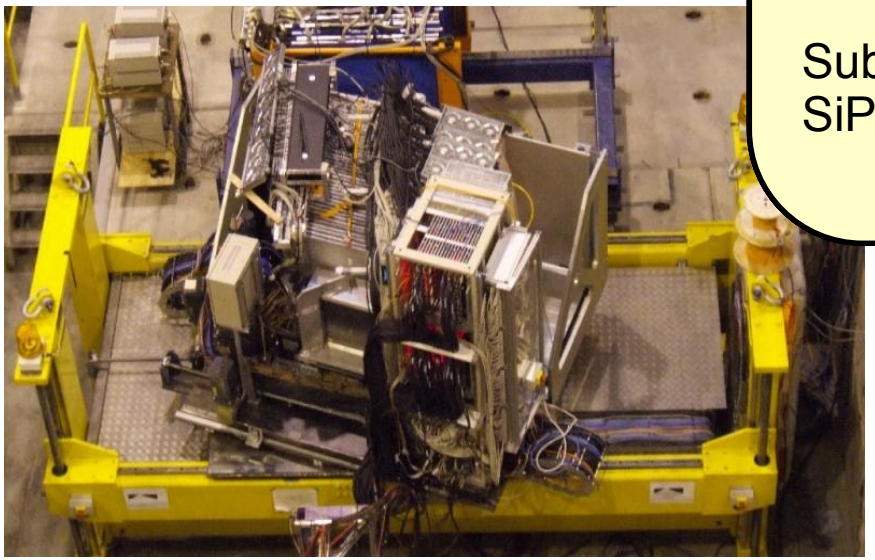
- Development of novel technologie
- Development of new calorimeter c
- Experimental precision investigatic
  hadronic calorimetry

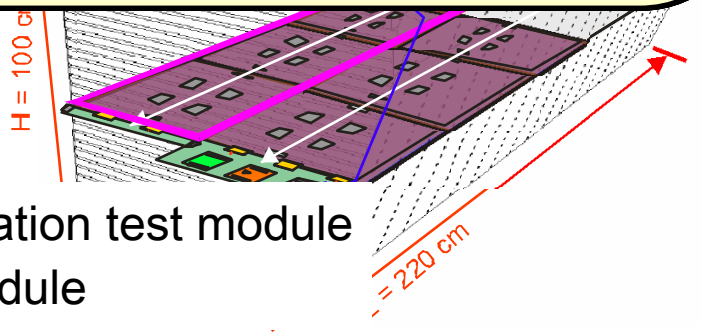
SIPM

Key component of HCAL developments

Close cooperation with University of Hamburg and other groups.

Subject also of future development for advanced SiPM sensors.



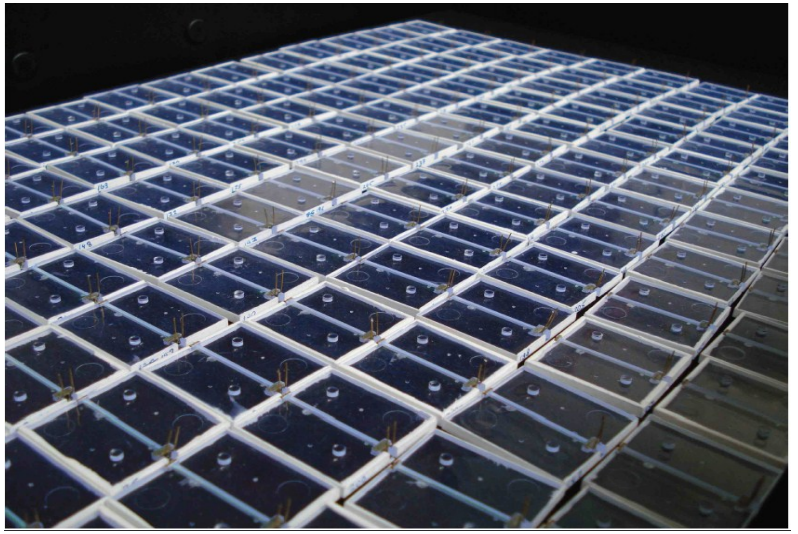


Next generation test module
EUDET module

Calorimeter

Prototype of a realistic calorimeter module including novel mechanical structures

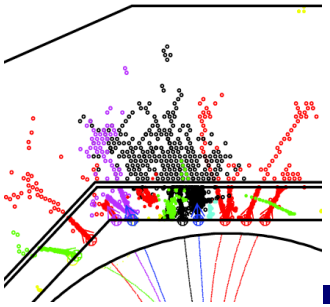
Picture of a scintillator plane



Plan: develop and built the next generation prototype (EUDET module)

Also part of new EU proposal AIDA
(Advanced Infrastructure for Detector at Accelerators)

Spinoffs:
Medical imaging
CMS calorimeter



CALICE and Japan

- Long cooperation with Japan, today work with Kyushu, Shinshu and Tsukuba
- DESY develops integrated electronics for 2nd generation scintillator strip ECAL prototype
  - Synergies with HCAL development
  - Scalable to multi-million channels

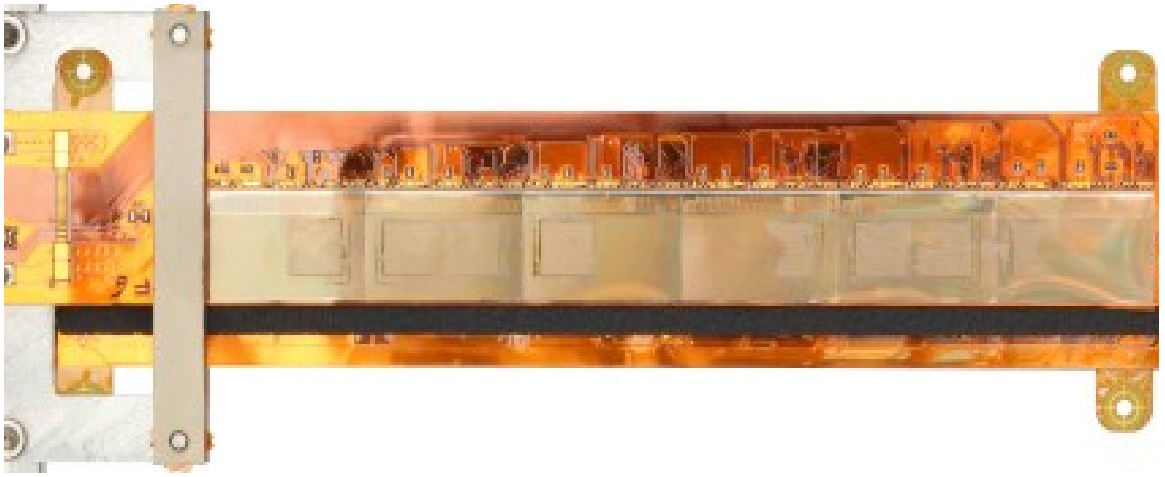
Collaboration meeting in Matsumoto, Japan, March 2012

CALICE Calorimeter for ILC

PLUME: Pixelated Ladder with Ultra-low Material Embedding

Bristol/ DESY/ Oxford/ Strassbourg collaboration

- Prototyping a low mass ladder for the linear collider detector
- First prototypes 2009, first full-scale ladders were designed and fabricated in 2011
  - micro-cables are made of two 20 μm thick metal layers of copper interleaved with 100 μm thick polyimide
  - spacer material was chosen as silicon carbide foam with an 8 % density



8 Mpixels, mass 10 g equivalent to 0.6 % X_0 (cross section) and sensitive surface of 12.7 × 1.1 cm^2

- Good electrical and mechanical performance
- First beam test in November 2011: data is being analyzed

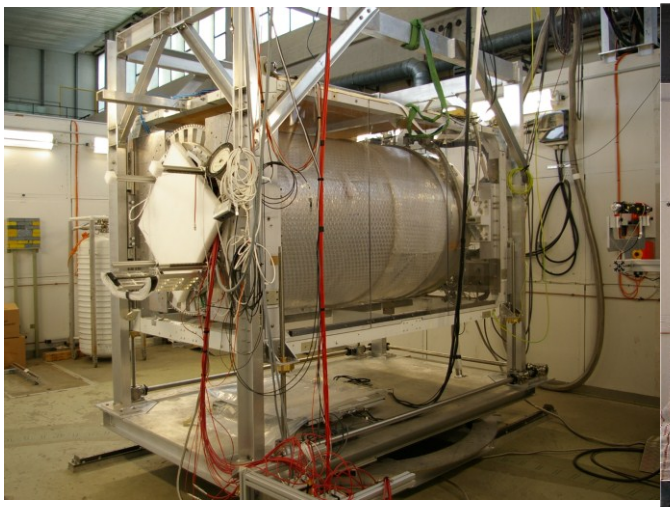
AT DESY:
- Detailed FEA simulations
- Power pulsing studies
- Laser tests
- Preparation of studies in a magnetic field

Tracking R&D

Development of precision tracking:
Time projection chamber

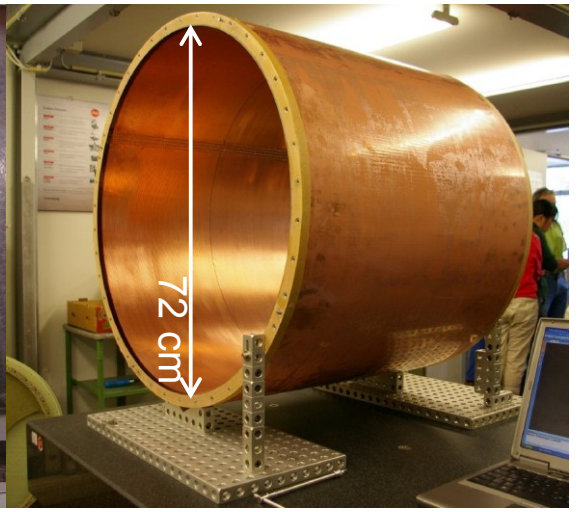
international effort: LC-TPC collaboration

Initial installation and operation in DESY test beam



1.2 T magnet on loan from KEK

Fieldcage



- Develop new gas amplification technologies (GEM readout)
- Develop a TPC for ILC (high Precision device)
- Do extensive test beam experiments (here at DESY) to validate concept

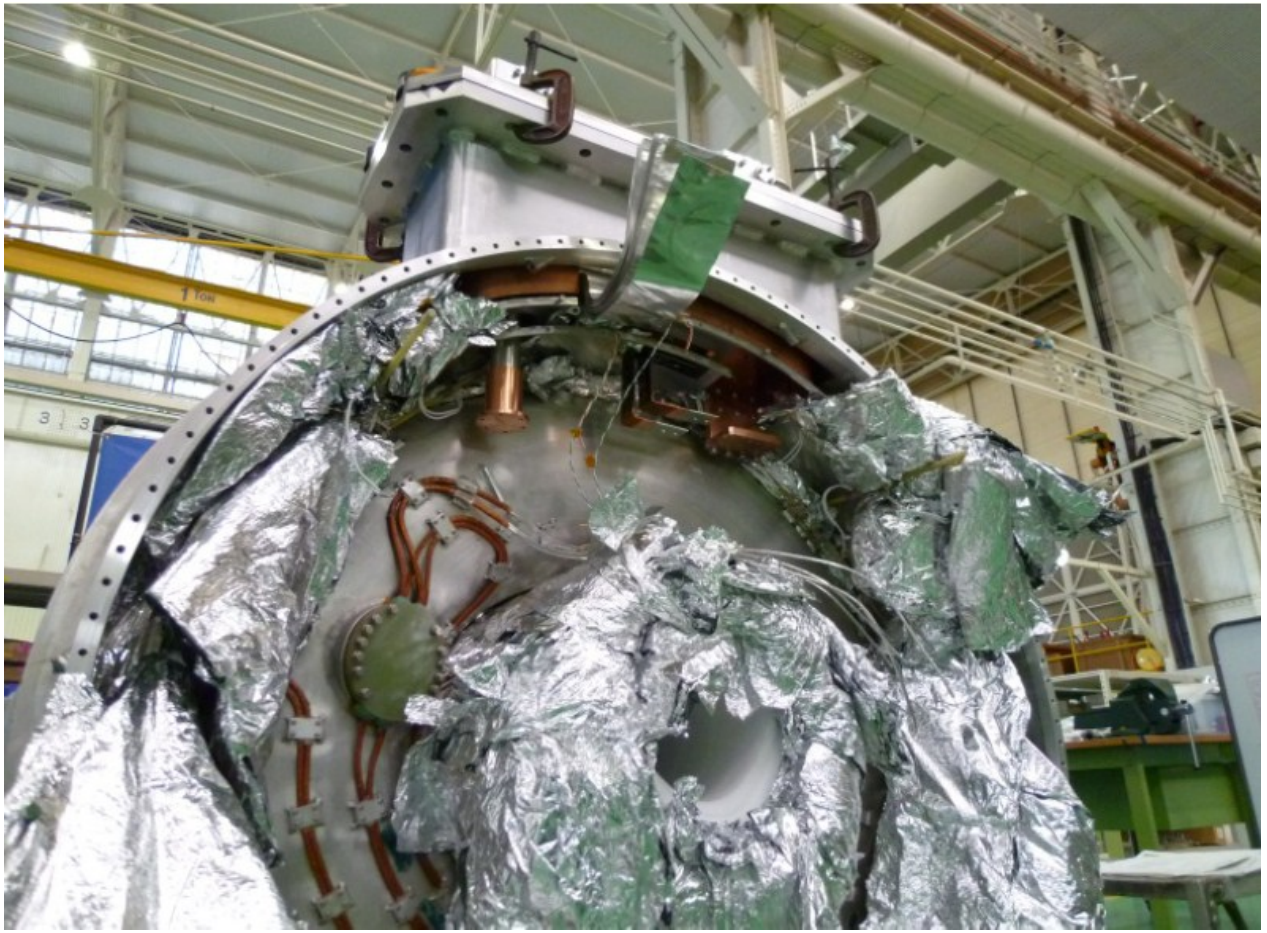
Tracking R&D

Developmen
Time project

collaboration

Initial installati

1.2 T magnet



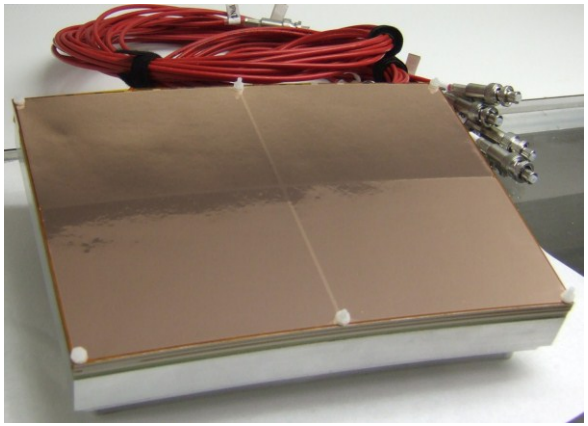
- Develop nev
- Develop a T
- Do extensiv

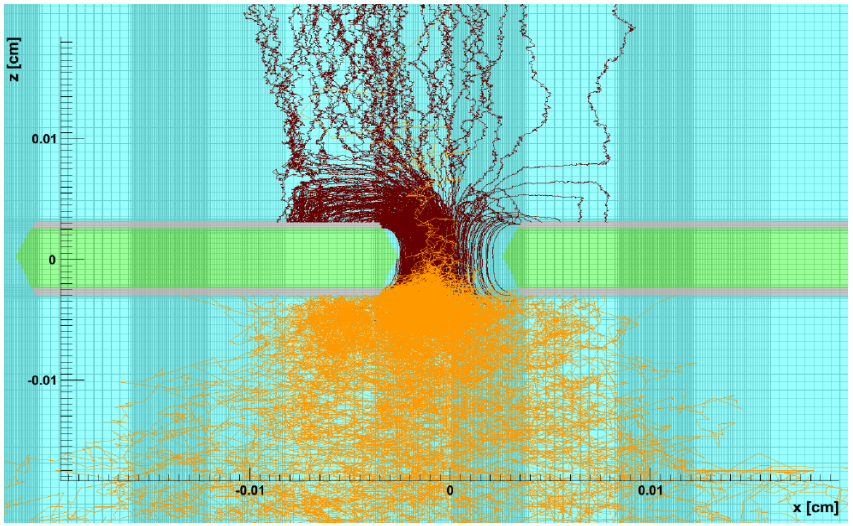
Magnet currently back at KEK/ Toshiba for modification and upgrade.

GEM R&D

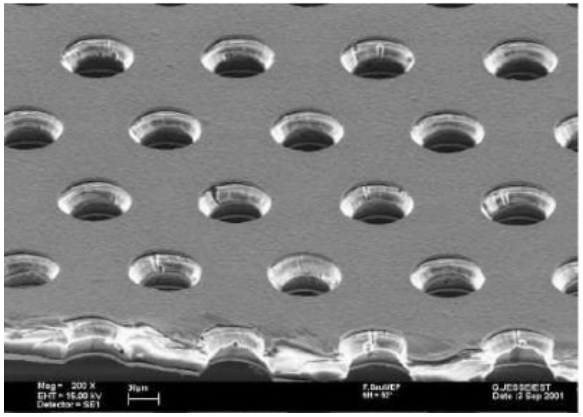
TPC readout module based on GEM technology

- Ceramic spacers
- Low mass/ low dead area construction
- First prototypes 2011, first modules expected 2012





Detailed electrostatic simulations
of the GEM system and simulation
of the amplification step



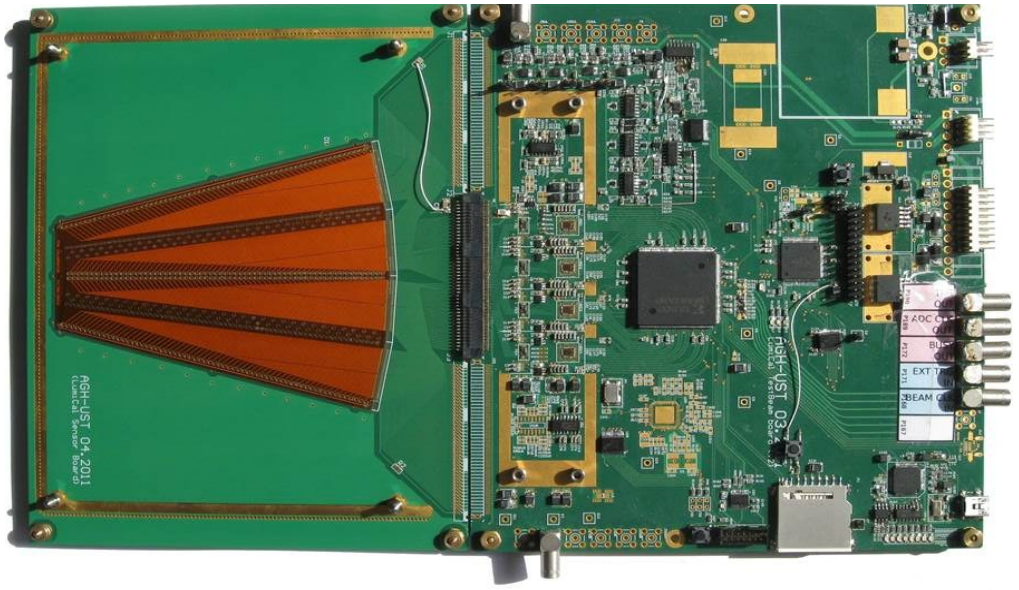
Significant expertise in the handling/ operating
and simulating of GEM systems

Forward Calorimetry for ILD

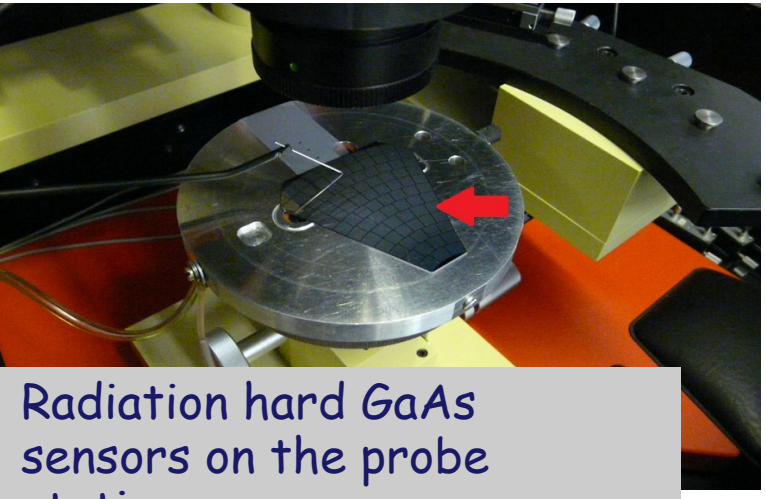
Challenges

- radiation hard sensors (> 1MGy)
- high precision (luminosity)
- compact and fine grained (electron
- detection)
- Fast readout, power pulsing

Fully assembled sensor plane prepared for testbeam measurements



Dedicated FE ADC ASICs (FCAL coll.)

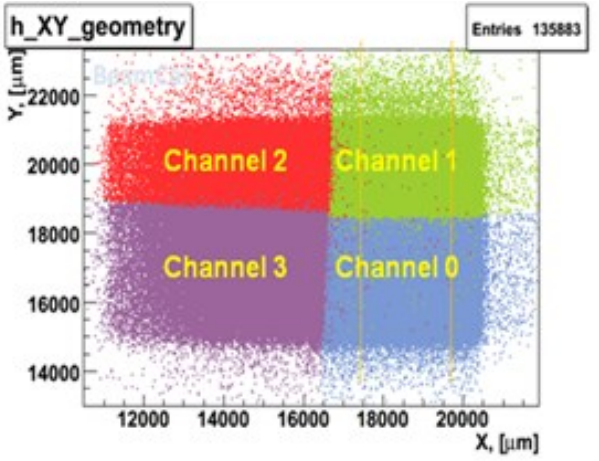


Radiation hard GaAs sensors on the probe station

Test beam results:

- S/N > 20
- Small cross talk
- Excellent homogeneity

Next step within AIDA: Calorimeter prototype

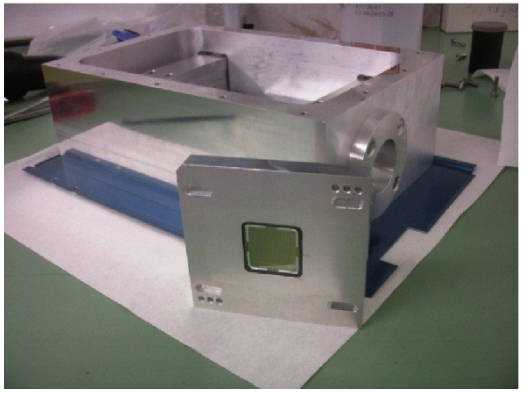


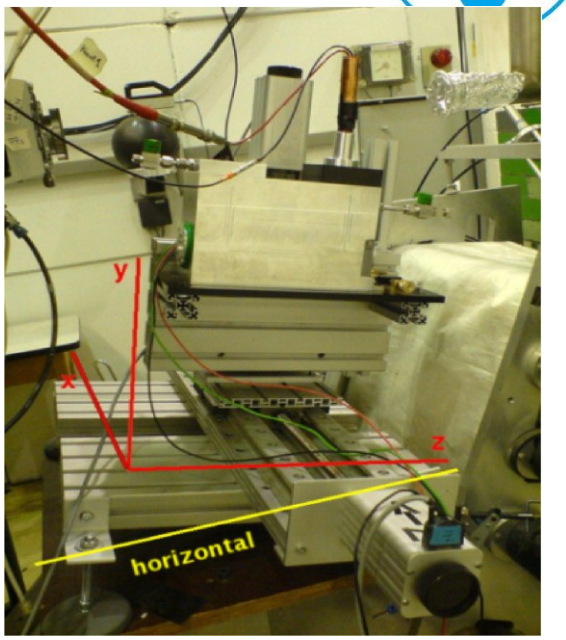
Beam Instrumentation

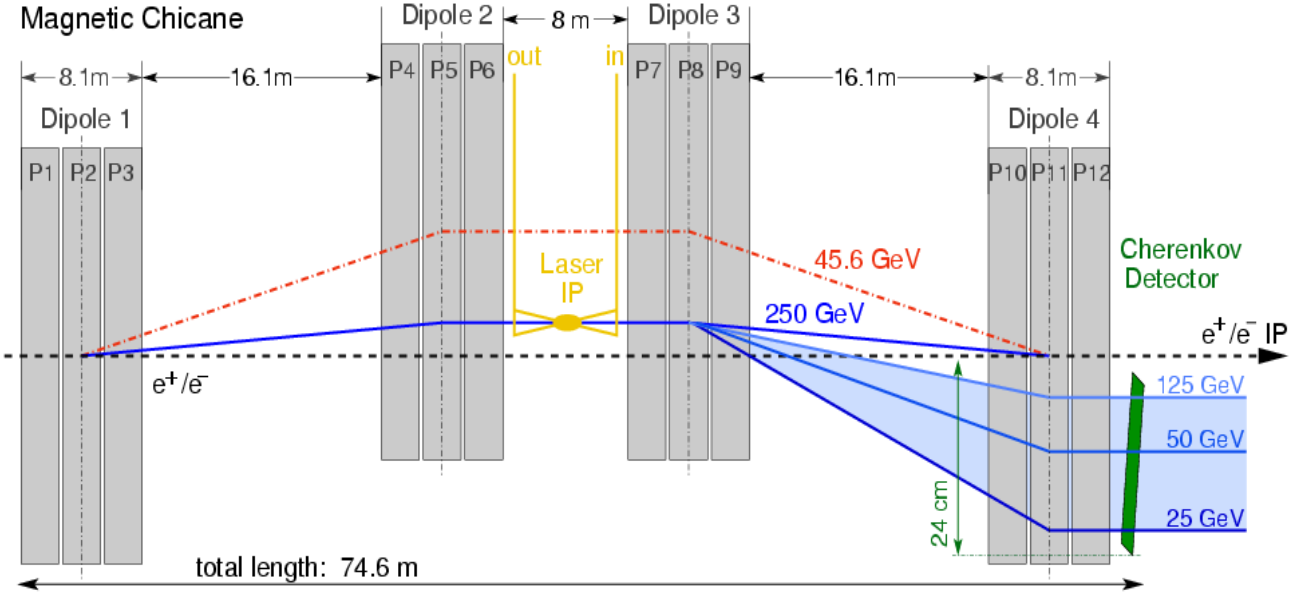
High energy polarimetry for lepton colliders:

- Detector development for unprecedented precision
- Design of polarimeter chicanes including magnets, lasers, detectors (e.g. Cherenkov detector, with SiPM)
- Spin tracking from polarimeters to collision point

=> impact on accelerator design!







Summary

For LHC: strong focus on Silicon technologies

establish DESY as a main center for LHC upgrade projects in Germany

For future projects

Pursue a number of key technologies needed for high precision detectors
Calorimetry
Tracking

Develop key expertise for modern precision detectors

DESY: remain a strong partner in international detector projects in particle physics,
Strong in detector integration
Leading in innovative technologies

Strong and excellent relations to KEK in detector projects