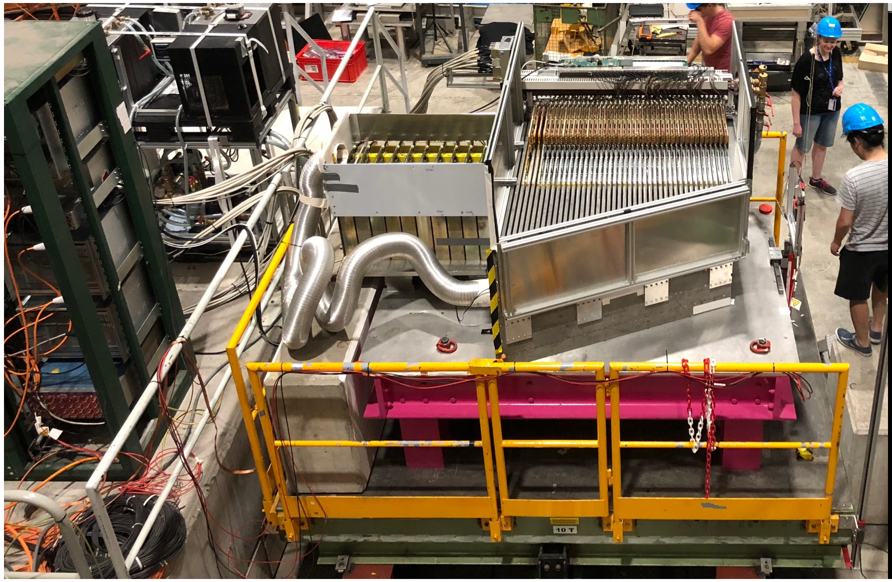
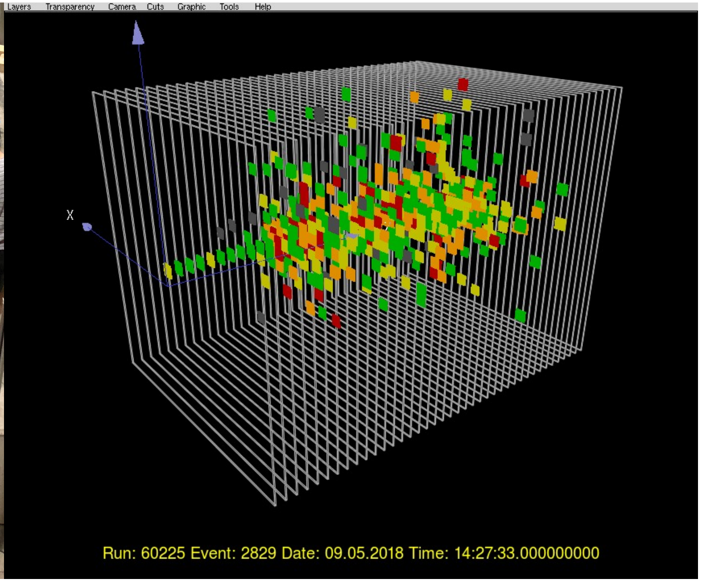
ILC R&D



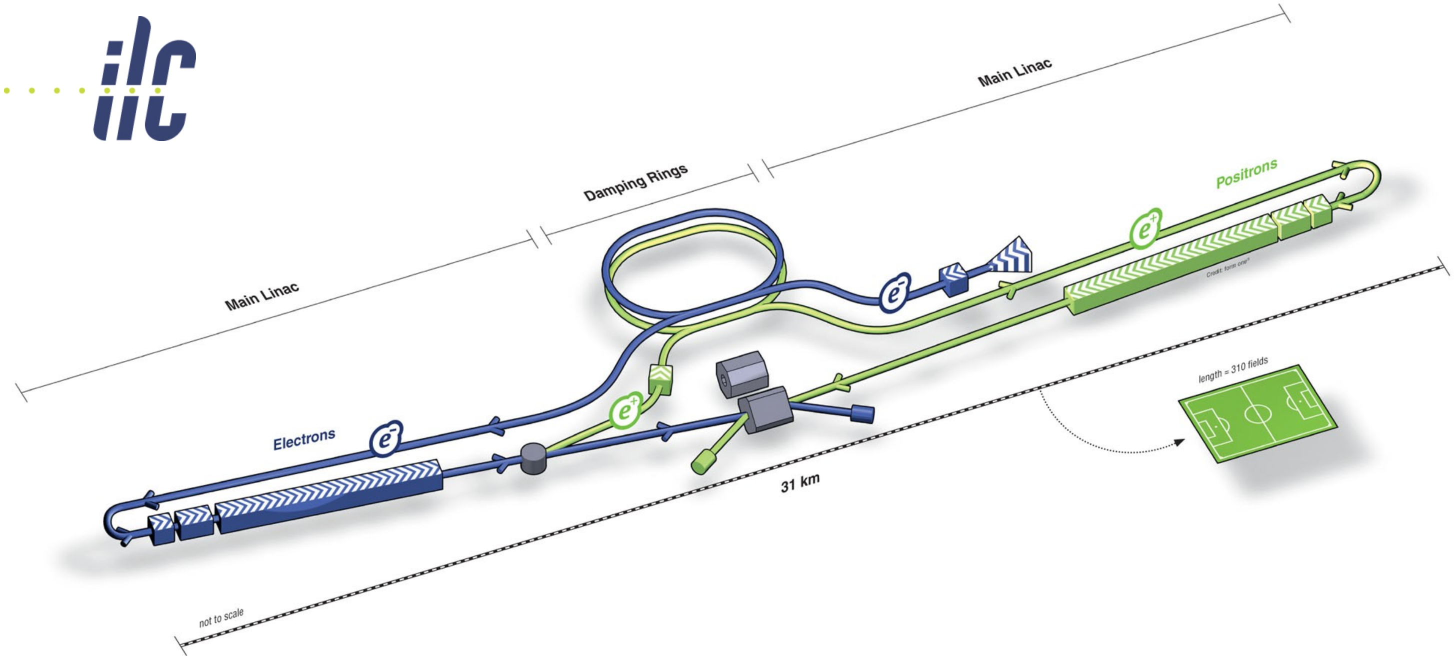


Katja Krüger

86. Physics Research Committee

DESY Zeuthen, 16. October 2018

The International Linear Collider – ILC



- e⁺e⁻ collider with √s from 90 GeV to 1 TeV, initial stage at 250 GeV
- 31 km long, SCRF technology
- global collaboration (~130 institutes)
- 2 detector concepts: ILD and SiD

- under political consideration in Japan. Input expected for European Strategy Update in 2018

ILC in Japan

ILC Timeline

2013 2017	US･EU･Labs. in the world Support ILC in Japan
2018	Japan-France･Japan-Germany Established Government – Politic- Academic Body July 2018 Expert Committee in MEXT by fall 2018 Discussion in Science Council of Japan by the end of Dec. 2018 Expression of Interest from Japanese government
2019	Japan-US intergovernmental discussion Discussion of 5 year European Strategy

S. Yamashita at FCCJ

ILC at DESY

strong effort in several key areas

- accelerator
  - SCRF cavities
  - positron source
- machine detector interface
- detector development
  - Time Projection Chamber
  - forward calorimeter
  - highly granular scintillator SiPM-on-tile calorimeter (AHCAL)
- analysis
  - Higgs
  - BSM
- software

ILC at DESY

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- machine detector interface
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  - Time Projection Chamber
  - forward calorimeter
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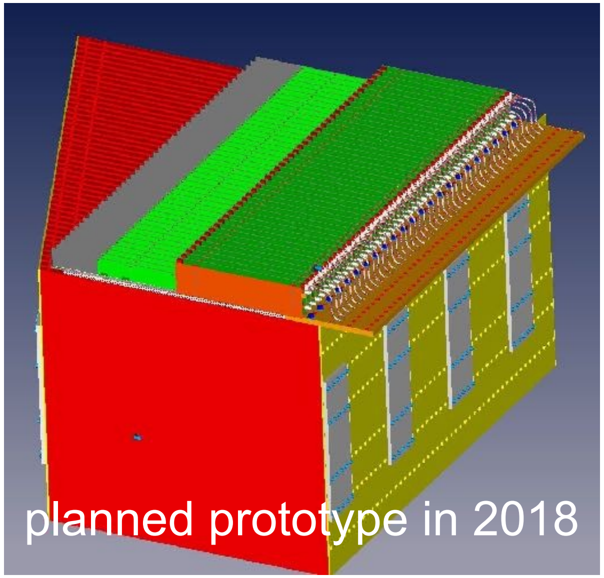
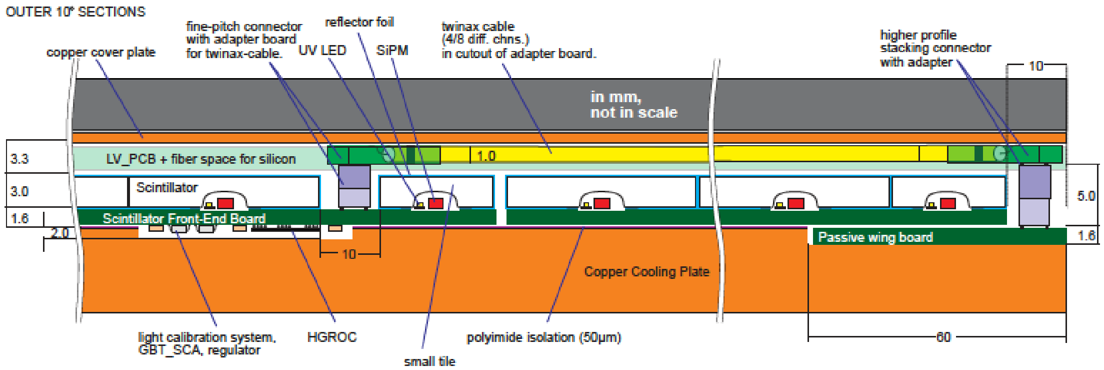
- analysis
  - Higgs
  - BSM
- software

Highly granular SiPM-on-tile calorimeter: 1 year ago

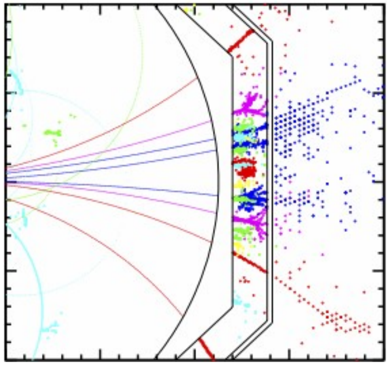
status 1 year ago (last report in PRC open session)

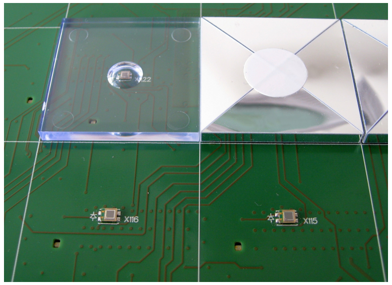
- CALICE AHCAL
  - plan to operate a large prototype in beam in 2018
  - production in full swing, but no complete layer assembled yet
- CMS calorimeter endcap upgrade for HL-LHC
  - adopted SiPM-on-tile technology for backward part
  - finalizing the Technical Design Report
  - first common testbeams with small prototypes



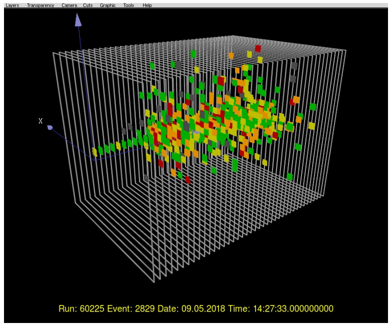


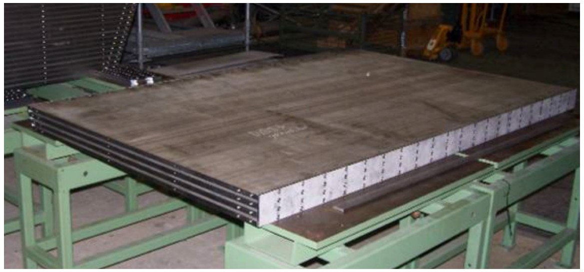
AHCAL prototype





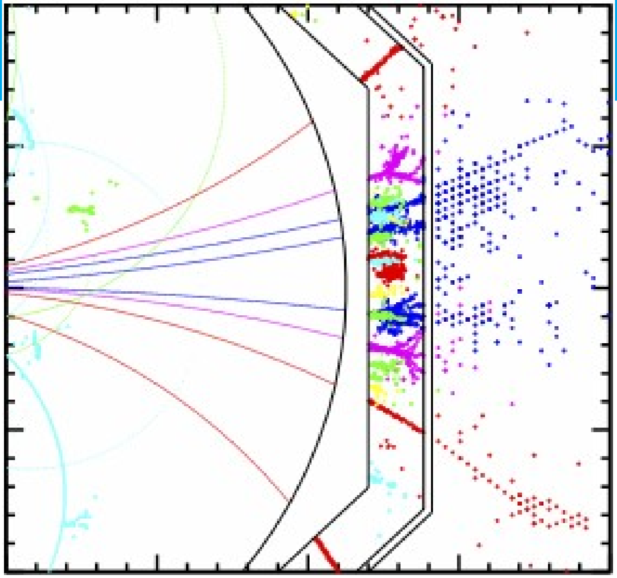
- motivation
- design
- construction
- testbeam experience
- future plans

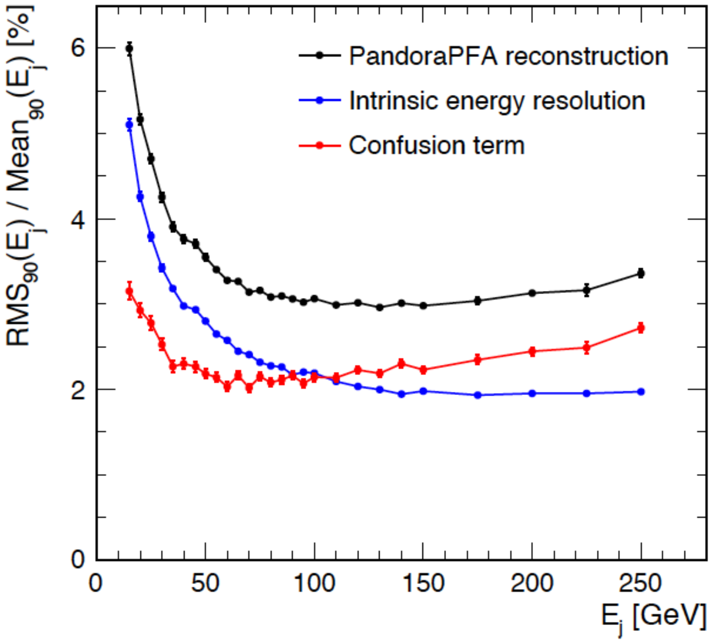




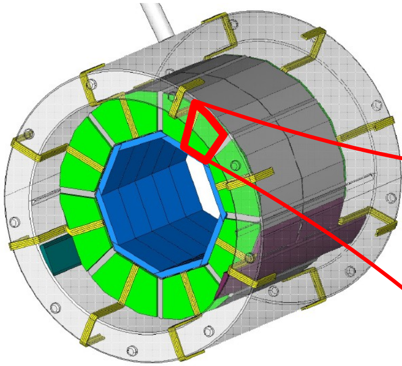
Particle Flow Reconstruction

- aim for ILC detectors: 3-4% jet energy resolution
- not possible with calorimeter information alone
  → use Particle Flow Algorithms
- idea: for each individual particle in a jet, use the detector part with the best energy resolution
- „typical" jet:
  ~ 60% charged particles → tracker
  ~ 30% photons → EM calorimeter
  ~ 10% neutral hadrons → HAD calorimeter
  ~ 1% neutrinos → undetected
- separating the energy depositions of individual particles requires high granularity
- calorimeter energy resolution is still important
  - dominates for jets up to 100 GeV
  - contributes to resolving confusion
- small scintillator tiles provide both: good spatial and good energy resolution

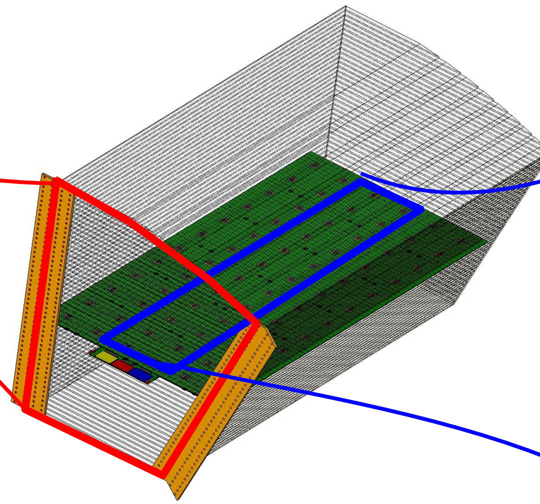


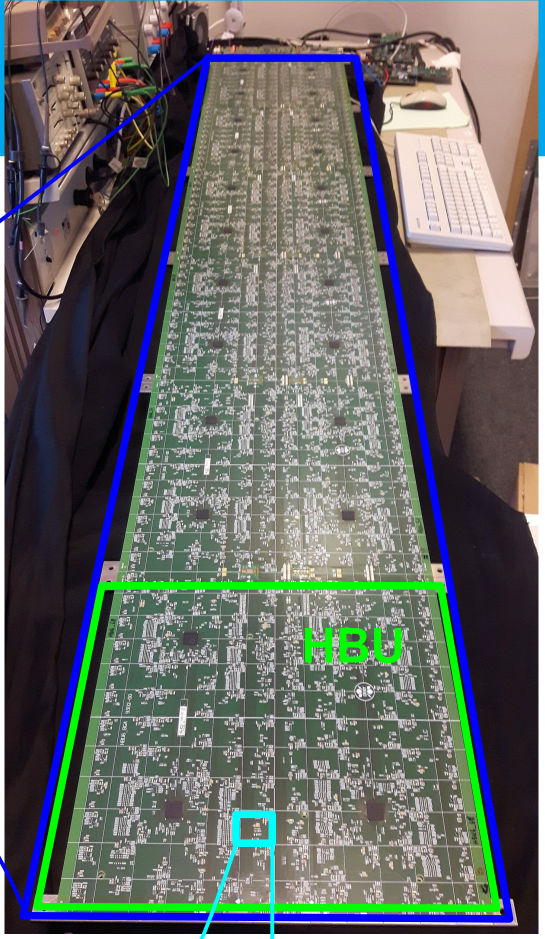


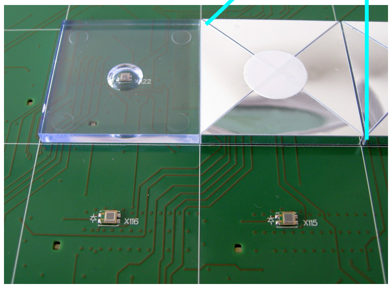
AHCAL technological prototype: design



ILD barrel





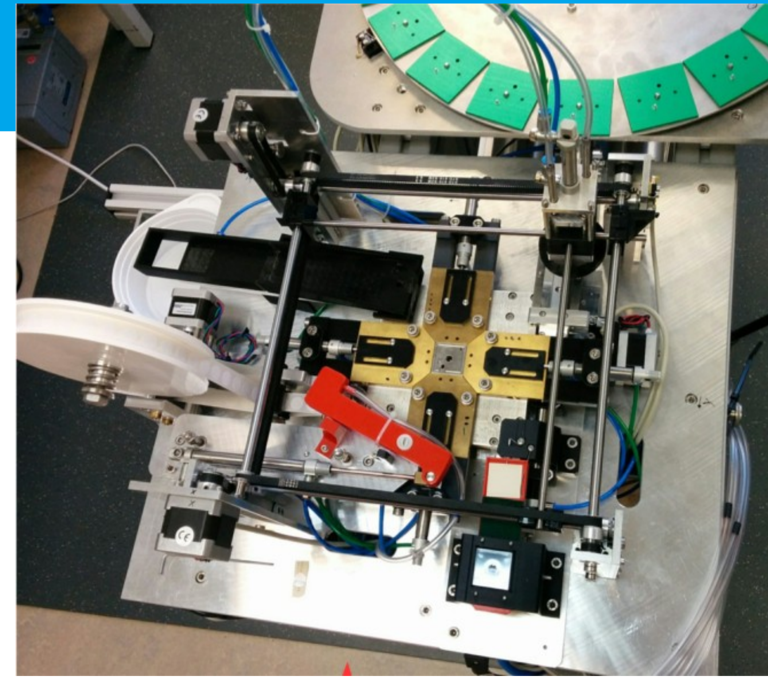


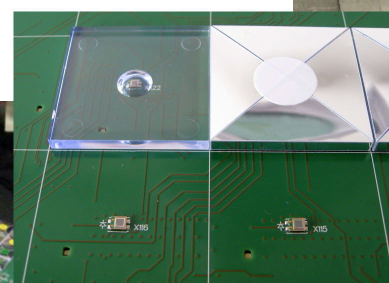
- highly granular scintillator SiPM-on-tile hadron calorimeter, 3*3 cm² scintillator tiles
- fully integrated design
  - front-end electronics, readout
  - voltage supply, LED system for calibration
  - no cooling within active layers
- scalable to full detector (~8 million channels)
- **H**CAL **B**ase **U**nit: 36*36 cm^2, 144 tiles, 4 ASICs
  - slabs of 6 HBUs
  - up to 3 slabs per layer

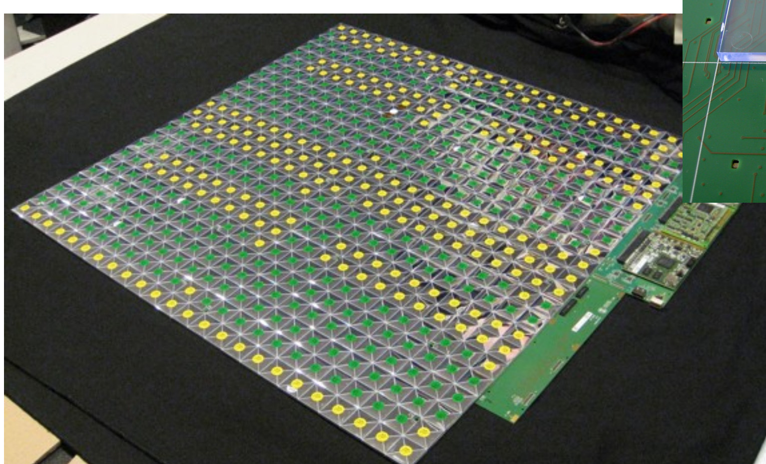
DESY.

AHCAL prototype design

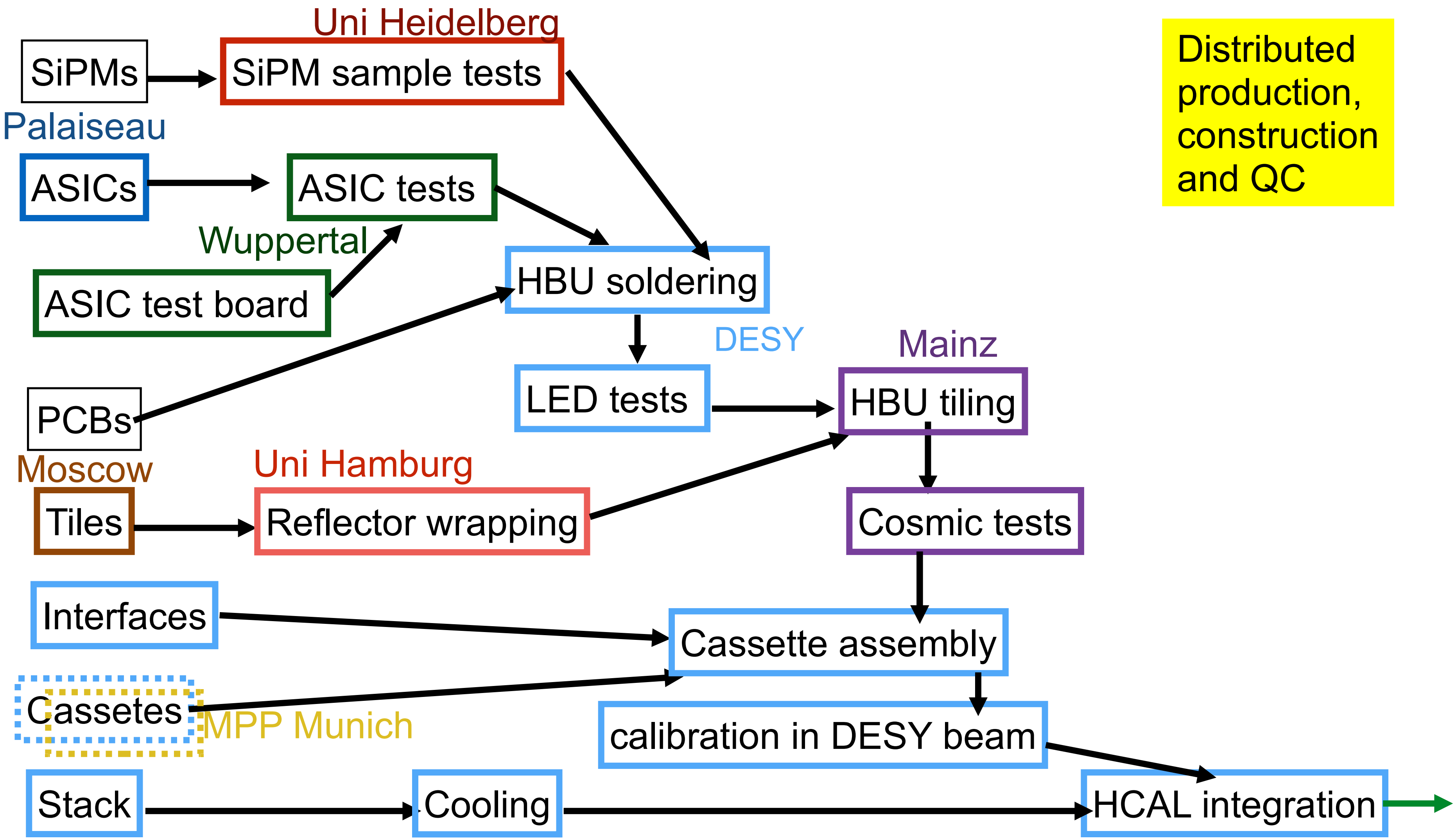
- 38 active layers of 2*2 HBUs (72*72 cm²)
- in total: 608 ASICs, ~22000 channels
  - ~0.5% of ILD barrel
- design optimized for mass production
  - surface-mount SiPMs
  - injection-moulded polystyrene tiles
  - automatic wrapping in ESR reflector foil
  - glueing of tiles with screen printer and pick-and-place machine





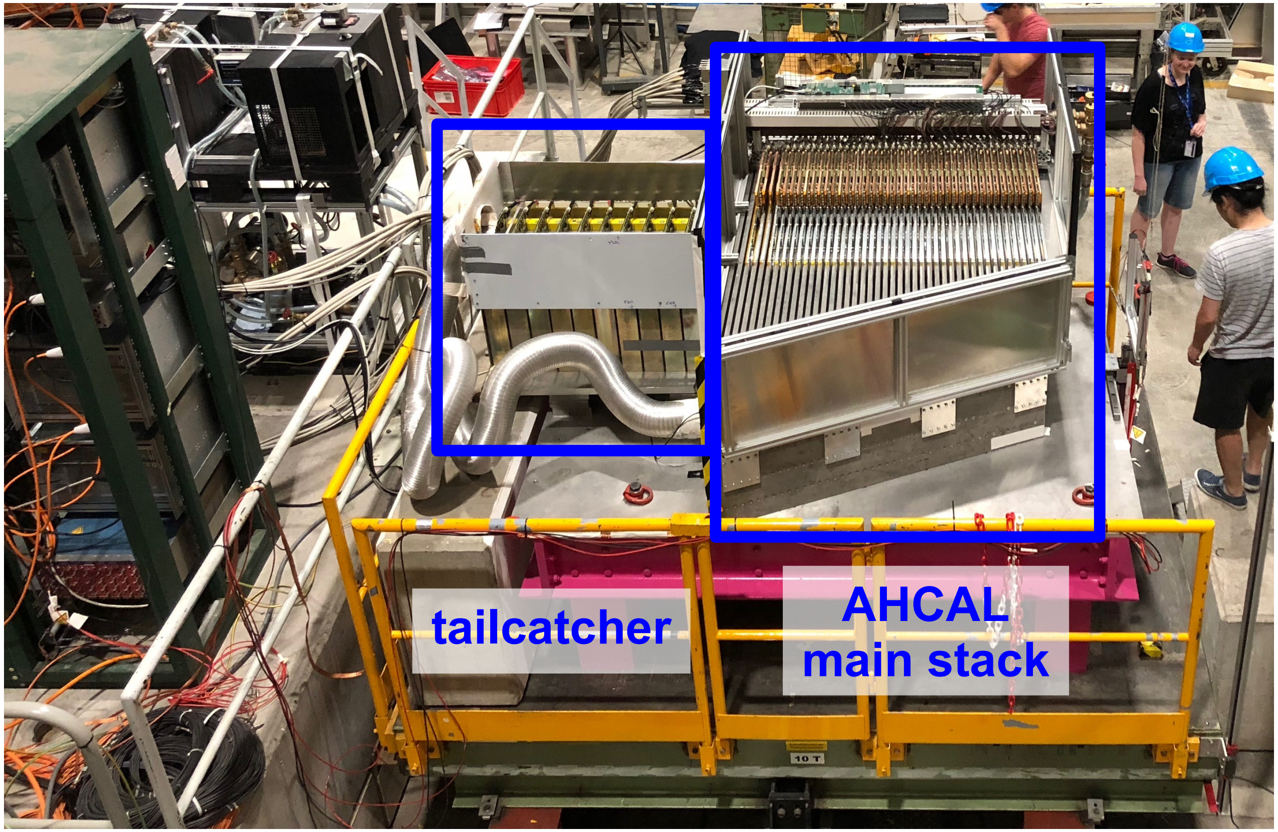


AHCAL prototype construction: work flow



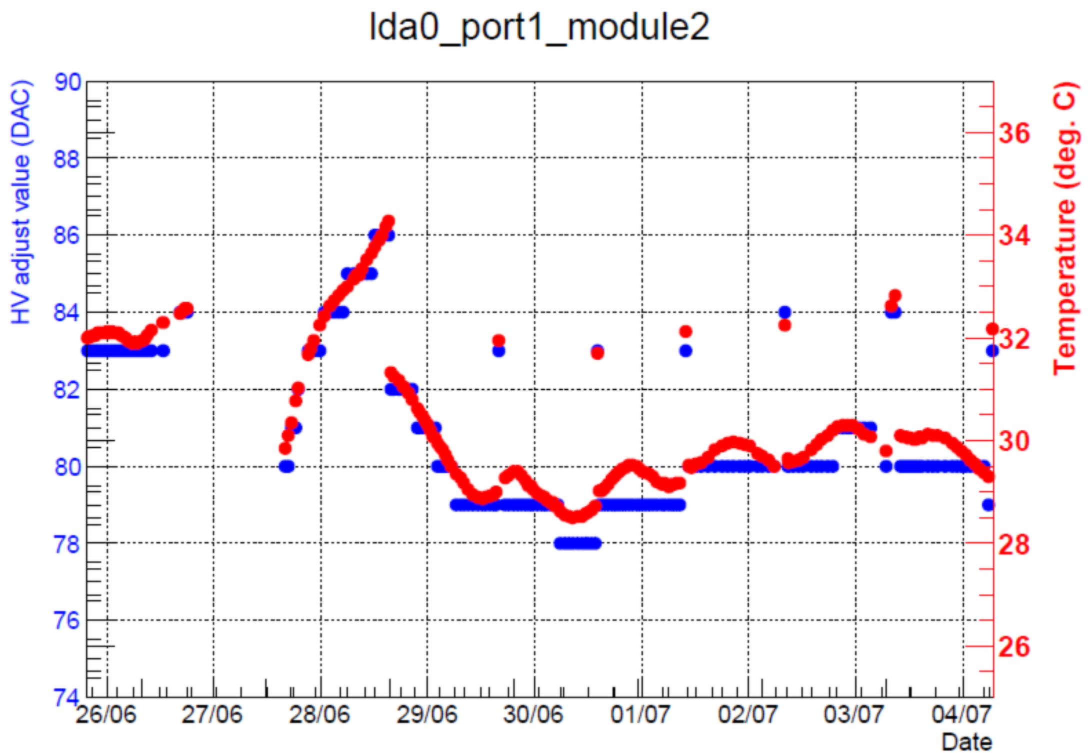
Distributed production, construction and QC

AHCAL Testbeam: 3 weeks at CERN SPS in May and June 2018



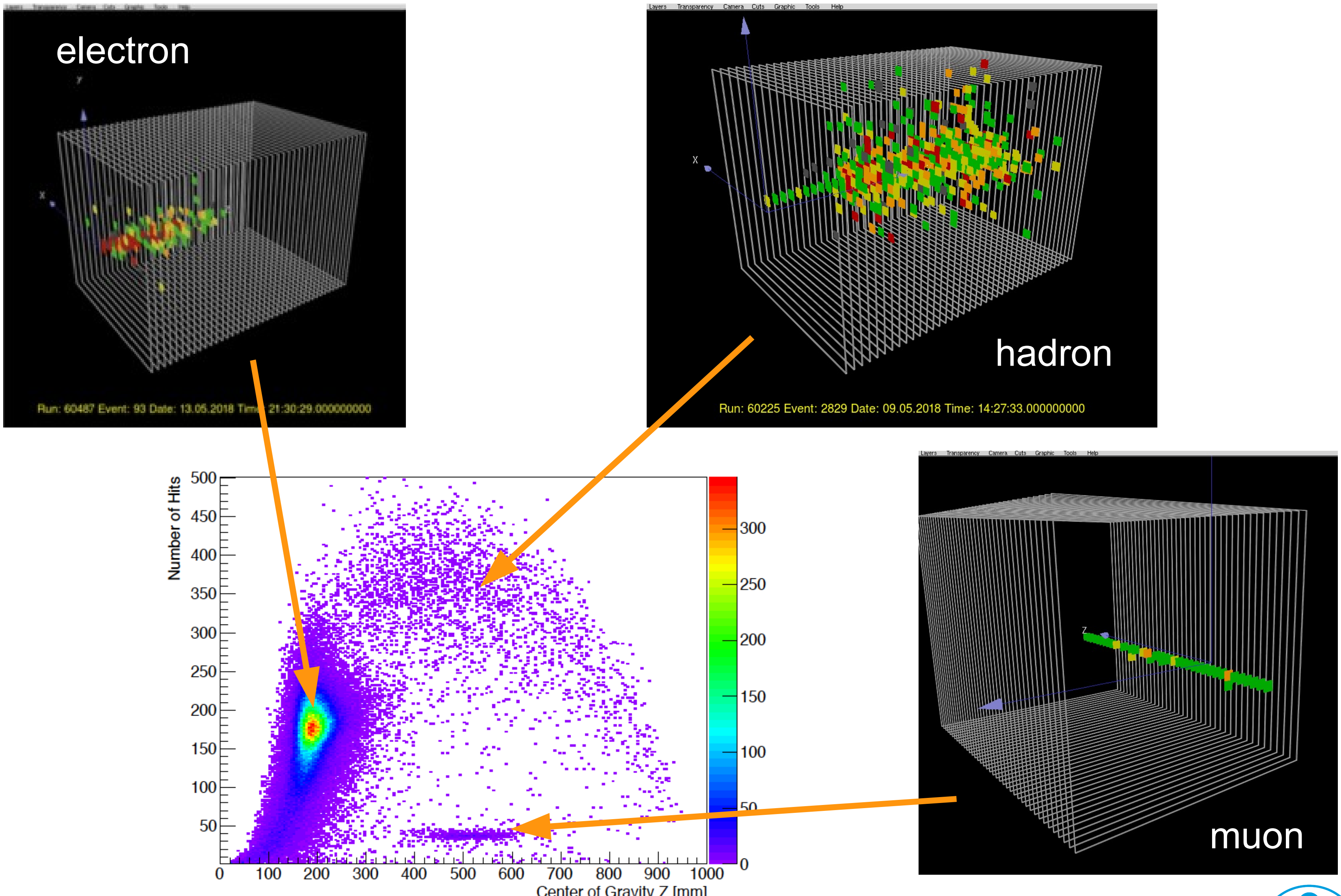
- setup:
  - AHCAL with 39 active layers of 4 HBUs, 1.7 cm steel absorber (~4 λ)
  - tailcatcher: 12 layers of 1 HBU (older generation), 7.4 cm steel absorber (~4 λ)
- mounted on the movable platform, allows position scans
- very successful data taking (>50 mio events), **<1‰ dead channels**

AHCAL Testbeam operation: temperature compensation

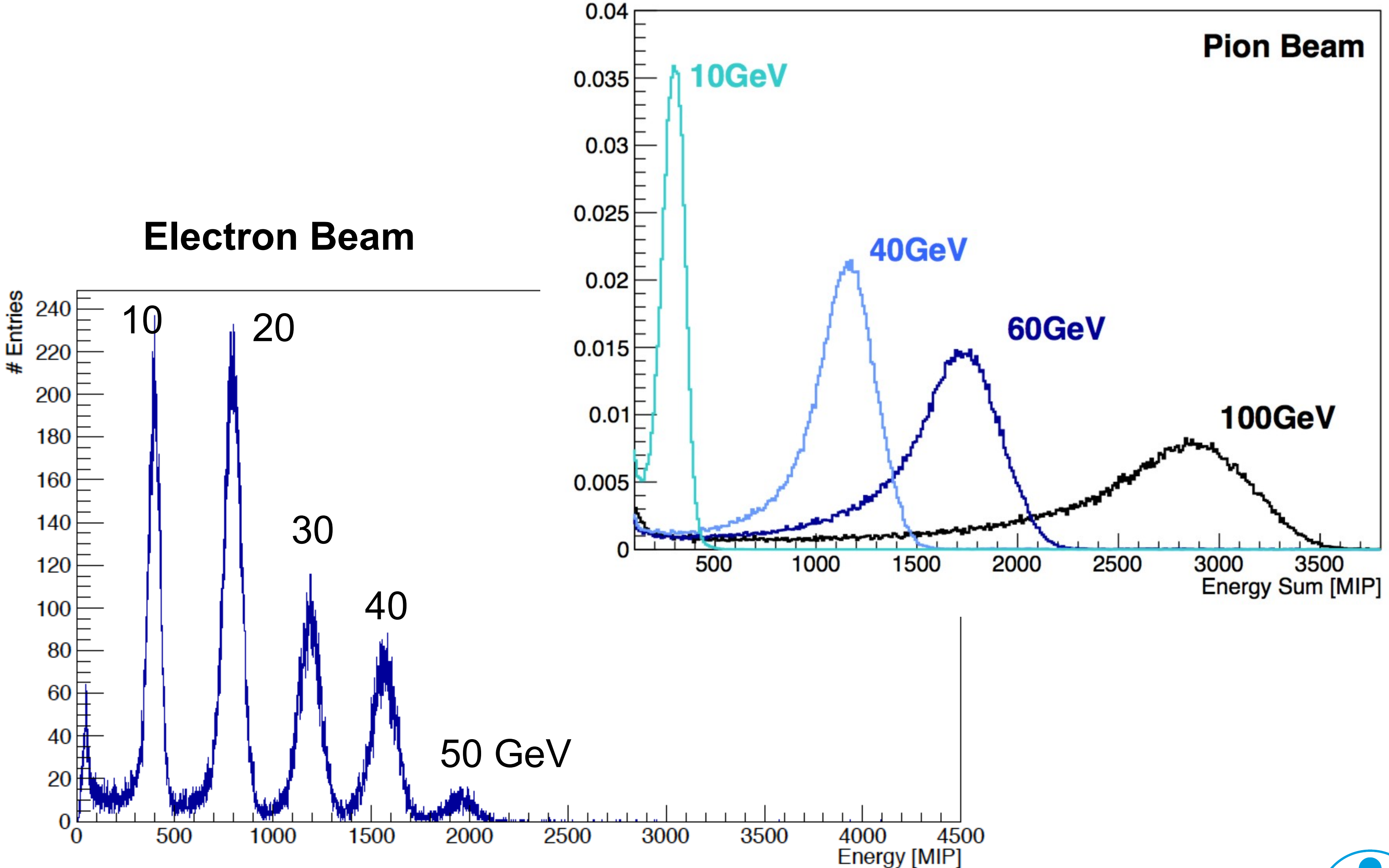


- gain and photon detection efficiency of SiPMs depend on temperature
  - can avoid changes by stabilizing temperature or adapting bias voltage (HV)
- temperature compensation: use mean temperature in a layer to adjust HV
- used routinely, HV changes as expected, gain stays stable

AHCAL testbeam: event displays

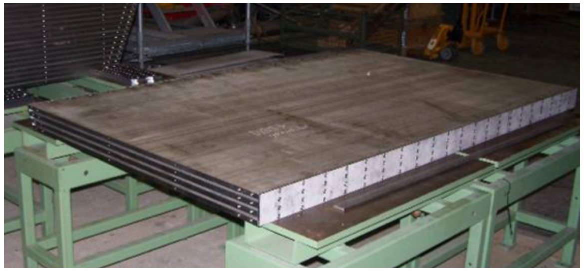


AHCAL Testbeam: Energy Sums (Online Monitoring)



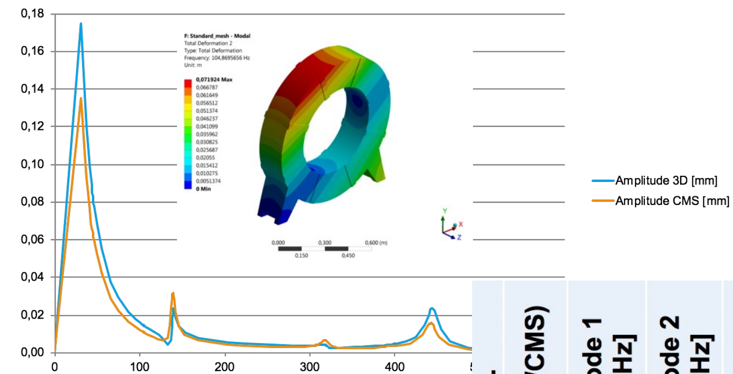
AHCAL prototype: future plans

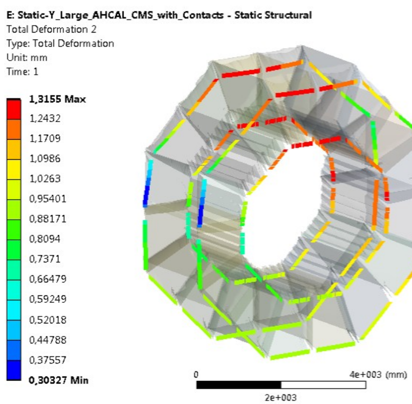
- have collected a unique dataset
  - can resolve spatial and temporal development of hadronic showers in detail
  - of general interest for the understanding and modeling of hadronic showers
  - analysis has high priority now
- future tests with the prototype
  - ongoing: combined testbeam with CMS HGCAL prototype at CERN SPS
  - further plans will depend on overall progress of linear collider projects
    - combined beam test with electromagnetic calorimeter in front is highly desirable for realistic performance studies
  - beam tests with faster clock to reach expected timing resolution of ~1ns
  - beam tests with (existing) tungsten absorber structure
  - test of full-sized ILD layers (3*6 HBUs), absorber structure for 3 layers available



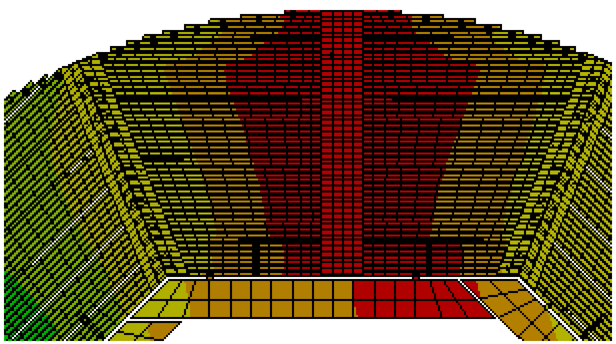
AHCAL for ILD: earthquake simulations

- ambitious design without vertical discs to keep electronics accessible
- earth quake stability dynamical simulations computational challenge
- Component Mode Synthesis (CMS) method reduces data volume by 2 orders of magnitude
- reproduce eigen modes and response for simplified model
- updated dimensions of full model, integrated ECAL and optimised static rigidity
- dynamic validation next





Pos.	Type (3D/CMS)	Eigenmode 1 at f [in Hz]	Eigenmode 2 at f [in Hz]	Eigenmode 3 at f [in Hz]	Eigenmode 4 at f [in Hz]
1	CMS	7,2	15,0	21,9	28,3
2	3D	7,0	14,9	22,1	28,4



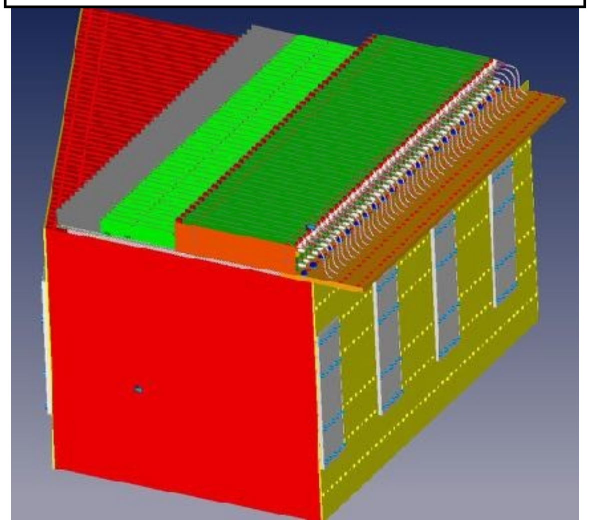
SiPM-on-tile technology: possible applications

SiPM-on-tile technology has many advantages, making it interesting for application in several areas of particle physics

- e^+e^- colliders
  - ILC: ILD, SiD
  - detector for CLIC
  - detector for CepC
- pp colliders
  - upgrade of CMS calorimeter endcap for HL-LHC (HGCAL)
- neutrino beam experiments
  - DUNE near detector

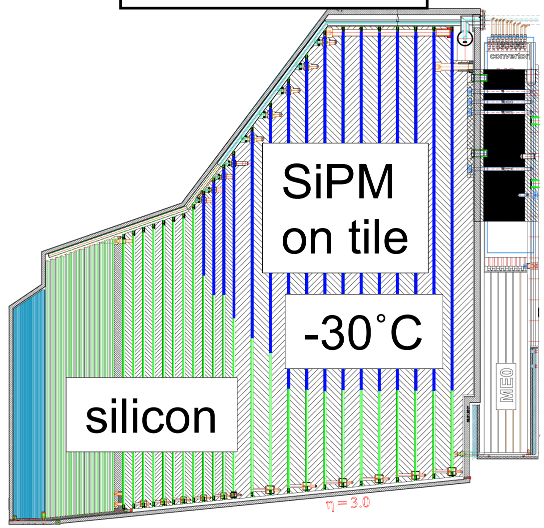
Scintillator part of CMS HGCAL

CALICE AHCAL prototype



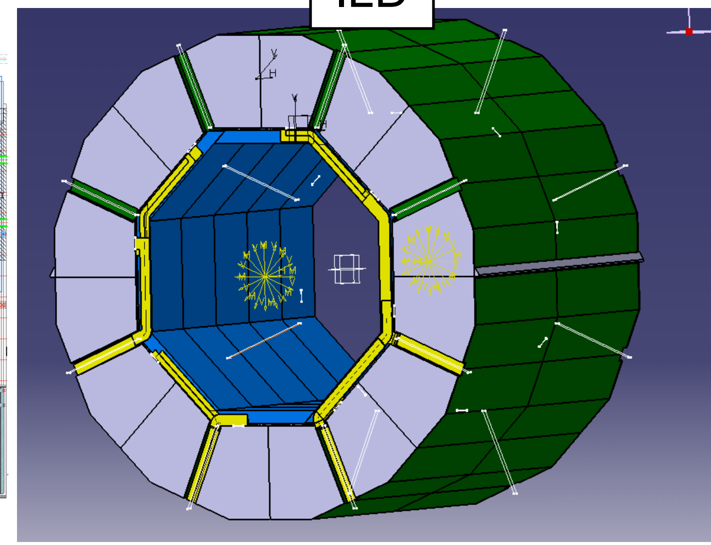
22’000 SiPMs

CMS HGCAL



500’000 SiPMs

ILD



8’000’000 SiPMs

- design: scintillator with SiPM-on-tile technology where allowed by radiation
- Intermediate scale, new challenges: radiation, high data rate, operation -30 °C
- Technical Design Report approved in February 2018
- Engineering Design Report and start of production for many components in 2021
- assembled endcaps need to be ready for lowering in August and Dec. 2024

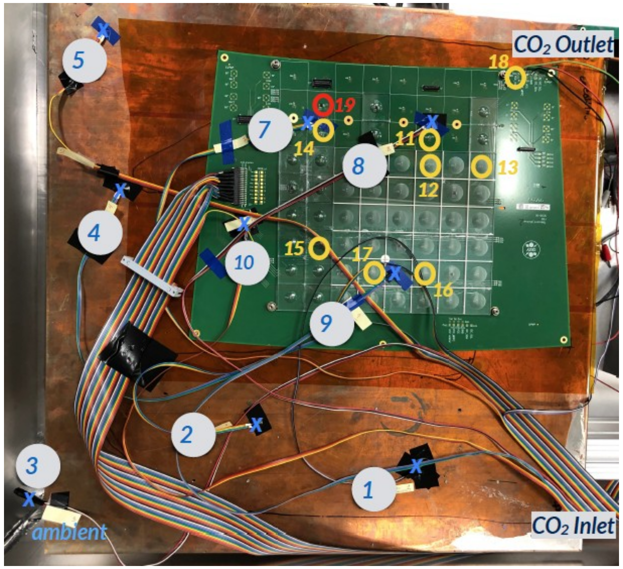
DESY involvement in CMS HGCAL

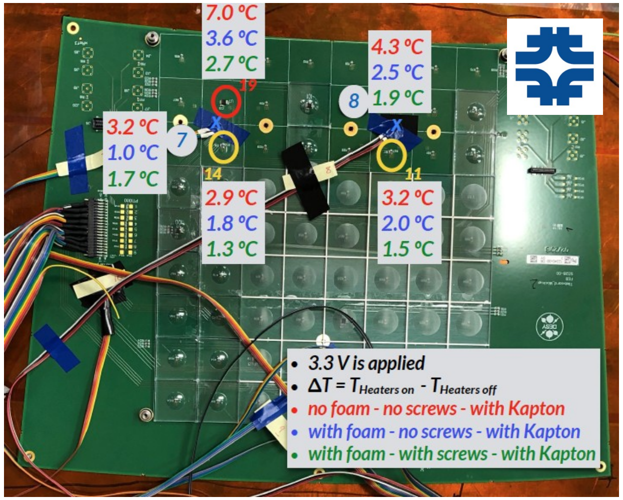
- DESY has unique experience in key areas of SiPM-on-tile technology
  - ideal partner for CMS HGCAL project
  - mutual benefits

- DESY has taken over responsibilities in HGCAL in these areas:
  - board level design for SiPM-on-tile readout boards (“Tileboards”)
  - preparation and optimization of production techniques and test procedures for the assembly of the readout boards with tiles
  - combined testbeam with AHCAL prototype as prototype for the scintillator part of the HGCAL, coordination

DESY involvement in HGCAL: Tileboard design

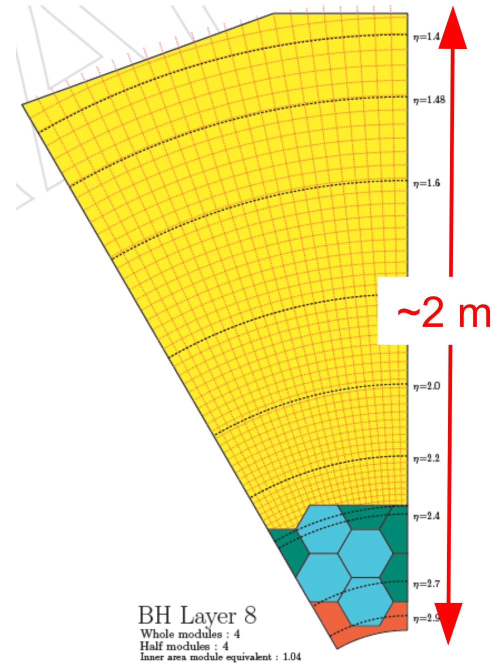
- Tileboards are similar in size and functionality to HBUs, but have a number of major differences
  - different readout ASIC
  - much higher data rate
  - radiation hardness
  - operation at –30°
  - cooling of SiPMs through the PCB
- design in steps:
  - thermo-mechanical mockup
    - designed and produced at DESY, tested at Fermilab, results look good
  - Tileboard-0: communication via GBT
    - schematics done, in layout now
    - profit from GBT expertise at DESY (ATLAS Upgrade)
  - Tileboard-1: first board with HGCROC-DV1 and SiPMs

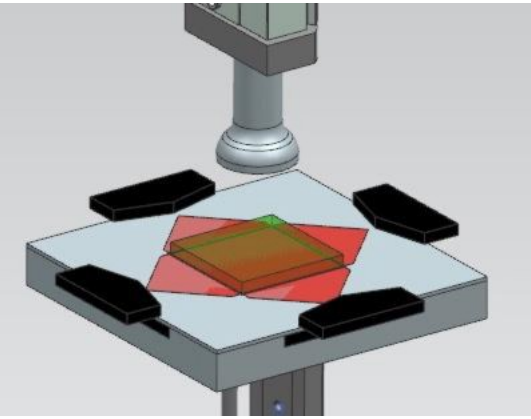


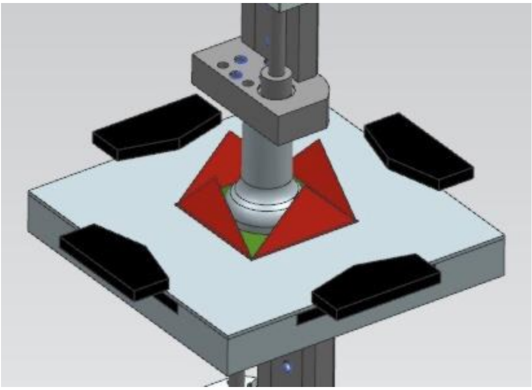


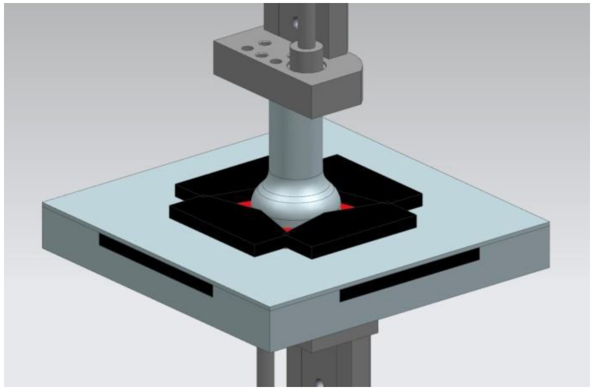
HGCAL at DESY: preparation of production technique

- production and construction of large CALICE AHCAL prototype worked very well, but also identified some room for improvement, especially in the handling of the wrapping foil
- CMS HGCAL differs in some aspects
  - tiles are not quadratic, but trapezoids
  - tiles have various sizes from ~2 to 5.5 cm side length
- plan to set up a pilot Tileboard Assmbly Center at DESY that demonstrates the full chain of the board assembly

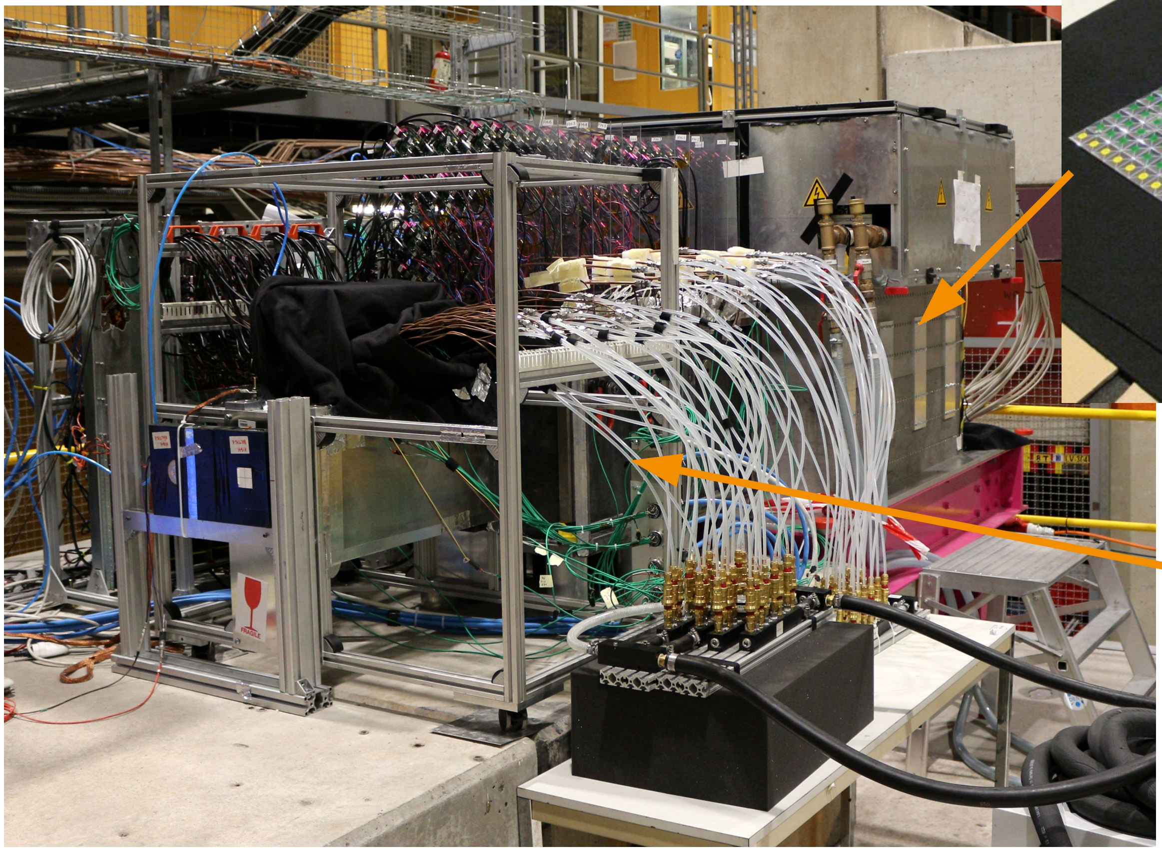


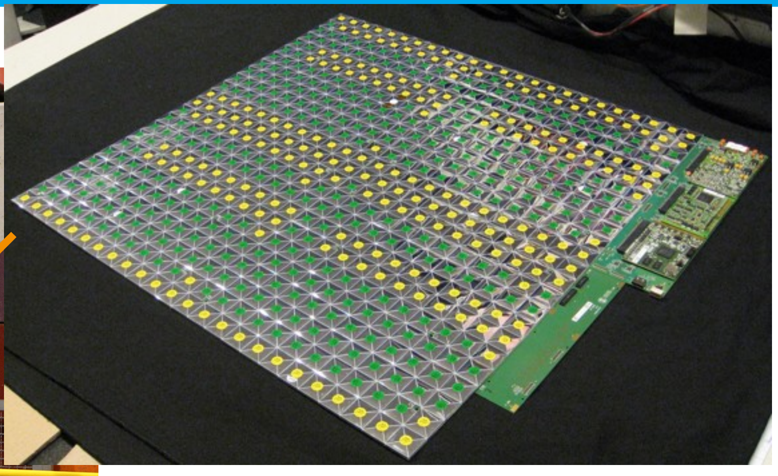


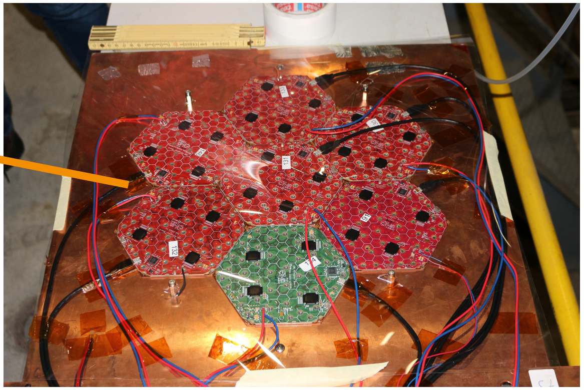




DESY involvement in HGCAL: combined testbeam

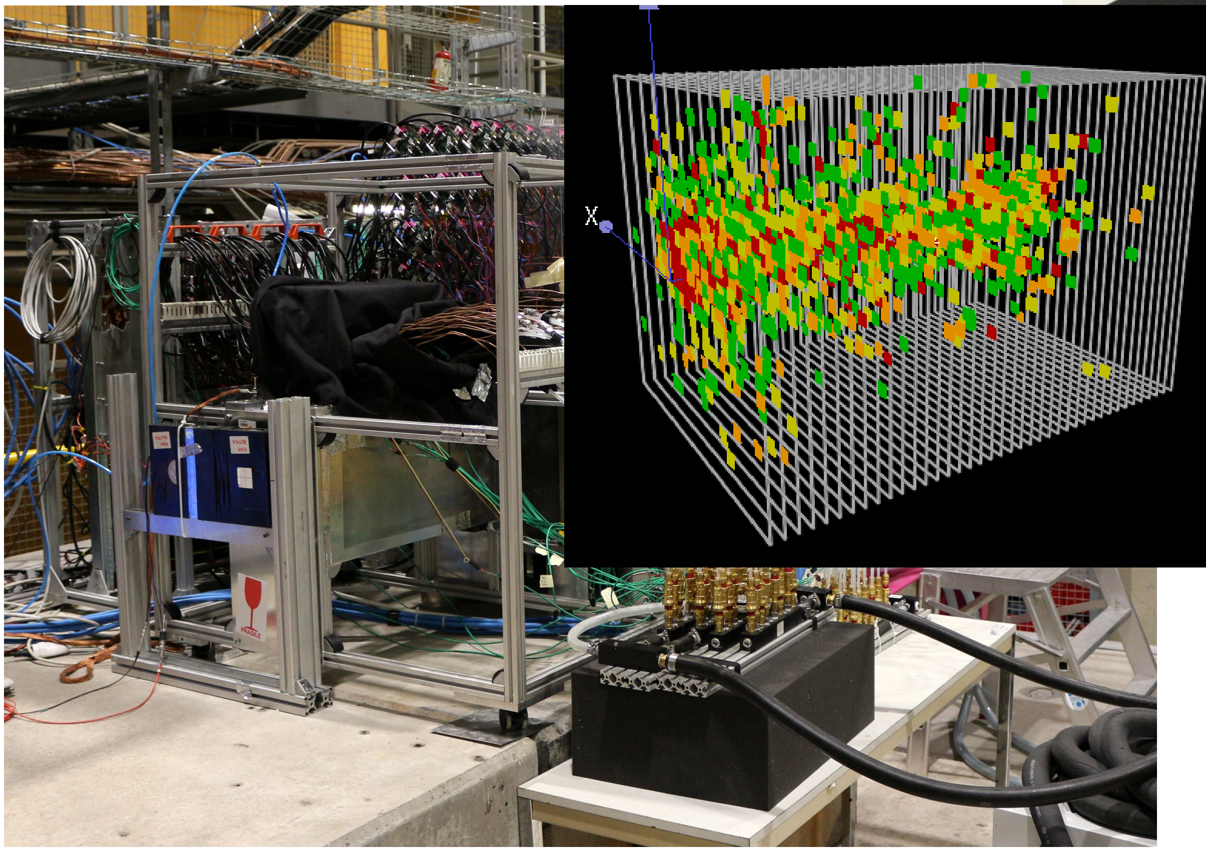


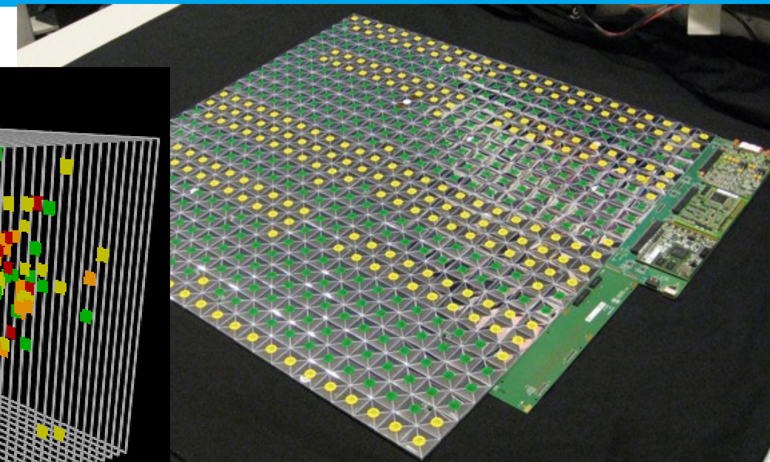


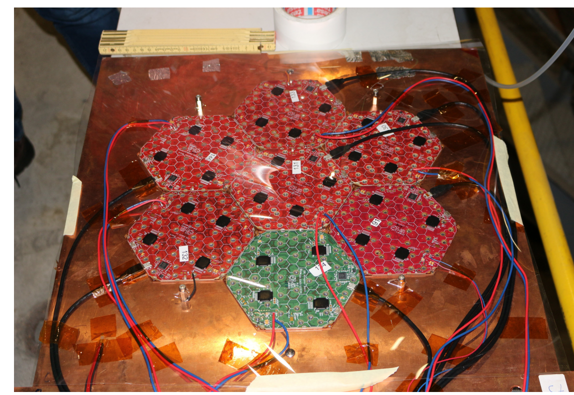


- 2 weeks of combined testbeam at CERN SPS, ongoing
- 28 layers HGCAL EE (silicon/lead), 12 layers HGCAL FH (silicon/steel), 39 layers AHCAL (scintillator/steel)
- important test of concept, important information for simulation of showers

DESY involvement in HGCAL: combined testbeam







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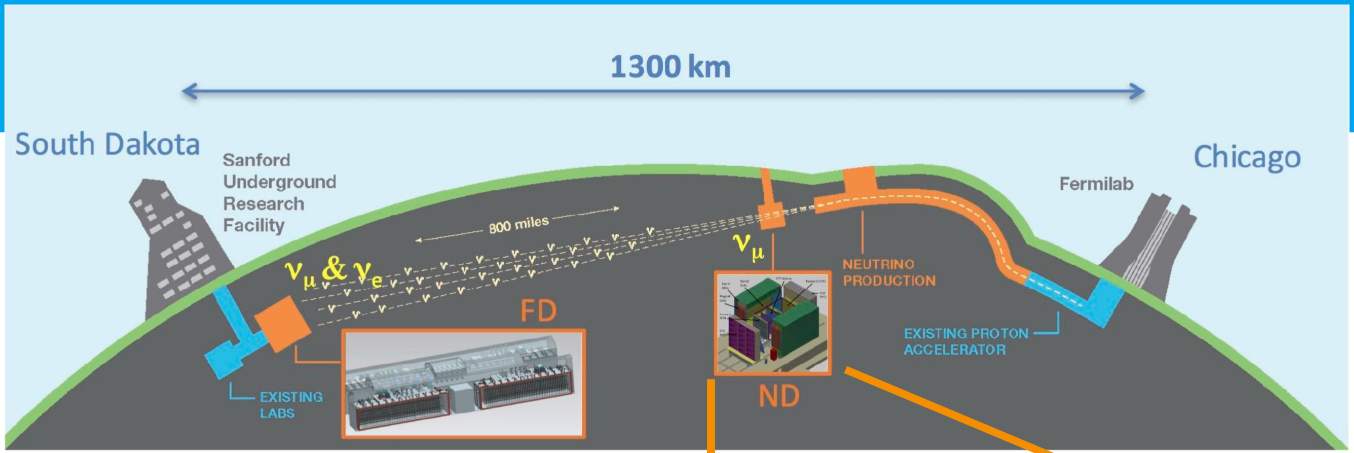
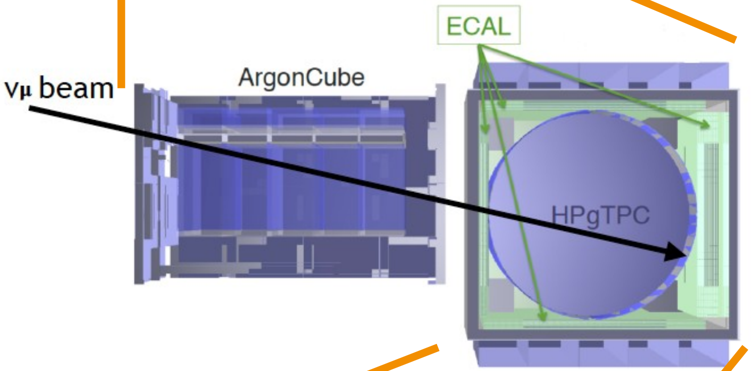
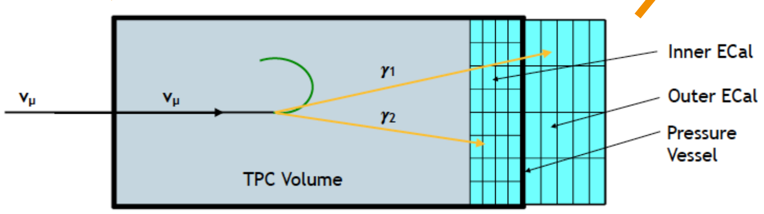
DUNE



- DUNE Far Detector: start data taking 2024
- Near Detector (ND): measure beam before oscillation
  - installation 2025-2026
  - start data taking 2026
- goal: detect π^0 from neutral current interactions and neutrons from interactions of neutrinos with Argon nuclei
  - typical energies of a few 100 MeV
- need good energy and direction measurement
- DESY: simulation studies
  - absorber material and thickness
  - influence of pressure vessel





Summary

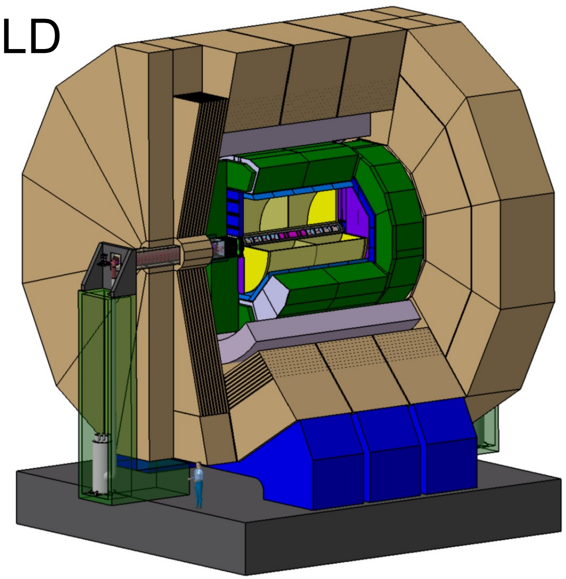
- expect a statement from Japanese government on ILC soon

- SiPM-on-tile technology developed at DESY is an interesting option for calorimeters
  - CALICE AHCAL
    - new large prototype successfully built and operated in beams, now concentrating on analysis
    - plan further tests with large layers, beam tests with ECAL in front, better timing and tungsten absorber
  - Scintillator part of CMS HGCAL
    - very dynamic development, in crucial design phase now
  - DUNE
    - simulation studies for detection of low energy particles

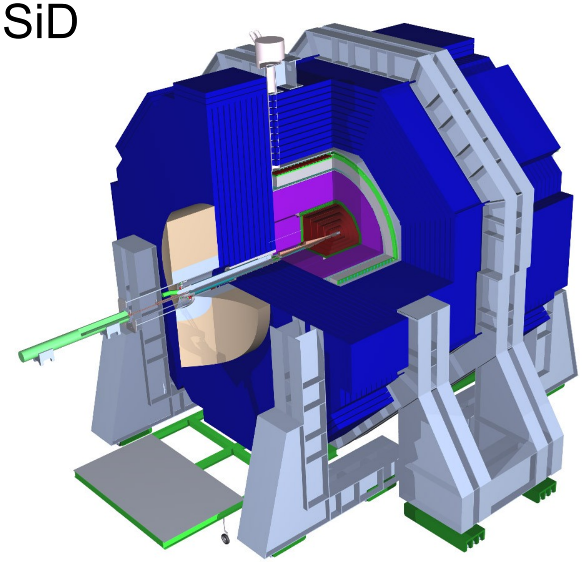
Backup

ILC Detector Concepts

ILD



SiD



- 2 detector concepts for ILC: ILD and SiD
  - both optimised for particle flow algorithms
  - complementary technologies
  - DESY has strong role in ILD
- Within the concepts
  - Simulation and reconstruction software
  - Engineering and integration
  - Detector optimisation
  - Physics analysis studies
- Detector R&D
  - R&D collaborations inform the concepts:
    - LCTPC: Time Projection Chamber (ILD)
    - CALICE: calorimetry (ILD &SiD)
    - FCAL: very forward calorimetry (ILD & SiD)
  - Polarimetry
  - Vertex detector