Federal Ministry
of Education
and Research

CALICE
Low Energy Plans

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NA61/SHINE at Low Energy
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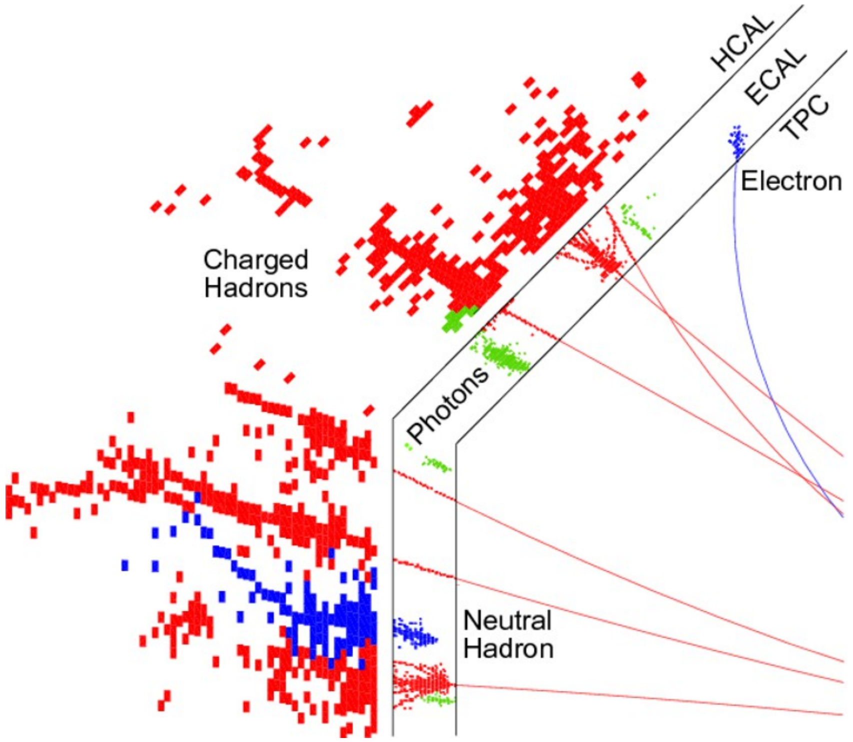
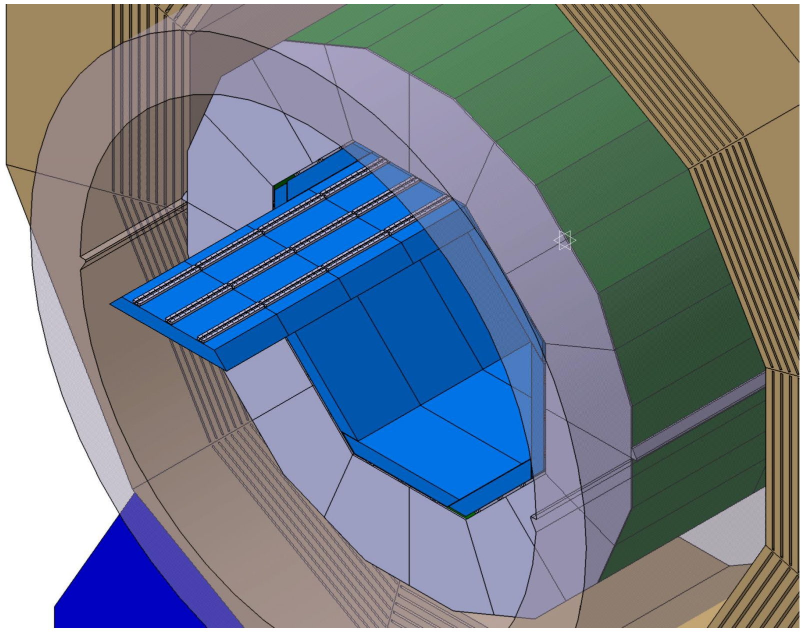
Challenges

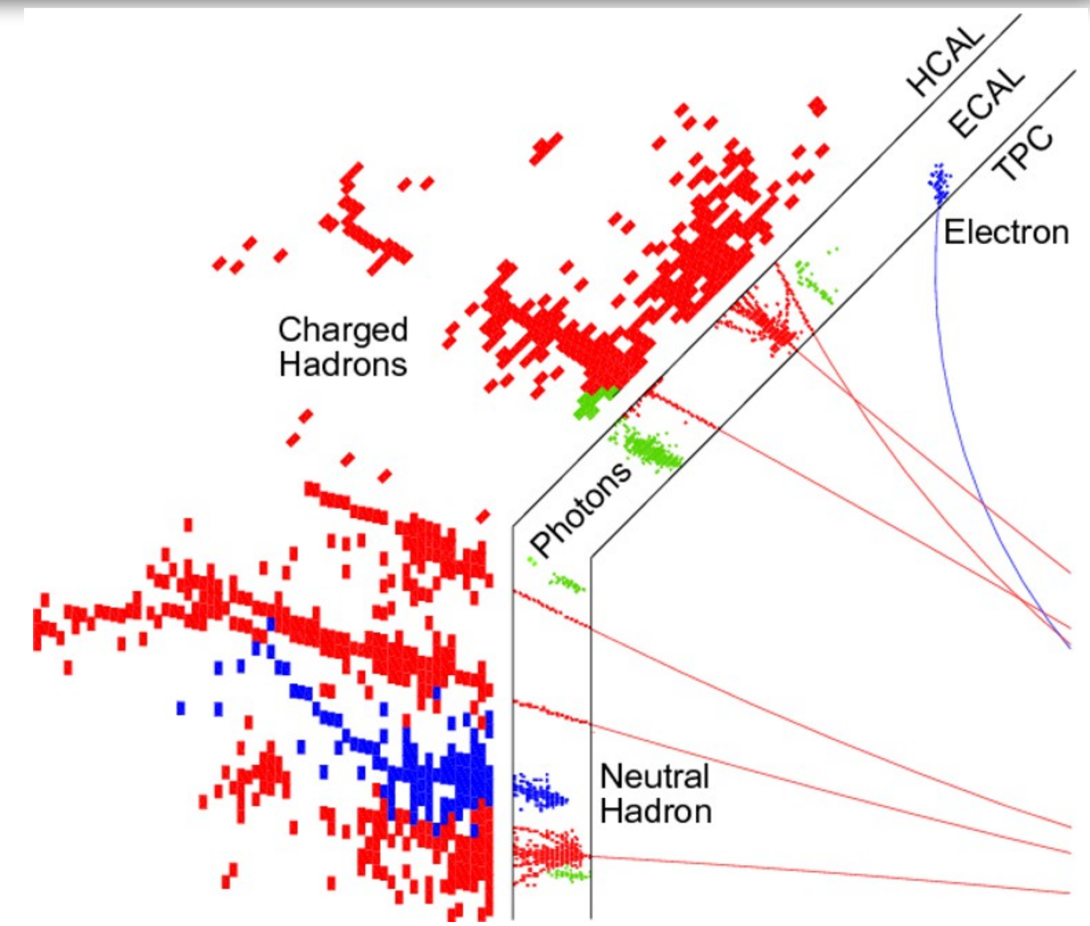
- Physics requirements e.g. at ILC
  - W/Z separation → 3% energy resolution
  - Particle Flow Algorithm → high granularity
- Technology
  - Low noise SiPMs
  - Highly integrated front-end electronics including trigger and timing
  - Large surface detectors
- Production and system integration
  - Very large number of channels
  - Compact detector operated in magnetic field
  - Low power consumption
- Characterisation with testbeams





Particle flow

- General idea
  - Base measurement as much as possible on measurement of charged particles in tracking devices
  - Separate signals by charged and neutral particles in highly granular calorimeters
  - Overlap between showers compromises correct assignment of calorimeter hits
  - Granularity used to minimise confusion term



$$\sigma_{Jet} = \sqrt{\sigma^2_{Track} + \sigma^2_{Had.} + \sigma^2_{elm.} + \sigma^2_{Confusion}}$$

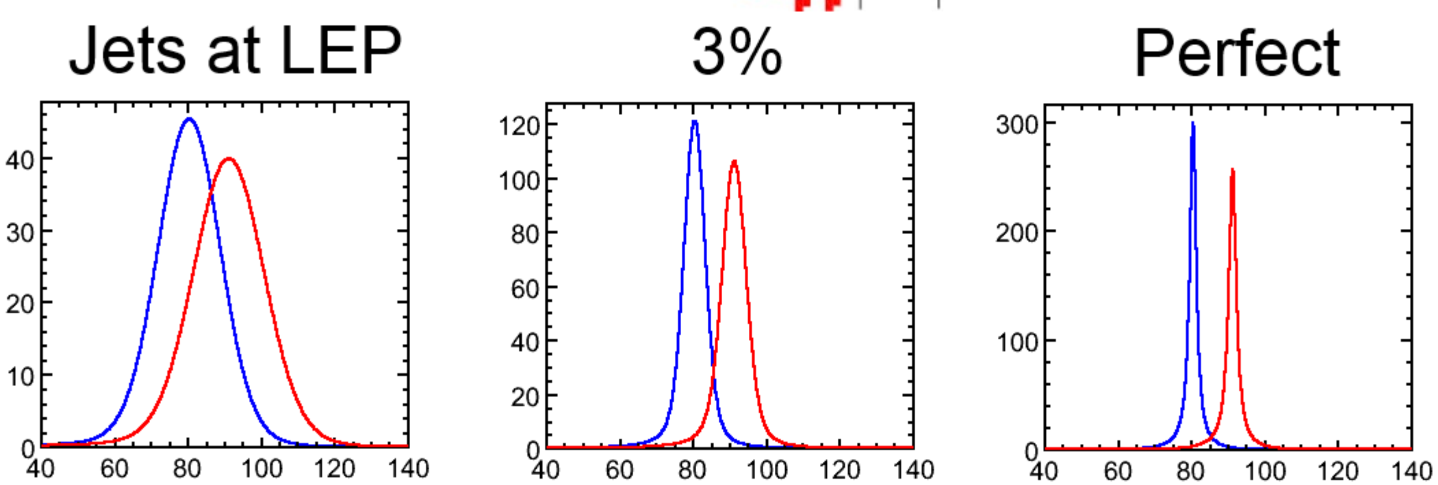
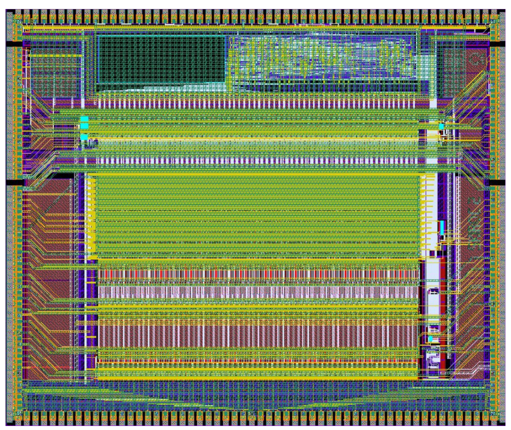


Figure by M. Thomson

Technological premises

Highly integrated front end electronics

e.g. SKIROC (for SiW Ecal)

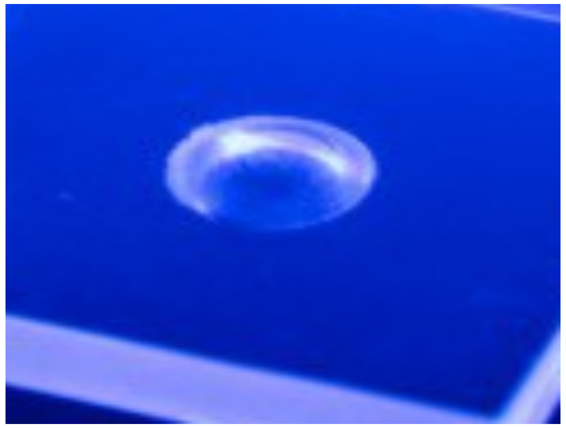


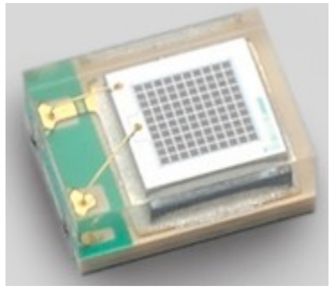
Size 7.5 mm x 8.7 mm, 64 channels

- Analogue measurement
- On-chip triggering
- Data buffering
- Digitisation

... all within one ASIC

Miniaturisation of r/o devices

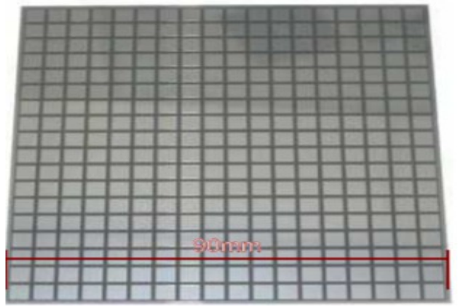




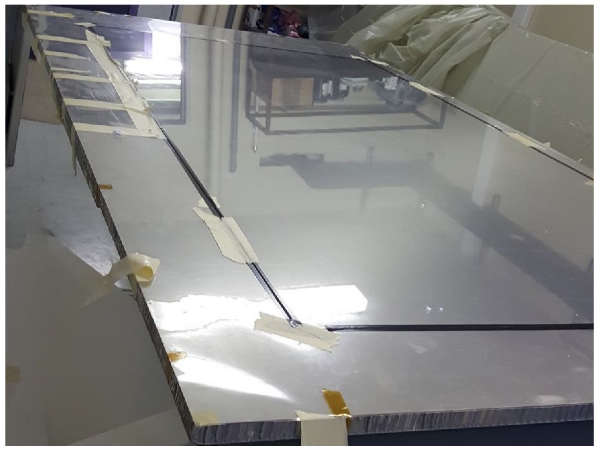
- Small scinitllating tiles
- (Low noise) SiPMs

Large surface detectors

Si Wafer



RPC layers

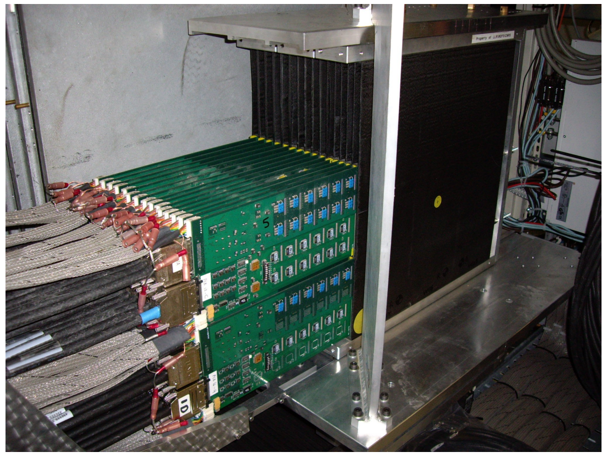


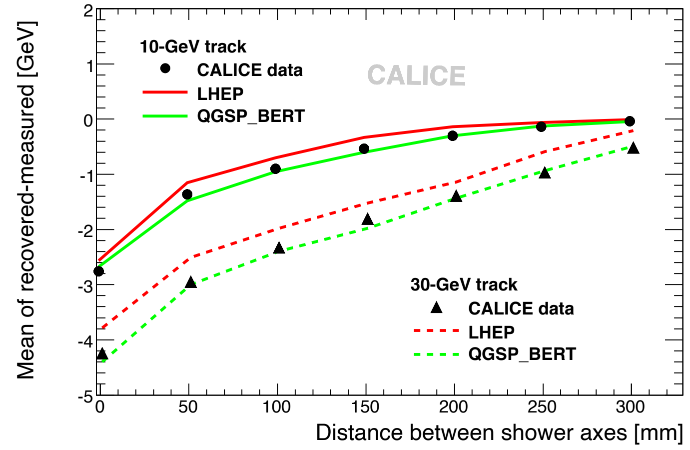
Many things that look familiar to you today were/are pioneered/driven by CALICE

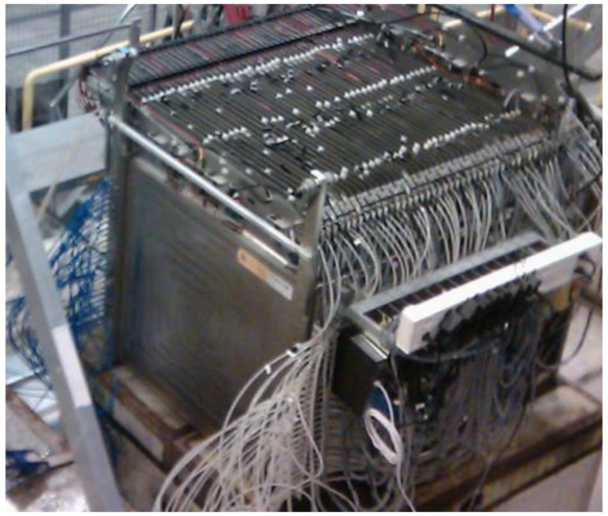
Slide by R. Pöschl

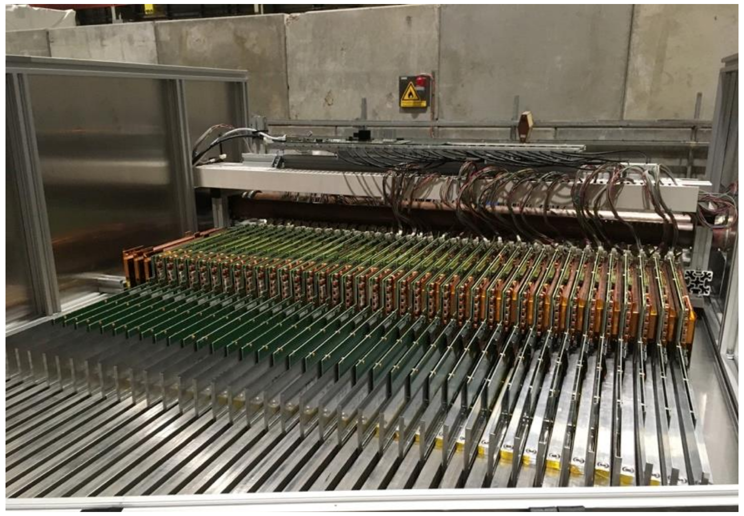
History of R&D

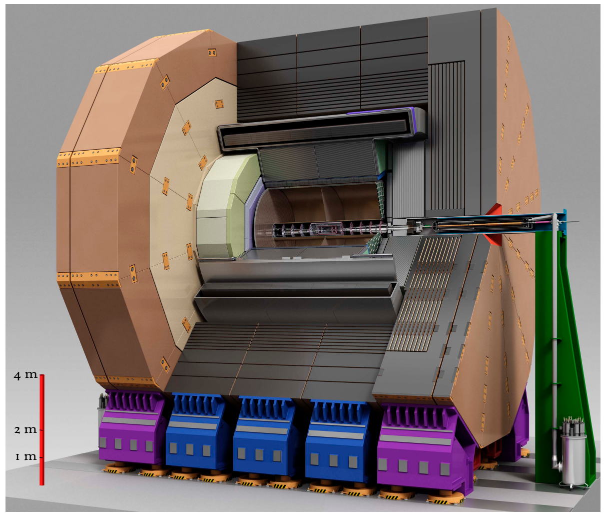
- Physics prototypes 2003-2012
  - Proof of principle of granular calorimeters
  - Large scale combined beam tests
  - Validation of GEANT4 physics lists
- Technological prototypes since 2010
  - Engineering challenges
  - Higher granularity
  - Lower noise
- Linear Collider detectors
  - Typically 10^8 calorimeter cells



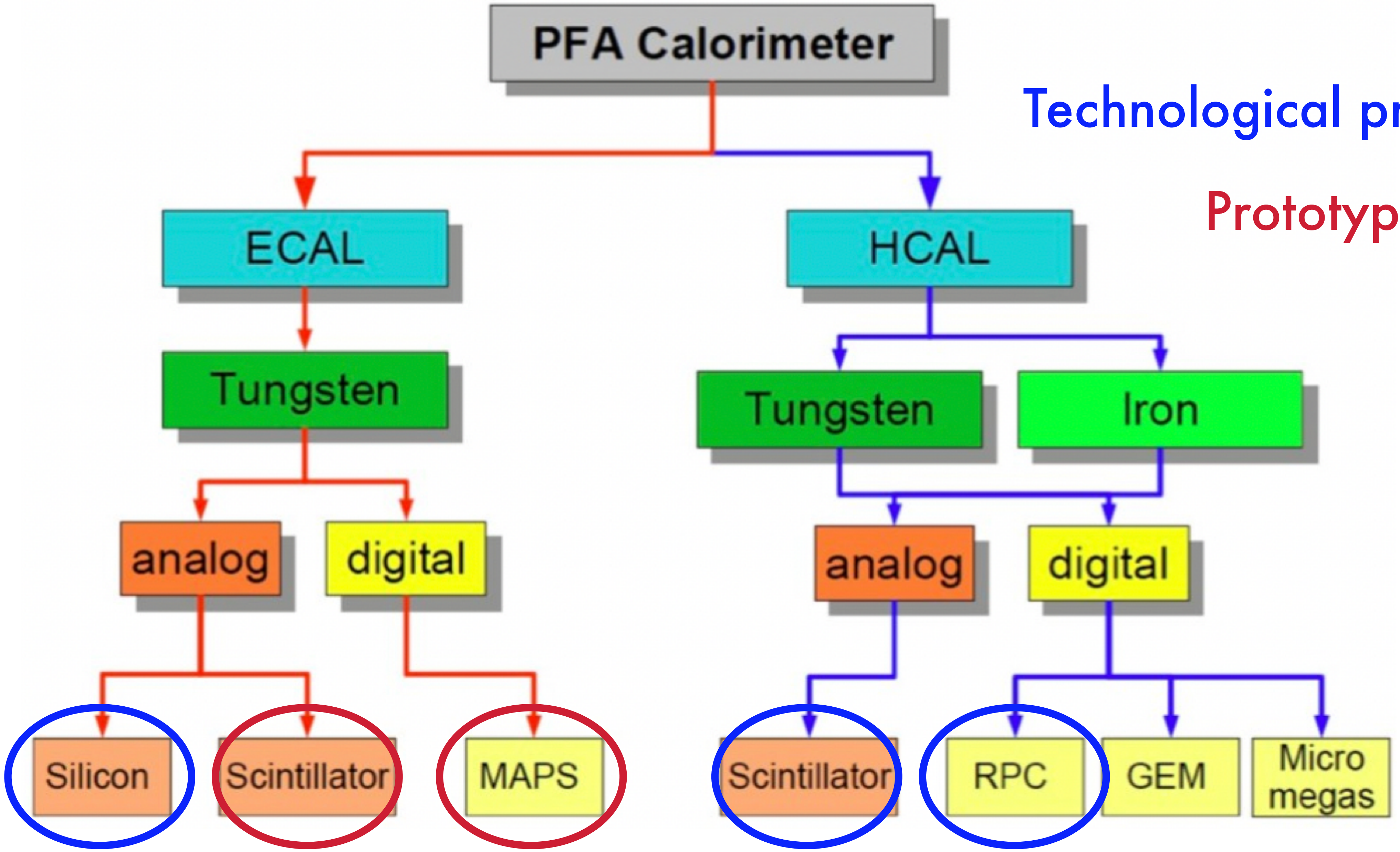








Technology overview

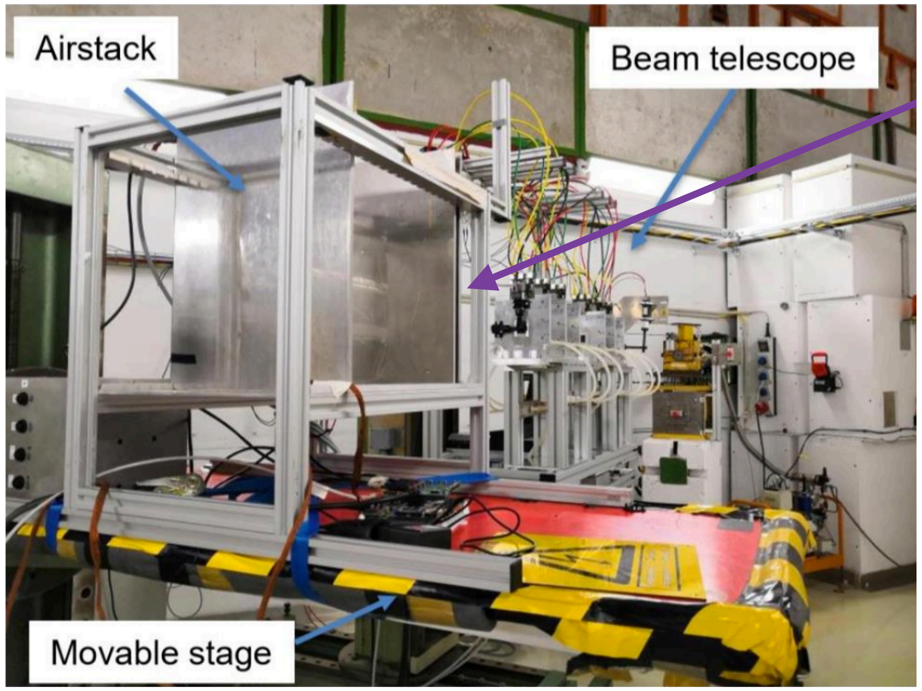


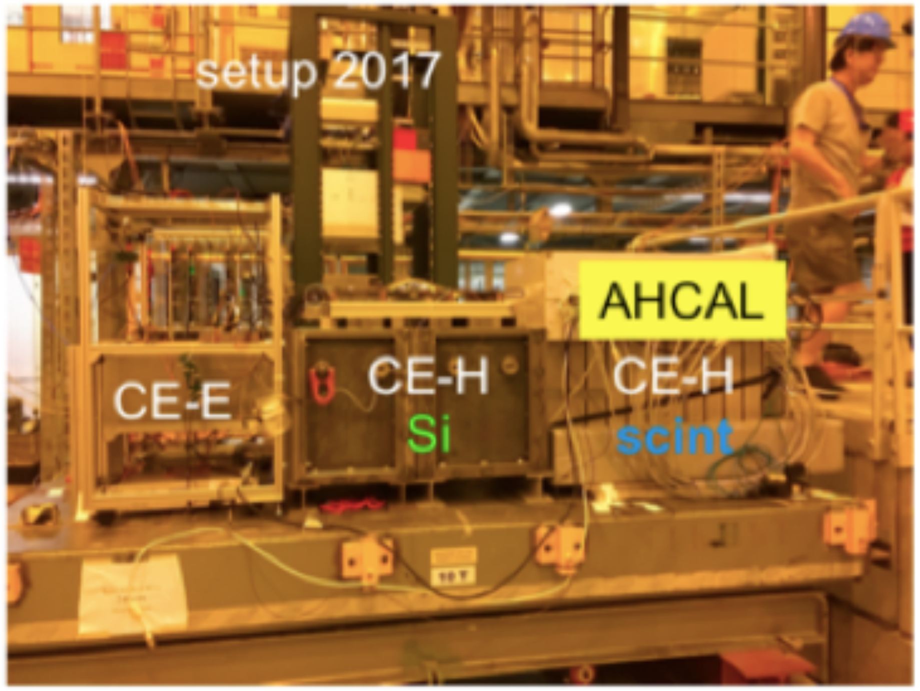
Technological prototypes running

Prototypes in preparation

Testbeam examples

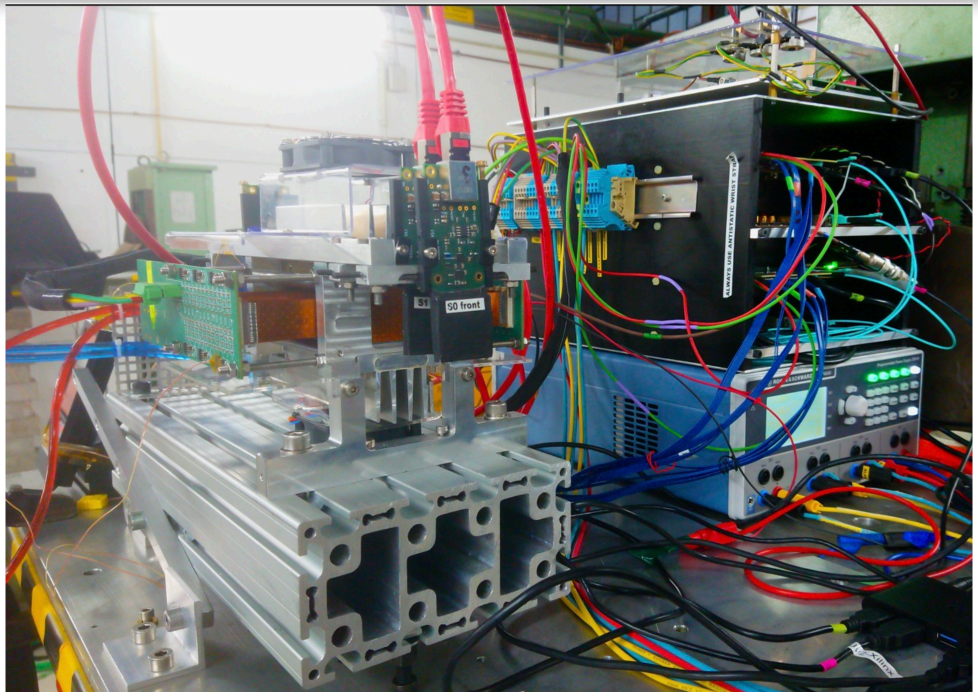
- Analog HCAL technological prototype at CERN SPS and DESY
  - At CERN: electrons, pions and muons, 10-80 GeV
    - Aim to study details of hadron showers and timing performance, using electrons and muons mostly as "calibration"
  - At DESY: electrons only, 1-5 GeV
    - Mostly to test new components, technological improvements
- Combined testbeams for CMS HGCAL
  - At CERN SPS
    - Early start of tests of new components in combination with mature CALICE prototypes

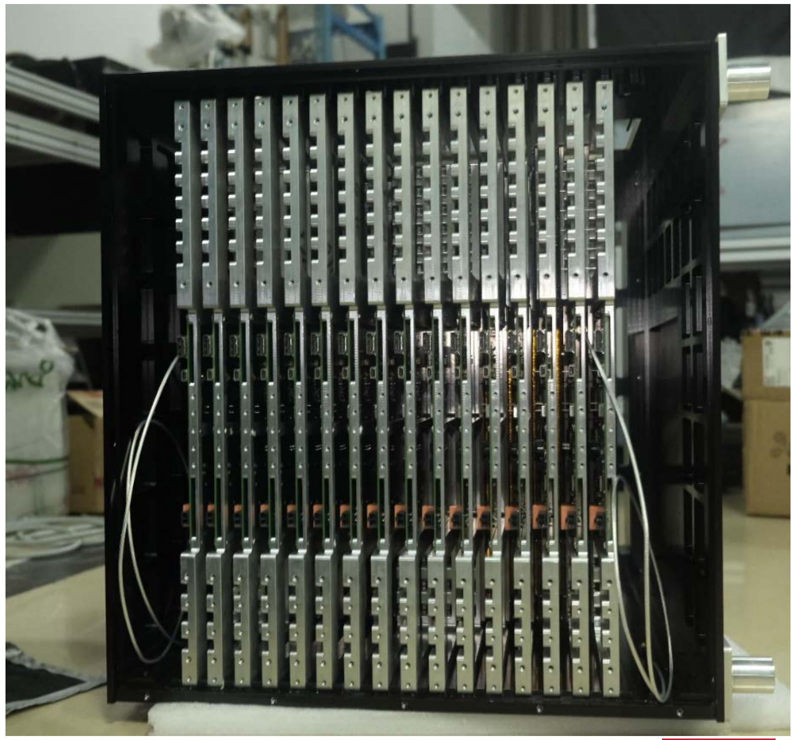




Testbeam plans

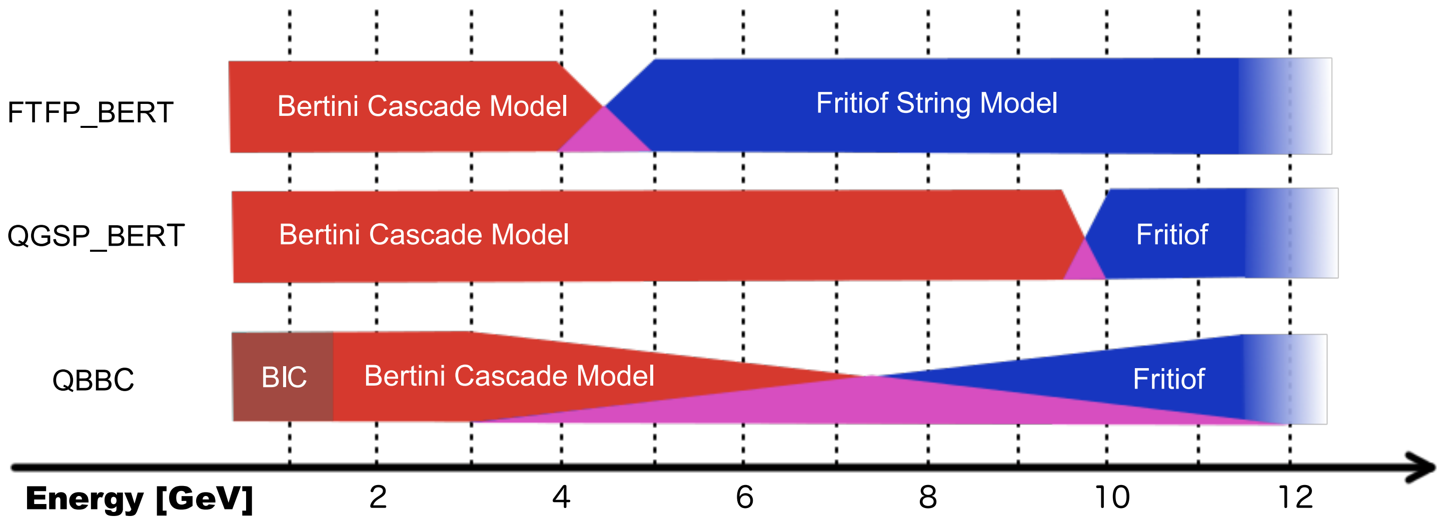
- MAPS ECAL for ALICE FoCAL upgrade
  - ALPIDE-based prototype gave very promising results at DESY
  - Testbeam at CERN SPS is the next step
- Scintillator ECAL for CEPC
  - New prototype first tested at IHEP
  - Testbeam at DESY planned next year
- Silicon ECAL technological prototype
  - 15-layer prototype being finalised
  - Testbeam at DESY planned next year
- Combined testbeams
  - Silicon ECAL and Analog HCAL with common data taking at DESY in Spring 2021





Interest in low E H2 line

- Beam particles and energies
  - Pions, electrons, mixed beams with hadrons and electrons up to 20 GeV to:
    - cover energy of transition region between GEANT 4 physics lists
    - more precise measurement of sampling term for energy resolution
  - Neutrons from 50 MeV upwards would be interesting, protons can probably be used as proxy to:
    - study neutron response of different materials in high energy hadronic showers
    - determine resolution of time-of-flight measurement e.g. in DUNE ND
- Advantages of low energy beams at the North Area
  - Obvious logistic simplification wrt Eest Area for combined tests at low and high energies
- Required instrumentation
  - Cherenkov counter to particle identification
  - Beam telescope for uniformity studies



Conclusions

- CALICE
  - Pioneer work in development of highly granular calorimeters, now considered state of the art and under construction for High Luminosity LHC upgrade, e.g. in CMS
  - Close collaboration with GEANT 4 developers allowed for improvement of simulation of electromagnetic and hadronic showers
  - Platform for exchange on calorimetry development based on different technologies and for usage in several future experiments
- Current and future R&D activities
  - Completion of technological prototypes ongoing, to address engineering and construction challenges
  - Characterisation of the prototypes in testbeams will be a central activity in the next years
- Interest in low energy beams
  - Detectors are planned for high energy physics, but in the R&D phase low energy beams are extremely valuable to improve simulation of single particles in showers