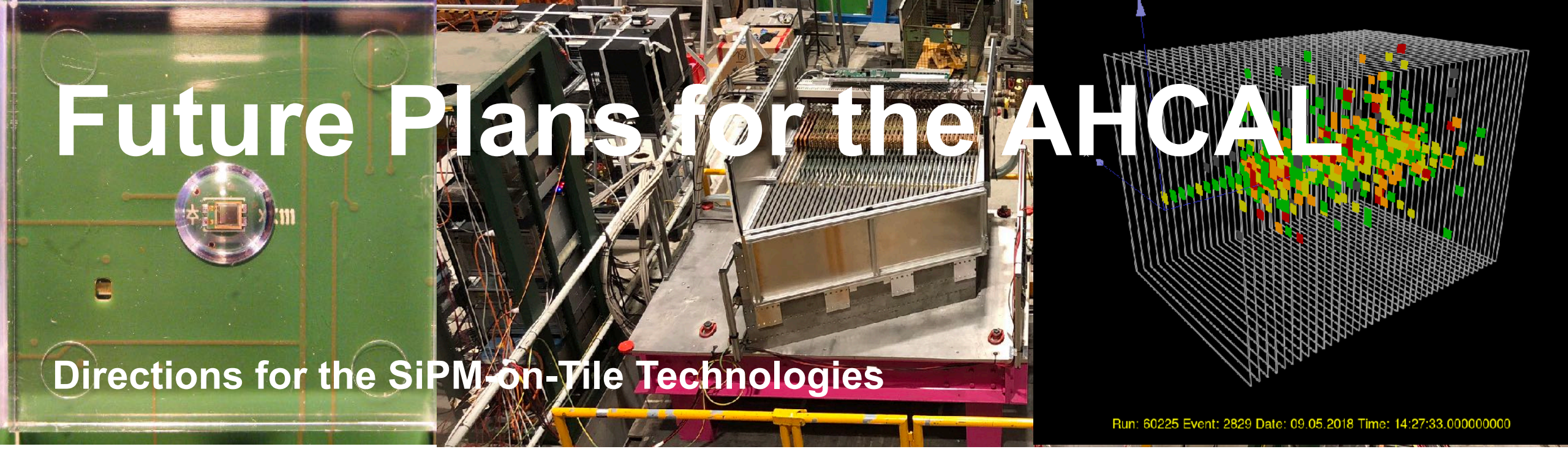


Future Plans for the AHCAL

Directions for the SiPM-on-Tile Technologies

CALICE Collaboration Meeting

Utrecht, April 10, 2019

Felix Sefkow
DESY

Topics

Old and new, near and far.

Outlook on current activities

- CALICE AHCAL
- ILD HCAL
- CMS

Near-term opportunities

- Calorimeters for other e+e- colliders
- DUNE

Future and far future

- 5D calorimetry with SiPMs

CALICE AHCAL

Core business

2017 construction and 2018 test beam were a big success

- fantastic team, fantastic spirit - many groups contributing

To fully exploit its potential:

Test beam data analysis

- performance, shower studies and test of simulation models, particle flow
- beneficial for entire HEP community, Geant 4
- link to machine learning
- link to CMS test beam - bring in long-long-term experience
    - in particular detector modelling (“digitisation”), particle flow, software compensation

Optimise timing performance

- 1 ns or better s possible, shown on test bench and with cosmics
- to be established in DESY beam with electrons

Further hadron beam tests with optimised timing

- with existing steel and tungsten absorbers
- 2021 at CERN

On-going hardware developments

- DESY is partner in German BMBF grant

KLAUS ASIC

- developed at Heidelberg
    - optimised S/N for smaller SiPM gain / pixels, larger dynamic range
- read-out board integration on-going: DESY
- firmware integration: Heidelberg

Mega-tiles

- developed at Mainz
- potential for further streamlining of production process
- first beam tests last month

Excellent training ground for students

ILD (and SiD) AHCAL

The big system

AHCAL prototype effort well synchronised with ILD IDR

- but not perfect: 1 year earlier would have resulted in significantly more performance results
- test beam analysis will benefit ILD (+ SiD) directly if there is a future of ILD

Main contribution beyond R&D

- costing and service estimates
- documentation
- absorber structure

Dynamical simulations (“earthquake studies”)

- methodology was new territory, involved ANSYS support teams and followed with interest by other mechanical engineering projects at DESY
- application to final structure on-going
- computational problems as expected, but also more confidence and experience
- plan to conclude by summer
- document and ideally publish

If ILC continues:

- follow SiECAL group at LAL in interface miniaturisation
- revise system engineering
- validate dynamical simulations with prototypes on shaker table
- new ASICs
- new SiPMs
- start designing details, e.g. PCBs with different sizes
- learn from CMS

CMS HGCAL

Strategic perspective

Many synergies with CALICE developments, important fraction fo CALICE community

- Key activity to maintain leading position in highly granular calorimetry for future collider projects

Current DESY commitment: development of tileboard and production / QC procedures for EDR in 2021

Many other CALICE groups involved:

- **OMEGA** designing the ROC for Si and SiPM
- Support for SiPM version of HGCROC at **U Heidelberg**
- **Imperial College for the DAQ (“back-end”)**
- In addition studies with irradiated SiPMs at **U Hamburg** and **LPI MEPHI, Moscow**
- **Northern Illinois** working in scintillator choice and assembly procedures (with Fermilab), **JINR** starting

The project will be a success - and we should be part of it

Near and Near-term Opportunities

SiPM-on-Tile for Other e+e- Colliders

AHCAL universality

Essentially all e+e- detectors have a SiPM-on-Tile option or baseline for the hadron calorimeter

- really all? There is a small village ruled by Chief Fibermatrix..

Read-out electronics needs to be adapted, with system consequences

Linear: CLIC:

- the nearest relative, “only" different bunch structure
- CDR based on time resolution of existing CALICE electronics
- faster would be better, if power budget can be kept small
- follow SiECAL group at LAL in interface miniaturisation

Circular: CEPC and FCC-ee

- continuous readout most likely requires active cooling
  - no power pulsing and higher data rates
  - benefit from CMS experience
- and different digital back-end electronics (concentrators)
- KLAUS chip planned for CEPC ECAL prototype
  - continuous dead-time free read-out
  - directly applicable to FCC-ee

DUNE ND-ECAL

Same, but different.

Exploring options for a scintillator (strip and tile) based ECAL for the Near Detector at the Long Baseiine Neutrino Facility at Fermilab

See talk by Eldwan

Next steps:

- most important: further optimisation
- in parallel: present CALICE AHCAL R&D is dual-use
  - KLAUS chip, megatiles
  - Mainz also studies scintillator strips for SHIP
  - read-out board

Next phase / funding period:

- ECAL prototype
  - compared to AHCAL: 10% of channels
  - possibly new solutions for electronics integration required
  - new mechanical structure: thin copper sheets
- System engineering
  - absorber structure, services
- DAQ, ….
- Establish collaboration
- Unknown territory, other community

Future and Far Future

5-dimensional Calorimetry

Trends and Perspectives

4D is the accepted calorimeter standard now - even for Dual r/o

5D is gaining importance

- pile-up rejection
- assist particle flow
- software compensation

Require few 10 ps precision (< 1 cm)

Exploring projects:

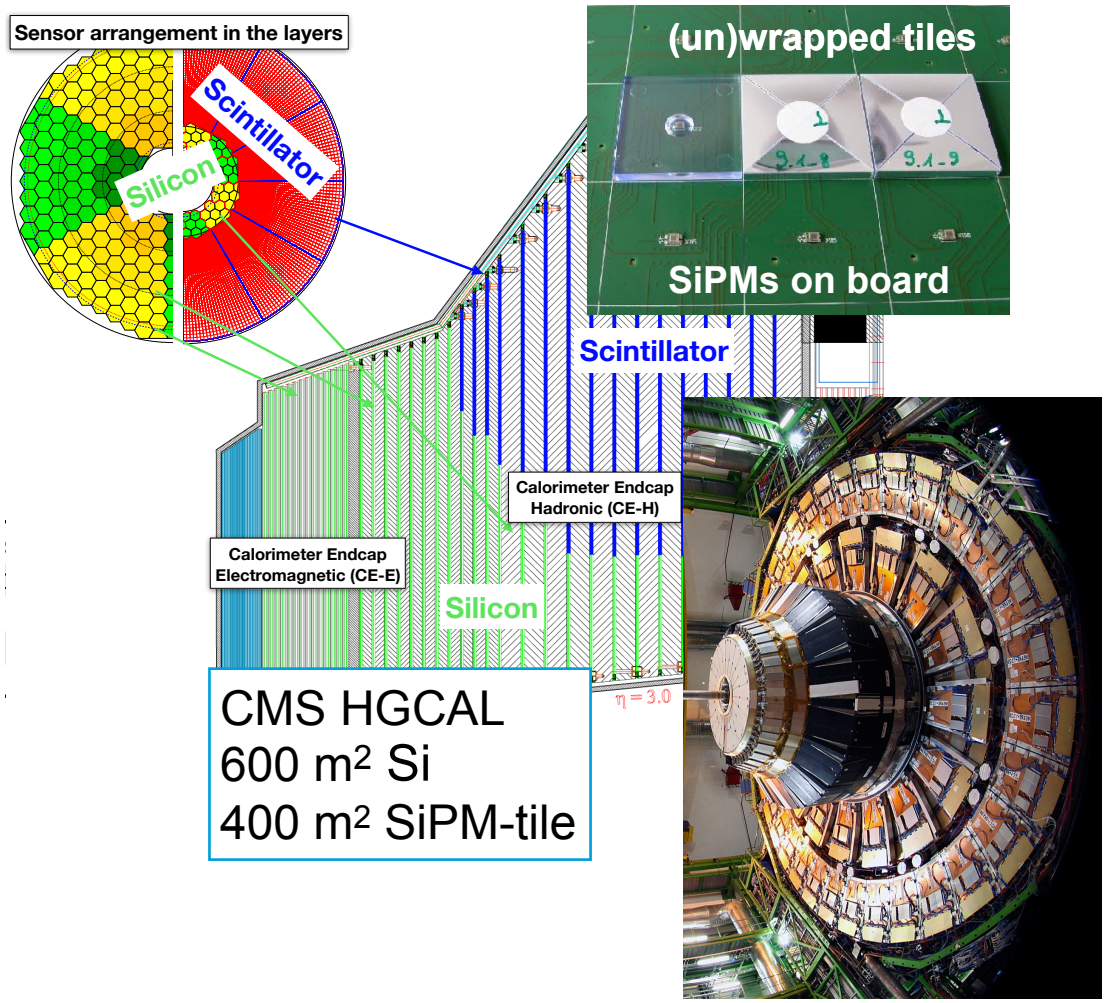
- CMS HGCAL: timing mostly Si
- CMS Barrel Timing Layer: SiPMs + crystals, TOFPET electronics
- Mu3e timing layer (CALICE spin-off at Heidelberg)

Activities in Hamburg (DESY and UHH):

- Rad-hard SiPMs and engineering solutions for HGCAL-scint
- reconstruction algorithms and machine learning

Prespectives:

- Organic scintillator-based calorimeter with fast electronics
- Understand limiting factors: tiles, SiPMs, electronics
- small prototypes and electron test beam



Summary

For Discussion

Outlook on current activities

- CALICE AHCAL: core program, component R&D, test beam and analysis
- ILD HCAL: system study, concluding
- CMS: the current mainstream, strategically central

Near-term opportunities

- Calorimeters for other e+e- colliders: AHCAL applicable, can afford to wait and see
- DUNE: exploring possible opportunities

Future and far future

- 5D calorimetry with SiPMs: the obvious next step

Back-up

CALICE review by ECFA Detector R&D Panel

November 7, 2018

Recommendations by the Committee https://twiki.cern.ch/twiki/pub/CALICE/WebHome/CALICEReport2018_final.pdf

- Independent of this future development, the committee recommends that the CALICE collaboration **continues to analyse the rich set of data** that has been and will be collected in a number of test beam campaigns with prototypes of different technologies and to publish the results. These data are a **crucial input for an improved understanding of hadronic showers**.
- The CALICE studies established important **ingredients for the decision and design of the CMS HGCAL**, thus demonstrating the fertility of the CALICE effort. The HGCAL realisation offers the opportunity to **validate the detector concepts in a full experiment and to profit from an advancement in integration aspects, mechanical engineering and development of electronics using technologies suited for future applications.**
- Since the calorimeter concepts studied by CALICE will be **valuable for for particle physics experiments in general, including circular colliders, the CALICE collaboration shall be open for such applications.** We encourage to explore the possibility of a **un-pulsed, continuous operation** of the calorimeters, which includes aspects of electronics readout, cooling and layout optimisation.
- The future CALICE test beam programme shall thus **explore the timing capabilities of the new prototypes**.

CERN Roadmap

CERN Roadmap for Detector R&D

Broad process in 2018

Working Groups → packages
WP 1: Silicon detectors
WP 2: Gas detectors
WP 3: Calorimetry and light based detectors
WP 4: Detector Mechanics
WP 5: IC technologies
WP 6: High Speed Links
WP 7: Software
WP 8: Detector Magnets

"The R&D programme focuses on areas where the **EP department** has significant expertise and infrastructure and already plays a leading or unique role."

Excellent starting point
Does not fully reflect FCCee as starting phase of FCC
Need to integrate community presently not oriented towards CERN projects
New AIDA++ proposal will have to balance coherence and complementarity

R&D report, CERN-OPEN-2018-006, ~100 pages

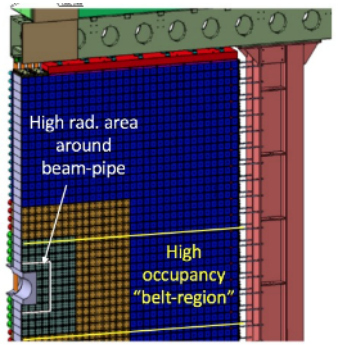
Input to the European Strategy Group, 10 pages
→ see EP R&D website

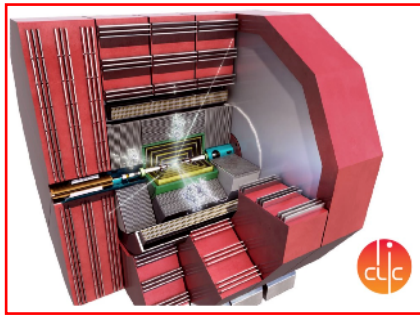
WP3: Calorimetry & Light Based Det's.

EP R&D

'Potential clients'

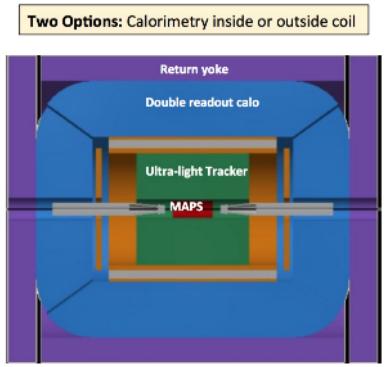
LHCb Upgrade II (2031): 3MGy, $3 \cdot 10^{15}$ n. require timing + good σ_E





CLIC/ILC calorimeters optimized for Particle Flow (CALICE)

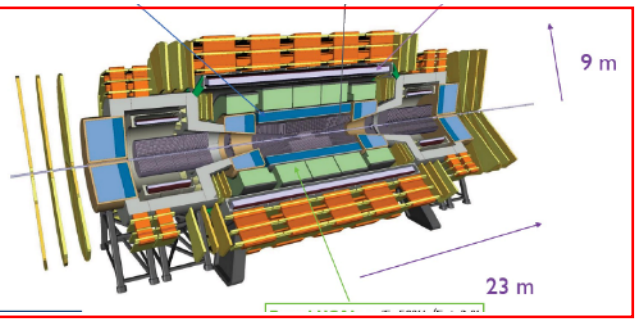
FCC-ee excellent jet energy resolution, particle ID, Particle flow or dual readout



Scintillating fibre technology

Ring Imaging Cherenkov (RICH) detectors

FCC-hh: extreme pile-up (up to 1000) High radiation (2×10^{16} - 5×10^{18} n) in forward region), high granularity, high resolution, good timing



Convenors: Martin Aleksa and Carmelo D'Ambrosio

New Call

Informal news from Brussels

FP8 Call 5: Large initiatives and support measures to foster the innovation potential of research infrastructures (expected in summer):

- New directions in EC funding instruments, addressing established communities
- Following consultations with communities to prepare for FP9 - and lobbying

INFRAINNOV-03-2020 - Co-Innovation platform for RI technologies (xx M€)

- This is where ATTRACT phase 2 will be
- Aims at **innovation for markets outside RI,** competitive

INFRAINNOV-04-2020 - Innovation pilots (yy M€, max zz M€ each)

- Innovation in light source technologies
- **Innovation in detector technologies**
- Innovation in accelerator technologies
- Aims at **innovation for the delivery of services, or new services of RI**
    - can be incremental

Deadline March 17, 2020

- Open Call for Expressions of Interest in May / June
- Open community meeting September 5 at CERN (t.b.c.)

Not just another AIDA

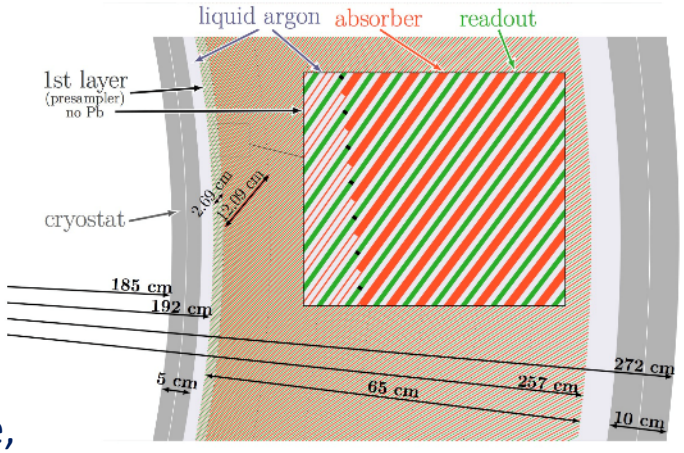
- emphasis on involvement of **industrial partners** - ideally as beneficiaries
- development of **roadmap / strategic agenda** - proposal and implementation stage
- **sustainability** plan (co-funding)
- **no transnational access**
- **complementarity** with other actions: exclude double funding

LAr

Activities

1) **High granularity noble liquid calorimetry (LAr),** reference design for FCC-hh, but potentially also interesting for FCC-ee.

Electrode design, time resolution, LAr properties, high ionisation rates, cryogenic feedthroughs.



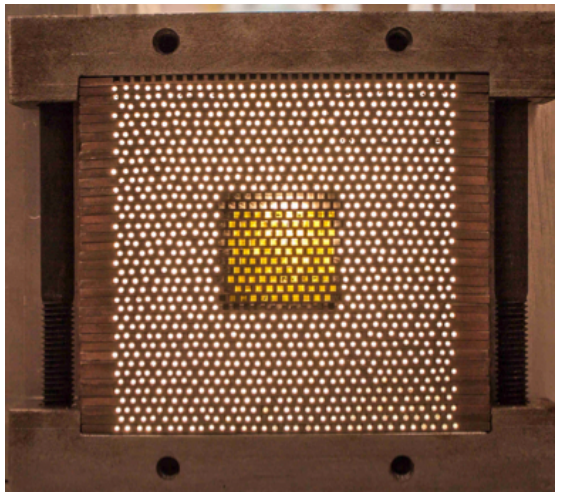
2) **Scintillator based calorimetry**. Good choice for hadronic calorimetry in FCC-hh,ee, CLIC, ILC, SHiP and LHCb ECAL upgrade II

Material R&D (scint, WLS), photodetectors (SiPM) at low temperatures, calo type, timing. Profit from RD18 (Crystal Clear) expertise!

Concentrate initially on 2 technologies

- Tile-cal like HCAL (FCC-hh)

- SPACAL ECAL studies (LHCb motivated).



LHCb test beam module (SPACAL) with various crystal and plastic fibre types

3) **High-granularity silicon-based sampling calorimeters** optimised for particle flow in CLICdet and CLD@FCC-ee.

Much can be learned through the CMS HGCAL @ HL-LHC project, which we support!

Further more specific studies shall follow at a later stage.

Highly Granular Liquid Argon Calorimeters

The other rad-hard technology

Proposed for FCC-hh

- recently also for FCC-ee

Emphasised by CERN detector R&D roadmap

- more finely segmented electrodes
- high density feed-throughs
- thin cryostat vessels

Cold electronics, embedded front end not yet followed

- “was discussed at time of ATLAS TDR and rejected"
- would be the real breakthrough

Opportunities

- Strong German and French LAr community

Far-far future

- Personally, I think it is a hadron collider technology