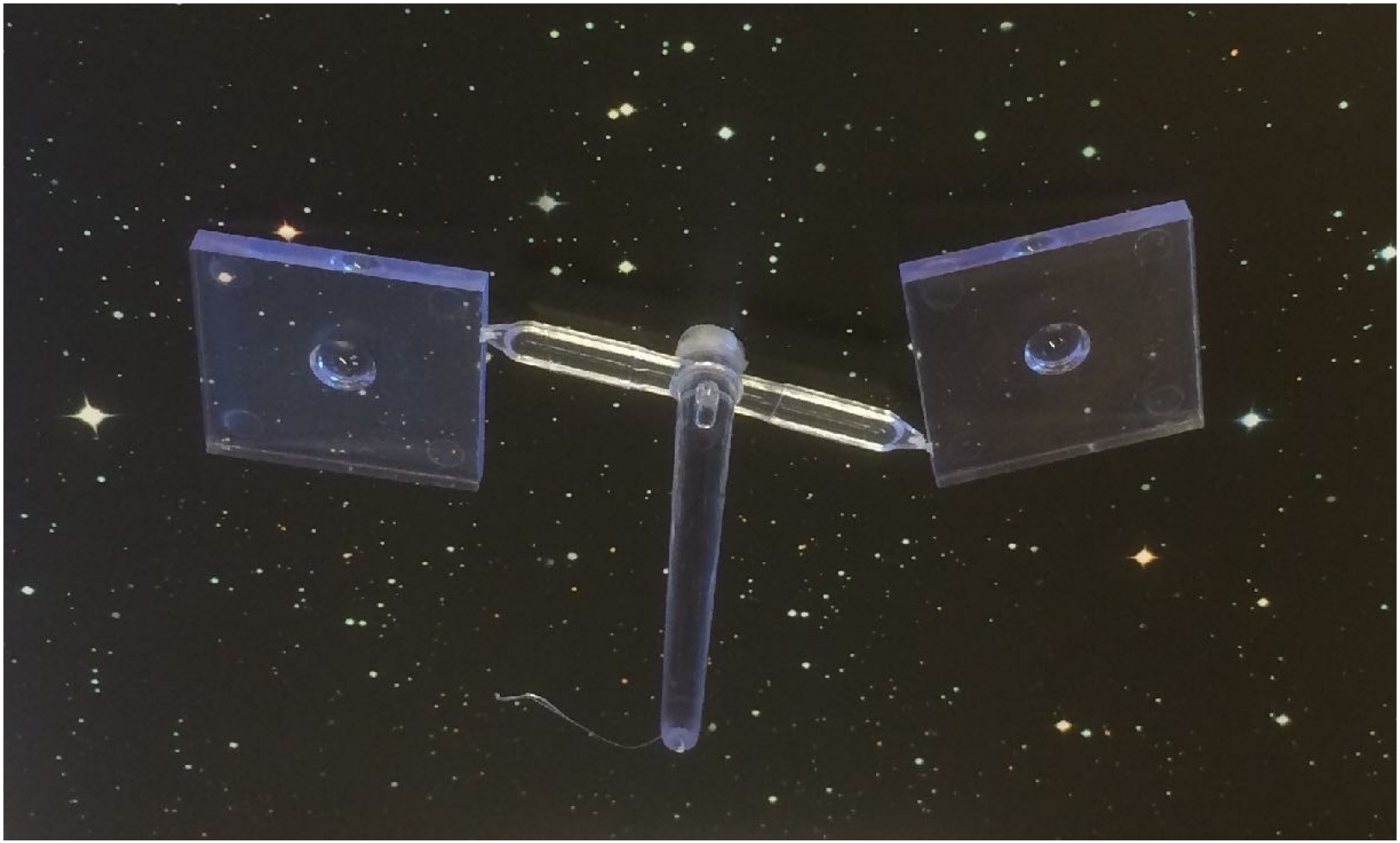
The new AHCAL prototype

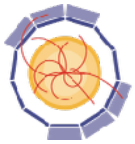
Felix Sefkow



CALICE Collaboration Meeting at LLR, Ecole Polytechnique, March 23, 2017

Overview

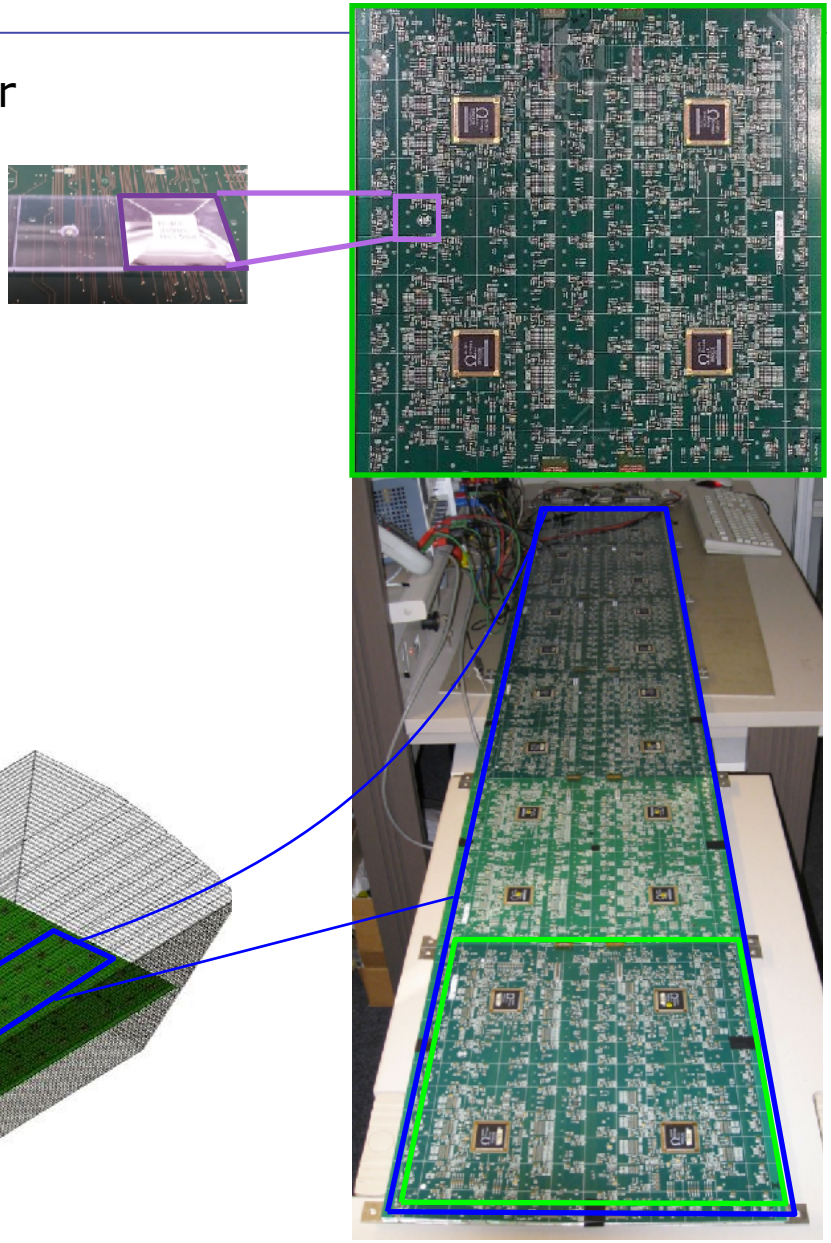
- New prototype construction effort
- Test beam plans
- Some news on granularity



AIDA2020

AHCAL architecture

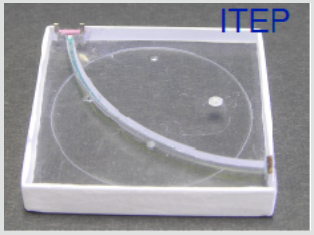
- Sandwich calorimeter based on scintillator tiles (3x3cm2) readout using Silicon Photomultipliers (SiPM)
- Fully integrated electronics
- HCAL Base Unit (HBU): 36x36cm2,
  - 144 channels readout by 4 ASIC chips
- In total 8M channels, challenge for data concentration
- Technological prototype: demonstrate scalability to full detector
- Improvement in all aspects compared to physics prototype



Progress in SiPMs and tile design

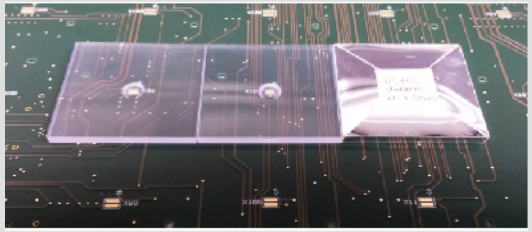
Physics prototype

2006 - 2011



Old ITEP tiles with WLS fibre
1200 px SiPMs

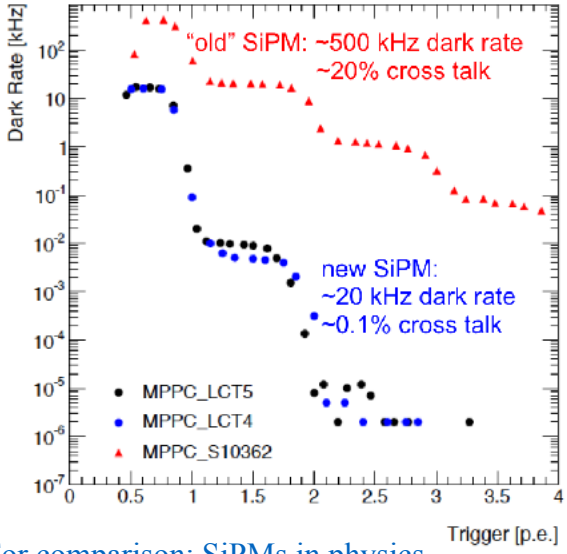
Technological prototype



Surface mounted SiPMs & tiles
- with *MPPC* SiPMs **2700** px

Suitable for automated mass assembly

- SiPMs sensitive to blue light → no need for WLS fibres
- New generation of industrial SiPMs: drastically improved over the past years
  - Dramatically reduced dark rate and increased photon detection efficiency
  - Better signal-to-noise ratio, allows simpler tile design
  - After-pulses and inter-pixel cross-talk largely reduced
  - Noise rate decreases quickly with threshold, much more stable operation
- Excellent uniformity (operating voltage, gain)
  - Simplified calibration
- High over-voltage operation
  - Reduced temperature sensitivity

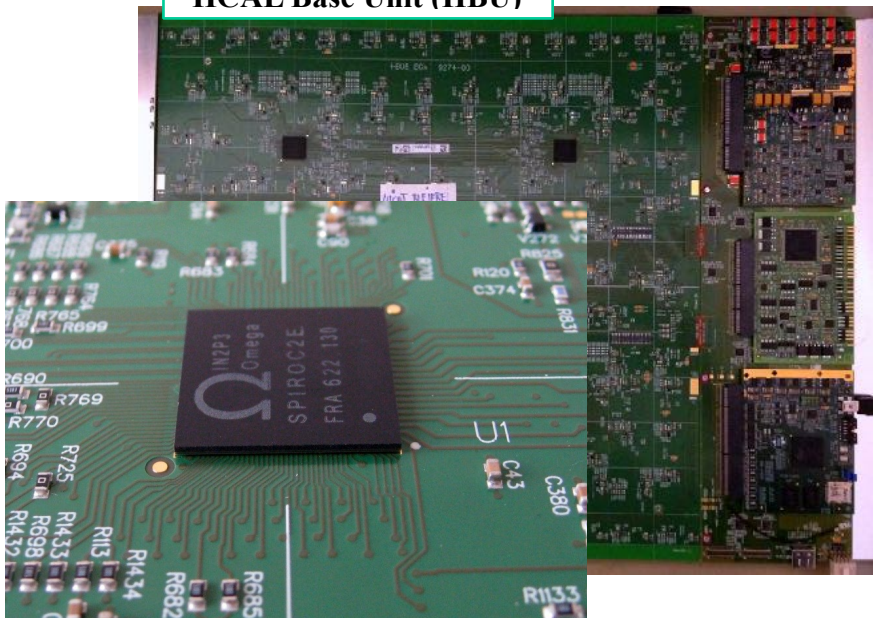


For comparison: SiPMs in physics prototype 2 MHz dark rate, 30% cross talk

Electronics and assembly

- Fully integrated electronics for mass production
- Latest generation read-out ASIC SPIROC2E successfully tested
  - reduced power consumption and many improvements
- BGA package of ASIC leads to significant PCB cost reduction and easier soldering
- HBU designed for surface mounted SiPMs & suitable for automated tile assembly
  - LED driver circuit improved channel uniformity: minimise time for test and calibration runs
- Tile assembly and cosmic test procedures established

HCAL Base Unit (HBU)



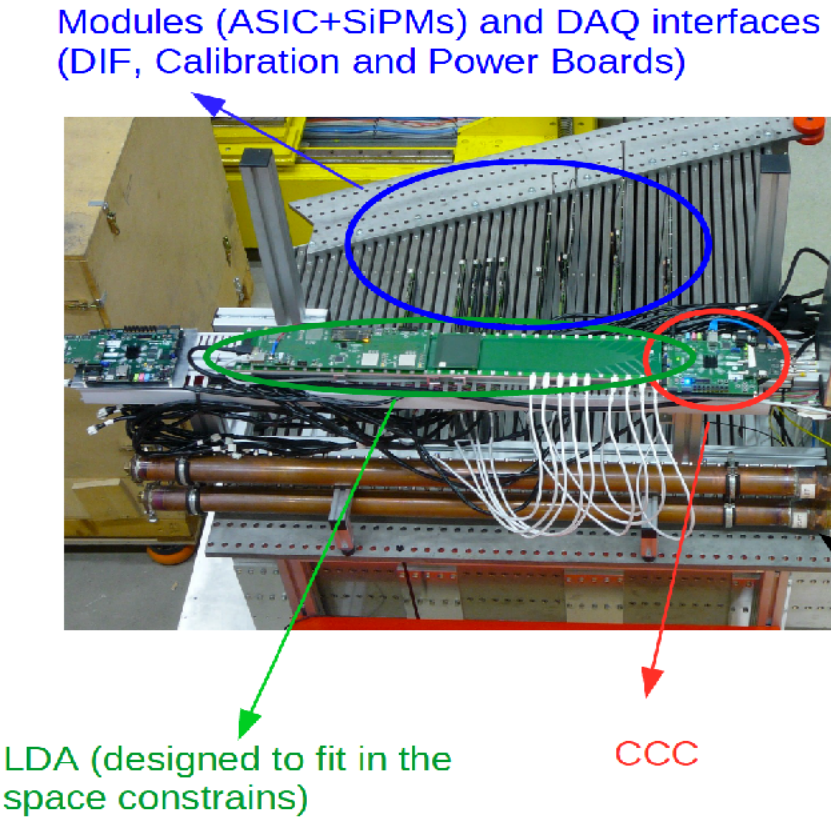
Tested in beam. Works perfectly!

Pick-and-place machine

Now used routinely

System integration

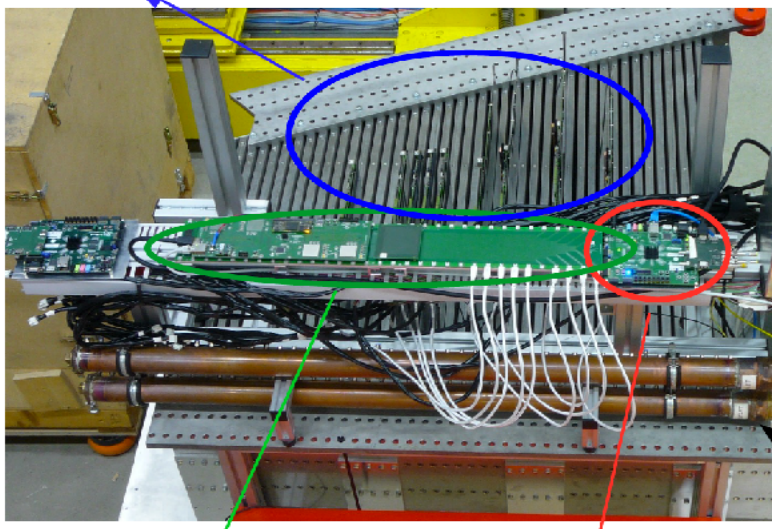
- Interface boards POWER, DIF, CALIB
  - can handle full layer of large detector
  - POWER board equipped with capacitor bank for power pulsing, active temperature compensation possible
  - DIF board uses more advanced FPGA to communicate with the ASICs
- Data concentration:
  - Wing-LDA designed for ILD-AHCAL successfully operated
  - Thanks to power pulsing mode, water-cooling only for interface boards needed (leak-less design)
- Data acquisition:
  - Integrated into EUDAQ system (chosen by LC community and actively supported by AIDA-2020): successful operation

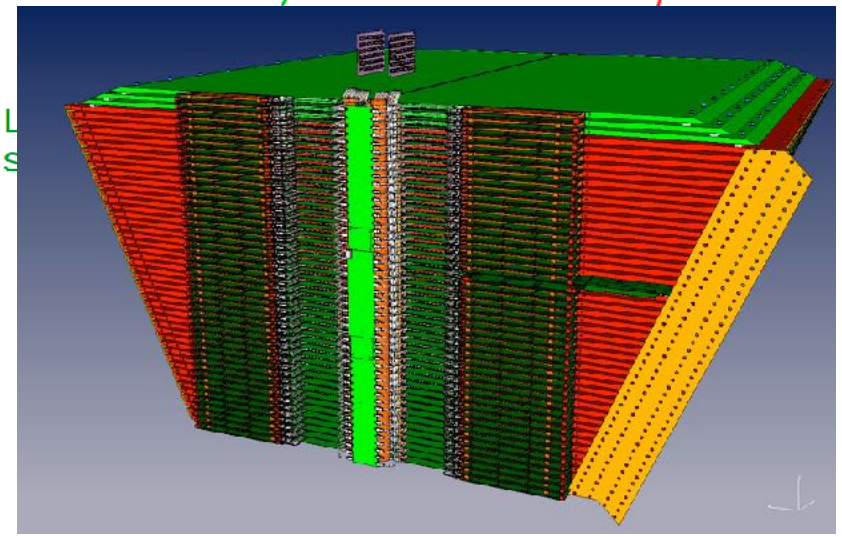


System integration

- Interface boards POWER, DIF, CALIB
  - can handle full layer of large detector
  - POWER board equipped with capacitor bank for power pulsing, active temperature compensation possible
  - DIF board uses more advanced FPGA to communicate with the ASICs
- Data concentration:
  - Wing-LDA designed for ILD-AHCAL successfully operated
  - Thanks to power pulsing mode, water-cooling only for interface boards needed (leak-less design)
- Data acquisition:
  - Integrated into EUDAQ system (chosen by LC community and actively supported by AIDA-2020): successful operation

Modules (ASIC+SiPMs) and DAQ interfaces (DIF, Calibration and Power Boards)

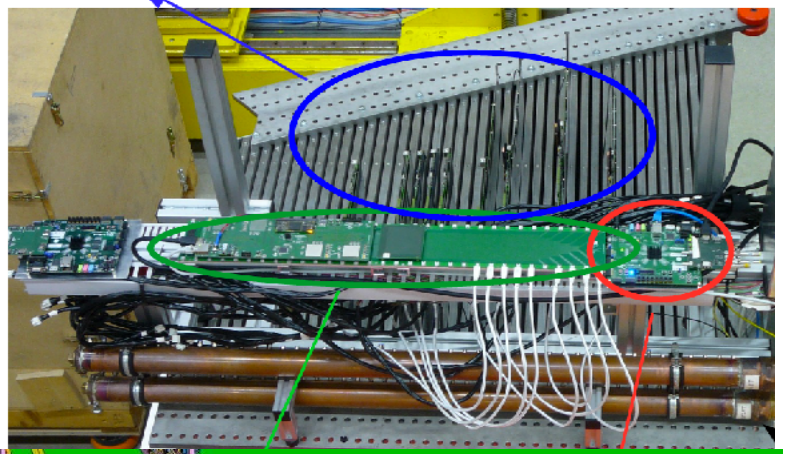


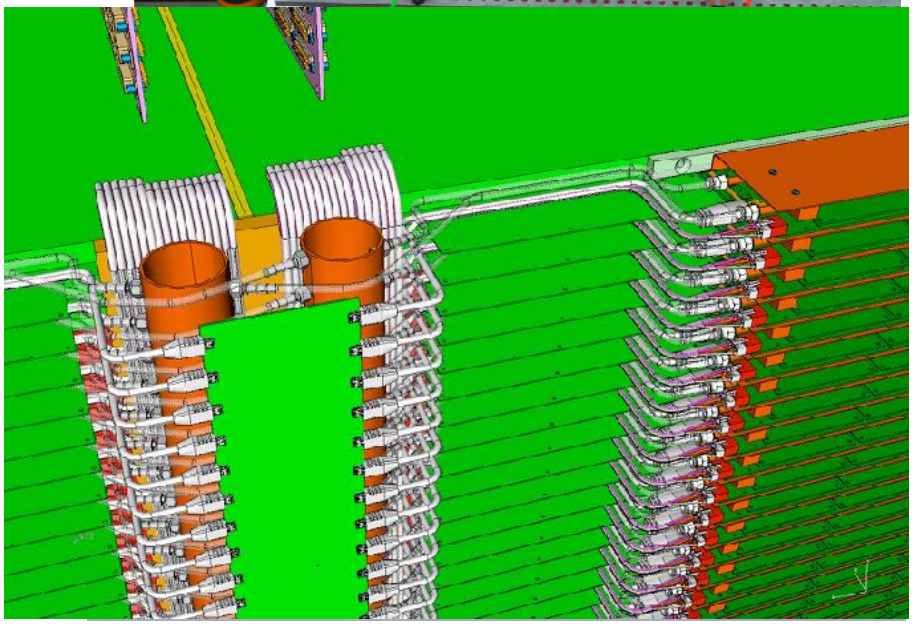


System integration

- Interface boards POWER, DIF, CALIB
  - can handle full layer of large detector
  - POWER board equipped with capacitor bank for power pulsing, active temperature compensation possible
  - DIF board uses more advanced FPGA to communicate with the ASICs
- Data concentration:
  - Wing-LDA designed for ILD-AHCAL successfully operated
  - Thanks to power pulsing mode, water-cooling only for interface boards needed (leak-less design)
- Data acquisition:
  - Integrated into EUDAQ system (chosen by LC community and actively supported by AIDA-2020): successful operation

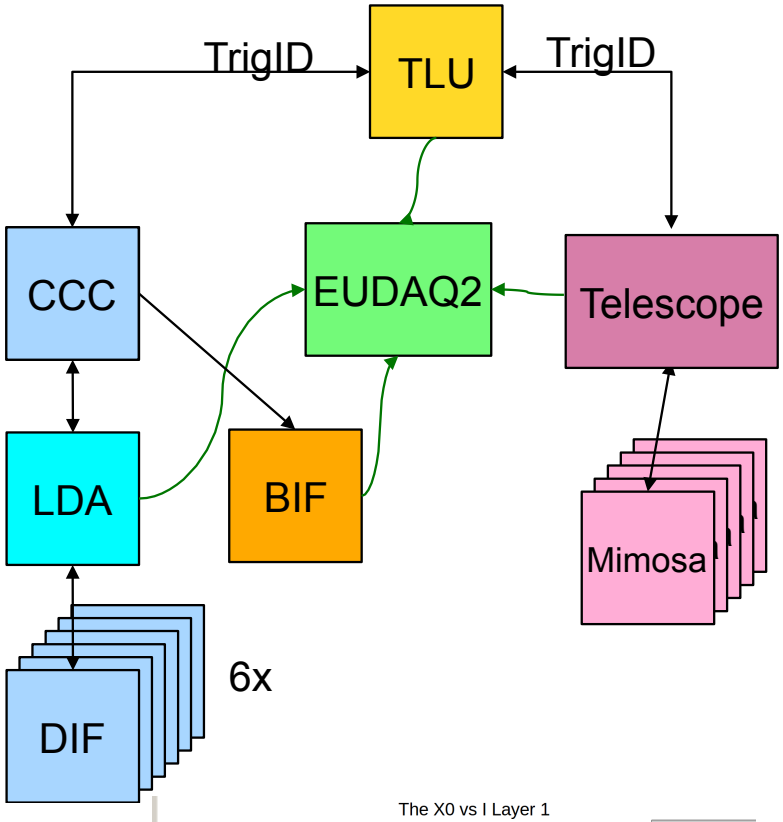
Modules (ASIC+SiPMs) and DAQ interfaces (DIF, Calibration and Power Boards)

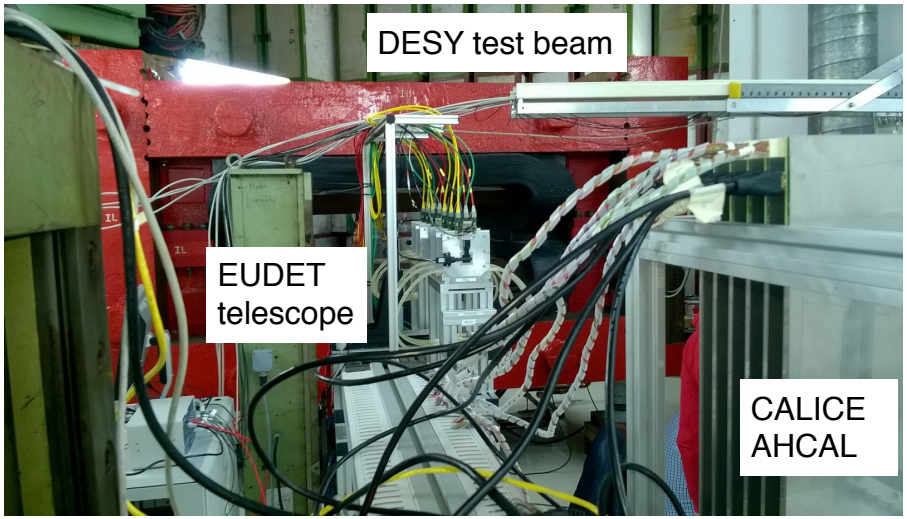


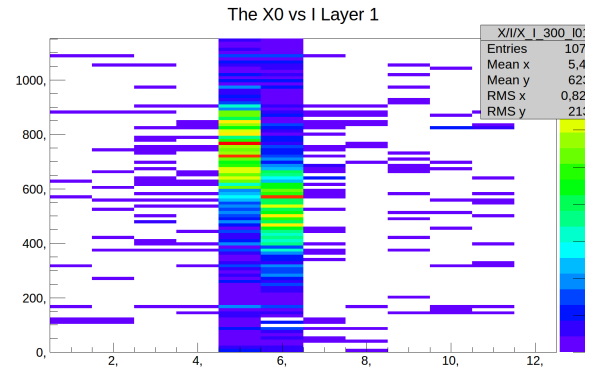


DAQ integration

- Within AIDA-2020 DAQ effort, established combined read-out of trigger-less time-stamped AHCAL and trigger-numbered EUDET telescope
- Opens many possibilities
- Proceeding towards debugging and commissioning of new trigger logic unit (TLU) and EUDAQ-2



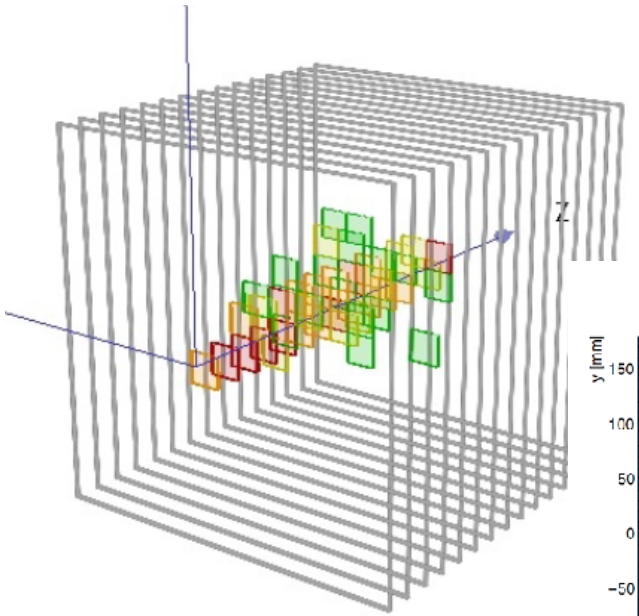


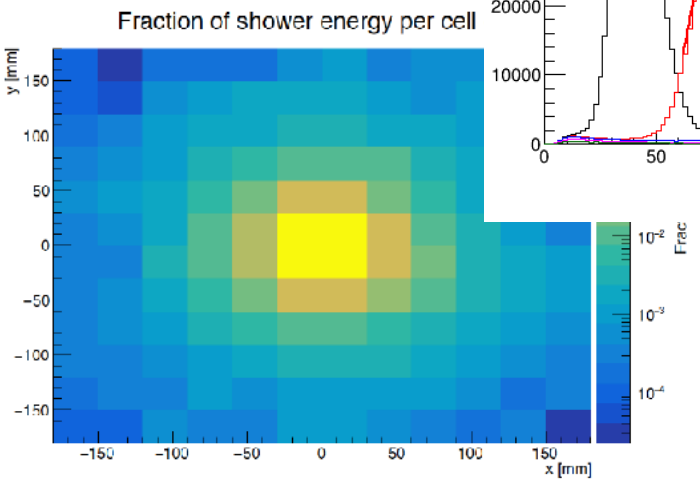


spatial correlation of synchronous pixel and HCAL hits

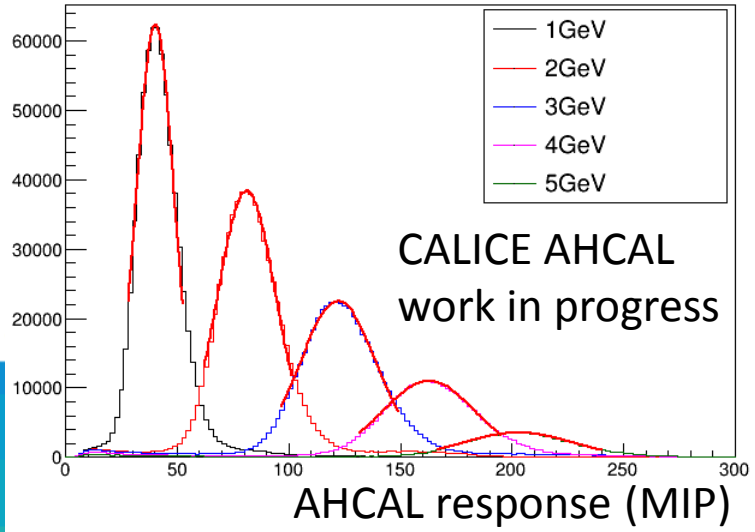
Online monitoring, software & analysis

- Online monitoring based on DQ4HEP framework
  - also handing correlations between detectors
- Quasi-online monitoring after event building and reconstruction
- Analysis in progress: energy and time
  - 2015 CERN and 2016 DESY data





energy spectrum for 1-5 GeV



Strategy

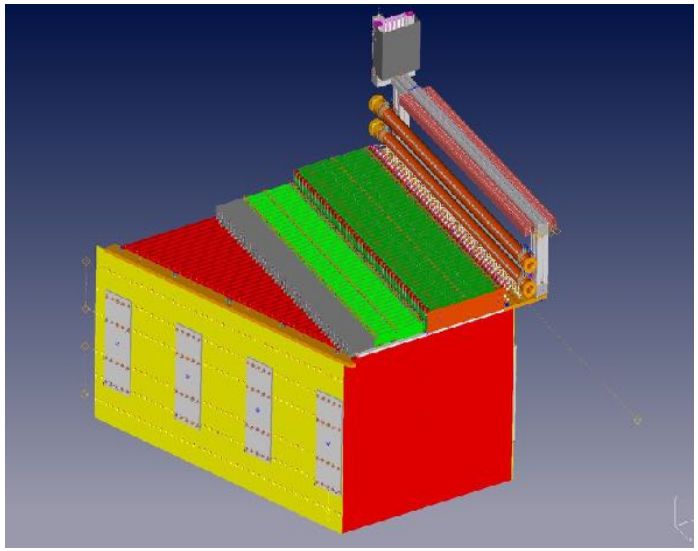
- From single HBUs via small to large stack

- Component test
- Assembly procedure
- Commissioning

15 layers of 1 HBU
electrons

- System integration
- Cooling, power consumption
- Data quality monitoring
- Feedback to:
  - hardware component
  - calibration, temperature compensation
  - performance

40 (or 48) layers of 2x2 HBUs
hadrons



- System test
  - Large-scale electronics assembly
  - Scalability to full detector
- Rich physics program
  - Hadron performance

Time line

- **2016**: warming up for the new prototype
  - 1000 MPPCs, 6 HBUs
  - automatised test and assembly procedures
  - small e.m. stack, including 9 other good HBUs
  - electron beam tests at DESY and EUDAQ integration
  - new ASICs, HBUs and interfaces
  - SiPM procurement

- **2017**: construction and commissioning
  - boards in summer, layers in fall, stack in winter
  - small stack tests going on in parallel at DESY and CERN

- **2018**: full hadronic stack test at CERN SPS

AHCAL technological prototype

Strong contribution from different international & German institutes

Uni. Wuppertal
Calibration system
ASIC tests

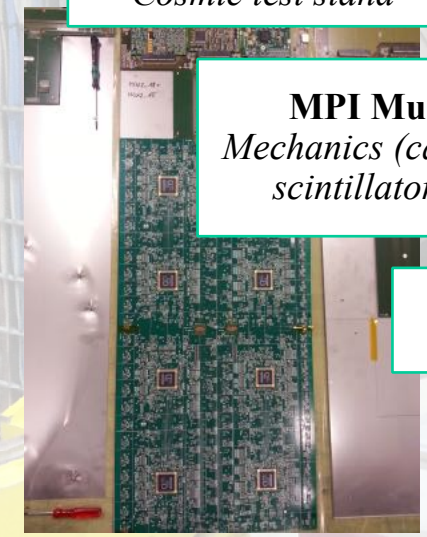
Uni. Hamburg
Tile & SiPM tests

Uni. Heidelberg
Tile & SiPM tests
ASICs

Uni. Mainz
DAQ, assembly
Cosmic test stand

DESY in leading role
Electronics & mechanics design
Commissioning
Testbeam software
Testbeam coordination

Uni. Sussex
Monitoring



MPI Munich
Mechanics (cassettes),
scintillator tests

All institutes
Analysis of data

Lebedev I
Tile production

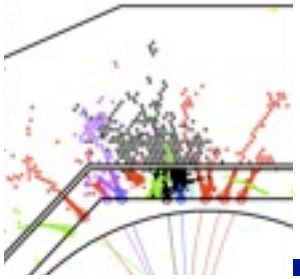
Omega (IN2P3)
ASICs

Prague
DAQ

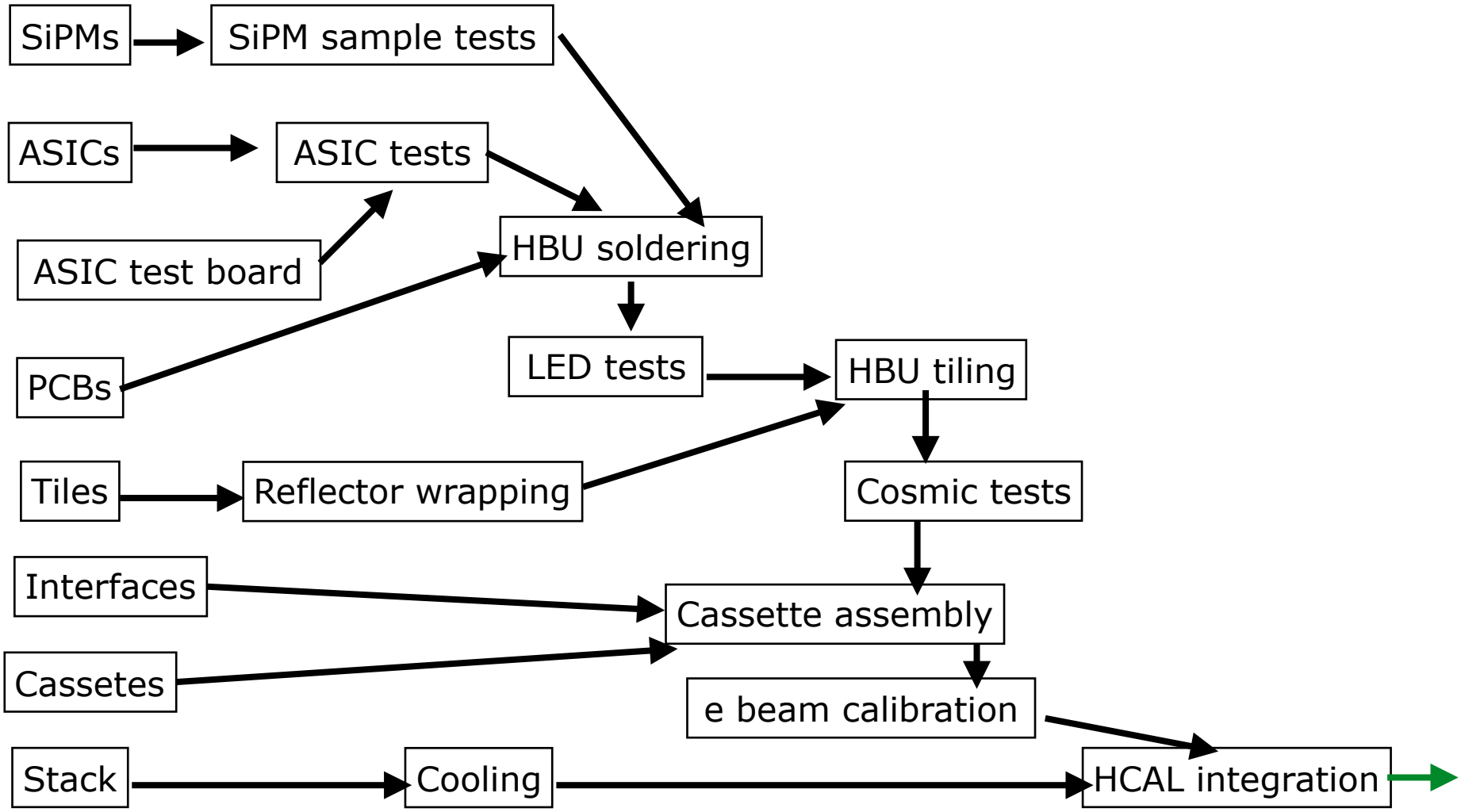
CERN
Tungsten structure,
test beam, logistics

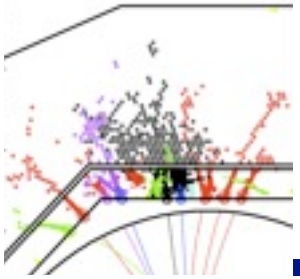
R&D contribution from additional partners

Shinshu Uni, Tokyo Uni (**Japan**)
JINR, Dubna, MEPHI, Moscow (**Russia**)
UT Arlington, Northern Illinois Uni (**USA**)

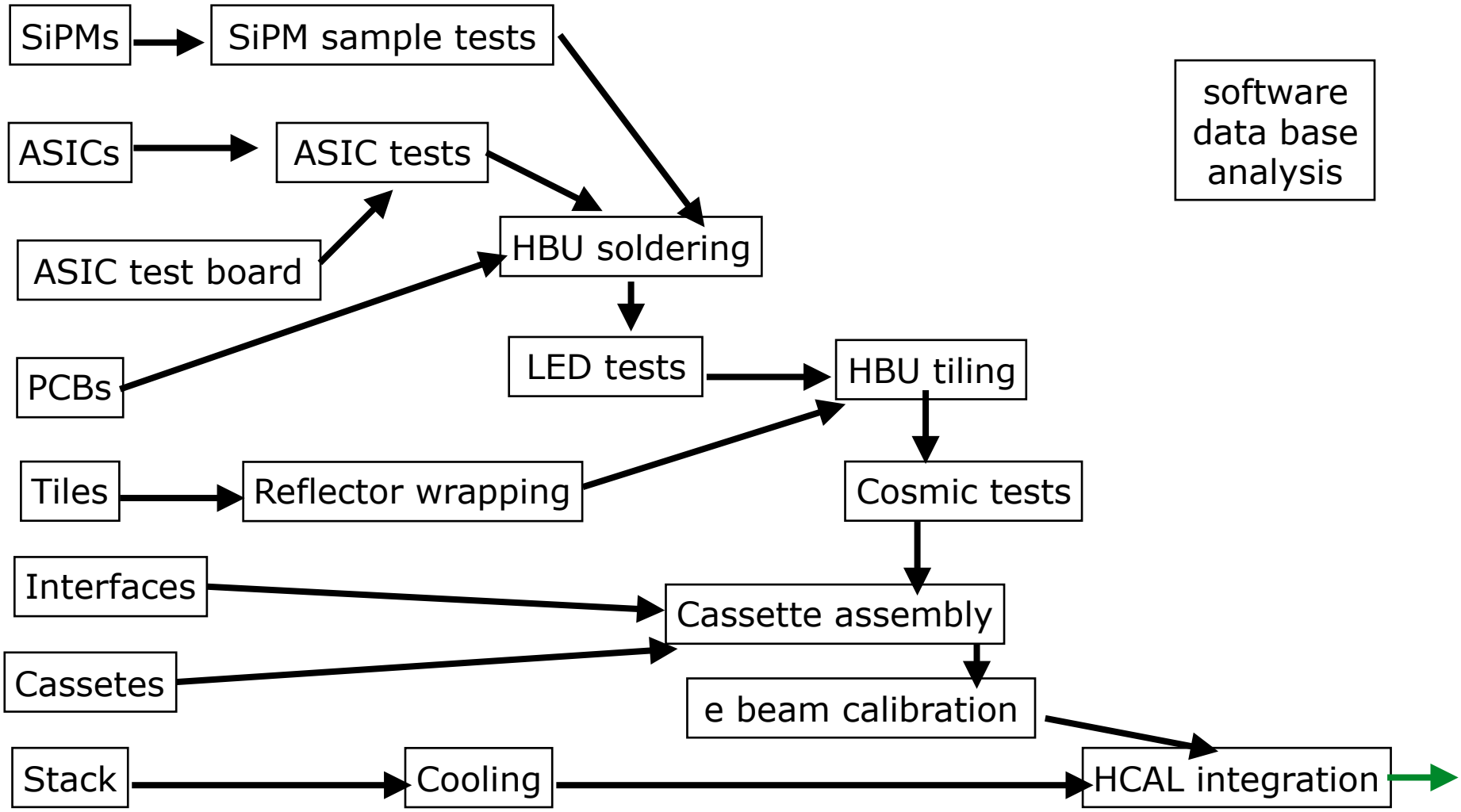


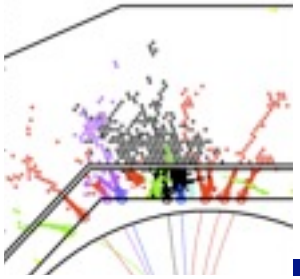
Flow


SiPMs
SiPM sample tests
ASICs
ASIC tests
ASIC test board
HBU soldering
PCBs
LED tests
HBU tiling
Tiles
Reflector wrapping
Cosmic tests
Interfaces
Cassette assembly
Cassetes
e beam calibration
Stack
Cooling
HCAL integration



Flow


SiPMs
SiPM sample tests
ASICs
ASIC tests
ASIC test board
PCBs
HBU soldering
LED tests
HBU tiling
software
data base
analysis
Tiles
Reflector wrapping
Cosmic tests
Interfaces
Cassette assembly
Cassetes
e beam calibration
Stack
Cooling
HCAL integration



Flow

Heidelberg

SiPMs → SiPM sample tests

Palaiseau

ASICs → ASIC tests

Wuppertal

ASIC test board

PCBs

HBU soldering

LED tests

Mainz

HBU tiling

Moskau

Tiles

Uni Hamburg

Reflector wrapping

Cosmic tests

Interfaces

Cassette assembly

Cassetes

MPP Munich

e beam calibration

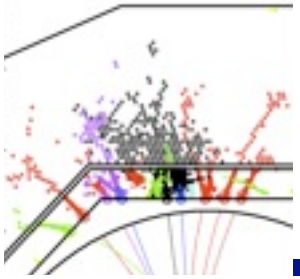
Stack

Cooling

HCAL integration

software
data base
analysis

excellent
opportunities
at DESY
in 2017-18



Flow

Heidelberg

SiPMs → SiPM sample tests

Palaiseau

ASICs → ASIC tests

Wuppertal

ASIC test board

PCBs

HBU soldering

LED tests

Mainz

HBU tiling

Moskau

Tiles

Uni Hamburg

Reflector wrapping

Cosmic tests

Interfaces

Cassette assembly

Cassetes

MPP Munich

e beam calibration

Stack

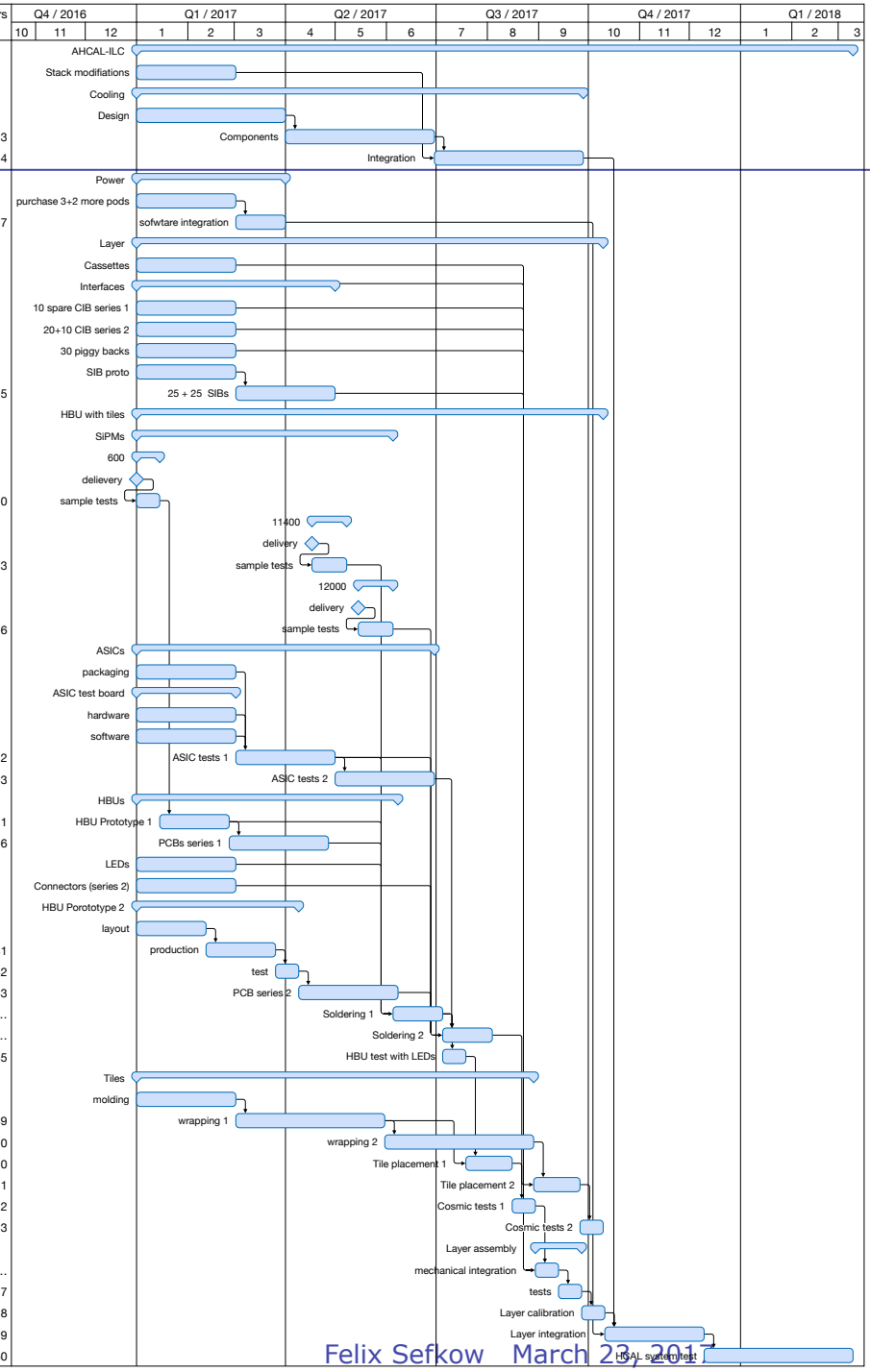
Cooling

HCAL integration

software
data base
analysis

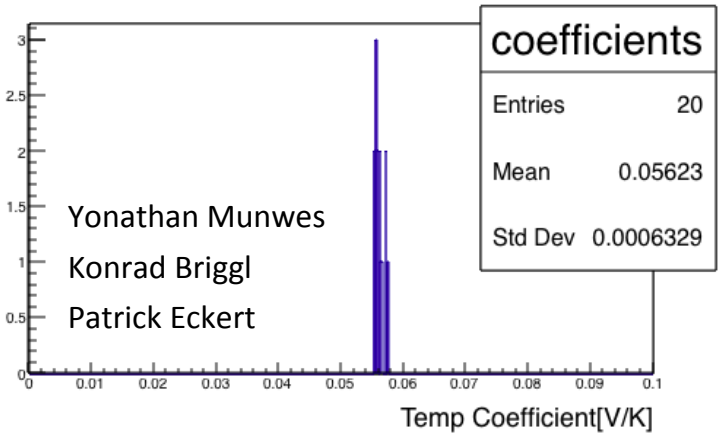
excellent
opportunities
at DESY
in 2017-18

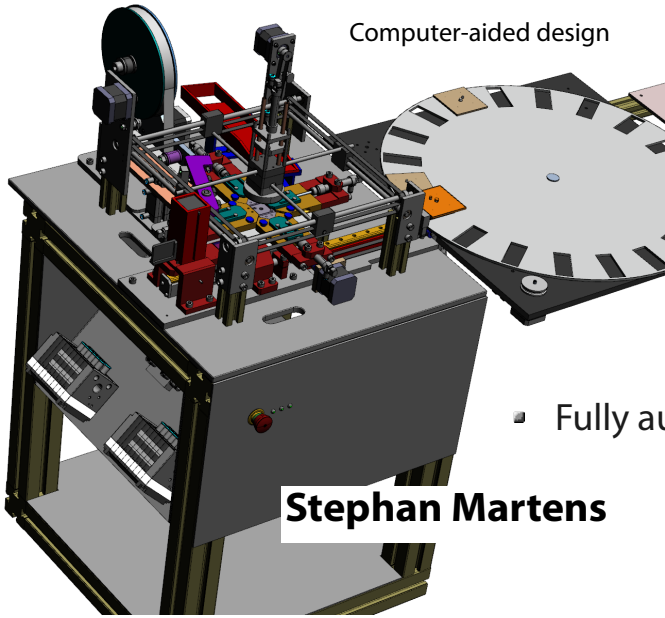
#	Traits	Title	Given Work	Given Earliest Start	Resources	Predecessors
0		**AHCAL-ILC**		**1 Jan 2017**		
1		Stack modifiations				
2		**Cooling**				
3		Design				
4		Components				3
5		Integration				1; 4
6		**Power**				
7		purchase 3+2 more pods				
8		sofwtare integration				7
9		**Layer**				
10		Cassettes				
11		**Interfaces**				
12		10 spare CIB series 1				
13		20+10 CIB series 2				
14		30 piggy backs				
15		SIB proto				
16		25 + 25 SIBs				15
17		**HBU with tiles**				
18		**SiPMs**				
19		**600**				
20		delievery		1 Jan 2017		
21		sample tests				20
22		**11400**				
23		delivery		17 Apr 2017		
24		sample tests				23
25		**12000**				
26		delivery		15/5/17		
27		sample tests				26
28		**ASICs**				
29		packaging				
30		**ASIC test board**				
31		hardware				
32		software				
33		ASIC tests 1				29; 31; 32
34		ASIC tests 2				33
35		**HBUs**				
36		HBU Prototype 1		1 Jan 2017		21
37		PCBs series 1				36
38		LEDs				
39		Connectors (series 2)				
40		**HBU Porotype 2**				
41		layout				
42		production				41
43		test				42
44		PCB series 2				43
45		Soldering 1		5 June 2017		24; 33; 36;...
46		Soldering 2				27; 33; 34;...
47		HBU test with LEDs				45
48		**Tiles**				
49		molding				
50		wrapping 1				49
51		wrapping 2				50
52		Tile placement 1				47; 50
53		Tile placement 2				46; 51
54		Cosmic tests 1				52
55		Cosmic tests 2				53
56		**Layer assembly**				
57		mechanical integration				10; 11; 12;...
58		tests				57
59		Layer calibration				58
60		Layer integration				5; 8; 59
61		HCAL system test				60



Status as of today

- MPPCs: first 600 delivered
  - characterised at U Heidelberg
    - excellent uniformity
  - mounted on PCBs, awaiting tiles
  - 11'400 more in April, 12'000 in May
- Tiles: 28’000 from Moscow delivered to DESY
  - first 144 to be wrapped manually
  - wrapping machine in preparation at U Hamburg
- ASICs: 400 @ DESY, 400 more to be packaged

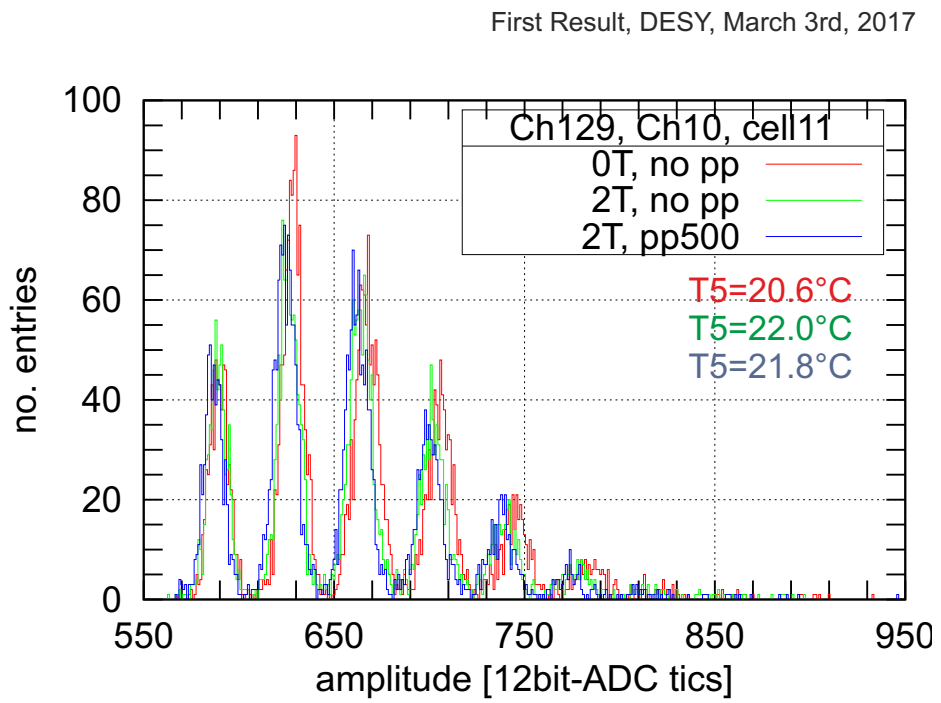


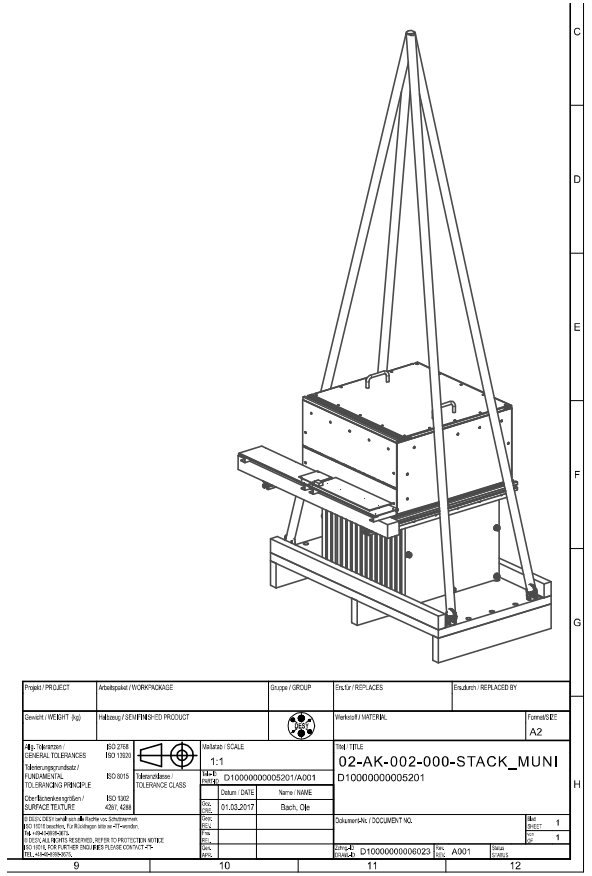


Tests with small stack

- May 2017: beam test in 3T magnetic field at SPS
- Electronics tested last week at DESY in 2T (w/o beam)
- Commissioning of active temperature compensation in preparation

HBU5_BGA test in 2T magnetic field



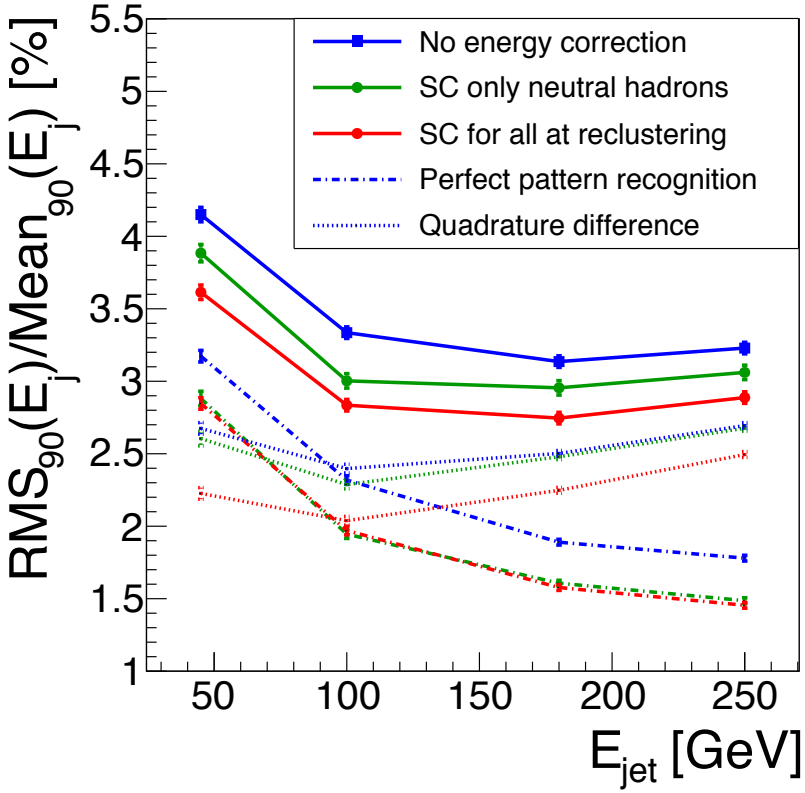


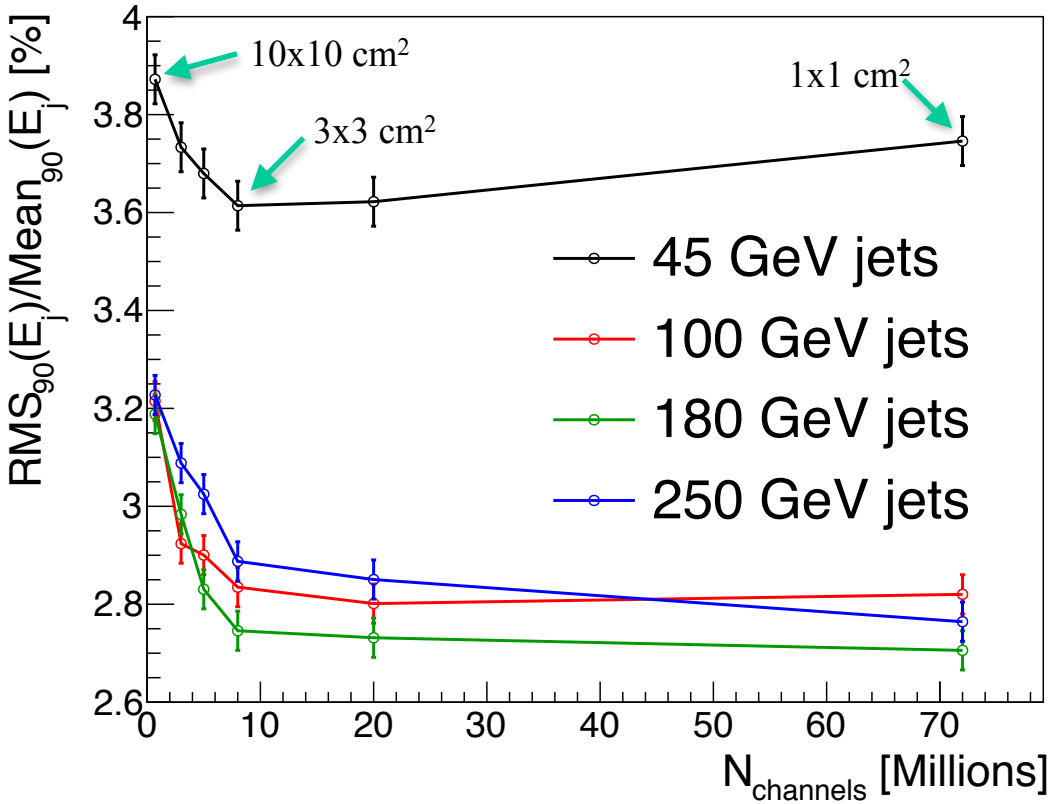
Short update on granularity and resolution

AHCAL studies using Pandora

- Done in collaboration with Cambridge
- Software compensation implemented
  - works also for SDHCAL
  - paper this month
- New study with two granularity regions

To be done for CLIC detector with deeper HCAL

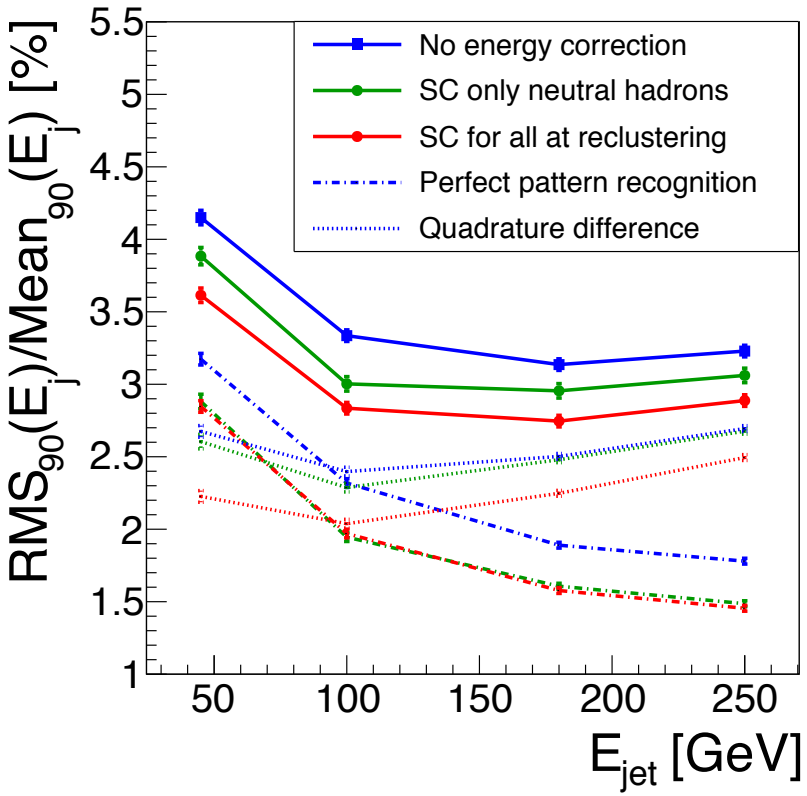


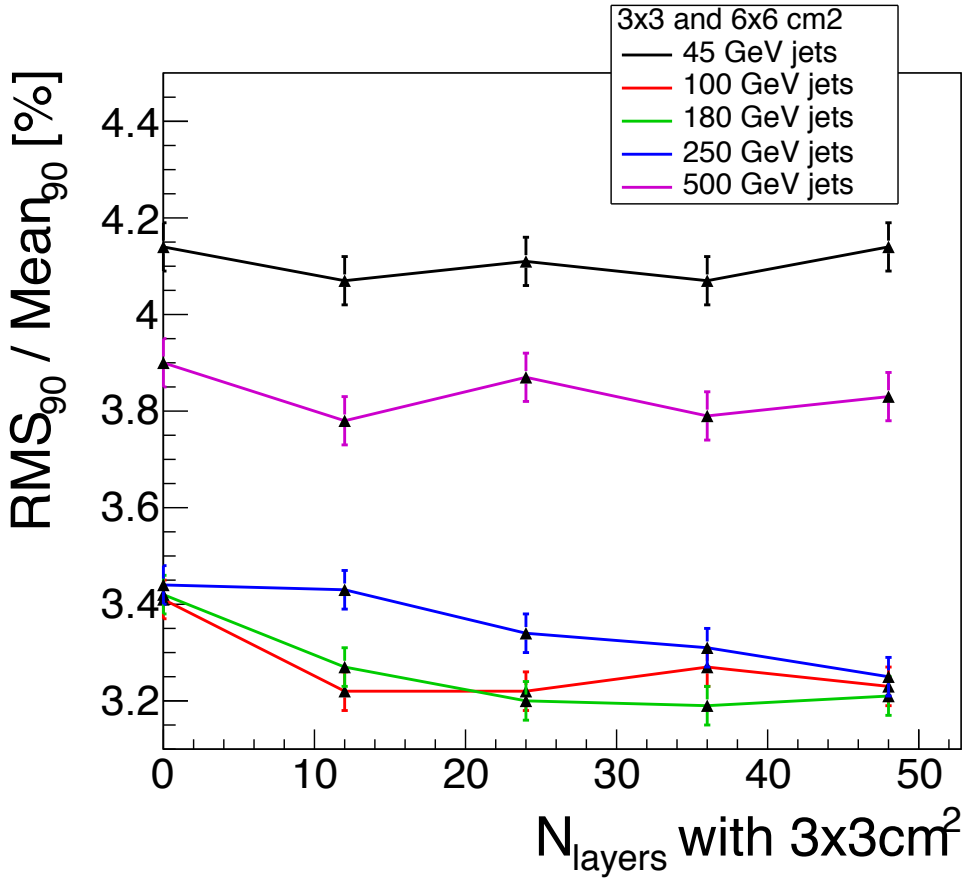


AHCAL studies using Pandora

- Done in collaboration with Cambridge
- Software compensation implemented
  - works also for SDHCAL
  - paper this month
- New study with two granularity regions

To be done for CLIC detector with deeper HCAL

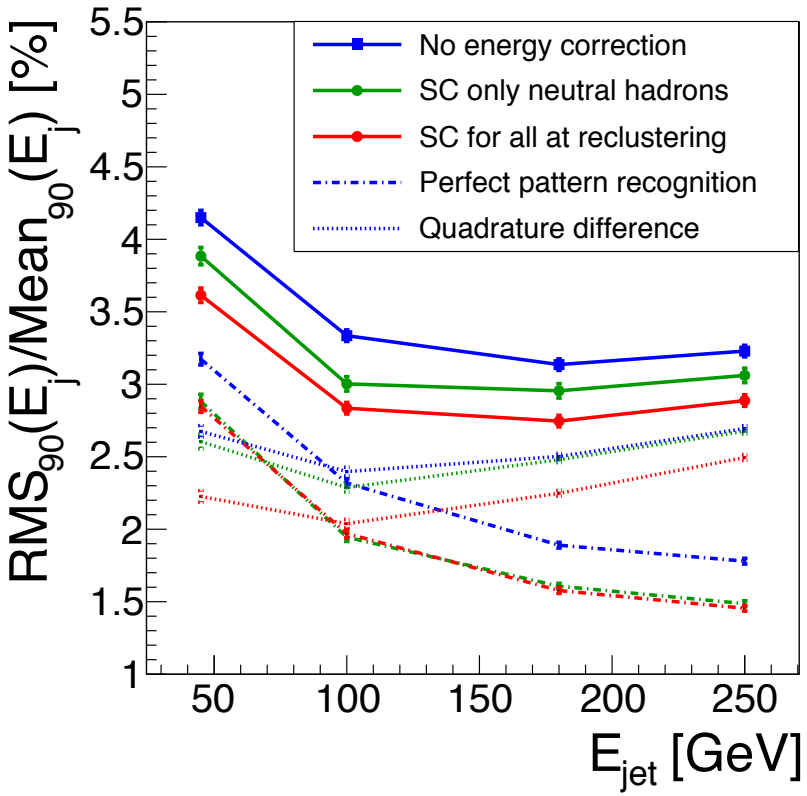


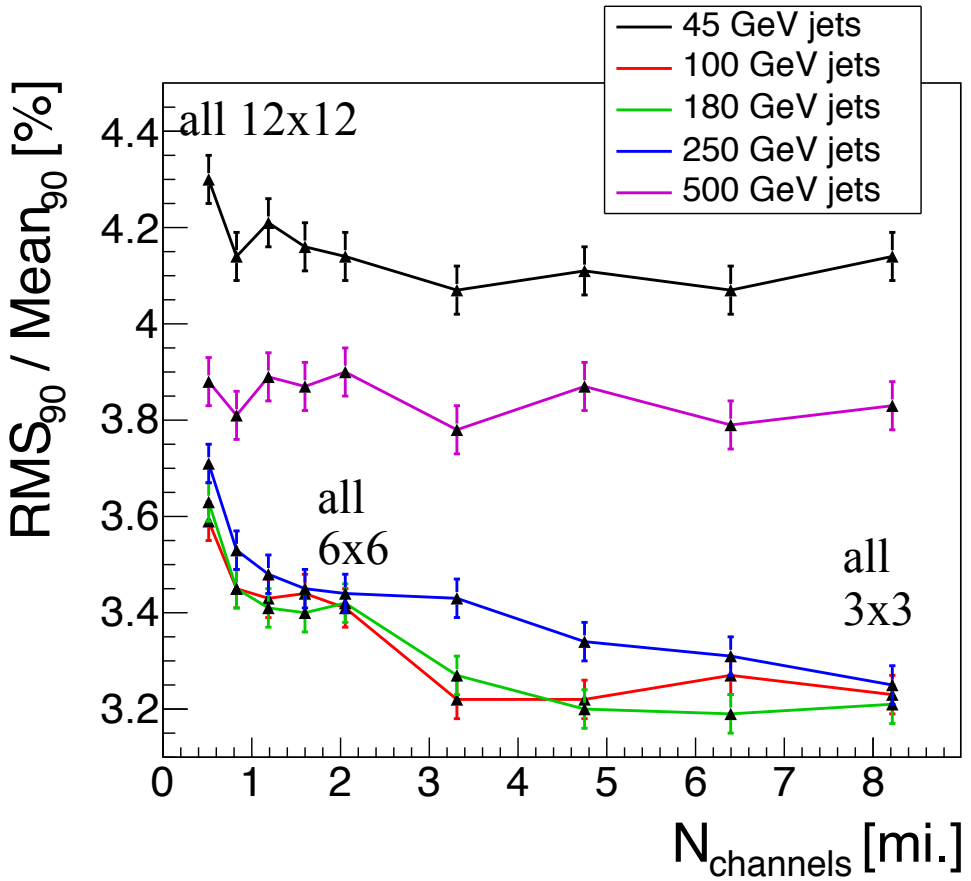


AHCAL studies using Pandora

- Done in collaboration with Cambridge
- Software compensation implemented
  - works also for SDHCAL
  - paper this month
- New study with two granularity regions

To be done for CLIC detector with deeper HCAL





Summary

- Construction of a new AHCAL prototype with allover improved technologies started for beam test at CERN in 2018
- Tile size optimisation reveals cost saving potential
- R&D continues, e.g. on mega-tiles, ASICs
- Cooperation with CMS HGCAl on scintillator read-out electronics and beam test started