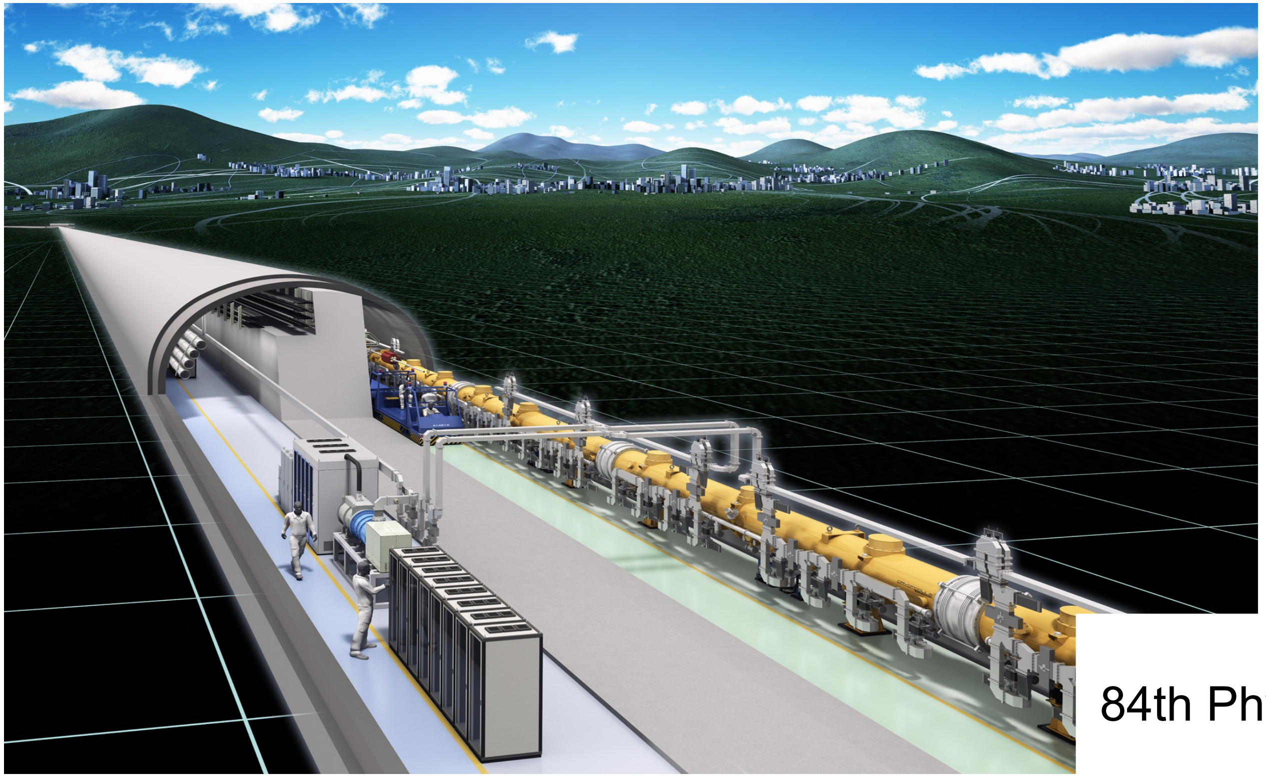
International Linear Collider – Physics & Detectors.

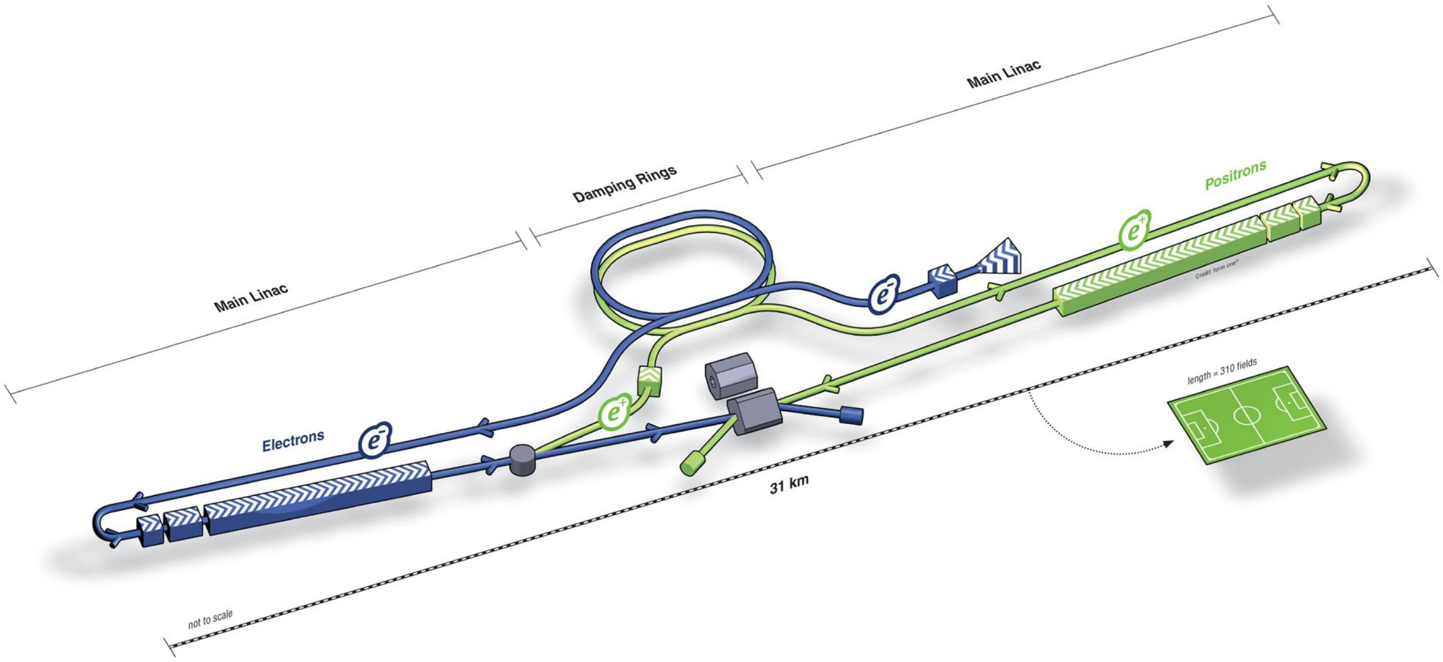


Dimitra Tsionou

84th Physics Research Committee

DESY, 19-Oct-2017

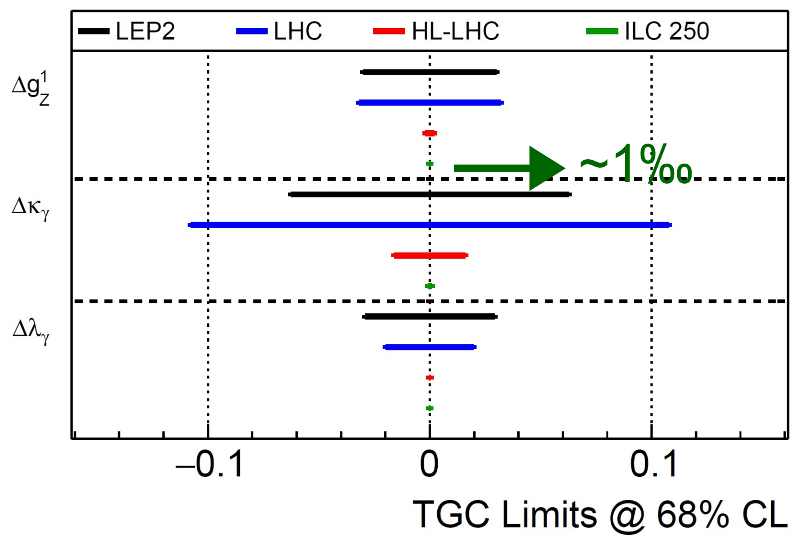
The International Linear Collider – ILC



- e^+e^- collider from 90 GeV to 1TeV
- Initial stage of 250 GeV
- Under political consideration in Japan. Input expected for European Strategy in 2018

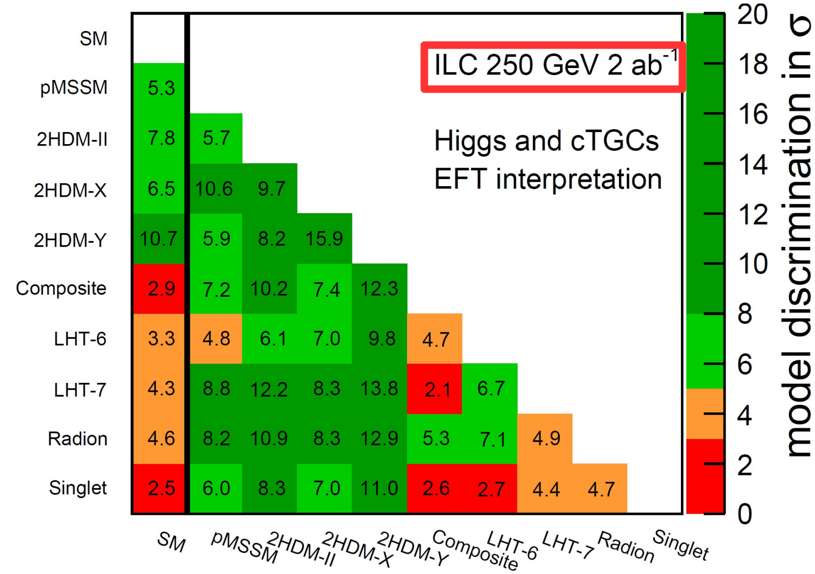
Physics Highlights

- Studies on aTGCs in WW pair production and limit comparison with the LHC



R. Karl, PhD thesis in preparation

- Higgs and aTGC input to distinguish between SM and different BSM points



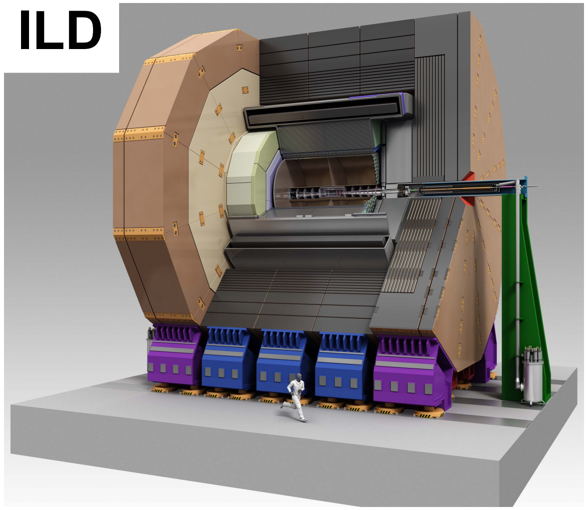
	SM	pMSSM	2HDM-II	2HDM-X	2HDM-Y	Composite	LHT-6	LHT-7	Radion
pMSSM	5.3								
2HDM-II	7.8	5.7							
2HDM-X	6.5	10.6	9.7						
2HDM-Y	10.7	5.9	8.2	15.9					
Composite	2.9	7.2	10.2	7.4	12.3				
LHT-6	3.3	4.8	6.1	7.0	9.8	4.7			
LHT-7	4.3	8.8	12.2	8.3	13.8	2.1	6.7		
Radion	4.6	8.2	10.9	8.3	12.9	5.3	7.1	4.9	
Singlet	2.5	6.0	8.3	7.0	11.0	2.6	2.7	4.4	4.7

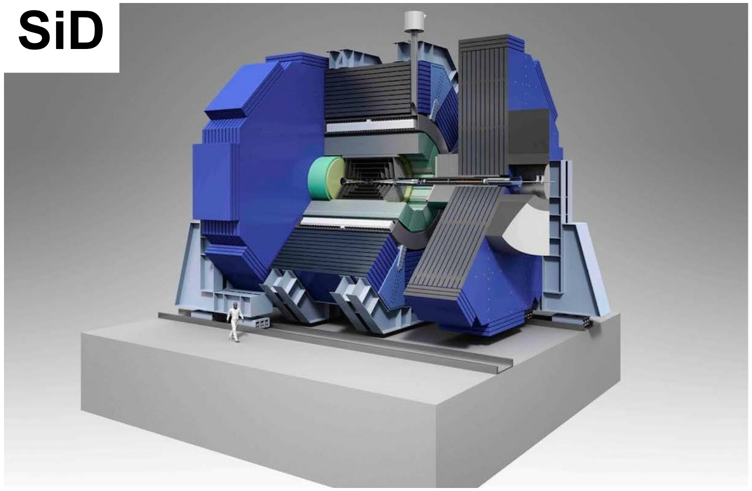
arXiv: 1708.08912

- For the specific example points chosen, discovery signal potential at ILC while no new particles will be observable at the LHC and HL-LHC

Major improvements in software and new MC production in preparation

Main DESY activities on Physics & Detectors at the ILC

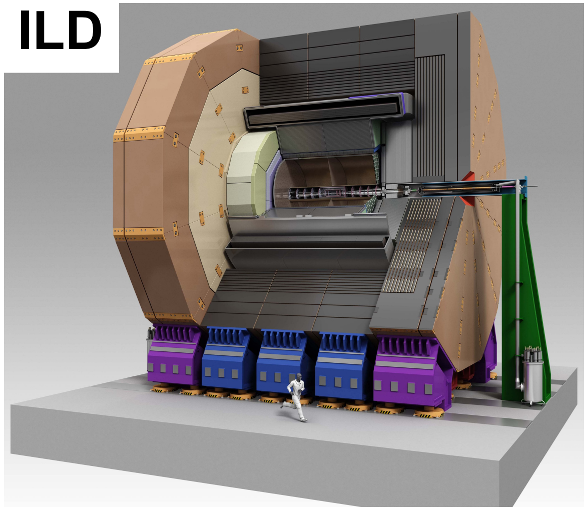


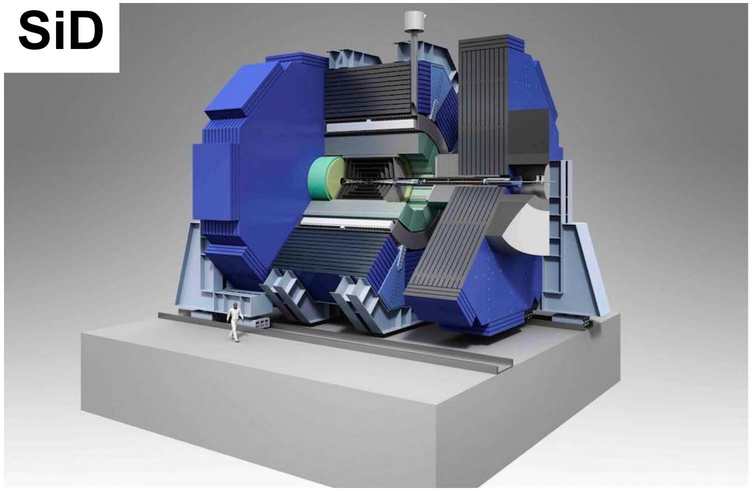


- Detector R&D
  - TPC
  - Calorimetry (hadronic calorimeter)
- Physics analysis → focus on centre of mass energy at 250 GeV
- Software
- Integration

- Additional efforts
  - Vertex detector, PLUME
  - Forward Calorimeter
  - Polarimetry
  - Coordination and Management

Main DESY activities on Physics & Detectors at the ILC





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  - **TPC**
  - **Calorimetry (hadronic calorimeter)**
- Physics analysis → focus on centre of mass energy at 250 GeV
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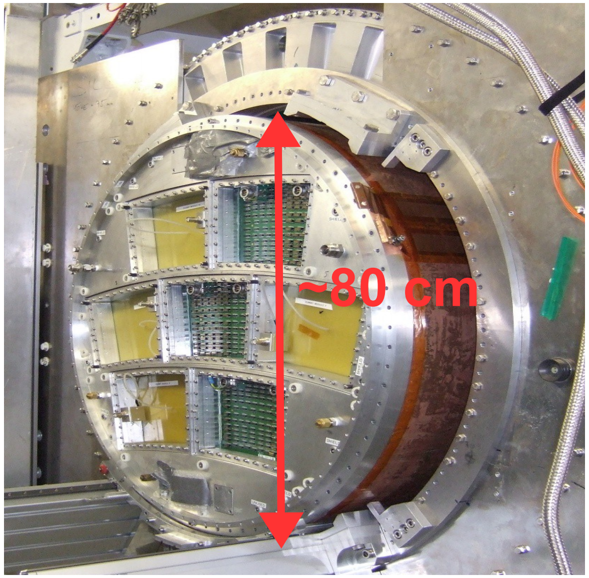
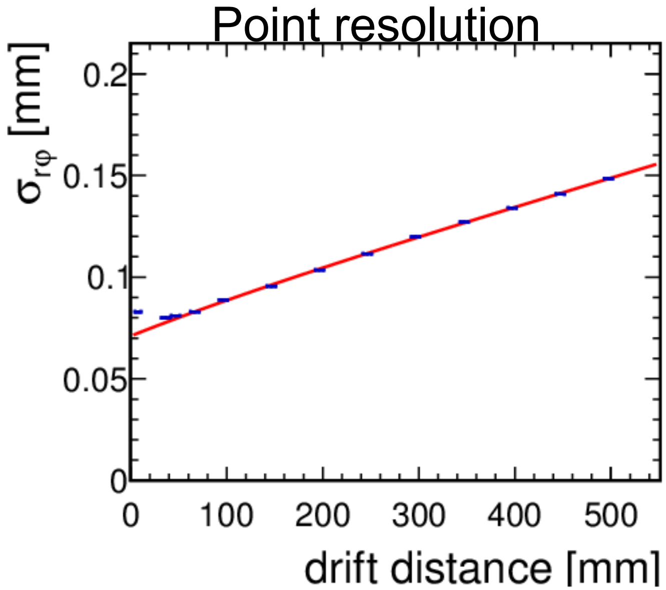
- Additional efforts
  - Vertex detector, PLUME
  - Forward Calorimeter
  - Polarimetry
  - Coordination and Management

In this talk, I will focus on synergies between ILC detectors and other fields

Large Prototype TPC and Current Infrastructure

- DESY test beam infrastructure includes a large bore 1T magnet
  - 20% X0 material budget
- It is widely used by the LCTPC collaboration, Belle, ATLAS,...
- Momentum resolution inside the magnet is essential



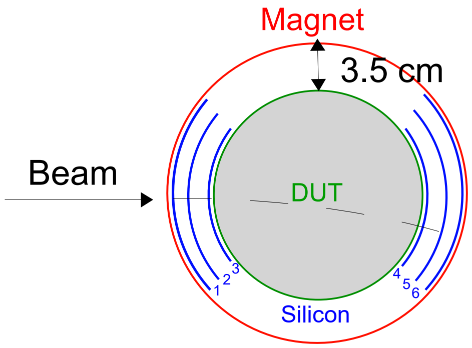


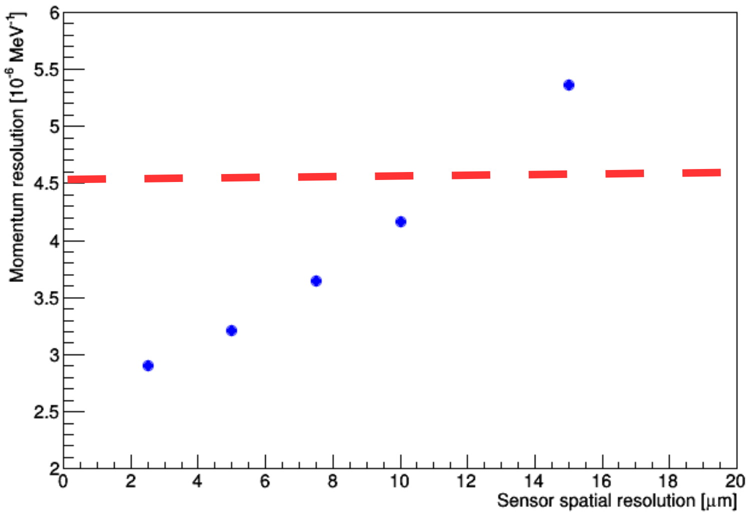
F. Müller, PhD thesis
P. Malek, PhD thesis in preparation

- TPC test beams show performance within expectation
- What is still missing is the momentum resolution measurement (ILD TPC: 10^{-4} /GeV)
- For this and other applications a reference telescope is needed

A Silicon Telescope to fulfill TPC and other DUT needs

- Improve infrastructure for test beams within AIDA2020
- Requirements and limitations imposed by the TPC (and other users) include:
- A large telescope area (order of 10x10 cm^2)
- Sensors with excellent point resolution (<10 µm)
  - Imposed by limited distance between telescope layers in one arm (3.5 cm available per arm)
- Cannot be done with standard ATLAS/CMS sensors

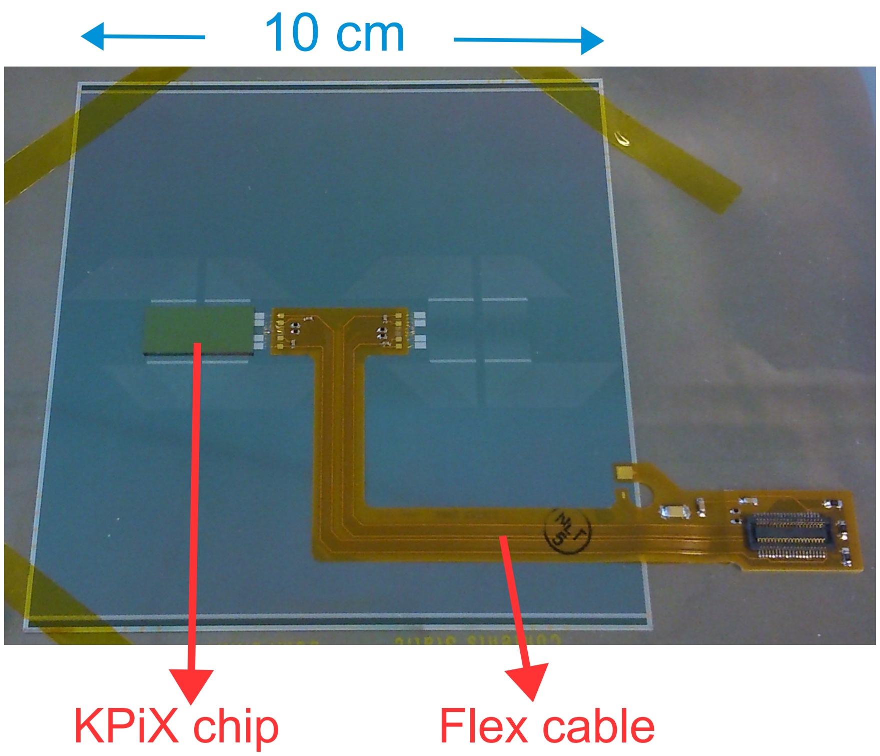




TPC prototype expected momentum resolution

Hardware and what has happened

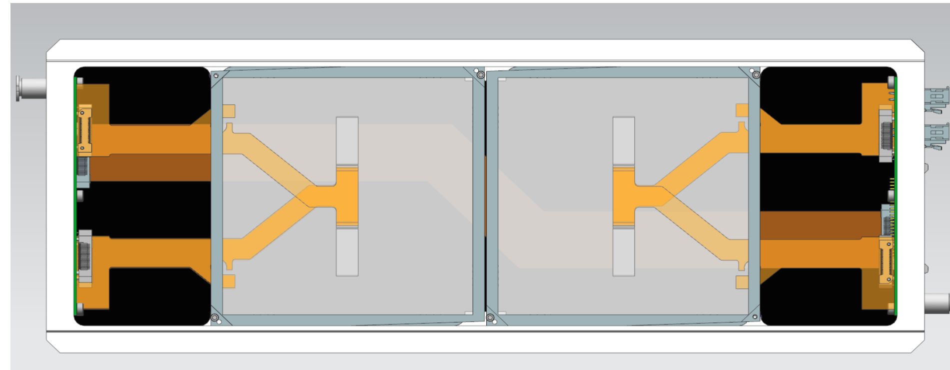
- Desired system identified
- Silicon strip sensors of
  - 10x10 cm^2 area
  - 25 μm pitch → expected spatial resolution 7-8 μm
- Fully integrated system: double metal layer and bump bonded to chip (KPiX)

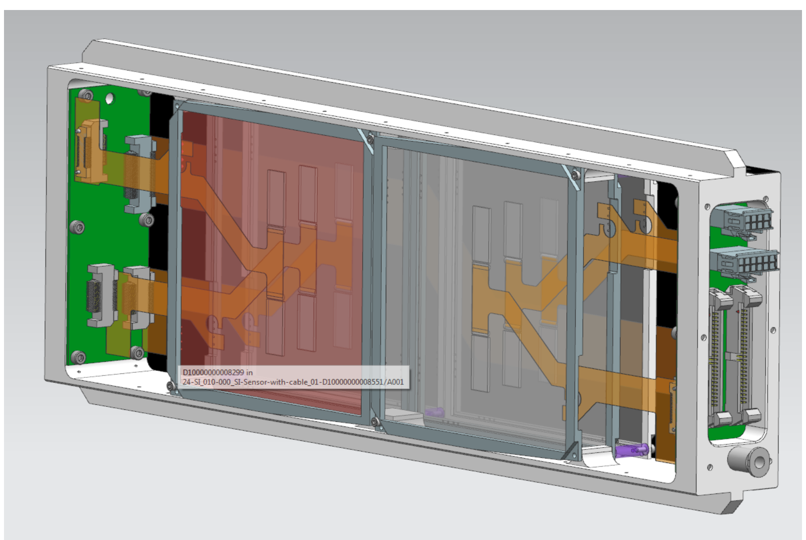


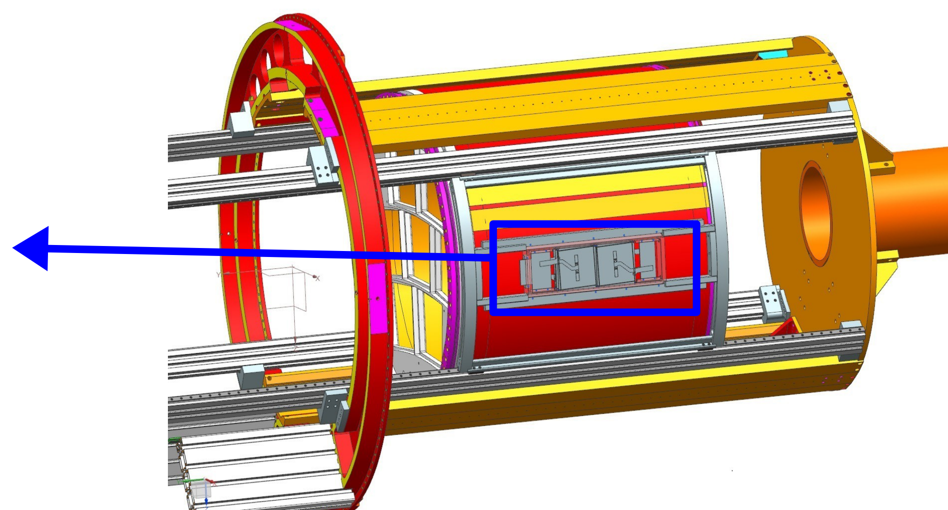
- Sensor and chip developed within the SiD context (SLAC)
- Collaboration between DESY FLC, DESY ATLAS, DESY FEB, DESY ZE, DESY test beam, SLAC, Bristol and AIDA2020 work packages (DAQ)

Final System layout

- The silicon strip telescope will cover a large area (10x20 cm^2)
- It will consist of 3+3 layers of silicon sensors with a small stereo angle (2°)
- It will be housed in a movable cassette for flexibility



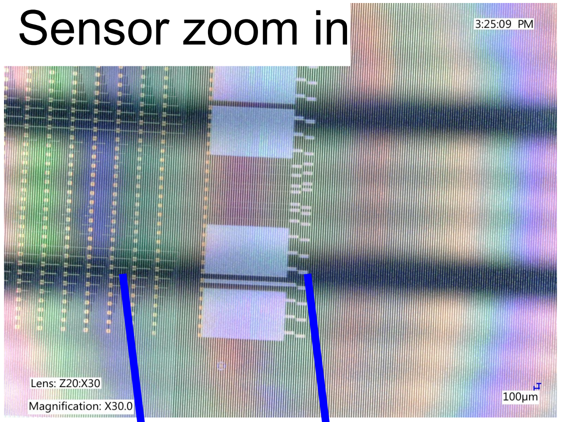




Silicon Strip Sensors – Lab measurements

- Sensors delivered to DESY by Hamamatsu in July and are currently in IZM for bump bonding
- Cable design, production and wire bonding in DESY FEB and ZE
- Sensors electrically tested upon arrival in the clean room

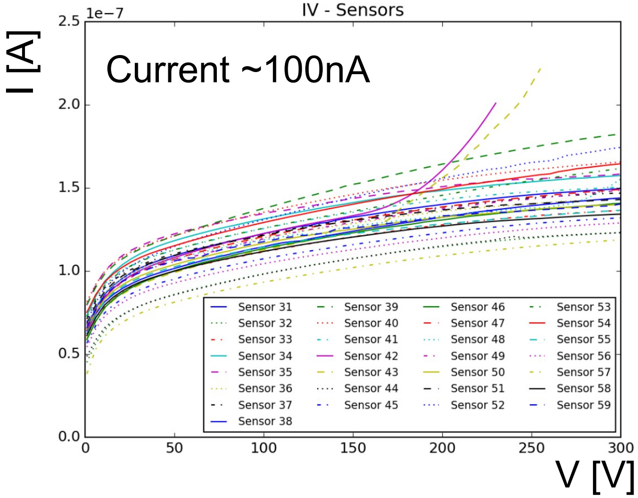
Sensor zoom in

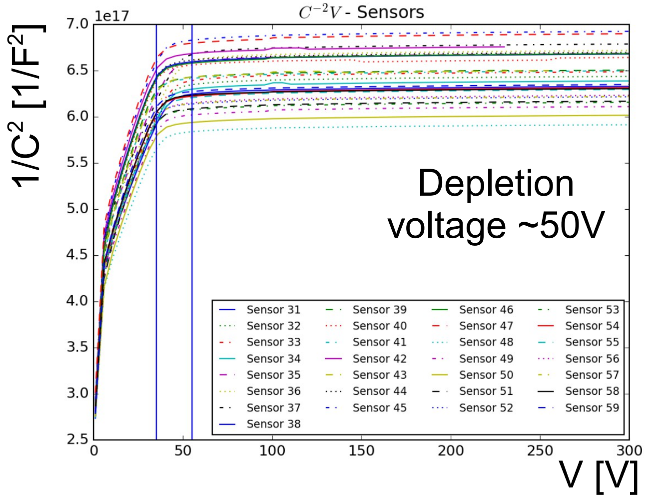


Bump bond pads

Wire bond pads

Good performance of sensors in IV-CV measurements

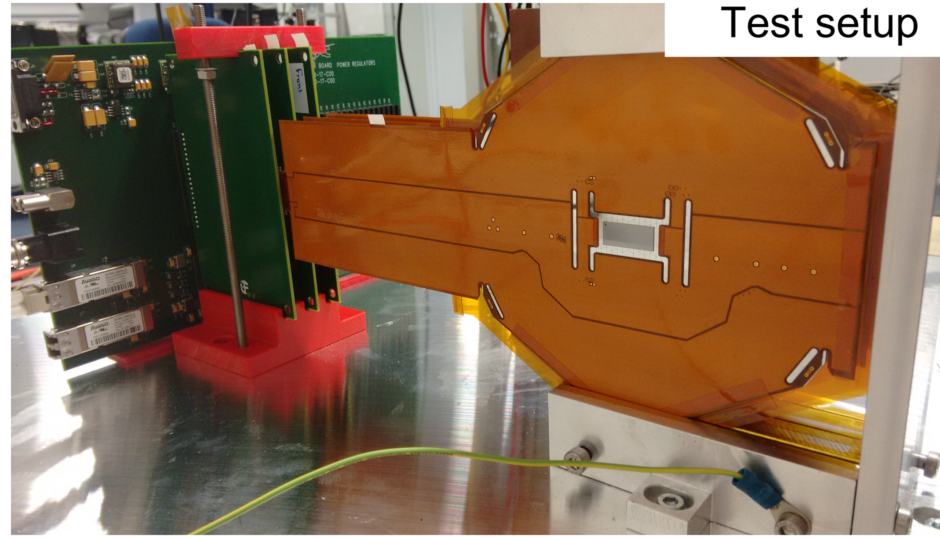




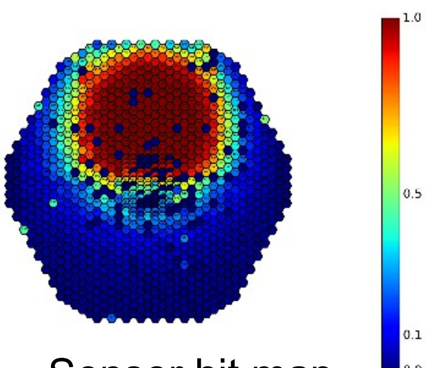
Successful summer student project, A. Weiser

Test setup

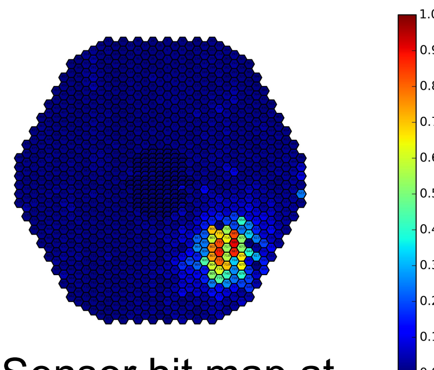
- Test setup at DESY including KPiX chips bump bonded to large pixel sensors (~5x5 mm^2. Sensor was designed for SiD ECal)
- System has been tested with calibration runs, noise runs and radio active source
- Test beams in 2017 to test KPiX operation and EUDAQ software implementation



Test setup



Sensor hit map with source



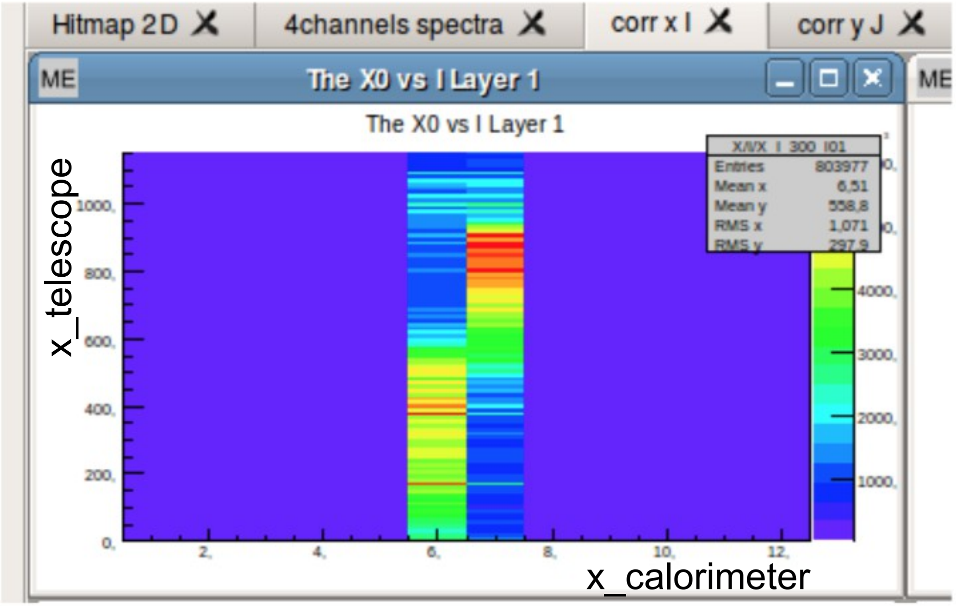
Sensor hit map at test beam

Project well on track.

To be delivered in Spring 2018.

EUDAQ

- Common DAQ software defined by the ILC detector community and supported by AIDA and AIDA2020
- Main advantage: Possibility to have combined test beams with more than one detectors
- Data synchronisation and online event building

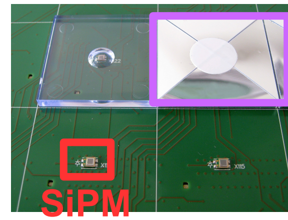


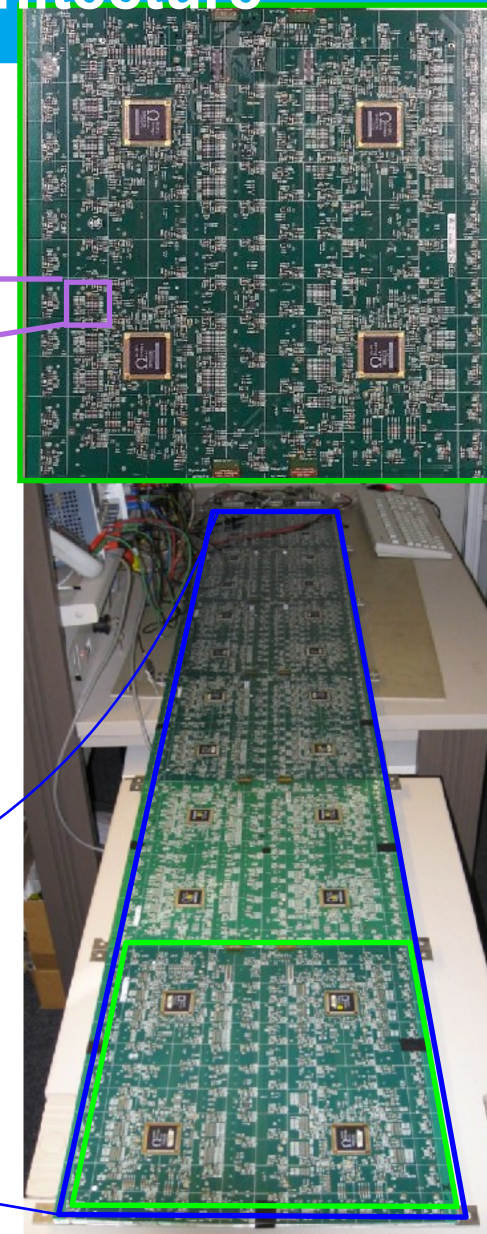
Example of time correlated hits between a Mimosa telescope and tile calorimeter (AHCAL)

- EUDAQ is now widely used by the community
- Strip telescope and TPC integration will profit from this
- New version EUDAQ2 commissioned with Mimosa pixel telescope and tile calorimeter (AHCAL)

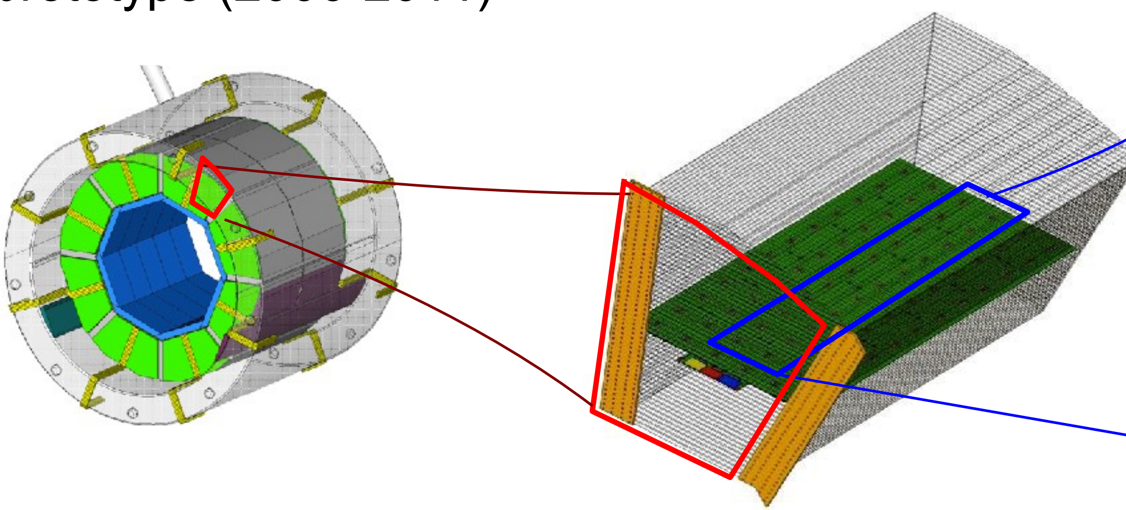
Analog Hadronic Calorimeter (AHCAL) architecture

- AHCAL concept: Highly granular calorimeter with SiPM on tile technology
- Each tile (3x3 cm^2) is read out individually using Silicon Photomultipliers (SiPM)
- Fully integrated electronics (SiPM on PCB)



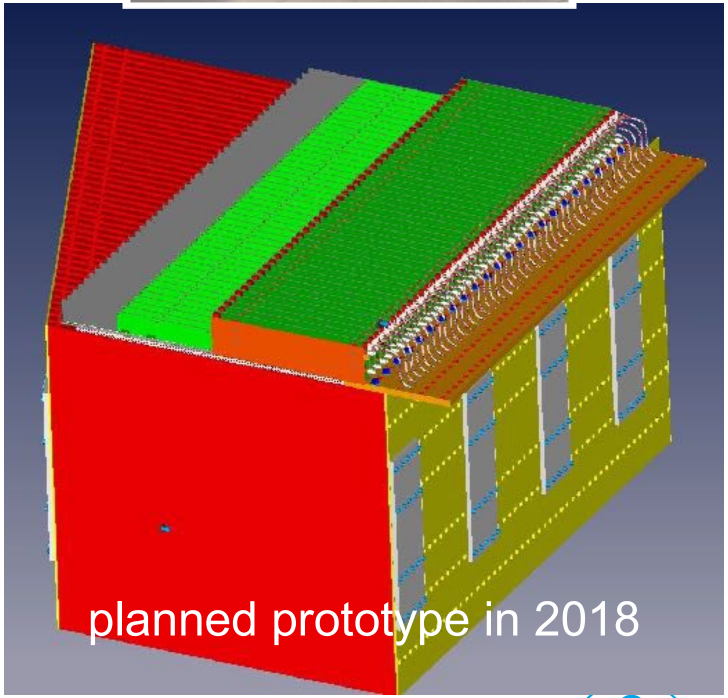


- Technological prototype: demonstrate scalability to full detector (ILD, SiD, CLIC)
- Improvement in all aspects compared to physics prototype (2006-2011)

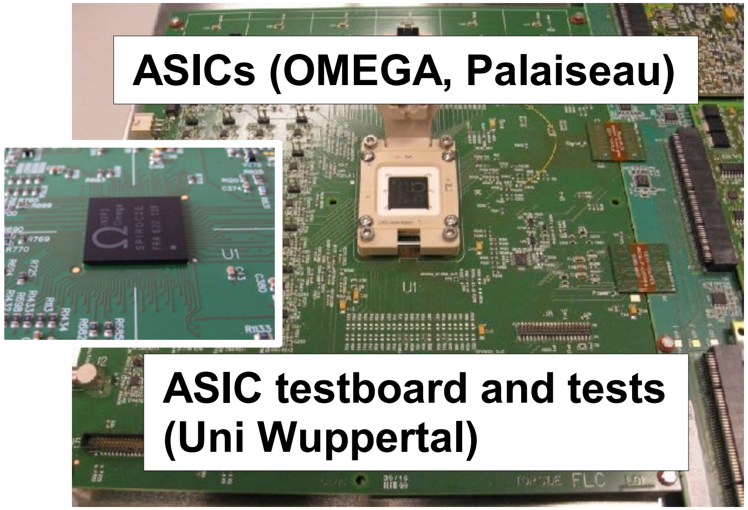


Prototyping strategy

- 2012 - 2015: tests with partially equipped prototypes
  - converge on a final design for tiles and SiPMs
- 2016 - 2017: tests with small “e.m.” prototype ~(0.4m)³
  - Addresses technological questions: power pulsing, high B field, compensation of temperature effects
- 2018 ++: tests with a large prototype. Wedge of ILD barrel ~(0.8m)³
  - steel stack corresponds to ~1% of ILD barrel
  - Scalability, “mass” production
  - Physics of hadron showers, including time evolution



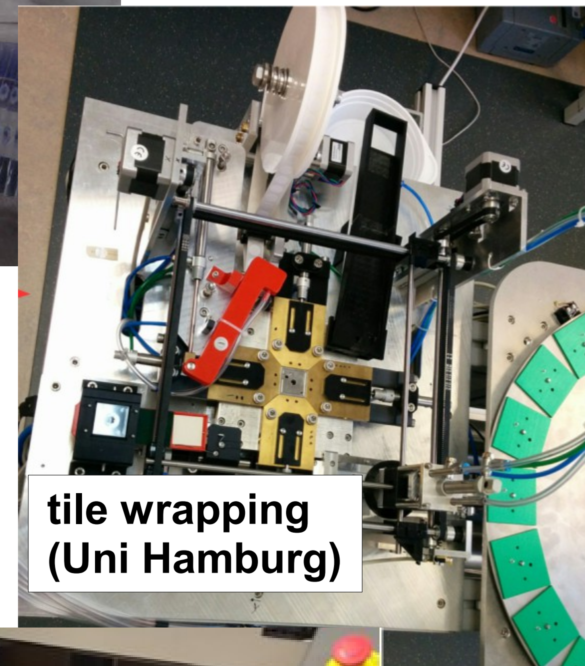
Non-DESY contributions – Infrastructure for mass production



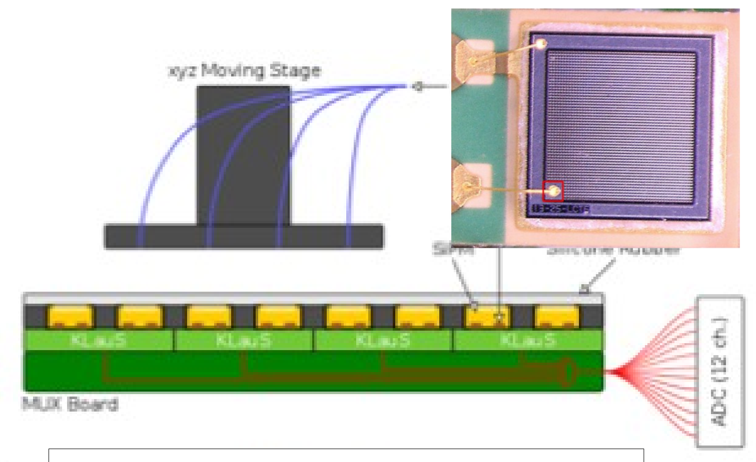
ASICs (OMEGA, Palaiseau)

ASIC testboard and tests (Uni Wuppertal)

tiles (Moscow)



tile wrapping (Uni Hamburg)



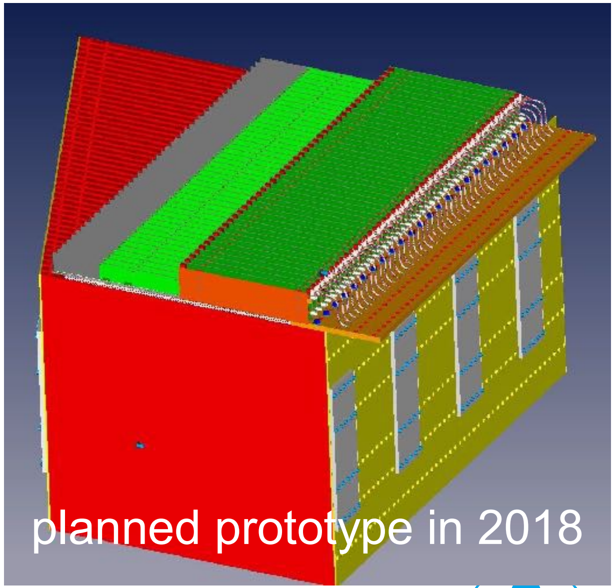
SiPM tests (Uni Heidelberg)

tile assembly & cosmic test (Uni Mainz)

DESY: Electronics and Integration

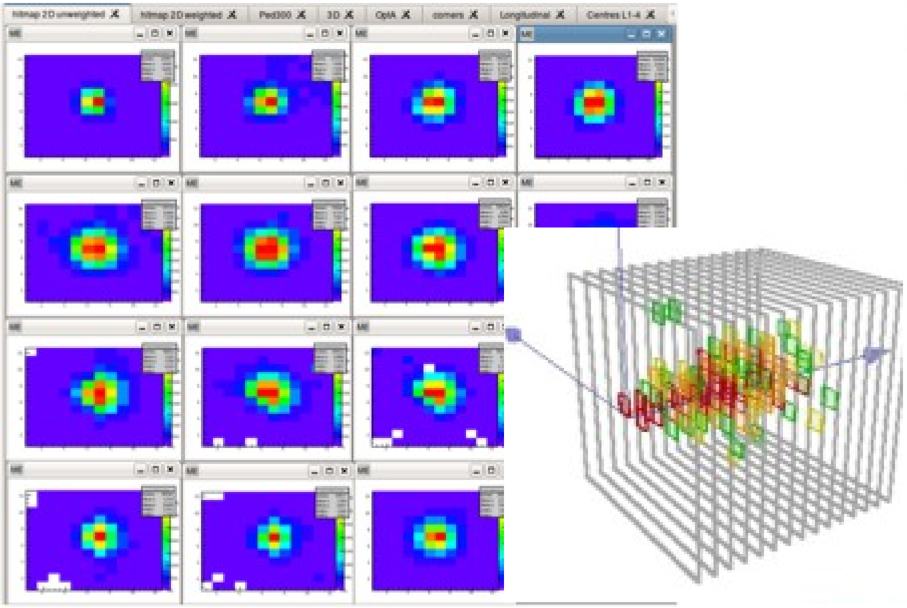
- All electronics boards designed by DESY (FEB)
- PCB production in industry, assembly at DESY (ZE)
  - ~75% of ~400 needed boards done, rest by the end of the year
  - close link FE-ZE, in-house strategy paid off
- First tests with LED system at DESY FEB (without tiles)
  - Entire electronic signal chain - excellent quality

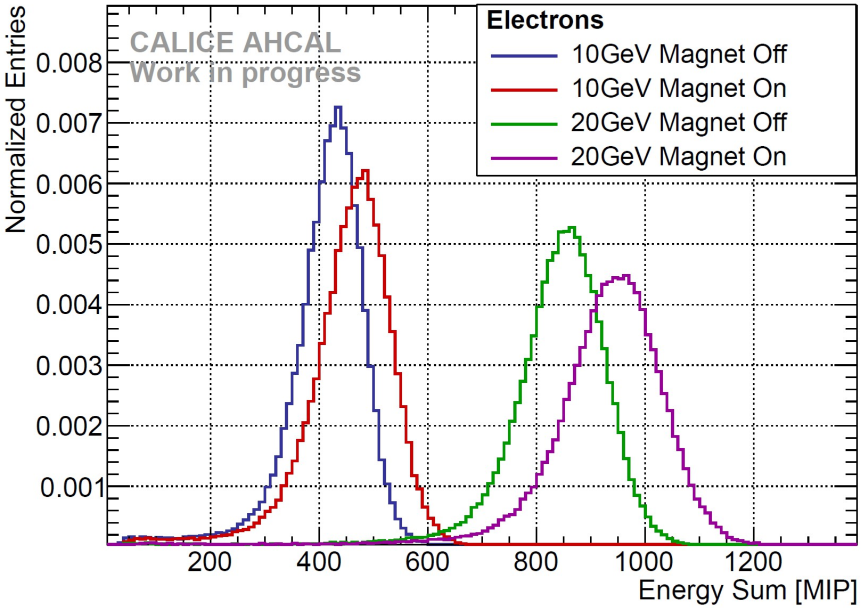
- Integration of cassettes into absorber stack
- Services: power, cooling, data concentration
- Integrated into EUDAQ system
- Most systems dimensioned for full detector



Test in high magnetic field

- May 2017, SPS H2
  - only 1.5 T possible
- Technical: power pulsing in high magnetic field
- Physics: performance with electrons
- Analysis in progress
- Data quality very good

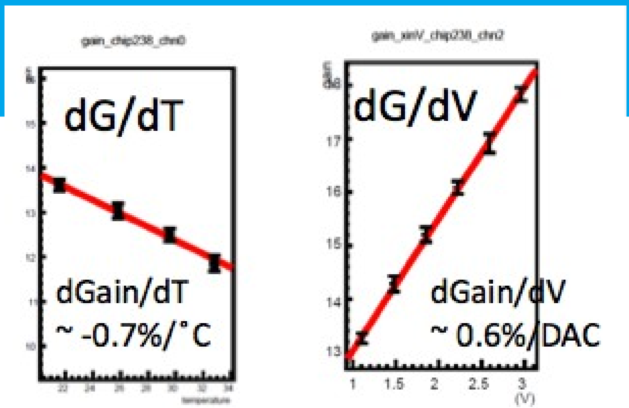


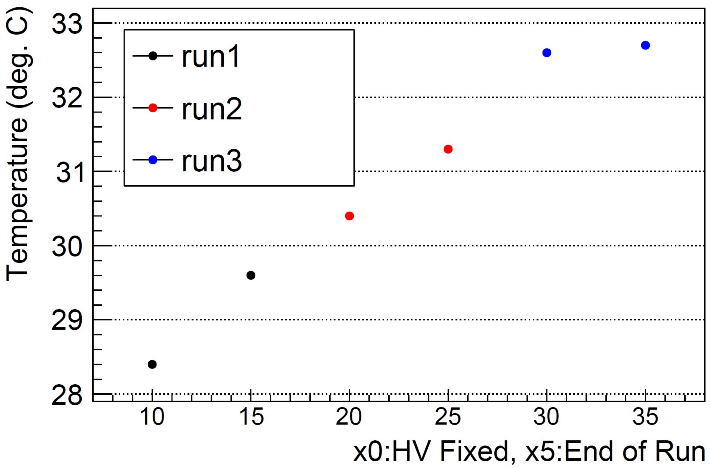


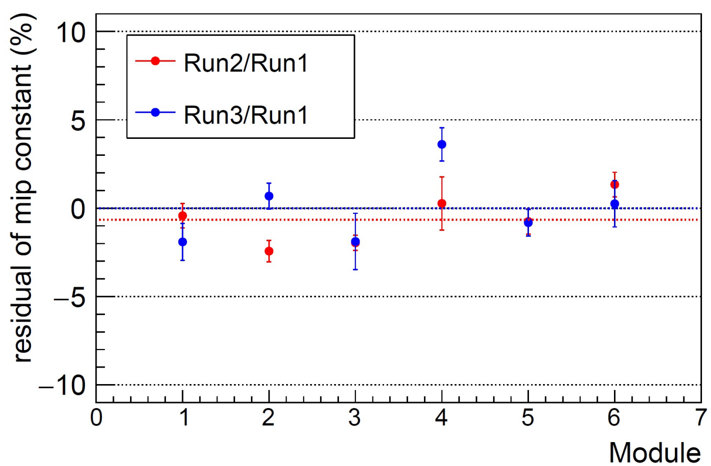
Temperature compensation

- Gain of SiPMs depends on temperature because the breakdown voltage changes with temperature
  - can be corrected for in the analysis
  - or can be compensated by adjusting the operating voltage (active temperature compensation)

- First system test at CERN SPS
  - expected change of muon signal from temperature change: ~ -4.5%
  - Observed with temperature compensation: ~ -0.5%
  - non-perfect correction expected because of temperature rising during the run and finite step width in voltage adjustment

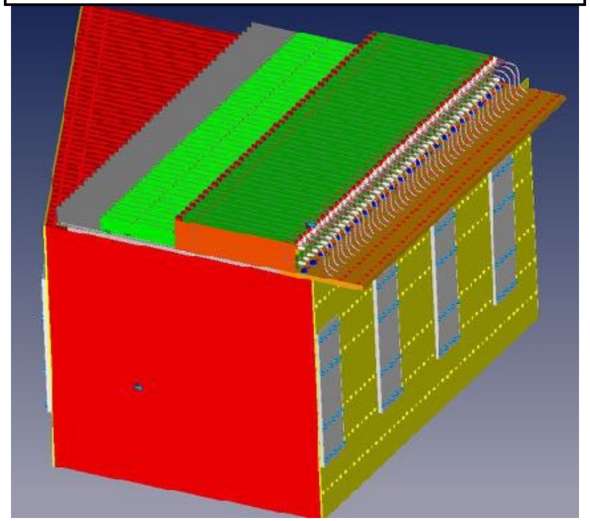






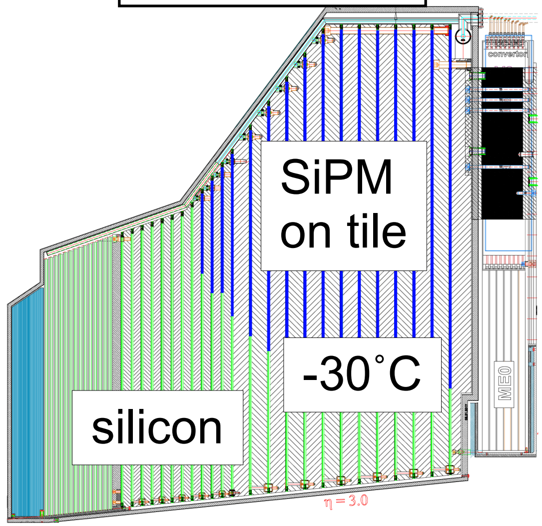
Scintillator part of CMS HGCAL

CALICE AHCAL prototype



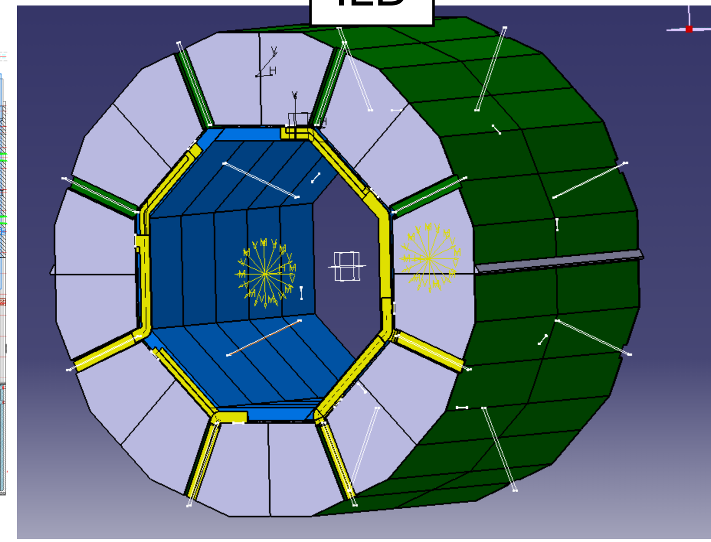
23’000 SiPMs
tile size 3 cm

CMS HGCAL



500’000 SiPMs
tile size 2 - 5.5 cm

ILD



8’000’000 SiPMs
tile size 3 cm

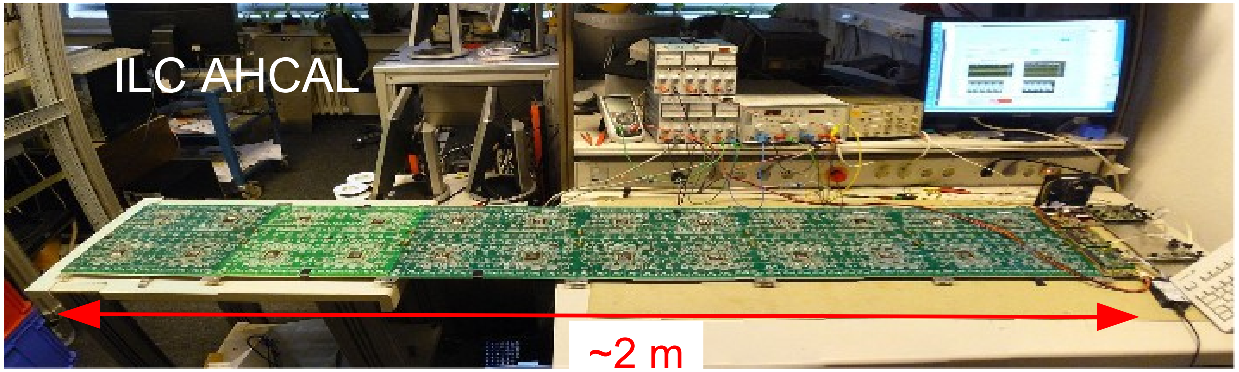
- CMS calorimeter upgrade → SiPM on tile technology decided
- Knowledge transfer between CALICE and CMS
- Intermediate scale, new challenges
- Radiation damage to silicon and scintillator at LHC
- High speed data transmission (several Gb/s/ASIC)
- Operation at -30 °C

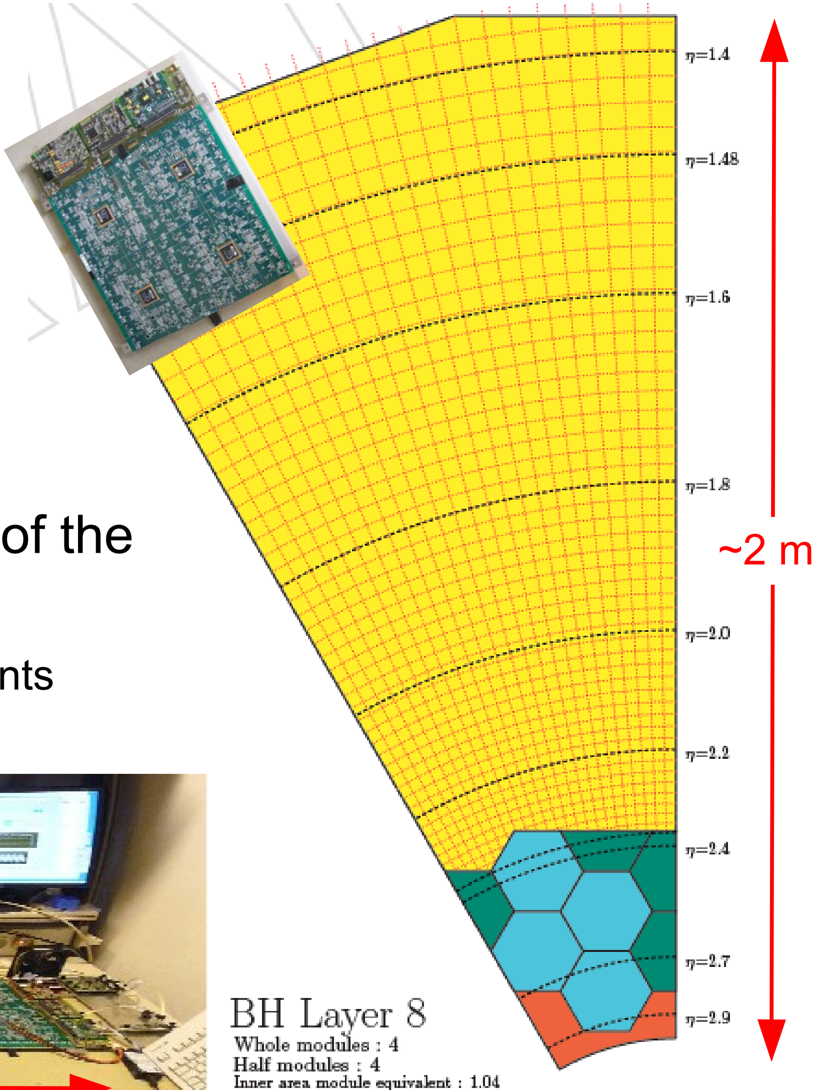
The "typical" HGCAL scintillator (+silicon) layer

- Many similarities to ILC AHCAL
  - Overall dimensions
  - Cell size
  - Front end electronics

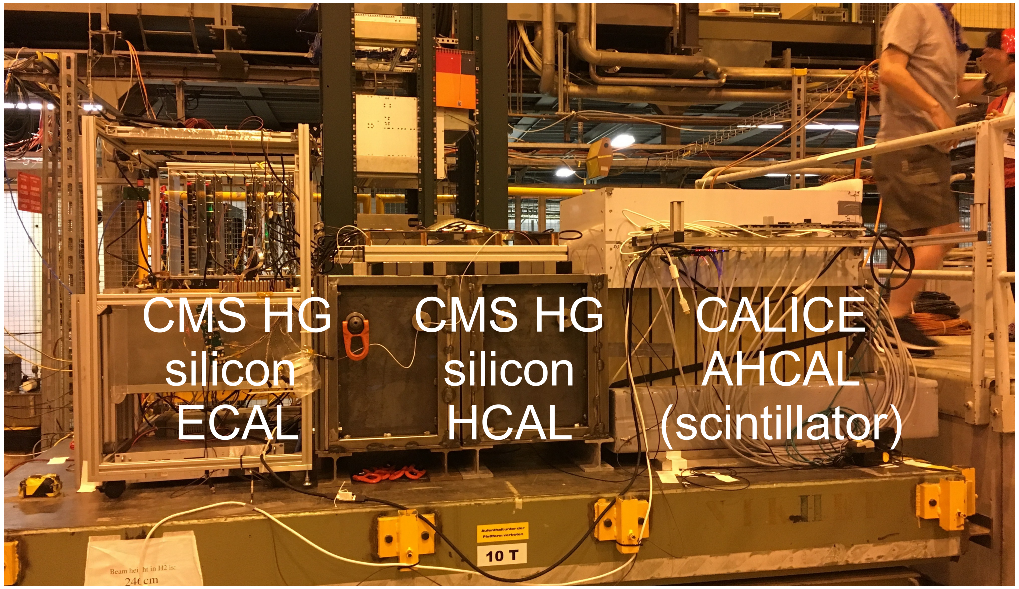
  but also new challenges

- DESY will contribute to the development of the electronics boards
  - → synergies between ILC and LHC developments





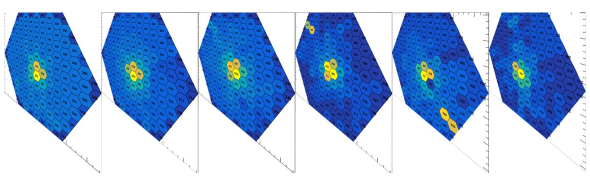
CALICE+CMS common beam test



- Several beam periods at SPS
- Easy DAQ integration since both detectors use EUDAQ
- Data quality very good
- **Active temperature compensation** in use

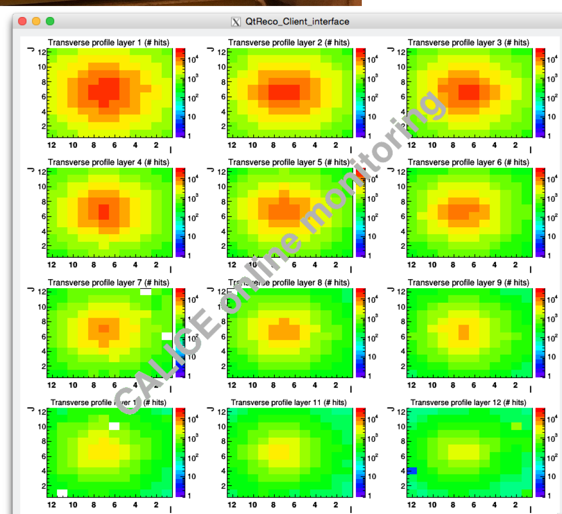
CMS and CALICE (quasi-) online monitoring

beam →



2 CMS HG silicon ECAL layers

4 CMS HG silicon HCAL layers



12 CALICE AHCAL scintillator layers

Conclusions

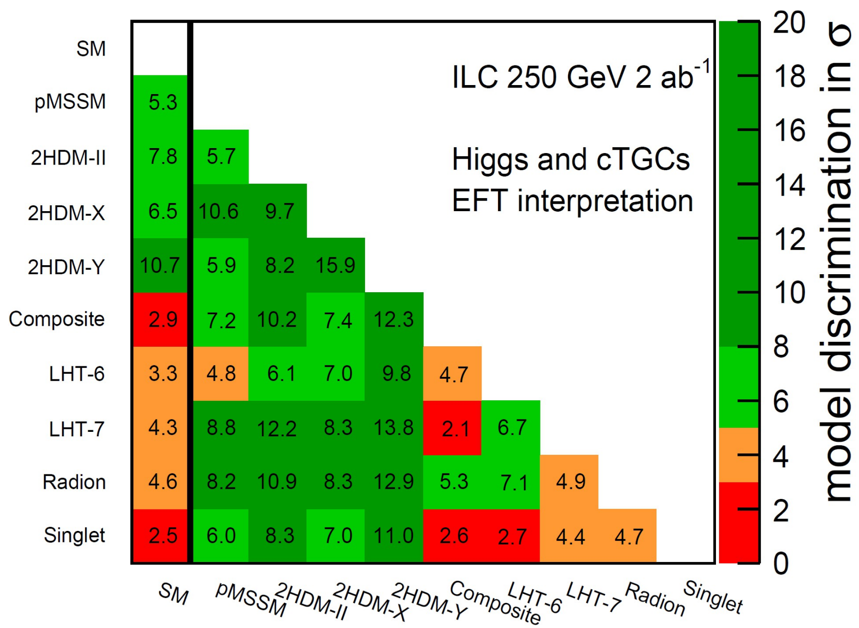
- Advances on ILC-driven detector technologies bear fruit for the HEP detector community at large

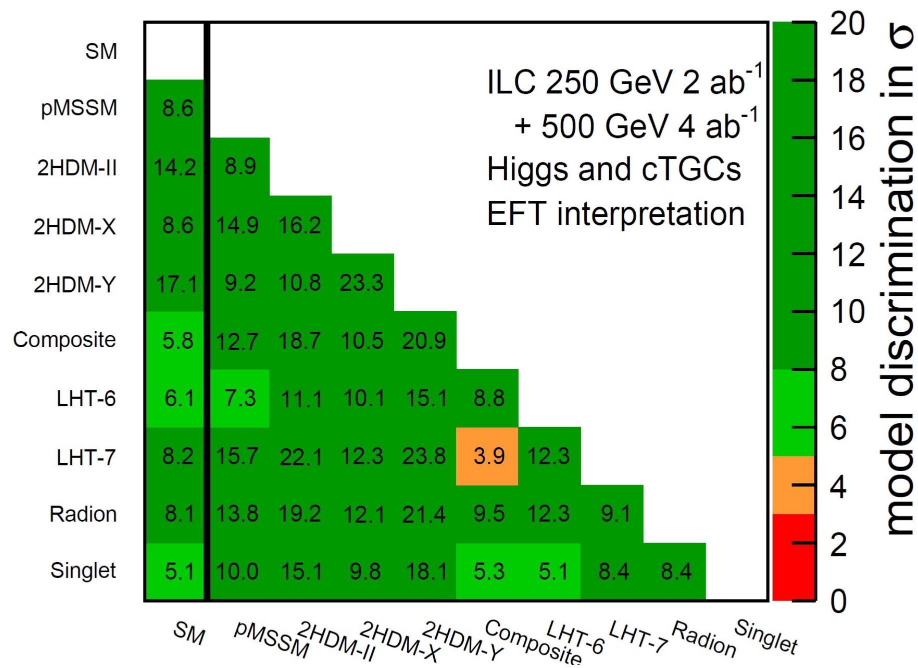
- Construction of large area silicon telescope with very ambitious parameters based on ILC technology
- Cooperation with SLAC and Bristol for hardware and DAQ (AIDA2020)

- Construction of new AHCAL technological prototype in full swing towards hadron beam tests in 2018
- Small beam tests: power-pulsed operation in magnetic field and active temperature compensation established
- Cross-fertilisation with CMS HGCAL project is gaining speed

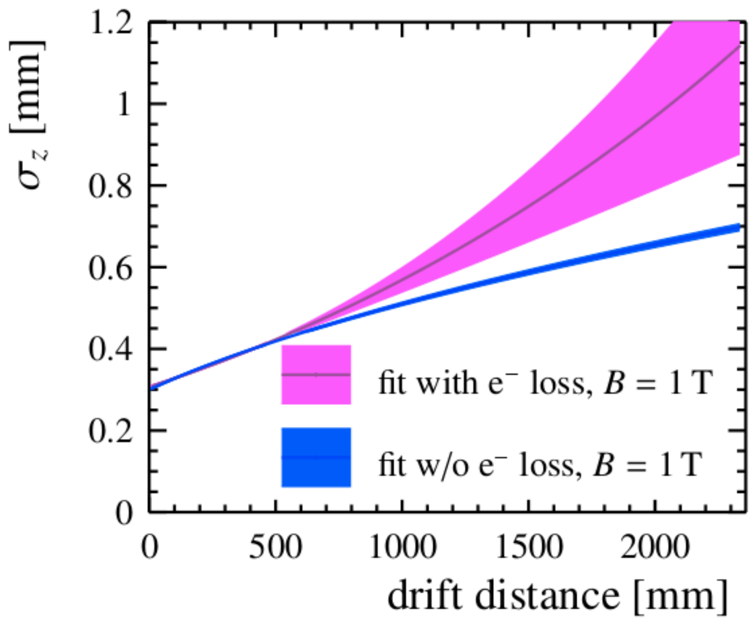
BackUp

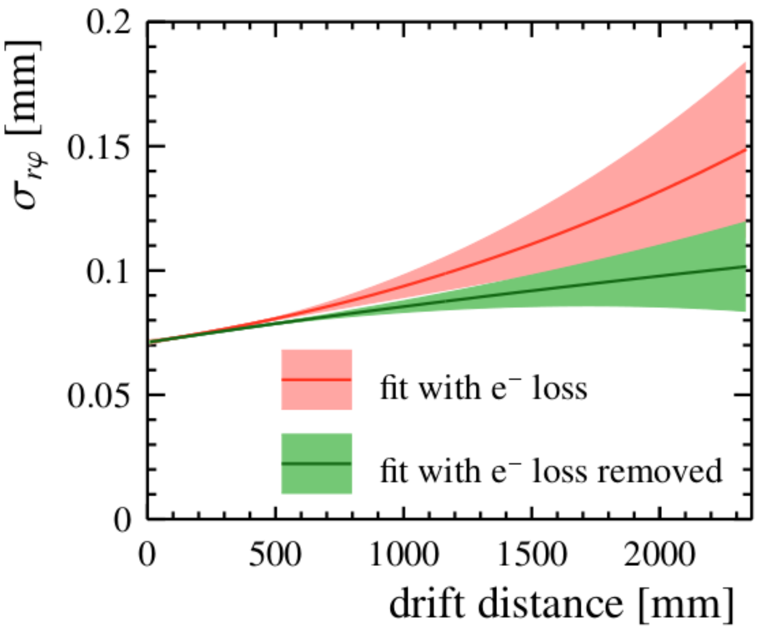
SM and BSM studies





TPC point resolution

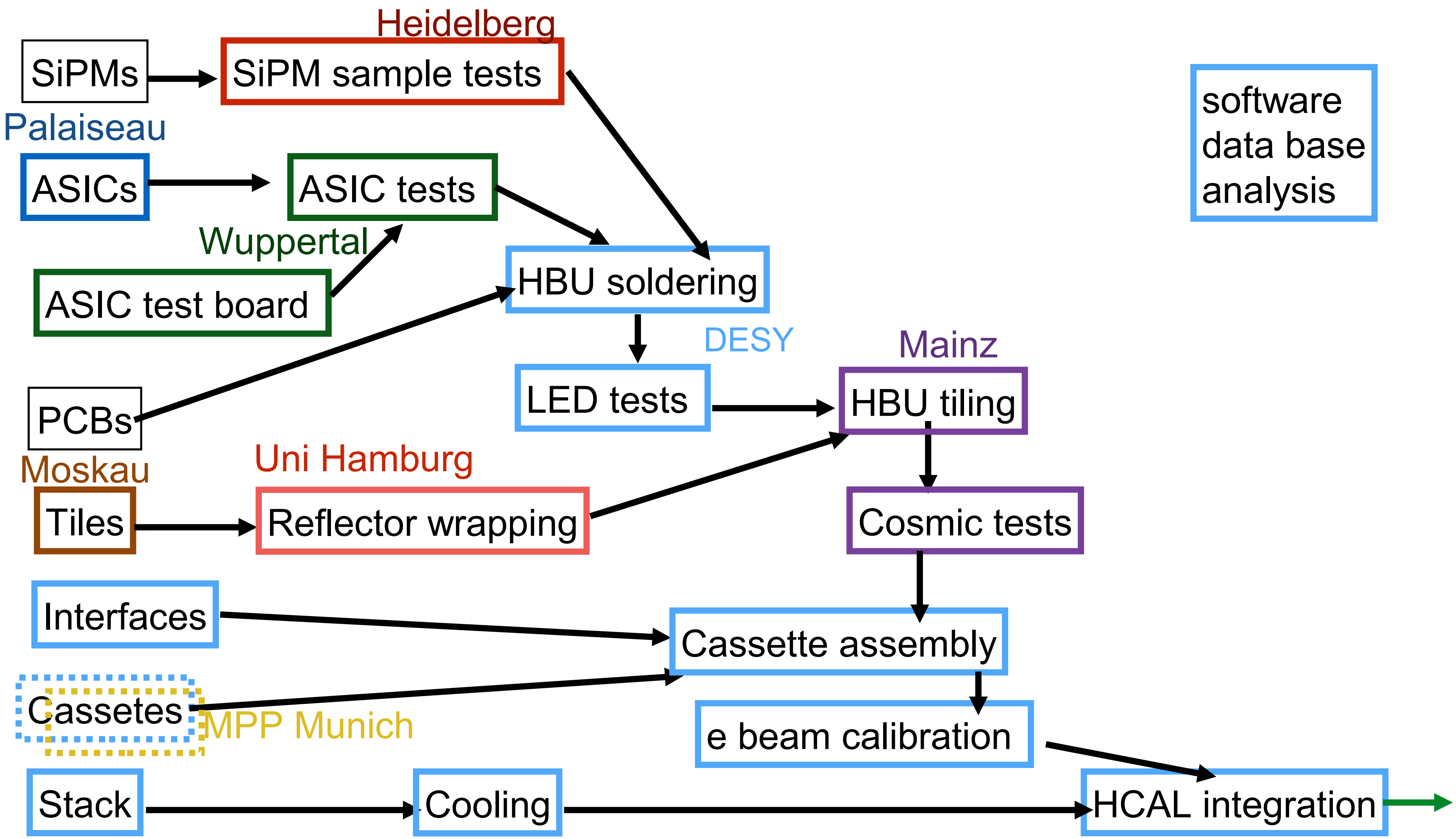




- Meets the requirement for the ILD detector σ_z<1.4mm

- The $\sigma_{r\varphi}$<100 µm resolution can be achieved if the gas quality is tightly controlled and therefore the electron attachment is insignificant

Work flow



- Towards hadron beam test at CERN SPS in 2018

First steps: HGCAL SiPM electronics

- readout ASIC for HGCAL (and AHCAL) being developed by Omega
  - silicon readout more challenging than SiPM because of smaller signals
  - coupling of SiPM to readout ASIC needs to be studied
- first step: test readout of SiPM with first test ASIC, SKIROC2-CMS (Omega, DESY)