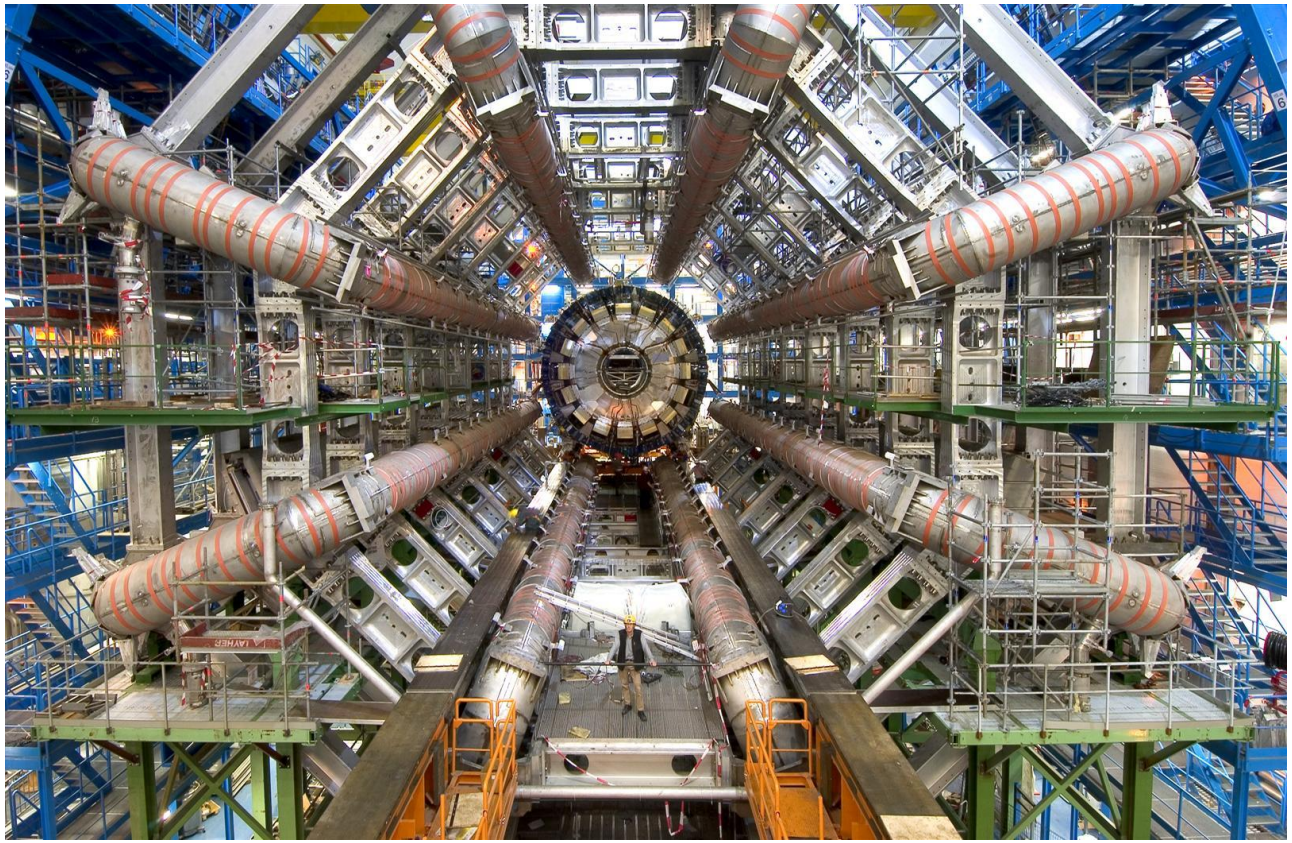
Computing and ATLAS Highlights

90th PRC meeting



Ruchi Gupta
on behalf of the DESY-ATLAS group
Nov 5, 2020

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

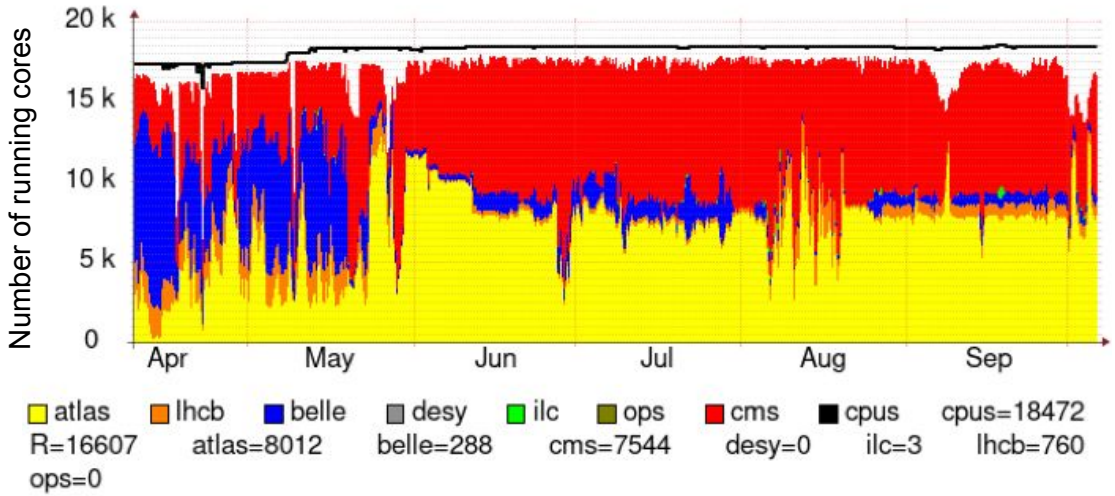
Computing Highlights

Computing Resources at DESY

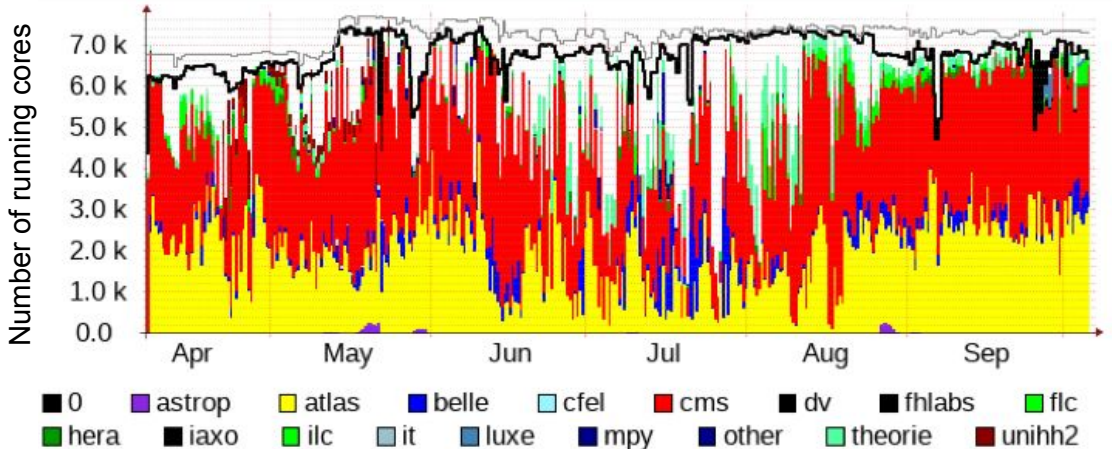
- **Significant WLCG T2 Grid resources at DESY**
  - 18k CPU cores, majority from ATLAS and CMS
  - Almost 20 PB of disk storage
  - DESY significantly **exceeds the WLCG pledges**, CPU and disk, for both ATLAS and CMS
  - Very reliable and stable service

- **National Analysis Facility (NAF)**
  - Complements Grid infrastructure for more interactive end user analysis
  - Access for German HEP groups
  - Batch system CPU heavily utilised
  - Exclusively **Centos7 from December**
  - Fast local parallel file system with several PB, still sufficient remaining capacity
  - **Access to DESY GPU resources**

Grid Farm at DESY-HH

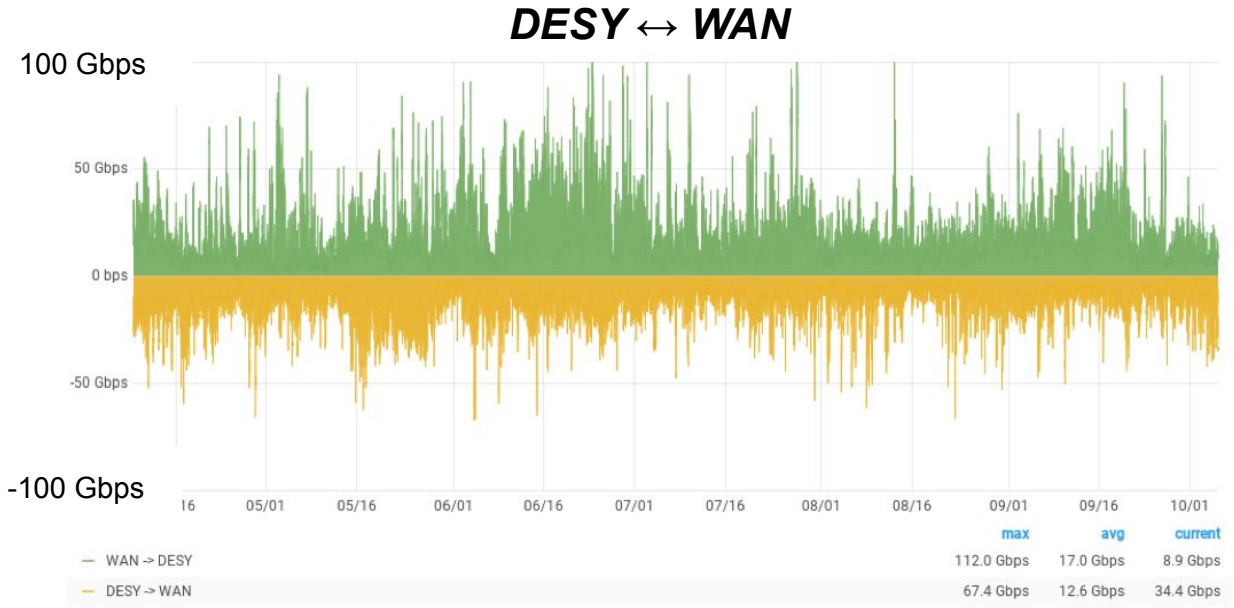


NAF Batch System CPU



Transitions, Improvements and New Initiatives

- Network improvements
  - **Up to 100 Gbps** for up- and download
  - Good utilisation, occasionally reaching the maximum rate
- ATLAS and CMS also in transition away from deprecated GridFTP transfers to Third Party Copy
  - Gradual move to WebDAV and XrootD



- CMS migration to use **Rucio by end of November**
  - Replacement for Phedex + DDM
  - Almost all central services are now switched
  - Education of users, expansion of the Rucio community
  - Opens new opportunities for management of user data

RUCIO
SCIENTIFIC DATA MANAGEMENT

- New Helmholtz funded project: **Deep Generative models for fast and precise physics Simulation (DeGeSim)**
  - ATLAS-CMS combined project to work on deep generative models for simulation for pile-up in Run 3 (ATLAS) and calorimeters in HL-LHC (CMS)
  - Two PhD students funded by Helmholtz AI
  - Project team involves ML experts from Jülich Helmholtz Center and TRIUMPH (Canada)

Covid Simulations: ATLAS and CMS contributions to Folding@Home

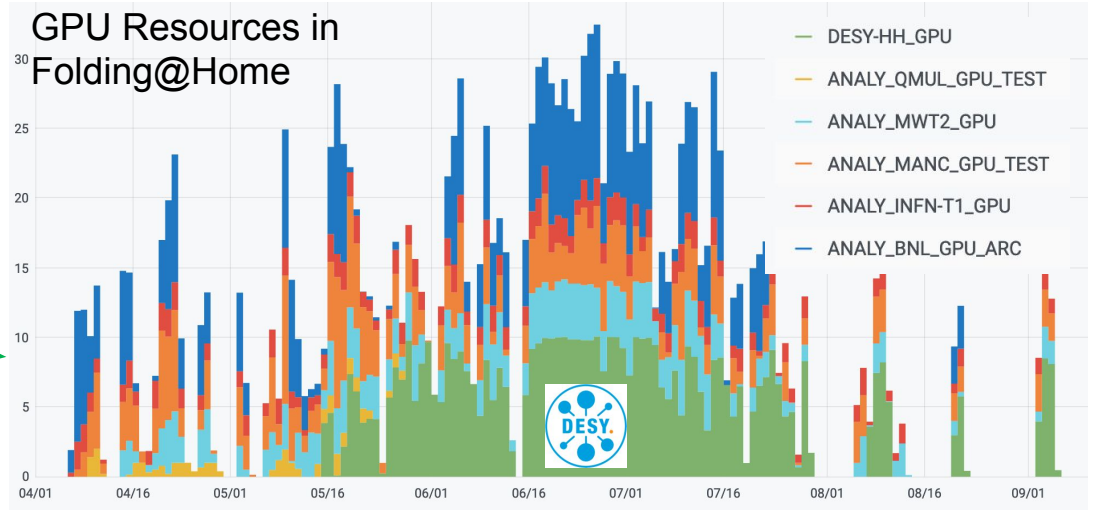
- Significant volunteer computing contributions by DESY to aid research into the Corona Virus
  - Integration of non-standard workflows into distr. compute
- Both ATLAS and CMS contributed to the **Folding@Home** effort as part of the "CERN & LHC Computing" team for 6 months this year
  - ATLAS: ~ 30k slots from trigger farm and another 30k slots from WLCG resources, shared among about 55 sites, including DESY-HH/ZN
  - CMS: ~ mainly running on HLT (60k cores), with Grid sites providing an additional 5k, including DESY-HH
- **ATLAS and CMS top contributors to CERN & LHC Computing team, followed by the IceCube GPUs at DESY-Zeuthen**
- ATLAS also submitted Folding@Home jobs on up to 32 GPUs
  - **Collaboration with DESY-IT to use up to ten of the GPUs in the NAF (ATLAS/CMS/Uni-HH)**

Team: CERN & LHC Computing

Date of last work unit	2020-10-07 08:23:47
Active CPUs within 50 days	489,568
Team Id	38188
Grand Score	80,991,255,501
Work Unit Count	16,049,784
Team Ranking	17 of 255075
Homepage	http://public.web.cern.ch/public/
Fast Teampage URL	https://apps.foldingathome.org/teamstats/team38188.html

Team members

Rank	Name	Credit	WUs
15	ATLAS_CPU	28,596,030,395	5,819,208
27	CMS-Experiment	20,196,806,077	3,744,040
66	DESY-ZN_GPU	10,183,629,994	87,284
90	ALICE-FLP	8,052,345,743	710,071
174	LHCbHLT	4,813,610,672	614,017
332	CERN_Cloud	2,595,660,530	1,102,210



ATLAS Highlights

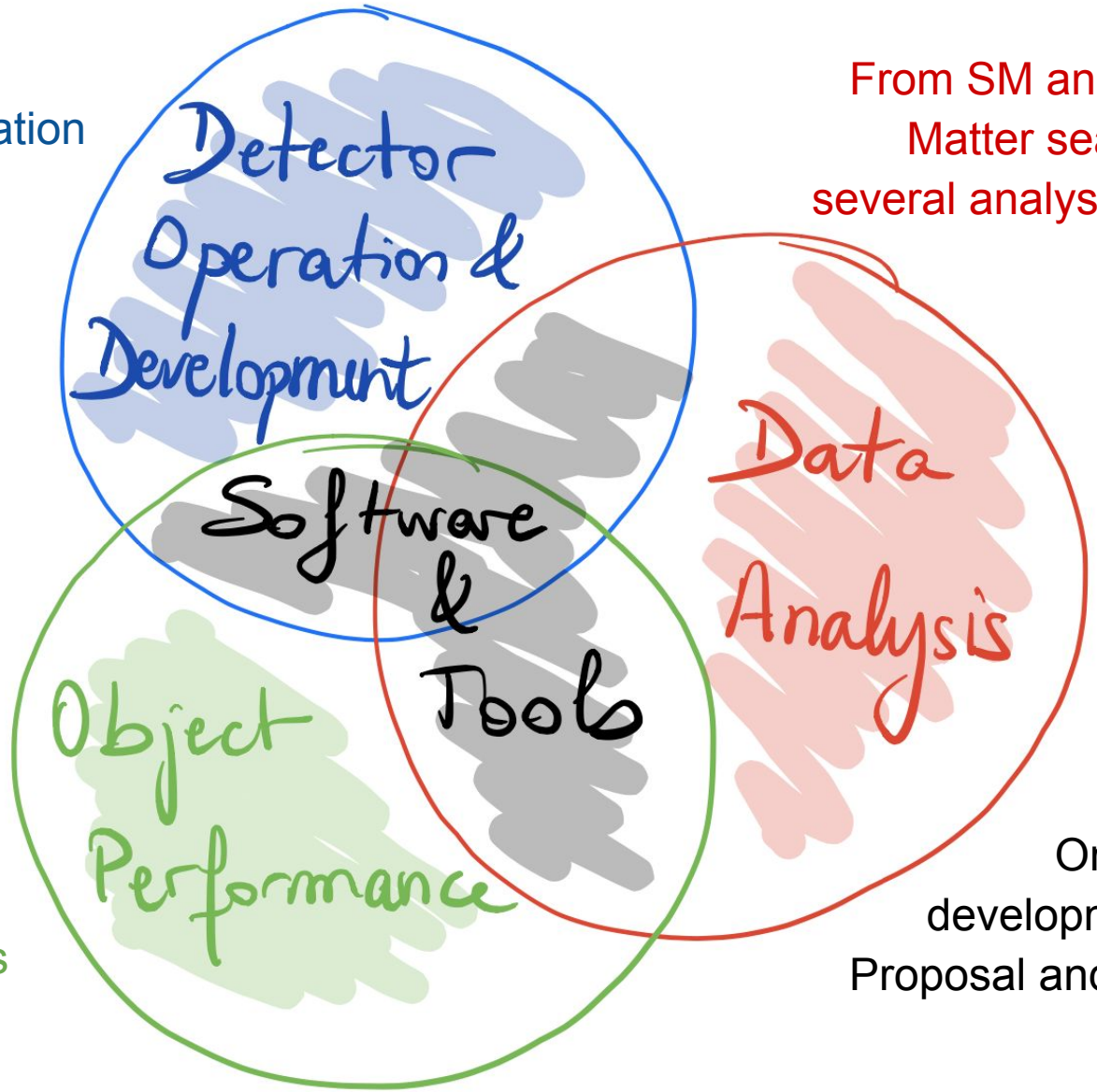
ATLAS group during the COVID-19 era

Annual group outing
(virtual) Oct,2020

Overview of Group Activities

Detector Operation and Upgrade

- Operation, monitoring and calibration of current detector (Pixels/SCT)
- Design, tests and assembling of future detector: ITk



Data analysis

From SM and Higgs boson to Dark Matter searches: involvement in several analyses, relying on detector and object expertise

Object performance

- Relies also on detector expertise
- Identification and calibration of jets, b-jets, electrons and photons

Software and tools

Online & offline software development and maintenance
Proposal and development of tools and methods

Highlights of ATLAS Analysis Results

since April, 2020

Several publications and conference results

- **Standard Model Measurements**
  - Single boson measurements
  - PDF fitting
  - Photon induced WW production
- **Higgs Precision Measurements and Searches**
  - $H \to 4\ell$
  - $H \to \gamma\gamma$
  - Higgs combination
  - ttH(H→bb), $H \to Z\gamma$
- **Top quark processes**
  - 4tops production
  - Lepton flavor violation
- **Search for new phenomena :**
  - Dark Matter production and coupling to the higgs boson
  - SUSY searches
  - Extra dimensions, majorana neutrinos

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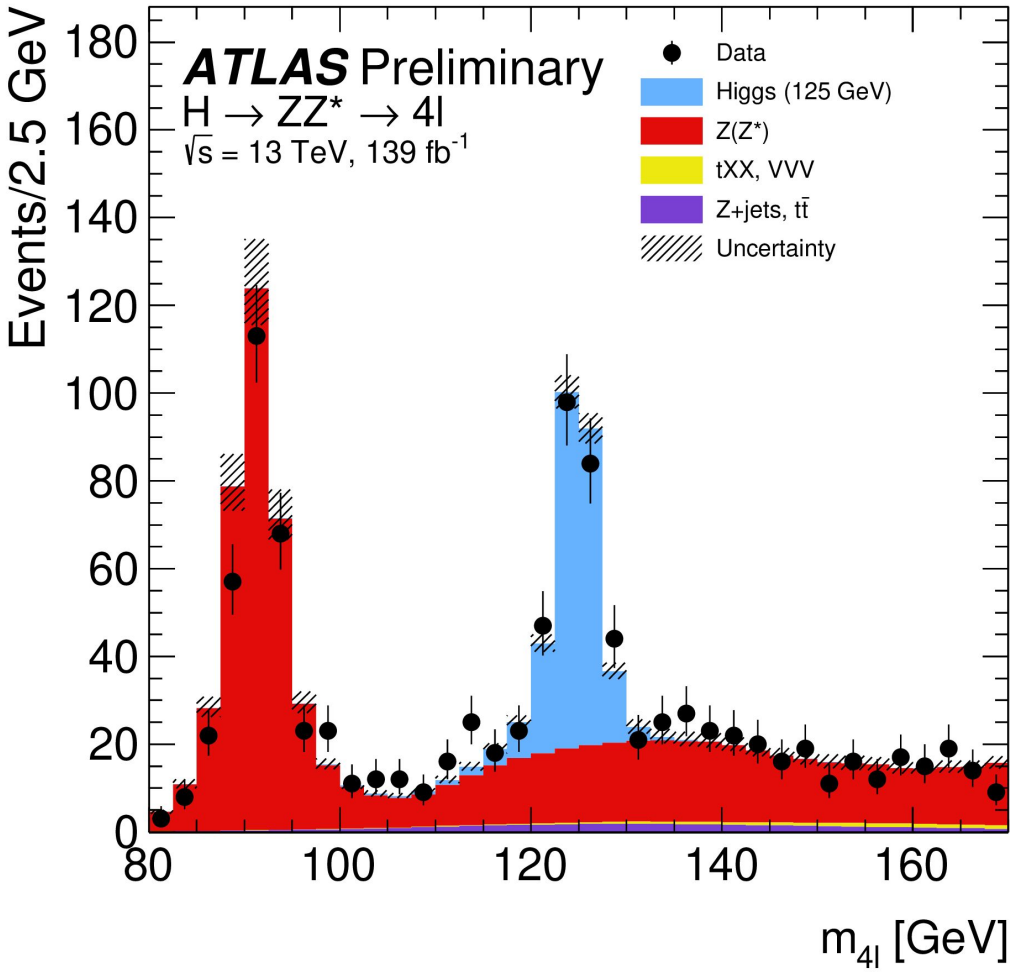
Higgs Mass Measurement



- $H \rightarrow ZZ^* \rightarrow 4l$:
  - Clean final state
  - Excellent Higgs mass resolution
- First Higgs mass measurement with full Run-2 dataset

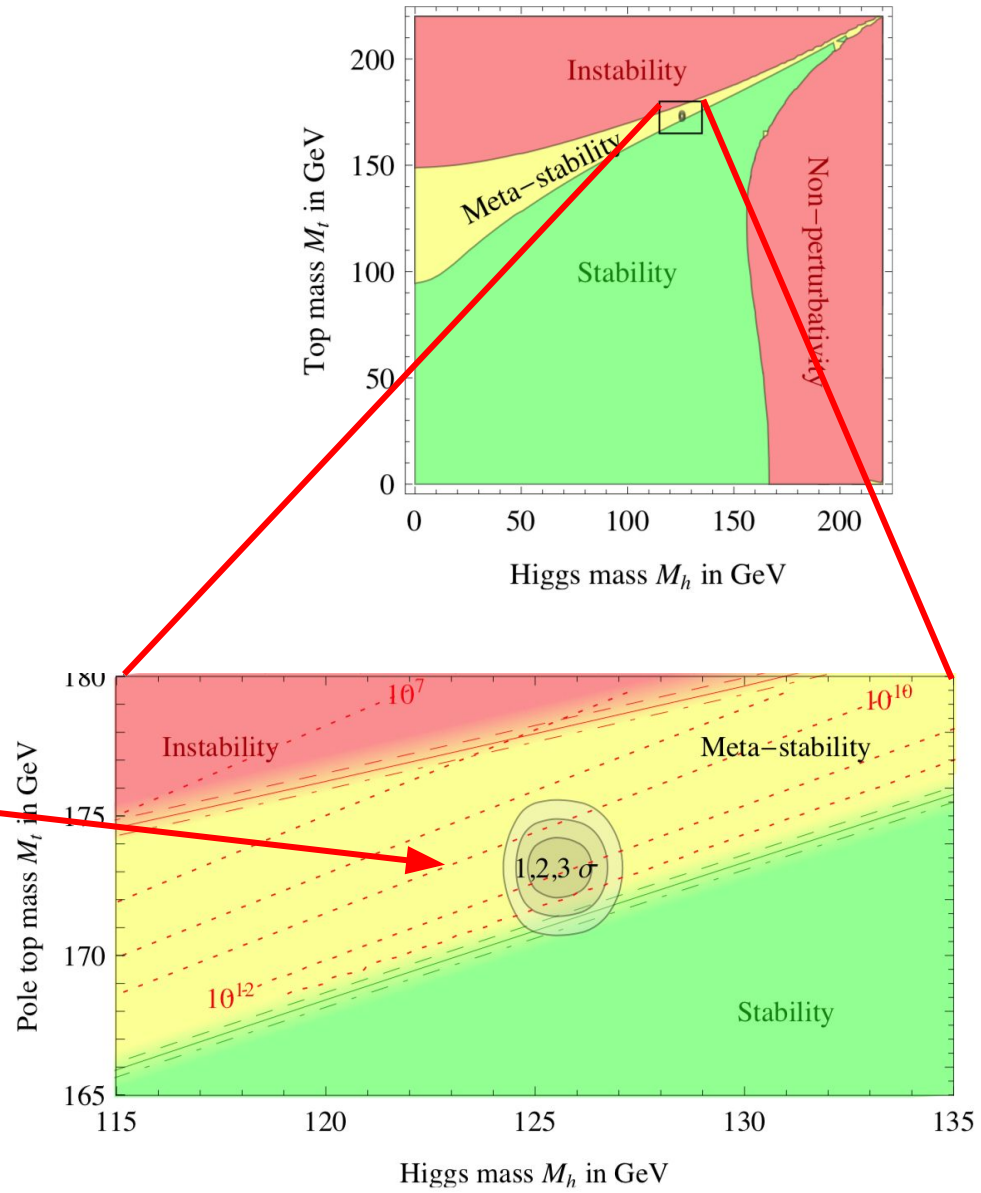
ATLAS-CONF-2020-005

Higgs Mass Measurement

- Higgs boson mass m_H is a free parameter in SM
- All properties of the Higgs boson are predicted in SM once the value of m_H is fixed
  - Important when looking for deviations from SM in the Higgs sector

- Higgs mass as currently measured lies at the edge of EW instability and stability regions for the SM.
  - Precise measurement of higgs (and top) mass important for understanding the stability of the EW vacuum

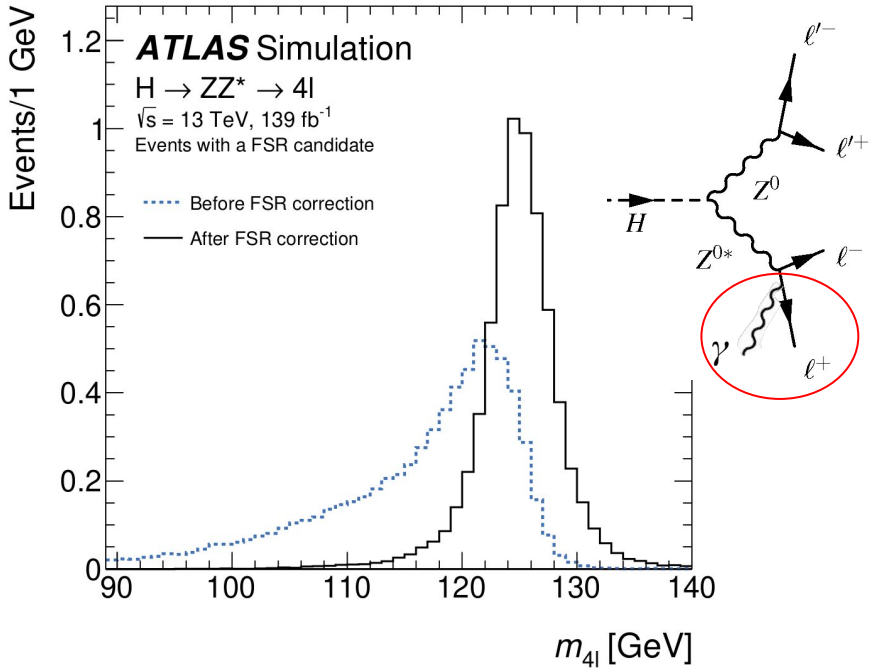
Degrassi et al., arXiv:1205.6497



Analysis Strategy

H→4ℓ

- Recover final state radiation (FSR)
  - 1% improvement in m_H resolution
- Constrain leading lepton pair mass to m_Z distribution
  - Improves m_H resolution by 17%
- Replace the mass width by per-event m_{4l} resolution
  - Obtained for every event using dedicated NN
  - ~2% improvement in m_H precision, more robust to fluctuations



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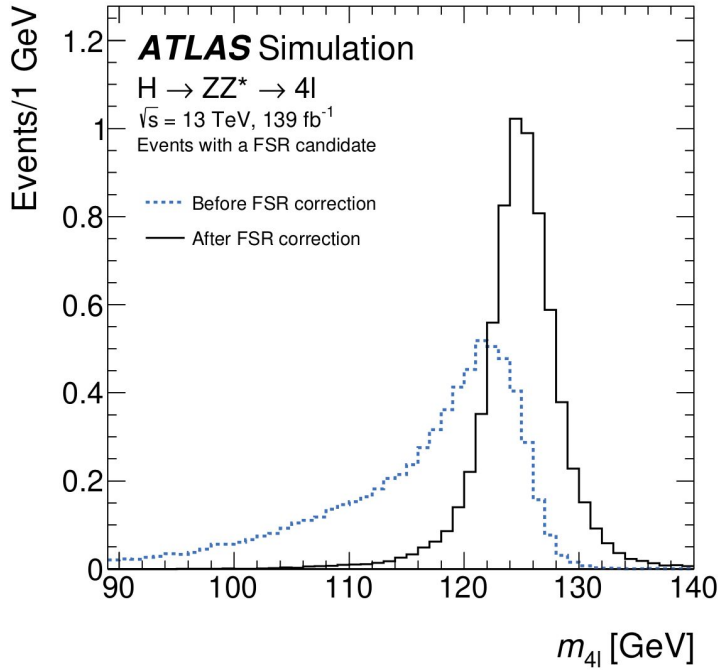
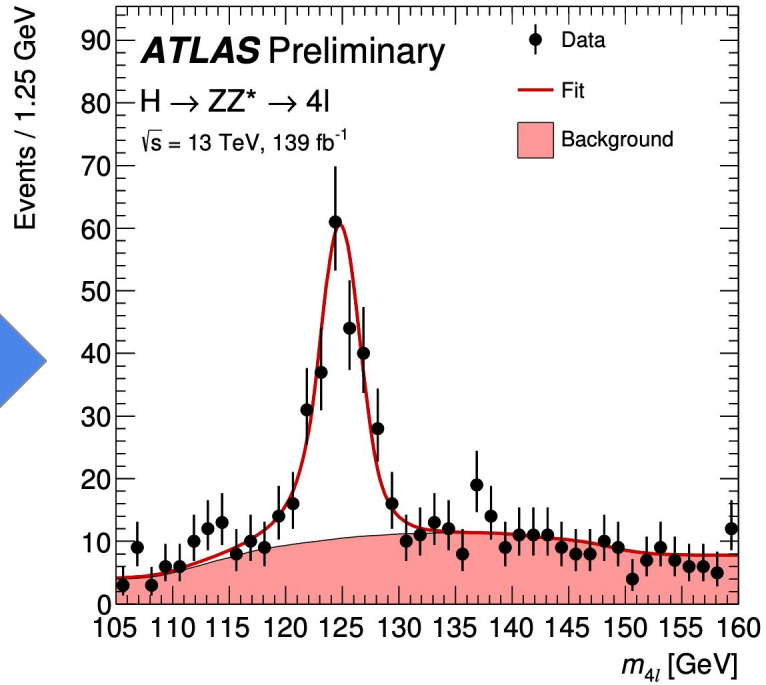
- Replace mass width by per-event m_{4l} resolution
  - Obtained for every event using dedicated NN
  - ~2% improvement in m_H precision, more robust to fluctuations
- Background ZZ^* shapes from smoothed MC
- Parametrize m_{4l} distribution as double-sided Crystal Ball function
- Analysis categories based on lepton flavour and a boosted decision tree (BDT)





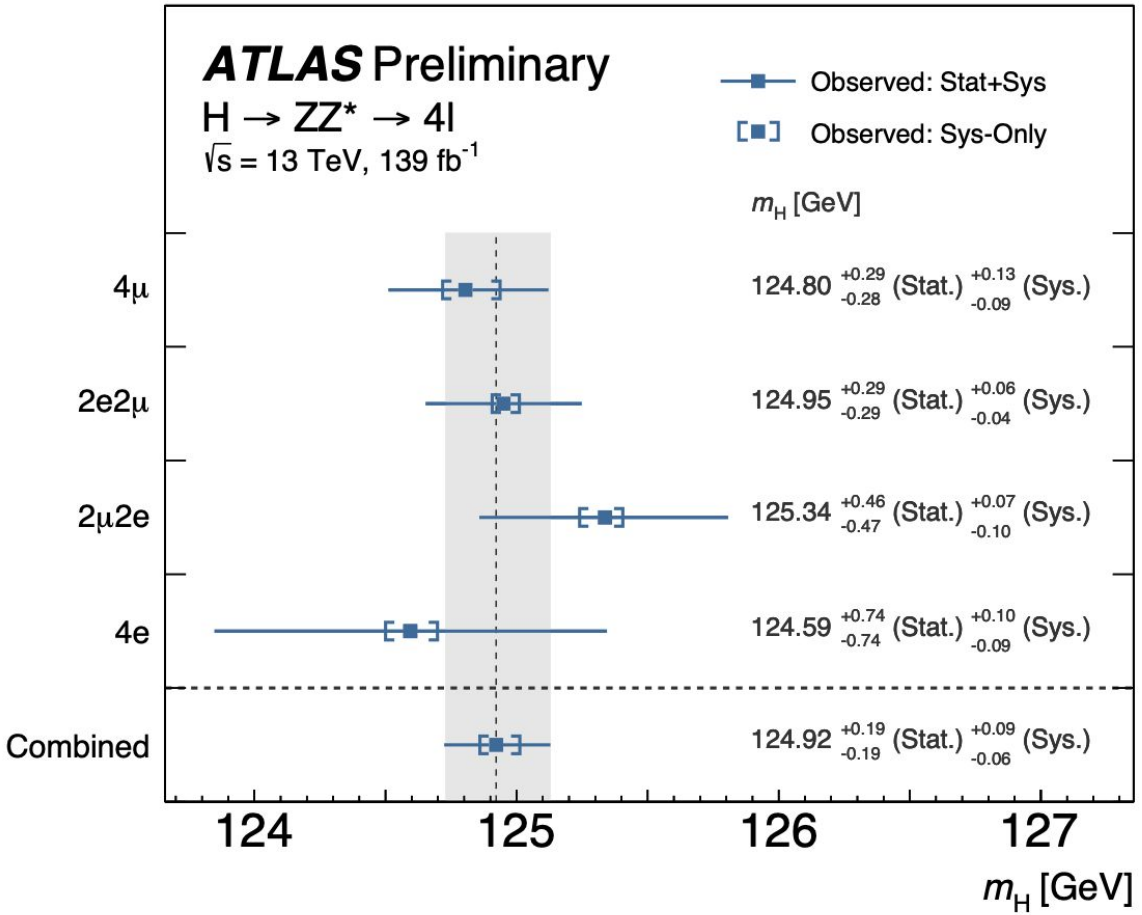
Mass Measurement

H→4ℓ

- Obtain m_H from log-likelihood fit to 16 categories
- Higgs Mass : $m_H = 124.92 \pm 0.21$ GeV
- 15% improvement over previous ATLAS result

Leading systematic uncertainties

Systematic Uncertainty	Impact (GeV)
Muon momentum scale	+0.08,−0.06
Electron energy scale	±0.02
Muon momentum resolution	±0.01
Muon sagitta bias correction	±0.01



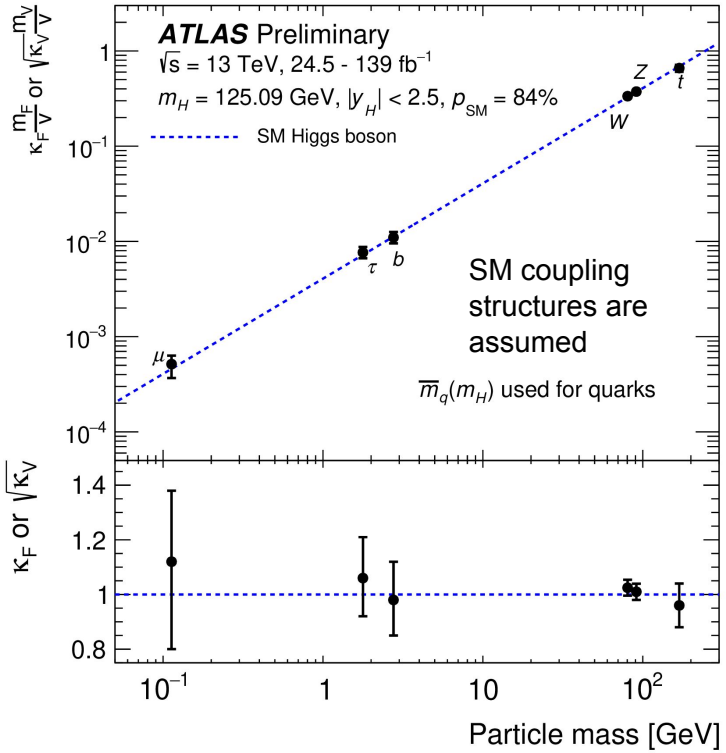
Measurement statistically limited

Higgs Couplings Combination

Combination of several Higgs measurements in the main Higgs decay channels with up to 139 fb^{-1} of data

- Higgs production mode cross-sections measured
- Particle coupling to the higgs boson vs particle mass

ATLAS-CONF-2020-027



Higgs Couplings Combination

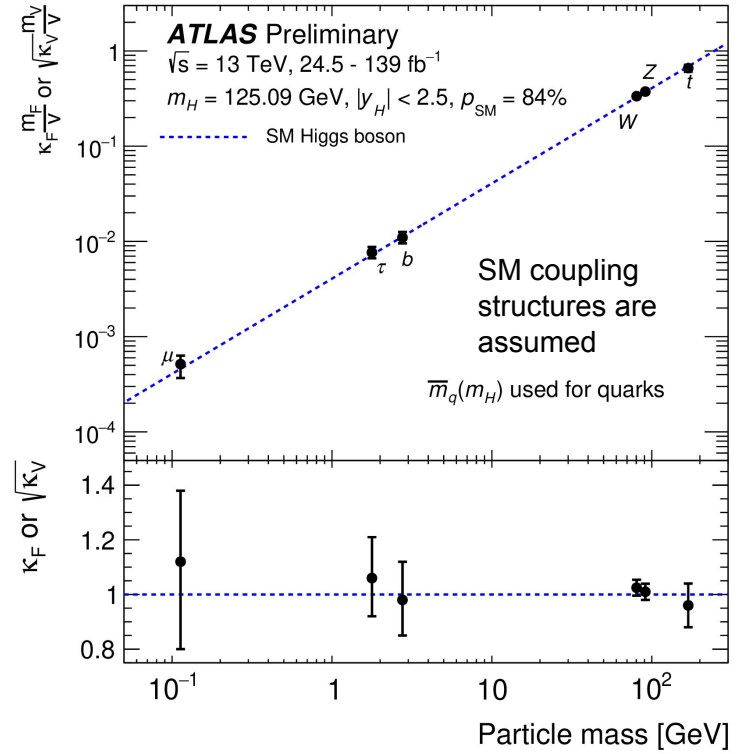
Combination of several Higgs measurements in the main Higgs decay channels with up to 139 fb^{-1} of data

- Higgs production mode cross-sections measured
- Particle coupling to the higgs boson vs particle mass

- Interpretation of combined measurements
  - 2 Higgs Doublet Model (2HDM)
  - Minimal Supersymmetric extension of Standard Model (MSSM)
  - Standard Model Effective Field Theory (SMEFT)
    i. linearized model as well as including quadratic BSM terms
    ii. Now able to fit multiple strength parameters simultaneously

All measured parameters are consistent with the SM expectation within their uncertainty.

ATLAS-CONF-2020-027



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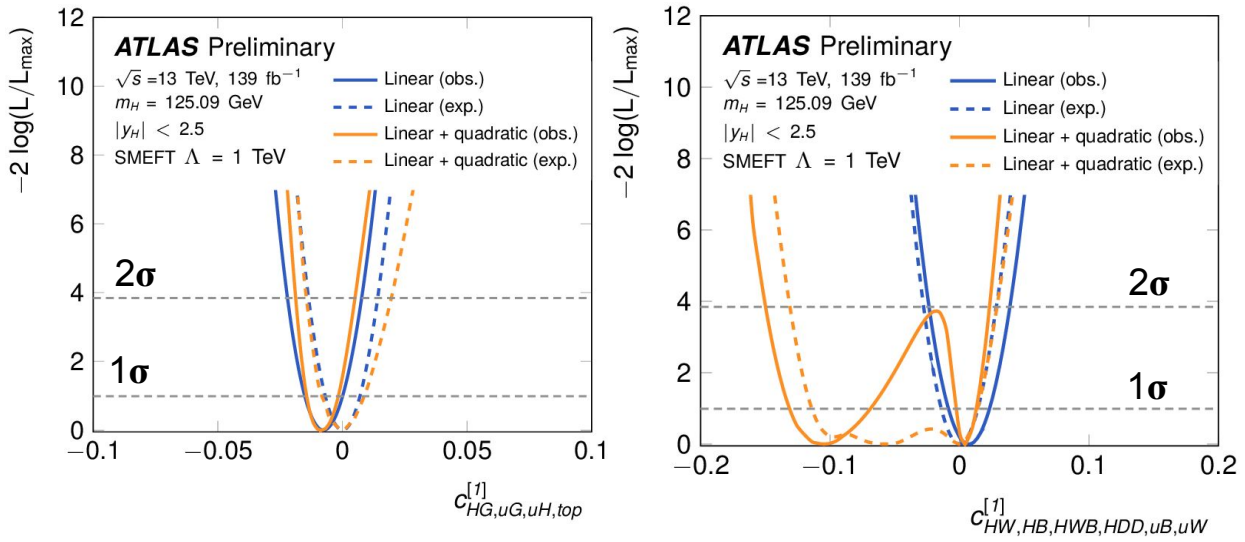
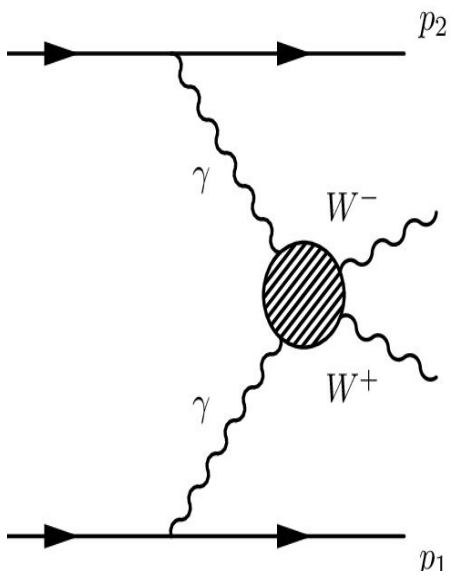
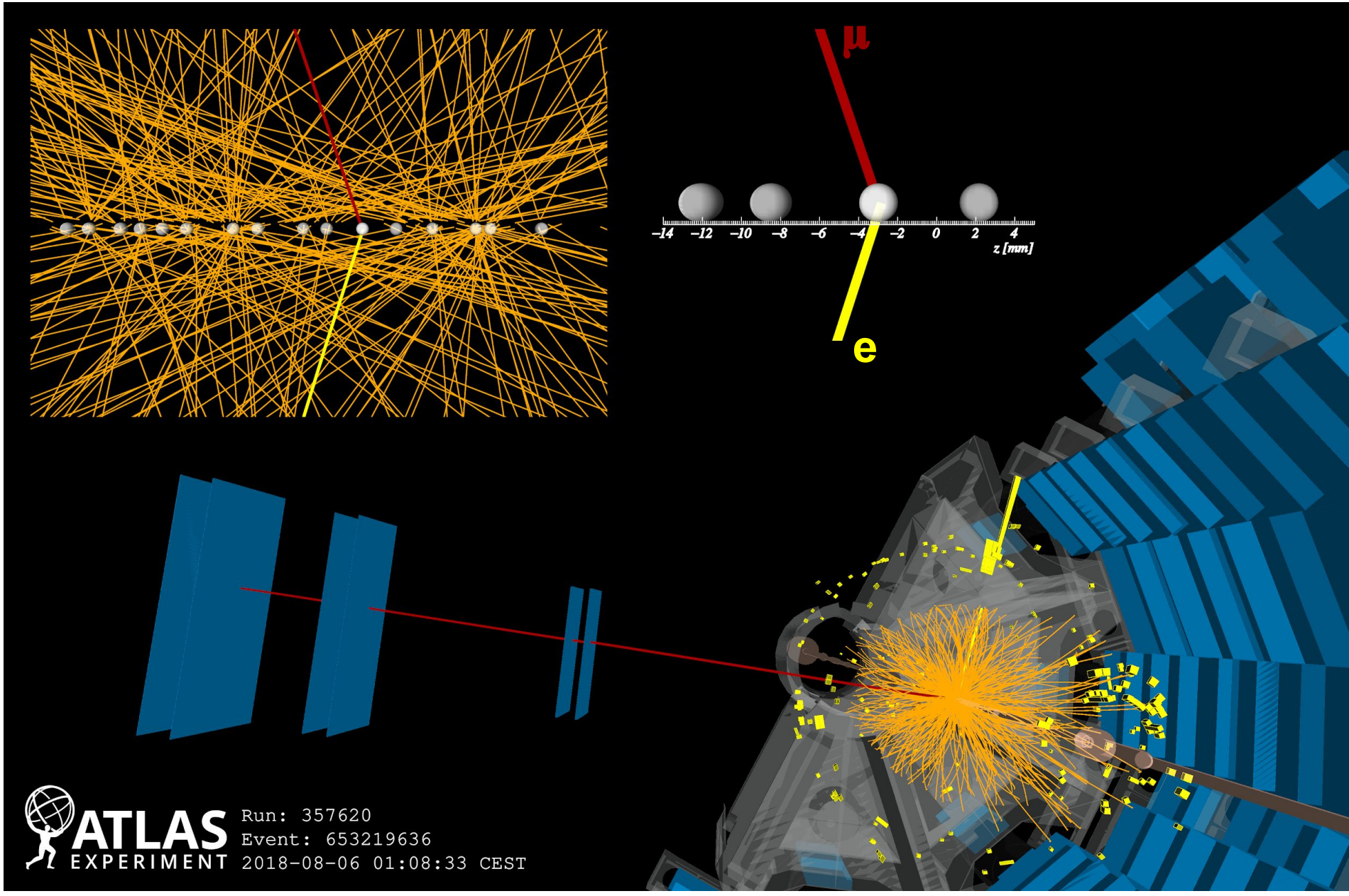


LHC as a photon collider





[arXiv:2010.04019]

Submitted to Phys Lett B

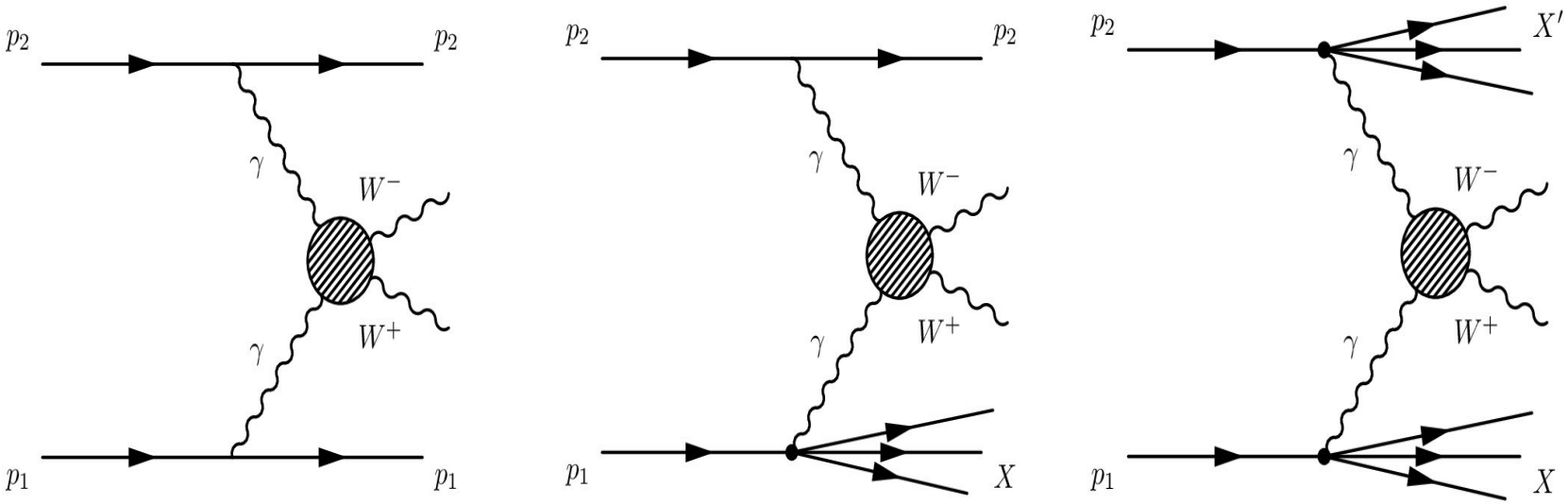
[Link to ATLAS Physics Briefing]

[Link to CERN Courier Post]

[Link to DESY News]

Photon induced WW Production at the LHC

γγ→WW



Elastic **Single dissociative** **Double dissociative**

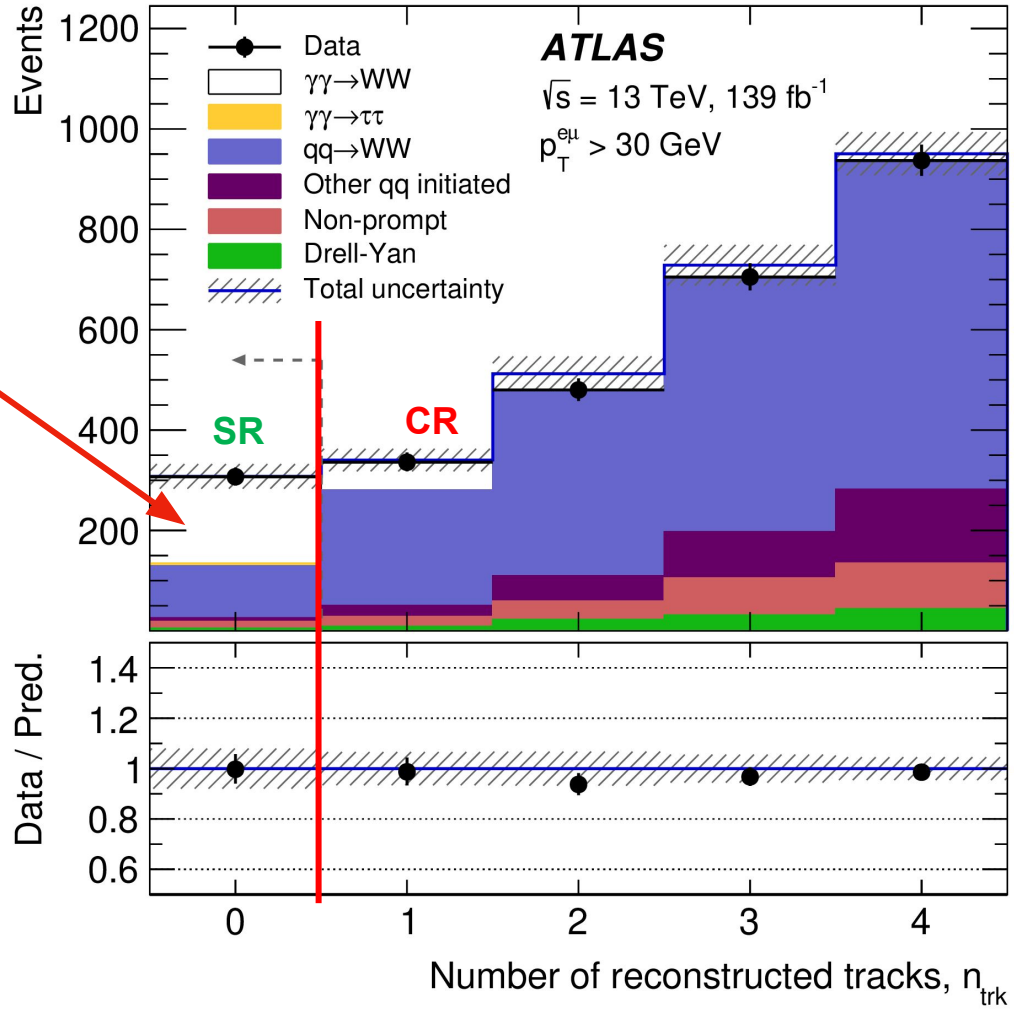
- Test the gauge structure of standard model (SM)
  - Leading order involves only the processes with **self-coupling** of electroweak gauge bosons
- Search for signs of anomalous **quartic gauge couplings** (WWγγ)

Analysis Strategy

$\gamma\gamma \rightarrow WW \rightarrow e\nu\mu\nu$

- Full run 2 data analysed
- Events with an $\mathbf{e^{\pm}\mu^{\mp}}$ pair
- No additional tracks near the **eμ** vertex (ie. $n_{trk} = 0$)

- **Main Backgrounds**
  - **$pp \rightarrow WW$** and Drell-Yan (DY) **$pp \rightarrow Z \rightarrow \tau\tau$**
  - Tracks from pile-up vertices
- **Main Challenge:**
  - Modelling of n_{trk} for various backgrounds



Signal and Background Corrections

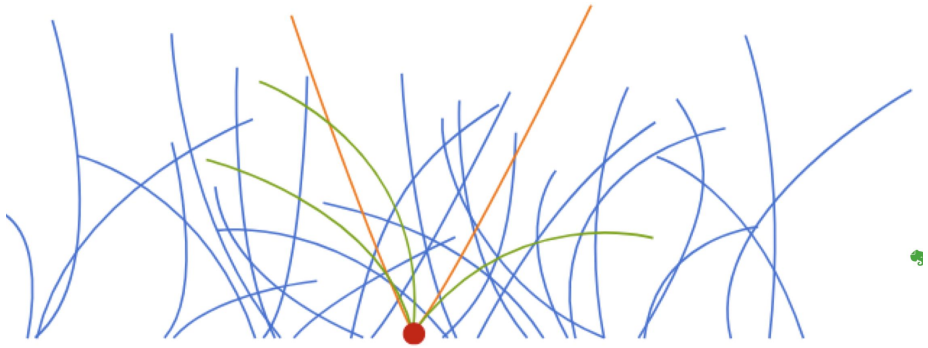
Background modelling of n_{trk}

pp->WW and DY $\tau\tau$ processes

- Underlying Event (UE) activity not modelled well by MC
- corrections using pp→Z→ll data events

n_{trk} from pile-up interactions :

- Tracks coming from pile-up vertices could be matched to the event vertex
- Correct pile-up MC due to imperfect modelling of tracks from PU vertices
  - using pp→Z→ll data events



Tracks from pile-up interactions

Signal MC is corrected for

a. Probability that proton interacts inelastically after the photon radiation

b. Simulation of dissociative $\gamma\gamma$→WW is not available

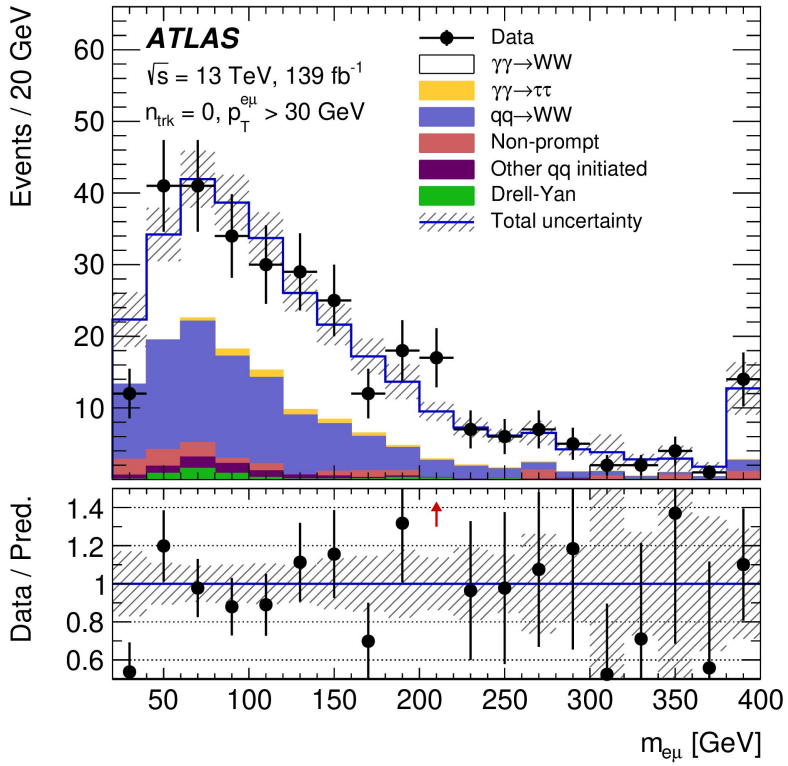
- Data-driven correction factor derived from $\gamma\gamma$→ll
- Signal Scale Factor = 3.59 ± 0.15 (tot.)

Photon induced WW Production at the LHC

Signal Extraction

- Simultaneous fit to 4 regions in n_{trk}, $p_T^{e\mu}$ space
- 307 observed, 132 background events expected
- First observation of this process with **8.4σ (6.7σ expected)**
- **Fiducial Cross-section:**

$$\sigma_{\text{meas}} = 3.13 \pm 0.31\,(\text{stat.}) \pm 0.28\,(\text{syst.})\,\text{fb}$$



Towards Run3

Towards Run3

- Analysis of Run2 data will continue until 2022 and beyond
- **ATLAS Software**
  - **New release (r22)** under preparation for re-processing of Run 2 (spring 2021) data and then for Run 3
  - **Coordination** of the AthenaMT/Configuration **migration for tracking**
- Migration/re-write and validation of several ATLAS packages in new software release (r22)
- **Monte Carlo Production**
  - New workflows to speed up the production process
  - Possible Implement of new hardware (HPC, GPU) into the production system
  - Improve pile-up simulation in Monte Carlo samples
- **Luminosity Measurement** : Automate Tier 0 processing for luminosity determination
- **SCT Operation**:
    - Time dependent noisy channels in calibration database
    - Optimisation of preamplifier and shaper currents
- **Missing Transverse Energy Trigger** : Tuning and optimisation of new algorithms on the new L1 hardware
- Object Reconstruction and Performance
  - **Flavour Tagging** : Study impact of new tracking and vertexing software
  - **e/gamma**
    - Tuning of e/γ reconstruction including **new conditions (TRT gas)**
    - Re-derive ad improve identification algorithms and energy calibration

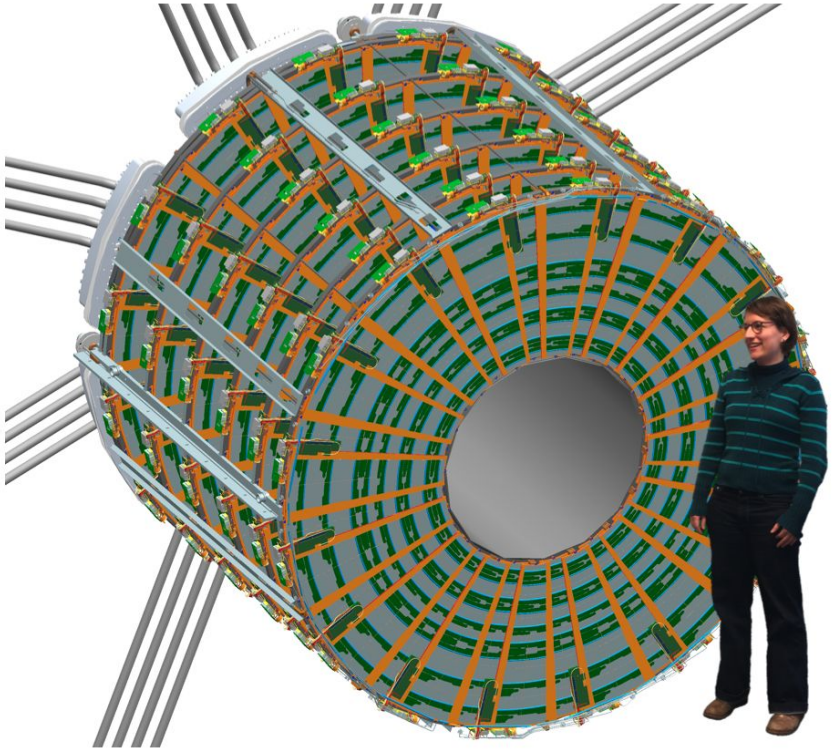
High Luminosity LHC

Overview of Upgrade Activities

Silicon strip tracker for HL-LHC

- Working on the realisation of one full end-cap for the ATLAS ITk Strip detector

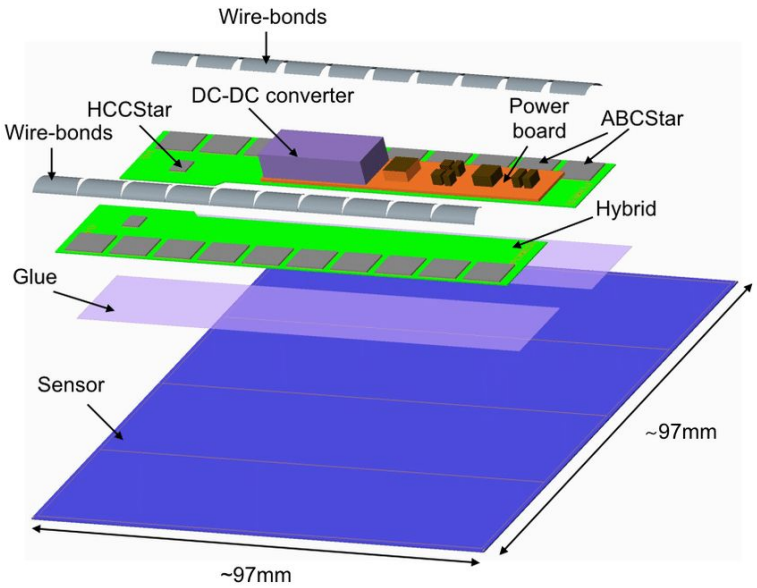
- At DESY:
  - Sensor studies and quality control testing
  - Module development, building and testing
  - Module loading onto petal cores
  - Petal core production and testing
  - End of substructure (EoS) card
  - Endcap integration at DESY and CERN
  - CO_2 cooling
  - And many other tasks ….



Last 6 months: Concentrating in Hamburg and Zeuthen to move from single module production and testing to more complete systems.

ITk strips Endcap

DESY involved in every step!



Module Building :
Gluing and Wirebonding

ITk strips Endcap

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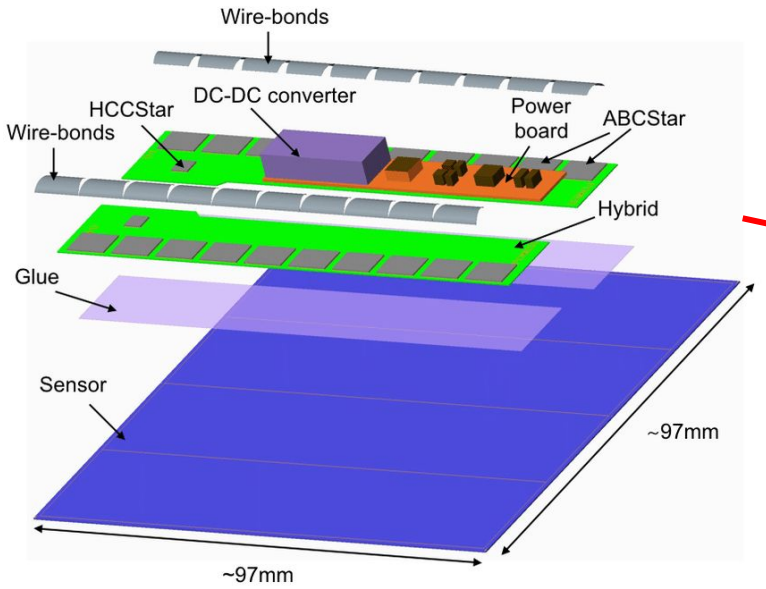

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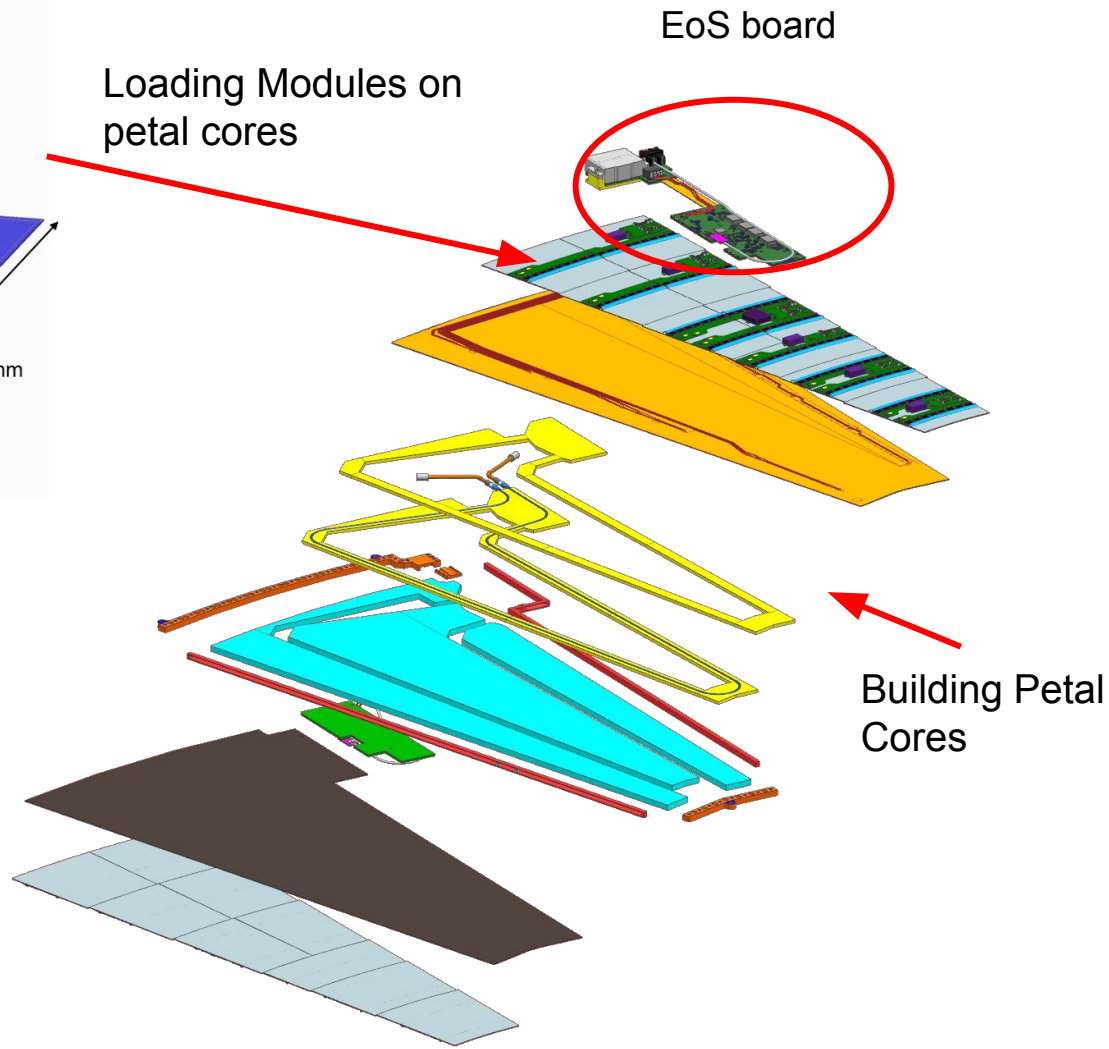

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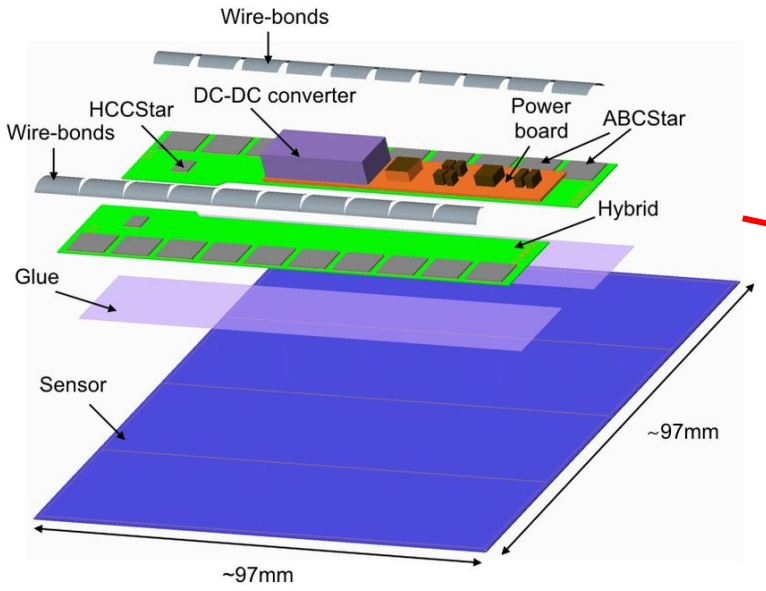
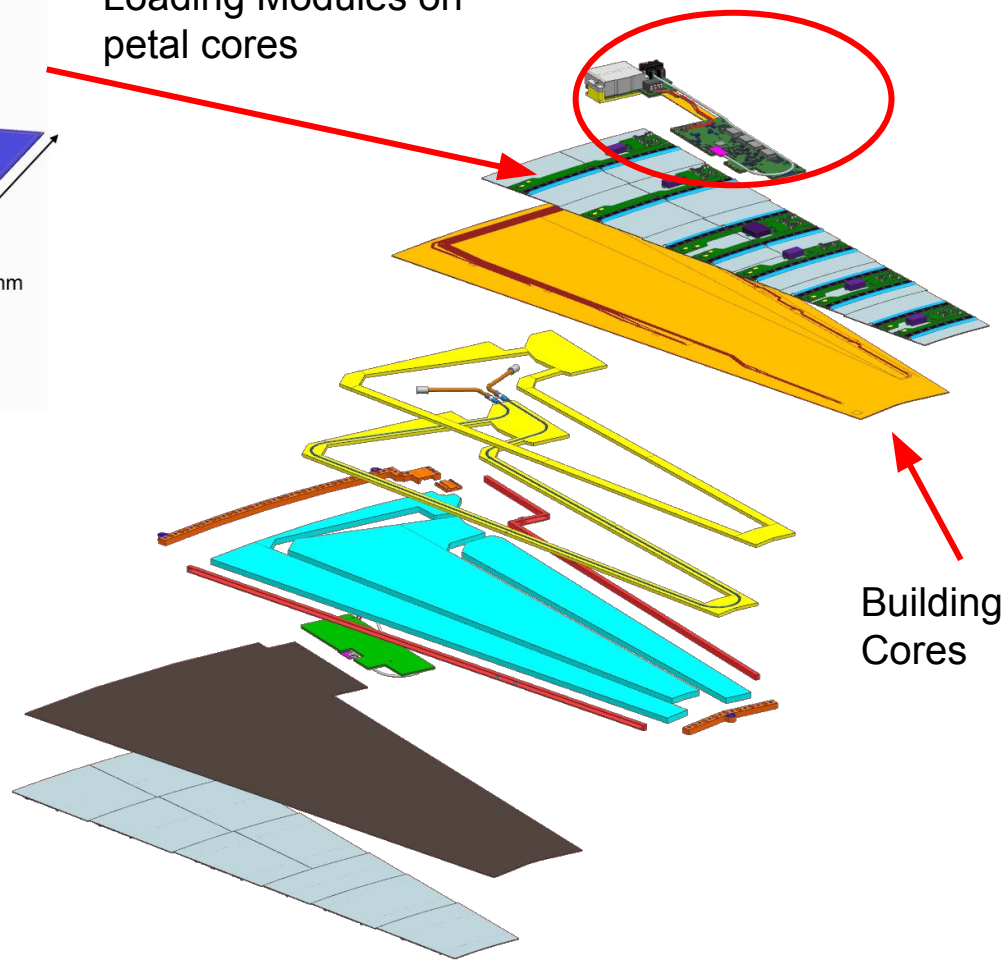


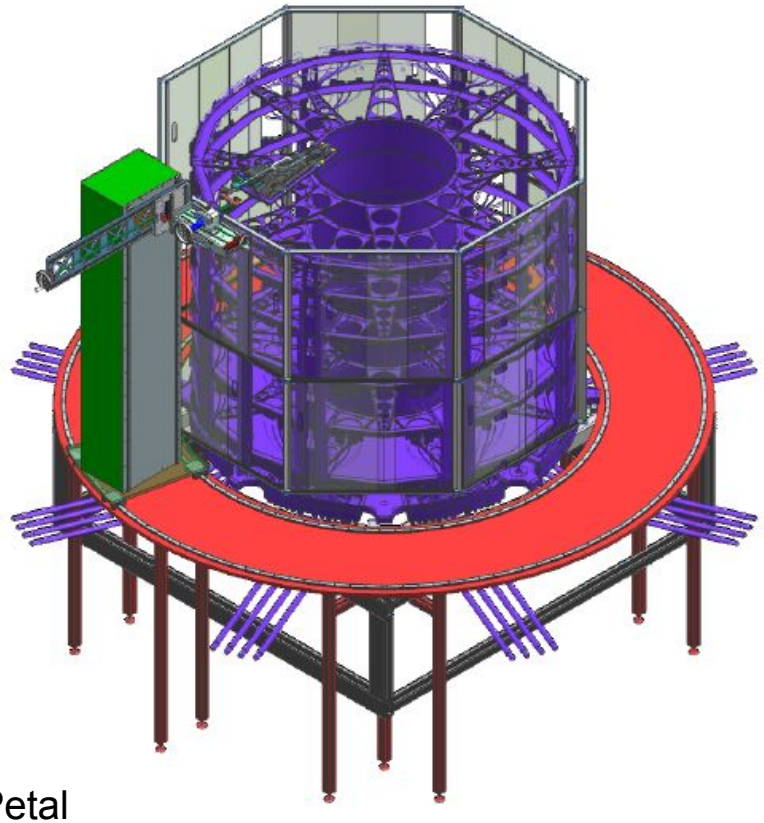
Module Building :
Gluing and Wirebonding

Loading Modules on petal cores

EoS board



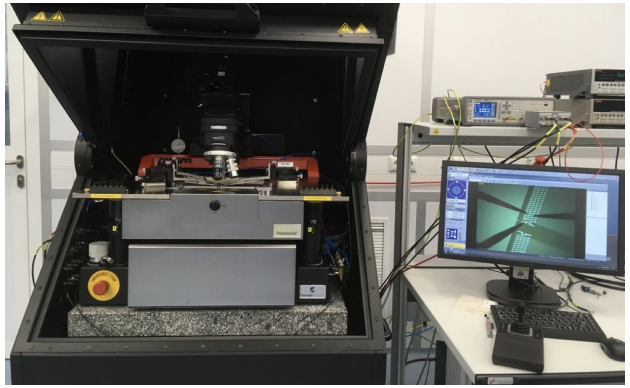
Building Petal Cores



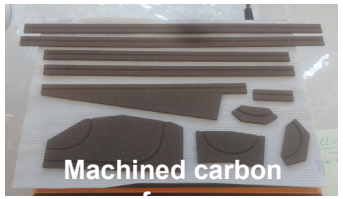
Super tool with end-cap and petal insertion tool

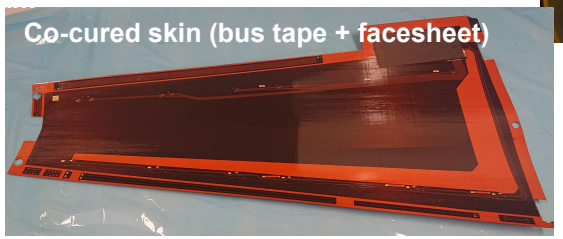
A lot going on at DESY ...

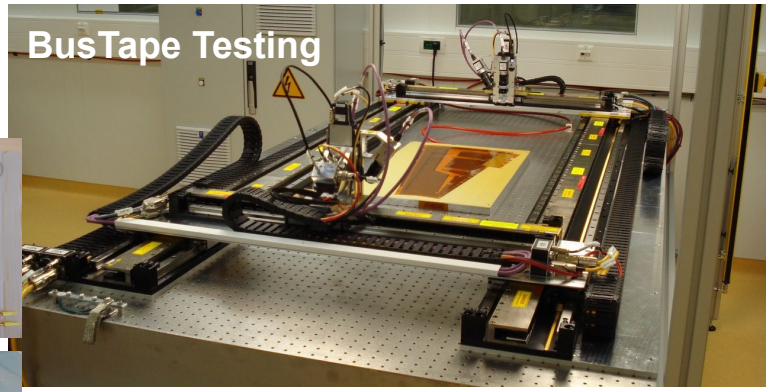
Sensor Testing

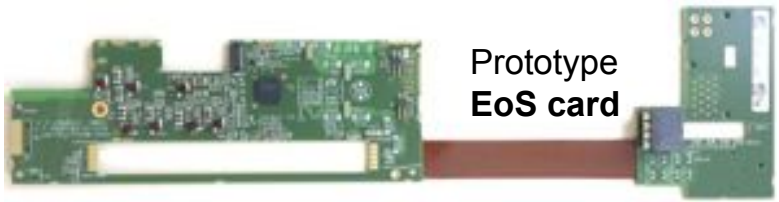


Petal Building



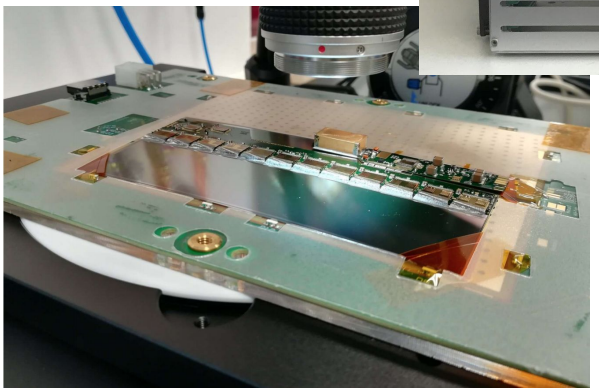




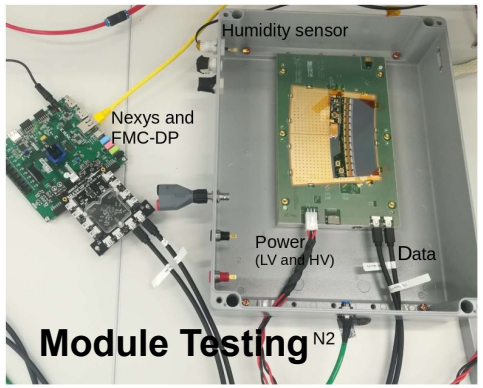


Hybrid Burn-in

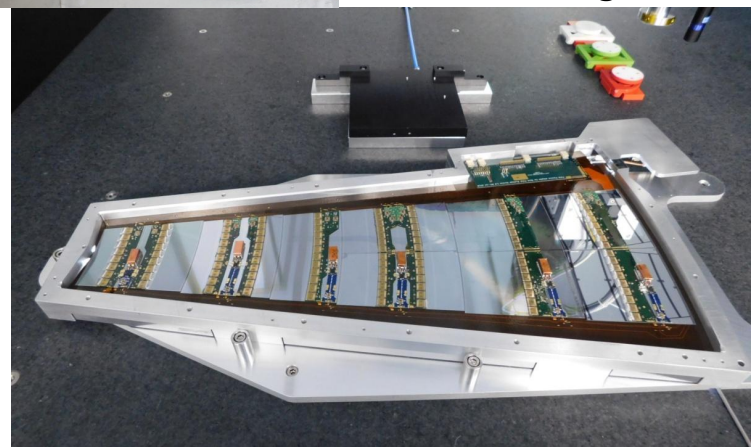
Insertion tool v1.0



Module Building



Petal Loading



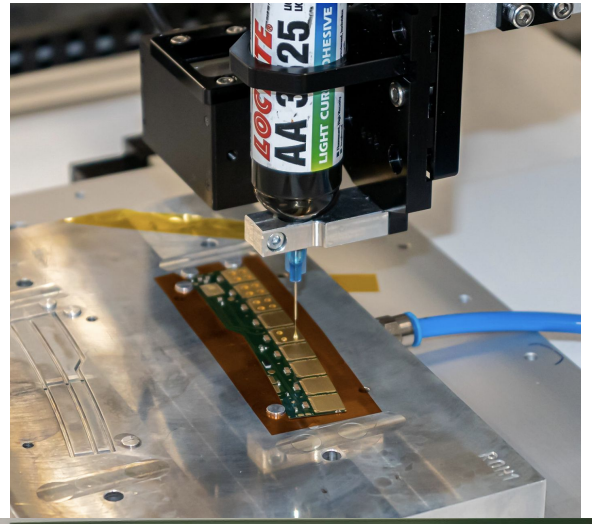
Module Building

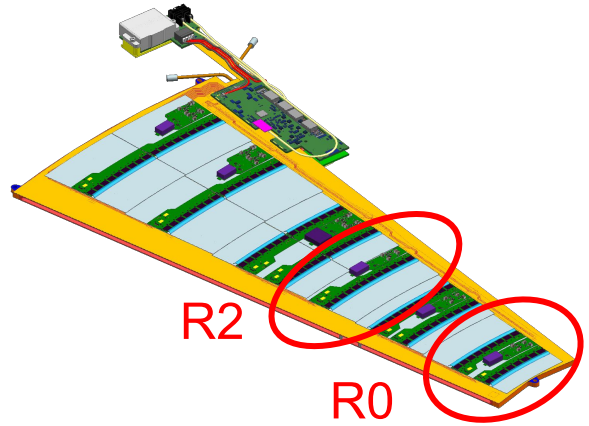
Gluing of ASICs on hybrid and hybrids on sensor

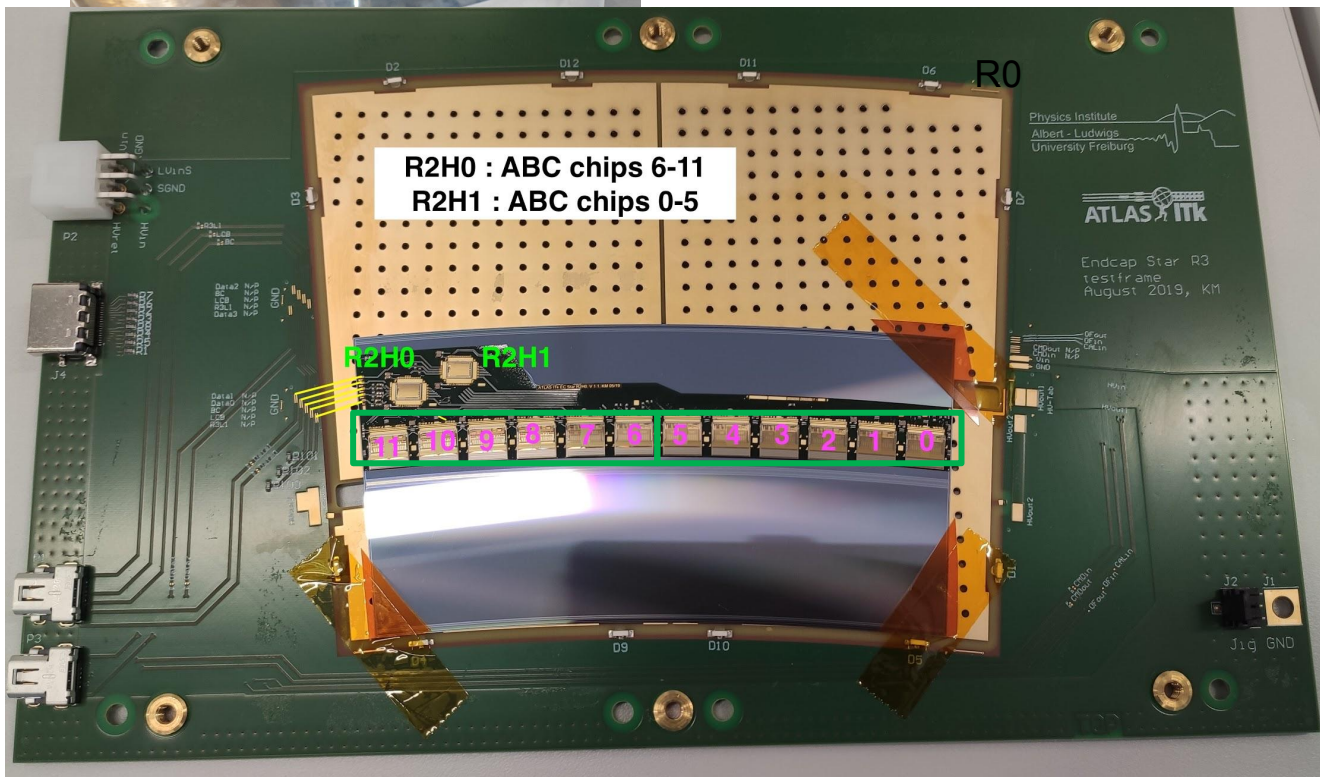
- Using glue dispensing robot and tools
- Metrology done using 3D optical measurement - glue heights and sensor flatness well within the specifications
- High repeatability and accuracy achieved in glue dispensing - exceeding specification

Built and tested **first R2 module** for the ITk

- Optimization of gluing for the module of new geometry done within a short timescale
- **Gluing performed at Hamburg, wirebonding at Zeuthen**
- Important to test modules of all geometries (R0-R5)
- To be loaded on the first ABCStar (close to final) version of an electric petal





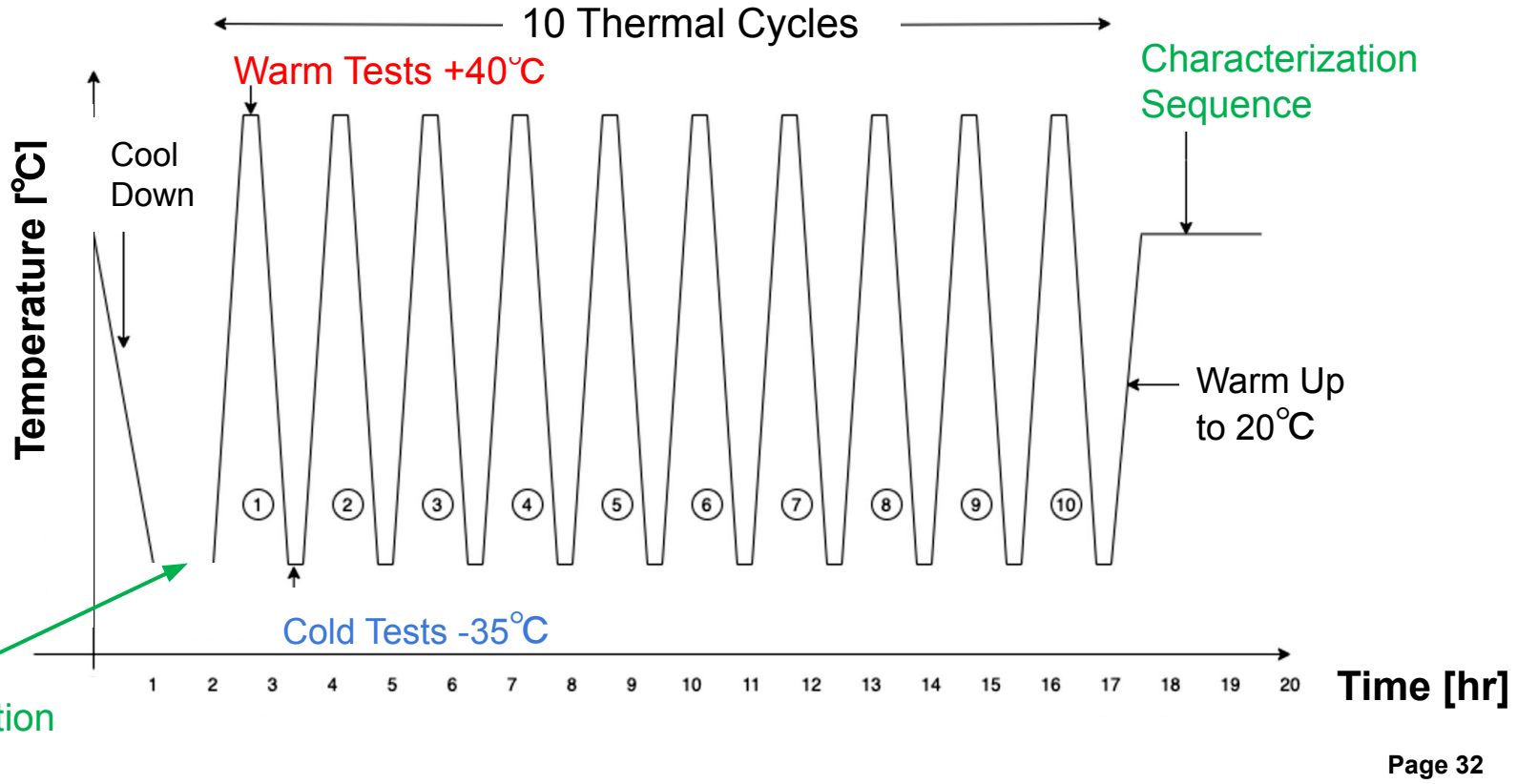


Thermal and Electric Module Testing

- Stringent Quality Control (QC) for every device during the production
- Module QC : 10 thermal cycles between -35℃ and +40℃
- Electric Tests done using an injected calibration pulse
  - Establish the overall functionality and readout of the module
  - Measure gain and input noise of all the channels in the module

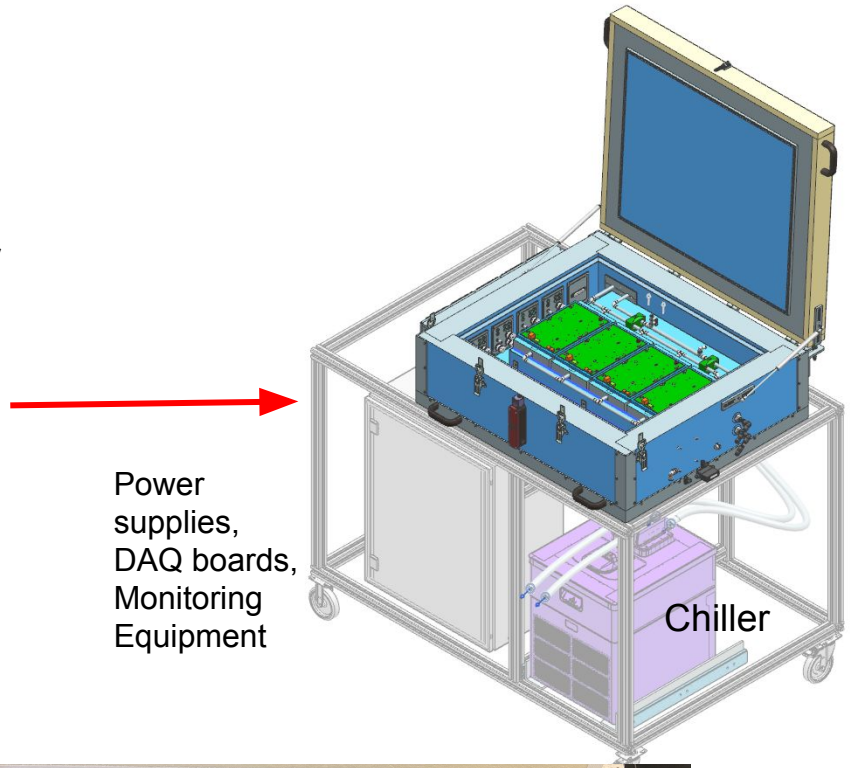
Two sets of electric tests defined

- Characterization Sequence (~1 h) : before and after thermal cycling.
- Confirmation Sequence (~ 15 mins) : at cold -35℃ and warm +40℃

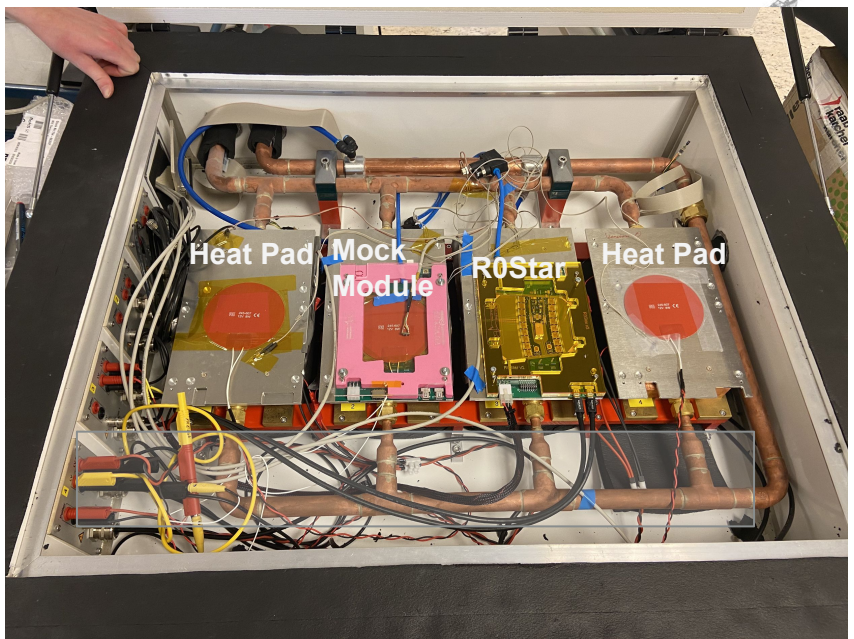


Endcap Module Testing Setup

- An automated testing system necessary to have quality control under coherent conditions at all the production sites
- Electric Testing expertise gained by testing numerous devices built/received at DESY
- First prototype of coldbox **designed and built at DESY** for ITK strips endcap
- Commissioning of the coldbox with an R0 ABCStar module
  - Use heat pads and a mock module structure on the other three chucks

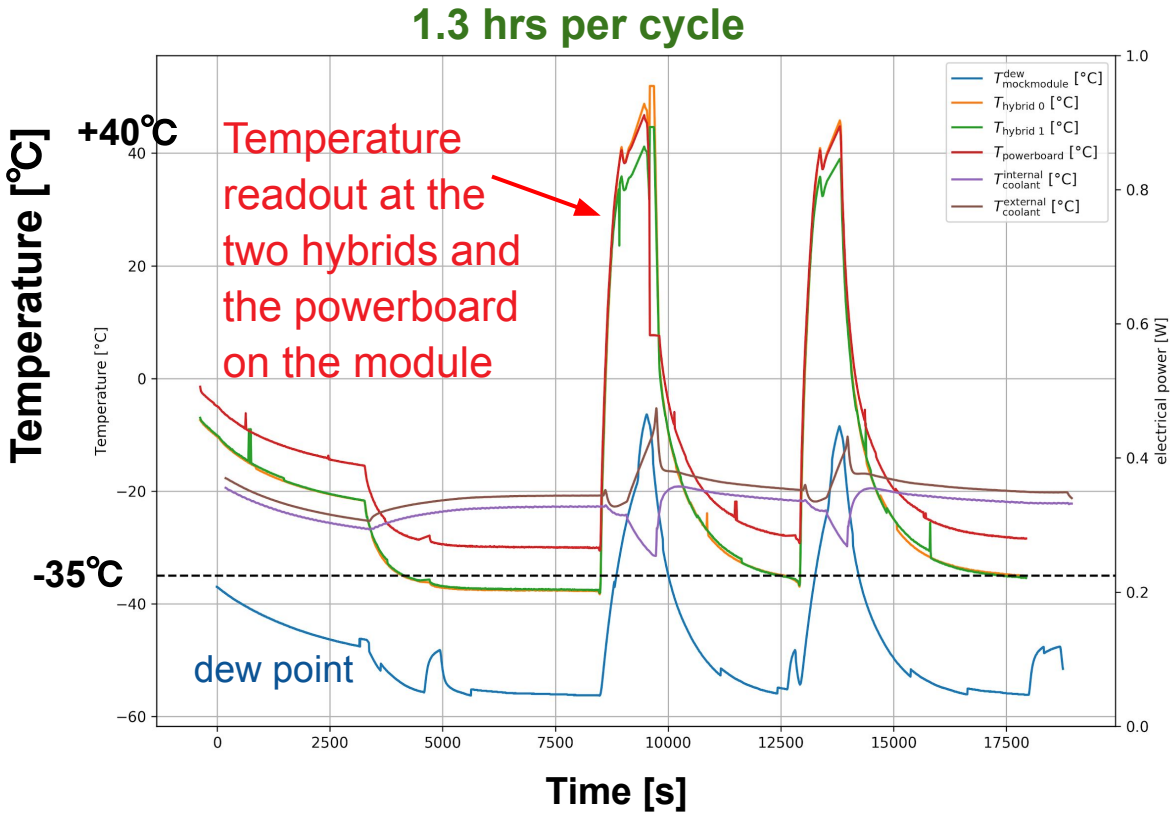


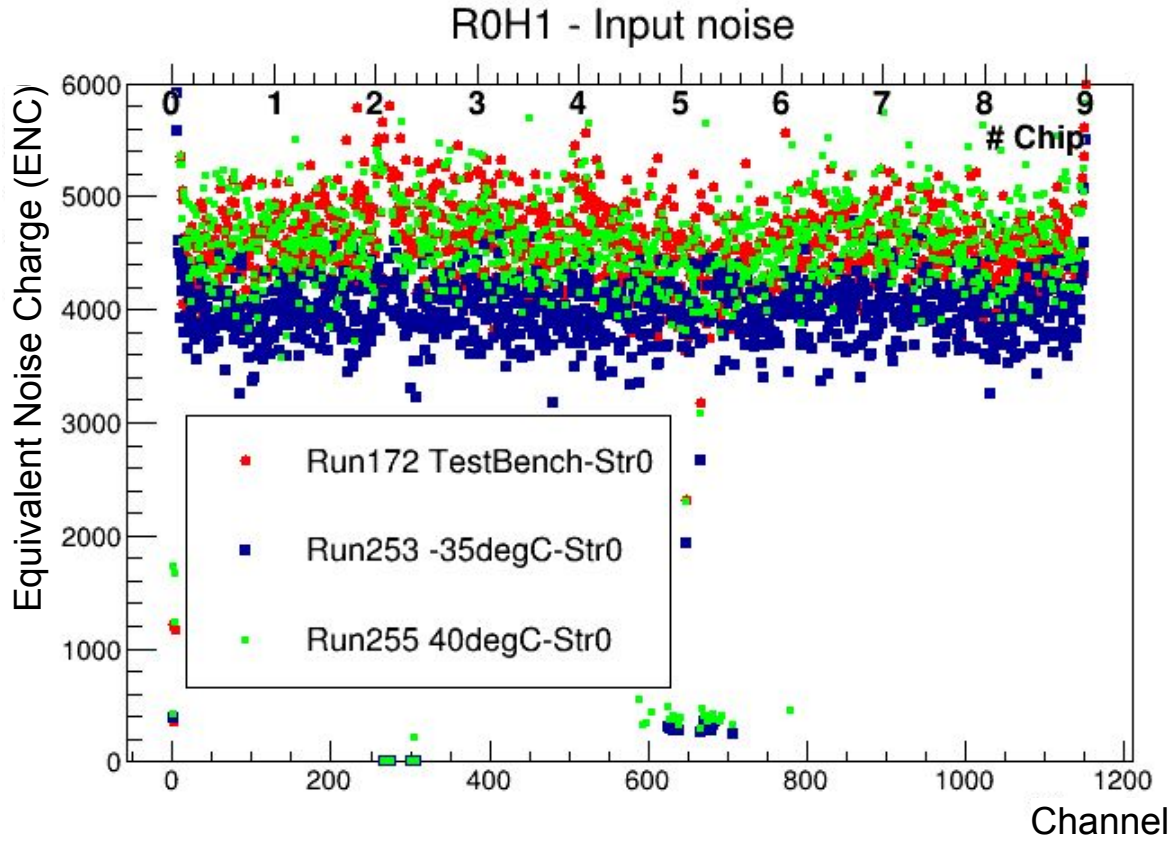
- **Coldbox Setup**
  - 4 chucks for modules of any endcap geometry
  - Use an industrial chiller with peltier coolers to reach the desired temperatures



Cold Box Commissioning

- Using one R0 ABCStar module
- Electric Tests at extreme temperatures compared with test bench results
- Further improvements in place to reduce cycle time
- Complete Automation of thermal cycling and electric testing - Ongoing





Summary

- Computing infrastructure working efficiently and being used heavily.
- DESY continues to play an important role in ATLAS detector operation, upgrade projects, computing, simulation, measurements and searches for new phenomena
  - Most of the activities not discussed today
- 16 journal papers and 8 preliminary results with a strong DESY contribution released since the last PRC

- ATLAS Highlights presented today illustrating:
  - leading role in Run2 physics measurements and searches covering wide range of physics
  - Strong presence in preparations for Run3 in software, reconstruction and performance groups
  - Excellent progress toward the construction of an ITk strip end-cap for the HL-LHC