ATLAS Group Highlights.

84th Meeting of the DESY Physics Review Committee

Hamburg, 19th-20th October 2017

Katharina Behr
On behalf of the DESY ATLAS Group

HELMHOLTZ ASSOCIATION

ATLAS EXPERIMENT

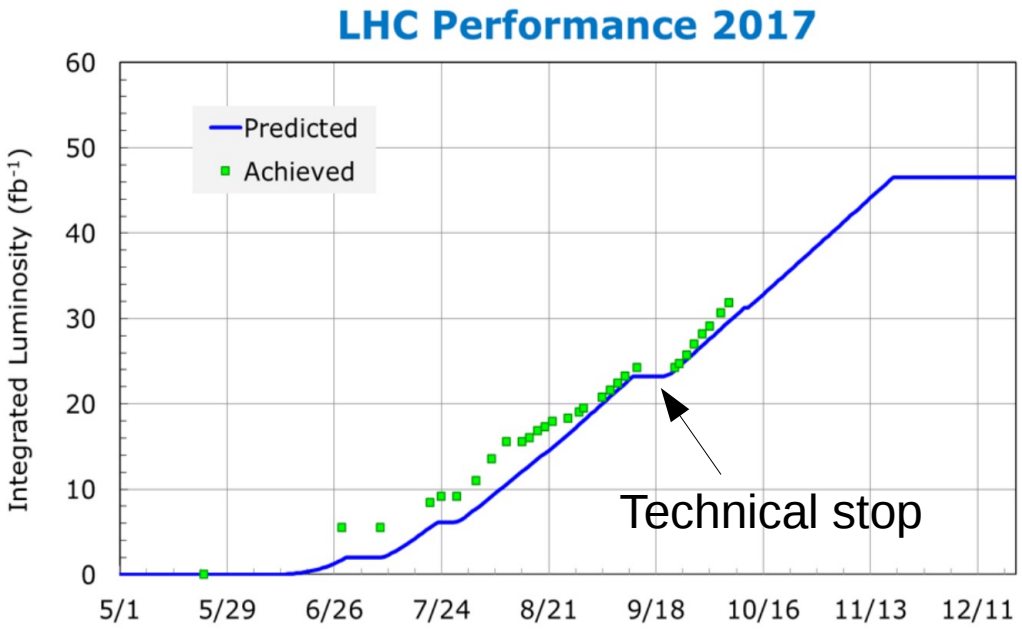
DESY

LHC Status

LHC Operation

- Continue operation at 13 TeV
- First beams: 29/04
- Start of data taking: 23/05
- **Record luminosity** (early August):

  $1.7 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$



- Frequent beam dumps due to losses at 16L2 interconnection (through August)
  - Most likely due to air inlet into beam pipes during winter 16/17 shutdown
  - Coping mechanism: different bunch filling scheme (8b4e)
    - Fewer bunches, more pile-up
  - Luminosity levelled around $1.5 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ (from late September)

Still on track towards 2017 goal of 40 fb^{-1}

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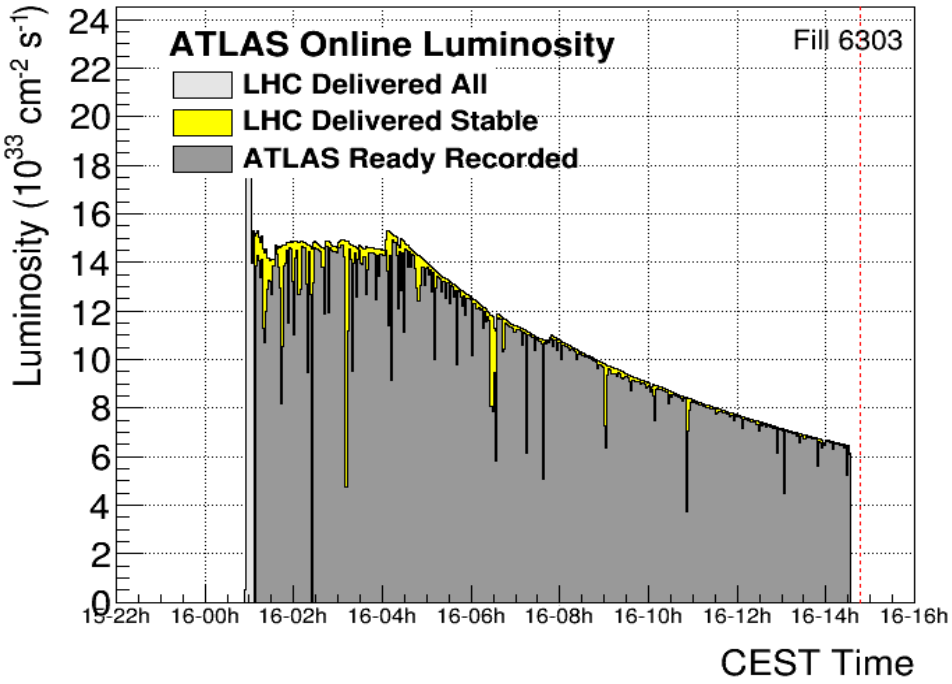

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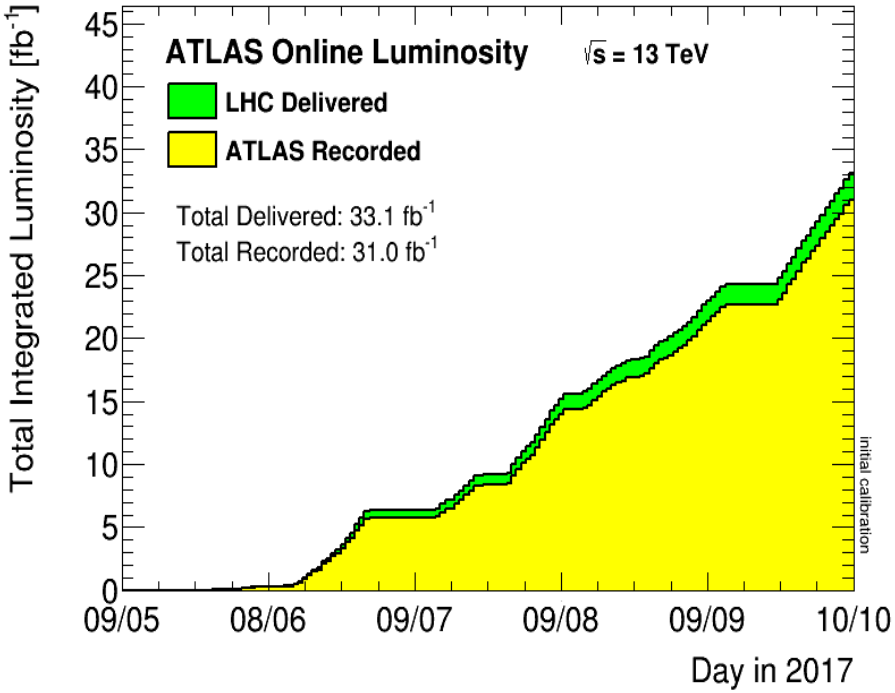
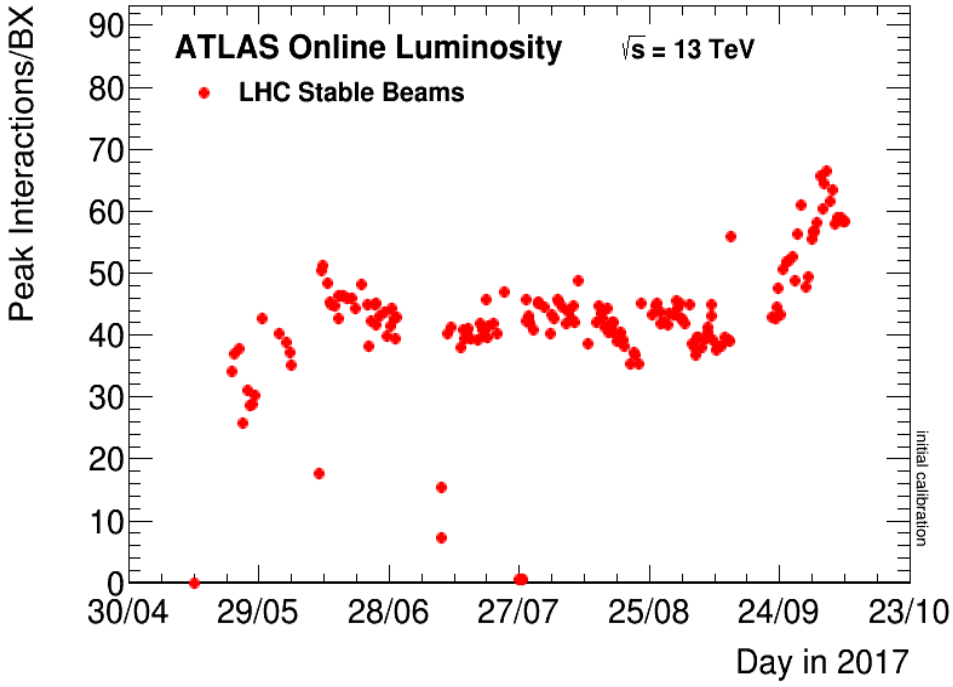
Still on track towards 2017 goal of 40 fb^{-1}

ATLAS Data-taking Performance

> Excellent detector performance: recorded 93.8% of the data delivered by the LHC

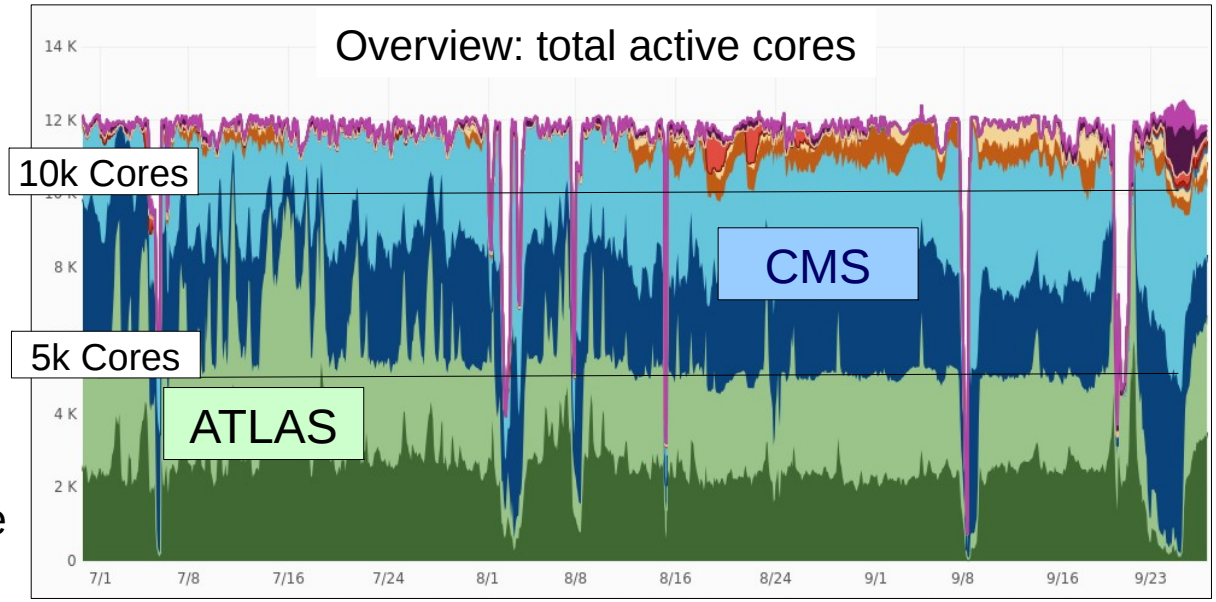




LHC Computing @ DESY

> Tier-2 grid site

- Shared facility for ATLAS, CMS, LHCb, Belle, ILC ...
- One of the biggest and most reliable Tier-2s
- Sizeable pledged LHC resources: CPU and disk
- Up to ~10k cores available opportunistically



- Significant disk space (many PBs)
- Plans to increase pledges for 2018 according to requests

> National Analysis Facility

- Complements grid resources with focus on interactive end user analysis
- About 6k CPU cores available to all German HEP groups
- Dedicated fast storage system, capacity to be doubled shortly

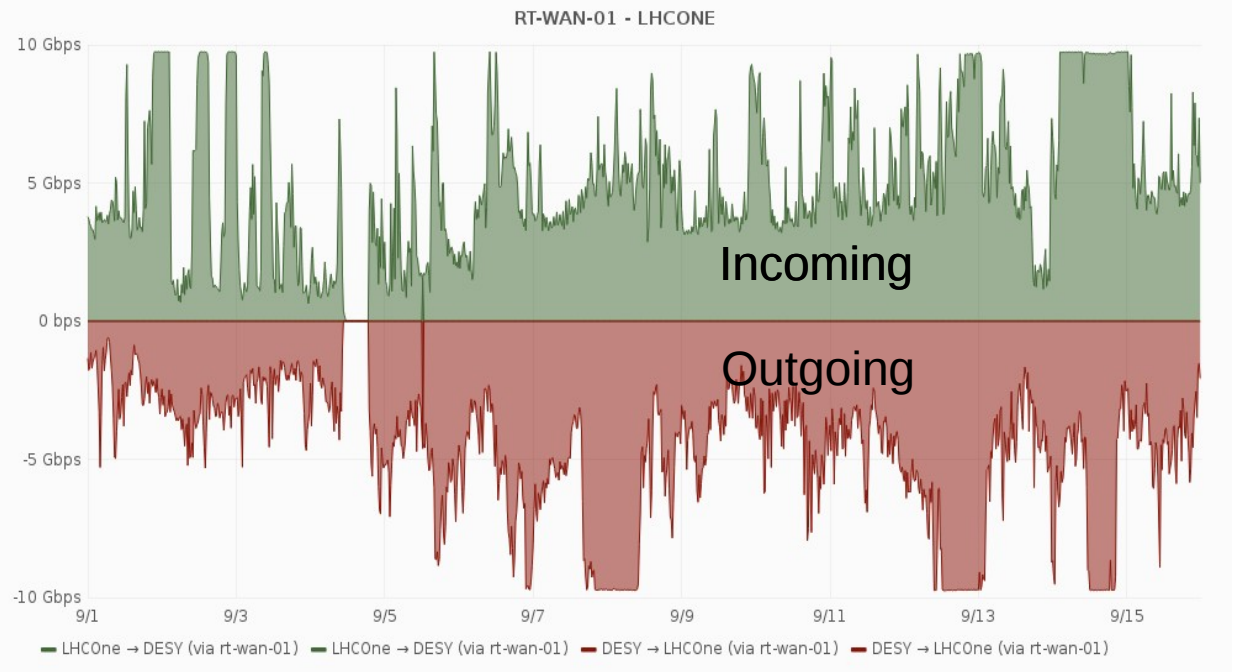
LHC Computing @ DESY

> **Network becoming more important for CMS and ATLAS** (and soon others)

- More data being accessed remotely
- Tight disk space managed rather actively by automatic DDM tools

> First signs of saturation:

- LHC-ONE (2x 10GBit/s connectivity) via dedicated LHC network
- WAN (2x 5 GBit/s uplink, not limited), general purpose, also used for some LHC traffic



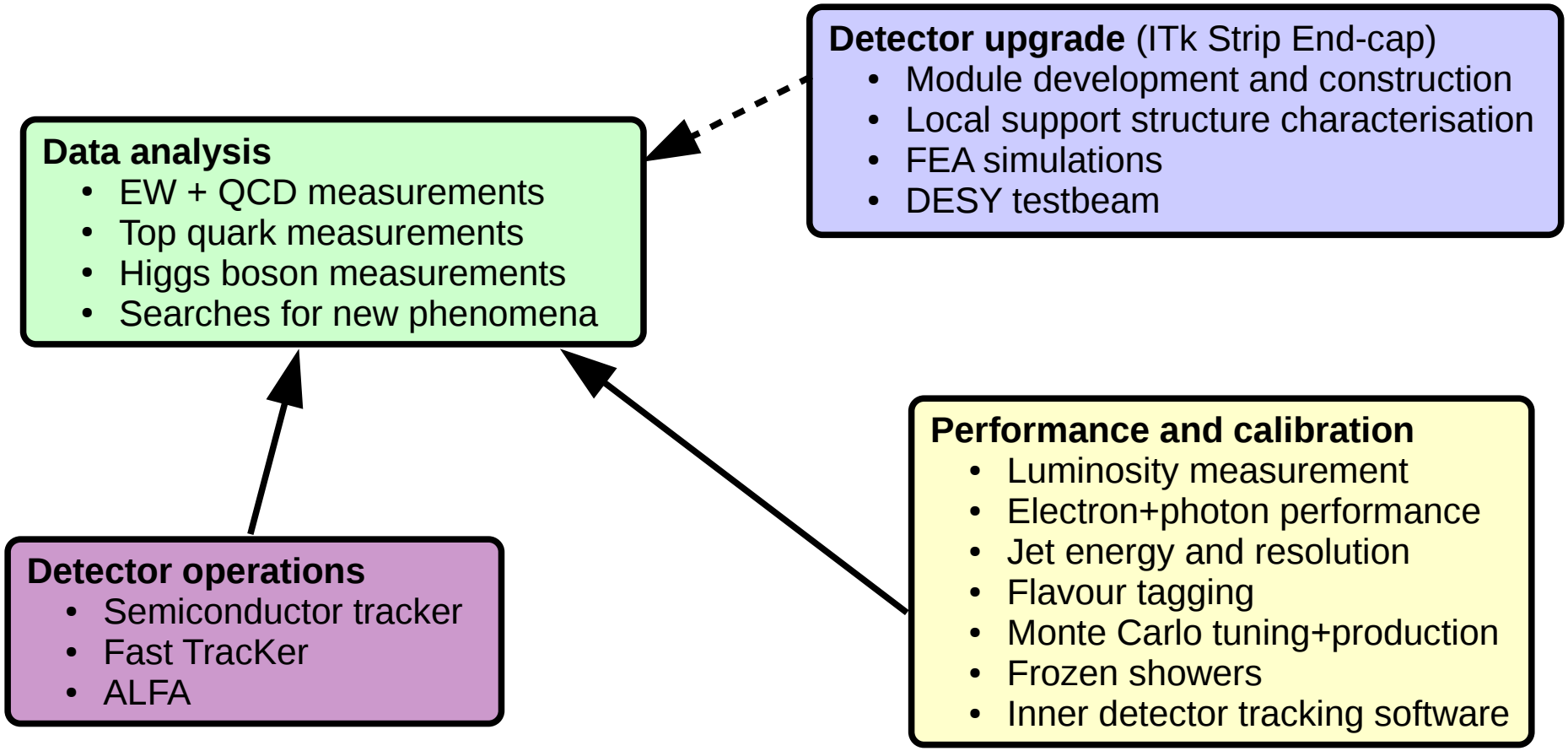
> **Both ATLAS and CMS groups strongly support upgrade**

- Demand on networking from the LHC will continue to increase
- Belle will add to this issue soon

ATLAS Group Highlights

In a Nutshell

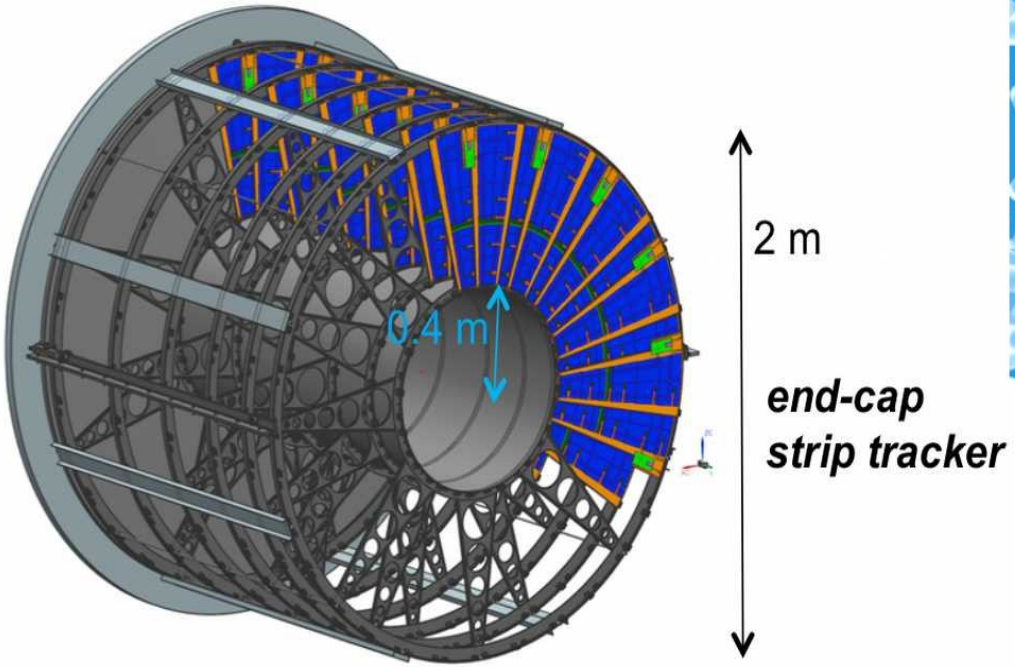
- ATLAS group activities cover a diverse range of topics
- Group members held leading roles in various projects
- Published 13 papers and 2 conference notes in the last 6 months

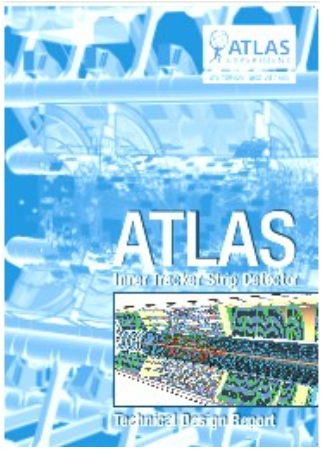


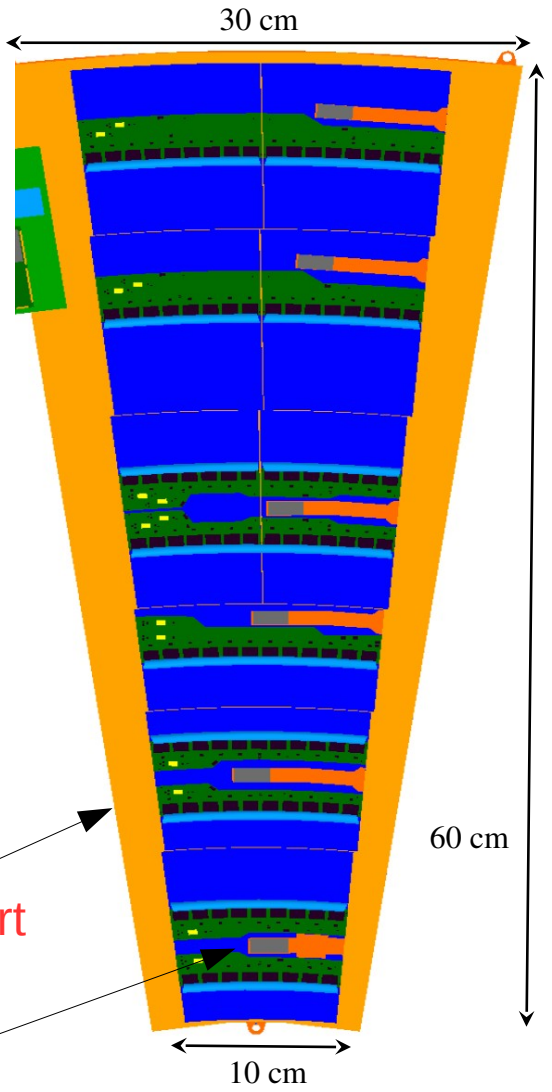
Phase-II Upgrade:
ITk Strip End-cap

One ITk Strip End-cap

- ATLAS will replace current inner tracking detector with **all-silicon tracker (ITk)**
  - During LHC Long Shutdown 3 (2024-2026)
- DESY group plays a leading role in the ITk project
  - One end-cap to be assembled at DESY
- **Milestone**: TDR submitted (April), approved by LHCC (June)

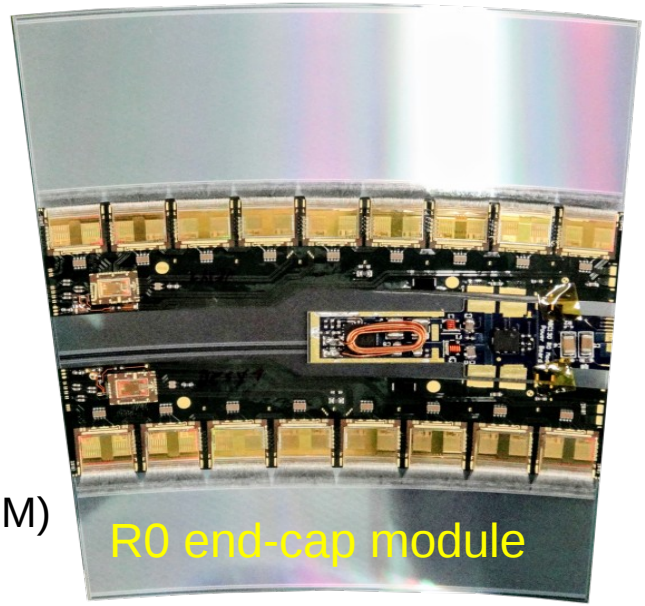






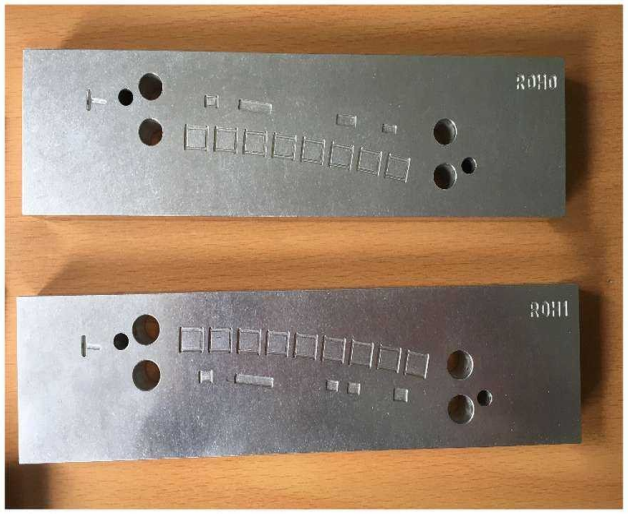
Module Developments

First end-cap specific modules built at DESY (Zeuthen)



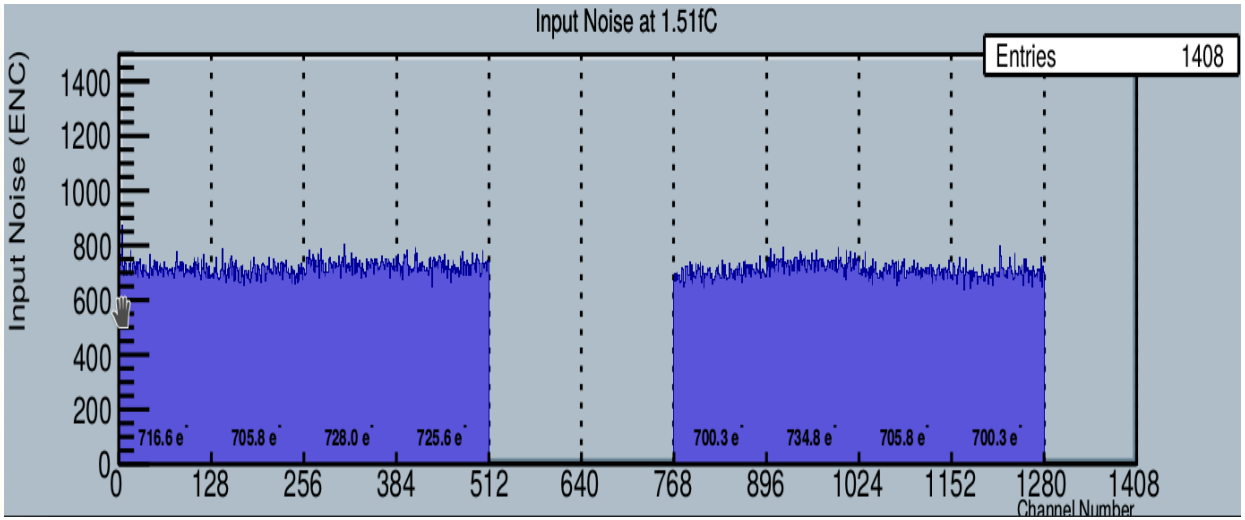
- Now ramping up module production in Hamburg
- All module assembly tools ready
- Measured with optical Coordinate Measuring Machine (CMM)

Everything within tolerances



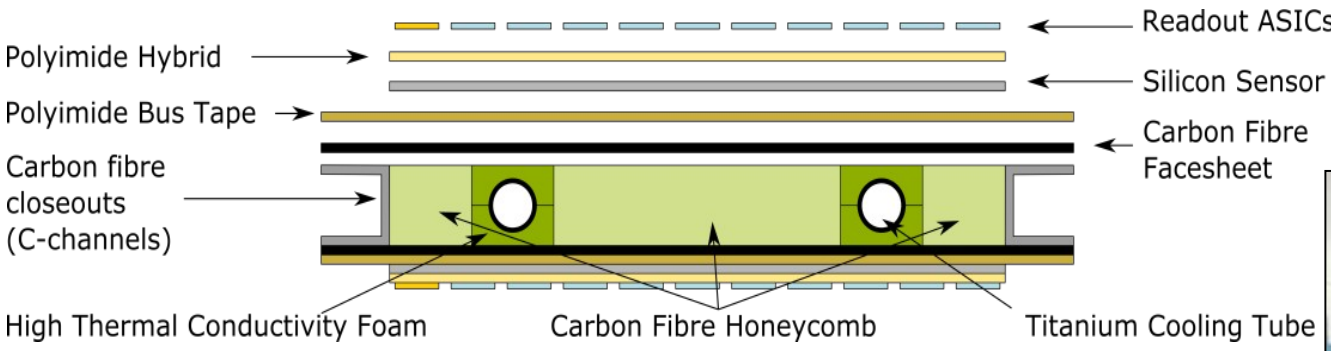
R0H0 and R0H1 chip trays

Response Curve Input Noise
U = -350V, $T_{chiller}$ = 5°C



Petal Production and Quality Assurance

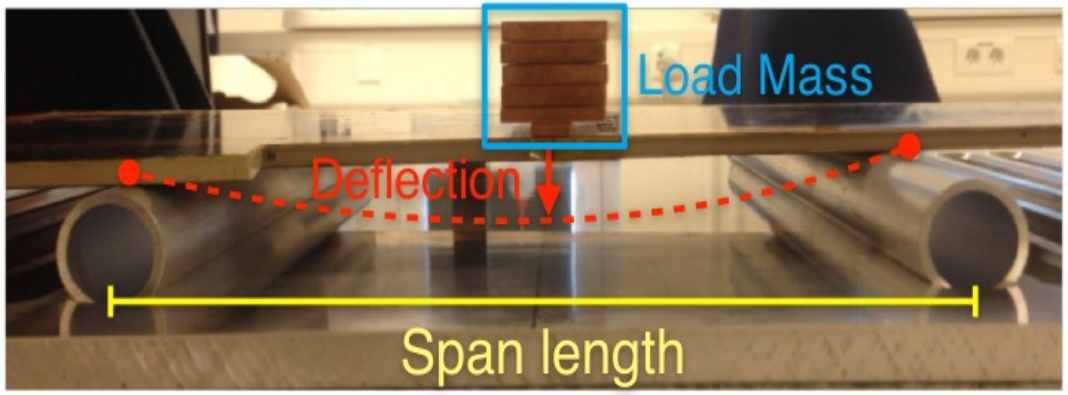
DESY is currently the only place producing and testing the cores for the local support petals



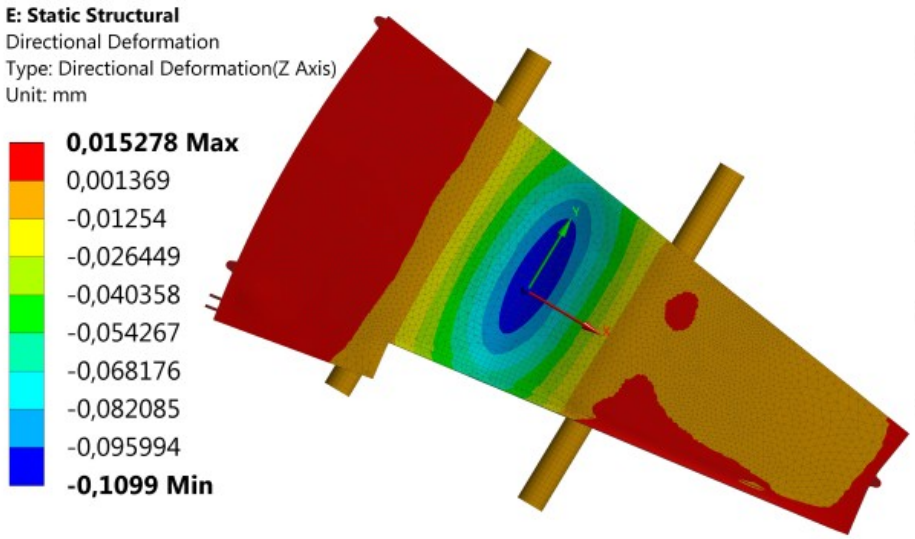
- Ramped up team around petal design&construction and quality assurance
  - Autoclave now in operation and first facing produced
  - First completely DESY-built petals

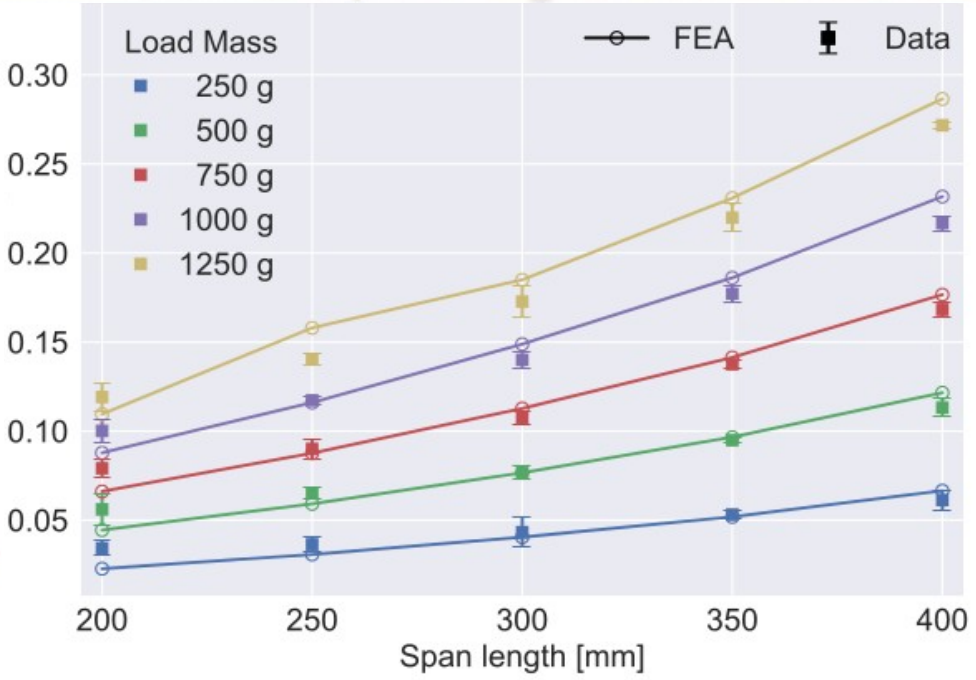
ITk: Petal - Mechanical Properties

- **Goal:** understand effects of environmental vibrations and minimise amount of material
- Bending tests:
  extraction of Young's modulus
- Vibration tests:
  extraction of resonance frequencies



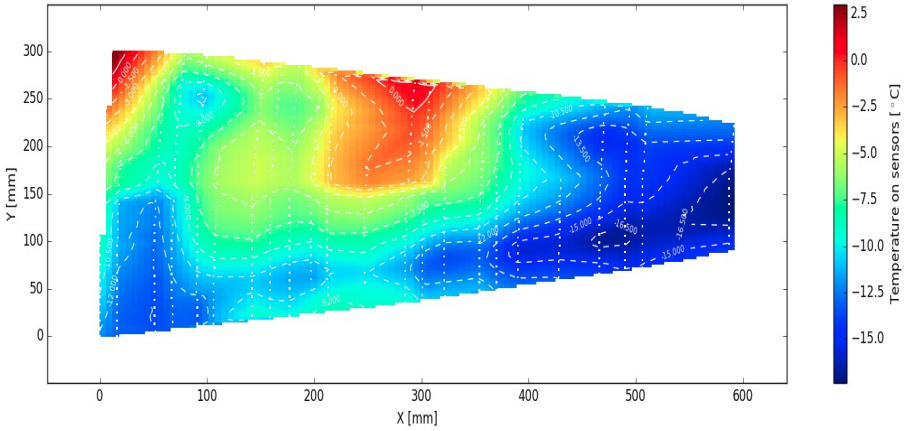
Measurements of deflection matches FEA simulations

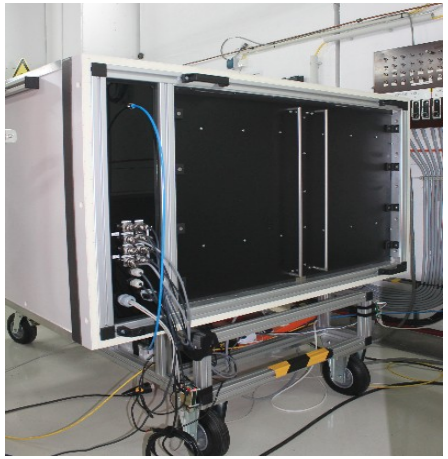




ITk: Petal - Thermal Properties

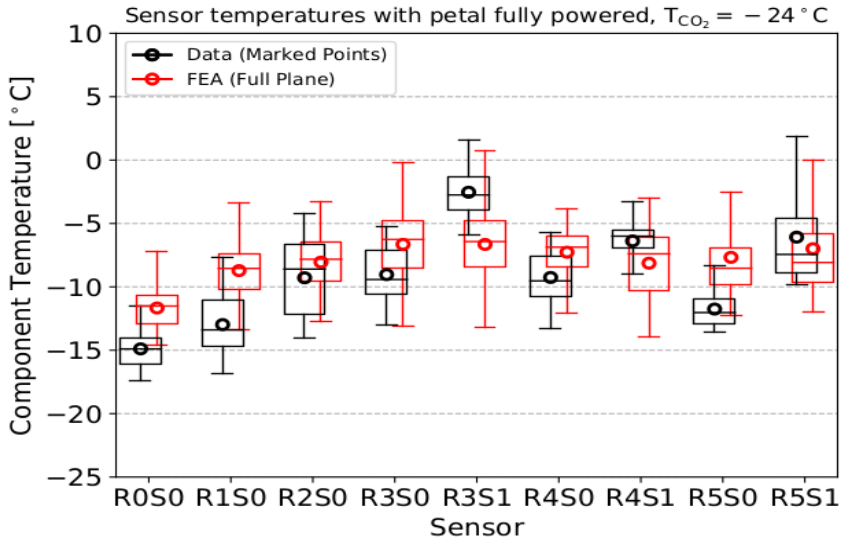
- Thermo-mechanical petal prototype powered with dummy electronics: ~25 W / side
- CO2 dual-phase evaporative cooling with TRACI system (realistic detector environment)
- Custom-made thermal chamber with IR camera





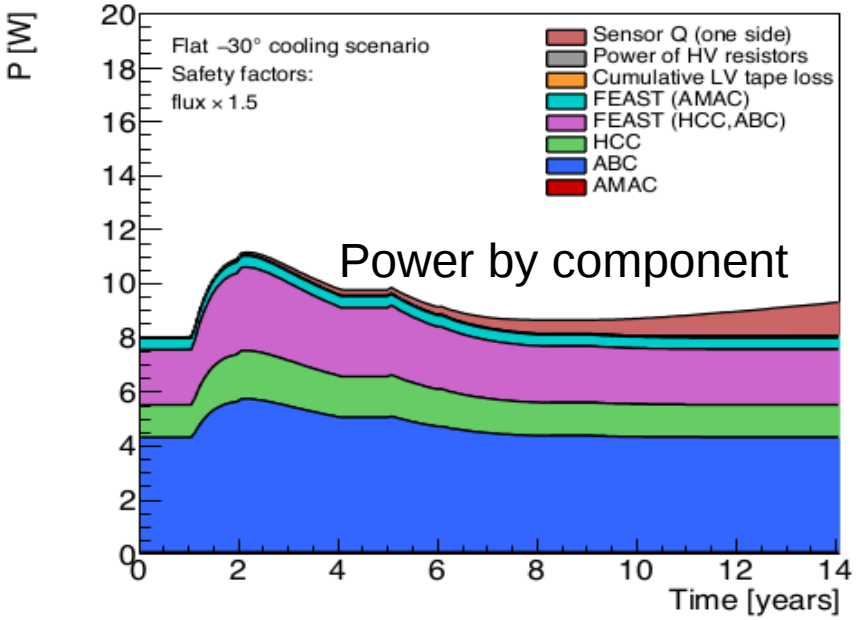
- Emissivity corrections applied to measurements, calibrated for silicon
- Used to validate FEA simulations!

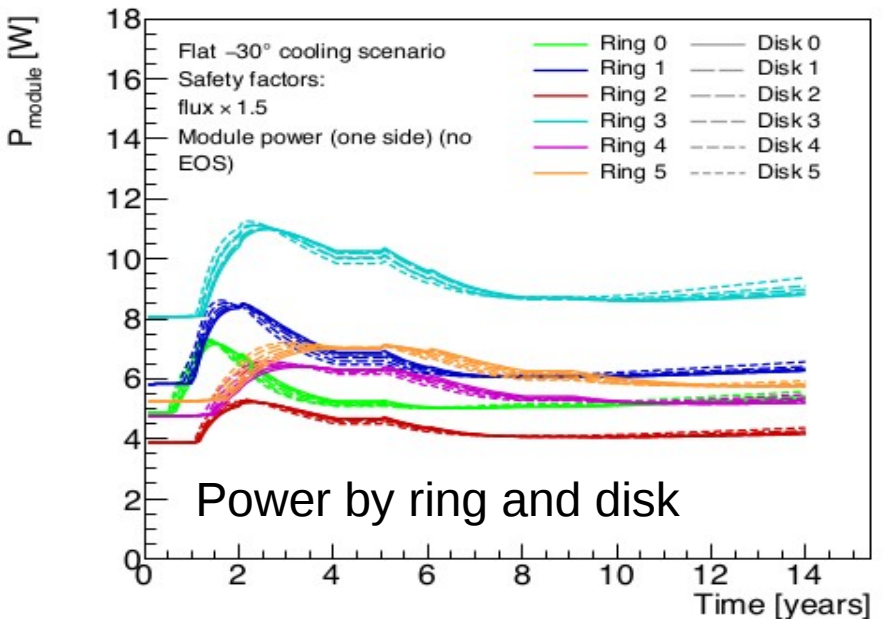
Measurements match FEA simulations



ITk: Thermo-electrical Simulations (full end-cap)

- Input from FEA simulations to model thermal pathways
- Estimate temperature and total power of end-cap modules
  - Current power consumption estimate of both end-caps: 38 - 45 kW
- Power consumption as function of time to study observed current bump
  - Due to surface radiation damages in the front-end chip
- Study used to deliver realistic specifications for ASICs, bus tapes, and cooling systems





Higgs cross-sections
2-photon and 4-lepton final states*

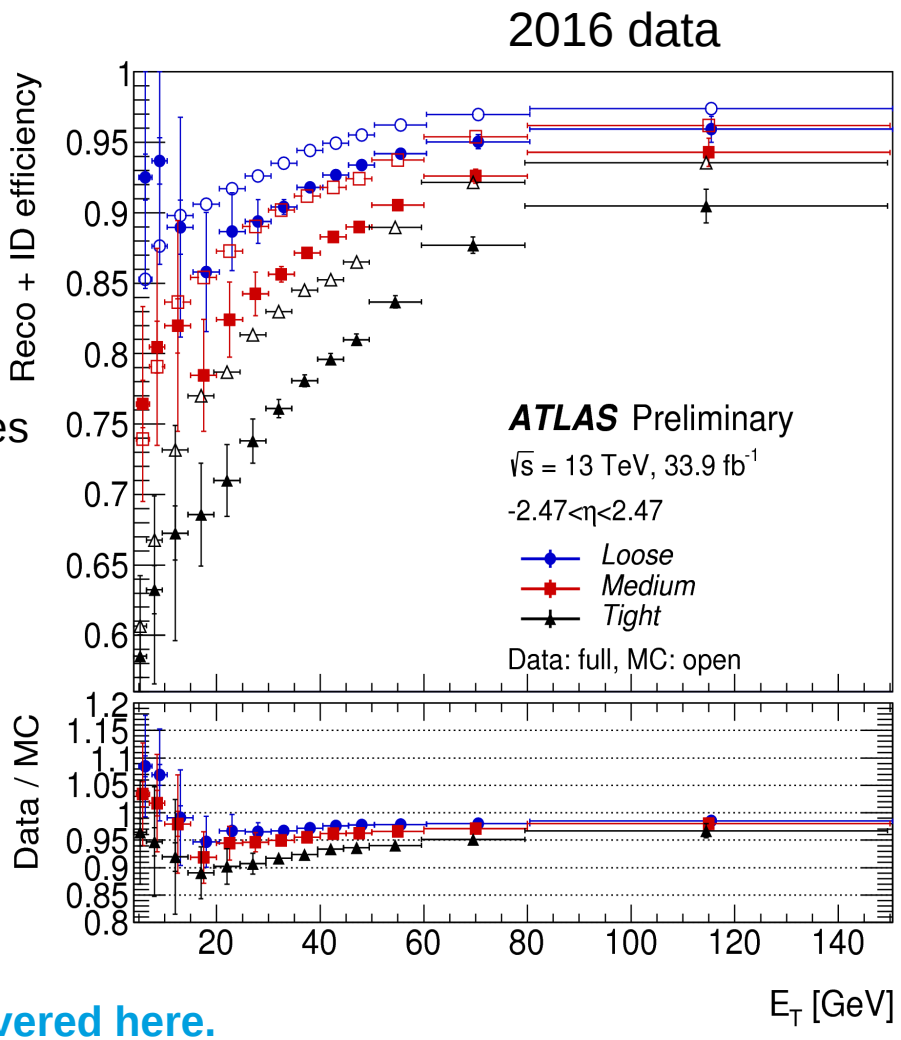
*Measurements in other final states by the DESY ATLAS group are not shown here.

4-lepton channel: Electron performance*

[Public plots: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/EGAM-2017-003/]

Measurements and searches rely on high performance of electron reconstruction and identification

- Efficiency measurement:
  $Z \rightarrow ee$ tag-and-probe
- Compare reco+ID efficiency in data and simulation for three electron quality categories
  - Loose
  - Medium
  - Tight
- Derive scale factors to correct efficiencies in simulation to those in data



***Also involved in muon performance. Not covered here.**

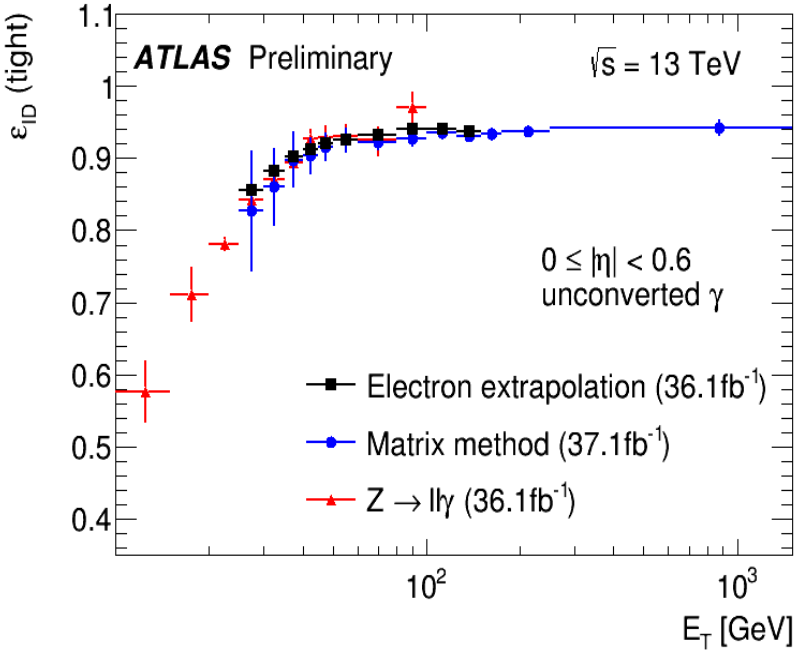
2-photon channel: Photon performance

[Public plots: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/EGAM-2017-004/]

Measurements and searches rely on excellent efficiency and resolution of photons

- 3 methods to measure identification efficiencies
- DESY: electron extrapolation
  - Based on $Z \rightarrow ee$ tag-and-probe
  - Covering E_T = 25-120 GeV
- Derive scale factors to correct efficiencies in simulation to data
- Involved in the photon reconstruction for
  - 2015 and 2016 reprocessing
  - 2017 and planned 2018 data taking

2015+2016 data

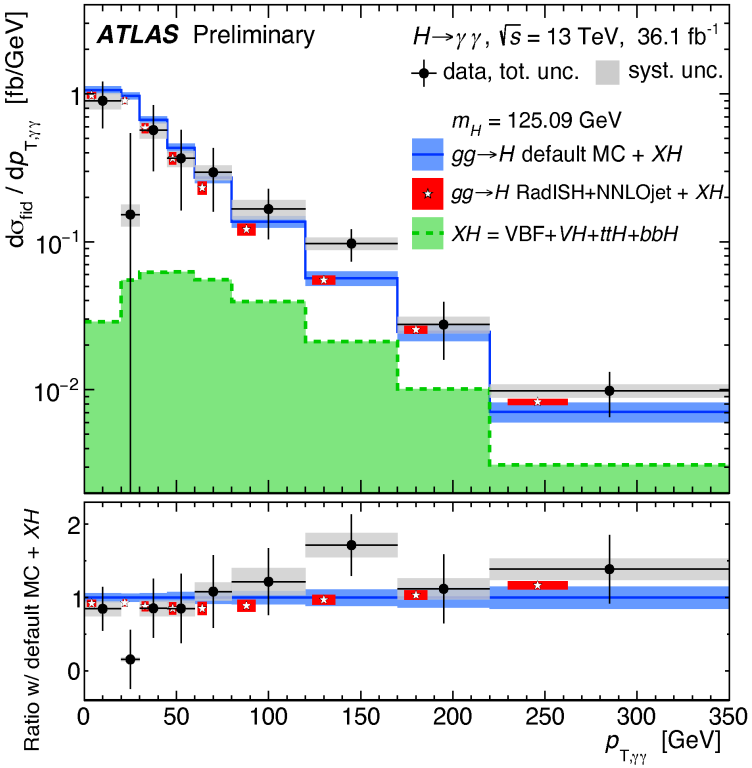


2-photon channel: differential cross sections

Full 2015+2016 dataset: 36.1 fb^{-1},√s=13 TeV

[ATLAS-CONF-2017-045]

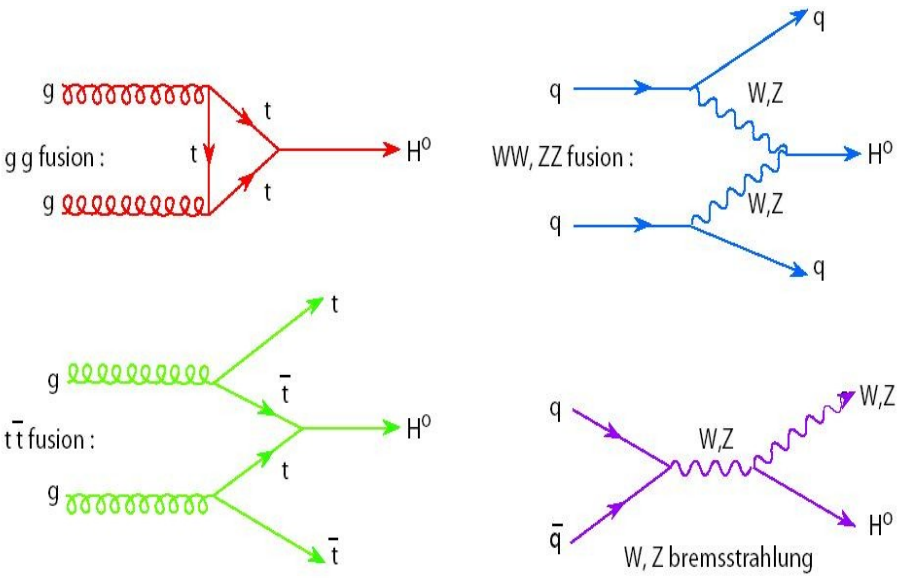
- Decays $h \to \gamma\gamma$ provide a clean signal despite BR = 0.23%
  - Large signal yield due to highly efficient photon reconstruction and identification
  - Excellent photon energy resolution → Signal yield from fitting peak in $m_{\gamma\gamma}$
- Significantly larger statistics (compared to Run-1) for rare processes
  - Higgs bosons at high transverse momentum
  - Associated production with $t\bar{t}$
- Measure differential distributions probing:
  - Higgs kinematics
  - Jet multiplicities & kinematics
  - VBF-sensitive variables
  - Spin-CP sensitive variables

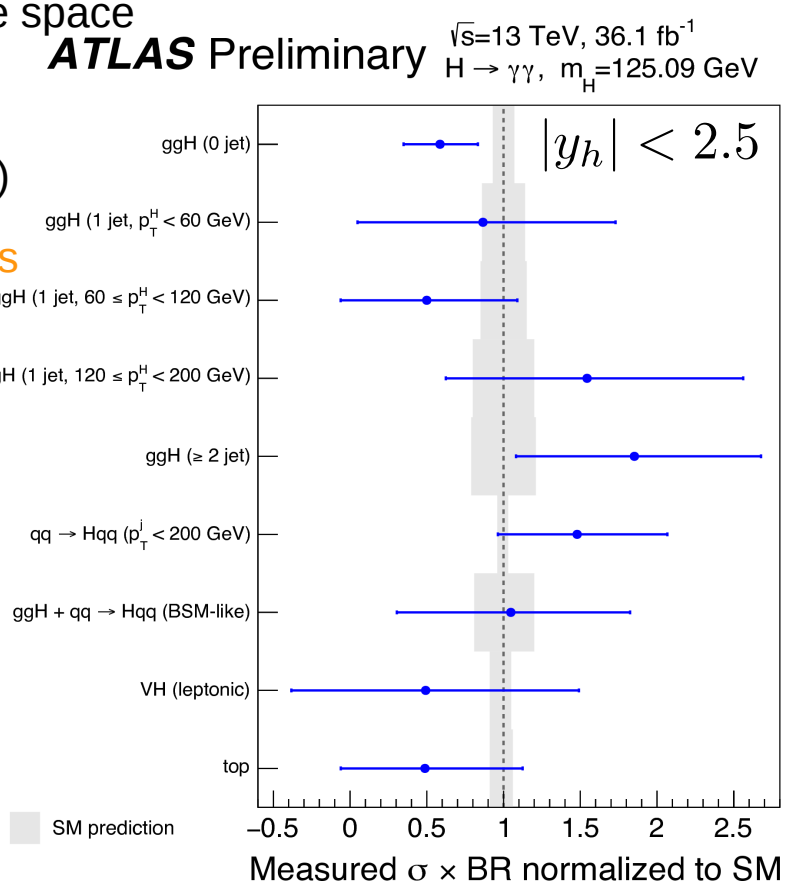


2-photon channel: simplified template cross sections (STXS)

Full 2015+2016 dataset: 36.1 fb^{-1},√s=13 TeV [ATLAS-CONF-2017-045]

- STXS as an evolution from signal strength measurements $\mu_i = \sigma_i / \sigma_i^{\mathrm{SM}}$
- Measure cross sections in 9 (later 31) simplified, mutually exclusive fiducial volumes
  - No model-dependent extrapolation to total phase space
  - Reduced dependence on theory uncertainties
  - Facilitates combinations (channels, experiments)
- Optimised sensitivity for different production modes

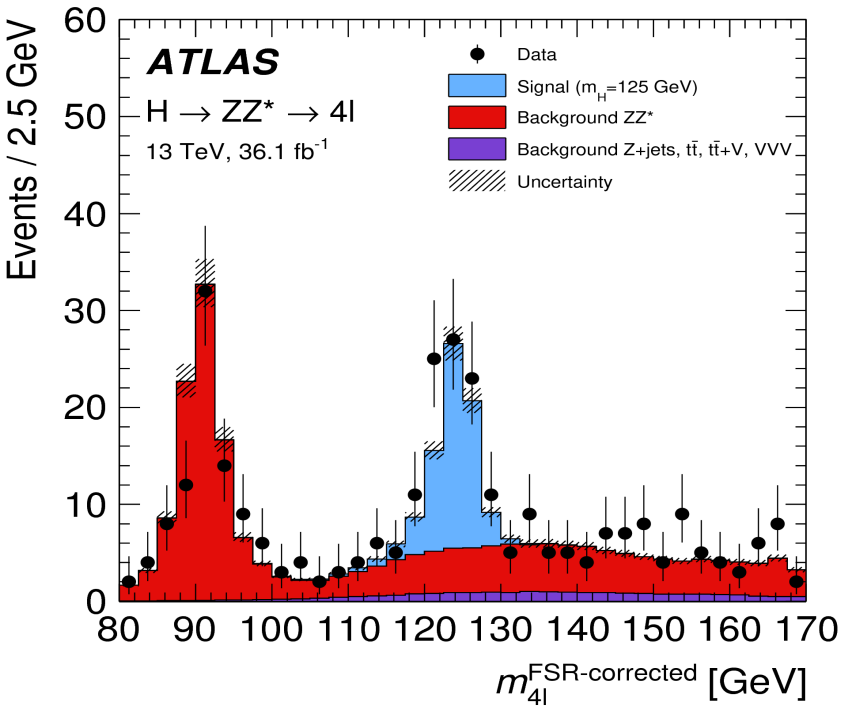


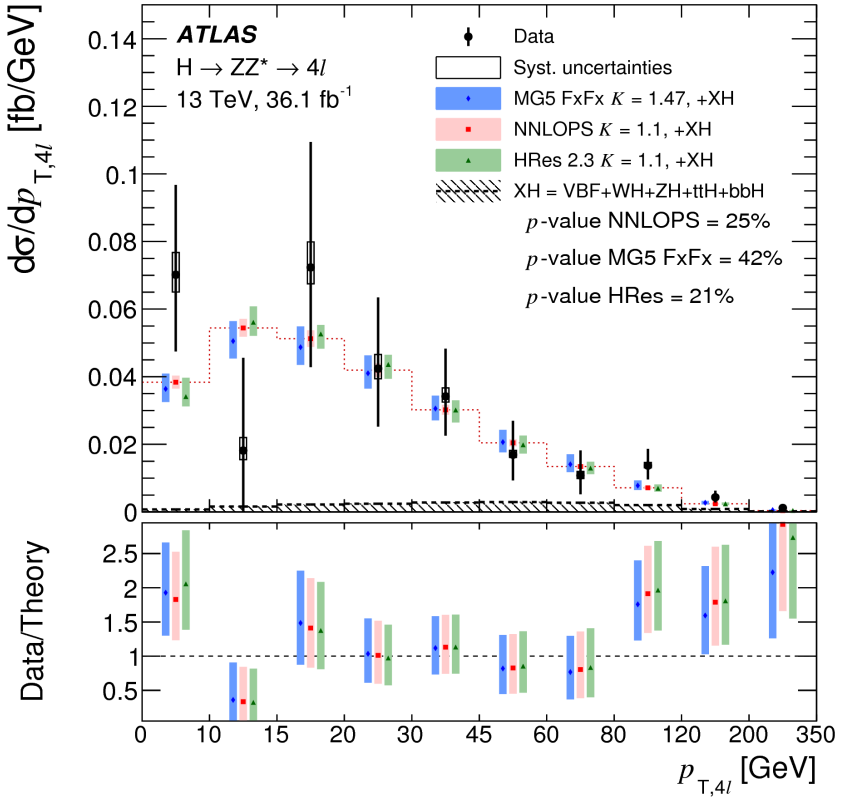


4-lepton channel: differential cross sections

Full 2015+2016 dataset: 36.1 fb^{-1},√s=13 TeV [arxiv:1708.02810, subm. to JHEP]

- Another clean signal with small BR = 0.13%: $h \to ZZ^* \to 4\ell \; (\ell = e, \mu)$
  - Large signal yield due to high efficiency of ATLAS lepton reconstruction and ID
- Large dataset provides unprecedented statistics for differential distributions





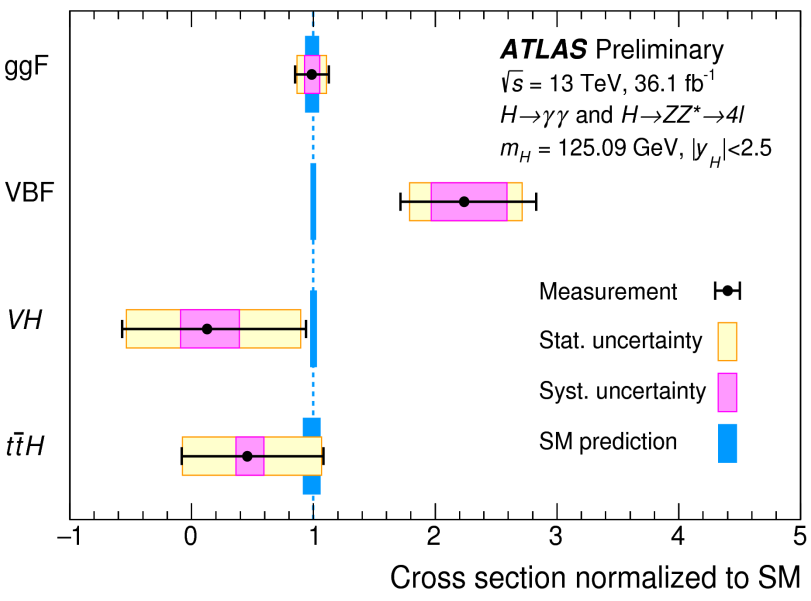
Combination of the 2-photon and 4-lepton channels

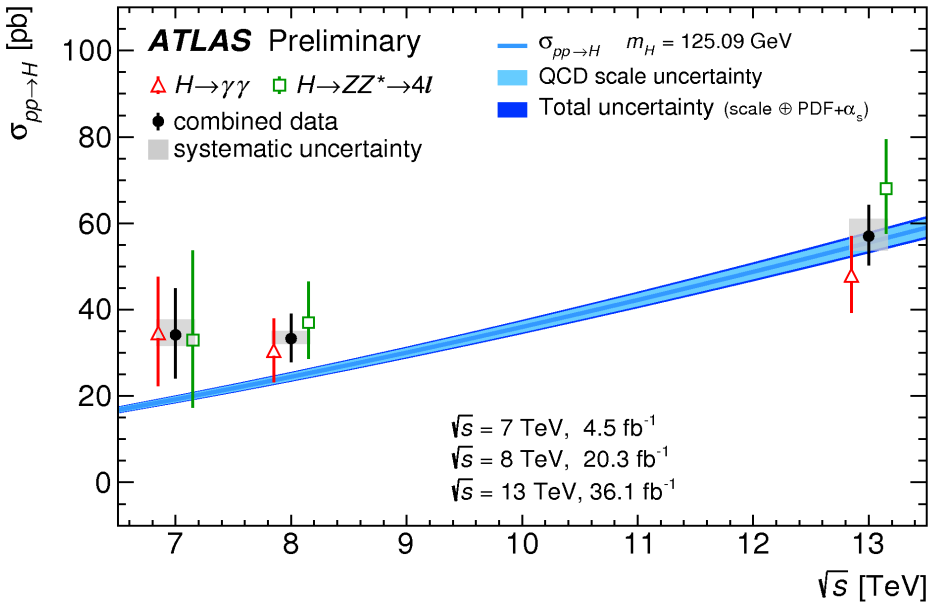
Full 2015+2016 dataset: 36.1 fb^{-1},√s=13 TeV

[ATLAS-CONF-2017-047]

- Increase precision by combining $h \to \gamma\gamma$ and $h \to 4\ell$ measurements
- Combined measurements of
  - Higgs total and production mode cross sections
  - Simplified template cross sections
  - Coupling modifiers κ_i

No significant deviation from the SM





Extra Higgs Bosons?

Search for heavy Higgs bosons decaying to top quarks

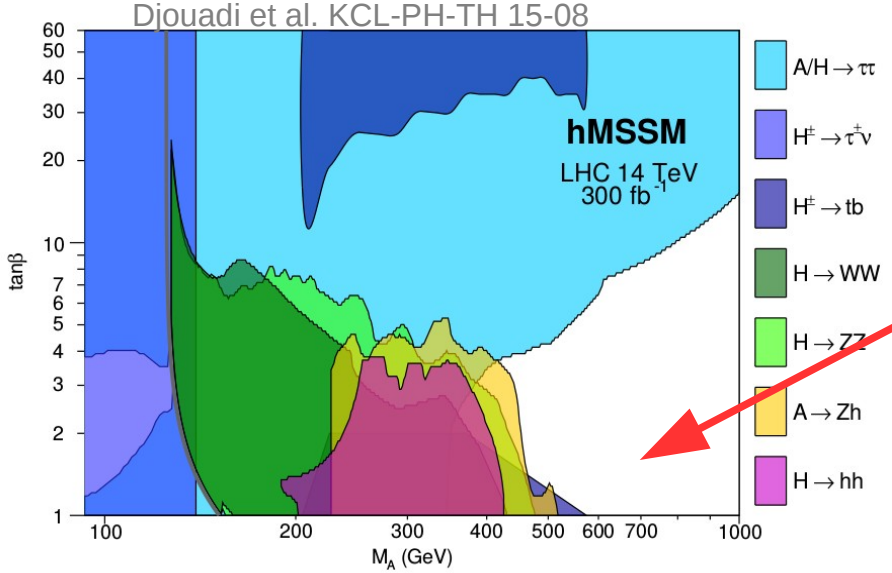
> Additional massive Higgs bosons predicted by many Standard Model extensions

- Supersymmetry (MSSM, hMSSM, ...)
- Dark matter models: axion models, ...

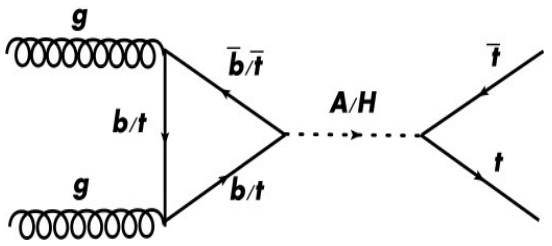
> **Two-Higgs-doublet models (2HDM)**

- **5 Higgs bosons**: including additional scalar H and pseudoscalar A Higgs boson
- Parameters of interest: m_A, m_H, tanβ (= ratio of the two vacuum expectation values)

Djouadi et al. KCL-PH-TH 15-08



Region with m_A>500 GeV and tanβ < 3 can only be probed directly by searches for $A/H \to t\bar{t}$



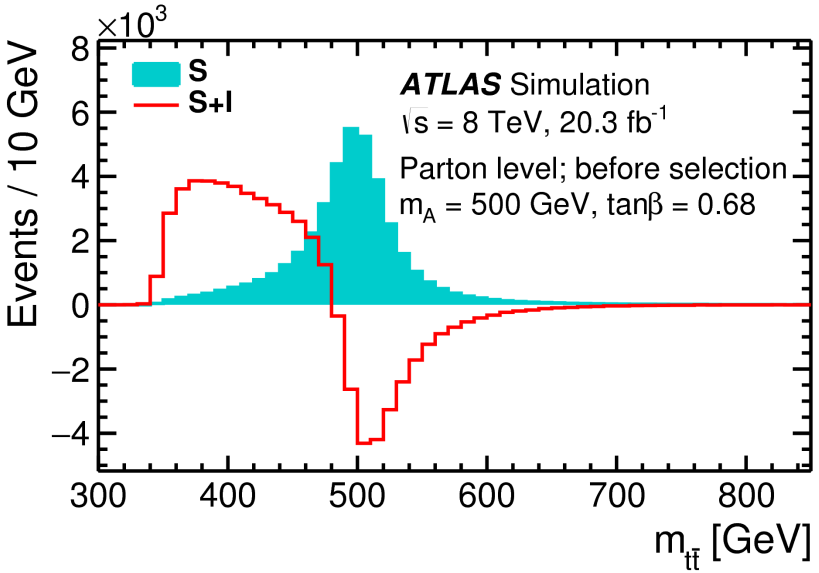
Search for heavy Higgs bosons decaying to top quarks

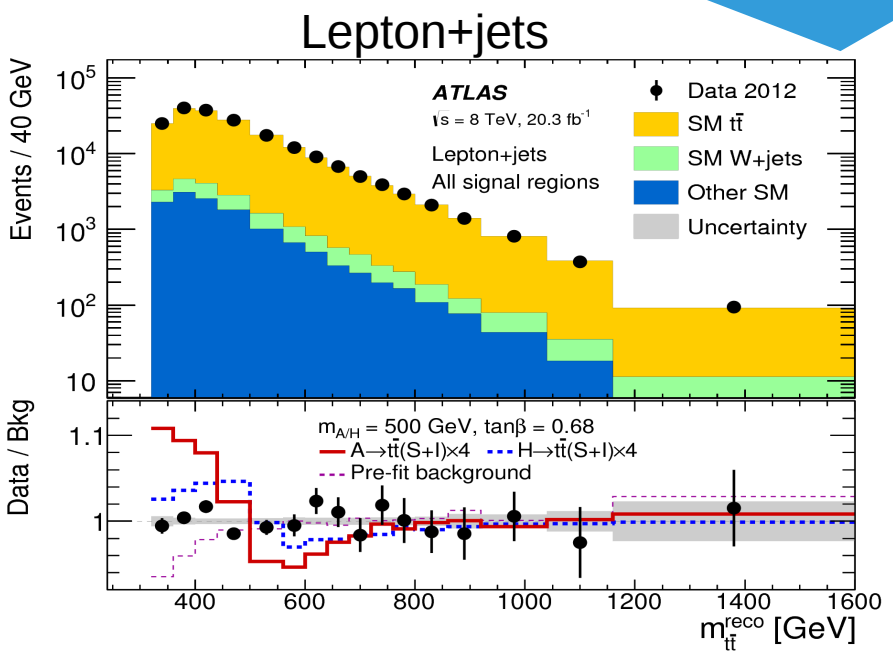
Including interference effects

[arxiv:1707.06025. Accepted by PRL]

- Strong interference between $gg \to A/H \to t\bar{t}$ and background from $gg \to t\bar{t}$
- Complex signal shape: peak-dip structure
- Reduced sensitivity in traditional "bump hunts" at the LHC (and Tevatron)
- **Challenges**: generating interference patterns, adapting statistical tools
- Search requires very well understood dataset
  - 2012 dataset: √s= 8 TeV, 20.3 fb^{-1}

DESY-only search





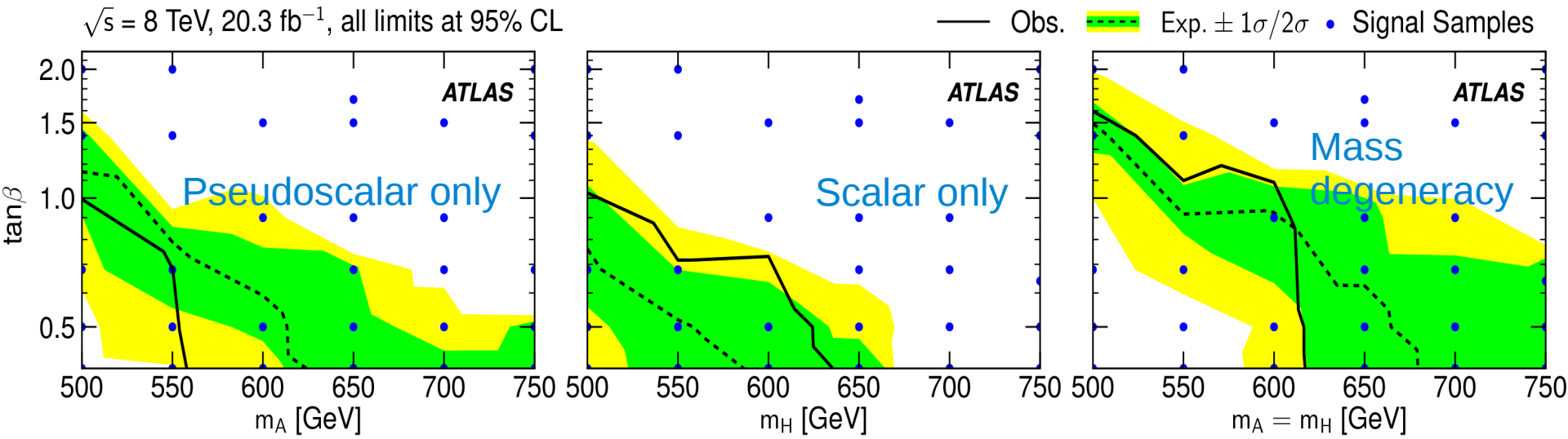
Search for heavy Higgs bosons decaying to top quarks

Including interference effects

[arxiv:1707.06025. Accepted by PRL]

- No significant deviation from Standard Model expectation
- Derive exclusion limits on type-II 2HDM
  - Alignment limit = lighter scalar *h* is SM Higgs boson

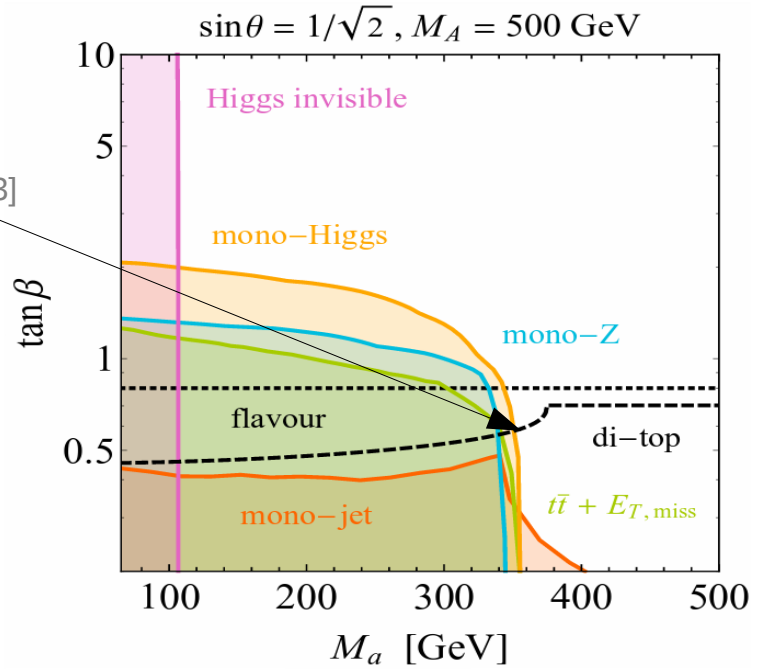
First direct limits in this parameter region!



Constraints on dark matter

- Many DM models involve an extended Higgs sector
- For example: **2HDM+pseudoscalar mediator**
  - M. Bauer, U. Haisch, F. Kahlhoefer (then in DESY Theory) [JHEP 1705 (2017) 138]
- New benchmark model for DM searches in both ATLAS and CMS
  - Little constraints from direct detection
  - Rich collider phenomenology

- Constraints from $A/H \rightarrow t\bar{t}$ [ATLAS-CONF-2016-073]
- Interesting for other DM searches conducted in the DESY ATLAS group
  - Invisible Higgs decays
  - Mono-Z
  - $t\bar{t} + E_T^{\mathrm{miss}}$

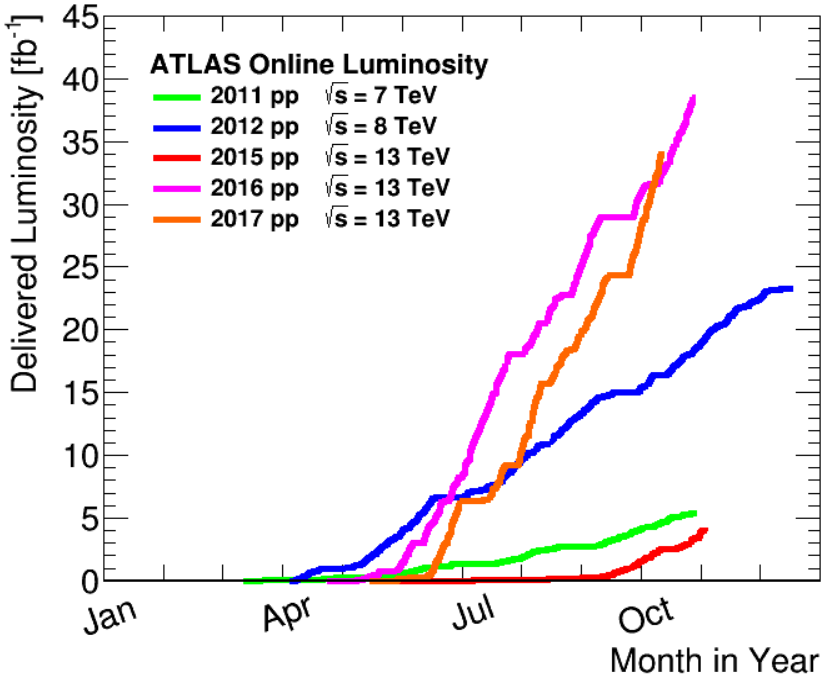


Stay tuned for future PRC meetings ...

Summary

- Productive half year for the DESY ATLAS group
- Continue to play major role in ITk strip upgrade
- Actively involved in detector operations and a variety of performance studies
- Published various searches and measurements, including (**but not limited to**)
  - Higgs cross-section measurements
  - BSM Higgs searches
  - ...
- Many more in progress/close to publication...

  ... and more data keeps coming in!



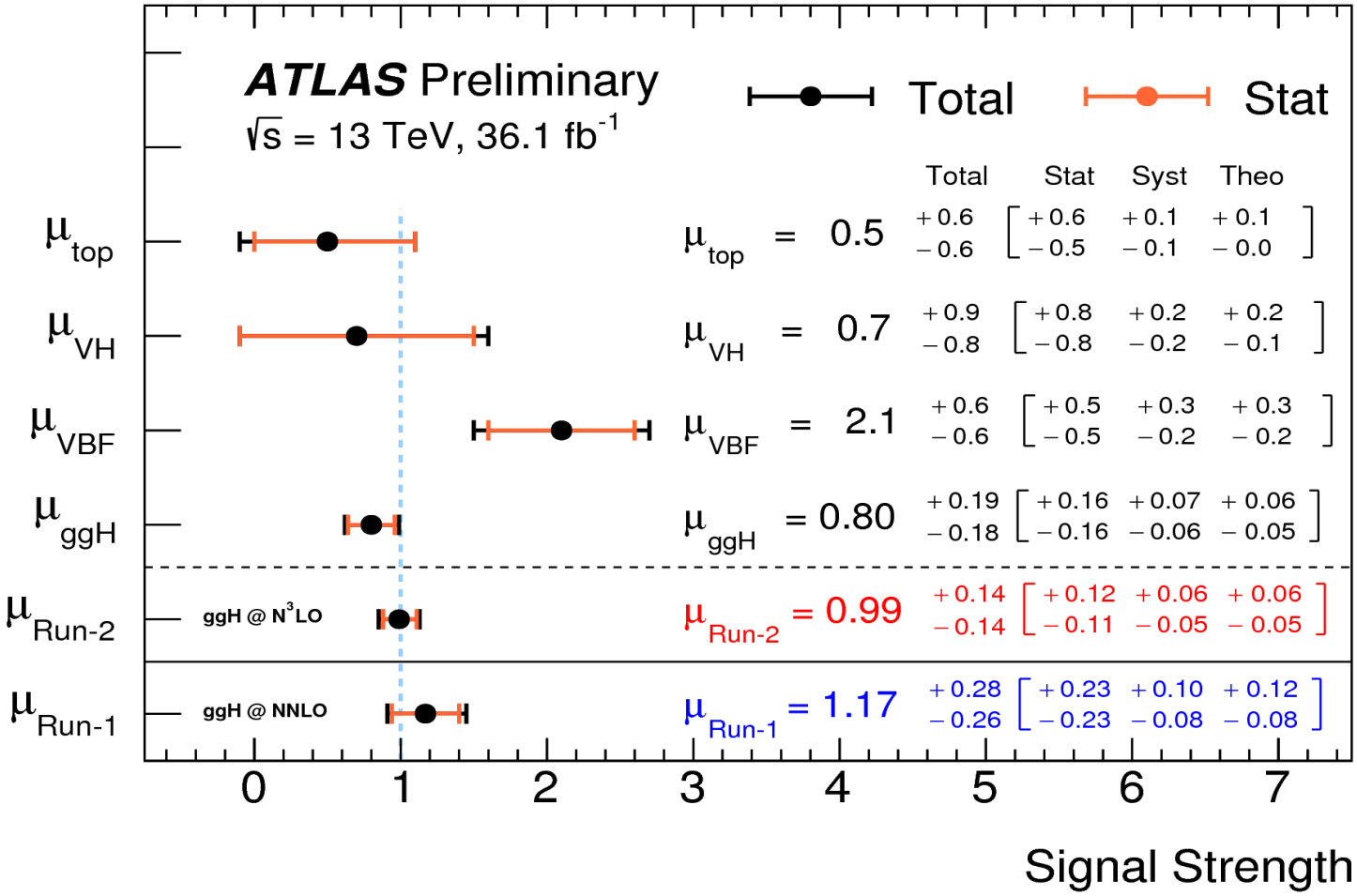
Additional Material

2-photon channel: signal strength measurement

Full 2015+2016 dataset: 36.1 fb-1,√s=13 TeV

[ATLAS-CONF-2017-045]

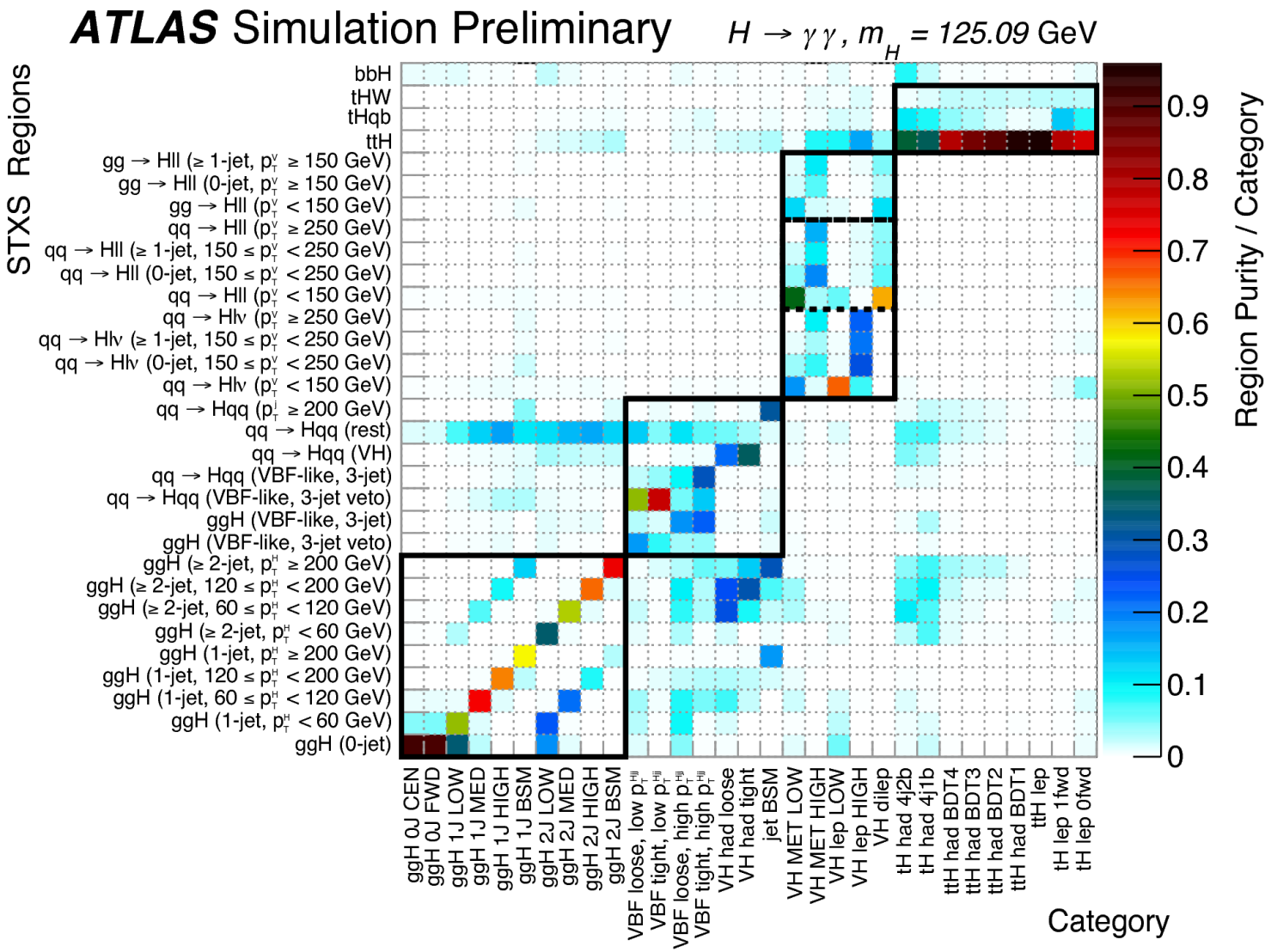
> Signal strengths $\mu_i = \sigma_i / \sigma_i^{\mathrm{SM}}$



2-photon channel: STXS

Full 2015+2016 dataset: 36.1 fb-1,√s=13 TeV

[ATLAS-CONF-2017-045]

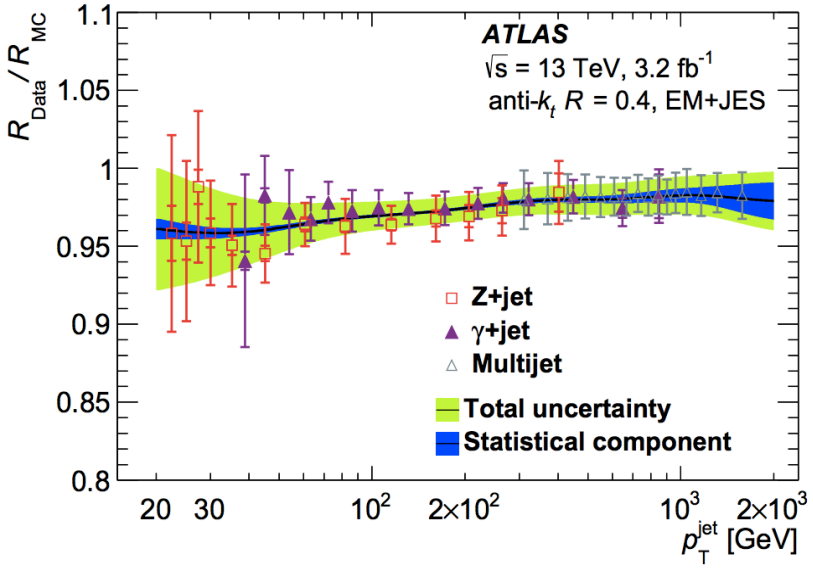


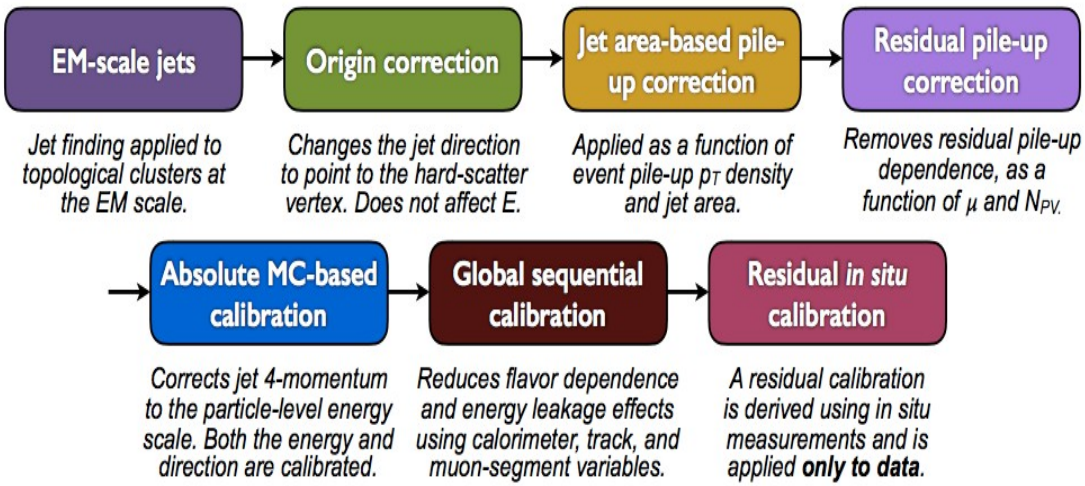
Jet energy scale and resolution

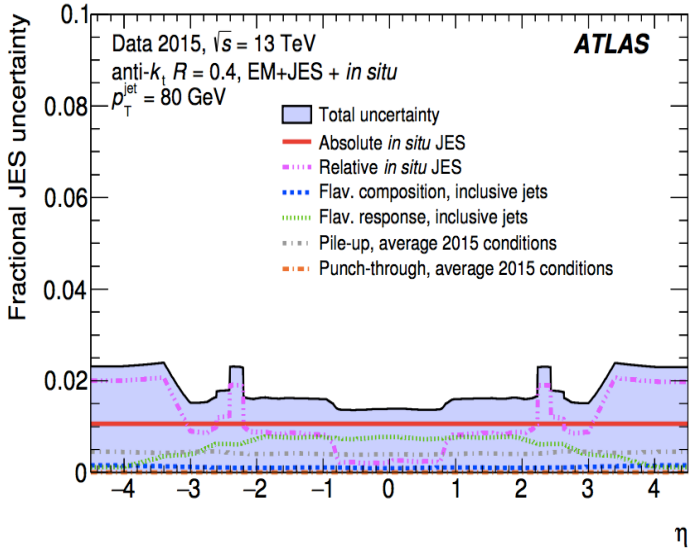
[arxiv:1703.09665] (accepted by PRD)

Input to all Run-2 analyses using jets

- DESY has a key role in the calibration of the jet energy scale (JES) and jet energy resolution (JER) and evaluation of the related uncertainties in √s = 13 TeV data.
- In particular: dijet η-intercalibration
  - Data-driven jet response calibration
  - Evaluation of uncertainty on Monte Carlo (MC) modelling of jets







Search for heavy Higgs bosons decaying to top quarks

Including interference effects

[arxiv:1707.06025. Accepted by PRL]

- No significant deviation from Standard Model expectation
- Derive exclusion limits on type-II 2HDM (alignment limit)
- Signal shape parameterised in terms of signal strength μ

$$\mu \cdot S + \sqrt{\mu} \cdot I + B = \sqrt{\mu} \cdot (S + I) + (\mu - \sqrt{\mu}) \cdot S + B$$

First direct limits in this parameter region!