LHC physics with ATLAS and CMS

A selection of highlights with significant DESY contributions

Helmholtz Program: Matter and the Universe (MU)

PoF III Topic: Fundamental Particles and Forces

DESY Research Unit: Experimental Particle Physics

Elisabetta Gallo
Center Evaluation DESY, 5 – 9 February 2018

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY

The DESY groups in ATLAS and CMS

DESY joined ATLAS and CMS late, in 2006

- Since then, the two groups have grown considerably
  FTE in 2016: ATLAS 32, CMS 39
- Groups now have high visibility and leading roles in detector operation, object reconstruction, physics analysis and upgrades.

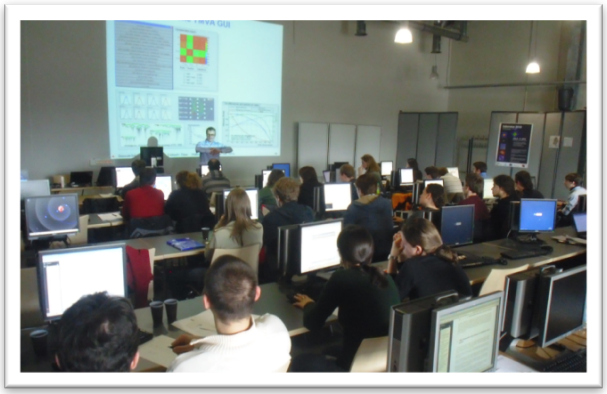
Many management positions covered by DESY scientists, e.g.

- Kerstin Borras: CMS deputy spokesperson
- Beate Heinemann: ATLAS deputy spokesperson
- Matthias Kasemann: CMS Collaboration Board Chair

Unique environment at DESY

- Close vicinity of ATLAS and CMS groups, close-by theory group.
- Flourishing academic life, “LHC physics discussions”
- Many national/international meetings held at DESY, Helmholtz schools.

LHC discussion



Terascale Alliance school

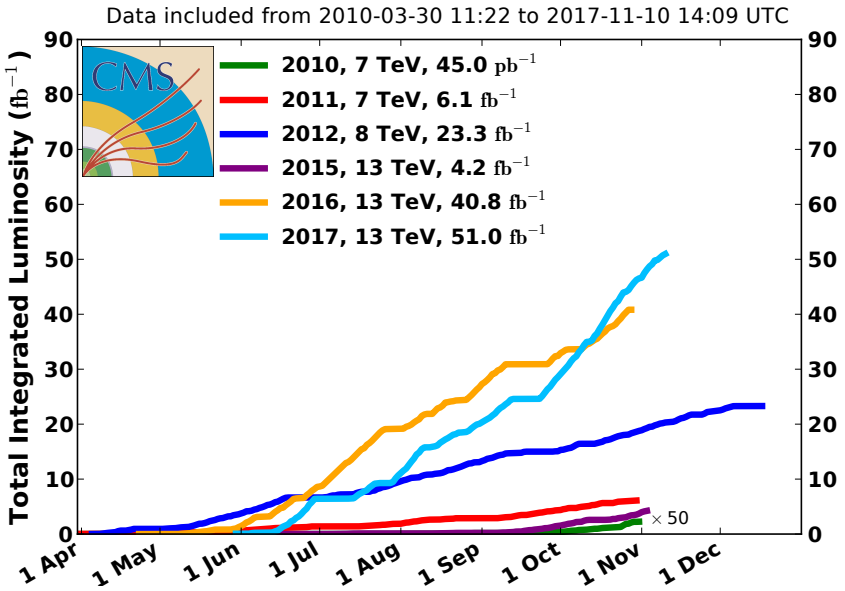
Physics at ATLAS and CMS

What drives us: understanding the major open questions in particle physics today

Physics analyses along two major themes in MU:

- Higgs and standard model precision physics
- Search for new physics and for dark matter candidates

Focus on few analysis topics to foster teamwork and to build expertise for certain channels.

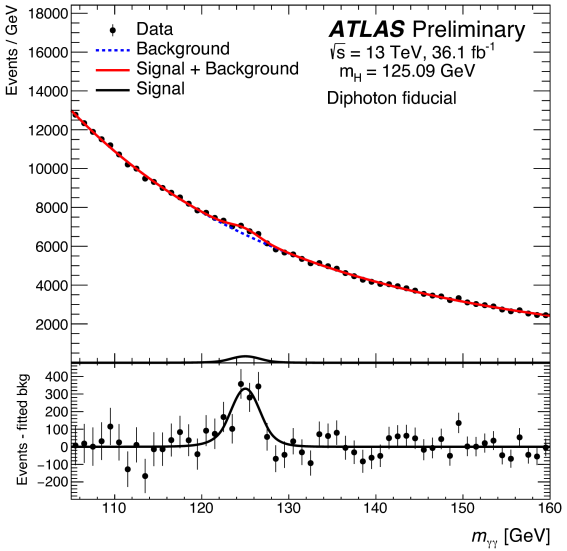


Exploiting the excellent performance of LHC

- Approximately 25 fb^{-1} at $\sqrt{s}$=7, 8 TeV (Run 1) and 90 fb^{-1} at $\sqrt{s}$=13 TeV (Run 2) accumulated per experiment.
- Move from Higgs discovery (DESY contribution!) in Run 1 to precision physics and BSM searches.
- Prominent contributions to physics object reconstruction in the harsh pp environment (pile-up).

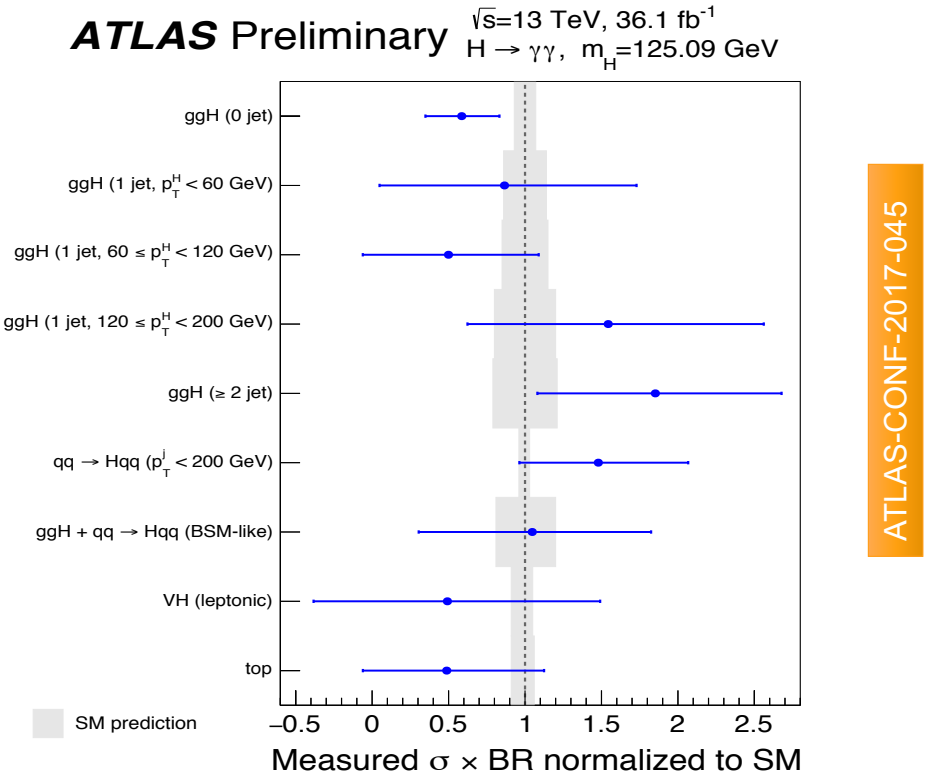
Higgs physics in ATLAS

Higgs in bosonic channels and ttH production



Kerstin Tackmann
YIG ATLAS,
ERC Grant

Sarah Heim,
YIG ATLAS



ATLAS-CONF-2017-045

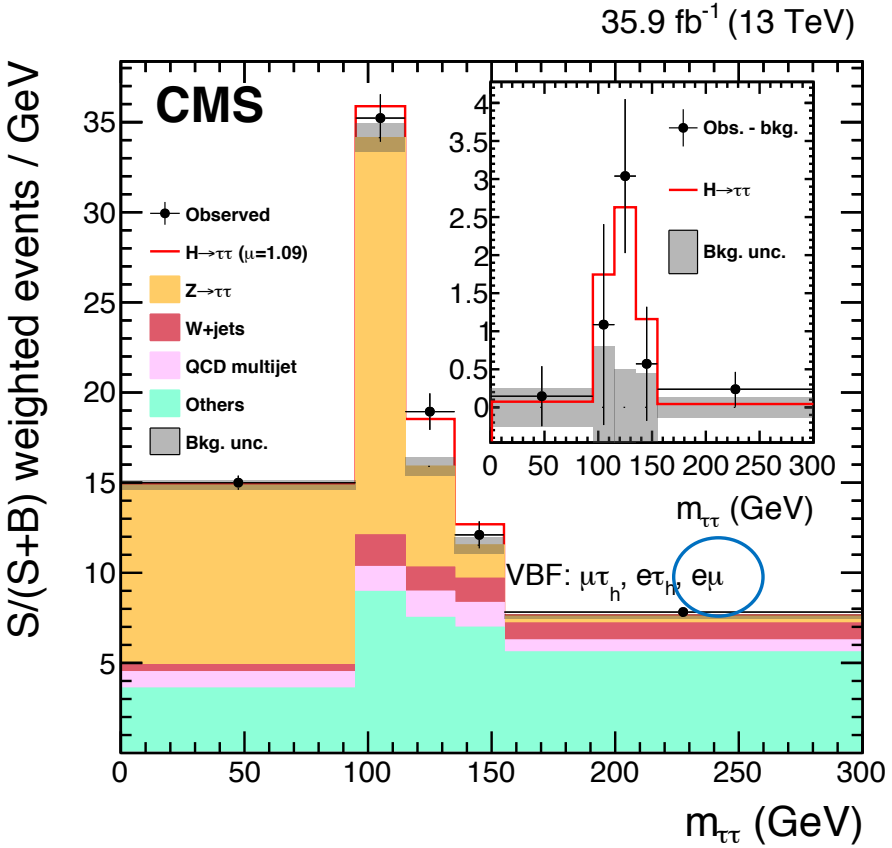
Higgs in γγ

- DESY **main player** in photon reconstruction, Run 1 discovery, precision measurements in Run 2
- **Pioneering** differential cross sections and simplified template cross section, in close collaboration with DESY theory

Higgs physics in CMS

Higgs in fermionic channels and ttH production

Alexei Raspereza
YIG, CMS



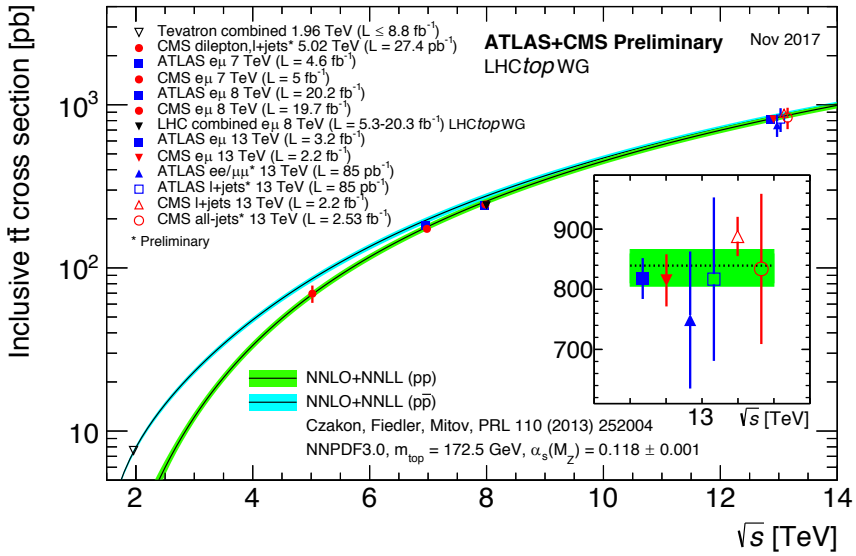
arXiv:1708.00373

Standard Model Higgs in ττ

- **Observation** of the Higgs decay into ττ with 2016 data, **another milestone** in the characterization of the Higgs boson.
- DESY group **one of the driving forces** since Run 1, contributing with the leptonic tau decays and many tools.

Top physics

Cross sections and properties

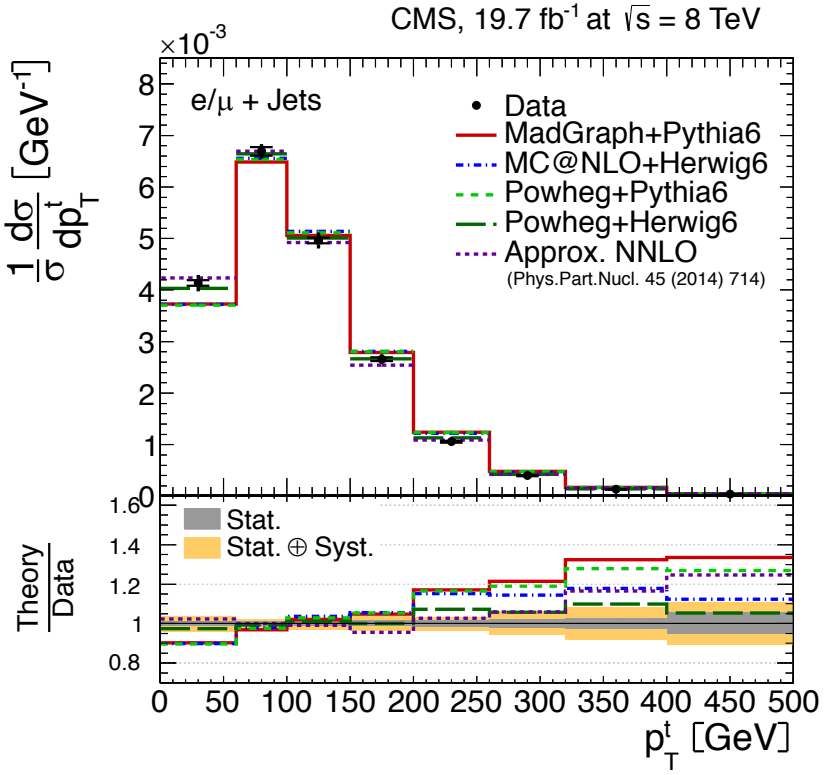


Top cross sections

- DESY **continous and coherent** engagement at all center-of-mass energies
- **Pioneering** differential cross section, i.e. study of top p_T, lively discussion with theory.

Yvonne Peters
YIG, ATLAS

Maria Aldaya
YIG, CMS



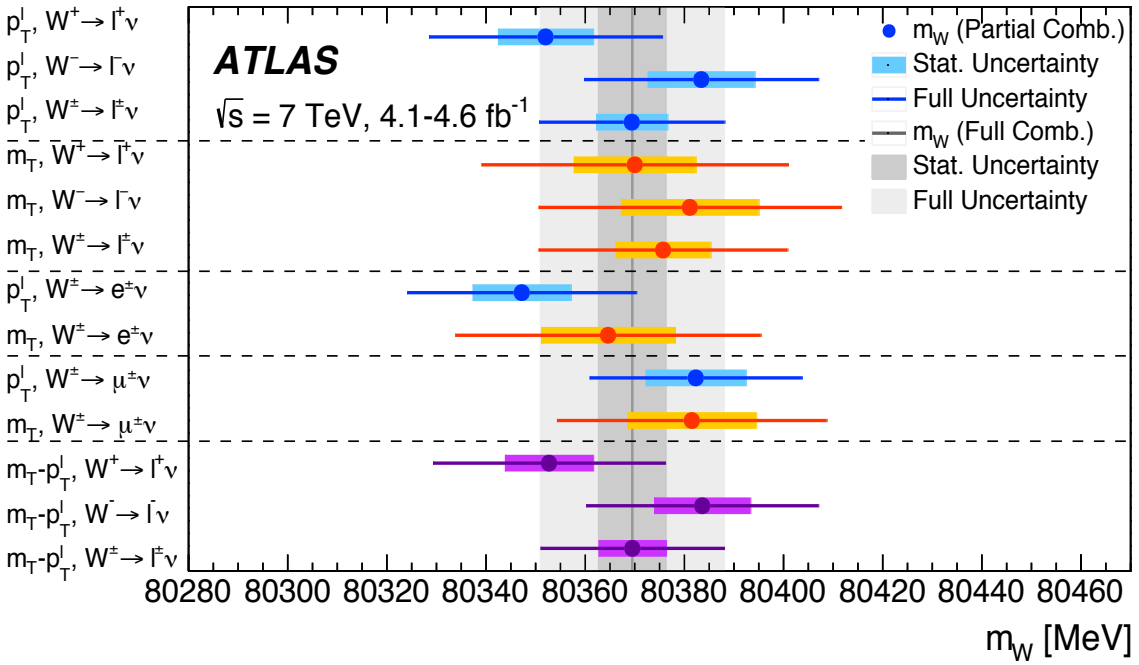
EPJC 75 (2015) 542

Standard Model physics

W mass, proton parton densities, jets, vector boson production, light-by-light scattering

Measurement of the W mass at ATLAS

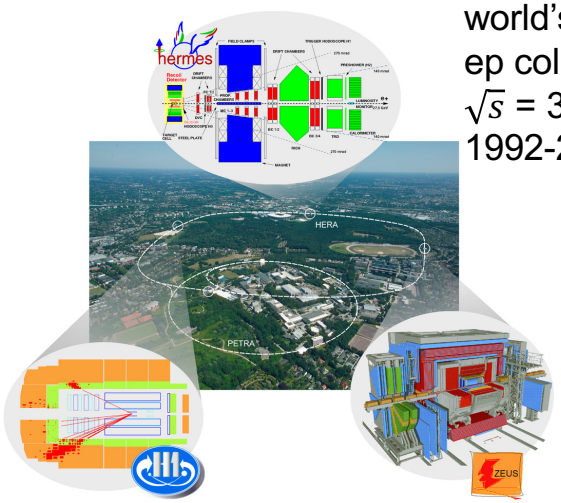
- **m_W = 80370 ± 19 MeV,** similar precision to CDF or D0 alone.
- **Essential contribution** from DESY on Monte Carlo modeling, combination for the final result.
- Expertise on proton parton densities extraction, **building on the HERA heritage.**



arXiv:1701.07240

HERA data analysis

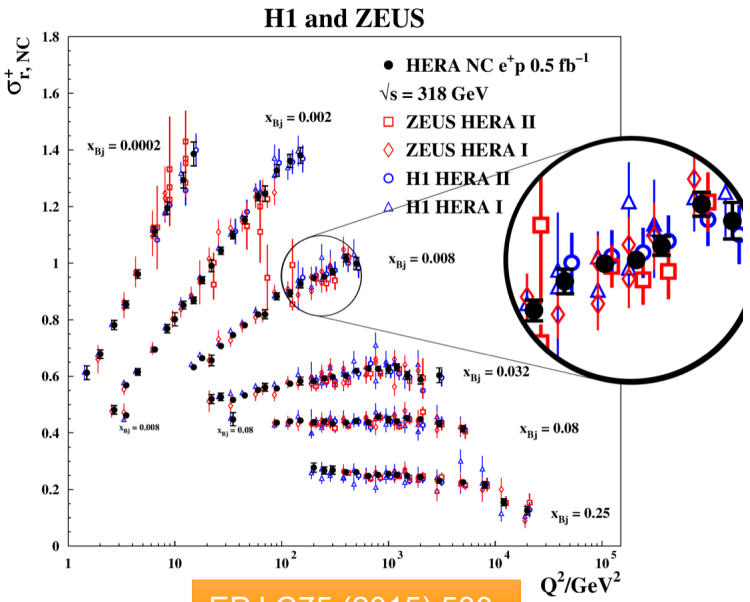
The HERA heritage: 550 publications from H1, ZEUS, HERMES in 1992-2017, and still ongoing



world's only ep collider
$\sqrt{s}$ = 320 GeV
1992-2007

HERA data are preserved for analysis and long-term storage.

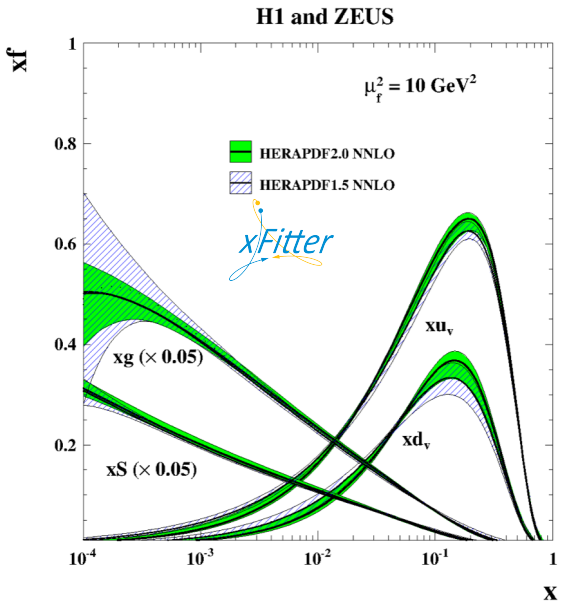
100-250 authors per publication, e.g. for ZEUS: Bonn, DESY, Glasgow, Hamburg, Heidelberg, KEK, MPI Munich, Oxford, Padova, Temple, UCL, Warsaw, …



EPJ C75 (2015) 580

Final result on inclusive DIS from combination of H1 and ZEUS data, with a precision of ~ 1% for many data points.

~200 citations in only 2.5 years. Data used as backbone by all PDF fitting groups.



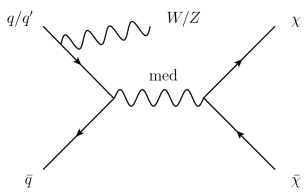
xFitter open-source tool: originally developed for HERA PDF analyses.

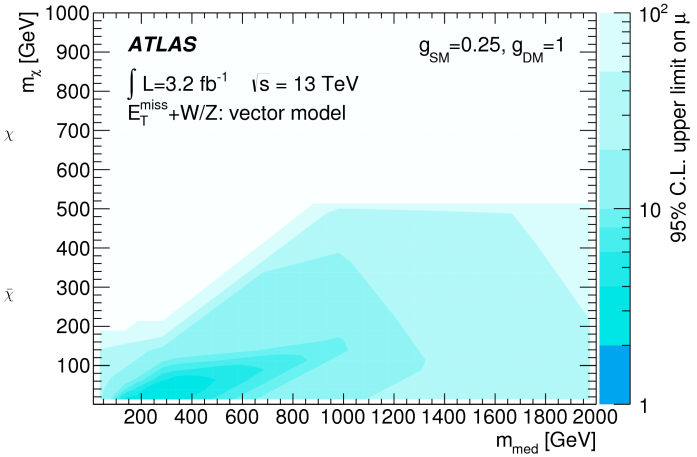
Used by many groups (e.g. ATLAS, CMS) to study impact of their data on PDFs.

Searches for physics beyond the SM

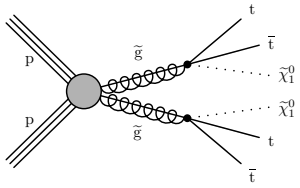
Dark matter, Supersymmetry, diboson and top resonances

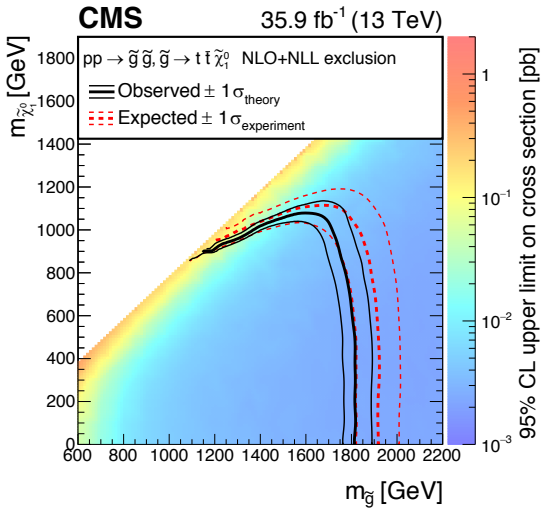
Isabell Melzer-Pellmann
YIG, CMS





PLB 763 (016) 251





arXiv:1709.09814

Search for dark matter in association with W/Z

- One of the **key search** channels for DM production at the LHC, exclusion limits interpreted in simplified models, **close collaboration with DESY theorists**

Search for gluinos

- Stringent constraints on natural SUSY models, m(gluino)>1.8 TeV, m(neutralino)> 1.1 TeV, analysis **conducted by** DESY.

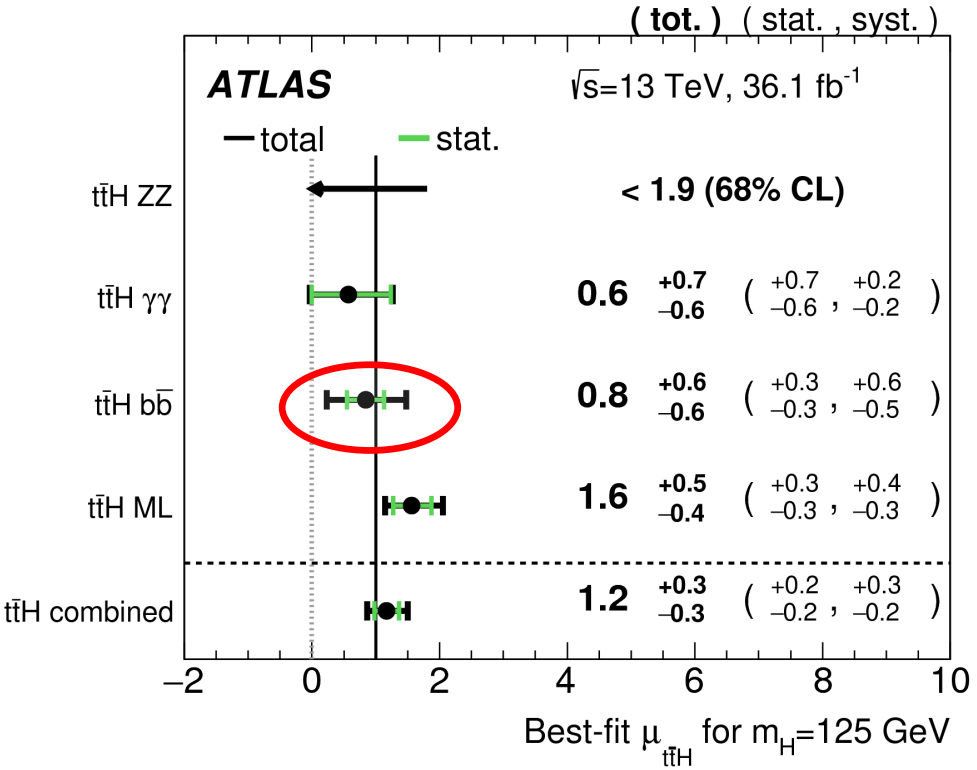
Outlook

Plan for the next years

The DESY ATLAS and CMS groups have made strong and highly visible contributions to LHC physics.

We will continue the pursuit along three main themes:

- **Higgs and SM precision physics:** Precision coupling measurements and differential distributions.
- **Searches for BSM physics:** Concentrate on channels where we can make the difference.
- **Searches for Dark Matter candidates**: New ideas in collaboration with DESY theory, new techniques.



Evidence with ttH production with ATLAS 2016 data arXiv:1712.08891

Conclusions

- The DESY groups have acquired a **high impact** in the Collaborations, impact now larger than commensurate to size.
- **Vicinity** of ATLAS and CMS and close-by theory group have brought to novel and original ideas to the field.
- We are **a hub for the German** ATLAS and CMS communities.
- Only some physics **highlights** shown here: 49 PhD theses (ATLAS 20, CMS 29) in 2013-2017.
- 3% of the full LHC/HL-LHC data accumulated so far: prepare to **fully exploit** the wealth of LHC data – get the full “return on investment” of our upgrade efforts – see next presentation by Ingrid Gregor.