# LHC Status and Physics Update

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*Lancaster University, 14 September 2017*

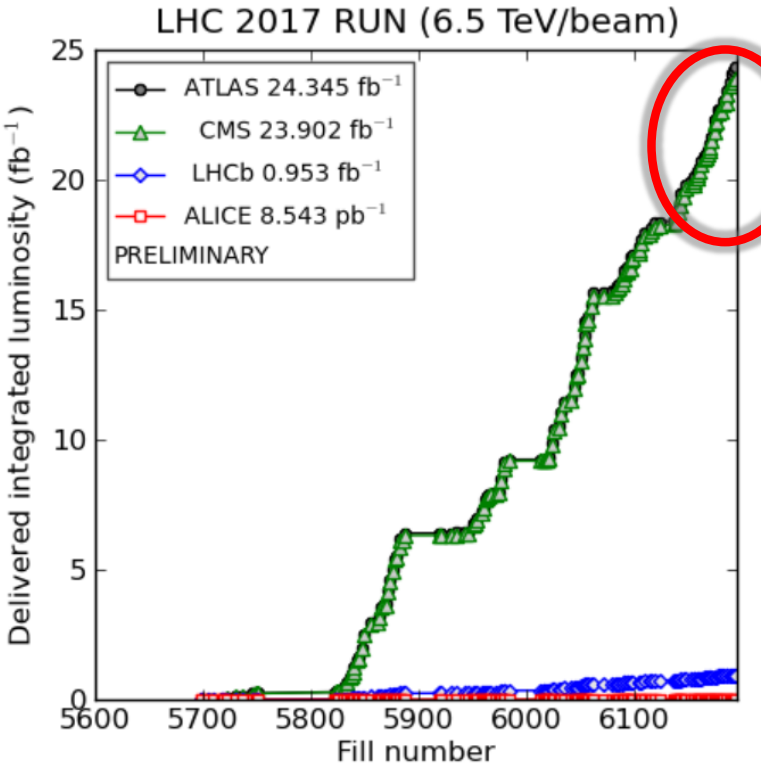
GridPP39

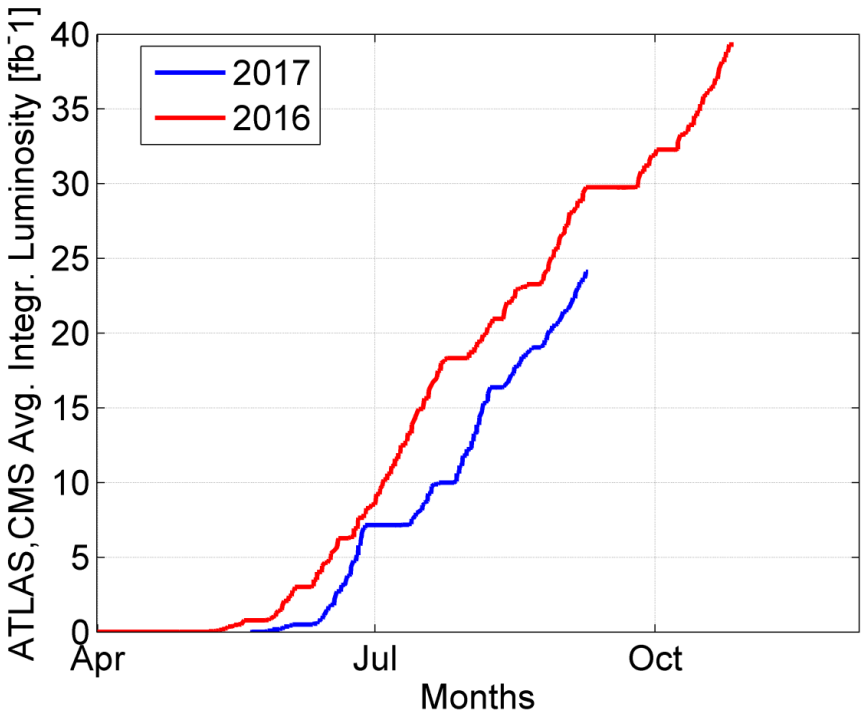
# Overview

- LHC Accelerator Update
- I will present details on recent analyses from LHC experiments (highlighting some Lancaster results and a bias towards ATLAS).
  - Higgs Production Cross Section
  - ATLAS Higgs Mass
  - ATLAS & CMS: Higgs → $b\bar{b}$
  - CMS: Higgs → ττ
  - ATLAS Resonance Searches & Dark Matter
  - LHCb: $\Xi_{cc}^{++}$
  - LHCb: $B_s$ → eμ
  - Alice: Hypertriton Lifetime
- Summary

# Accelerator Status

- Currently ~25 $fb^{-1}$ delivered to ATLAS and CMS.
- So far it has been a difficult year for LHC
  - Many beam dumps due to issues with “16L2” group of magnets - cause unknown - has been limiting luminosity
  - Some progress, but still an ongoing problem.



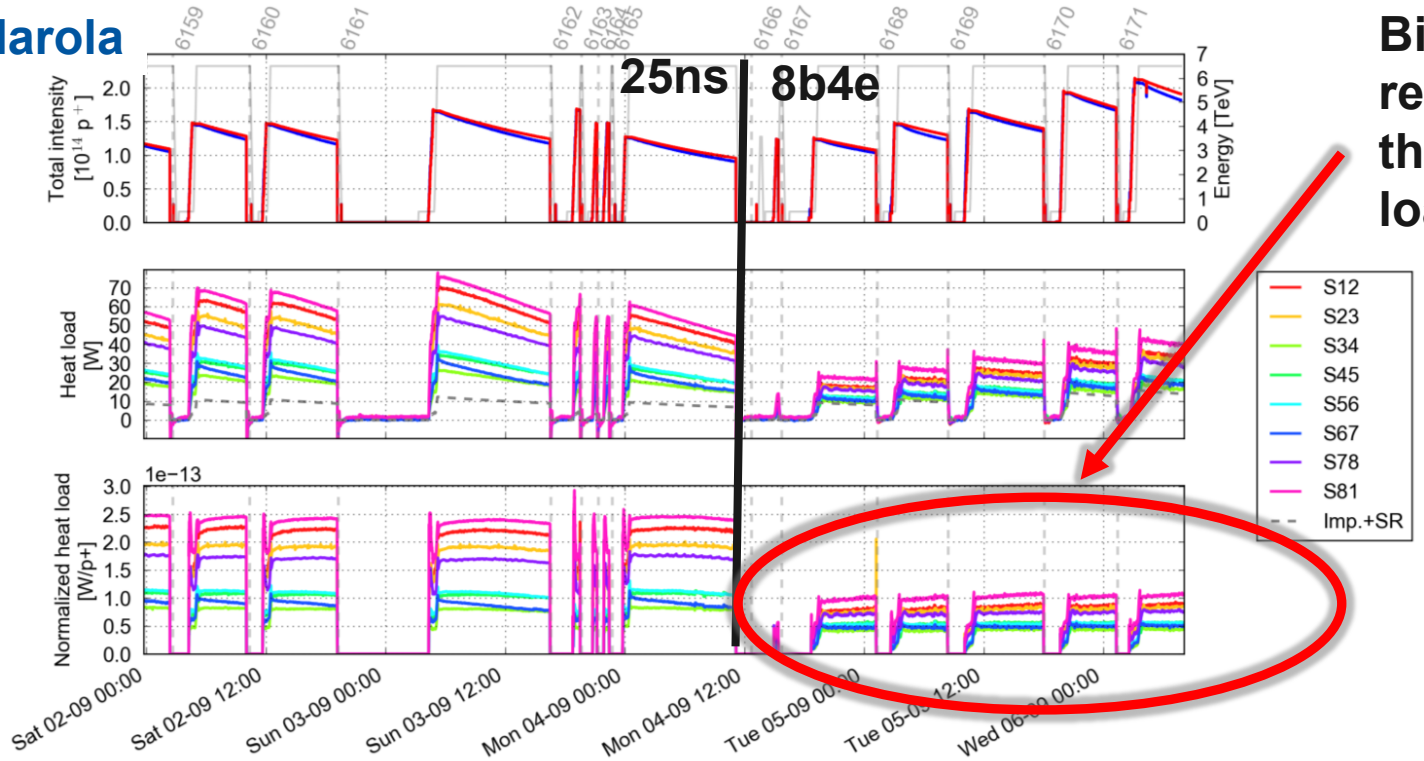



# Main operation limitations: Losses@16L2

- 8b4e: reduced e-cloud (induced heat-load)
  - Fast intensity ramp-up to 1916b without any dump with average intensities 1.1x10$^{11}$ p/b
  - **However could not increase intensity more than 1.2x10$^{11}$ p/b**

- Study is ongoing with additional diagnostics in the cell

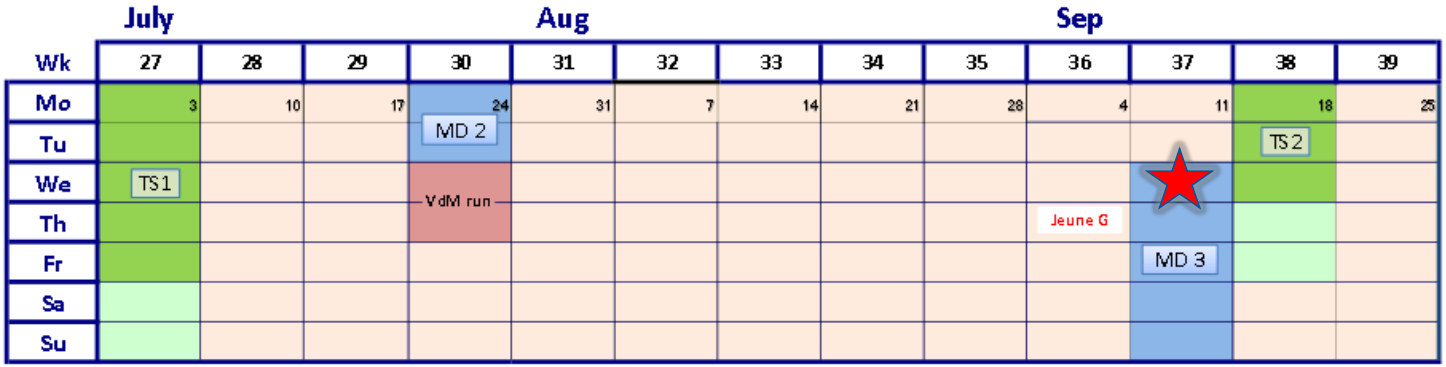
**G. Iadarola**



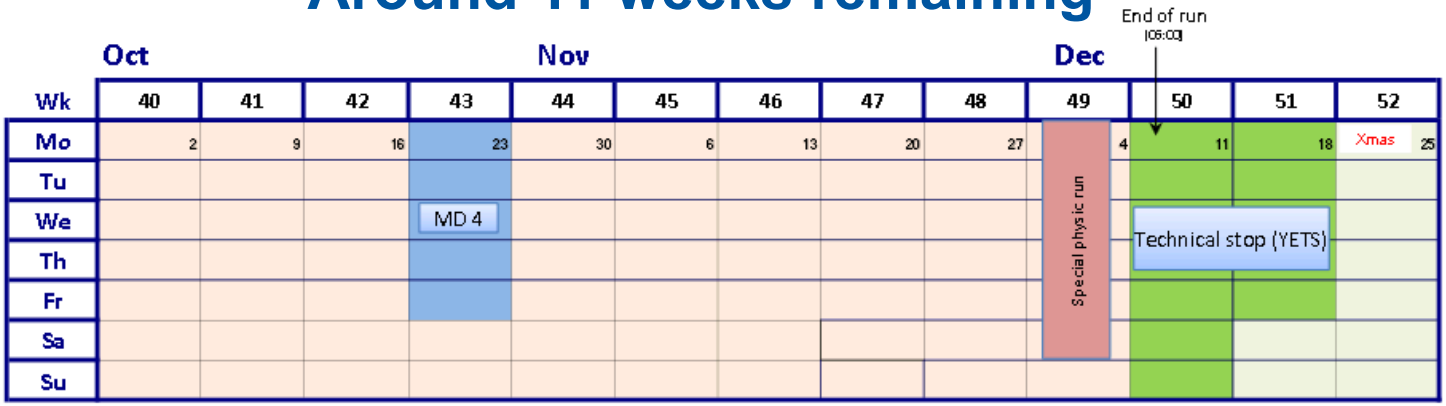

**Big reduction in the heat load**

# Accelerator Status

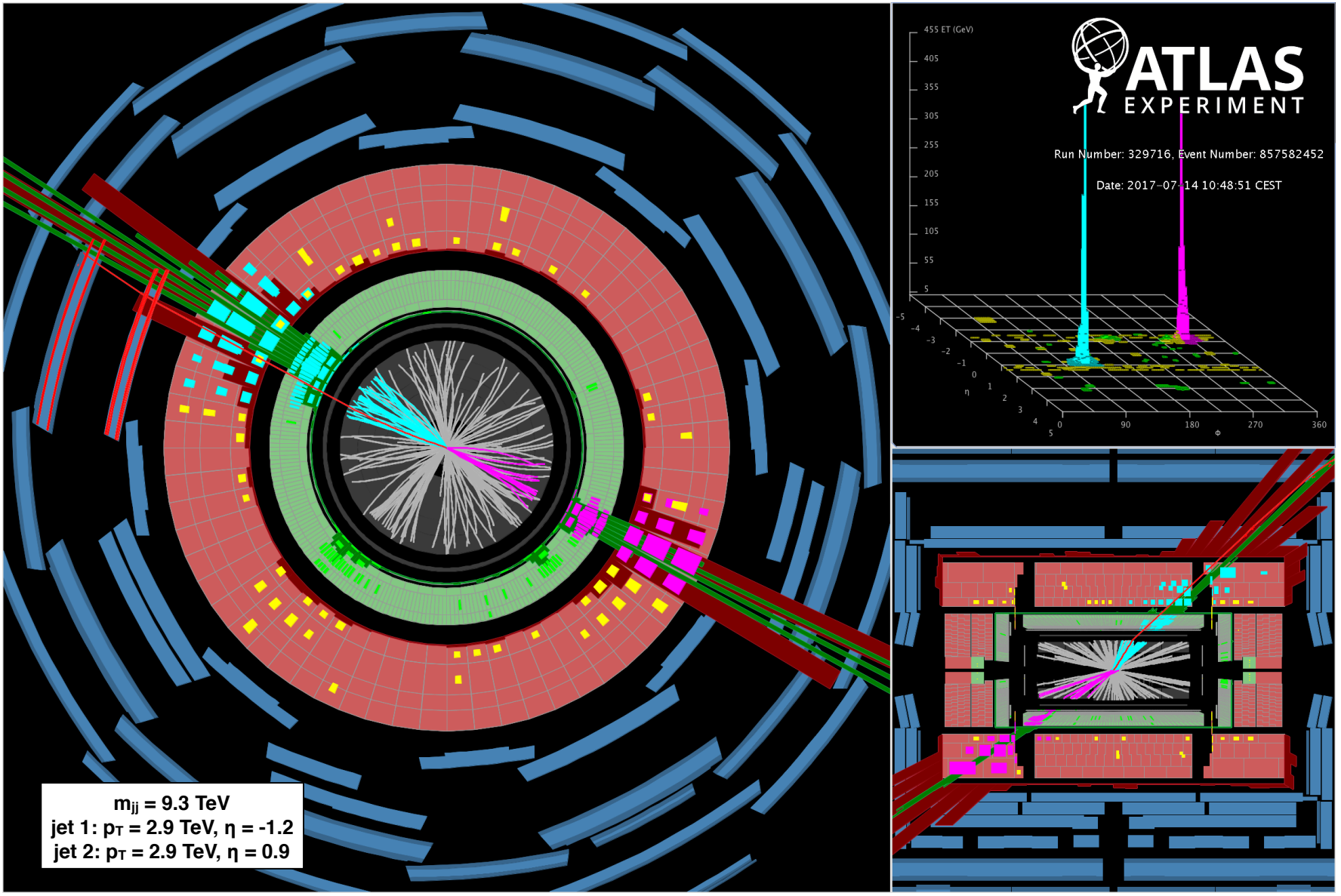
- Target integrated luminosity of 45 $fb^{-1}$ is still achievable.
  - Preparation of special physics runs are ongoing
  - High β* at 450 GeV and 2.51 TeV runs
  - No special runs in 2018 — significant luminosity production to satisfy the Run-2 targets (90 $fb^{-1}$)




## Around 11 weeks remaining



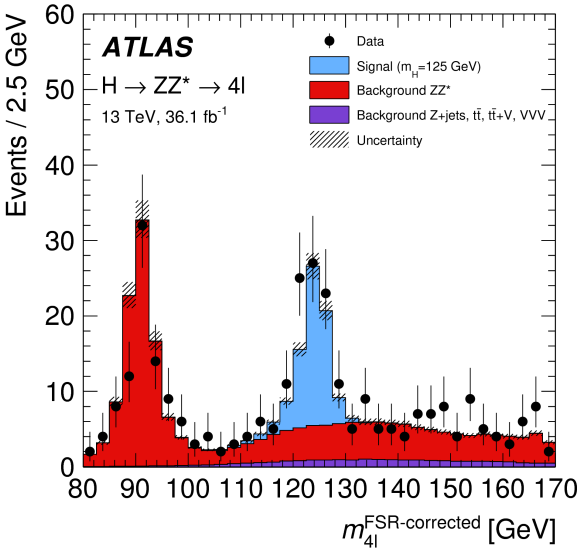
# Di-jet Event with $m_{jj}$=9.3 TeV

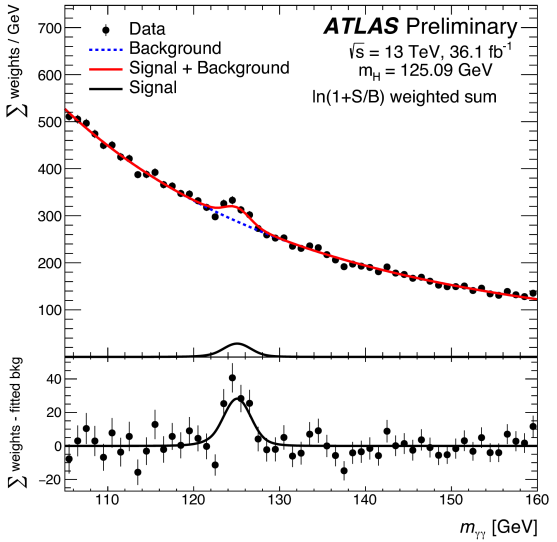


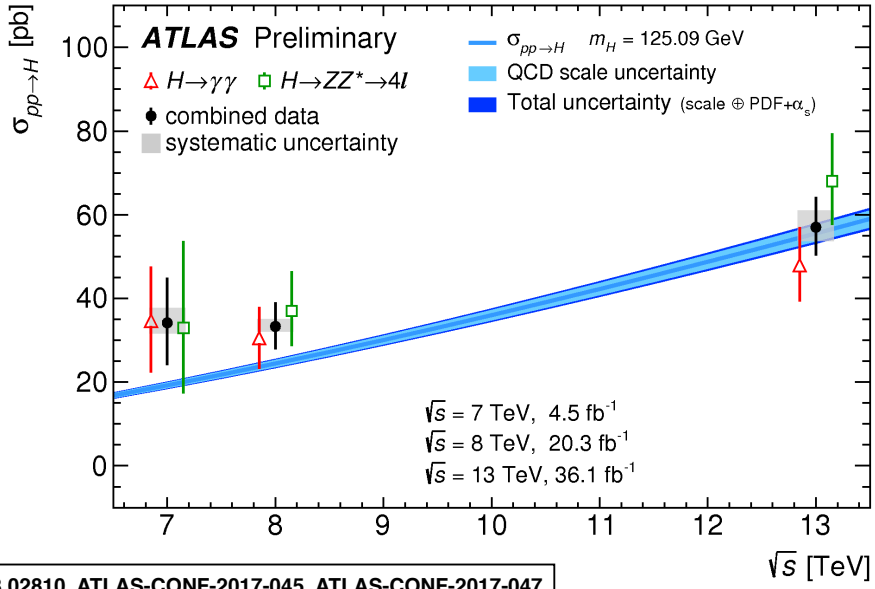
# Higgs Boson Production

- New results in the $H \to ZZ^* \to 4\ell$ and $H \to \gamma\gamma$ channels.
  - Combined measurements of fiducial and total production cross sections (assuming SM branching ratios).
- Combined global signal strength compatible with the Standard Model:

$$\mu = 1.09 \pm 0.12$$
$$= 1.09 \pm 0.09\,(\text{stat.})\,^{+0.06}_{-0.05}\,(\text{exp.})\,^{+0.06}_{-0.05}\,(\text{th.}).$$



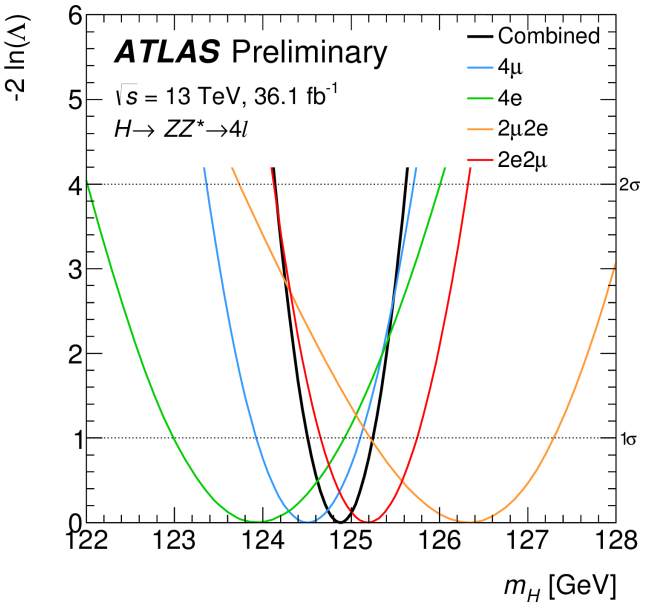



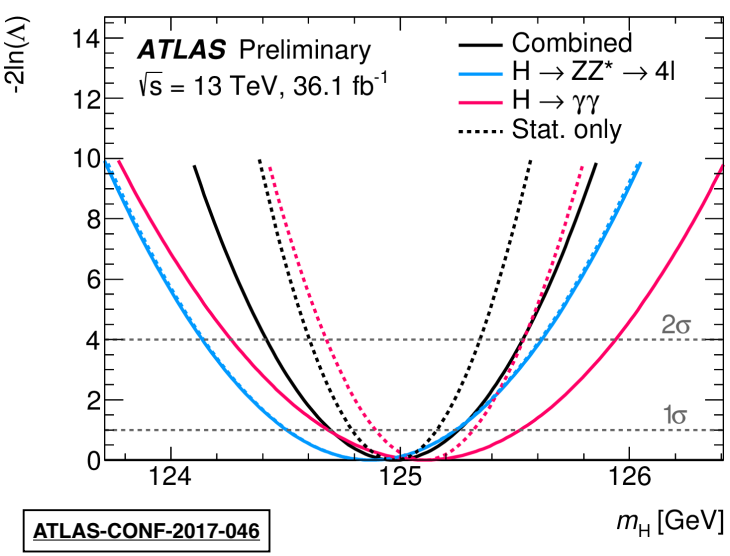




arxiv:1708.02810, ATLAS-CONF-2017-045, ATLAS-CONF-2017-047

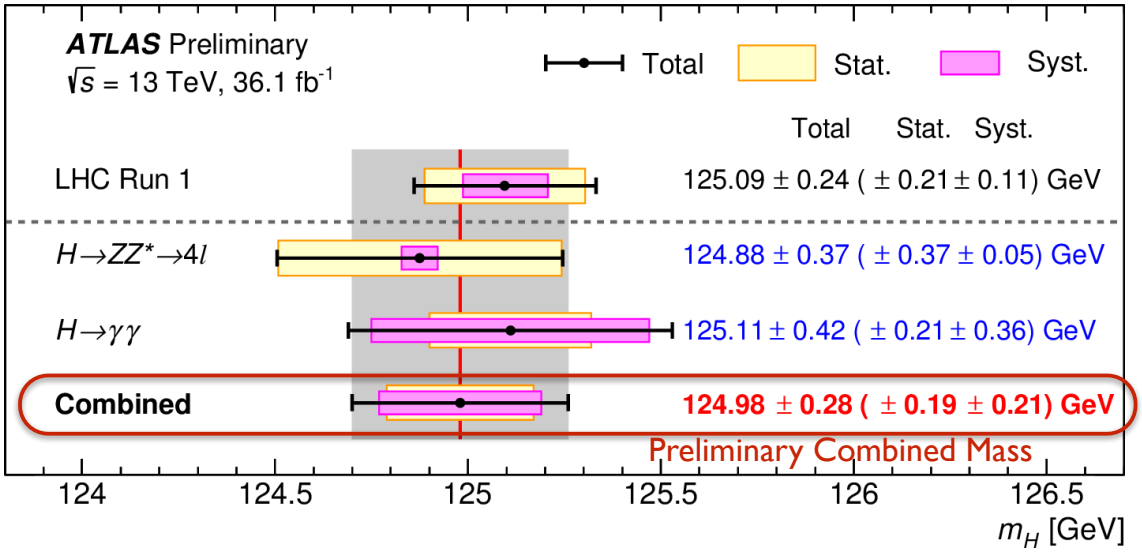
# Higgs Boson Mass

- Higgs boson mass measurements in the $H \to ZZ^* \to 4\ell$ and $H \to \gamma\gamma$ channels complementary:
  - $4\ell$ channel the stat uncertainty dominates.
  - $\gamma\gamma$ channel dominated by syst uncertainties (most notably the $\gamma$ energy scale calibration).
- Measurements consistent between sub-channels, and consistent with the Run 1 combined result.



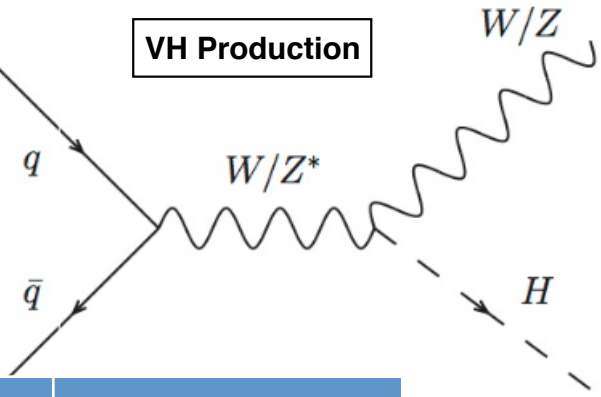




ATLAS-CONF-2017-046

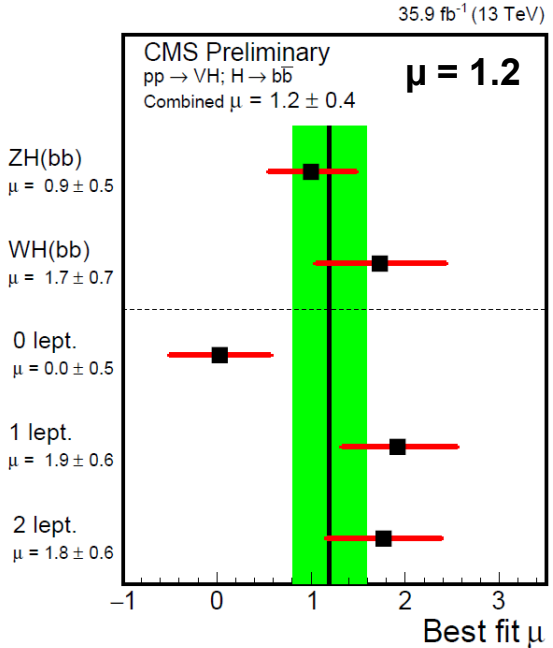


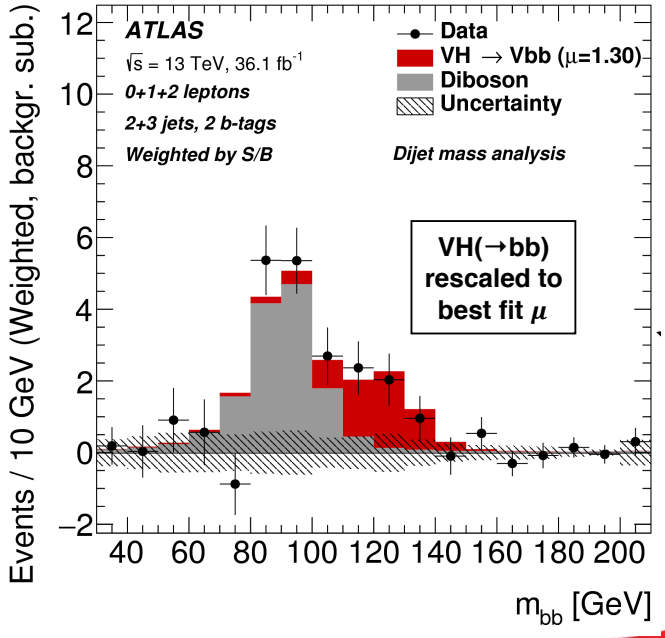
# $H \to b\bar{b}$

- Most sensitive channel to look for the decay H→bb is associated production,VH (V=W/Z) with H→bb.
  - Largest Higgs branching ratio BR(H→bb) ≈ 58%
  - with Z→ee, μμ, $\nu\nu$ and W→e$\nu$, μ$\nu$
- CMS and ATLAS both use BDT to separate signal from background




| | Expected Significance | Measured Significance | Signal Strength |
|---|---|---|---|
| ATLAS | 4.0σ | 3.6σ | $0.90^{+0.28}_{-0.26}$ |
| CMS | 3.8σ | 3.8σ | $1.06^{+0.31}_{-0.29}$ |



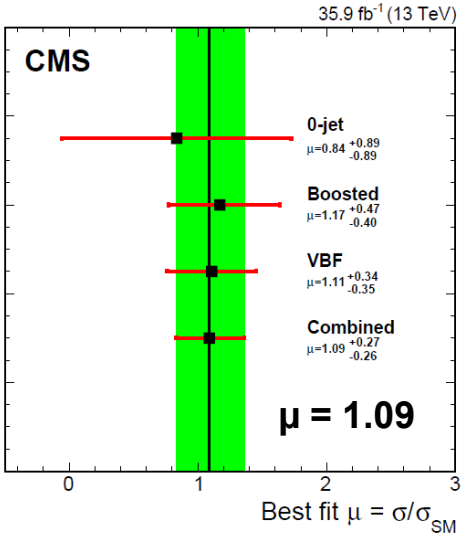
# Observation of $H \to \tau^+\tau^-$

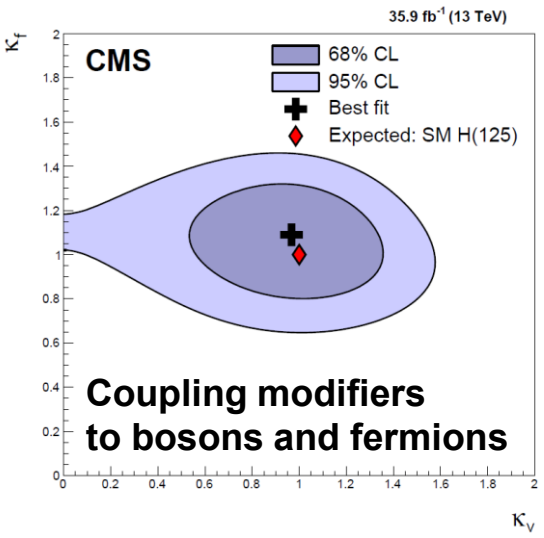
- Branching ratio (BR) = 6.3%, best channel to establish coupling of Higgs boson to fermions
- 12 categories: VBF, 0-jet (~gluon fusion), boosted (~others), for each $\tau_h\tau_h$, $e\tau_h$, $\mu\tau_h$, $e\mu$
- Signal extraction from max. likelihood fits to 2D distributions in signal & control regions
- Significance of 4.9$\sigma$ observed (4.7$\sigma$ expected) using 13TeV data
- **Combination with 7 & 8 TeV data: 5.9$\sigma$ obs. (5.9$\sigma$ exp.) and μ = 0.98 $\pm$ 0.18**

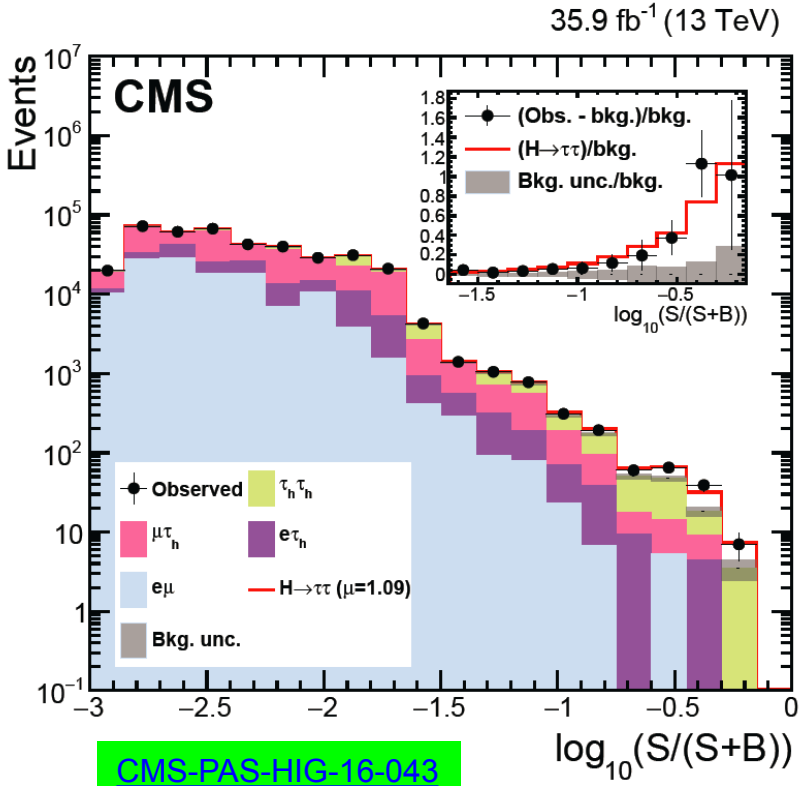
**First direct observation by a single experiment of coupling of H to fermions**

– Observed before in CMS+ATLAS combination

**First direct observation of H coupling to leptons and to fermions of the 3rd generation**



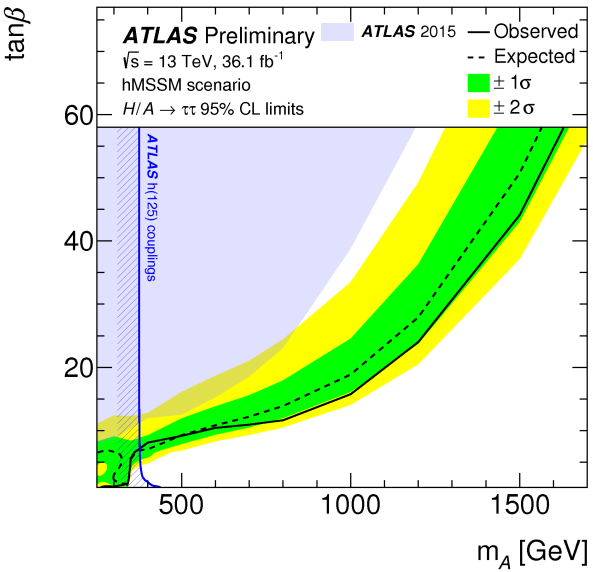



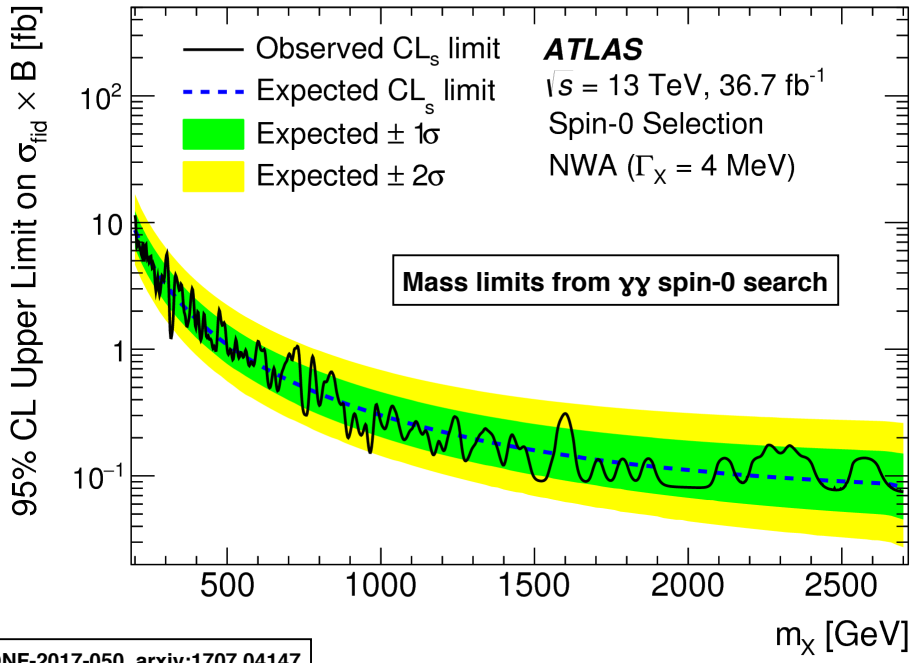



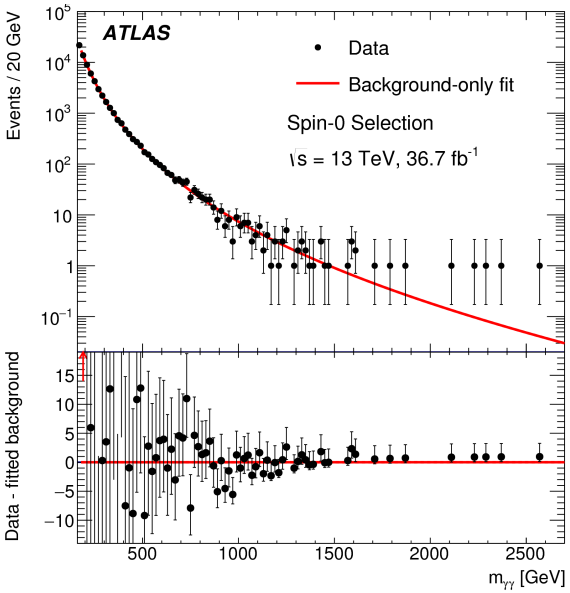

CMS-PAS-HIG-16-043

# Resonance Searches ($\gamma\gamma$, $\tau\tau$)

- Diphoton and ditau searches sensitive to new heavy scalars, e.g. Higgs bosons.
  - $\gamma\gamma$ search also targets spin-2 (graviton) production with a dedicated selection.
  - $\tau\tau$ searches sensitive to SUSY Higgs (H/A).
- No significant excess over the SM expectation.



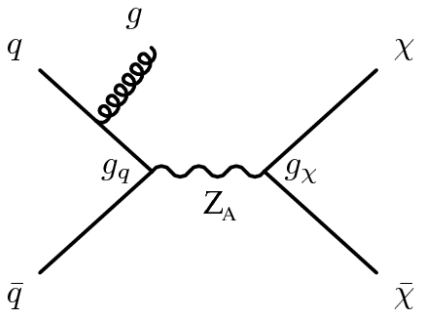



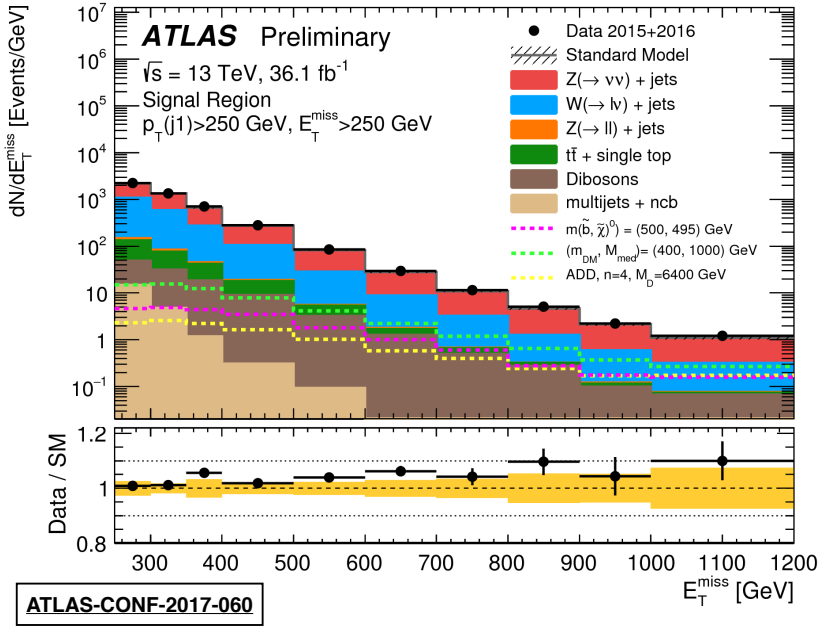

ATLAS-CONF-2017-050, arxiv:1707.04147

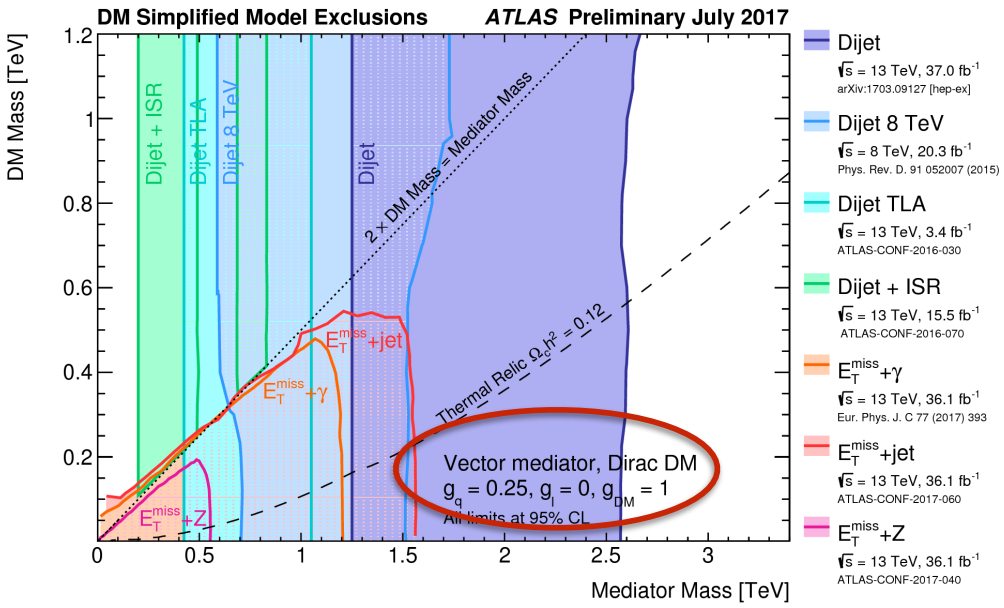
# Searches for Dark Matter

Jonas Strandberg

- Generic dark matter models tested with searches for mono-jet/γ/Z/H(→γγ/bb)+$E_T^{miss}$, with recoil against invisible dark matter particle(s).
  - Complementary to direct dark matter searches, and direct searches for the mediator decaying to e.g. a pair of jets.
- Phenomenology depends on mass of DM, mass of heavy mediator and value and type of couplings.
- No significant excesses over the SM predictions.



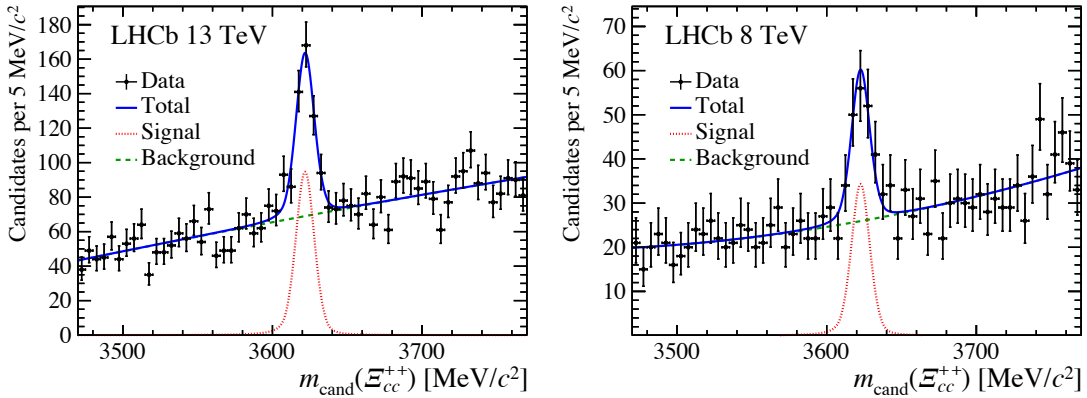



# Observation of $\Xi_{cc}^{++}$

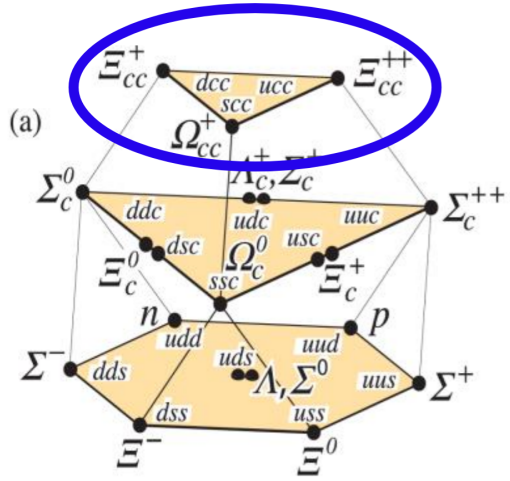
LHCb-PAPER-2017-018

- Doubly charmed baryons predicted by quark model
- Observation of $\Xi_{cc}^{+}$ claimed by SELEX [Phys. Lett. B 628 (2005) 18-24]
- No evidence observed by BaBar, FOCUS, Belle and LHCb
- Search in LHCb for $\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^-$
- Data sample: 2.0 (8 TeV) + 2.0 (13 TeV) fb$^{-1}$




- Highly significant peak: 7.6 $\sigma$ (2012), 12.9 $\sigma$ (2016)
- Combined yield: 426 $\pm$ 39
- The mass is measured with the 2016 sample

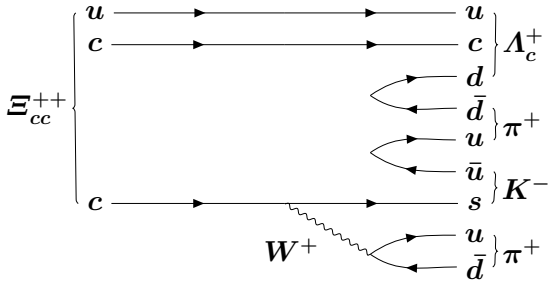
$$m(\Xi_{cc}^{++}) = 3621 \pm 0.72\ (\text{stat}) \pm 0.31\ (\text{syst})\ \text{MeV}/c^2$$




Lattice QCD calculations

$m(\Xi_{cc}^{++}) = 3606 \pm 11 \pm 8\ \text{MeV}/c^2$

[arXiv: 1704.02647]



# Search for the decays $B^0_{(s)} \to e^{\pm}\mu^{\mp}$ NEW

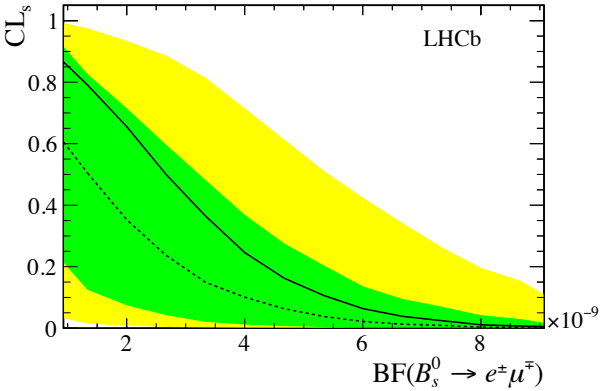
LHCb-PAPER-2017-031

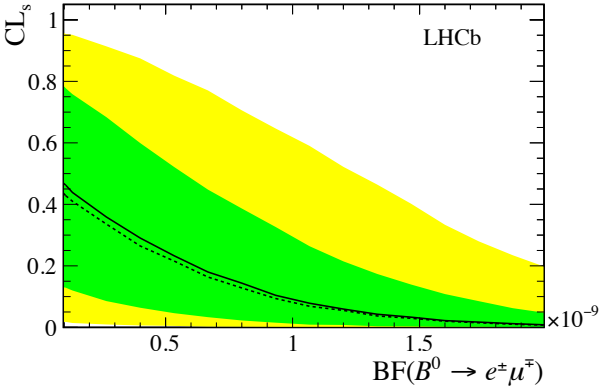
- Lepton-flavour violating decays
- No excess of signal observed wrt background
- Put a limit to the BF

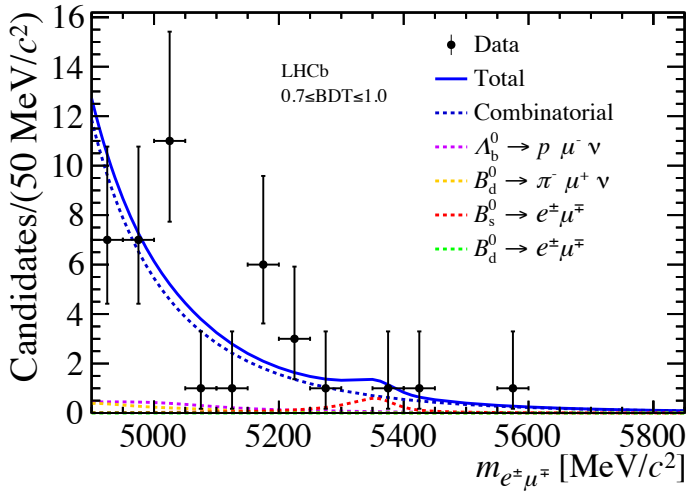
$$\mathcal{B}(B^0_s \to e^{\pm}\mu^{\mp}) < 5.4\ (6.3) \times 10^{-9}$$
$$\mathcal{B}(B^0 \to e^{\pm}\mu^{\mp}) < 1.0\ (1.3) \times 10^{-9}$$
at 90 (95)% CL

- Best upper limits to date and a factor 2-3 better than the previous results from LHCb

- Data sample: 1.0 (7 TeV) + 2.0 (8 TeV) $\text{fb}^{-1}$

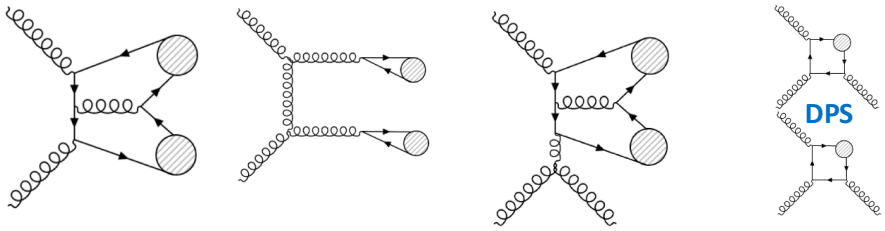


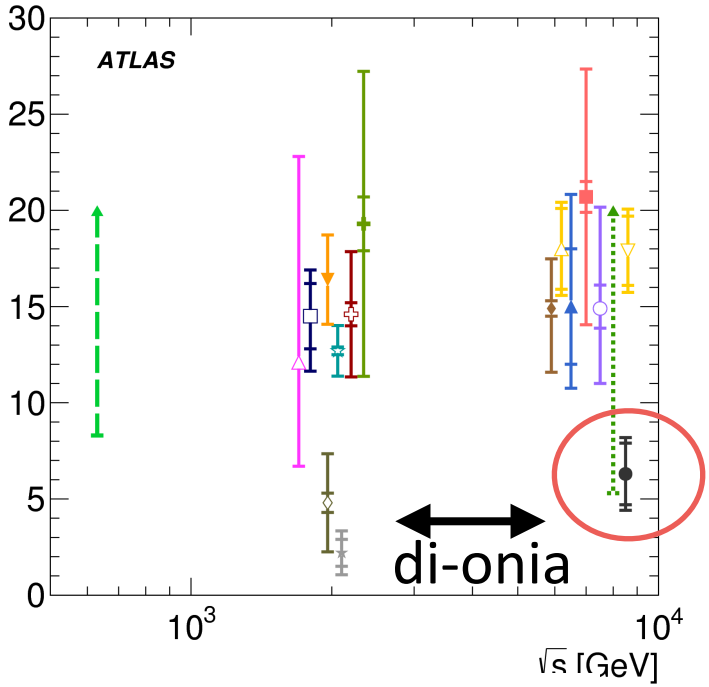



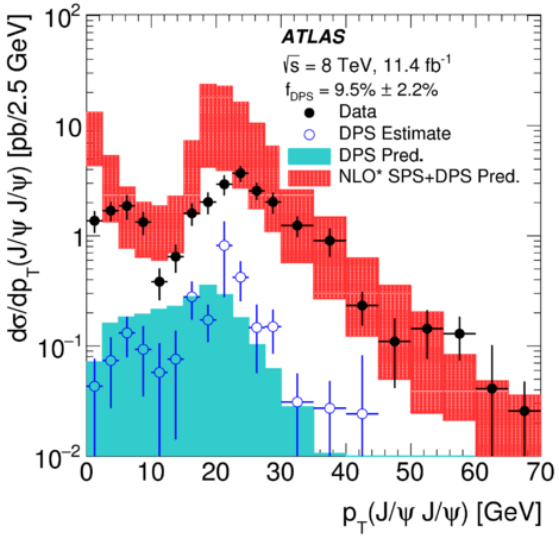



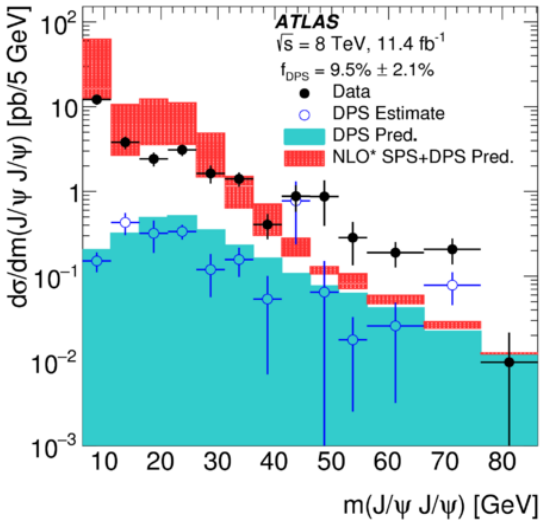
# Prompt J/ψ pair Production

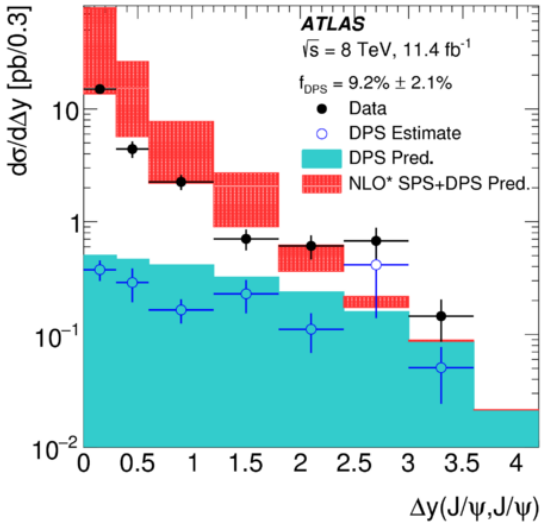
- Understanding of non-perturbative QCD, also sensitive to NLO and higher pQCD corrections
- Measure double parton scattering (DPS)
- Important background for NP searches



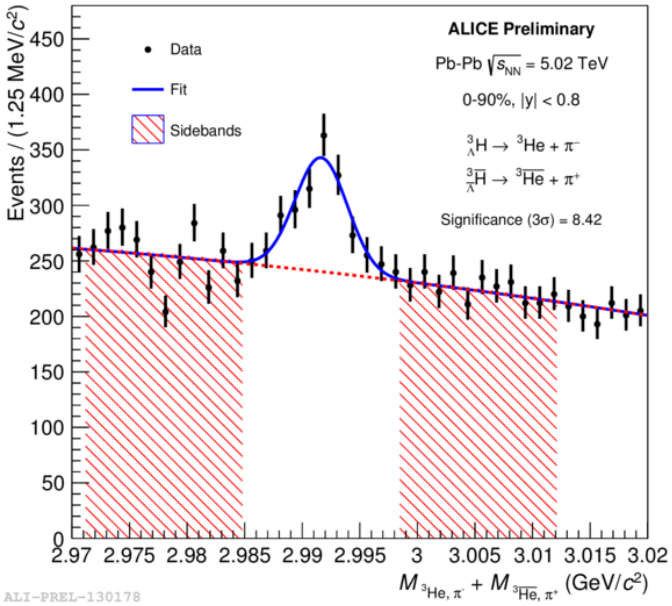



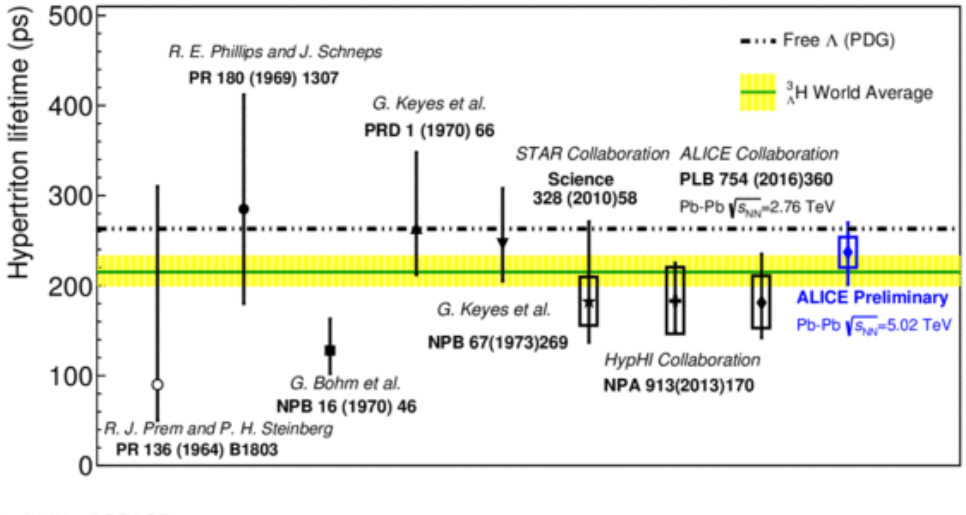



# Measurement of the (anti-)hypertriton lifetime in Pb-Pb collisions



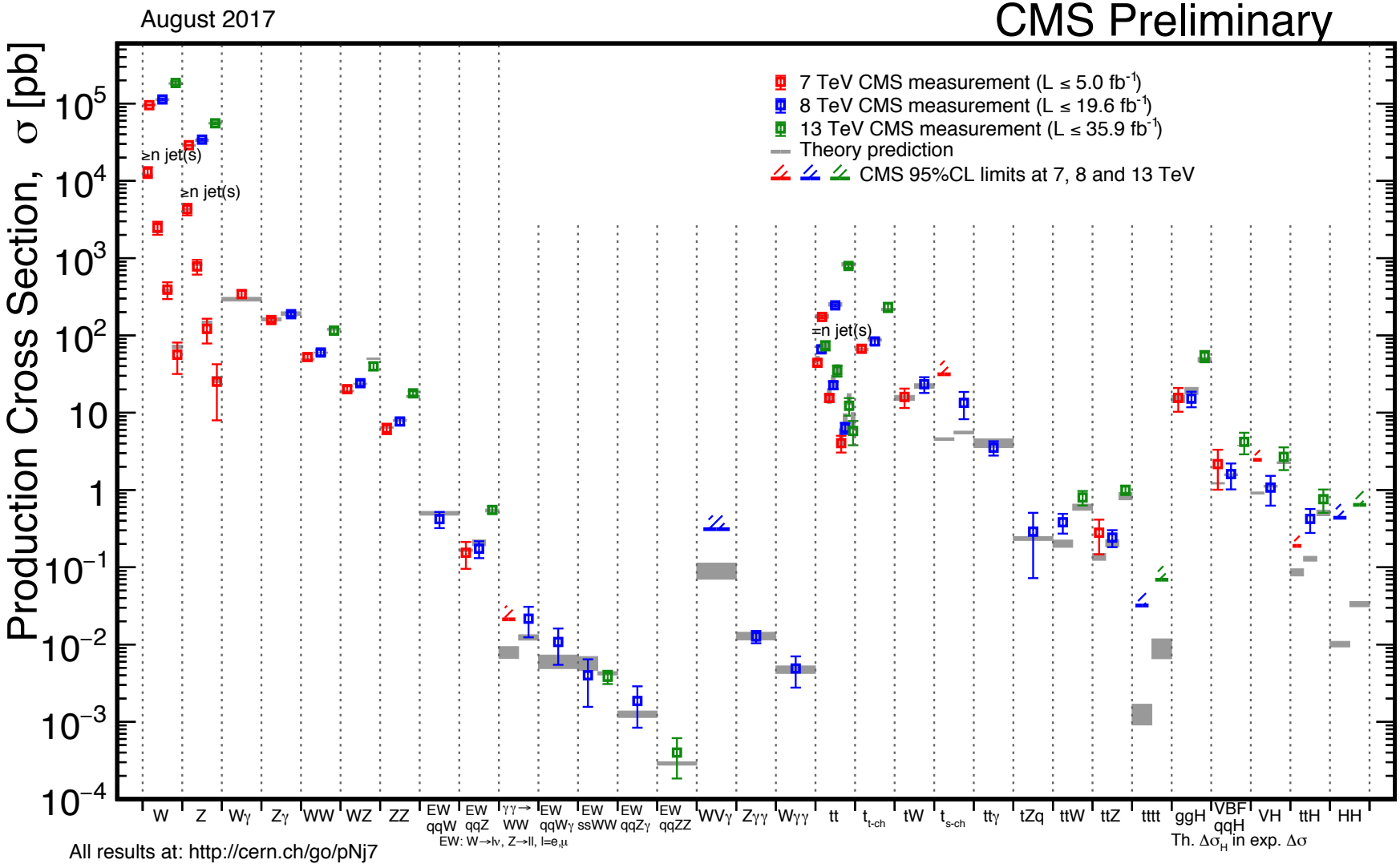

$^{3}_{\Lambda}H$ reconstructed in the $^{3}He$-$\pi$ decay channel ($^{3}He$ identification via E-loss in TPC)

Result fully **compatible with the world-average and with the free $\Lambda$ lifetime**

**Significantly improved uncertainties wrt Run I**

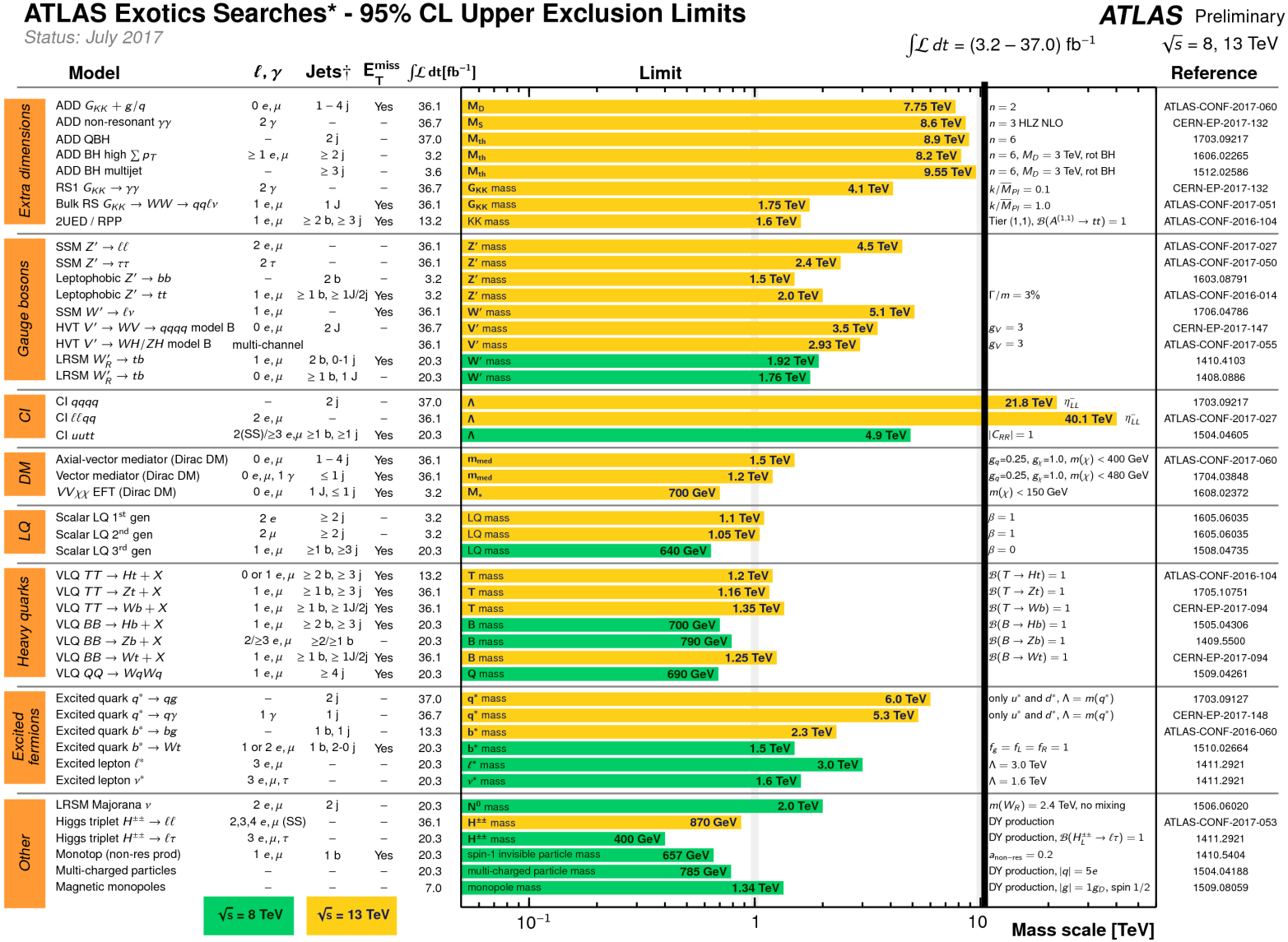
(and one of the most precise available measurements)

# CMS SM Results




All results at: http://cern.ch/go/pNj7

# Exotic Searches




*Only a selection of the available mass limits on new states or phenomena is shown.

†Small-radius (large-radius) jets are denoted by the letter j (J).

10 TeV

- LHC Run 2 is in full swing - hundreds of results - with more expected
  - ATLAS: https://twiki.cern.ch/twiki/bin/view/AtlasPublic
  - CMS: http://cms-results.web.cern.ch/cms-results/public-results/publications/
  - LHCb: http://lhcbproject.web.cern.ch/lhcbproject/Publications/LHCbProjectPublic/Summary_all.html
  - Alice: http://aliceinfo.cern.ch/ArtSubmission/submitted
  -
- These results rely on the efforts of the Grid community and the computing resources supplied by the UK.