CMS Update

23 November 2018

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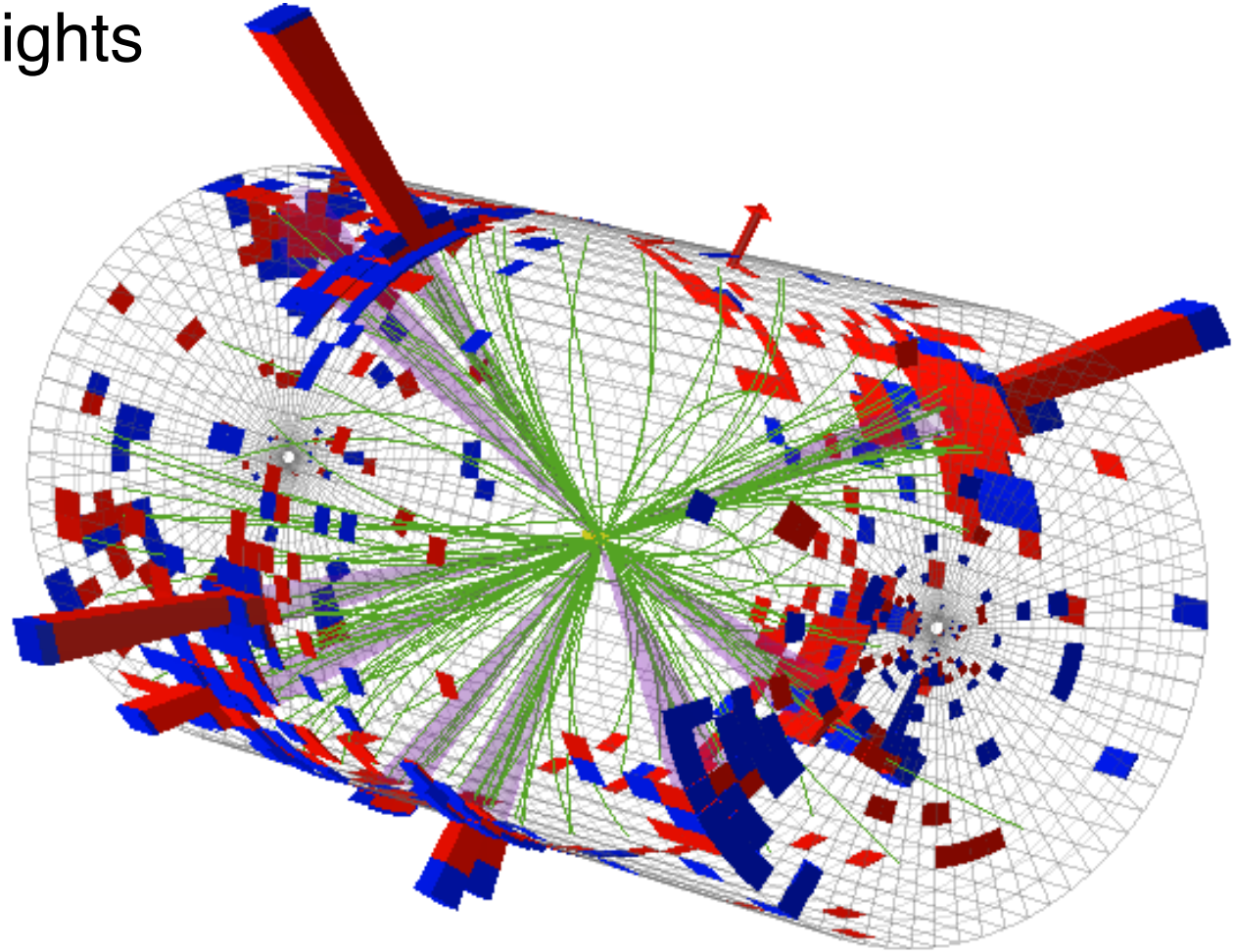
Particle Physics

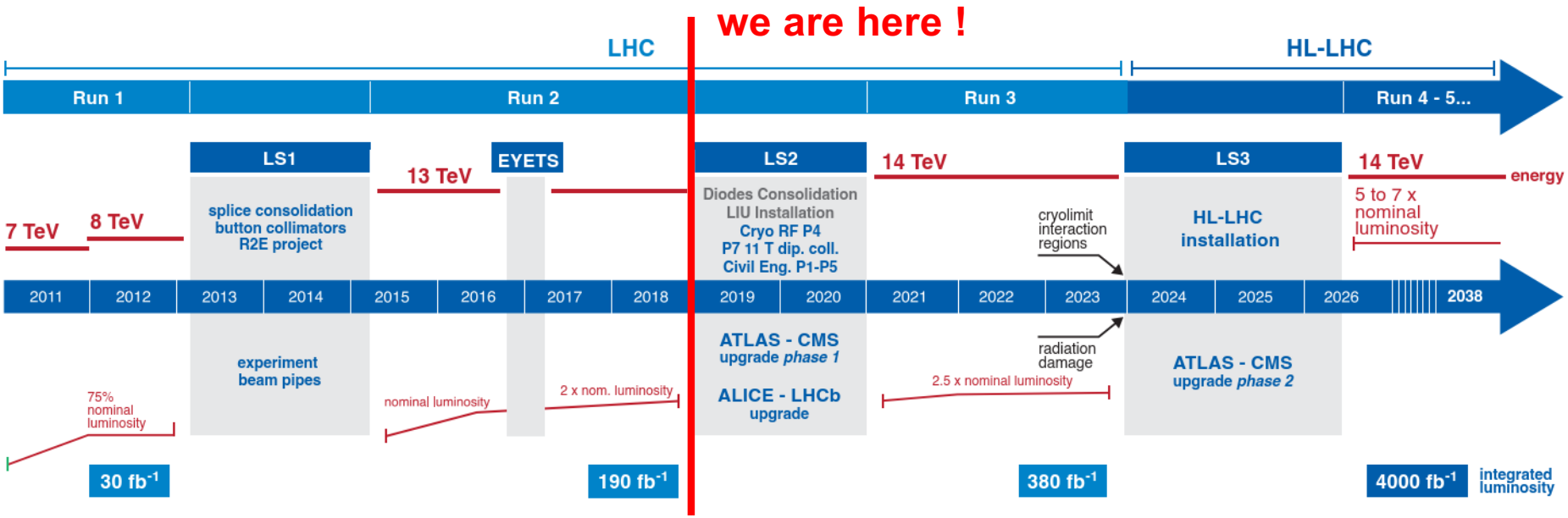
Day 2018

Overview

- LHC and detector performance
- Physics highlights
- Outlook



Run 2 in a nutshell



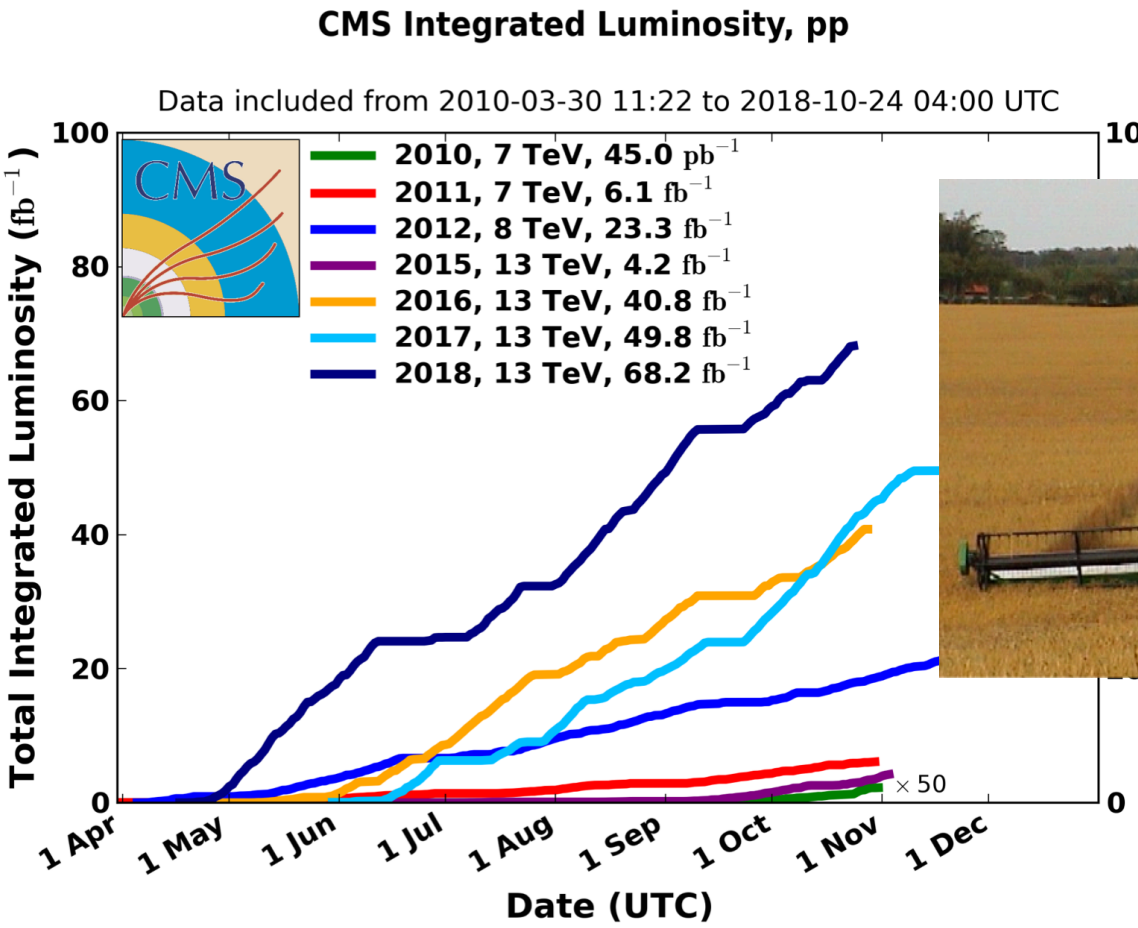
- Run 2 about to conclude
- pp data taking ended in October
- Heavy Ion run ongoing for another week

Parameter (typical)	2018	Design
Energy [TeV]	**6.5**	7.0
No. of bunches	**2556**	2808
E_{max} per beam (MJ)	**312**	362
β* [cm]	**30→25**	55
p/bunch [10^{11}]	**1.1**	1.15
Norm **emittance** [μm]	**~1.8**	3.75
L_{peak} [10 $nb^{-1}s^{-1}$]	**2.1**	1.0

A spectacular "Run II"

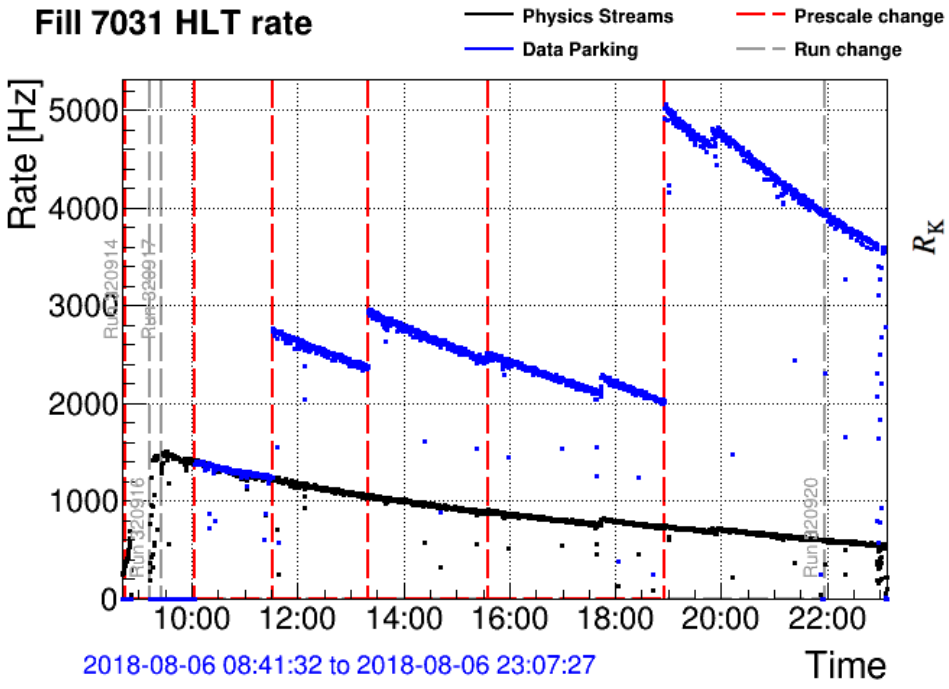
Machine availability ~ 50 %

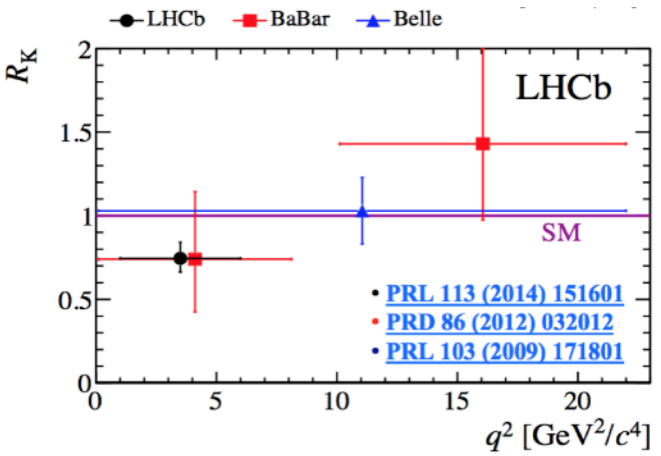
Run 2 pp in a nutshell

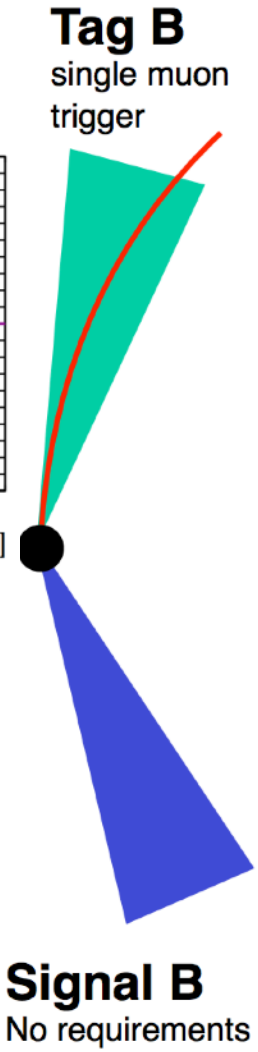


- Loads of data harvested: ~160 fb^{-1}
- No smoking gun new physics at 13 TeV
- Casting nets even wider to search for new physics
- Diverse SM measurement programme, 2018 “year of the Yukawa couplings”

2018 specialty: CMS as a B factory

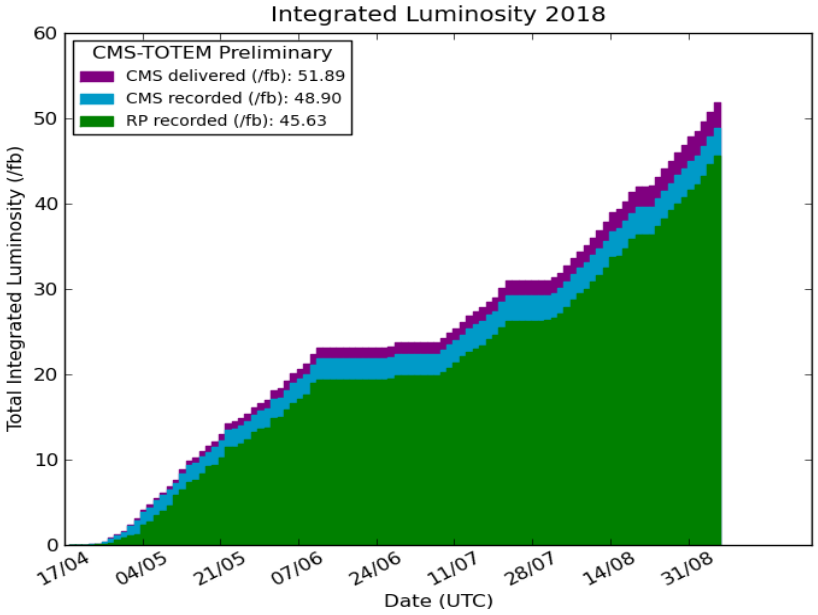


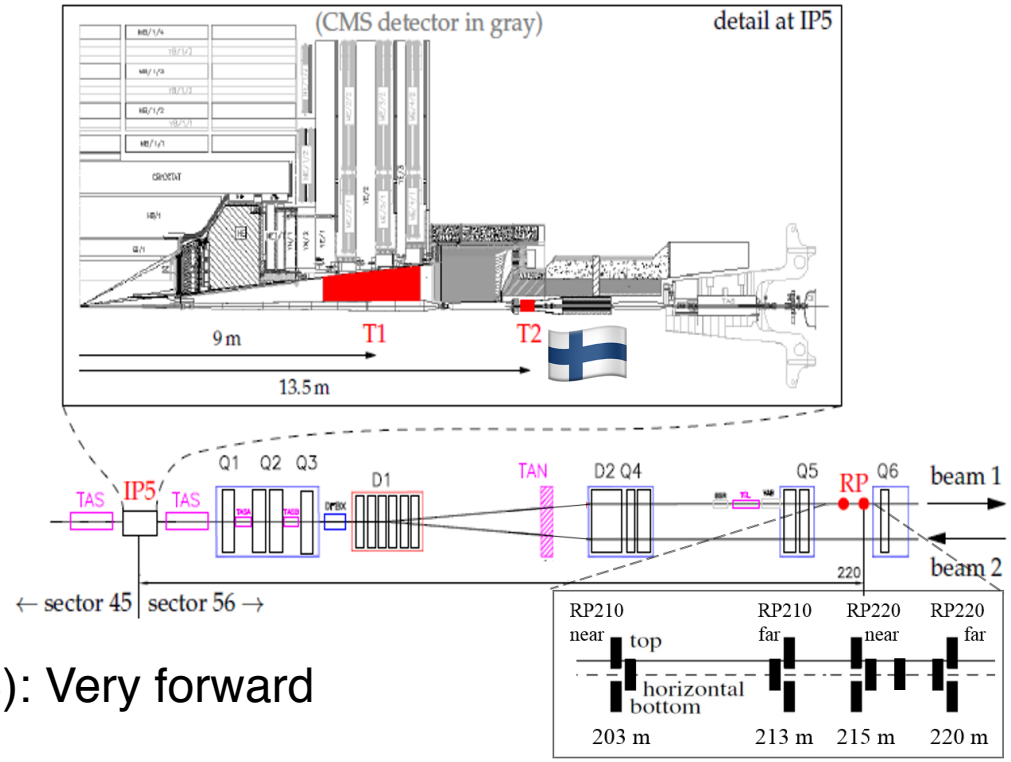




- Collect[ed] dataset of >10^{10} B hadron decays in 2018
- Parked data: Written at rates of up to 5 kHz to tape, reconstructed next year (with optimised low p_T electron reconstruction)
- Goal: generic dataset + establish competitive measurements for all the major B anomalies

Continued PPS integration into CMS physics

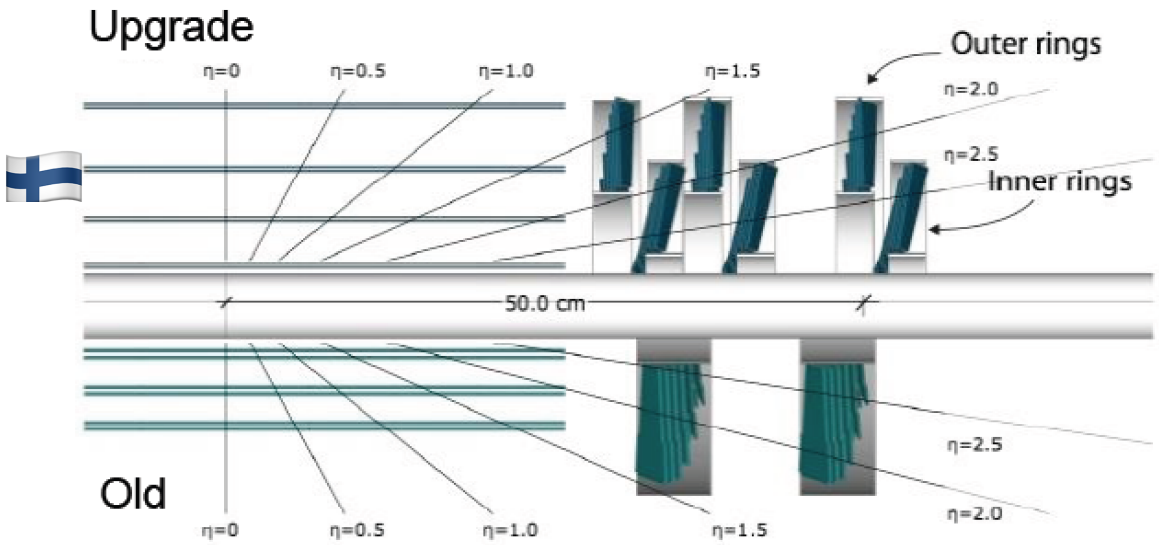


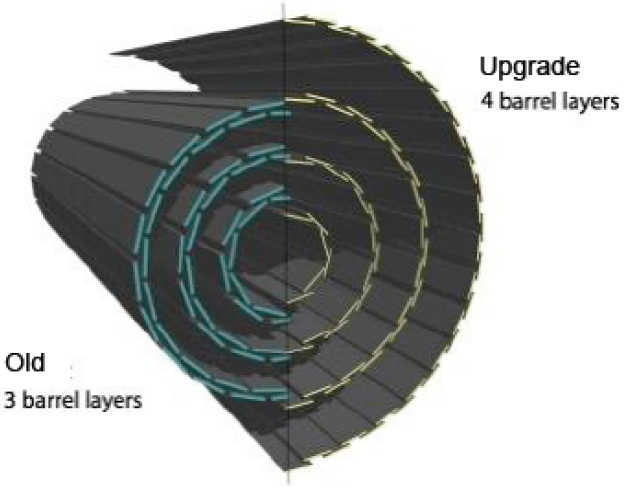


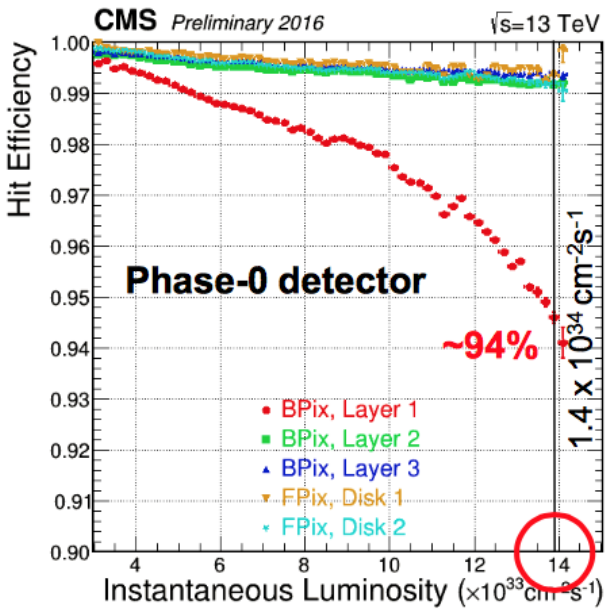
- Proton precision spectrometer (PPS): Very forward proton tracking and timing
- Very good performance of PPS in 2018
- PPS data available in ~95% of the CMS data

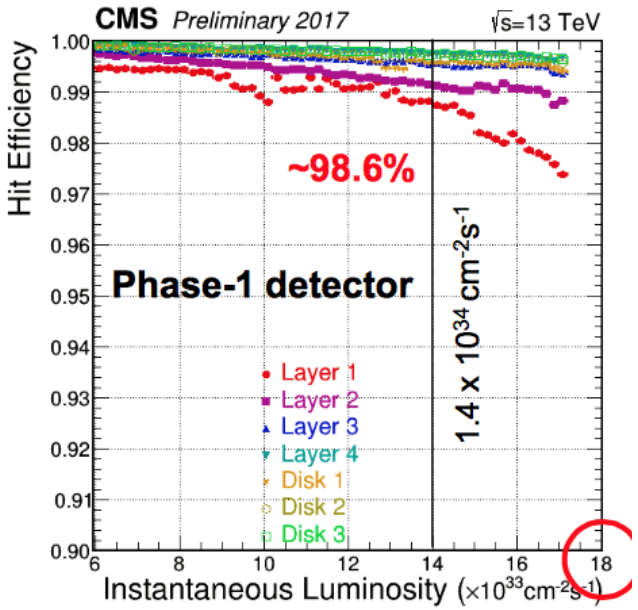
- "Physics object group" formed for protons, just like for muons, jets, taus, etc.
- Analysis activities pursued in the relevant "physics analysis groups"
- Seizing the opportunity of intensifying collaboration between Finnish TOTEM and CMS activities

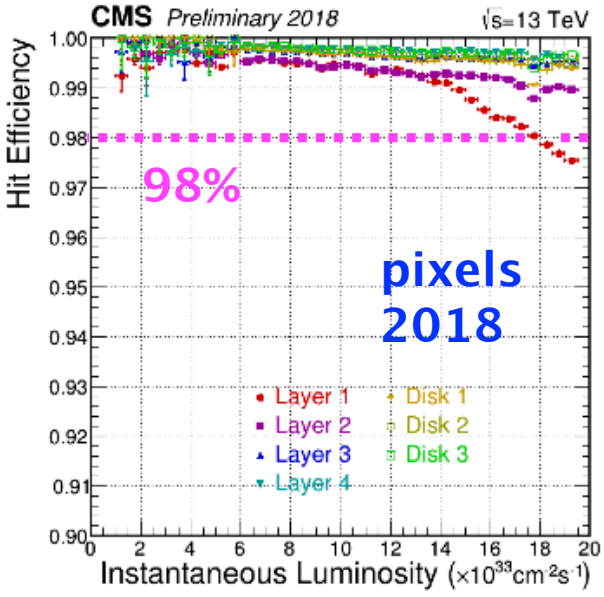
Almost new pixel detector (2017/2018)



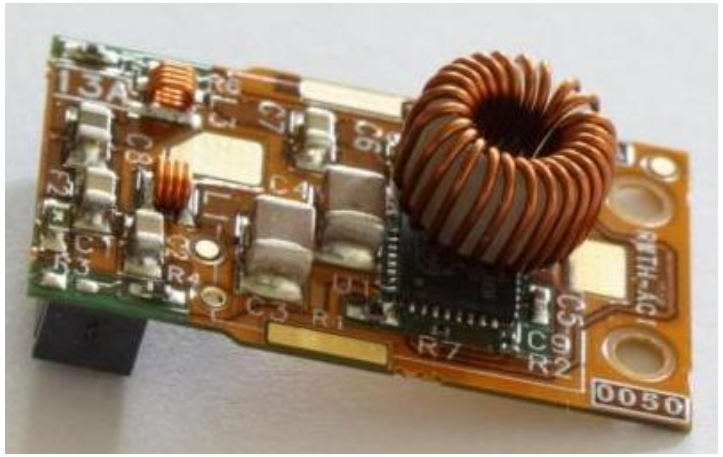


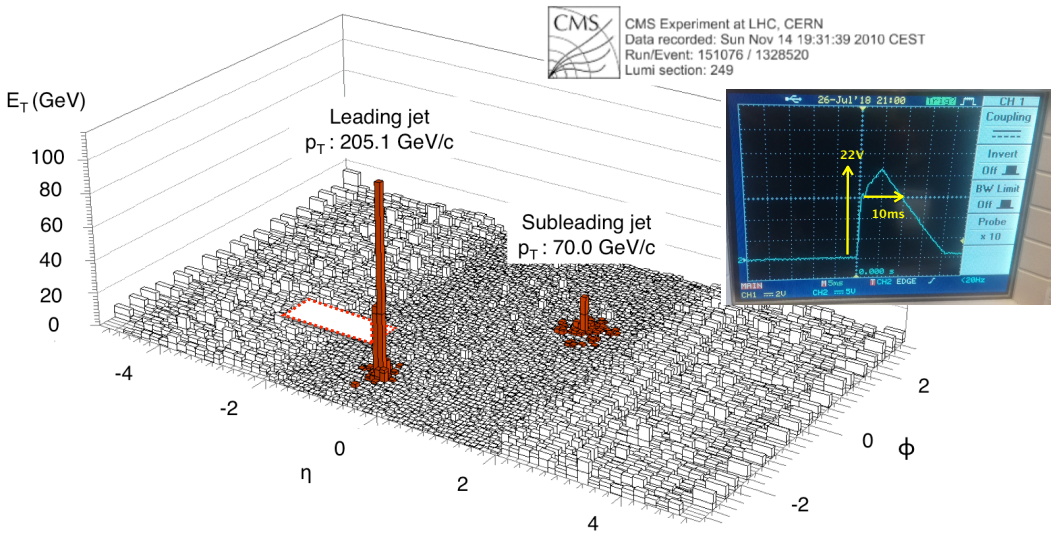






Post mortem of detector issues (Pixel+HCAL)

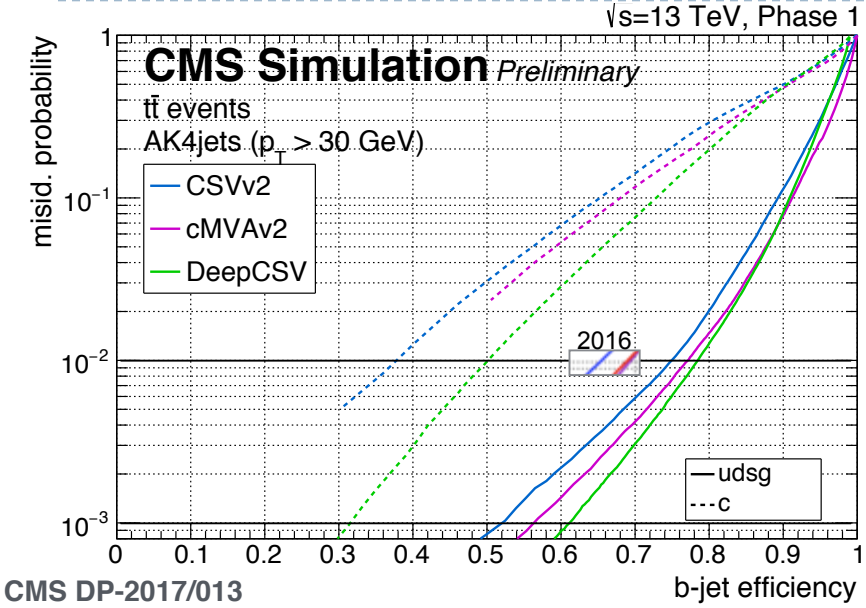




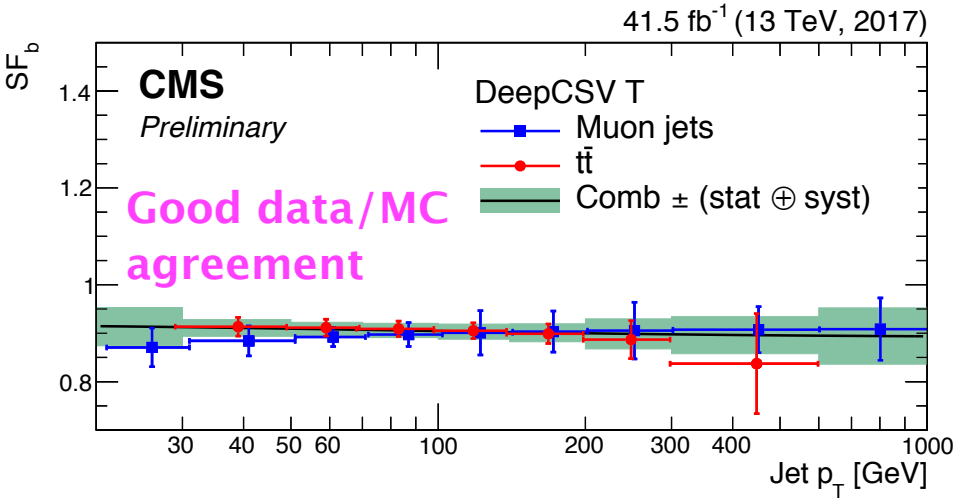
- In late 2017, CMS observed failures of DC/DC convertors in pixel detector, NOT recoverable
- Bottom line: damage occurs only for disabled device after high cumulative radiation damage.
- No disable/re-enable cycles in 2018: no further damage
- LS2: Replace layer 1 + all DC/DC converters + upgrade power supplies

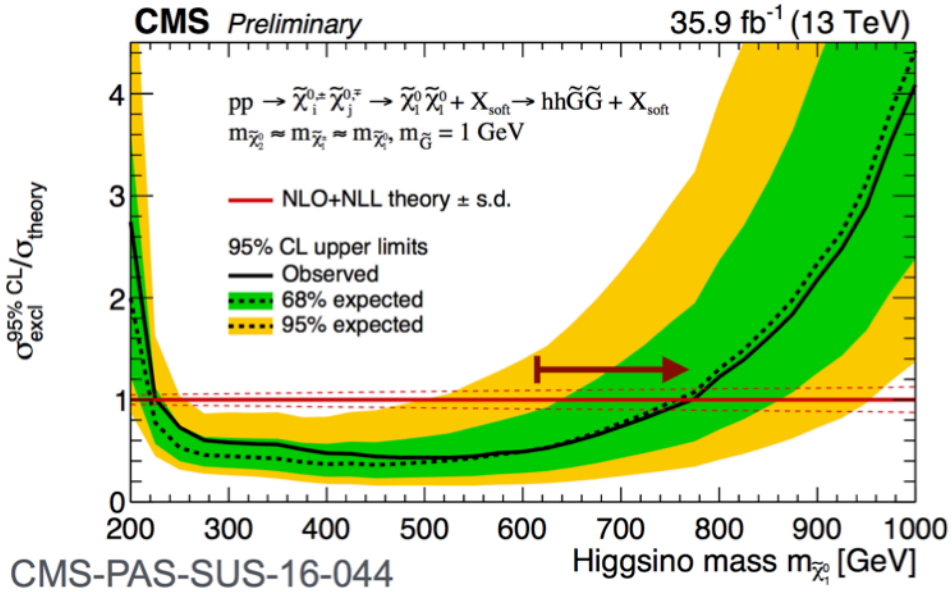
- A fake fire alarm ended up in the loss of two adjacent sectors in hadronic calorimeter endcap (HE): 40° in one endcap, 2% of HCAL coverage.
- On power up, 10V power supply (PS) unable to read internal calibration.
  - PS sent 22V/10ms pulse to detector, exceeded its own 14V max rating, damaged on-detector components with 12V rating.
- Mitigation in re-reconstruction

Reconstruction with DNNs



CMS DP-2017/013



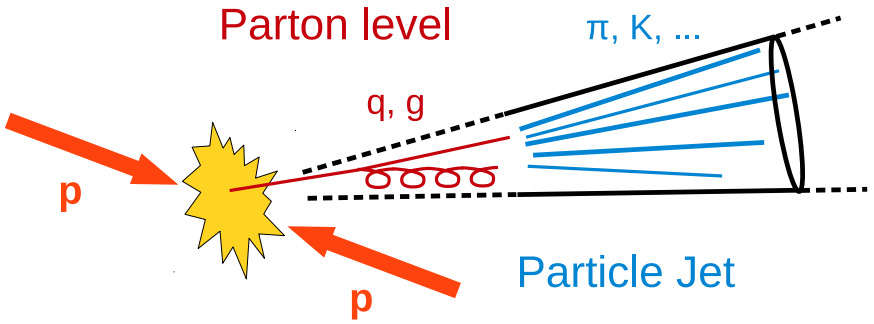


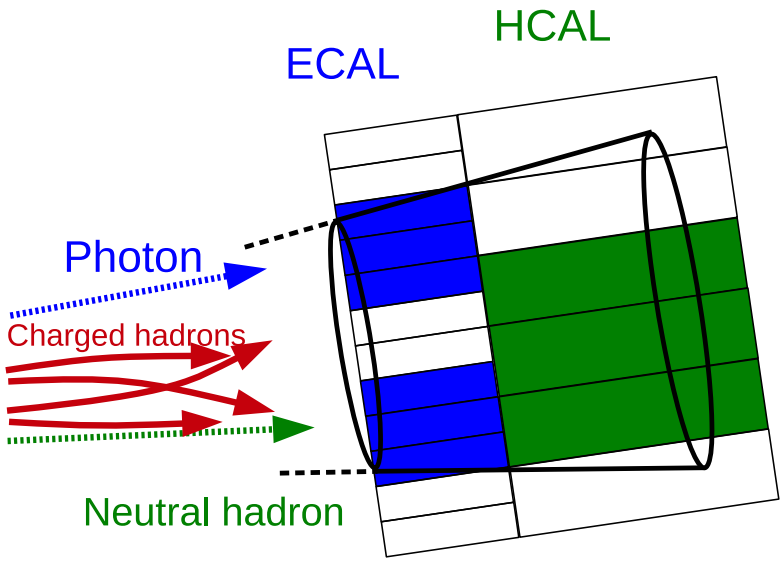
CMS-PAS-SUS-16-044

- Deep neural networks becoming widely used “everywhere"
- First successful application: b-tagging using ~same inputs as previous standard
  - Now evolving towards integrated “flavor+W/Z/H” classification
- Also under study for track quality estimate 🇫🇮 and energy regression 🇫🇮

Jets are territory at CMS and it grows

- Almost everything can become a jet: g/q/t/W/Z/H

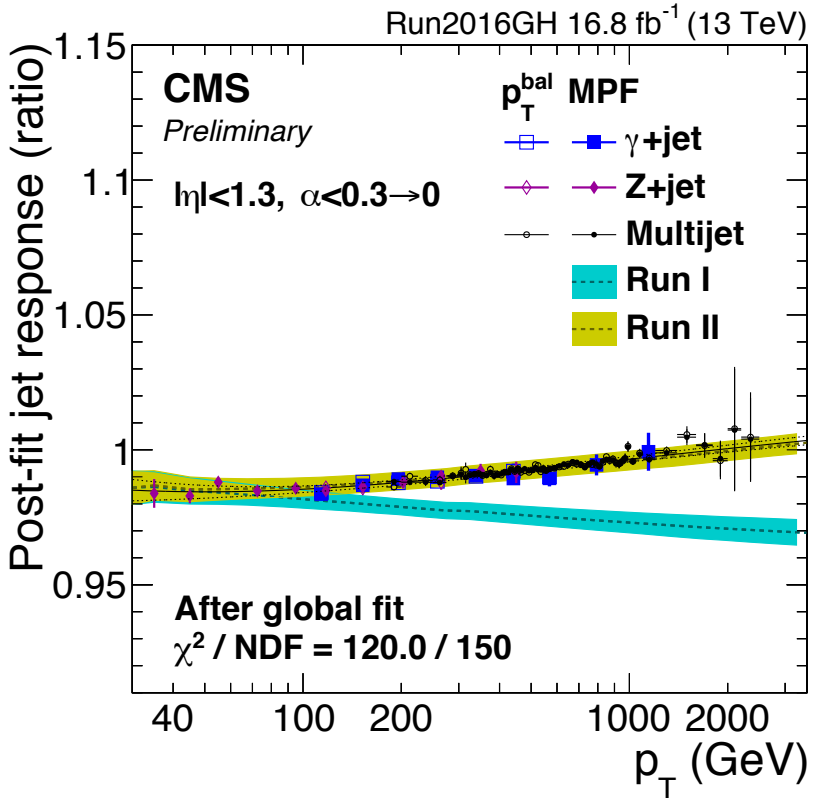


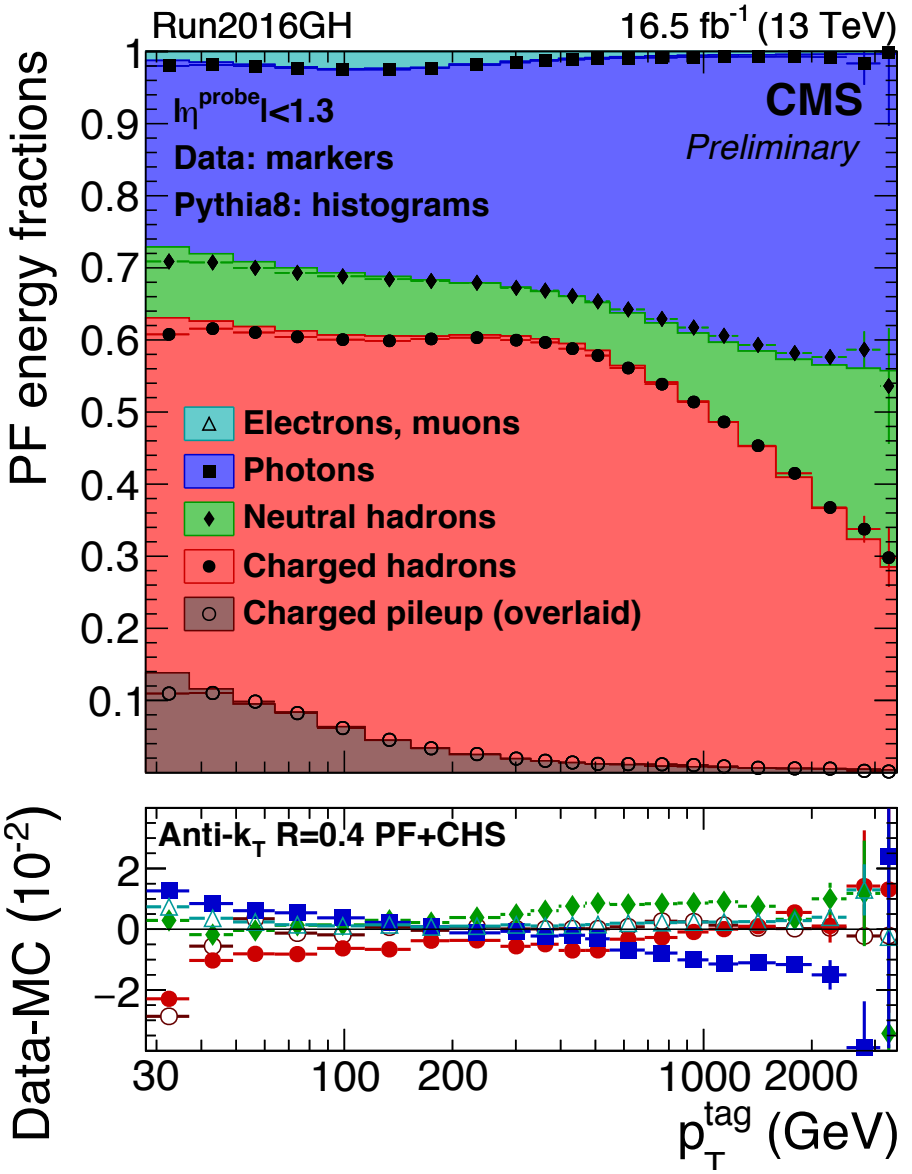


- Particle flow reconstruction key to very successful CMS physics programme

Highlight: Jets@ICHEP

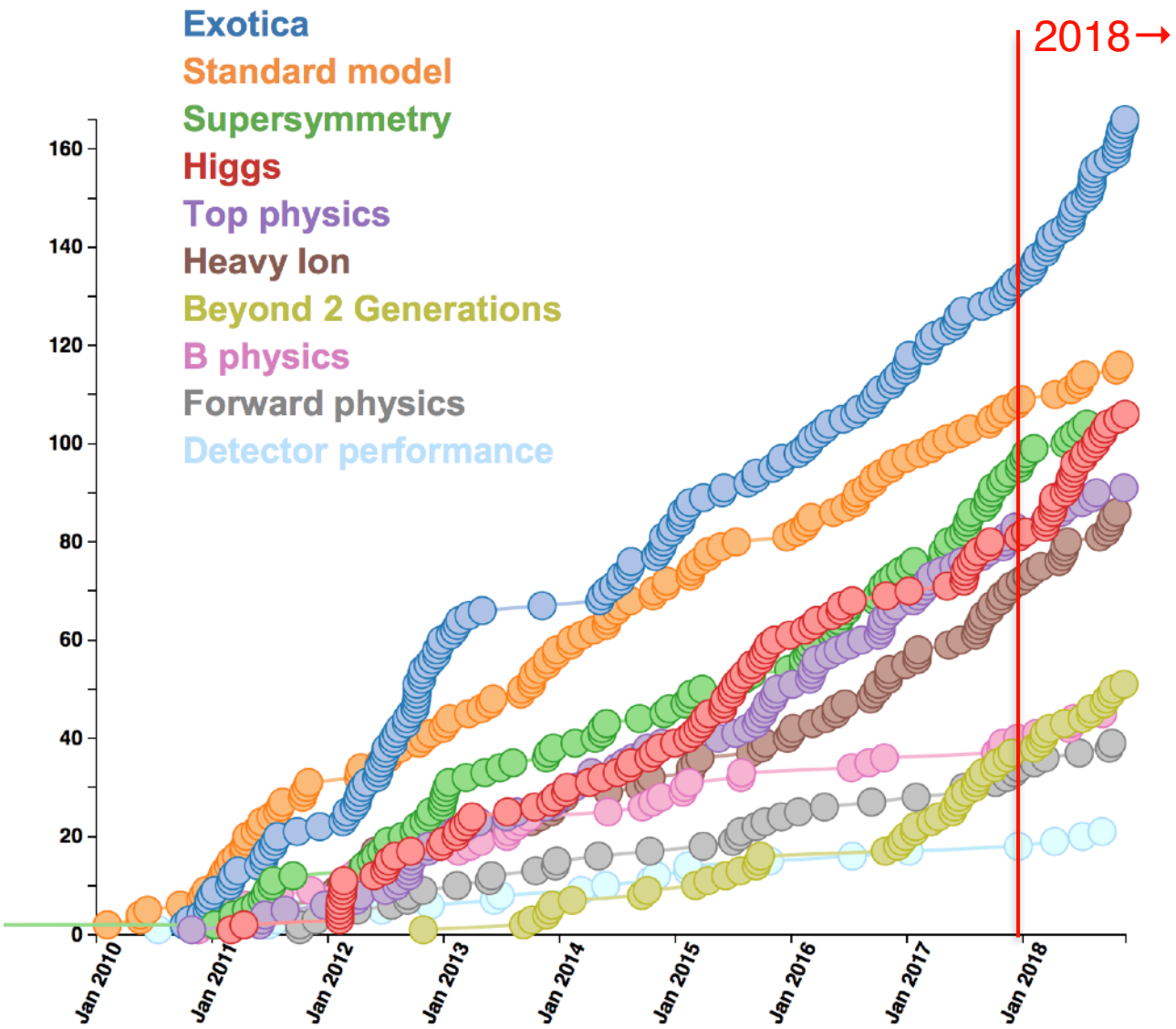
- Jets and missing ET performance on 2016 legacy re-reco reported at ICHEP2018
- 🇫🇮: JEC global fit, uncertainties, PF composition, R&D to improve state-of-the-art precision





Publications

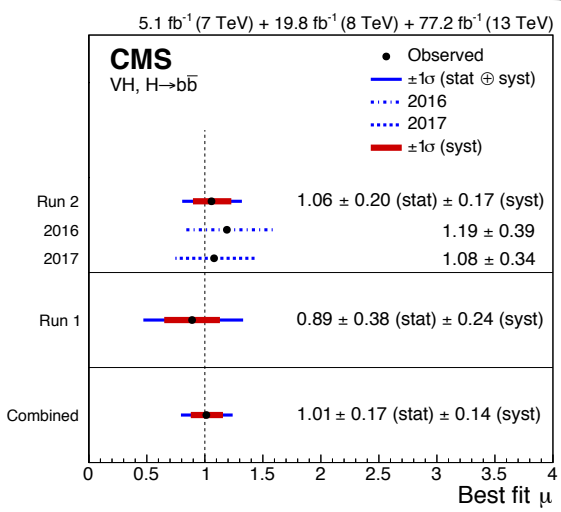
- Staggering publication rate: 104 per year since Jan 2010
- No sign of slowing, 144 papers in past year

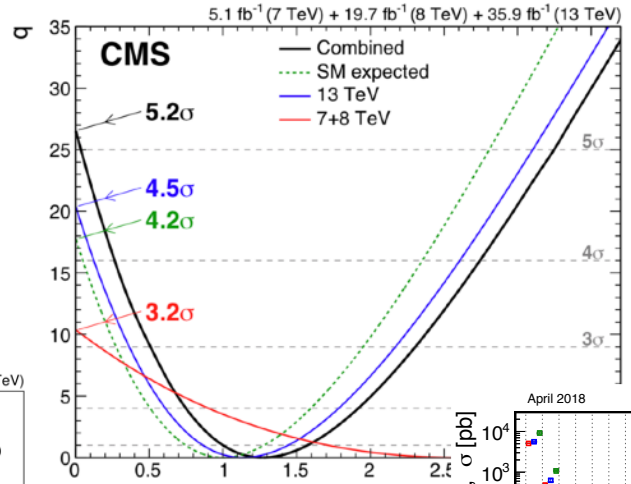


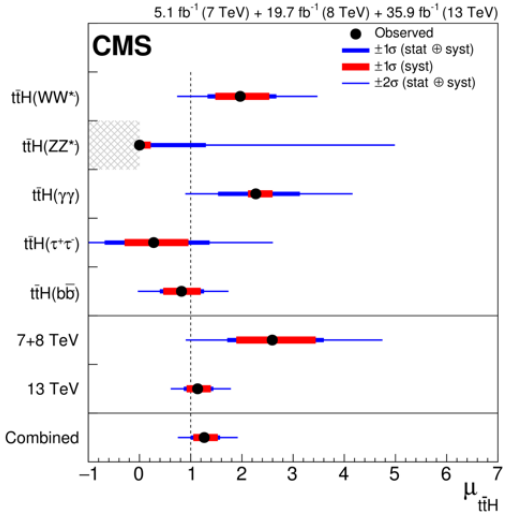
Recent physics highlights

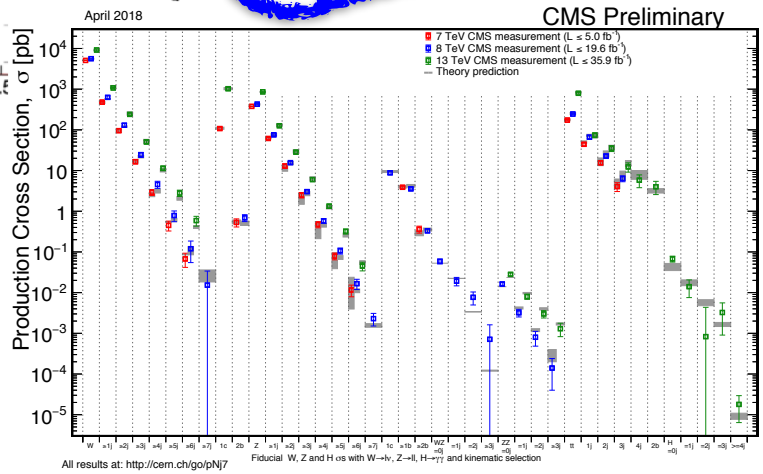
Rencontres de Moriond

ICHEP2018 SEOUL
XXXIX INTERNATIONAL CONFERENCE ON high Energy PHYSICS
JULY 4 - 11, 2018 COEX, SEOUL





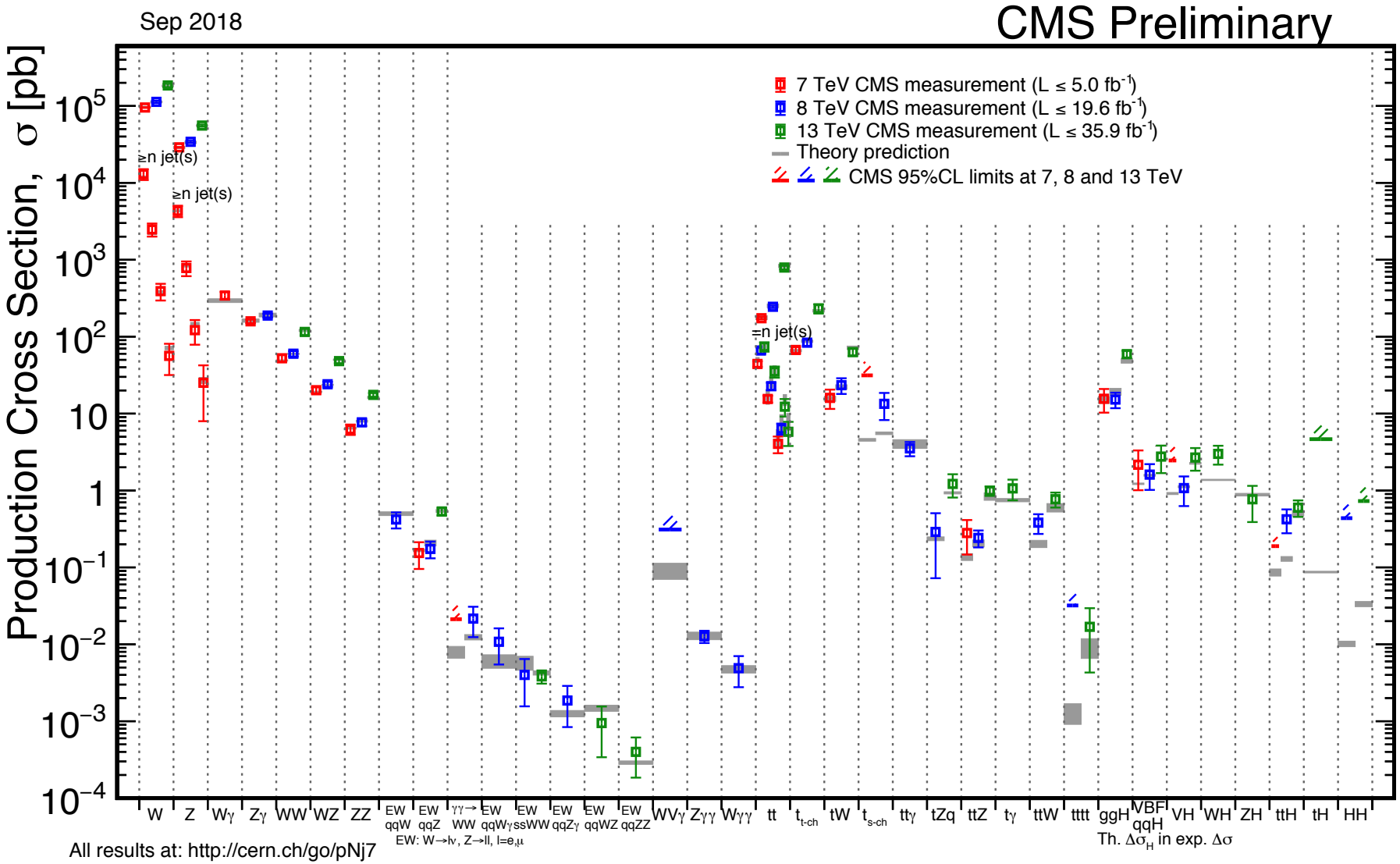




TOP 2018

Top results covered by Minsuk

Standard model works

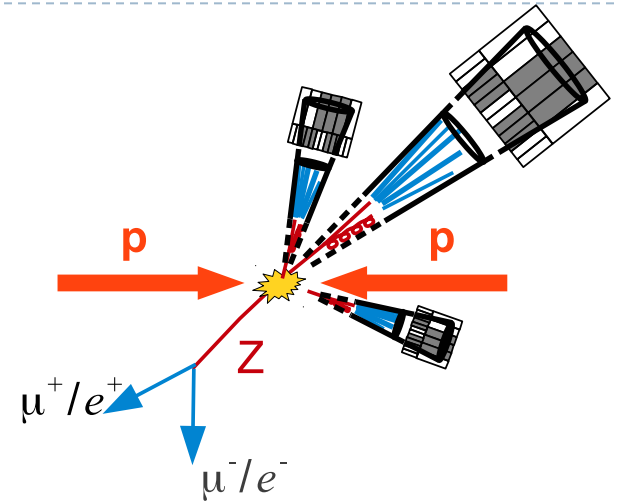


- 13 TeV results for most SM processes, many recent results

Z+Jets

arXiv:1804.05252

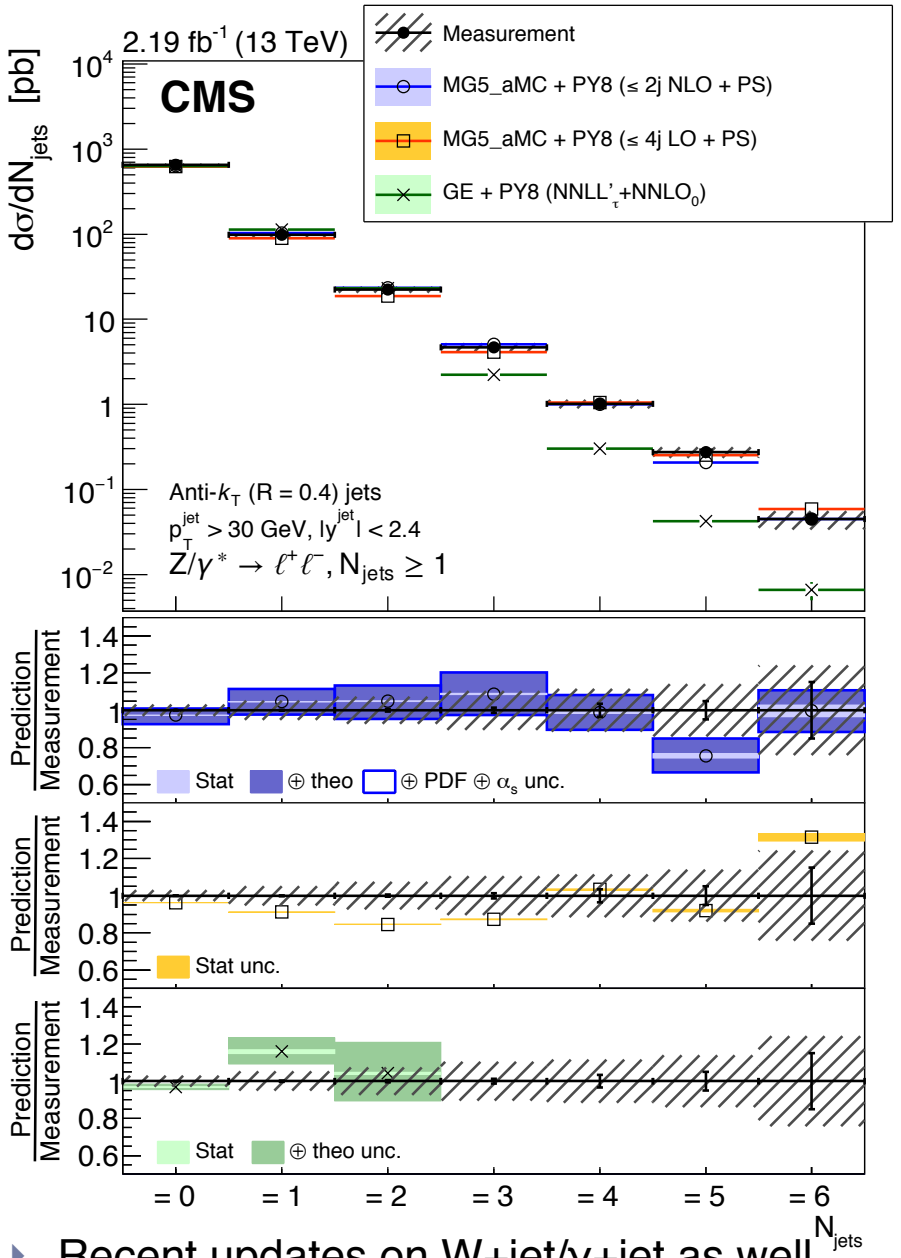
An example: Differential Z+jet cross sections



- leptons: p_T>30 GeV; |η|<2.4
- m(ll)=91±20 GeV
- p_T(jet)>30 GeV; |η|<2.4; ΔR(jet,l)>0.4

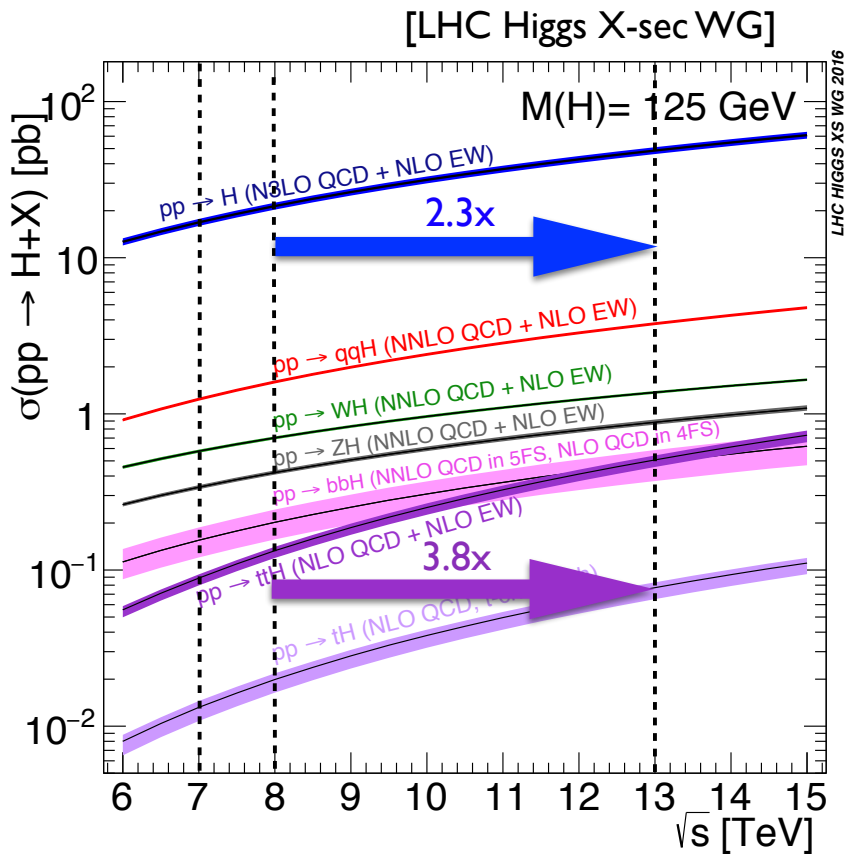
- pp collisions 2015: 2.19/fb
- Backgrounds estimated from simulation
- ttbar dominant background at high jet multiplicities

- Unfolding to generator level for many observables: N_{Jets}; p_T(jet1/2/3); y(jet1/2/3); HT; p_T balance; jet-Z balance (JZB)



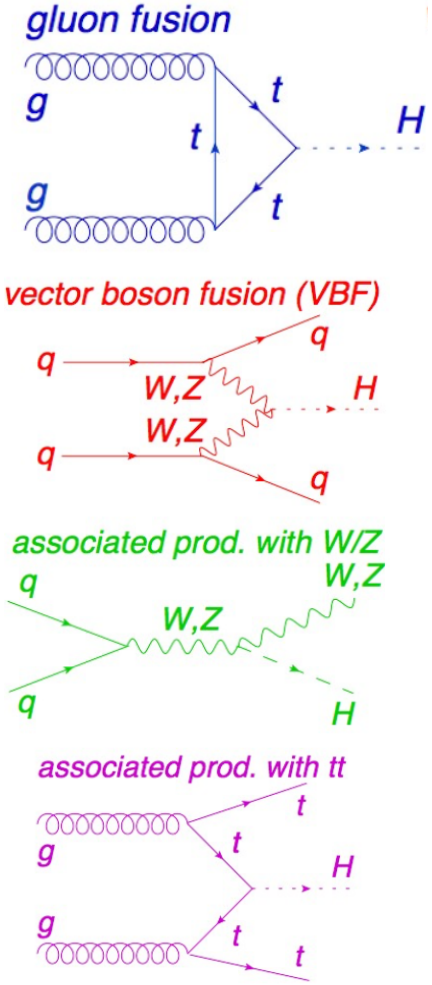
- Recent updates on W+jet/γ+jet as well

Era of precision Higgs physics



- Significant increase in production rate due to higher center-of-mass energy from Run-1 to Run-2

Production modes



Higgs bosons produced in Run 2 (2015-2017)

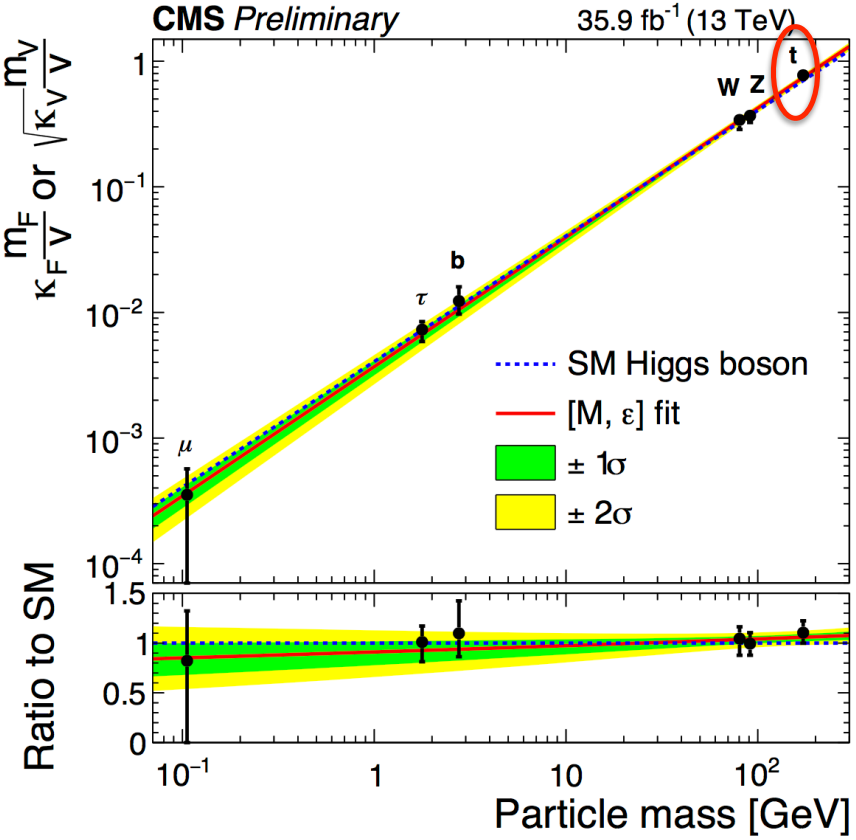
~4M

~300k

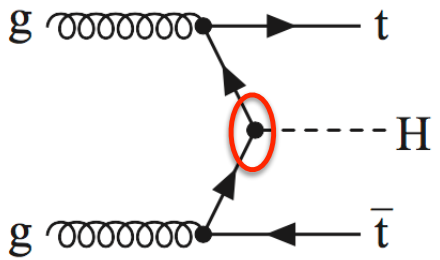
~200k

~40k

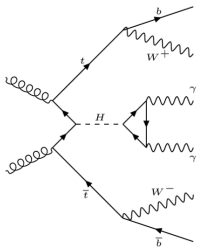
ttH observation



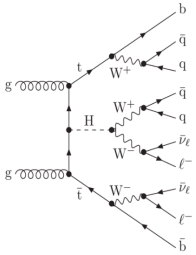
ttH production



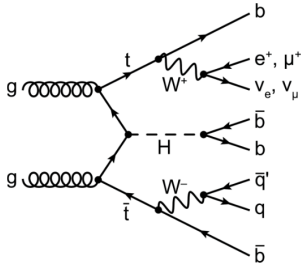
- Yukawa coupling proportional to fermion mass
  - Largest coupling to top quarks
  - Very sensitive to new physics!



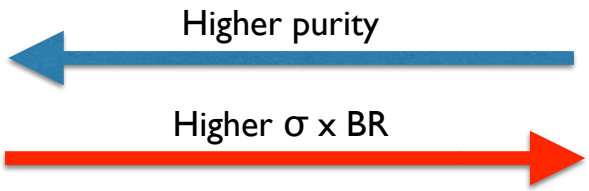
$H \to ZZ^* \to 4\ell$
$H \to \gamma\gamma$



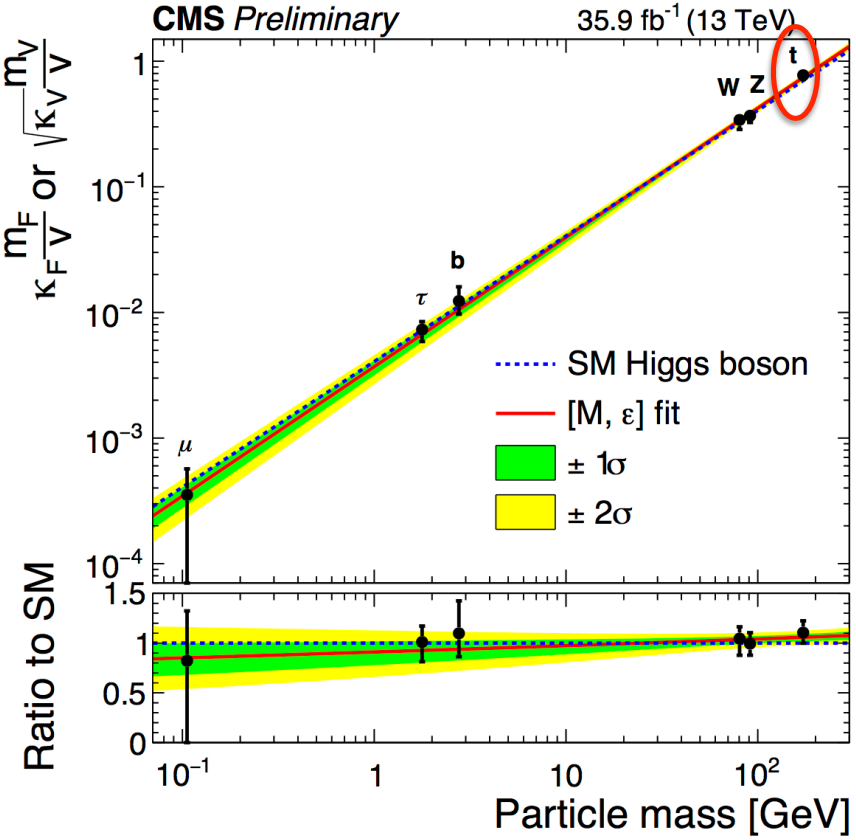
$H \to WW^* \to \ell\nu\ell\nu$
$H \to \tau\tau$
(multi-leptons)

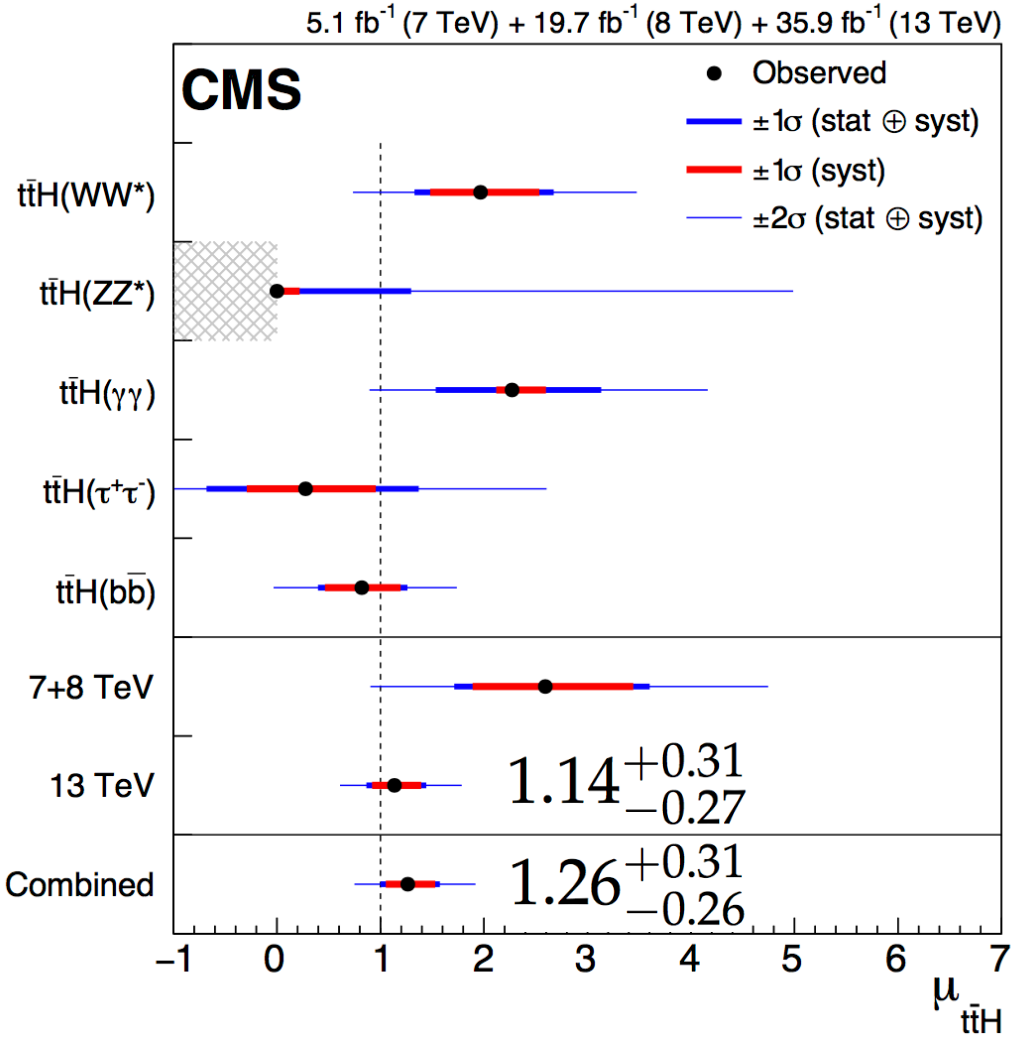


$H \to b\bar{b}$



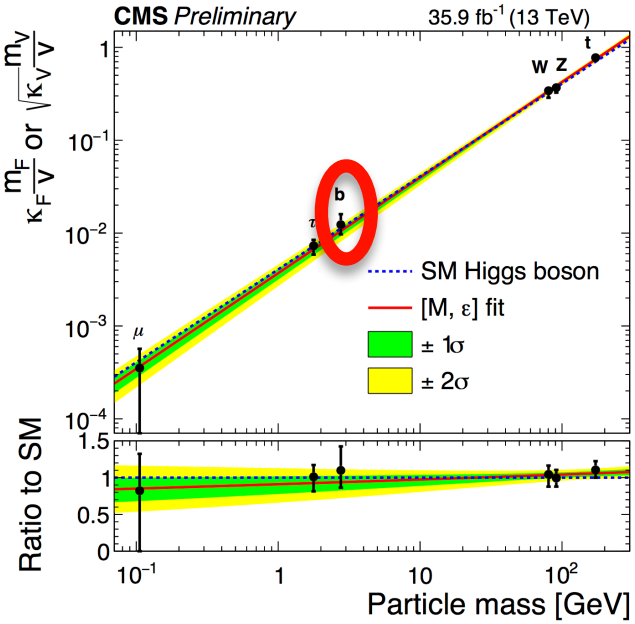
ttH observation

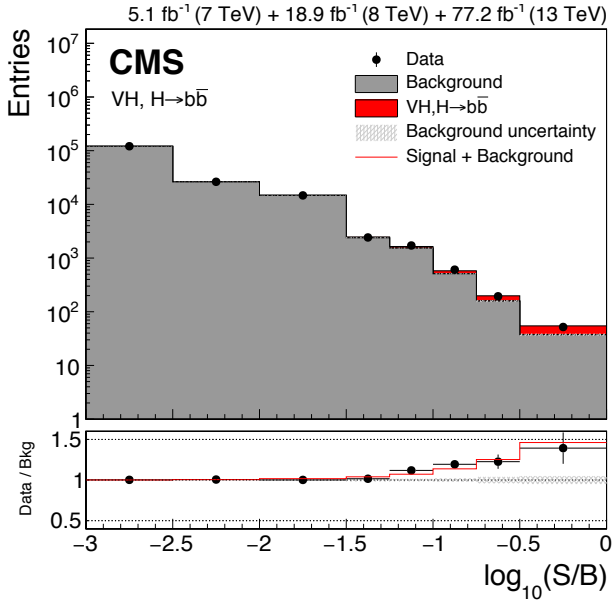


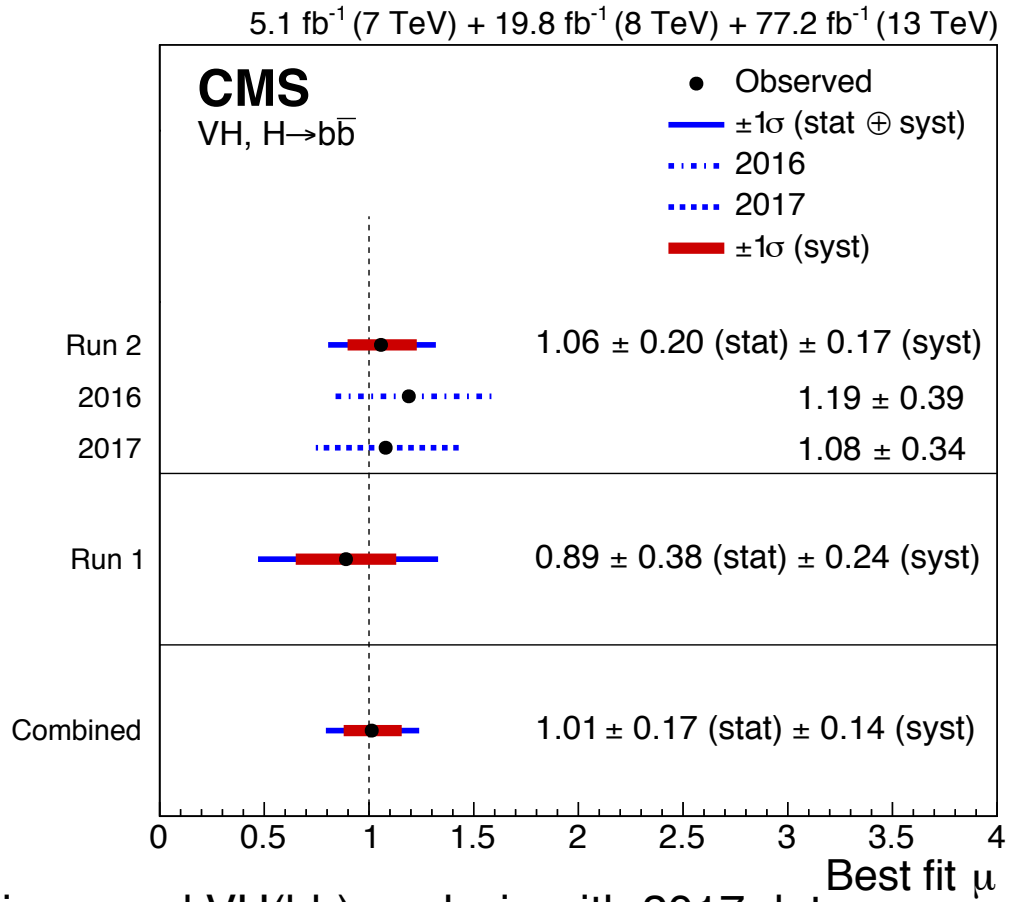


CMS
Run-1+Run-2: **5.2σ** (4.2σ exp.)

$H \to b\bar{b}$

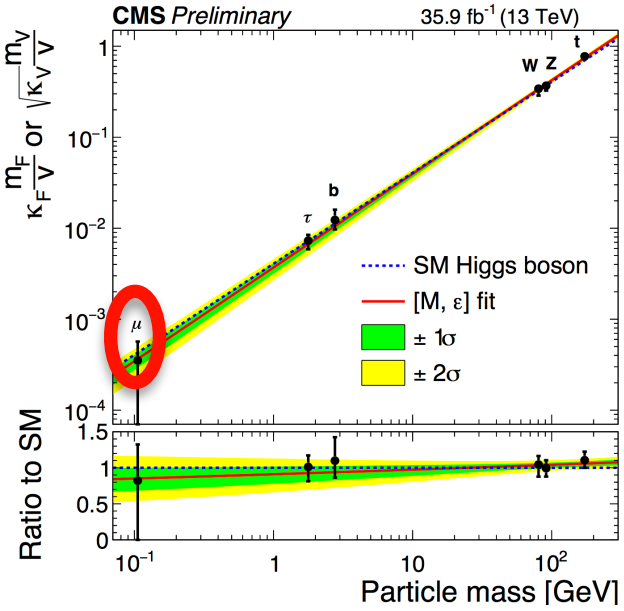


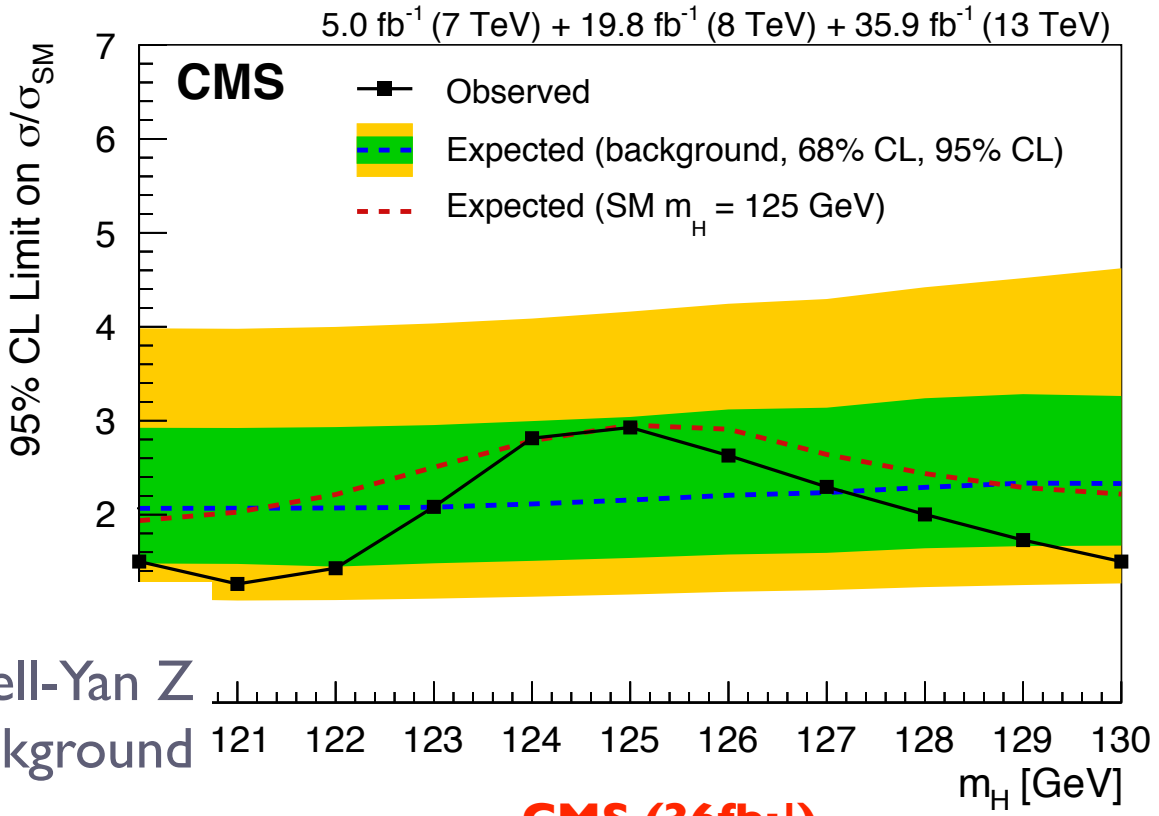


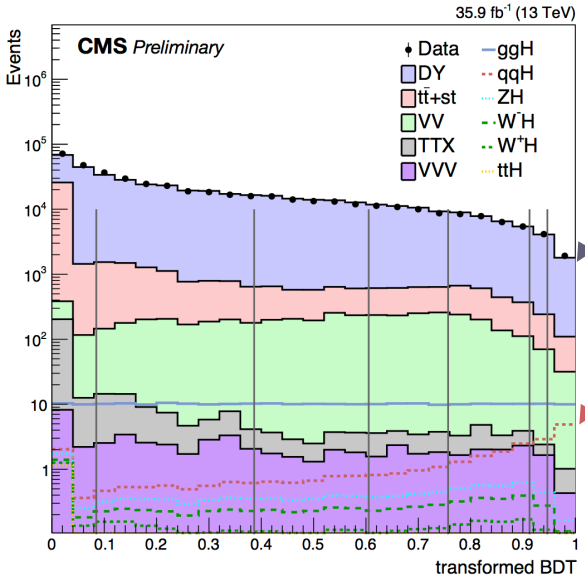


- improved VH(bb) analysis with 2017 data combination VH(bb): 4.8 obs; all production modes: 5.6 obs
- released early Aug. and highlighted in a common seminar with ATLAS
- completes cycle of observations of Yukawa interactions with 3rd generation fermions

$H \to \mu\bar{\mu}$







Drell-Yan Z background

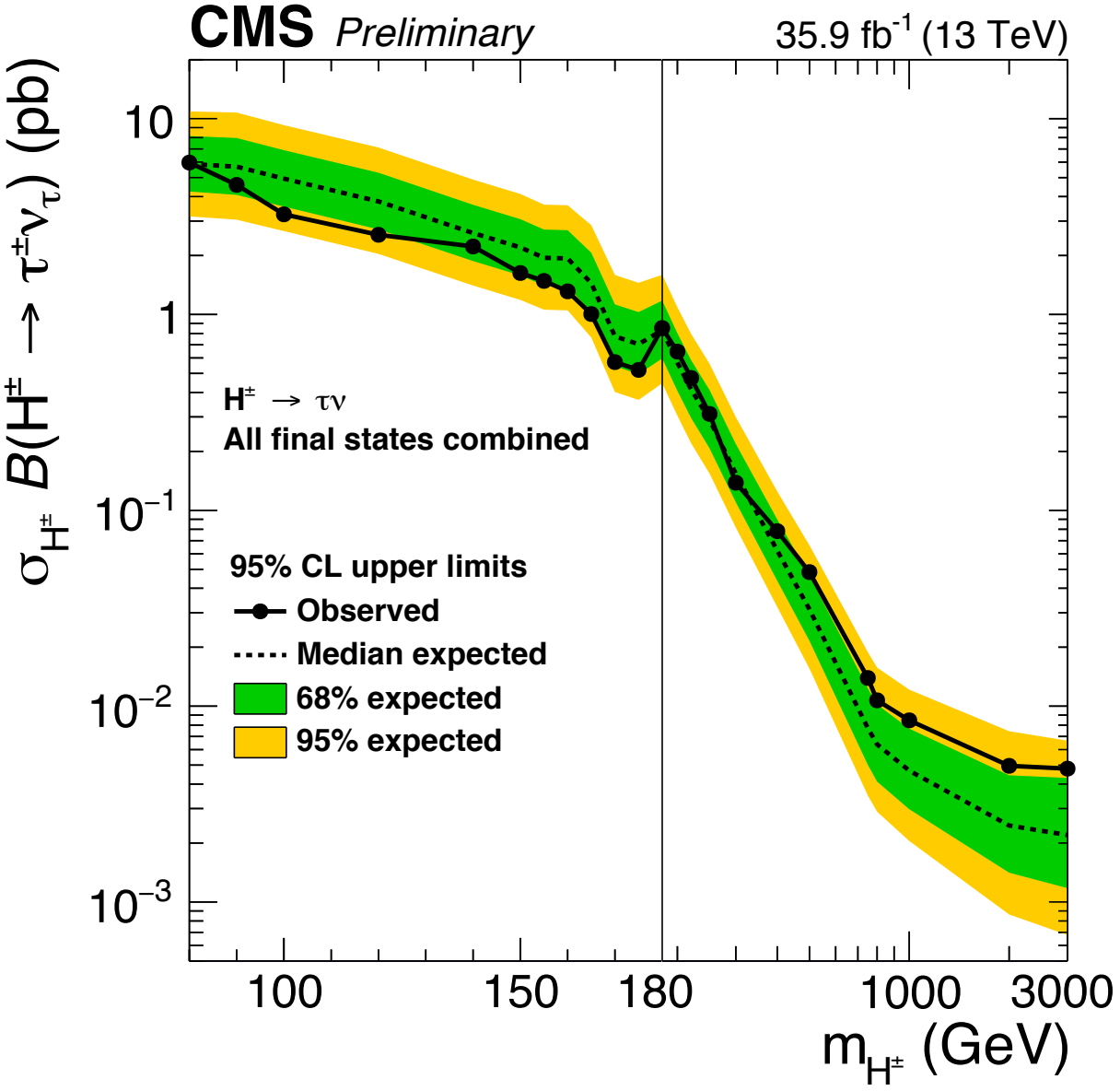
VBF Higgs

CMS (36fb⁻¹)

$\mu_{\mu\mu}$	0.7 ± 1.0
95% CL	$\mu_{\mu\mu} < 2.6\ (2.1\ \text{exp})$

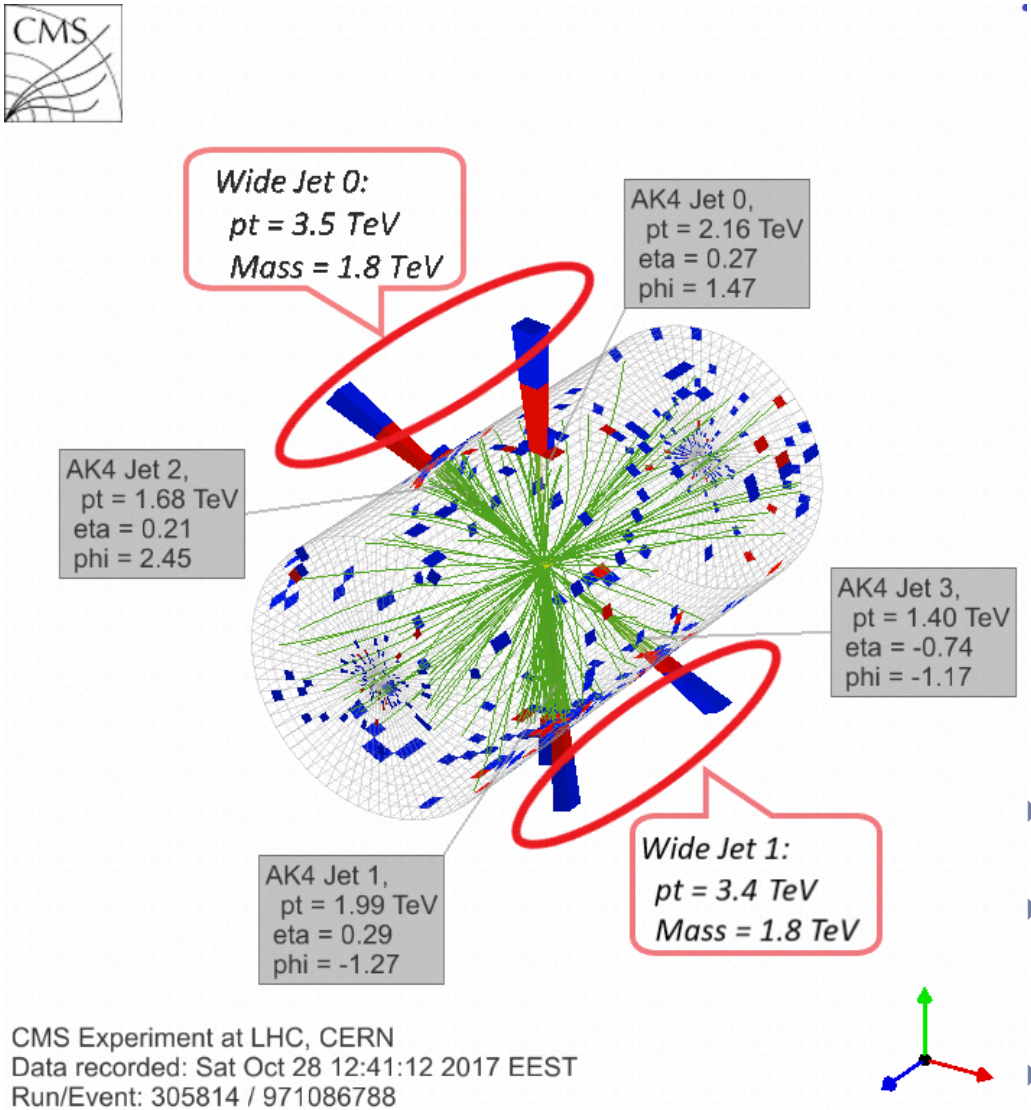
- Not quite there, yet.

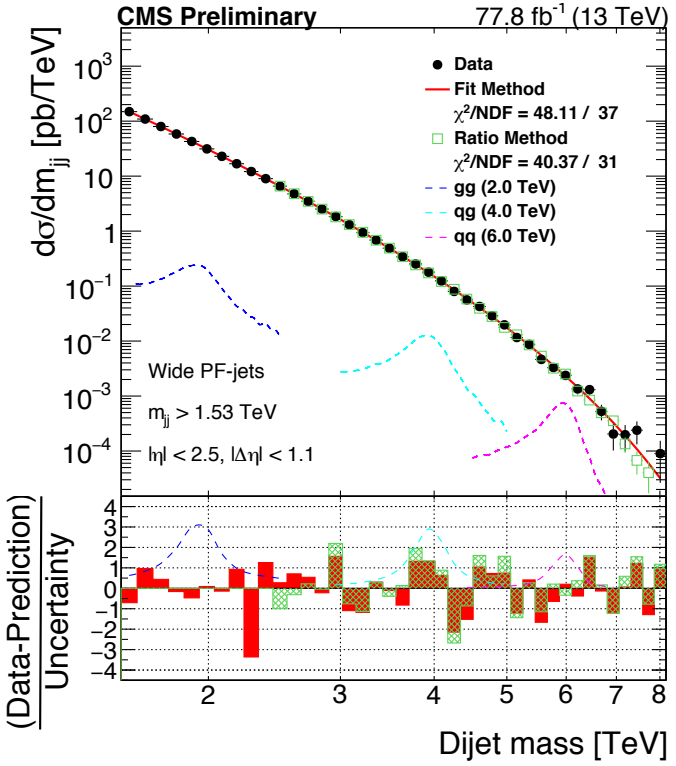
BSM: Charged Higgs $H^+ \to \tau^+\nu$ 🇫🇮



- Long time flagship analysis in Helsinki
  - September 2018: Full 2016 data result released
  - Hadronic and leptonic final state
  - Search extended to 3 TeV
  - $m_{H^\pm} \sim m_t$ covered for the first time in CMS

Dijet resonance search



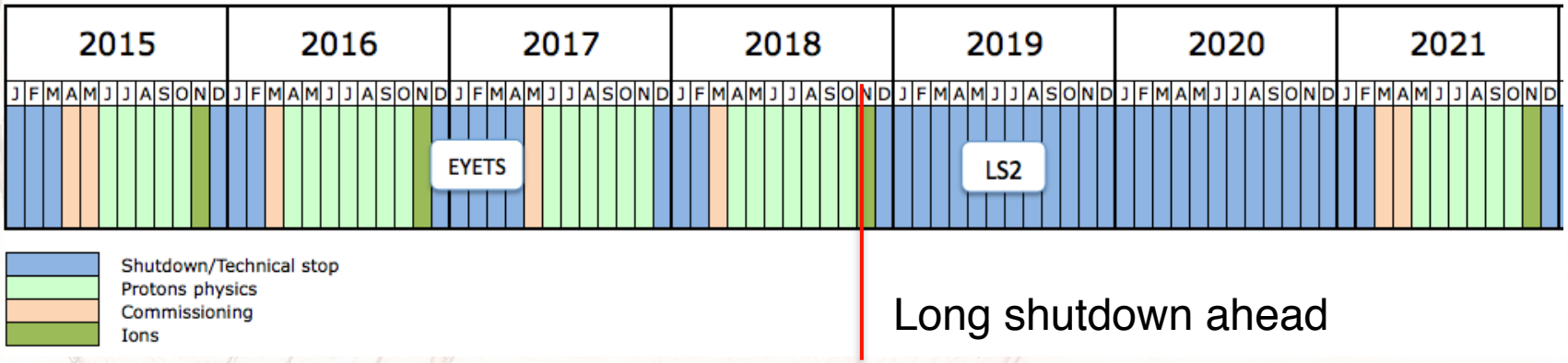


- Improved analysis methods: complement parametric background estimation with
- prediction from high sideband
  - reduces systematics
  - used at higher resonance masses
- Extends limits obtained with 2016 data
- Highest mass event with 2 wide jets of ~the same mass, each, discussed in, e.g., https://arxiv.org/abs/1810.09429

Conclusions

- No discovery, yet
- However, many observations + exciting avenues to pursue
- Many of the “standard searches” (e.g. SUSY) not reloaded with 2017 data, instead focus on improving techniques and aiming to release early 2019

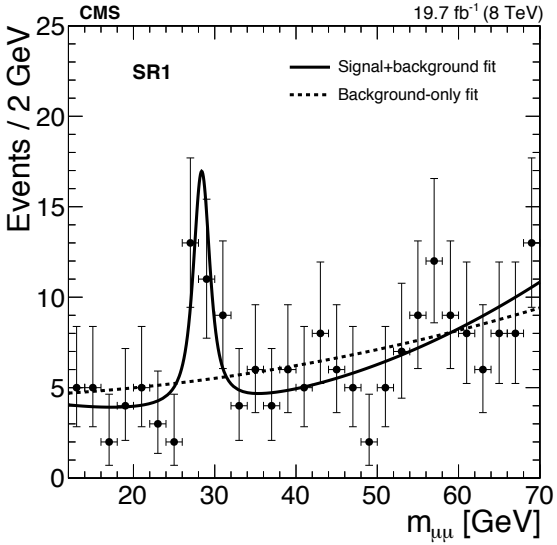
- Focus is now on physics reach with >160 fb^{-1} collected
  - Both: precision measurements and searches
  - Helsinki involved in many interesting analyses and playing a crucial role for jets in all of CMS
  - PPS part of CMS, actively exploring common projects within Helsinki group[s]

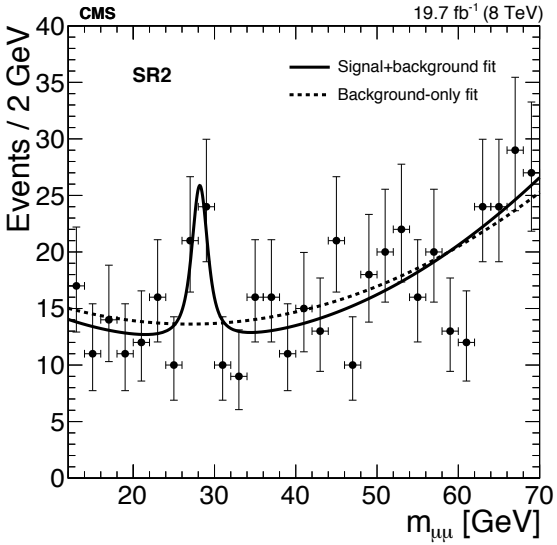


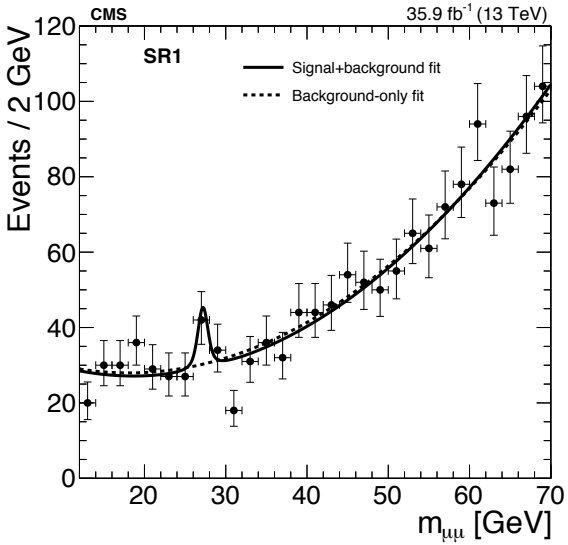
Backup

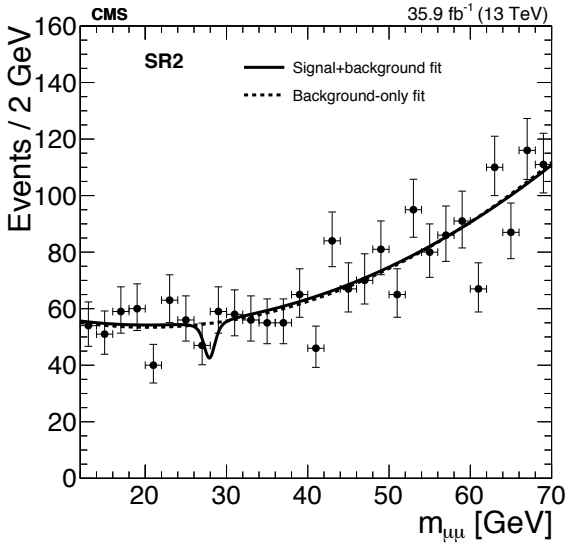
SUOMEN AKATEMIA

28 GeV bump [at 8 TeV]









- http://cms-results.web.cern.ch/cms-results/public-results/publications/HIG-16-017/index.html
- "An excess of events above the background near a dimuon mass of 28 GeV is observed in the 8 TeV data, corresponding to local significances of 4.2 and 2.9 standard deviations for the first and second event categories, respectively. A similar analysis conducted with the 13 TeV data results in a mild excess over the background in the first event category corresponding to a local significance of 2.0 standard deviations, while the second category results in a 1.4 standard deviation deficit."