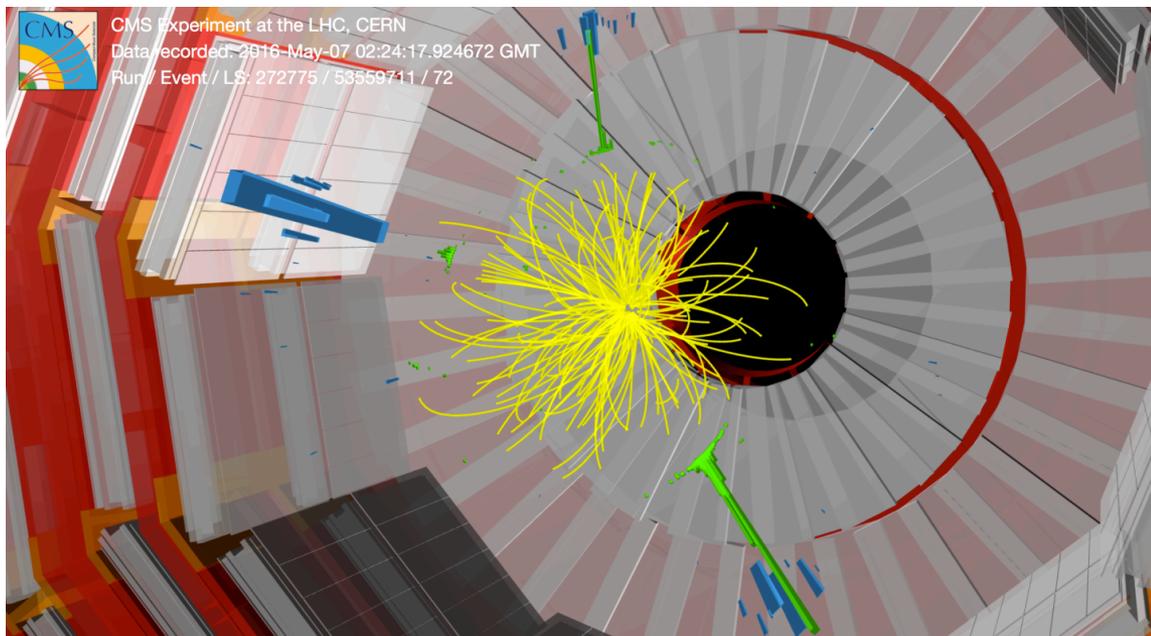
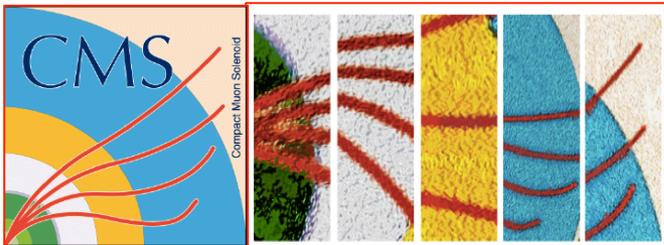


- The talk is a 25' plenary talk containing recent CMS results.
- The title is:
Selected Recent results from CMS
- Please send me corrections, comments and suggestions.
- A certain numbers of slides are just pictures or titles of sections so they will not take much time during the presentation but still I think I will have to move a few of the slides into the spare part.

Thank you

---cristina

cristina.biino@cern.ch



Selected Recent Results from CMS

Cristina Biino - INFN Torino

ICNFP2016: 5th International Conference on New Frontiers in Physics
Orthodox Academy of Crete, Kolymbari, 6-14 July 2016

LHC and CMS



LHC Large Hadron Collider



- Diameter 8.5 km
- Beam energy: 7 TeV
- Luminosity: 10^{34}
- Protons/bunch: 1.15×10^{11}
- Bunches: 2808
- Bunch spacing: 25 ns
- Machine current: 0.5 A
- Beam Stored energy: 362 MJ
- Operating temperature: 1.9 K
- Number of magnets: ~9300
- Magnet Stored Energy 8800 MJ
- Power consumption: ~120 MW
- Cost: 9.0×10^9 \$

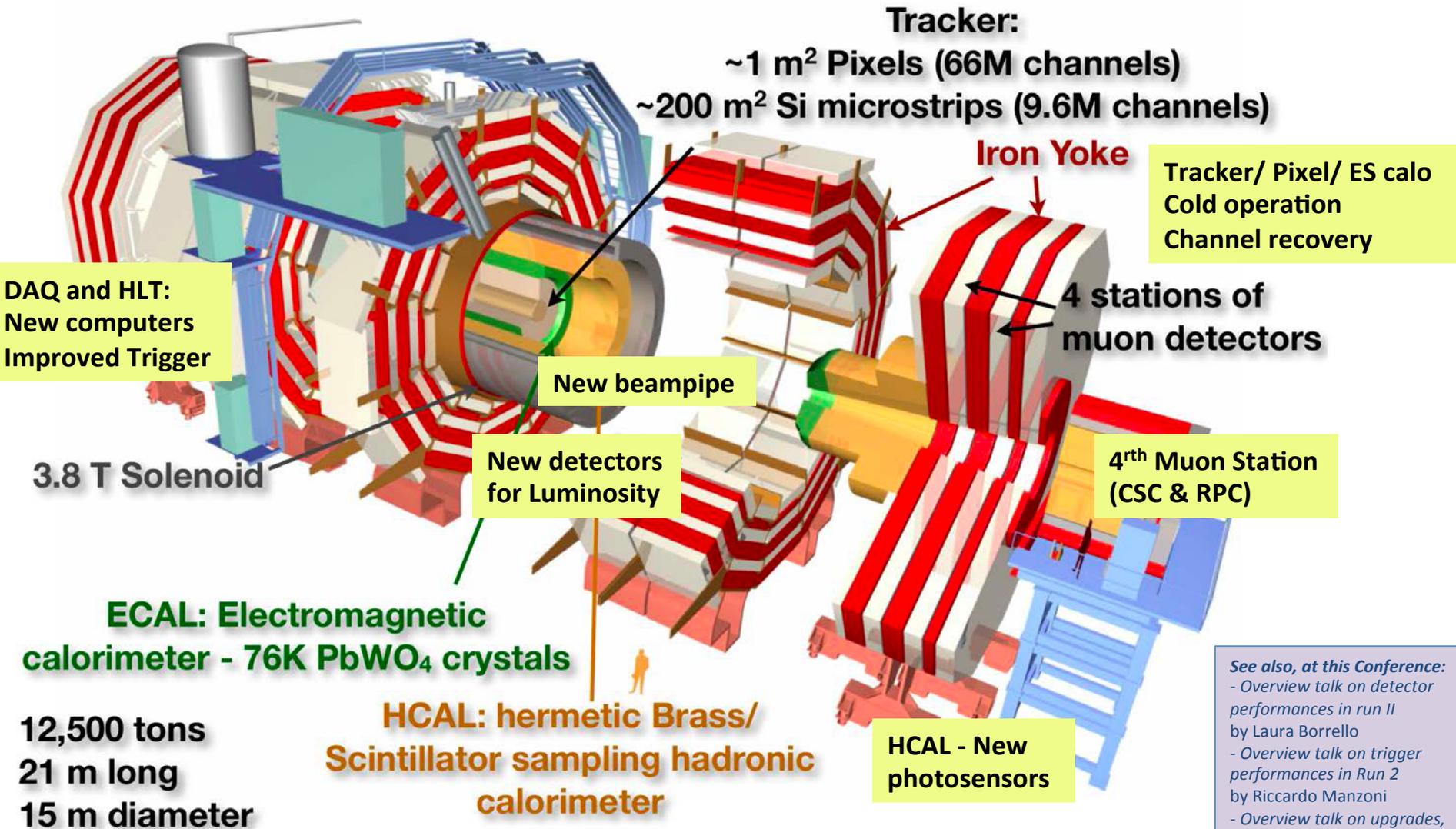
The Large Hadron Collider (LHC), one of the largest and truly global scientific projects ever

- pp collisions at a centre of mass energy of 7, 8 and 13 TeV
- PbPb collisions at a centre of mass energy of 2.76 TeV/nucleon.



5200 members: 1900 physicists, 1800 students, 950 engineers/technicians from 193 institutions, 43 countries

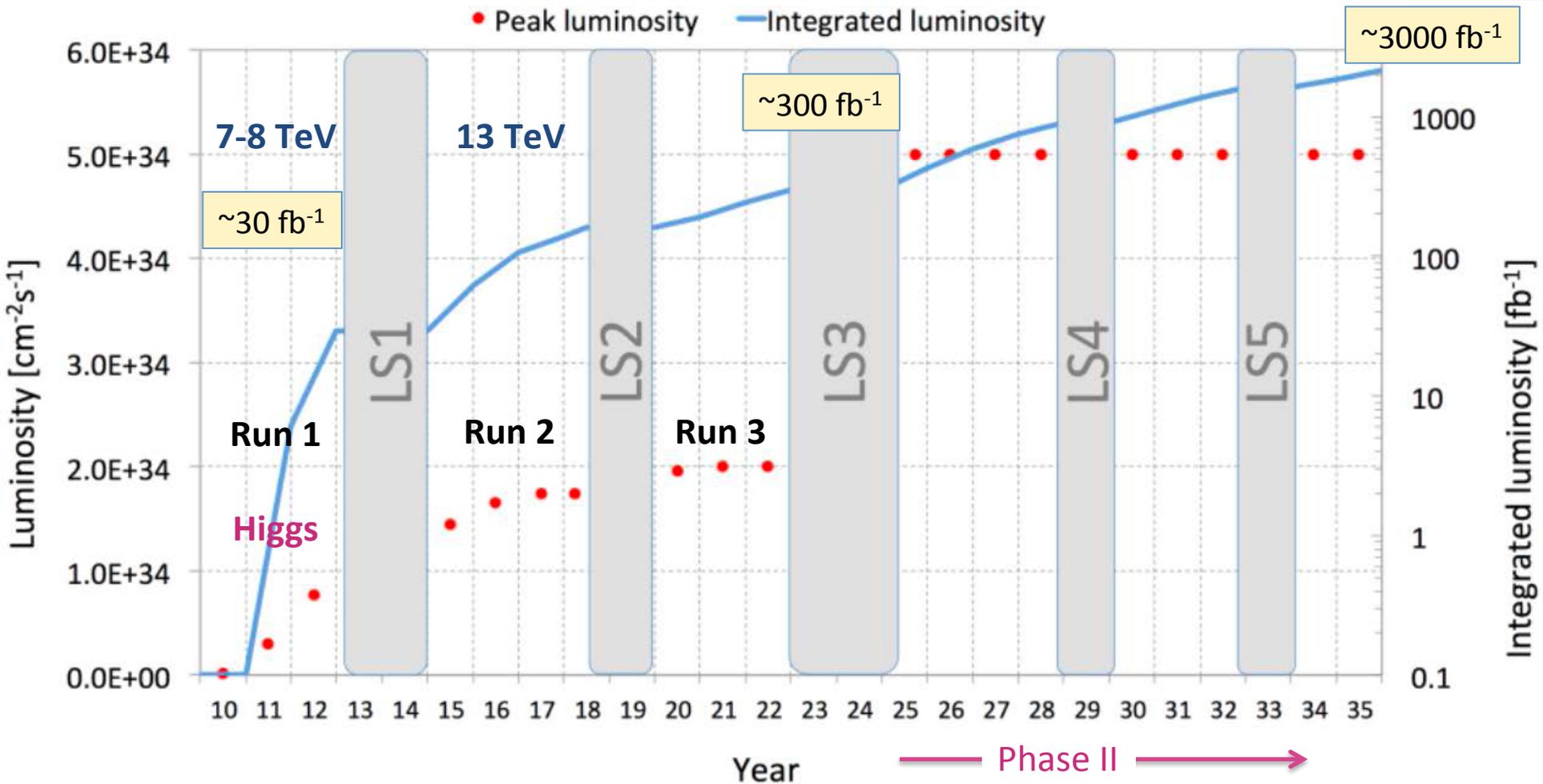
CMS - after LS1



See also, at this Conference:

- Overview talk on detector performances in run II by Laura Borrello
- Overview talk on trigger performances in Run 2 by Riccardo Manconi
- Overview talk on upgrades, future plans and prospects by Giacomo Bruno

LHC – 2010-2035



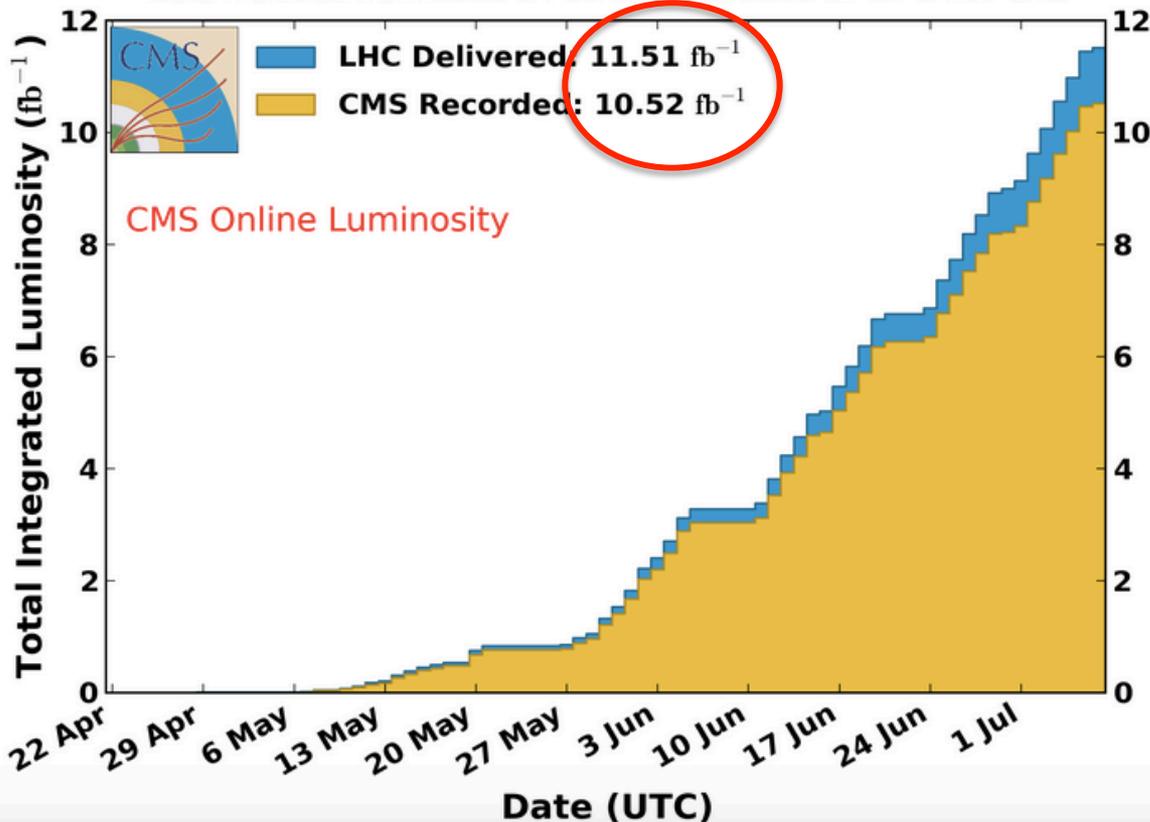
- Major Achievement: **Higgs discovery** and characterization → Mass, spin, coupling, ...
- Top Quark: LHC is a top quark factory → High precision measurements: mass, decays, spin...
- Searches for SUSY and other exotic particles BSM → Many limits for masses and couplings

13 TeV Operation and Luminosity



CMS Integrated Luminosity, pp, 2016, $\sqrt{s} = 13$ TeV

Data included from 2016-04-22 22:48 to 2016-07-07 04:17 UTC



25 ns bunch spacing instead of 50 ns in Run1

2016 - LHC outstanding performance

Record fills with up to 0.7/fb
Delivery >10/fb by ICHEP conference → ~25/fb by end of 2016 seems possible

Major work accomplished during end-of-the-year shutdown

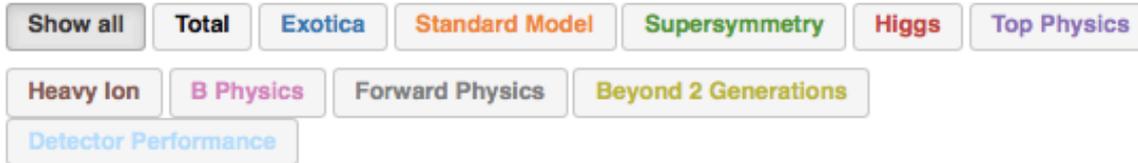
Solenoid cooling system fixed successfully, magnet stable at 3.8 T

<https://twiki.cern.ch/twiki/bin/view/CMSPublic/LumiPublicResults>

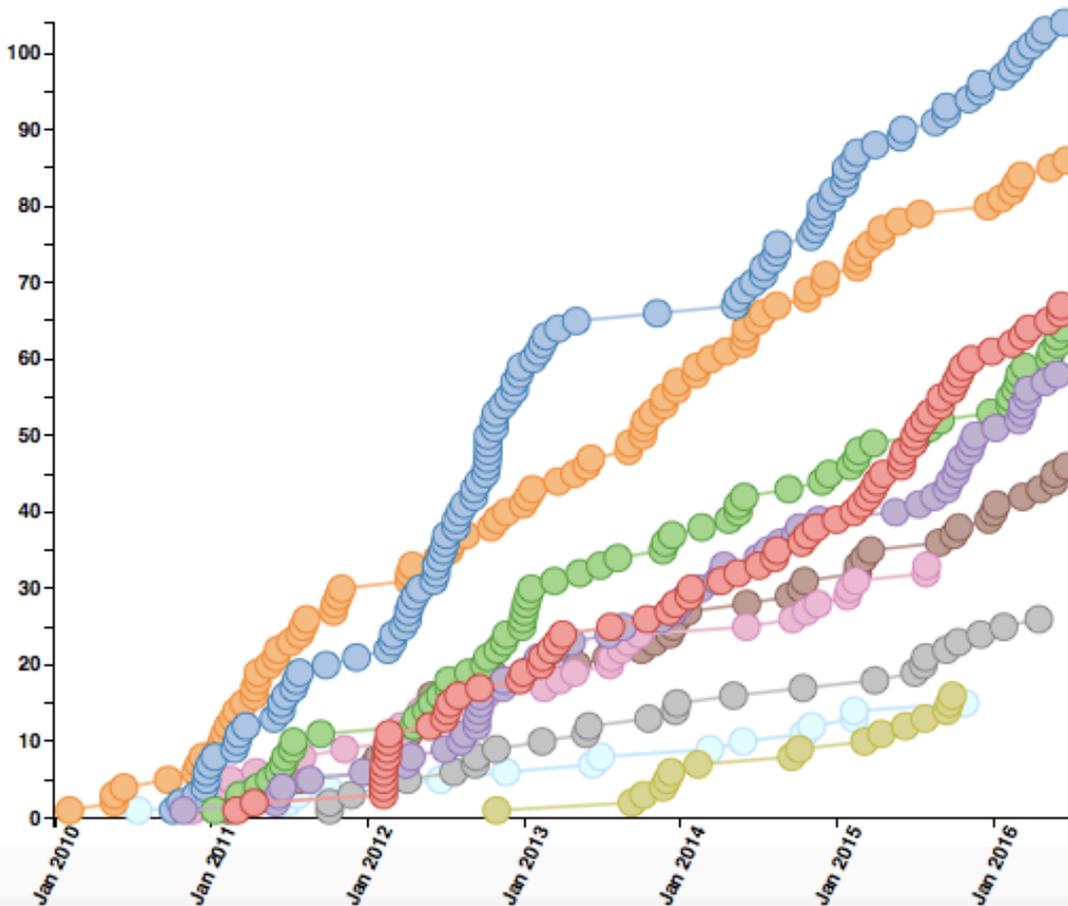
In 2015 @ 13 TeV: LHC delivered 4.2 fb⁻¹ ; CMS recorded 3.8(2.8) fb⁻¹
Instantaneous luminosity >8 10³³ cm²/s; reached 1.1 10³⁴ cm²/s; PU ~25

Recovery of dead regions. All detectors in excellent shape for data taking.

CMS – Physics Results

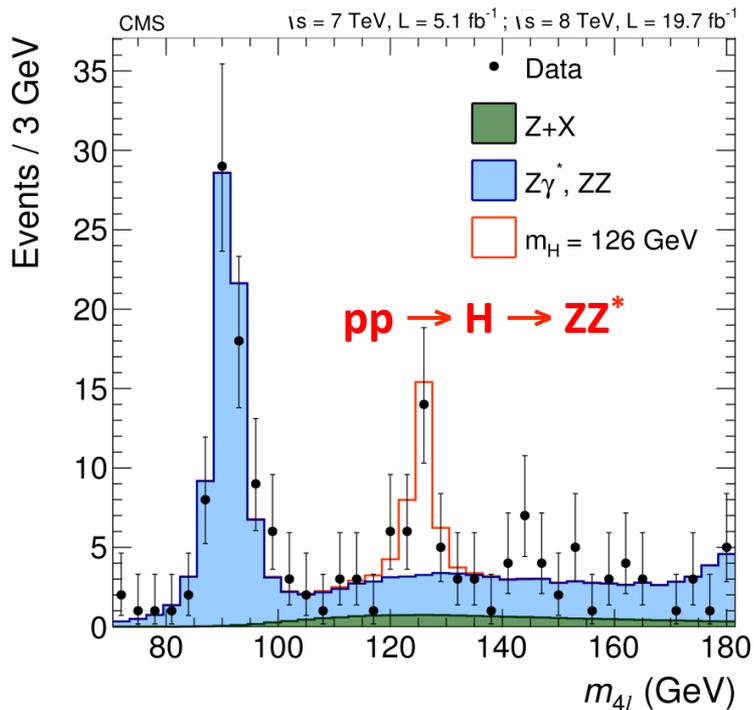


514 collider data papers submitted as of 2016-06-21



- In total over 500 papers submitted/published
- Already ~100 Run 2 public results
- Recent Run 1 legacy papers on precision measurements:
 - Higgs - Top
 - Electroweak - QCD
 - Heavy Flavour

To be remembered from Run1



Phys. Rev. D 89 (2014) 092007

Eur. Phys. J. C 74 (2014) 3076

The Economist

In praise of charter schools
Britain's banking scandal spreads
Volkswagen overtakes the rest
A power struggle at the Vatican
When Lonesome George met Nora

A giant leap for science

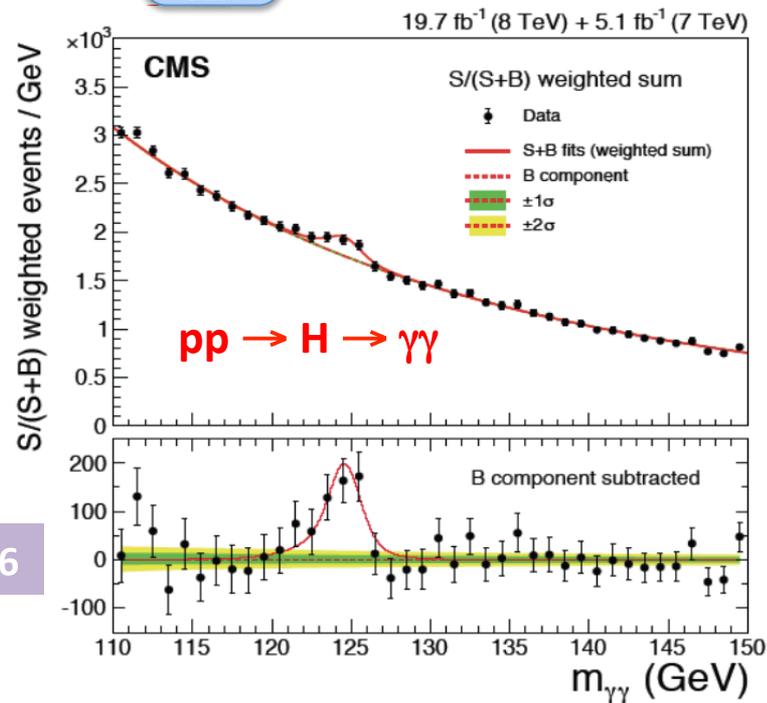
17,000 news articles in
108 countries in
2 days

Finding the Higgs boson

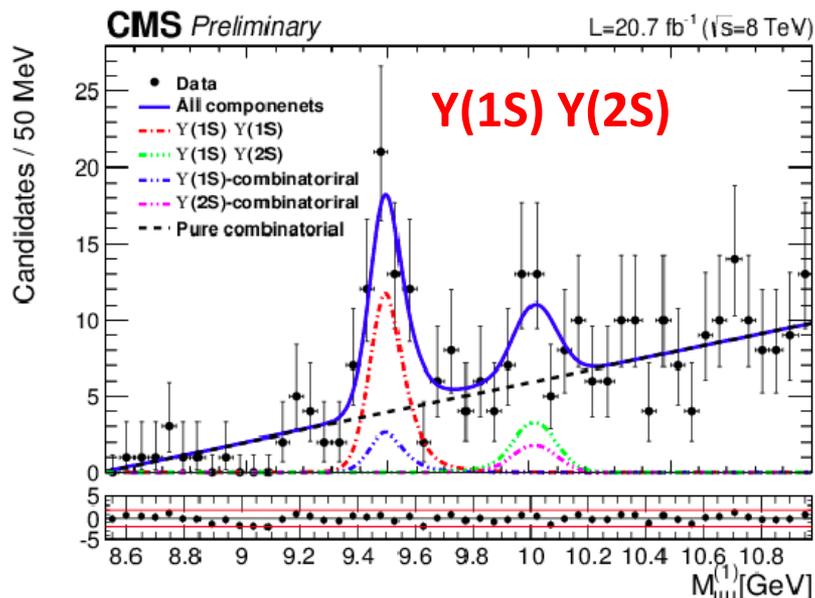
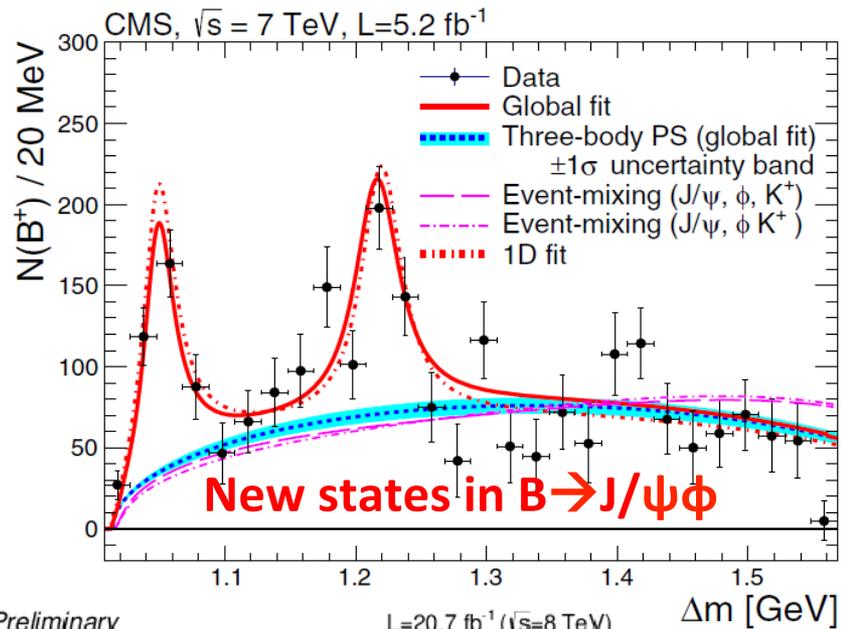
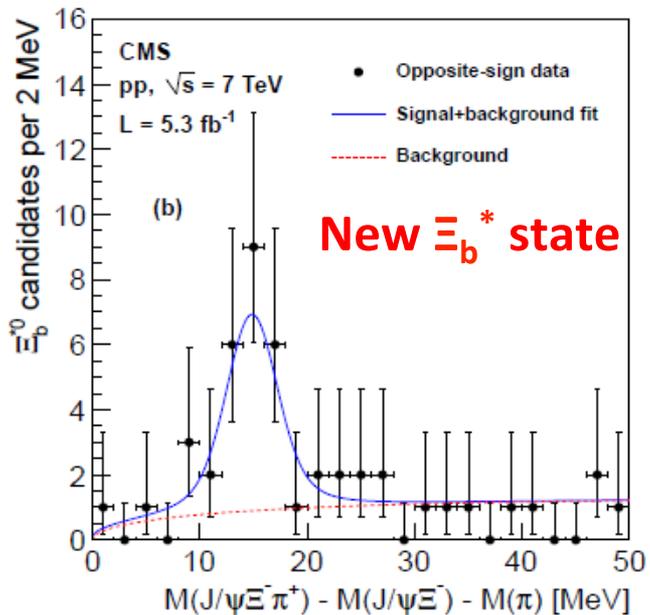
Science

BREAKTHROUGH of the YEAR
The HIGGS BOSON

> 1 billion people saw TV footage
1,034 TV stations
5,016 Broadcasts



To be remembered from Run1

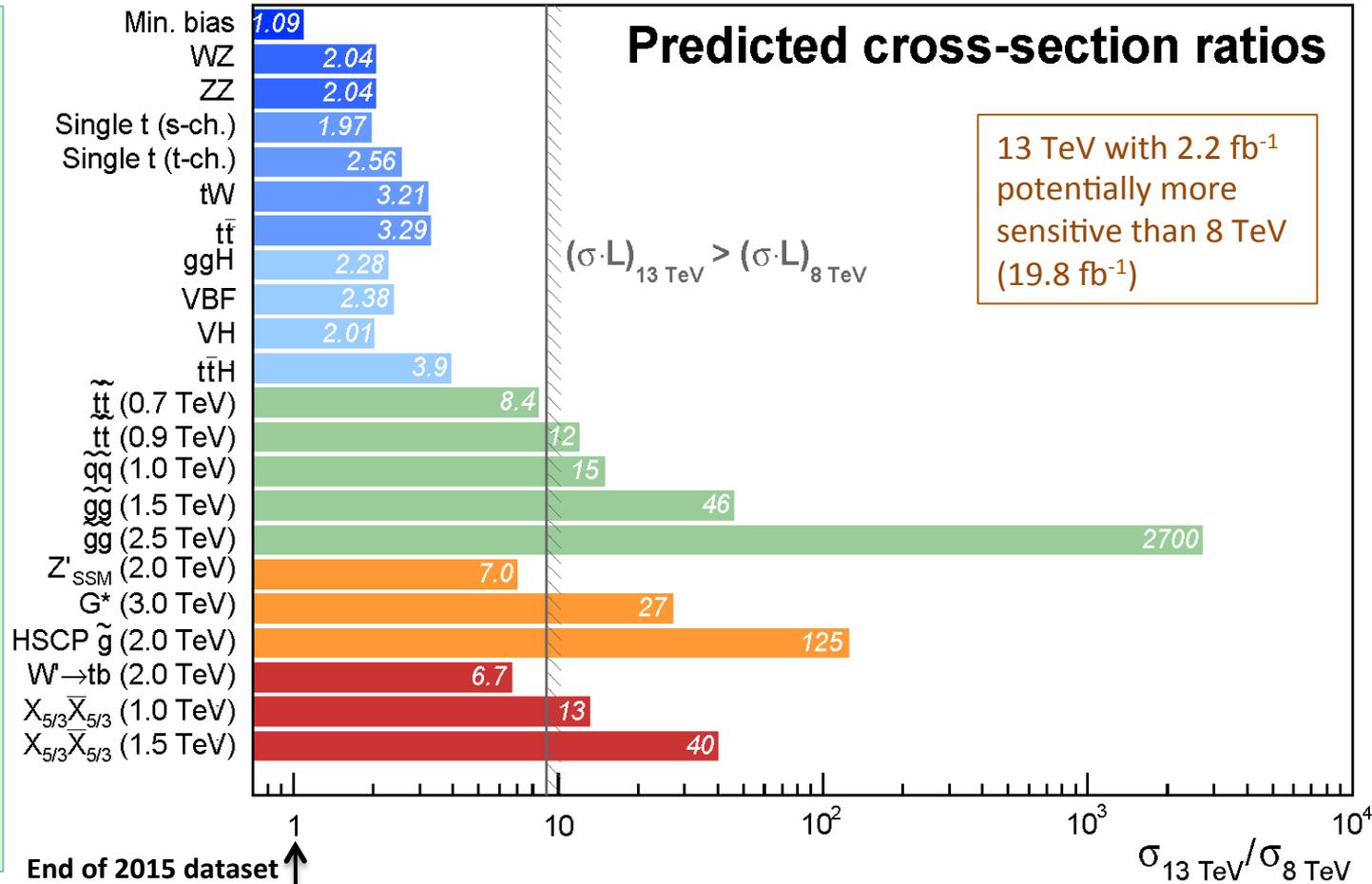


Reach Increase @ 13 TeV

A gain in parton luminosity has a significant effect on the discovery reach for new particles, and the full exploitation of this new phase space is a primary goal of the actual run after LS1

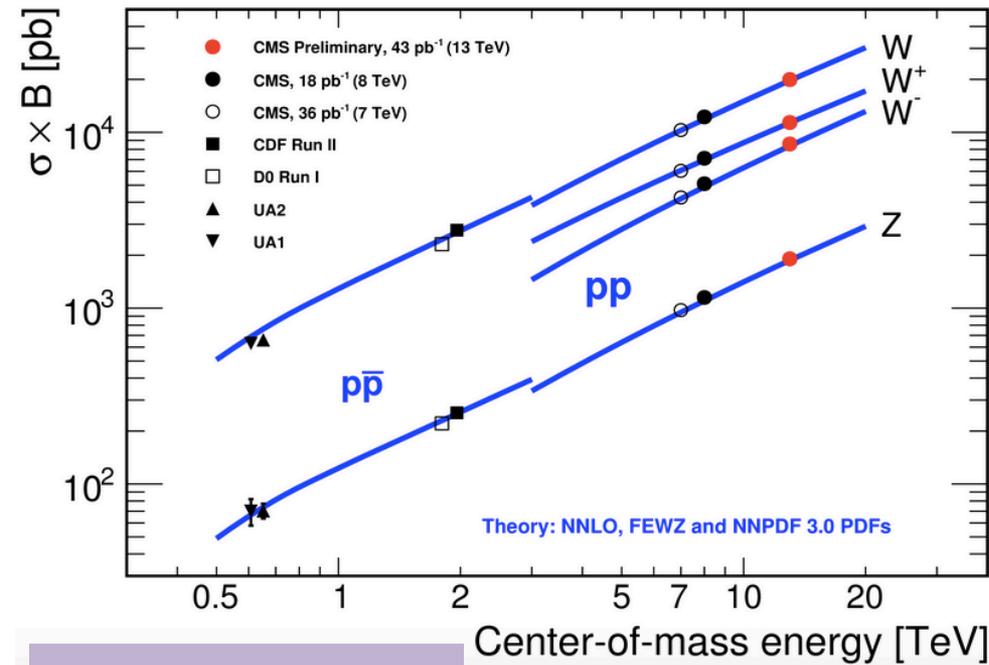
Example physics potential with $L \sim 10 \text{ fb}^{-1}$

- 750 GeV mass resonance searches (if gg-produced)
- H(125) full programme
- Better sensitivity for Dark Matter in high-mass mediator region
- Searches for $X \rightarrow VV$ with $M_X \sim \text{TeV}$
- New vector-like quarks
- SUSY via EWK interactions
- Search for anomalous couplings



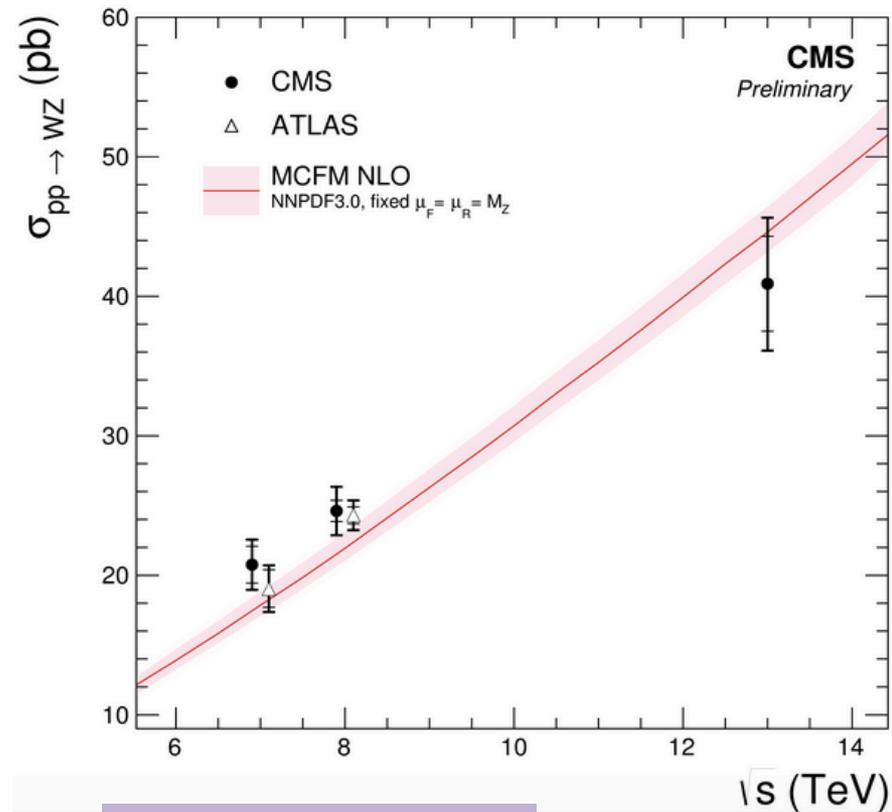
Standard Model at $\sqrt{s} = 13$ TeV

Inclusive W, Z productions Including $\sqrt{s} = 13$ TeV result



CMS-PAS-SMP-15-004

Diboson productions Including at $\sqrt{s} = 13$ TeV



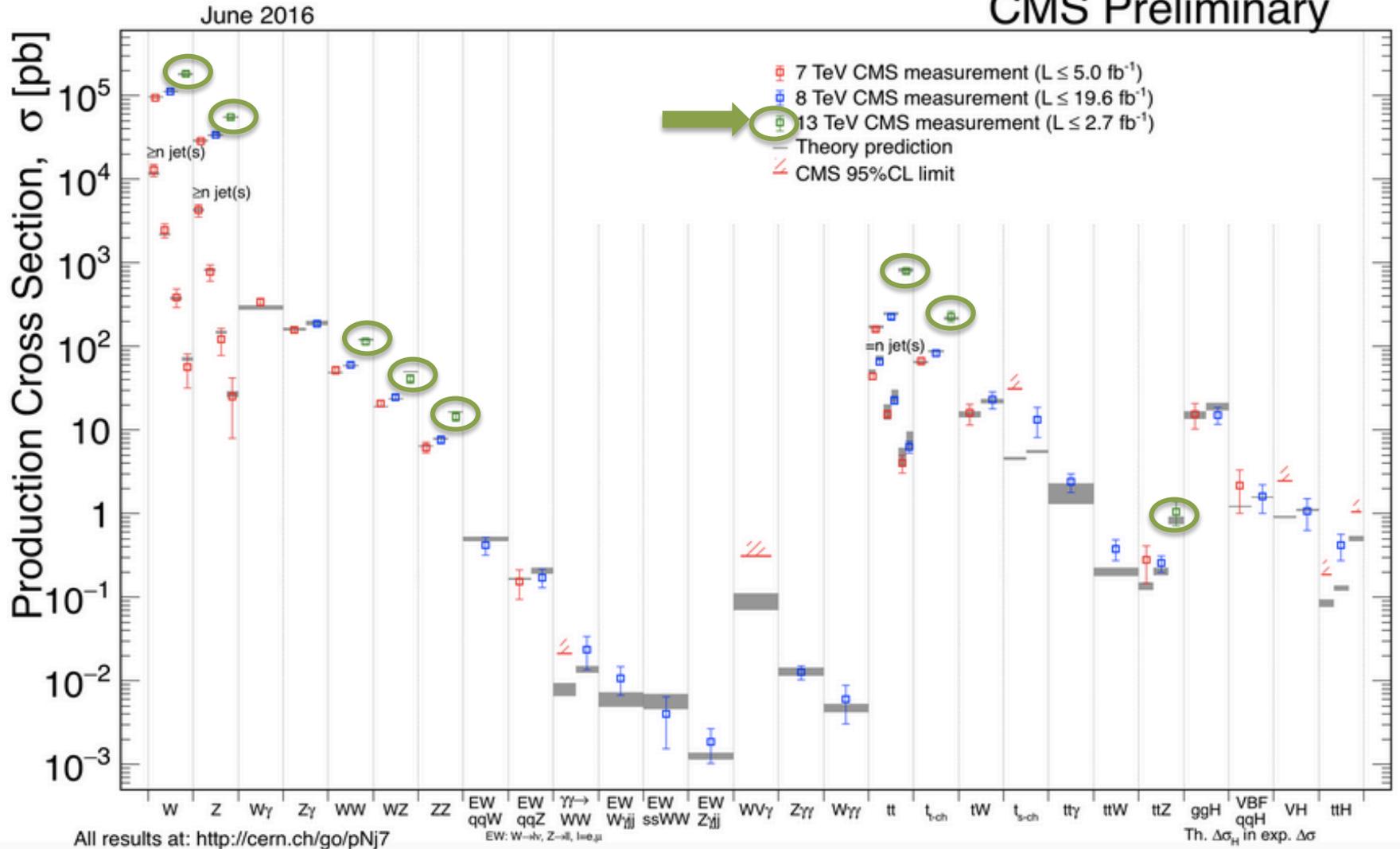
CMS-PAS-SMP-16-002

SM - summary @ 13 TeV



Good agreement between data and theory

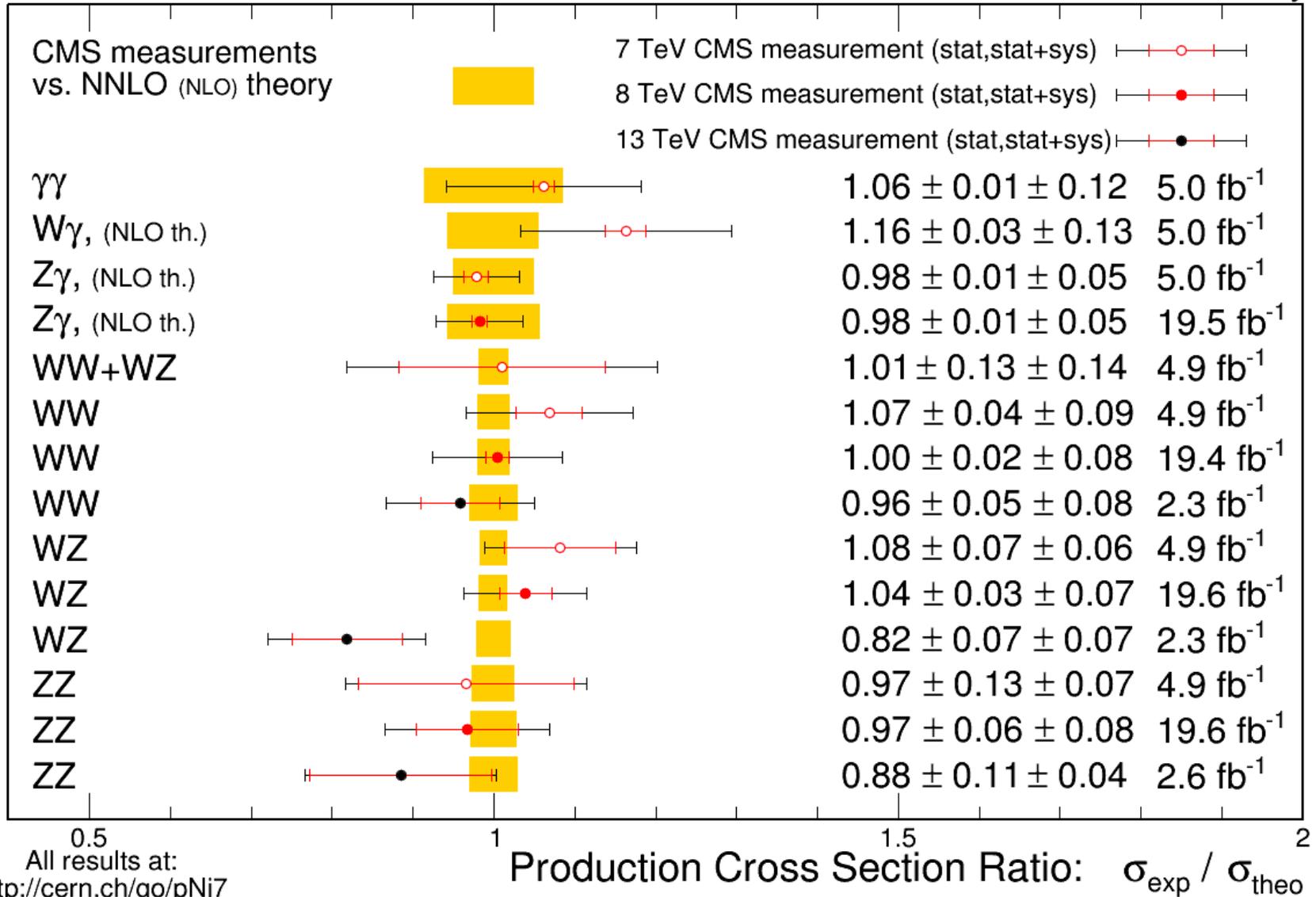
CMS Preliminary



Summary of diboson production

June 2016

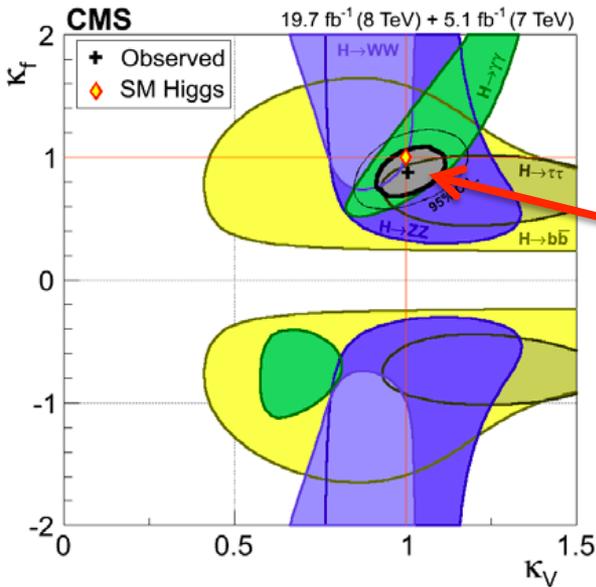
CMS Preliminary



Higgs combination (Run 1)

- Five main decay channels all published
- All results consistent with SM Higgs

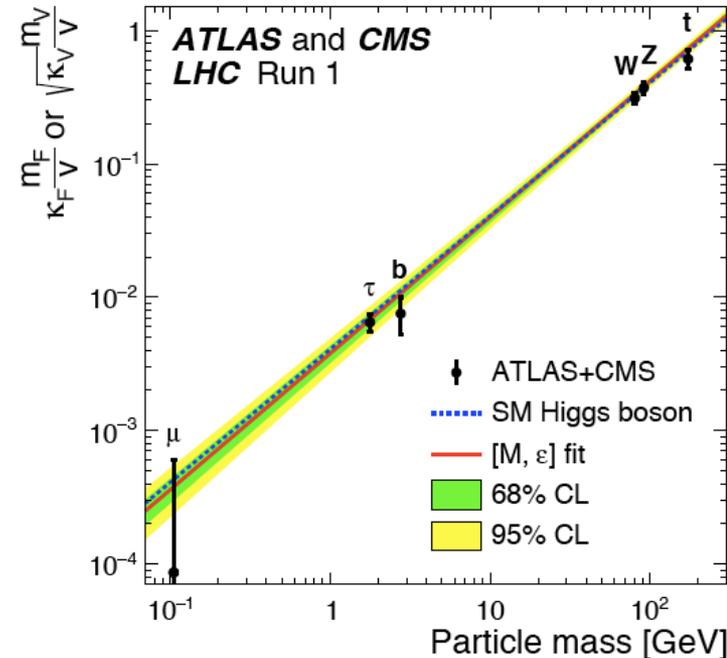
$$m_H = 125.02^{+0.26}_{-0.27} \text{ (stat.) }^{+0.14}_{-0.15} \text{ (syst.) GeV}$$



SM

Channel	Obs (σ)	Exp(σ)
H → ZZ	6.5	6.3
H → γγ	5.6	5.3
H → WW	4.7	5.4
H → ττ	3.8	3.9
H → bb	2.0	2.6
H → μμ	<0.1	0.4

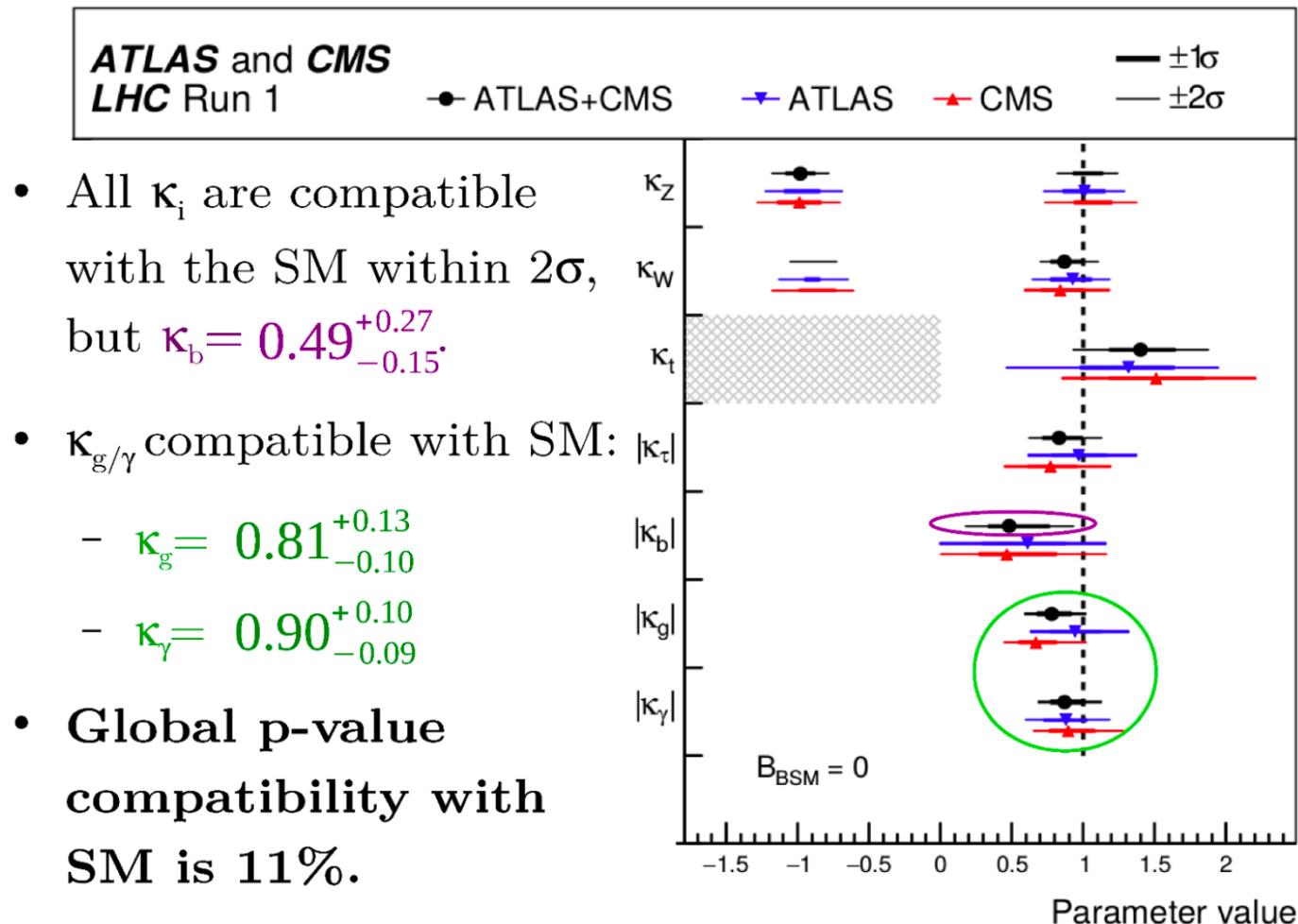
arXiv: 1606.02266



Higgs coupling combination (Run 1)

Measurements of the Higgs boson production and decay rates and constraints on its couplings from a combined ATLAS and CMS analysis of the LHC pp collision data at \sqrt{s} 7 and 8 TeV

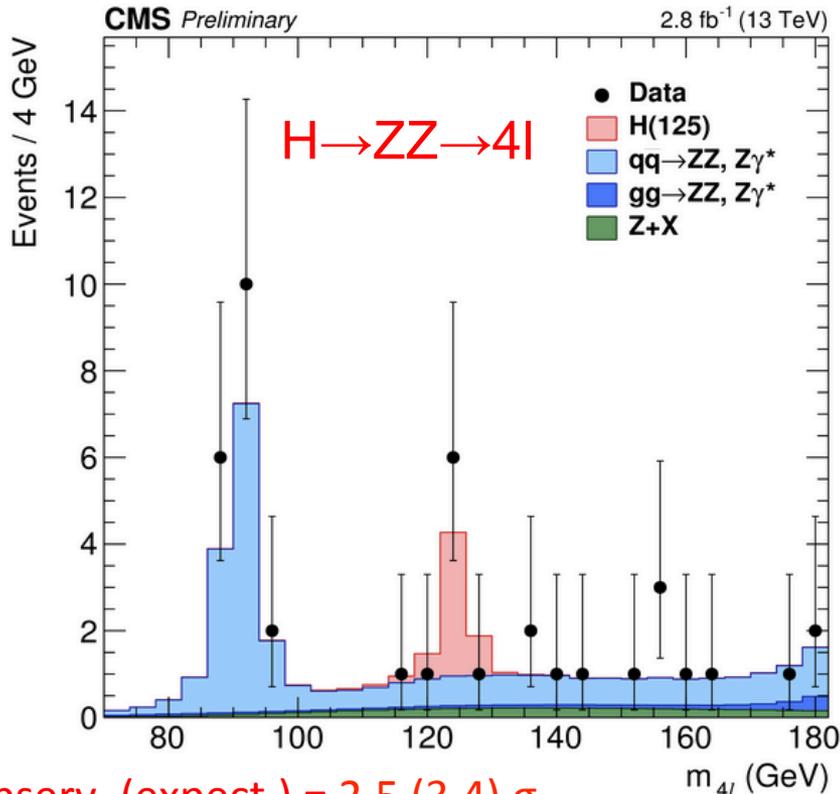
arXiv: 1606.02266



Higgs re-discovery at 13 TeV

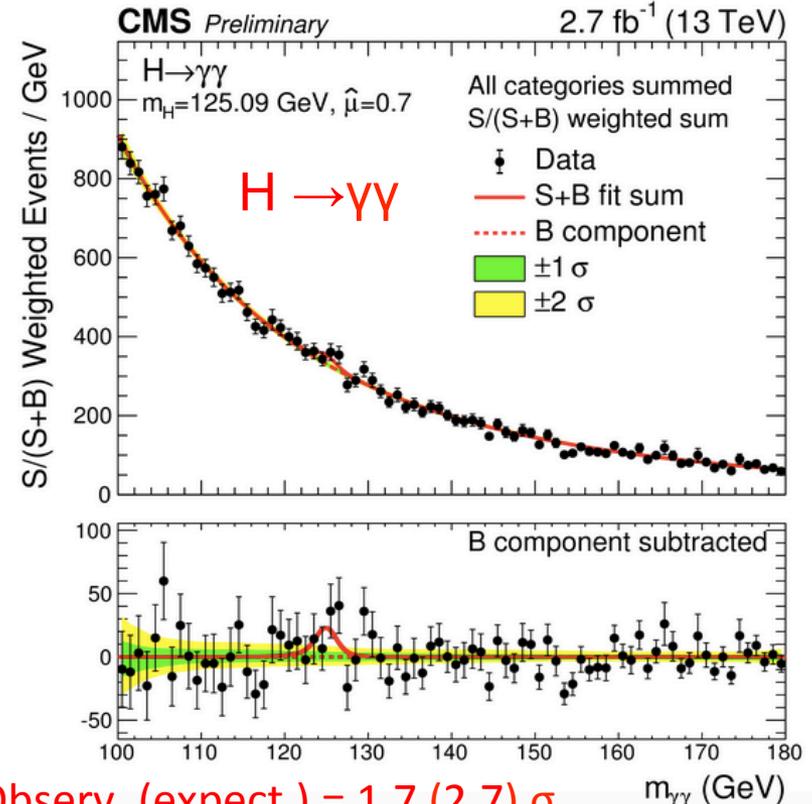


Higgs “discovery” decays to bosonic channels



Observ. (expect.) = 2.5 (3.4) σ
 $\mu = 0.82^{+0.57}_{-0.43}$

CMS-PAS-HIG-15-004



Observ. (expect.) = 1.7 (2.7) σ
 $\mu = 0.69^{+0.47}_{-0.42}$

CMS-PAS-HIG-15-005

Higgs: signal strength is consistent with SM

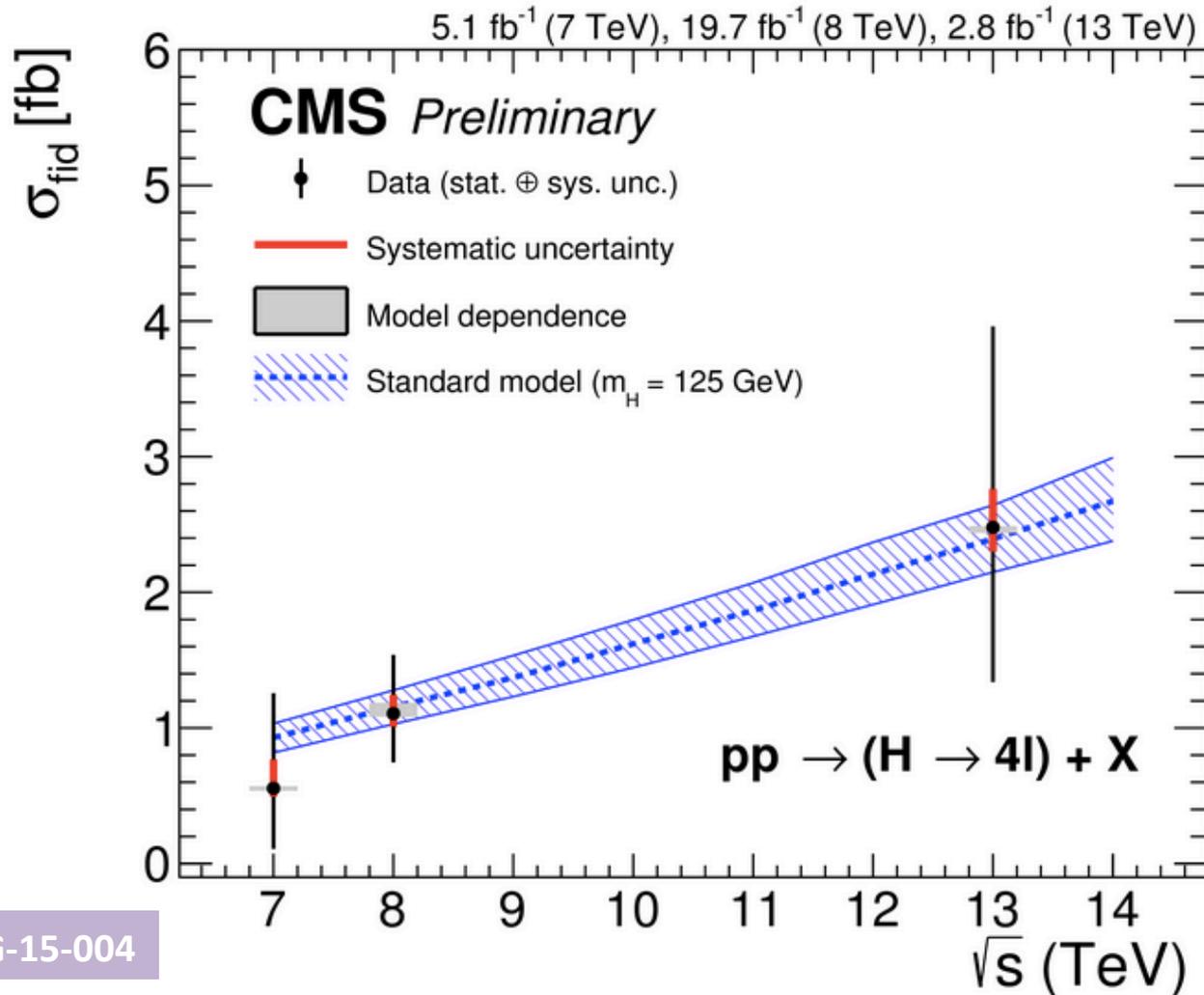
→ Studies of Higgs properties and searches of BSM Higgs boson

Higgs re-discovery



Energy dependence

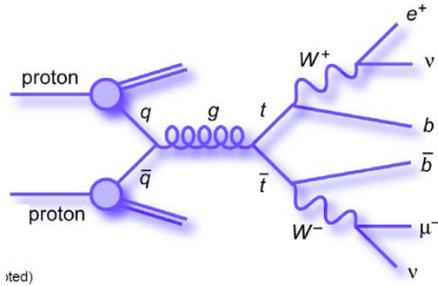
$H \rightarrow ZZ^* \rightarrow 4l$



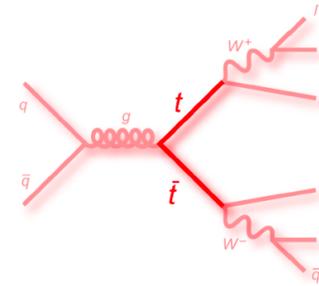
CMS-PAS-HIG-15-004

Top quark – precision physics

Top pair to di-leptons



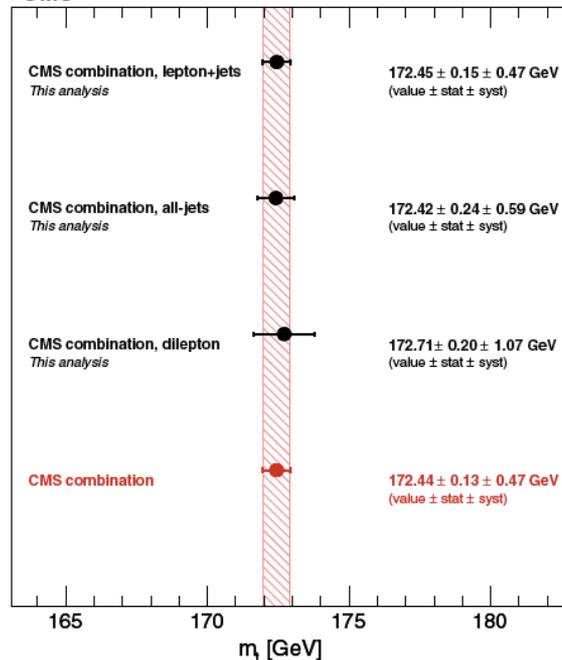
Top pair leptons+jets



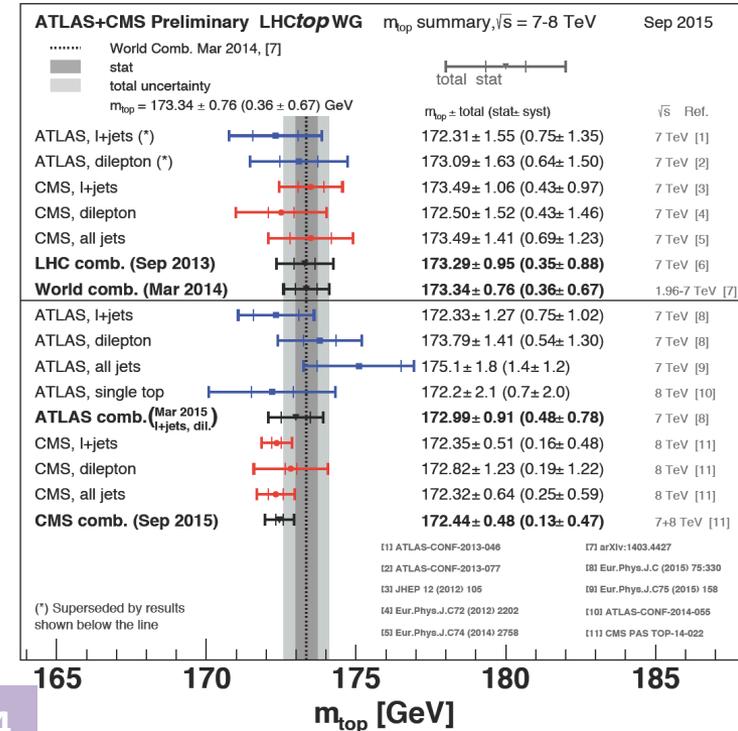
Top pair all hadronic

- Top quark mass is an important parameter of the SM.
- Precise measurements of top quark mass provide critical inputs to the fits of global EW parameters.
- Internal consistency check with the SM.
- Affect the stability of the SM Higgs potential.
- Check the validity of perturbative QCD.

CMS

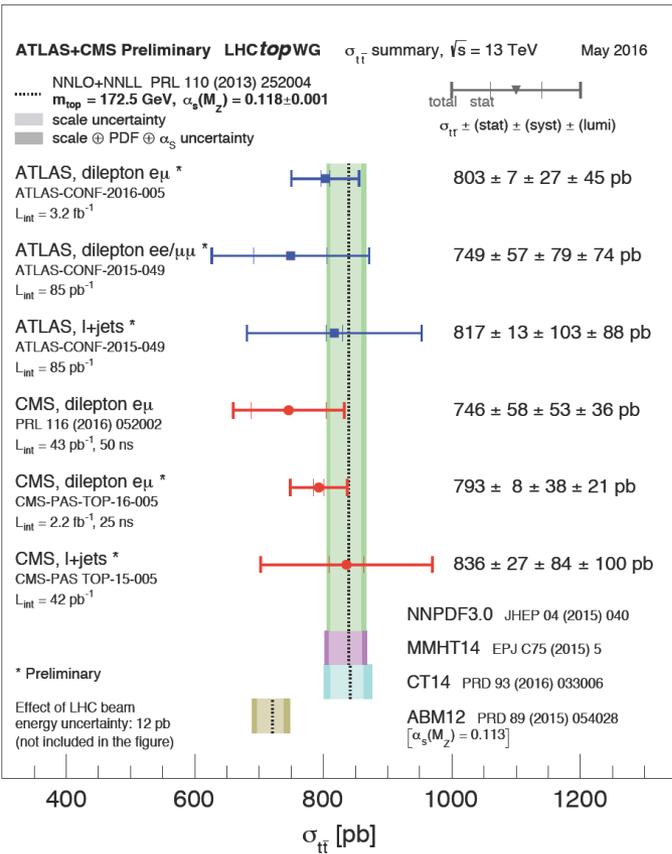


Phys. Rev. D 93 (2016) 7, 072004

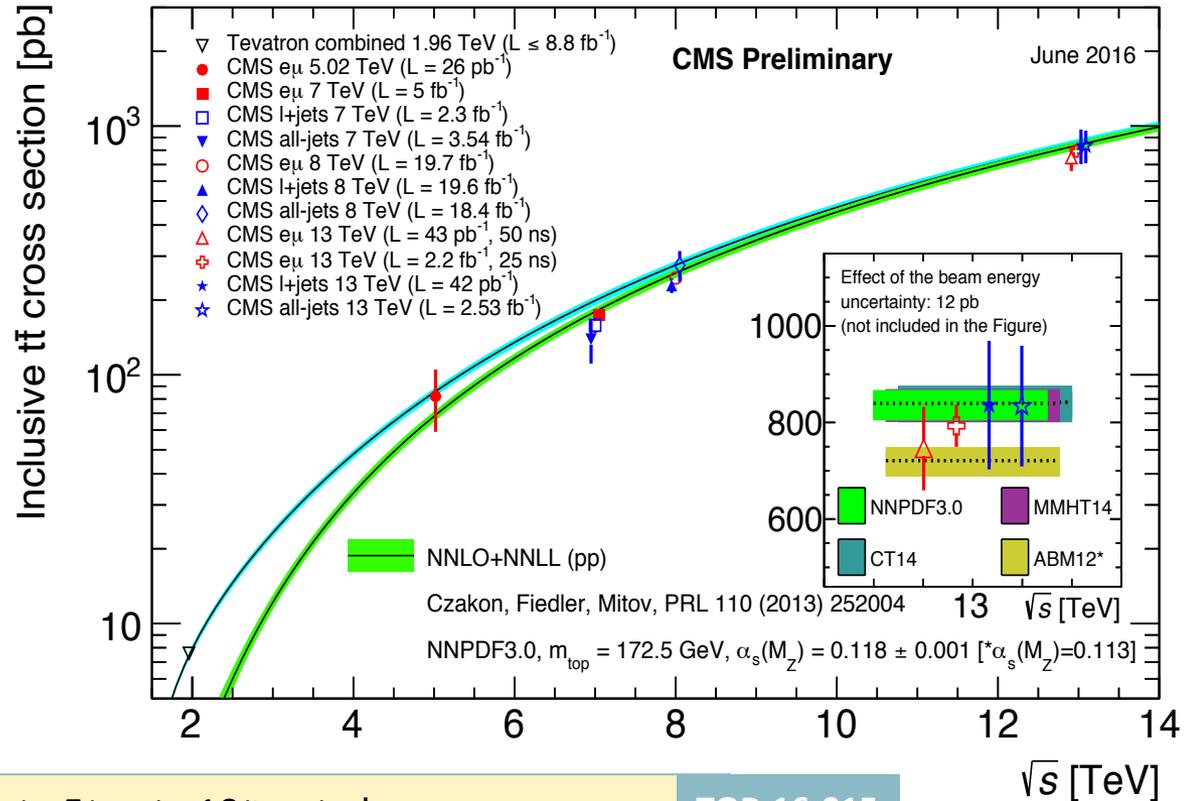


High precision top quark measurements with preliminary Run 1 combinations

Top quark – precision physics



$t\bar{t}$ cross-section



$\sigma(t\bar{t})$ @ 5.02 TeV, 26 pb $^{-1}$ = $82 \pm 20(\text{stat}) \pm 5(\text{syst}) \pm 10(\text{lumi})$ pb

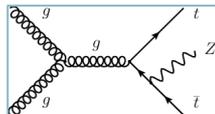
$\sigma(t\bar{t})$ @ 13 TeV, 2.53 fb $^{-1}$ = $834 \pm 25(\text{stat}) + 118-104(\text{syst}) \pm 23(\text{lumi})$ pb, in all jets

$\sigma(t\bar{t})$ @ 13 TeV, 2.2 fb $^{-1}$ = $793 \pm 8(\text{stat}) \pm 38(\text{syst}) \pm 21(\text{lumi})$ pb, in $e\mu$ 2jets

TOP-16-015

TOP-16-005

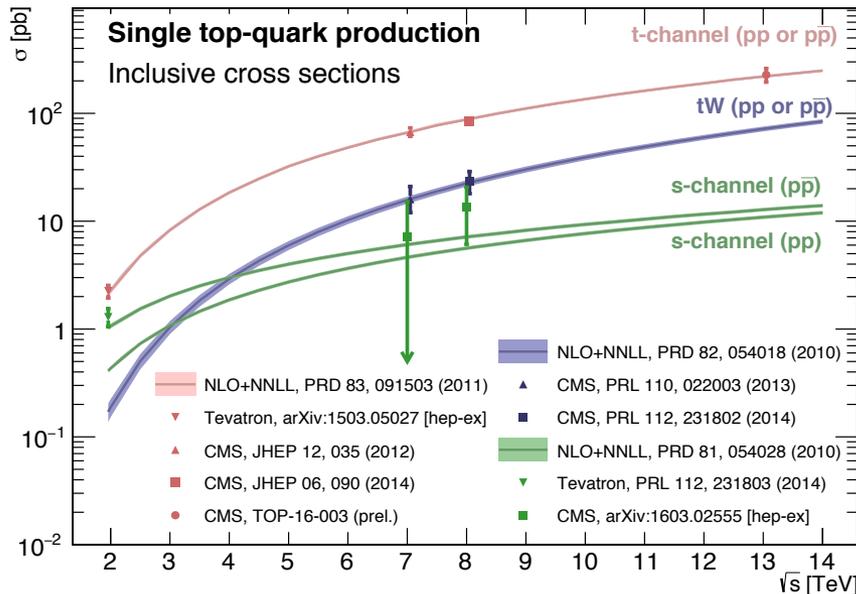
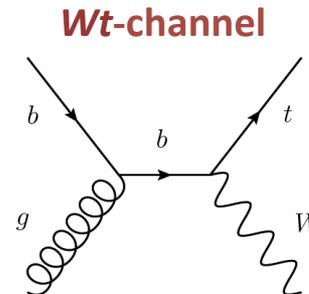
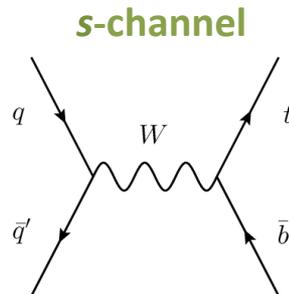
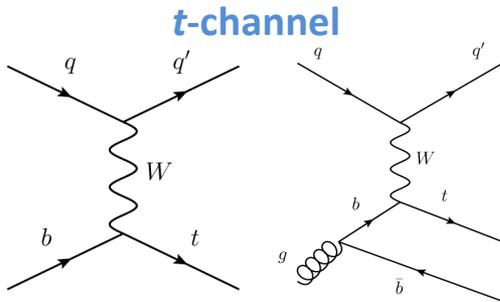
TOP-16-013



$\sigma(t\bar{t}Z)$ @ 13 TeV, 2.7 pb $^{-1}$ = $1065 + 352-313(\text{stat}) + 168-142(\text{syst})$ fb

TOP-16-009

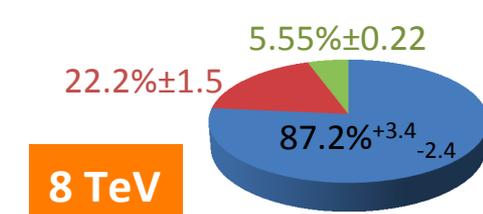
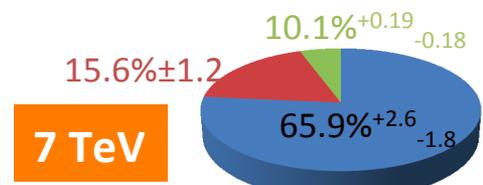
Single Top at $\sqrt{s} = 13$ TeV



$$\sigma_{t\text{-chan}}^{13\text{TeV}} \sim 2.5 \times \sigma_{t\text{-chan}}^{8\text{TeV}}$$

NNLO precision for single top t-channel production rate

- Theory: $\sim 1\%$
- Measurements:
 - $\sim 10\%$ at 8 TeV, with 20/fb
 - $\sim 15\%$ at 13 TeV with 2.3/fb



TOP-16-003

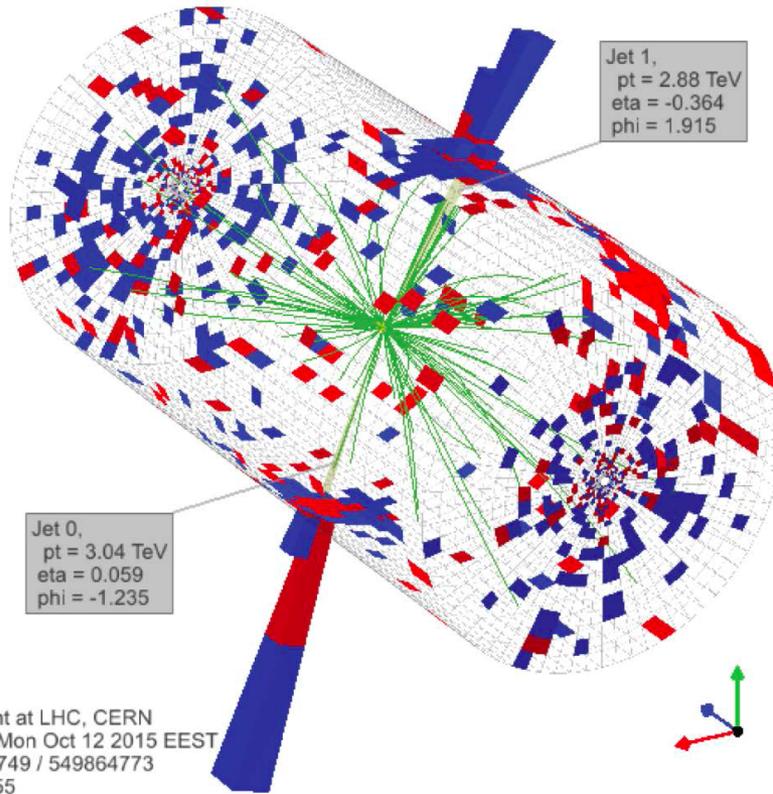
$$\sigma_{t\text{-ch.,t}} = 141.5 \pm 6.7 \text{ (stat)} \pm 9.4 \text{ (exp)} + 19.3\text{--}19.6 \text{ (theo)} \pm 3.8 \text{ (lumi)} \text{ pb}$$

$$= 141.5_{-23.0}^{+22.8} \text{ pb,}$$

$$\sigma_{t\text{-ch.,t}^-} = 81.0 \pm 6.2 \text{ (stat)} \pm 8.1 \text{ (exp)} + 10.9\text{--}10.9 \text{ (theo)} \pm 2.2 \text{ (lumi)} \text{ pb}$$

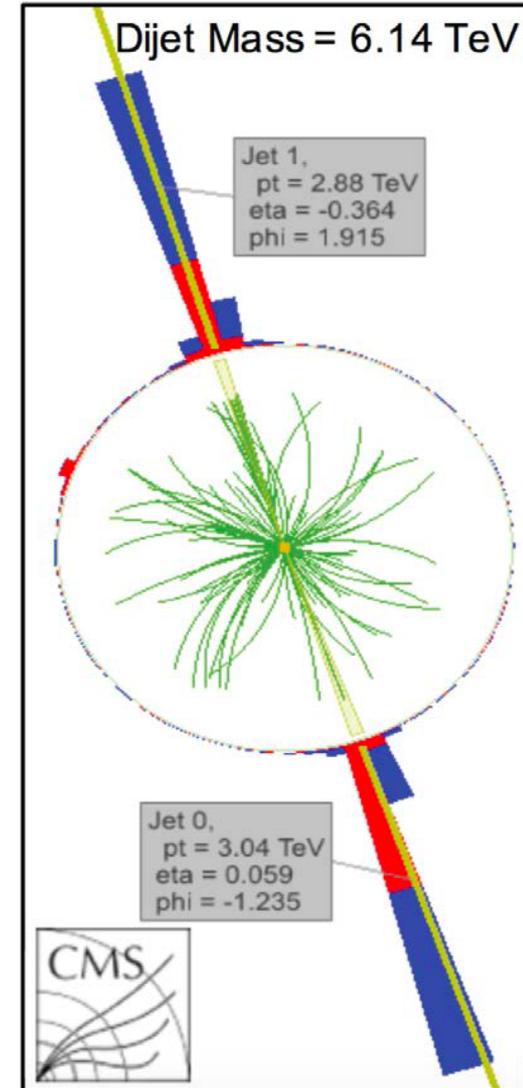
$$= 81.0_{-15.1}^{+15.1} \text{ pb.}$$

Event Display: high mass dijet



CMS Experiment at LHC, CERN
Data recorded: Mon Oct 12 2015 EEST
Run/Event: 258749 / 549864773
Lumi section: 355
Dijet Mass: 6.14 TeV

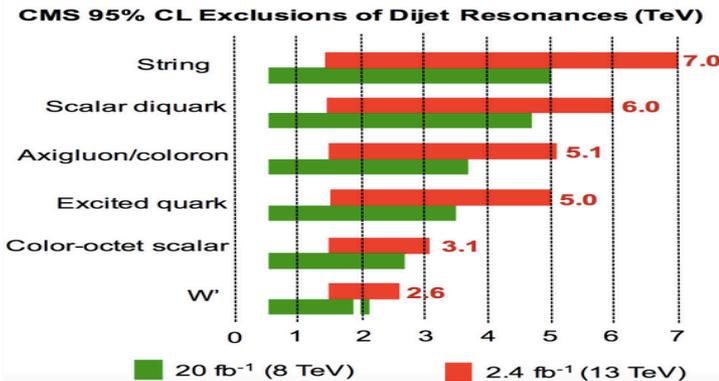
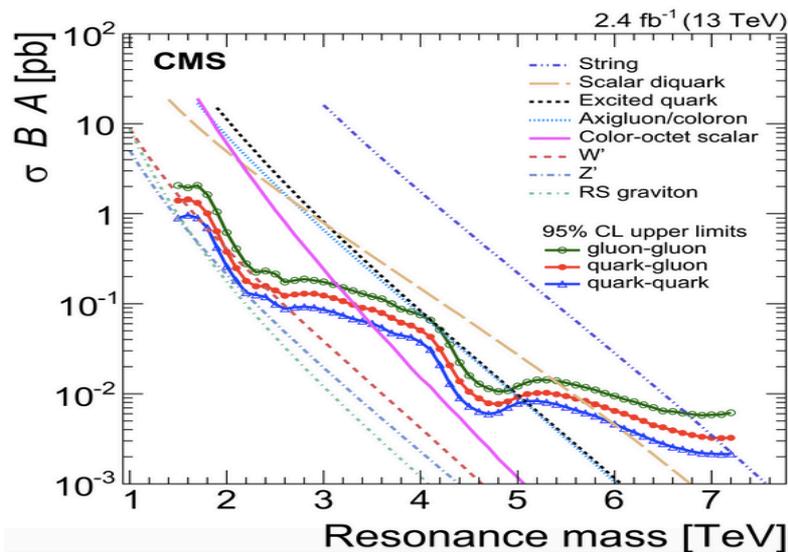
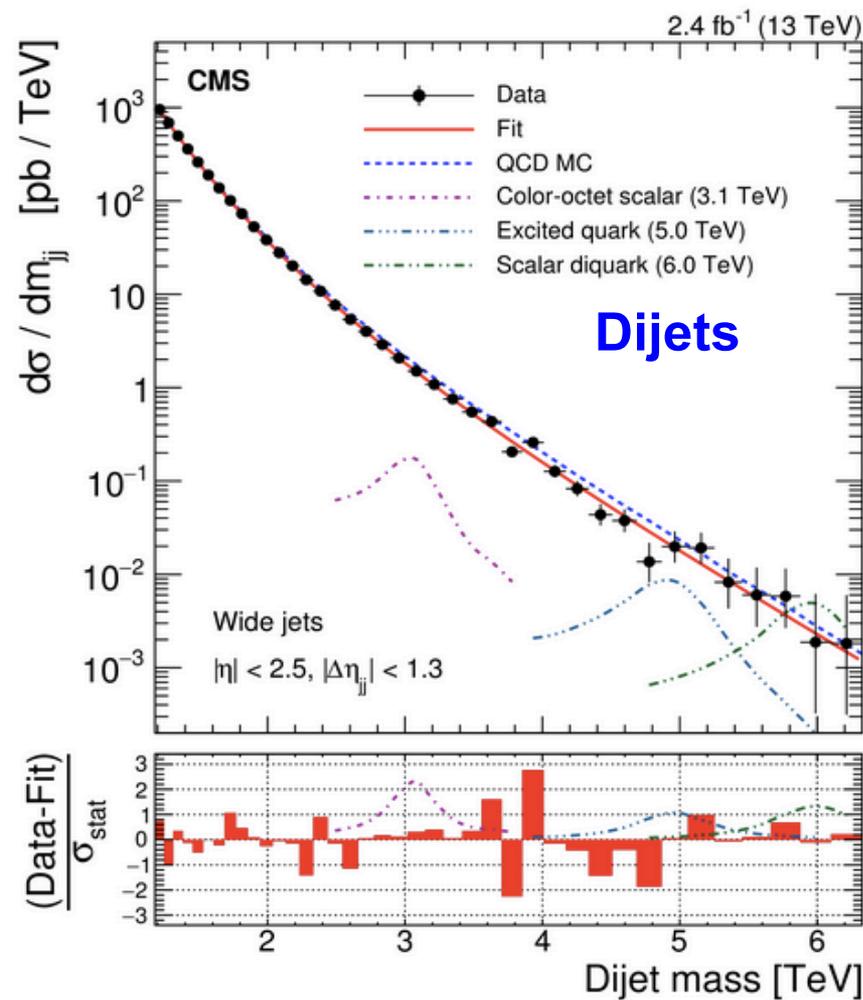
$M_{jj} = 6.14 \text{ TeV}$



Search for high mass resonances in Dijets

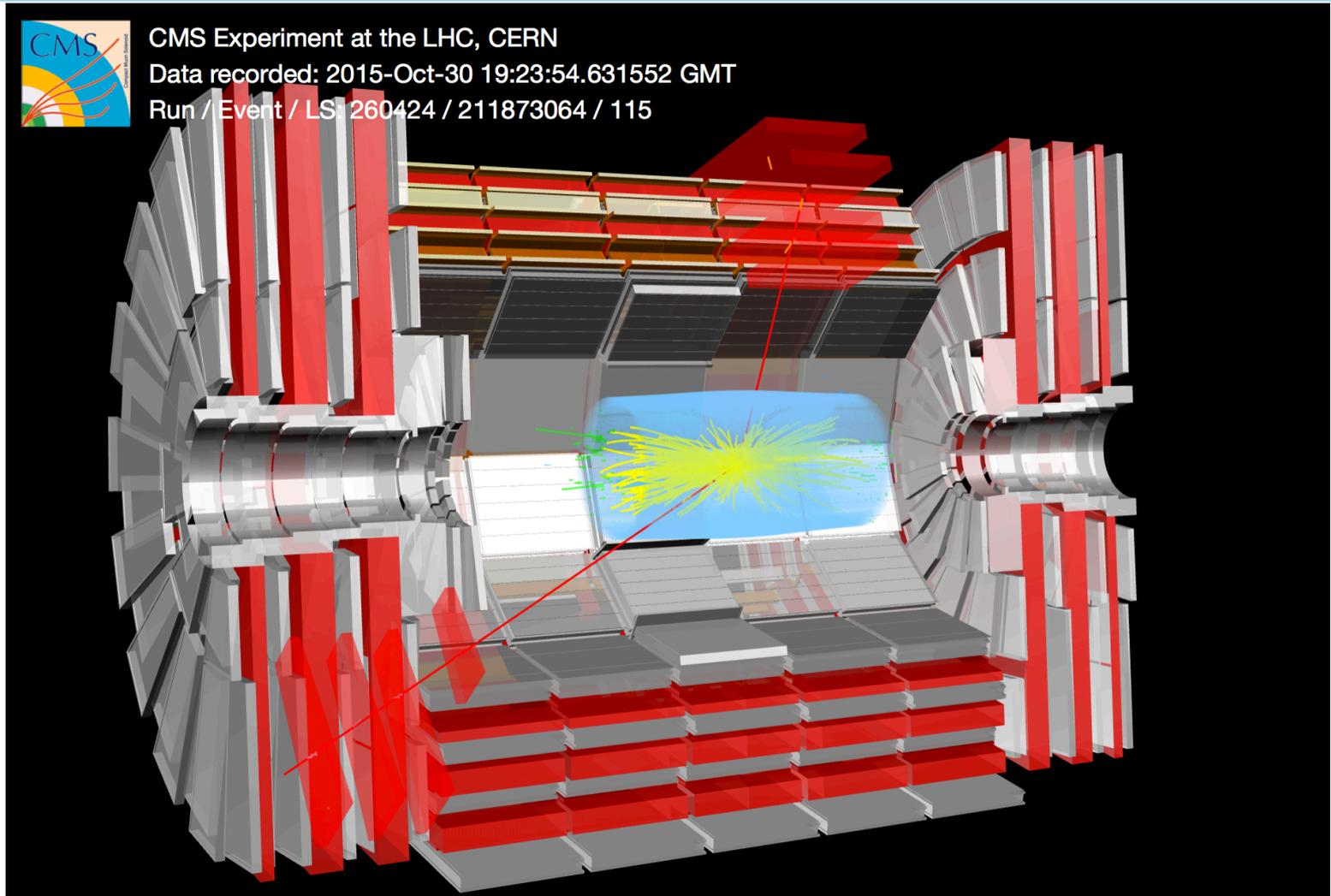
No signal around 2 TeV: Run 1 excess is not confirmed

2.4 fb⁻¹ limits from 13 TeV already surpass the 20 fb⁻¹ limits from 8 TeV



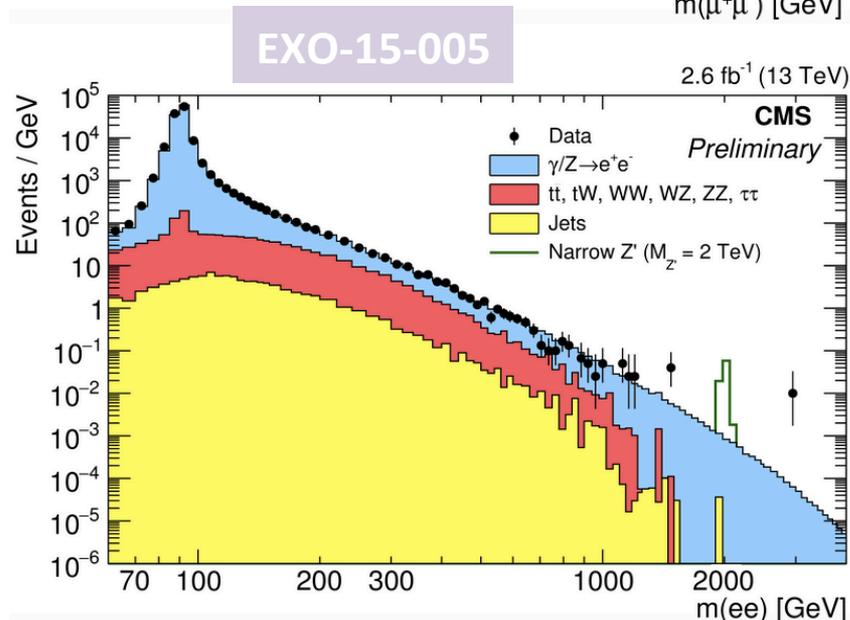
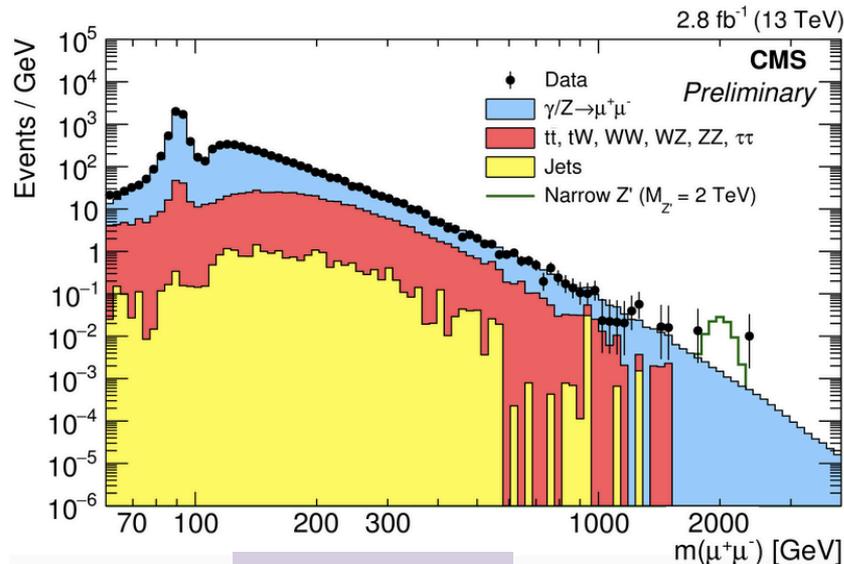
[Phys. Rev. Lett. 116 \(2016\) 071801](https://arxiv.org/abs/1607.07180)

Event Display: high mass dilepton

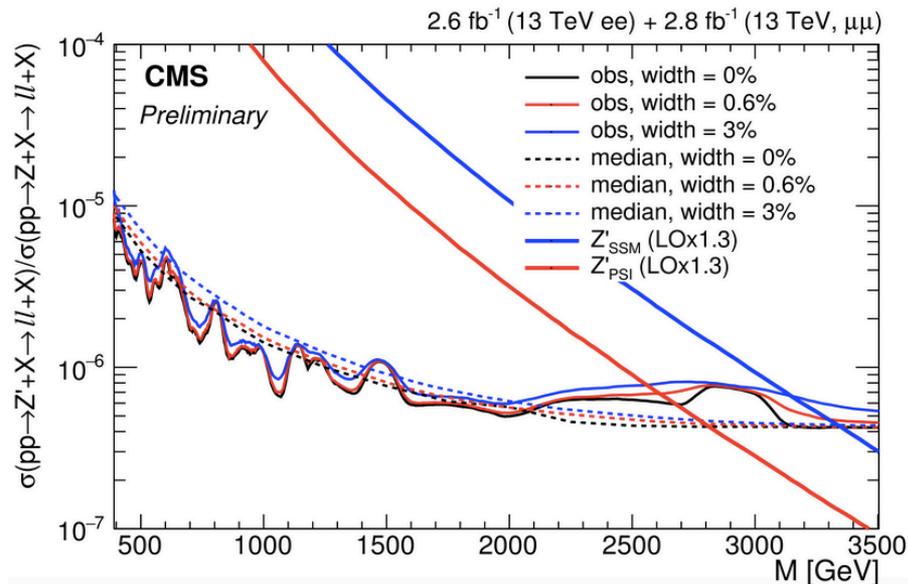


Highest mass dimuon pair observed: 2.4 TeV

Search for Z' : dilepton mass spectra

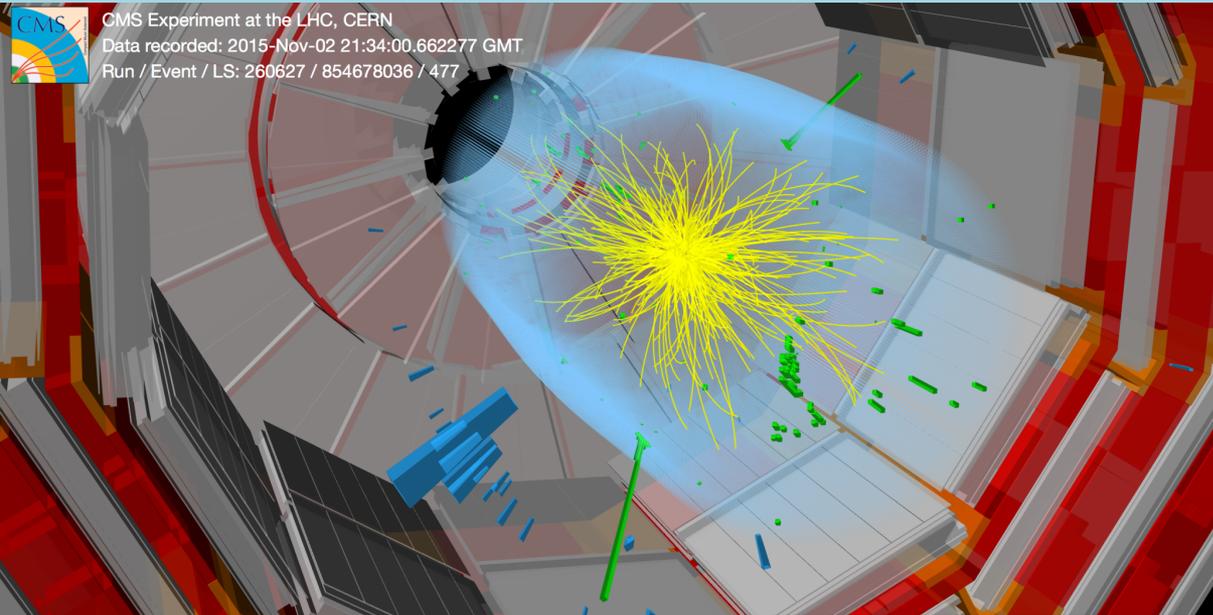


- Search for localized excess in the mass spectra of muon and electron pairs, clean signature with very low background at high mass
- **Highest mass events:**
 Muon – 2.4 TeV ; Electron – 2.9 TeV
- **P-value to observe at least one event in the range $m(ee) > 2.8 \text{ TeV}$ is 3.6%**

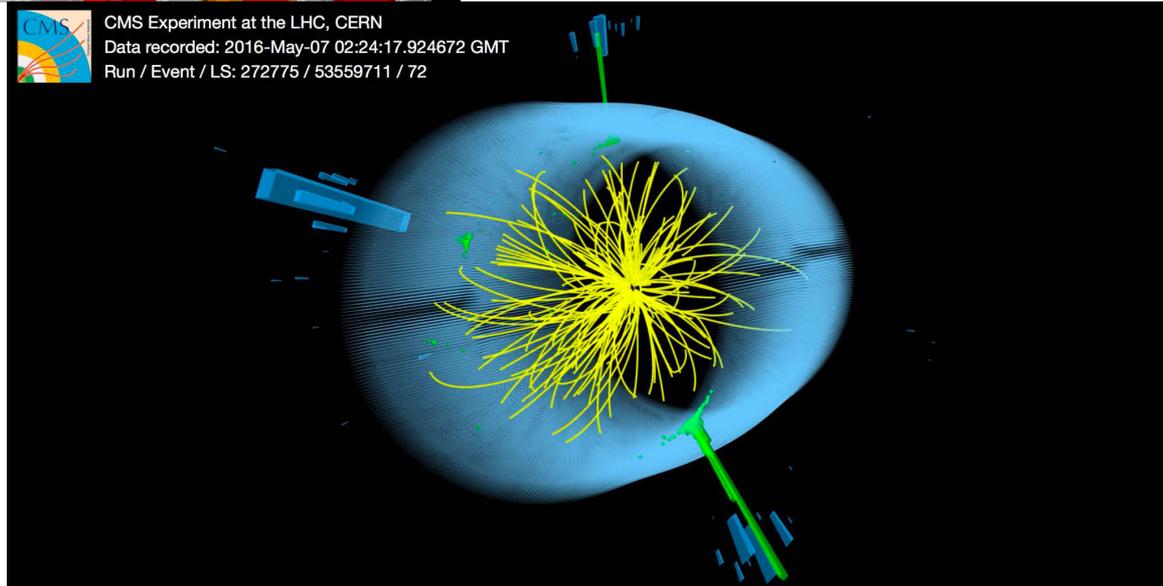


Data are consistent with SM

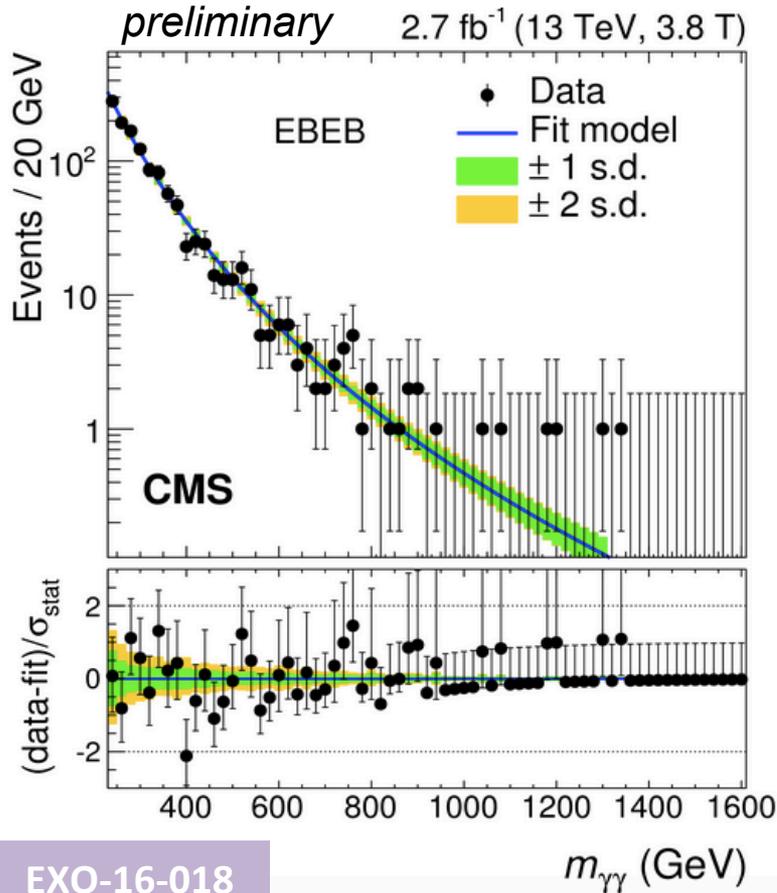
Event Display: high mass diphoton



**Diphoton event with
 $m(\gamma\gamma) = 745 \text{ GeV}$**



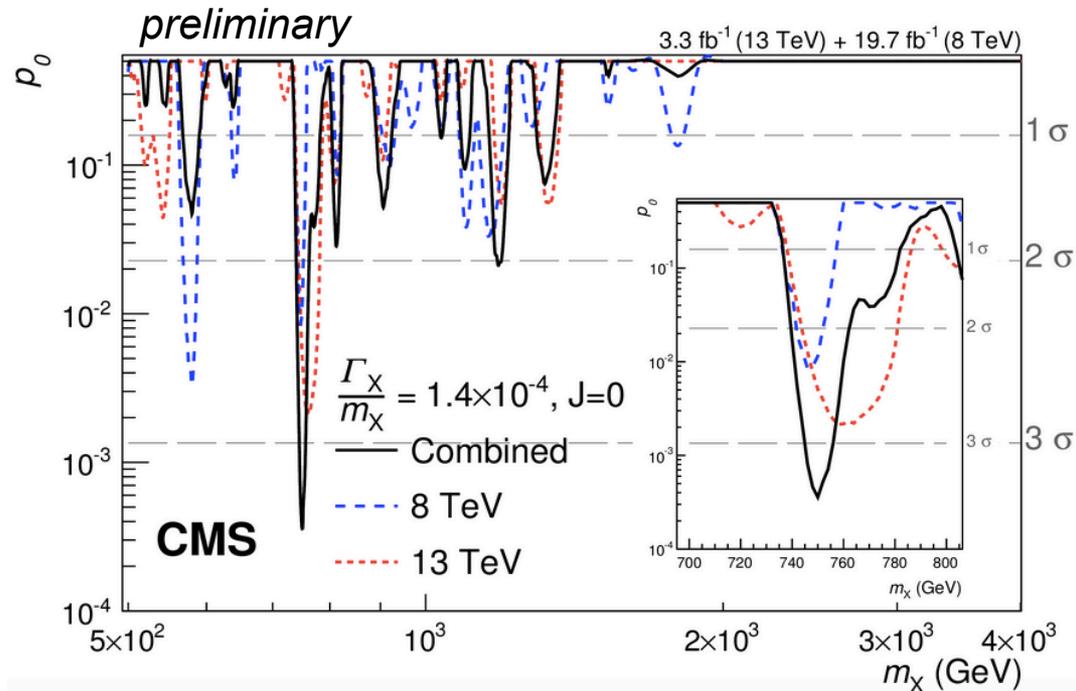
Diphoton results



A lot of theoretical works attempt to explain this hypothetical effect:
> 300 papers since Dec. 2015

Need more data!

CMS combined (13+8 TeV) analysis of spin-0 and spin-2 states:
Excess around ~750 GeV with 3.4 σ (local) and 1.6 σ (global) for both states



ATLAS combined (13+8 TeV) analysis:
3.9 σ (local) and 2.0 σ (global) for spin-0
3.6 σ (local) and 1.8 σ (global) for spin-2

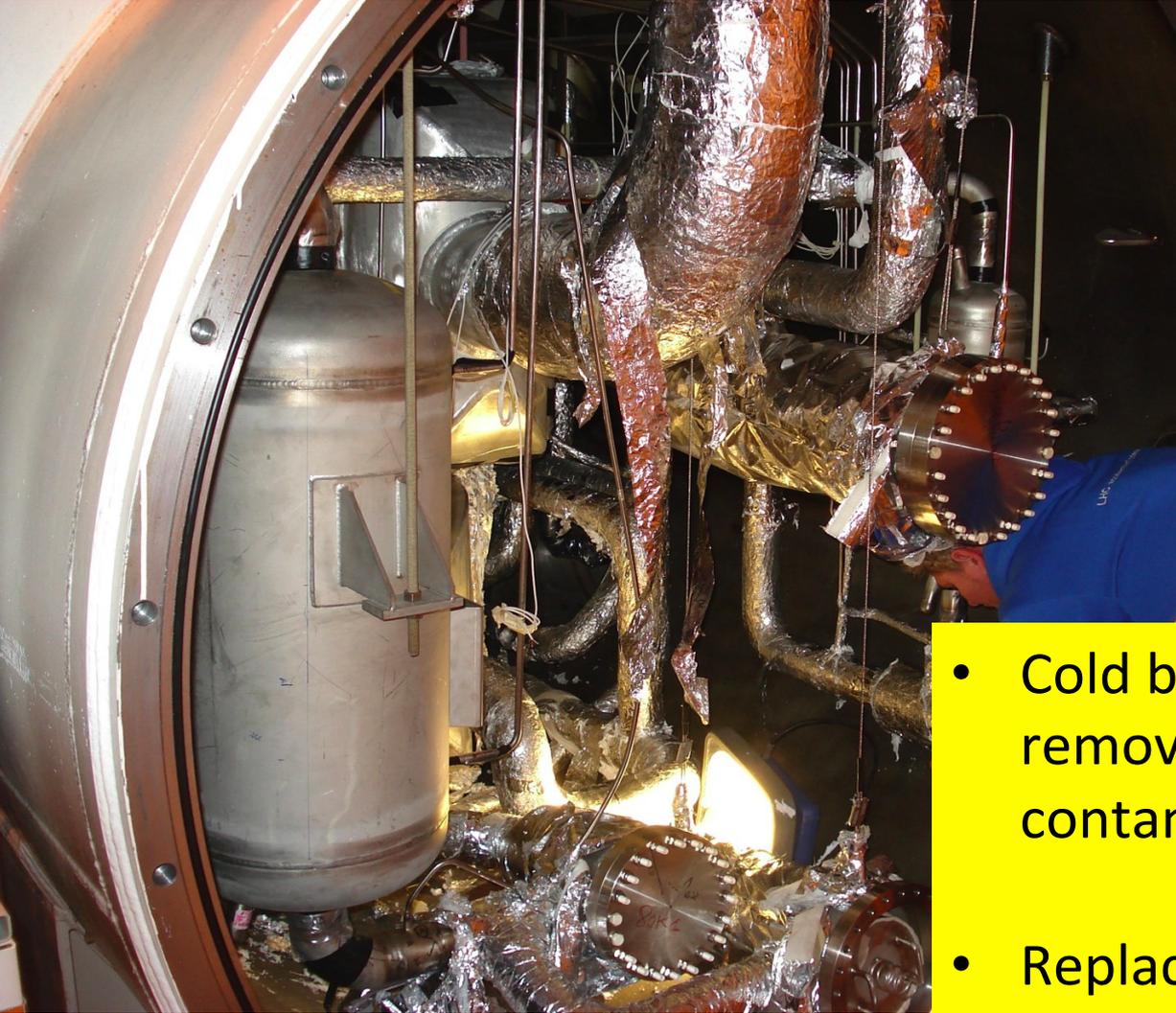
1606.03833

Summary

- Run 1 data demonstrated the triumph of the SM, the Higgs boson discovery but no significant signal of New Physics.
 - CMS improved detectors, trigger and reconstruction algorithms during the LS1.
 - 2015 has been the commissioning year for LHC and CMS @13 TeV.
 - LHC accelerator and CMS experiment are performing well: we are back to discovery mode.
 - For the moment Run 1 excesses have not been confirmed.
 - Unexpected mild excess in the diphoton invariant mass requires more data.
 - 2016-2018 data taking will deliver:
 - high precision measurements at new energy regime
 - searches for New Physics
- exciting times ahead!

SPARES

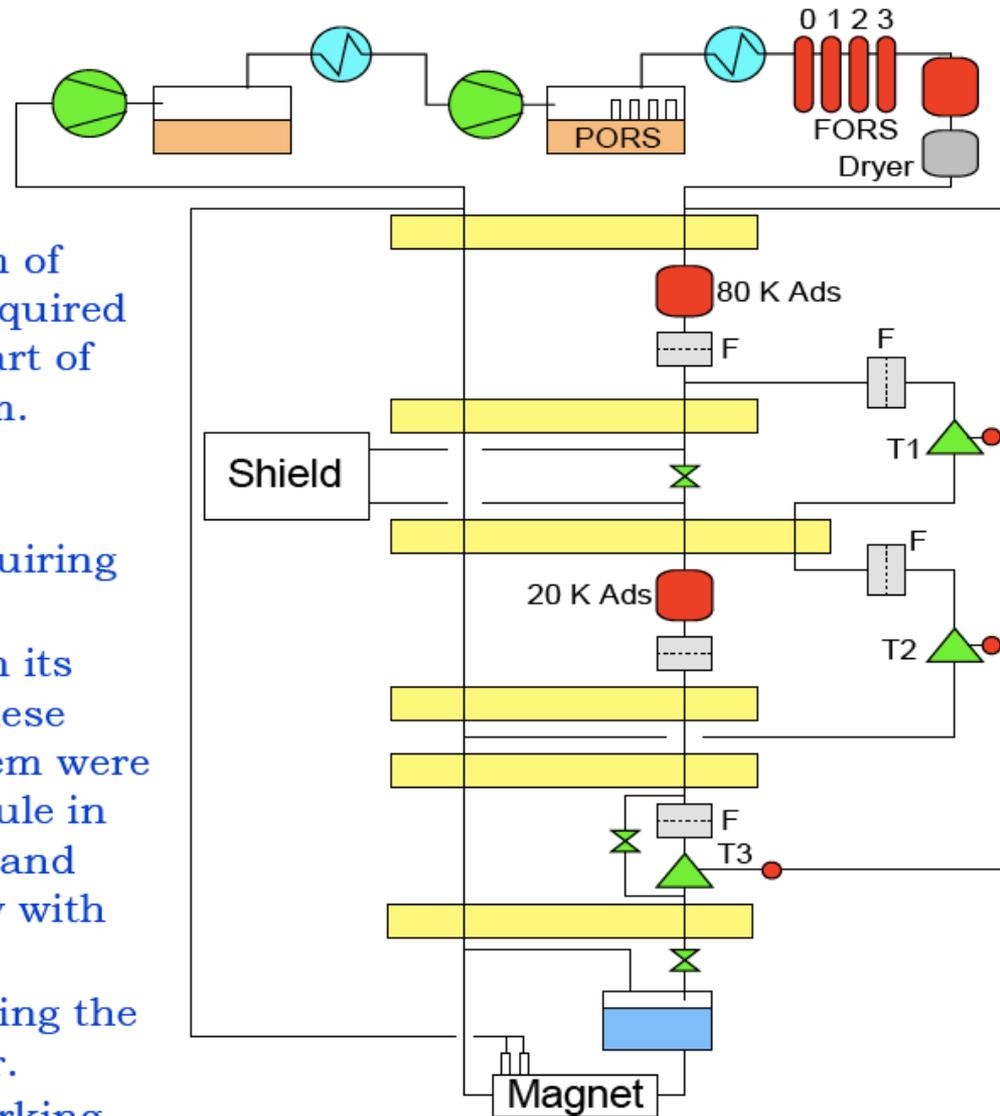
**Intense program
to refurbish the
cryogenic system
for $B=3.8$ T
operation in 2016**

- 
- A photograph showing the interior of the CMS cryogenic system. The scene is filled with complex machinery, including large cylindrical vessels, pipes, and various components wrapped in reflective, gold-colored thermal insulation. A person wearing a blue shirt is visible on the right side, working on a component. The lighting is focused on the central area, highlighting the intricate details of the system.
- Cold box cleaning to remove traces of Breox contaminant
 - Replacement of primary oil removal system

CMS Magnet's Cryogenic Plant



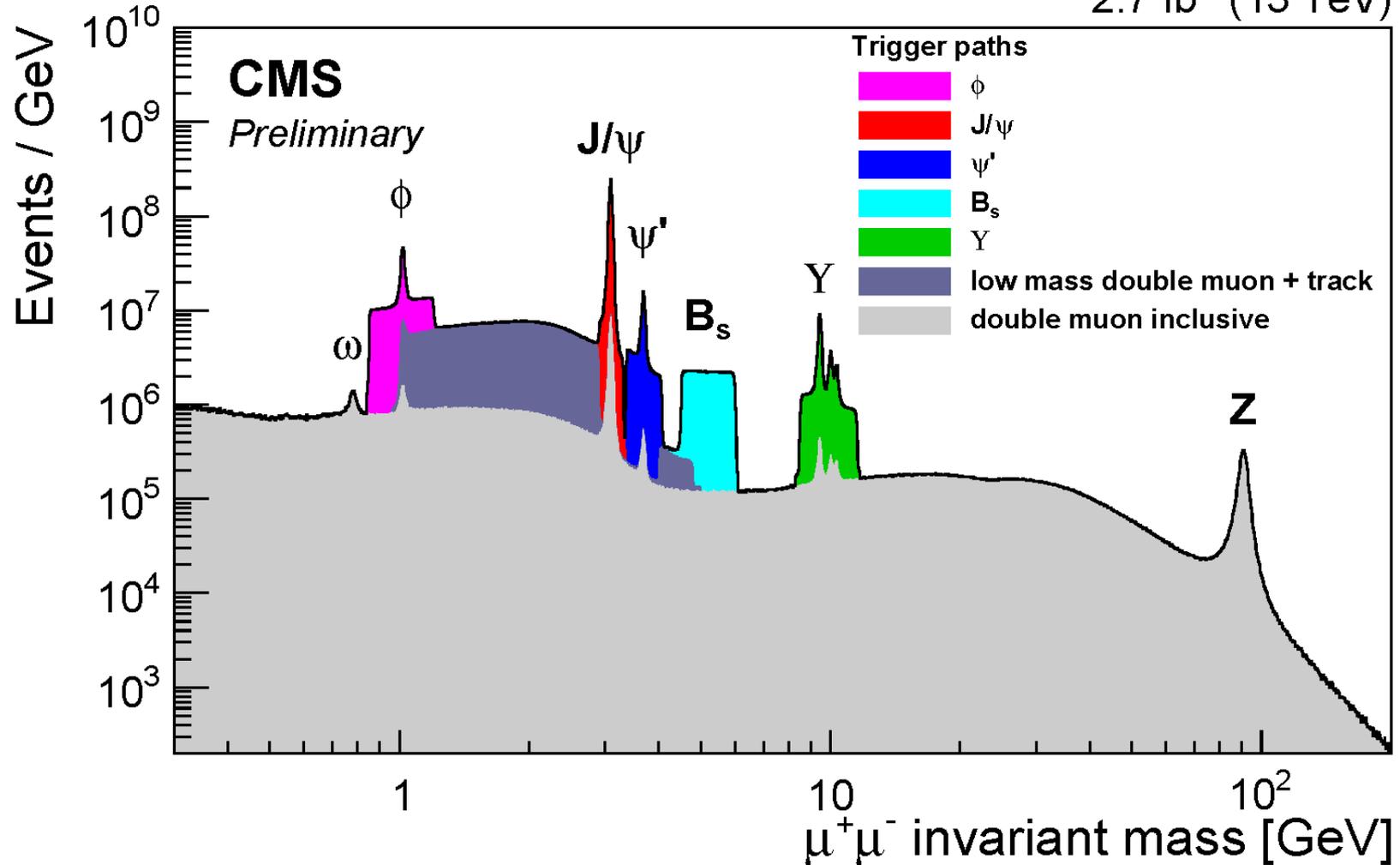
- The restart of the CMS magnet after LS1 was difficult due to problems with the cryogenic system in providing liquid Helium.
- Inefficiencies of the oil separation system of the compressors for the warm Helium required several interventions and delayed the start of routine operation of the cryogenic system.
- The magnet could be operated, but the continuous up-time was limited by the performance of the cryogenic system requiring more frequent maintenance than usual.
- A comprehensive program to re-establish its nominal performance was performed. These recovery activities for the cryogenic system were synchronized with the accelerator schedule in order to run for adequately long periods and enabled CMS to take $\frac{3}{4}$ of the luminosity with magnet on.
- A thorough cleaning was performed during the long the technical stop at end of the year.
- All went very well and the cold box is working flawlessly





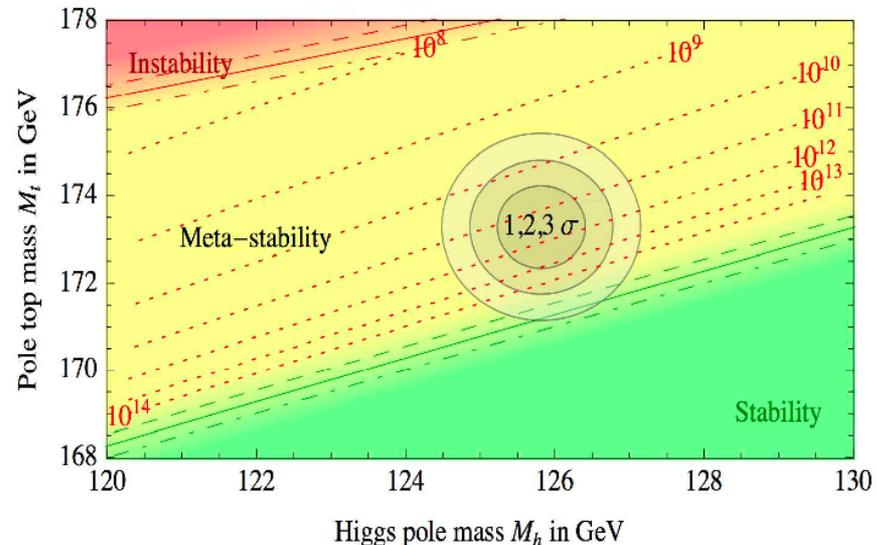
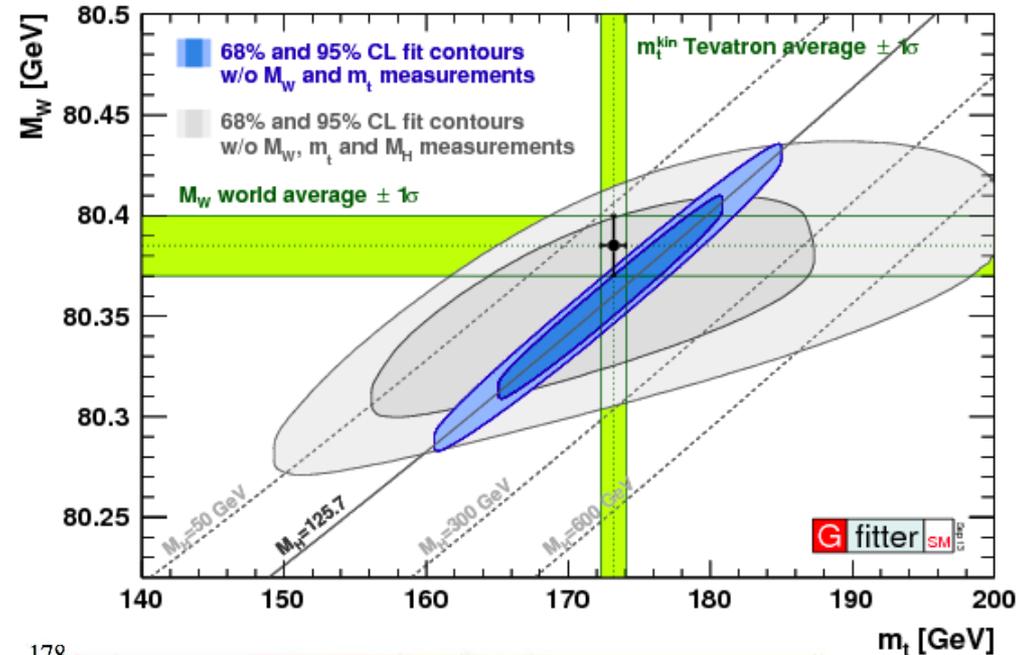
CMS shows a good performance to detect different signals

2.7 fb⁻¹ (13 TeV)



Top quark mass – precision physics

- o Top quark mass is an important parameter of the standard model.
- o Precise measurements of top quark mass provide critical inputs to the fits of global electroweak parameters.
- o Internal consistency check with the SM.
- o Affect the stability of the SM Higgs potential.
- o To check the validity of perturbative QCD.



SM - summary @ 13 TeV



Good agreement between data and theory

