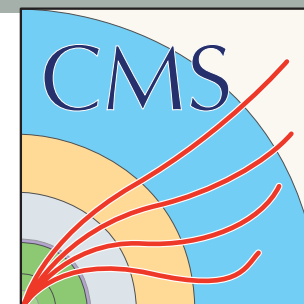




Istituto Nazionale  
di Fisica Nucleare  
Sezione di Trieste



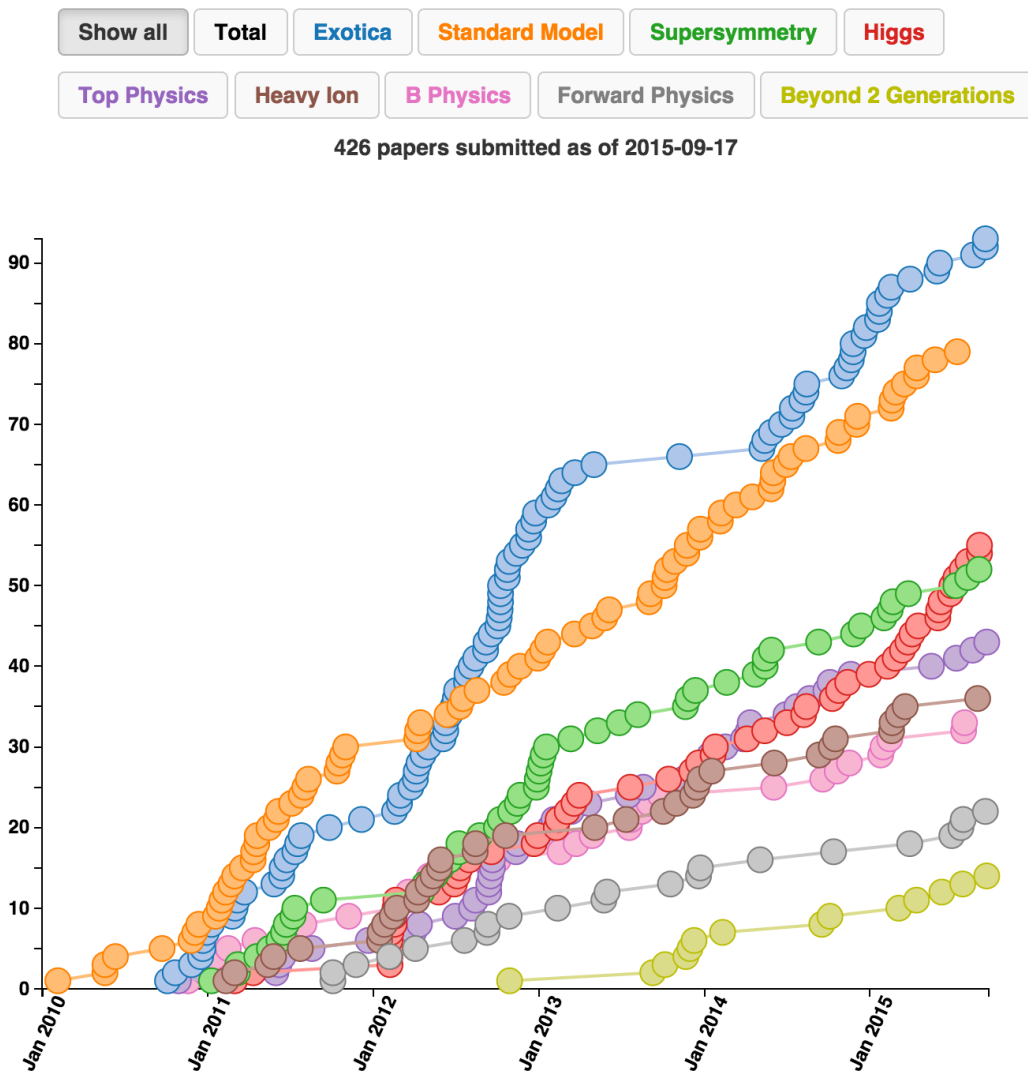
# CMS RUN2: PRIMI RISULTATI E PROSPETTIVE

---

***F. Cossutti, INFN Trieste***  
*per la Collaborazione CMS*

*Società Italiana di Fisica, 101° Congresso annuale*  
*Università di Roma "La Sapienza", Roma, 22/9/2015*

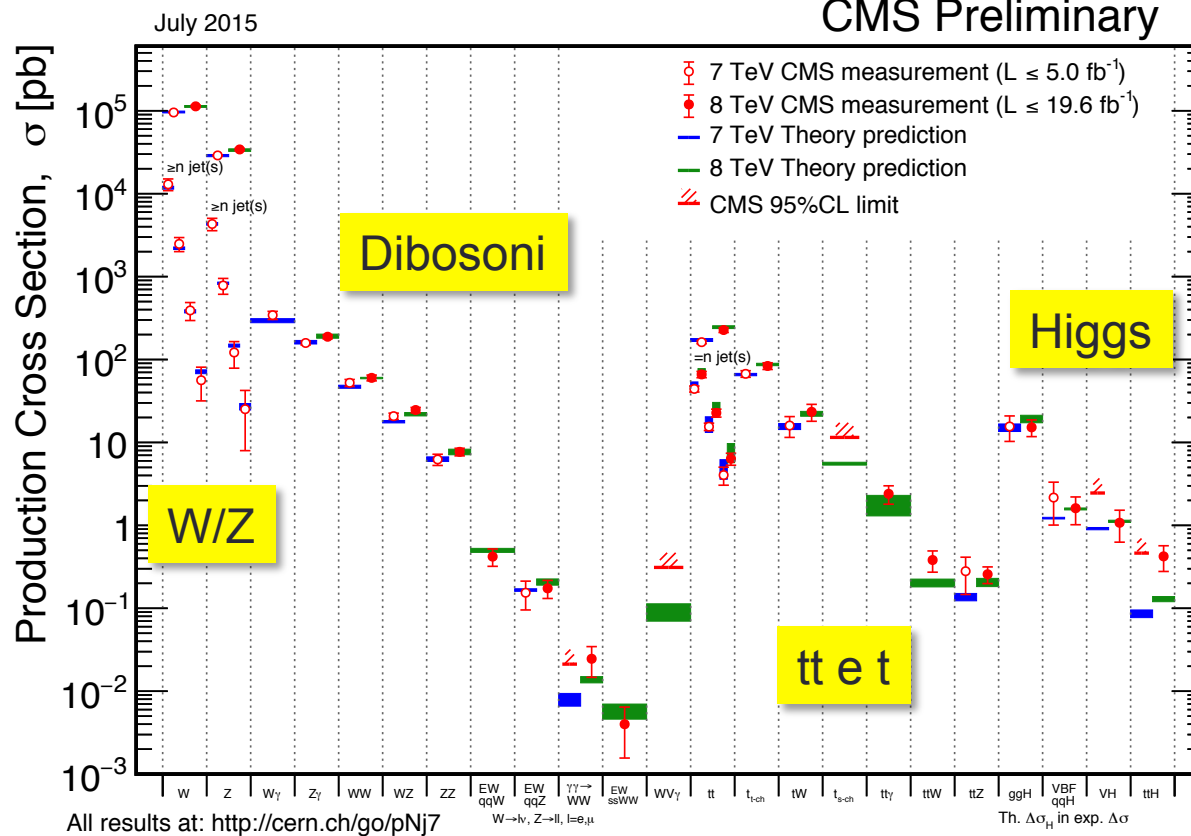
# RUN1: ANALYSIS STATUS



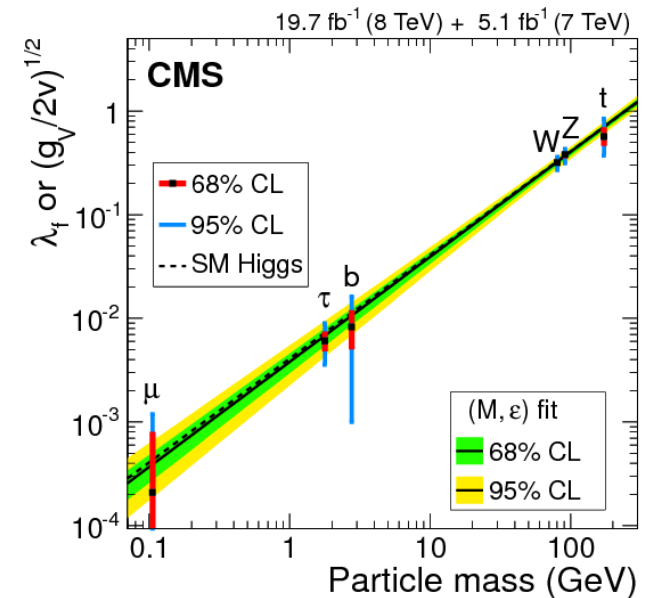
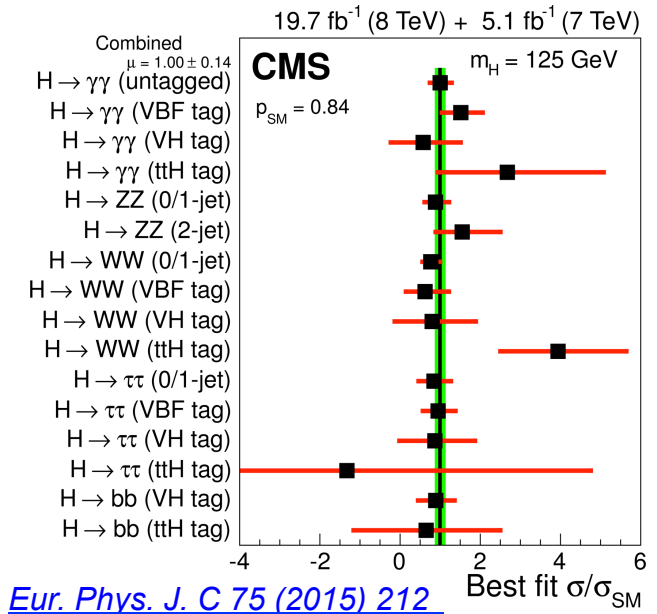
- 426 papers on collisions studies
- 24 papers on detector performances with data taking from cosmic rays
- Rich program of measurements of electroweak, QCD, top and bottom physics is continuing and producing results

# RUN1 RESULTS SUMMARY

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



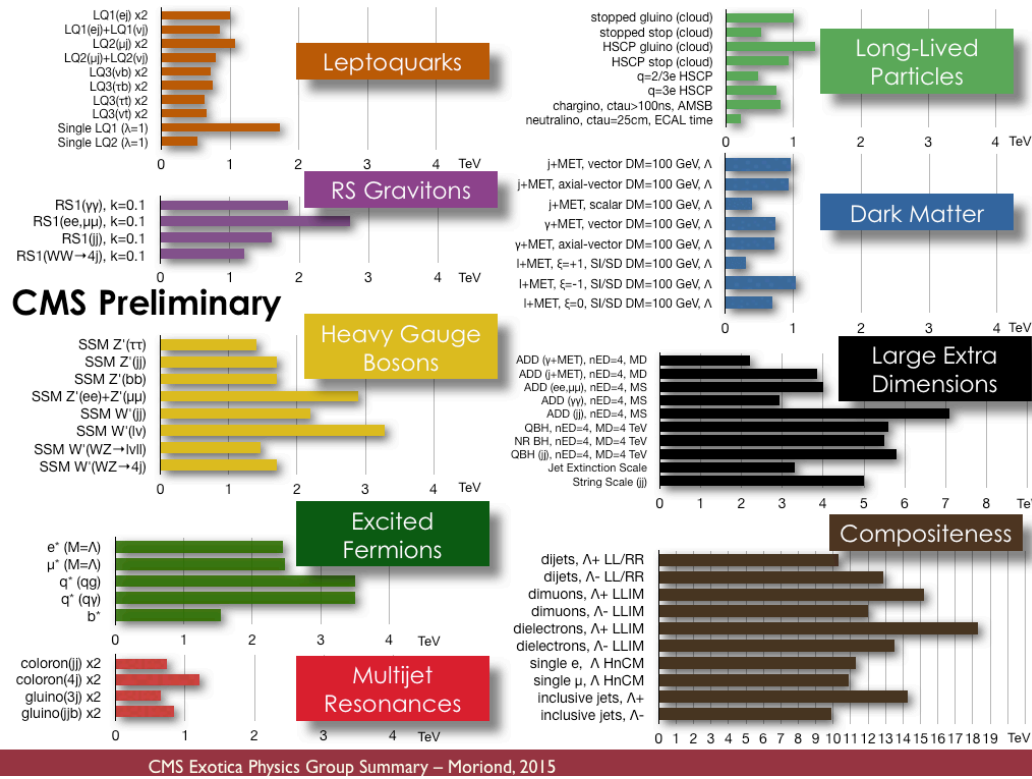
- Studied processes with cross sections spanning 8 orders of magnitude
- No surprise from the Higgs boson, for the time being...



# RUN1: NEW PHYSICS SEARCH

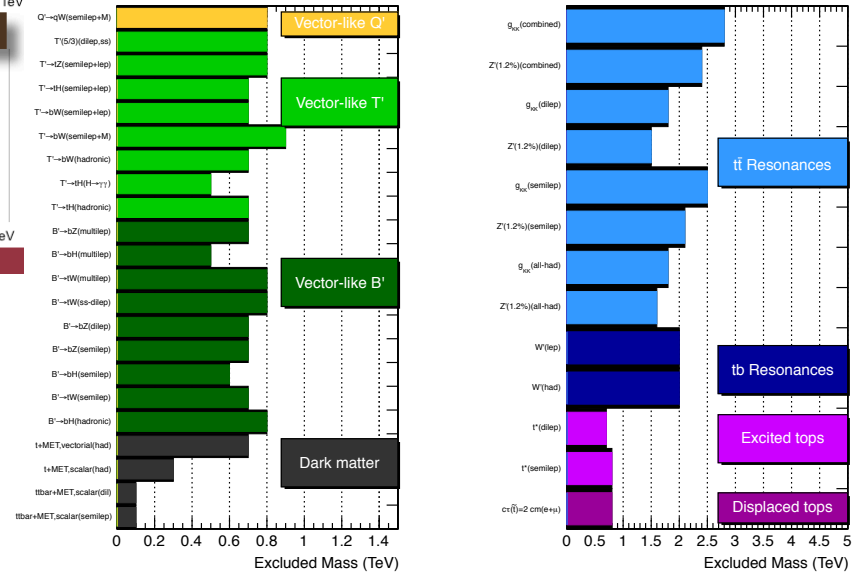
<https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsCombined>

- Wide spectrum of physics processes examined



No evidence of new physics signals

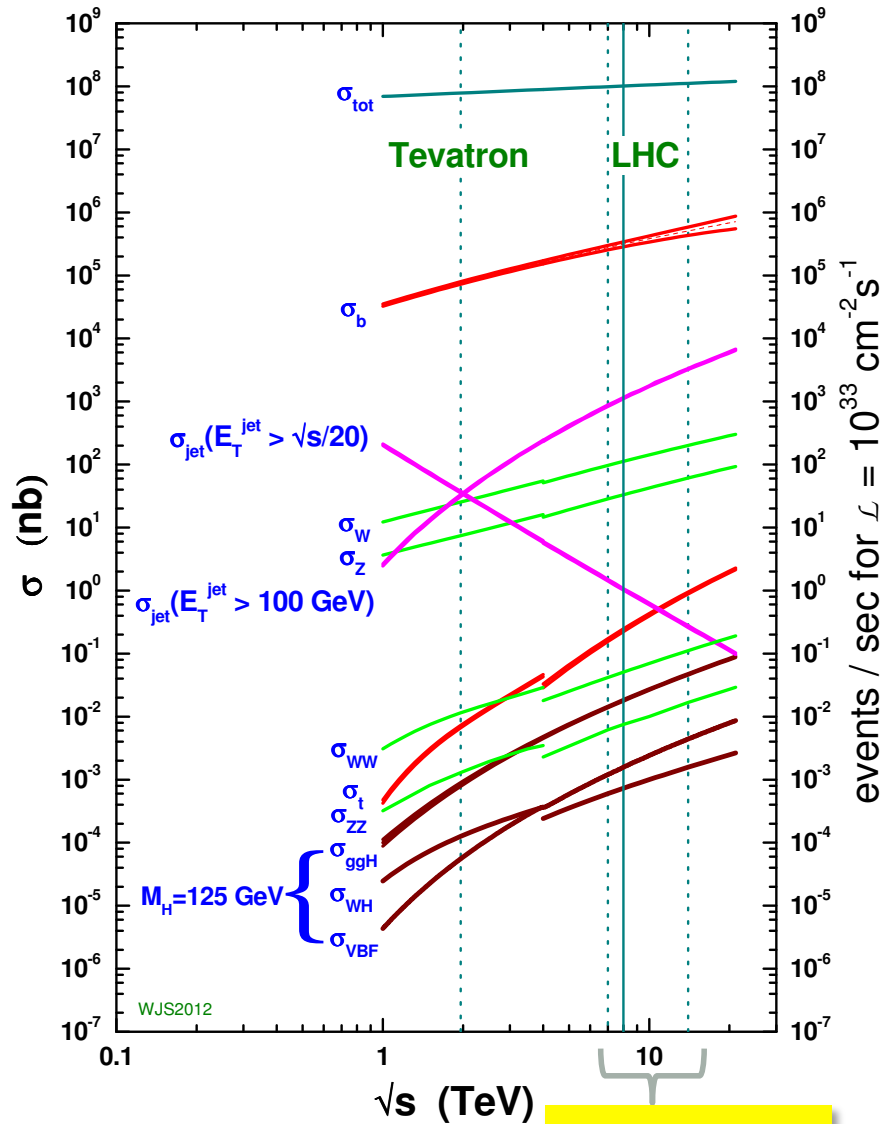
CMS Searches for New Physics Beyond Two Generations (B2G)  
95% CL Exclusions (TeV)



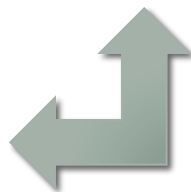
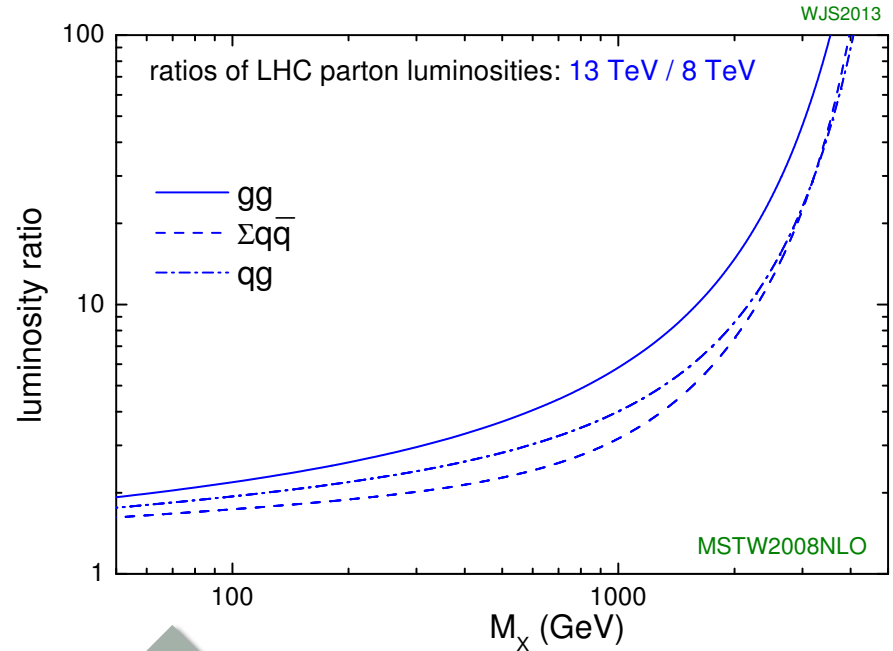


# RUN2: WHAT'S NEW IN PHYSICS

proton - (anti)proton cross sections



**RUN2 - RUN1**



- Parton luminosities significantly increase with the change in energy
- besides wider phase space accessible, higher statistics available than in Run1, for the same integrated luminosity

# RUN2: WHAT'S NEW IN CMS

## CMS DETECTOR

Total weight : 14,000 tonnes  
 Overall diameter : 15.0 m  
 Overall length : 28.7 m  
 Magnetic field : 3.8 T

STEEL RETURN YOKE  
 12,500 tonnes

SILICON TRACKER  
 Pixel (100x150  $\mu\text{m}$ )  $\sim 16\text{m}^2 \sim 66\text{M}$  channels  
 Microstrips (80x180  $\mu\text{m}$ )  $\sim 200\text{m}^2 \sim 9.6\text{M}$  channels

**low temperature tracker operations  
 pixel inactive channels recovered**

SUPERCONDUCTING SOLENOID  
 Niobium titanium coil carrying  $\sim 18,000\text{A}$

MUON CHAMBERS  
 Barrel: 250 Drift Tube, 480 Resistive Plate Chambers  
 Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers

**New DAQ2  
 New CPUs for HLT  
 Multi-threading  
 computing/ multi-  
 core queues**

**muon chambers  
 4<sup>th</sup> station**

PRESHOWER  
 Silicon strips  $\sim 16\text{m}^2 \sim 137,000$  channels

FORWARD CALORIMETER  
 Steel + Quartz fibres  $\sim 2,000$  Channels

**new beampipe**

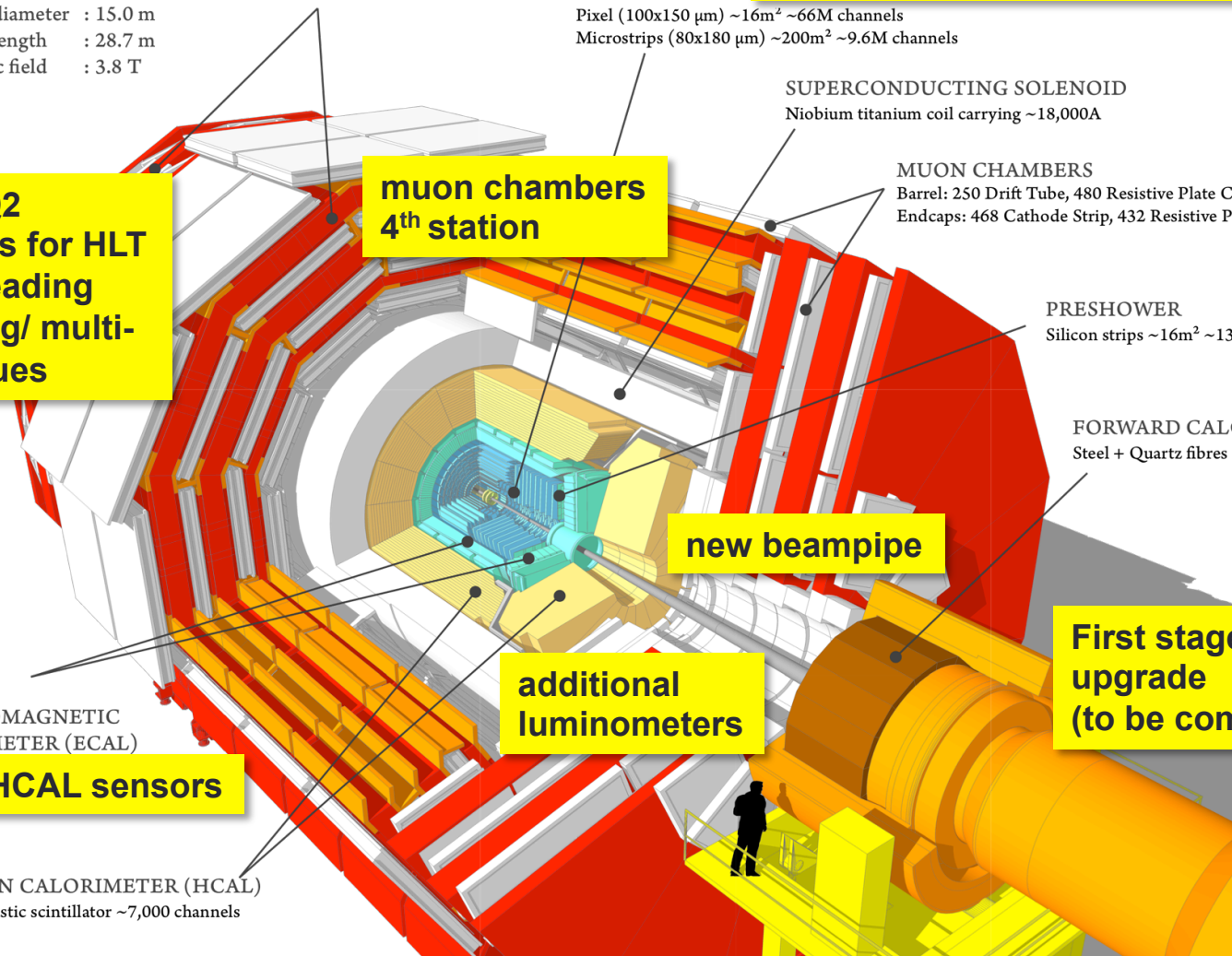
**additional  
 luminometers**

**First stage of L1 trigger  
 upgrade  
 (to be completed in 2016)**

CRYSTAL  
 ELECTROMAGNETIC  
 CALORIMETER (ECAL)

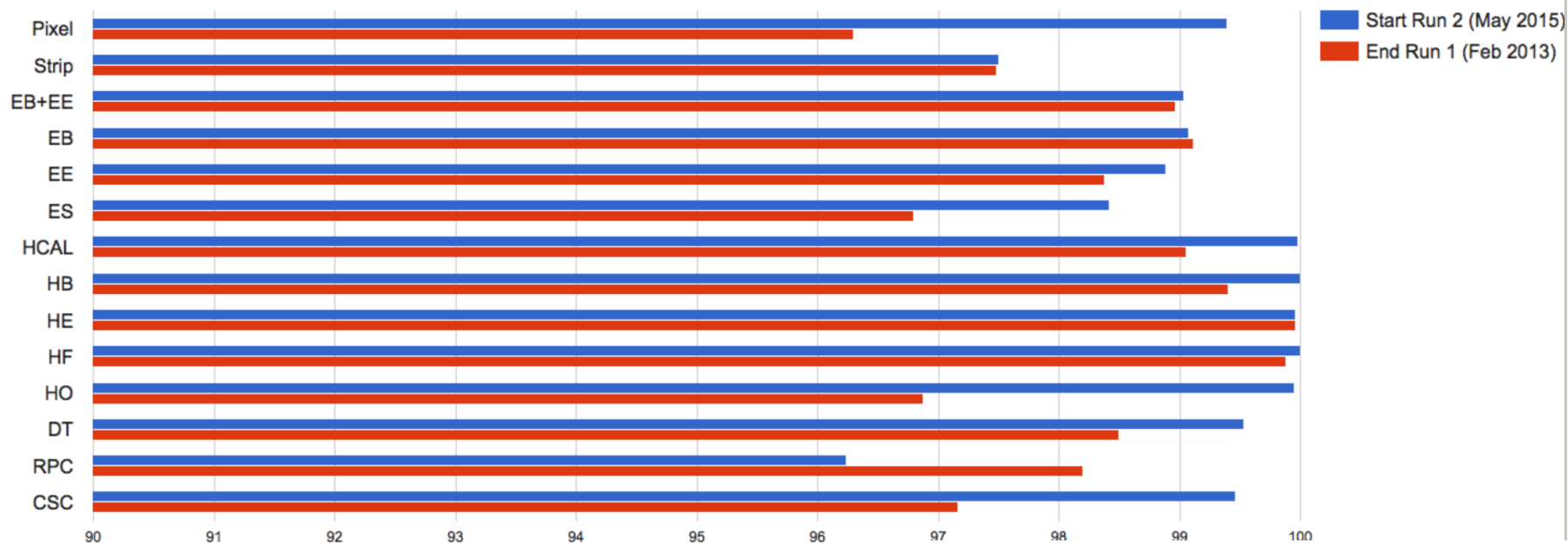
**new HCAL sensors**

HADRON CALORIMETER (HCAL)  
 Brass + Plastic scintillator  $\sim 7,000$  channels



# RUN2: CMS STATUS

Active Detector Fraction Run 1 to Run 2

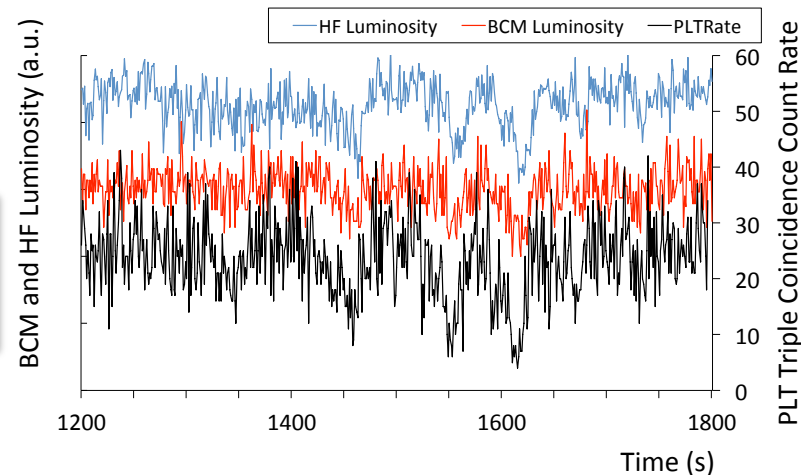


All subdetectors are working, with an active channel fraction better than at the Run1 end

Fraction (%)

New luminometers are operative

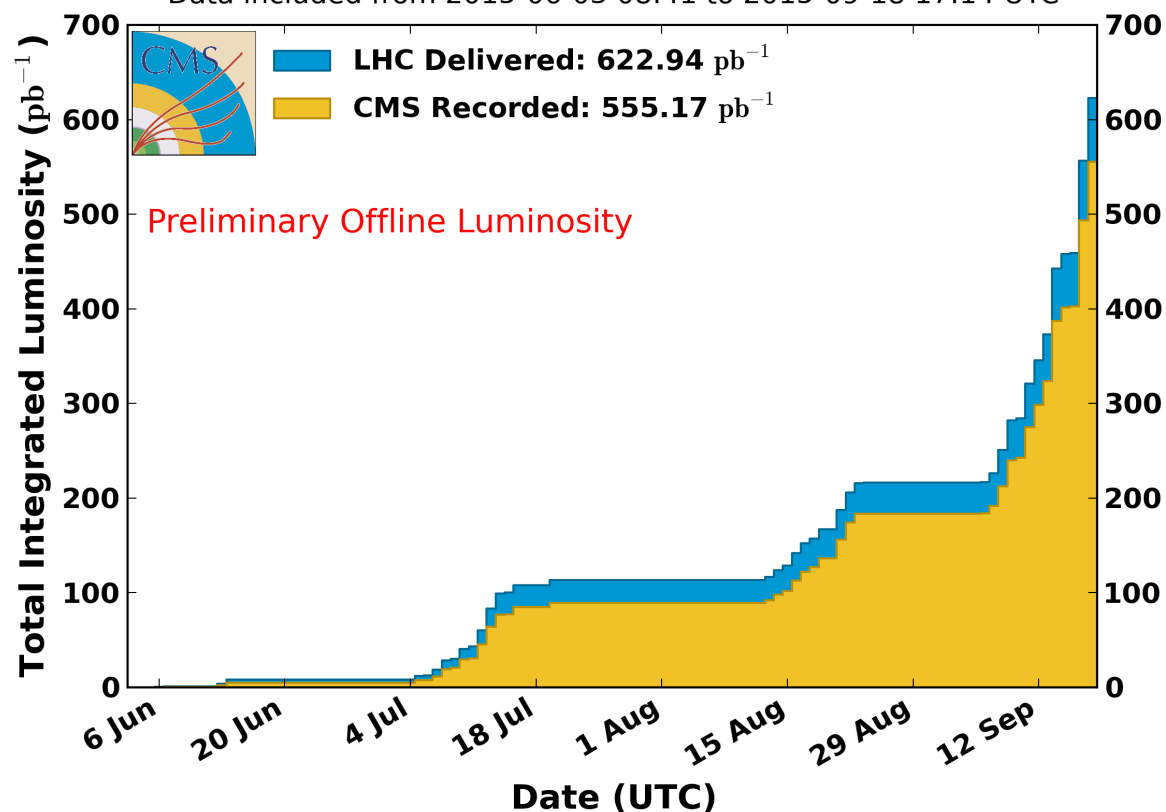
CMS Preliminary Fill 3679, 450GeV



# RUN2: DATA TAKING STATUS

## CMS Integrated Luminosity, pp, 2015, $\sqrt{s} = 13$ TeV

Data included from 2015-06-03 08:41 to 2015-09-18 17:14 UTC

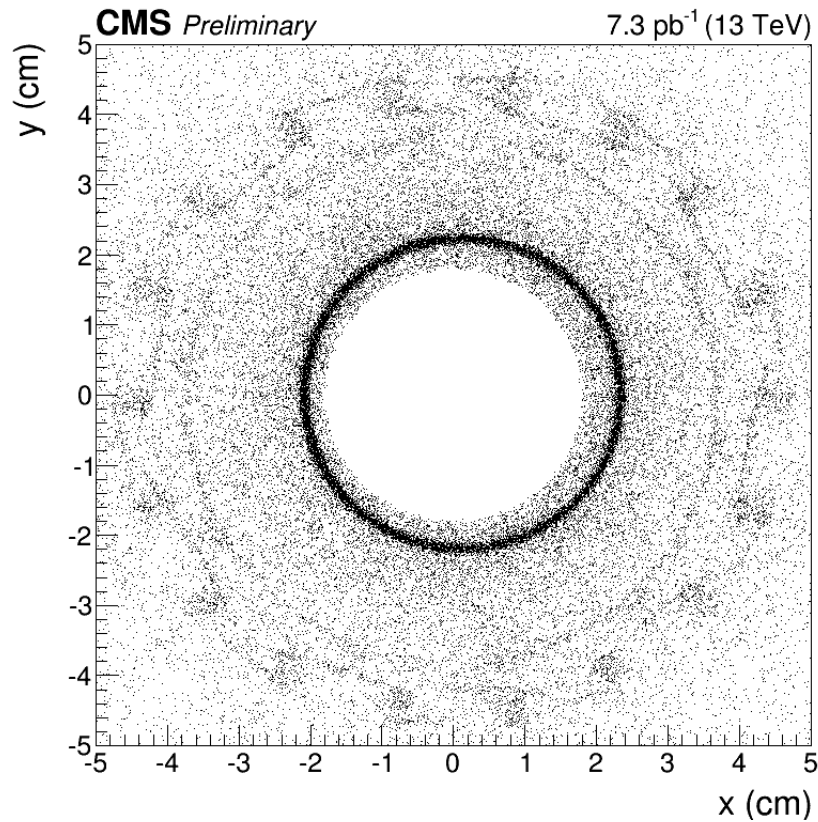


Problems with the solenoid cold box forced part of the data taking at B=0T

At B=3.8T:

- LHC delivered  $0.19 \text{ fb}^{-1}$
- CMS recorded  $0.17 \text{ fb}^{-1}$ 
  - efficiency 89%
- Analysis certification:
  - processed  $97.30 \text{ pb}^{-1}$
  - validated for analysis  $84.56 \text{ pb}^{-1}$
  - efficiency 87%

# RUN2: GEOMETRY AND ALIGNEMENT

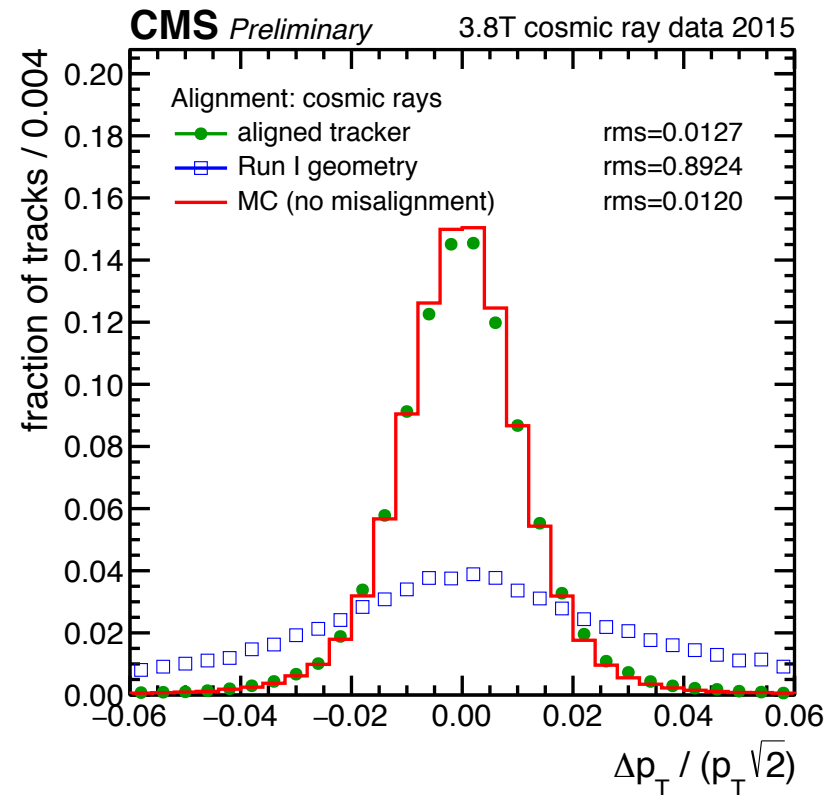


Beampipe and first pixel layer “radiography” with reconstructed nuclear interactions

[CMS-DP-2015-024/CDS:2039957](https://cds.cern.ch/record/2039957)

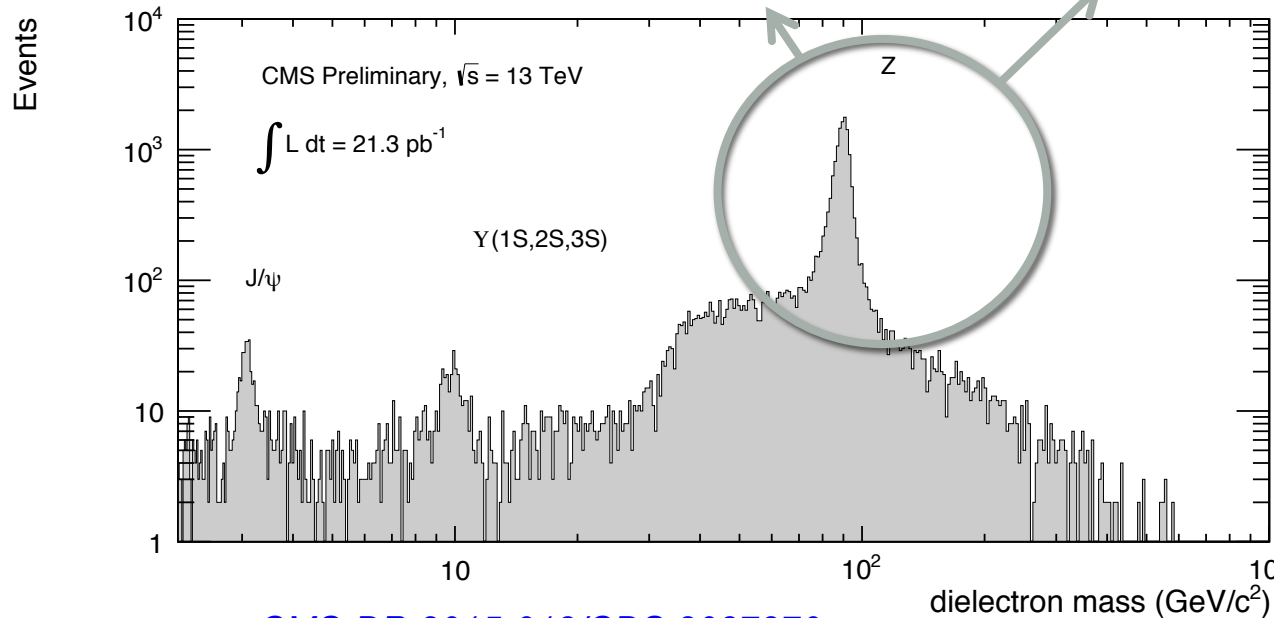
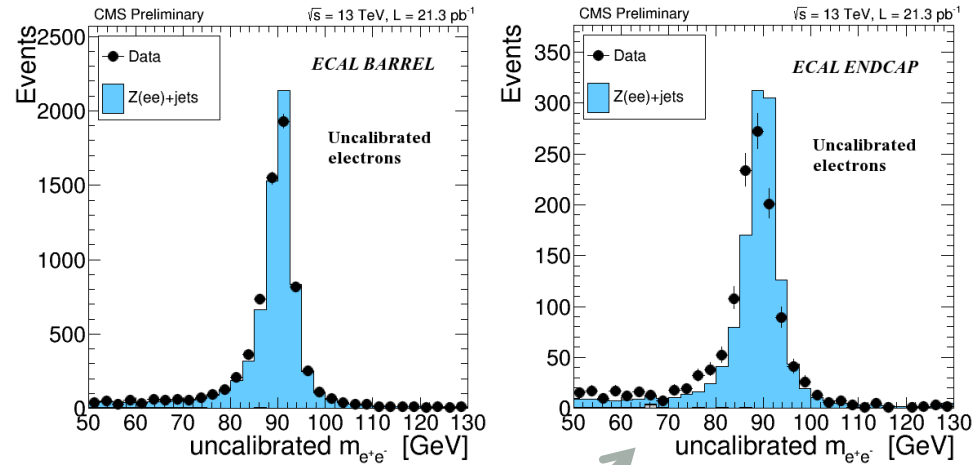
Alignment with cosmic rays  
New geometry with recentered pixels  
Close to ideal geometry

[CMS-DP-2015-029/CDS:2041841](https://cds.cern.ch/record/2041841)

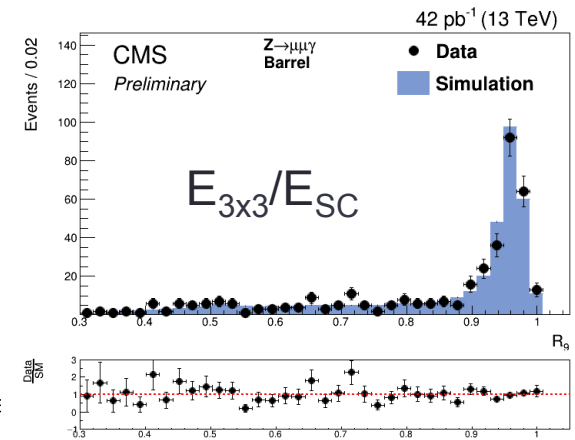


# RUN2: ELECTRONS AND PHOTONS

- Electron identification validated
- Energy scale derived from Run1 already good

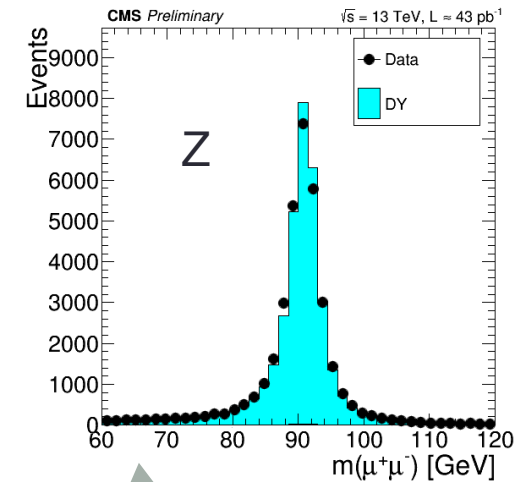
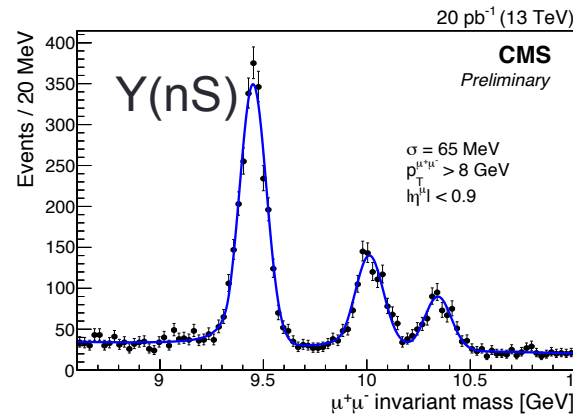
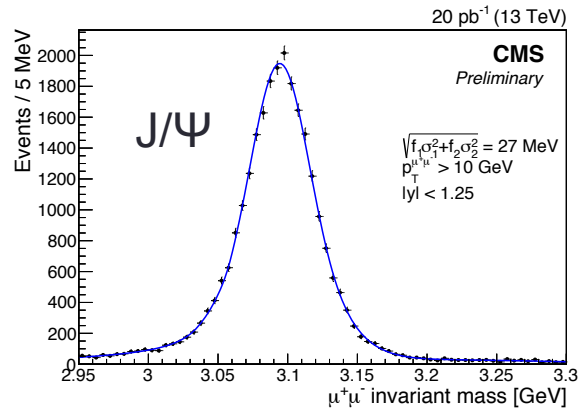


Using photons from  $Z \rightarrow \mu\mu\gamma$

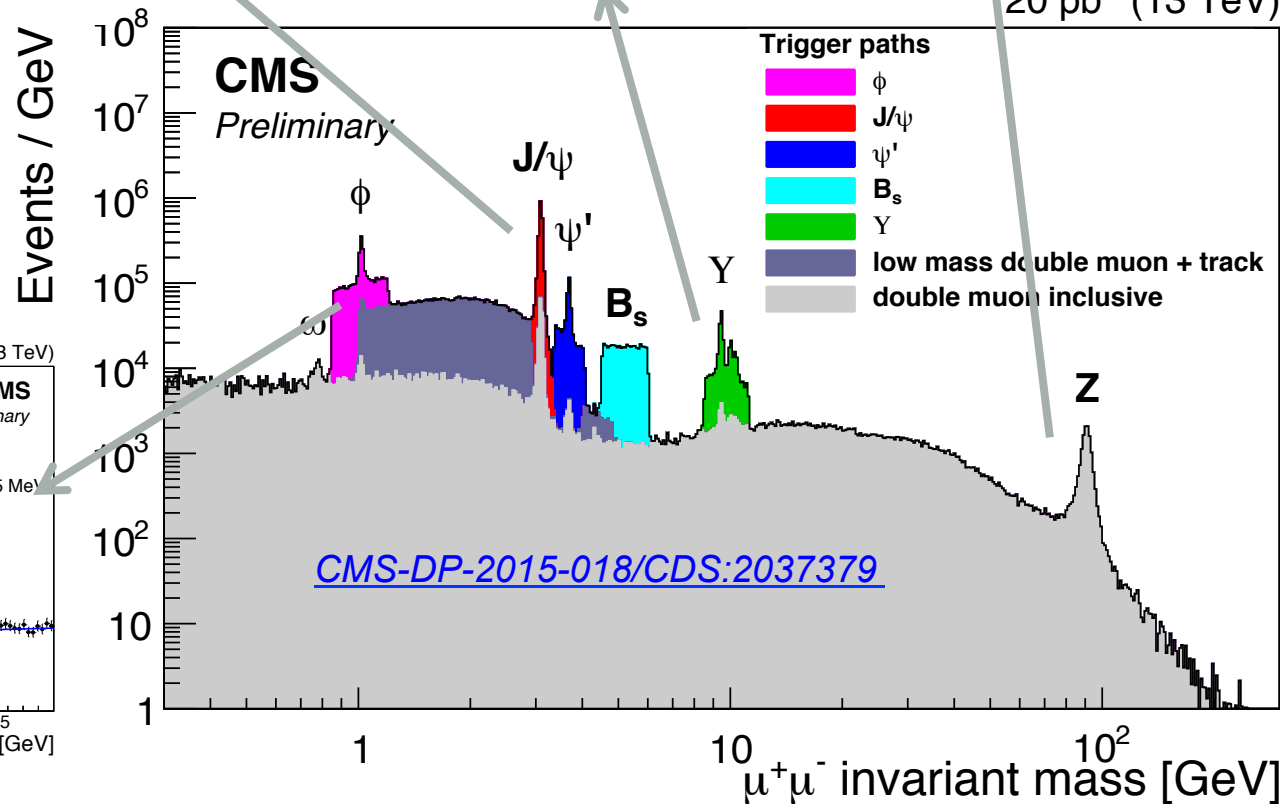
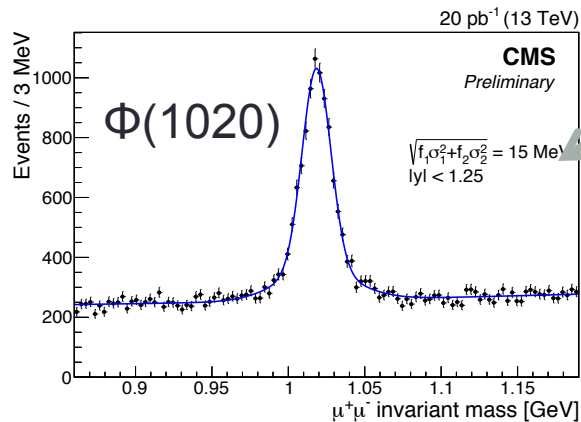


# RUN2: MUONS

[CMS-DP-2015-015/CDS:2037372](#)

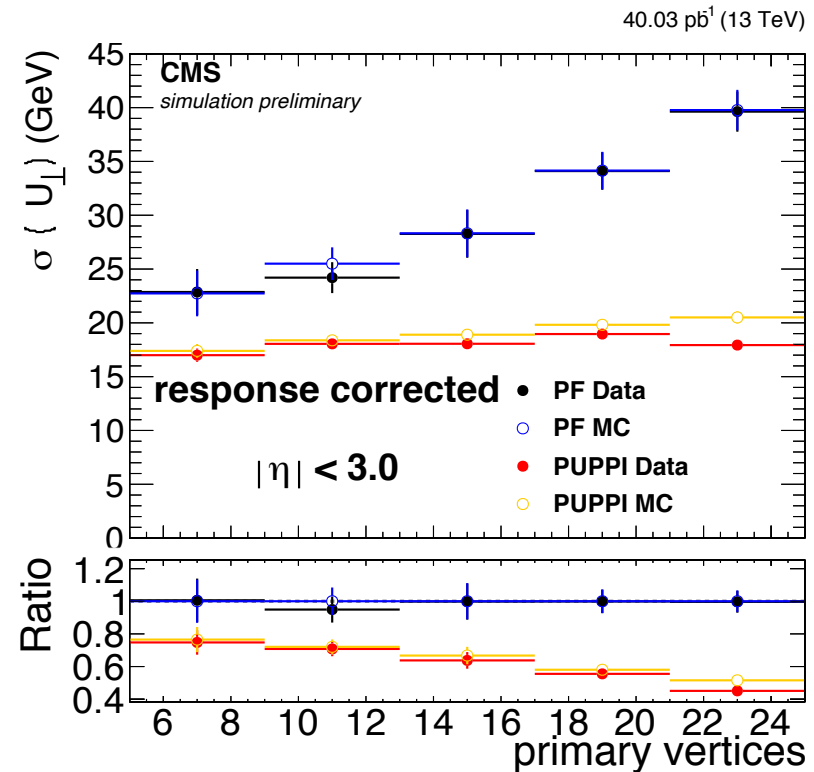
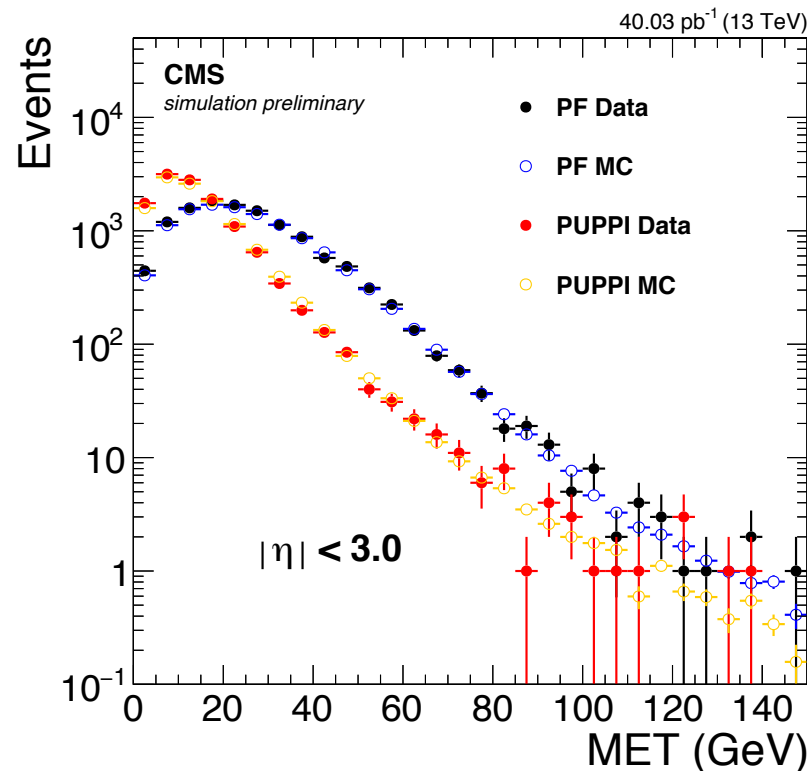


All standard candles are under control





# RUN2: MISSING ENERGY AND PILEUP



With the anticipated pileup increase in Run2 it becomes essential to improve the jet energy and missing energy correction, besides traditional Particle Flow (PF) PUPPI: Pile Up Per Particle identification

[arXiv.1407.6013](https://arxiv.org/abs/1407.6013)

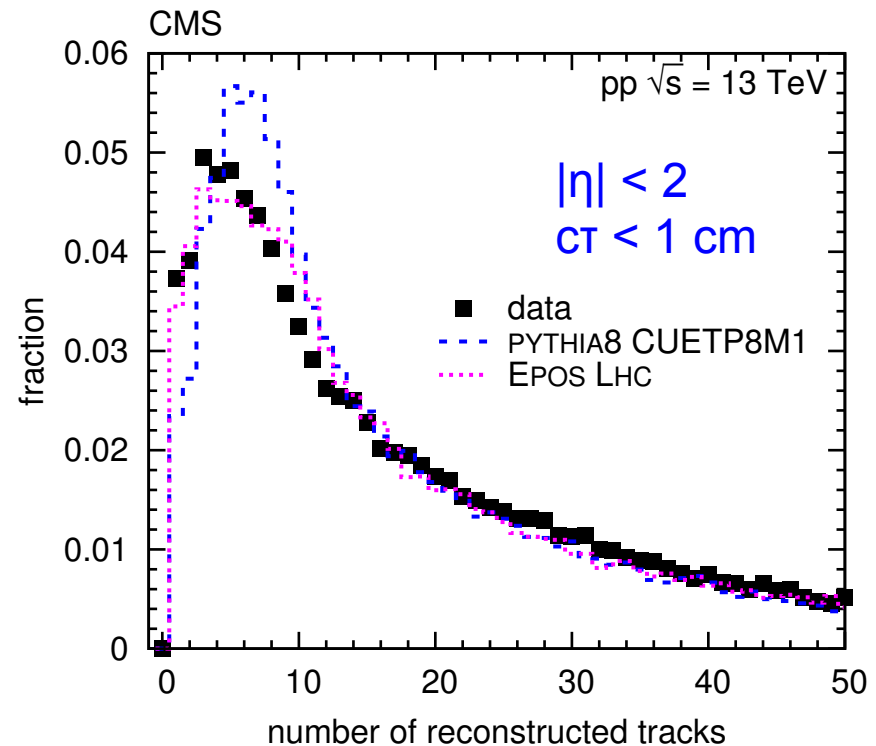
[CMS-PAS-JME-14-001](#)



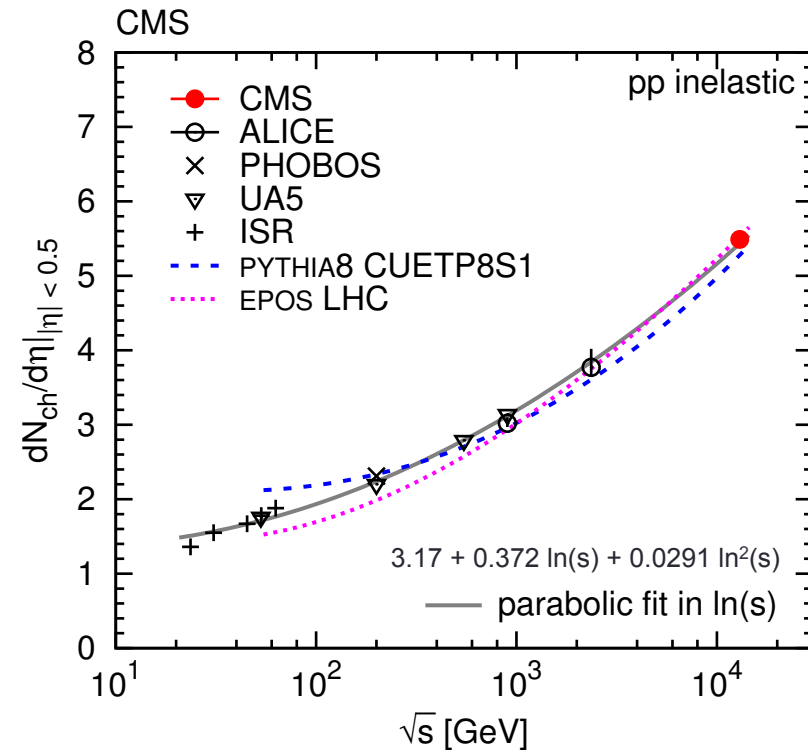
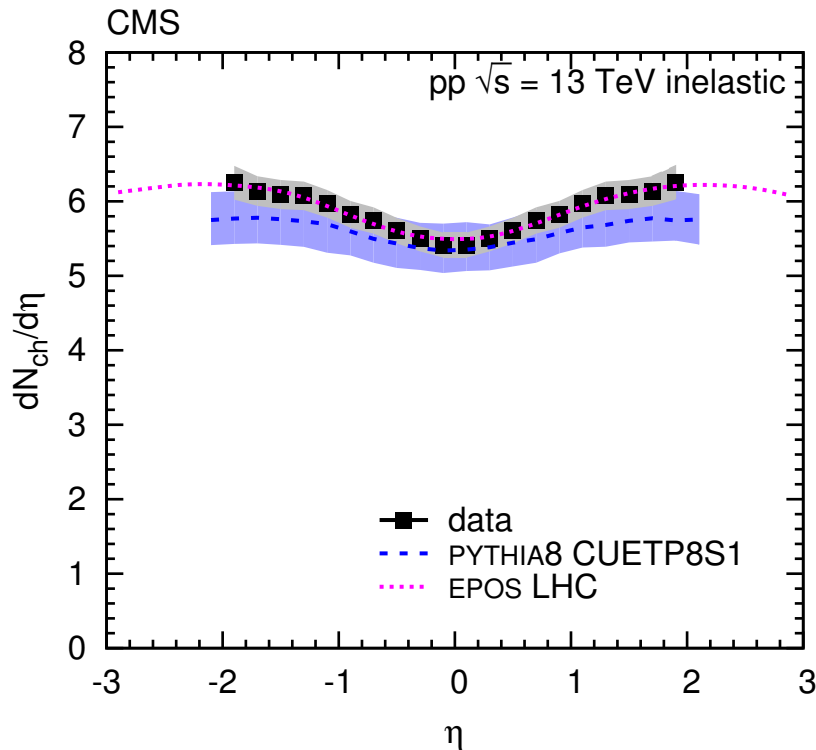
# FIRST PUBLICATION AT 13 TEV: $dN_{ch}/d\eta$

- Charged particle multiplicity measurement
  - $\sqrt{s}$  dependence is important to discriminate the soft and hard collision components
  - Special run at low PU (0.2%-5%), 11.5M event
  - at B=0T
- combined use of pixel hits from different layers
  - “tracklet” (hit pixel pairs)
  - tracks (hit pixel triplets)
- different background contamination
  - consistent within 2-3%
  - combination as average

[arXiv.1507.05915](https://arxiv.org/abs/1507.05915)  
Submitted to PLB



# FIRST PUBLICATION AT 13 TEV: $dN_{ch}/d\eta$



$$dN_{ch}/d|\eta|(|\eta| < 0.5) = 5.49 \pm 0.01 \text{ (stat)} \pm 0.17 \text{ (syst)}$$

- Consistent with Pythia8 (CUETP8S1/CUETP8M1) and EPOS LHC predictions
- Rapidity distribution better described by EPOS

# $\sigma(t\bar{t})$ WITH DILEPTON RECONSTRUCTION: INCLUSIVE CROSS SECTION

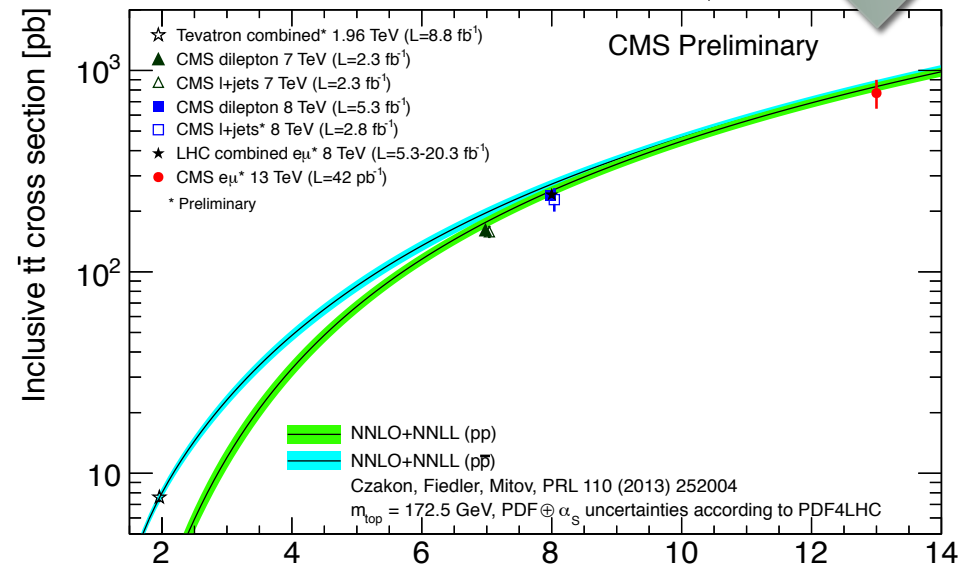
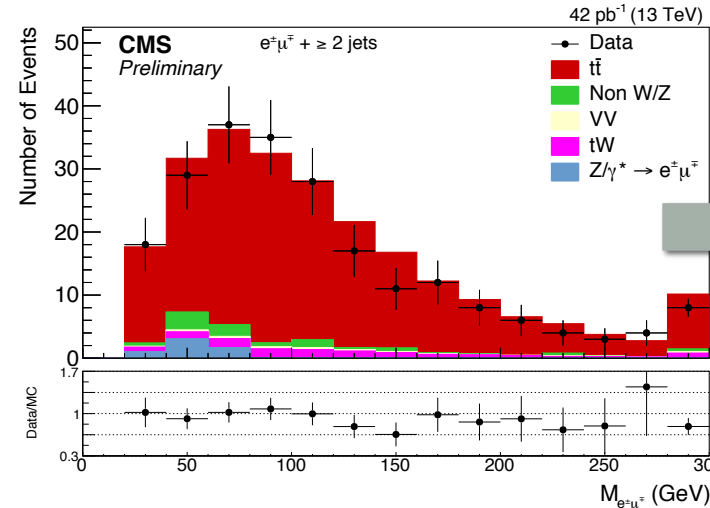
[CMS-PAS-TOP-15-003](#)

- Measurement based on 42 pb<sup>-1</sup>
- events with e $\mu$  lepton pairs
  - $p_T(l) > 20$  GeV,  $|\eta(l)| < 2.4$
  - $M_{e\mu} > 20$  GeV
- at least 2 jet anti-k<sub>T</sub> R=0.4
  - $p_T(j) > 30$  GeV,  $|\eta(j)| < 2.4$



Source	$\Delta\sigma_{t\bar{t}}$ (pb)	$\Delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}}$ (%)
Data statistics	60	7.7
Trigger efficiencies	39	5.0
Lepton efficiencies	33	4.3
Lepton energy scale	< 1	$\leq 0.1$
Jet energy scale	20	2.6
Jet energy resolution	< 1	$\leq 0.1$
Pileup	2.8	0.4
Scale ( $\mu_F$ and $\mu_R$ )	1.5	0.2
$t\bar{t}$ NLO generator	15	1.9
$t\bar{t}$ hadronization	14	1.8
PDF	12	1.5
Single top quark	14	1.8
VV (V = W or Z)	3.5	0.5
Drell-Yan	3.9	0.5
Non-W/Z leptons	8	1.0
Total systematic (no integrated luminosity)	62	8.0
Integrated luminosity	93	12
Total	126	16.4

- preliminary uncertainty on luminosity: 12%
- Vdm scan analysis ongoing...



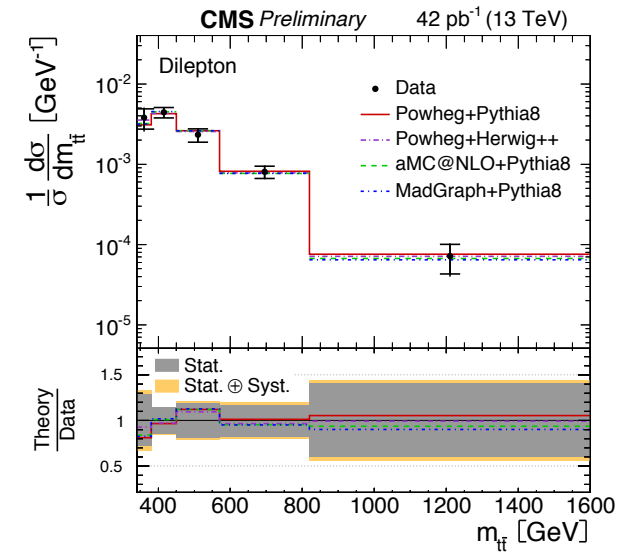
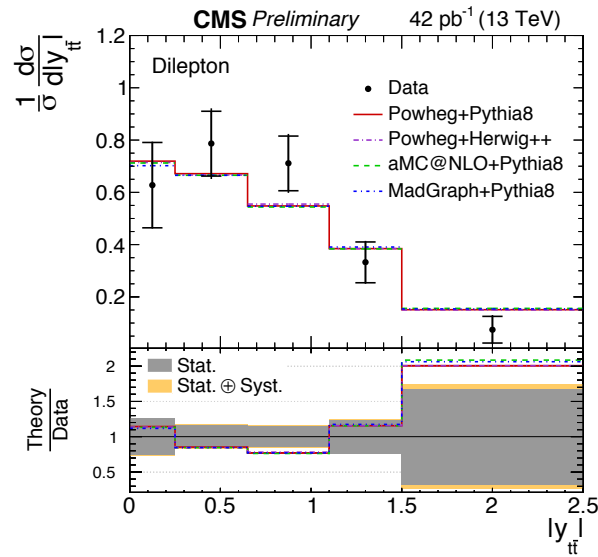
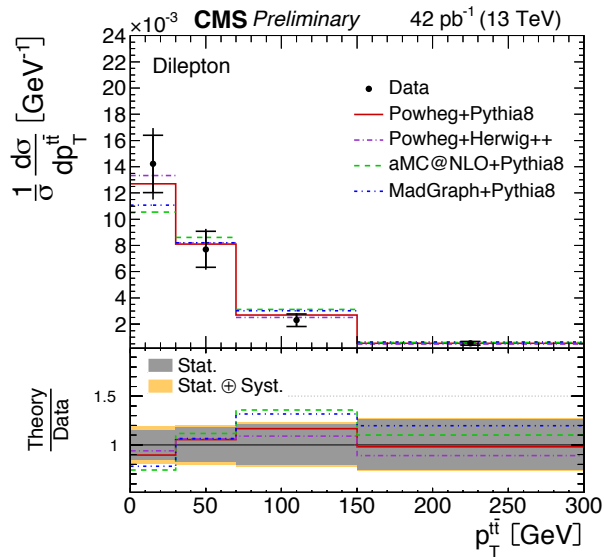
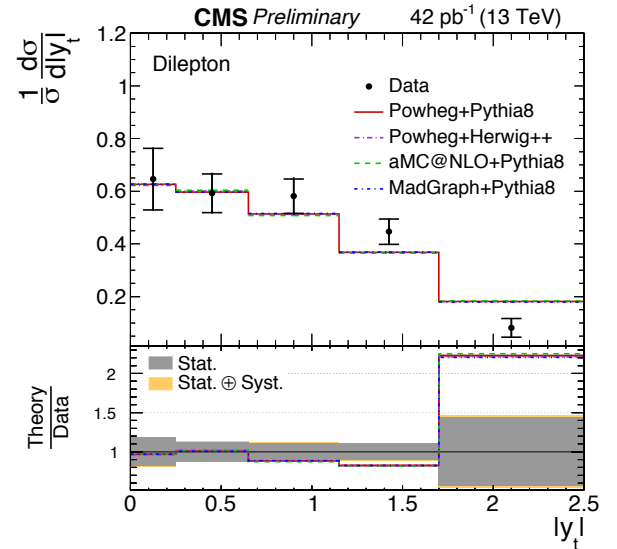
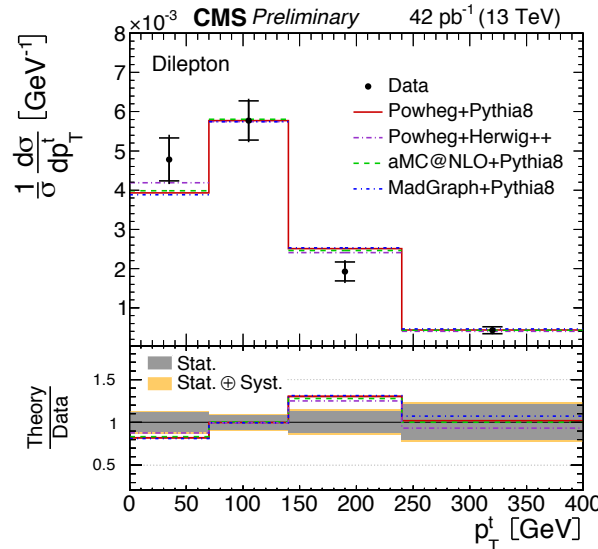
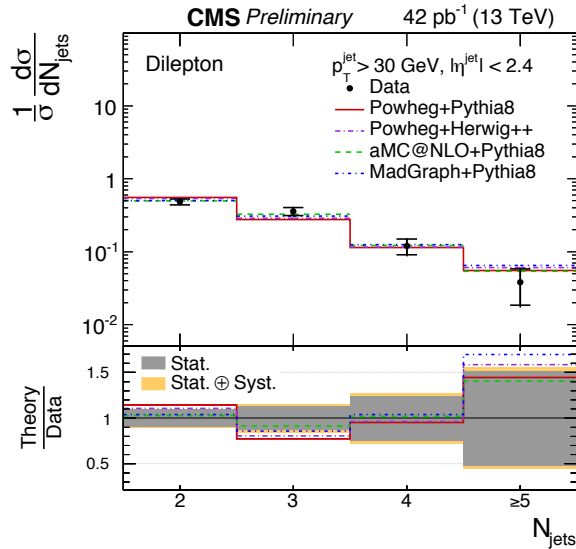
$\sigma_{t\bar{t}}(13 \text{ TeV}) = 772 \pm 60 \text{ (stat)} \pm 62 \text{ (syst)} \pm 93 \text{ (lumi)} \text{ pb}$   
 $\sigma(\text{NNLO+NNLL}, m_t=172.5 \text{ GeV}) = 832^{+40}_{-46} \text{ pb}$

$\sqrt{s}$  [TeV]

# $\sigma(t\bar{t})$ WITH DILEPTON RECONSTRUCTION: DIFFERENTIAL DISTRIBUTIONS

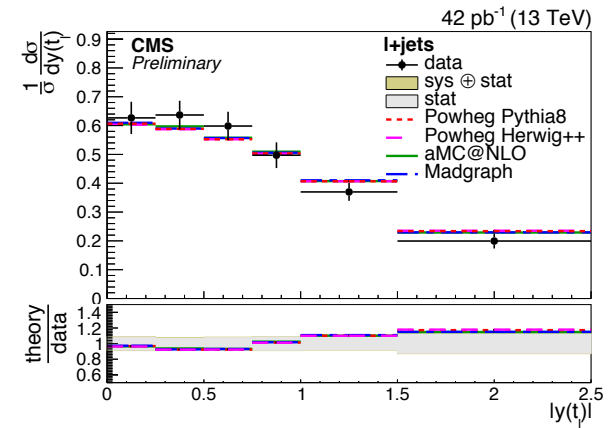
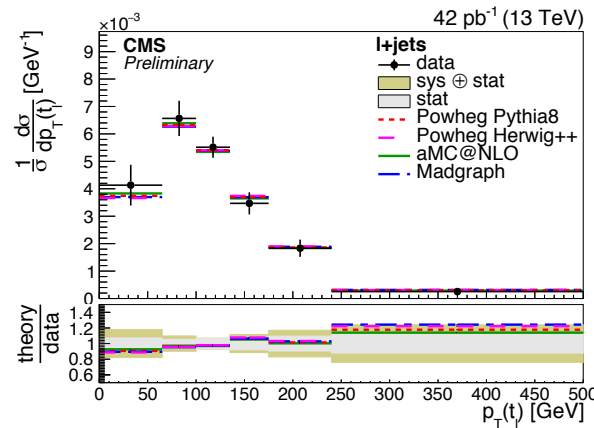
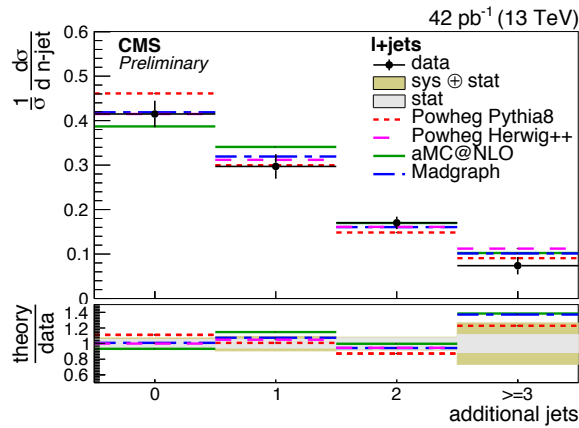
[CMS-PAS-TOP-15-010](#)

using every ee/ $\mu\mu$ /e $\mu$  combination



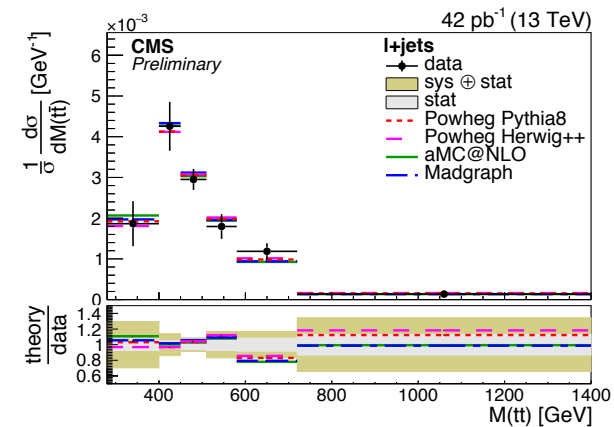
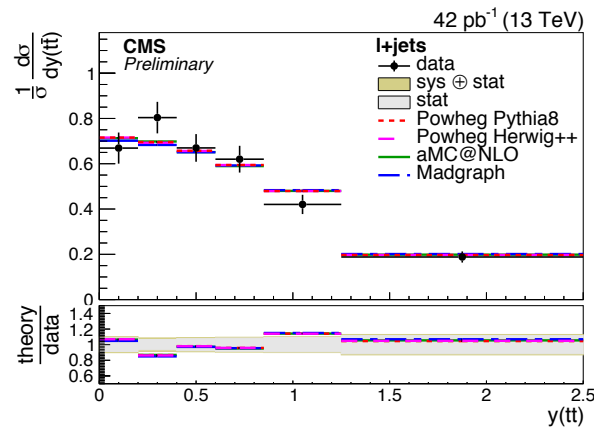
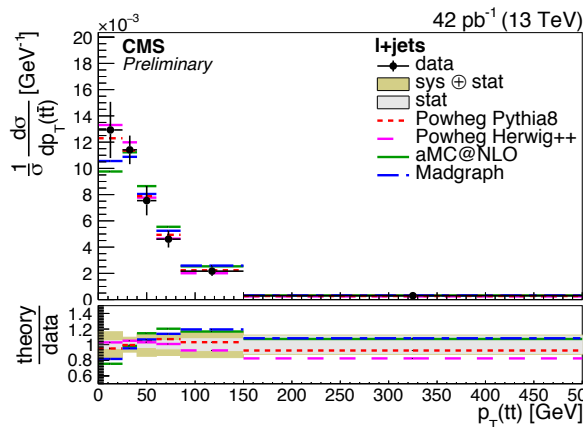
# $\sigma(tt)$ WITH SEMILEPTONIC RECONSTRUCTION

[CMS-PAS-TOP-15-005](#)



**$\sigma_{tt}(13 \text{ TeV}) = 836 \pm 27 \text{ (stat)} \pm 84 \text{ (syst)} \pm 100 \text{ (lumi)} \text{ pb}$   
 $\sigma(\text{NNLO+NNLL}, m_t=172.5 \text{ GeV}) = 832^{+20}_{-29} \text{ (scale)} \pm 35 \text{ (PDF)} \text{ pb}$**

$p_T(tt)$  well reproduced by POWHEG

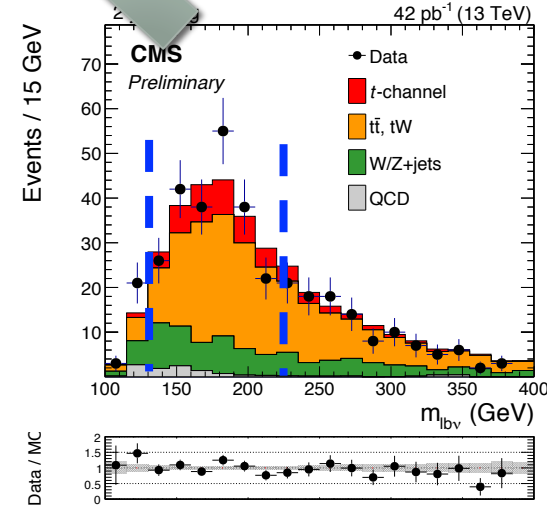
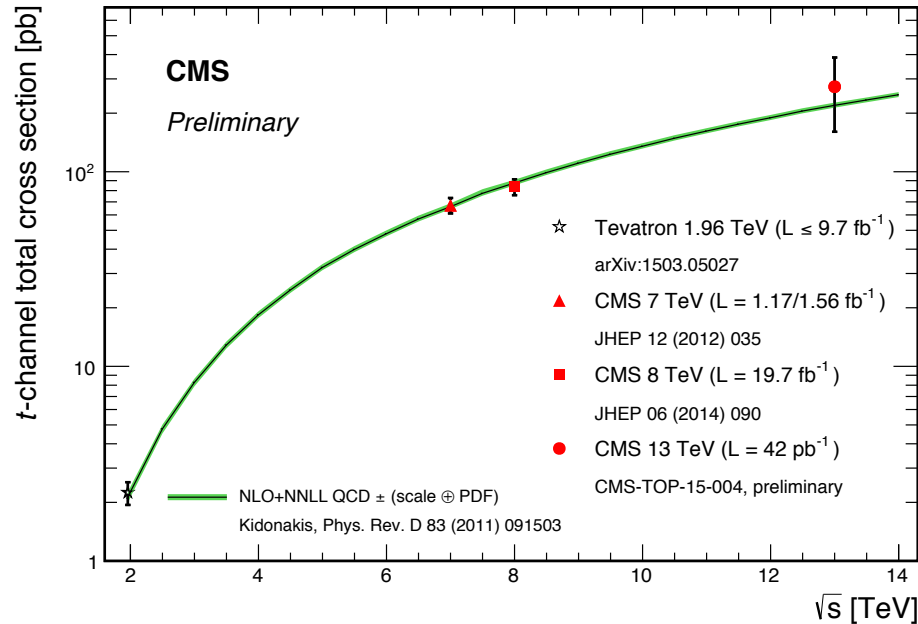
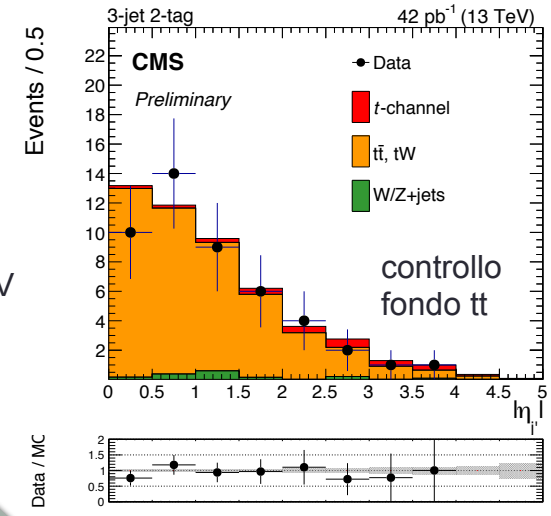
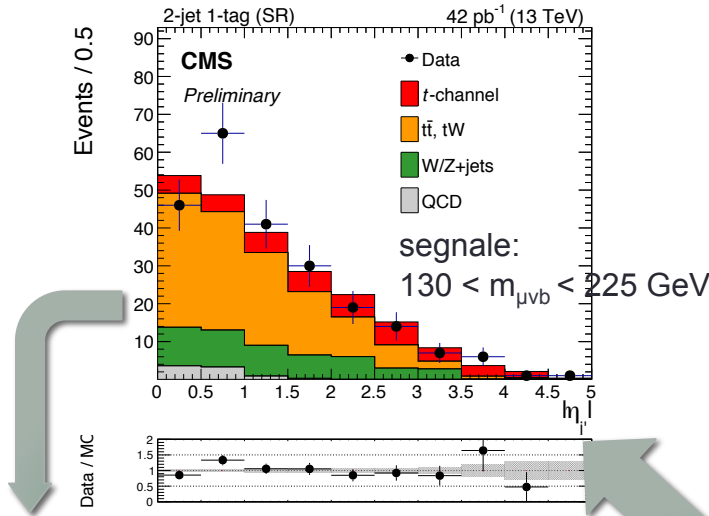


# SINGLE TOP QUARK IN T CHANNEL

CMS-PAS-TOP-15-004

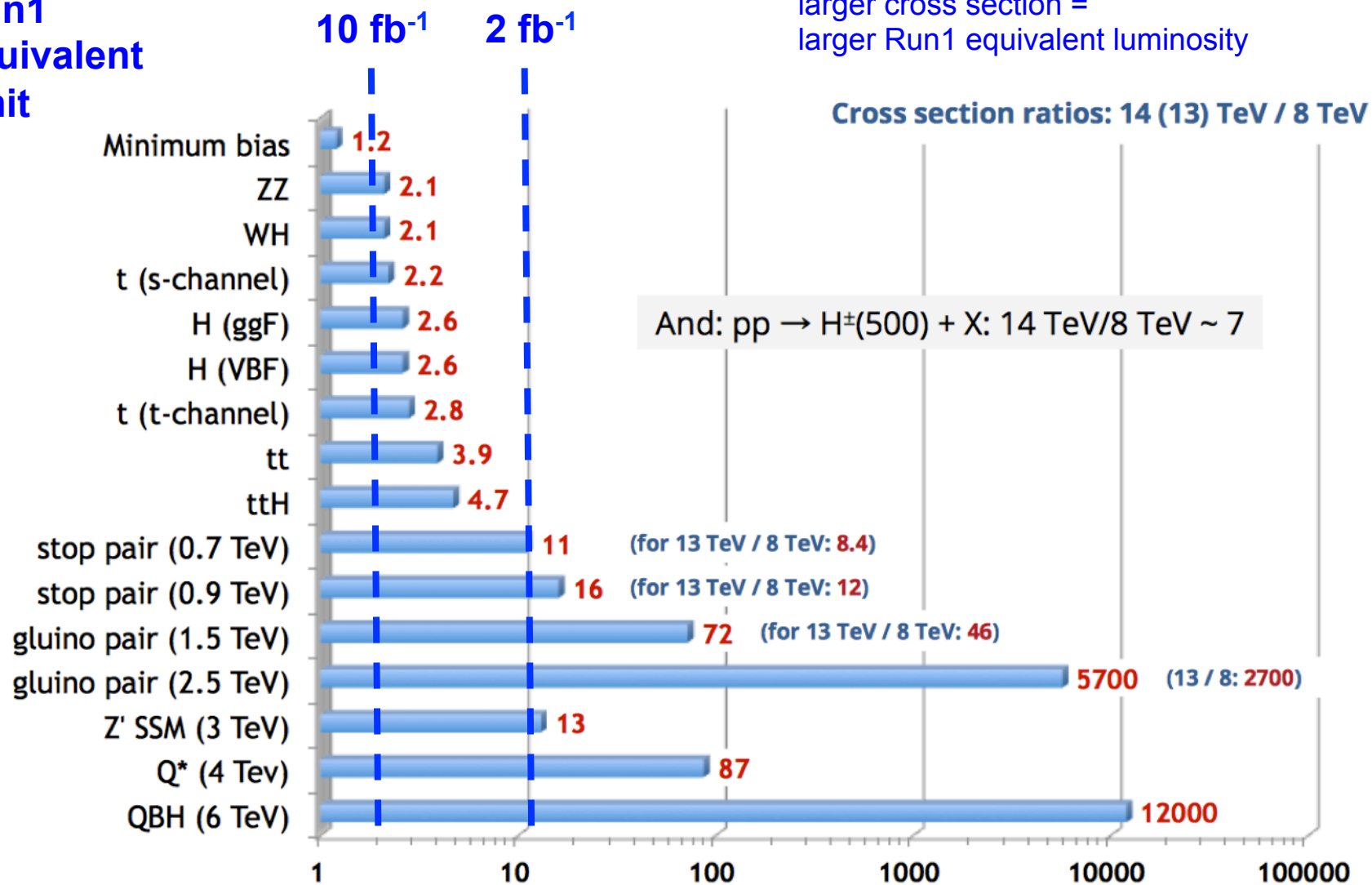
- Based on 42 pb<sup>-1</sup>
- 1 μ, p<sub>T</sub> > 22 GeV, |η| < 2.1
- jets anti-k<sub>T</sub> R=0.4
  - p<sub>T</sub> > 40 GeV, |η| < 4.7
  - b-tagged jet multiplicity discriminates signal and background
- ΔR(μ,j) > 0.3, m<sub>T</sub> > 50 GeV

$\sigma_{t\text{-ch}}(13 \text{ TeV}) = 274 \pm 98 \text{ (stat)} \pm 52 \text{ (syst)} \pm 33 \text{ (lumi)} \text{ pb}$   
 $\sigma(\text{NLO}) = 216.99^{+6.62}_{-4.64} \text{ (scale)}$   
 $\pm 6.16 \text{ (PDF)} \text{ pb}$



# RUN2: NEW PHYSICS PERSPECTIVES

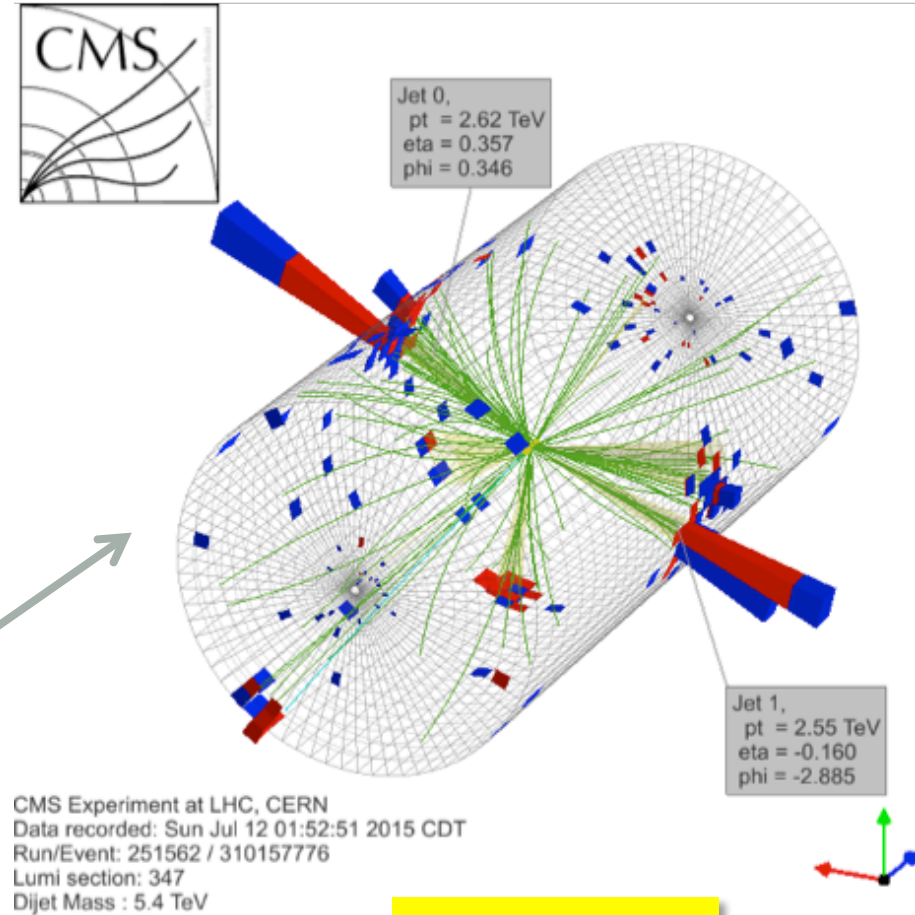
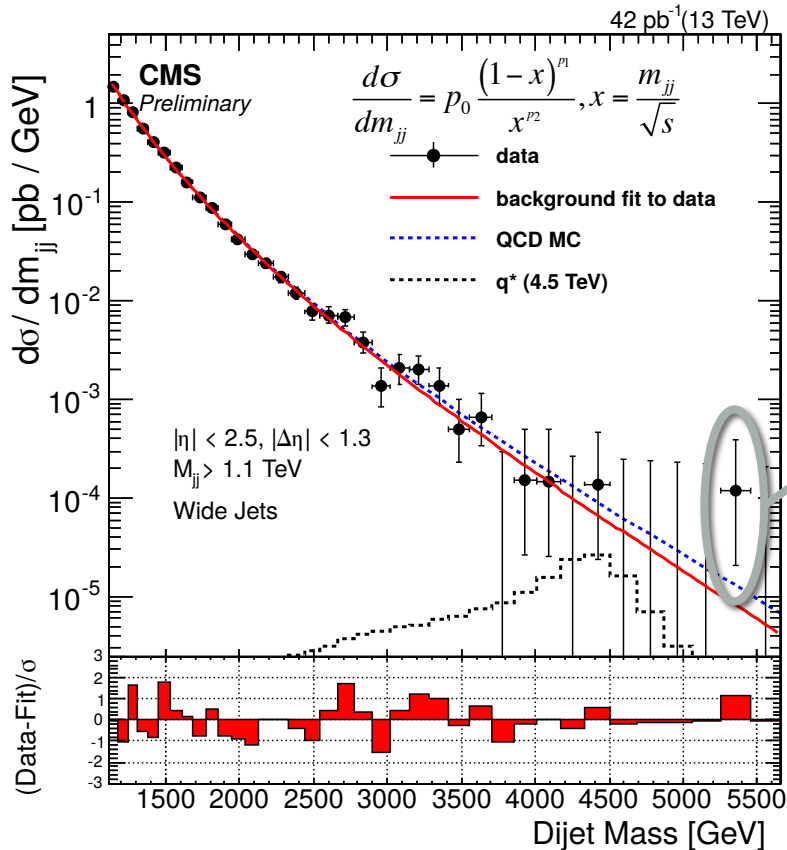
Run1  
equivalent  
limit



# DIJET RESONANCES SEARCH

CMS-PAS-EXO-15-001

- jets anti- $k_T$ ,  $R=0.4$
- combined into two wide jets
- $|\Delta\eta_{jj}| < 1.3$ ,  $|\eta| < 2.5$

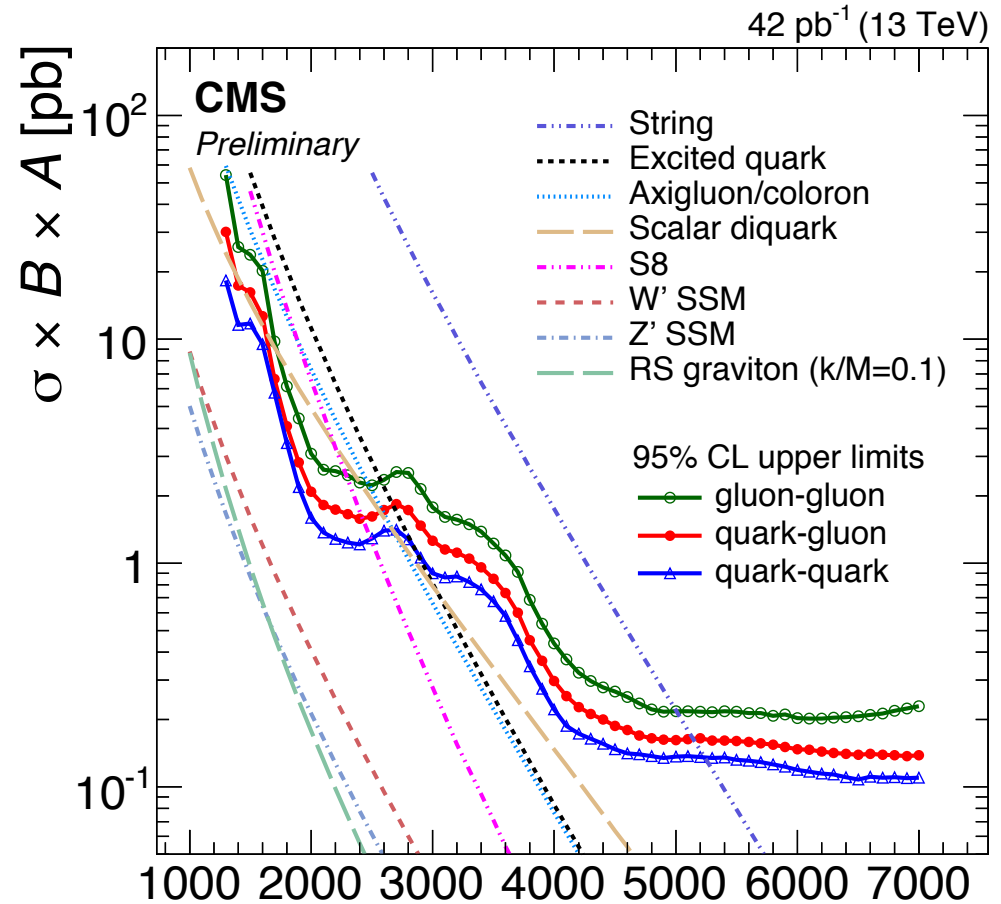


**$m_{jj} = 5.4 \text{ TeV}$**

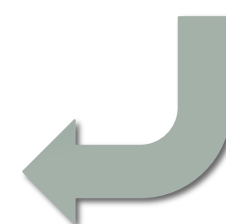


# DIJET RESONANCES SEARCH

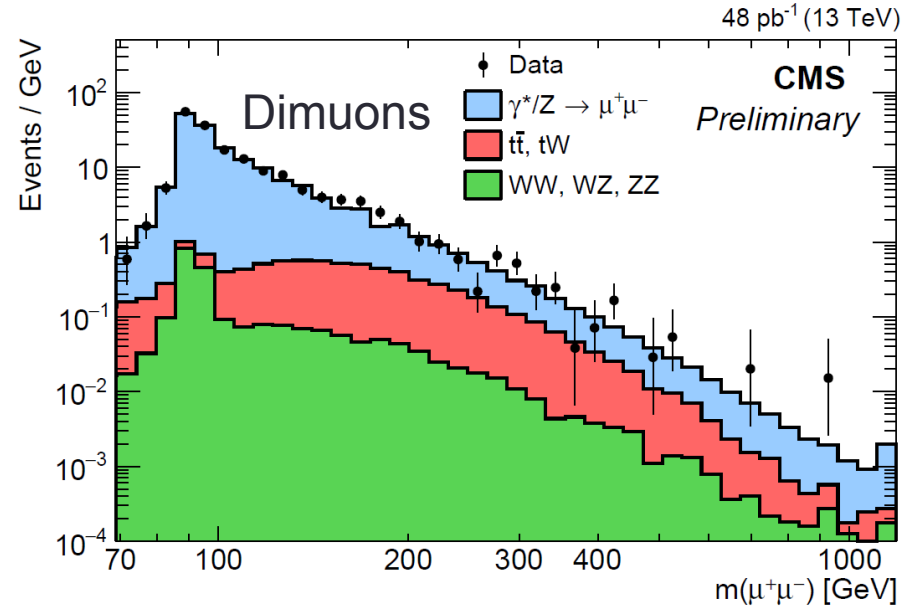
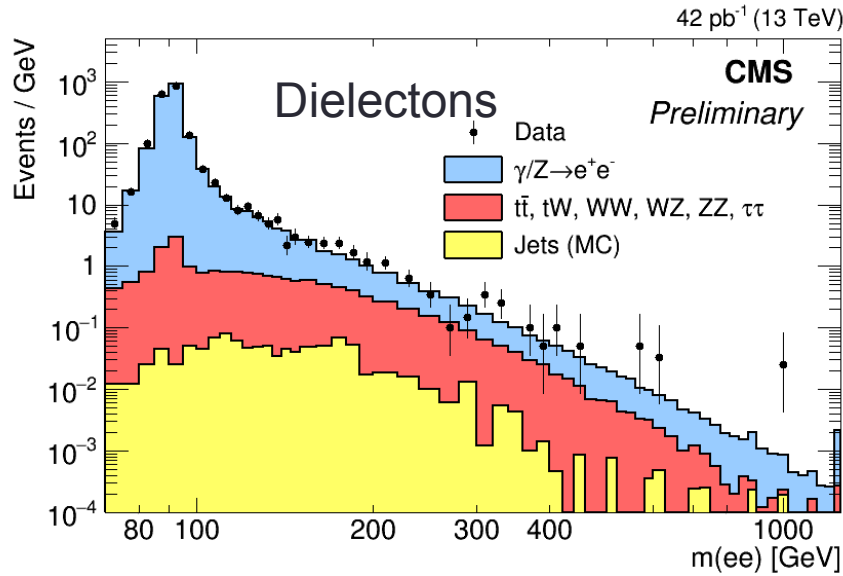
- Observed limits at 95% CL
- separated according to final state: qq, qg, gg
- Final state gluons: more radiation
  - worst resolution
- Sensitivity larger than at 8 TeV for masses beyond 5 TeV



Model	Final State	Obs. Mass Limit [TeV]	Exp. Mass Limit [TeV]
String Resonance (S)	qg	5.1	5.2
Excited Quark (q*)	qg	2.7	2.9
Scalar Diquark (D)	qq	2.7	3.3
Axigluon (A)/Coloron (C)	q $\bar{q}$	2.7	2.9
Color Octet Scalar (s8)	gg	2.3	2.0

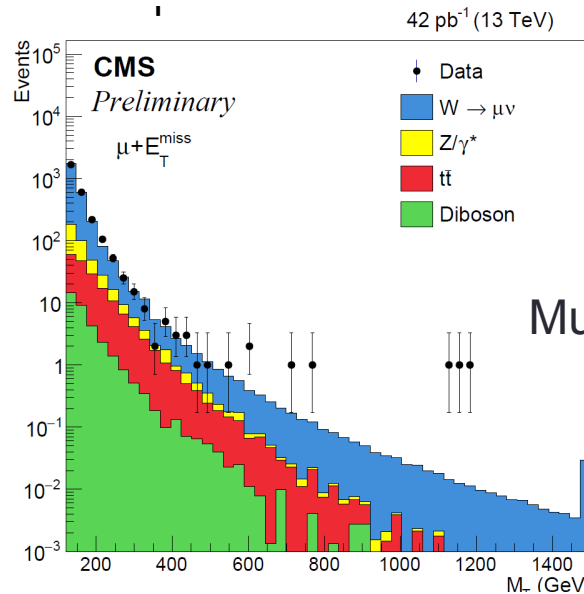


# LEPTONIC RESONANCES SEARCH



- Electrons:  $E_T > 35$  GeV,  $|\eta| < 2.5$ , at least one  $|\eta| < 1.44$
- Predictions normalize to data in  $60 < m_{ee} < 120$  GeV

- Muon:  $p_T > 55$  GeV,  $|\eta| < 2.4$
- veto second muon with  $p_T > 25$  GeV
- $0.4 < p_T(\mu)/E_T^{miss} < 1.5$
- $\Delta\phi(\mu, E_T^{miss}) > 2.5$

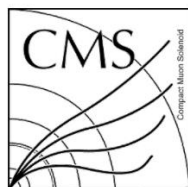
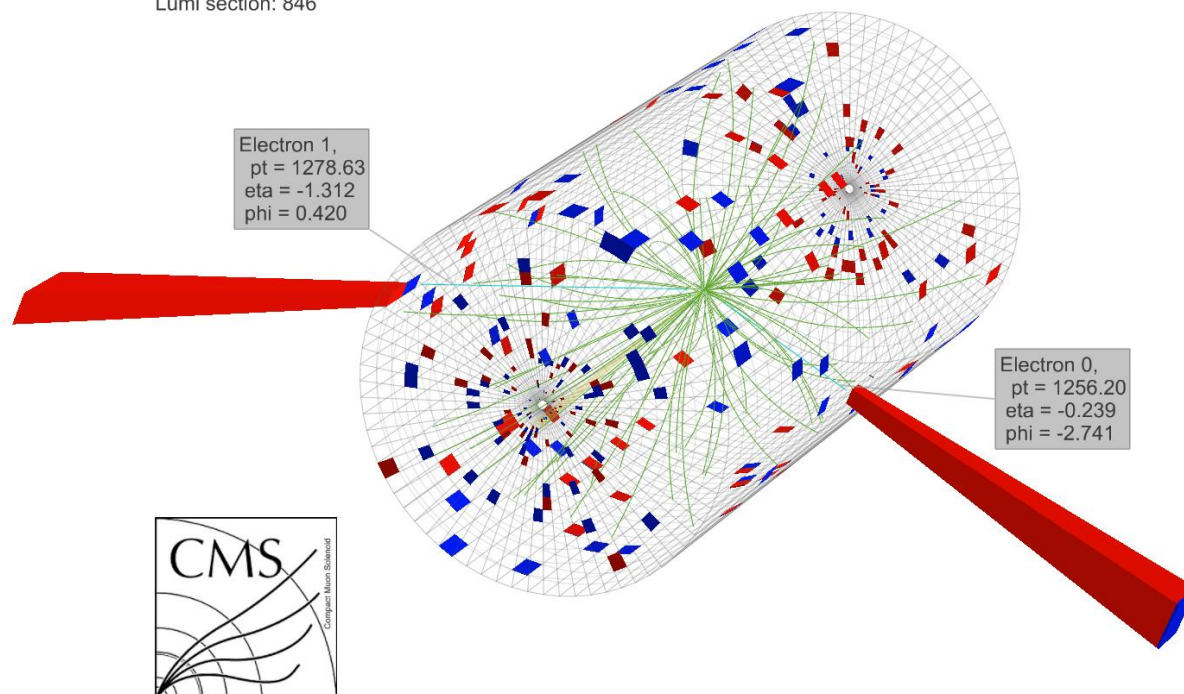


- Muons:  $p_T > 48$  GeV,  $|\eta| < 2.4$
- opposite sign

# DIELECTRON RESONANCE SEARCH

**$m_{ee} = 2.9 \text{ TeV} !$**

CMS Experiment at LHC, CERN  
Data recorded: Sat Aug 22 04:13:48 2015 CEST  
Run/Event: 254833 / 1268846022  
Lumi section: 846



[CMS-DP-2015-039/CDS:2048626](https://cds.cern.ch/record/2048626/files/CMS-DP-2015-039)

- negative  $\cos\theta_C$ 
  - Drell-Yan background mostly positive
- $\sim 0.002$  expected background events above 2.5 TeV
- not excluded by Run1 search

	electron 0	electron 1
$E_T$	1260 GeV	1280 GeV
$\eta$	-0.24	-1.31
$\phi$	-2.74 rad	0.42 rad
charge	-1	+1
mass	2.91 TeV	
$\cos\theta_{CS}^*$	-0.49	
$y$	-0.78	

# SUMMARY



- After a 2 years shutdown and upgrade CMS is operative
- First results produced, one paper already submitted, more coming
- First extension of new physics reach
- Ready for some surprise...

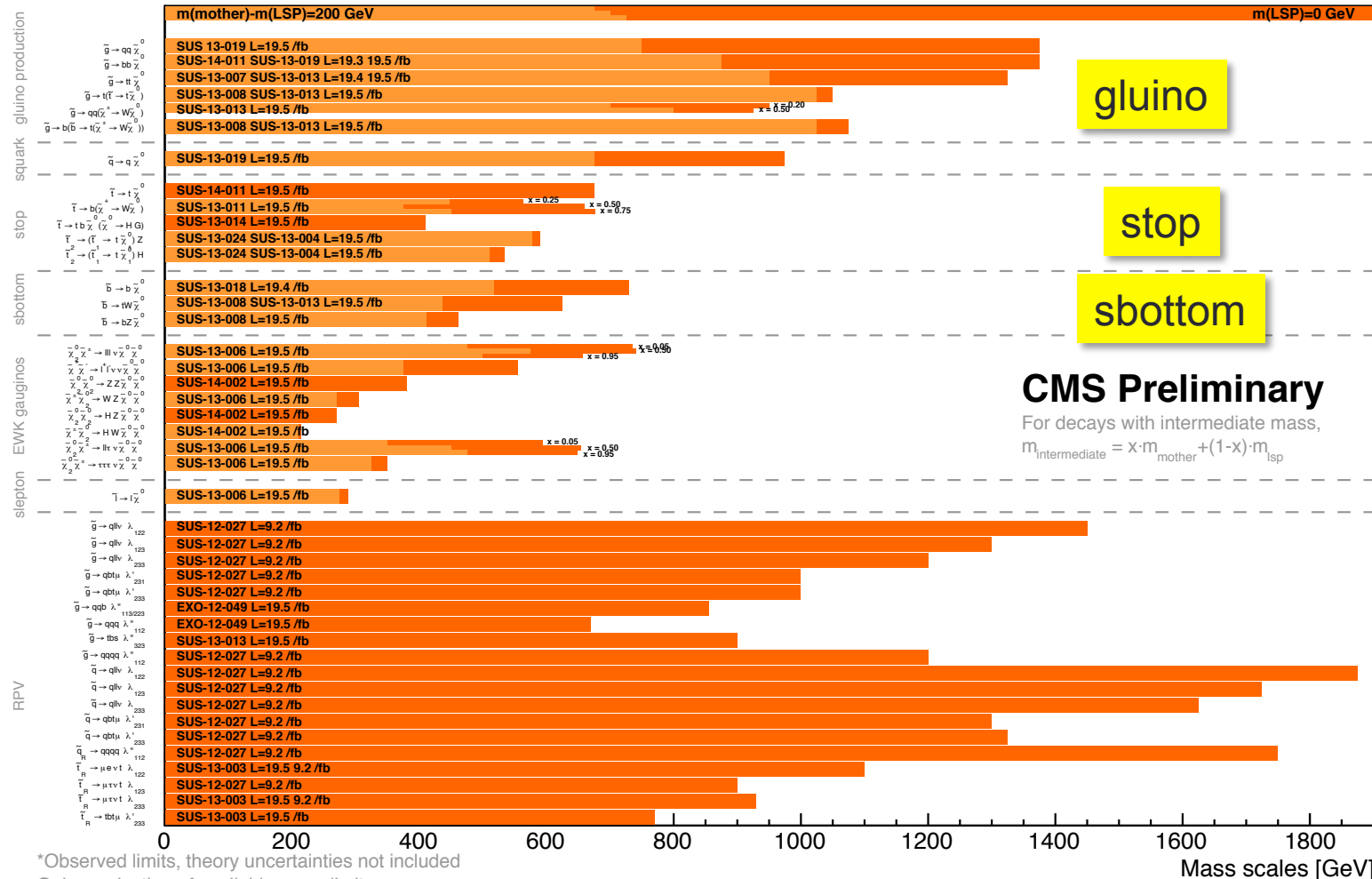
# BACKUP MATERIAL

# RUN1: NEW PHYSICS SEARCH

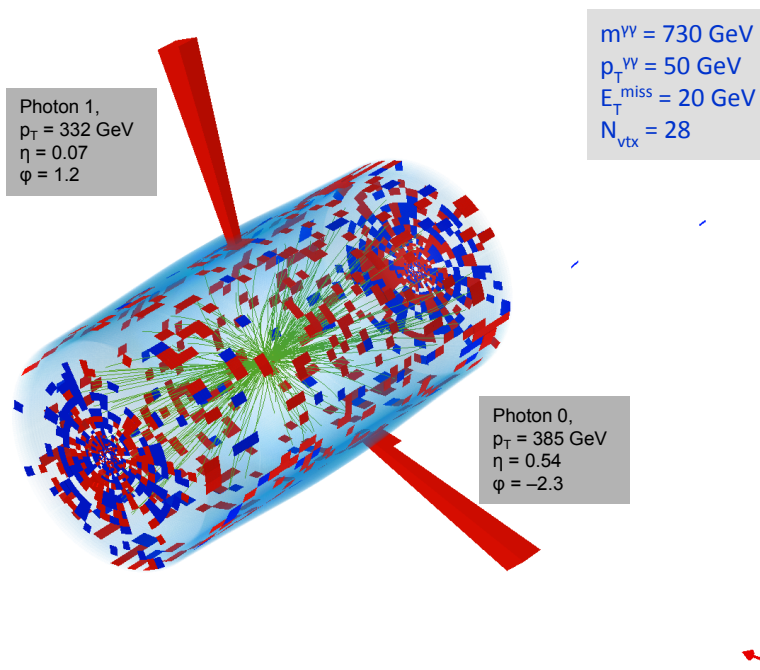
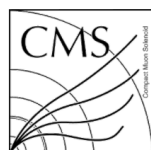
<https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsCombined>

## Summary of CMS SUSY Results\* in SMS framework

ICHEP 2014



# HIGHEST MASS DIPHOTON CANDIDATE



CMS Experiment at LHC, CERN  
Data recorded: Thu Jul 16 04:37:00 2015 CEST  
Run/Event: 251883 / 108749975  
Lumi section: 171  
Orbit/Crossing: 44591162 / 323

3D event display of the highest-mass diphoton candidate passing the event selection. The diphoton invariant mass is 730 GeV.

[CMS-DP-2015-037/CDS:2048094](https://cds.cern.ch/record/2048094/files/CMS-DP-2015-037)