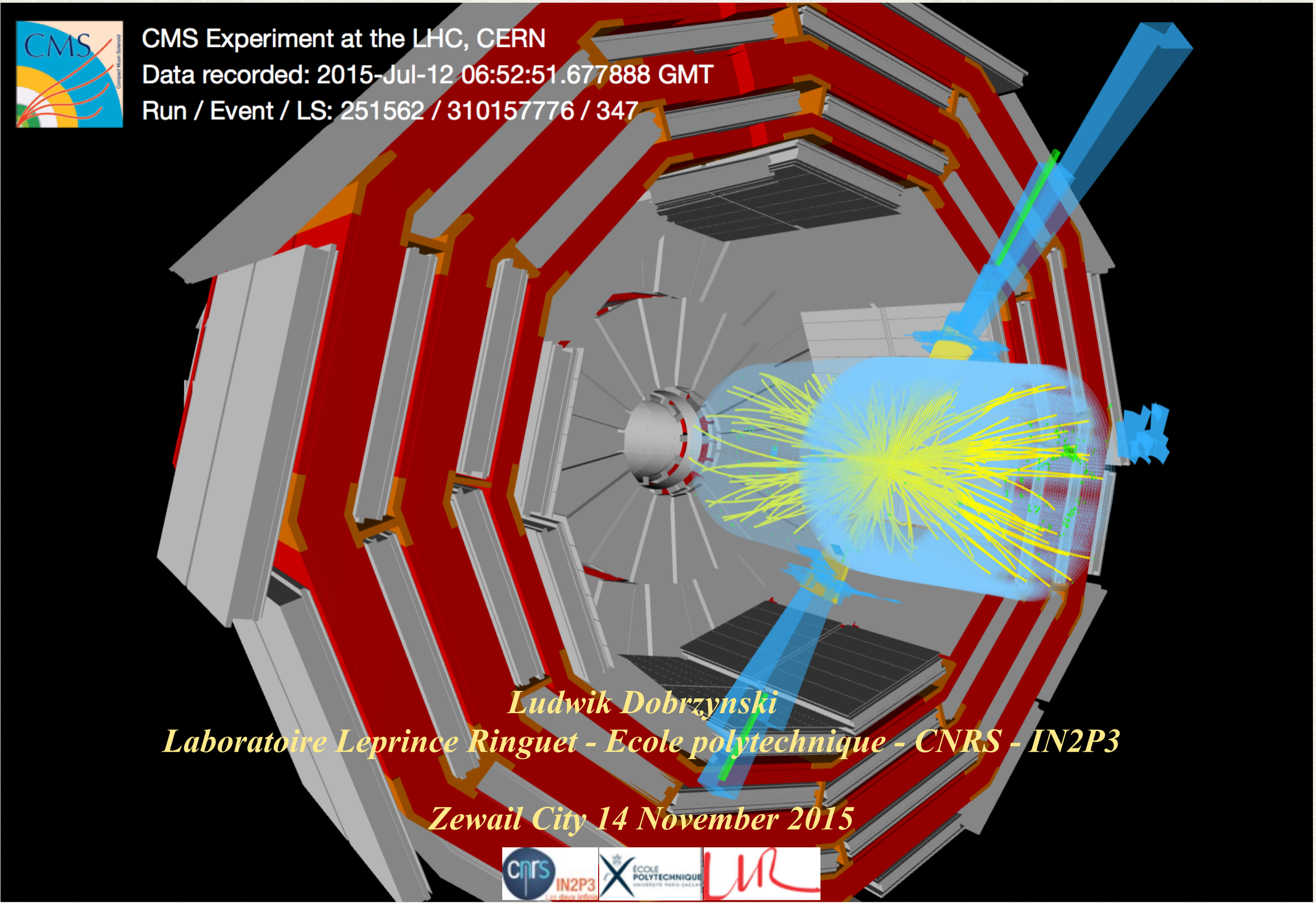
First look at 13TeV data



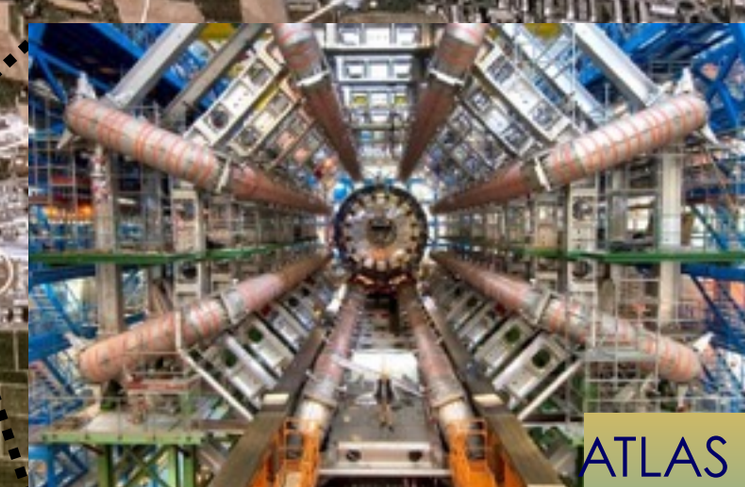
Ludwik Dobrzynski
Laboratoire Leprince Ringuet - Ecole polytechnique - CNRS - IN2P3

Zewail City 14 November 2015

Enter a New Era in Fundamental Science

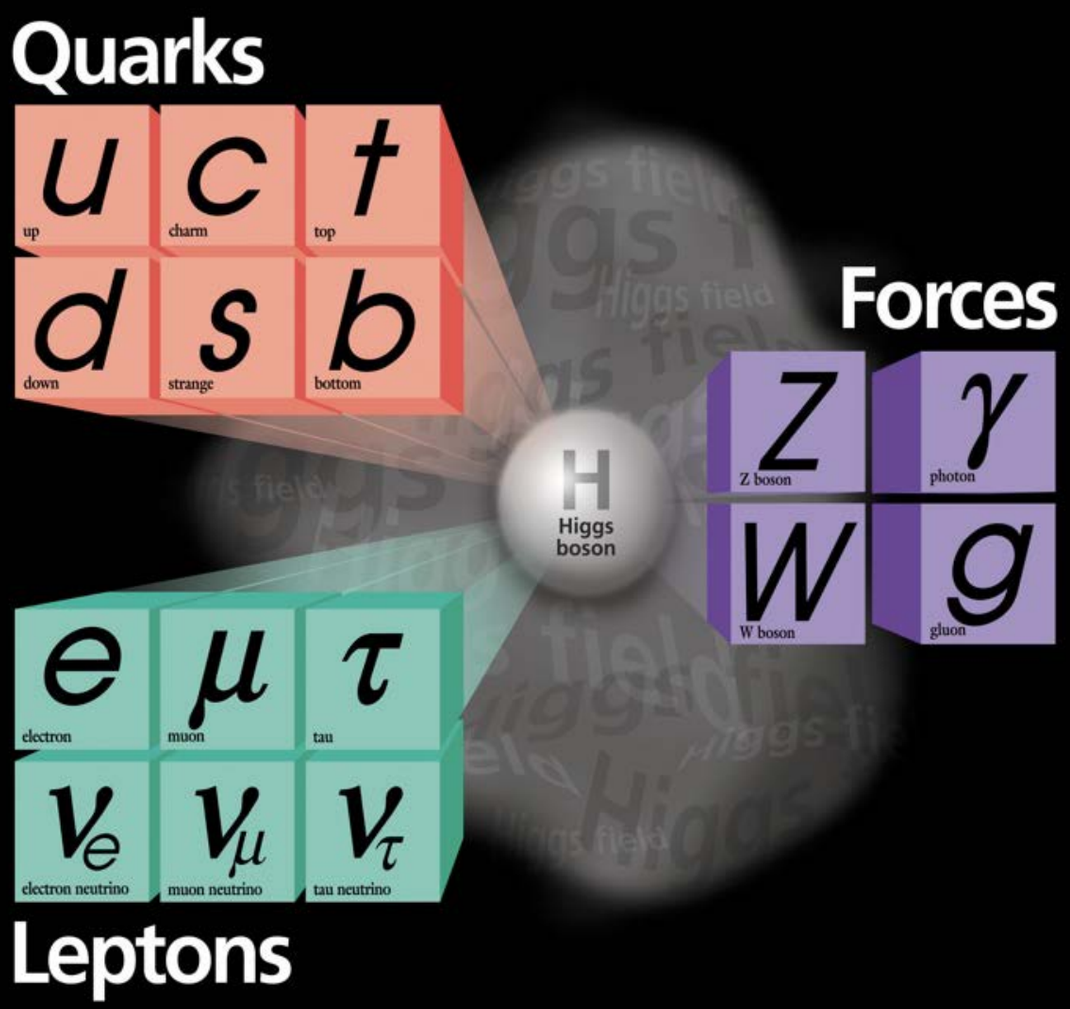
Start-up of the Large Hadron Collider (LHC), one of the largest and truly global scientific projects ever, is the most exciting turning point in particle physics.

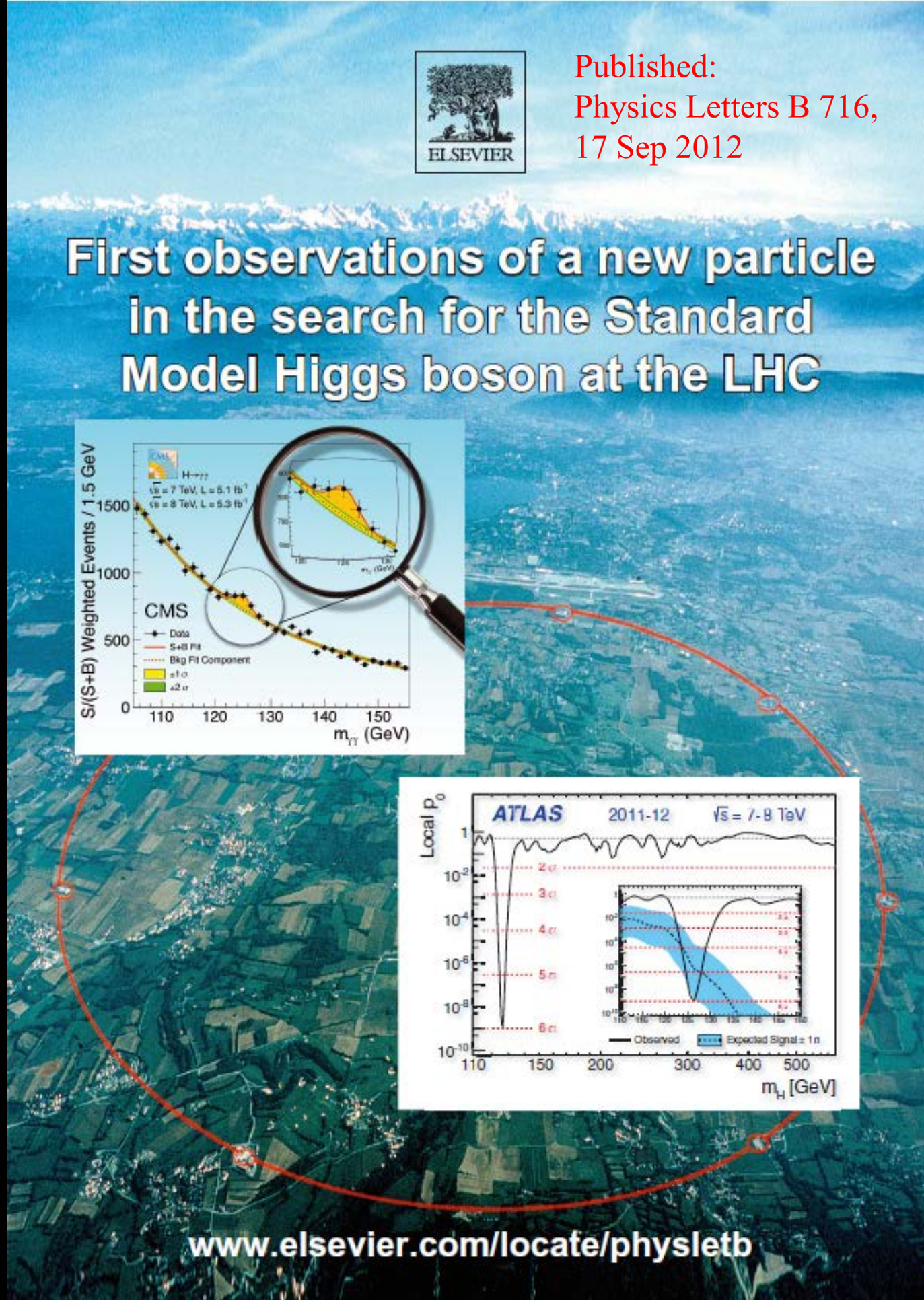
Exploration of a new energy frontier
Proton-proton collisions at E_{CM} up to 14 TeV



The discovery of the **Higgs particle** – the most important result from LHC (currently)

4.07.2012





CMS

Total weight 14000 t
Overall diameter 15 m
Overall length 28.7 m

The design goals of CMS:

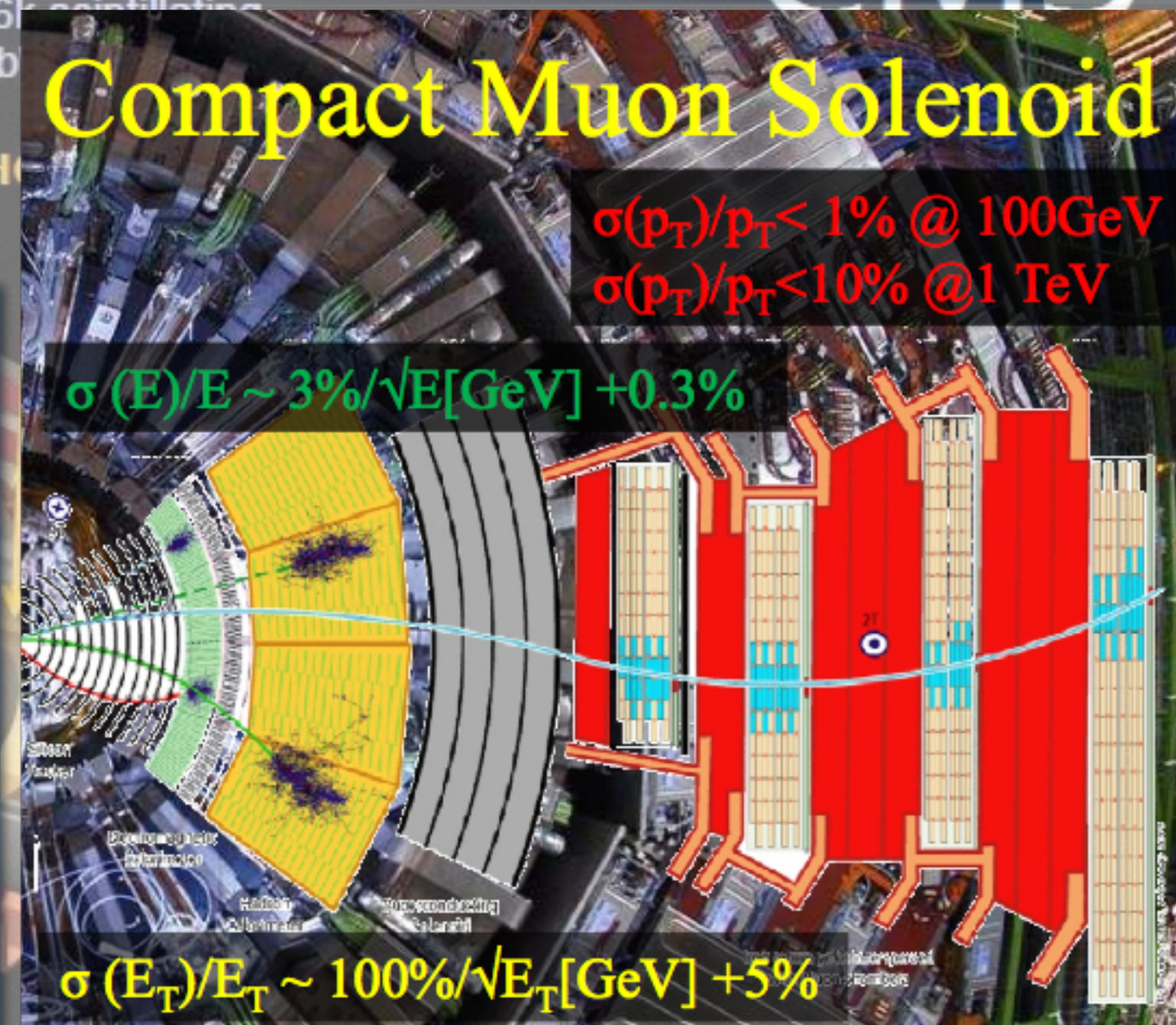
1. A very good and redundant muon system
2. The best possible ECAL consistent with 1)
3. A high quality central tracking to achieve 1) and 2)
4. A financially affordable detector

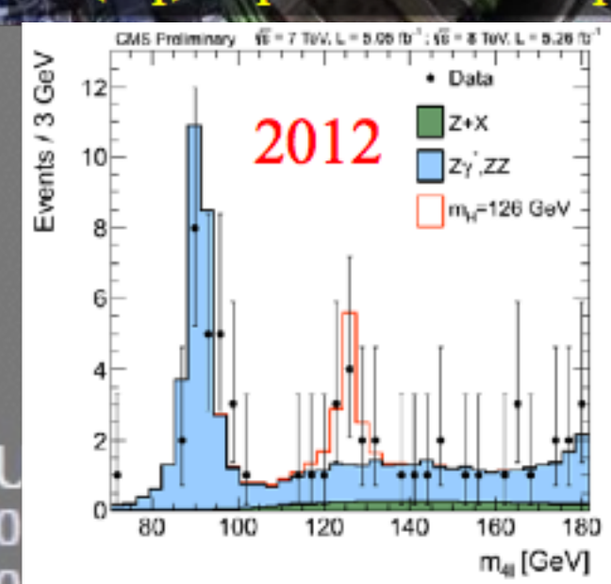
-3.8T solenoid 13m long, 6m diameter
- high eta HCAL coverage
-Silicon based inner tracking system supplementing all types of reconstr.

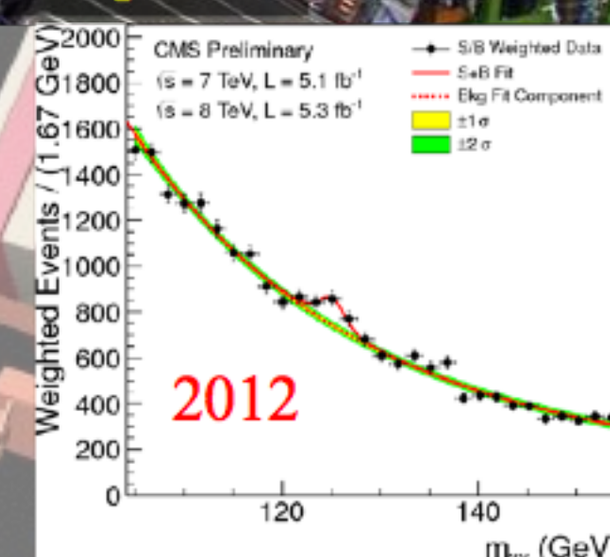
Powerful reconstruction of:

μ, e/γ, τ-jets, jets, MET

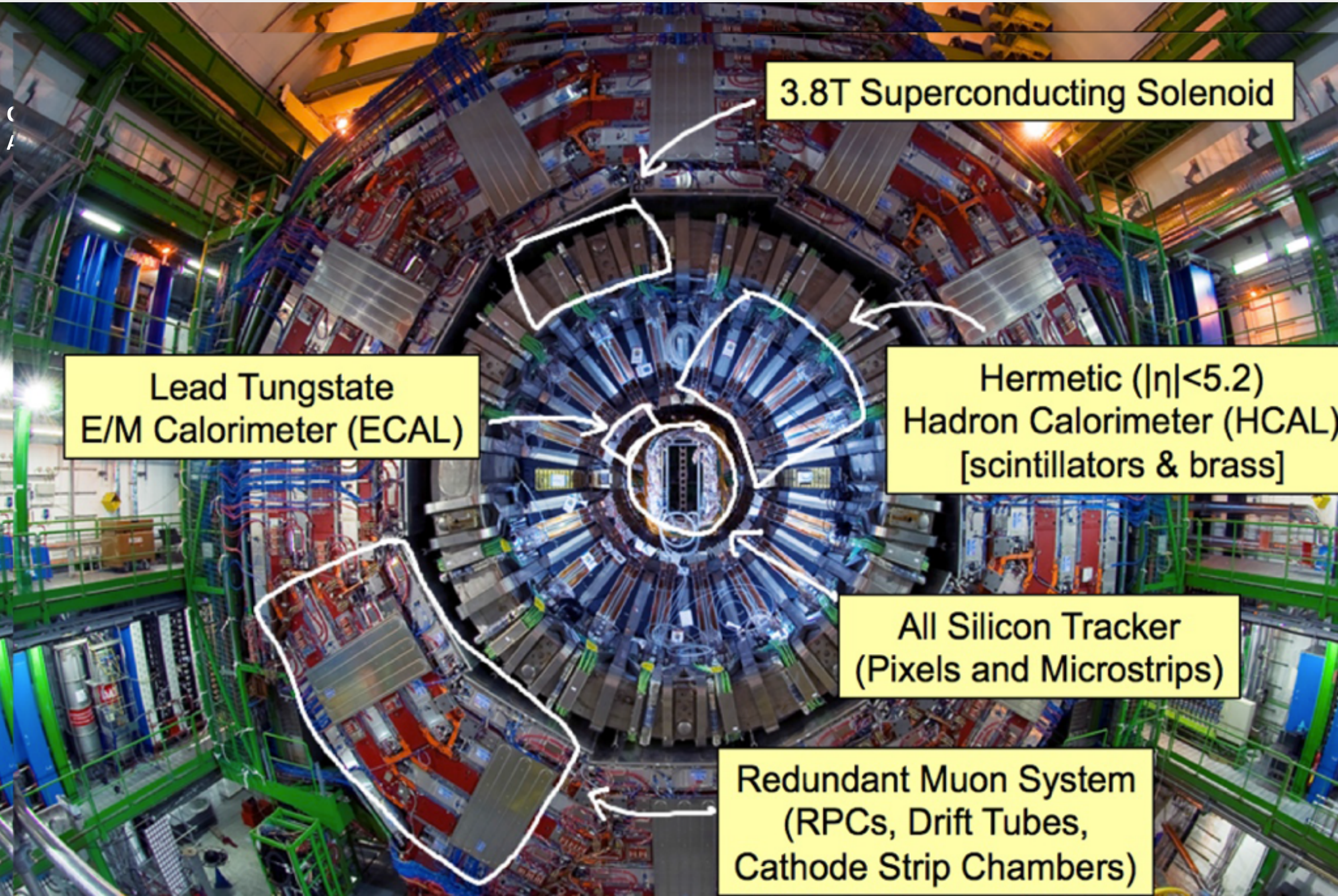
(+tracks, vertices)







The real CMS detector

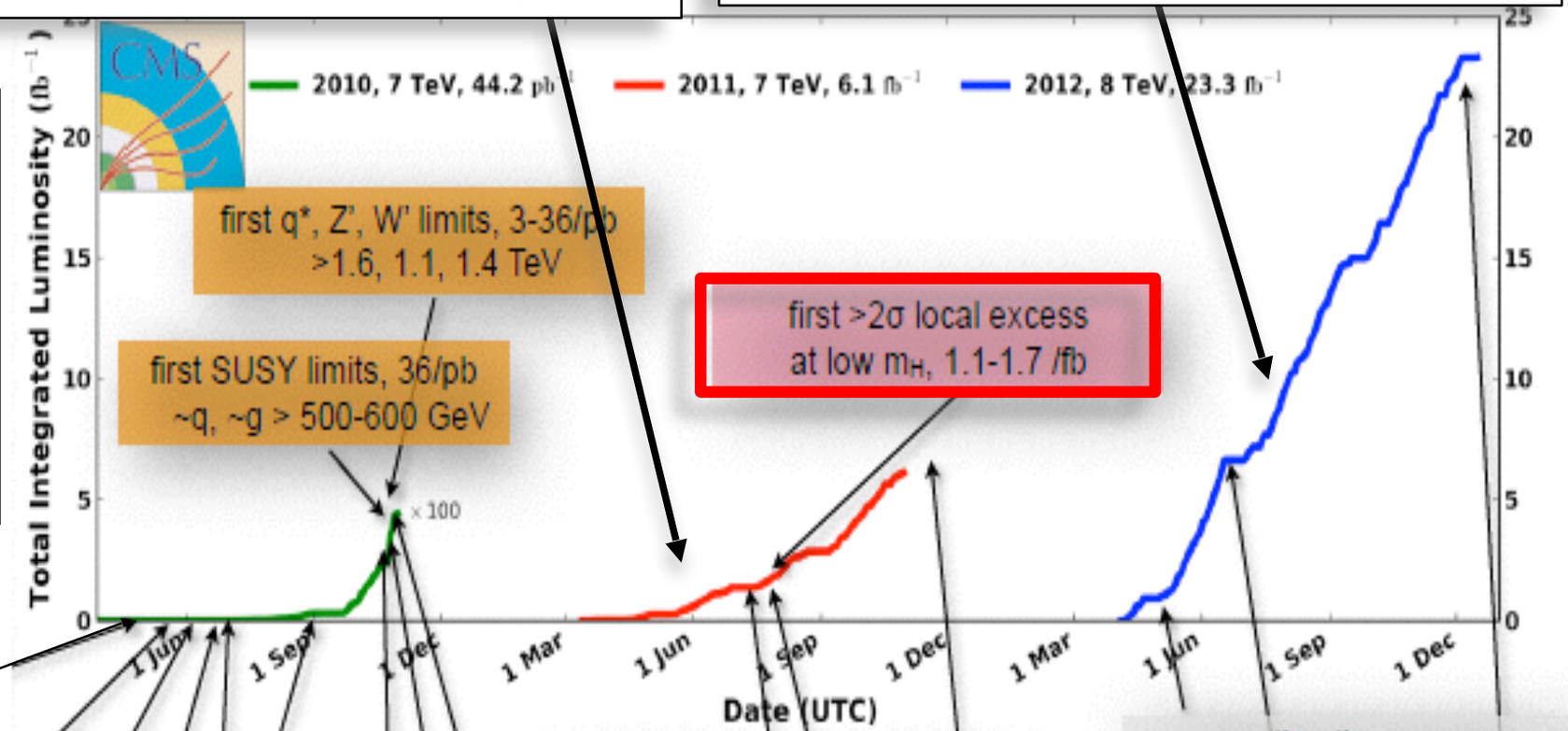


Plenty of barrel muons in online display!

100 Khz barrel muons (all pt)

2009 running:
- Hard to see anything apart from min bias in the displays.
- Serious analysis to find muons in the barrel.

What a run!



first q*, Z', W' limits, 3-36/pb >1.6, 1.1, 1.4 TeV

first SUSY limits, 36/pb ~q, ~g > 500-600 GeV

first >2σ local excess at low m_H, 1.1-1.7 /fb

repeating the program at 8 TeV

first MinBias / UE studies, particle multiplicities

first top xsec, 3/pb δ ~ 40%

first ZZ xsec, 1.1 /fb δ ~ 40%

first incl. b x-section, 8/nb δ ~ 15 %

first single top xsec, t-chan., 36/pb δ ~ 36%

going more differential, e.g. Z/W + j,b,c

a new boson is announced, 5 /fb

first incl. jet x-section, PF jets 60/nb δ ~ 20-30%

first m_{top}, 36/pb Δ ~ 6.5 GeV

first significant limit on $B_s \to \mu\mu$, BR<1.9x10⁻⁸

first incl. W/Z x-sections, 200/nb δ ~ 4-6%, +11% lumi

first WW xsec, 36/pb δ ~ 40% first limit on HWW

first particle discovered by CMS: Ξ_b

first incl. J/Ψ x-section, 100/nb δ ~ 20%

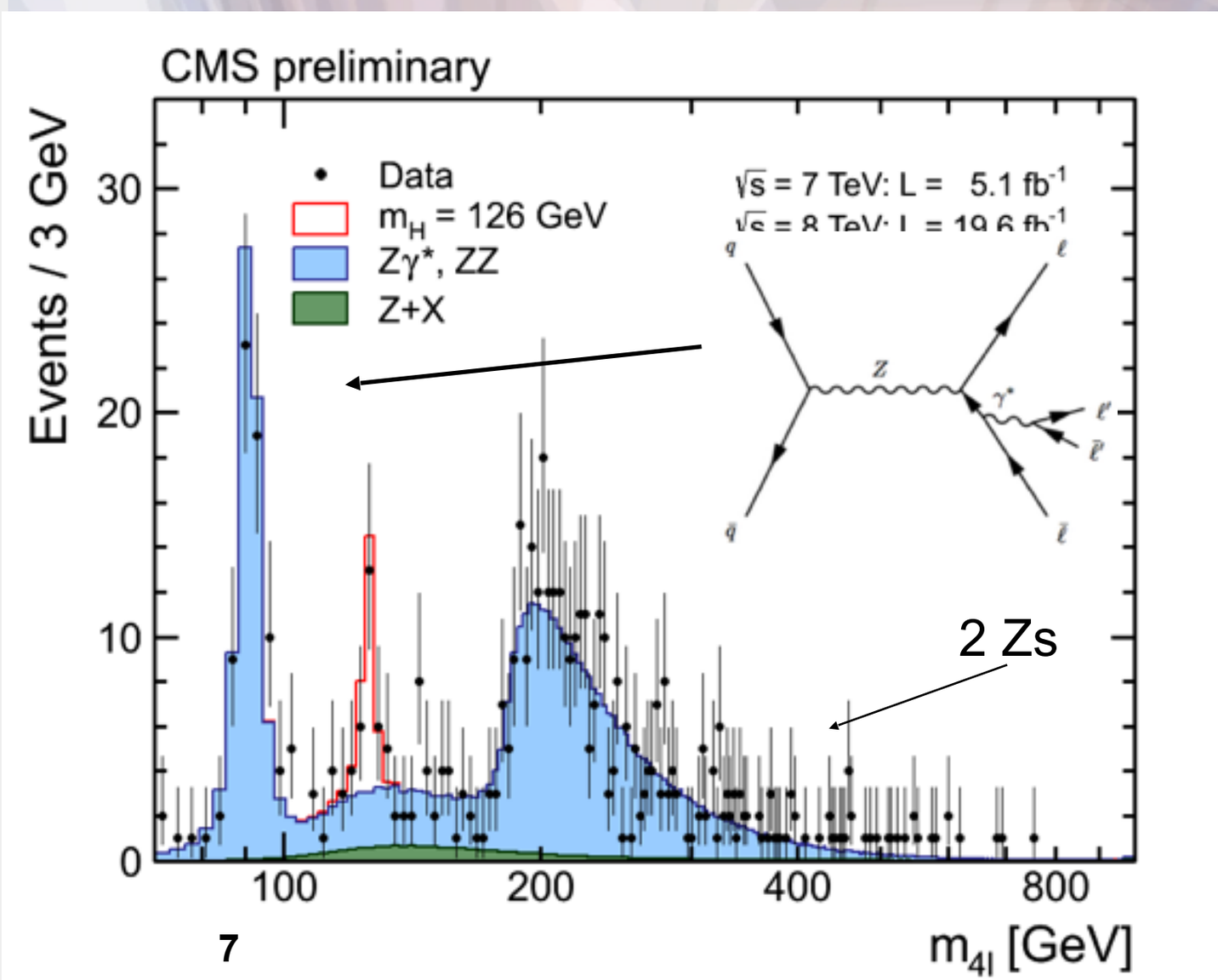
BSM searches continue, limits pushed

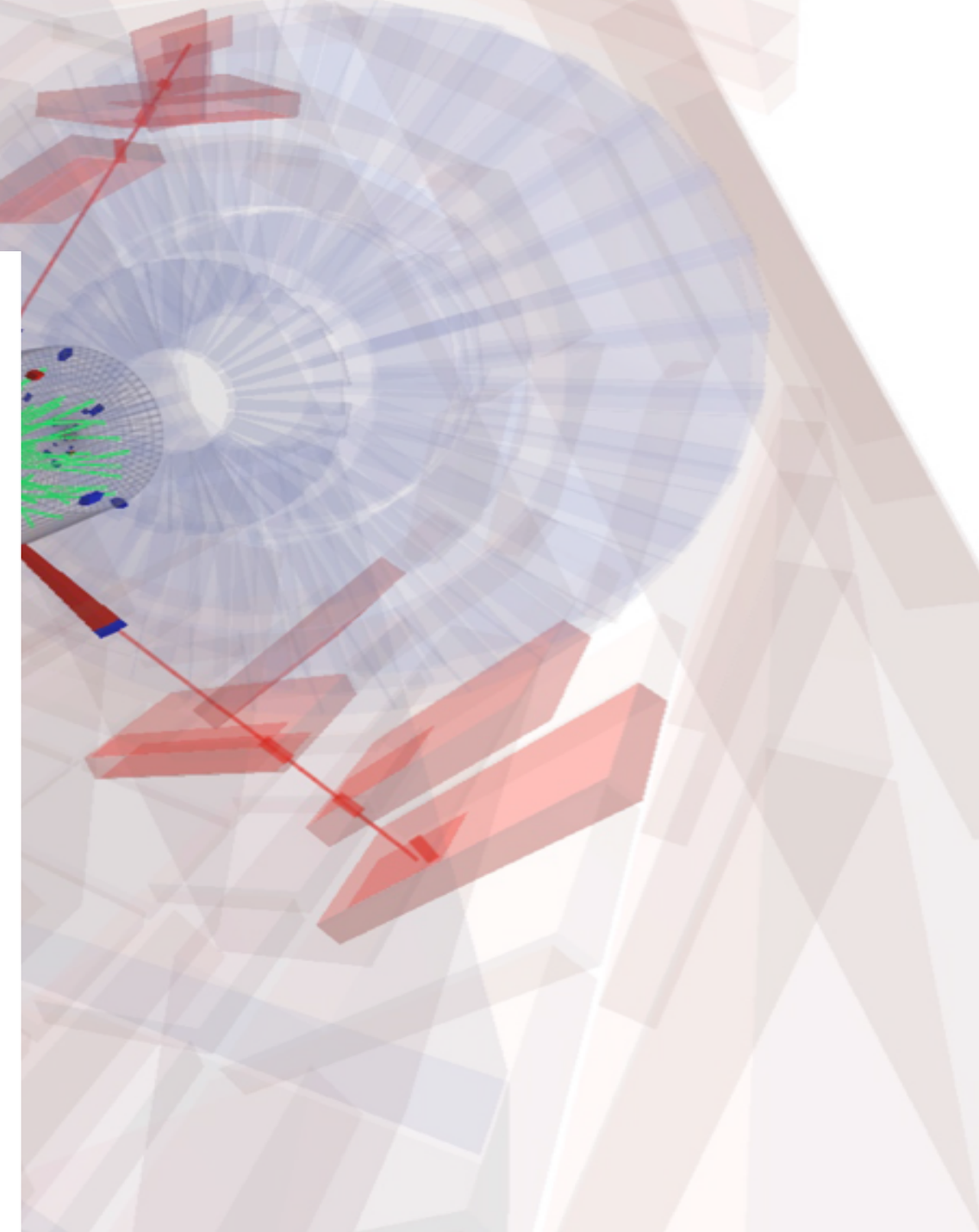
first spin parity analysis of the boson, 17 /fb

δ .. relative uncert Δ .. absolute uncert.

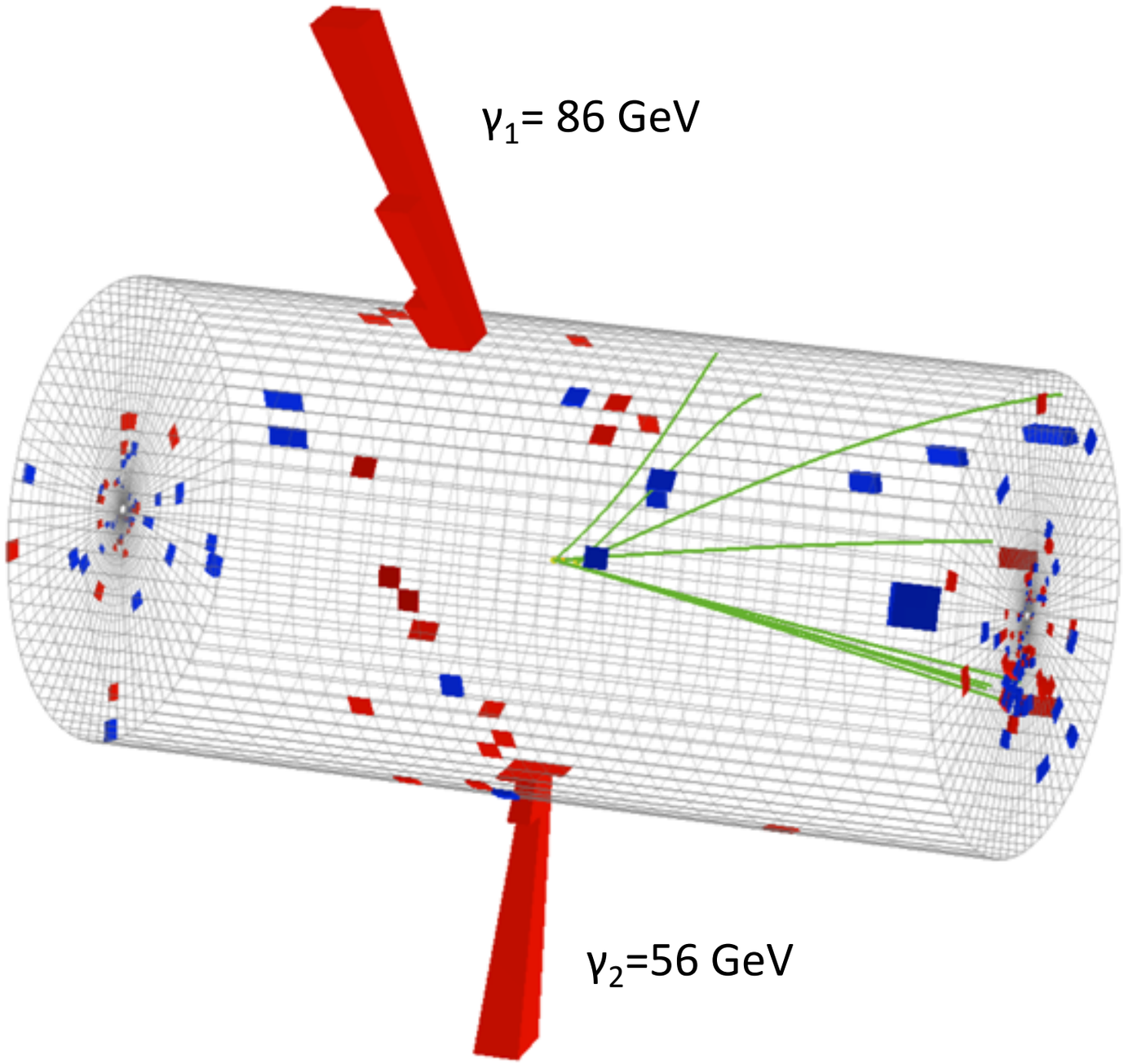
G. Dissertori

CMS in action: H->4 lepton

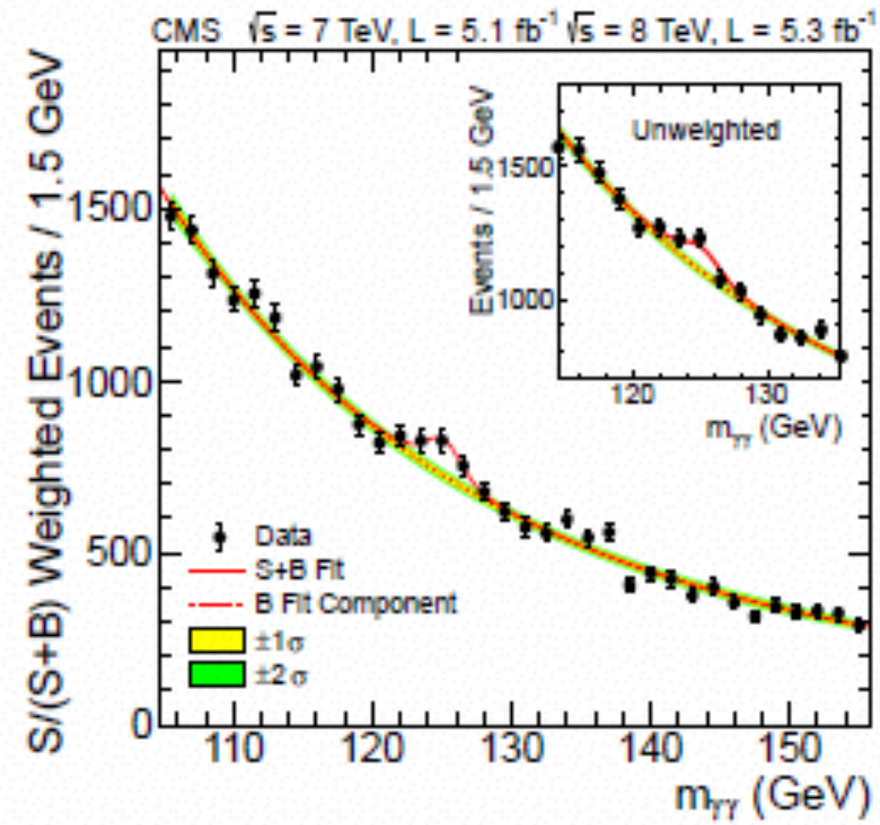




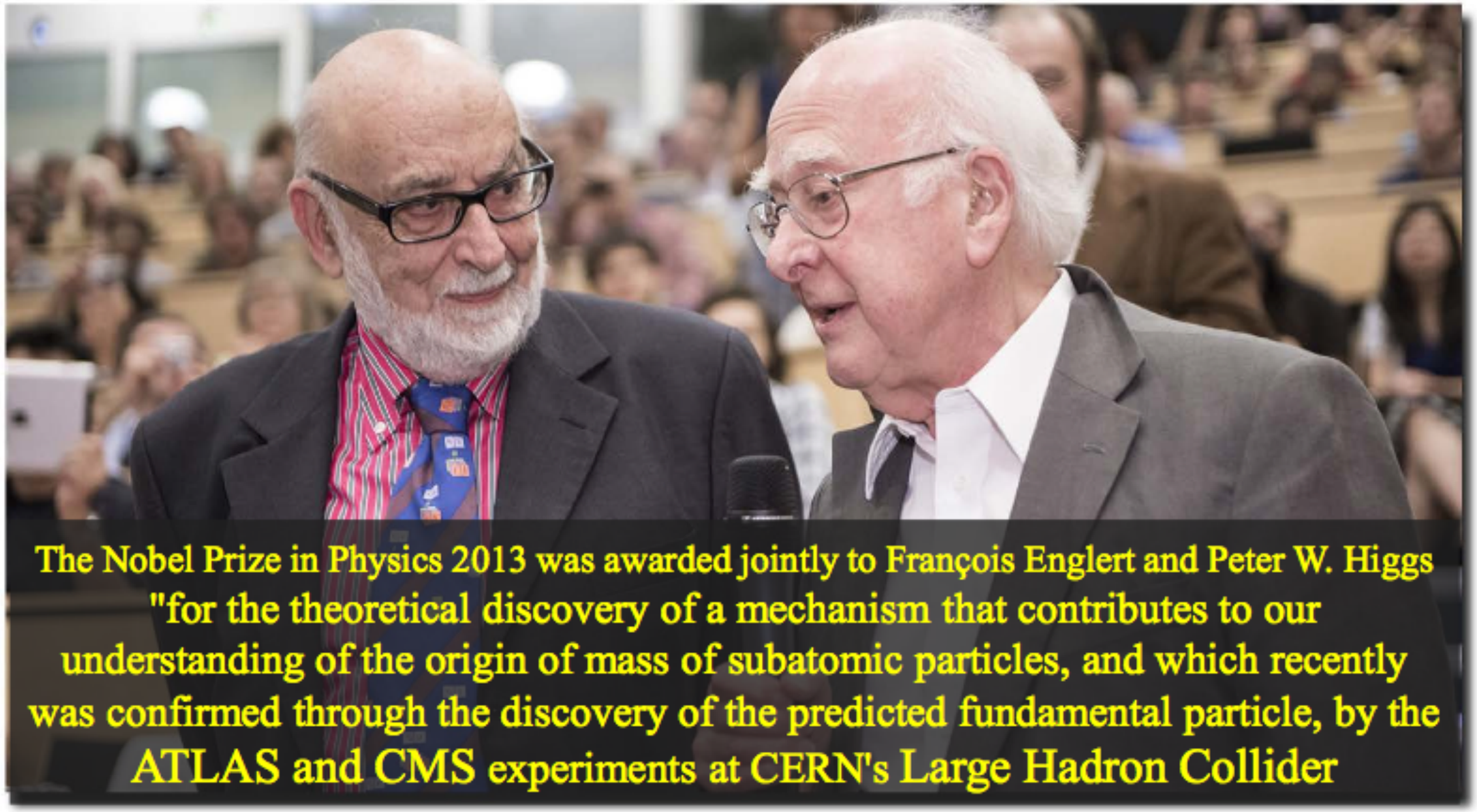
CMS in action: H->2γ

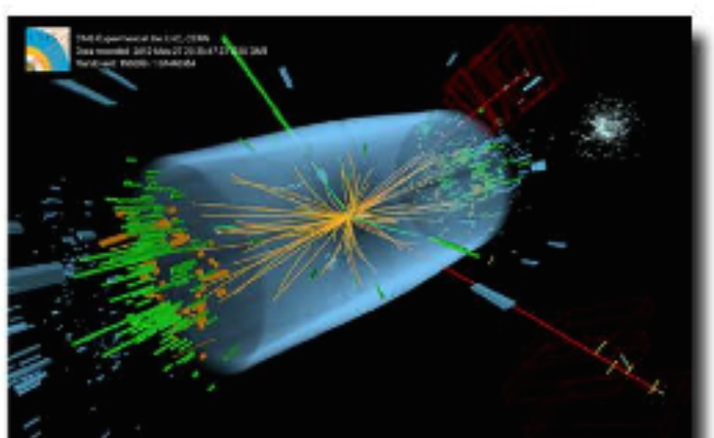


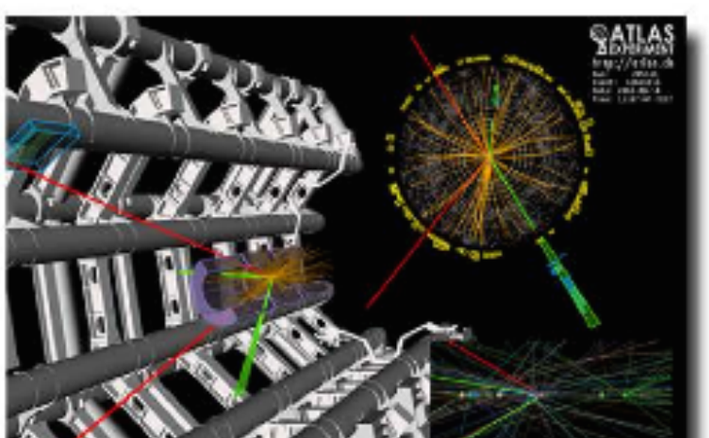
CMS Collaboration,
Phys. Lett. B716 (2012) 30-61



The Nobel Prize in Physics 2013







Computing and Data handling

Reconstructed events

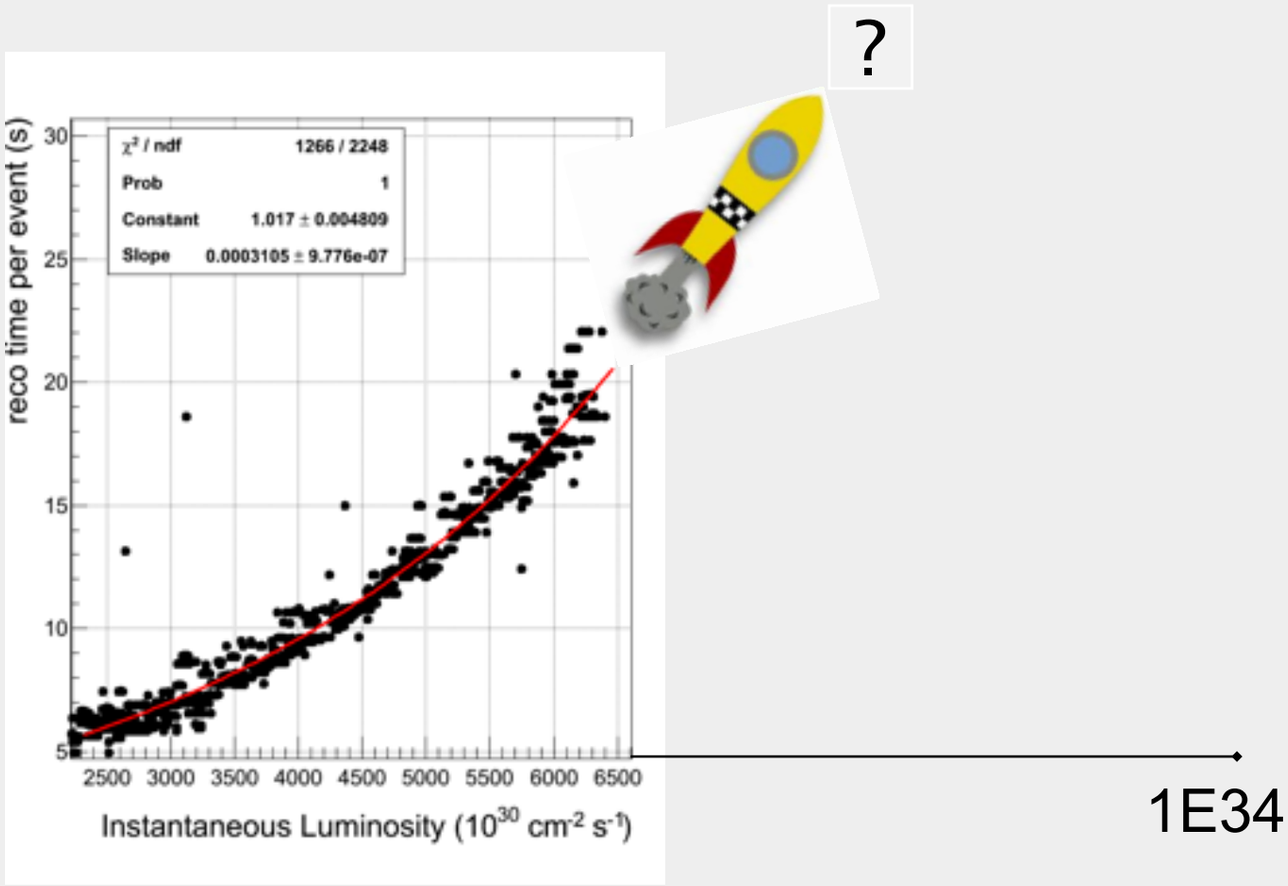
- 20 billion simulated events
- 12 billion data events

Data volume

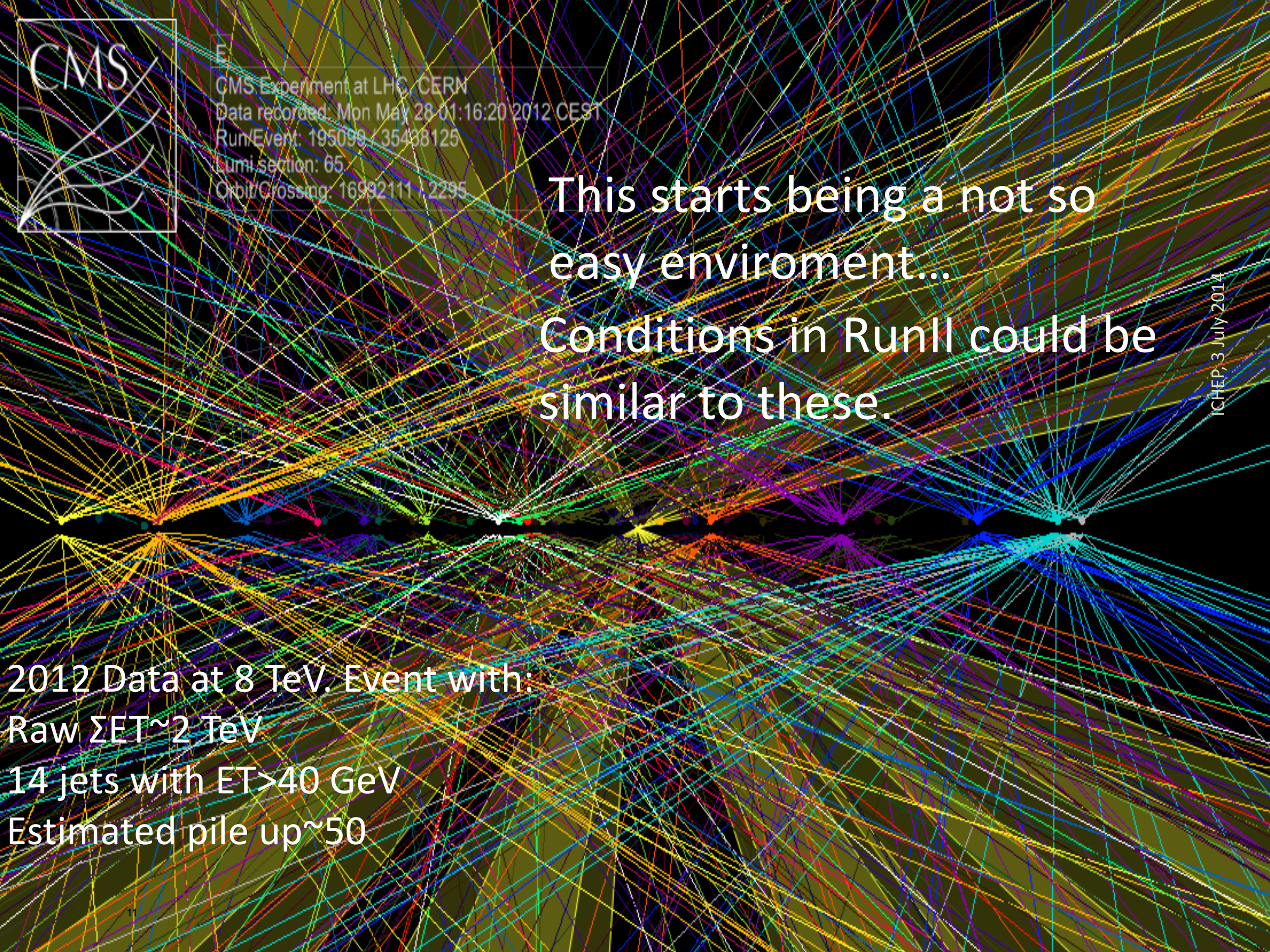
More than 25PB moved to Tier-1s

70PB moved to Tier-2s

- Improvements in the reconstruction code to cope with pile up
- Reconstruction time per event reduced by maintaining the physics performance.
  - Non-linear with PU → explodes



Quite a challenge: All things equal, 2015 computing needs increase x10



This starts being a not so easy enviroment…

Conditions in RunII could be similar to these.

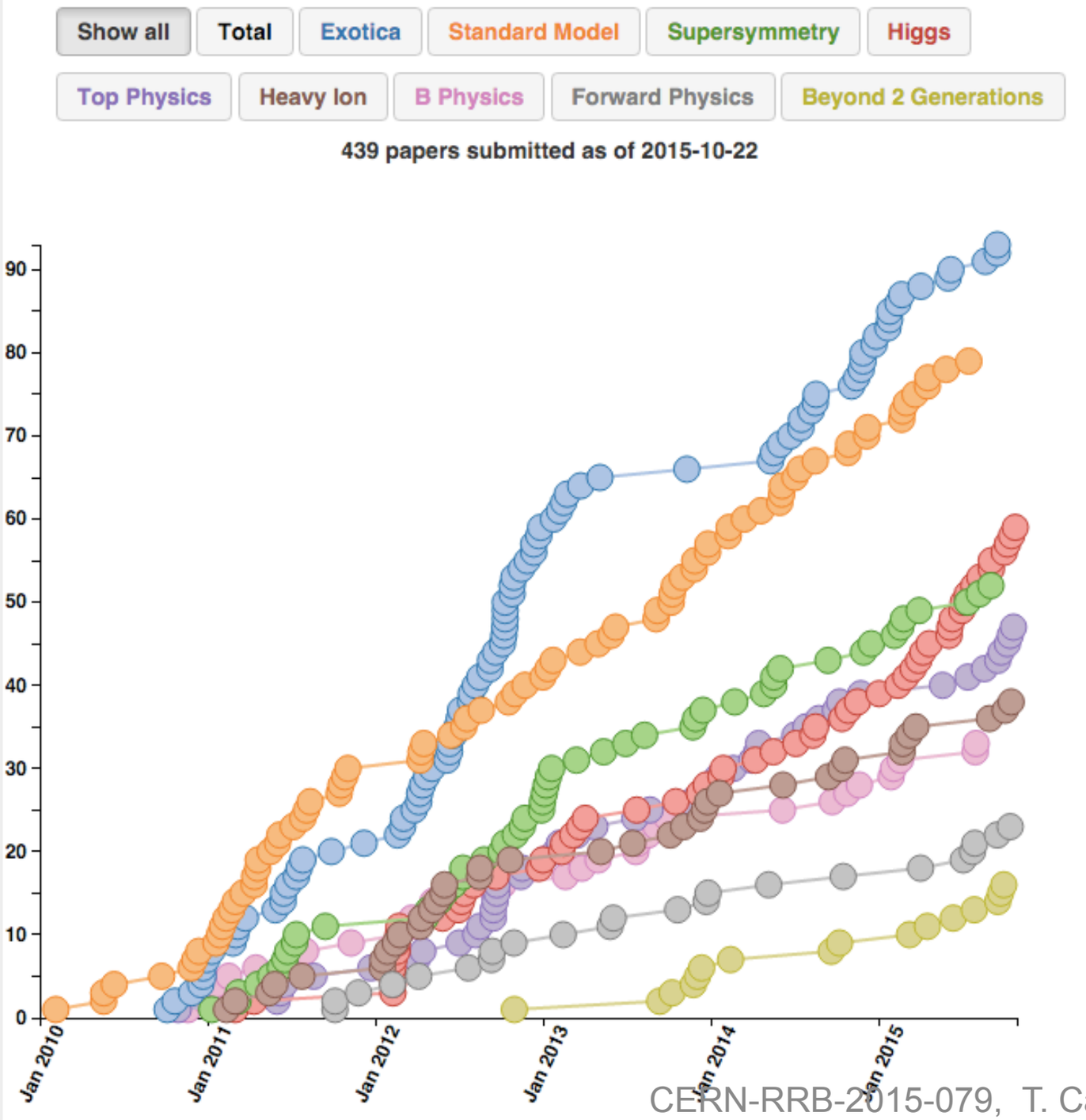
2012 Data at 8 TeV. Event with:

Raw ΣET~2 TeV

14 jets with ET>40 GeV

Estimated pile up~50

Publications



439 papers submitted:
+23 CRAFT based
+48 ready for CWR or later

In review process (ready for pre-app or later): 60

36 Run 1 analyses in “Analysis WG”

37 Run 2 analyses in “Analysis WG”

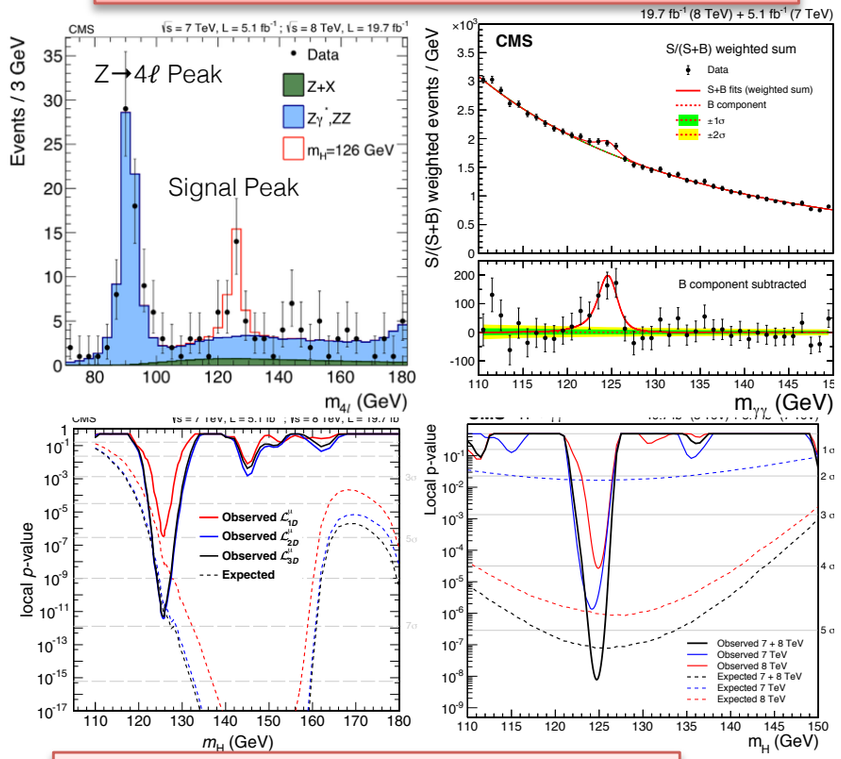
1 paper on 13 TeV accepted
1 submitted
1 in Final Reading

CERN-RRB-2015-079, T. Camporesi

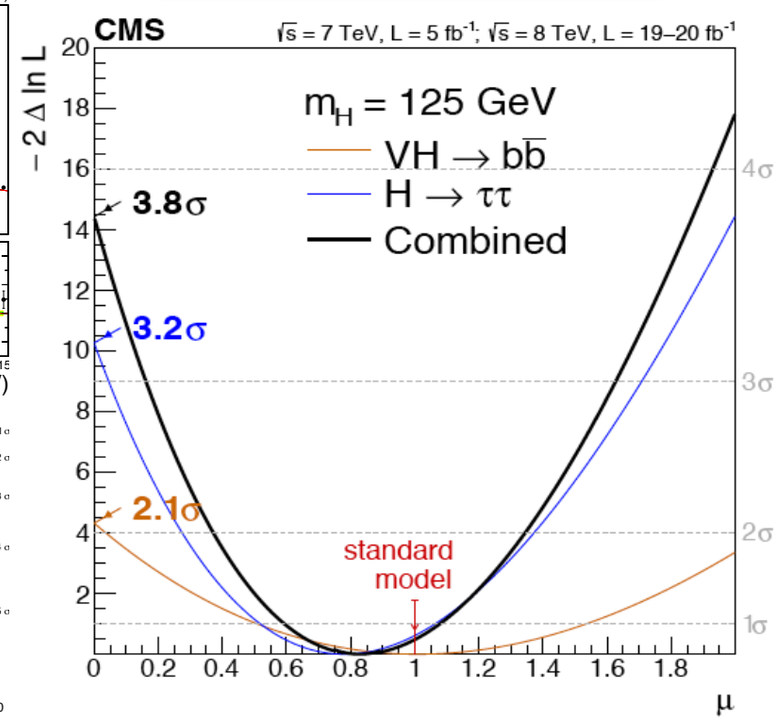
4

The new boson: looks like the expected one

Significance: huge

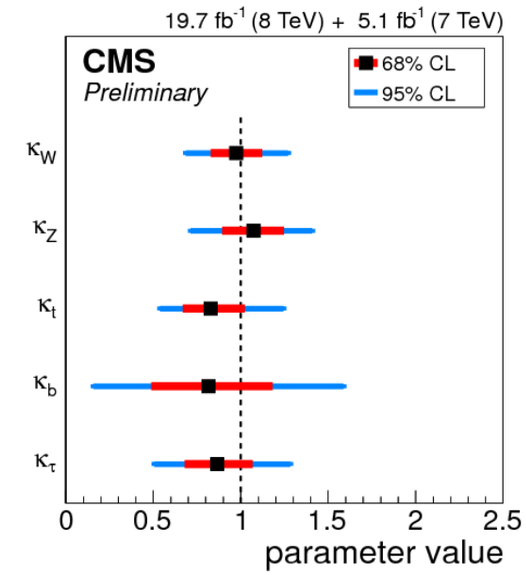


H→ττ + H→bb

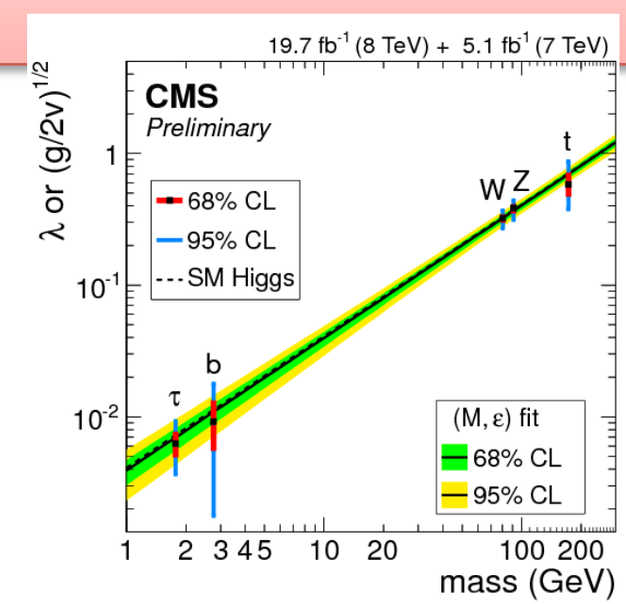


Significance	Exp	Obs
CMS (ττ)	3.4 σ	3.2 σ
CMS (bb)	2.1 σ	2.1 σ

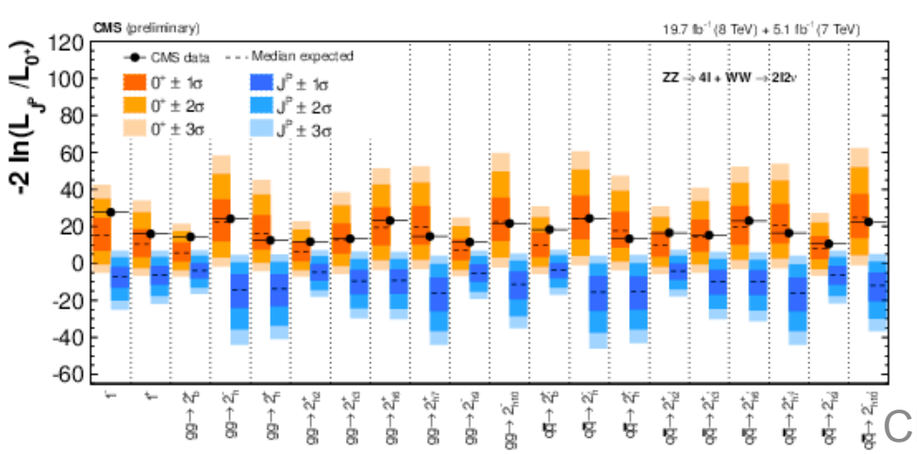
Couplings wrt SM



g~m² non-universality
As expected by SM

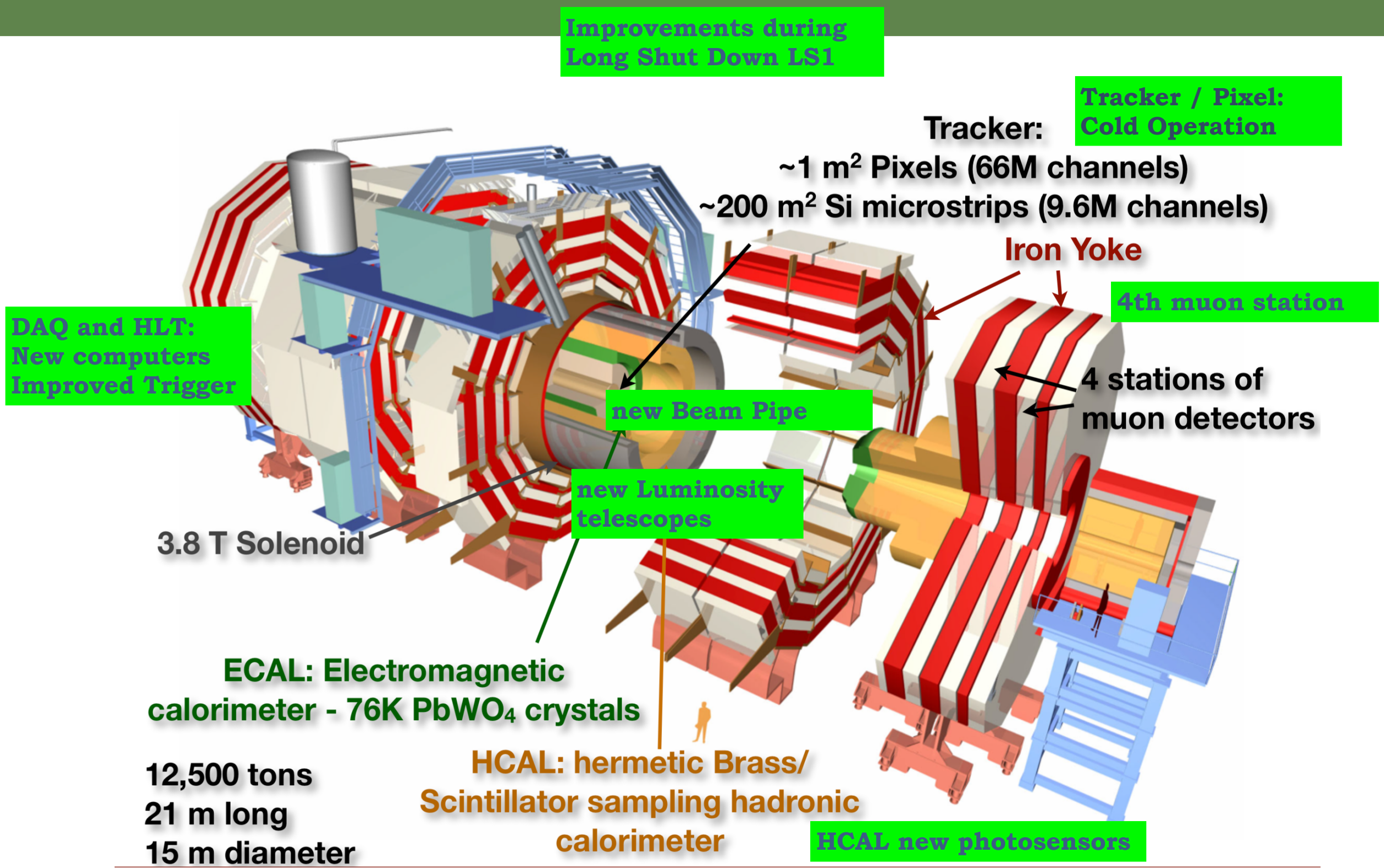


Spin-parity: 0⁺
As expected by SM

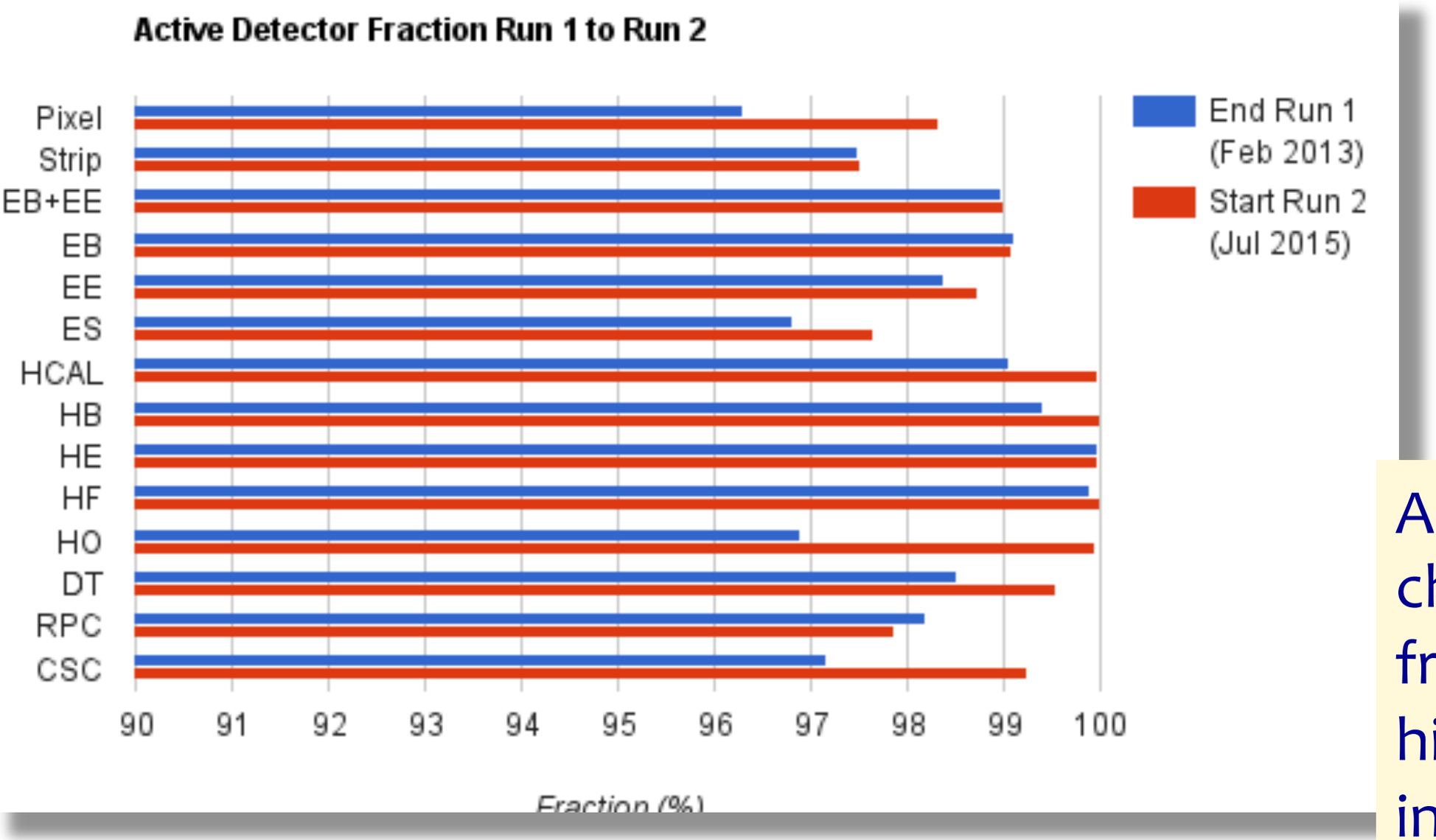


Put simply:
it couples to fermions

CMS detector for Run2

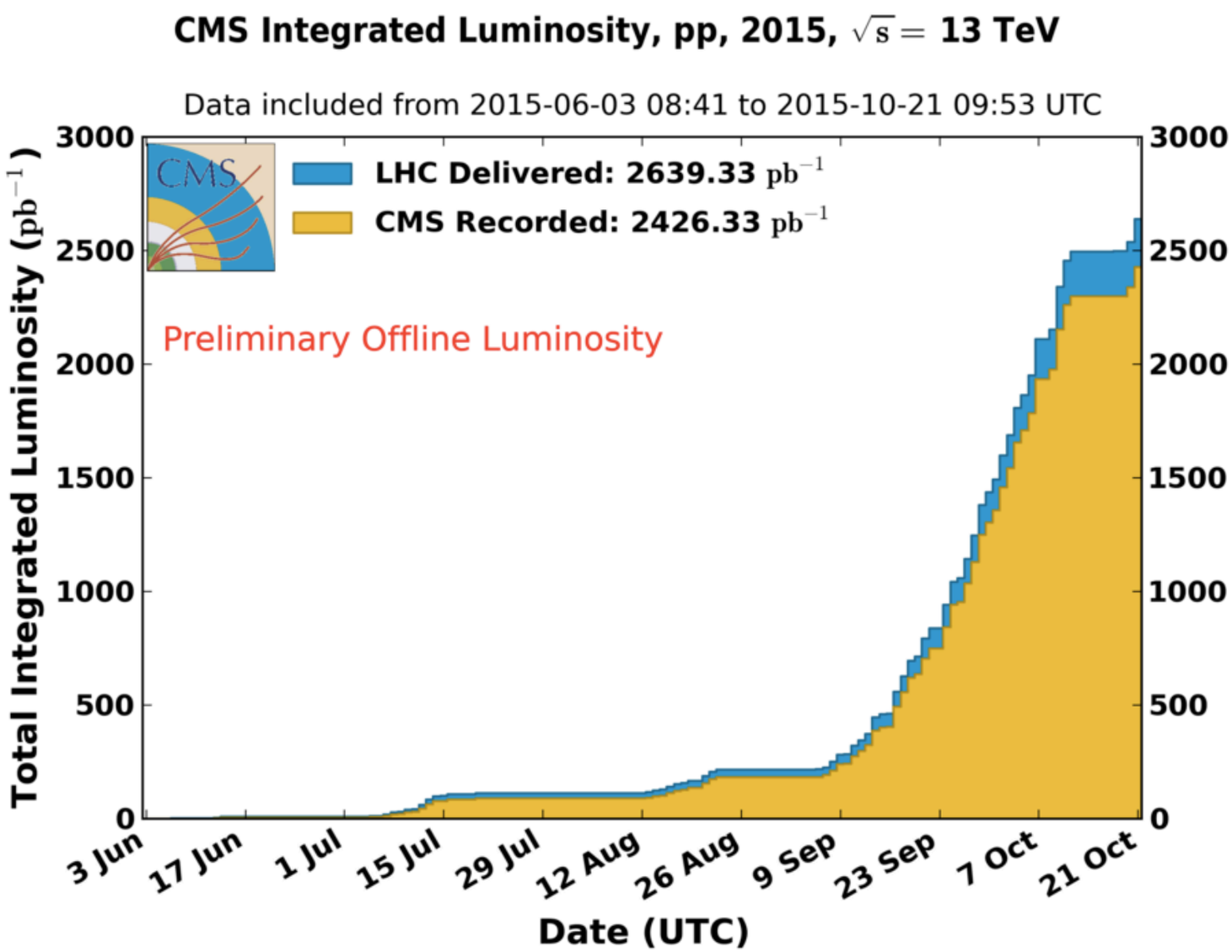


Run II: Detector &SW in great shape



Active channel fraction higher than in Run I

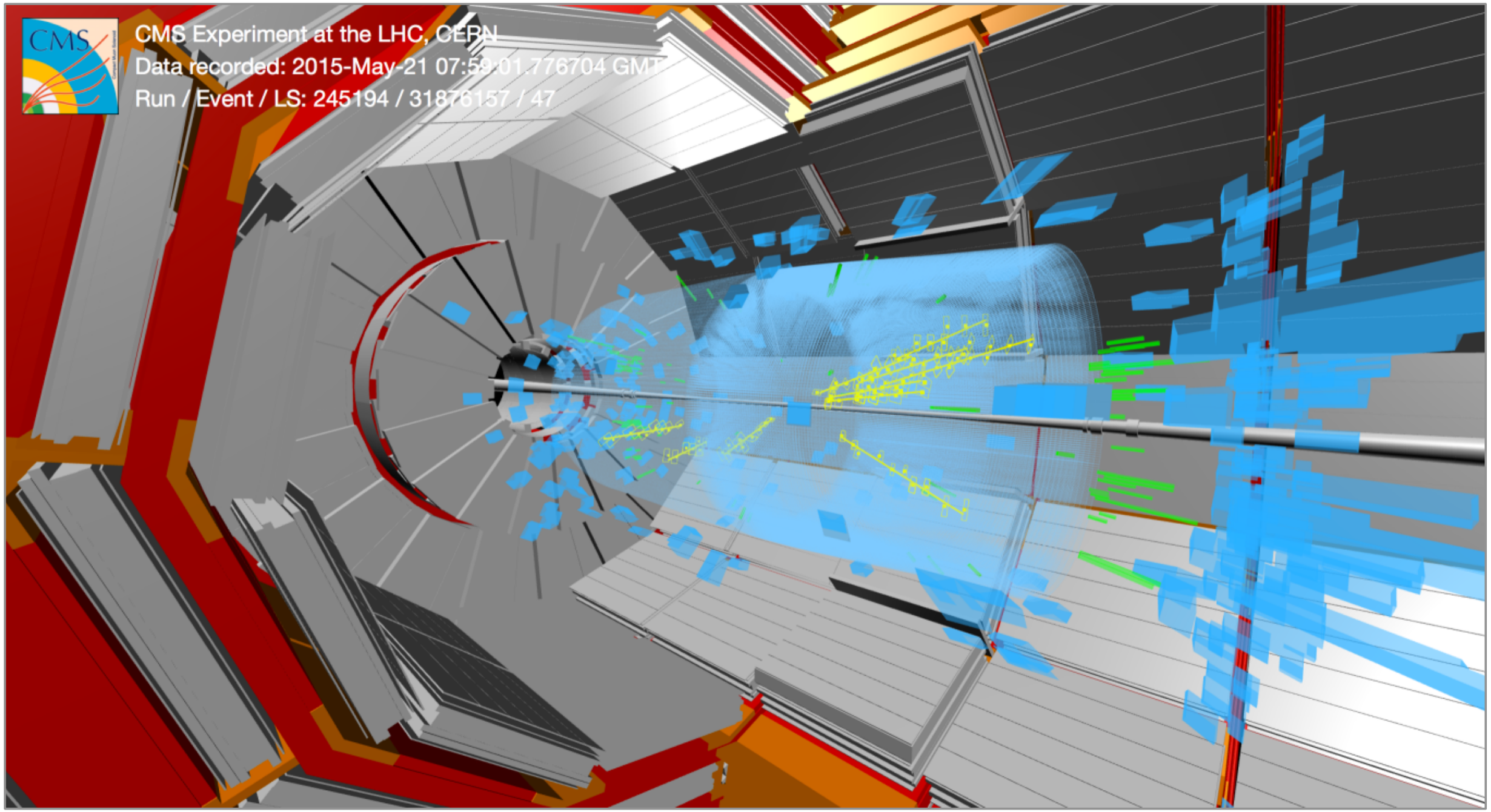
Run II: data taking



Overall data taking efficiency >92%

Of note: we logged data@10 KHz during special CMS-TOTEM run

First Physics collision @ 13 TeV



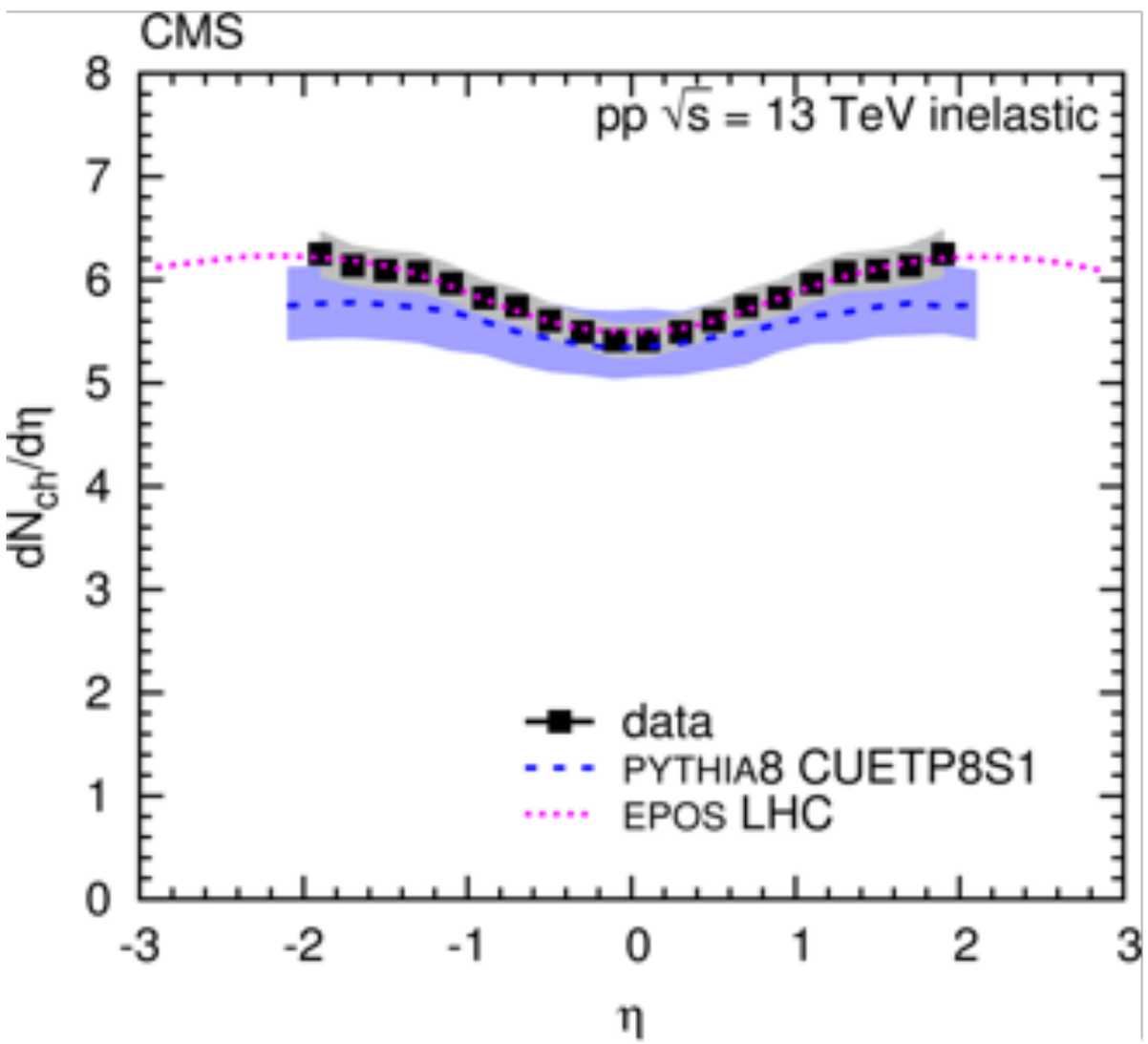
First LHC publication

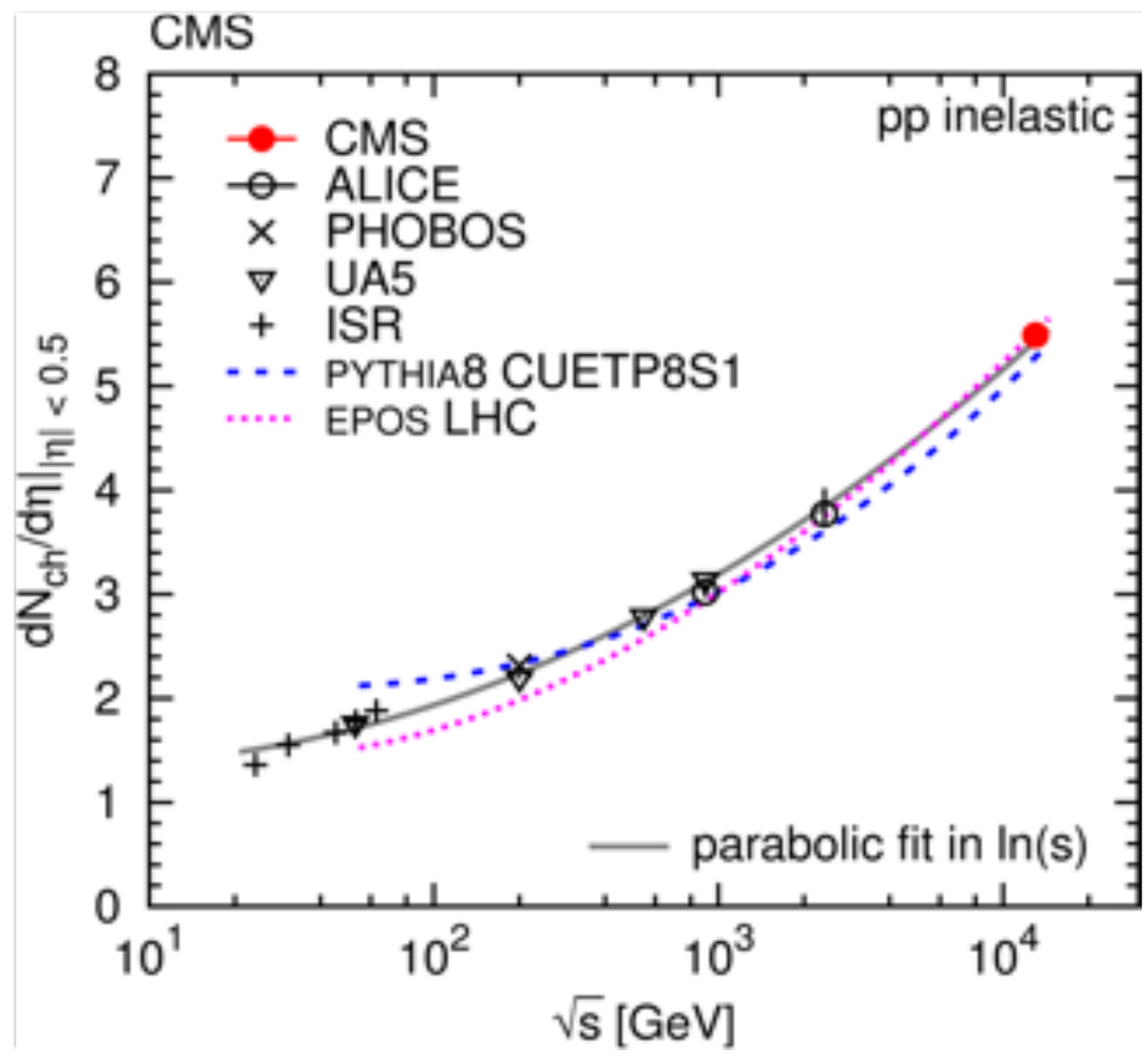
Lack of B field has not prevented us from exploiting the first runs taken at low luminosity

Submitted to PLB

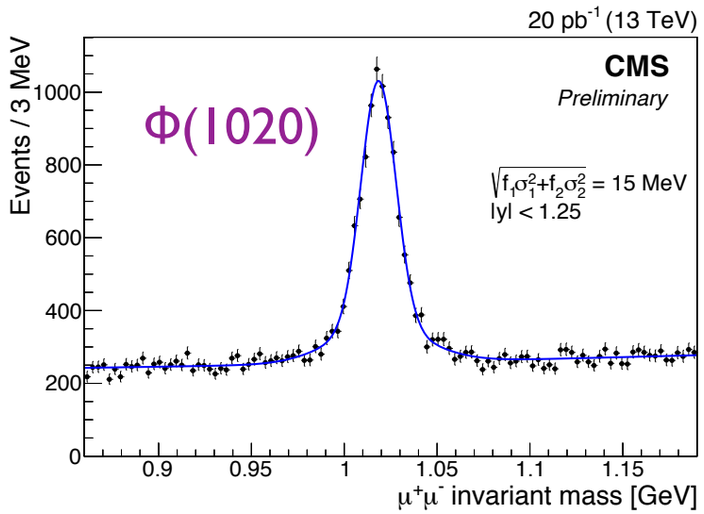
http://arxiv.org/abs/1507.05915

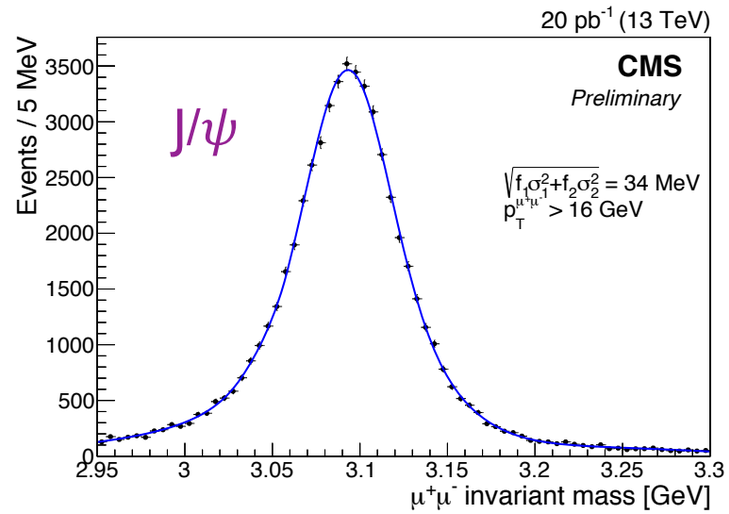
$dN_{ch}/d\eta|_{|\eta|<0.5} = 5.49 \pm 0.01\ (stat) \pm 0.17\ (syst)$

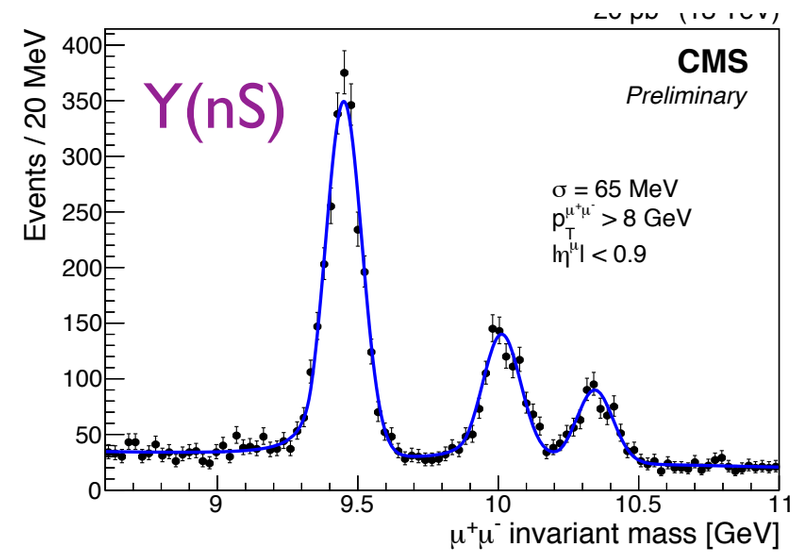


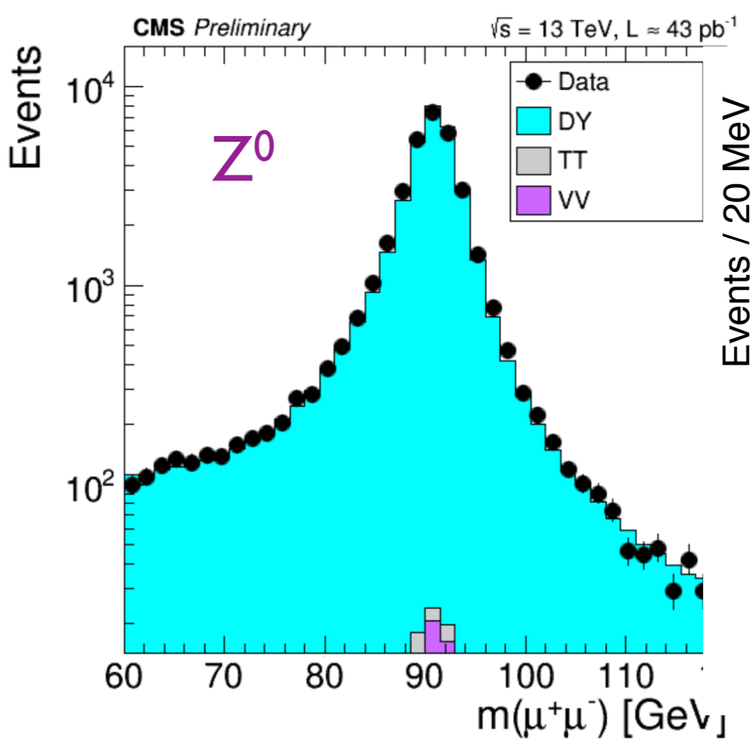


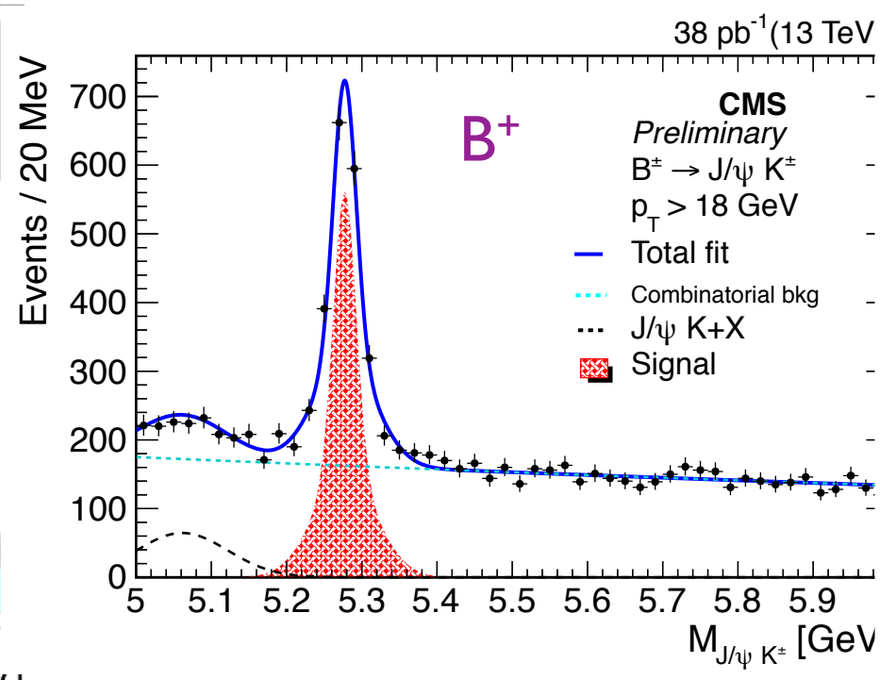
Di-muon spectroscopy:
standard candles resonances and first B mesons

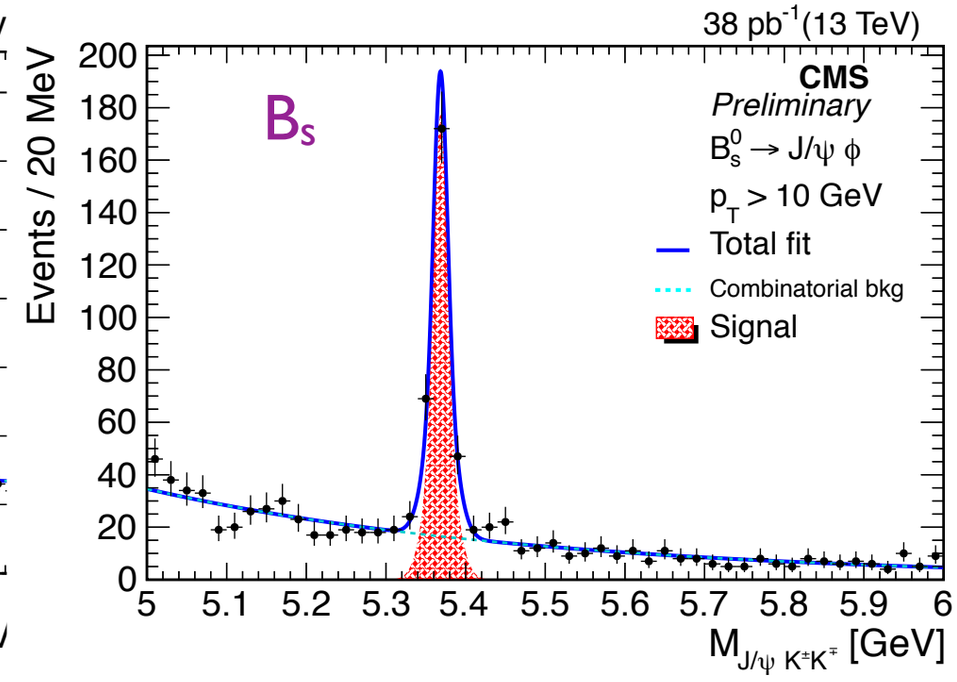




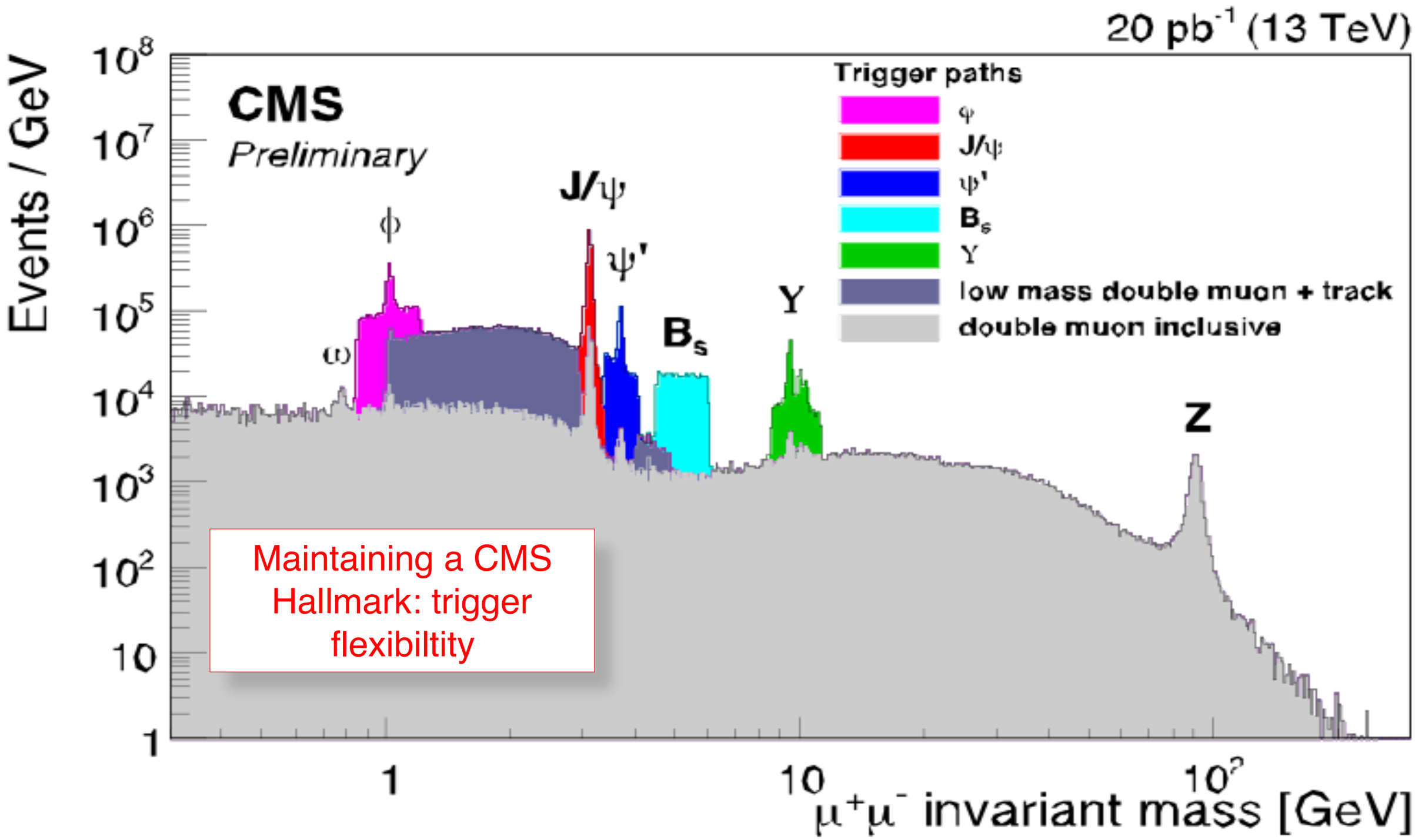




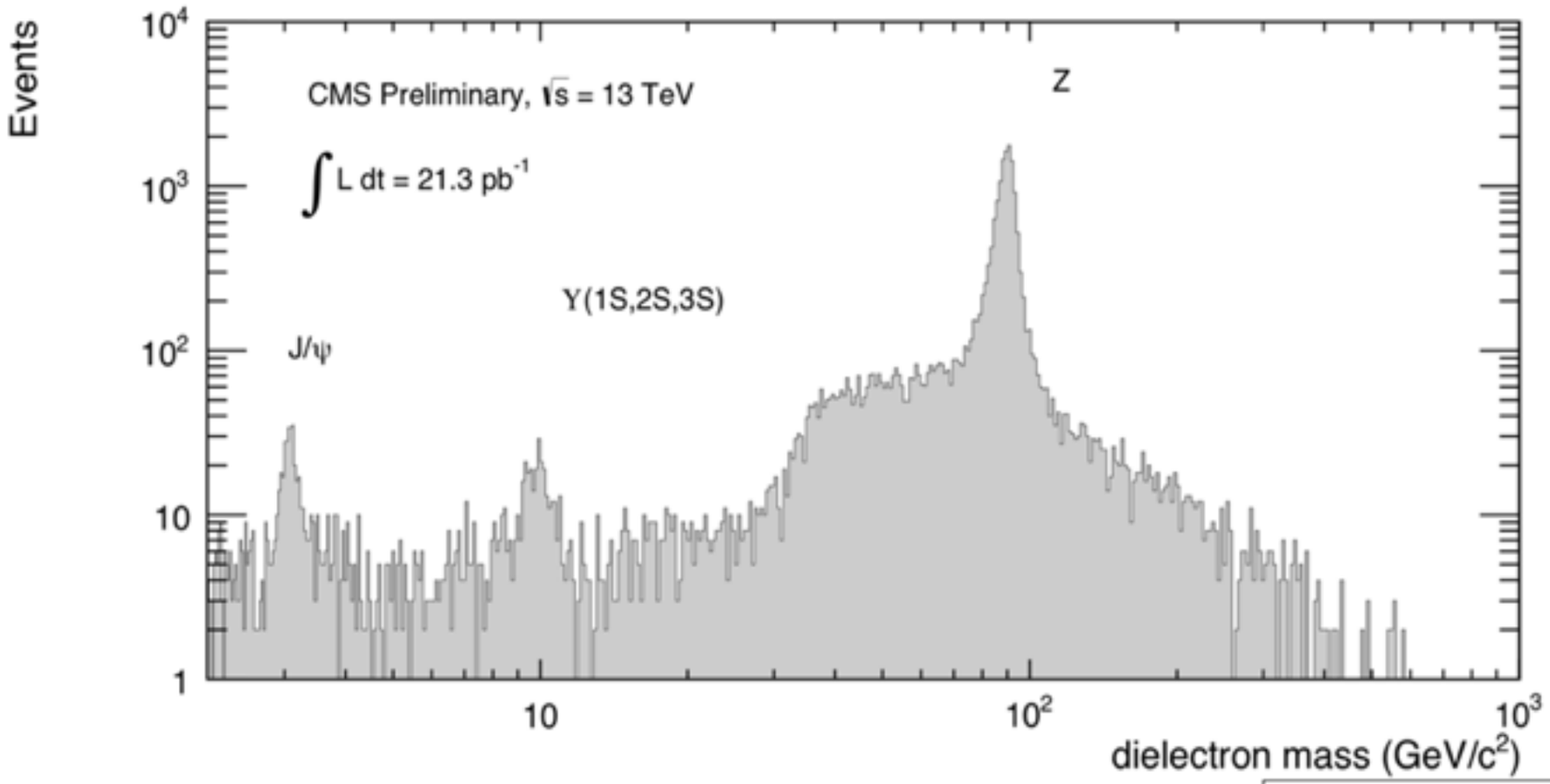




Run II performance: Di-muon spectroscopy, 13 TeV

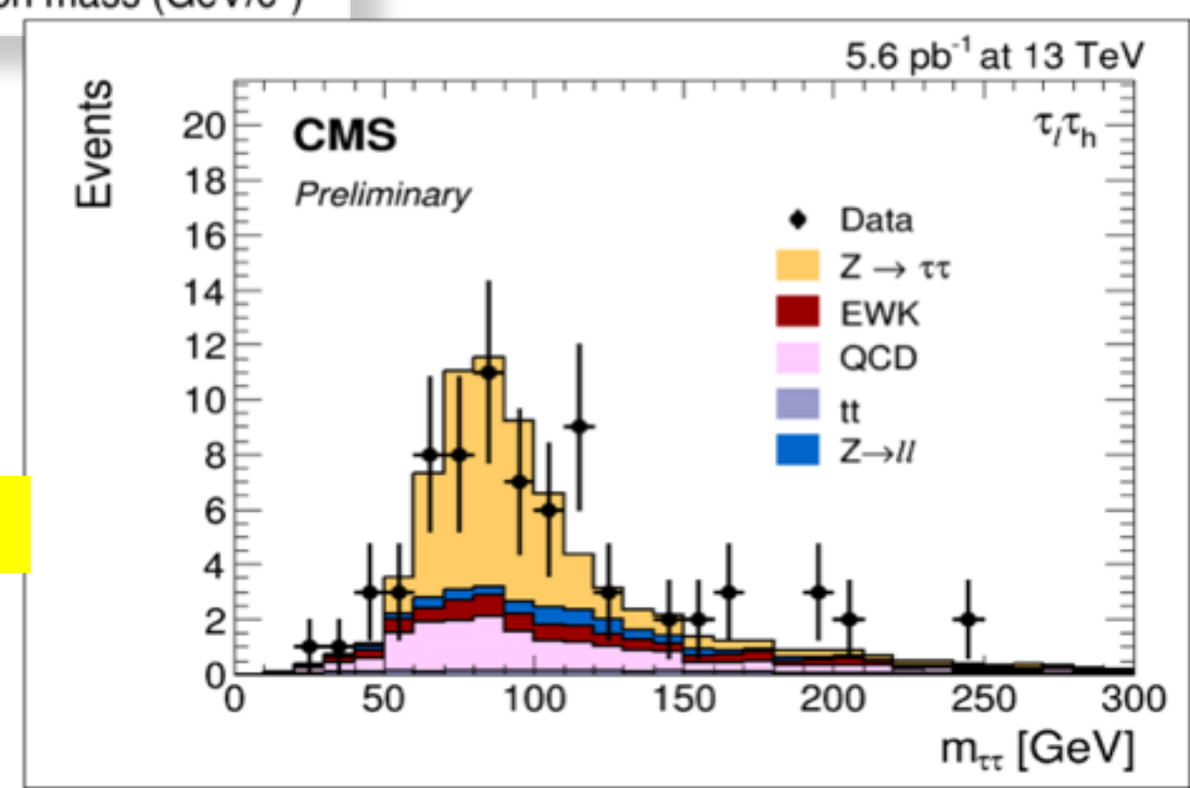


…and electrons and taus

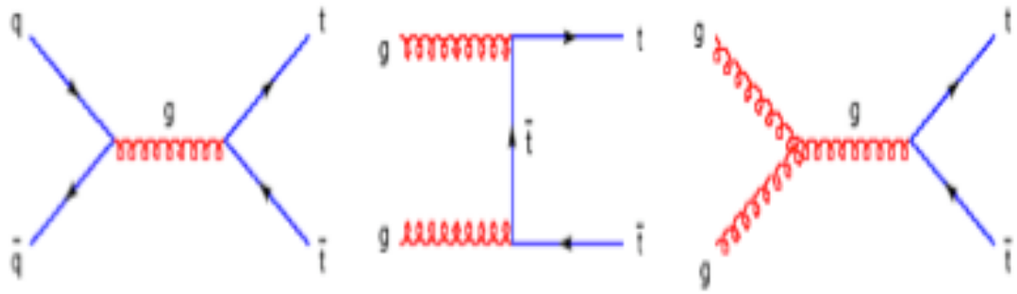


Di-electrons

Di-taus



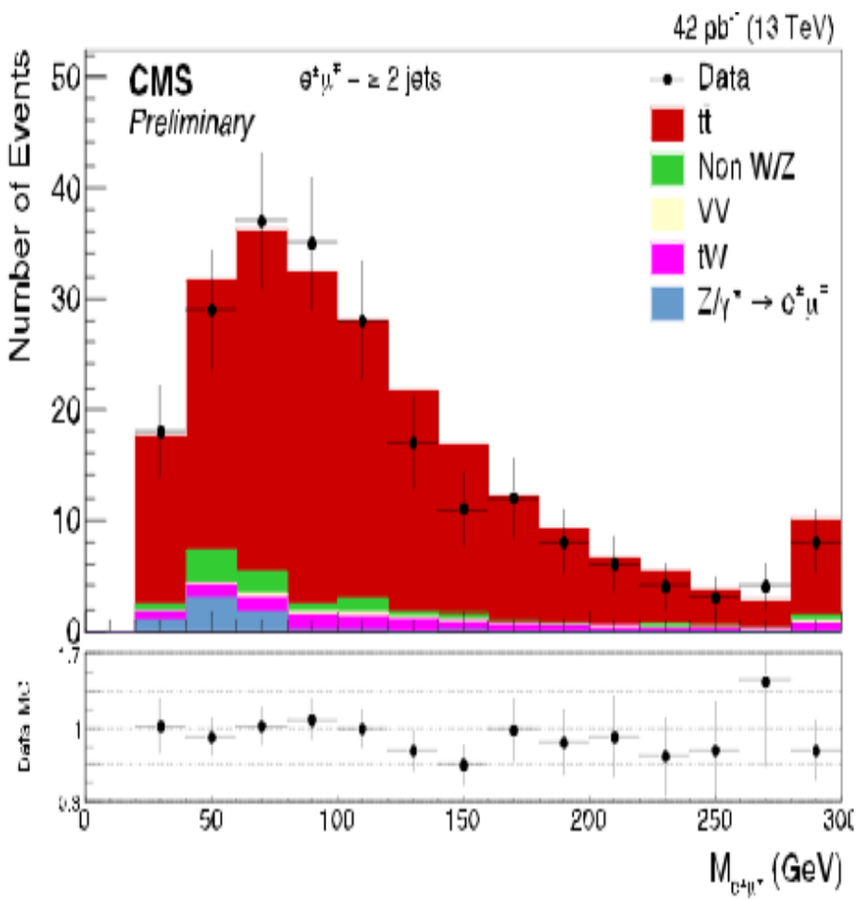
t-tbar cross section, 13 TeV, CMS

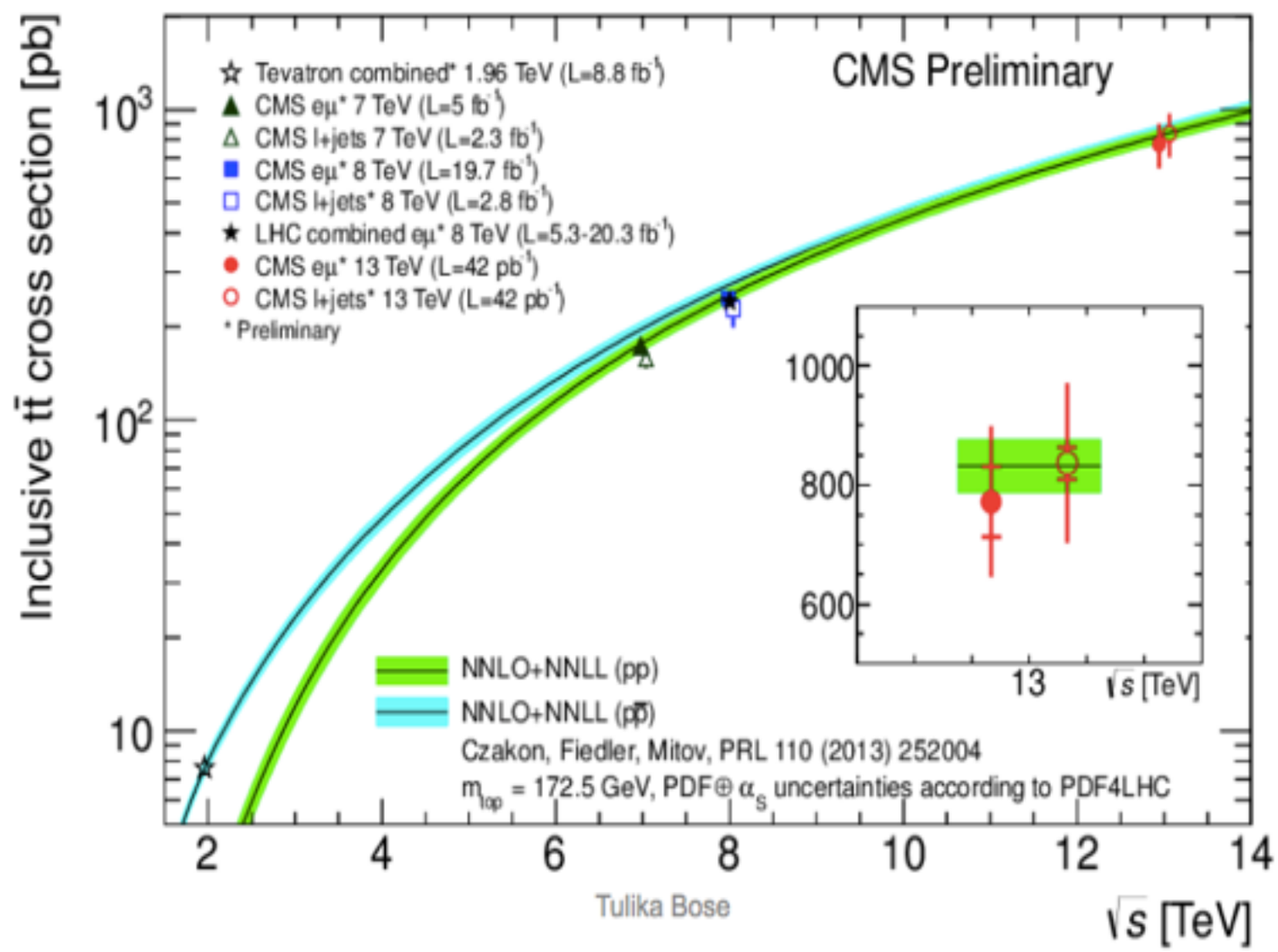


Inclusive ttbar cross section @13 TeV measured:

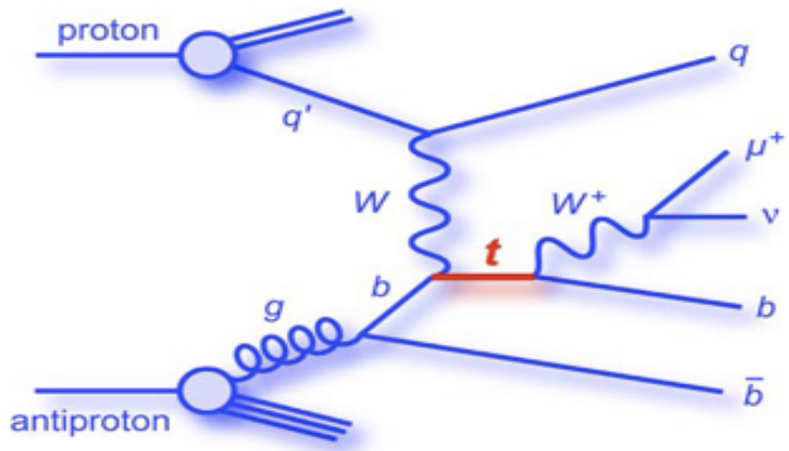
- eμ and semi-leptonic channels

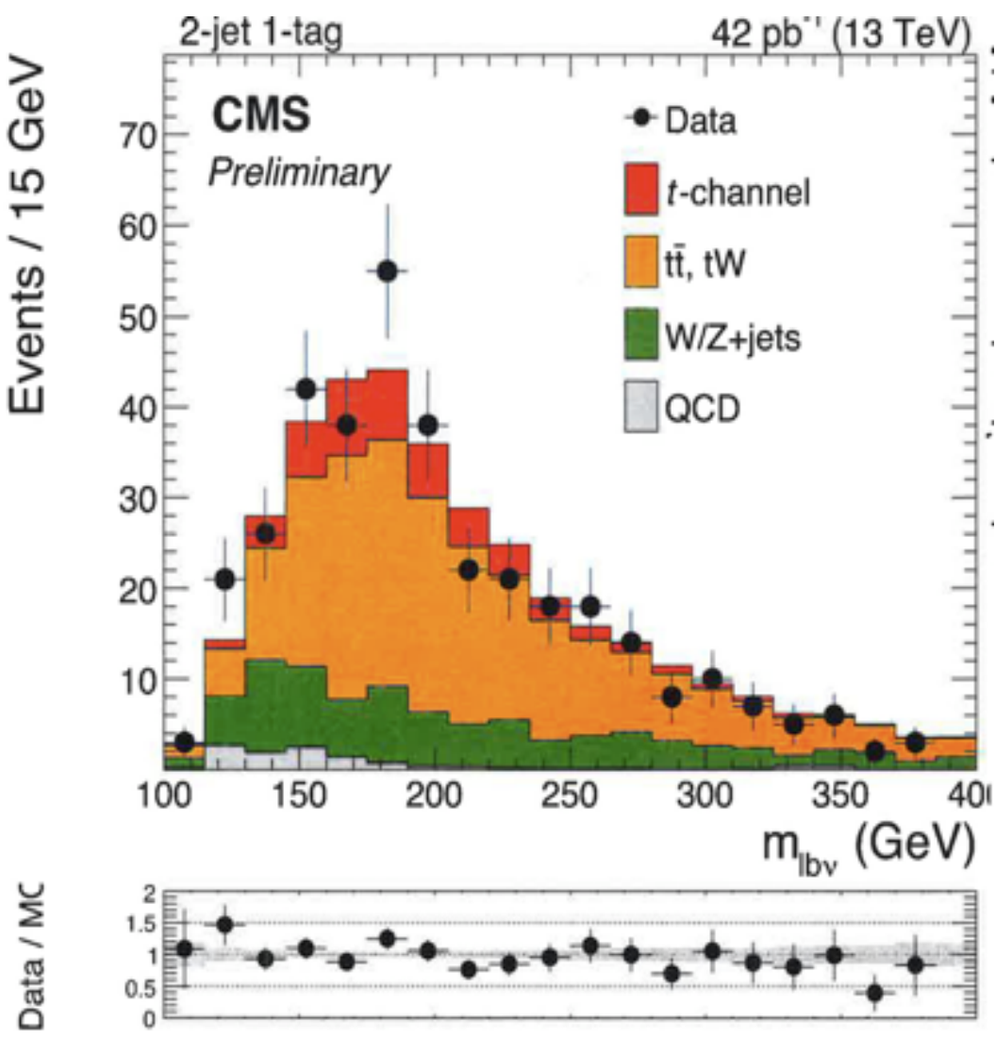
TOP-15-005
TOP-15-003

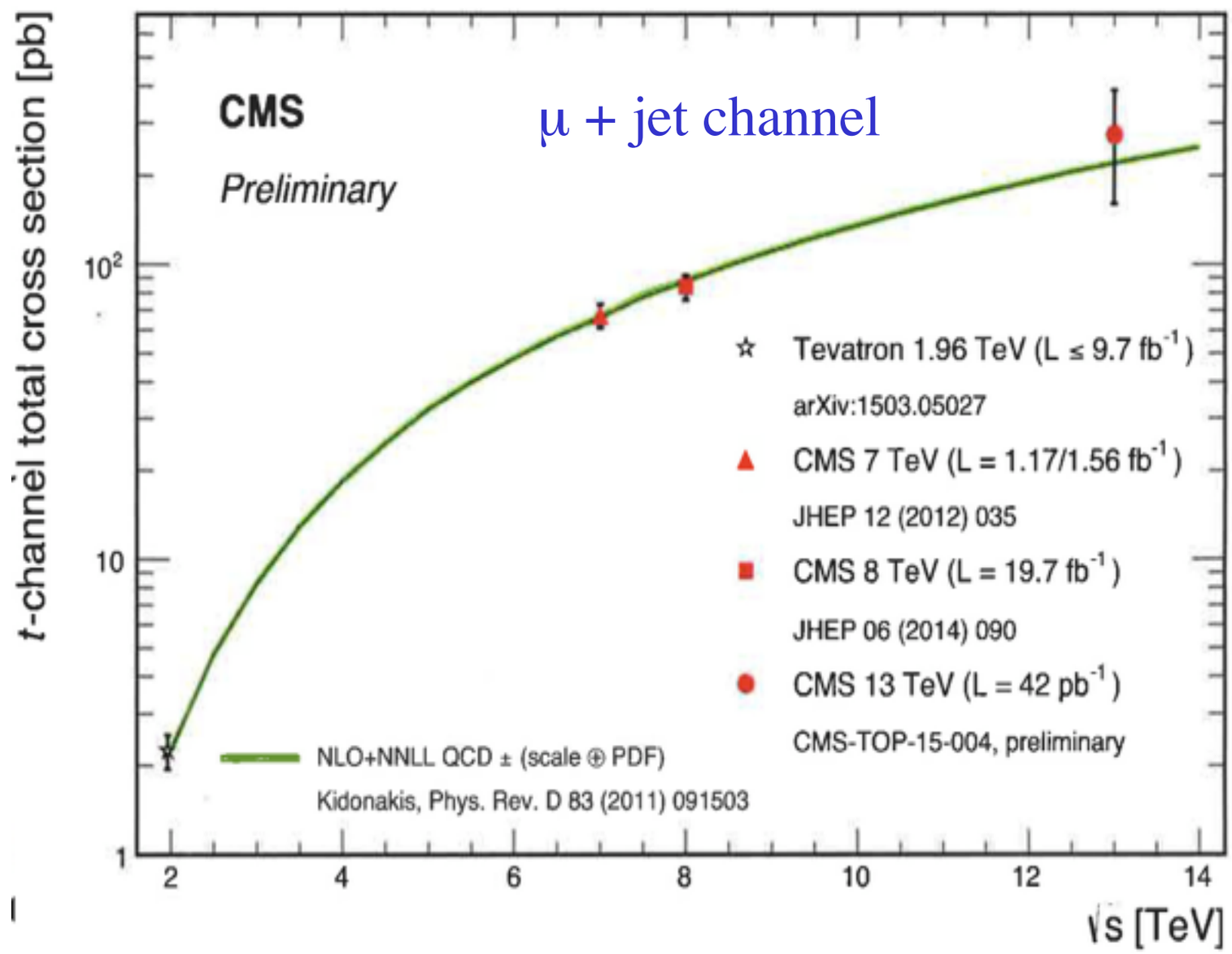




Single top (t-channel) at 13 TeV - cross-section



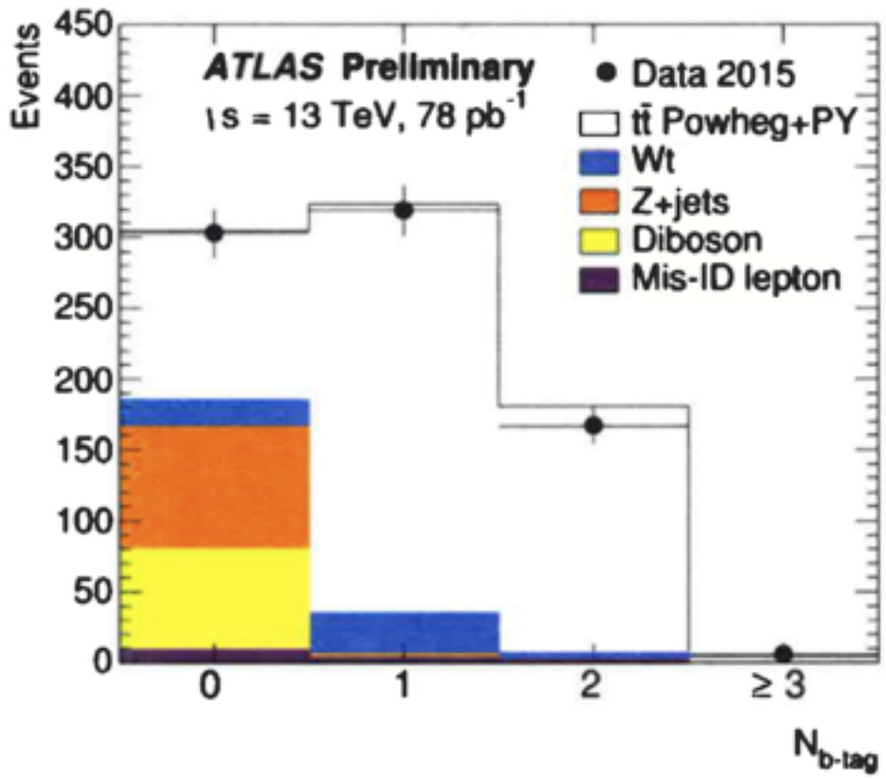


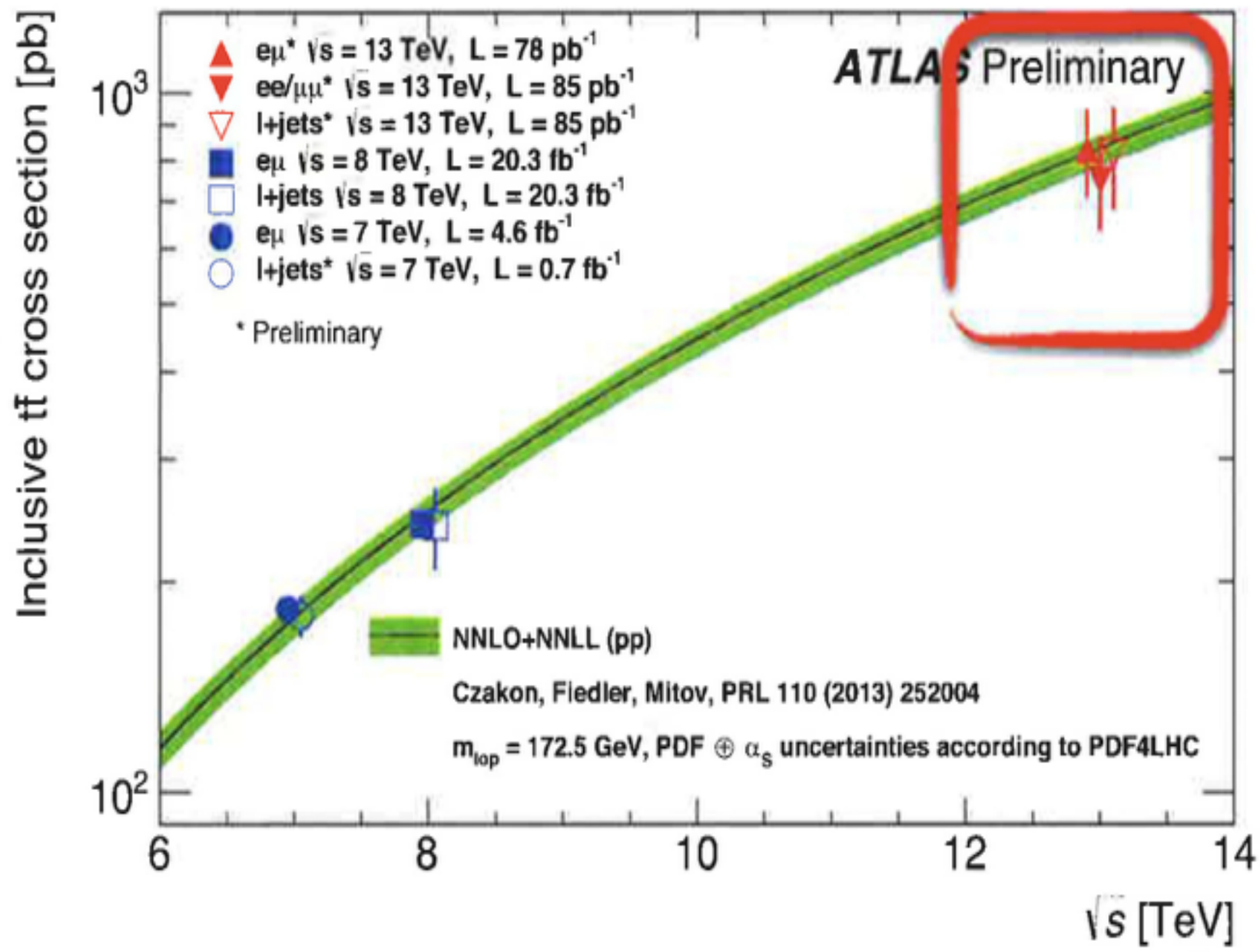


$\sigma_{t\text{-cha}} = 274 \pm 98\ (\text{stat.}) \pm 52\ (\text{syst.}) \pm 33\ (\text{lumi.})\ \text{pb}$

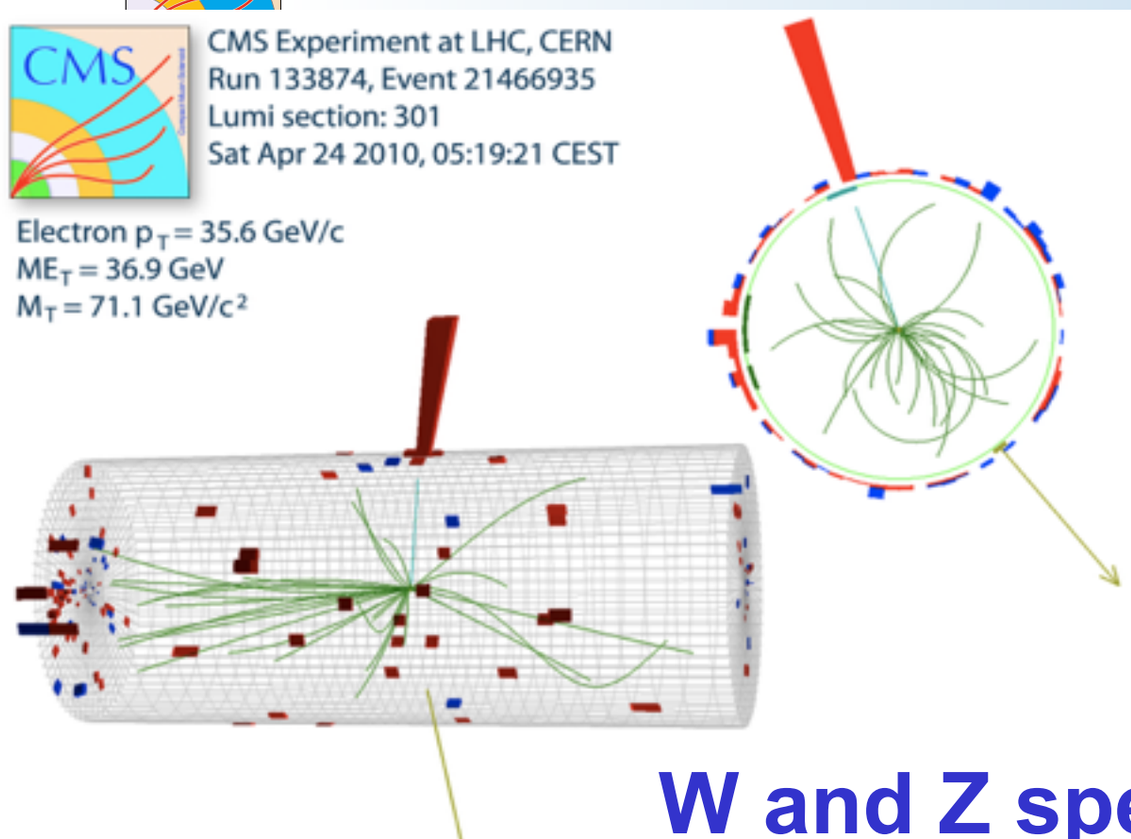
$|V_{tb}| = 1.12 \pm 0.24\ (\text{exp.}) \pm 0.02\ (\text{theor.})$

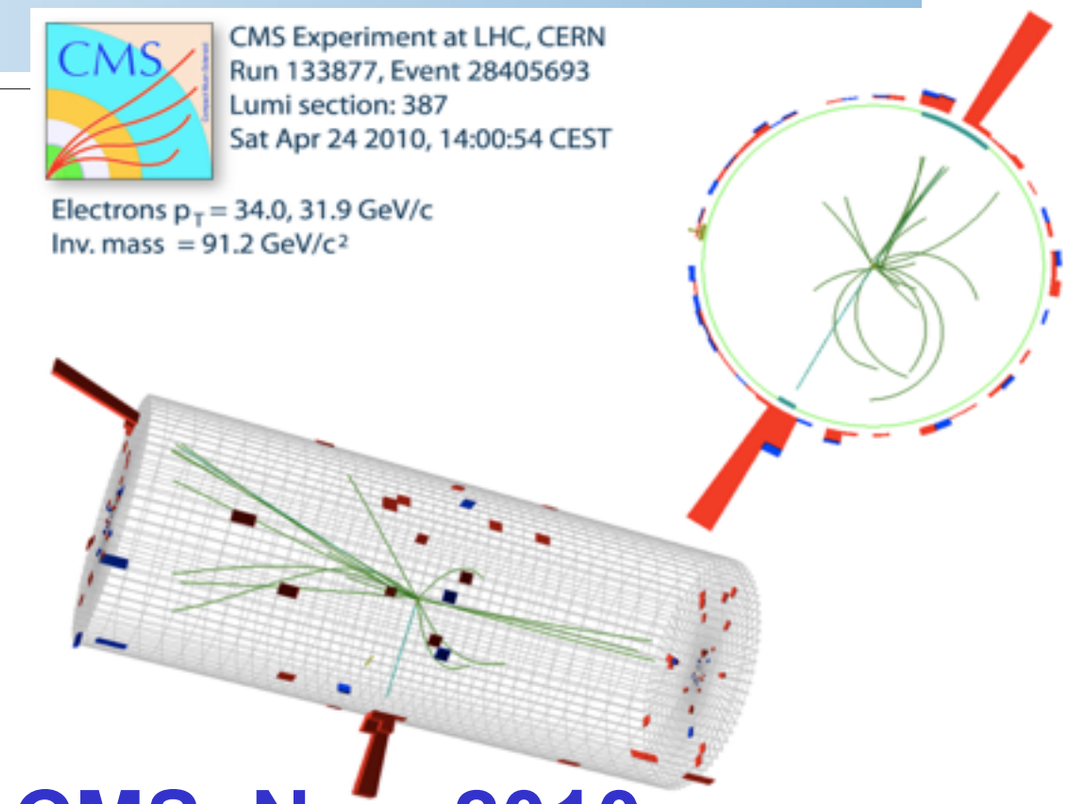
t-tbar cross section, 13 TeV, ATLAS



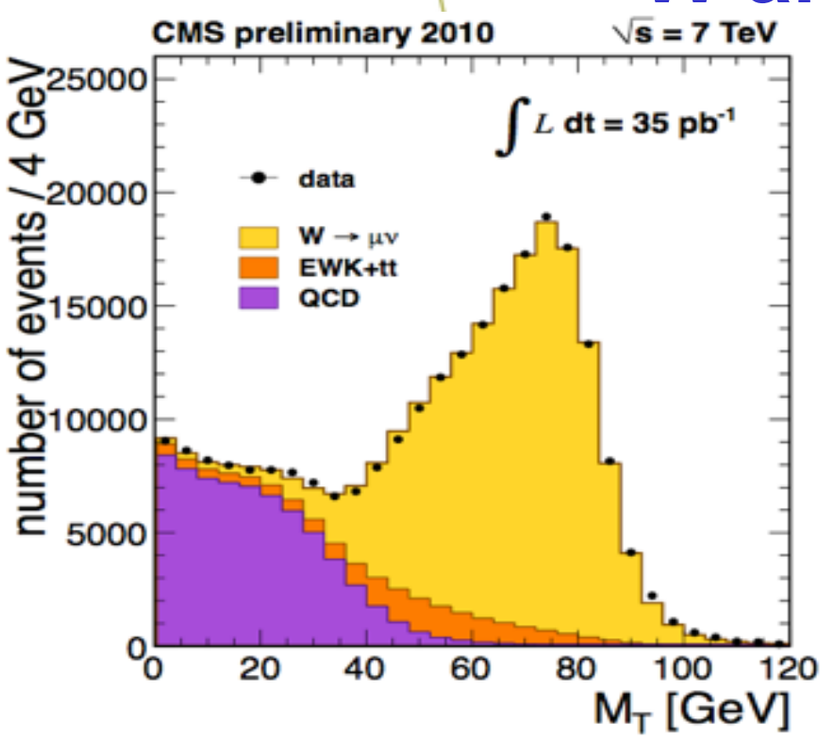


LHC: First W → eν and Z → e^+e^- events, April 2010

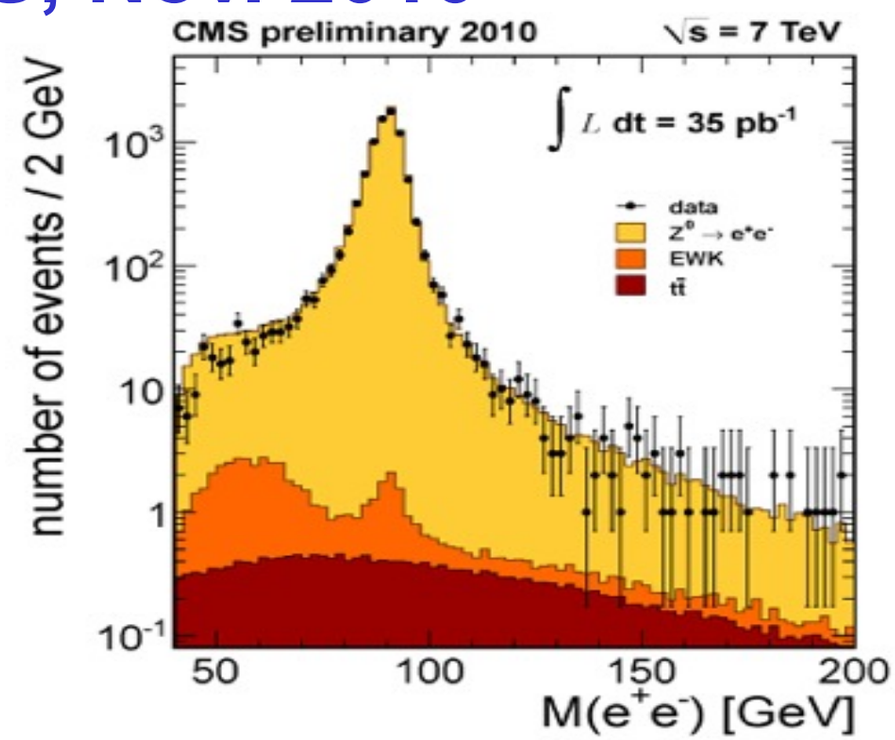




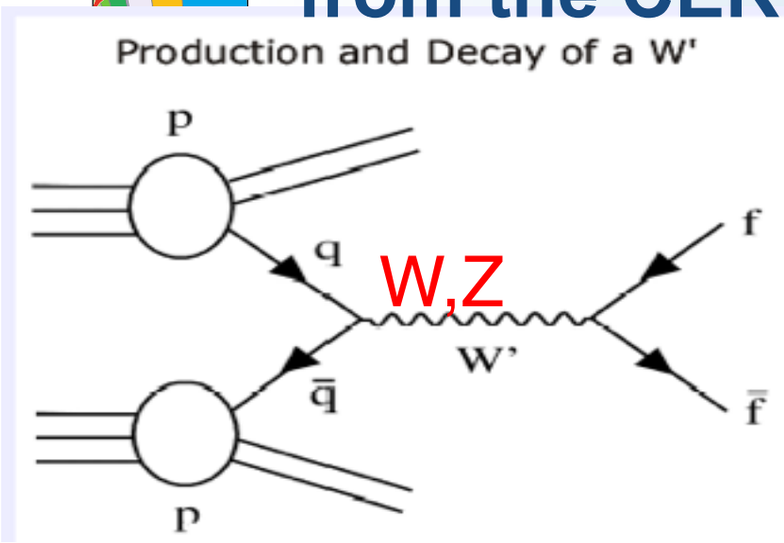
W and Z spectra in CMS, Nov. 2010



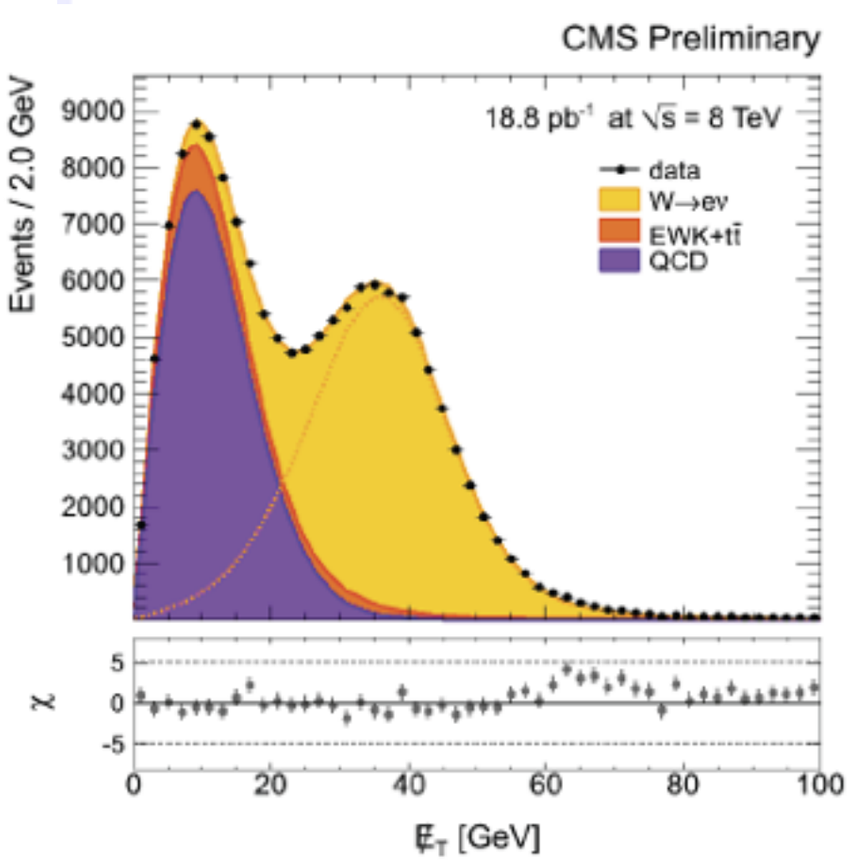
By end-2012 we had ~150.000.000 W and ~15.000.000 Z decaying leptonically!!

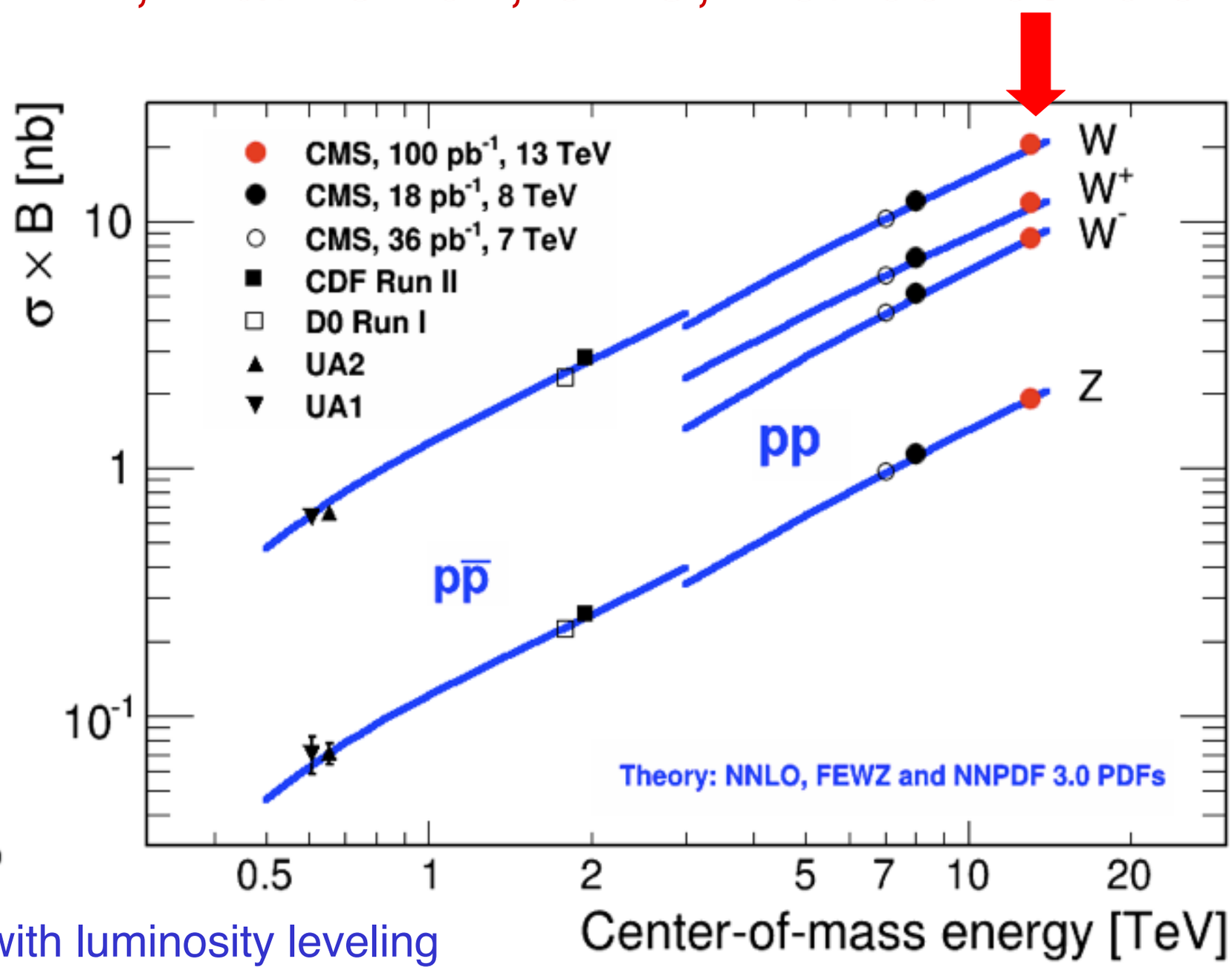


W, Z production cross sections, testing QCD
from the CERN pp-bar collider to the Tevatron and the LHC



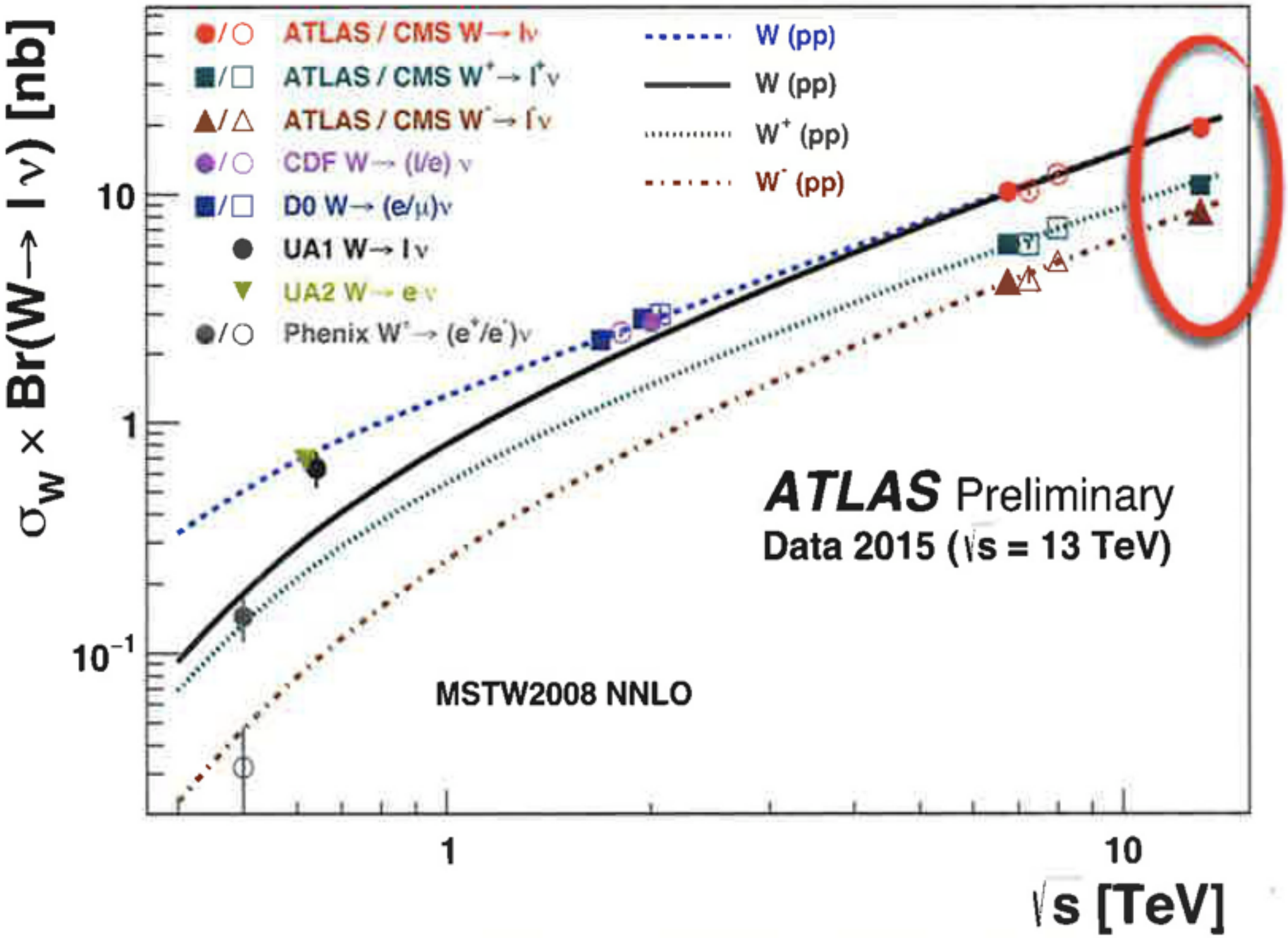
W, Z at 13 TeV, CMS, first look June 3rd



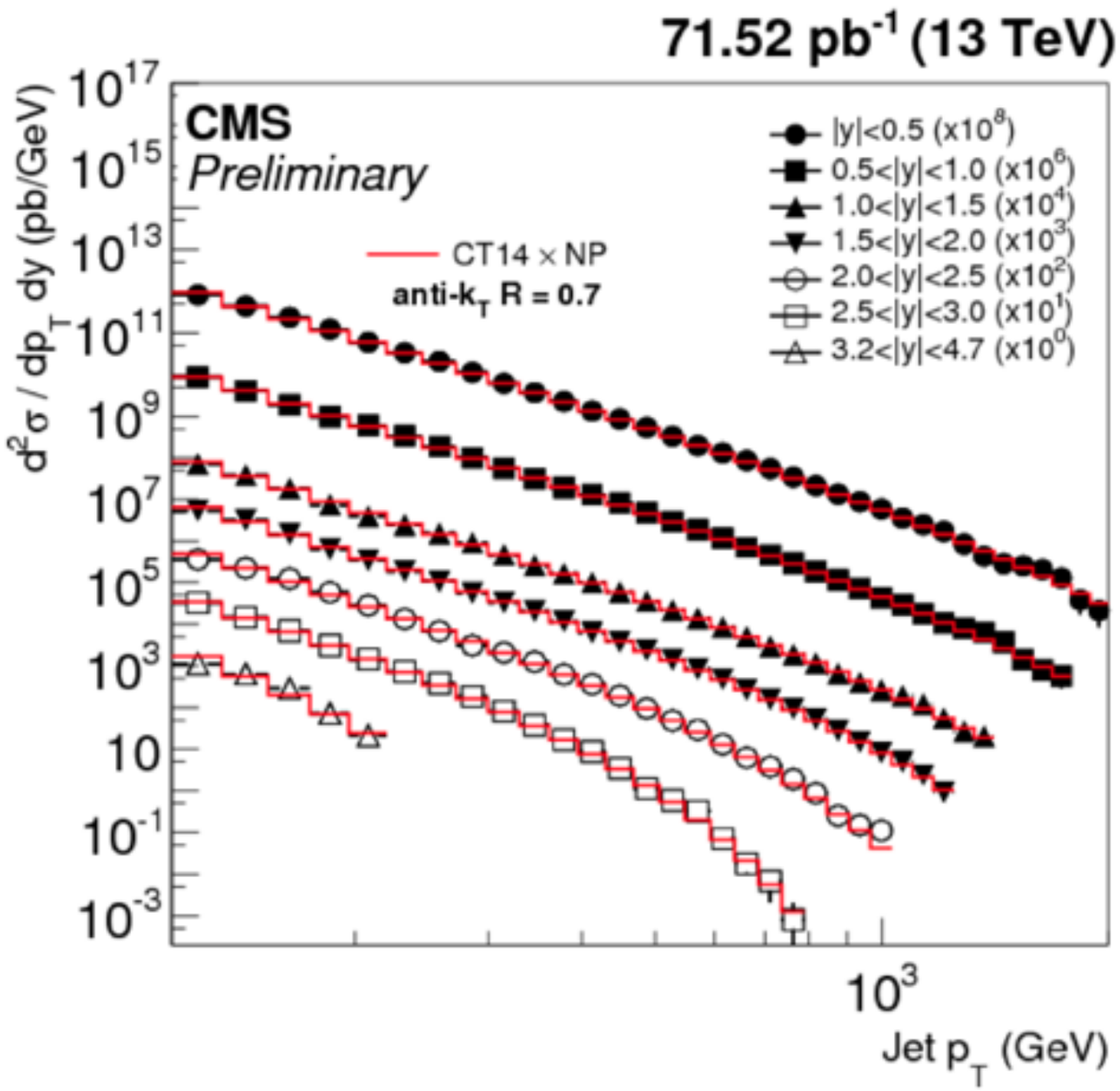


Use special low-pile-up runs with luminosity leveling

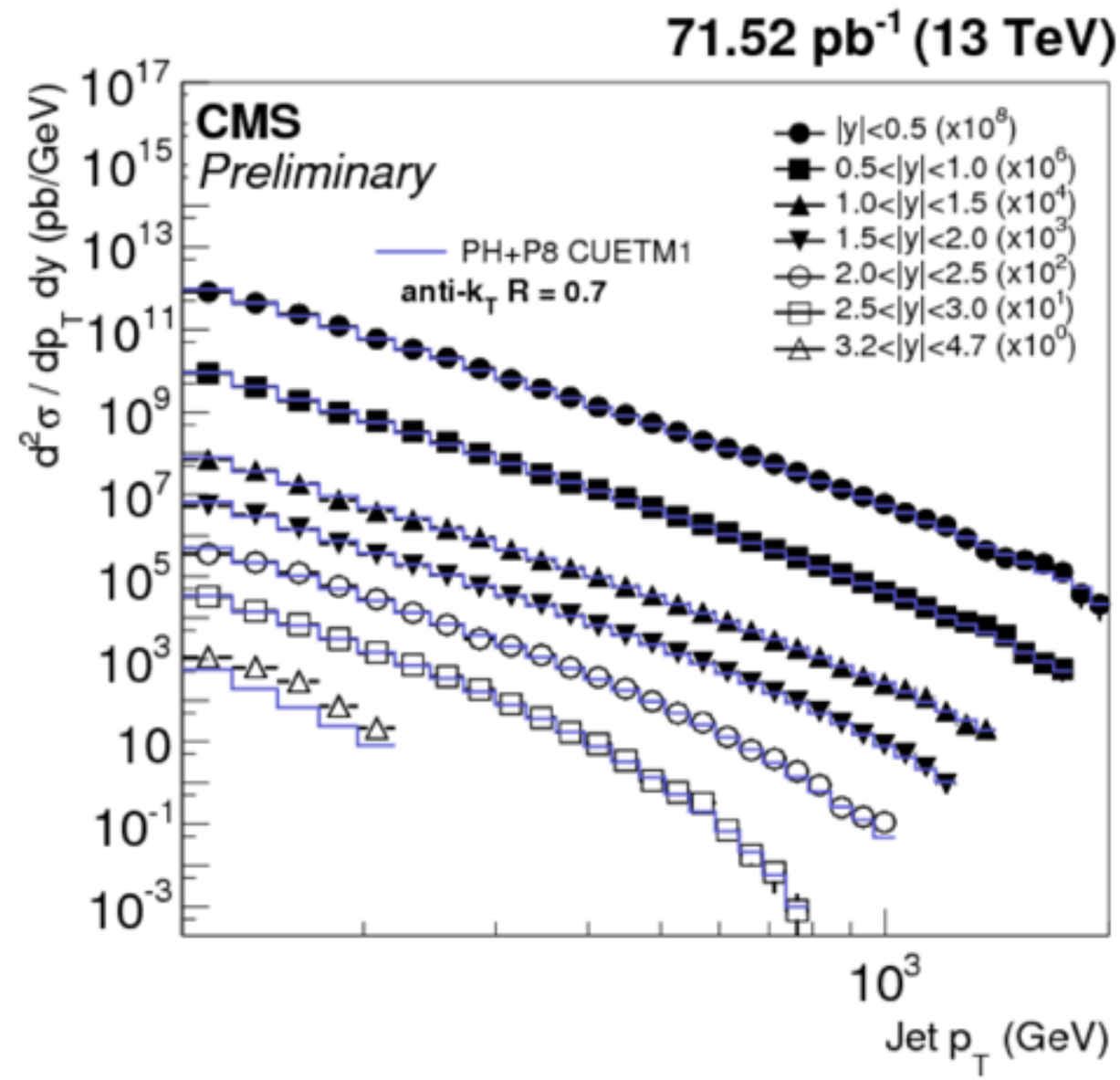
W cross sections at 13 TeV, ATLAS



First look at 13 TeV for JETS

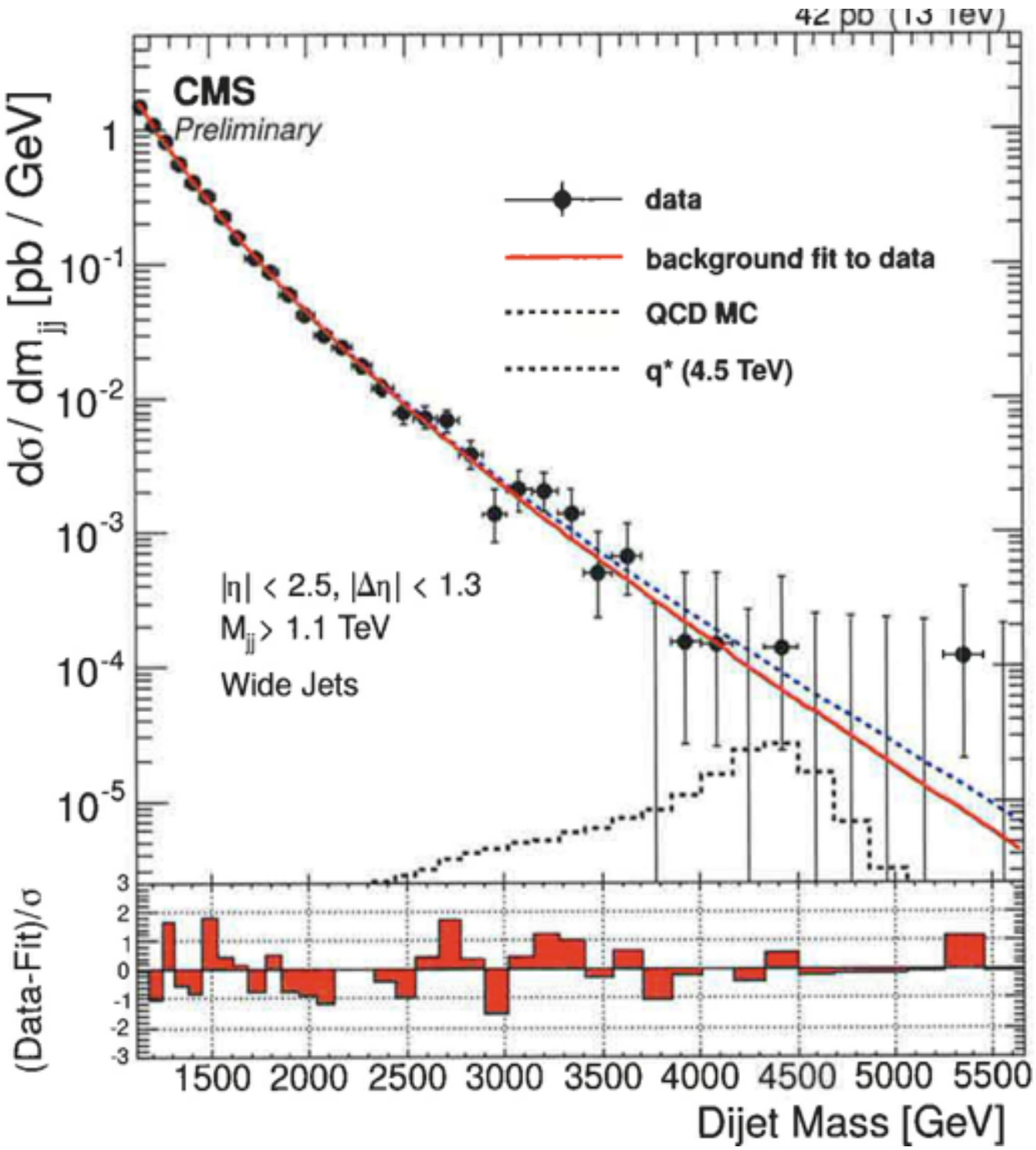


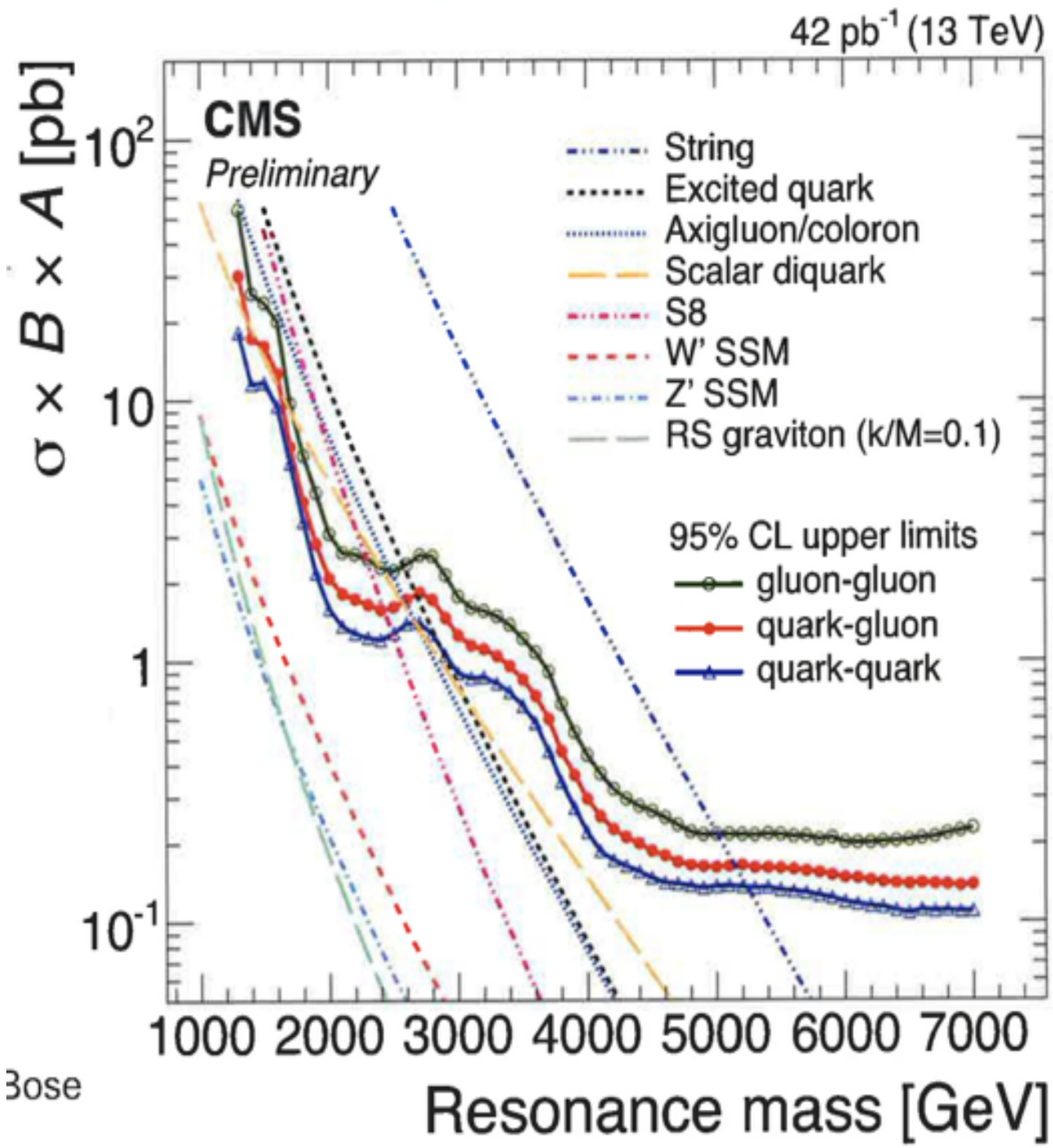
NLOJet++



Powheg+Py8 (CUETM1)

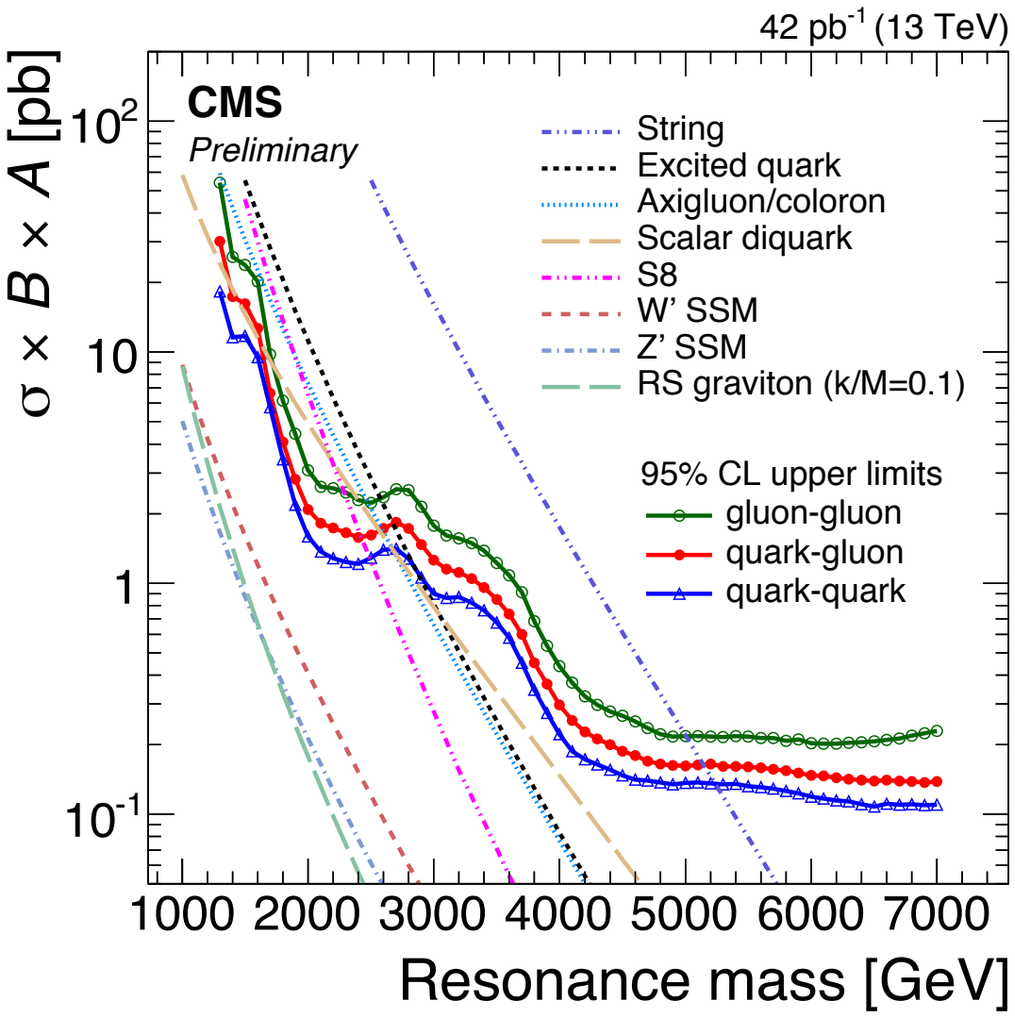
Inclusive di-jets at 13 TeV, 2015 data, CMS
- already excluding heavy resonances with 42 pb^{-1}





Bose

Di-jet resonance search



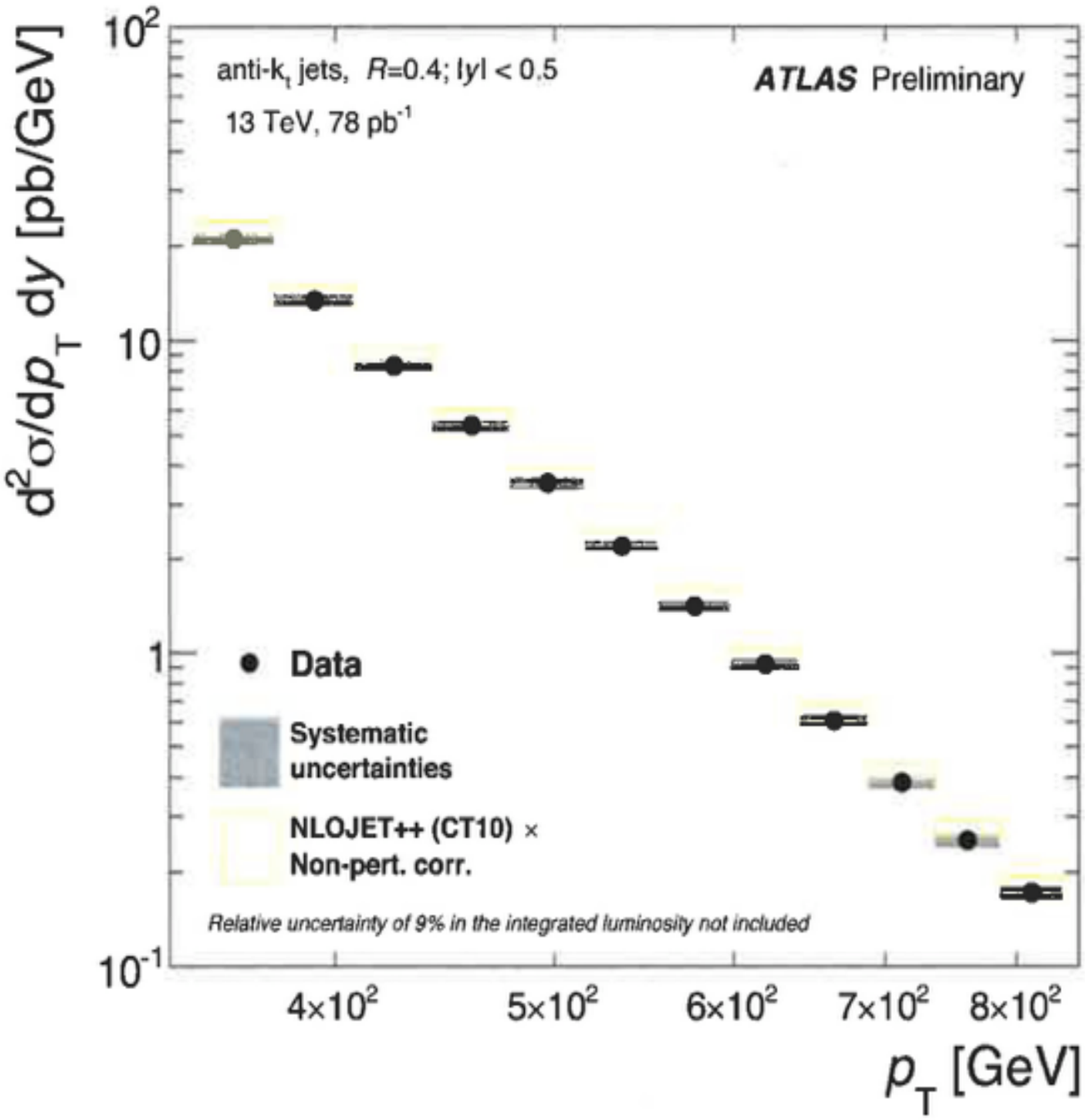
Confirms Run2 is already more sensitive than Run1 for M> 5 TeV

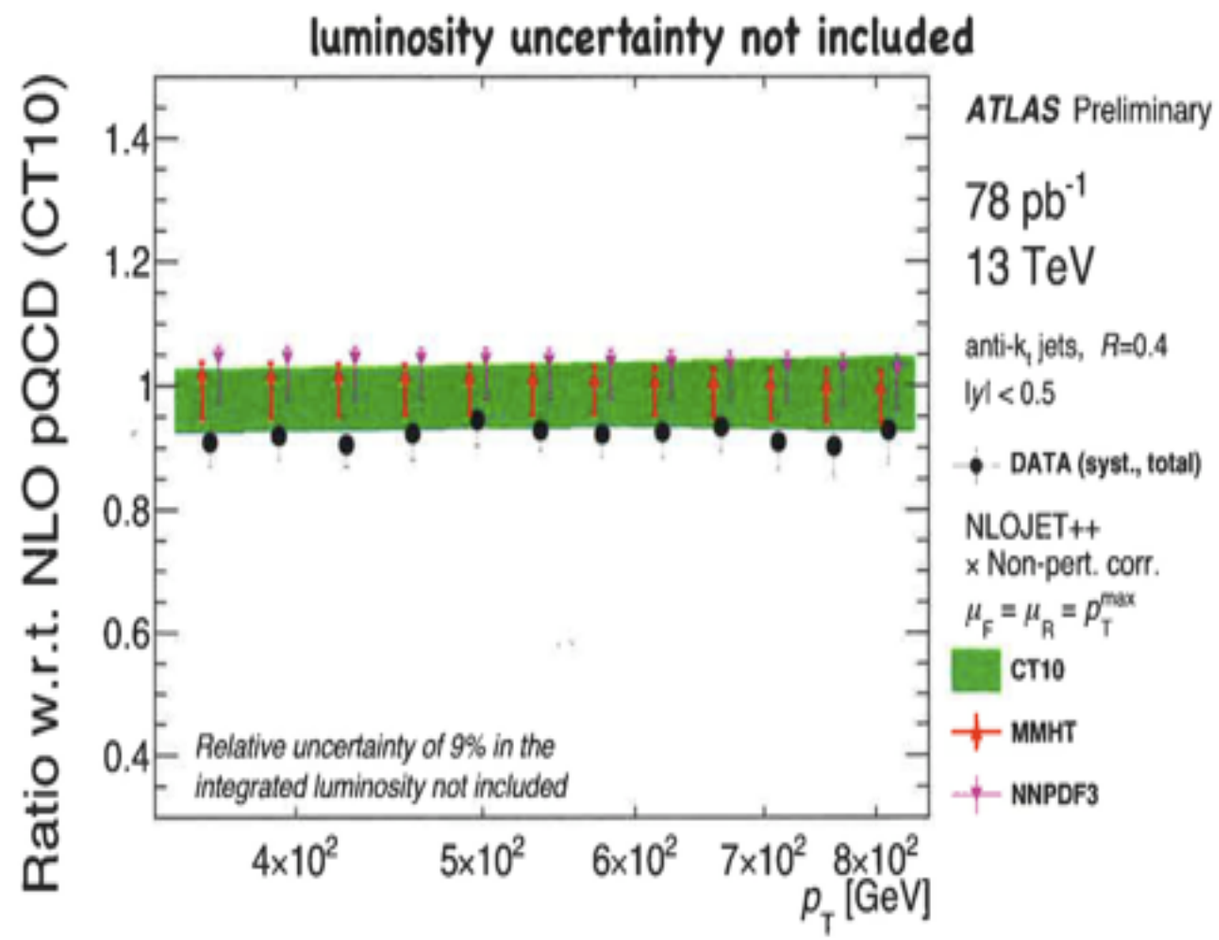
CMS PAS EXO-15-001

- Observed limits at 95% CL on cross section of qq, qg, gg resonances
- Get worse when there are gluons in the final state because radiation increases and resolution degrades
- Extend to 7 TeV in di-jet mass for the first time
- plateaus at high mass due to absence of events

Model	Mass Limits (TeV)			
	Run 1 (20 fb^{-1})		Run 2 (42 pb^{-1})	
	Observed	Expected	Observed	Expected
String Resonance (S)	**5.0**	**4.9**	**5.1**	**5.2**
Excited Quark (q*)	**3.5**	**3.7**	**2.7**	**2.9**
Axigluon (A) / Coloron (C)	**3.7**	**3.9**	**2.7**	**2.9**
Scalar Diquark (D)	**4.7**	**4.7**	**2.7**	**3.3**
Color Octet Scalar (S8)	**2.7**	**2.6**	**2.3**	**2.0**

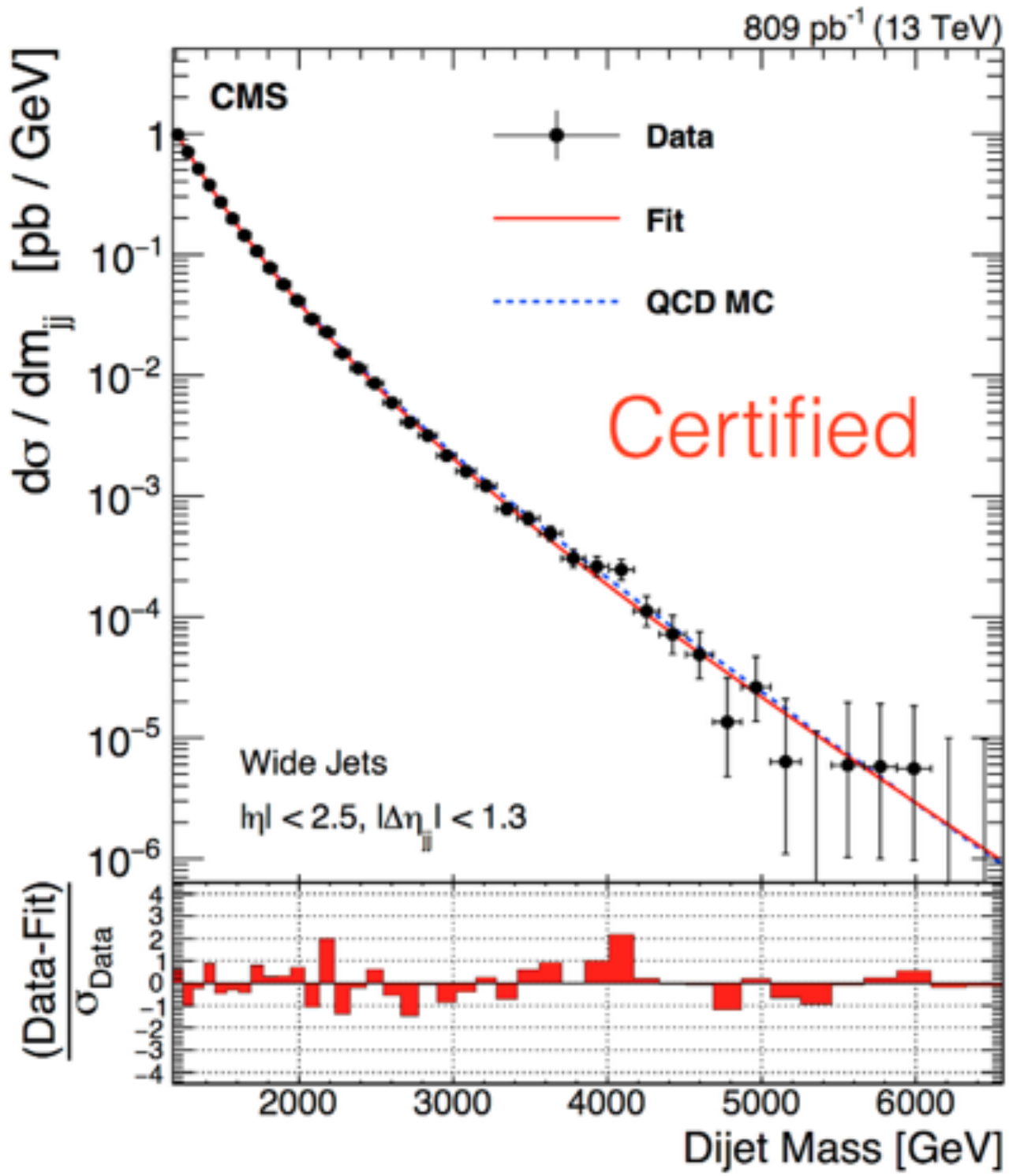
Inclusive jets at 13 TeV, 2015 data, ATLAS



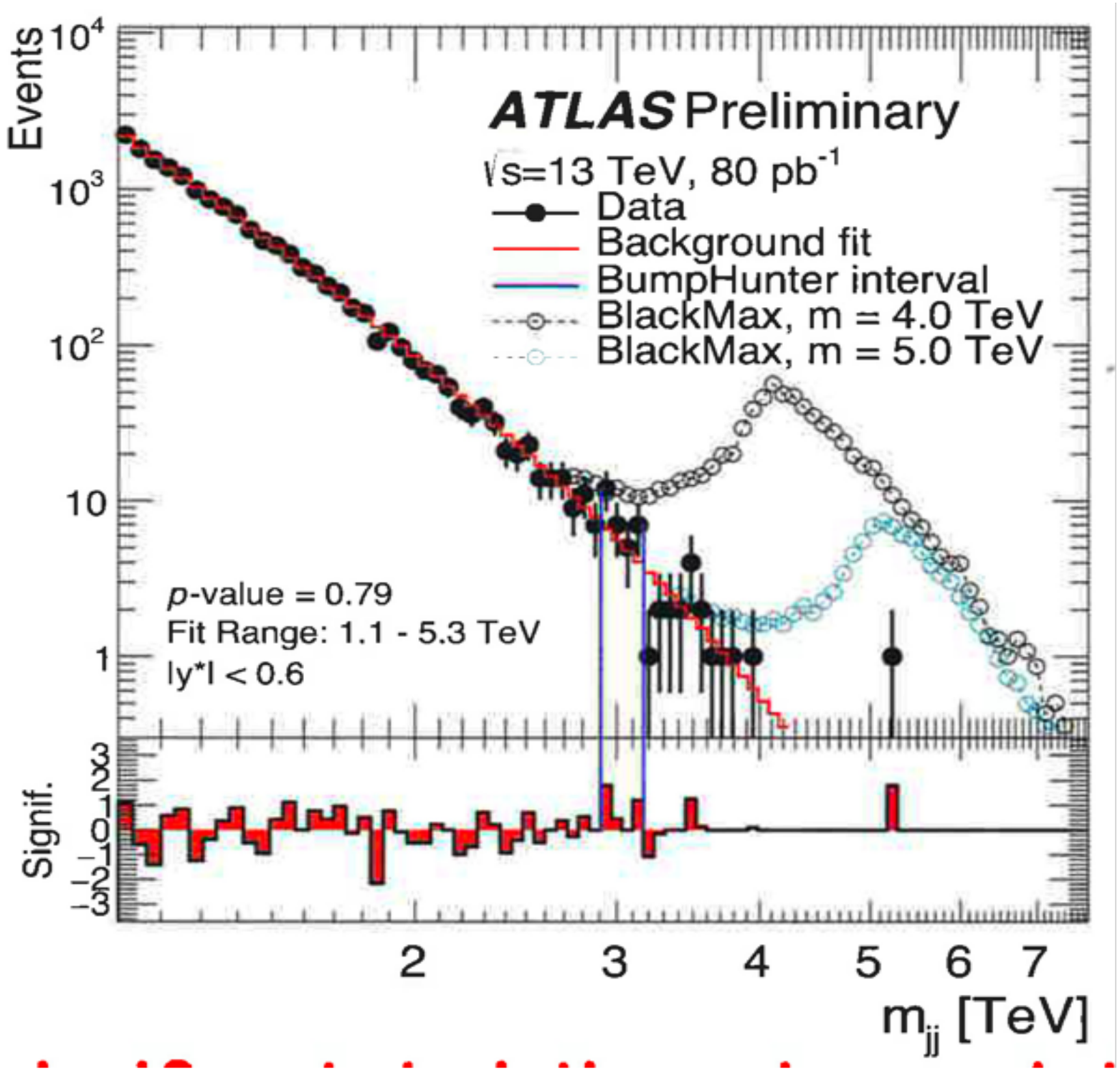


good agreement with pQCD calculation

Dijets – effective mass



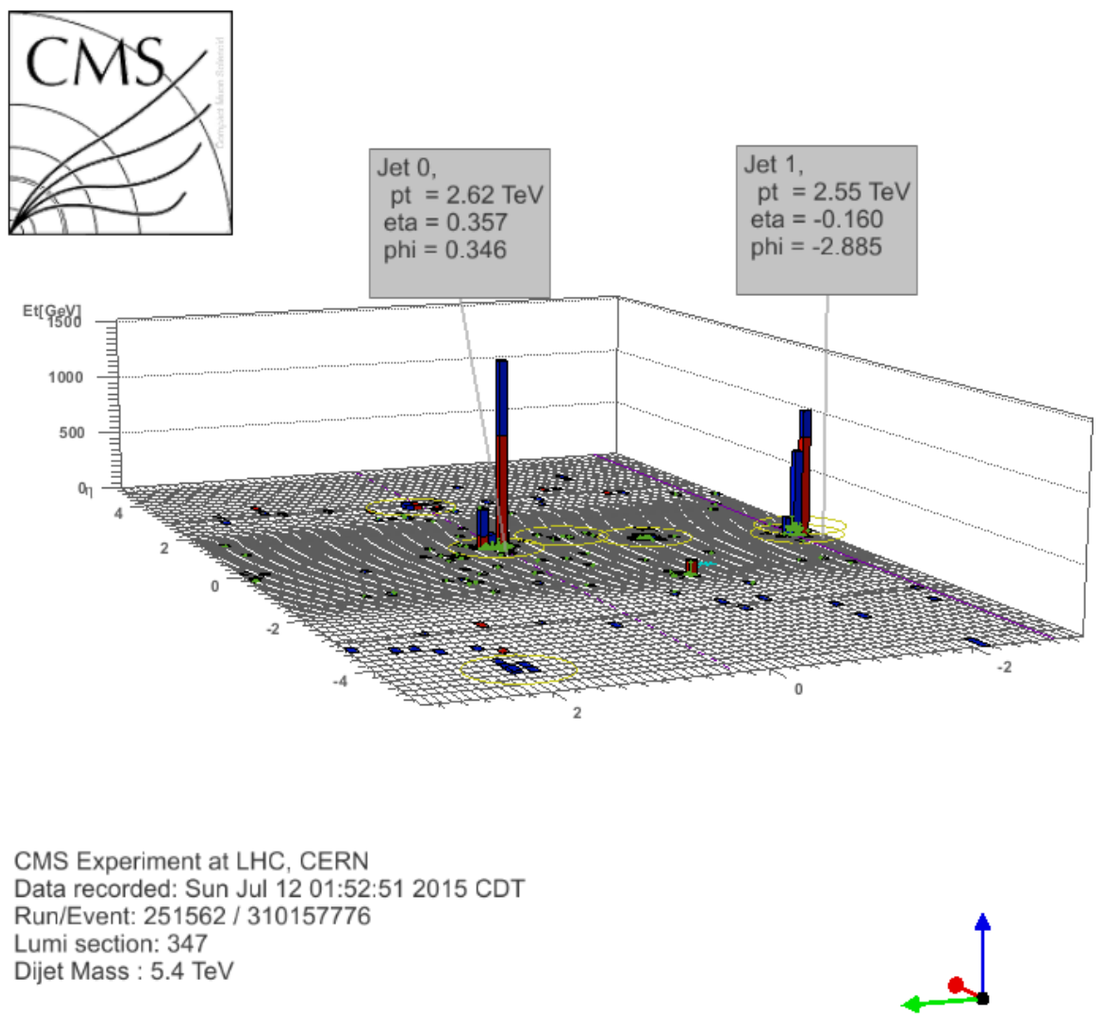
Dijet masses, ATLAS, 13 TeV, Black Holes exclusion

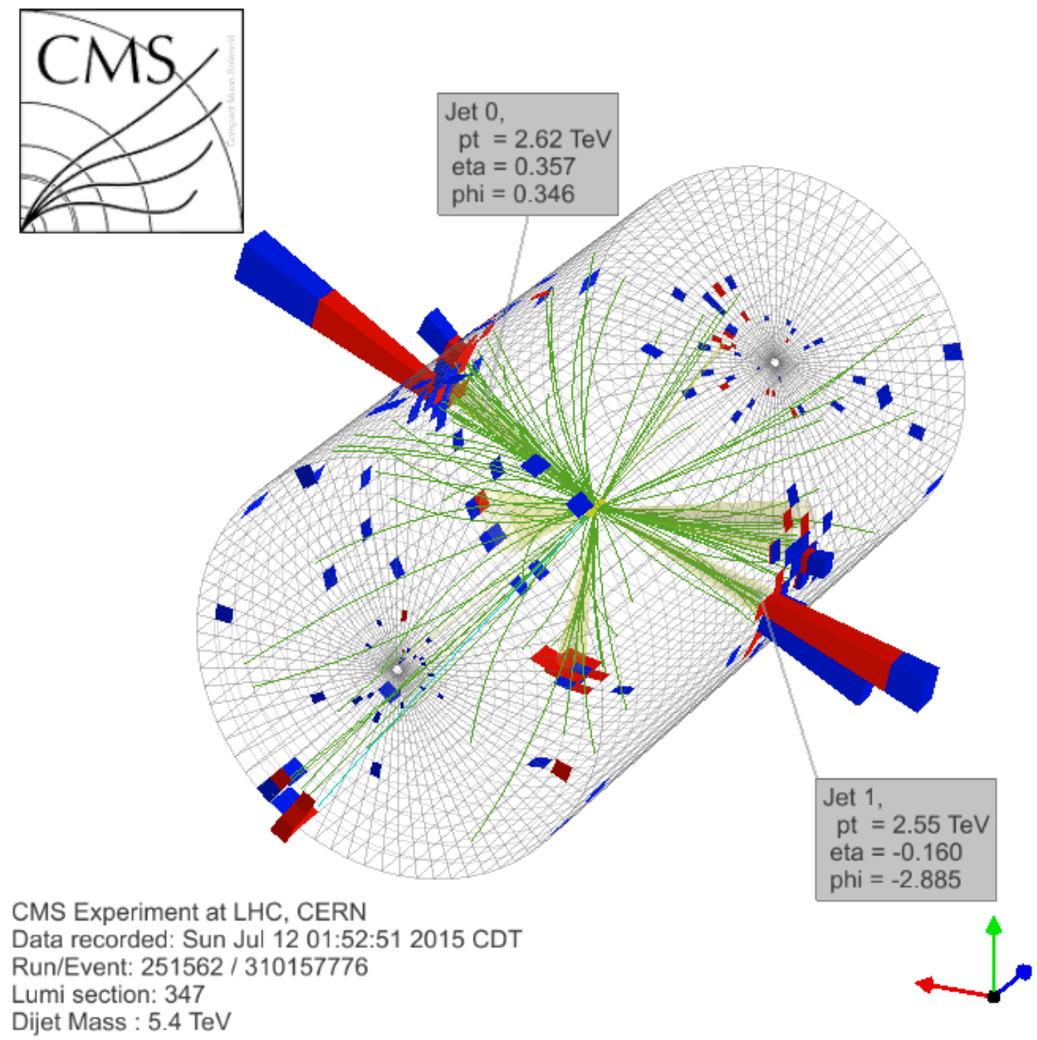


Di-jet resonance search

CMS PAS EXO-15-001

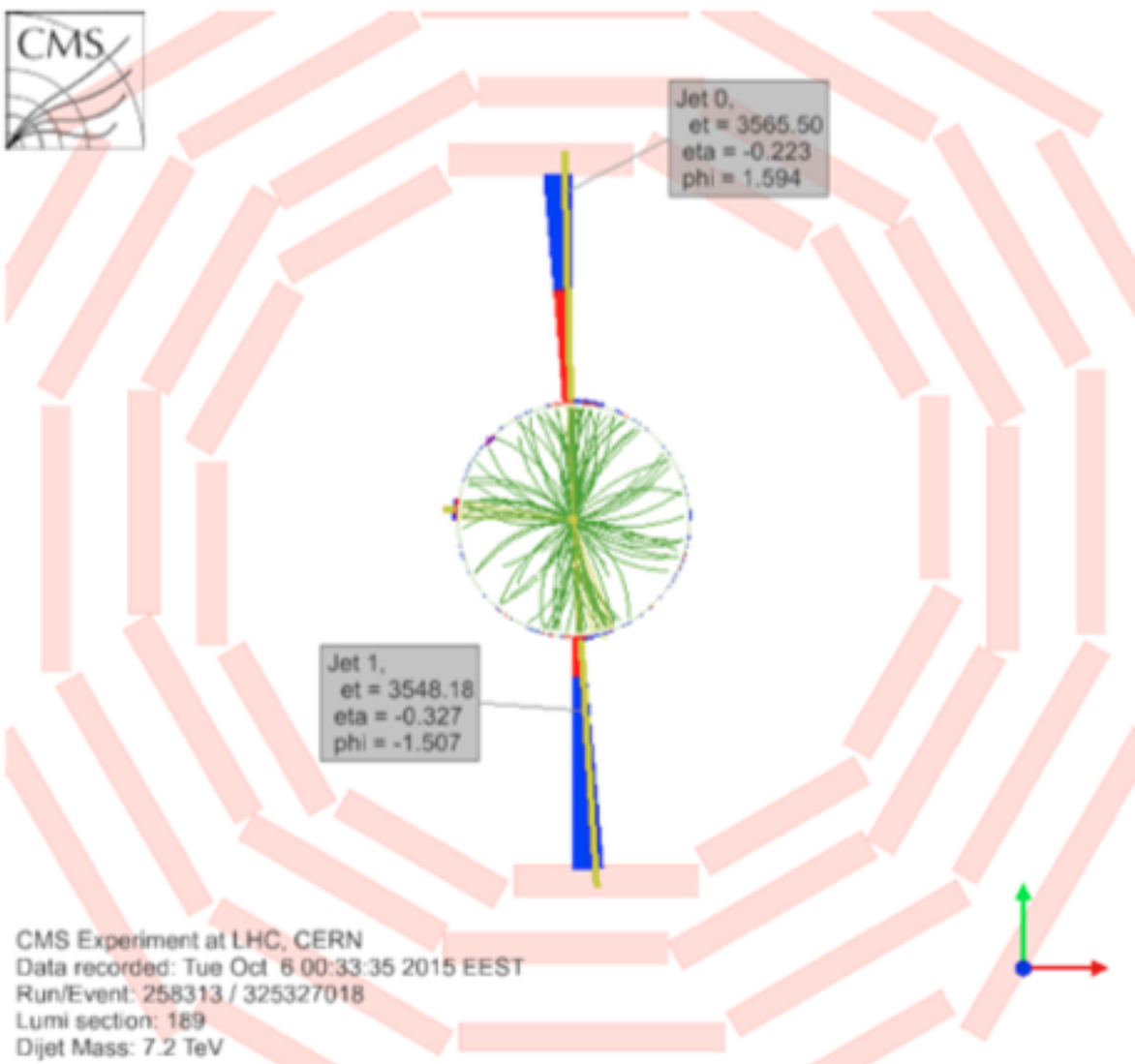
Highest Mass di-jet event M =5.4 TeV

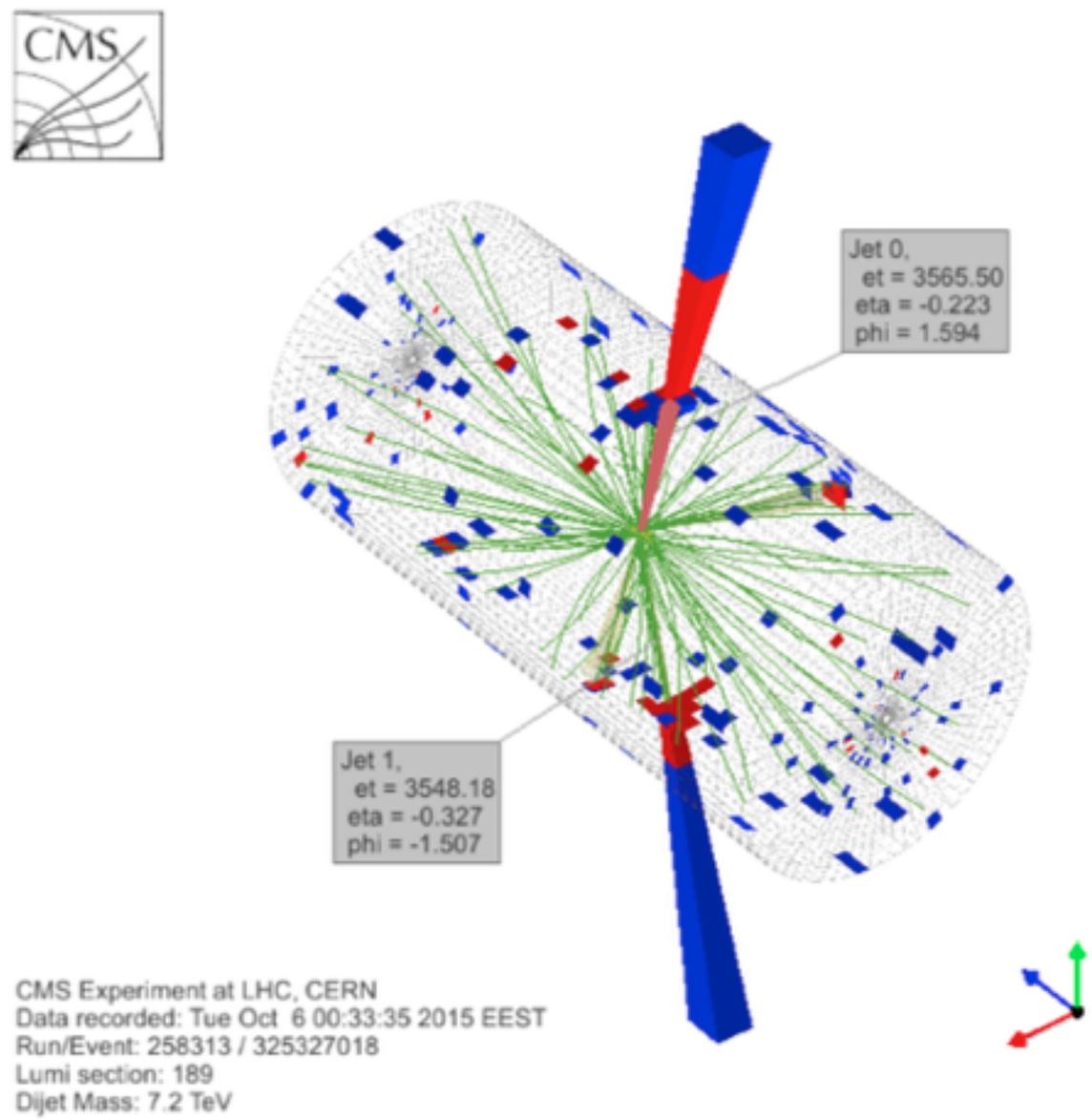




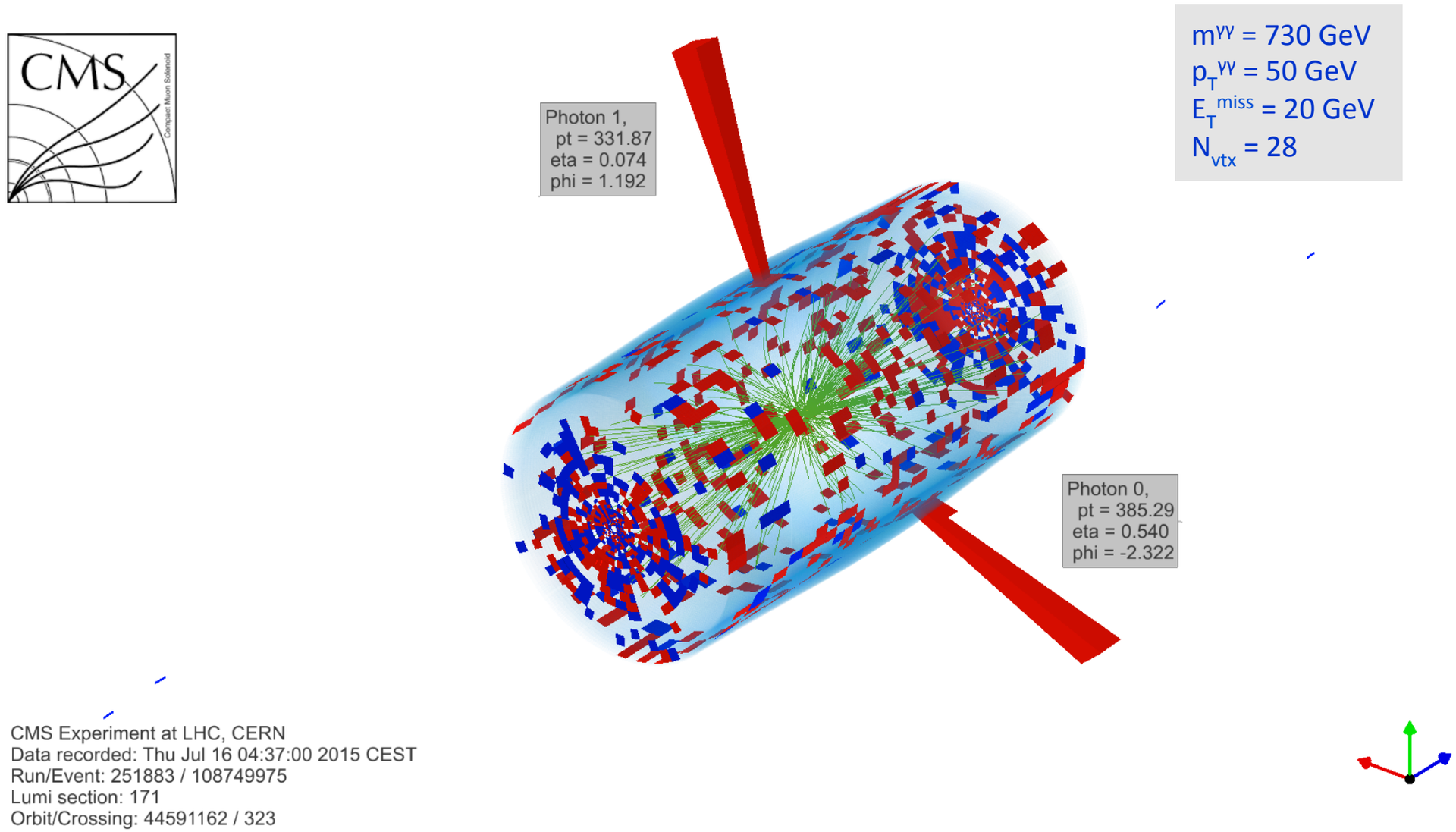
Highest dijet mass event

- **Dijet mass = 7.2 TeV**
  - very-well balanced dijet event





Event display of the highest mass di-photon candidate (M = 730 GeV)

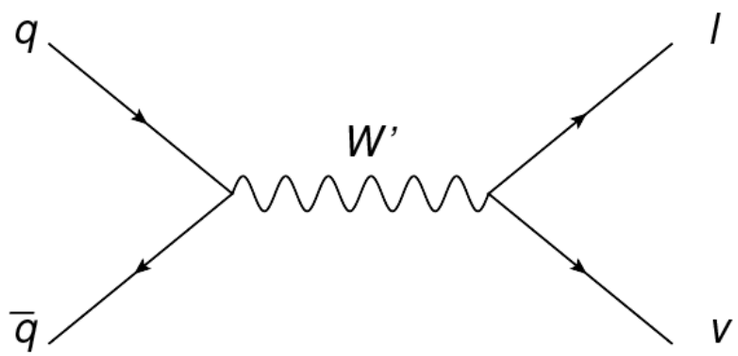


Photon selection

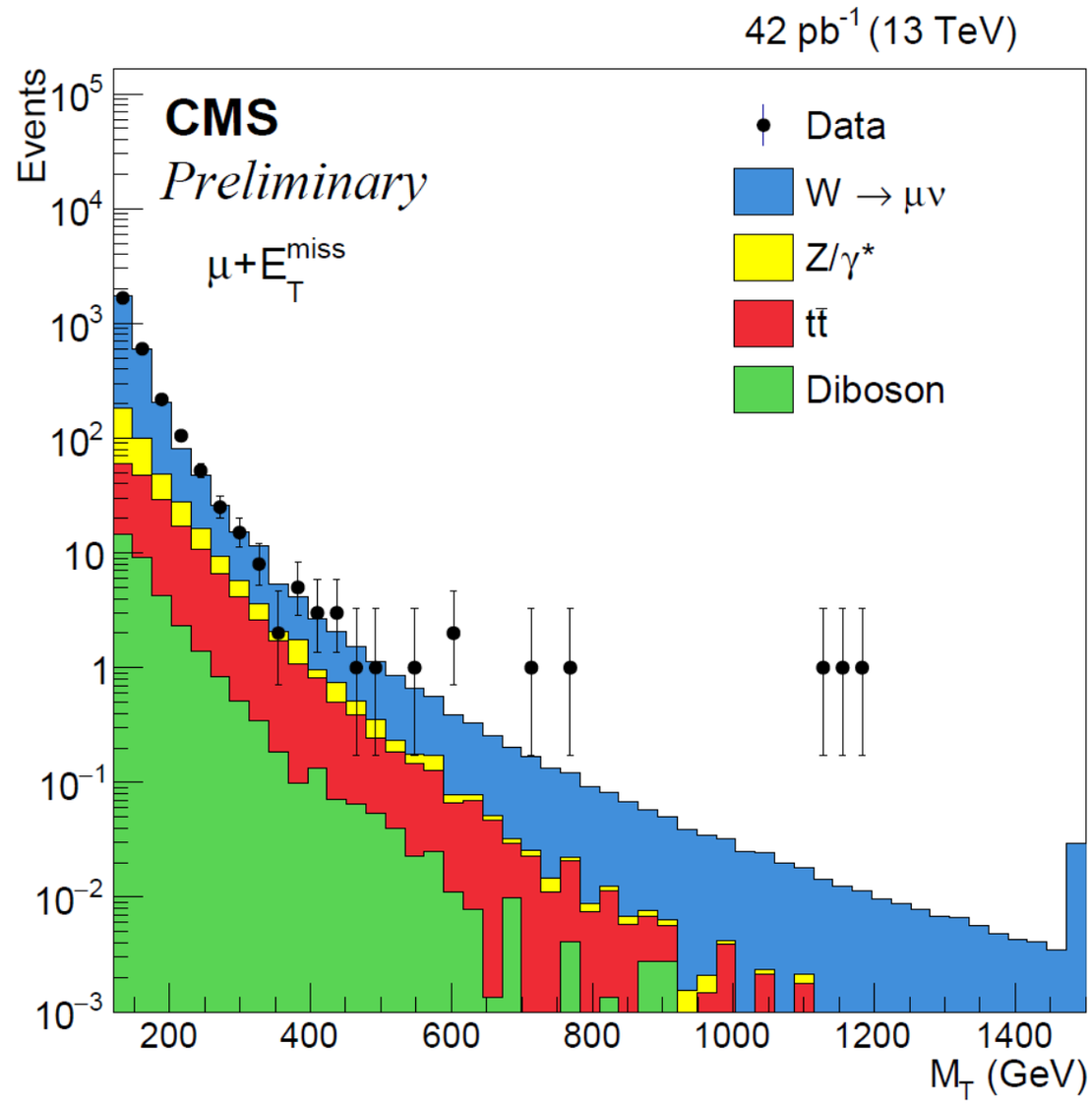
p_T> 100 GeV and |η| <2.5 with at least one candidate in the ECAL Barrel with |η| <1.4442

isolated photons with shape in ECAL compatible with prompt photon

Muon + MET resonance Search



Early Alignment used in data



transverse mass

last bin includes overflow

Muon selection

Good-quality isolated high-p_T muon with p_T> 55 GeV and $|\eta|$ <2.4

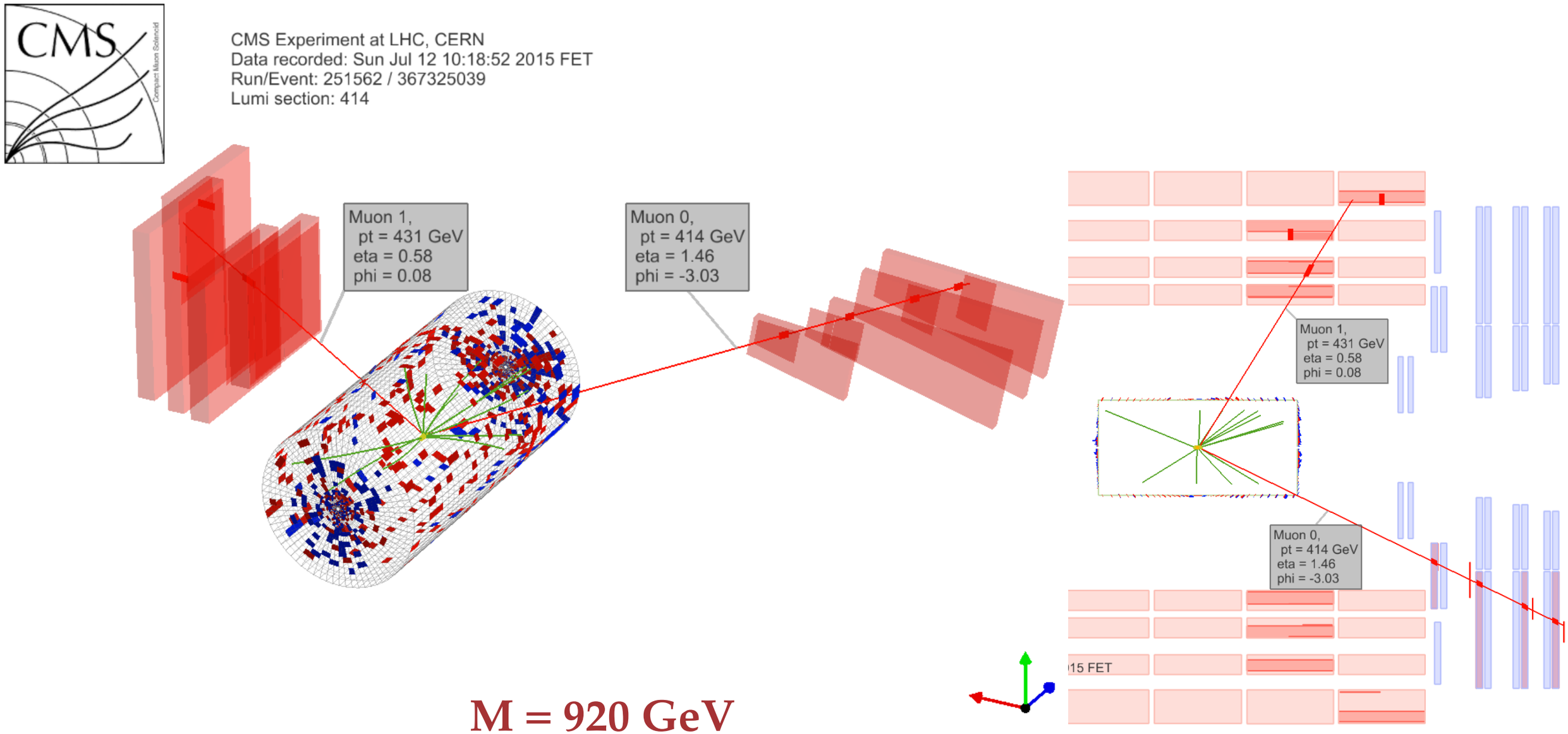
Event selection

- Single high-p_T muon accompanied by a large missing transverse energy (E_T^{miss}).
- Events containing additional muons with p_T> 25 GeV are vetoed
- Kinematic selection:

$0.4 < p_T(\mu)/ E_T^{miss} < 1.5$

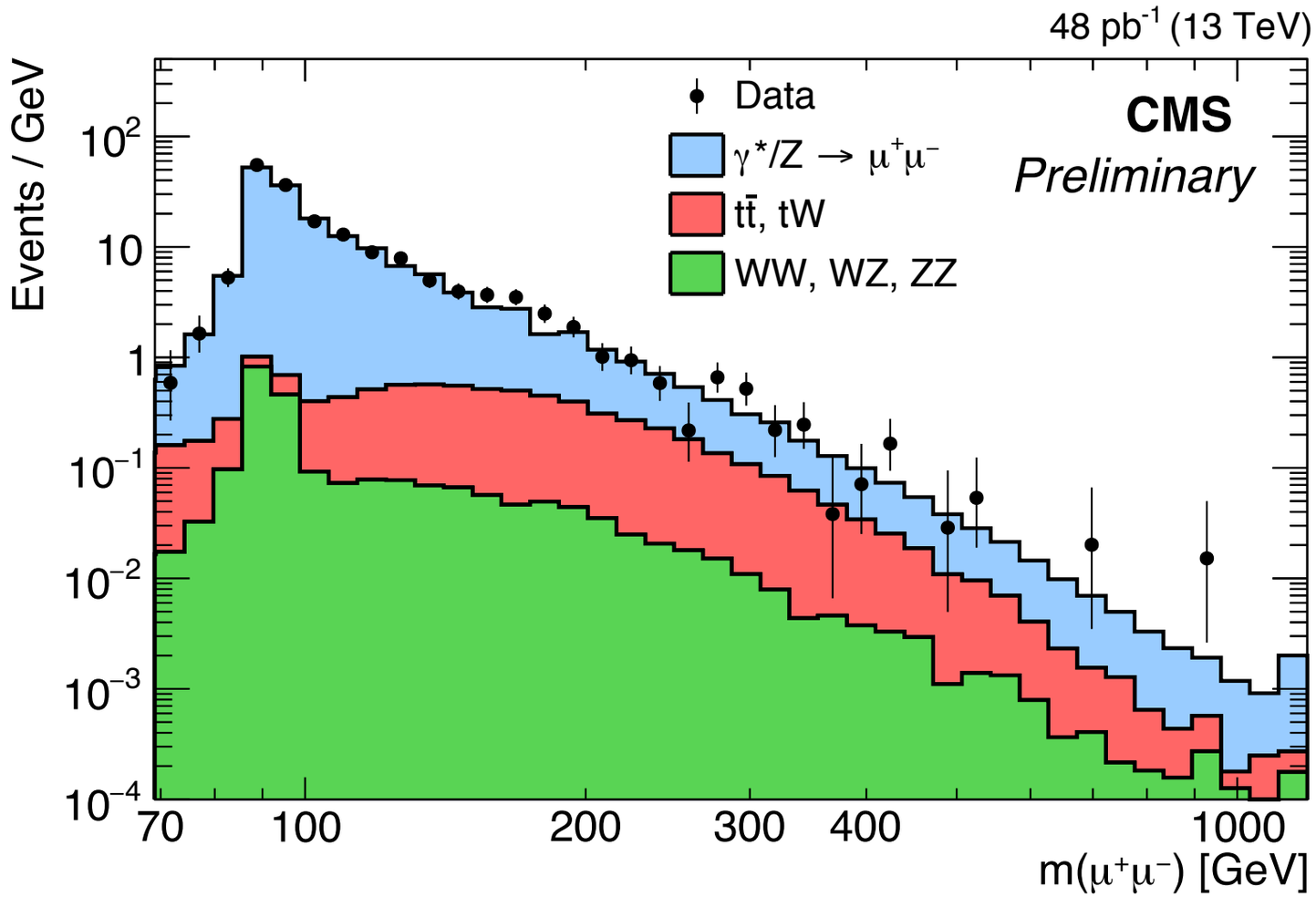
$\Delta\Phi(\mu, E_T^{miss}) > 2.5$

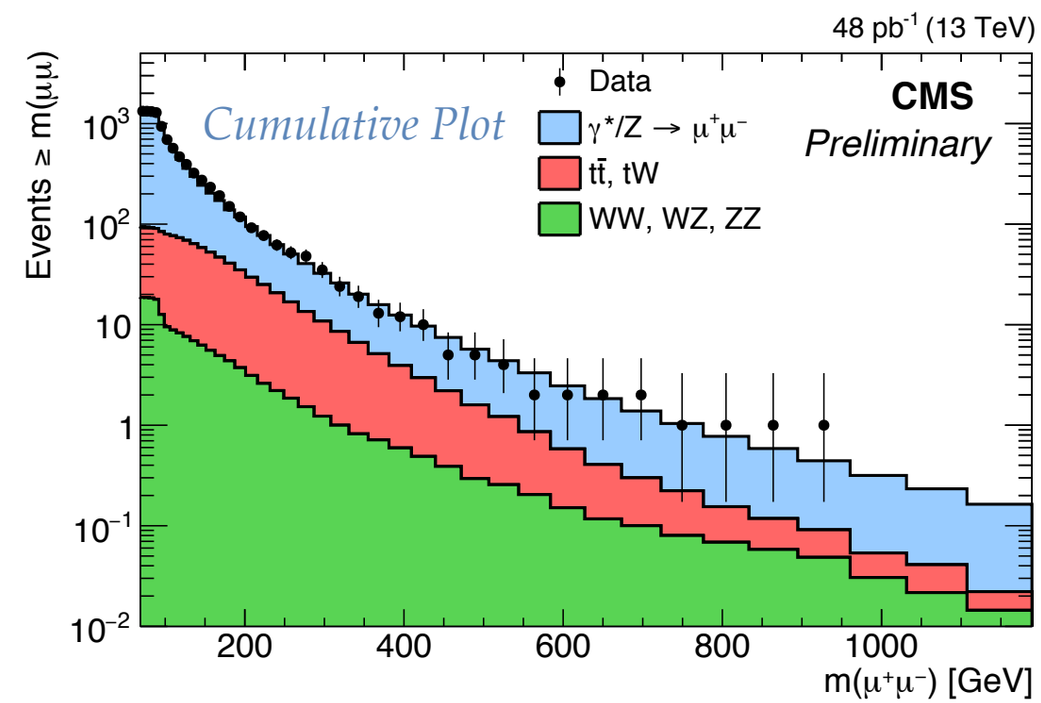
Di-muon resonance search



M = 920 GeV

Di-muon resonance search





last bin includes overflow

Highest mass event = 920 GeV

Early alignment of Muon system and Tracker used in data

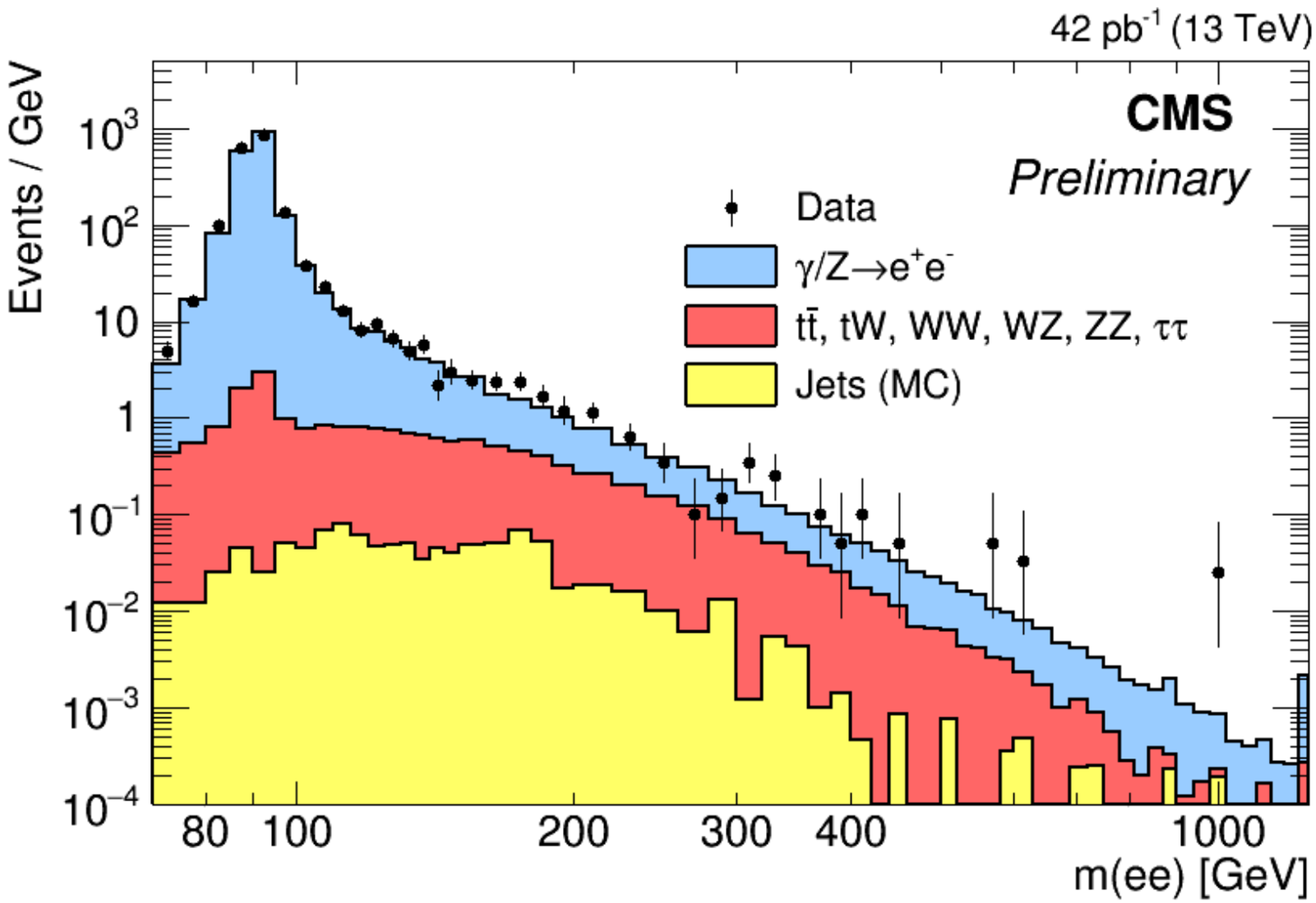
contribution from di-jets negligible and not shown

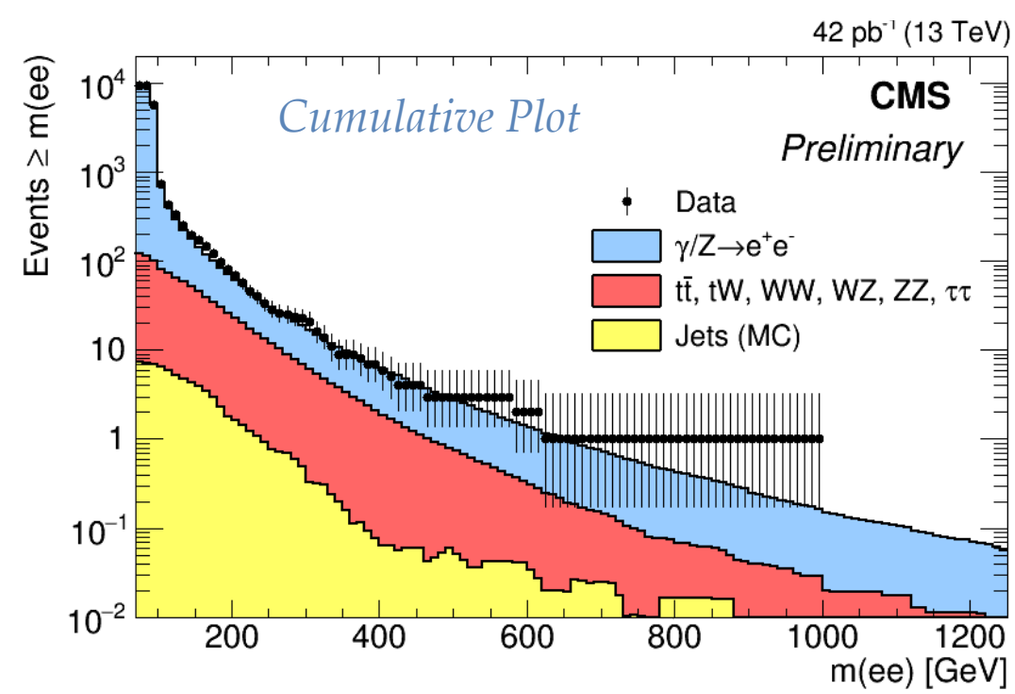
2 isolated muons muons are required to satisfy:

$p_T > 48$ GeV and $|\eta| < 2.4$

MC samples: aMC@NLO for Drell-Yan, POWHEG for ttbar and dibosons

Di-electron resonance search





last bin includes overflow

Highest mass event ~ 1 TeV

Run1 Limit for SSM Z′ < 2.9 TeV

Run1 sensitivity will be reached after about 2 fb^{-1}

2 electrons in ECAL with $E_T > 35$ GeV and at least one electron in the ECAL barrel

($|\eta| < 1.4442$ or $1.566 < |\eta| < 2.5$ with one electron within $|\eta| < 1.4442$)

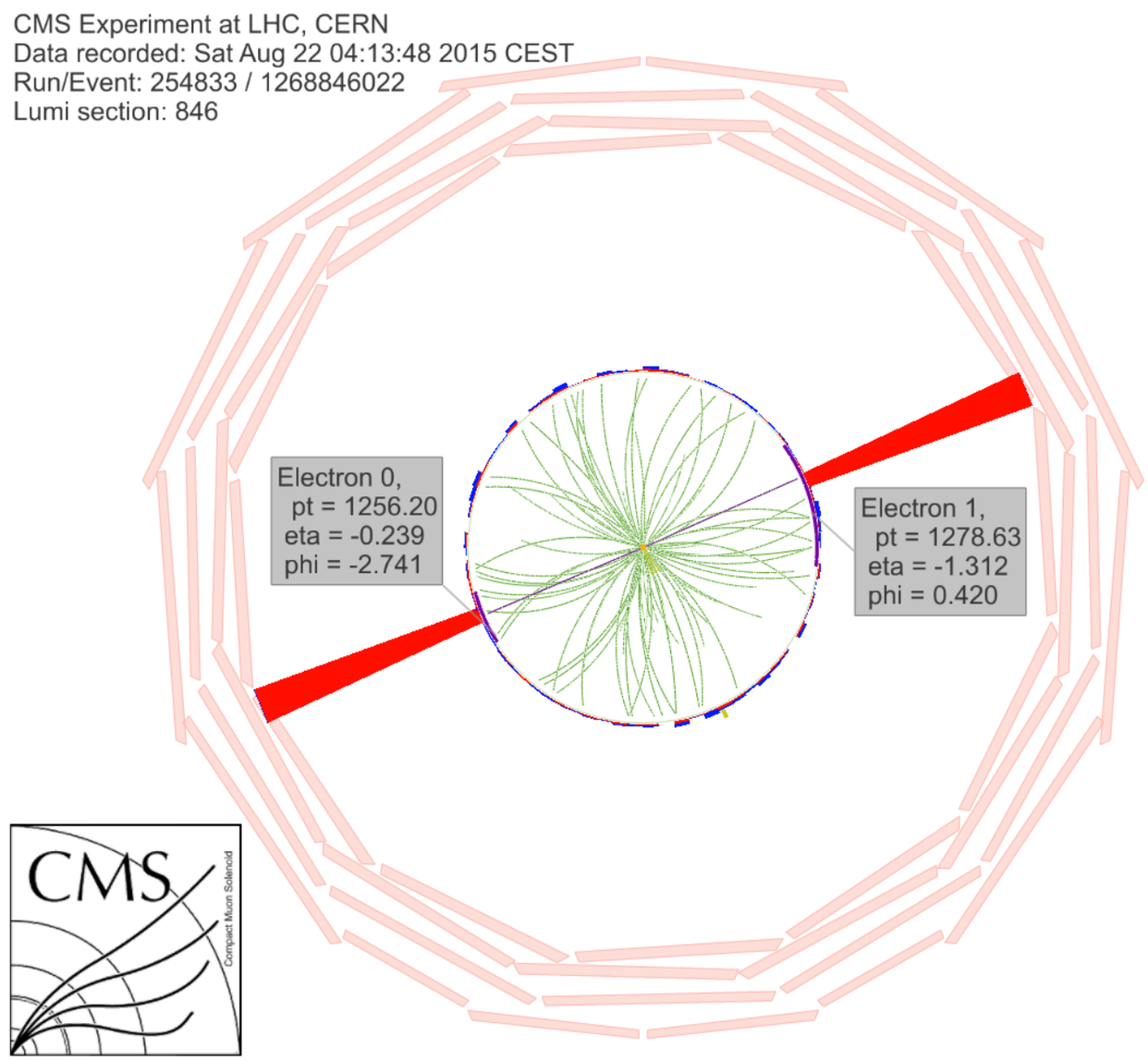
Di-electron resonance search

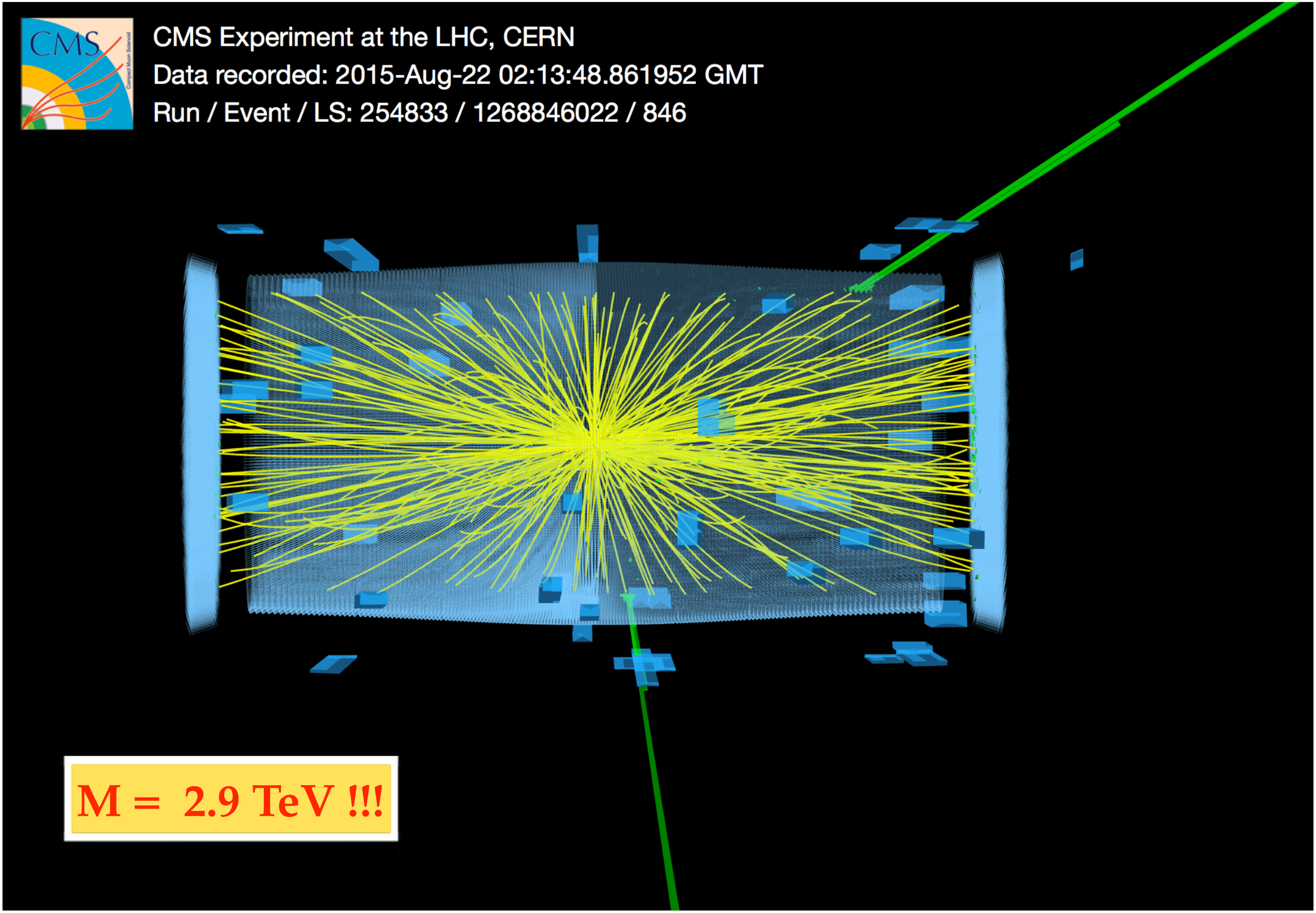
In the additional 25 pb^{-1} data @13 TeV and 50 ns processed last Wednesday:

An event with a di-electron mass of 2.9 TeV has been observed

The event consists in two perfectly balanced electrons and no other significant activity

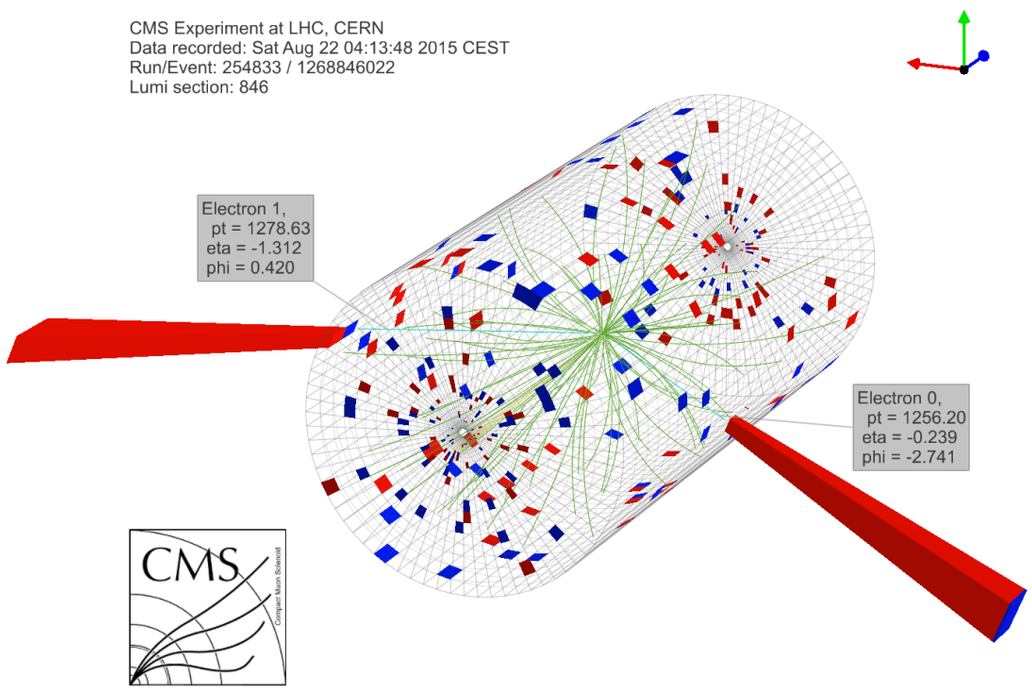
M = 2.9 TeV !!!

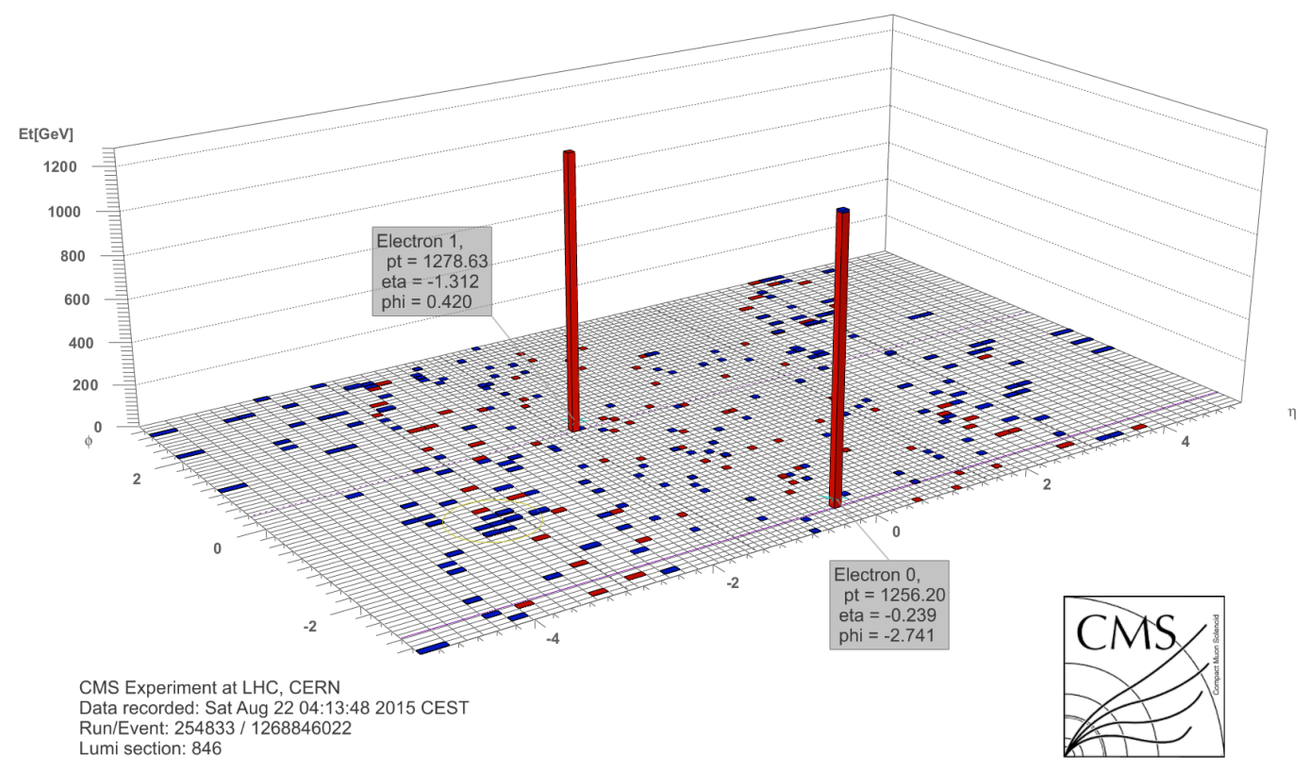



CMS Experiment at the LHC, CERN
Data recorded: 2015-Aug-22 02:13:48.861952 GMT
Run / Event / LS: 254833 / 1268846022 / 846
M = 2.9 TeV !!!

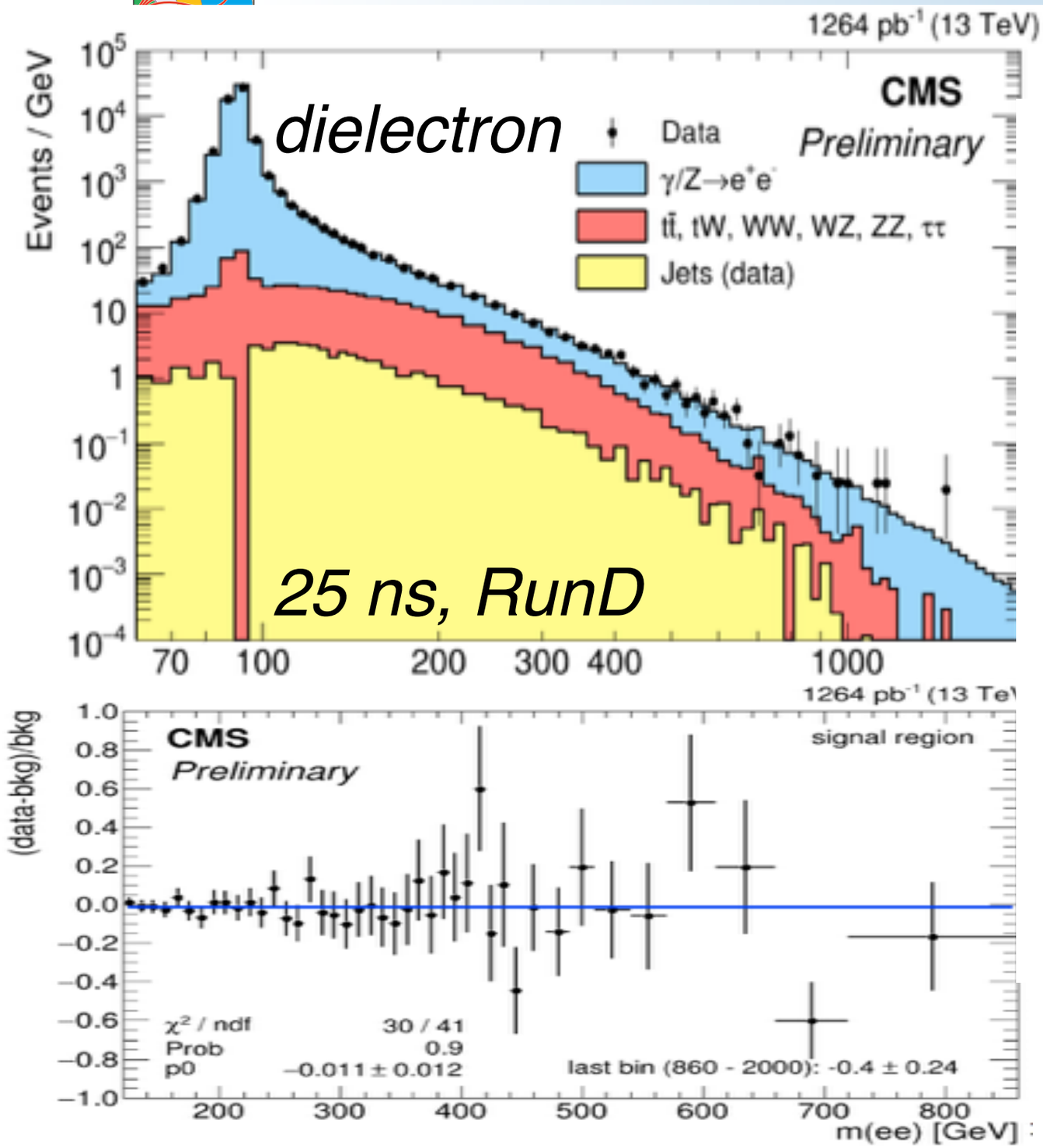
Di-electron resonance search

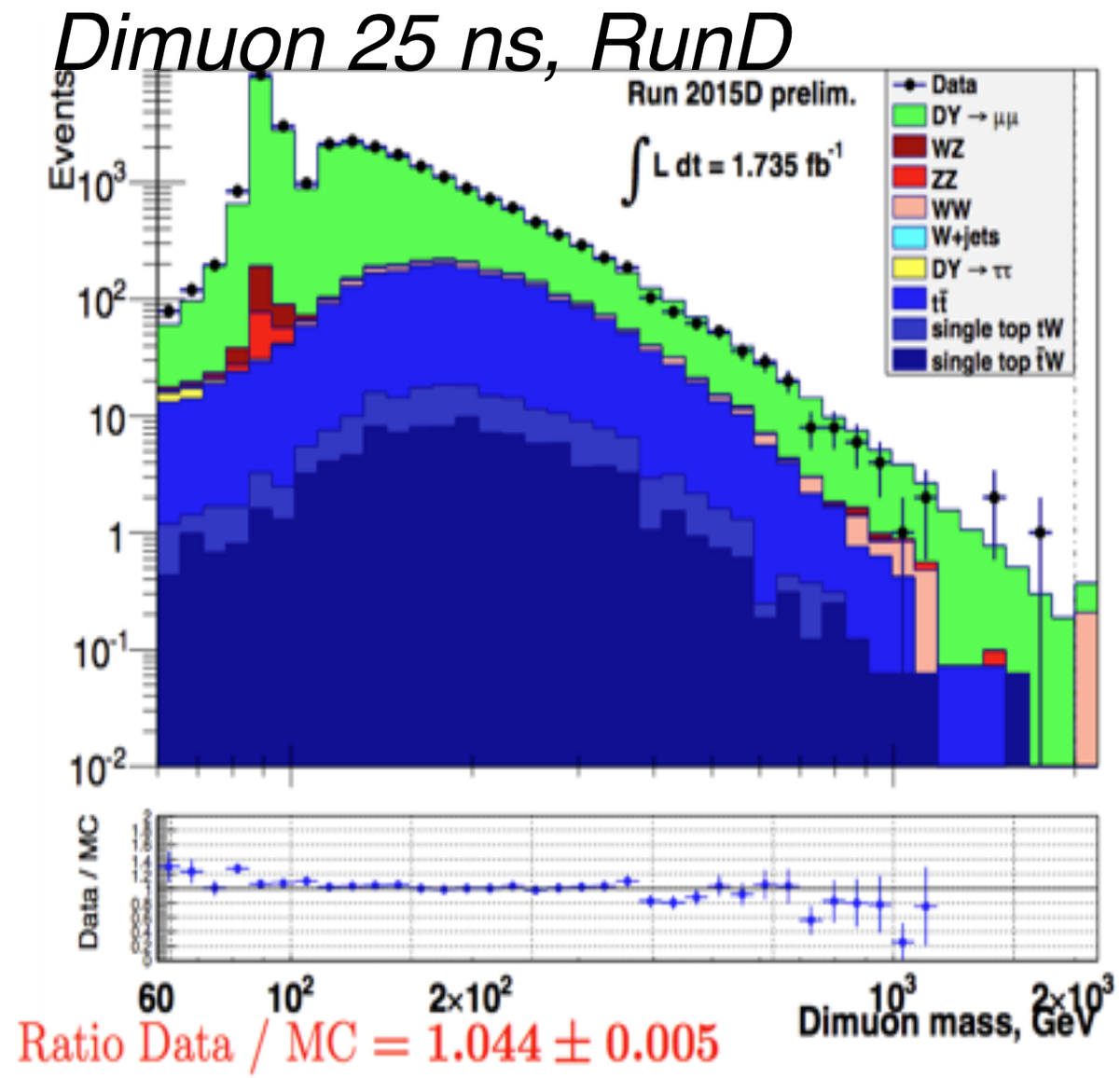
M = 2.9 TeV !!!





Drell-Yan pairs - Dilepton spectra

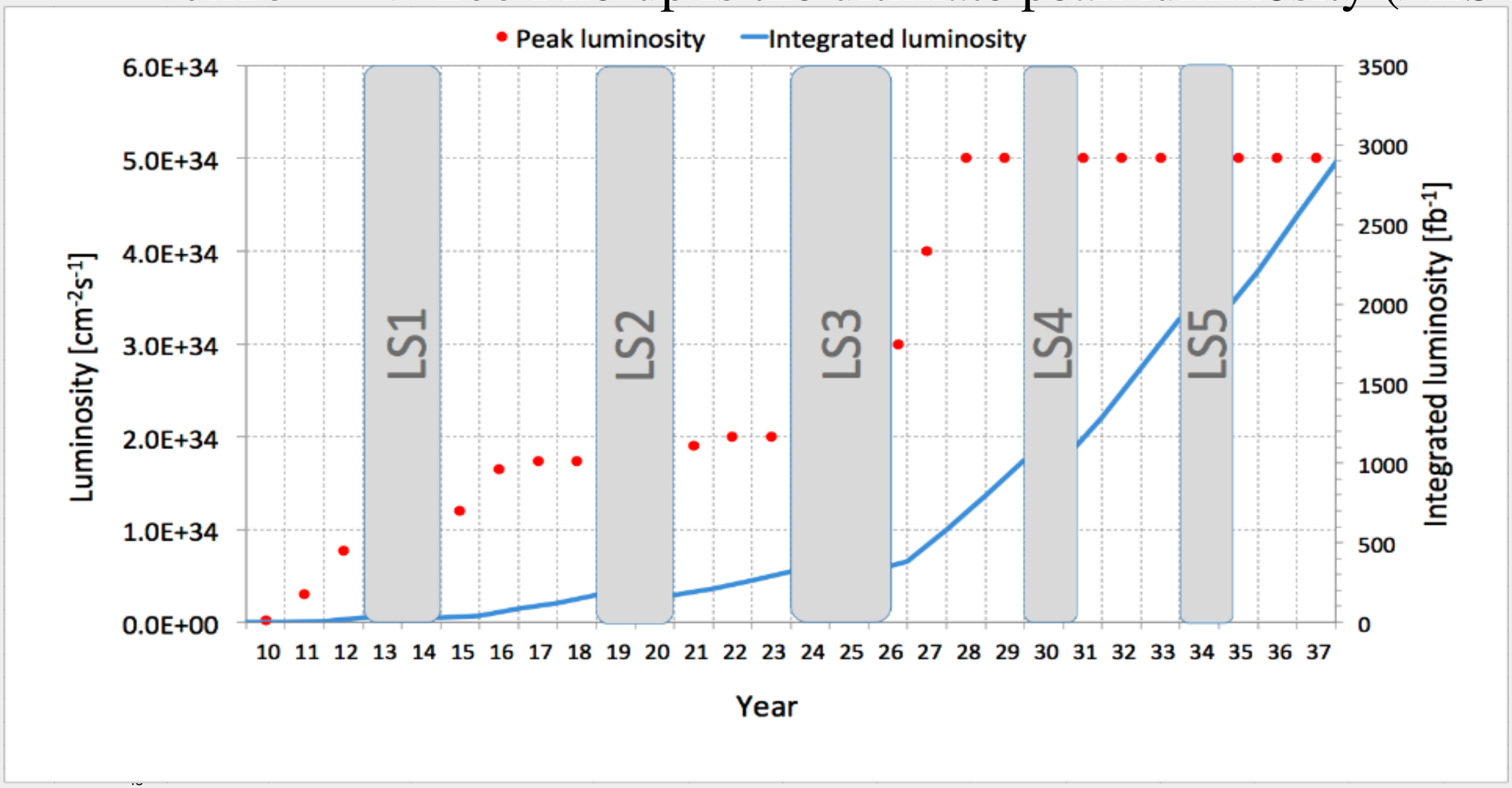




No new events at 2.9 TeV

HL-LHC physics goals and running conditions

- 3000 fb^{-1} is the target integrated luminosity
- $5x10^{34}$ —> 140 Pile-up is the nominal peak luminosity
- $7x10^{34}$ —> 200 Pile-up is the ultimate peak luminosity (>LS4)



But … Cryogenics problem

- Since March 2015 the “Cold Box” (CB) that produces liquid He for the operation of the CMS magnet has had problems, following a compressor oil pollution of the CB circuit.
- For a definitive recovery, the system requires an overall cleanup which takes several months.
- Meanwhile, the CERN cryogenics group, in collaboration with the CMS Technical Coordination group, has been trying to find a way to operate the Cold Box with a reasonable Duty Cycle (> 70%) that would allow operation of the magnet synchronized with physics operation of the LHC until the Year End Technical Stop.
- During TS2: augmented surface filters were installed; in addition, a special “regeneration cycle” has resulted in allowing a continued magnet operation since.