A snapshot of recent results from the CMS detector

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On behalf of the CMS collaboration

Highlights in Heavy-Ion Physics
A Symposium in Honour of Nikola Cindro
September 22-24, 2011, Split, Croatia

Outline:

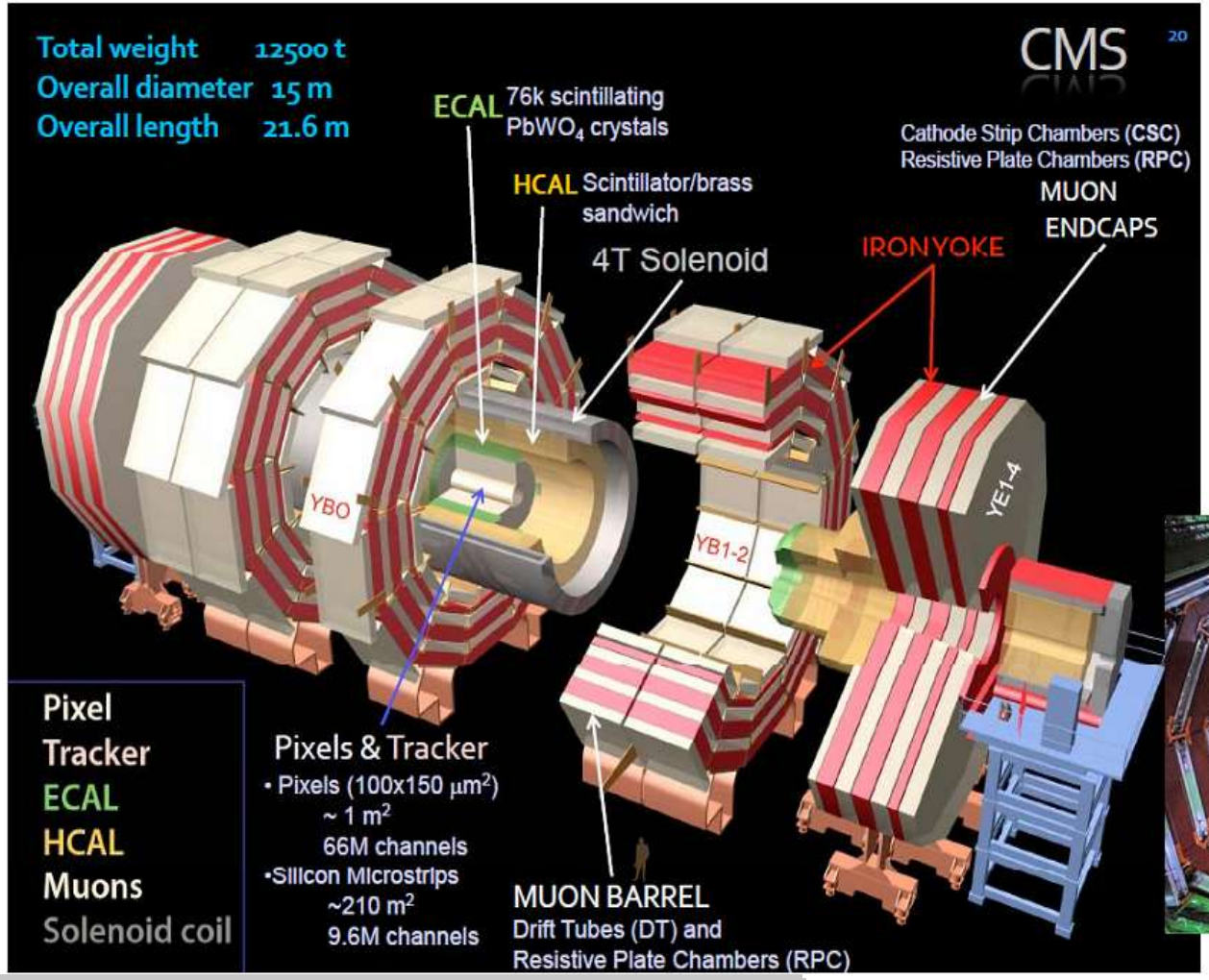
- LHC and CMS performance
- Rediscovering of the Standard Model of elementary particles
- Searches for physics Beyond Standard Model
- Summary

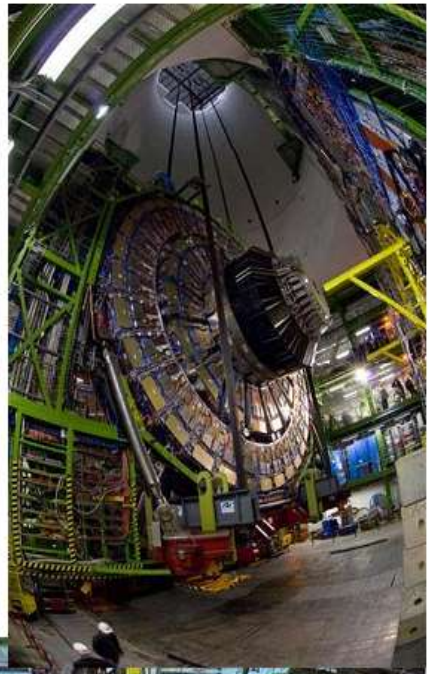
Disclaimer: Higgs physics covered by a talk of Ivica Puljak

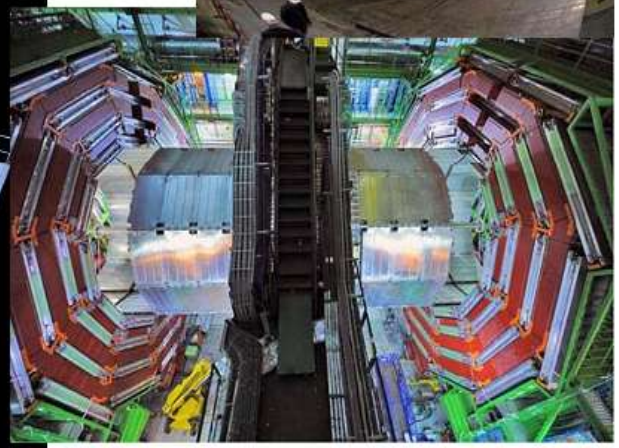
Large Hadron Collider (LHC)

The CMS collaboration

~3400 scientists and engineers (including ~840 students) from 173 institutes in 40 countries

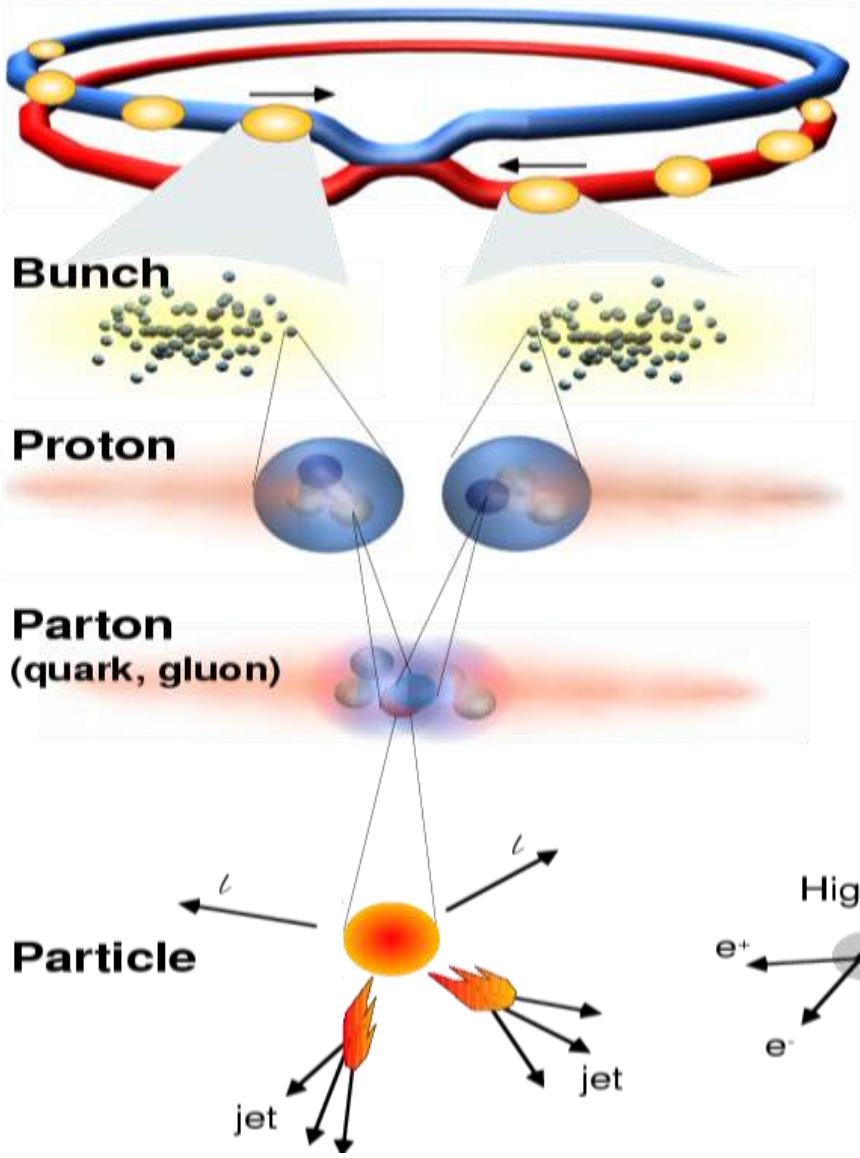




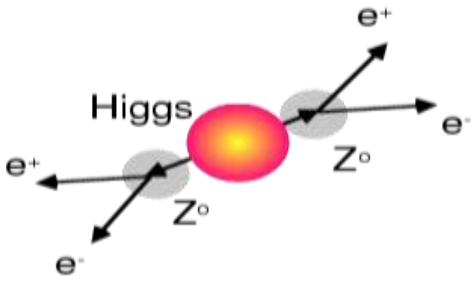


http://cms.cern.ch

LHC pp operations in 2011



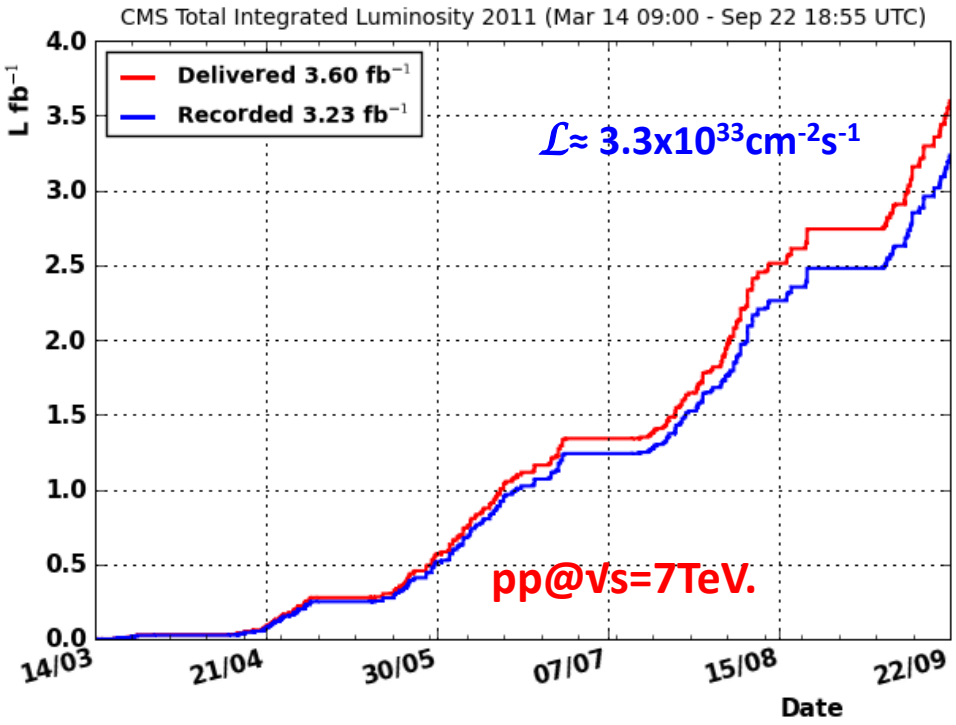
Proton-Proton	1404 x 1404 bunches
Protons/bunch	1.25×10^{11}
Beam energy	3.5 TeV
Luminosity	3.3×10^{33} cm^{-2}s^{-1}
Crossing rate	20 MHz
Collisions ≈	10^{7}-10^{8} Hz



Higgs

SUSY.....

LHC pp operations



- **Excellent LHC performance in 2011**.
- The goal (1 fb^{-1}) for the whole 2011 achieved in the first three months of running.
- Another factor of 3 gained since.
- New record of instantaneous luminosity achieved every week.
- Good perspective to get additional factors by November.

DAQ/L1/HLT running smoothly at L >10^{33}

Typical operating conditions (pp)

At start of fill: Lumi ~ 3.3x10^{33},

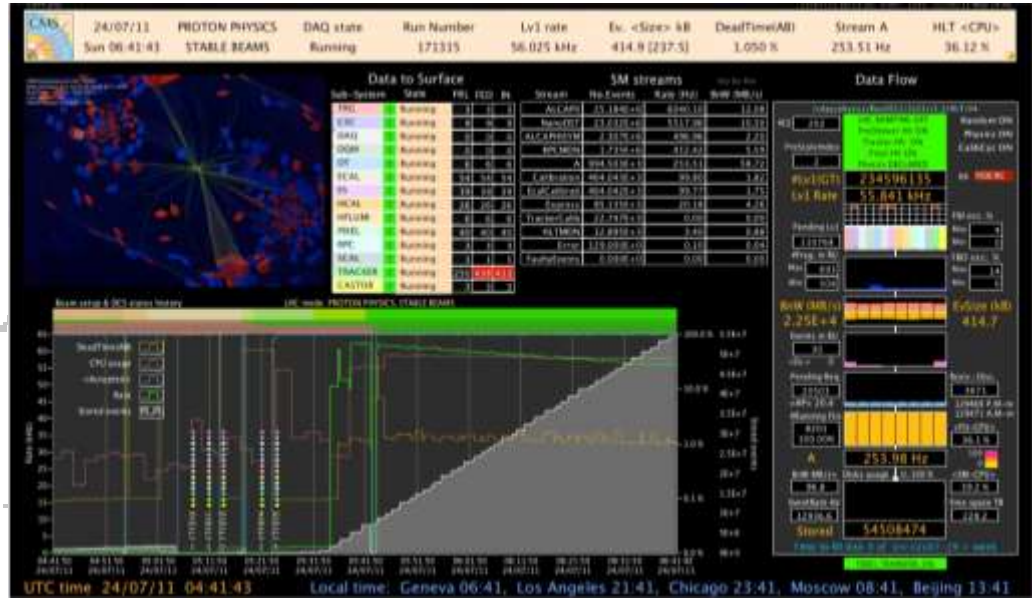
~15 PU events per BX,

ev. size ~ 550kB

Level-1 rate ~ 65 kHz, 50% HLT CPU

300 - 400 Hz rate of data recording

Central DAQ availability ~99%

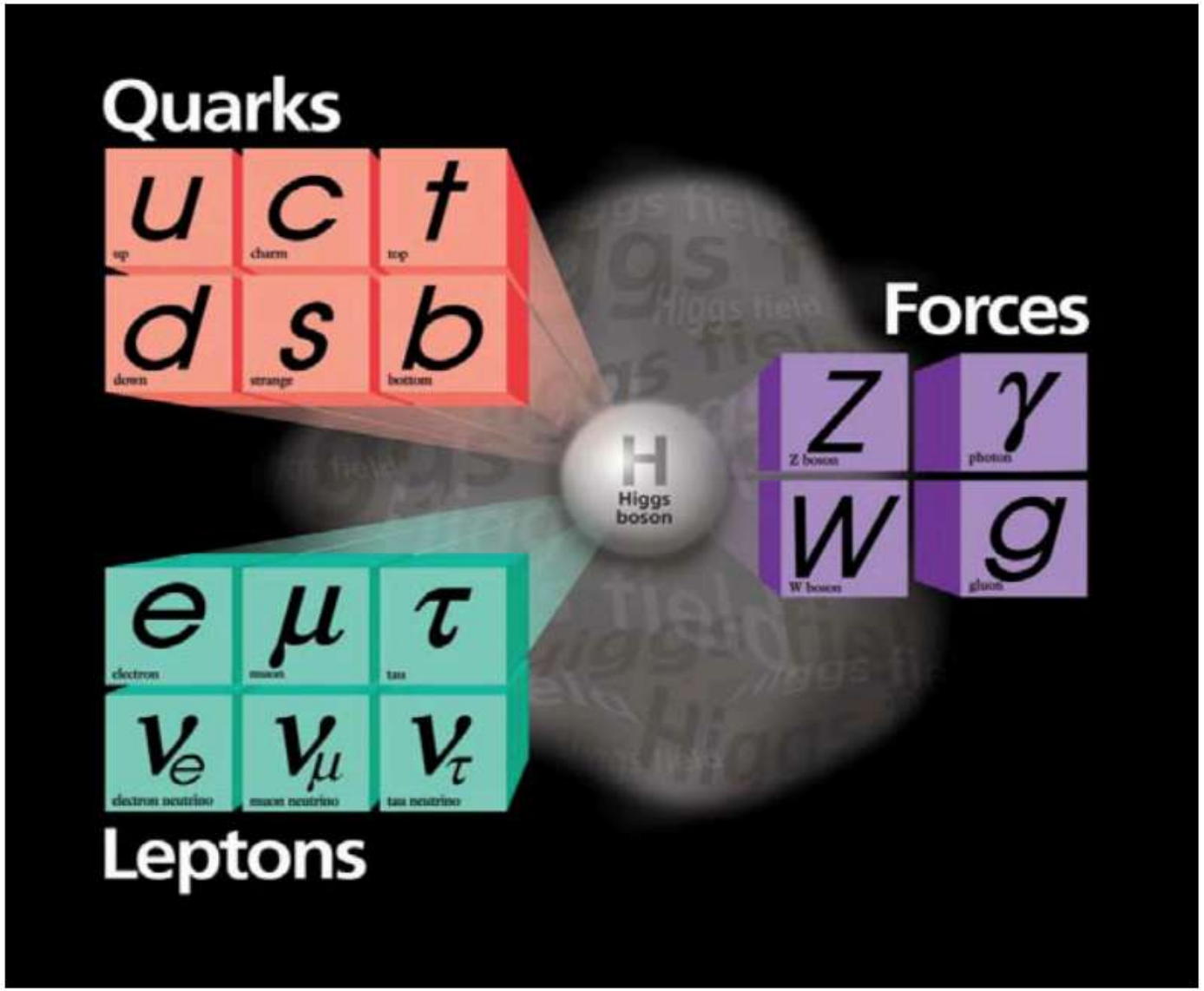


The pile-up seems to behave as expected in terms of event size

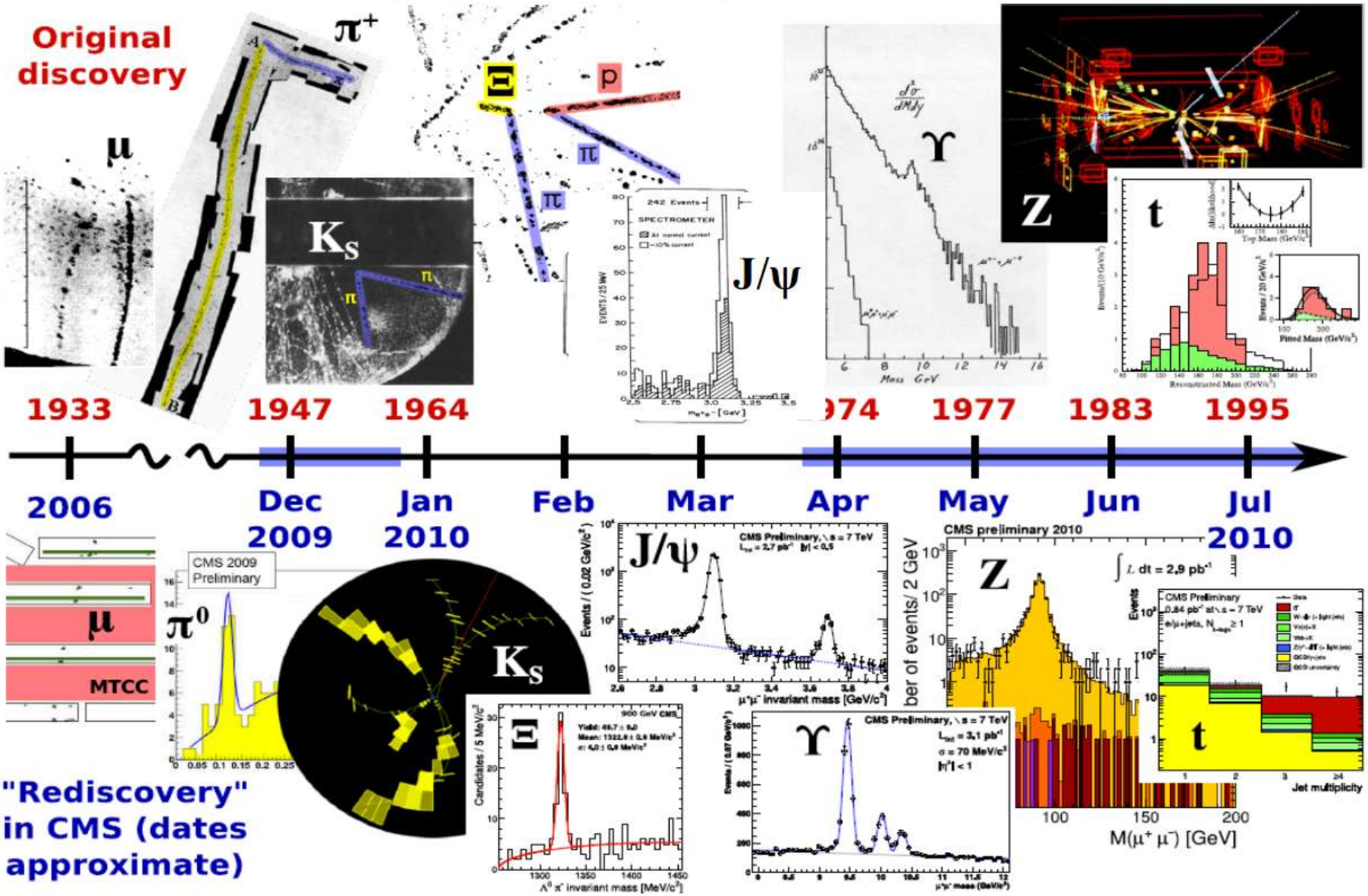
DAQ Limitations for further increase of the PU:

1) Total size < ~1MByte. **Even with 25PU** (~750kByte) looks OK
2) No single FEDs (FRL) > 2 KB/evt @100kHz. OK tested with tracker in Heavy Ion run.

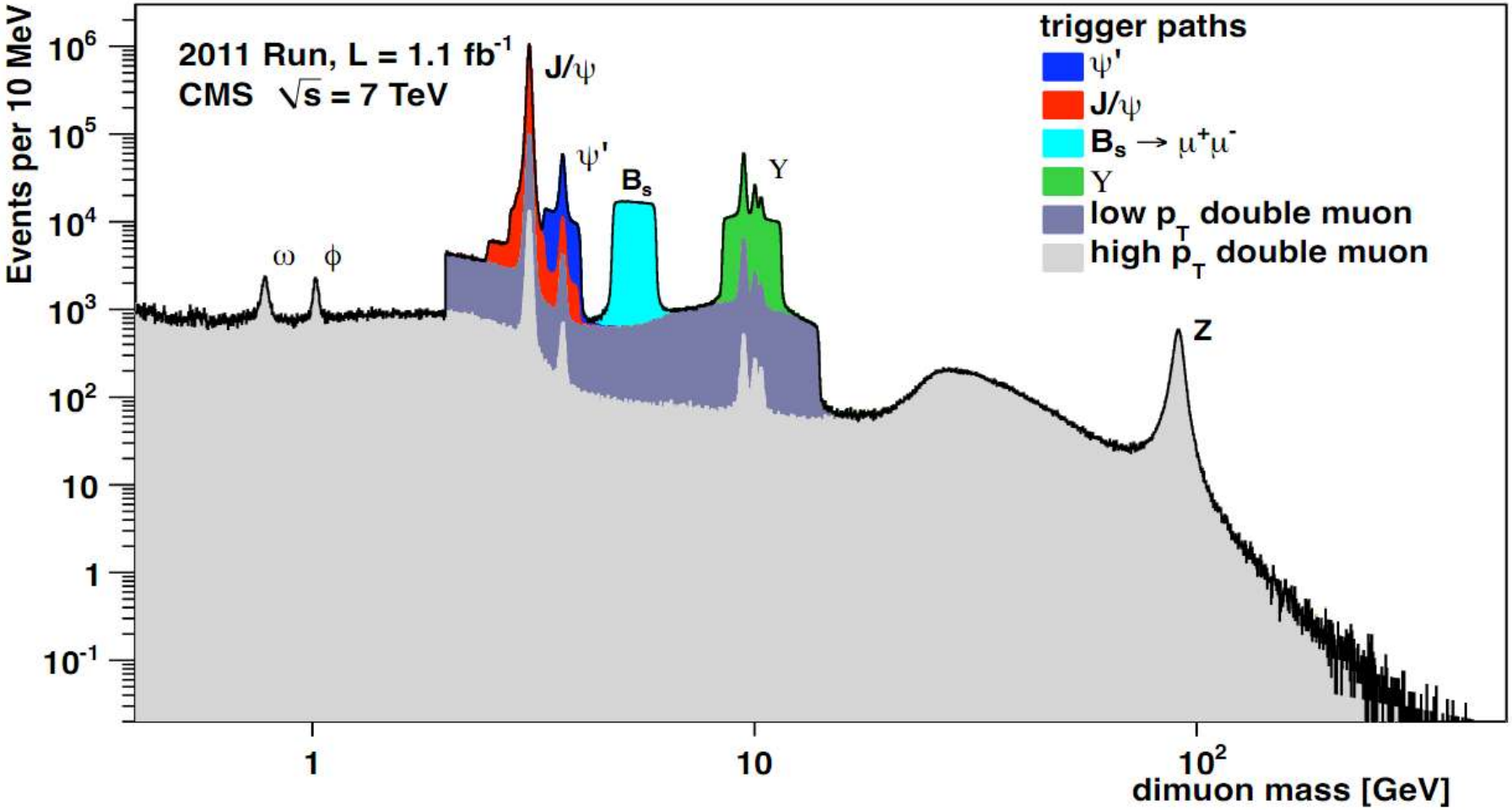
The Standard Model of Particle physics:



Discovery and re-discovery of the SM



Triggering on di-muons at 10^{32}-10^{33} $cm^{-2}s^{-1}$ with CMS



Dimuon mass distribution obtained from overlapping several trigger paths.

Jets: Inclusive jet cross sections

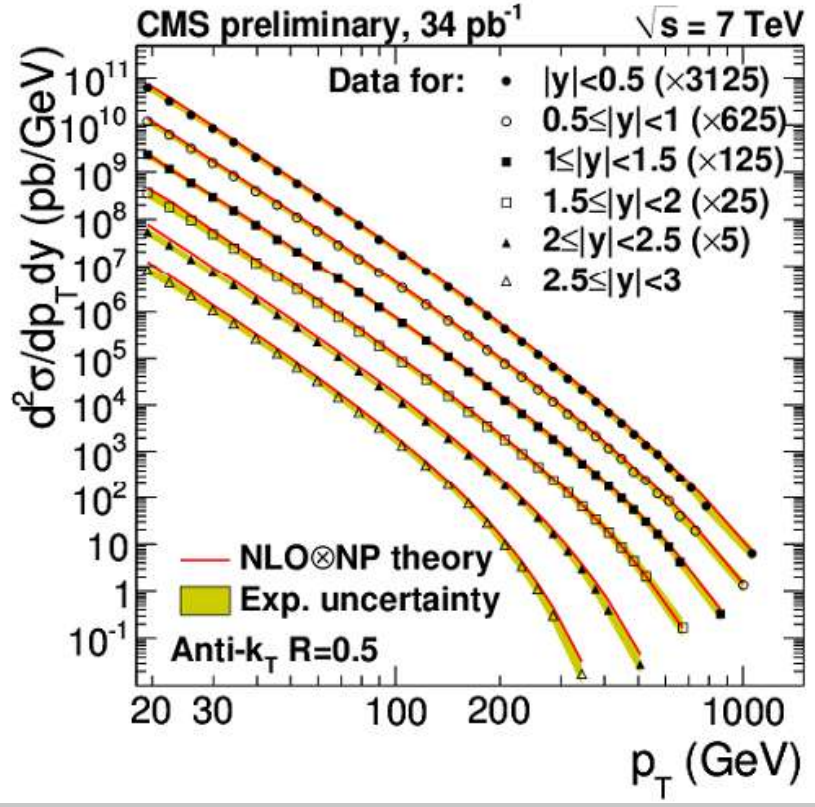
CMS-PAS-QCD-2010-011, accepted by PRL Ph.Lett. B 702 (2011) 336

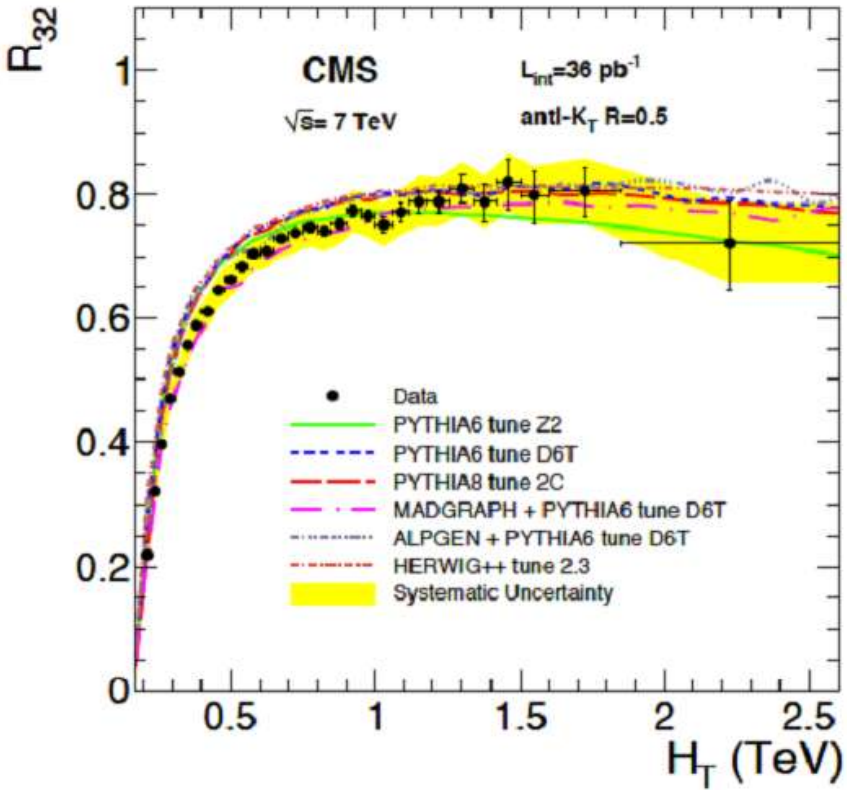
Jet pT 18-1100 GeV
Rapidity < 3

R_{32} = ratio 3 jets/2 jets events

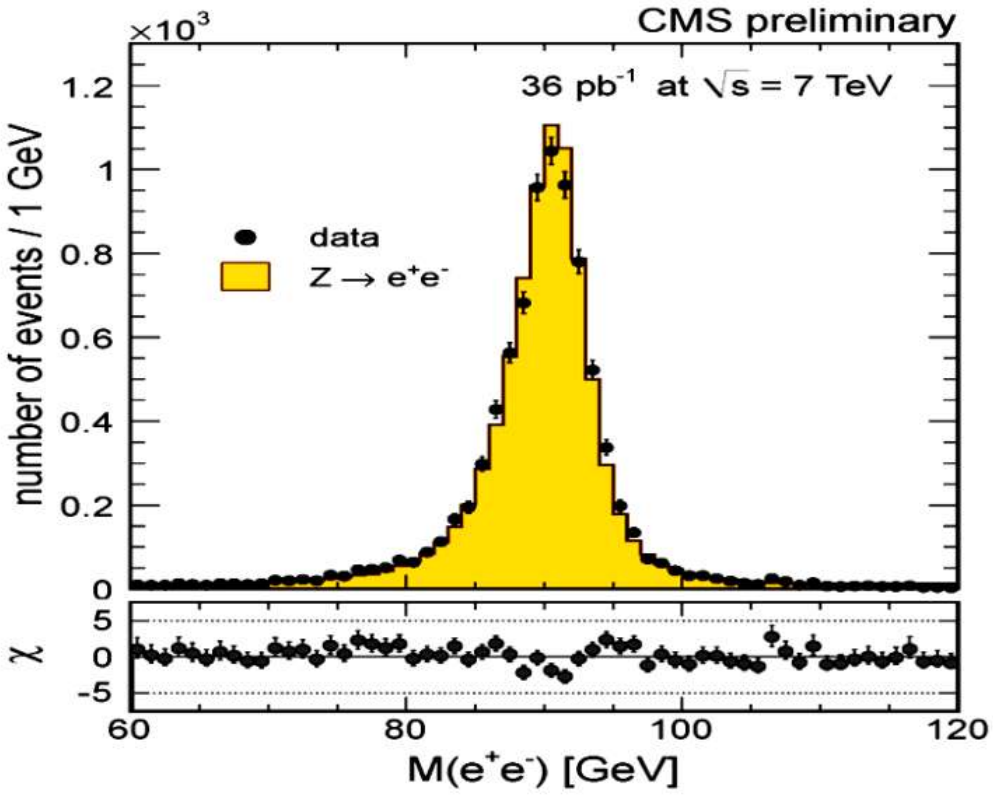
Extends to HT range not explored before

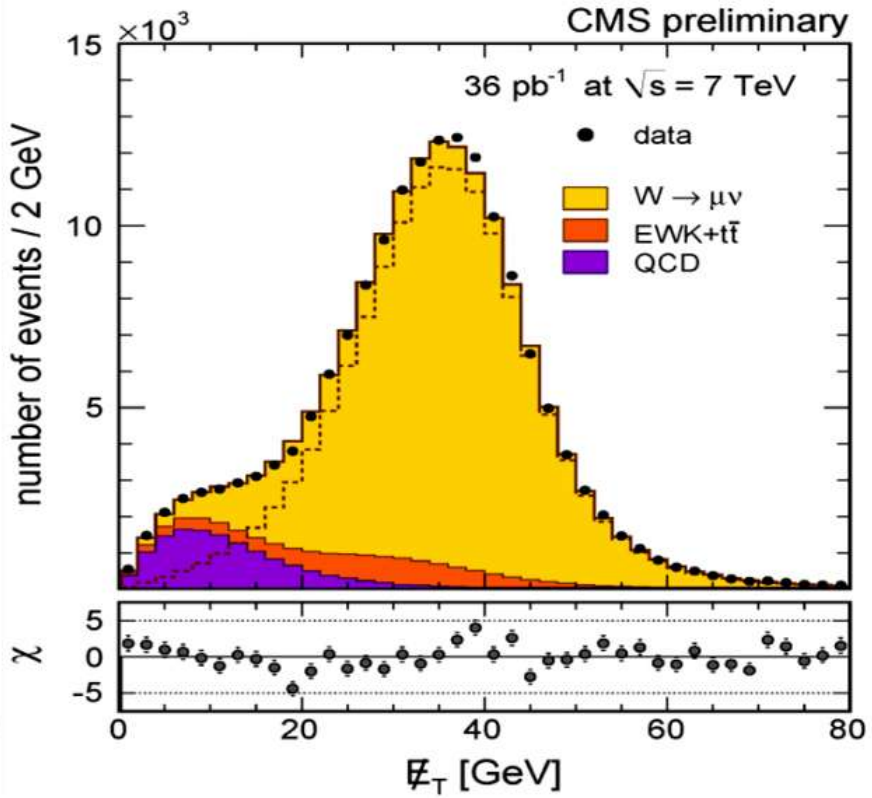
Agreement with NLO pert. QCD predictions





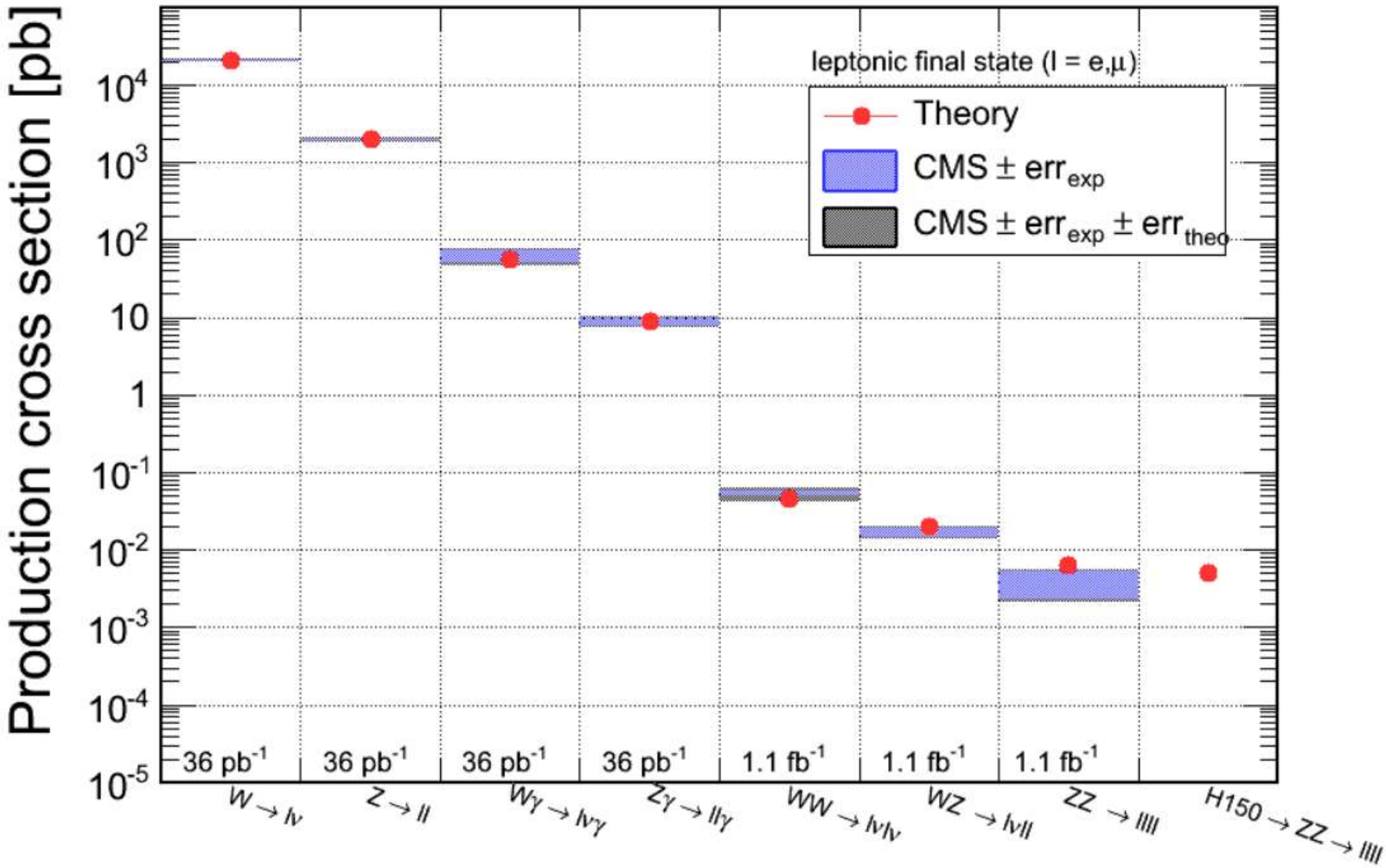
W and Z: the gauge bosons





- **Very good understanding of the detector.**
- **Energy scale calibration.**

EWK bosons and di-bosons



Di-bosons: WW, WZ, ZZ

With 2011 data updated measurement of the W^+W^- cross section and first measurements of the WZ, ZZ production cross sections at 7TeV.

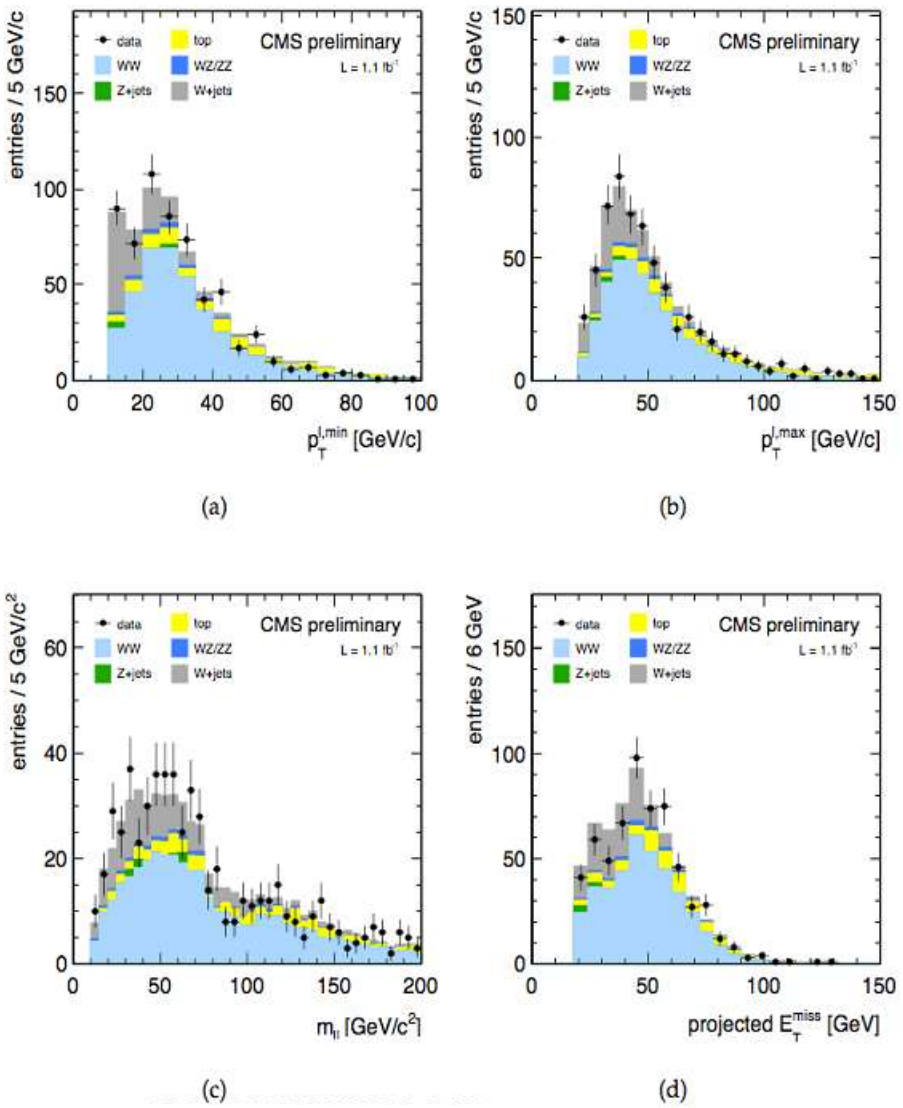
$\sigma(pp \rightarrow W^+W^- + X) = 55.3 \pm 3.3(stat.) \pm 6.9$ (syst.) $\pm$ 3.3 (lumi.) pb.

$\sigma(pp \rightarrow WZ + X) = 17.0 \pm 2.4(stat.) \pm 1.1$ (syst.) $\pm$ 1.0 (lumi.) pb.

$\sigma(pp \rightarrow ZZ + X) = 3.8 +1.5(stat.) \pm 0.2$ (syst.) $\pm$ 0.2 (lumi.) pb.

All measured values are consistent with the standard model predictions.

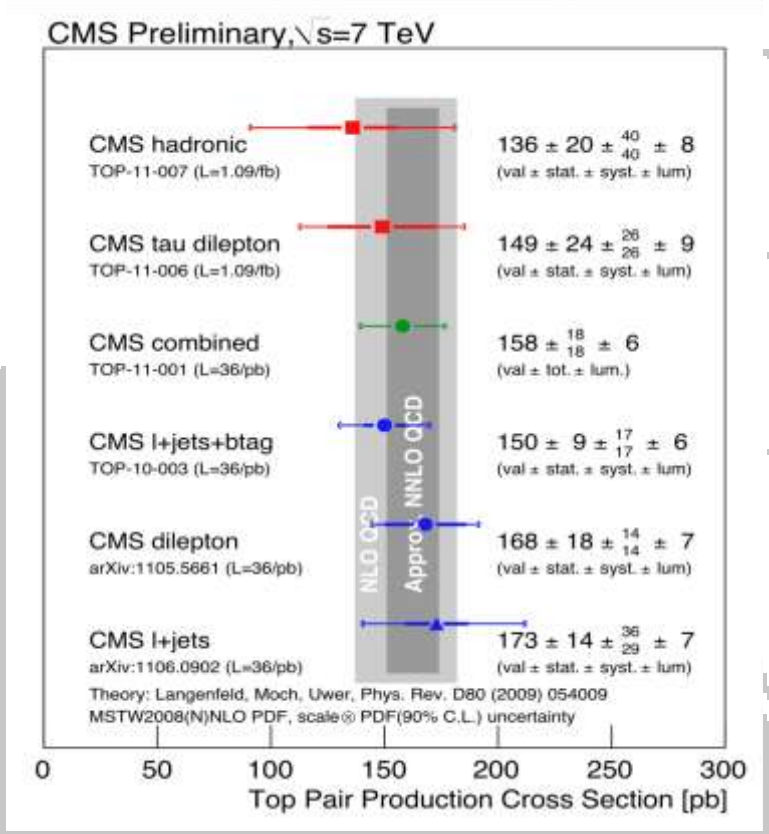
Data driven methods are used to understand the background.

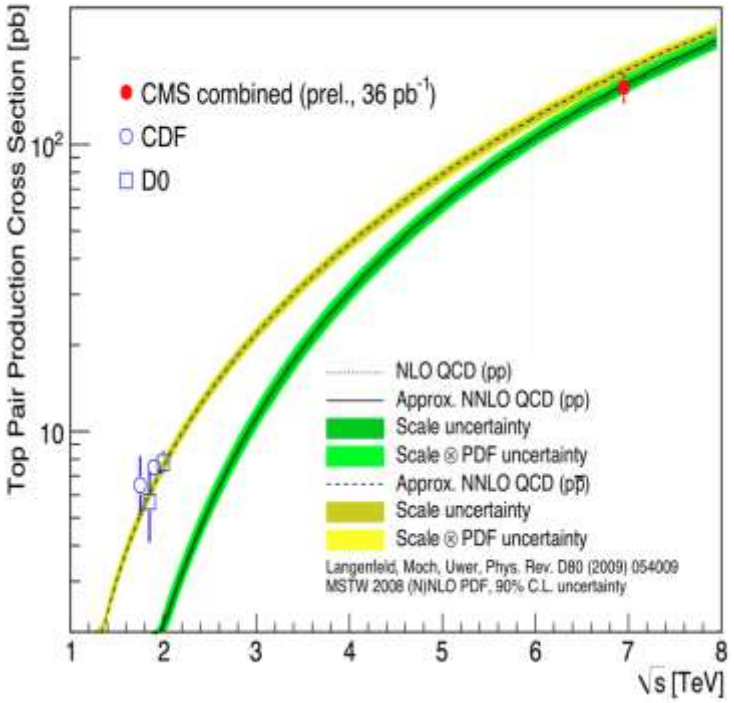


Top quark cross section combined result

Combined measurement of the top cross section (dileptons e, μ and τ, leptons+jets with and without b-tagging, fully hadronic decay)

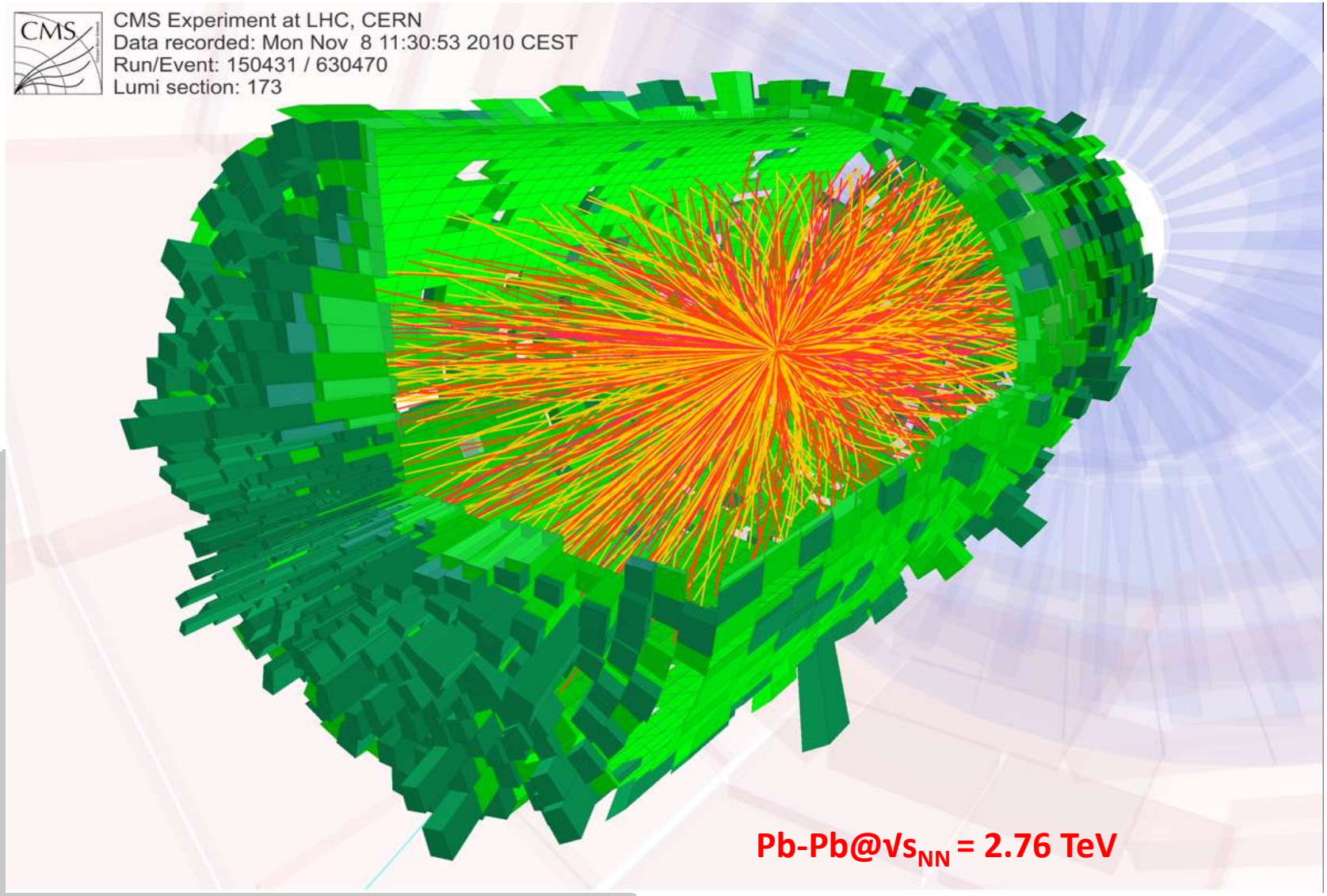
σ = 158±18(stat+syst)±6(lumi) pb





arXiv:1105.5661; arXiv:1106.0902;

November 2010: Pb-Pb collisions in LHC



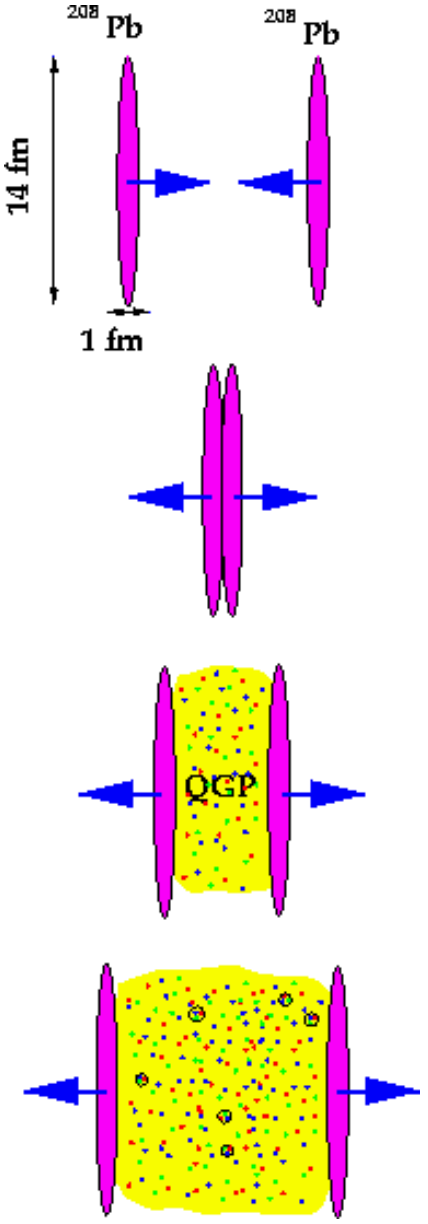
Basic Idea

Compress large amount of energy in a very small volume

→ produce a "fireball" of hot matter:

temperature O(10^{12} K)

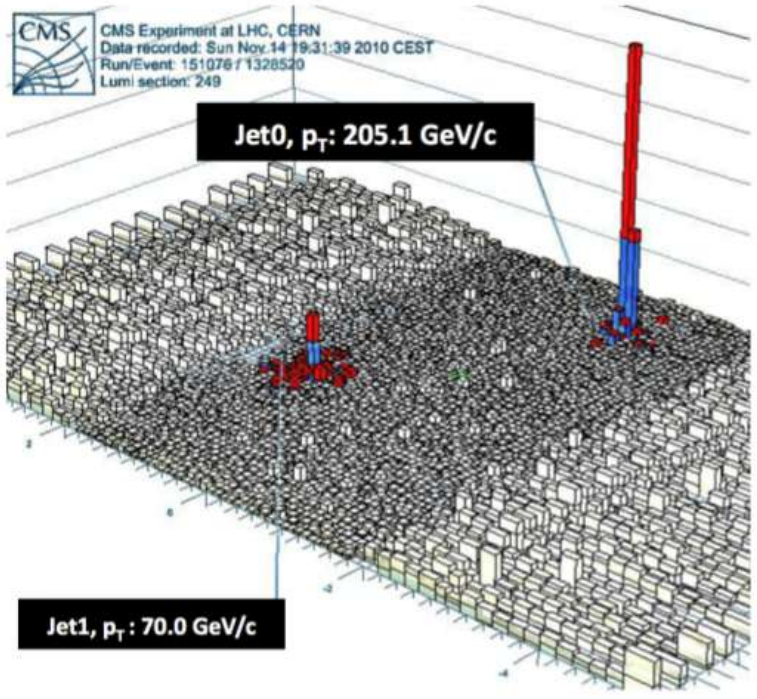
- ~ 10^5 x T at centre of Sun
- ~ T of universe @ ~ 10 μs after Big Bang

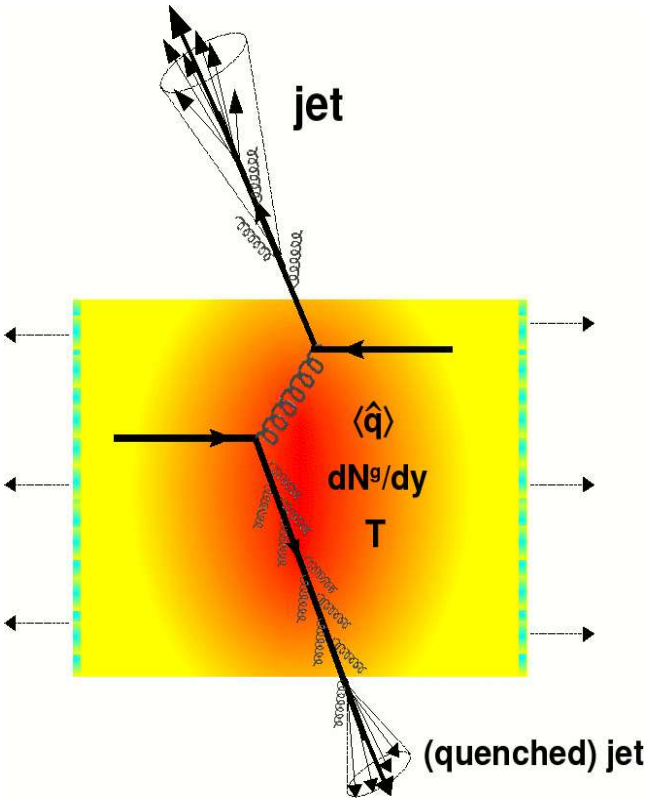


- how does matter behave under such extreme conditions?
  - →study the fireball properties
  - →QCD predicts state of deconfined quarks and gluons (Quark-Gluon Plasma)
  - →Look at the new state of matter in full detail

Jet-quenching

First direct evidence of strong jet quenching observed in LHC Heavy Ion collisions by ATLAS and CMS.





Indirect evidence of strong jet quenching measured at RHIC in single particle spectra and particle correlations.

Searching for new physics

SUSY Search Strategy

0-leptons	1-lepton	OSDL	SSDL	≥3 leptons	2-photons	γ+lepton
Jets + MET	Single lepton + Jets + MET	Opposite-sign di-lepton + jets + MET	Same-sign di-lepton + jets + MET	Multi-lepton	Di-photon + jet + MET	Photon + lepton + MET

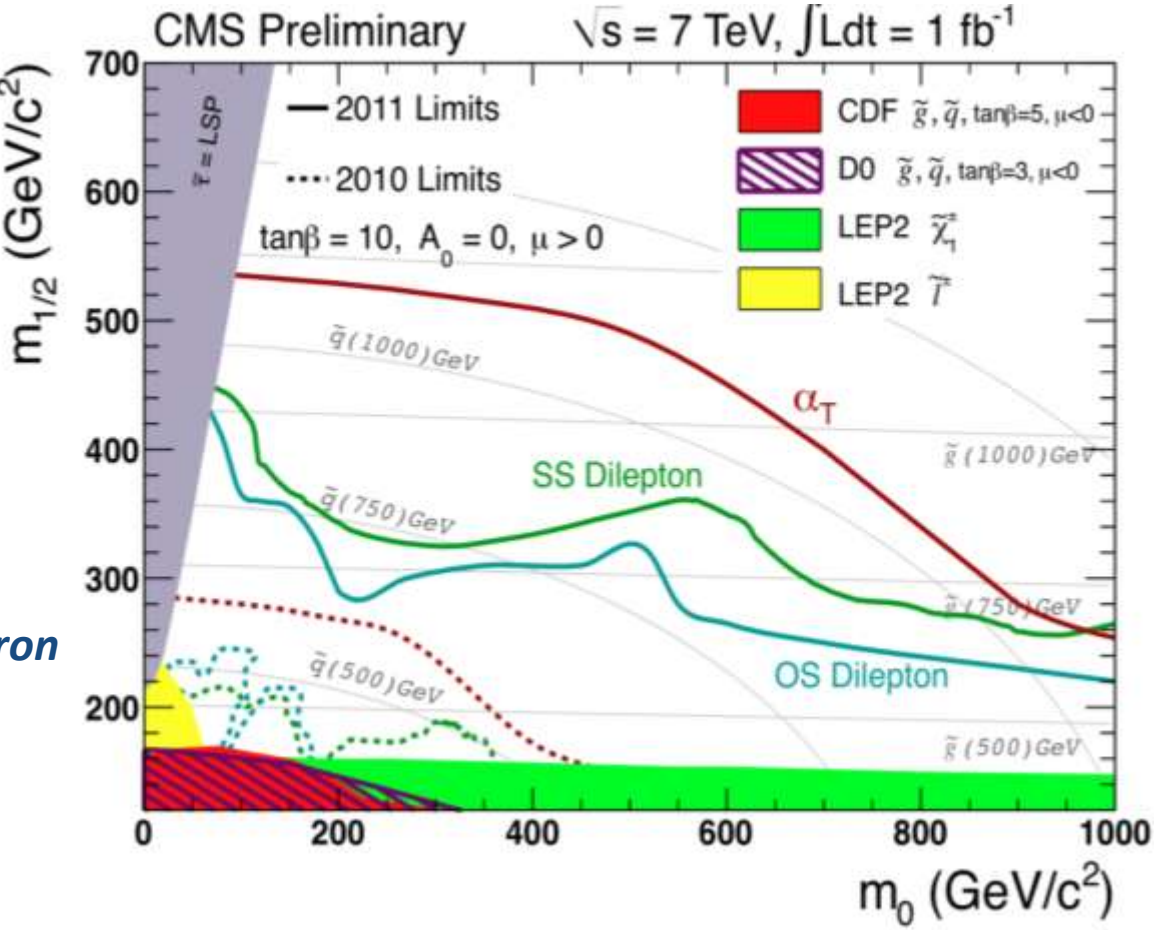
- **Basic analysis strategy:**

- Focus on topology using different kinematic observables
  - So that types of SM bkg and detector strong assets drive the searches
- Use well understood CMS 'objects'
  - Leptons, photons, jets, MET; Particle Flow to increase sensitivity everywhere
- Use data driven background whenever possible
- Full results at https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

Progress on SUSY

Results of the first three SUSY analyses completed on 2011 data (α_T, Same Sign and Opposite Sign dileptons).

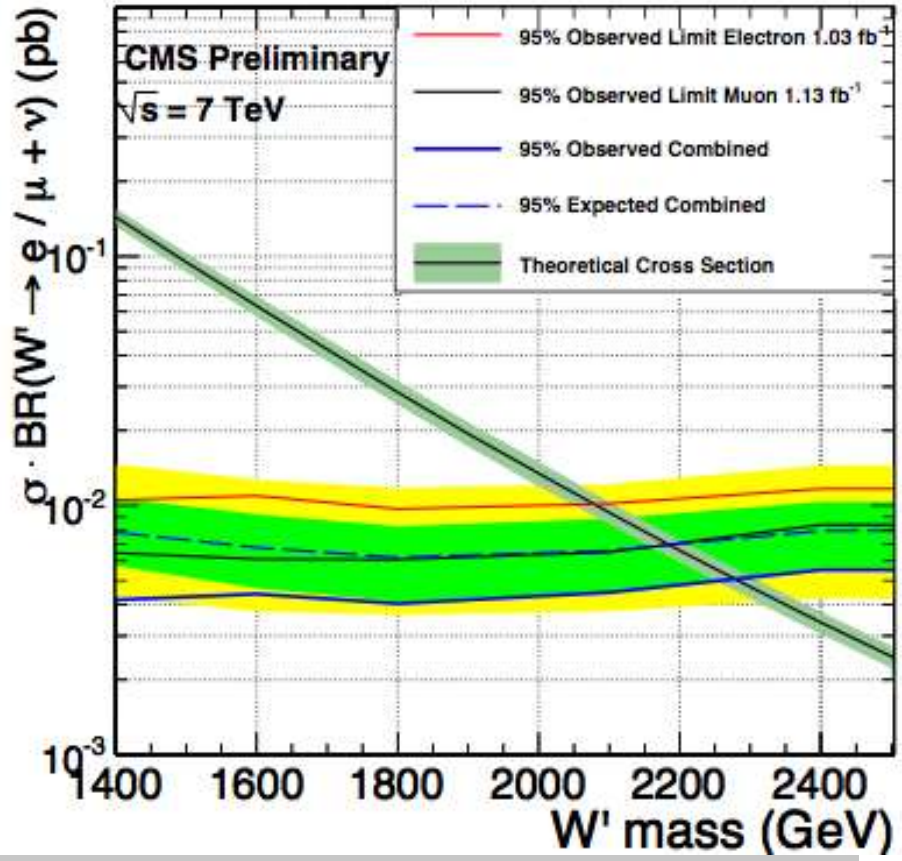
Much stringent constrains than ones obtained by LEP and Tevatron

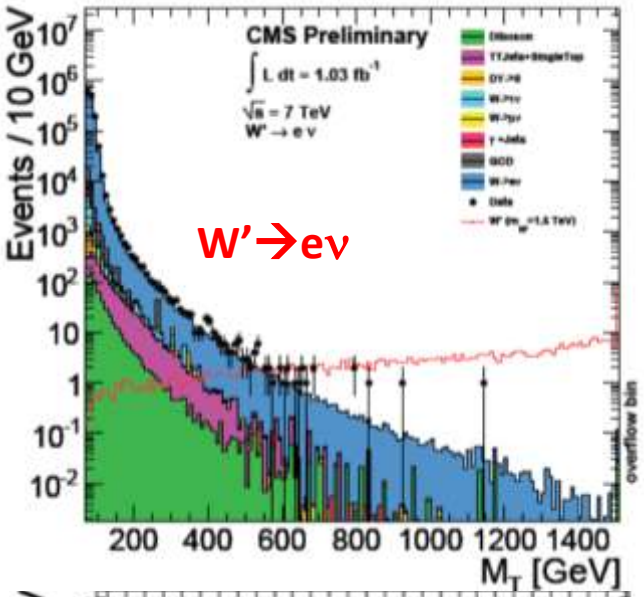


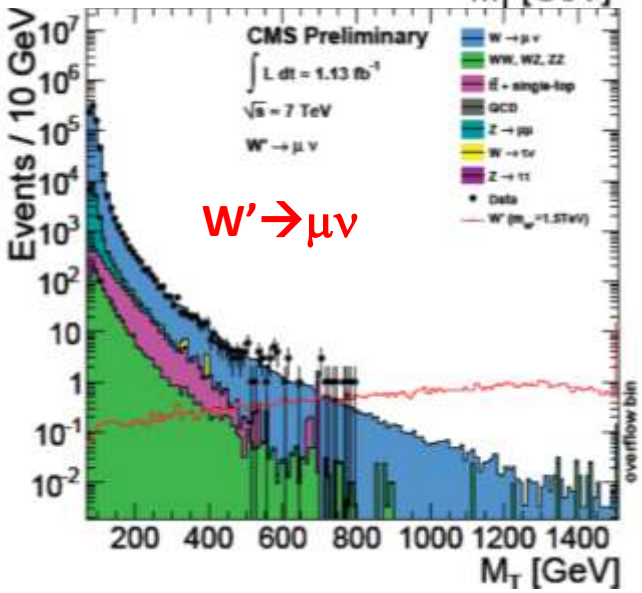
- **Within the constrained MSSM models we are crossing the border of excluding gluinos and squarks up to 1TeV and beyond.**
- **The air is getting thin for constrained SUSY.**
- **More conclusive results after summer.**

Looking for massive extra-bosons

Assuming standard-model-like couplings and decay branching fractions we exclude a SSM W' with mass <2.27 TeV (95%CL)





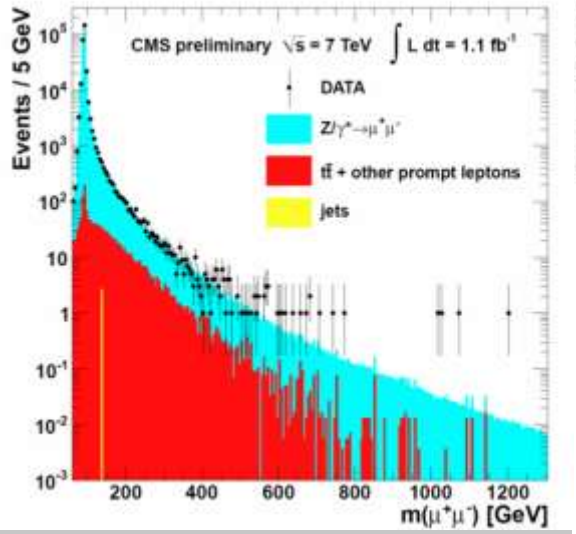


CMS-PAS-EXO-11-024.

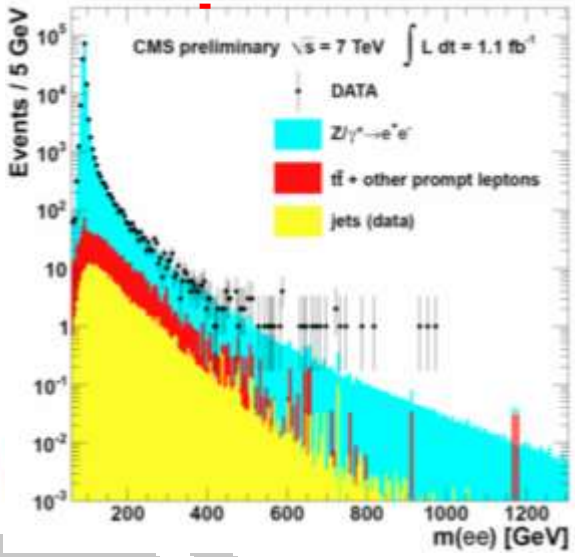
High p_T di-leptons

We study in detail the high mass tail of the Z. Since spectra are consistent with known SM processes we extract 95% CL limits.

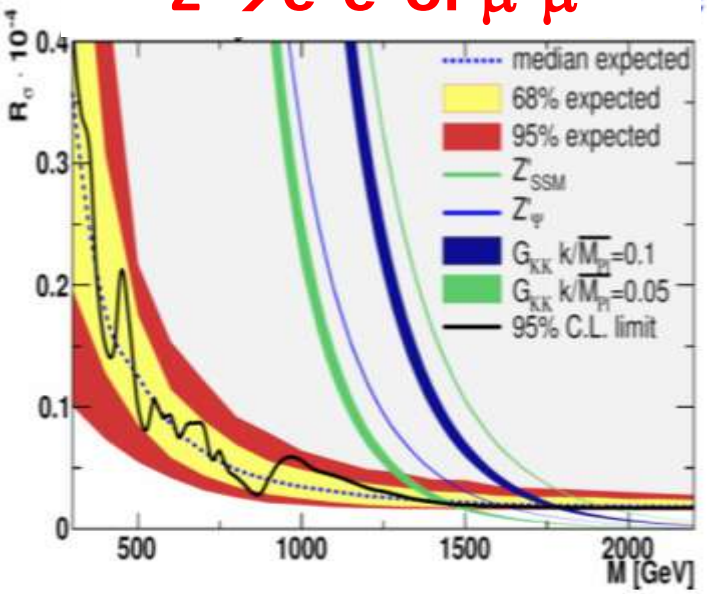
Z'→$\mu^+\mu^-$



Z'→e^+e^-

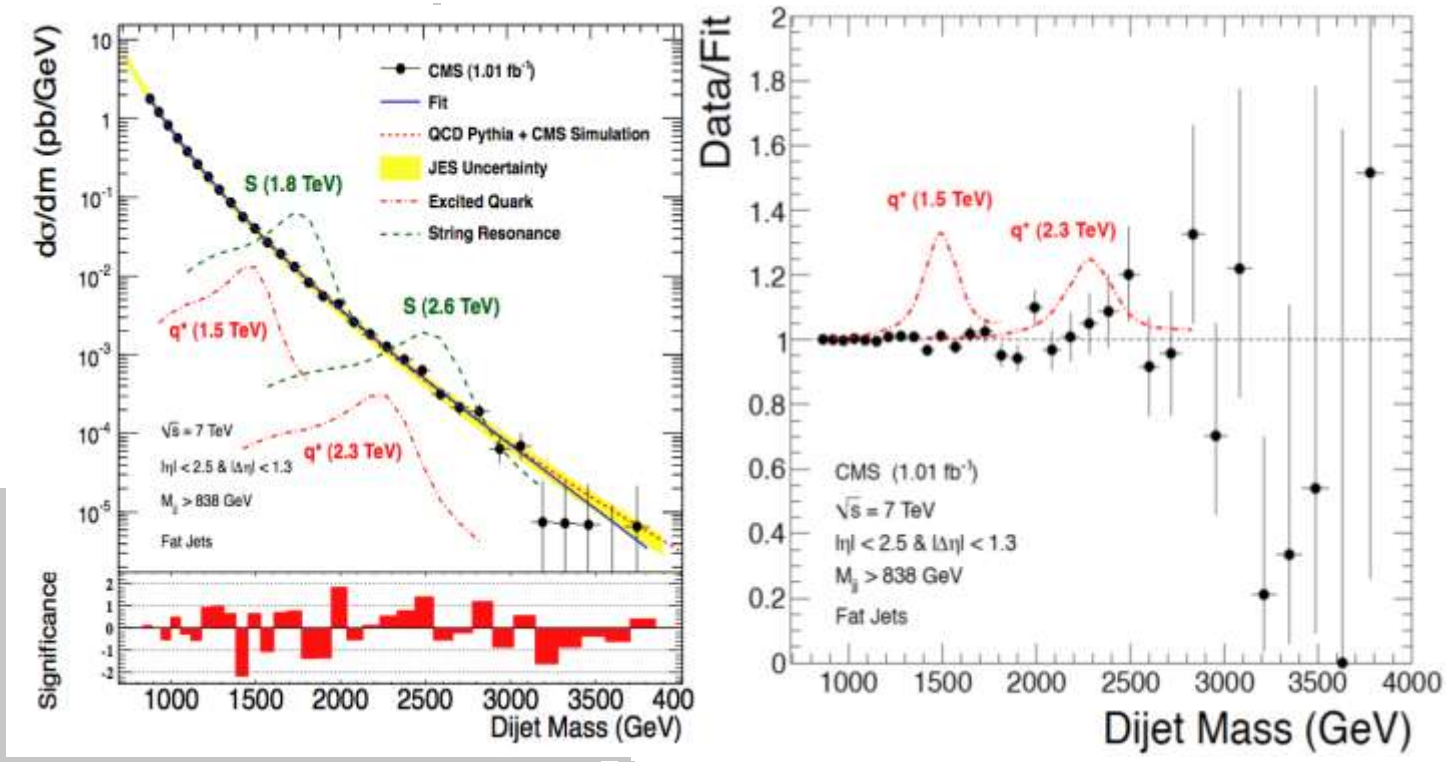


Z'→e^+e^- or $\mu^+\mu^-$



- ***1940 GeV*** for the Sequential Standard Model Z'_{SSM},
- ***1620 GeV*** for Super-String inspired models, Z'_ψ.
- ***1450-1780 GeV*** for RS Kaluza-Klein Gravitons for (k/M_{Pl}) 0.05-0.1.

Search for di-jet resonances



The data can be used to exclude at 95%CL new particles predicted in several models:

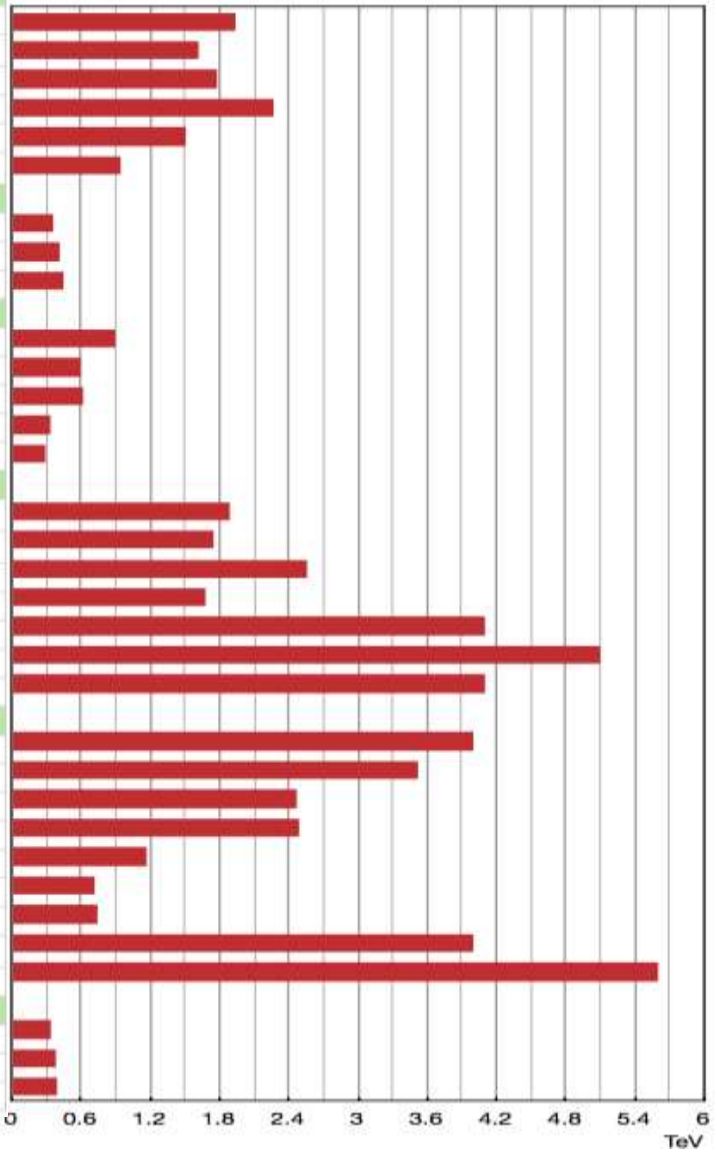
- excited quarks with M(q∗)<2.49TeV,
- string resonances with mass M(S)<4.00TeV et al.

arXiv: submit/0288036 [hep-ex] CERN-PH-EP/2011-119 2011/07/24 *Submitted to Physics Letters B*

24 July 2011: first paper on 2011 data

Summary of the searches in EXOTICA

	Limits in TeV	
Heavy Bosons		
Z'_{SSM} ll	1.94	2011
Z'_{ψ} ll	1.62	2011
G_{KK} ll k/M = 0.1	1.78	2011
W' lν	2.27	2011
W' dijet	1.51	2011
G_{KK} γγ k/M = 0.1 (2010)	0.945	2010
4th Generation		
$M_{b'}$, b' ⇒ tW (2010)	0.361	2010
$M_{t'}$, t' ⇒ tZ (100%)	0.417	2011
$M_{t'}$, t' ⇒ bW (100%), l+jets	0.45	2011
Heavy Stable Particles		
M_{gluino}, HSCP	0.899	2011
M_{gluino}, Stopped Gluino	0.601	2011
M_{stop}, HSCP	0.620	2011
M_{stop}, Stopped Gluino	0.337	2011
M_{stau}, HSCP	0.293	2011
Large Extra Dimensions		
M_S, γγ, GRW (2010)	1.89	2010
M_S, μμ, GRW (2010)	1.75	2010
M_D, monojet, n_{ED} = 2 (2010)	2.56	2010
M_D, monojet, n_{ED} = 6 (2010)	1.68	2010
M_{BH}, rotating, M_D=3.5 TeV, n_{ED} = 2	4.1	2011
M_{BH}, non-rot, M_D=1.5 TeV, n_{ED} = 6	5.1	2011
String Ball M, M_D=2.1, M_s=1.7, g_s=0.4	4.1	2011
Compositeness and Contact Interactions		
String Resonances	4.0	2011
E_6 diquarks	3.52	2011
Axigluon/Coloron	2.47	2011
q* , dijet	2.49	2011
q* , boosted Z	1.17	2010
e*, Λ = 2 TeV	0.720	2010
μ*, Λ = 2 TeV	0.745	2010
C.I. Λ , dijet mass (3 pb^{-1})	4.0	2010
C.I. Λ , X analysis	5.6	2010
LeptoQuark		
LQ1, β=0.5 (2010)	0.340	2010
LQ1, β=1.0 (2010)	0.384	2010
LQ2, β=1.0 (2010)	0.394	2010



Elegant summary of searches

	Lower Limit (95% C.L.)
SUSY ($m_{\tilde{q}} = m_{\tilde{g}}$)	1 TeV
Gauge bosons (SSM)	2 TeV
Excited quark	3 TeV

Summary

- **LHC is working excellently**
- **So far in 2011, CMS collected about 3 fb^{-1} at 7 TeV of pp data, already 3x more than planned**
- **QCD and ElectroWeak data are in a good agrement with the Standard Model**
- **No sign yet of physics Beyond Standard Model**
- **Mass limits for exotic states and SUSY particles were extended considerably**