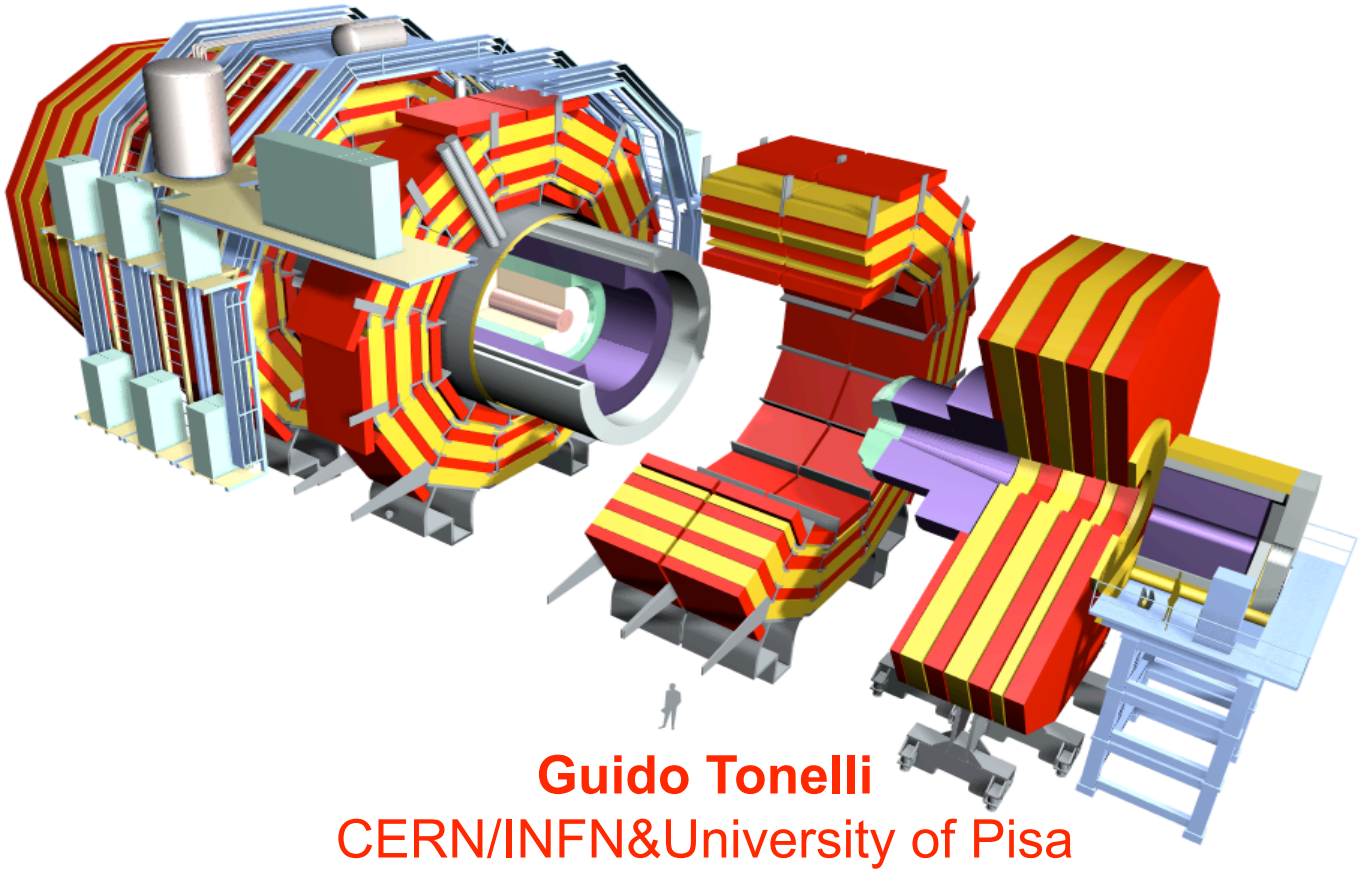
Physics Results from CMS

Les Rencontres de Physique de la Vallée d'Aoste



Guido Tonelli
CERN/INFN&University of Pisa
On behalf of the CMS COLLABORATION

CMS papers on Collision Data

1. Search for Heavy Bottom-like Fourth Generation Quark in tW Final State at CMS in pp Collisions at √s=7TeV.
2. Strange Particle Production in pp collisions at √s= 0.9 and 7 TeV
3. Measurement of BB Angular Correlations based on Secondary Vertex Reconstruction at √s=7TeV in CMS
4. Measurement of Dijet Angular Distributions and Search for Quark Compositeness in pp collisions at √s=7TeV
5. Observation and studies of jet quenching in PbPb collisions $\sqrt{S_{NN}}$= 2.76 TeV
6. First Measurement of Hadronic Event Shapes in pp collisions at √s=7TeV
7. Dijet Azimuthal Decorrelations in pp Collisions at √s=7TeV
8. Measurement of Bose–Einstein Correlations in pp Collisions
9. Inclusive b-hadron production cross section with muons in pp collisions
10. Search for Heavy Stable Charged Particles in pp collisions
11. Search for Supersymmetry in pp Collisions at 7 TeV in Events with Jets and Missing Transverse Energy
12. Measurement of the B+ Production Cross Section in pp Collisions at √s = 7TeV
13. Search for a heavy gauge boson W' in final states with electrons and large missing ET in pp collisions
14. Upsilon production cross section in pp collisions at √s = 7TeV
15. Search for Pair Production of Second-Generation Scalar Leptoquarks in pp Collisions at √s= *7TeV*
16. Search for Pair Production of First-Generation Scalar Leptoquarks in pp Collisions at √s= *7TeV*
17. Search for Microscopic Black Hole Signatures at the Large Hadron
18. Measurements of Inclusive W and Z Cross Sections in pp Collisions at √s *= 7TeV*
19. Measurement of the Isolated Prompt Photon Production Cross Section in pp Collisions at √s= 7TeV
20. Search for Stopped Gluinos in pp collisions at √s*= 7TeV*
21. Charged particle multiplicities in pp interactions at √s= 0.9, 2.36, and 7 TeV
22. Prompt and non-prompt J/ production in pp collisions at √s= 7TeV
23. First Measurement of the Cross Section for Top-Quark Pair Production in Proton-Proton Collisions
24. Search for Quark Compositeness with the Dijet Centrality Ratio in pp Collisions at √s*= 7 TeV*
25. Search for Dijet Resonances in 7 TeV pp Collisions at √s=7TeV
26. Observation of Long-Range, Near-Side Angular Correlations in Proton-Proton Collisions at the LHC.
27. CMS Tracking Performance Results from Early LHC Operation.
28. First Measurement of the Underlying Event Activity at the LHC with √s *= 0.9 TeV*
29. First Measurement of Bose-Einstein Correlations in pp collisions at √s=0.9 and 2.36 TeV at the LHC
30. Transverse momentum and pseudorapidity distributions of charged hadrons at √s=0.9 and 2.36 TeV

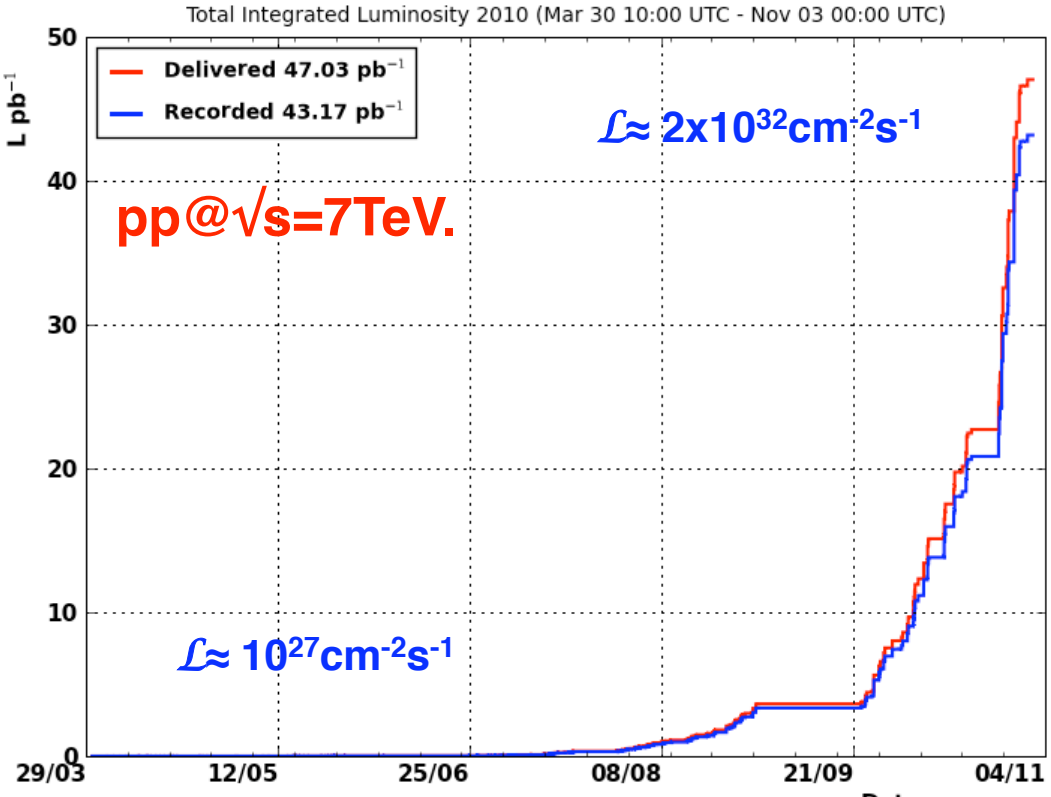
+ 10 in CWR + many other analyses in the pipeline of the approval process for the Winter Conferences.

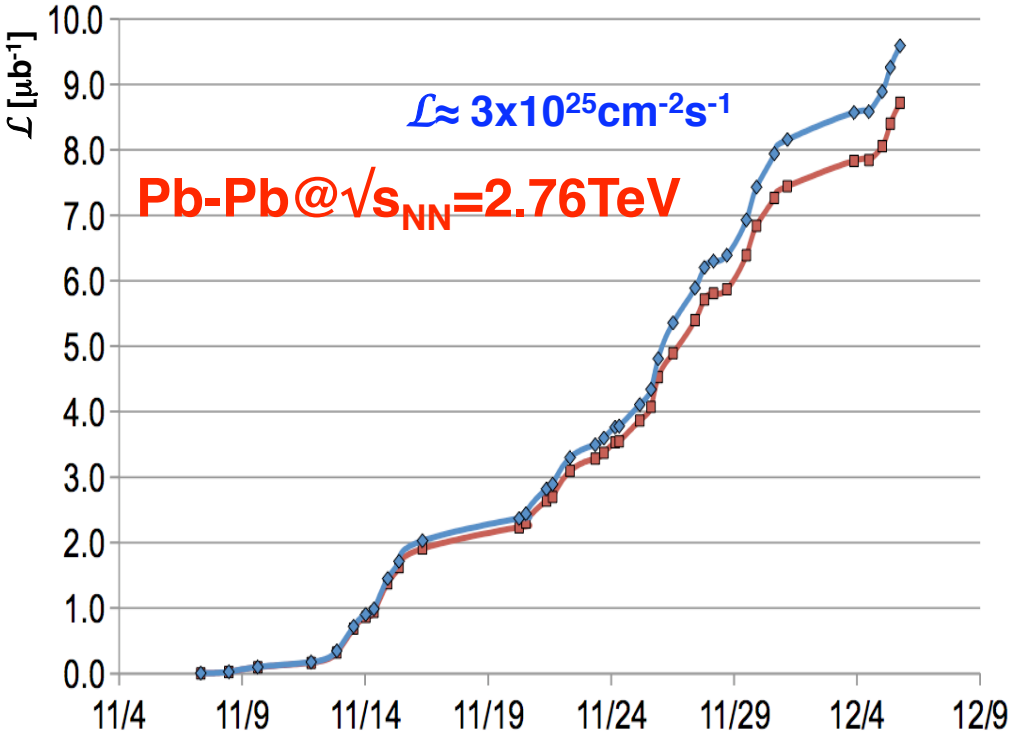
Outline of the talk

- First results from HI running
- Standard Model Measurements at 7 TeV
- Searches for New Physics
- Prospects for Higgs Search in 2011-12
- Conclusion

LHC/CMS operations: p-p and Pb-Pb collisions

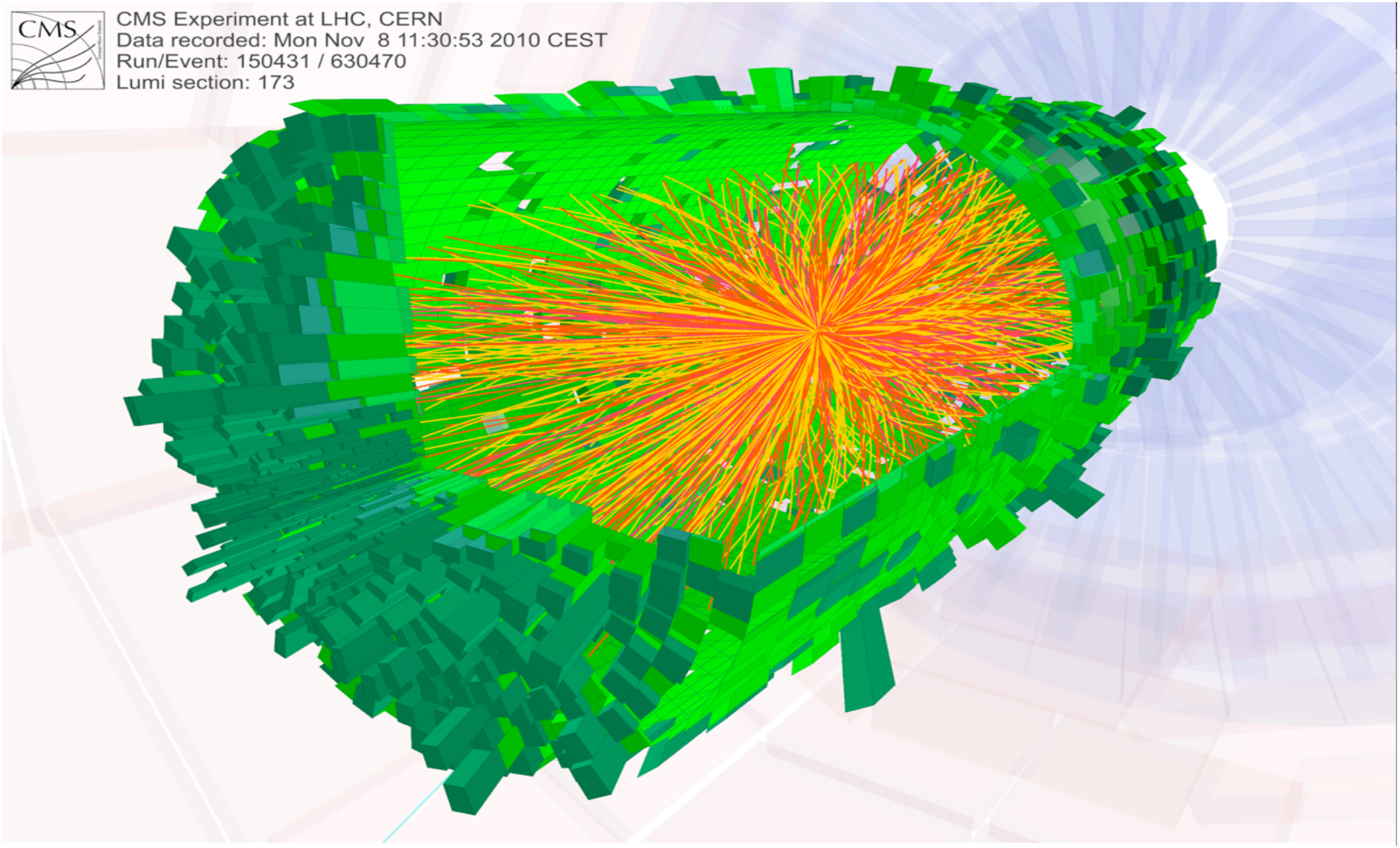
pp: **~47pb^{-1}** delivered by LHC and **~43pb^{-1}** collected by CMS.
Pb-Pb: ~9.5 μb^{-1} delivered and **~8.7 μb^{-1}** recorded.
Overall data taking efficiency **~92%.**



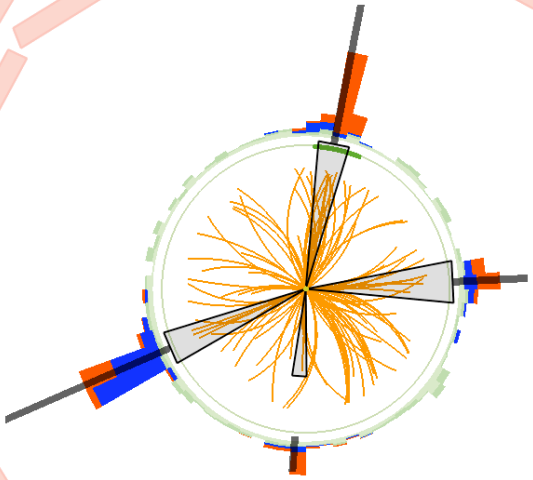


Average fraction of operational channels per CMS sub-system **>99%.** Quality of the data for physics (any analysis)**~85%** of recorded data.

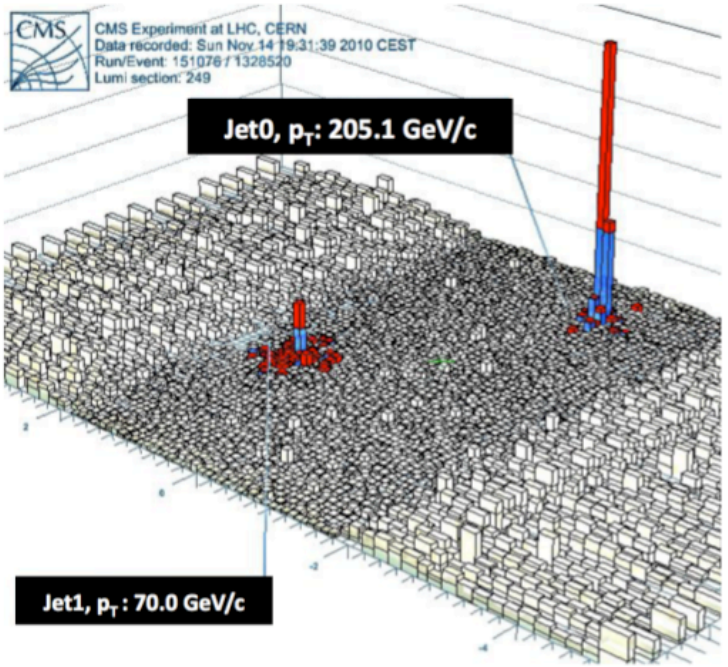
Pb-Pb collisions in LHC

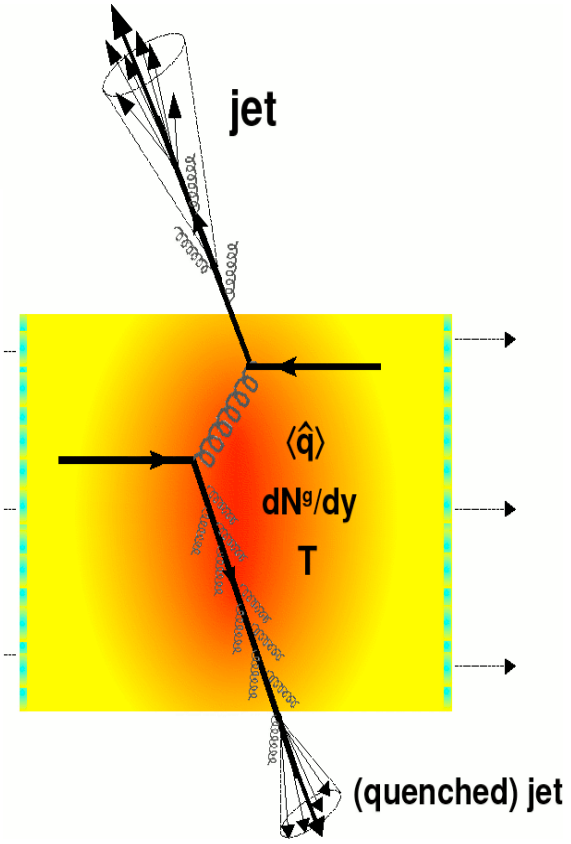


Jet-quenching



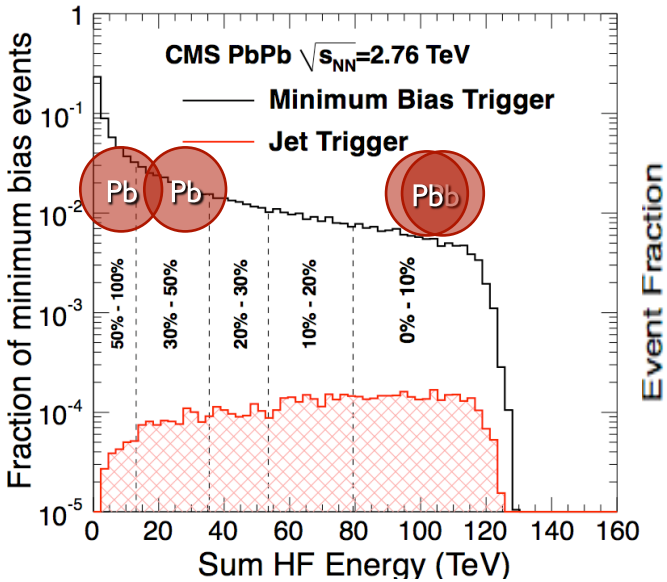
Indirect evidence of strong jet quenching measured at RHIC in single particle spectra and particle correlations.

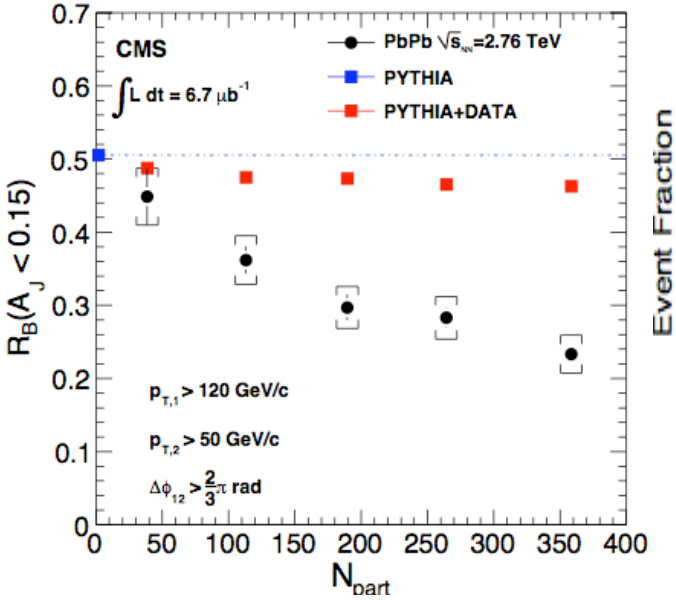


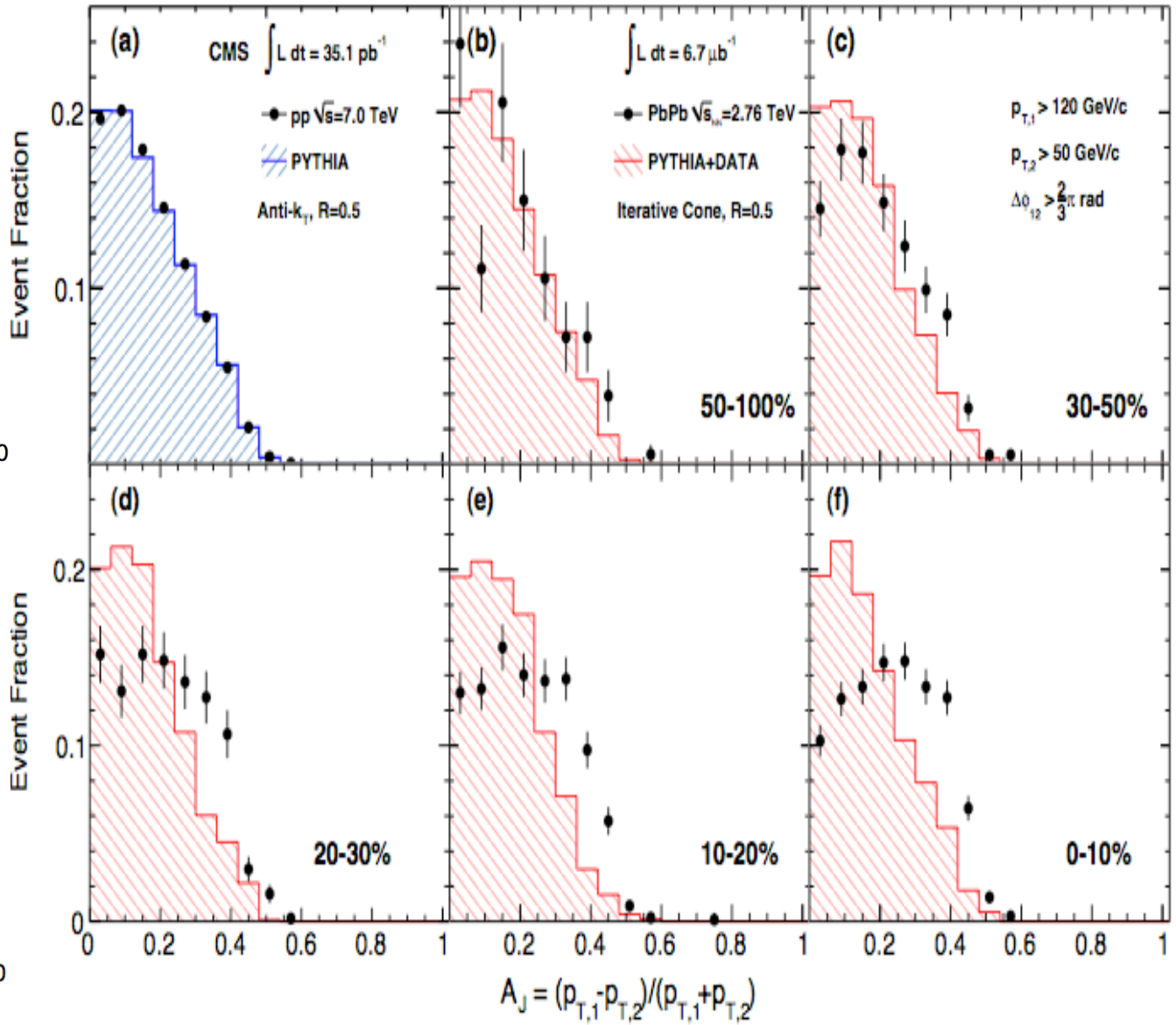


First direct evidence of strong jet quenching observed in LHC HI collisions (by CMS and ATLAS).

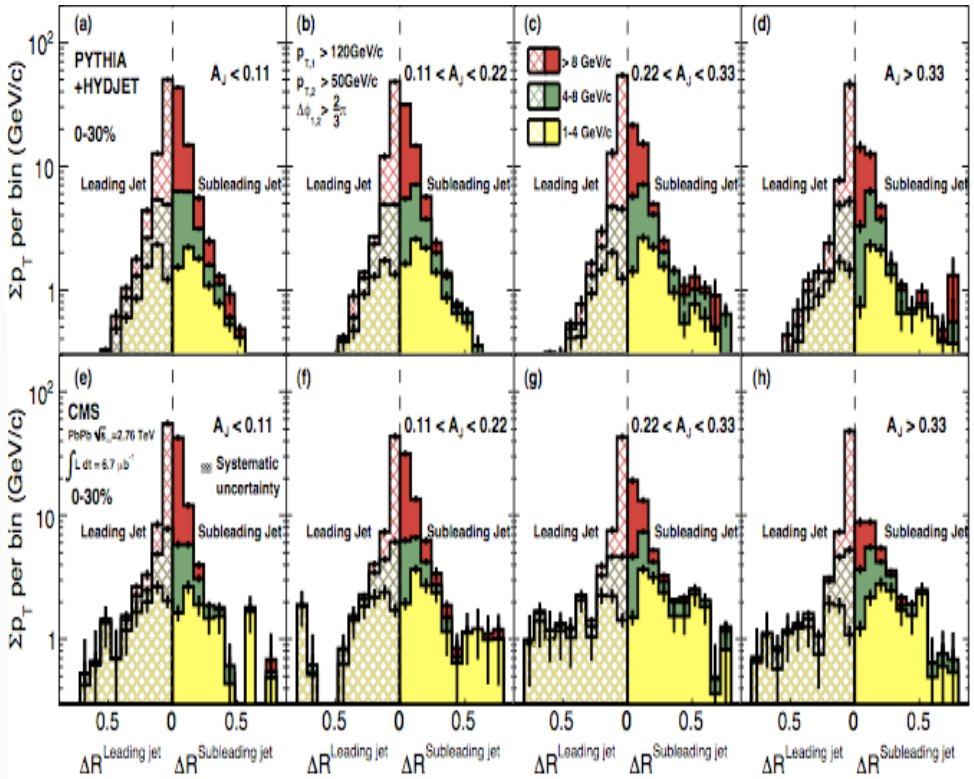
First direct observation of Jet-quenching

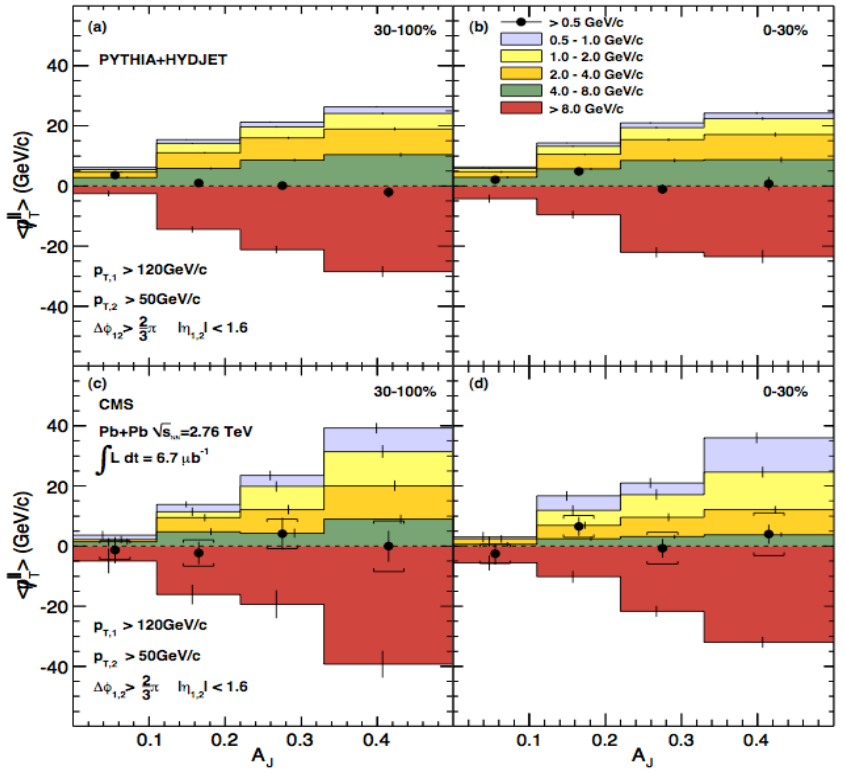






First detailed understanding of jet quenching



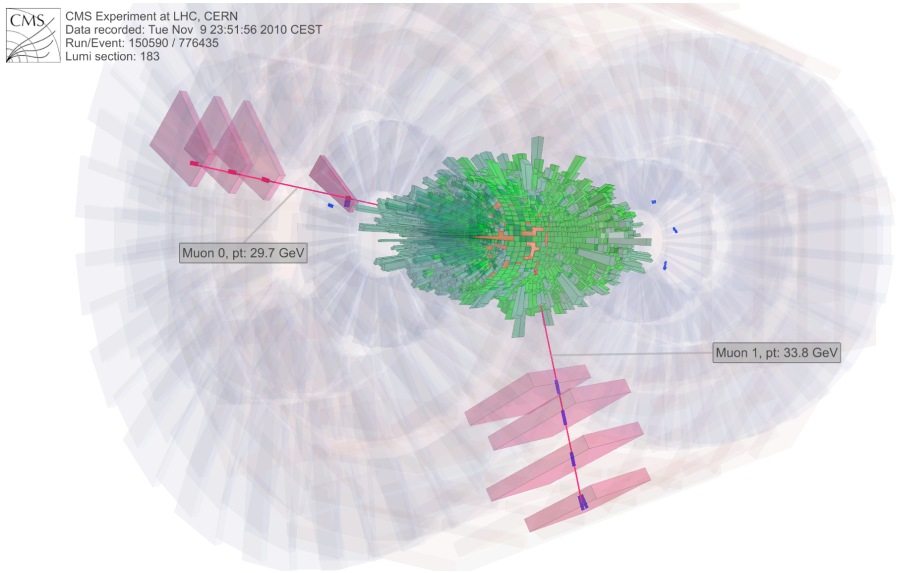


The phenomenon of jet quenching in Heavy-Ion collisions is now described in detail and fully understood.

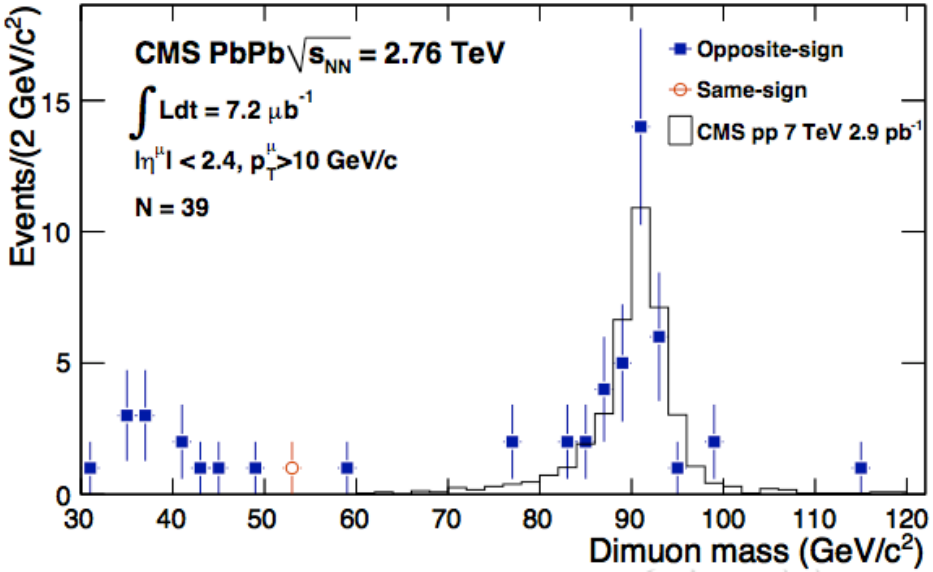
The di-jet momentum balance is fully recovered if we consider the low p_T tracks distributed over a wider angular range wrt the jet axis.

arXiv:1102.1957 ; CMS-HIN-10-004 ; CERN-PH-EP-2011-001. Submitted to Physical Review C

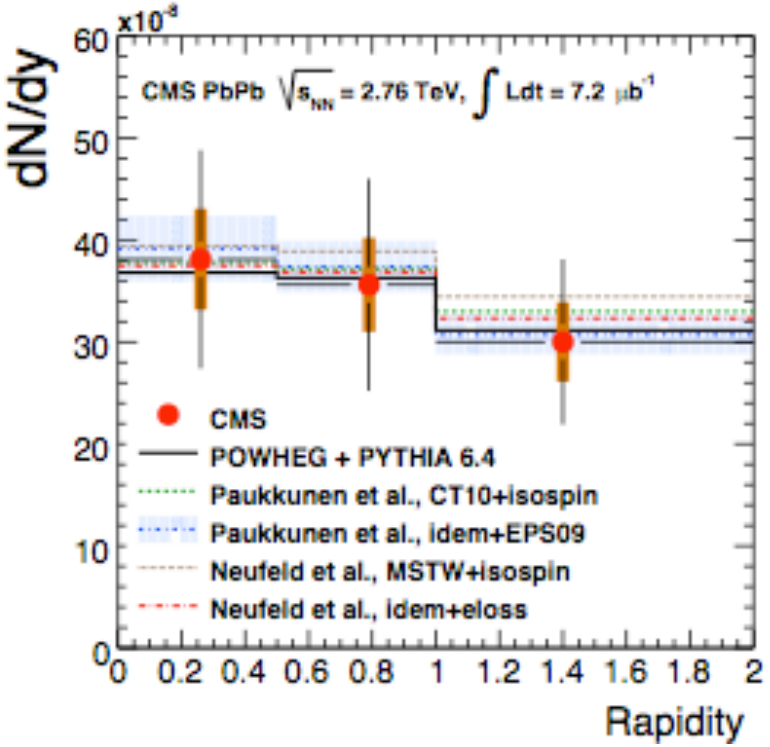
First observation of Z produced in HI collisions



The measurement of Z bosons in heavy-ion collisions at LHC could be used as a standard reference of the initial state when studying the Quark-GluonPlasma at the TeV scale.



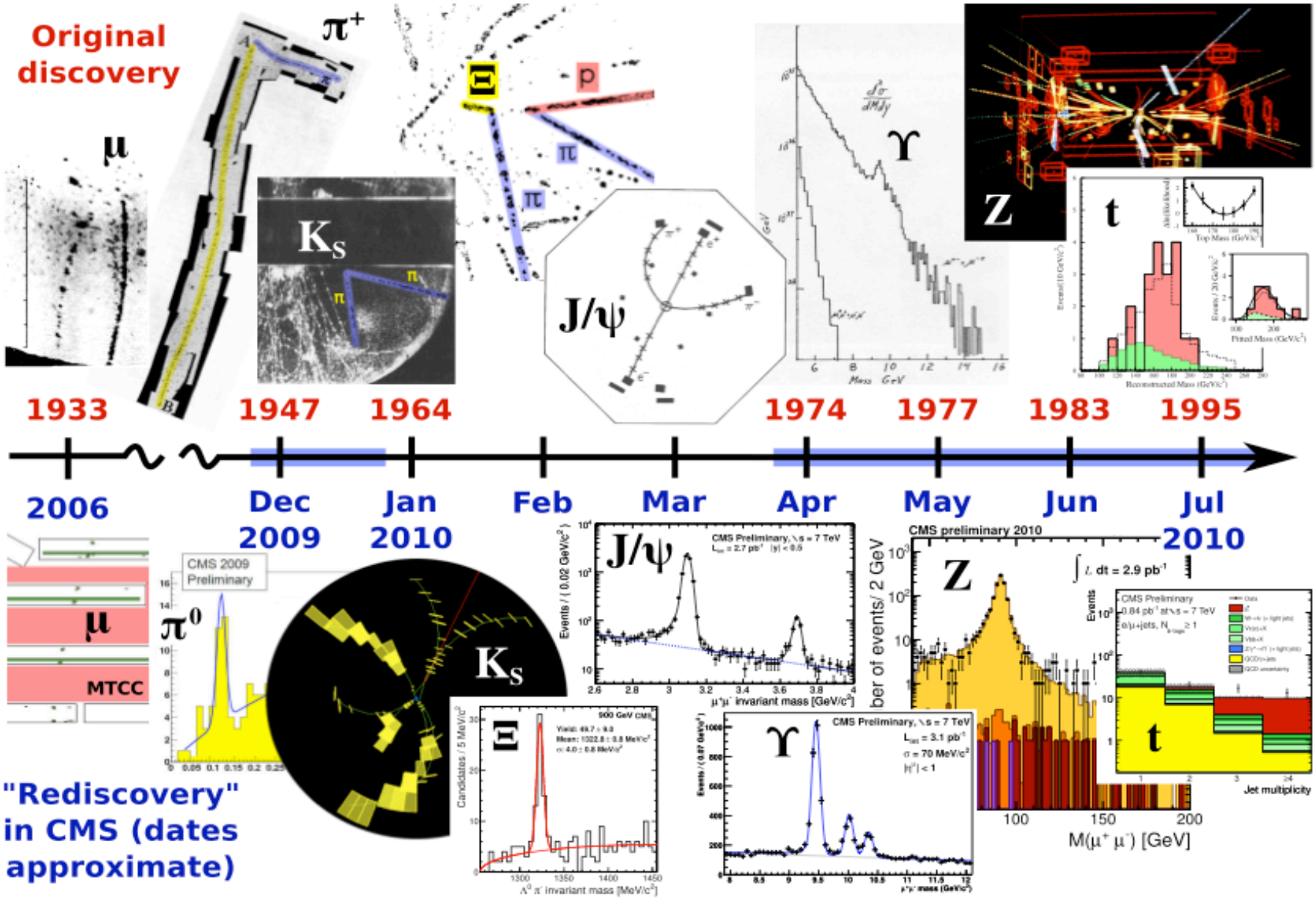
CMS PAPER HIN-10-003



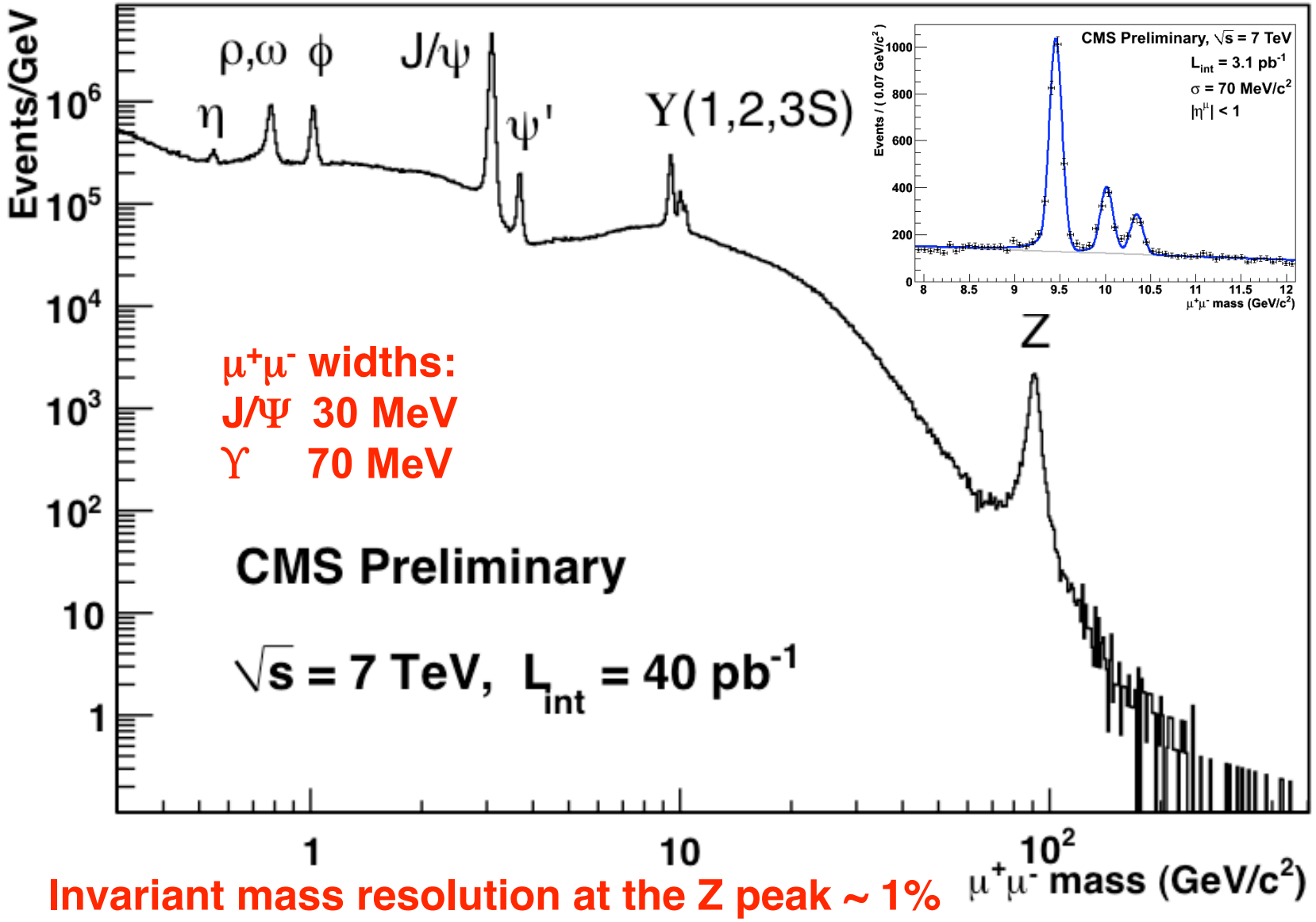
Outline of the talk

- CMS 2010 data taking
- First results from HI running
- **Standard Model Measurements at 7 TeV**
- Searches for New Physics
- Prospects for Higgs Search in 2011-12
- Conclusion

Re-discovering the Standard Model at 7TeV

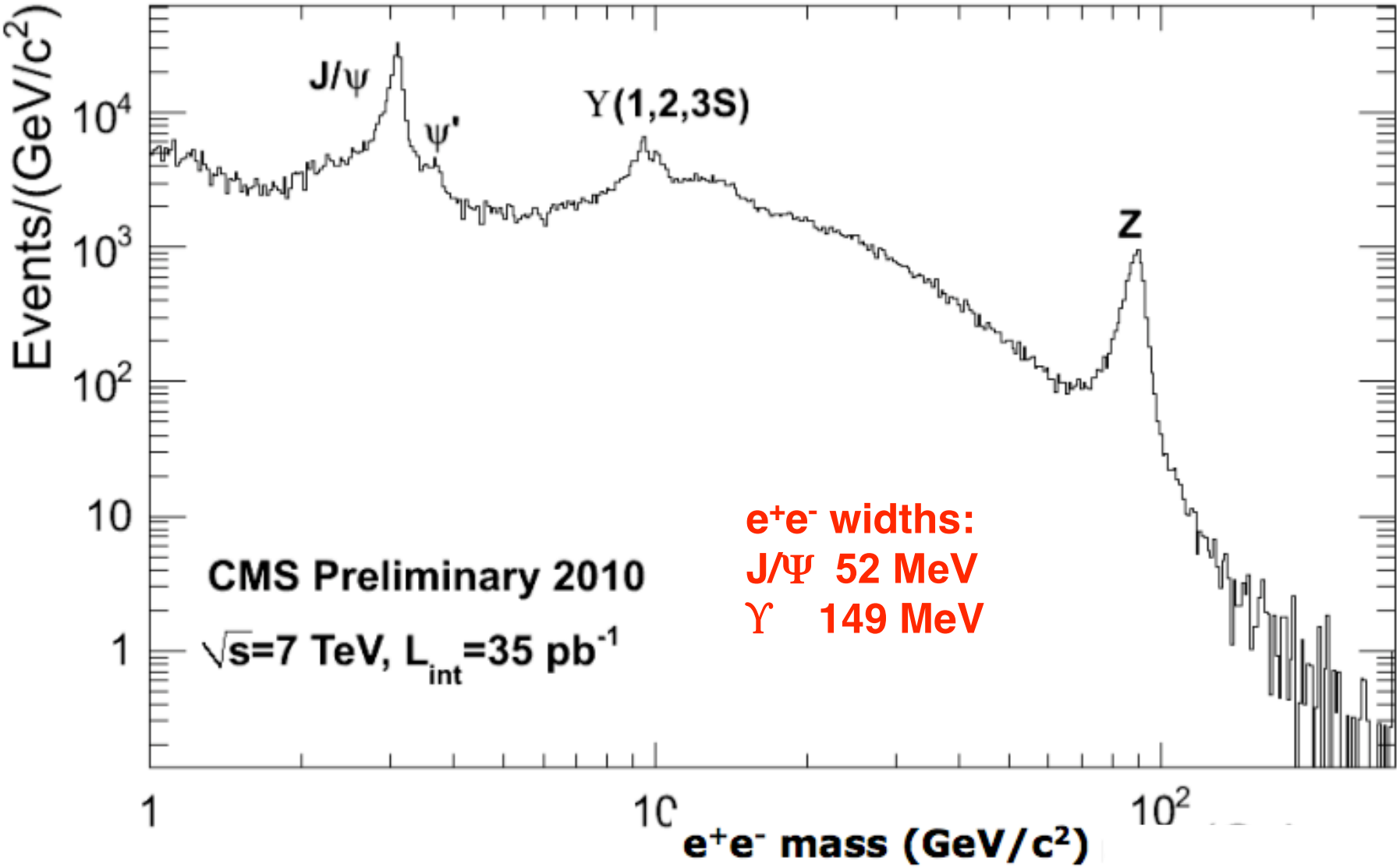


Here it comes the Compact Muon Solenoid



Invariant mass resolution at the Z peak ~ 1%

also excellent as Compact Electron Solenoid

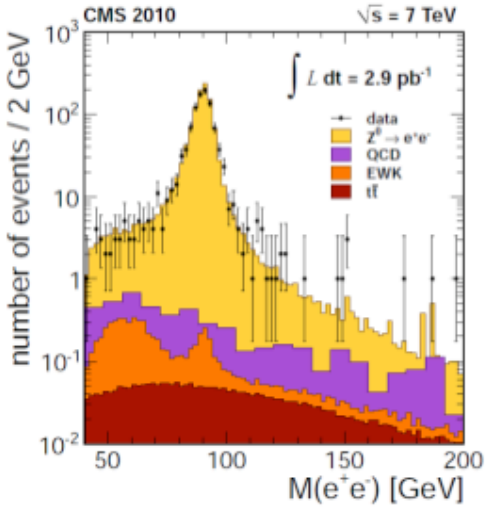


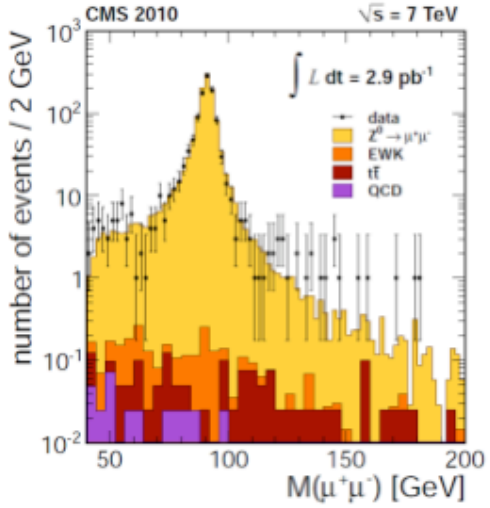
Re-discovering the Standard Model at 7TeV

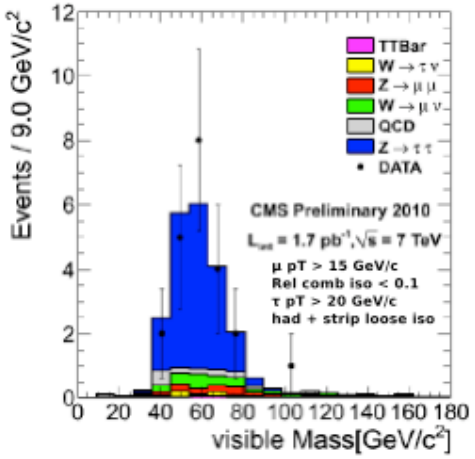
2.9pb^{-1}

electron(s) **muon(s)** **tau(s)**

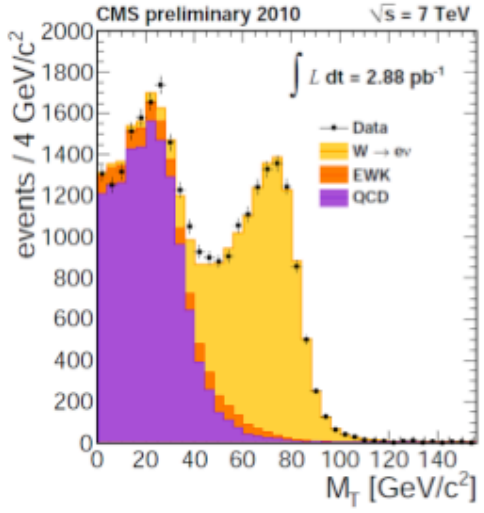
Z boson

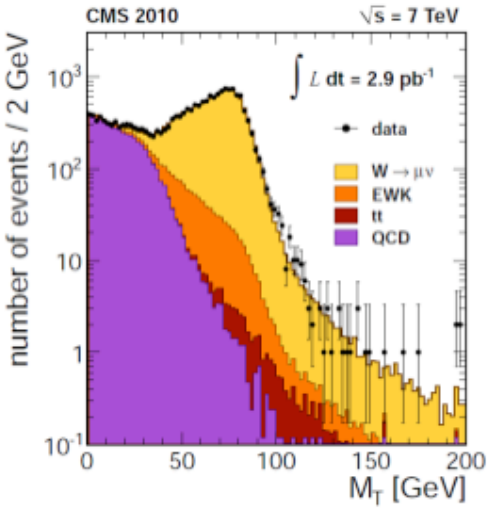


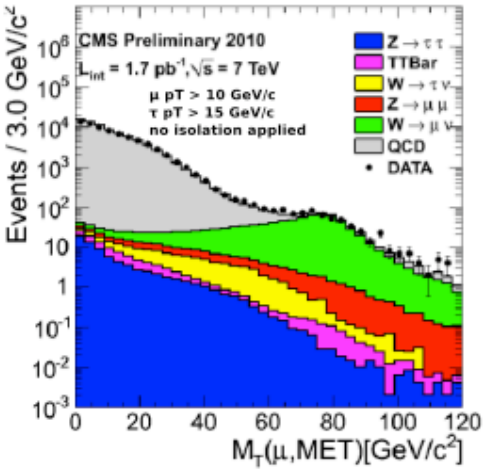




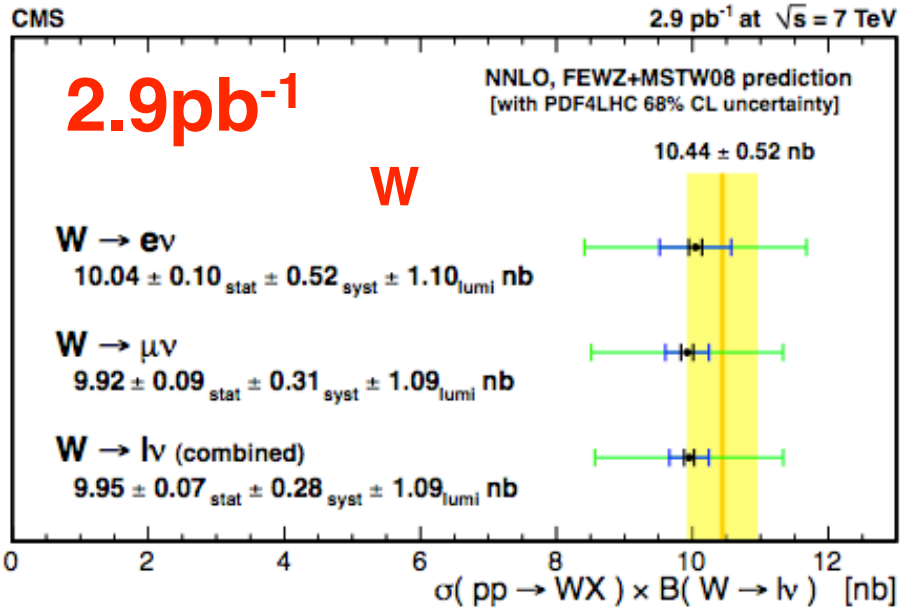
W boson

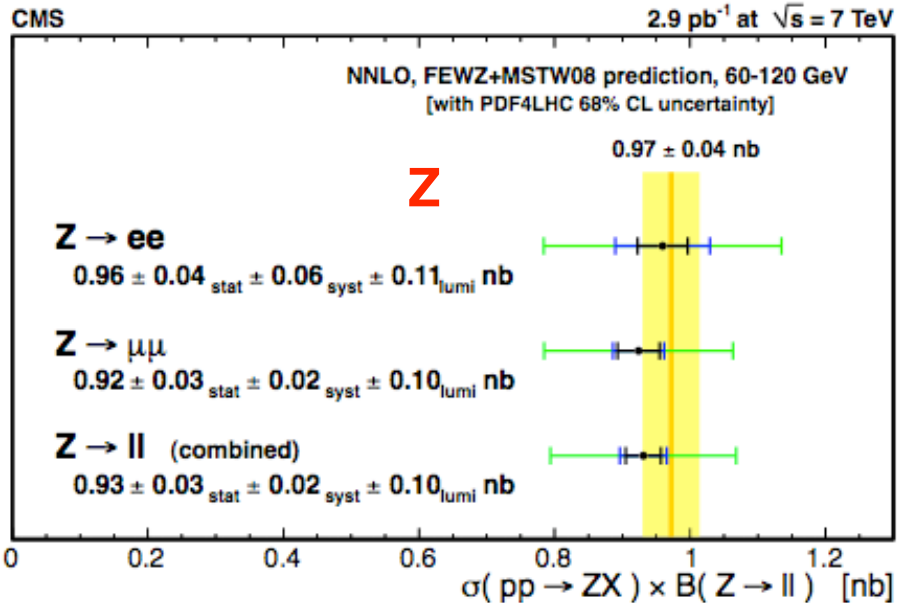


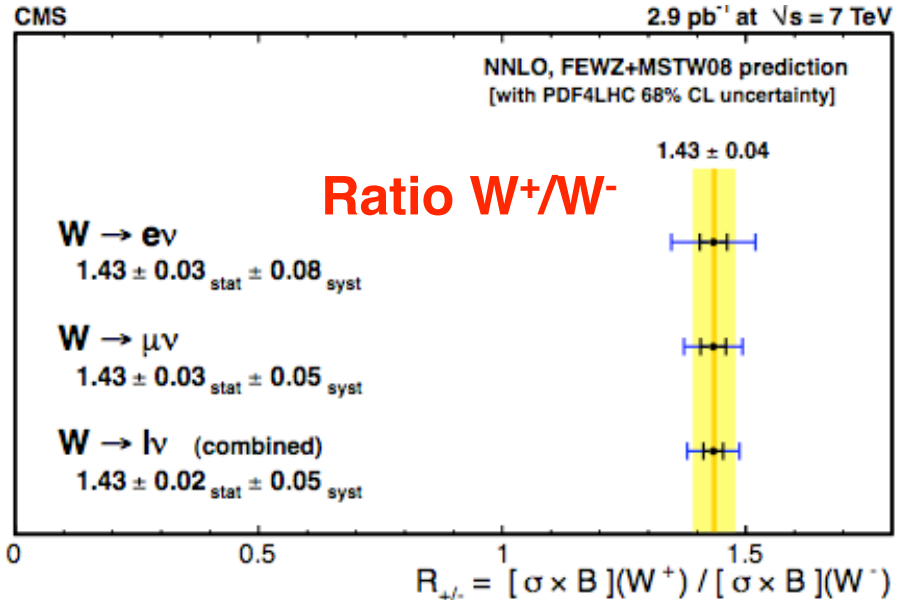


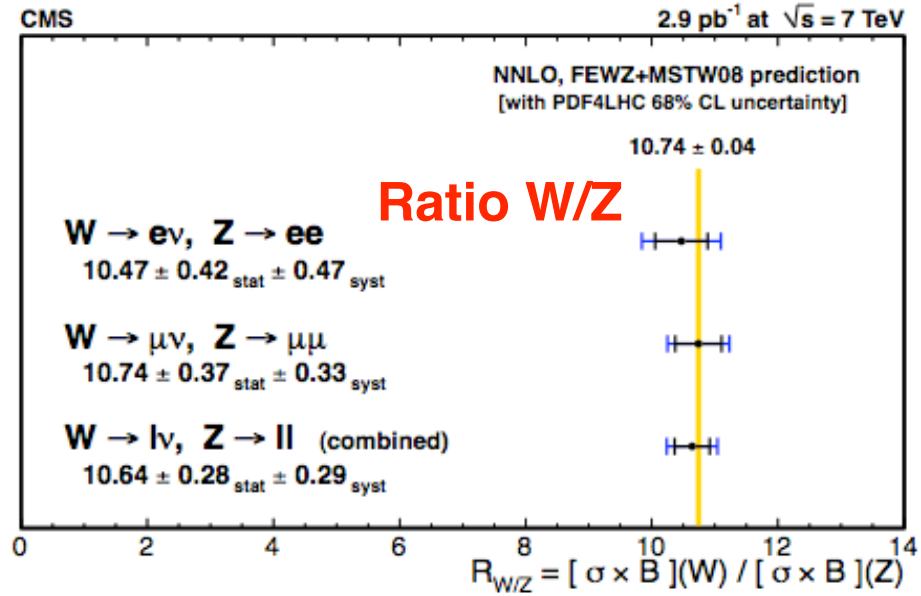


Precise and complete set of EWK measurements

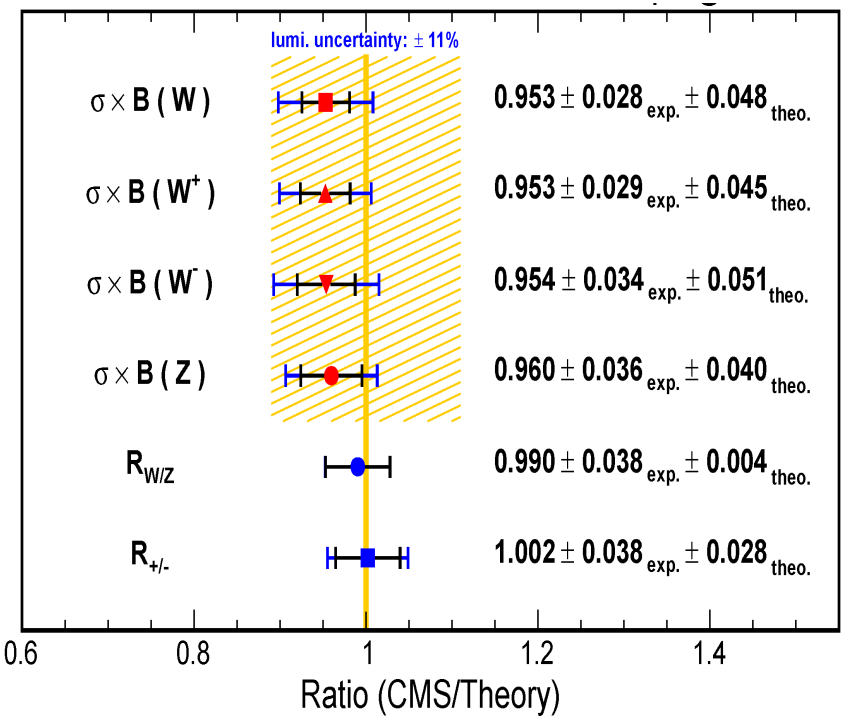




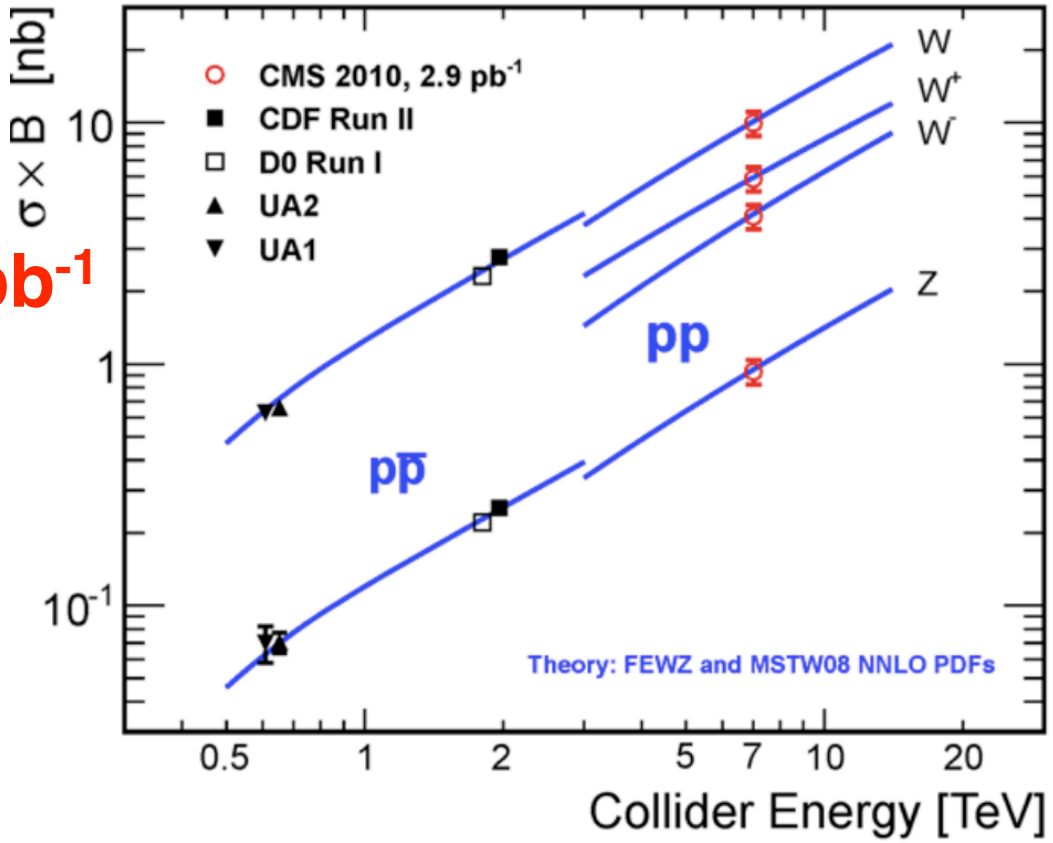




W and Z production cross sections



2.9pb^{-1}

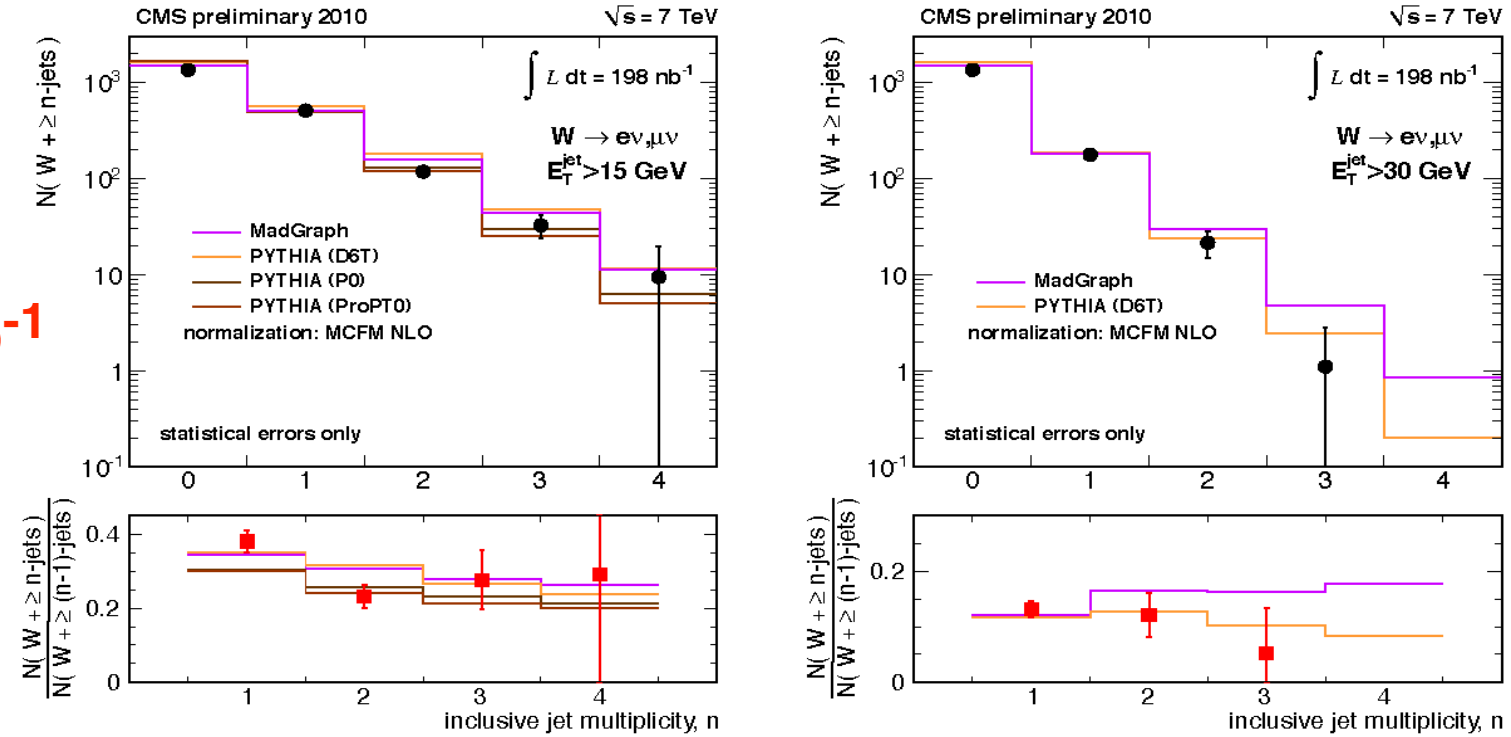


Notice: all major components of the measurements (efficiency, background, systematic errors etc) have been carefully evaluated using data driven methods.

arXiv:1012.2466 ; *J. High Energy Phys. 01 (2011) 080*

W+ jets (E_T>15 and 30GeV)

0.2pb^{-1}



Inclusive jet multiplicities accompanying W→lν for jets above a threshold of 15 (left) and 30GeV (right). Ratio N(W+n jets)/ N(W+(n-1)jets) .Comparison with theory (PYTHIA –different tunes- and MADGRAPH)

CMS PAS EWK-10-001

First measurement of the lepton charge asymmetry in inclusive W

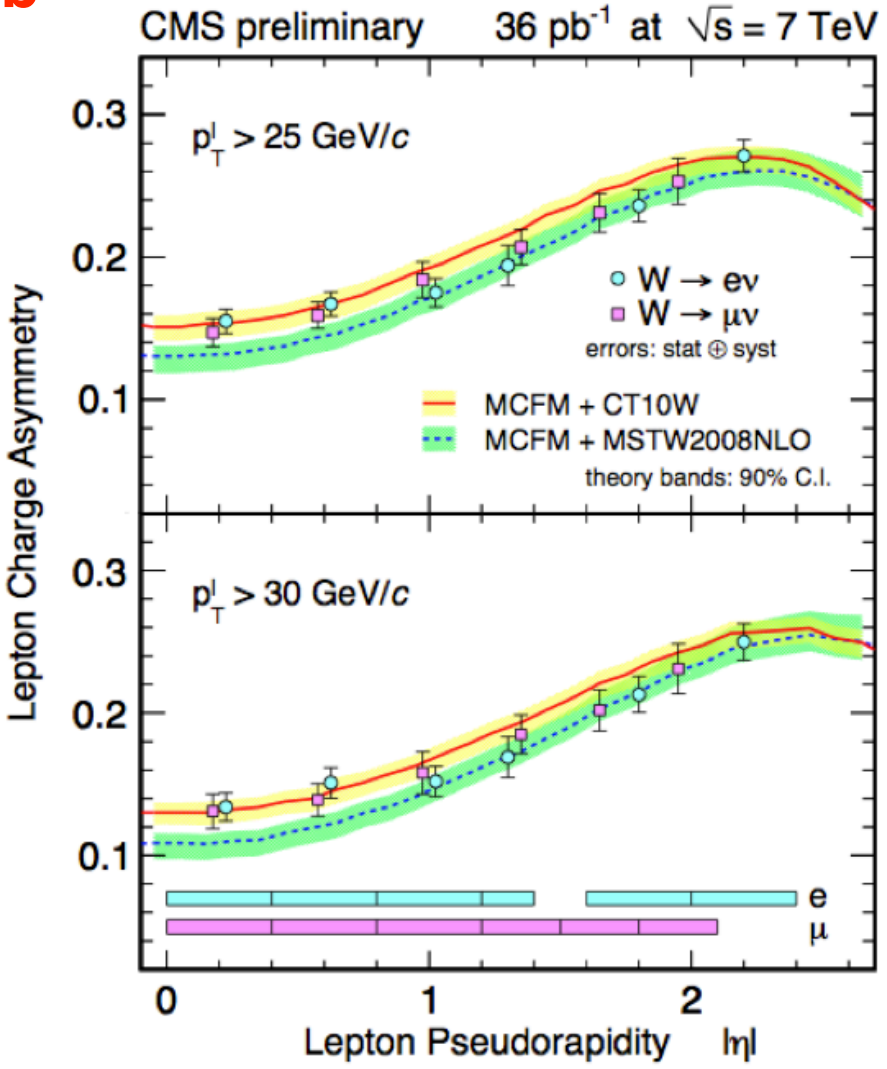
CMS PAS EWK-10-006

36pb^{-1}

	$p_T^\ell > 25$ GeV		$p_T^\ell > 30$ GeV	
$\|\eta^e\|$	$\mathcal{A}(e)$ ($\pm$stat $\pm$ sys)	Prediction	$\mathcal{A}(e)$ ($\pm$stat $\pm$ sys)	Prediction
[0.0 - 0.4]	$0.155 \pm 0.006 \pm 0.007$	$0.157^{+0.010}_{-0.010}$	$0.134 \pm 0.007 \pm 0.007$	$0.134^{+0.009}_{-0.009}$
[0.4 - 0.8]	$0.167 \pm 0.006 \pm 0.007$	$0.169^{+0.010}_{-0.011}$	$0.151 \pm 0.007 \pm 0.008$	$0.146^{+0.009}_{-0.010}$
[0.8 - 1.2]	$0.175 \pm 0.007 \pm 0.008$	$0.193^{+0.009}_{-0.011}$	$0.152 \pm 0.007 \pm 0.008$	$0.169^{+0.009}_{-0.011}$
[1.2 - 1.4]	$0.194 \pm 0.010 \pm 0.009$	$0.216^{+0.010}_{-0.012}$	$0.169 \pm 0.011 \pm 0.009$	$0.191^{+0.010}_{-0.012}$
[1.6 - 2.0]	$0.236 \pm 0.008 \pm 0.009$	$0.256^{+0.010}_{-0.014}$	$0.213 \pm 0.009 \pm 0.009$	$0.234^{+0.011}_{-0.015}$
[2.0 - 2.4]	$0.271 \pm 0.008 \pm 0.009$	$0.271^{+0.012}_{-0.017}$	$0.250 \pm 0.009 \pm 0.009$	$0.257^{+0.013}_{-0.018}$
$\|\eta^\mu\|$	$\mathcal{A}(\mu)$ ($\pm$stat $\pm$ sys)	Prediction	$\mathcal{A}(\mu)$ ($\pm$stat $\pm$ sys)	Prediction
[0.0 - 0.4]	$0.147 \pm 0.006 \pm 0.008$	$0.157^{+0.010}_{-0.010}$	$0.131 \pm 0.007 \pm 0.010$	$0.134^{+0.009}_{-0.009}$
[0.4 - 0.8]	$0.159 \pm 0.006 \pm 0.007$	$0.169^{+0.010}_{-0.011}$	$0.139 \pm 0.007 \pm 0.009$	$0.146^{+0.009}_{-0.010}$
[0.8 - 1.2]	$0.184 \pm 0.006 \pm 0.011$	$0.193^{+0.009}_{-0.011}$	$0.158 \pm 0.007 \pm 0.013$	$0.169^{+0.009}_{-0.011}$
[1.2 - 1.5]	$0.207 \pm 0.007 \pm 0.010$	$0.220^{+0.009}_{-0.012}$	$0.185 \pm 0.008 \pm 0.011$	$0.196^{+0.010}_{-0.012}$
[1.5 - 1.8]	$0.231 \pm 0.008 \pm 0.011$	$0.246^{+0.010}_{-0.014}$	$0.202 \pm 0.008 \pm 0.012$	$0.222^{+0.011}_{-0.014}$
[1.8 - 2.1]	$0.253 \pm 0.008 \pm 0.014$	$0.265^{+0.010}_{-0.015}$	$0.231 \pm 0.009 \pm 0.015$	$0.245^{+0.011}_{-0.016}$

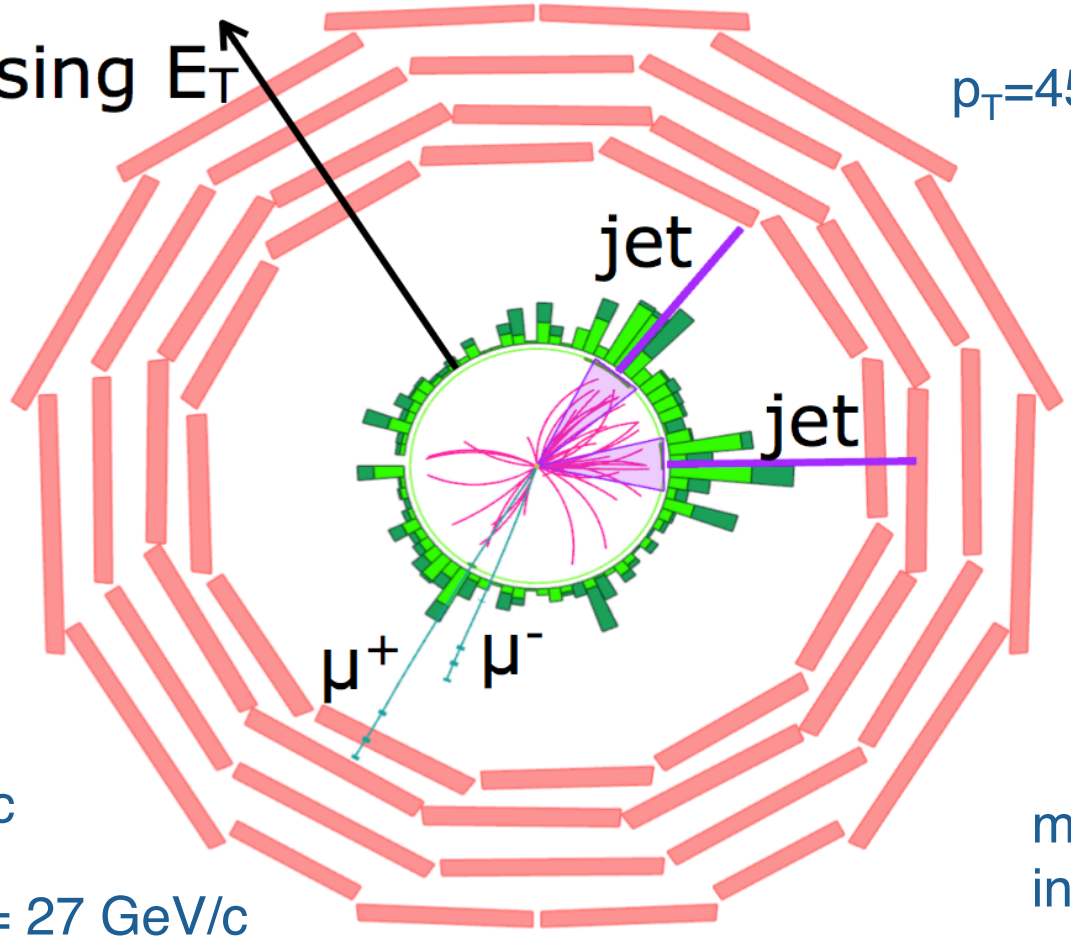
Precision EWK measurements are already being produced from LHC.
The values of the charge asymmetry between electrons and muons are in good agreement with each other.
The precision of the measurement is good enough to provide new inputs to the PDF global fits.

Comparison with PDF Models



Observation of top quark candidates

2 opposite sign muons +jets+large MET



MET= 57 GeV/c

p_T=45 GeV/c

0.2pb^{-1}

p_T = 56 GeV/c

μ^- p_T = 57 GeV/c

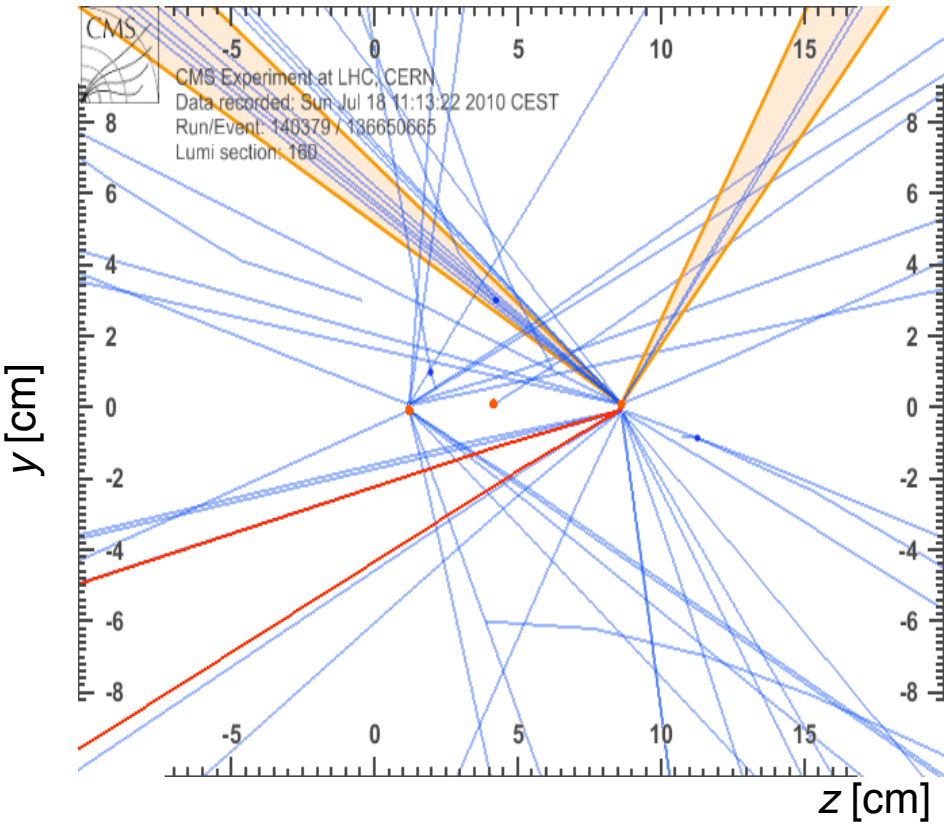
$m(\mu\mu)$ = 26 GeV/c^2
incompatible with Z

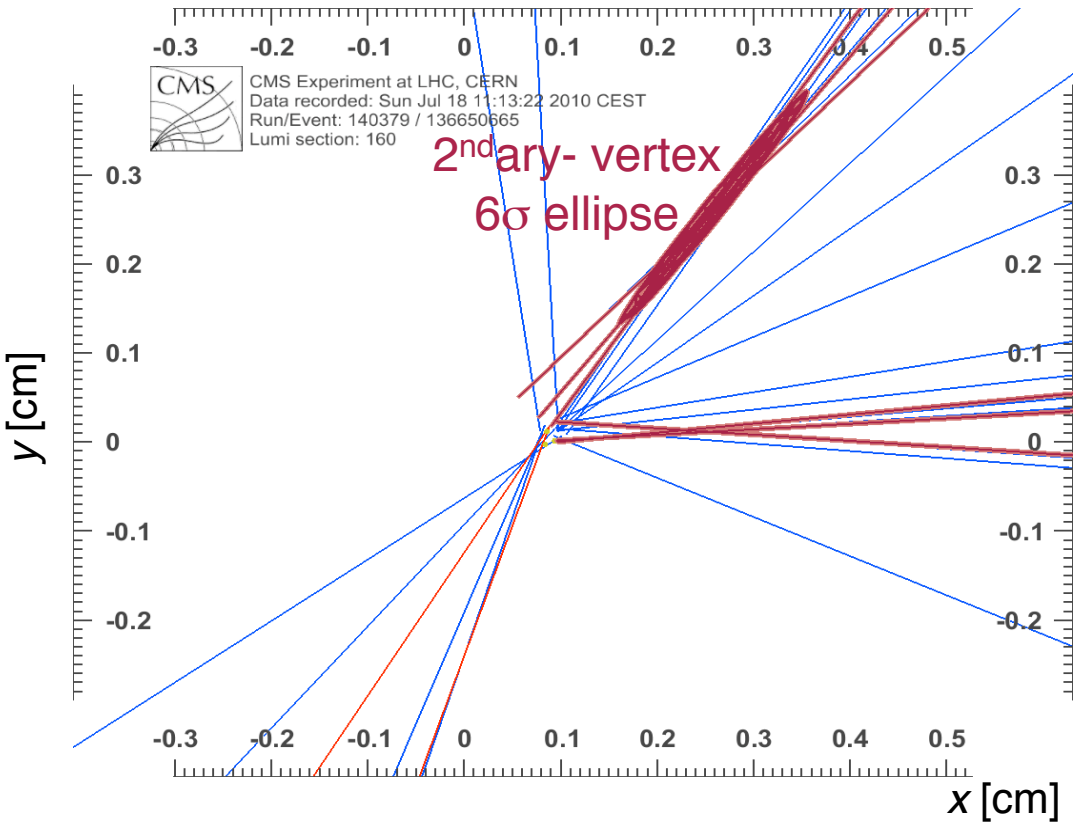
μ^+ p_T = 27 GeV/c

Top Di-Muon Candidate Event

Observation of top quark candidates

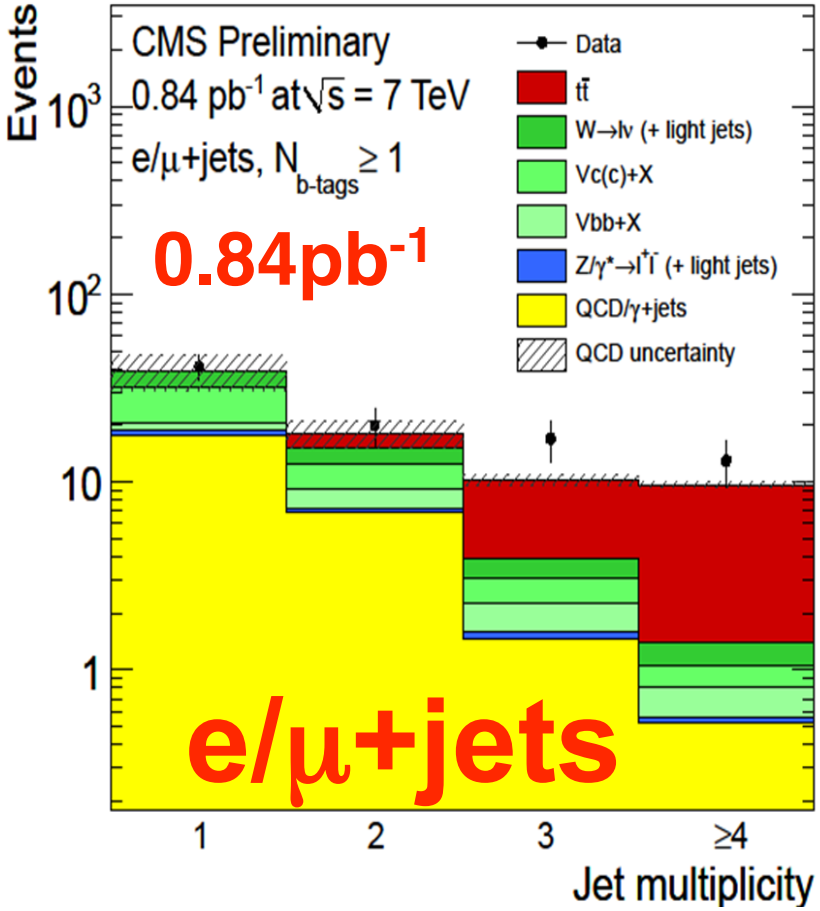
Event passes all cuts of full selection: 2 jets, both w/ good/clear *b*-tags and secondary vertices and additional cross checks: muons and jets coming from the same interaction vertex.

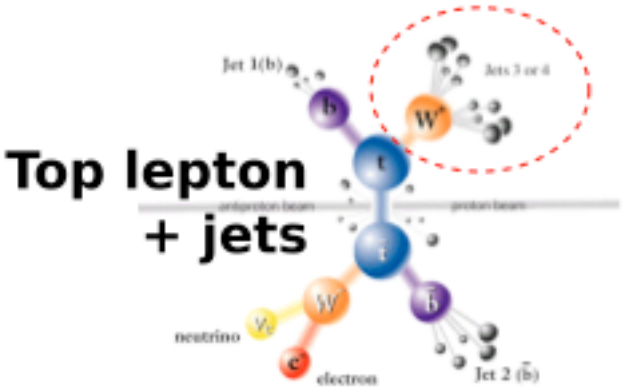




First observation of top at LHC

Using 0.84pb^{-1} of data and **requiring at least 1 jet b-tagged** (secondary vertex tagger with ≥2 tracks; high efficiency with ~1% fake rate)





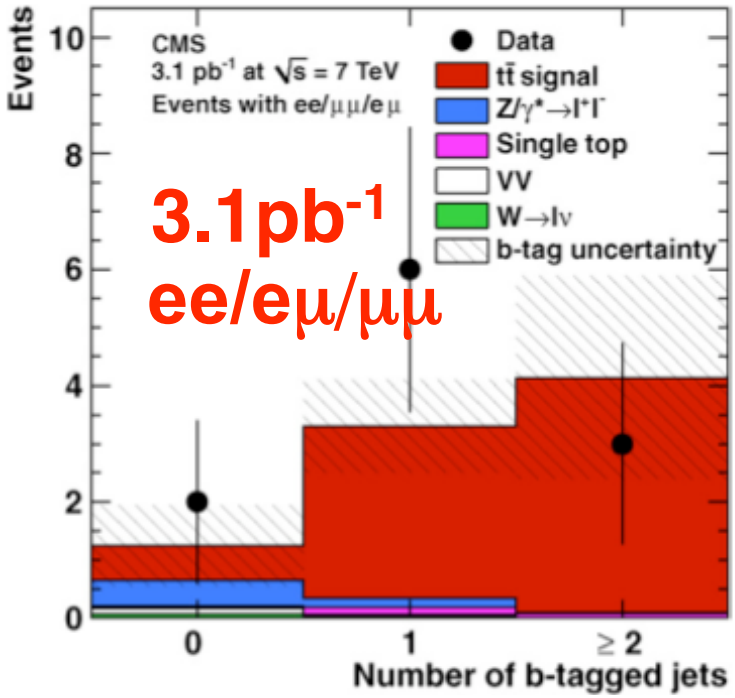
For N(jets)≥3 we count **30 signal candidates over a predicted background of 5.3**

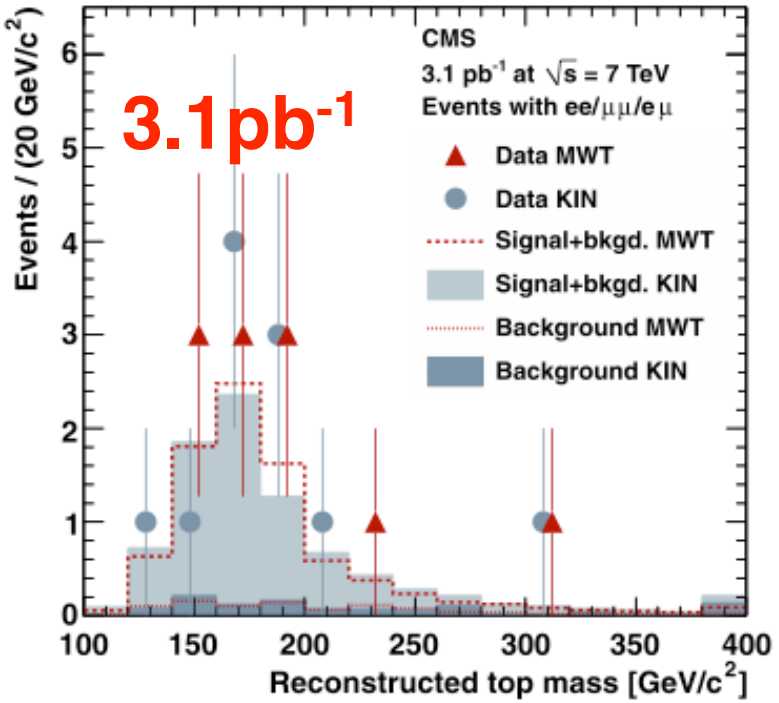
t-tbar events observed in CMS at a rate consistent with NLO cross section, considering experimental (JES, b-tagging) and theoretical (scale, PDF, HF modelling, …) uncertainties.

Top signal at LHC clearly established.

First measurement of the top cross section at LHC

- Top in dileptons +jets
- Full selection applied: Z-bosonVeto, |M(ll)-M(Z)|>15 GeV
- MET >30 (20) GeV in ee,μμ,(eμ); N(jets)≥2





σ(pp → tt+ X) = 194±72(stat.)± 24(syst.)± 21(lumi.) pb. Consistent with NLO prediction of 158(+23–24) pb for a top quark mass of m_t = 172.5 GeV/c^2

Much more on W,Z, top in Michele De Gruttola's talk on Thursday

arXiv:1010.5994 ***Phys. Lett. B 695 (2011) 424-443***

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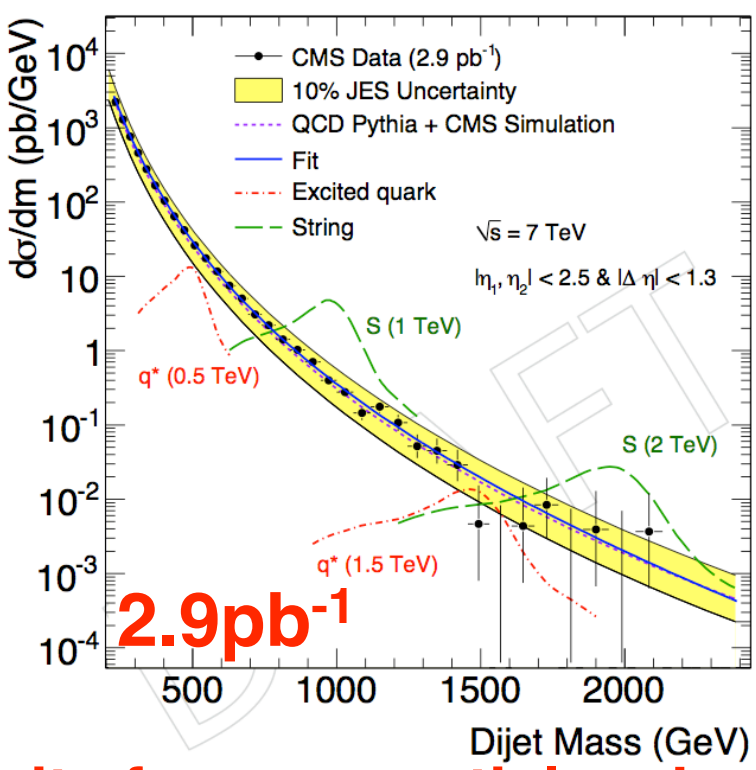
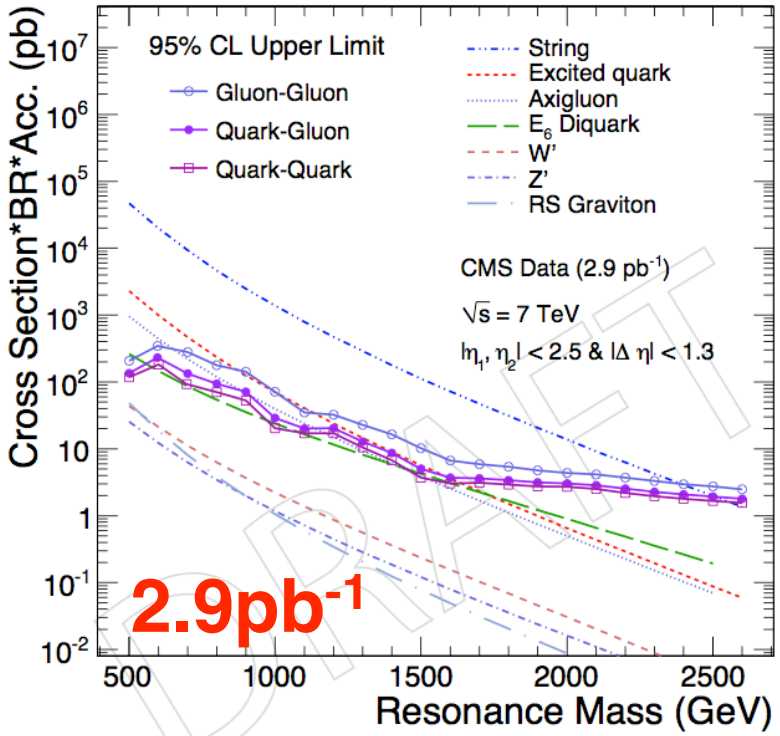
- First results from HI running
- Standard Model Measurements at 7 TeV
- **Searches for New Physics**
- Prospects for Higgs Search in 2011-12
- Conclusion

Search for narrow resonances in di-jet final states.

We have measured, in 2.9pb^{-1} of data, the dijet mass differential cross section for $|\eta_1,\eta_2|<2.5$ and $|\Delta\eta_2|<1.3$. The distribution is sensitive to the coupling of any new massive object to quarks and gluons.



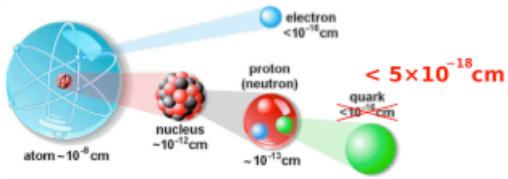


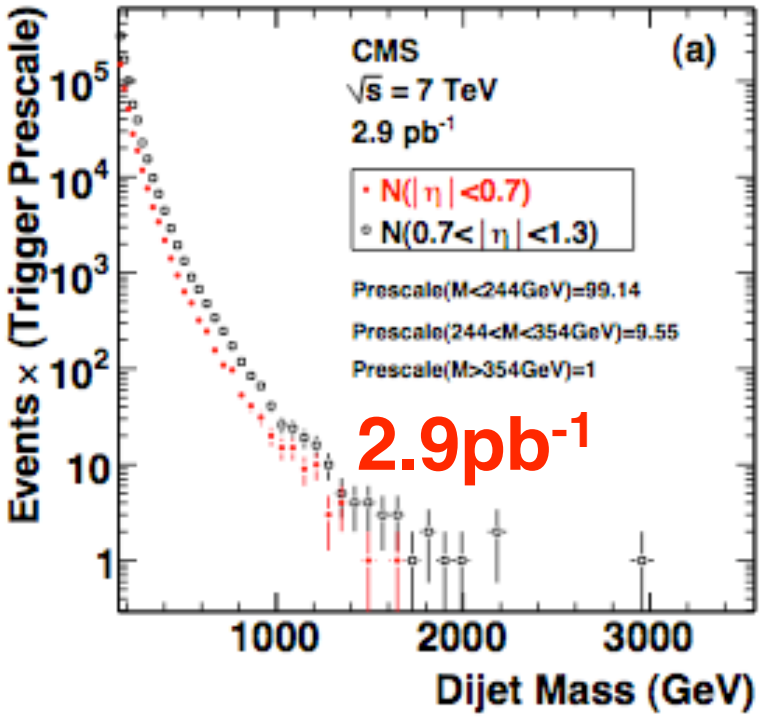
arXiv:1010.0203;
CERN-PH-EP-2010-035;
CMS-EXO-10-010
Phys. Rev. Lett., 105, (2010) 211801

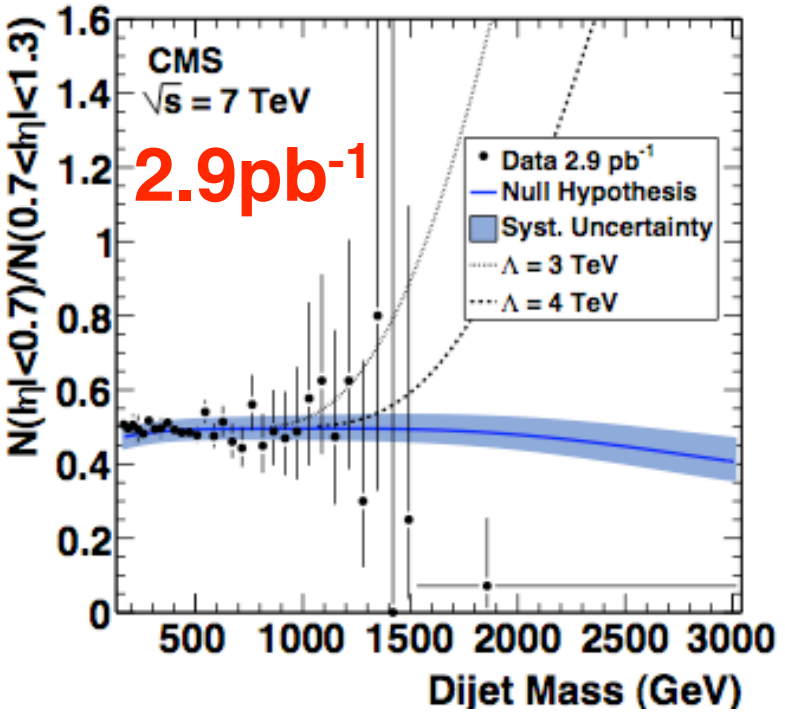
95% CL mass limits for new particles decaying to parton pairs: String resonances >2.5TeV; Excited quarks >1.58TeV….

Search for new physics: quark compositeness

The dijet centrality ratio, the ratio of the number of events with the two leading jets within pseudo- rapidity |η| <0.7 to the number with both leading jets within 0.7<|η| <1.3. is a very sensitive variable to deviations from the Standard Model coming from quark sub-structures.



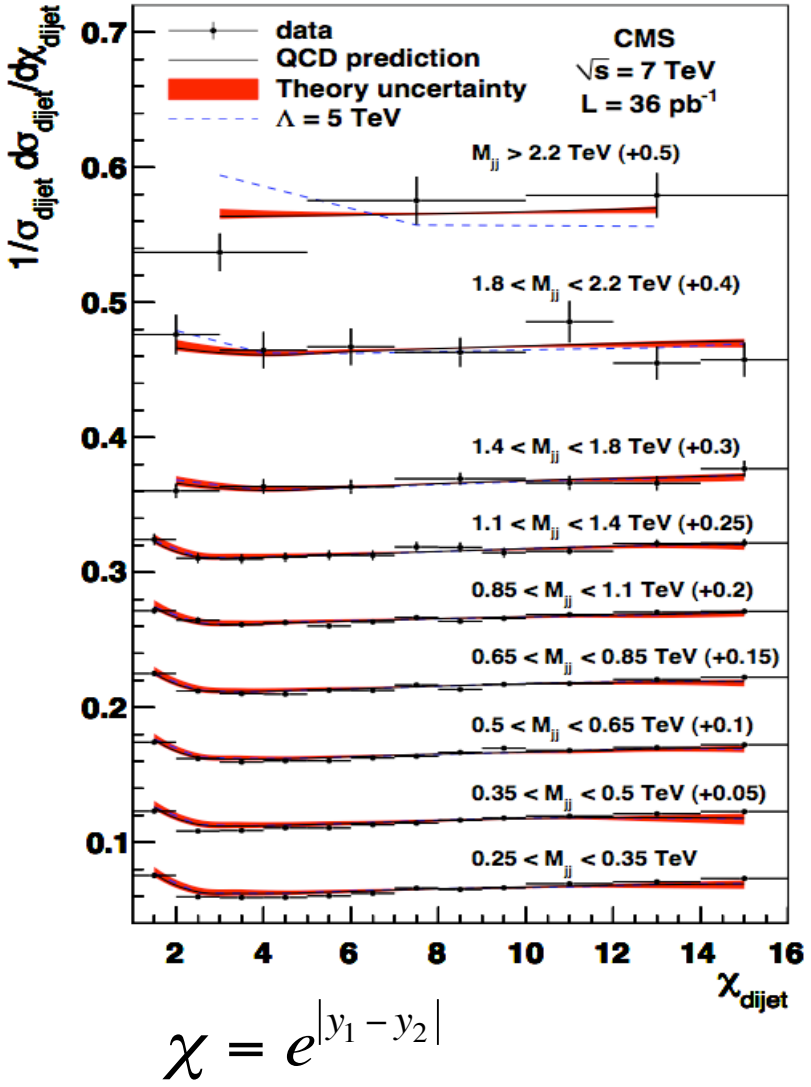




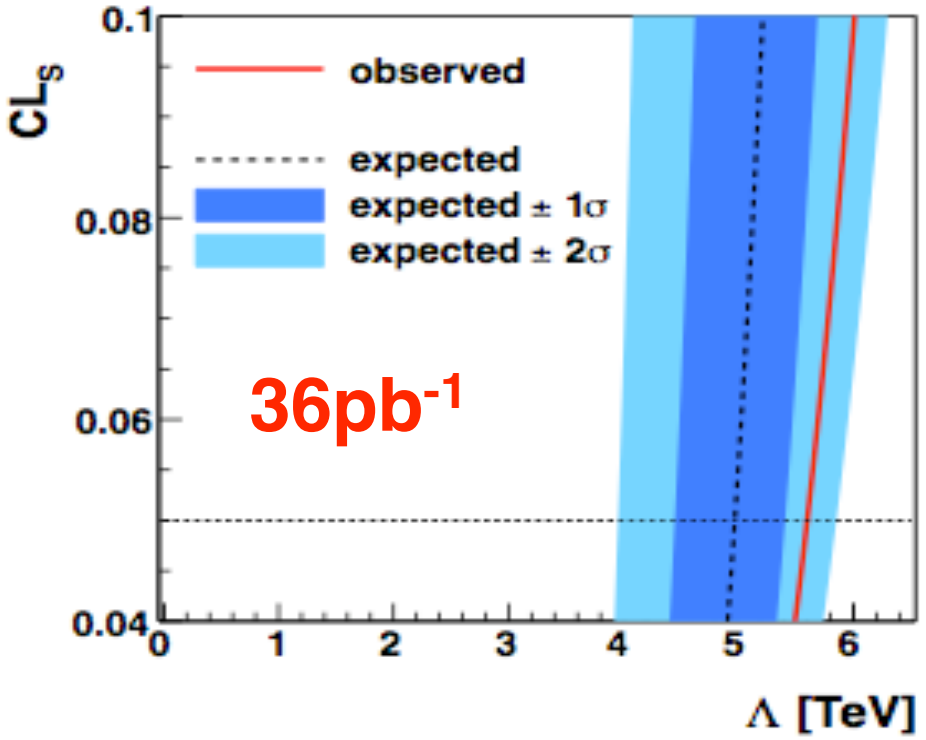
arXiv:1010.4439;
CERN-PH-EP-2010-038;
CMS-EXO-10-002
Phys. Rev. Lett. 105 (2010) 262001

The ratio shows a little dependence on m_{jj} and agrees with the SM expectations.
We exclude quark compositeness at energy scales of Λ<4.0TeV at the 95%CL.

Search for quark compositness



$$\chi = e^{|y_1 - y_2|}$$



The dijet angular distributions are compatible with pQCD predictions for dijet invariant mass of 250GeV up to>2.2TeV. We put a lower limit on the contact interaction scale of **Λ=5.6 TeV** at 95% CL. This is the most stringent limit to date.

arXiv:1102.2020; CERN-PH-EP-2010-092; CMS-QCD-10-016-003. Submitted to Physical Review Letters

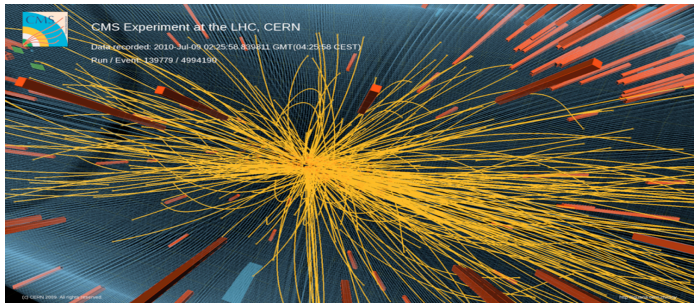
First observation of new phenomena at LHC

High Energy Physics - Experiment arXiv:1009.4122v1 [hep-ex]

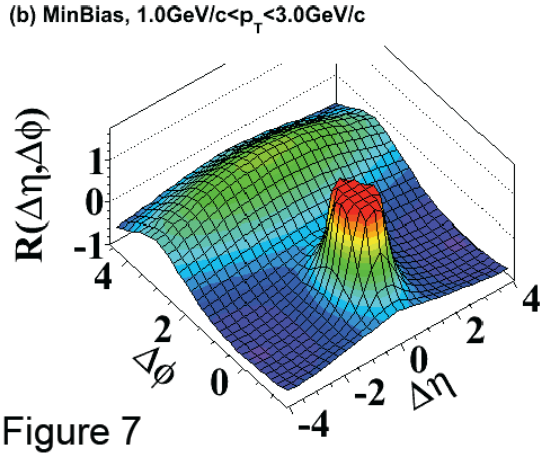
Observation of Long-Range Near-Side Angular Correlations in Proton-Proton Collisions at the LHC

CMS Collaboration

(Submitted on 21 Sep 2010) ***JHEP 2010, Number 9, 1-38***



MinBias



high multiplicity (N>110)

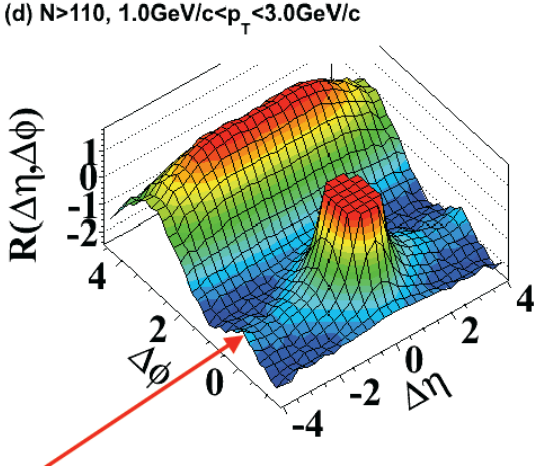
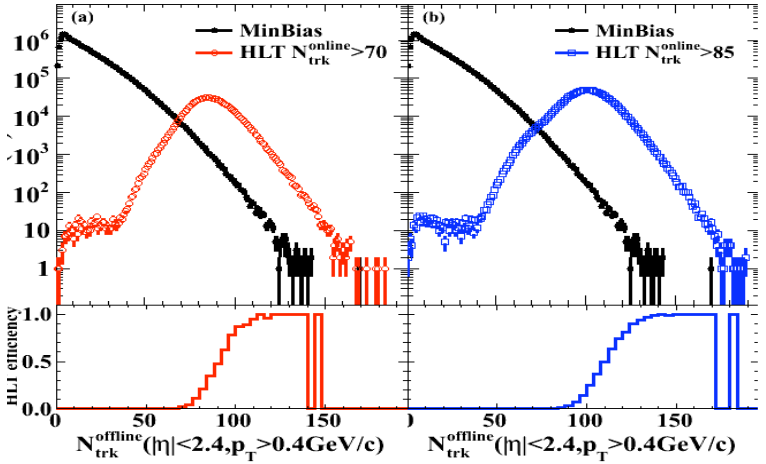


Figure 7



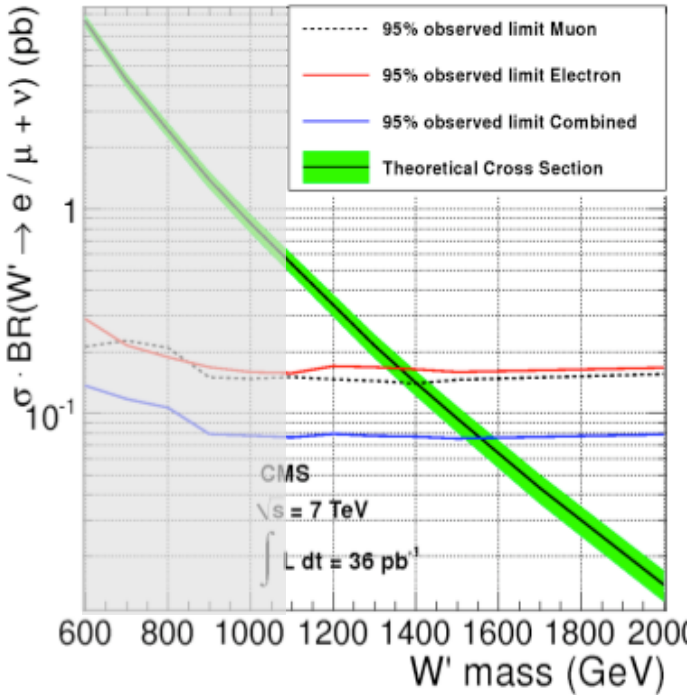
New correlation measured in high multiplicity events

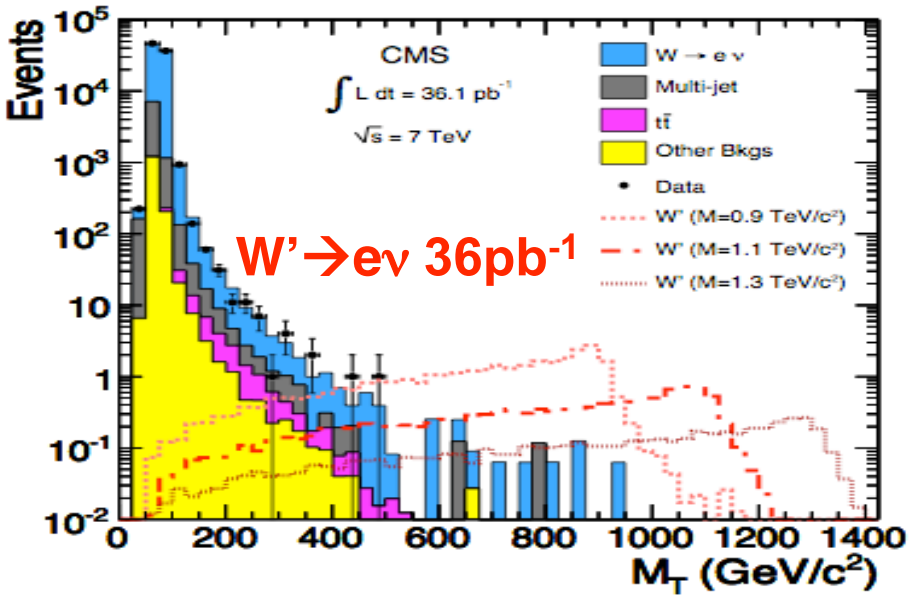
Several papers on possible interpretations. New set of measurements to understand better the dynamics. It will be very interesting to compare the measurements in pp and heavy-ions modes.

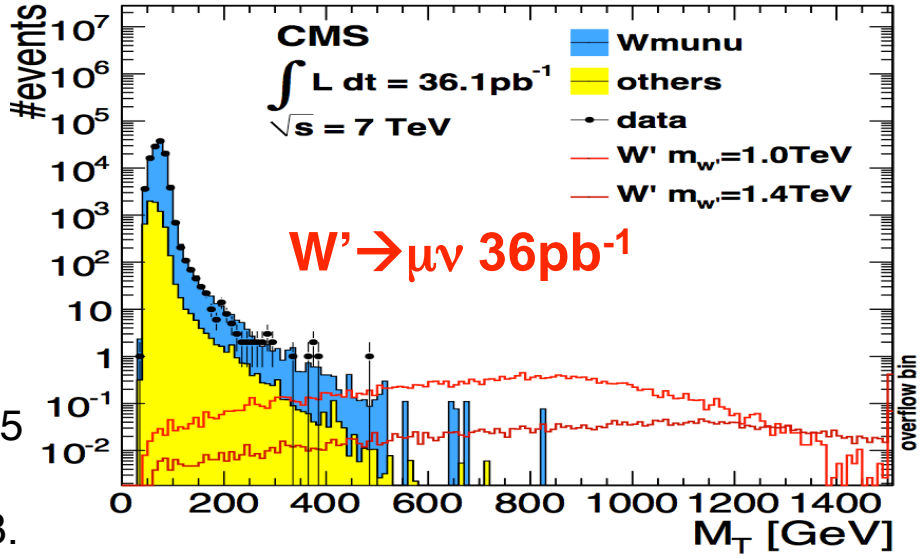
Looking for extra-dimensions

Evidence of very massive extra bosons could possibly hint at extra-dimensions or other new physics models. With 2010 statistics we have been able to produce limits on W' and Z' exceeding the current limits set by the Tevatron experiments.

Assuming standard-model-like couplings and decay branching fractions we exclude a W' with mass<1.58 TeV (95%CL)



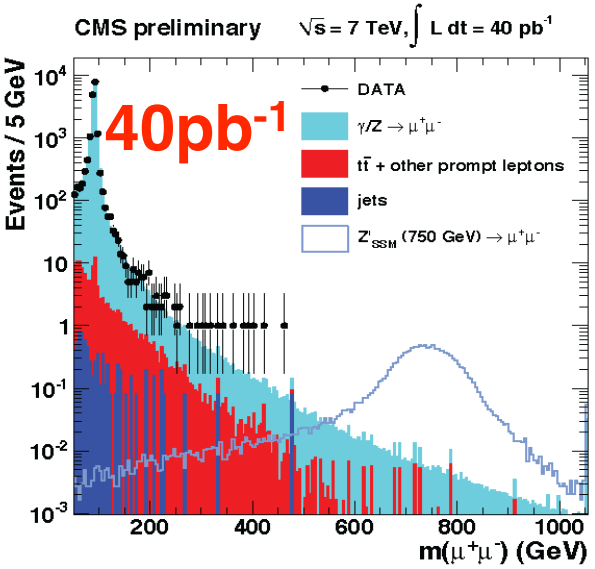




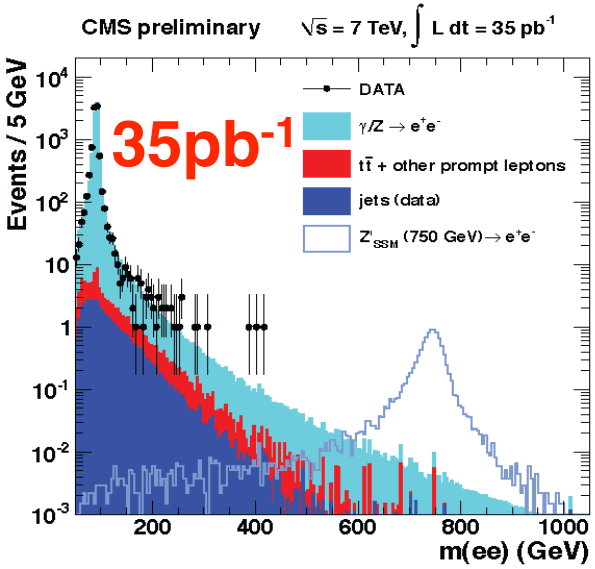
arXiv:1012.5945
CMS-EXO-10-015
Submitted to Physics Letters B.

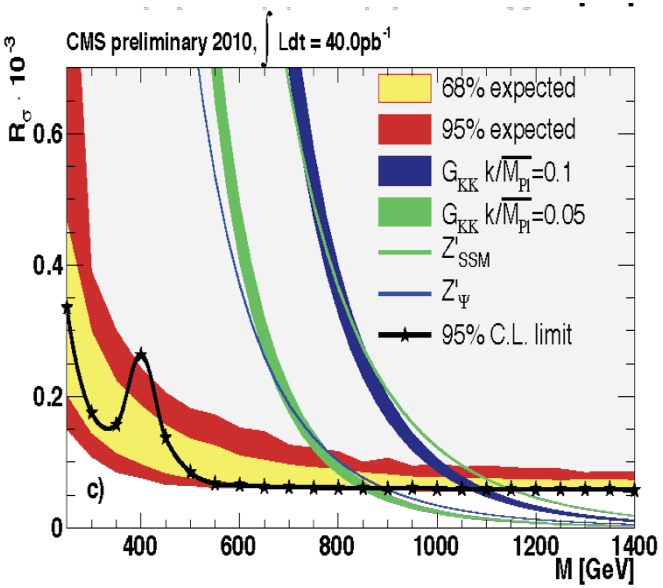
Search for Z' in dileptons

Z'→$\mu^+\mu^-$



Z'→e^+e^-



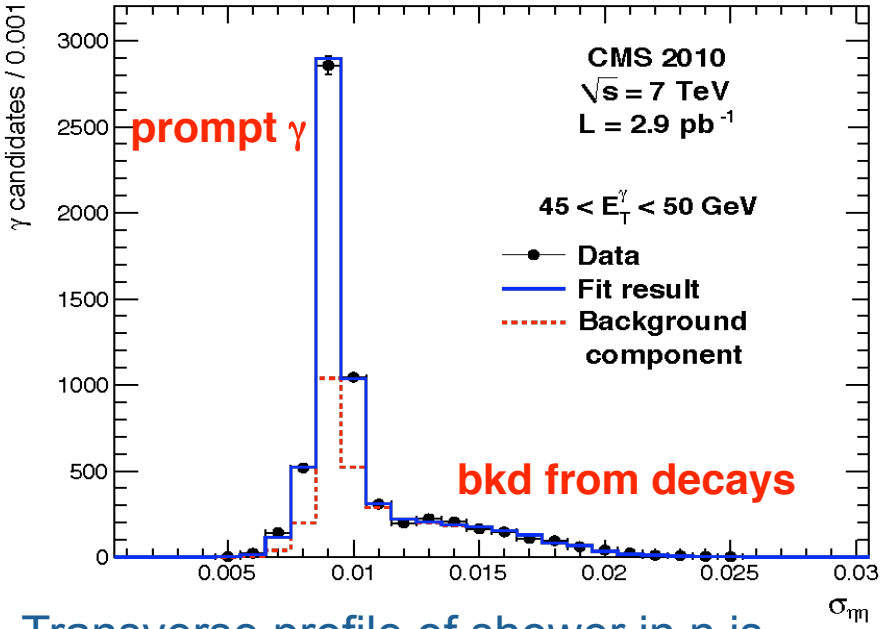


The spectra are consistent with known SM processes. By combining the $\mu^+\mu^-$ and e^+e^- channels, the following 95% C.L. lower limits on the mass of a Z′ resonance are obtained: **1140 GeV** for the Sequential Standard Model Z'_{SSM}, and **887 GeV** for Super-String inspired models, Z'_ψ. RS Kaluza-Klein Gravitons are excluded below **855-1079 GeV** at 95% C.L. for values of couplings parameters (k/M_{Pl}) 0.05-0.1.

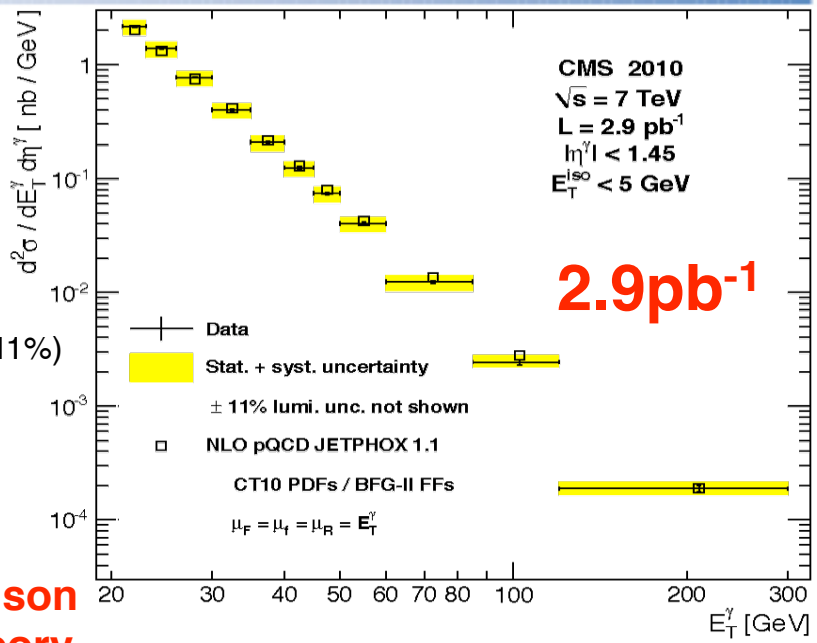
Most stringent limits to date.

CMS EXO-10-013 . Prospects for 2011-12: explore deeply the multi TeV region.

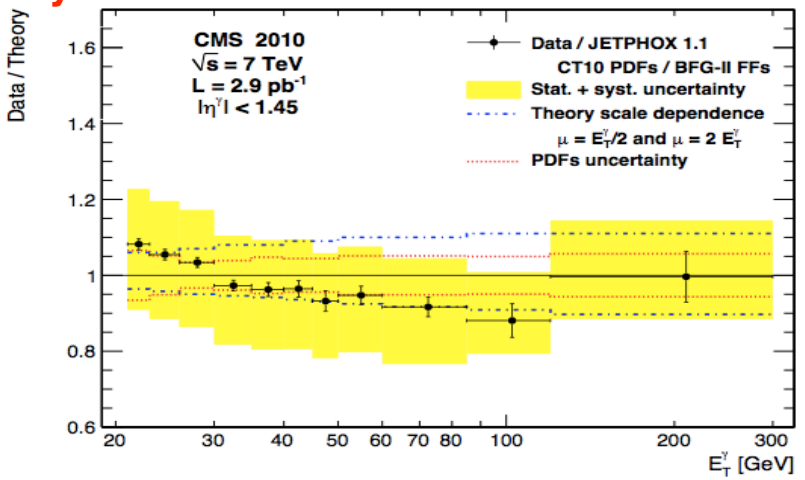
Understanding the photons: Isolated Photon Spectrum



Lumi error (11%) not included



Comparison with theory



Transverse profile of shower in η is used to separate high energy isolated photons from π^0 enriched jets

Measurement at higher Q^2 and lower $x_t=2E_t/\sqrt{s}$ than Tevatron

Isolated photon rate agrees well with QED + NLO pQCD radiation

arXiv:1012.0799v1 CERN-PH-EP-2010-053; CMS-QCD-10-019.- ***Phys. Rev. Lett. 106 (2011) 082001***

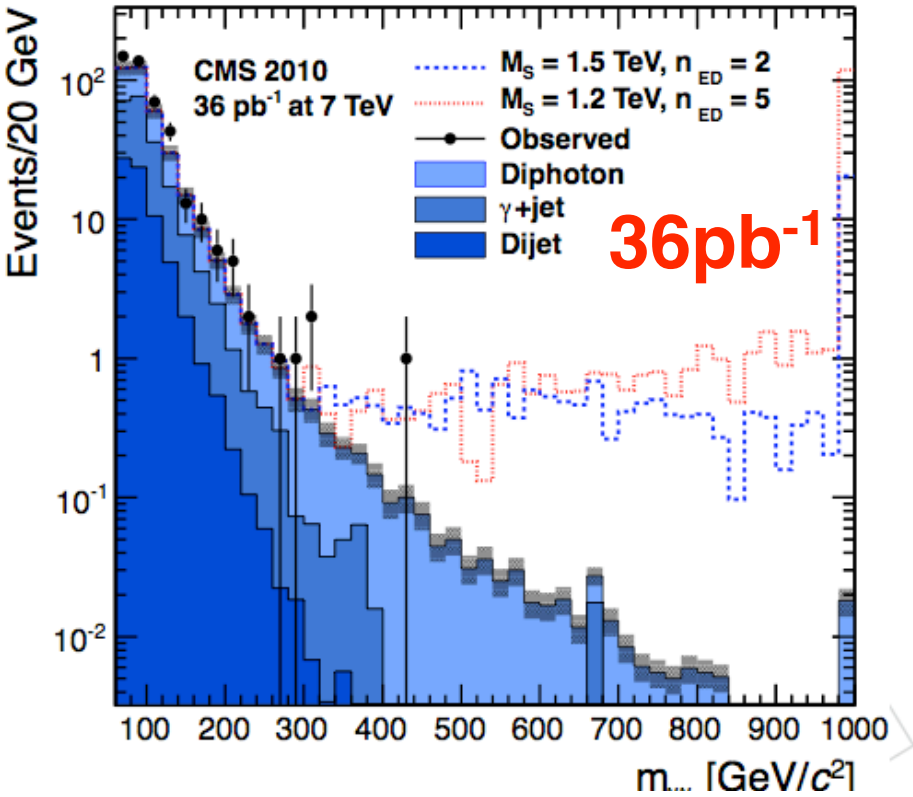
Using photons to look for Large Extra-Dimensions

A search for large extraspatial dimensions via virtual graviton exchange in the di-photon channel has been carried out. The graviton exchange would enhance the di-photon production.

σxBR >110fb excluded at 95% CL for $M_{\gamma\gamma} > 500$ GeV

Lower limit on cutoff scale M_S = 1.6–2.3 TeV depending on n_{ED} and model.

For larger n_{ED} >2 this results is better than Tevatron limit

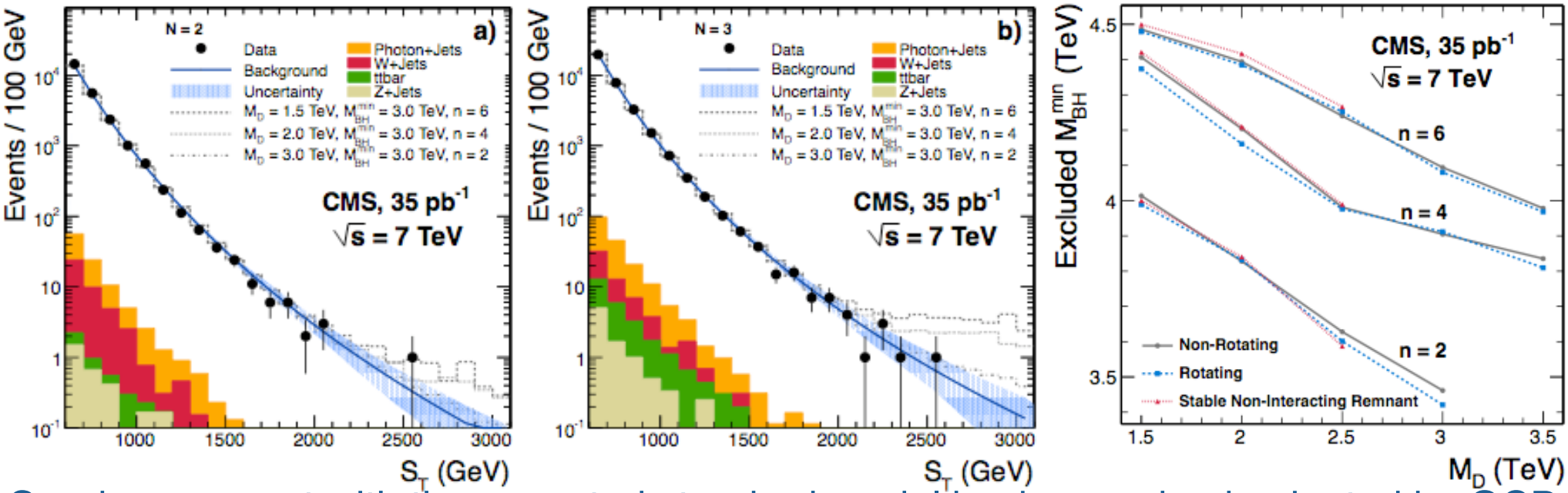


The new limits obtained in the range of 1.6–2.3TeV, at the 95% confidence level, depending on the number of extradimensions, can be interpreted as the lower limits on the effective Planck scale in these models, and are the most restrictive limits on the existence of large extradimensions to date for their number greater than two.

CMS PAPER EXO-10-026

First direct search of microscopic black holes signatures at a particle collider.

Events with large total transverse energy are analyzed for the presence of multiple high-energy jets, leptons, and photons, typical signal expected from a microscopic black hole.



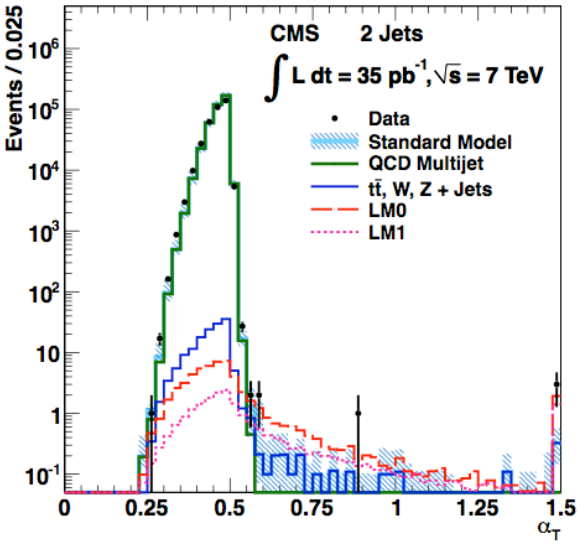
Good agreement with the expected standard model backgrounds, dominated by QCD multijet production, is observed for various final-state multiplicities. Limits on the minimum black hole mass are set, in the range **3.5–4.5 TeV**, for a variety of parameters in a model with large extra dimensions.

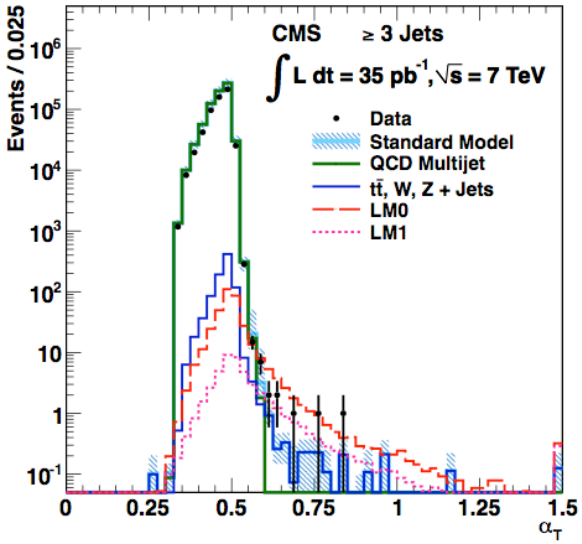
arXiv:1012.3375; CMS-EXO-10-017; CERN-PH-EP-2010-073. Accepted by PLB.

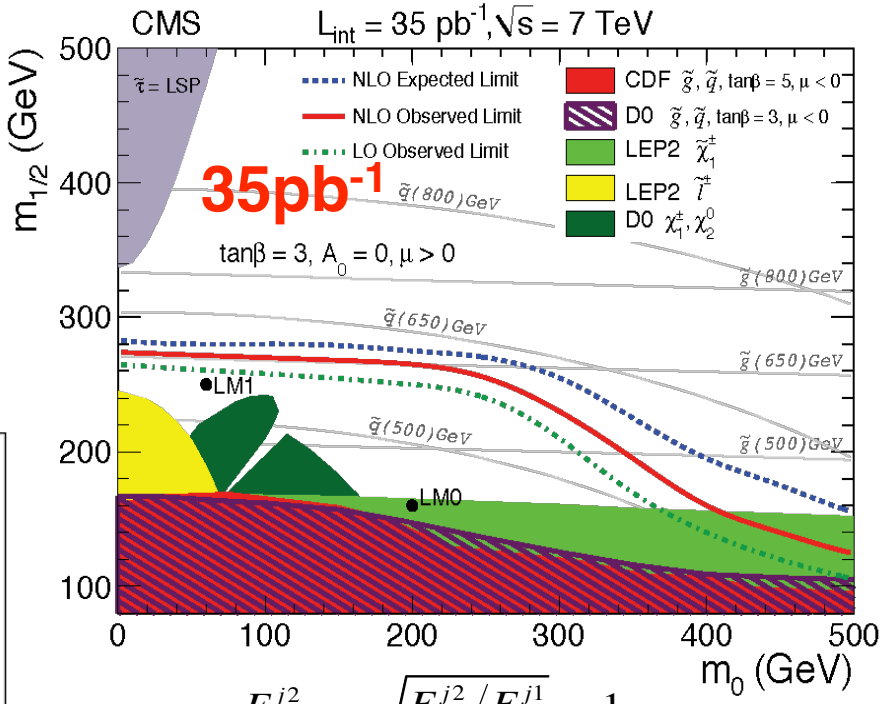
First SUSY result from LHC

Using very clean signatures for early SUSY signals (α_T, di-photon+MET, multi-leptons etc) we are already exceeding limits on SUSY set by the Tevatron experiments.

In a few months the eclusion range established in the last 20 years expanded by ~factor two.







$$\alpha_T = \frac{E_T^{j2}}{M_T^{j1,j2}} = \frac{\sqrt{E_T^{j2}/E_T^{j1}}}{2} < \frac{1}{2} \text{ for QCD}$$

$$\alpha_T > \frac{1}{2} \text{ possible when there is large MET}$$

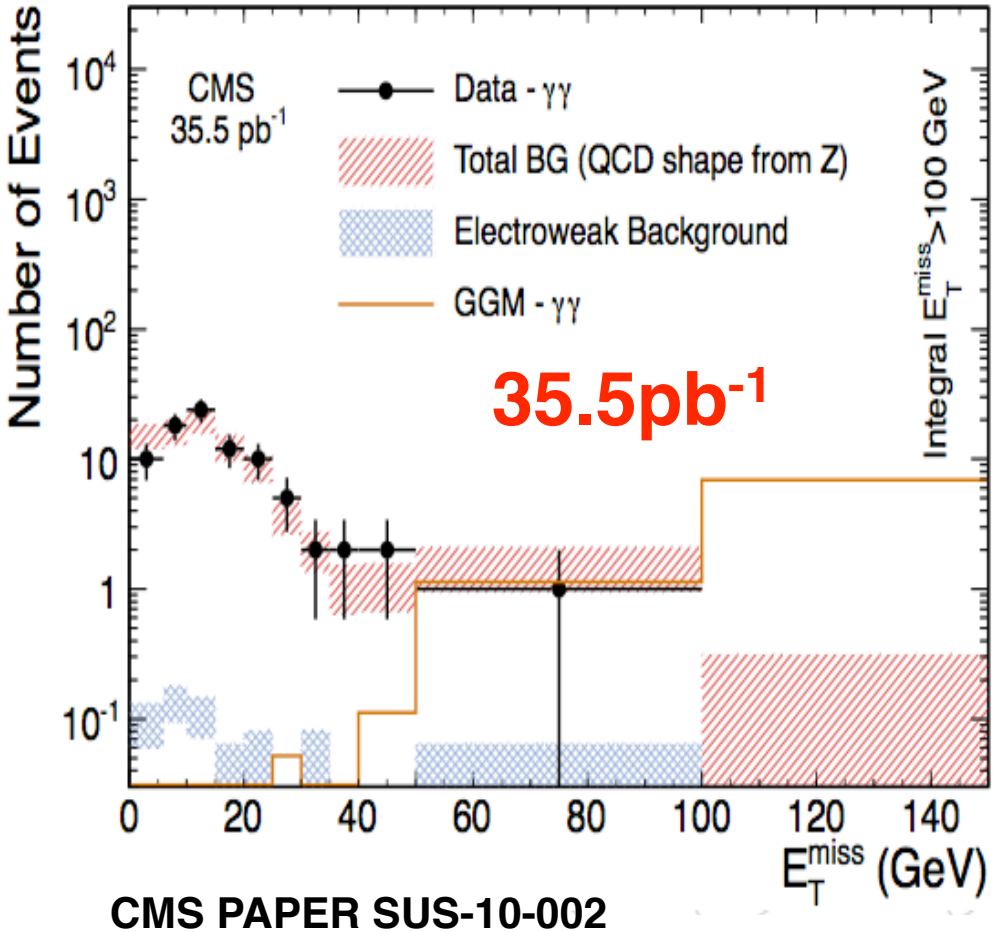
Extend for multi-jet topology

Prospects for 2011-12: discover squarks and gluinos (if SUSY is a symmetry of nature) above 1TeV.

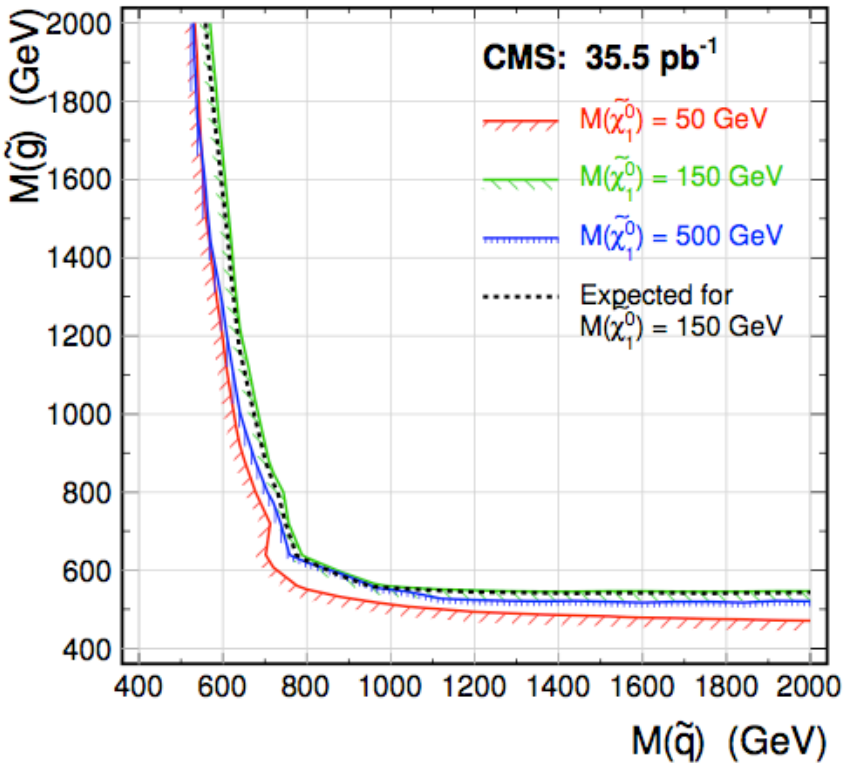
arXiv:1101.1628 ; CMS-SUS-10-003 ; CERN-PH-EP-2010-084. – 2011 Submitted to Physics Letters B

Search for SUSY in events with γγ +jet and MET

Two isolated photons with $E_T > 30$ GeV in the barrel ($\eta<1.4$) and at least 1 jet $E_T > 30$ GeV
No Signal Found, data matches well to background.
1 Event MET >50 GeV; Exp. Bkgd: 1.2 +/-0.8



CMS PAPER SUS-10-002



Search for SUSY General Gauge-Mediated (GGM) breaking with the lightest neutralino as the next-to-lightest supersymmetric particle and the gravitino as the lightest. Limits on the cross section for GGM supersymmetry between 0.3 and1.1pb (95% CL) for different mass scenarios. **Best limits to date.**

First measurement of the WW cross section at LHC

W^+W^- candidates are selected in events with two leptons, electrons or muons.

Lepton $P_T > 20$ GeV

Projected MET > 35 GeV
or > 20 GeV for eμ

M_{ll} Veto: $M_Z \pm 15$ GeV

Jet Veto: $P_T > 25$ GeV

Top Veto: bTag + soft-μ

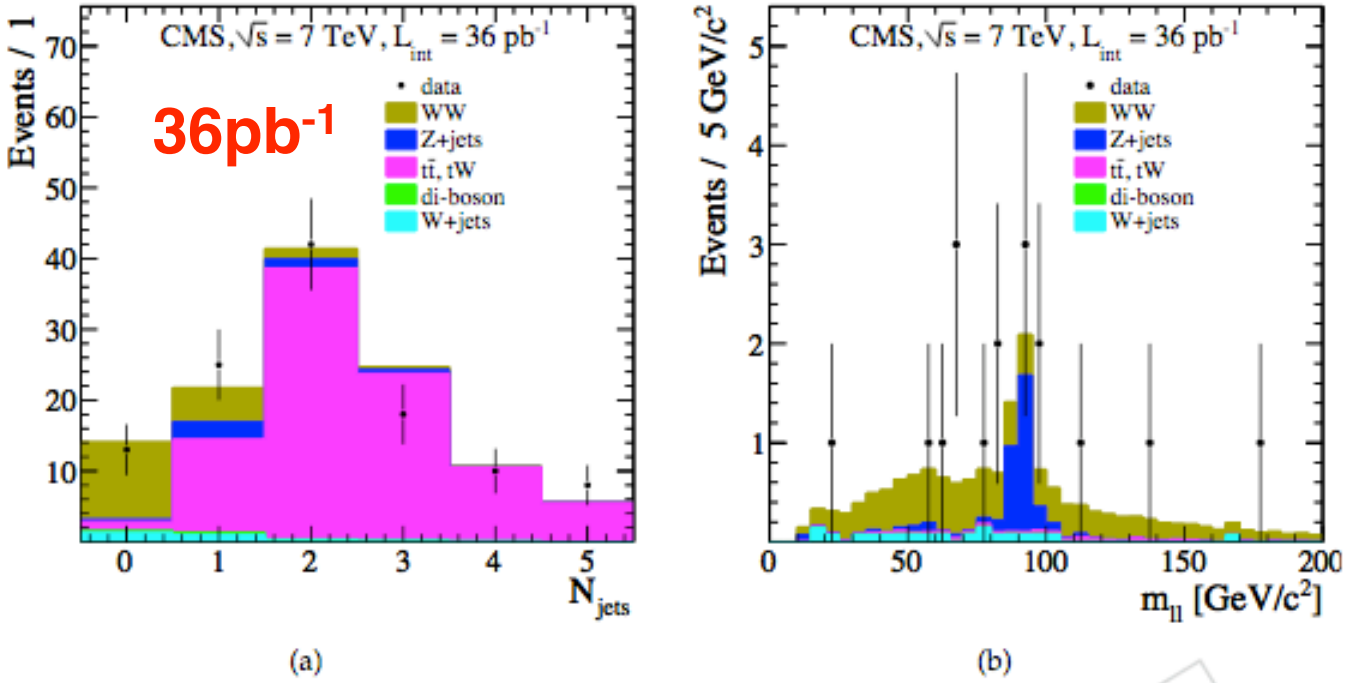


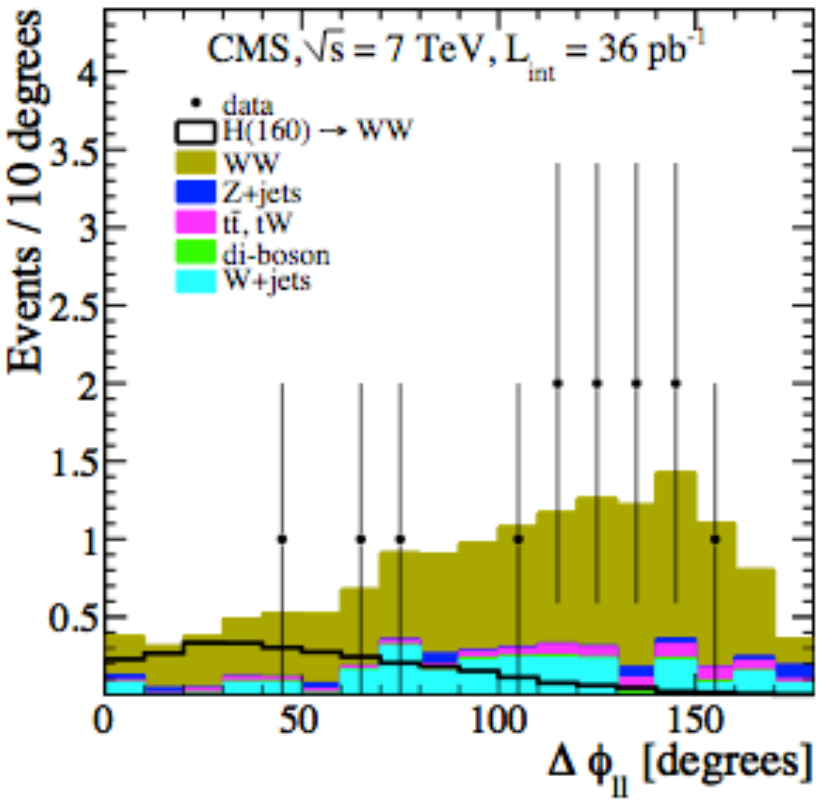
Figure 1: (a) Jet multiplicity distribution after applying all W^+W^- selection criteria, except th top veto and jet veto requirements. (b) Dilepton mass distribution for the events passing th final event selections, except the Z mass removal cut. All the selected events on data are show

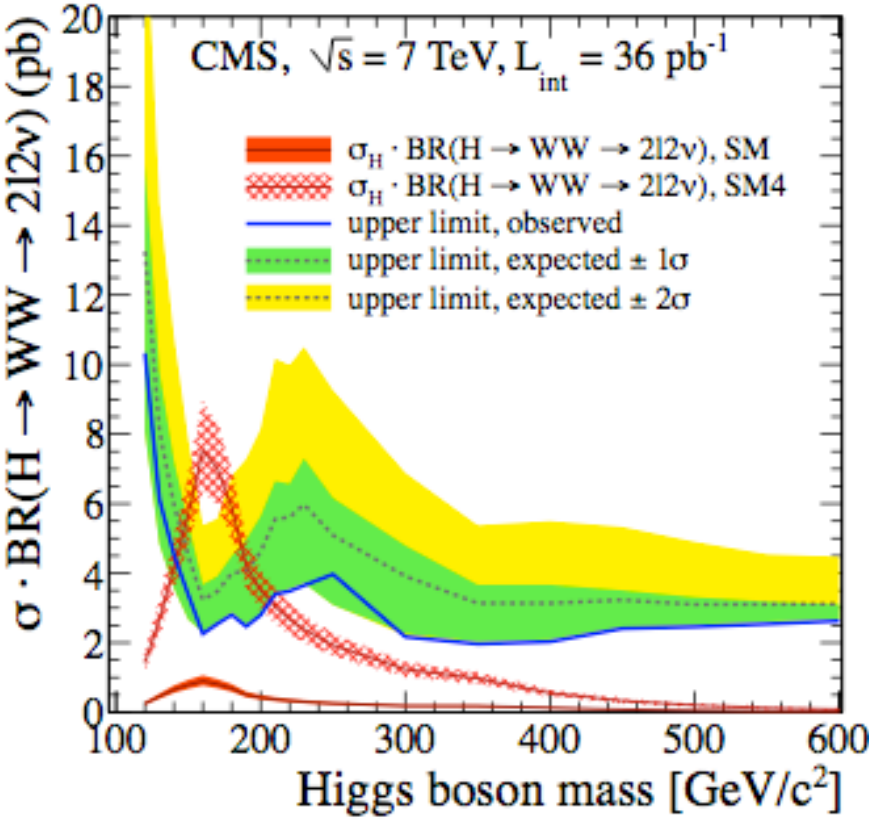
The $pp \rightarrow W^+W^-$ cross section is measured to be 41.1±15.3(stat.)±5.8(syst.)±4.5(lumi.) pb, consistent with the standard model predictions (43.0 ± 2.0 pb) at NLO.

arXiv:1102.5429v1; CMS EWK-10-009 CERN-PH-EP/2011-015 2011/02/26

First LHC result on the SM Higgs: H→WW

36pb^{-1}





- ☞ 4th-f generation case: excluded region m_H = [144 – 207] GeV
- ☞ SM case: excluded ~× 3 SM expectation at m_H = 160 GeV

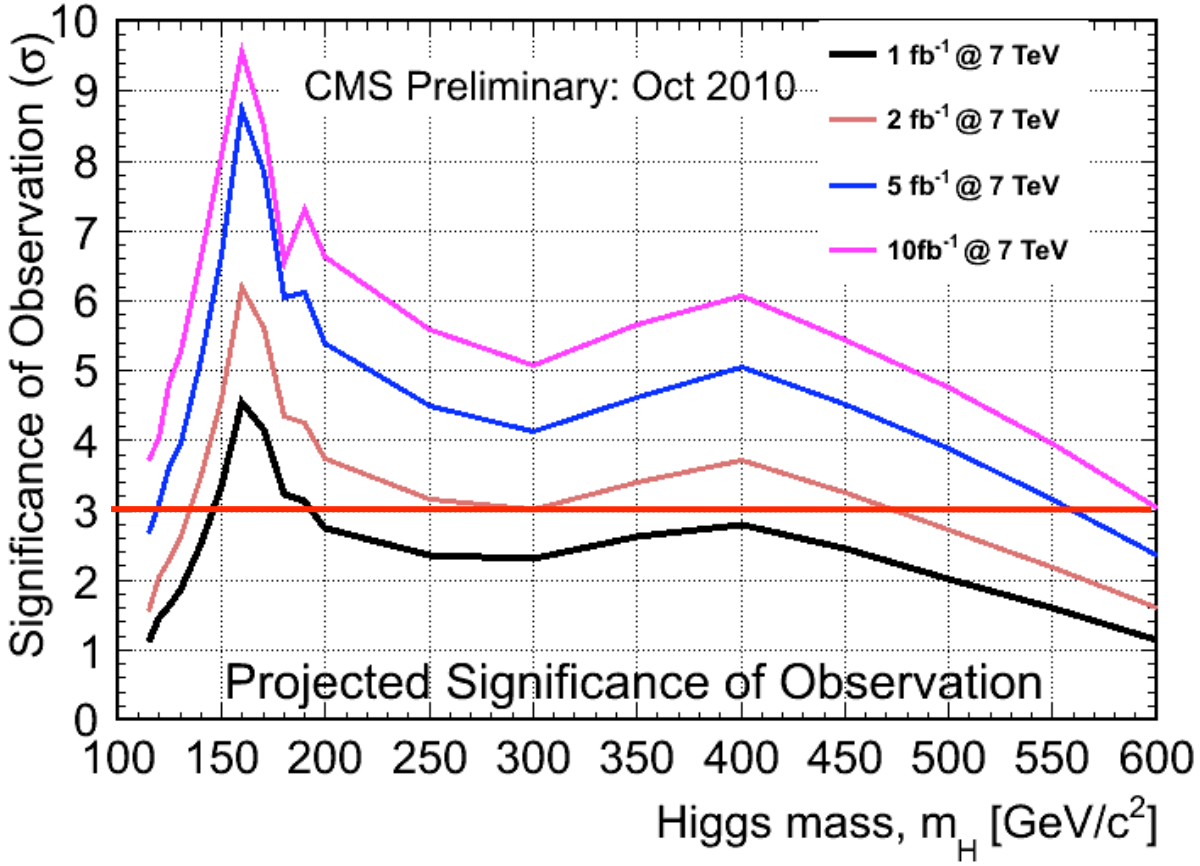
Much more on searches for new physics in Henning Flaecher's talk on Friday

arXiv:1102.5429v1; CMS EWK-10-009 CERN-PH-EP/2011-015 2011/02/26

Outline of the talk

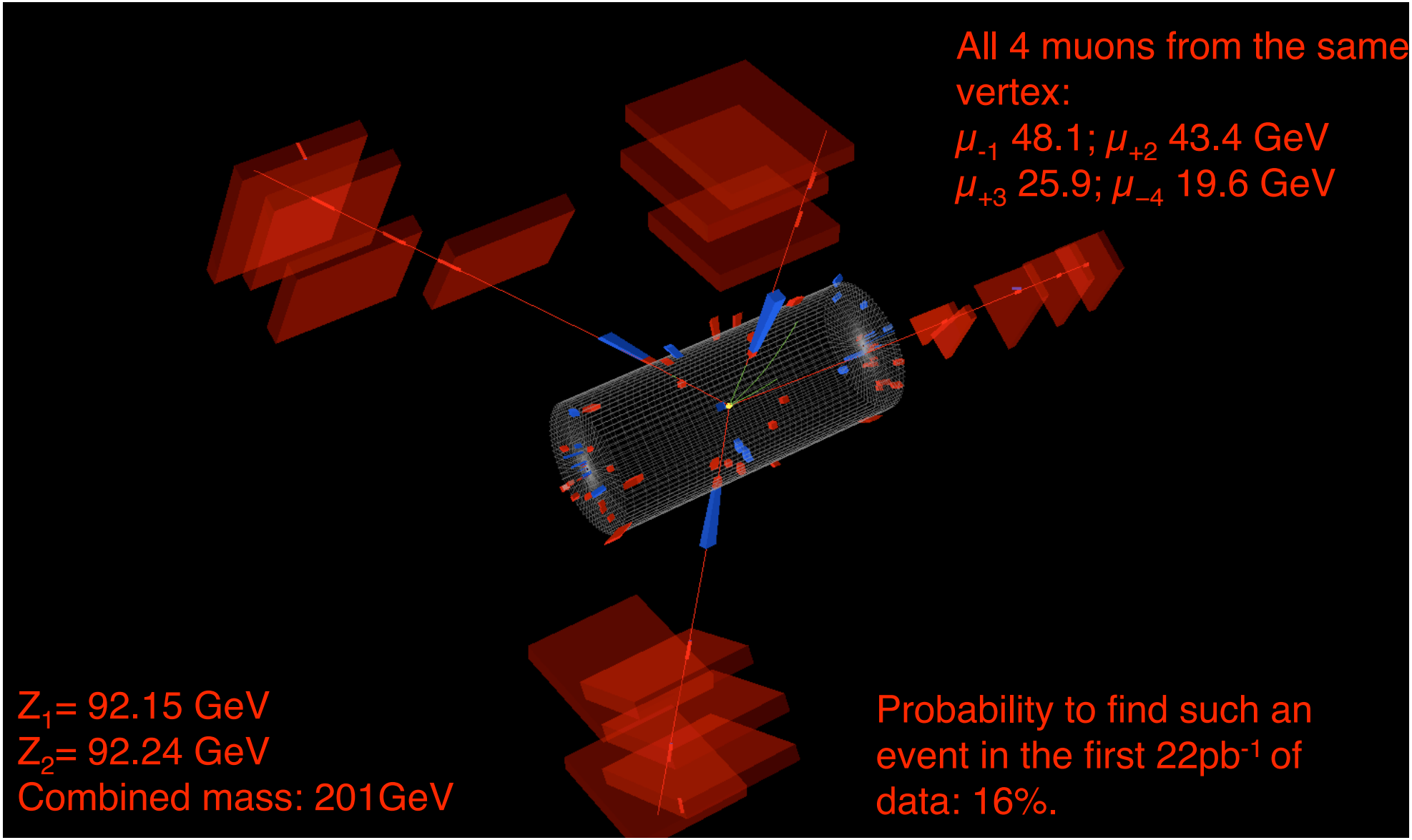
- CMS 2010 data taking
- First results from HI running
- Standard Model Measurements at 7 TeV
- Searches for New Physics
- **Prospects for Higgs Search in 2011-12**
- Conclusion

CMS sensitivity vs Higgs mass



Given the excellent performance of LHC in 2010 and the prospects of getting more integrated luminosity in 2011-12 we have recently re-evaluated the reach of CMS 2011; preliminary studies done, considering for the moment only the most promising channels: **with 10fb^{-1} we can have a 3σ significance for the discovery of the Higgs boson over the mass range between ~115 and ~600GeV.**

The first ZZ→4μ event



Conclusion

• With the 2010 data taking CMS has been able to perform a comprehensive set of Standard Model measurements at 7 TeV.

•The Search for New Physics has started soon afterwards. New limits have been set, in many areas, exceeding the current best limits available from the Tevatron Collider.

• The first results from HI running show new phenomena that are actually under detailed investigation.

• Prospects for Susy, Higgs and Extra-dimensions Search in 2011-12 appear to be very promising.

Stay tuned