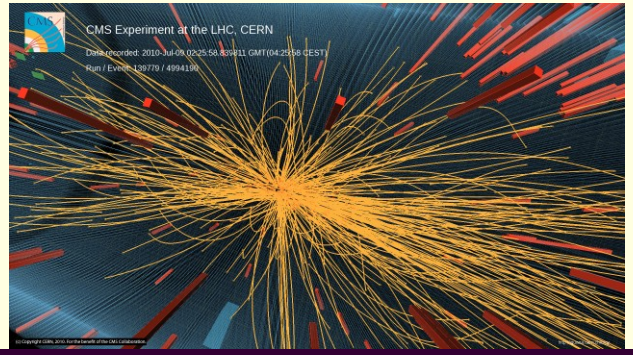
Physics Results from CMS

(First 12 Months of 7 TeV Physics)

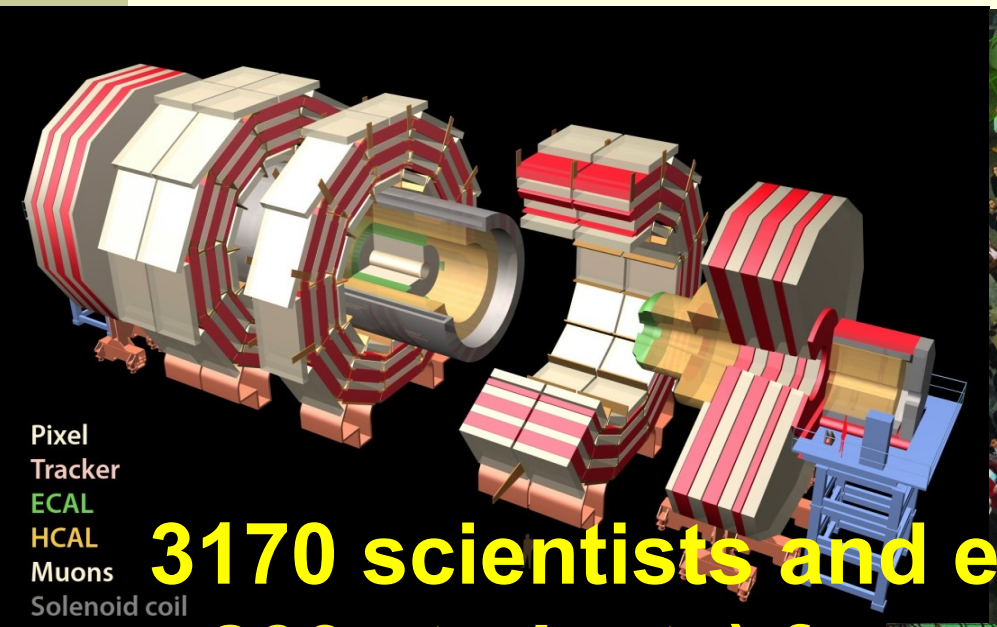


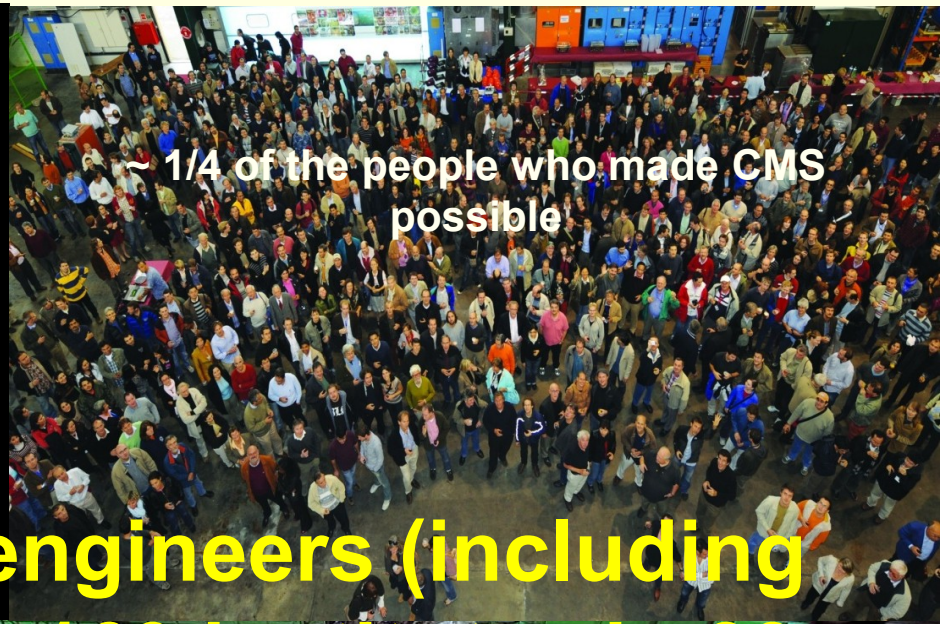
P. SPAGNOLO

CMS Collaboration

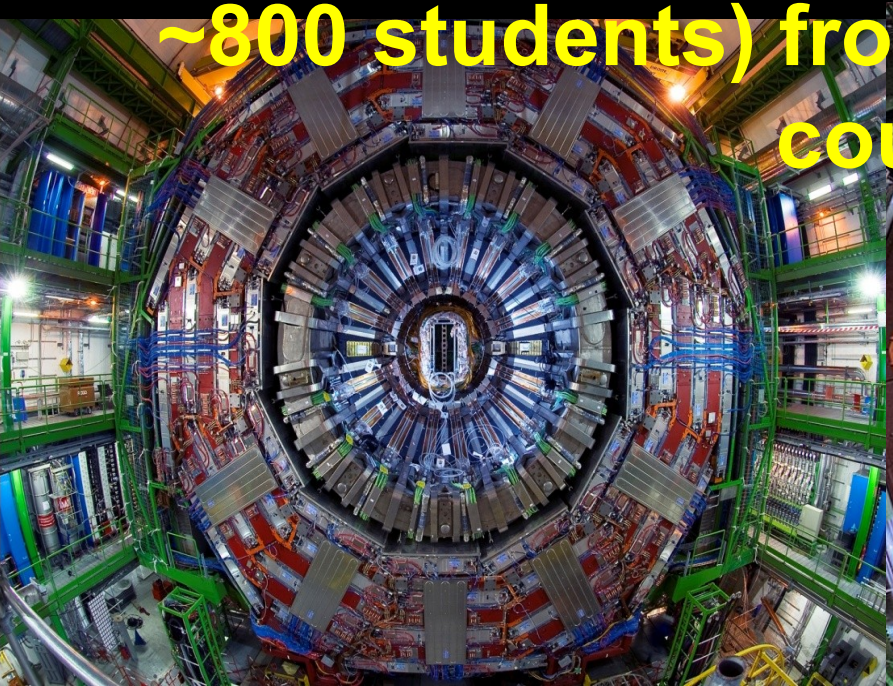
INFN Pisa / CERN

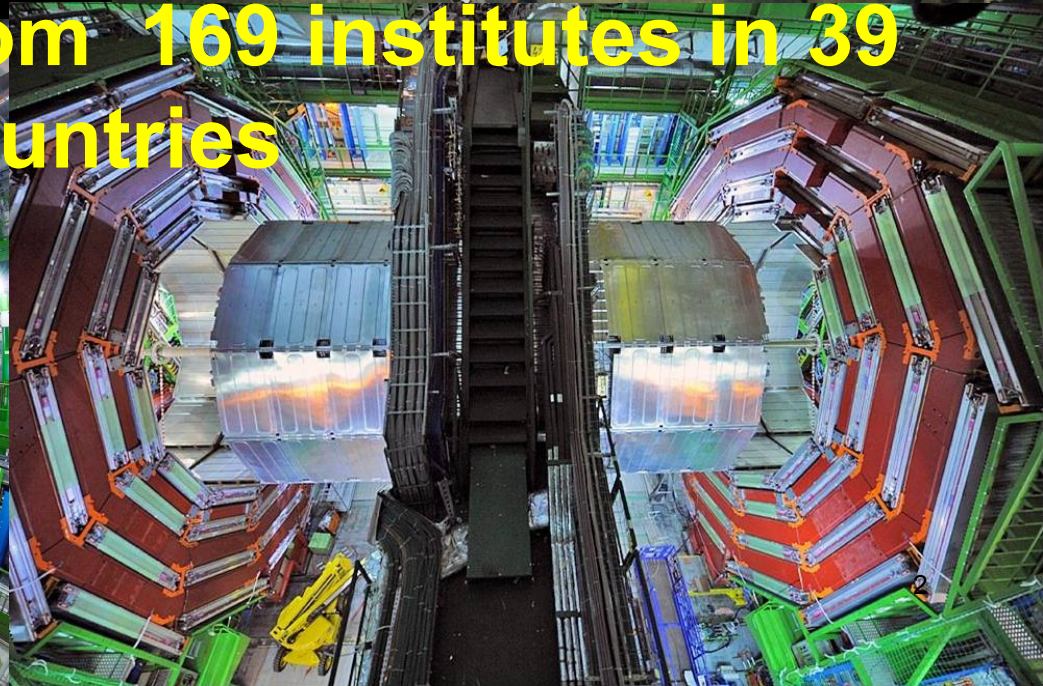
The CMS Collaboration



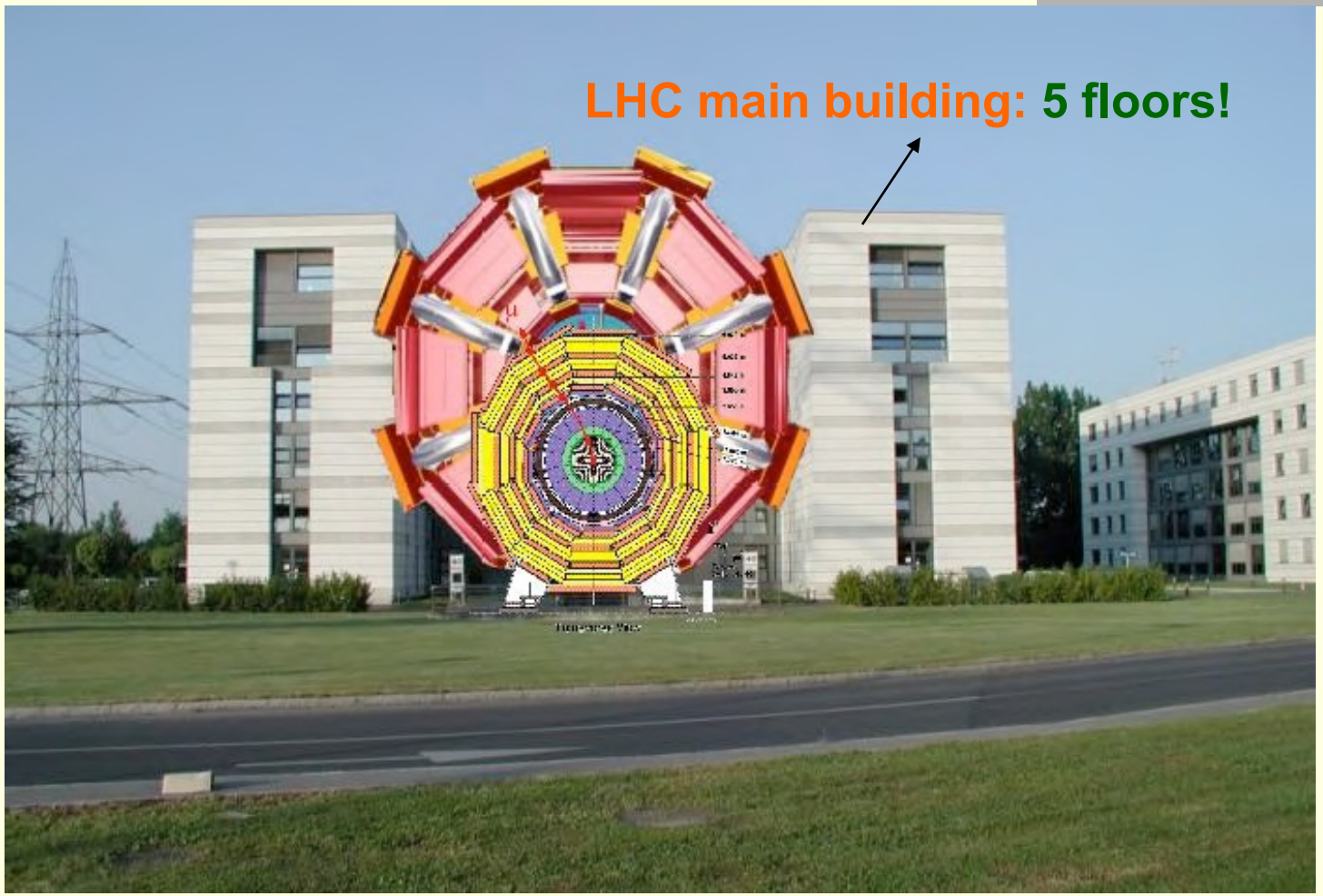


3170 scientists and engineers (including ~800 students) from 169 institutes in 39 countries

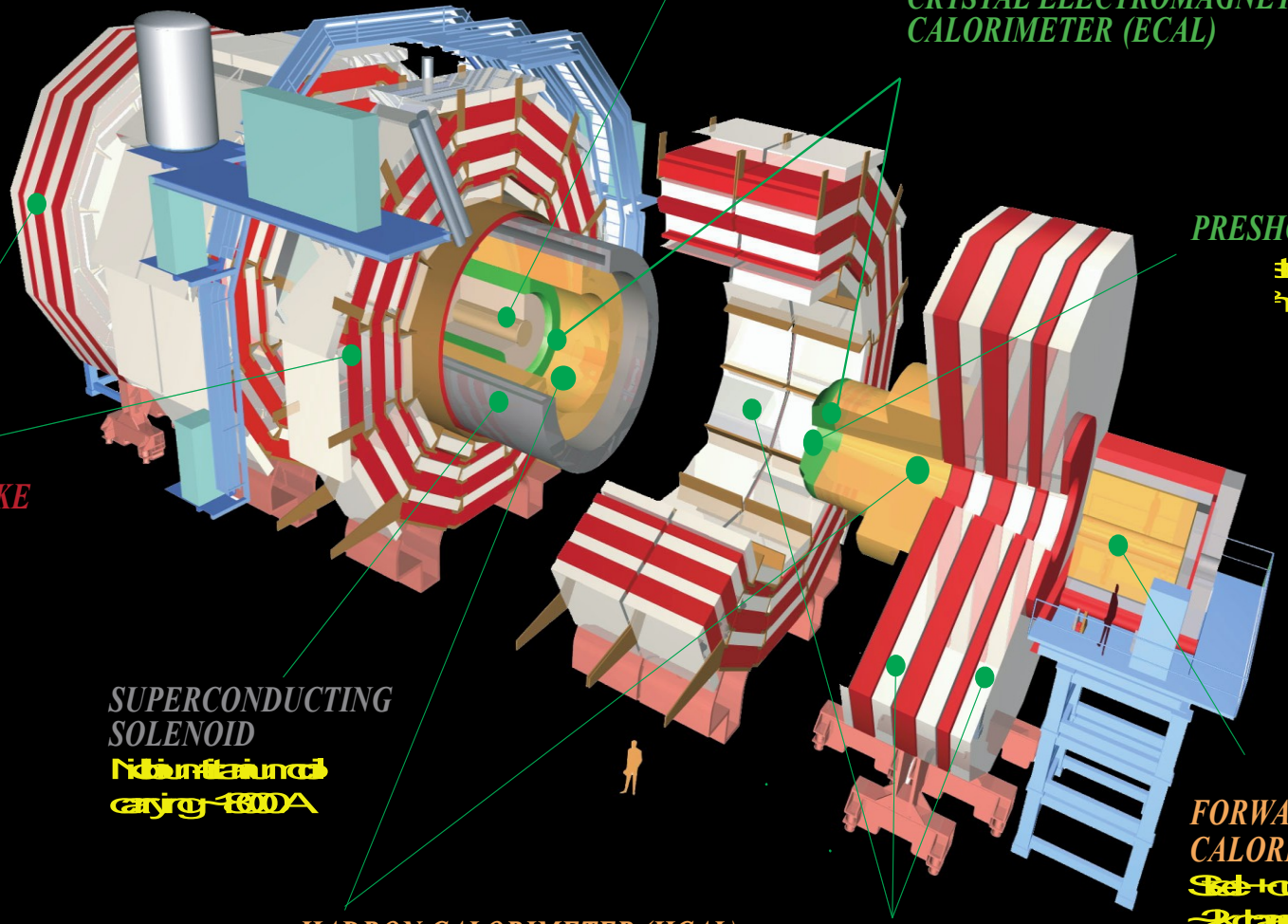




CMS is a Compact Experiment (2x2x2 smaller than ATLAS)



CMS Detector



SILICON TRACKER
Pixels (100 x 150 μm²)
~1 m² ~66 M channels
Microstrips (80 x 180 μm)
~200 m² ~9.6 M channels

CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)

PRESHOWER
Silicon strips
~16 m² ~137 K channels

STEEL RETURN YOKE
~13000 tonnes

SUPERCONDUCTING SOLENOID
Niobium-titanium coil
carrying ~18000 A

HADRON CALORIMETER (HCAL)
Brass + plastic scintillator
~7 K channels

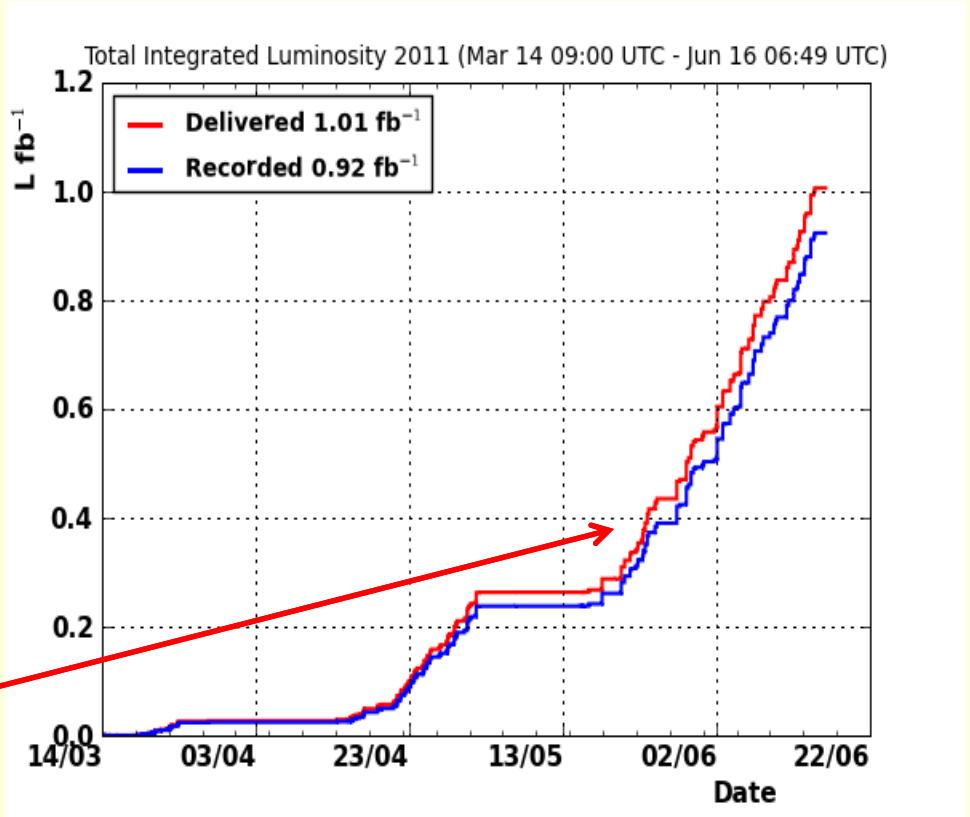
FORWARD CALORIMETER
Steel + quartz fibres
~2 K channels

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

Total weight	: 14000 tonnes
Overall diameter	: 15.0 m
Overall length	: 28.7 m
Magnetic field	: 3.8 T

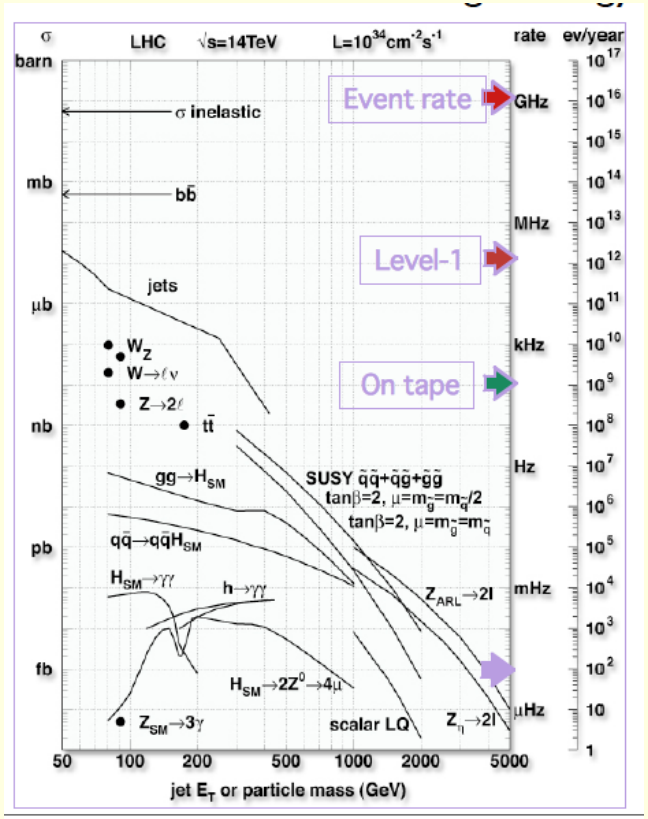
Statistics available in CMS

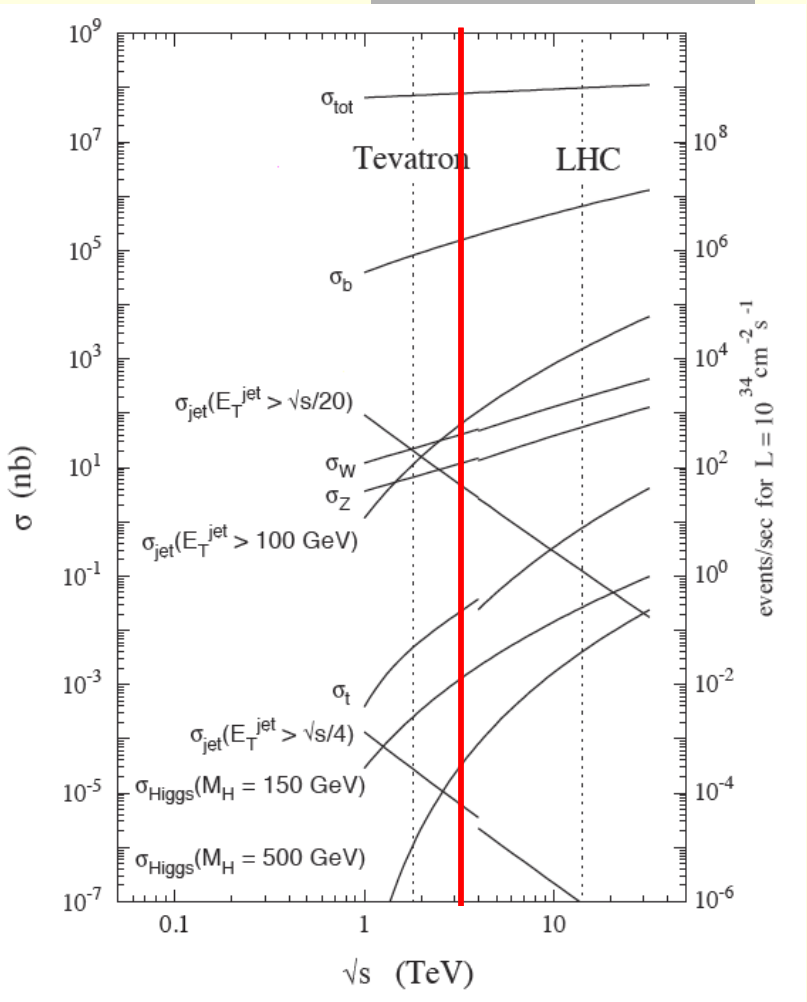
- 2010 @ 7 TeV :
  - 43 pb^{-1}
- 2011 till today:
  - **~ 1 fb^{-1}**
- Important jumps in luminosity (reached **10^{33} $cm^{-2}s^{-1}$**)



LHC vs Tevatron reach as function of energy and luminosity

Even @ 7 TeV LHC is a copious source of SM processes: W, Z and jets





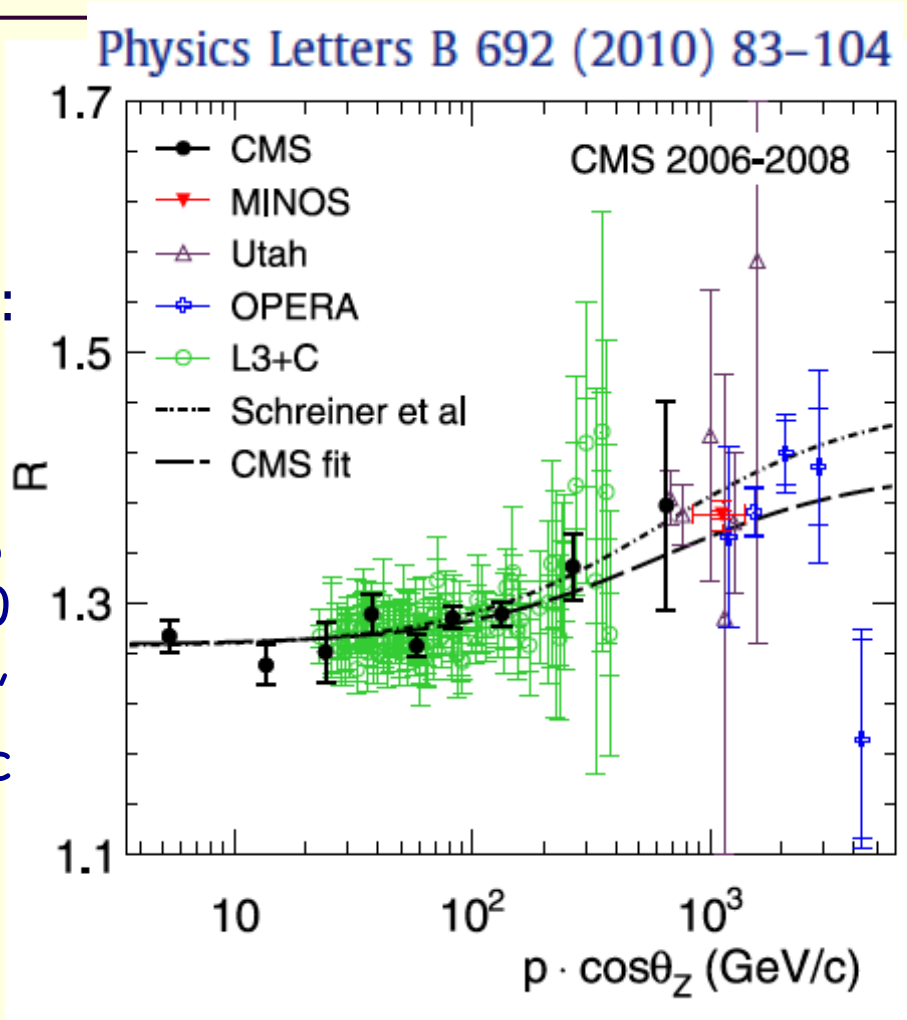
Achievements of CMS

- Physics commissioning (in advanced progress)
- Soft Physics (many results)
- Jet Physics (many results)
- EWK Physics (W and Z cross sections, properties)
- B (and charm) physics at 7 TeV (cross sections)
- Top Physics (the birth of a top factory)
- Search for New Physics (entering a new land)

This talk will not cover the Heavy Ion collisions

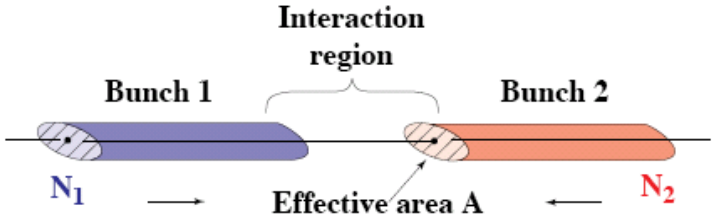
Physics commissioning

- We started well … we owe a lot to **cosmic rays**
- They even provided physics measurements for new PDG
- **Nature, Vol. 6, No 9, Sept 2010**: " ahead of high-energy proton collisions, from cosmic-data-taking runs in 2006 and 2008 ***CMS has achieved the most precise measurement so far***, for muons of momenta lower than 100 GeV/c, of the **muon charge ratio**, which is the ratio of the number of positively charged atmospheric muons to the number of negatively charged ones arriving at the Earth's surface."



How well do we know the absolute luminosity ? Van Der Meer scans

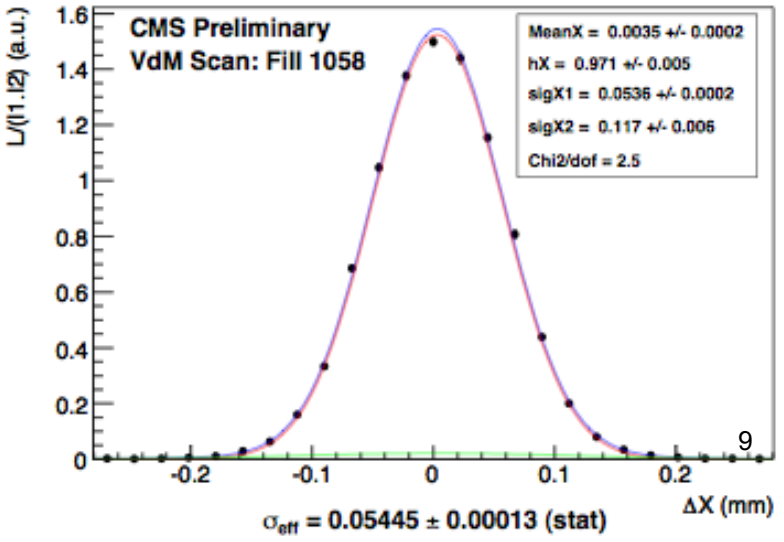
$$\mathcal{L} = \frac{N_1 N_2 f}{A_{\text{eff}}}$$



Beam intensities and crossing frequency are known with good accuracy
The effective overlap area A can be determined by scans in separation

- The present uncertainty dominated by the knowledge of the beam currents.
- 4% in the reprocessed 2010 data
- ~10% in the 2011 (will decrease soon to 4%)

- Event counts with "Monte Carlo cross sections" give consistent results



Soft Physics

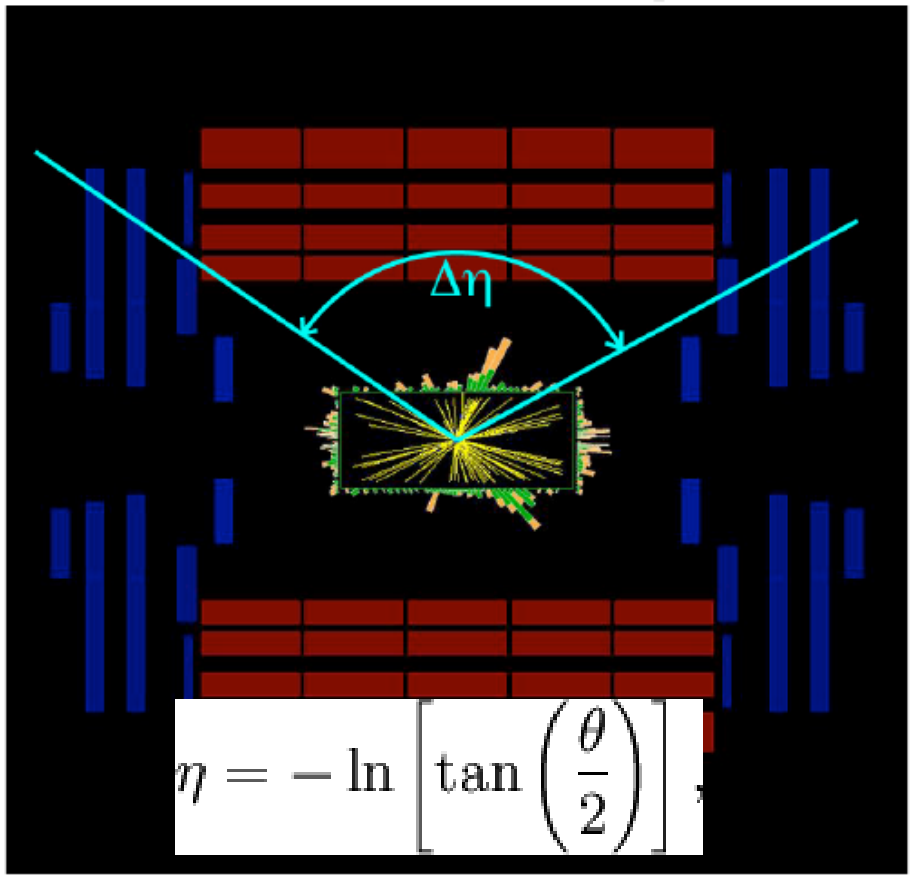
At nominal luminosity (**10^{34}**) 25 inelastic collisions will be superimposed to the interesting events (**pileup**)

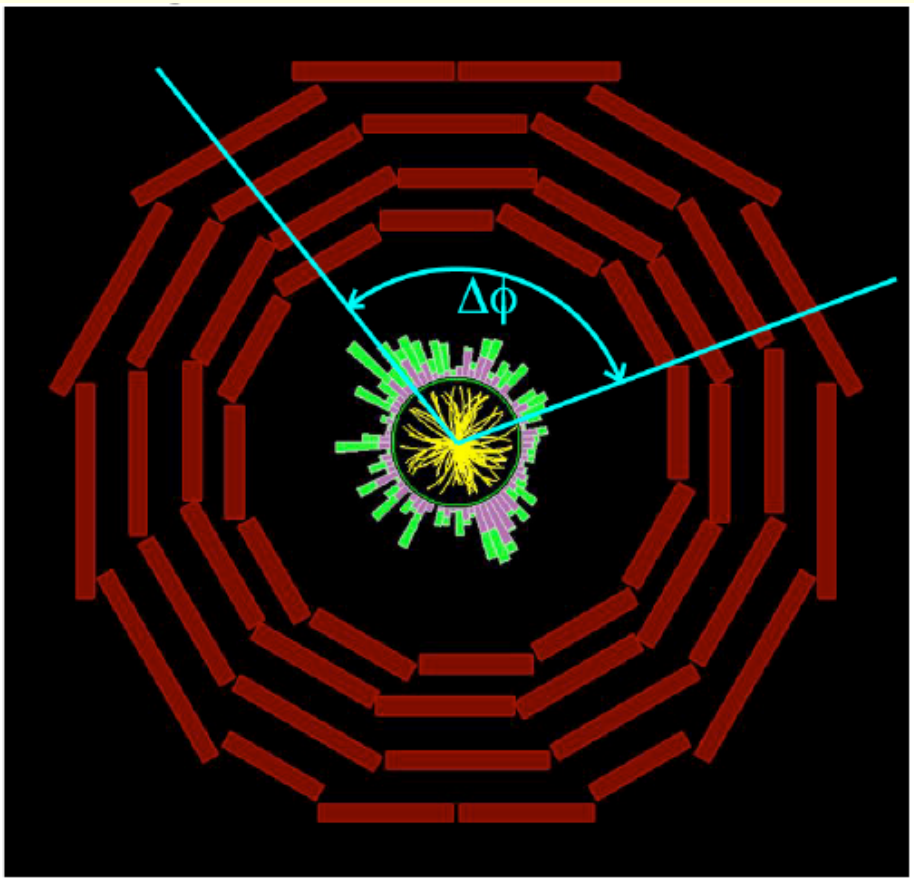
The initial phase (**10^{28} - 10^{31}**) was the right moment to study their properties: we had "**minimal trigger bias**"

We needed also to **tune** the general properties of our **Monte Carlo generators**

We have also to "**calibrate**" the **Heavy Ion** collisions

ϕ η angles definition



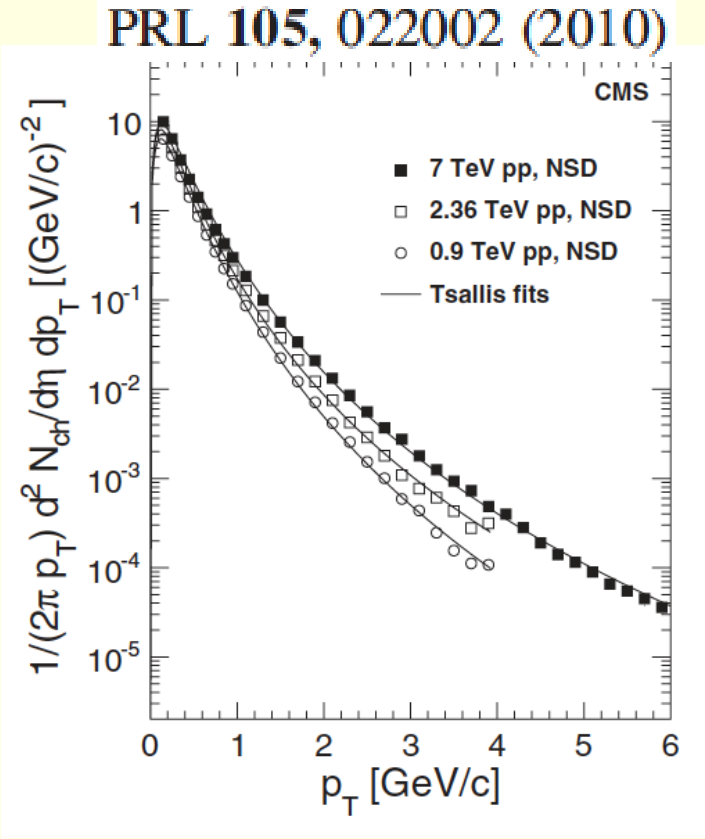


CHARGED HADRONS

Charged-hadron yield in the range|η|<2.4
(systematics smaller than symbols)

1 μb^{-1}

1 hour of data taking
@7 TeV



$$E\frac{d^3N_{\rm ch}}{dp^3} = \frac{1}{2\pi p_{\rm T}}\frac{E}{p}\frac{d^2N_{\rm ch}}{d\eta\, dp_{\rm T}} = C\frac{dN_{\rm ch}}{dy}\left(1+\frac{E_{\rm T}}{nT}\right)^{-n}$$

Multiplicity distributions

J. High Energy Phys. 01 (2011) 079

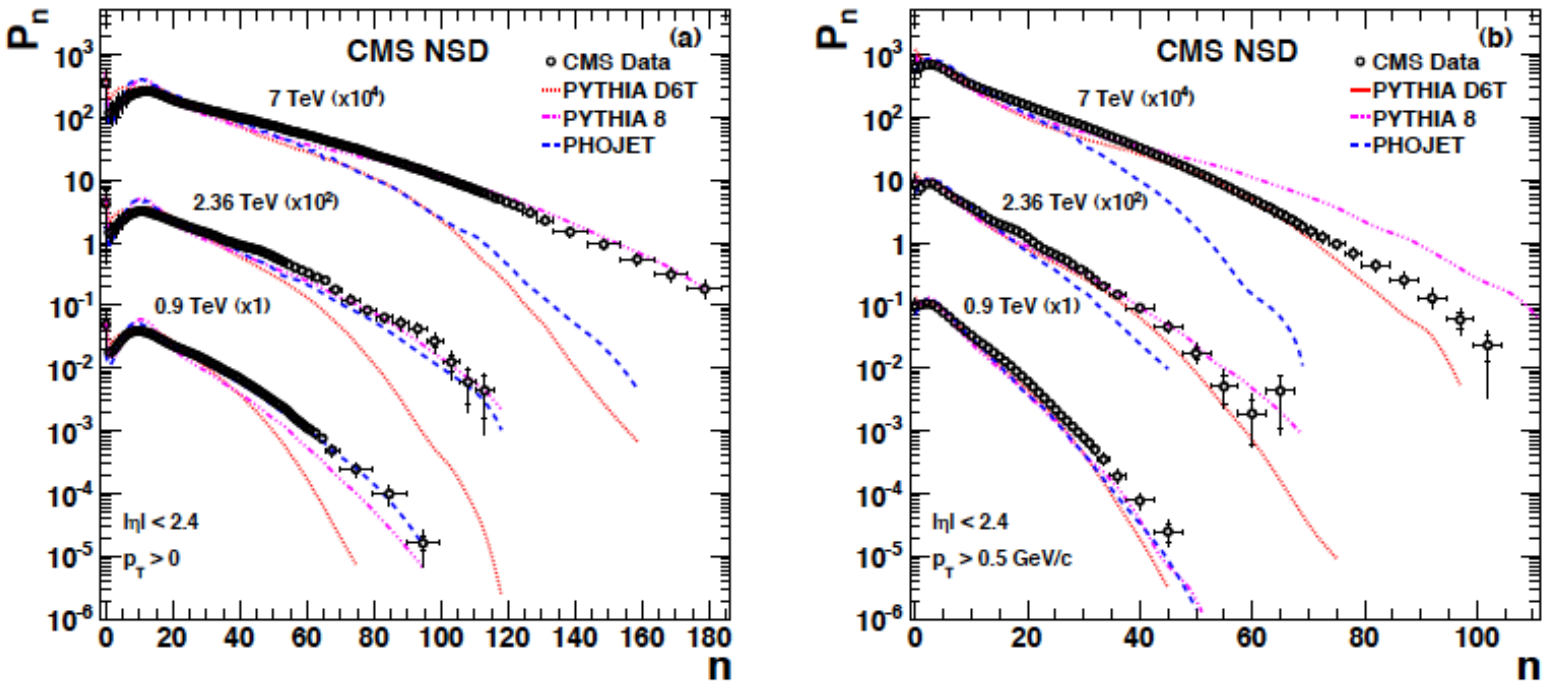


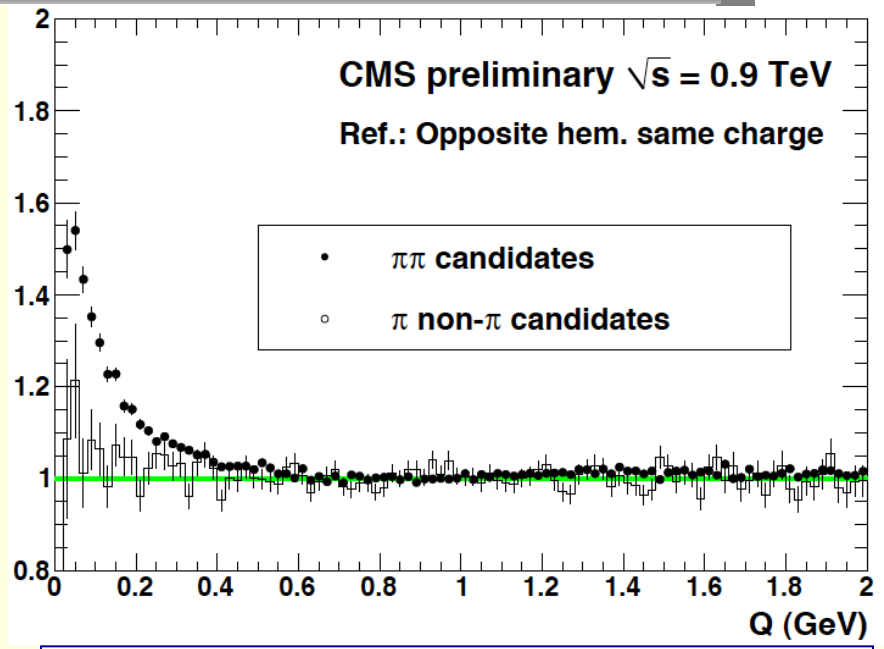
Figure 3: The charged hadron multiplicity distributions with $|\eta| < 2.4$ for (a) $p_{\mathrm{T}} > 0$ and (b) $p_{\mathrm{T}} > 500\,\mathrm{MeV}/c$ at $\sqrt{s} = 0.9$, 2.36, and 7 TeV, compared to two different PYTHIA models and the PHOJET model. For clarity, results for different centre-of-mass energies are scaled by powers of 10 as given in the plots.

Bose-Einstein Correlations

Phys. Rev. Lett. : 105 (2010) , pp. 032001

Correlation is studied using the ratio R between join probability of emission of a pair of bosons and the individual probabilities.

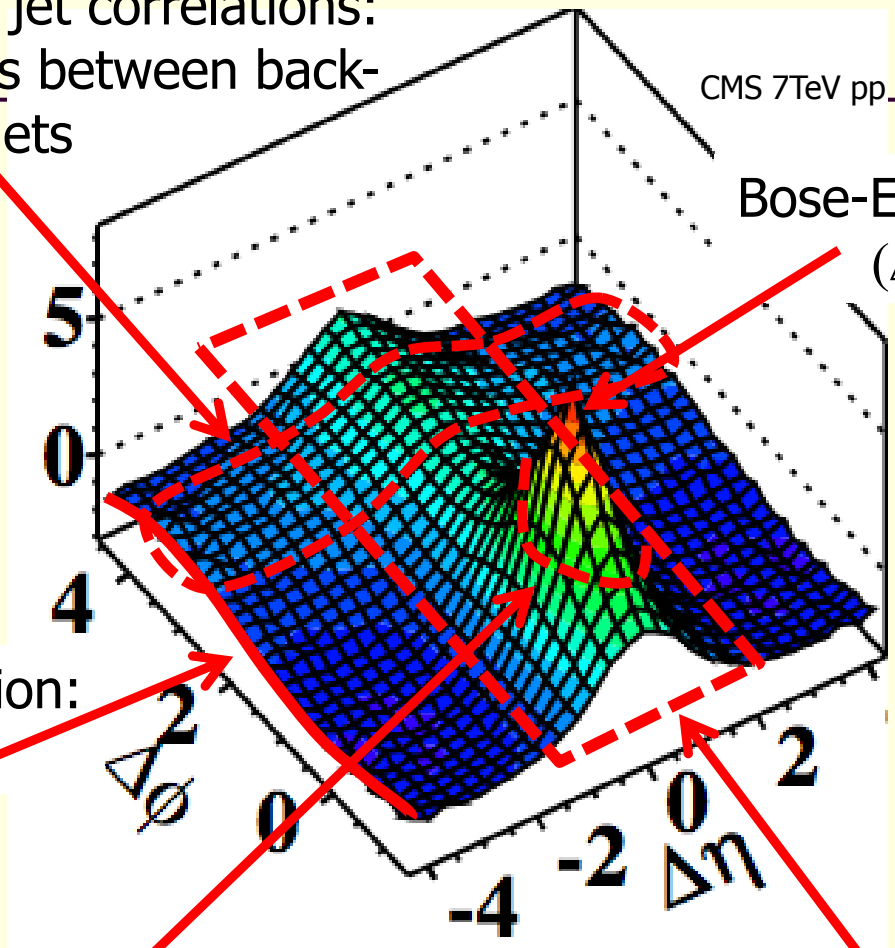
$$R = \frac{P(p_1,p_2)}{P(p_1)\ P(p_2)}$$



$$Q = \sqrt{-(p_1 - p_2)^2} = \sqrt{m_{inv}^2 - 4m_\pi^2}$$

Angular Correlation Functions

"Away-side" ($\Delta\phi \sim \pi$) jet correlations: Correlation of particles between back-to-back jets



Bose-Einstein correlations: ($\Delta\phi$,$\Delta\eta$) ~ (0,0)

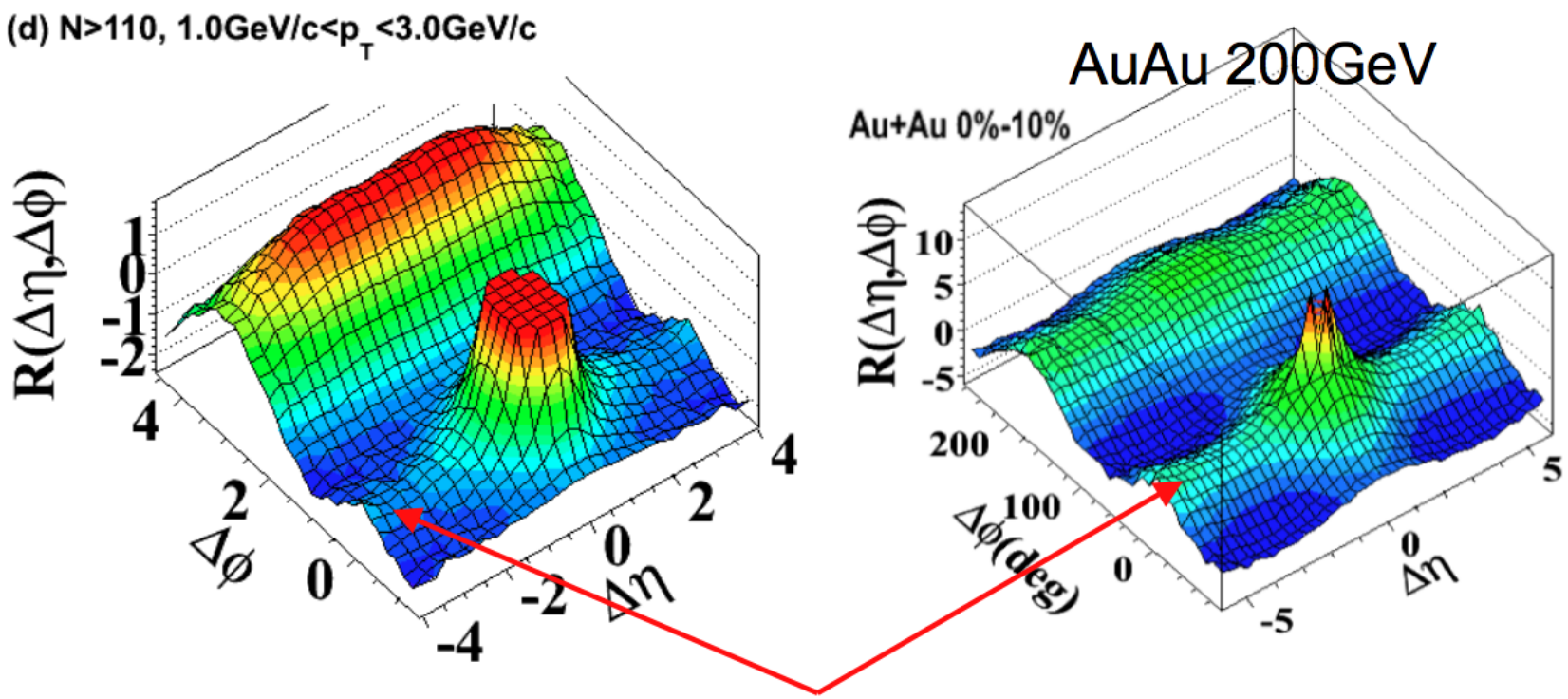
Momentum conservation: ~ -cos($\Delta\phi$)

"Near-side" ($\Delta\phi \sim 0$) jet peak: Correlation of particles within a single jet

Short-range correlations ($\Delta\eta < 2$): Resonances, string fragmentation, "clusters"

Long-range near-side correlations in high multiplicity events (N>110)

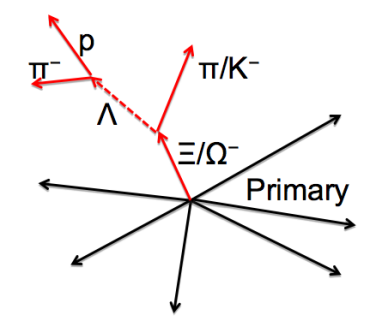
J. High Energy Phys. 09 (2010) 091



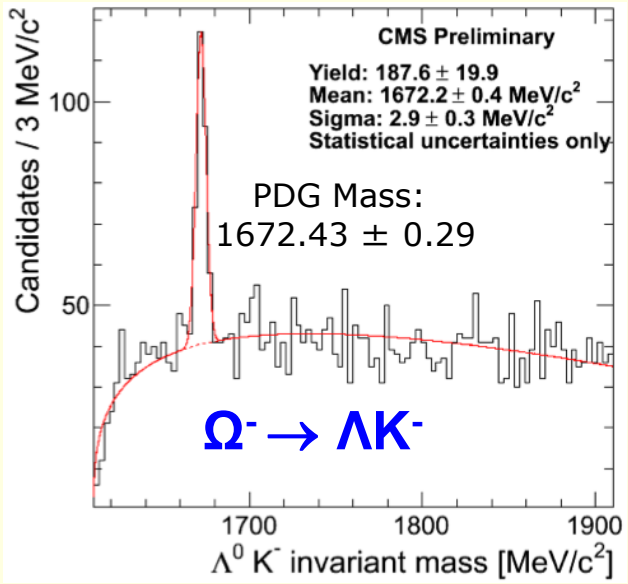
Similar "ridge" in high multiplicity pp
(even similar p_T dependence)

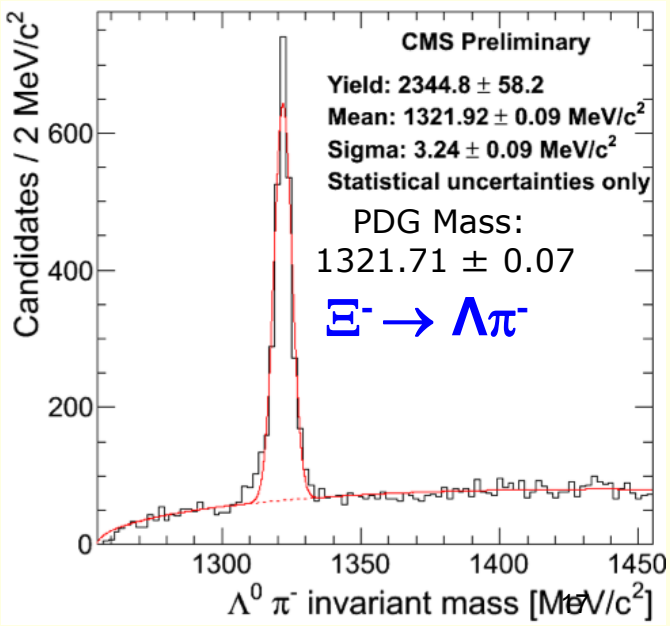
Low mass resonances

- Tracks displaced from primary vertex ($d_{3D} > 3\sigma$)
- Common displaced vertex ($L_{3D} > 10\sigma$)



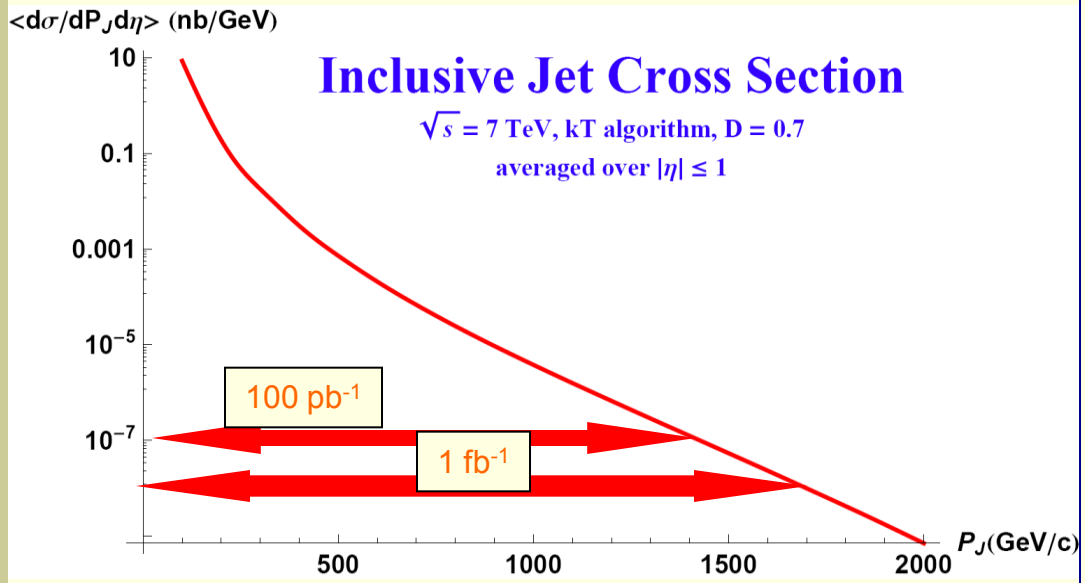
Invariant mass distribution for different combinations ($\Omega^{\pm} \to \Lambda K^{\pm}$ or $\Xi^{\pm} \to \Lambda\pi^{\pm}$) fit to a common vertex.





Jets

Jet Physics has started

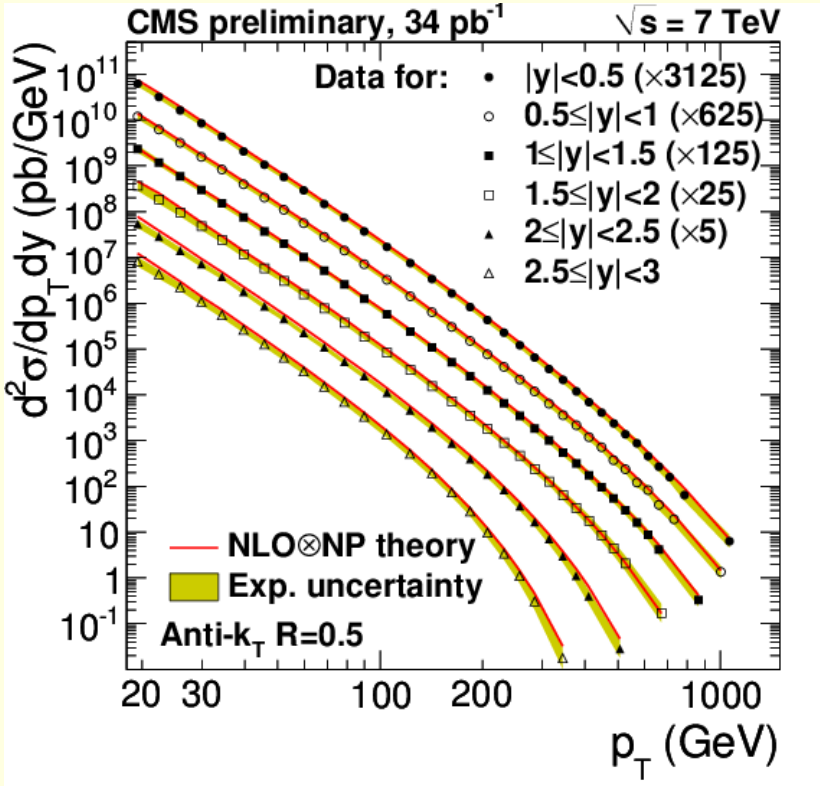


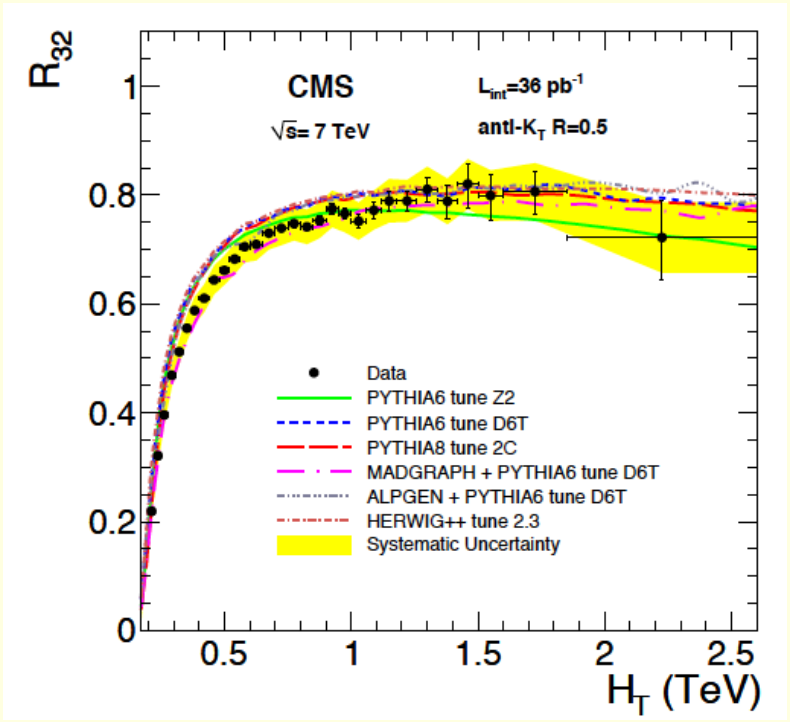
- Expect to reach jets with E_T's of around 1.7 TeV after the first 1 fb^{-1}
- Reminder: as a rule of thumb, the sensitivity to a contact interaction Λ is roughly 4x the E_T of the most energetic jet.

NLO QCD jet spectrum – no detector effects included

Inclusive jet cross sections

CMS-PAS-QCD-2010-011/12

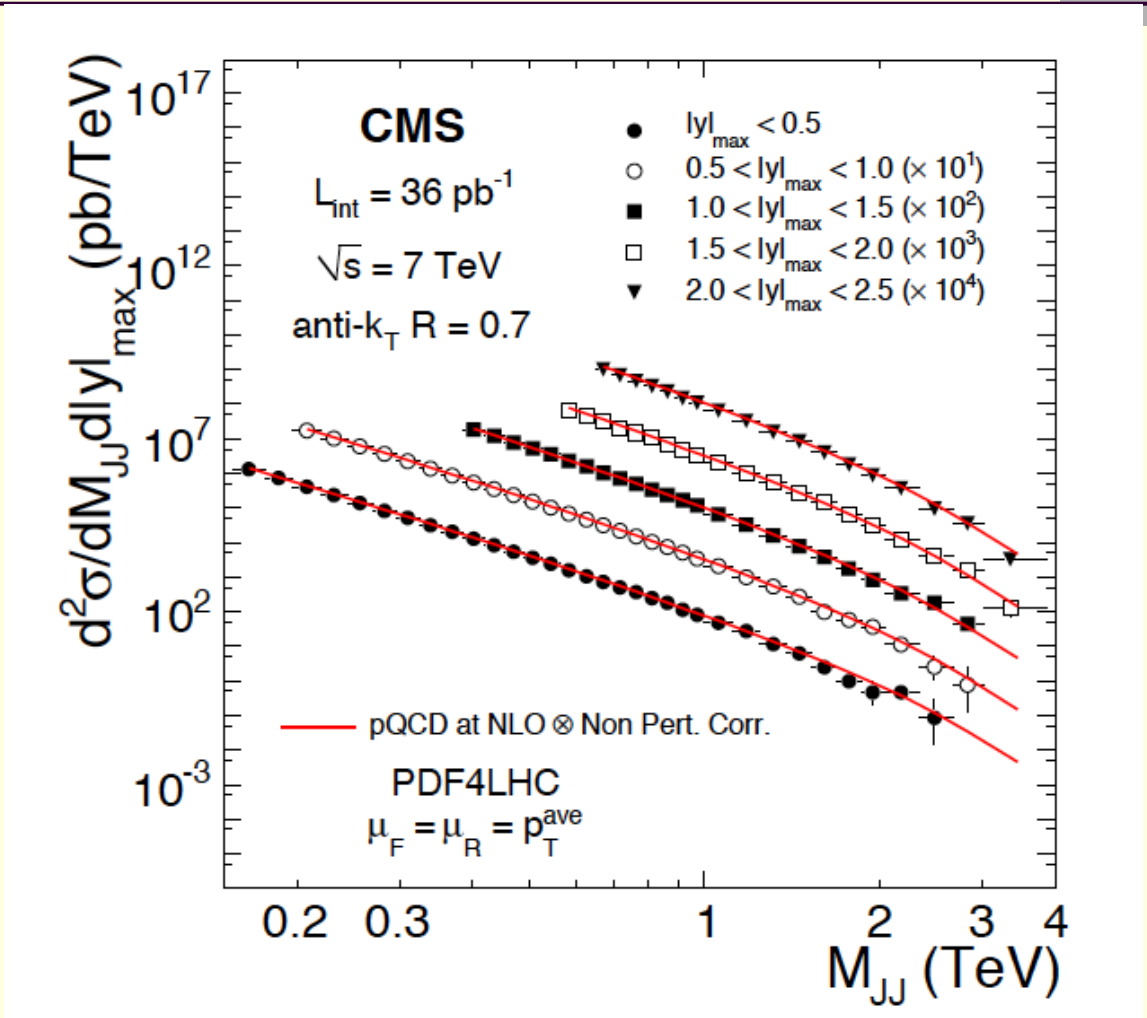




R_{32} = ratio 3 jets/2 jets events

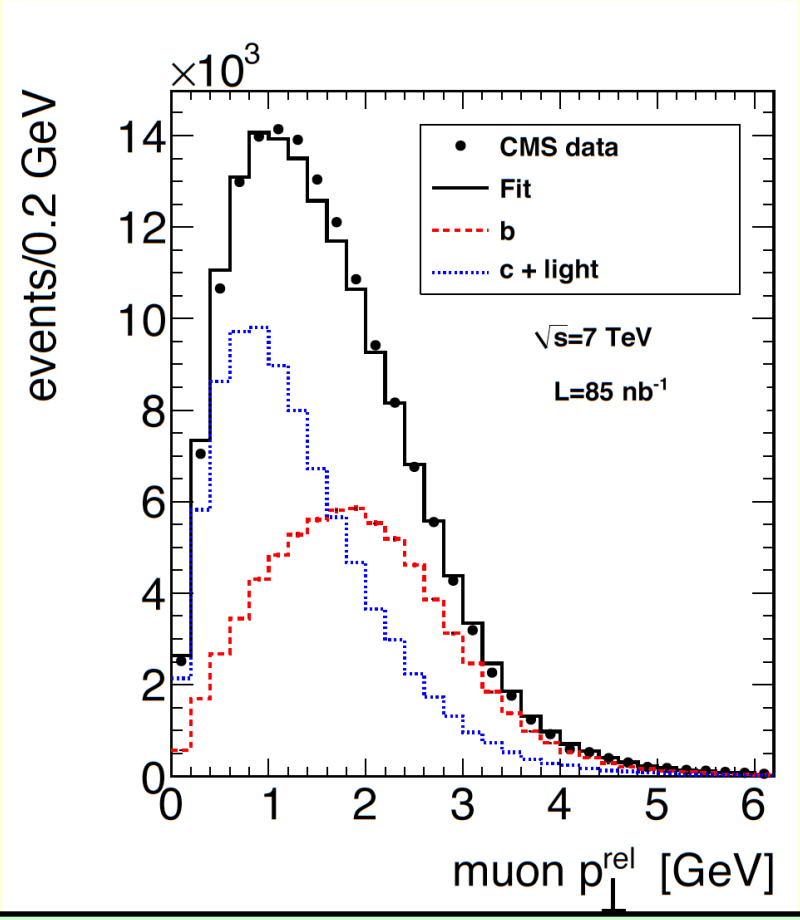
Inclusive jet cross sections

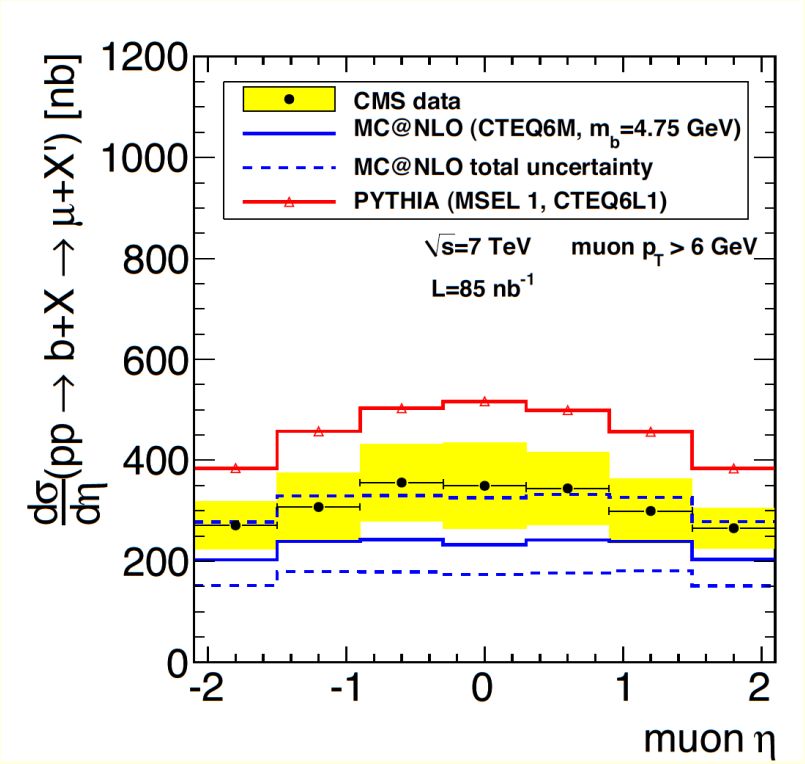
CMS-PAS-QCD-2010-025
Accepted by Phys. Lett. B



First b cross section measurements at 7 TeV : lepton tagging

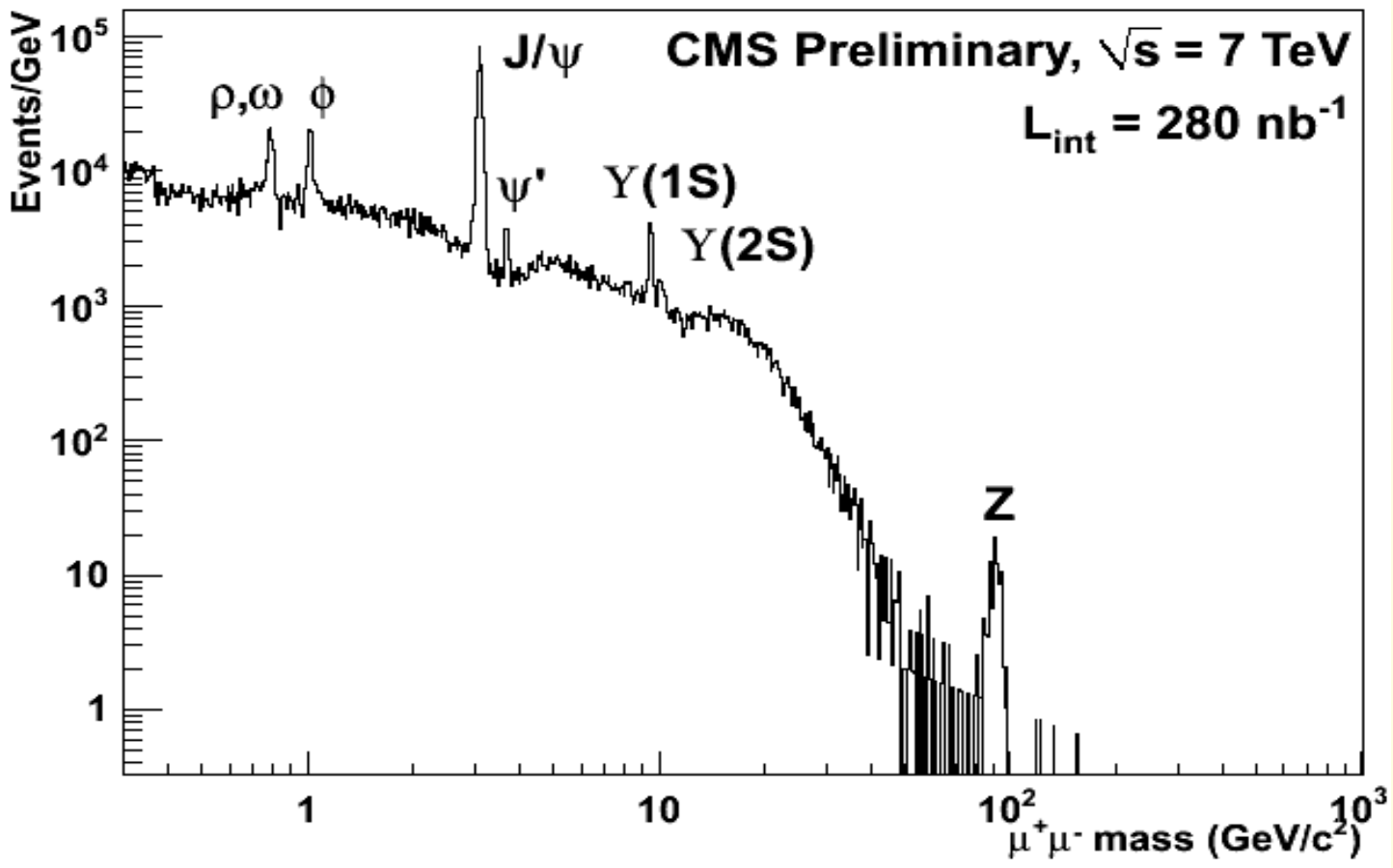
JHEP 1103 (2011) 090





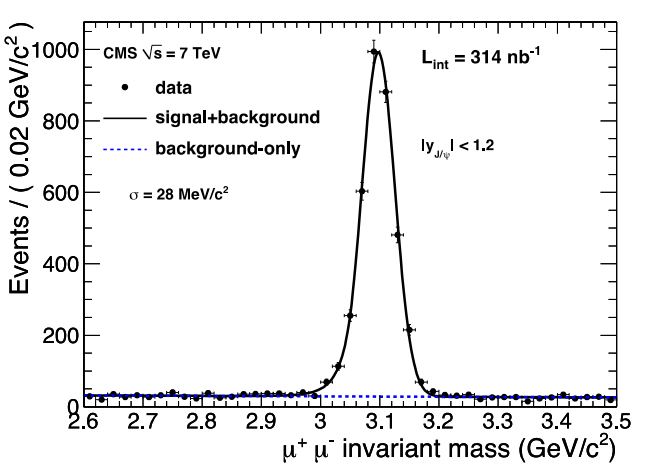
$\sigma(pp \to b + X \to \mu + X') = 1.32 \pm 0.01(stat) \pm 0.30(syst) \pm 0.15(lumi) \mu b$

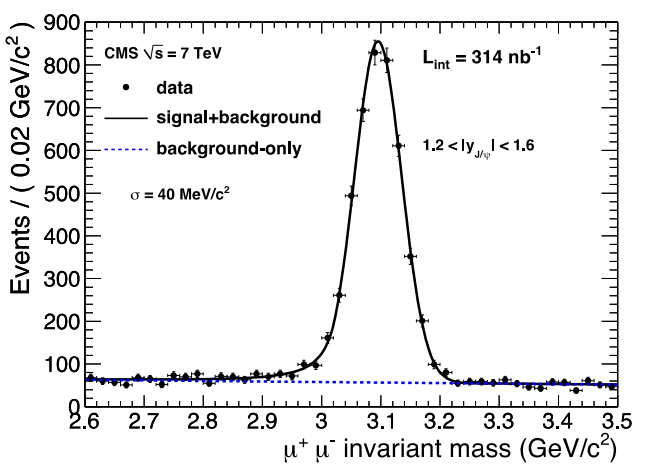
Dilepton resonances at 7 TeV

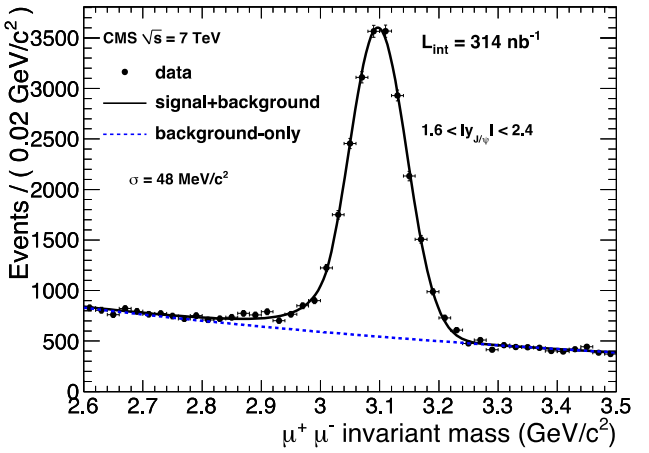


$J/\psi \rightarrow \mu^+\mu^-$

$$\sigma(pp \rightarrow J/\psi + X) \cdot \mathrm{BR}(J/\psi \rightarrow \mu^+\mu^-) = 97.5 \pm 1.5(\mathrm{stat}) \pm 3.4(\mathrm{syst}) \pm 10.7(\mathrm{luminosity})\ \mathrm{nb}.$$

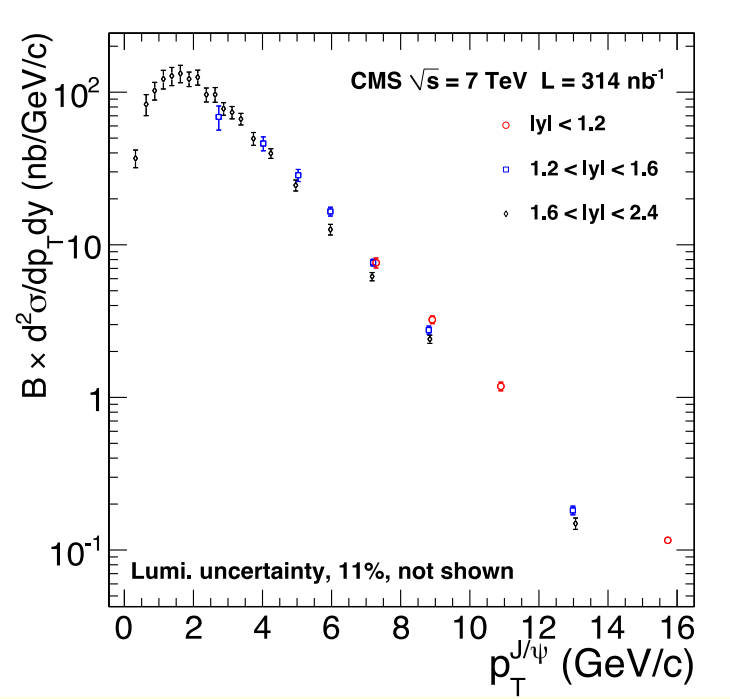


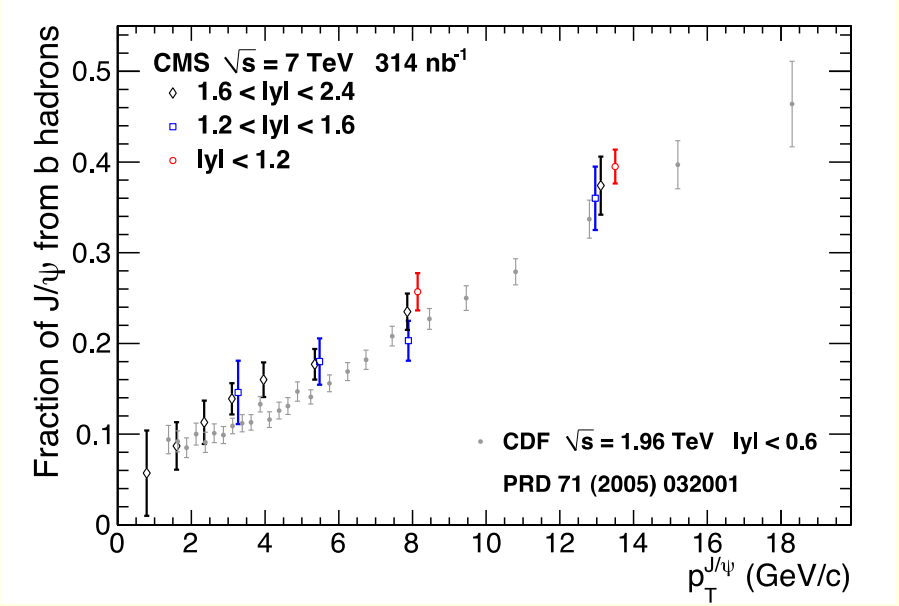




Inclusive J/ψ cross section and fraction from b

Eur.Phys.J. C71 (2011) 1575



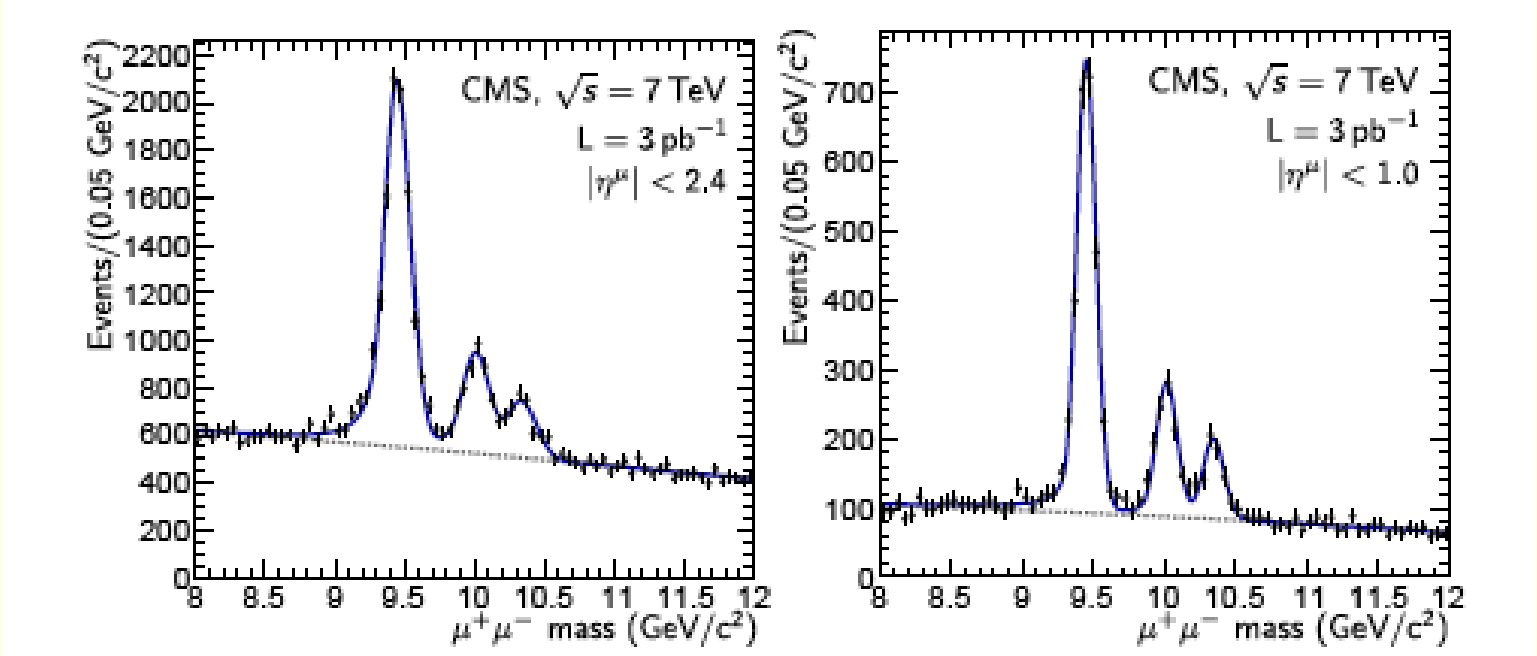


$$BR(\mathrm{J}/\psi \to \mu^+\mu^-) \cdot \sigma(\mathrm{pp} \to \text{prompt J}/\psi) = 70.9 \pm 2.1 \pm 3.0 \pm 7.8 \text{ nb}$$

$$BR(\mathrm{J}/\psi \to \mu^+\mu^-) \cdot \sigma(\mathrm{pp} \to bX \to \mathrm{J}/\psi X) = 26.0 \pm 1.4 \pm 1.6 \pm 2.9 \text{ nb}$$

First Upsilon measurements at 7 TeV

CERN-PH-EP-2010-055

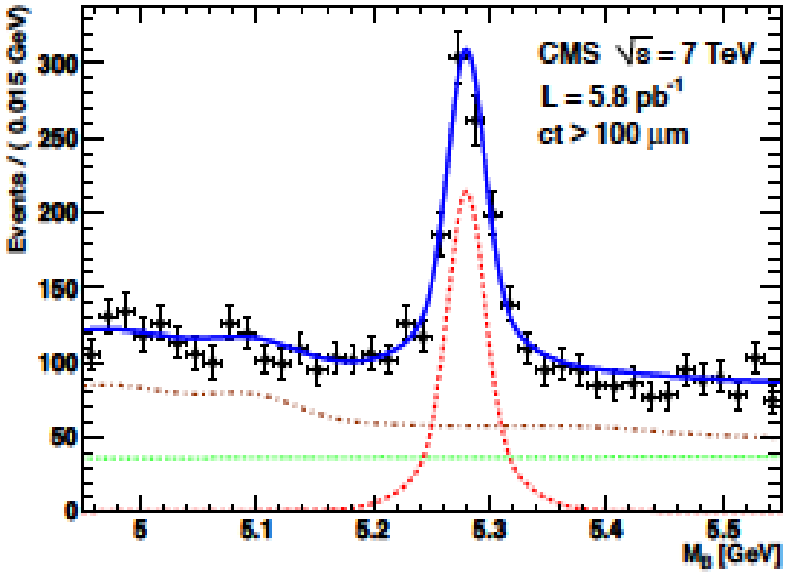


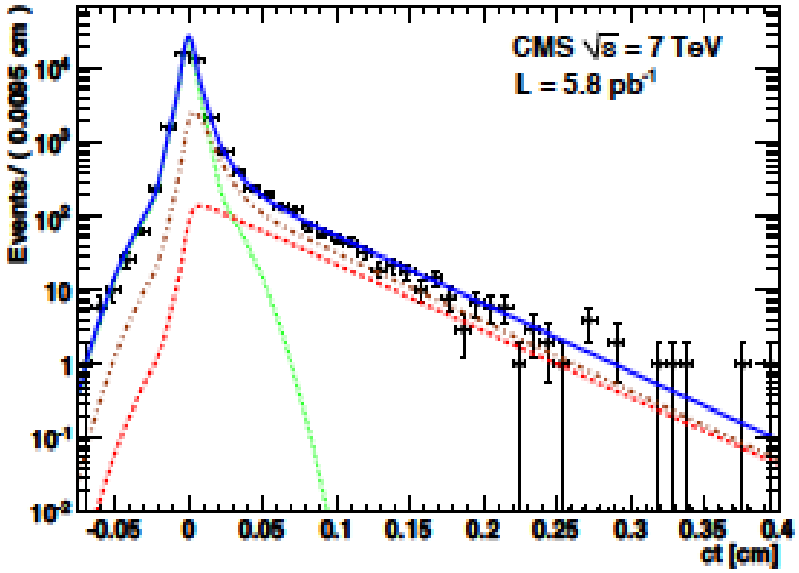
$$\sigma(\mathrm{pp} \to \Upsilon(1S)X) \cdot \mathcal{B}(\Upsilon(1S) \to \mu^+\mu^-) = 7.37 \pm 0.13(\mathrm{stat.})^{+0.61}_{-0.42}(\mathrm{syst.}) \pm 0.81(\mathrm{lumi.})\,\mathrm{nb},$$
$$\sigma(\mathrm{pp} \to \Upsilon(2S)X) \cdot \mathcal{B}(\Upsilon(2S) \to \mu^+\mu^-) = 1.90 \pm 0.09(\mathrm{stat.})^{+0.20}_{-0.14}(\mathrm{syst.}) \pm 0.24(\mathrm{lumi.})\,\mathrm{nb},$$
$$\sigma(\mathrm{pp} \to \Upsilon(3S)X) \cdot \mathcal{B}(\Upsilon(3S) \to \mu^+\mu^-) = 1.02 \pm 0.07(\mathrm{stat.})^{+0.11}_{-0.08}(\mathrm{syst.}) \pm 0.11(\mathrm{lumi.})\,\mathrm{nb}.$$

Cross-section of $B^+ \rightarrow K^+ J/\psi$

L = 5.8 pb^{-1}

Phys.Rev.Lett.106:112001,2011





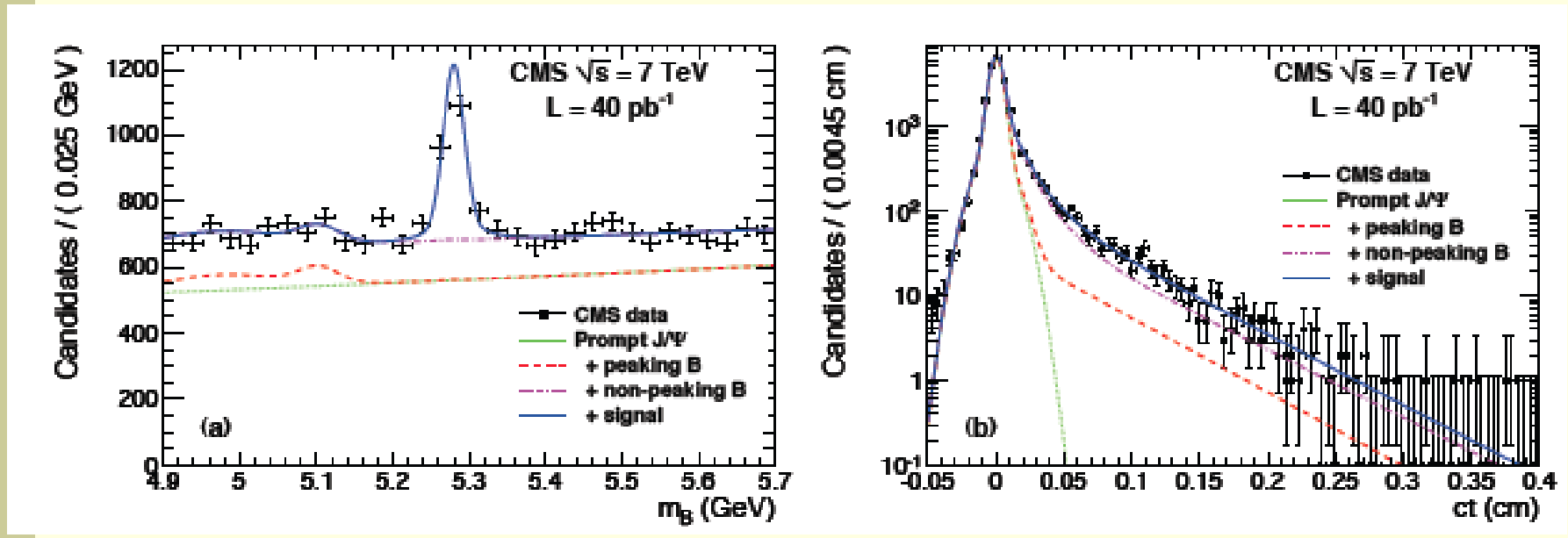
for $p_T^B > 5\,\text{GeV}$ and $|y^B| < 2.4$

The total integrated cross section = $28.1 \pm 2.4 \pm 2.0 \pm 3.1\ \mu b$

Cross-section of $B^0 \rightarrow K^0_s J/\psi$

L = 5.8 pb^{-1}

CERN-PH-EP-2011-034



$$p_T^B > 5\,\text{GeV and } |y^B| < 2.2$$

The total integrated cross section = $33.2 \pm 2.5 \pm 3.5\ \mu b$

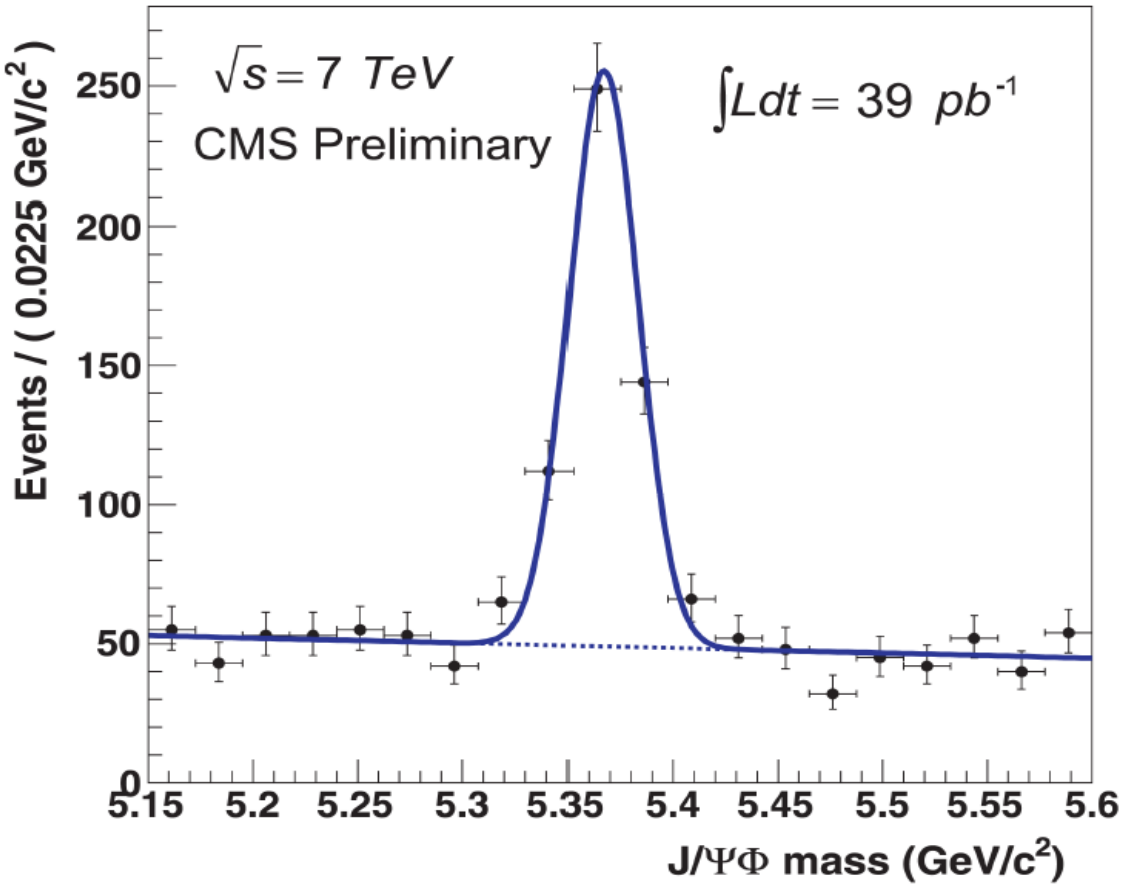
Bs → J/Ψφ mass peak

Fit:

an extended maximum likelihood fit with a single Gaussian plus a first order polynomial curve, all parameters free to float.

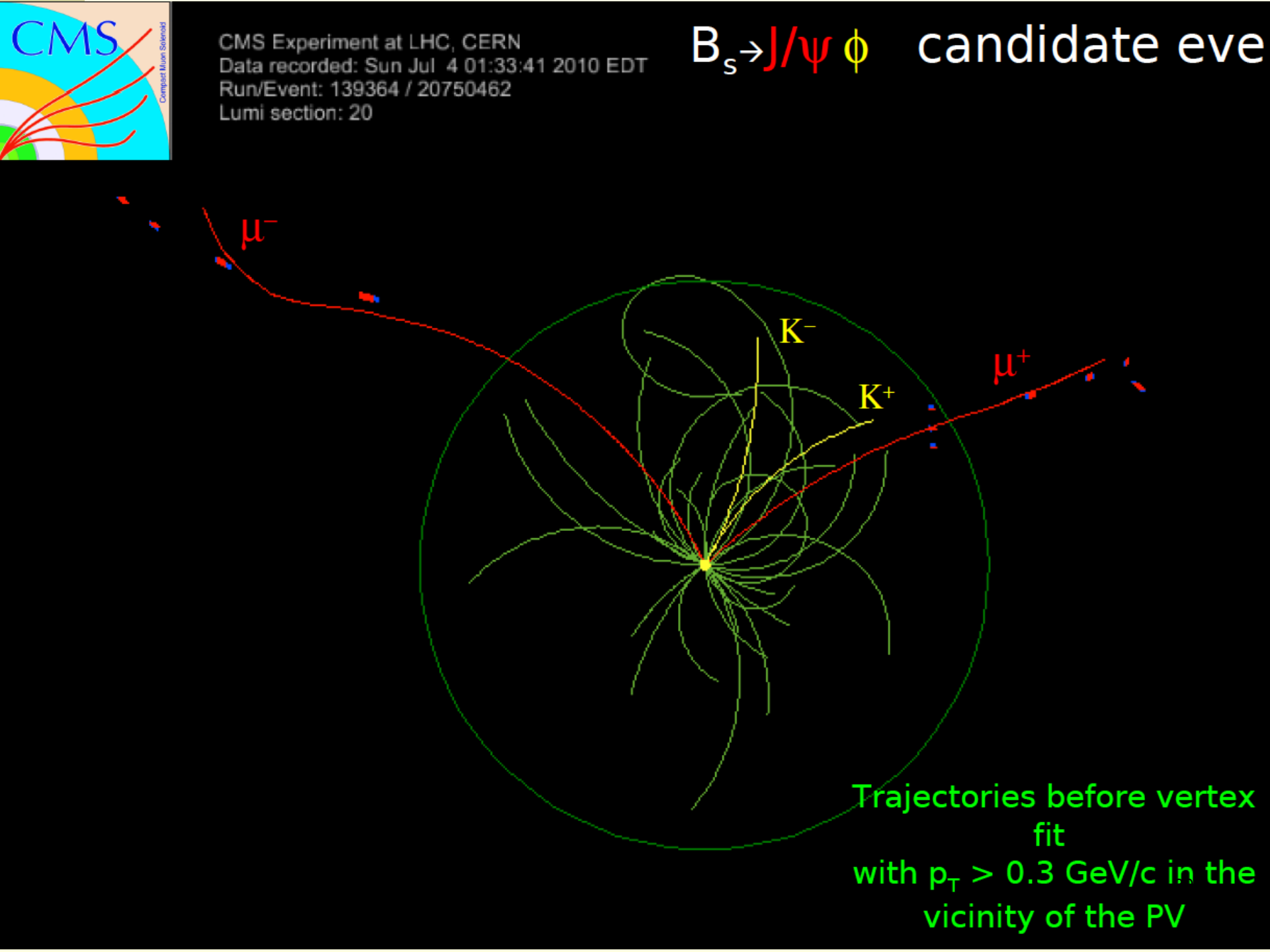
Fit results:

μ_{gauss} = 5.3670 ± 0.0012 GeV/c²
σ_{gauss} = 16.4 ± 1.2 MeV/c²
N_{signal} = 377 ± 26
N_{BG} = 978 ± 36
χ^2/ndof = 0.91
S/√(S+B) ≈ 10
S/B ≈ 0.4

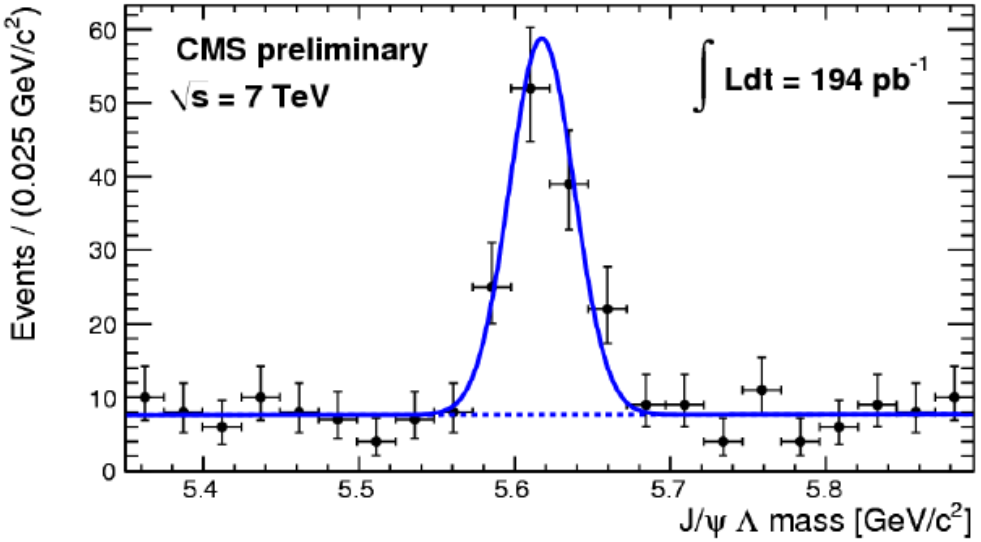


Kaons: transverse momentum p_T (K)>0.6 GeV/c and |η|<2.5;

φ: candidate mass within 10 MeV/c² around the mass PDG value;


CMS
CMS Experiment at LHC, CERN
Data recorded: Sun Jul 4 01:33:41 2010 EDT
Run/Event: 139364 / 20750462
Lumi section: 20
$B_s \rightarrow J/\psi\,\phi$ candidate eve
μ^-
K^-
K^+
μ^+
Trajectories before vertex fit
with $p_T > 0.3$ GeV/c in the vicinity of the PV

Detector performance plot: Λ_b invariant mass peak

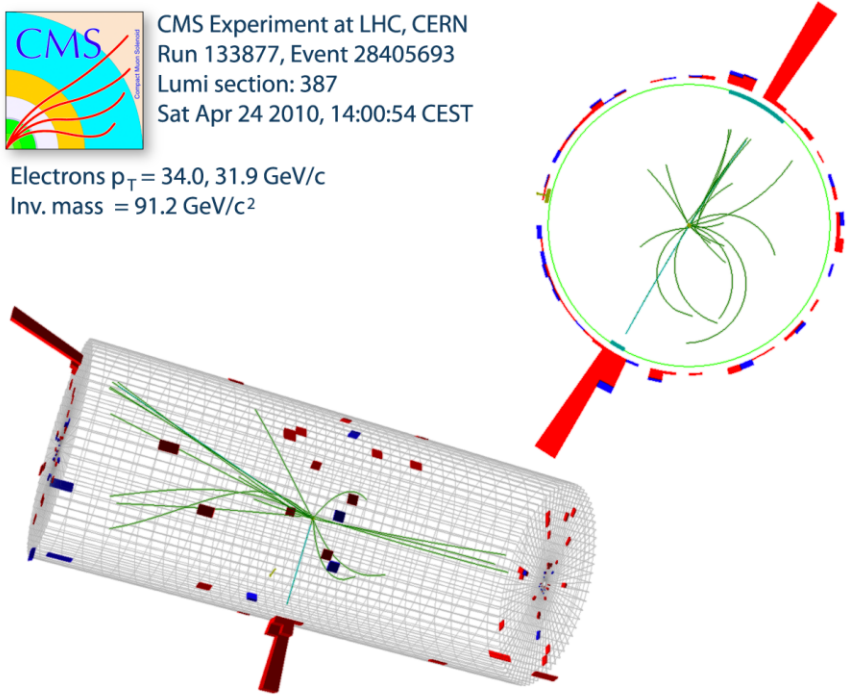


Full $\eta(\mu_i)$ coverage:

μ_{Gauss}	$= 5.617 \pm 0.003\,\text{GeV}/c^2$
σ_{Gauss}	$= 0.021 \pm 0.002\,\text{GeV}/c^2$
N_{signal}	$= 106 \pm 12$
$N_{\text{background}}$	$= 32 \pm 3$
$S/\sqrt{S+B}$	$= 9.0 \pm 1.1$
S/B	$= 3.3 \pm 0.5$

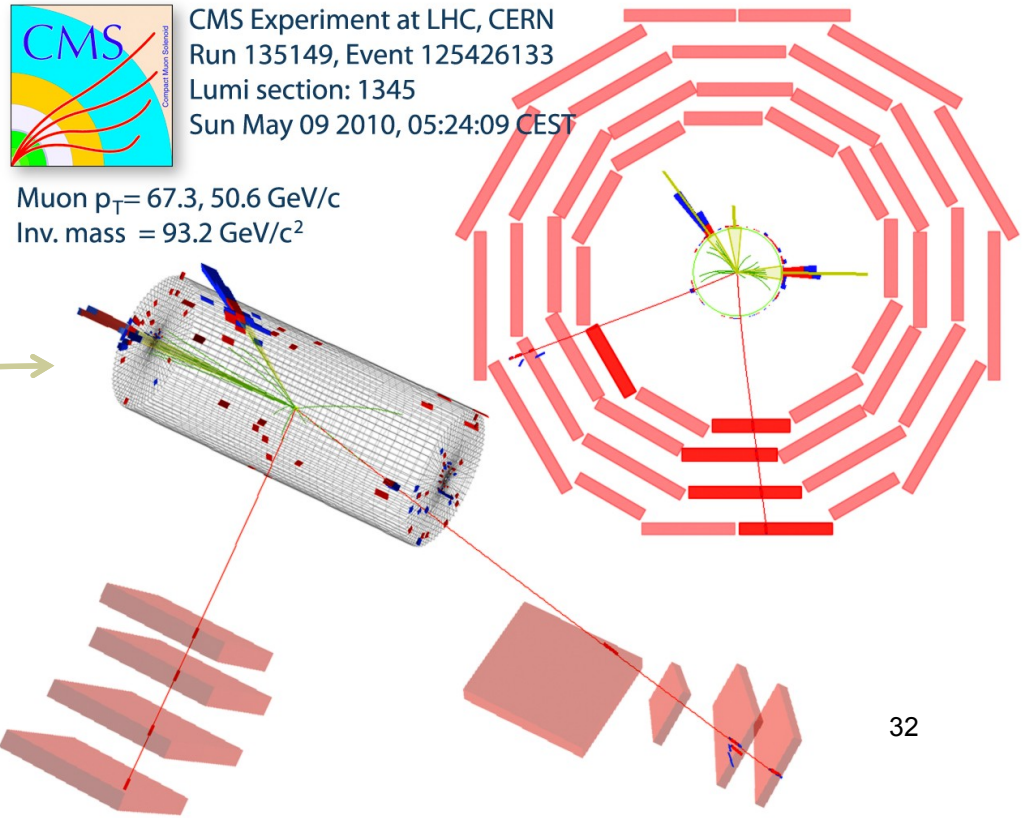
- Exclusive channel: $\Lambda_b \to J/\psi(\mu\mu)\Lambda^0(p\pi)$
- Unbinned likelihood fit for final mass fit, Gaussian plus linear background
- All signal estimations $\pm 2.5\sigma$ around peak
- All errors statistical only.

Contact: cms-pag-conveners-bph@cern.ch


CMS Experiment at LHC, CERN
Run 133877, Event 28405693
Lumi section: 387
Sat Apr 24 2010, 14:00:54 CEST
Electrons p_T = 34.0, 31.9 GeV/c
Inv. mass = 91.2 GeV/c²

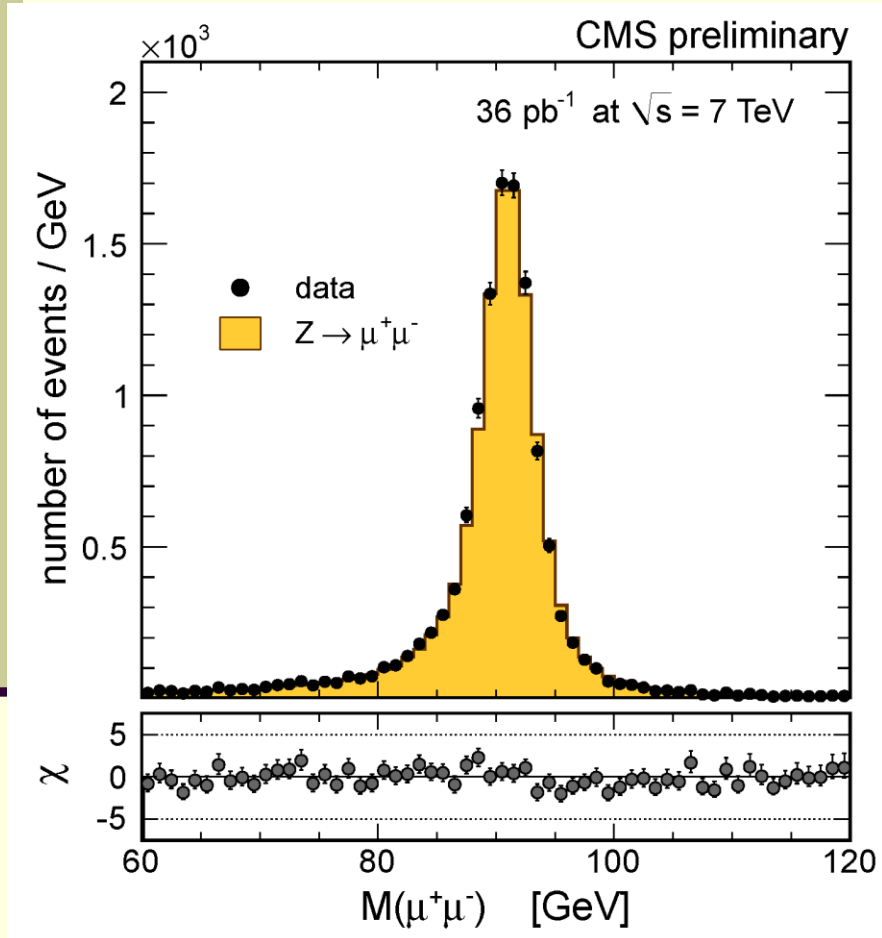
Z → ee

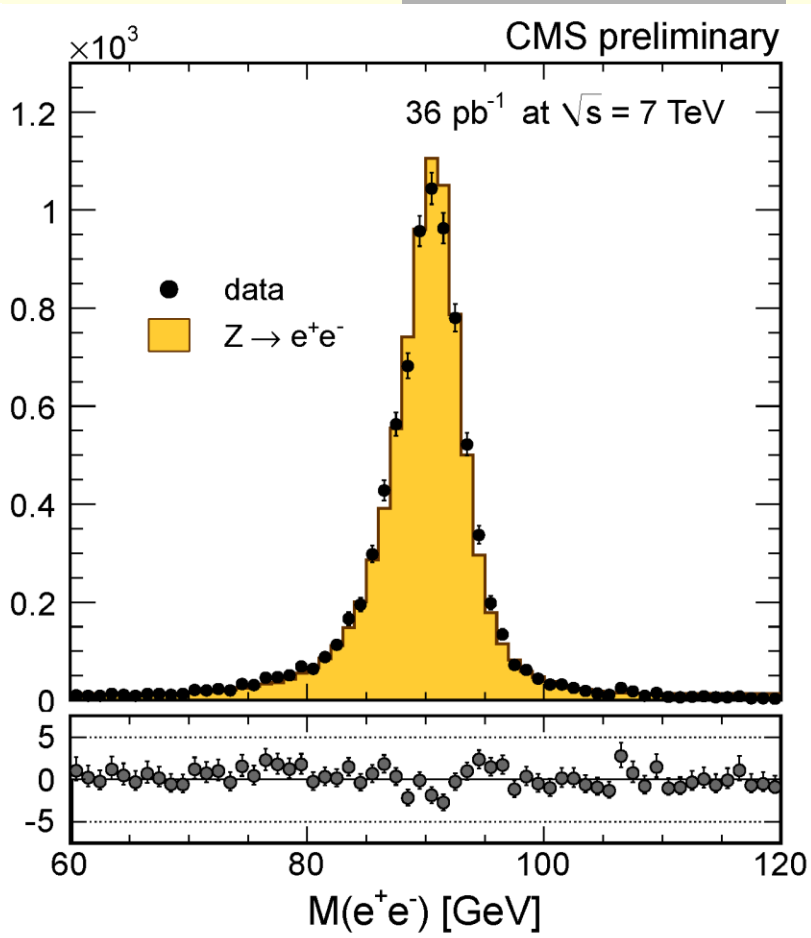
Z → μμ


CMS Experiment at LHC, CERN
Run 135149, Event 125426133
Lumi section: 1345
Sun May 09 2010, 05:24:09 CEST
Muon p_T= 67.3, 50.6 GeV/c
Inv. mass = 93.2 GeV/c²

CMS-PAS-EWK-2010-005

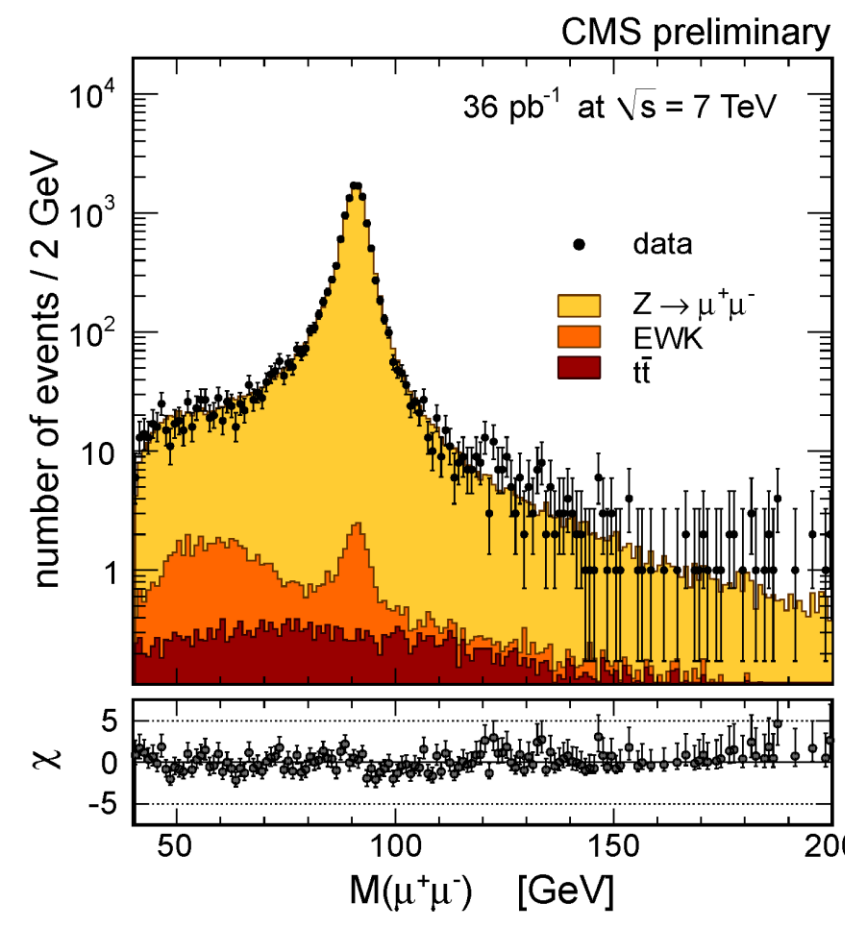
Z → μμ Z →ee

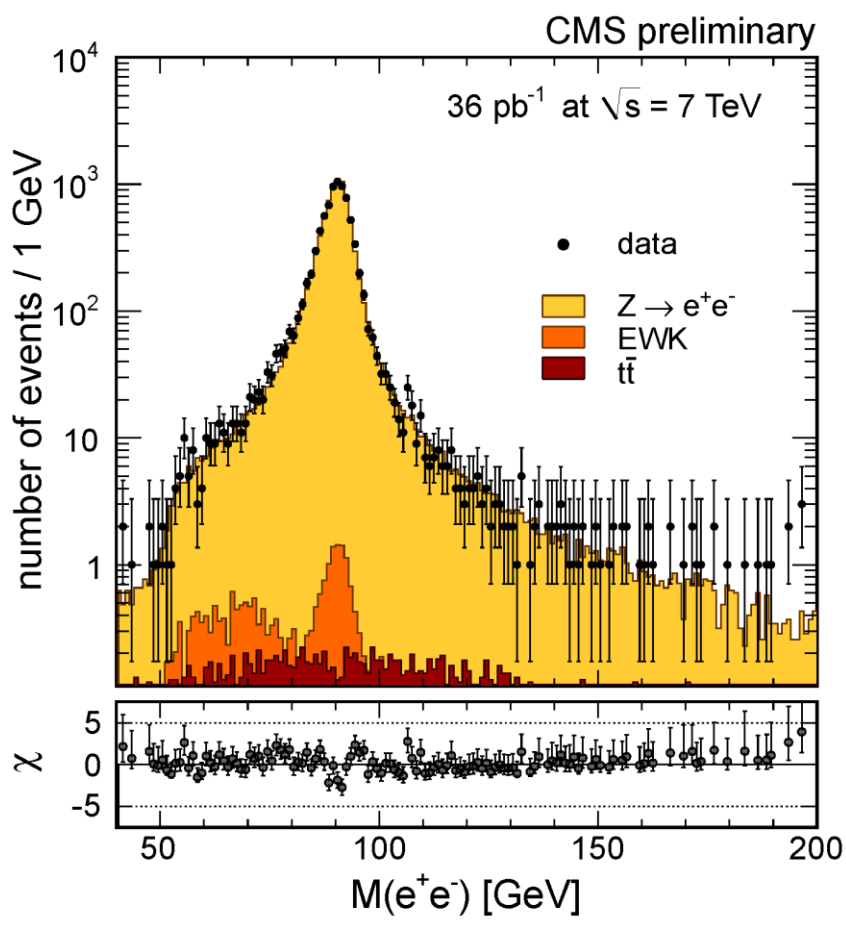




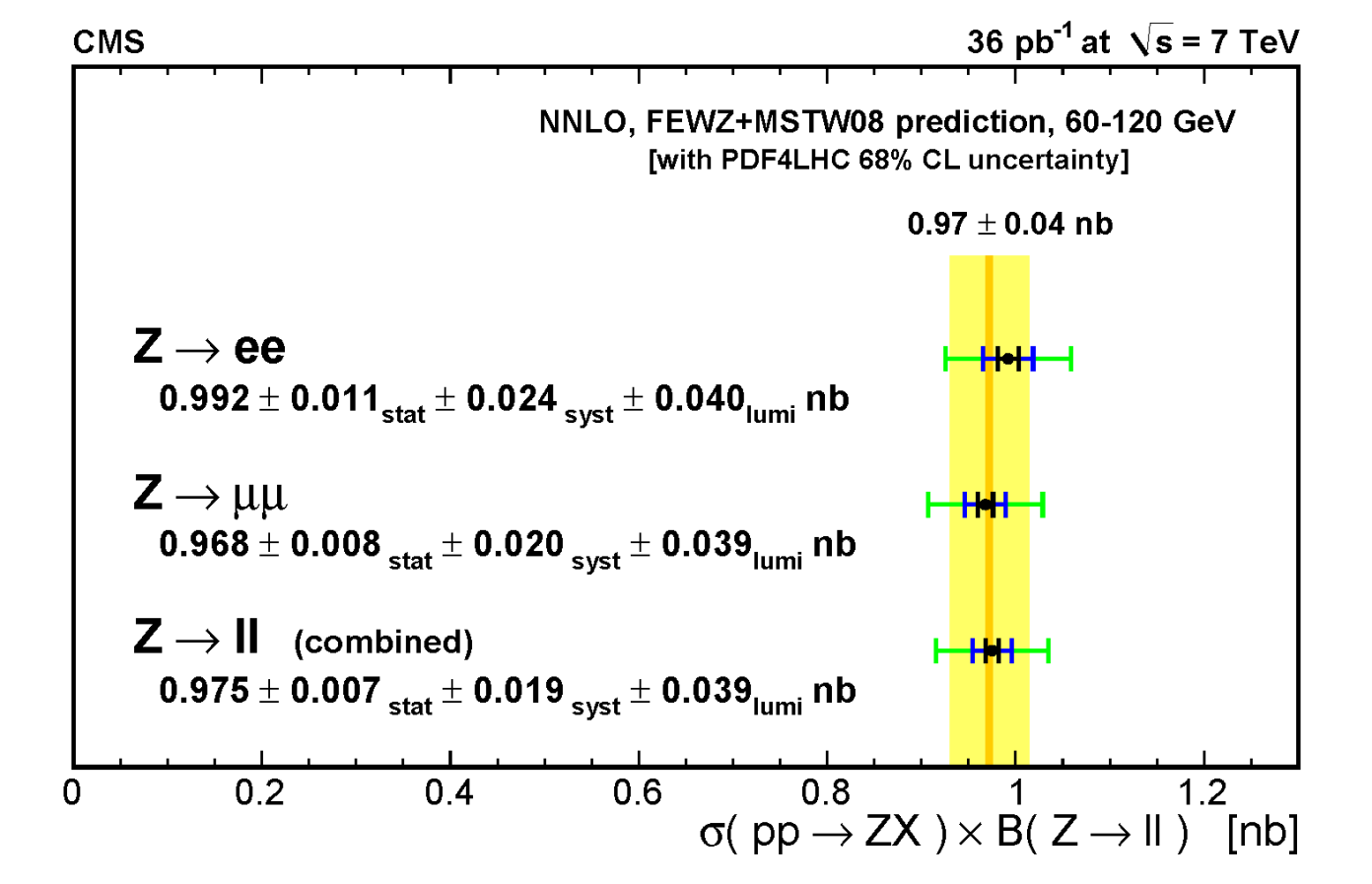
CMS-PAS-EWK-2010-005

Z → μμ Z →ee



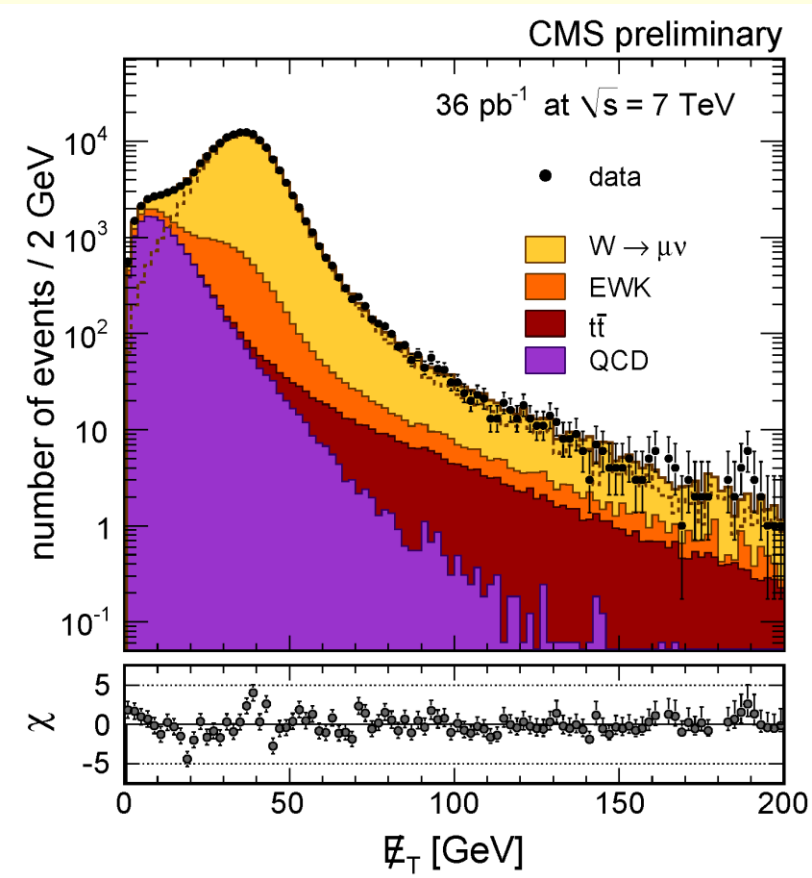


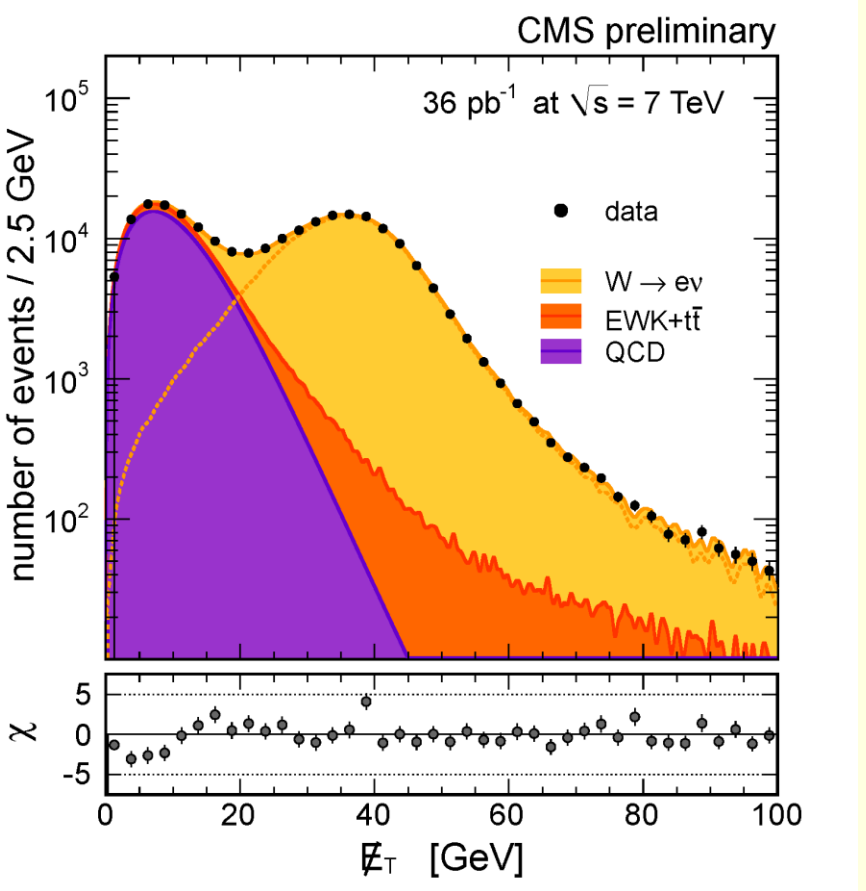
Z cross-section measurements



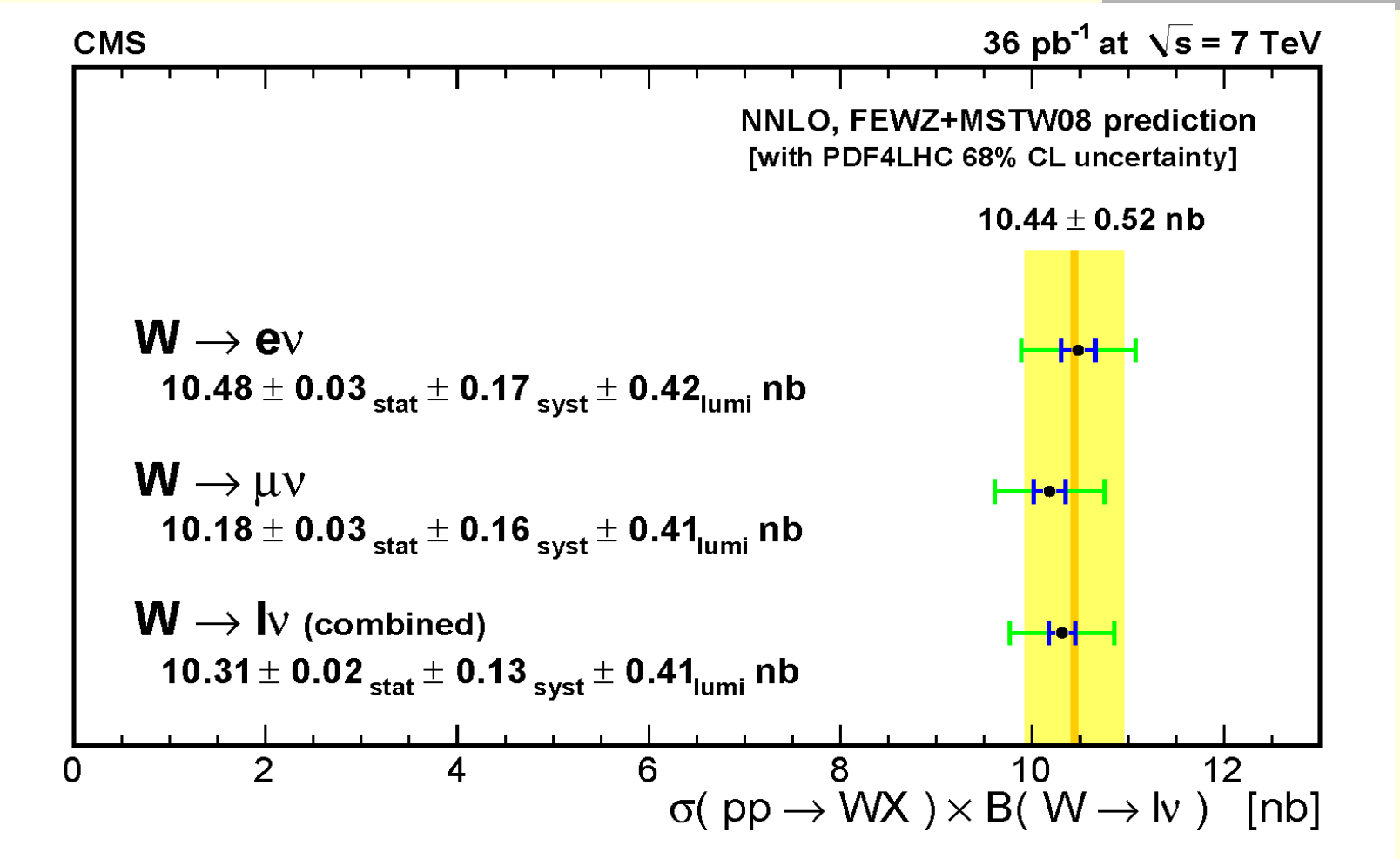
CMS-PAS-EWK-2010-005

The W jacobians

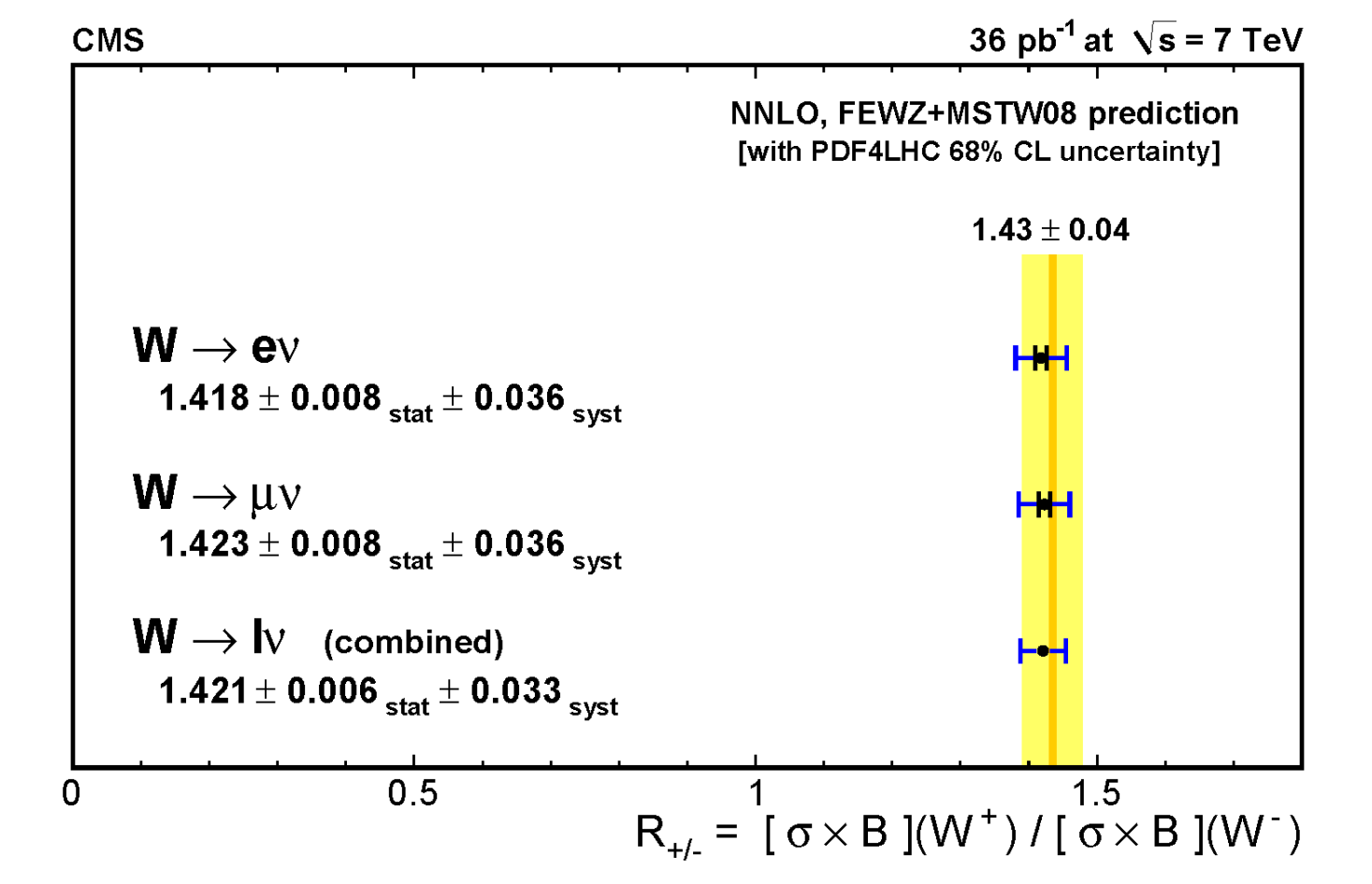




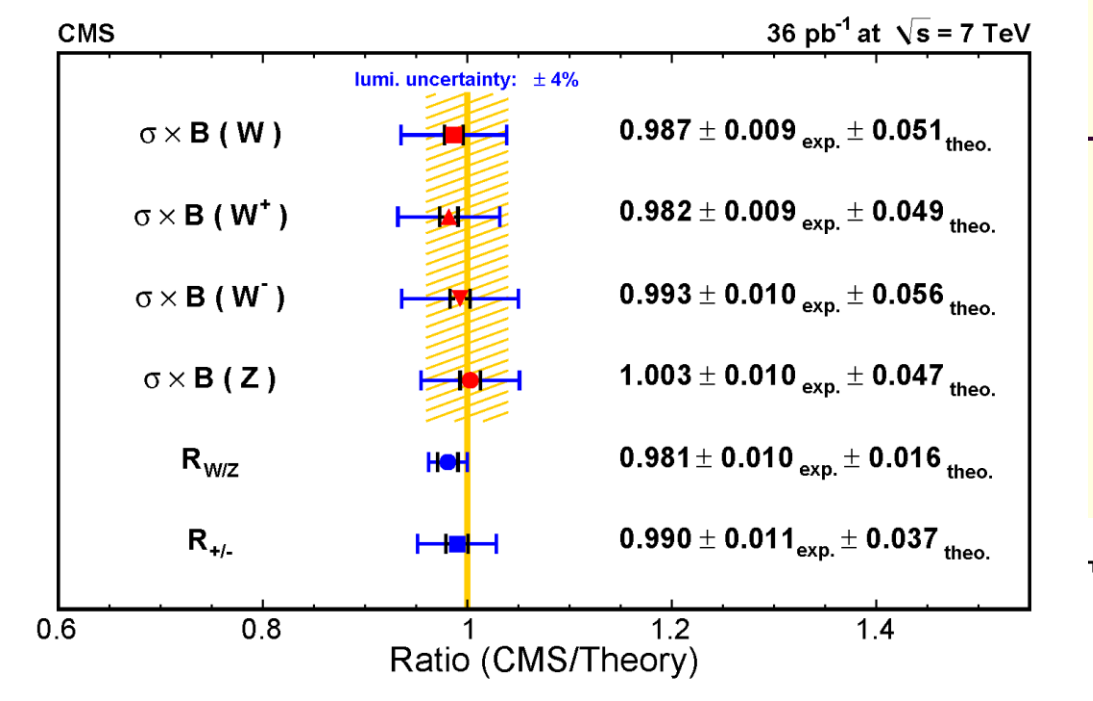
W cross-section measurements

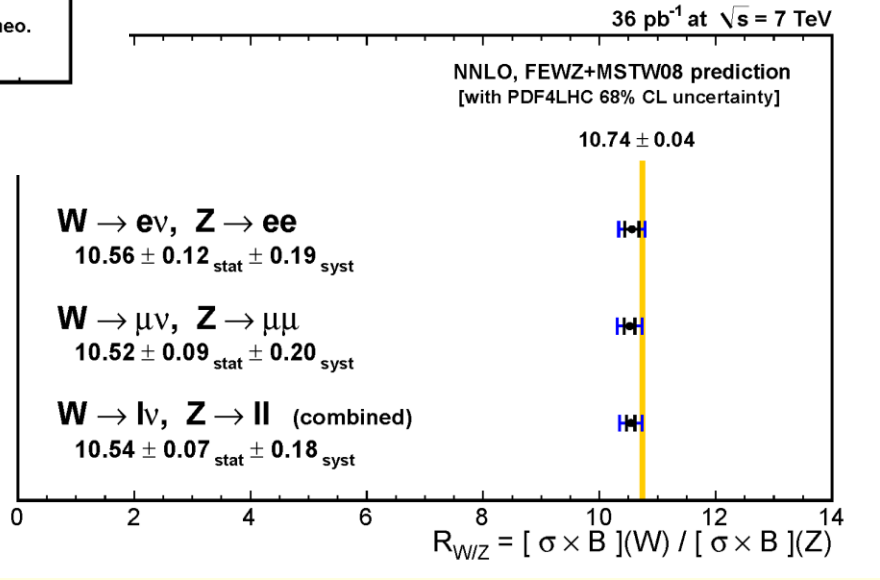


W cross-section measurements



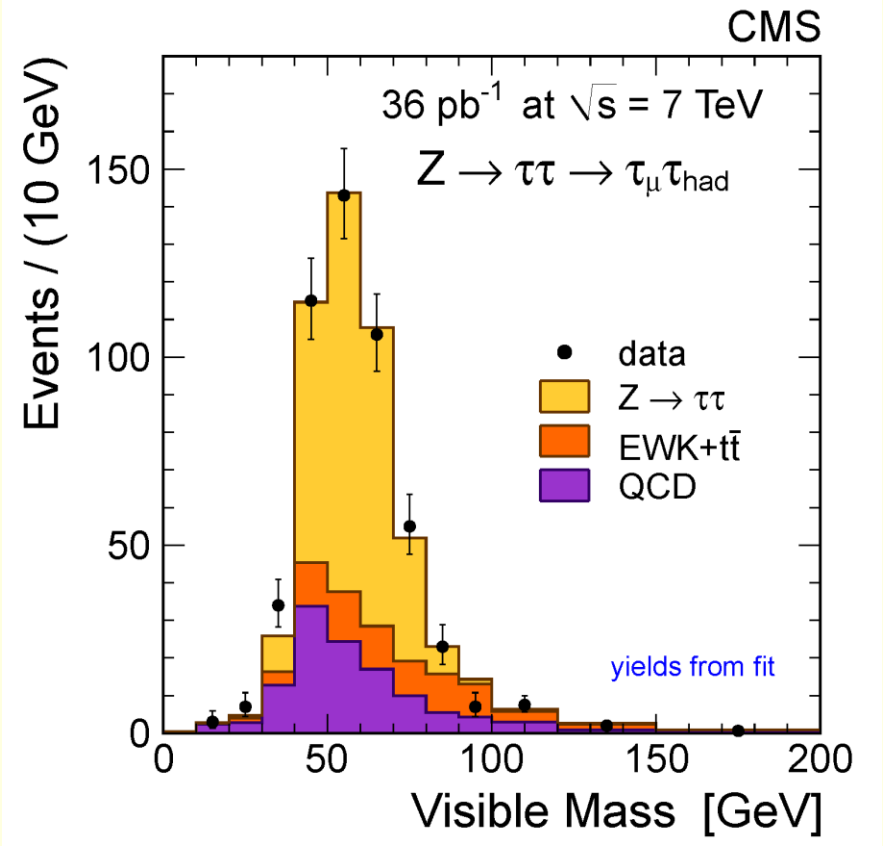
W, Z cross sections

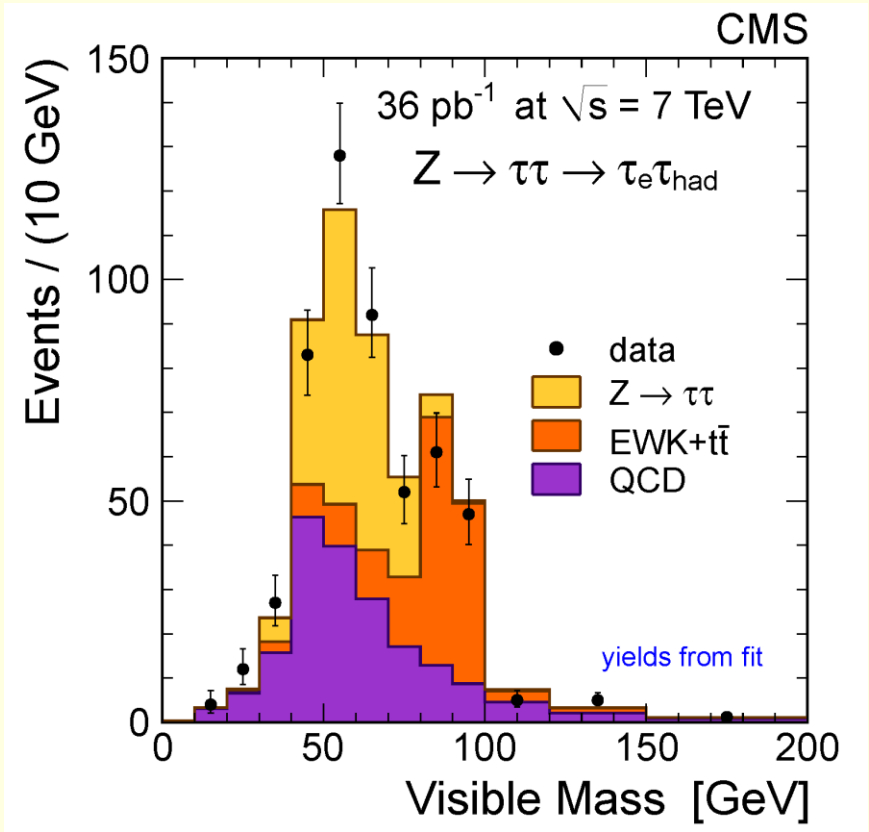




$Z \rightarrow \tau\tau$

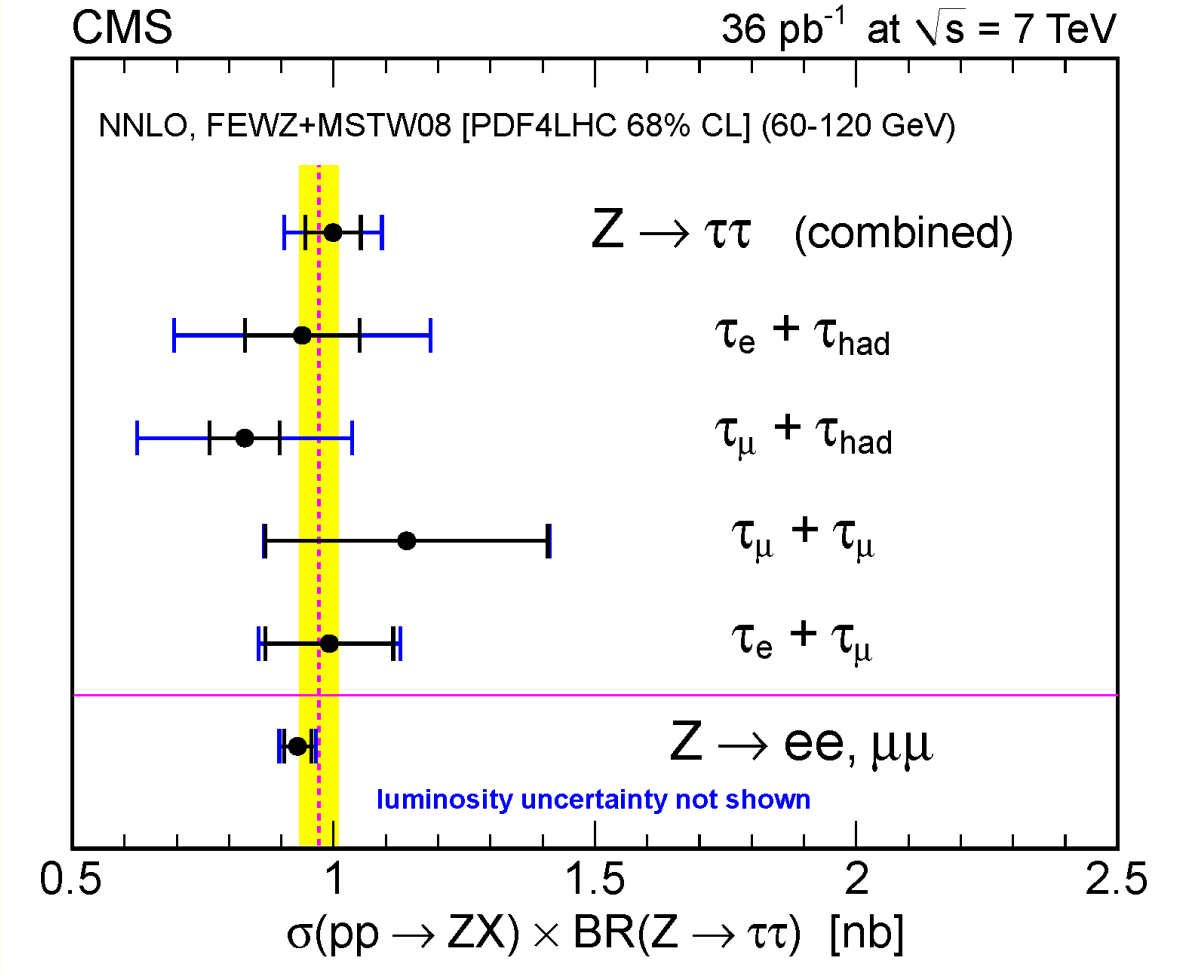
CMS-PAS-EWK-2010-013



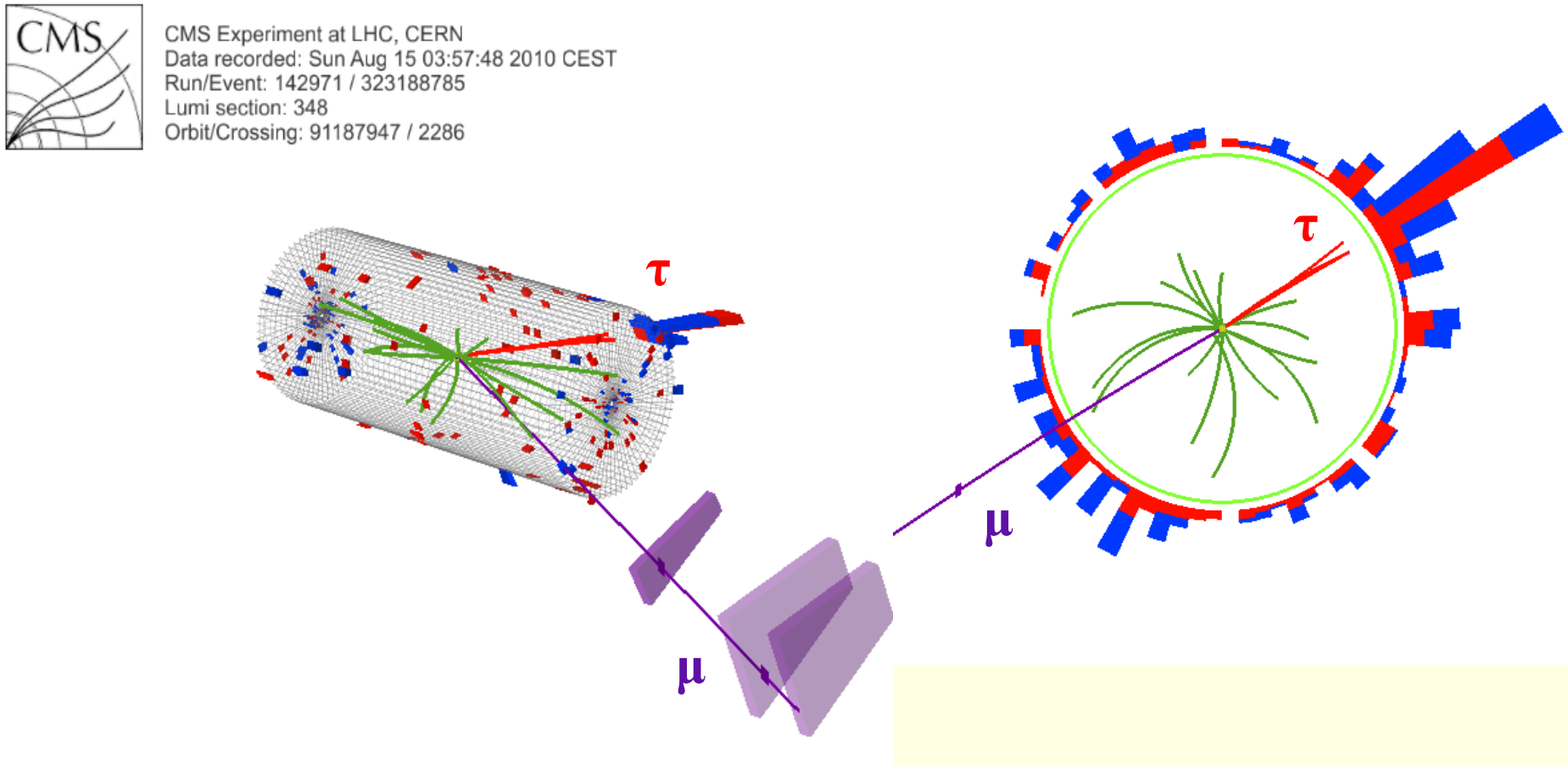


$Z \rightarrow \tau\tau$

CMS-PAS-EWK-2010-013



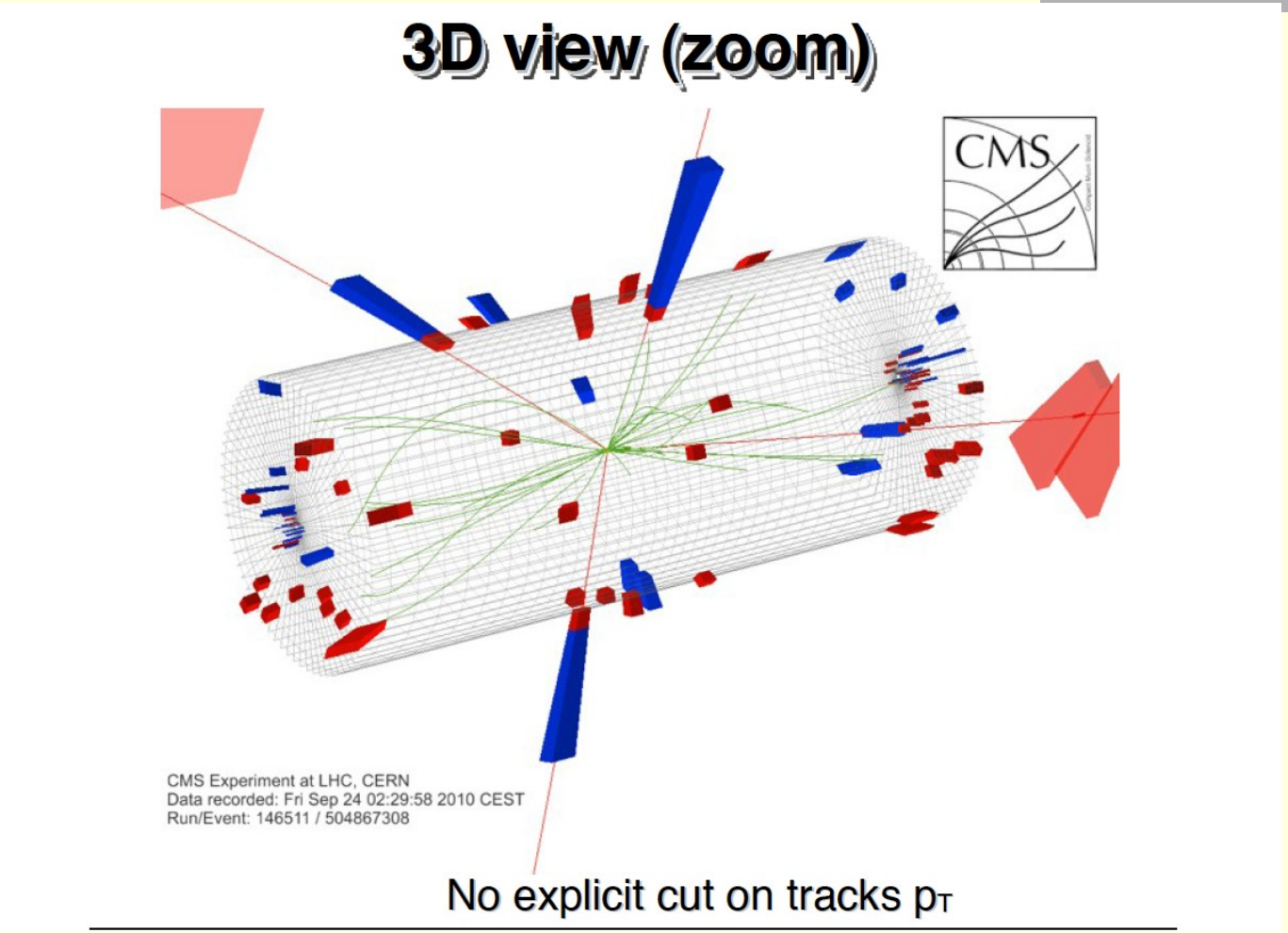
$Z \rightarrow tau\ tau \rightarrow mu + tau_{had}$ (three prong tau)



μ Pt = 32.4 GeV/c η = 1.7	τ Pt = 37.4 GeV/c η = 1.5 Mass = 1.2GeV/c^2	Vis. Mass= 70 GeV/c^2 M_T(μ,MET) =4.1 GeV

First candidate ZZ →4μ

$\mu_0 + \mu_1$: 92.15 GeV (total(Z) p_T 26.5 GeV, ϕ -3.03),
$\mu_2 + \mu_3$: 92.24 GeV (total(Z) p_T 29.4 GeV, ϕ +.06),



WW production (W→lepton)

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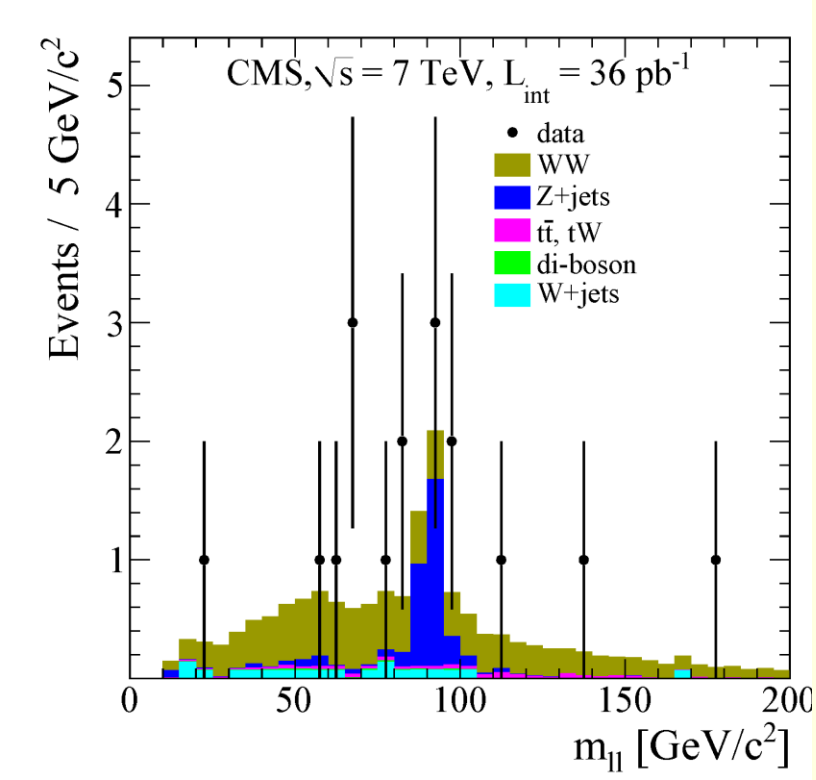
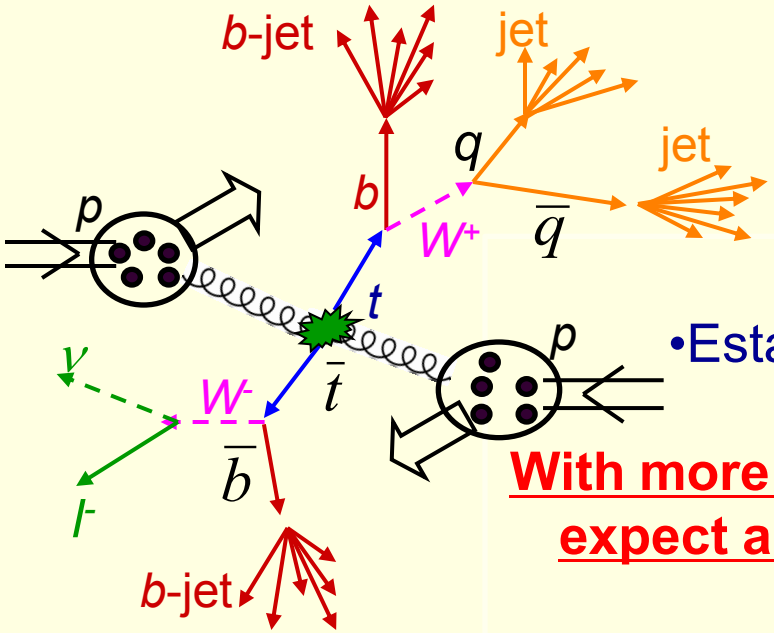


pp → WW cross section = 41.1 ± 15.3(stat) ± 5.8 (syst) ± 4.5 (lumi) pb

The birth of a top factory !

29th October 2010: First Measurement of Top-Quark Pair Production Cross Section in Proton-Proton Collisions at sqrt(s)= 7 TeV (Physics Letters B695 (2011) 424)



Early measurement

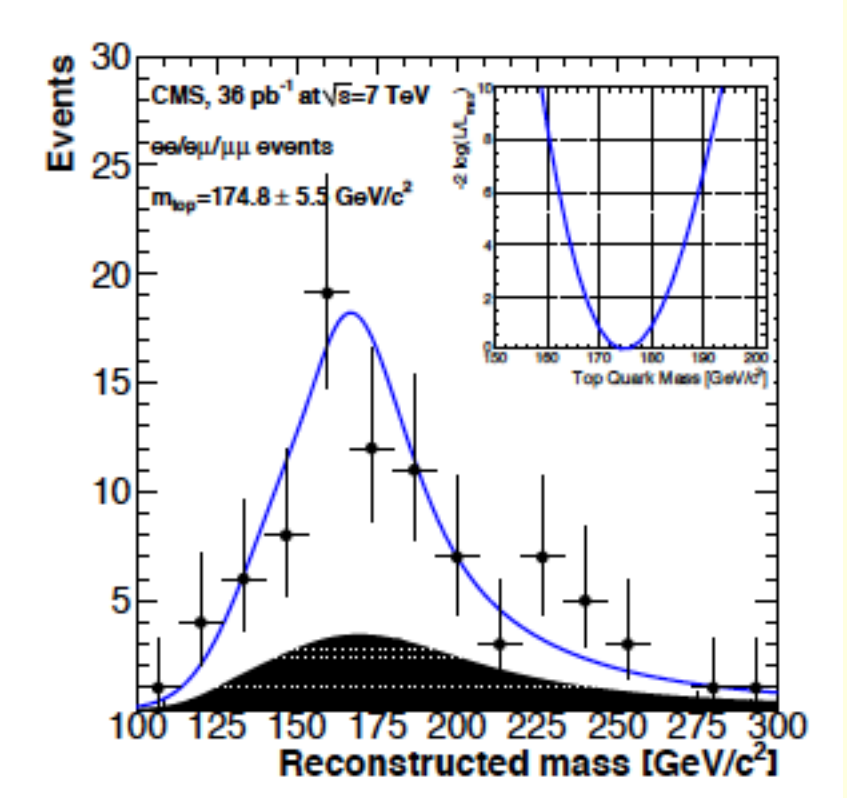
- Establish the ttbar cross section at 7 TeV

With more luminosity and understood detectors expect a rich program of top physics al LHC

- single top production
- ttbar resonances
- top rare decays
- single top and ttbar spin measurement
- …. eventually precision mass measurement

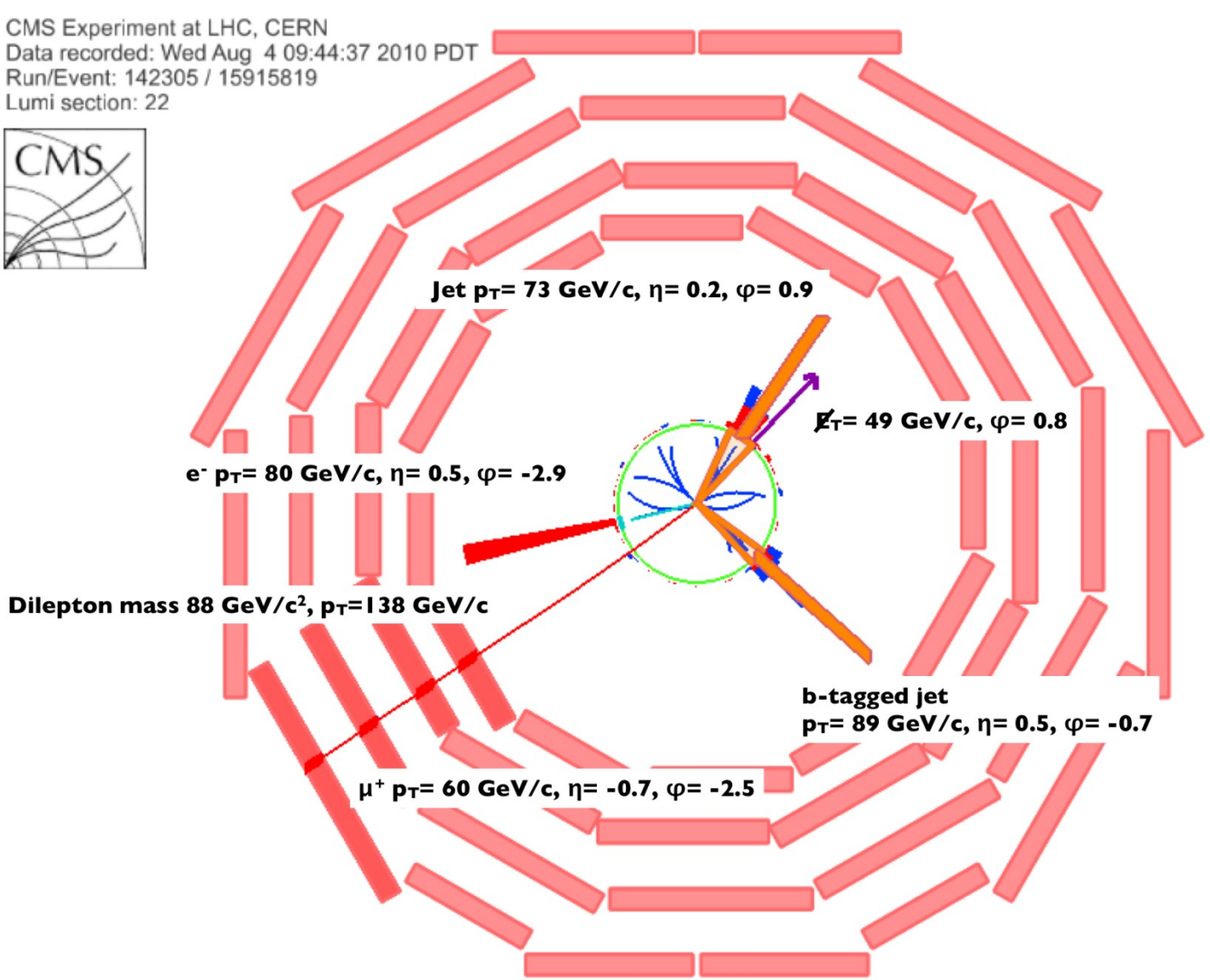
Dilepton channel, mass measurement

- Xsection low, but less background; mostly from lepton misidentification
  - 2 isolated leptons, not compatible with a Z decay; with two or more jets p_T>30
  - Sizeable (> 30 GeV) missing E_T accounting for the neutrinos



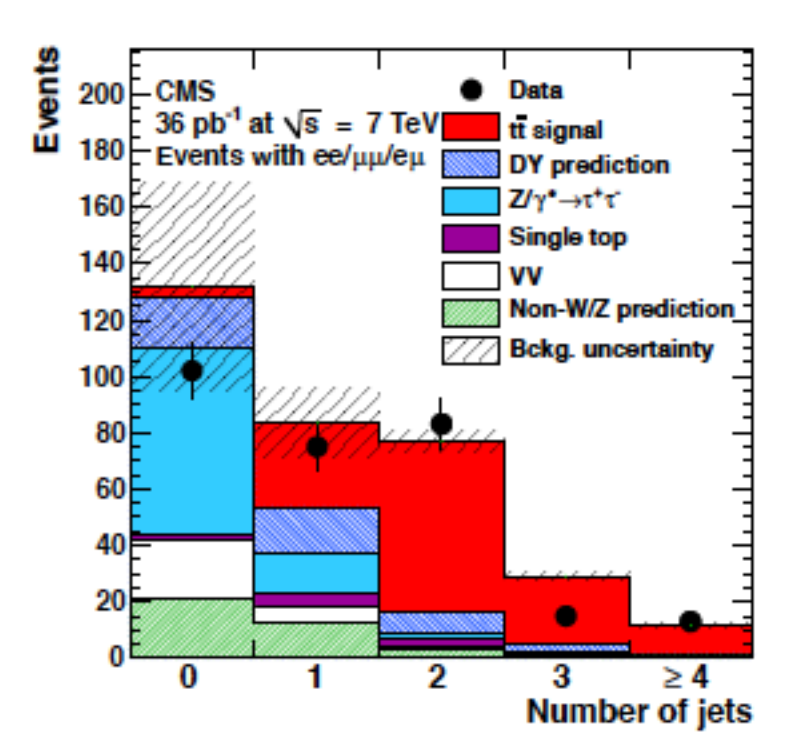
$m_{top} = 175.5 \pm 4.6(stat) \pm 4.6(syst)$ GeV/c^2

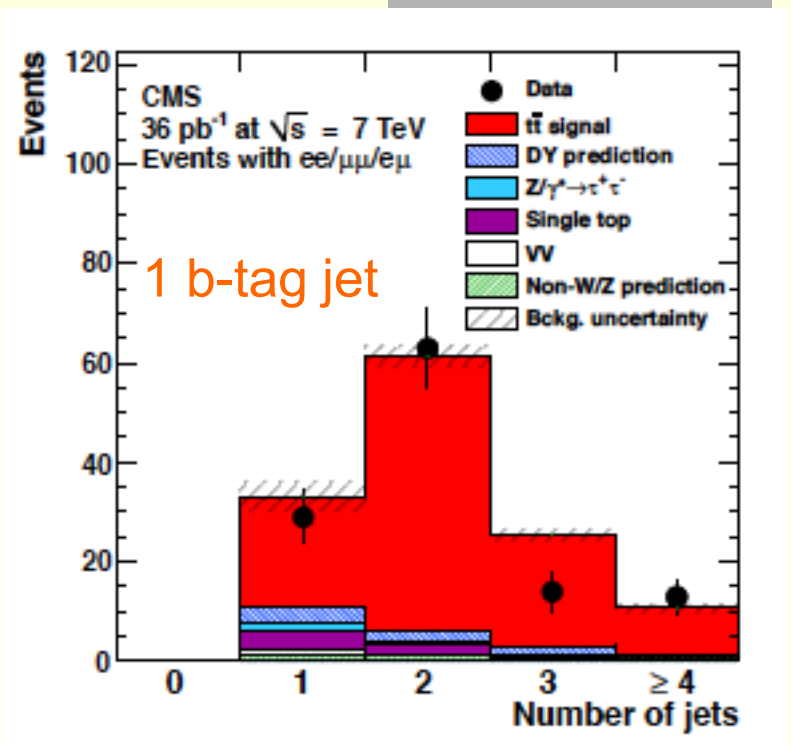
e+mu dilepton candidate event



Dilepton channel, electrons or muons

arXiv:1105:5661



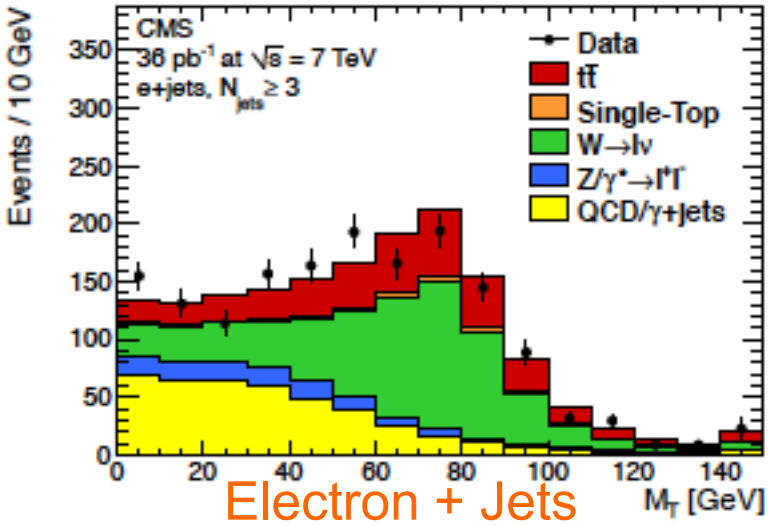


$$\sigma_{t\bar{t}} = 168 \pm 18\,(\text{stat.}) \pm 14\,(\text{syst.}) \pm 7\,(\text{lumi.})\ \text{pb}$$

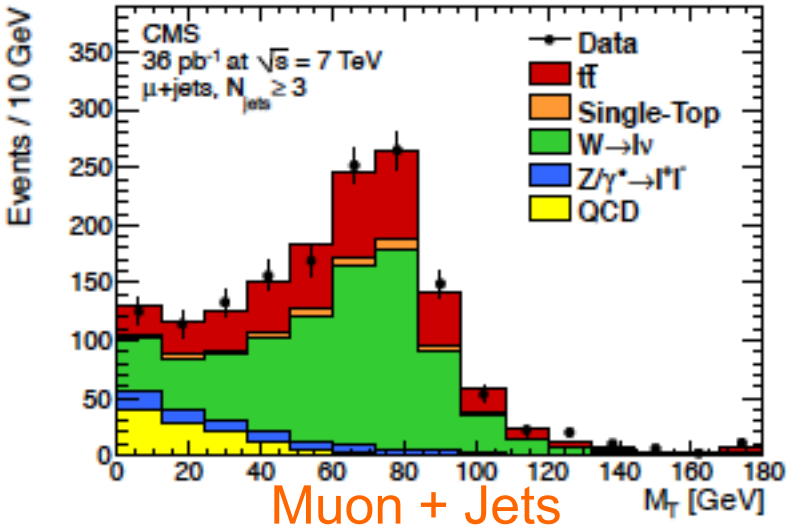
Semileptonic channel, 1 lepton + jets

arXiv:1106:0902

$$\sigma_{t\bar{t}} = 173^{+39}_{-32}\,(\text{stat.} + \text{syst.}) \pm 7\,(\text{lumi.})\,\text{pb}$$



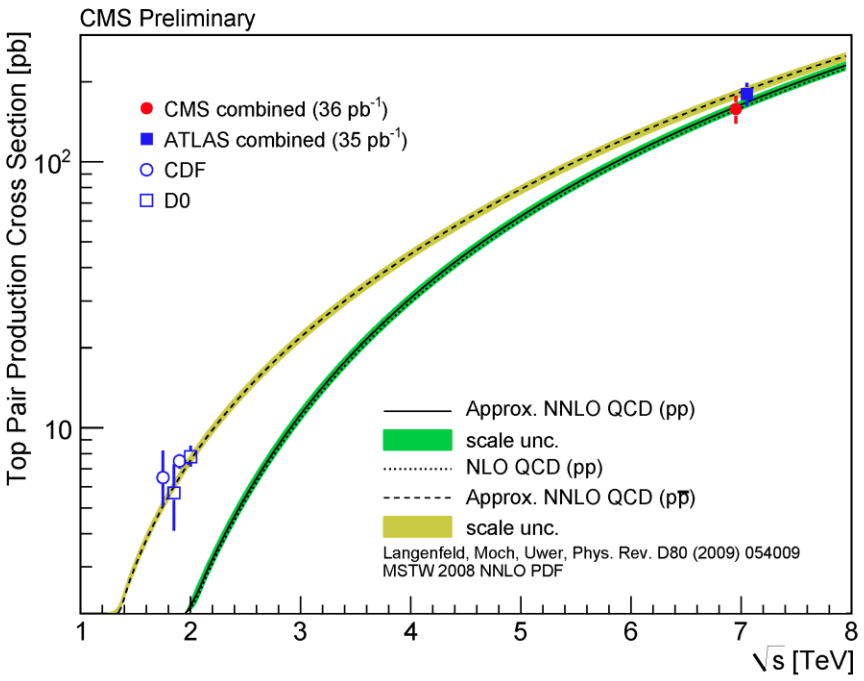
Electron + Jets



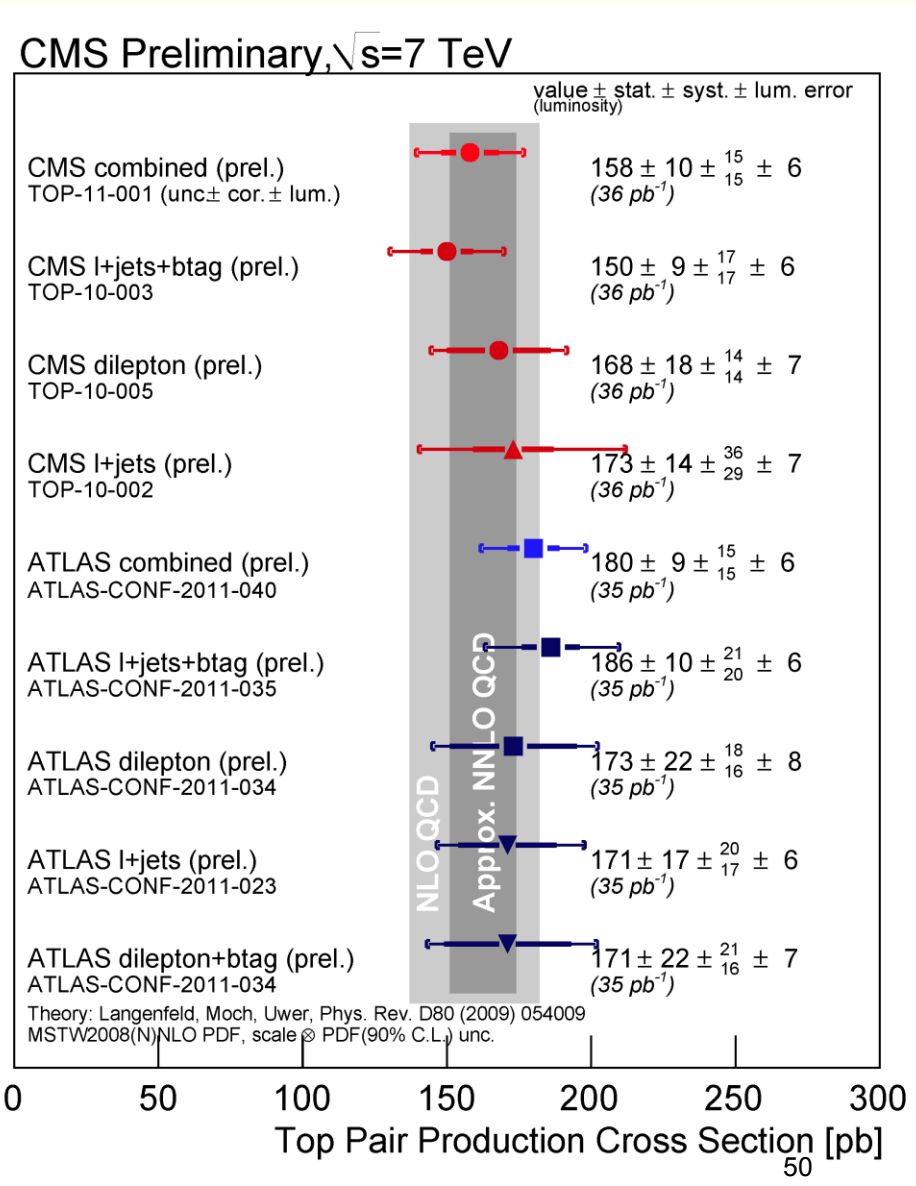
Muon + Jets

$$m_t = 173.1 \pm 2.1(\text{stat})^{+2.8}_{-2.5}(\text{syst})\ \text{GeV}.$$

Top xsection



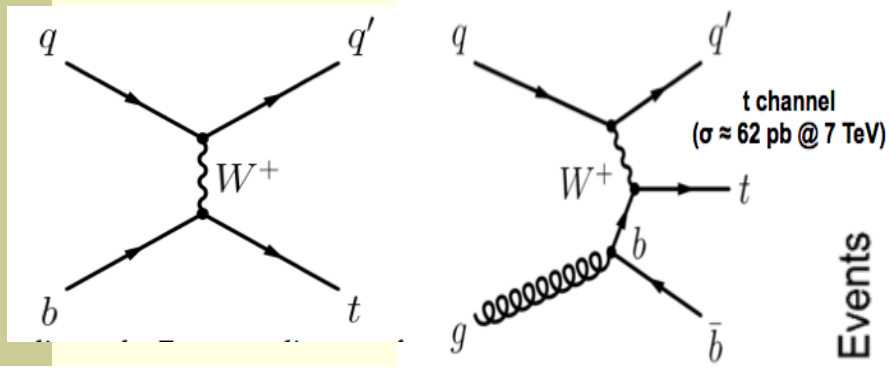
CMS PAS TOP-11-001

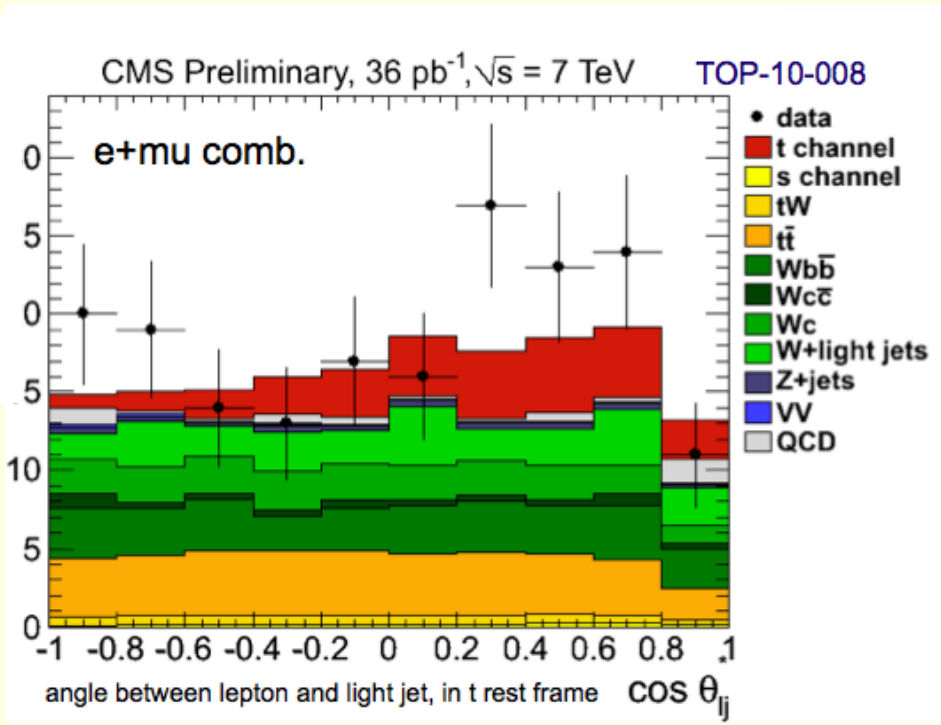


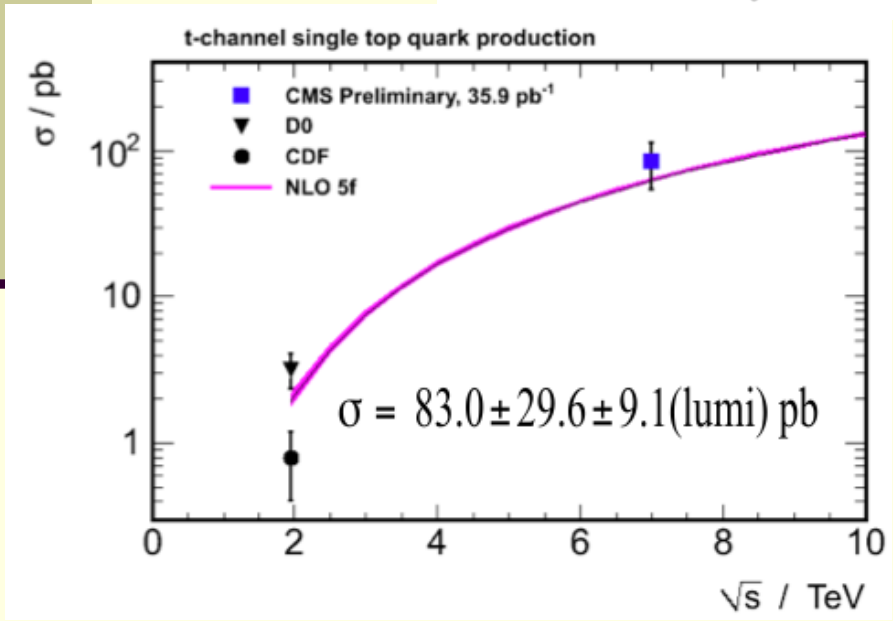
Single Top cross section

- Two different analysis using leptonic W decays
  - Cut based, using angular info + 1 btagged jet
  - BDT, based on kinematic observables

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta^*_{lj}} = \frac{1}{2}(1 + A\cos\theta^*_{lj})$$



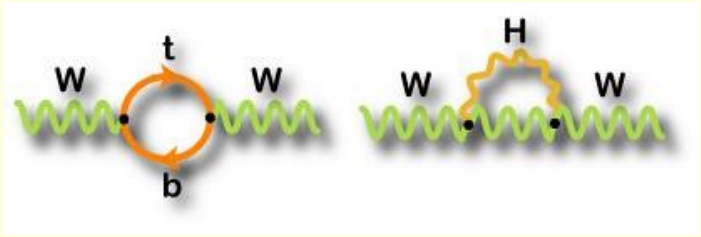




Single top at 3 sigma level in both analyses

Constrains on Higgs Mass

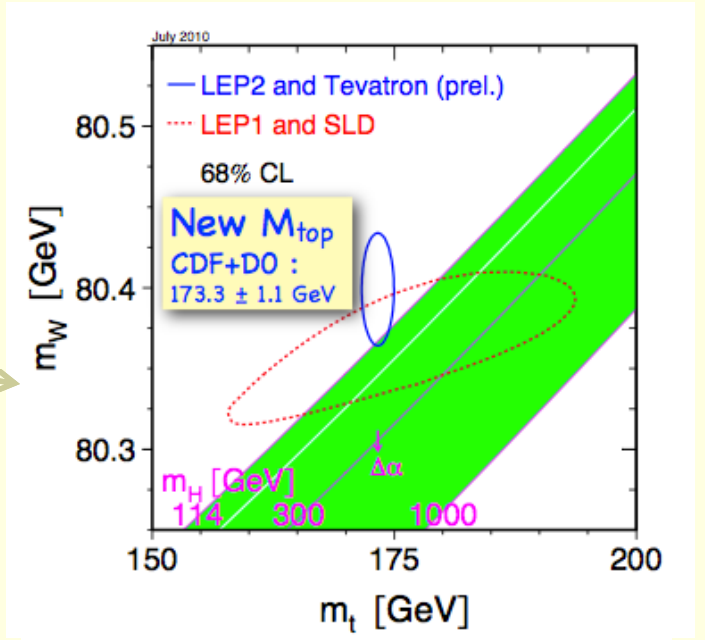
- M_H free parameter in SM
  - Indirect measurements:
    - From EWK precision data through radiative corrections

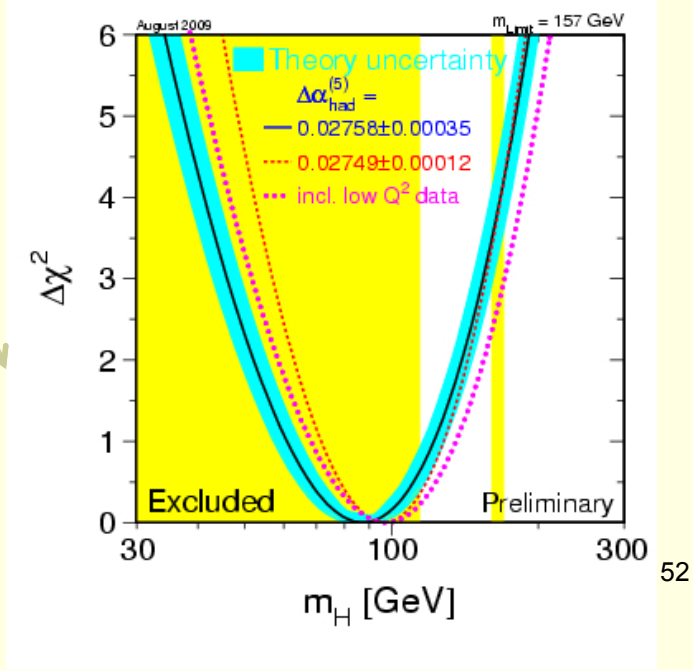


$M_H = 89.0^{+35}_{-26}$ GeV

Excluded M_H>158 GeV (@95%)

  - From direct searches at LEP
    - M_H>114.4 GeV/c^2 @ 95% C.L.
  - From direct searches at Tevatron
  - **Now: from direct searches at LHC**





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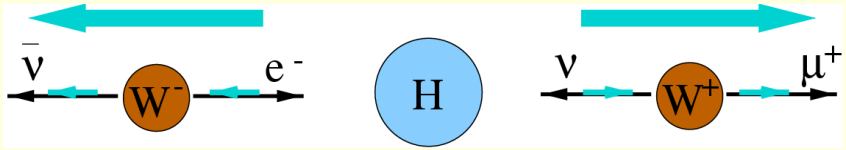
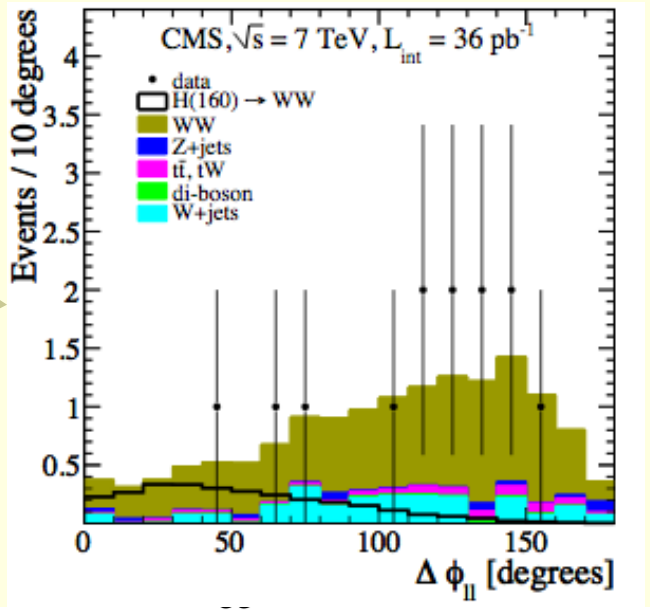
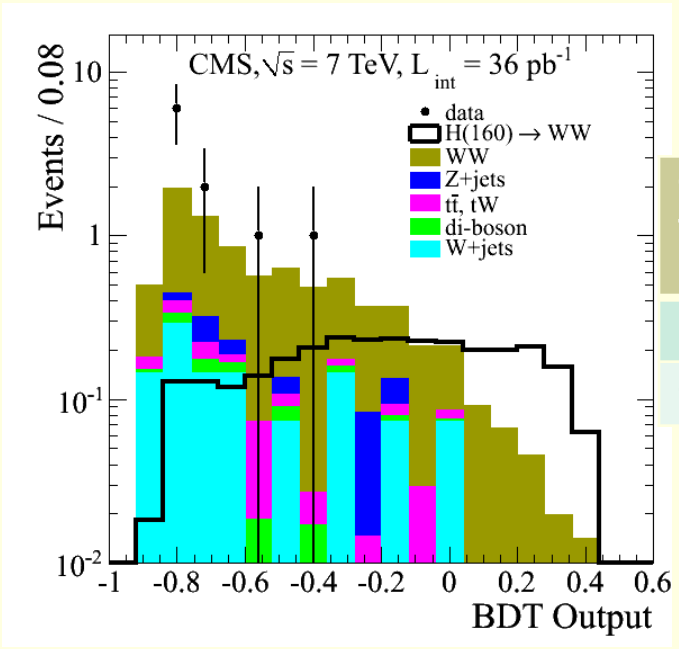
H→WW→2l2ν

Direct WW production is irreducible background
Main handle is Helicity conservation:
spin 1 (Z*→WW) vs. spin 0 (H→WW)
For H, charged leptons tend to go in the same direction

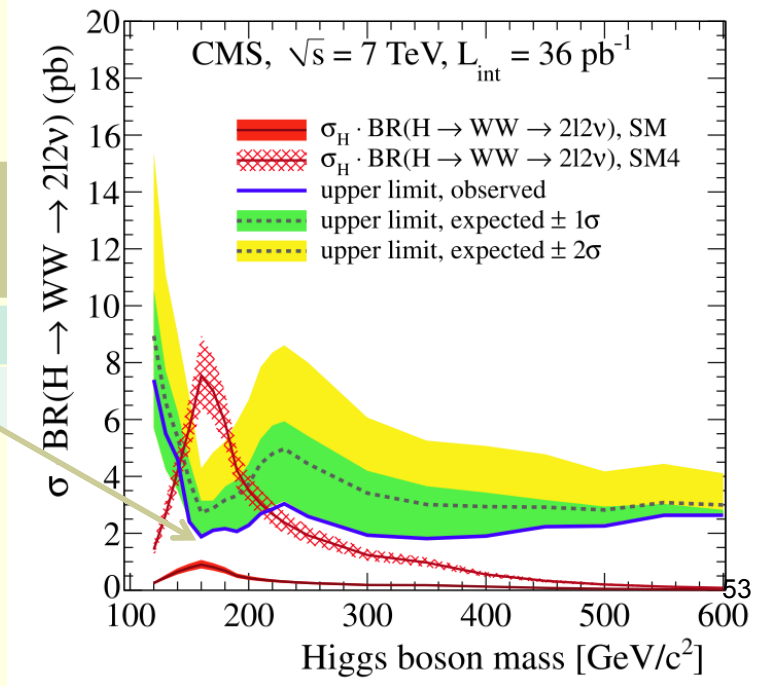




Same pre-selection as WW analysis
S/B poor: rely on MVA techniques (BDT)



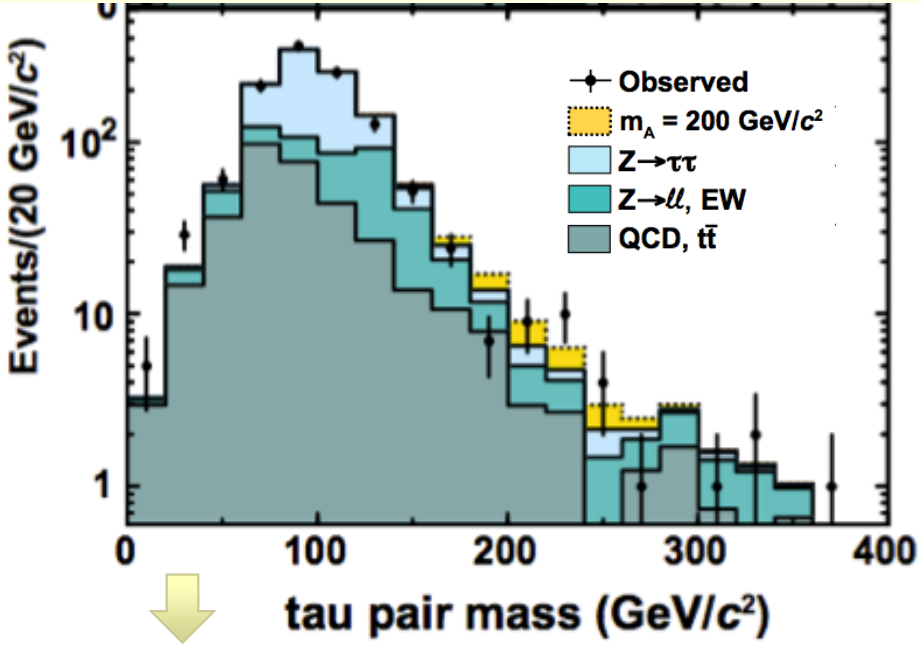
95 % CL Limit for M_H = 160 GeV	CMS (Bayesian)
Expected	3.0 x SM
Observed	2.1 x SM

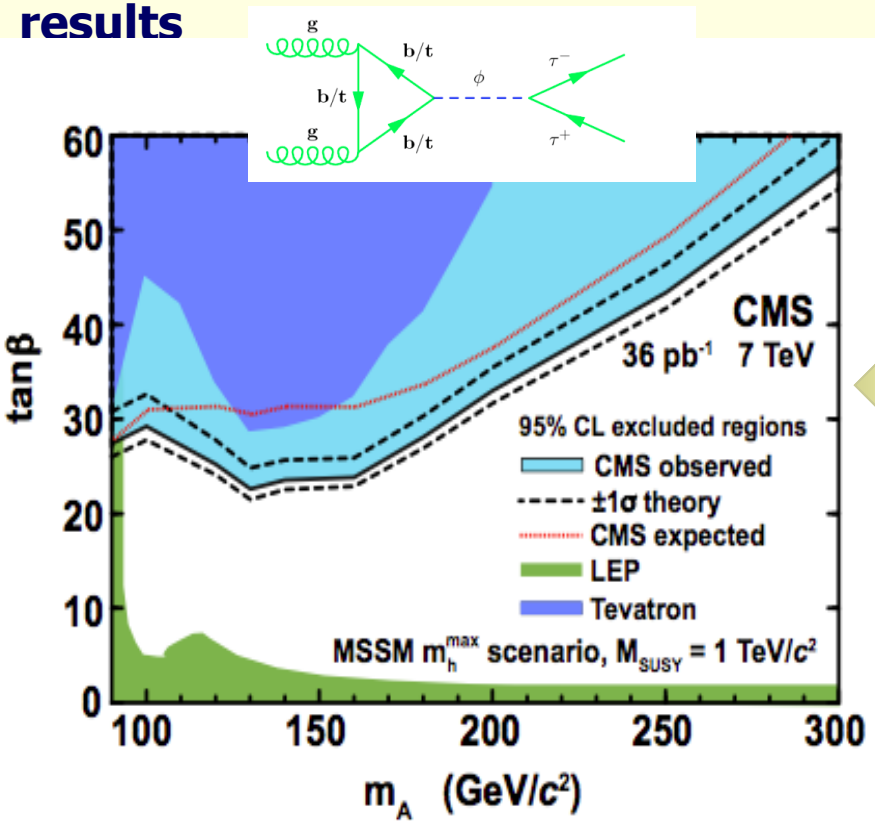


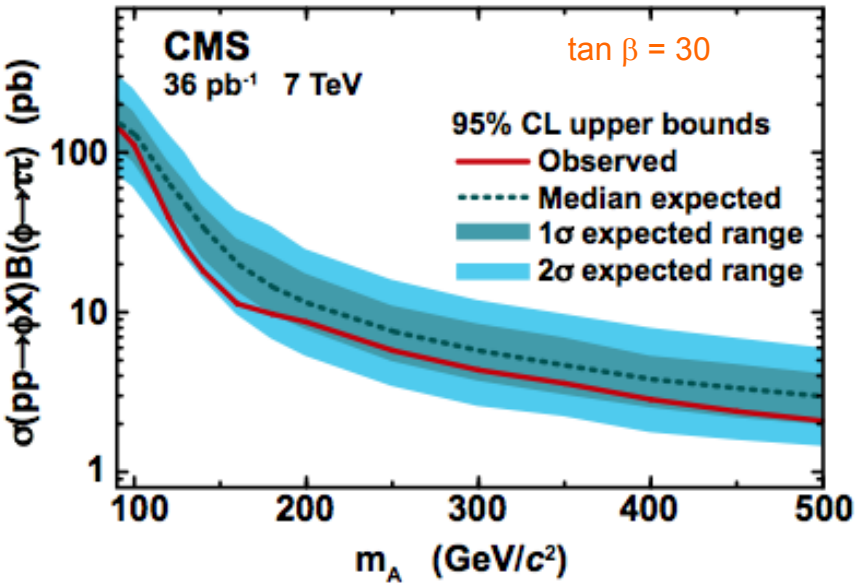
(MSSM) A → τ τ

arXiv:1104.1619

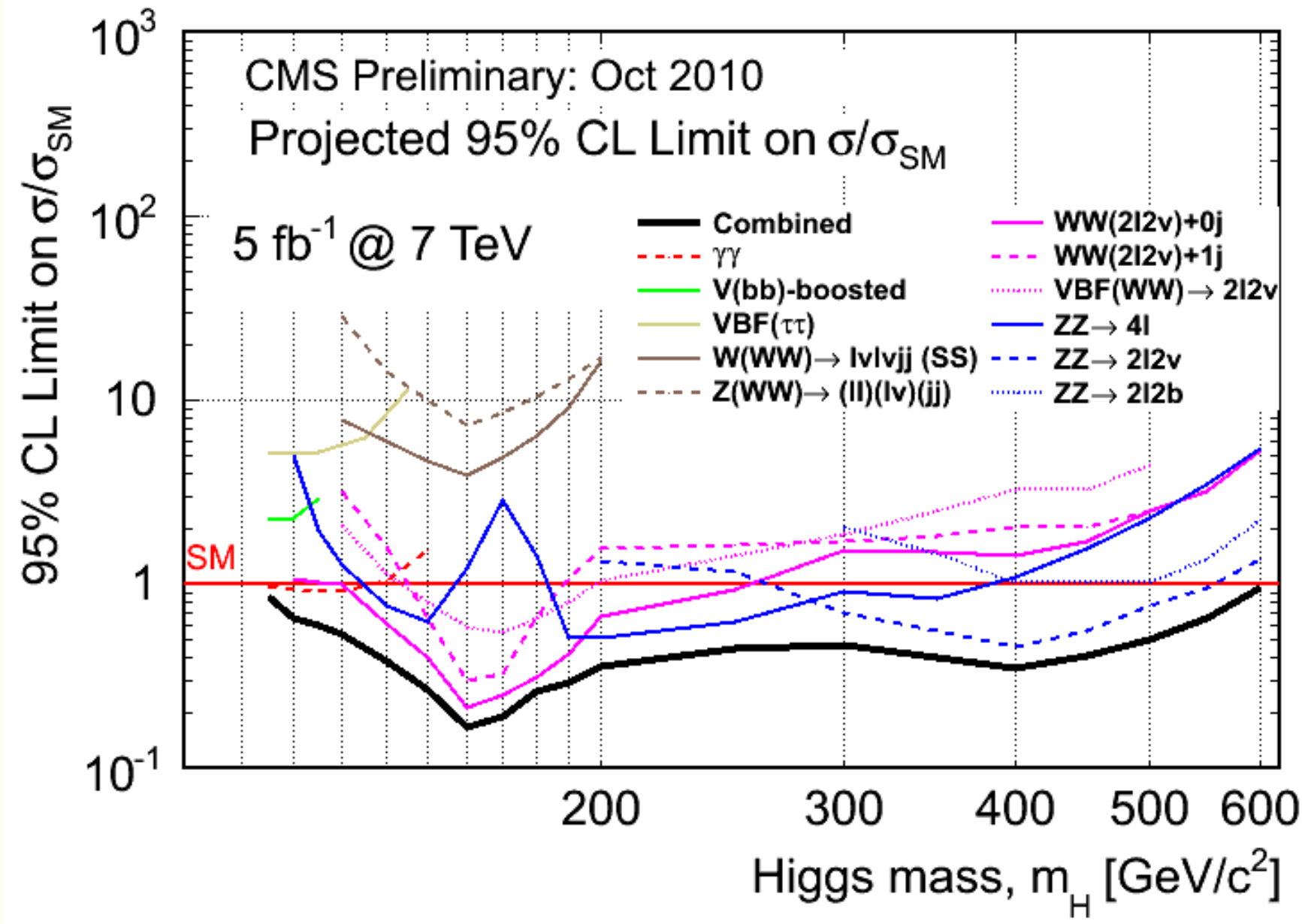
- Channels used: e-mu, e-had, mu-had
- improved mass reconstruction (better resolution) using likelihood, based on tau decay kinematics of visible decay products and MET
- Limits on MSSM Higgs production, **already improving on the Tevatron results**



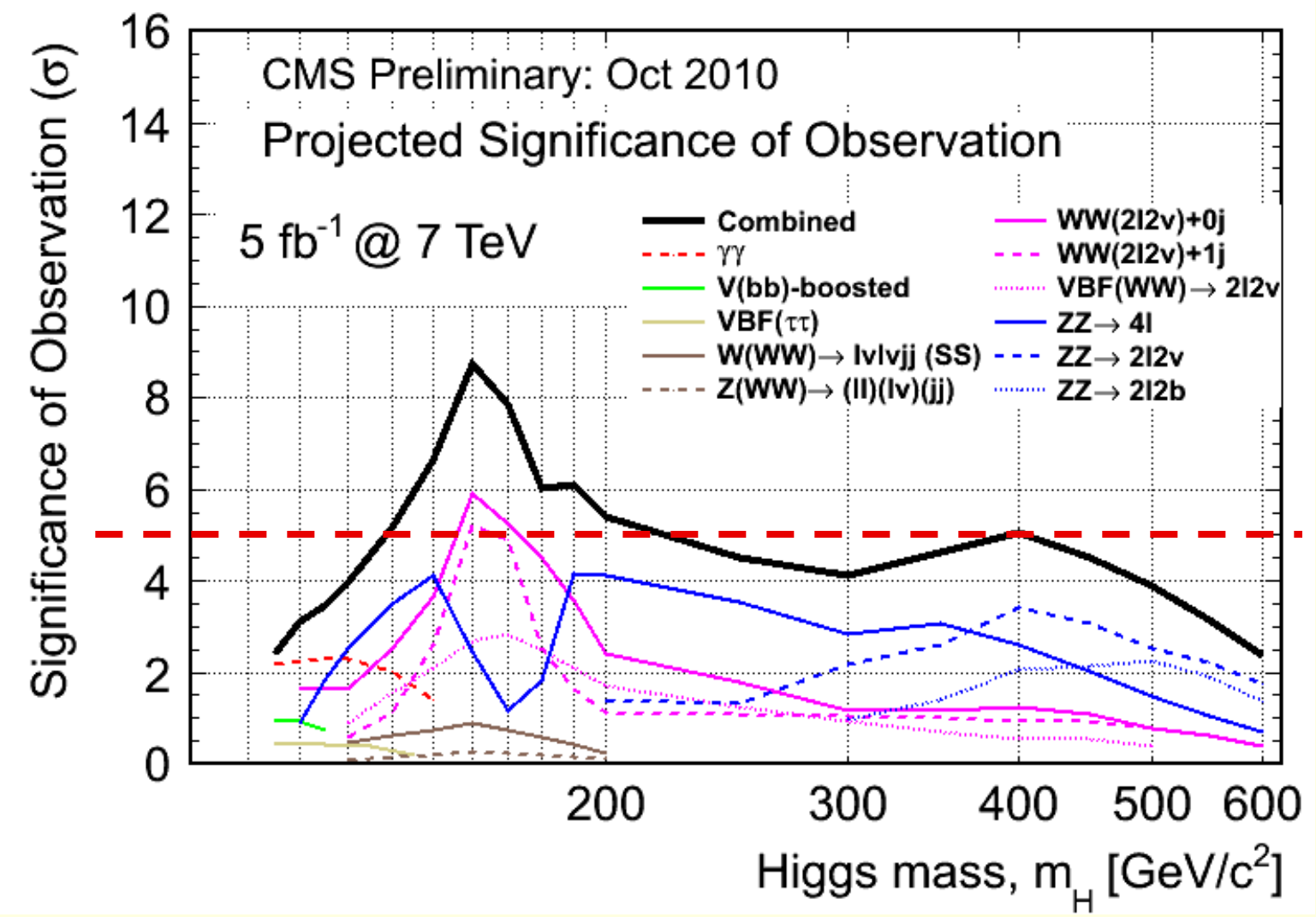




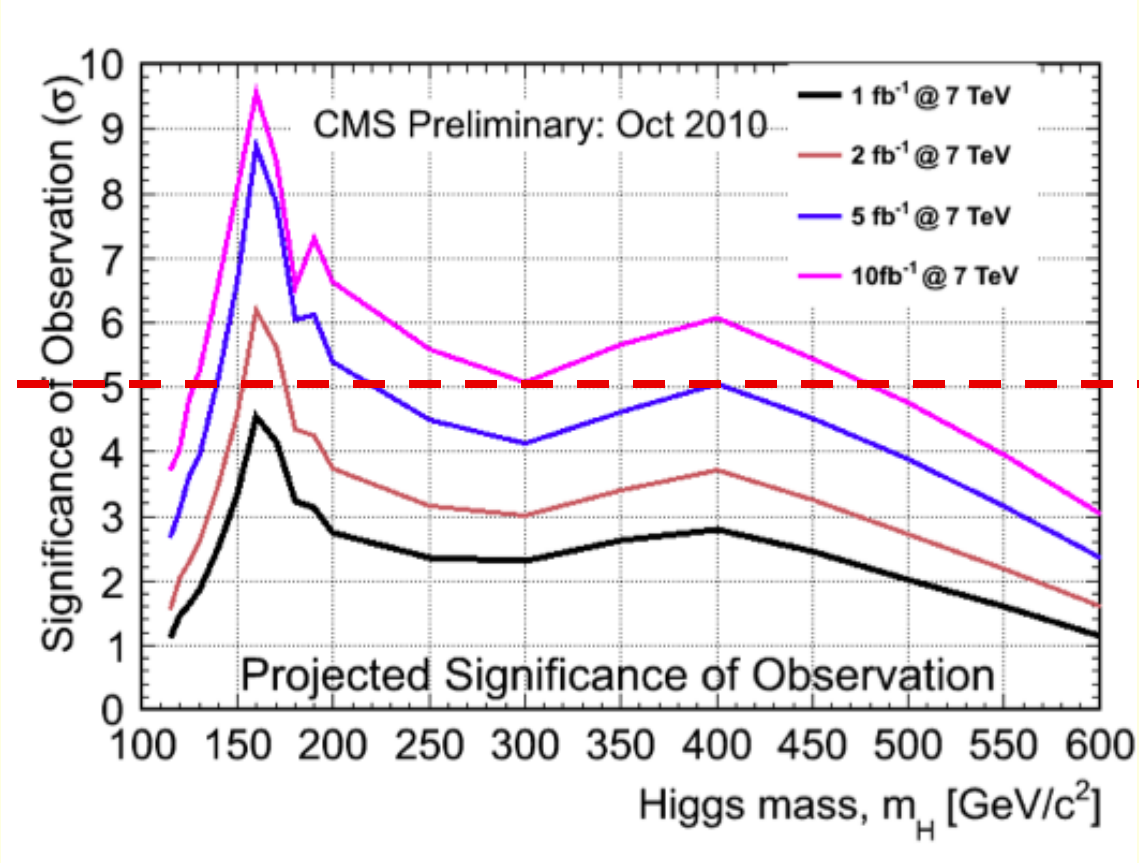
CMS Sensitivity Projections @ 5 fb^{-1}



CMS Significance of Obs. @ 5 fb^{-1}



CMS Significance vs Luminosity



LHC sensitivity vs Luminosity

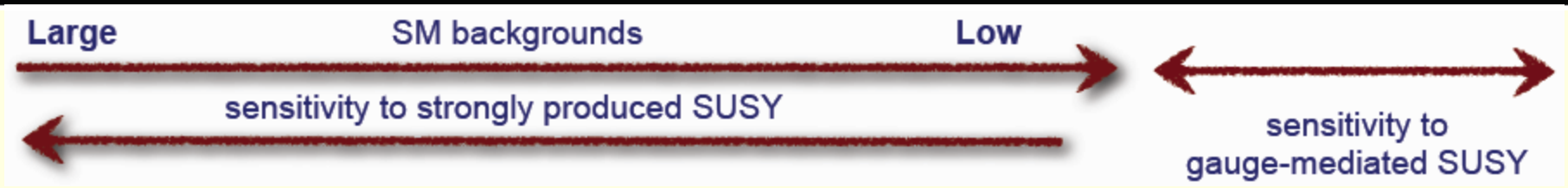
ATLAS + CMS ≈ 2 x CMS	95% CL exclusion	3σ sensitivity	5σ sensitivity
1 fb^{-1}	120 - 530	135 - 475	152 - 175
2 fb^{-1}	114 - 585	120 - 545	140 - 200
5 fb^{-1}	114 - 600	114 - 600	128 - 482
10 fb^{-1}	114 - 600	114 - 600	117 - 535

Searches

- At LHC exotic not Standard Models can be tested
- Similar Signatures: high invariant mass of the final state, isolated high-p_T leptons, large missing E_T, very energetics photons and jets, ..
- First data may not be enough to distinguish between the different models
- However we can see if there is new physics!
- *New vector bosons*
- *Extra dimensions*
- *Contact interactions*

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

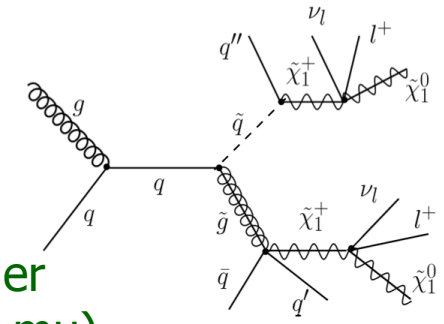
- 2011: setting the best limits is important, but we should be prepared for discovery
- Some examples follow… Full results at

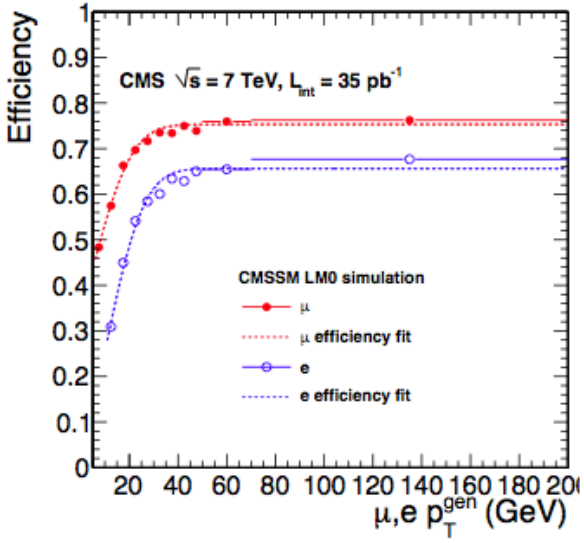
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

Analysis	Approved Plots	CDS Entry	Luminosity	Comment
Search for Physics Beyond the Standard Model in Z + MET + Jets events at the LHC	SUS10010	PAS-SUS-10-010	34/pb	
Inclusive search for new physics at CMS with the jets and missing momentum signature	SUS10005	PAS-SUS-10-005	36/pb	
Further interpretation of the search for SUSY based on αT	SUS11001	PAS-SUS-11-001	35/pb	
Inclusive search for squarks and gluinos at √s = 7 TeV	SUS10009	PAS-SUS-10-009	35/pb	
Search for New Physics in pp Collisions at √s = 7 TeV in Events with a Single Lepton, Jets, and Missing Transverse Momentum	SUS10006		36/pb	
Search for Supersymmetry in pp Collisions at √s = 7 TeV in Events with A Lepton, Photon, and Missing Transverse Energy	SUS11002	CERN-PH-EP-2011-058	35/pb	arxiv:1105.3152
Search for Physics Beyond the Standard Model Using Multilepton Signatures in √s = 7 TeV pp Collisions with the CMS Detector at the LHC	SUS10008		35/pb	
Search for new physics with same-sign isolated di-lepton events with jets and missing transverse energy at the LHC	SUS10004	CERN-PH-EP-2011-033	35/pb	arxiv:1104.3168
A Search for New Physics in b-tagged dijet and multi-jet events with Missing Energy in pp collisions at √s=7 TeV	SUS10011	PAS-SUS-10-011	35/pb	
Search for Physics Beyond the Standard Model in Opposite-Sign Dilepton Events in pp Collisions at √s = 7 TeV	SUS10007	CERN-PH-EP-2011-016	34/pb	arxiv:1103.1348
A Search for Supersymmetry in pp Collisions at 7 TeV Using Events with Two Photons and Large Missing Transverse Energy	SUS10002	CERN-PH-EP-2011-007	36/pb	arxiv:1103.0953
Search for Supersymmetry in pp Collisions at 7 TeV in Events with Jets and Missing Transverse Energy	SUS10003	CERN-PH-EP-2010-084	35/pb	arXiv:1101.1628
Performance of Methods for Data-Driven Background Estimation in SUSY Searches	SUS10001	PAS SUS-10-001	11-76/nb	

A clear channel: same sign dileptons searches

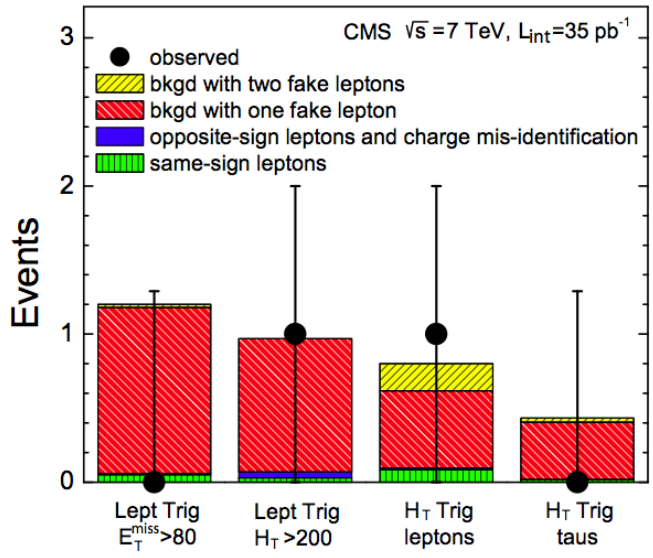
arxiv:1104.3168

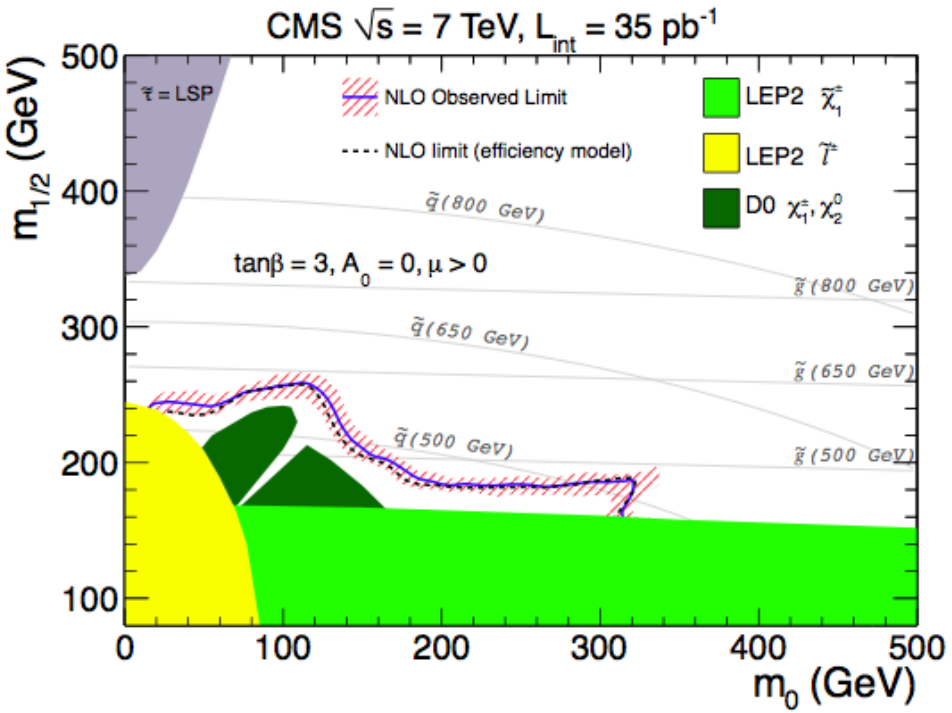




Data driven lepton efficiency

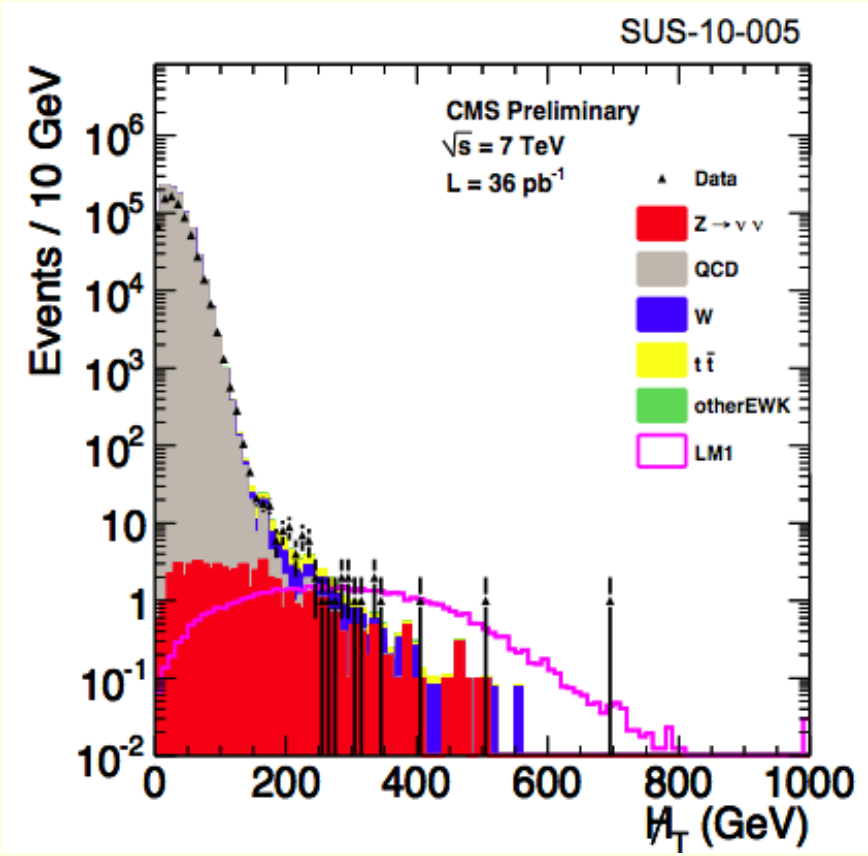
- Easy selection
  - Start from a lepton or HT trigger
  - Ask for 2 same sign leptons (e,mu) with sizeable P_T
  - Ask for at least 2 jets
  - Ask for a sizeable MET
- Bkg mostly from fake leptons and leptons from ttbar (but overall < 1 event expected)





More difficult: Missing Momentum signatures

- You really need to understand your detector in details
  - Particle flow essential here
- Ask for
  - HT triggers
  - At least 3 jets
  - Sizeable HT and Missing momentum
- All bkgs are estimated with data driven techniques



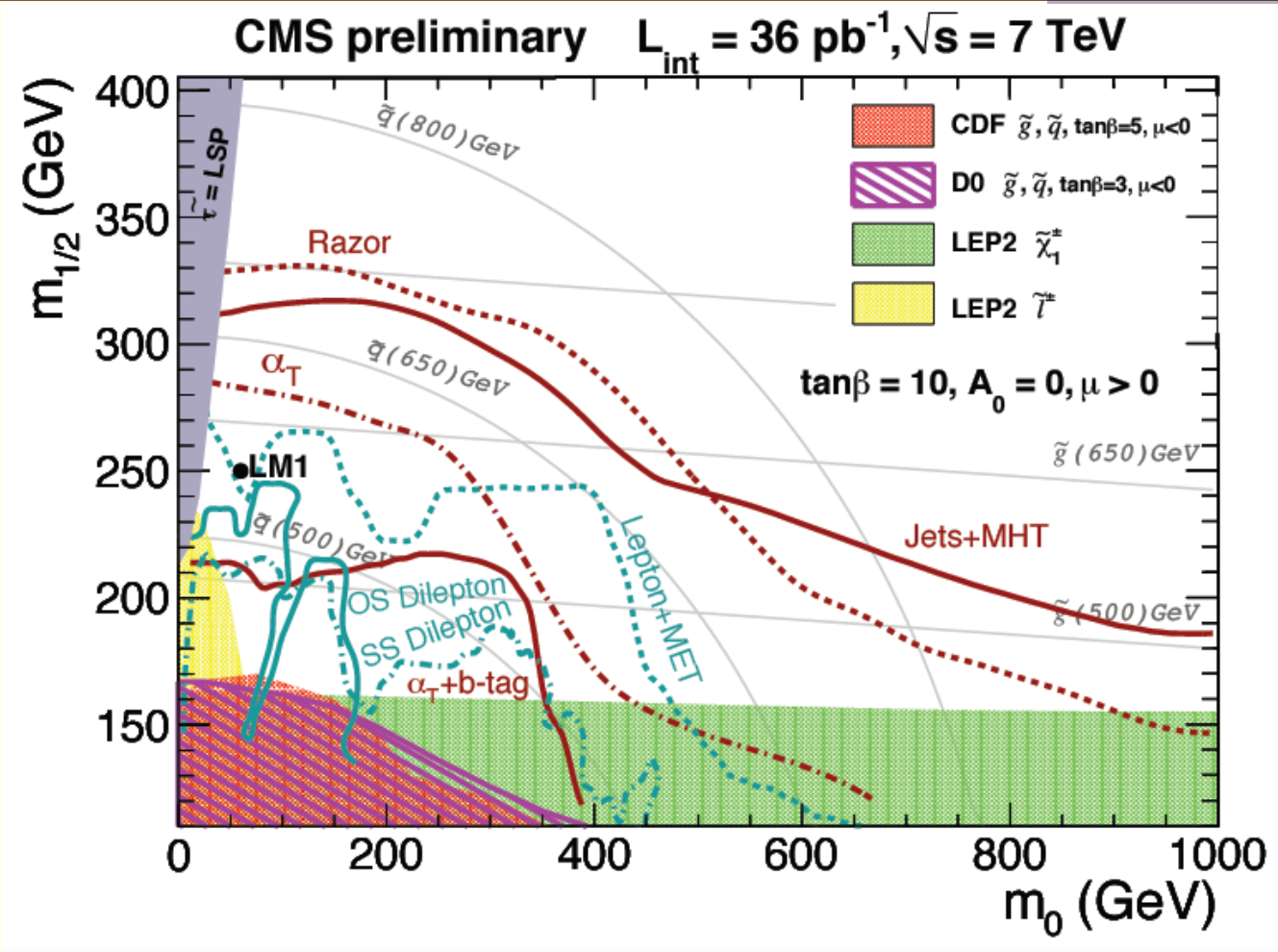
CMS-PAS-SUS-10-005

Method	Baseline selection		High-$\not{H}_T$ selection		High-H_T selection	
$Z \to \nu\bar{\nu}$ from γ+jets	26.3	±4.8	7.1	±2.2	8.4	±2.3
$t\bar{t}/W \to e, \mu$+X lost-lepton method	33.0	±8.1	4.8	±1.9	10.9	±3.4
$t\bar{t}/W \to \tau_{had}$+X method	22.3	±4.6	6.7	±2.1	8.5	±2.5
QCD Rebalance+Smear method	29.7	±15.2	0.16	±0.10	16.0	±7.9
QCD factorization method	25.2	±13.4	0.4	±0.3	17.3	±9.4
Total data-driven background	111.3	±18.5	18.8	±3.5	43.8	±9.2
Observed in 36 pb^{-1} of data	111		15		40	

- CMS LM1:
  - mSUGRA
  - M0=60 GeV
  - M(1/2)=250 GeV
  - A0=0
  - tan(β)=10
  - μ>0

CMS Combined Exclusion Plot

Limits extend beyond LEP/Tevatron reach



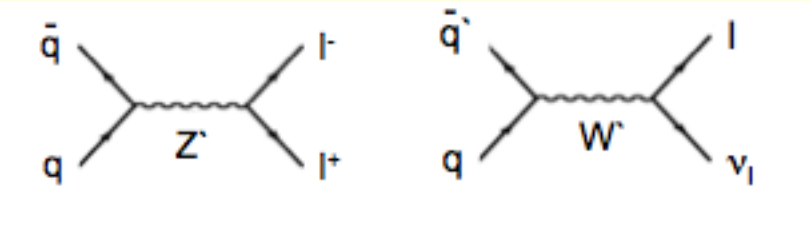
Exotica

- "generic" Z', W'
  - extra gauge bosons, KK graviton, RS, etc
- Extra dimensions
- Black Holes

- Full list of results:
- https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO

Analysis	ArXiv Entry	Luminosity	Publication Status	Approved Plots
Search for Light Resonances Decaying into Pairs of Muons as a Signal of New Physics NEW	1106.2375 (hep-ex)	35/pb	Submitted to JHEP	EXO11013
Search for Same-Sign Top-Quark Pair Production at √s = 7 TeV and Limits on Flavour Changing Neutral Currents in the Top Sector NEW	1106.2142 (hep-ex)	35/pb	Submitted to JHEP	EXO11065
Search for First Generation Scalar Leptoquarks in the evjj channel in pp collisions at √s = 7 TeV NEW	1105.5237 (hep-ex)	36/pb	Submitted to PLB	EXO10006
Search for Large Extra Dimensions in the Diphoton Final State at the Large Hadron Collider	1103.4279 (hep-ex)	36/pb	Accepted by JHEP	EXO10026
Search for Resonances in the Dilepton Mass Distribution in pp collisions at √s = 7 TeV	1103.0981 (hep-ex)	40/pb	Accepted by JHEP	EXO10013
Search for a W' boson decaying to a muon and a neutrino in pp collisions at √s = 7 TeV	1103.0030 (hep-ex)	36/pb	Submitted to PLB	EXO10015
Search for a Heavy Bottom-like Quark in pp Collisions at √s = 7 TeV	1102.4746 (hep-ex)	34/pb	Accepted by PLB	EXO10018
Measurement of Dijet Angular Distributions and Search for Quark Compositeness in pp Collisions at √s = 7 TeV	1102.2020 (hep-ex)	36/pb	10.1103/PhysRevLett.106.201804	EXO10009
Search for Heavy Stable Charged Particles in pp collisions at √s = 7 TeV	1101.1645 (hep-ex)	3.1/pb	10.1007/JHEP03(2011)024	EXO10011
Search for for a heavy gauge boson W' in the final state with an electron and large missing transverse energy in pp collisions at √s = 7 TeV	1012.4945 (hep-ex)	36/pb	10.1016/j.PhysLetB.2011.02.048	EXO10014
Search for Pair Production of First-Generation Scalar Leptoquarks in pp Collisions at √s = 7 TeV	1012.4031 (hep-ex)	33/pb	10.1103/PhysRevLett.106.201802	EXO10005
Search for Pair Production of Second-Generation Scalar Leptoquarks in pp Collisions at √s = 7 TeV	1012.4033 (hep-ex)	34/pb	10.1103/PhysRevLett.106.201803	EXO10007
Search for Microscopic Black Hole Signatures at the Large Hadron Collider	1012.3375 (hep-ex)	35/pb	10.1016/j.PhysLetB.2011.02.032	EXO10017
Search for Stopped Gluinos in pp Collisions at √s = 7 TeV	1011.5861 (hep-ex)	10/pb	10.1103/PhysRevLett.106.011801	EXO10003
Search for Quark Compositeness with the Dijet Centrality Ratio in pp Collisions at √s = 7 TeV	1010.4439 (hep-ex)	2.9/pb	10.1103/PhysRevLett.105.262001	
Search for Dijet Resonances in 7 TeV pp Collisions at CMS	1010.0203 (hep-ex)	2.9/pb	10.1103/PhysRevLett.105.211801	

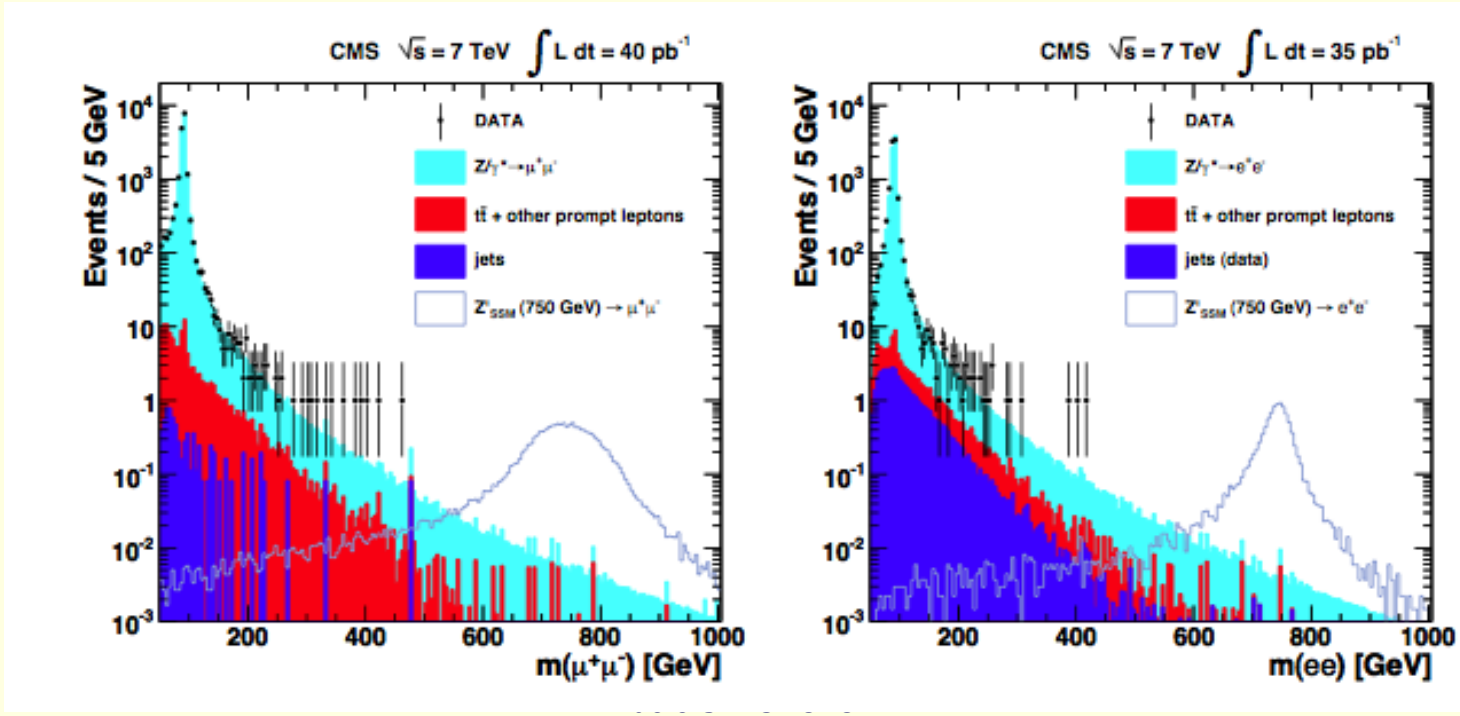
W′, Z′ to leptons



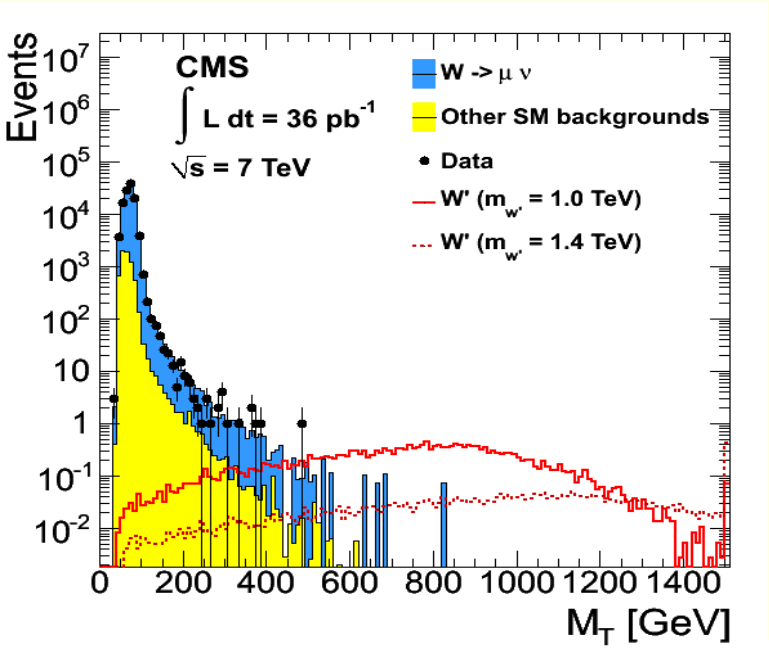
- Z′: search for a clear peak mass under DY continuum

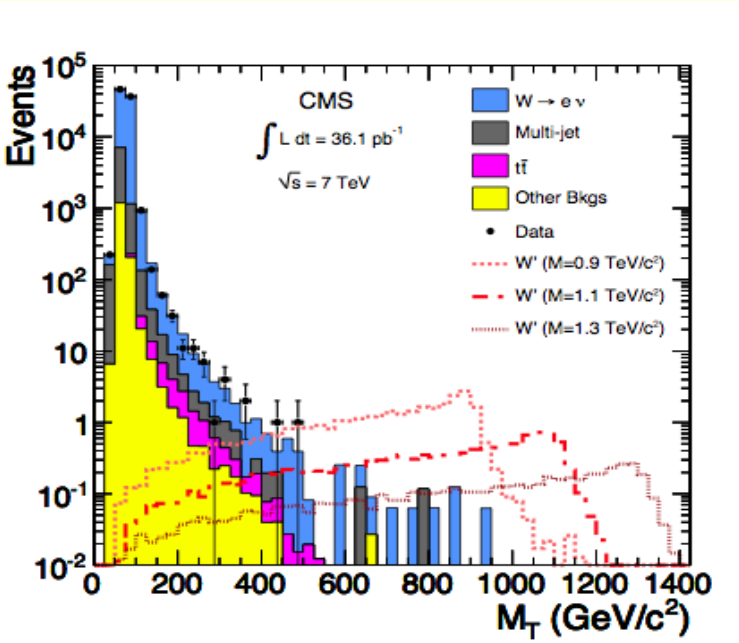
arXiv:1103.0981

Channel	μμ	ee	Combined
Z_{SSM}	1027 GeV	958 GeV	1140 GeV
Z_{ψ}	792 GeV	731 GeV	887 GeV
G_{KK}, $k/M_{Pl} = 0.05$	778 GeV	729 GeV	855 GeV
G_{KK}, $k/M_{Pl} = 0.10$	987 GeV	931 GeV	1079 GeV



W': search for peaks in the $M_T(l,\nu)$ spectrum



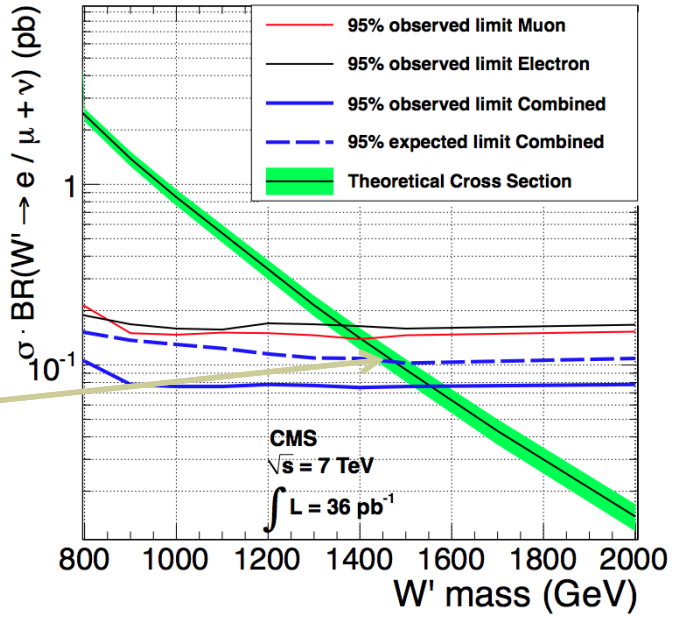


$$M_{\mathrm{T}} = \sqrt{2 \cdot p_{\mathrm{T}} \cdot E_{\mathrm{T}}^{\mathrm{miss}} \cdot (1 - \cos \Delta\phi_{\mu,\nu})}$$

CMS limits (36 pb^{-1})

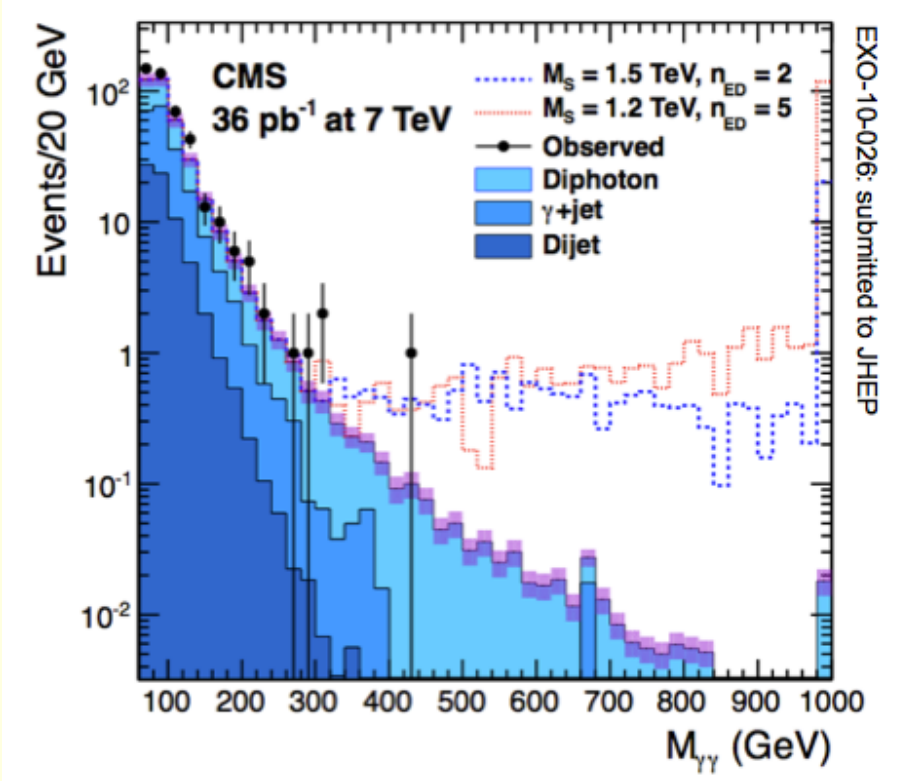
eν	1.36 TeV
μν	1.4 TeV
eν+μν	1.58 TeV

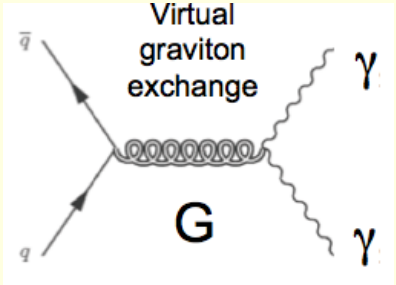
eν arXiv:1012.5945, Accepted by PLB
μν arXiv:1103.0030, Submitted to PLB



Extra dimensions in γγ

- Require two high energy isolated photons, with Mγγ > 60 GeV
- Use barrel photons only, since they have highest purity
- Divide the spectrum in control, intermediate and signal region, and use control to assess the backgrounds



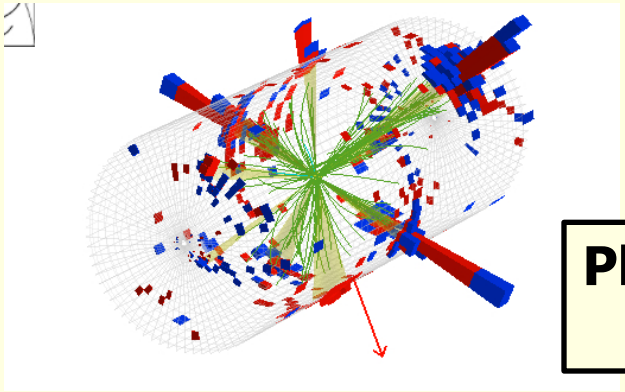


Process	$60 < M_{\gamma\gamma} < 200$ GeV	$200 < M_{\gamma\gamma} < 500$ GeV	500 GeV$< M_{\gamma\gamma}$
Dijets	70 ± 28	0.5 ± 0.2	0.0009 ± 0.0004
γ + Jets	145 ± 7	2.3 ± 0.3	0.016 ± 0.003
Diphotons	150 ± 35	6.2 ± 1.4	0.29 ± 0.07
Total Backgrounds	365 ± 49	9.0 ± 1.5	0.30 ± 0.07
Observed	428	12	0

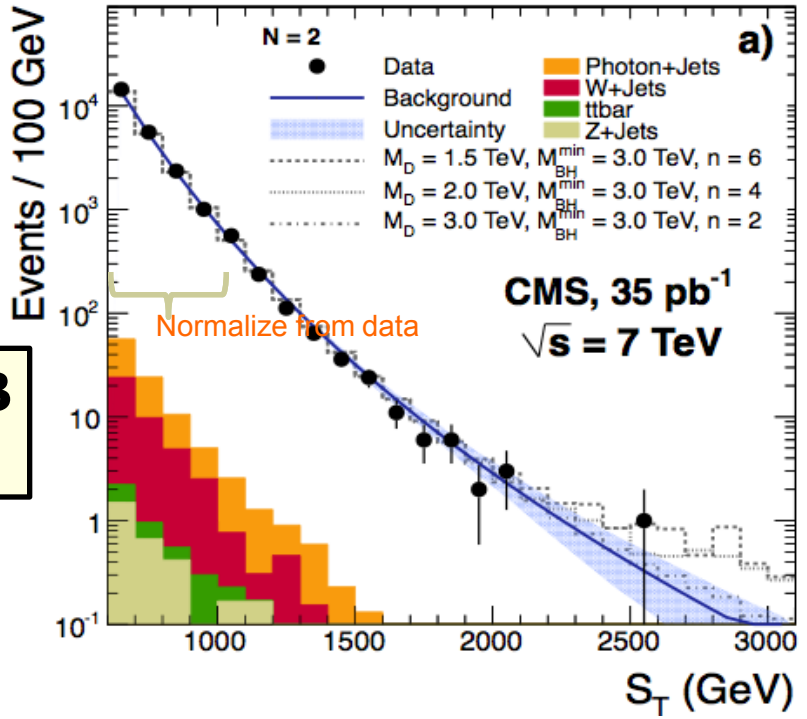
Upper limit on σ x BR < 0.11 pb for Mγγ> 500 GeV
Lower limits on Effective Planck scale in the range 1.6-2.3 TeV (depending on the # of ED)

1103.4279 (hep-ex)

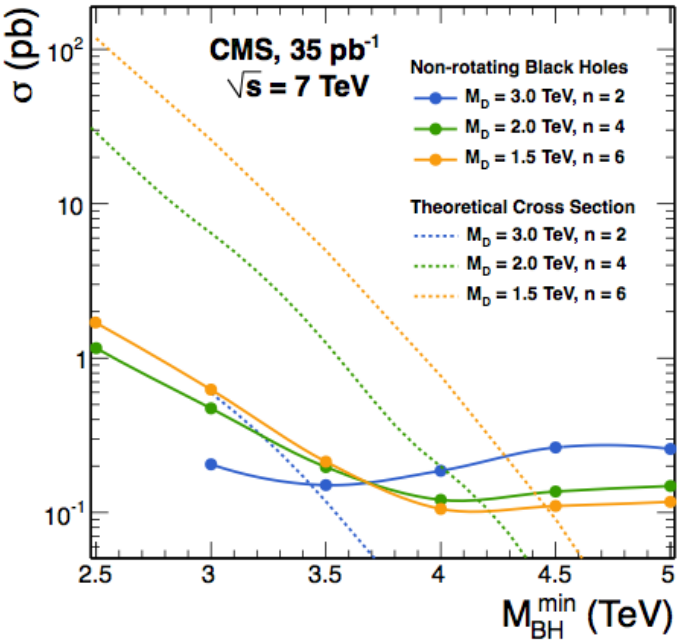
Microscopic black holes



Physics Letters B
697,2011, 434



- Spectacular signature! BH decays via Hawking radiation "democratically" to SM particles
  - Events with large number of energetic final state particles (quarks and gluons but also leptons, photons…)
- Look for excess in S_T with S_T defined as the scalar sum of all sizeable (E>50 GeV) 'objects' (jets, leptons, photons, MET)
- Bkg: mostly multijet QCD; from data S_T<1100 GeV



Limits on the black hole mass are set in the range 3.5 – 4.5 TeV (model dependent)

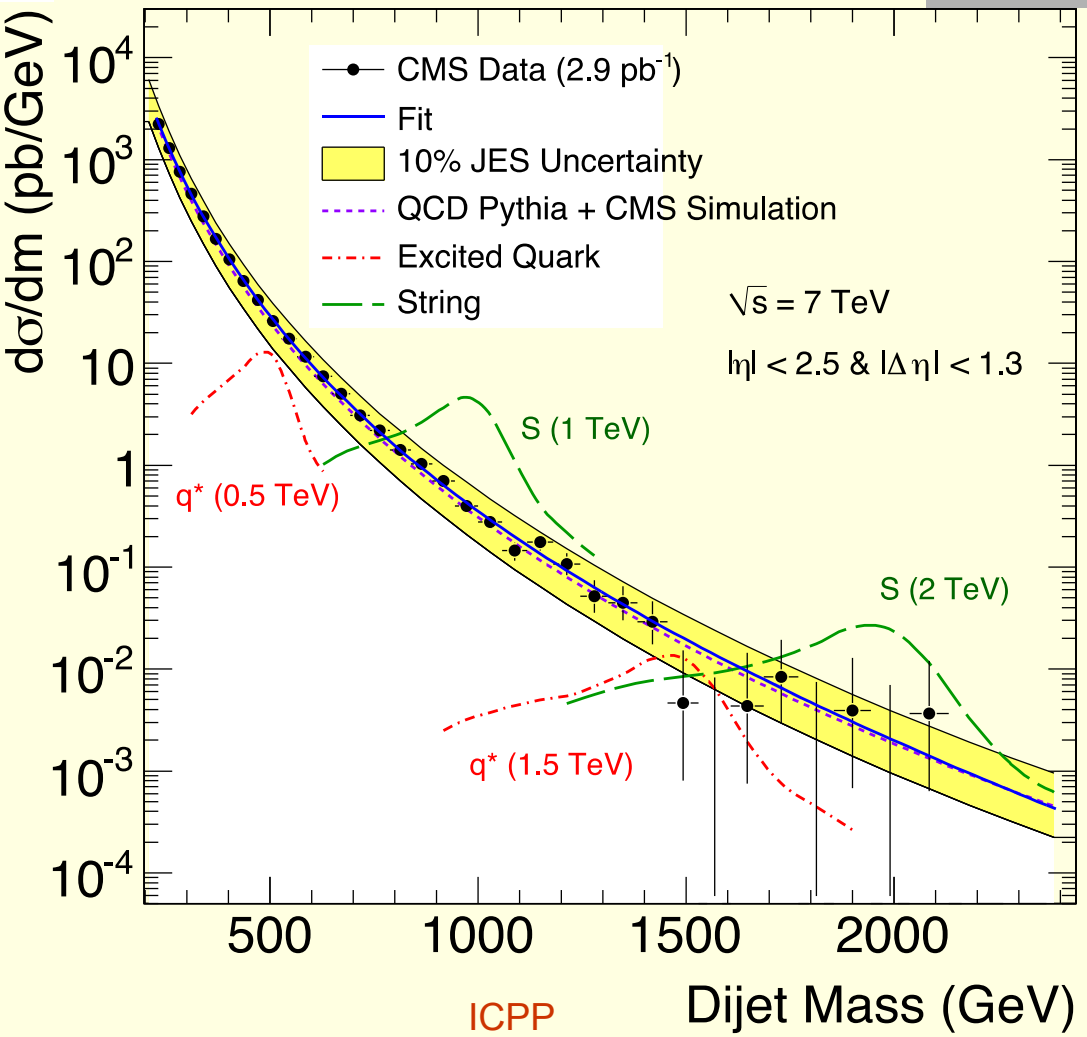
Conclusions

- Impressive wealth of results from first 12 months of run at 7 TeV
- CMS is doing very well and LHC exceeds expetactions
  - Usefull training on cosmics to understand detectors
  - Data usable from day 1
- Many preliminary results to be upgraded to final and published with 20 X statistics (and more…)
- I didn't mention Heavy Ions and many other interesting analyses
- 2011-12 will be exciting, approaching 10 fb^{-1}
- New physics is (hopefully) around the corner

Back-up slides

Search for di-jet resonances

Phys. Rev. Lett. 105, 211801 (2010)

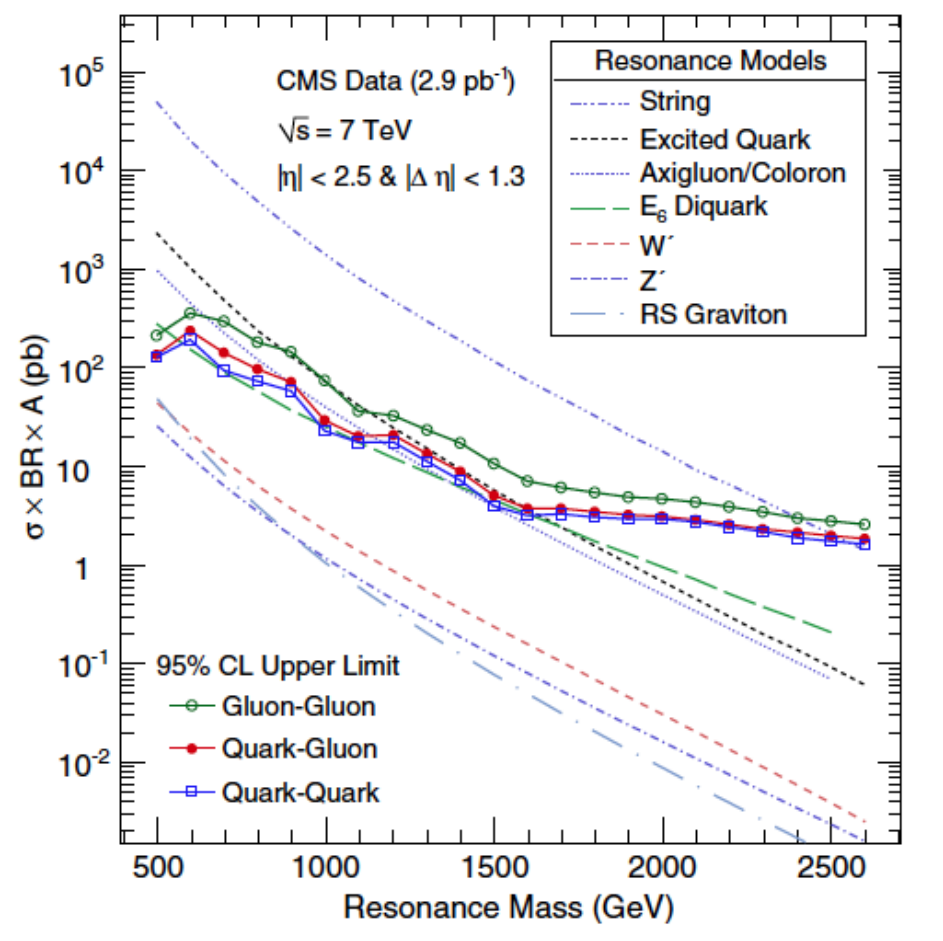


Search for di-jet resonances

0.5<M(q*)<1.58 TeV

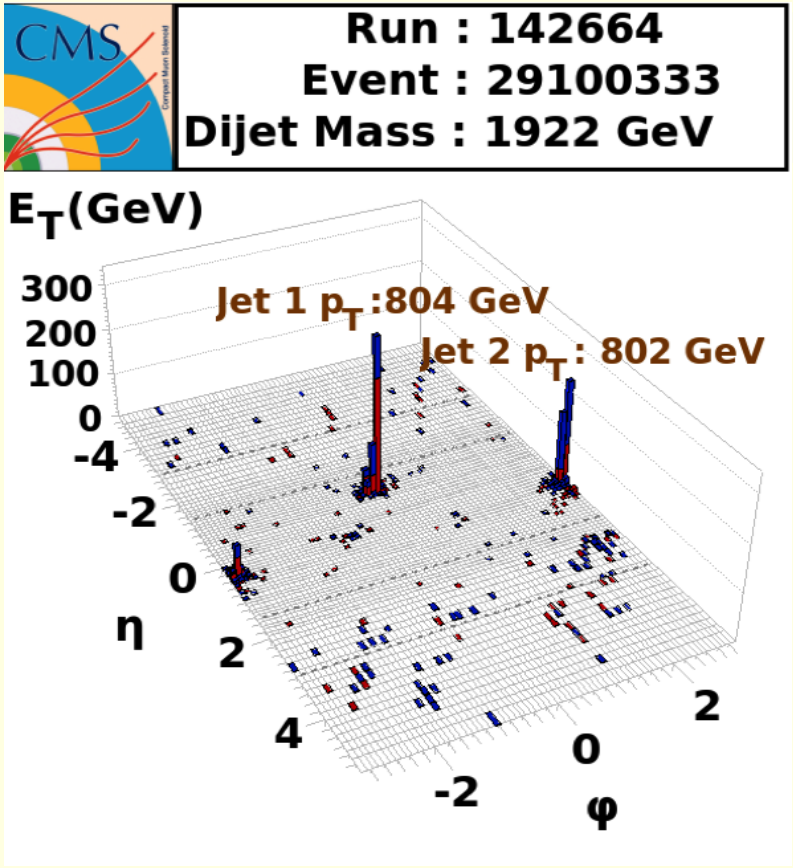
Other models excluded in given mass windows

Approaching Z' and W' with the analysis of all the collected 40 pb^{-1}

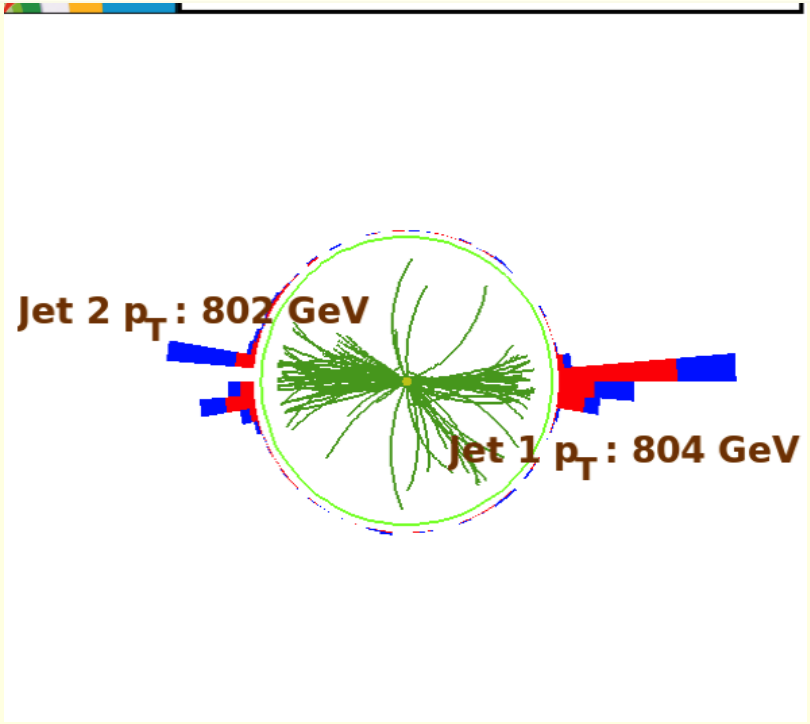


Di-jet mass and search for resonances

CMS-PAS-EXO-2010-010



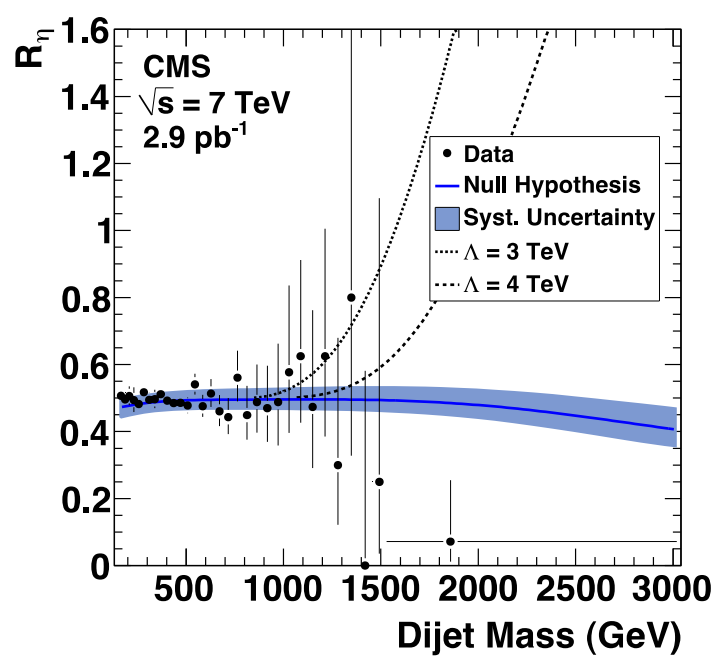
Highest Di-jet Mass Event Observed
Mjj = 1.922 TeV

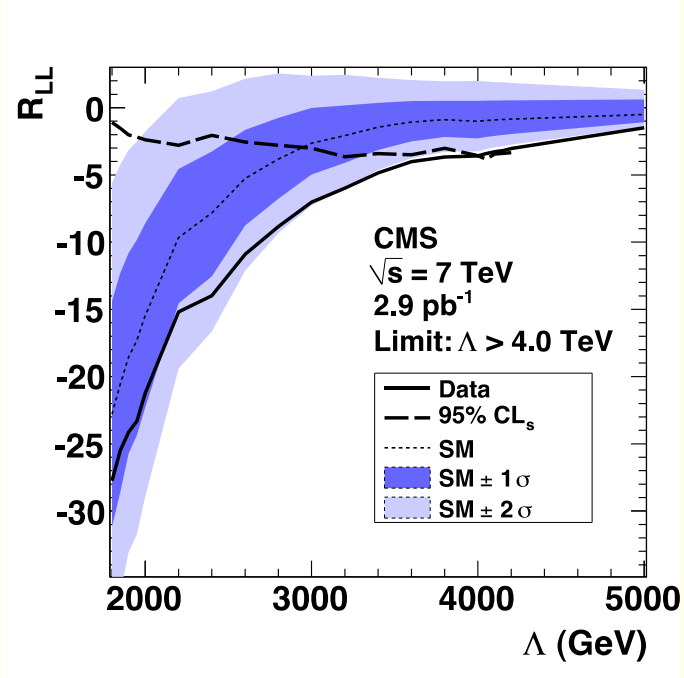


Limit on contact interactions

CMS-PAS-EXO-2010-002

- Di-jet centrality ratio (jets at $|\eta|<0.7$ vs $0.7<|\eta|<1.3$)



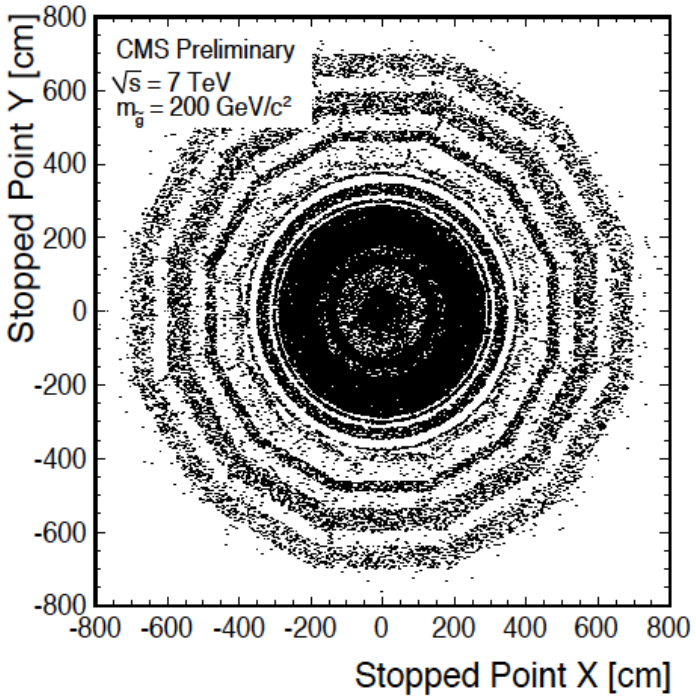


Λ > 4 TeV Limit from Tevatron (Λ > 2.8 TeV) surpassed

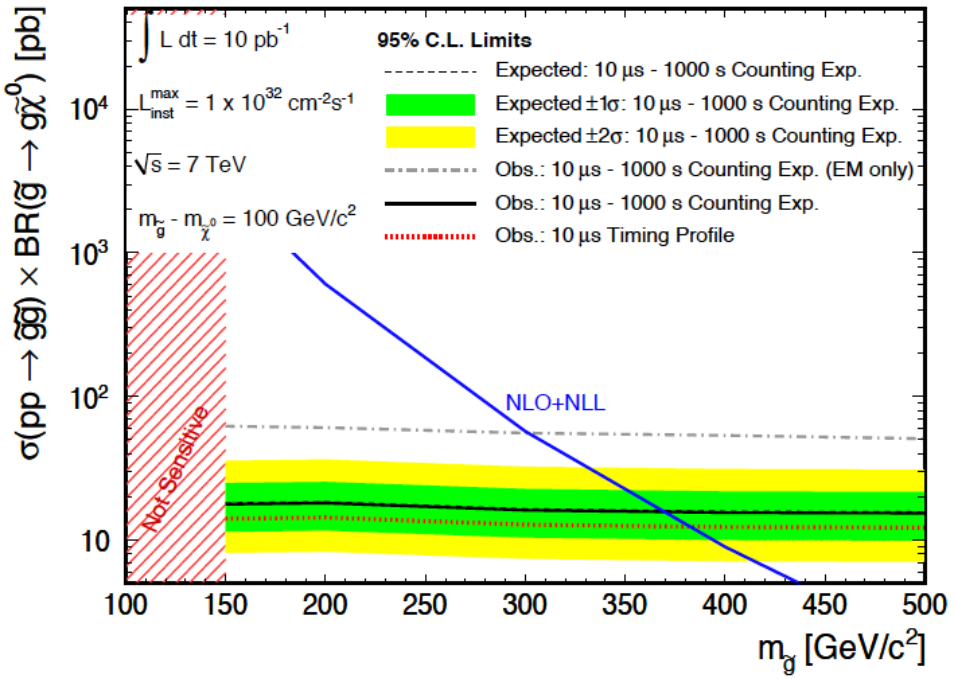
Search for Stopped Gluinos

Submitted to PRL arxiv:1011.5861

- Searched for long-lived gluinos that stops in CMS and decays producing a signal in HCAL
- Explored a region uncovered by Tevatron,

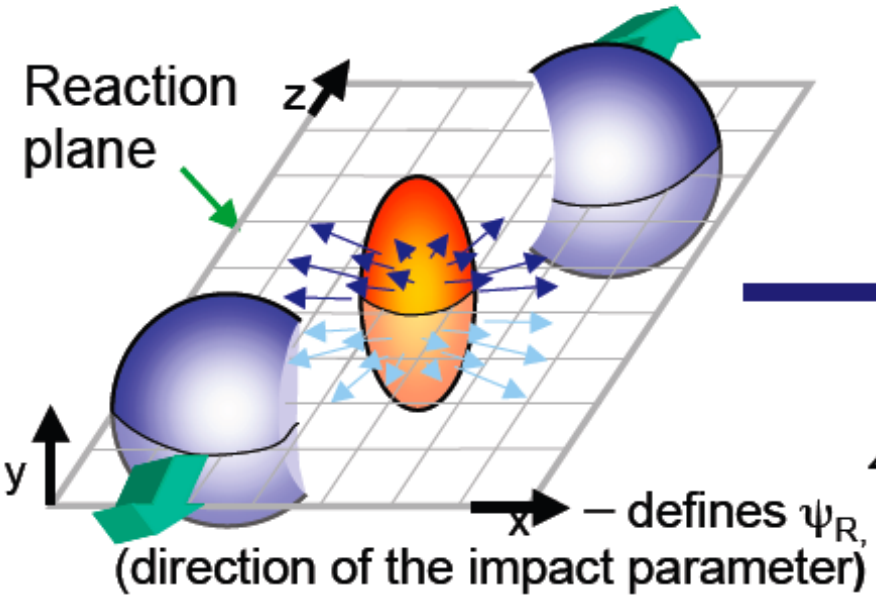


Esclude M>370 GeV

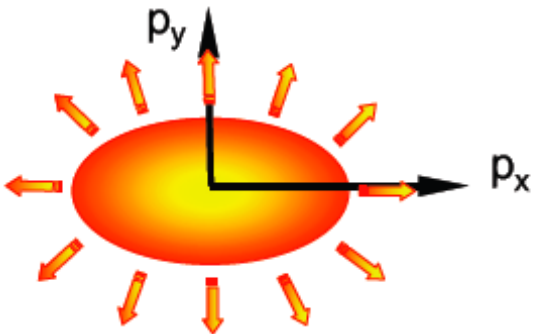


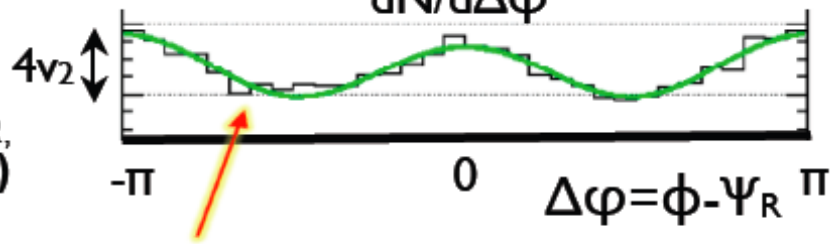
Prologo: Correlations in Heavy Ions

Collective flow phenomena:



Pressure driven expansion





~ cos(2Δφ) (long-range in η)

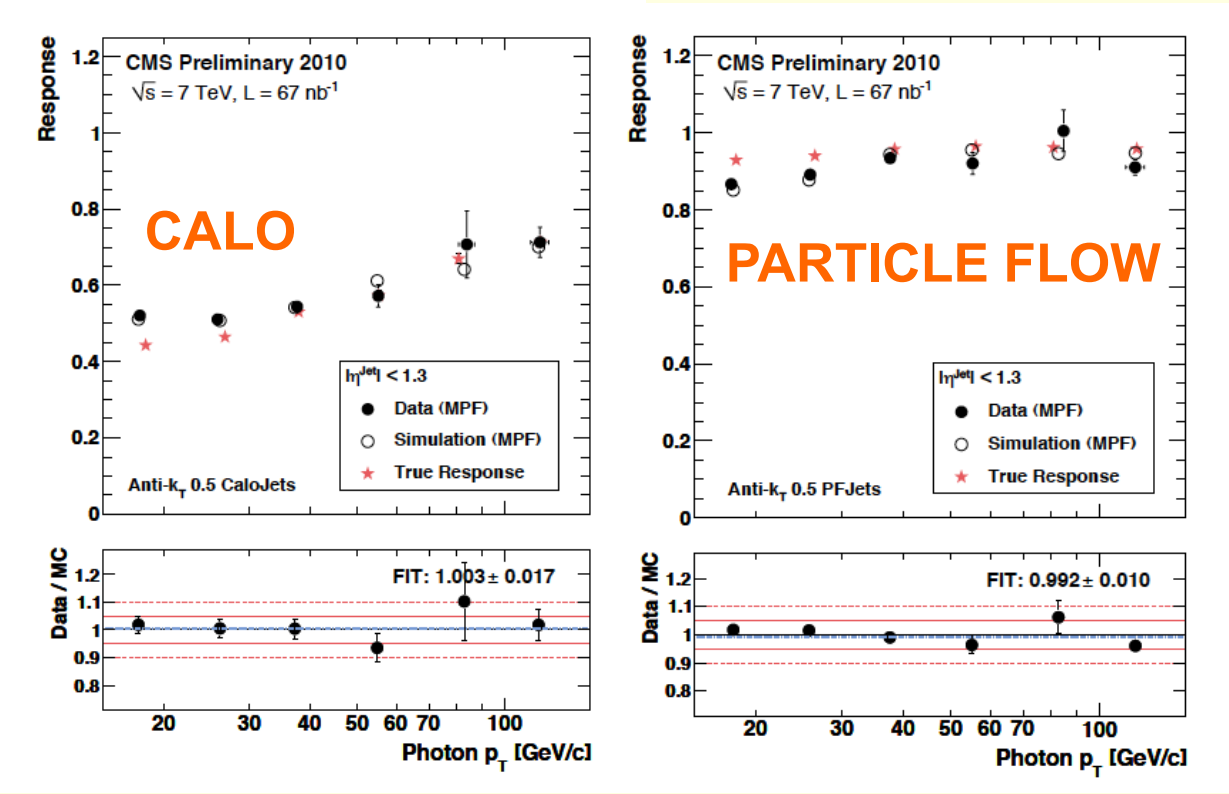
Extracted shear viscosity of the medium found to be close to theoretical lower bound 1/4π

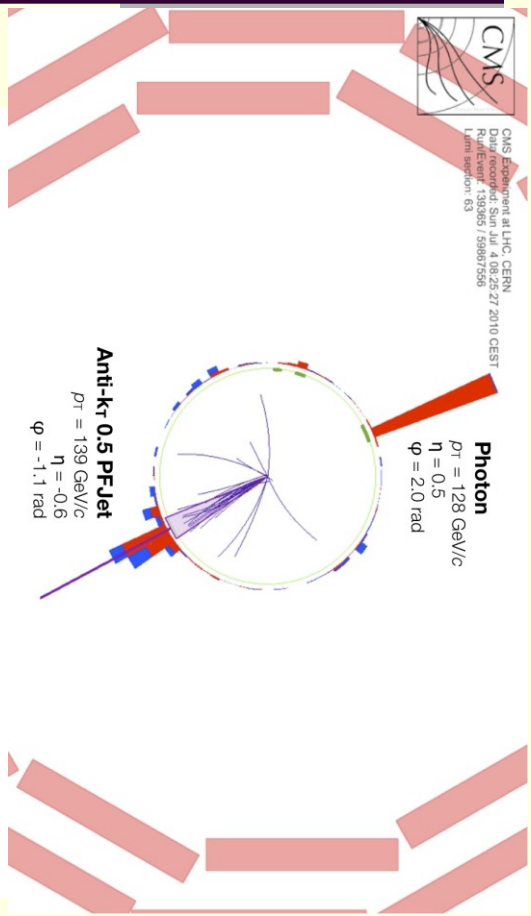
Most convincing evidence of "perfect liquid" at RHIC!

Jet corrections

- Absolute calibration from γ+jet events

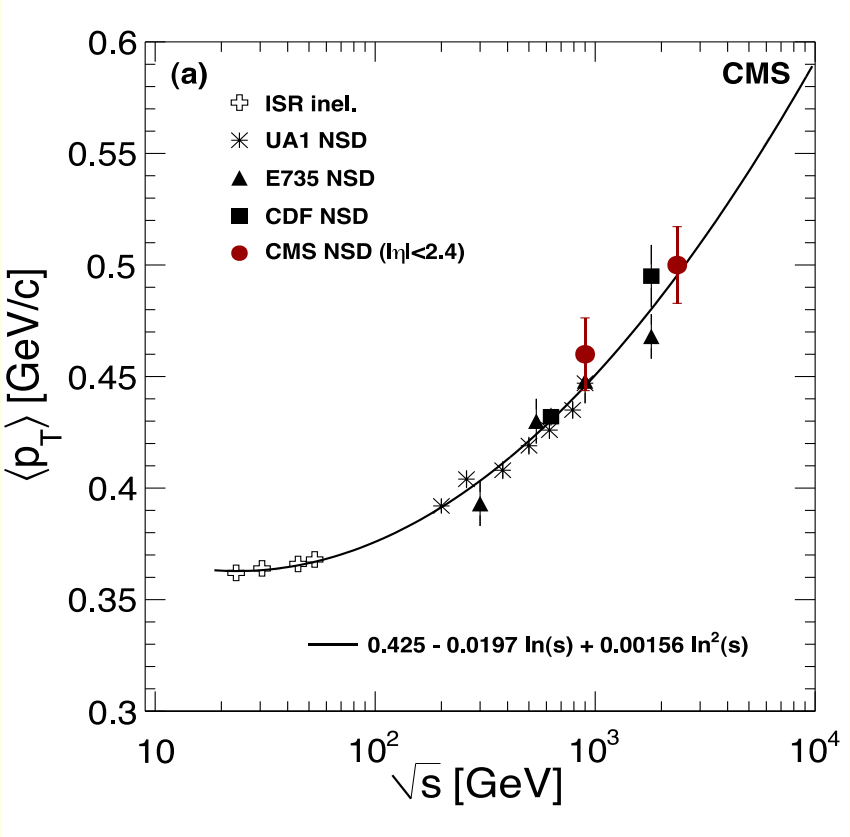
CMS-PAS-JME-2010-003

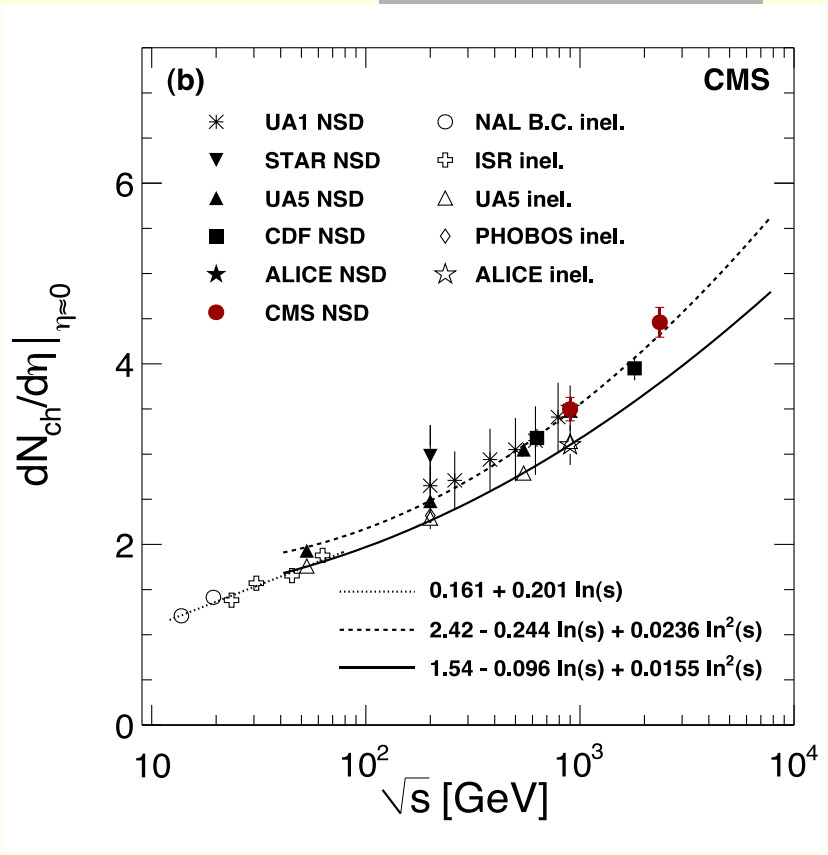




CMS: absolute correction ~ 10% for CALO and 5% for PF as uncertainty

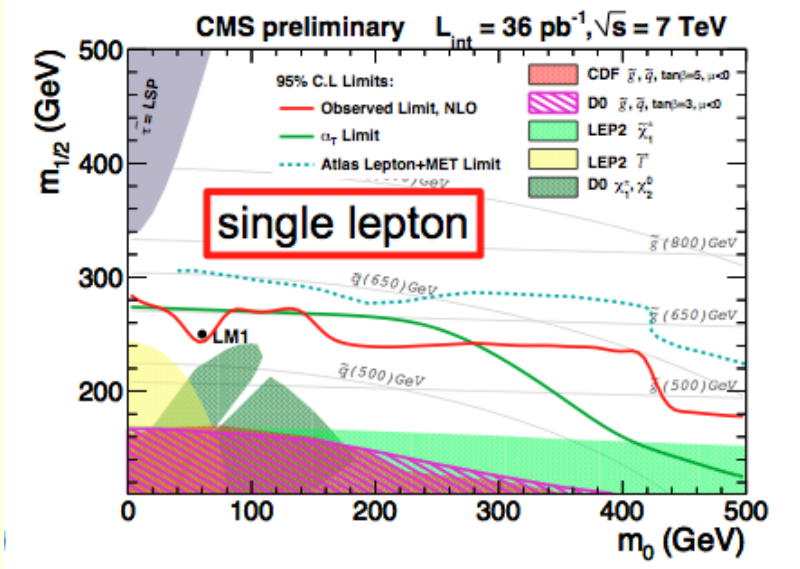
Charged hadrons vs E_{cm}

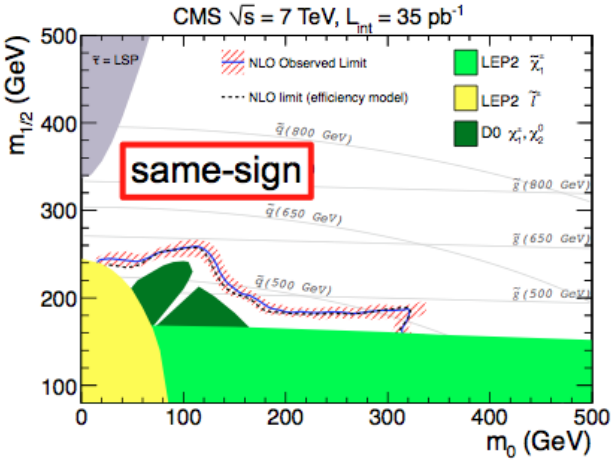


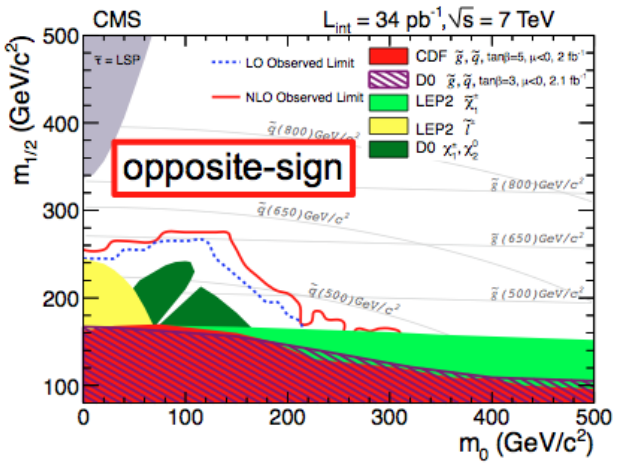


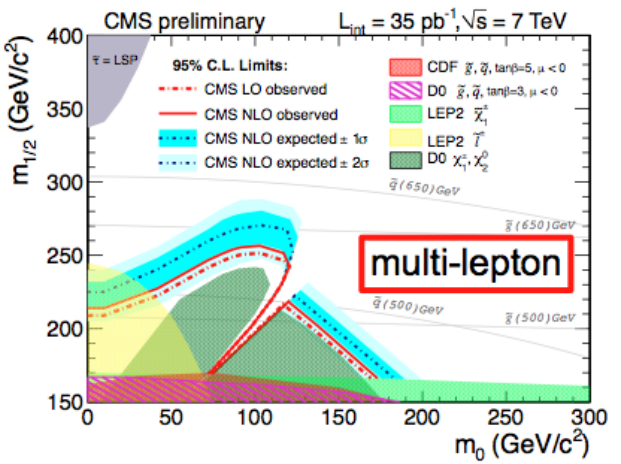
Rise of dN/dη in data stronger than currently used models

“N” leptons
mSUGRA exclusions with tanβ= 3, μ> 0 and A0= 0





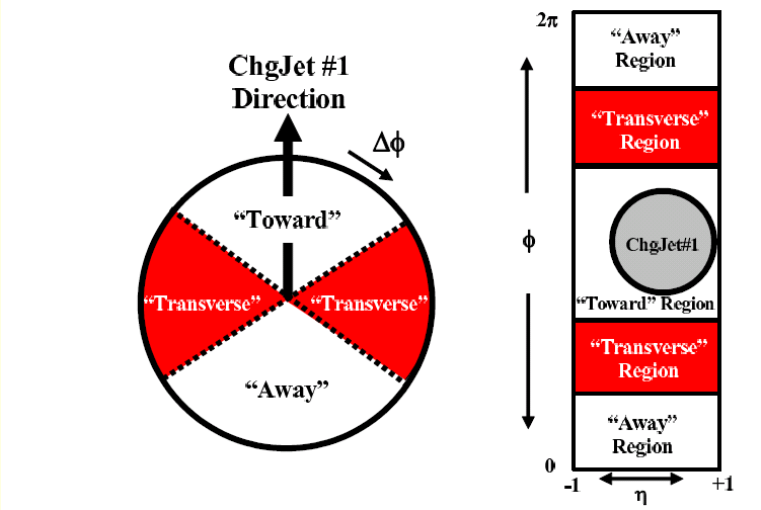


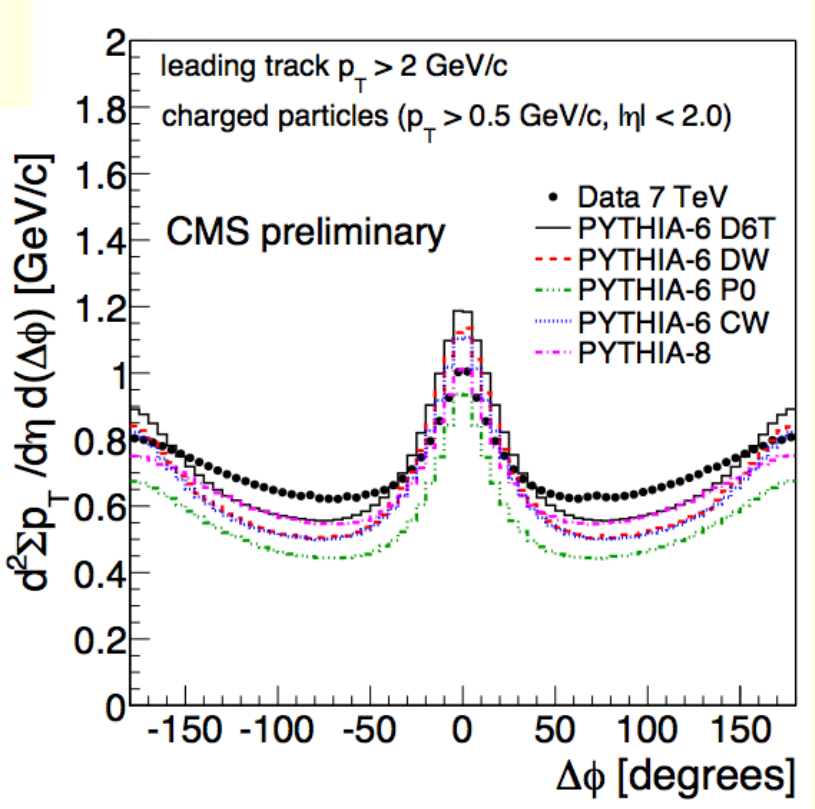


Underlying events at 7 TeV

CMS-PAS-QCD-2010-010

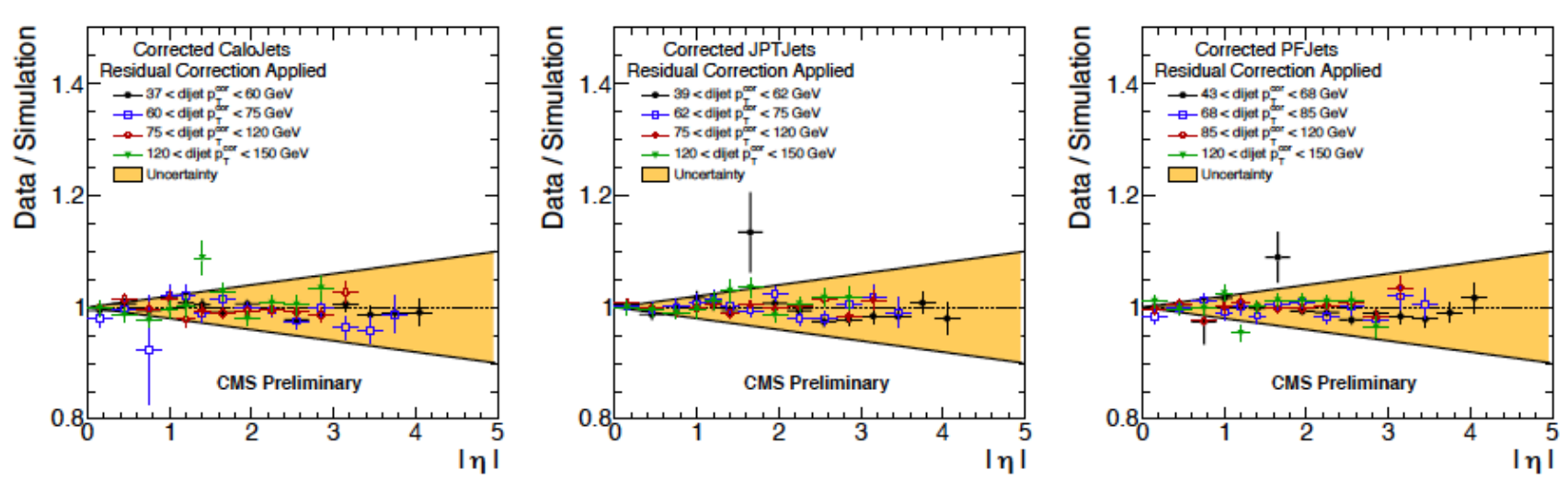
Main observables:
- $dN/d\eta d\phi$, charged density
- $-d(P_T^{sum})/d\eta d\phi$, energy density





Jet corrections

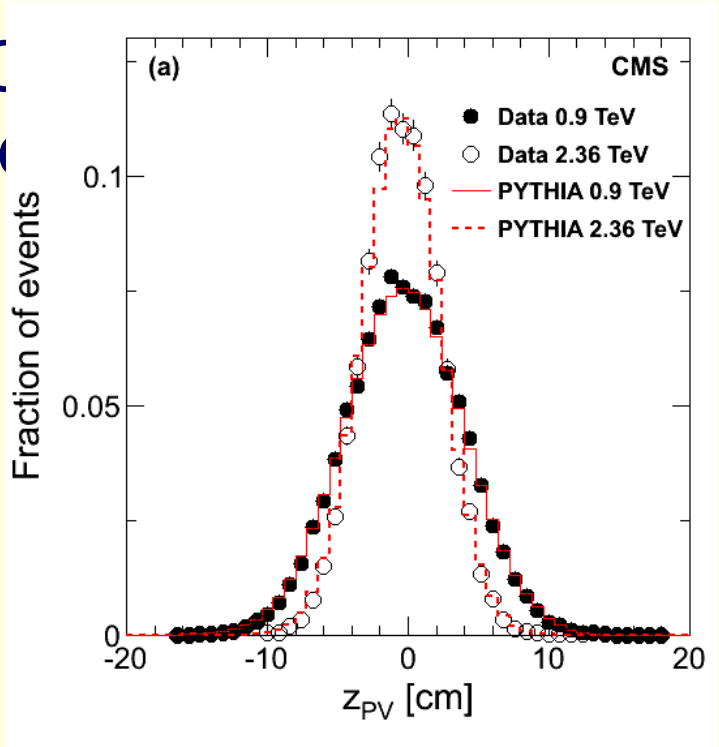
- Relative corrections (jet equalization) from di-jet balancing (data/MC) CMS-PAS-JME-2010-003



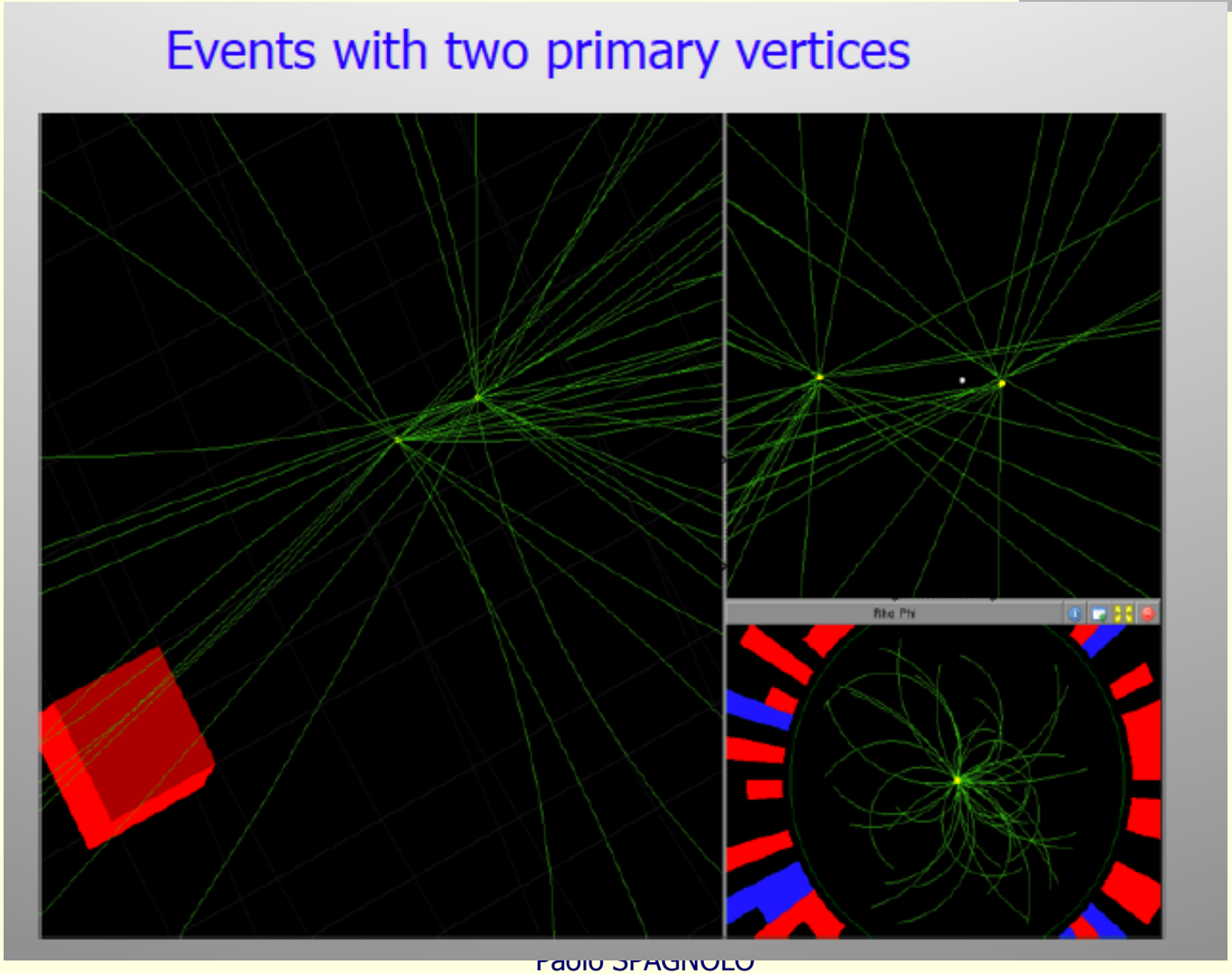
CMS: For relative corrections take 2%|eta| as uncertainty

Example : dN/dη from CMS

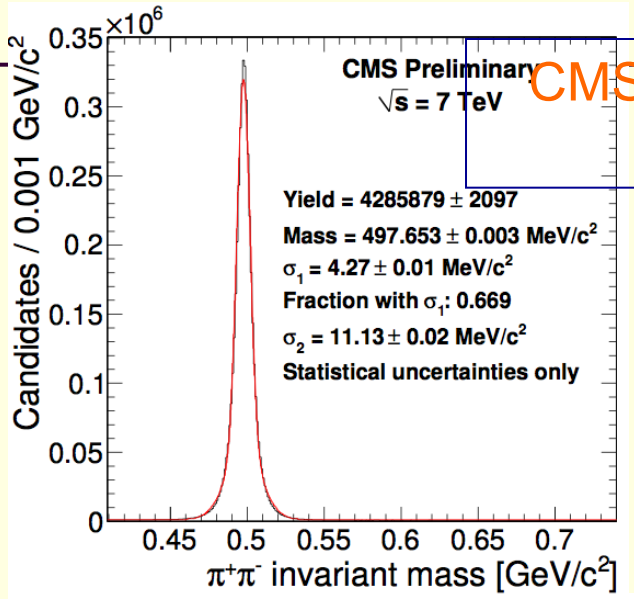
- Event selection:
- – >3 GeV total energy on both sides in the Forward Calorimeter (HF)
- – Beam Halo rejection (BSC
- – Beam background rejecti
- – Collision vertex
- Measure NSD $|\eta| < 2.5$
- Efficiencies:
  - NSD: ~**86 %**
  - SD: ~19 %
  - DD: ~34 %



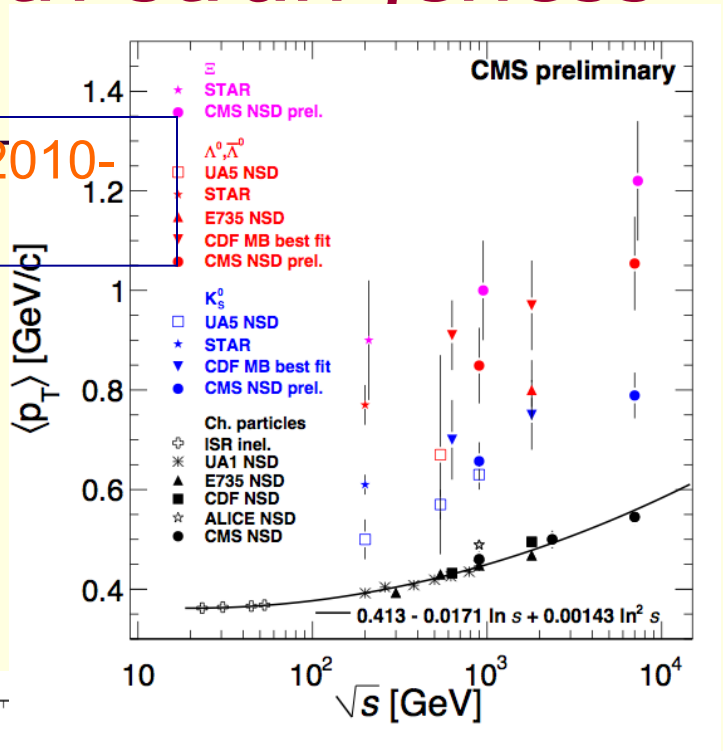
Events with multiple primary vertexes were rare at that luminosity

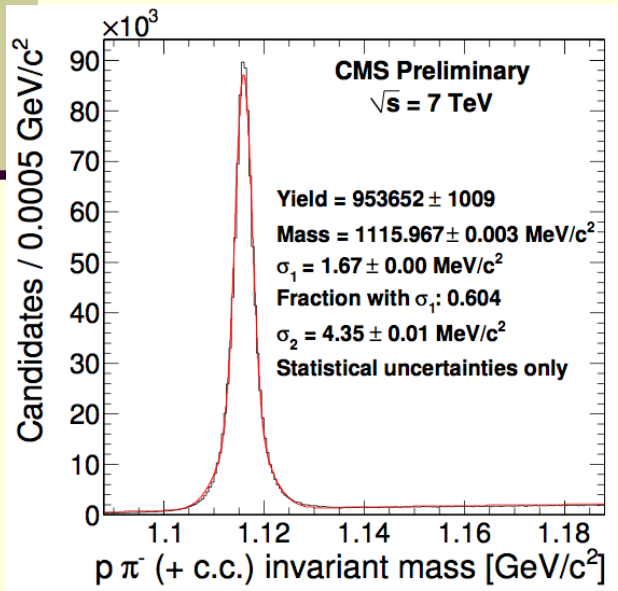


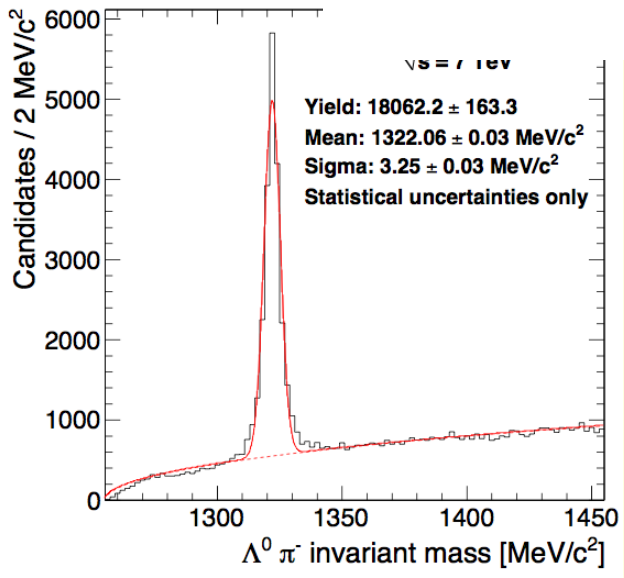
Spectra of particles with strangeness



CMS-PAS-QCD-2010-007



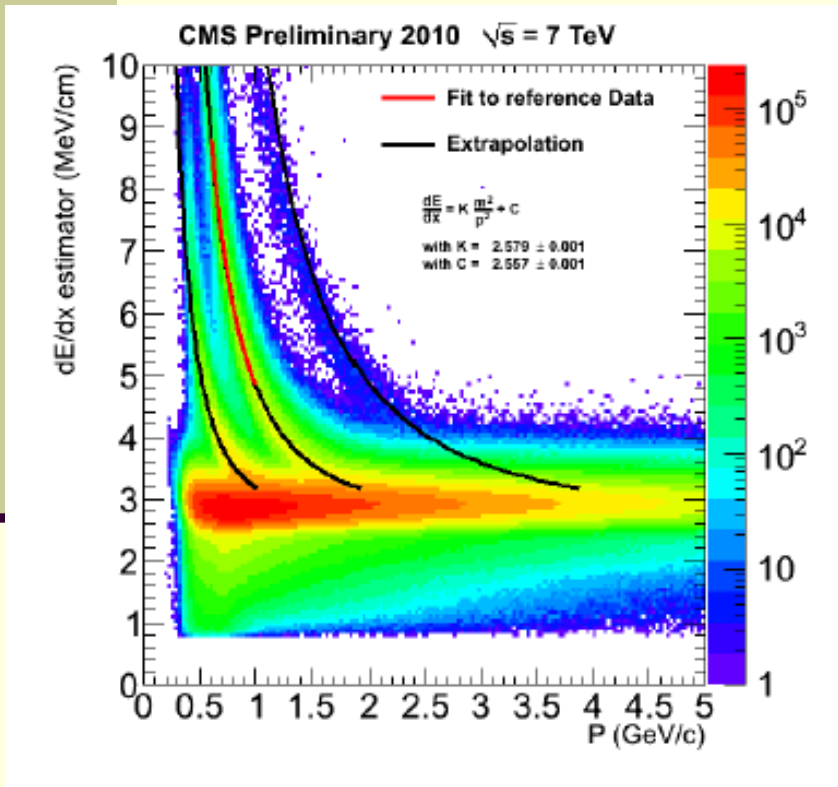


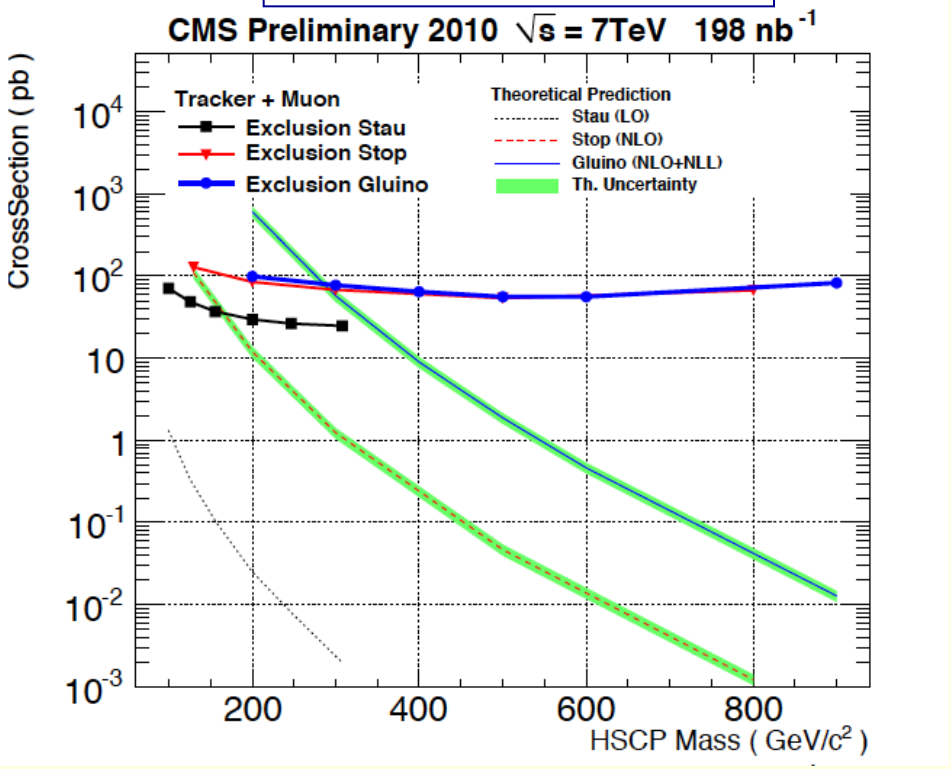


Heavy Stable Charged Particles

- A very early analysis: dE/dx and possibly Time-of-Flight based
- dE/dx part is well understood from cosmic runs
- Sensitivity beyond the Tevatron with as little as 1 pb^{-1} of data

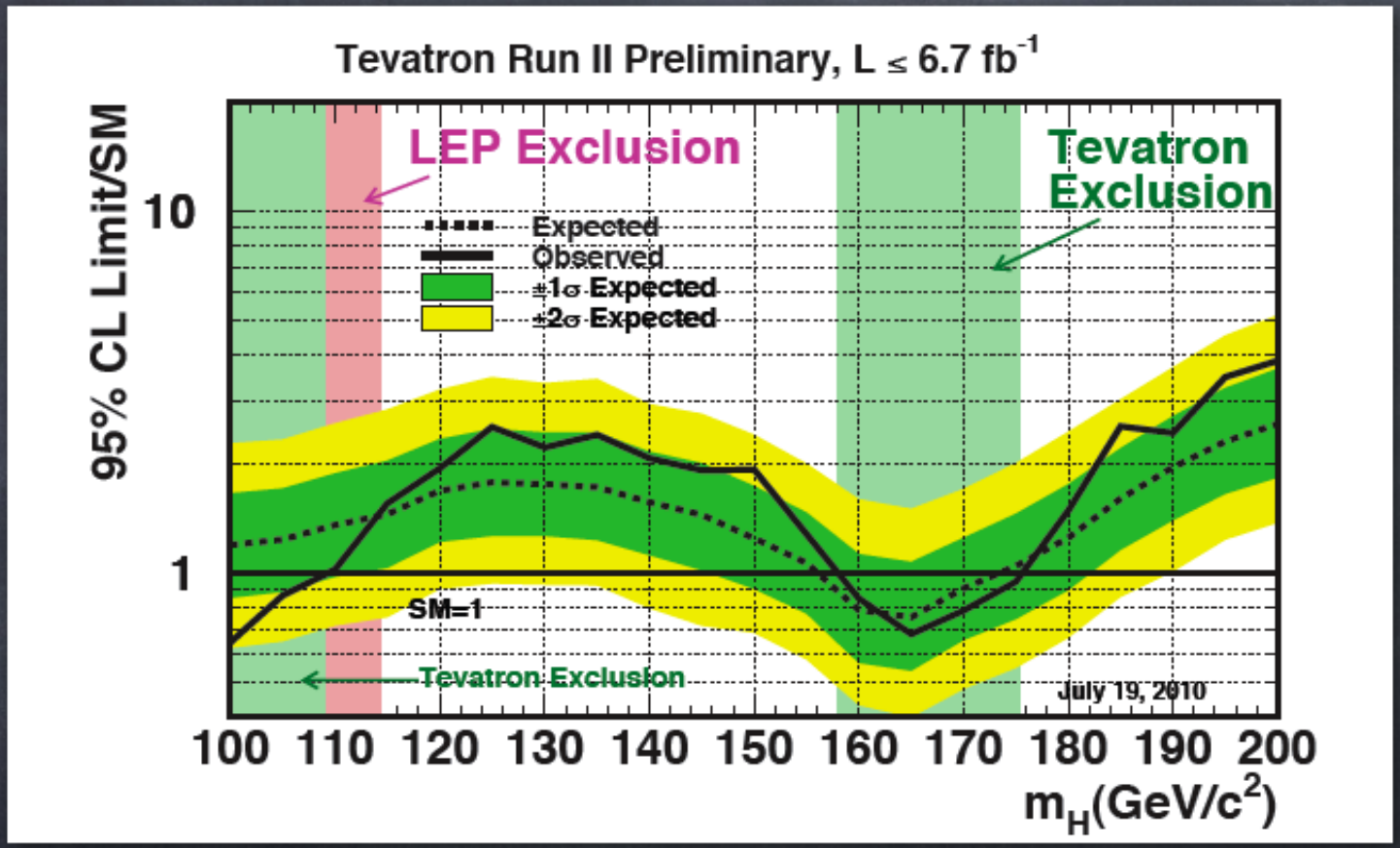
CMS-PAS-EXO-2010-004





Tevatron combination

"Expected sensitivity"



- High mass 95% CL exclusion :
  - $158 < m_H < 175$ GeV
    - 4 times previous (162 - 166 GeV)
    - Expected ($156 < m_H < 175$ GeV)

The dN/dη distribution

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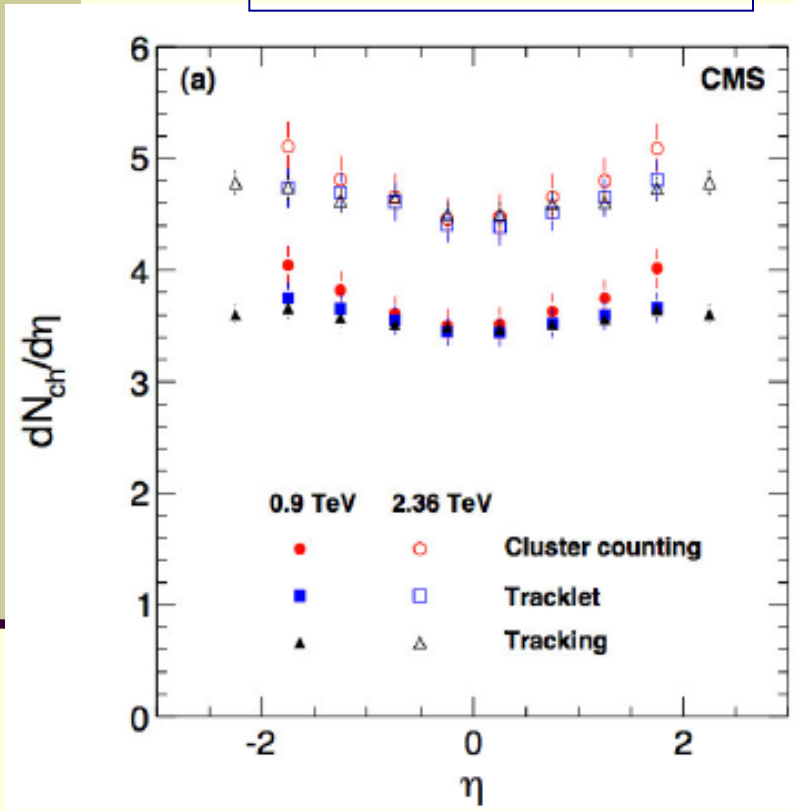
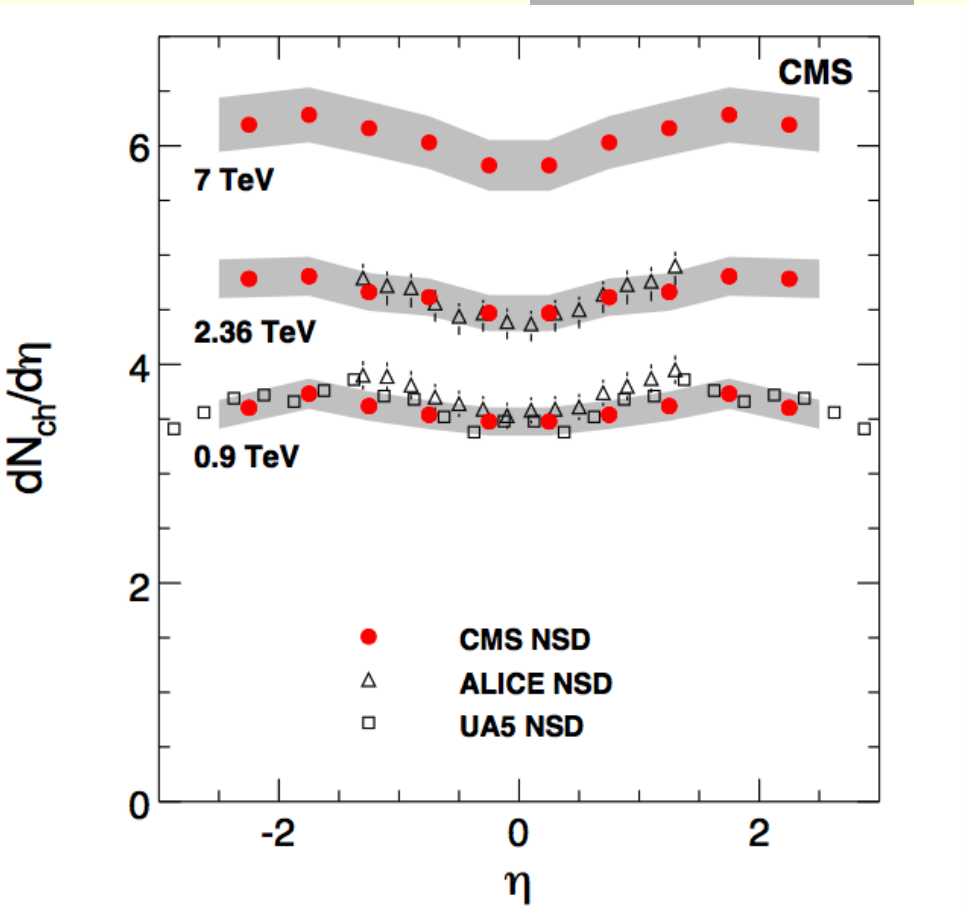
The three methods

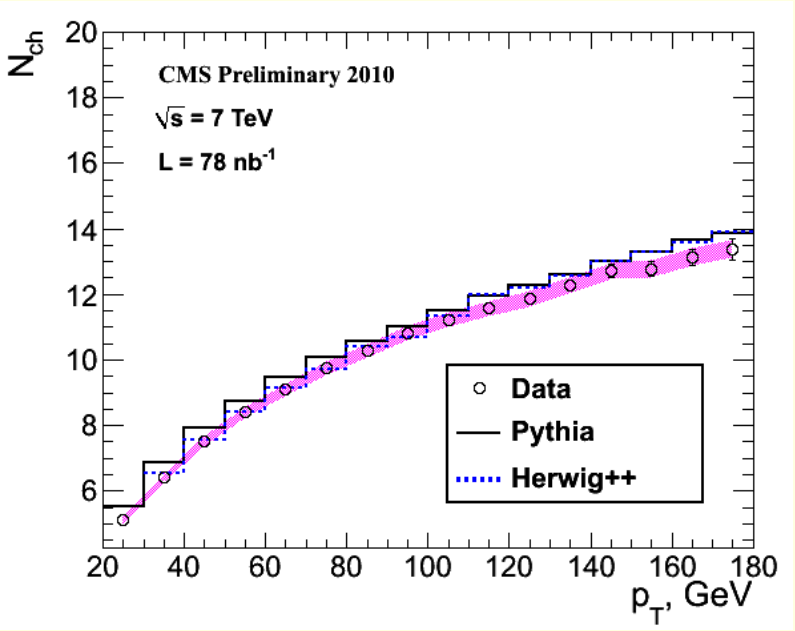




Correction for Single diffractive dissociation ~ few% controlled with data

Jet transverse structures

CMS-PAS-QCD-2010-014



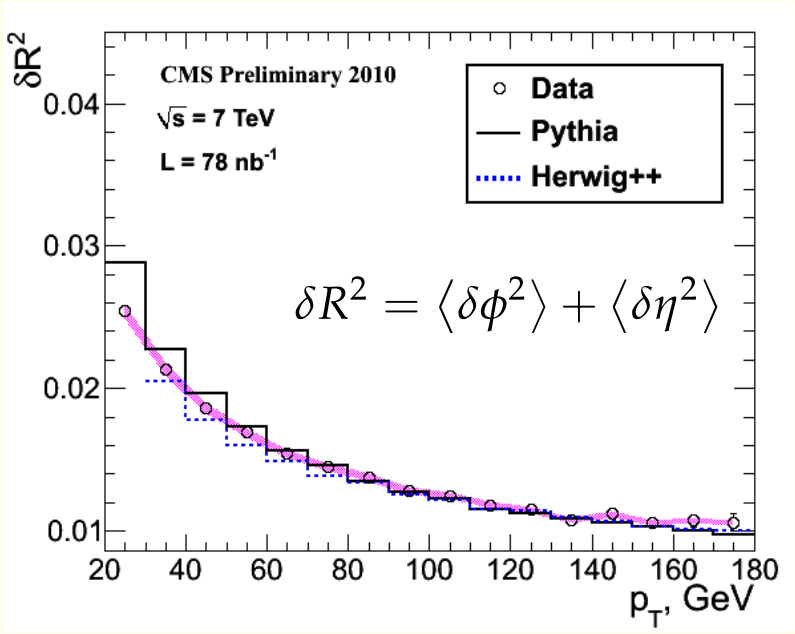
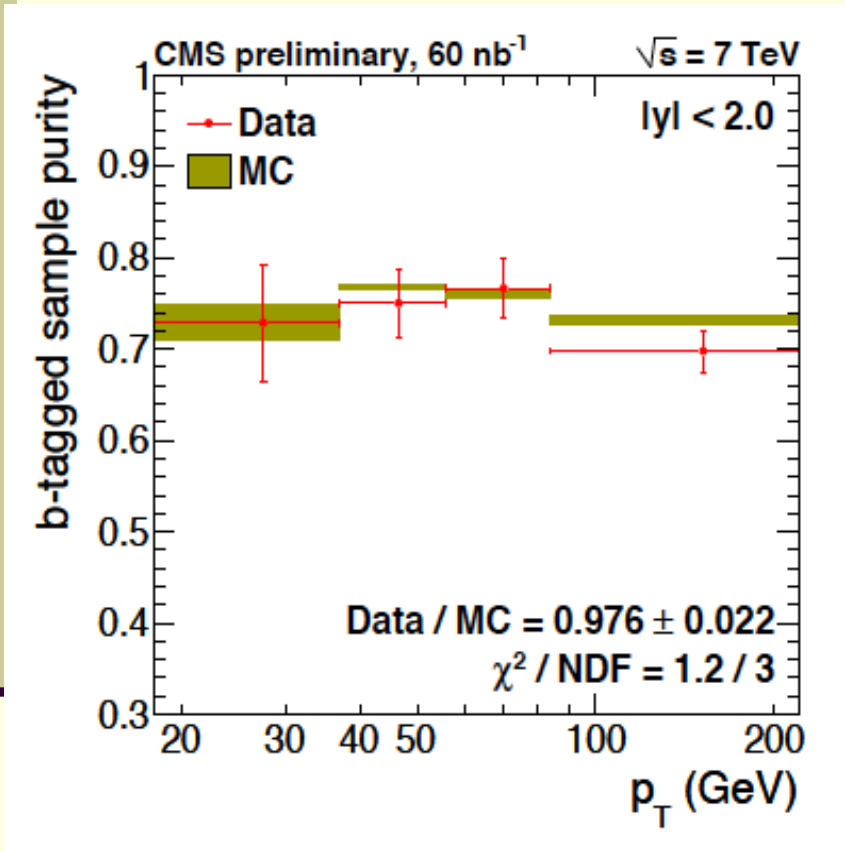
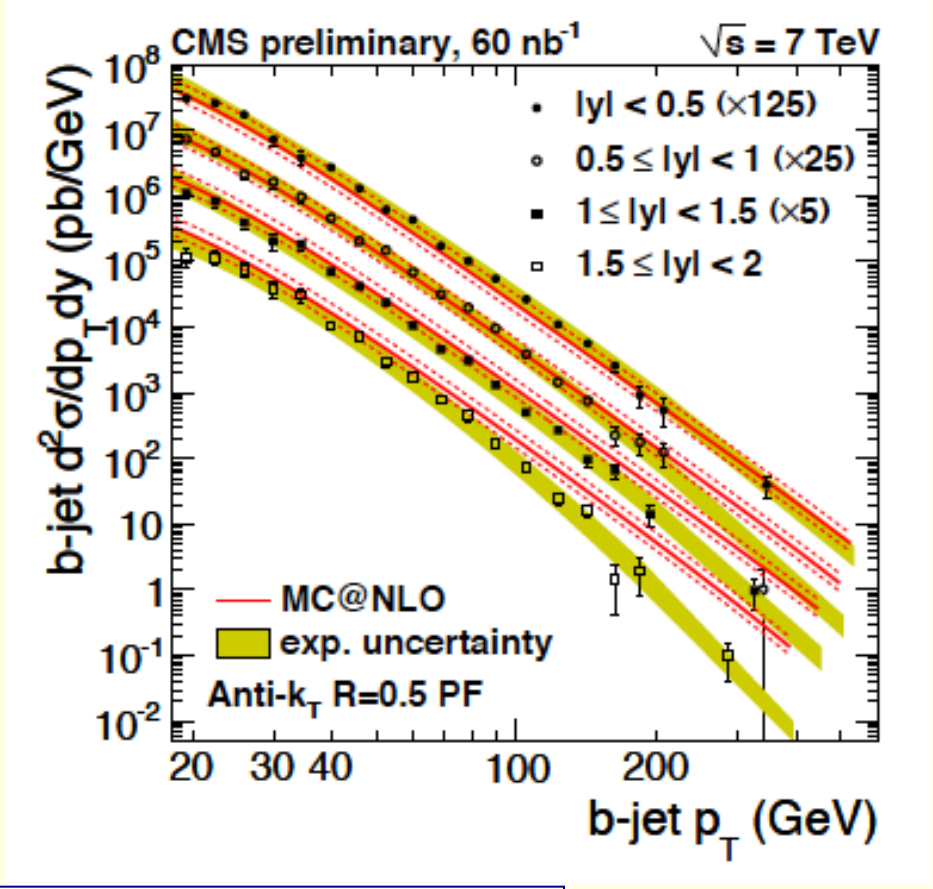


Figure 3: Charged particle multiplicity N_{ch} (left) and transverse jet shape δR^2 (right) as function of JPT corrected jet transverse momentum p_T for a dijet sample. Data (cross symbols) are shown with statistical error bars and a band denoting systematic errors. Also shown are predictions based on the Pythia 6.401 tune D6T (filled histogram) and Herwig 2.2.0 (solid line) event generators.

First b cross section measurements at 7 TeV : lifetime tagging

CMS-PAS-BPH-2010-009





Efficiency and purity determined from data