LHC Physics
Part I:
Machine, Experiments and the Standard Model

Albert De Roeck
CERN, Geneva, Switzerland
Antwerp University Belgium
Davis University USA

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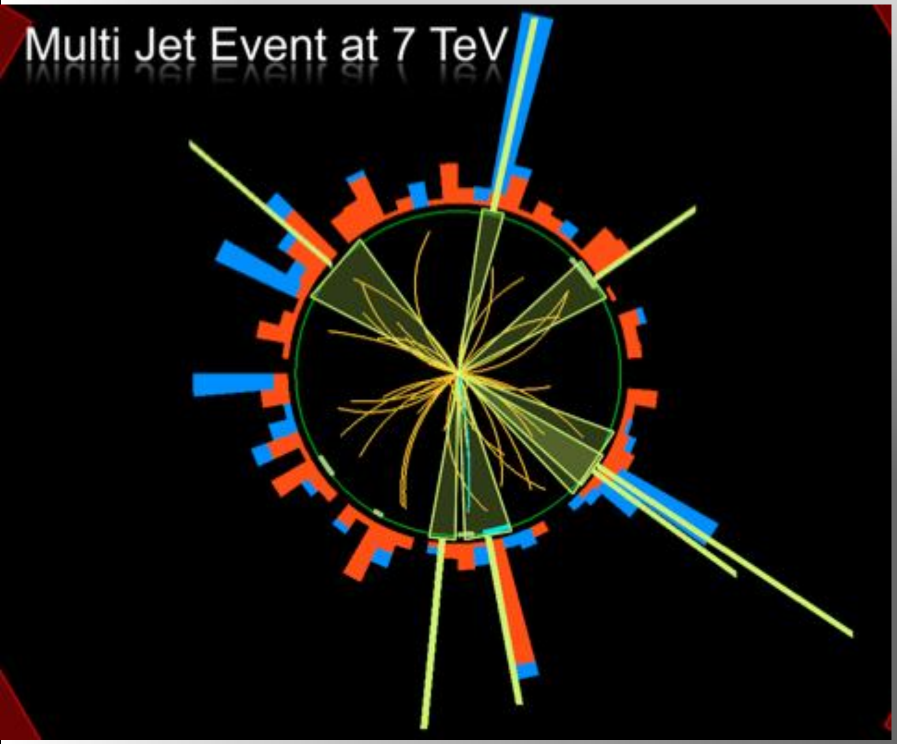
GK Hochenergiephysik und Teilchenastrophysik

KIT
Karlsruher Institut für Technologie



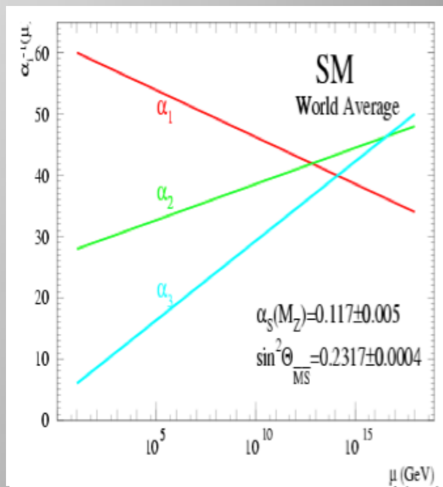
Outline

- Short Introduction
- The LHC & Experiments
- Standard Model Physics at 7 TeV
- Searches for the Higgs

Physics case for new High Energy Machines

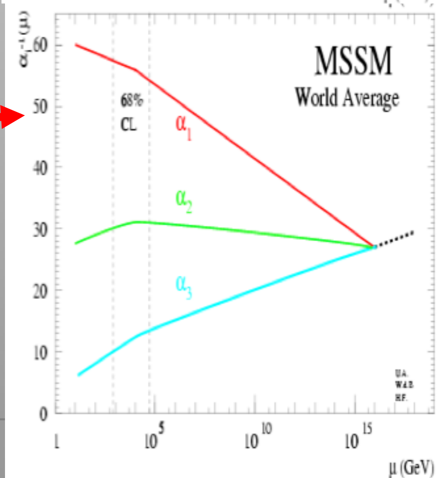
- Understand the mechanism Electroweak Symmetry Breaking
- Discover physics beyond the Standard Model

Reminder: The Standard Model
- tells us how but not why
  3 flavour families? Mass spectra? Hierarchy?
- needs fine tuning of parameters to level of 10^{-30} !
- has no connection with gravity
- no unification of the forces at high energy



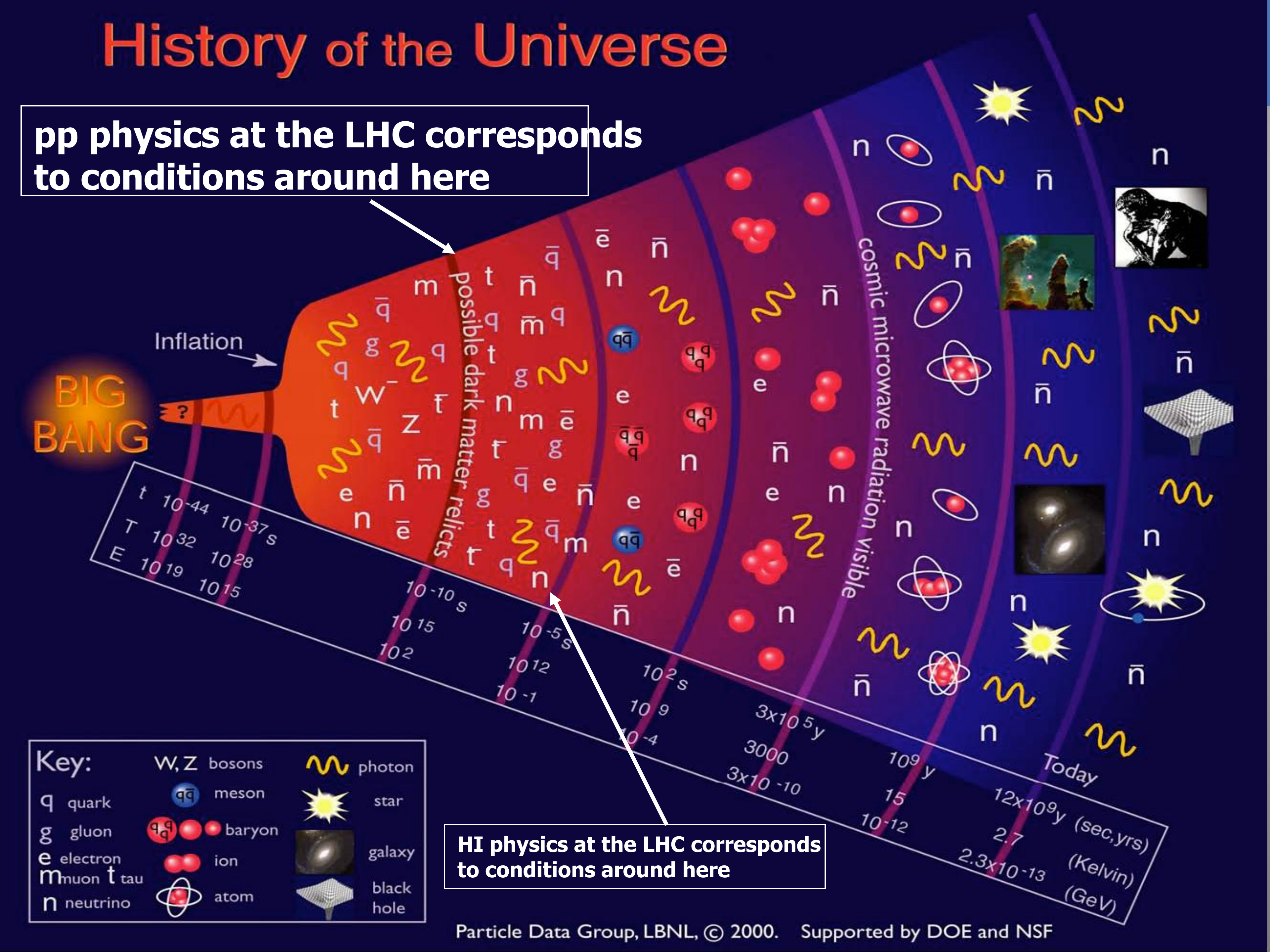
Most popular extensions these days

If a Higgs field exists:
- Supersymmetry
- Extra space dimensions



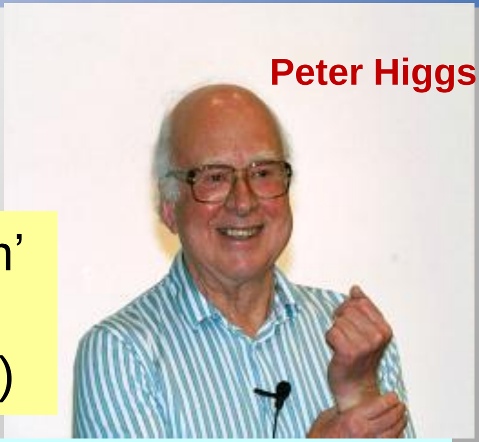
If there is no Higgs below ~ 700 GeV
- Strong electroweak symmetry breaking around 1 TeV

Other ideas: more symmetry & gauge bosons, L-R symmetry, quark & lepton substructure, Little Higgs models, Technicolor, Hidden Valleys…

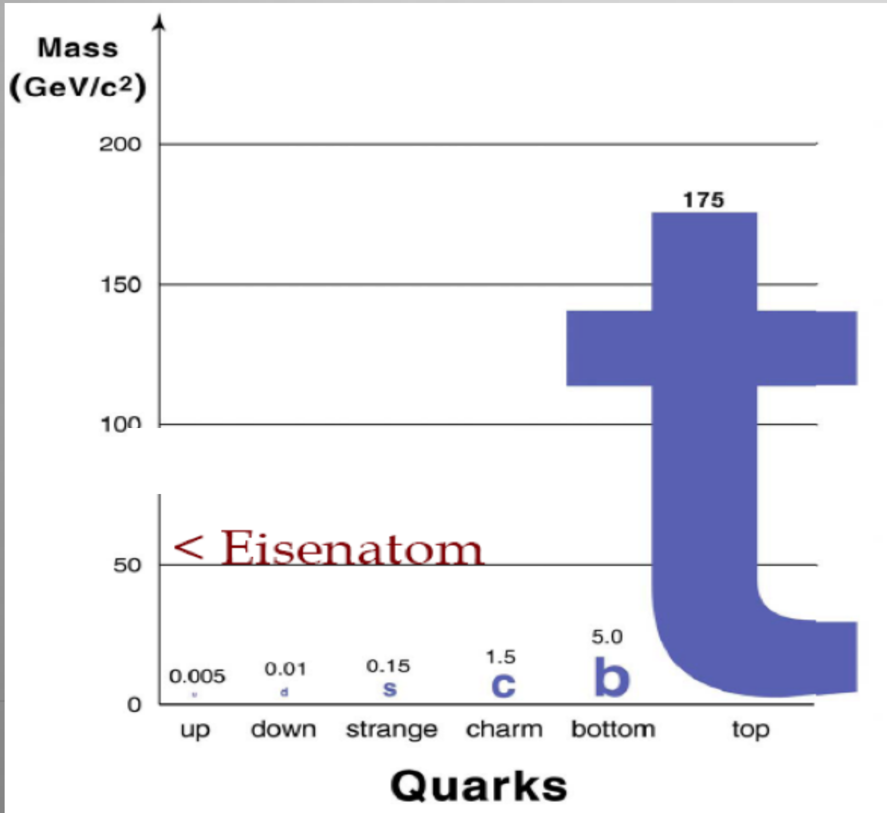

History of the Universe
pp physics at the LHC corresponds to conditions around here
Inflation
BIG BANG
possible dark matter relicts
cosmic microwave radiation visible
t 10^{-44} 10^{-37} s
T 10^{32} 10^{28}
E 10^{19} 10^{15}
10^{-10} s
10^{15}
10^{2}
10^{-5} s
10^{12}
10^{-1}
10^{2} s
10^{9}
10^{-4}
$3x10^{5}$ y
3000
$3x10^{-10}$
10^{9} y
15
10^{-12}
Today
$12x10^{9}$ y (sec,yrs)
2.7 (Kelvin)
$2.3x10^{-13}$ (GeV)
Key:
q quark
g gluon
e electron
m muon t tau
n neutrino
W,Z bosons
meson
baryon
ion
atom
photon
star
galaxy
black hole
HI physics at the LHC corresponds to conditions around here
Particle Data Group, LBNL, © 2000. Supported by DOE and NSF

The Origin of Particle Masses

A most basic question is why particles (and matter) have masses (and so different masses)

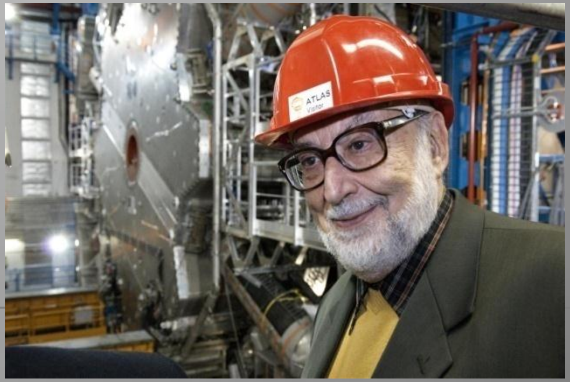


The mass mystery could be solved with the 'Higgs mechanism' which predicts the existence of a new elementary particle, the 'Higgs' particle (theory 1964, P. Higgs, R. Brout and F. Englert)



The Higgs (H) particle has been searched for since decades at accelerators, but not yet found…

The LHC will have sufficient energy to produce it for sure, if it exists



Supersymmetry

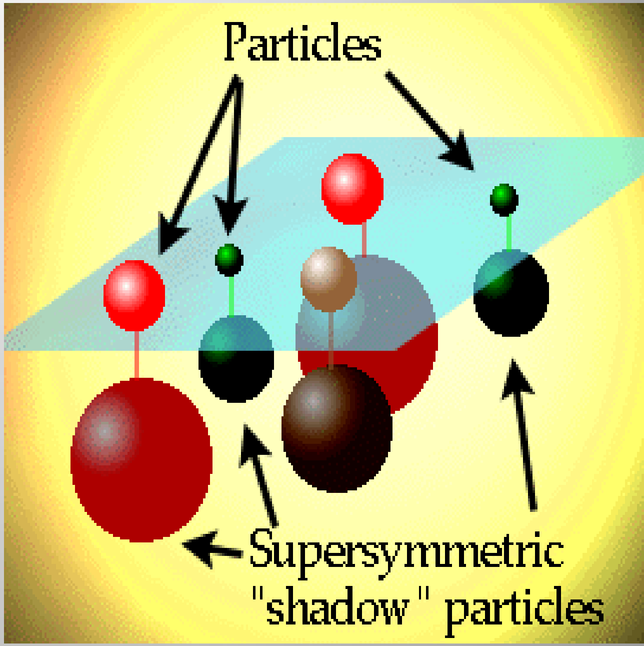
(Julius Wess and Bruno Zumino, 1974)

Establishes a symmetry between fermions (matter) and bosons (forces):

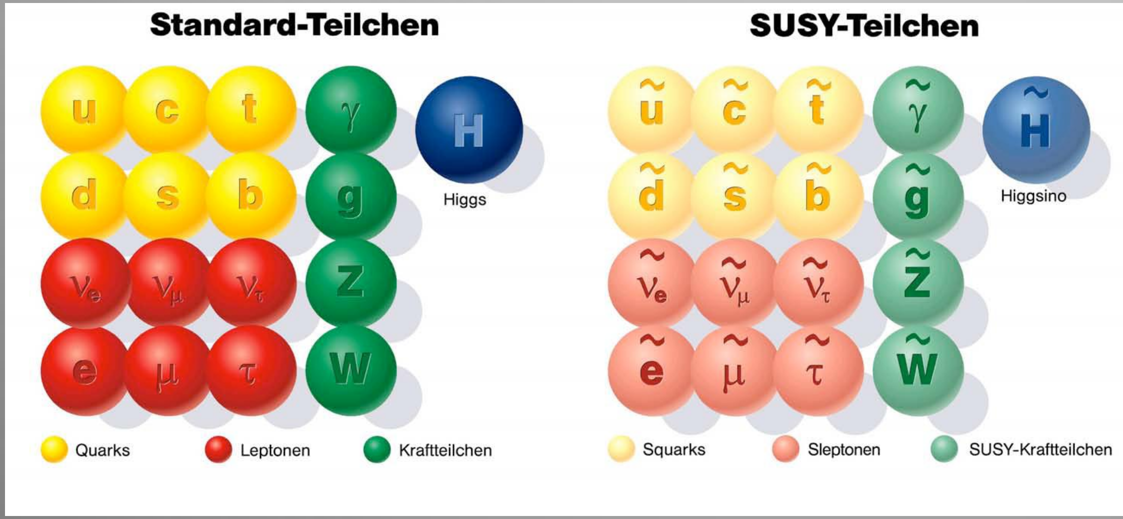
- Each particle p with spin s has a SUSY partner $\tilde{p}$ with spin s -1/2

- Examples q (s=1/2) → $\tilde{q}$ (s=0) squark

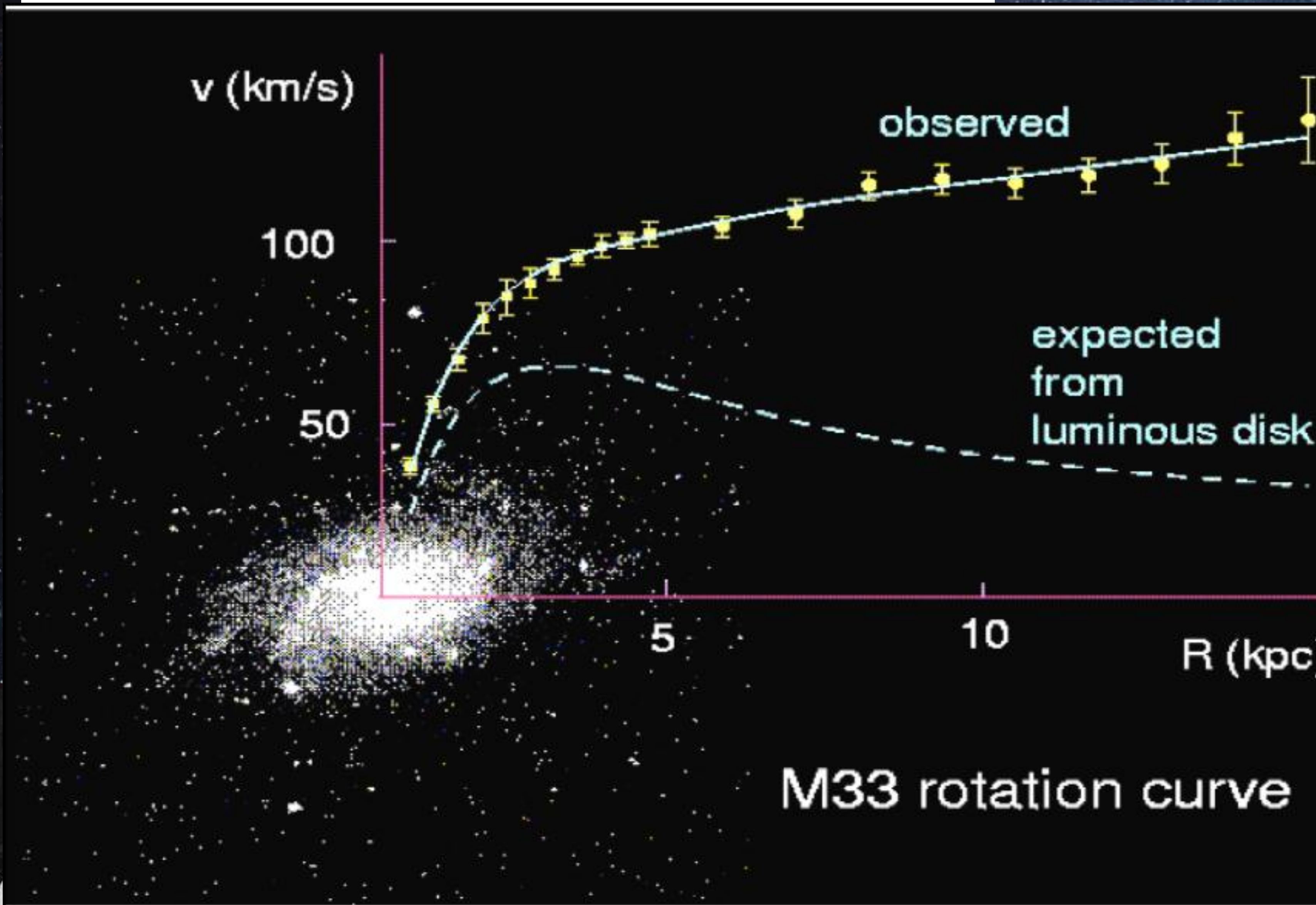
g (s=1) → $\tilde{g}$ (s=1/2) gluino



Our known world **Maybe a new world?**



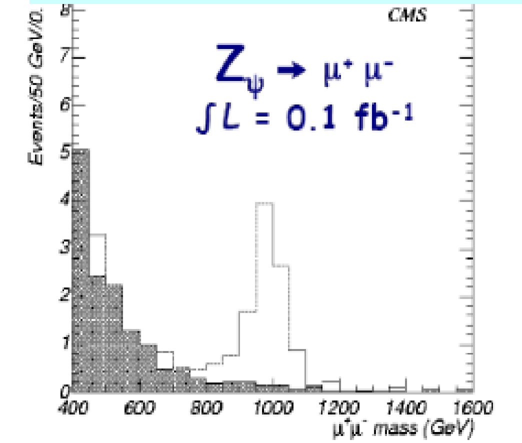
Motivation:
- Unification (fermions-bosons, matter-forces)
- Solves some deep problems of the Standard Model



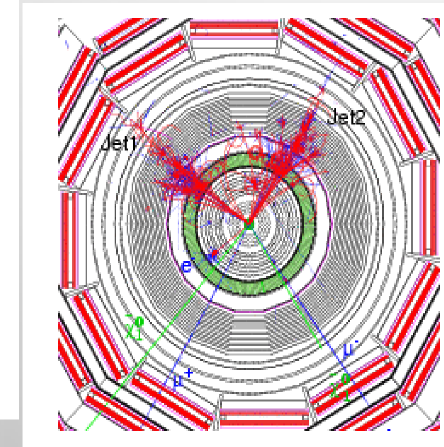
F. Zwicky 1898-1974

New Physics at High Energies?

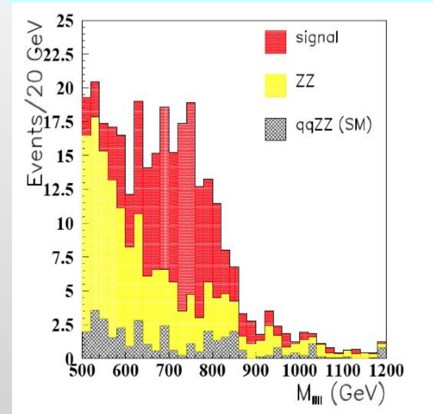
New Gauge Bosons?



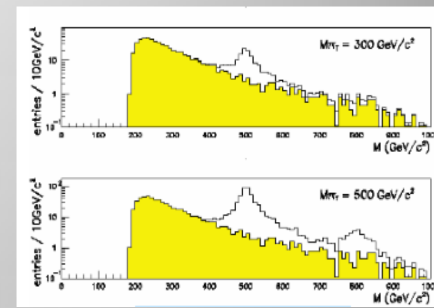
Supersymmetry



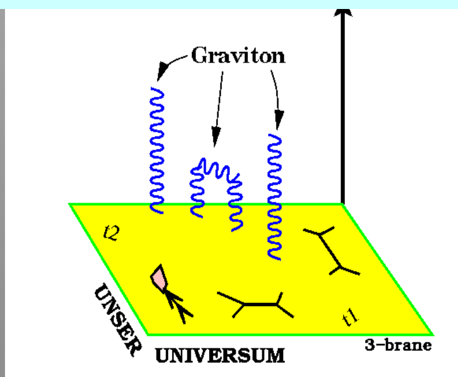
ZZ/WW resonances?



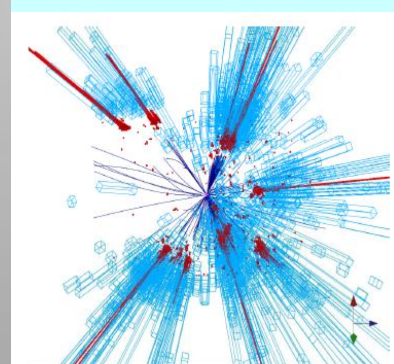
Technicolor?



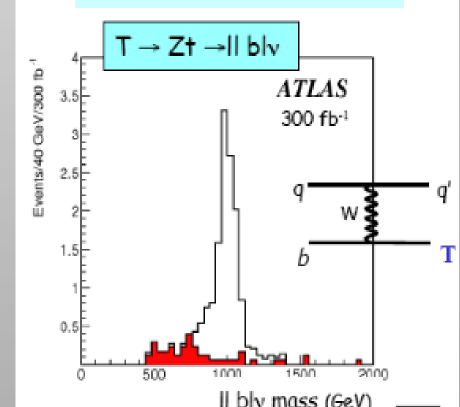
Extra Dimensions?



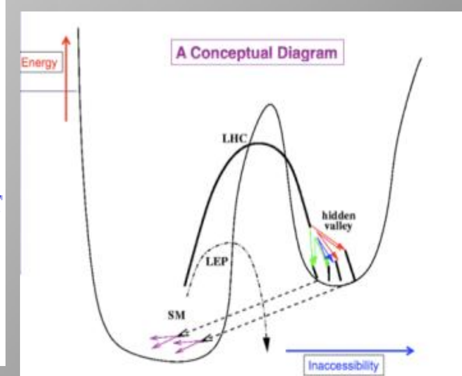
Black Holes???



Little Higgs?



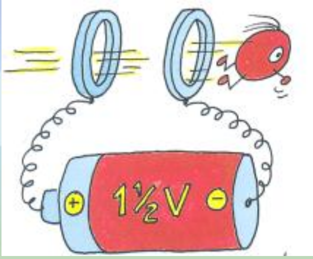
Hidden Valleys?

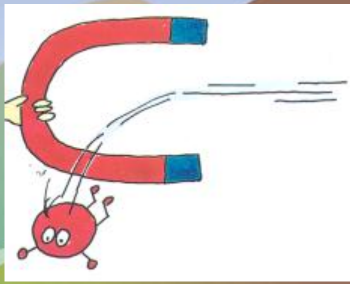


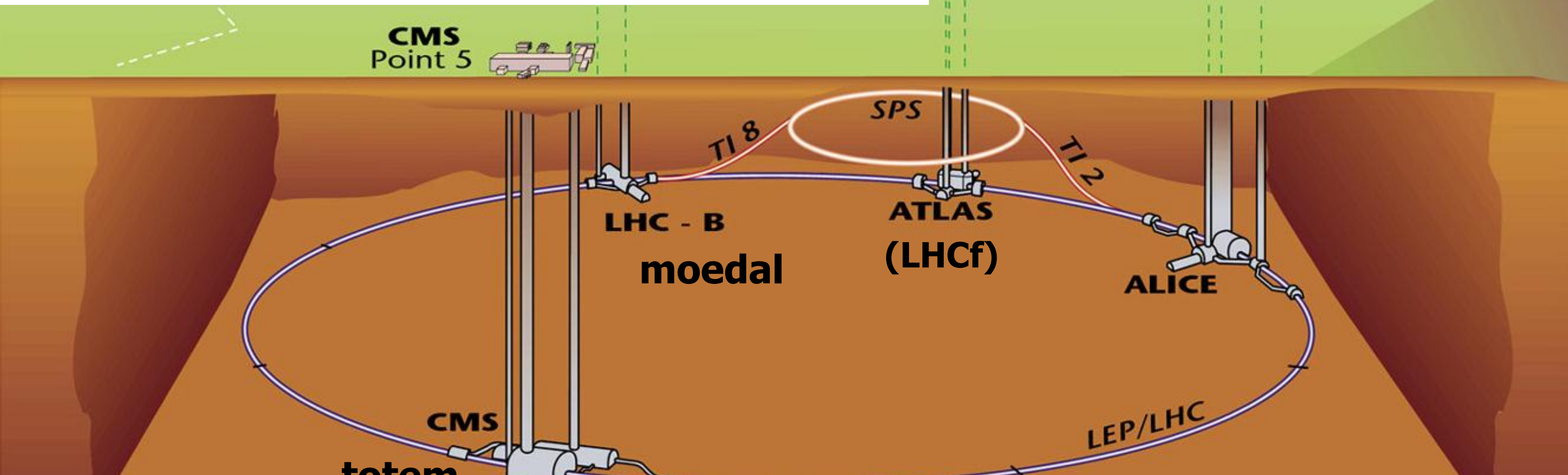
We do not know what is out there for us…
A large variety of possible signals. We have to be ready for that

The LHC Machine and Experiments

LHC is 100m underground
LHC is 27 km long
Magnet Temperature is 1.9 Kelvin = -271 Celsius
LHC has ~ 9000 magnets
LHC: 40 million proton-proton collisions per second
LHC: Luminosity 10-100 fb^{-1}/year (after start-up phase)
CM system energy: 7 TeV (13-14 TeV in 2014)



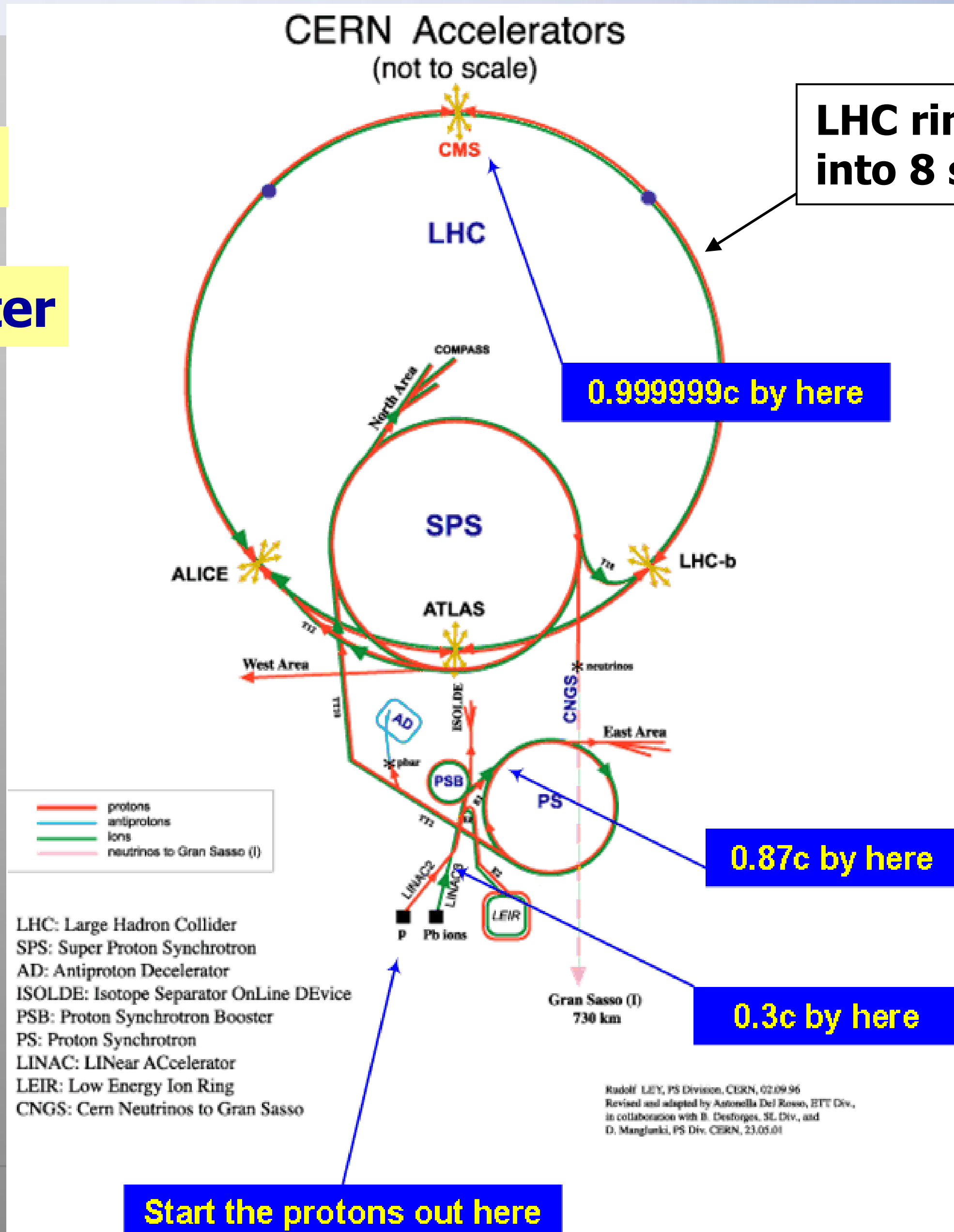


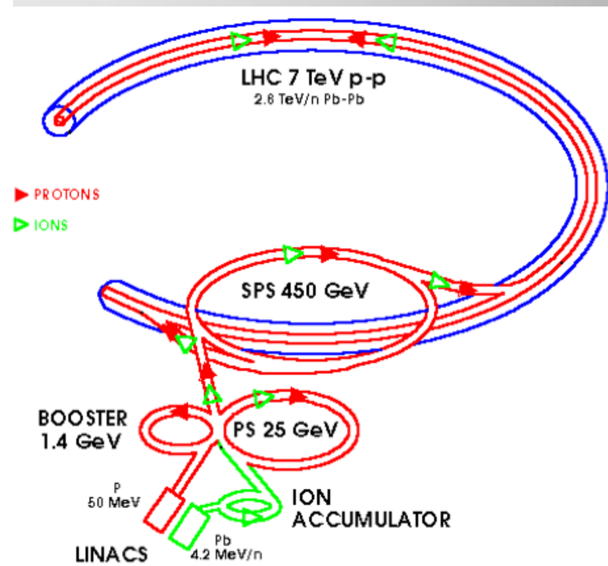


- High Energy ⇒ factor 3.5-7 increase w.r.t. present accelerators
- High Luminosity (# events/cross section/time) ⇒ factor 100 increase

The full LHC accelerator complex

Linac
↓
Booster
↓
PS
↓
SPS
↓
LHC

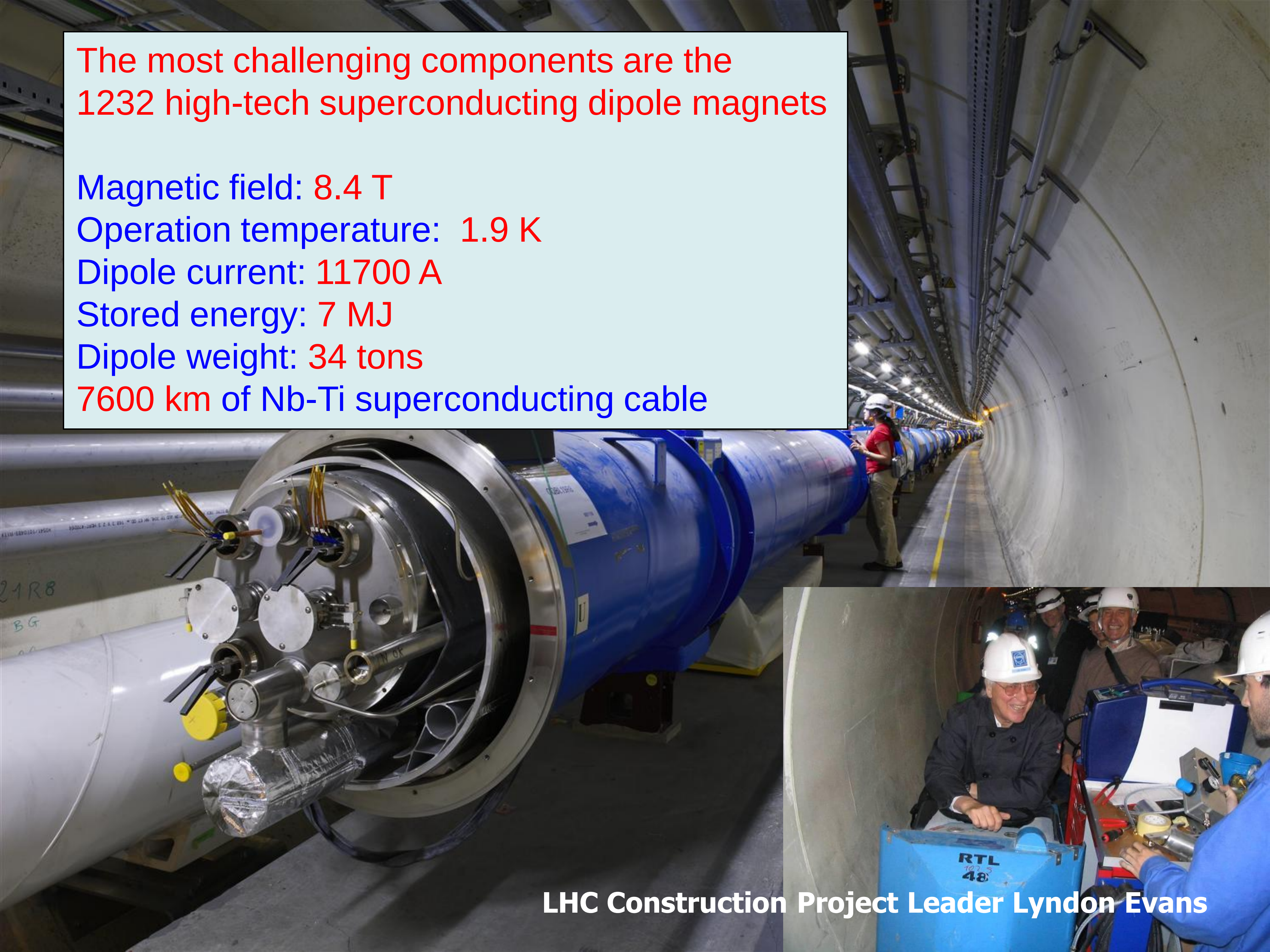




> 50 years of CERN history still alive and operational

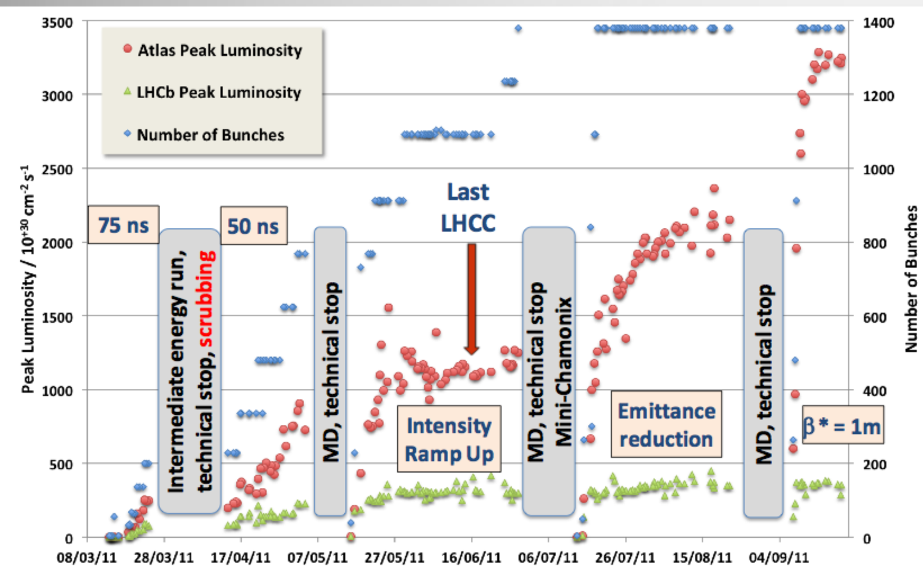
The most challenging components are the 1232 high-tech superconducting dipole magnets

Magnetic field: 8.4 T
Operation temperature: 1.9 K
Dipole current: 11700 A
Stored energy: 7 MJ
Dipole weight: 34 tons
7600 km of Nb-Ti superconducting cable

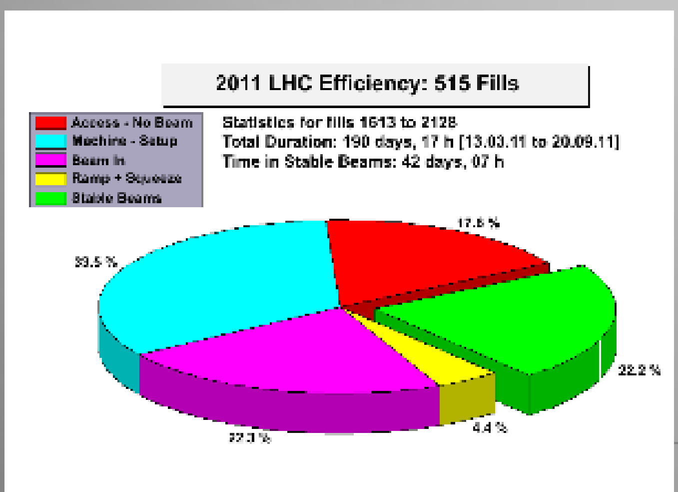


LHC Construction Project Leader Lyndon Evans

2011 Run (till mid September)



	2010	2011	Nominal
Energy [TeV]	3.5	3.5	7
β* [m] (IP1,IP2,IP5,IP8)	3.5, 3.5, 3.5, 3.5	1.0, 10,1.0,3.0	0.55, 10, 0.55, 10
Emittance [μm] (start of fill)	2.0 – 3.5	**1.5 – 2.2**	3.75
Transverse beam size at IP1&5 [μm]	60	23	16.7
Bunch population	1.2×10^{11} p	$1.4\times10^{+11}$ p	1.15×10^{11} p
Number of bunches	368	1380	2808
Number of collisions (IP1 & IP5)	348	1318	-
Stored energy [MJ]	28	110	360
Peak luminosity [$cm^{-2}s^{-1}$]	2×10^{32}	$3.3\times10^{+33}$	1×10^{34}
Max delivered luminosity (1 fill) [pb^{-1}]	6.23	116	-
Longest Stable Beams fill [hrs]	12:09	25:59	-



Fill 2105 (Sept. 14, 2011)

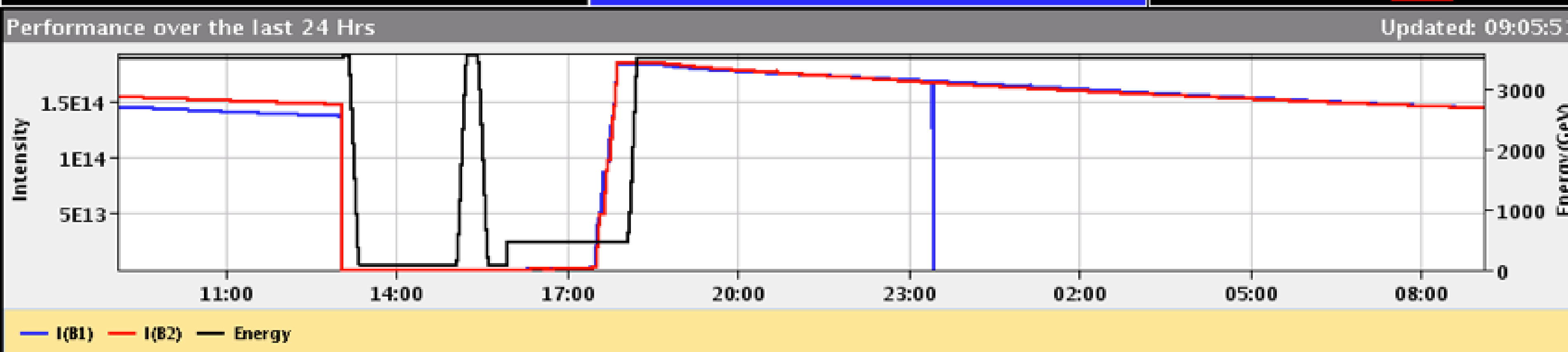
- Duration: 16.5 hours
- Delivered: 117.4 pb^{-1}
- Recorded: 113.4 pb^{-1}
- Data Taking Efficiency: 96.6%
- 2.6 times the CMS recorded luminosity for 2010
- ~ Same as Tevatron Run I!
- Approximately 18,000 top pairs produced during this fill!

Last Weekend…

03-Oct-2011 09:05:53 Fill #: 2178 Energy: 3500 GeV I(B1): 1.44e+14 I(B2): 1.44e+14

	ATLAS	ALICE	CMS	LHCb
Experiment Status	PHYSICS	STANDBY	PHYSICS	THNX LHC!!
Instantaneous Lumi (ub.s)^-1	1317.5	1.883	1351.5	343.8
BRAN Luminosity (ub.s)^-1	1335.4	1.817	1336.9	332.3
Fill Luminosity (nb)^-1	104907.4	78.1	107071.9	17789.6
BKGD 1	0.090	0.687	3.961	0.911
BKGD 2	14.076	19.760	1.320	16.853
BKGD 3	13.571	4.192	2.732	1.246

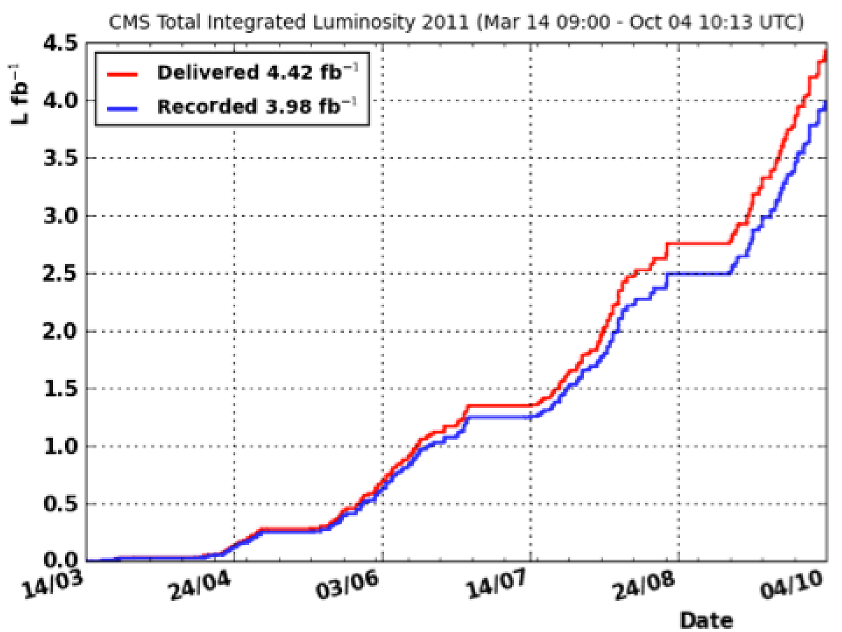
LHCb VELO Position IN Gap: -0.0 mm STABLE BEAMS TOTEM: OFF



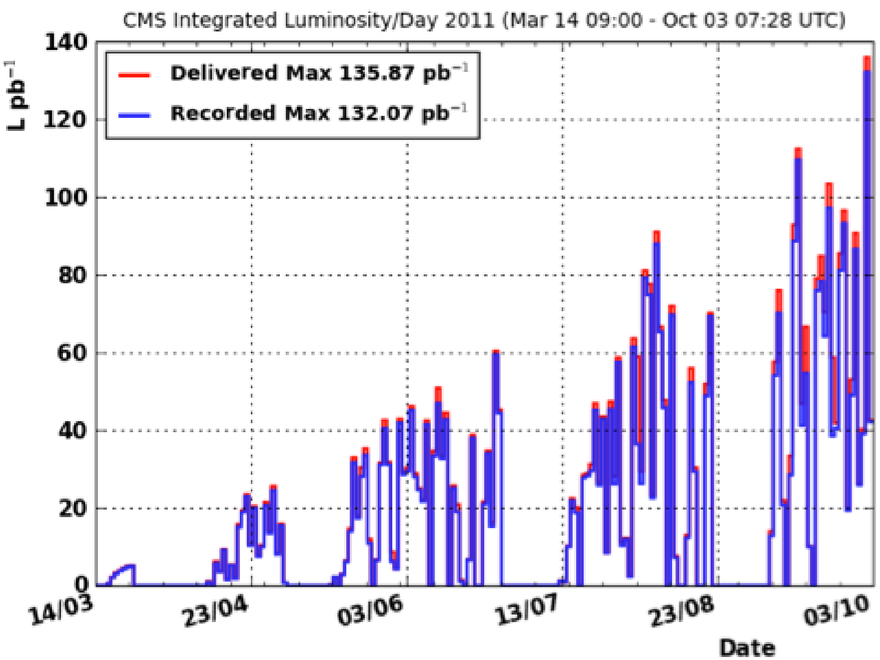
2 Fills with more than 100 pb^{-1} each within 36 hours!!!

Luminosity in 2011 so far

Total luminosity



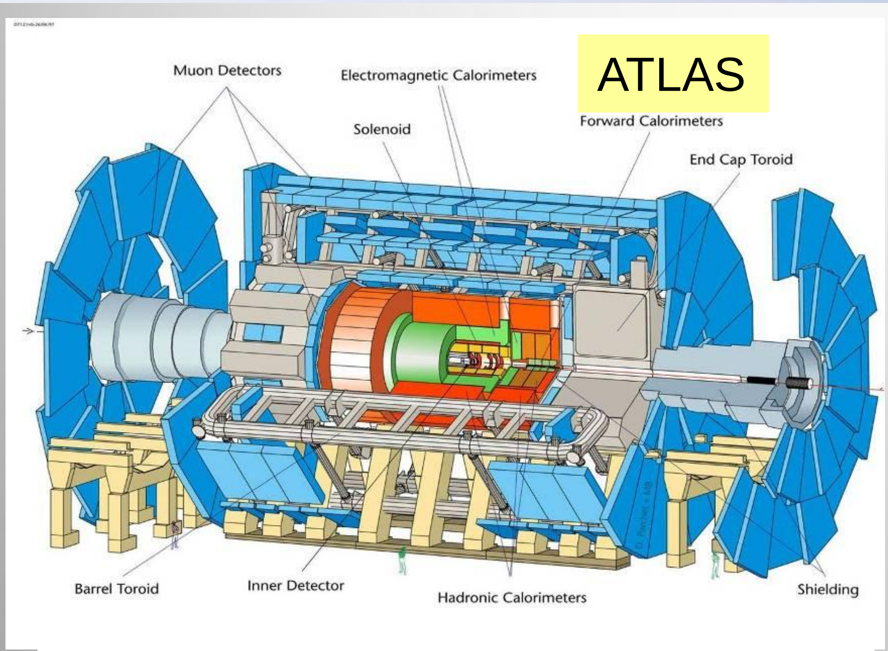
Daily luminosity in 2010

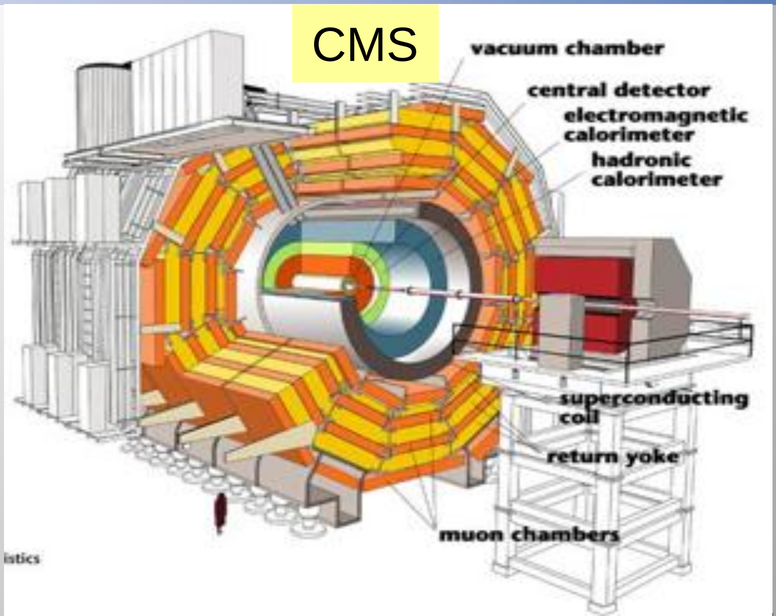


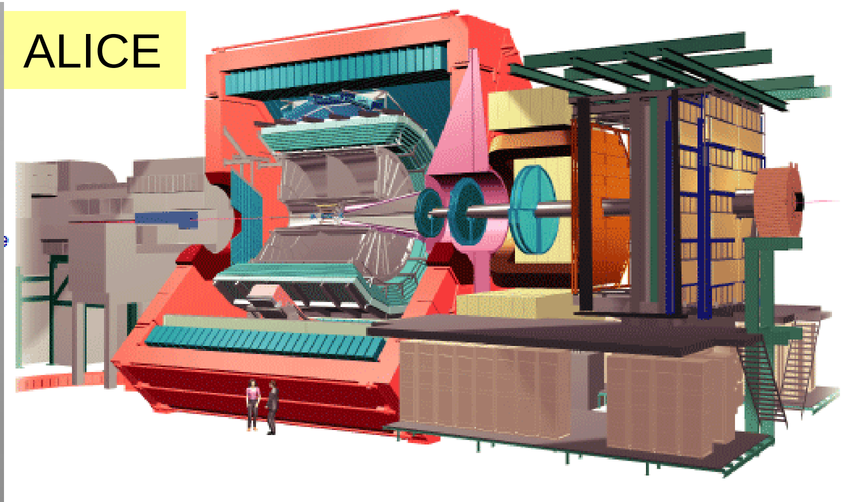
- The LHC restarted on March 13 2011 after a winter stop
- The LHC has produced already ~100 times more luminosity compared to 2010
- LHC running now with 1380 bunches and ~$3.3 \cdot 10^{33} cm^{-2} s^{-1}$ luminosity

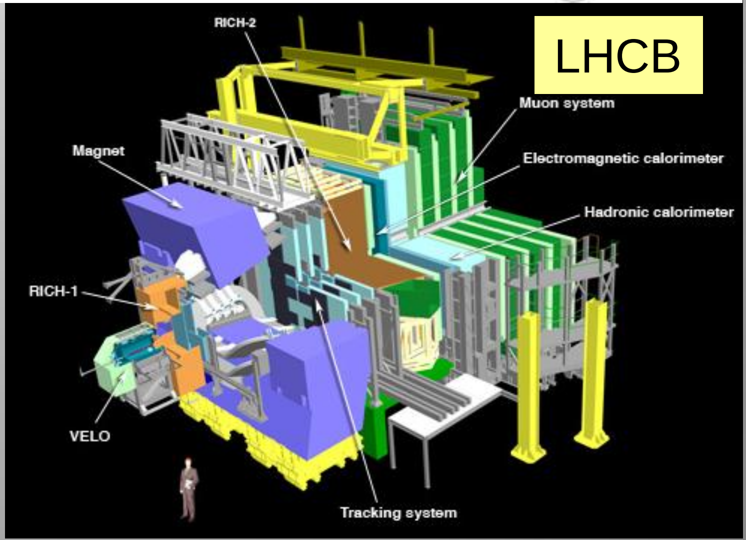
-> 4 fb^{-1} now; 5 fb^{-1} or more by the end of the October

The Four Main LHC Experiments

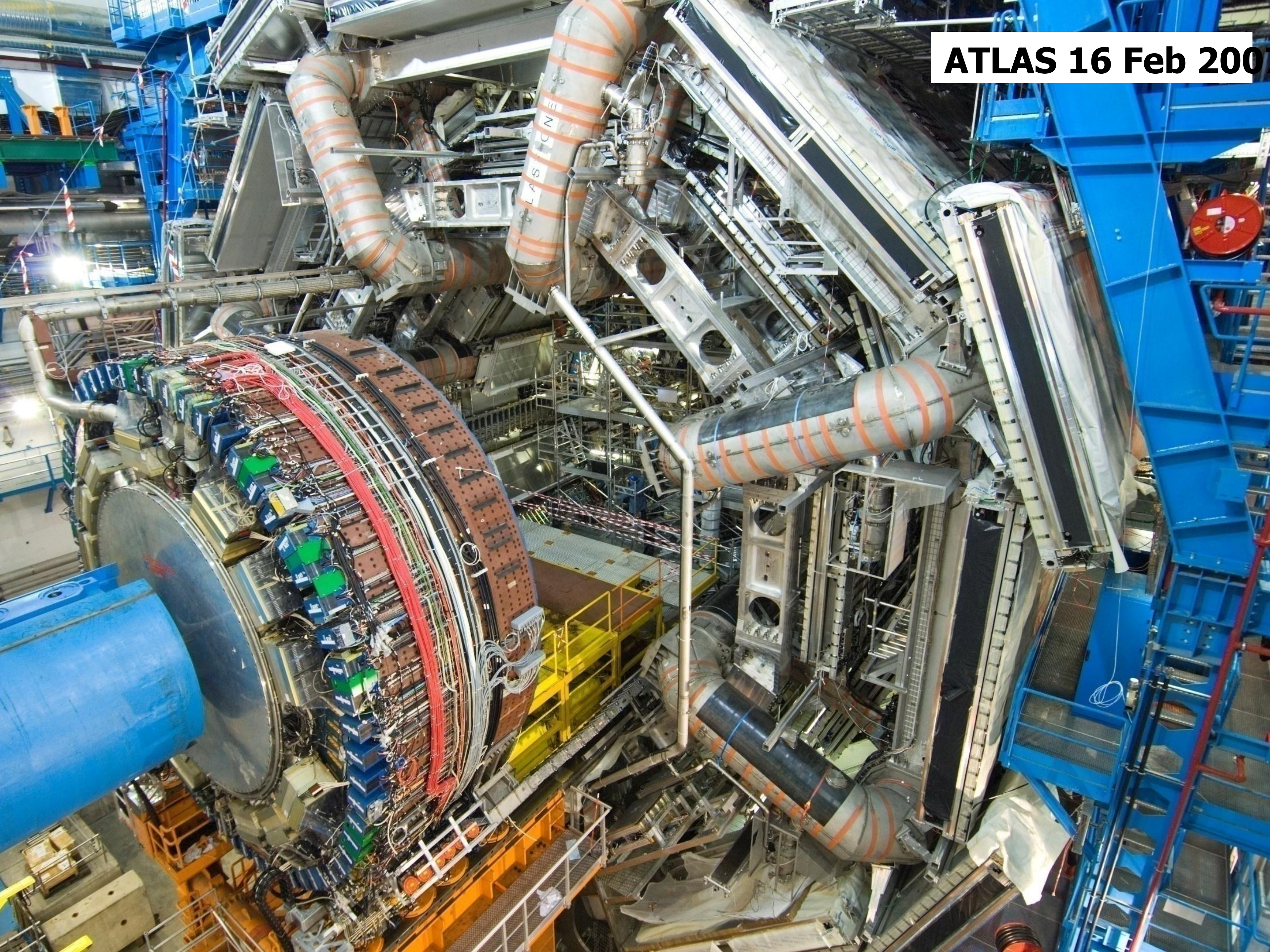






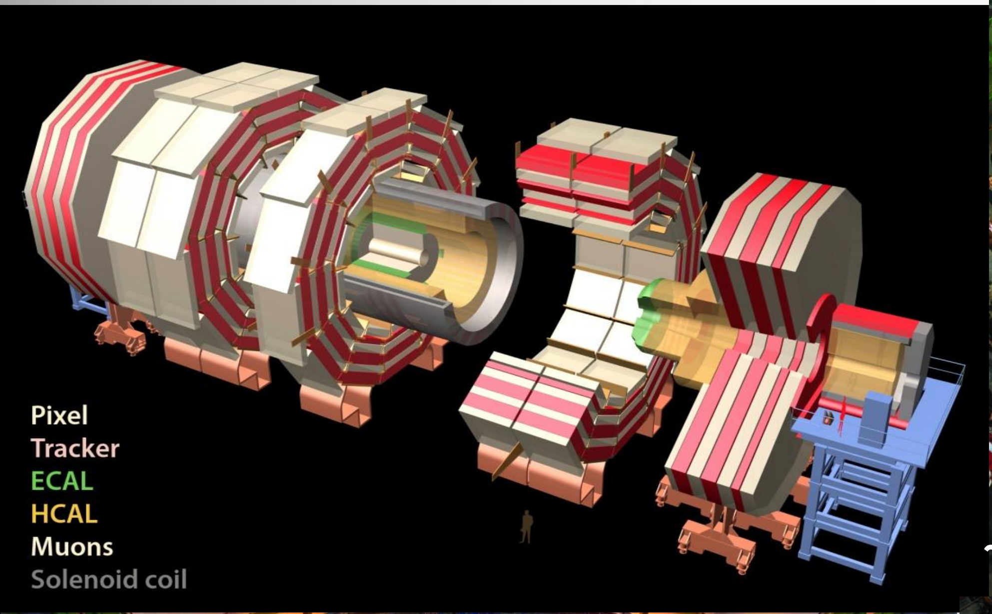


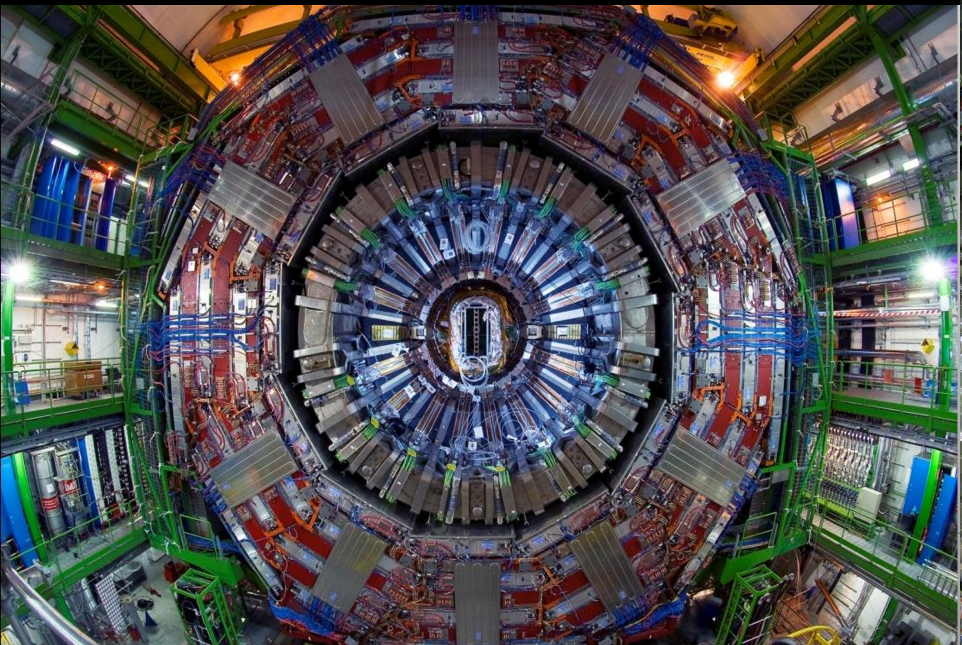
+TOTEM, LHCf, MOEDAL


ATLAS 16 Feb 200

CMS before closure

The CMS Collaboration: >3000 scientists and engineers, >800 students from 189 Institutions in 39 countries .

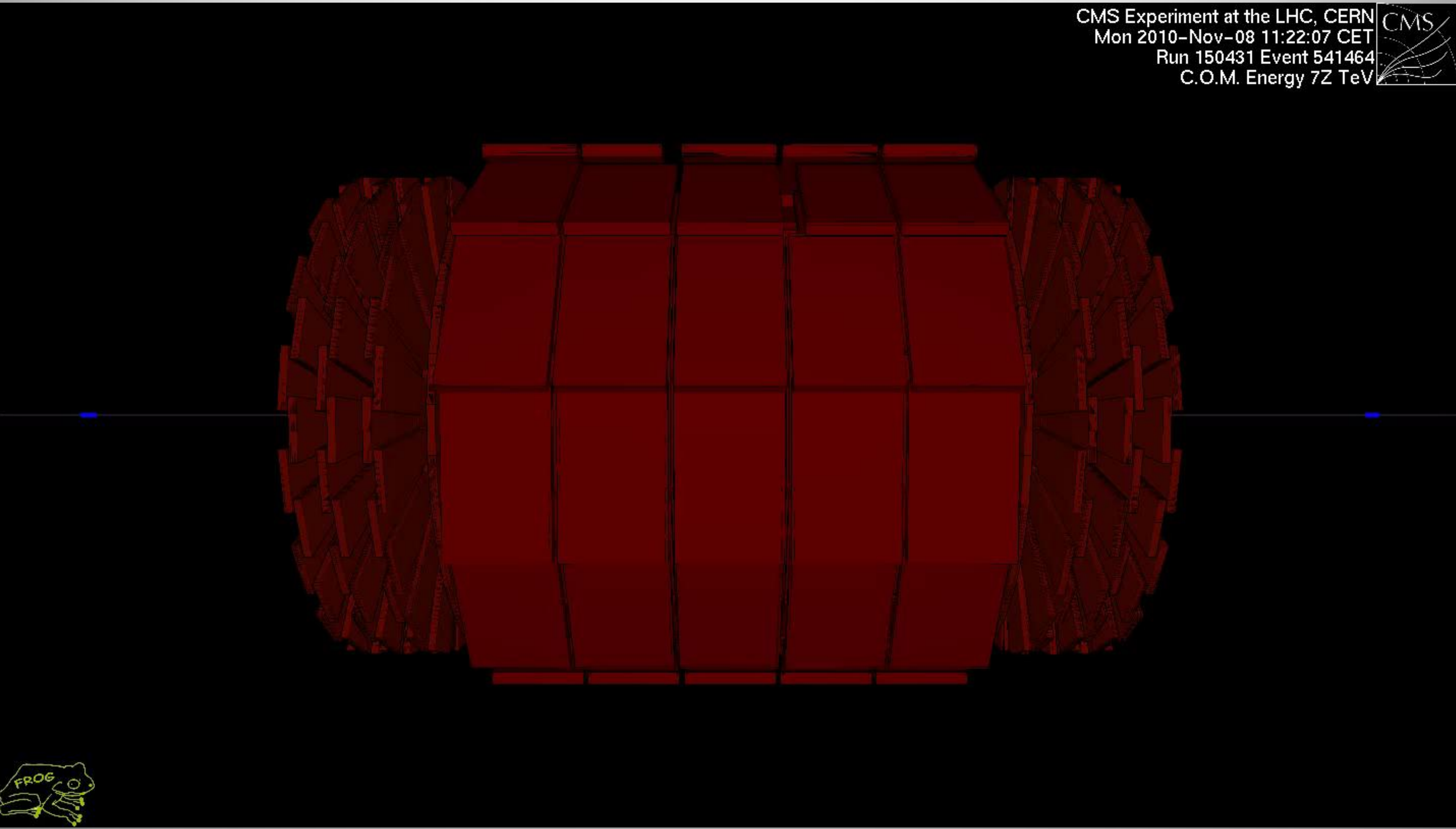




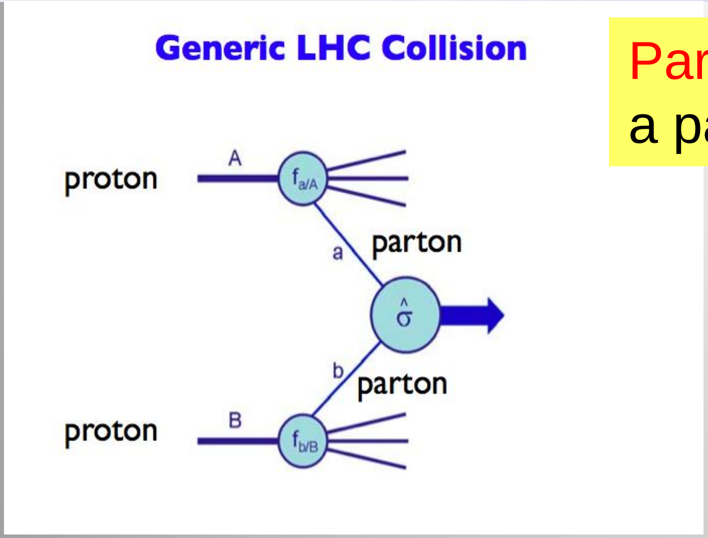
Great Moments

Some of the key moments the last years

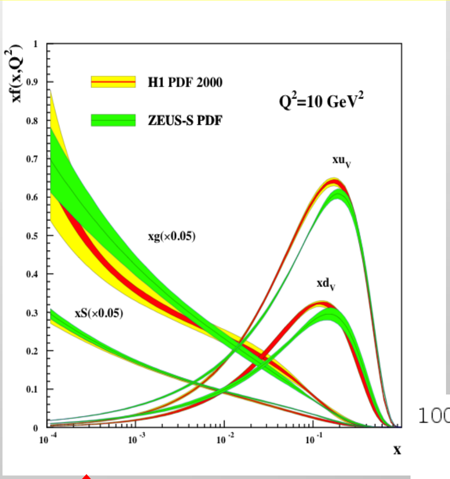
A Recorded Heavy Ion Collision

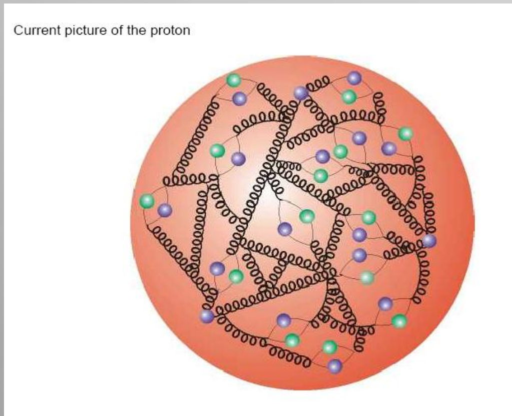


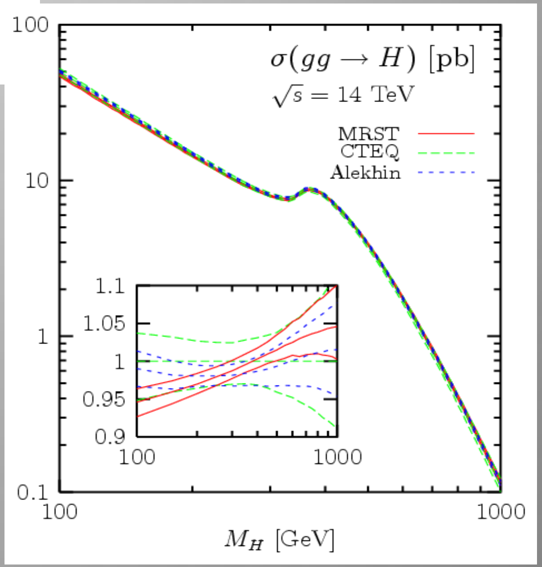
Proton-proton collisions



Parton Distribution Functions: the probability of finding a parton with momentum fraction x in the proton

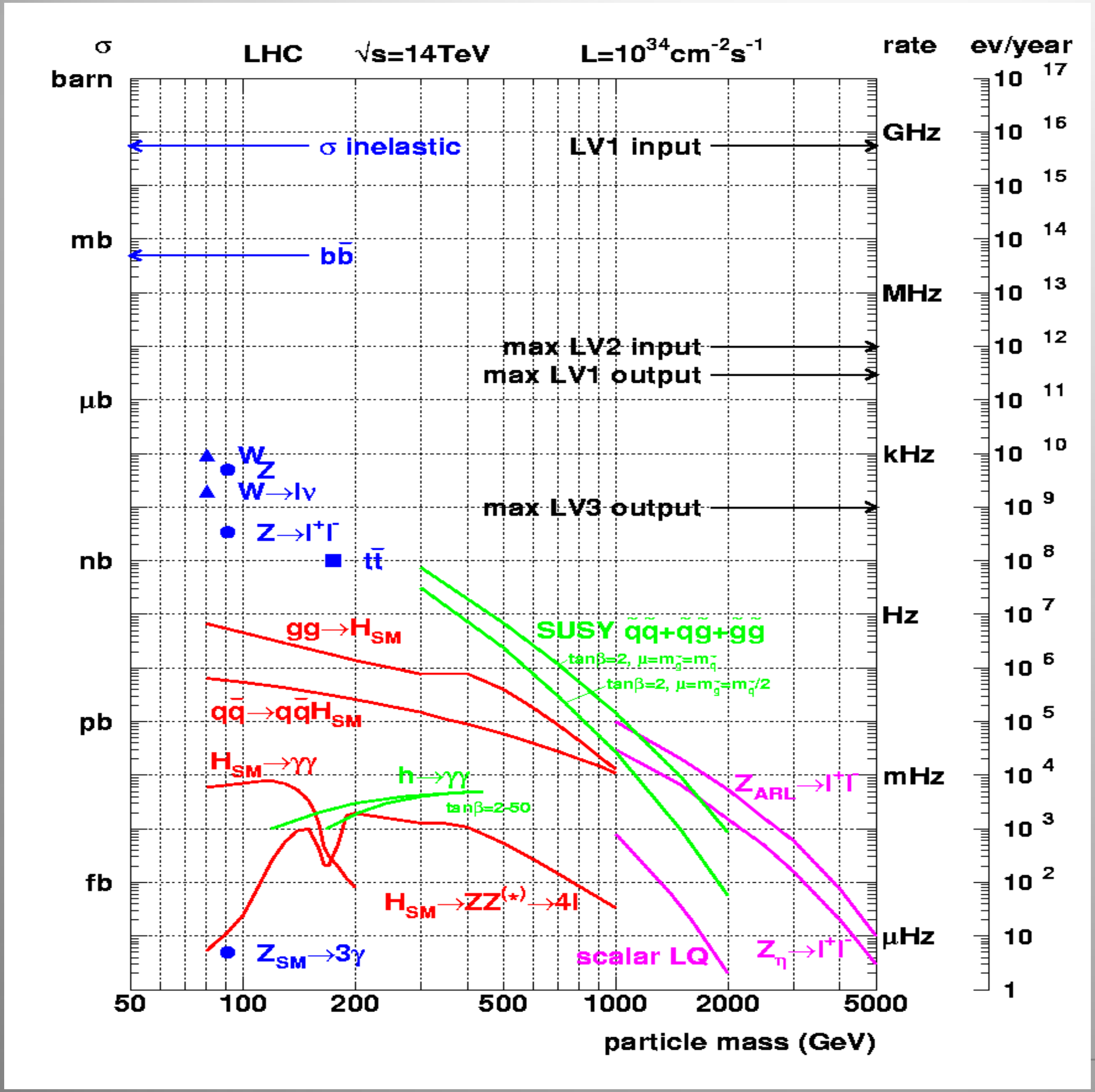






Structure function measurements eg from HERA

Cross sections at the LHC

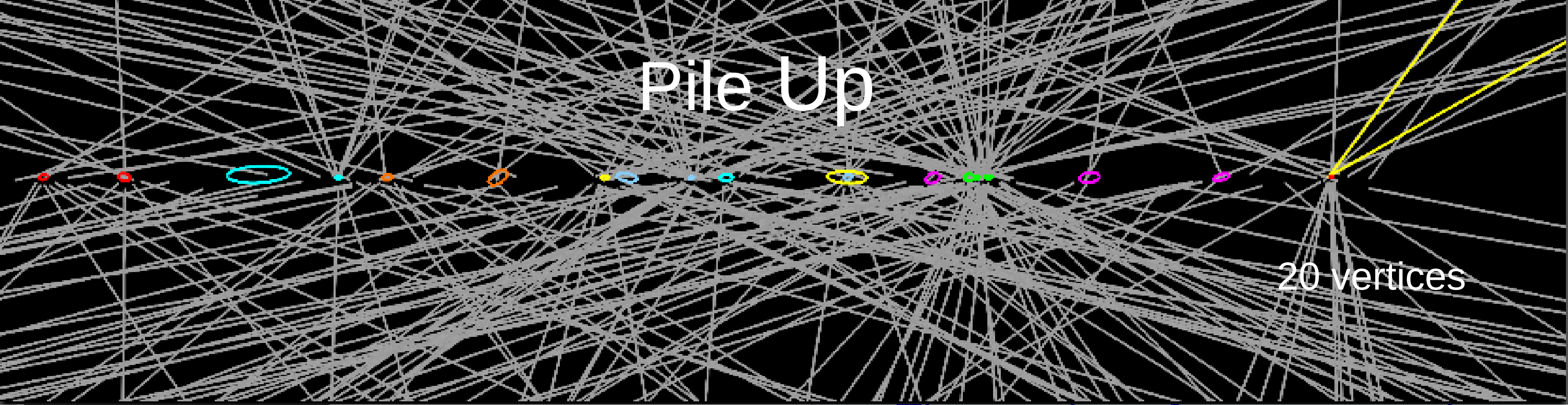


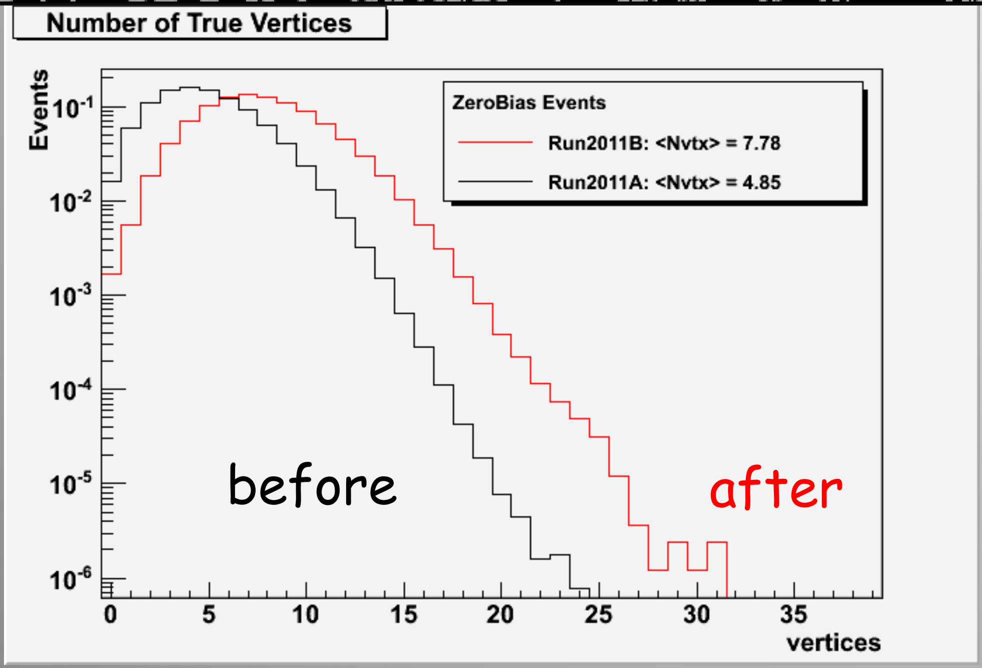
"Well known" processes, don't need to keep all of them …

New Physics!!

This we want to keep!

Pile Up





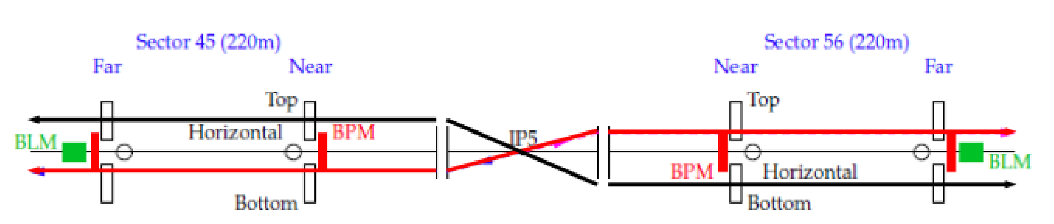
Averaged over fills.
$N_{rec} \sim 0.7 \times N_{pu}$

- The number of reconstructed vertices after the August Technical Stop increased by factor 1.5 (β^*=1.5m → 1m)
  - Fills start with ~15 pile-up interactions
  - Vertex reconstruction still quite linear with luminosity

- Total inelastic cross section also has been measured from pile-up
  - σ_{inel}**(pp)=** 68.0 ± 2.0 **(**Syst**)** ± 2.4 **(**Lum**)** ± 4 **(**Extrap.**)** mb.

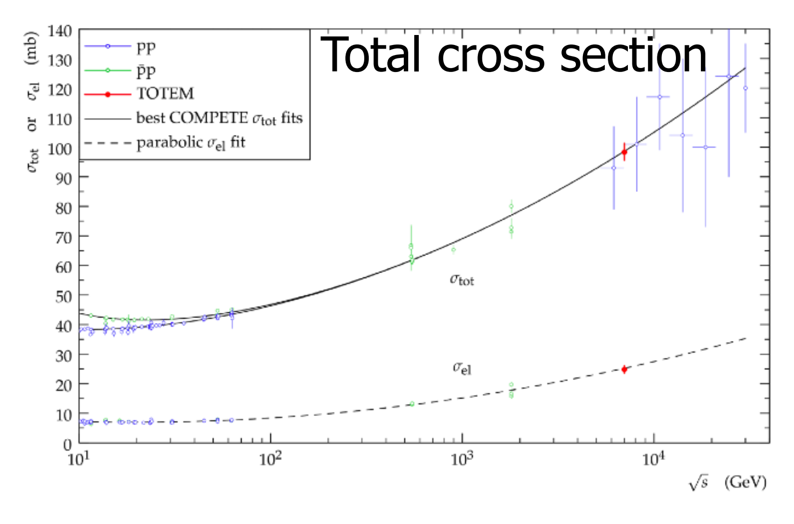
TOTEM: Total Cross Section

September 2011



- Totem: uses the same interaction point as CMS
- September LHCC: release of the first total pp cross section at 7 TeV using elastic scattering and the CMS luminosity measurement

Total = elastic+diffraction+non-diffractive events



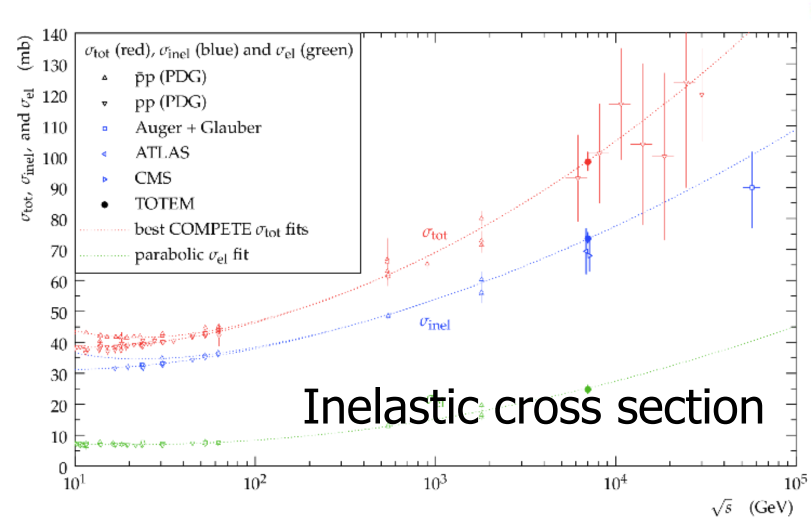
$$\sigma_T = \left(98.3 \pm 0.2^{(stat)} \pm 2.7^{(syst)} \begin{bmatrix} +0.8 \\ -0.2 \end{bmatrix}^{(syst\ from\ \rho)}\right)\ mb$$

$$\sigma_{el} = 8.3\ mb^{(extrapol.)} + 16.5\ mb^{(measured)} = \left(24.8 \pm 0.2^{(stat)} \pm 2.8^{(syst)}\right) mb$$

$$\sigma_{inel} = \sigma_{tot} - \sigma_{el} = \left(73.5 \pm 0.6^{(stat)} \begin{bmatrix} +1.8 \\ -1.3 \end{bmatrix}^{(syst)}\right) mb$$

σ_{inel} (CMS) = $(68.0 \pm 2.0^{(syst)} \pm 2.4^{(lumi)} \pm 4.0^{(extrap)})$ mb

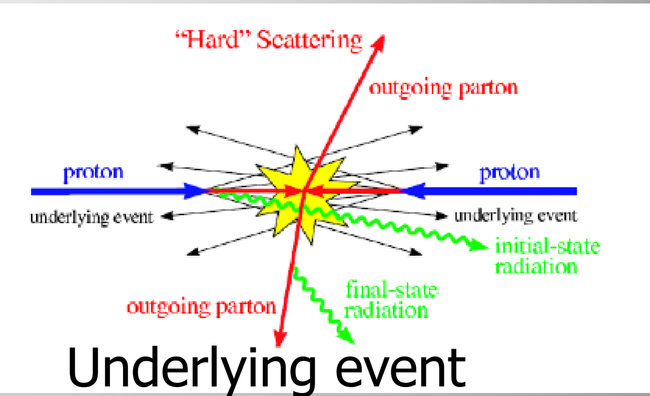
σ_{inel} (ATLAS) = $(69.4 \pm 2.4^{(exp)} \pm 6.9^{(extrap)})$ mb



Important for pile-up in ATLAS and CMS

Physics Results

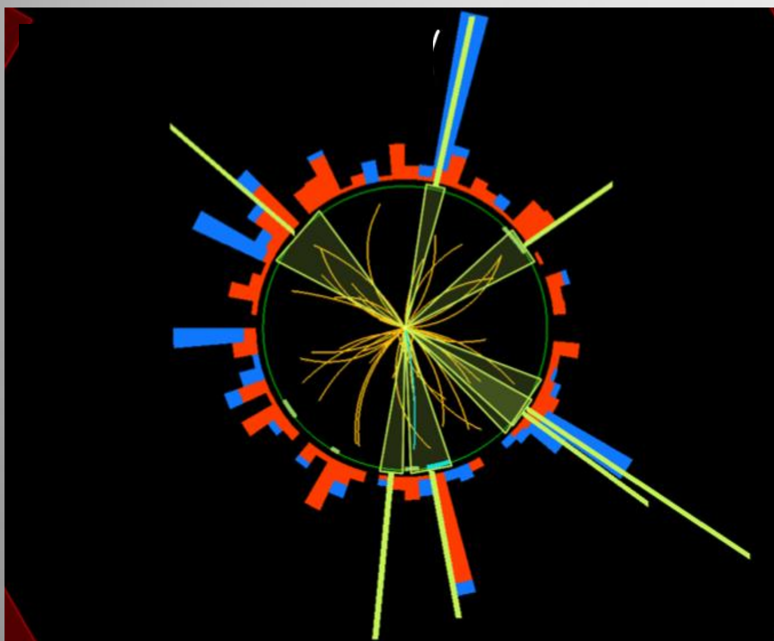
- Studies of general characteristics of minimum bias soft events (now our pile-up)
- Study of the underlying event in x with a hard scattering

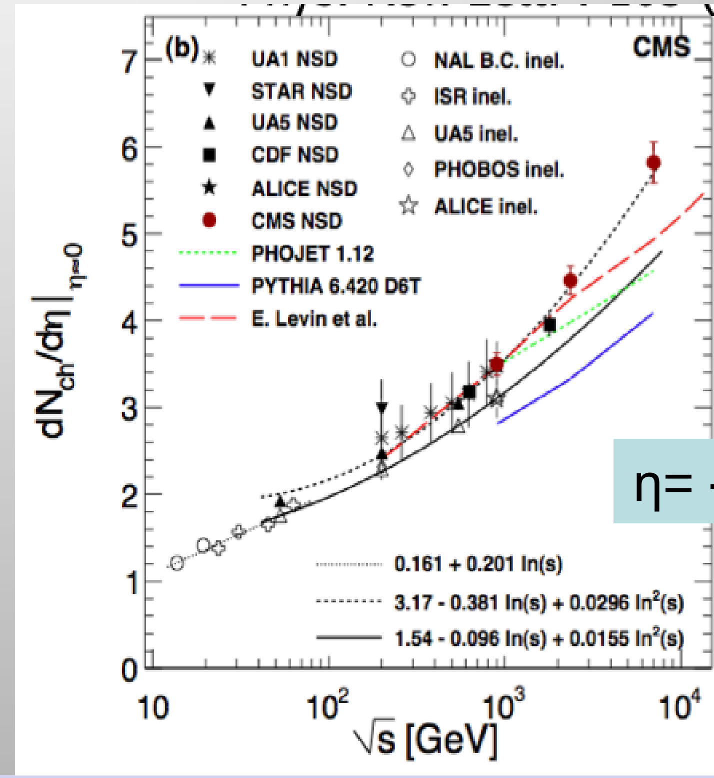


- Jet physics & QCD
- B-physics
- W,Z boson production at 7 TeV
- Top at 7 TeV
- Searches for new physics
- Heavy Ion collisions at 2.76 TeV
- …

LHC: 7 TeV Early Analysis

We learn a lot of particle production at the highest energies!!



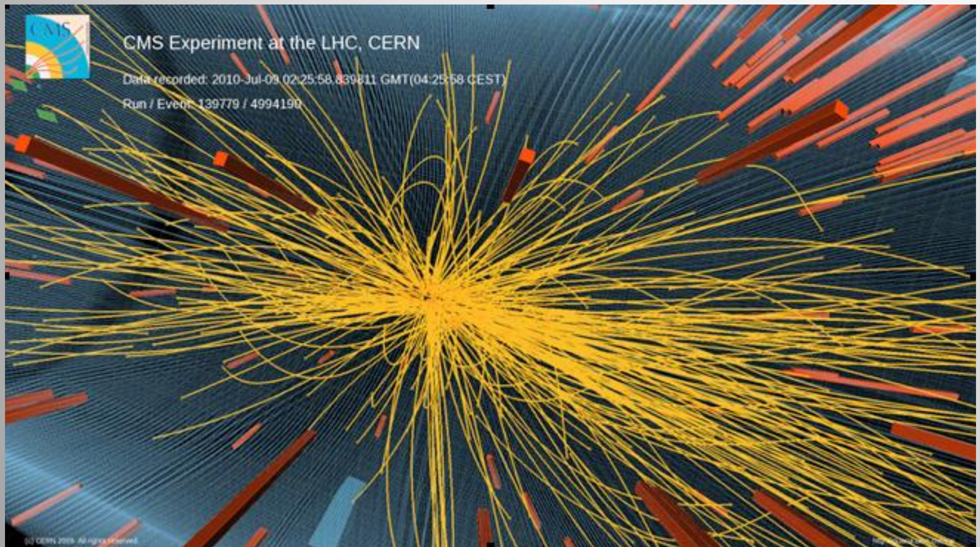


η= -ln tanθ/2

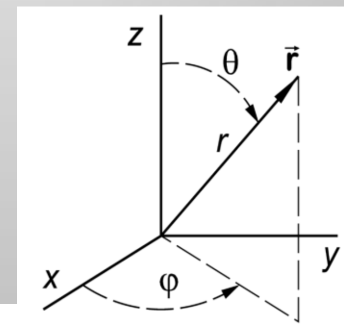
Measurement of the charged particle density in proton proton collisions at 7 TeV

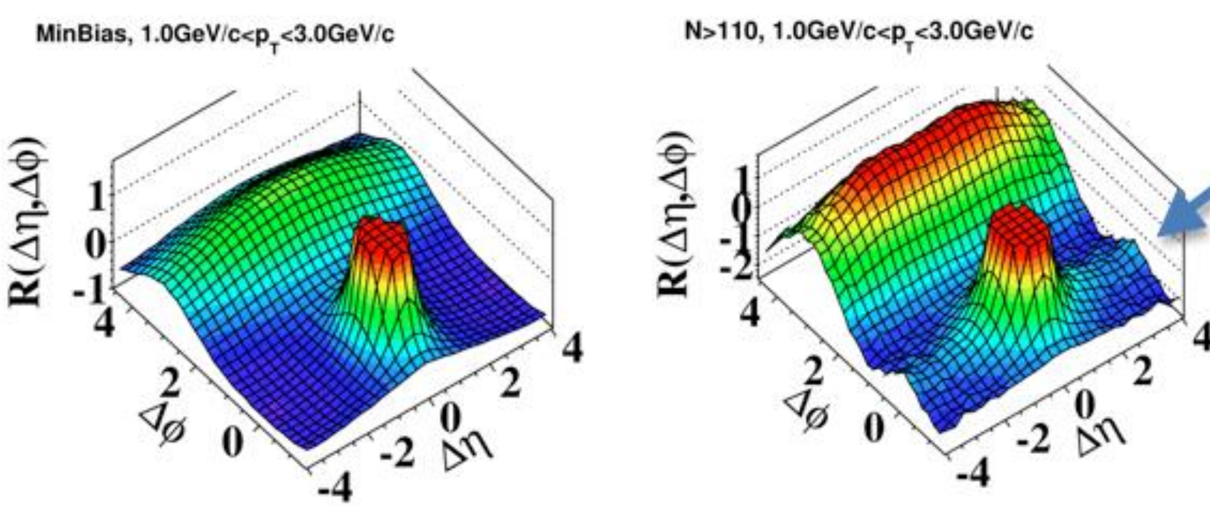
Strong rise of the central particle density with energy

Correlations Between Produced Particles



- Select high multiplicity events
- Study the correlation between two charged particles in the angles φ (transverse): Δφ and θ (longitudinal): Δθ

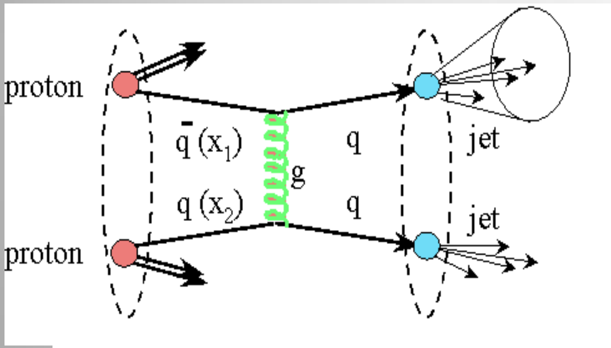




A new phenomenon in the 'stronge force' seen for the first time But not considered New Physics

$\eta = -\ln \tan\theta/2$

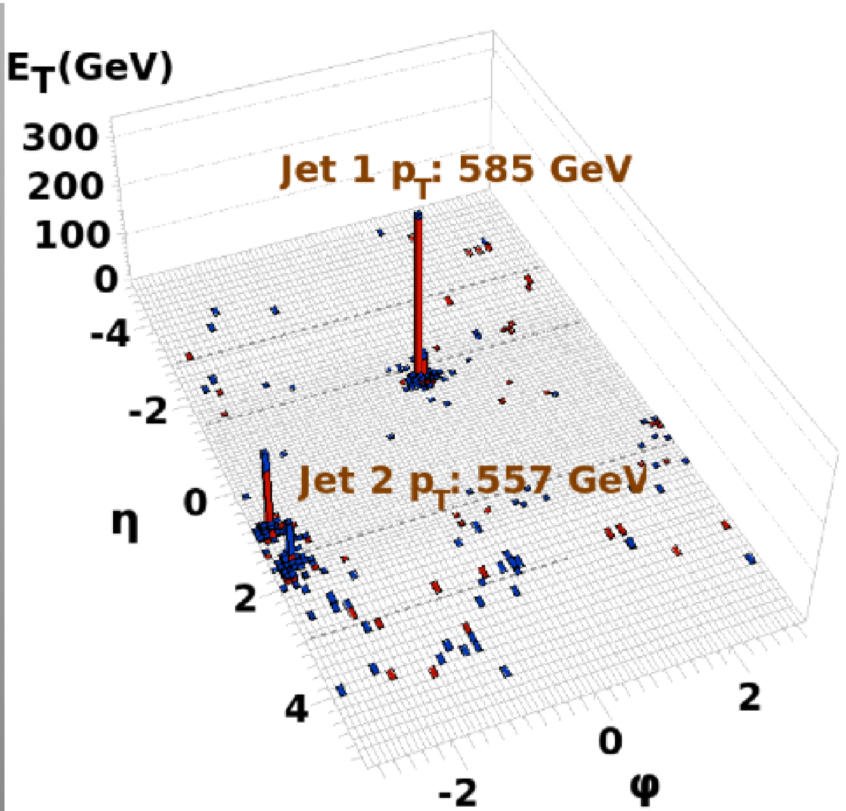
Jet Production at 7 TeV

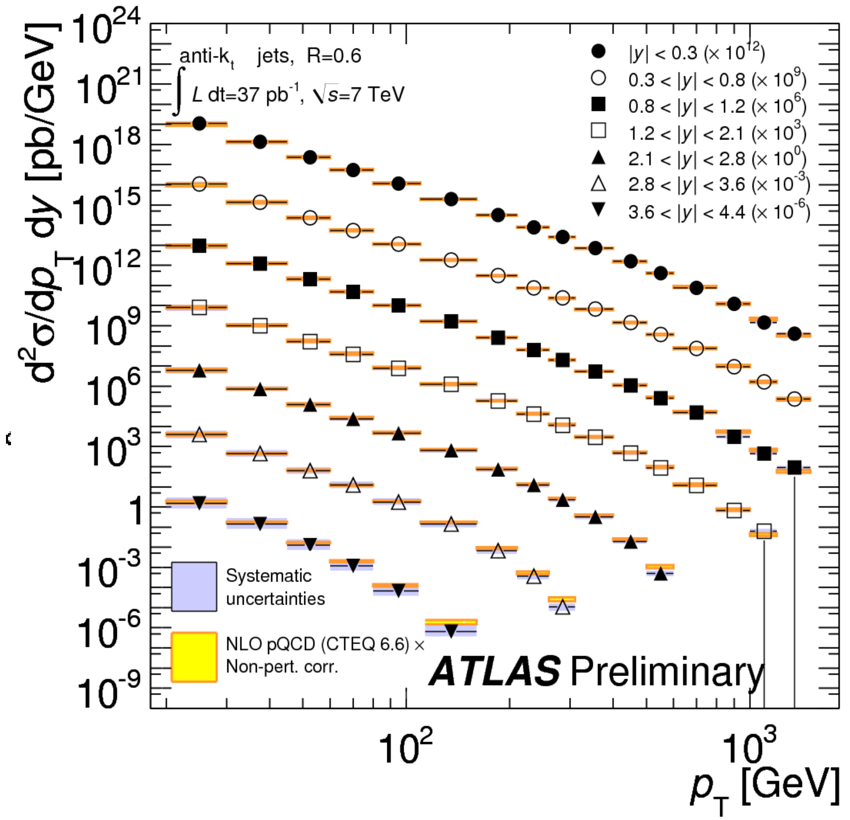


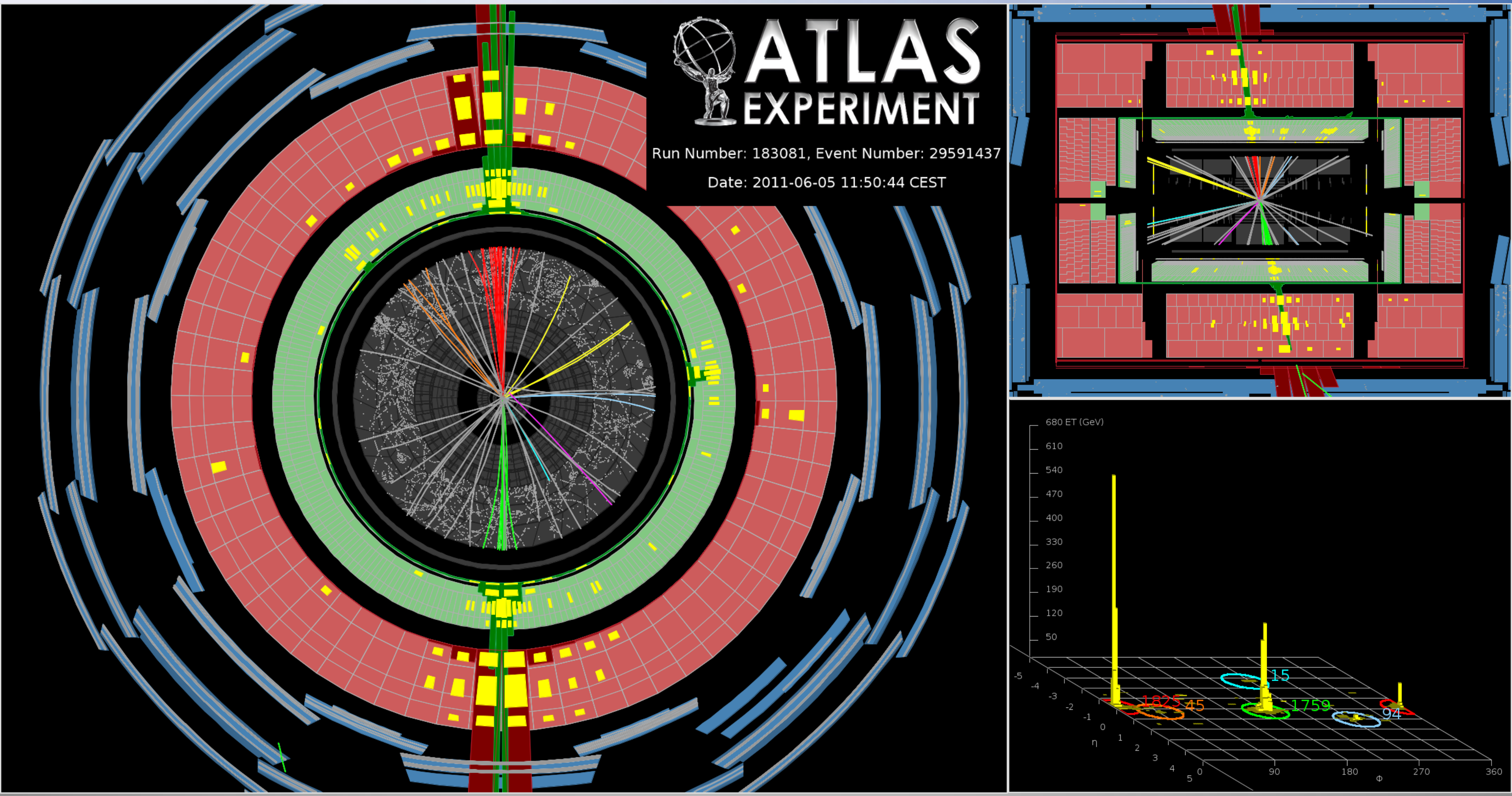
The data are spanning:

-20 GeV < p_T < 1500 GeV and |η| < 4.4

-Up to 12 orders of magnitudes in cross-sections







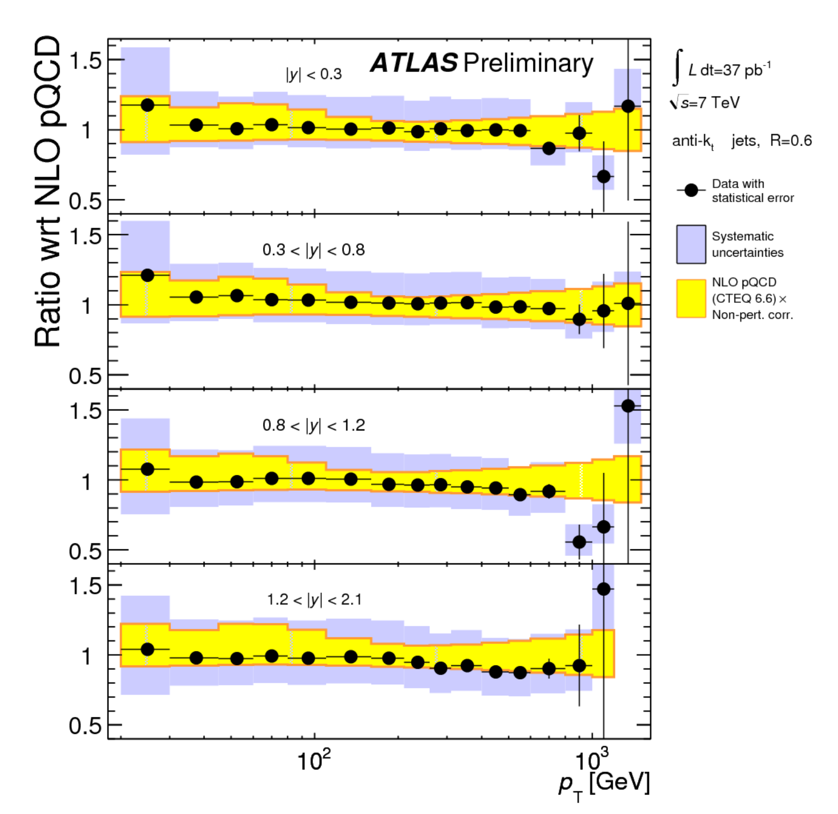
Jets

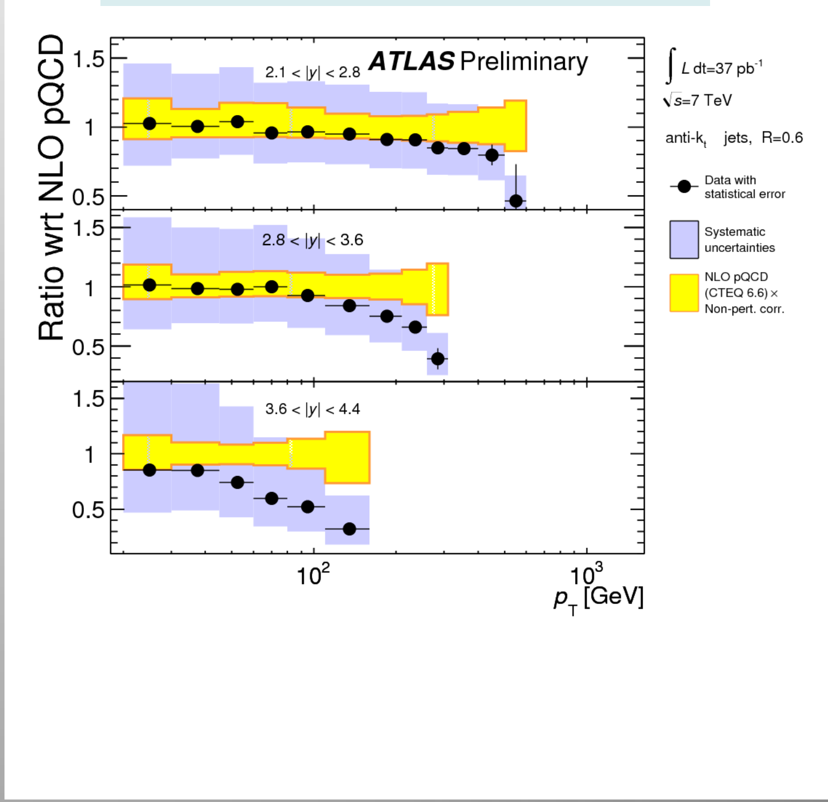
Jets with 1.9 and 1.7 TeV transverse momenta (p_T)

Jets: Data with NLO Theory

Good agreement between data and NLO pQCD with various PDFs globally…

… except in some specific regions, for example in the forward directions
→Should be able soon to constrain PDFs



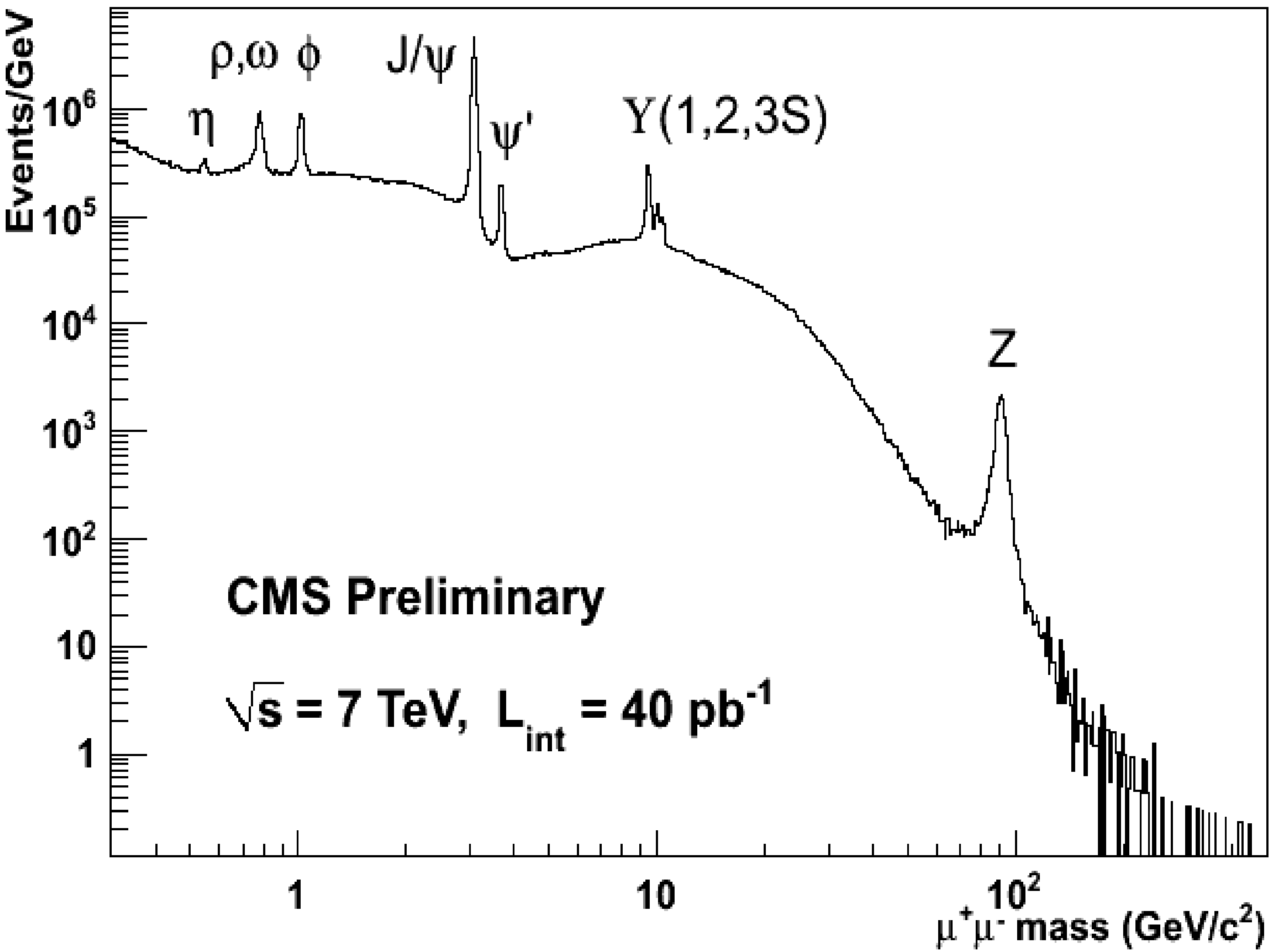


Importance of energy scale uncertainty!

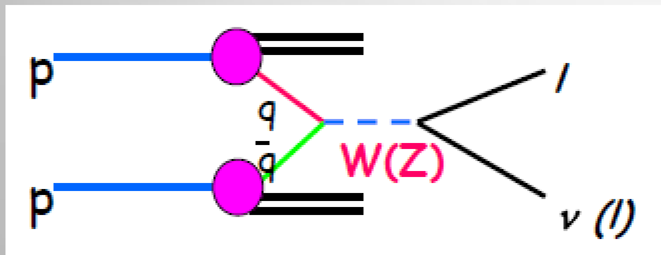
ATLAS-CONF-2011-047

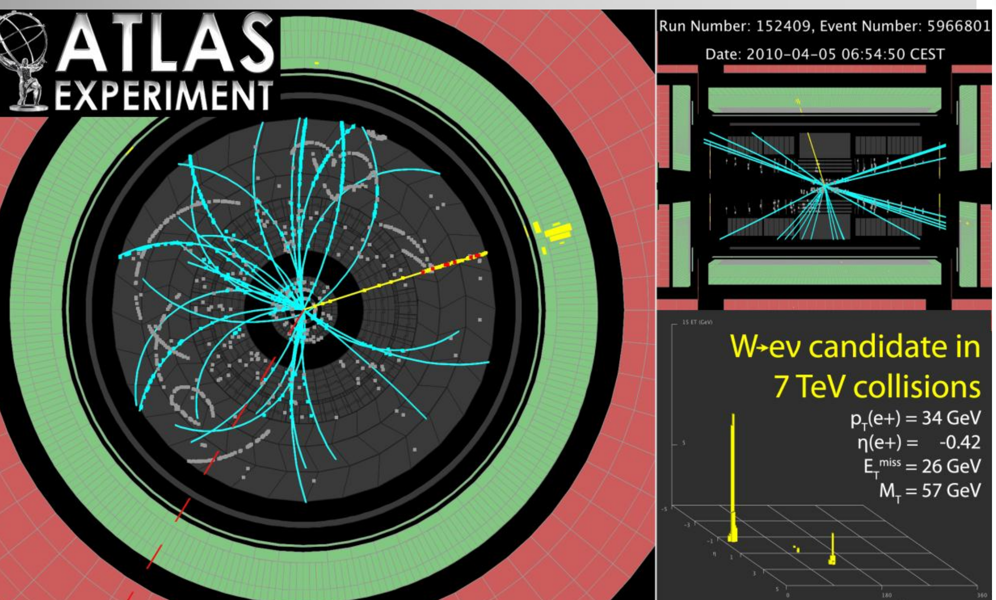
Di-lepton Invariant Mass

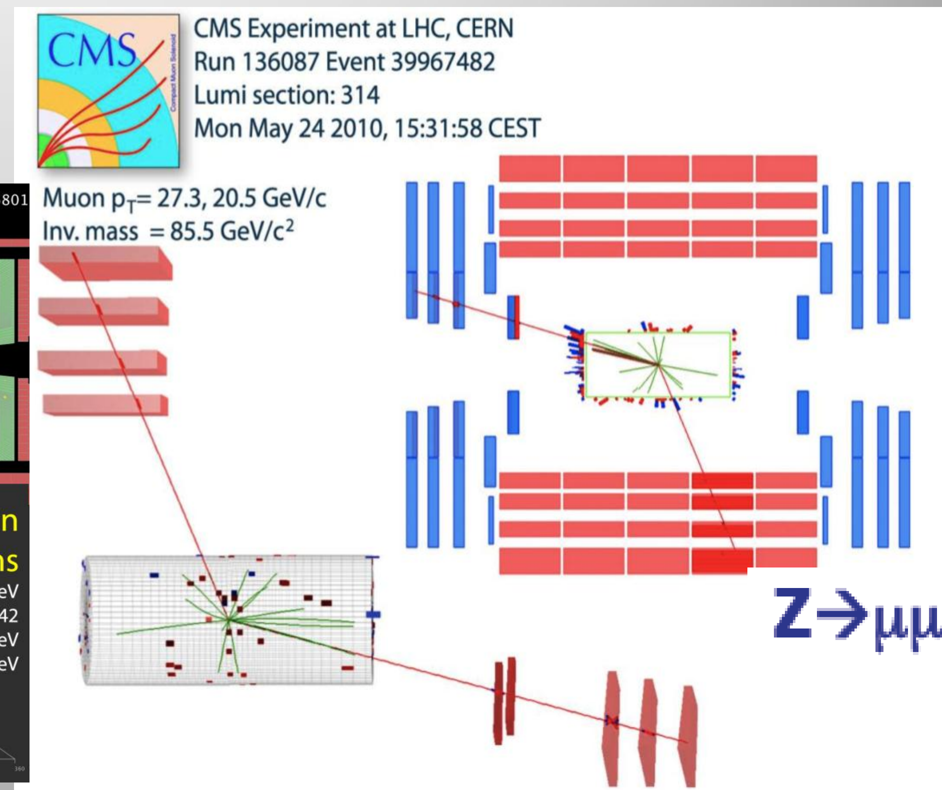
The di-muon spectrum recalls a long period of particle physics:



Heavy Bosons Production



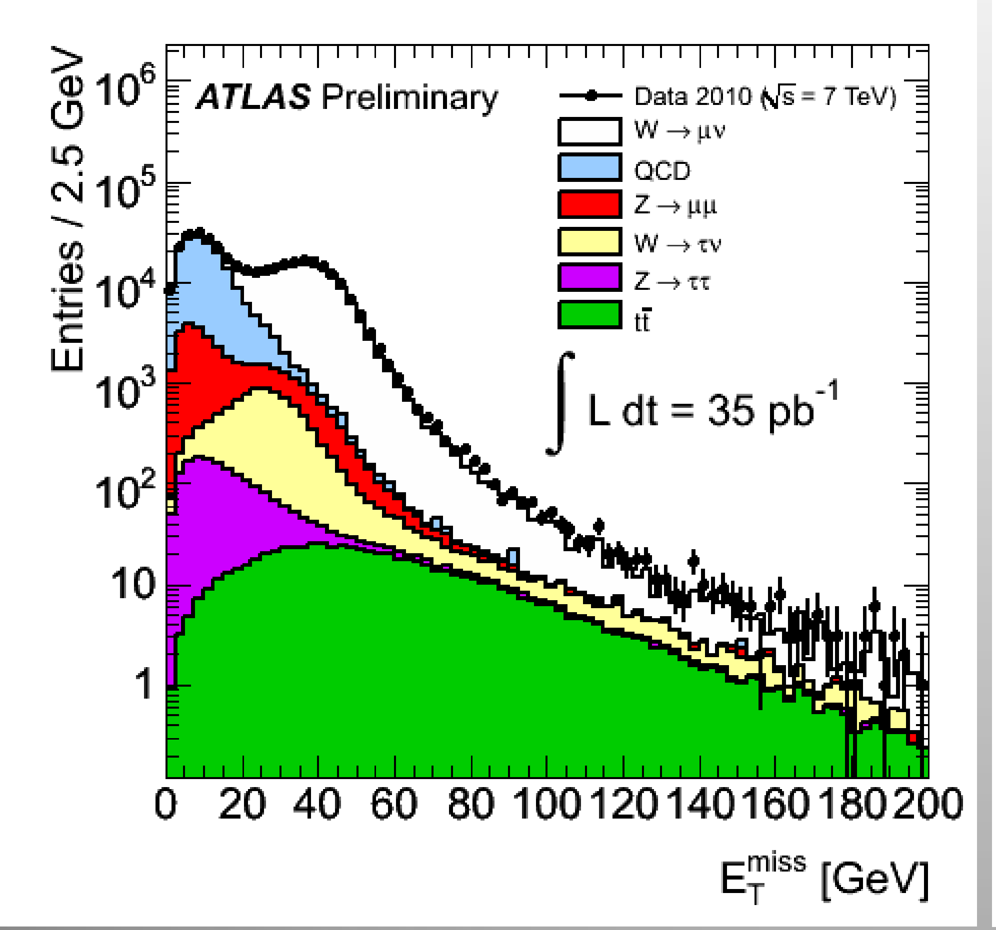


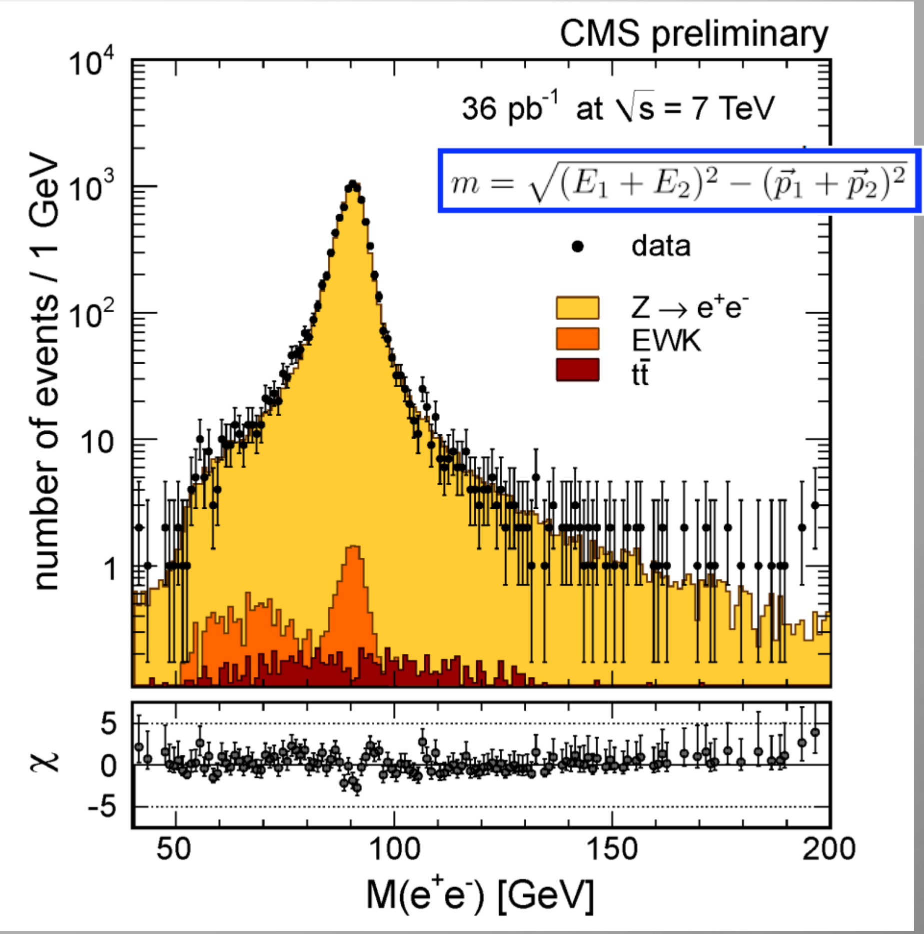


The first W & Z bosons showed up in May 2010 in the experiments
Now: about 6M W and 600K Z events/fb^{-1} for analysis (e+μ final states)

W and Z Boson Production

Sub. to JHEP
arXiv:1107.4789[hep-ex]

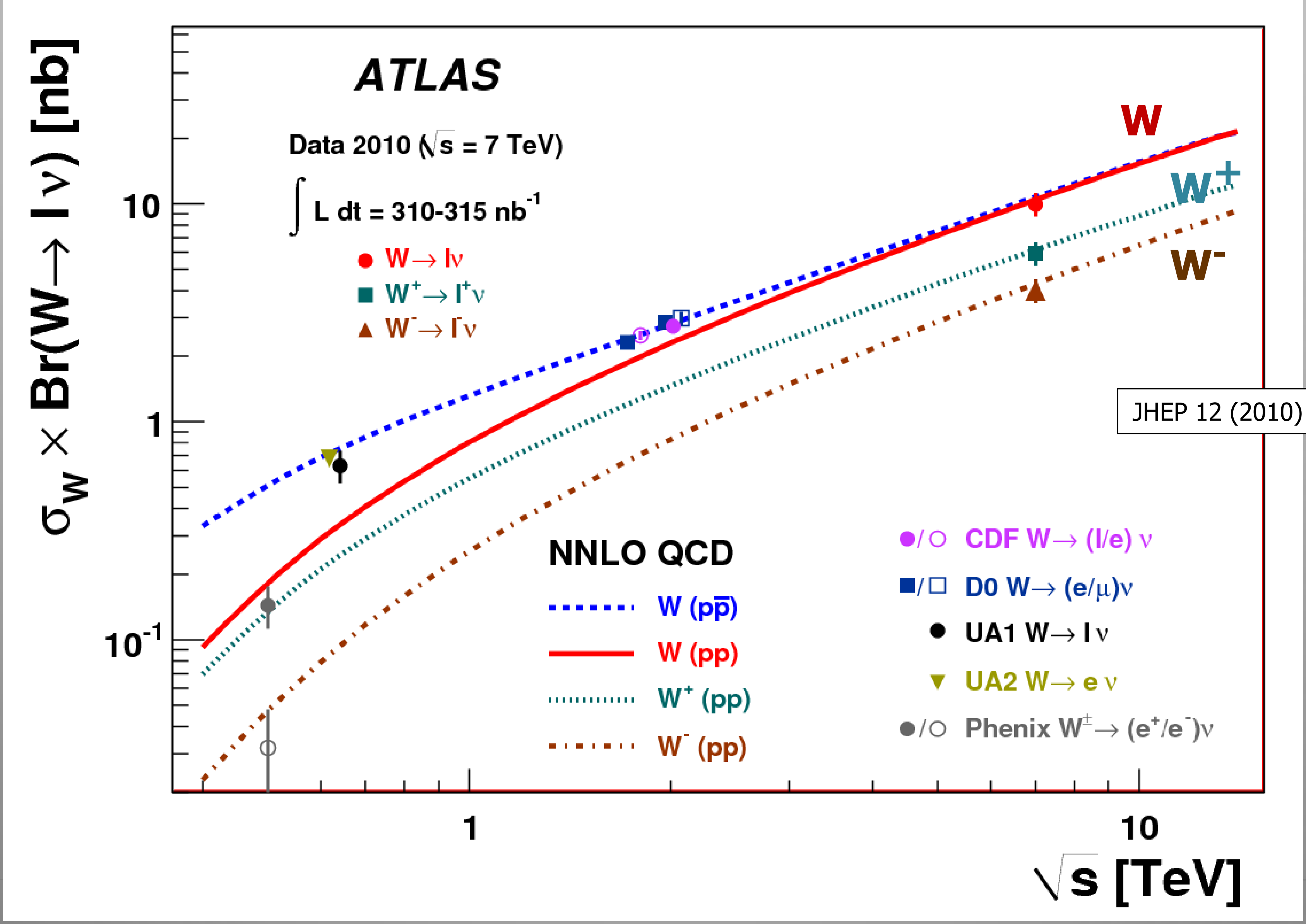




Missing transverse energy from the W → μ + ν decays

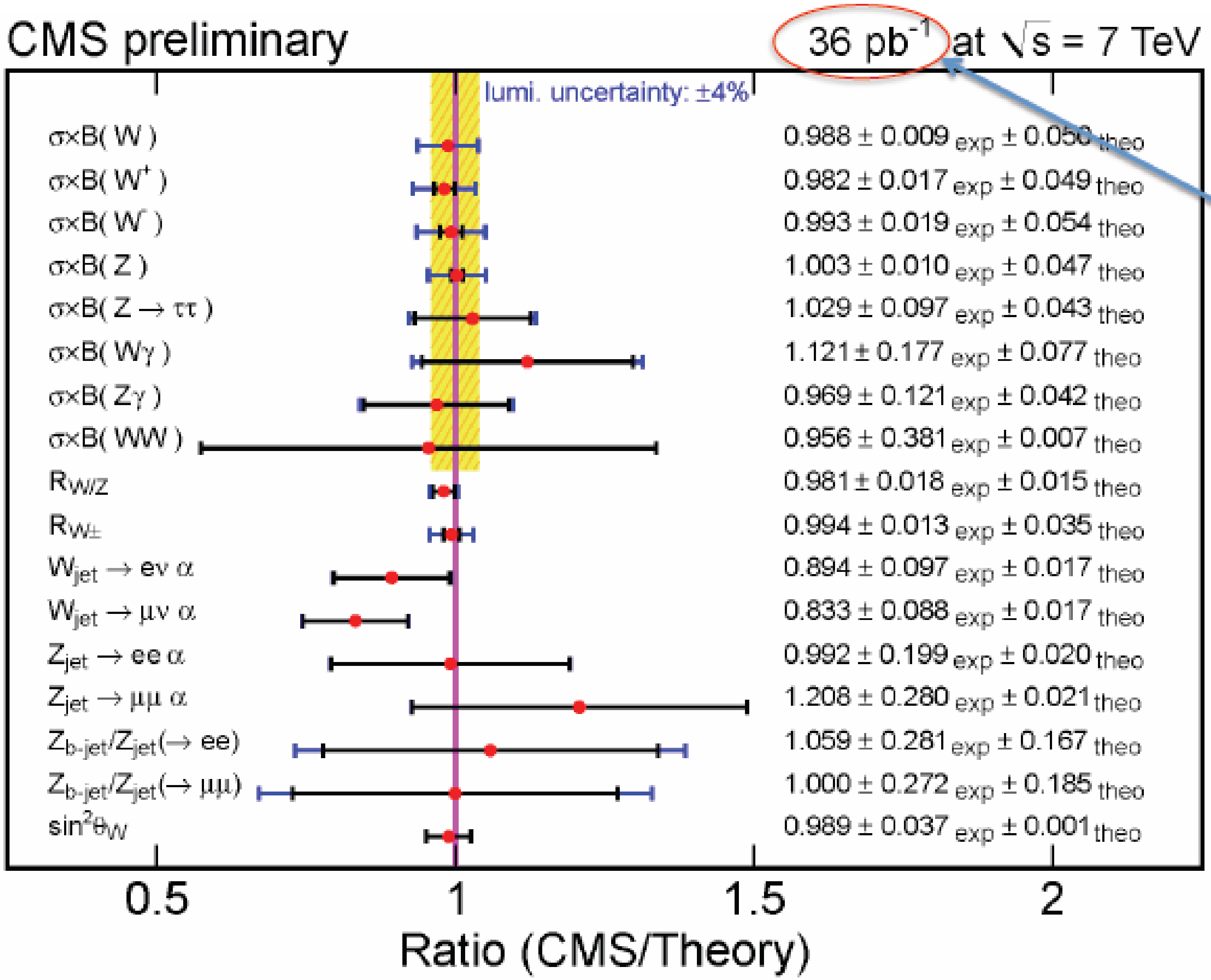
Z peak (di-lepton pair mass distributions)

Early W cross section measurements



JHEP 12 (2010) 060

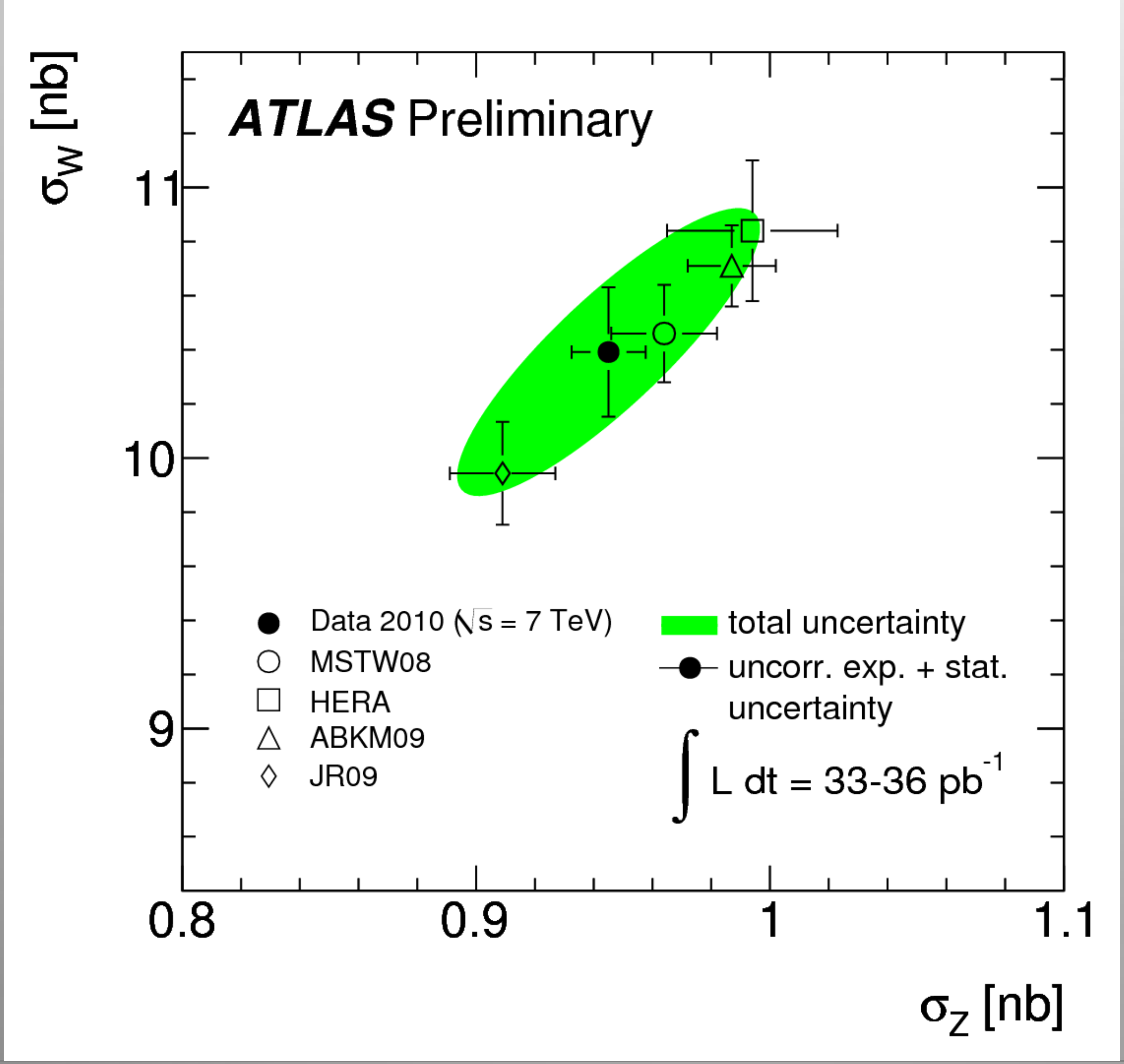
Full 2010 Data Set Measurements



Note:
There are now results with 2 fb^{-1}

I show this table to highlight the range of EWK measurements

W-Z Cross Sections

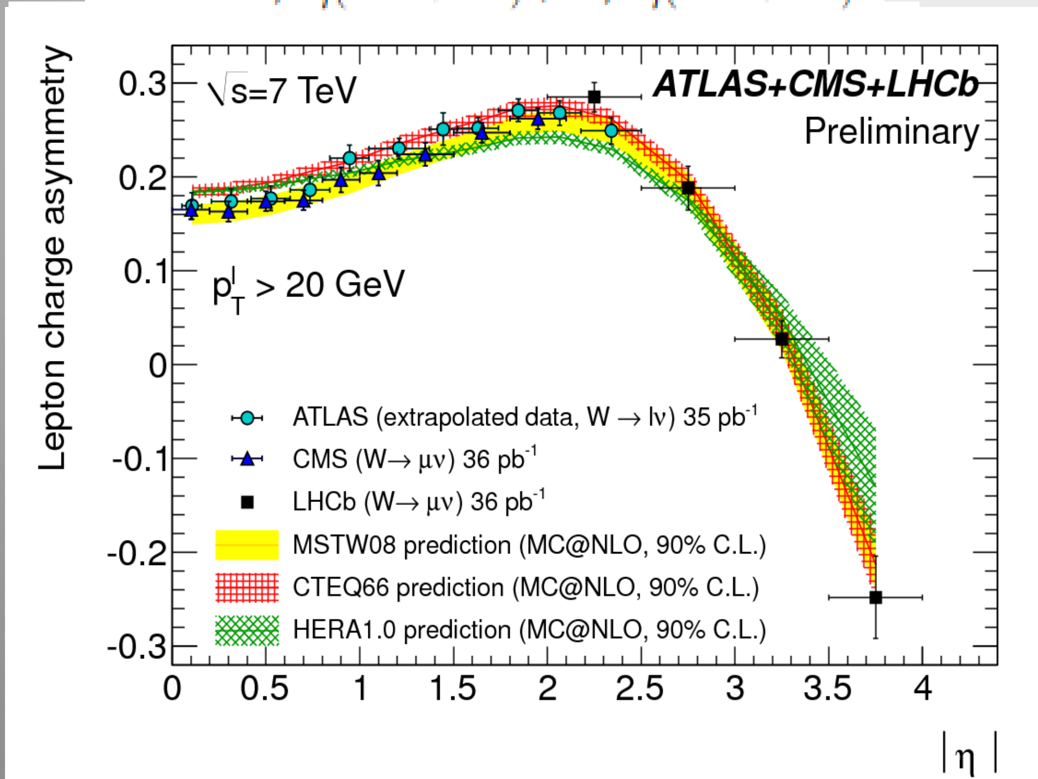


ATLAS-CONF-2011-041

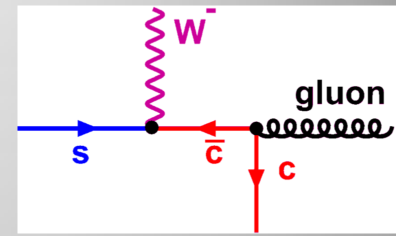
Electroweak: access to proton PDFs

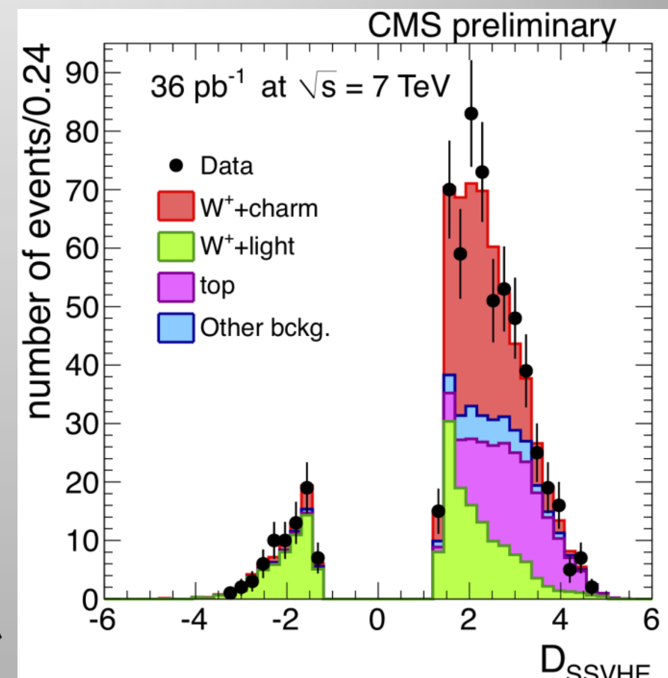
PAS EWK-11-005, 013

$$A(\eta) = \frac{d\sigma/d\eta(W^+ \to \ell^+\nu) - d\sigma/d\eta(W^- \to \ell^-\bar{\nu})}{d\sigma/d\eta(W^+ \to \ell^+\nu) + d\sigma/d\eta(W^- \to \ell^-\bar{\nu})},$$



W+charm





$R^{\pm}_c = \sigma(W^+c)/\sigma(W^-c) = 0.92 \pm 0.19(\text{stat.}) \pm 0.04(\text{syst.})$

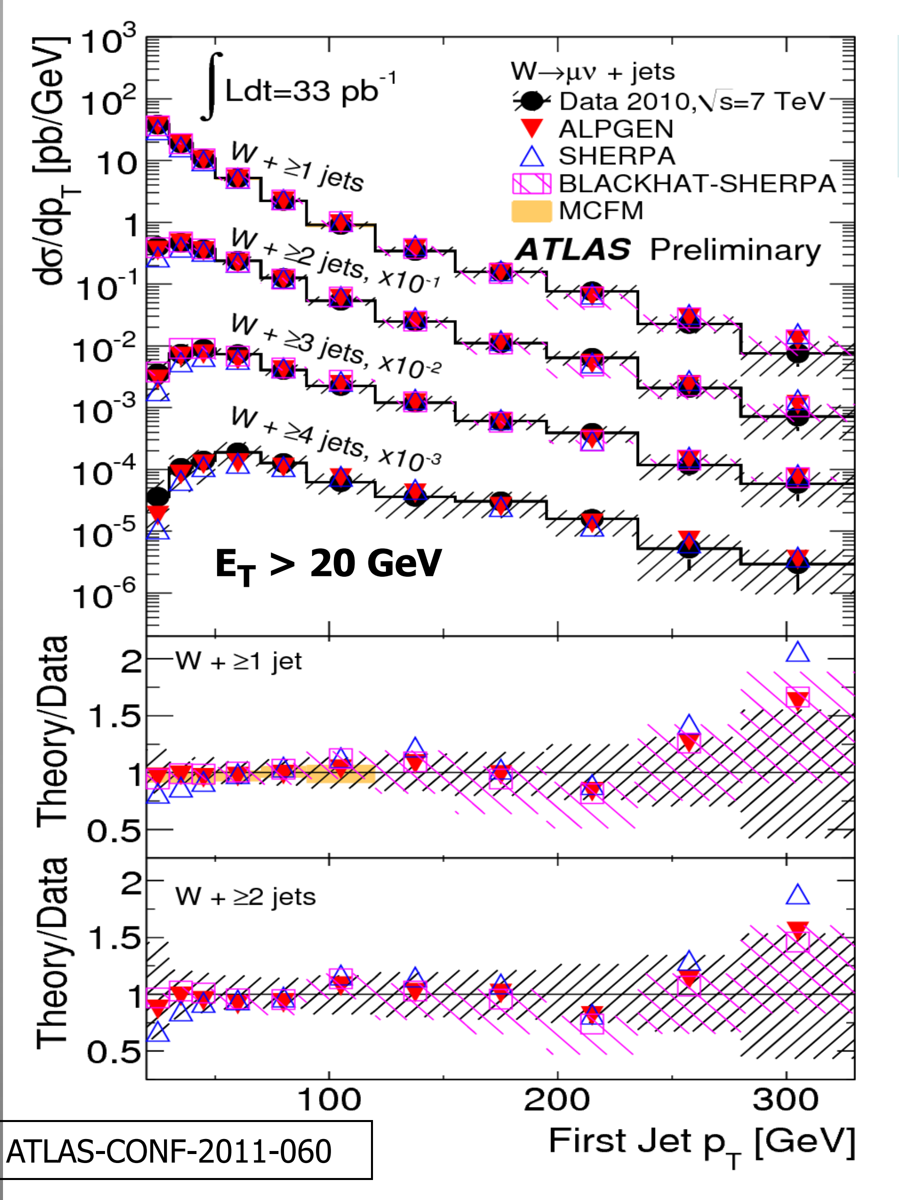
$R_c = \sigma(Wc)/\sigma(W+\text{jets}) = 0.143 \pm 0.015(\text{stat.}) \pm 0.024(\text{syst.})$

NLO predictions:

$R^{\pm}_c = 0.91 \pm 0.04$ $R_c = 0.13 \pm 0.02$

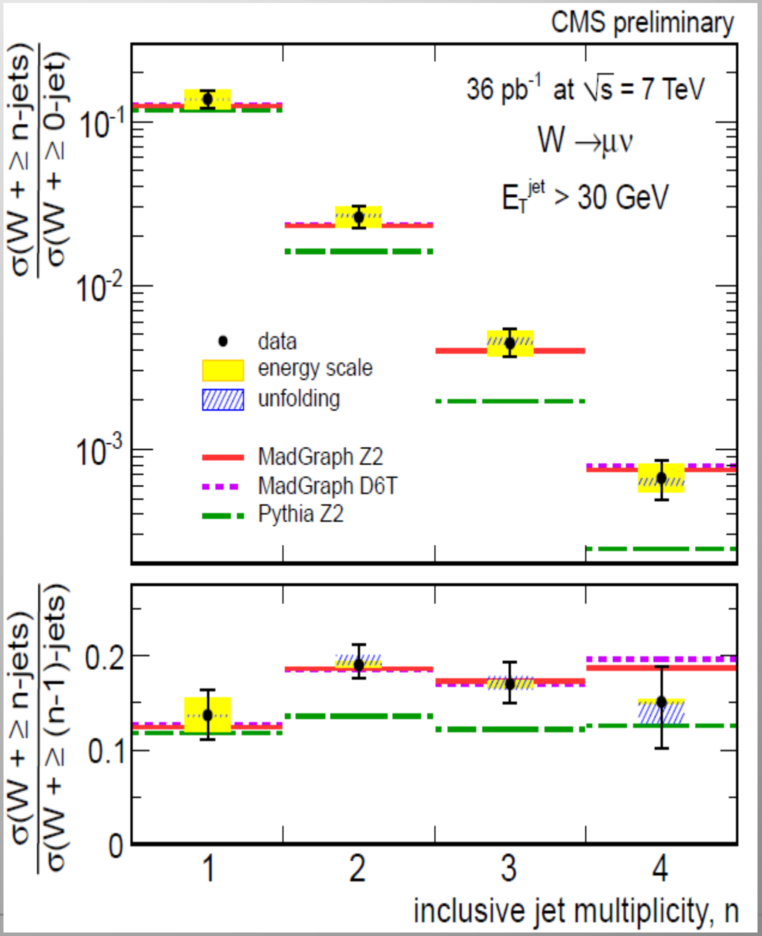
Secondary vertex decay length discriminator

W + jet(s) production



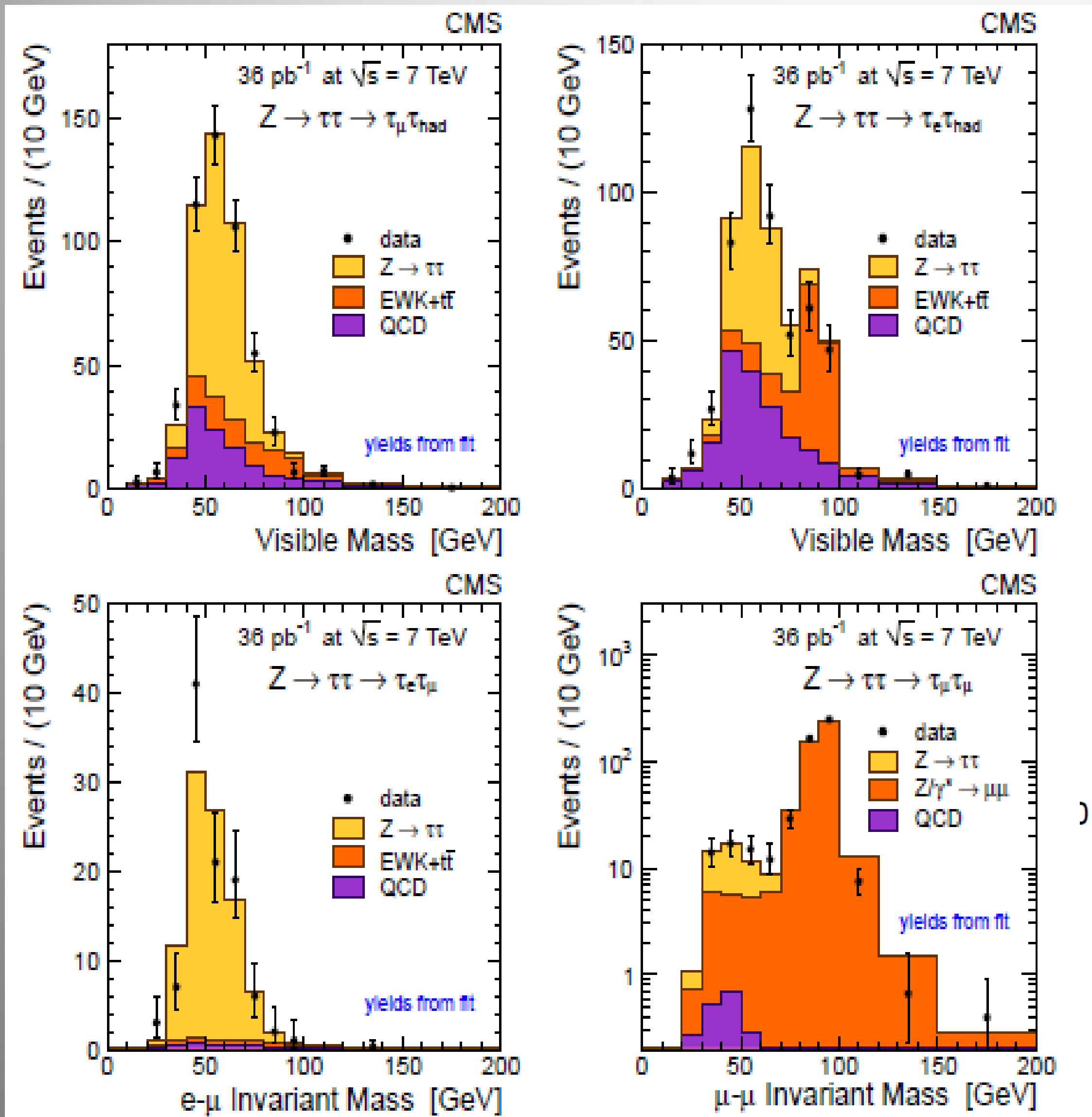
ATLAS-CONF-2011-060

Both an interesting QCD measurement as well as a dominant background to searches

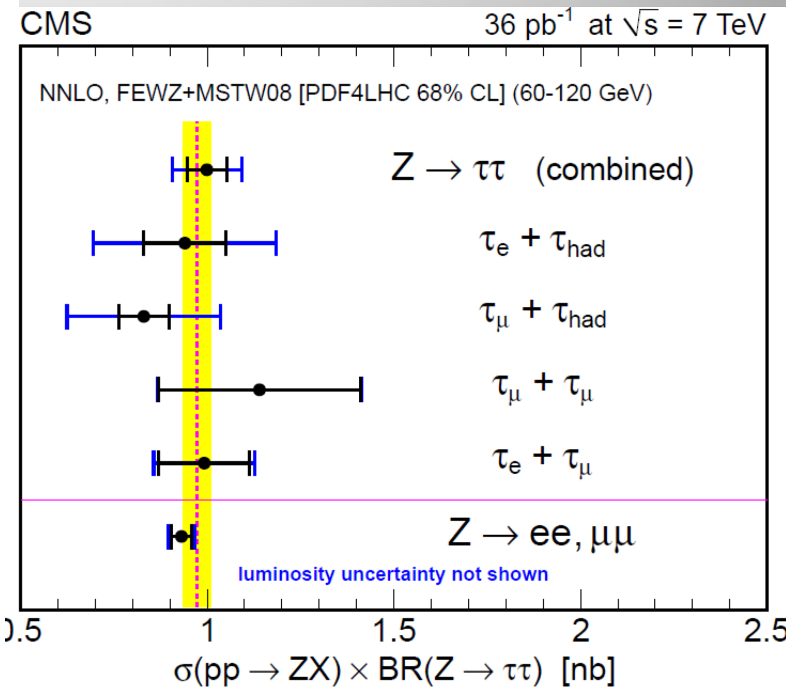


CMS PAS EWK 10-012

Using Tau leptons

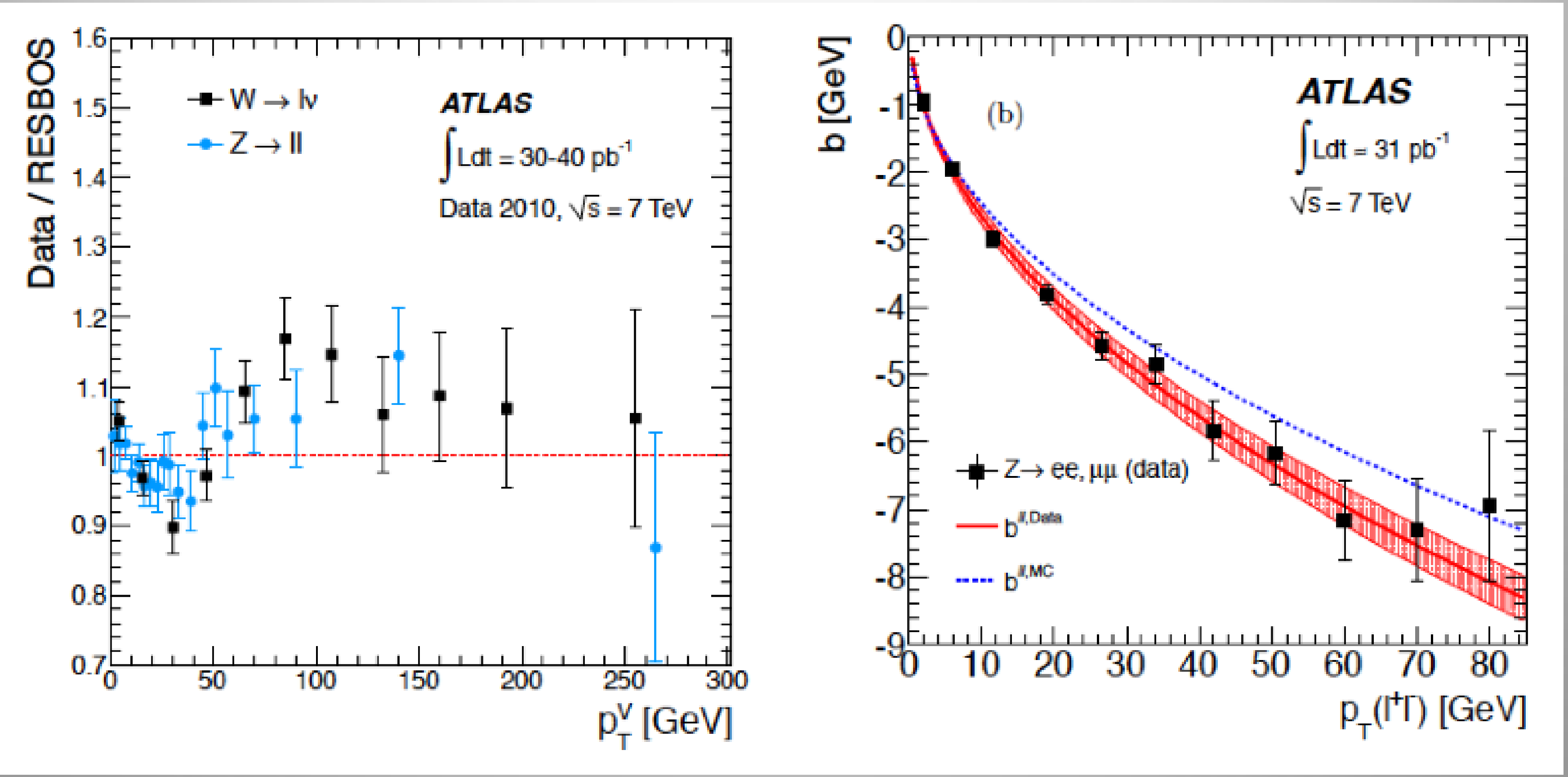


Example of using τ's



Sub. to JHEP
arXiv:1104.1617[hep-ex]

Differential W, Z Cross Sections



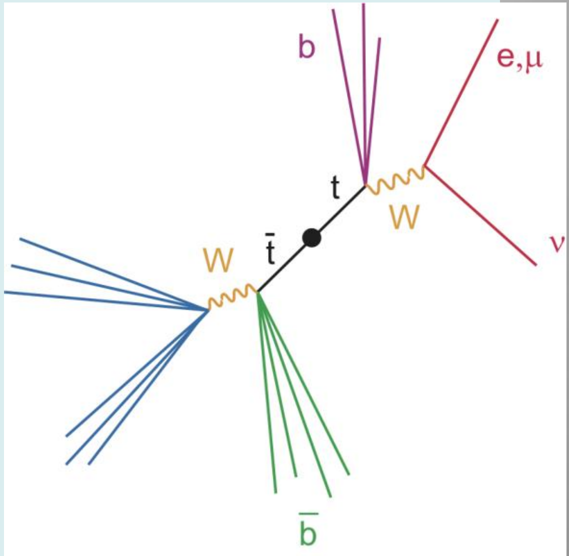
Very sensitive to QCD calculations and new effects

RESBOS = Resummed QCD program for Vector Boson Production

Studies of the TOP Quark

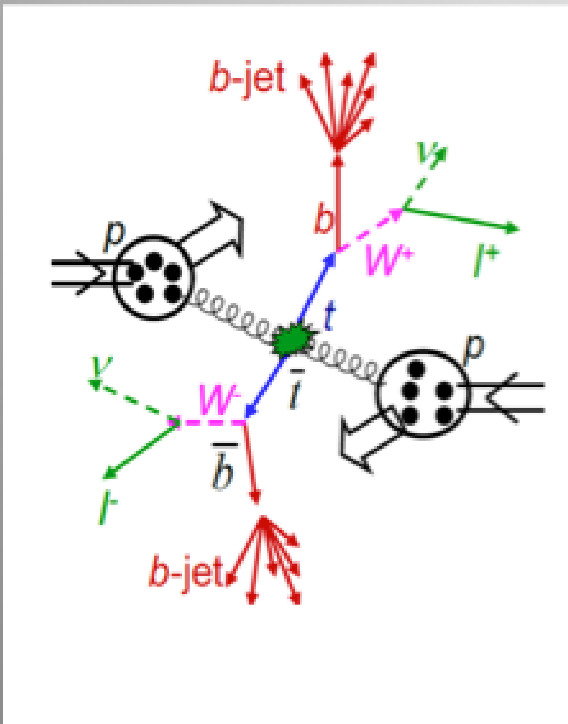
- Complete set of ingredients to investigate production of ttbar, which is the next step in verifying the SM at the LHC:
  - e, μ, E_T^{miss}, jets, b-tag

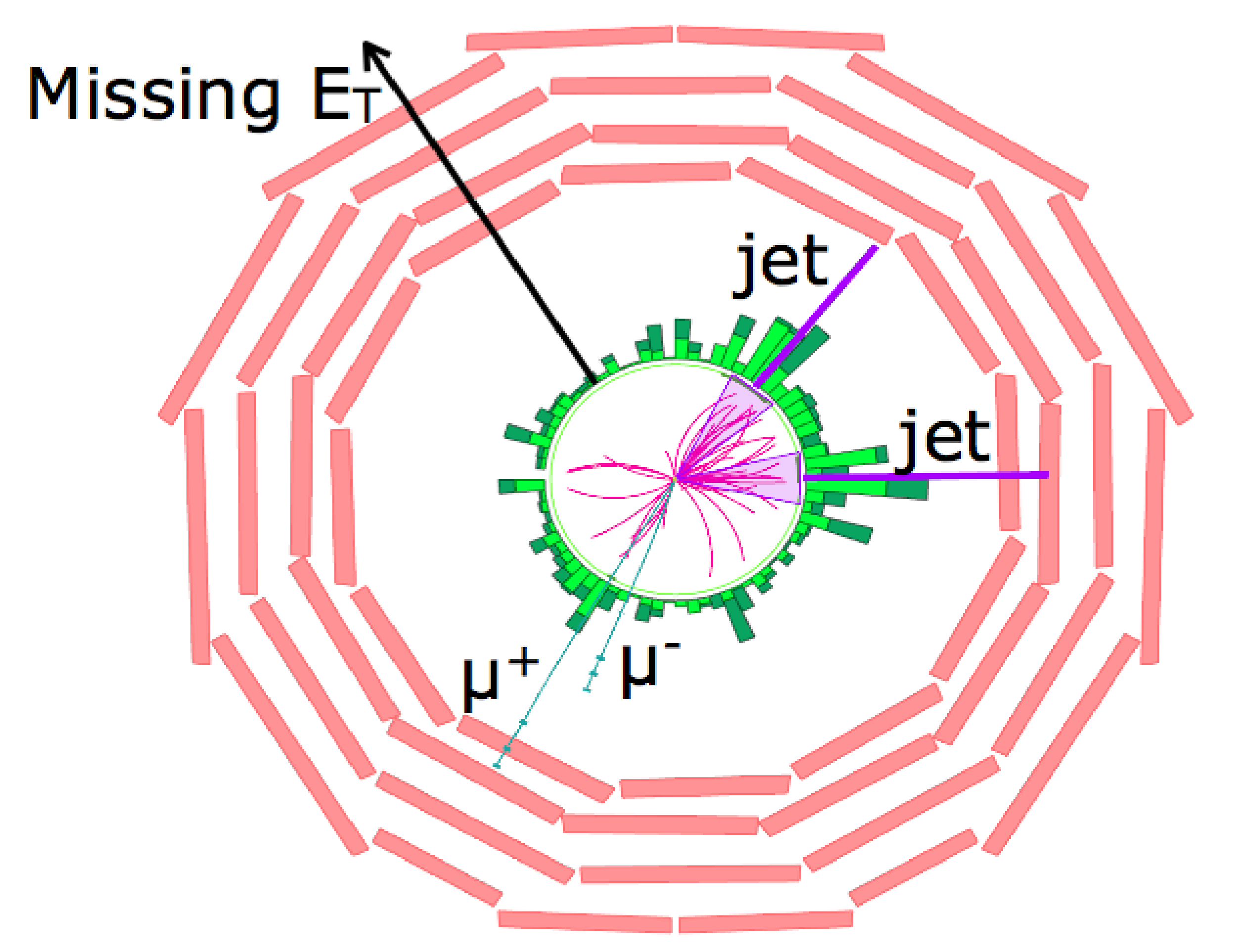
- Assume all tops decay to Wb: event topology then depends on the W decays:
  - one lepton (e or μ), E_T^{miss}, jjbb (37.9%)
  - di-lepton (ee, $\mu\mu$ or eμ), E_T^{miss}, bb (6.46%)
  - All hadronic channel



- Data-driven methods to control QCD and W+jets backgrounds

Candidate Event for Top Production

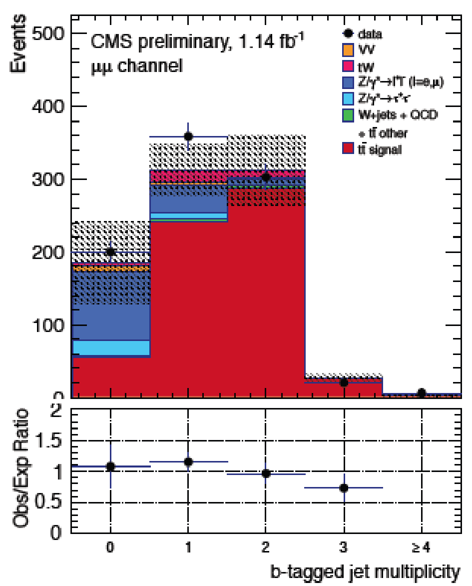


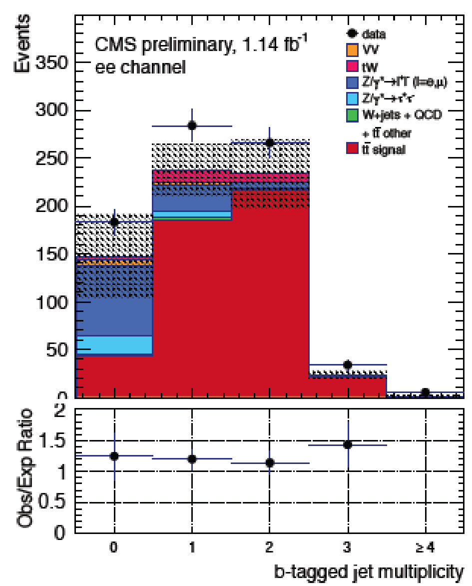


Top Di-Muon Candidate Event

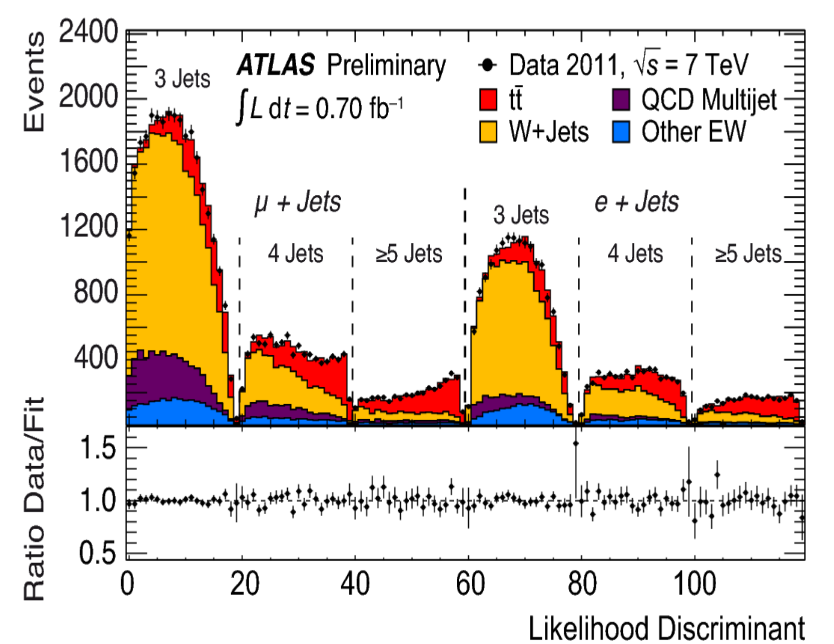
Top Analyses: Examples

2 leptons + jets + ETmiss





1 lepton + multi-jets + ETmiss



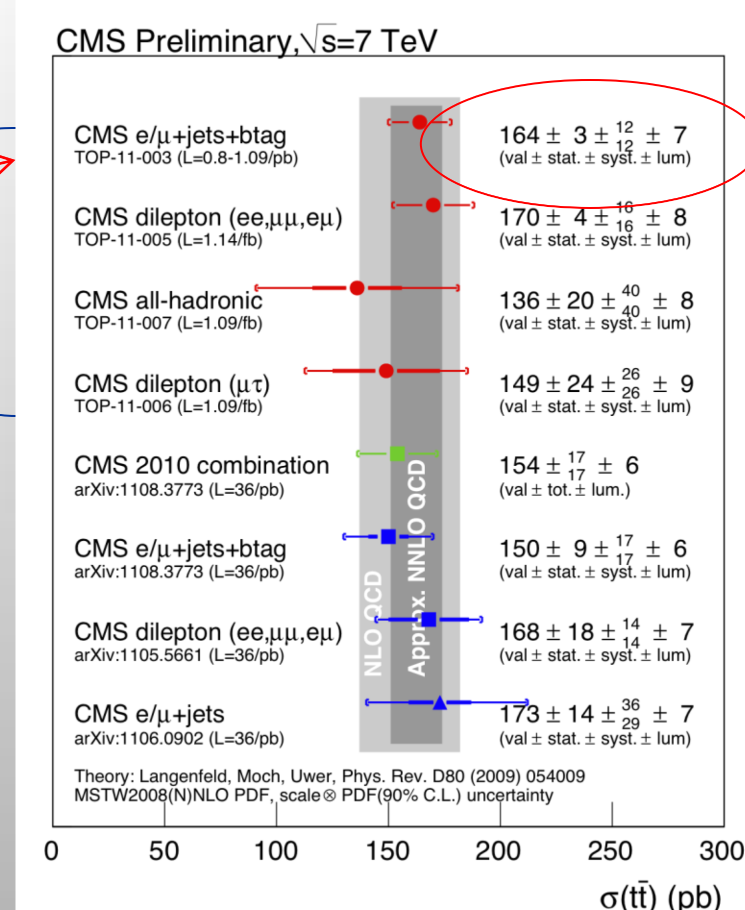
results with global kinematical fit

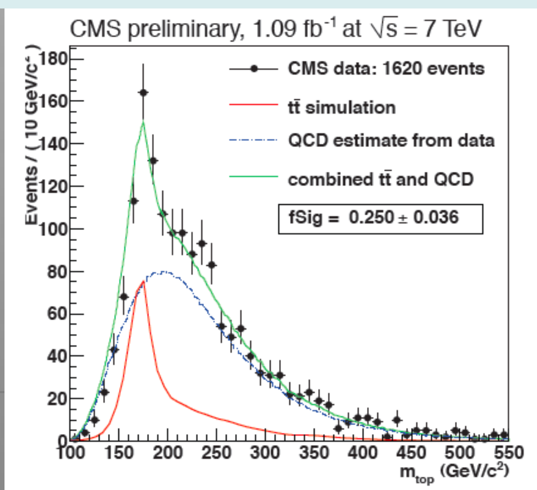
Top-Pair Cross Section

$\sigma(NLO)=158\pm24$ pb

- Lepton+jets+b-tag
  - Most precise to-date for CMS !
- Dilepton channel (ee,eμ,μμ)
  - Require at least 1 b-tag
- Dilepton channel (μ-τ)
  - Reconstruct hadronic tau decay
- All-hadronic channel
  - kinematic fit for m_{top}
  - QCD shape from anti-b-tag data

2011





This is the most precise top pair cross-section measurement so far:

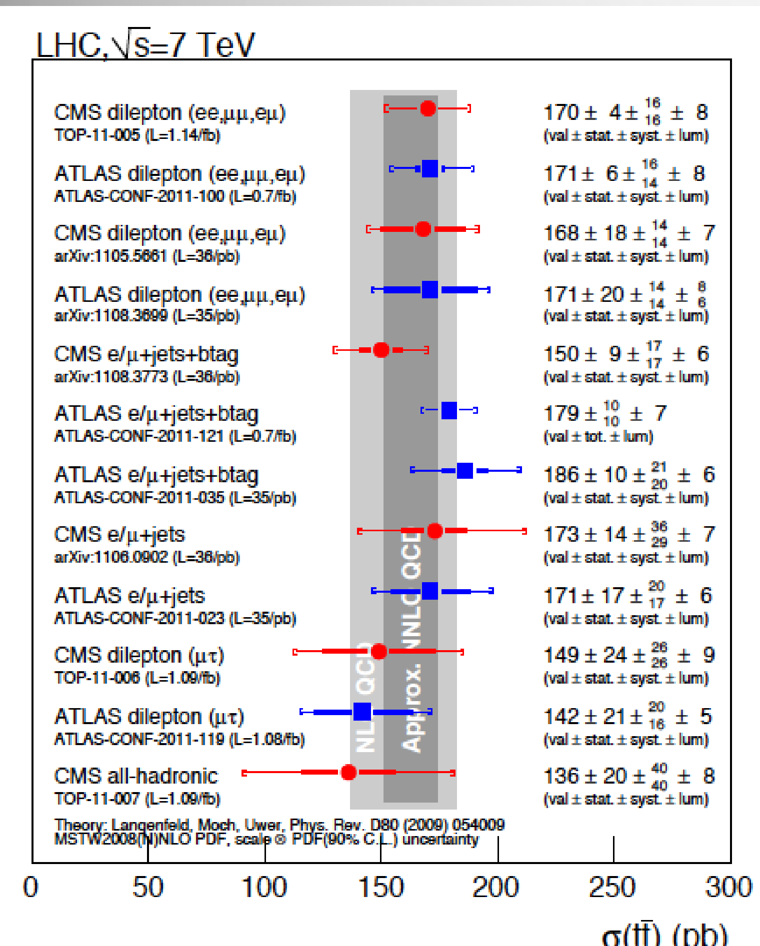
$$\sigma_{t\bar{t}} = 179.0^{+7.0}_{-6.0}(stat+syst) \pm 6.6(lumi)pb$$

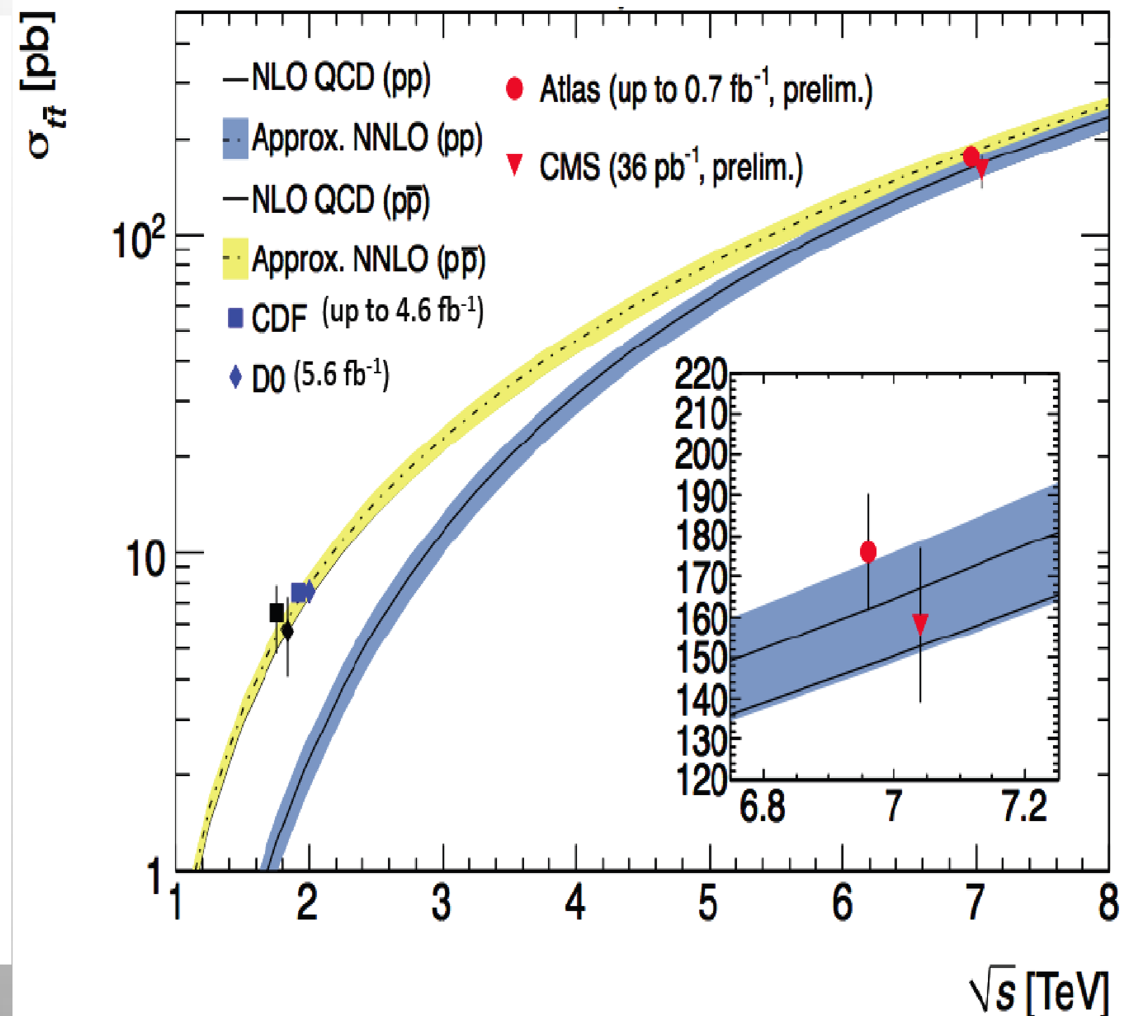
$$\frac{\delta\sigma}{\sigma} \sim 6.6\%$$

ATLAS: Lepton+ jets

Already challenging for theoretical uncertainties!

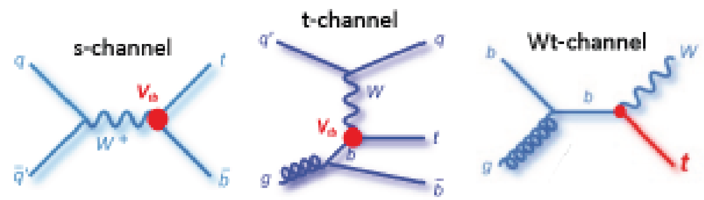
Top Pair Production at 7 TeV



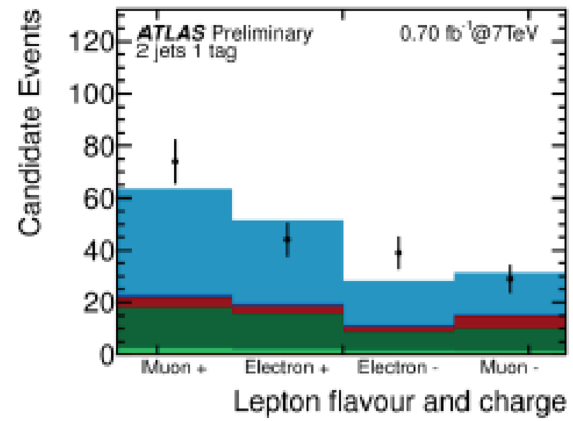


ATLAS and CMS have also made first single top cross-section measurements in agreement with NLO QCD expectations

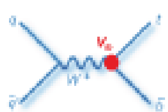
Single Top Production



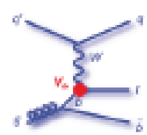
For M_t = 172.5 GeV	σ_{tb}	σ_{tqb}	σ_{tW}
$p\bar{p}$ @ 1.96 TeV	1.04 ± 0.04 pb	2.26 ± 0.12 pb	0.28 ± 0.06 pb
pp @ 7 TeV	4.6 ± 0.3 pb	64.6 +3.3 -2.6 pb	15.7 ± 1.4 pb

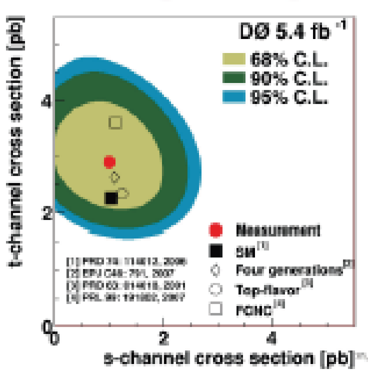


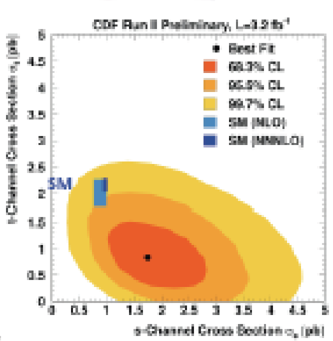
Try to distinguish s and t channel production

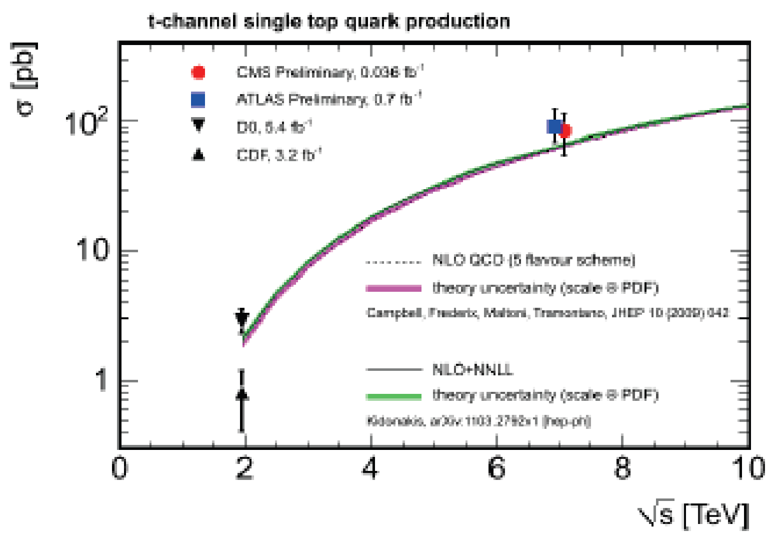


VS







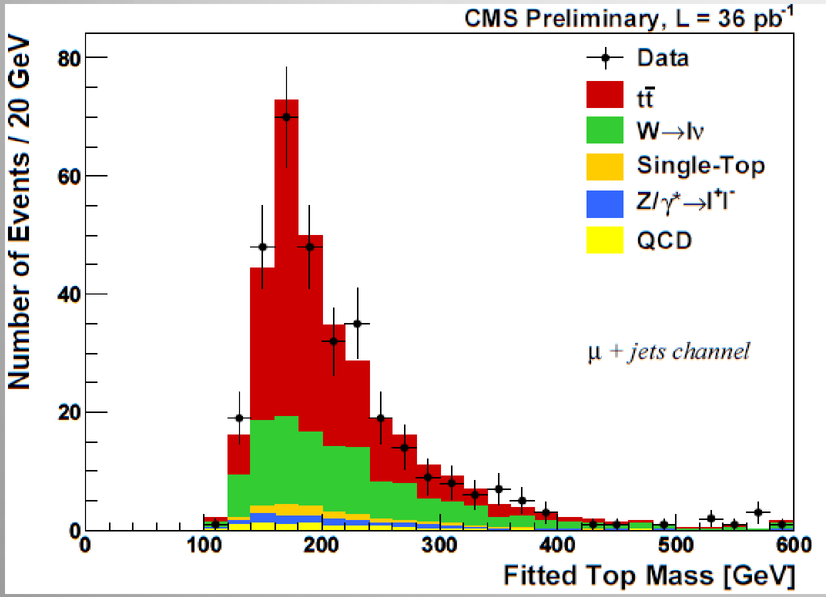


σ_{tqb} (pb) for $m_t = 172.5$ GeV:

CDF (3.2 fb^{-1})	0.8 ± 0.4	
D0 (5.4 fb^{-1}, arXiv:1105.2788)	2.90 ± 0.59	5.5σ
CMS (36 pb^{-1}, arXiv:1106.3052)	$83.6 \pm 29.8(\text{stat}+\text{syst}) \pm 3.3(\text{lumi})$	3.7σ
Atlas (0.7 fb^{-1})	90^{+32}_{-22}	7.6σ

Examples of Top quark properties

CMS mass measurement with l + jets (kinematic fit, 4 or more jets)

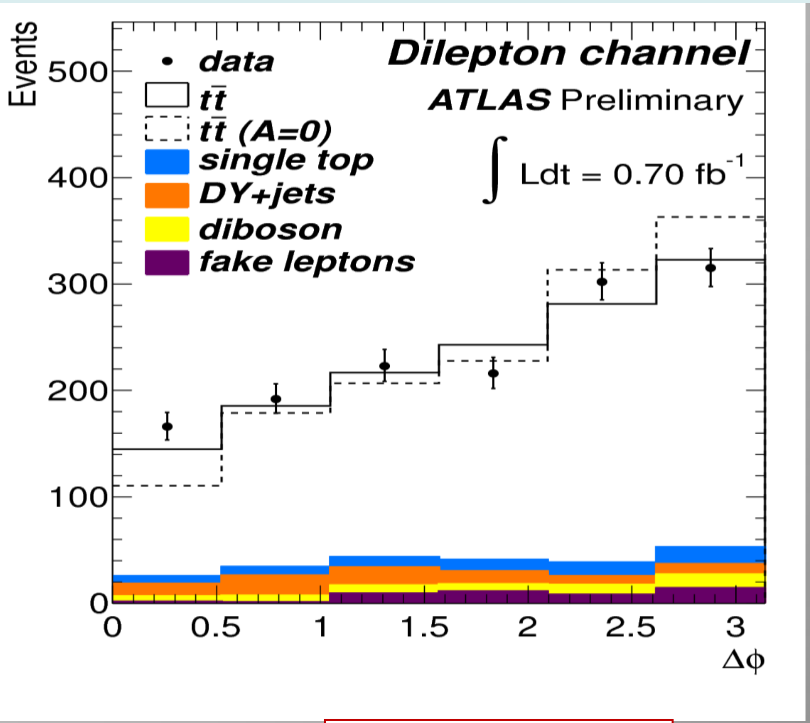


Result when combined with di-lepton analysis

$$m_t = 173.4 \pm 1.9(\text{stat}) \pm 2.7(\text{syst})\ \text{GeV}.$$

CMS-PAS-TOP-10-009

ATLAS t-tbar spin correlation as measured in di-lepton events (Δφ between leptons in azimuthal plane in the t-tbar lab frame)



$$C_{helicity} = 0.34^{+0.15}_{-0.11}$$

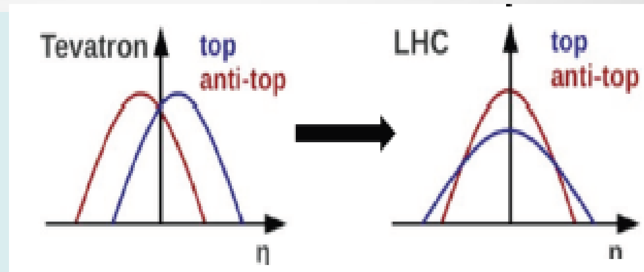
(SM predicts ~ 0.32)

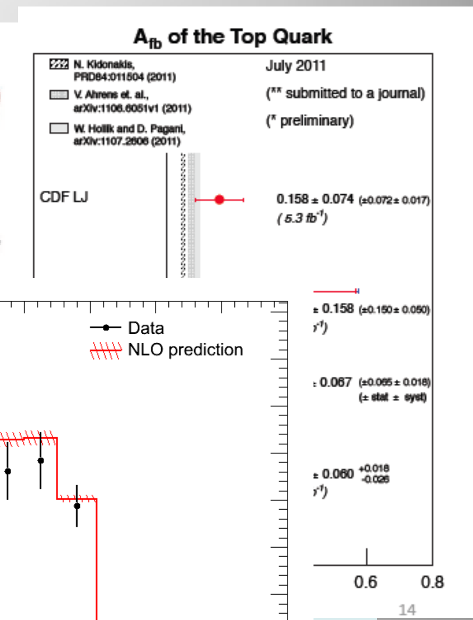
ATLAS-CONF-2011-117

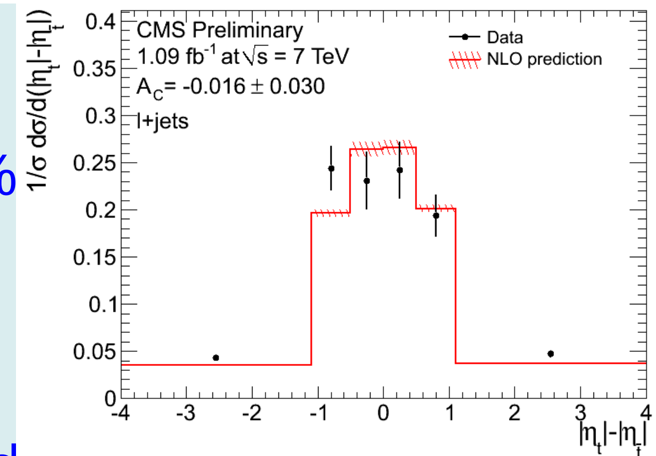
(Soon) competitive with TeVatron…

Top Charge and Mass Asymmetries

- Top charge asymmetry
  - Larger than expected @ Tevatron!
  - Lepton+Jets channel
  - $\Delta(|\eta|) = |\eta_t| - |\eta_{tbar}|$
  - $A_C = [N(\Delta>0) - N(\Delta<0)]/N_{tot}$ $= -1.6 \pm 3.0(\text{stat})\ ^{+1.0}_{-1.9}(\text{syst})\ \%$
  - A_C (theory) = 1.3%
- t-tbar mass difference
  - Muon+jets channel
  - Kinematic fit to the mass of the hadronically decaying top
  - Ideogram method
    - Likelihood calculated for each event to be consistent with m_t
  - Ideogram method applied separately to μ^++jets and μ^-+jets
  - $\Delta m(\text{t-tbar}) = -1.20 \pm 1.21(\text{stat}) \pm 0.47(\text{syst})$ GeV

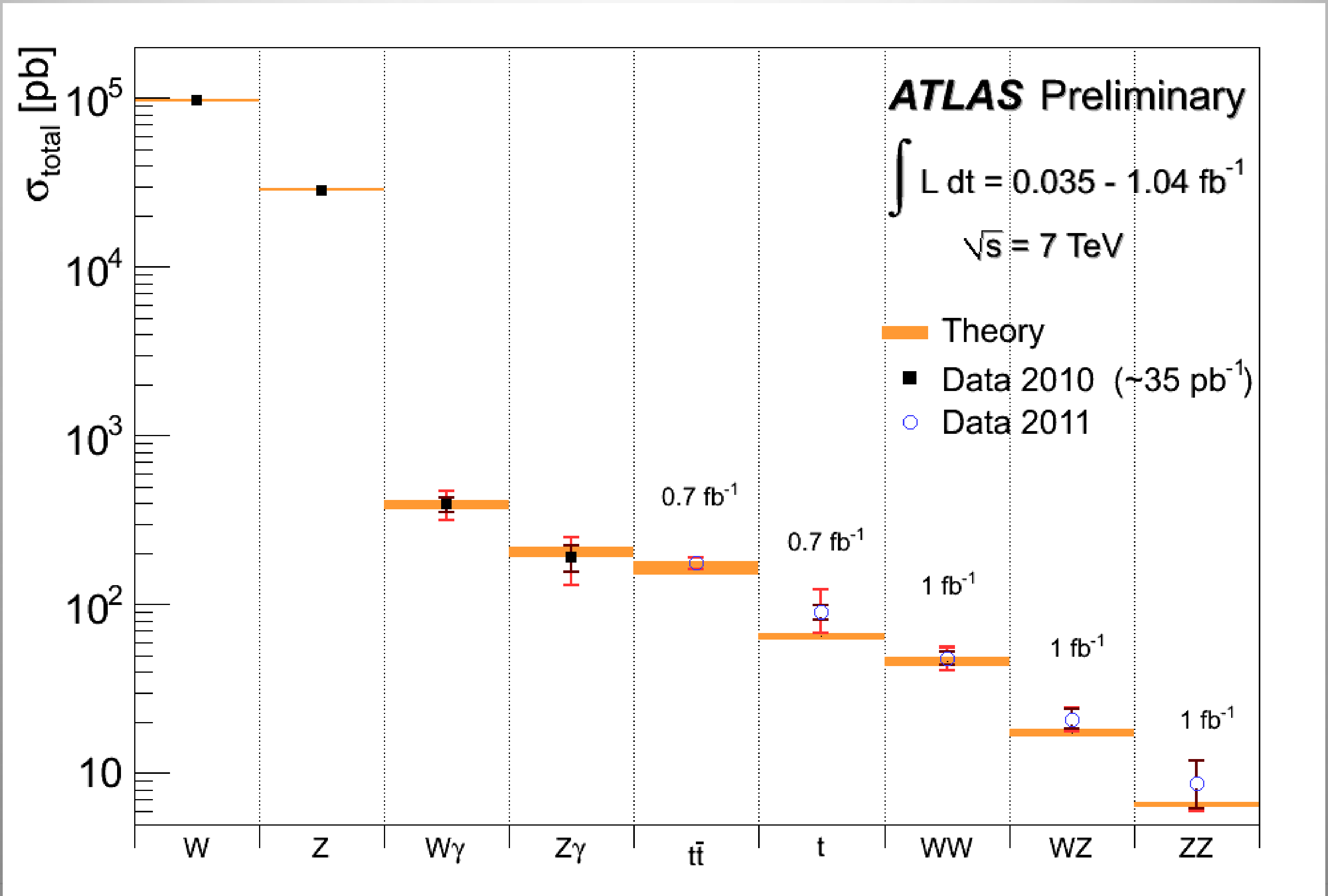


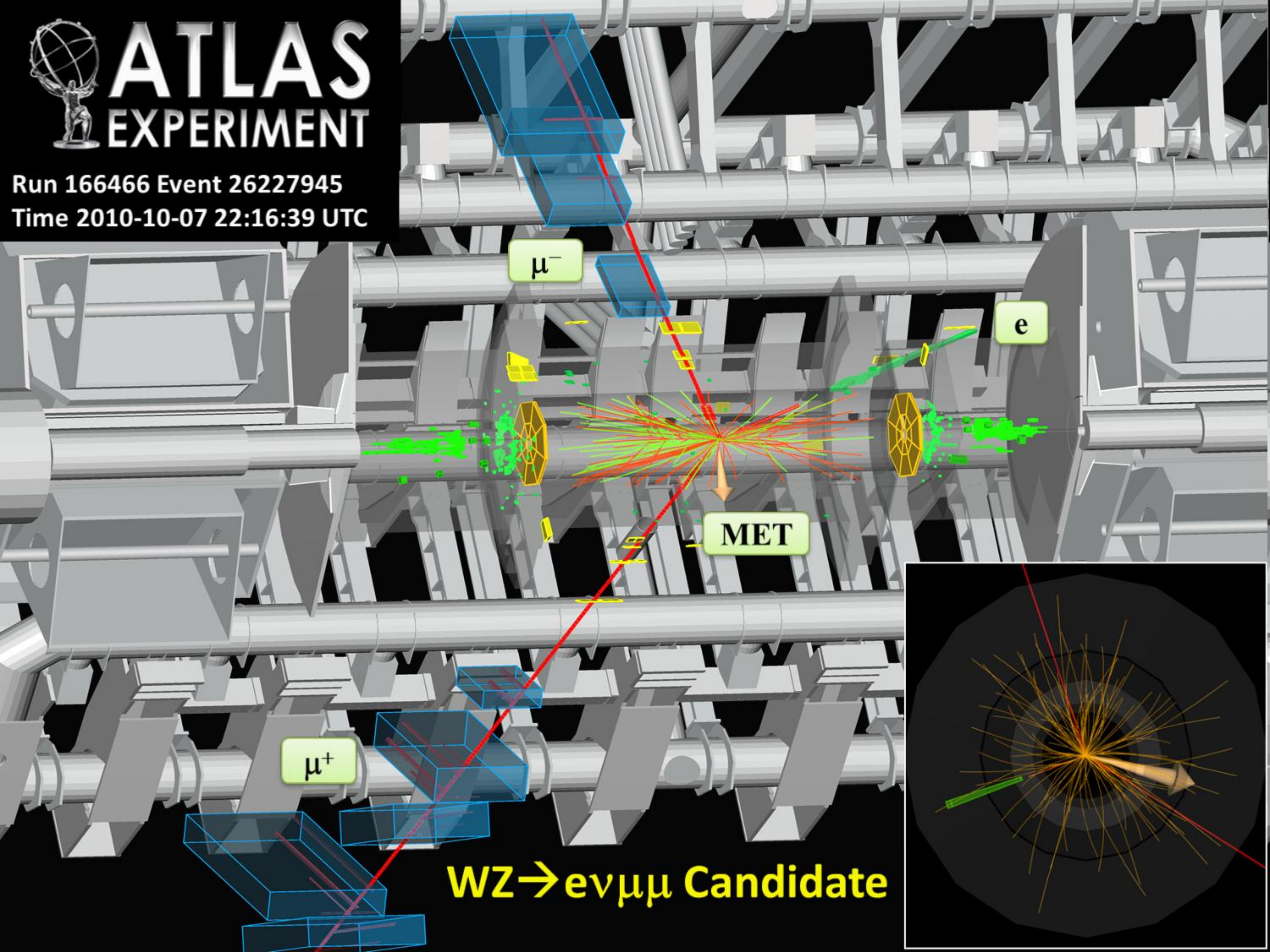




Exceed's Tevatron precision

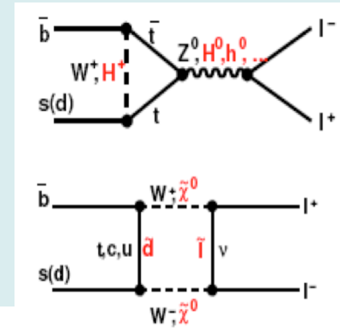
Measured Cross sections at 7 TeV



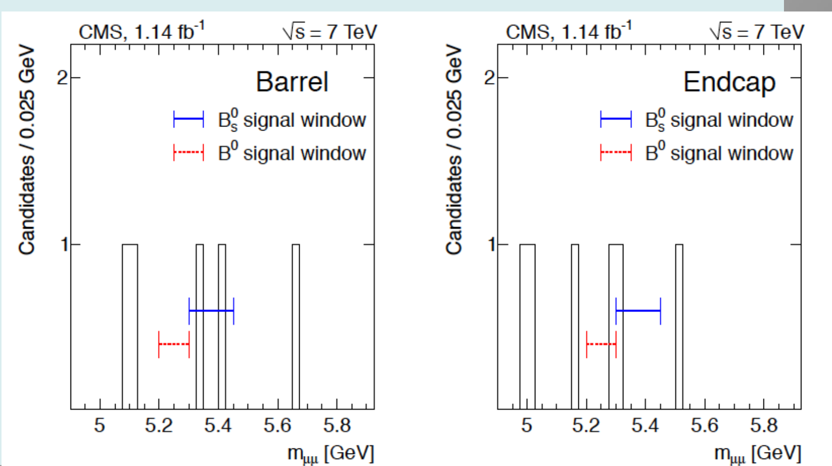

ATLAS EXPERIMENT
Run 166466 Event 26227945
Time 2010-10-07 22:16:39 UTC
μ^-
e
MET
μ^+
WZ→eνμμ Candidate

Search for $B_{s(d)} \rightarrow \mu\mu$

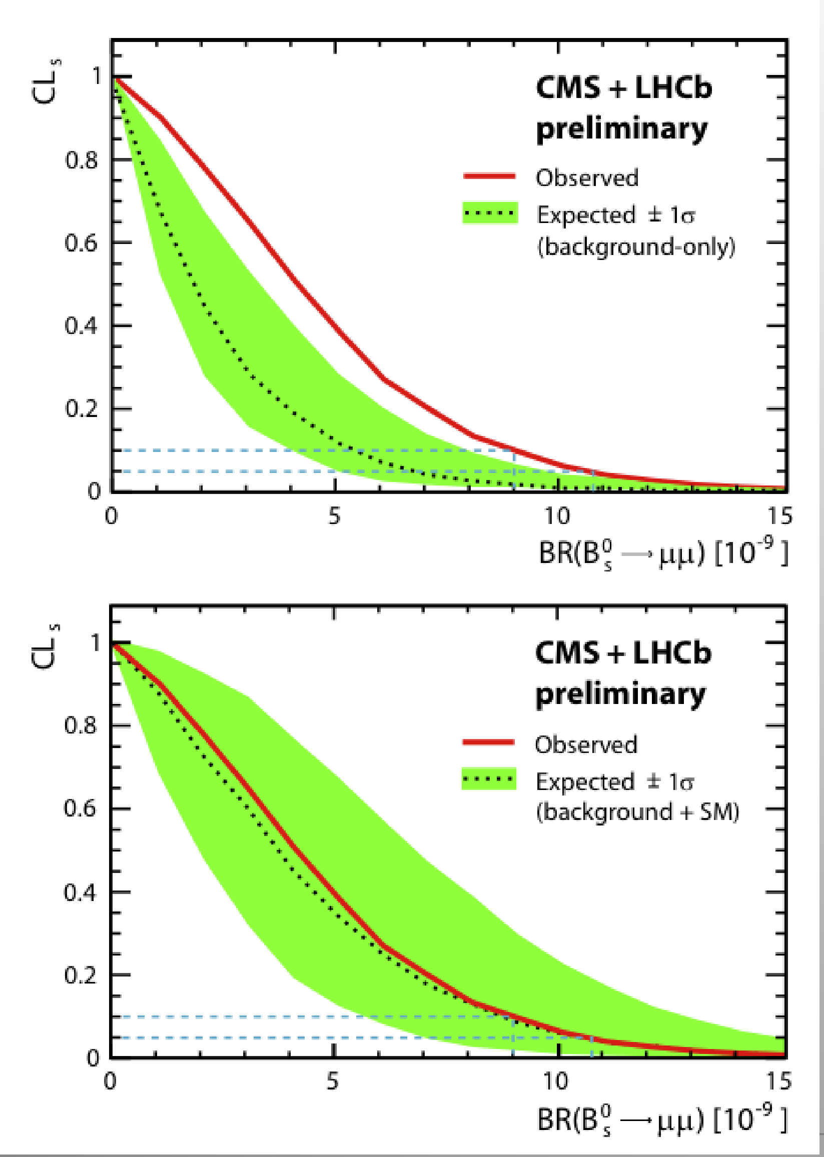
- Decays are highly suppressed in the SM
  - $BR(B_s \rightarrow \mu\mu)$: $(3.2 \pm 0.2)\text{x}10^{-9}$, $B_d \rightarrow \mu\mu$: $(1.0 \pm 0.1)\text{x}10^{-10}$
- Indirect sensitivity to new physics
  - MSSM: $BR \propto (\tan\beta)^6$



- Blind analysis
  - $B^+ \rightarrow J/\psi\ K^+$ used for normalization
  - $B^0 \rightarrow J/\psi\ \phi$ used as control regions for efficiencies
  - Events observed in the unblinded windows are consistent with bkg. plus SM expectations.
- CMS BR Limits at 95% CL
  - $B_s \rightarrow \mu^+\mu^- < 1.9 \times 10^{-8}$
  - $B_d \rightarrow \mu^+\mu^- < 4.6 \times 10^{-9}$



CMS + LHCb Combination $B_s \to \mu\mu$



- CMS BR Limit
  - $B_s \to \mu^+\mu^- < 1.9 \times 10^{-8}$
- LHCb BR limit
  - $B_s \to \mu^+\mu^- < 1.5 \times 10^{-8}$
- Combination of LHCb+CMS:
  - $B_s \to \mu^+\mu^- < 1.08 \times 10^{-8}$
- The value of CLs is in good agreement with background + SM

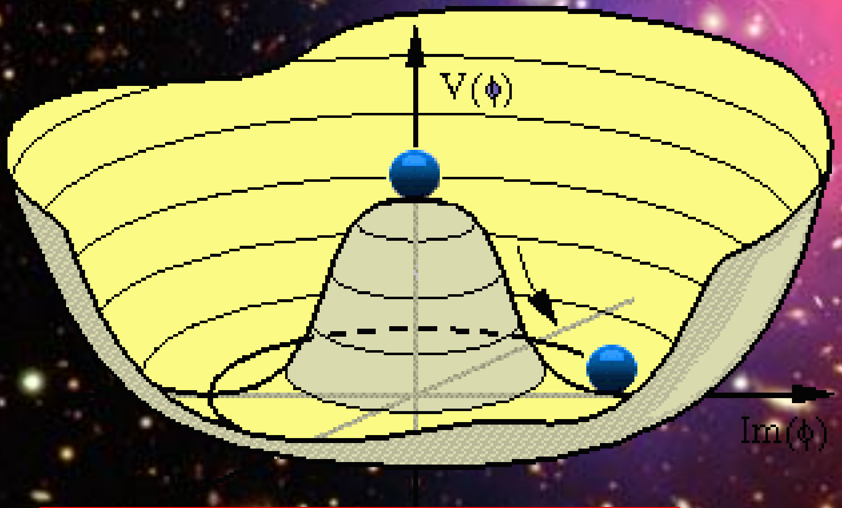
LHCb-CONF-2011-047
CMS PAS BPH-11-019

The Origin of Mass

Some particles have mass, some do not

Where do the masses come from?

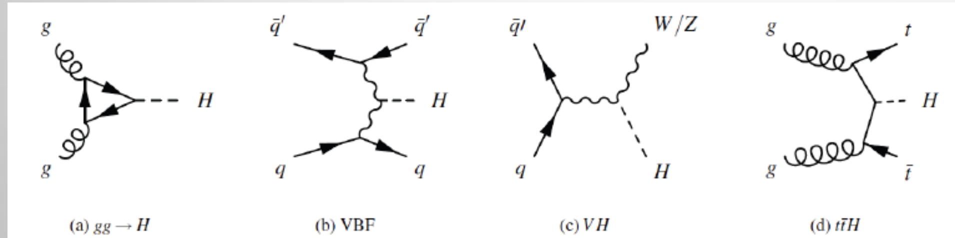
Explanation of Profs P. Higgs R. Brout en F. Englert
$\Rightarrow$ A new field and particle

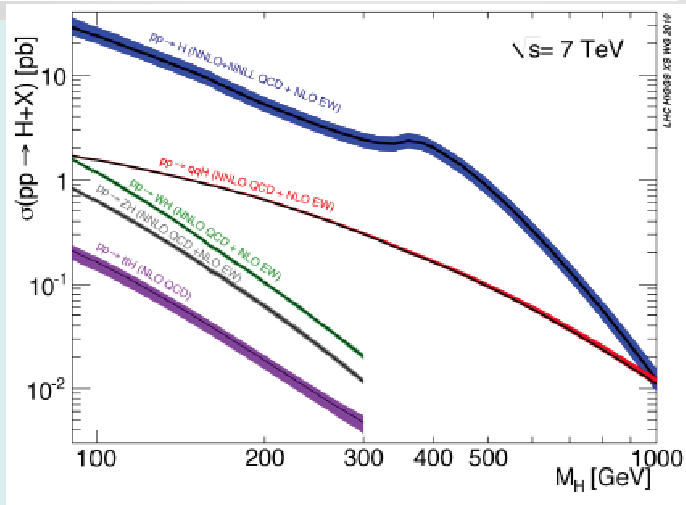


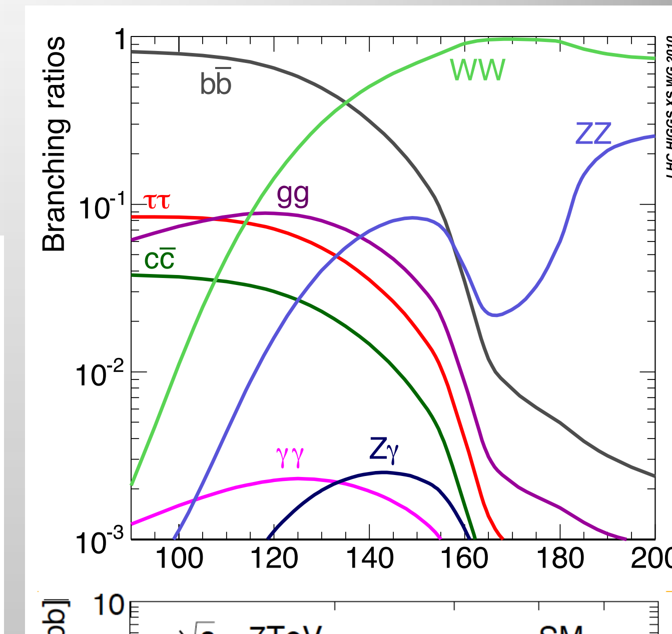
Scalar field with at least one scalar particle

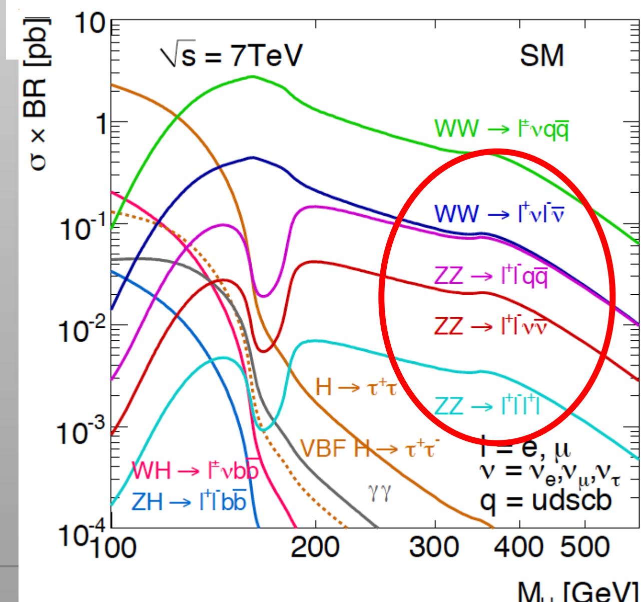
The key question:
Where is the Higgs?

Overview of Searches







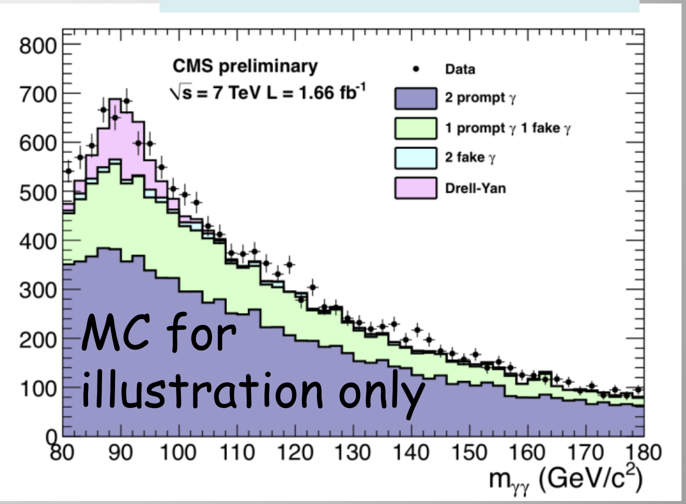


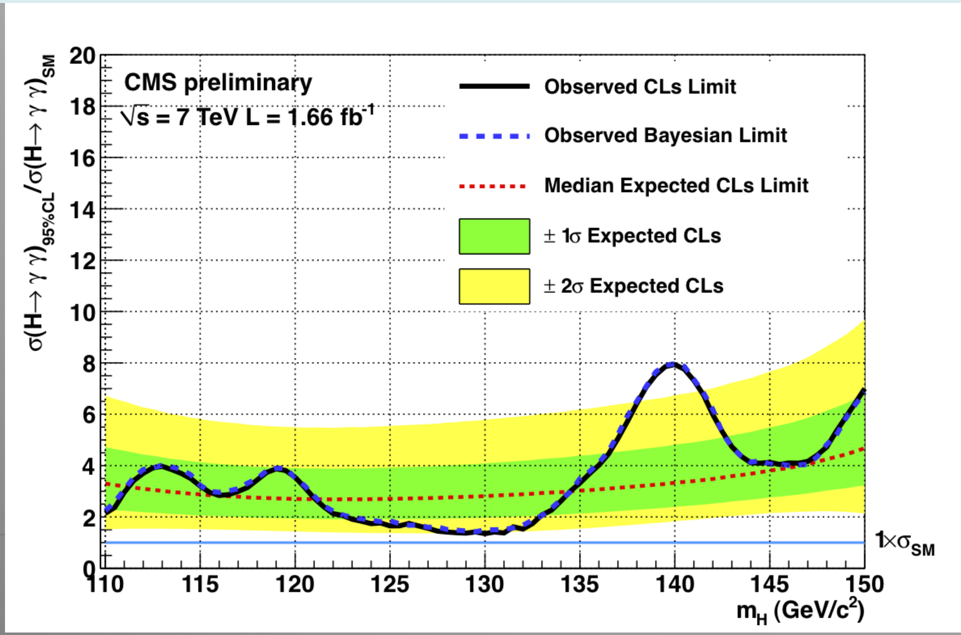
- Light Higgs
  - H→bb
  - H→ττ
  - H→γγ
  - H→WW
  - H→ZZ→4l
- Medium to Heavy Higgs
  - H→WW→2l2v (+jets)
  - H→ZZ→ (2l2j, 2l2v, 4l, 2l2τ)

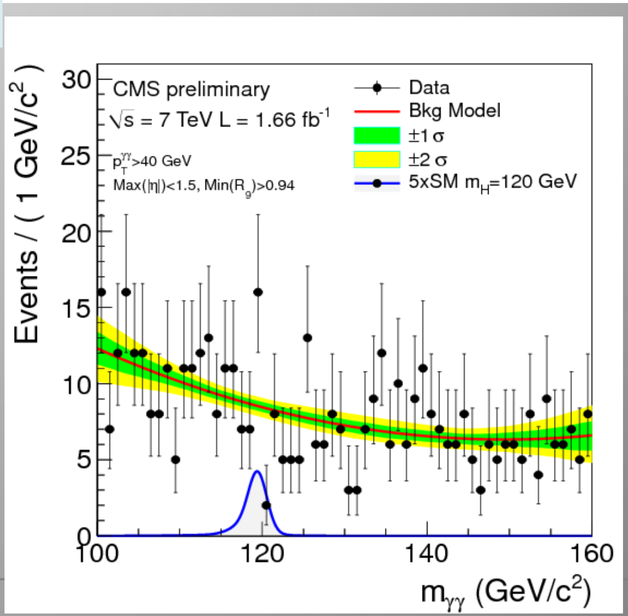
H→ 2 Photons Channel

- Strategy
  - 2 isolated γ's with P_T>40, 30 GeV
  - Data divided into 8 categories depending on resolution and $p_T(H)$
    - σ_{eff}(mass) varies from 1.4 – 7.9 GeV
  - Background shape fitted by 2^{nd} order polynomial in each category
  - Signal energy resolution extracted from Z→ee data

PAS HIG-11-021



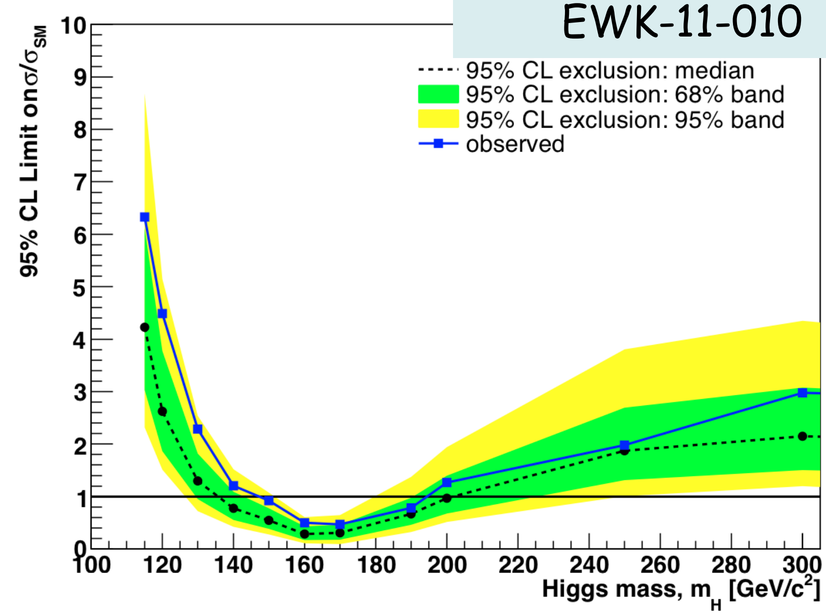


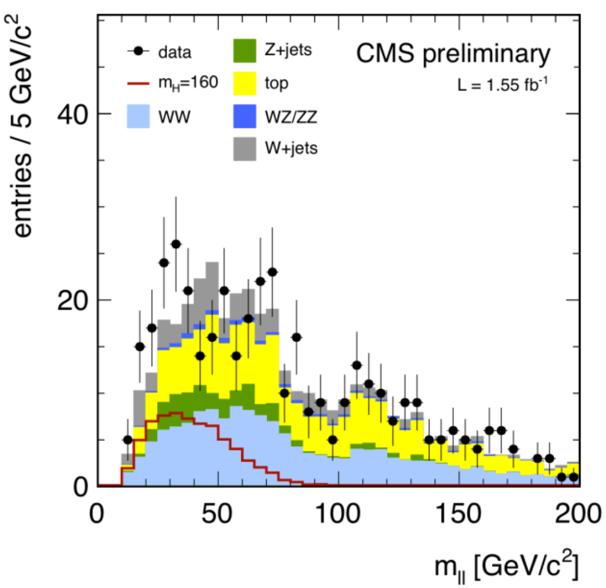


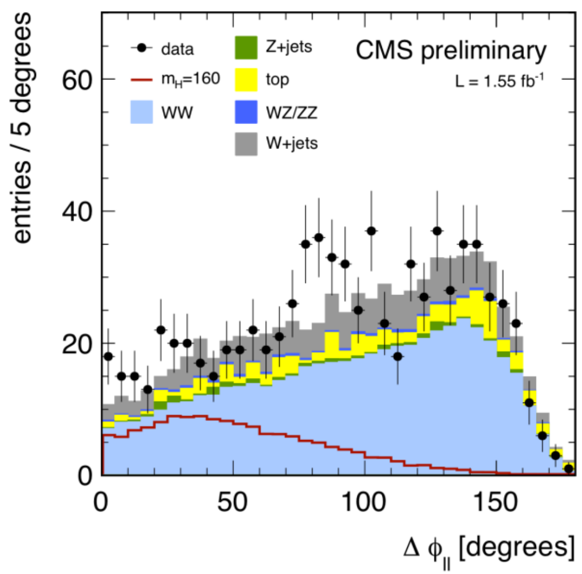
H→WW→2l2v Channel

- 2 isolated leptons, large MET, no b-tags (to suppress top)
- 3 categories
  - 0, 1, 2 jets (VBF)
- No mass peak
  - Kinematic discrimination using M_{ll} ,$\Delta\phi_{ll}$, exploiting scalar decay

PAS HIG-11-014
EWK-11-010





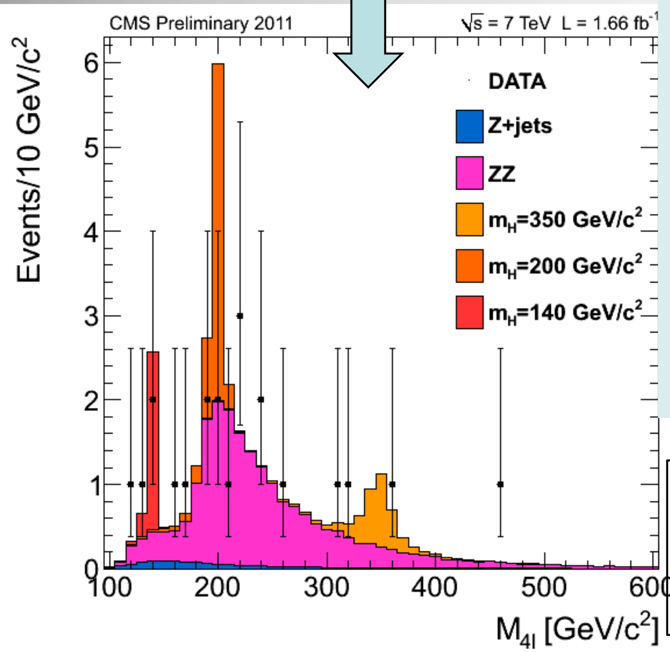


Exclude 147–194 GeV @ 95% CL (130-200 expected)

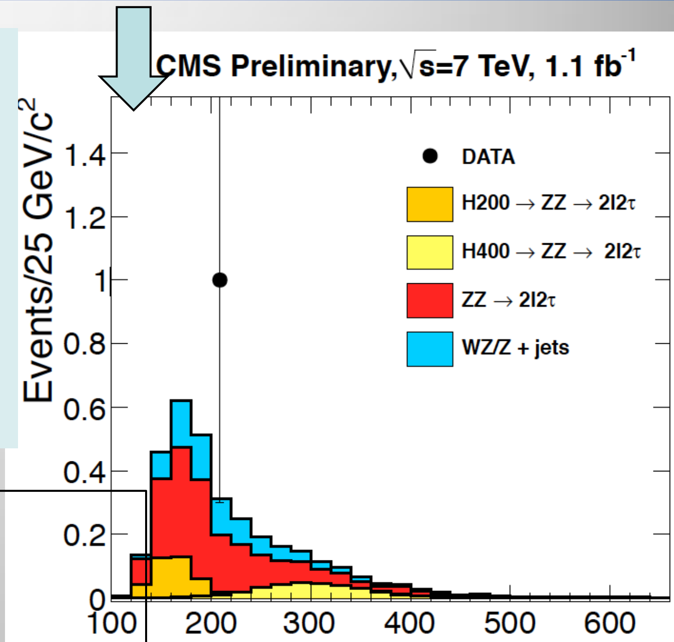
$\sigma(pp \rightarrow W^{+}W^{-}+X)$= 55.3 ± 3.3(stat.)±6.9(syst.)±3.3 (lumi) pb

σ(NLO)=43±2pb

H→ZZ →4 lepton channel

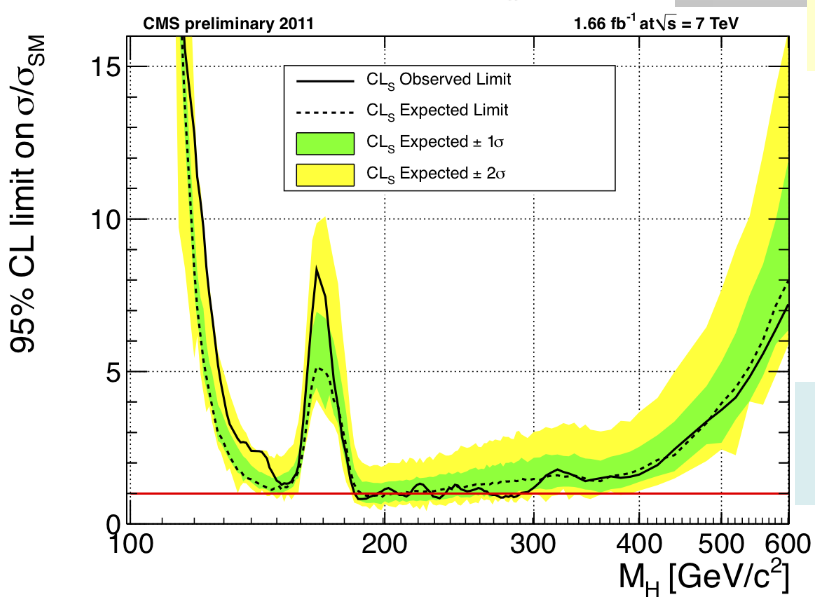


- "Golden" decay mode
- 4lepton mass resolution is O(2-3) GeV

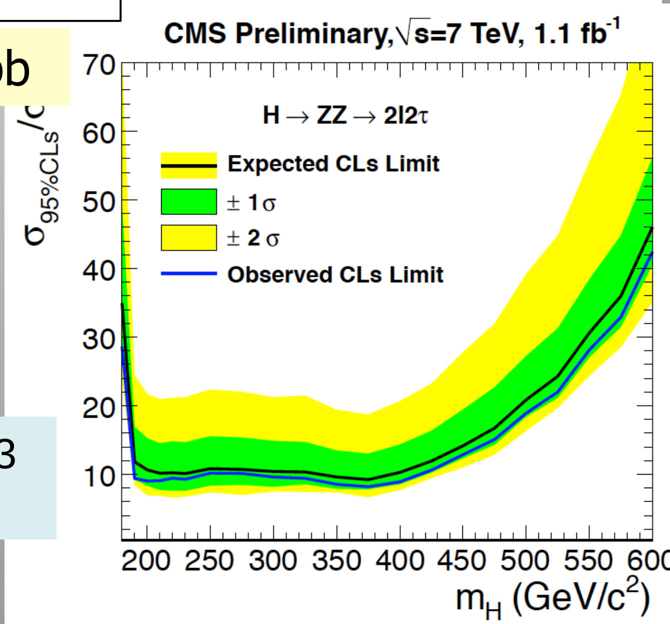


$\sigma(pp \to ZZ+X) = 3.8^{+1.5}_{-1.2}(\text{stat.}) \pm 0.2(\text{syst.}) \pm 0.2(\text{lumi})$ pb

$\sigma(\text{NLO}) = 6.4 \pm 0.6$ pb



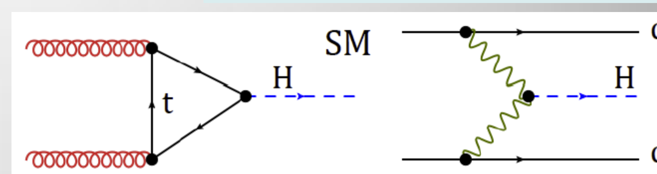
PAS HIG-11-015, 013
EWK-11-010

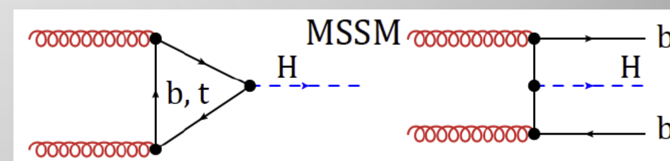


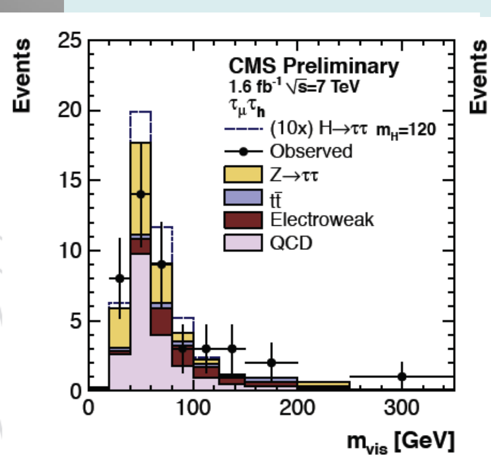
H→ 2 Taus Channel (SM/MSSM)

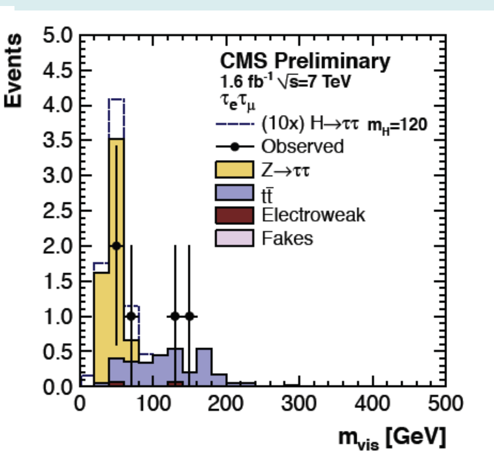
PAS HIG-11-020

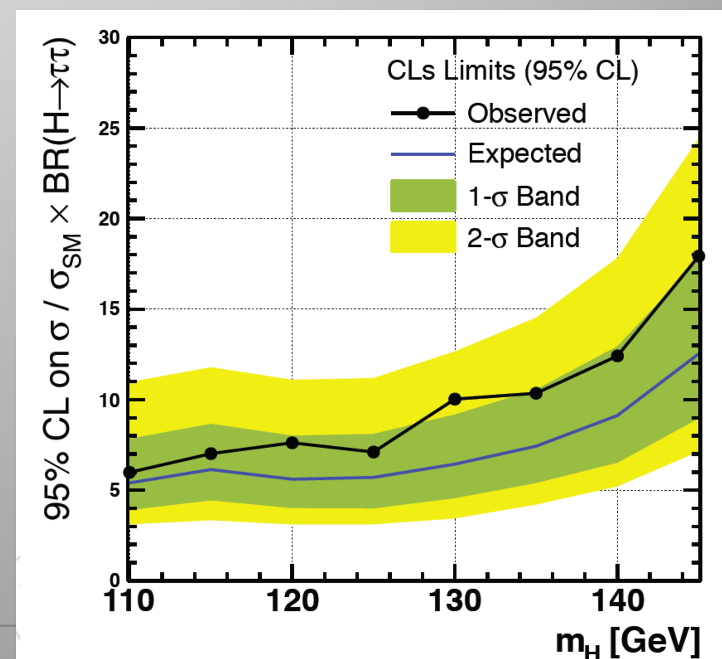
- SM categories
  - VBF: 2 jets with $\Delta\eta>3.5$, $m_{jj}>350$
  - Non-VBF: <2jets or 2 failing VBF tag
- MSSM categories
  - B-tag: ≥1 b jet $p_T>20$
  - Non-b-tag: <2 jets and no b-tags
- Topologies
  - $\mu\tau_h$, $e\tau_h$, $e\mu$ (1.6 fb^{-1}), $\mu\mu$ (1.1fb^{-1})
  - τ_h ID by "hadron plus strips", 6% efficiency uncertainty
- Fit visible mass distribution



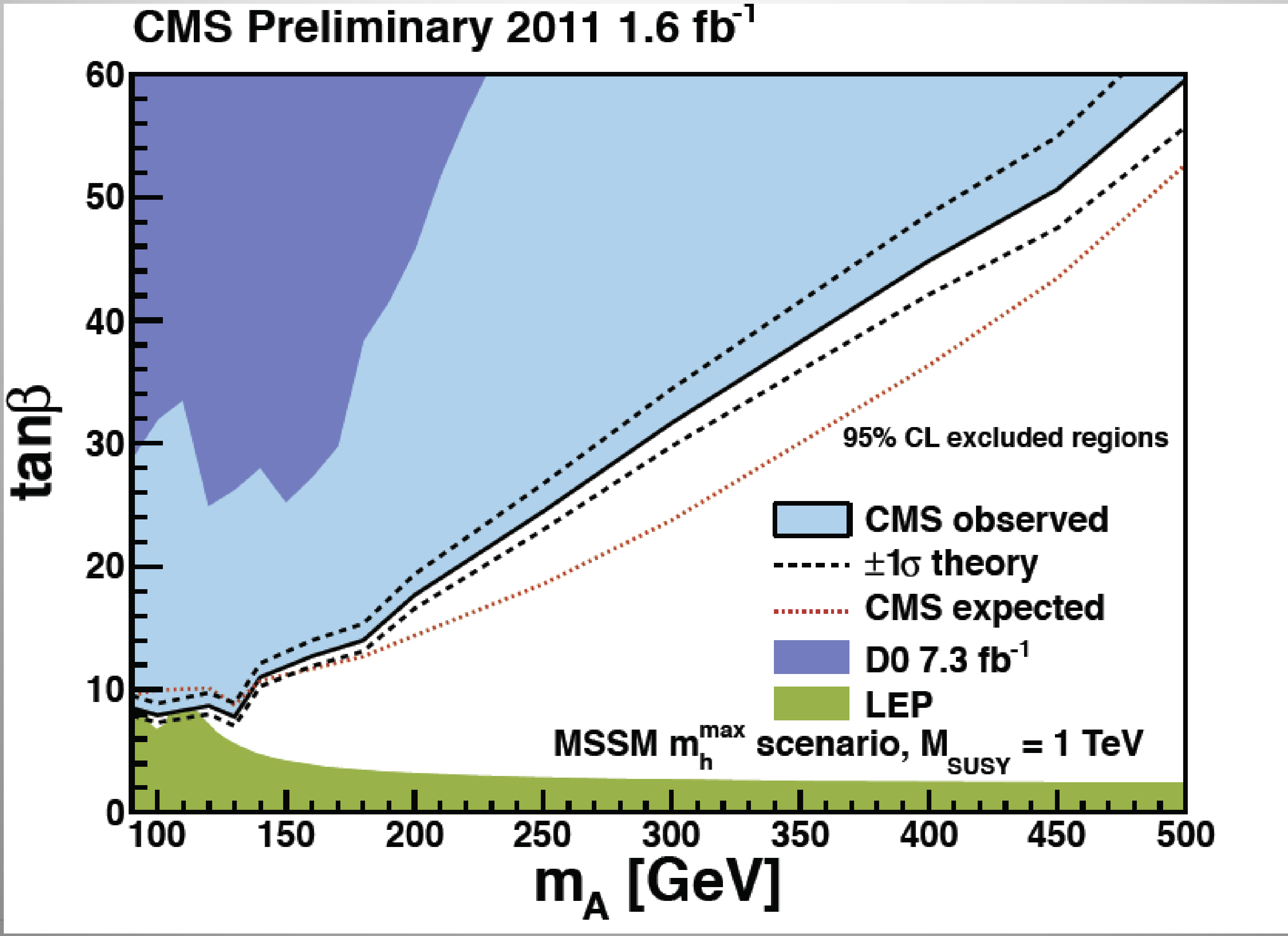








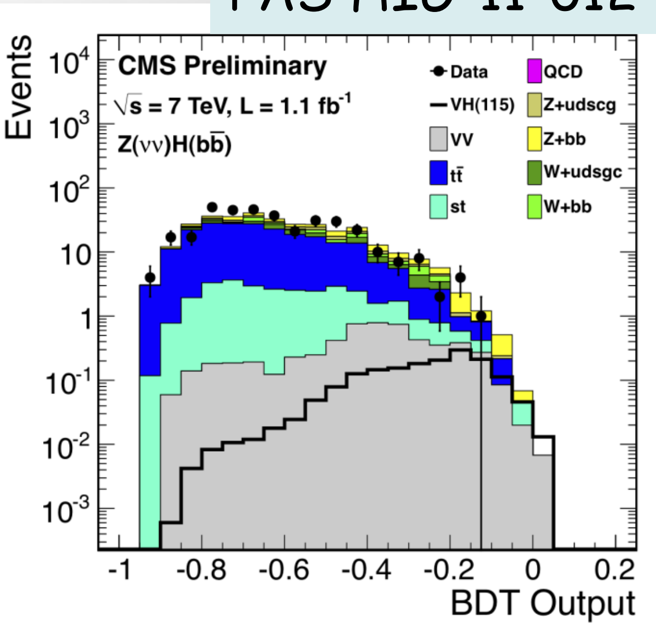
H→ 2 Taus, MSSM Exclusion

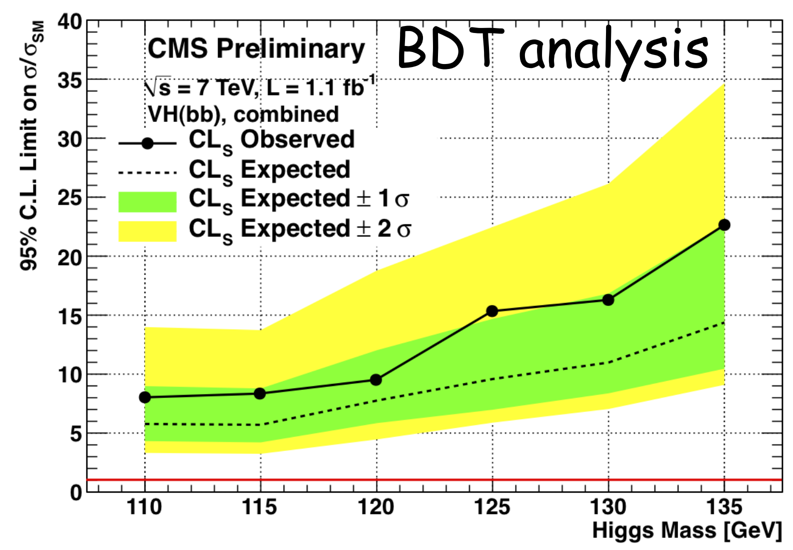


H→bb Channel

PAS HIG-11-012

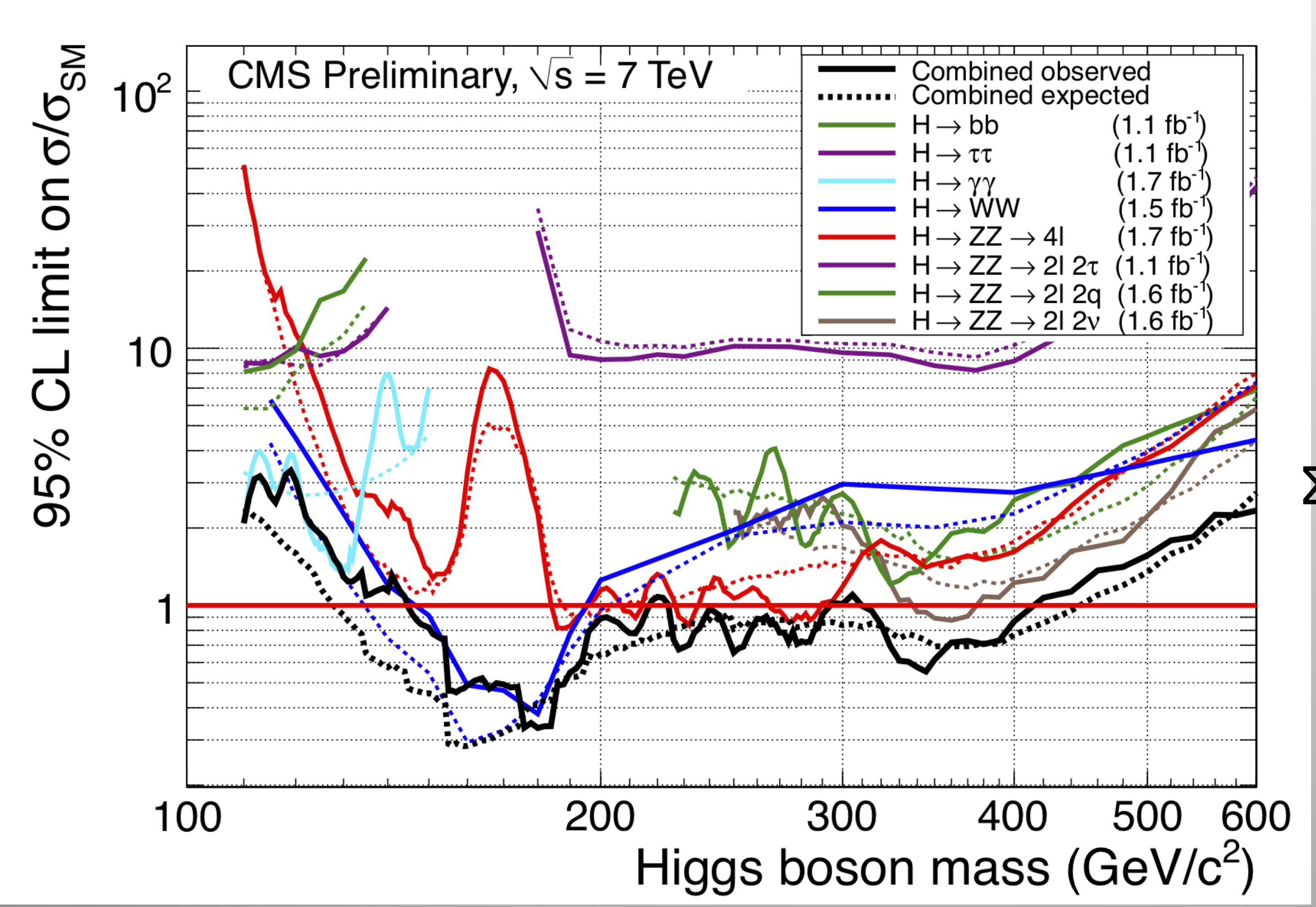
- Search strategy:
  - Associated production with W/Z
  - Boosted W/Z topology, with H back-to-back with W/Z
  - 2 b-jets (~10% mass resolution)
  - 5 topologies:
    - WH → μνbb, eνbb
    - ZH → μμbb, eebb
    - ZH → ννbb
  - Two complementary analyses:
    - Cut and count in M_{bb}
    - MVA with boosted decision tree
- Yields are in good agreement with data-driven background estimates





Summary of all Searches (CMS)

PAS HIG-11-022

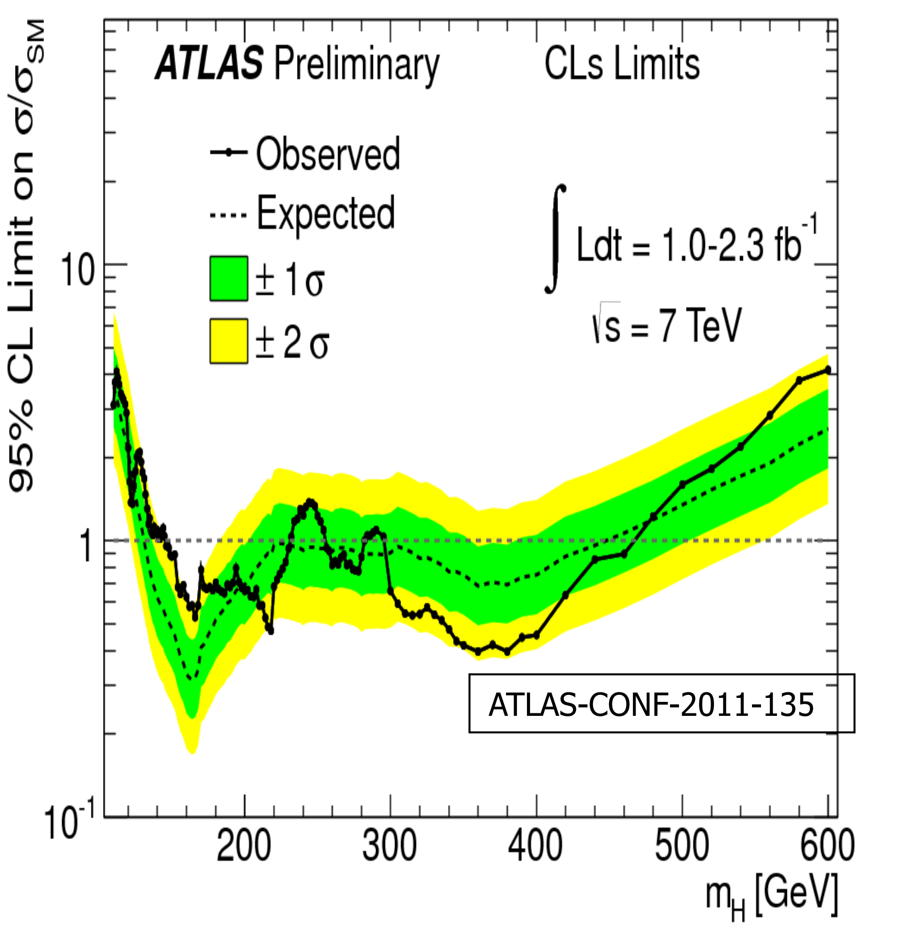


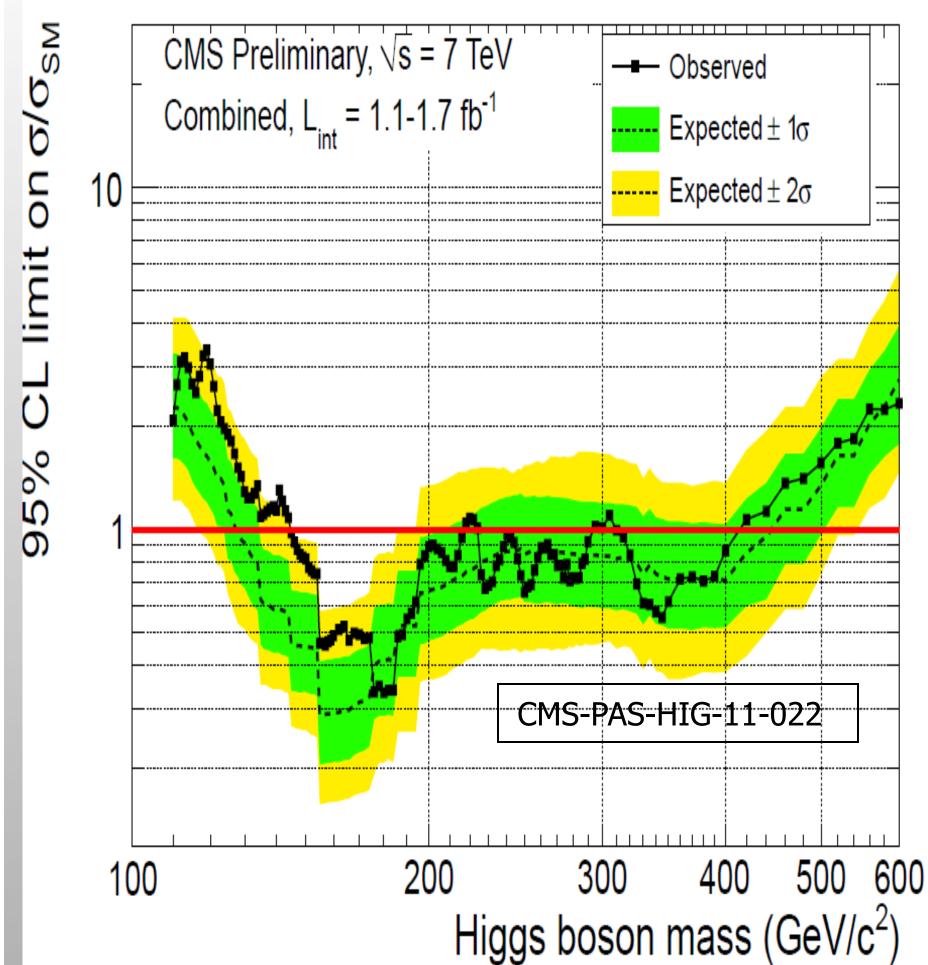
..plus other channels eg other Z decays modes at higher masses

Σ (all this work)

- Solid lines: observed limits @ 95% CL
- Dashed lines: expected limits

Status of Lepton Photon Conference Mumbai, 22nd Aug 2011

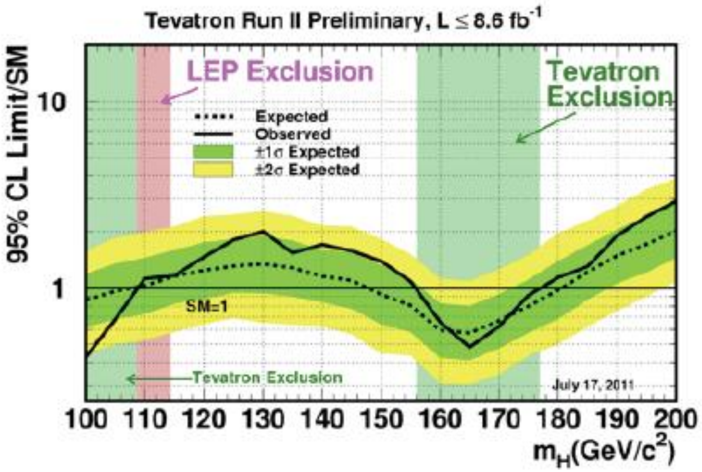


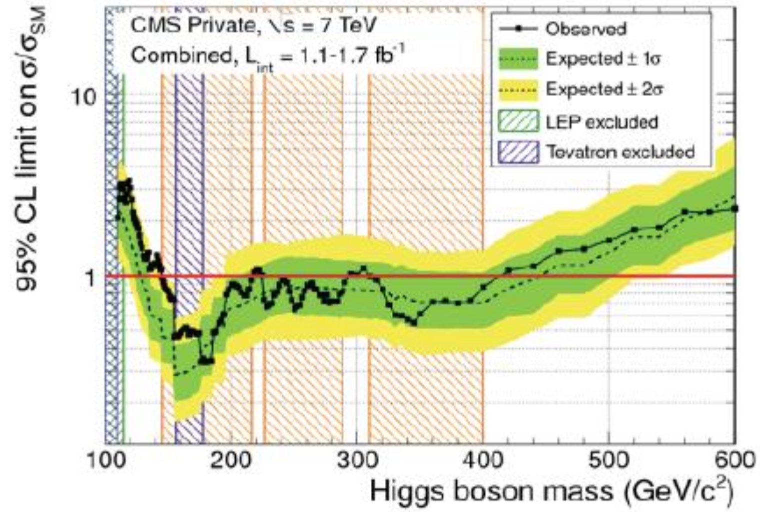


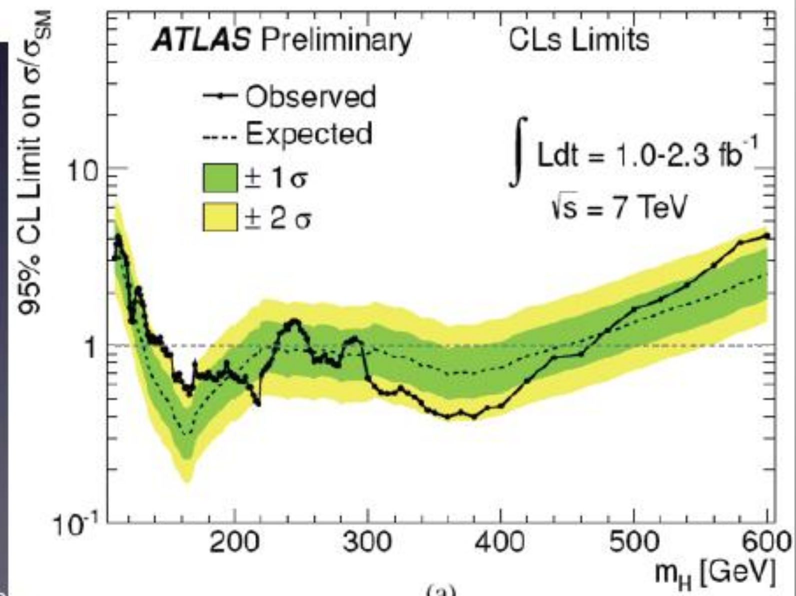
95% CL "disfavoured" SM Higgs mass ranges (GeV)

	ATLAS	CMS
Expected	131 – 447	130 – 447
Data	146 – 232, 256 – 282, 296 – 466	145 – 216, 226 – 288, 310 - 400

World Higgs Map







- truly impressive progress
- 115-145? >466?
- if not standard model, maybe ~2σ excess around 120 or 140 GeV?
- If m_h>130, MSSM dead!
- If m_h>466, need BSM!
- Anyway, a lot to look forward to!

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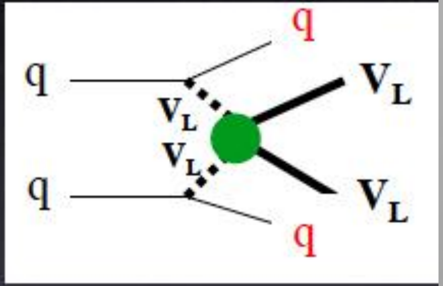
H. Murayama
ICFA seminar

The Higgs

no Higgs

- not preferred by precision EW
- no Higgs = a great discovery!
- test unitarity cancellation at high E
- $qq \rightarrow qqWW$, $WW \rightarrow WW$ scattering
- if strong → go higher energy to understand the underlying theory
- if weak → we had missed it! hadrophilic? invisible?
  - lower LHC energy? ILC?



Summary of Part I

- LHC is running well in 2011. Peak luminosity close to 3.5 E33cm^{-2}s^{-1}. The total delivered luminosity this year will be O(5) fb^{-1}
- Experiments are taking excellent data with high efficiency!
- Extended program of Standard Model Physics measurements at the LHC by all experiments.
  - Total pp cross sections at 7 TeV; soft event studies
  - QCD measurements (particle, jets, photon production) at the highest energies; b-physics
  - Studies of W, Z boson production
  - Top quark studies
- The search for the Higgs particle is in full swing
  - No evidence yet, large disfavored regions. Watch that space!

Ready for Searches for New Physics: PART II backup