Hadron Collider Physics I:
PPP-II Lecture 12 (FS 2012)

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22.5.2012

15.5.2012 Introduction: Why we want(ed) the LHC?

15.5.2012 From "low" Q^2 pp physics to W, Z and other medium Q^2
LHC questions and answers.

22.5.2012 QCD, TOP and "known"(?) SM physics at the LHC,
status and perspectives.

29.5.2012 Higgs@LHC and searches for new phenomena, status and perspectives.

29.5.2012 "Some kind of PPP2 "Summary": The next few years at the LHC.

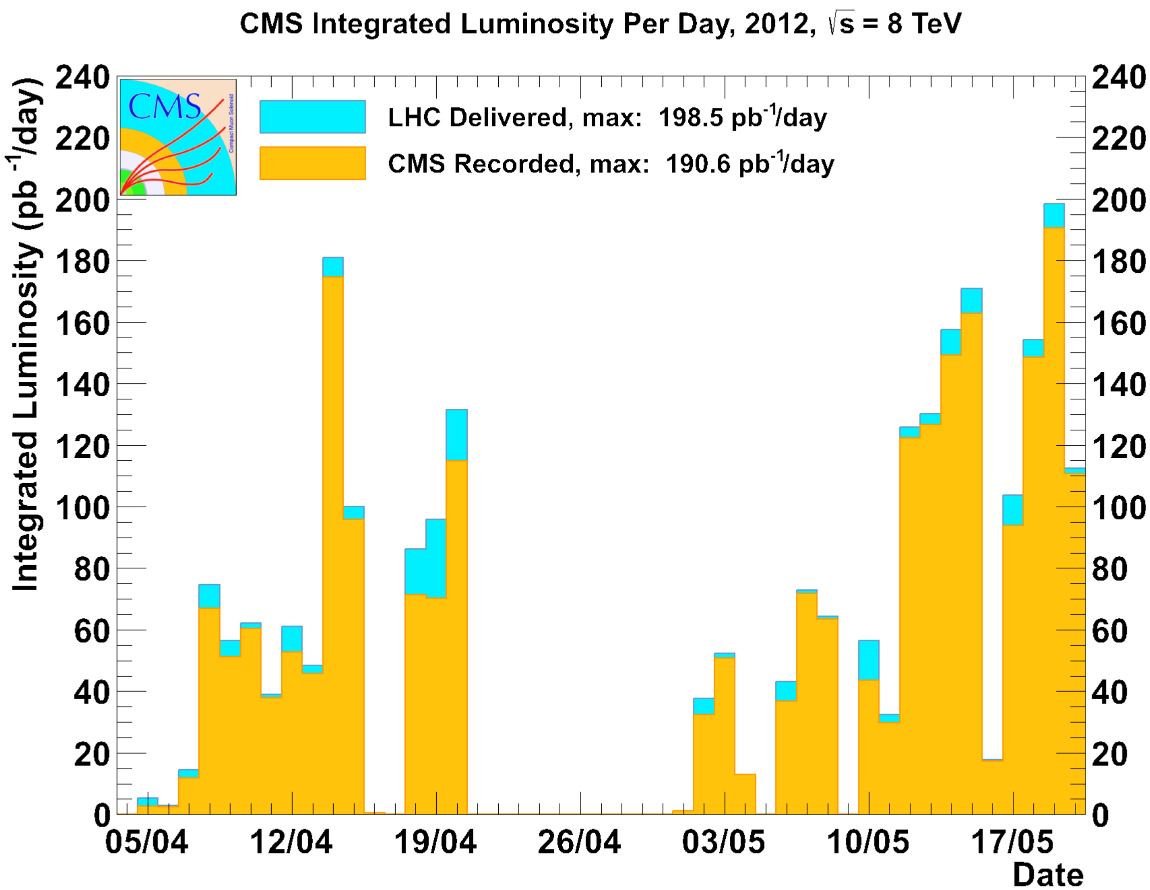
Hadron Collider Physics:
PPP-II Lecture 12 (22.5.2012)

- Status and prospect for LHC running.
- QCD physics at the LHC.
- Physics with the top quark at the LHC.
- “known” electroweak SM physics at the LHC.

Status and Prospects for LHC data taking (I)

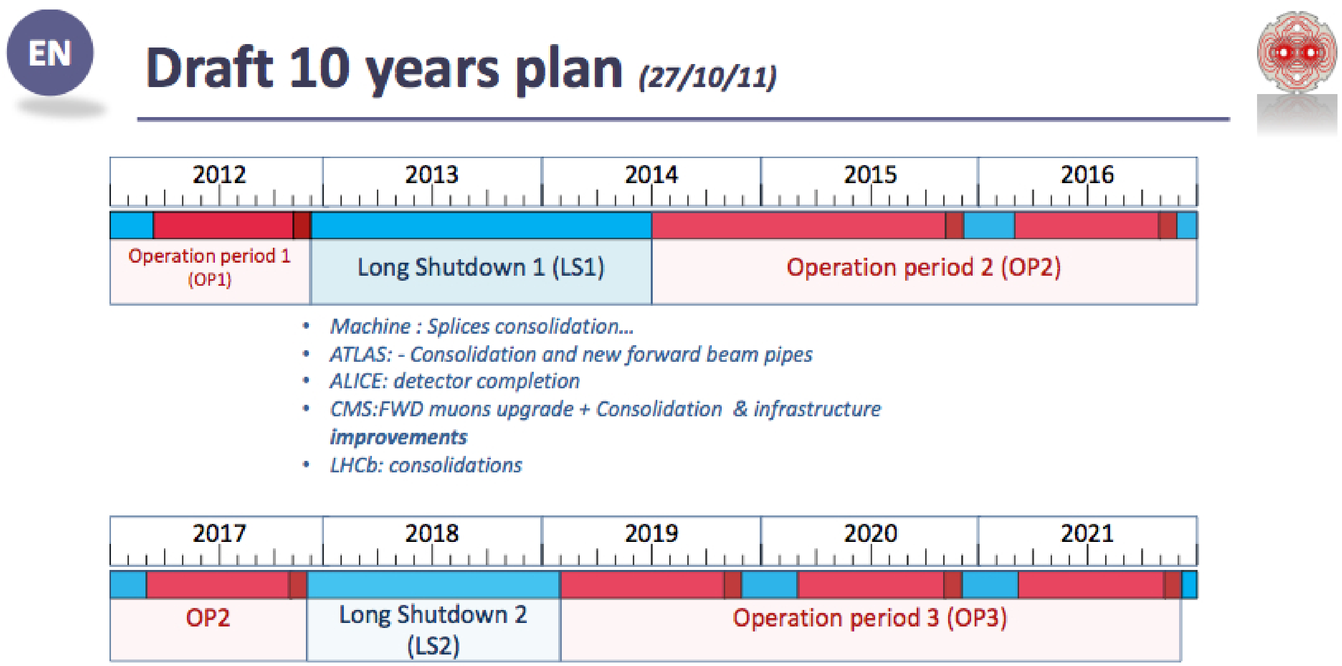
- ℓHC started at $\sqrt{s} = 7$ TeV (2010)
  collecting roughly 0.05 fb^{-1} (50 pb^{-1}) in 2010, 5 fb^{-1} in 2011.

- Already 2.5 fb^{-1} collected April/May at 8 TeV
  and with a new peak luminosity $5 \times 10^{33}/sec/cm^2$!).



Status and Prospects for LHC data taking (II)

- The ℓHC will end 2012. We expect 15 fb^{-1} at 8 TeV
- Long Shutdown (LS) 1 (2013-14) for upgrade and repair
- Real LHC at 13 (14?) TeV running between 2015-2017.
- Long Shutdown (LS) 2 in "2018" to increase luminosity and upgrade experiments for high luminosity LHC (a few 100 fb^{-1}/year)



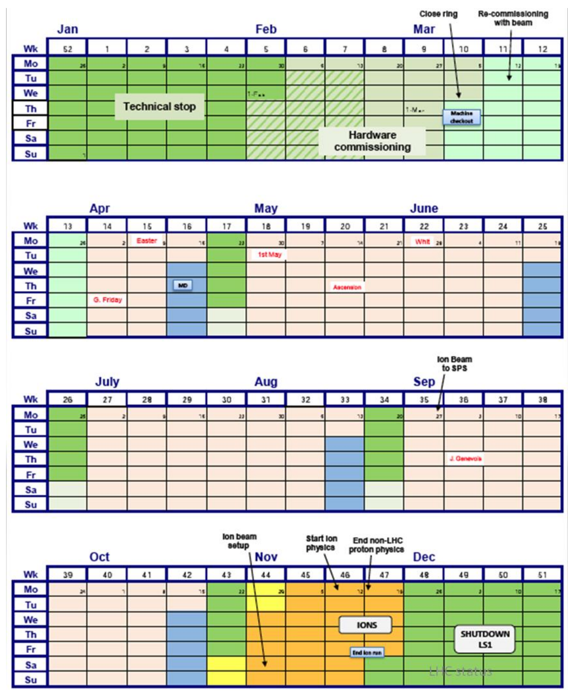
Status and Prospects for LHC data taking (III)

How do people predict sensitivities and integrated Luminosities? $\mathrm{N_{event}} = \sigma \times \mathrm{L(umi)}$

- Peak and average luminosity? Record so far in 2012: $5 \times 10^{33}/sec/cm^2$
  Average "fill luminosity" $\approx 1/2 \times L_{peak}$.

- One "good(?)" day = 24×3600 sec = 86400 sec ($\approx 10^5$ sec). Expected integrated daily luminosity = 2.5 $\times 10^{33}/sec/cm^2 \times 4 \times 10^4 sec$ (collisions for 50% of the time)
  L(day) $\approx 10^{38}/cm^2$ = 100 pb^{-1}/ day!
  For a cross section of 1 pb(arn) = $10^{-12} \times 10^{-24} cm^2$ and L(umi) = $100 \times 10^{38}/cm^2$ expect 100 events/day!
  (with 1 barn^{-1} = $10^{-24} cm^{-2}$ more at http://en.wikipedia.org/wiki/Barn_(unit))

- LHC (2012): expected luminosity 10-20 fb^{-1}.



2012

	Days
Commissioning	23
MD	22
Technical stops	20
Recovery & ramp-up	16
Initial ramp-up	16
Proton running	~130
Special runs	~8
Ion setup	4
Ion run	24

- Possible energy increase?
- 50 ns versus 25 ns?

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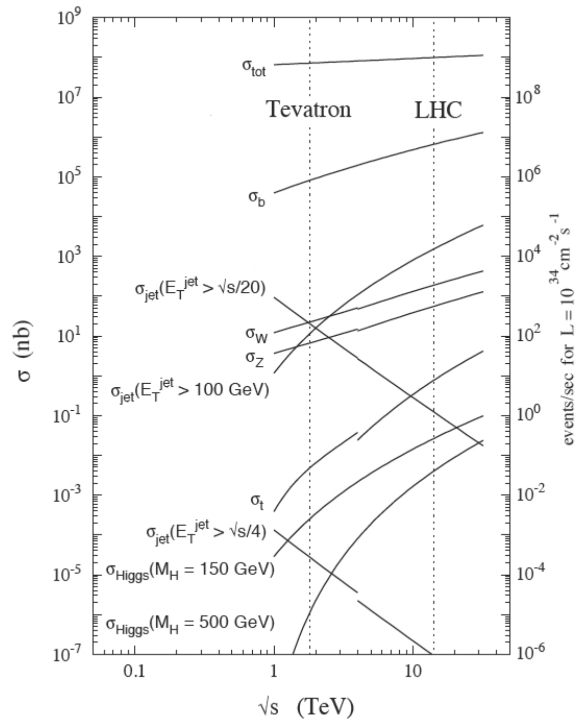
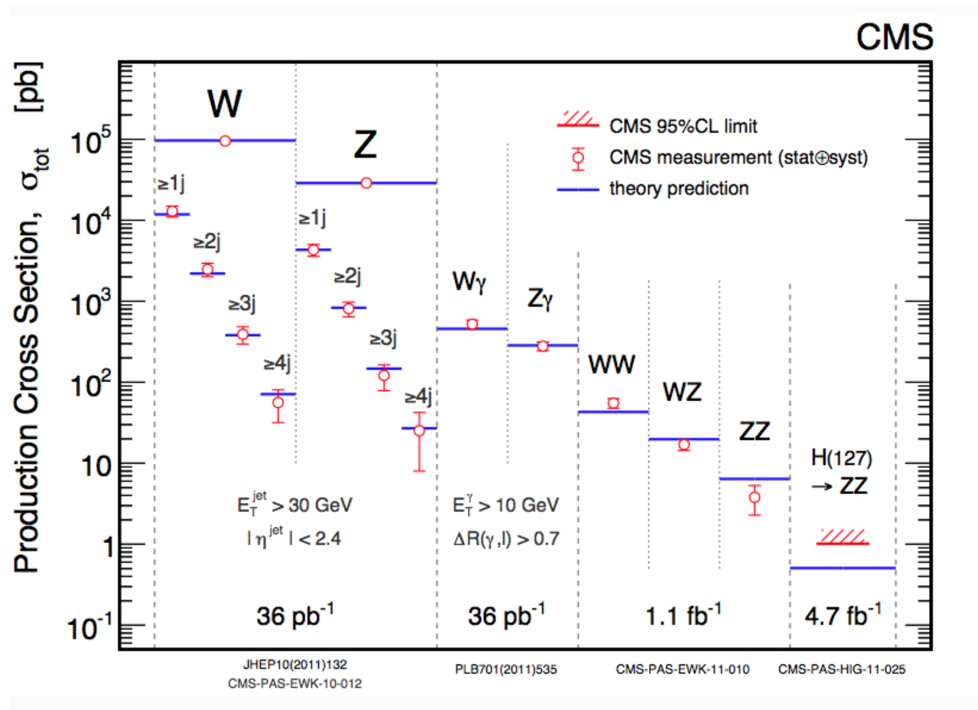
Status and Prospects for LHC data taking (IV)

hard QCD physics, top production, W, Z production with many jets and high mass Z^*, and pair production of WW, WZ and ZZ.

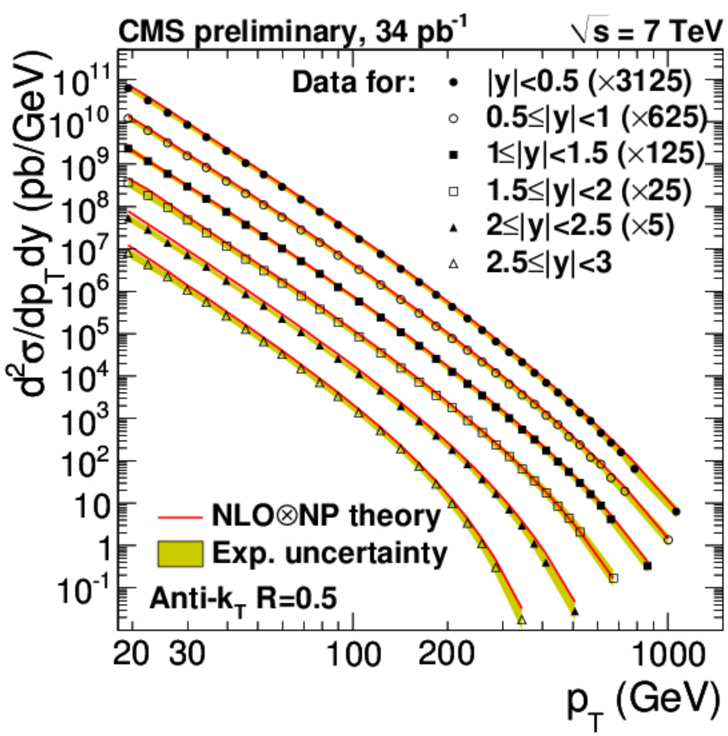


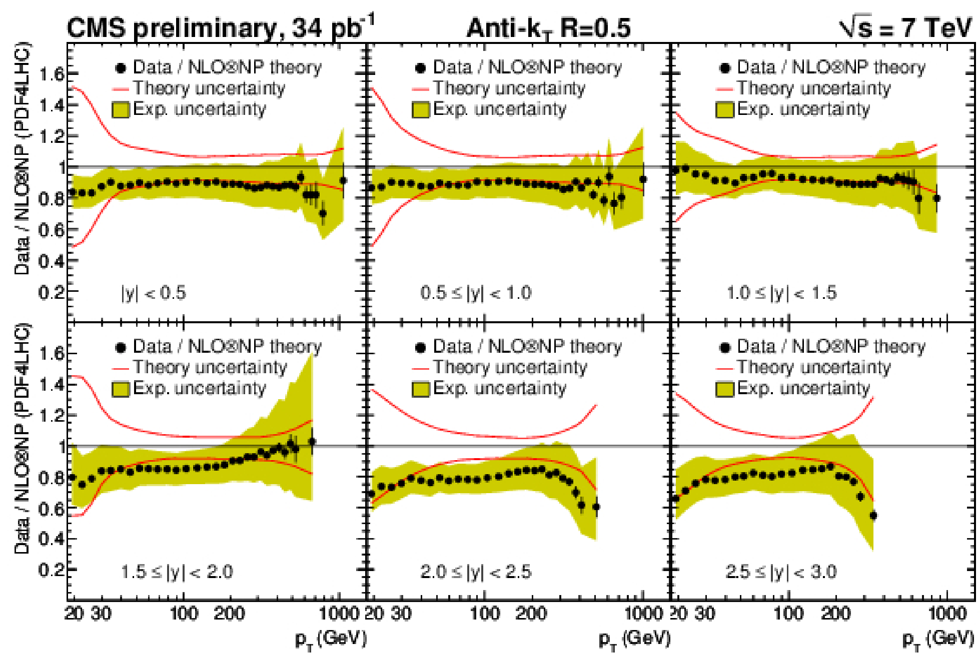


hard QCD Physics at the 7 TeV LHC (I)

hard QCD physics with Q^2 to multi TeV^2:
$\mathrm{gg}, \mathrm{qg}, \mathrm{q\bar{q}} \rightarrow$ multi jet final states.

Comparing data versus theory for different "observables":
$d^2\sigma/dp_t/d\eta$ for jets (or jet systems); invariant mass of jet system(s);
jet multiplicity versus mass of the jet system, substructure of jets.





hard QCD Physics at the 7 TeV LHC (II)

Comparing data versus theory for different "observables":
invariant mass of jet system(s);

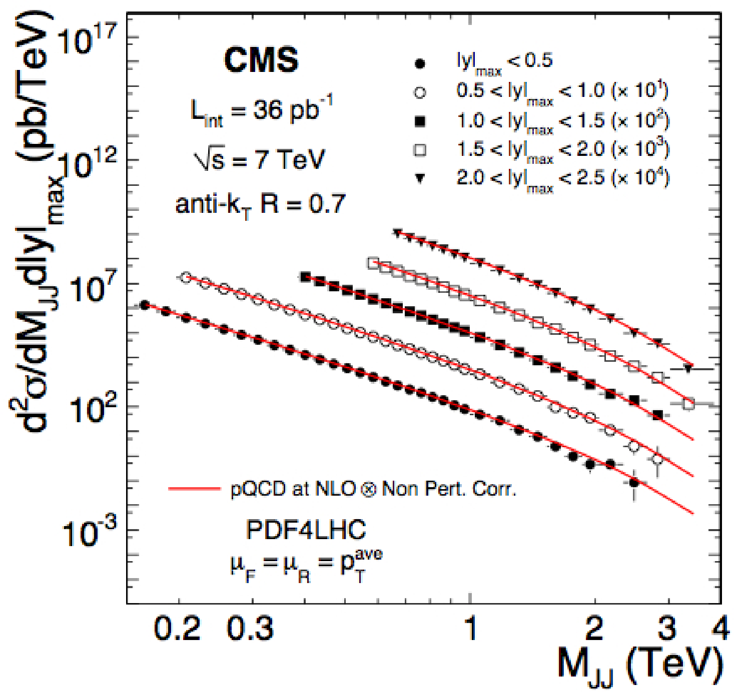


Figure 1: Measured double-differential dijet production cross sections (points), scaled by the factors shown in the figure, as a function of the dijet invariant mass, in bins of the variable $|y|_{max}$, compared to the theoretical predictions (curves). The horizontal error bars represent the bin widths, while the vertical error bars represent the statistical uncertainties of the data.

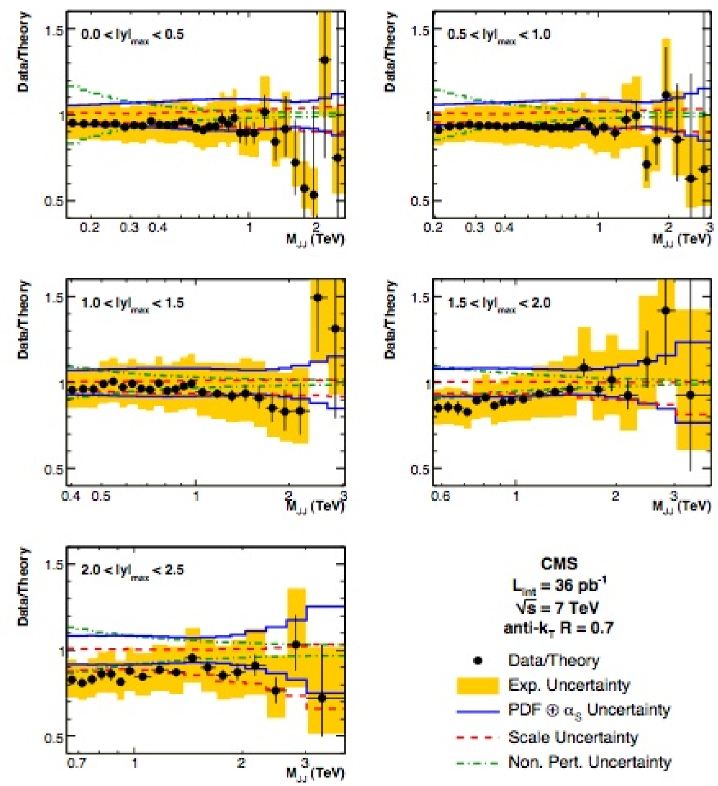
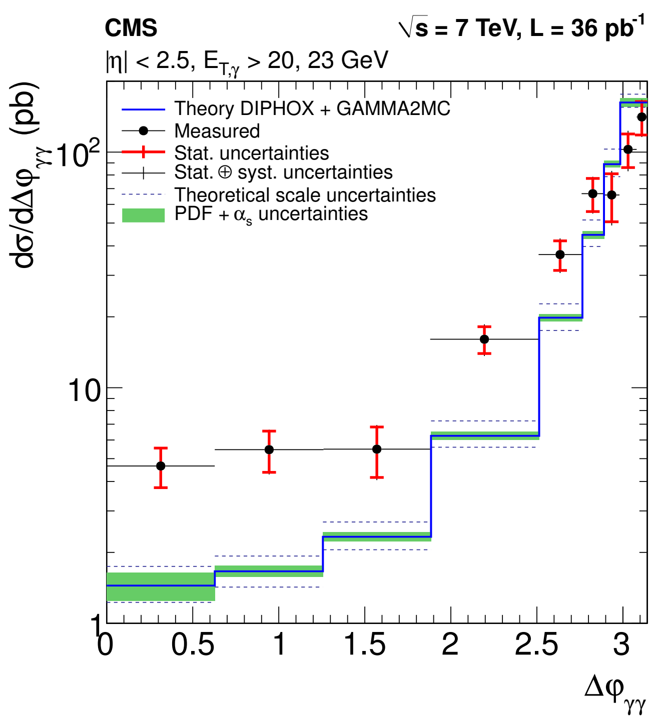


Figure 2: Ratio of the measured double-differential dijet production cross section over the theoretical prediction in different rapidity bins. The solid band represents the experimental systematic uncertainty and is centered around the points. The error bars on the points represent the statistical uncertainties. The theoretical uncertainties due to PDF and the strong coupling constant $\alpha_S(M_Z)$ (solid blue), renormalization and factorization scales (dashed red), and non-perturbative effects (dashed-dotted green) are shown as curves centered around unity.

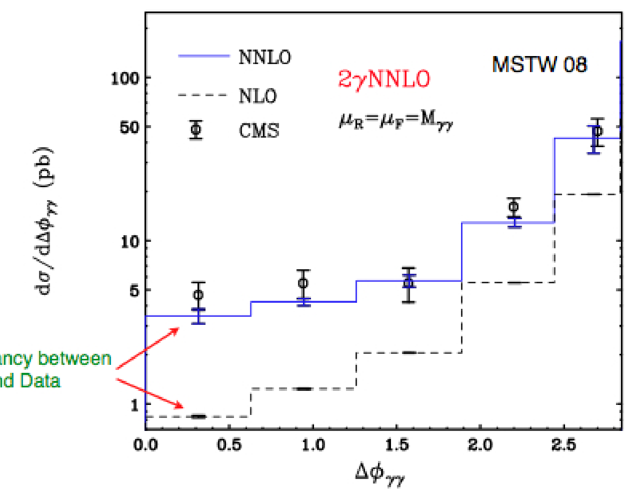
hard QCD Physics at the 7 TeV LHC (III)

A particular sensitive "QCD" final state: $pp \to \gamma\gamma X$
(NNLO calculation, M. Grazzini et al 2012!)



NNLO Corrections much larger in some kinematical regions → "away from back-to-back configuration"

NLO effectively lowest order



large discrepancy between NLO and Data

$\sqrt{S} = 7\,\mathrm{TeV}$

CMS diphoton cuts

$p_T^{\gamma\,hard} \geq 23\,\mathrm{GeV}$

$p_T^{\gamma\,soft} \geq 20\,\mathrm{GeV}$

$|\eta^\gamma| \leq 2.5$

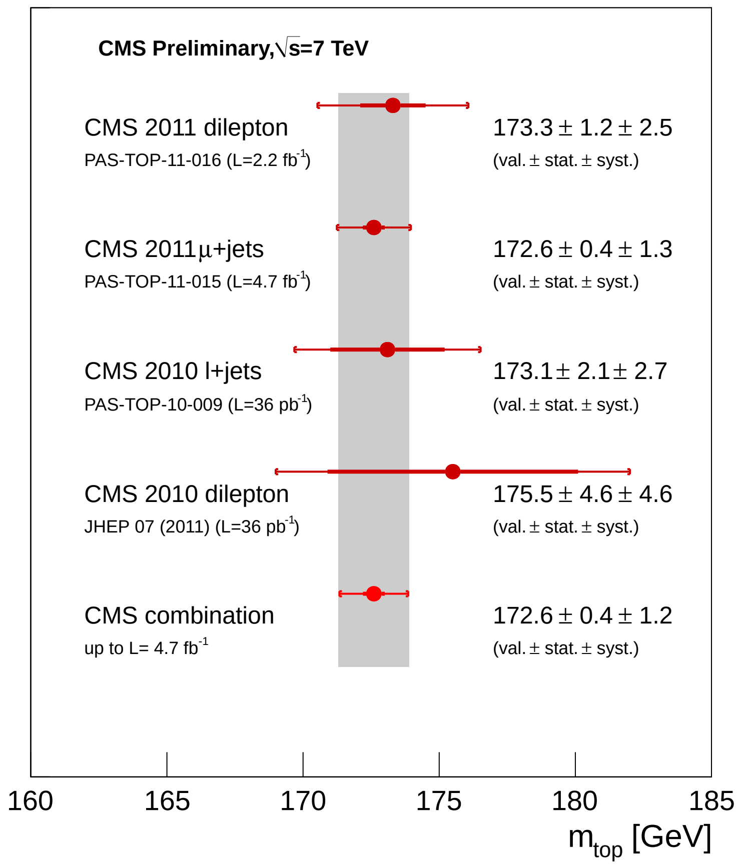
$R_{\gamma\gamma} > 0.45$

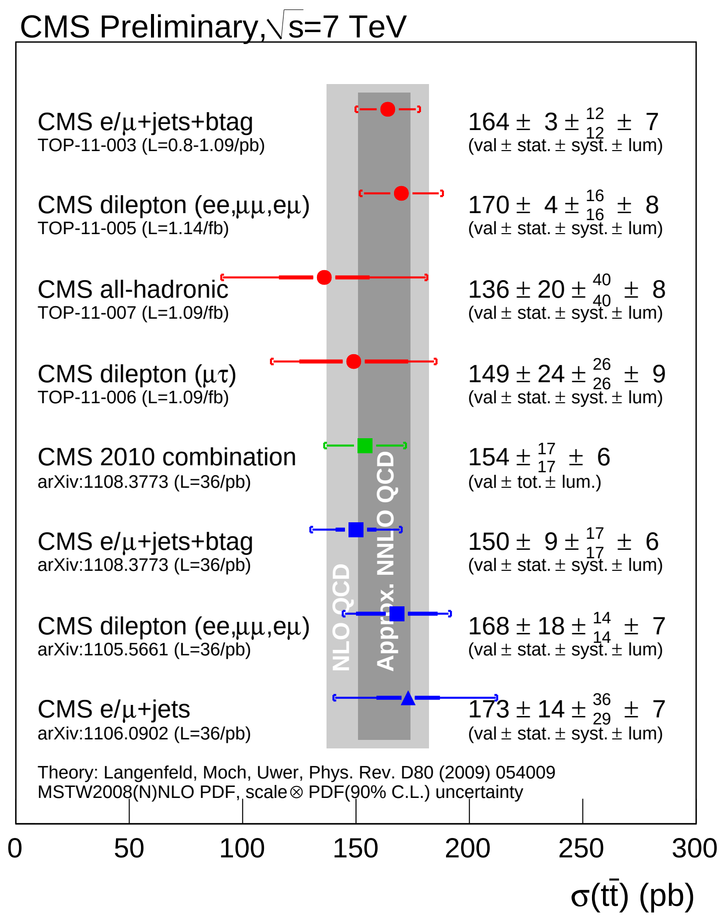
smooth cone isolation

NNLO corrections essential to understand the data

Physics with top quarks at the LHC (I)

Top quark: What we would like to know?
mass of the top quark, decays other than $t \to Wb$, production cross section and the mass of the $t\bar{t}X$ system.
(Or, as always: properties, decays and production/interaction dynamics)





(for the record.. but, how did we get there?)

Physics with top quarks at the LHC (II)

Identification of $pp \to t\bar{t} \to W^+bW^-\bar{b}$ events:
Require 1 or 2 isolated leptons, some missing transverse momentum and some b-flavored jets. Next measure "event" dynamics and "correct" for background, efficiency and detector effects.

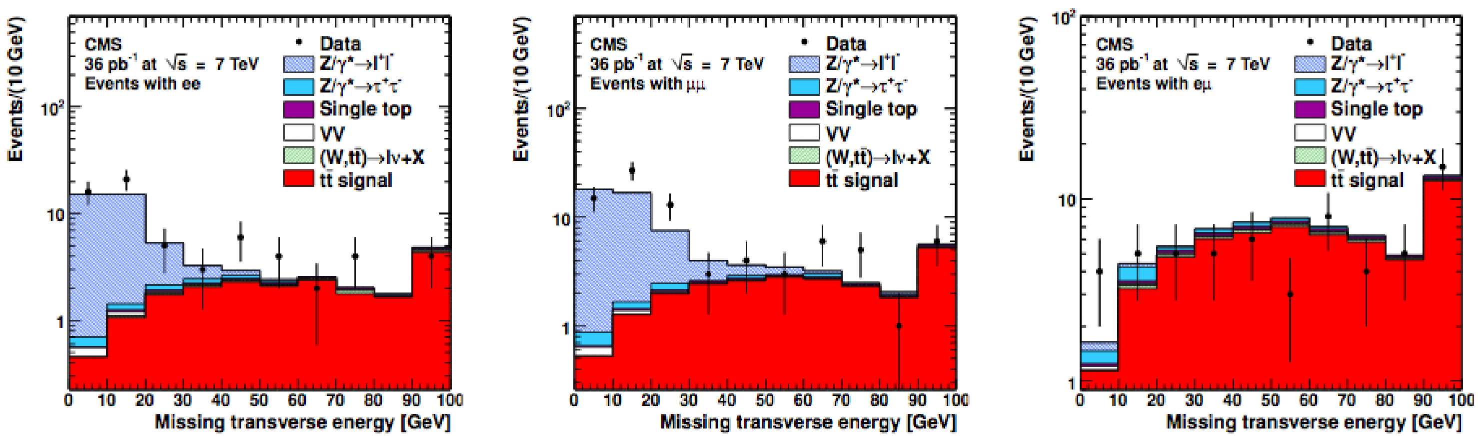


Figure 2. Distribution of $\not{E}_T$ for events with at least two selected jets and passing the full dilepton selection criteria without b tagging, except for the $\not{E}_T$ requirement for e^+e^- (left), $\mu^+\mu^-$ (centre), and $e^\pm\mu^\mp$ (right) from data (points). The signal and background predictions from simulation are shown as the histograms. The last bin includes the overflow contribution.

known electroweak SM physics at the LHC (I)

$W(Z)$ production with many jets,
in agreement with theoretical calculations (so far!)

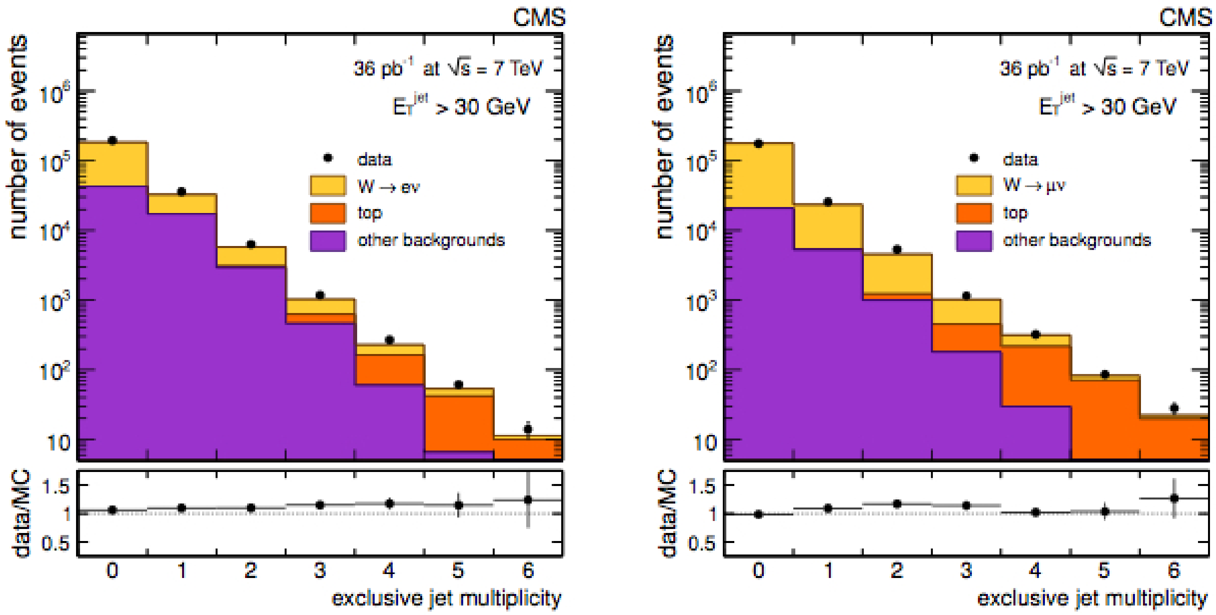
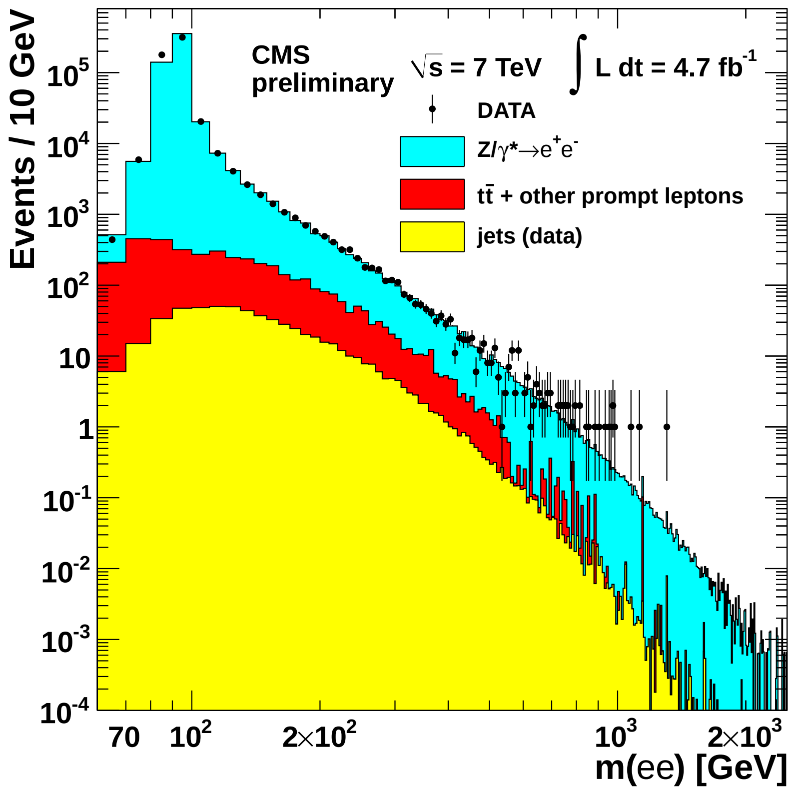
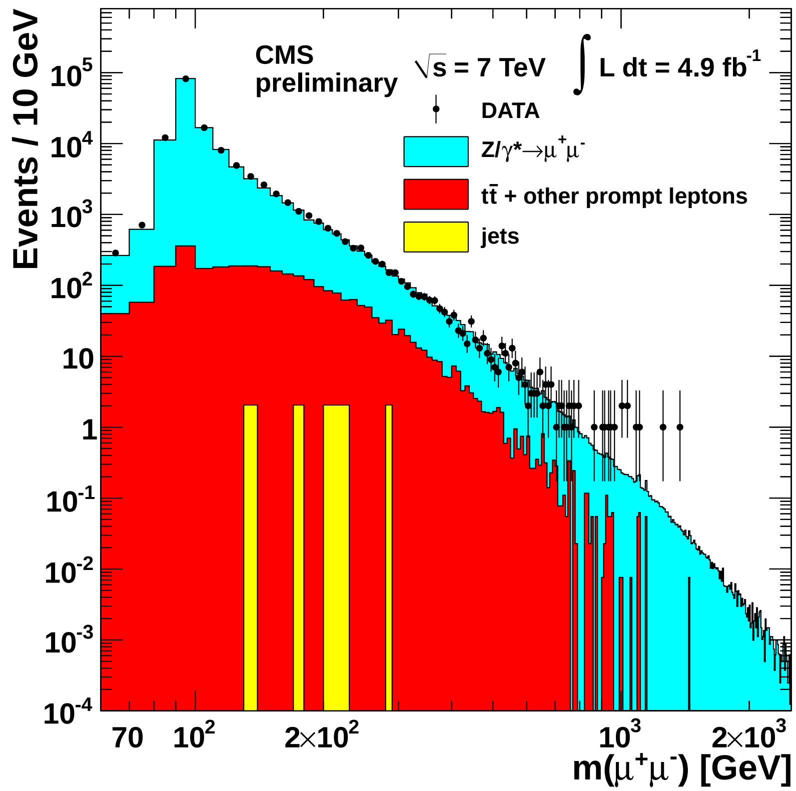


Figure 5. Exclusive number of reconstructed jets in events with $W \to e\nu$ (left) and $W \to \mu\nu$ (right). Points with error bars are data, histograms represent simulation of the signal (yellow), $t\bar{t}$ and single top backgrounds (orange) and other backgrounds (purple). Error bars represent the statistical uncertainty on the data. These distributions have not been corrected for detector effects or selection efficiency. The ratio between the data and the simulation is shown in the lower plots.

known electroweak SM physics at the LHC (II)

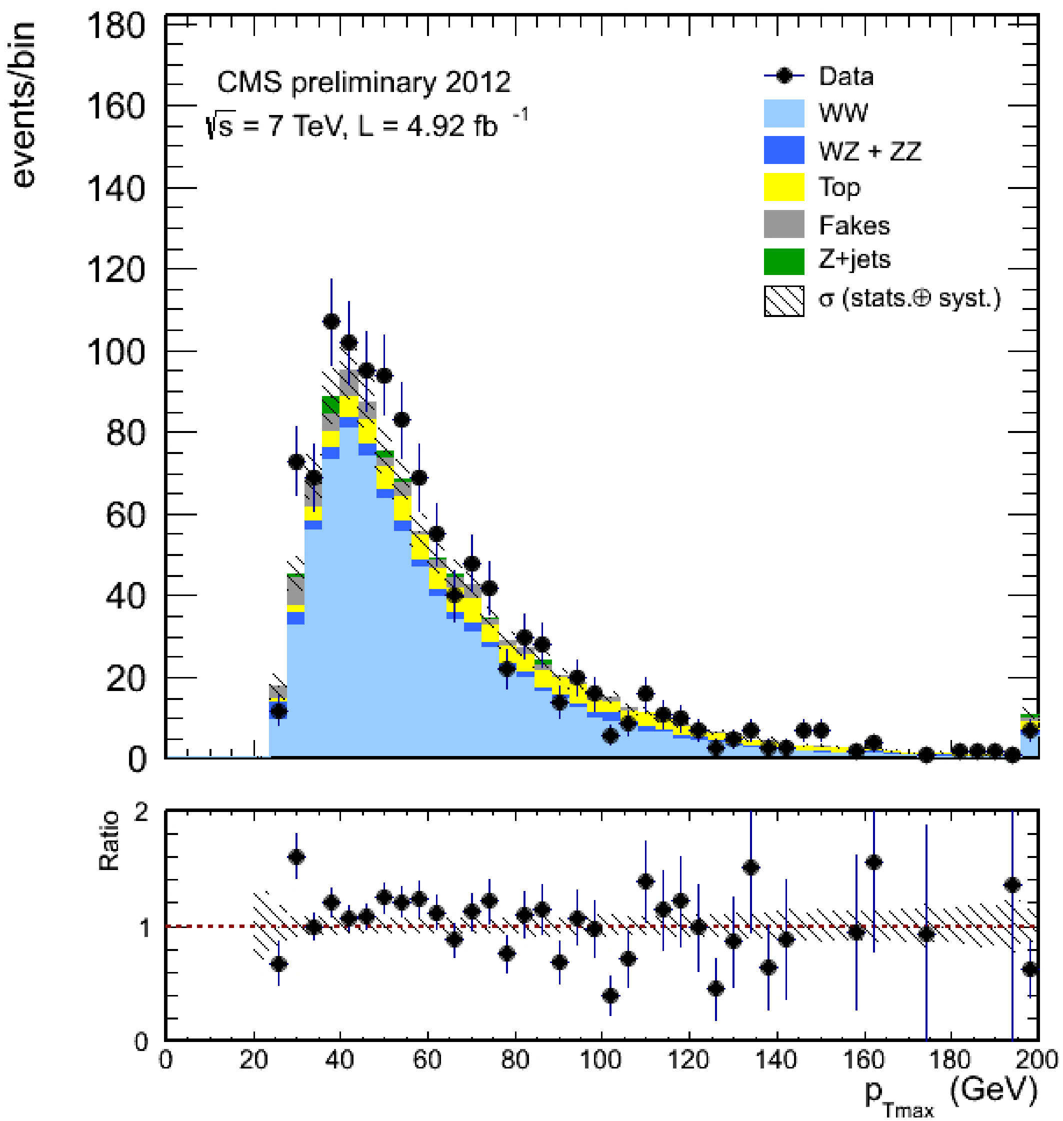
High $(\gamma, Z)^*$ production: no excess found!





known electroweak SM physics at the LHC (III)

WW (and WZ, ZZ) production so far "unfortunately" in good agreement with theory



Summary and outlook for the final lecture (next week 29.5.2012)

SM measurements at the 7 TeV LHC demonstrated:

- Excellent agreement between theory calculations and experiments. Some deviations can be understood from the absence from higher order theory calculations.
- Little "room" left to observe surprises with such measurements.
- Unfortunately also little room left for significantly higher precision measurements in many areas!

Next week 29.5.2012 (final lecture): Status and Prospects of Higgs, Supersymmetry and other searches. Followed by a "discussion" about future collider physics after the 7-8 TeV LHC and ..
a little round table apero chat!