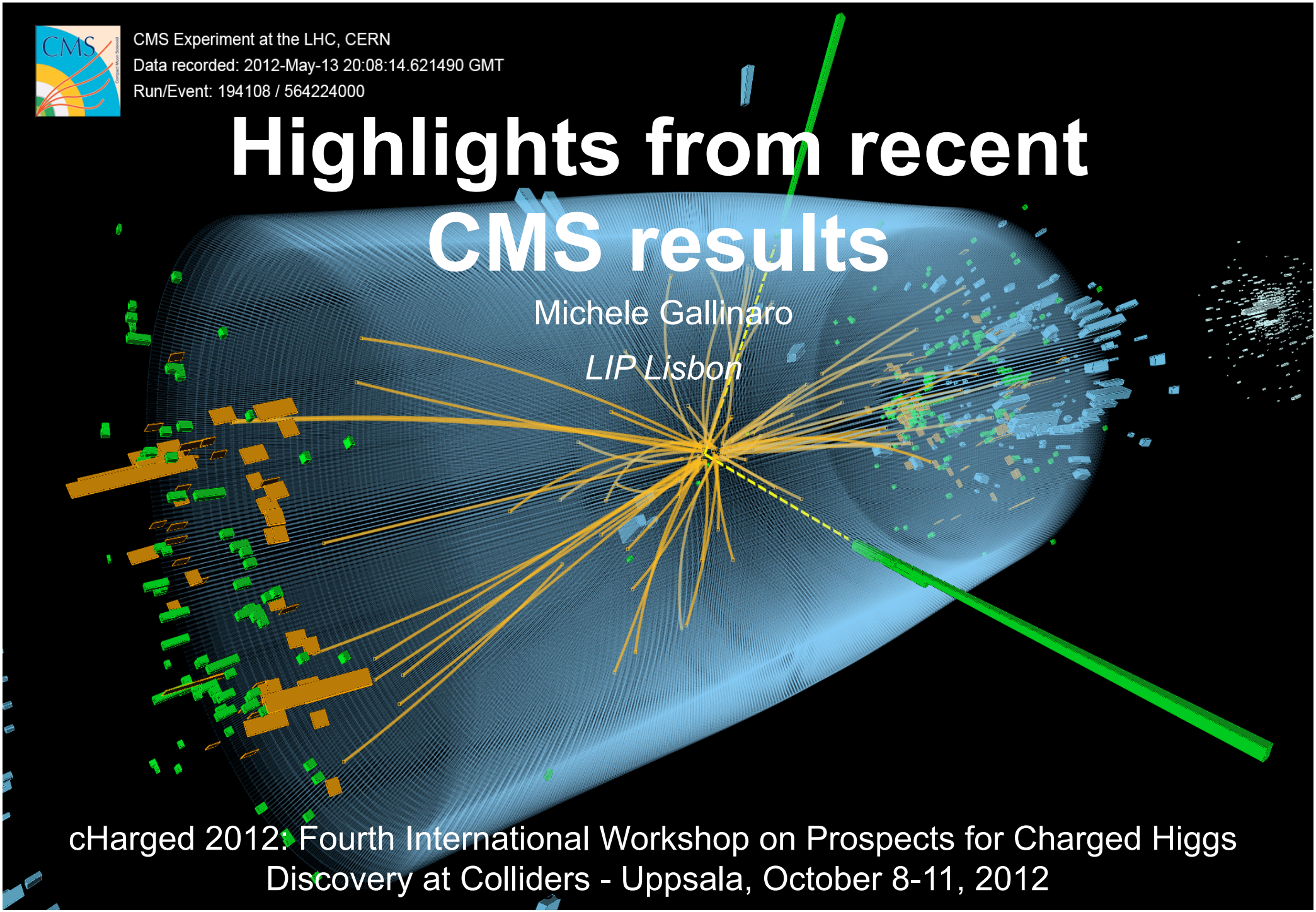


Highlights from recent CMS results

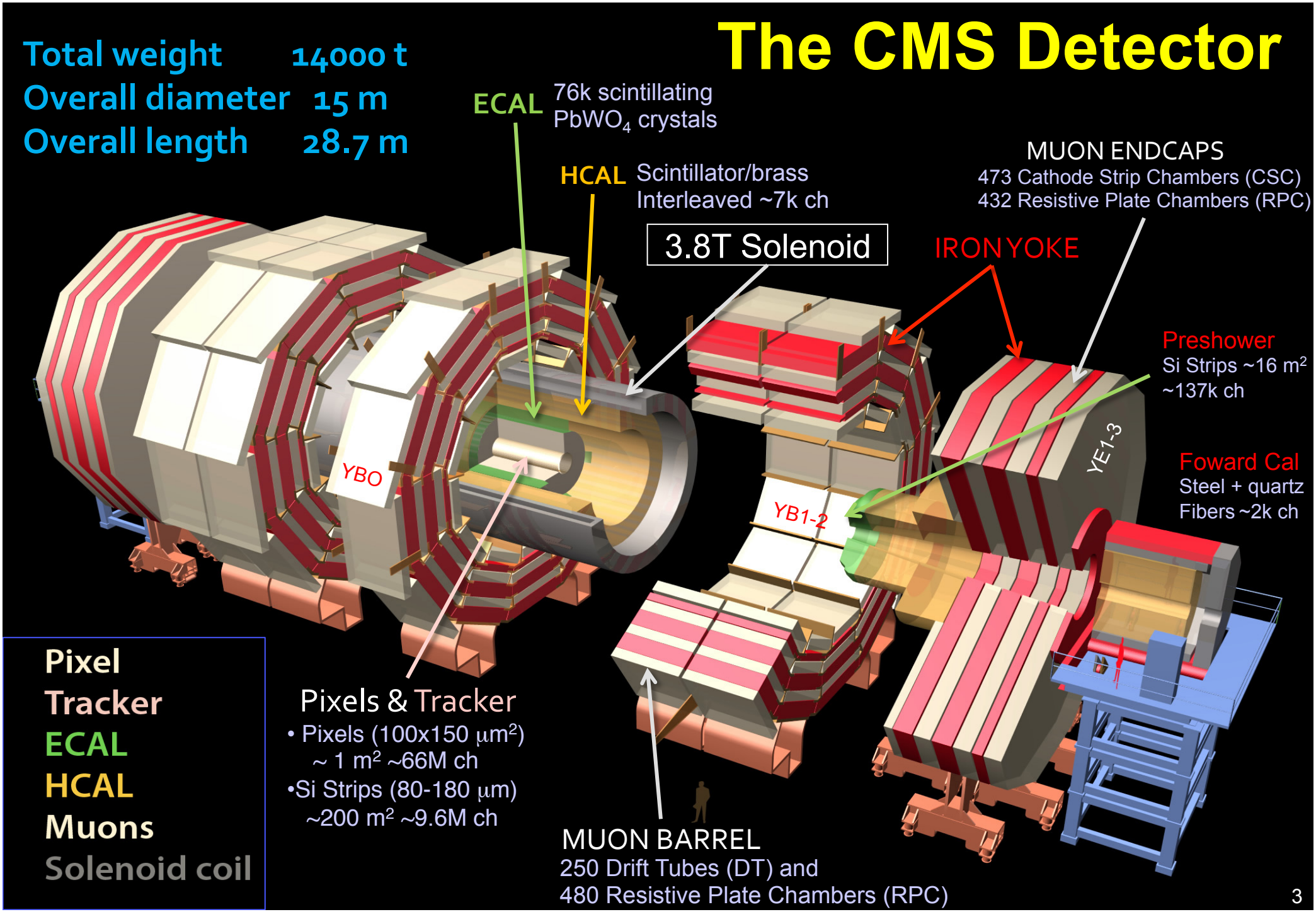
Michele Gallinaro

LIP Lisbon

cHarged 2012: Fourth International Workshop on Prospects for Charged Higgs Discovery at Colliders - Uppsala, October 8-11, 2012

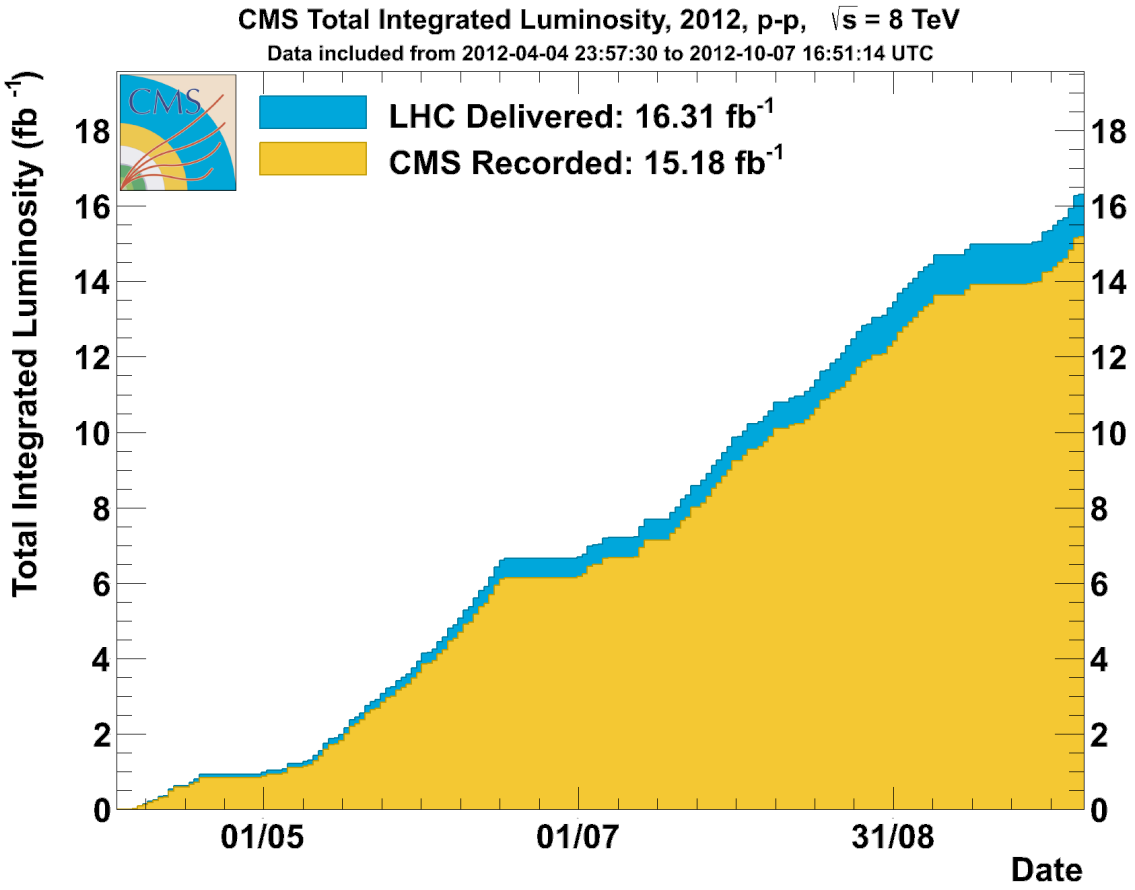
On behalf of the CMS collaboration

The CMS Detector

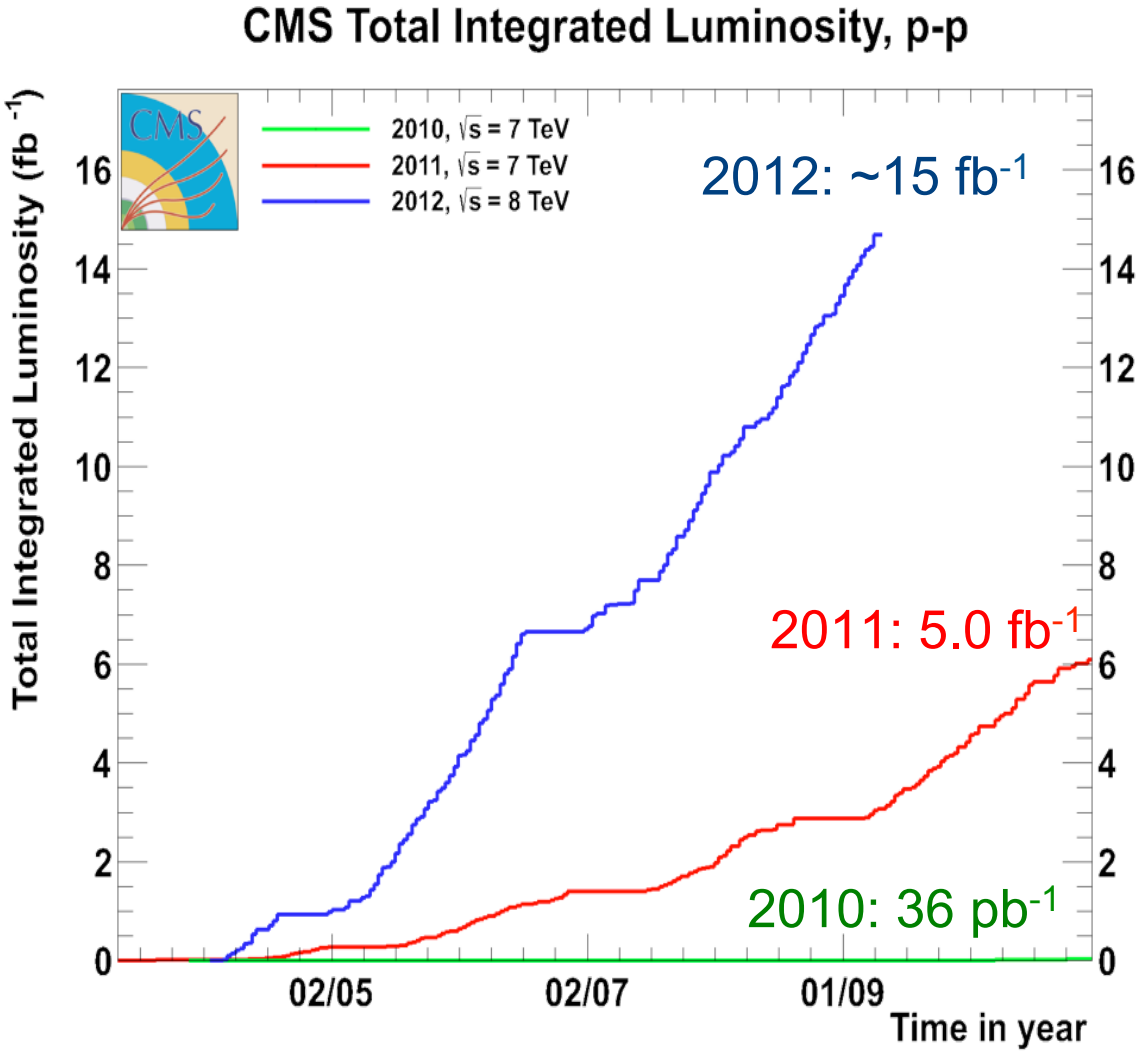


Data taking

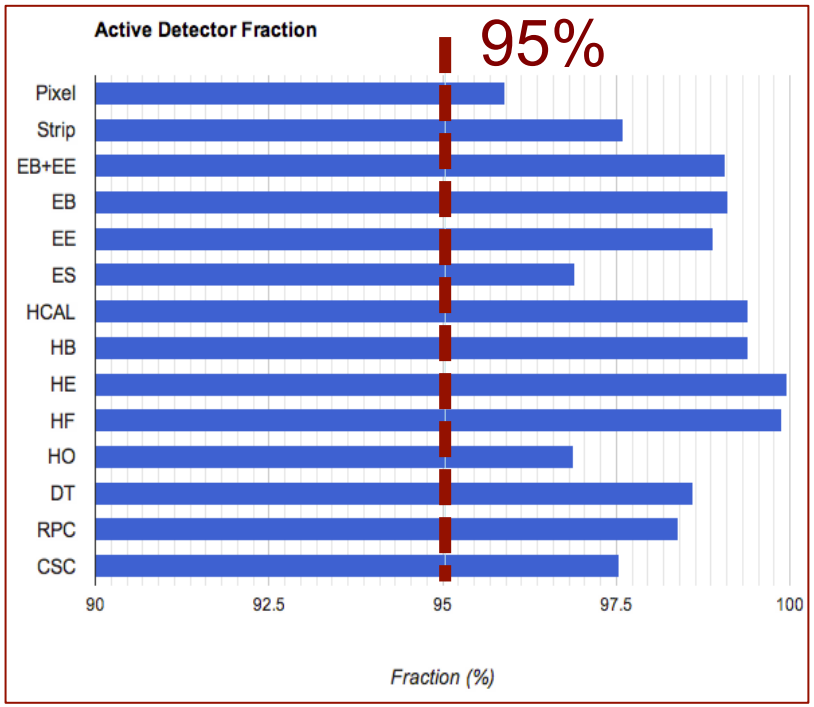
- Lumi: 16/fb delivered, 15/fb recorded
- Detector status and operational efficiency are very good
  - Recent fills 96-97% efficiency
- Magnet fast discharge
  - 0.5/fb recorded with B=0 T
  - Data used for calibration/alignment



CMS integrated luminosity

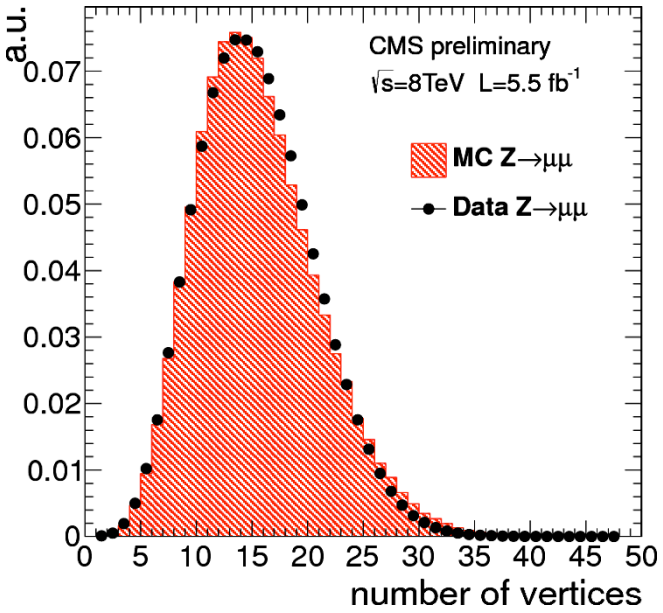


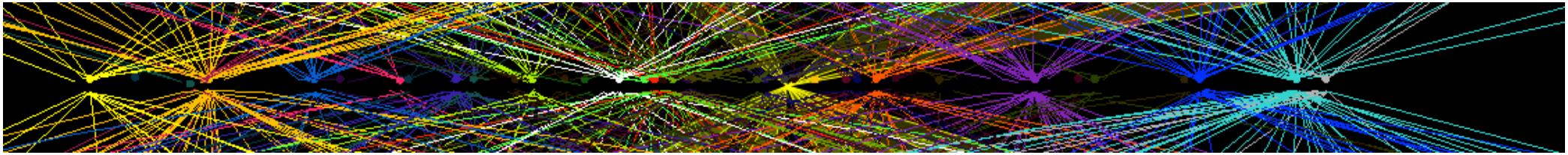
- Peak luminosity: 7.5e33
- Pile-up: 35 events
- Efficiency: >93%
- More than doubled 7 TeV dataset



Pile-up

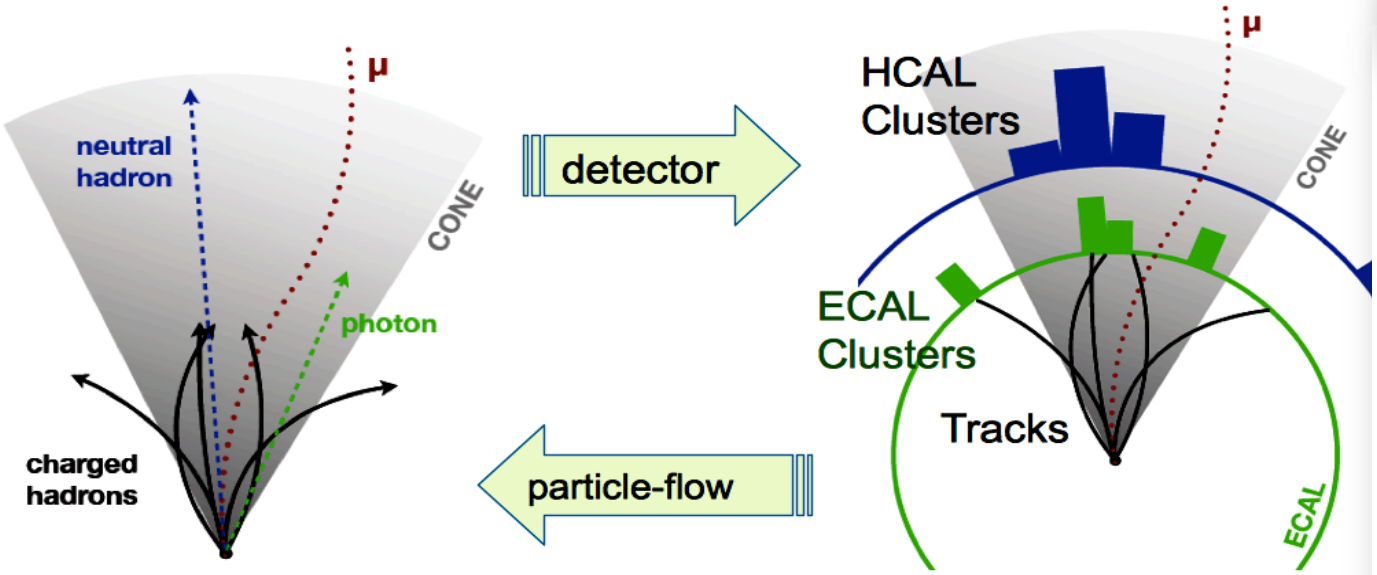
- About ~30 pp collisions per bunch crossing
- High multiplicity
  - ~1-2 thousand low energy charged particles/crossing
  - ~1-2 thousand low energy photons/crossing
- Challenge to reconstruct hard collisions
  - Jets and MET reconstruction
  - Lepton isolation
- Assignment of particles to primary vertex
  - Particle flow reconstruction
  - Neutral energy: event-by-event energy subtraction

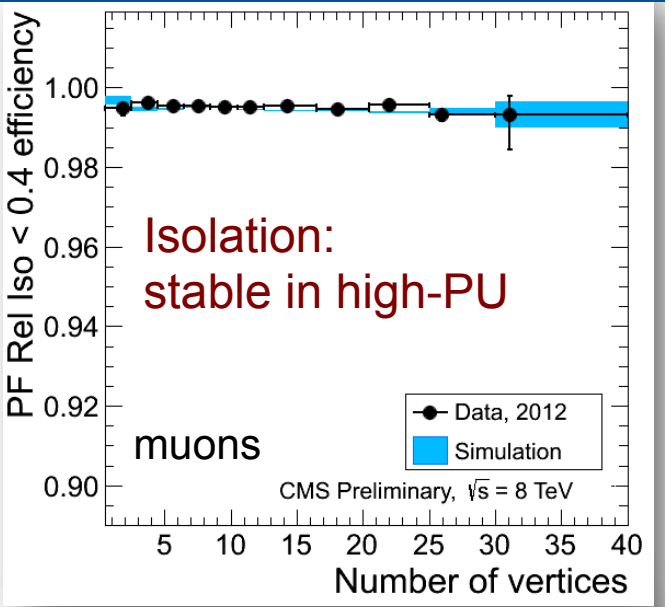


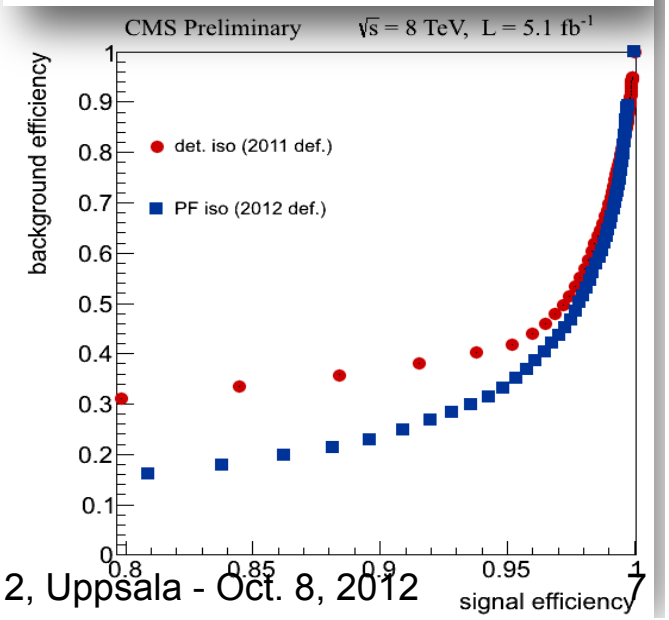


Particle-flow reconstruction

- Optimal combination of information from all sub-detectors
- Returns a list of reconstructed “particles”
- Identifies charged particles from pile-up
- Minimizes impact of PU on jet reconstruction, lepton & photon isolation

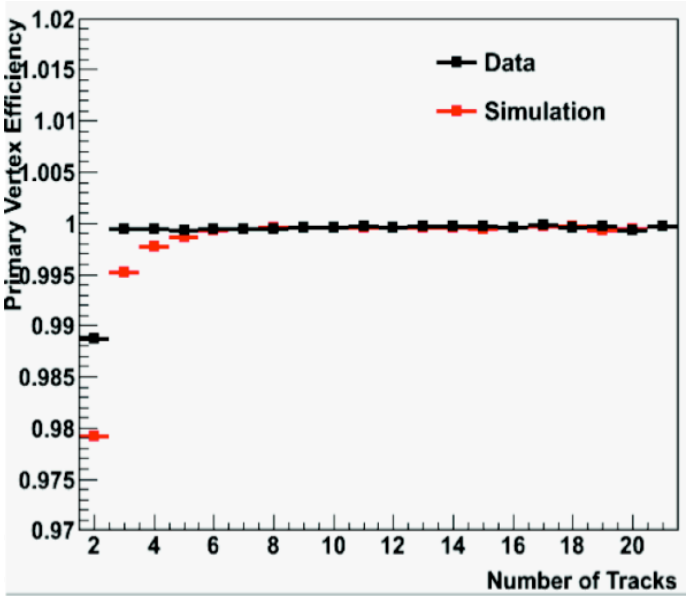


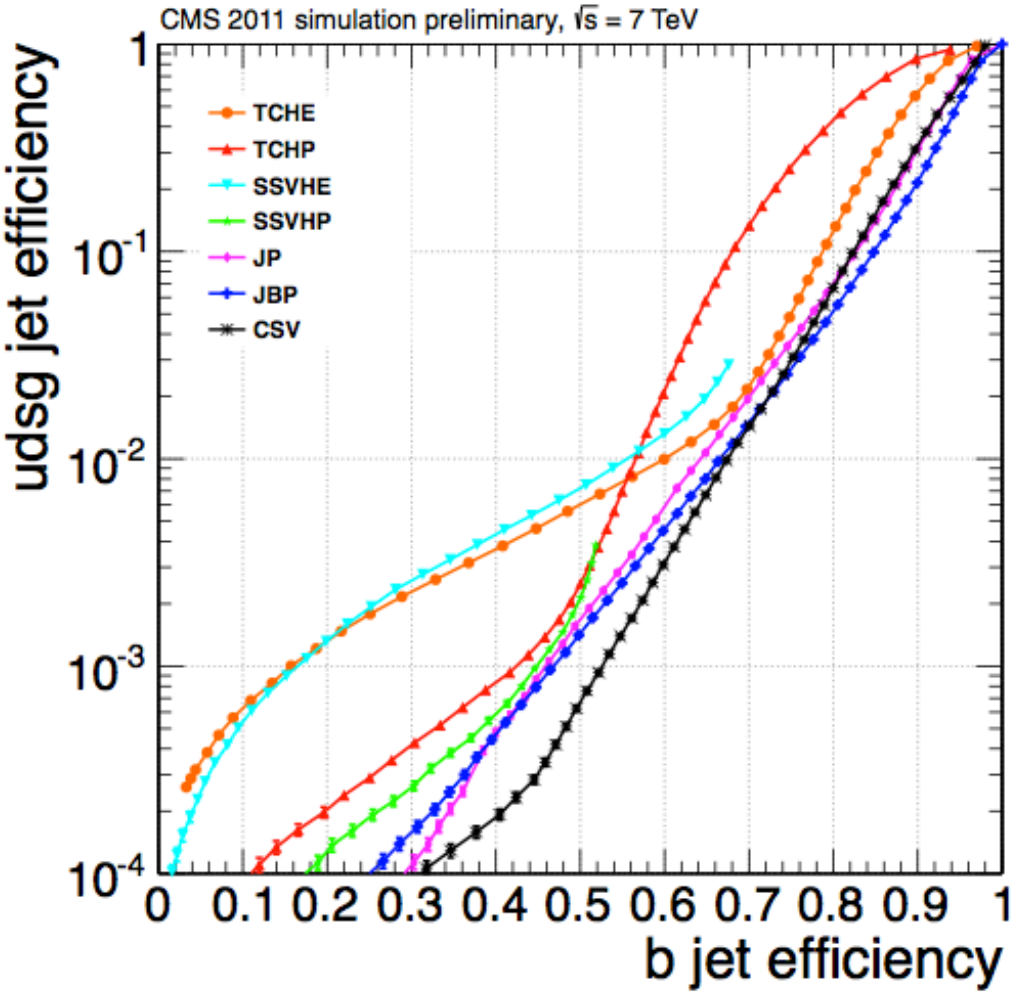




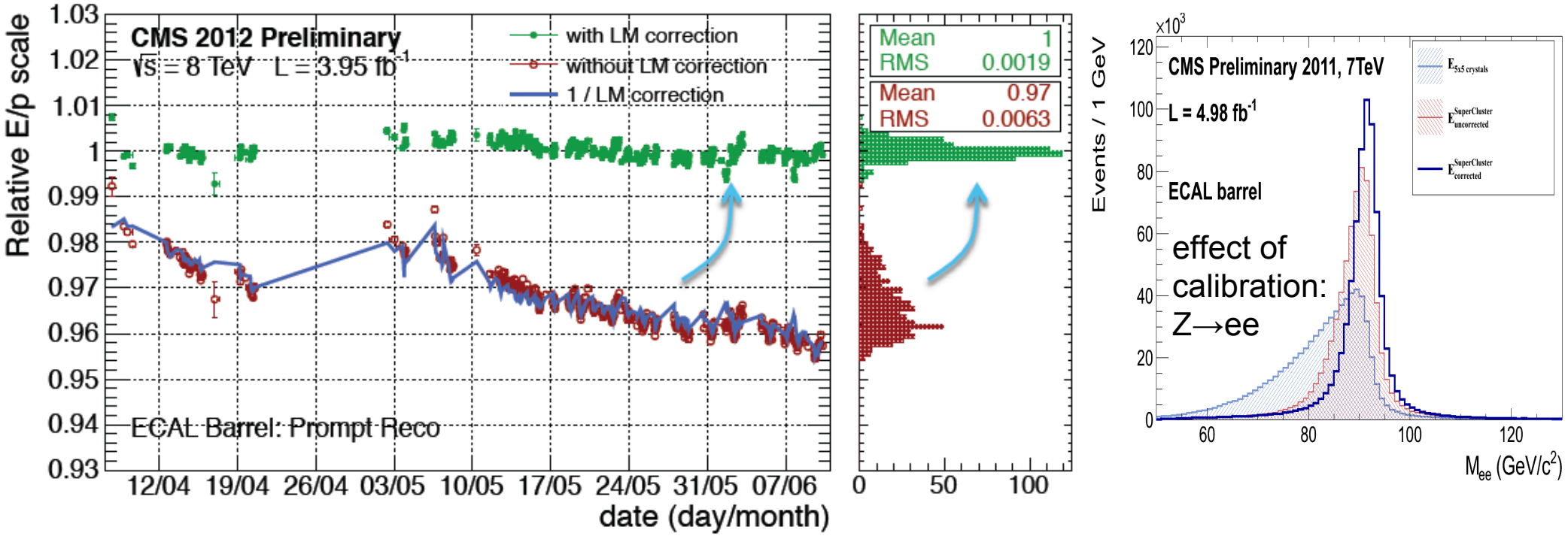
Vertex and b-tagging

- Vertex resolution better than vertex separation
  - Resolution ~10mm for large # of tracks
  - No surprise to get efficiency ~100%
- Several algorithms for b-tagging purposes





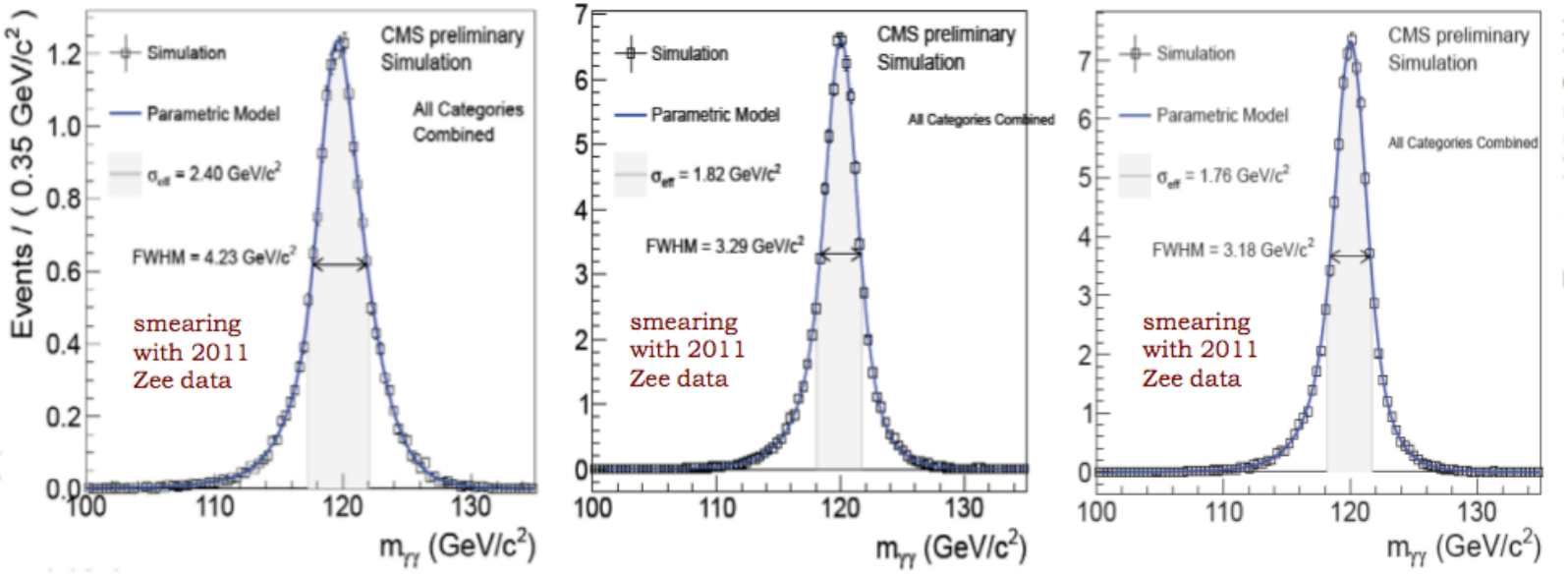
ECAL performance



- Automated calibration procedure
  - New laser calibration: automated 48-hr loop
  - Crystal-by-crystal transparency corrections
- Excellent stability with prompt calibration

Progress in ECAL calibration

July 2011 EPS	March 2012 Moriond	July 2012 ICHEP
FWHM/2.35 = 1.80 GeV (1.50%)	FWHM/2.35 = 1.40 GeV (1.17%)	FWHM/2.35 = 1.35 GeV (1.13%)



Resolution is approaching the nominal value

Missing E_T and resolution

- MET resolution for different N_{PV} is fitted with:

$$\sigma_{\text{tot}} = \sqrt{c^2 + \frac{N_{\text{PV}}}{0.7} \cdot \sigma_{\text{PU}}}$$

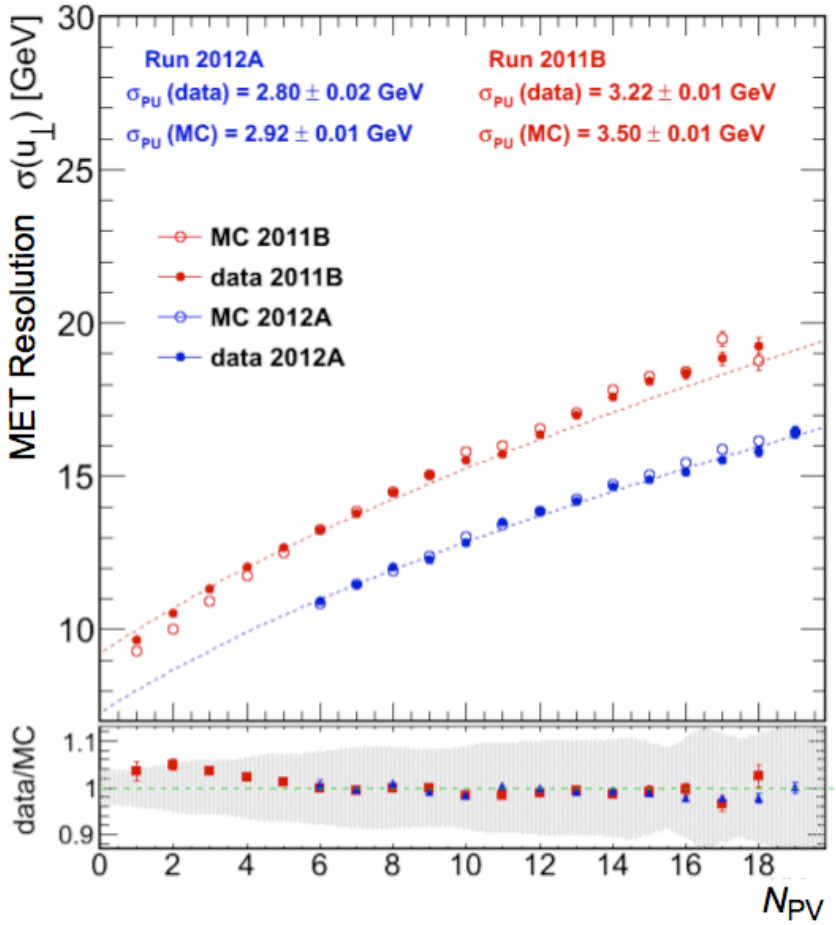
- the fit yields:

  c : average resolution without PU

  σ_{PU} : degradation in resolution caused by PU

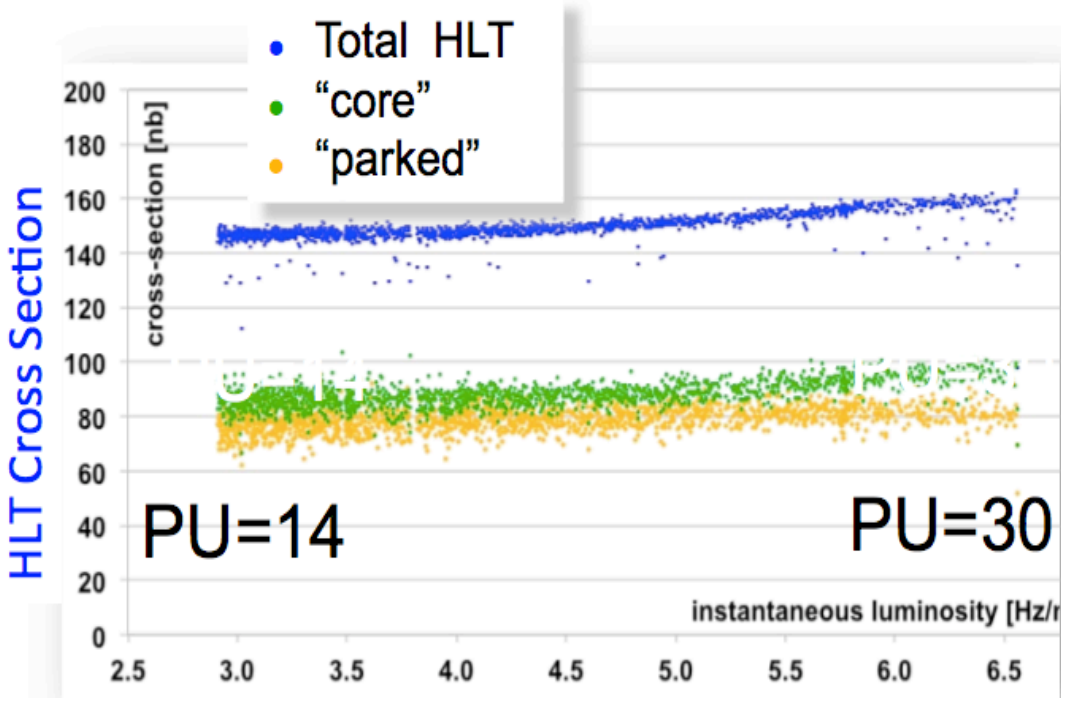
- improved resolution in 2012 for fixed N_{PV}
  - improved ECAL/HCAL energy reconstruction

    ⇒ reduces out-of-time pileup effects
  - MET pile-up corrections applied
- pile-up introduces an additional smearing of ~ 3 GeV on MET resolution σ_{PU} (in quadrature)

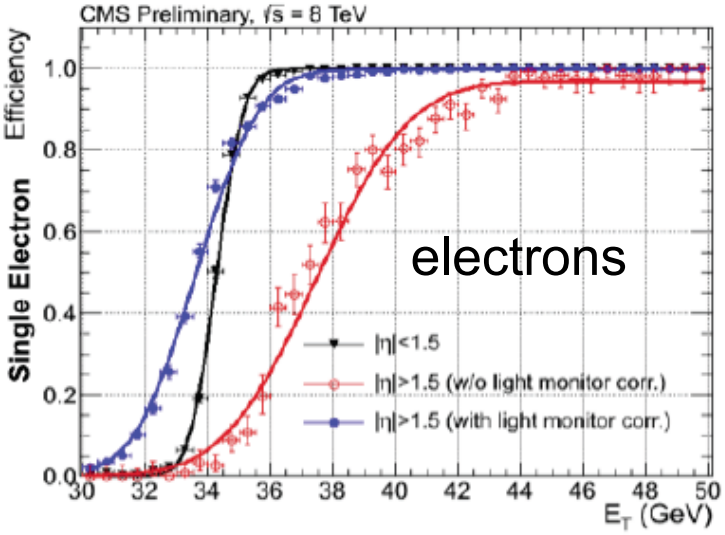


Trigger

- Trigger system is a very simple concept: two levels
  - L1 is hardwired to a flexible/programmable High Level Trigger
- Challenge is to keep “reasonable” rate cross section with varying pile-up conditions, without “loosing” physics
- Full use of the flexible HLT system
- Some of the offline features (PF and PU corrections) are implemented online

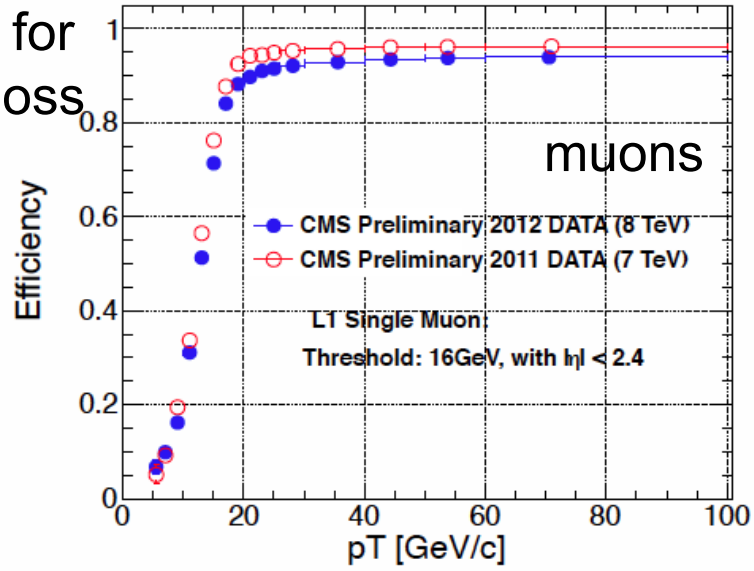


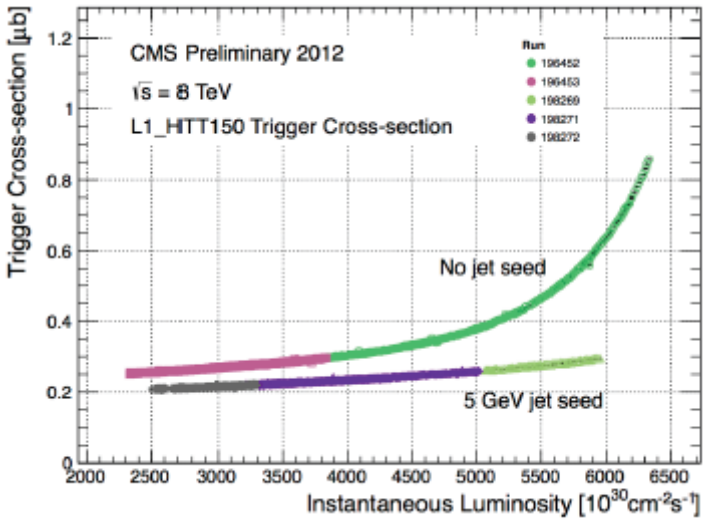
Trigger performance



Sharper turn-on curve in fwd region (new corrections)

Muon rate cut 50% for a few % efficiency loss

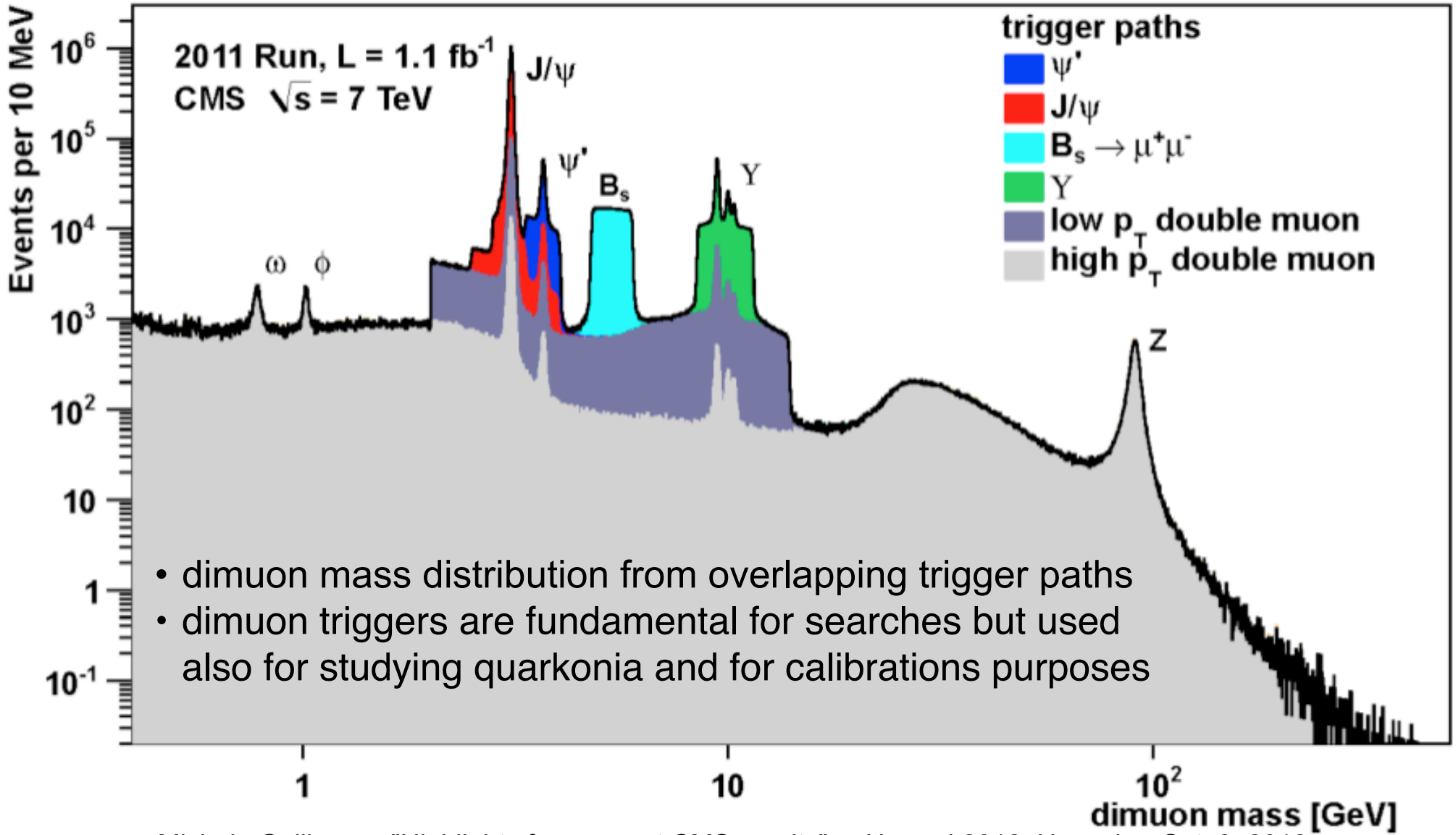




Jets: added a 5 GeV jet seed threshold

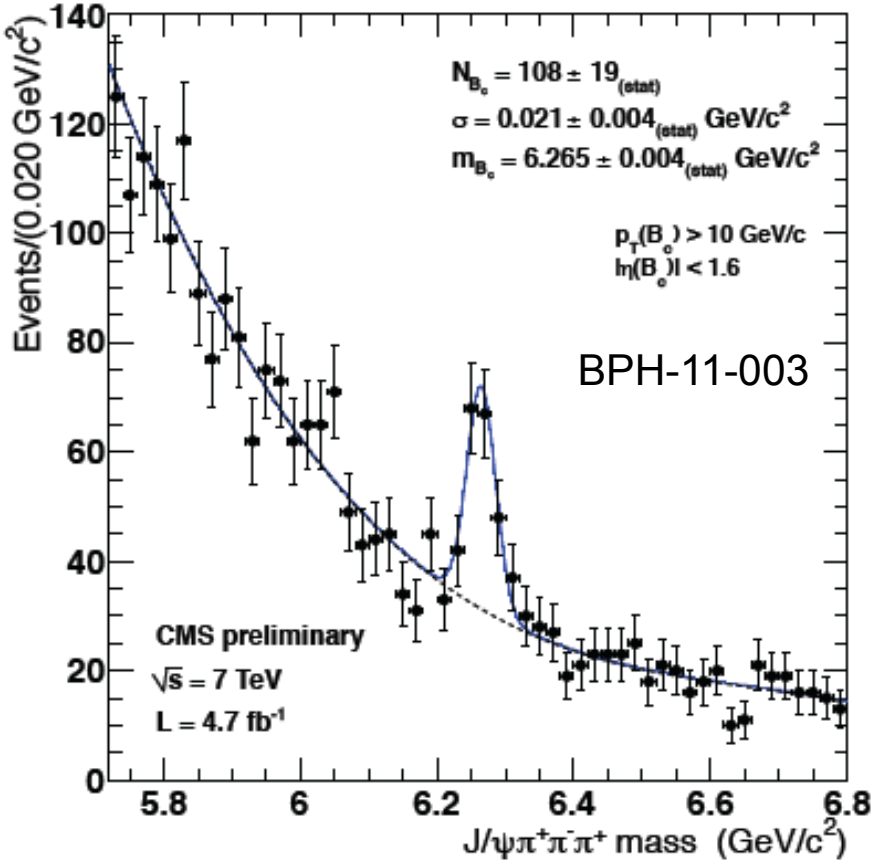
(no loss in physics)

The standard model



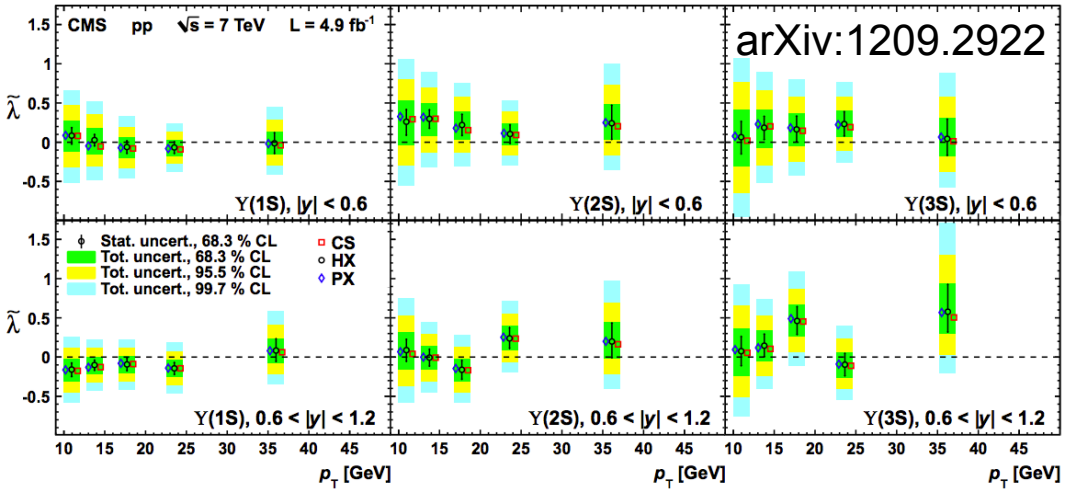
- dimuon mass distribution from overlapping trigger paths
- dimuon triggers are fundamental for searches but used also for studying quarkonia and for calibrations purposes

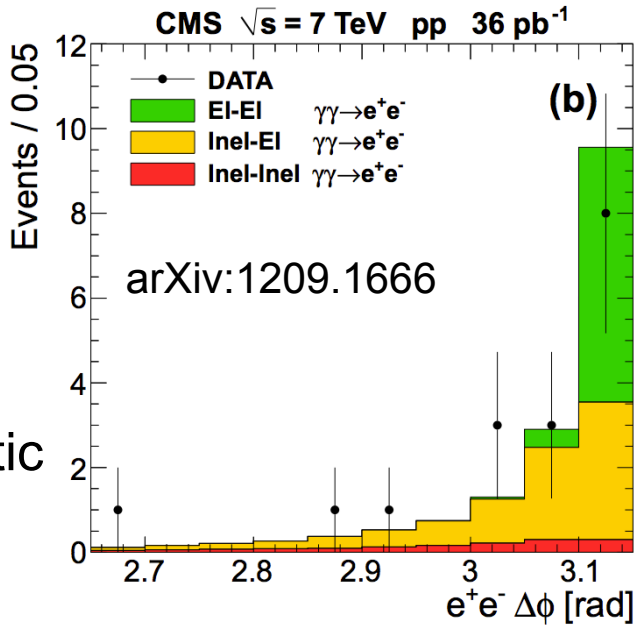
B and forward physics

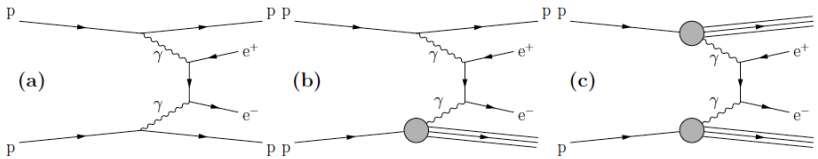


Observation of $B_c^+ \to J/\psi\, \pi^+\pi^+\pi^-$

Y(1s,2s,3s): no evidence for large polarization



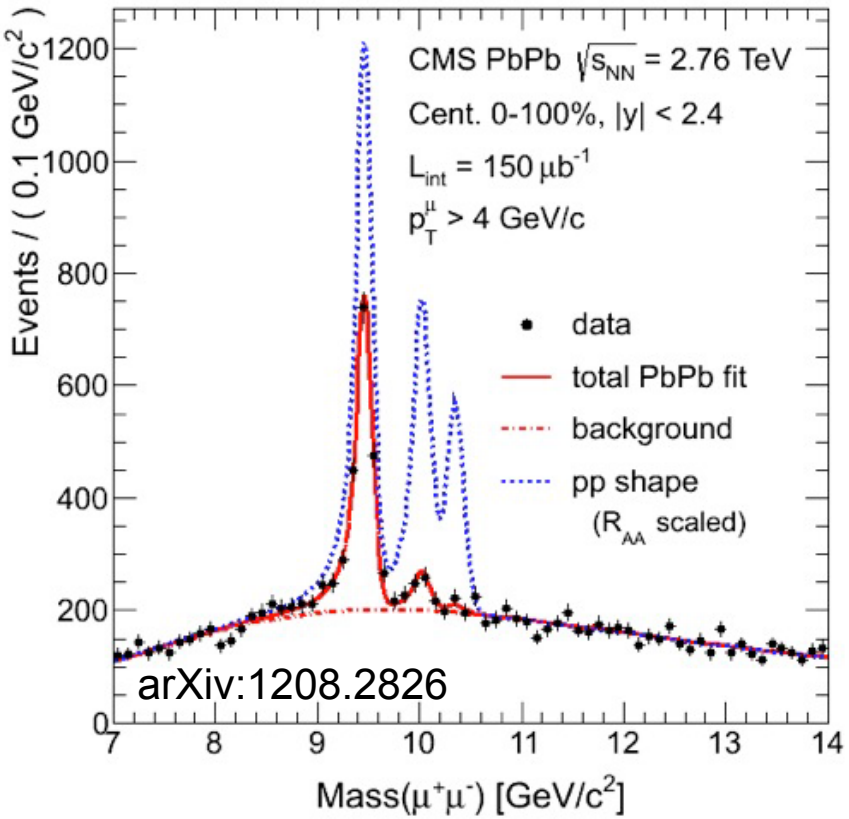


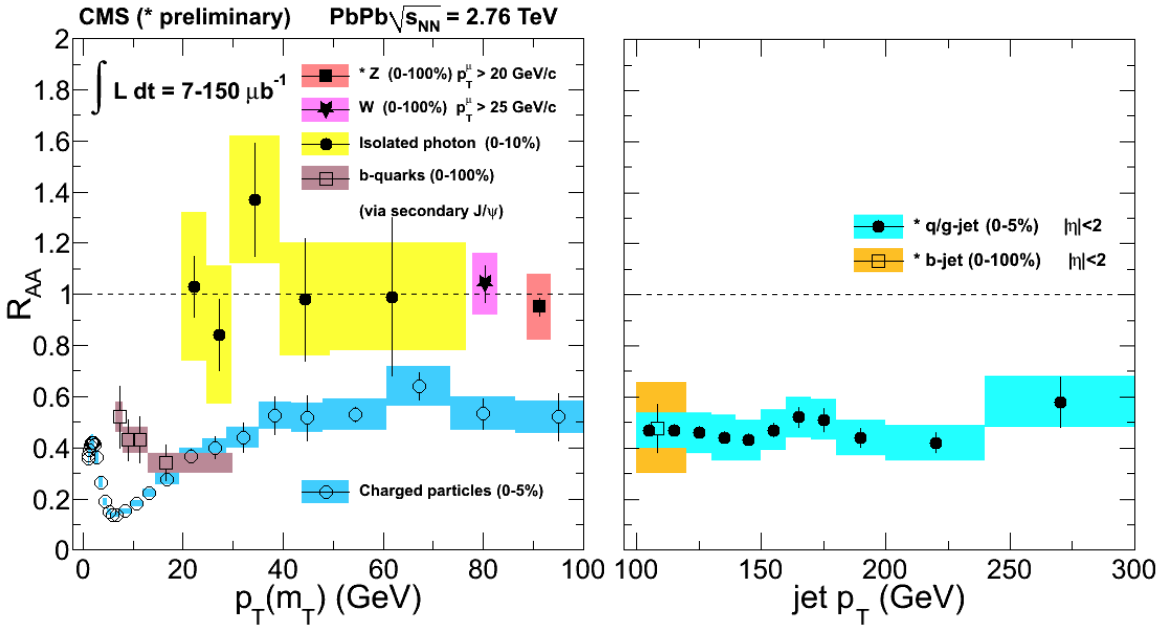


Observation of elastic e+e- production

Heavy Ion physics

Observation of Y suppression



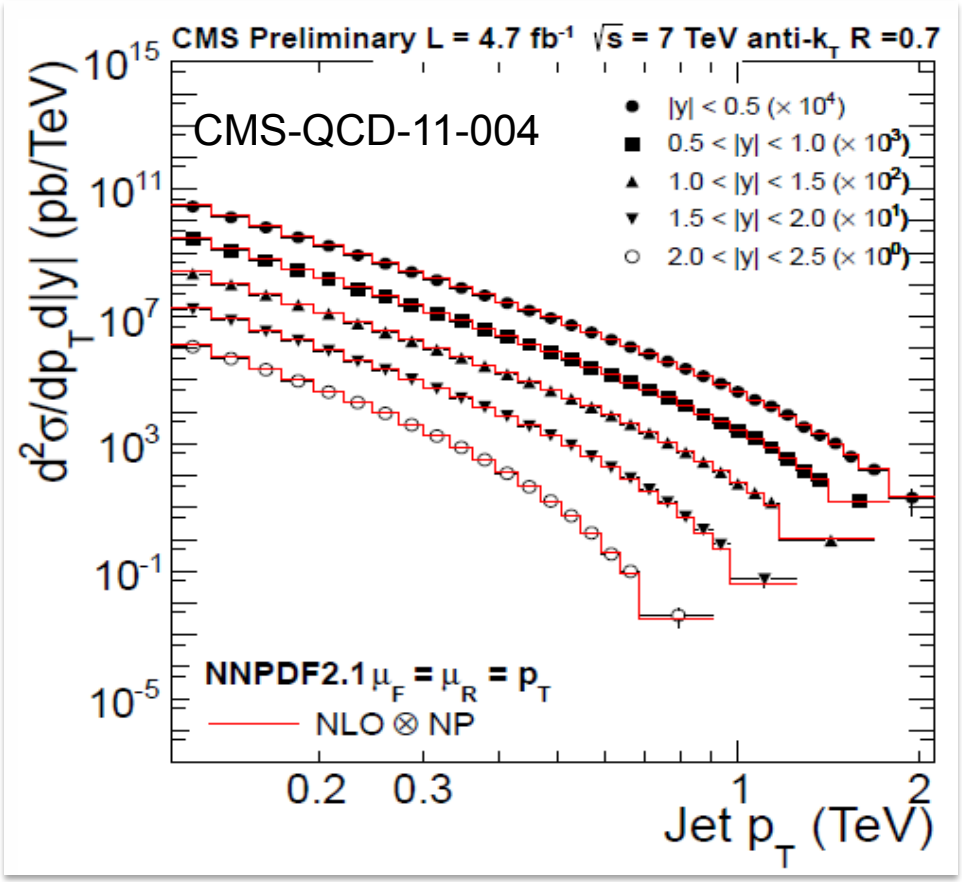


Many different probes (W, Z, g, b, etc)

QCD and standard model

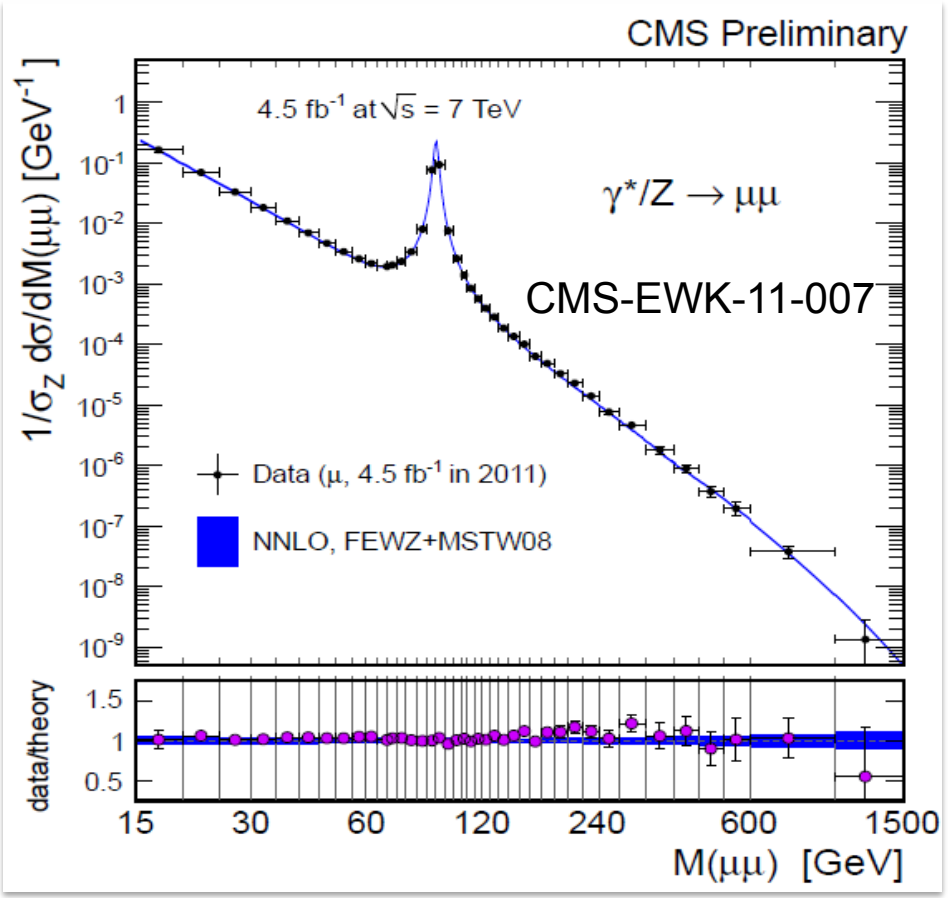
Inclusive jet and dijets:

- NLO describes data over 9 orders of magnitude
- Constrains gluon PDF up to x=0.6.



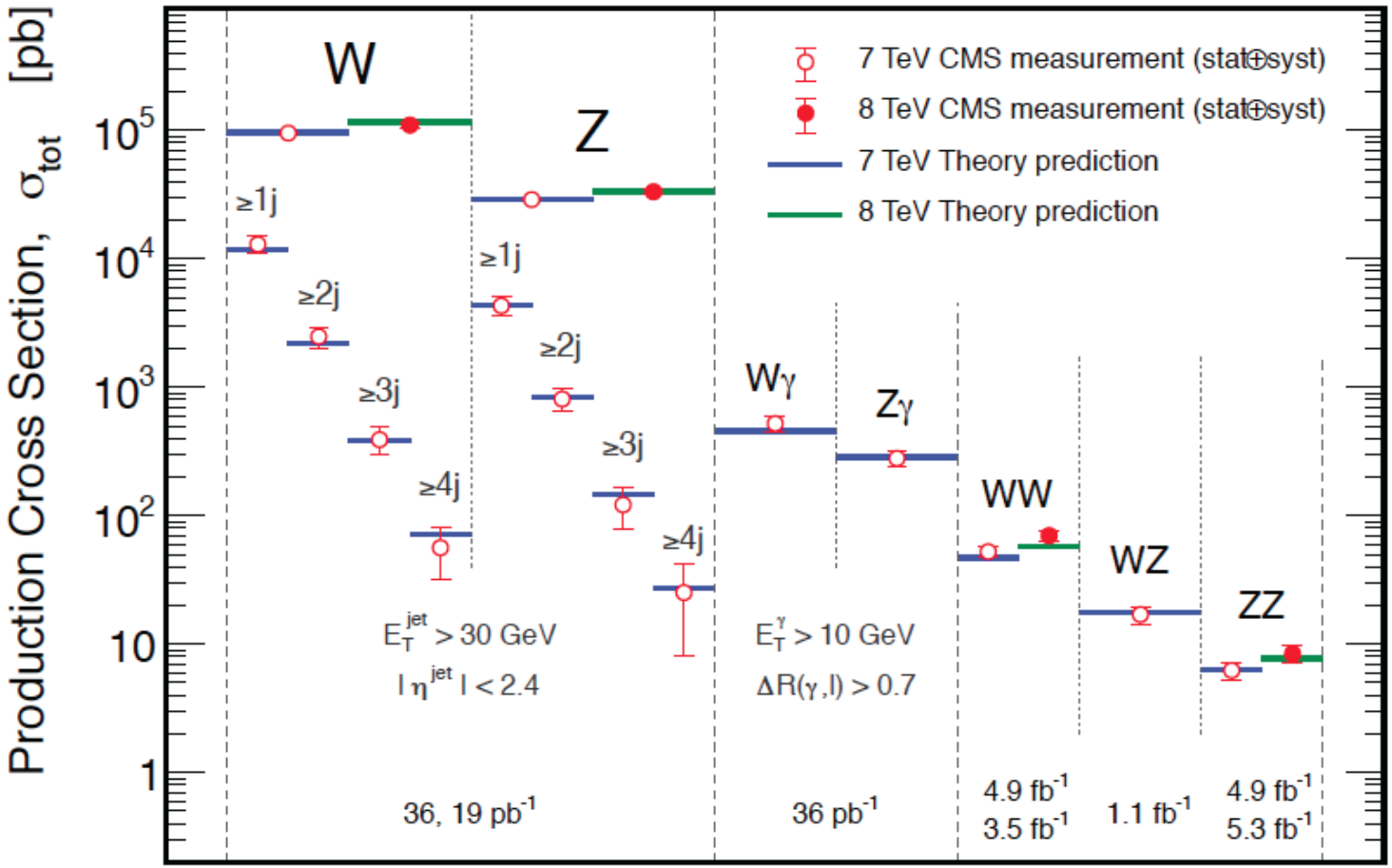
Differential DY cross section:

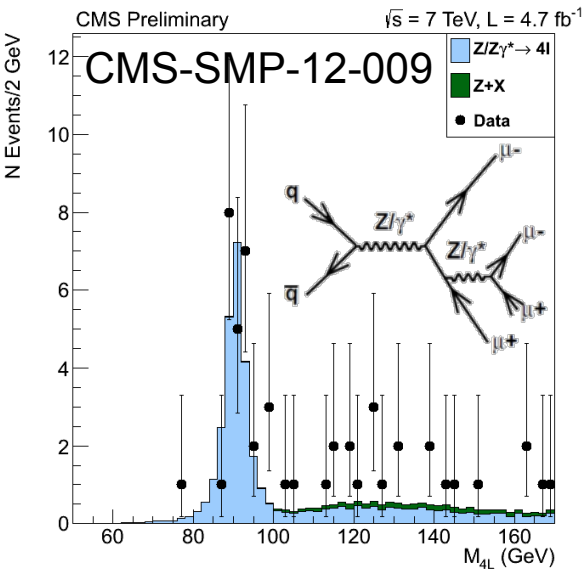
- 2.5M Z→μμ pairs test NNLO cross sections and PDFs



Electroweak physics

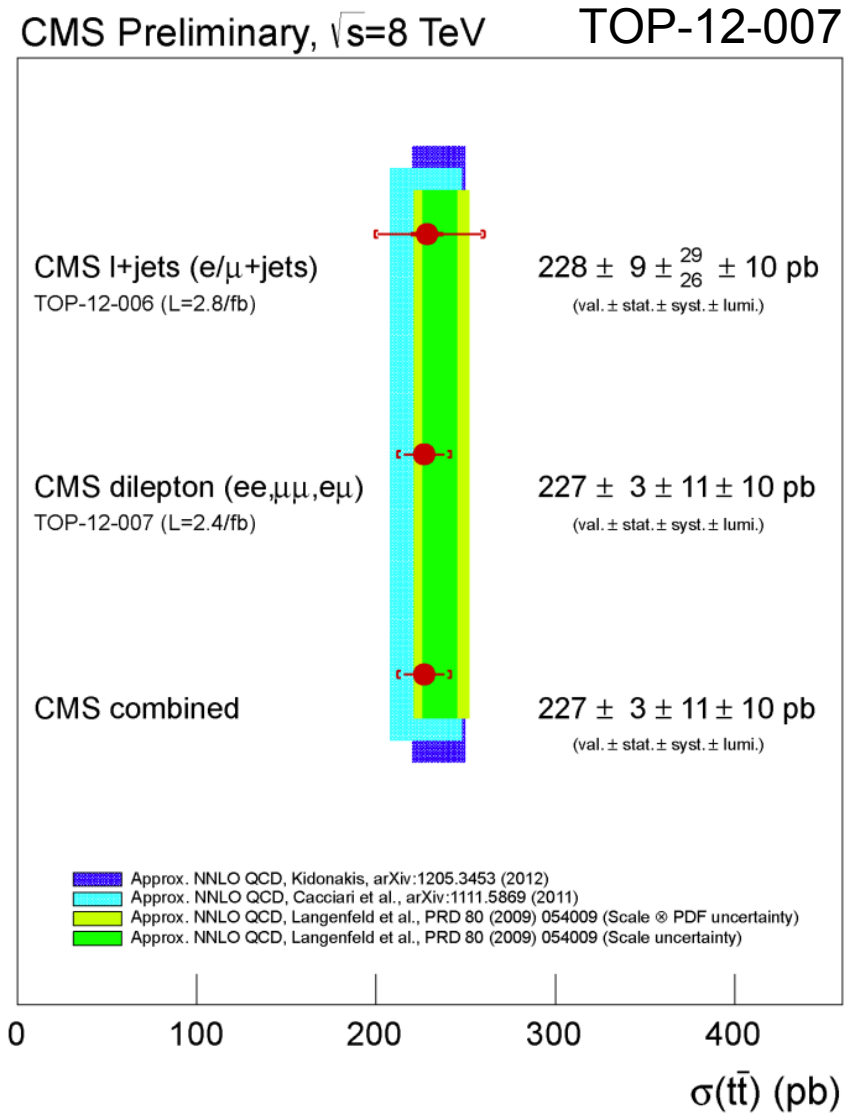
Single and multi-boson measurements CMS

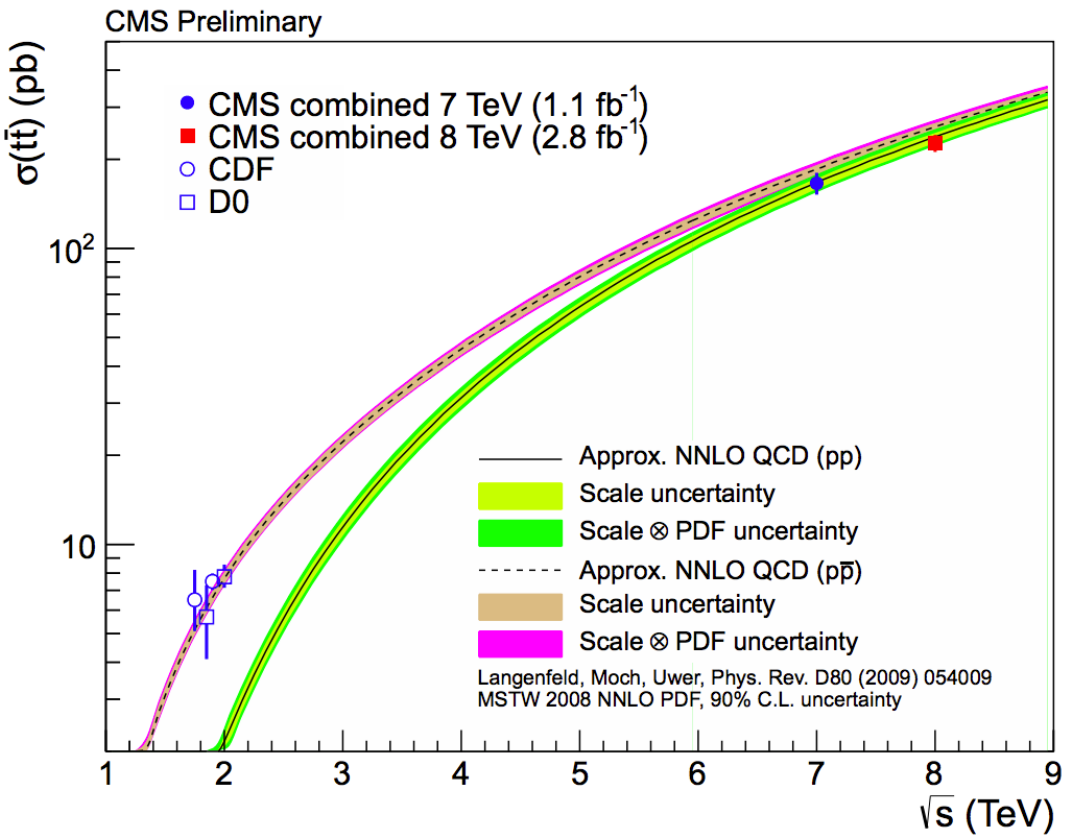




observation of ZZ→4l

Top quark pair production





At 7 TeV:

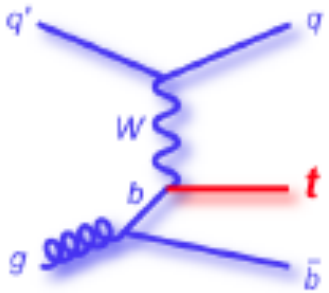
$$\sigma_{t\bar{t}} = 161.9 \pm 2.5\,(\text{stat.})\,^{+5.1}_{-5.0}\,(\text{syst.}) \pm 3.6\,(\text{lumi.})\,\text{pb}$$

arXiv:1208.2671

±4%

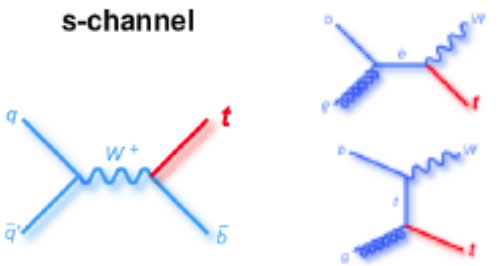
Single top production

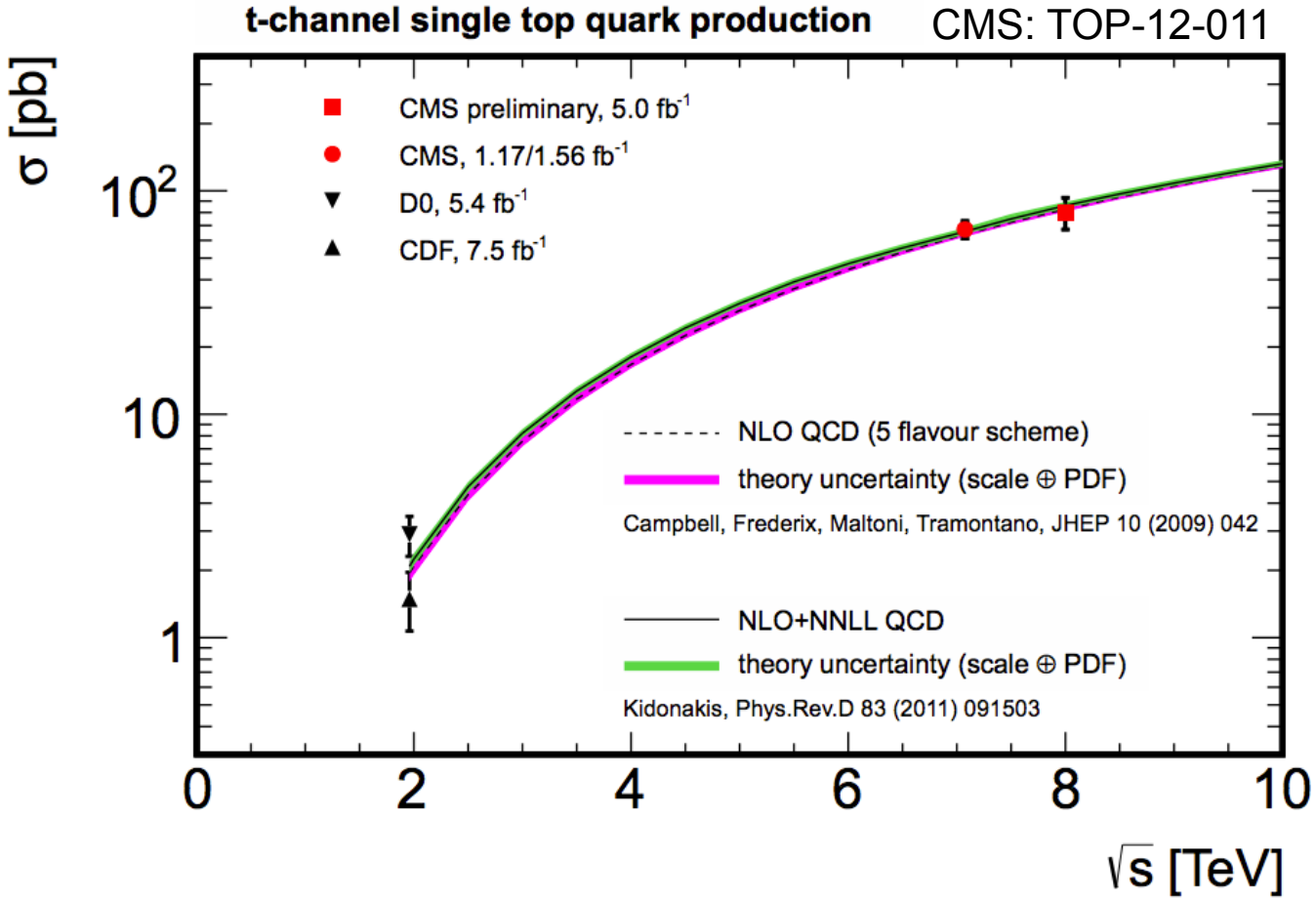
t-channel



Wt-channel

s-channel





arXiv:1209.3489

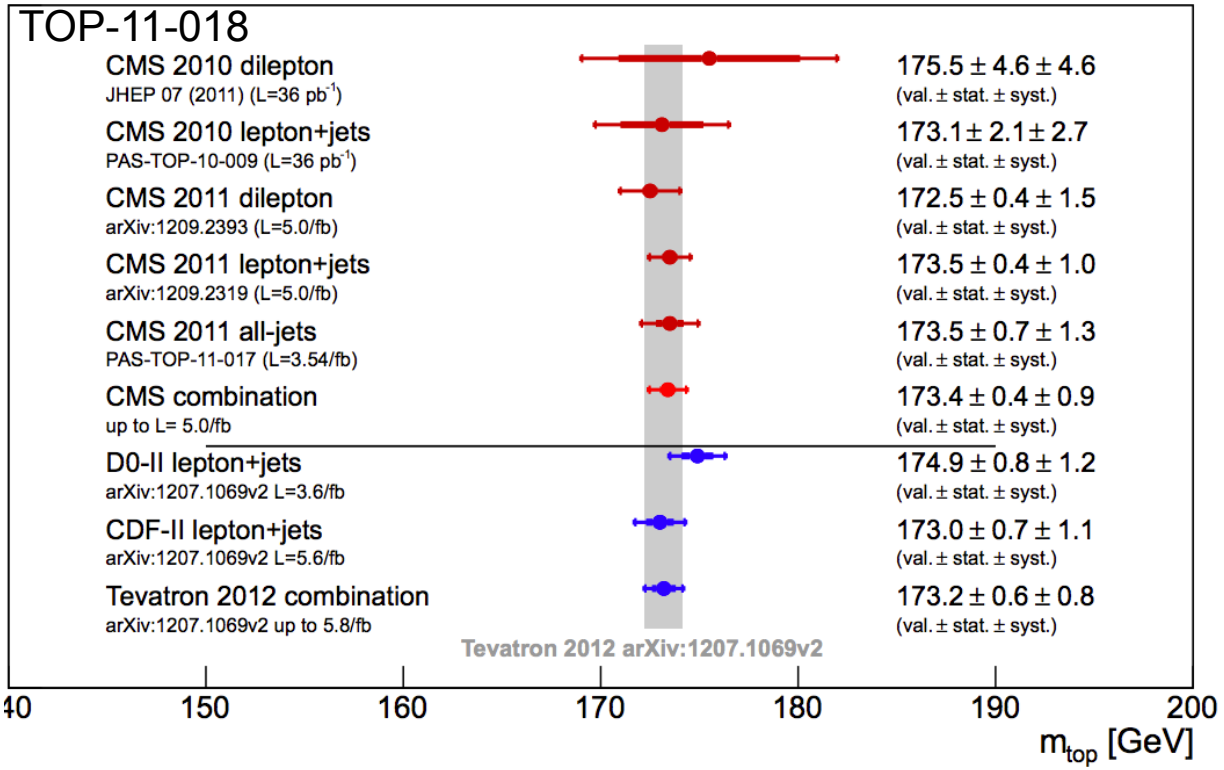
$\sigma_{Wt} = 16^{+5}_{-4}\ (\text{stat} \oplus \text{syst})\ \text{pb}$

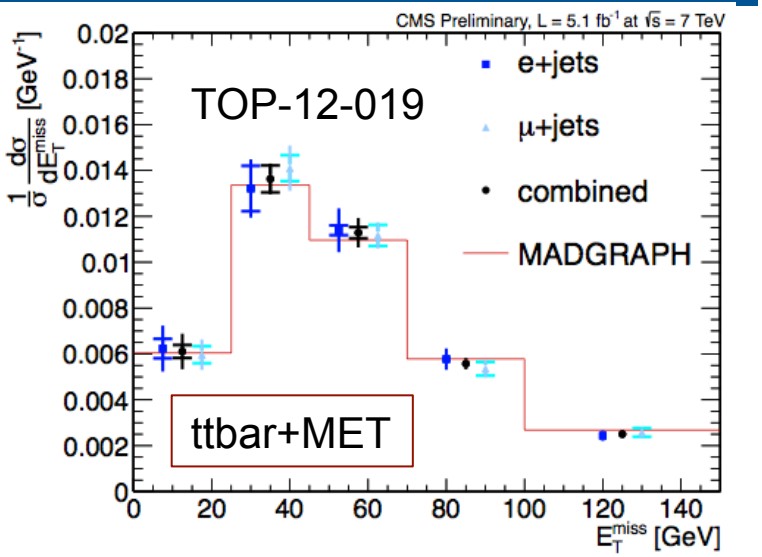
$$\sigma_{t-\text{ch.}} = 80.1 \pm 5.7(\text{stat.}) \pm 11.0(\text{syst.}) \pm 4.0(\text{lumi.})\ \text{pb}$$

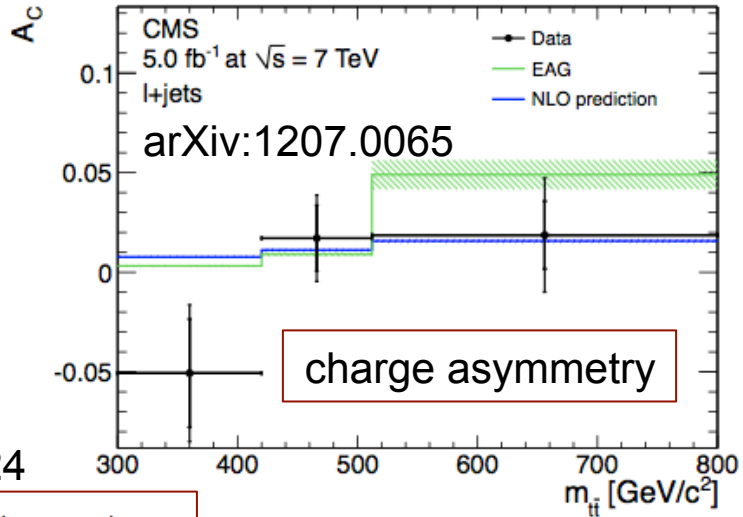
$$R_{8\ TeV/7\ TeV} = 1.14 \pm 0.12(\text{stat.}) \pm 0.14(\text{syst.})$$

Top quark mass and properties

m_{top} = 173.4 ± 0.4 (stat) ± 0.9 (syst) GeV







FCNC: B(t →Zq)<0.24% @95CL TOP-11-028

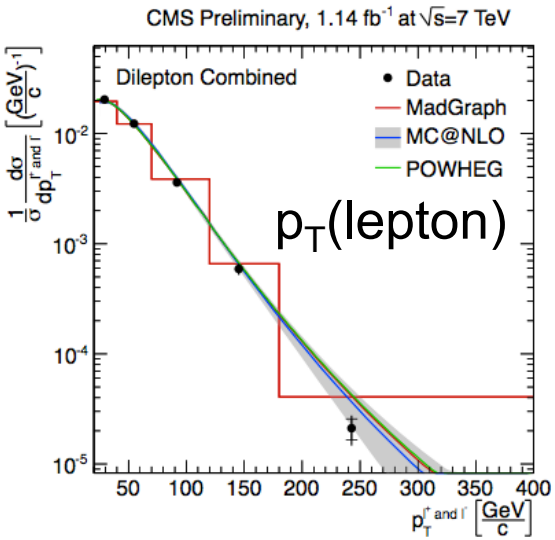
TOP-12-024

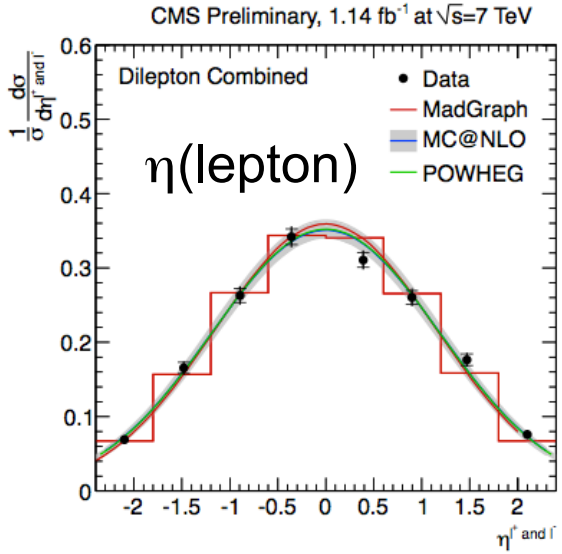
tt+bb production: $\sigma(t\bar{t}b\bar{b})/\sigma(t\bar{t}jj) = 3.6 \pm 1.1(\text{stat.}) \pm 0.9(\text{syst.})\%$

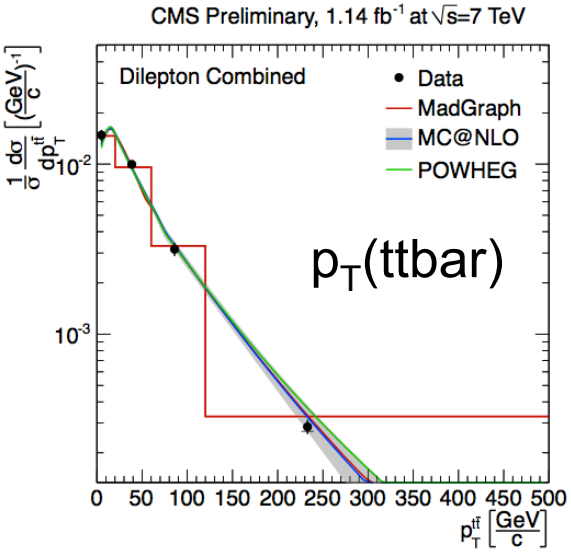
Differential cross section in ttbar pairs

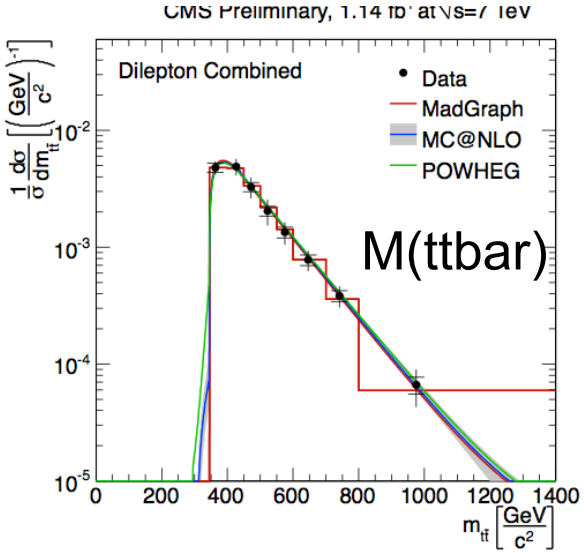
$$\frac{1}{\sigma_{t\bar{t}}}\frac{d\sigma_{t\bar{t}}}{dX}$$

- Test SM predictions in differential distributions
  - Constrain MC predictions
  - Sensitive to new physics
- Unfold detector effects
- MC describes data well
- Both l+jets and dilepton channels





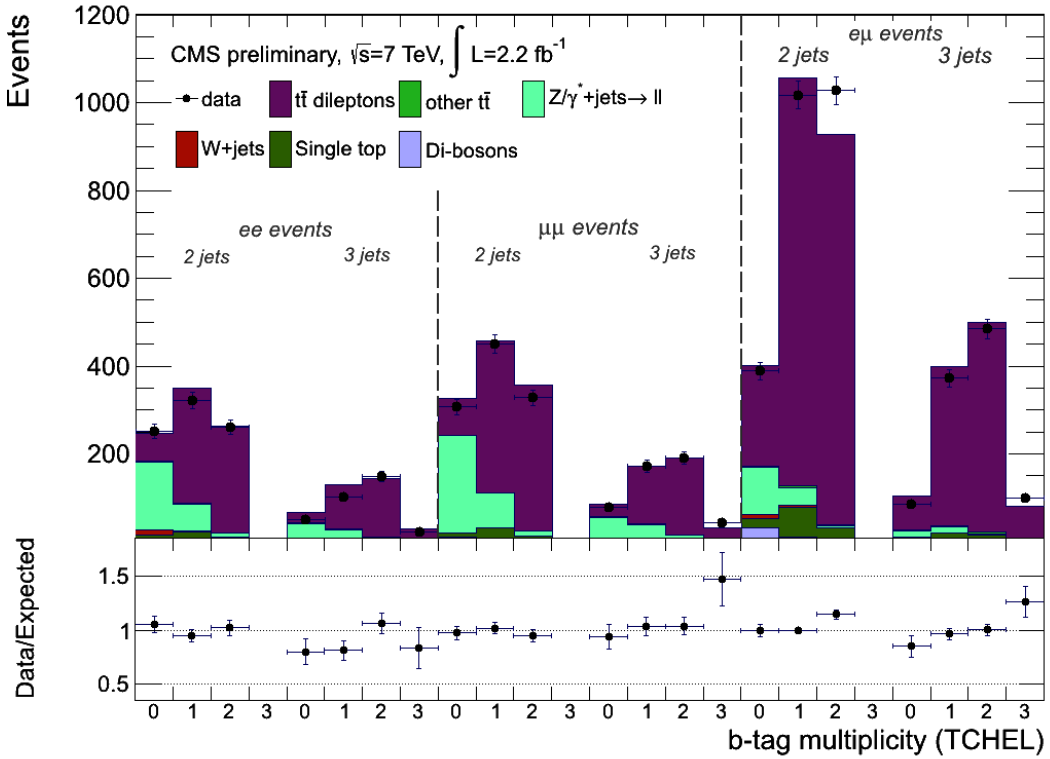


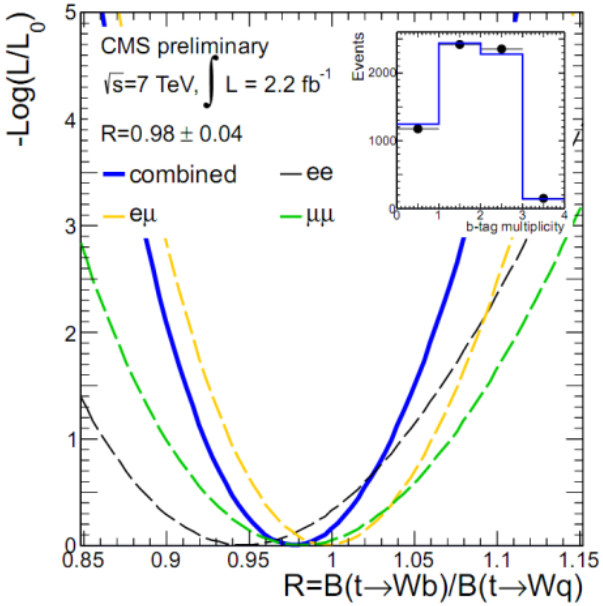


TOP-11-013

Top quark: Wtb coupling

- Branching fraction: $R = B(t \to Wb)/B(t \to Wq)$
- Fully "data-driven" background determination
  - Use wrong assignment in Mlb distribution
- b-tagging multiplicity parametrized as function of R, ε_b, ε_q
  - Fit R, using ε_b from inclusive b-jet production





$R = 0.98 \pm 0.04$

$R > 0.85$ at 95% C.L.

CMS TOP-11-029

W helicity & constraints on Wtb vertex

- Measure W helicity fraction in ttbar l+jets
  - Top decays before hadronization
  - Spin is directly transferred to its decay products (t→Wb)
- Sensitive to anomalous tWb coupling

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_\ell^*} = \frac{3}{8}(1+\cos\theta_\ell^*)^2 F_R + \frac{3}{8}(1-\cos\theta_\ell^*)^2 F_L + \frac{3}{4}\sin^2\theta_\ell^* F_0$$

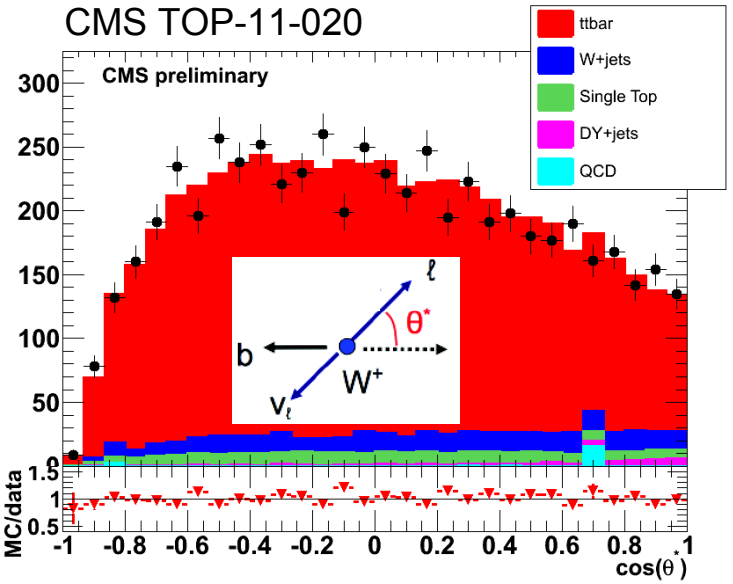
- Measure θ*: angle between lepton and b-jet (in W rest frame)
  - 3 possible W polarization modes:

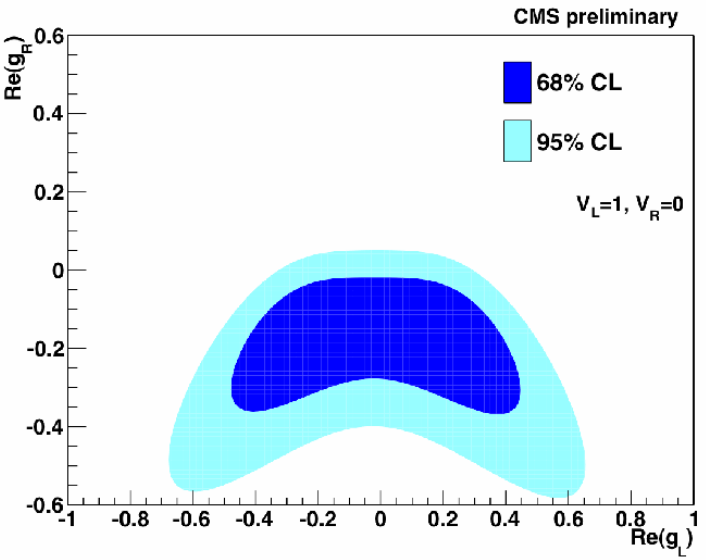
$$F_0 = 0.698, \quad F_L = 0.301, \quad F_R = 4.1 \times 10^{-4}.$$

$$\begin{aligned} F_0 &= 0.567 \pm 0.074(\text{stat.}) \pm 0.047(\text{syst.}) \\ F_L &= 0.393 \pm 0.045(\text{stat.}) \pm 0.029(\text{syst.}) \\ F_R &= 0.040 \pm 0.035\ (\text{stat.}) \pm 0.044(\text{syst.}) \end{aligned}$$

⇒results consistent with SM

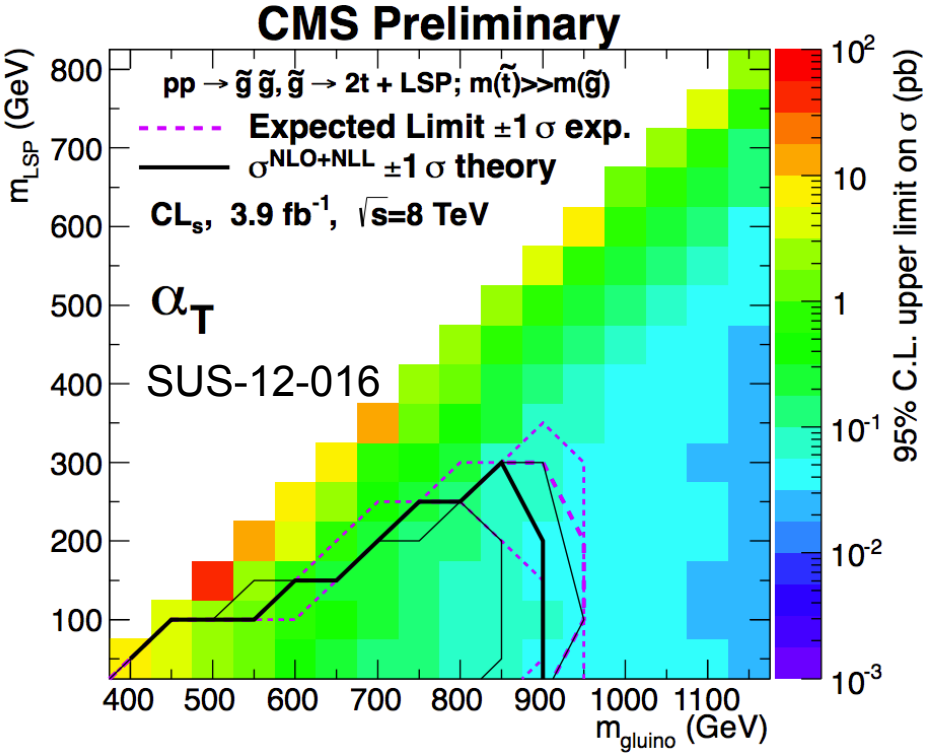
- Set limits on anomalous couplings of Wtb vertex

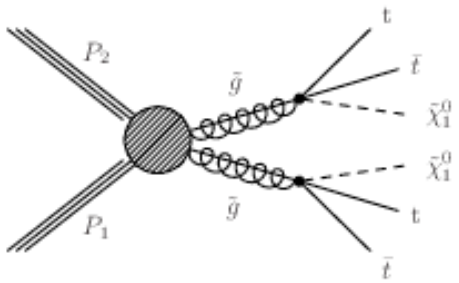




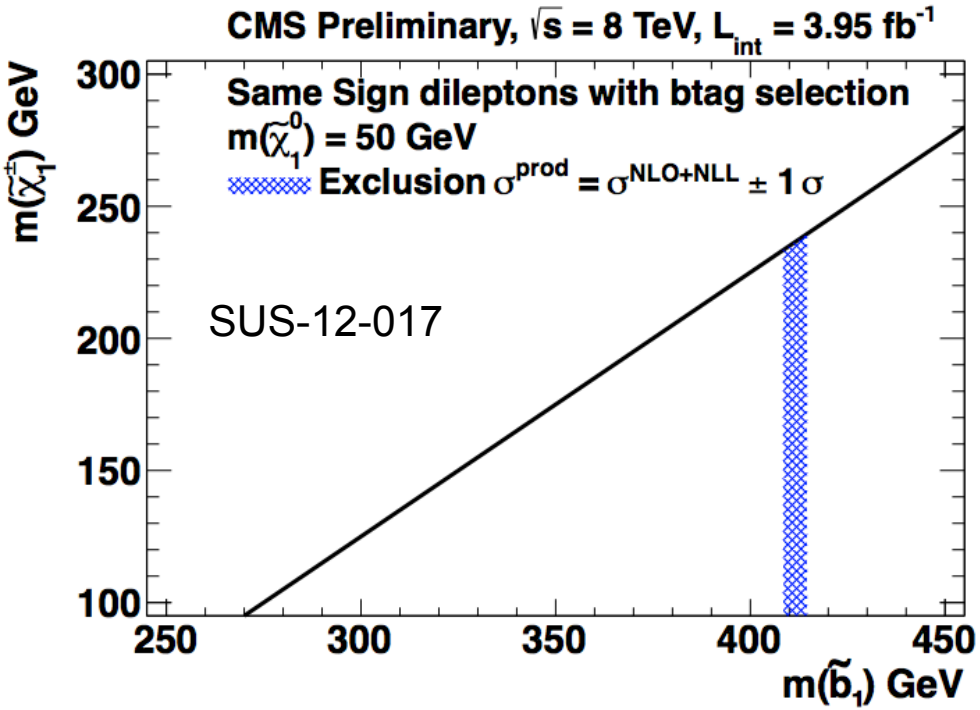
SUSY at 8 TeV

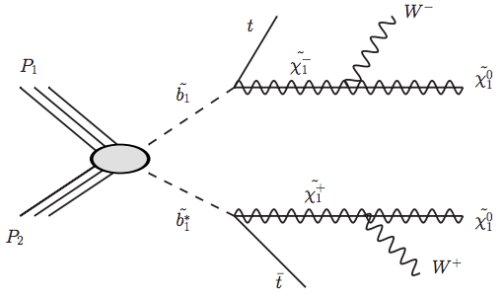
gluino: MET and 0-3+ b-jets with α_T





sbottom: same-sign dileptons + b-jets



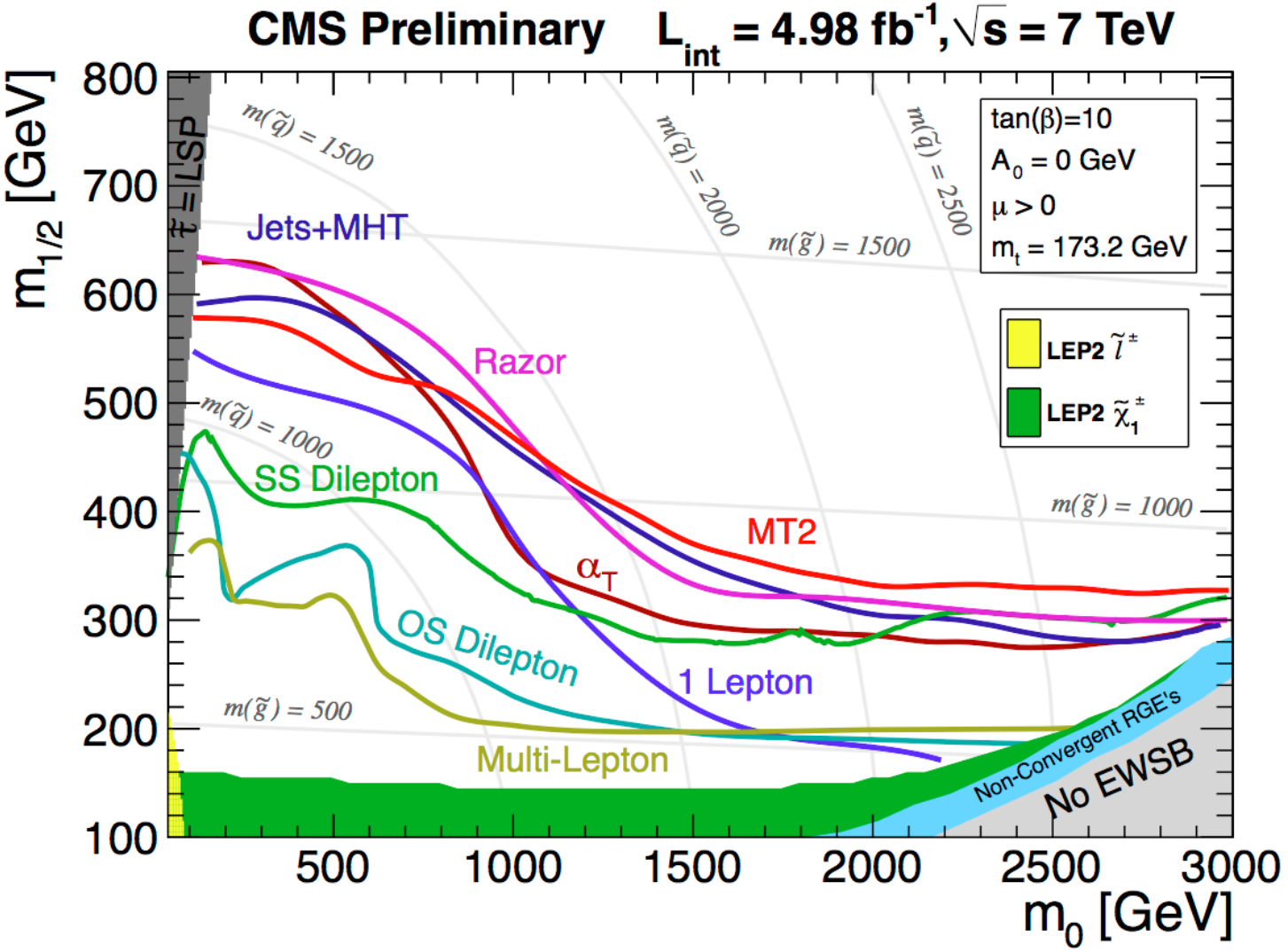


No SUSY…yet

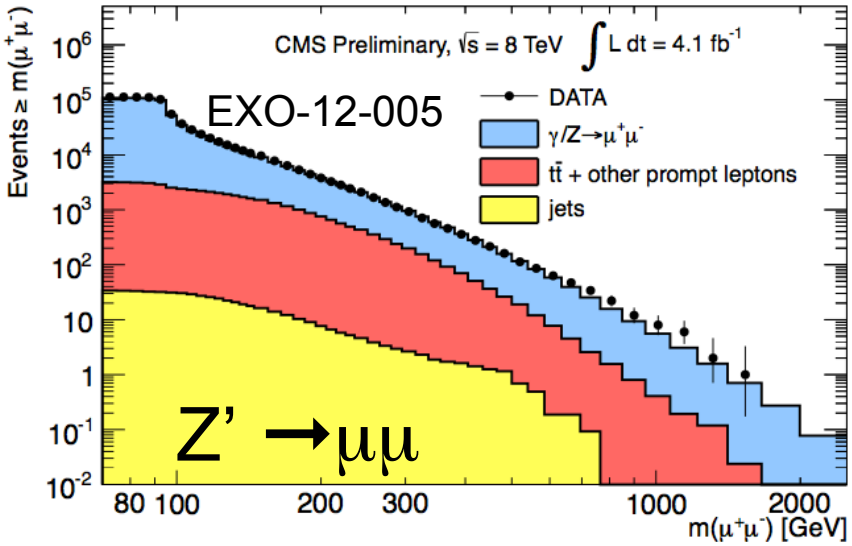
CMSSM limits

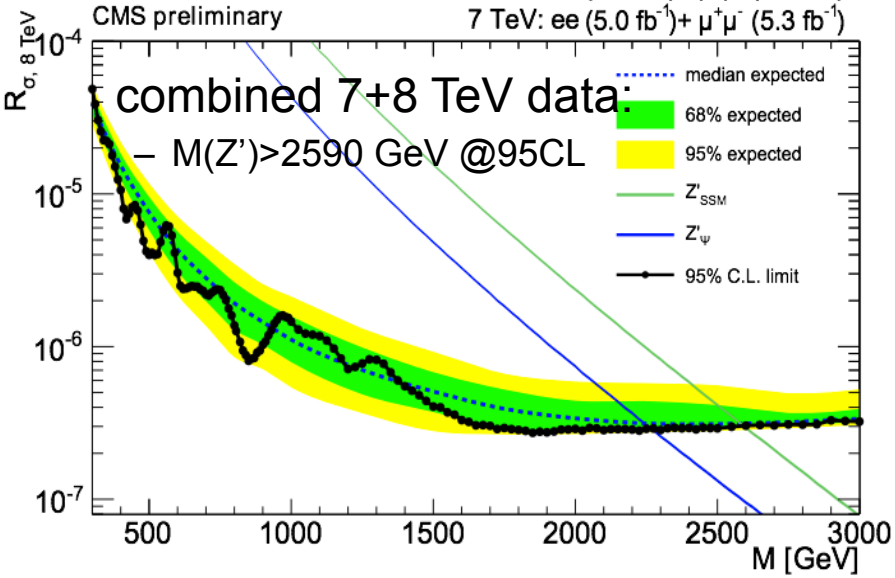
Next is naturalness:

- Search for stop and sbottom in gluino decays
- Direct search for light stop and sbottom
- Chargino and neutralino production

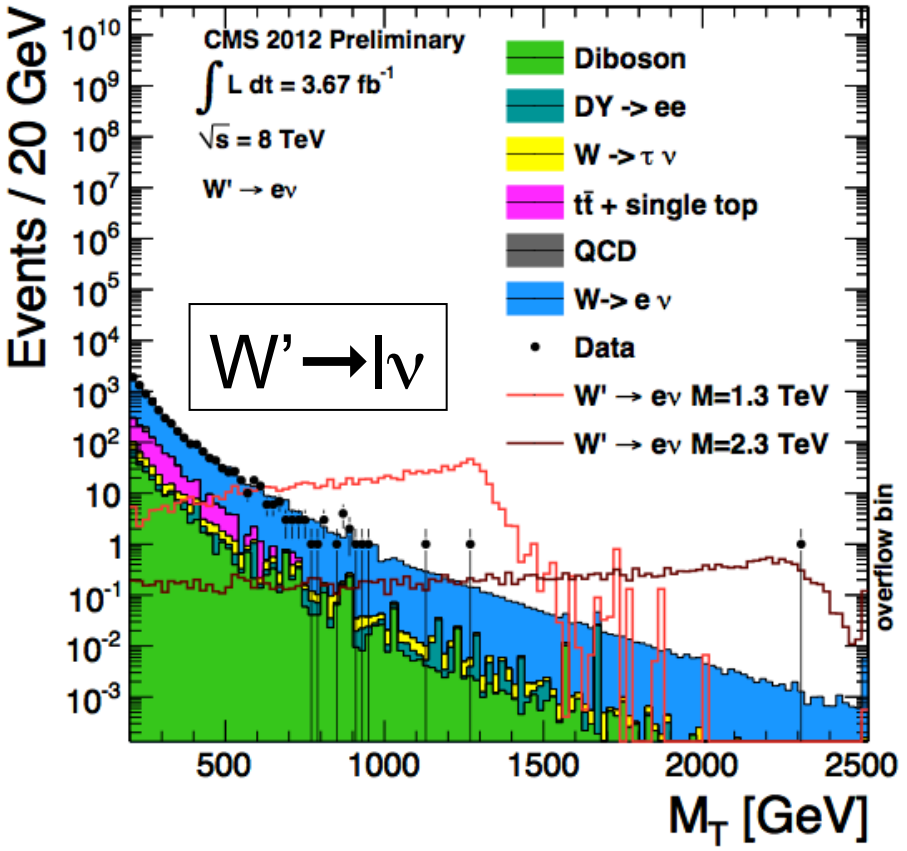


Exotica at 8 TeV: Z'/W'/dijets

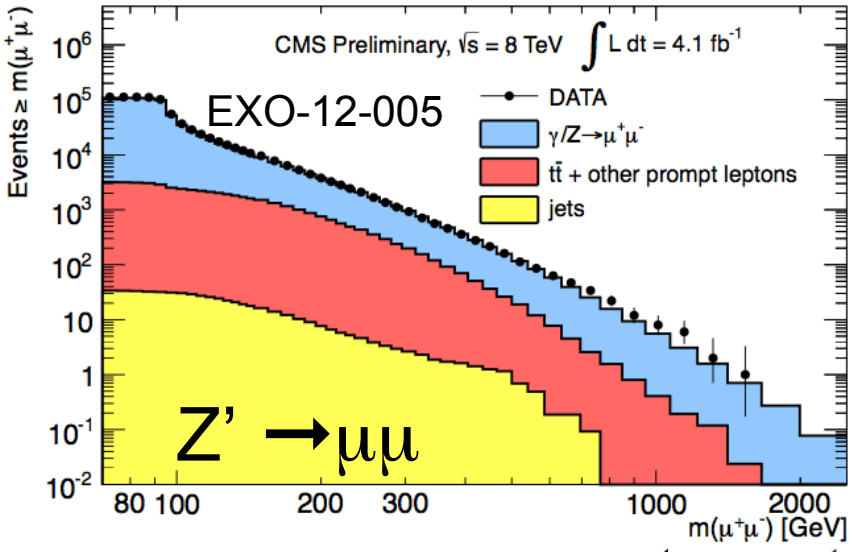


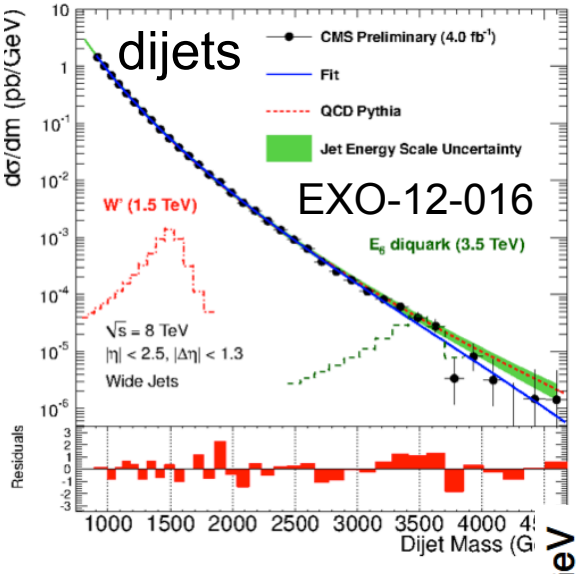


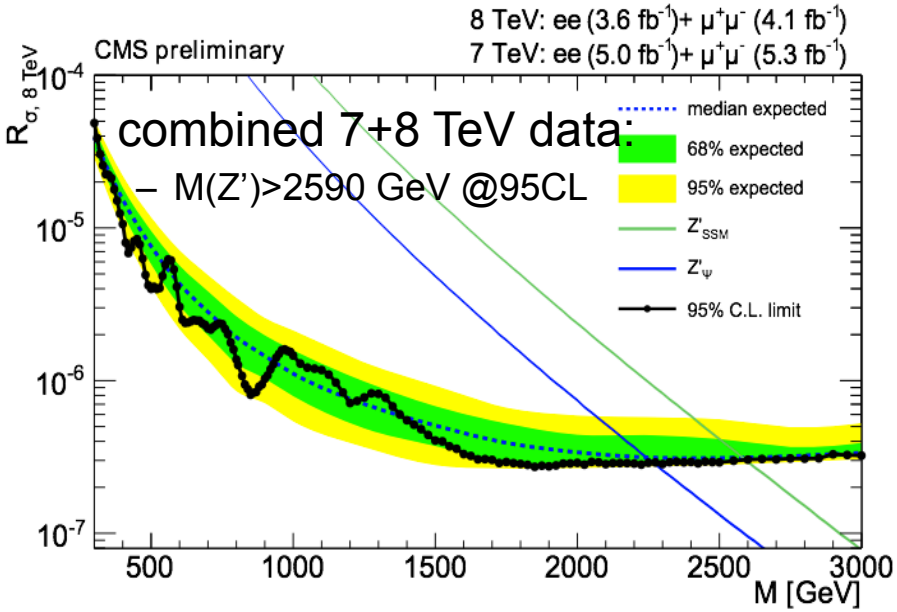
EXO-12-010



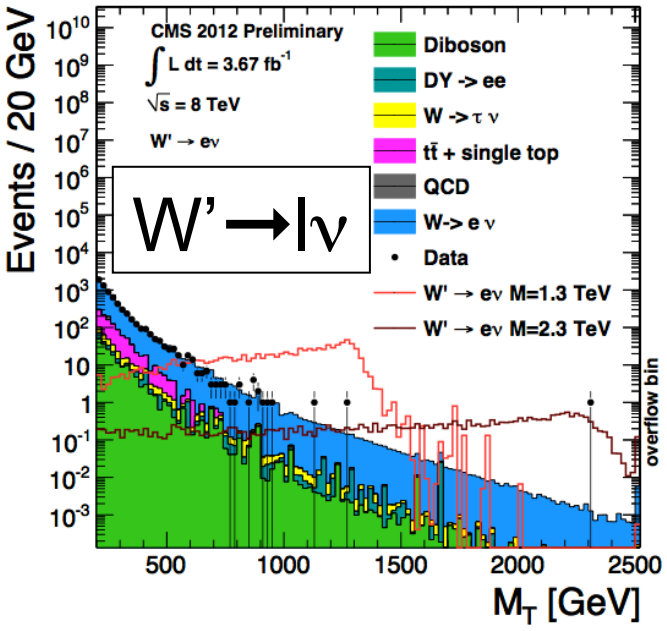
Exotica at 8 TeV: Z'/W'/dijets







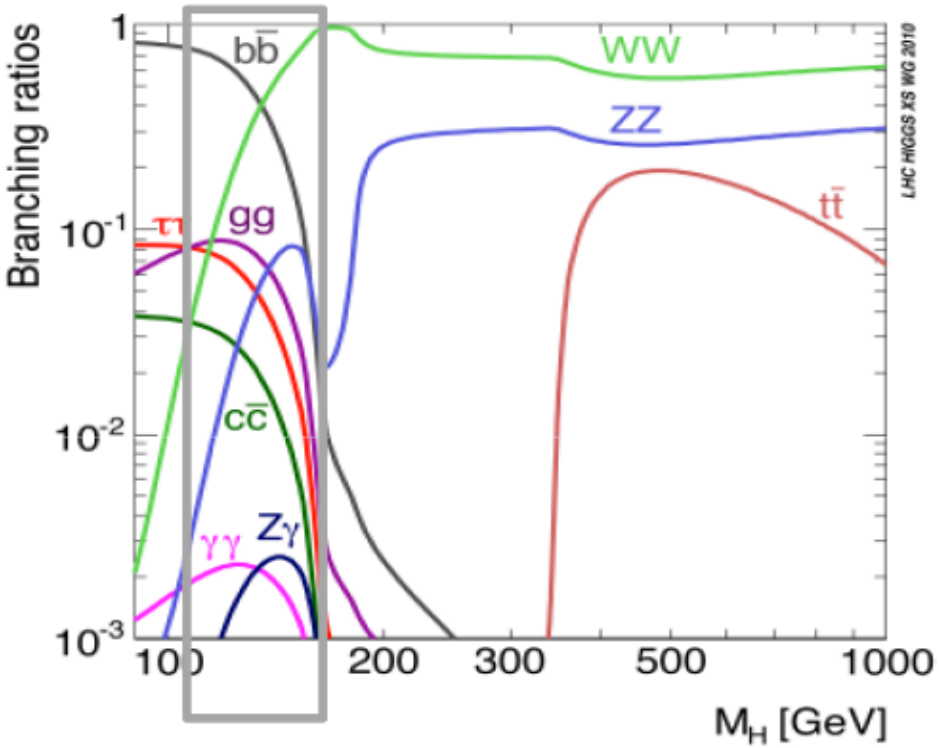
EXO-12-010



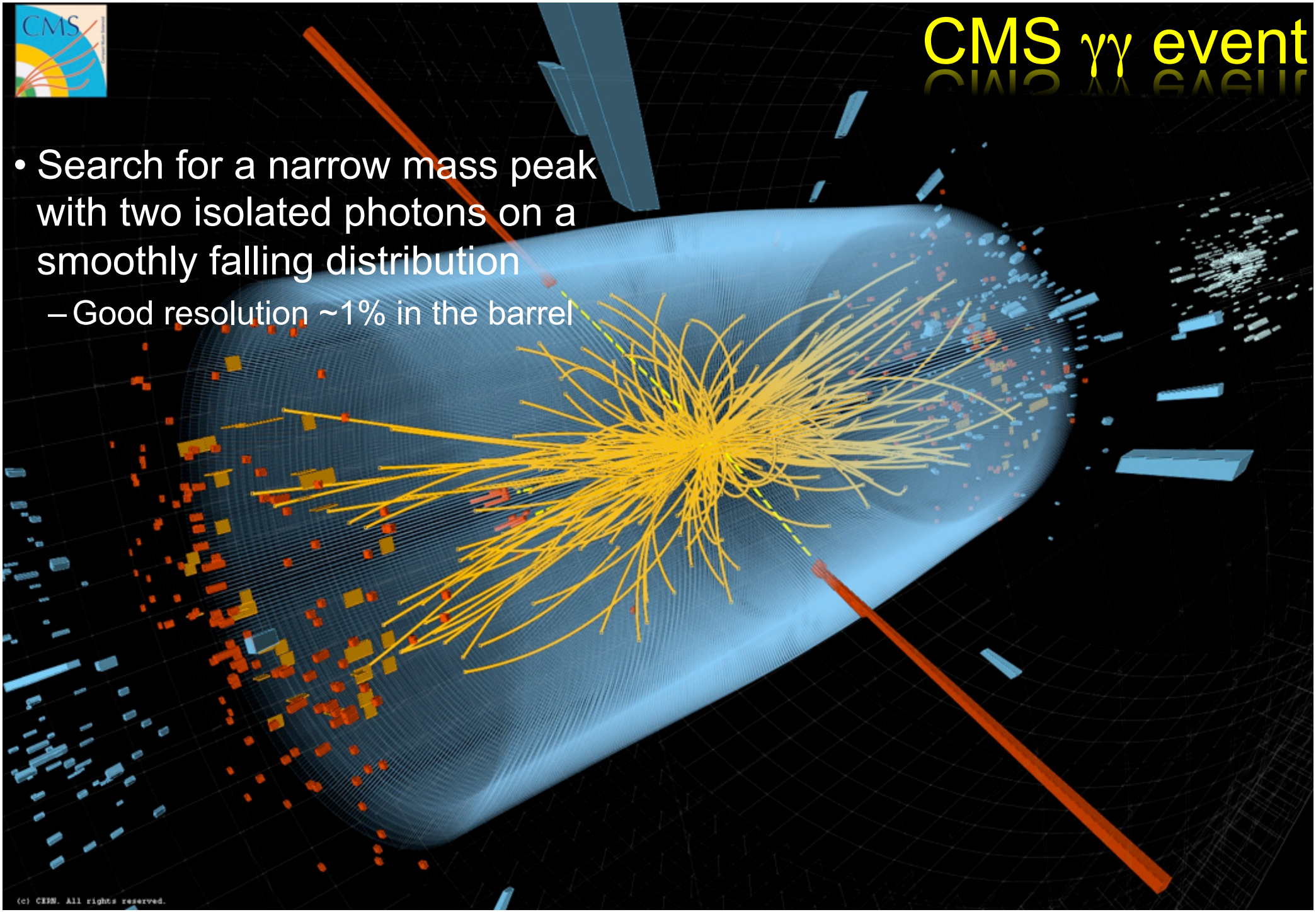
Higgs boson

5 decay modes studied:

- High mass: WW, ZZ
- Low mass: bb, ττ, WW, ZZ, γγ
- Low mass region is very challenging
- Very good mass resolution ~1% (γγ, 4l)

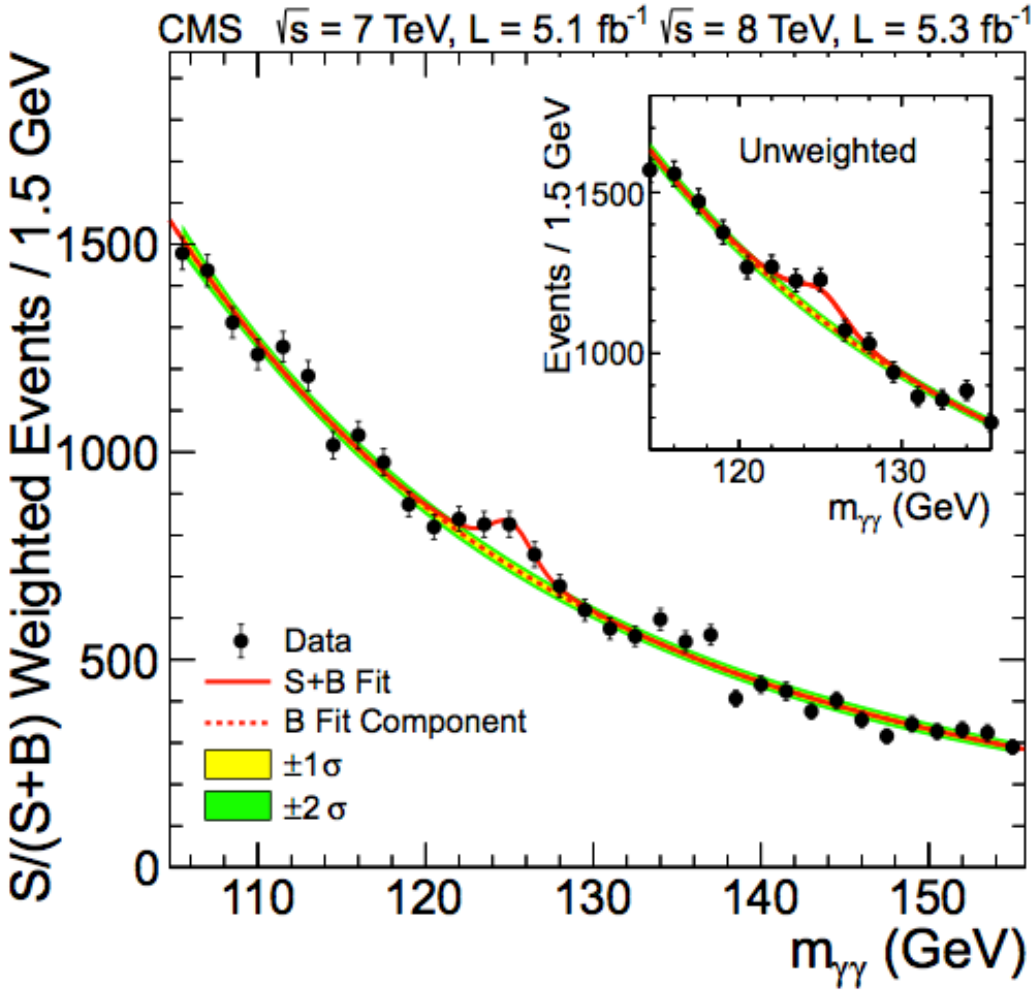


Decay mode	Production tagging	No. of subchannels	m_H range (GeV)	Int. Lum. (fb^{-1}) 7 TeV	8 TeV
γγ	untagged dijet (VBF)	4 1 or 2	110–150	5.1	5.3
ZZ	untagged	3	110–600	5.1	5.3
WW	untagged dijet (VBF)	4 1 or 2	110–600	4.9	5.1
ττ	untagged dijet (VBF)	16 4	110–145	4.9	5.1
bb	lepton, E_T^{miss} (VH)	10	110–135	5.0	5.1

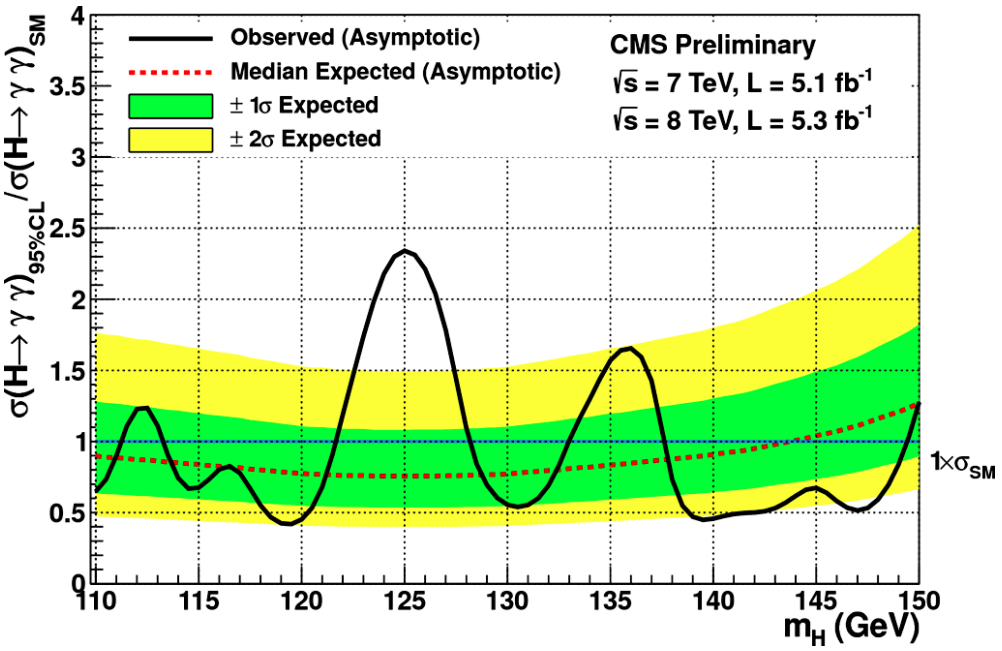

CMS γγ event
• Search for a narrow mass peak with two isolated photons on a smoothly falling distribution
– Good resolution ~1% in the barrel
(c) CERN. All rights reserved.

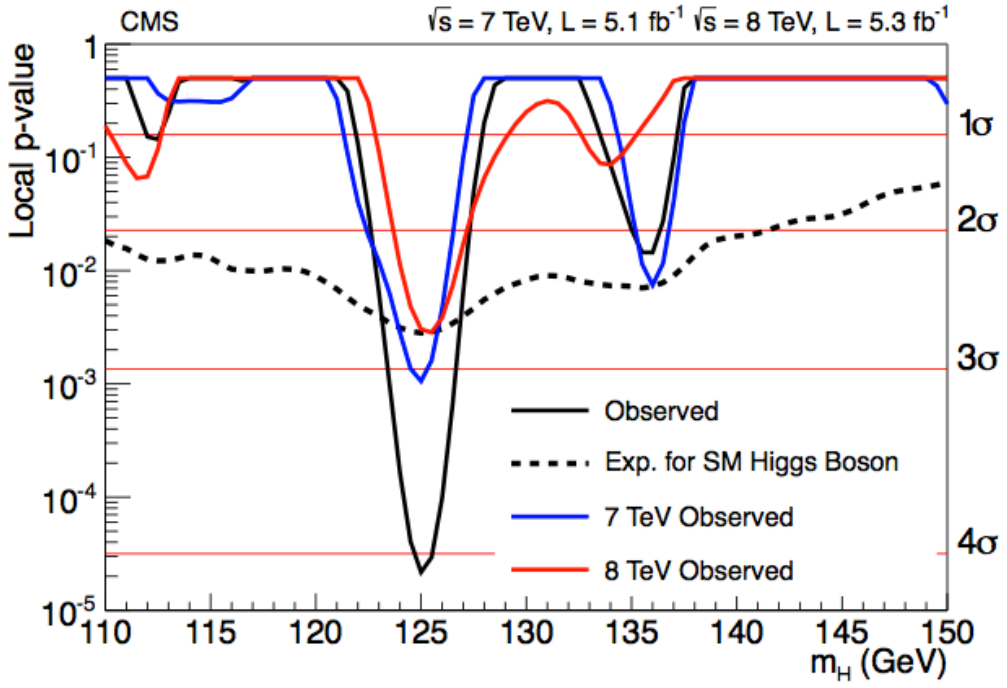
H→γγ: analysis strategy

- Analysis optimized by categorizing events by γ ID
  - MVA analysis for γ-ID and event classification
  - Divide events into non-overlapping samples
  - Cross-check with cut-based analysis
  - MVA gives ~15% better sensitivity



H→γγ: results

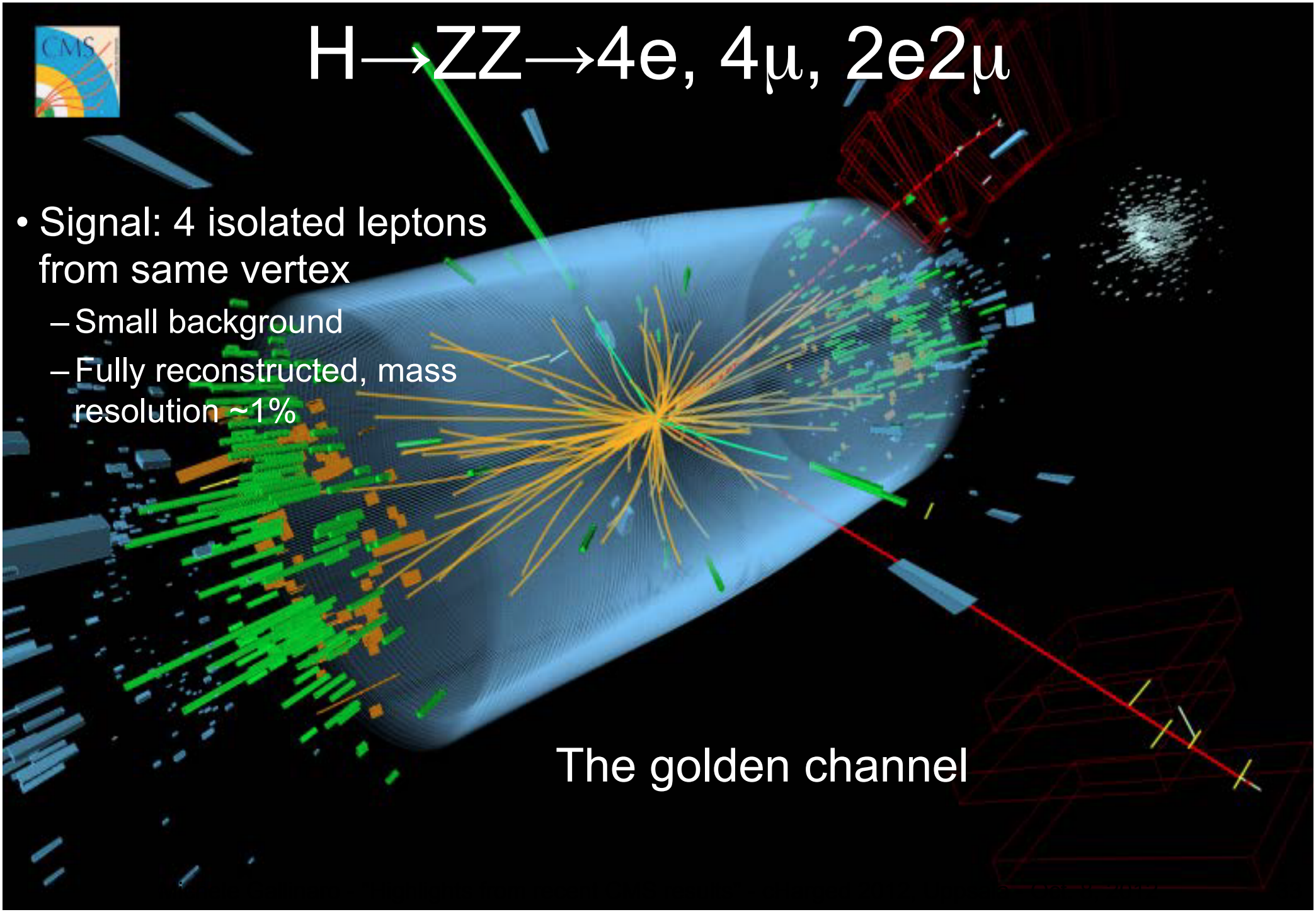




- Largest excess at ~125 GeV
  - Similar excess in 2011 and 2012

H→ZZ→4e, 4μ, 2e2μ

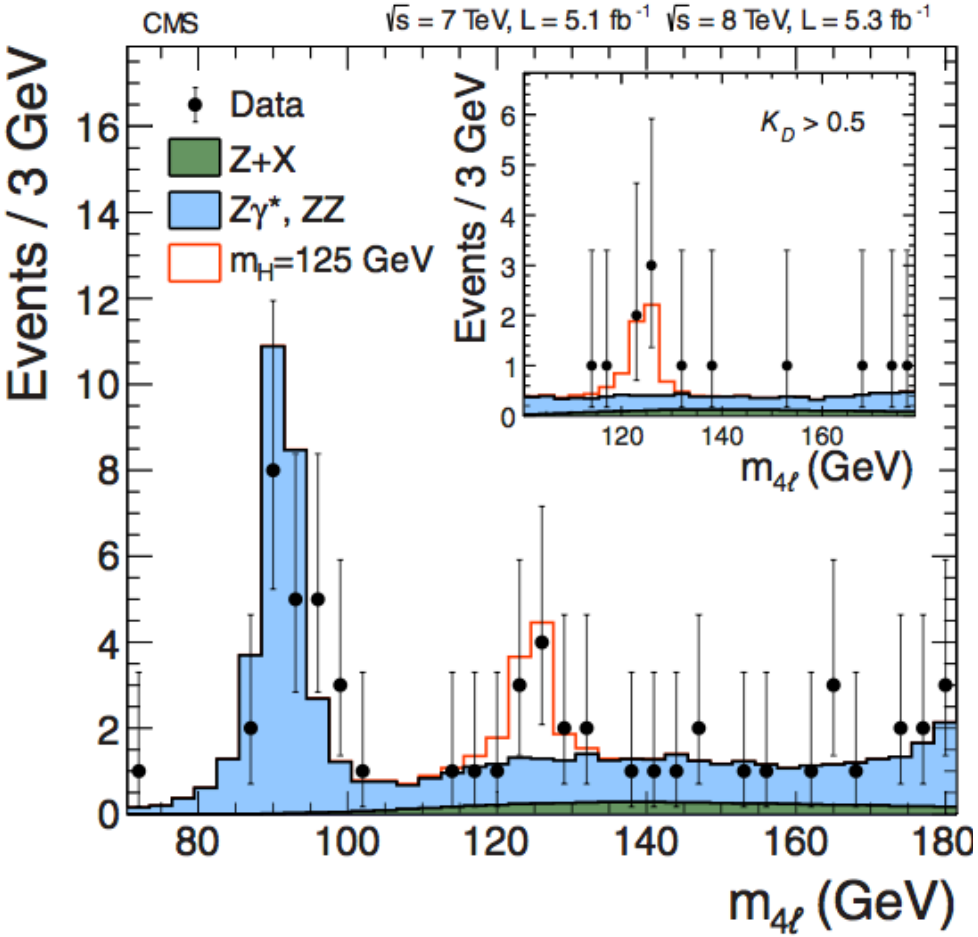
- Signal: 4 isolated leptons from same vertex
  - Small background
  - Fully reconstructed, mass resolution ~1%



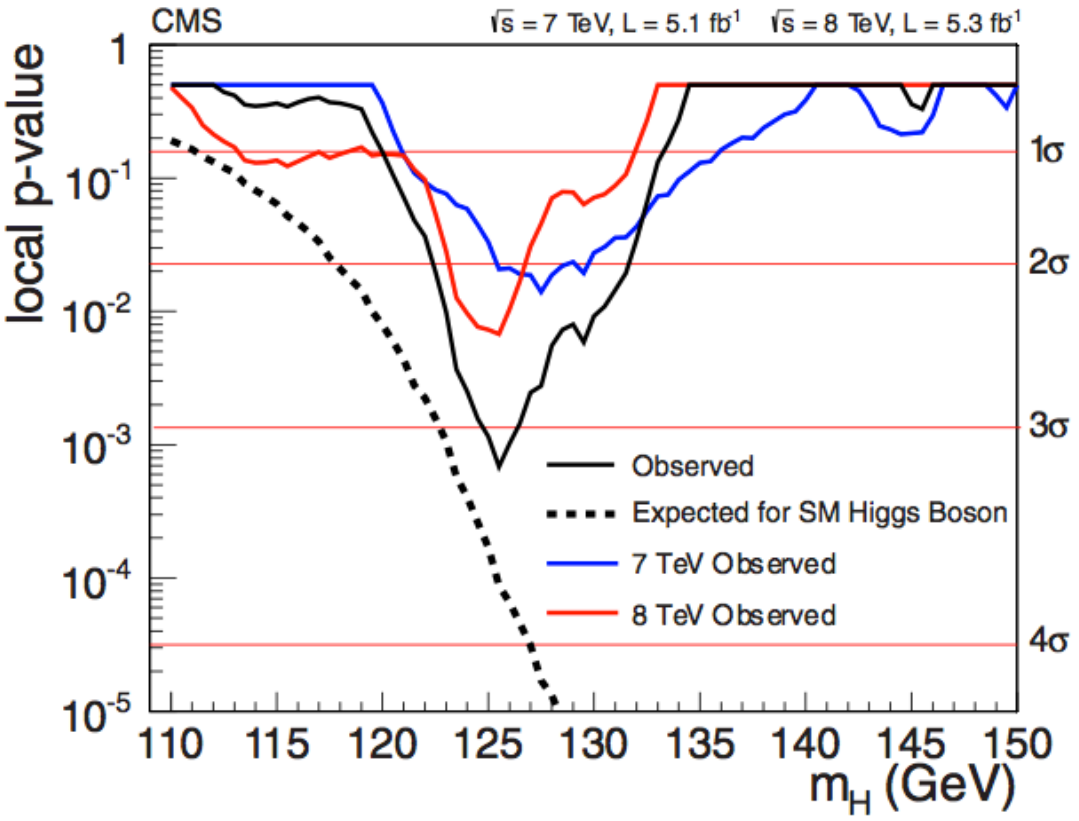
The golden channel

H→ZZ→4l

Mass distribution

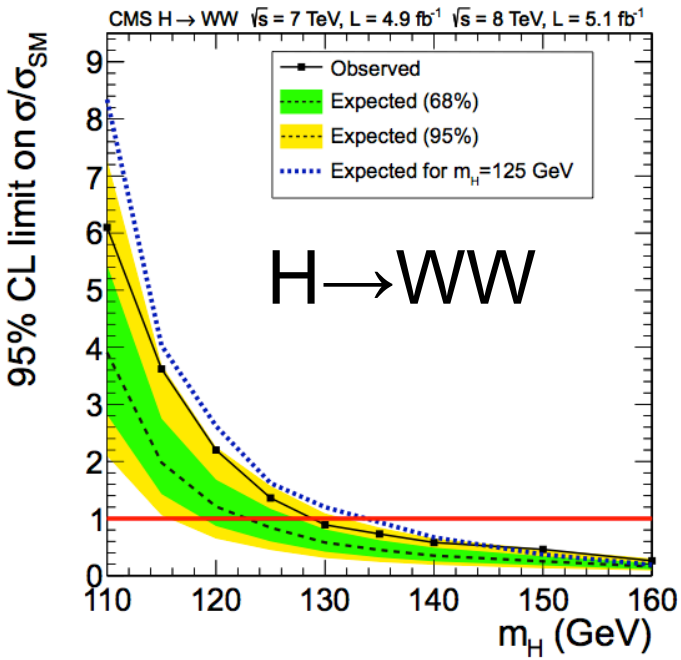


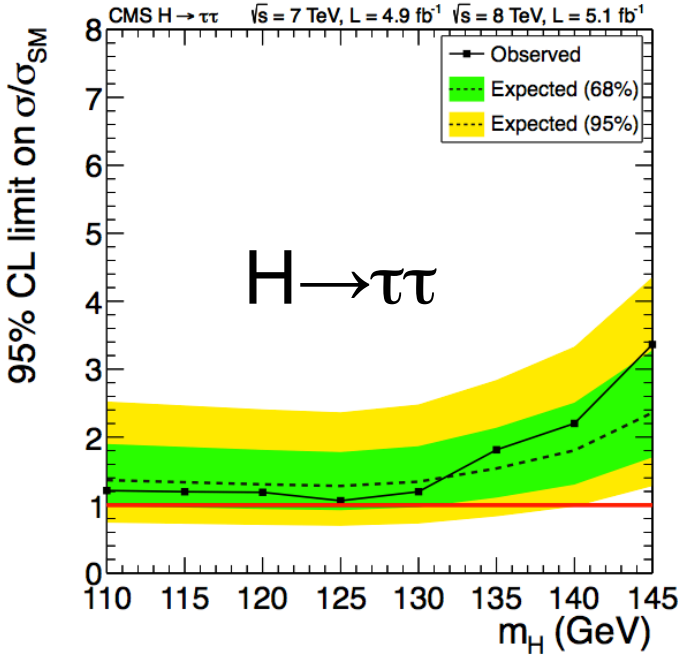
Significance slightly smaller than expectations

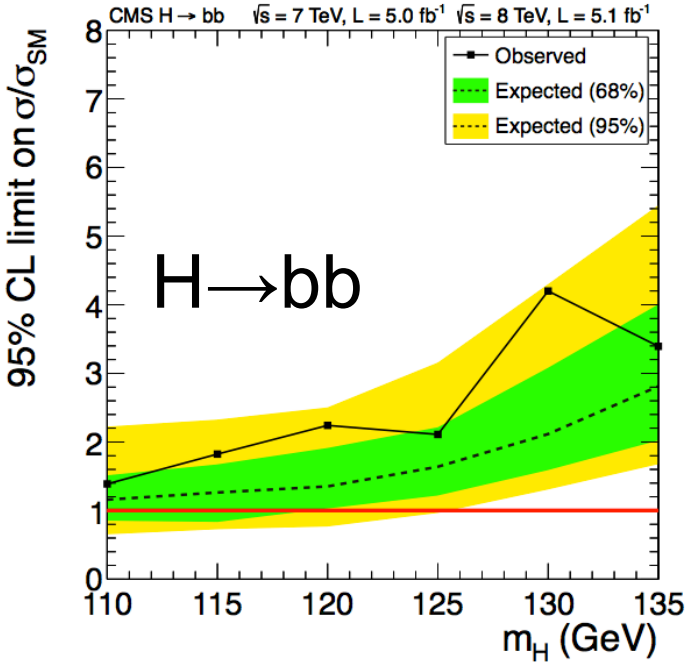


Low mass resolution channels

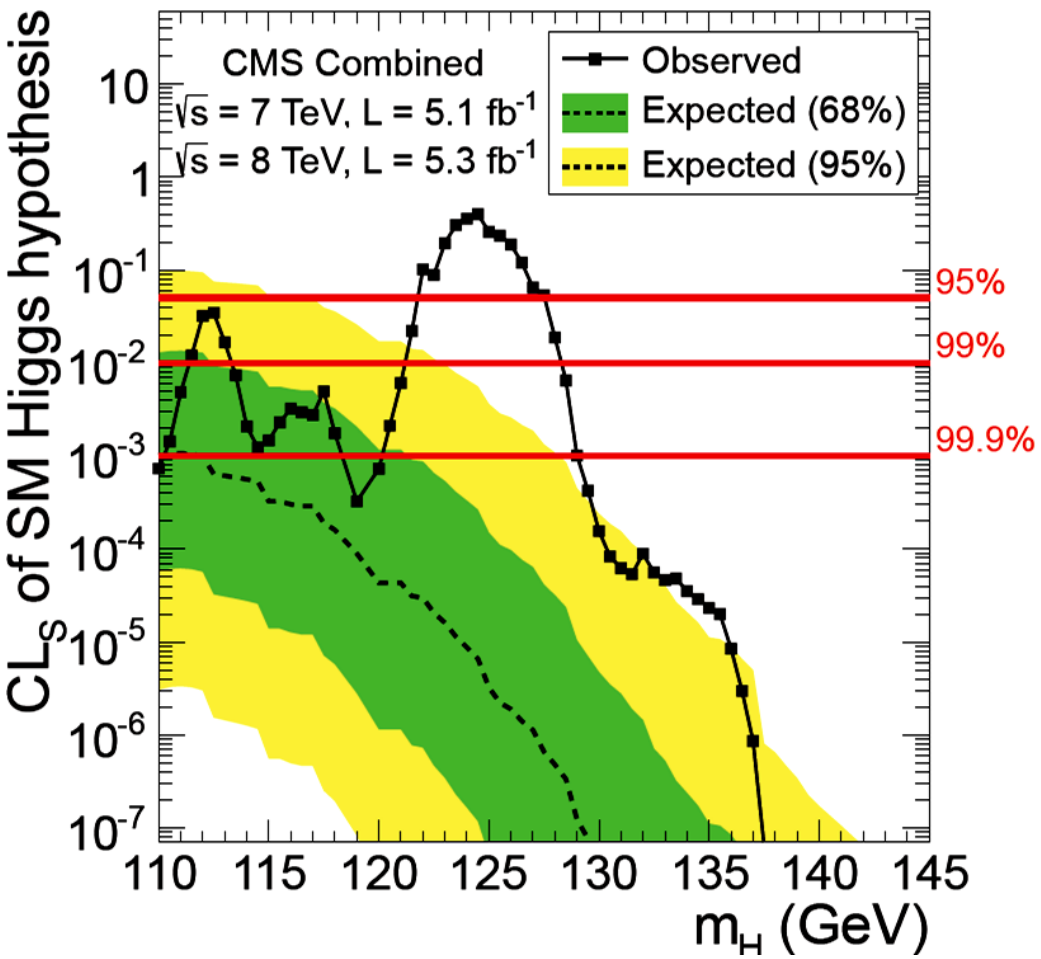
Decay mode	Production tagging	No. of subchannels	m_H range (GeV)	Int. Lum. (fb^{-1}) 7 TeV	8 TeV
WW	untagged dijet (VBF)	4 1 or 2	110–600	4.9	5.1
$\tau\tau$	untagged dijet (VBF)	16 4	110–145	4.9	5.1
bb	lepton, E_T^{miss} (VH)	10	110–135	5.0	5.1

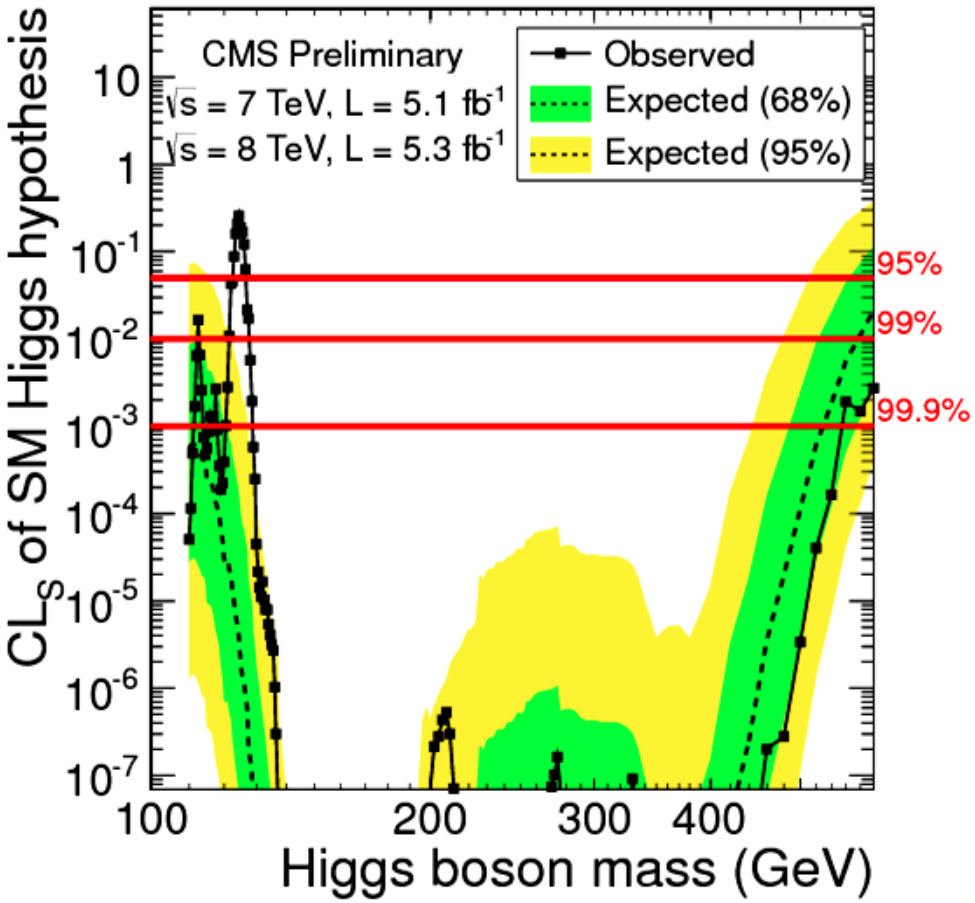






Combined: SM Higgs limits





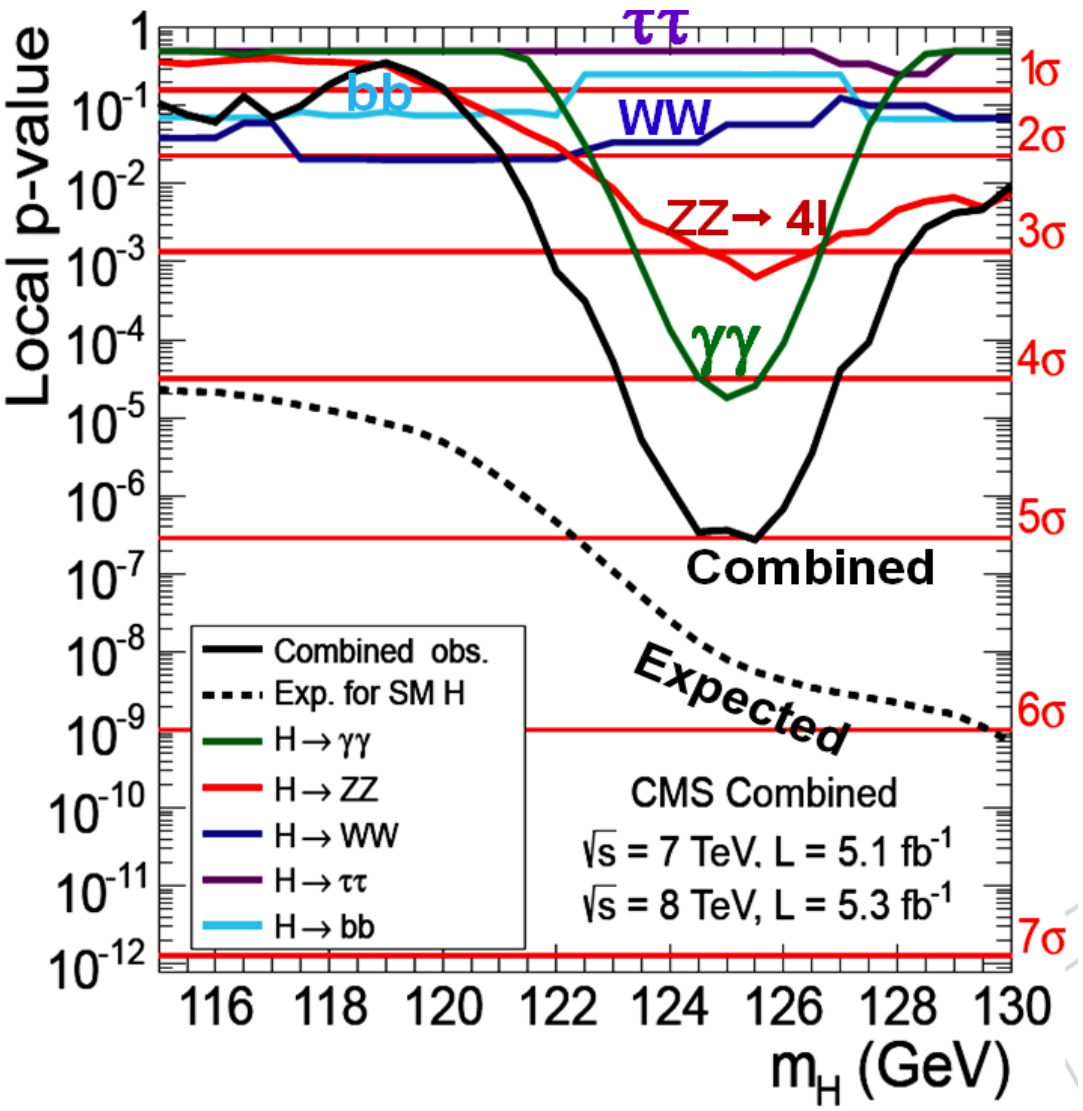
Combined results

Excess at 125 GeV:

- in 7 TeV data: 3.0 σ
- in 8 TeV data: 3.8 σ

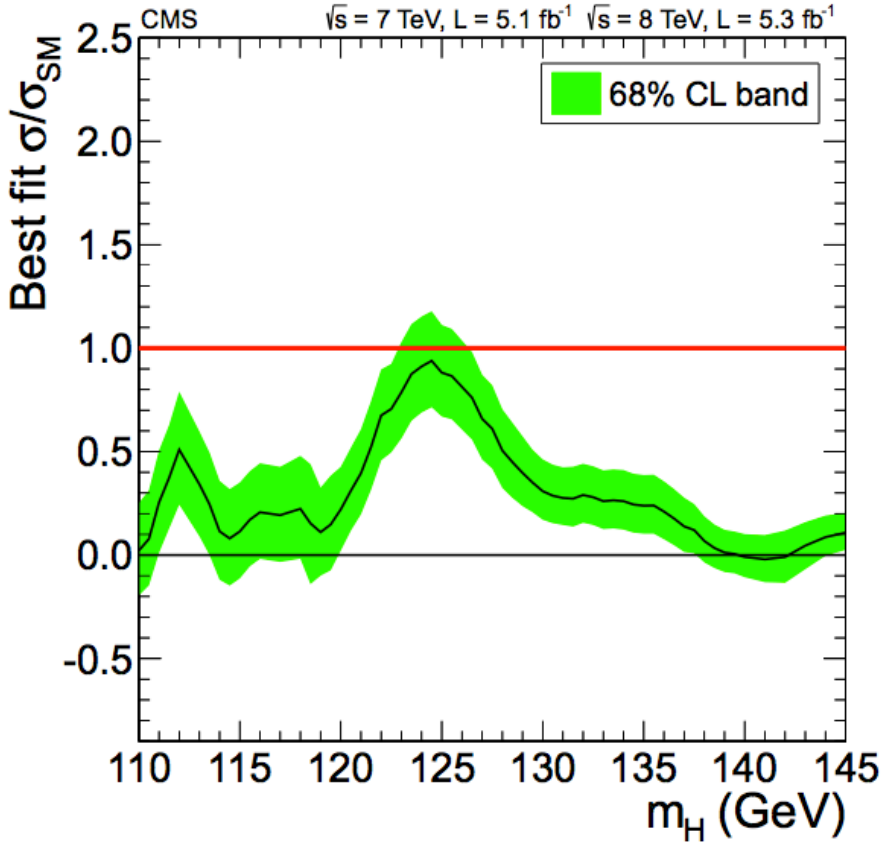
High sensitivity channels: γγ, 4l

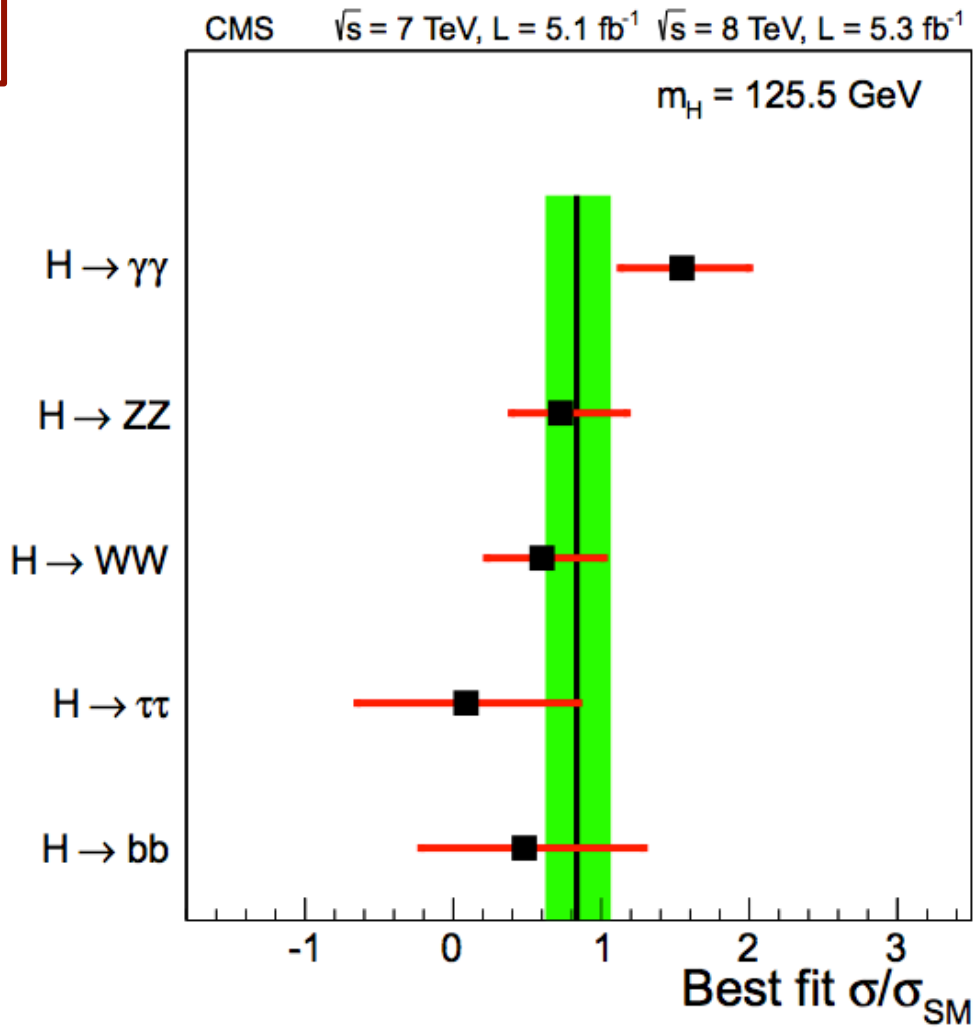
Decay mode/combination	Expected (σ)	Observed (σ)
$\gamma\gamma$	2.8	4.1
ZZ	3.6	3.1
$\tau\tau$ + bb	2.4	0.4
$\gamma\gamma$ + ZZ	4.7	5.0
$\gamma\gamma$ + ZZ + WW	5.2	5.1
$\gamma\gamma$ + ZZ + WW + $\tau\tau$ + bb	5.8	5.0



Combined results

Overall strength: $\sigma/\sigma_{SM}=0.87\pm0.23$

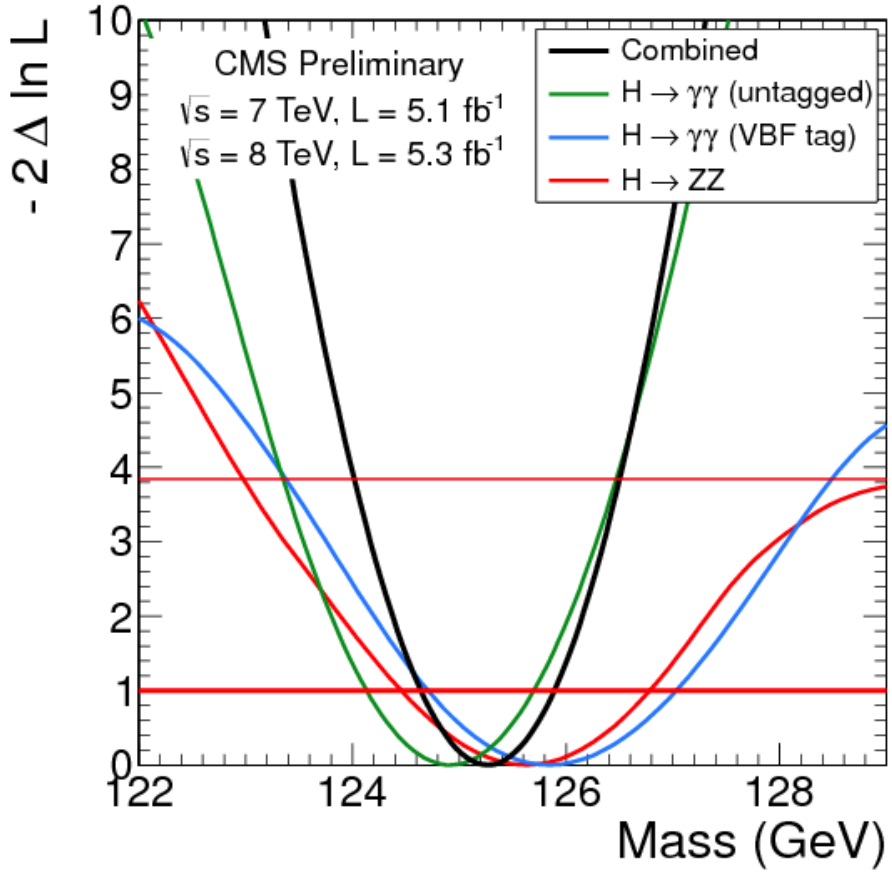


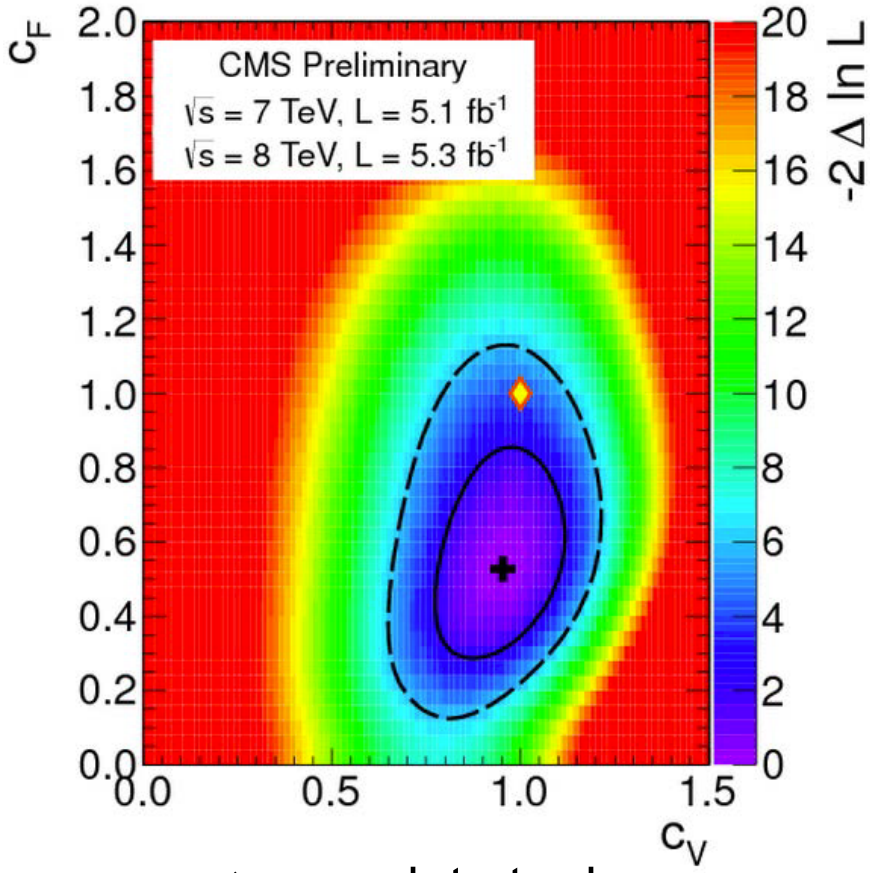


Mass & couplings

Model-independent mass measurement from high resolution channels:

⇒ m_X=125±0.4(stat)±0.5(syst) GeV

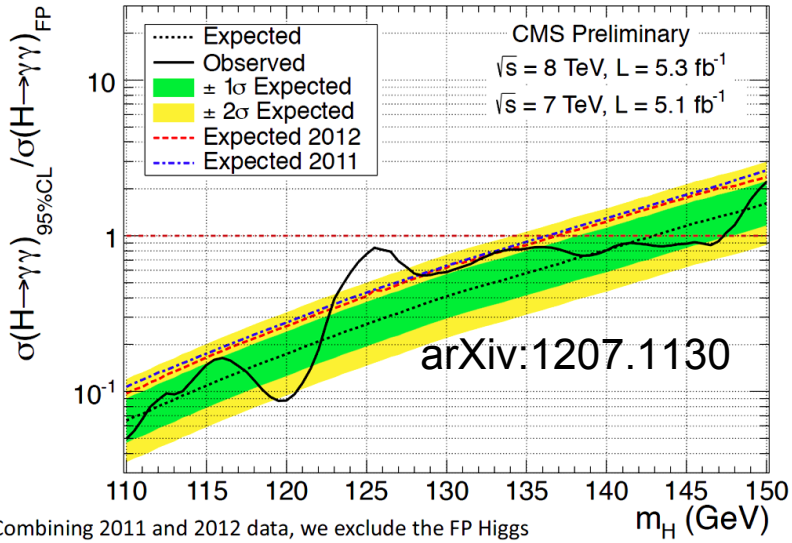




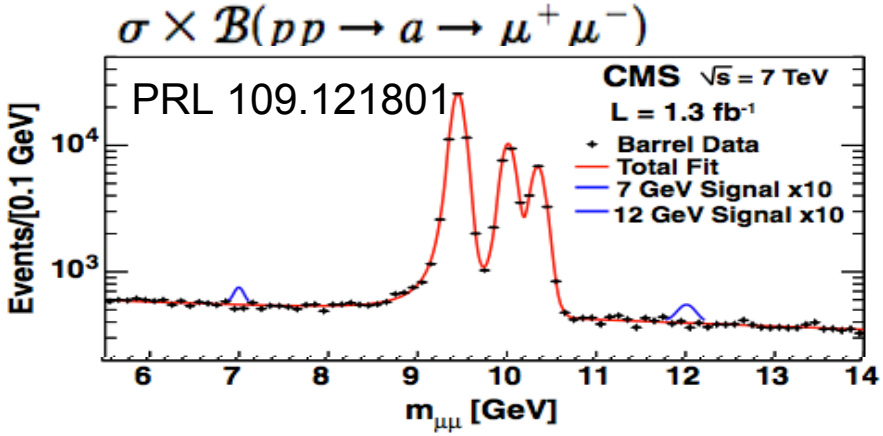
⇒more data to draw definite conclusions

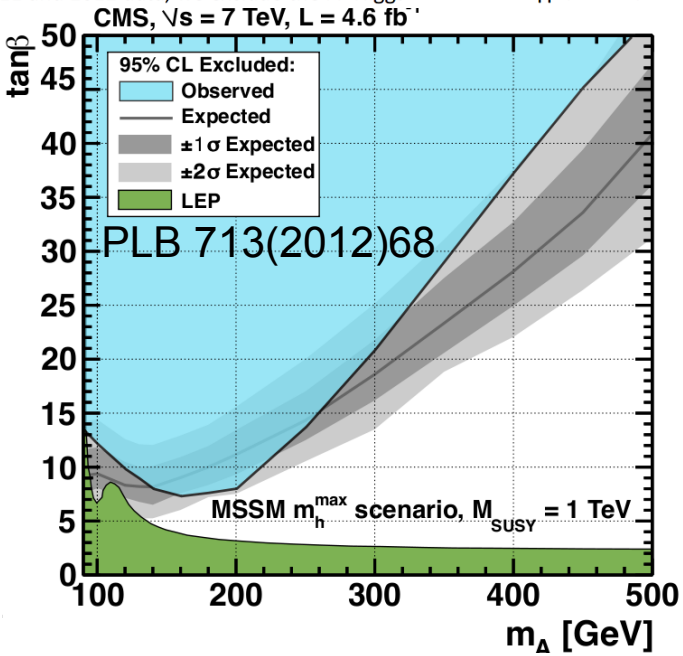
BSM Higgs overview

- Extensions to the SM:
  - Fermiophobic Higgs
- Supersymmetry
  - MSSM with 2 Higgs doublets:
    - $H^0 \to bb, \tau\tau$
    - $H^{\pm} \to \tau\nu$
- NMSSM with additional scalar field: $a \to \mu^+\mu$
  - Add scalar singlet to MSSM family



Combining 2011 and 2012 data, we exclude the FP Higgs

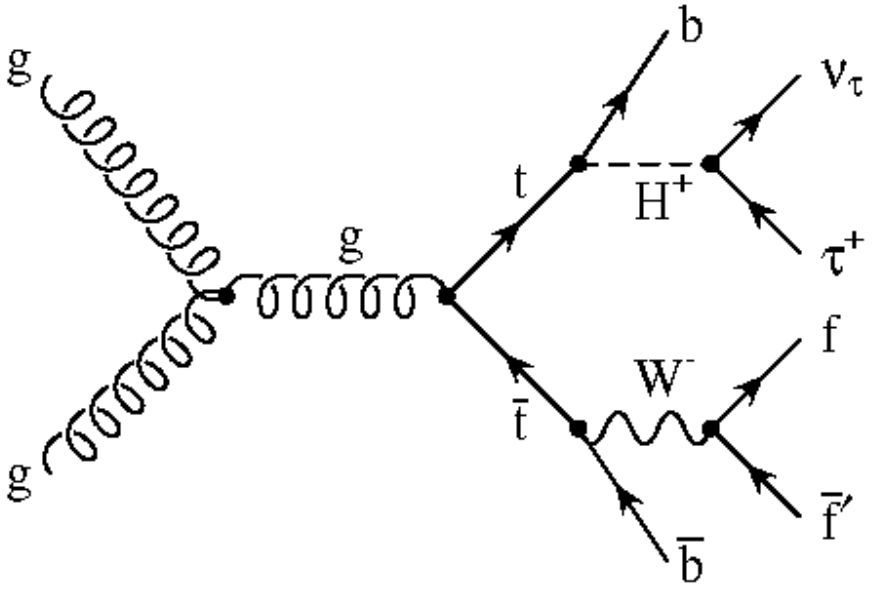




Charged Higgs

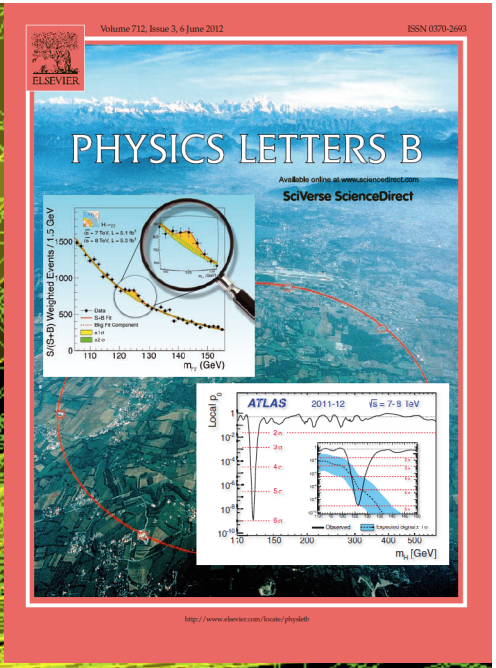
Look for three classes of events:

– Tau+jets, tau+lepton, eμ final states



Alexandros ATTIKIS: “Search for H+-> tau+nu with fully hadronic final state in CMS”
Pietro VISCHIA: “Search for H+-> tau+nu with l+tau(->had) and ll final states in CMS”
Aruna NAYAK: “Physics object reconstruction in CMS: tau, b-jets, Etmiss...”
Matti KORTELAINEN: “Data-driven background estimation in CMS”
Lauri WENDLAND: “Future H+ prospects at LHC”

Summary



- 2012 run at 8 TeV started very successfully
- Physics analyses in full force
  - Impressive turn-around of physics results

- Analysis of 2011+2012 data:
  ⇒discovered new boson with a mass of 125 GeV
- Looking forward to surprises