Strong and ElectroWeak Matter 2012, Swansea University

Latest Results of LHC: Atlas and CMS

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For the Atlas and CMS Collaborations

July 12, 2012

Outline

- LHC, ATLAS and CMS
- Physics results
  - Standard model
  - Exotics and Susy
  - Higgs

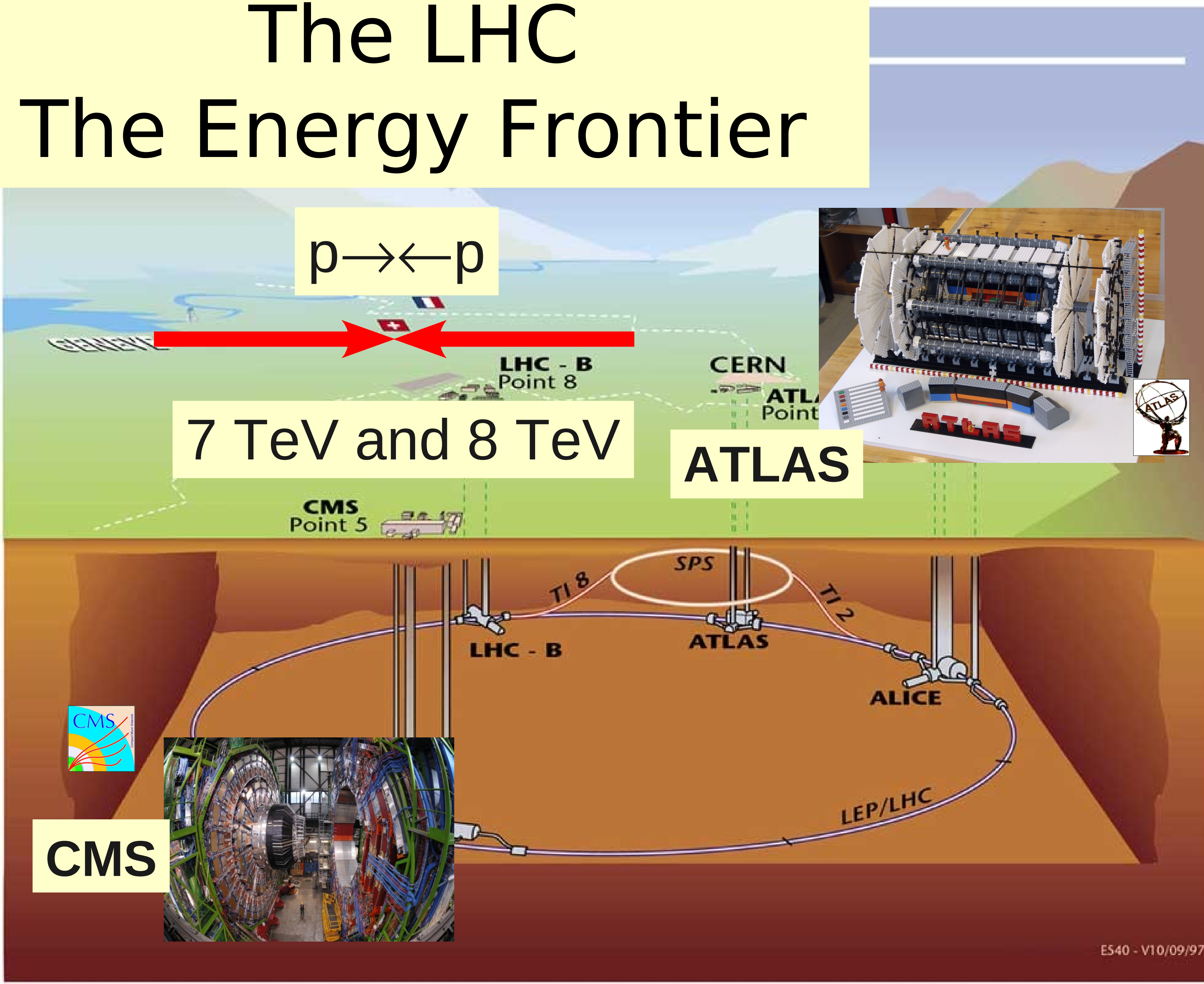
The LHC
The Energy Frontier

p→←p

7 TeV and 8 TeV

ATLAS

CMS



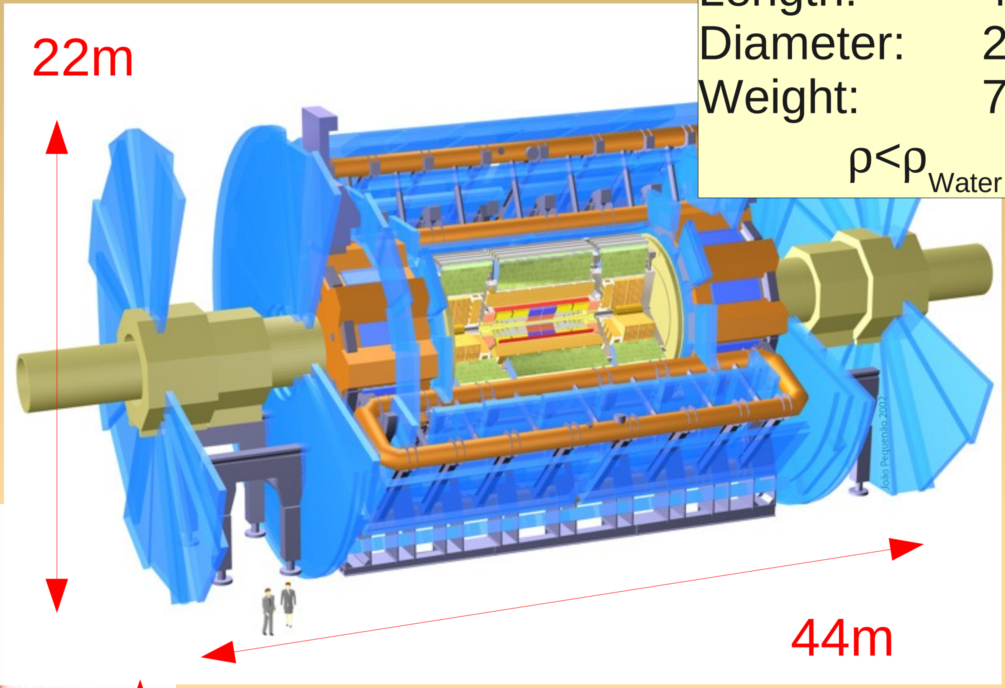
ATLAS and CMS

ATLAS:

Big and Light

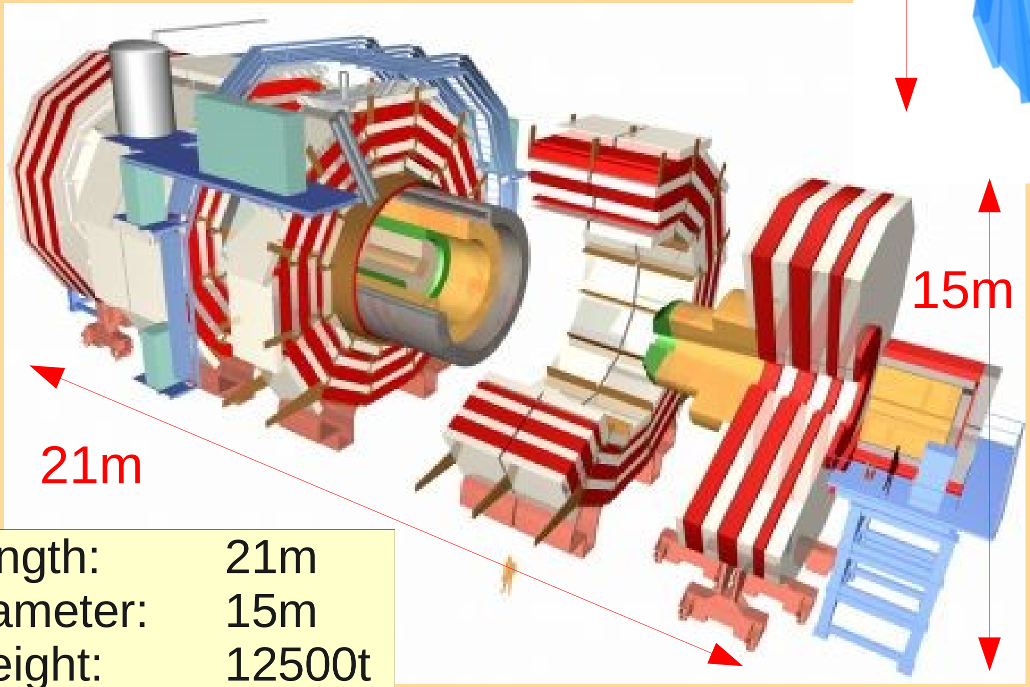
CMS:

Compact and Heavy



Length:	44m
Diameter:	22m
Weight:	7000t

$\rho < \rho_{Water}$



Length:	21m
Diameter:	15m
Weight:	12500t

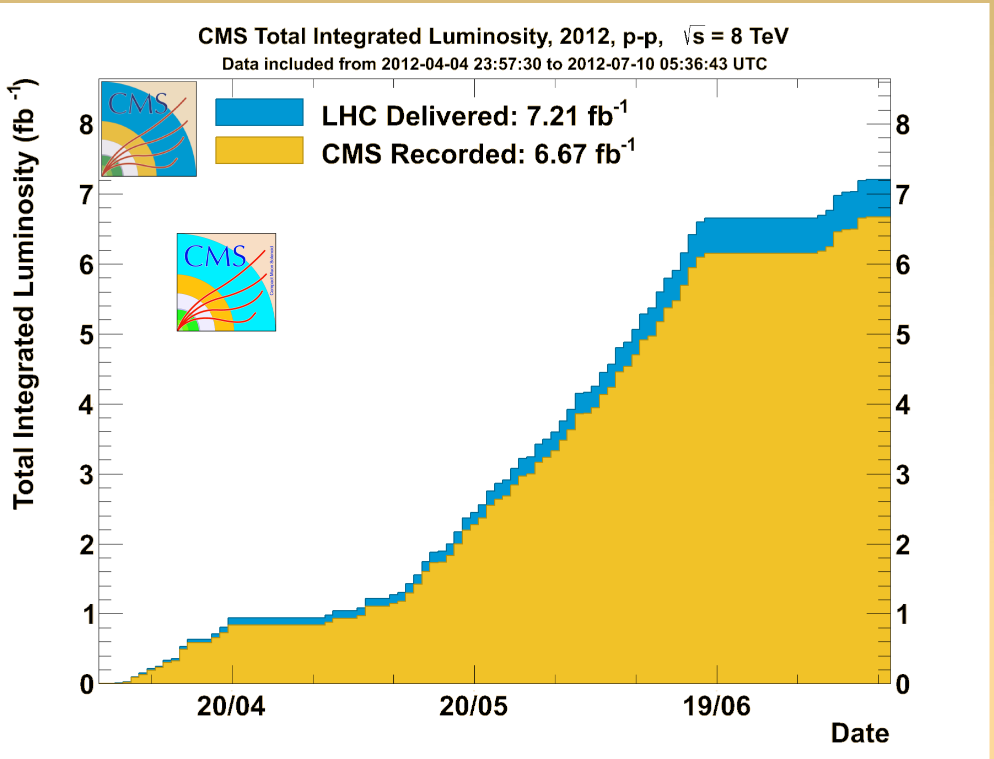
$\rho > \rho_{Water}$

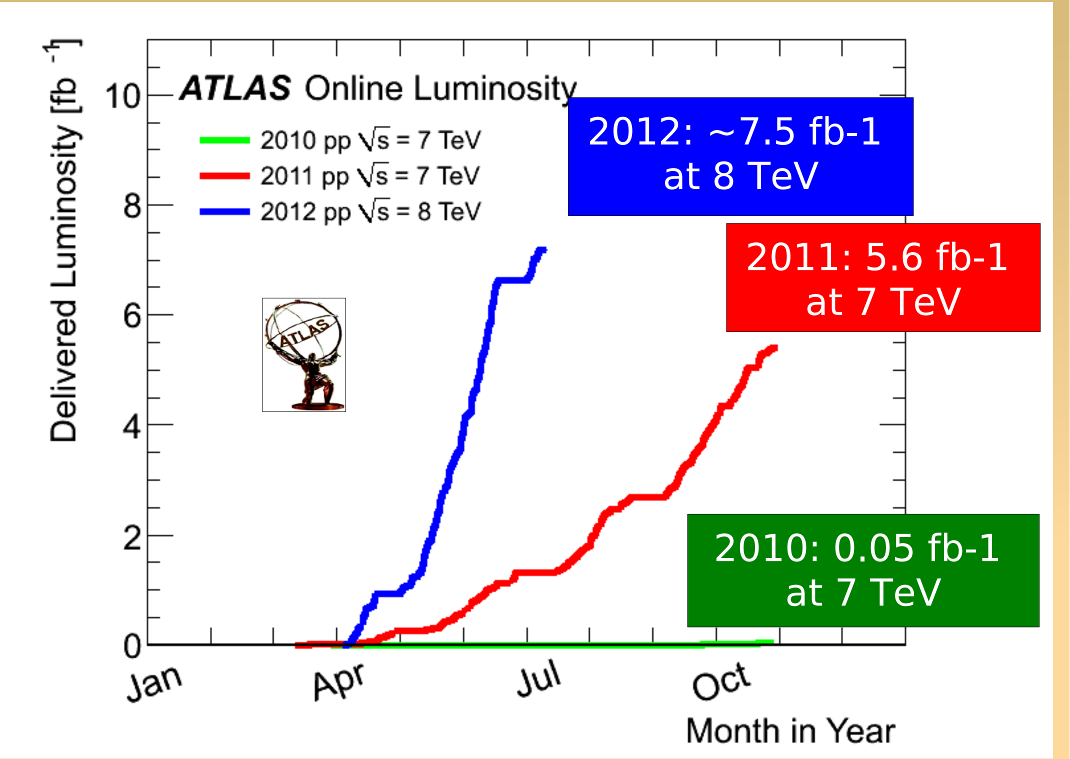
Mammoth collaborations

2x

>3000 collaborators from >170 institutes in >38 countries

LHC Operations

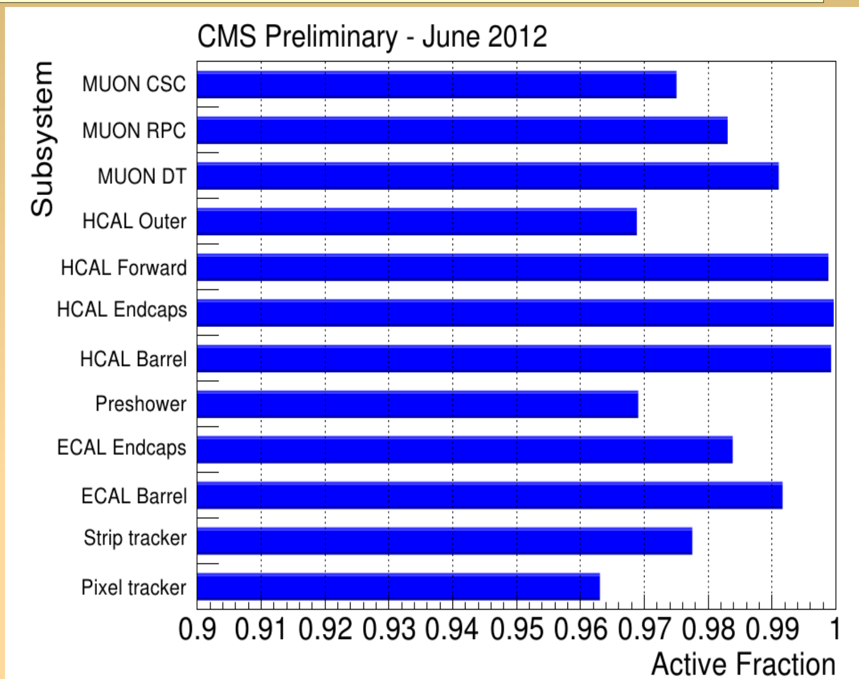




- LHC performance have been fantastic
- 2011-7TeV: reached **x5** goals in Luminosity; 5.3/5.7 fb^{-1} Atlas/CMS
- 2012-8TeV: goal is to deliver **20**$\mathbf{fb^{-1}}$ to experiments
  - running with max number of filled bunches (1380) Δt 50 ns spacing
  - more than 6fb^{-1} per experiment so far

Experiments Operations

Fraction of Active subsystems (CMS)



Fraction of Luminosity with good data-quality from the various subsystems (Atlas)

ATLAS 2012 p-p run										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
100	99.4	100	95.0	98.7	100	99.2	100	99.9	100	100

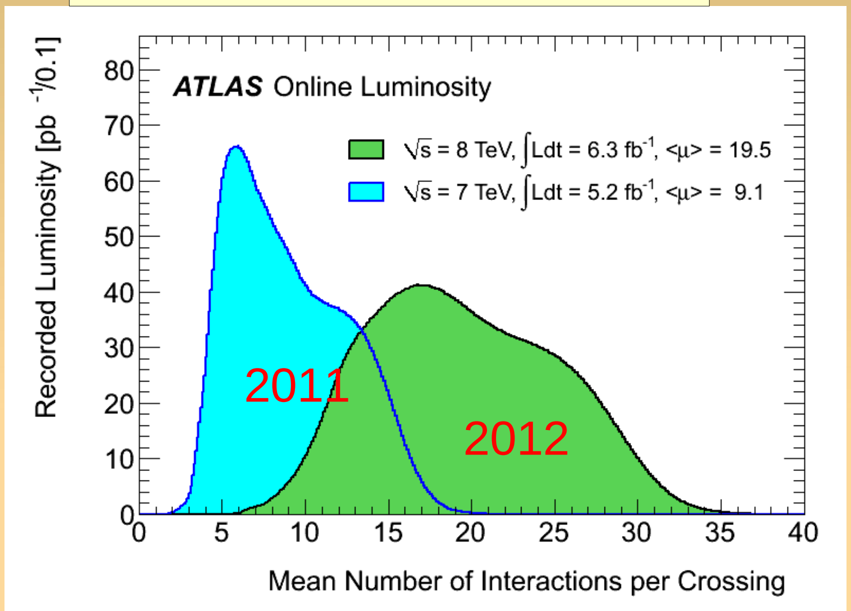
Luminosity weighted relative detector uptime and good quality data delivery during 2012 stable beams in pp collisions at $\sqrt{s}=8$ TeV between April 4th and May 31st (in %) – corresponding to 3.5 fb^{-1} of recorded data. The inefficiencies in the LAr calorimeter will partially be recovered in the future.

- Experiments operation quite outstanding too
- Close to 100% detector uptime: ~96%
- Close to 100% good quality data during stable beams: ~94%
- Detectors operating close to their highest:

  ~90% of Lumi used for analyses

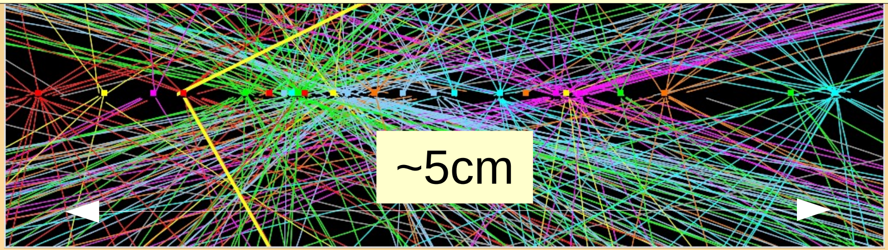
Pile-up: the challenge

Numbers of interactions per bunch crossing (ATLAS)



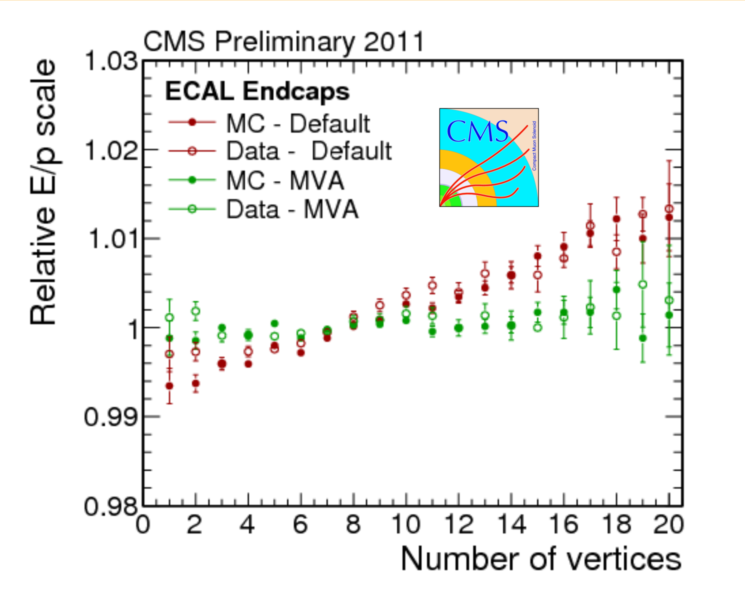
- 50 ns bunch spacing with higher than nominal bunch charges
- Pile-up much larger than expected

$Z \rightarrow \mu\mu$ event with 25 reconstructed vertices



Challenge for:

Tracking, isolation, Jet Energy Scale (JES)/resolution, Missing Transverse energy (MET)

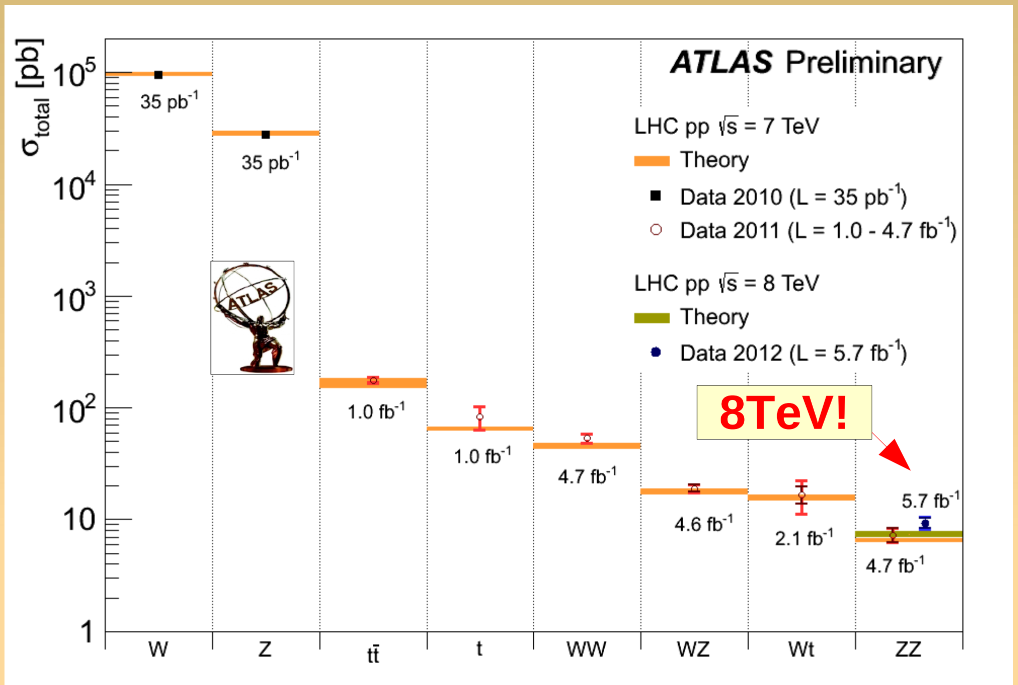


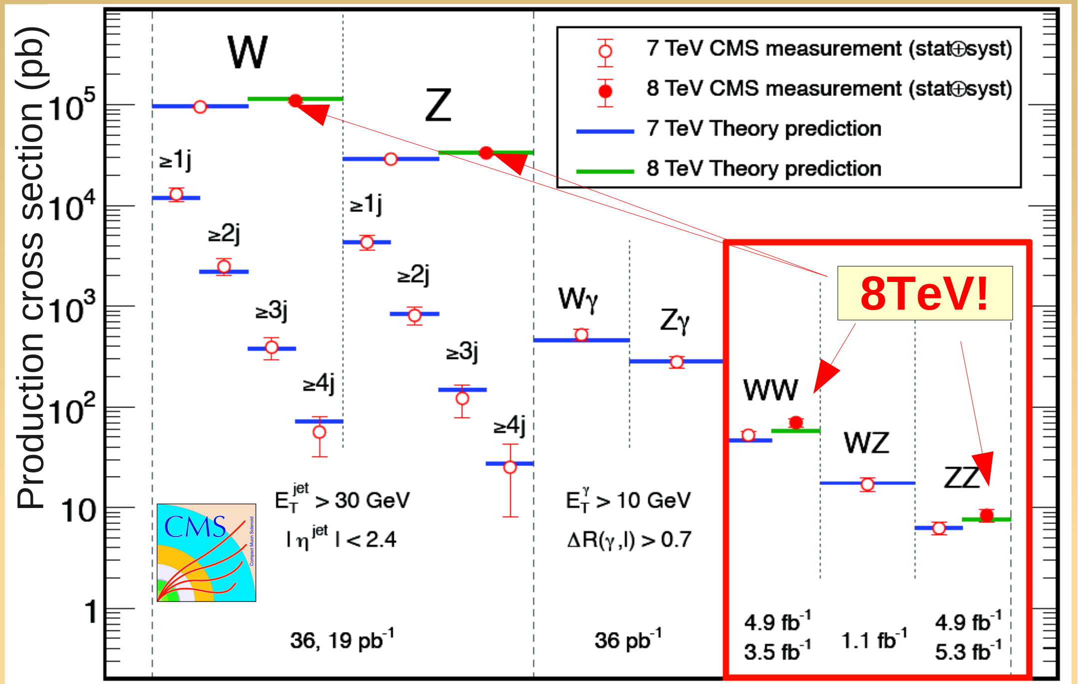
Energy scale dependence corrected with a multivariate analysis technique (CMS)

Physics Results

- Standard Model measurements
  - Cross-sections measurements
  - $Z \rightarrow 4l$
  - Di-Boson and anomalous Triple Gauge Couplings
  - Flavour Changing Neutral Current in $t\bar{t}$
- Beyond Standard Model: Exotics and Susy
  - Di-lepton resonance
  - Microscopic Black Holes
  - Direct production of light stop
- SM Higgs search

Cross sections measurements

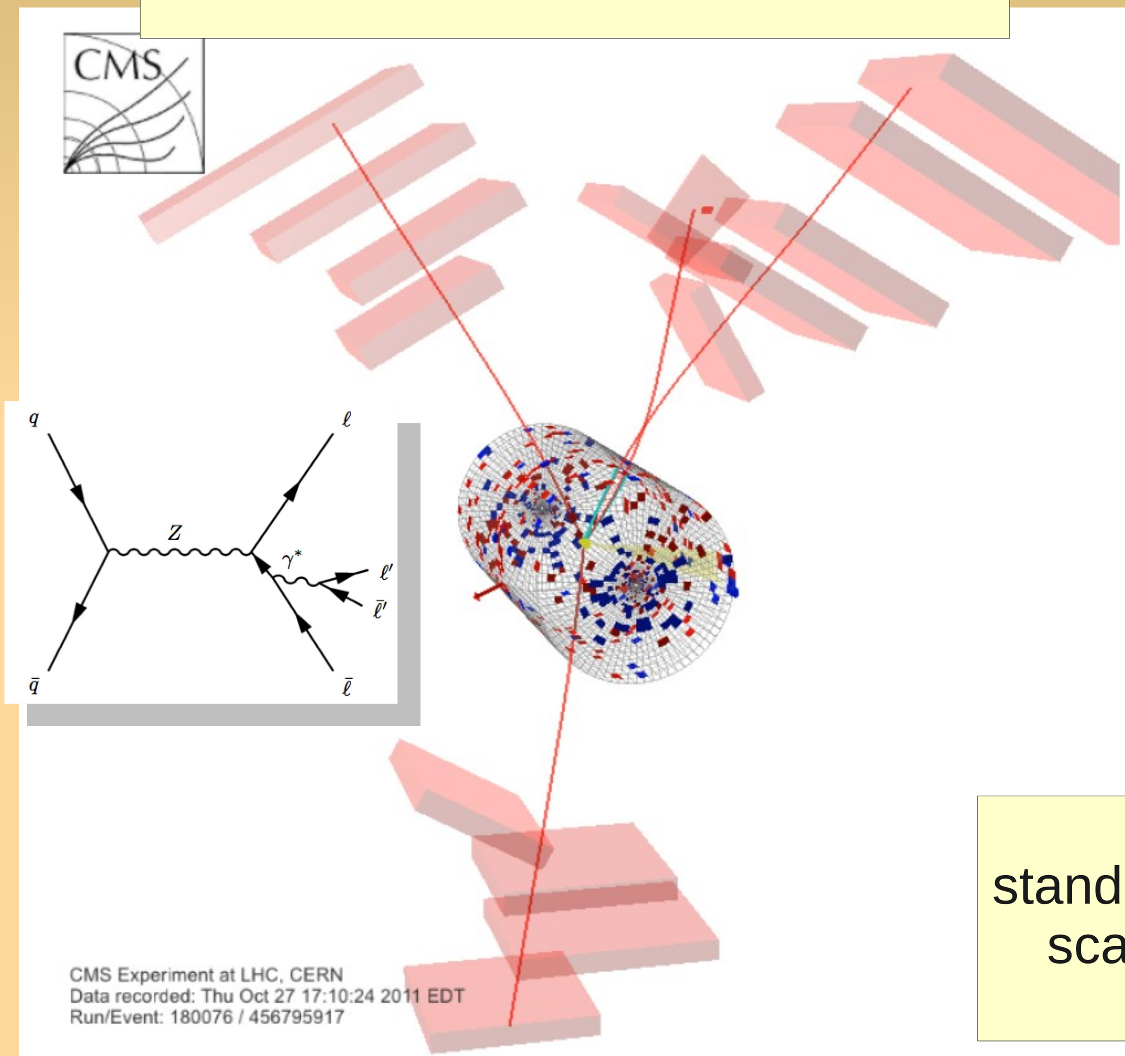


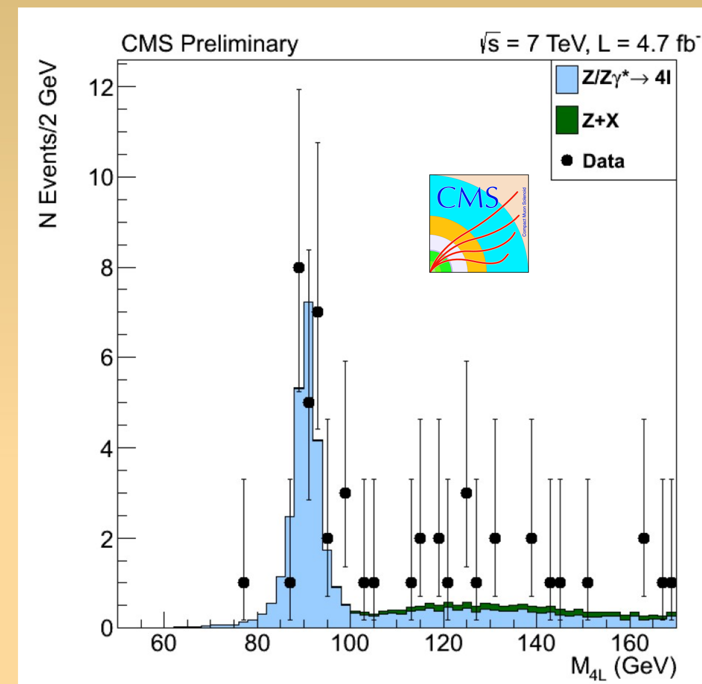


- Comparison to the predictions at NLO or more
- Agreement over ~4 orders of magnitude
- Validate detector/physics simulation, objects reconstruction, event selections and in general analysis techniques

Z→4l

Very simple process

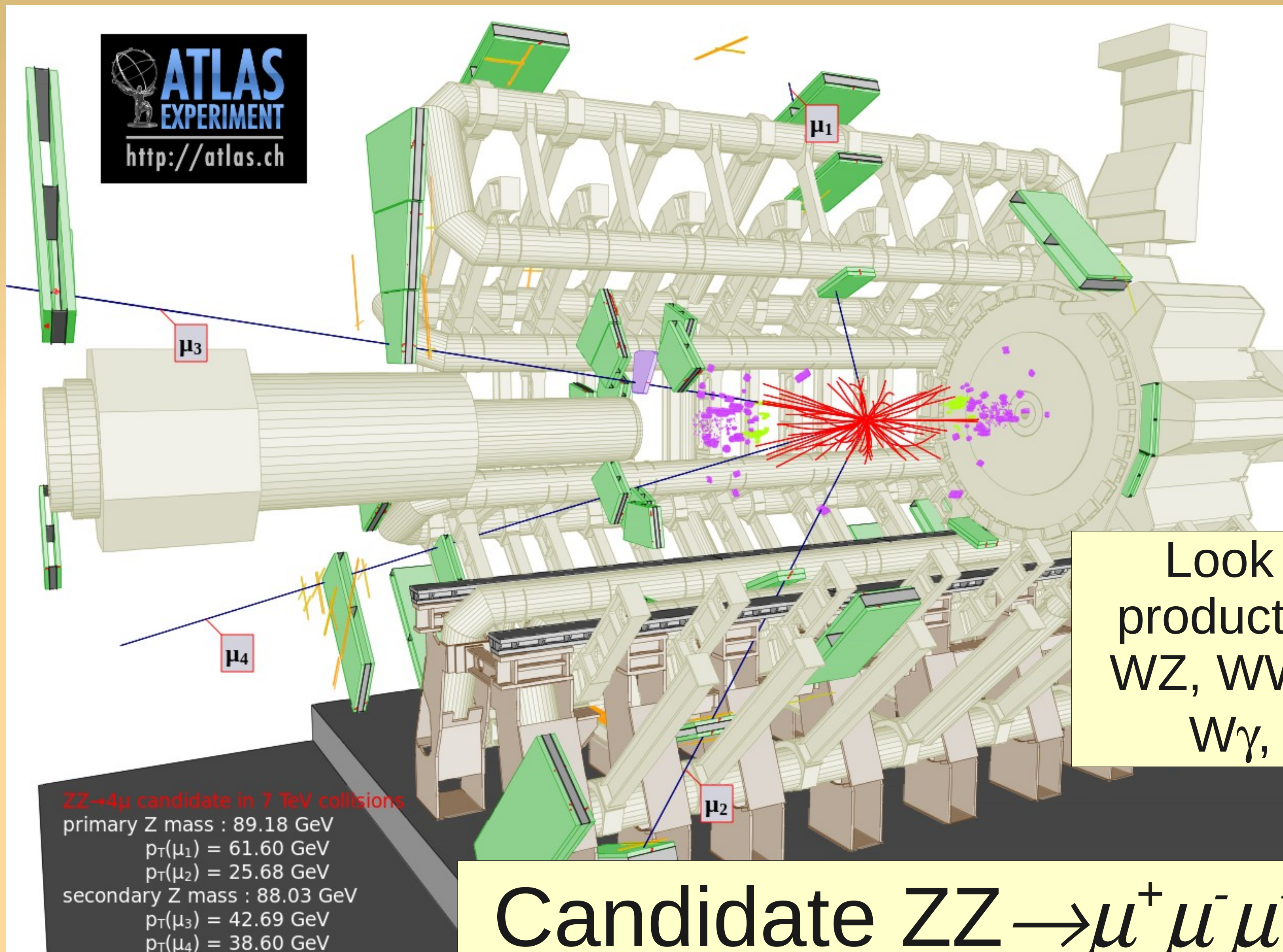




CMS: CMS-PAS-SMP-12-009

Clean resonant peak:
standard candle for calibration of the 4l mass scale and resolution and in phase space similar to the H 4l decays.

Di-Boson: ZZ→4l

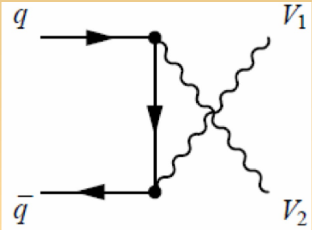


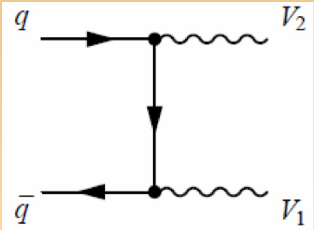
Look for production of WZ, WW, ZZ, Wγ, Zγ

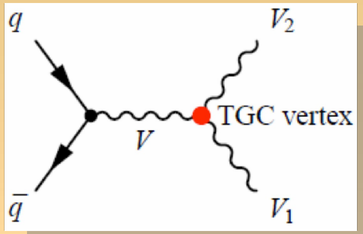
Candidate $ZZ \rightarrow \mu^+\mu^-\mu^+\mu^-$

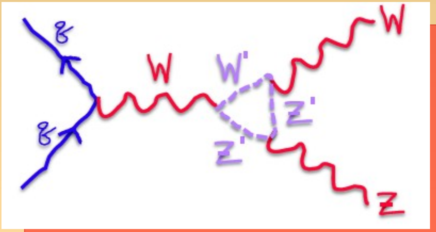
Di-Boson

- Tests of SM predictions
- Modelling of backgrounds for Higgs and for other searches
- Probe new phenomena: anomalous Triple Gauge Couplings







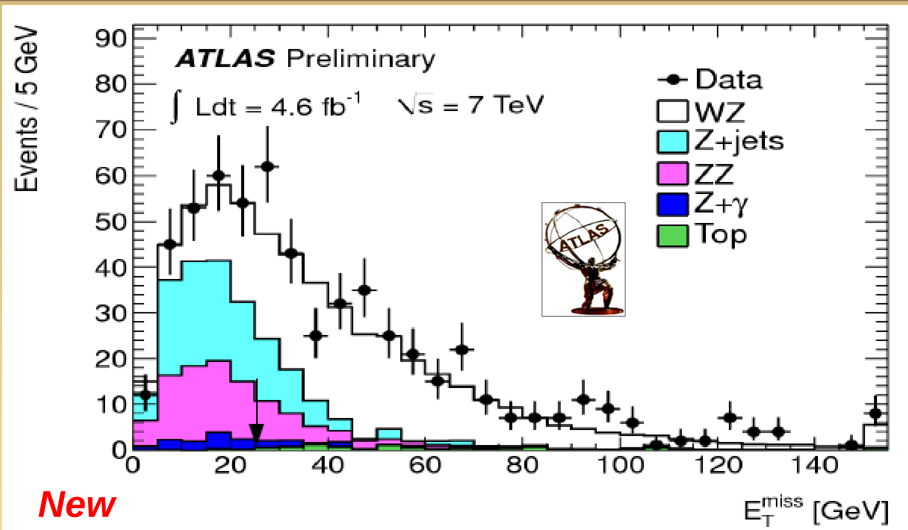


coupling	parameters	channel
$WW\gamma$	λ_γ, $\Delta\kappa_\gamma$	WW, $W\gamma$
WWZ	λ_Z, $\Delta\kappa_Z$, Δg_1^Z	WW, WZ
$ZZ\gamma$	h_3^Z, h_4^Z	$Z\gamma$
$Z\gamma\gamma$	h_3^γ, h_4^γ	$Z\gamma$
$Z\gamma Z$	f_{40}^Z, f_{50}^Z	ZZ
ZZZ	f_{40}^γ, f_{50}^γ	ZZ

- Effective Lagrangian for model independent triple gauge couplings depends on number of parameters
- Anomalous TGC modify total production rate as well as rate at high p_T

- Experimentally, sizeable clean signal using leptonic W/Z decay channels
- Isolated high pt leptons
- Data driven methods used as much as possible

Di-Boson: WZ→lνll



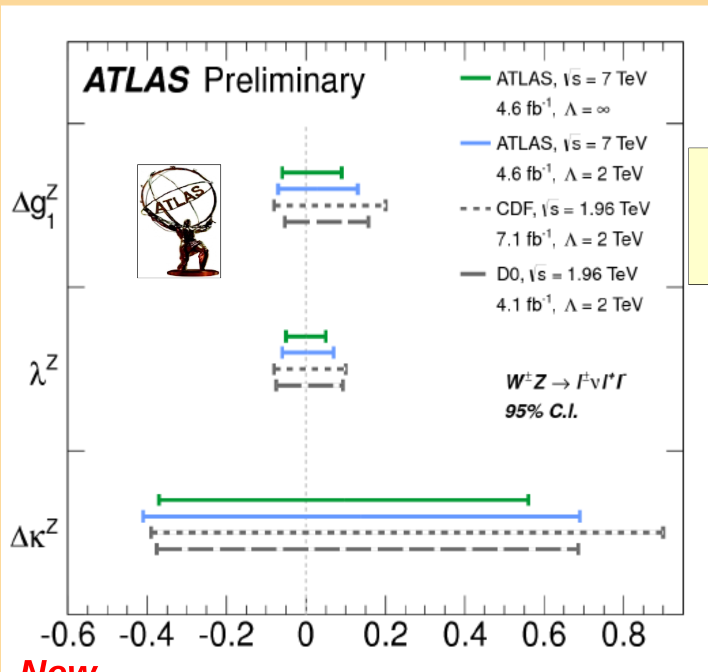
Backgrounds (S/B~4):
ZZ and W/Z+γ, from MC
W/Z+j, $t\bar{t}$,single t from Data Driven methods

$$ATLAS:(4.7\mathrm{fb}^{-1}) \quad \sigma_{WZ} = 19.0^{+1.4}_{-1.3}(stat) \pm 0.8(syst) \pm 0.4(lumi)\, pb$$

$$CMS:(1.1\mathrm{fb}^{-1}) \quad \sigma_{WZ} = 17.0 \pm 2.4(stat) \pm 1.1(syst) \pm 1.0(lumi)\, pb$$

$$\sigma_{WZ}^{SM}(NLO) = 17.6^{+1.1}_{-1.0}\, pb(Atlas\ estimate)$$

Good agreement with SM/NLO



Anomalous TGC limits based on Z p_T spectrum
Competitive with Tevatron limits

Less recent anomalous TGC limits from ZZ and WW channels are competitive with or more restrictive than LEP and Tevatron limits

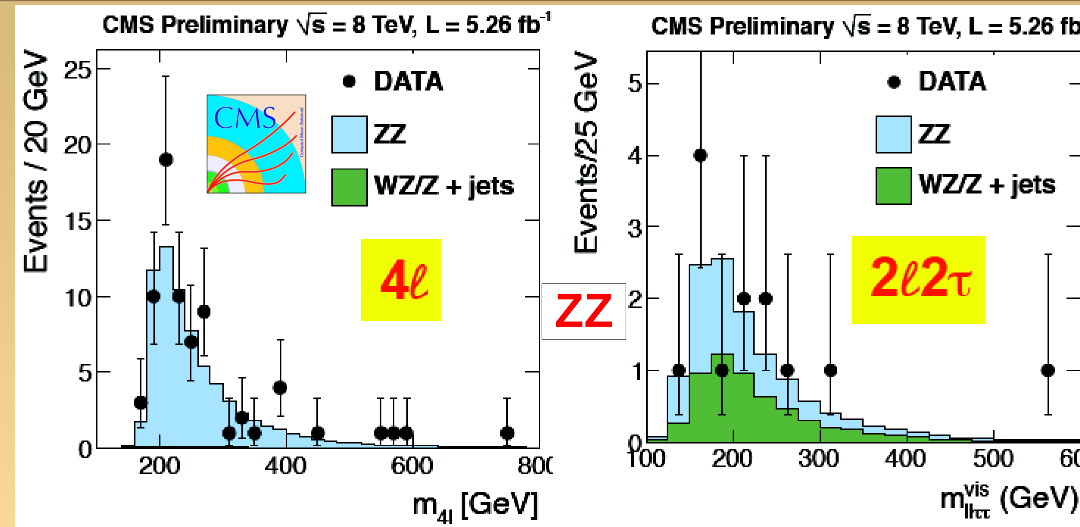
Measurements still dominated by statistic

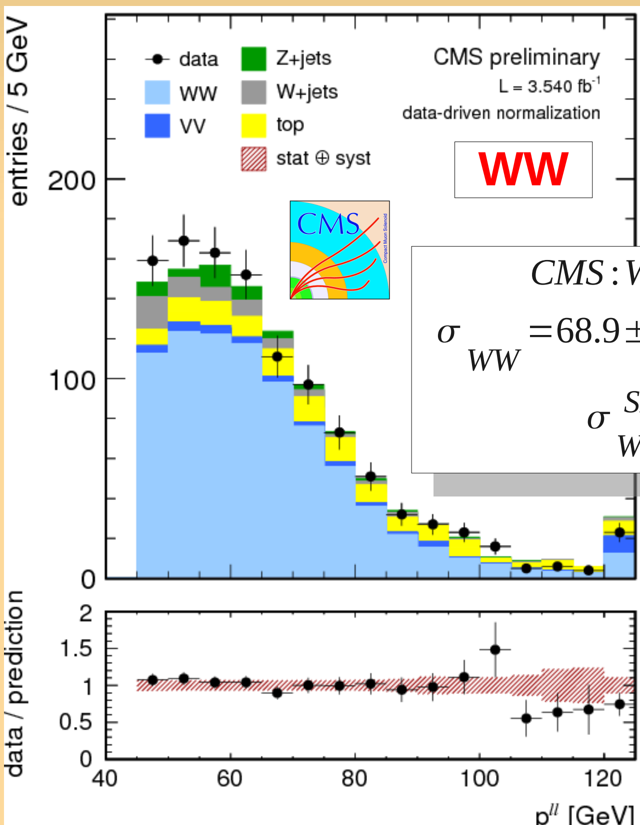
Di-Boson: WW and ZZ at 8TeV!!

$$CMS: ZZ \rightarrow 4l \quad 5.3\text{fb}^{-1} \; at \;\; 8\text{TeV}$$

$$\sigma_{ZZ} = 8.4 \pm 1.0 \pm 0.7 \pm 0.4\,(lumi)\, pb$$

$$\sigma_{ZZ}^{SM}(NLO) = 7.7 \pm 0.4\; pb$$

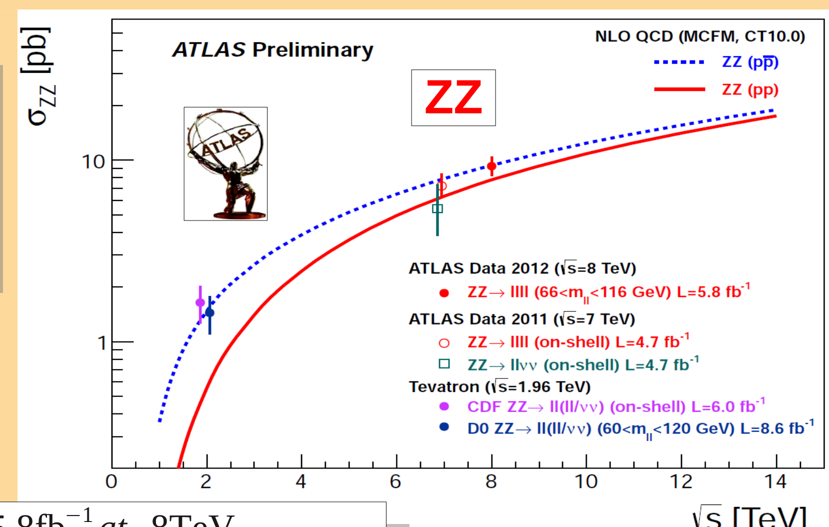




$$CMS: WW \rightarrow 2l2\nu \quad 3.5\text{fb}^{-1} \; at \;\; 8\text{TeV}$$

$$\sigma_{WW} = 68.9 \pm 2.8\,(stat) \pm 5.6\,(syst) \pm 3.1\,(lumi)\; pb$$

$$\sigma_{WW}^{SM}(NLO) = 57.25^{+2.35}_{-1.60}\; pb$$



$$ATLAS: ZZ \rightarrow 4l \quad 5.8\text{fb}^{-1} \; at \;\; 8\text{TeV}$$

$$\sigma_{ZZ} = 9.3^{+1.1}_{-1.0}\,(stat)^{+0.4}_{-0.3}\,(syst) \pm 0.3\,(lumi)\; pb$$

$$\sigma_{ZZ}^{SM}(NLO) = 7.4 \pm 0.4\; pb$$

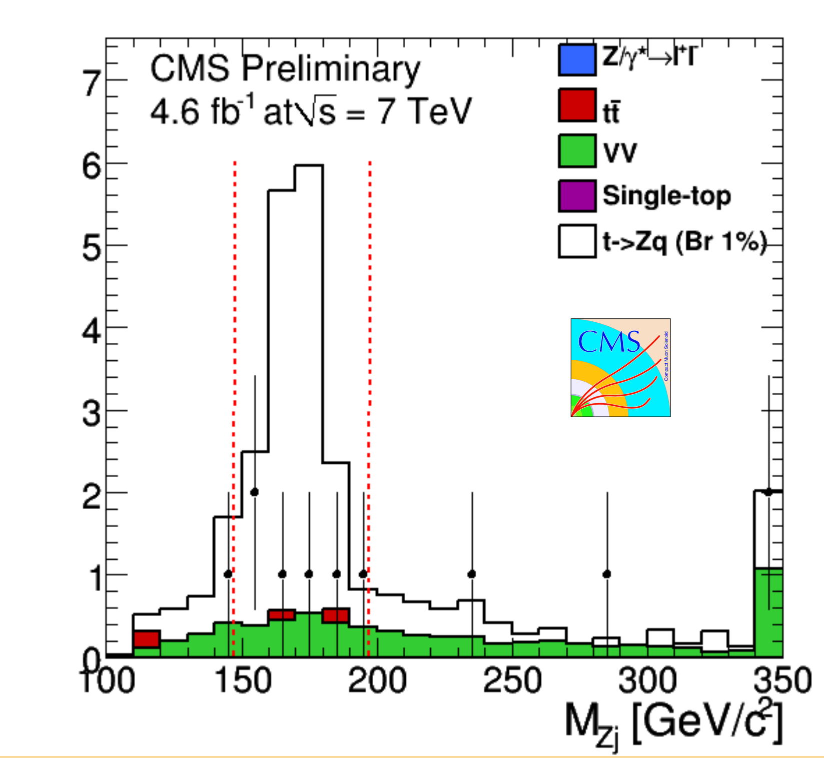
ATLAS: ATLAS-COM-CONF-2012-098

Flavour Changing Neutral Current in $t\bar{t}$

- $t \to Wb$ ~100% in SM
- t->Z/γq (q=c,u) very rare top decays in SM: O(10^{-14})
- New Physics models (Susy, technicolor) predict enhancement up to O(10^{-4}) for $t \to Zq$
- Very clean signature using W and Z leptonic decays:

$tt \to (Wb)(Zj) \to 3$ isolated leptons + 2 jets + E_t^{miss}

masses constraint (W,Z,t) , b- tagging or S_T cut



Best Tevatron limit
BR($t \to Zq$) < 3.2% (D0)

LHC limits
CMS (4.6 fb^{-1}) : BR($t \to Zq$) < 0.34%
Atlas (2.1 fb^{-1}) : BR($t \to Zq$) < 0.73%

CMS: TOP-11-028
ATLAS: arxiv: 1206.0257

Physics Results

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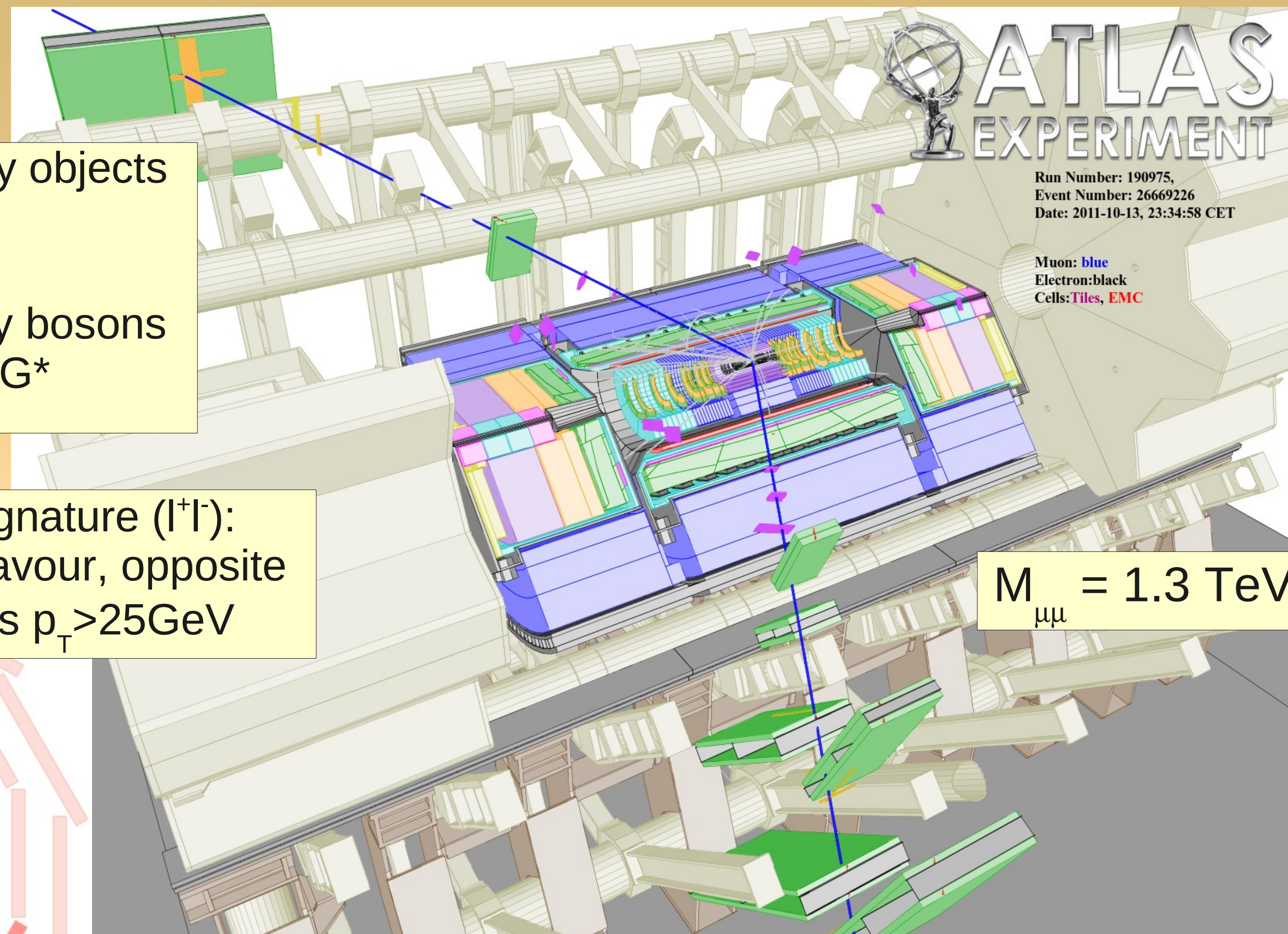
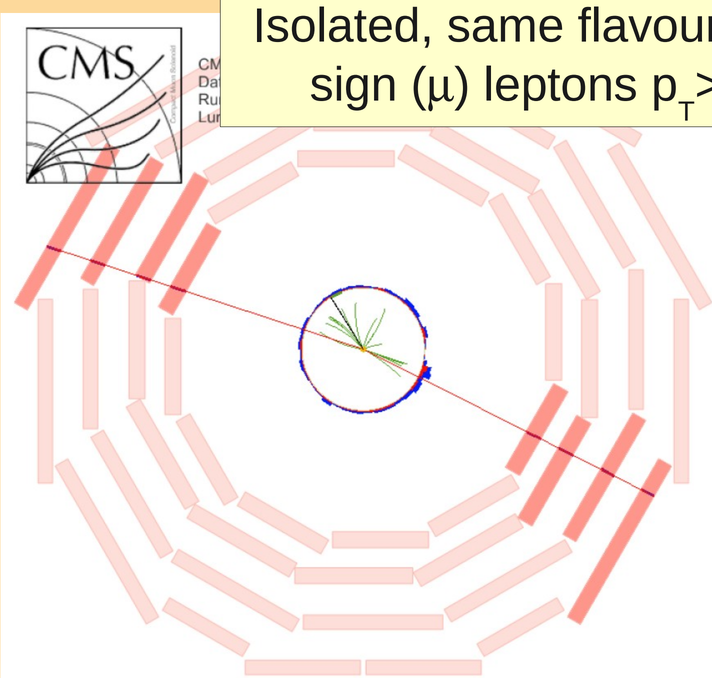
Di-lepton resonance



Several models suggest heavy objects decaying to l^+l^- or $l\nu$

- SSM Z'/W': heavy SM Z/W
- GUT: E6->SU(5) new heavy bosons
- Randall-Sundrum graviton: G*



Very simple signature (l^+l^-): Isolated, same flavour, opposite sign (μ) leptons p_T>25GeV

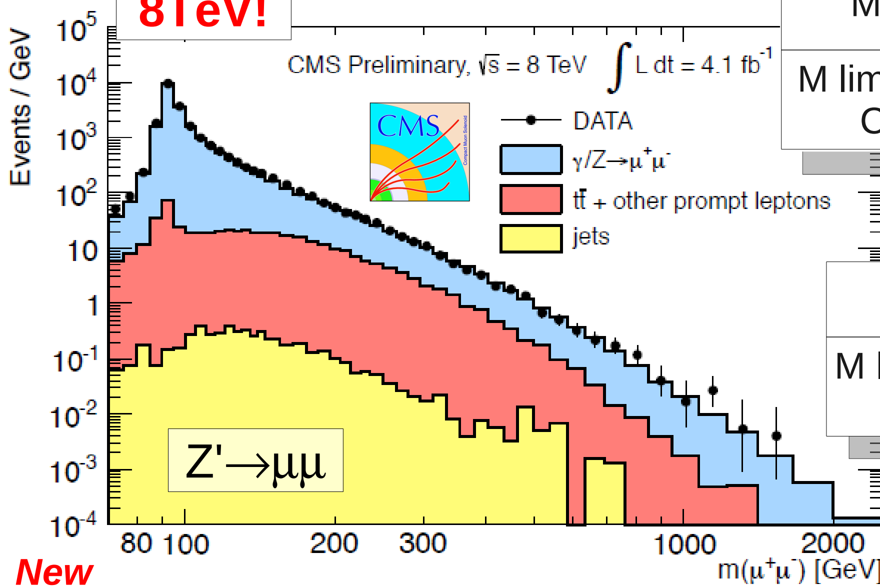
$M_{\mu\mu}$ = 1.3 TeV

Important Backgrounds (l^+l^-)::

- Z/γ^* (Drell-Yan) : dominant and irreducible (MC at NLO)
- tt and dibosons : small (diboson MC)
- QCD and W+jets: reducible (Data-driven methods)

Di-lepton resonance

8TeV!

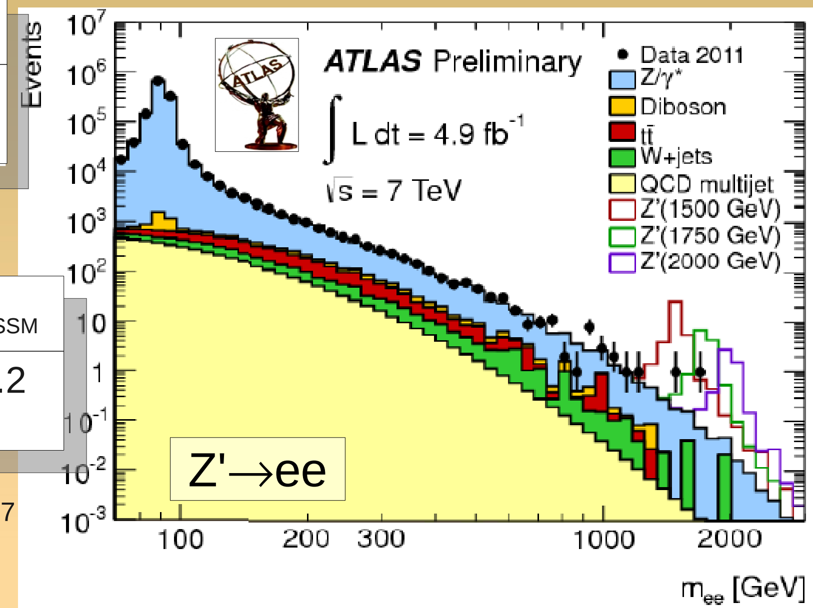


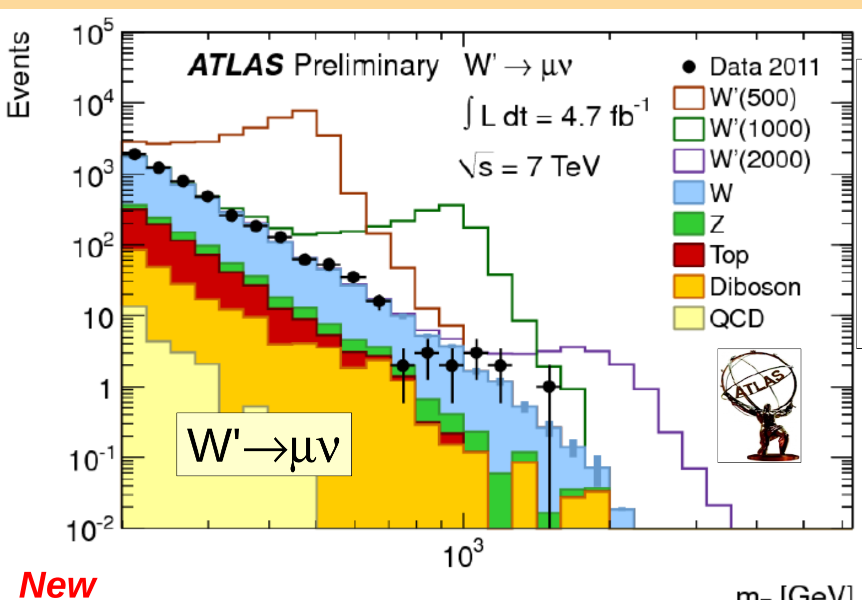
New

Model	Z'$_\Psi$	Z'$_{SSM}$
M limit (TeV) CMS	2.3	2.6

Model	Z'$_\Psi$	Z'$_{SSM}$
M limit (TeV) Atlas	1.8	2.2

Atlas: ATLAS-CONF-2012-007
CMS: EXO-12-015, hep-ex 1206.1849, EXO-11-019





New

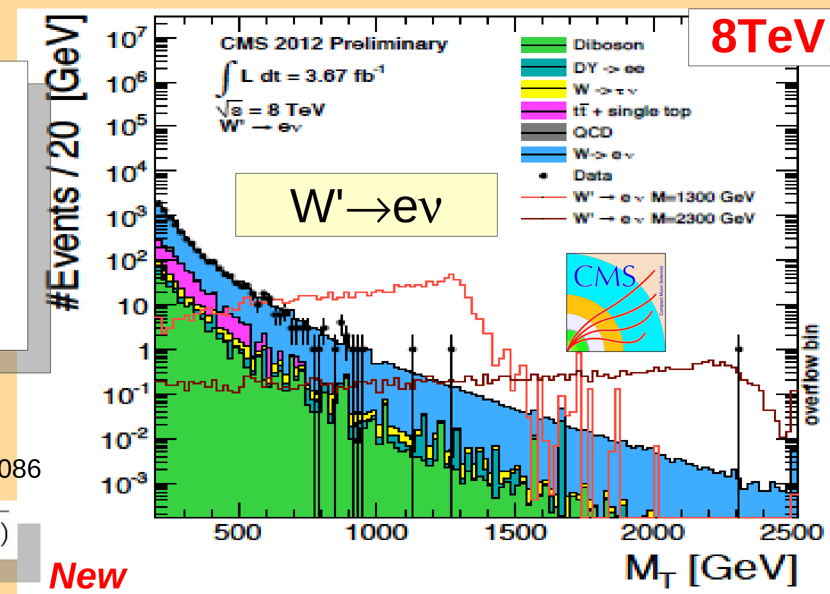
CMS (4fb^{-1}, 8TeV) $M_{W'}$>2.8TeV

Atlas (4.7fb^{-1},7TeV) $M_{W'}$>2.6TeV

CMS: EXO-12-010
Atlas: ATLAS-CONF-2012-086

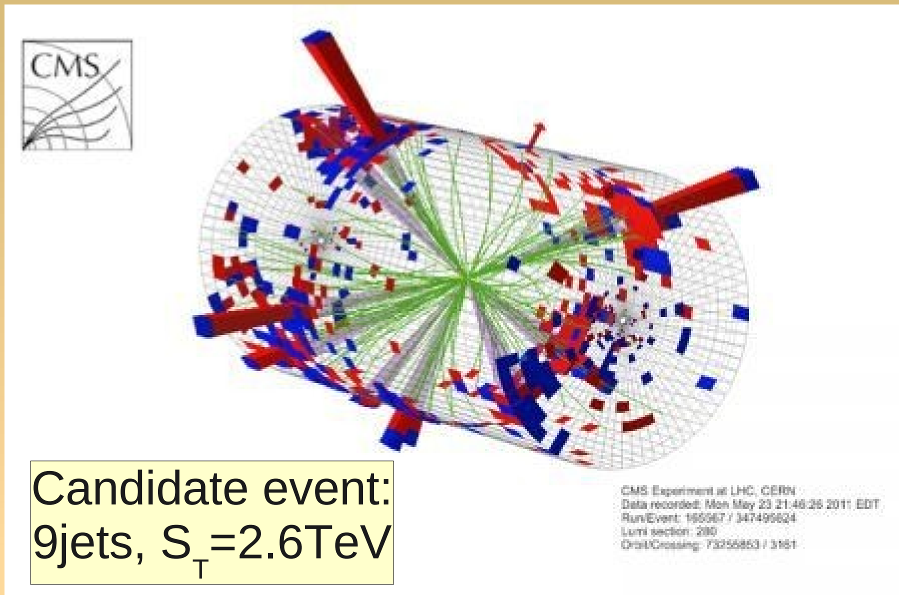
$$M_T = \sqrt{2 \cdot p_T^\ell \cdot E_T^{miss} \cdot (1 - \cos \Delta\phi_{\ell,\nu})}$$

8TeV!



New

Microscopic Black Holes

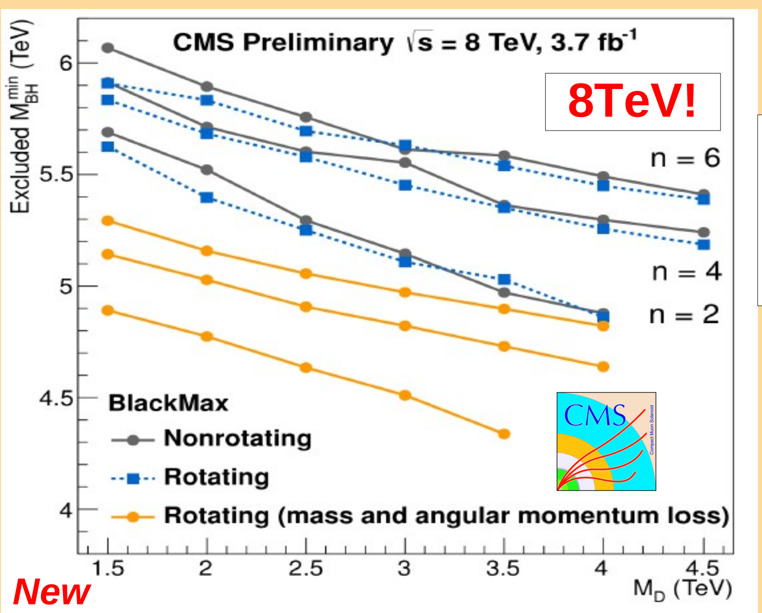


Candidate event:
9jets, S_T=2.6TeV

Arkani-Hamed, Dimopoulos,Dvali (ADD) model:

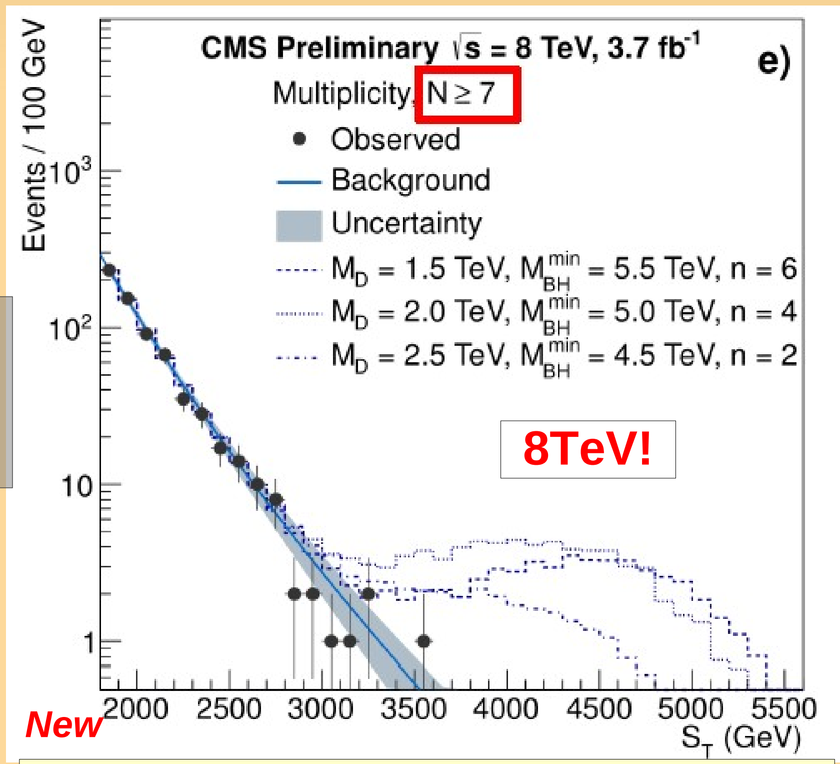
- Extra spatial dimensions
- Multi-dim Planck scale M_D

- Predicts formation of microscopic black holes
- Spectacular signature with large number N of energetic particles: jets, W/Z/γ/leptons



Model dependent exclusion limits 2.8 – 5.3 TeV

CMS:
10.1007/JHEP04(2012)061
CMS-PAS-EXO-12-009



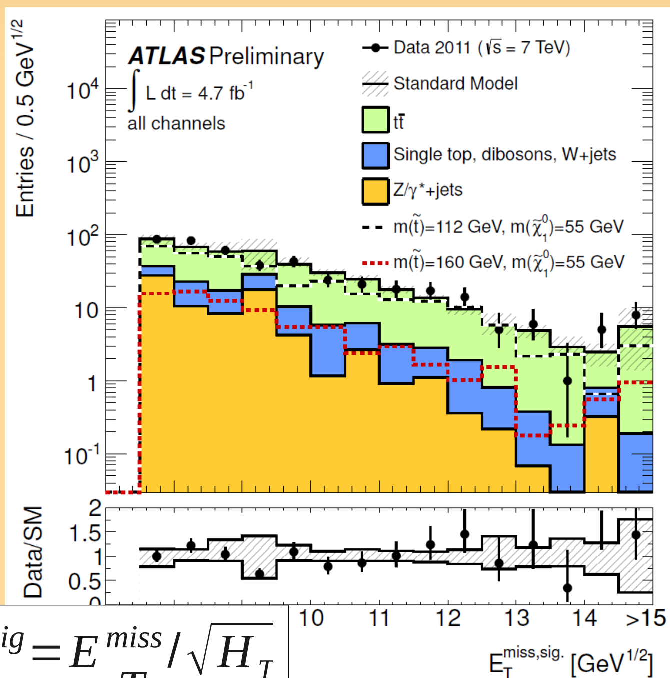
S_T: scalar sum of the E_T of γ, e, μ and jets

Susy: one example, light stop

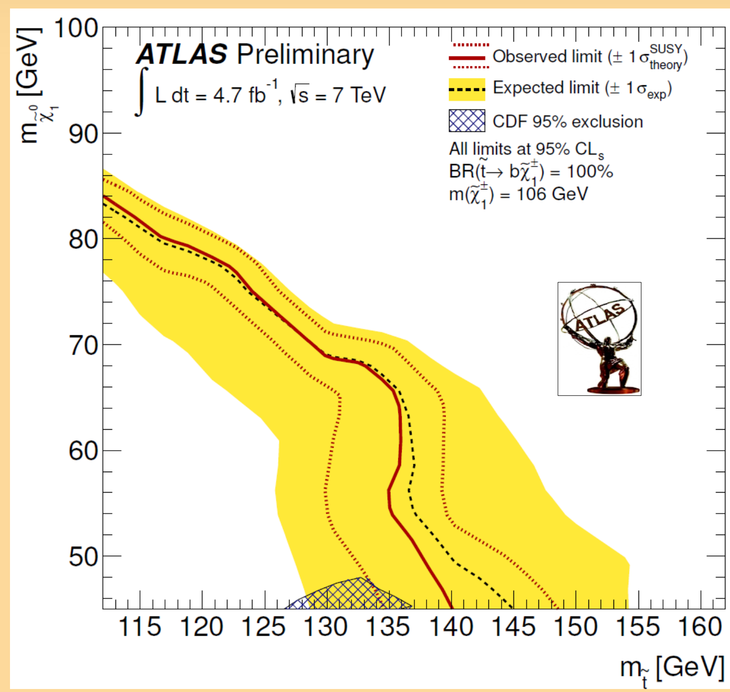
If the third generation squarks can be light then Supersymmetry solves “naturally” the hierarchy problem

Search strategy optimized to look for light stop (and/or sbottom)

Here direct light stop production lighter than top, decay to b and Chargino
2 opposite-sign leptons + ≥1 jet + high E_T^{miss}



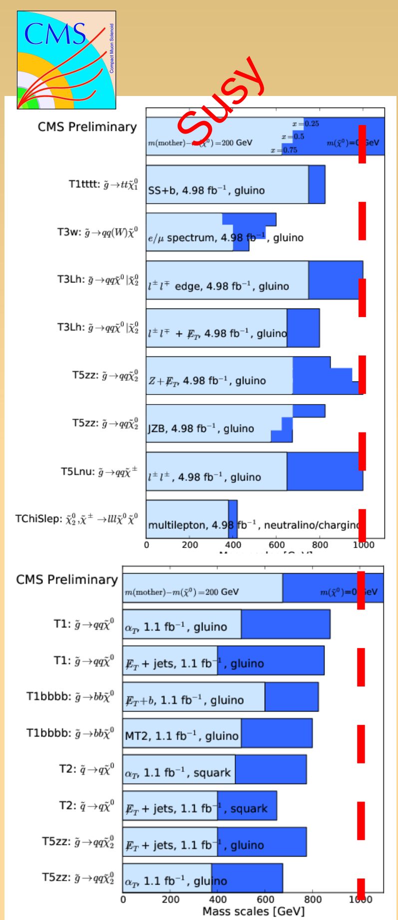
$$E_T^{miss,sig} = E_T^{miss} / \sqrt{H_T}$$

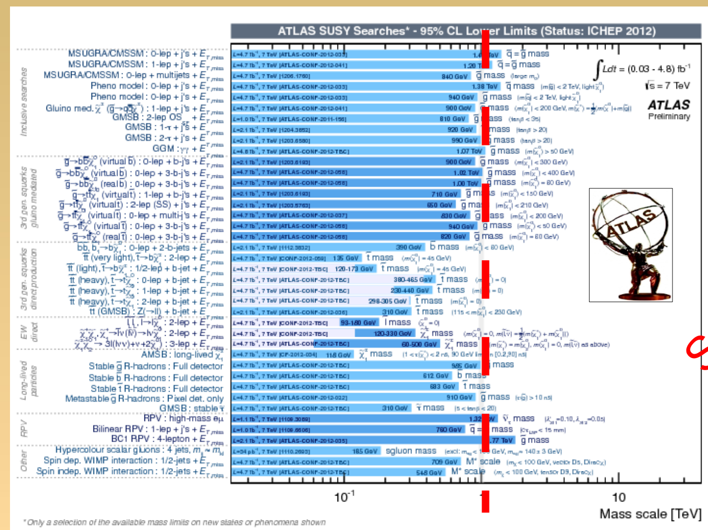


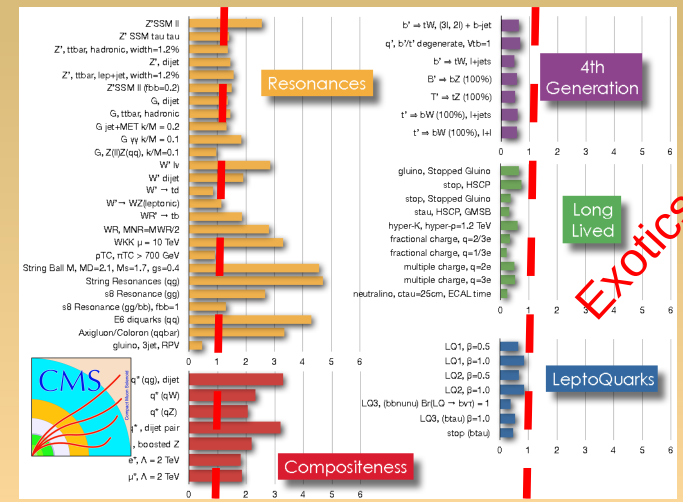
Excludes stop lighter than 130 GeV

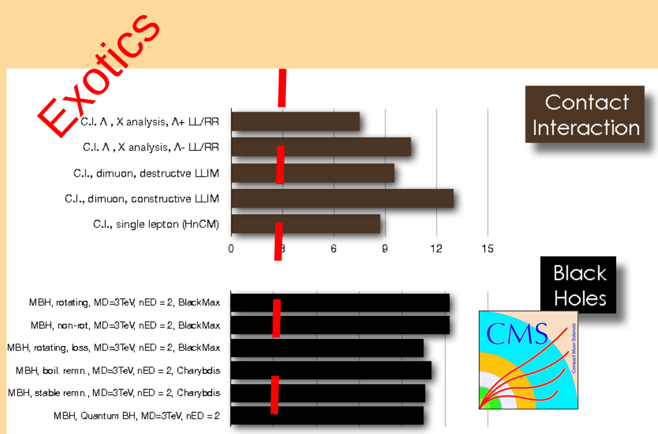
ATLAS-CONF-2012-059

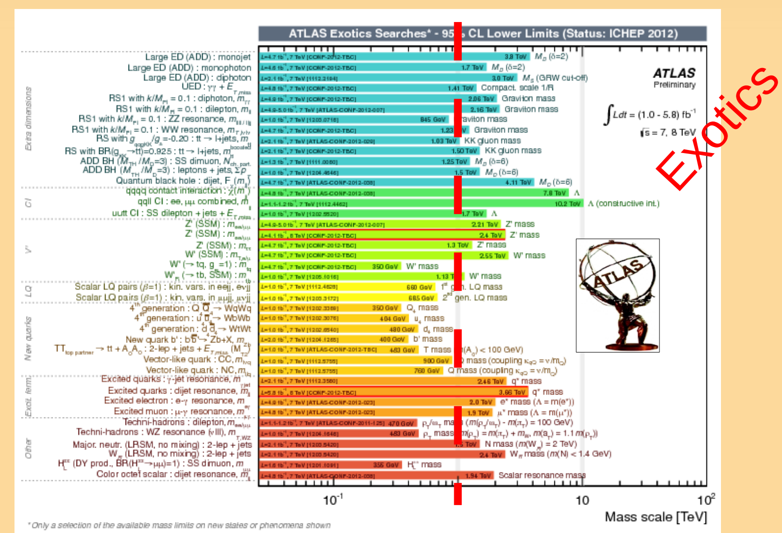
Many others Exotics/SUSY searches











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

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

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults

Physics Results

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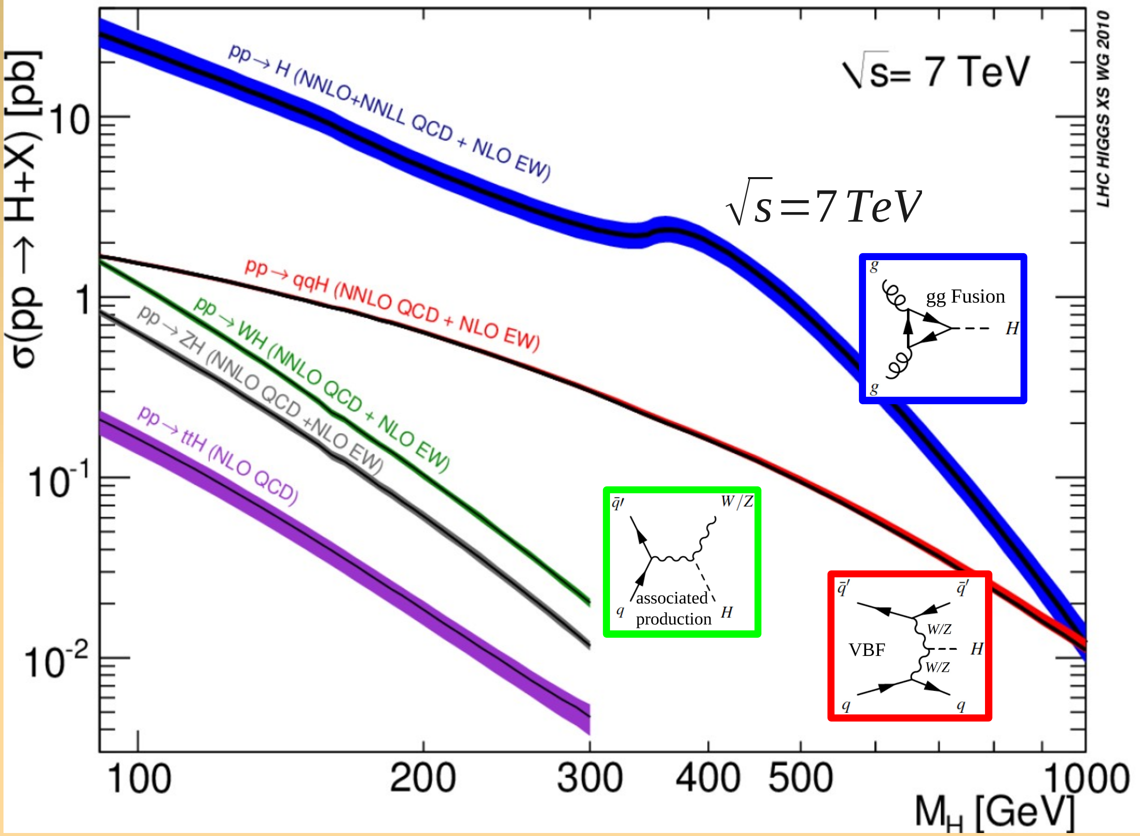
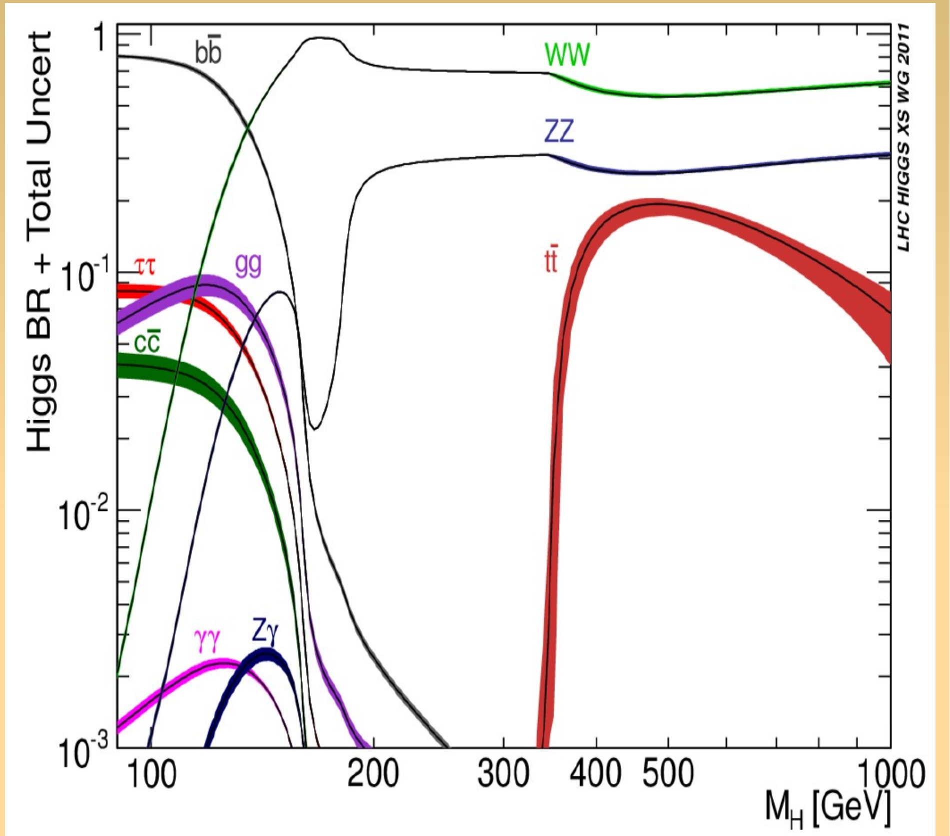
Higgs Boson Production and Decay



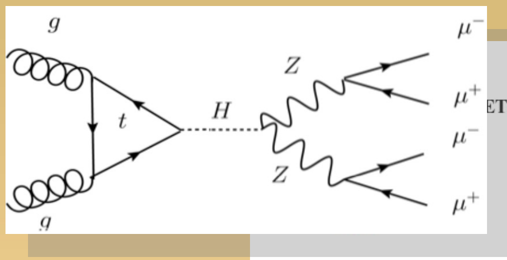


σ_H ~15 pb @125 GeV, 10 pb @ 150 GeV
Huge effort of the theory community to compute NLO and NNLO cross-sections for Higgs production and backgrounds
Theoretical (most NNLO) uncertainty < 15%

Most important channels at low H mass

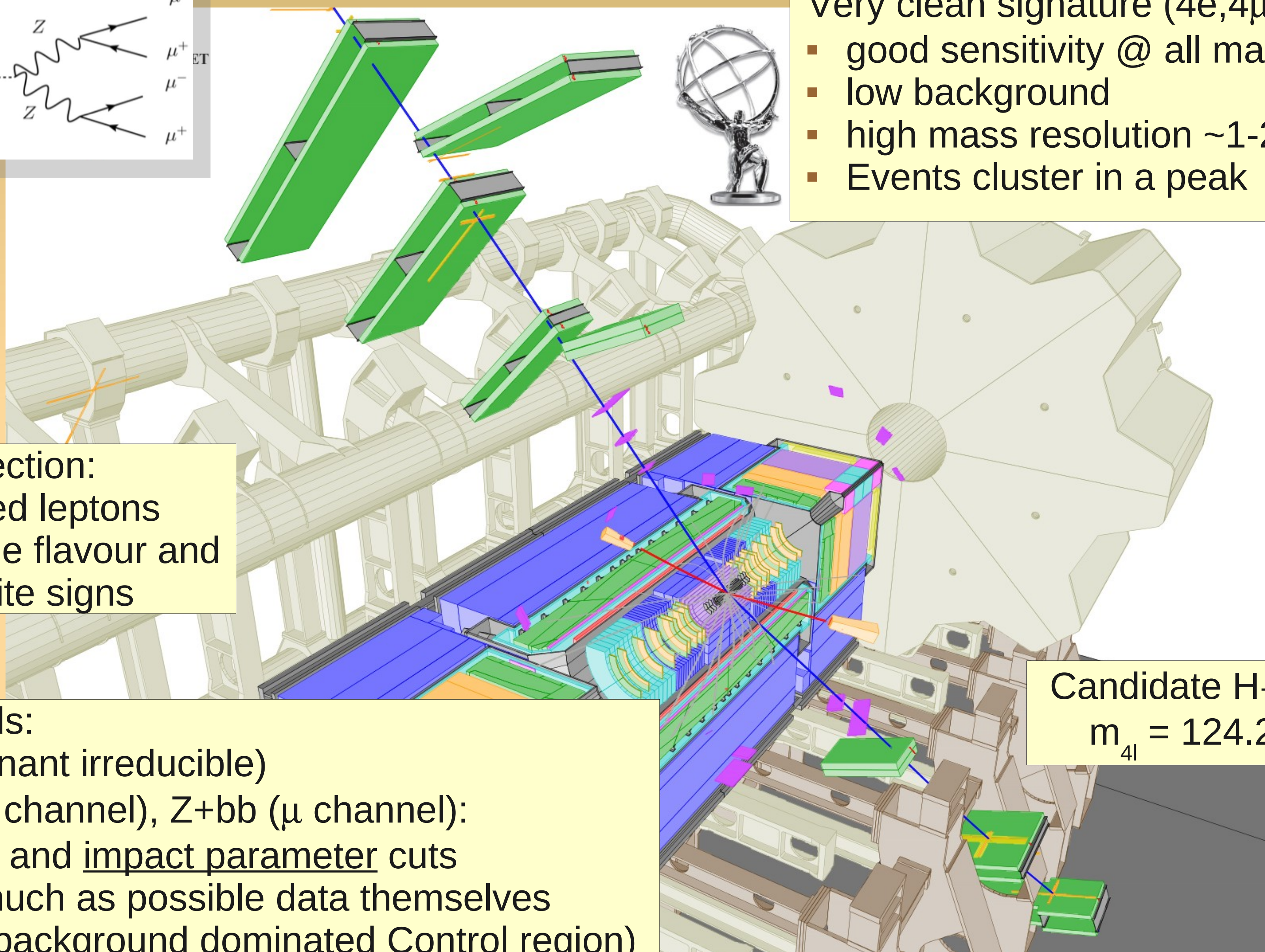
- $H\to\gamma\gamma$, $H\to ZZ^{(*)}\to 4l$
- $H\to WW^{(*)}\to l\nu l\nu$
- $H\to\tau\tau$, (W/Z)($H\to bb$)

H→ZZ*→4l : the "golden"



Very clean signature (4e,4μ,2e2μ)

- good sensitivity @ all masses
- low background
- high mass resolution ~1-2%
- Events cluster in a peak



Selection:
4 isolated leptons
2 pairs same flavour and opposite signs

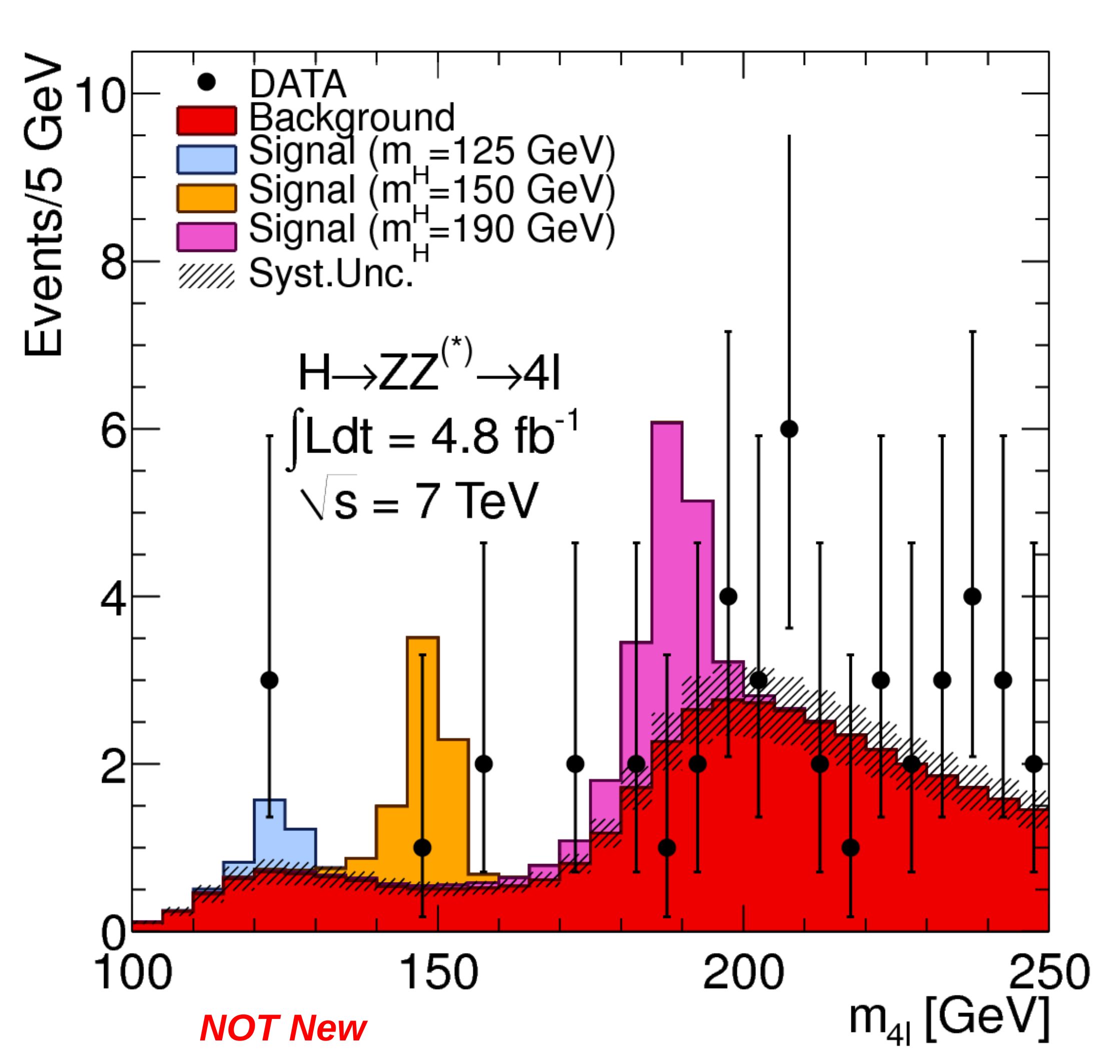
Candidate H→2e2μ
m_{4l} = 124.2 GeV

Backgrounds:

- ZZ (dominant irreducible)
- Z+jets (e channel), Z+bb (μ channel): <u>isolation</u> and <u>impact parameter</u> cuts
- Use as much as possible data themselves (defined background dominated Control region)

How we do

Published results on 7 Tev data



NOT New

71 candidates; expected background 62±9

In the region m_H<141 GeV, 3 events are observed

Try to describe data with

μ x S + B where

S is H signal
B is background
μ is the Signal Strength

First put *upper* limit on μ:

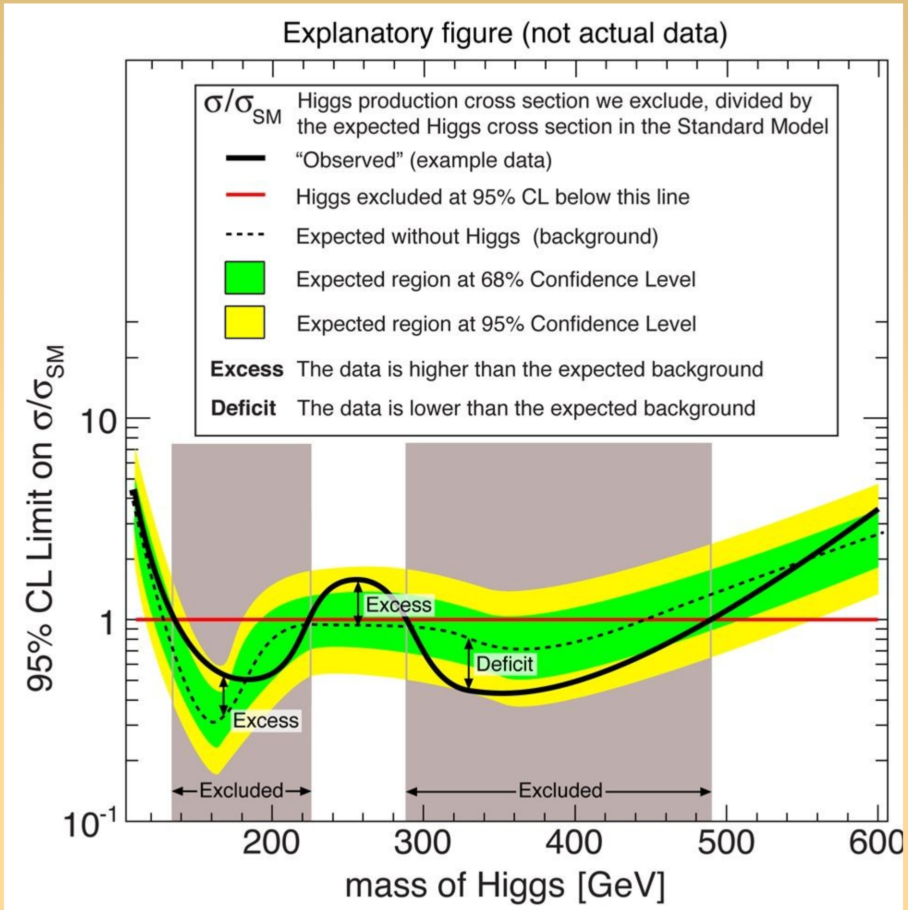
at 95% CL, $\mu < \mu_{up}$

Exclusion Limits

If no Higgs is observed in your dataset, how well can you discriminate the prediction that there is one?

- This depends on the power of your experimental observations and the channel/mass range you are looking at.
- In some cases you will be unable to tell anything, because your discriminating power is too low (e.g too much or too uncertain background)
- In other places where you will have the discriminating power to tell (e.g. background free, good mass resolution)
- You can anticipate before the observation, saying that you will be not lucky/unlucky, just normal ("Expected");
- But at the end of the day what you have in hands will decide ("Observed")

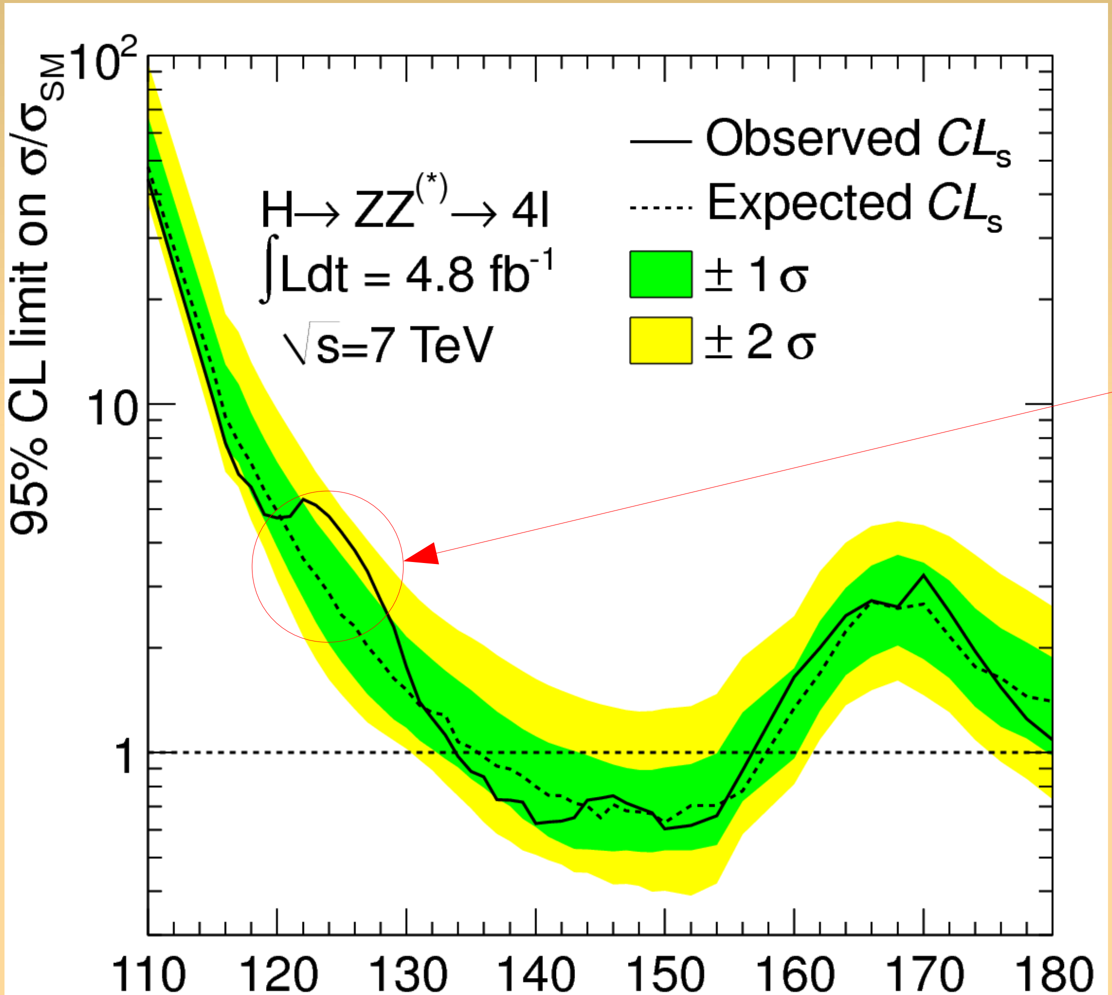
Exclusion plots



Upper limit on μ

Exclusion Limits

Published results on 7 Tev data



NOT New

Excluded (95% CL): 134-156 GeV

Expected(95%CL): 137-157 GeV

Is that all?

It could be that the Observed μ_{up} is high because there is an excess in data... or a simple Background fluctuation

Right question:

can the Background *reasonably* fluctuate up to the observed?

Significance of an excess

Is what you observe in your data compatible with Background only?

P0 is the probability that a background only exp. be more signal like than observed

Compute it with your data: “Observed”

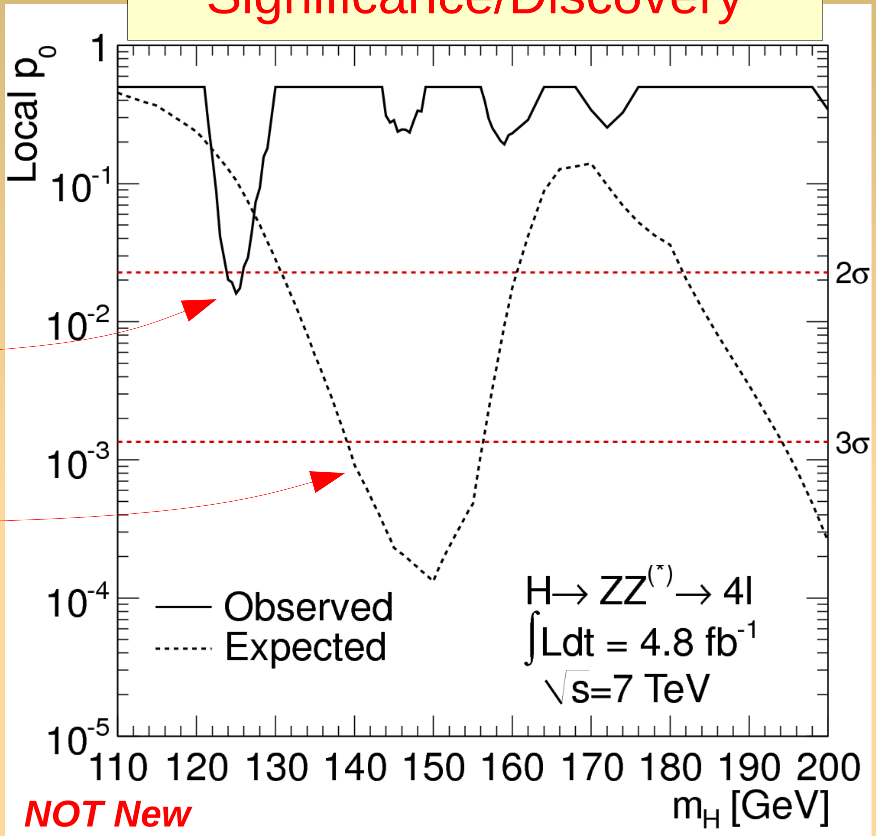
But what if actually, your data did contain a signal from a H? What will be the p0? “Expected”

For the 125 GeV excess

- the local p0 is 2.2 σ (a SM Higgs would give 1.2 σ)
- But the probability to find a bump increases with the range you are looking at (Look Elsewhere Effect: LEE):

  the probability of the excess is then 50%

Significance/Discovery



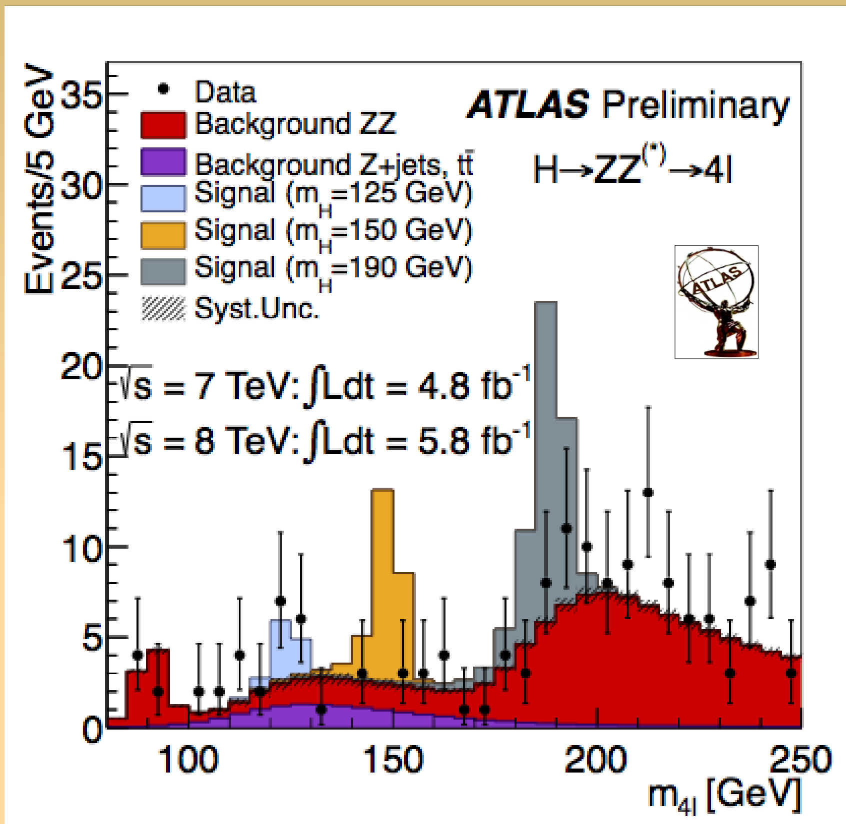
What is unreasonable?

HEP rule:

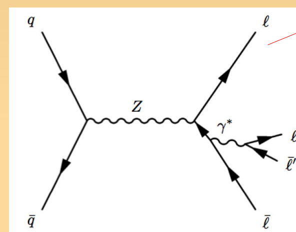
3 σ ⇒ Evidence

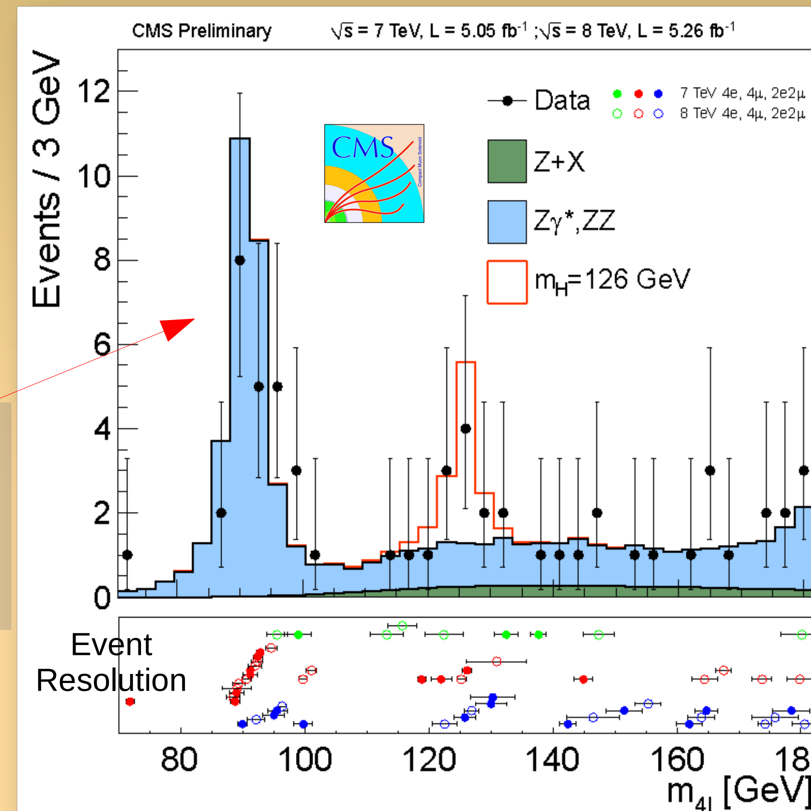
5 σ ⇒ Discovery

2012: H→ZZ*→4l : the “golden”



7+8TeV data





In the region 125±5GeV

2011+2012	4μ	2e2μ	4e
Data	6	5	2
Expected S/B	1.6	1	0.6
Reducible/Total B	5%	45%	55%

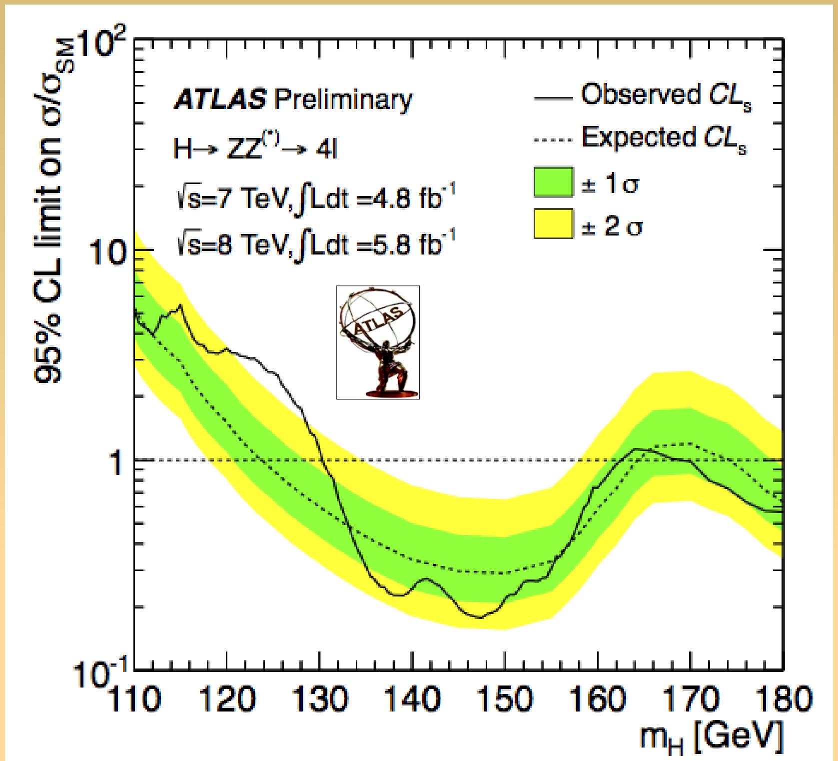
ATLAS-CONF-2012-092

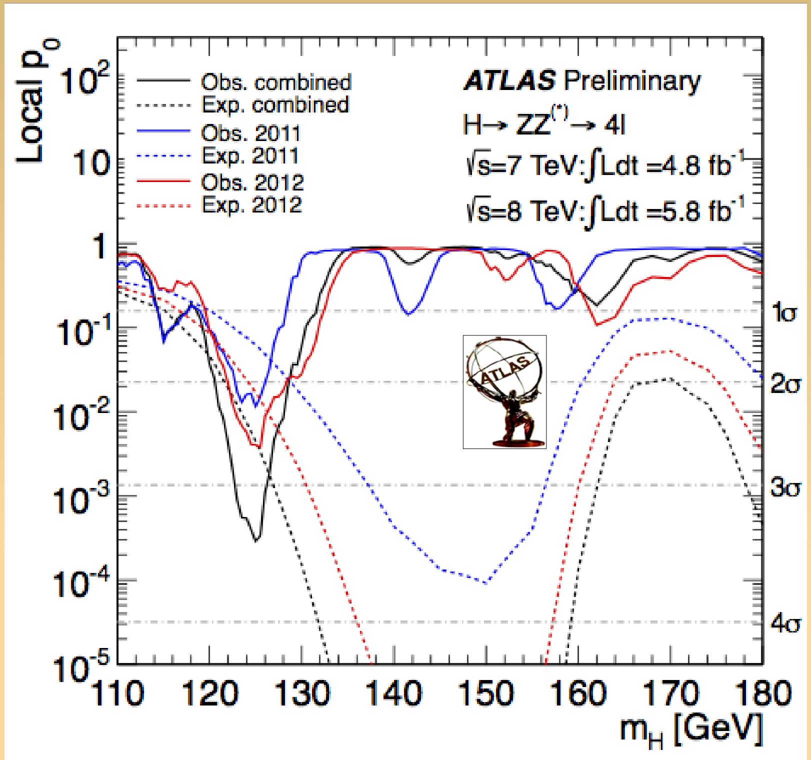
Between 110 and 160 GeV

Channel	4e	4μ	$2e2\mu$	4ℓ
ZZ background	2.7 ± 0.3	5.7 ± 0.6	7.2 ± 0.8	15.5 ± 1.0
Z+X	$1.2^{+1.1}_{-0.8}$	$0.9^{+0.7}_{-0.6}$	$2.3^{+1.8}_{-1.4}$	$4.4^{+2.2}_{-1.7}$
All backgrounds	$3.9^{+1.1}_{-0.8}$	$6.6^{+0.9}_{-0.8}$	$9.5^{+2.0}_{-1.6}$	$19.9^{+2.4}_{-2.0}$
$m_H = 120\,\mathrm{GeV}$	0.8 ± 0.2	1.6 ± 0.3	1.9 ± 0.5	4.4 ± 0.6
$m_H = 126\,\mathrm{GeV}$	1.5 ± 0.5	3.0 ± 0.6	3.8 ± 0.9	8.3 ± 1.2
$m_H = 130\,\mathrm{GeV}$	2.1 ± 0.7	4.1 ± 0.8	5.4 ± 1.3	11.6 ± 1.6
Observed	6	6	9	21

CMS-PAS-HIG-12-016

2012: H→ZZ*→4l : the “golden”





Excluded (95% CL)

131-162, 170-460 GeV

Expected (95%CL)

124-164, 176-500GeV

- Observed significance at 125.5 GeV

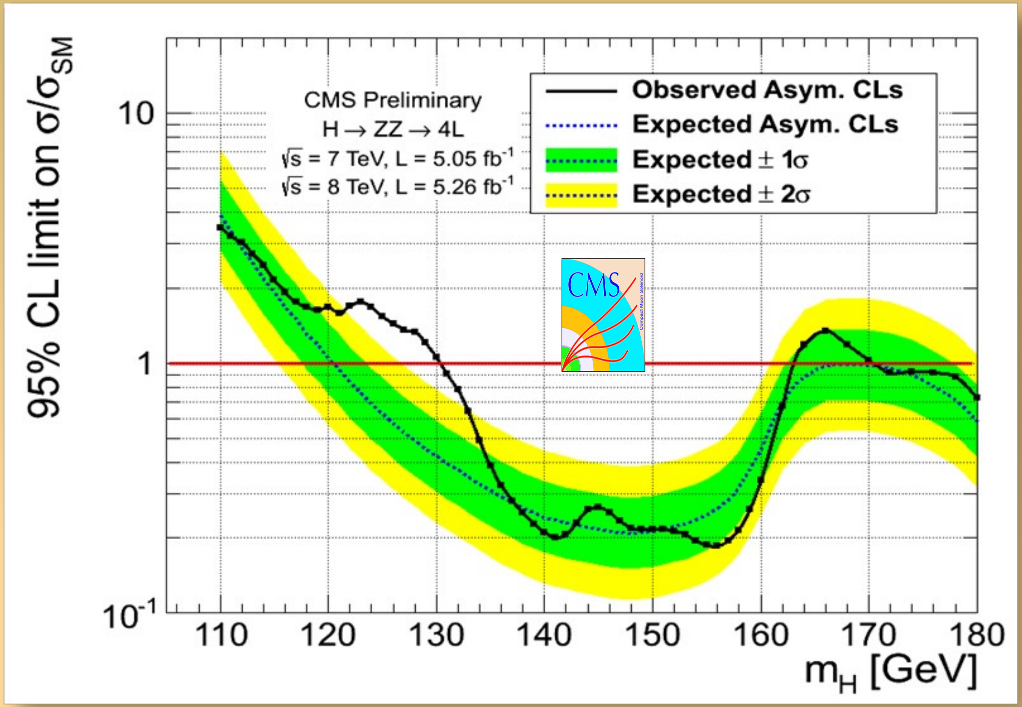
  3.4 σ

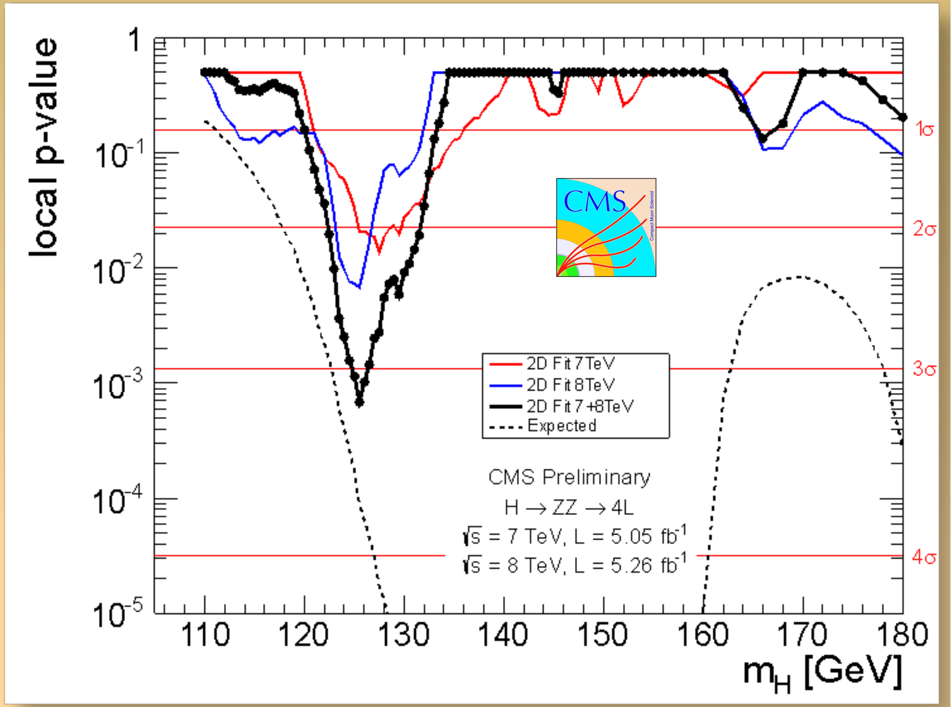
- Expected significance at 125.5 GeV

  2.6 σ

Exclusion limits and significance

2012: H→ZZ*→4l : the "golden"





Excluded (95% CL)

131-162; 172-530 GeV

Expected (95%CL)

121-550 GeV

- Observed significance at 125.5 GeV

  3.2 σ (LEE 2.1 σ)

- Expected significance at 125.5 GeV

  3.8 σ

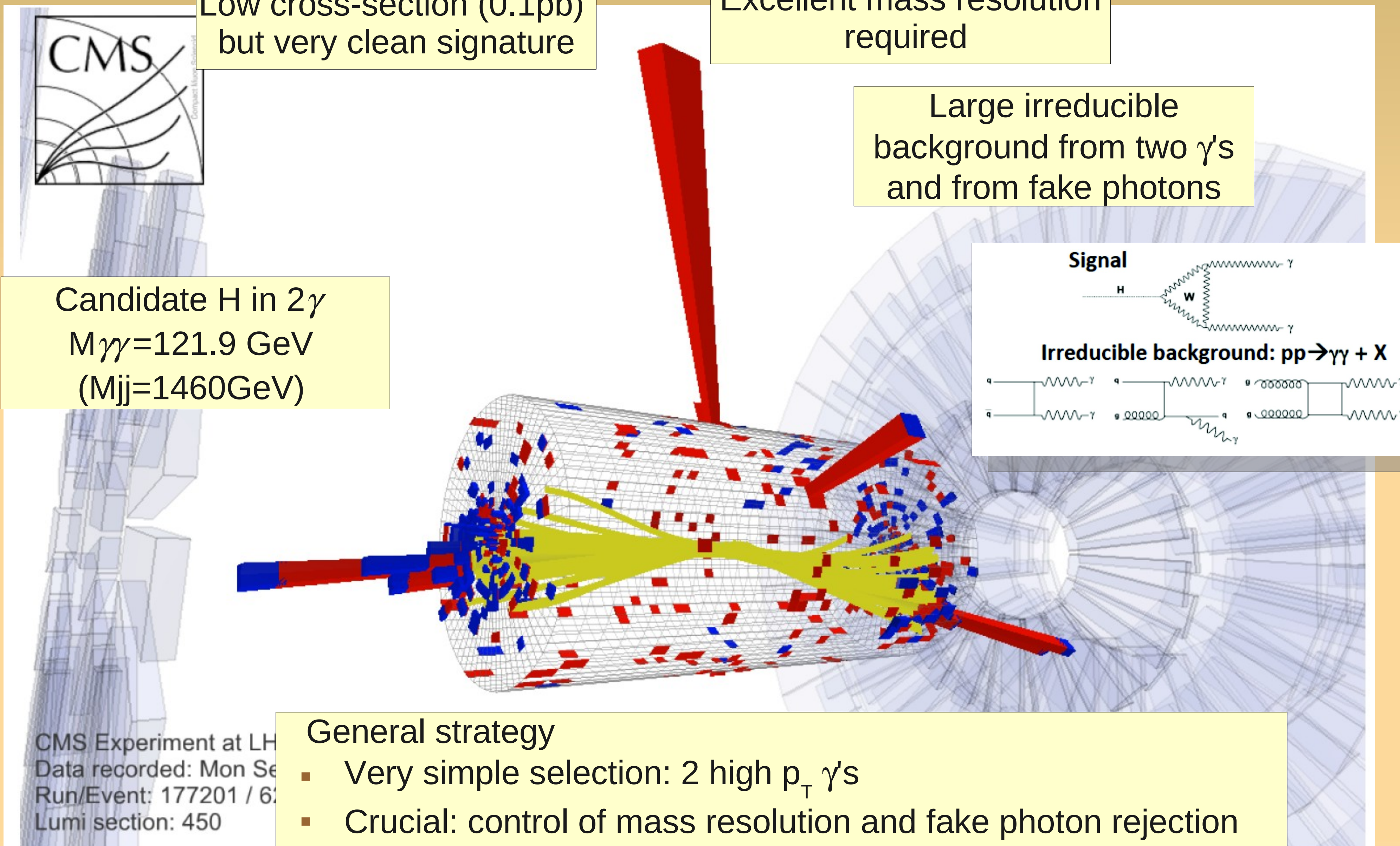
Exclusion limits and significance

H→2γ : the "beautiful"

Low cross-section (0.1pb) but very clean signature

Excellent mass resolution required

Large irreducible background from two γ's and from fake photons



Candidate H in 2γ
$M\gamma\gamma$=121.9 GeV
(Mjj=1460GeV)

General strategy

- Very simple selection: 2 high p_T γ's
- Crucial: control of mass resolution and fake photon rejection
- Categorize: Cuts based categories (ATLAS), MVA (CMS)

H→2γ : the "beautiful"

- Categorisation allows to optimize analysis
- ATLAS: cuts based
  - γ converted or not, photon η, Low/high "pt", New VBF category (2jets, large mass, large η gap)

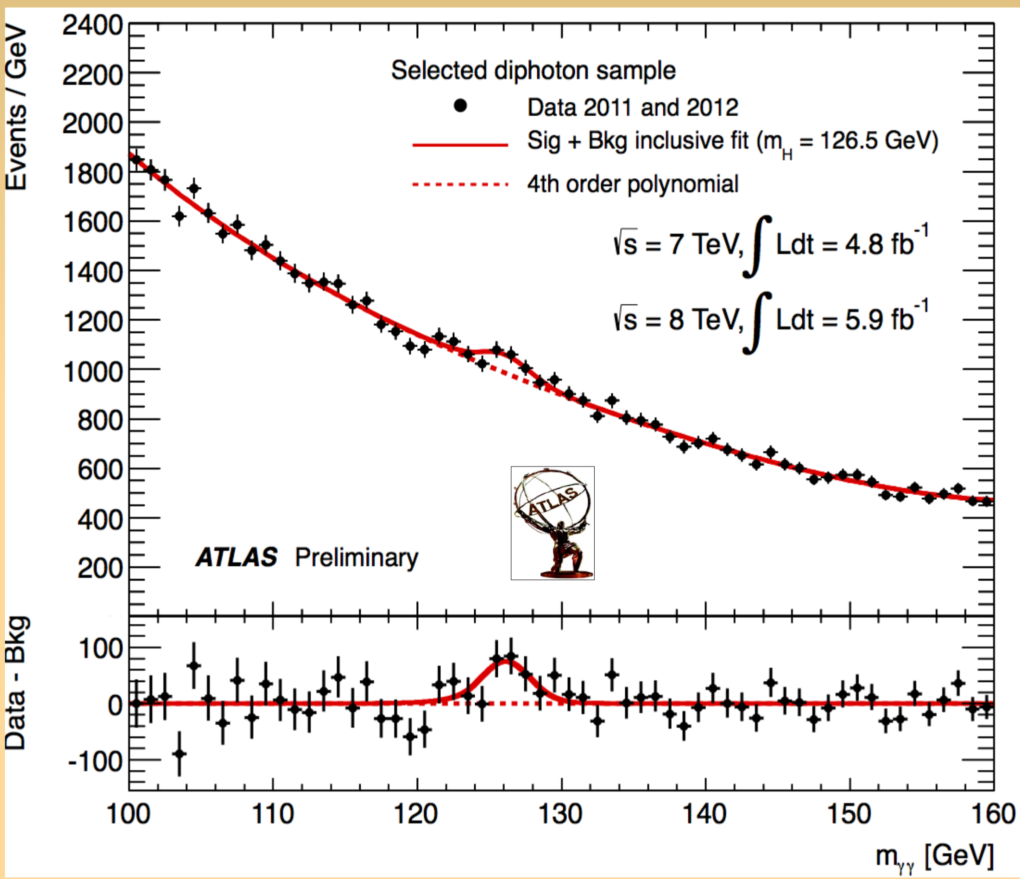
8 TeV sample window

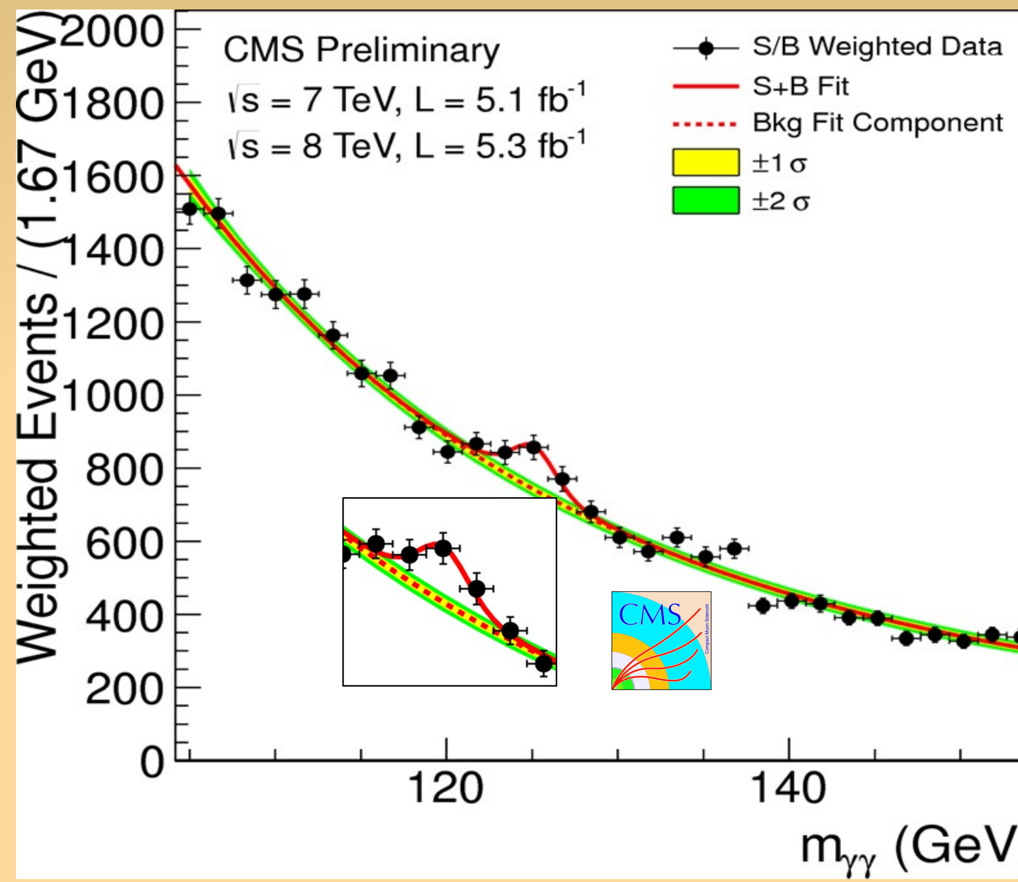
Category	σ_{CB} [GeV]	FWHM [GeV]	Observed [N_{evt}]	S [N_{evt}]	B [N_{evt}]
Inclusive	1.63	3.87	3693	100.4	3635
Unconverted central, low p_{Tt}	1.45	3.42	235	13.0	215
Unconverted central, high p_{Tt}	1.37	3.23	15	2.3	14
Unconverted rest, low p_{Tt}	1.57	3.72	1131	28.3	1133
Unconverted rest, high p_{Tt}	1.51	3.55	75	4.8	68
Converted central, low p_{Tt}	1.67	3.94	208	8.2	193
Converted central, high p_{Tt}	1.50	3.54	13	1.5	10
Converted rest, low p_{Tt}	1.93	4.54	1350	24.6	1346
Converted rest, high p_{Tt}	1.68	3.96	69	4.1	72
Converted transition	2.65	6.24	880	11.7	845
2-jets	1.57	3.70	18	2.6	12

- CMS: Multivariate techniques (cuts based analysis carried out previously)
  - Event by event mass resolution $\sigma(m_{\gamma\gamma})$
  - photon ID Boosted Decision Tree (BDT)T output
  - Di-photon kinematic
  - vertex probability
  - Events split in 5 categories
    - 4 based on di-photon BDT classifier
    - 1 VBF category

2012: H→2γ : the "beautiful"

Mass spectra results



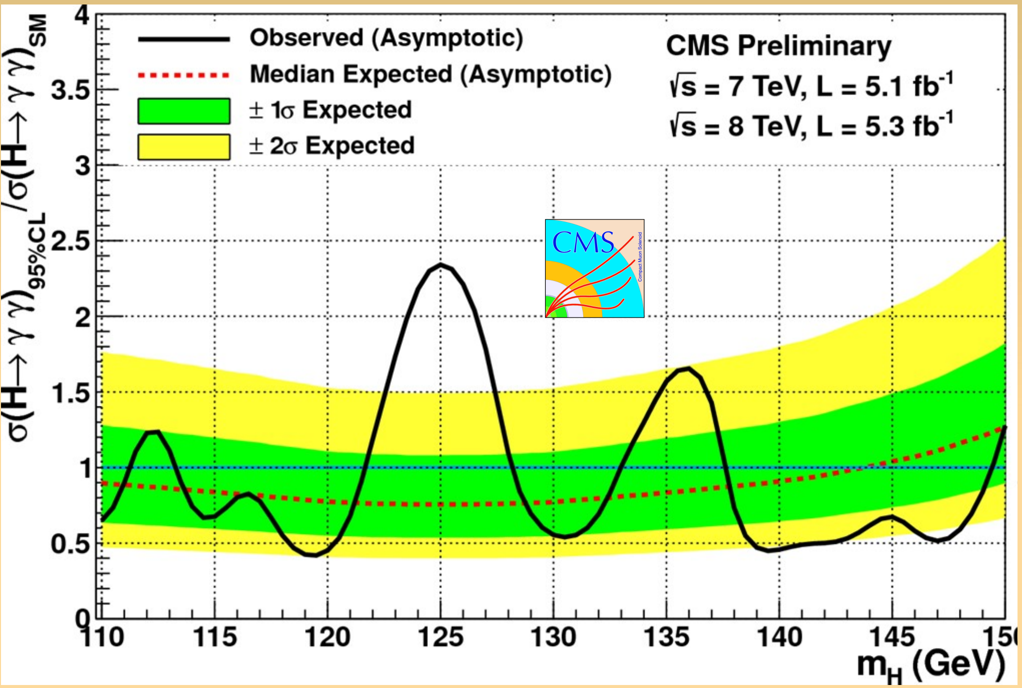


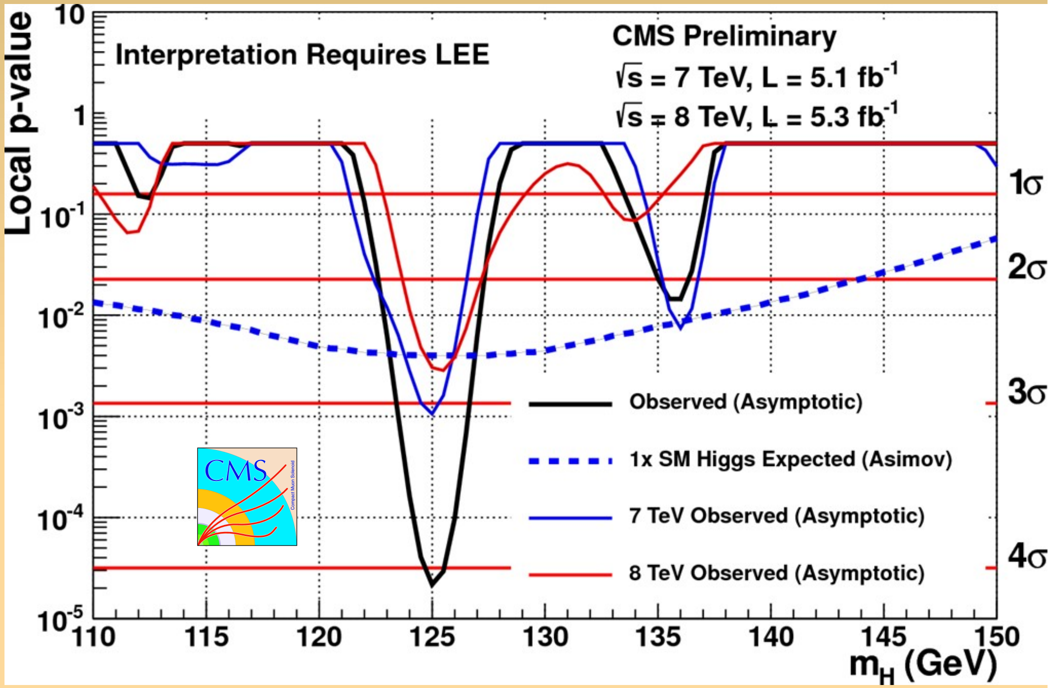
ATLAS-CONF-2012-091

CMS-PAS-HIG-12-015

2012: H→2γ : the "beautiful"

Exclusion limits and significance





Excluded (95% CL):

114-121; 129-132;

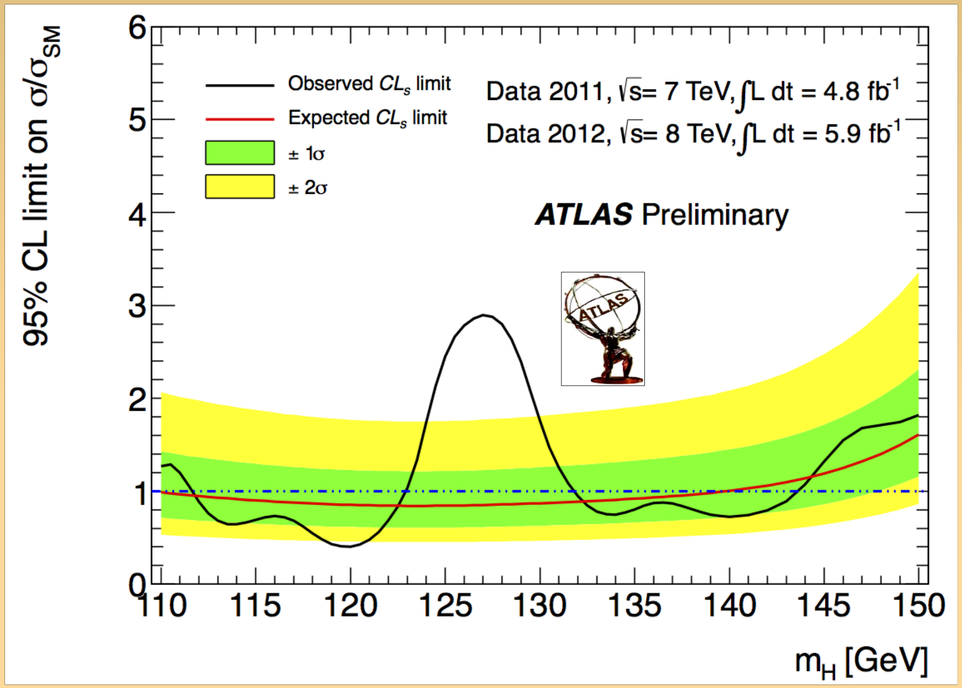
138-149 GeV

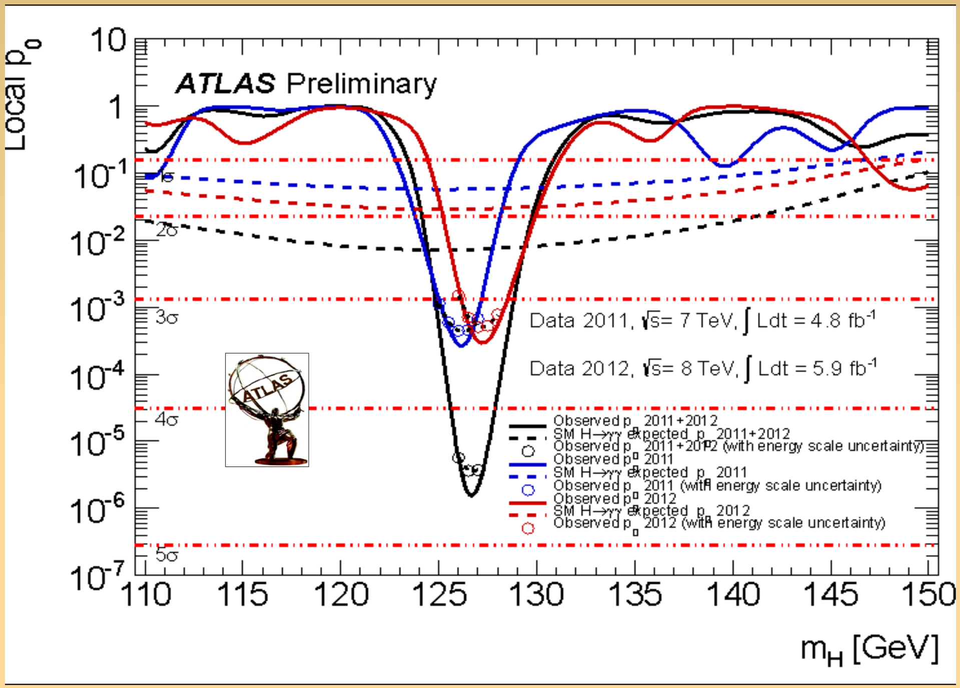
- Observed significance at 125.5 GeV

  4.1 σ (LEE 3.2 σ)

2012: $H\rightarrow 2\gamma$: the "beautiful"

Exclusion limits and significance





Excluded (95% CL):

112-122.5 GeV, 132-143 GeV

Expected(95%CL):

110-139.5 GeV

- Observed significance at 126.5 GeV

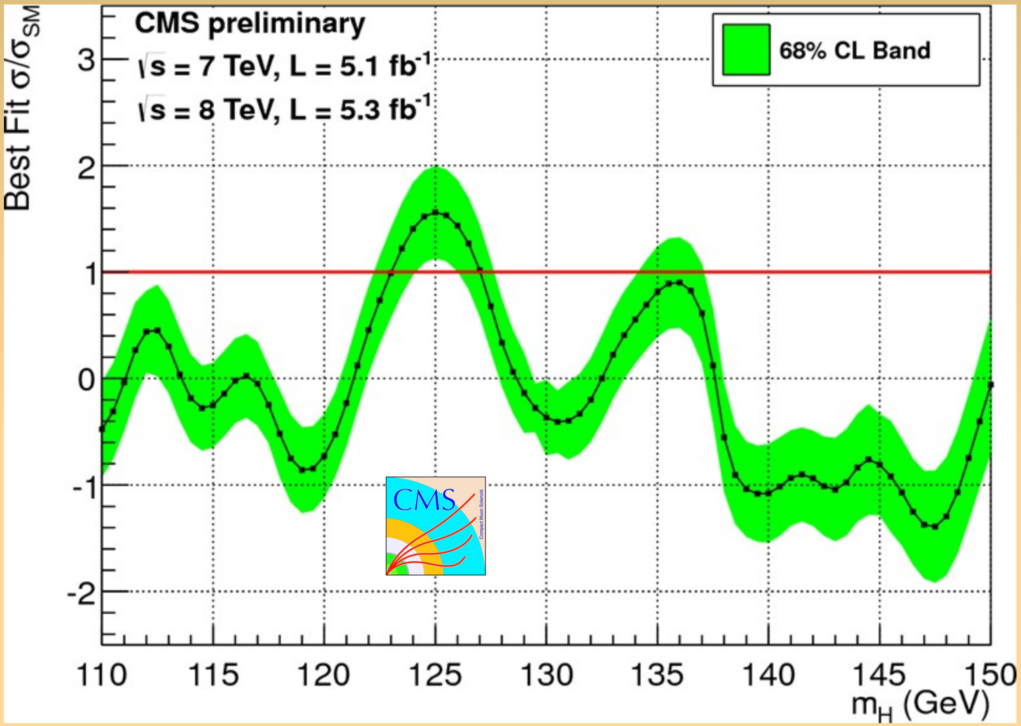
  4.5 σ (LEE 3.6 σ)

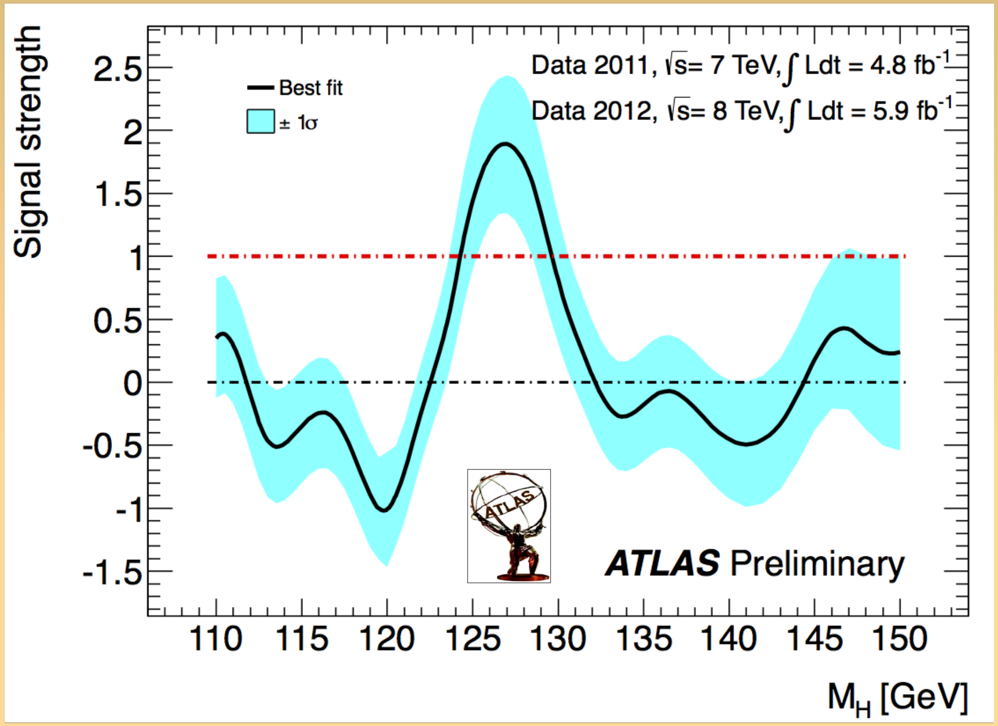
- Expected significance at 126.5 GeV

  2.4 σ

2012: H→2γ : the "beautiful"

Best-fit value of Signal strength





Best-fit value at 125 GeV

μ=1.56 ± 0.43

Best-fit value at 126.5 GeV

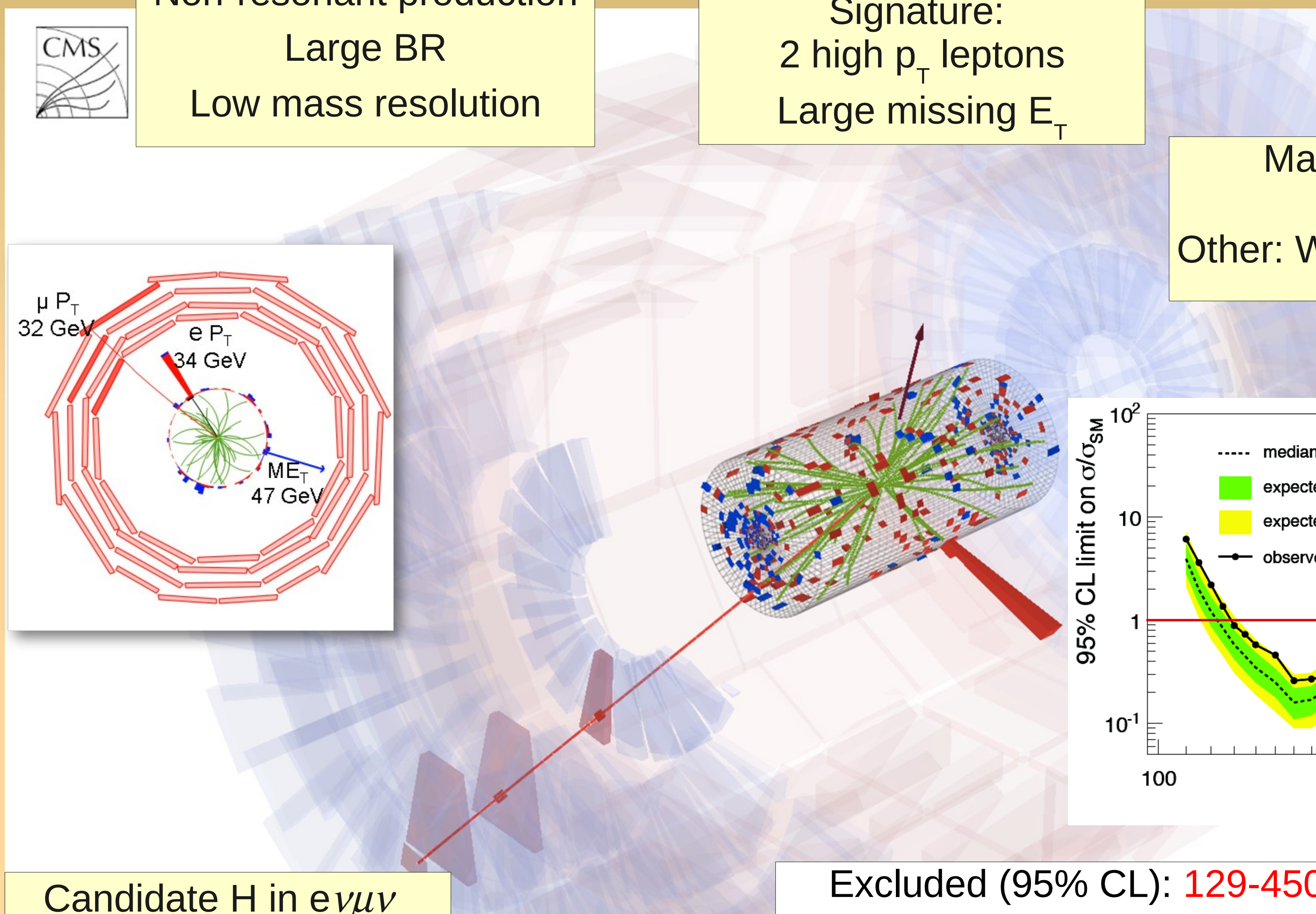
μ=1.9 ± 0.5

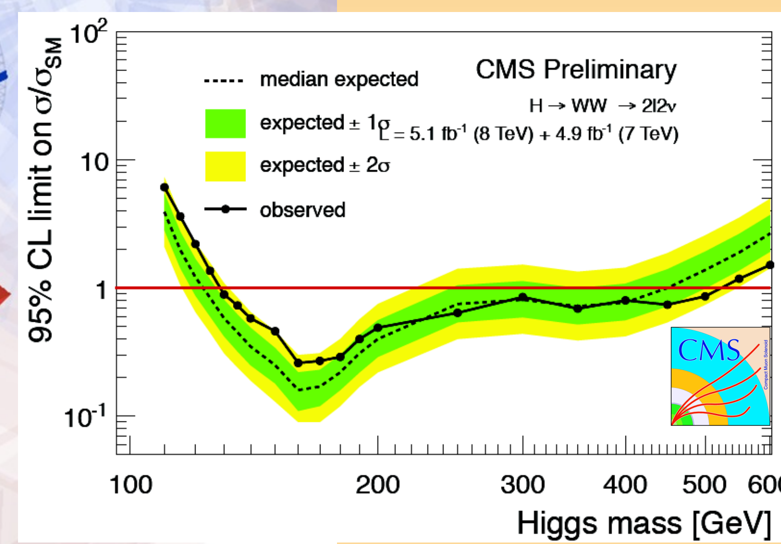
2012: $H \to WW^* \to 2\nu 2l$

Non-resonant production
Large BR
Low mass resolution

Signature:
2 high p_T leptons
Large missing E_T

Main Backgrounds
WW, top
Other: W+jet, Z/γ , WZ,ZZ,Zγ



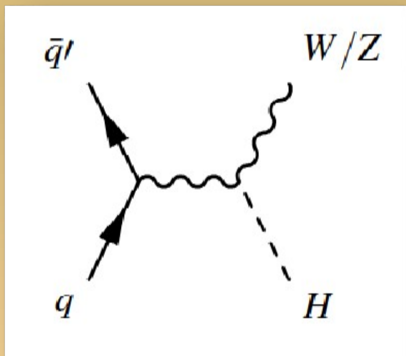


Candidate H in $e\nu\mu\nu$

CMS-PAS-HIG-12-017

Excluded (95% CL): 129-450 GeV
Expected(95%CL): 123-520 GeV

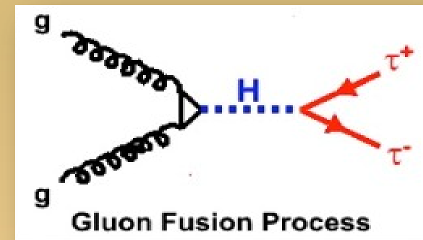
2012: VH→Vbb and H→ττ

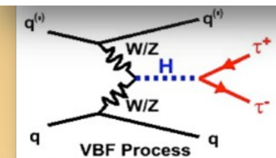


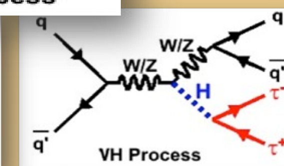
Largest BR

Huge QCD Background ($\times 10^7$)

Search in associated production with W or Z





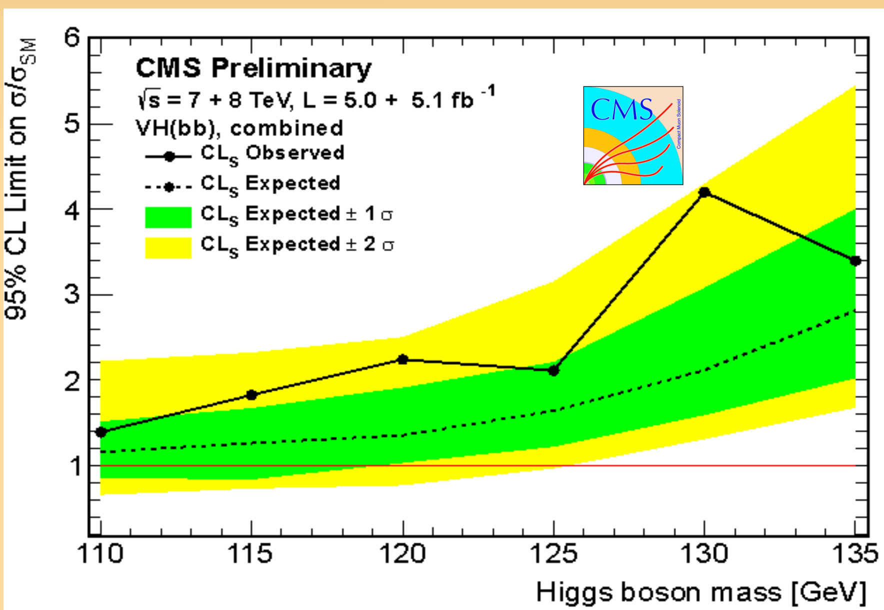


Large σ.BR

Probe coupling to fermion

Difficult Backgrounds

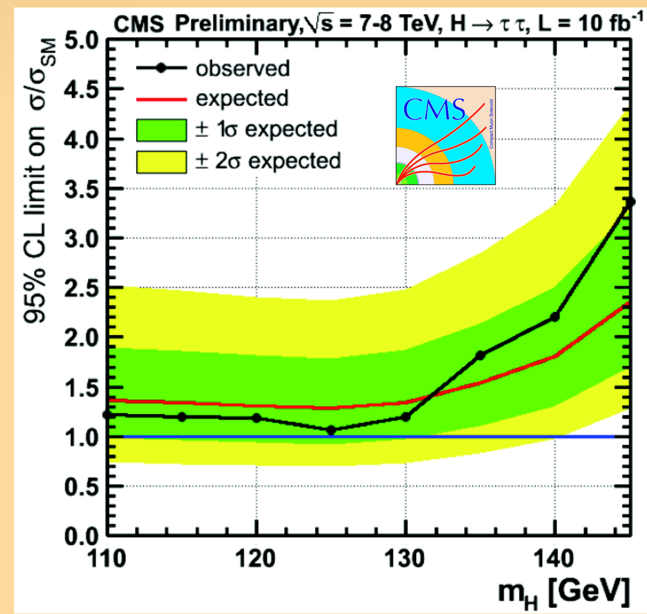
DY, W+jets, QCD



No exclusion observed

None expected

CMS-PAS-HIG-12-019



No exclusion observed

None expected

CMS-PAS-HIG-12-018

2012: All H analyses together

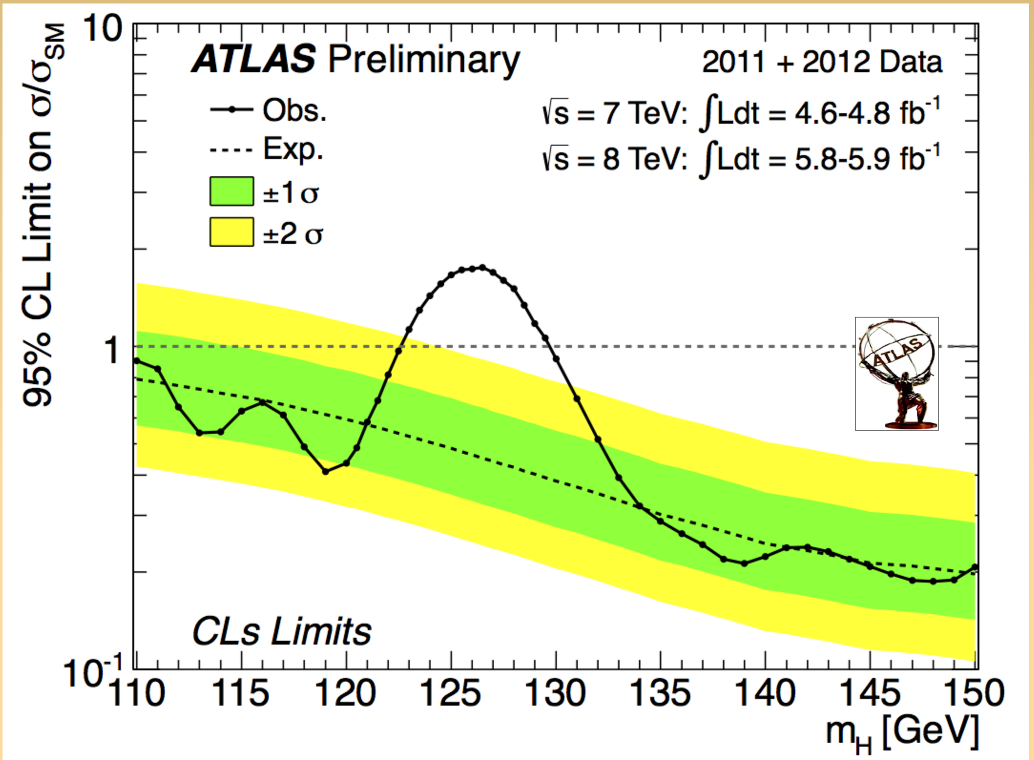
Significance of excesses found in single channel analyses

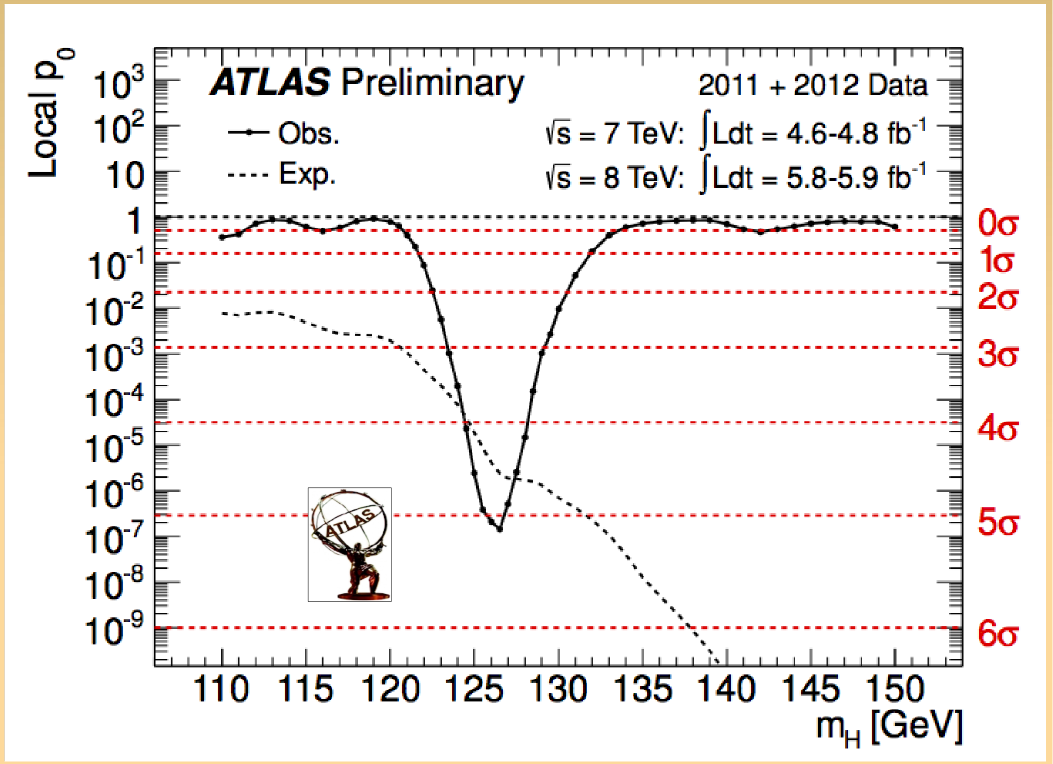
	Atlas	CMS
$H \to 4l$	$3.4\ \sigma$	$3.2\ \sigma$
$H \to \gamma\gamma$	$4.5\ \sigma$	$4.1\ \sigma$

Then combine these results
(within each collaboration)

2012: All H analyses together

ATLAS: New analysis of 2012/2011 2γ's and 4l and former results for others channels





Excluded (95% CL):

110-122.6; 129.7-558 GeV

Expected (95%CL): 110-582 GeV

Excluded (99% CL):

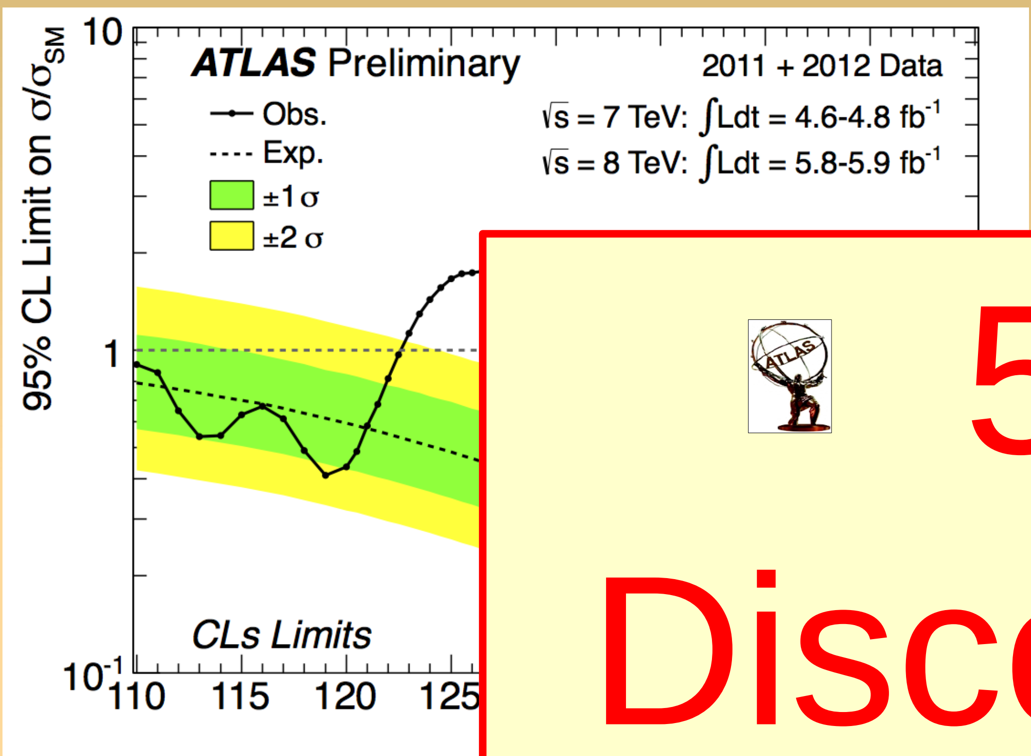
111.7-121.8; 130.7-523 GeV

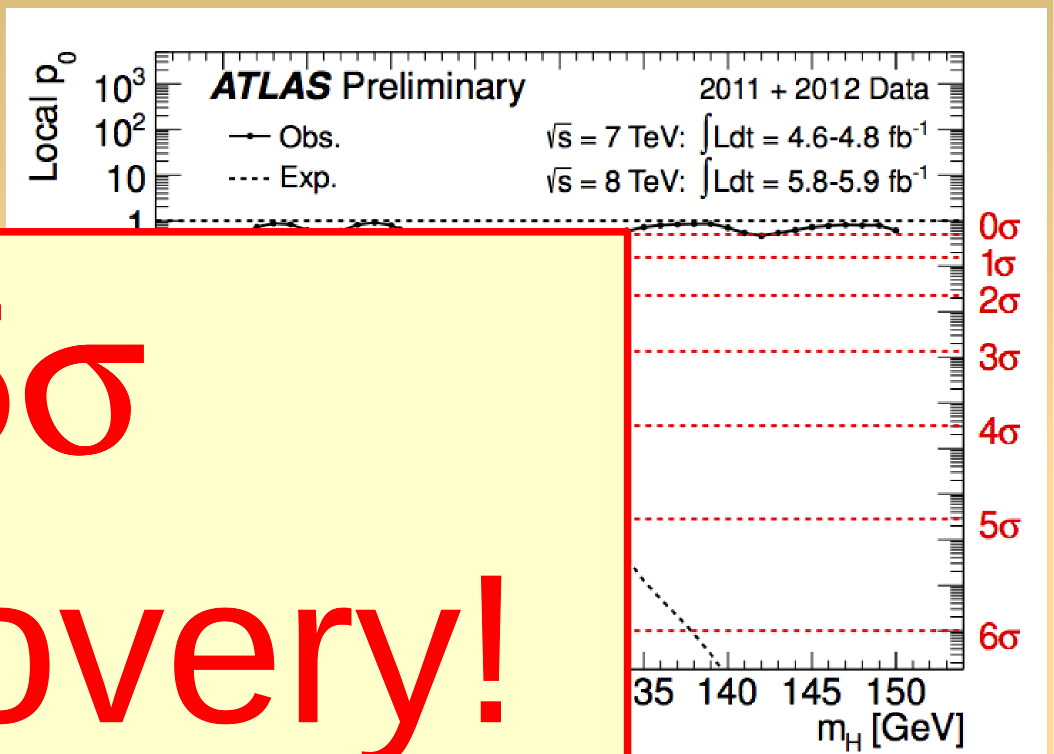
- Maximum excess observed at m_H =126.5 GeV
- Local significance 5.0 σ
- Expected from SM Higgs m_H=126.5 4.6 σ
- Global: 4.1-4.3 σ (LEE over 110-600 or -150 GeV)

ATLAS-CONF-2012-093

2012: All H analyses together

ATLAS: New analysis of 2012/2011 2γ's and 4l and former results for others channels





5σ Discovery!

Excluded (95% CL):
110-122.6; 129.7-558 GeV
Expected (95%CL): 110-582 GeV
Excluded (99% CL):
111.7-121.8; 130.7-523 GeV

- Maximum excess observed at m_H =126.5 GeV
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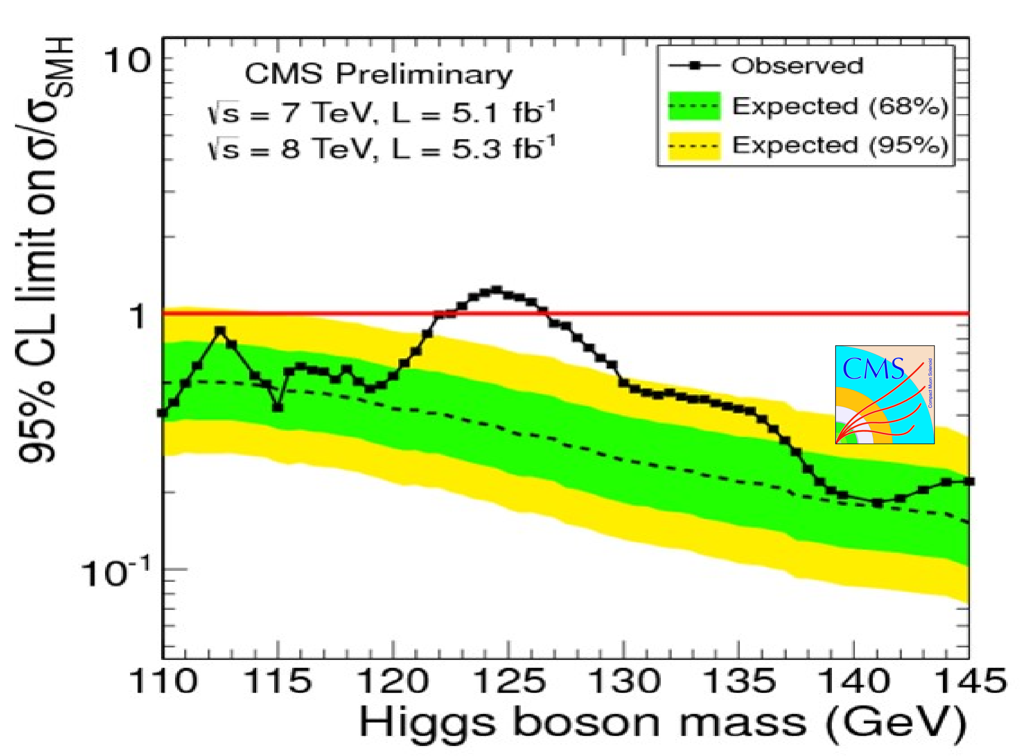
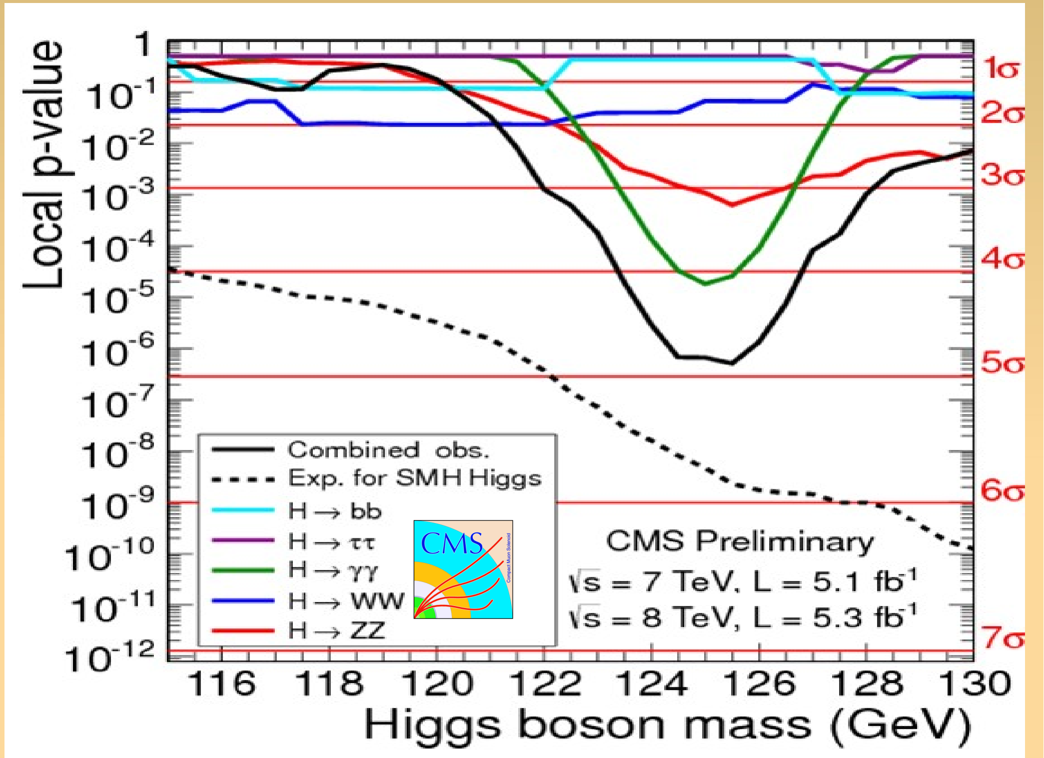
ATLAS-CONF-2012-093

2012: All H analyses together

CMS: all analyses of all channels presented





Excluded (95% CL):

110-122.5; 127-600 GeV

Expected (95%CL): 110-600 GeV

Excluded (99% CL):

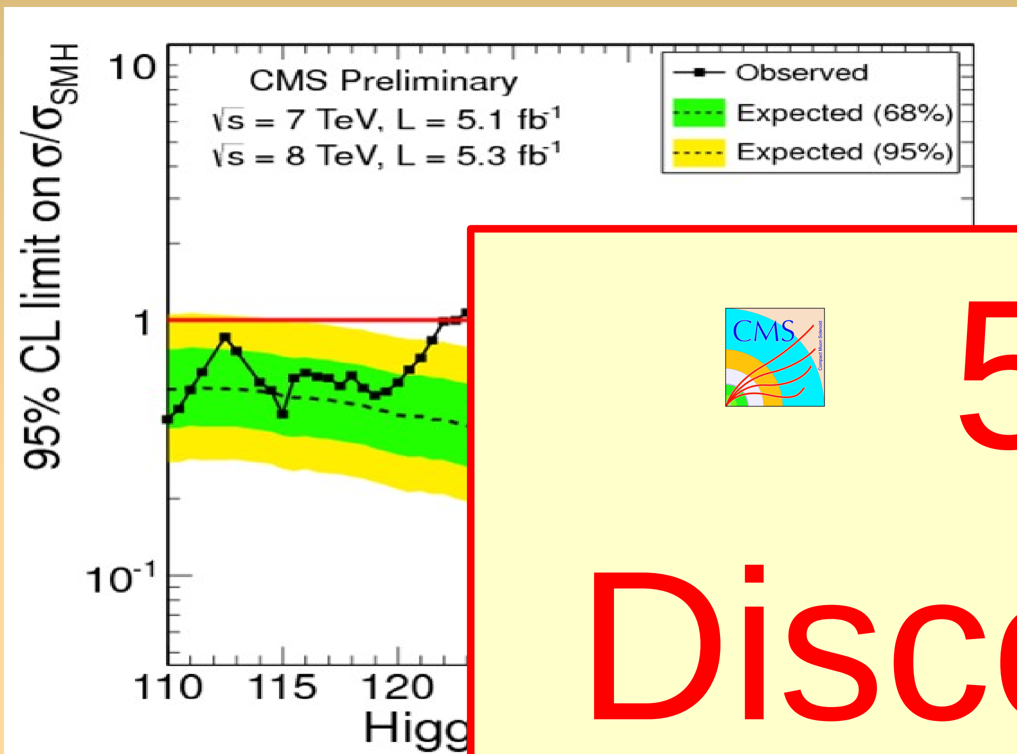
110-112; 113-121.5; 128-600 GeV

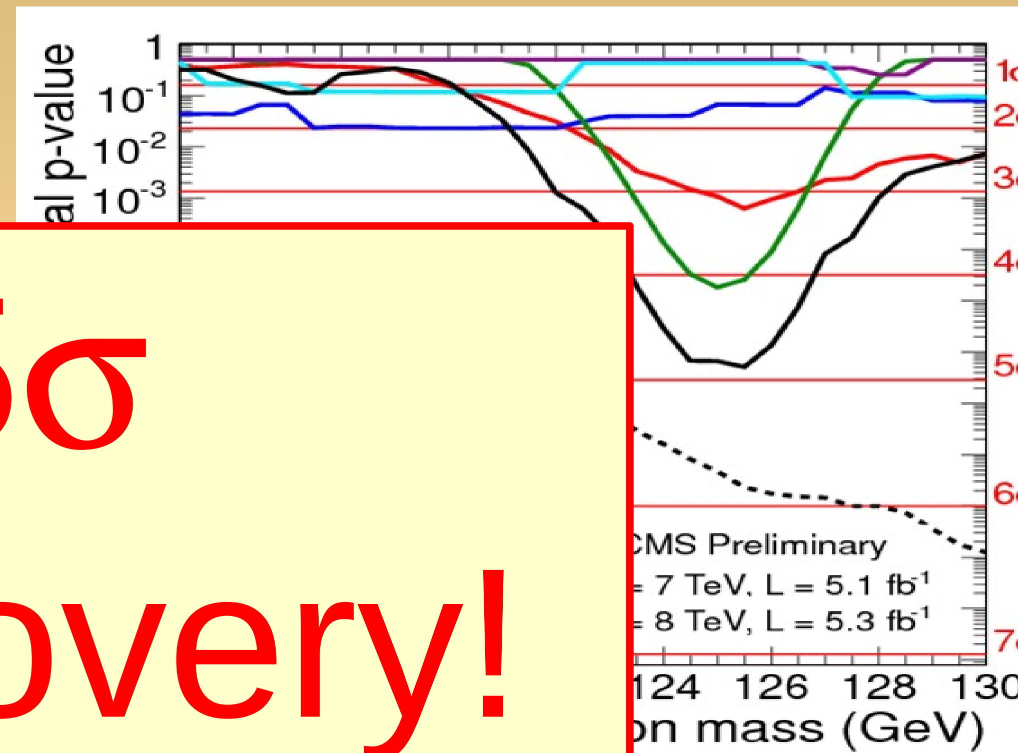
- Maximum excess observed at m_H =125 GeV
- Local significance 4.9 σ
- Expected from SM Higgs m_H=126.5 5.9 σ
- Global: 4.0-4.4 σ (LEE over 110-600 or -145 GeV)

CMS-PAS-HIG-12-020

2012: All H analyses together

CMS: all analyses of all channels presented





5σ
Discovery!

Excluded (95% CL):
110-122.5; 127-600 GeV
Expected (95%CL): 110-600 GeV
Excluded (99% CL):
110-112; 113-121.5; 128-600 GeV

- Maximum excess observed at m_H =125 GeV
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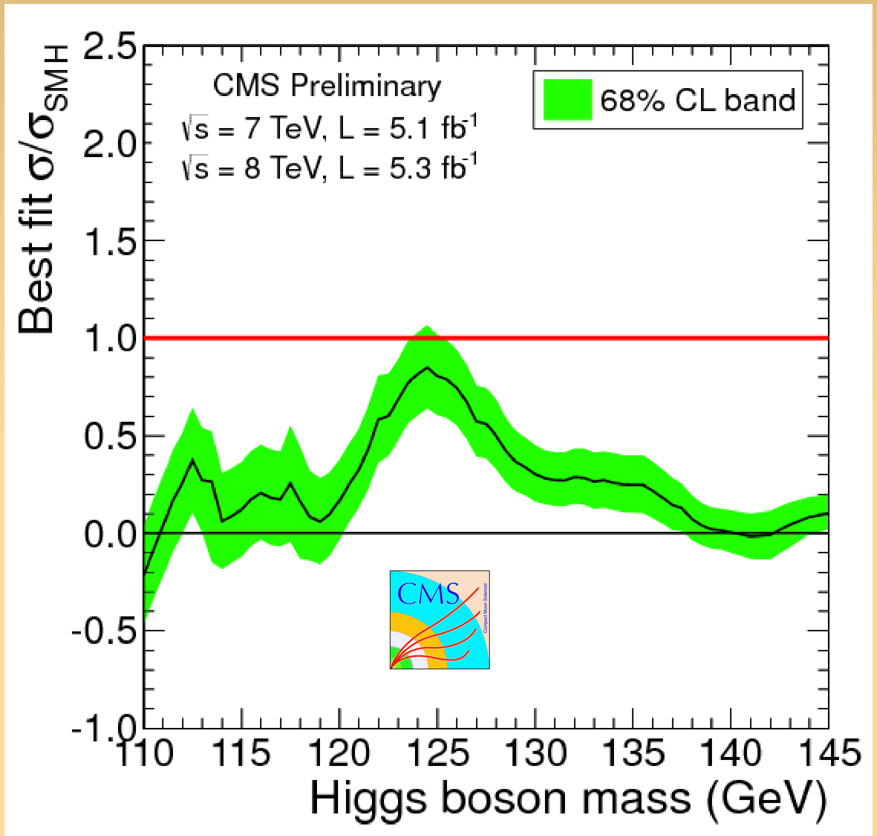
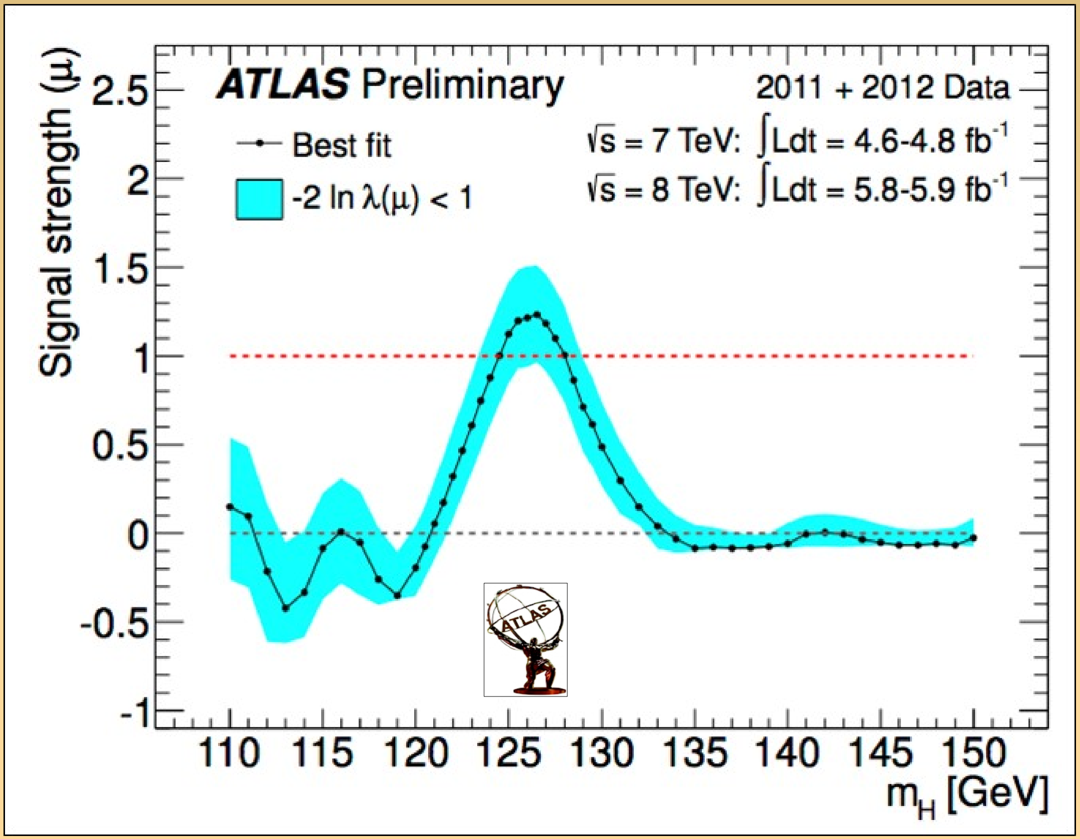
- Expected from SM Higgs m_H=126.5 5.9 σ
- Global: 4.0-4.4 σ (LEE over 110-600 or -145 GeV)

CMS-PAS-HIG-12-020

2012: All H analyses together

Best-fit value of Signal strength





Best-fit value at 125 GeV

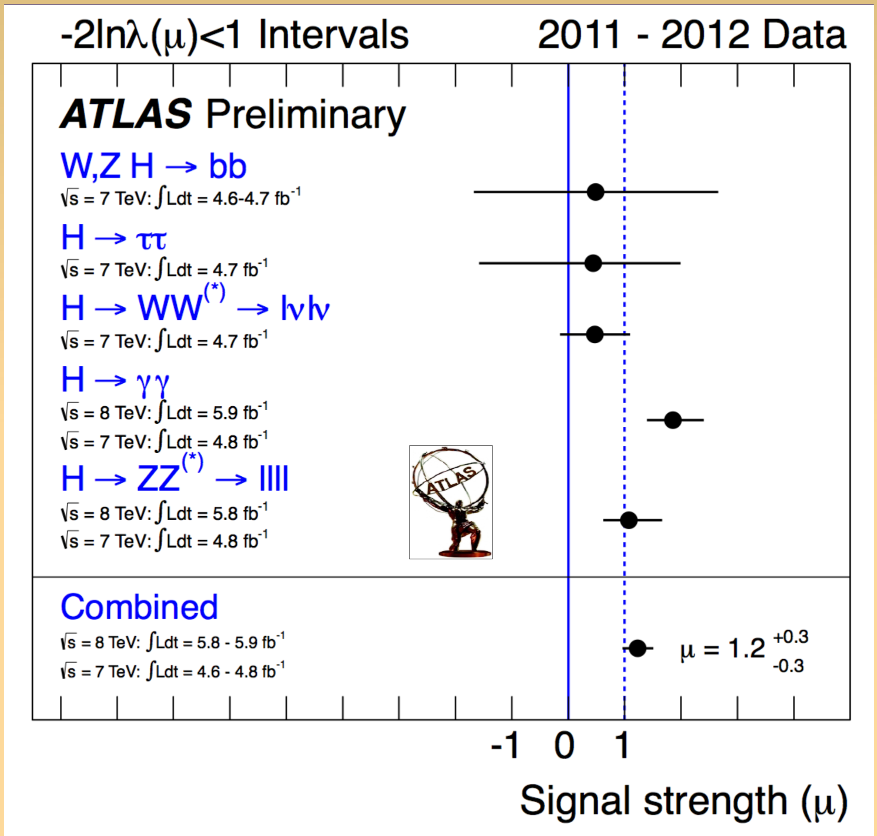
$\mu = 0.80 \pm 0.22$

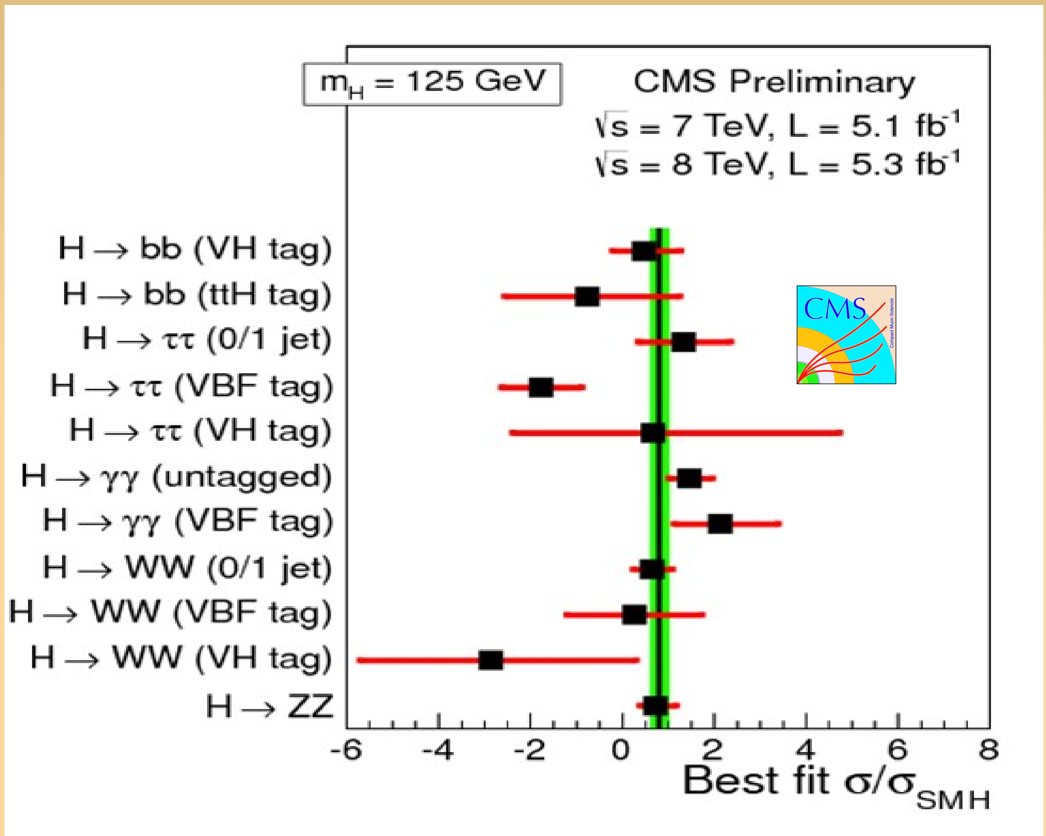
Best-fit value at 126.5 GeV

$\mu = 1.2 \pm 0.3$

2012: All H analyses together

Best-fit value of Signal strength

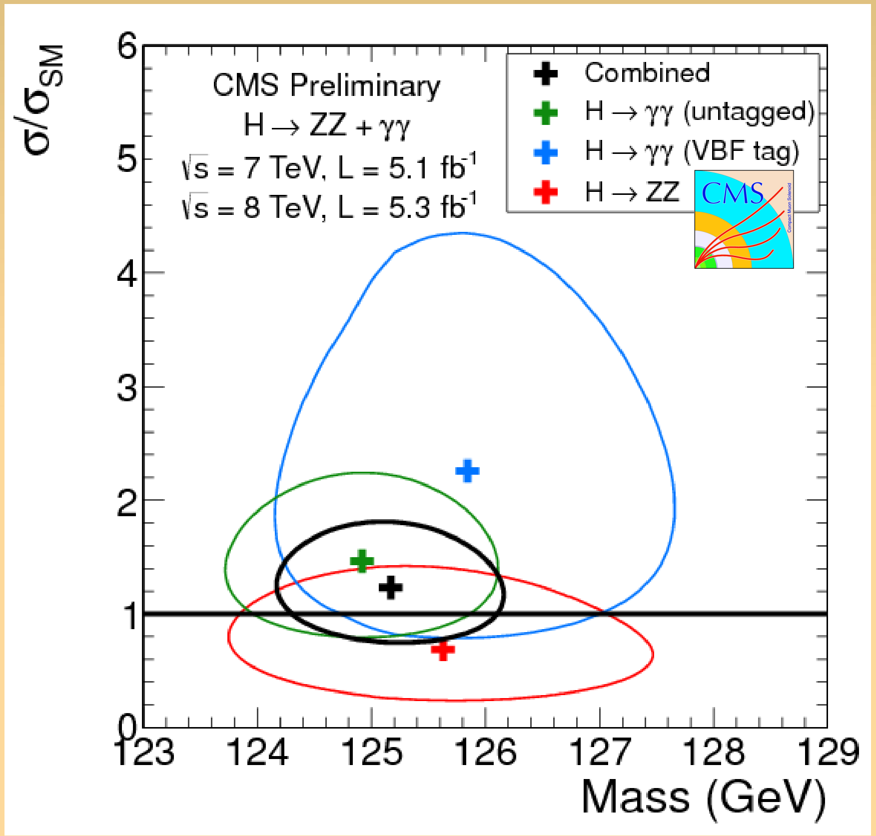


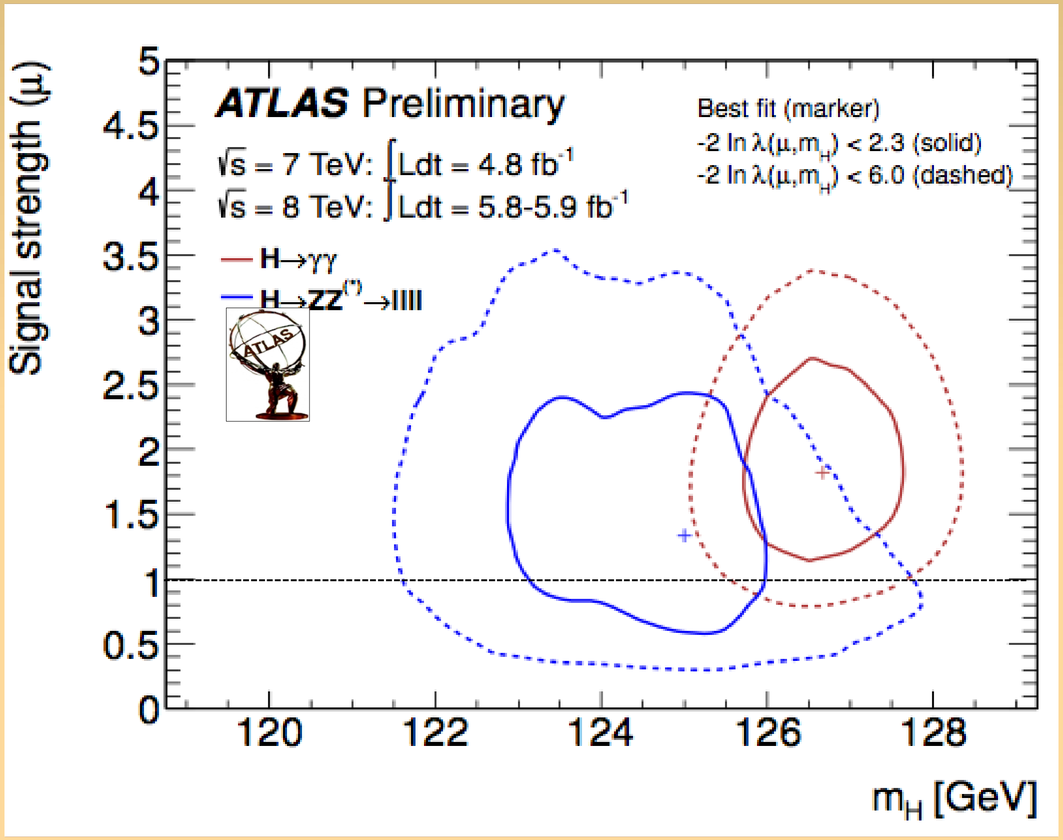


Consistent results from various categories within uncertainties

2012: All H analyses together

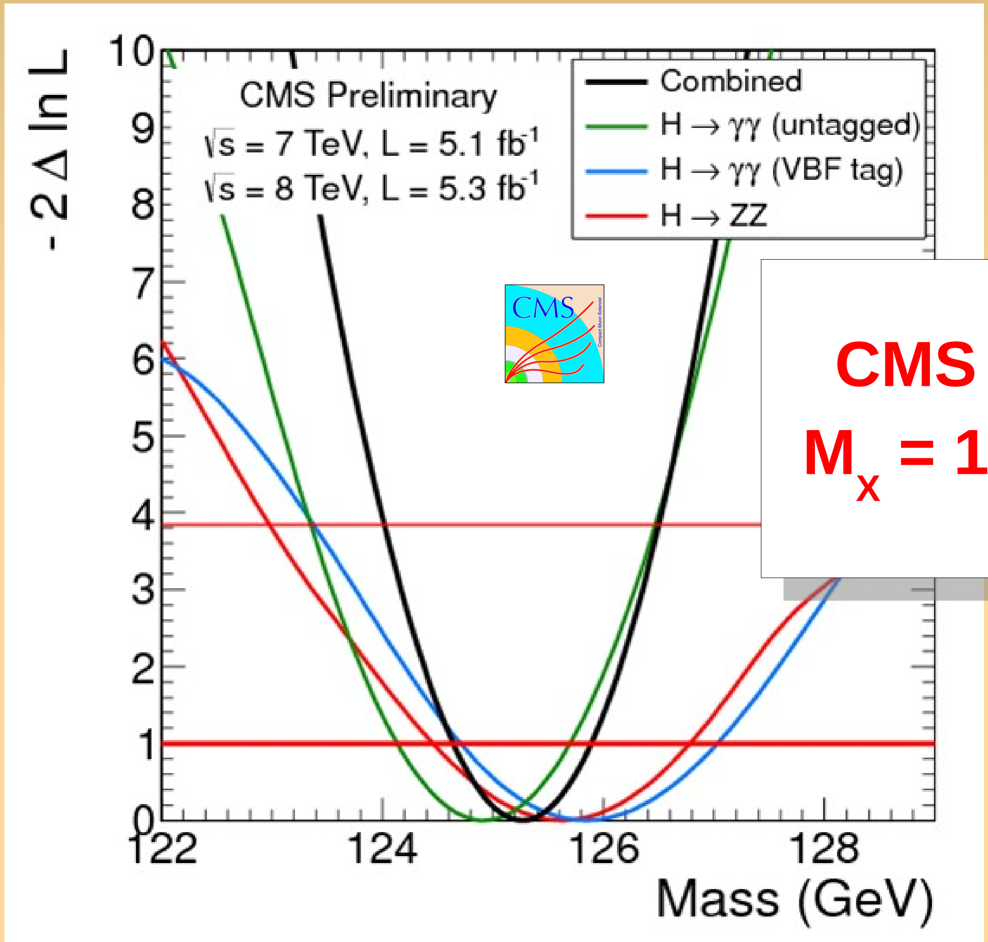
Signal Strengths for single channel and combined analyses vs m_H





Consistency of the global picture

2012: All H analyses together



CMS presents a mass measurement

M_X = 125.3 ± 0.4 (stat) ± 0.5(syst) GeV

Conclusions

- LHC performance have been extraordinary
- Atlas and CMS fully exploited the high quality data delivered by the machine and undertook a rich program of studies of the Standard Model and beyond SM Physics

The CMS and Atlas collaborations announce the discovery of a neutral resonance of mass m_H~125/126.5 GeV

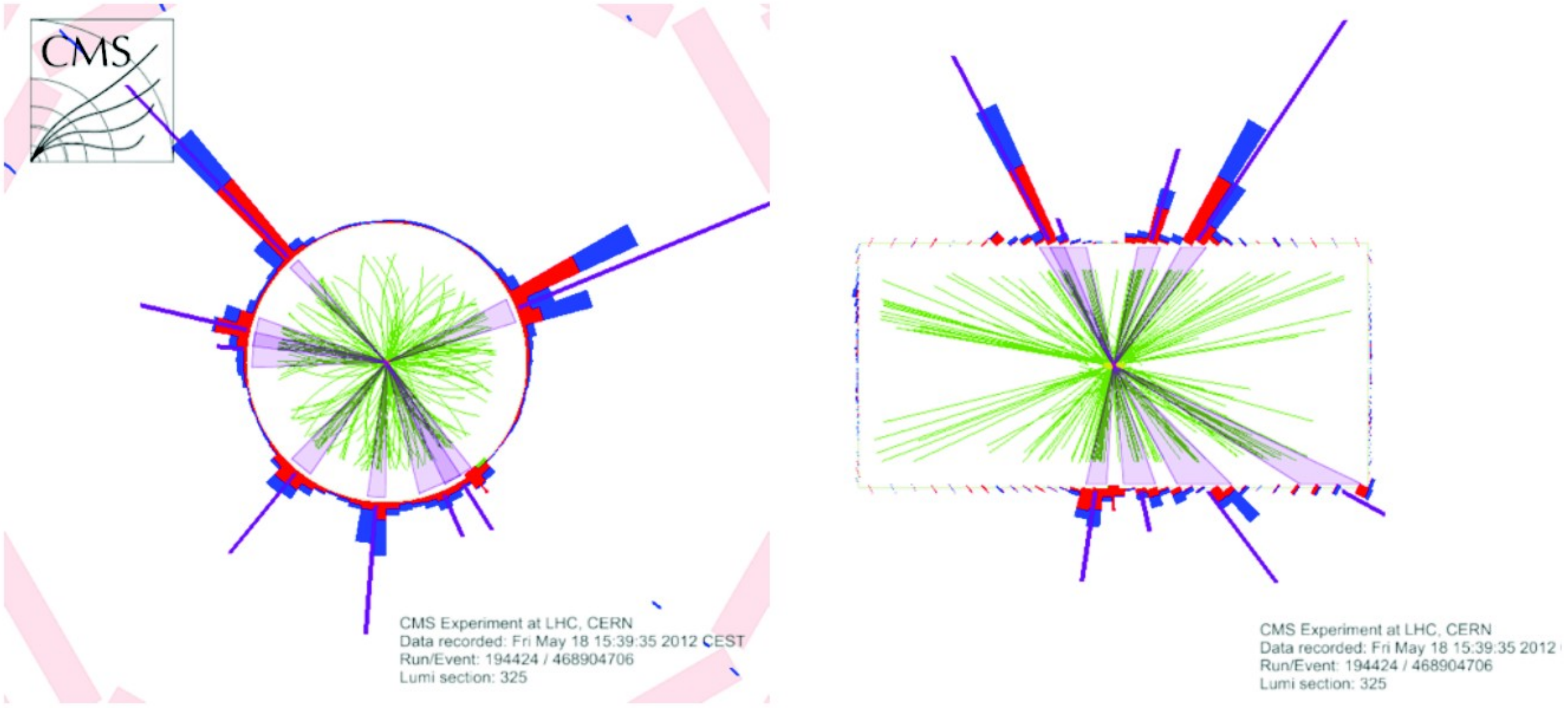
at the 5 σ significance level

Thank you

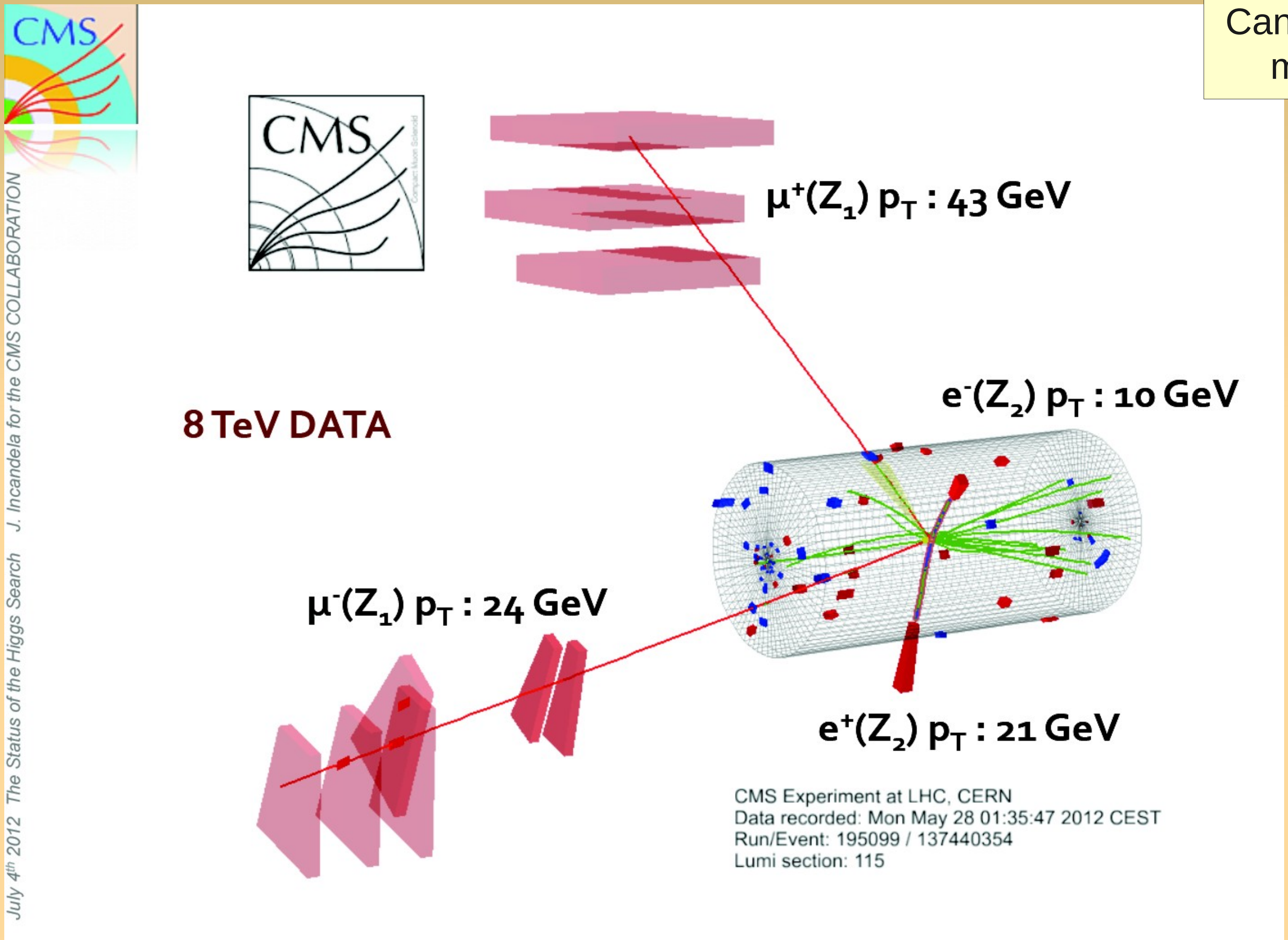
Additional material

Microscopic Black Holes

8-Jet Event, S_T = 3 TeV



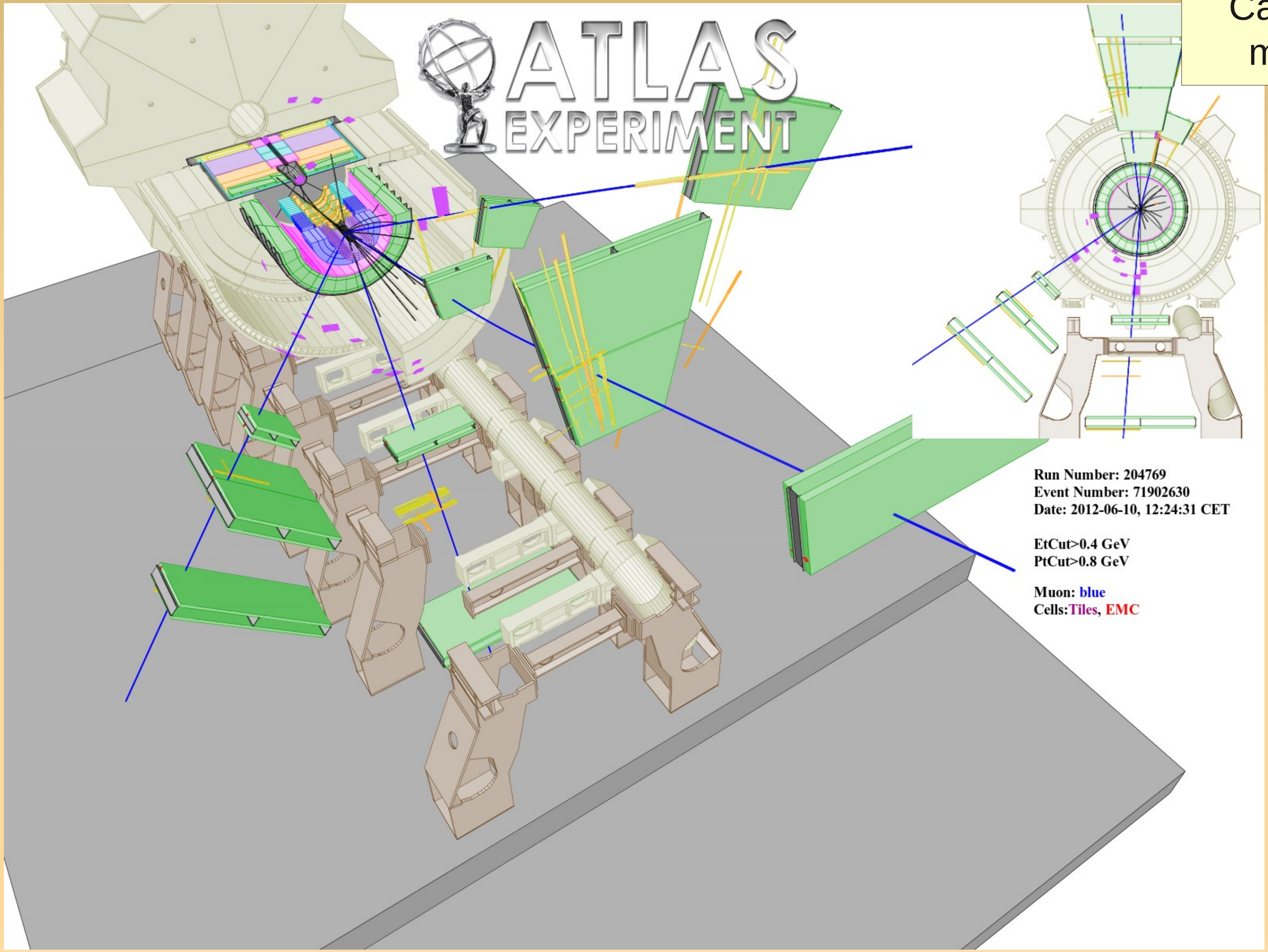
H→2e2μ candidate @8TeV



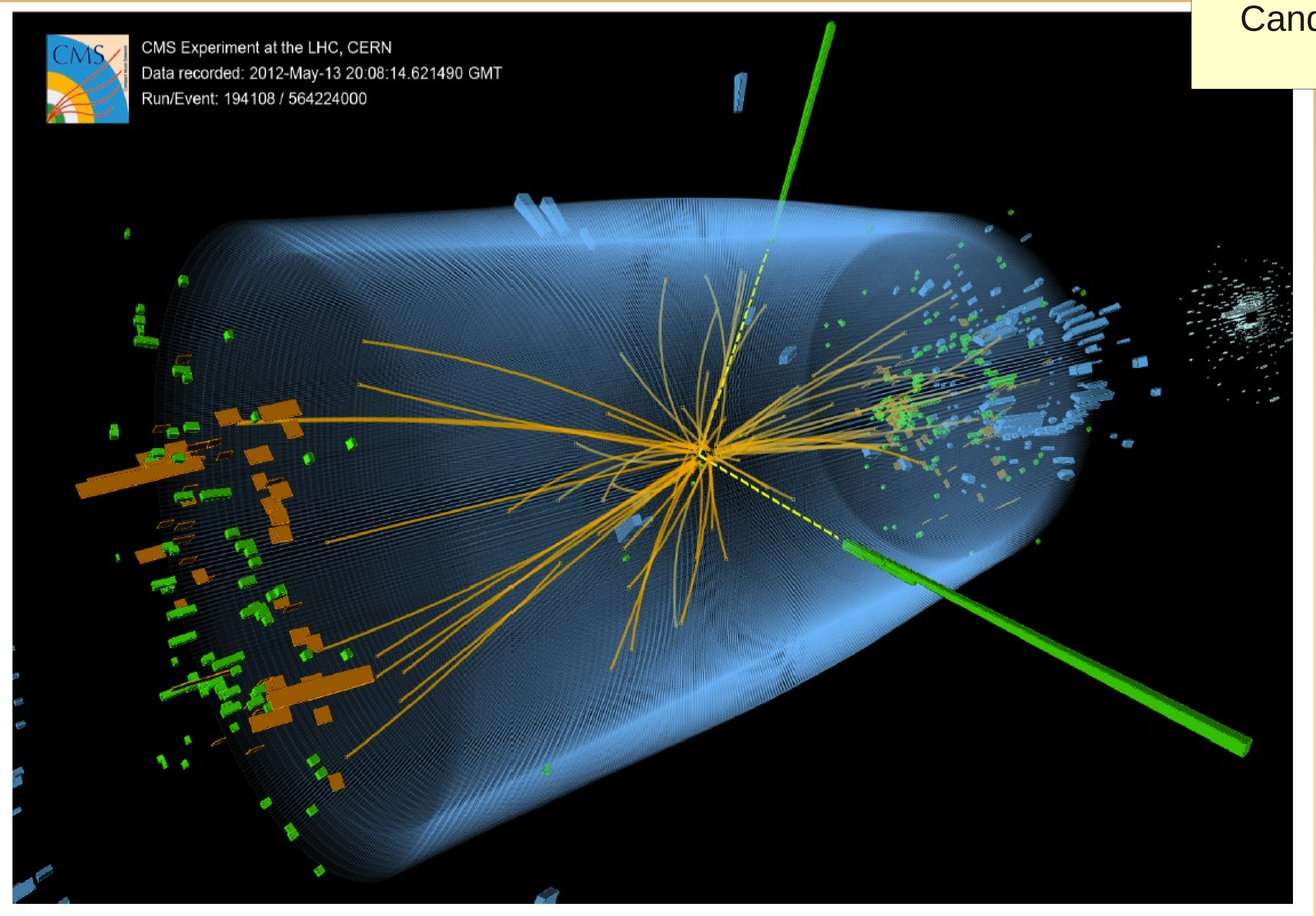
Candidate H in 2e2μ
m_{4l} = 126.9 GeV

H→4μ candidate @8TeV

Candidate H in 4μ
m_{4l} = 124.1 GeV



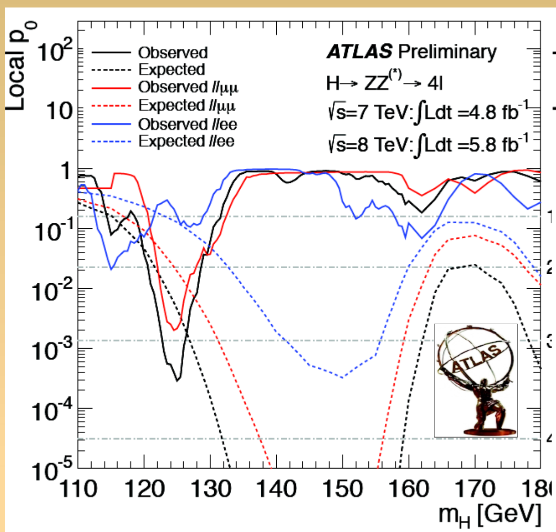
H→2γ



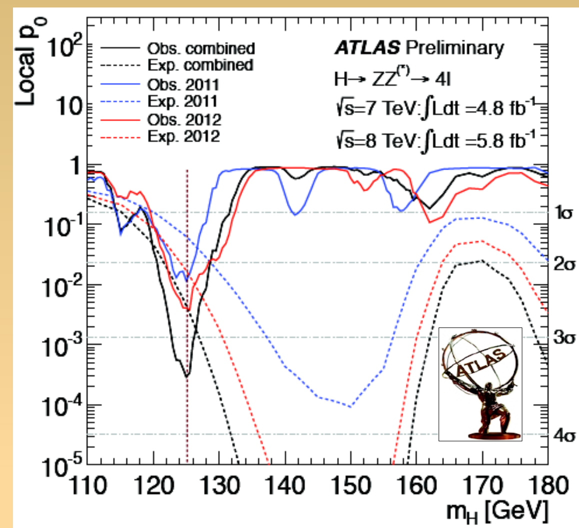
Candidate H in 2γ

H→ZZ*→4l : the "golden"

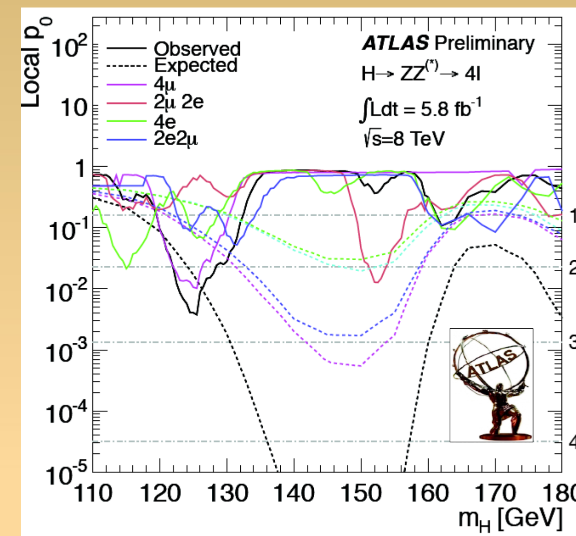
p0 plots



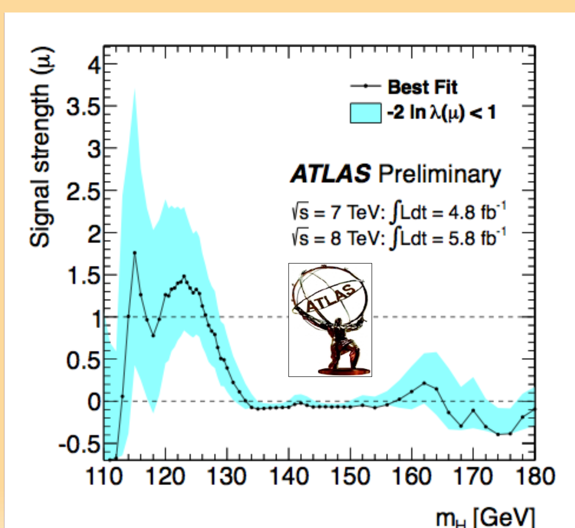
Separating according to sub-leading ll flavour



Separating according to year

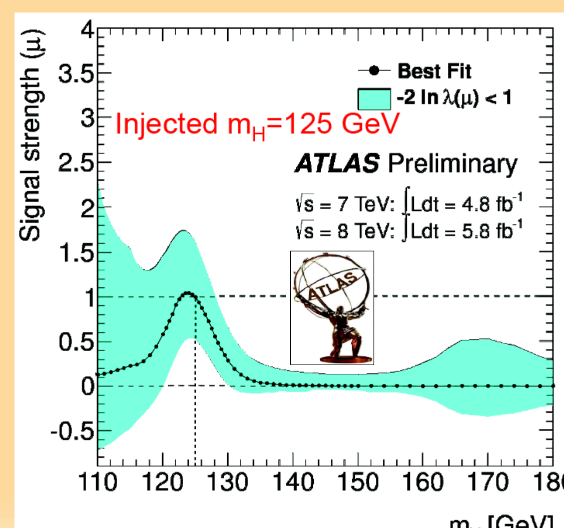


Separating according to final states



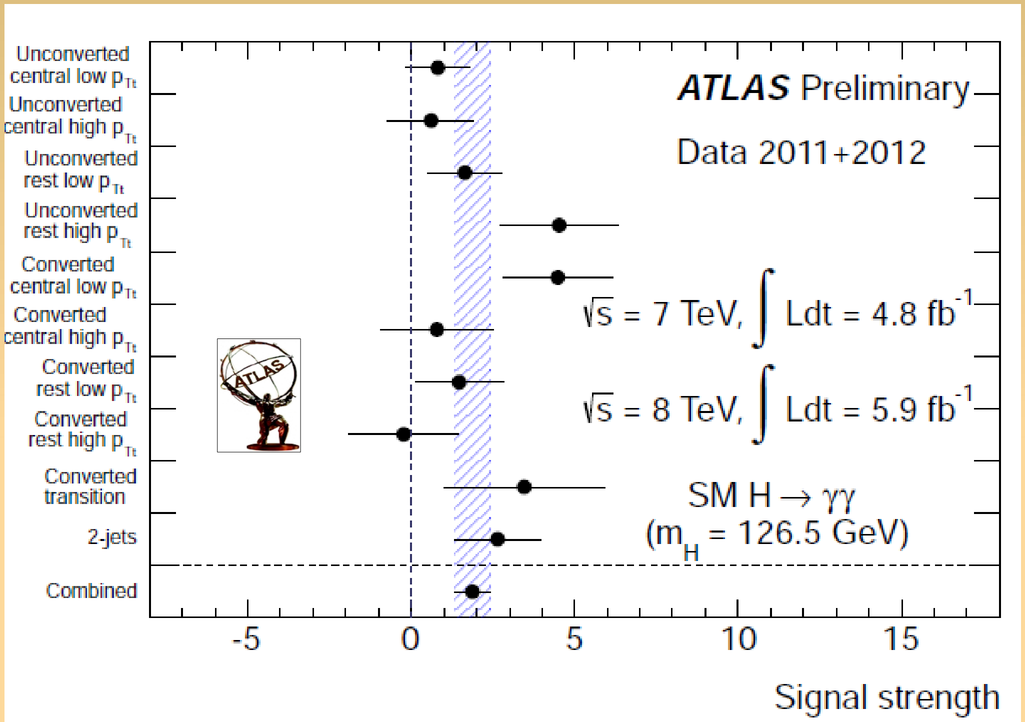
Best-fit value of Signal strength

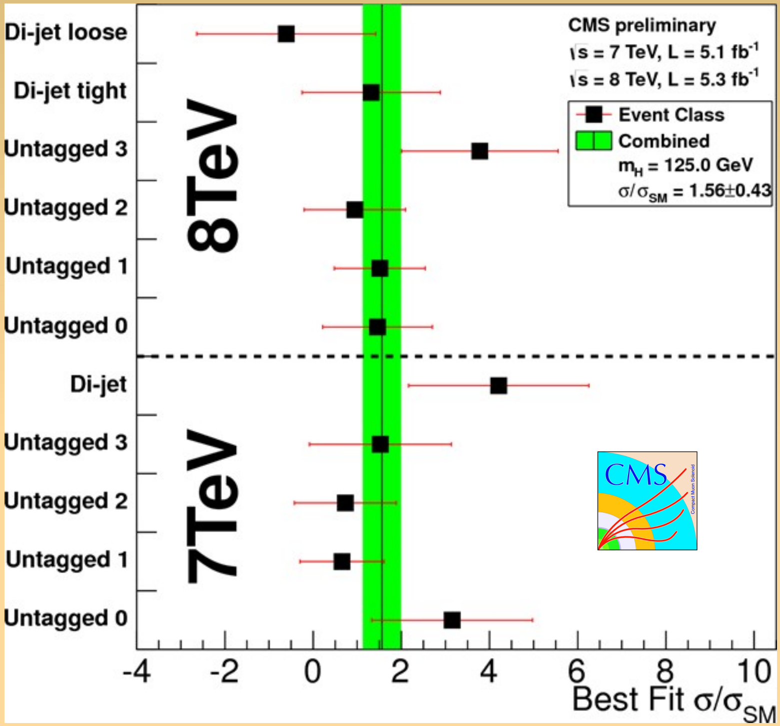
Compare data with MC with a H 125 GeV



2012: H→2γ : the "beautiful"

Best-fit value of Signal strength





Best-fit value at 126.5 GeV

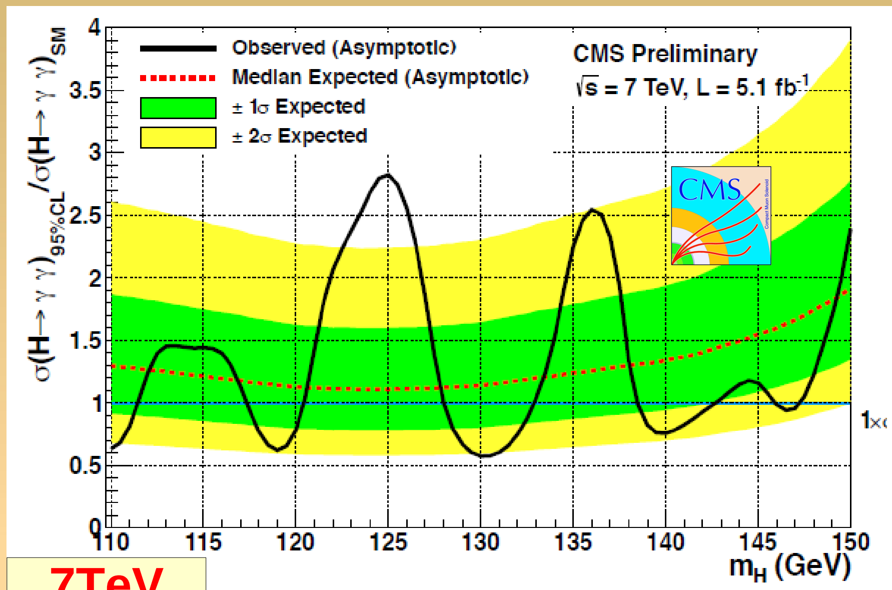
μ=1.9 ± 0.5

Best-fit value at 125 GeV

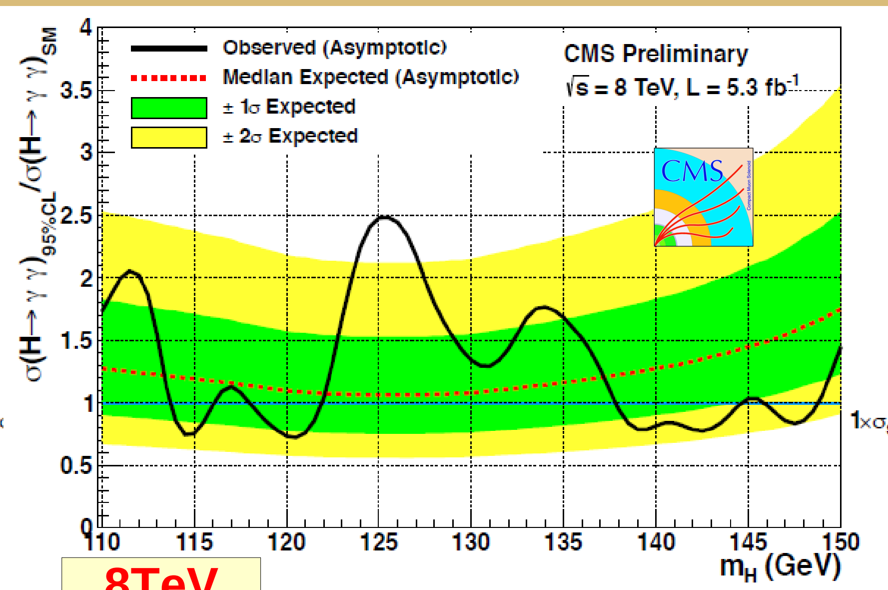
μ=1.56 ± 0.43

Comparing classes in γγ channel

2012: H→2γ : the "beautiful"

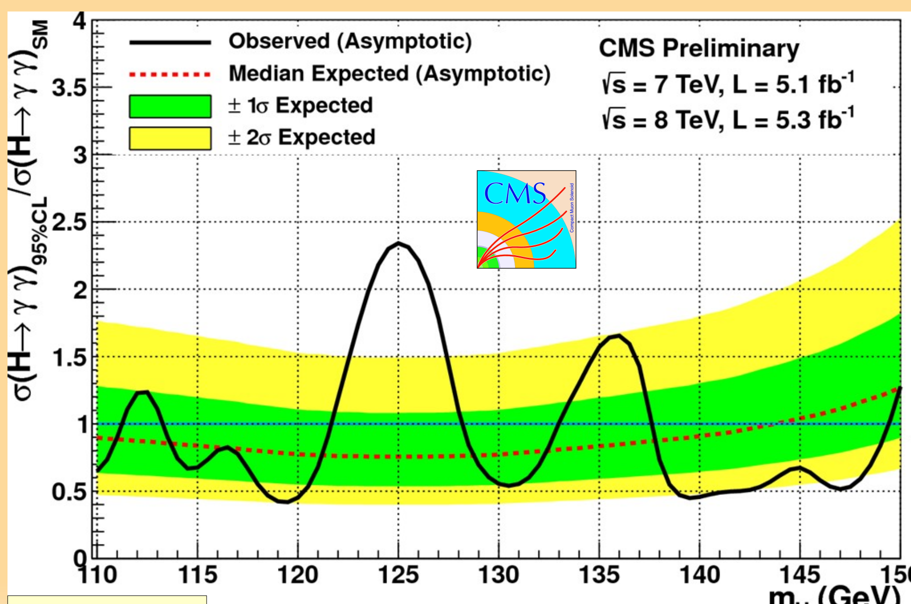


7TeV



8TeV

Comparing data sets in $\gamma\gamma$ channel

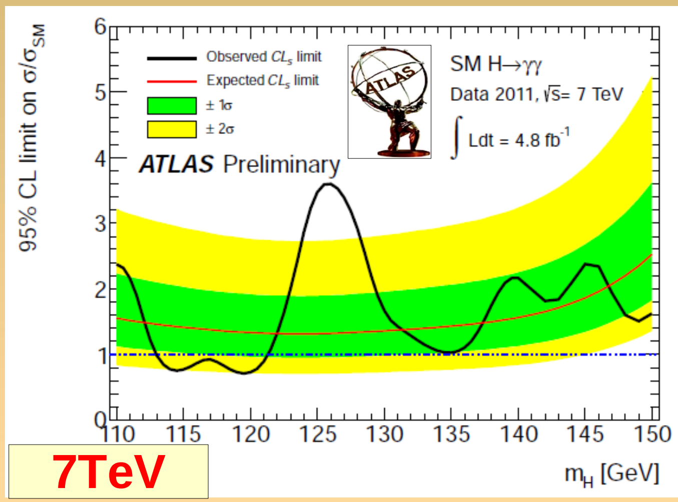


7+8TeV

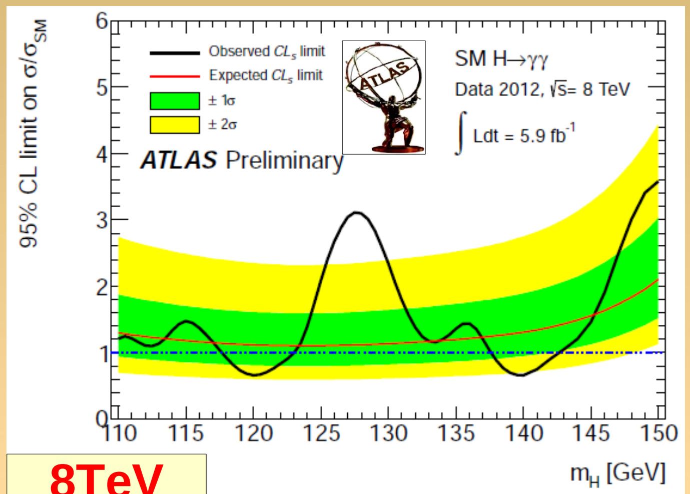
Exclusion plots

2012: H→2γ : the "beautiful"

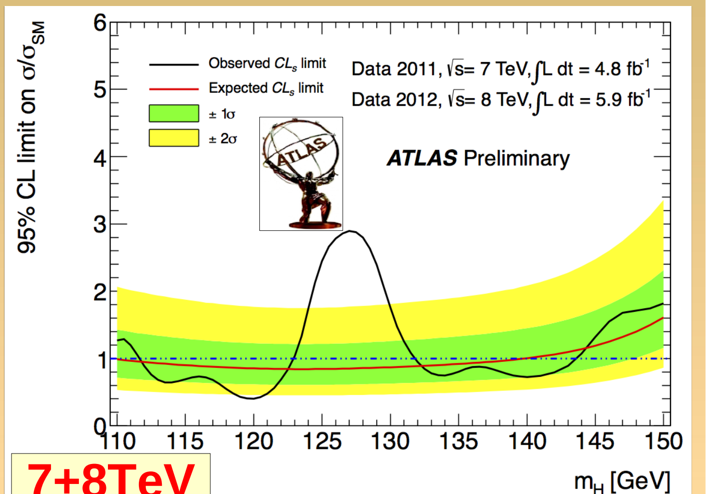
Exclusion plots



7TeV

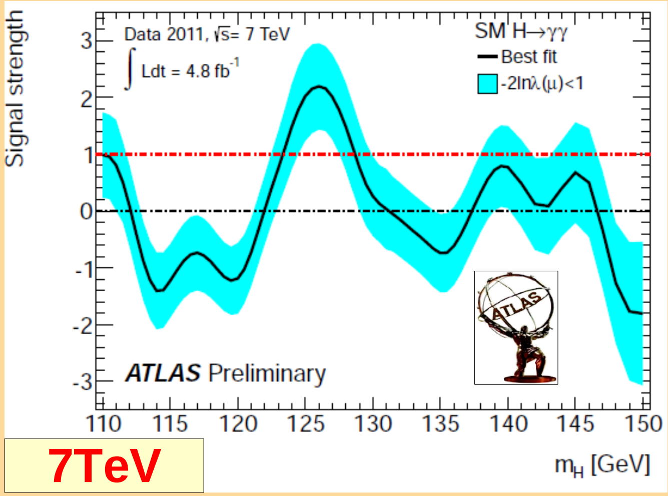


8TeV

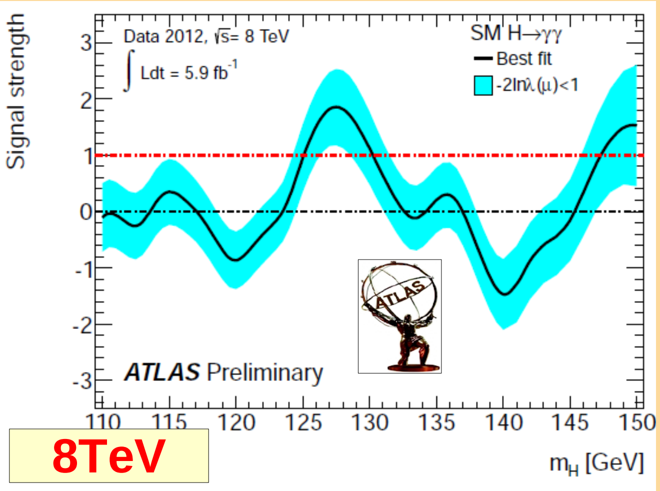


7+8TeV

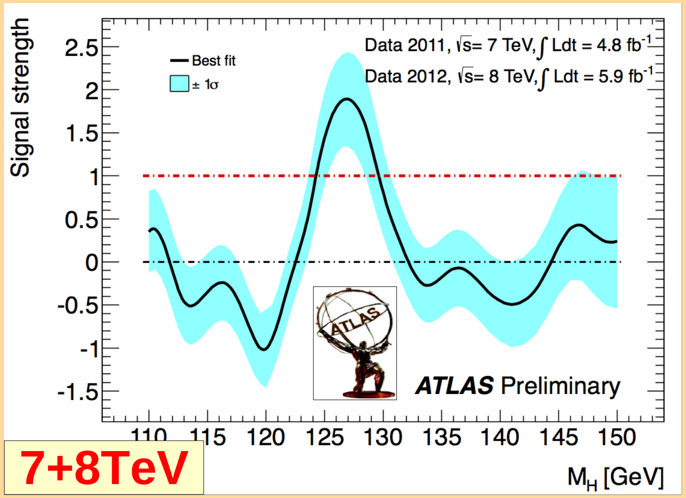
Best-fit value of Signal strength



7TeV



8TeV

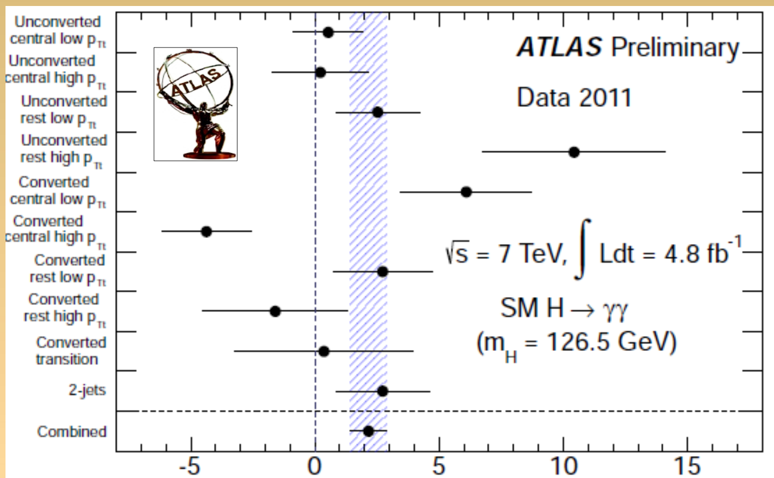


7+8TeV

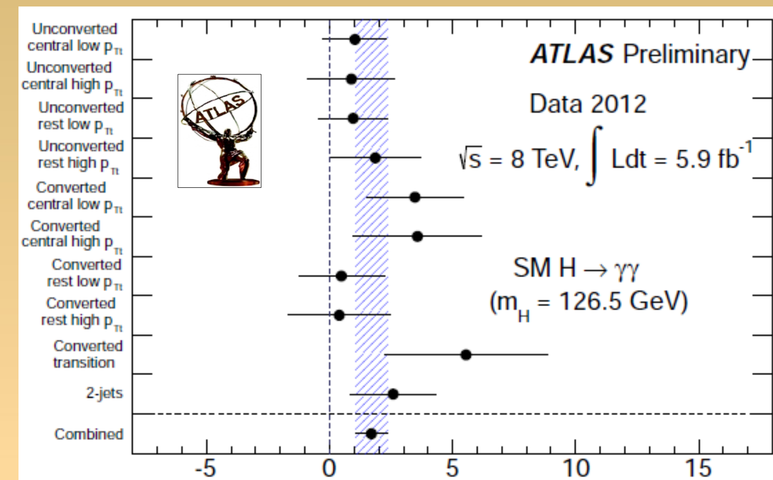
Comparing data sets in γγ channel

2012: H→2γ : the "beautiful"

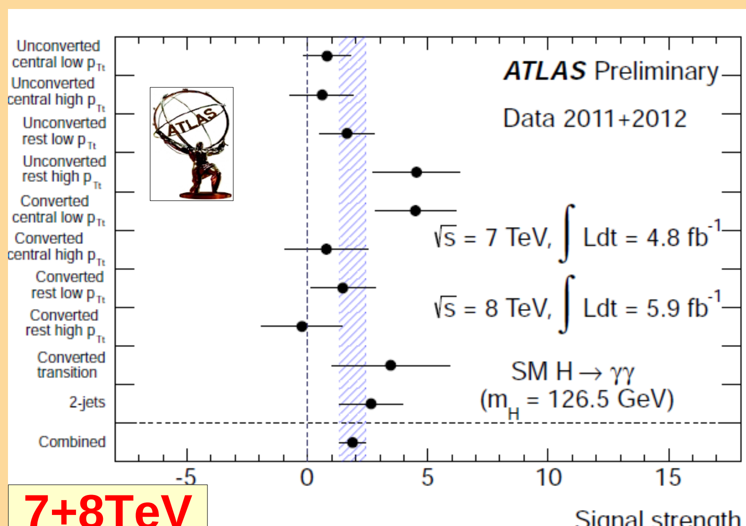
Best-fit value of Signal strength



7TeV



8TeV

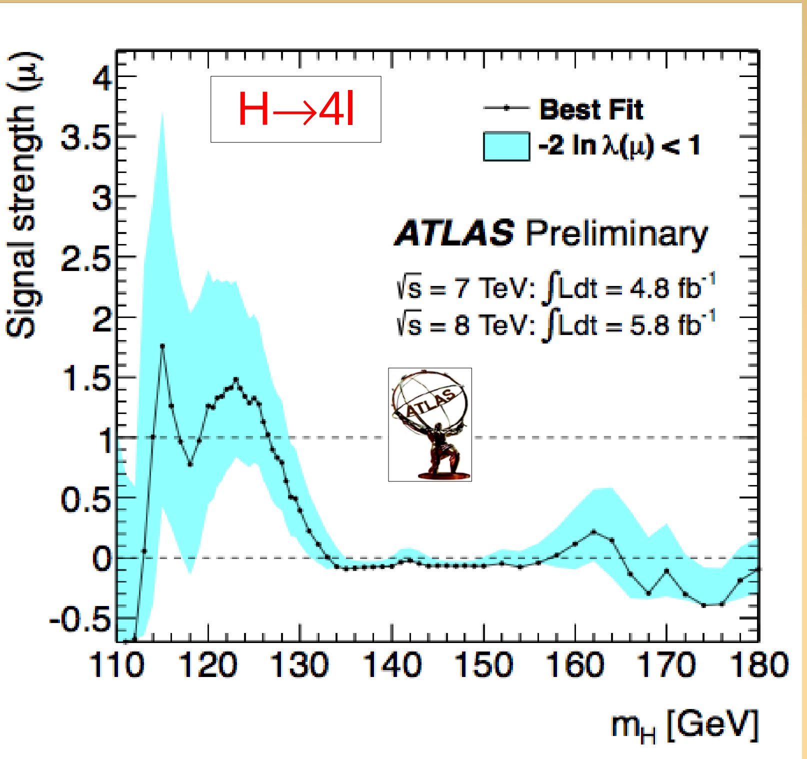


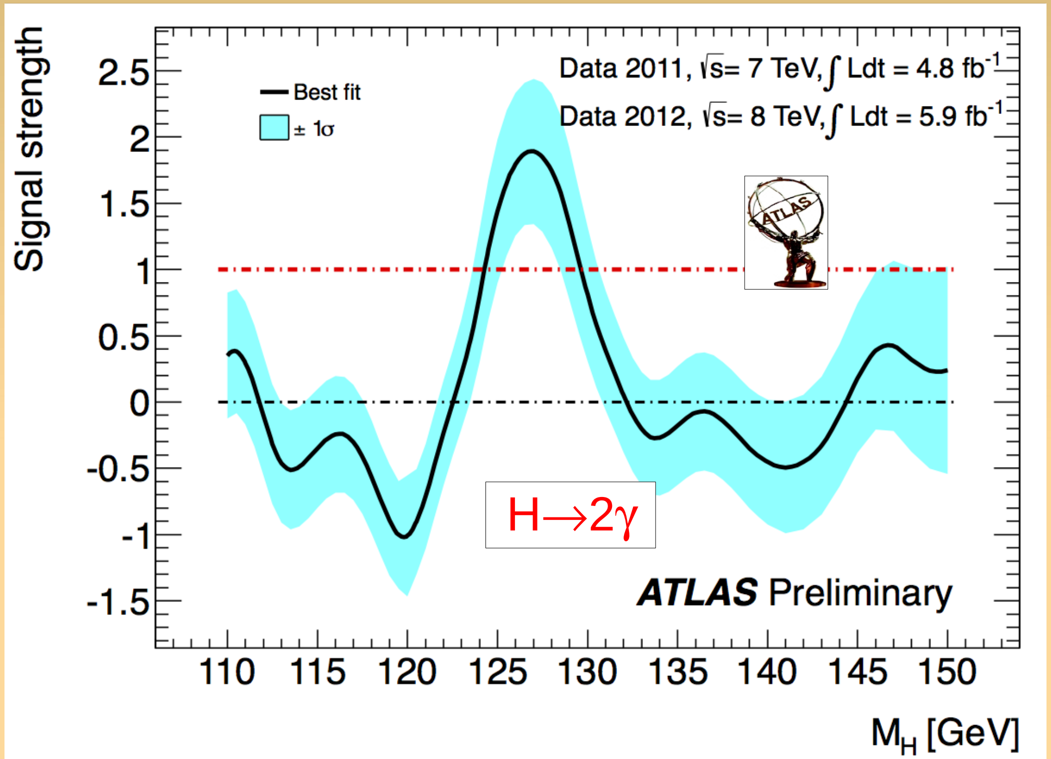
7+8TeV

Compare channel and classes results and data sets in γγ channel

2012: H→2γ and H→ZZ*→4l

Best-fit value of Signal strength





Best-fit value at 125 GeV

μ=1.3 ± 0.6

Best-fit value at 126.5 GeV

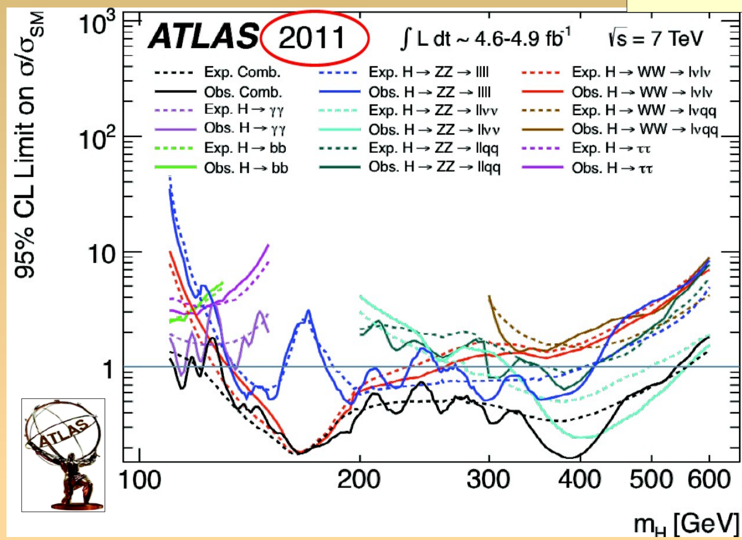
μ=1.9 ± 0.5

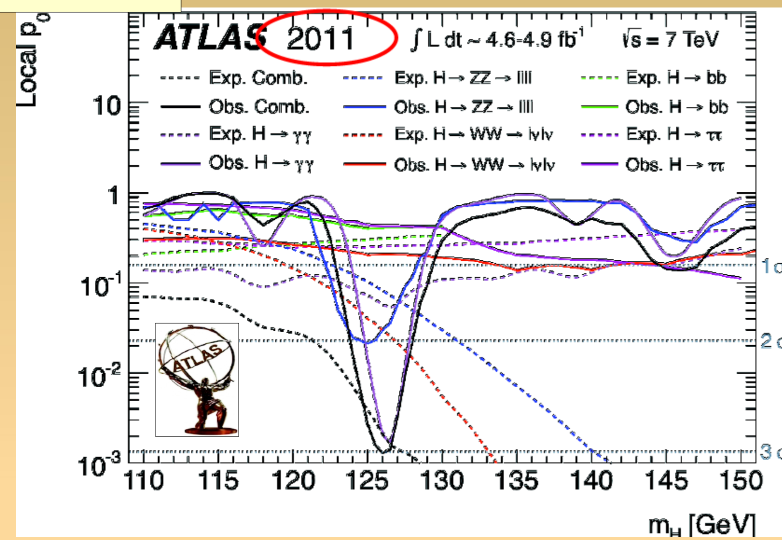
Comparing 4l and $\gamma\gamma$ channels

2012: All H analyses together

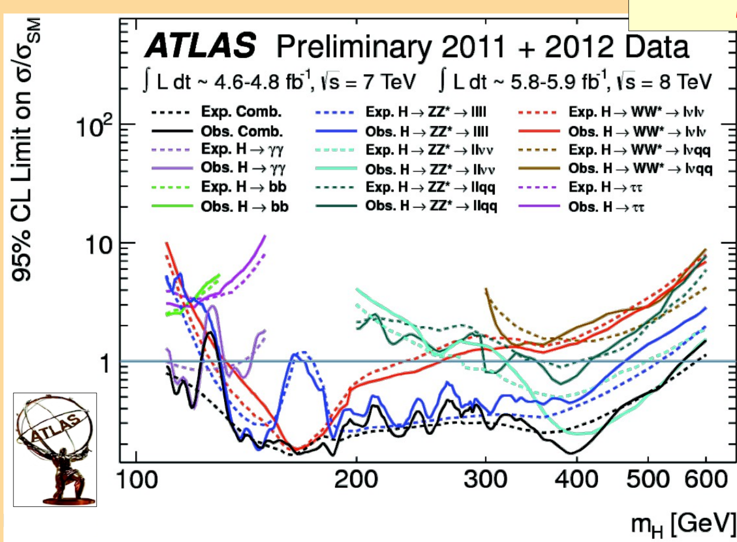
p0 plots

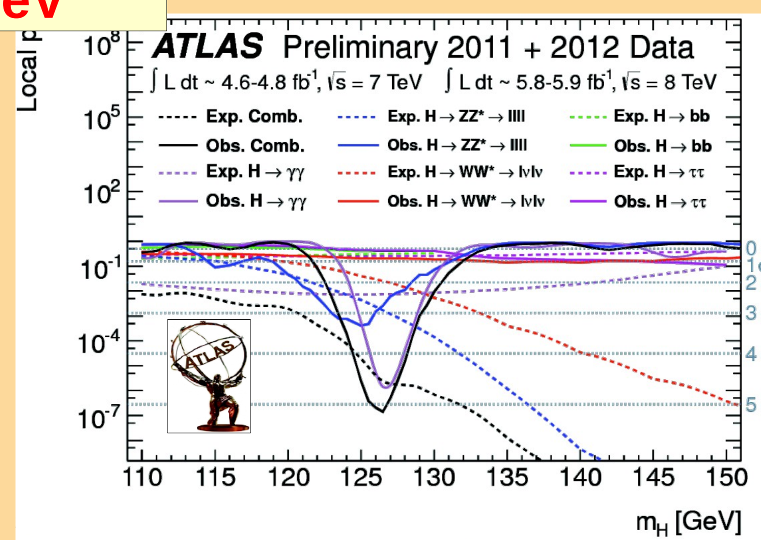
7TeV





7+8TeV

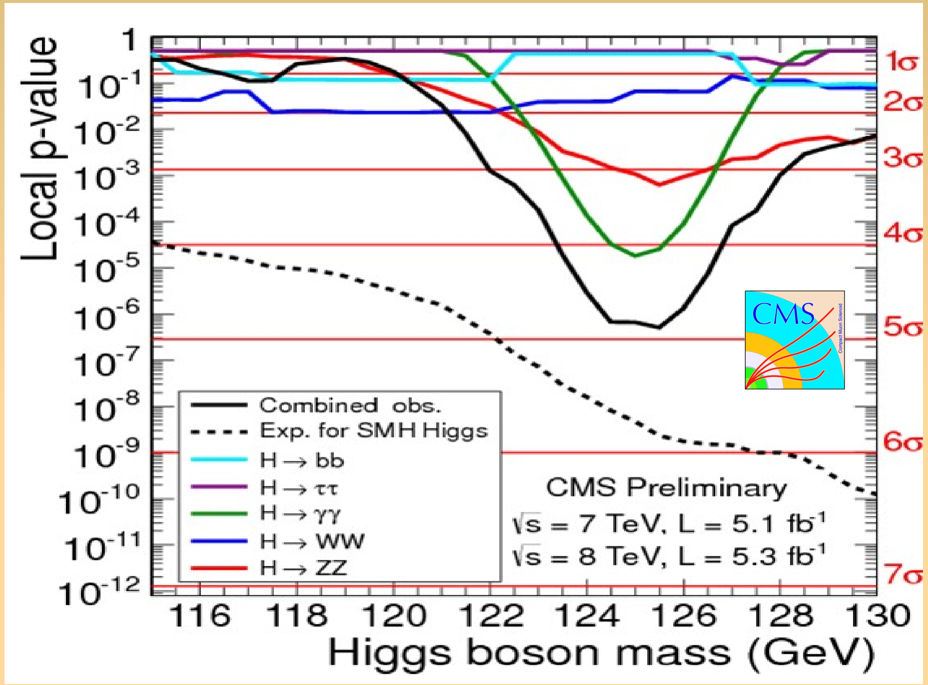


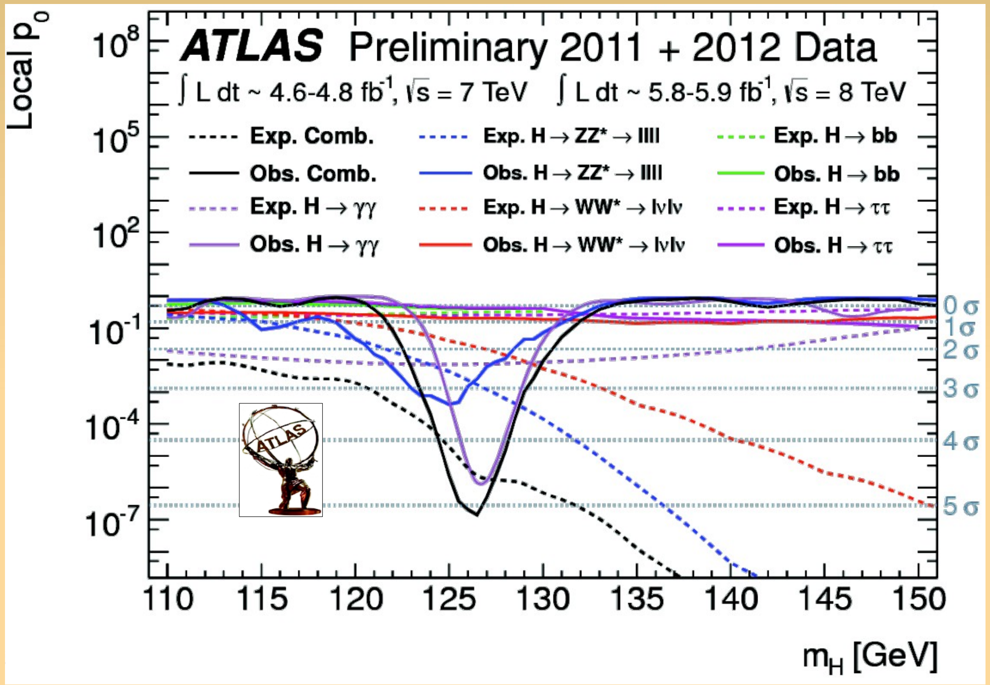


Comparing Combined analyses

2012: All H analyses together

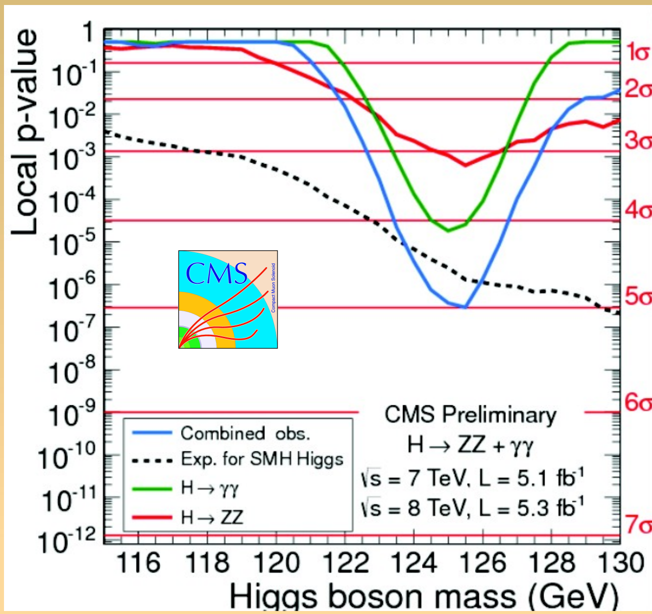
p0 plots





Compare combined and single channel results

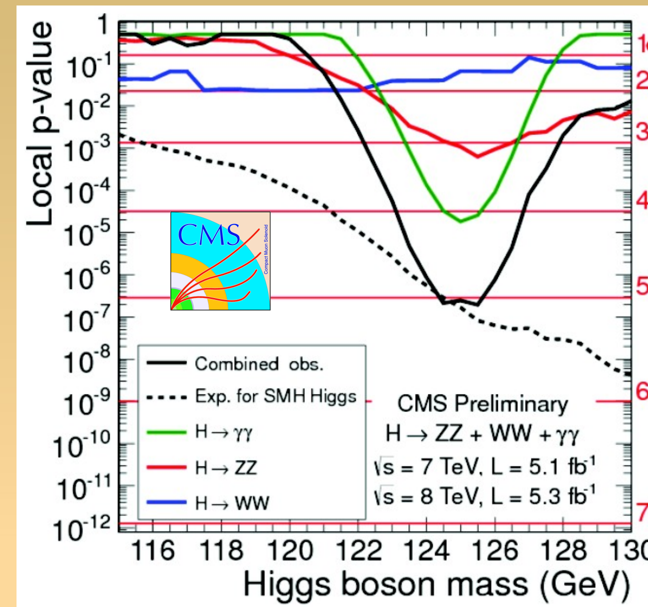
2012: All H analyses together



γγ + 4l

Obs.: 5.0 σ

Expec.: 4.7 σ

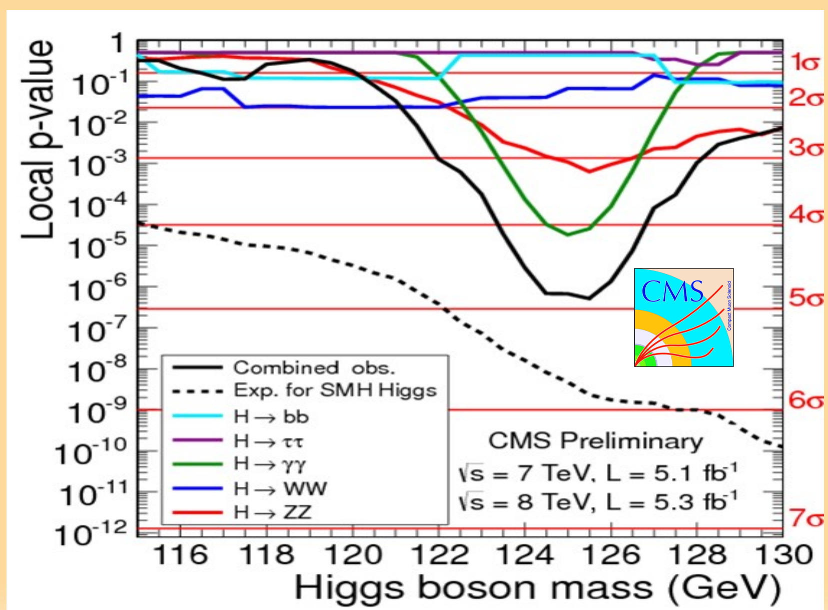


γγ + 4l + WW

Obs.: 5.1 σ

Expec.: 5.2 σ

Adding more and more channels



All channels

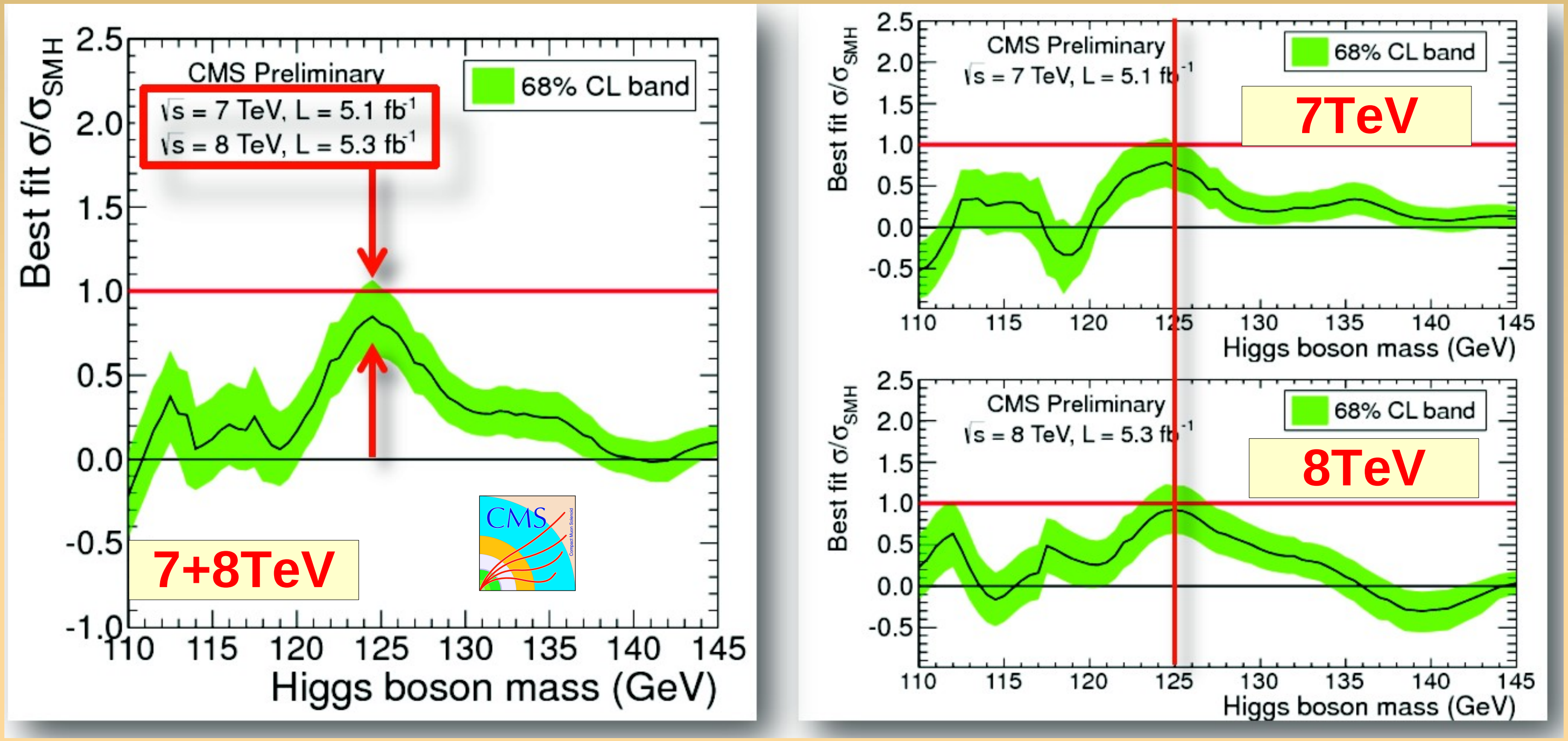
Obs.: 4.9 σ

Expec.: 5.9 σ

p0 plots

2012: All H analyses together

Best-fit value of Signal strength



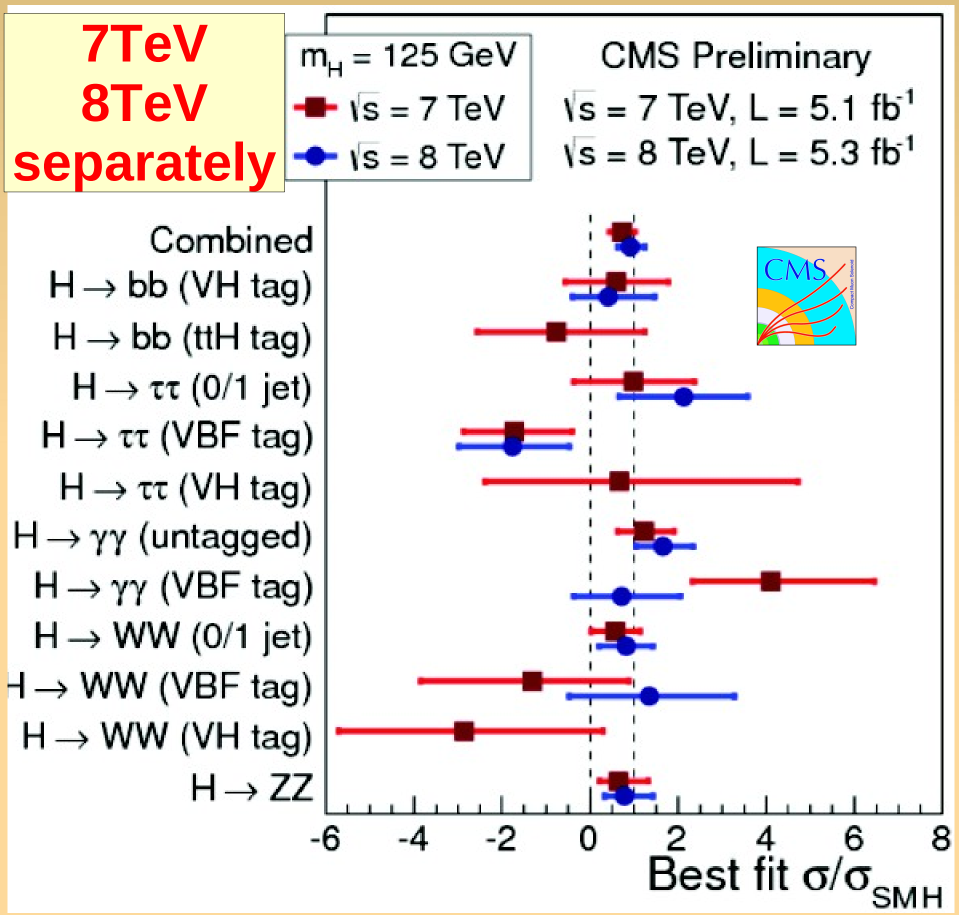
Comparing data sets

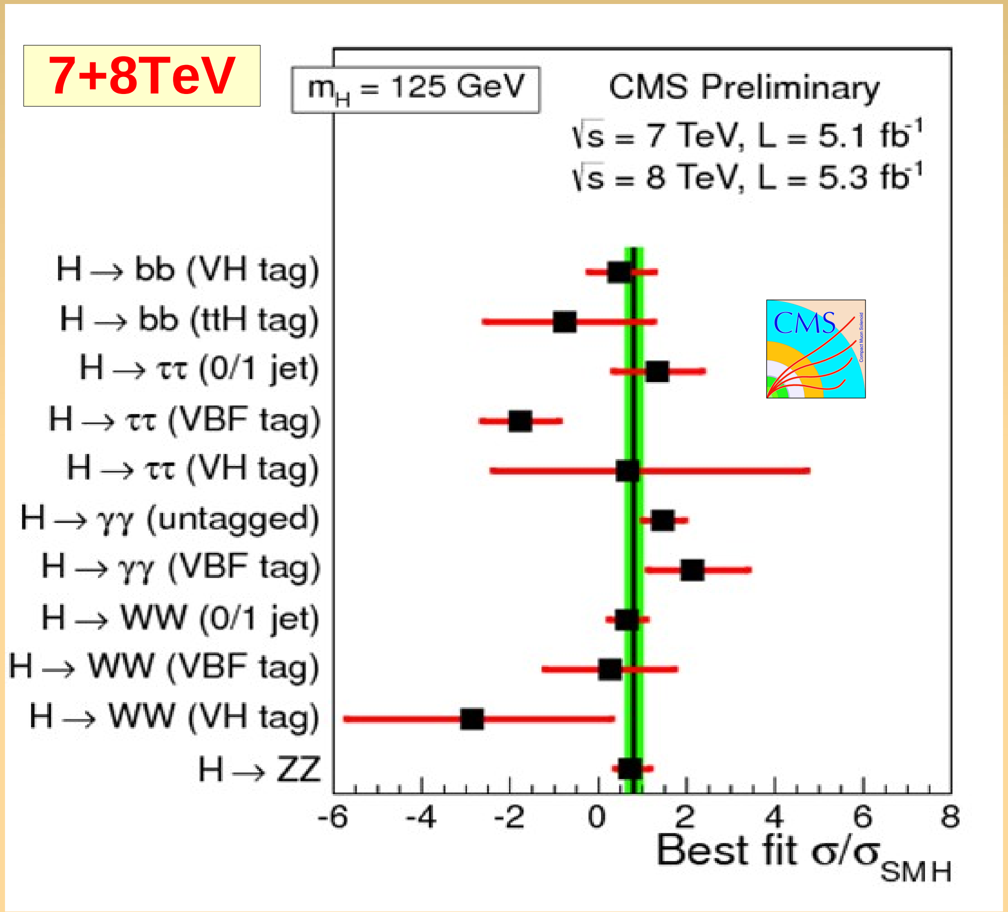
Best-fit value at 125 GeV

$\mu = 0.80 \pm 0.22$

2012: All H analyses together

Best-fit value of Signal strength

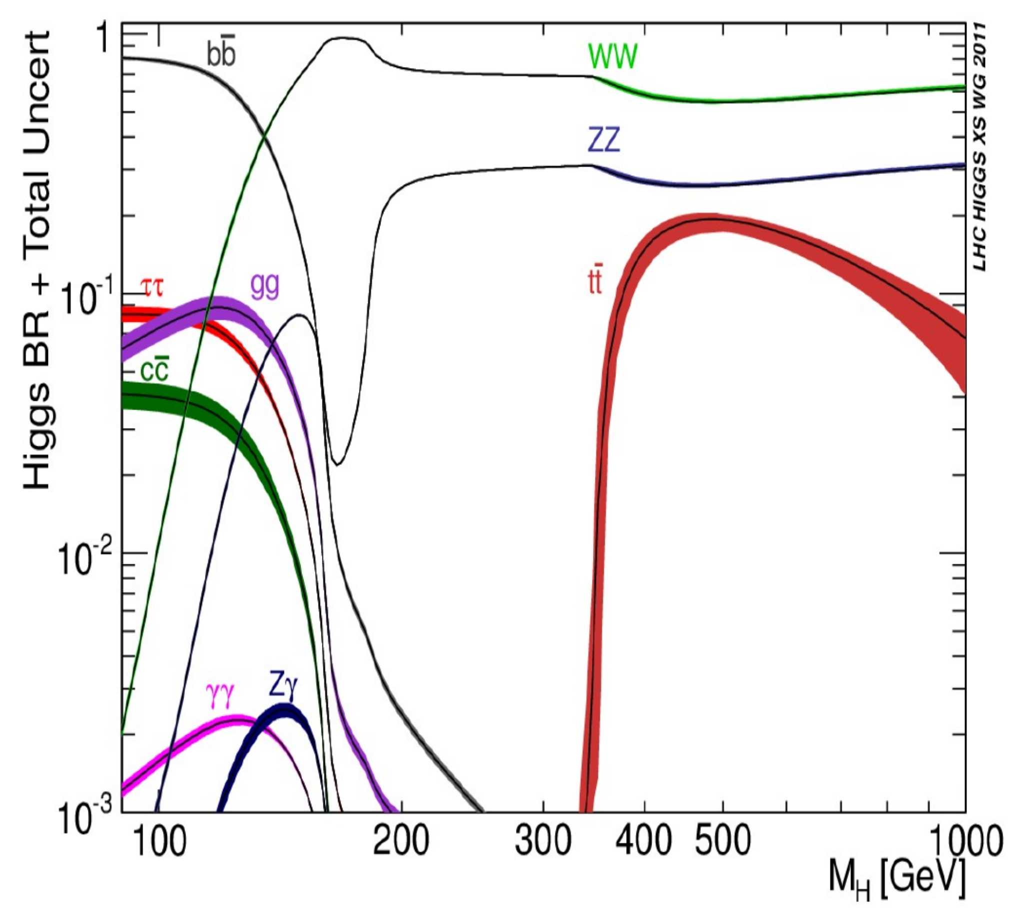




Comparing data sets

Higgs decays

SM Higgs decay depends only on m_H



- Good H mass resolution channels
  - $H \to \gamma\gamma$ 110-150 GeV
  - $H \to ZZ^{(*)} \to 4l$ 110-600 GeV

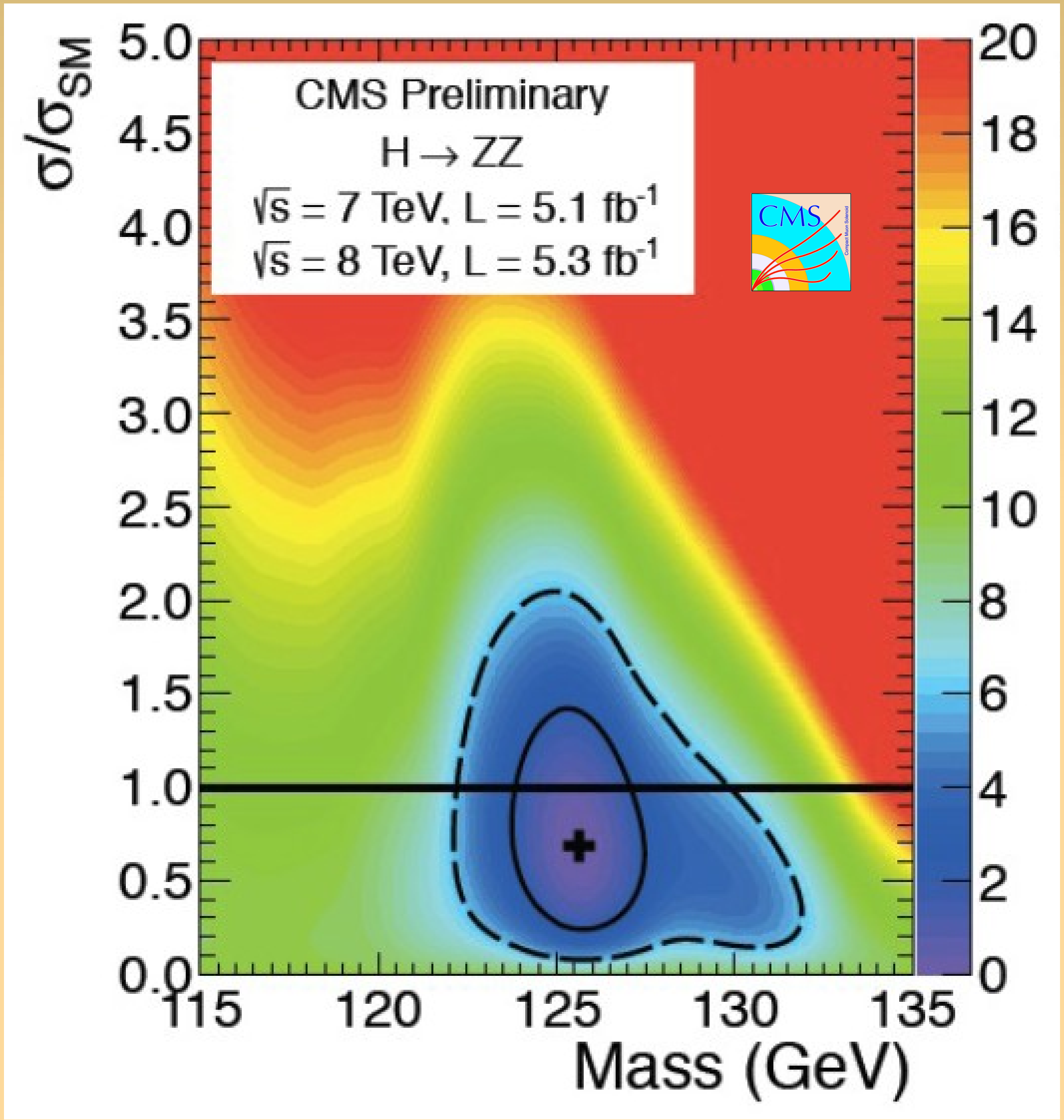
  Small BR but clean signature
- Moderate resolution channels
  - $(W/Z)(H \to bb)$ 110-130 GeV
  - $H \to ZZ \to llqq$ 200-600 GeV
  - $H \to WW \to l\nu qq$ 300-600 GeV
- Poor resolution channels
  - $H \to \tau\tau$ 110-150 GeV
  - $H \to WW \to l\nu l\nu$ 110-660 GeV
- For low mass H the major channels are: $H \to \gamma\gamma$, $H \to ZZ^{(*)} \to 4l$ and $H \to WW \to l\nu l\nu$

H→ZZ*→4l : the “golden”

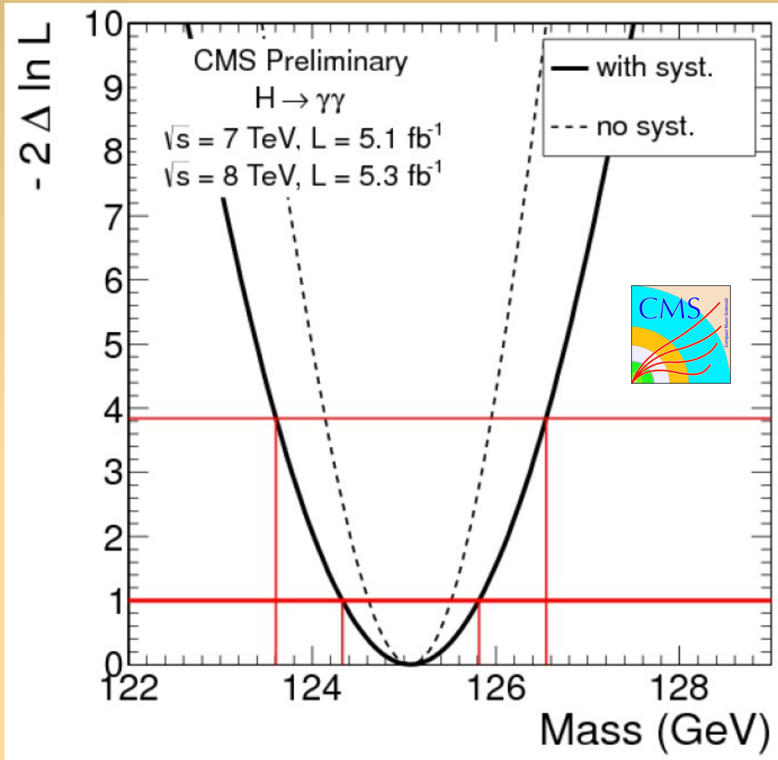
Likelihood scan performed on full dataset

- Global minimum of likelihood
  m(4l) = 125.6 ± 1.2 GeV
  μ = 0.7 ± 0.4

- Ellipses indicate 68% and 95% CL contours



2012: H→2γ : the "beautiful"

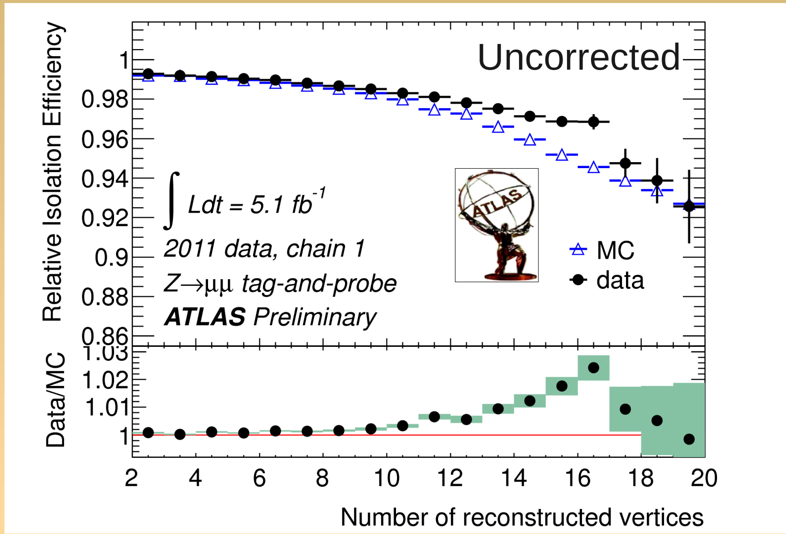


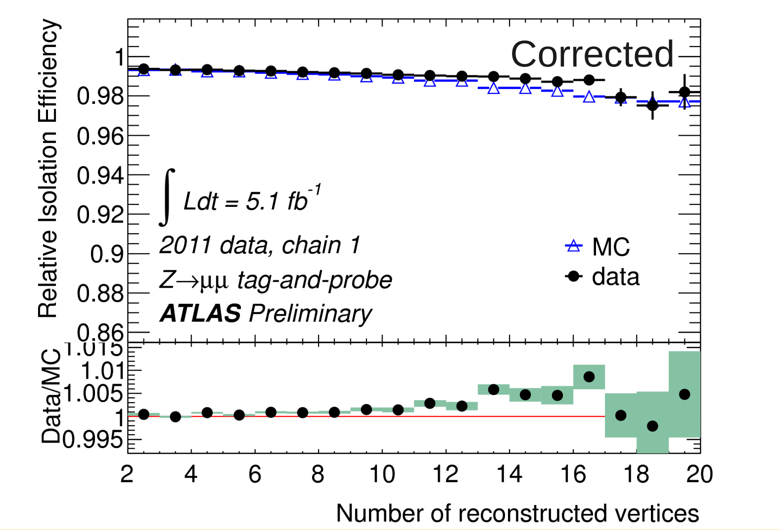
CMS: H→2γ

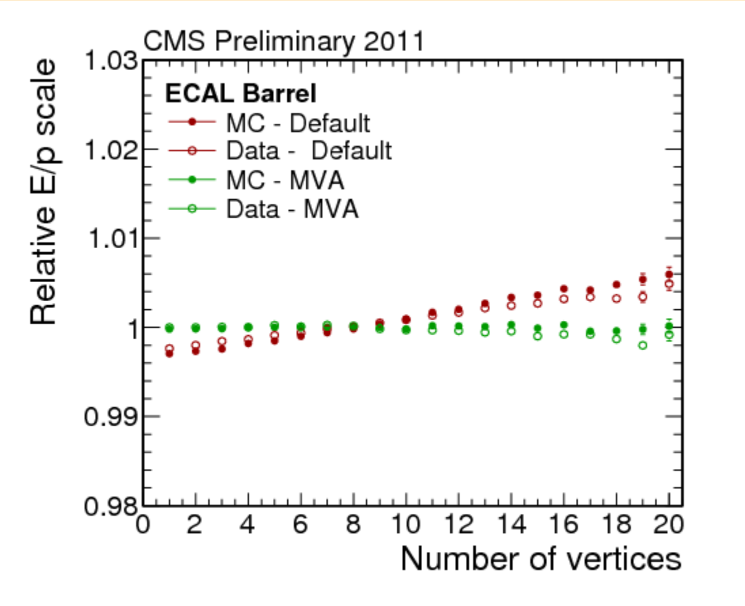
M_X = 125.1 ± 0.4 (stat) ± 0.6 (syst) GeV

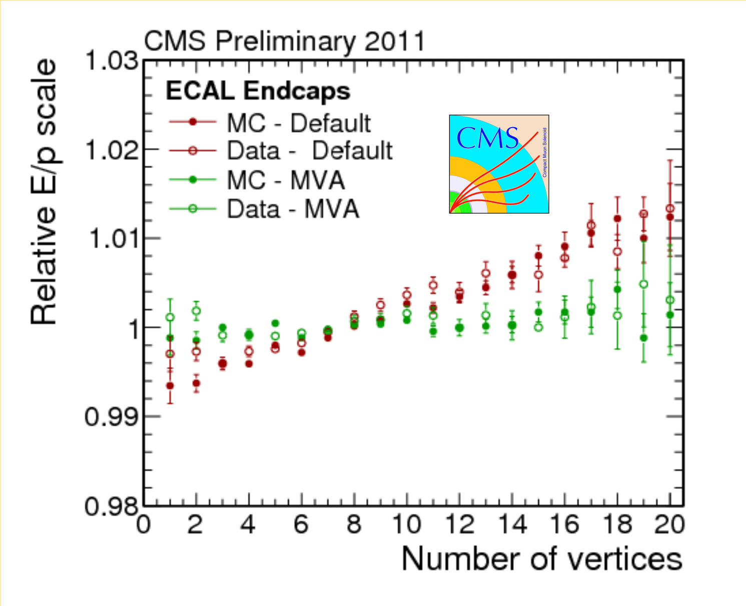
Pile-up: the challenge

Muon isolation calorimeter based without and with corrections for pile-up (Atlas)





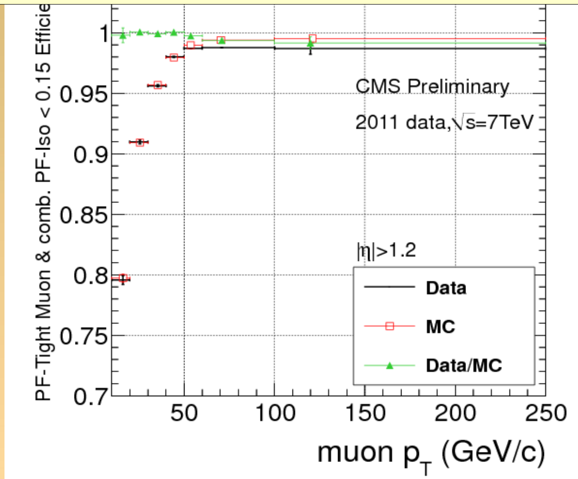




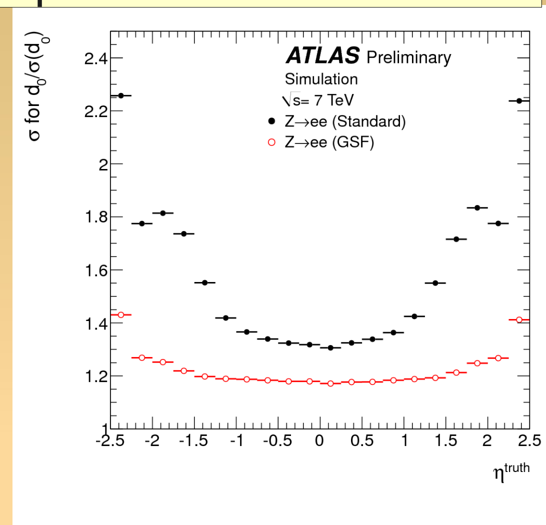
Energy scale dependence corrected with a multivariate analysis technique (CMS)

Calibration: in-situ, Data/MC improvements

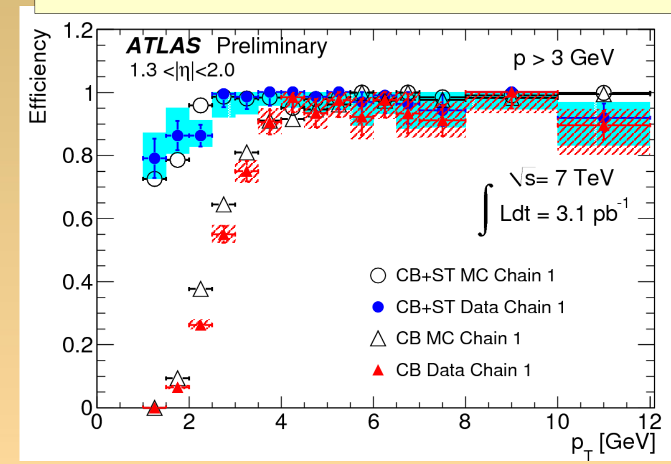
Muon isolation from Z→μμ



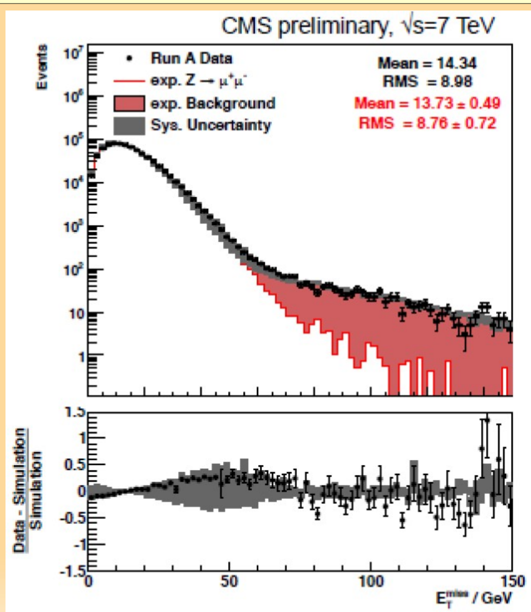
Improved e track Impact parameter resolution



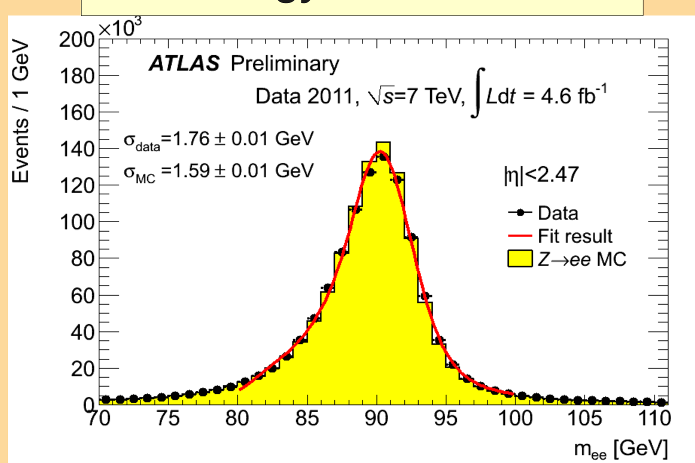
Muon efficiency from J/ψ→μμ



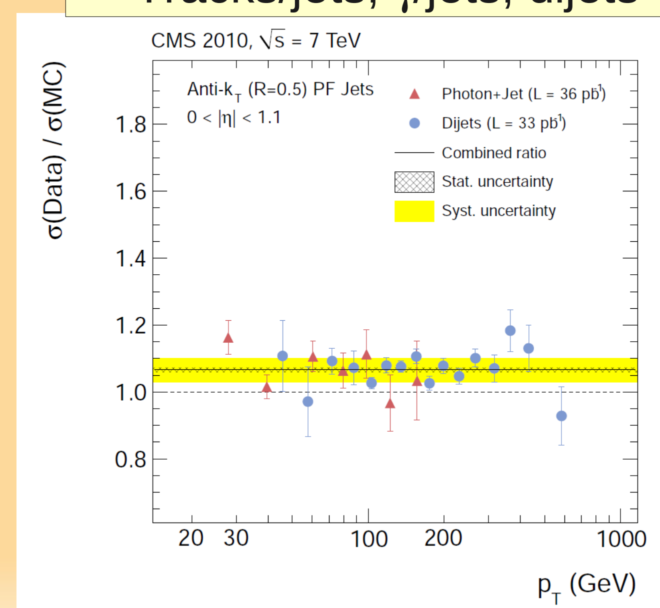
MET in Z→μμ



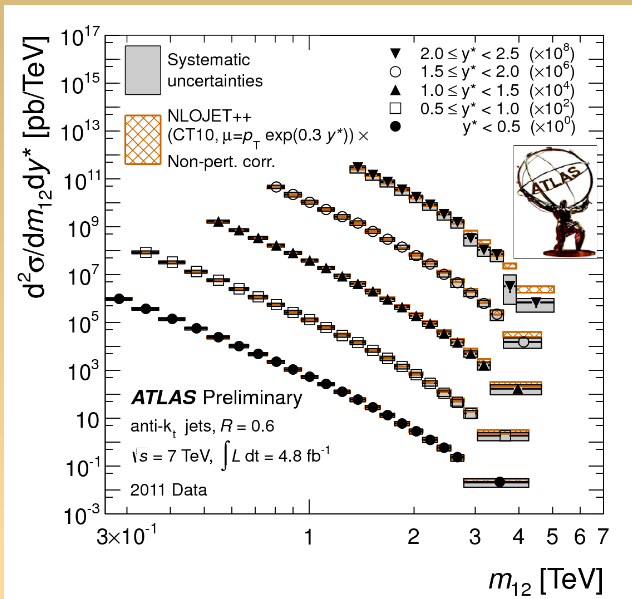
e Energy Scale Z→ee



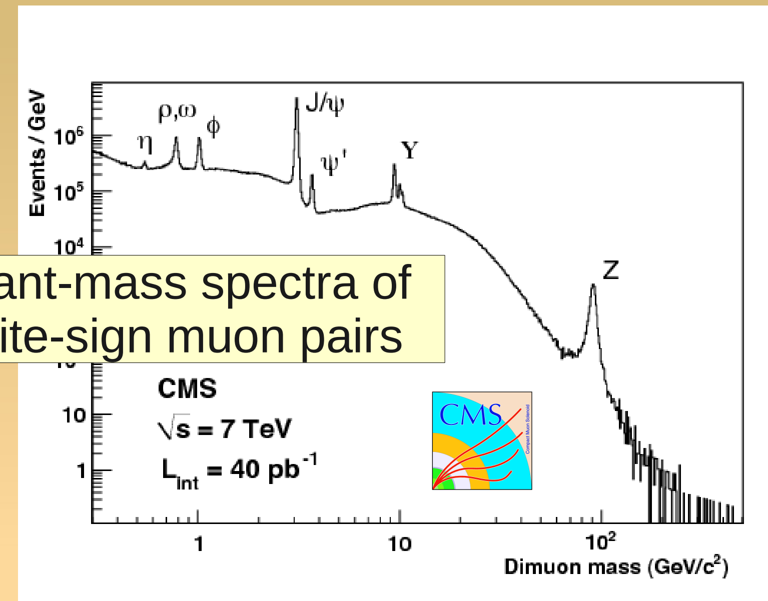
JES from various methods Tracks/jets, γ/jets, dijets



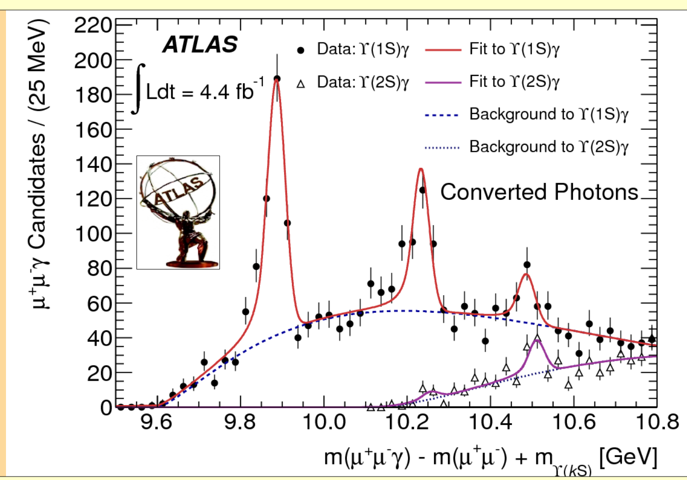
Detectors/Physics Performance



Dijet double-differential cross section

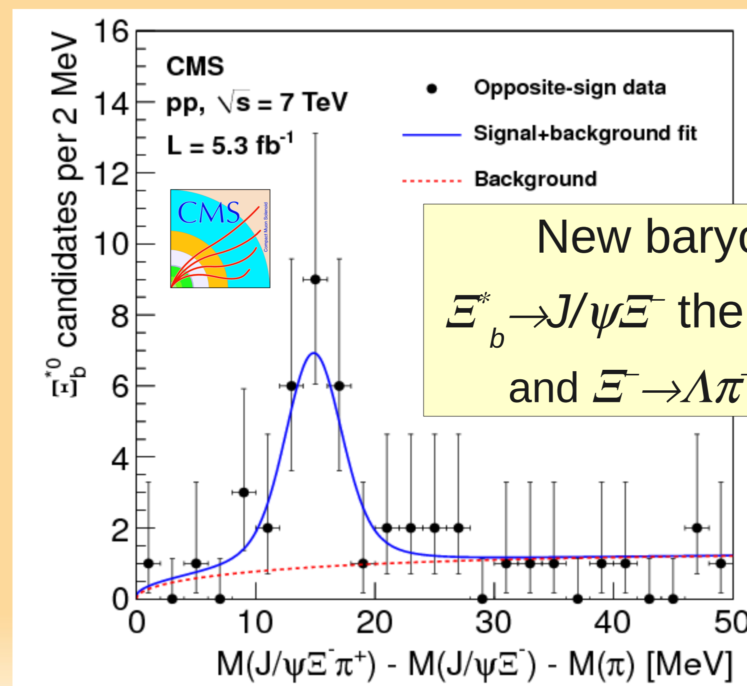


Invariant-mass spectra of opposite-sign muon pairs



Observation of a new χ_b State

$\chi_b(nP) \rightarrow \Upsilon(1S)\gamma \; \chi_b(nP) \rightarrow \Upsilon(2S)\gamma \; \Upsilon(1S,2S) \rightarrow \mu^+\mu^-$



New baryon Ξ^*_b!

$\Xi^*_b \rightarrow J/\psi\,\Xi^-$ then $J/\psi \rightarrow \mu^+\mu^-$

and $\Xi^- \rightarrow \Lambda\pi^- \rightarrow p\pi^-\pi^-$