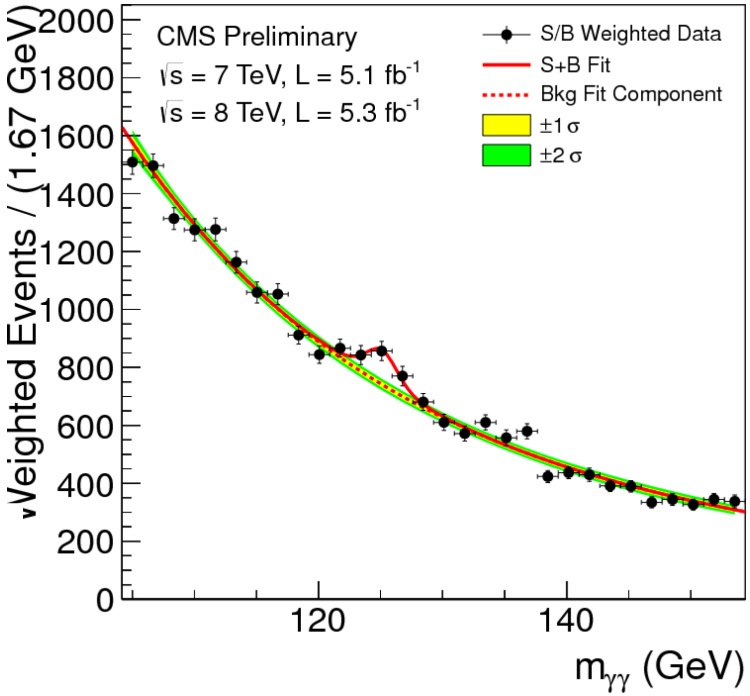
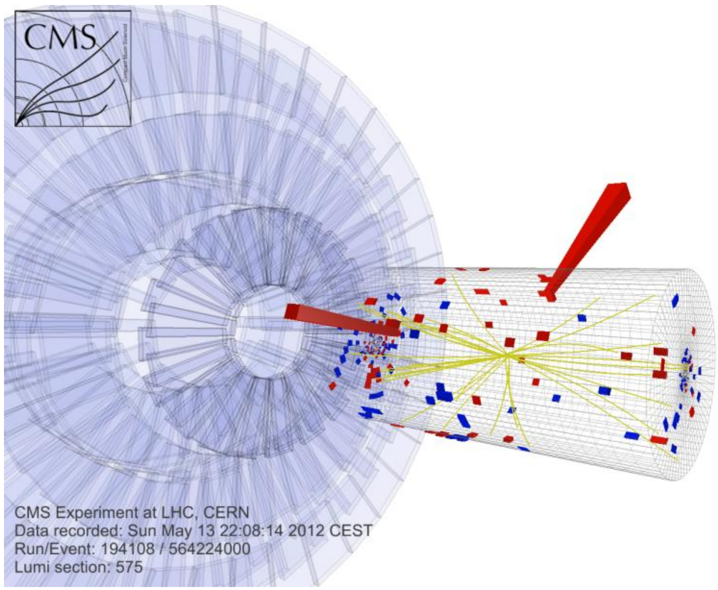
How to find a Higgs boson





Jonathan Hays
QMUL

12th October 2012

Outline

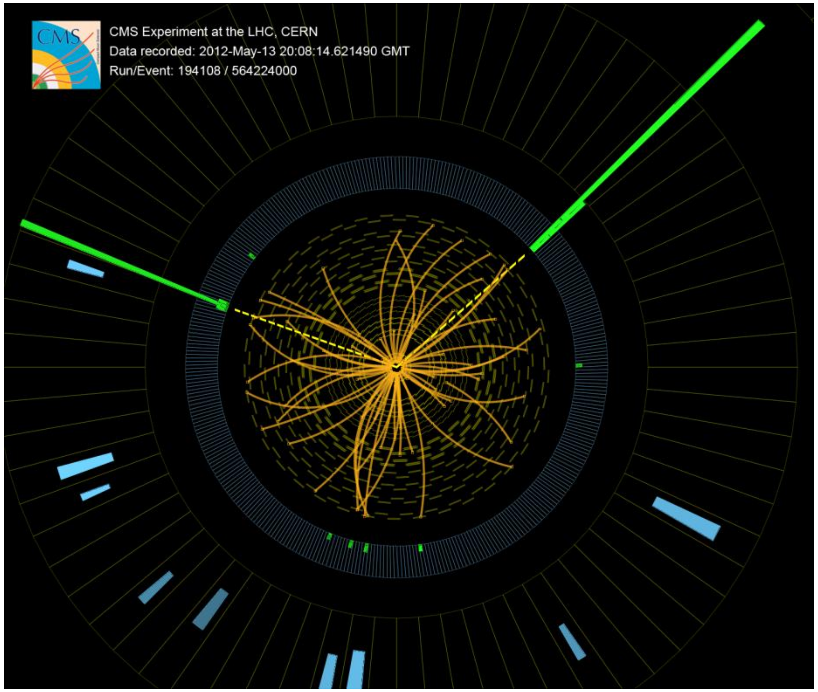
Introducing the scalar boson

Experimental overview

Where and how to search

Higgs properties

Prospects and summary



The Scalar boson

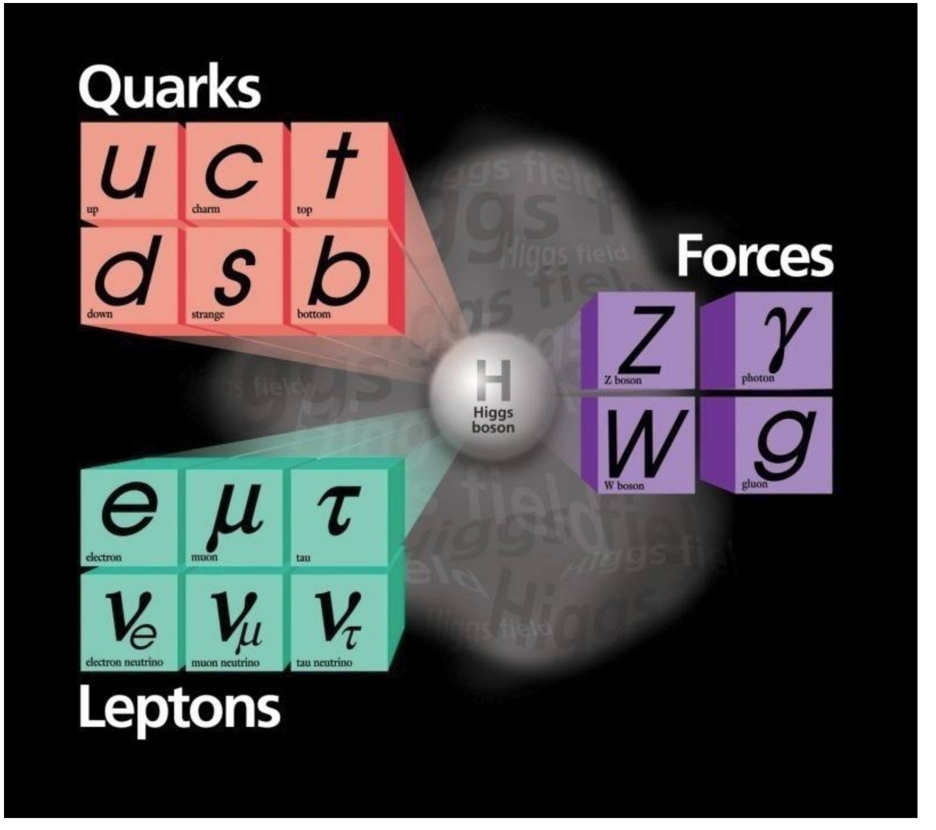
Makes the SM work

allows massive W & Z

allows fermion masses

Testable prediction of Electroweak theory

Scalar Higgs Boson

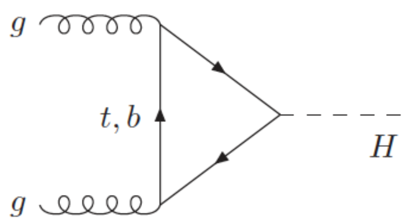


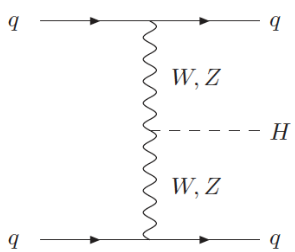
SM Higgs bosons

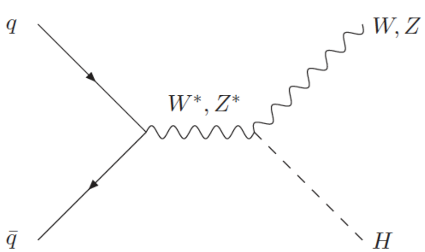
Identifying a SM Higgs boson or "how to get Peter Higgs (and others) a Nobel prize" ☺

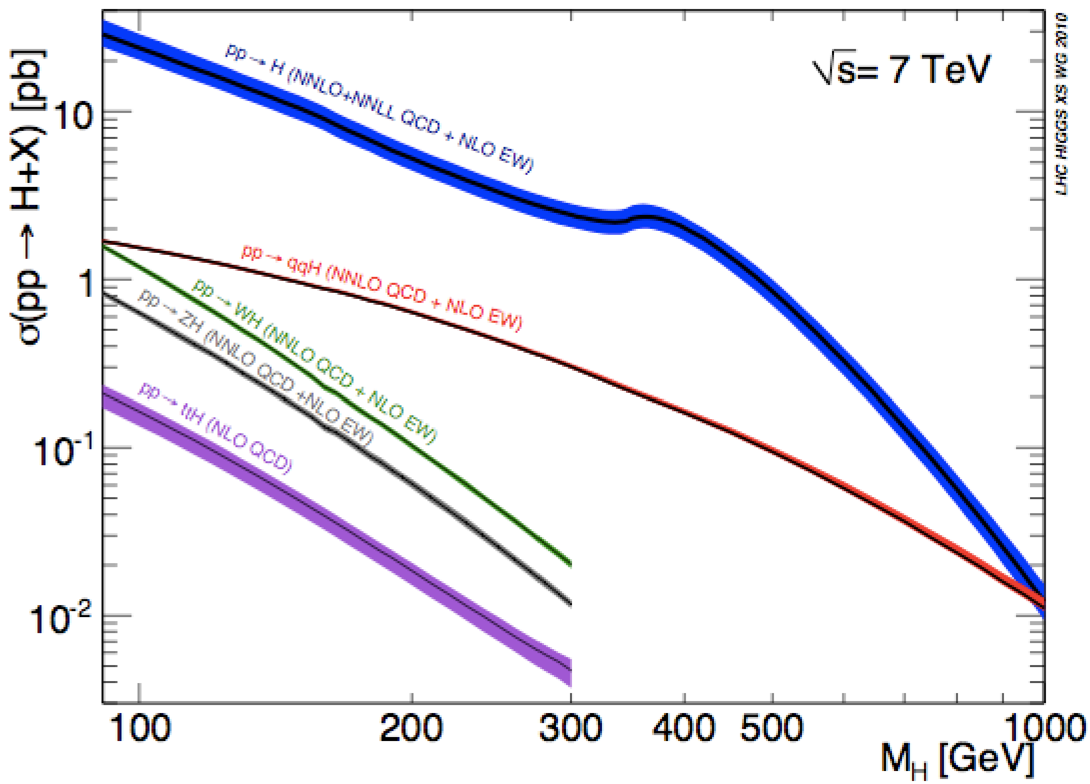
Neutral
Mass consistent with EWK fits
Spin-0
Correct couplings

Production at the LHC

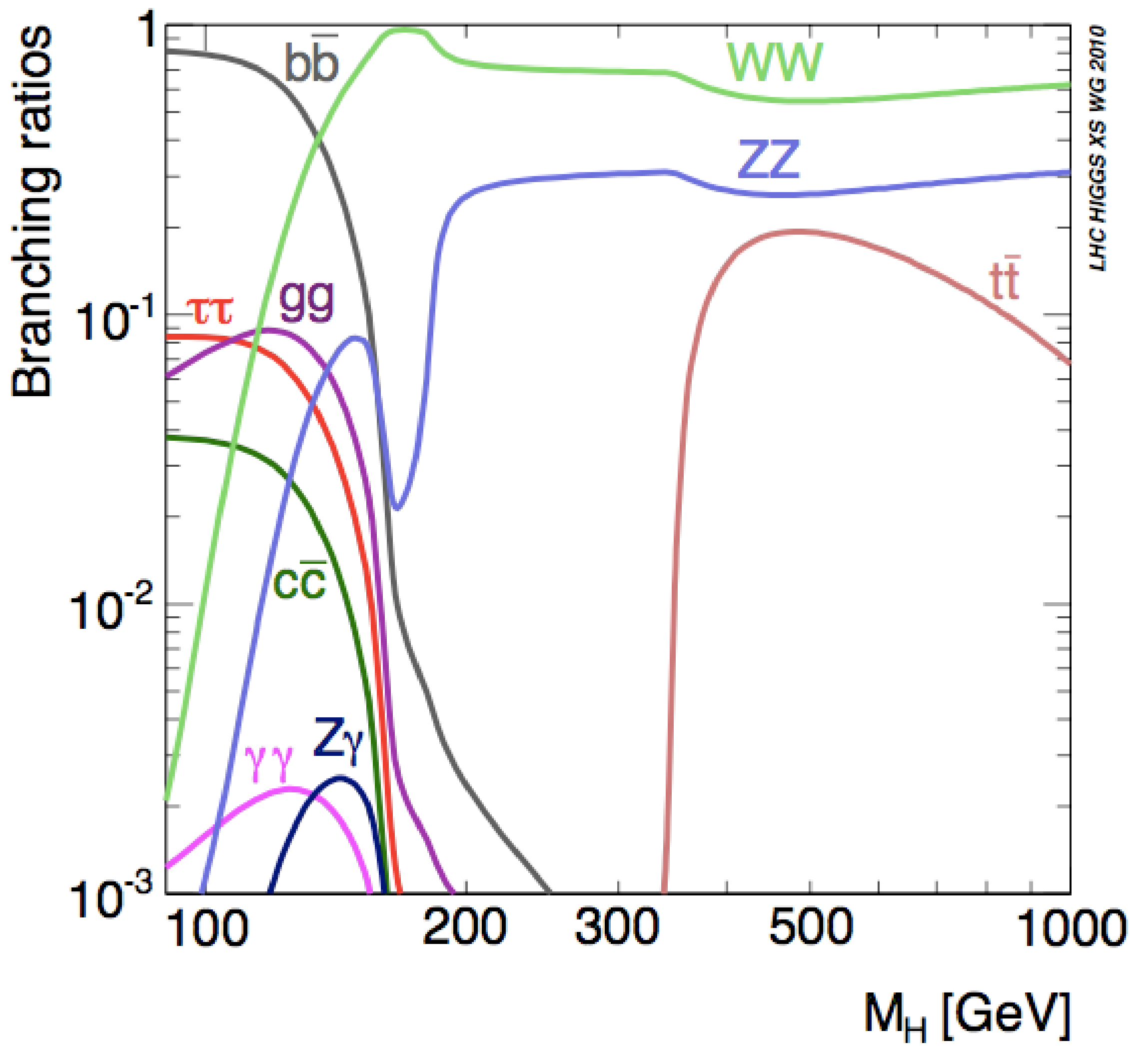




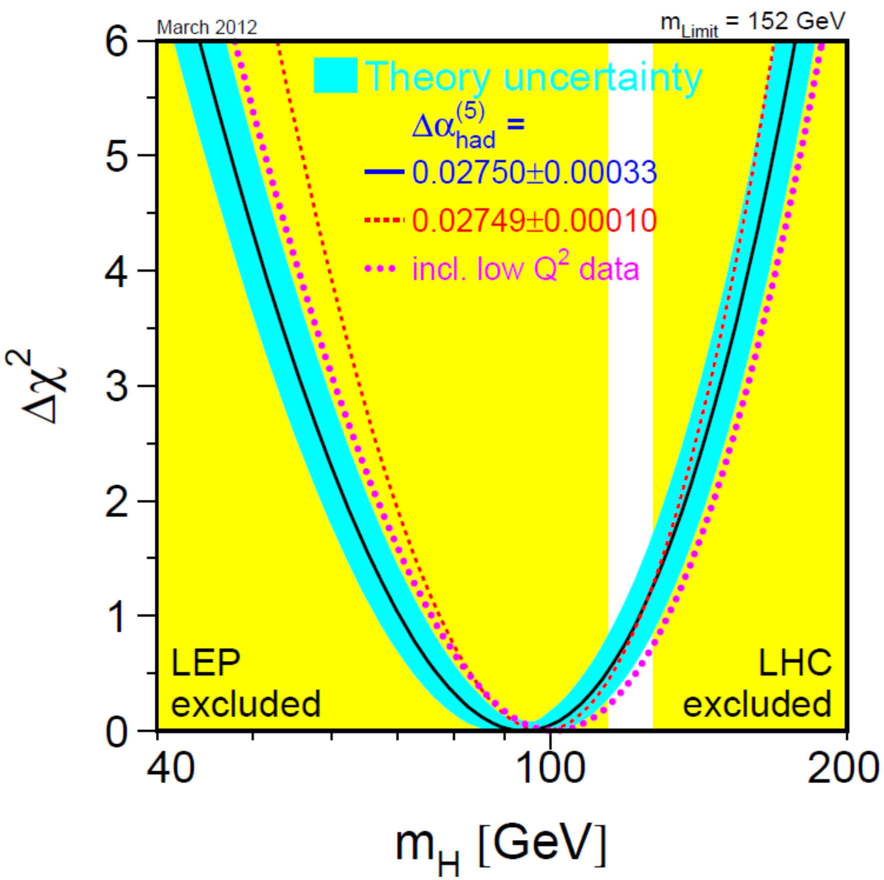


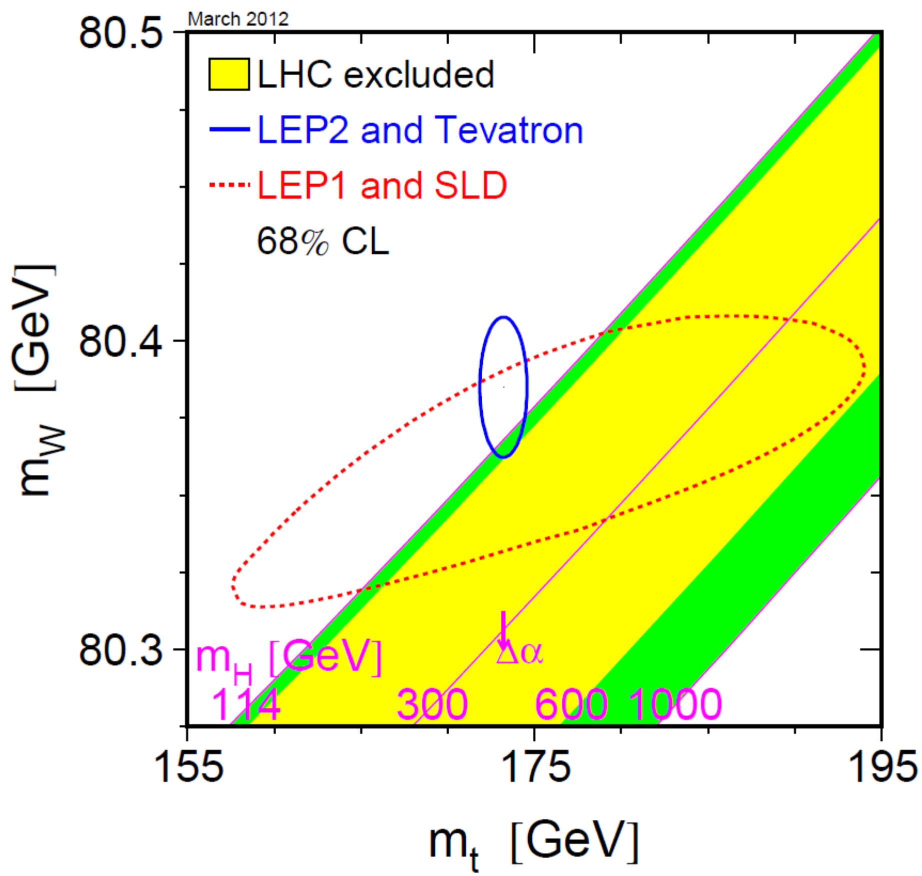


Higgs decay


Branching ratios
1
10-1
10-2
10-3
100
200
300
500
1000
M_H [GeV]
bb̄
WW
ZZ
tt̄
ττ
gg
cc̄
Zγ
γγ
LHC HIGGS XS WG 2010

Indirect Constraints on the Higgs





Latest indirect constraints prior to discovery…

How to find a Higgs

Lots of energy to make them

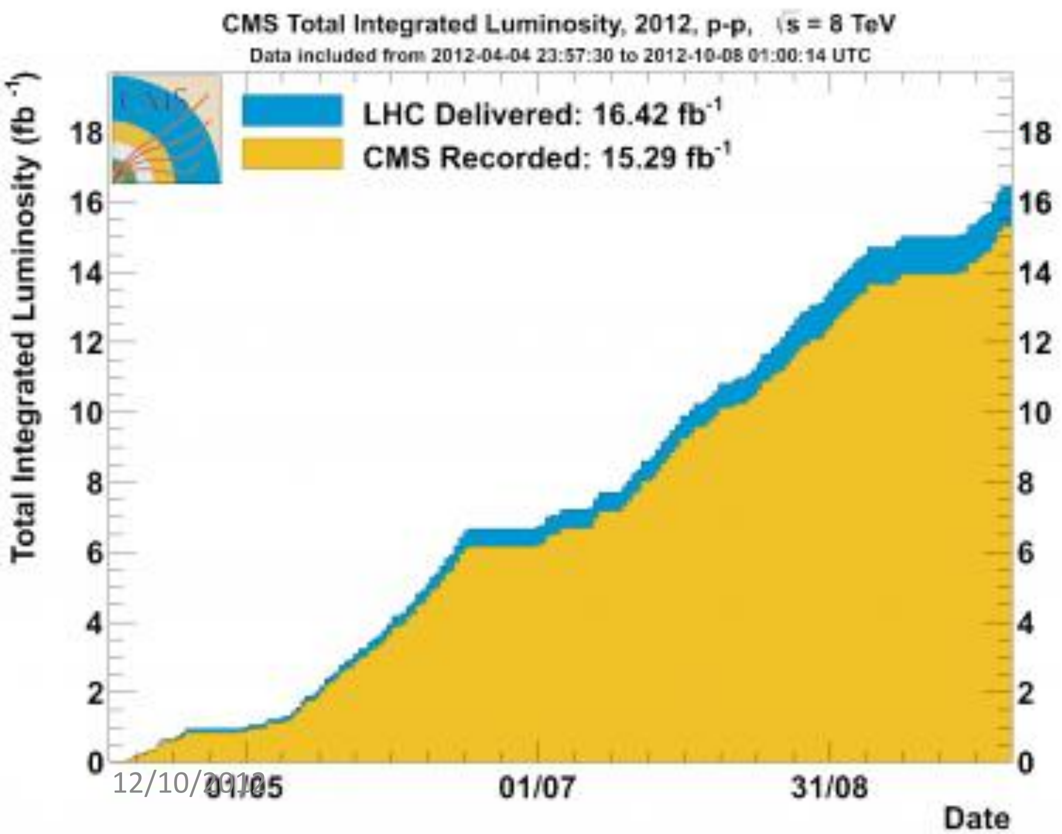
Sensitive detector(s)

Some smart people to make it work and analyze the data

Look everywhere you can

Large Hadron Collider

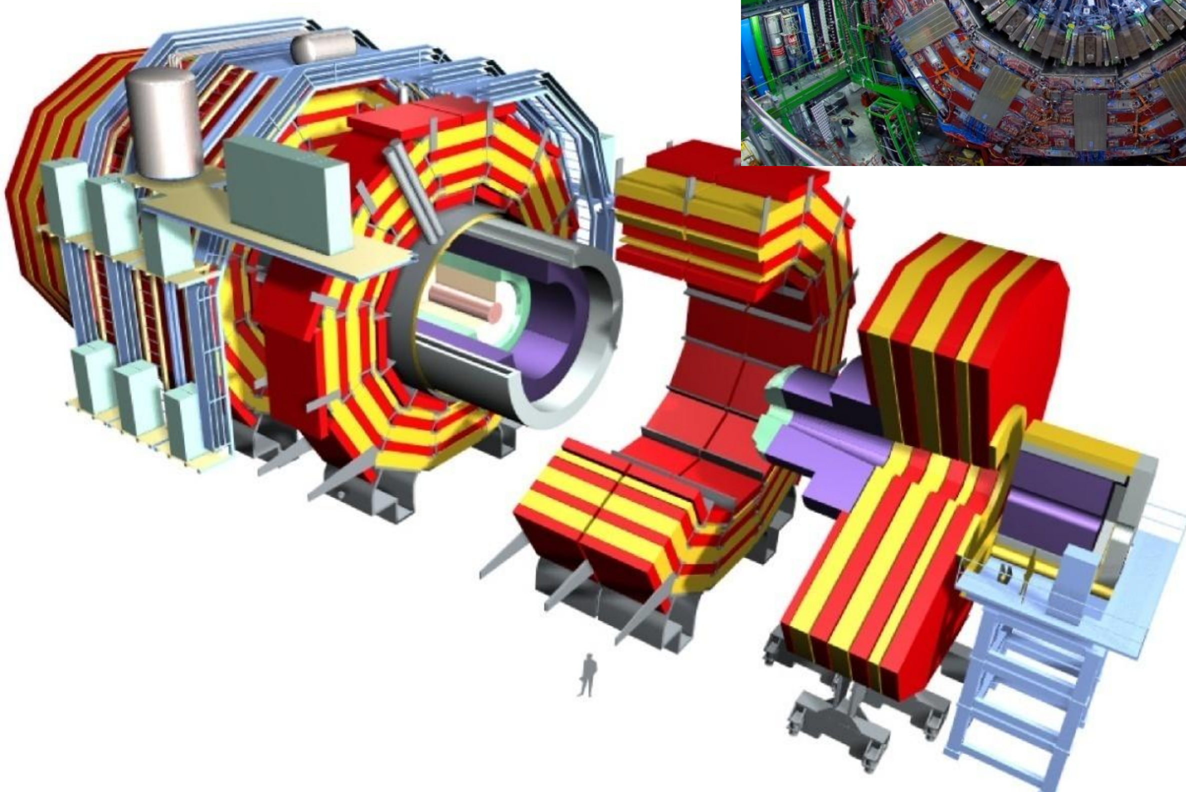
Proton-proton collider
Designed to run at $\sqrt{s}$=14 TeV

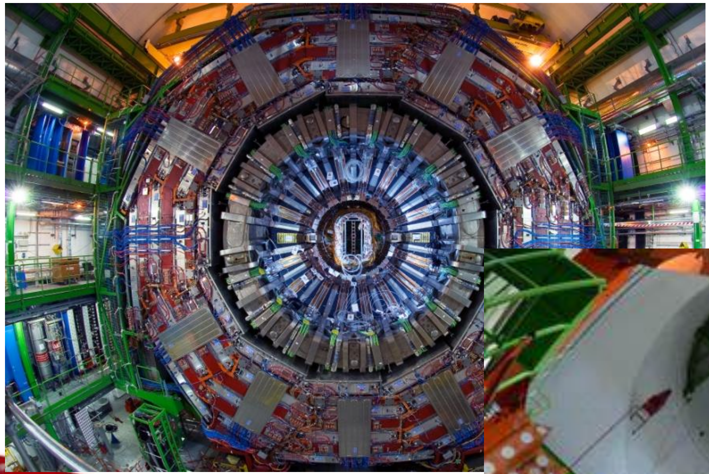


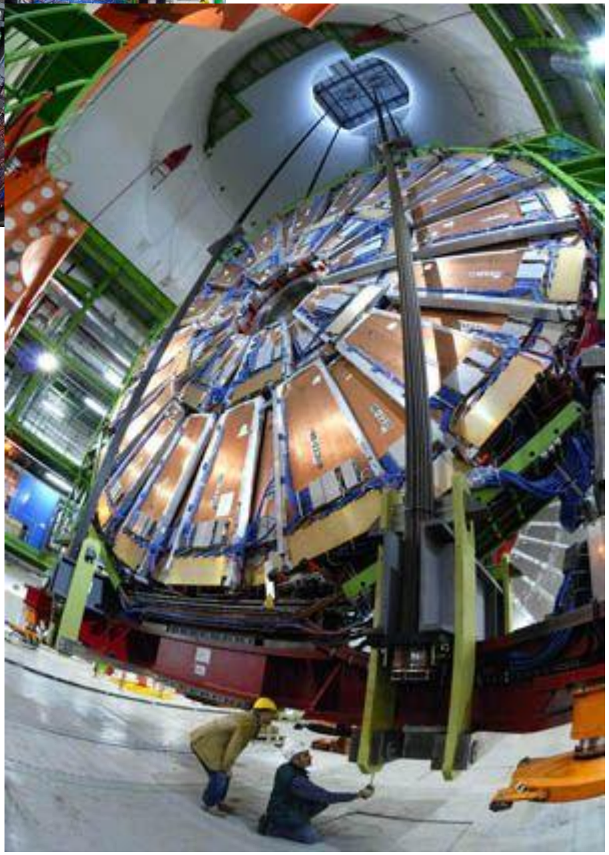
7TeV in 2011
8TeV in 2012

About 10fb^{-1} data in results here
Another 10fb^{-1} already recorded

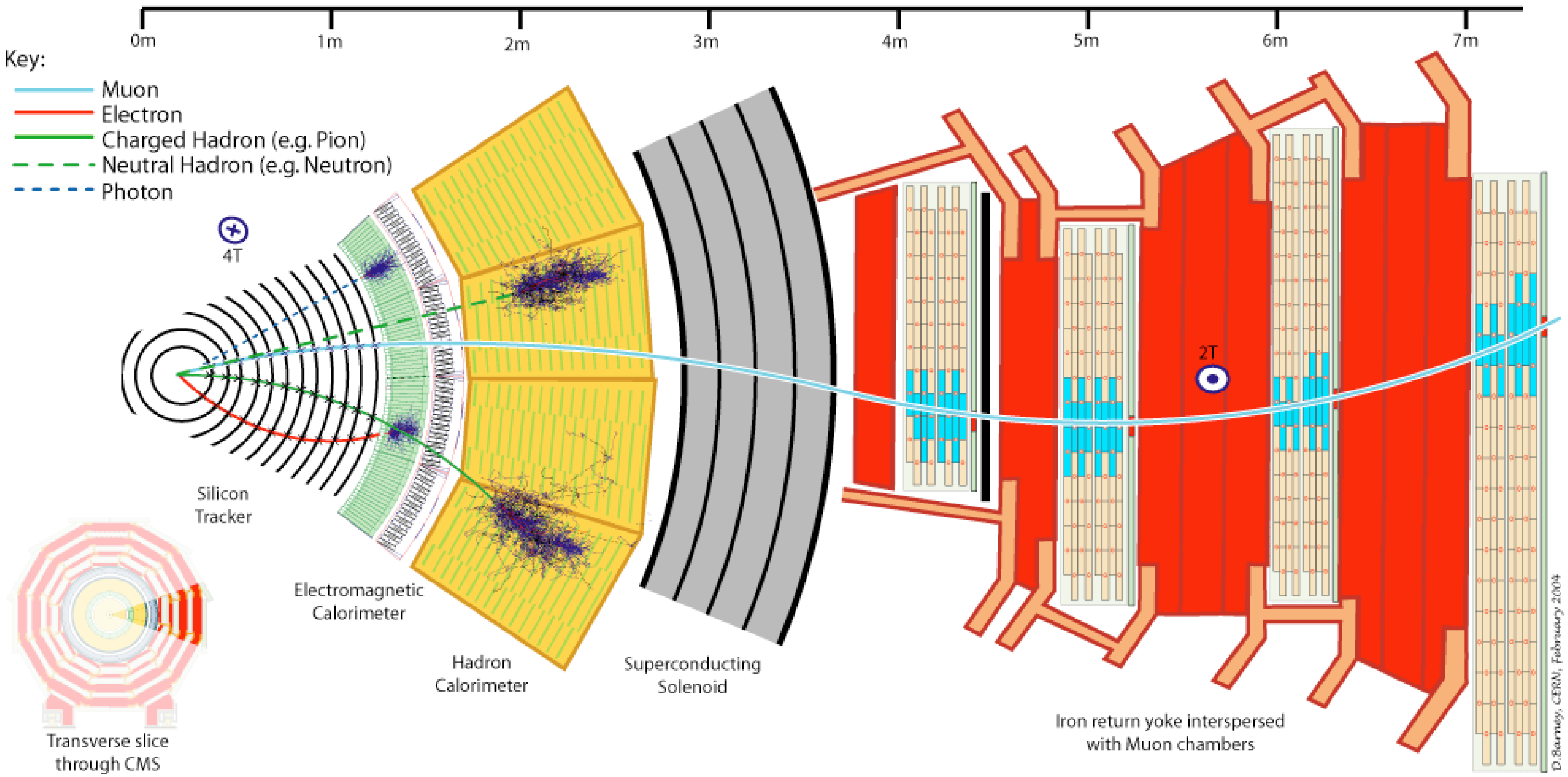
Compact Muon Solenoid







Compact Muon Solenoid



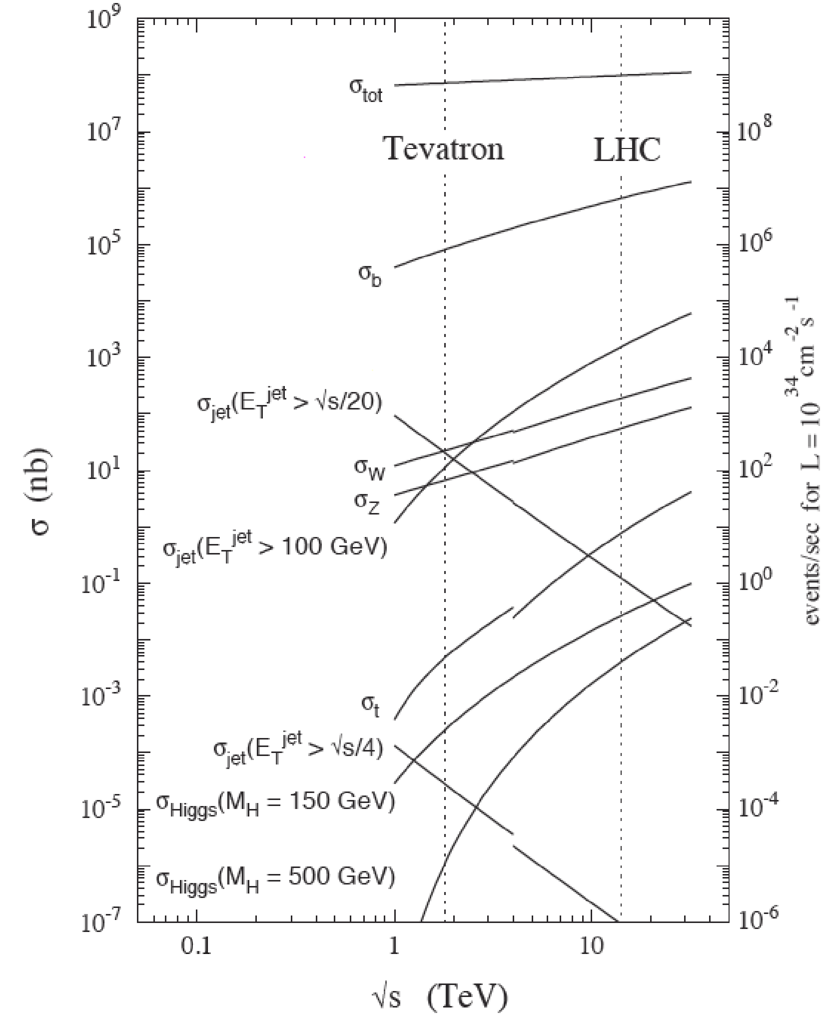
Triggering

Event rates of Higgs several orders of magnitude smaller than total cross section

Reading out every event would be TB/s !

Need a good trigger system to cut the rate down and reject backgrounds

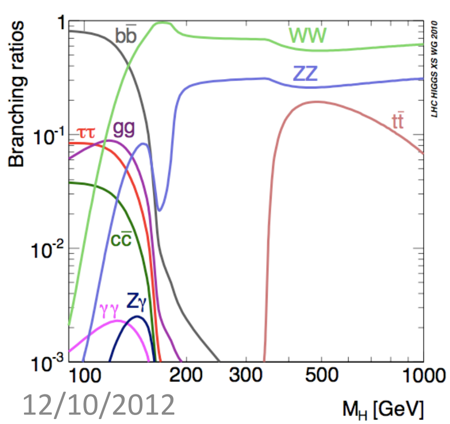
Two level solution at CMS
L1 fast decision, factor 1000 reduction
HLT down to about 100 Hz

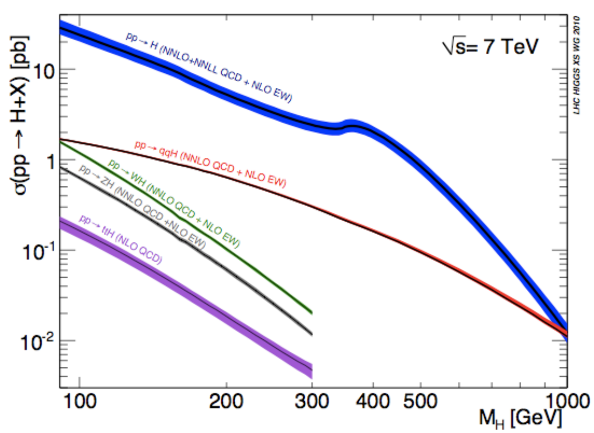


Over 4000 collaborators now on CMS!

Channel Overview

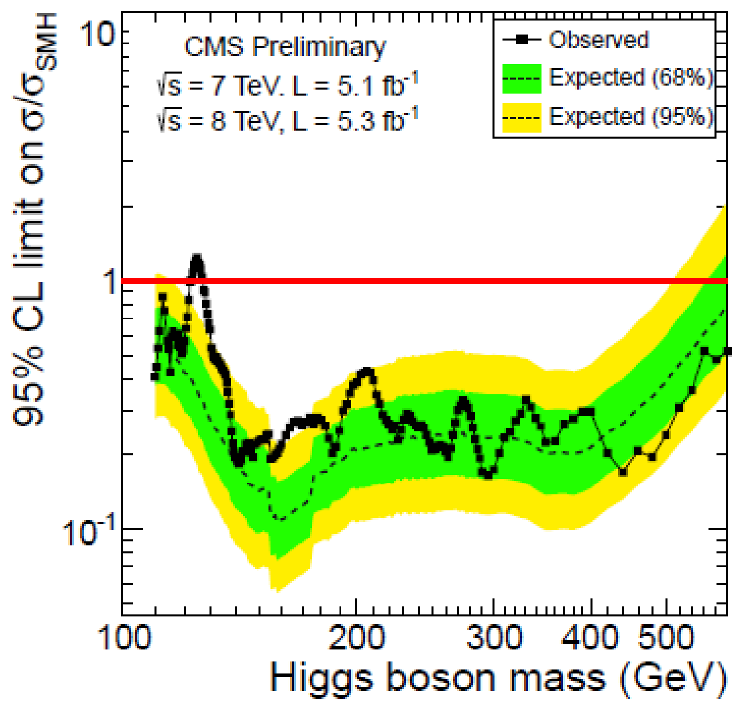
H decay	H prod	Analyses Exclusive final states	No. of channels	m_H range (GeV)	m_H resolution	Lumi (fb^{-1}) 7 TeV	Lumi (fb^{-1}) 8 TeV	Ref
$\gamma\gamma$	untagged	$\gamma\gamma$ (4 diphoton classes)	4	110–150	1-2%	5.1	5.3	[73]
	VBF-tag	$\gamma\gamma + (jj)_{VBF}$ (low or high m_{jj} for 8 TeV)	1 or 2	110–150	1-2%	5.1	5.3	[73]
bb	VH-tag	($\nu\nu$, ee, $\mu\mu$, $e\nu$, $\mu\nu$ with 2 b-jets)$\otimes$ (low or high p_T^V)	10	110–135	10%	5.0	5.1	[74]
	ttH-tag	(ℓ with 4,5,$\geq$6 jets) $\otimes$ (3,$\geq$4 b-tags); (ℓ with 6 jets with 2 b-tags); ($\ell\ell$ with 2 or $\geq$3 b-tagged jets)	9	110–140		5.0	-	[75]
$H \to \tau\tau$	0/1-jets	($e\tau_h$, $\mu\tau_h$, $e\mu$, $\mu\mu$)$\times$ (low or high $p_T^{\tau\tau}$) $\times$ (0 or 1 jets)	16	110–145	20%	4.9	5.1	[76]
	VBF-tag	($e\tau_h$, $\mu\tau_h$, $e\mu$, $\mu\mu$) + $(jj)_{VBF}$	4	110–145	20%	4.9	5.1	[76]
	ZH-tag	(ee, $\mu\mu$) $\times$ ($\tau_h\tau_h$, $e\tau_h$, $\mu\tau_h$, $e\mu$)	8	110–160		5.0	-	[77]
	WH-tag	$\tau_h ee$, $\tau_h\mu\mu$, $\tau_h e\mu$	3	110–140		4.9	-	[78]
$WW \to \ell\nu qq$	untagged	($e\nu$, $\mu\nu$)$\otimes$$(jj)_W$ with 0 or 1 jets)	4	170–600		5.0	5.1	[79, 80]
$WW \to \ell\nu\ell\nu$	0/1-jets	(DF or SF dileptons) $\otimes$ (0 or 1 jets)	4	110–600	20%	4.9	5.1	[81, 82]
$WW \to \ell\nu\ell\nu$	VBF-tag	$\ell\nu\ell\nu + (jj)_{VBF}$ (DF or SF dileptons for 8 TeV)	1 or 2	110–600	20%	4.9	5.1	[81, 82]
$WW \to \ell\nu\ell\nu$	WH-tag	$3\ell 3\nu$	1	110–200		4.9	-	[83]
$WW \to \ell\nu\ell\nu$	VH-tag	$\ell\nu\ell\nu + (jj)_V$ (DF or SF dileptons)	2	118–190		4.9	-	[84]
$ZZ \to 4\ell$	inclusive	$4e$, 4μ, $2e2\mu$	3	110–600	1-2%	5.0	5.3	[85]
$ZZ \to 2\ell 2\tau$	inclusive	(ee, $\mu\mu$) $\times$ ($\tau_h\tau_h$, $e\tau_h$, $\mu\tau_h$, $e\mu$)	8	200–600	10-15%	5.0	5.3	[85]
$ZZ \to 2\ell 2q$	inclusive	(ee, $\mu\mu$)$\times$($(jj)_Z$ with 0, 1, 2 b-tags)	6	{130–164 200–600	3%	4.9	-	[86]
$ZZ \to 2\ell 2\nu$	untagged	((ee, $\mu\mu$) with MET) $\otimes$ (0 or 1 or 2 non-VBF jets)	6	200–600	7%	4.9	5.1	[87]
$ZZ \to 2\ell 2\nu$	VBF-tag	(ee, $\mu\mu$) with MET and $(jj)_{VBF}$	2	200–600	7%	4.9	5.1	[87]

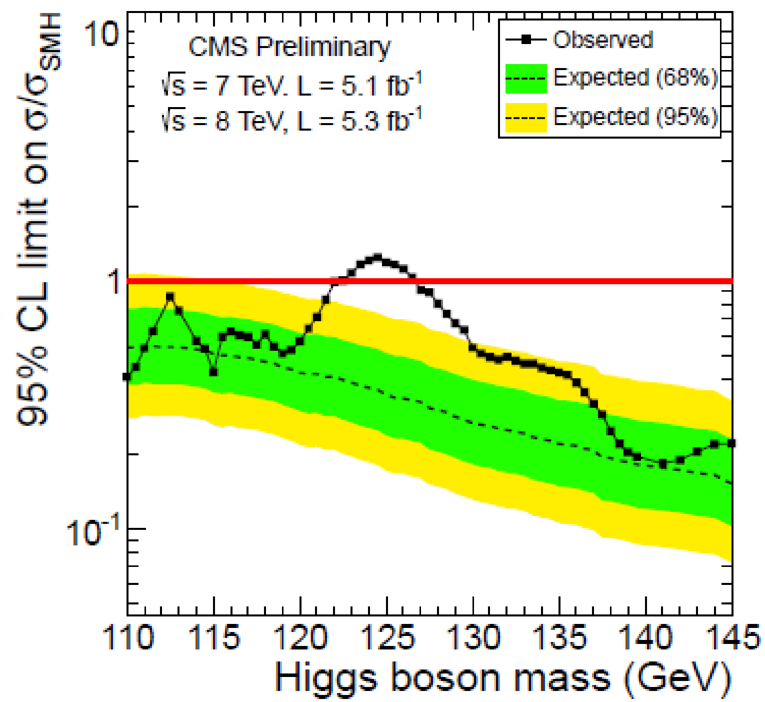




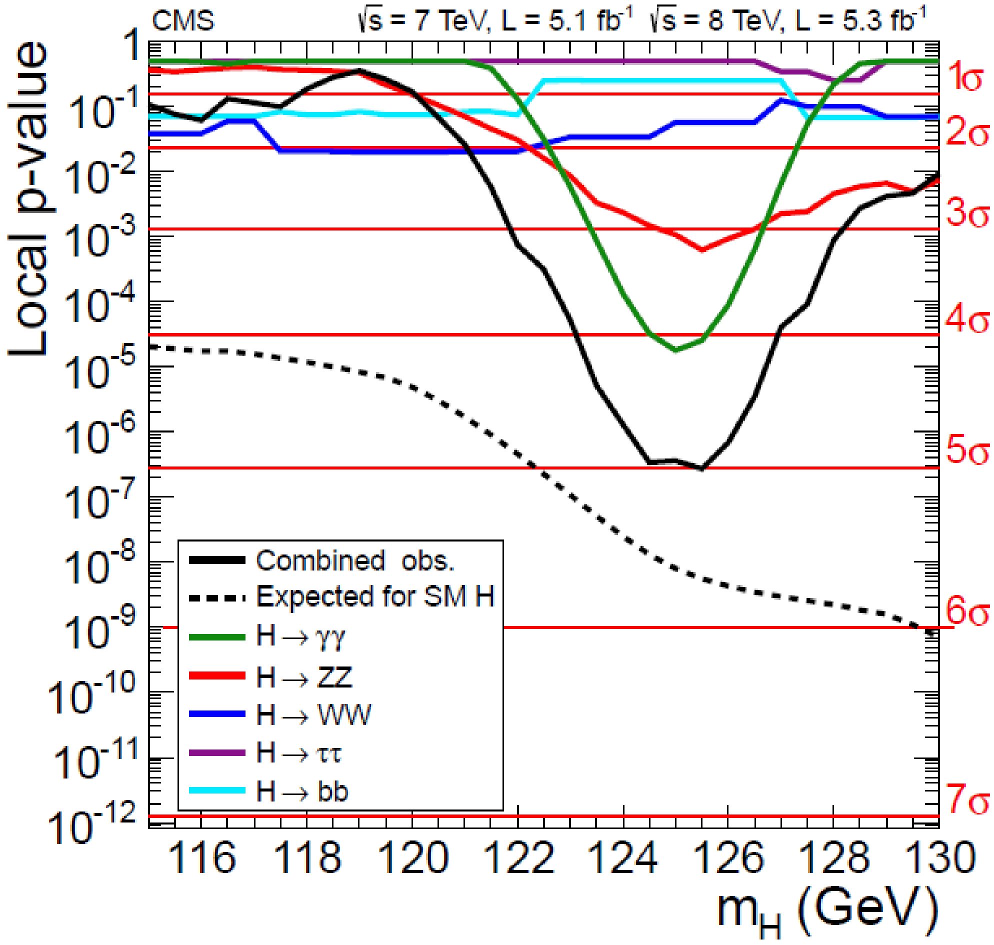
	untagged	VBF-tag	VH-tag	ttH-tag
$H \to \gamma\gamma$	✓	✓		
$H \to bb$			✓	✓
$H \to \tau\tau$	✓	✓	✓	
$H \to WW$	✓	✓	✓	
$H \to ZZ$	✓			

Higgs Discovery?





Higgs? Discovery



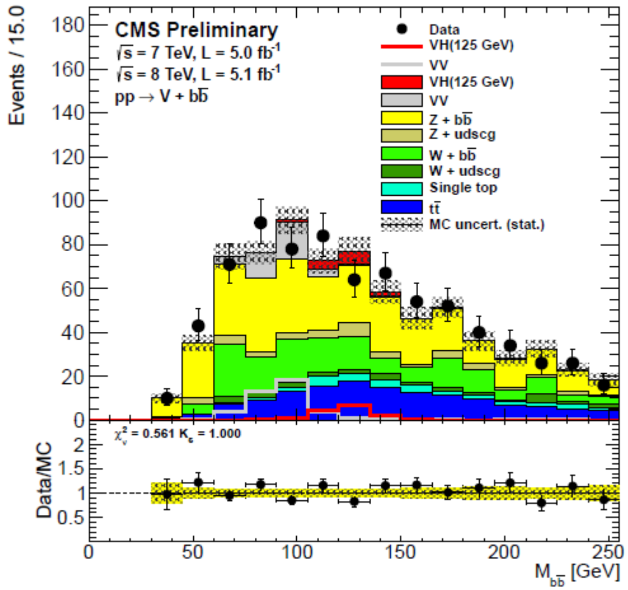
h→bb

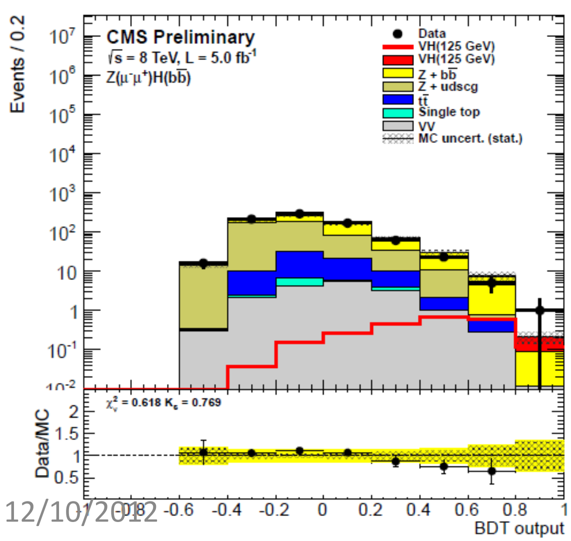
Associated production pp->VH
Leptonic (e,μ,υ) decays give clean signature

Events classification: lepton species and Higgs boost

Require:

- isolated leptons
- missing transverse energy (neutrinos)
- 2 b-tagged jets





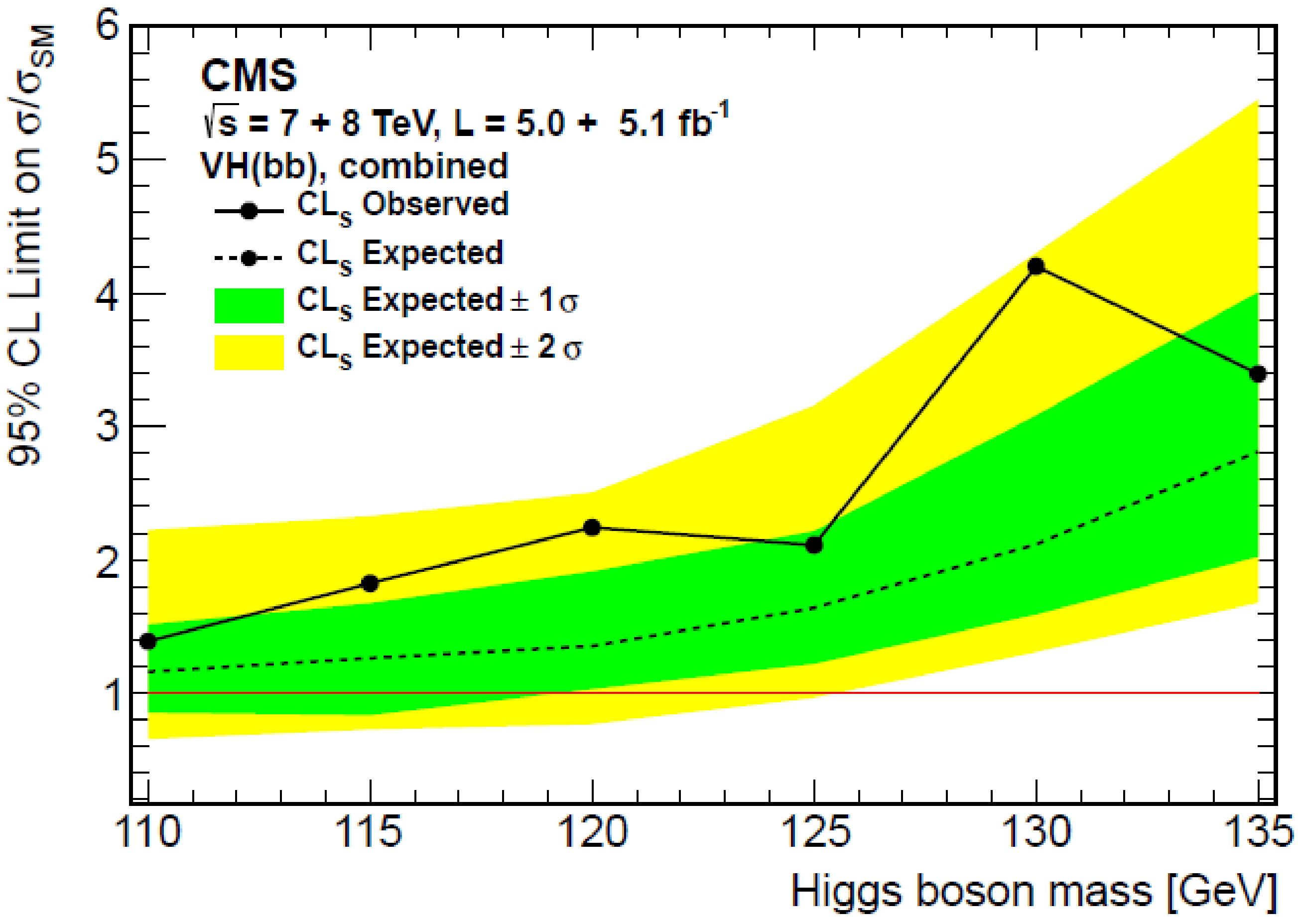
Boosted Decision Tree used to discriminate between signal and backgrounds

Output distribution of the BDT used in statistical analysis

Main backgrounds: W/Z+jets and top pairs – rates from control samples

Additional channel included sensitive to ttH production

h→bb

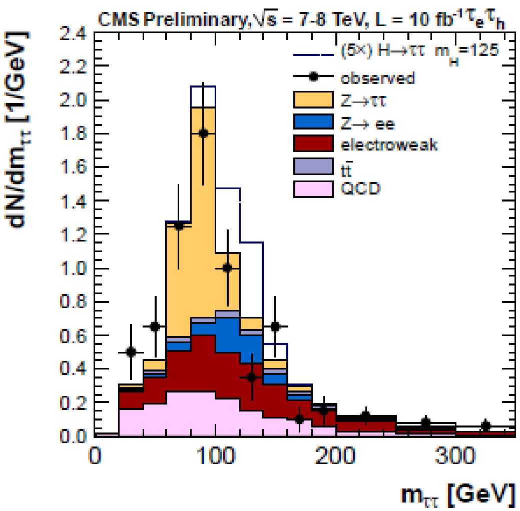


Not quite sensitive to SM yet, next update should achieve that

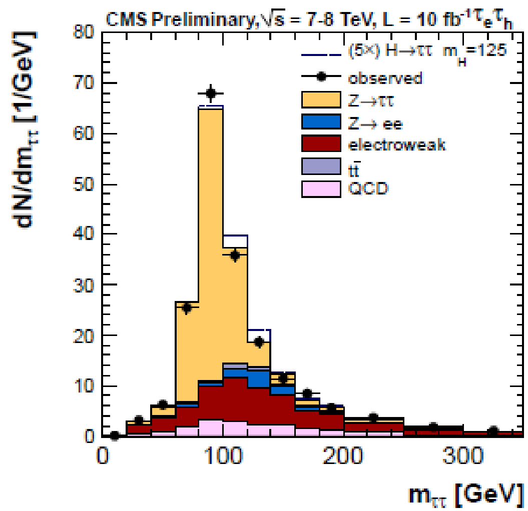
$h \rightarrow \tau\tau$

Select events with one or more leptonic tau decays: categorize according to flavour: $e\mu$, $e\tau_h$ $\mu\tau_h$

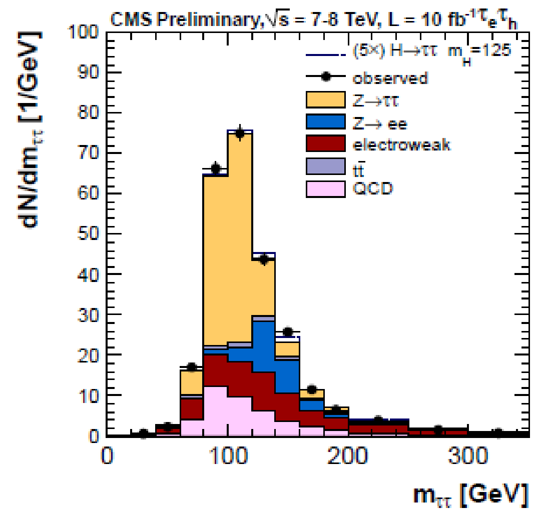
Further subdivide into 3 categories:
- VBF : + 1 forward, 1 backward jets
- Boost : +1 high pT jet
- 0-jet: remaining events



VBF



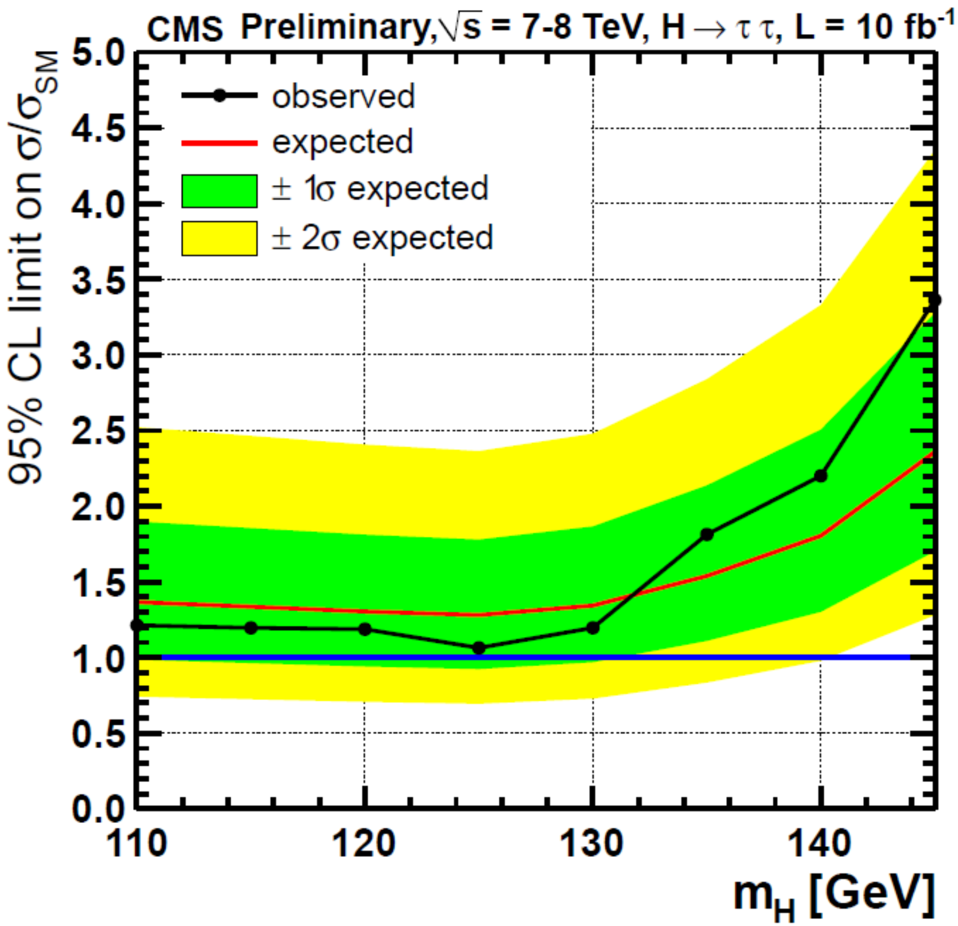
Boosted



0-jet

Dominant backgrounds estimated from control samples in data

$h \rightarrow \tau\tau$



Close to SM sensitivity and no sign of a Higgs – though be aware of the size of the bands! Next updates should prove interesting!

(W/Z)h→WW(W/Z)

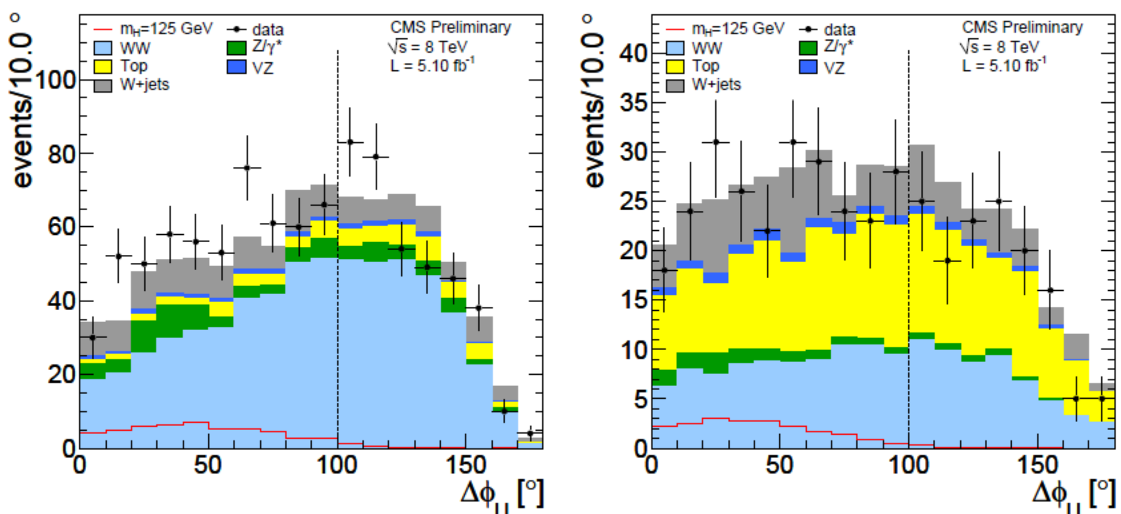
Four basic channels: 2l2υ, lυjj, 3l3υ, 2l2υjj

Classify events according to lepton flavour and charge and jet multiplicity

Select events with isolated leptons, missing transverse energy and up to 2 jets

Main backgrounds come from diboson production, top pairs and W+jets - depending on category.
Data driven for major contributions

MVA techniques, eg BDTs and NN, used to enhance sensitivity as well as cut based selection

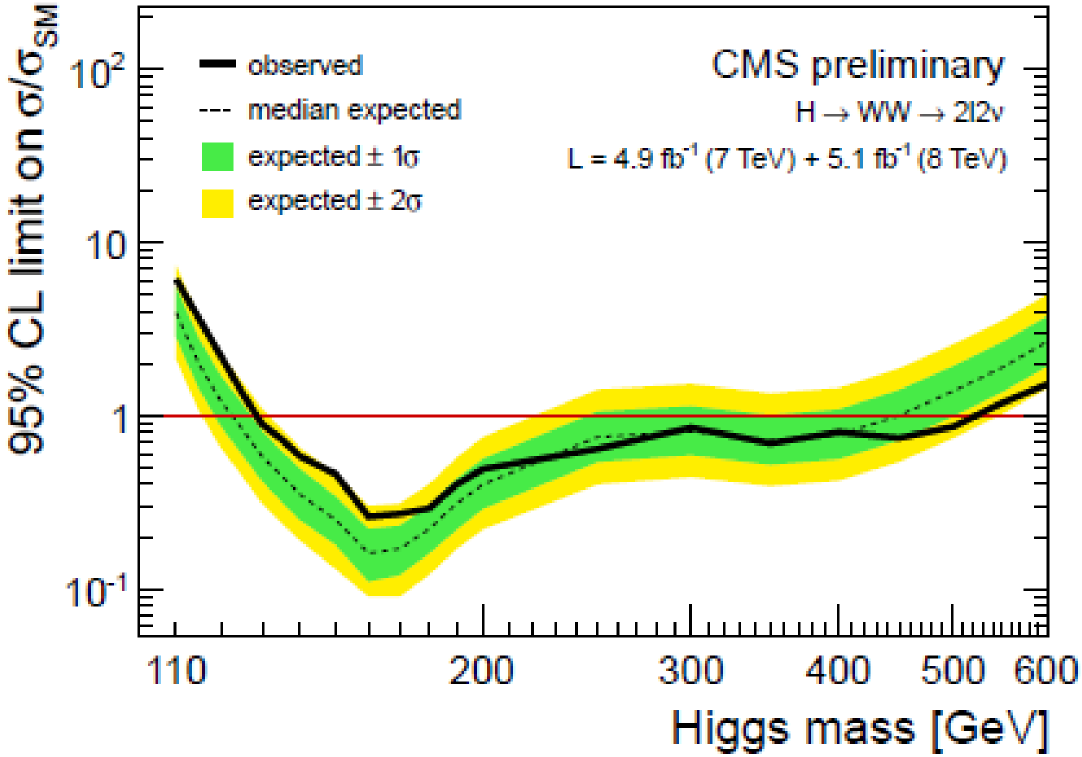


0-jet 1-jet

Cut based @ 8TeV

h→WW→2l2υ

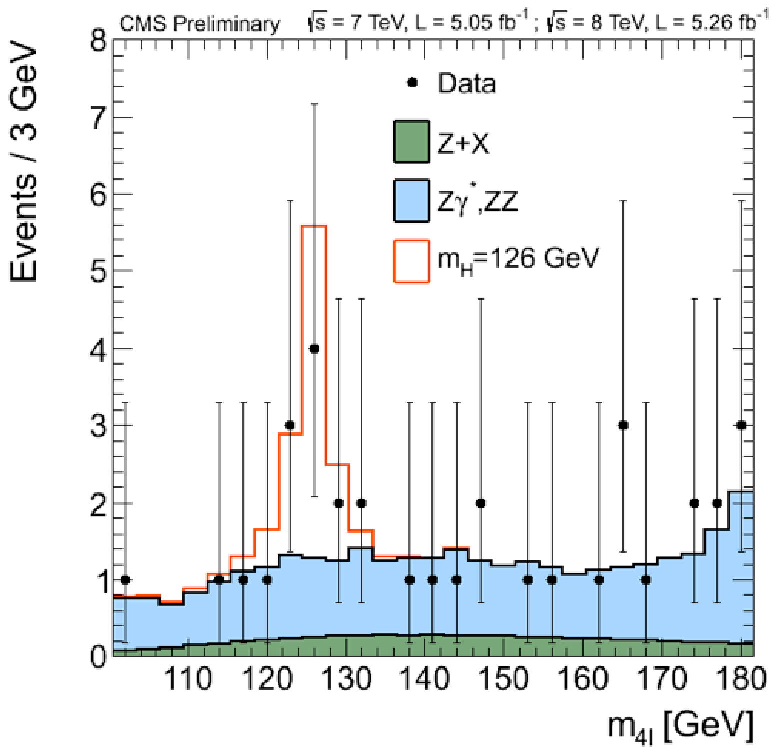
Sensitivity dominated by 2l2υ



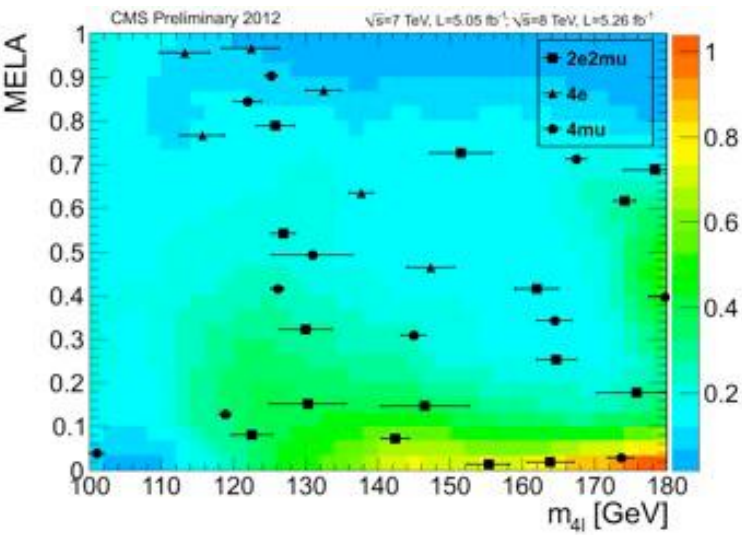
SM like Higgs excluded across much of the mass range.
Broad excess in low mass region compatible with SM Higgs

Golden channel: h→ZZ→4l

4 isolated leptons give extremely clean signature
Excellent energy resolution gives narrow signal peak

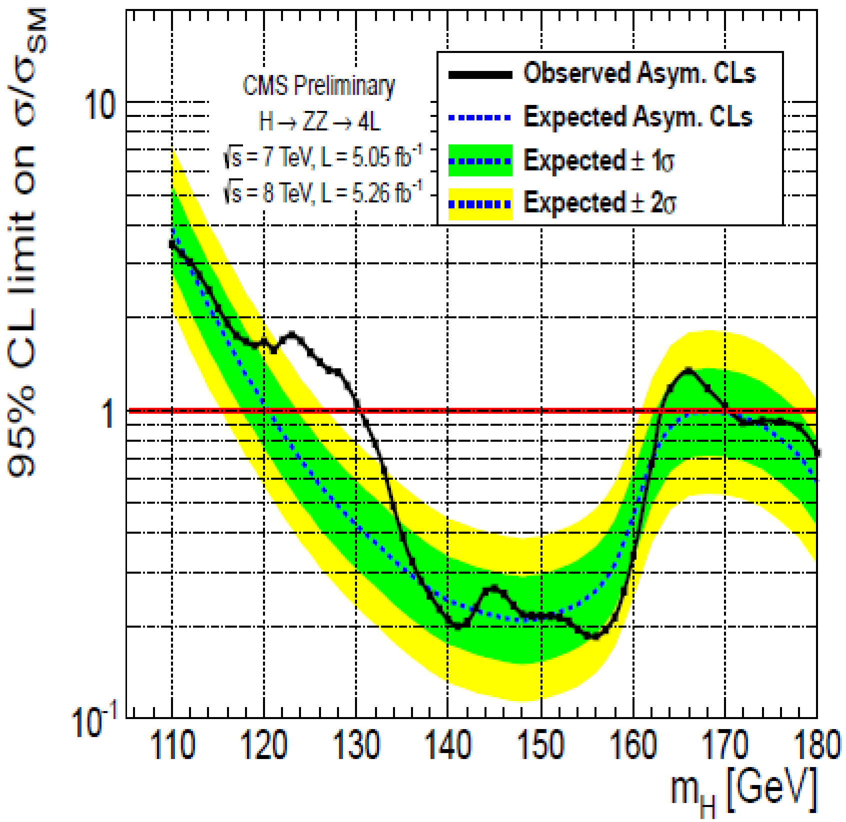


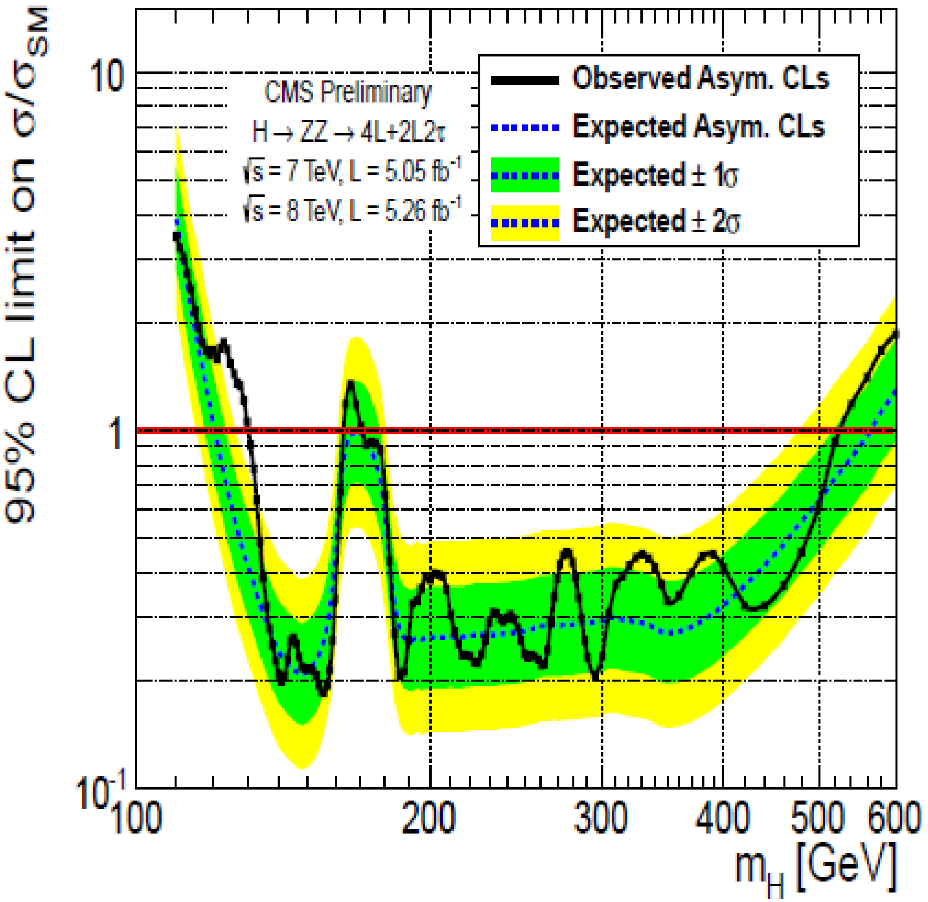
$$\text{MELA} = \left[1 + \frac{\mathcal{P}_{\text{bkg}}(m_1, m_2, \theta_1, \theta_2, \Phi, \theta^*, \Phi_1 | m_{4\ell})}{\mathcal{P}_{\text{sig}}(m_1, m_2, \theta_1, \theta_2, \Phi, \theta^*, \Phi_1 | m_{4\ell})}\right]^{-1}$$



Angular analysis using matrix-element likelihood approach enhances sensitivity

Golden channel: h→ZZ→4l



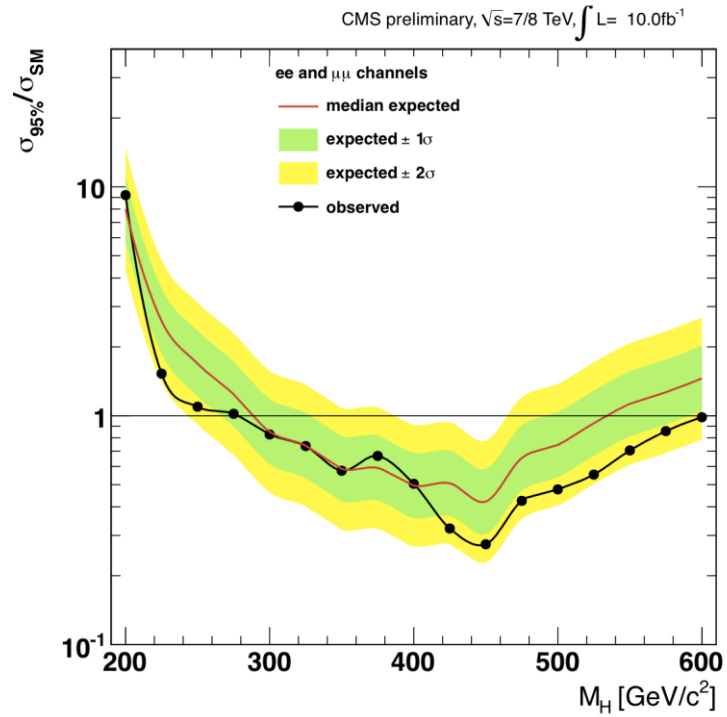


Other ZZ channels

Look for two leptons and large missing transverse energy

Table 33: Expected number of signal and background events for an integrated luminosity of 5.0 fb^{-1} at 8 TeV after applying the full higgs selection compared to the number of observed events in data. Uncertainties for ZZ/WZ/Z+Jets and non-resonant backgrounds as well as for signal include the statistical and systematic components.

channel	ZZ	$WZ \to 3l\nu$	$Z \to ll(data)$	$Top/WW/W(data)$	$Total$	$ggH(200)$	$qqH(200)$	$Data$
$ee = 0$ $jets$	7.0 ± 0.2	4.4 ± 0.1	$1.6 \pm 0.3 \pm 1.6$	$6.1 \pm 1.5 \pm 1.5$	$19.1 \pm 1.5 \pm 2.2$	0.003 ± 0.003	0.005 ± 0.005	13
$\mu\mu = 0$ $jets$	12.0 ± 0.3	7.2 ± 0.2	$3.2 \pm 0.6 \pm 3.2$	$11.0 \pm 2.6 \pm 2.7$	$33.3 \pm 2.7 \pm 4.2$	0.012 ± 0.008	0.0004 ± 0.0003	27
$ee = 1$ $jets$	3.7 ± 0.2	3.4 ± 0.1	$7.4 \pm 0.7 \pm 7.4$	$11.2 \pm 2.0 \pm 2.8$	$25.7 \pm 2.2 \pm 7.9$	0.4 ± 0.2	0.08 ± 0.01	32
$\mu\mu = 1$ $jets$	6.2 ± 0.2	5.2 ± 0.1	$12.3 \pm 1.2 \pm 12.3$	$20.1 \pm 3.6 \pm 5.0$	$43.8 \pm 3.8 \pm 13.3$	0.6 ± 0.2	0.14 ± 0.02	49
$ee \geq 2$ $jets$	1.3 ± 0.1	1.02 ± 0.06	$6.0 \pm 0.6 \pm 6.0$	$7.1 \pm 1.6 \pm 1.8$	$15.4 \pm 1.7 \pm 6.2$	0.3 ± 0.1	0.18 ± 0.03	28
$\mu\mu \geq 2$ $jets$	2.3 ± 0.1	1.57 ± 0.07	$10.3 \pm 1.0 \pm 10.3$	$12.8 \pm 2.8 \pm 3.2$	$27.0 \pm 3.0 \pm 10.8$	0.5 ± 0.1	0.23 ± 0.03	34
ee vbf	0.04 ± 0.02	0.04 ± 0.01	$0.21 \pm 0.08 \pm 0.21$	$0.34 \pm 0.34 \pm 0.09$	$0.6 \pm 0.4 \pm 0.2$	0.010 ± 0.007	0.11 ± 0.02	0
$\mu\mu$ vbf	0.04 ± 0.02	0.04 ± 0.01	$0.4 \pm 0.1 \pm 0.4$	$0.6 \pm 0.6 \pm 0.2$	$1.1 \pm 0.6 \pm 0.4$	0.0006 ± 0.0006	0.18 ± 0.02	1
channel	ZZ	$WZ \to 3l\nu$	$Z \to ll(data)$	$Top/WW/W(data)$	$Total$	$ggH(300)$	$qqH(300)$	$Data$
$ee = 0$ $jets$	7.0 ± 0.2	3.5 ± 0.1	$0.8 \pm 0.2 \pm 0.8$	$3.7 \pm 1.2 \pm 0.9$	$15.1 \pm 1.2 \pm 1.2$	3.1 ± 0.3	0.11 ± 0.01	11
$\mu\mu = 0$ $jets$	11.3 ± 0.3	5.2 ± 0.1	$1.6 \pm 0.4 \pm 1.6$	$6.7 \pm 2.1 \pm 1.7$	$24.9 \pm 2.1 \pm 2.3$	5.6 ± 0.5	0.18 ± 0.01	14
$ee = 1$ $jets$	4.2 ± 0.2	2.8 ± 0.1	$2.6 \pm 0.3 \pm 2.6$	$2.7 \pm 1.0 \pm 0.7$	$12.3 \pm 1.1 \pm 2.7$	5.3 ± 0.4	0.74 ± 0.03	14
$\mu\mu = 1$ $jets$	6.3 ± 0.2	4.1 ± 0.1	$4.4 \pm 0.5 \pm 4.4$	$4.9 \pm 1.7 \pm 1.2$	$19.6 \pm 1.8 \pm 4.5$	7.4 ± 0.5	0.98 ± 0.03	23
$ee \geq 2$ $jets$	1.18 ± 0.09	0.71 ± 0.05	$1.2 \pm 0.2 \pm 1.2$	$0.7 \pm 0.5 \pm 0.2$	$3.8 \pm 0.5 \pm 1.2$	2.0 ± 0.3	0.39 ± 0.02	12
$\mu\mu \geq 2$ $jets$	2.0 ± 0.1	1.14 ± 0.06	$2.1 \pm 0.3 \pm 2.1$	$1.2 \pm 0.9 \pm 0.3$	$6.5 \pm 0.9 \pm 2.1$	2.8 ± 0.3	0.47 ± 0.02	12
ee vbf	0.04 ± 0.02	0.04 ± 0.01	$0.21 \pm 0.08 \pm 0.21$	$0.34 \pm 0.34 \pm 0.09$	$0.6 \pm 0.4 \pm 0.2$	0.17 ± 0.06	0.50 ± 0.02	0
$\mu\mu$ vbf	0.04 ± 0.02	0.04 ± 0.01	$0.4 \pm 0.1 \pm 0.4$	$0.6 \pm 0.6 \pm 0.2$	$1.1 \pm 0.6 \pm 0.4$	0.14 ± 0.05	0.66 ± 0.03	1
channel	ZZ	$WZ \to 3l\nu$	$Z \to ll(data)$	$Top/WW/W(data)$	$Total$	$ggH(400)$	$qqH(400)$	$Data$
$ee = 0$ $jets$	2.3 ± 0.1	0.71 ± 0.05	$0.15 \pm 0.05 \pm 0.15$	$0.17 \pm 0.17 \pm 0.04$	$3.3 \pm 0.2 \pm 0.2$	2.1 ± 0.2	0.045 ± 0.007	2
$\mu\mu = 0$ $jets$	2.9 ± 0.2	1.14 ± 0.07	$0.4 \pm 0.1 \pm 0.4$	$0.30 \pm 0.31 \pm 0.08$	$4.8 \pm 0.4 \pm 0.4$	3.1 ± 0.3	0.067 ± 0.008	3
$ee = 1$ $jets$	1.5 ± 0.1	0.71 ± 0.05	$0.7 \pm 0.1 \pm 0.7$	$0.17 \pm 0.17 \pm 0.04$	$3.1 \pm 0.3 \pm 0.7$	3.8 ± 0.3	0.31 ± 0.02	3
$\mu\mu = 1$ $jets$	2.3 ± 0.1	1.04 ± 0.06	$1.1 \pm 0.2 \pm 1.1$	$0.30 \pm 0.31 \pm 0.08$	$4.8 \pm 0.4 \pm 1.1$	5.5 ± 0.4	0.49 ± 0.02	6
$ee \geq 2$ $jets$	0.56 ± 0.06	0.25 ± 0.03	$0.49 \pm 0.08 \pm 0.49$	$0.17 \pm 0.17 \pm 0.04$	$1.5 \pm 0.2 \pm 0.5$	1.6 ± 0.2	0.119 ± 0.010	0
$\mu\mu \geq 2$ $jets$	0.79 ± 0.07	0.37 ± 0.04	$0.8 \pm 0.1 \pm 0.8$	$0.30 \pm 0.31 \pm 0.08$	$2.2 \pm 0.3 \pm 0.8$	2.2 ± 0.2	0.21 ± 0.01	5
ee vbf	0.04 ± 0.02	0.04 ± 0.01	$0.21 \pm 0.08 \pm 0.21$	$0.34 \pm 0.34 \pm 0.09$	$0.6 \pm 0.4 \pm 0.2$	0.07 ± 0.03	0.31 ± 0.02	0
$\mu\mu$ vbf	0.04 ± 0.02	0.04 ± 0.01	$0.4 \pm 0.1 \pm 0.4$	$0.6 \pm 0.6 \pm 0.2$	$1.1 \pm 0.6 \pm 0.4$	0.16 ± 0.06	0.45 ± 0.02	1
channel	ZZ	$WZ \to 3l\nu$	$Z \to ll(data)$	$Top/WW/W(data)$	$Total$	$ggH(600)$	$qqH(600)$	$Data$
$ee = 0$ $jets$	0.61 ± 0.08	0.15 ± 0.02	$0.008 \pm 0.008 \pm 0.008$	$0.17 \pm 0.17 \pm 0.04$	$0.94 \pm 0.19 \pm 0.04$	0.28 ± 0.05	0.018 ± 0.002	0
$\mu\mu = 0$ $jets$	0.88 ± 0.09	0.22 ± 0.03	$0.04 \pm 0.08 \pm 0.04$	$0.30 \pm 0.31 \pm 0.08$	$1.45 \pm 0.33 \pm 0.09$	0.46 ± 0.06	0.029 ± 0.002	0
$ee = 1$ $jets$	0.53 ± 0.06	0.15 ± 0.02	$0.22 \pm 0.05 \pm 0.22$	$0.17 \pm 0.17 \pm 0.04$	$1.1 \pm 0.2 \pm 0.2$	0.95 ± 0.08	0.134 ± 0.005	1
$\mu\mu = 1$ $jets$	0.86 ± 0.08	0.26 ± 0.03	$0.37 \pm 0.09 \pm 0.37$	$0.30 \pm 0.31 \pm 0.08$	$1.8 \pm 0.3 \pm 0.4$	1.09 ± 0.09	0.171 ± 0.006	2
$ee \geq 2$ $jets$	0.27 ± 0.04	0.05 ± 0.01	$0.10 \pm 0.04 \pm 0.10$	$0.17 \pm 0.17 \pm 0.04$	$0.6 \pm 0.2 \pm 0.1$	0.39 ± 0.05	0.049 ± 0.003	0
$\mu\mu \geq 2$ $jets$	0.33 ± 0.04	0.05 ± 0.01	$0.17 \pm 0.06 \pm 0.17$	$0.30 \pm 0.31 \pm 0.08$	$0.9 \pm 0.3 \pm 0.2$	0.61 ± 0.06	0.059 ± 0.003	1
ee vbf	0.04 ± 0.02	0.04 ± 0.01	$0.21 \pm 0.08 \pm 0.21$	$0.34 \pm 0.34 \pm 0.09$	$0.6 \pm 0.4 \pm 0.2$	0.05 ± 0.01	0.130 ± 0.005	0
$\mu\mu$ vbf	0.04 ± 0.02	0.04 ± 0.01	$0.4 \pm 0.1 \pm 0.4$	$0.6 \pm 0.6 \pm 0.2$	$1.1 \pm 0.6 \pm 0.4$	0.06 ± 0.02	0.172 ± 0.006	1



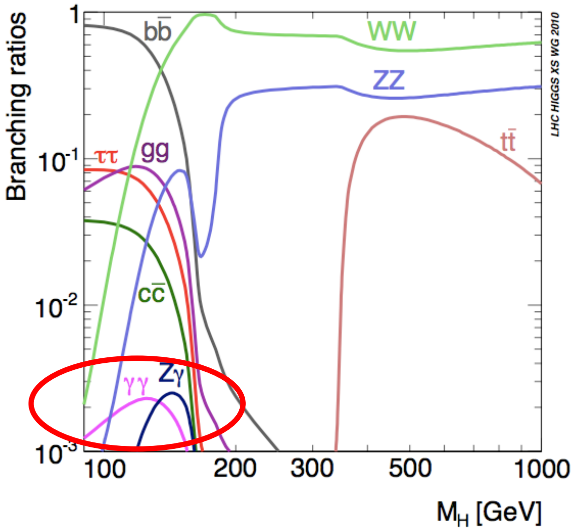
Golden Low Mass Channel: $h \to \gamma\gamma$

Tiny branching ratio but very clean signature

Two isolated high pT photons

Narrow resonance – performance completely driven by the detector

Was the benchmark channel for the ECAL design



ECAL TDR

Table 12.7: Signal significance for $H \to \gamma\gamma$ (m_H = 100 GeV)

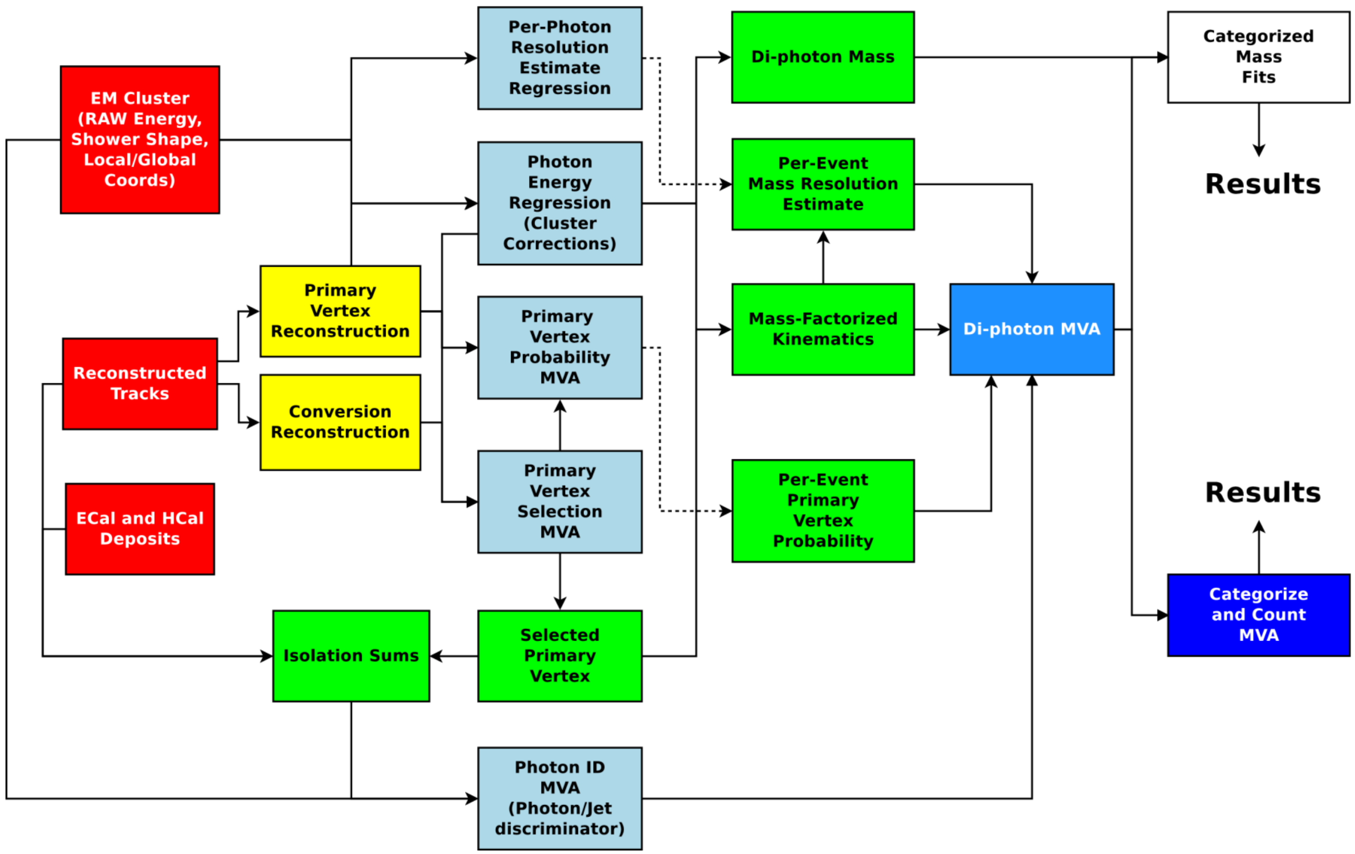
Integrated luminosity	Signal significance
$30 fb^{-1}$ taken at 10^{33} $cm^{-2}s^{-1}$	5.0
$100 fb^{-1}$ taken at 10^{34} $cm^{-2}s^{-1}$	8.3

In principle a simple analysis:

- look for a bump in diphoton mass spectrum
- accumulate data and wait for it to appear!

h→γγ

Slightly more complicated than making a mass plot and waiting for a signal!



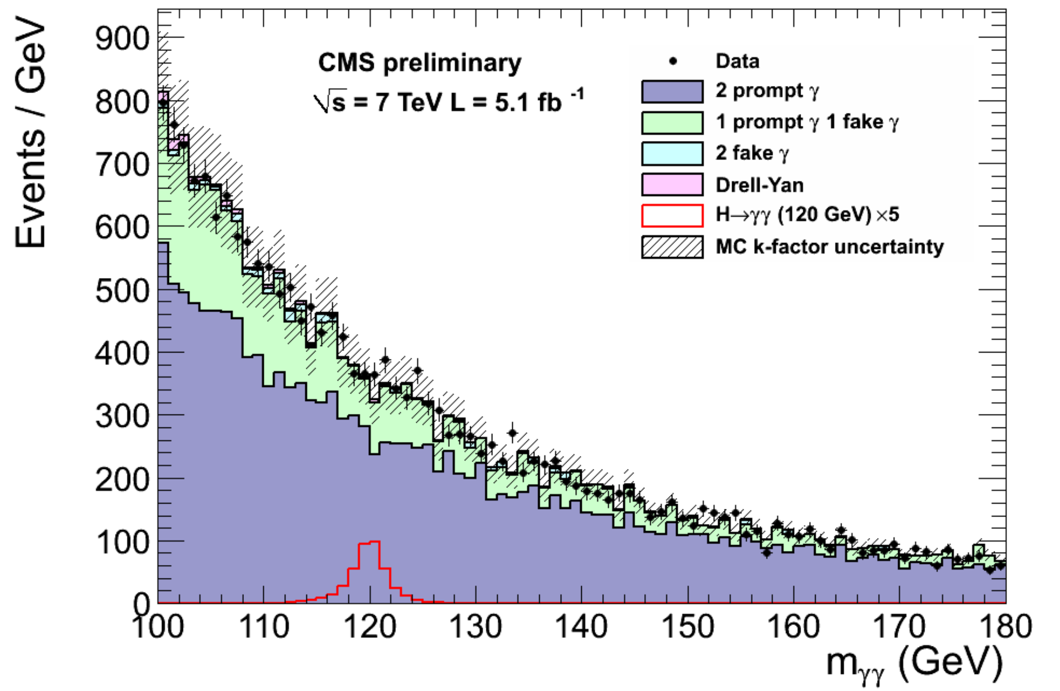
Event selection

Select events with 2 isolated photons, with cuts on pt/M

2 high-pt jets plus high jet mass for VBF search

Split events into different categories to optimize sensitivity

Look for a bump on a smoothly falling backgound

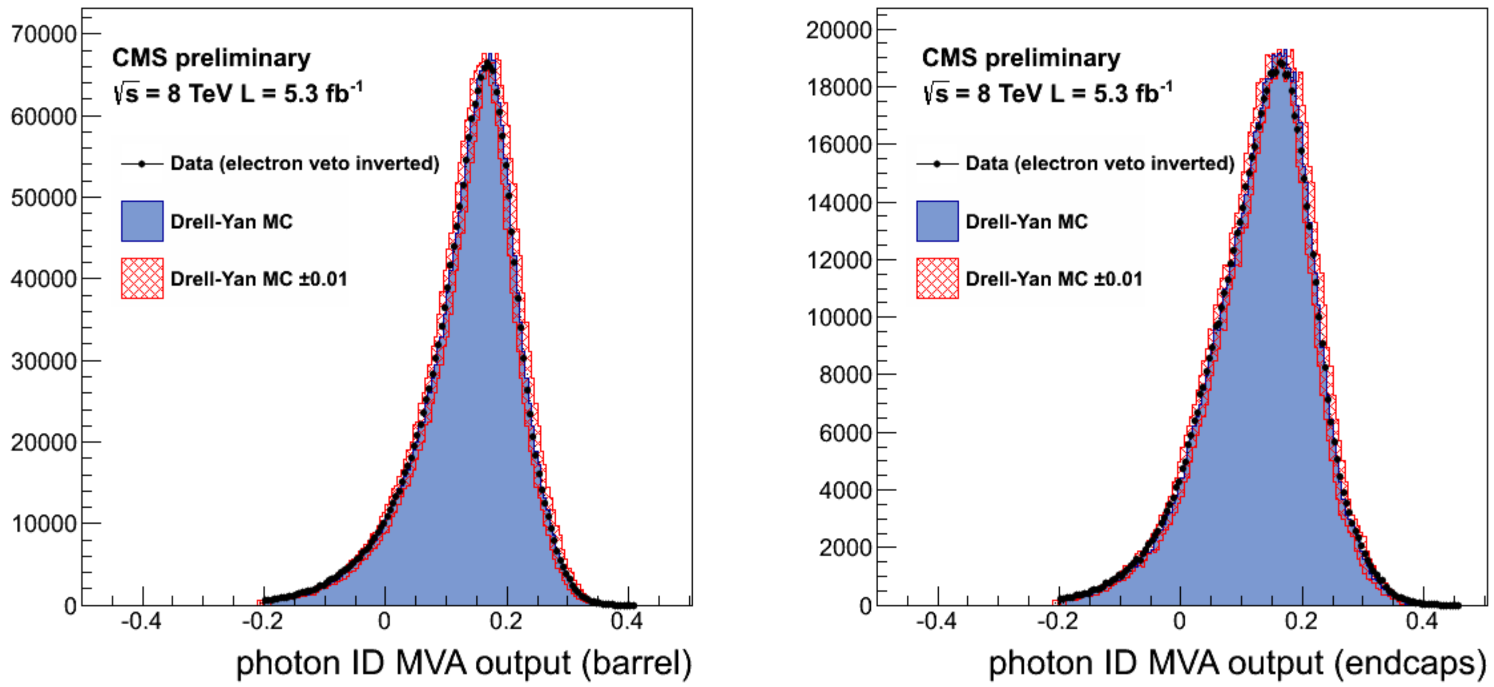


Pretty good agreement between MC and data

Photon ID

Boosted decision tree trained to separate prompt photons from π^0

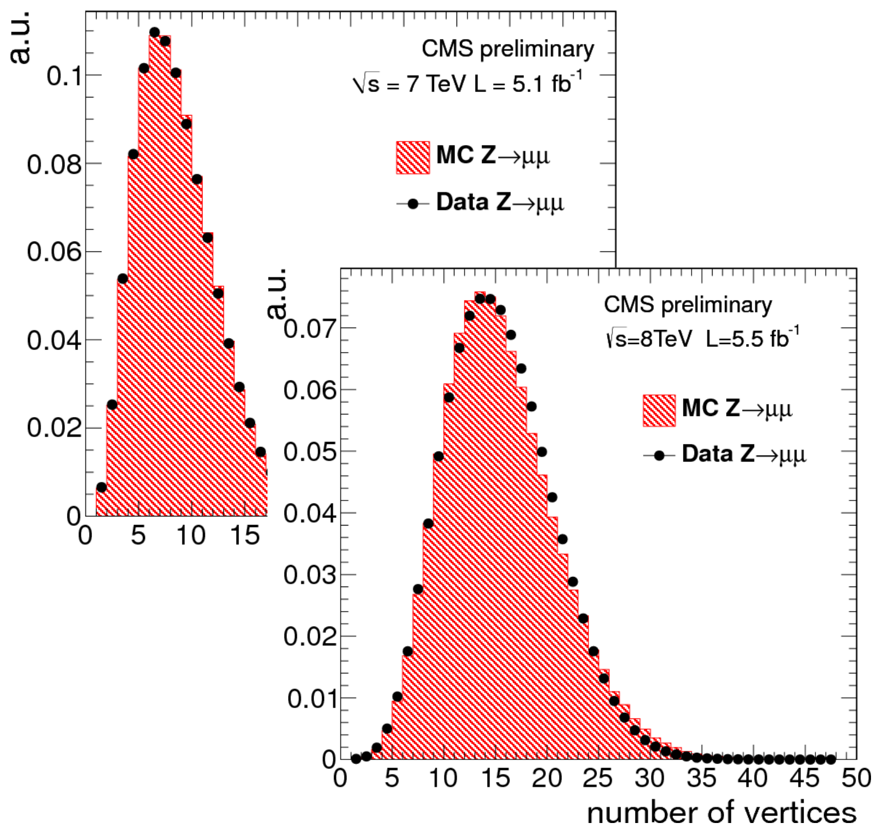
Use isolation, shower shape and related



Efficiency measured in $Z \to ee$ with corrections to photons derived from MC

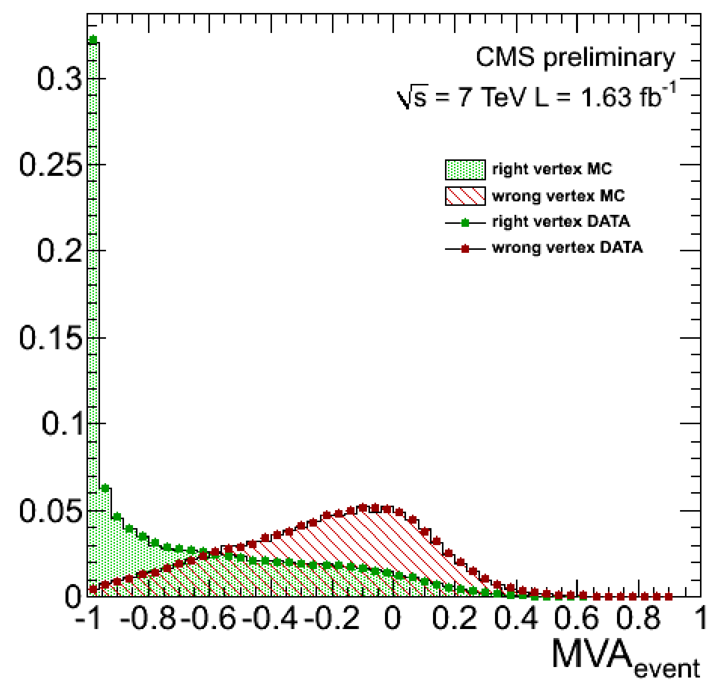
Vertexing

Correct vertex needs to be identified precision < 10mm



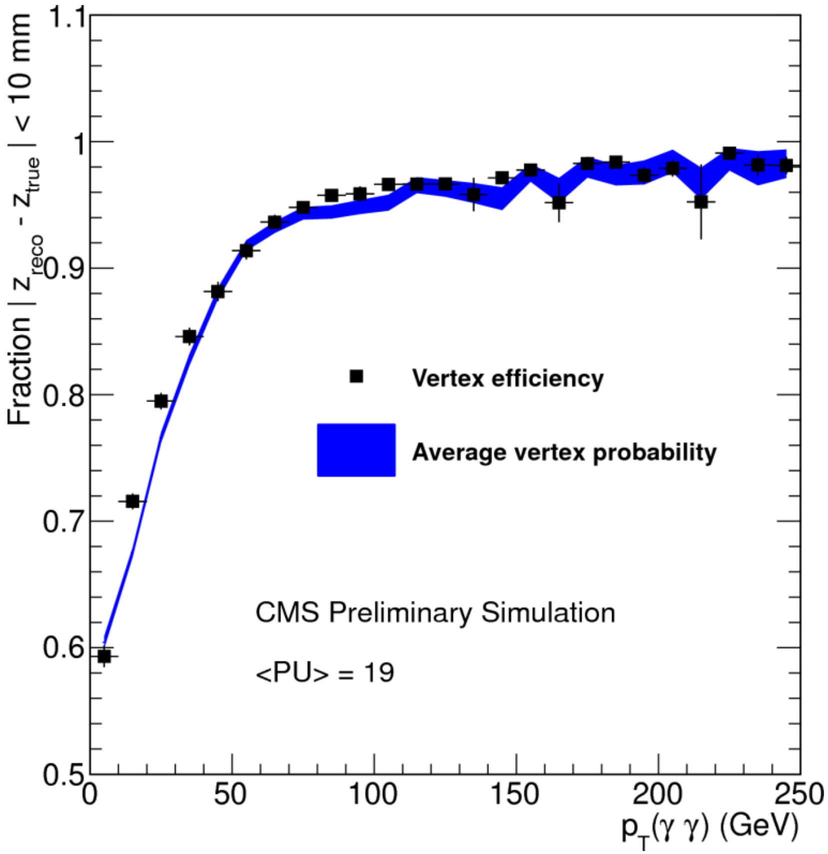
BDT based vertexing algorithm based on event kinematics

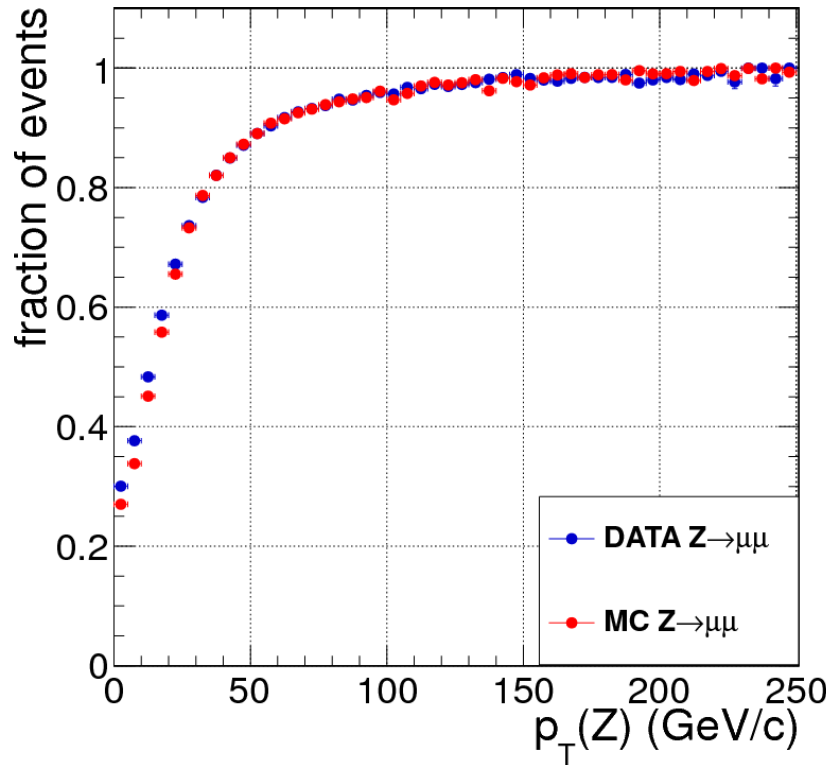
Gives vertex + event-by-event error estimate



Vertexing

Methods validated on Z→μμ events by throwing away muon tracks





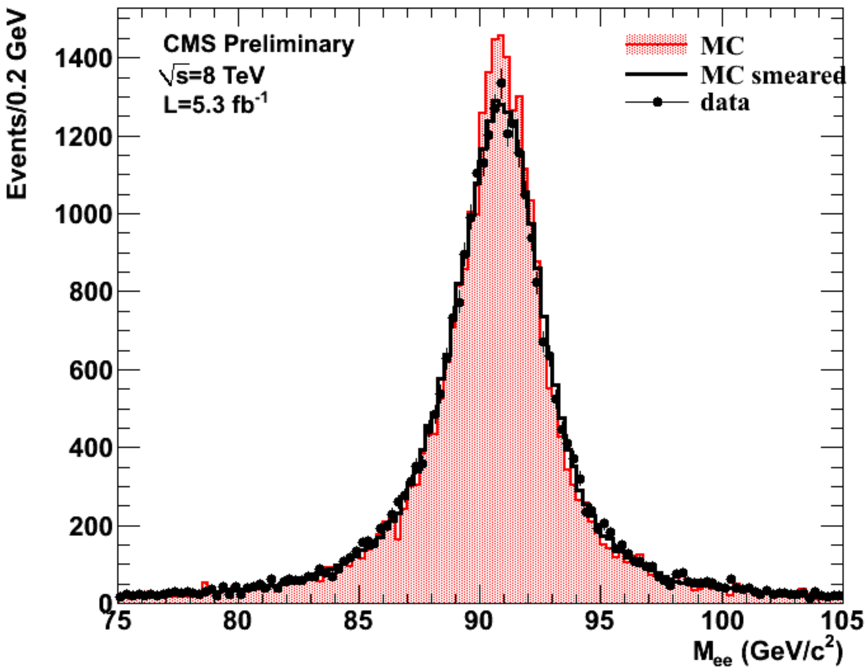
Energy Reconstruction

Number of corrections applied to ECAL cluster energies:

shower containment
conversion recovery
pile-up mitigation

BDT based regression algorithm used trained on MC

MC tuned to data in Z→ee events



Signal Extraction

3 procedures used:

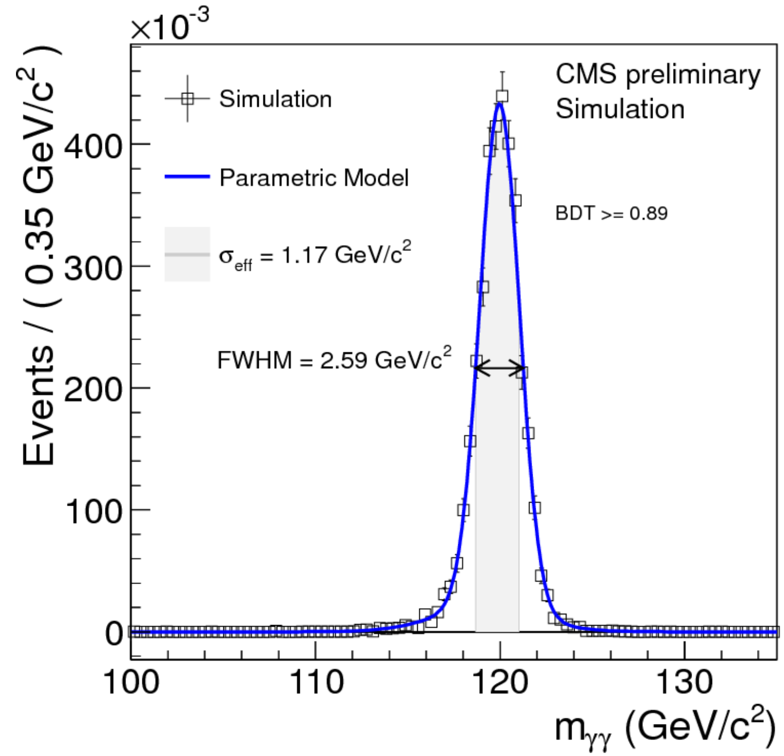
simple categorisation with mass fit

used for earlier results now dropped

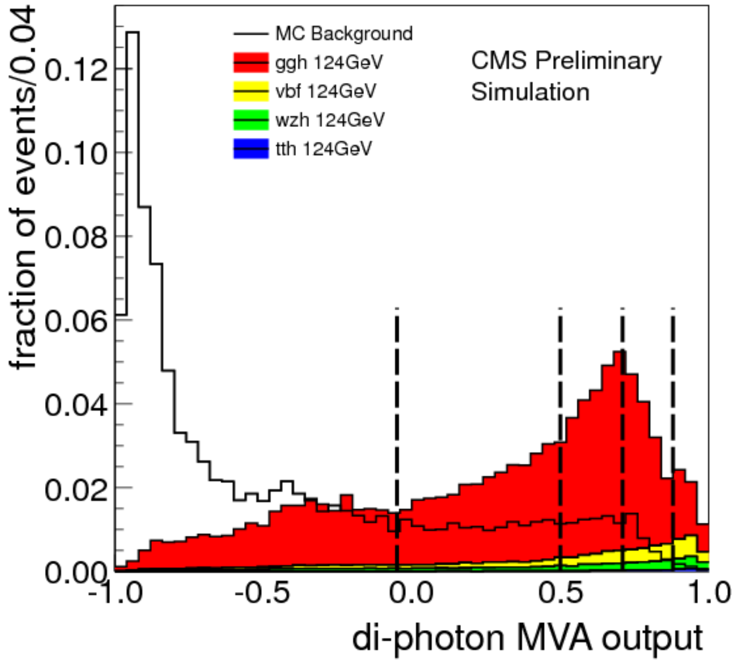
BDT categorisation with mass fit

"mass factorised"

BDT categorisation with "sideband method"

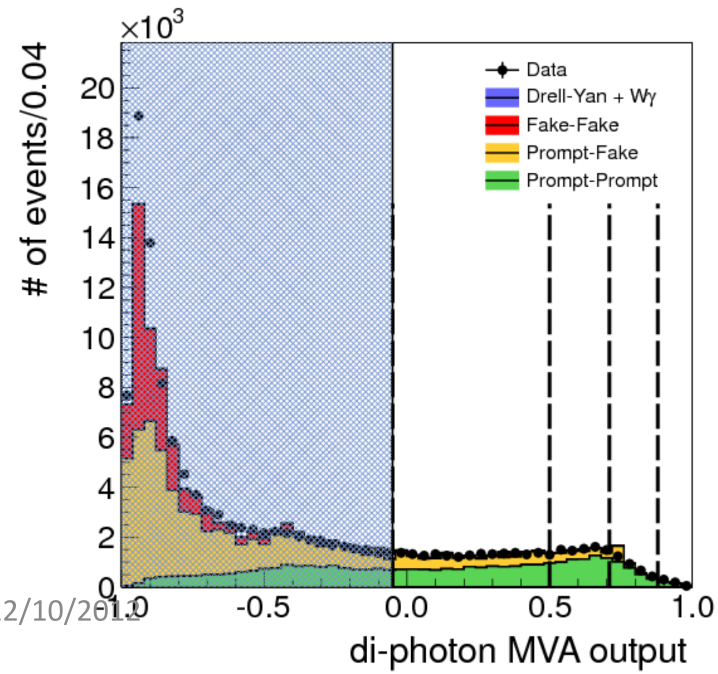


"Mass factorized" : Categorisation



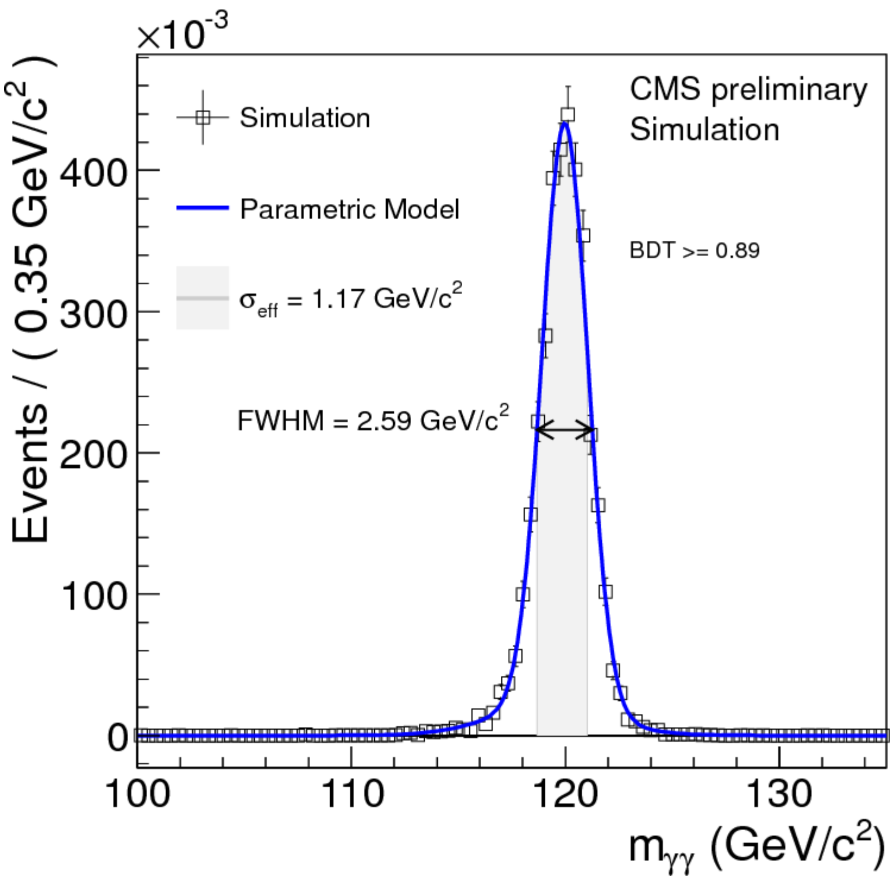
Train a BDT with photon-ID and kinematic information

Choose carefully to avoid dependence on mass hypothesis



Use BDT output value to define categories – optimised for best expected sensitivity from simulation

"Mass factorized" : Signal Model



Sum of gaussians fit to tuned Monte-Carlo in each category

Systematics mapped onto variations in model parameters

MC generated at 5 GeV intervals in mass – parameters interpolated inbetween

Category	0	1	2	3	VBF1	VBF2
Resolution / GeV	1.34	1.44	1.82	2.96	1.87	2.13

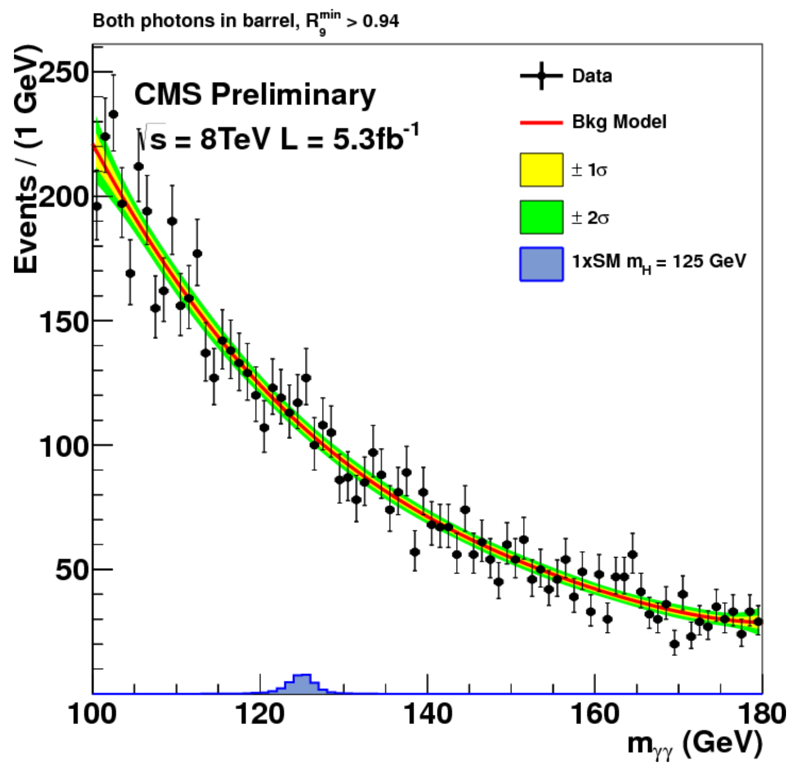
“Mass factorized” : Background Model

Problem: how to chose a parameterised model?

Solution: compare performance with many classes of functions in simulation

Generate with one function – fit with another

Pick the function with the best performance with respect to biases in the signal extraction

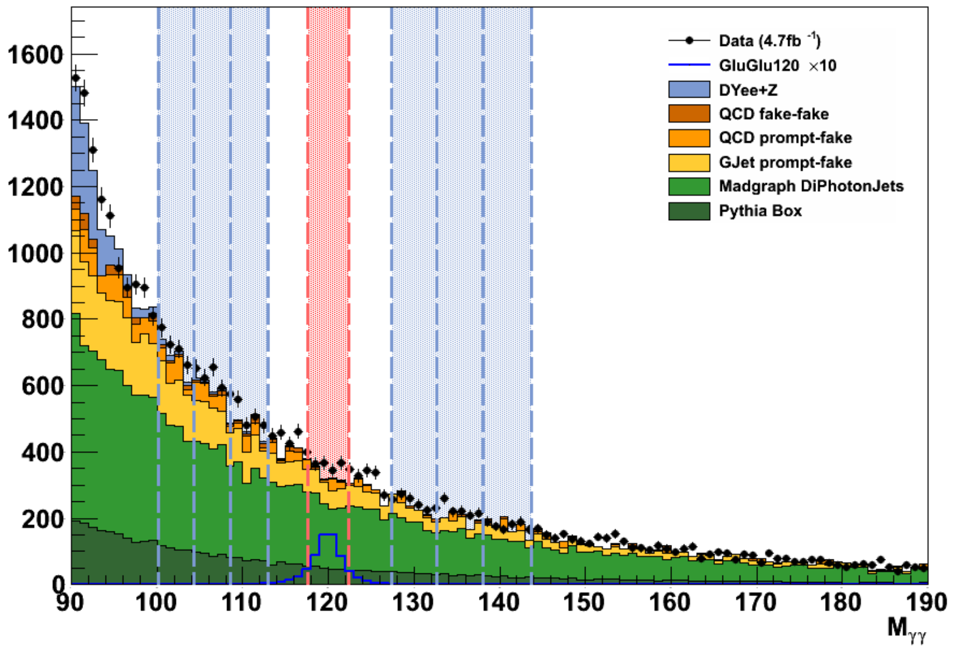


Separate fit in each category

Polynomials give smallest bias, order ranges from 3 to 5 depending on cat.

Sideband Method

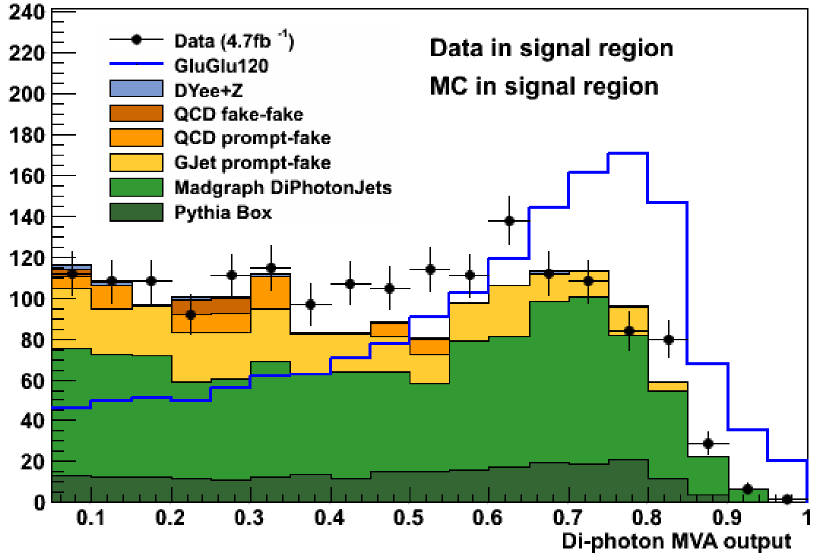
Alternative approach designed to avoid some pitfalls of pure parametric approach



For each mass hypothesis:
Split mass spectrum into windows +/-2% wide

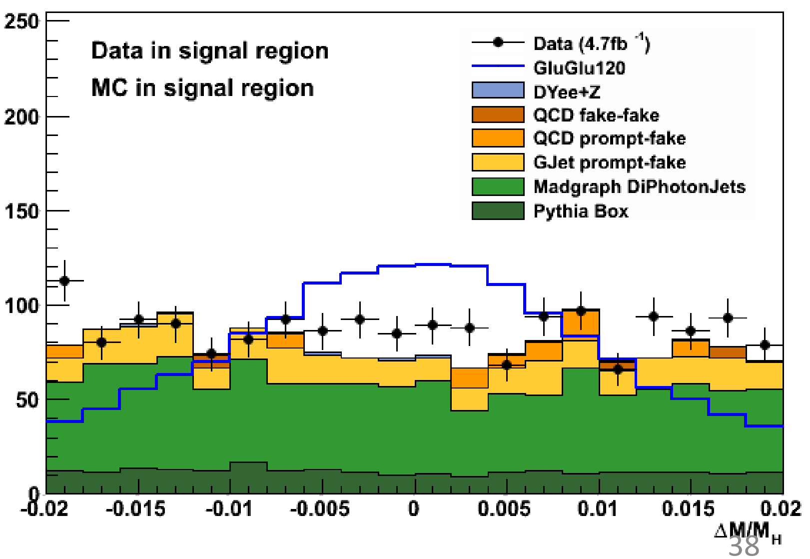
Use data from sidebands to constrain a model of the background in the signal window

Sideband Method



Instead of mass fit:
combine information from diphoton BDT with $\Delta M/M_H$ in a further BDT

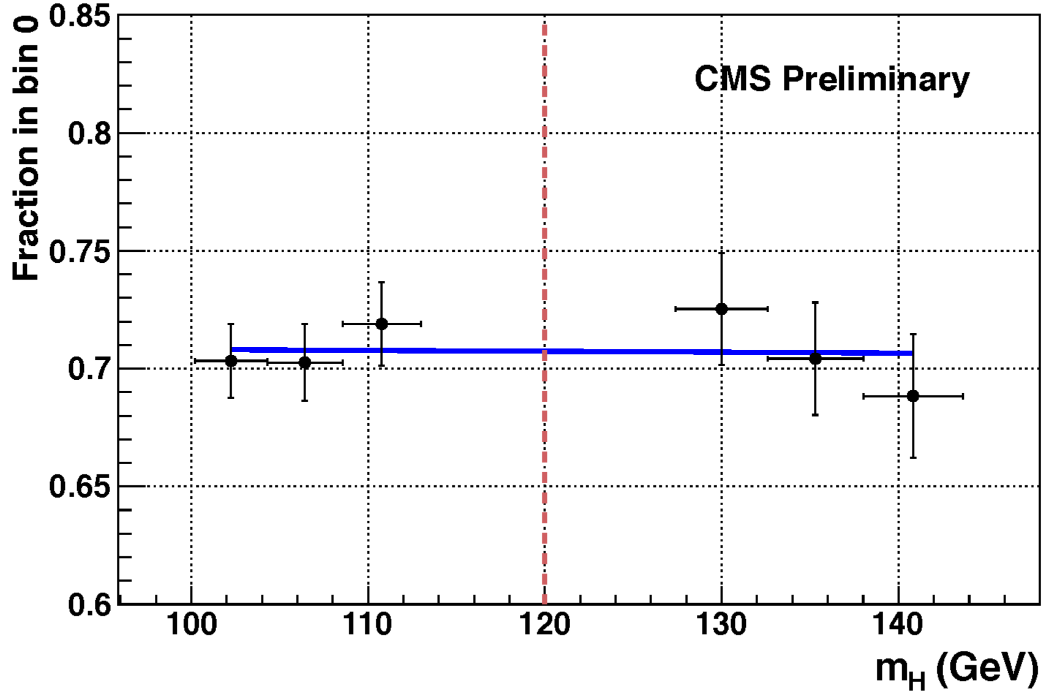
Use output of BDT to categorize events with similar S/B



Sideband Method

Assume that variation of fractional yield in a category from one sideband to another approximately constant

Follows from approximate independence of diphoton BDT to mass hypothesis

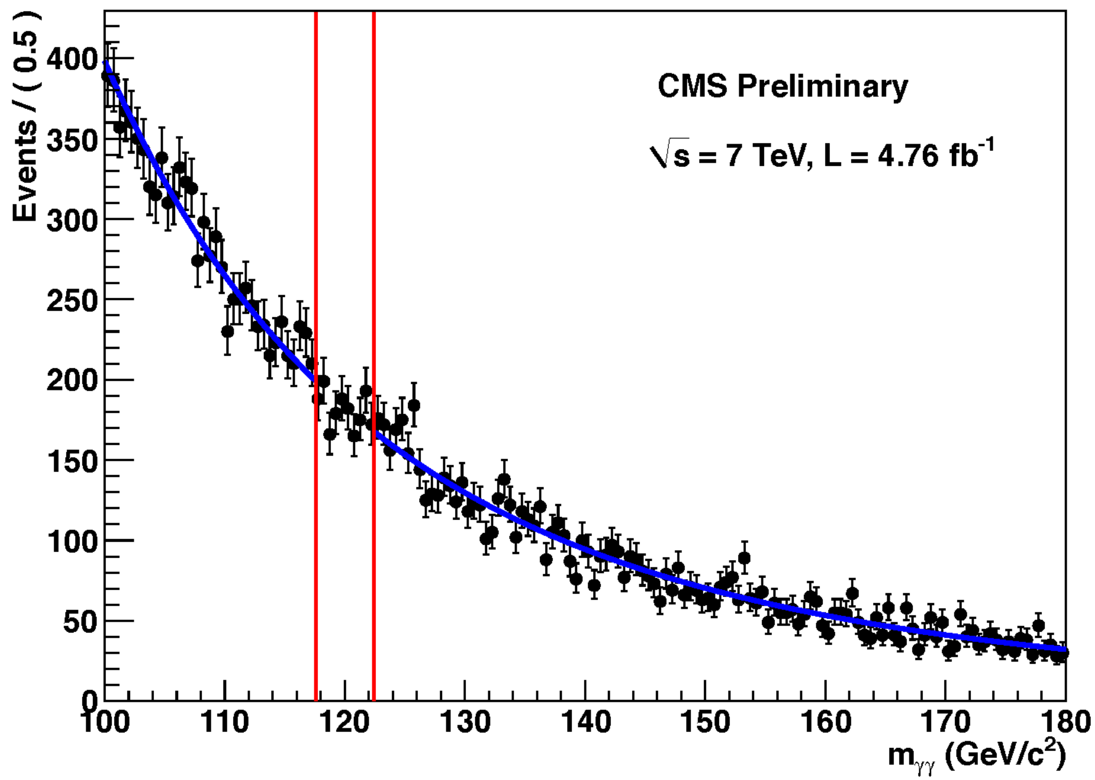


Fit a straight line and parabola to extract relative yield in the signal region

Uncertainties propagated forward from fit and systematic variation from comparing parabola and straight line fit

Sideband Method

Fit “double-power-law” across sum of all categories to estimate total yield in signal region



In practise can do all fits in one big simultaneous method

Add uncertainties to yield in each category based on global fit uncertainties and estimate of bias from MC studies similar to those in the “mass factorised” method

Sideband Method

Advantages:

each assumption has an associated systematic uncertainty

no need to re-determine polynomial order as data accumulate

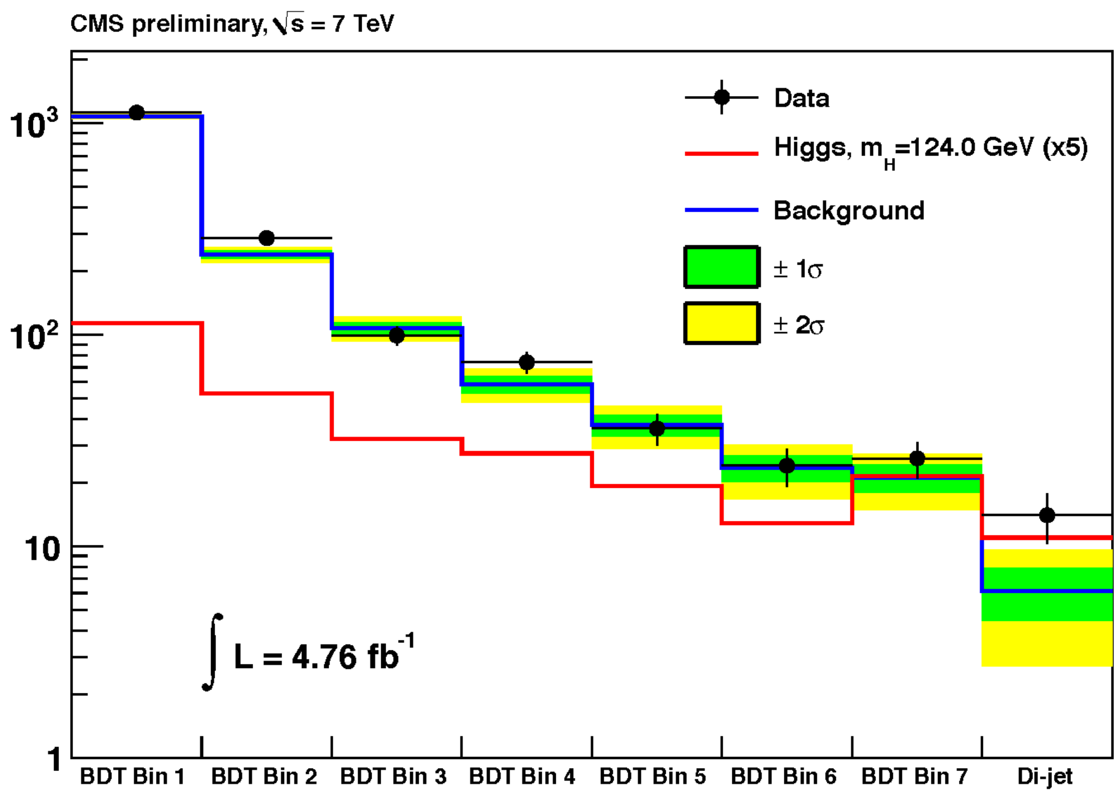
constraints on background yields across categories

Disadvantages:

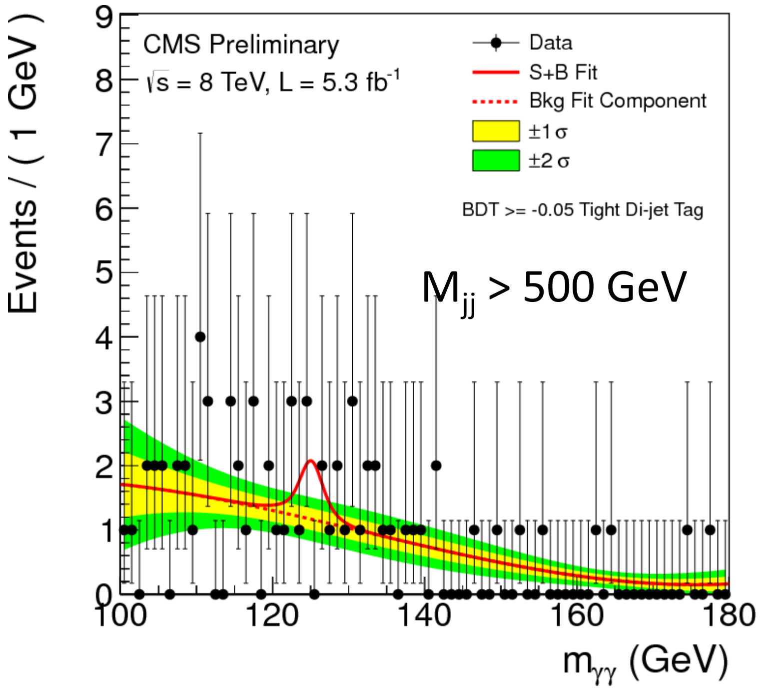
complexity

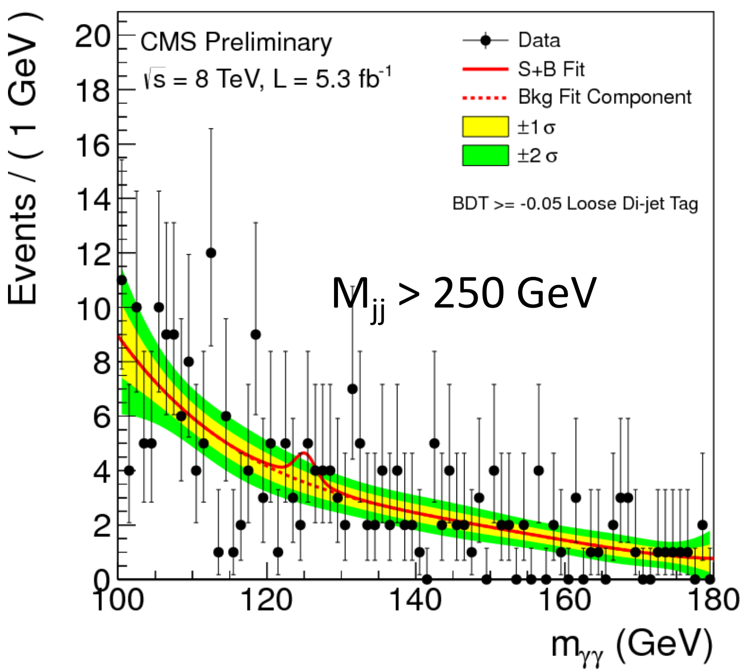
non-parametric

less smooth variation of results



VBF Tagged Categories





2 Categories for 2012, 1 cat categories for 2011 running

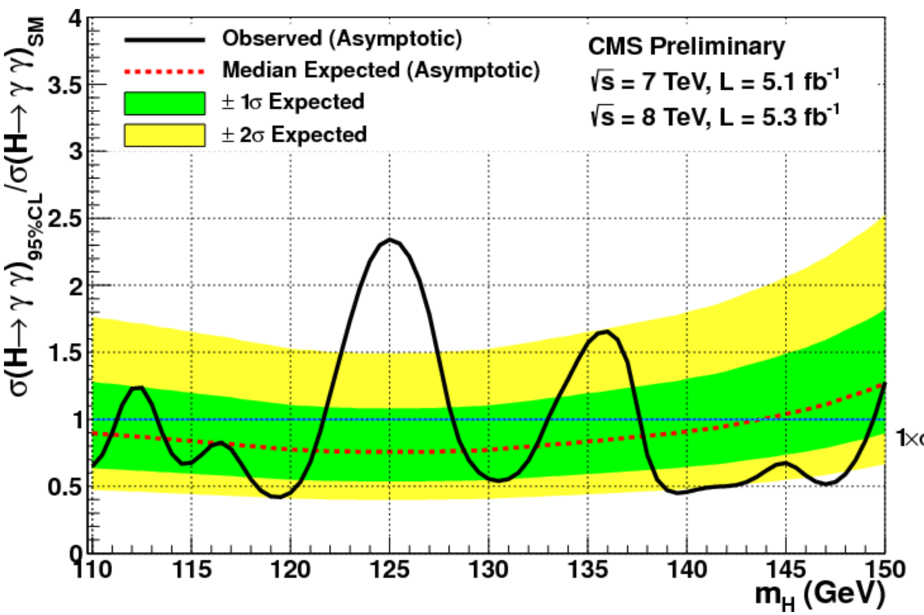
2-jets well separated in rapidity, select for high dijet mass to further enrich VBF content

Large systematics from jet modelling and “category migration” (large on ggH)

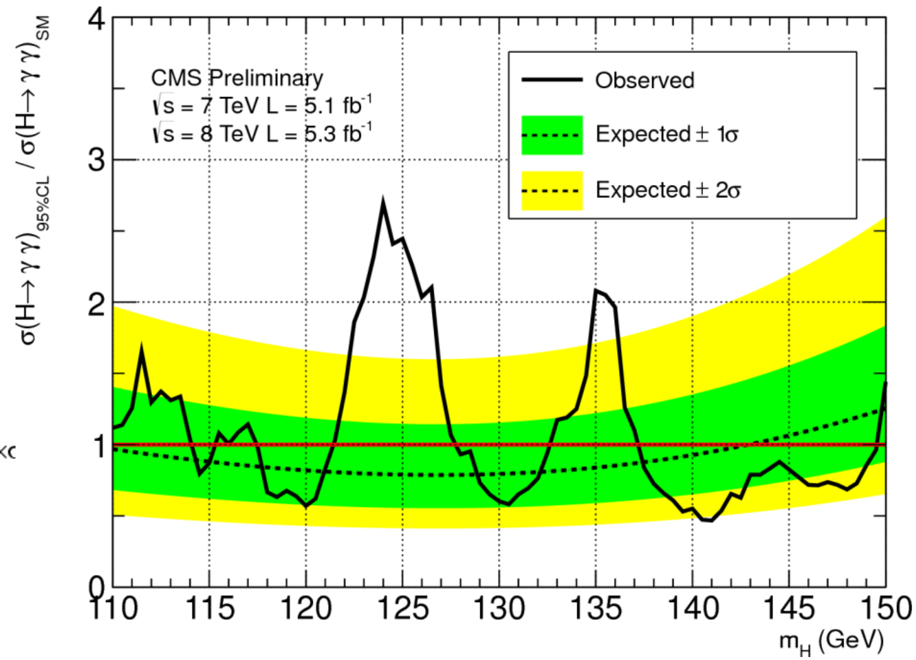
Results

Results of inclusive + VBF searches

"Mass factorised"

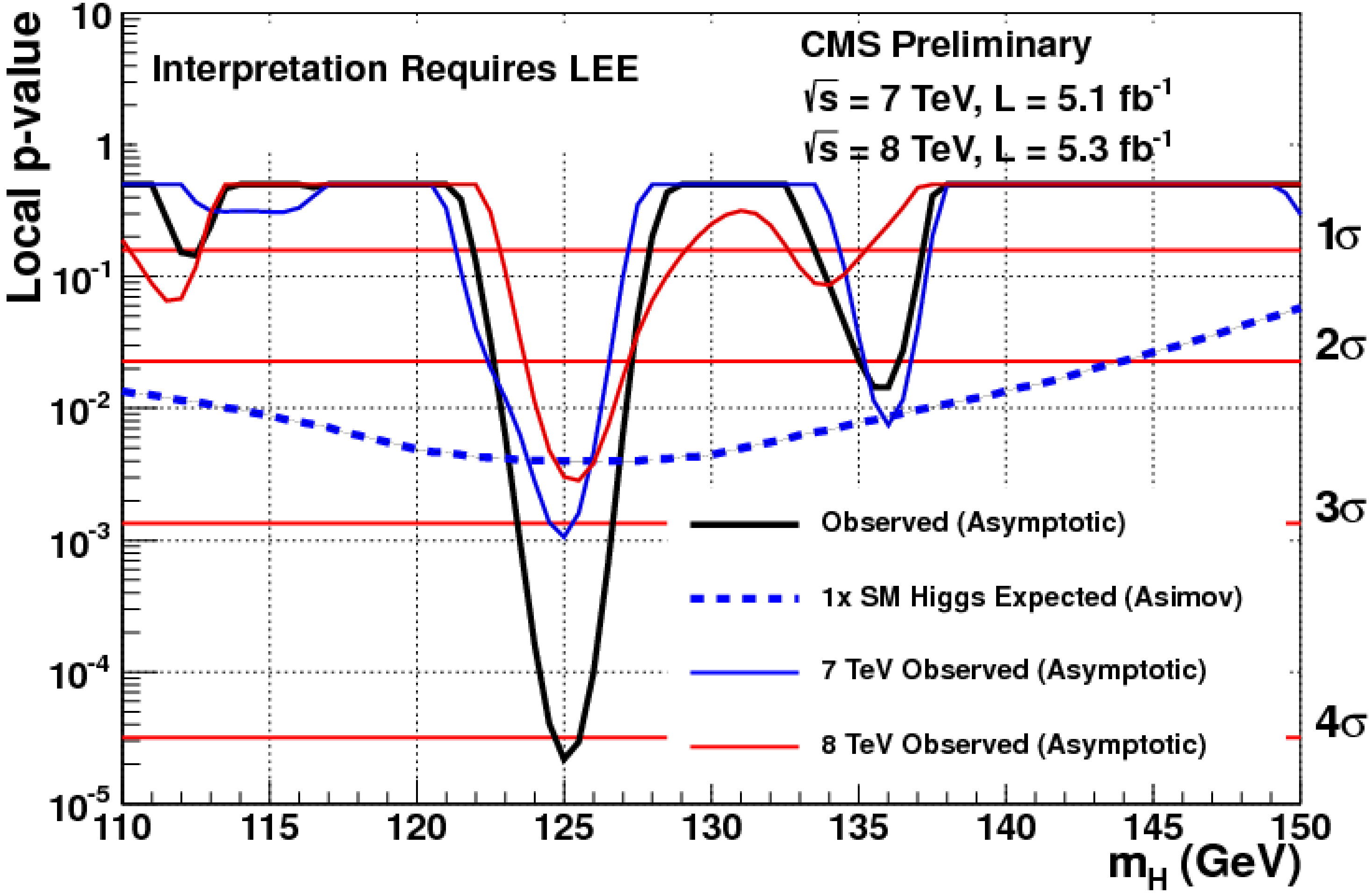


"sideband"



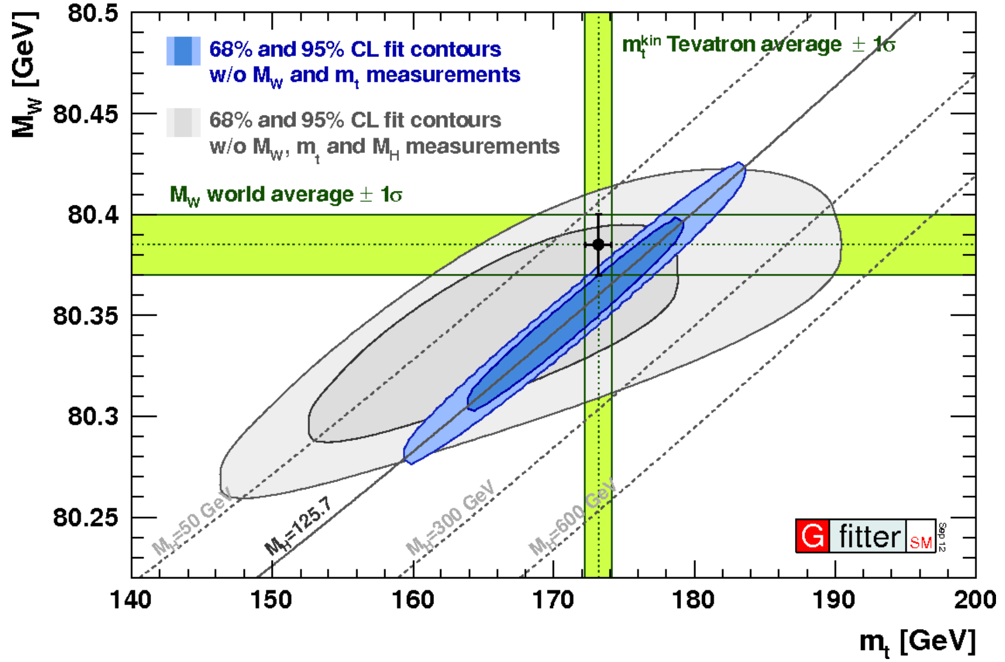
Both methods give consistent results

Results

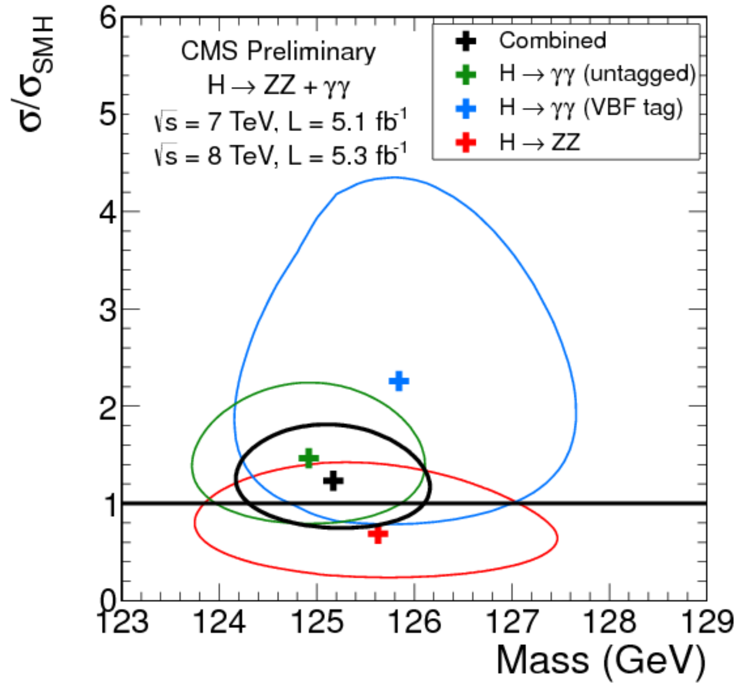


Local p-value
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
Interpretation Requires LEE
CMS Preliminary
$\sqrt{s}$ = 7 TeV, L = 5.1 fb^{-1}
$\sqrt{s}$ = 8 TeV, L = 5.3 fb^{-1}
1σ
2σ
3σ
4σ
Observed (Asymptotic)
1x SM Higgs Expected (Asimov)
7 TeV Observed (Asymptotic)
8 TeV Observed (Asymptotic)
110
115
120
125
130
135
140
145
150
m_H (GeV)

Higgs Properties: Mass

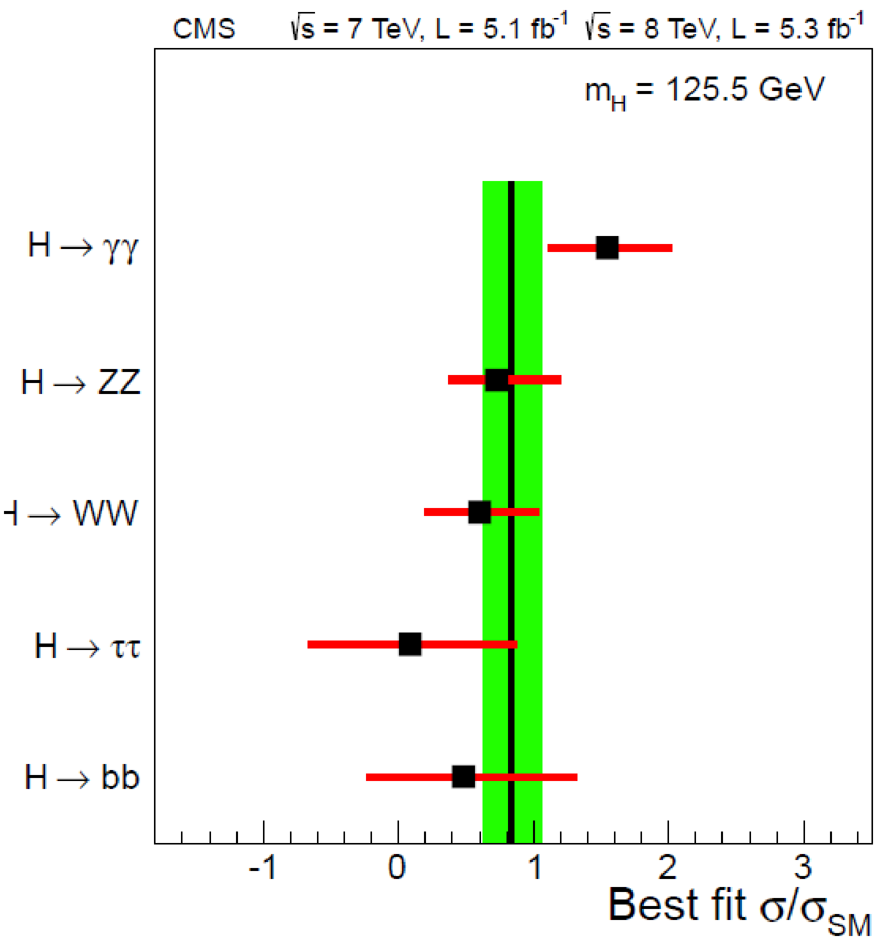


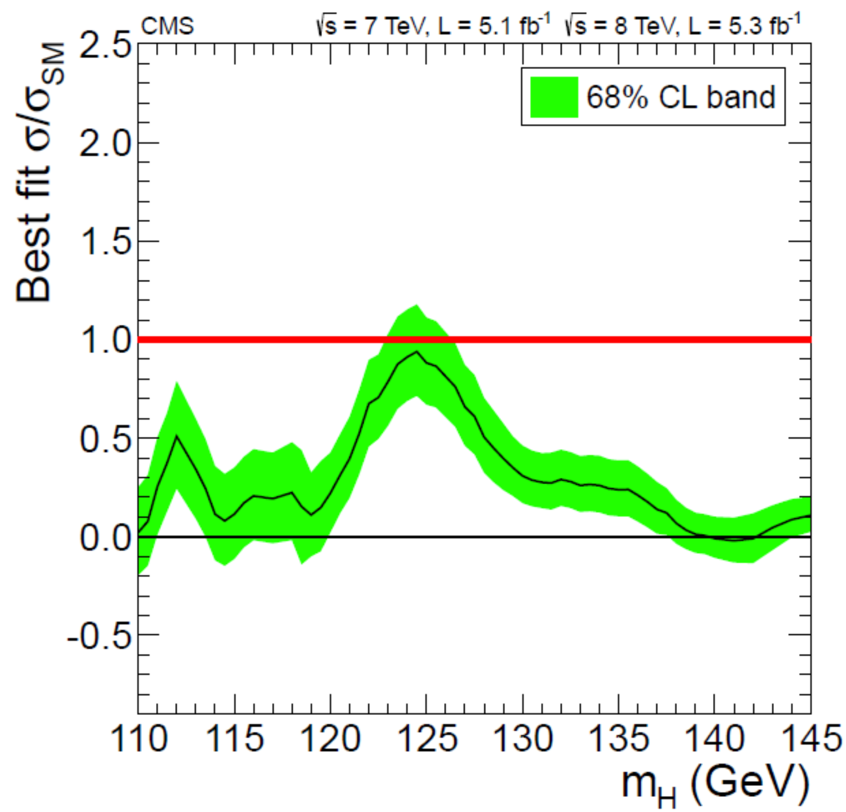
Eur. Phys. J. C 60, 543 (2009)



 2D likelihood scan. Approach using 2D Feldman-Cousins also underway

Higgs properties: Cross section





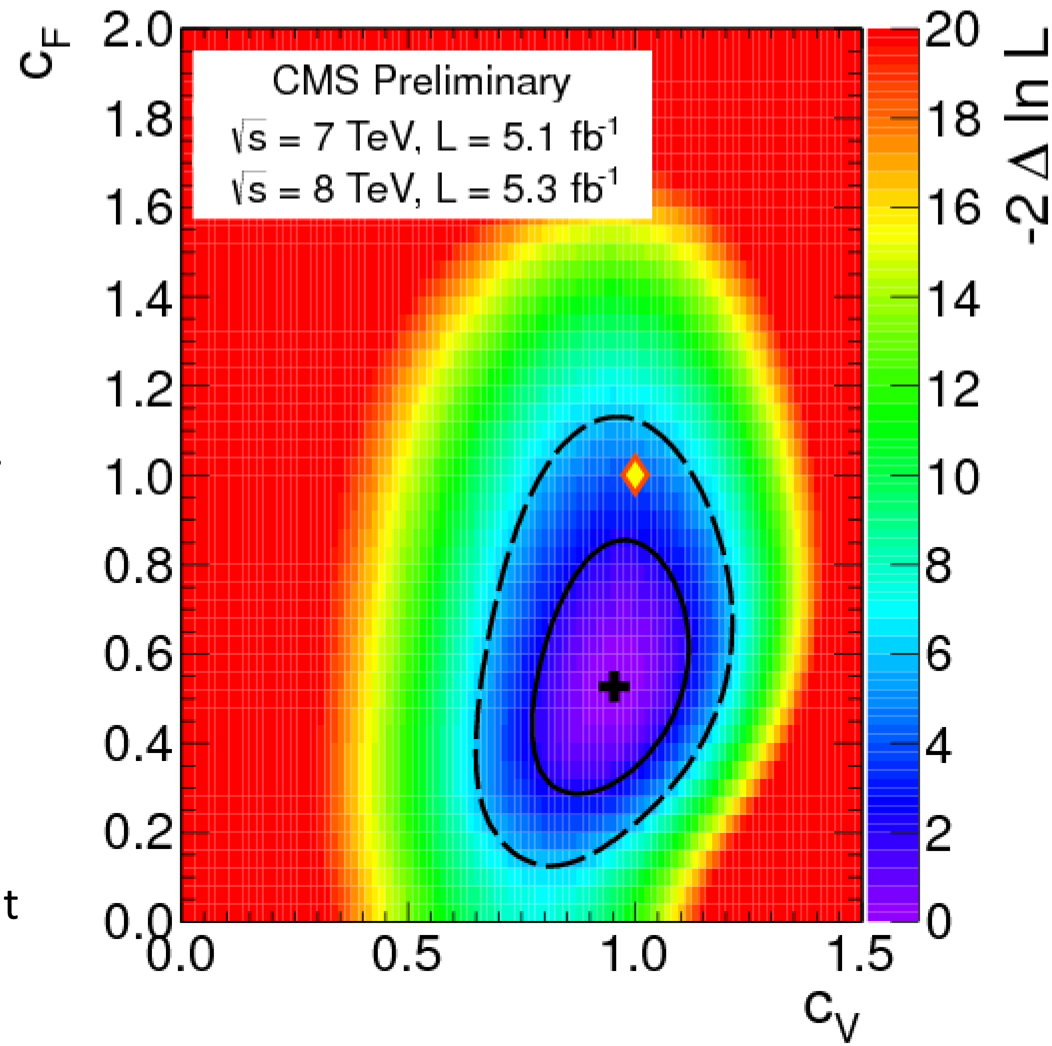
For the moment everything looks consistent with the SM

Higgs Properties: Couplings

Fit data with simplified models for couplings

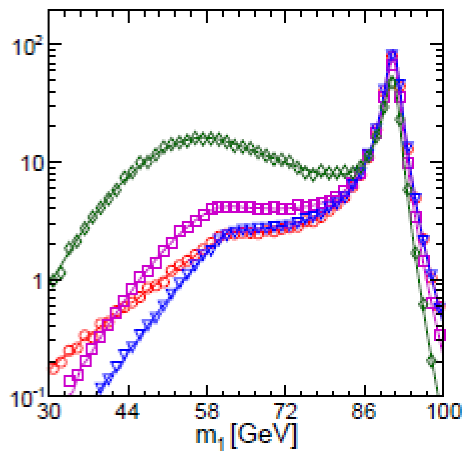
Revisit analyses to optimise for parameter extraction rather than discovery

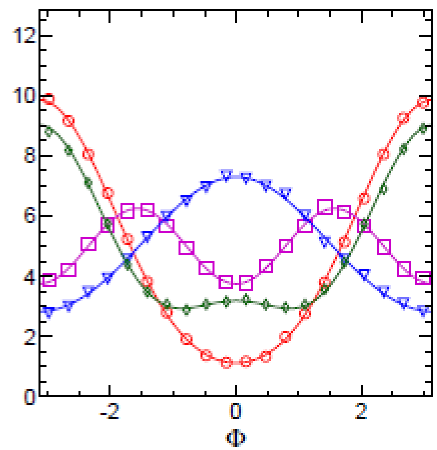
Systematic uncertainties will become increasingly important

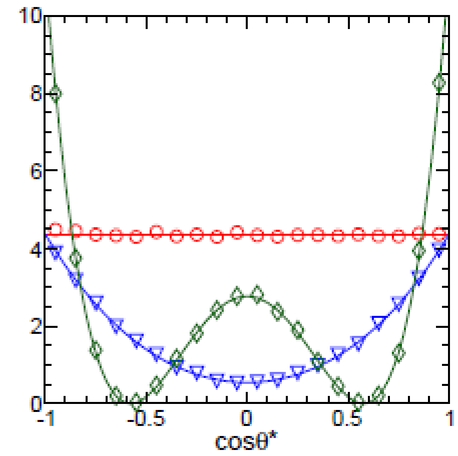


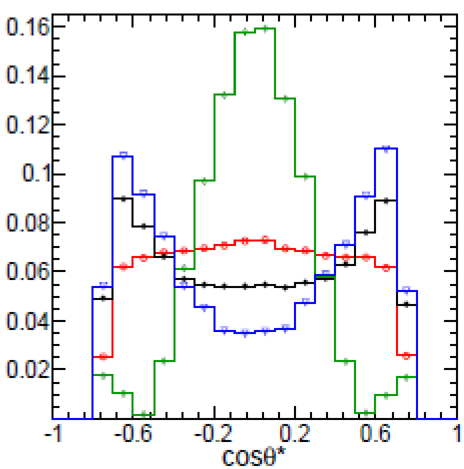
Higgs Properties: Spin and CP

arXiv:1208.4018









Scalar Higgs

Pseudo-scalar Higgs

Spin-2 minimal graviton-like

Spin-2 higher order couplings

Background

Might start to see some separation with 2012 data but likely nothing conclusive until 14TeV

Prospects and Summary

After nearly 60 years the easy bit is done!

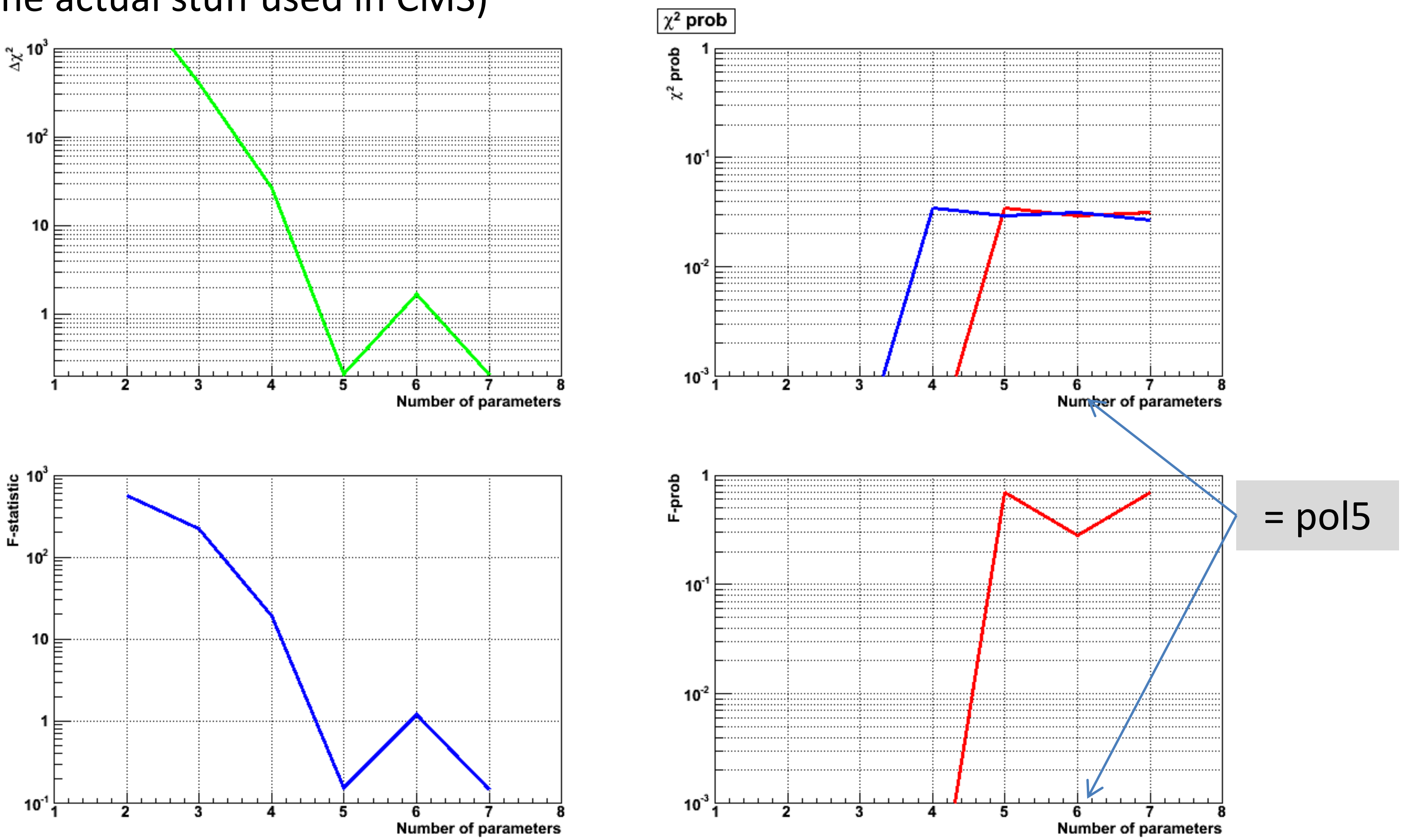
A good candidate for a Higgs boson has been discovered at ~125 GeV

2012 Data may yet reveal some surprises! But probably not conclusive on SM nature of the boson

Post-shutdown era will hopefully be Higgs Physics instead of Higgs searches!

Polynomials

Toy simulations generating a mass spectrum with different models and then fitting it (NB not the actual stuff used in CMS)



F-prob = probability to falsely claim model 2 better than model 1

BDT