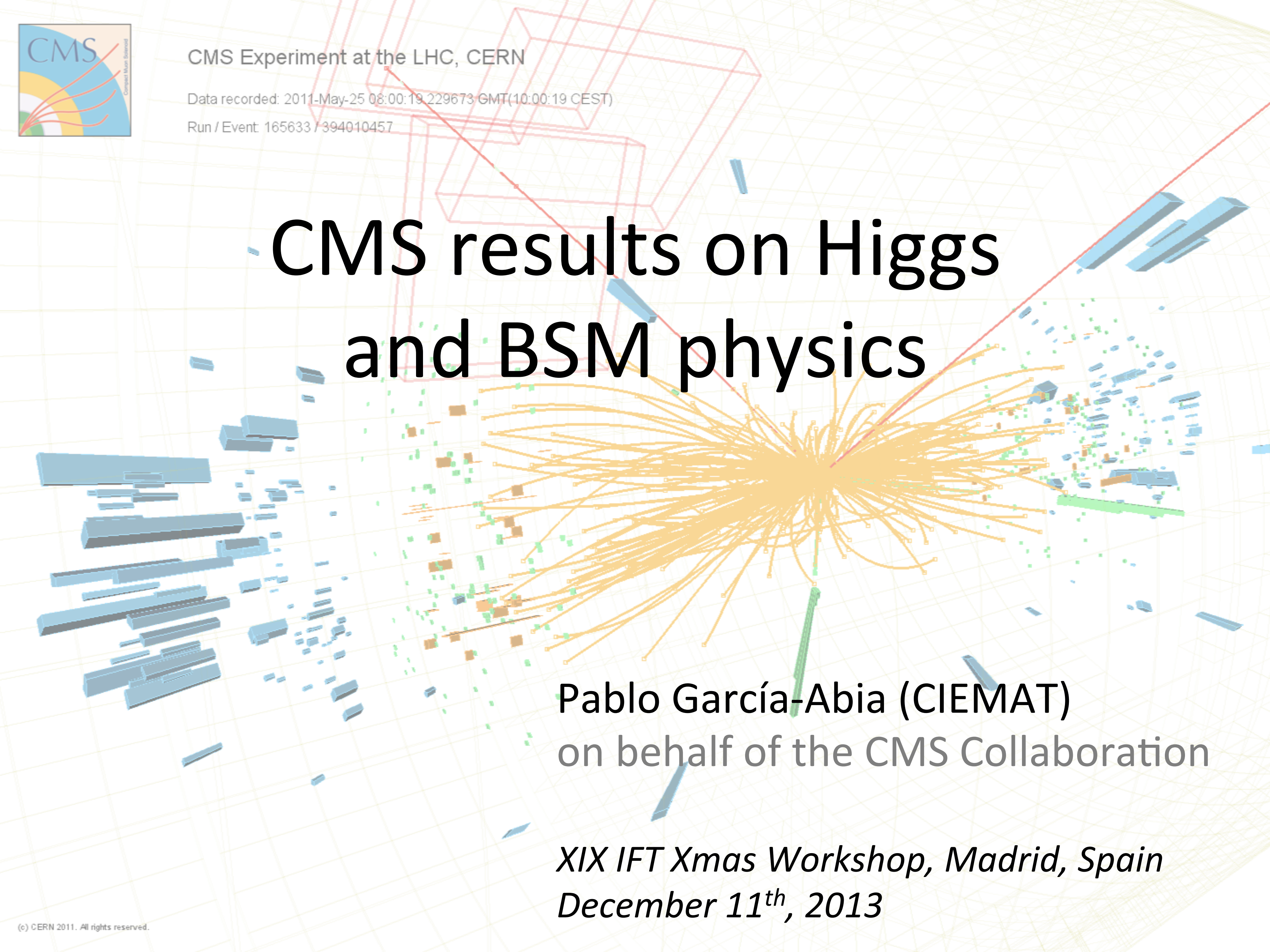


CMS results on Higgs and BSM physics

Pablo García-Abia (CIEMAT)
on behalf of the CMS Collaboration

XIX IFT Xmas Workshop, Madrid, Spain
December 11th, 2013

Outlook

The ATLAS and CMS experiments probe new physics (NP) at the TeV scale: EWSB (Higgs), SUSY, and a plethora of other models.

Experimental challenge: tiny cross sections, huge amount of data.

Done for about 3 years thanks to the excellent performance of the LHC and the detectors.

Many interesting results from SM measurements, to discoveries and stringent limits to some NP scenarios. I'll review some of these results, focusing on Higgs (SM and BSM).

Plenty of room for NP in the coming years: few words about the future of the LHC program.

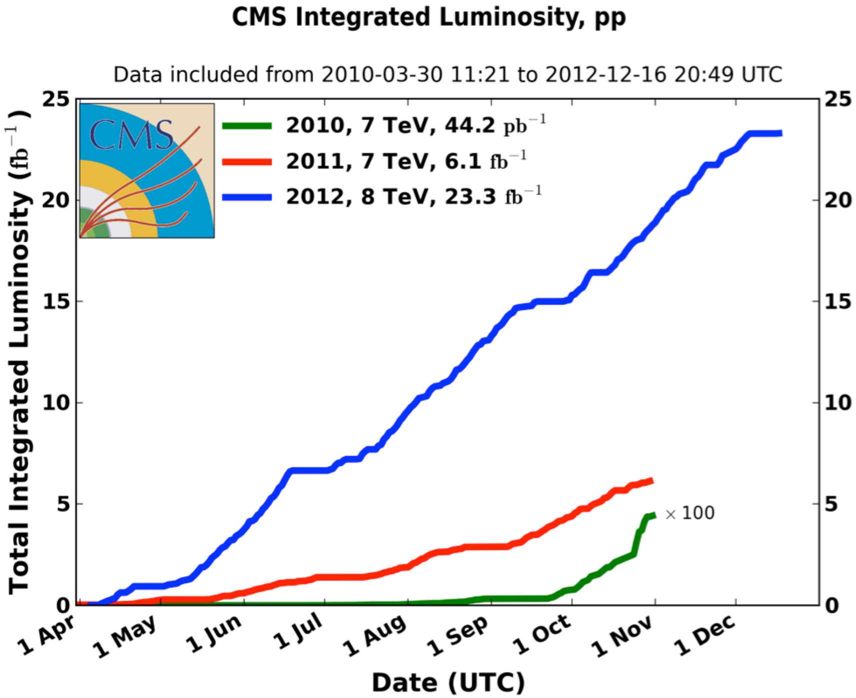
LHC

Provides pp collisions at high luminosity, significantly increasing since startup:

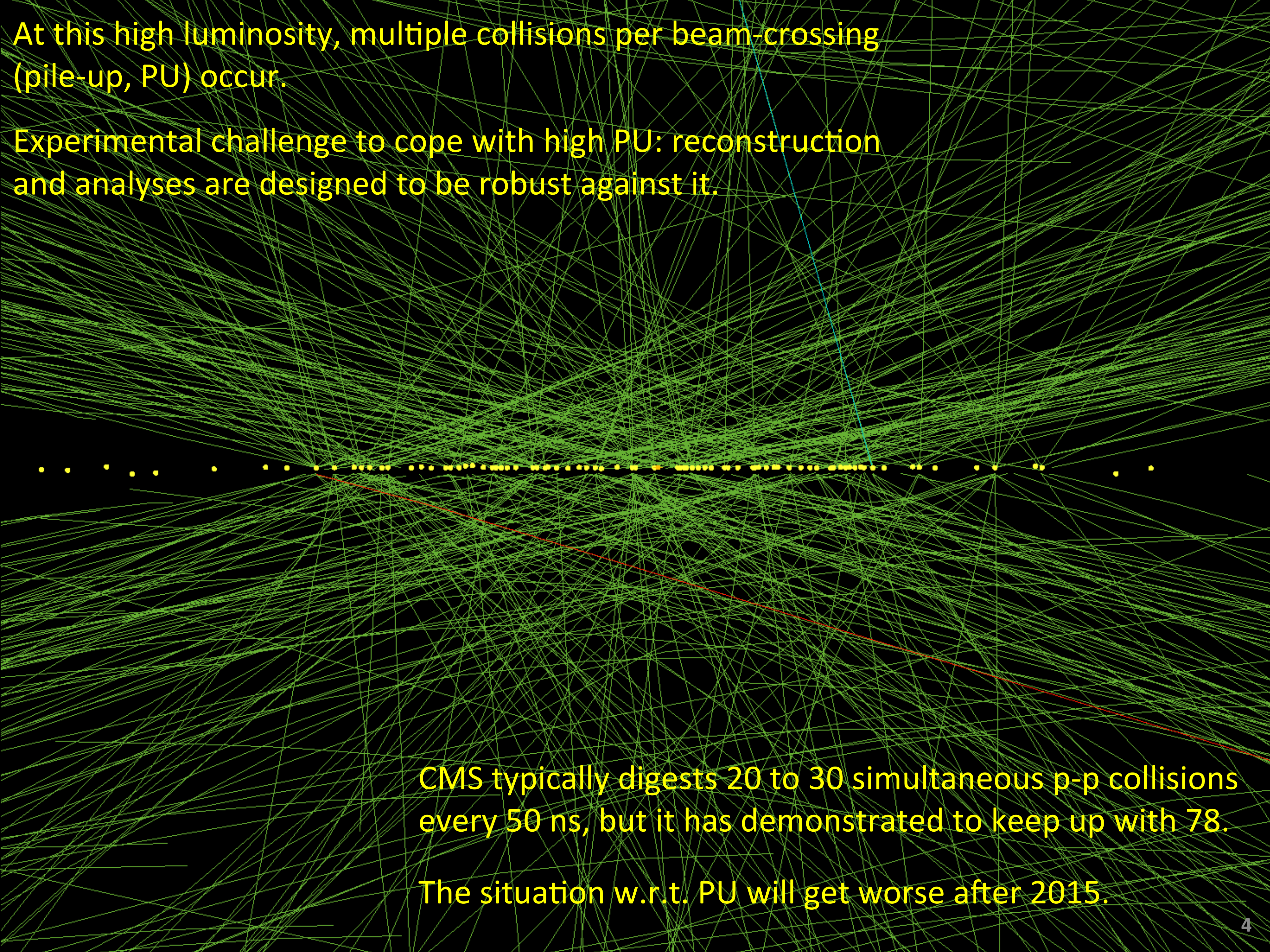
2011, 6.1 fb^{-1} at 7 TeV,

2012, 23.3 fb^{-1} at 8 TeV.

Congratulations to the LHC team for the excellent performance !!



Peak instantaneous luminosity
7.7×10^{33} cm^{-2} s^{-1}



At this high luminosity, multiple collisions per beam-crossing (pile-up, PU) occur.

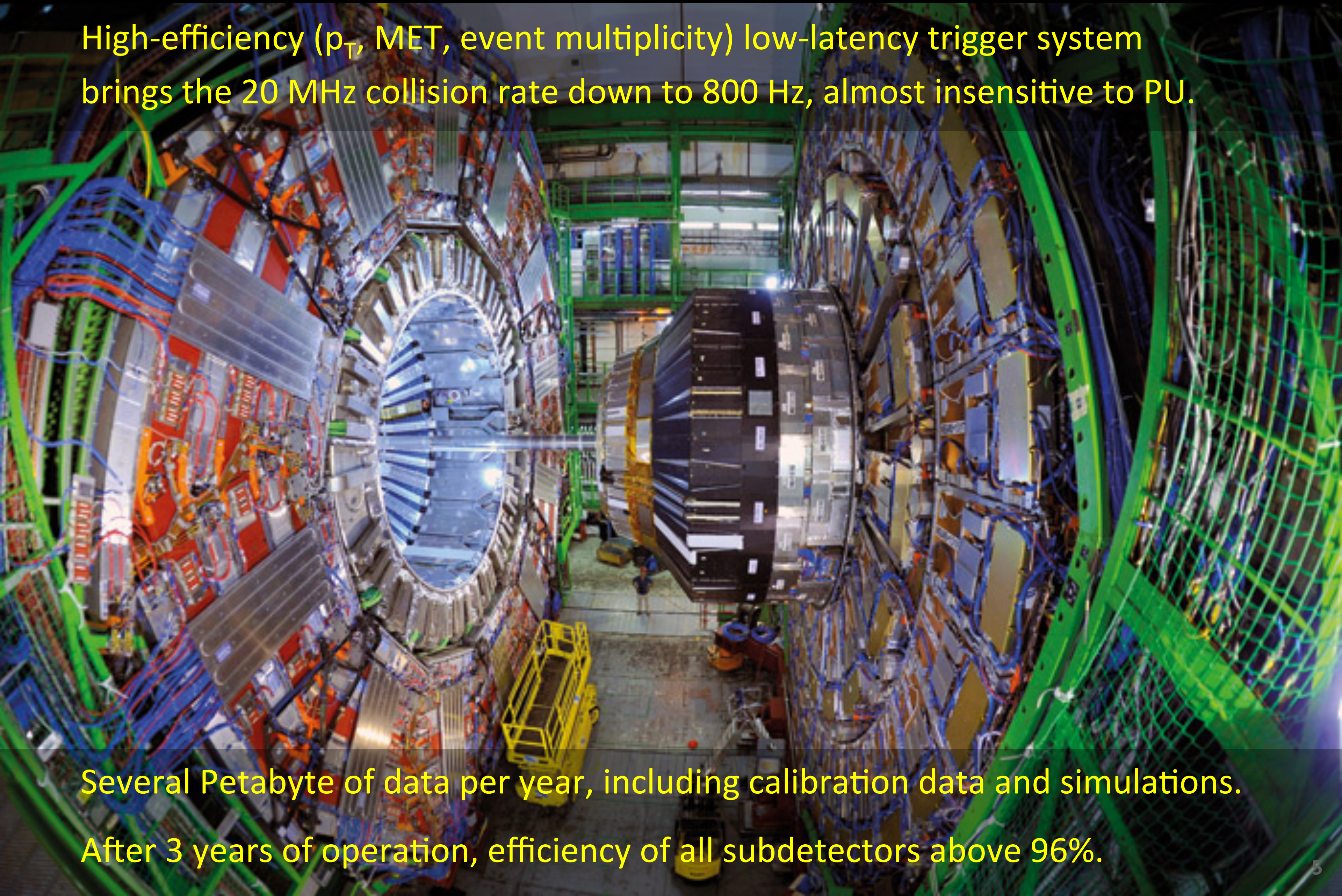
Experimental challenge to cope with high PU: reconstruction and analyses are designed to be robust against it.

CMS typically digests 20 to 30 simultaneous p-p collisions every 50 ns, but it has demonstrated to keep up with 78.

The situation w.r.t. PU will get worse after 2015.

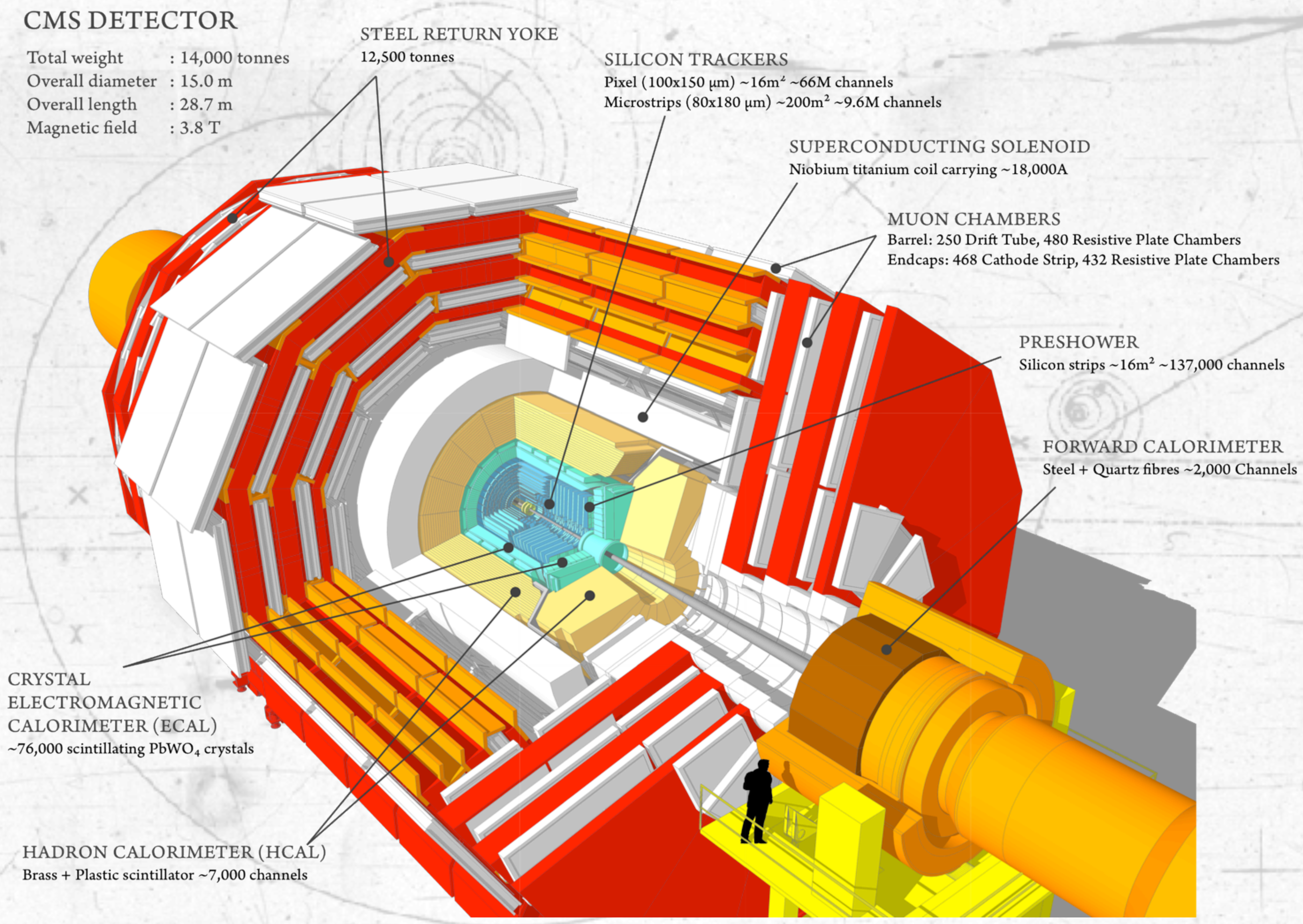
CMS is a large compact fast-electronics detector (>80 M channels, 40 MHz), embedded in a 3.8 T magnetic field, precise 3D event reconstruction.

High-efficiency (p_T, MET, event multiplicity) low-latency trigger system brings the 20 MHz collision rate down to 800 Hz, almost insensitive to PU.



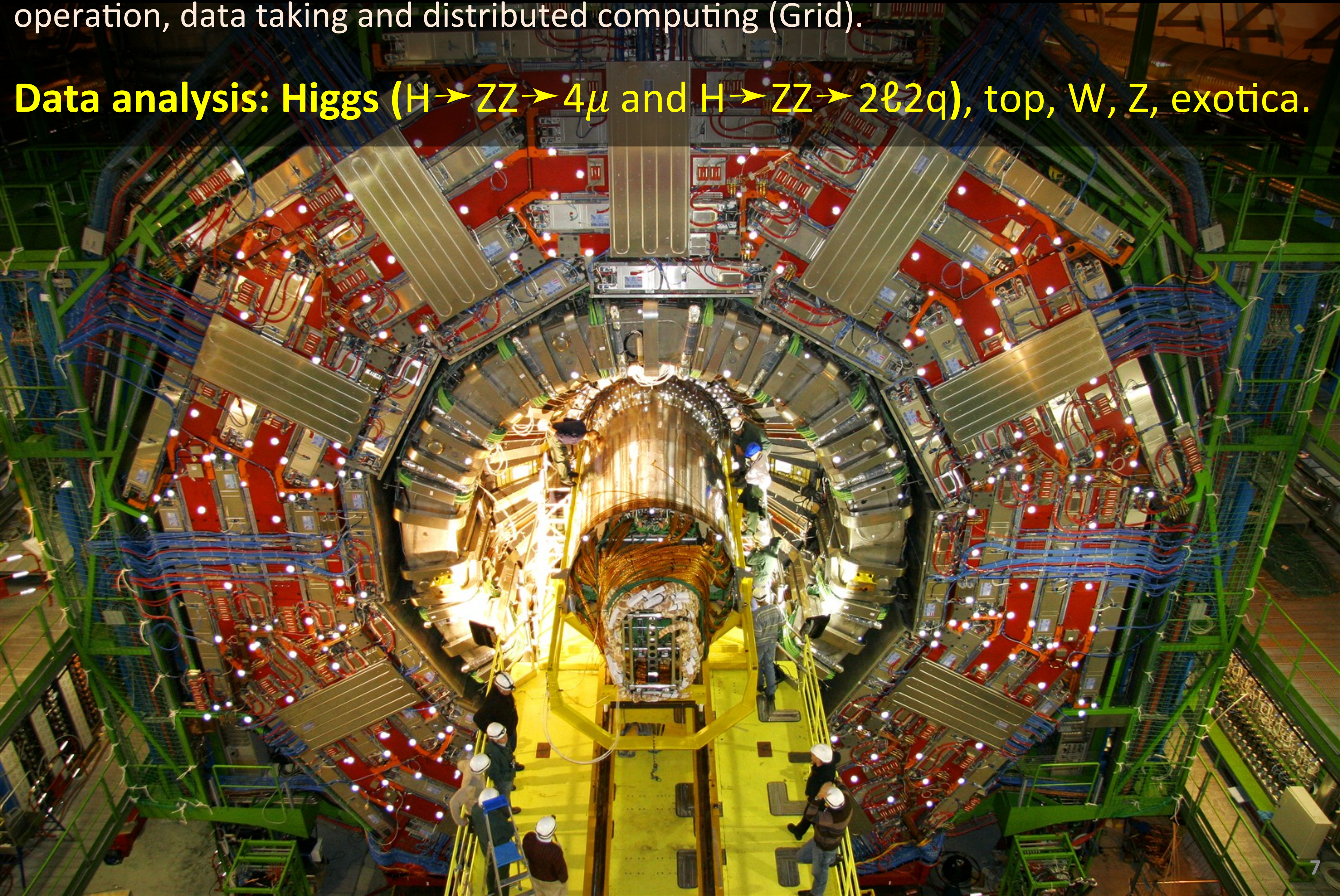
Several Petabyte of data per year, including calibration data and simulations.

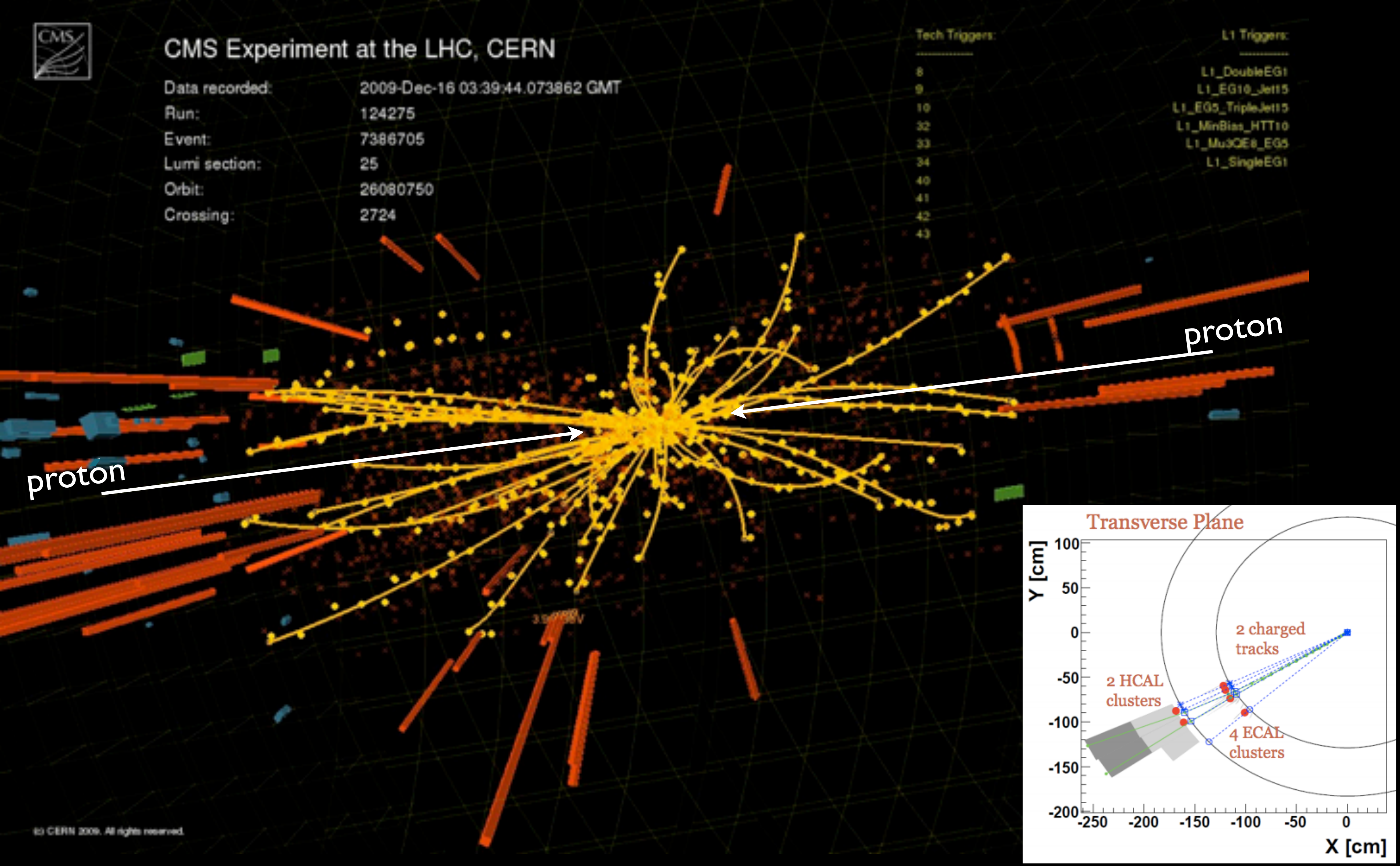
After 3 years of operation, efficiency of all subdetectors above 96%.


CMS DETECTOR
Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T
STEEL RETURN YOKE
12,500 tonnes
SILICON TRACKERS
Pixel (100x150 μm) ~16m² ~66M channels
Microstrips (80x180 μm) ~200m² ~9.6M channels
SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying ~18,000A
MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers
PRESHOWER
Silicon strips ~16m² ~137,000 channels
FORWARD CALORIMETER
Steel + Quartz fibres ~2,000 Channels
CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76,000 scintillating $PbWO_4$ crystals
HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator ~7,000 channels

UAM+CIEMAT (4+28 authors in 2013): muon trigger (DTTF), muon chambers (30% of barrel DTs + associated electronics), alignment, installation, maintenance and operation, data taking and distributed computing (Grid).

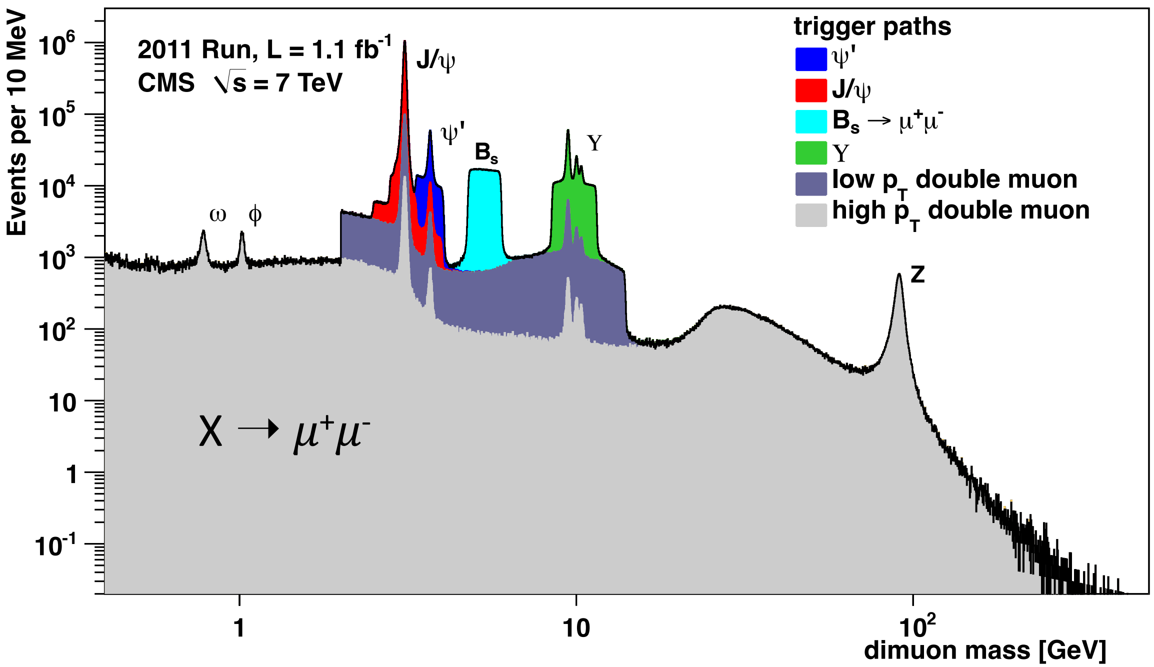
Data analysis: Higgs ($H \rightarrow ZZ \rightarrow 4\mu$ and $H \rightarrow ZZ \rightarrow 2\ell 2q$**)**, top, W, Z, exotica.

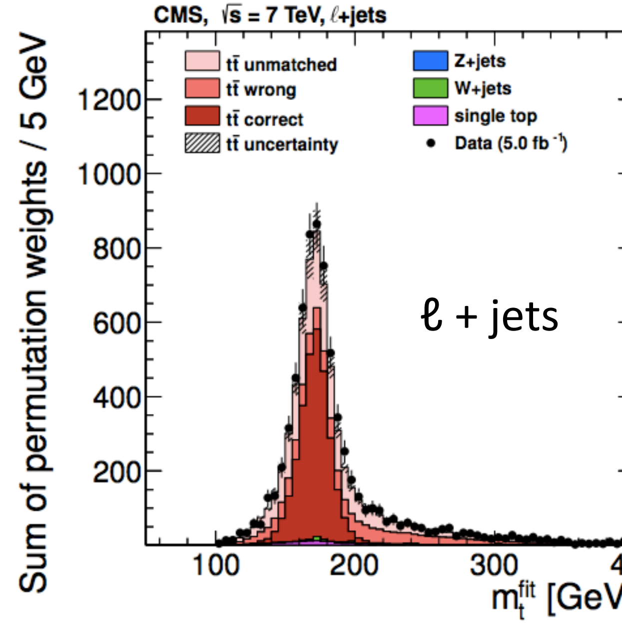


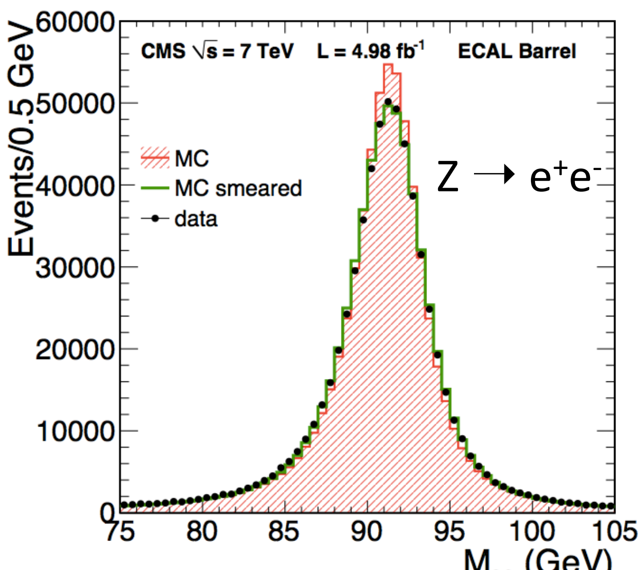


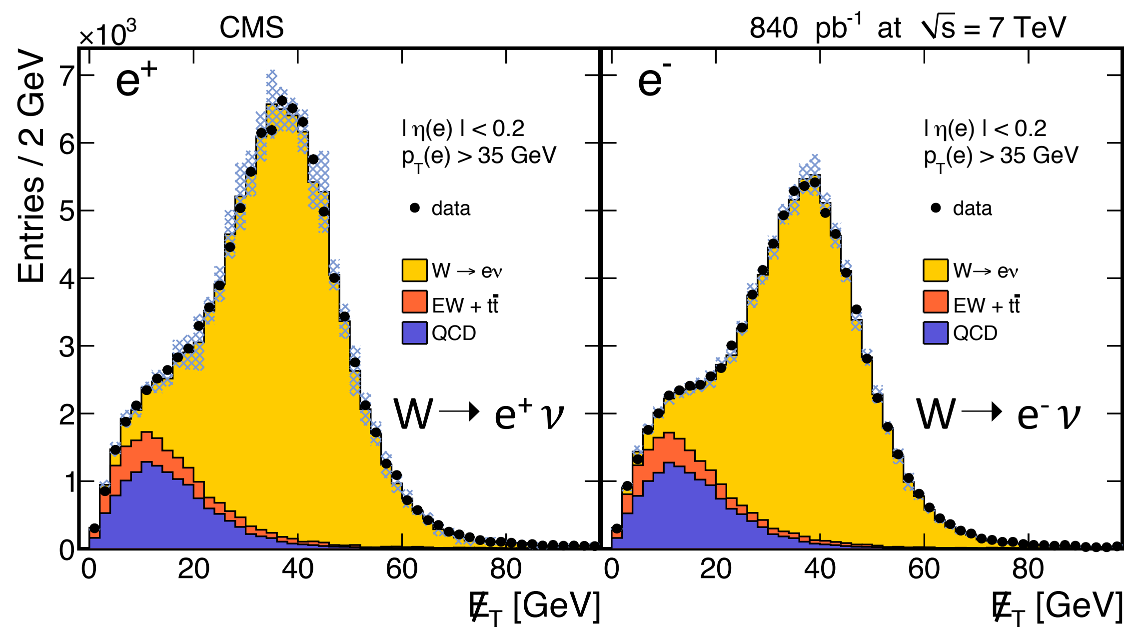
Particle flow algorithm: reconstruct all the individual particles in the event: photons, charged and neutral hadrons, electrons, muons, MET (neutrinos), with high efficiency, good angular, energy and momentum resolution, robust against pile-up.

CMS performance: SM

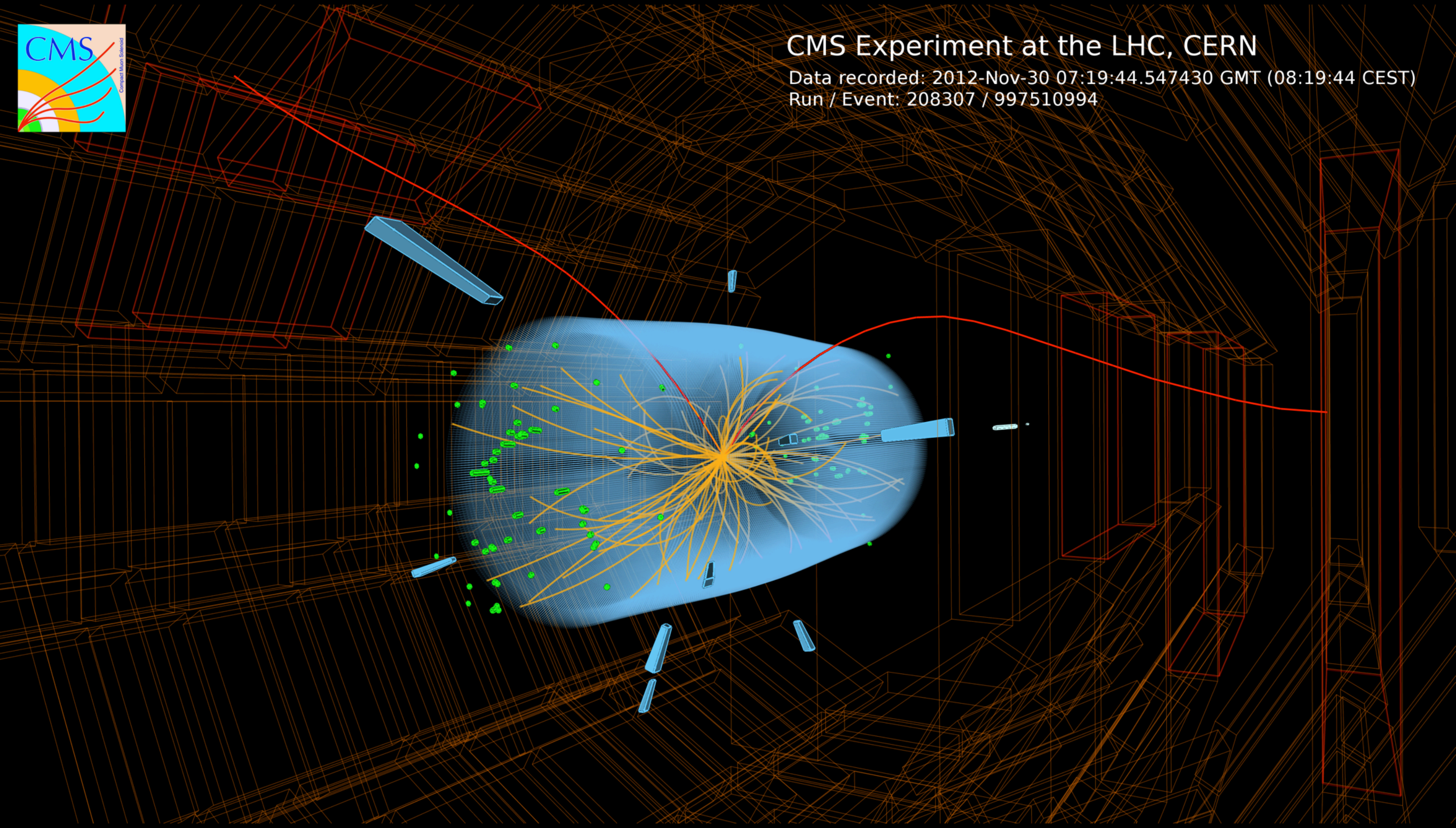




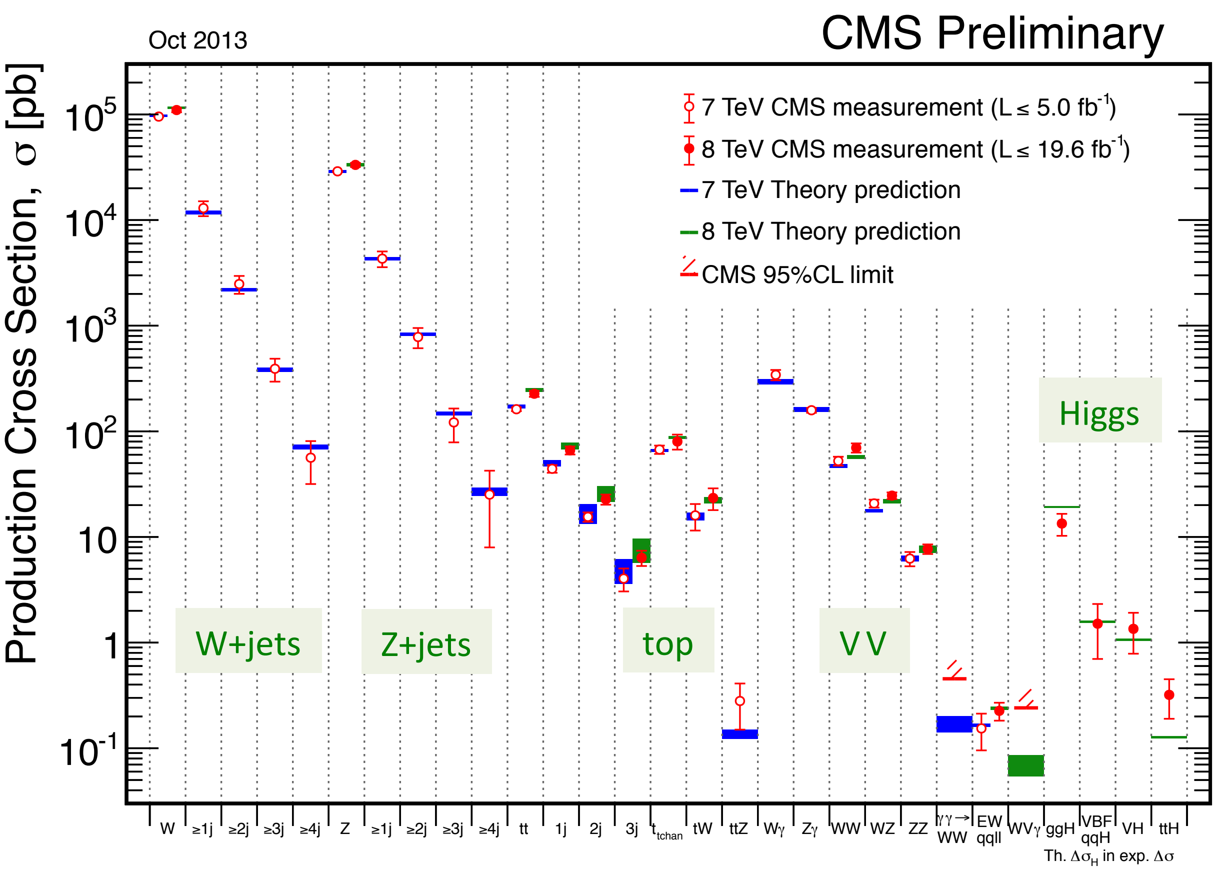


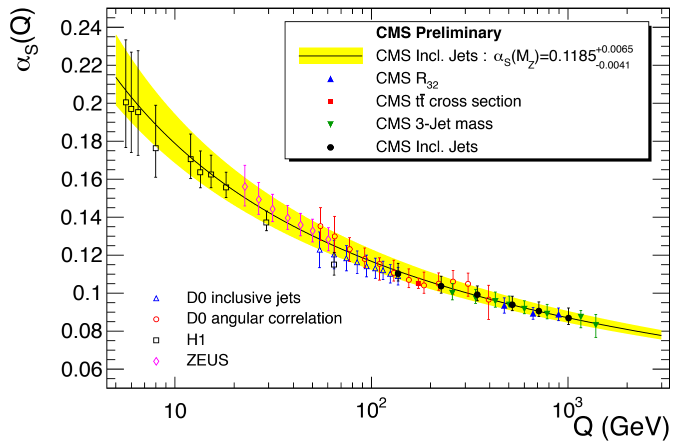


$B_s \rightarrow \mu\mu$ event recorded in the CMS detector in 2012 at 8 TeV



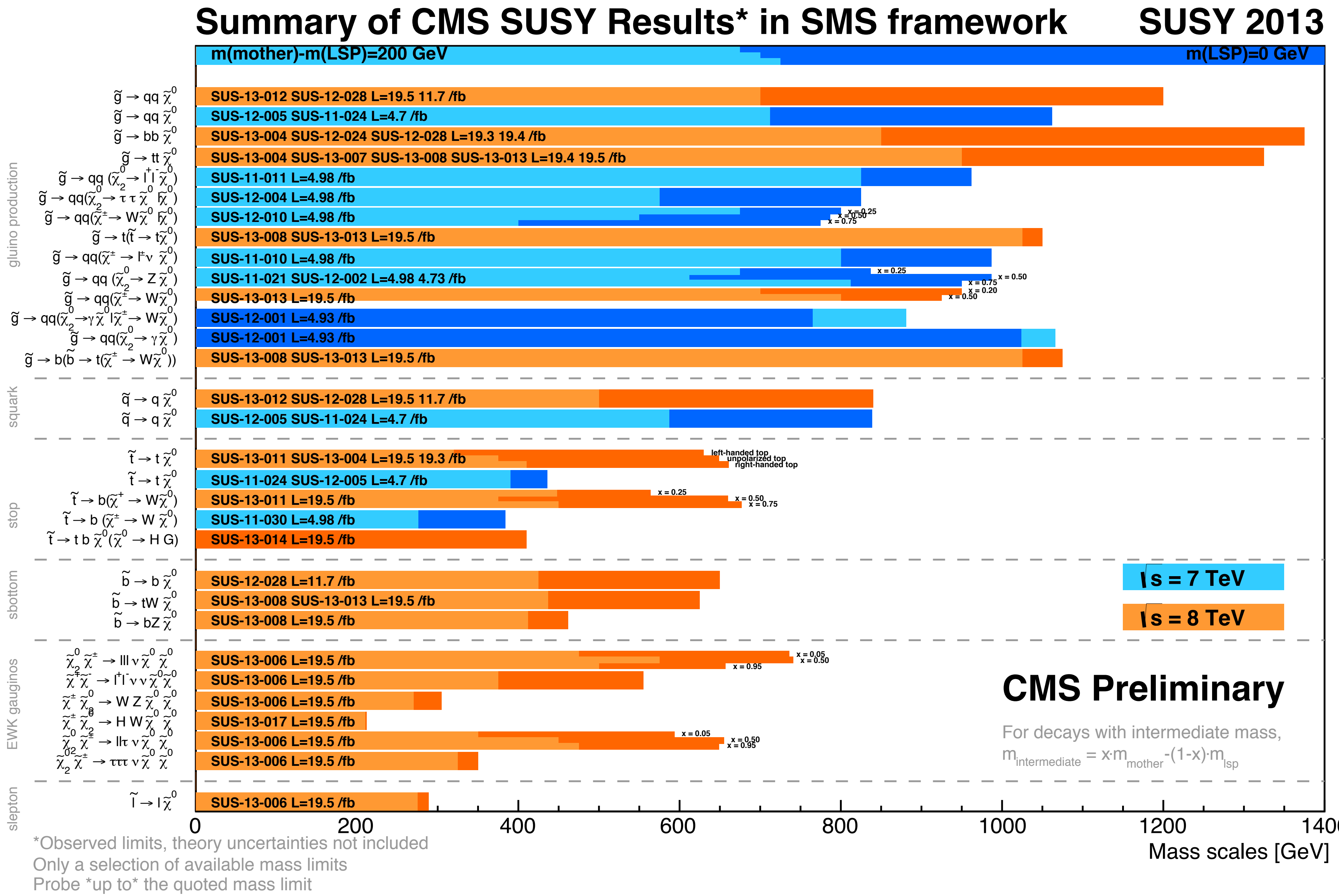
Precise SM measurements, the key to discovery





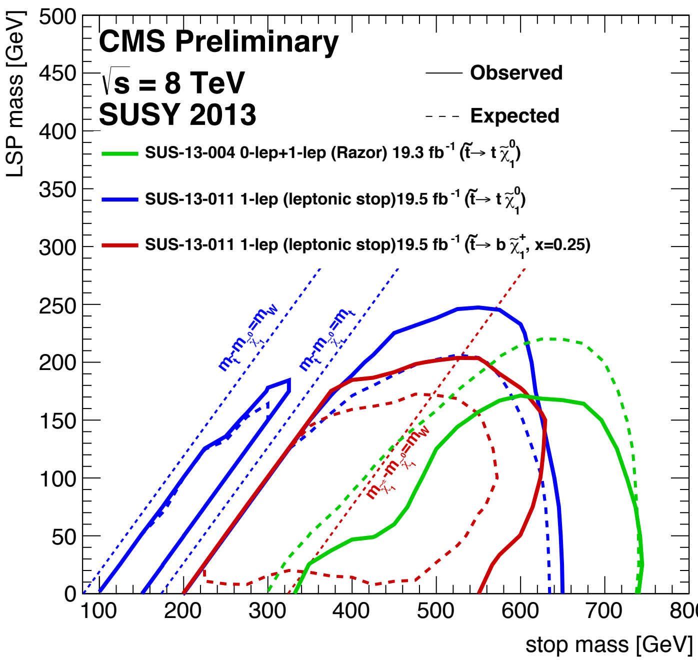
New measurements of $\alpha_S(Q)$ from various processes.

These measurements require good understanding of the detector, and of the SM predictions (backgrounds to signals of new physics).

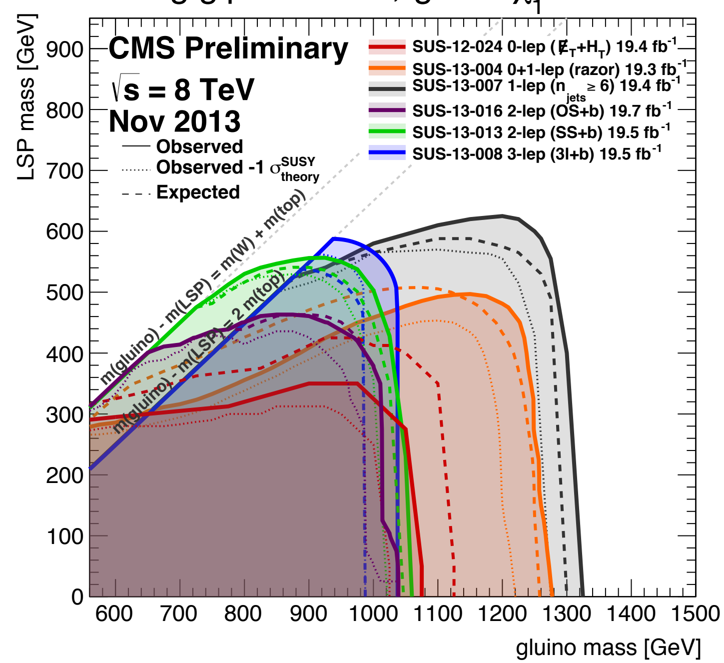


With simplified models space we can interpret results directly on simplified sparticle spectra for specific topologies of interest – building blocks that can be used to generalize to a more complete 'model'-space direct stop searches

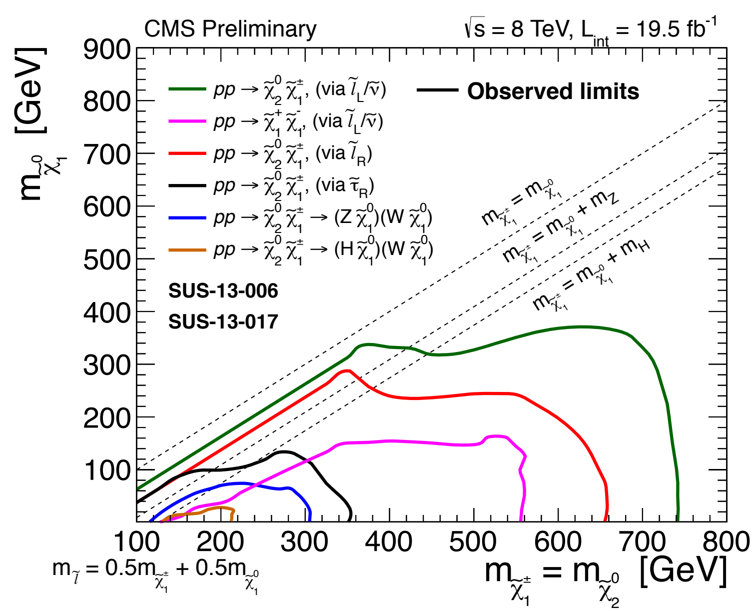
$\tilde{t}$-$\tilde{t}$ production



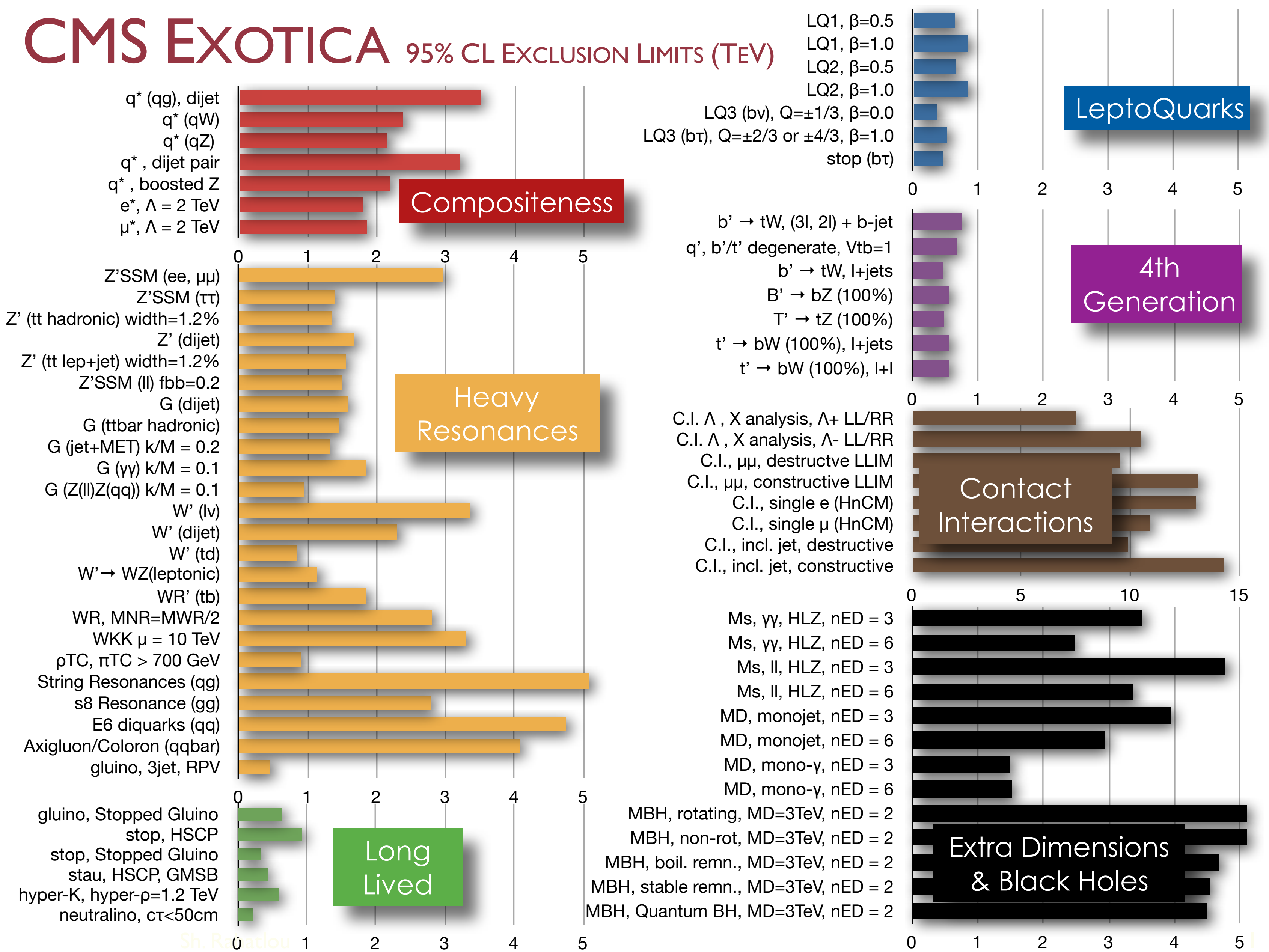
$\tilde{g}$-$\tilde{g}$ production, $\tilde{g} \rightarrow t\,\bar{t}\,\tilde{\chi}_1^0$



gluino pair production: 3-body decay into t-tbar neutralino



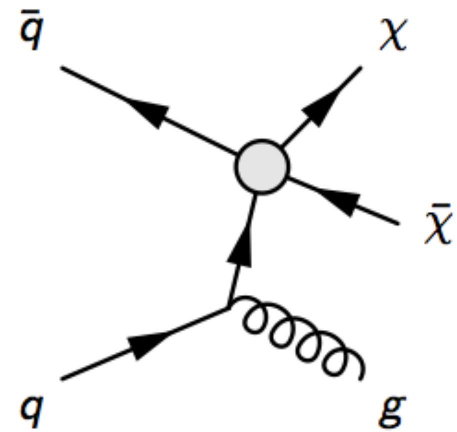
observed limits for EWKino models



CMS Exotica 95% CL Exclusion Limits (TeV)
Compositeness
q* (qg), dijet
q* (qW)
q* (qZ)
q* , dijet pair
q* , boosted Z
e*, Λ = 2 TeV
μ*, Λ = 2 TeV
Heavy Resonances
Z'SSM (ee, μμ)
Z'SSM (ττ)
Z' (tt hadronic) width=1.2%
Z' (dijet)
Z' (tt lep+jet) width=1.2%
Z'SSM (ll) fbb=0.2
G (dijet)
G (ttbar hadronic)
G (jet+MET) k/M = 0.2
G (γγ) k/M = 0.1
G (Z(ll)Z(qq)) k/M = 0.1
W' (lν)
W' (dijet)
W' (td)
W'→ WZ(leptonic)
WR' (tb)
WR, MNR=MWR/2
WKK μ = 10 TeV
ρTC, πTC > 700 GeV
String Resonances (qg)
s8 Resonance (gg)
E6 diquarks (qq)
Axigluon/Coloron (qqbar)
gluino, 3jet, RPV
Long Lived
gluino, Stopped Gluino
stop, HSCP
stop, Stopped Gluino
stau, HSCP, GMSB
hyper-K, hyper-ρ=1.2 TeV
neutralino, cτ<50cm
LeptoQuarks
LQ1, β=0.5
LQ1, β=1.0
LQ2, β=0.5
LQ2, β=1.0
LQ3 (bν), Q=±1/3, β=0.0
LQ3 (bτ), Q=±2/3 or ±4/3, β=1.0
stop (bτ)
4th Generation
b' → tW, (3l, 2l) + b-jet
q', b'/t' degenerate, Vtb=1
b' → tW, l+jets
B' → bZ (100%)
T' → tZ (100%)
t' → bW (100%), l+jets
t' → bW (100%), l+l
Contact Interactions
C.I. Λ , X analysis, Λ+ LL/RR
C.I. Λ , X analysis, Λ- LL/RR
C.I., μμ, destructve LLIM
C.I., μμ, constructive LLIM
C.I., single e (HnCM)
C.I., single μ (HnCM)
C.I., incl. jet, destructive
C.I., incl. jet, constructive
Extra Dimensions & Black Holes
Ms, γγ, HLZ, nED = 3
Ms, γγ, HLZ, nED = 6
Ms, ll, HLZ, nED = 3
Ms, ll, HLZ, nED = 6
MD, monojet, nED = 3
MD, monojet, nED = 6
MD, mono-γ, nED = 3
MD, mono-γ, nED = 6
MBH, rotating, MD=3TeV, nED = 2
MBH, non-rot, MD=3TeV, nED = 2
MBH, boil. remn., MD=3TeV, nED = 2
MBH, stable remn., MD=3TeV, nED = 2
MBH, Quantum BH, MD=3TeV, nED = 2
0 1 2 3 4 5
0 5 10 15

Monojets: dark matter

EXO-12-048



Indirect evidence of dark matter (DM) based on gravitational effects.

DM particles could be produced in pairs after ISR:

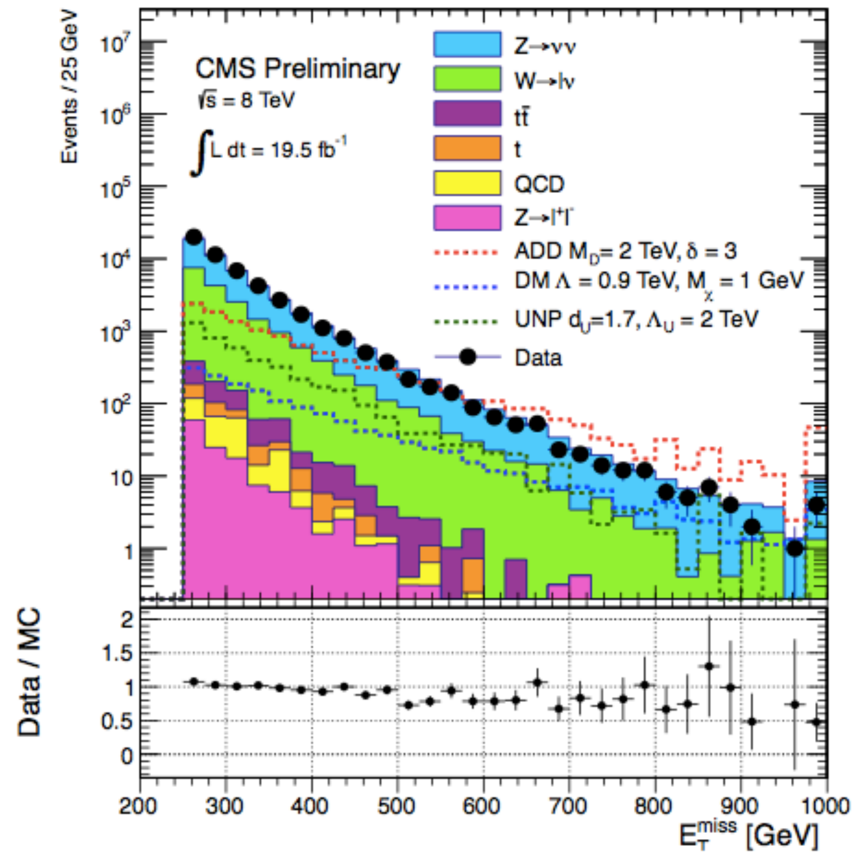
- signature: MET and mono-jet/photon/W/Z
- dominant background is Z→ νν+X

Couplings between SM and DM can be probed and compared with direct detection results

- interpretation in spin (in)dependent EFT

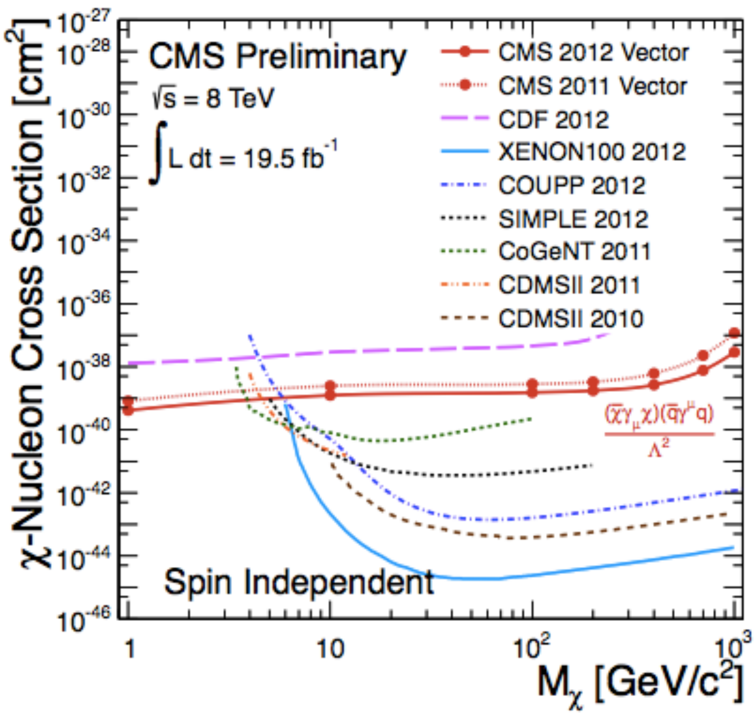
Search for non-SM contribution of hard jets recoiling against something invisible.

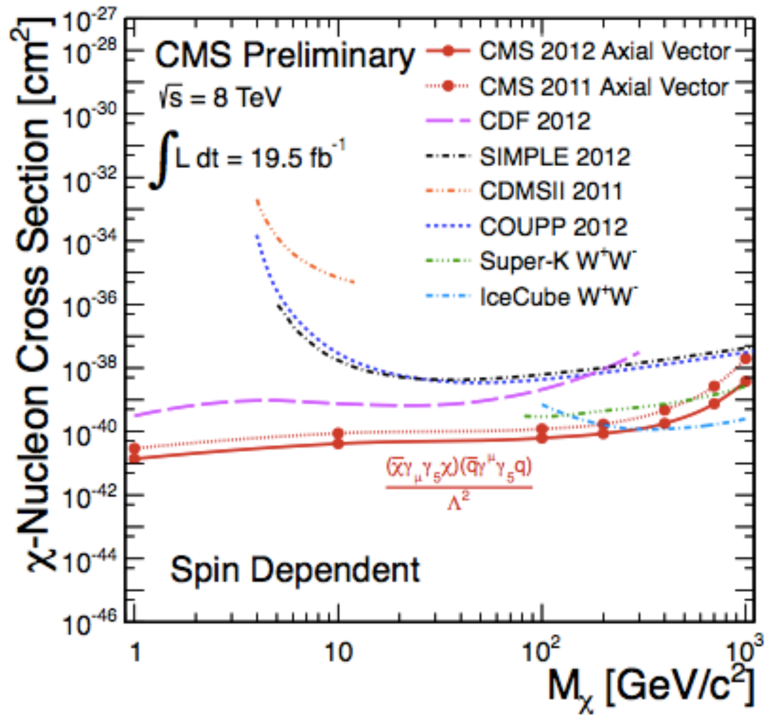
Data are consistent with SM background expectation.



Monojets: dark matter

EXO-12-048



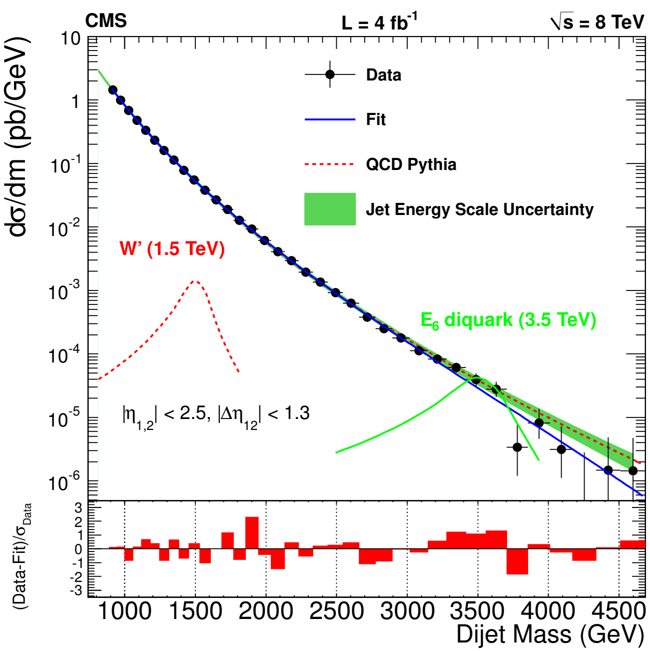


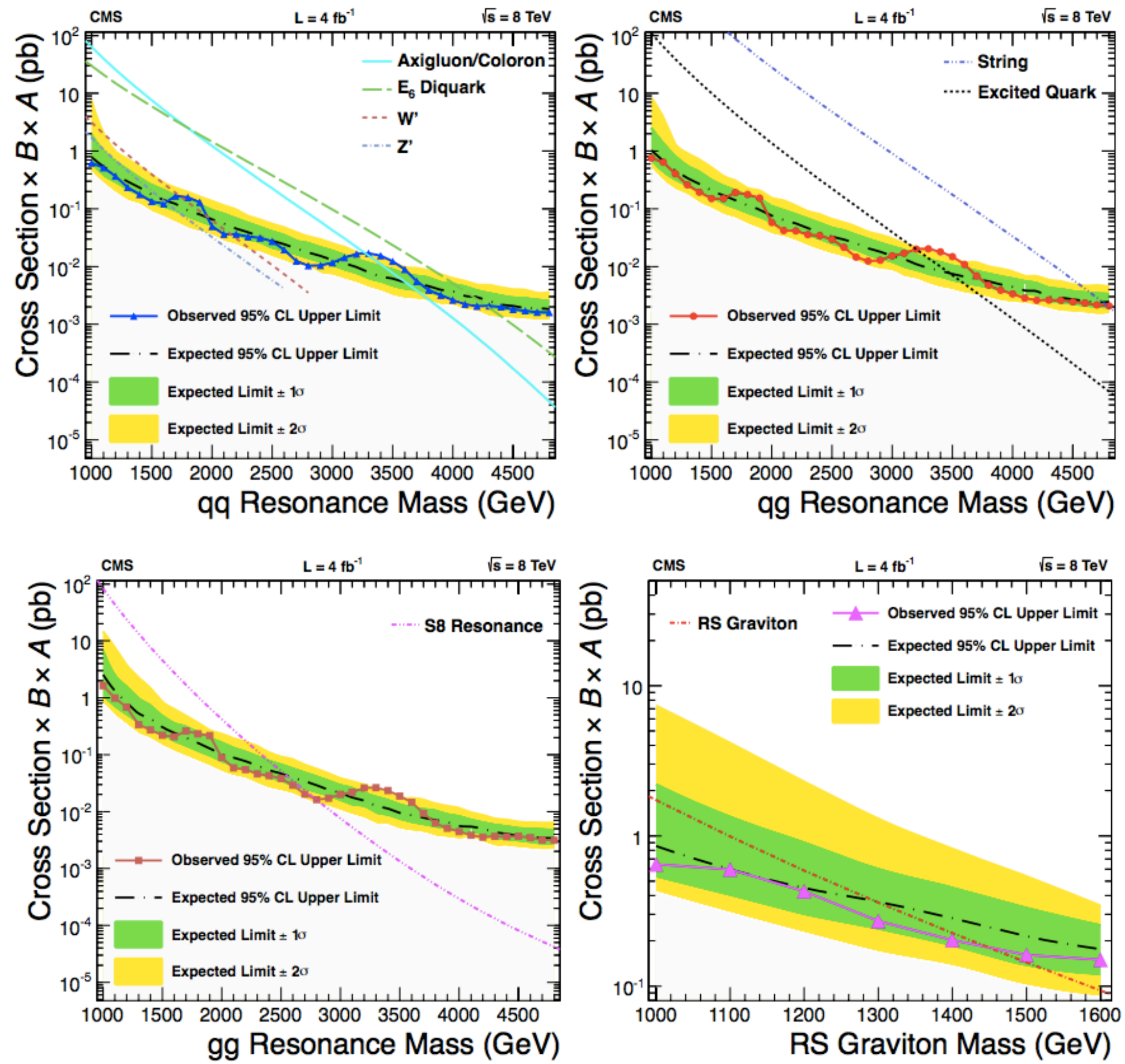
DM particles are assumed to be Dirac fermions. Collider results dominate in spin-dependent searches (axial-vector interactions). Relevant at low mass for spin-independent searches (vector and scalar interactions).

Narrow dijet mass resonances

EXO-12-059

Many extensions of the SM predict new massive objects that couple to quarks and gluons, yielding mass resonances.





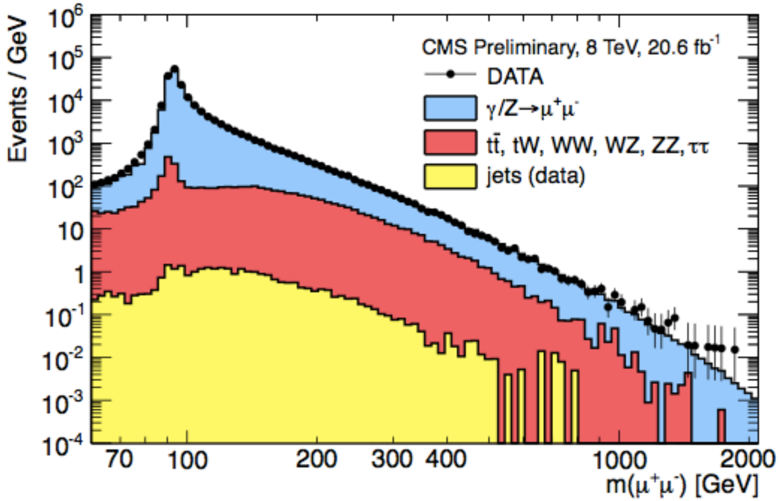
Upper limits on σ × Br × A in the range 1 TeV to 4.8 TeV are presented for specific models, which can be applied to any model of narrow m_{jj} production.

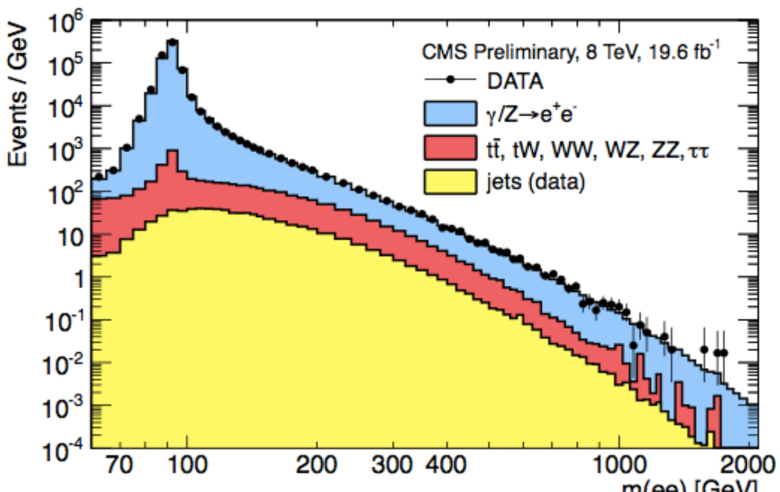
Dilepton Z' searches

EXO-12-061

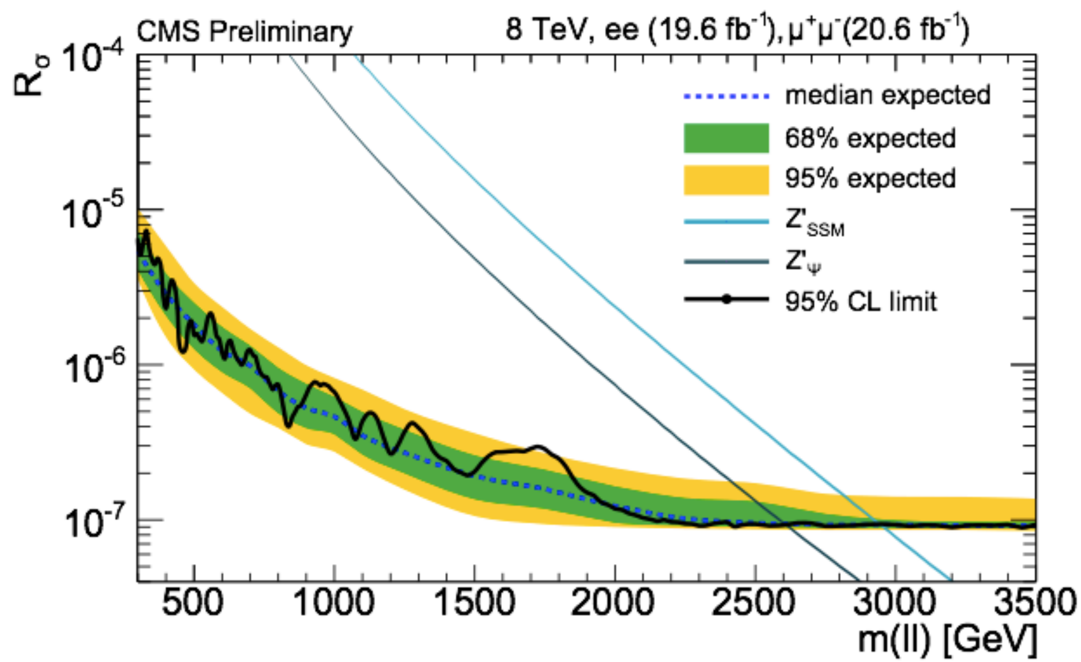
Data/MC agreement over many orders of magnitude: no deviations from background expectations

$$R_\sigma = \frac{\sigma(pp \to Z' + X \to ll + X)}{\sigma(pp \to Z + X \to ll + X}$$





Many systematic uncertainties cancel out in R_σ



SM-like couplings: $m_{Z',SSM} > 2.96$ TeV

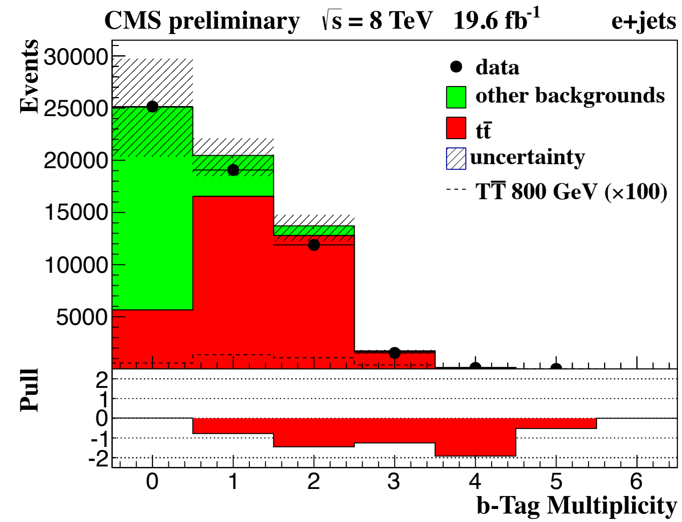
Superstring-inspired: $m_{Z',\psi} > 2.6$ TeV

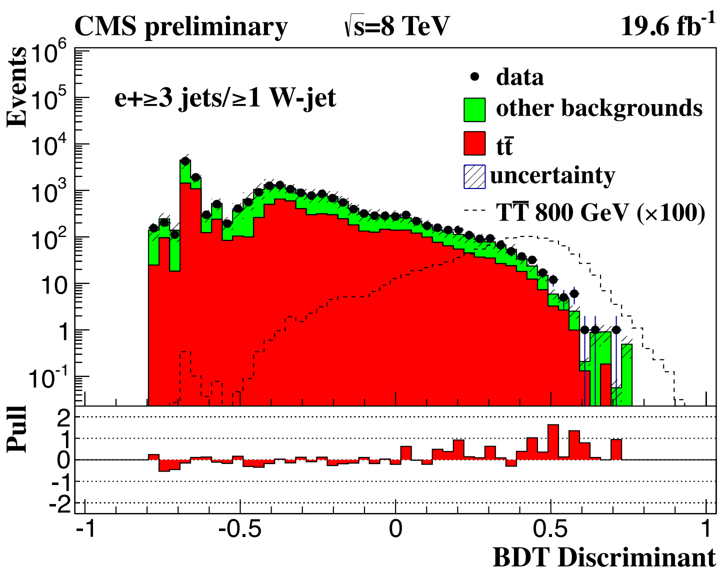
Inclusive search for vector-like T quark

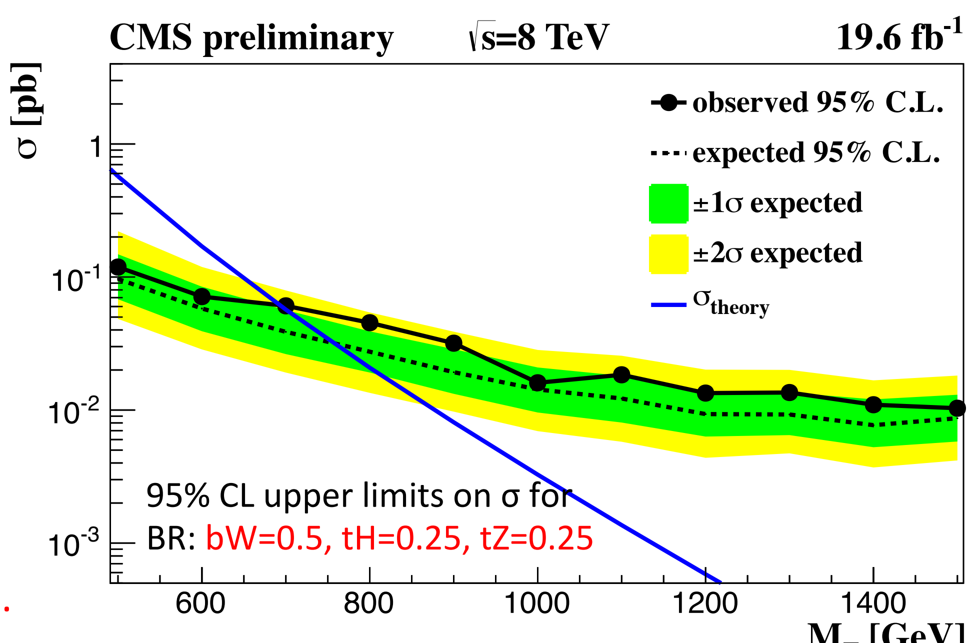
Search for pair-produced massive new vector-like T quarks with charge 2/3. Search independent of the BR.

T quark assumed to decay into bW, tZ and tH (6 possible final states). Background from $t\bar{t}$, W and Z.

The analysis exploits the b-jet multiplicity. Highly boosted jets reconstructed with the CA (substructure) jet algorithm.







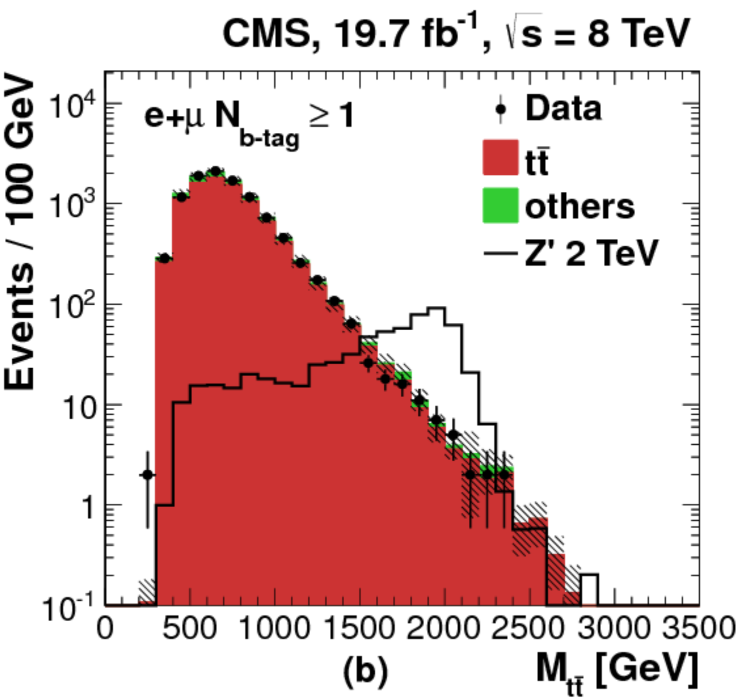
No deviation from the SM: T mass limits between 687 and 782 GeV for all possible branching fractions.

Anomalous $t\bar{t}$ production

B2G-13-001

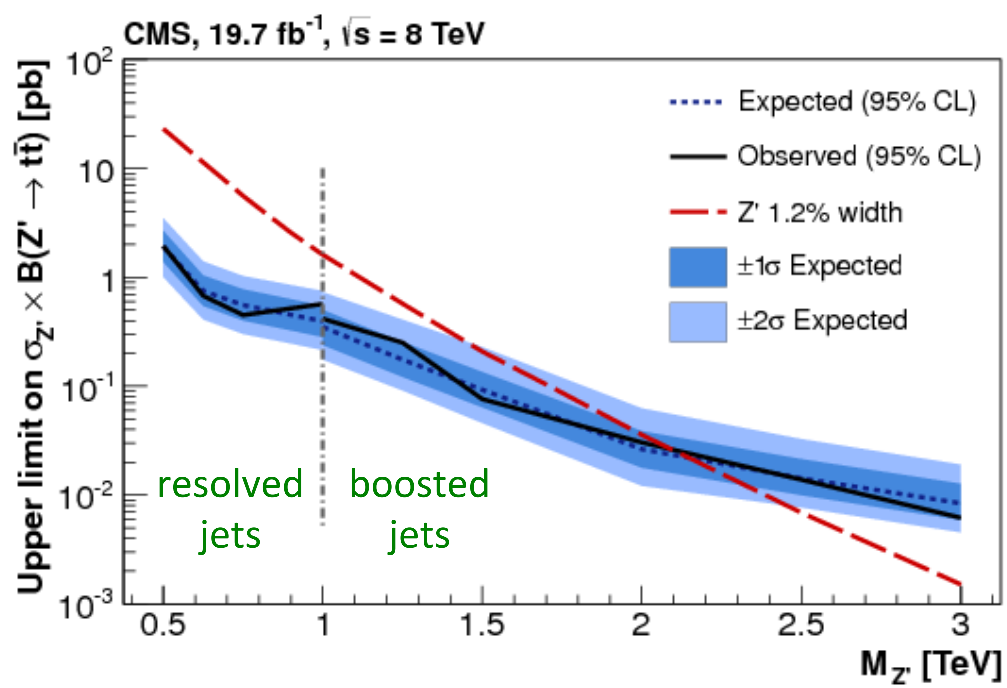
ED models contain KK excitations of particles, including gravitons and gluons, which can have enhanced couplings to $t\bar{t}$. Proposed new gauge bosons (Z') also couple preferentially to $t\bar{t}$, as well as additional spin-0 resonances.

Exploit the $M_{t\bar{t}}$ distribution for events with leptons and/or b-jets (boosted at high mass).



boosted semi-leptonic analysis with ≥1 b-jet. Z' sample normalized to 1 pb.

95% CL upper limits on σ × BR as a function of $M_{t\bar{t}}$ for Z' resonances with Γ/M=1.2% compared to the prediction for a leptophobic topcolor Z' decaying to $t\bar{t}$.

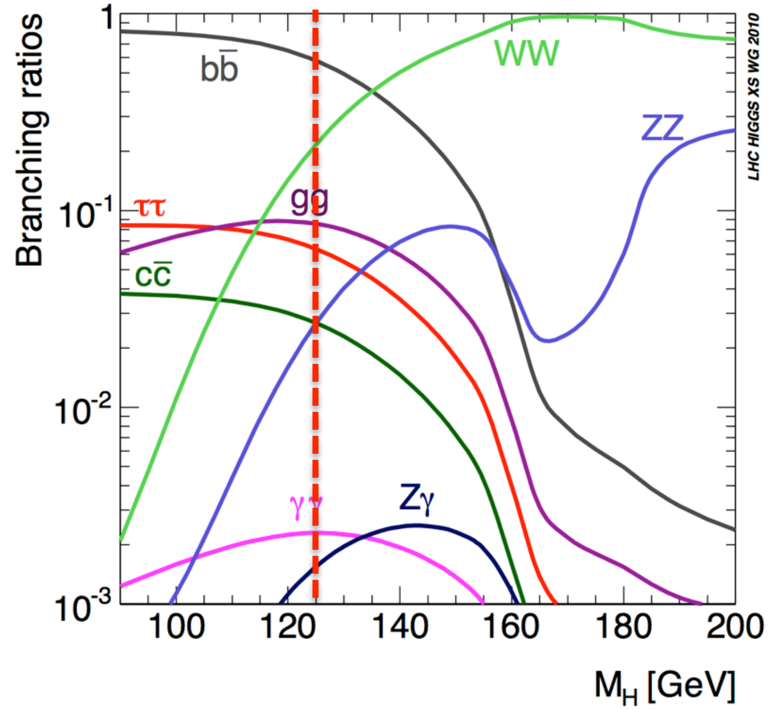


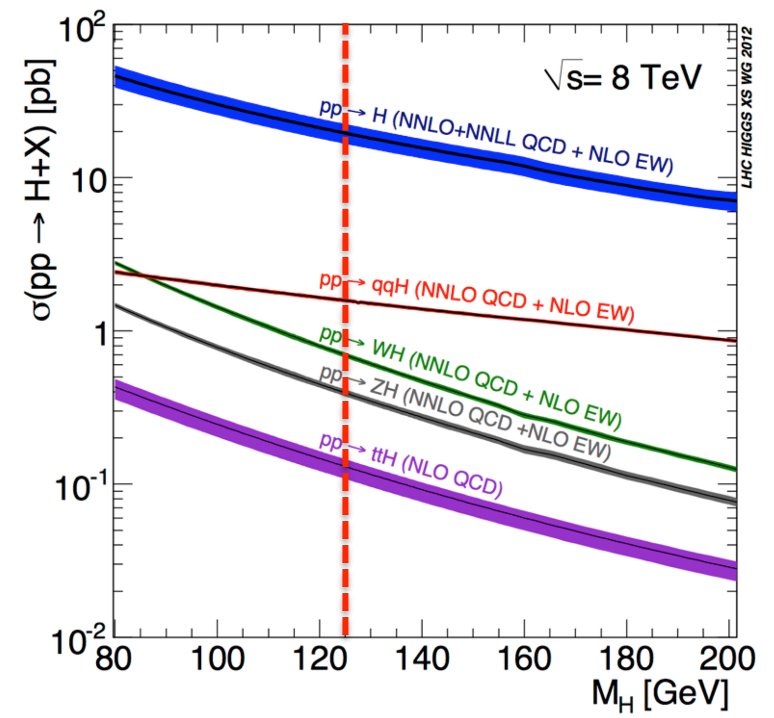
Higgs boson

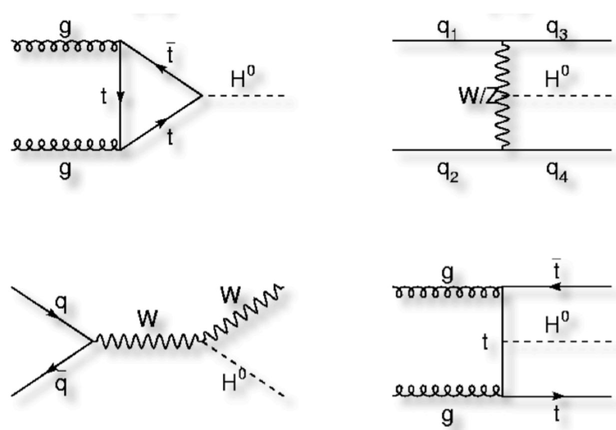
First observed by ATLAS and CMS, the main issue for the experiments now is to establish its nature (SM vs. NP): measuring its properties.

Decay processes are identified through the particle content of the events and their kinematic properties: $\gamma\gamma$, 4l (ZZ), 2l2ν (WW), $\tau\tau$, bb, and so on.

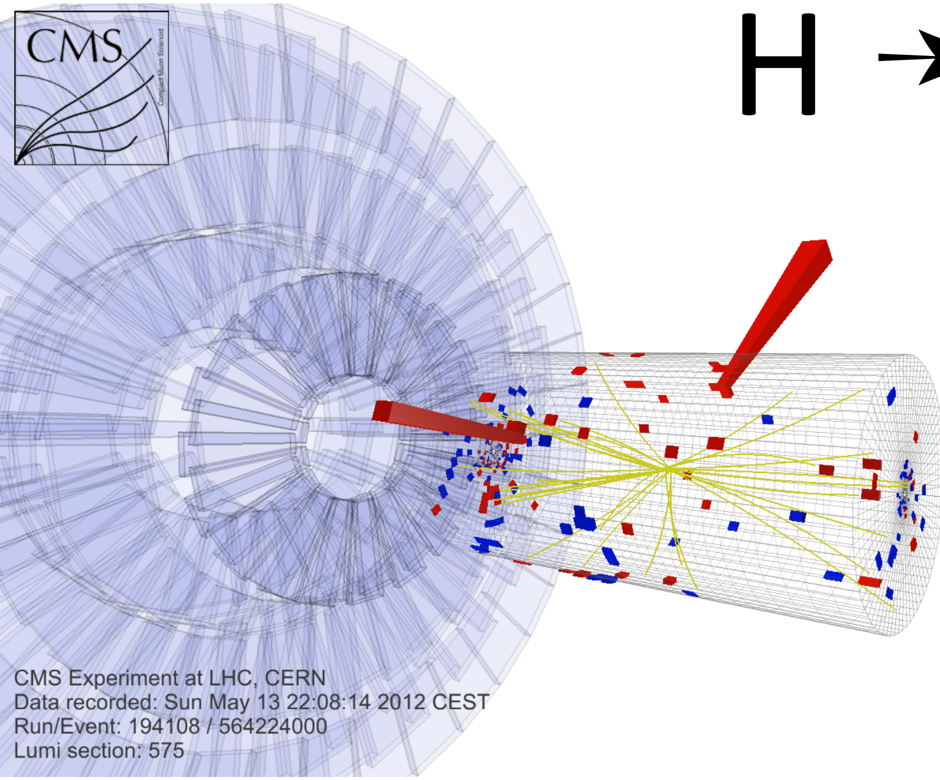
Some insight on the production mechanism can be obtained from the topological analysis of the events, based on the jet content.

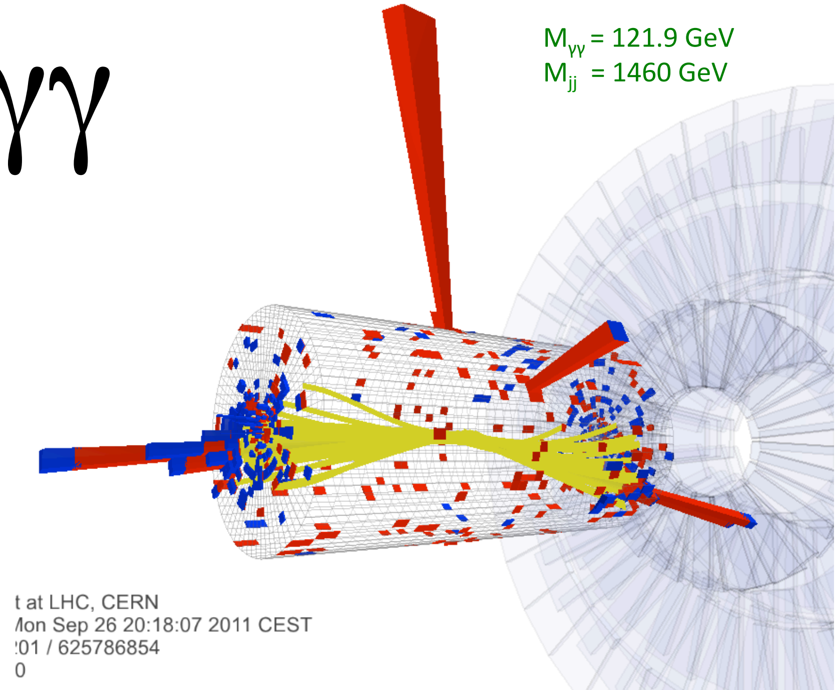






$H \rightarrow \gamma\gamma$

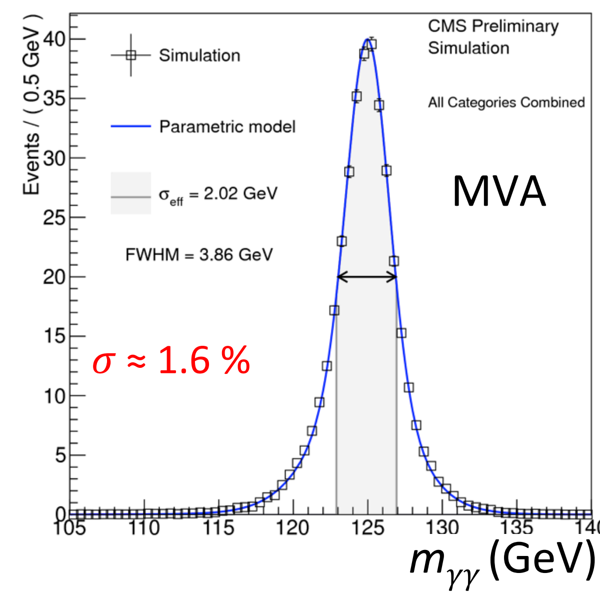




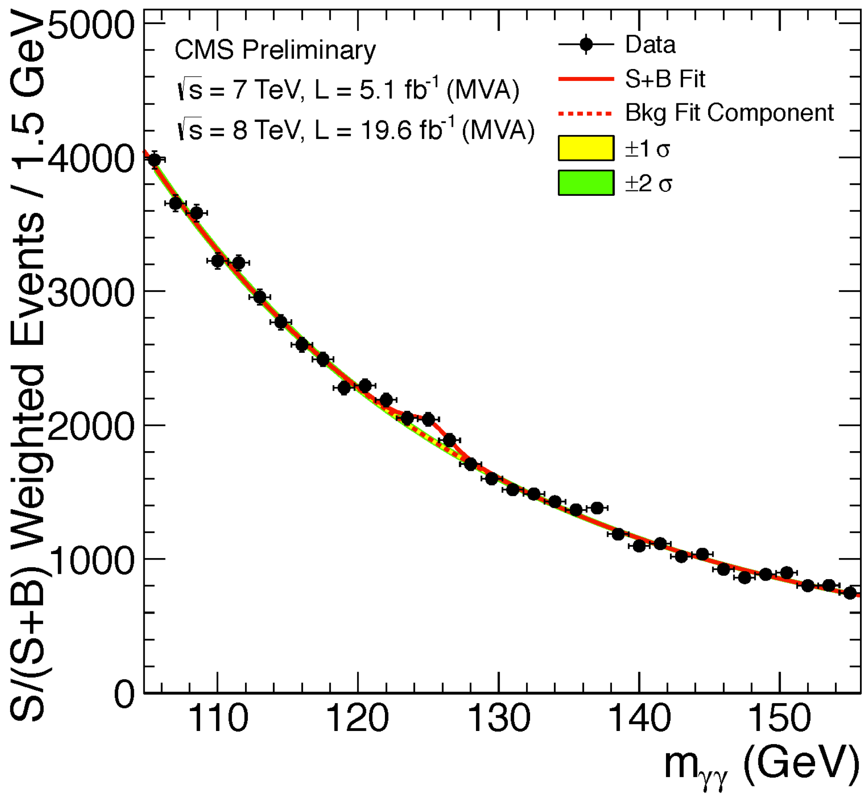
Two high-p_T isolated photons with a narrow mass distribution, $m_{\gamma\gamma}$, steeply falling for the background, evaluated from a fit to the data, no reference to the simulation.

MVA techniques to perform γ identification, and vertex determination. 4 event categories with different S/B and $m_{\gamma\gamma}$ resolution.

3 VH channels: e, μ, MET tag and VBF: 2 dijet categories.



$m_{\gamma\gamma}$ distribution with each event weighted by the S/(S+B) value of its category (for visualization only).

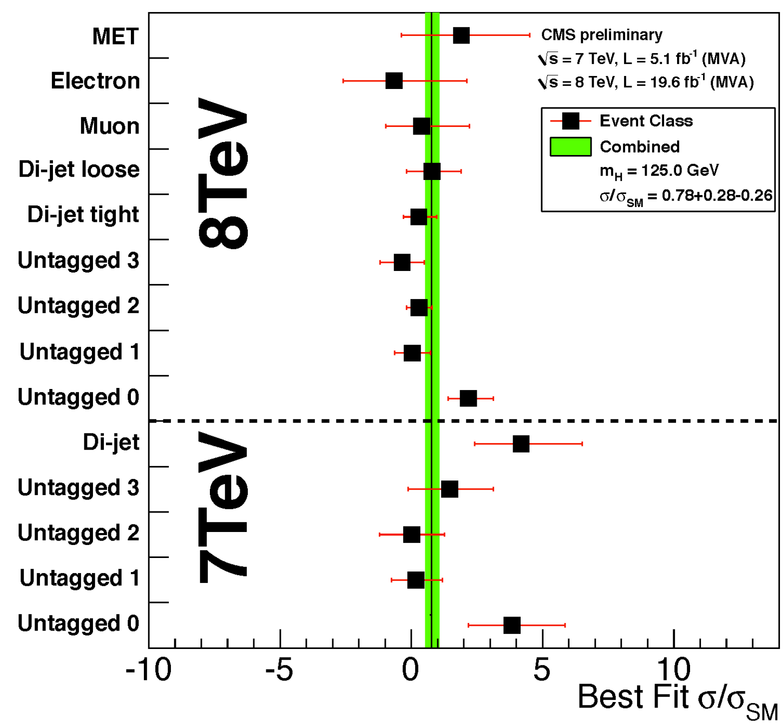


$m_H = 125.4 \pm 0.5$ (*stat.*) $\pm\ 0.6$ (*sys.*) GeV

Significance (σ) for m_{H} = 125 GeV

observed 3.2, expected 4.2

Ratio of the production cross section times the relevant branching fractions over the SM expectation: $\sigma/\sigma_{\mathrm{SM}}$ = 0.78 ± 0.27 (m_{H} = 125 GeV)

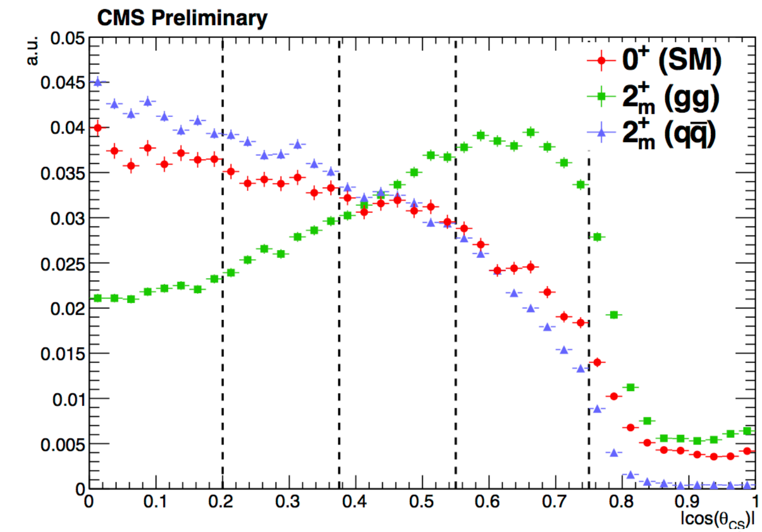


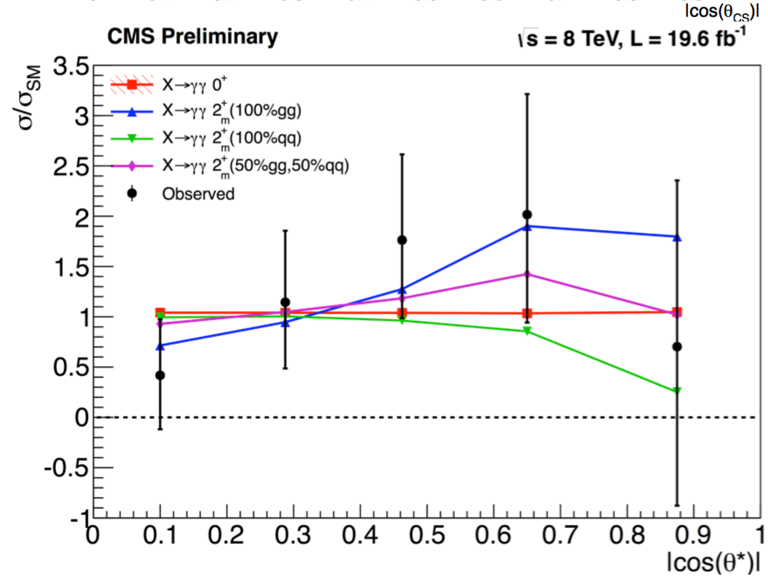
H ➤ γγ spin analysis

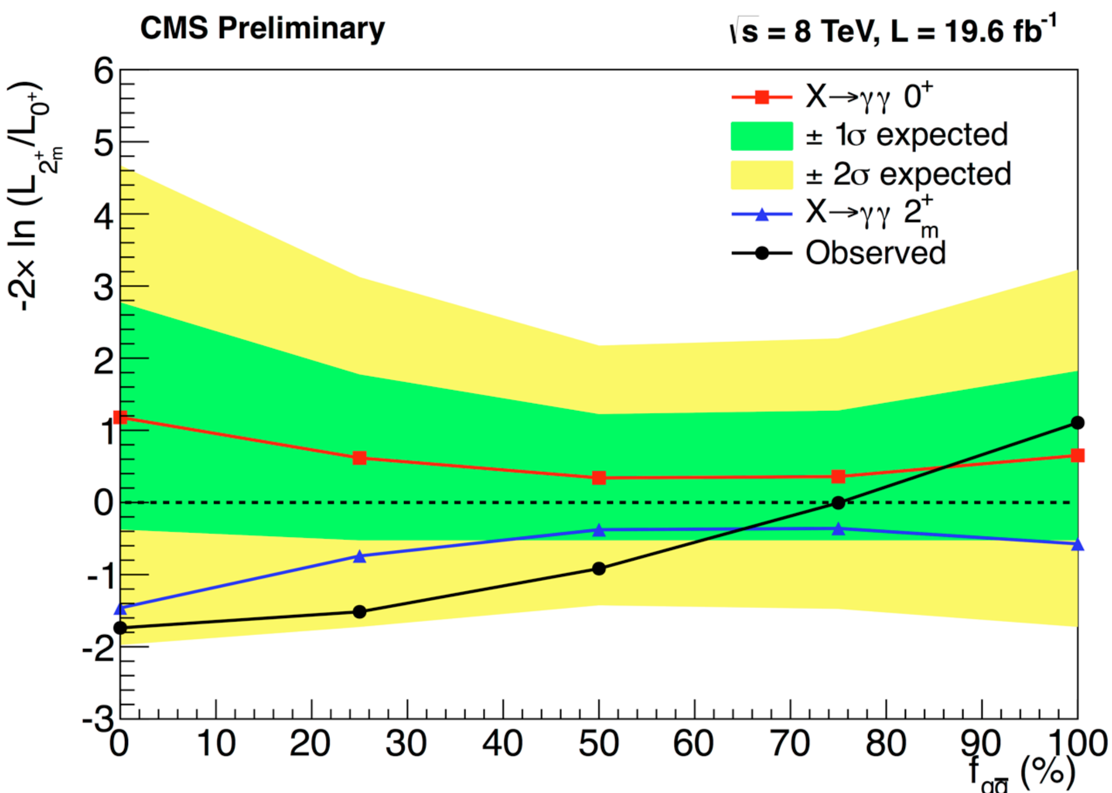
Spin-1 H decay into γγ forbidden by Landau-Yang theorem.

Consider graviton-like hypothesis 2^+_m, production can be either gg fusion or qq annihilation. Lower sensitivity for high qq fraction.

scattering angle in the Collins-Soper frame







The current data cannot exclude this particular model of spin-2, whilst compatible with SM within 1σ.

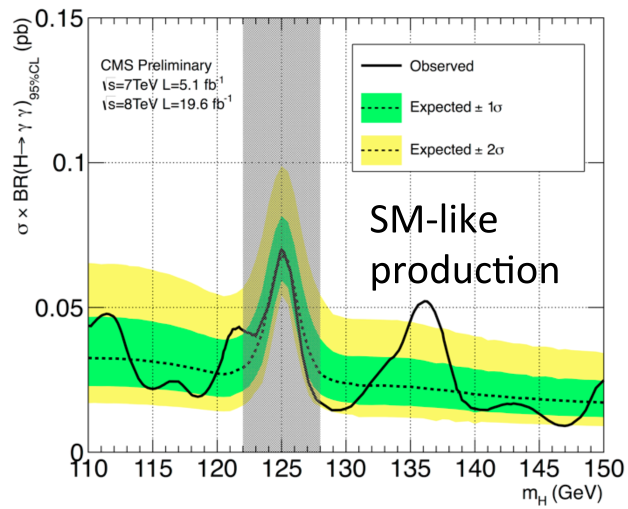
Additional Higgs-like states

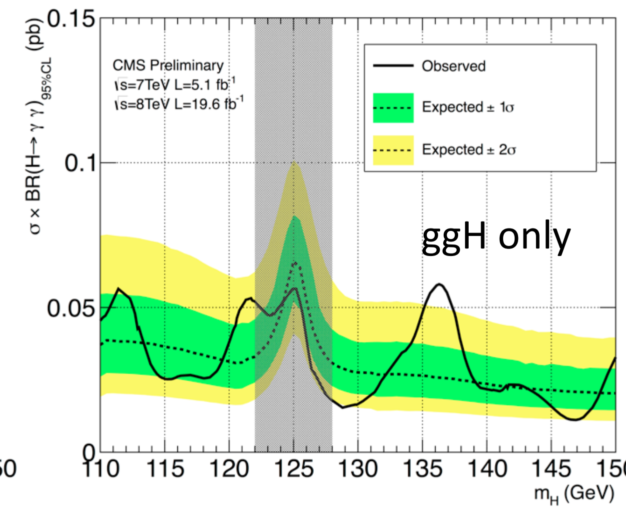
SM background includes H (126) signal:

$m_{H'}$ = 136.5 GeV

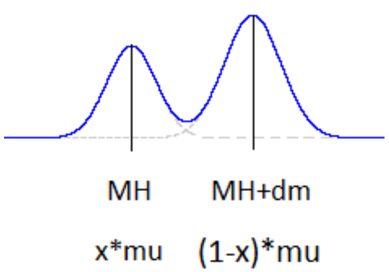
Significance:

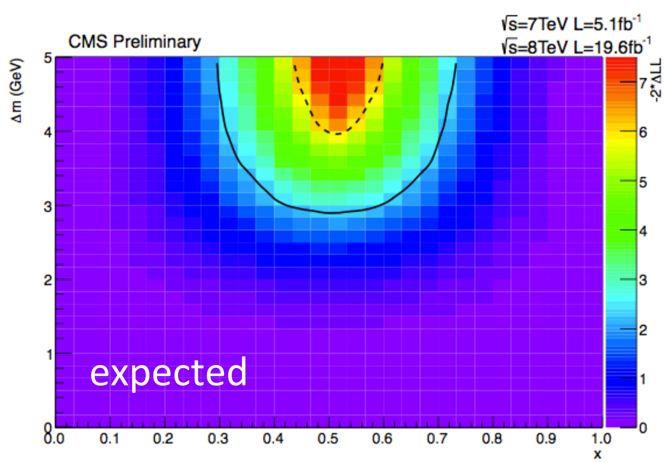
local 2.9 σ, global < 2σ

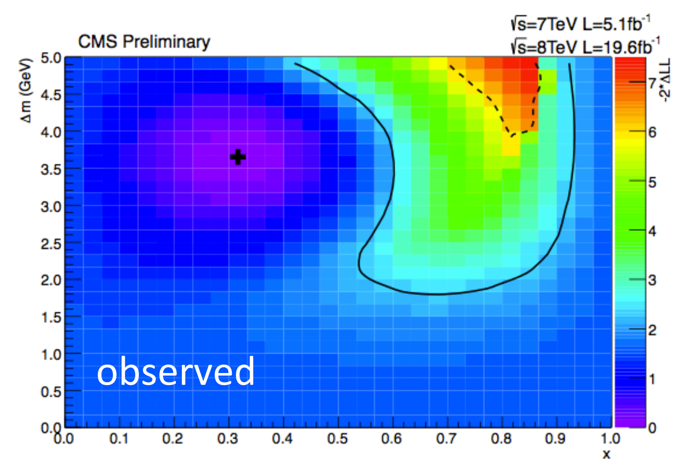




Two near mass-degenerate states: sensitive to dm ≳ experimental resolution on $m_{\gamma\gamma}$ and x ≈ 0.5







Allows to exclude parameters in the 2HDM when two Higgs bosons interpreted as h,H or h,A

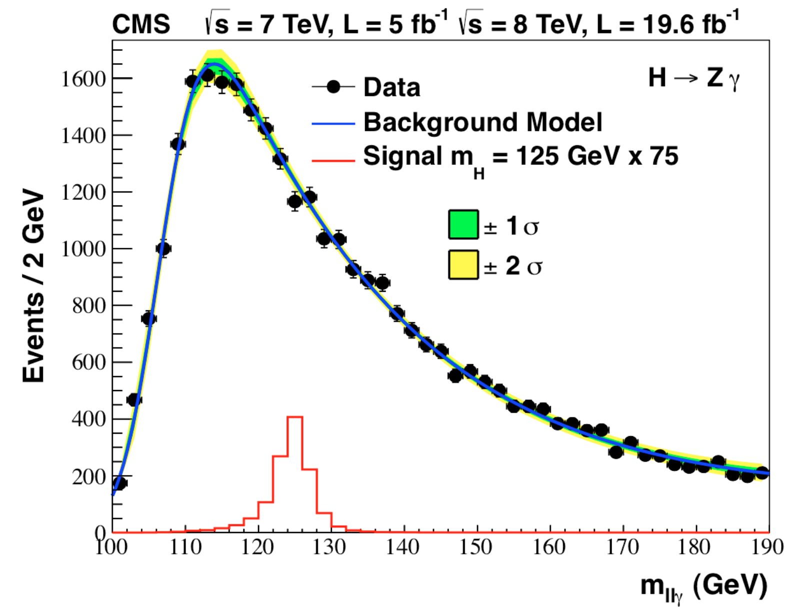
H ➛ Zγ

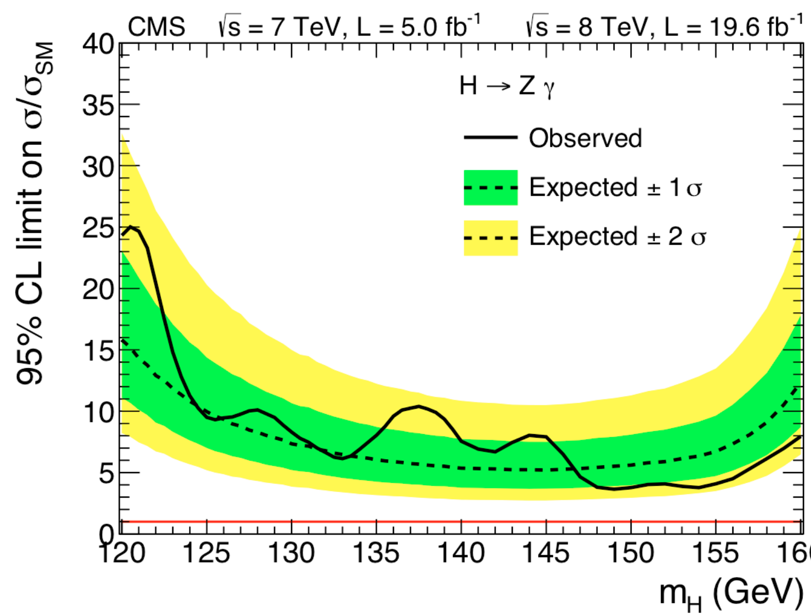
H ➛ Zγ cross section similar to H ➛ γγ.

Final states with Z➛ee and Z➛μμ, significantly lower rates.

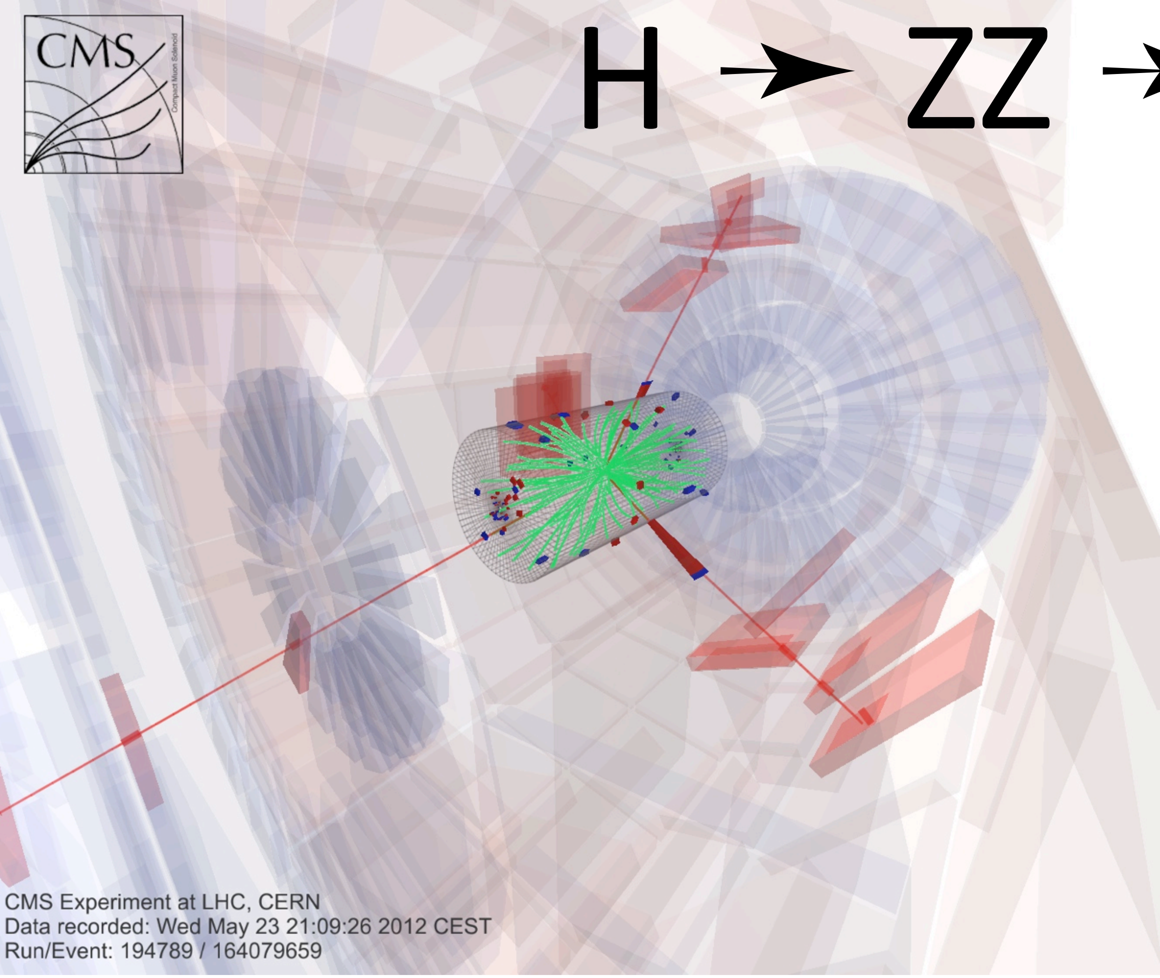
Large background from Drell-Yan with ISR.

In some models, the branching ratio to Zγ is above 100 x SM, preserving the SM H ➛ γγ branching ratio.

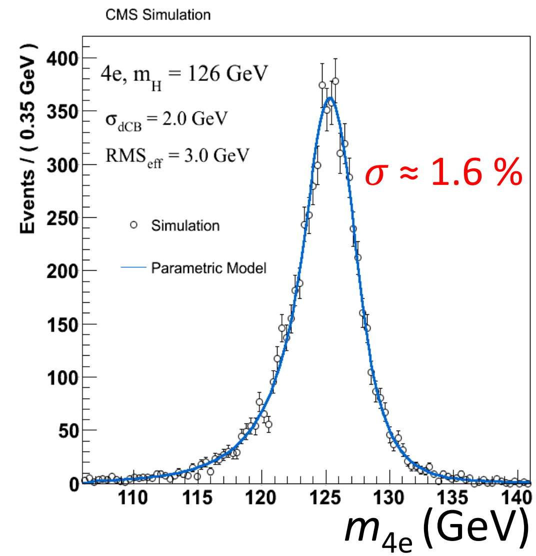


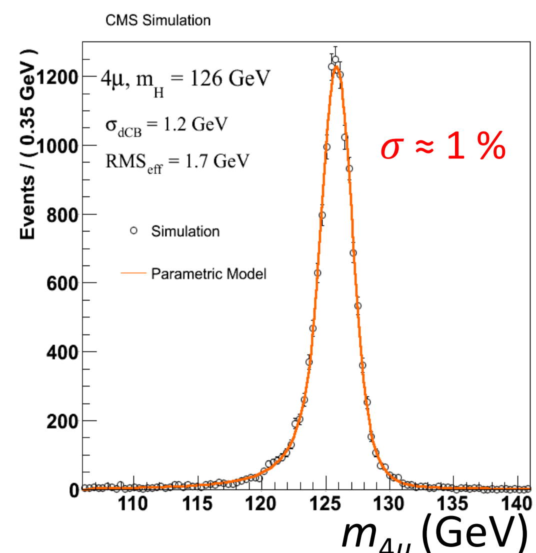


H → ZZ → 4ℓ



signal model





Four high-p_T isolated leptons from the primary vertex.
Clean 4e, 4μ and $2e2\mu$ events, but low branching ratio.

Narrow 4-lepton mass distribution, keep resolution and momentum scale under control, and high efficiency .

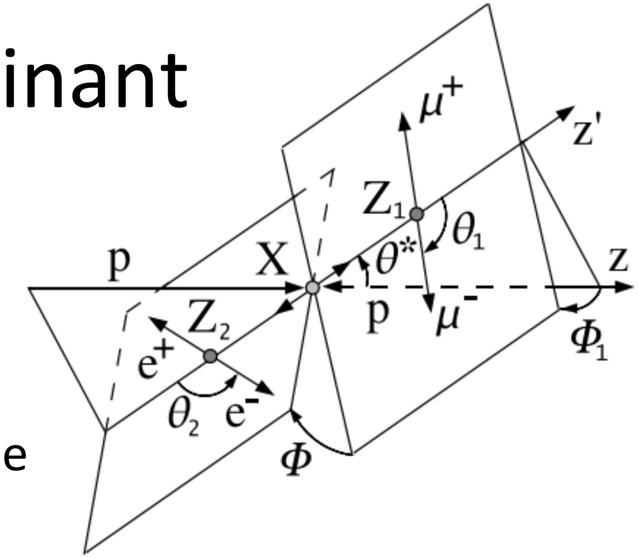
Two jet categories: untagged (0/1) and dijet tagged (≥ 2).

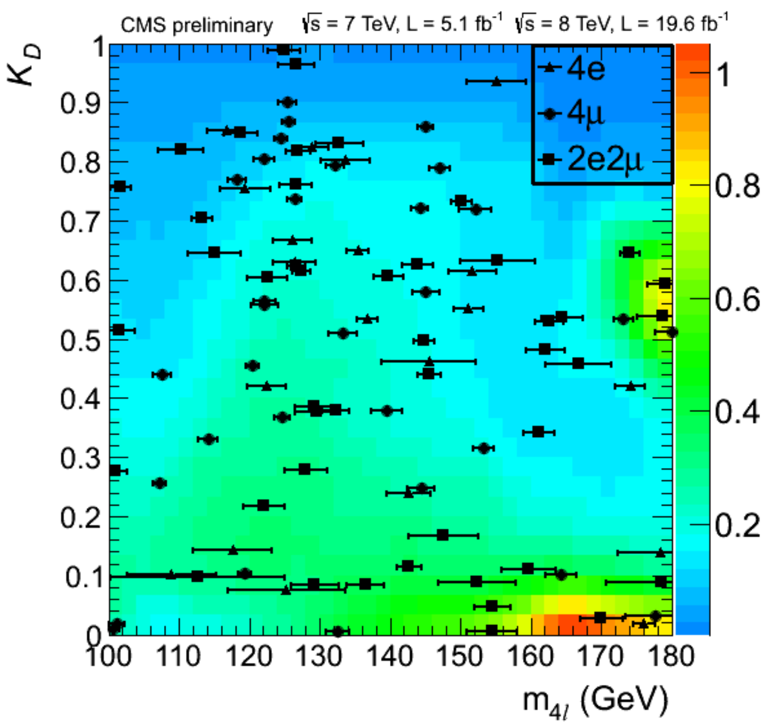
J^P-dependent Kinematic Discriminant

$K_D = P_S \,/\, (\, P_S \; + P_B\,)$

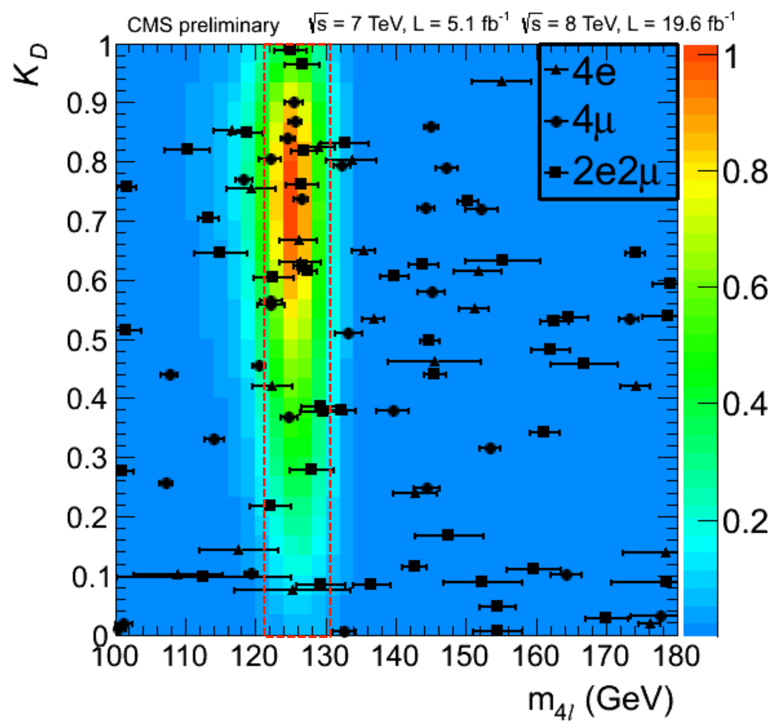
where $P_{S,B} = f\,(m_1, m_2, \theta_1, \theta_2, \Phi_1, \theta^*, \Phi^* \,|\, m_{4\ell})$

calculated from production and decay kinematics in the Z's and H rest frames.





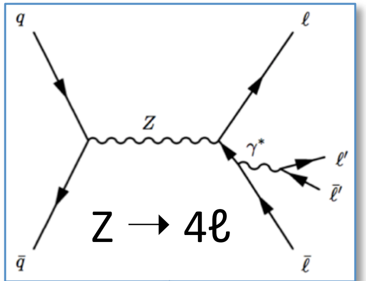
background expectation

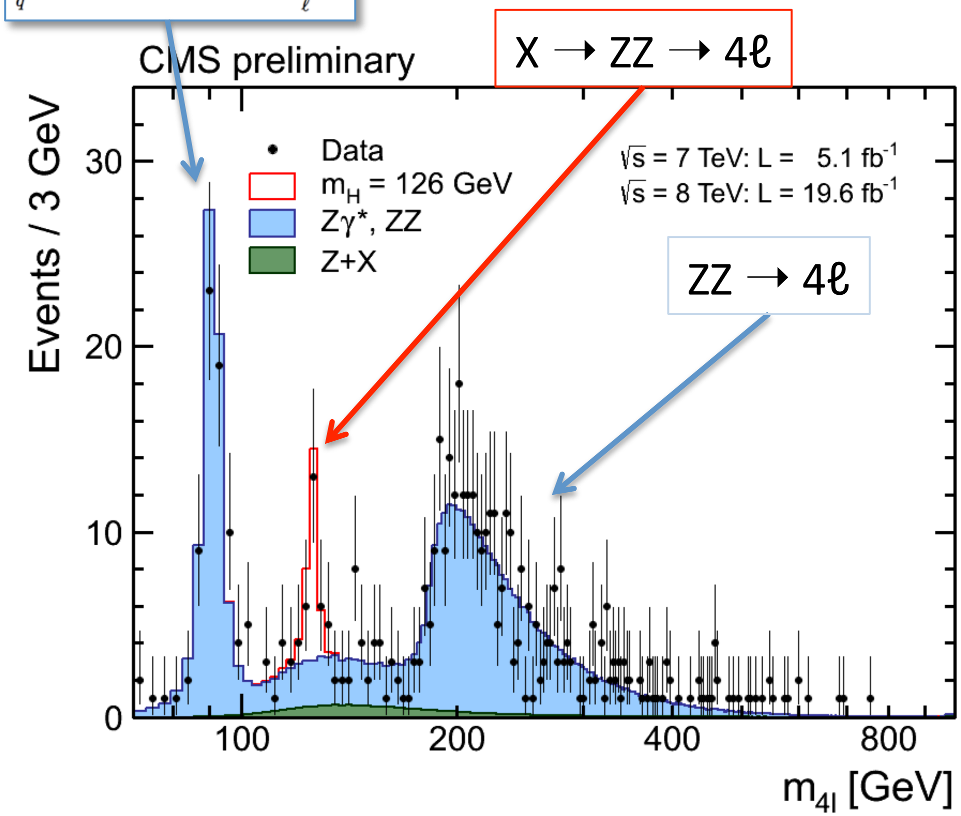


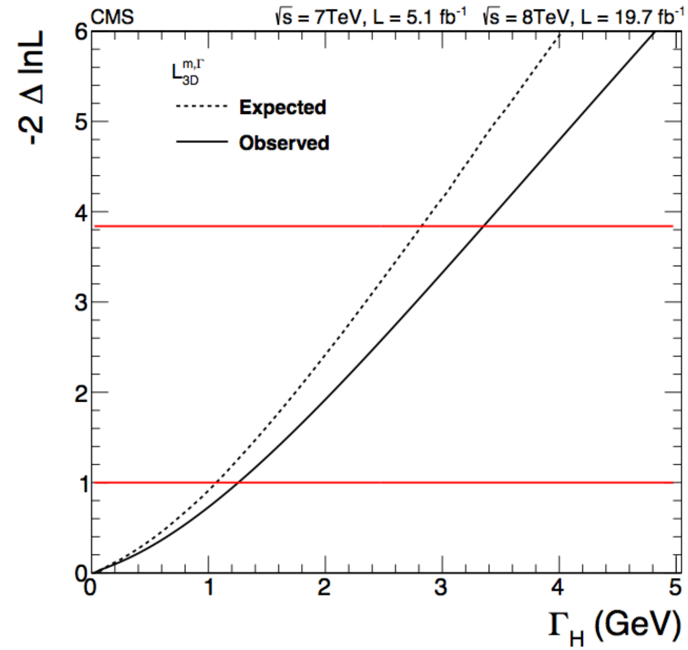
m_H = 126 GeV signal

3D fit to $m_{4\ell}$, K_D and (for jet categories) $p_T(4\ell)/m_{4\ell}$ or linear discriminant (VBF).

4-lepton reconstructed mass for the 4e, 4μ, and 2e2μ channels combined: m_H = 125.8 ± 0.5 (*stat.*) ± 0.2 (*sys.*) GeV







Significance (σ) for m_H = 125.8 GeV: observed 6.7, expected 7.2

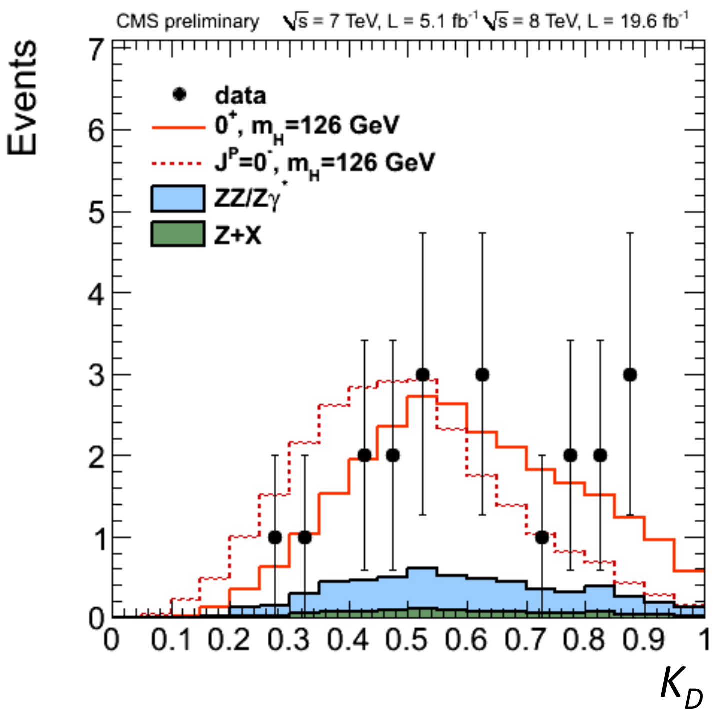
σ/σ_{SM} = $0.91^{+0.30}_{-0.24}$

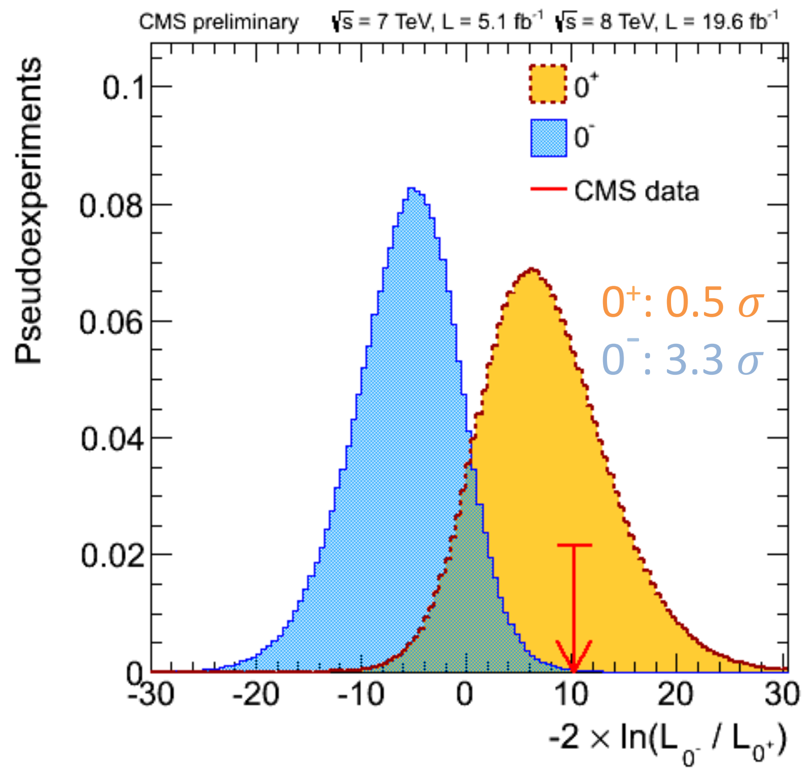
Data compatible with a narrow-width resonance: Γ_H < 3.4 GeV (at 95% CL), expected 2.8 GeV.

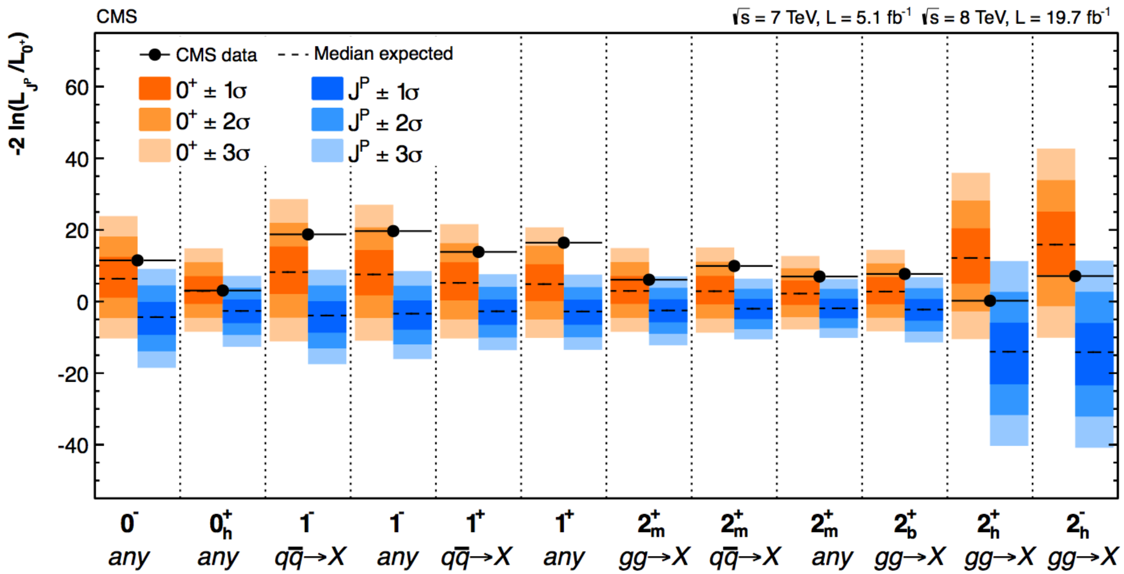
spin-parity: several J^P hypotheses tested

J^P	production	comment	expect (μ=1)	obs. 0^+	obs. J^P	CL_s
0^-	$gg \to X$	pseudoscalar	2.6σ (2.8σ)	0.5σ	3.3σ	0.16%
0^+_h	$gg \to X$	higher dim operators	1.7σ (1.8σ)	0.0σ	1.7σ	8.1%
2^+_{mgg}	$gg \to X$	minimal couplings	1.8σ (1.9σ)	0.8σ	2.7σ	1.5%
$2^+_{mq\bar{q}}$	$q\bar{q} \to X$	minimal couplings	1.7σ (1.9σ)	1.8σ	4.0σ	<0.1%
1^-	$q\bar{q} \to X$	exotic vector	2.8σ (3.1σ)	1.4σ	>4.0σ	<0.1%
1^+	$q\bar{q} \to X$	exotic pseudovector	2.3σ (2.6σ)	1.7σ	>4.0σ	<0.1%

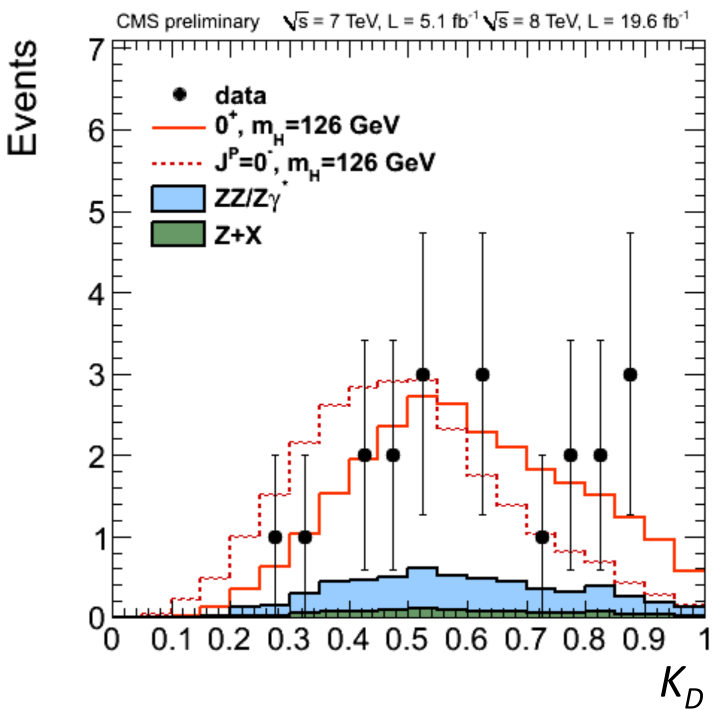
K_D constructed for different J^P Higgs-like states, having different kinematics.

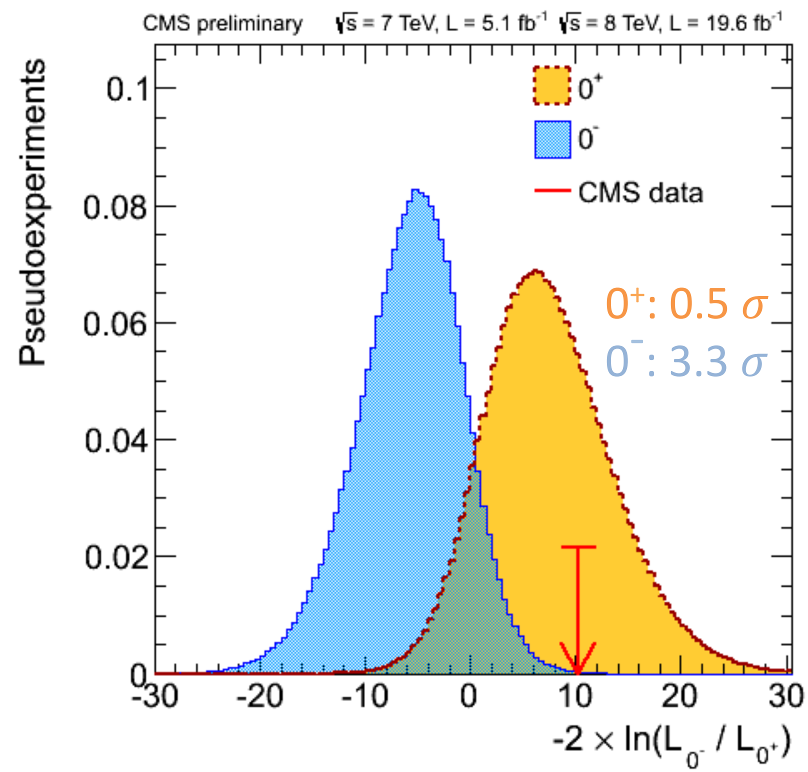






K_D constructed for different J^P Higgs-like states, having different kinematics.





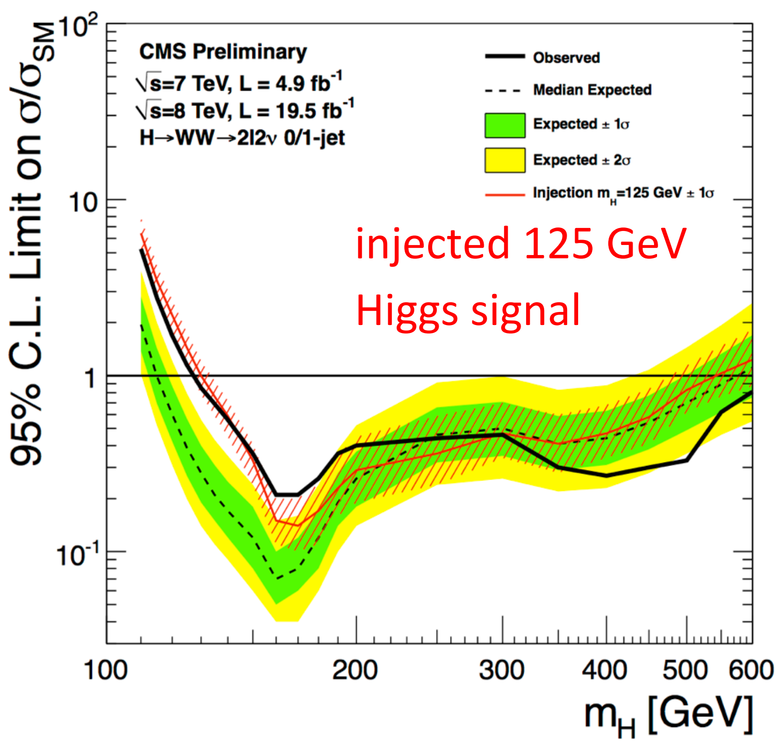
H ➤ WW ➤ 2ℓ 2ν

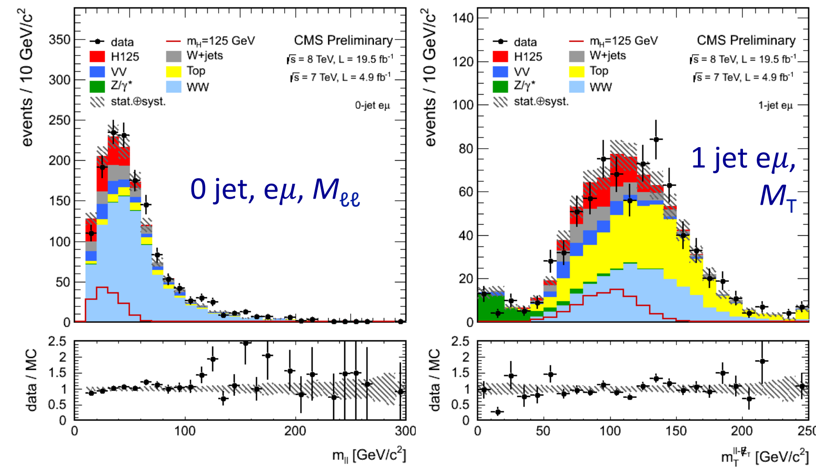
Broad excess compatible with a Higgs signal at low mass.

Significance (σ) for m_H = 125 GeV:

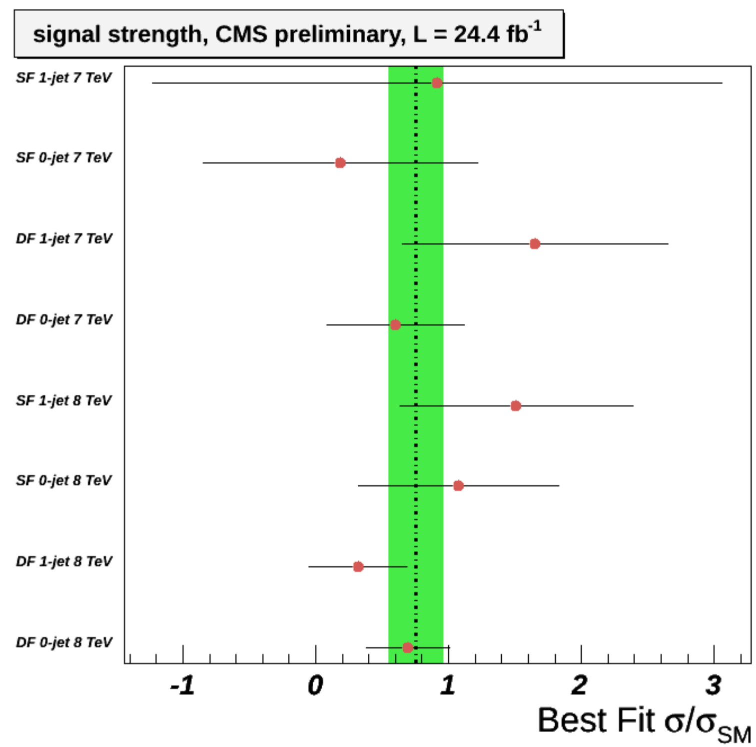
observed 4, expected 5.1

σ/σ_{SM} = 0.76 ± 0.21

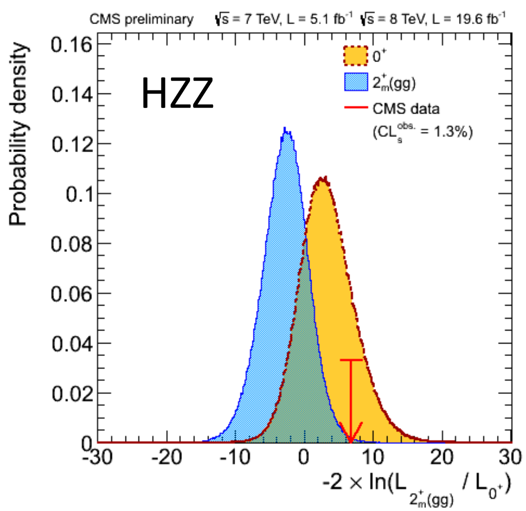


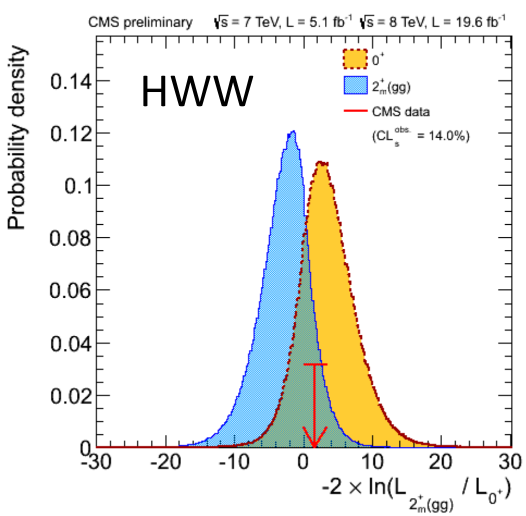


Consistency among analyses.

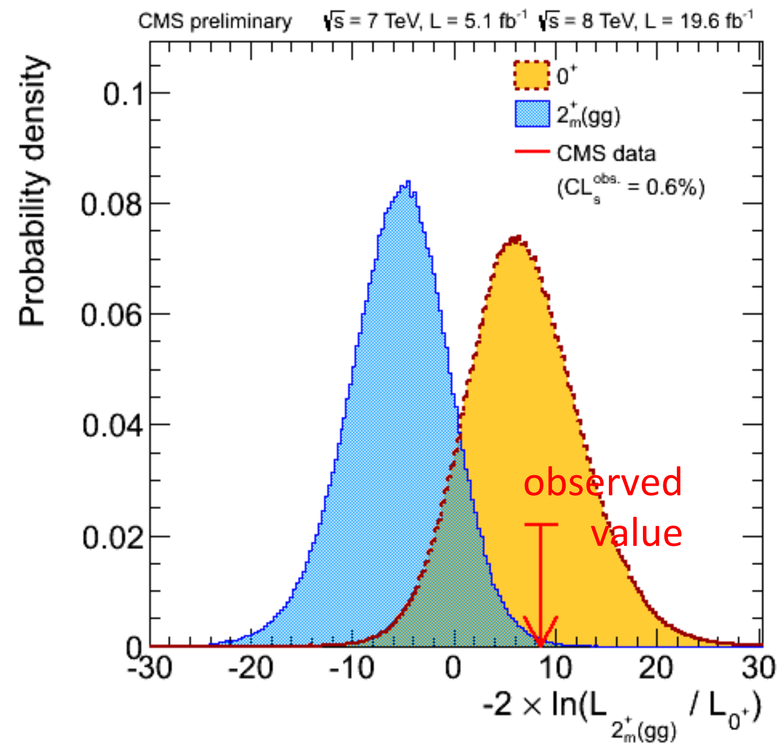


Combined WW+ZZ results for spin 2





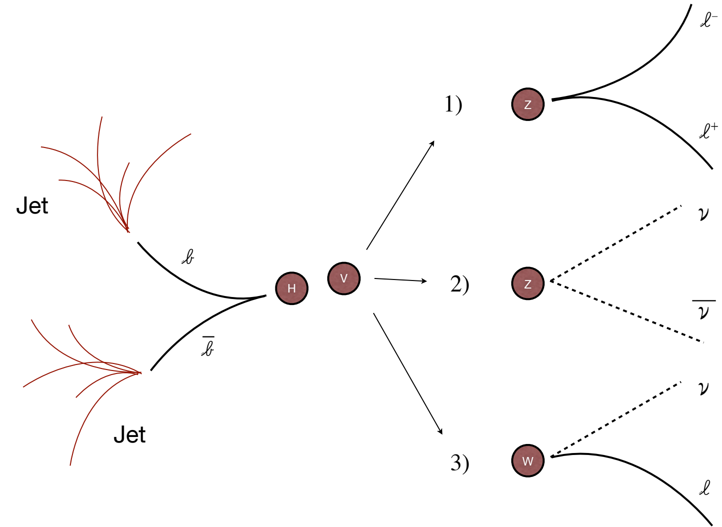
Test statistic comparing the signal J^P hypotheses 0^+ and $2^+_m(gg)$ in the best fit to the data.



Graviton-like boson with minimal couplings to gg disfavored by data

Post-fit model (μ_i profiled)	$ZZ \to 4\ell$	$WW \to \ell\nu\ell\nu$	Combined
$P(q \leq q^{\text{obs.}} \mid 0^+)$	-0.90σ	0.44σ	-0.34σ
$P(q \geq q^{\text{obs.}} \mid 2^+_{\text{m}}(\text{gg}))$	2.81σ	1.32σ	2.84σ
$1 - \text{CL}_\text{s}^{\text{obs.}}$	98.6%	86.0%	99.4%

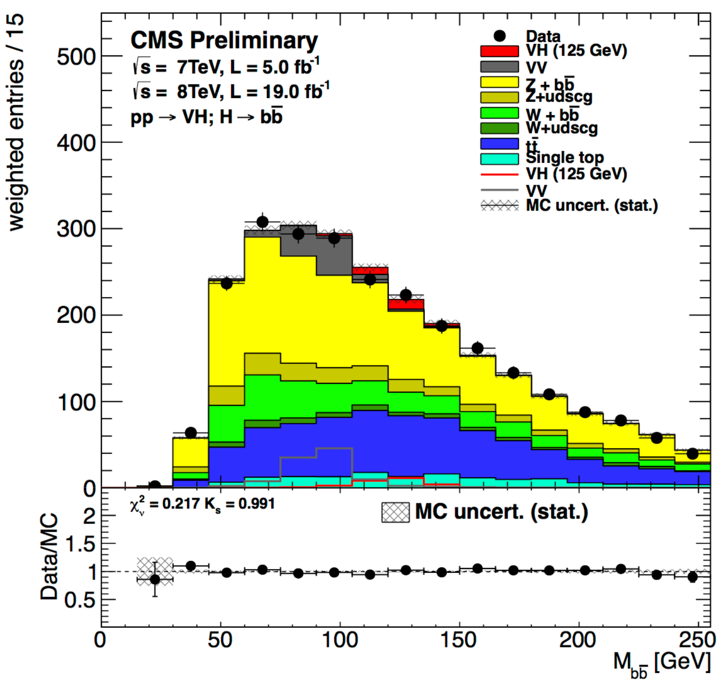
VH ➤ bb + X



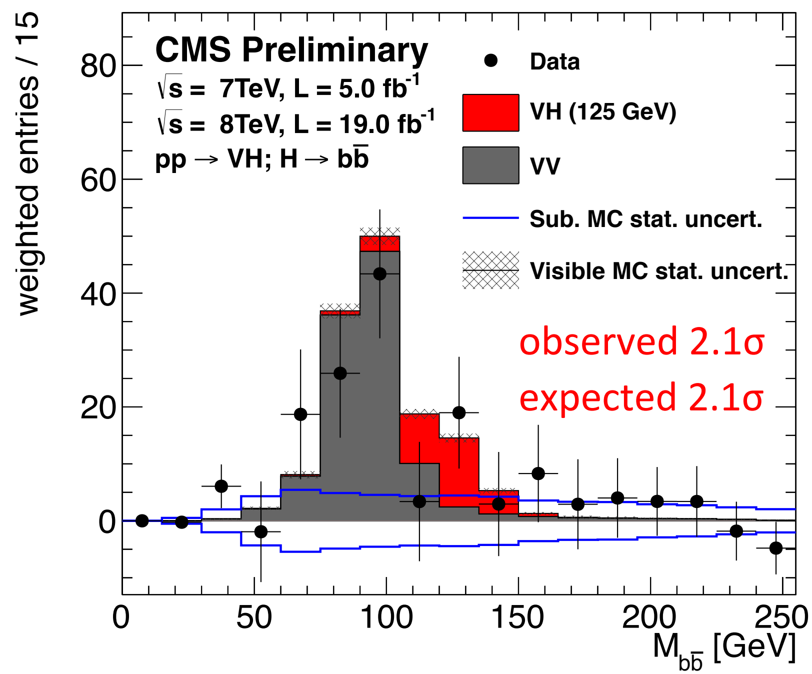
2 central b jets plus V (W, Z) decaying into leptons and neutrinos. Background from V+jets, VV, top+X.

<u>BDT shape analysis</u>: jets and V kinematics, b tagging.

all channels combined

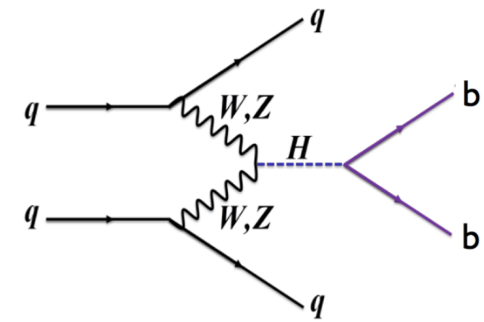


Background (except VV) subtracted mass distribution.

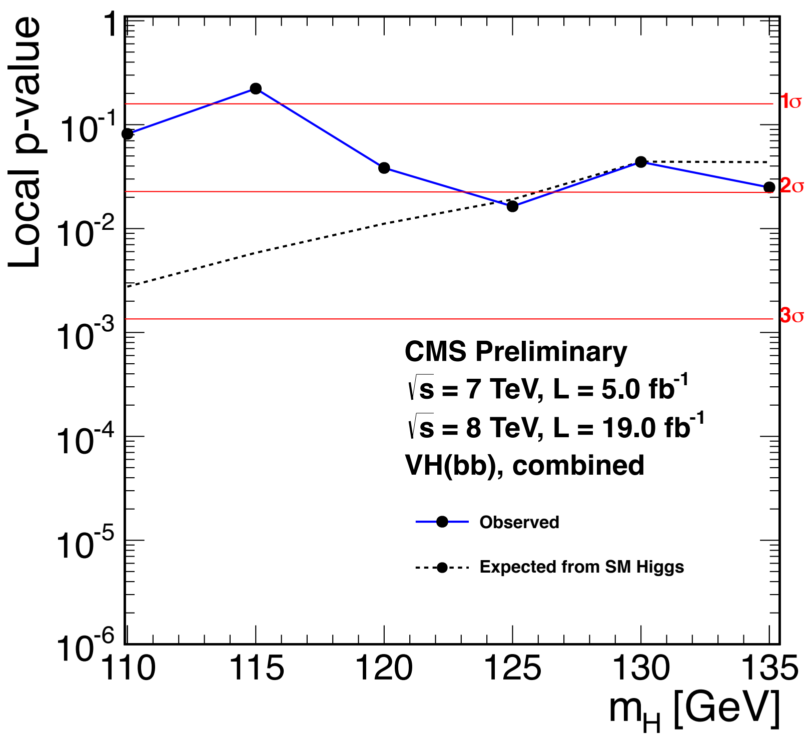


Broad excess (jet resolution) compatible with a Higgs signal at low mass.

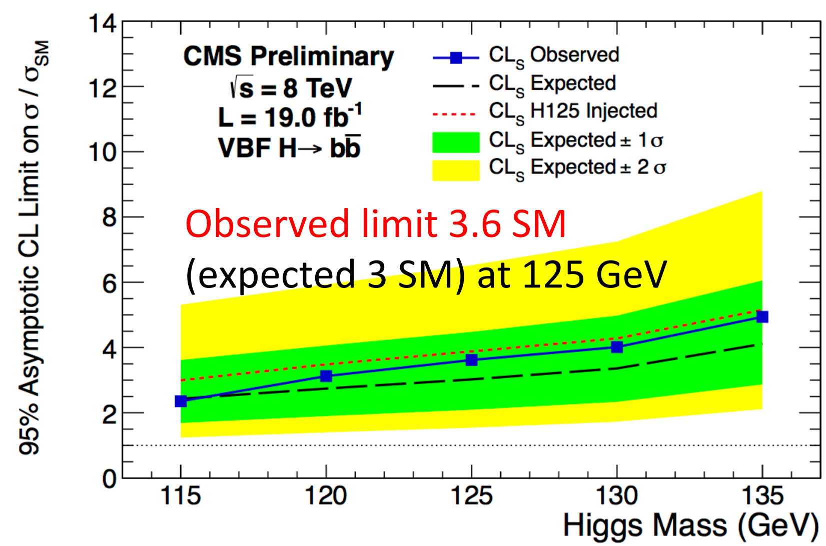
Consistent among analyses: bbℓℓ, bbνν, bbℓν.



VBF H ➛ bb



Fully hadronic final state (b jets), dominated by QCD background.



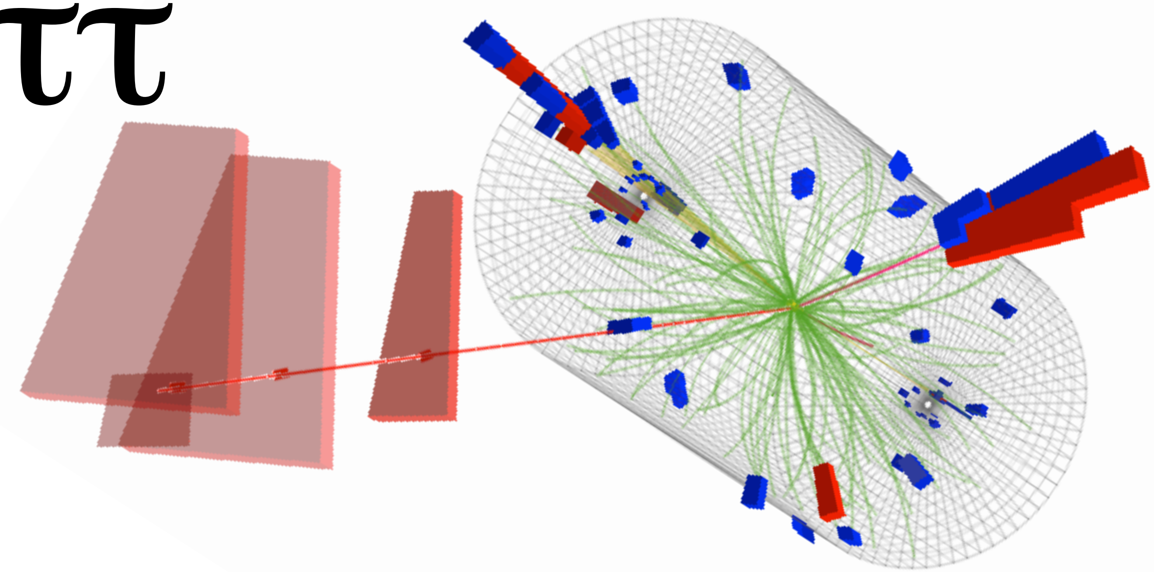
Significance (σ) for m_H = 125 GeV:

observed 2.1, expected 2.1

σ/σ_{SM} = 1.0 ± 0.5

$H \rightarrow \tau\tau$

New results



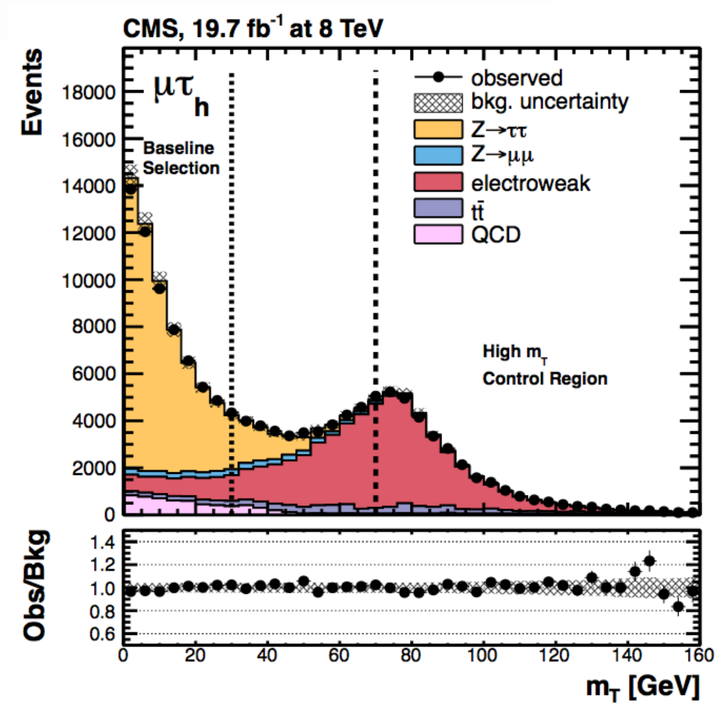
Isolated leptons, τ_h, using MVA algorithm.

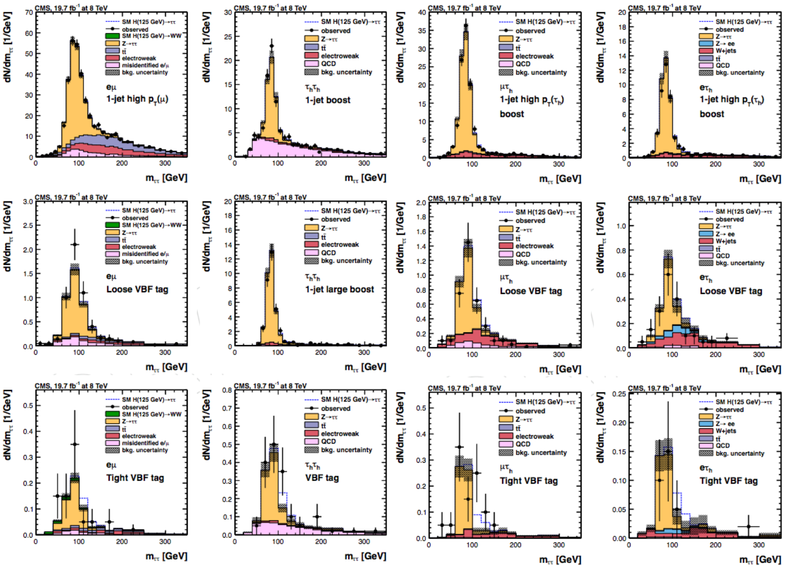
Final states: $\mu\tau_h$, eτ_h, eμ, $\tau_h\tau_h$, $\mu\mu$ and VH ($\tau\tau$).

Background from QCD, Z($\tau\tau$)+jets, W+jets.

Categories: 0/1 jet (background), 2 jets (VBF).

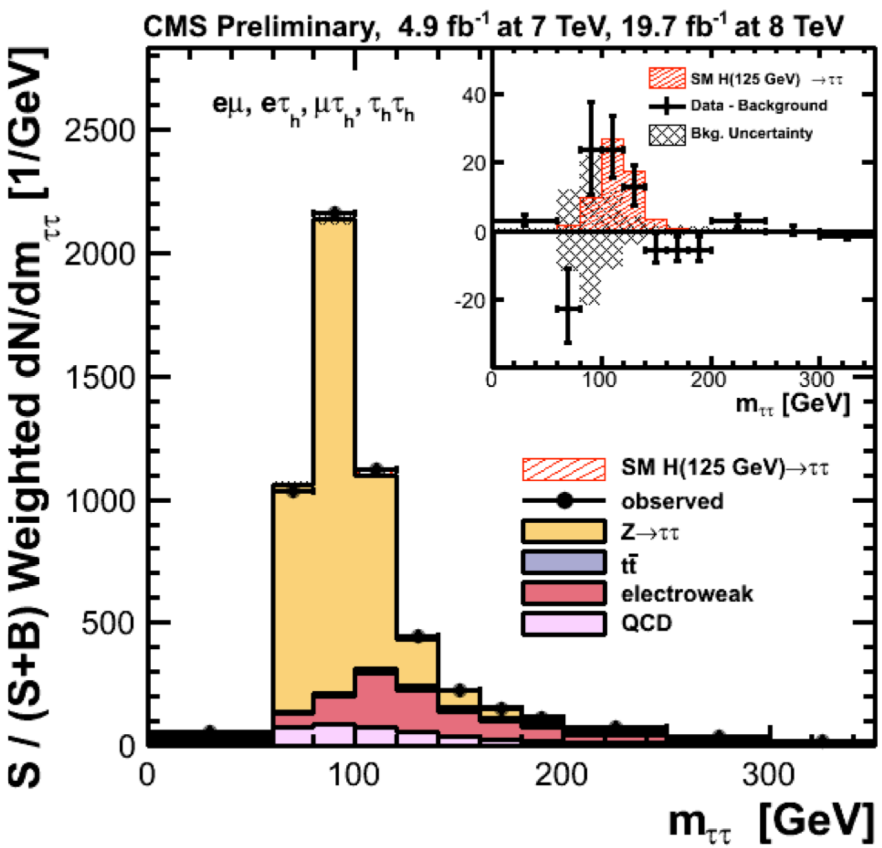
$m_{\tau\tau}$ from template fit.

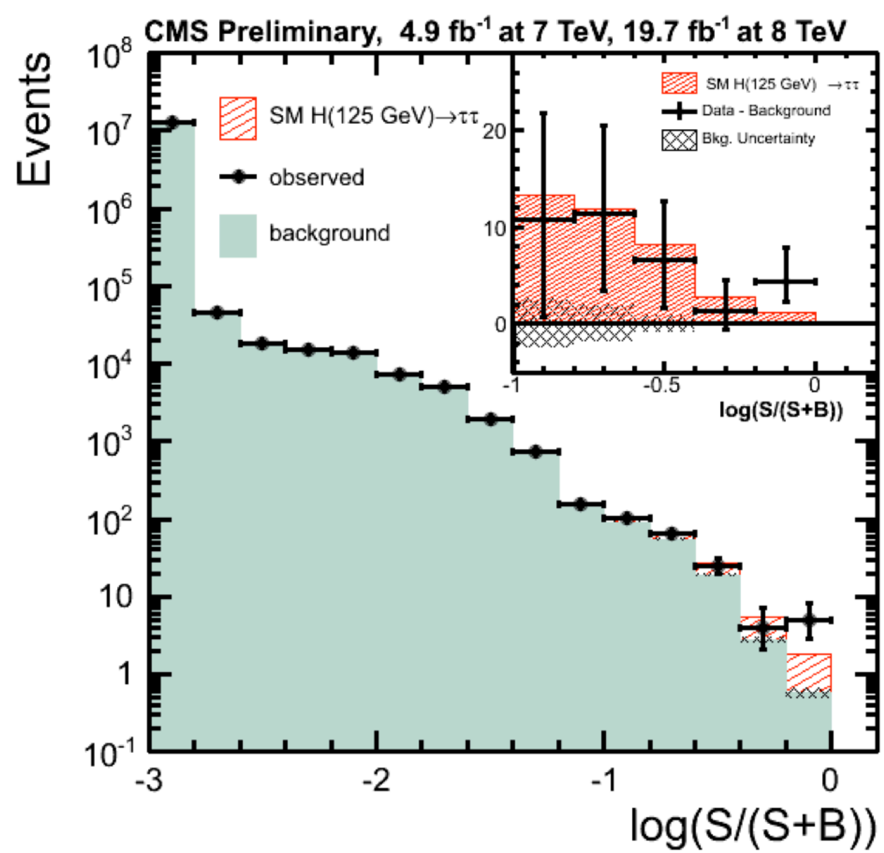




$m_{\tau\tau}$ distributions

Channels combined weighted with S/B.

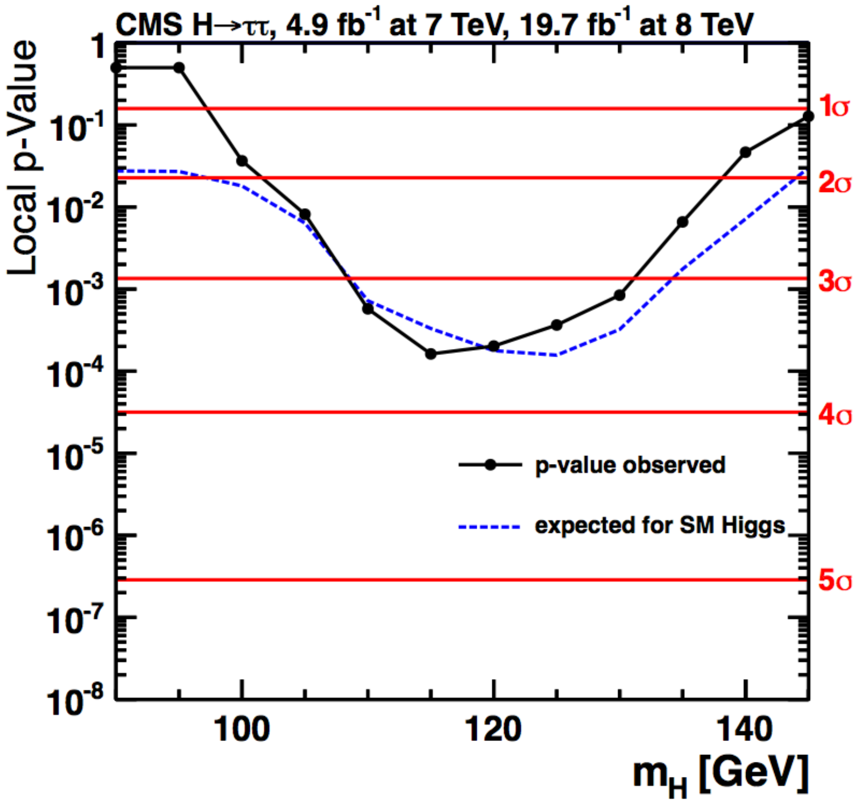


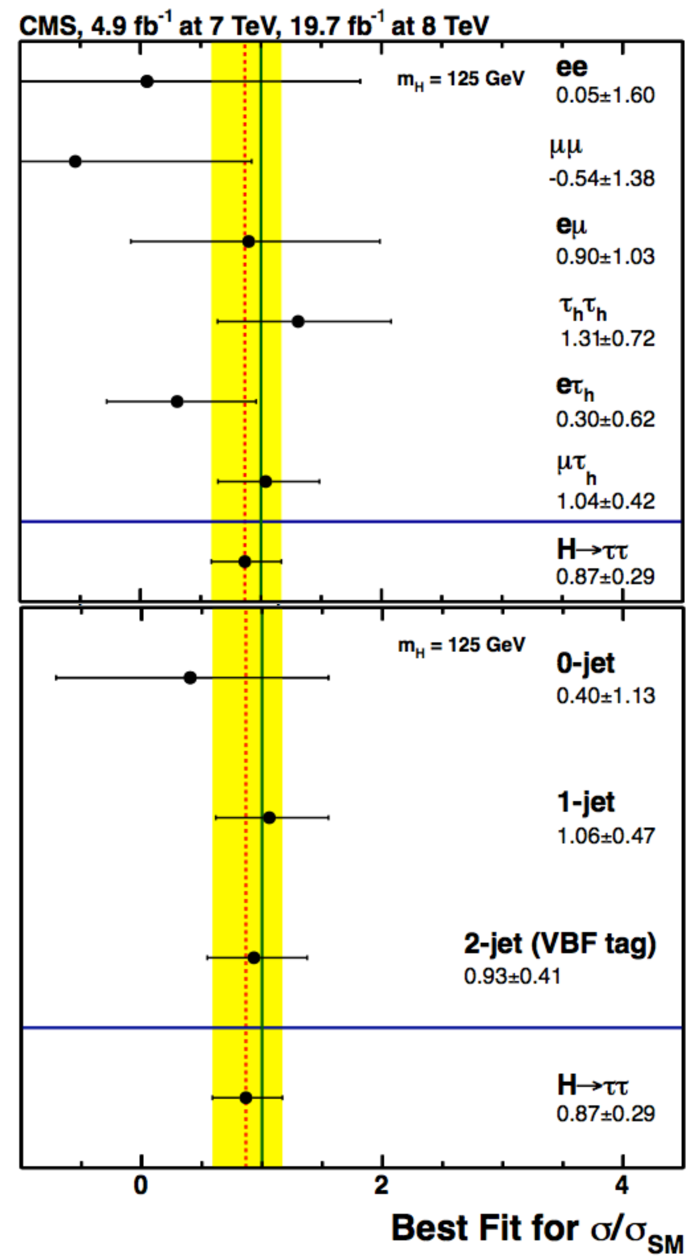


Broad low mass excess compatible with a 125 GeV Higgs signal.

Significance (σ) for m_H = 125 GeV:
observed 3.4, expected 3.6
σ/σ_{SM} = 0.87 ± 0.29

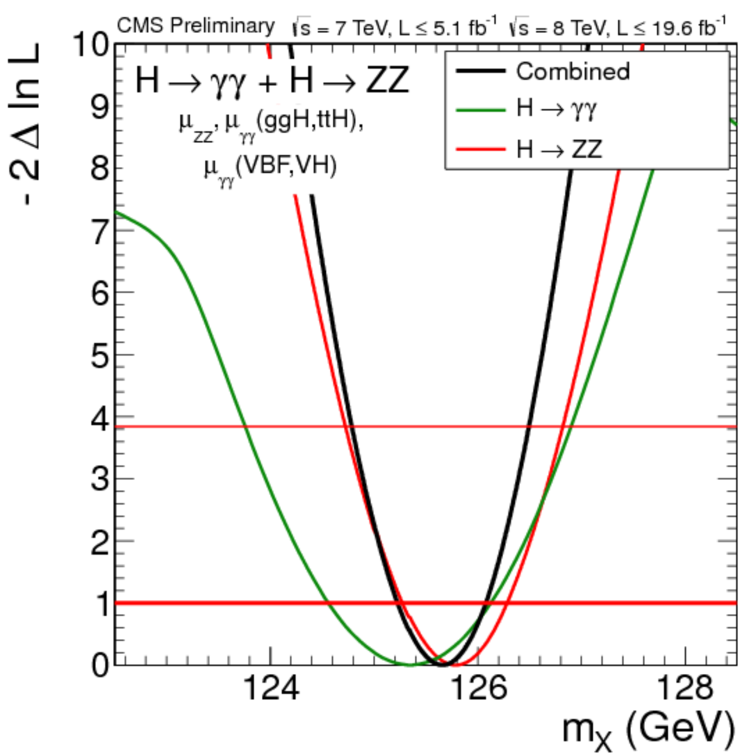
Channel M_H= 125 GeV	Significance		μ
	Expected	Observed	
VH→bb	2.1 σ	2.1σ	1.0±0.5
H→ττ	3.6σ	3.4σ	0.87±0.29
Combination	4.2σ	4.0σ	0.90±0.26

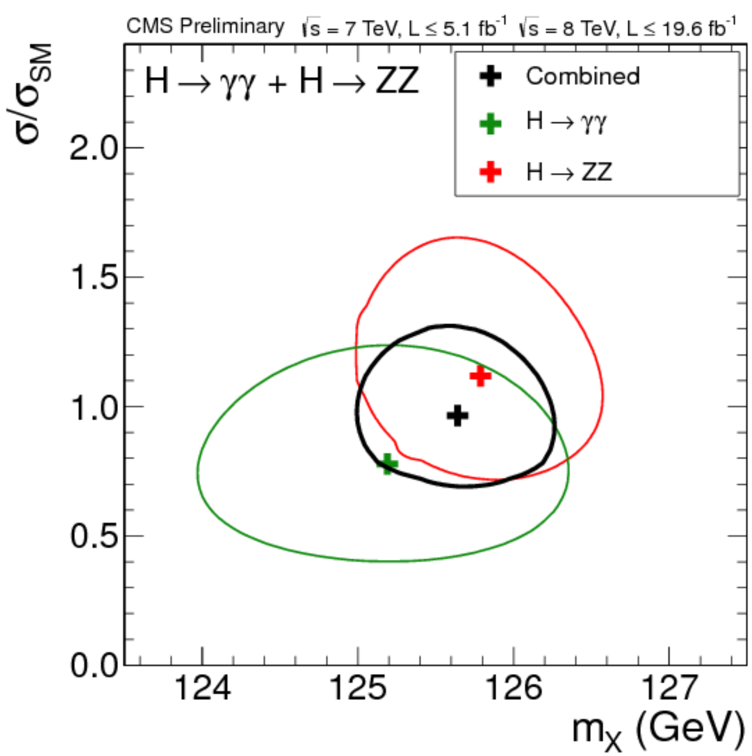




Mass of the observed state

$$m_H = 125.7 \pm 0.3\ (stat.) \pm 0.3\ (sys.)\ \text{GeV}$$
$$= 125.7 \pm 0.4\ \text{GeV}$$





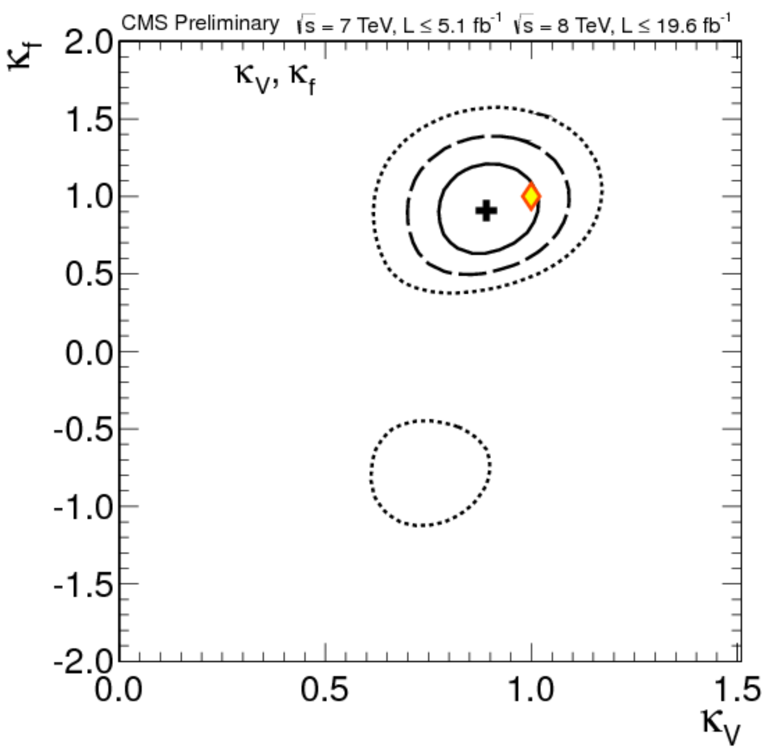
Couplings to fermions and bosons

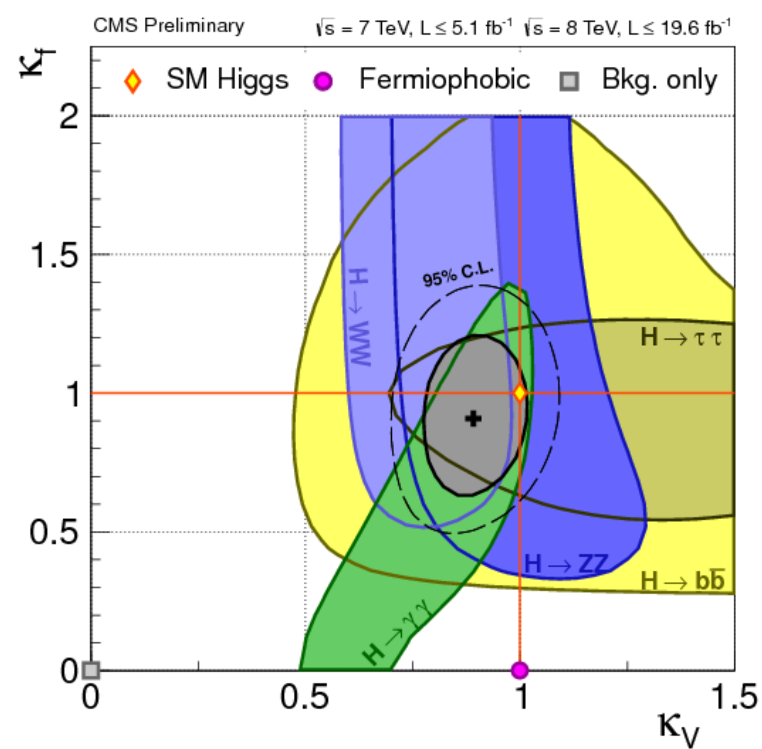
$$(\sigma \cdot \mathrm{BR})\,(x \to \mathrm{H} \to ff) = \frac{\sigma_x \cdot \Gamma_{ff}}{\Gamma_{\mathrm{tot}}}$$

x is ggH, VBF, WH and ZH, and ttH
Γ_{ff} partial decay width, ff = W, Z, b, t, γ, Zγ;
Γ_{tot} total width of the H.

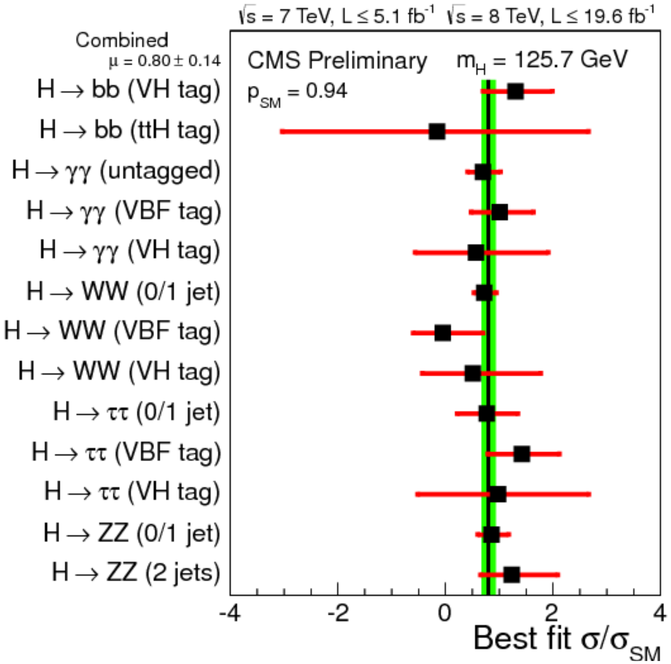
Γ_{ff} proportional to effective H couplings (g_i) $\rightarrow$ scale factors: $\kappa_i = g_i / g_i^{SM}$

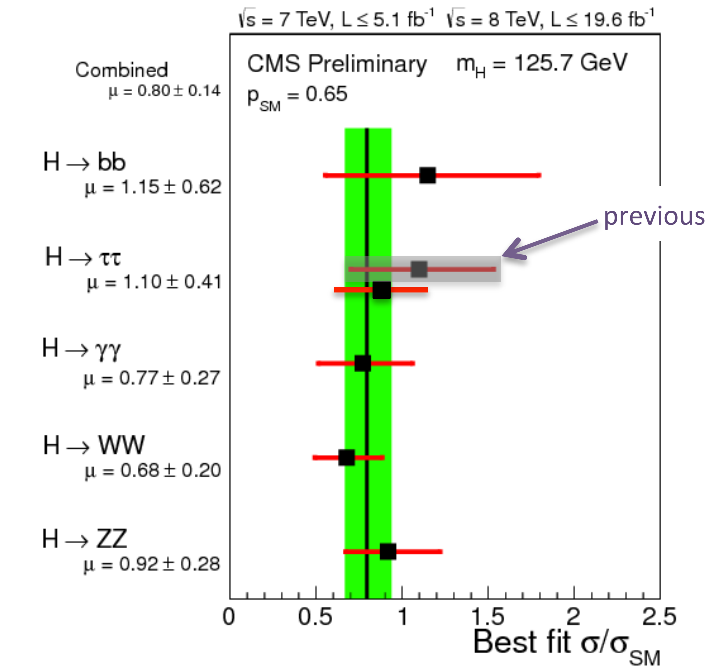
Mass fixed to the measured value, 125.7 GeV



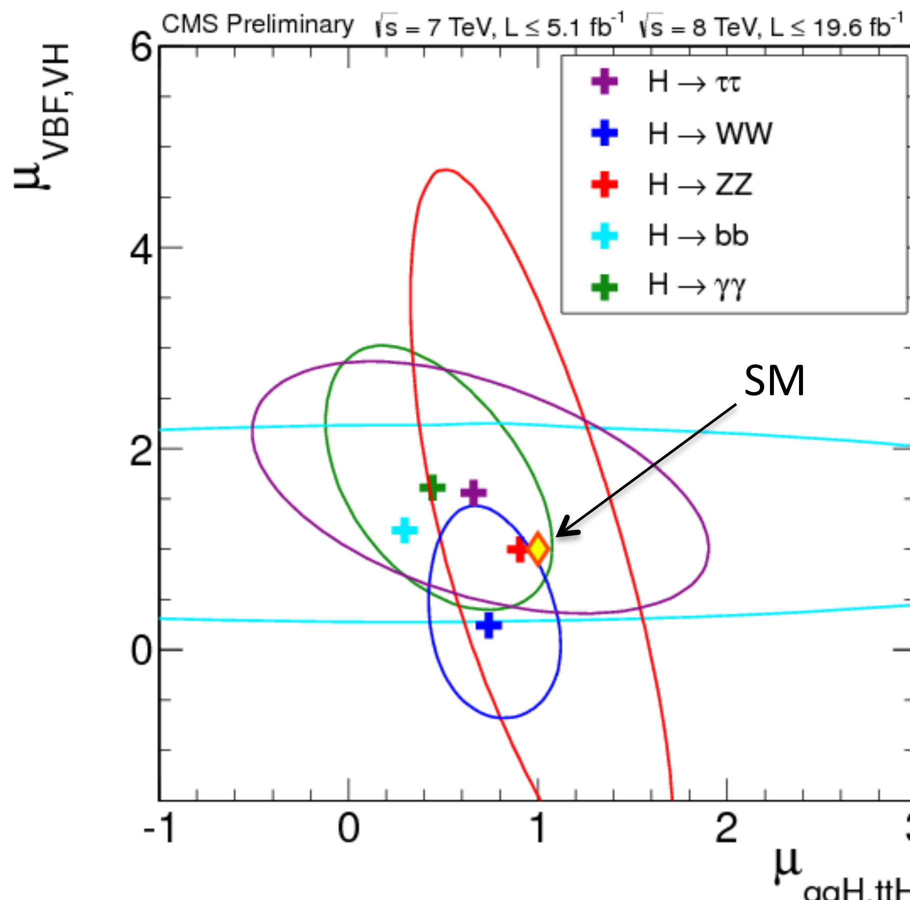


test production modes

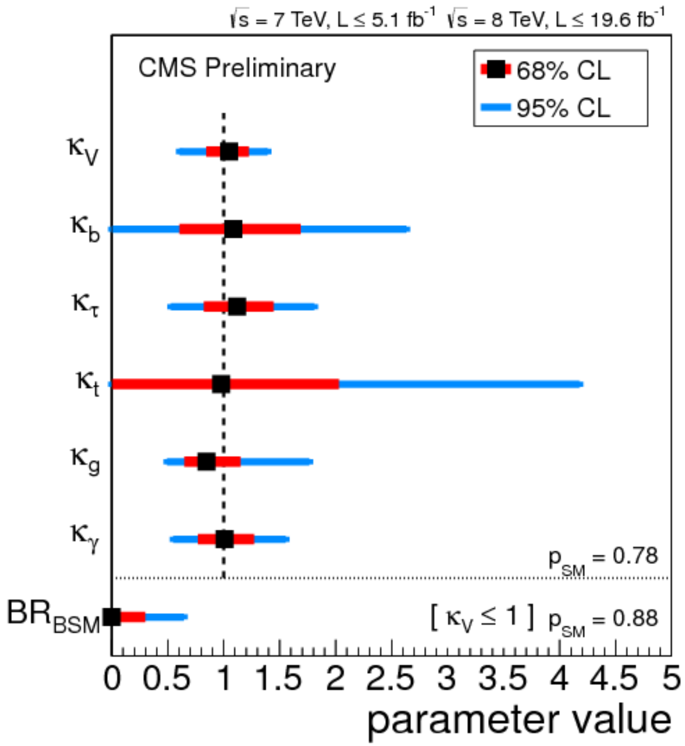




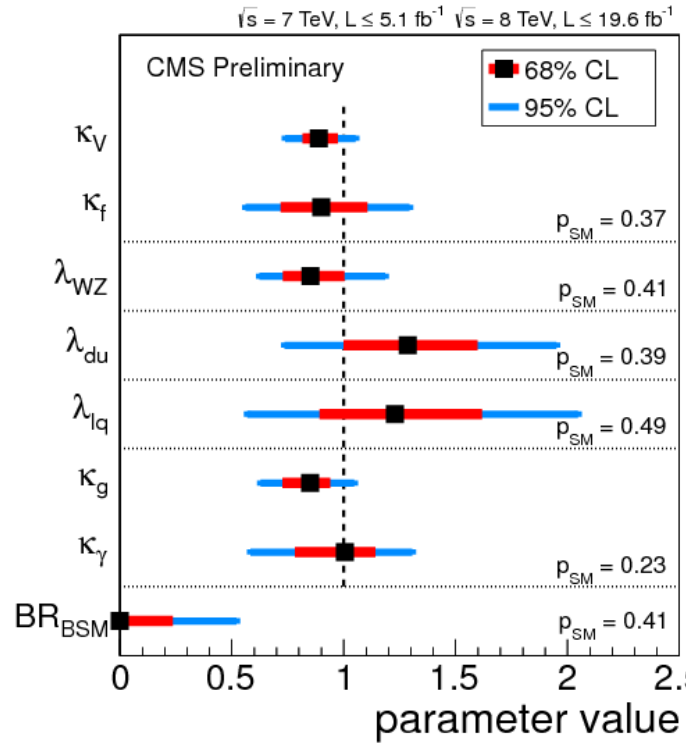
Best σ/σ_{SM} = 0.80 ± 0.14



Summary of deviations in the couplings for various models

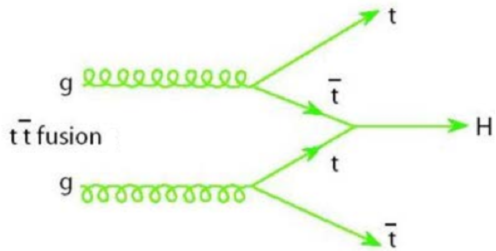


Generic six-parameter model



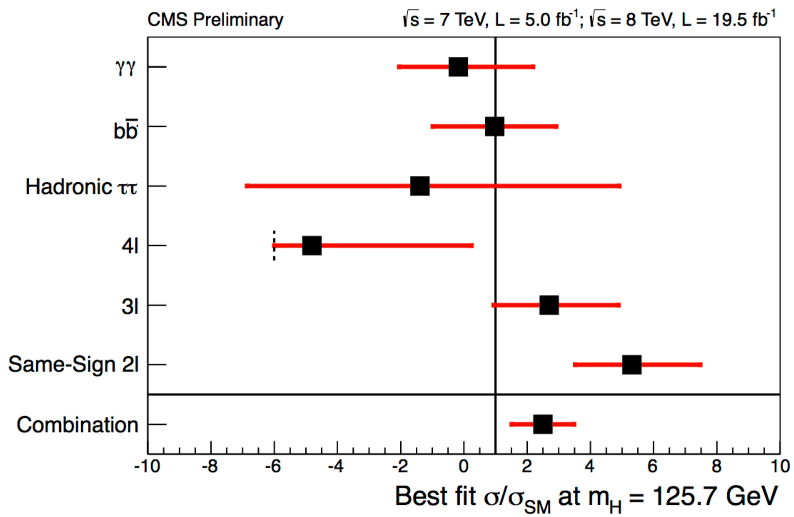
LHC XS WG benchmark models (arXiv:1209.0040)

$t\bar{t}H$

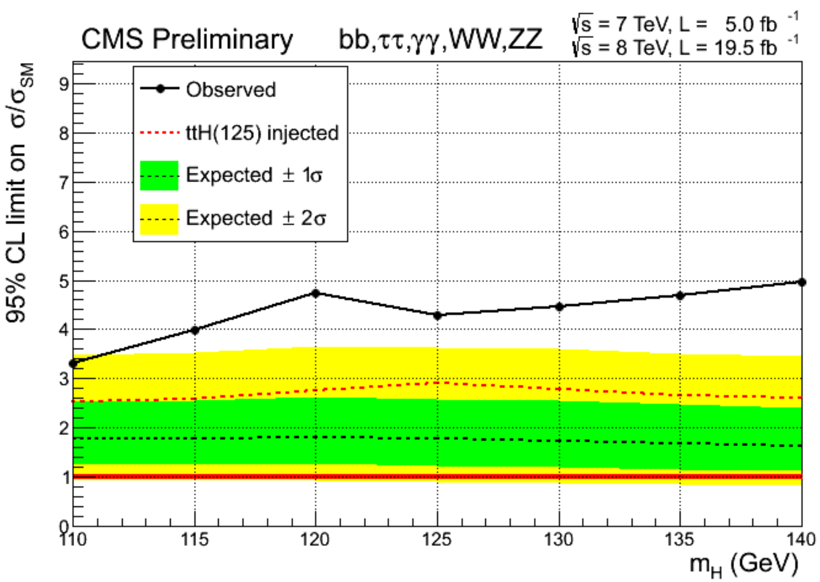


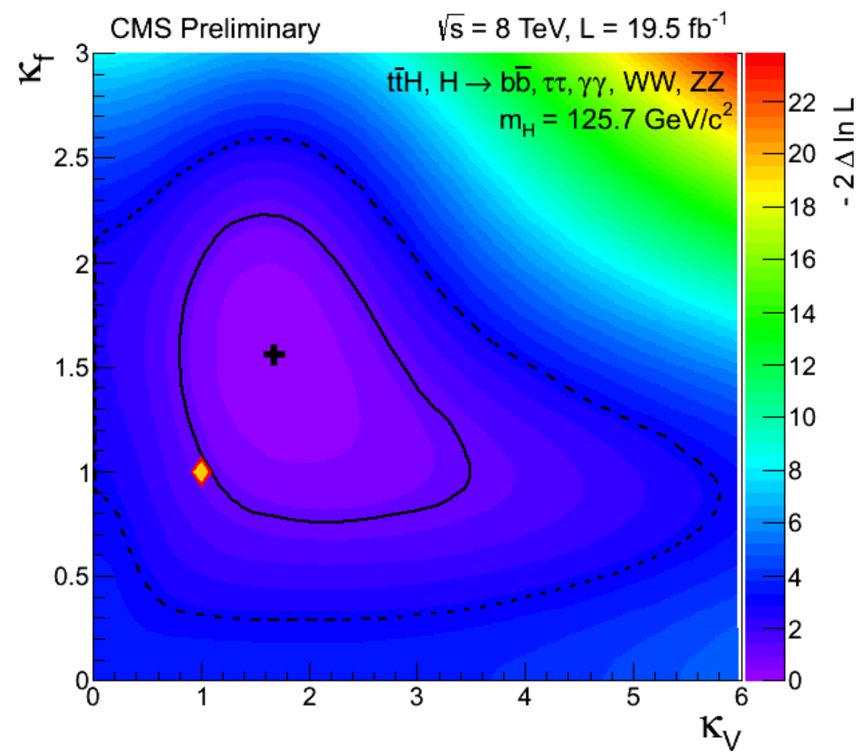
Direct hint of the Higgs coupling to top quarks.

H decays into fermions and bosons exploited, γγ, ZZ, WW, bb and ττ, as well as fully hadronic, fully leptonic and semiletponic tt decays.



Coupling ratios larger than SM expectations, consistent at 1σ level.





Beyond SM Higgs search

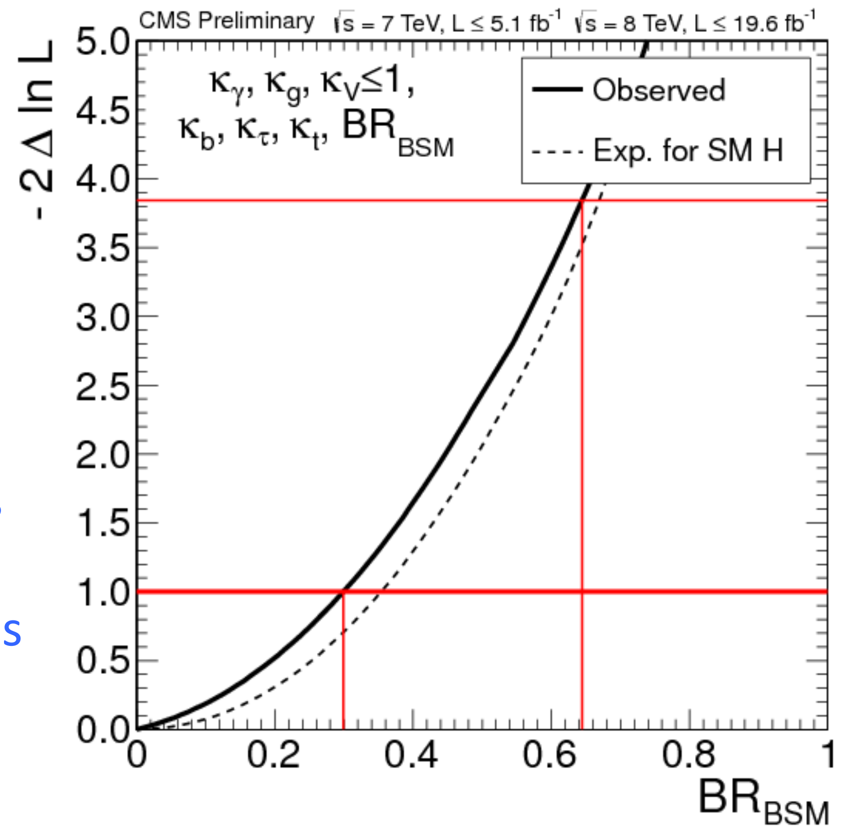
Given the precision of the existing measurements, the observed state is compatible with the SM Higgs boson.

There is plenty of room for BSM decays of the H(125).

Extended Higgs sectors:

- additional SM-like Higgs: high mass searches
- MSSM: 2 complex scalar fields, 5 bosons
- NMSSM: MSSM + additional singlet, 7 bosons
- 2HDM: more general model with 2 scalar fields (MSSM is a type II 2HDM)
- exotic H bosons: fermiophobic, invisible

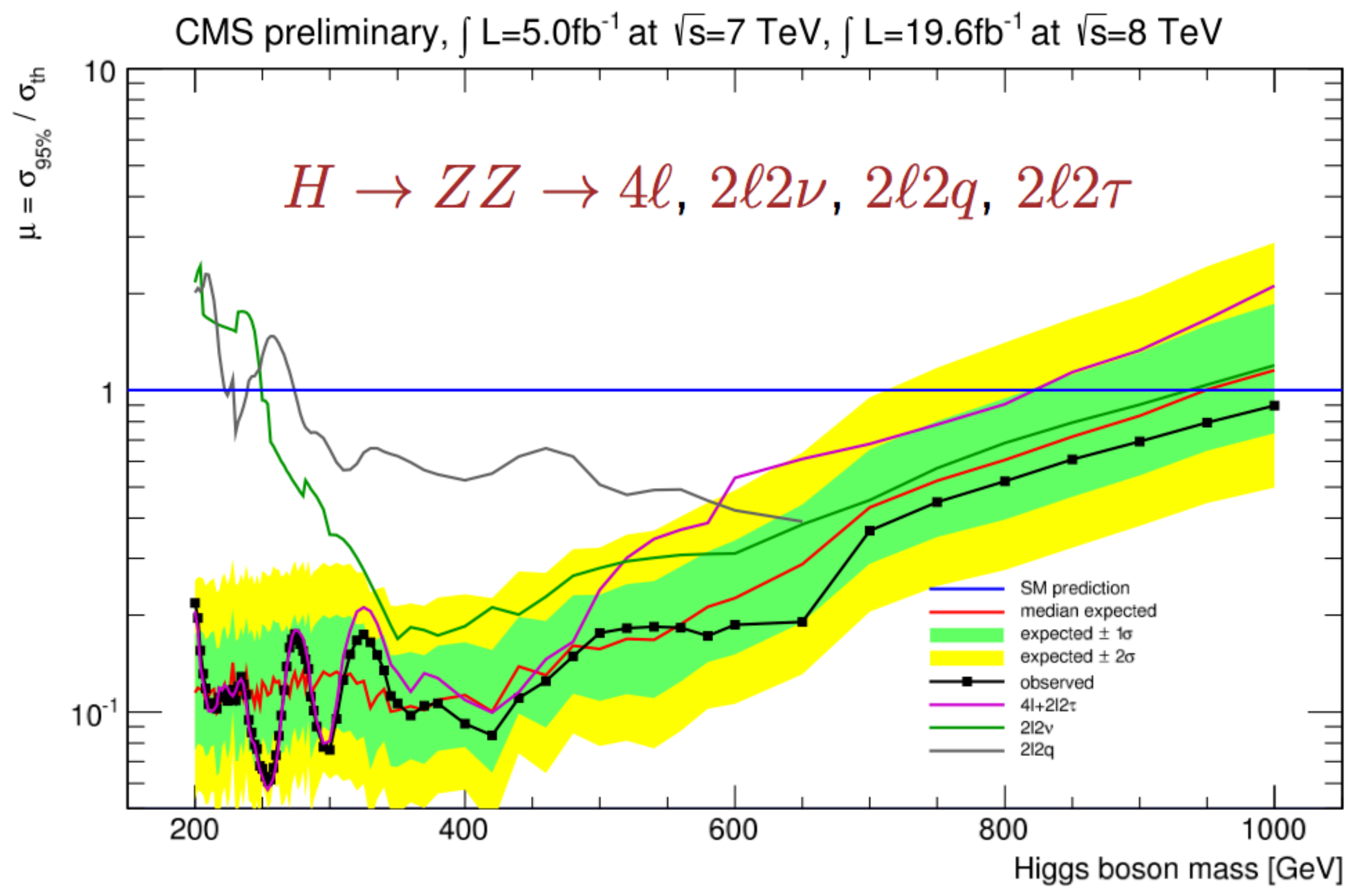
BR_{BSM} < 52% at 95% CL



H ➛ ZZ: high mass Higgs search

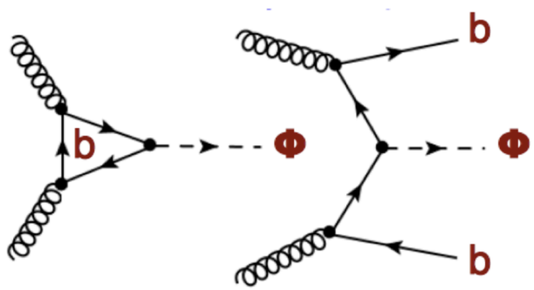
Combine all the H➛ZZ final states. Full dataset analyzed: SM-like Higgs boson excluded in the mass range from 200 GeV to 1 TeV.

Interpretation of the results in BSM models ongoing: EW singlet, 2HDM.



Search for MSSM H➛ττ

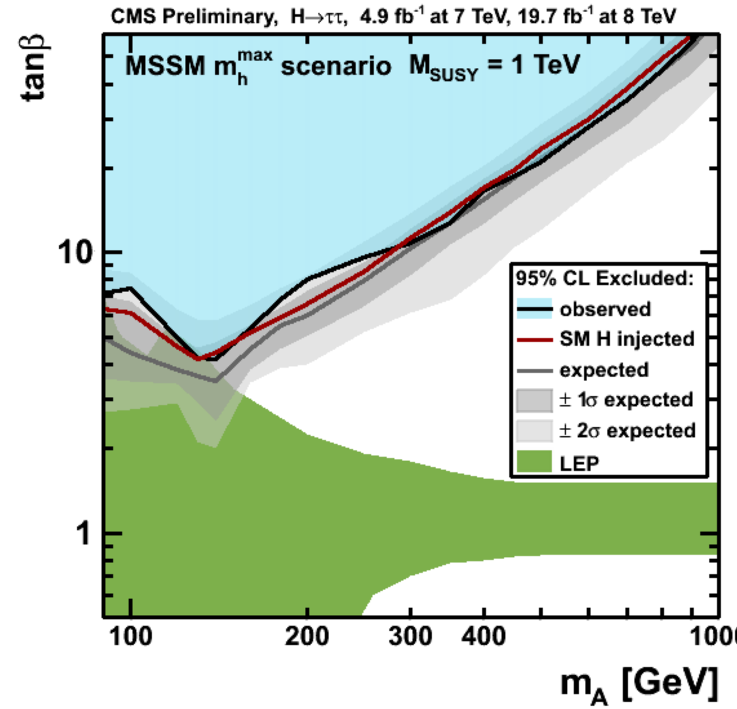
H ➛ ττ is enhanced in MSSM for large tanβ:

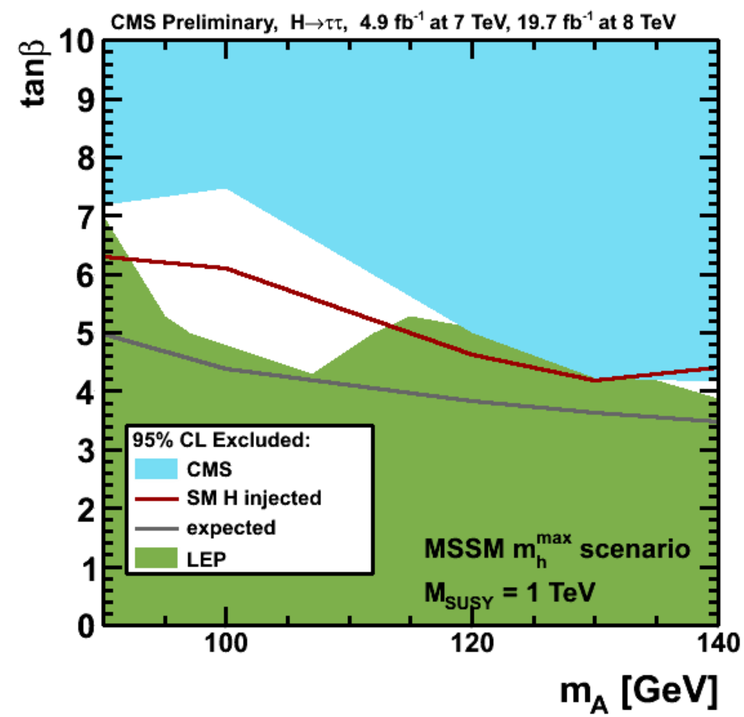


Final states: $\mu\tau_h$, $e\tau_h$, $e\mu$, $\mu\mu$, $\tau_h\tau_h$.

Sensitivity increased by selecting events in two exclusive categories: 0 b-jets and ≧ 1 b-jet.

Large region of tanβ–m_A plane excluded in the m_H^{max} scenario. Other interpretations in progress.



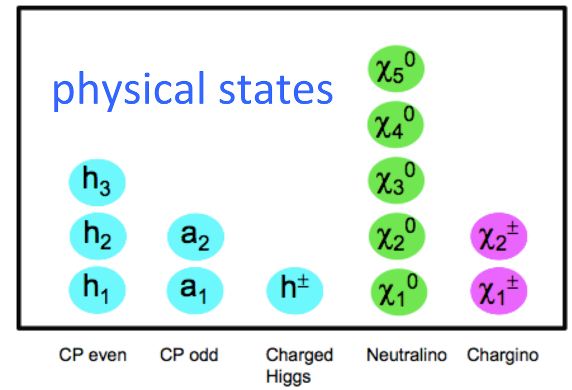


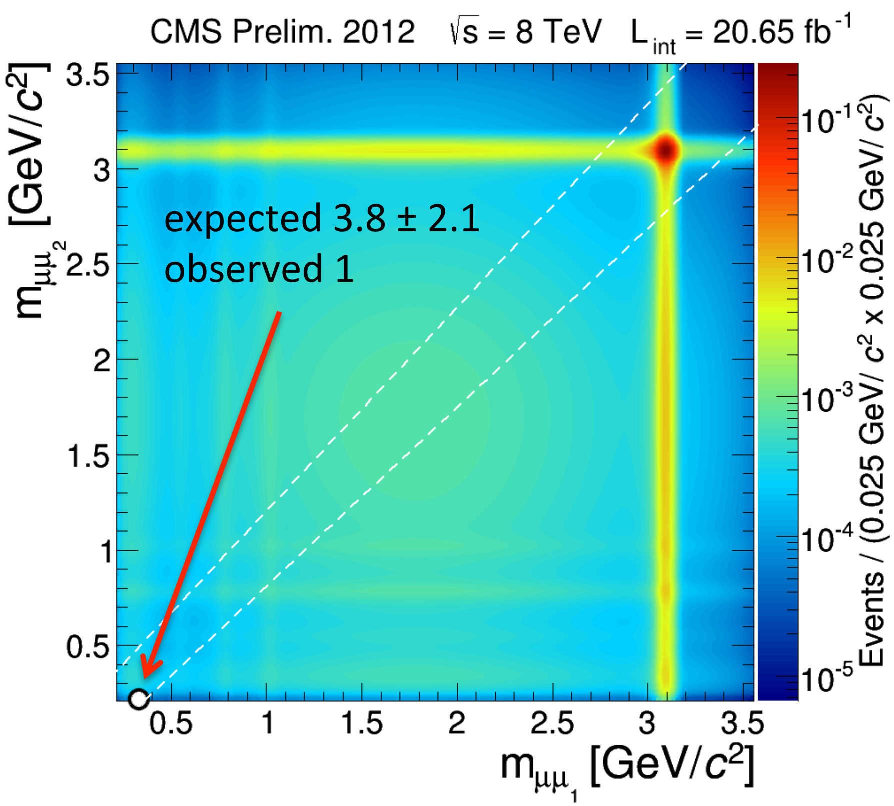
NMSSM: $h_{1,2} \rightarrow a_1 a_1 \rightarrow \mu\mu\ \mu\mu$

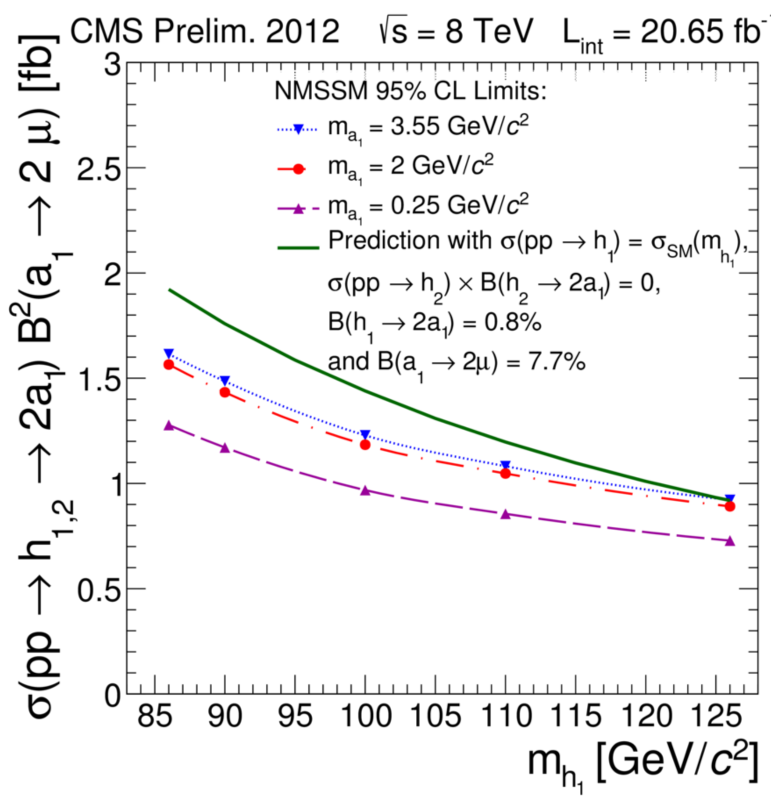
2 complex Higgs doublets plus an additional scalar field. Either h1 or h2 could correspond to observed H(125), and $m_{a1} < 2m_\tau$.

BSM H decay into 2 pairs of boosted muons, with $m_{\mu\mu 1} \approx m_{\mu\mu 2}$.
Background from J/ψ and bb events, decaying to muons.

Search for light a_1, with mass in the range 0.25-3.55 GeV.





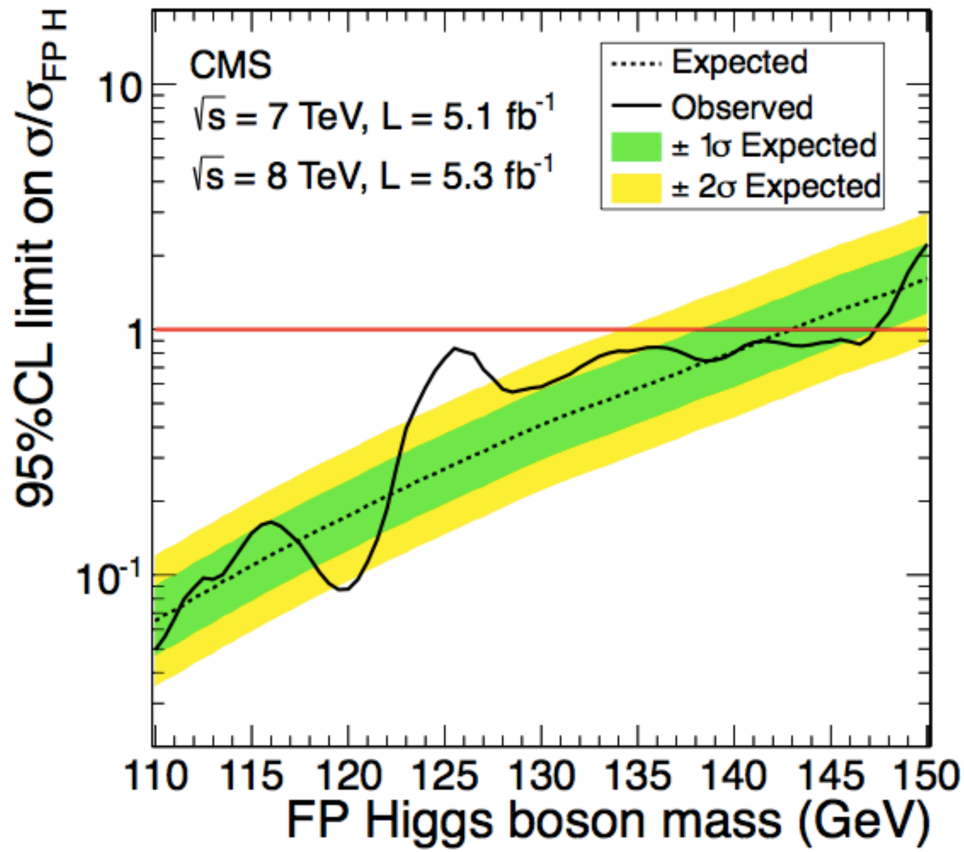


Fermiophobic Higgs

If a Higgs boson does not couple to fermions ggH production is impossible.

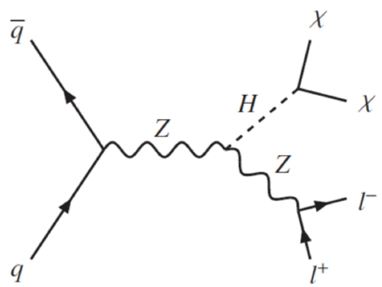
Standard production mechanisms are VBF (qqH) and VH, enhanced BR's for diboson channels.

SM-H-like analysis excludes fermio-phobic Higgs within m_H = 100-147 GeV.



Invisible Higgs

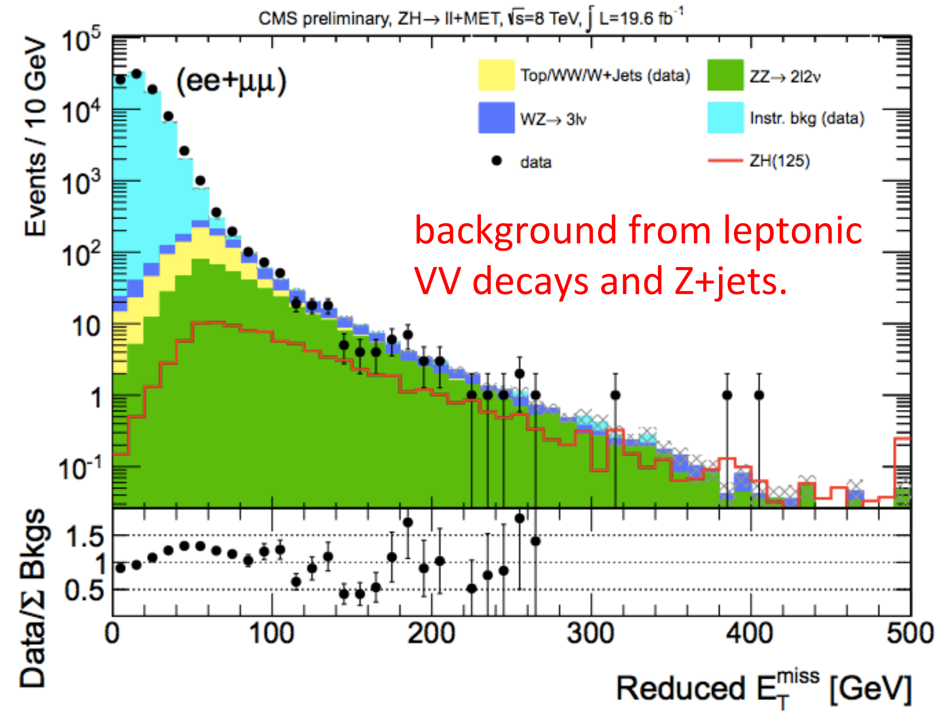
A Higgs decaying with a significant fraction to invisible particles might be detectable in ZH events, with $Z \rightarrow \ell^+\ell^-$ and large missing ET.

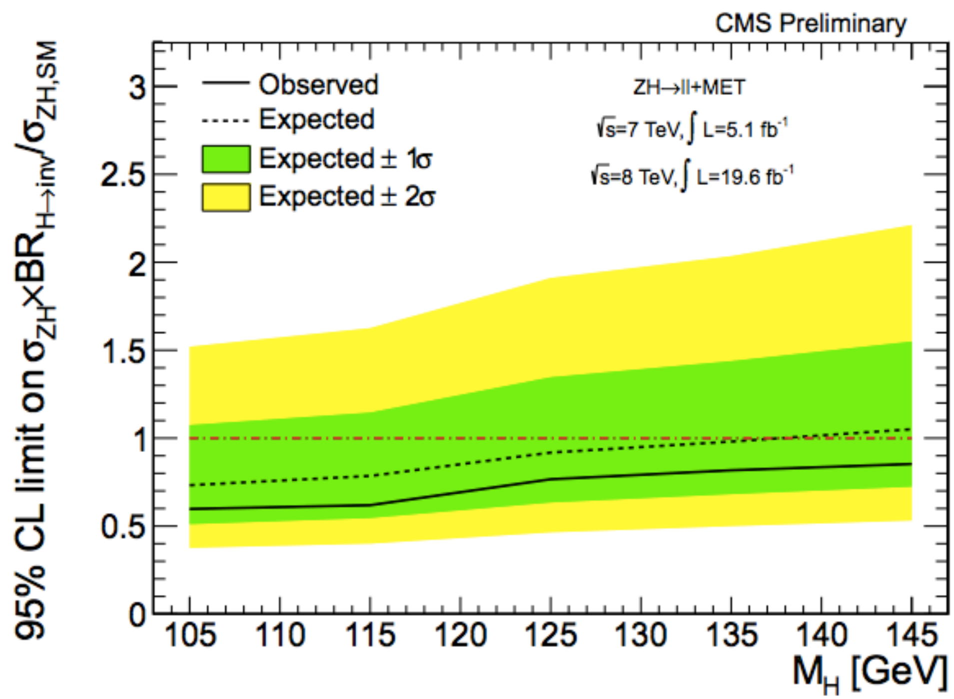


Invisible BR < 75% at 95% CL for SM Higgs @ 125 GeV.

Invisible Higgs can also be searched in VBF (qqH): invisible BR < 69% at 95%.

Plenty of room for invisible decay modes.





Future of LHC

ultimate luminosity **3000 fb^{-1}**

LHC schedule beyond LS1

Only EYETS (19 weeks)   (no Linac4 connection during Run2)

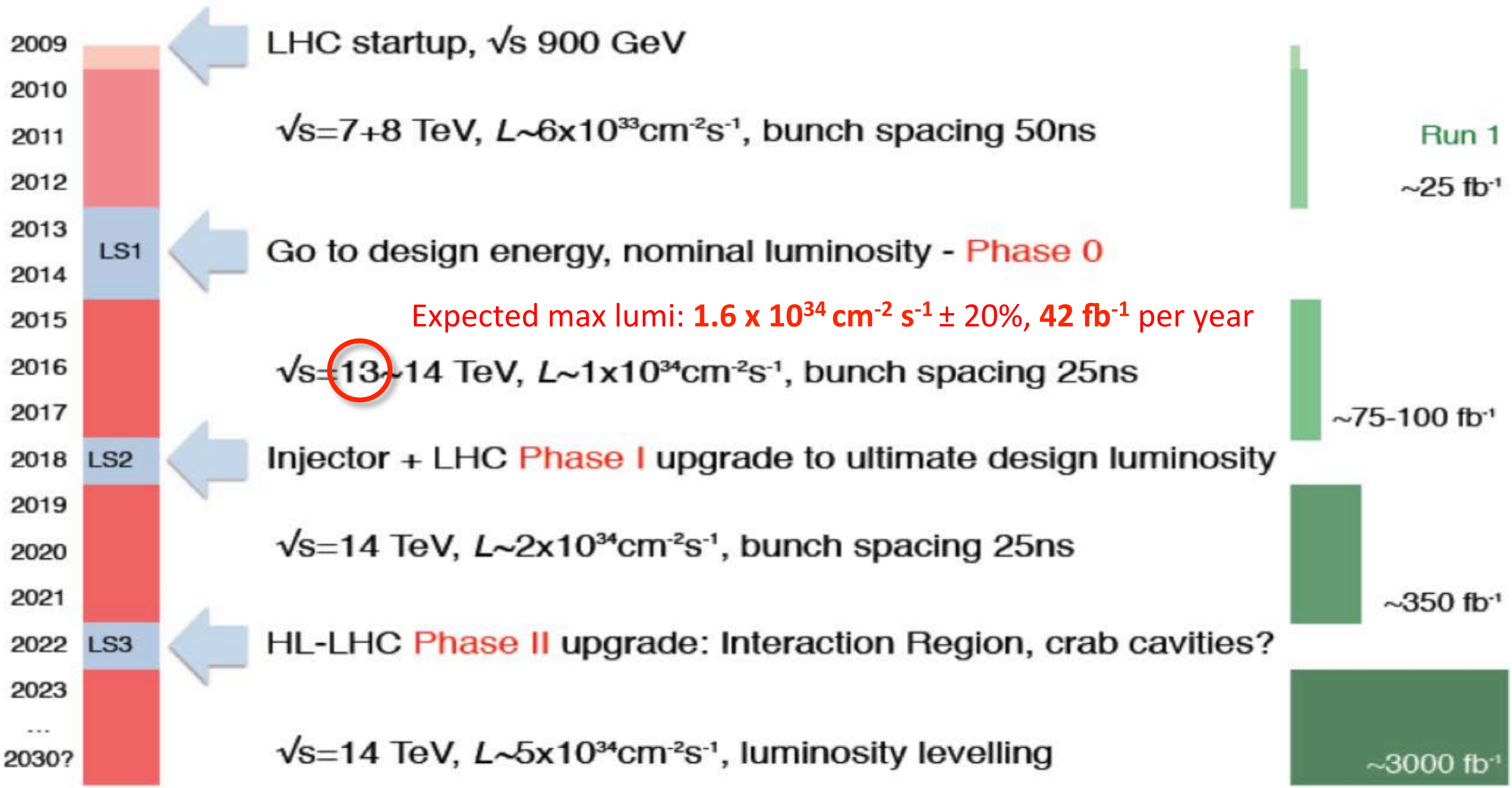
LS2   starting in 2018 (July)   18 months + 3months BC (Beam Commissioning)

LS3   LHC: starting in 2023 =>   30 months + 3 BC

injectors: in 2024   =>   13 months + 3 BC

LHC schedule approved by CERN management and LHC experiments spokespersons and technical coordinators
Monday 2nd December 2013

CMS upgrade

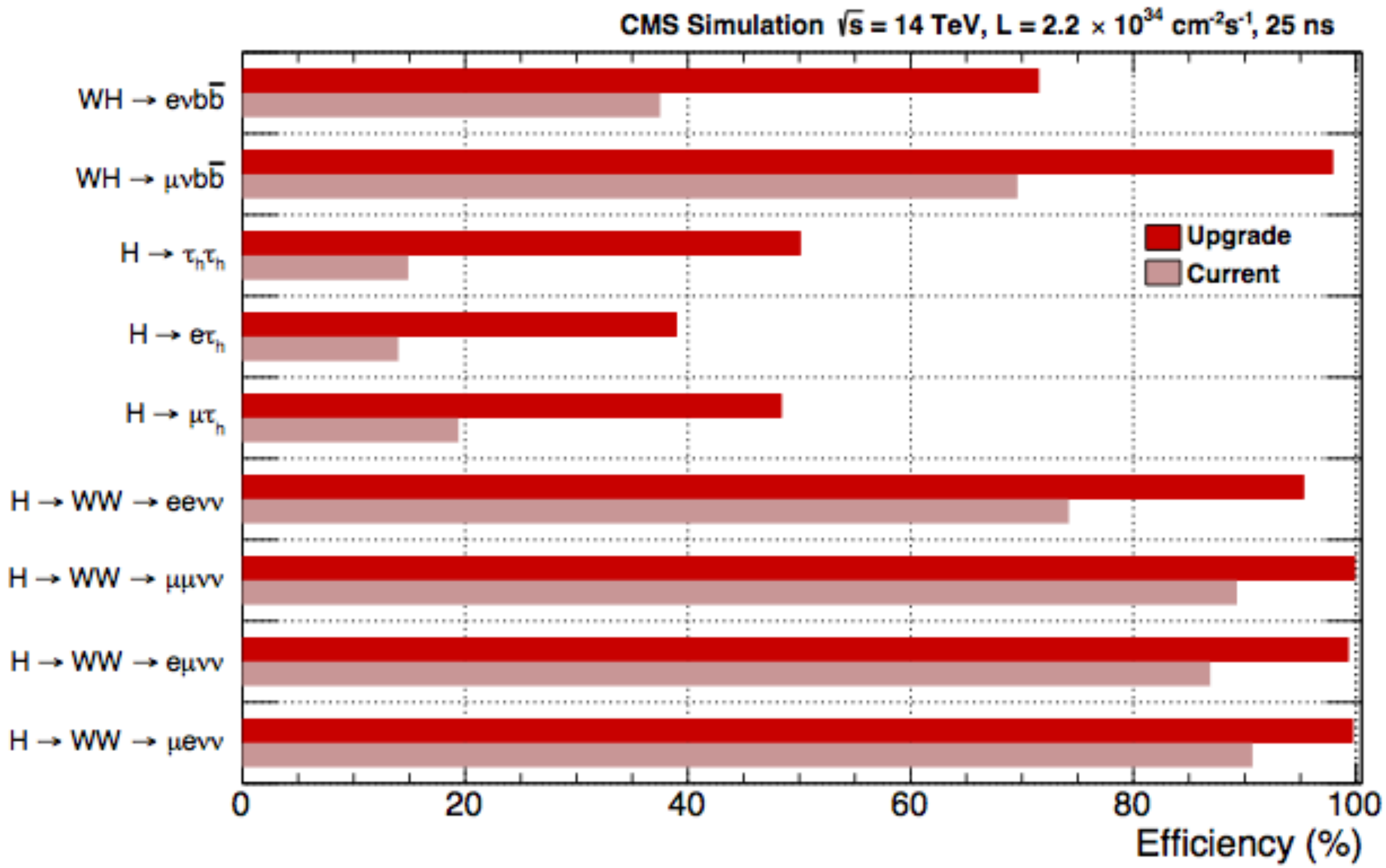


LS1: complete muon coverage (ME4), improve muon trigger, DT electronics, replace HCAL photo-detectors in Forward (new PMTs) and Outer (HPD→SiPM)

LS2: new pixel detector, HCAL SiPM and electronics, L1 trigger upgrade

LS3: new tracker and forward detectors, further trigger upgrade

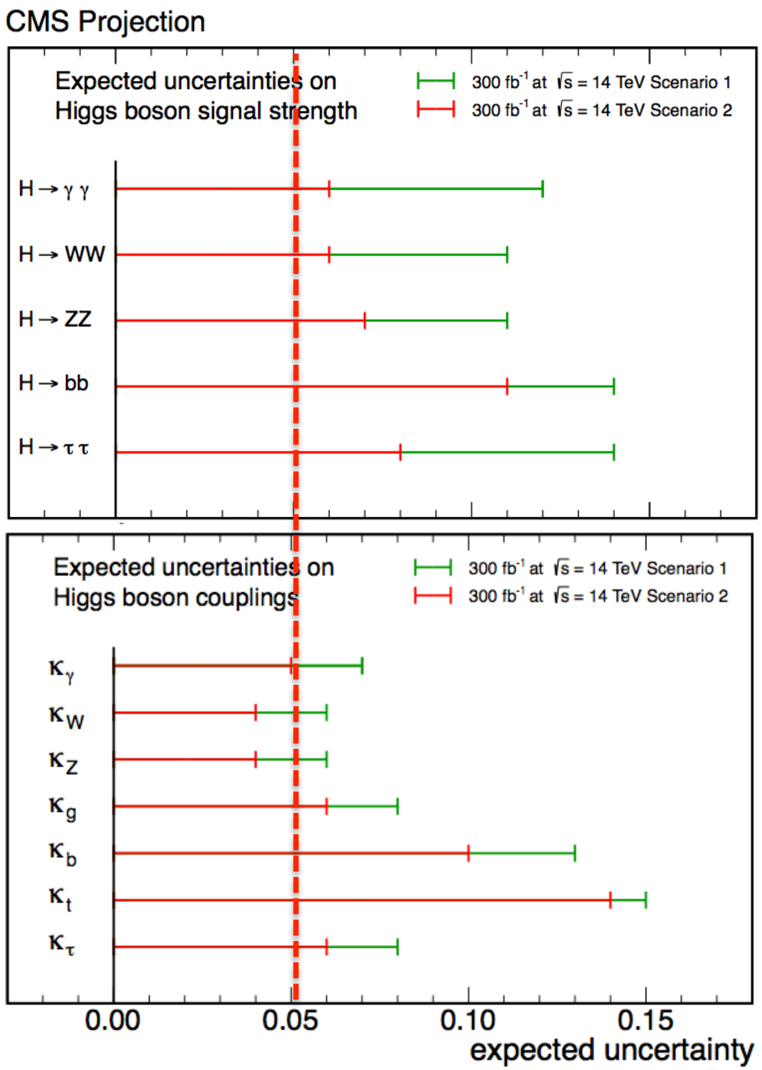
performance after upgrade

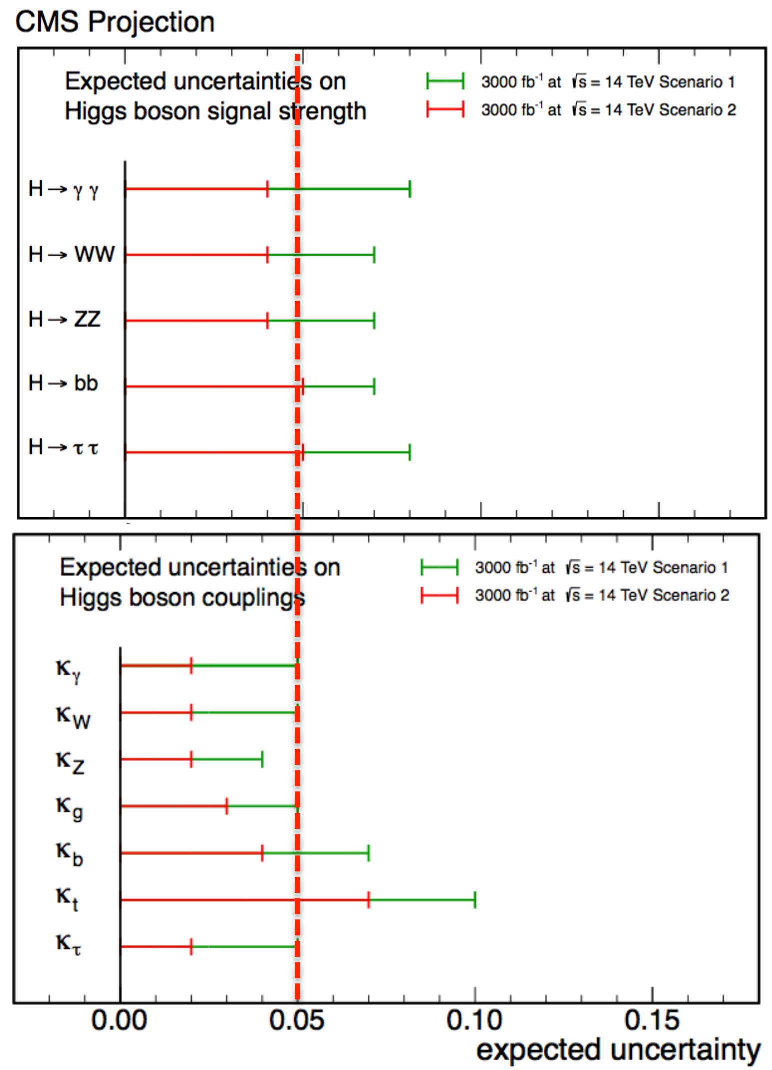


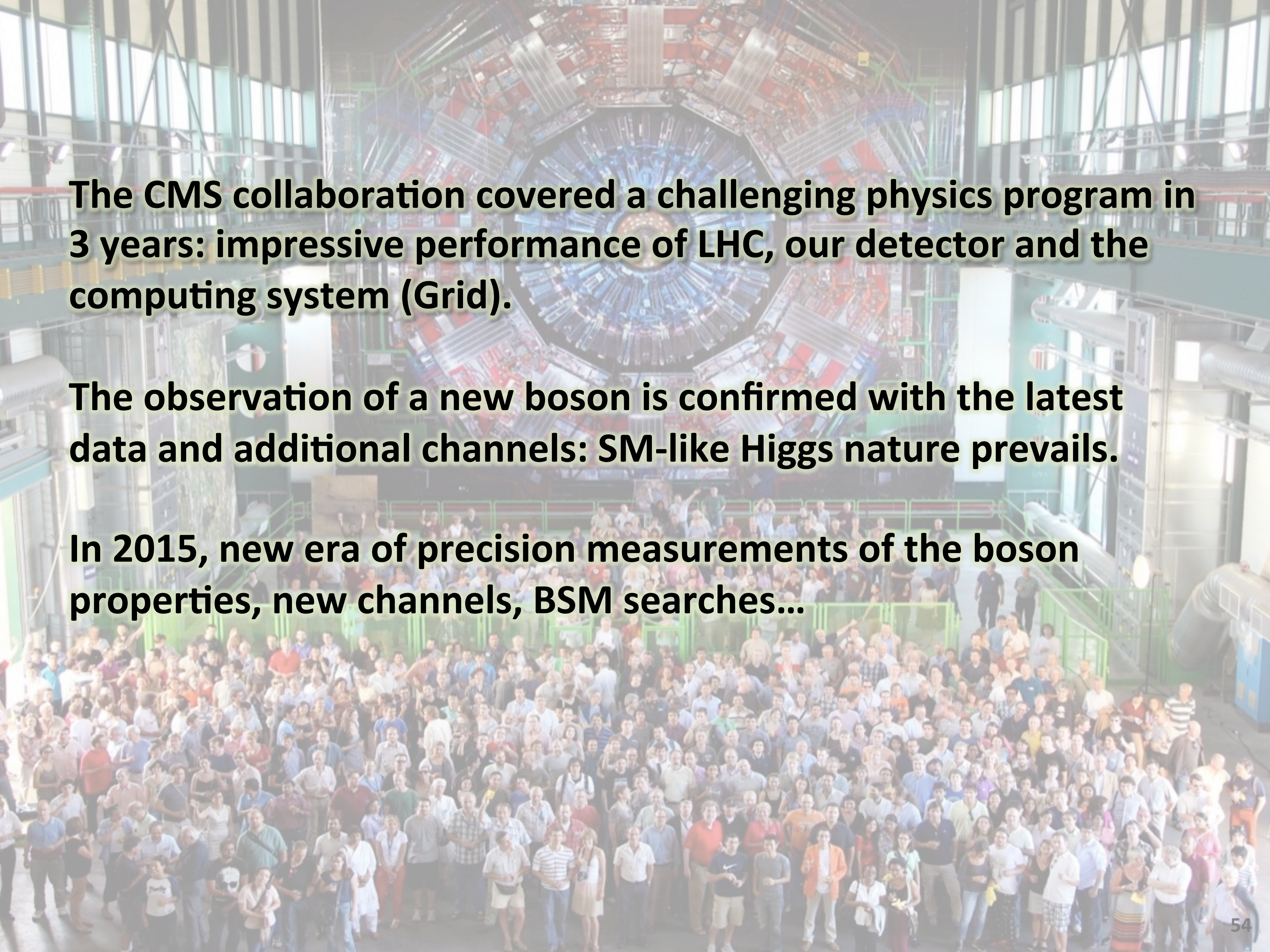
Just an example, most analyses will greatly benefit from the upgraded detector.

The new pixel detector (after LS1.5) will improve significantly tracking and vertex reconstruction.

H couplings in the long term







The CMS collaboration covered a challenging physics program in 3 years: impressive performance of LHC, our detector and the computing system (Grid).

The observation of a new boson is confirmed with the latest data and additional channels: SM-like Higgs nature prevails.

In 2015, new era of precision measurements of the boson properties, new channels, BSM searches…

CMS results - public documents

All CMS results can be found in

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

Specific pages for major topics:

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

where XYZ = HIG, TOP, SUS, EXO …