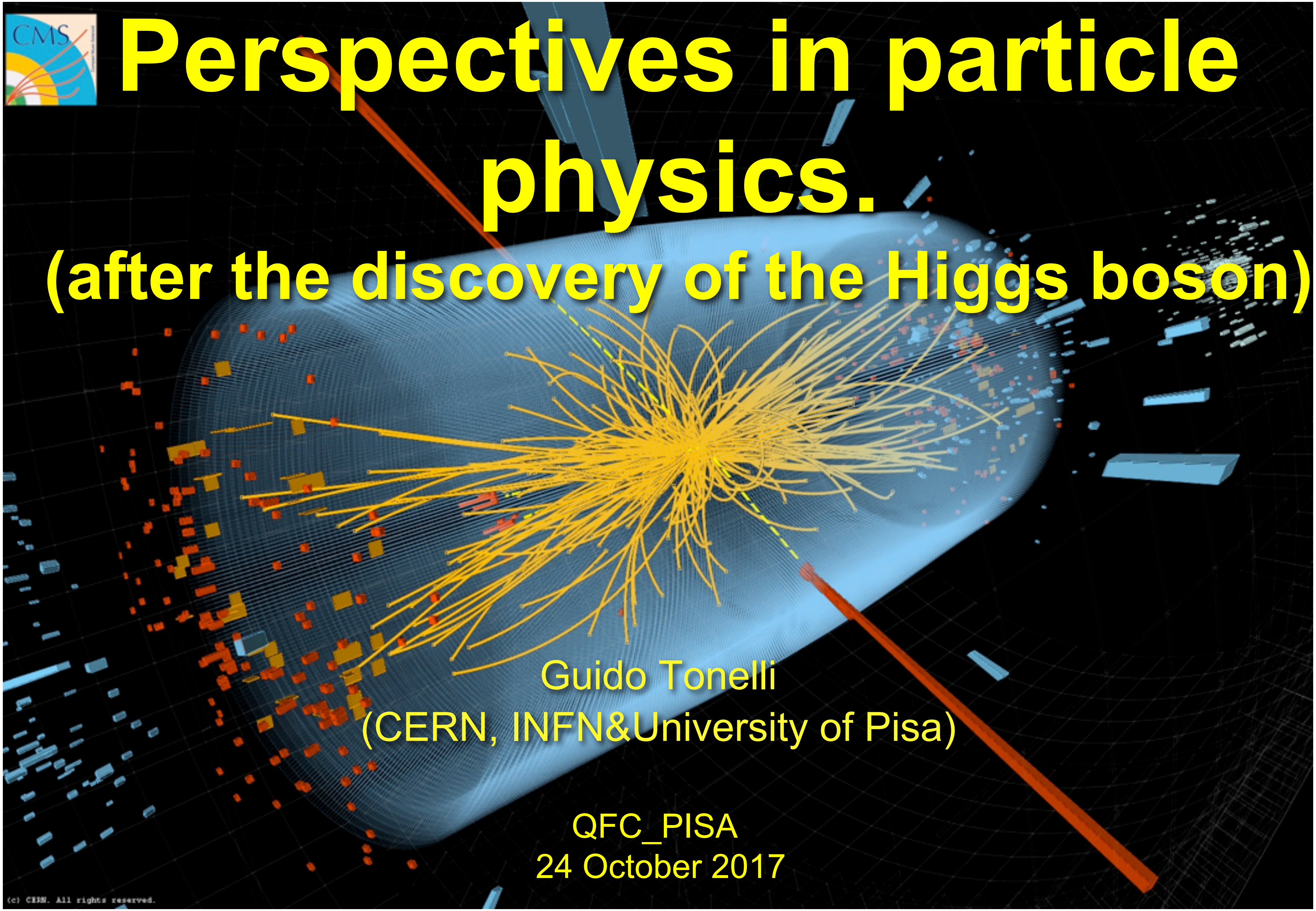
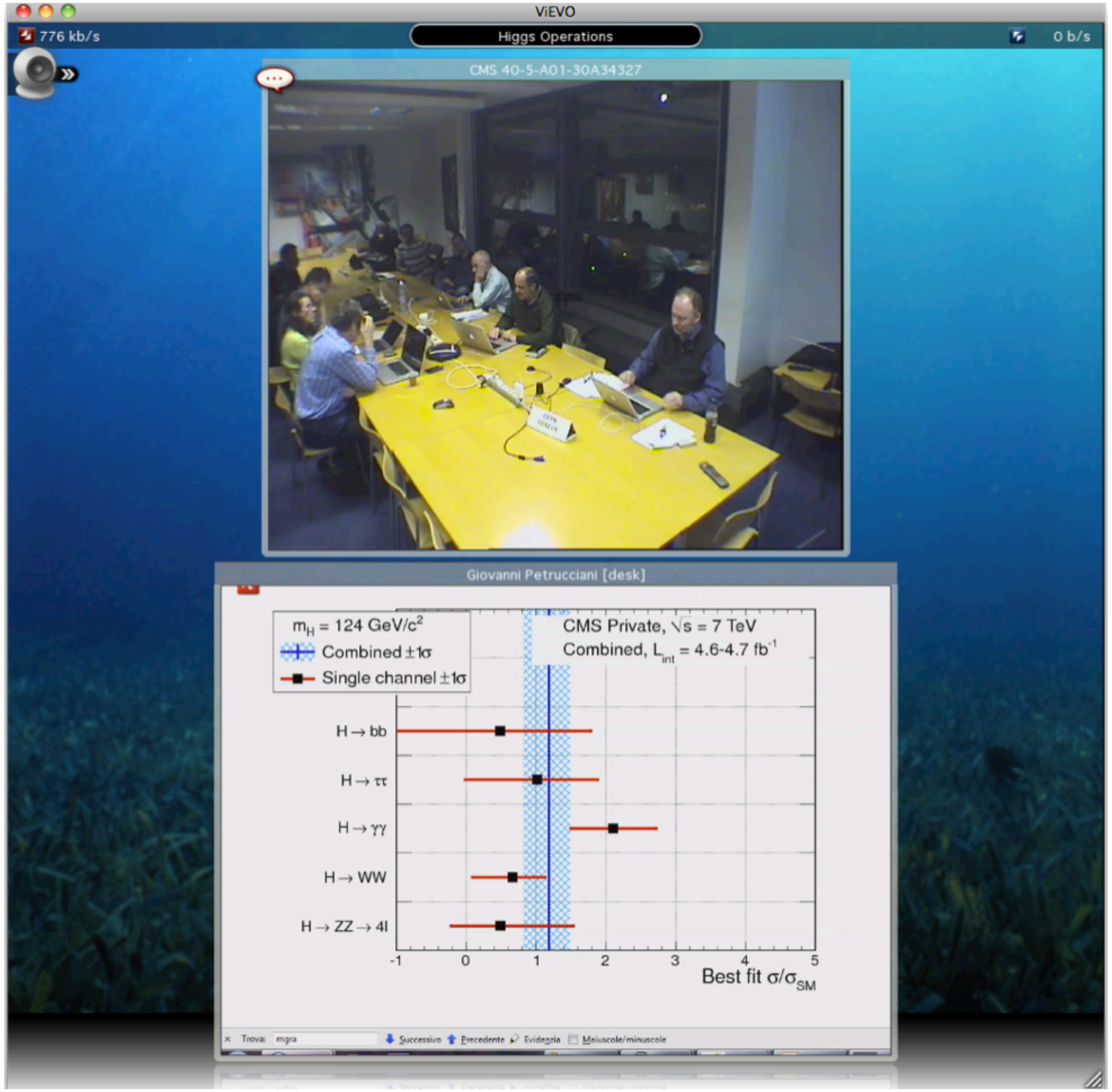
Perspectives in particle physics.
(after the discovery of the Higgs boson)



Guido Tonelli
(CERN, INFN&University of Pisa)

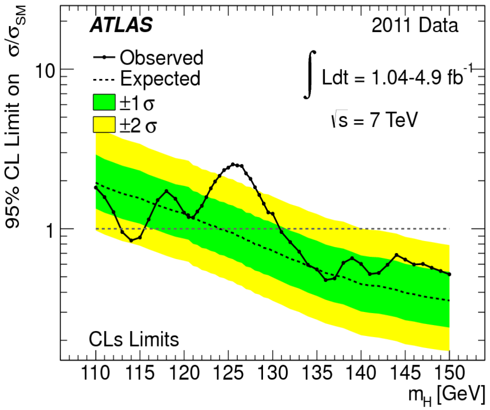
QFC_PISA
24 October 2017

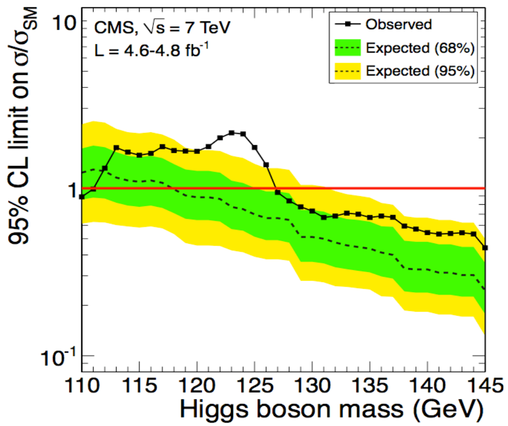
Hectic moments Dec.10 2011 19:08:56



December 13th 2011: the moment of truth.

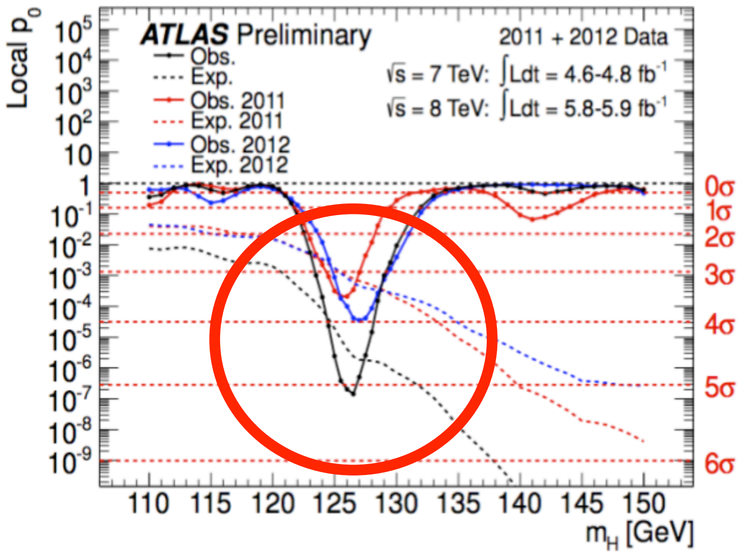
First evidence of an excess around 125 GeV



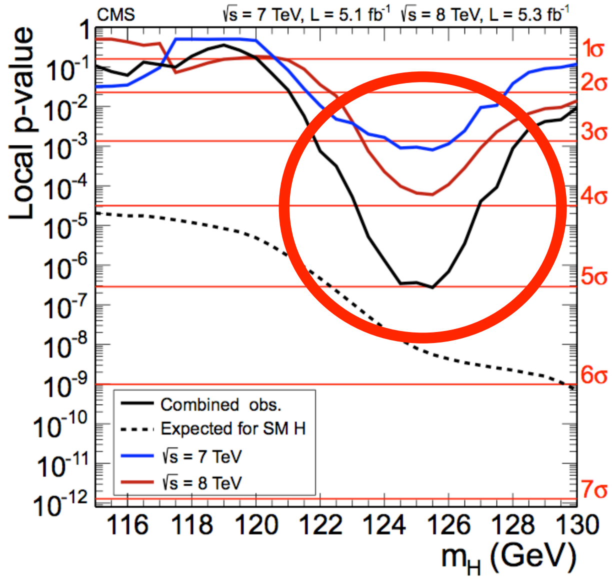


July 4th 2012: Higgsdependence day.

Discovery of a Higgs-like boson at LHC.



Combined significance 5.0σ at 125-126GeV for each experiment.



Observation of a New Particle in the Search for the Standard Model Higgs Boson with the ATLAS Detector at the LHC

arXiv: 1207.7214v1.

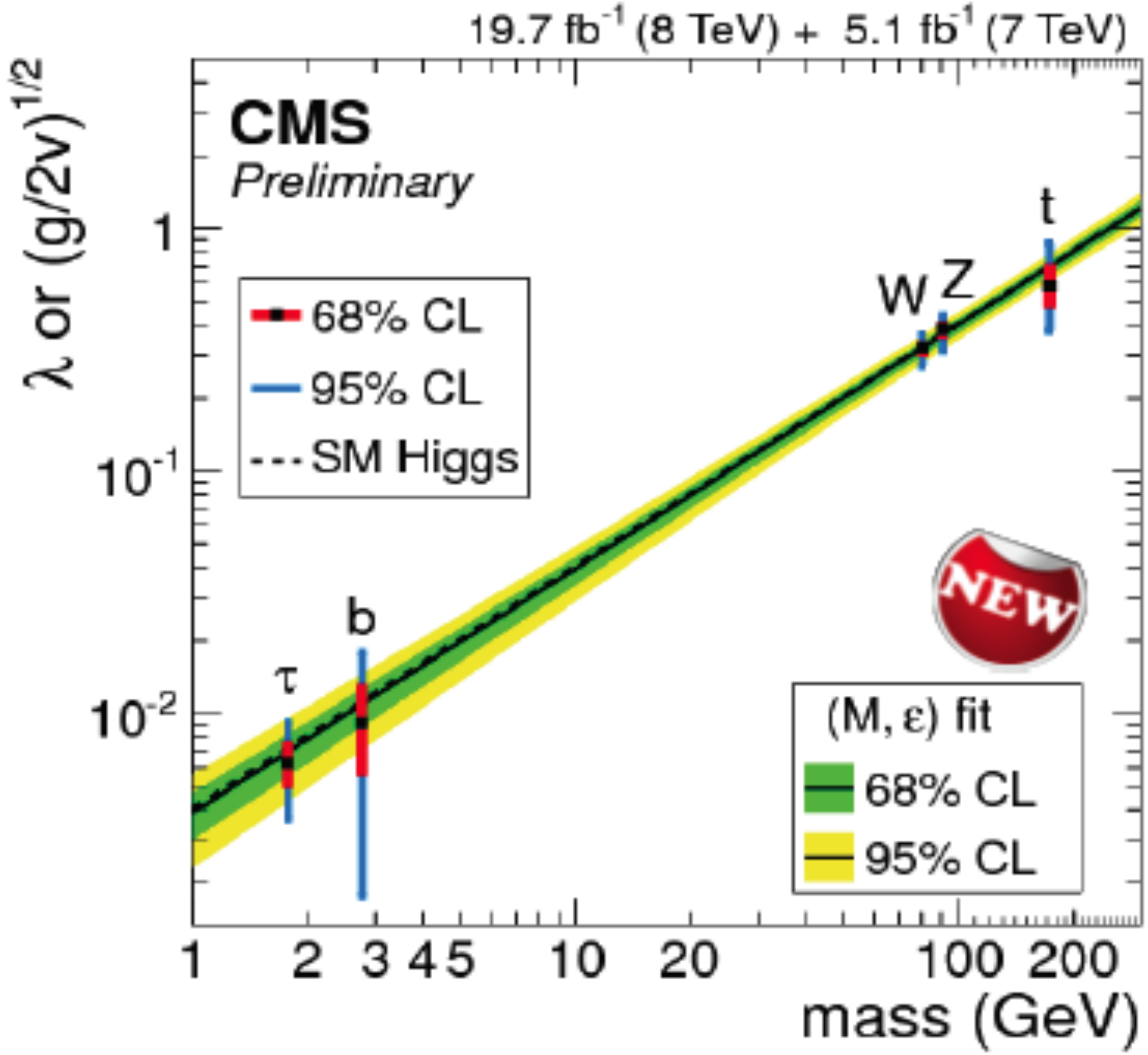
Observation of a New Boson at a Mass of 125 GeV with the CMS Experiment at LHC

arXiv 1207.7235v1

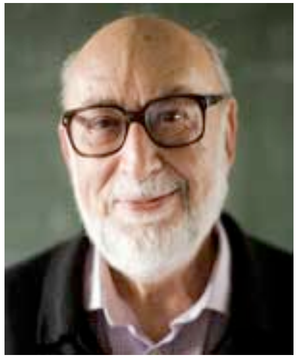
It walks like a duck, quacks like a duck….

It is a spin 0 particle.

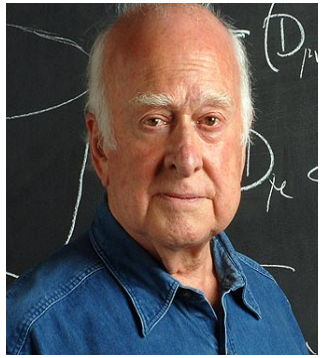
The strength of its interactions with the SM particles is very similar to what was predicted by R. Brout, F. Englert and P. Higgs back in 1964.



Nobel Prize for Physics 2013



Francois Englert



Peter Higgs

jointly assigned to François Englert and Peter W. Higgs ***"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider "***

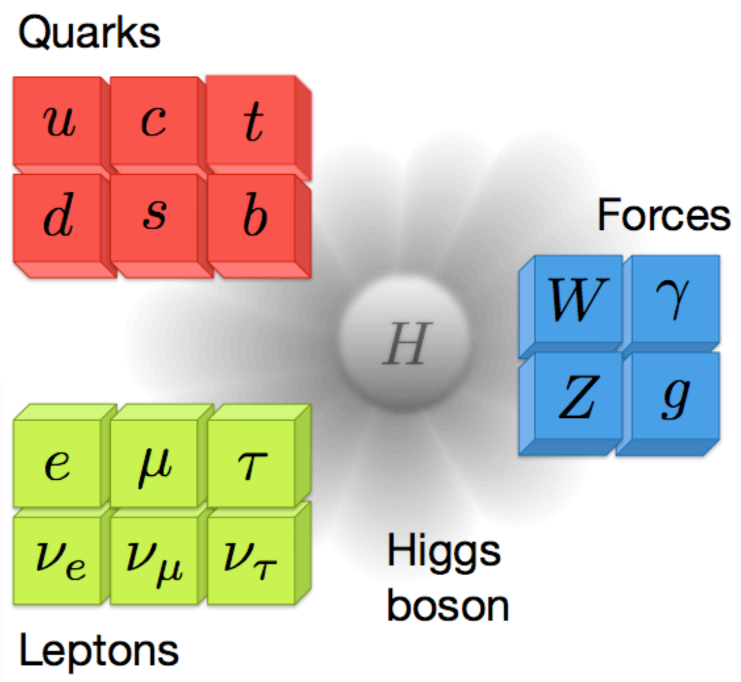
A new, fundamental particle has been discovered a few years ago. The Standard Model is now complete.

Where are we today?

The problematic triumph of the Standard Model

Despite this further success, we know that the SM does not explain several important observations:

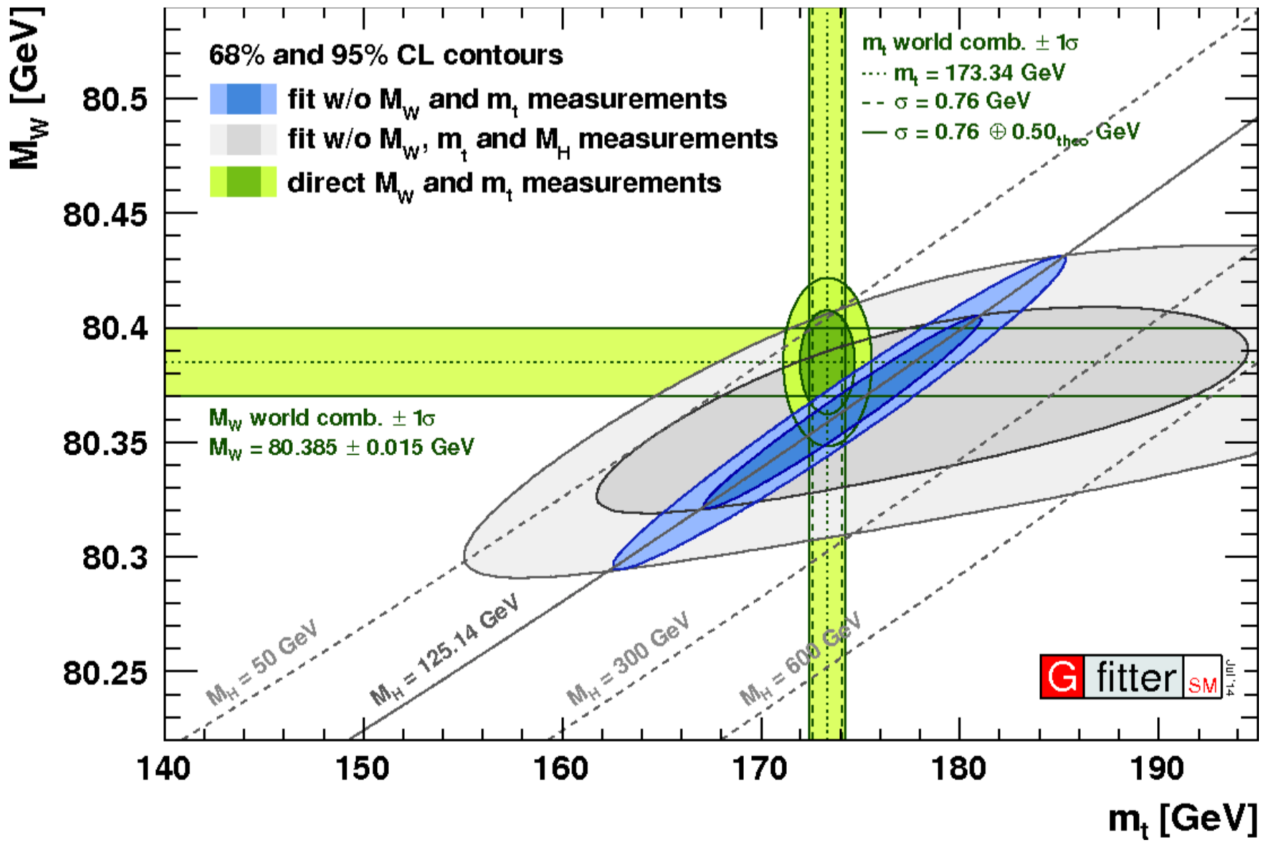
- **Dark matter.**
- **Dark energy.**
- **Inflation.**
- **Unification of forces and role of gravity.**
- **Neutrinos masses and hierarchy.**
- **Matter anti-matter asymmetry.**
- **Leptogenesis and bariogenesis.**
- **..**



To understand all this we need to look for physics beyond the Standard Model; **but at which energy scale?**

No much room left for new physics.

New Electroweak fit

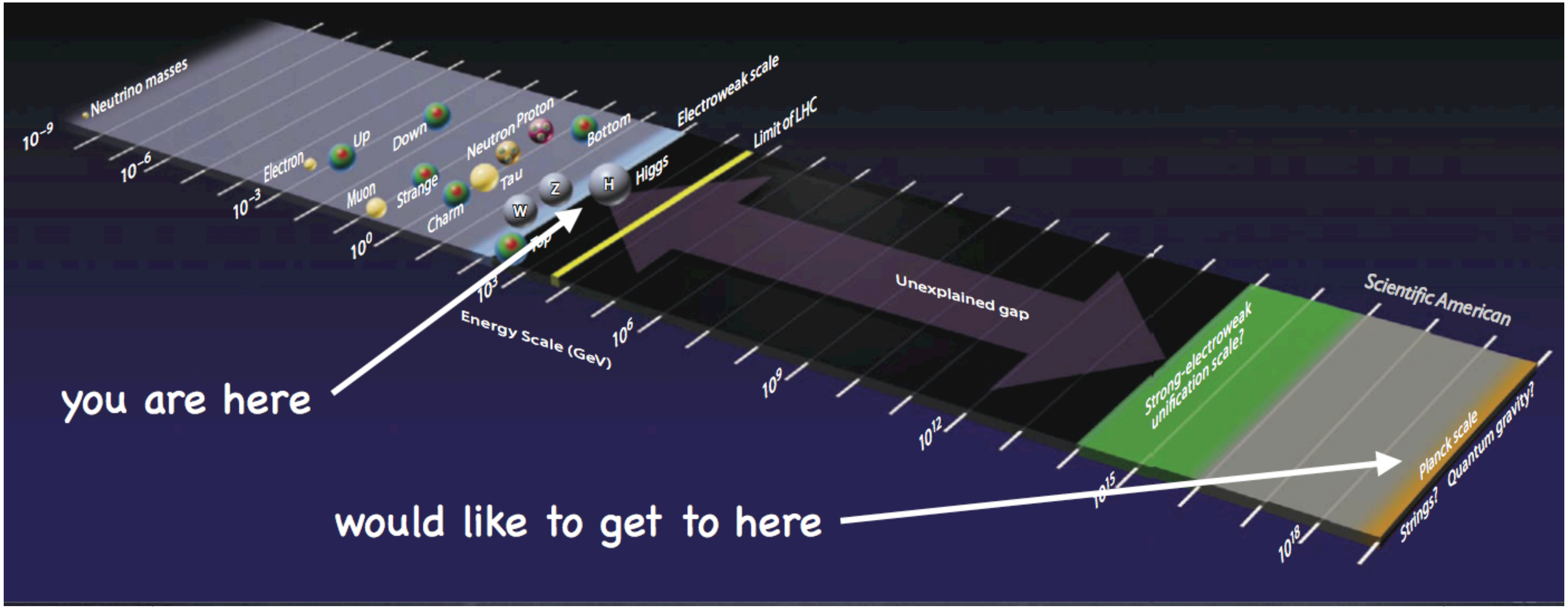


New physics, if it does exists, appears to be weakly coupled to the Electroweak scale.

A 125GeV boson is a very special object

A light boson, could in principle rule its self-interaction and the Yukawa interactions with fermions in such a way that the theory could remain weakly coupled up to the Planck scale without any dynamics appearing beyond the EWK scale.

This would be in itself an outstanding discovery: for the first time we would have seen a phenomenon that could be described by the same theory over 15 orders of magnitude in energy.

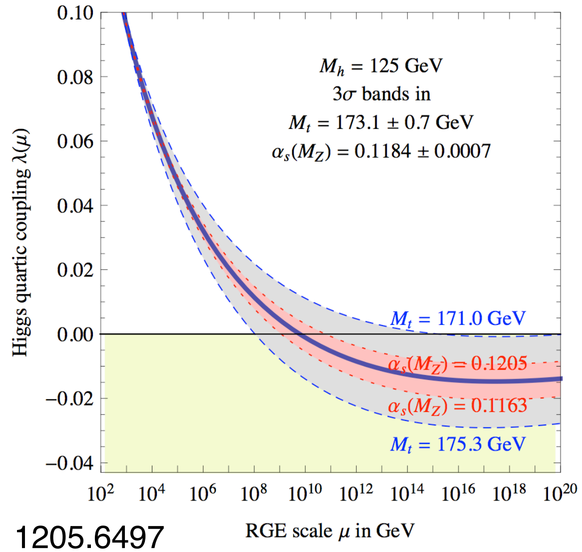


The importance of precision measurements

Is the Higgs potential vanishing at M_{Pl} ?

EWSB determined by Planck physics? absence of new energy scale between the Fermi and the Planck scale? Anthropic or natural EWSB?

$$\lambda(M_{\rm Pl}) = -0.0144 + 0.0028\left(\frac{M_h}{\rm GeV} - 125\right) \pm 0.0047_{M_t} \pm 0.0018_{\alpha_s} \pm 0.0028_{\rm th}$$



1205.6497

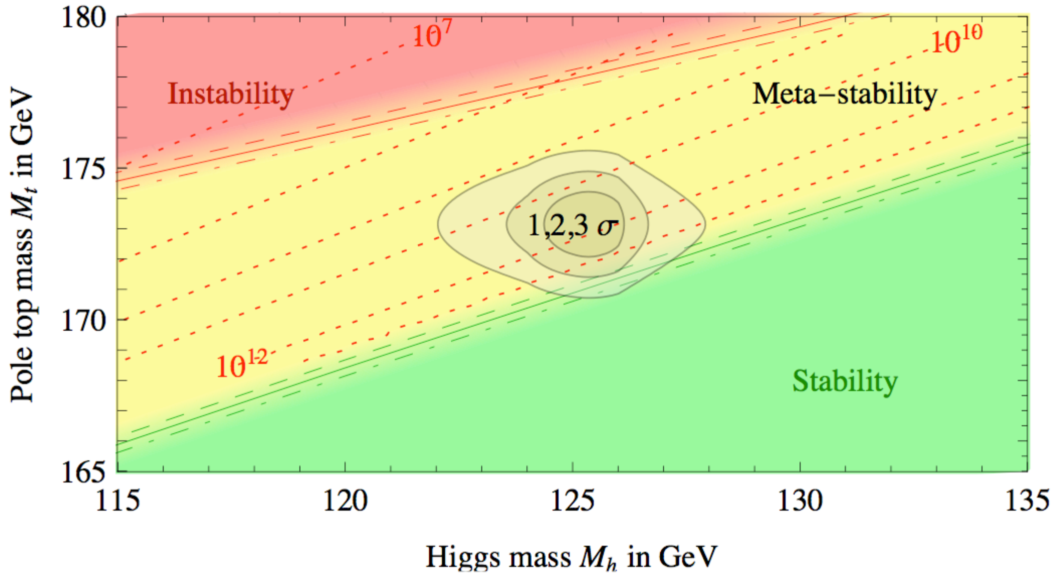
Although possible, this scenario would be severely constrained by the need that the couplings of the boson must be finely tuned to very well predicted values.

Precision measurements of the couplings could lead to unambiguous hints of the presence of New Physics beyond the EWK scale.

The Higgs boson properties must be studied in great detail with the goal of a <1% accuracy in the couplings.

Is the EWK vacuum stable ?

With a heavy top quark and a 125GeV Higgs the EWK vacuum in our Universe appears to be in a meta-stable state. The Higgs potential could develop an instability around **$10^{11\text{-}12}$ GeV**, with a lifetime still much longer than the age of the Universe. However, taking into account theoretical and experimental errors, stability up to the Planck scale cannot be excluded.



arXiv: 1205.6497

if $m_H = M_{stability}$ the SM is asymptotically safe, ie consistent up to arbitrary high energy

Precise determination of the Higgs mass as well as a new round of measurements of the top mass will be key ingredients of this game. Implications on the mass of RH neutrinos, temperature reheating after the inflation, leptogenesis etc.

if $m_H > M_{stability}$, the Higgs could serve as an inflaton

Could it be the inflaton?

Inflation is driven by a negative-pressure vacuum energy density

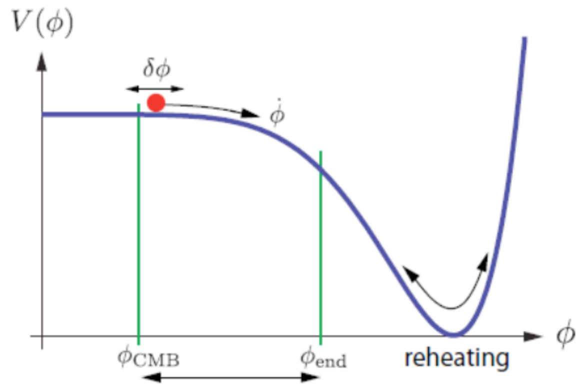
A slowly rolling scalar field could do the job

$$ds^2 = -dt^2 + a^2(t)d\vec{x}^2$$

$$\Rightarrow \quad \frac{\ddot{a}}{a} = -\frac{4\pi G}{3}(\rho + 3p)$$

$$\begin{cases} \rho = \frac{1}{2}\dot{\phi}^2 + V(\phi) \\ p = \frac{1}{2}\dot{\phi}^2 - V(\phi) \end{cases} \Rightarrow \quad \rho + 3p = 2(\dot{\phi}^2 - V(\phi))$$

$$\text{if} \quad \dot{\phi}^2 < V(\phi) \quad \Longrightarrow \quad \frac{\ddot{a}}{a} = -\frac{4\pi G}{3}(\rho + 3p) > 0$$



[Source - arXiv:0907.5424]

The Higgs potential could develop another minimum close to the Planck scale and sitting in this false EWK vacuum could drive the inflation and then end it through tunnel effect.

To match the amplitude of density perturbation the Higgs mass should have a well defined value: **m_H= 126.0± 3.5GeV** (for M_{top}=173.2GeV).

arXiv:1112.5430

SUSY and a 126GeV scalar

In the SM, the Higgs mass is essentially a free parameter.
In the MSSM, the lightest CP-even Higgs particle is bounded from above:
$M_h^{max} \approx M_Z |\cos 2\beta| +$ radiative corrections $\leq$110–135 GeV

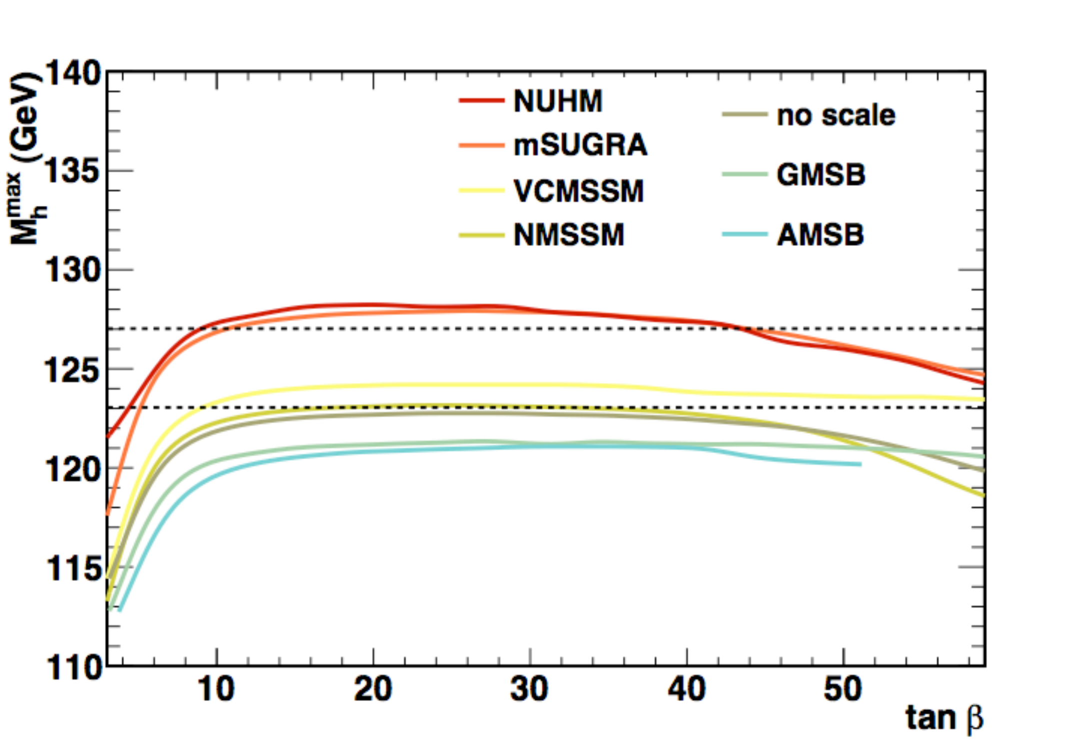
Imposing M_h places very strong constraints on the MSSM parameters through their contributions to the radiative corrections.

$$M_h^2 \overset{M_A \gg M_Z}{\approx} M_Z^2 \cos^2 2\beta + \frac{3m_t^4}{2\pi^2 v^2}\left[\log\frac{M_S^2}{m_t^2} + \frac{X_t^2}{M_S^2}\left(1 - \frac{X_t^2}{12 M_S^2}\right)\right]$$

- Important parameters for MSSM Higgs mass:
  - $\tan\beta$ and M_A
  - the SUSY breaking scale $M_S = \sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}}$
  - the mixing parameter in the stop sector $X_t = A_t - \mu\cot\beta$

SUSY models compatible with a 126GeV scalar

Maximal Higgs masses



A. Arbey, M. Battaglia, A. Djouadi, F.M., J. Quevillon, Phys.Lett. B708 (2012) 162

model	AMSB	GMSB	mSUGRA	no-scale	cNMSSM	VCMSSM	NUHM
$M_h^{\rm max}$	121.0	121.5	128.0	123.0	123.5	124.5	128.5

We have entered a new era.

In searching for physics beyond the Standard Model any new conjecture should include the new 125GeV object.

In addition, the Higgs boson itself will be used as a new, very sensitive, tool for the indirect detection of massive particles or new interactions.

Looking for Higgs decaying to dark matter.

The existence of dark matter in our universe is well established experimentally. The most recent data confirm that its amount is about five times that of ordinary matter.

Many extensions of the SM containing weakly interacting massive particles, like the lightest stable particles in SUSY, or the lightest Kaluza–Klein particle in extra dimensions, could explain dark matter.

Beyond the direct search of new massive particles, ATLAS and CMS search for invisible decay modes of the Higgs.

The typical signature for invisible H decays at LHC is a large missing transverse momentum recoiling against a distinctive visible system, usually a high-energy jet or a photon.

Study of the H invisible decay width.

There is still room for decays of H into invisible particles.

The search is done using two complementary approaches

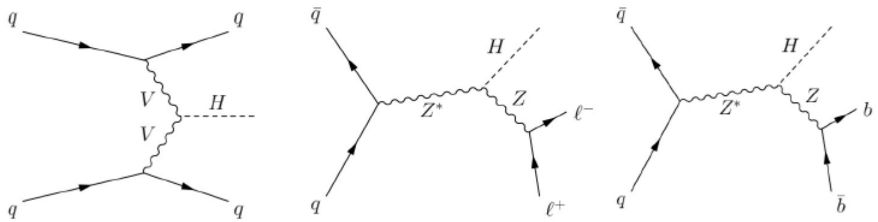
a) Fitting the invisible decay width from the coupling fits. Assuming SM coupling with possible BSM contributions in the loops

BR_{BSM}<40% at 95%CL @ 125GeV.

b) Using dedicated channels in looking for VBF production or associated production of a Higgs boson with a Z decaying leptonically or in b-jets.

arXiv:1701.02032

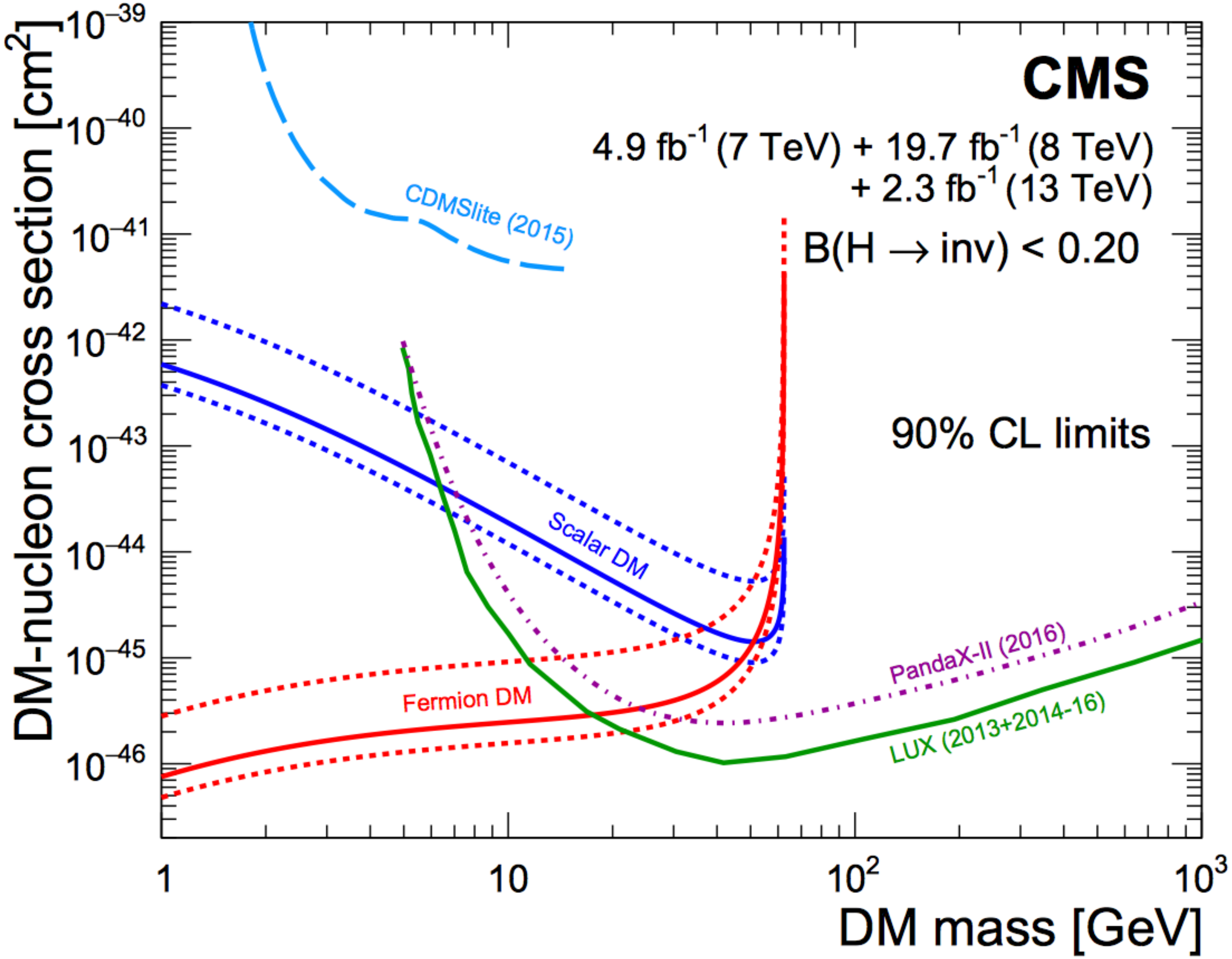
BR(H→χχ)<24% at 95%CL @ 125GeV.



Plenty of room for suprises.

Limits on DM-nucleon cross section.

Limits on the spin-independent DM-nucleon scattering cross section in Higgs-portal models assuming a scalar or fermion DM particle.



The LHC plans

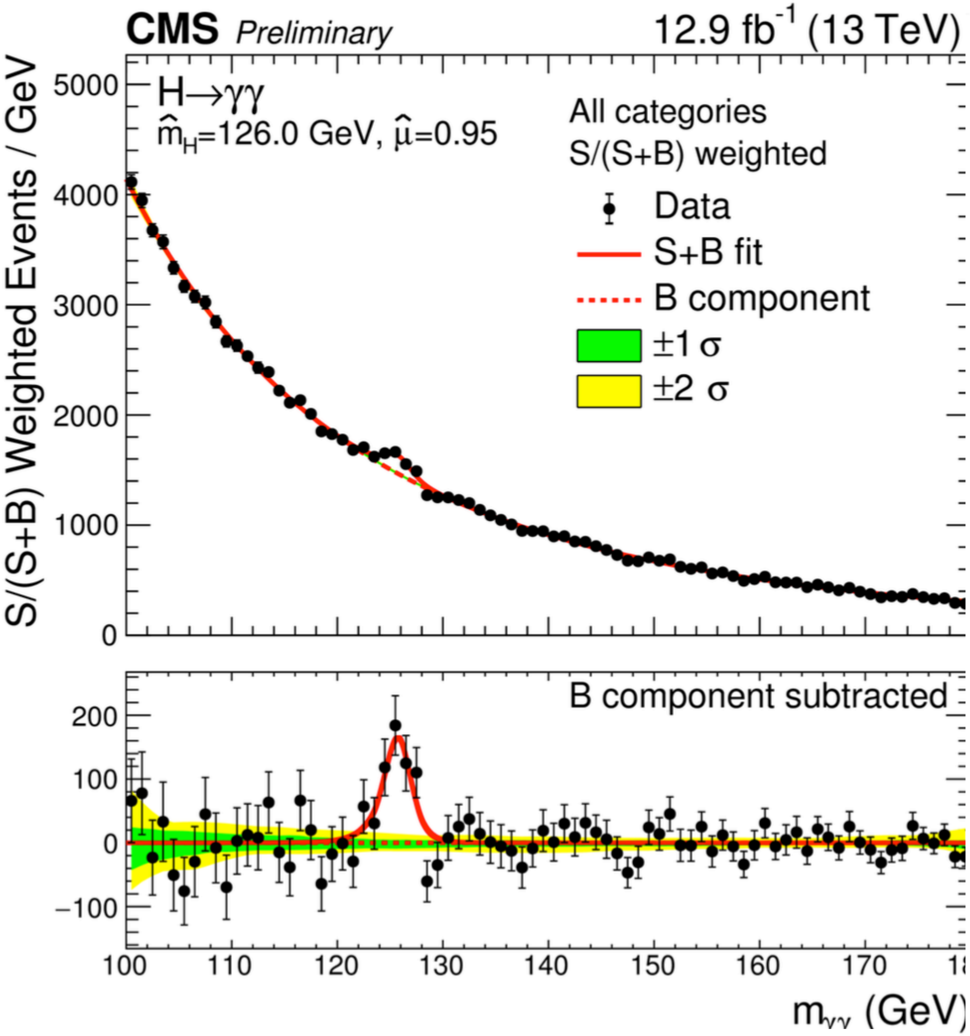
- **LHC RUN I**: 2012 run ended with ~23fb^{-1}
  - Combined with 2011 run (5.6fb^{-1}), a total **~25fb^{-1}**

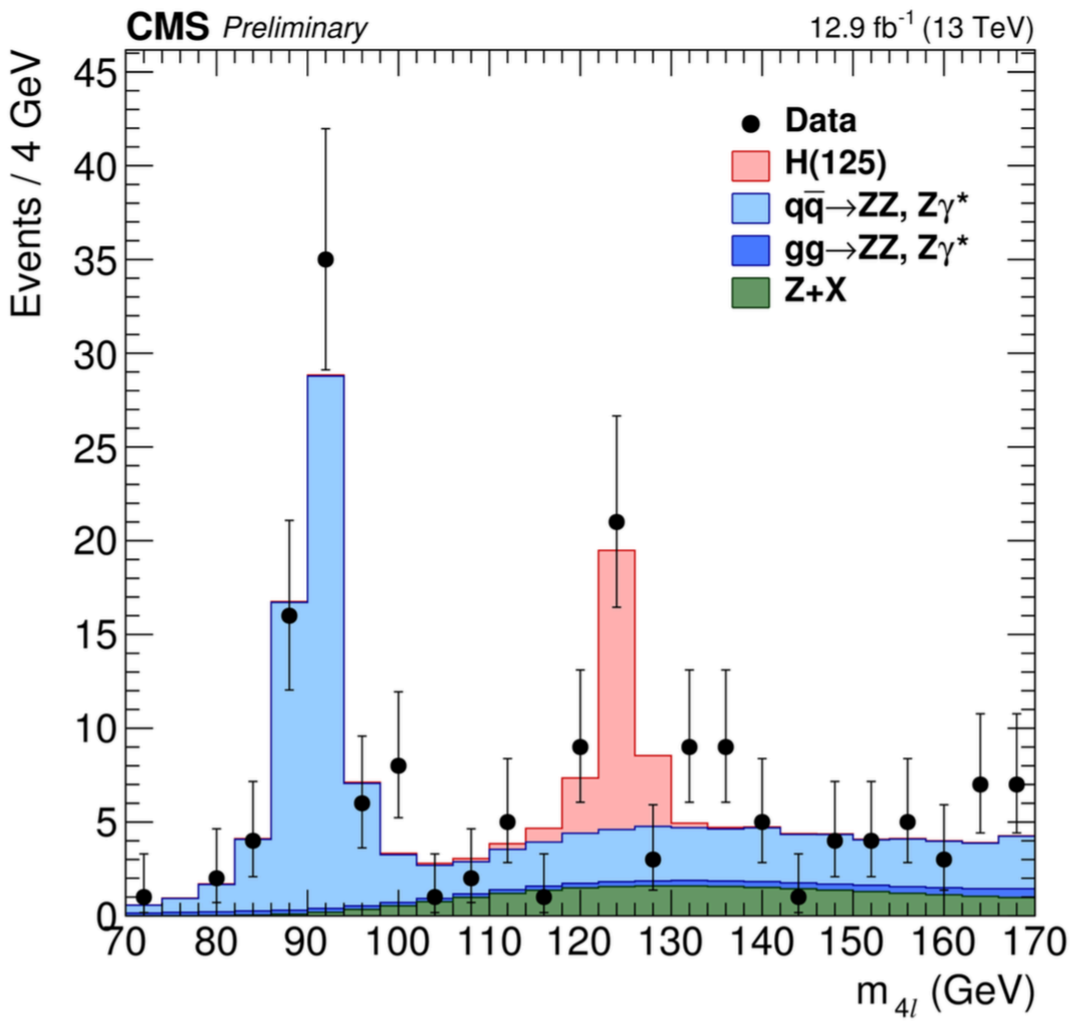
- Spring 2013 – 2014: shutdown (**LS1**) to go to 13TeV.
- **LHC RUN II a)**: 2015 – 2018 @13TeV, $\mathcal{L}$~10^{34}, **~100fb^{-1}**

- 2019-2020: Shut-down (**LS2)**
- **LHC RUN II b)**: 2021 – 2023 @14TeV, $\mathcal{L}$~$2x10^{34}$, **~300fb^{-1}**

- 2024 – 2025: Shut-down (**LS3**)
- **LHC RUN III:** 2026 – 2036 @14TeV, $\mathcal{L}$~5-$10x10^{34}$ (**HL-LHC**), **~3000fb^{-1}**

Higgs re-discovery at 13TeV.





- 5.6(6.2)σ @ 125.09 GeV
- 6.5 (6.2)σ @ 125.09 GeV

From search to precision measurement.

In the post-discovery era, focus moves from search to precision measurements.

Characteristics of the SM Higgs:

Rare decay modes

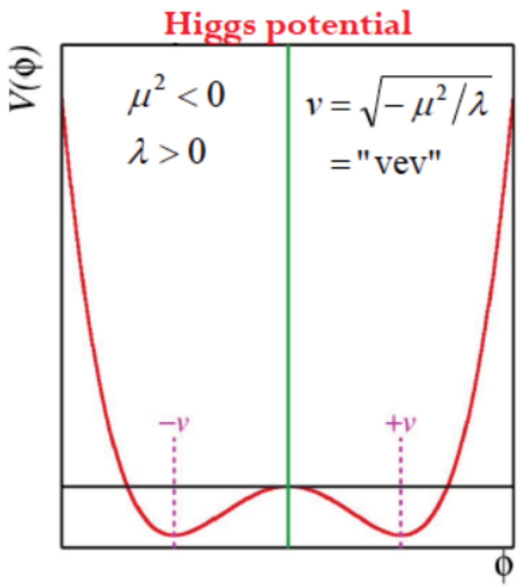
Coupling to other SM particles

Mass

Spin and Parity

Width and lifetime

Self-coupling.



$$L = \left(D_\mu \phi\right)^* \left(D^\mu \phi\right) - \left(\mu^2 \phi^2 + \lambda \phi^4\right) - \frac{1}{4} F^{\mu\nu} F_{\mu\nu}$$

$$g_{HVV} = 2\frac{m_V^2}{v} \qquad g_{Hff} = \frac{m_f}{v}$$

$$m_H = \sqrt{2\lambda} v$$

λ, μ unknown → m_H is a free parameter of the SM

LHC combined measurement of m_H.

- $H \rightarrow \gamma\gamma$: Events are divided into different $m_{\gamma\gamma}$ categories to improve sensitivity.
- $H \rightarrow ZZ \rightarrow e^-e^+\mu^-\mu^+$, $e^-e^+e^-e^+$, $\mu^-\mu^+\ \mu^-\mu^+$ analyzed separately
  ATLAS: 2D fit to $m_{4\ell}$ and BDT background discriminant
  CMS : 3D fit to $m_{4\ell}$, BDT background discriminant and per-event uncertainty in $m_{4\ell}$

$$\Lambda(\alpha) = \frac{L\left(\alpha, \hat{\theta}(\alpha)\right)}{L\left(\hat{\alpha}, \hat{\theta}\right)} = \frac{\text{Maximum likelihood for a given } \alpha}{\text{Global maximum likelihood}}$$

α = parameters of interest (eg. m_H)
θ = nuisance parameters (eg. systematics)

$\hat{\alpha}, \hat{\theta}$ = Best fit values

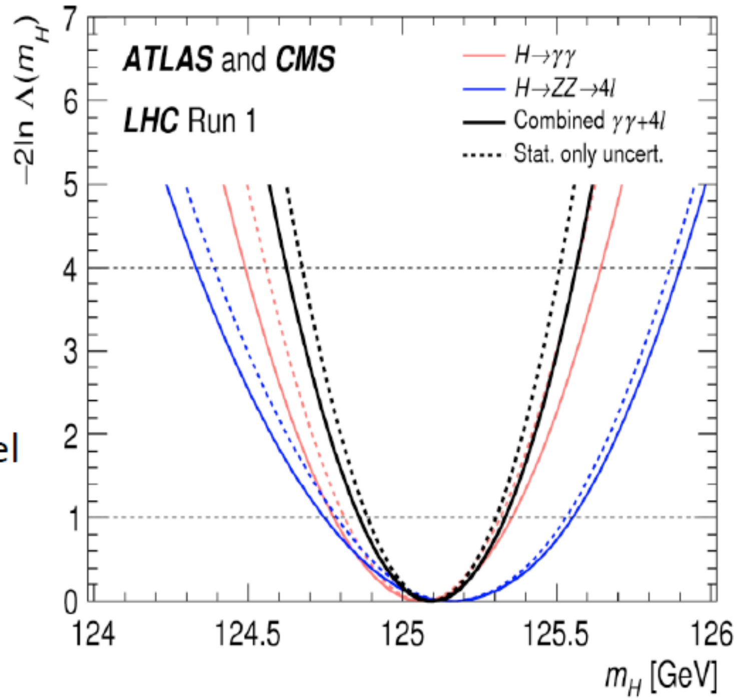
$L(\alpha,\theta)$ = product of signal and background PDFs.

To combine: multiply likelihood terms for each channel

$$\Lambda(m_H) = \frac{L\left(m_H, \hat{\mu}^{\gamma\gamma}_{ggF+ttH}(m_H), \hat{\mu}^{\gamma\gamma}_{VBF+VH}(m_H), \hat{\mu}^{4\ell}(m_H), \hat{\theta}(m_H)\right)}{L\left(\hat{m}_H, \hat{\mu}^{\gamma\gamma}_{ggF+ttH}, \hat{\mu}^{\gamma\gamma}_{VBF+VH}, \hat{\mu}^{4\ell}, \hat{\theta}\right)}$$

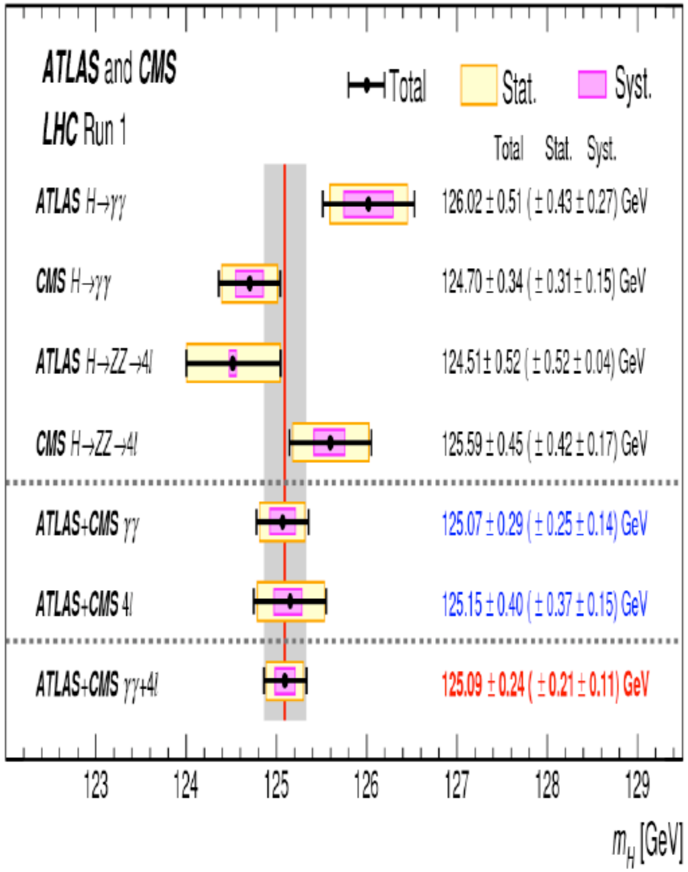
μ = signal strenght modifiers

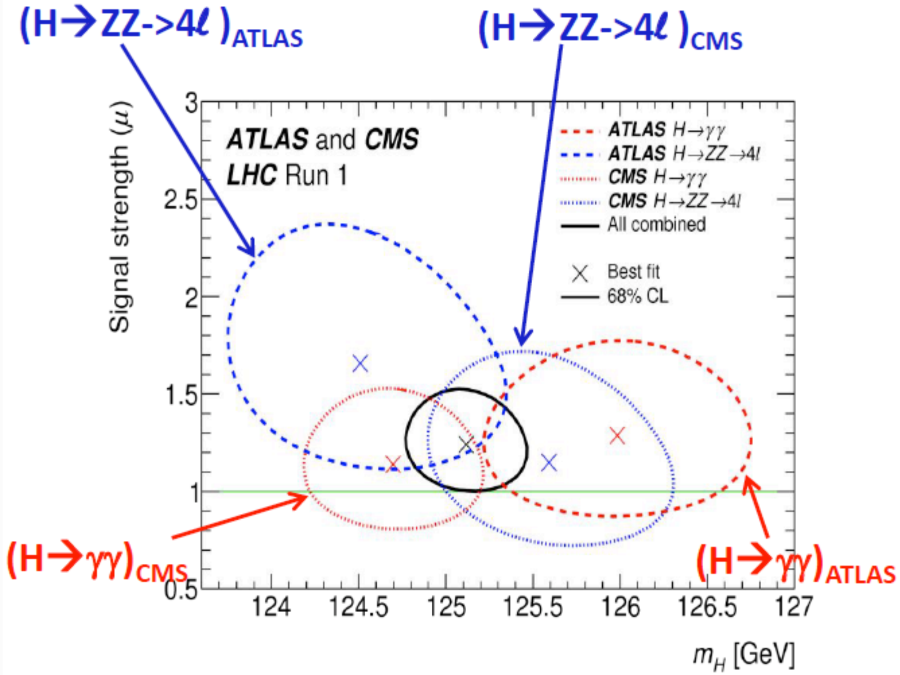
Phys. Rev. Lett. 114 (2015) 191803



Results.

Phys. Rev. Lett. 114 (2015) 191803





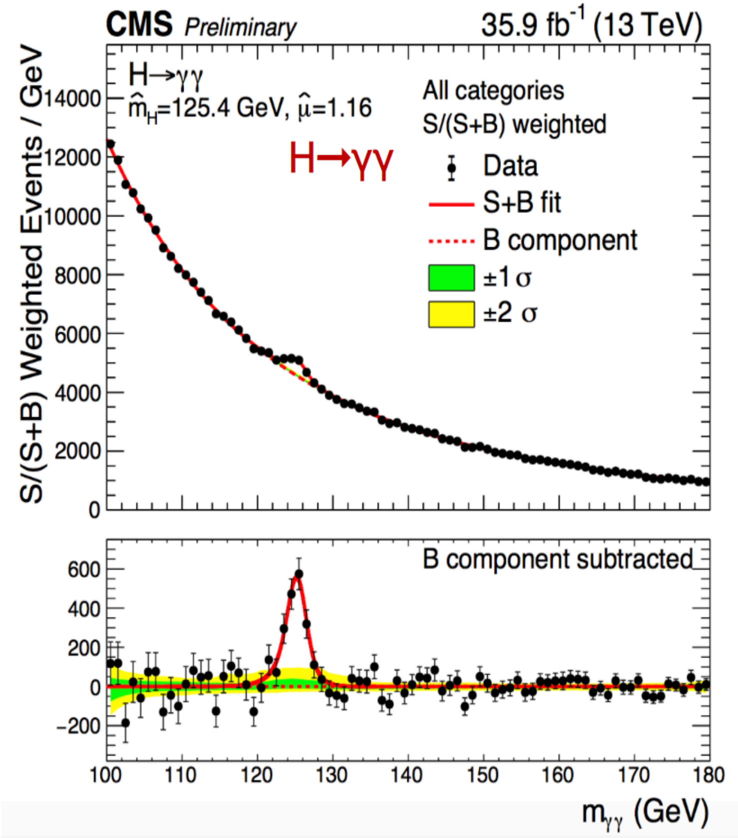
m_H=125.09±0.21±0.11 GeV

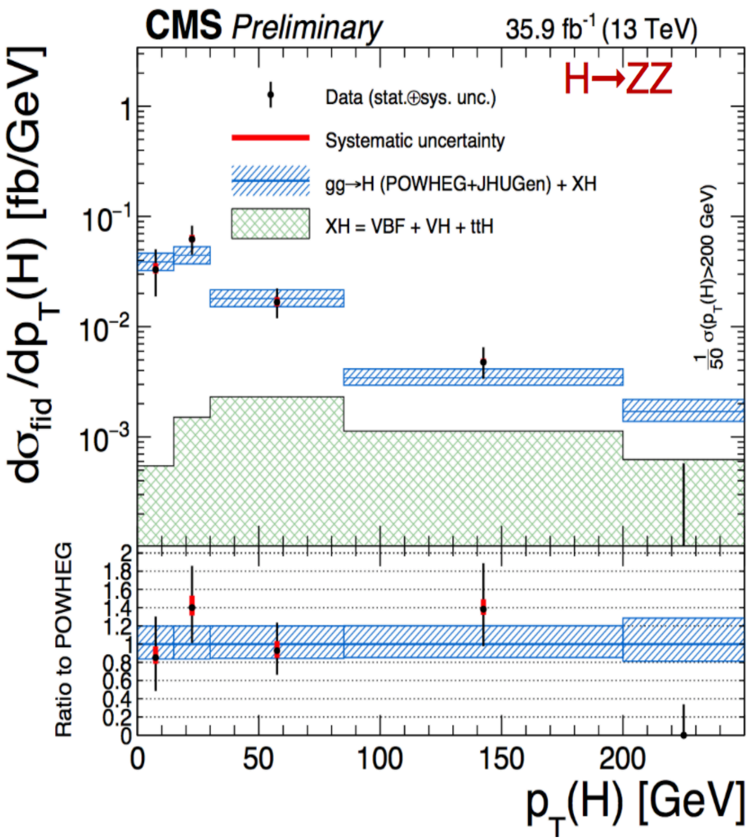
Statistical uncertainty dominates. Along with theory developments in cross-sections, allows detailed couplings comparisons.

We have already entered the Higgs precision era: ±0.19%.

Examples of precision Higgs physics

- Best single-channel mass measurement: 125.26 ± 0.20(stat) ± 0.08(sys) GeV, differential measurements





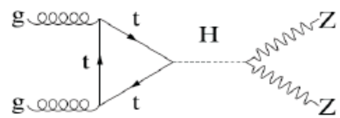
CMS-PAS-HIG-17-040

arXiv:1706.09936

Indirect measurement of Γ_H

[Phys. Lett. B 736 (2014) 64]

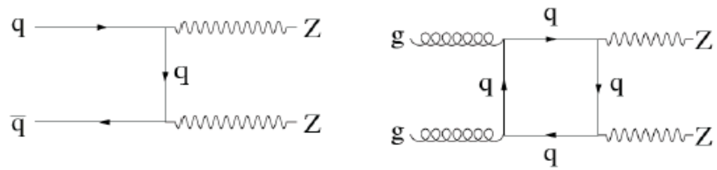
$H \to ZZ \to 4\ell$, $H \to 2\ell 2\nu$, (ℓ=e,μ),



Breit-Wigner production gg→H→ZZ:

$$\frac{d\sigma_{gg\to H\to ZZ}}{dm^2_{ZZ}} \sim \frac{g^2_{ggH}\, g^2_{HZZ}}{\left(m^2_{ZZ} - m^2_H\right)^2 + m^2_H \Gamma^2_H}$$

Dominant backgrounds:

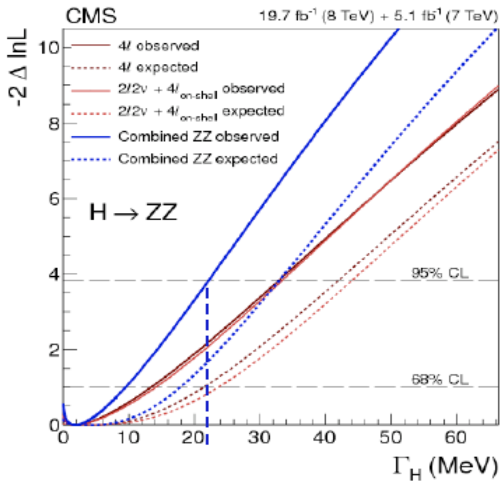


On-peak ($105.6 < m_{4\ell} < 140.6$ GeV) and off-peak cross sections ($m_{4\ell} > 220$ GeV):

$$\sigma^{\text{on-shell}} = \int_{|m-m_H|\le n\Gamma_H} \frac{d\sigma}{dm}\cdot dm \sim \frac{g^2_{ggH}\, g^2_{HZZ}}{m_H \Gamma_H}$$

$$\sigma^{\text{off-shell}} = \int_{m-m_H \gg \Gamma_H} \frac{d\sigma}{dm}\cdot dm \sim \frac{g^2_{ggH}\, g^2_{HZZ}}{(2m_Z)^2}$$

$$\frac{\sigma^{\text{off-shell}}}{\sigma^{\text{on-shell}}} \sim \Gamma_H$$



- Must include interference between gg→H→ZZ and gg→Box→ZZ
- K-factor of gg→ZZ not well known, assume the same as signal and add a sytematic uncertainty.

Γ_H< 22 MeV at 95% CL

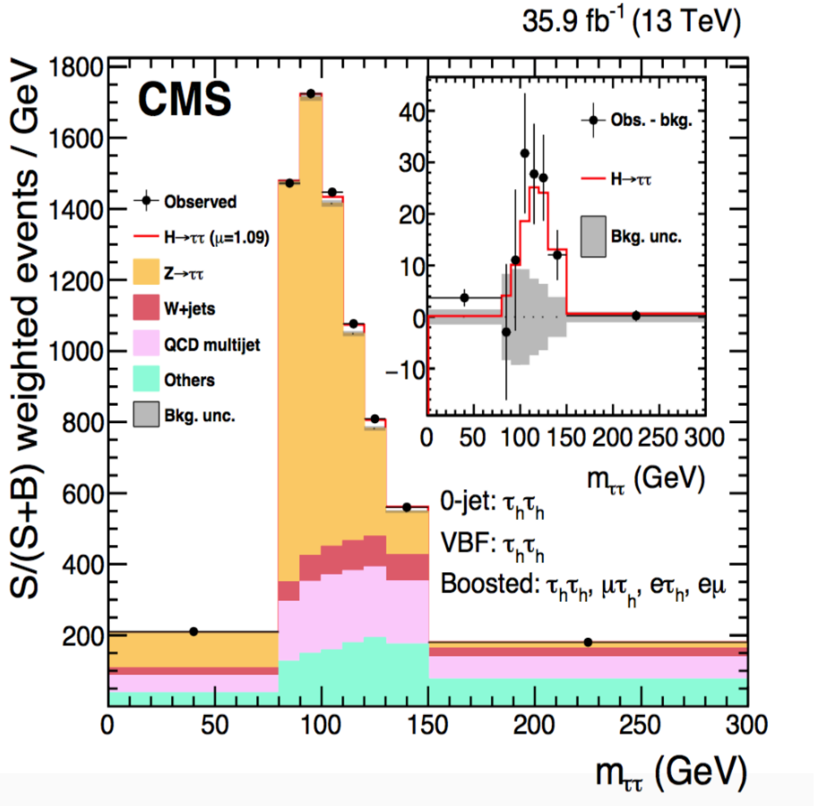
Focus on difficult/rare decays

- Leptonic decays (ττ, bb)
- ttH
- H→Zγ
- Very rare decays (H→μμ and H→ee)
- H pair production (HH)

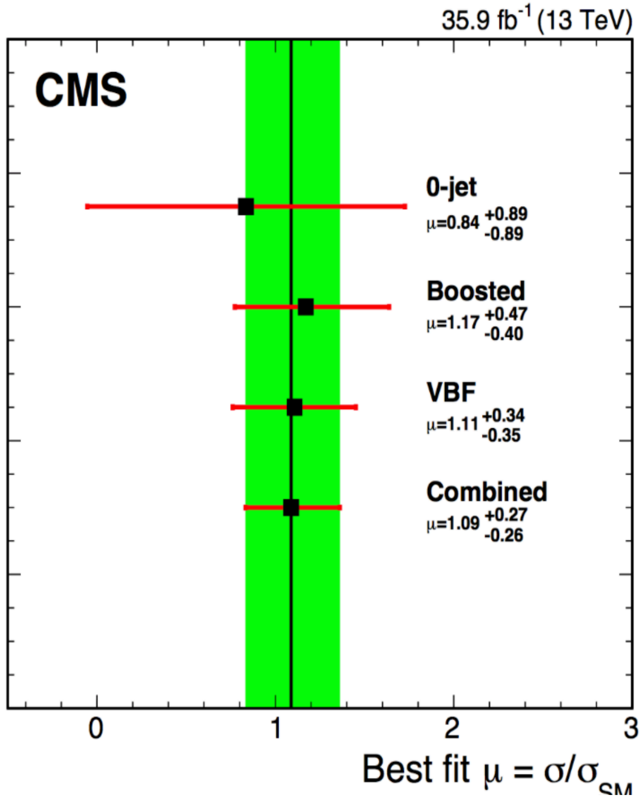
Observation of H→ττ

Important test of the Yukawa coupling of the Higgs to fermions.

- First single-experiment observation of H → ττ
  - Previously achieved with CMS+ATLAS combination

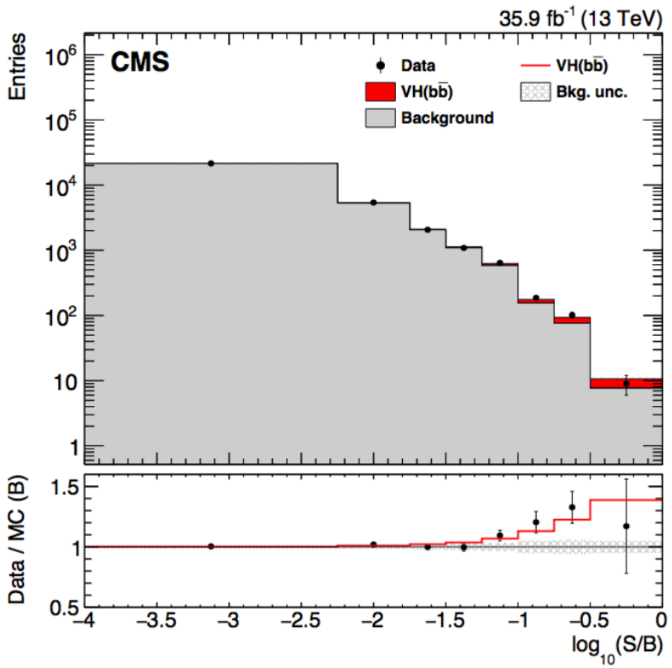


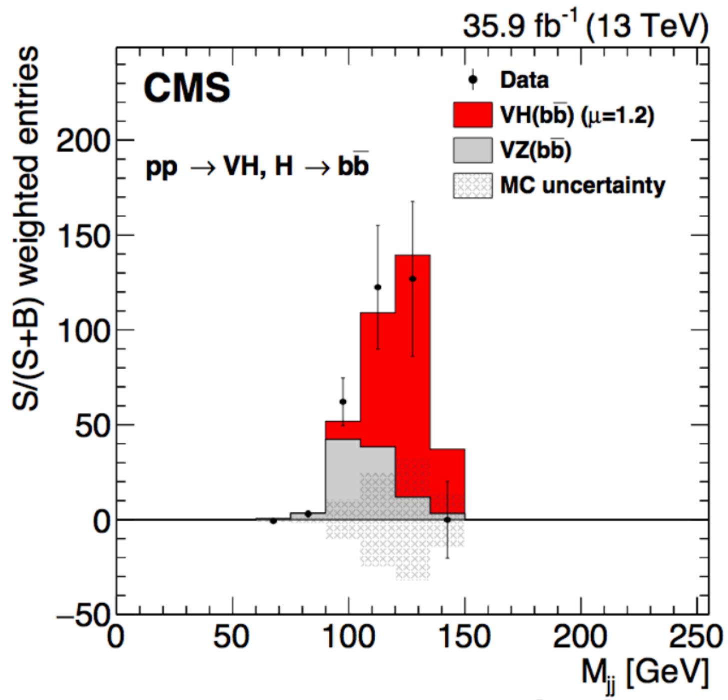
4.9σ (4.7σ expected)
Run 1 + Run 2: 5.9σ (obs. = exp.)



CMS-PAS-HIG-16-043
Submitted PLB

Evidence for (V)H→(V)bb





3.3σ evidence observed (2.8 expected)

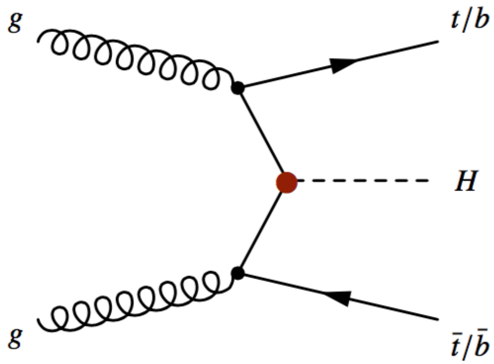
Run 1 + Run 2 : 3.8σ (3.8σ exp.)

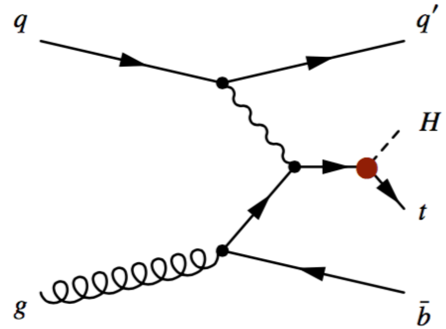
Similar result obtained by ATLAS

CMS-PAS-HIG-16-044
Submitted PLB

The importance of ttH

In SM the top quark Yukawa coupling is strongest one ($Y_t \propto m_{top}/v \approx 1$)
The top-Higgs vertex (●) is only directly accessible when H is produced in association with one or more top quarks





$\sigma(pp \to ttH)$ { 0.133 pb @ 8 TeV; 0.507 pb @ 13 TeV }

~1/96th of ggH production

$\sigma(pp \to tH)$ { 0.019 pb @ 8 TeV; 0.074 pb @ 13 TeV }

~1/15th of ttH production

Probes the modulus of Y_t

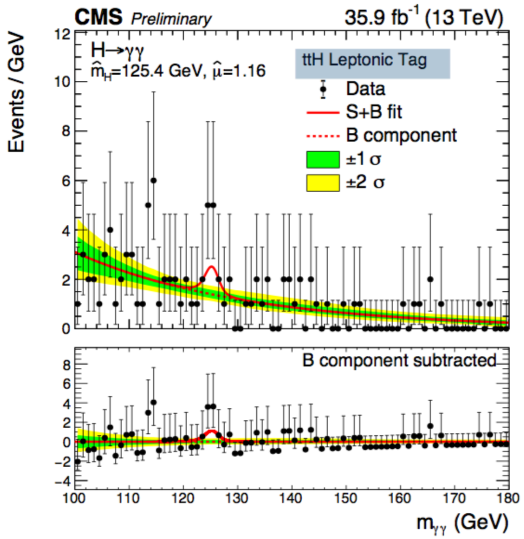
Probes the relative sign of Y_t

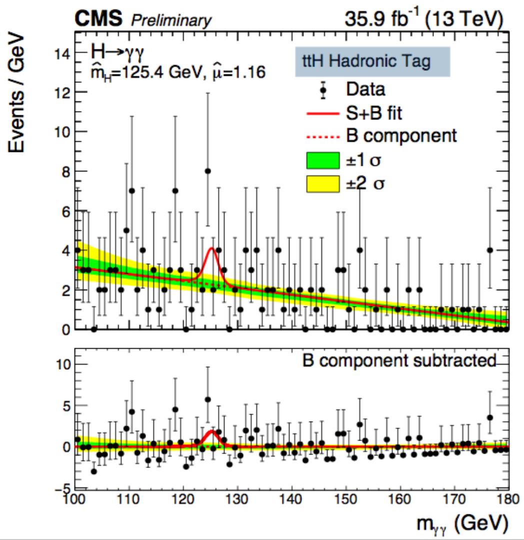
The comparison of the precise direct measurement of Y_t with the one from the loop-induced ggH (which in the SM is also dominated by the Y_t) can constrain contributions from new physics in the gluon fusion loop

Evidence for ttH@13TeV

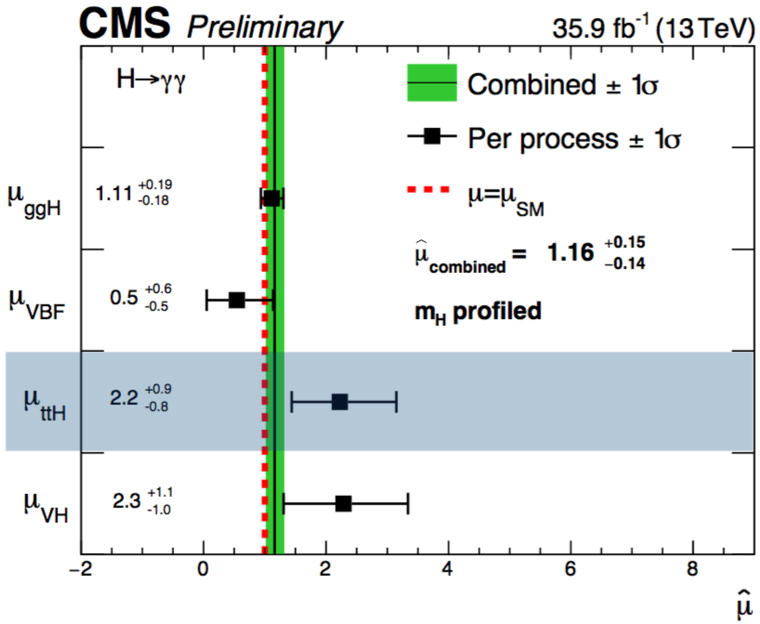
- Results based on **35.9 fb^{-1}** of data at **13 TeV** collected during **2016**

Signal plus background model fits to $m_{\gamma\gamma}$ distribution for ttH categories





Signal strength for each process



- Uncertainties are statistics dominated
- Signal significance **observed** (expected) : **3.3σ** (1.5σ)

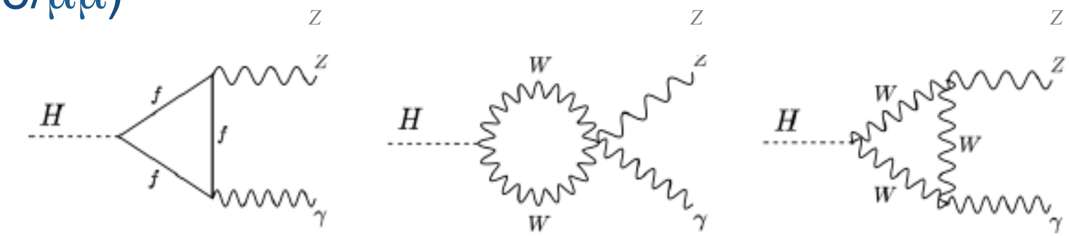
arXiv:1706.09936 CMS-PAS-HIG-16-040

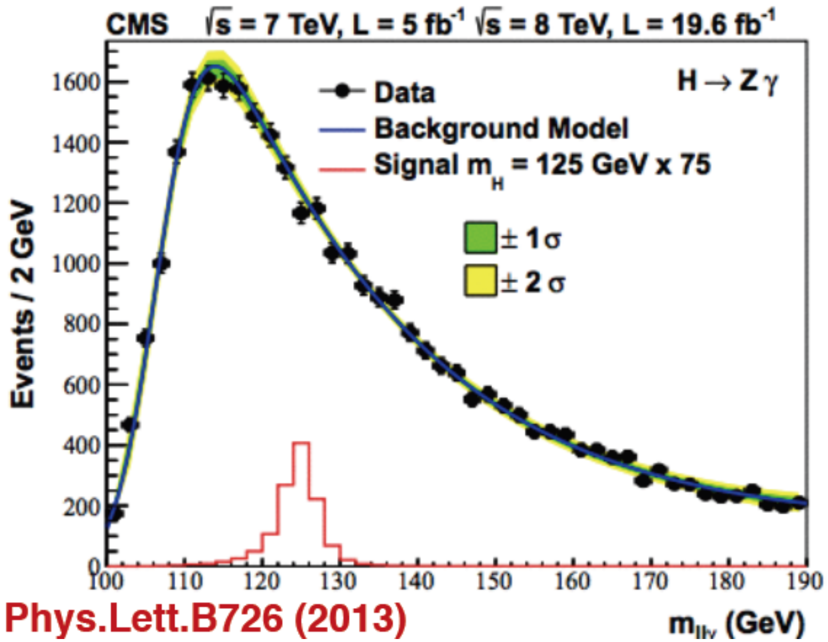
Rare decays: H→Zγ

Very sensitive to possible contributions from new physics via decay loops of new, heavy charged particles.

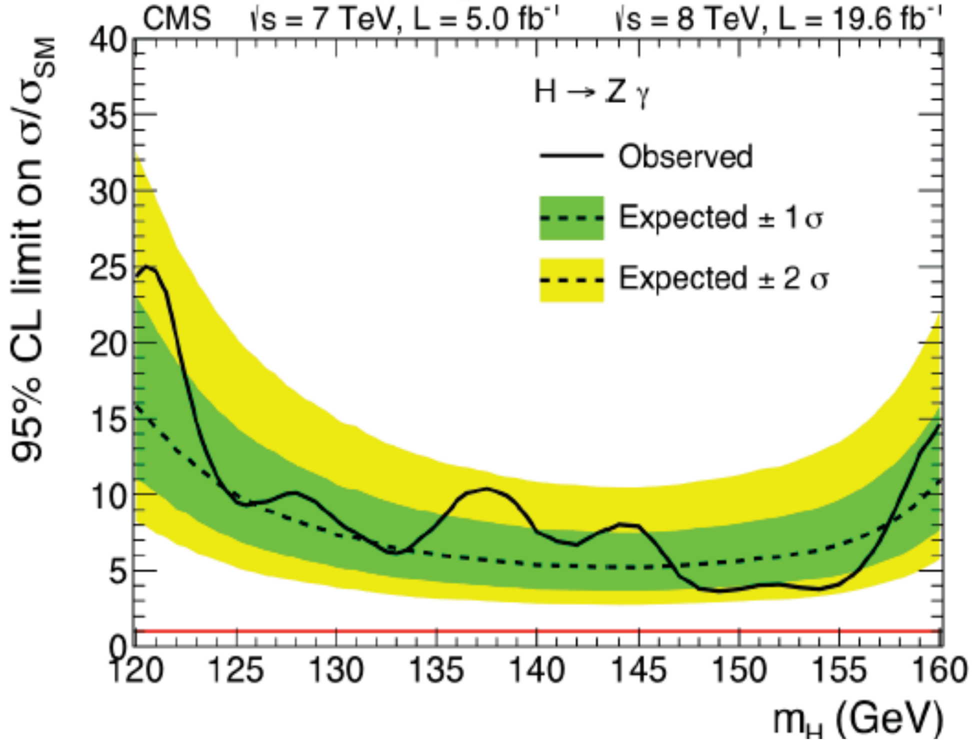
BR_{SM} 1.54x10^{-3} (~10^{-4} including Z→ee/μμ)

CMS results BR<9.5BR_{SM}





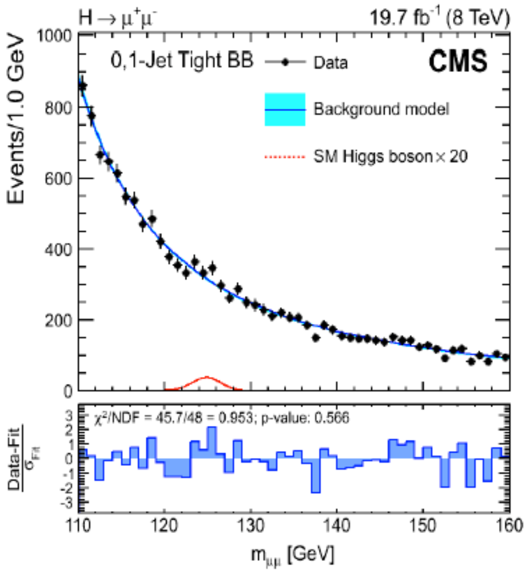
Phys.Lett.B726 (2013)

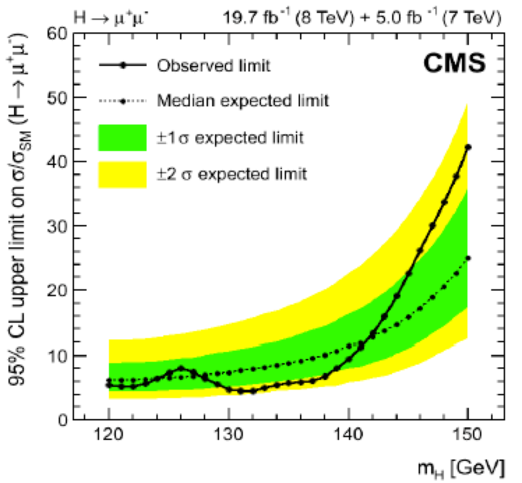


Very rare decays: H→μμ and H→ee

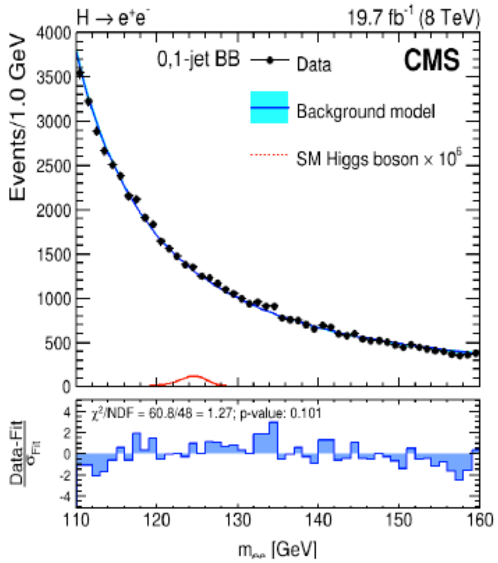
PLB 744 (2015) 184

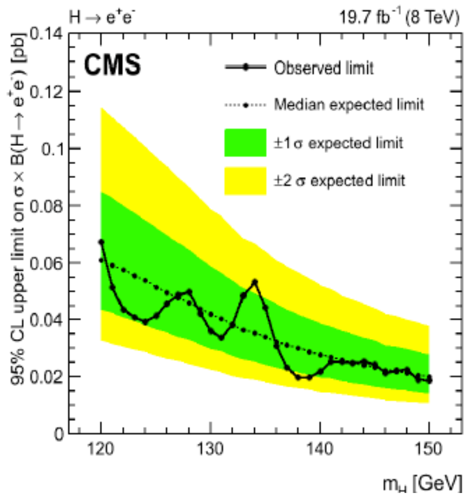
H→μμ





H→ee





- H→μμ, H→ee cleanest of fermionic decays.
- $B_{SM}(H\to\mu\mu) = 2.2\times10^{-4}$
- $B_{SM}(H\to ee) = 5\times10^{-9}$
- search performed in [120,150] GeV
- $\sigma B(H\to\mu\mu)<0.033$ pb, 95% CL

  $B(H\to\mu\mu)<0.0016$, 95% CL

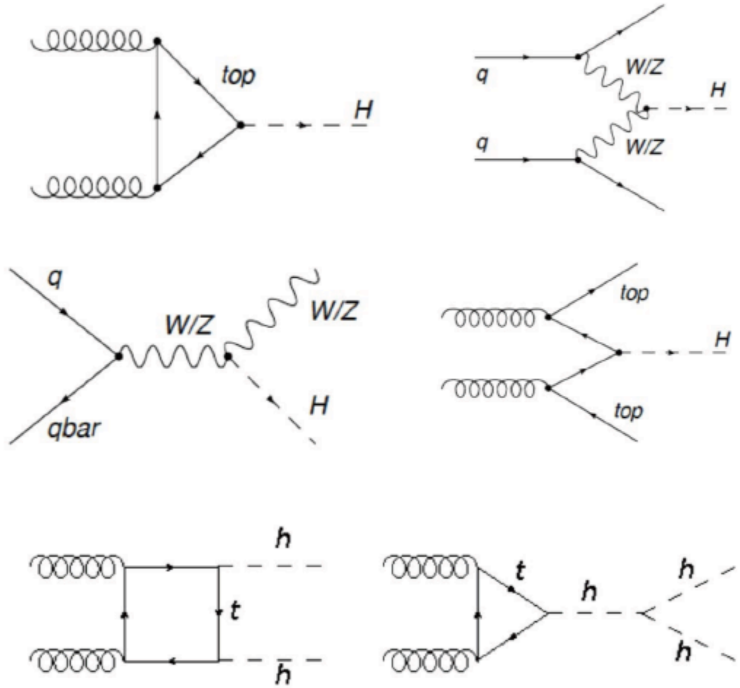
  $\mu = 0.8^{+3.5}_{-3.4}$
- $\sigma B(H\to ee)<0.041$ pb, 95% CL

  $B(H\to ee)<0.0019$ (3.7×10^{5} B_{SM})

Run 1 data show that couplings to fermions are not universal.

HL-LHC is a Higgs factory

Higgs bosons at $\sqrt{s}$=14 TeV 3000 fb^{-1}	
HL-LHC total	170 M
VBF (main decays)	13M
ttH (main decays)	1.8M
H→Zγ	230k
H→μμ	37k
HH (all)	121k



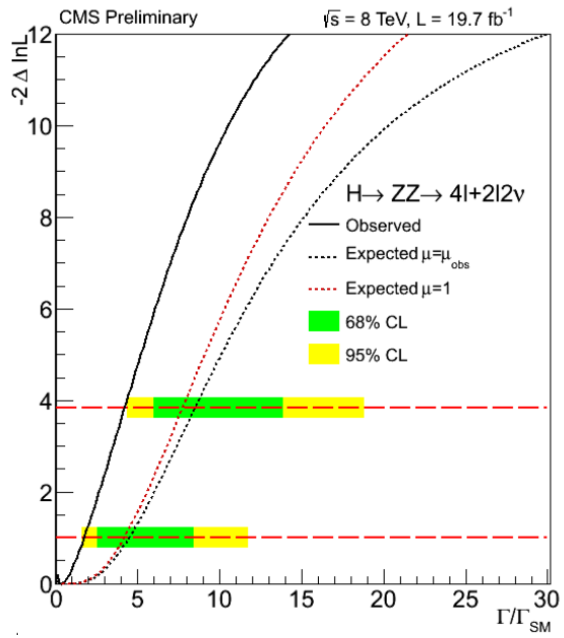
- Higgs physics goals
  - Rare decays and couplings
  - Spin/parity
  - Higgs pair productions

LHC will produce 150-200 million Higgs.

Higgs mass and width at HL-LHC

The large statistics in $H\rightarrow\gamma\gamma$ and $H\rightarrow ZZ^*\rightarrow 4l$ will allow a measurement of m_H challenging the systematics errors. We could also make the best use of VBF and possibly other exclusive channels. Large effort needed on the theory side: 50MeV on Δm_H corresponds to 0.5% uncertainty on the BR measurement.

Expectations for Δm_H@3000fb^{-1}: 15MeV(stat)±25MeV(syst).
It could be challenged only by a dedicated lepton Collider.



For the measurement of the width we'll continue using the powerful constraints from the off-shell Higgs.

The high statistics will bring sensitivity on the width down to the SM-level: Γ_H=4.2$^{+1.5}_{-2.1}$ MeV.
An independent handle to check for significant anomalous BR.

Observe rare/difficult decays with 3000fb^{-1}

- **ttH**

  Signal observation 7-8σ in single decay modes (i.e. ttH($\gamma\gamma$)); projected sensitivity on k_{top}~10%.
- **H→Zγ**
- Signal observation ~4σ; 20-25% precision on the signal strength
- **H→$\mu\mu$**

  Signal observation >7σ; 10-15% precision on the signal strength. Measure the coupling the second lepton generation.
- **H→invisible**

  Using ZH→ll+high missing E_T

  BR(H→$\chi\chi$)<5-10% at 95%CL.

What precision is necessary on the couplings?

- SM couplings can be modified by new physics entering the loops.
- Typical effect on the couplings from a heavy particle M or new physics at scale M.

$$\Delta \sim \left(\frac{v}{M}\right)^2$$

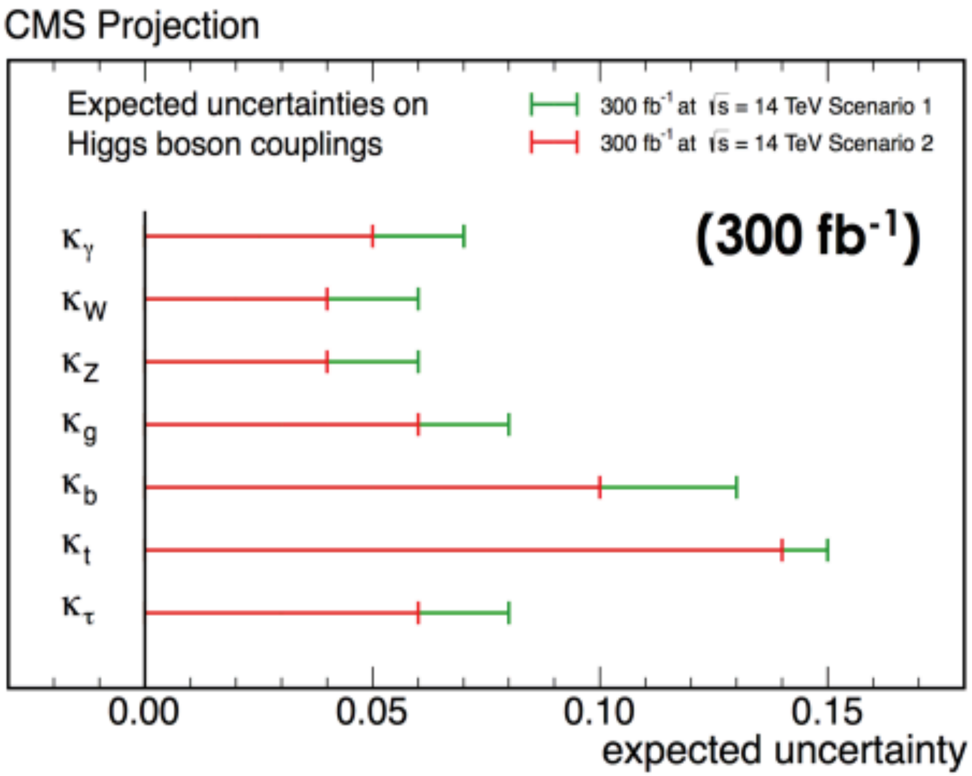
- **For new physics at the ~1TeV mass scale → Δ~5%**

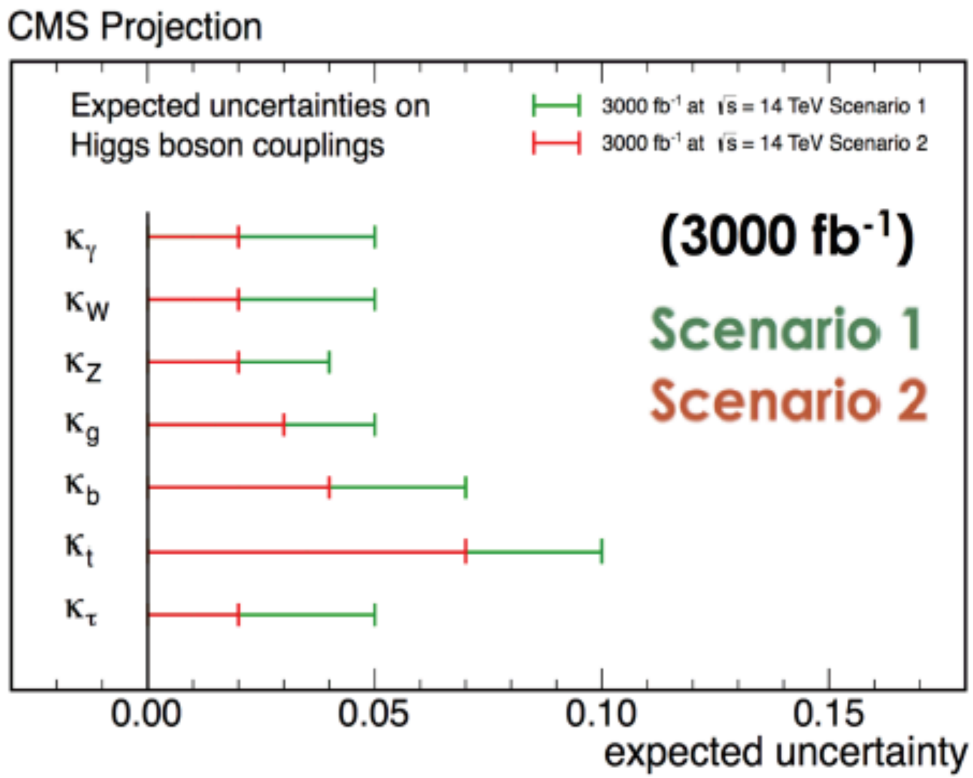
Model	κ_V	κ_b	κ_γ
Singlet Mixing	$\sim 6\%$	$\sim 6\%$	$\sim 6\%$
2HDM	$\sim 1\%$	$\sim 10\%$	$\sim 1\%$
Decoupling MSSM	$\sim -0.0013\%$	$\sim 1.6\%$	$\sim -.4\%$
Composite	$\sim -3\%$	$\sim -(3-9)\%$	$\sim -9\%$
Top Partner	$\sim -2\%$	$\sim -2\%$	$\sim +1\%$

arXiv:1310.8361

- Higher scales imply smaller effects

Perspectives on the couplings

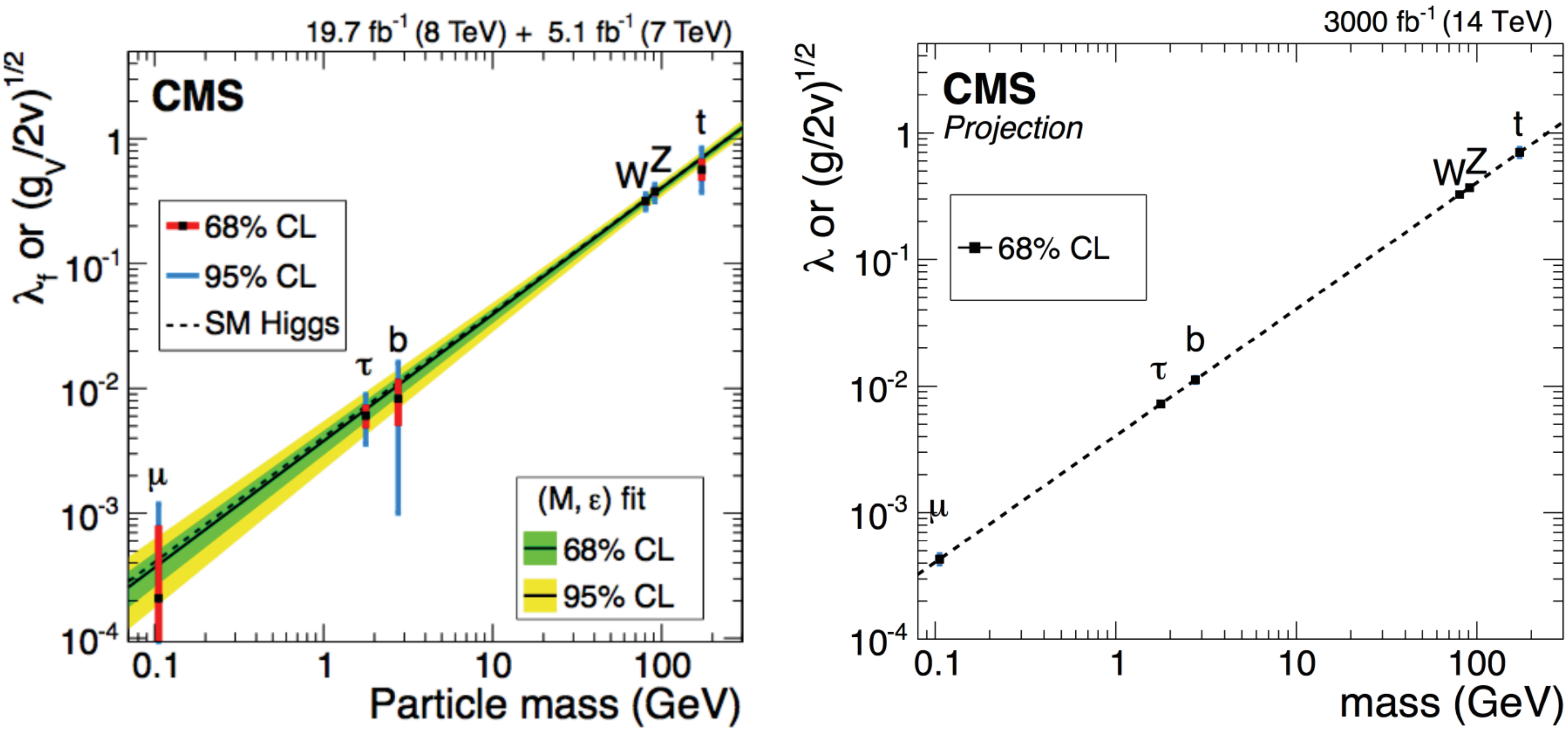




arXiv:1307.7135

Allowing new physics entering the loops: ultimate precision 2-10%.

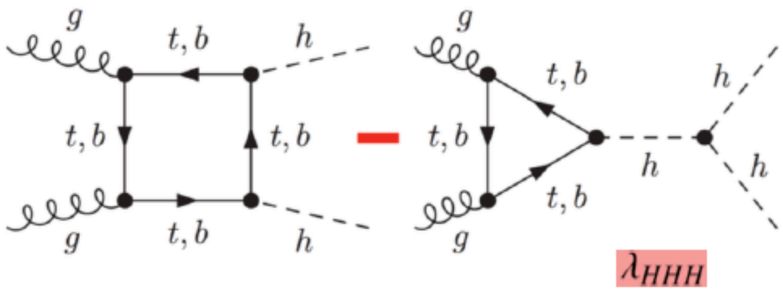
Perspectives on the couplings

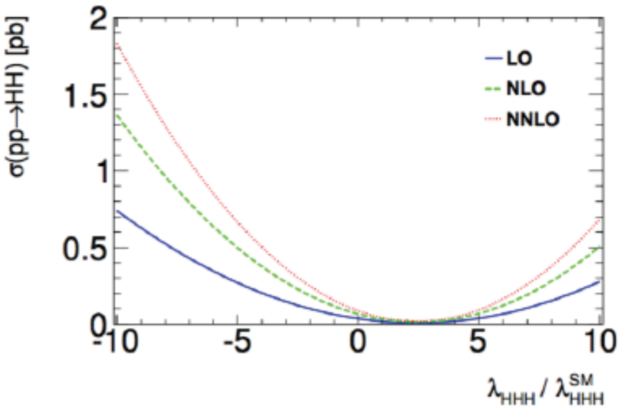


Allowing no new physics: percent level precision for most of the couplings

H self-coupling: HH production

- Probe Higgs self-interaction
  - crucial to test the Higgs sector to its full extent
  - primary channel to extract information on the Higgs potential → structure of the EWK Phase Transition
- Two interfering diagrams (destructive)





- SM cross section @ 14 TeV: 40.8 fb (NNLO)

~10^5 HH events produced with 3000fb^{-1} at HL-LHC ……but very large background (or tiny BR).

Higgs pair production.

- Extremely difficult channel.
- Trade-off between large branching ratio and background contamination.
- With reasonable extrapolations one would expect to reach 3σ per experiment.
- **Room for new ideas.**

Chan.	Obs. (exp.) 95% C.L. limit on σ/ ATLAS	CMS
bbbb	29 (38)	342 (308)
bbVV	-	79 (89)
$bb\tau\tau$	-	28 (25)
$bb\gamma\gamma$	117 (161)	91 (90)
$WW\gamma\gamma$	747 (386)	-

~3 fb^{-1} 13.3 fb^{-1} 35.9 fb^{-1}

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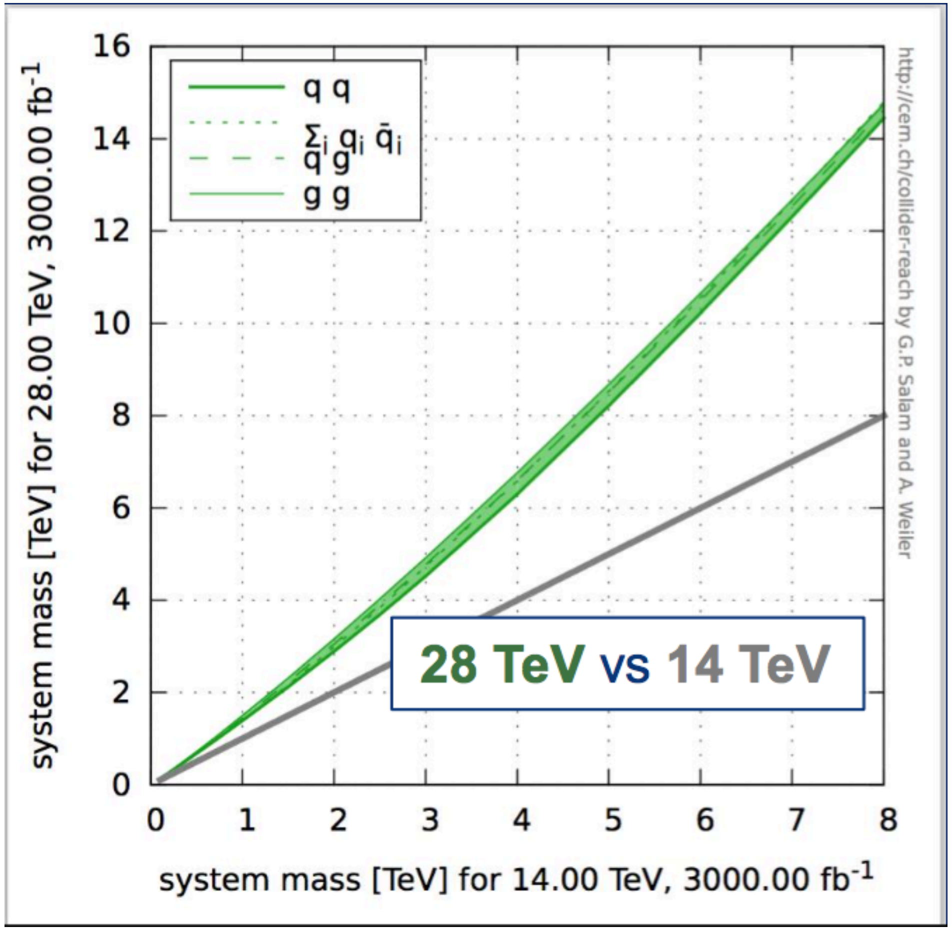
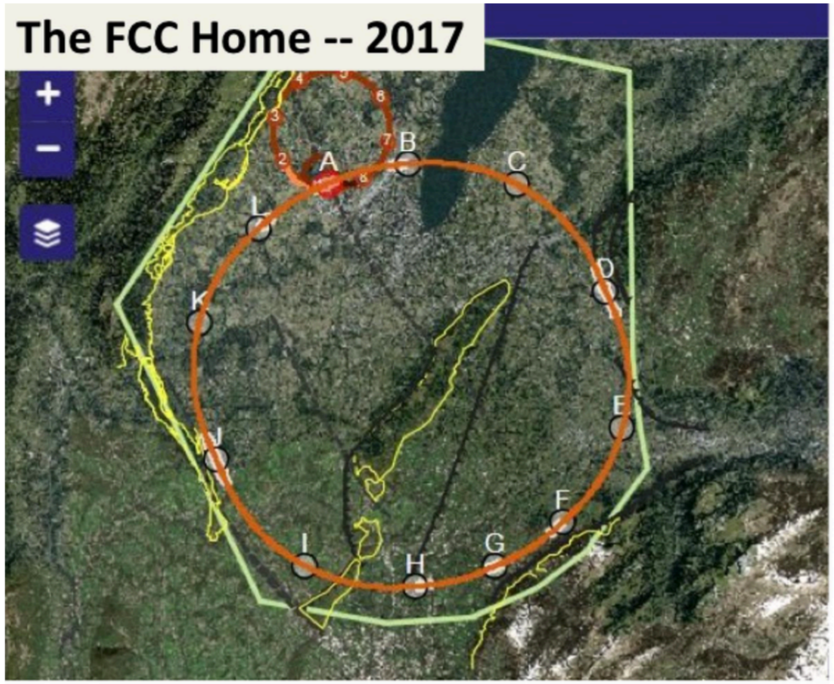
Beyond LHC: HE-LHC

- 16 T magnets in LHC tunnel (√s~ 30TeV)
- Use of existing tunnel and infrastructure;
- It can be built at fixed budget
- Strong physics case if new physics from LHC/HL-LHC



Beyond LHC: FCC.



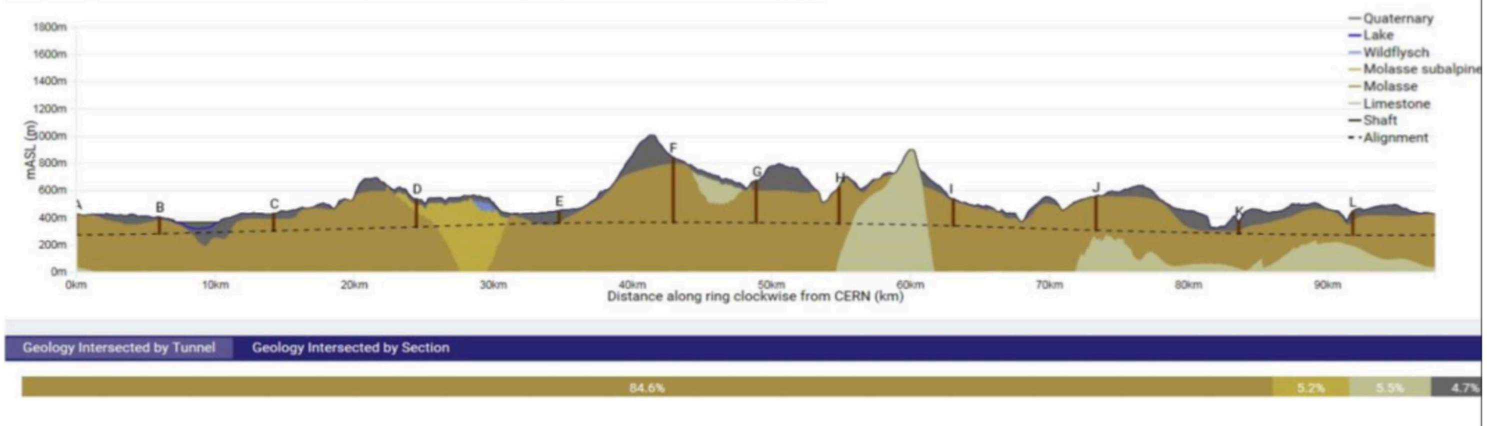
Optimisation in view of accessibility surface points, tunneling rock type, shaft depth, etc. optimum: **97.5 km**

Tunneling

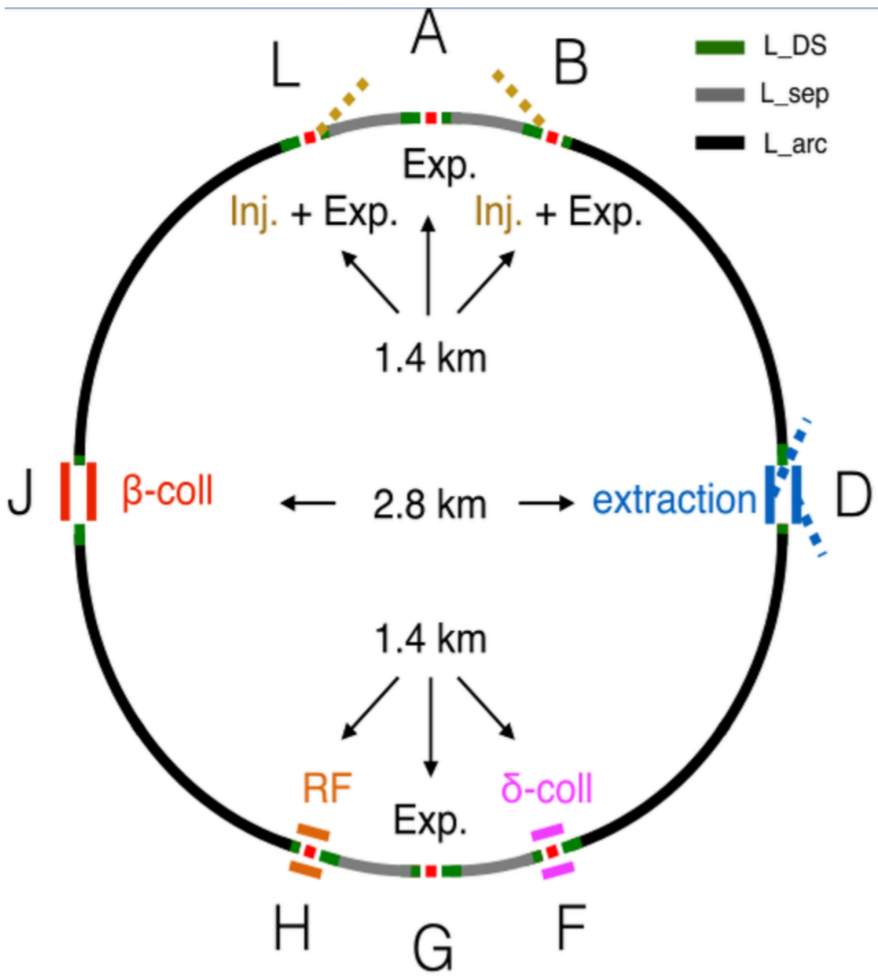
- Molasse 90% (good rock),
- Limestone 5%, Moraines 5% (tough)

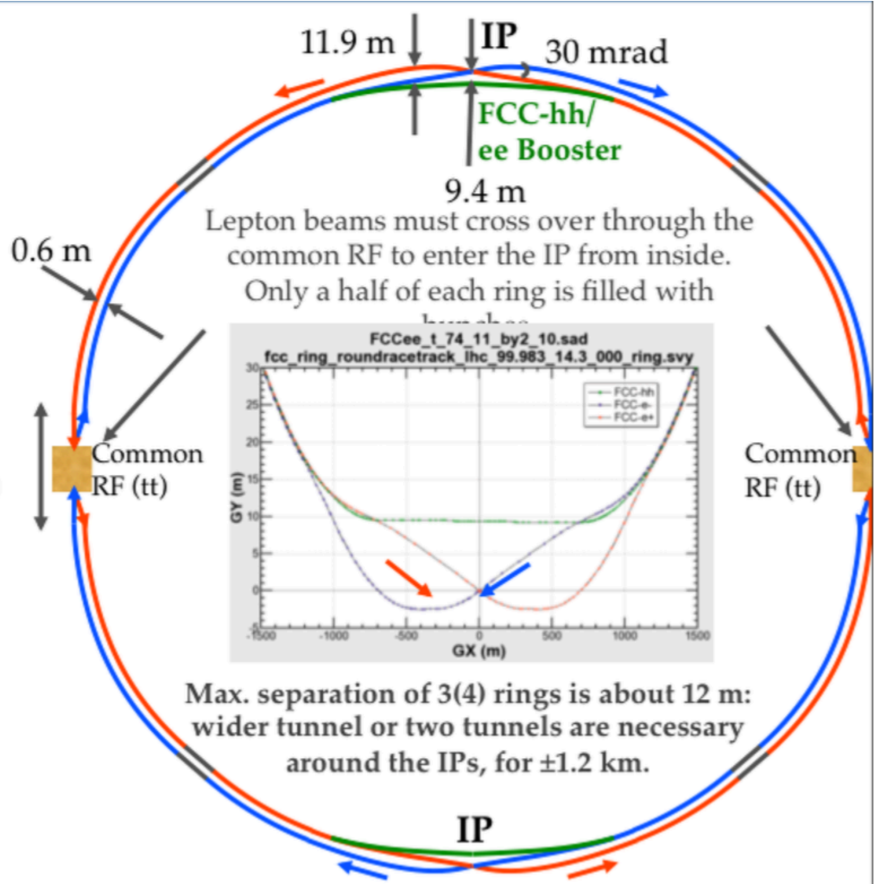
Shallow implementation

- ~ 30 m below Léman lakebed
- Reduction of shaft lengths etc...
- One very deep shaft **F** (476m) (RF or collimation), alternatives being studied, e.g. inclined access



FCC-ee and FCC-hh.





2 main IPs in A, G for both machines

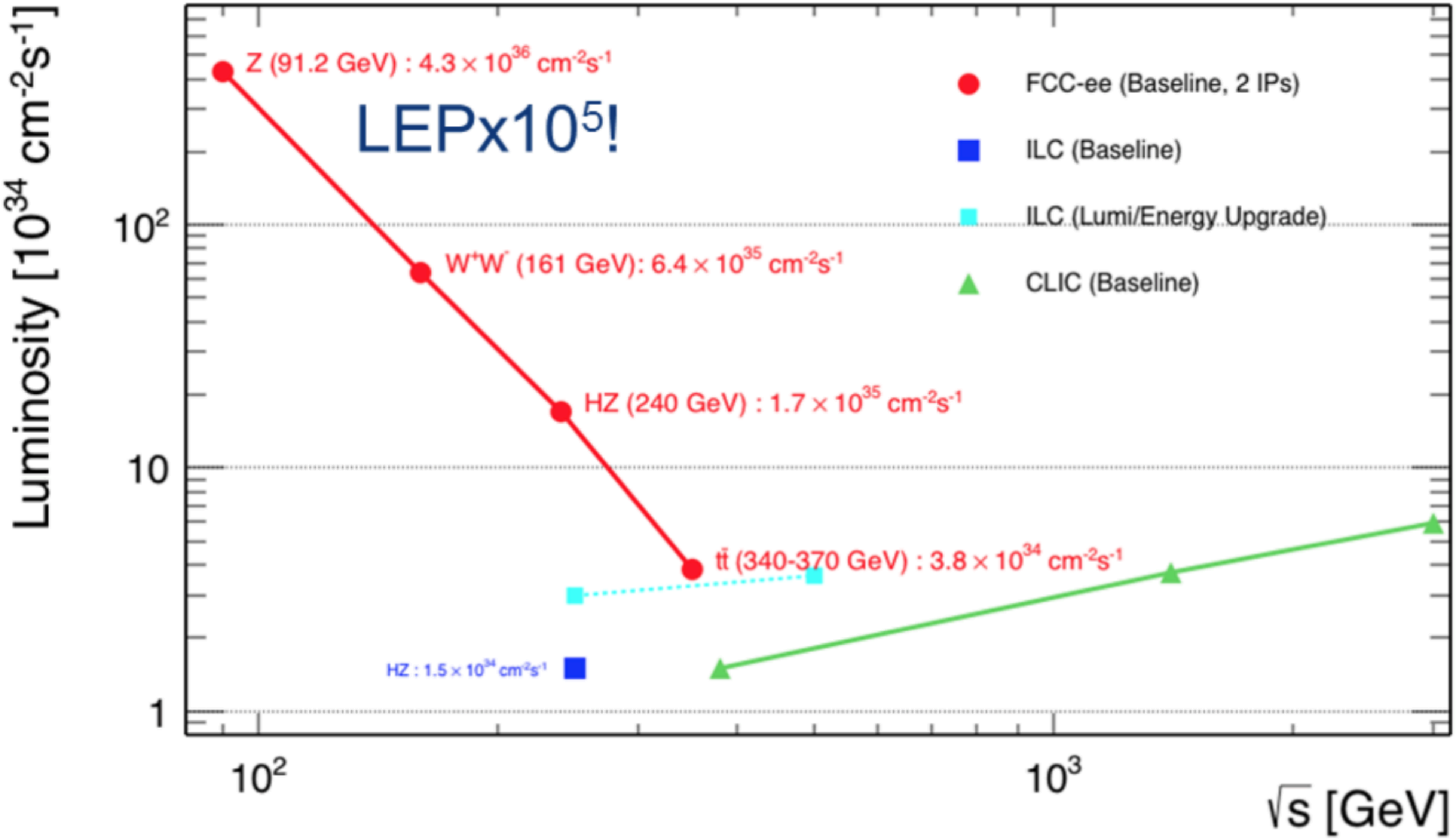
9/4/17 Alain Blondel The FCCs

FCC-ee 1, FCC-ee 2,

FCC-ee booster (FCC-hh footprint)

Asymmetric IR for ee, limits SR to expt

FCC-ee: high-lumi factory.



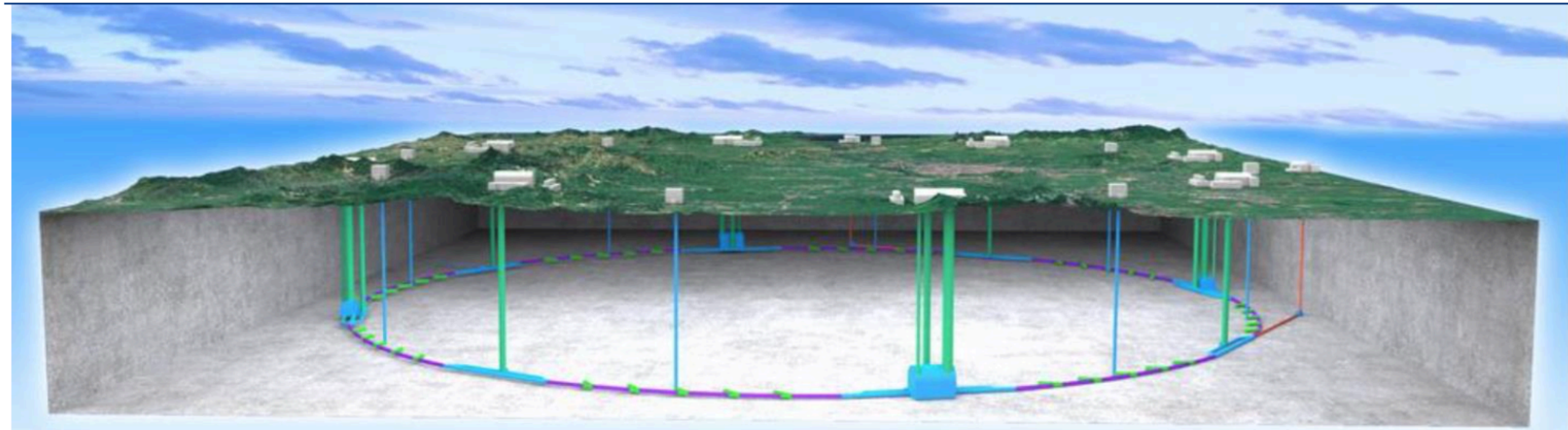
FCC: the ultimate discovery machine.

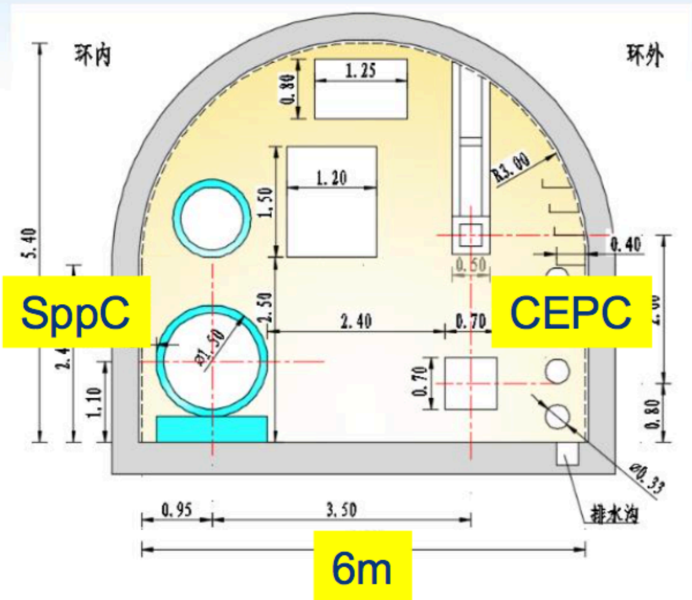
parameter	FCC-hh	
collision energy cms [TeV]	100	
dipole field [T]	16	
circumference [km]	100	
beam current [A]	0.5	
bunch intensity [10^{11}]	1 (0.2)	
bunch spacing [ns]	25 (5)	
norm. emittance $\gamma\varepsilon_{x,y}$ [μm]	2.2 (0.44)	
IP $\beta^*_{x,y}$ [m]	1.1	0.3
luminosity/IP [10^{34} cm^{-2}s^{-1}]	5	30
peak #events/bunch crossing	170	1000 (200)
stored energy/beam [GJ]	8.4	
SR power / beam [kW]	2400	
transv. emit. damping time [h]	1.1	
initial proton burn off time [h]	17.0	3.4

g_{Hxx}	FCC-ee	FCC-hh
ZZ	0.15 %	
WW	0.20%	
Γ_H	1%	
$\gamma\gamma$	1.5%	<1%
$Z\gamma$	--	1%
tt	13%	1%
bb	0.4%	
$\tau\tau$	0.5%	
cc	0.7%	
$\mu\mu$	6.2%	2%
uu,dd	H→ $\rho\gamma$?	H→ $\rho\gamma$?
ss	H→ $\phi\gamma$?	H→ $\phi\gamma$?
ee	ee → H	
HH	30%	~3%
inv, exo	<0.45%	10^{-3}

Alain Blondel The FCCs

The chinese project: CEPC/SppC

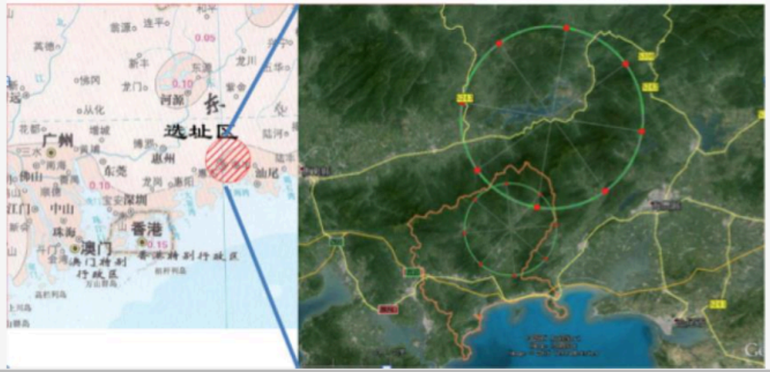




Site selection ongoing

Possibilities among others..

- Qinhuangdao (1 hr by train from Beijing)
- Close to Hong-Kong?...



Conclusion

- The discovery of the Higgs boson has opened a new era in physics.
- From now on the hunt for physics beyond the standard model will proceed along two deeply connected lines of research:
  - a) direct searches based on the study of collisions at the largest possible energy
  - b) indirect searches based on precision measurement of the Higgs properties and couplings
- Ultimate precision on key parameters for Higgs physics will probably require looking into a new family of accelerators.
- Various options of high intensity lepton colliders as well as high energy hadron colliders are currently under study.
- Stay tuned.