Future BEH studies at the HL-LHC

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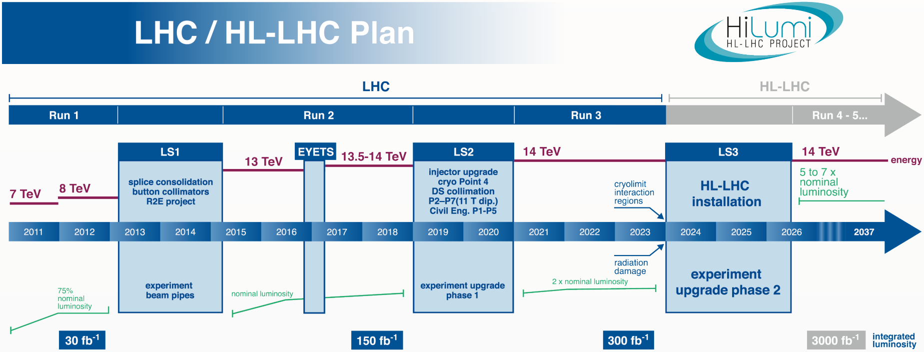
Solstice 2016 PAI Meeting
17 June 2016

Outline

- **Introduction**
  - The HL-LHC Project
  - The CMS Phase II Upgrade
- **SM Higgs:**
  - Precision coupling measurements
  - Rare processes
- **Summary**

The HL-LHC Project



The HL-LHC Project Link

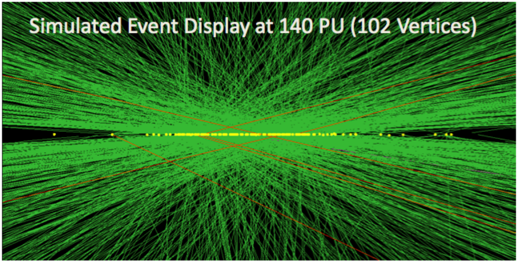
The HL-LHC Project

The HL-LHC is a very bright lamp to see physics details

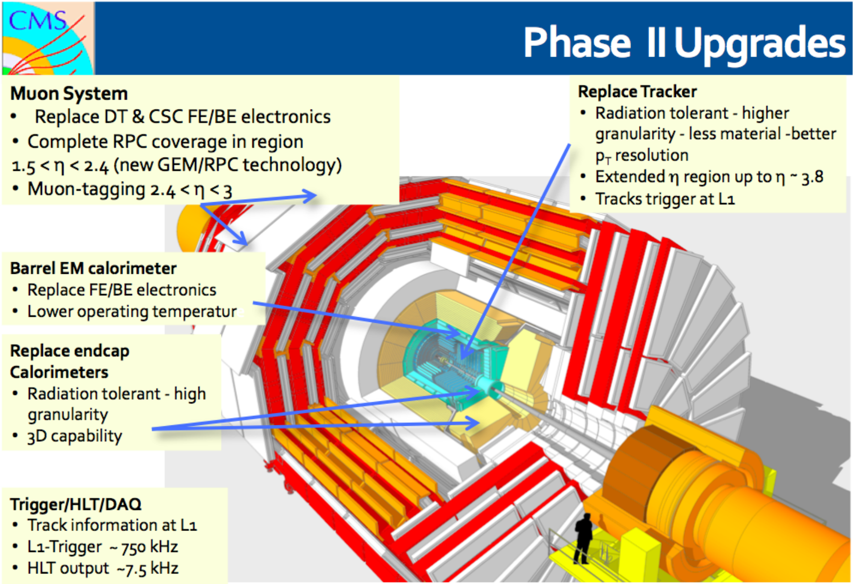
Collision energy 14 TeV, Instantaneous luminosity 5×10^{34} cm^{-2}s^{-1}, Integrated luminosity at the end of the run 3000 fb^{-1}

The HL-LHC environment:

- Radiation
- Pileup (200 PU interactions)



CMS Phase II Upgrades

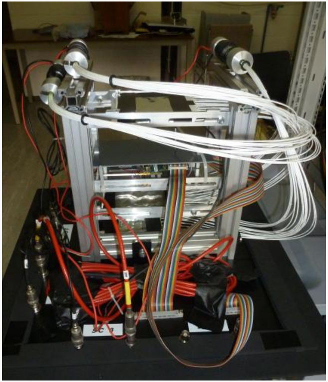


L. Silvestris INFN-Bari

CMS Phase II Upgrades - Belgium

Belgian effort focused on the tracker upgrade (strips in the Endcap)

- IIHE, Antwerp, (Gent), and CP3
- Test beam at CP3 with prototype, possibly next Fall
- Opening the door to new tests beam in the future
- Thinking on the detector assembly here in Belgium by 2021



HL-LHC Studies

The Higgs program is driven by the **precision** (couplings) and **rare processes** (H $\rightarrow \mu\mu$, HH) measurements.

Two different approaches:

- Projections from existing results
- Dedicated studies using the Phase II detector configuration (Based on **Delphes** and/or Fullsim)

Public results from Snomass (2013) & TP (2015)

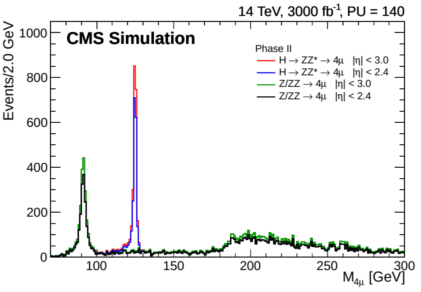
New studies targeting October this year (ECFA meeting)

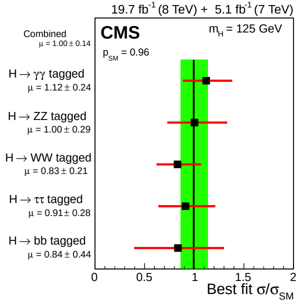
SM Higgs - Precision Measurements

Measuring the Higgs properties (spin and parity, mass, total width) through the five most sensitive analyses.

Extrapolations from Run I results to 300 and 3000 fb^{-1} at $\sqrt{s}$=14 TeV assuming the same detector performance.

- **Scenario 1**: All systematics unchanged
- **Scenario 2**: Theoretical uncertainties scaled by $1/2$, other systematics scale by $1/\sqrt{L}$





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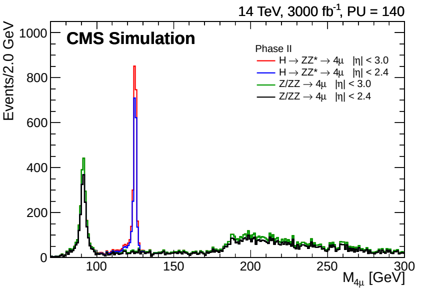
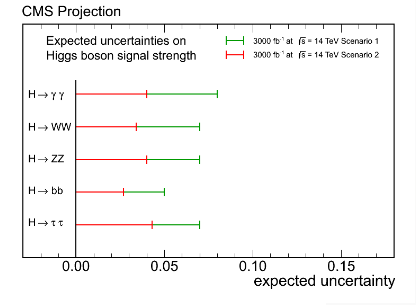




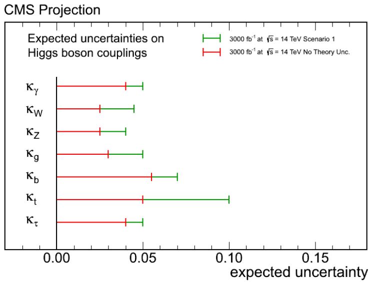
SM Higgs - Precision Measurements

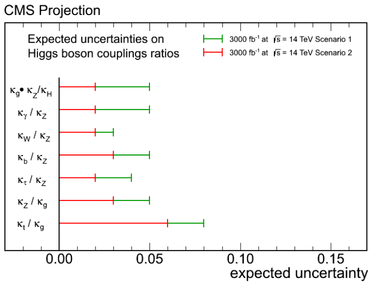
Higgs boson couplings and ratios

$$(\sigma \times BR)(x \to H \to ff) = \frac{\sigma_x \cdot \Gamma_{ff}}{\Gamma_{total}}$$

Γ_{ff} proportional to the effective H couplings (g_i^2):
Scale factors $\kappa_i = g_i / g_i^{SM}$

Estimated precision on the coupling modifier, and coupling modifier ratios under the assumption of one narrow Higgs resonance.



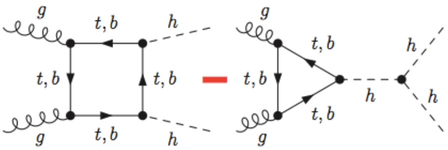


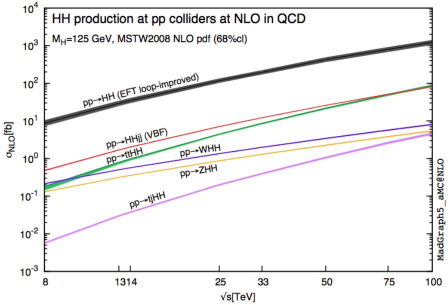
Higgs boson Pair Production & Self-coupling

Next milestone in Higgs physics

Access to the Higgs potential (λ_{HHH} determines the shape of the potential)

- Destructive interference $\sigma_{HH} \sim 30 fb$ (@ 13TeV)
- Large backgrounds
- Really challenging from the experimental point of view





http://arxiv.org/pdf/1401.7340.pdf

Higgs boson Pair Production & Self-coupling

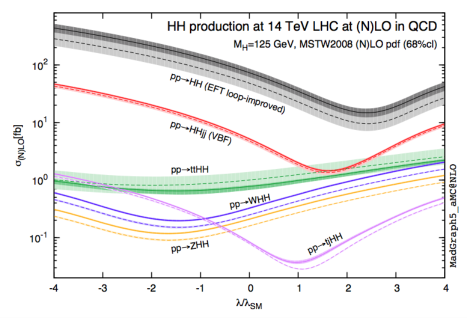
Public results on:

- $HH \rightarrow bb\gamma\gamma$
- $HH \rightarrow bb\tau\tau$
- $HH \rightarrow bbWW \rightarrow bbl\nu l\nu$

Work ongoing:

- $HH \rightarrow bbbb$
- $HH \rightarrow bbWW \rightarrow bbl\nu jj$

A measurement will probably need several channels and both ATLAS and CMS experiments



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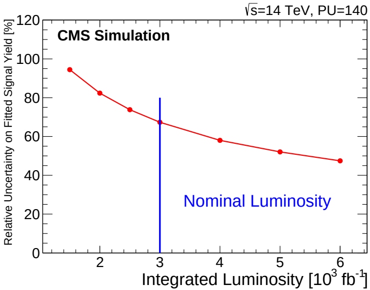
Deviations in the self-coupling, from the SM value, give significant variations in the cross section.

HH $\rightarrow bb\gamma\gamma$ and HH $\rightarrow bb\tau\tau$

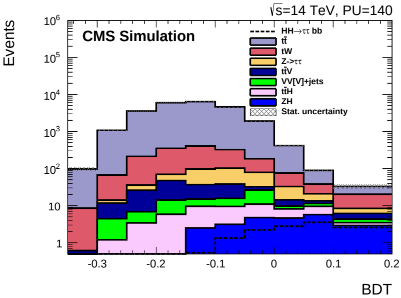
HH $\rightarrow bb\gamma\gamma$**:**

- Scale the efficiencies, fake rates, and resolutions taken from Phase II fully simulated samples
- 2D fit of M_{bb} and $M_{\gamma\gamma}$
- Expected significance of 1.6σ



HH $\rightarrow bb\tau\tau$**:**

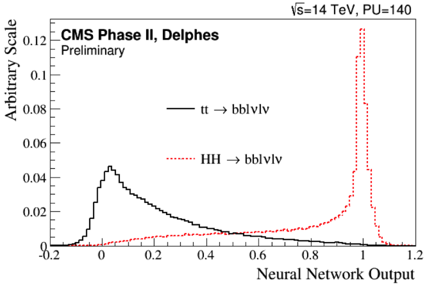
- Using Delphes simulation
- Overwhelming $t\bar{t}$ background
- $\tau_h\tau_h$ and $\tau_h\tau_\mu$ final states
- Significance of $0.9\ \sigma$

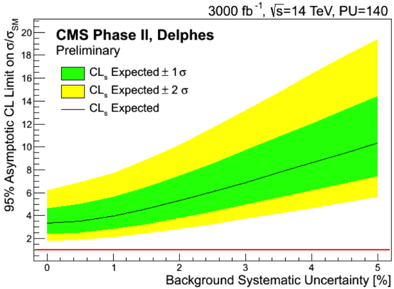


HH → $bbWW \to bbl\nu l\nu$

- Based on Delphes Phase II
- Only ttbar background considered
- Assuming background uncertainties at percent level from data driven estimation

Neural Network discriminant to suppress $t\bar{t}$. Input variables: M_{ll}, M_{jj}, ΔR_{ll}, ΔR_{jj}, ΔR_{jl}, E_T^{miss}, $\Delta\phi_{ll,jj}$, p_T^{jj}, and M_T

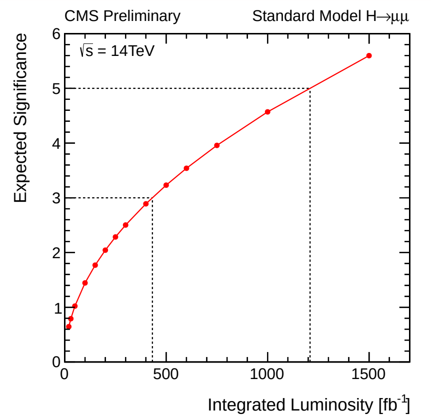




Rare Decays

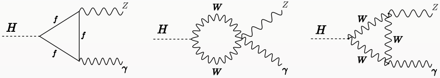
$H \to \mu\mu$

- Probe of the Higgs coupling dependence on lepton flavour
- Can contribute to the mass measurement
- 5σ significance with 1200 fb^{-1}



$H \to Z\gamma$

- Access to the loop structure



	$\Delta\mu/\mu$	
L (fb^{-1})	$Z\gamma$	$\mu\mu$
300	[62,62] %	[40,42] %
3000	[20,24] %	[20,24] %

Summary

The HL-LHC project is moving forward both in the accelerator and detector sides. Belgian involvement in the CMS upgrade.

SM Higgs results from Snowmass and Technical Proposal focused on

- Higgs couplings and rare processes.

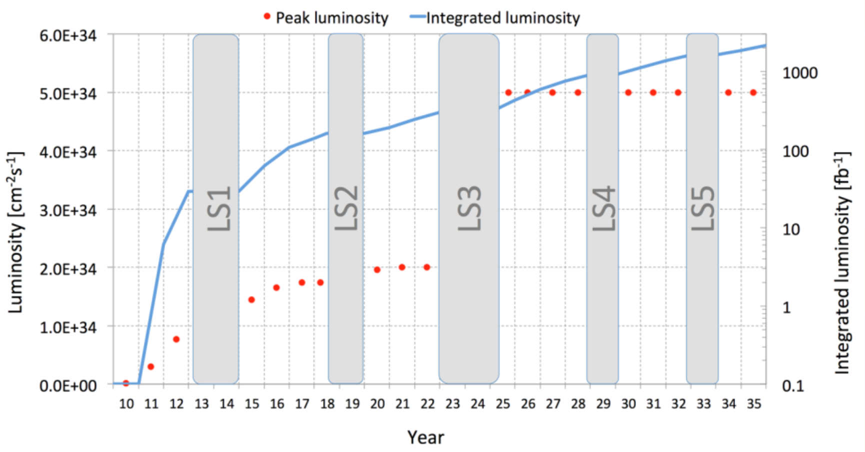
New studies and projections from Run II analyses:

- Coming next Fall
- Much more in the TDR's 2017-2018

BSM Higgs results also available, not covered in this talk

Backup Slides

HL-LHC Lumi



Peak luminosity
Integrated luminosity
6.0E+34
5.0E+34
4.0E+34
3.0E+34
2.0E+34
1.0E+34
0.0E+00
Luminosity [cm-2s-1]
1000
100
10
1
0.1
Integrated luminosity [fb-1]
LS1
LS2
LS3
LS4
LS5
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
Year

Physics & CMS Phase II Upgrades

Performance/ Physics	Higgs VBF $H \to \tau\tau$	Higgs $H \to \mu\mu$	Higgs $H \to ZZ \to 4l$	Higgs $HH \to bb\gamma\gamma$	Higgs $HH \to bb\tau\tau$	SMP VBS	SUSY VH(bb) +MET	EXO A_{fb} (Z')	EXO Dark Matter	EXO HCP	BPH $B_{s,d} \to \mu\mu$
Tracker											
Performance		*mass resolution*	mass resolution	*b-tagging*	*b-tagging*						*mass resolution*
Extensions	*forward jets / MET*		*acceptance*		*MET resolution*	*forward jets*	*MET resolution*	*acceptance*	*acceptance*		
Trigger											
Bandwidth	*acceptance*				*acceptance*						
Track Trigger	*background rejection*				*background rejection*						*background rejection*
Calorimeter											
ECAL	*forward jets / MET*		*acceptance*	*acceptance*	*MET resolution*	*forward jets*	*MET resolution*	*acceptance*	*acceptance*		
HCAL	*forward jets / MET*				*MET resolution*	*forward jets*	*MET resolution*				
Muons											
Extension			*acceptance*					*acceptance*	*acceptance*		