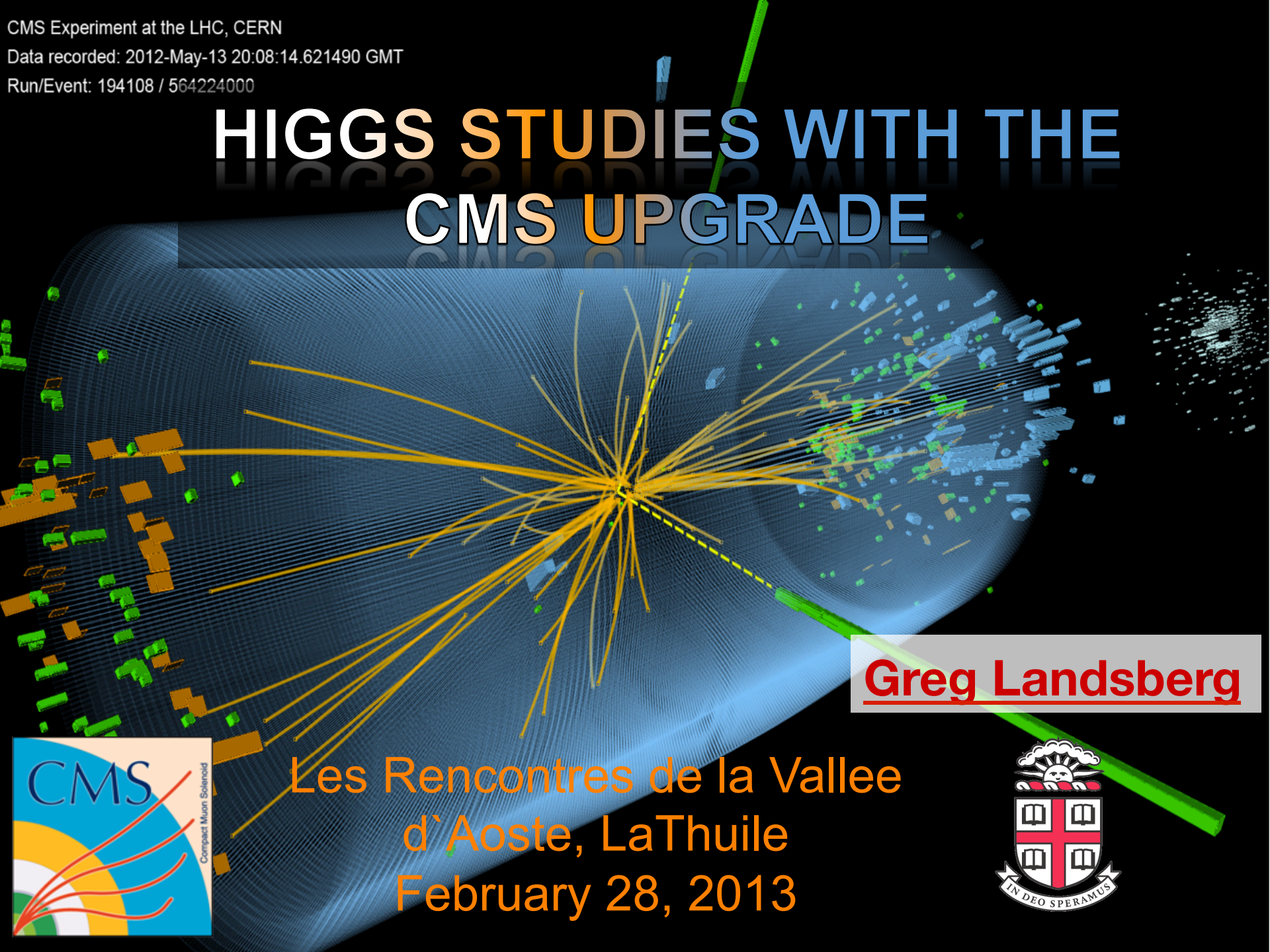
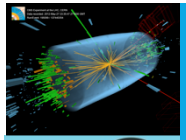
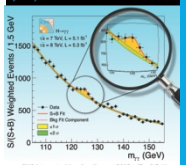


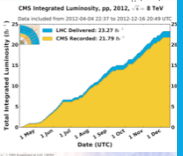
HIGGS STUDIES WITH THE CMS UPGRADE

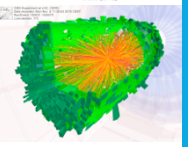
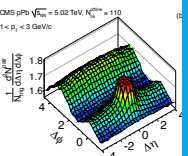
Greg Landsberg

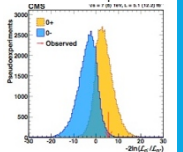
Les Rencontres de la Vallee d`Aoste, LaThuile

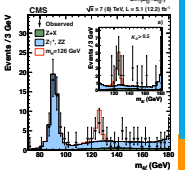
February 28, 2013

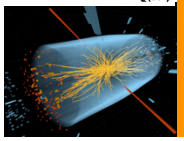











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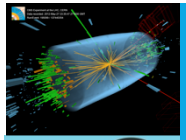
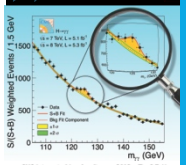
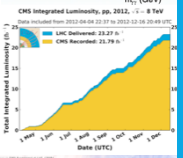
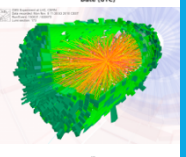
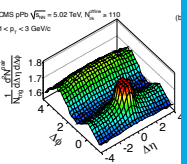
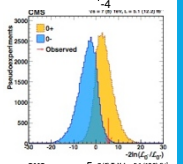
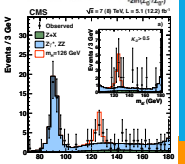
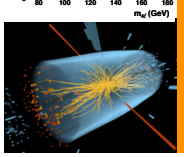
Slide 2

Projections for the next Decade

LHC: 10-Year Plan

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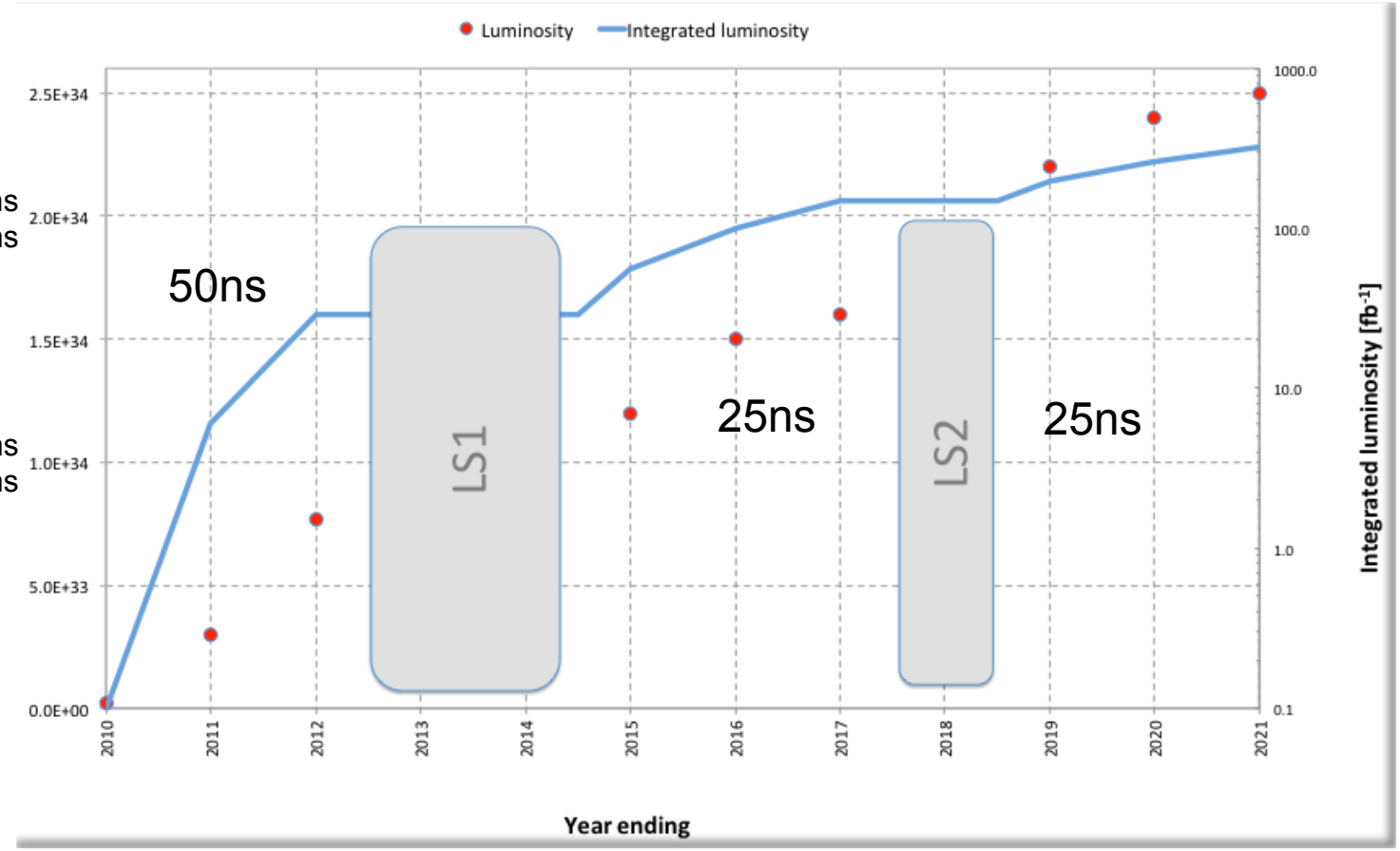
Slide 3

From Mike Lamont, CMS Upgrade Workshop, January 17, 2013

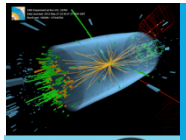
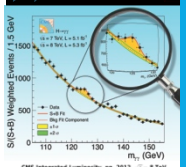
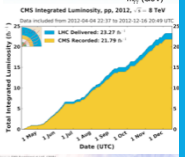
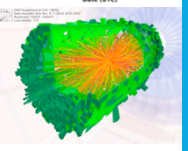
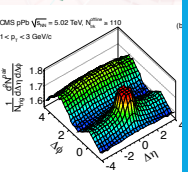
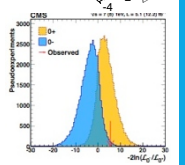
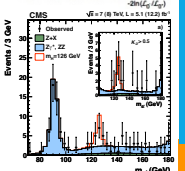
PU: 50@25ns
100@50ns

PU: 25@25ns
50@50ns



- 2013-2022: 300-400/fb by 2022
- 2023-2033: HL-LHC Upgrade with leveling at ~5x10^{34} cm^{-2}s^{-1}?

From LHC 14 to HL-LHC

- These projections were made as part of the ESPG report, CMS Note 2012-006
- They are based on extrapolation of the existing analyses to the conditions expected up to the HL-LHC operation period
- These studies are being repeated with more realistic detector simulation and will be updated ~ next Fall

Information | Discussion (0) | Files | Linkbacks

CMS Note

Report number	CMS-NOTE-2012-006 ; CERN-CMS-NOTE-2012-006
Title	**CMS at the High-Energy Frontier. Contribution to the Update of the European Strategy for Particle Physics**
Corporate author(s)	CERN. Geneva
Collaboration	CMS Collaboration
Imprint	24 Oct 2012. - 18 p.
Subject category	Detectors and Experimental Techniques
Accelerator/Facility, Experiment	CERN LHC ; CMS
Keywords	Physics
Abstract	We present a study of the physics potential of the upgraded CMS detector in Higgs physics, searches for new physics, top, and electroweak physics in three scenarios: the LHC (300 fb^{-1} at 14 TeV), HL--LHC (3000 fb^{-1} at 14 TeV), and HE--LHC (300 fb^{-1} at 33 TeV). We also discuss the potential to reduce the PDF uncertainties, which at the moment the limiting systematics for many of these studies. This document has been submitted to the European Strategy Planning Group.

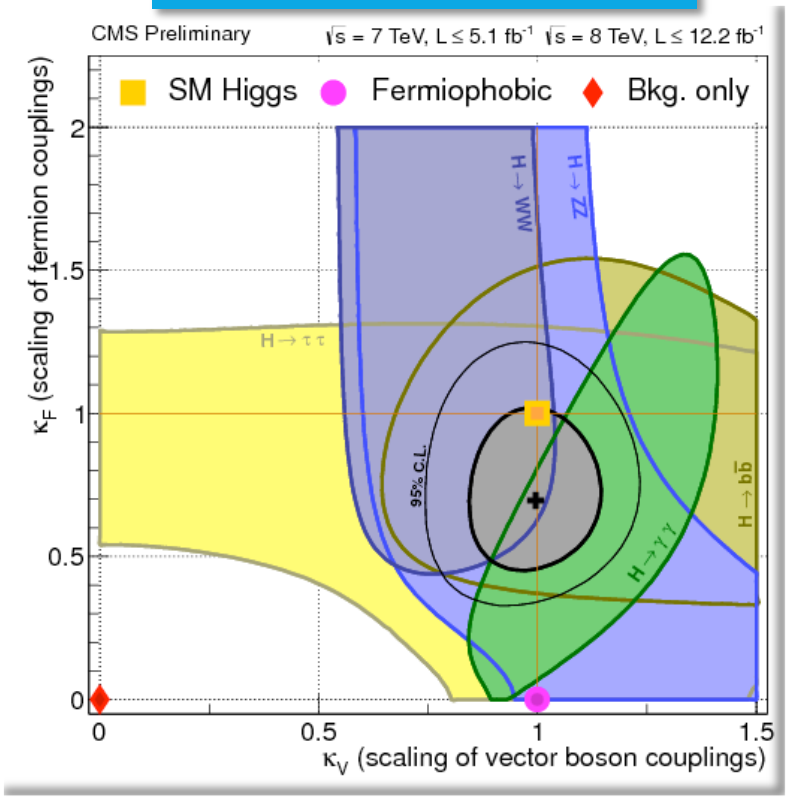
Record created 2012-11-19, last modified 2012-11-29

Similar records

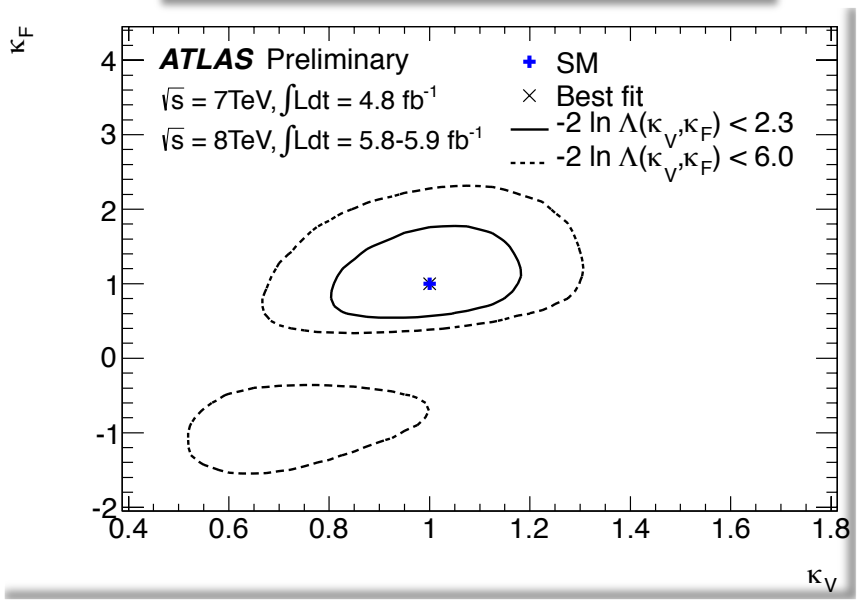
Couplings: Where are we Now?

- 2012: couplings consistent with the SM within 1σ
- Typical uncertainty: 25% (κ_V) – 50% (κ_F)
- Crucial to improve this precision to ~5% level or better
  - Many BSM Higgs scenarios predict coupling modification at that level

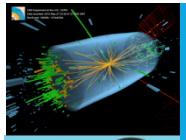
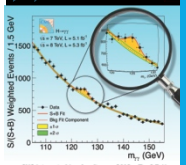
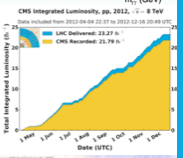
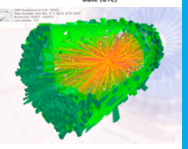
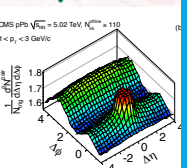
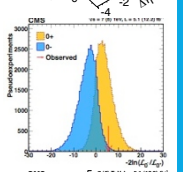
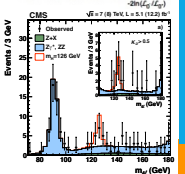
CMS PAS HIG-12-045



ATLAS-CONF-2012-127



Expectation for 2013

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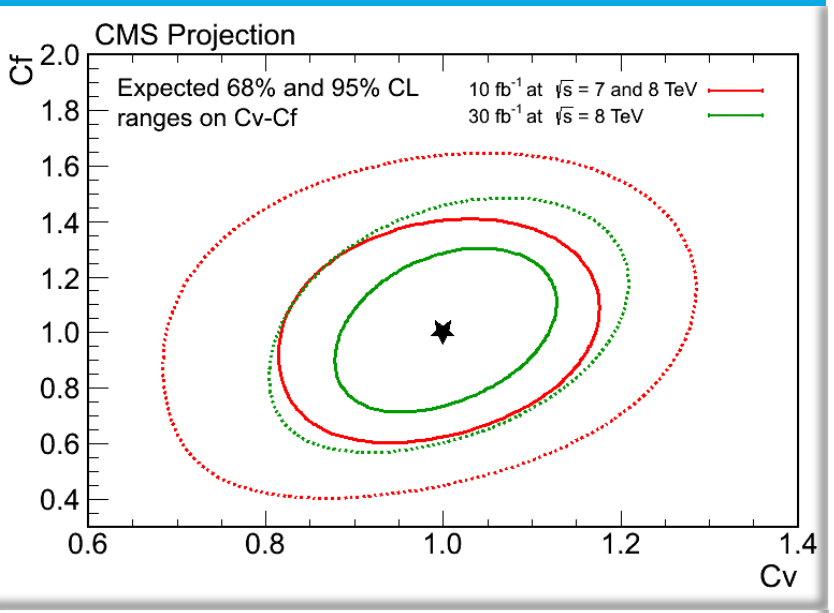
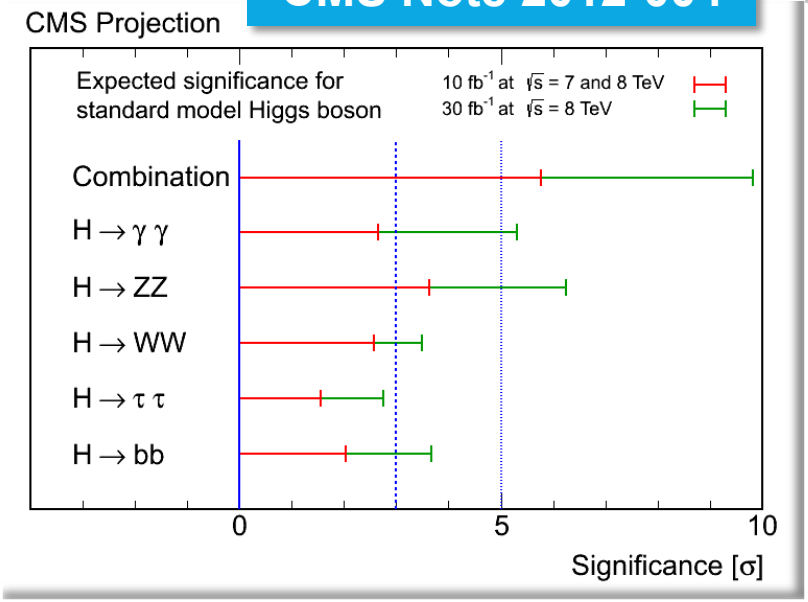
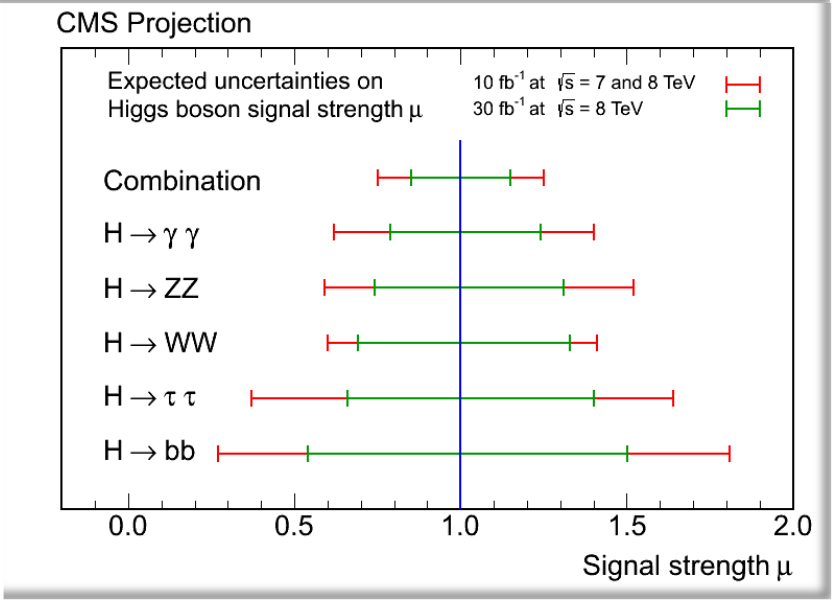
Slide 6

- Where we expect to be in a few months:
  - 15% (κ_V) – 25% (κ_F)



CMS Note 2012-004



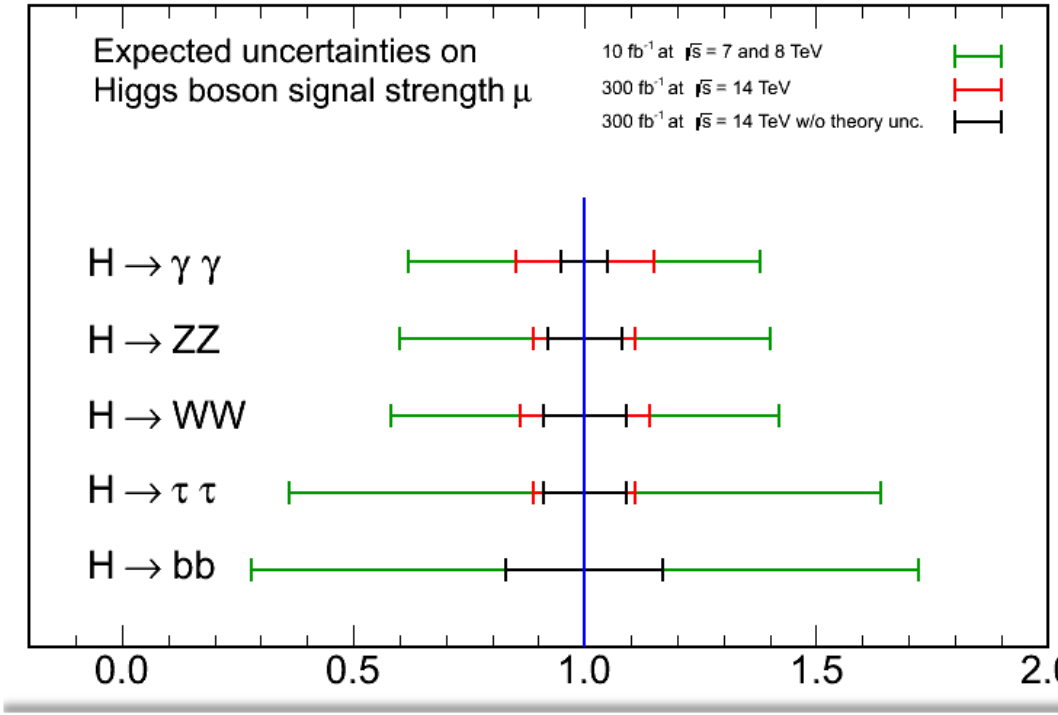


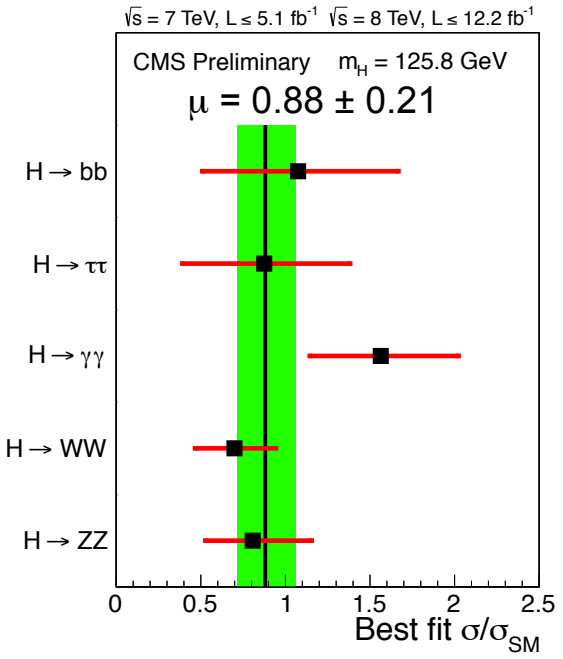
Signal Strength

- 20% precision has been already achieved in the combination
- 10-15% precision per channel is achievable w/ 300/fb
  - Effect of theory uncertainties is mostly important in the H(γγ) channel

CMS Note 2012-006

CMS Projection

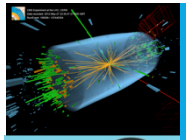
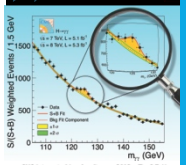
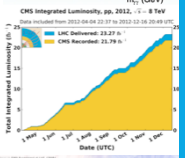
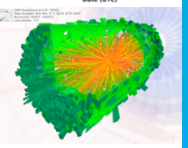
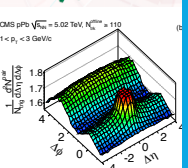
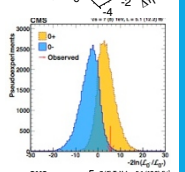
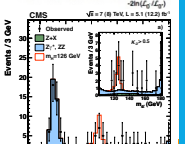
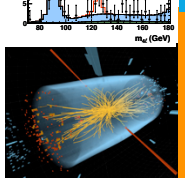




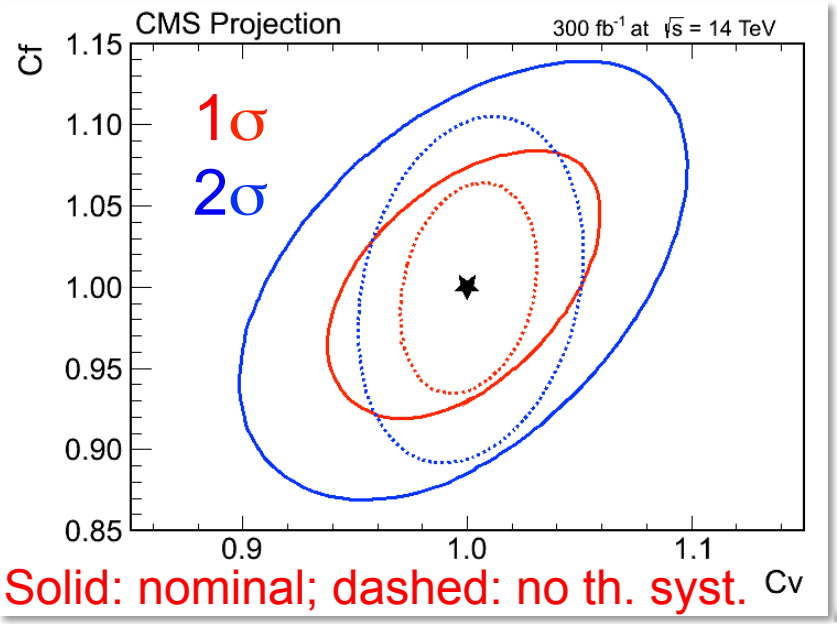
CMS PAS HIG-12-045

Green: ICHEP 2012
Red: 300/fb @ 14 TeV
Black: same, w/o theory uncertainties

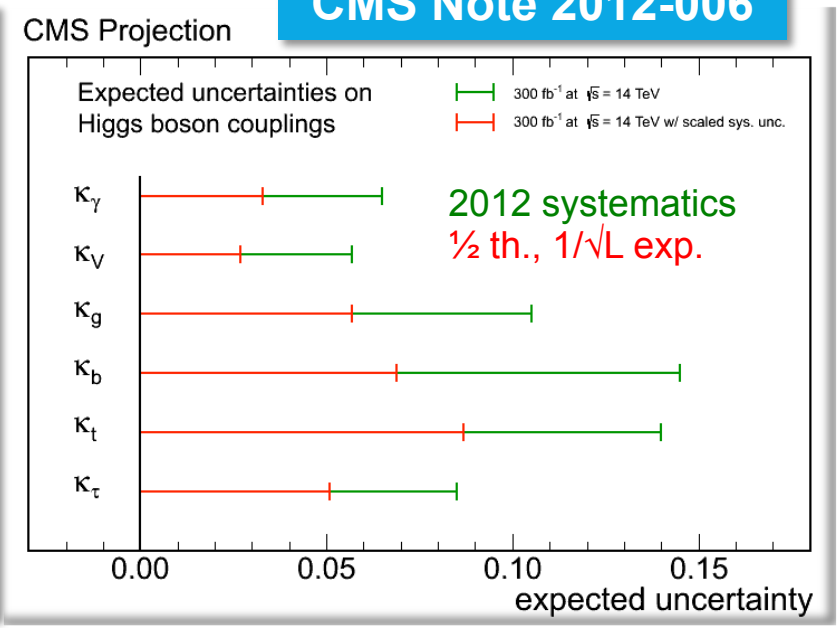
Couplings @ LHC 14

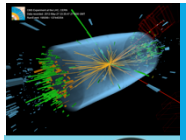
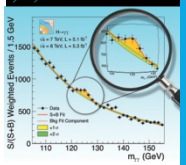
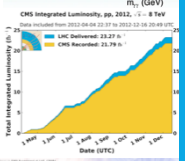
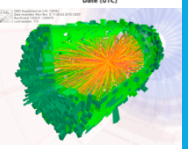
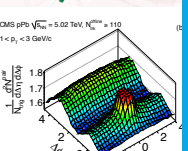
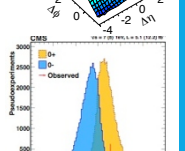
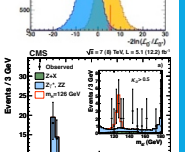
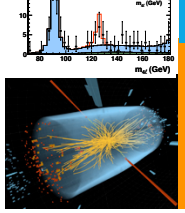
- Projections up to ~300/fb (~2022) are reasonably straightforward
- Two scenarios:
  - Scenario 1: same systematics as in 2012 - pessimistic
  - Scenario 2: theory systematics are halved; the rest scale as $1/\sqrt{L}$ – somewhat optimistic
- Couplings to muons have not been studied recently in CMS, but ~25% precision should be achievable



CMS Note 2012-006



Beyond 300/fb

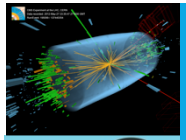
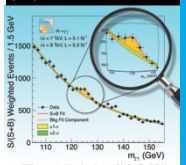
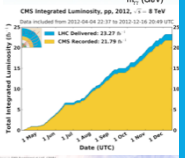
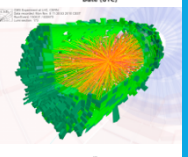
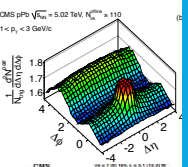
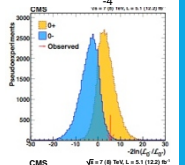
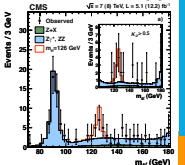
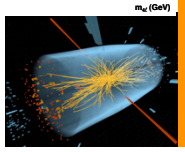









- Projections further out are subject of large uncertainties
  - The exact detector configuration & even technology are not quite known yet
  - The running conditions have not been defined completely yet
  - Theoretical progress in the next decade is hard to gauge
- Still, in the more realistic "Scenario 2" the HL-LHC would allow to do precision Higgs physics with individual couplings measured up to 1-3% precision
- Searches for exotic/invisible Higgs decay as a window on new physics

CMS Note 2012-006

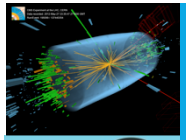
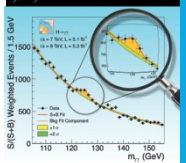
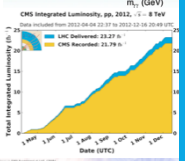
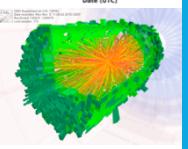
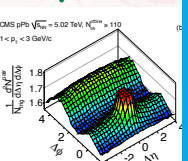
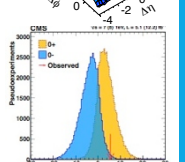
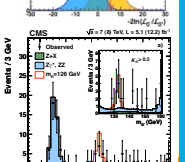
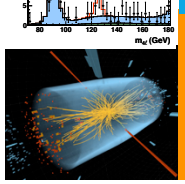
Coupling	Uncertainty (%)			
	300 fb^{-1}		3000 fb^{-1}	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
κ_γ	6.5	5.1	5.4	1.5
κ_V	5.7	2.7	4.5	1.0
κ_g	11	5.7	7.5	2.7
κ_b	15	6.9	11	2.7
κ_t	14	8.7	8.0	3.9
κ_τ	8.5	5.1	5.4	2.0

Strong Case for HL-LHC

- There are other unique measurements, which require to go far beyond 300/fb:
  - Establishing H(μμ) decay at >5σ significance and measurement of the Hμμ coupling to ~10% level
  - Measurement of the Higgs self-coupling (cross section for HH production is 33fb @ 14 TeV)
  - Observing how VV scattering amplitudes unitarize in the presence of H(125)
    - Are there other s-channel resonances involved?
- Higgs is not the only case for the HL-LHC
  - Answering the major question if we have entered the "desert" and there are no new weakly or strongly interacting states below a few TeV
  - Finding massive new physics or ruling out broad class of "natural" new physics model and demonstrating that SM is fine tuned
  - Probing higher energy scales via precision measurements

Just a Couple of Examples

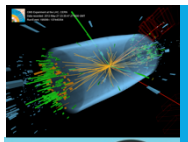









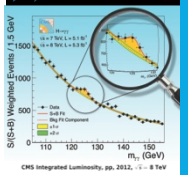
- If we find new physics (e.g., SUSY at the LHC-14, we will need to measure masses and decays precisely to shed light on:
  - Gaugino mass unification
  - Squark/slepton unification
  - SUSY flavor and CP violation
  - Baryogenesis
  - Neutrinos and leptogenesis
  - String compactifications
  - …

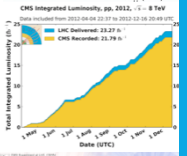
- If SUSY is not found at LHC 14, how far should we push?
  - Important to test naturalness to a limit
  - Certainly to ~1 TeV on the sbottom/stop
  - But also on χ_2^0 and $\chi^{\pm}$

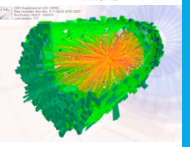
	300 fb-1	3000 fb-1
m(sq)=m(gl)	2600 GeV	3000 GeV
stop (b C1)	650 GeV	850 GeV
stop (t N1)	780 GeV	920 GeV
C1 N2	250 GeV	800 GeV

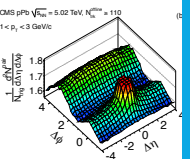
  - The latter is impossible at any foreseen e^+e^- collider

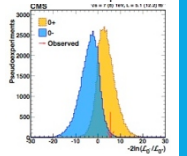


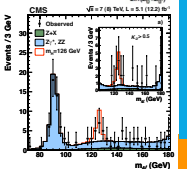


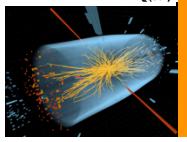












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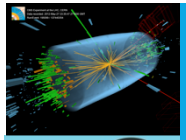
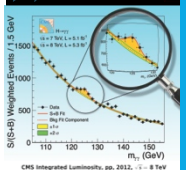
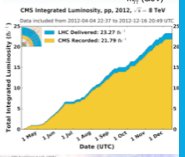
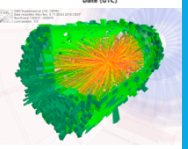
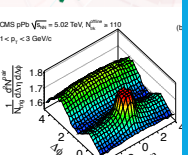
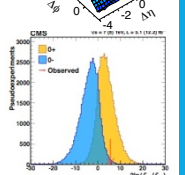
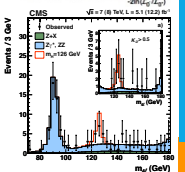
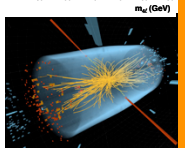
Projections?

How Reliable are They?

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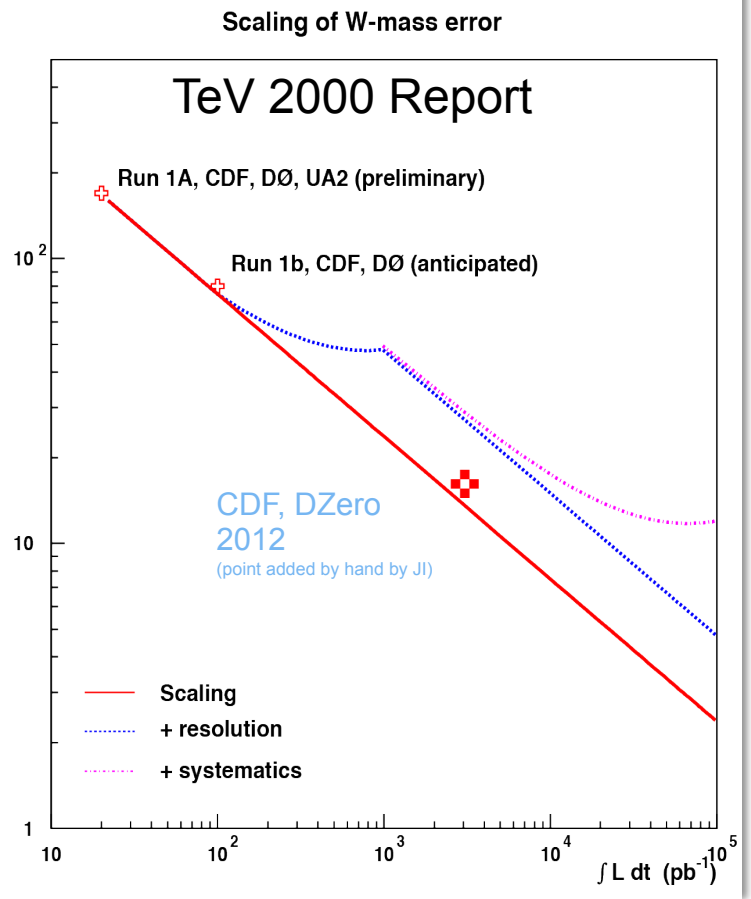
Slide 13

- **"Prediction is very difficult, especially about the future"** – Niels Bohr
- Yet, we have learned a lot about high-pileup running last year and we adjusted our requirements to the upgraded detectors to match current performance
- When challenged by real data, experimenters tend to work much harder than when making projections
- Do not understand our theory friends – there has been tremendous progress on the precision calculations over the past decade
- **So, let's look at the past…**

W-Mass Projections

- Twelve years of hard work allowed us to beat even rosiest of the projections!
- CDF 2012: $M_W = 80\ 387 \pm 12_{\rm stat} \pm 15_{\rm syst} = 80\ 387 \pm 19\ {\rm MeV}/c^2$

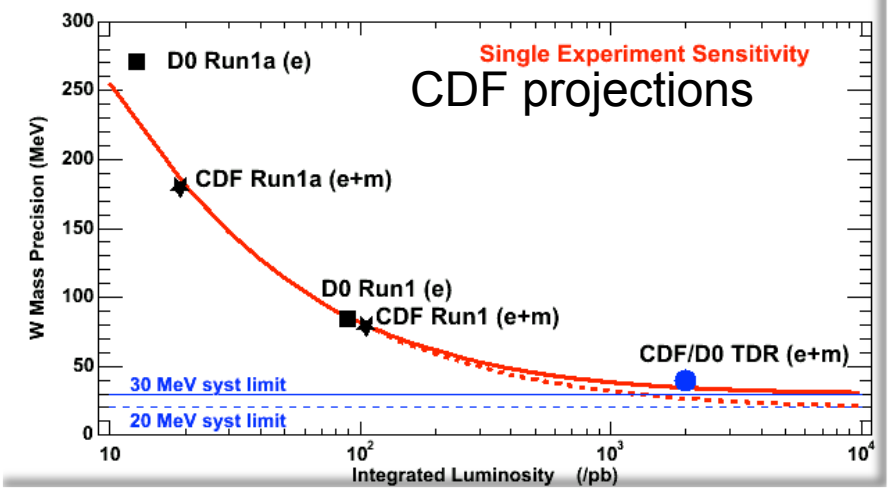


W PDG 2012 $J = 1$

Charge $= \pm 1\ e$

Mass $m = 80.385 \pm 0.015$ GeV

arXiv:1203.0275, 2.2 fb^{-1}, e-only



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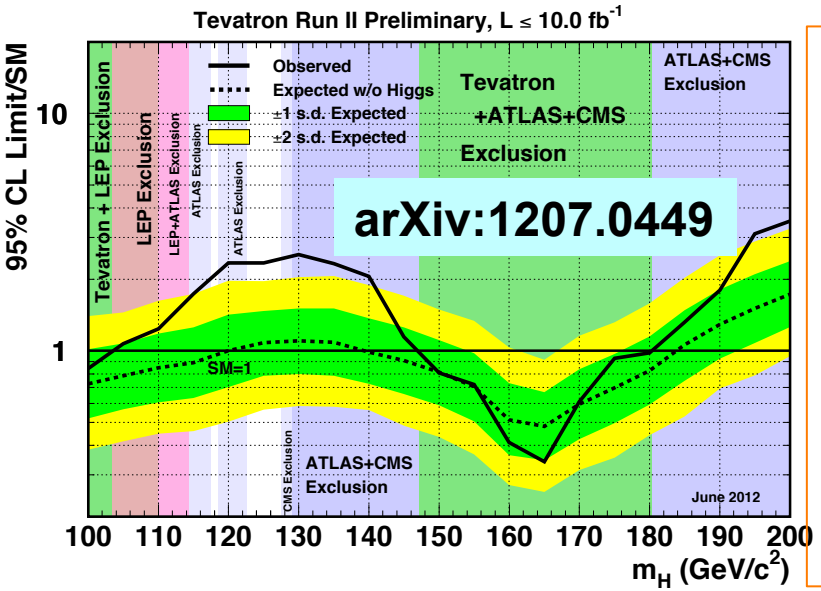
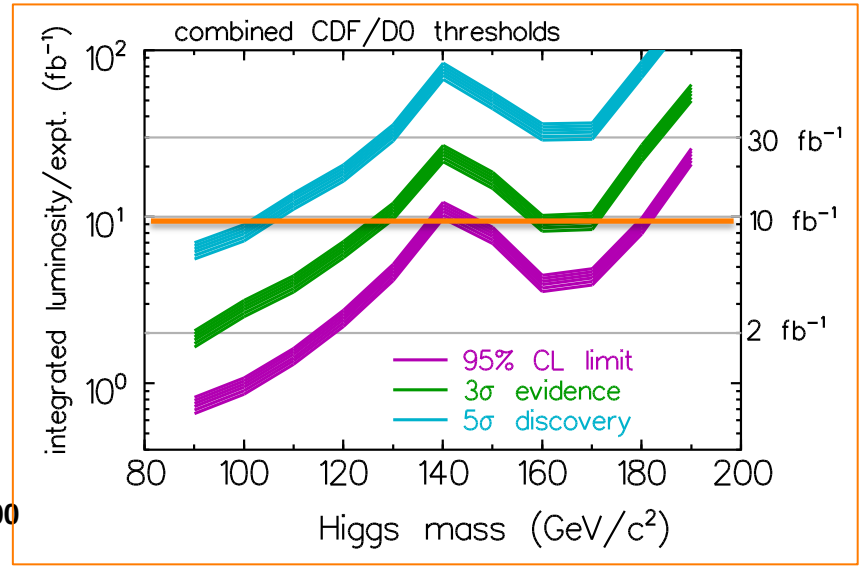
Higgs Discovery Projections

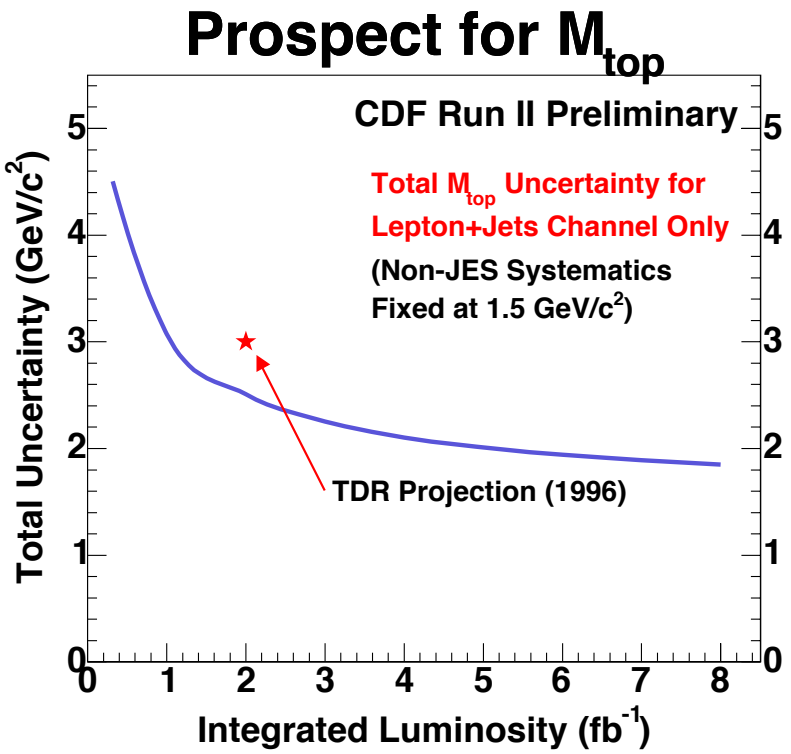
- 98-99 projections were bang-on with the 2012 results, despite a lot of early criticism that they are overoptimistic!

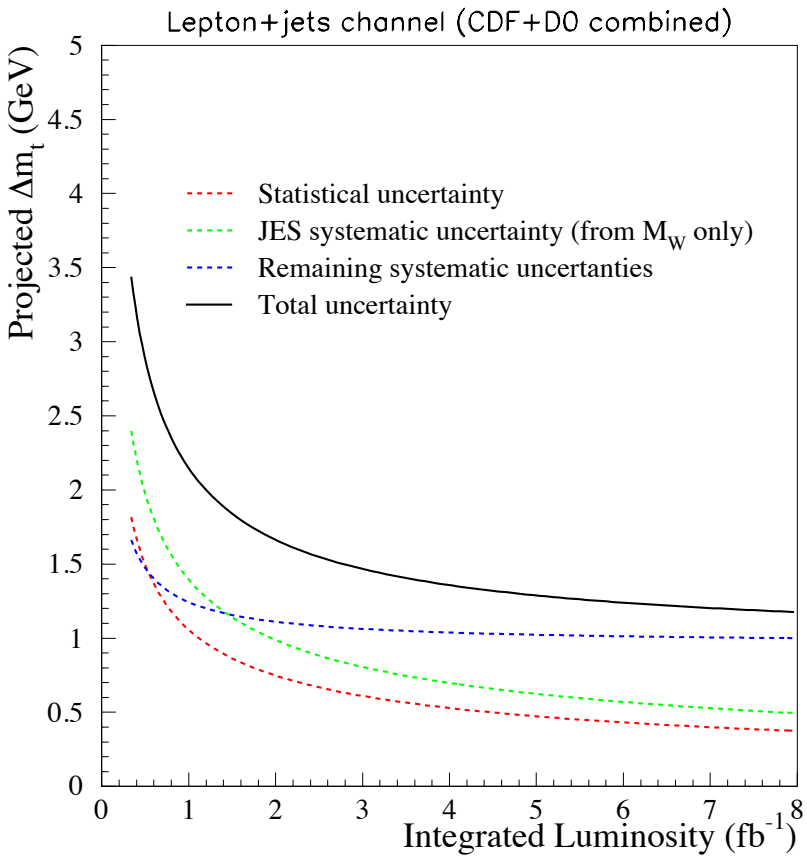


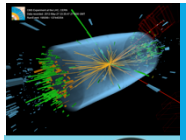
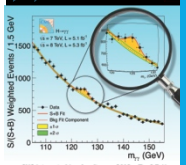


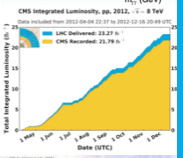
Top Mass Projections

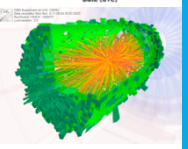
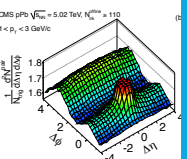
- …and the top mass projections were beaten several times by the Tevatron
- So, if history is a lesson, we will overdeliver again!

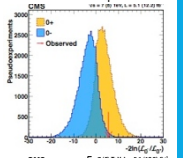


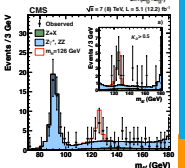


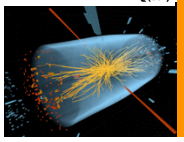











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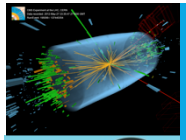
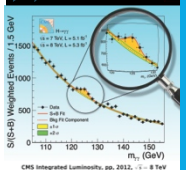
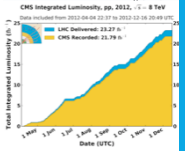
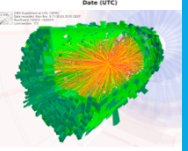
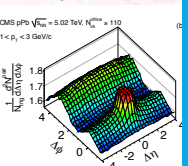
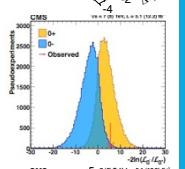
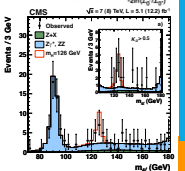
Backup

CMS Upgrade Phases

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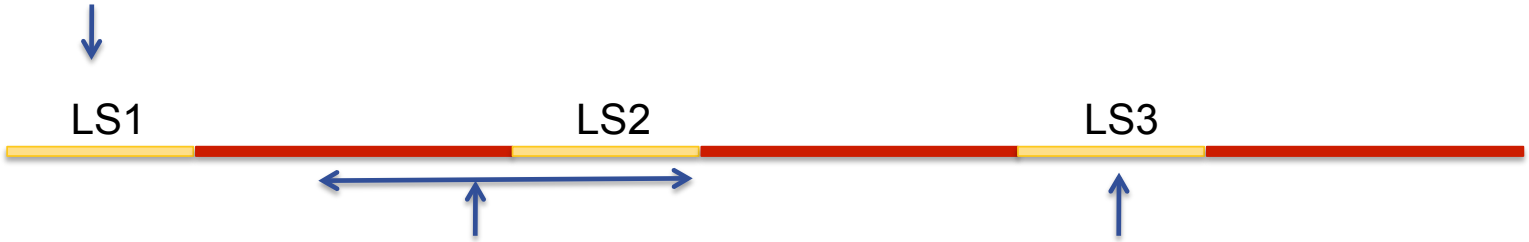
LS1 Projects:

- Completes muon coverage (ME4)
- Improve muon trigger (ME1), DT electronics
- Replace HCAL photo-detectors in Forward (new PMTs) and Outer (HPD → SiPM)



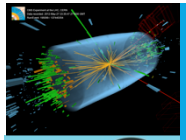
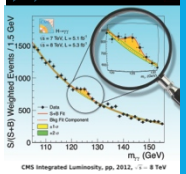
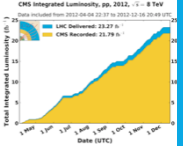
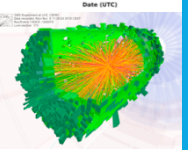
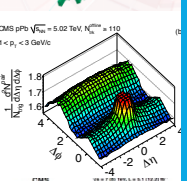
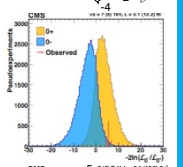
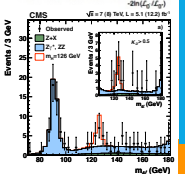
Phase 1 Upgrades:

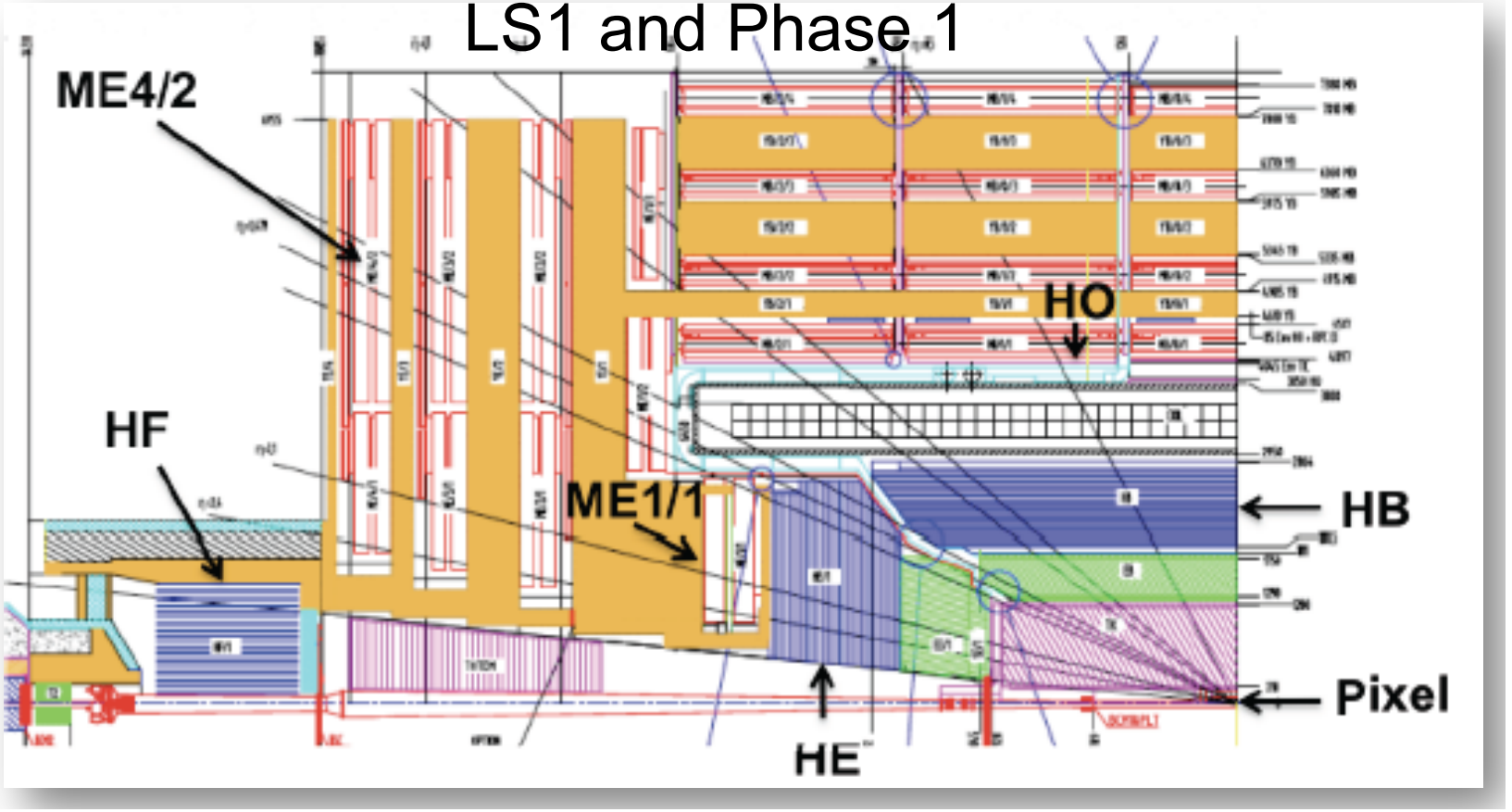
- New Pixels, HCAL SiPMs and electronics, and L1-Trigger
- Preparatory work during LS1:
  - new beam pipe
  - test slices of new systems

Phase 2 Upgrades: scope to be defined in Technical Proposal (2014)

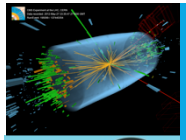
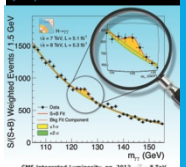
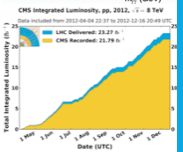
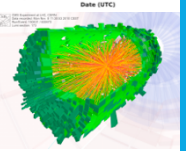
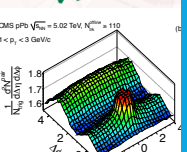
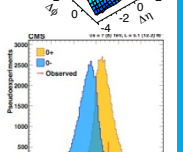
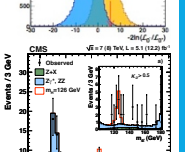
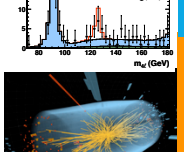
- Tracker Replacement
- Forward Calorimetry and Muons
- Further Trigger upgrade: Track Trigger

CMS Phase 1 Upgrade



Main Phase I Upgrade Components

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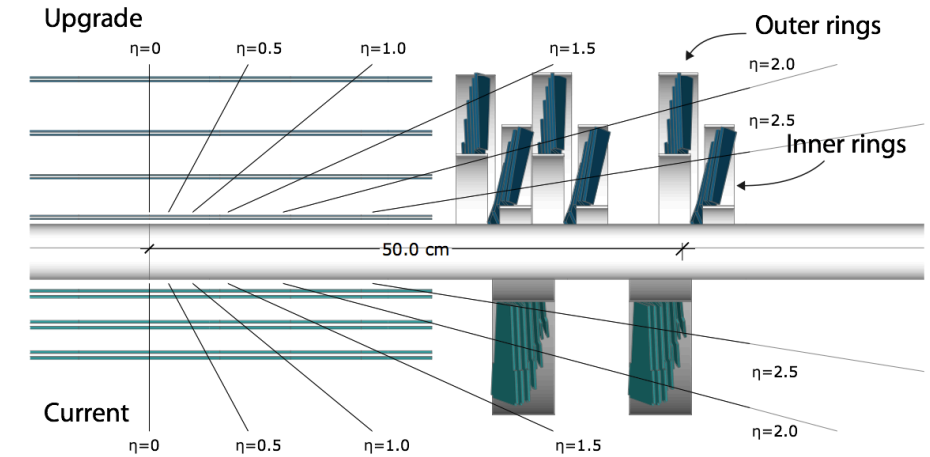
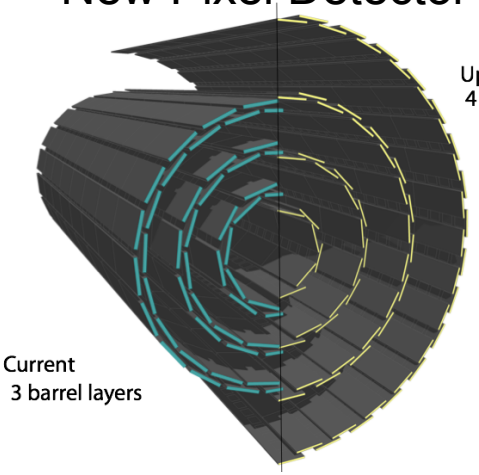
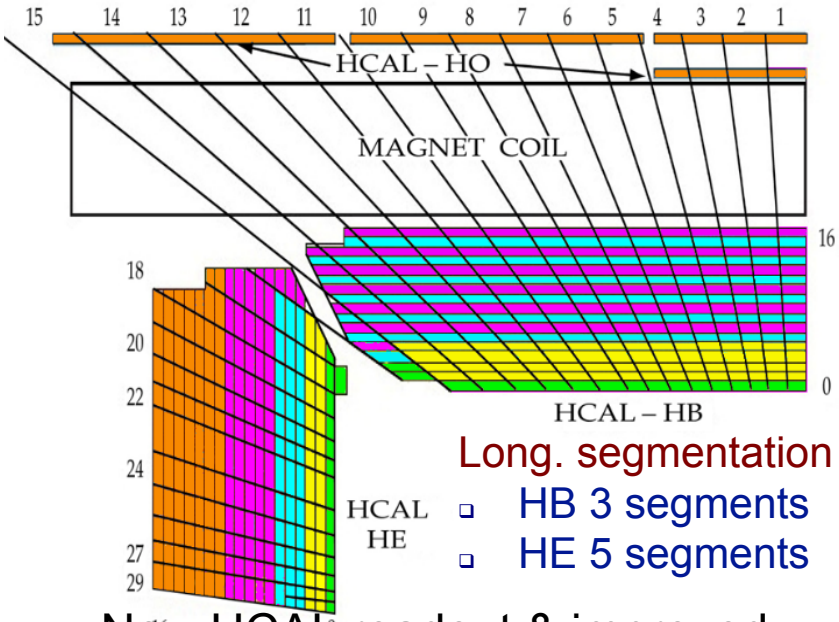


New Pixel Detector





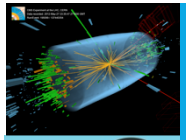
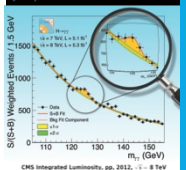
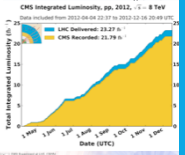
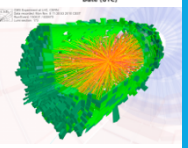
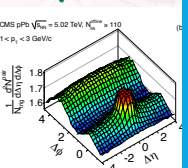
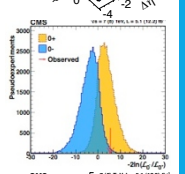
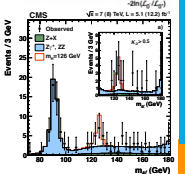
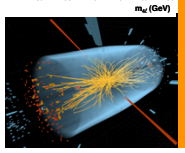
Long. segmentation

- HB 3 segments
- HE 5 segments

New HCAL readout & improved longitudinal segmentation

New calorimeter/muon/global trigger

Phase 2 CMS Upgrade Goals

- Aiming to operate at 5x design luminosity of the LHC with ~125 pileup interactions per bunch crossing
- Adding fast L1 track trigger
- Replacement of the entire silicon tracker
- Replacement of endcap and forward calorimeters (designed to take ~500/fb)
- New forward calorimetery and tracking with the focus on VBF physics (VV scattering, VBF production of Higgs and new physics)
- Possibly ultra-fast timing for pileup mitigation