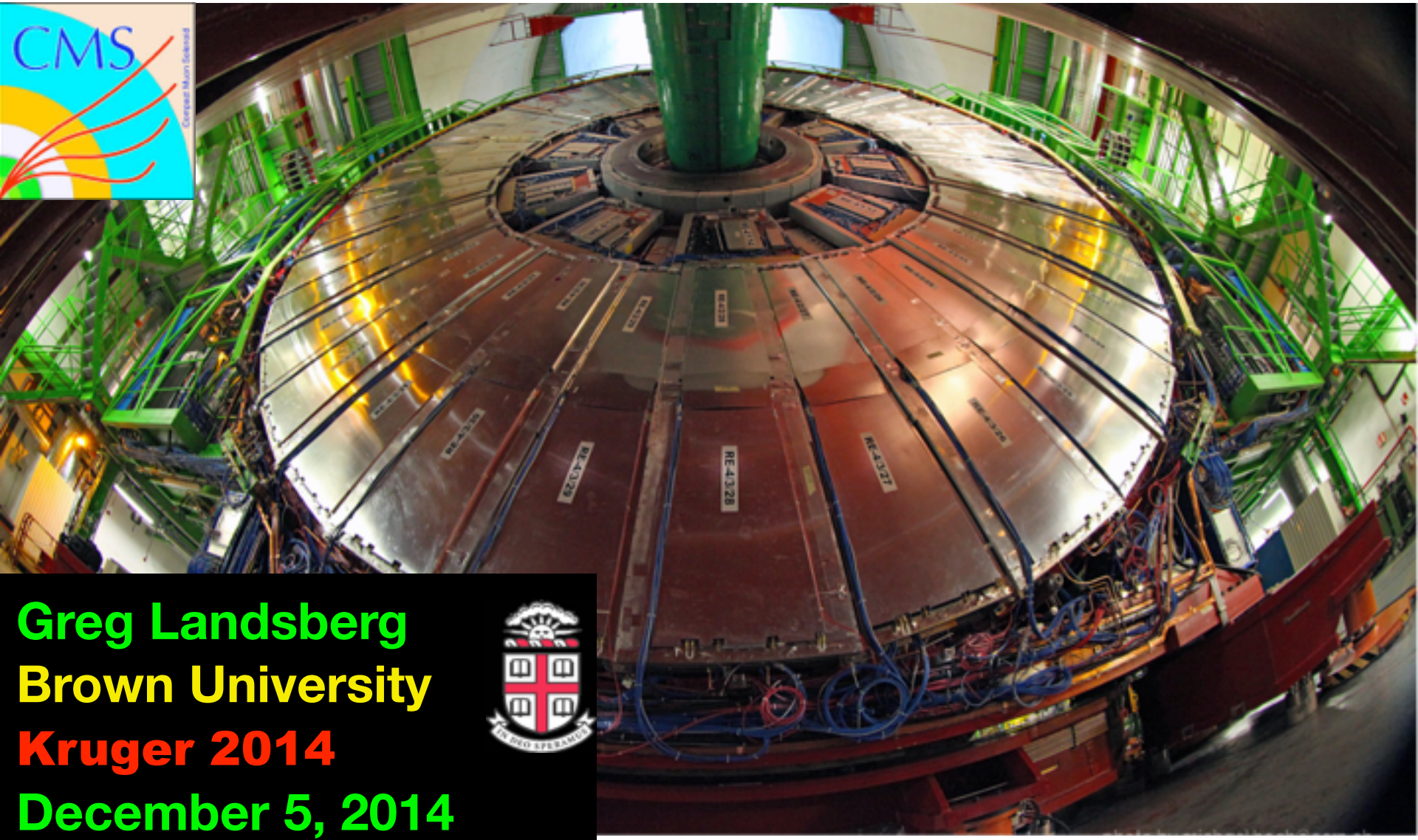
CMS: PAST, PRESENT, AND FUTURE



Greg Landsberg
Brown University

Kruger 2014

December 5, 2014

Big Five

- We are close to the end of this great conference in a magnificent and unique place
  - Many thanks to the organizers for a kind invitation!
- You heard excellent detailed talks on these subjects during the conference, including introductory talks with ATLAS and CMS physics highlights from Run 1
- The goal of this talk is to put the closing parenthesis by reminding you of some of the exciting results of Run 1 and discuss our preparations to new discoveries in Run 2 and beyond

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The Higgs

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The Higgs **pPb Surprises**

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The Higgs | **pPb Surprises** | **Precision SM measurements**

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The Higgs | **pPb Surprises** | **Precision SM measurements** | **Attack on naturalness and new physics**

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The Higgs | **pPb Surprises** | **Precision SM measurements** | **Attack on naturalness and new physics** | **$B_s(\mu\mu)$ and B-physics exploration**

Outline

- LS1 and CMS Consolidation
- Preparations for Run 2
- Beyond Run 2
- Harvesting Run 1 Physics Data
- Publish or Perish
- Conclusions

LS1 Progress

CMS Consolidation

- LS1 Work:
  - Completion of muon coverage (ME4)
  - Muon operation improvements: trigger (ME1), DT electronics
  - DAQ2 deployment
  - New Timing and Control System
  - Replacement of HCAL photo detectors
    - forward HCAL: new PMTs
    - outer HCAL: HPD → SiPM
  - Installation of a new beam-pipe
  - Maintenance and repairs
  - Beam Radiation Instrumentation and Luminosity (BRIL) hardware deployment
- Upgrades during Run 2:
  - L1 trigger upgrade
  - HCAL electronics upgrade
  - Pixel detector replacement (YETS 2016—17)
  - Preparatory work on new beam-pipe

LS1: Executive Summary

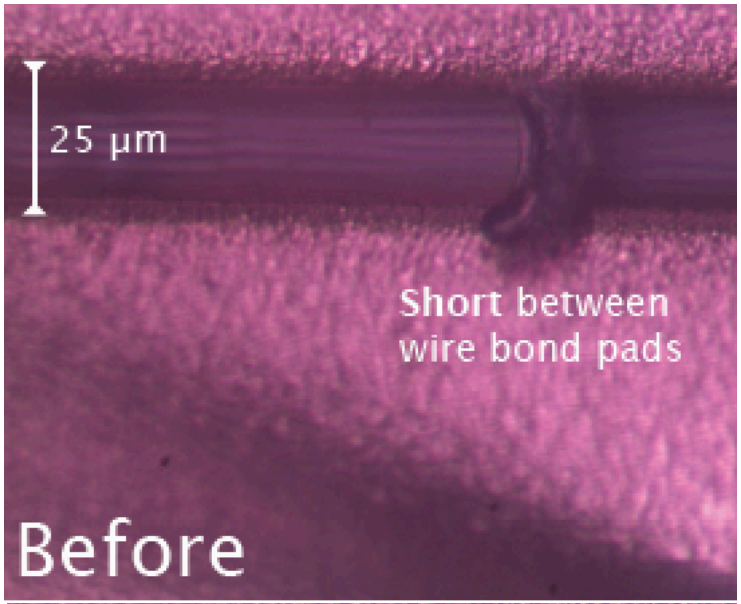
- Detector: LS1 has achieved its main goals
  - Main deadline in the near future:
    - Pixel insertion
- Trigger: on track
  - ORM-OSLB is now part of the system
  - Major milestones ahead
- Commissioning and Run:
  - DAQ2 and new Timing & Control Distribution System are actively tested in regular global runs
- Software:
  - Large amount of development to cope with 25 ns, increased pileup
  - Release strategies being discussed
- Computing:
  - No change in resources
  - Lots of work in improving processes and performance
- CSA14:
  - Well engaged, valuable feedback in software and computing areas
- PHYS14:
  - In preparation

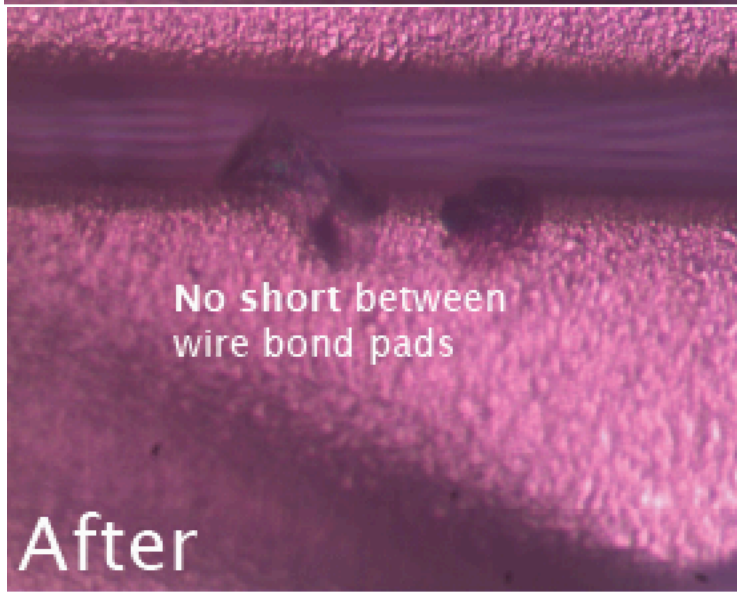
New Beam-Pipe

- New, thinner beam-pipe (⌀=45 mm) is installed, baked out, and ready for new pixel detector installation during the YETS 2016

Barrel Pixel Surprise

- BPIX quarter with 47 modules (7% of total BPIX modules) not responding or partially responding 2 weeks before the scheduled installation date
- The affected BPIX half-shell has been transported to PSI for repairs
- The other three quadrants have been checked again and are working fine
- The problem is an Ohmic short between wire bond pads on the high-density interconnect:
  - The shorts look like “whiskers” or “dendrites”
  - Resulted from the power test in high-humidity environment
- Repair: shorts can be removed easily (mechanically), in parallel produce new modules
  - 19 repaired modules
  - 40 new modules installed
  - Affected half-shell is fully operational now
- Insertion is scheduled for early December
- Despite a delay we will be ready in time for Run 2!





Beam Instrumentation

- Two new Si luminosity monitor telescopes are getting ready for installation (following BPIX)

Z=+/- 14.4 m, R=5 cm; R=28cm

BCM2L:

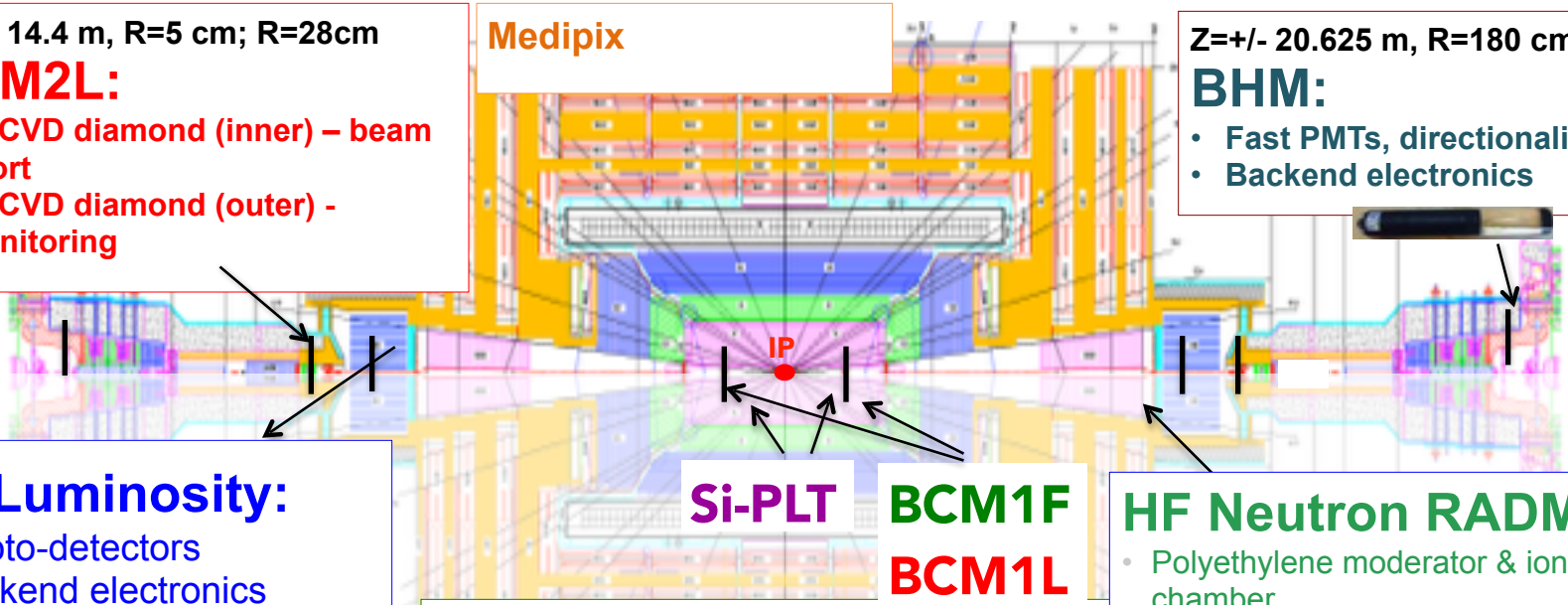
- 4 pCVD diamond (inner) – beam abort
- 8 pCVD diamond (outer) - monitoring

Medipix

Z=+/- 20.625 m, R=180 cm

BHM:

- Fast PMTs, directionality
- Backend electronics



HF Luminosity:

- Photo-detectors
- backend electronics

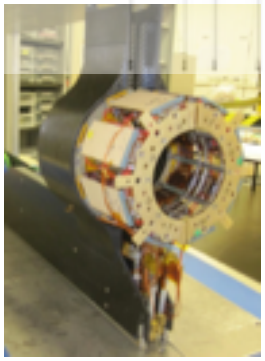
Si-PLT

BCM1F

BCM1L

HF Neutron RADMON:

- Polyethylene moderator & ionization chamber



Z=+/- 1.8 m, R=5-6 cm

Si-PLT:

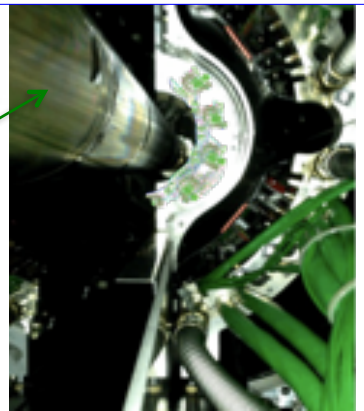
- 48 Si pixel sensors
- special 40 MHz readout

BCM1F:

- 48 single-crystal diamond sensors
- fast MIP counter, triggerless readout

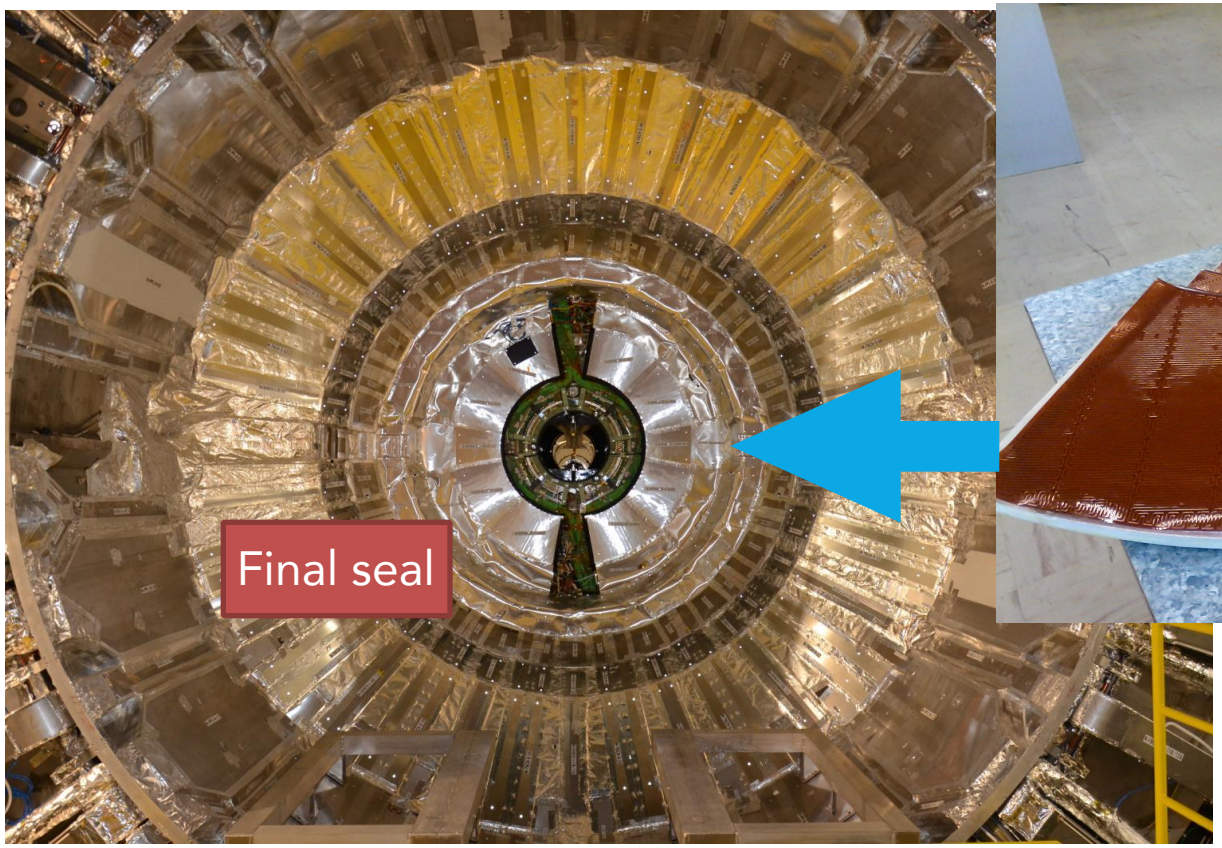
BCM1L:

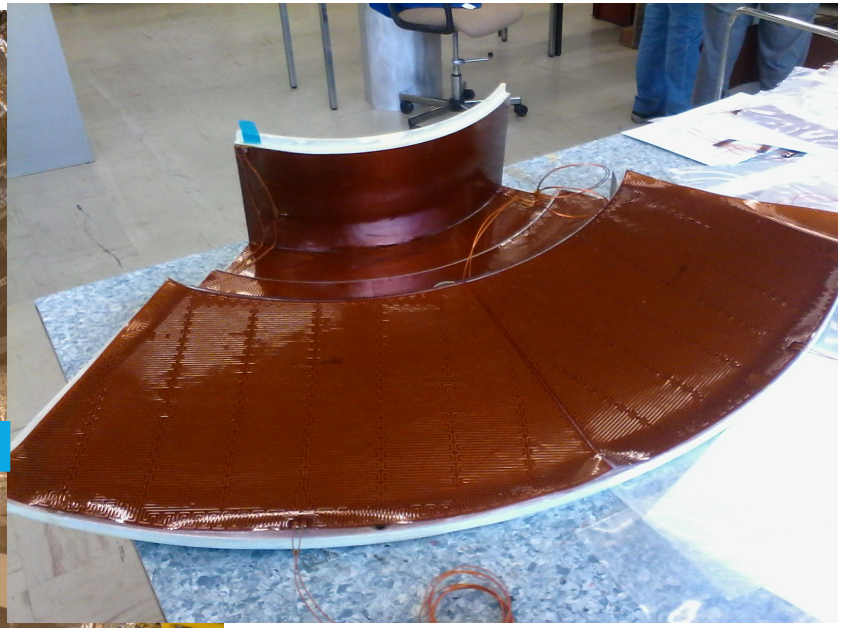
- 4 pCVD diamond – beam abort



Tracker Status

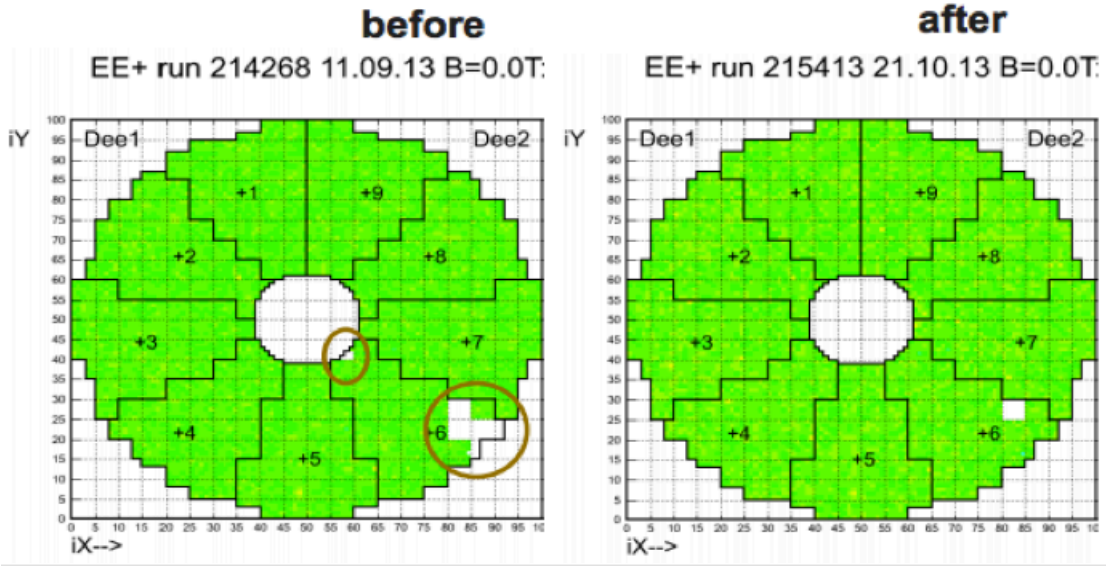
- Strip tracker commissioned to -15ºC (tested to -20ºC)
- Thermal shield installed; dew points sensors operational
- New molds are ready



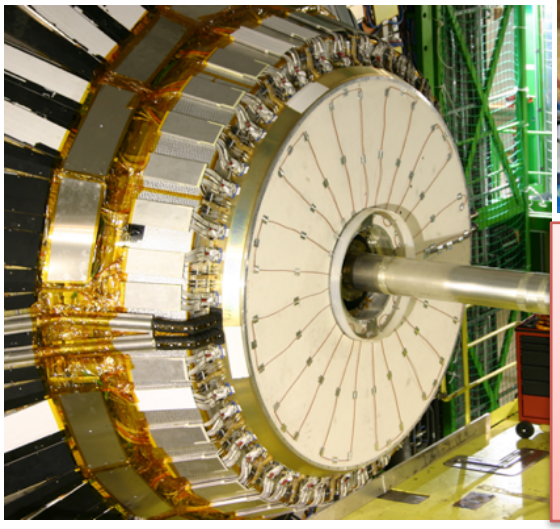


ECAL/ES Status

- Faulty ECAL endcap LV connector repair



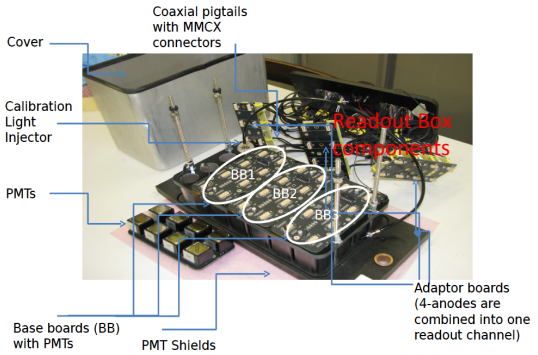
- HV connector repair on the preshower detectors

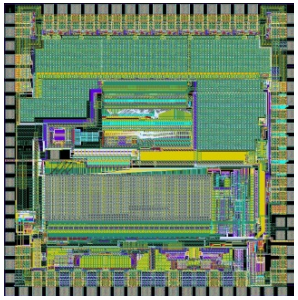


Nov. 2013: damaged connector found on ES- due to problematic PCB. Both ES removed from CMS to the surface for repair of two connectors per endcap

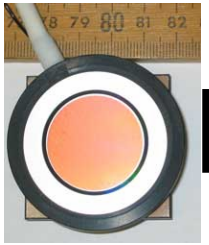
HCAL Status

- Number of significant upgrades:
  - New thin-window dual-anode readout PMTs in HF
    - Reduce Cherenkov noise from punch-through muons
  - New QIE10 ASIC chips for HF
    - Final tests; to be installed in early 2015
  - Replacement of HPDs with SiPMs in HO
    - Much better MIP identification
  - New μTCA back-end in HF
    - Supports larger data volumes
    - New μHTR trigger cards

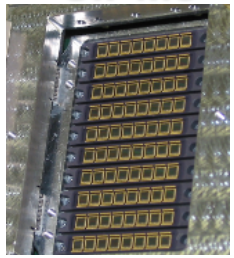


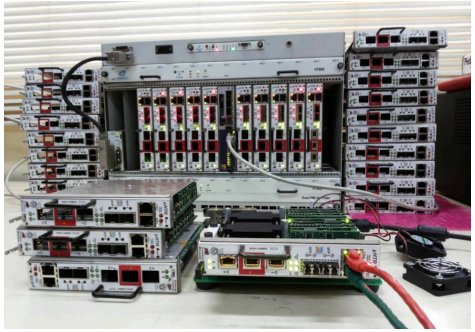


HPDs



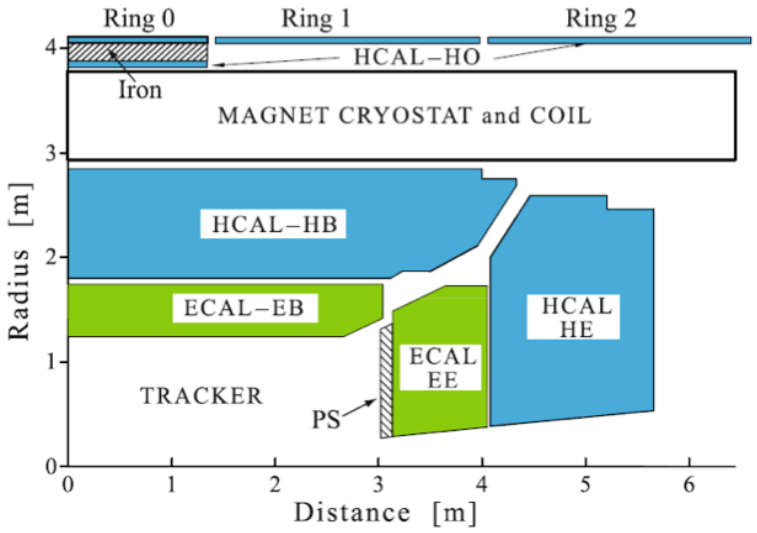
SiPMs

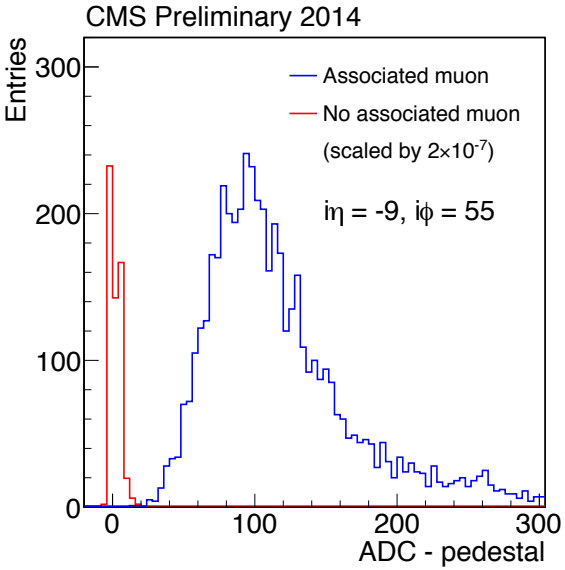


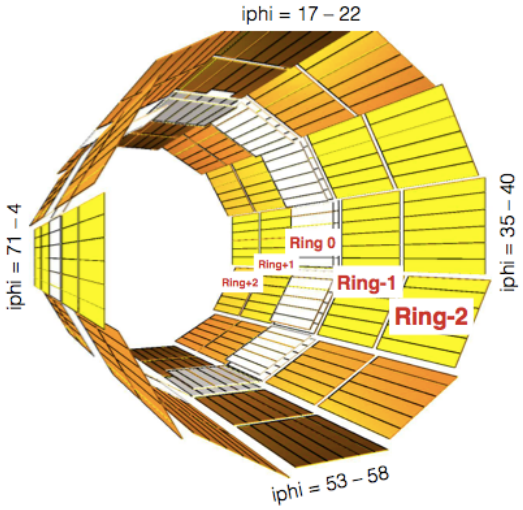


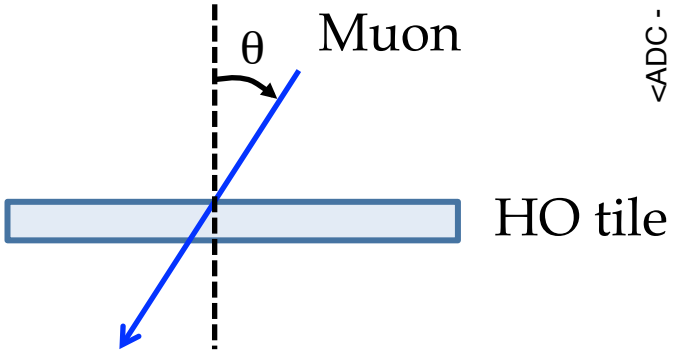
Outer Hadronic Calorimeter

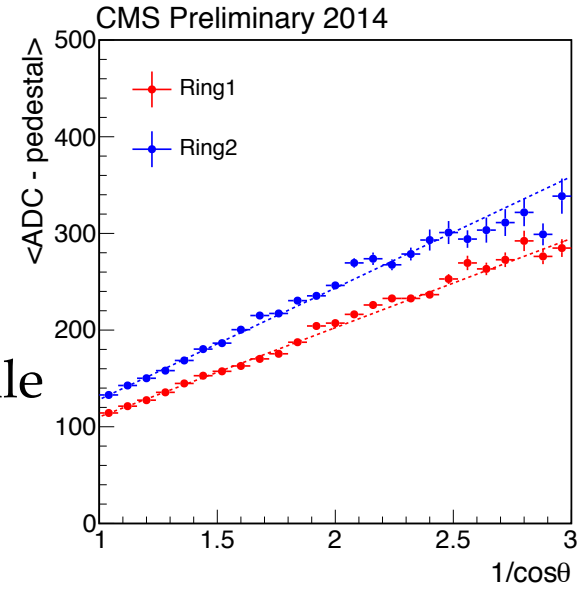
- Excellent performance after SiPM upgrade:









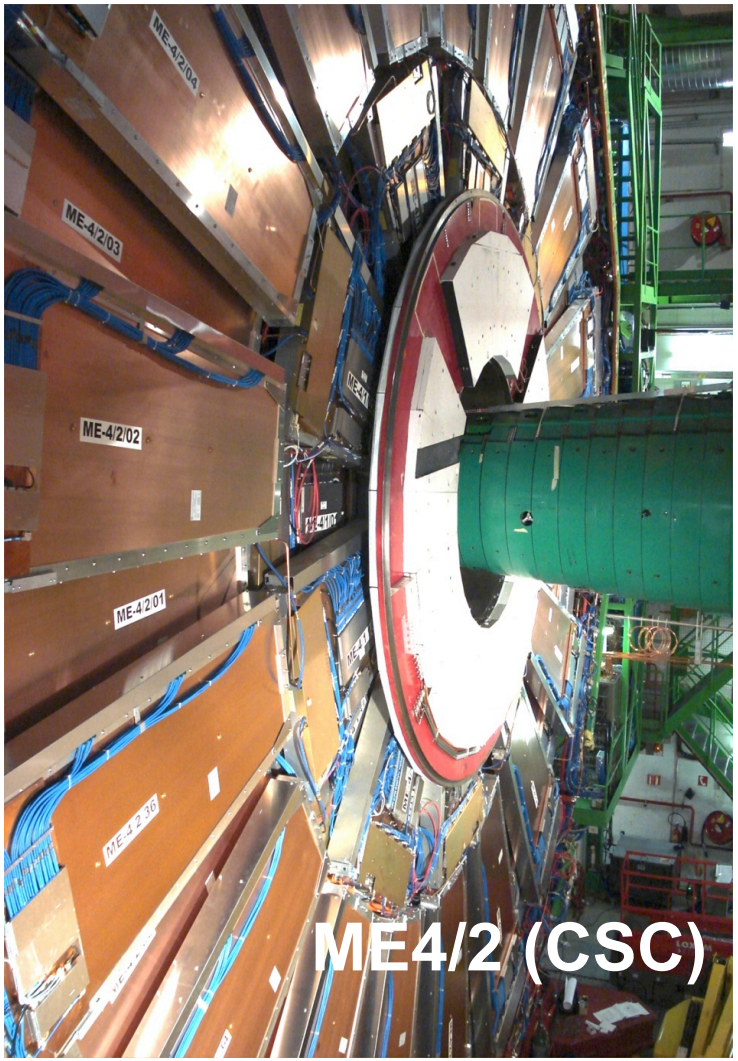


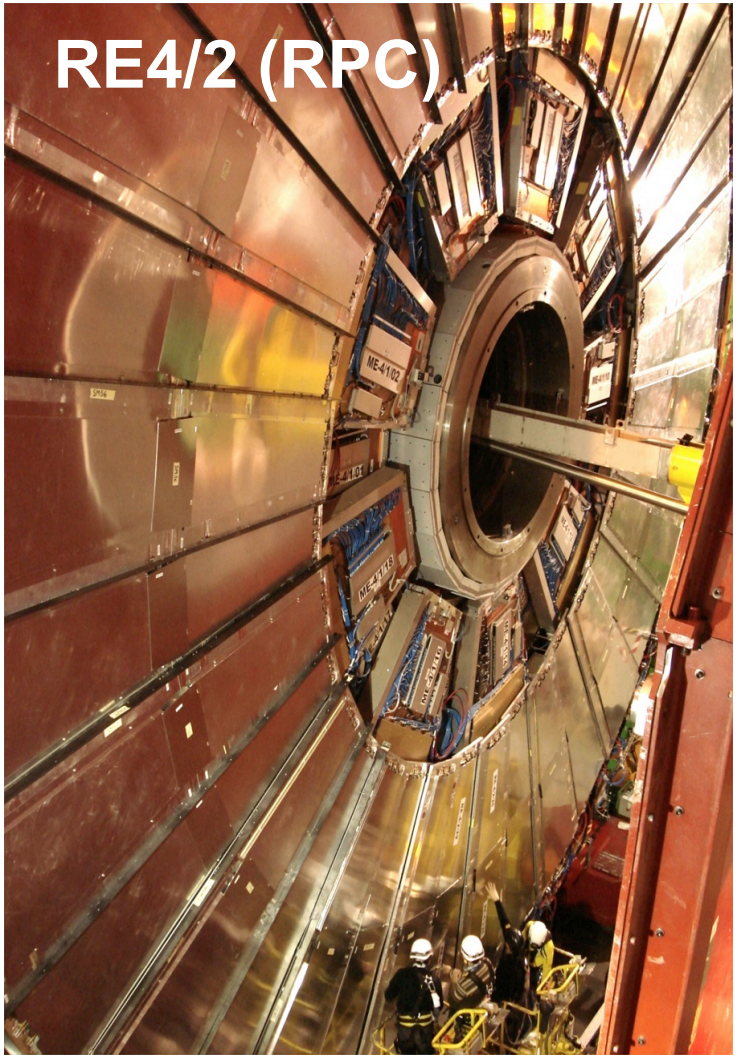
Muon Barrel Drift Tubes

- Chamber and on-detector electronics repair campaign:
  - 3200 Tubes recovered
  - 100% of problematic channels recovered
- Sector collector relocation:
  - 20 new electronics crates installed, cabled, and commissioned
  - 3500 optical links installed
- New Theta TRB:
  - Installed and commissioned 48 new on-detector theta trigger boards
- Online software & commissioning:
  - Timing-in w.r.t. other subsystems
  - TCDS integration (3 partitions done)

Muon System

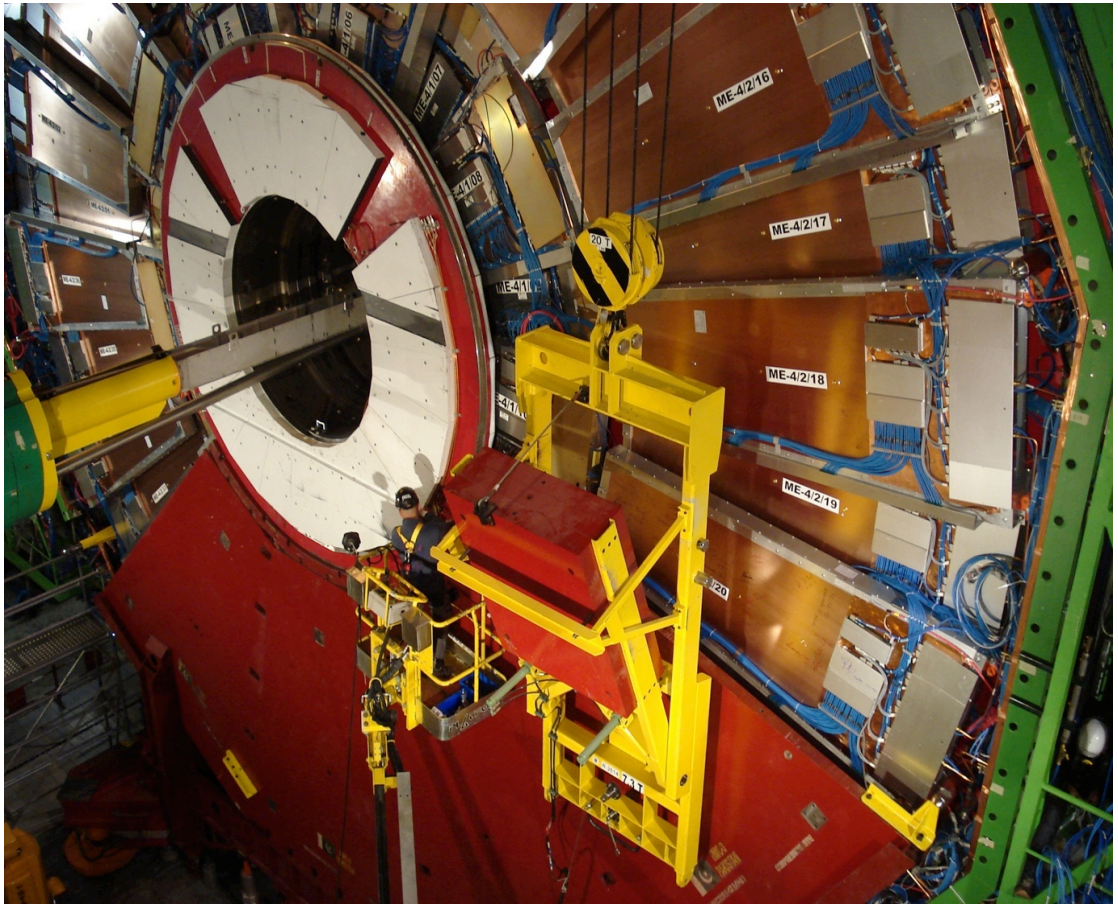
- Fourth layer of forward muon detectors completed

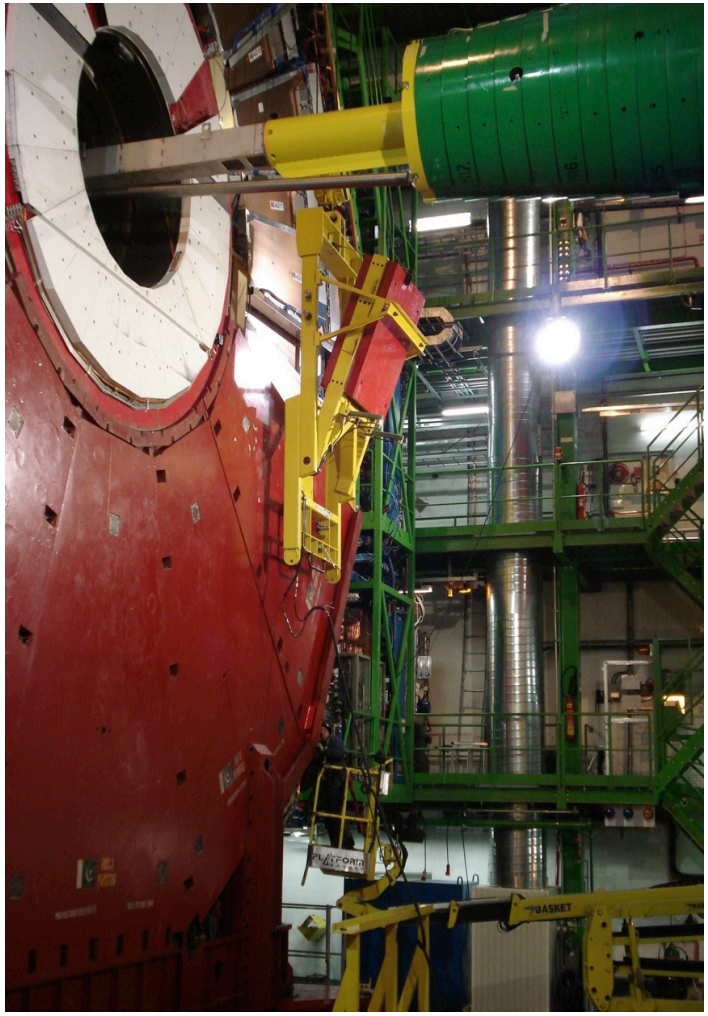




Muon Shielding

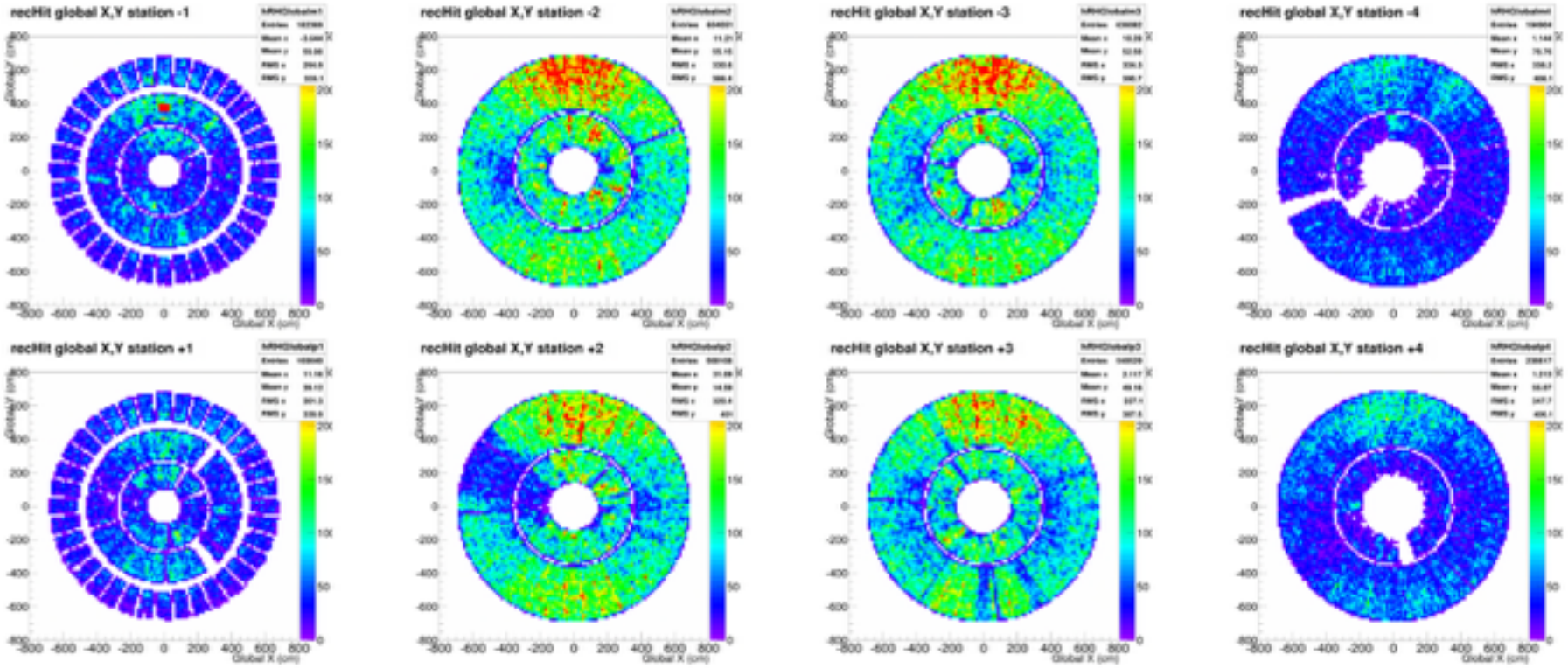
- Shielding disk YE4 is installed on both sides





CSC: Cosmic Ray Test

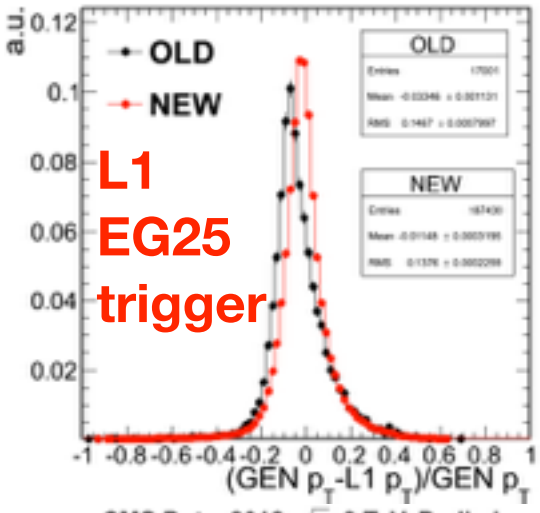
- Excellent performance of the new CSC muon chambers:

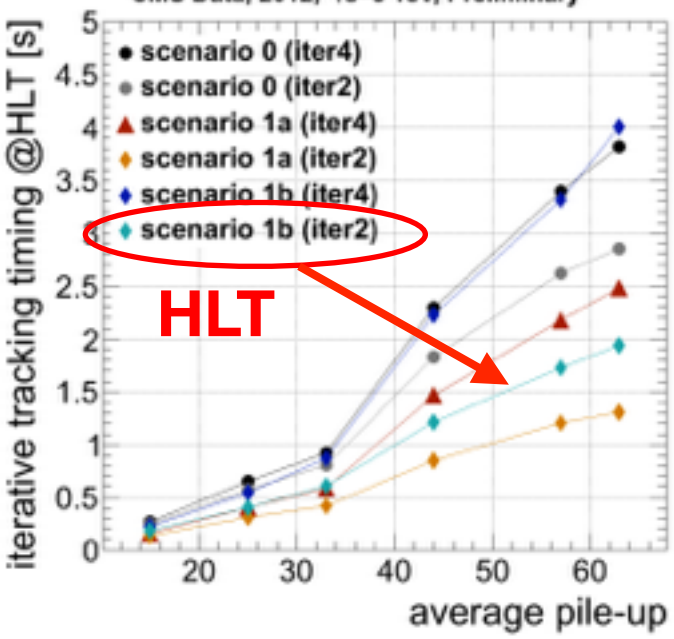


CSC cosmic ray hits in July

Trigger Challenges

- Trigger in 2015 aiming to cope with:
  - Factor of two increase in luminosity and a factor of two or more increase in cross sections
  - Increased CPU time/event at HLT because of higher pileup (PU ≈ 40)
  - Cater to the the Heavy Ion run: the trigger will be fundamental for the physics program (including PU subtraction)
- Goal: to keep the same acceptance for SM (e.g. Higgs) physics, and full sensitivity to new physics
  - Improved calorimeter algorithms (PU, isolation, taus)
  - Improved muon trigger due to new muon detectors
- Improved High-Level Trigger performance due to better tracking algorithm (goal: 1 kHz output)





New TCDS

- TCDS = Trigger Control and Distribution System
  - TTC + TCS (Trigger Control System) + TTS (Trigger Throttling System)
- Done:
  - Custom electronics boards: pre-series produced
  - TCDS demonstrator system established in USC (max 16 TTC partitions)
  - All sub-detectors have been connected with at least 1 TTC partition
  - Basic functionality demonstrated in global runs
- Ongoing:
  - Commissioning and enhancements in progress

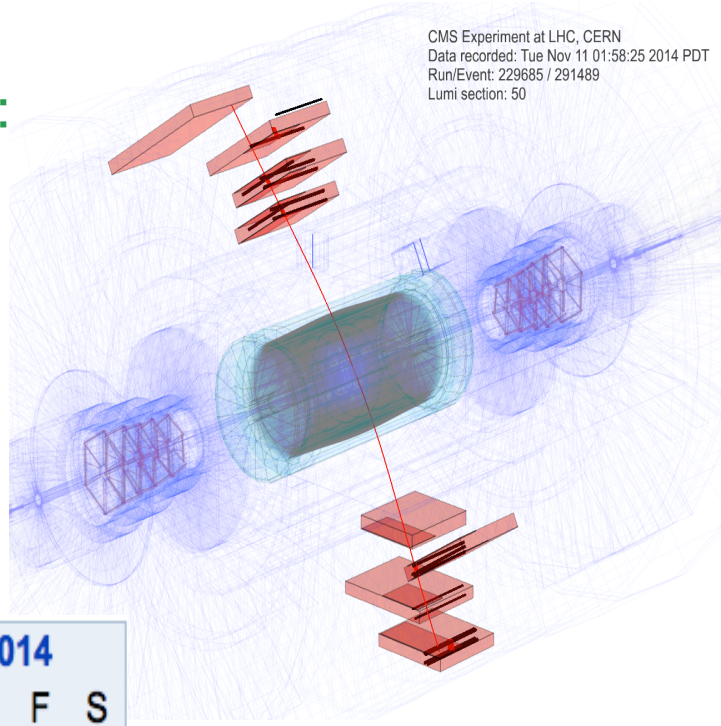
TCDS Demonstrator Full system installed in October

DAQ 2 Changeover

- Changeover to DAQ2 done
  - All custom electronics installed
  - Event builder network and nodes installed
  - Small HLT farm (~1/8)
  - File based HLT and DQM
  - Storage manager with Lustre (global file system) on legacy hardware
  - HLT farm monitoring with ElasticSearch data-analytics tool
  - mini-DAQ established
- Integration of TCDS
  - TCDS DAQ-link (uTCA slink-express)
  - Integration of TCDS in run control and monitoring
- Detector control system
  - Migration to blades, updated OS, JCOP framework and CMS DCS

Schedule 2014

- Focus on regular Mid-Week Global Runs testing system integration and extended cosmic run of November
- Magnet test at 3.8T successfully completed:
  - Closed the detector in ~1 month
  - Stayed at 3.8T for ~1.5 days
  - Collected 5.9M cosmic ray triggers at full magnetic field
  - Measured noise rate in HCAL and new PMT performance
  - Took ECAL laser calibration data



October 2014

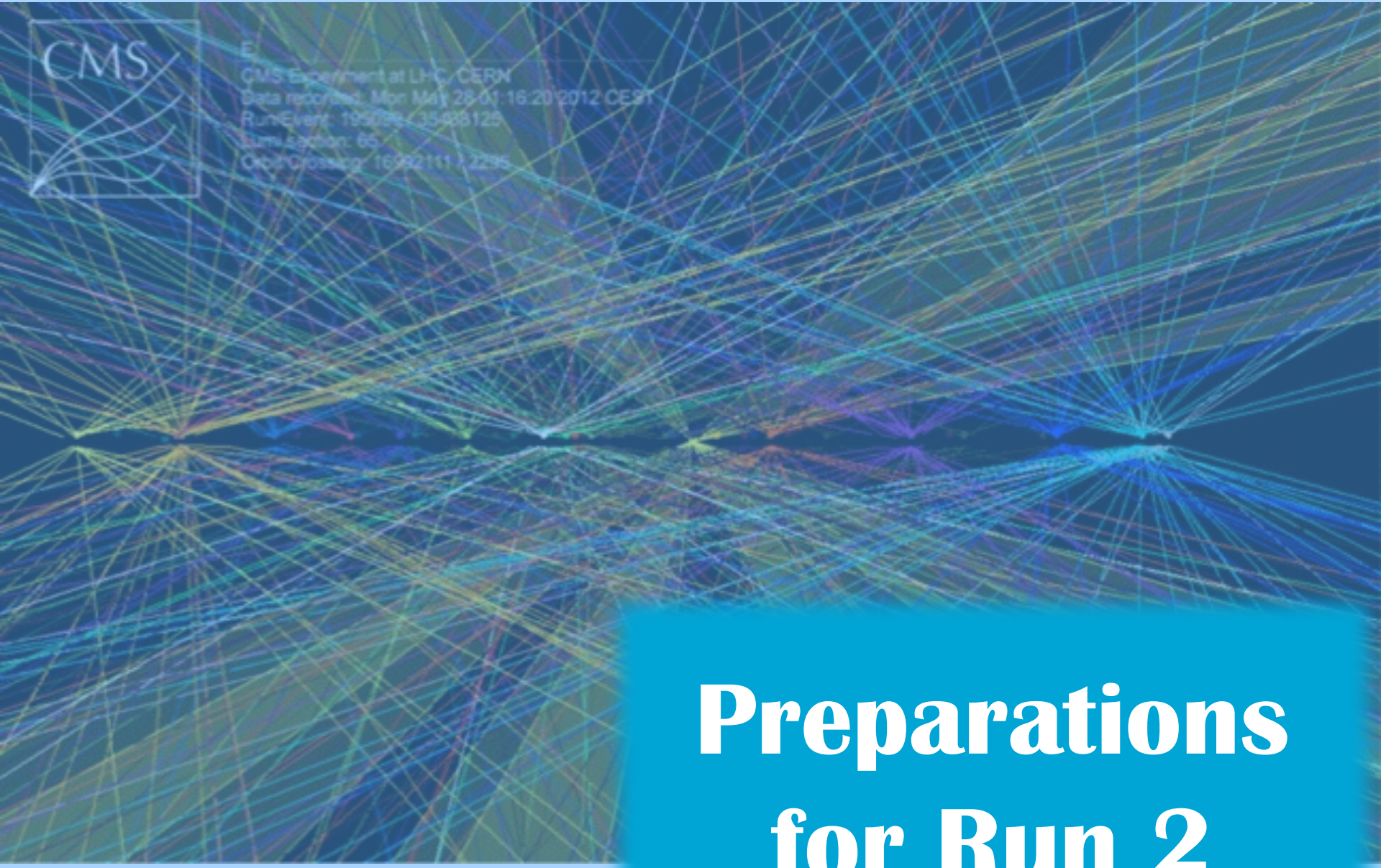
S	M	T	W	T	F	S
			1	2	3	4
5	MWGR8					11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	Ex. Cosmic Run					

November 2014

S	M	T	W	T	F	S
						1
2	Ex. Cosmic Run /					8
Mag.Test			12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

December 2014

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	MWGR9					13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			



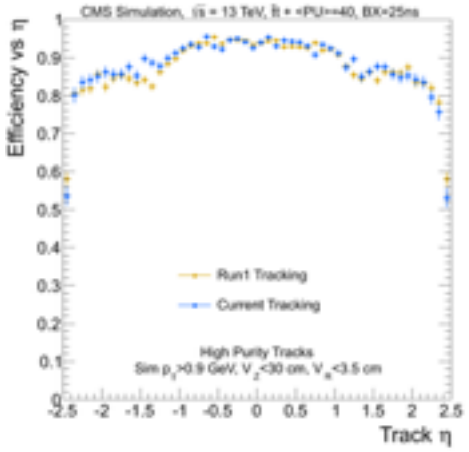
Preparations for Run 2

CSA14 Exercise

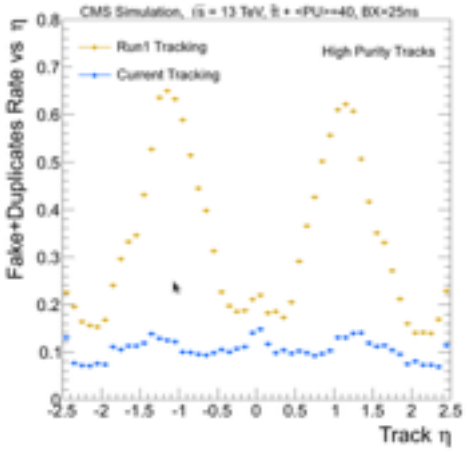
- Computing, Software, and Analysis 2014 exercise in preparation for Run 2
- Computing has been a key player in CSA14 and has commissioned a number of new tools and techniques developed during LS1
  - New miniAOD format, which is more than a factor 10 smaller than regular AOD
  - Data federation (AAA): the target is 20% of analysis access served over the wide area
  - Commissioning of the new job submission tool (CRAB3)
- Production and reconstruction of 13 TeV events under various pileup scenarios
- Readiness of the Computing/Offline/Data Preparation and Analysis chain: test a subset of the new software, computing, and analysis features that can benefit from a large-scale focused challenge
- To be followed by PHYS14 exercise testing high-priority analysis readiness to first Run 2 data

Software and Algorithms - I

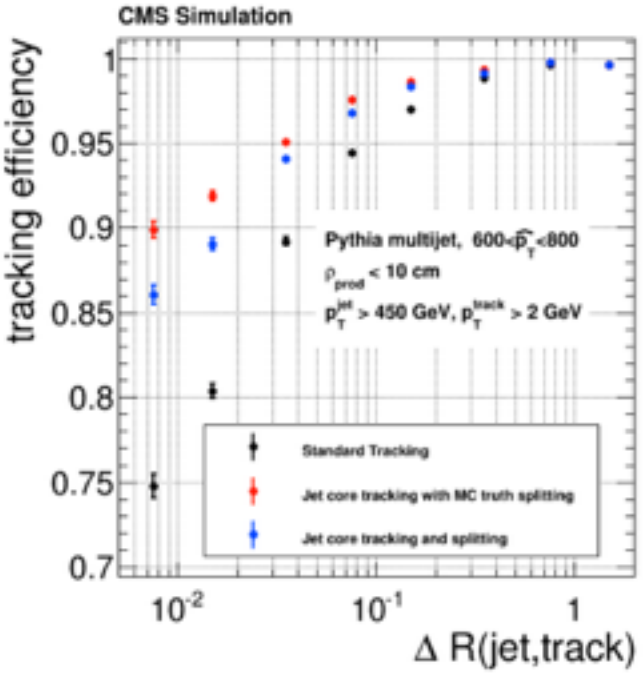
- New improved algorithms
  - Tracking: huge improvement in fake track rejection
    - Improved seeding from triplets
    - Cluster charge requirement to reduce out-of-time PU
  - Boosted jets tracking: especially for b and top quark ID
    - Use cluster splitting regionally around high-p_T jets
    - Improves efficiency at low ΔR
  - New ECAL/HCAL reconstruction developments for 25 ns running
  - Muon tracking
  - Jet/ME_T PU subtraction
- Improved detector simulation



high p_T prompt tracks



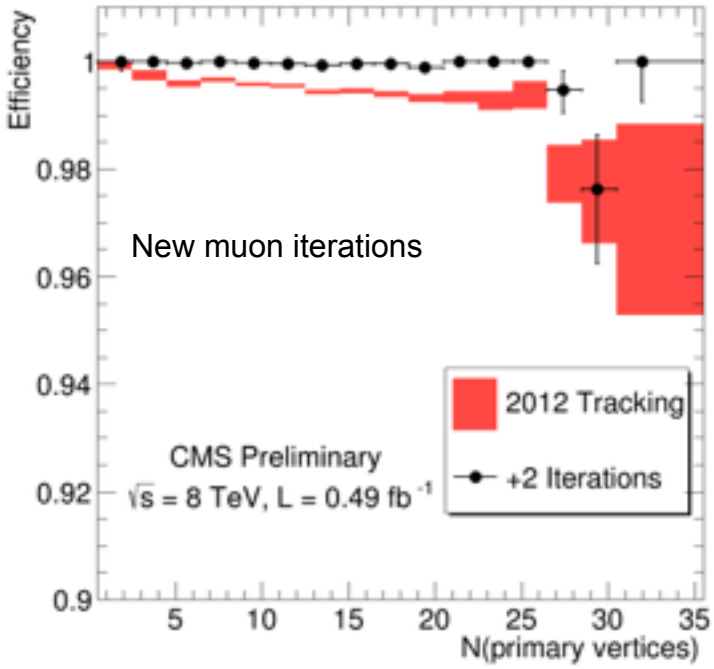
all tracks



Software and Algorithms - II

- New ECAL/HCAL 25 ns reconstruction:
  - Fits the pulse shapes for a superposition of several pulses
  - Yields 10-50% improvement in resolution relative to Run 1 method for ECAL
  - Improvement is also significant for HCAL
- Muon tracking improvements:
  - Adding outside-in and inside-out seeding

Energy	std reco: resolution	multifit: resolution	relative improvement
EB	%	%	%
1-5 GeV	13.10	6.70	48.9
5-10 GeV	5.76	2.94	49.0
10-30 GeV	2.72	1.83	32.7
30-100 GeV	1.48	1.28	13.5
EE			
1-5 GeV	22.90	15.20	33.6
5-10 GeV	10.70	7.03	34.3
10-30 GeV	5.15	4.12	20.0
30-100 GeV	2.72	2.53	7.0

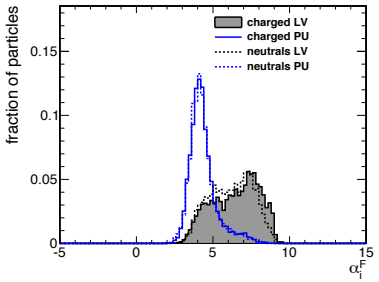


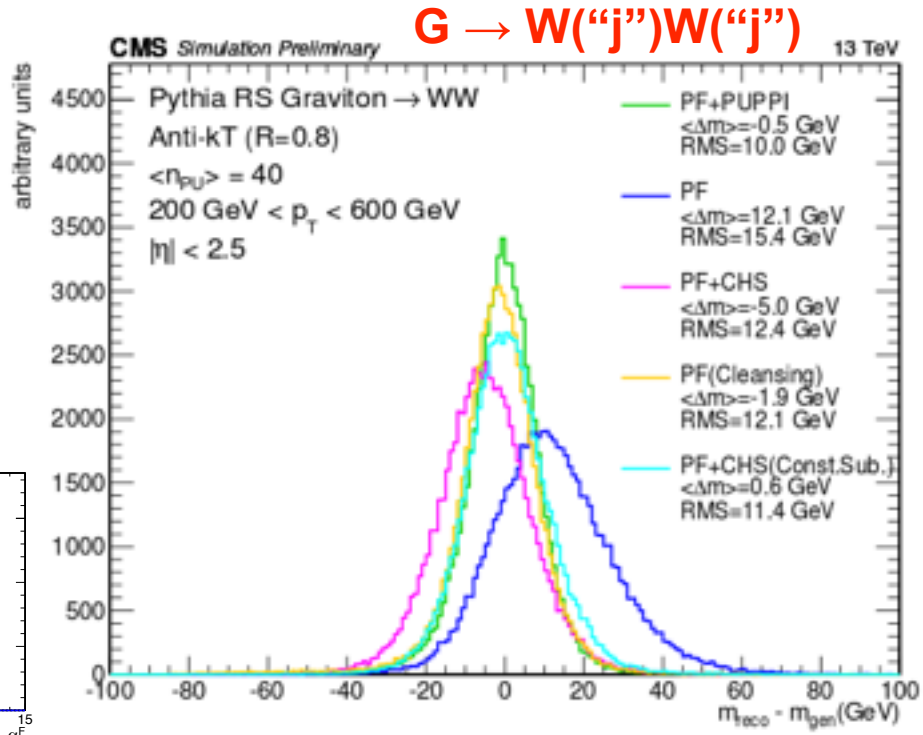
Software & Algorithms - III

- PUPPI [arXiv:1407.6013] technique uses per-particle PU subtraction
  - Assigns a weight per particle depending on its p_T and other features that can discriminate against PU
  - First results based on full reconstruction look promising
  - Can also be used for lepton isolation calculation

$$\alpha_i = \log \sum_{j \in \text{event}} \frac{p_{Tj}}{\Delta R_{ij}}$$

$$R_{\min} \leq \Delta R_{ij} \leq R_0$$





2015 Heavy Ion Run

- The heavy ion running period in 2015 will be the first high-luminosity Pb run in the LHC program
- Projected machine performance
  - Peak luminosity: ~4 x 10^{27} $cm^{-2}s^{-1}$
    - 4x LHC design value!
  - Maximum interaction rate: ~30kHz
    - 8x 2011 PbPb rate
  - Integrated luminosity:
    - 0.8-1.5 nb^{-1}
- Key hardware ingredient to cope with the high interaction rate is the L1 calorimeter trigger upgrade, as jet triggers need PU subtraction
  - Good progress on installation
- HLT, computing, offline software, DQM, and reconstruction areas have been staffed with dedicated HI contact persons in preparations for data taking

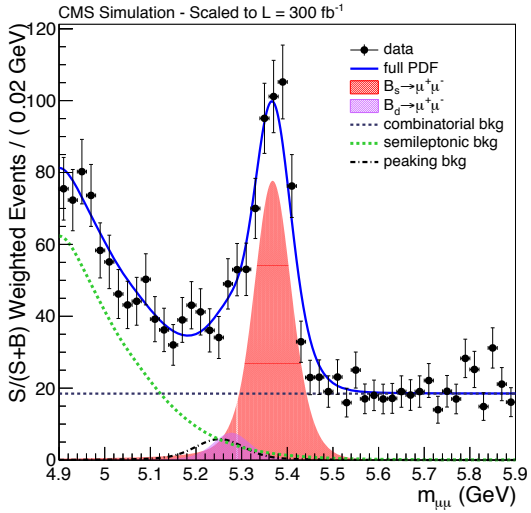
Beyond Run 2

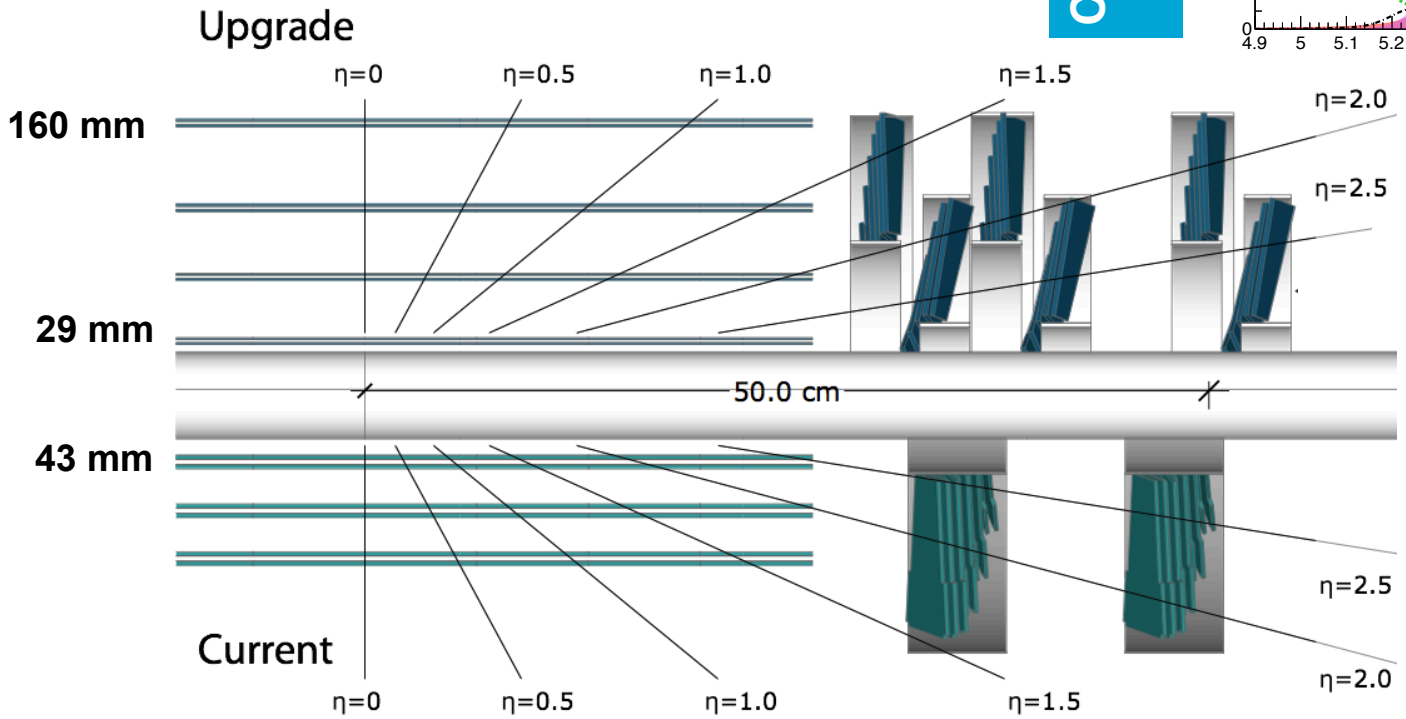
Phase I Pixel Detector

- Good progress with the Phase 1 Pixel Detector replacement
  - 4 layers; radiation hard to ~500/fb
  - Double number of channels to 124M
  - CD2/CD3 approval last month
  - Good progress on electronics, modules, and services; test insertion successful
  - To be installed during 2016—2017 YETS

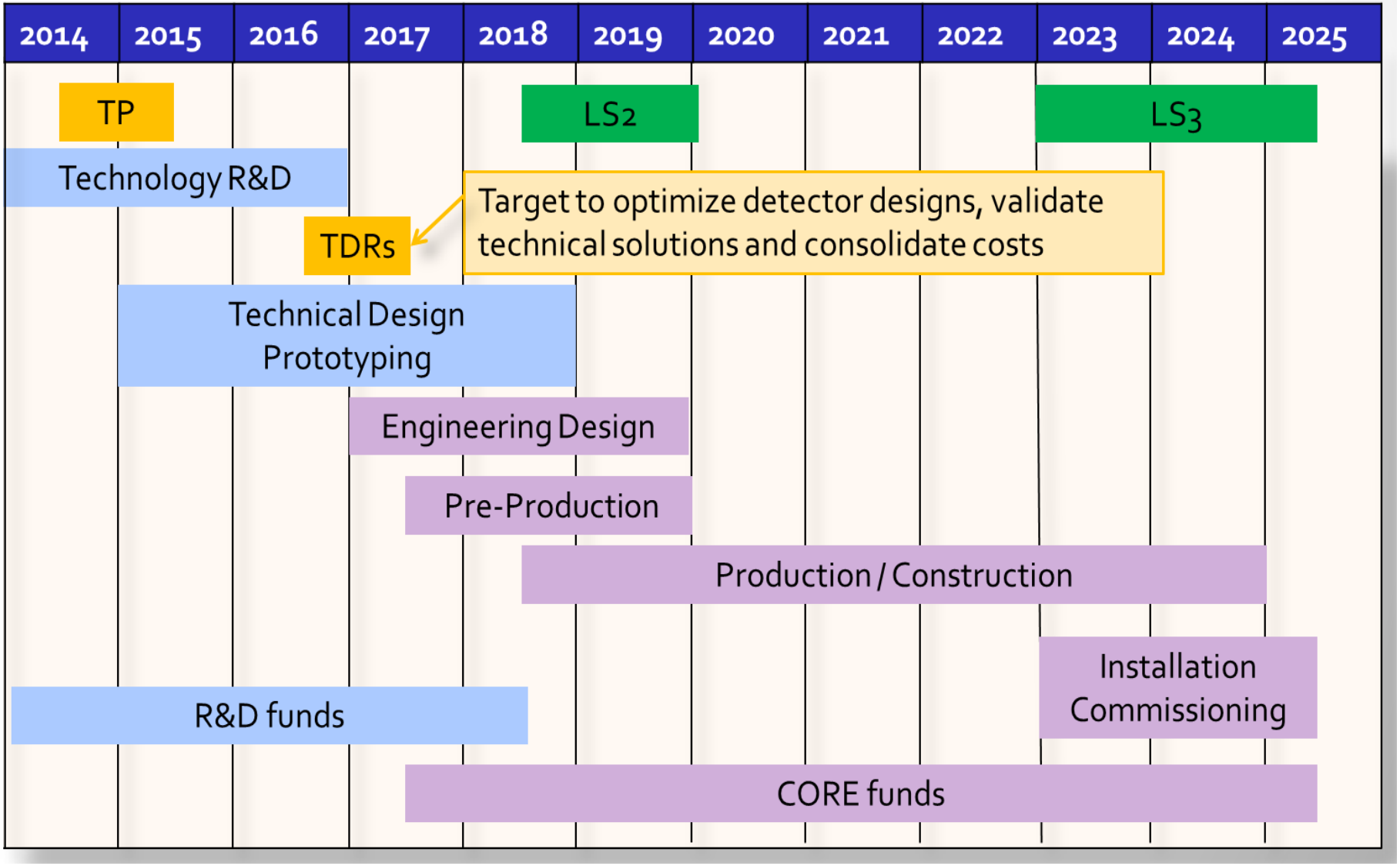
13% measurement of $B_s(\mu\mu)$

CMS Collaboration PAS FTR-14-015





A Decade of Upgrades

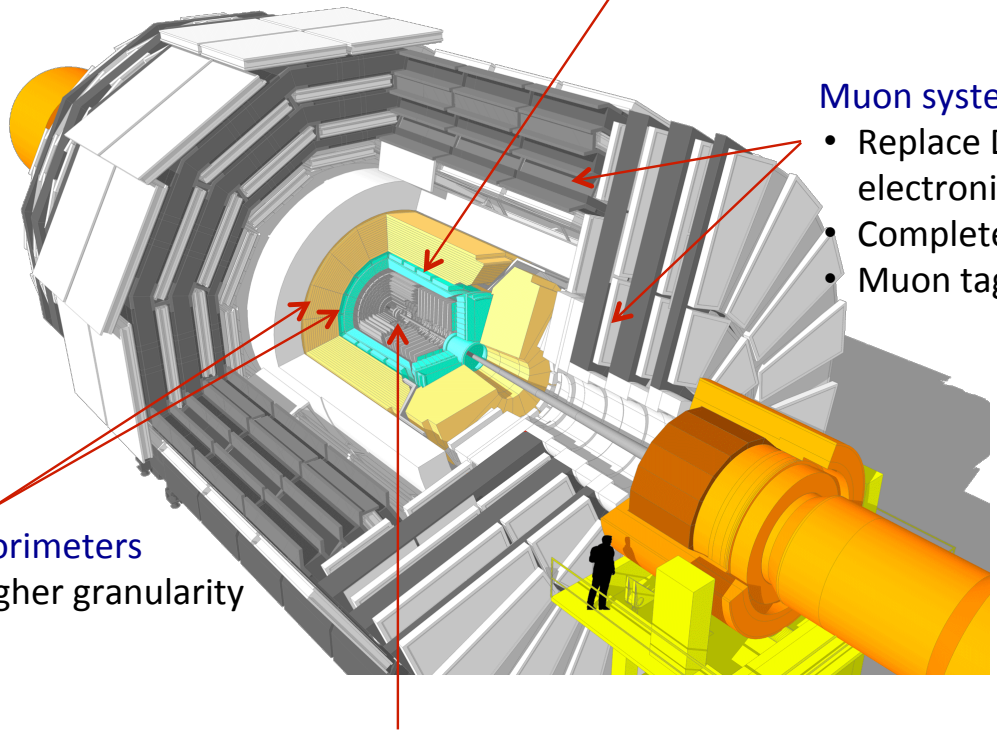


Phase 2 Upgrade

✦ Aggressive Phase 2 detector upgrade for HL-LHC

Trigger/DAQ
- L1 with track up to 750 kHz - 12.5 μs latency
- HLT output up to 7.5 kHz

Barrel EM calorimeter
- Replace FE electronics
- Cool detector APDs



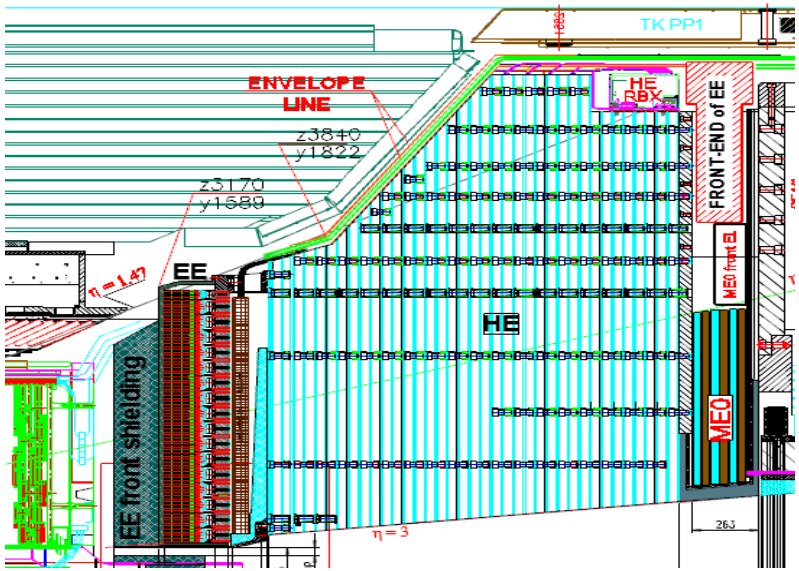
Muon systems
- Replace DT & CSC FE electronics
- Complete RPC coverage
- Muon tagging $2.4 < \eta < 3$

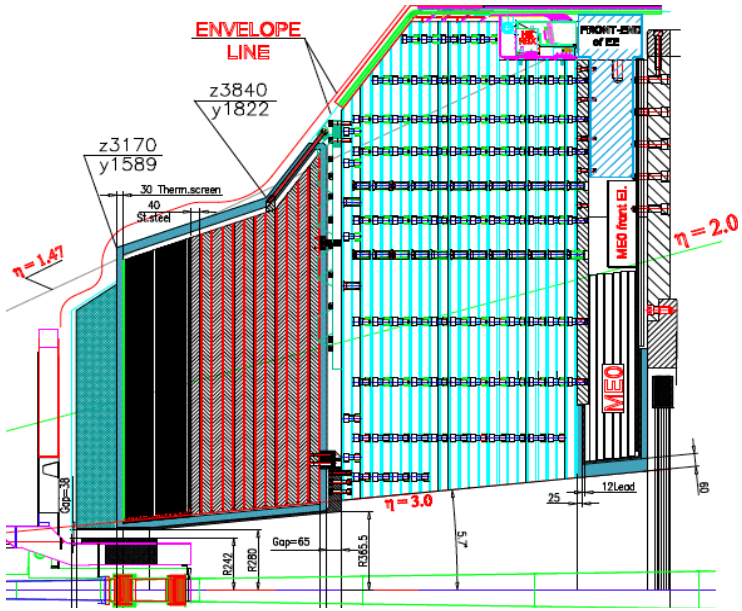
Replace Endcap Calorimeters
- Rad. Tolerant - higher granularity

Replace Tracker
- High granularity – less material- better p_T resolution
- Selective readout of outer tracker at 40 MHz for L1 trigger
- Extend η coverage to 4

Forward Calorimetry Upgrade

- The present ECAL endcap will largely degrade after 300/fb
- The forward rings of HCAL endcap (HE) will also sustain significant damage
- Need to replace forward calorimetry to take advantage of VBF jet tagging, boosted objects in the forward region, and increased acceptance to multi particle final states
- Two concepts are being pursued: Shashlik and silicon-based HGCAL
  - Both require a partial rebuild of HE
  - Decision in February 2015





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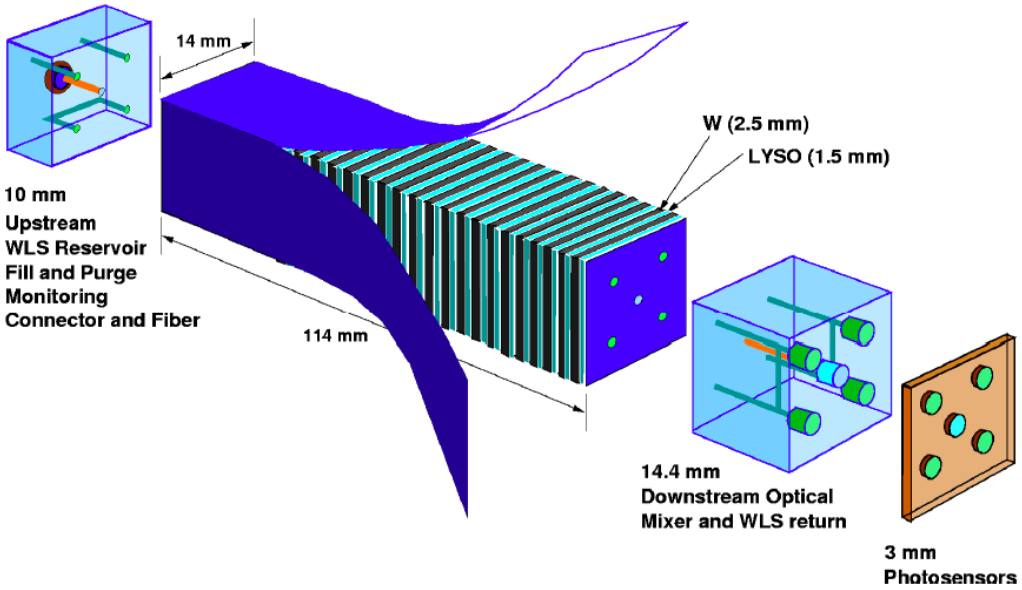

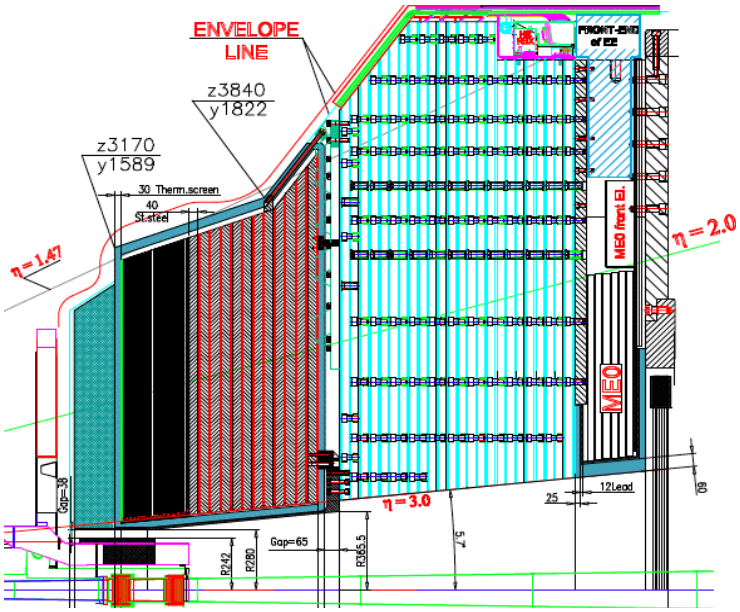

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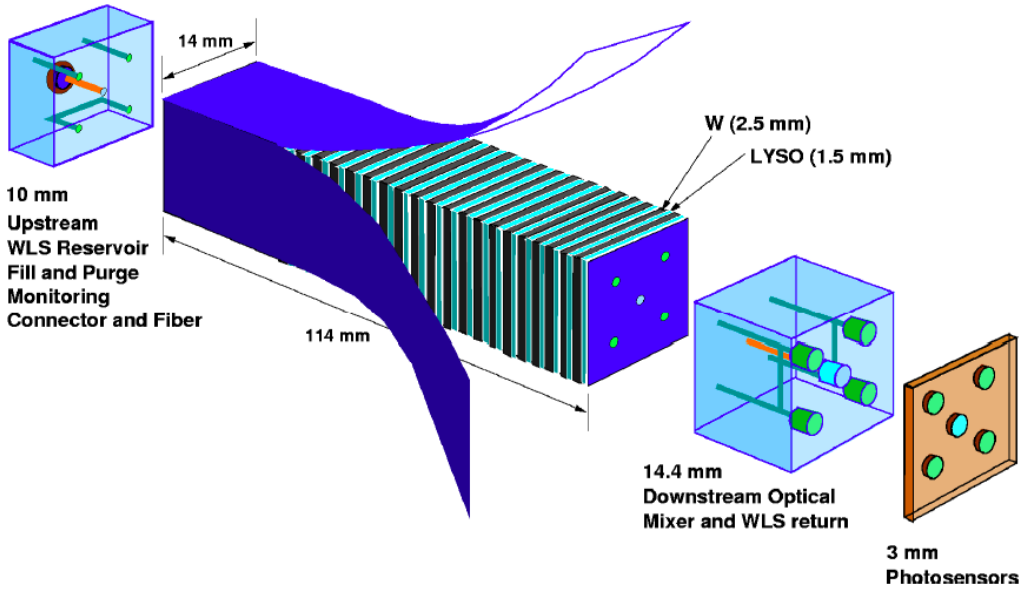
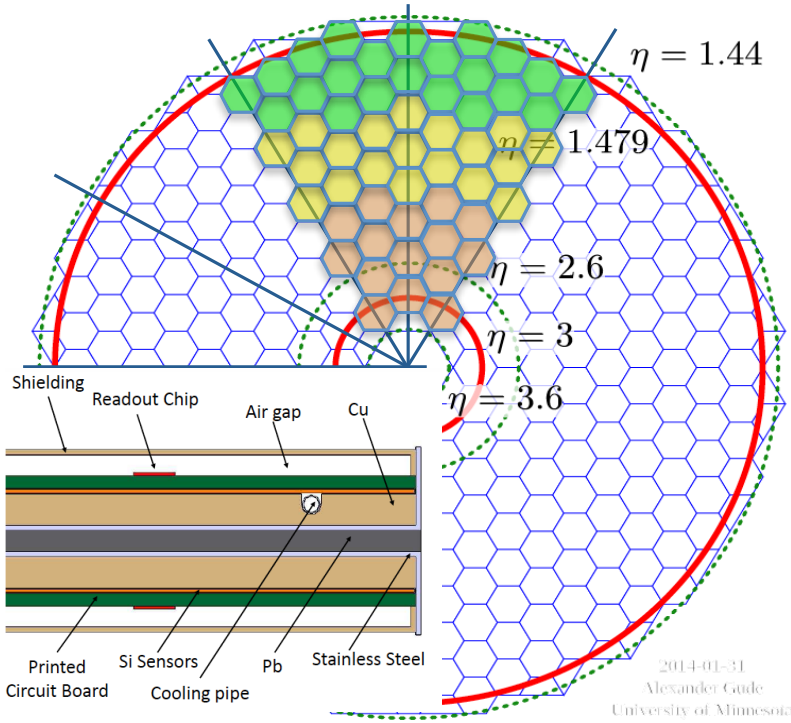
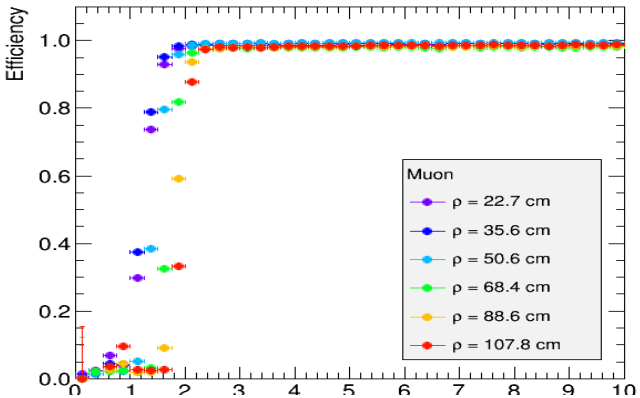


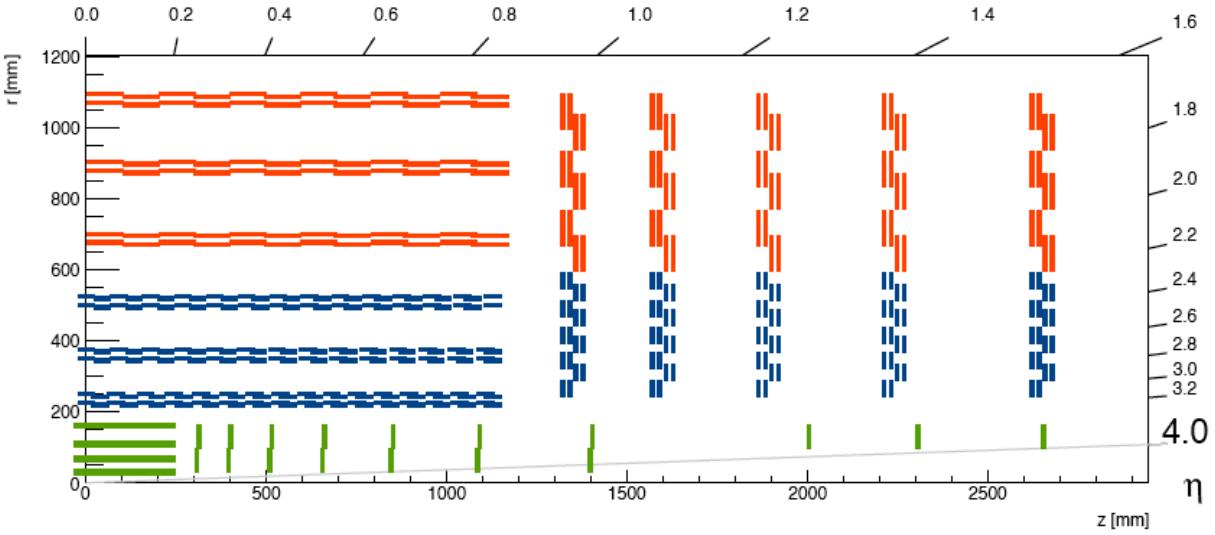


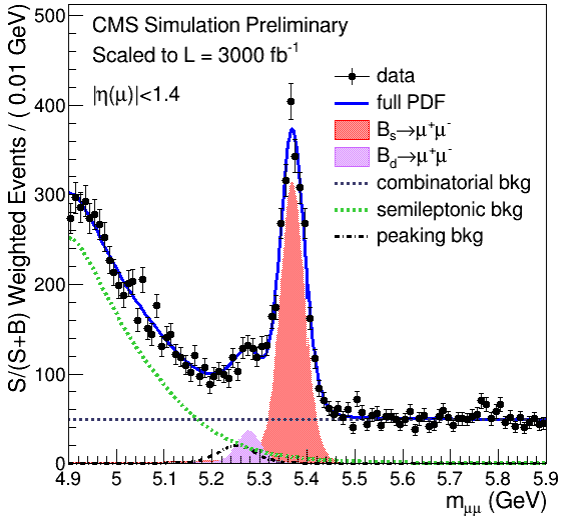
Tracker Upgrade

- New silicon tracker with extended rapidity coverage |h| < 4.0
- Augmented with a L1 track trigger
  - Will allow to keep dimuon trigger with low threshold necessary for $B_d(\mu\mu)$ measurement
  - 6.8σ discovery of the SM B_d signal made possible by the tracker and track trigger upgrade

L1 track trigger turn-on



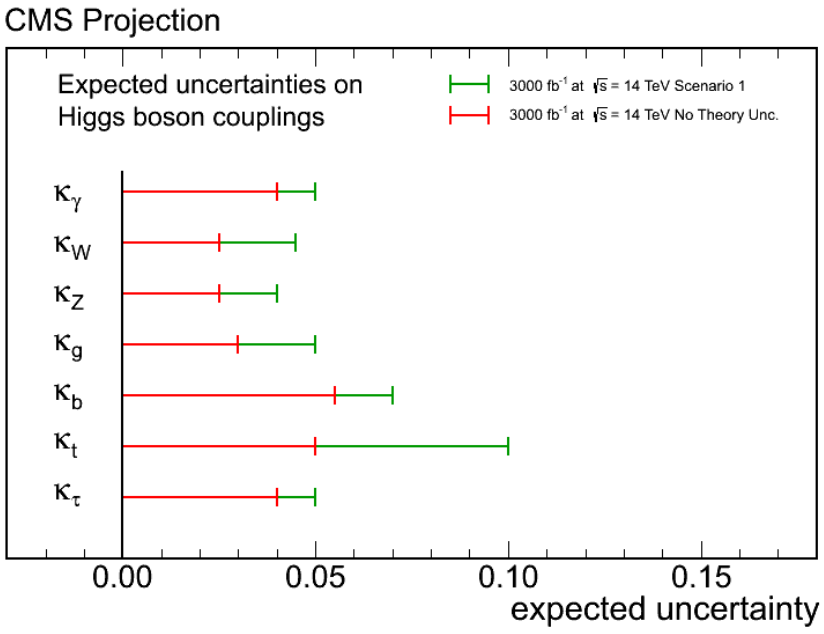


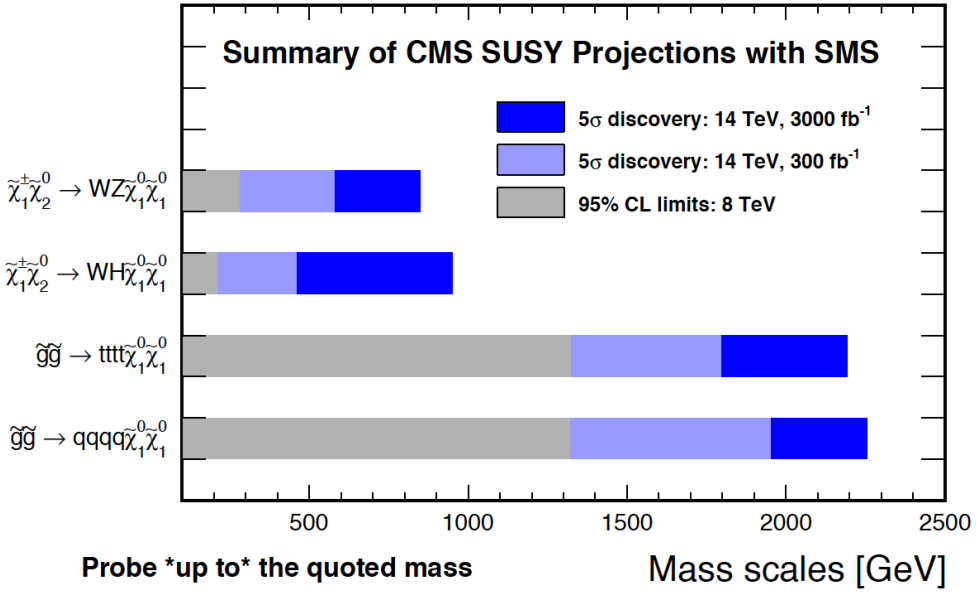


CMS Collaboration
PAS FTR-14-015

Some Benchmarks

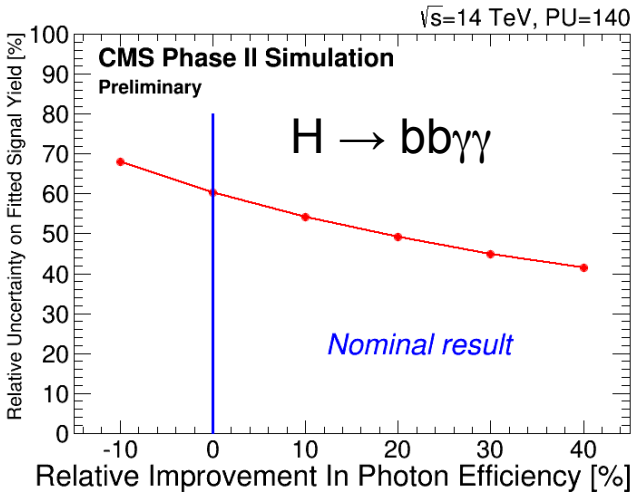
- Technical proposal for Phase 2 Upgrade is being finalized
  - Strong case has been already made for measurement of the Higgs boson couplings and extending reach for SUSY particles
  - Achievable precision is typically limited by theory uncertainties

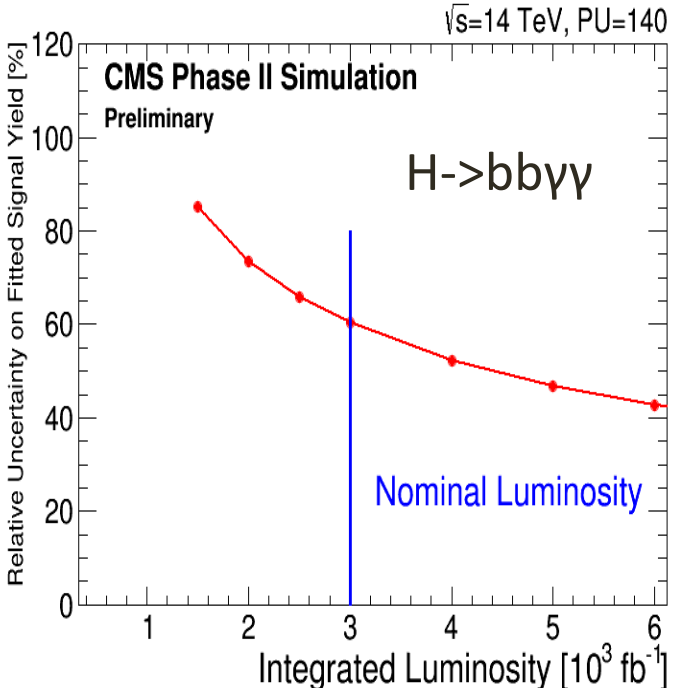


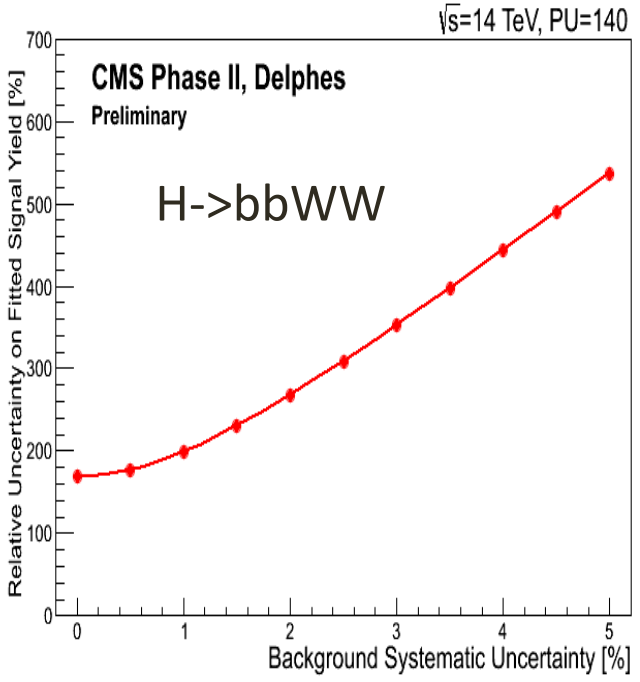


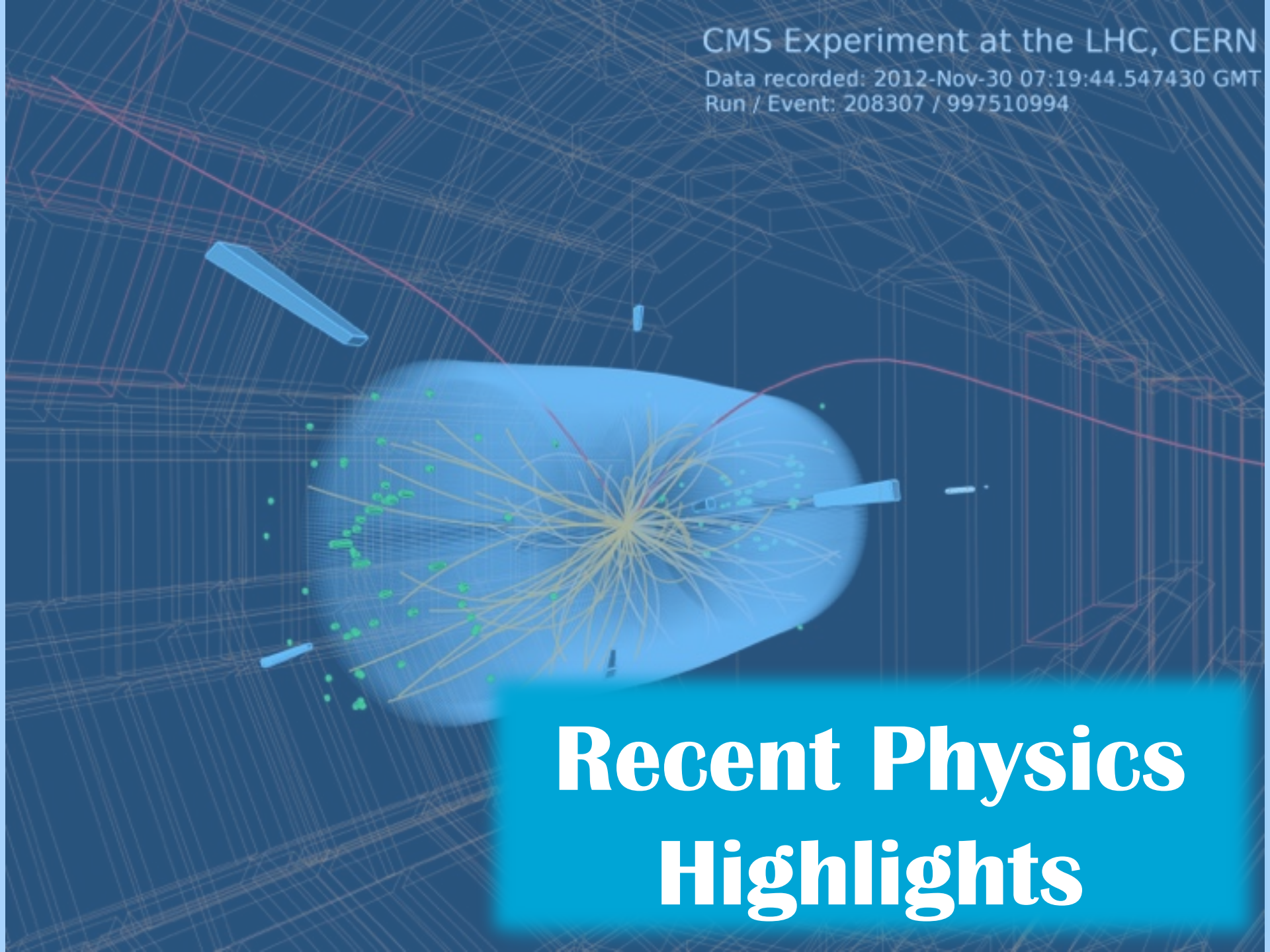
New Projections on Self-Coupling

- Double Higgs production remains one of the important goals for HL-LHC
- Focus of the studies shifted on improvement of sensitivity by exploring features of the upgraded detectors, e.g. better ID or better control of systematics
- Also looking into bbττ and bbbb final states
- The goal is to establish 3σ or better evidence for the Higgs self-coupling









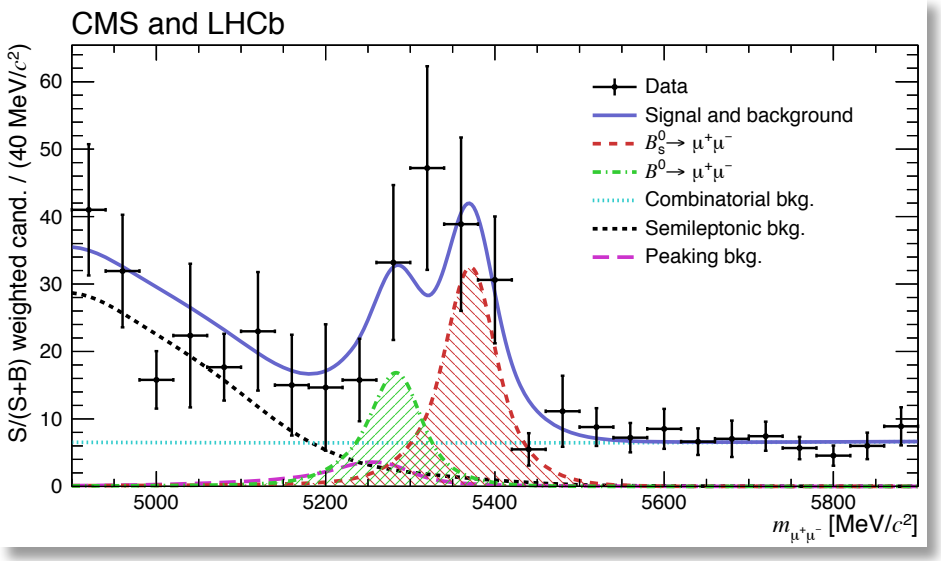
Recent Physics Highlights

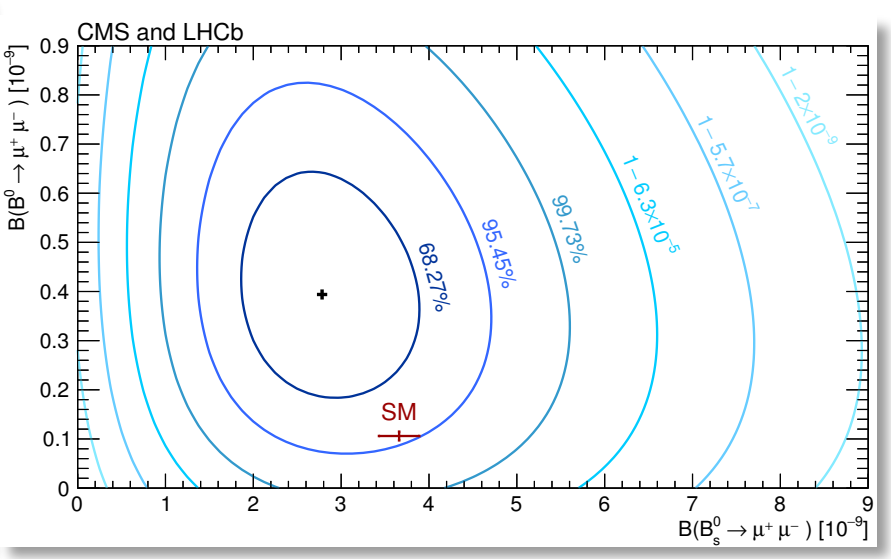
B-Physics

- New combined $B_s(\mu\mu)$ result with LHCb
- Based on 2013 publications:
  - CMS: Phys. Rev. Lett **111** (2013) 101804 (4.3σ obs/4.8σ exp.)
  - LHCb: Phys. Rev. Lett **111** (2013) 101805 (4.0σ obs/5.0σ exp.)
- New result: 6.2σ obs/7.4σ exp.
- Also, a 3.0σ excess over background is observed in the B_d^0 search, compatible with the SM prediction at 2.2σ

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = \left(2.8\,^{+0.7}_{-0.6}\right) \times 10^{-9}$$
$$\mathcal{B}(B^0 \to \mu^+\mu^-) = \left(3.9\,^{+1.6}_{-1.4}\right) \times 10^{-10}$$

CMS & LHC Collaborations, arXiv:1411.4413, Submitted to Nature

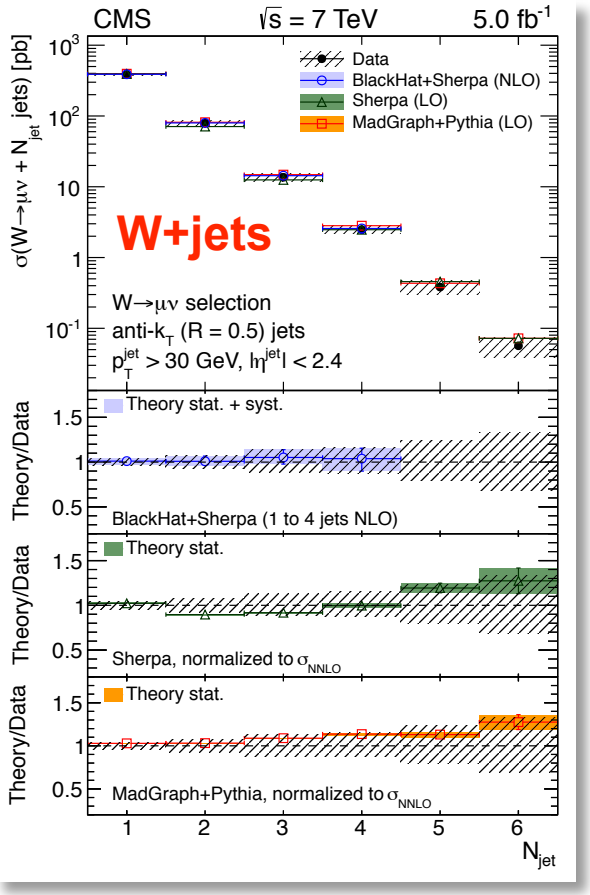




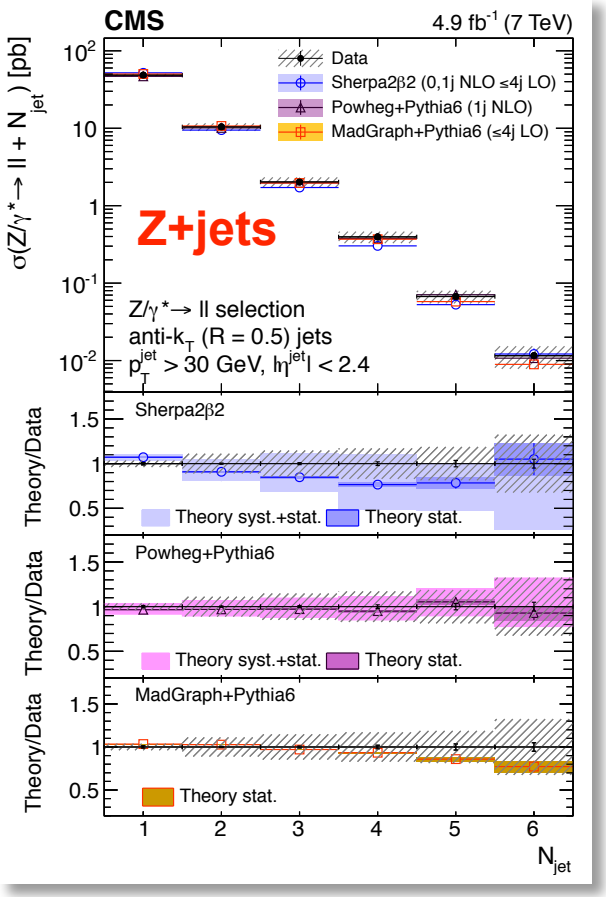
Standard Model Physics

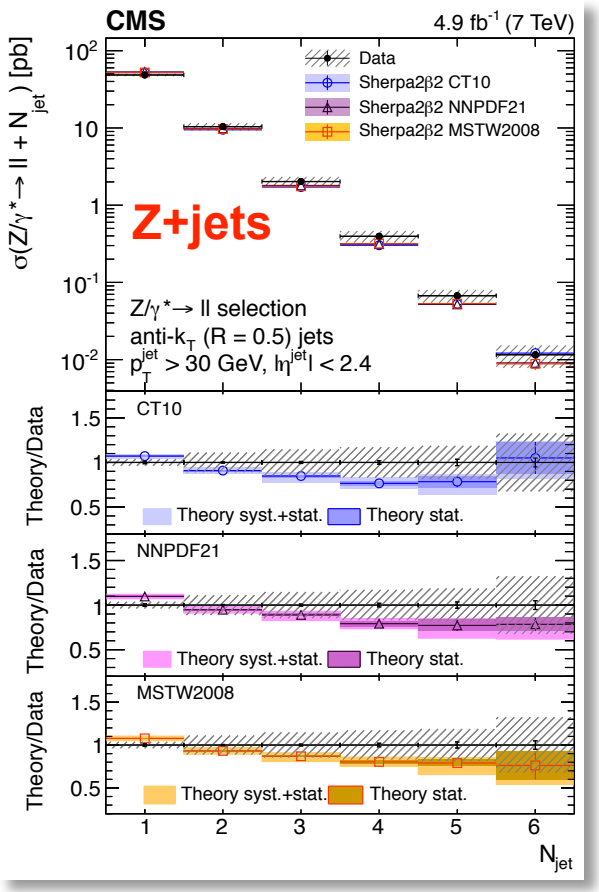
- Differential Z+jets and W+jets cross section measurements - probing matrix elements/parton shower generator prediction up to V + 6 jets
- Potential sensitivity to the PDFs

CMS Collaboration arXiv:1406.7533



CMS Collaboration arXiv:1408.3104

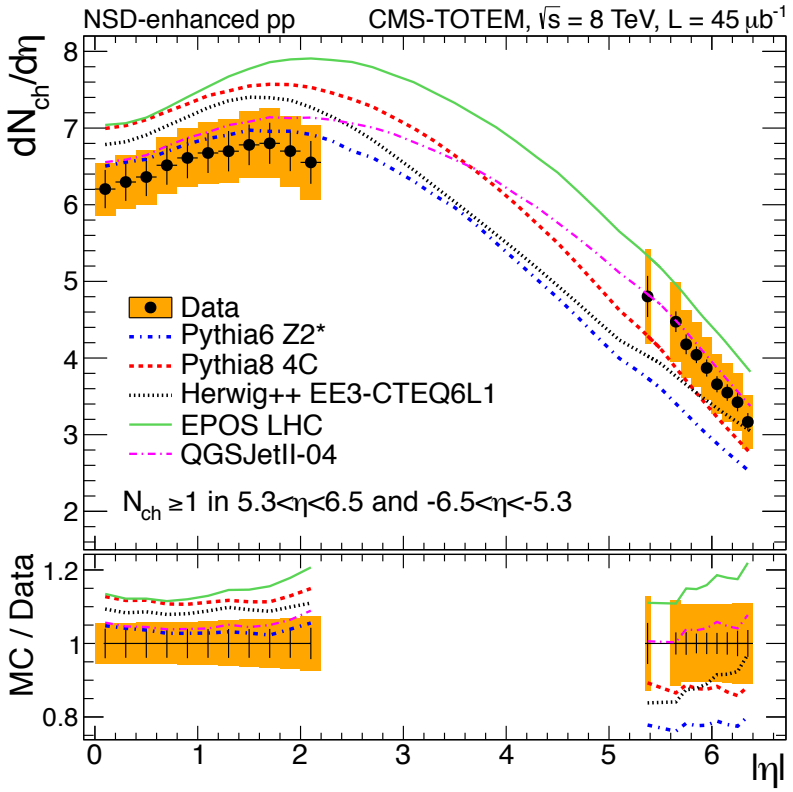




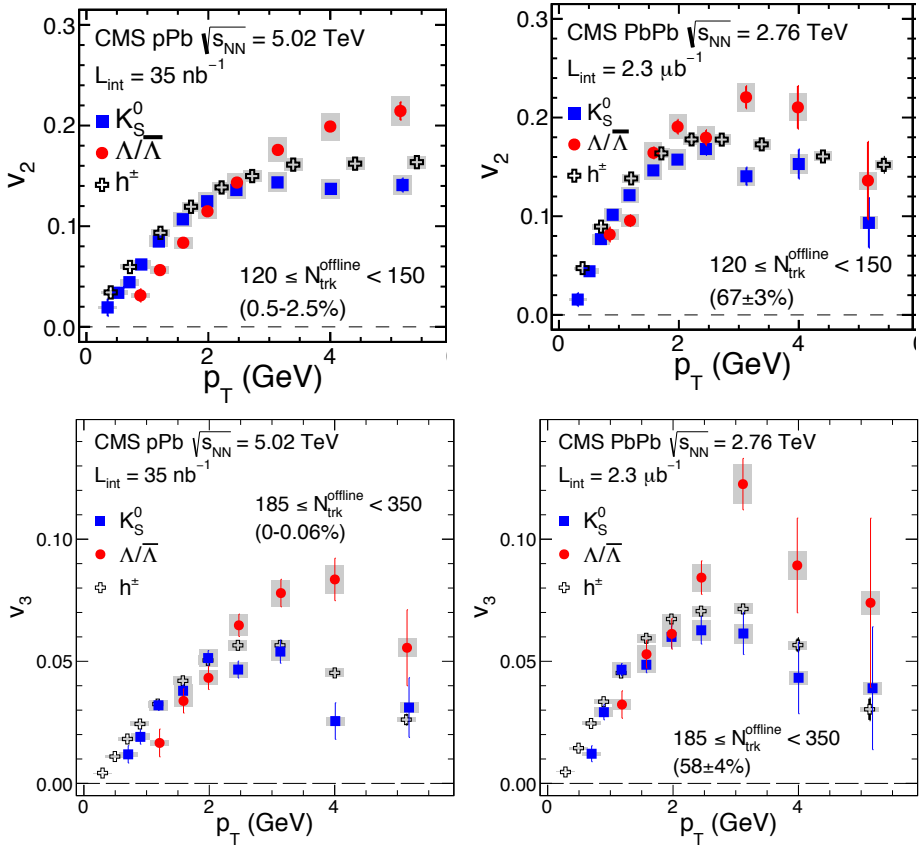
Forward & Heavy-Ion Physics

- Another joint publication - this time with TOTEM
  - First measurement of the $dN_{ch}/d\eta$ over a fairly large rapidity range
  - Most of the simulations fail to describe simultaneously the central and forward regimes
- Studies of the "ridge" with strange particles: v_2 and v_3 dependence on particle species

CMS & Totem Collaborations arXiv:1405.0722



CMS Collaboration, arXiv:1409.3392



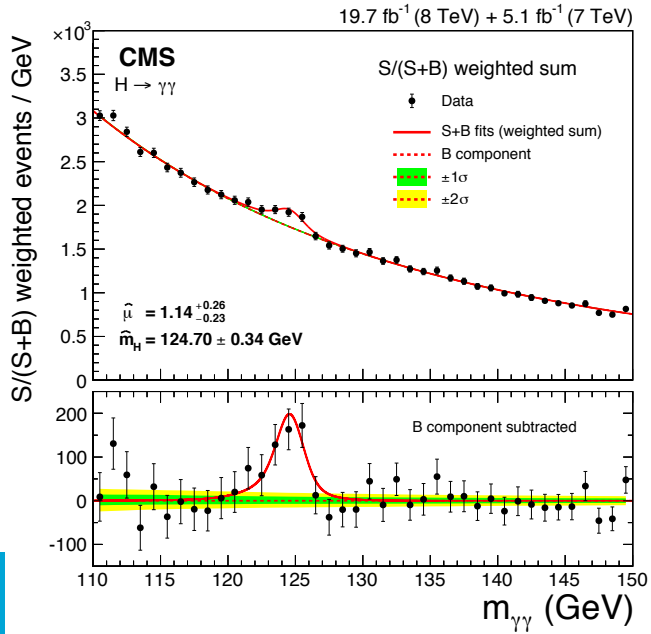
Higgs Physics

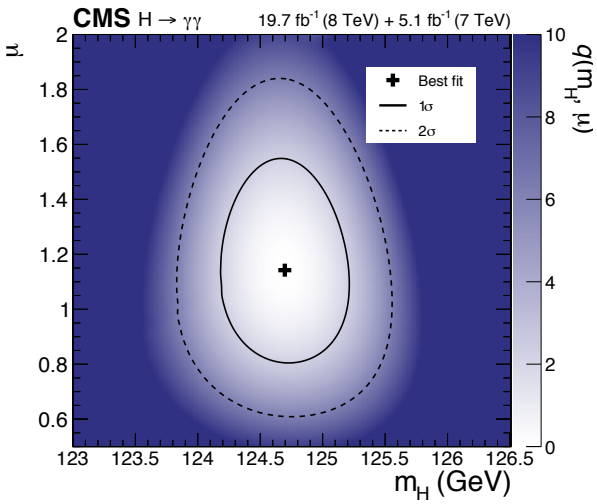
- Finished the highly successful H(γγ) analysis with the final improvements to the method and the latest ECAL calibration
- This finalizes CMS Run 1 “legacy" analyses in five main Higgs decay channels
- Paper [arXiv:1407.0558] is accepted by the EPJC
- Combination paper in preparation

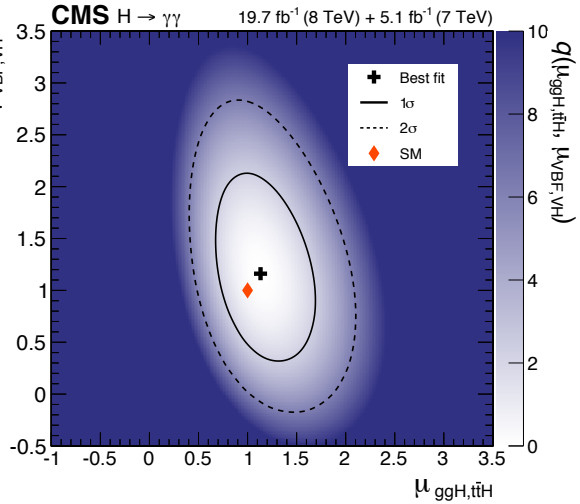
$\mu = 1.14^{+0.26}_{-0.23}$

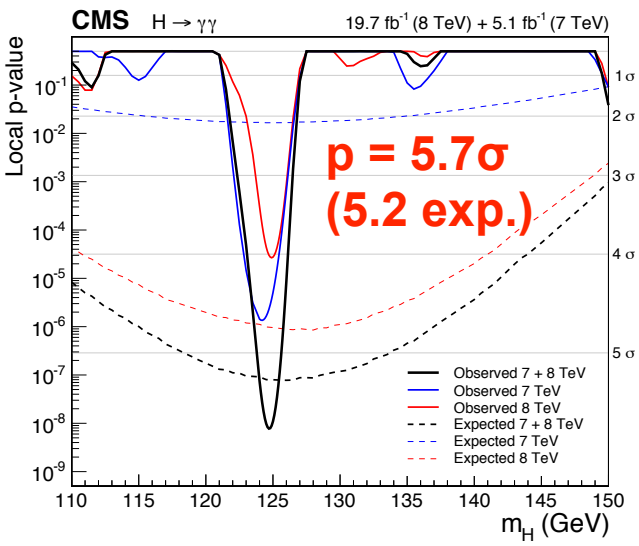
$m = 124.70 \pm 0.34$ GeV

CMS Collaboration
arXiv:1407.0558



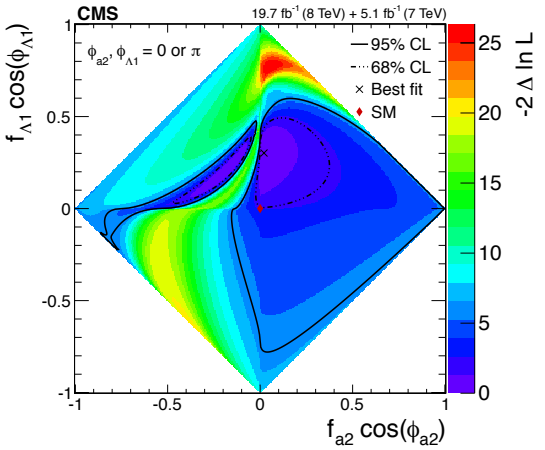


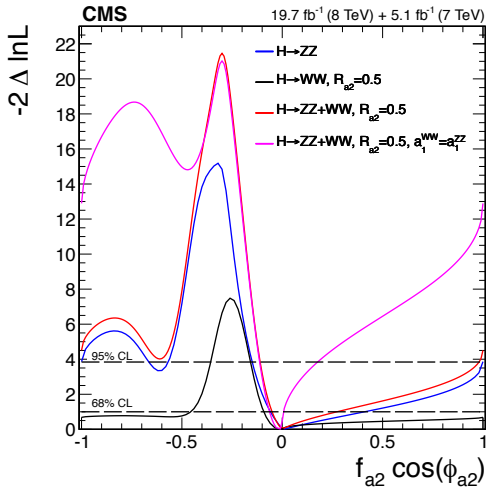


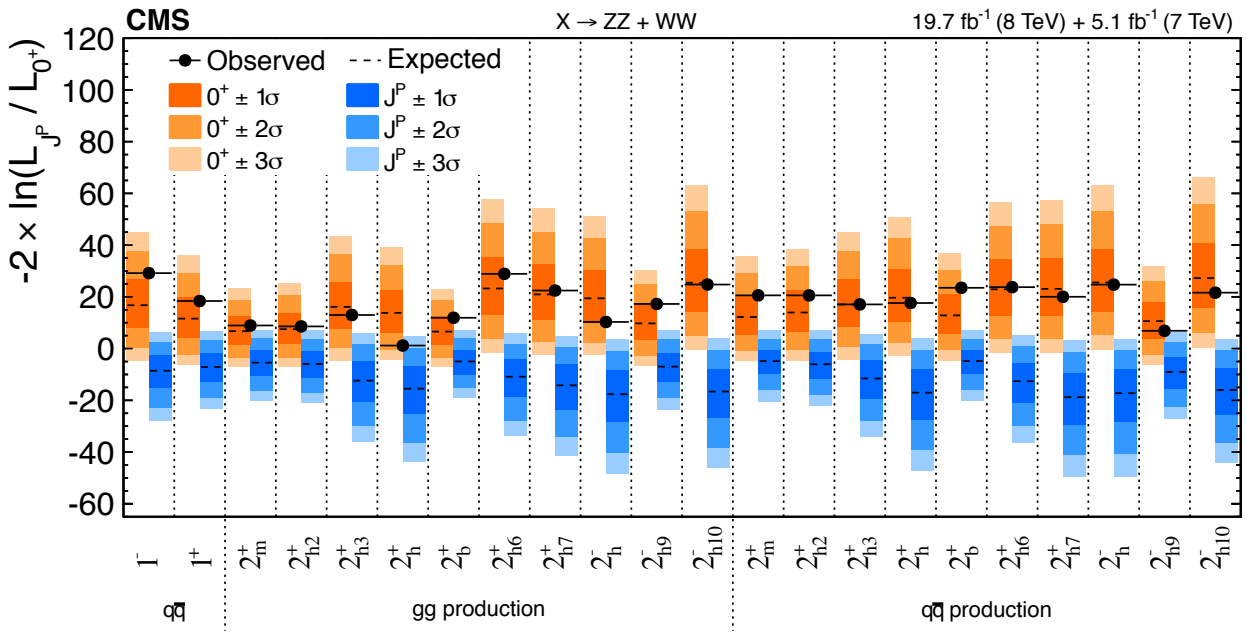


Dimension Six Operators

- New comprehensive study of alternative spin-parity hypotheses and anomalous interactions in the H(γγ), H(ZZ) and H(WW) channels
- The above analysis directly probes tensor structure of the SM Lagrangian and thus can be considered as the first step towards Fabio's dimension-six exploration program







CMS Collaboration
arXiv:1411.3441

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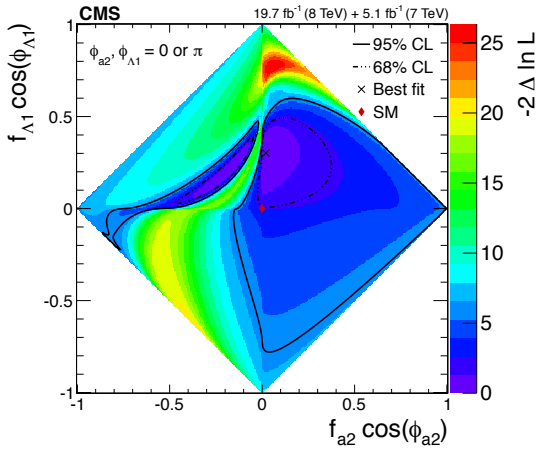
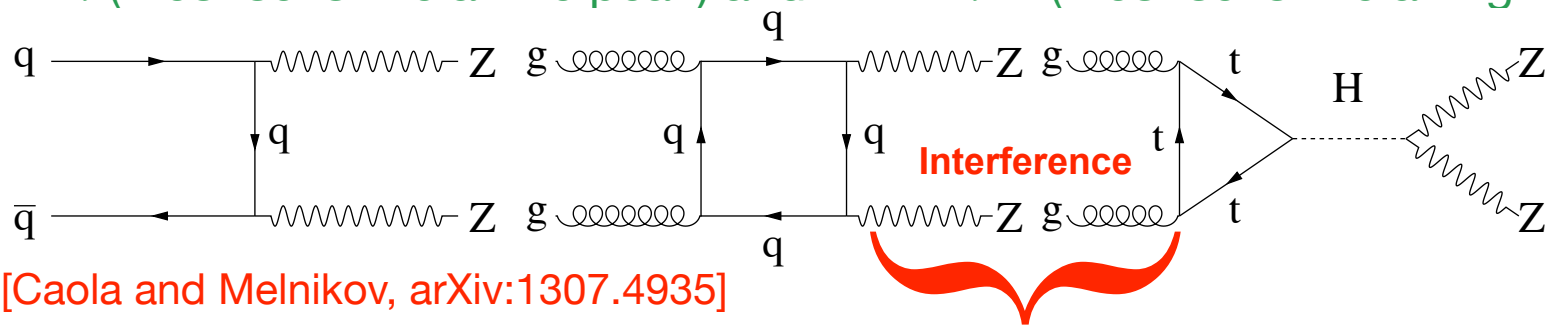


CMS Collaboration
arXiv:1411.3441

Higgs Boson Width

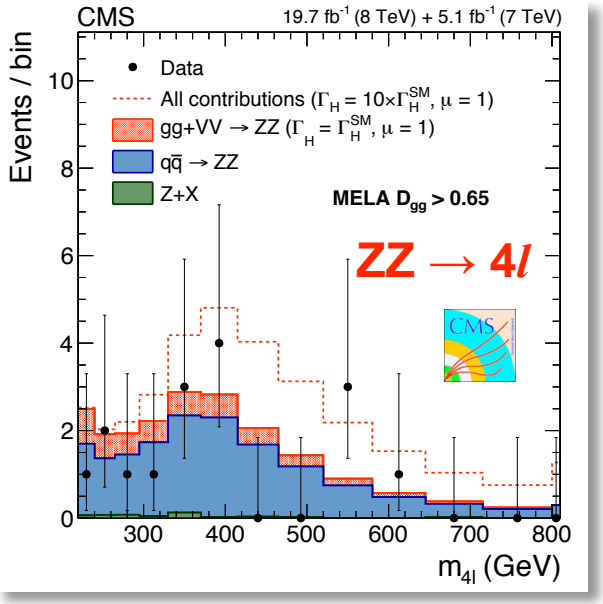
- Width from the interference of the on-peak and off-peak H(ZZ) production: ZZ → 4*l* (most sensitive at the peak) and ZZ →2*l*2ν (most sensitive at high mass)

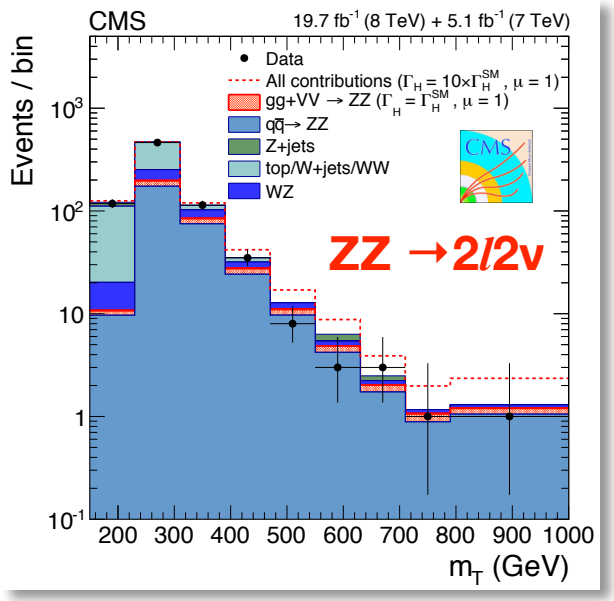


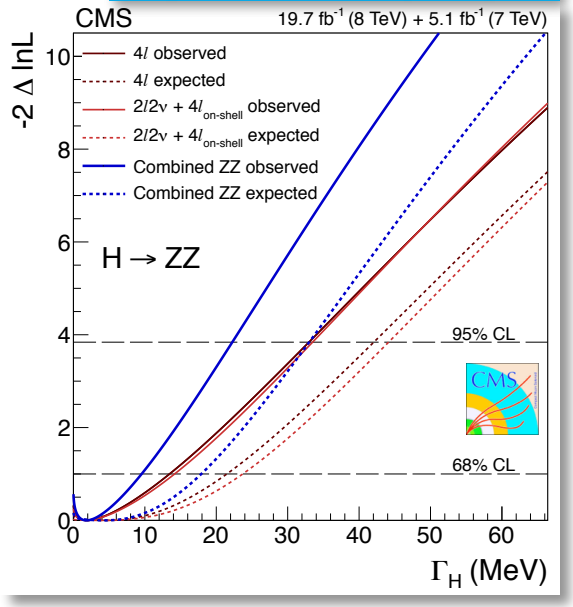
[Caola and Melnikov, arXiv:1307.4935]

- Set a stringent (O(100)!) limit Γ_H < 22 (33 exp.) MeV = 5.4 (8.0 exp.) Γ_{SM}
- Also, first direct measurement of off-shell Higgs couplings

CMS Collaboration
Phys. Lett. B736 (2014) 64





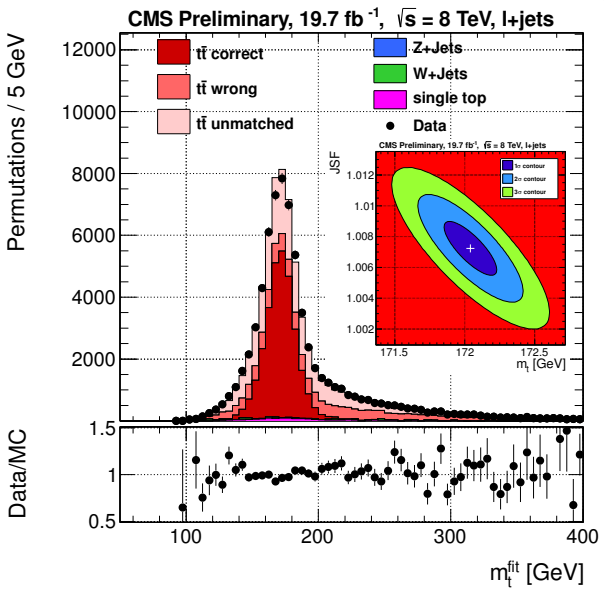


Top Physics

- CMS continues to lead with very precise measurements of the top-quark mass via different methods and in different channels
  - Top quark mass, along with the Higgs boson mass may have important implications for the EW vacuum stability
- Since the world combination, CMS has produced three new results: in l+jets, dilepton, and all hadronic decay channels

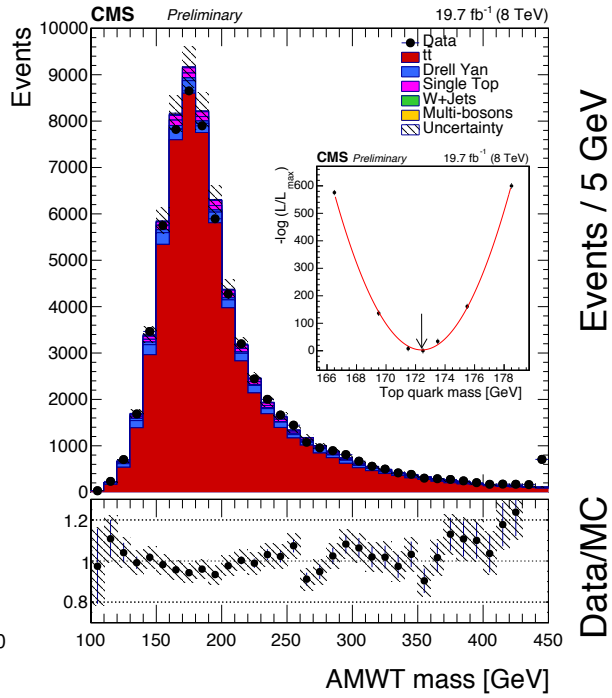
CMS Collaboration PAS TOP-14-001

$m_t = 172.04 \pm 0.19 \pm 0.75$ GeV



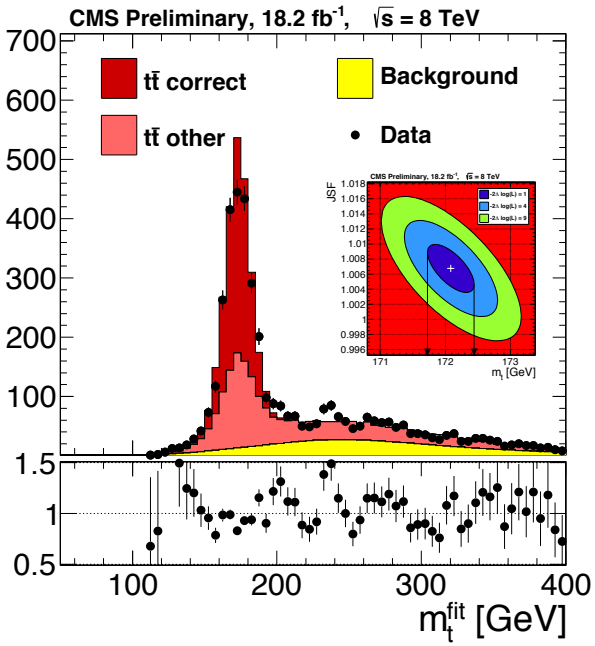
CMS Collaboration PAS TOP-14-010

$m_t = 172.47 \pm 0.17 \pm 1.40$ GeV



CMS Collaboration PAS TOP-14-002

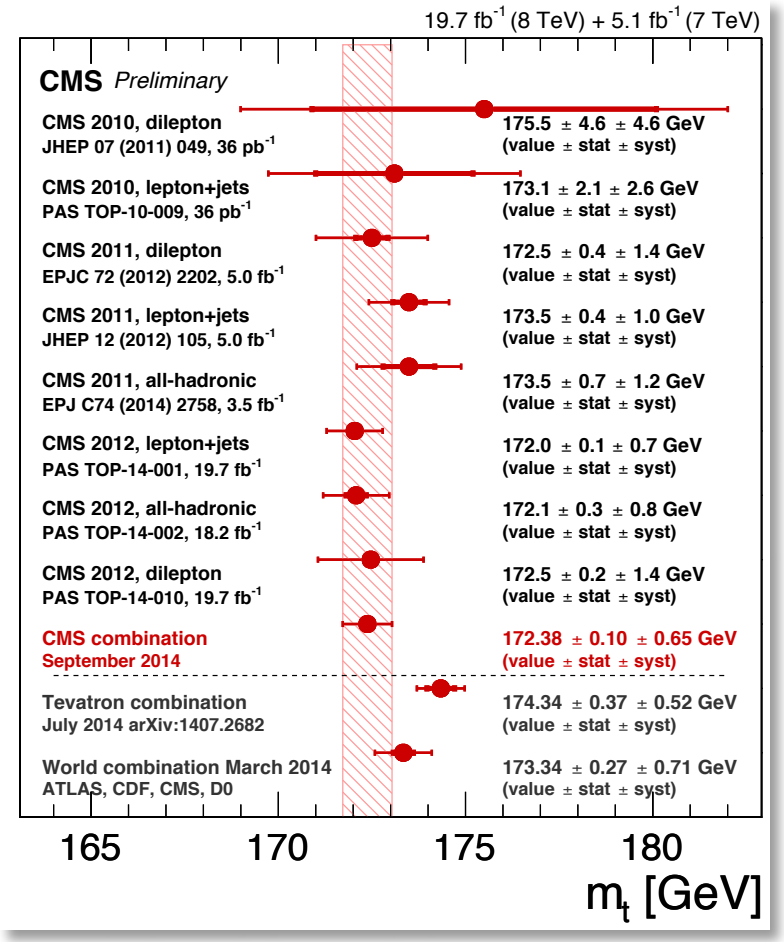
$m_t = 172.08 \pm 0.36 \pm 0.83$ GeV



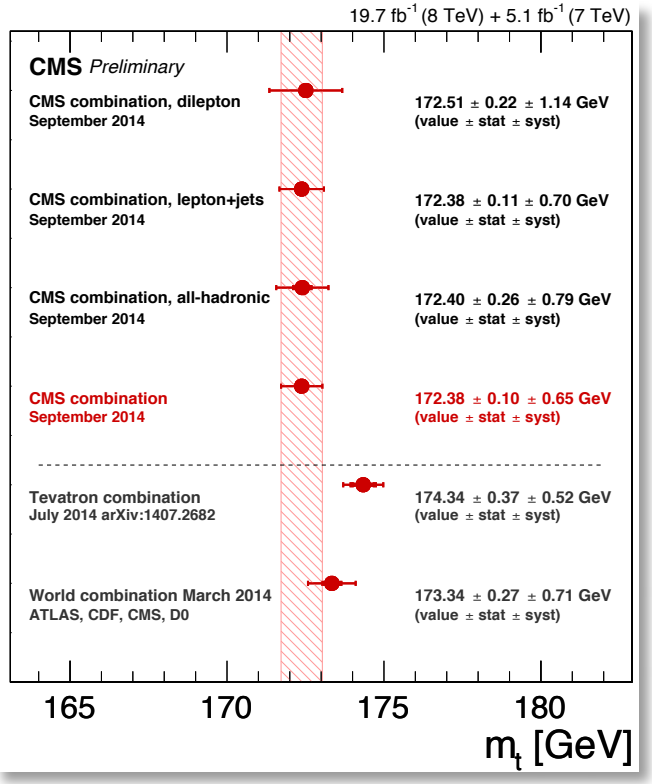
Making the World More Stable!

- New CMS top-quark mass combination with full Run 1 statistics

CMS: m_t = 172.38 ± 0.10 ± 0.65 GeV



CMS Collaboration PAS TOP-14-015



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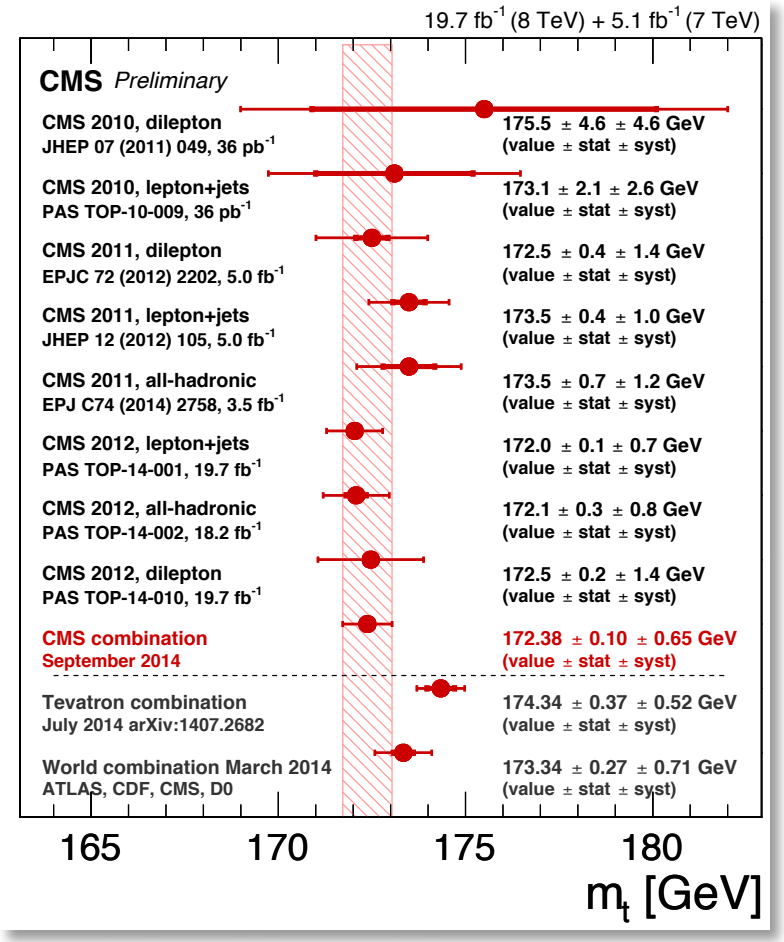
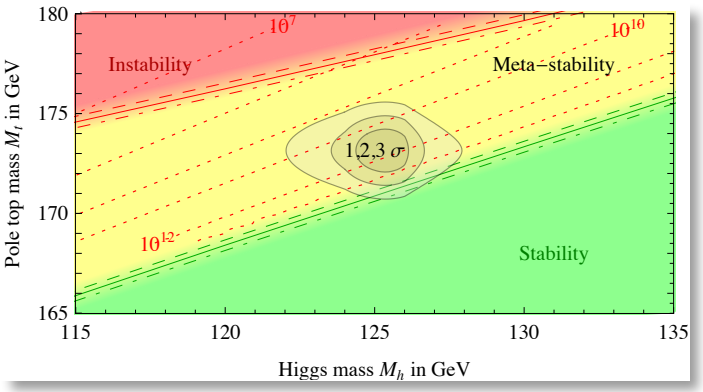
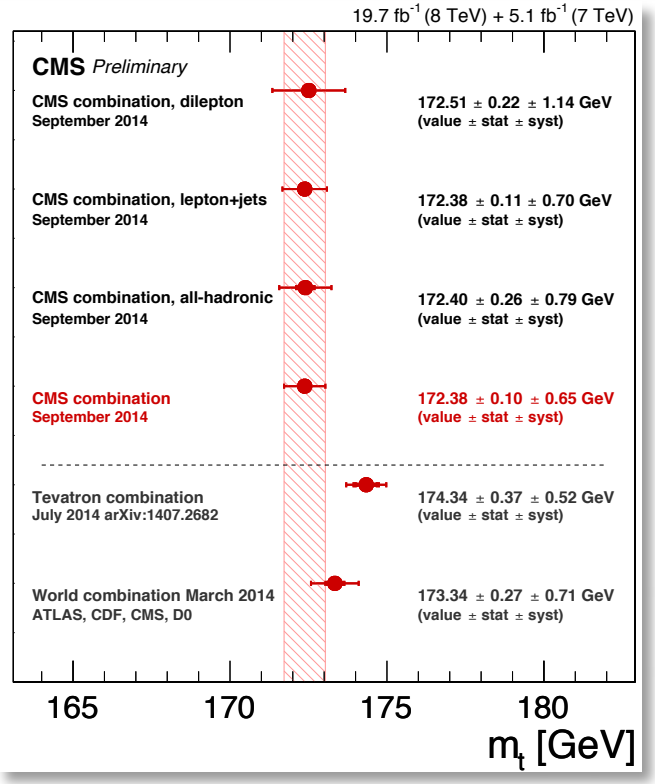
- New CMS top-quark mass combination with full Run 1 statistics

CMS: m_t = 172.38 ± 0.10 ± 0.65 GeV



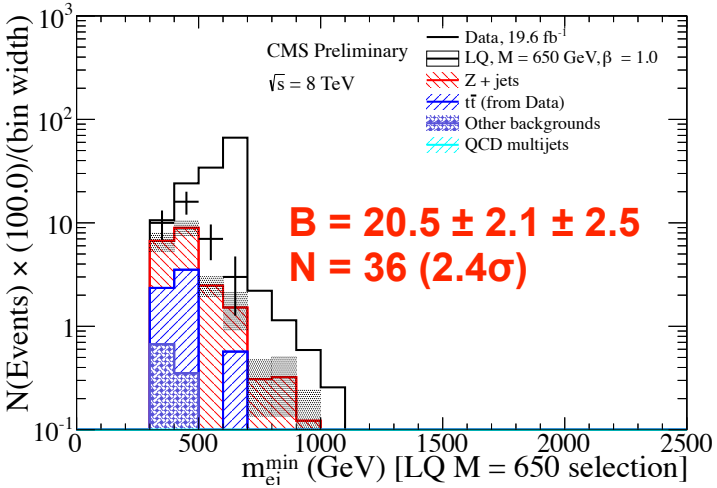


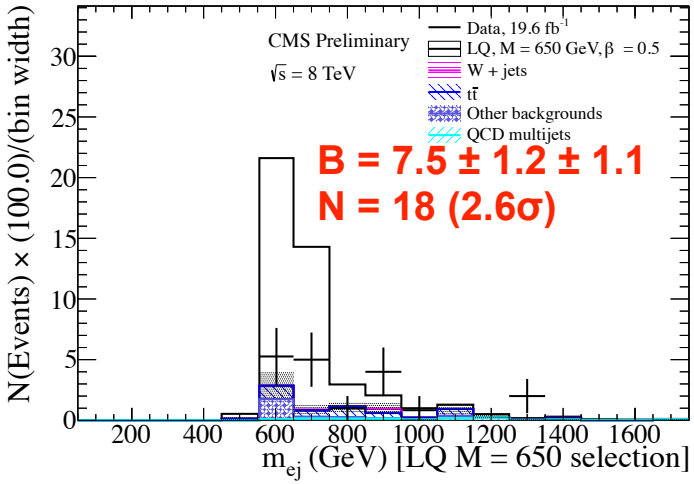
CMS Collaboration PAS TOP-14-015



Searches - I

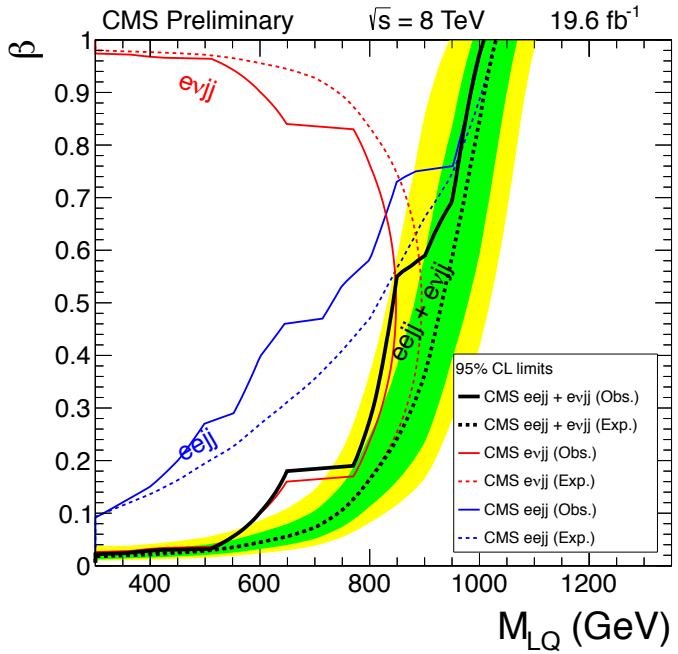
- Most of the searches are getting completed
- Will highlight just three, where slight excesses have been seen, and one more with novel technique





- Search for 1st generation LQ in the eejj + evjj channels
- Excess seen in both channels for the M(LQ) = 650 GeV selection
- Many cross-checks done: does not appear to be coupled between two channels or signal-like

CMS Collaboration PAS EXO-12-041

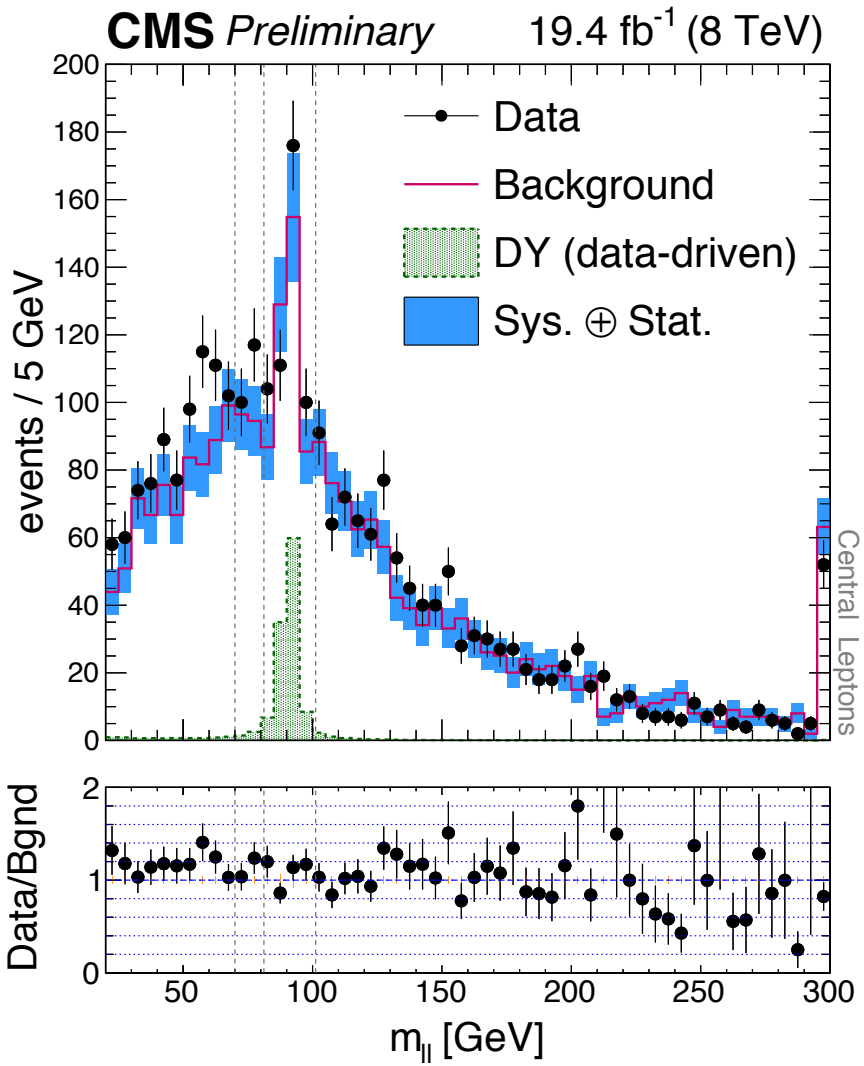


Searches - II

- SUSY opposite-sign dilepton "edge" search
  - Saw a slight excess at low mass in 2011 data at 7 TeV
  - After analyzing full 8 TeV dataset still see a small excess of 2.4σ compatible with an edge at ~80 GeV
  - Performed a huge number of cross-checks (took over a year!)
  - No corroborative evidence in any of the coupled channels
  - Attribute to a statistical fluctuation and wait for Run 2 data

CMS Collaboration
PAS SUS-12-014

	Central	Forward
Drell–Yan	158 ± 23	71 ± 15
Flav. Sym. [OF]	2270 ± 44	745 ± 25
$R_{SF/OF}$	1.03	1.02
Signal events	126 ± 41	22 ± 20
$m_{\ell\ell}^{edge}$ [GeV]	78.7 ± 1.4	
Local Significance [σ]	2.4	



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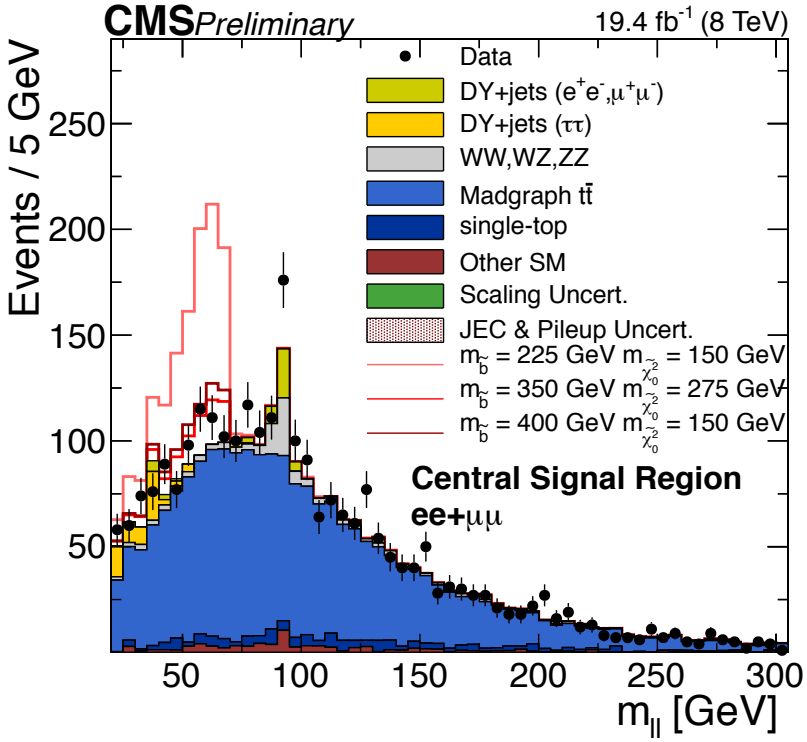
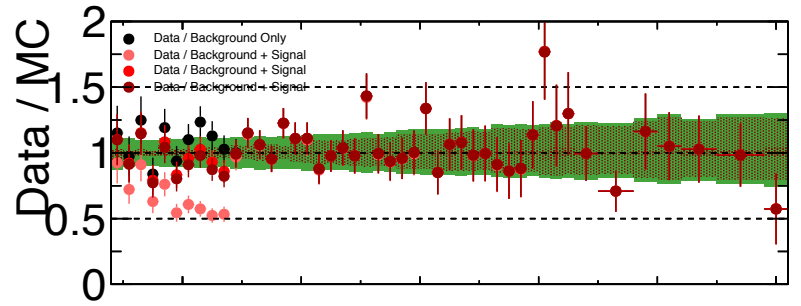
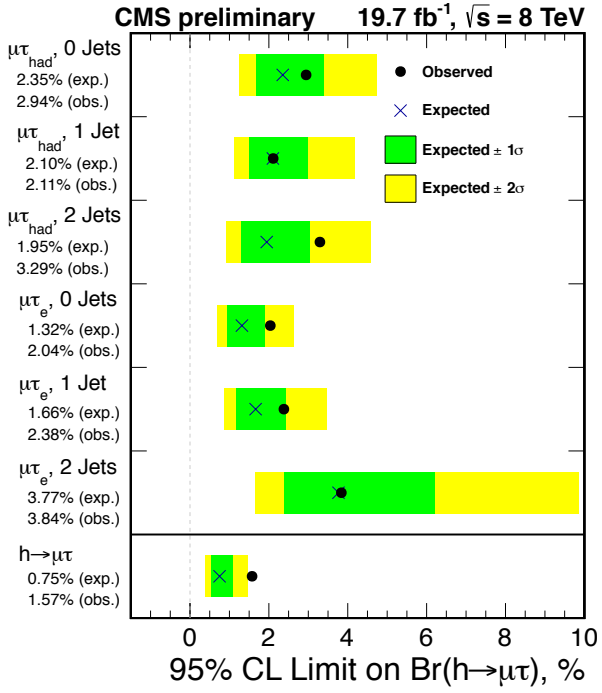
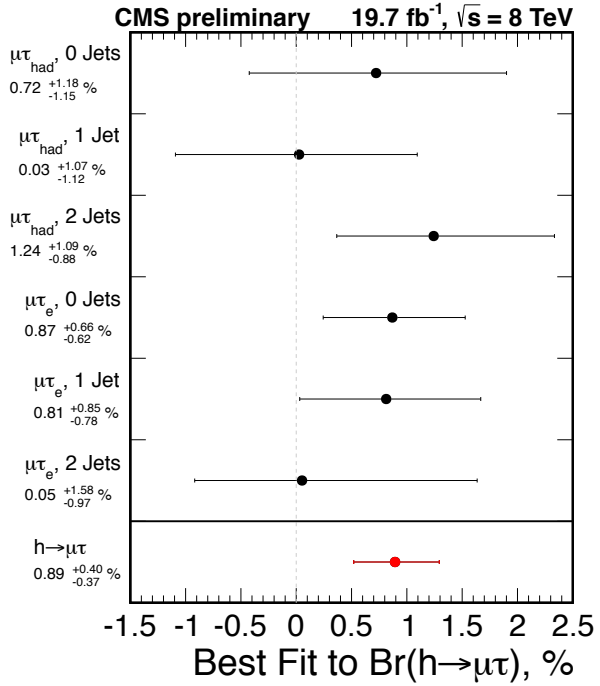


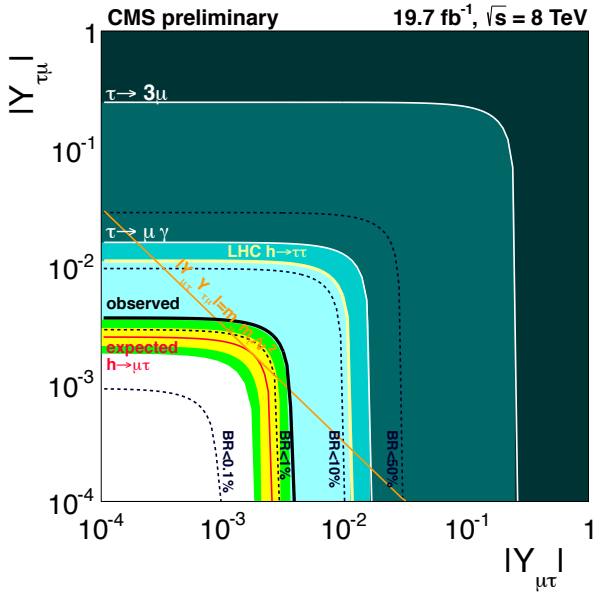


Searches - III

- First search for LFV Higgs boson decays in the $\mu\tau$ channel
  - Constraints from low-energy experiments are rather weak: ~10% on the branching fraction
  - Largely based on the SM H($\tau\tau$) search with two channels explored: $\mu\tau_e$ and $\mu\tau_h$
  - Slight excess (2.4σ) is seen in the combination, split between the channels; best-fit branching fraction is $0.84^{+0.39}_{-0.37}$; limit <1.51% @ 95% CL (0.75 expected)
  - Constraints on the off-diagonal Yukawa couplings set



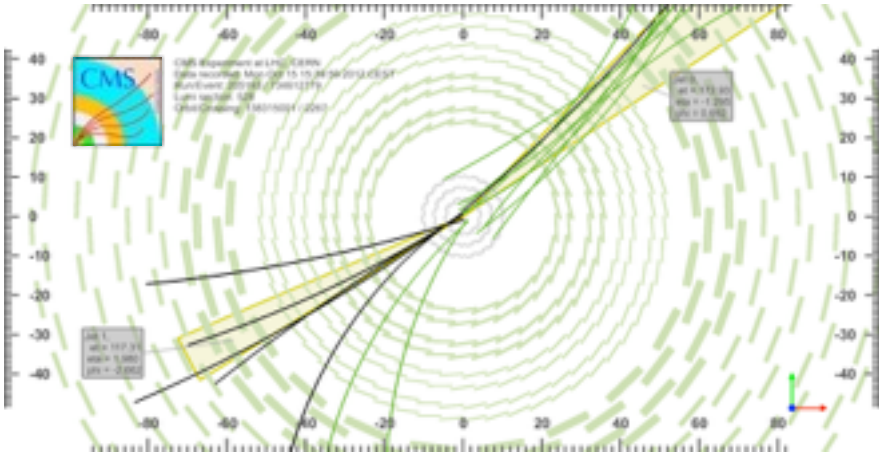




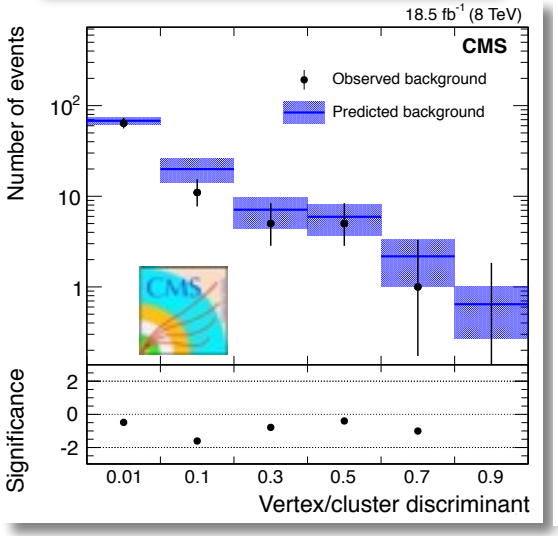
CMS Collaboration
PAS HIG-14-005

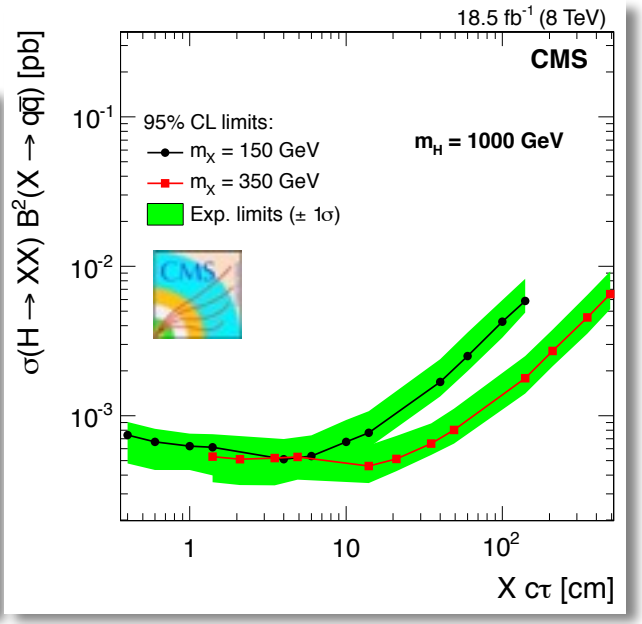
Search for Displaced Jets

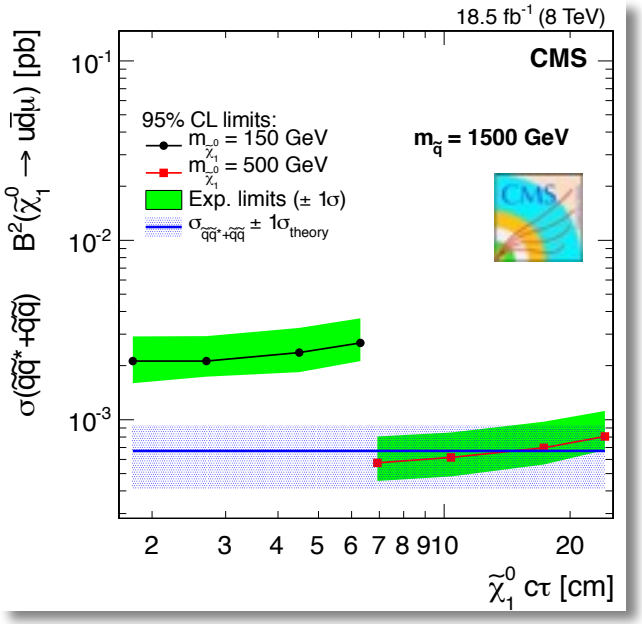
- New, innovative search looking for pairs of jets originated from the same, displayed vertex
- Looking for $H_0 \rightarrow X_0 X_0$; with $X_0 \rightarrow qq' \rightarrow jj$ and squark mediated RPV ${\chi_1}^0 \rightarrow jj\mu$ decays
- Sensitive to twin Higgs models
- Using vertex/cluster discriminant to distinguish between prompt and secondary vertices and special trigger



CMS Collaboration
arXiv:1411.6530





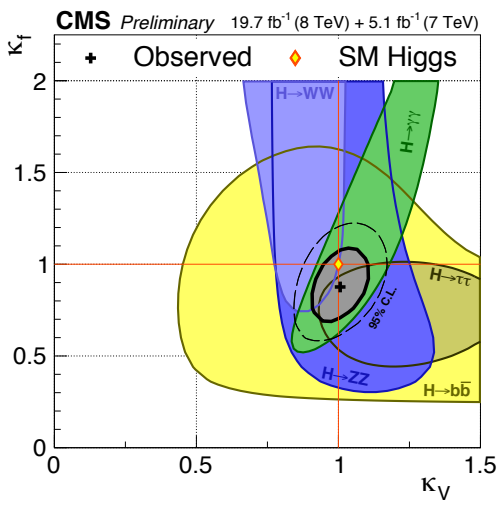


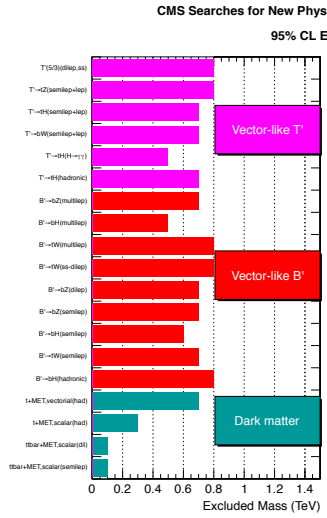
Parked Data Analyses

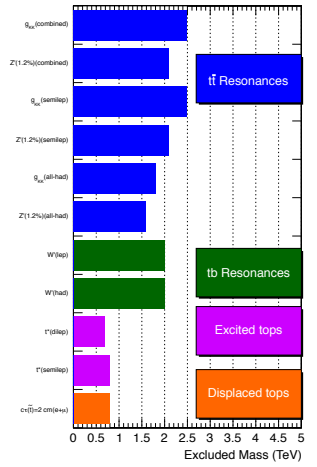
- In the middle of 2012, CMS decided to "park" some data, using high-rate triggers that probe specific topologies
  - The computing facilities did not have capacity to cope with reconstructing these data promptly, but given the LS1, it was clear that we could reconstruct these events later ("long-term parking")
- Main parked triggers:
  - VBF with softer selection (VBF H(bb), H(inv.))
  - All-hadronic triggers w/ low thresholds (SUSY compressed spectrum)
  - Monophoton trigger with low, 30 GeV photon threshold (generic ISR trigger for compressed SUSY, displaced signatures, etc.)
  - Low-mass dimuon trigger (variety of B-physics studies)
- These data are now being analyzed and the new result will start appearing in 2015 - still room for Run 1 surprises!

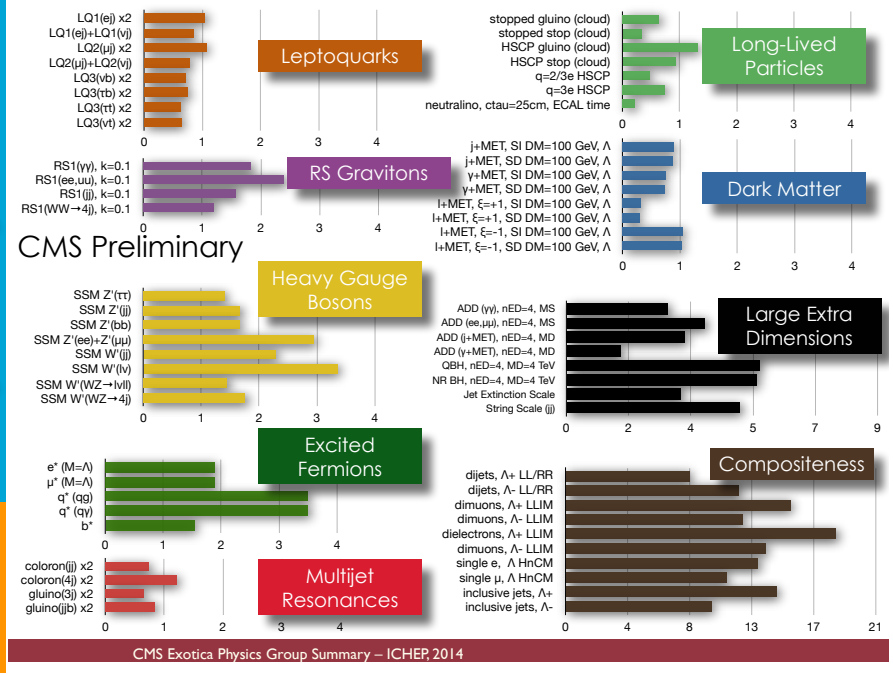
What Nature Taught Us?

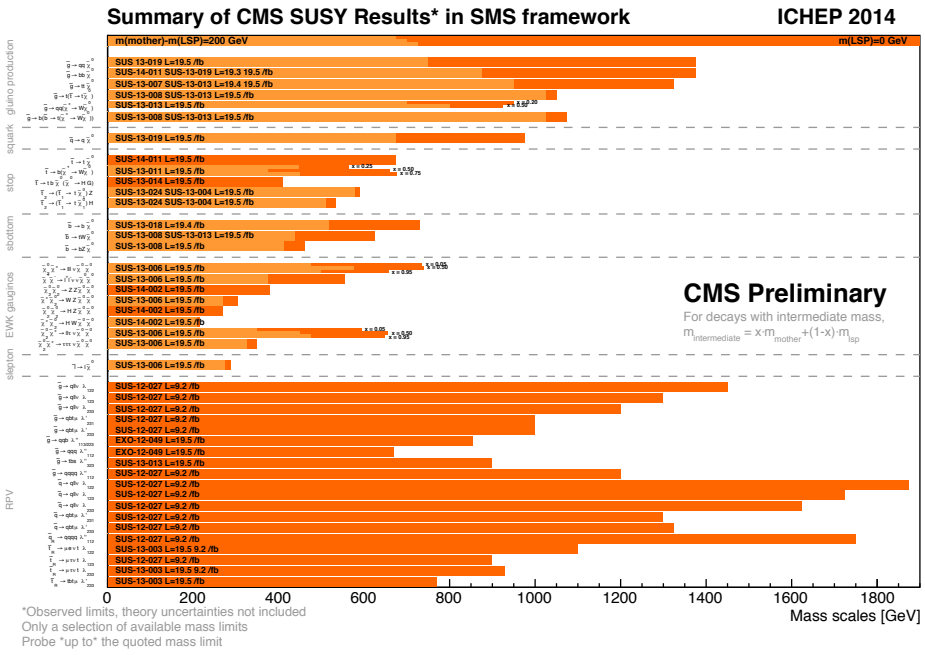
- CMS Run 1 scorecard:
  - ☑ SM-like Higgs boson
  - ☐ New Physics





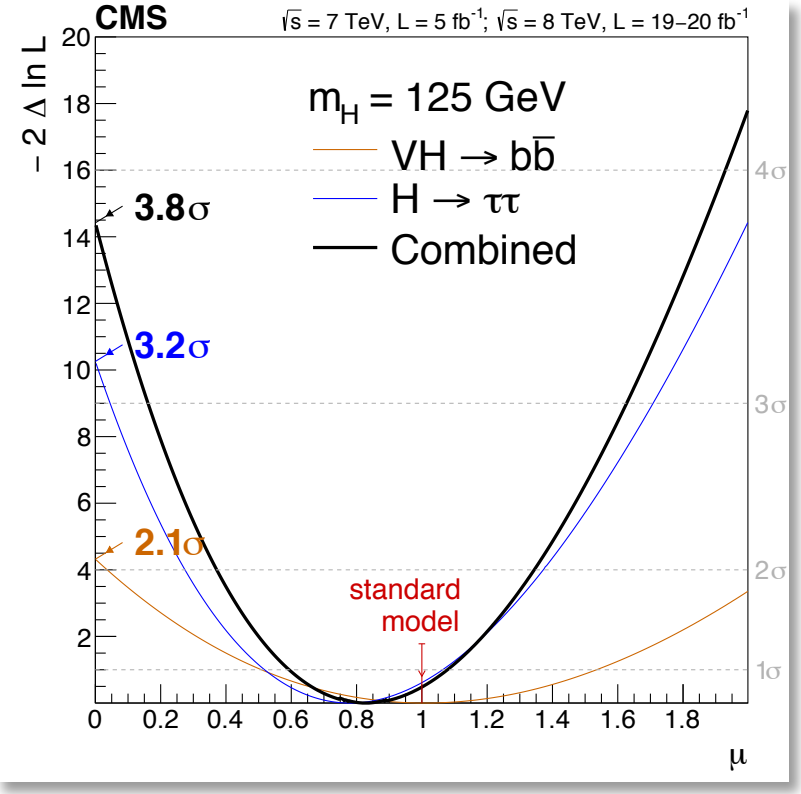


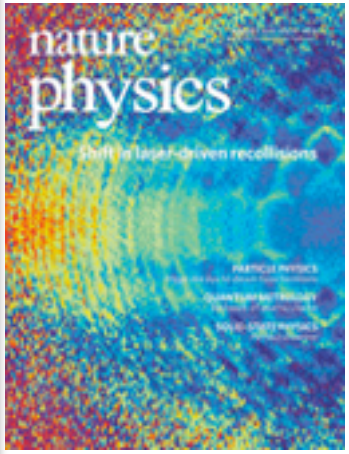




What We Taught Nature

- Particle physics is a “Natural” science!
- CMS has its first publication in Nature Physics and just submitted a joint publication with LHCb to Nature
- Recent combination of H(bb+ττ) channels results in **observed (expected)** significance of **3.8σ (4.4σ)** of the Higgs boson decay into third-generation, down-type fermions
- Strong direct evidence for Higgs boson coupling to fermions



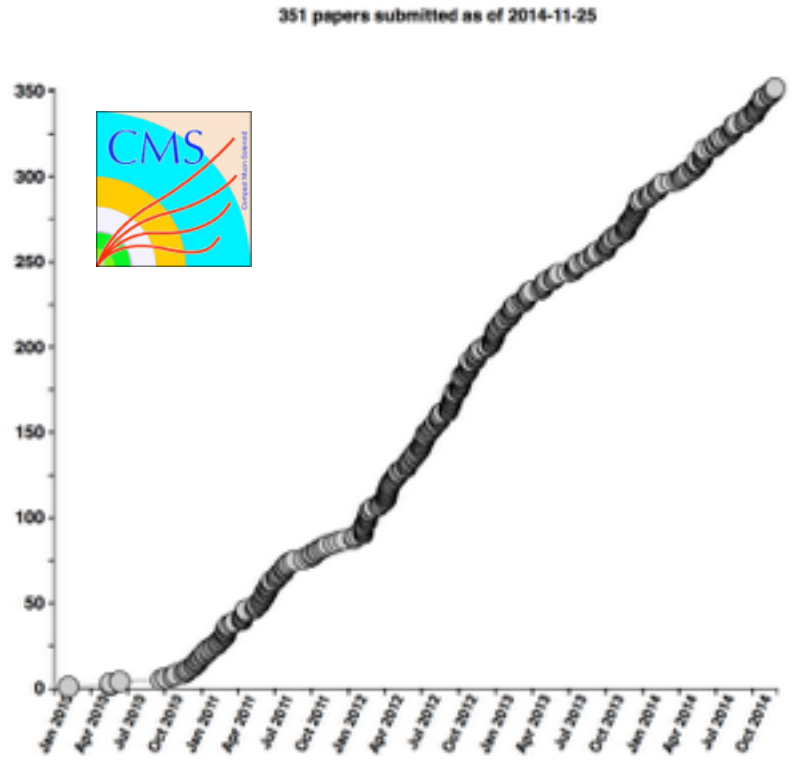


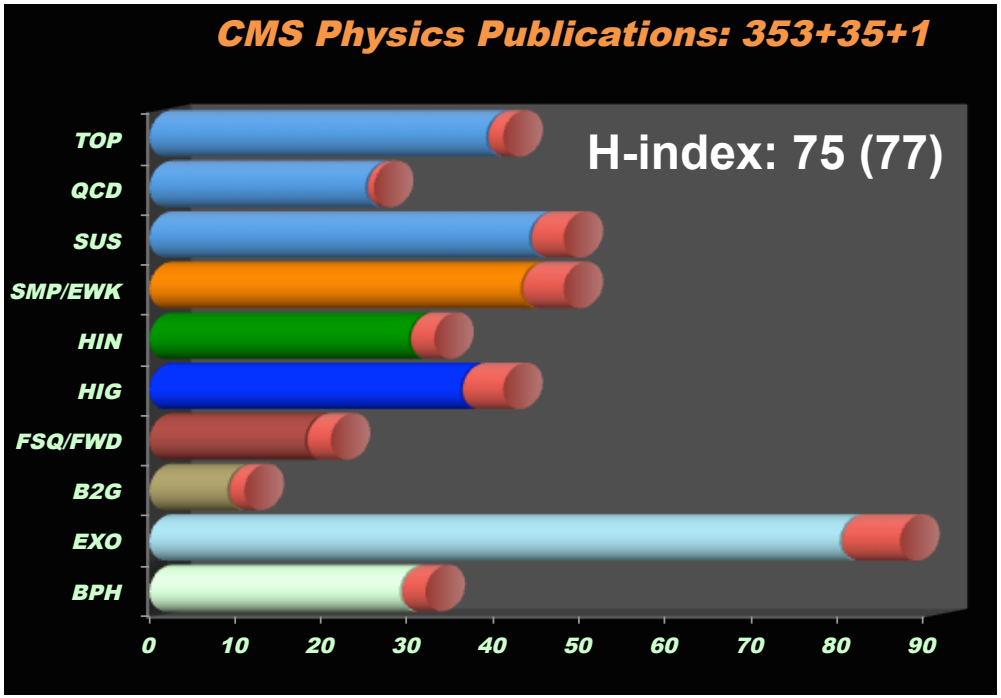
CMS Collaboration “Evidence for the direct decay of the 125 GeV Higgs boson to fermions” Nature Phys. 10 (2014) 557

Channel ($m_H = 125\,GeV$)	Significance (σ)		Best-fit μ
	Expected	Observed	
$VH \to b\bar{b}$	2.3	2.1	1.0 ± 0.5
$H \to \tau\tau$	3.7	3.2	0.78 ± 0.27
Combined	4.4	3.8	0.83 ± 0.24

CMS Publications

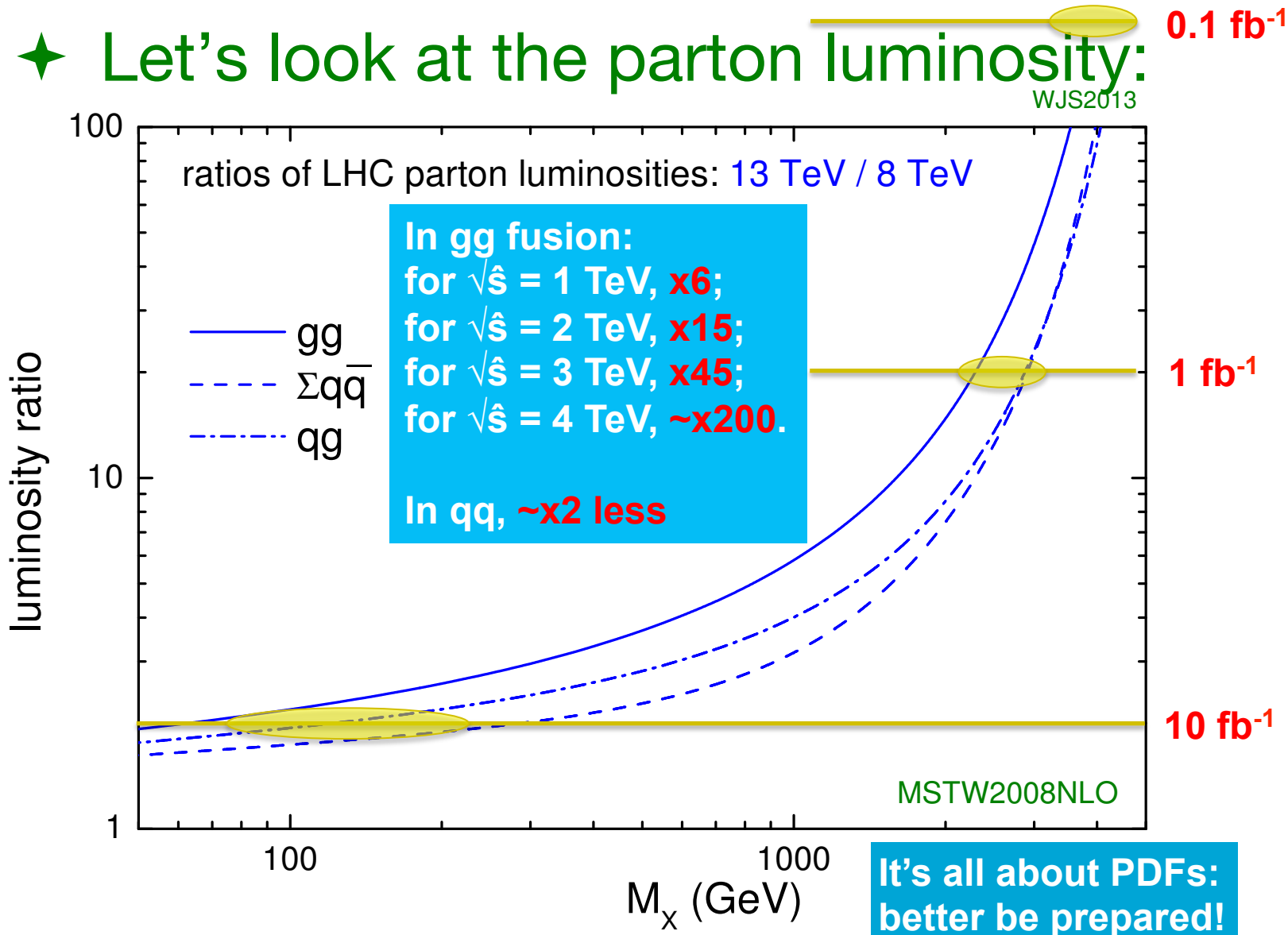
- Continue harvesting very rich Run 1 data
- Exploring new channels (e.g., Higgs boson in SUSY decay chains), finalizing precision measurements and searches requiring special techniques (e.g., long-lived particles)
- Publishing in high-impact journals, including Science, Nature Physics & (soon!) Nature
- 353 physics papers based on data, 14 technical, and 23 based on 2009 cosmic data
- H-index of 75 based on published physics papers only; 77 with technical papers





Discoveries May Come Early!

- Let's look at the parton luminosity:



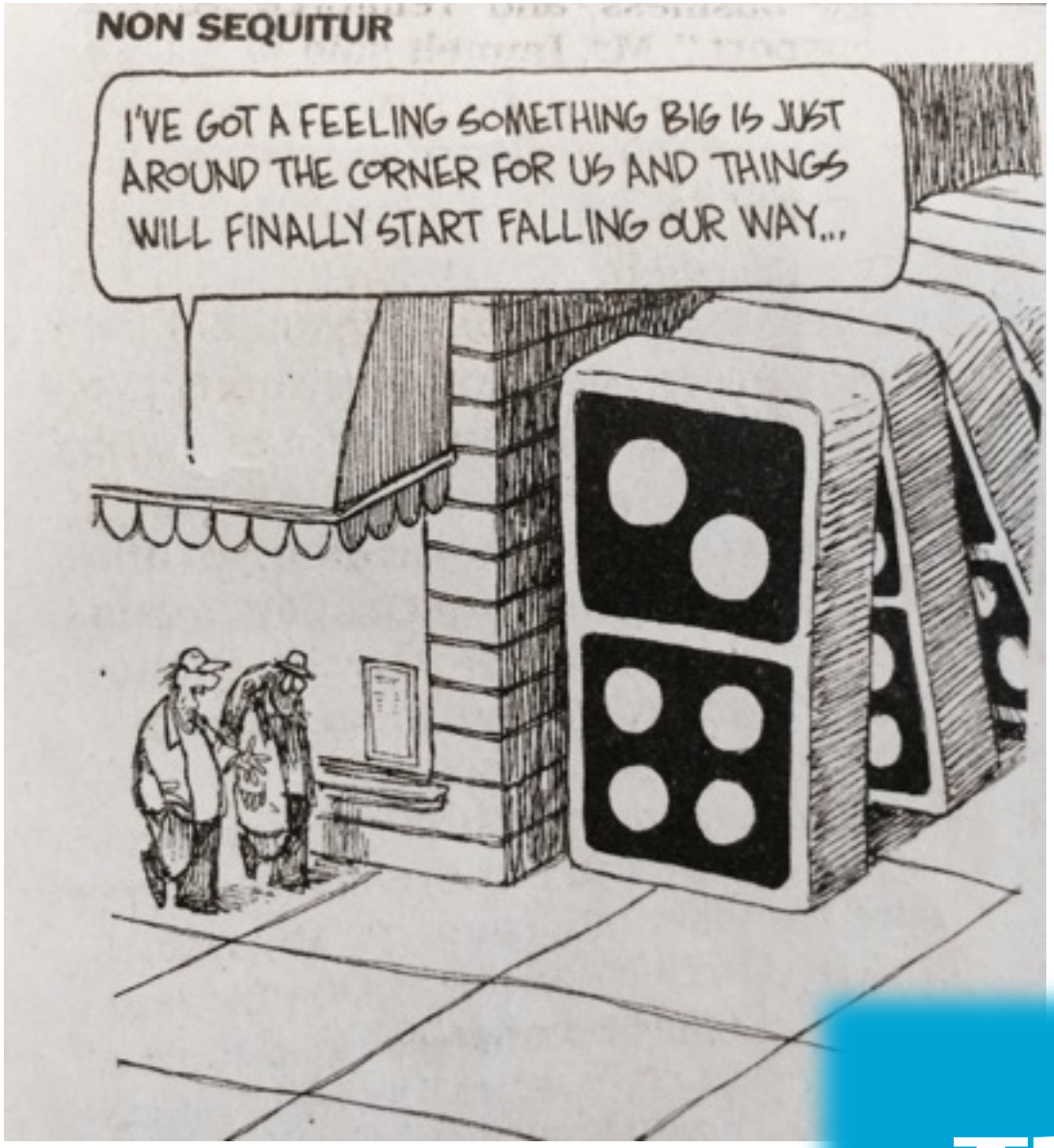
J. Stirling, http://www.hep.ph.ic.ac.uk/~wstirlin/plots/plots.html

But...

- Don't miss a big pray for a tiny thing!

Conclusions

- Nearing the end of a highly successful shutdown, with numerous improvements to the detector:
  - Installation and commissioning of multiple systems is under way at Point 5
  - The BPIX problem was recognized late, but has been solved and won't affect the schedule
  - System integration via regular global runs and forthcoming extended cosmic run
- Serious preparations for Run 2 and beyond are underway:
  - Optimization of reconstruction and simulation
  - Improvement in trigger and algorithm
  - Exercising computing and physics analysis
- Continuous flow of high-quality physics results and publications:s
  - Won't have any gap between Run 1 and Run 2
- CMS is ready to discover new physics in Run 2 - just bring it on!


NON SEQUITUR
I'VE GOT A FEELING SOMETHING BIG IS JUST AROUND THE CORNER FOR US AND THINGS WILL FINALLY START FALLING OUR WAY...

Thank You!