LHC News & Highlights

June 2013 - photo by Michael.Hoch@CERN.ch

Invisibles13 Workshop
Durham, UK

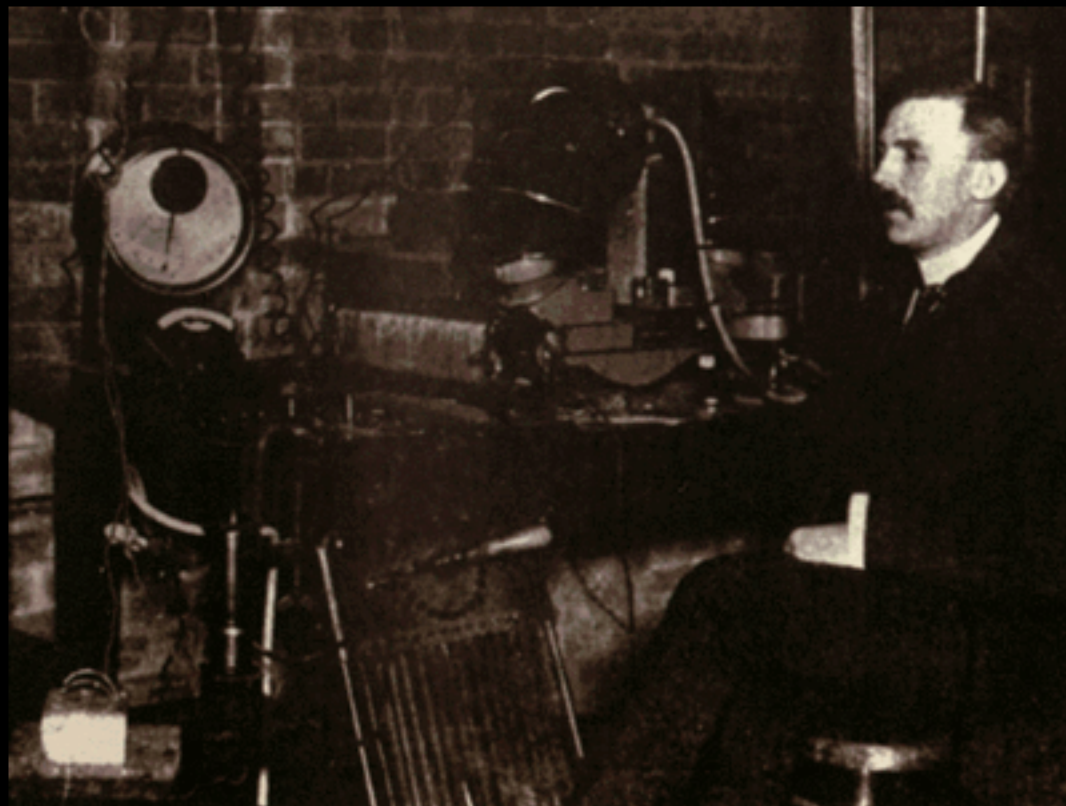
July 15, 2013

Joe Incandela
Santa Barbara/CERN

Major challenges on 5 different fronts

- Between now and first physics results ca. 2015
  1. Harvesting full 2011-12 dataset for physics
  2. Lessons learned and Run 2 preparations
  3. LS1 consolidation, early upgrades
  4. Phase 1 Upgrades 2016-19
  5. Phase 2 Upgrades 2022?

A bit of history…

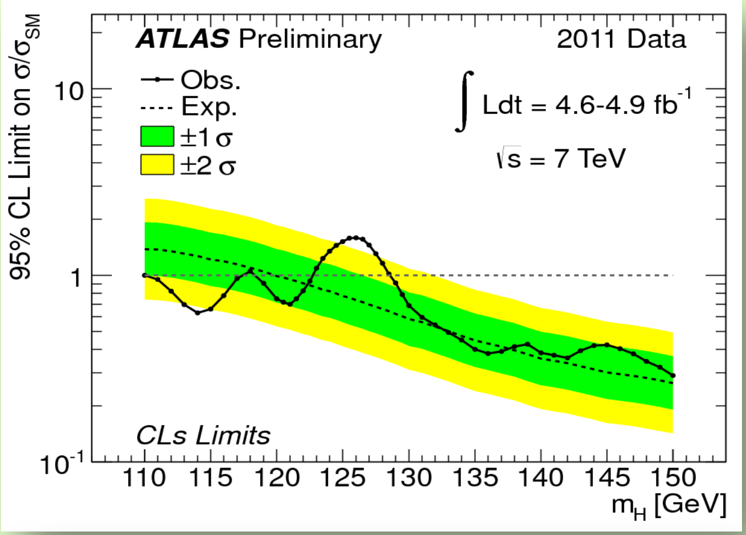


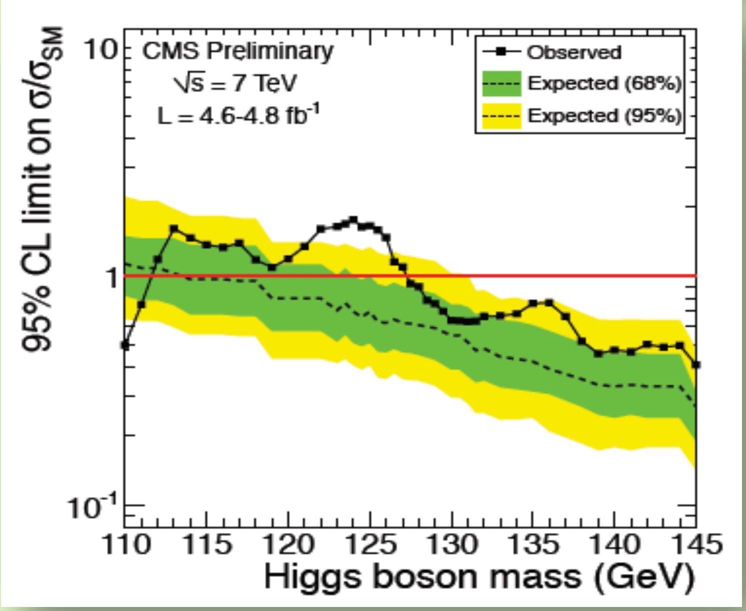
E.Rutherford ~110 years ago

Well, maybe not quite this far back…

2011

- Small excesses at 125 GeV
- Could not celebrate yet…
  - Not unprecedented to have coincidences at low significance
  - γγ channel the main contributor
- Critically important steps taken for the 2012 hunt
  - Luminosity increased and collision energy increased (3.5 TeV to 4 TeV)
    - Sensitivity to 110 GeV
  - Extended run by ~2.5 months
    - To characterize it if we found it…
  - 'Blinding' of 2012 data

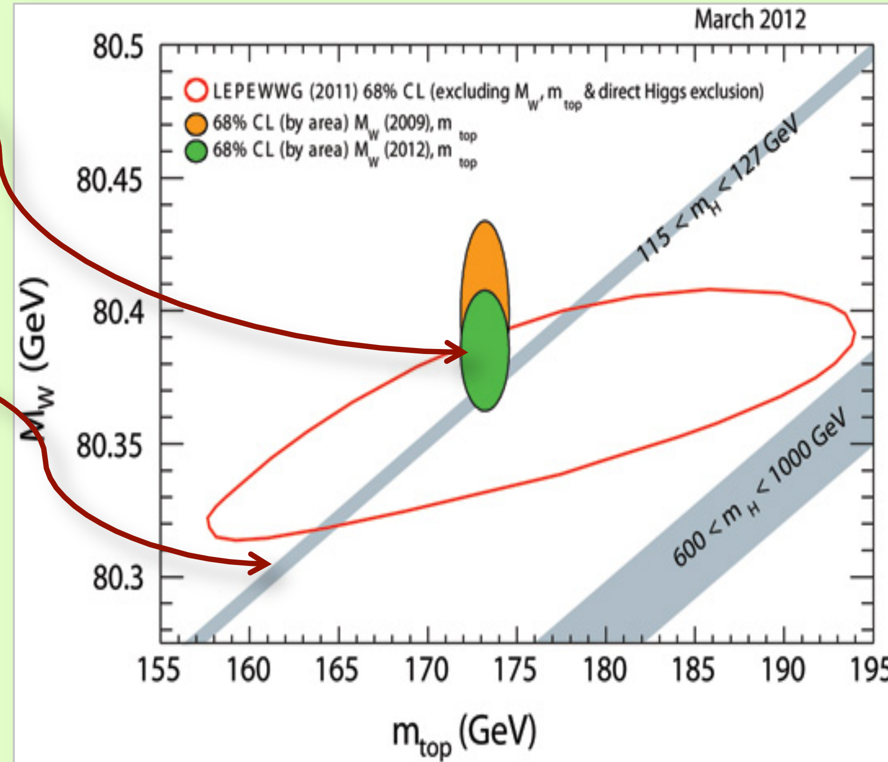




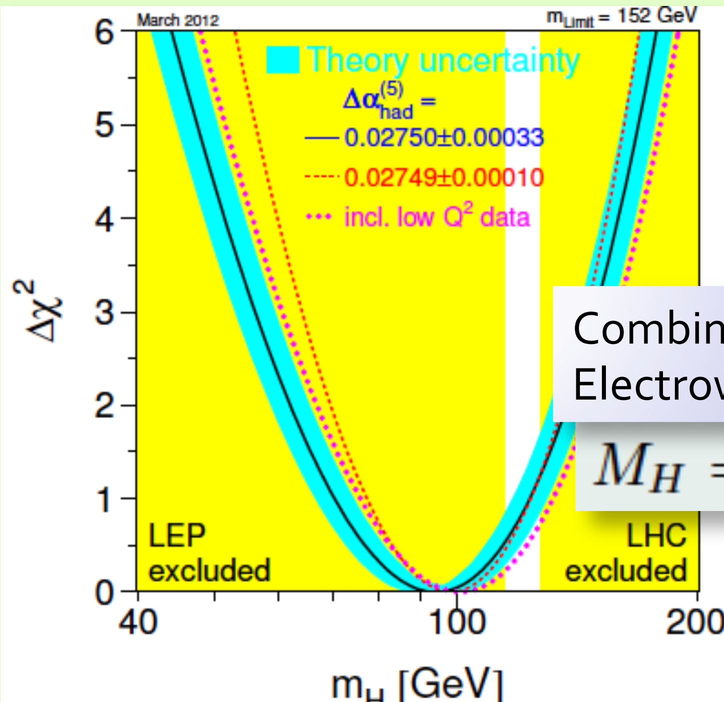
Based on slide ca. May 2012

March 2012

1. M_{top} vs. M_W
   - Tevatron M_W *Tour de Force!!*
     - m_W = 80385 ± 15 MeV
       (World Ave – Mar 2012)



2. Colliders leave little space



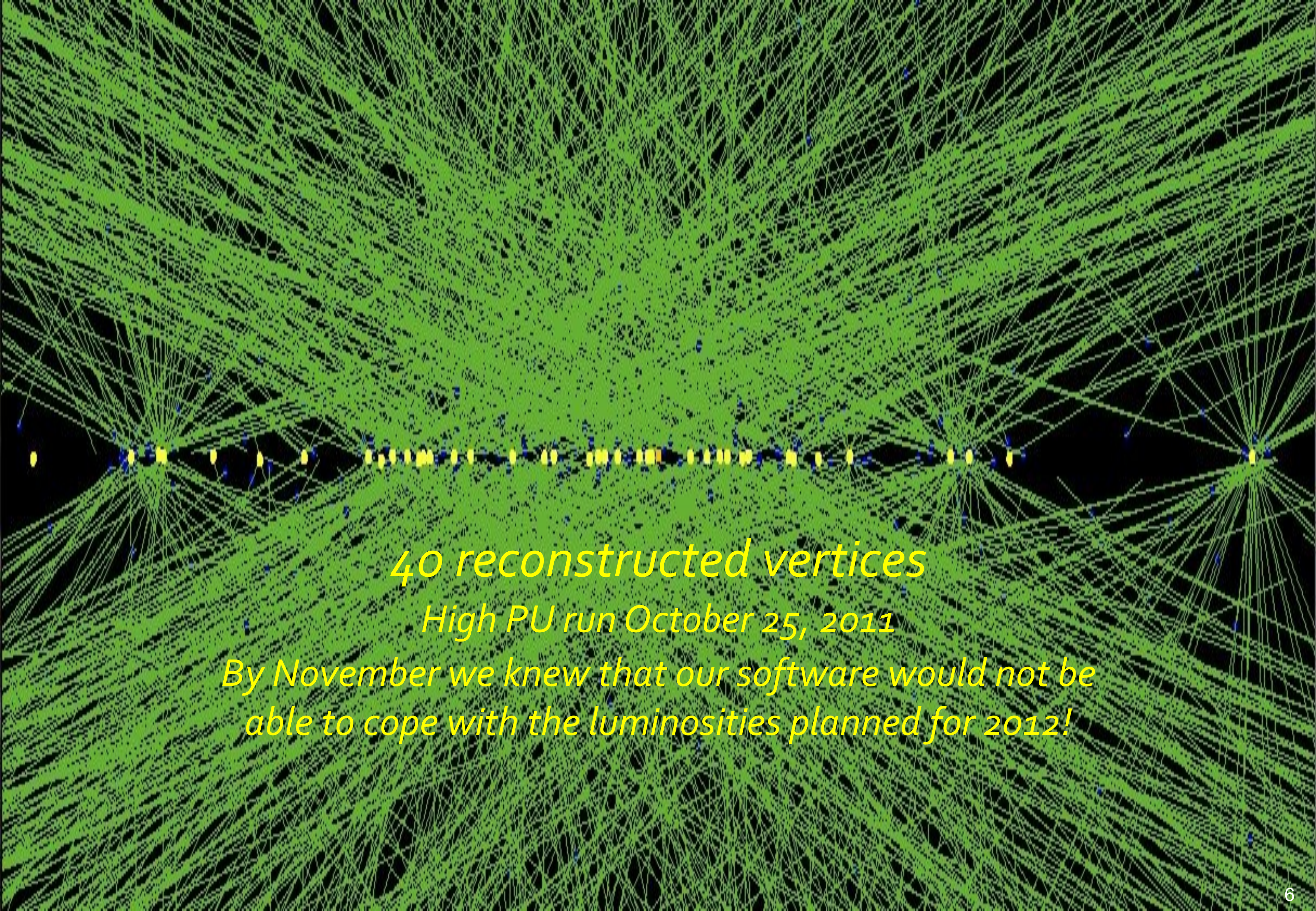
Combined precision
Electroweak data

$$M_H = 94^{+29}_{-24}$$

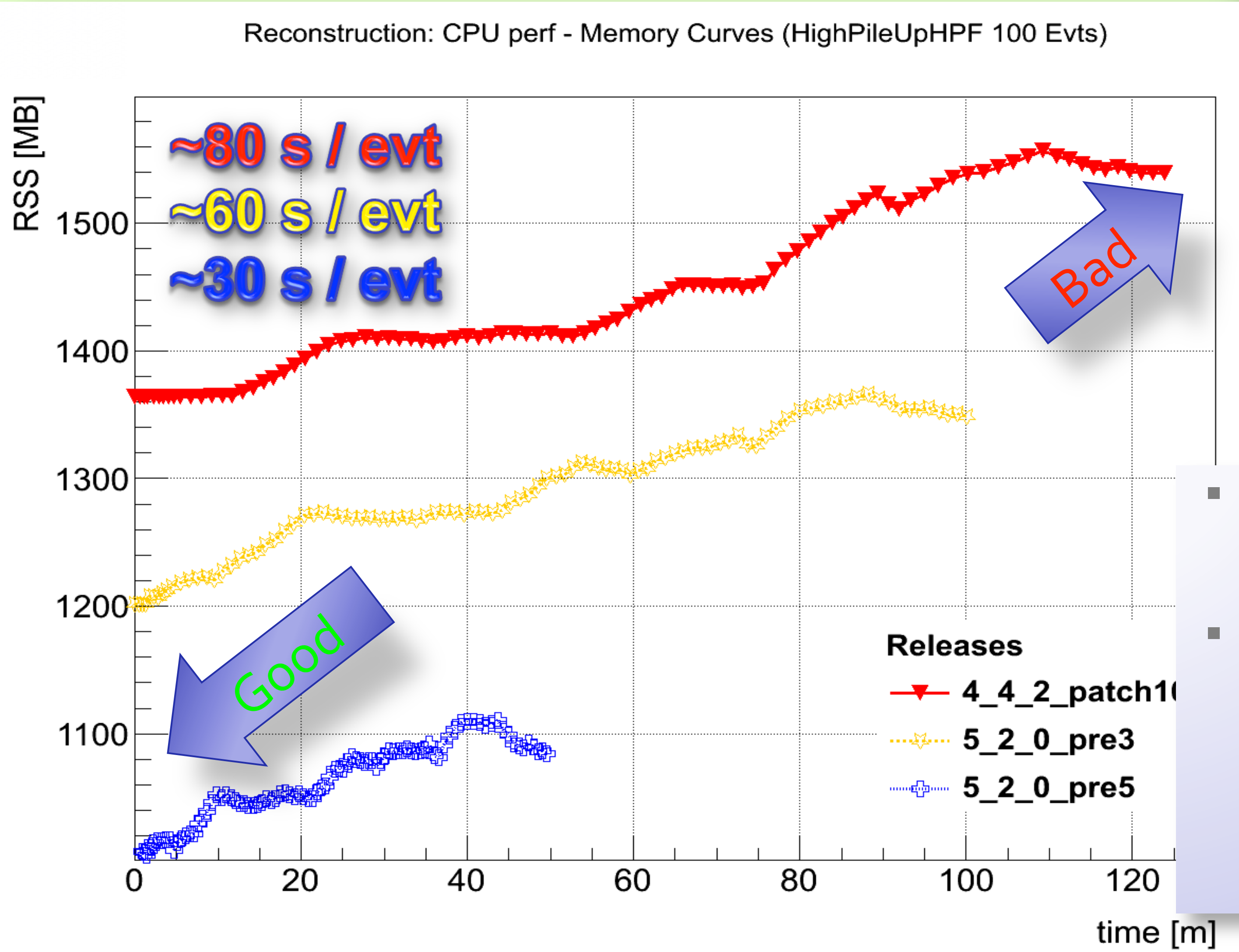
This is the main story of 2011

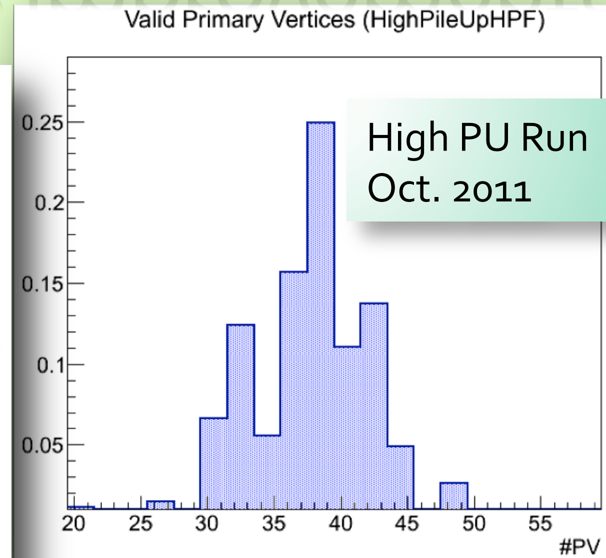
We eliminated >450 GeV of Higgs mass range.

Slide from spring 2012


40 reconstructed vertices
High PU run October 25, 2011
By November we knew that our software would not be able to cope with the luminosities planned for 2012!

Reconstruction Speed/Memory Improvements

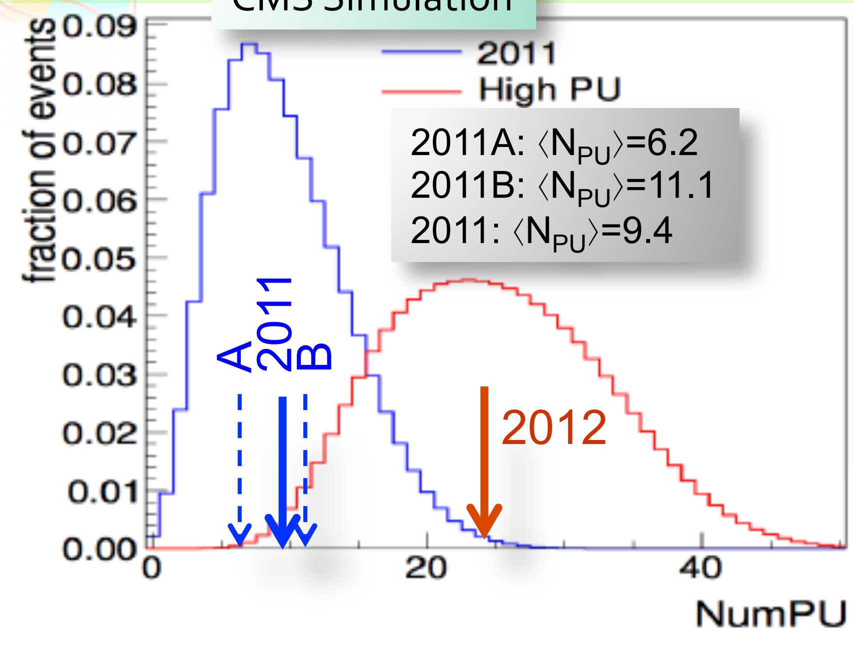




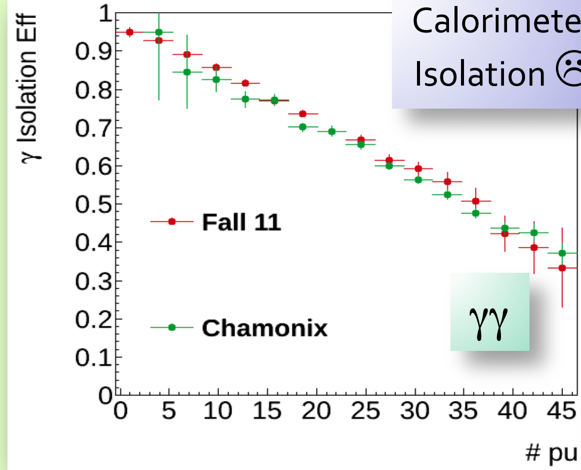
- *Technical Improvements*
  - *Compiler, ROOT, JEMalloc*
  - *Vectorization, Devirtualization*
- *Algorithmic (mainly tracking)*
  - *Seed filtering (extended to pairs) and seed combinations, Merging strategies, Loopers identification, Strip Template & cluster splitting, K2Tree template class*

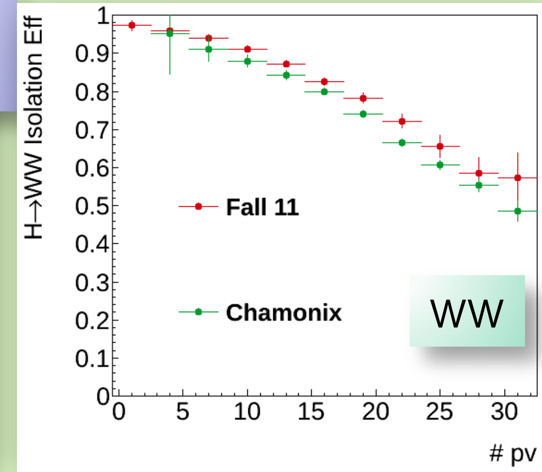
Losing control: pileup studies Feb 2012

CMS Simulation

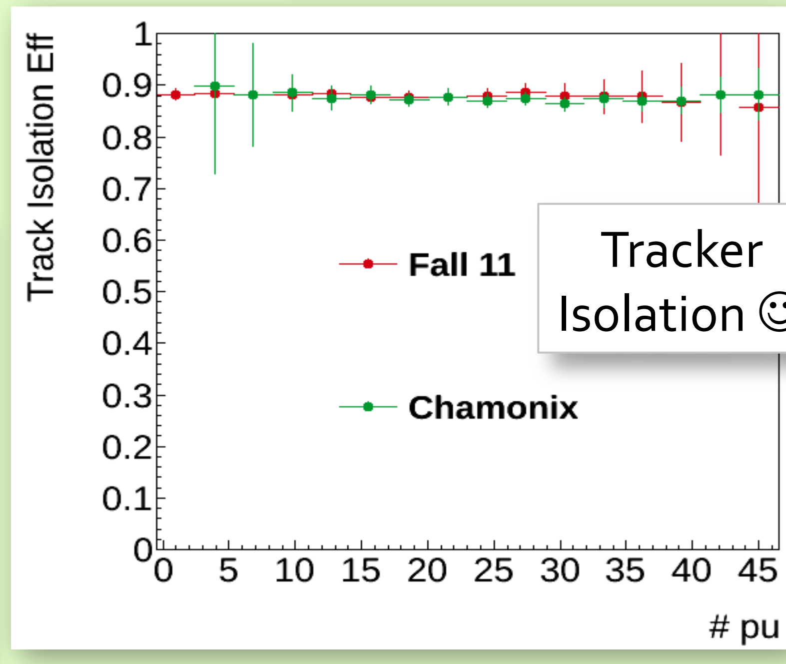


Calorimeter Isolation ☹

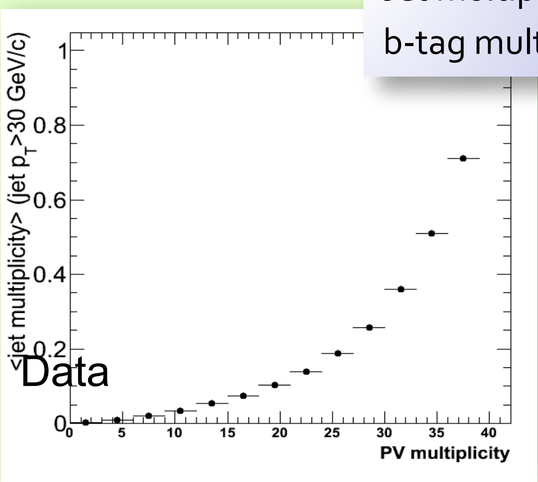


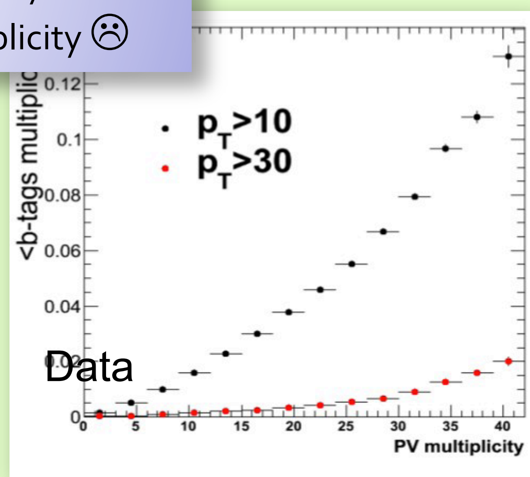


Tracker Isolation ☺



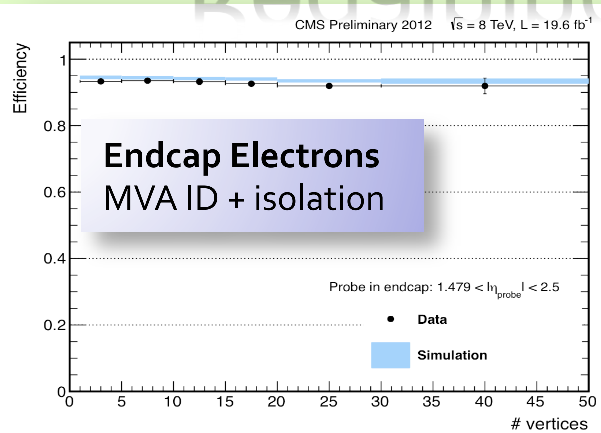
Jet multiplicity
b-tag multiplicity ☹

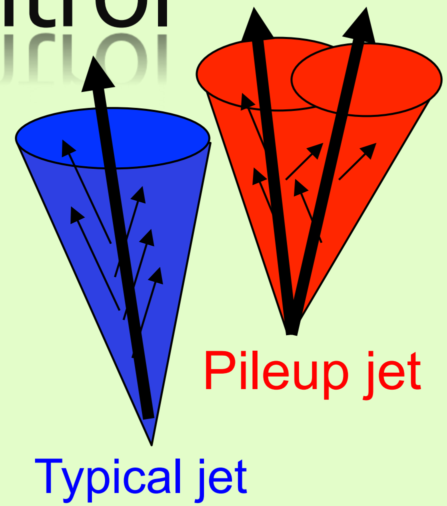


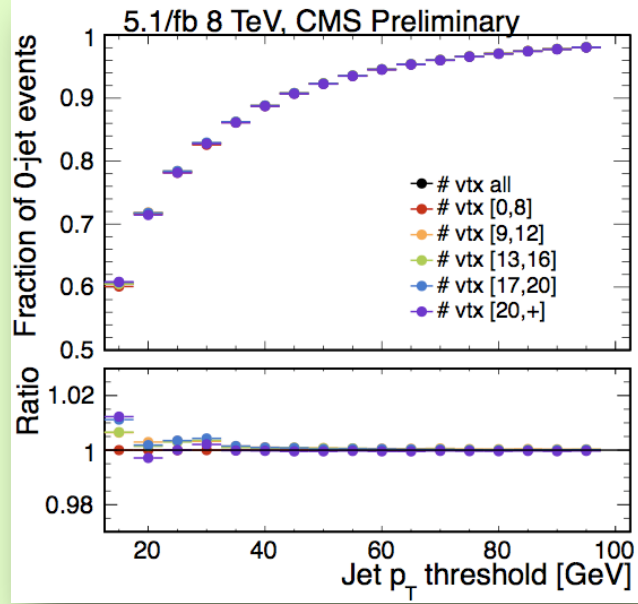


Regaining control

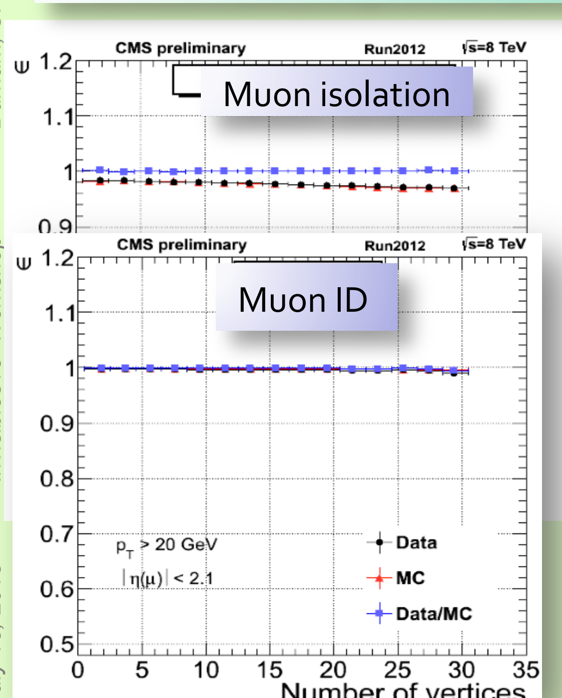
Ca. May-June 2012

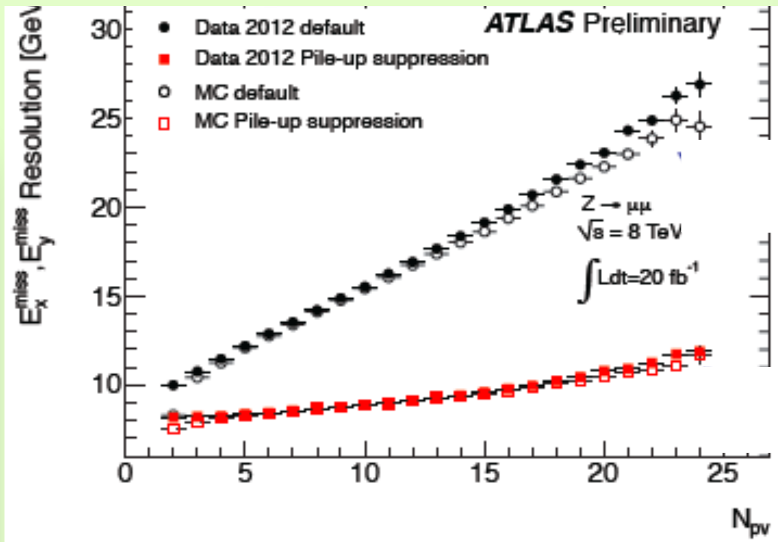




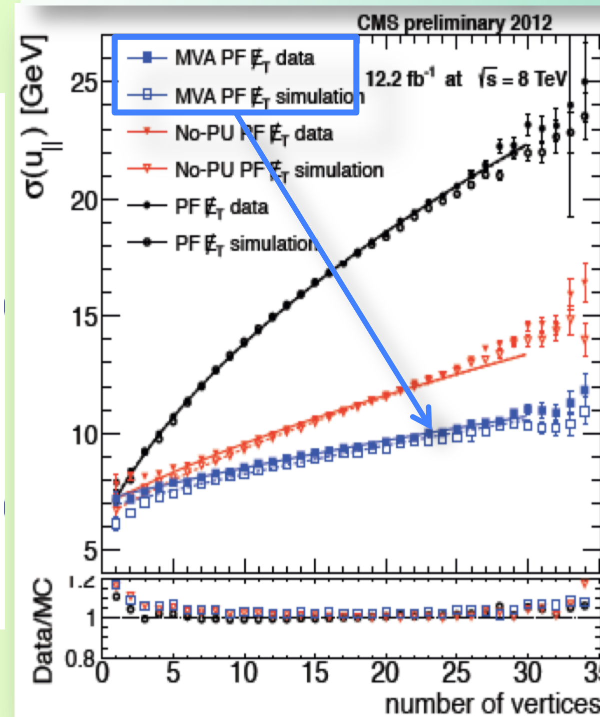


Particle flow , improved ID…



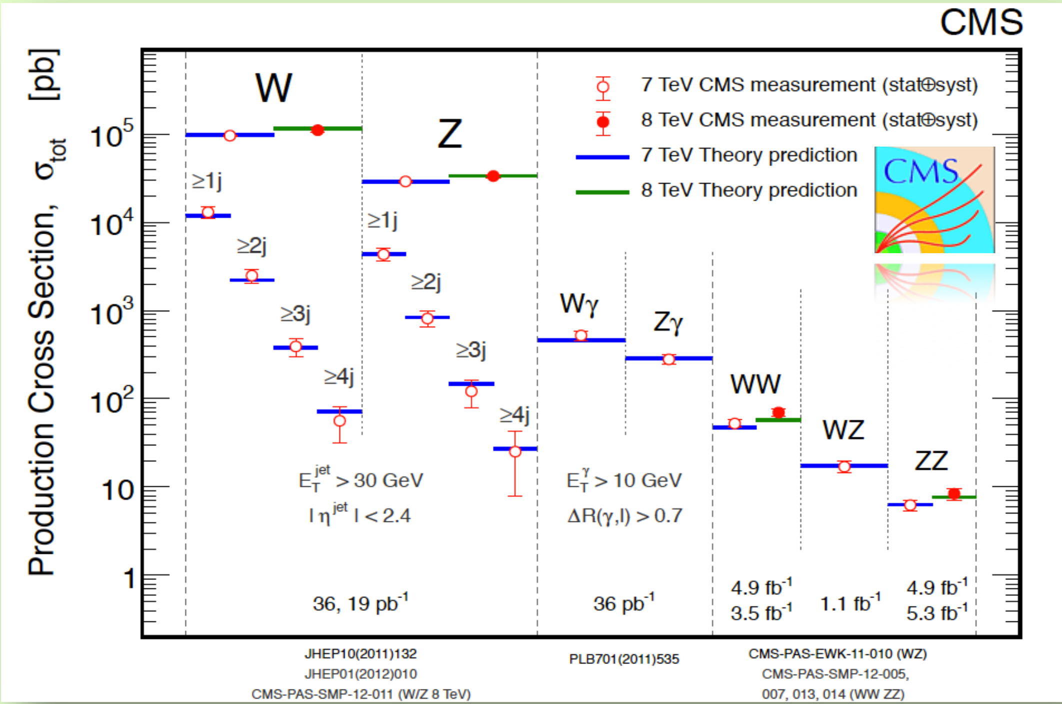


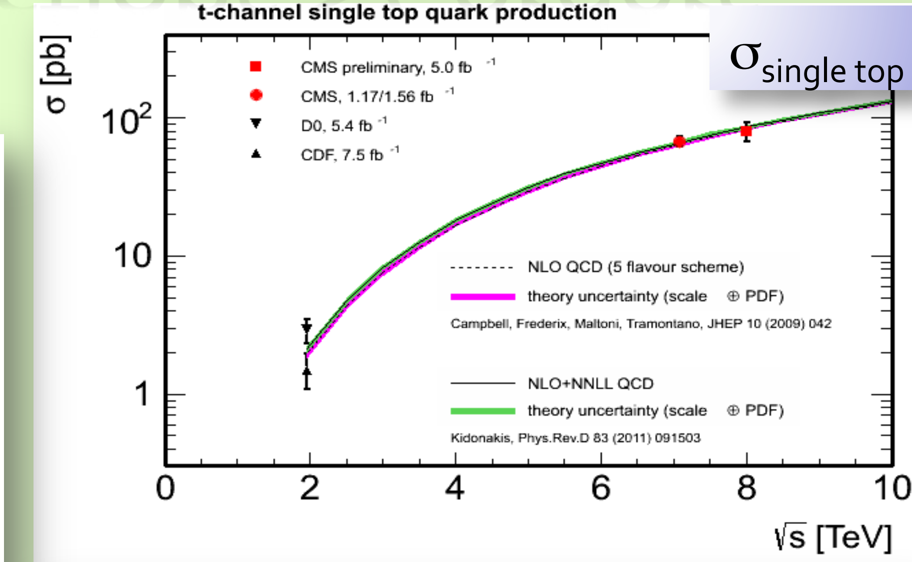
E_T^{miss} : PFlow and MVA regression

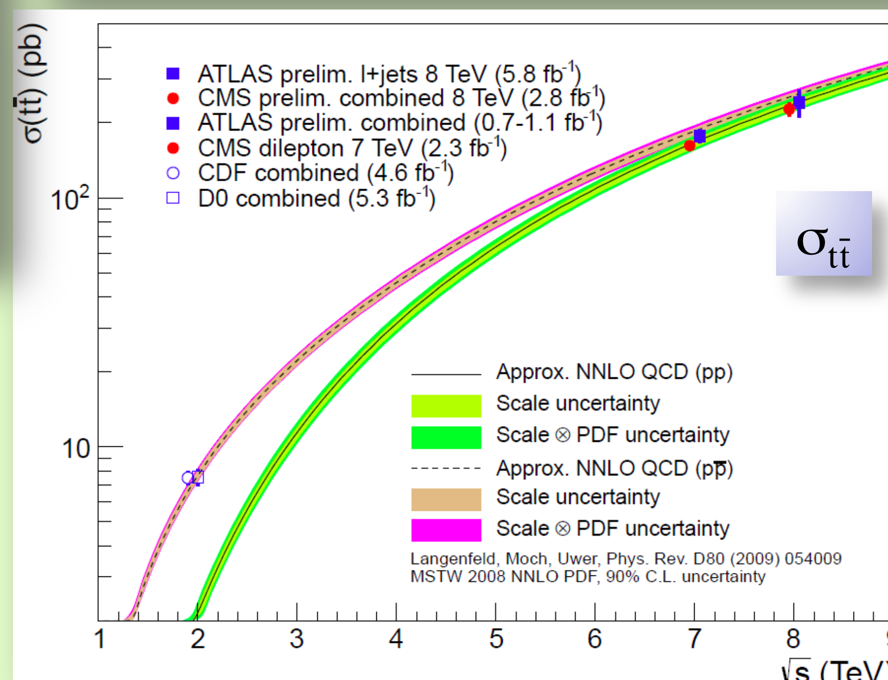


EWK and Top cross sections >4 orders

Electroweak Measurements

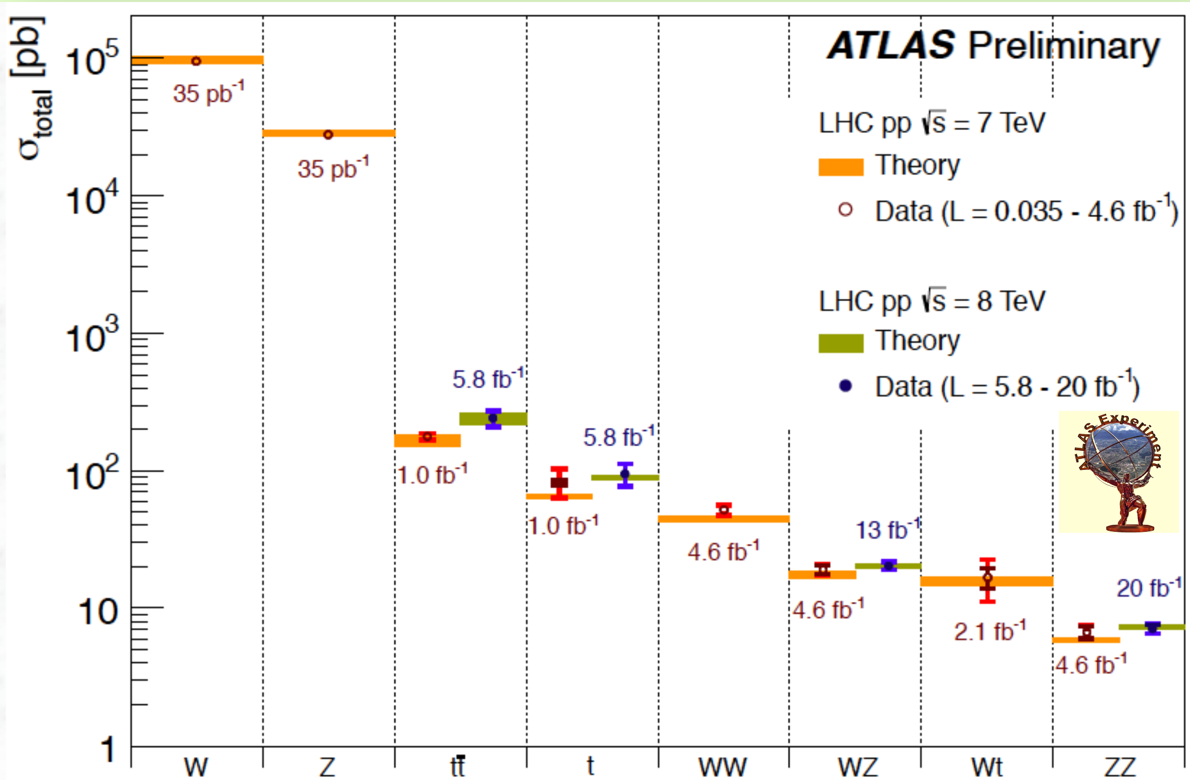


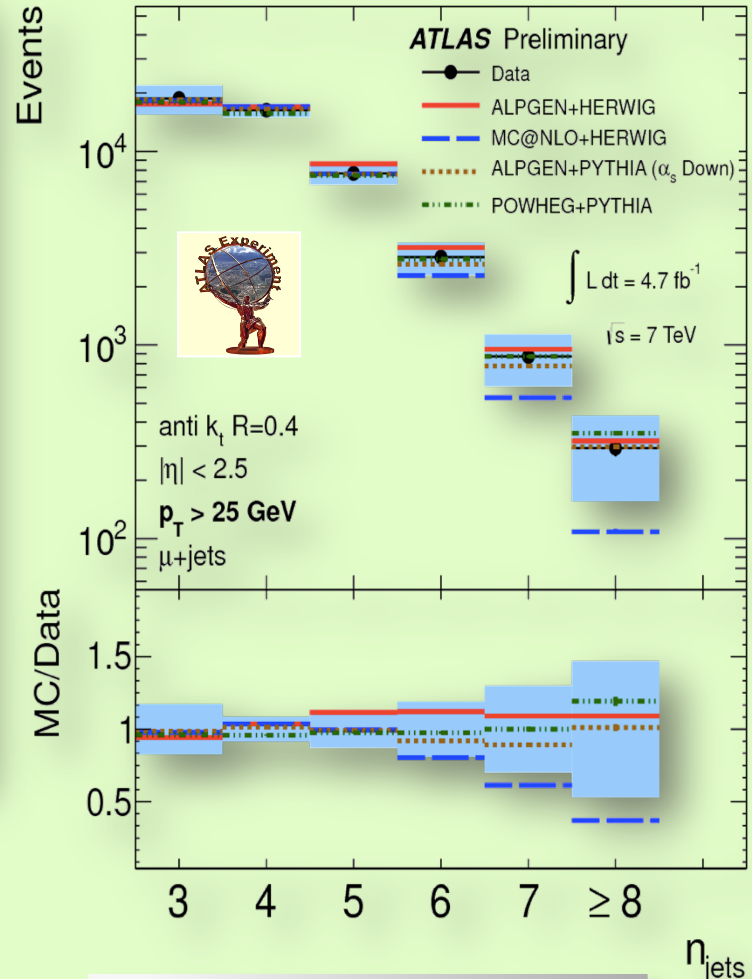




Good understanding of the detector
+ accurate theory predictions
→Precision SM measurements
→Excellent control of backgrounds

Differential cross sections, precision measurements



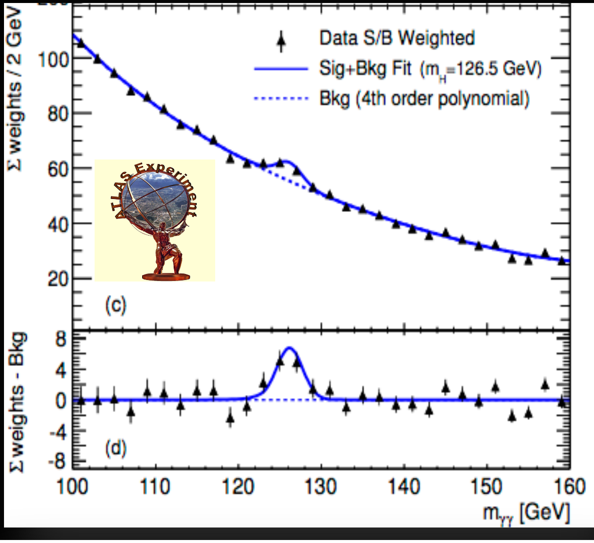


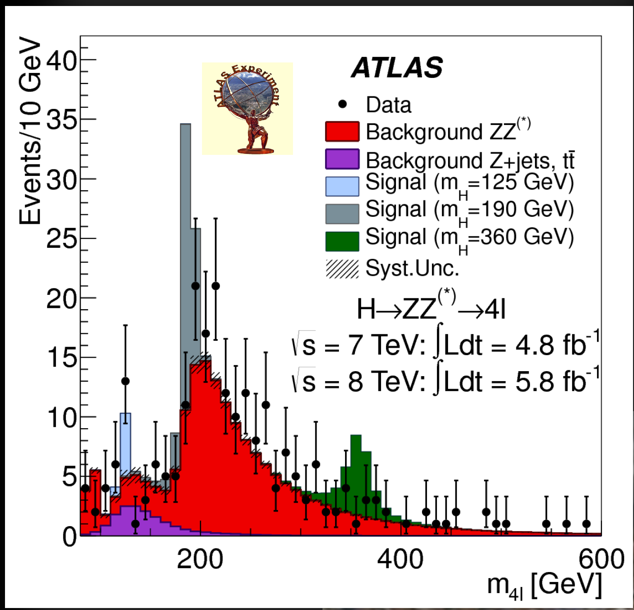
Top Mass Measurements	
Tevatron Combo	173.2 ± 0.87
CMS Combo (2011)	173.2 ± 0.6 ± 0.8
ATLAS L+jets (2011)	172.31 ± 0.23 ± 0.27 (JES) ± 0.67 (bJES) ± 1.35

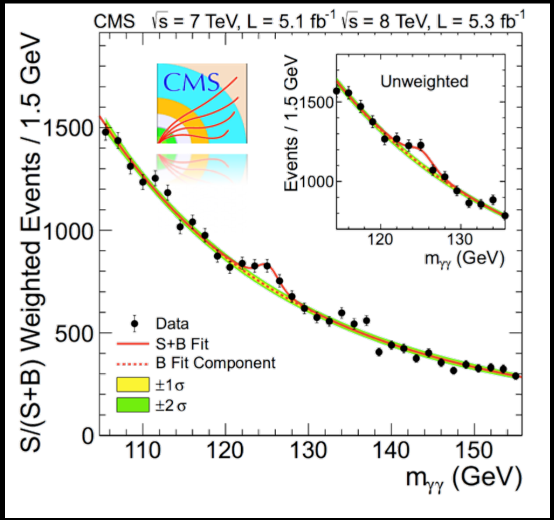
Constrain/tune/test generators and shower matching MCs

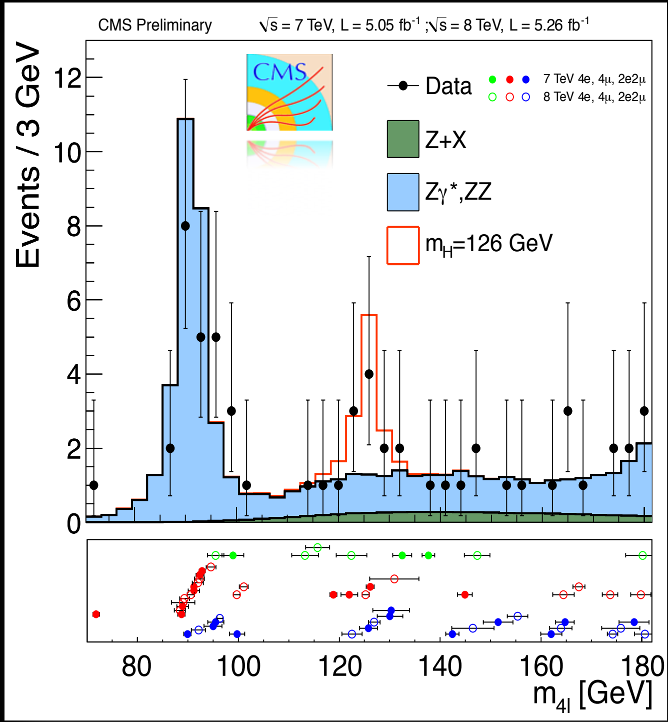
→ July 4th 2012

'Higgs-like' particle found







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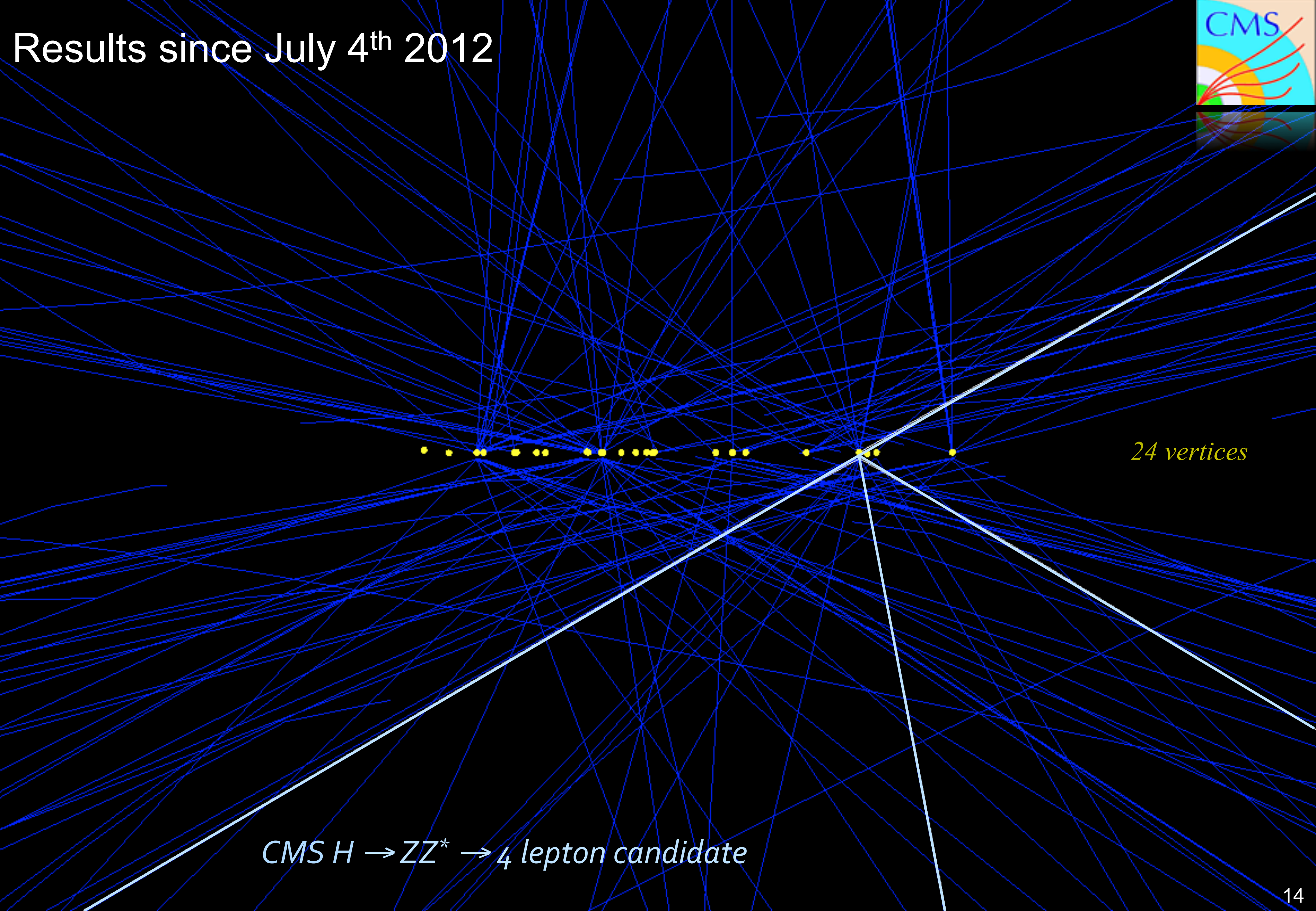
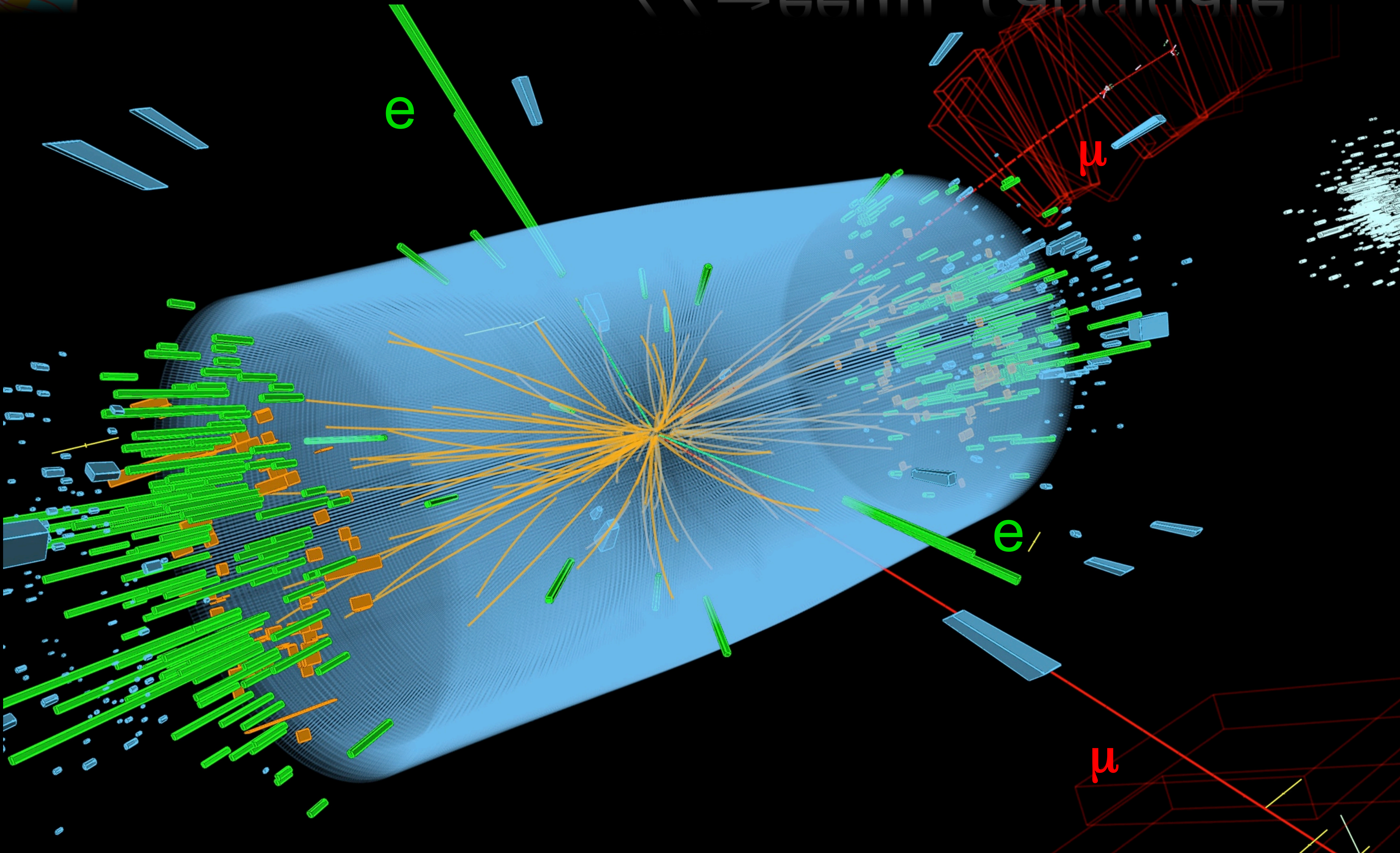
Britain's banking scandal spreads
Volkswagen overtakes the rest
A power struggle at the Vatican
When Lonesome George met Nora
Economist.com
A giant leap for science
Finding the Higgs boson


Science
21 December 2012 | $10
BREAKTHROUGH of the YEAR
The HIGGS BOSON
AAAS

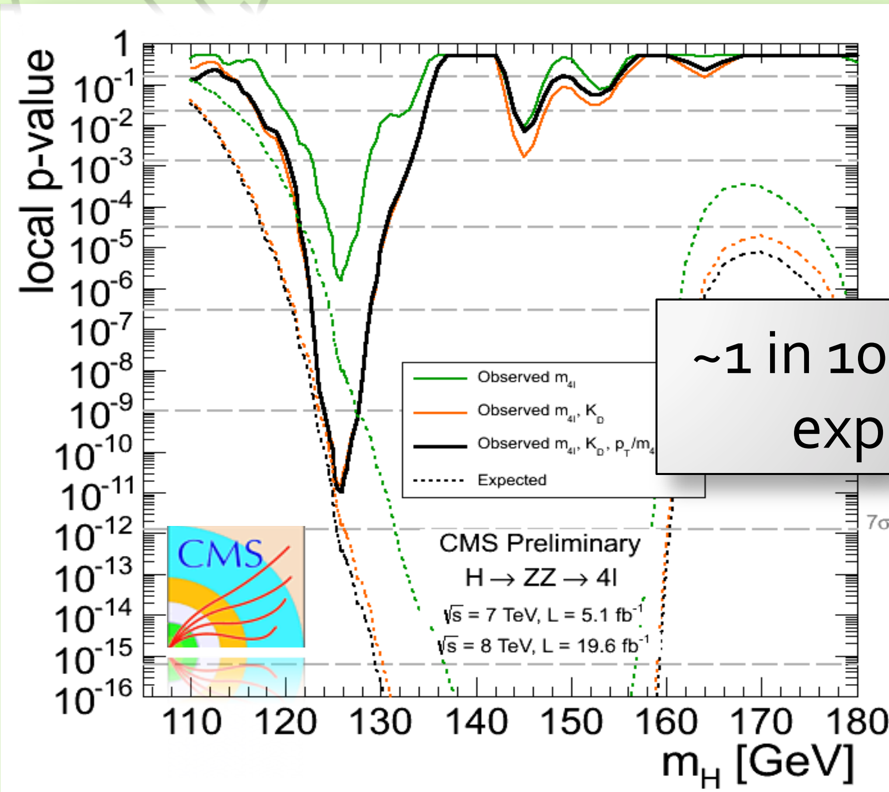
Results since July 4th 2012



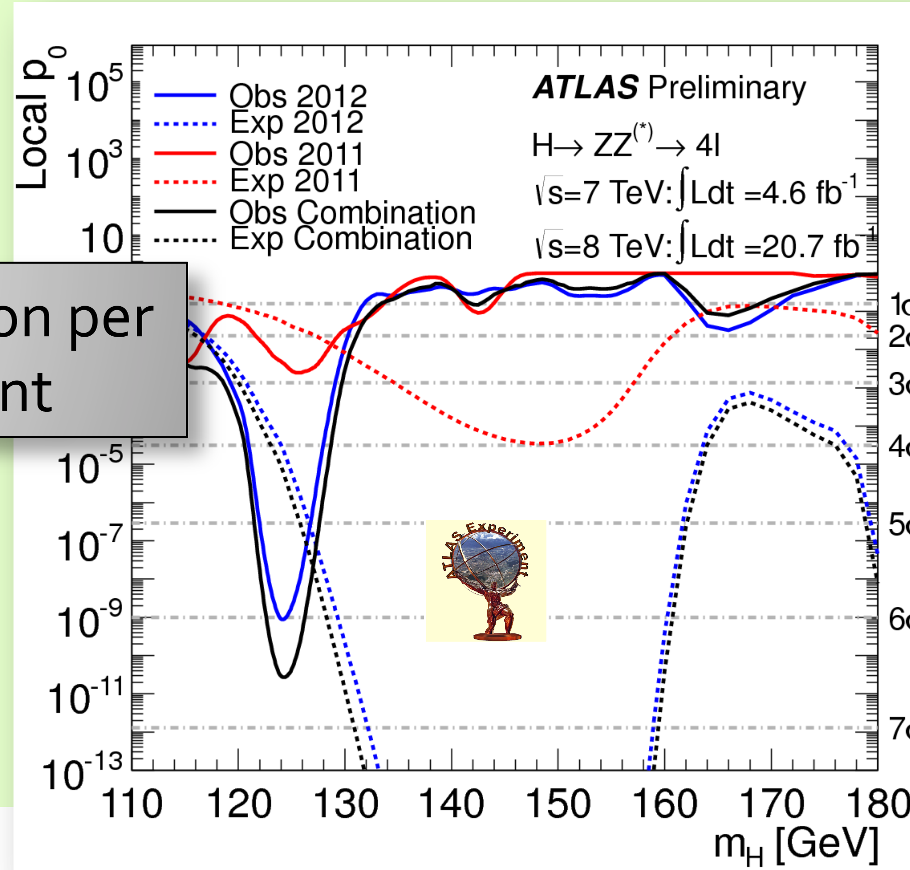
ZZ→eeμμ candidate



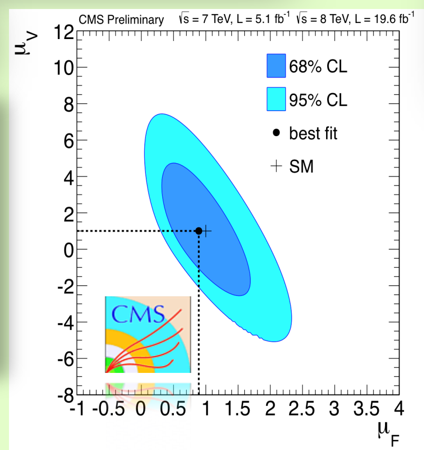
H→ZZ→4 leptons*



~1 in 100 billion per experiment



$125.8 \pm 0.5(stat.) \pm 0.2(syst.)$



6.7 σ (7.1 σ expected)

Signal strength relative to the Standard Model:

$\mu = 0.92 \pm 0.28$

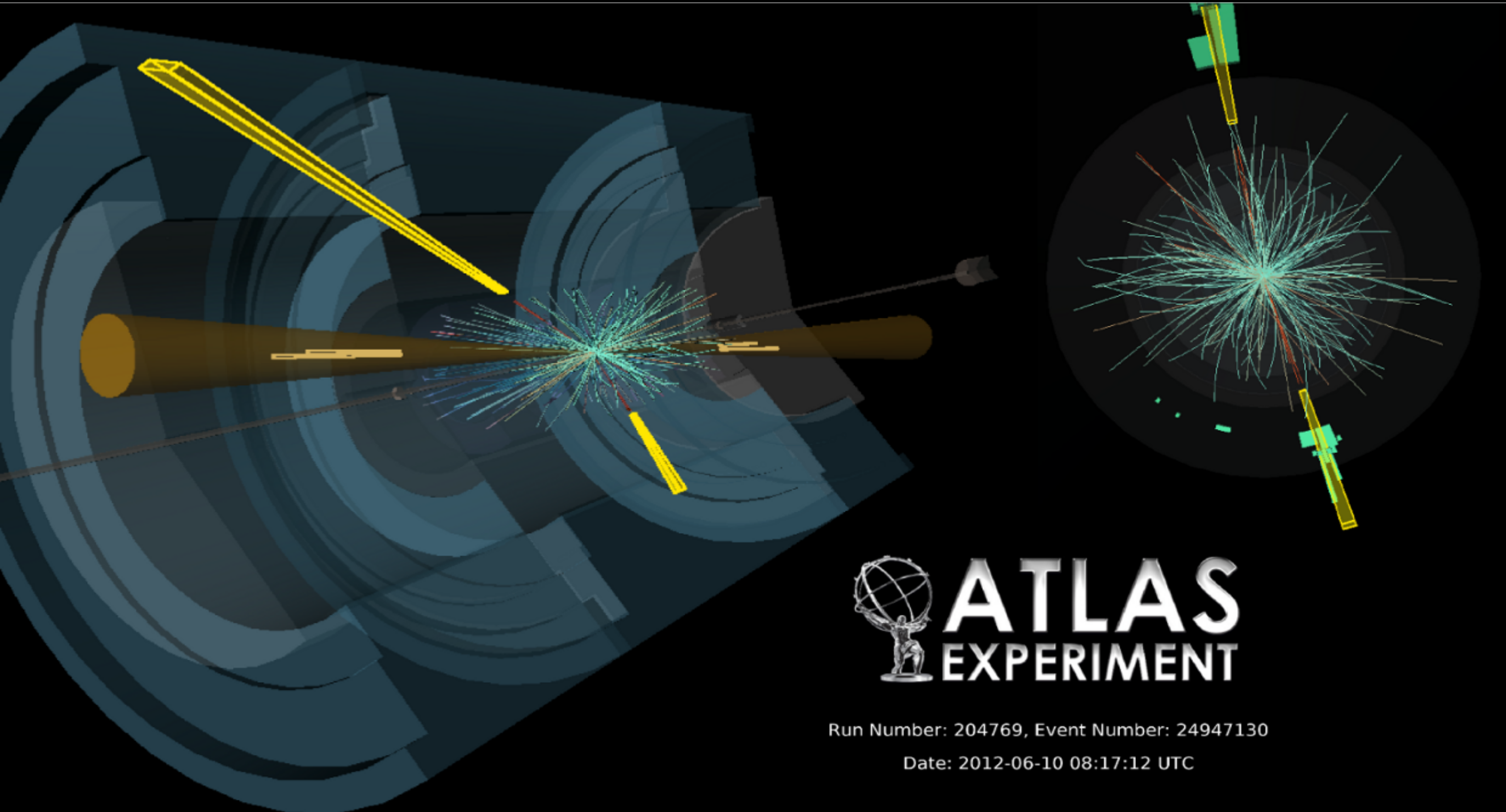
CMS HIG-13-002

6.6σ at 124.3 GeV (expect 4.4σ)

$m_H = 124.3 \pm ^{0.6}_{0.5} \pm ^{0.5}_{0.3}$ **GeV**

$\mu = 1.7 \pm ^{0.5}_{0.4}$

ATLAS-CONF-2013-013

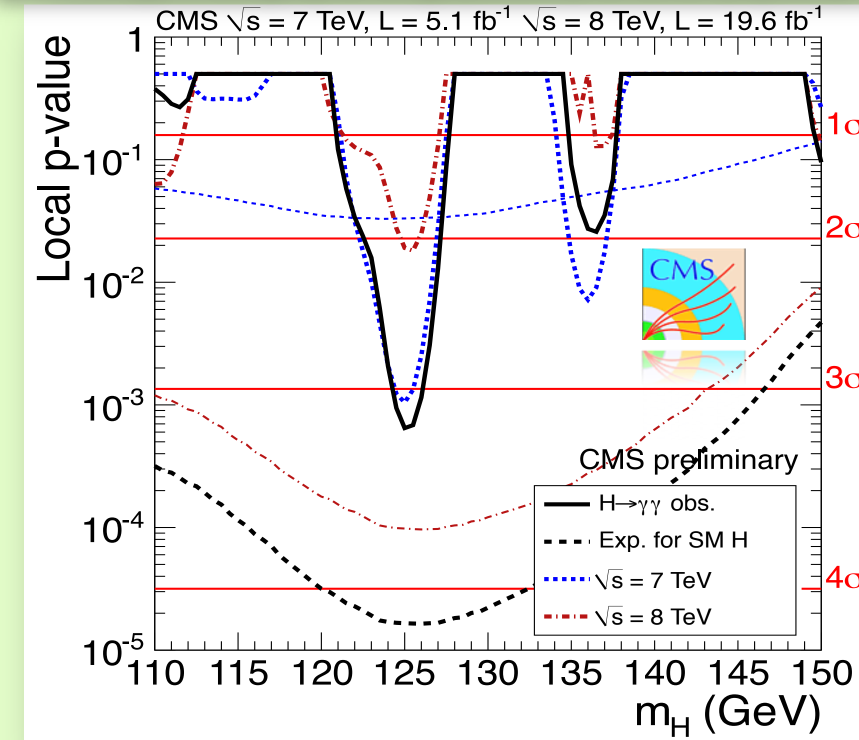


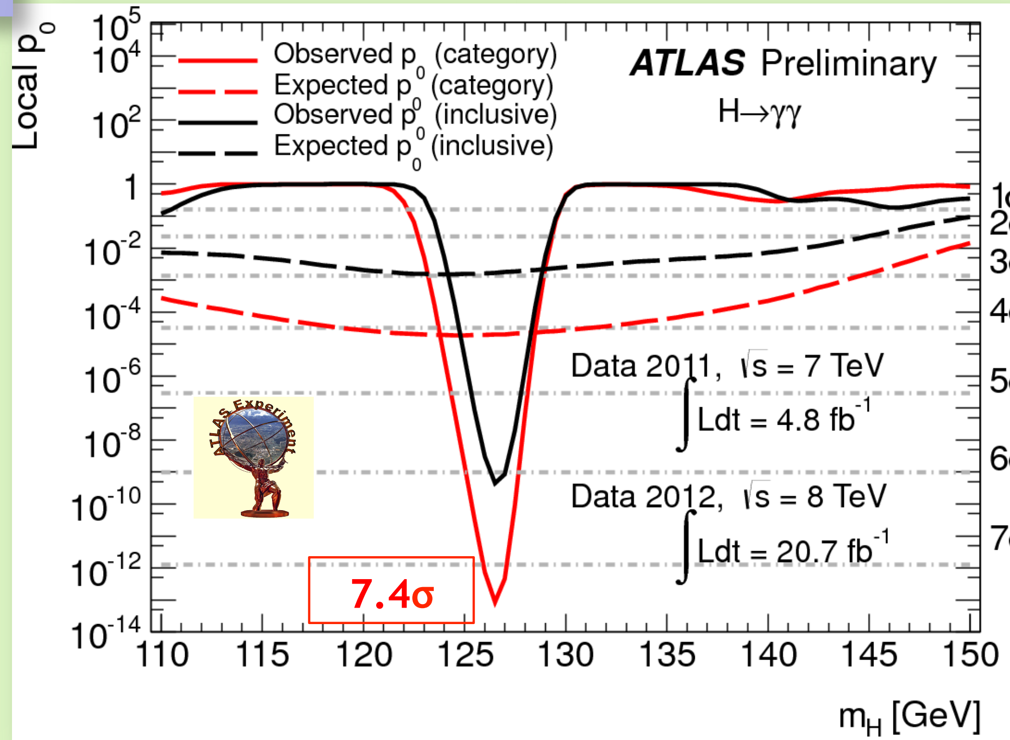
$H \rightarrow \gamma\gamma$ candidate: Vector Boson Fusion (VBF) category (2 jets in forward-backward regions)

H→ γγ

CMS 3.2σ (expect 4.2σ)

m_H = 125.4 ± 0.5 (stat.) ± 0.6 (syst.)





With additional data, the significance decreased relative to 4th of July!!

m_H = 125.4 ± 0.5 (stat.) ± 0.6 (syst.)

7.4σ (expect 4.1σ) 2.3σ from μ=1

m_H = 126.8 ± 0.2(stat) ± 0.7(syst) GeV

$\mu = 1.65 \pm 0.24(\text{stat}) \pm^{0.25}_{0.18}(\text{syst})$

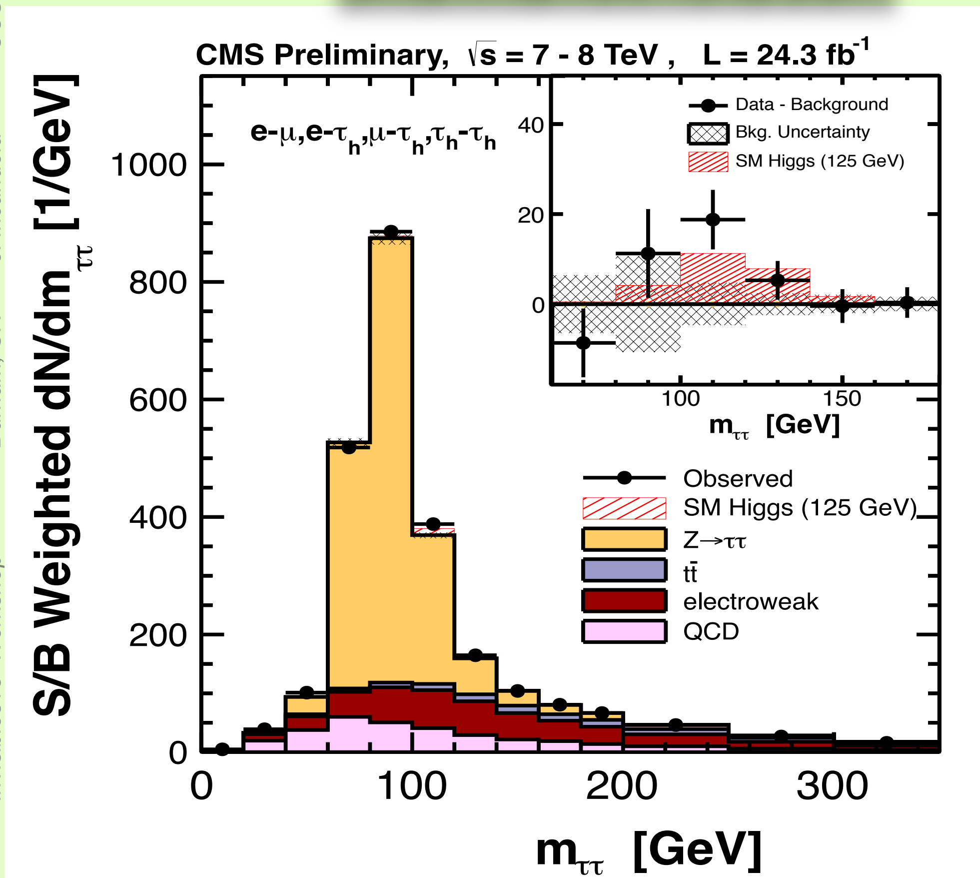
CMS HIG-13-001

ATLAS-CONF-2013-021

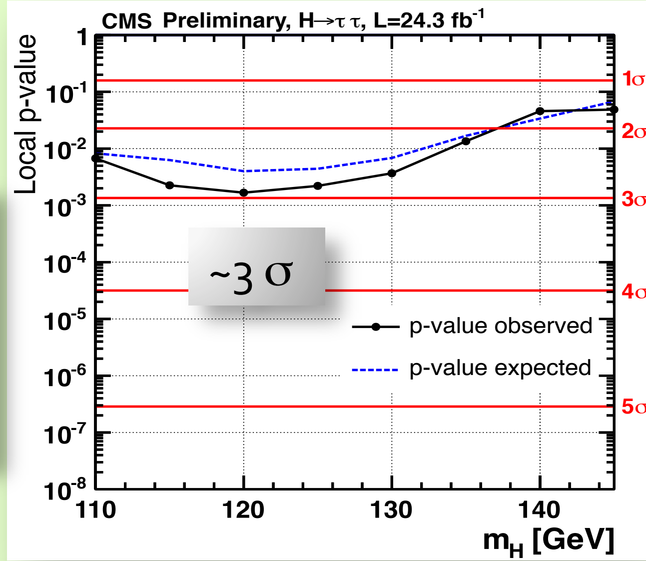
$H \rightarrow \tau\tau$

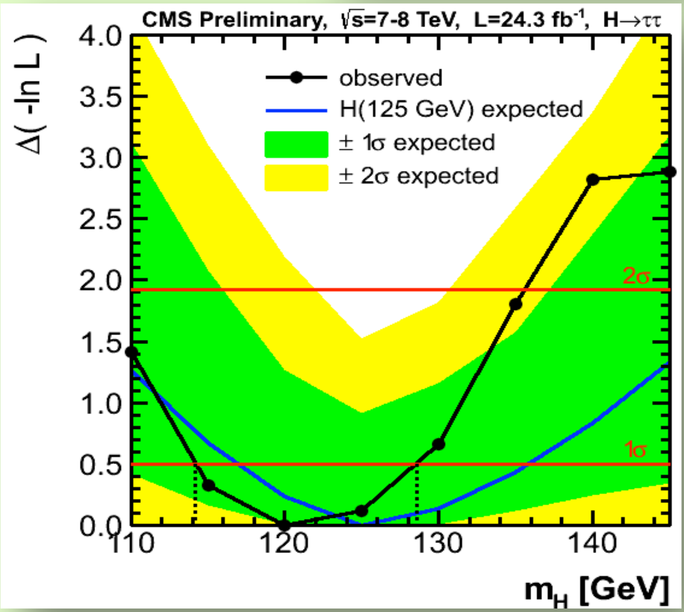
Moriond 2013

$\mu\tau_h, e\tau_h, e\mu, \tau_h\tau_h, \mu\mu$



First strong indication of decay to spin ½ particles



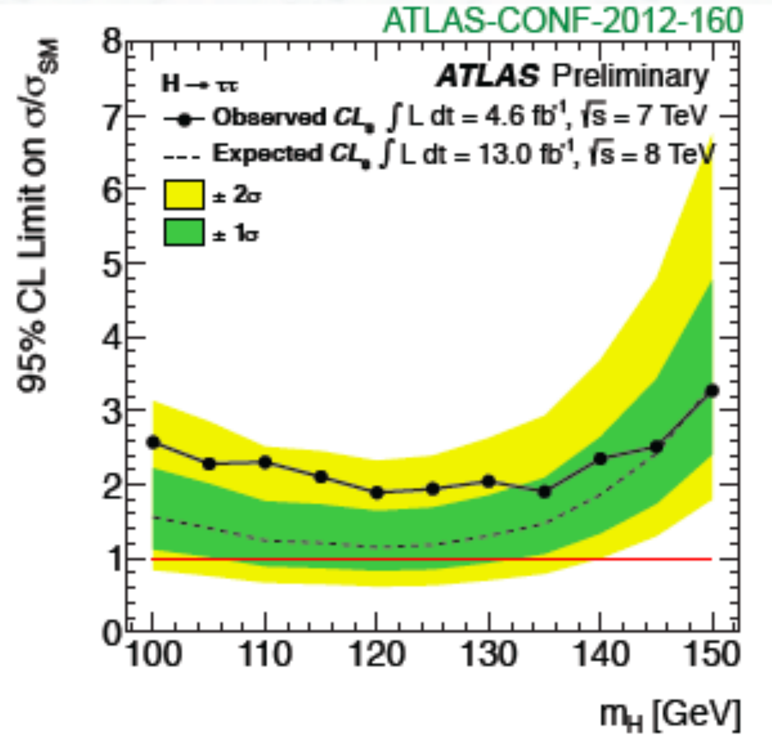


$m = 120^{+9}_{-7}$ (stat+syst) GeV

CMS HIG-13-004

Results on the search for $H \rightarrow \tau\tau$ decays

- Discovery sensitivity for a signal not yet reached
- → 95% C.L. limits on cross section
  (normalized to SM cross sections)



m_H = 125 GeV:

Observed 95% CL: 1.9 σ_{SM}
Expected (no Higgs): 1.2 σ_{SM}

Fitted signal strength
(all sub-channels):

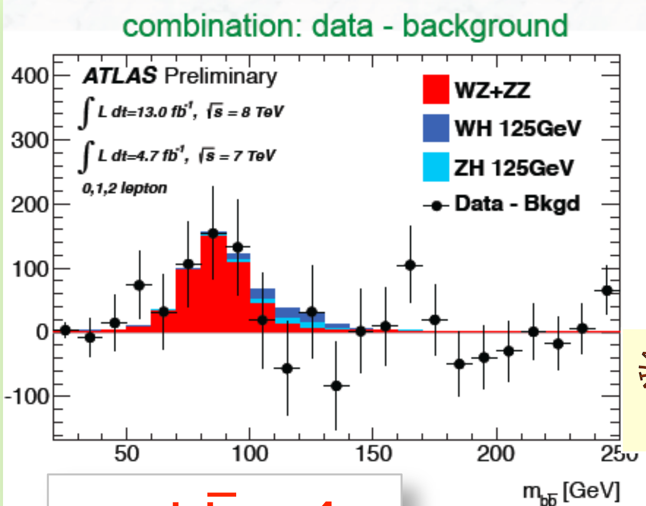
$\mu = 0.7 \pm 0.7$

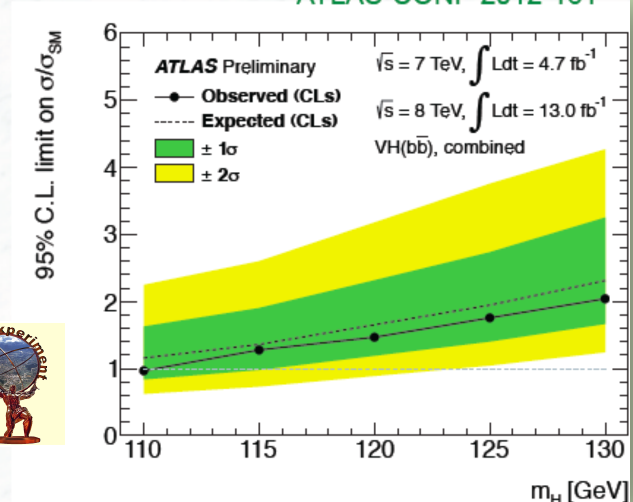
Updated analysis, including the full data sample, expected soon

ATLAS: μ_H = -0.4 ± 0.7 (stat) ± 0.8 (sys)

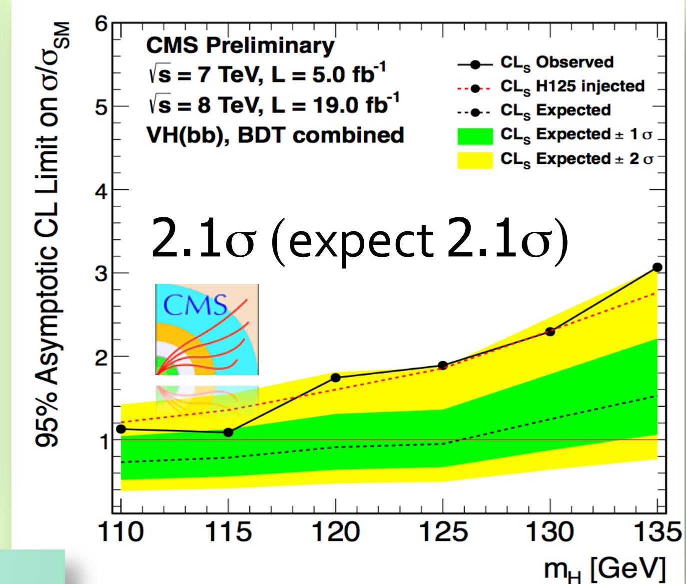
$H \rightarrow b\bar{b}$

ATLAS-CONF-2012-161

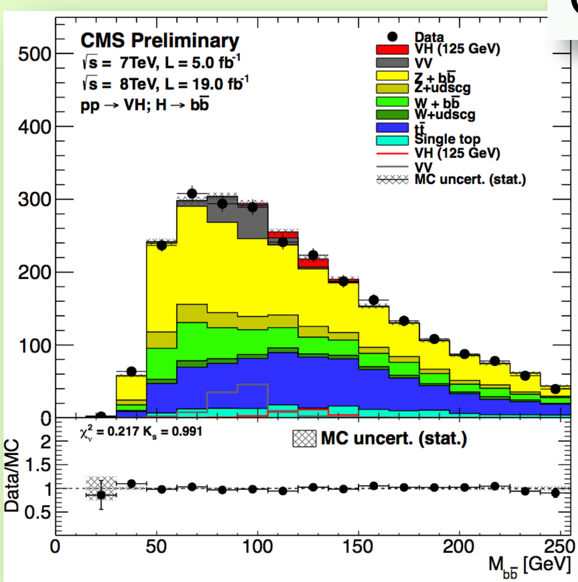


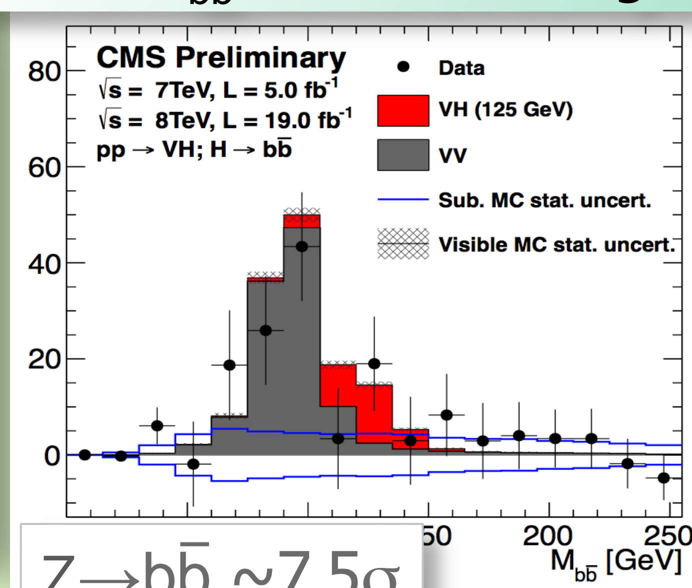


$Z \rightarrow b\bar{b}$ ~4σ

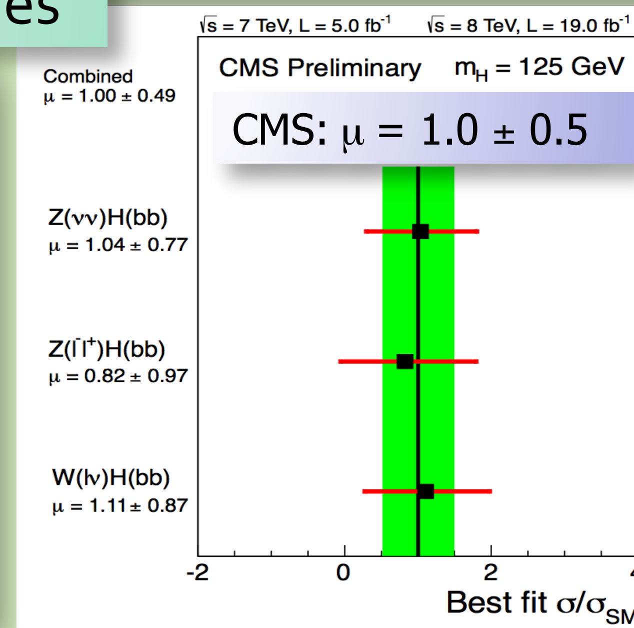


CMS: $M_{b\bar{b}}$ comb. all categories





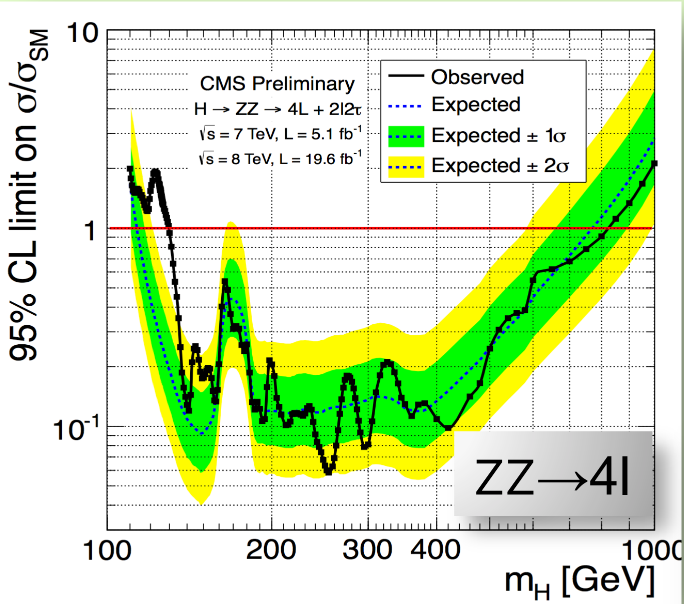
$Z \rightarrow b\bar{b}$ ~7.5σ

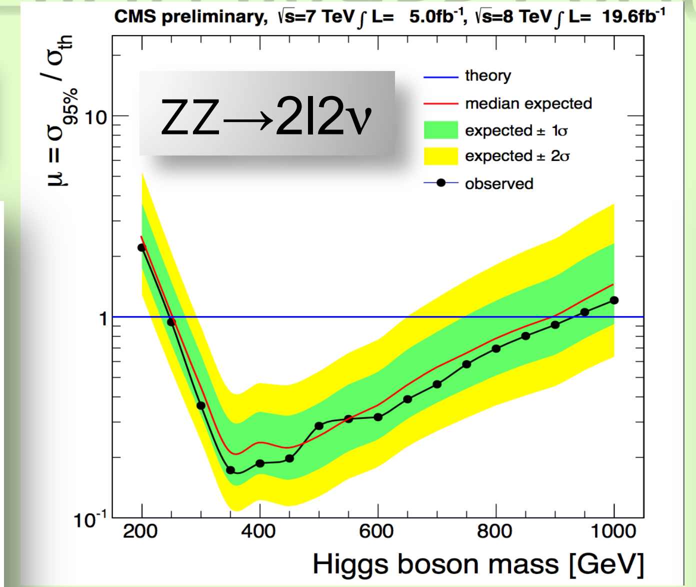


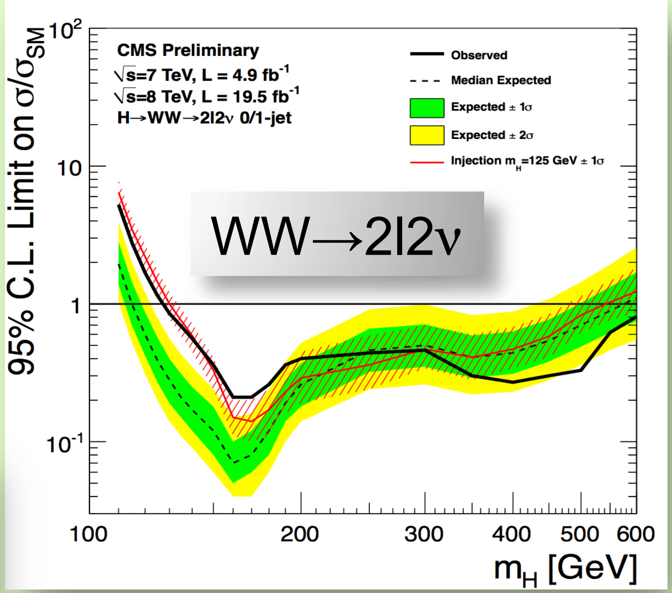
CMS: μ = 1.0 ± 0.5

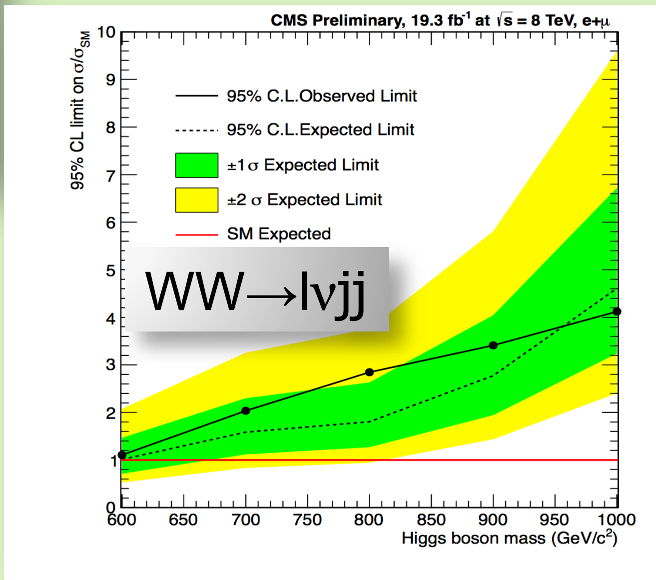
High Mass Higgs Searches

Sensitivity to ~ 1 TeV





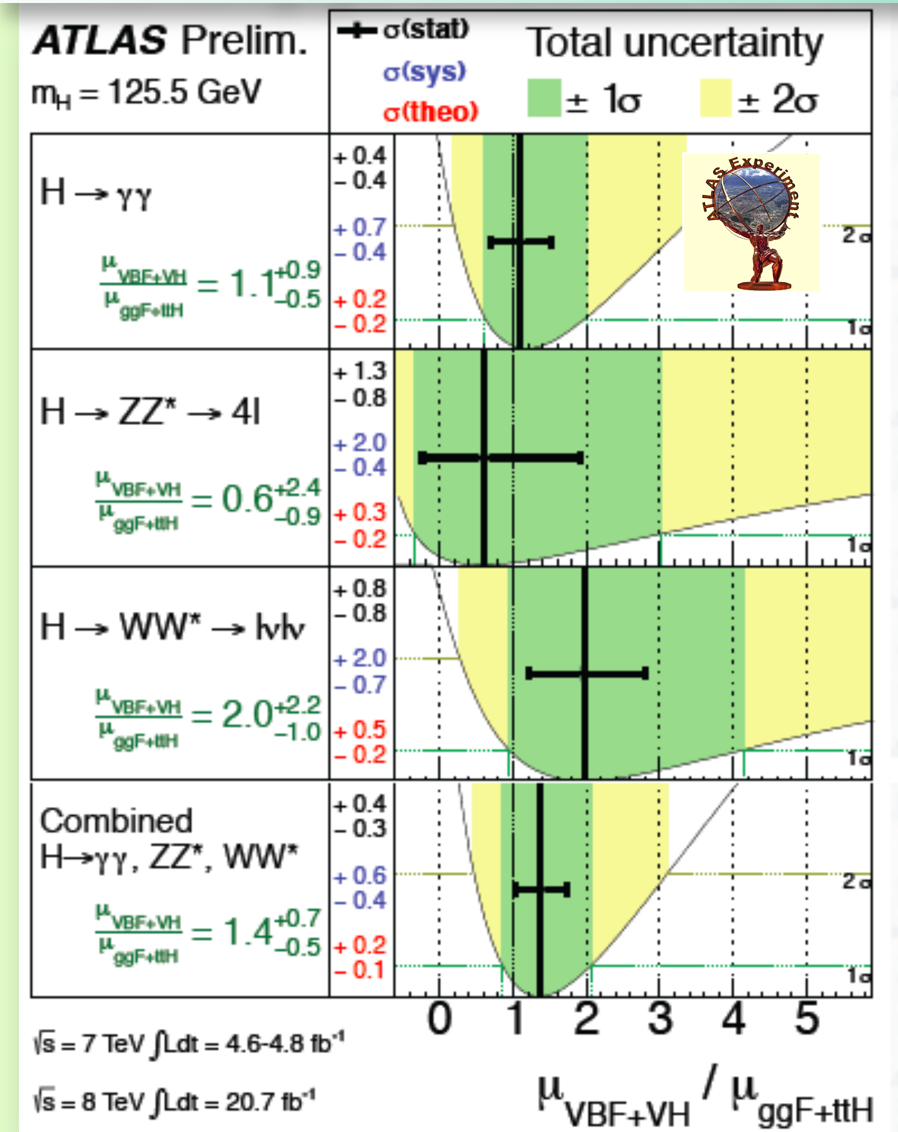




Interpretation of data in EW-singlet models and LHC XS WG benchmark models:
CMS-PAS-HIG-13-008
CMS-PAS-HIG-13-014

More …

ATLAS: 3.3σ Evidence for VBF



$$\mu_{VBF}/\mu_{ggF+ttH} = 1.4^{+0.4}_{-0.3}\,(\text{stat})\,^{+0.6}_{-0.4}\,(\text{sys})$$

arXiv: 1307.1427

CMS: 3.4σ Evidence for H→ $f\bar{f}$

Decay	Expected	Observed
ZZ	7.1 σ	6.7 σ
γγ	3.9 σ	3.2 σ
WW	5.3 σ	3.9 σ
bb	2.2 σ	2.1 σ
ττ	2.6 σ	2.8 σ

bb + ττ combined: 3.4 σ

m_H = 125.7

$b\bar{b}$: VH ⊕ VBF
WW: ggF⊕ VH⊕ VBF

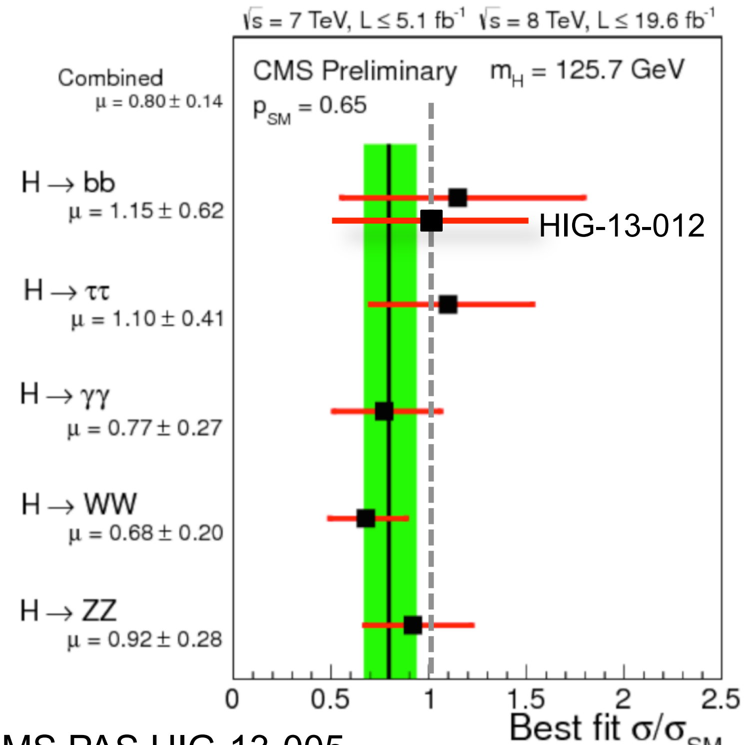
CMS-PAS-HIG-13-005

σ/σ_{SM} and Mass ($\gamma\gamma \oplus ZZ$)

CERN April 15, 2013

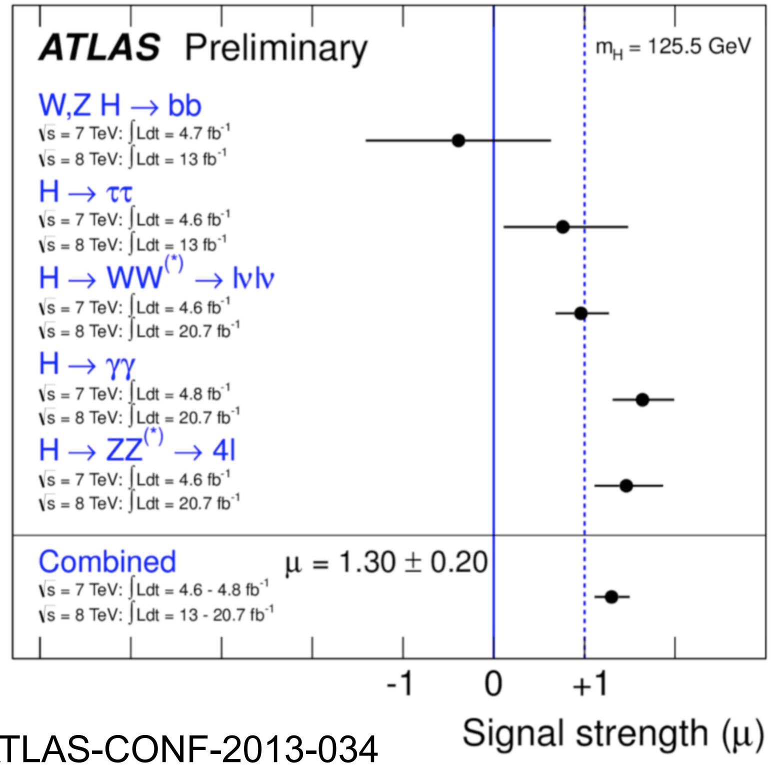
Spin tests, couplings also show consistency with Standard Model

$\mu = 0.80 \pm 0.14$



CMS PAS HIG-13-005

$\mu = 1.30 \pm 0.20$



ATLAS-CONF-2013-034

$m = 125.7 \pm 0.3^{(stat)} \pm 0.3^{(syst)}$ GeV

$m = 125.5 \pm 0.2\,^{+0.5}_{-0.6}$ GeV

All tests favor 0^{++}

- Both ATLAS and CMS strongly prefer $J^{PC} = 0^{++}$ over the alternatives
  - Pseudoscalar 0^{-+} and tensor 2^{++} hypotheses have been excluded at >3σ level by each experiment

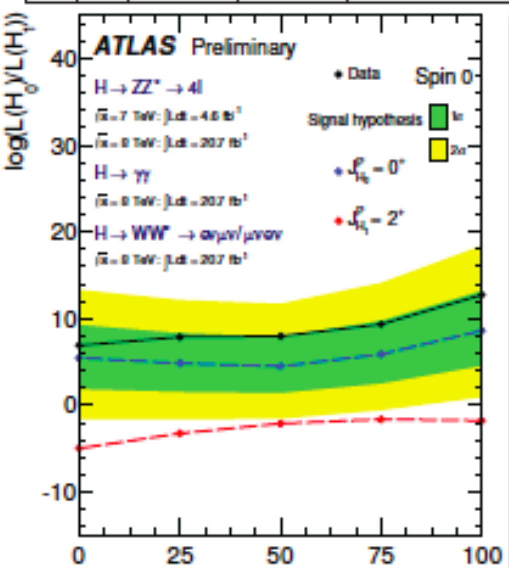
ATLAS-CONF-2013-013

		BDT analysis			
		tested J^P for an assumed 0^+		tested 0^+ for an assumed J^P	CL_s
		expected	observed	observed*	
0^-	p_0	0.0037	0.015	0.31	0.022
1^+	p_0	0.0016	0.001	0.55	0.002
1^-	p_0	0.0038	0.051	0.15	0.060
2^+_m	p_0	0.092	0.079	0.53	0.168
2^-	p_0	0.0053	0.25	0.034	0.258

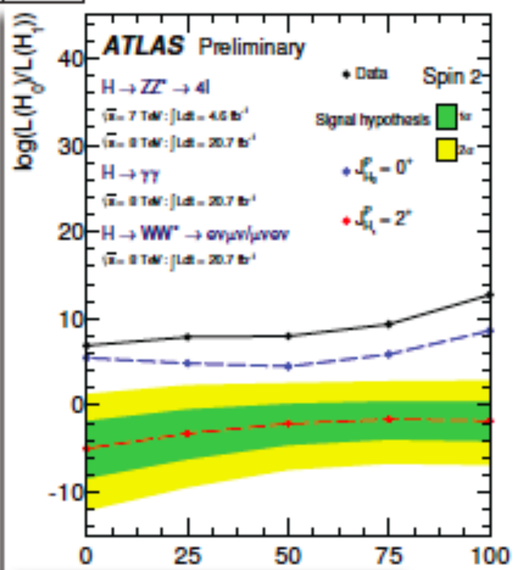
H(ZZ) alone

CMS PAS HIG-13-002

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

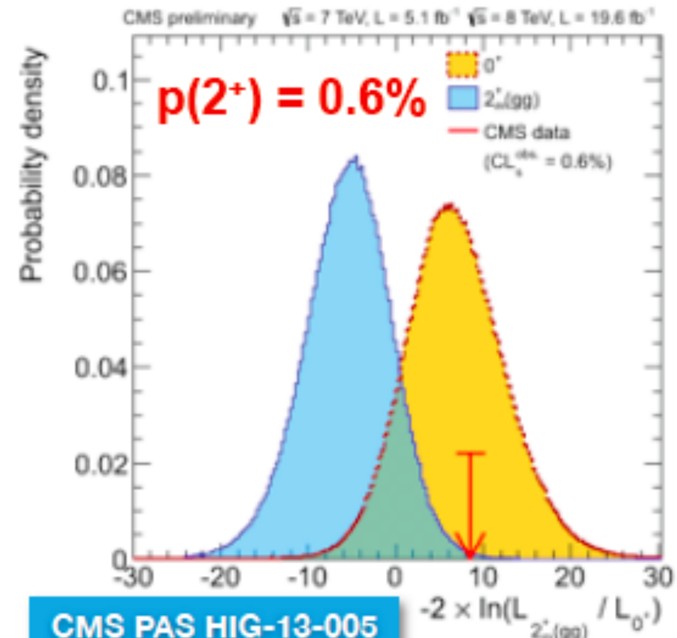


$p(2^+) = (0.2\text{-}4.0) \times 10^{-4}$



ATLAS-CONF-2013-040

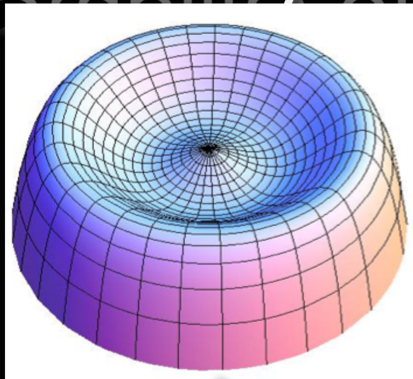
Combination

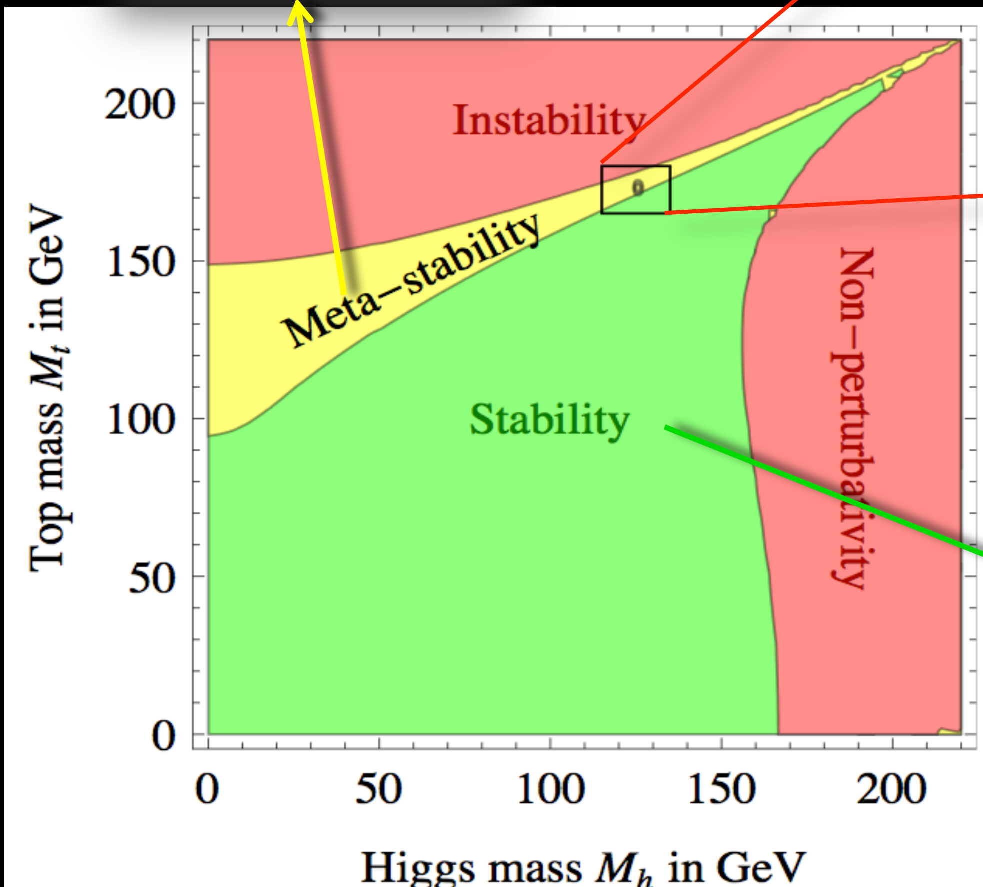


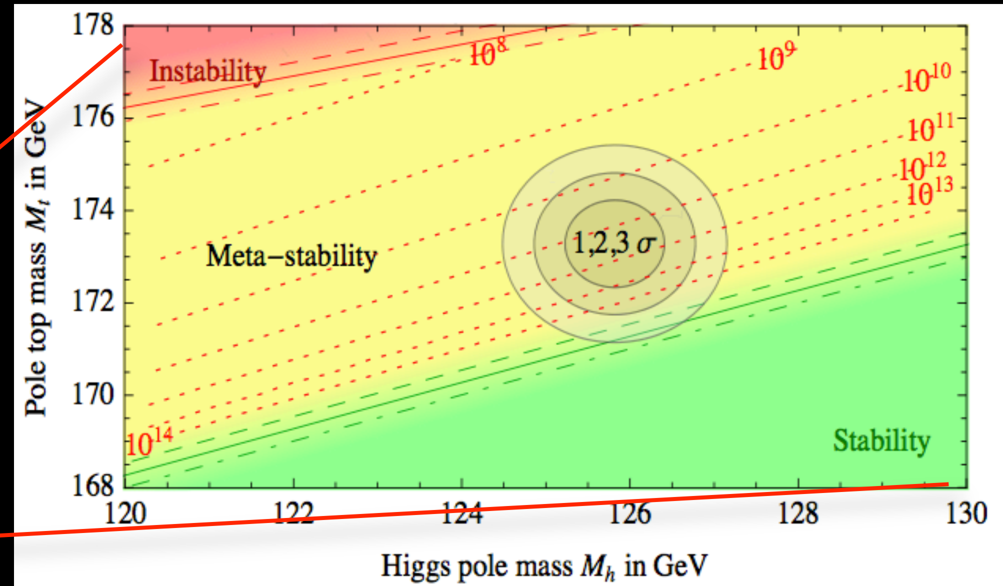
CMS PAS HIG-13-005

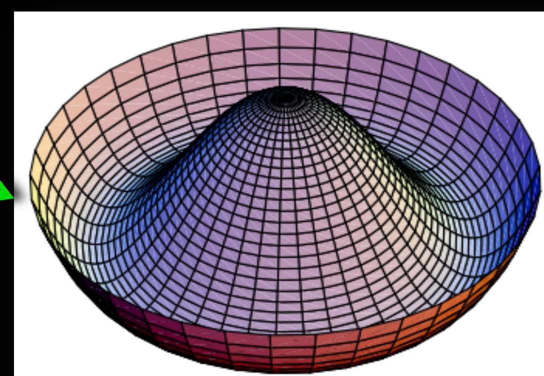
A big news week!

Stability of the universe in the Standard Model







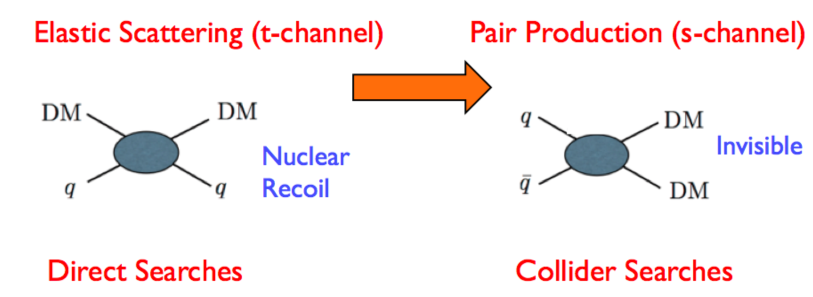


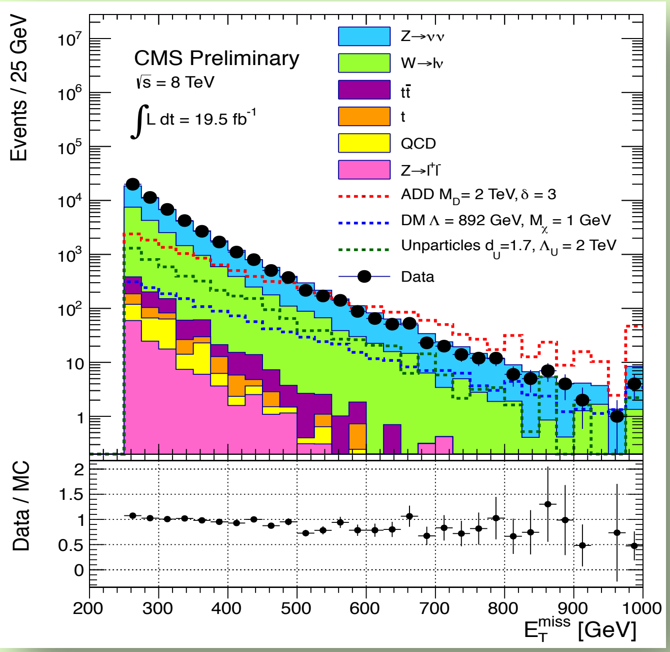
A. Strumia, Moriond EWK 2013

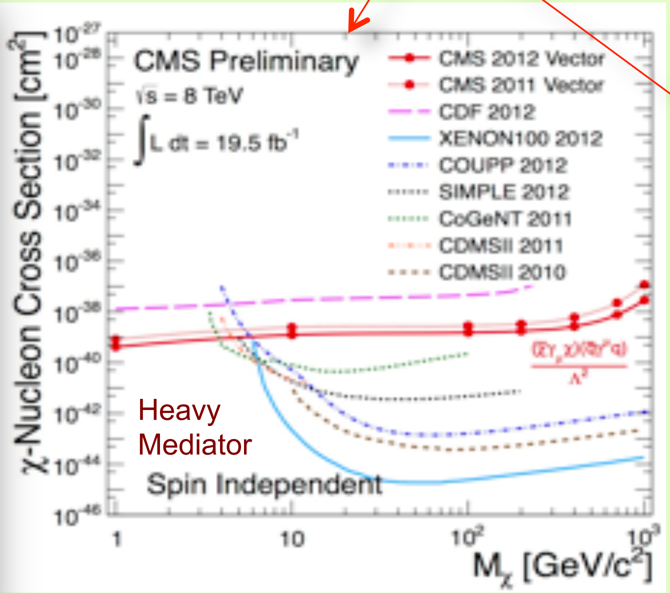
Other searches

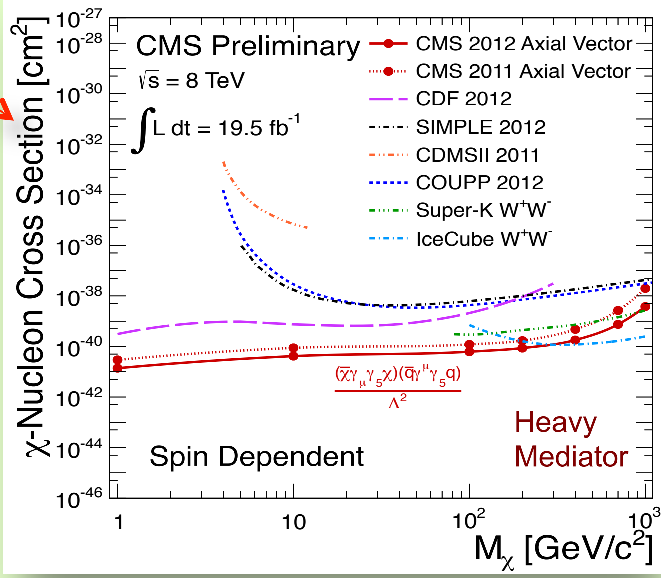
Dark matter

- Using monojets and mono-photons
  - Stringent DM limits for heavy mediators





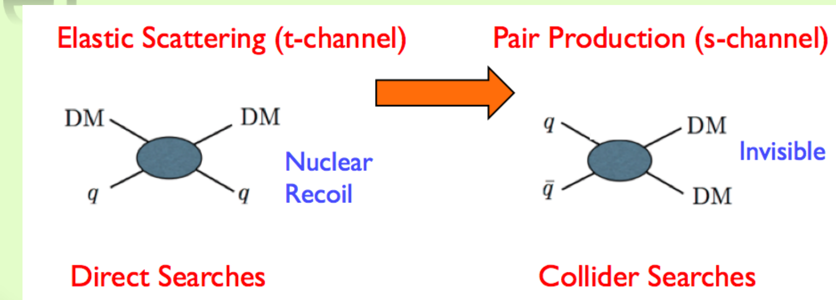


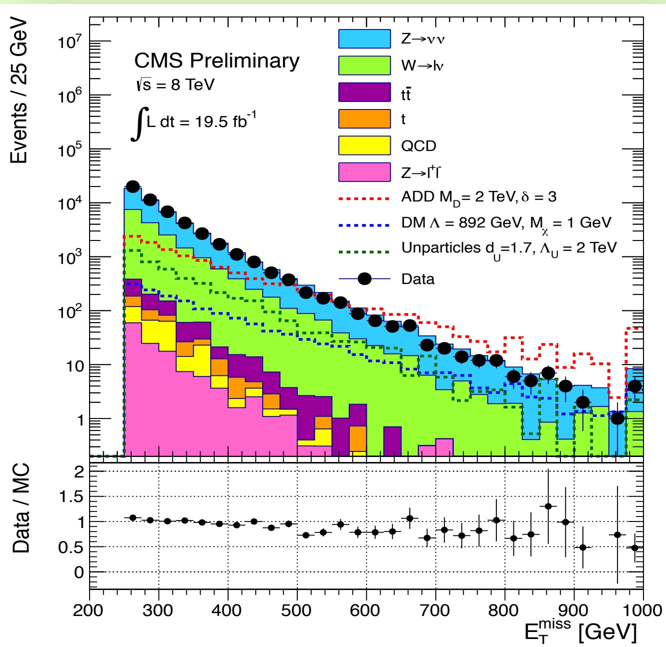


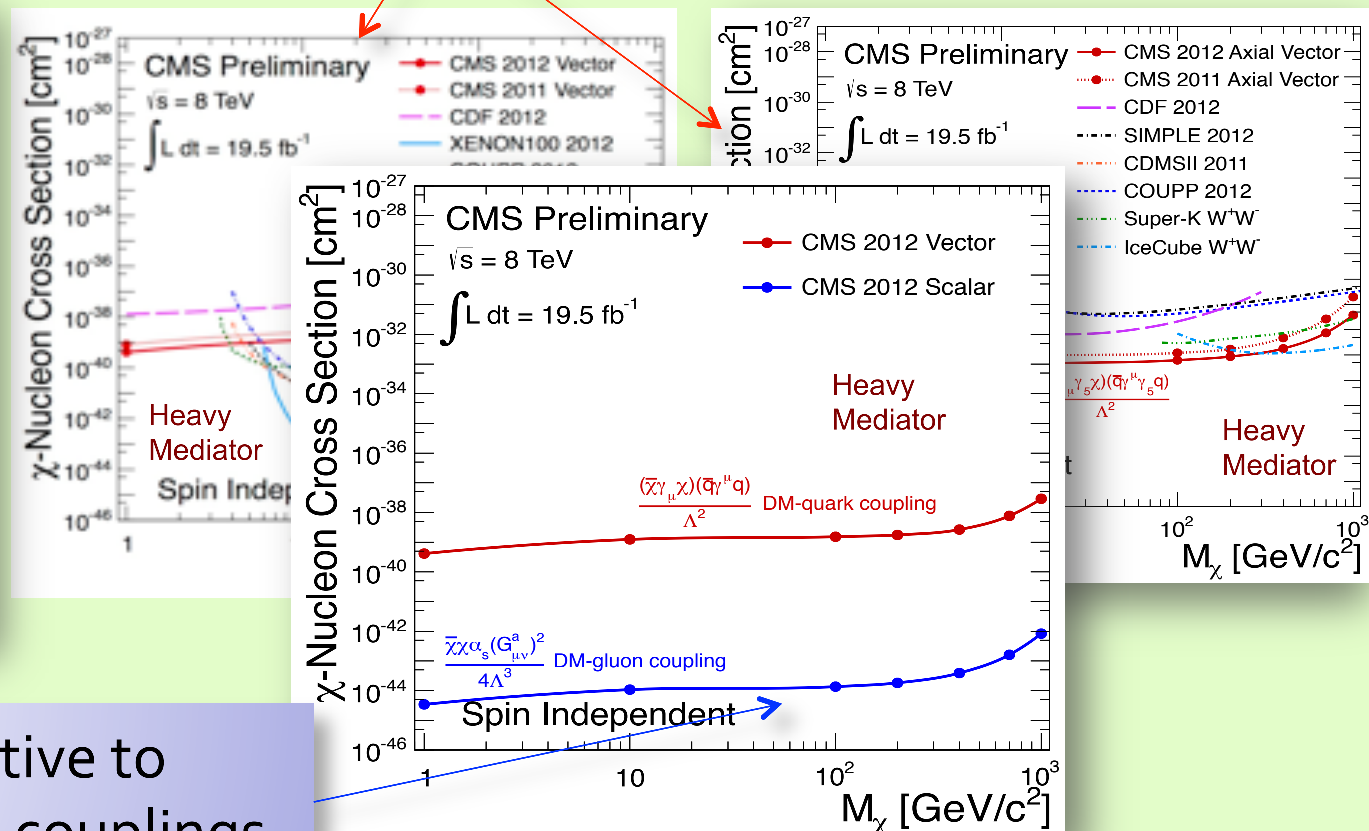
CMS-PAS-EXO-12-048

Dark matter

- Using monojets and mono-photons
  - Stringent DM limits for heavy mediators







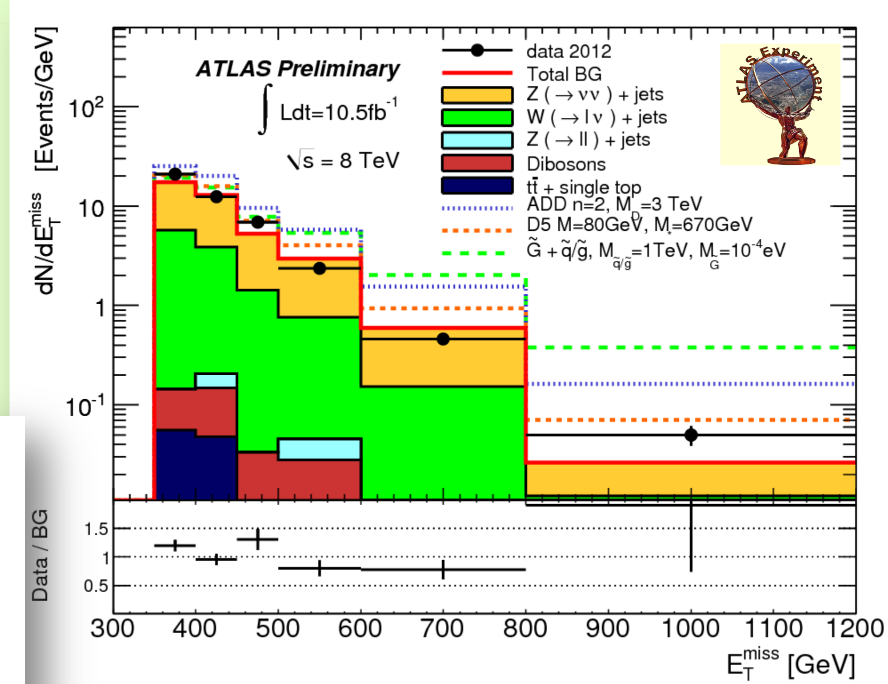
- Also sensitive to DM-gluon couplings

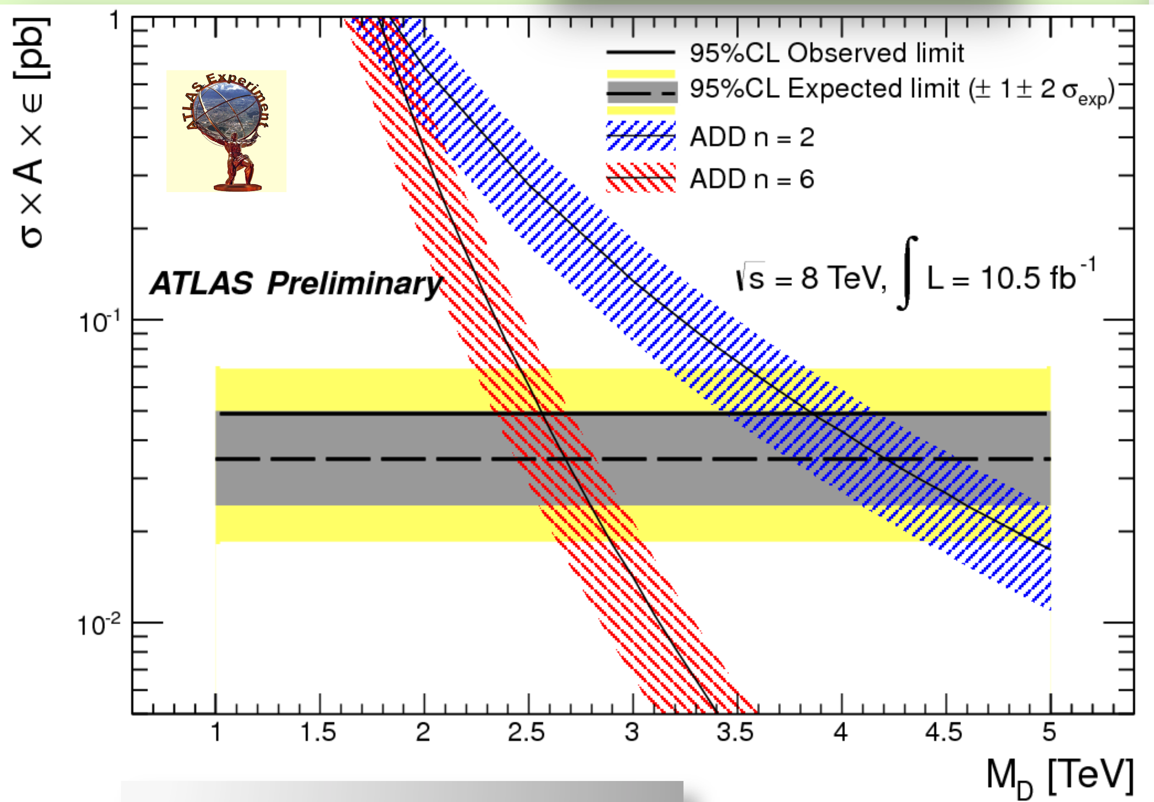
CMS-PAS-EXO-12-048

Extra dimensions

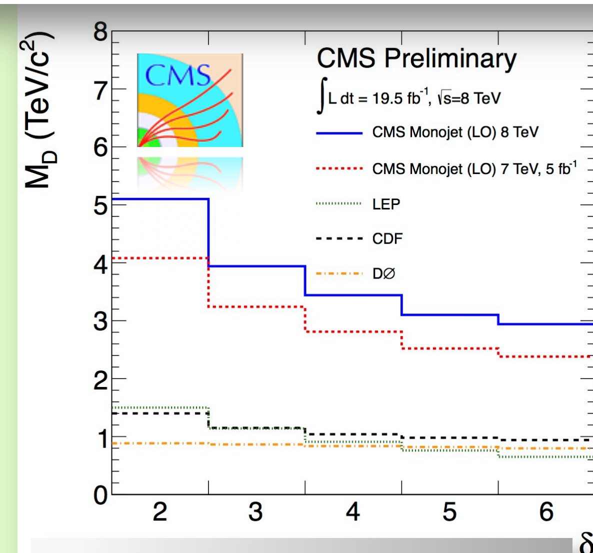
- Using monojets and mono-photons
  - Look for evidence of KK Gravitons
    - ADD Extra Dimensions

$$M_{Pl}^2 \sim M_D^{2+n} R^n$$





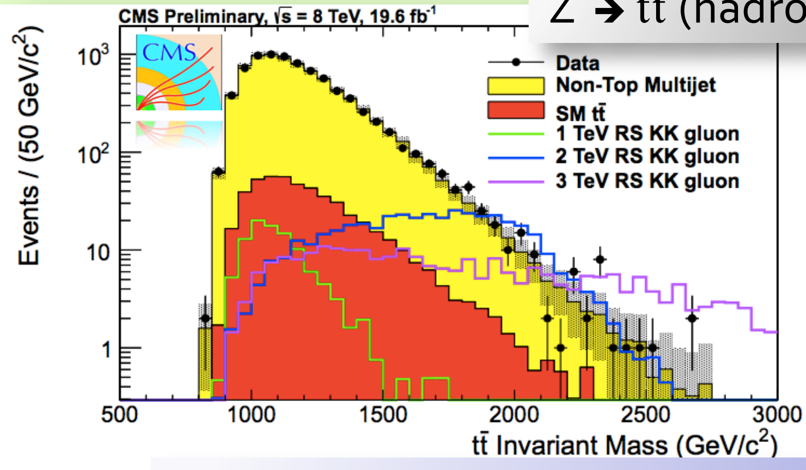
ATLAS-CONF-2012-147



CMS-PAS-EXO-12-048

Heavy Resonances

Z' ➔ $t\bar{t}$ (hadronic)



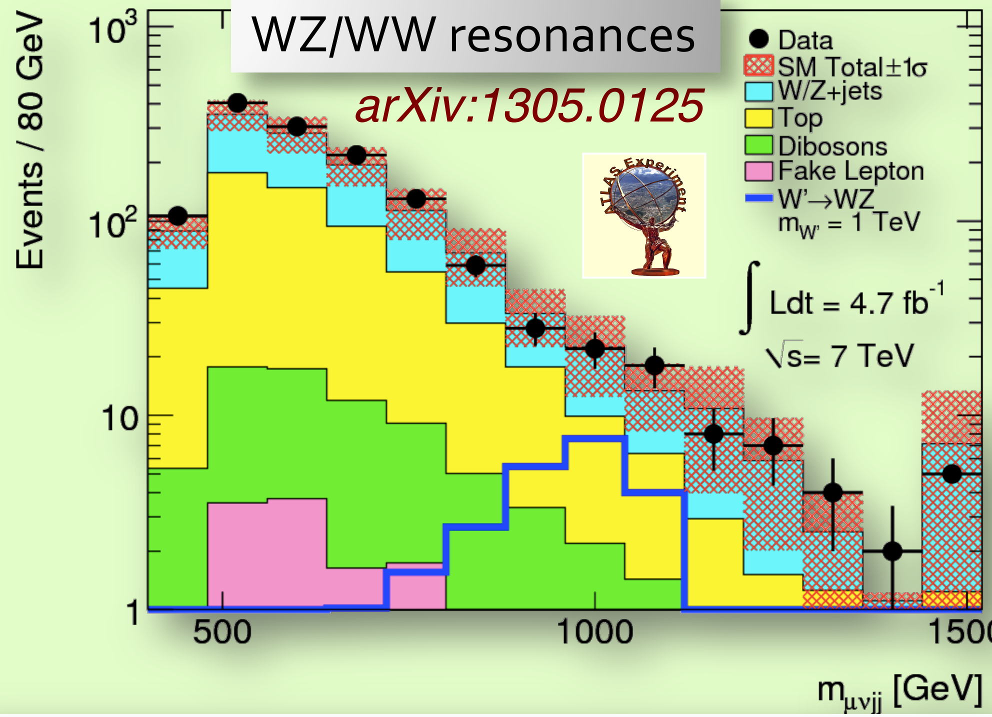
2 fat jets 140< M < 250

$M_{Z'}$ > 1.6 (2.3) TeV for 1.2 (10) % width

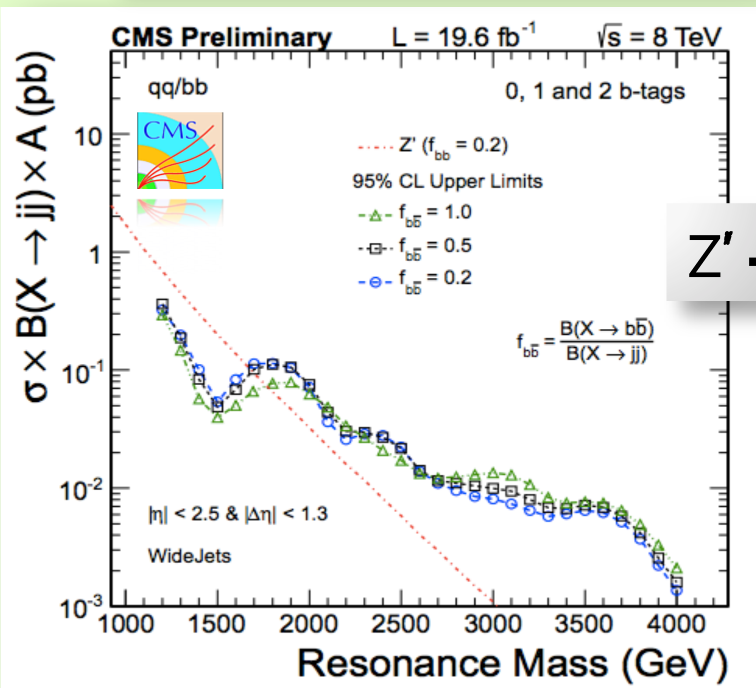
$M_{g(KK)}$ > 1.8 TeV

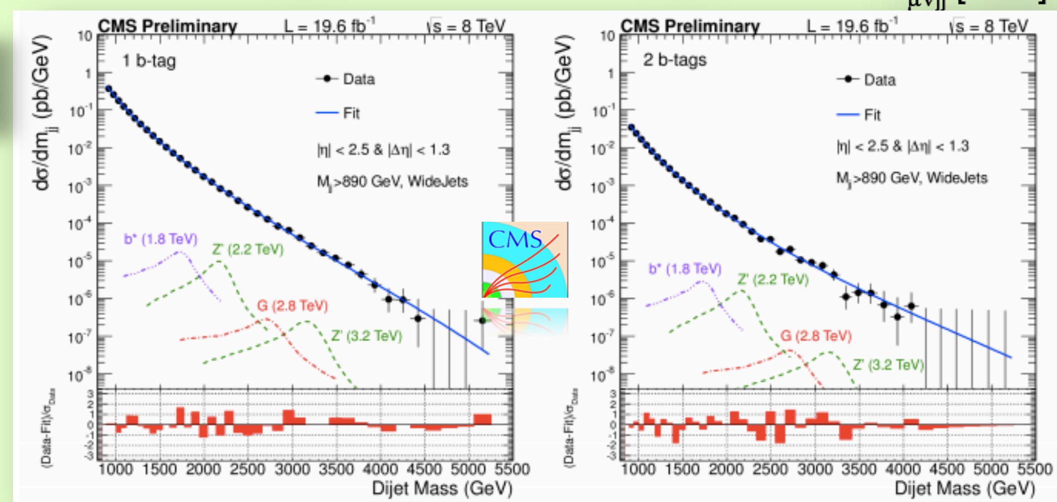
WZ/WW resonances

arXiv:1305.0125



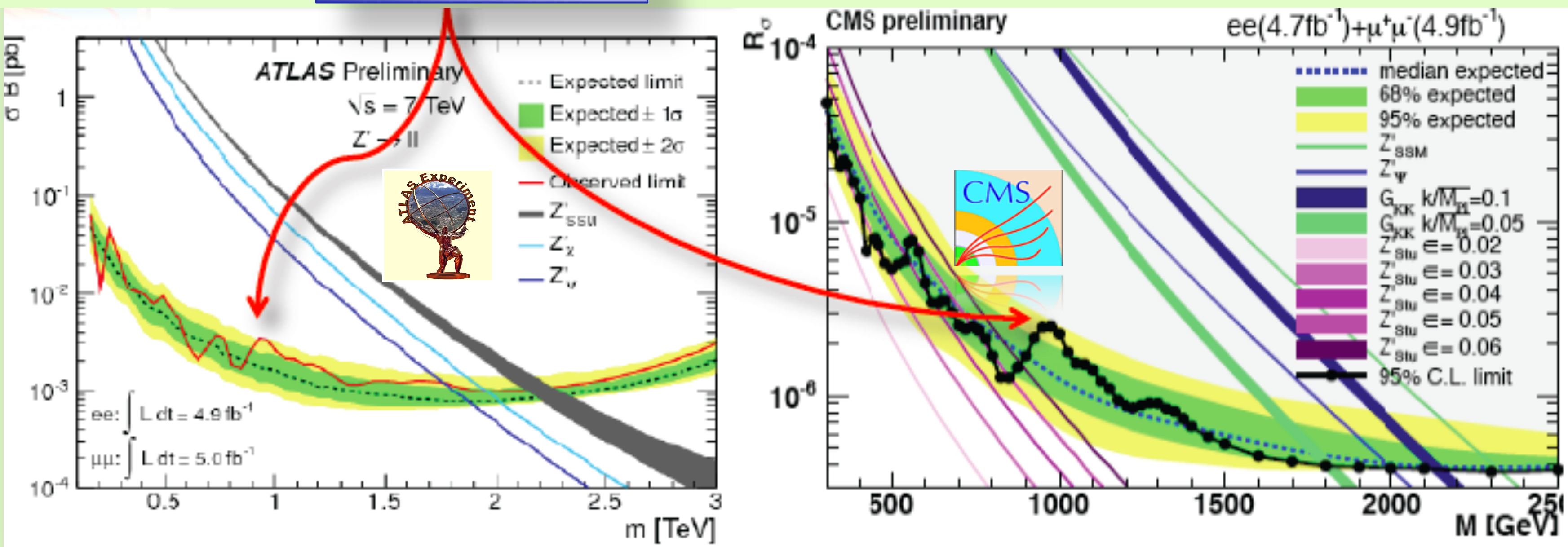
Z' ➔ $b\bar{b}$





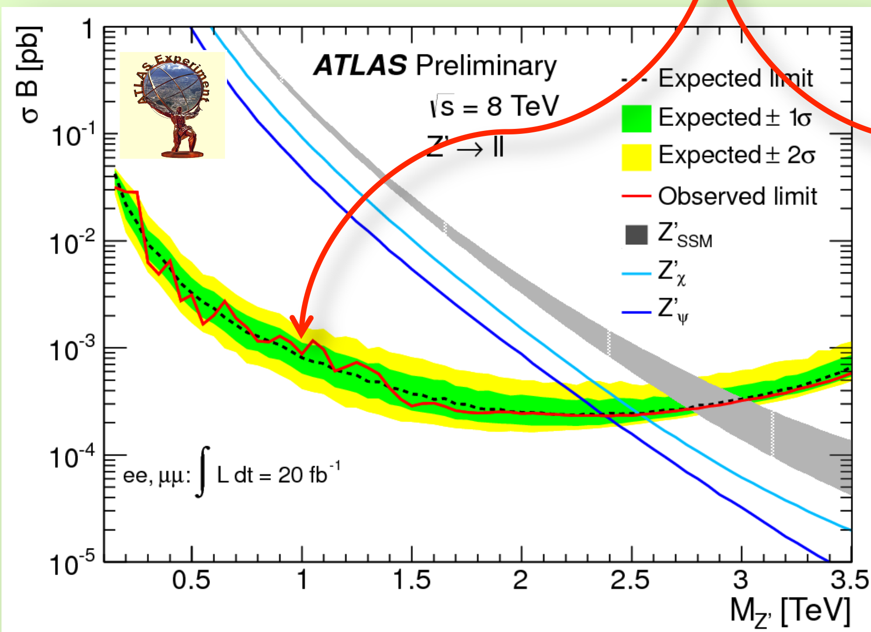
$Z' \rightarrow ll$: ca. Moriond 2012

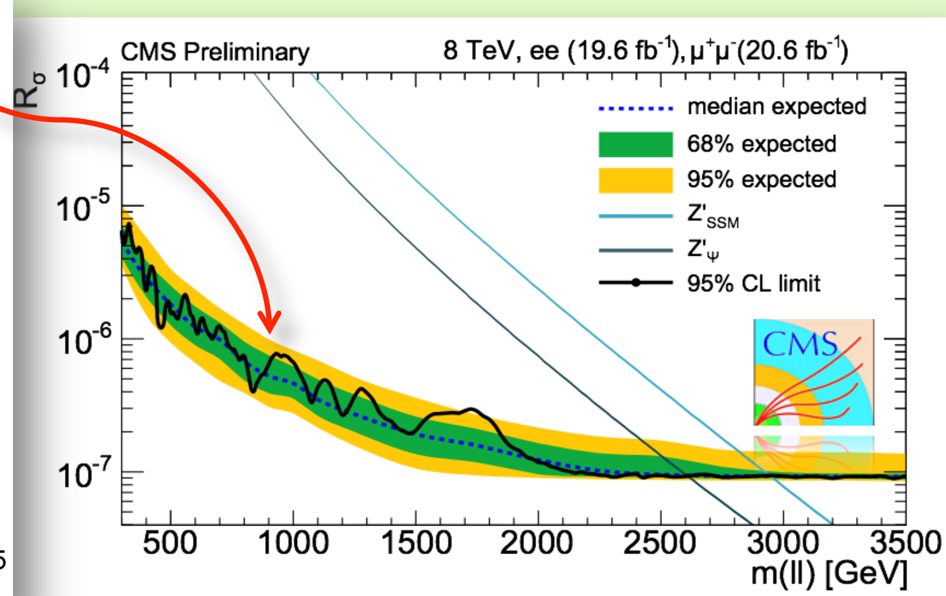
Going, going...

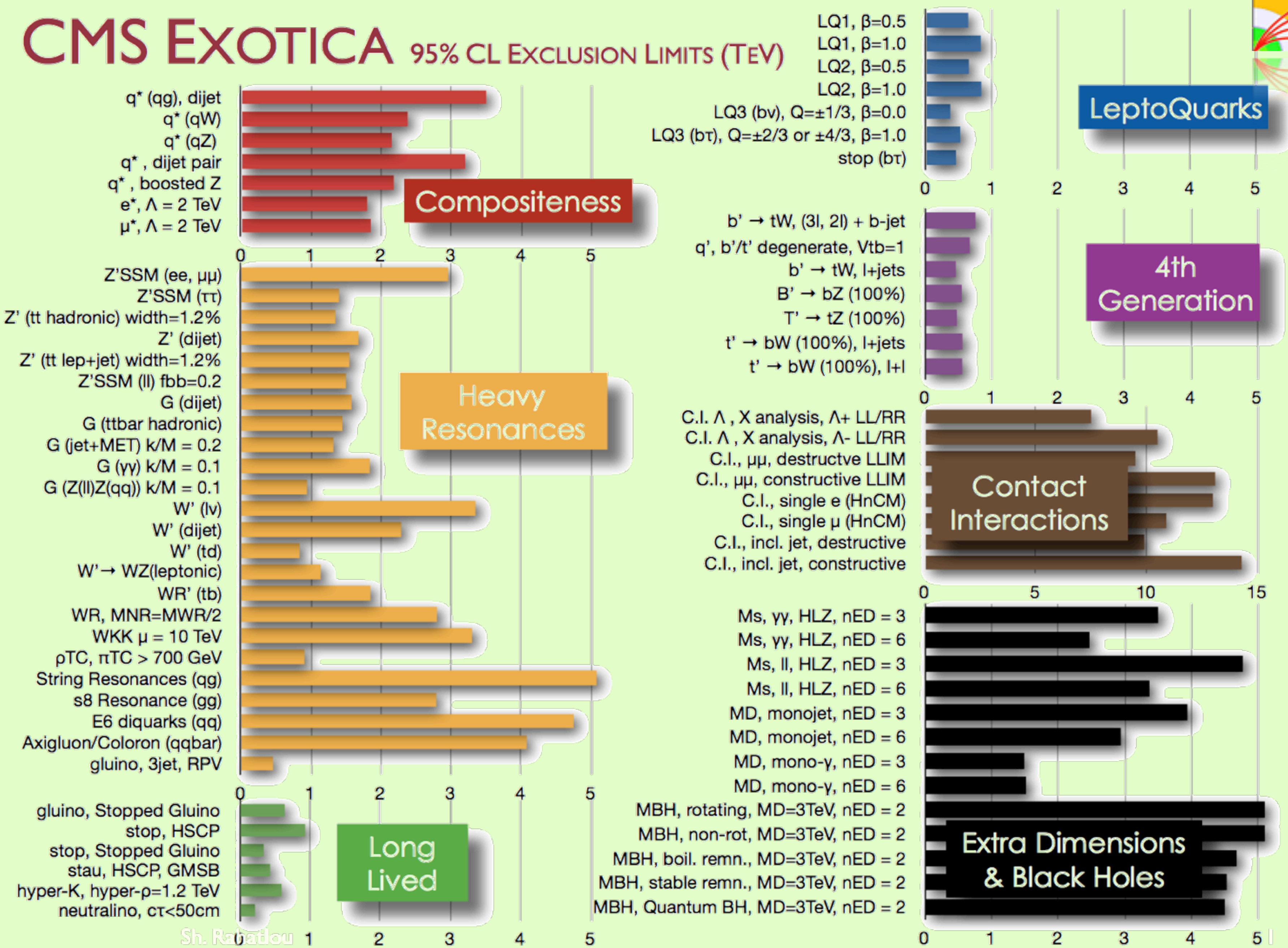


$Z' \to ll$: ca. Moriond 2013

gone

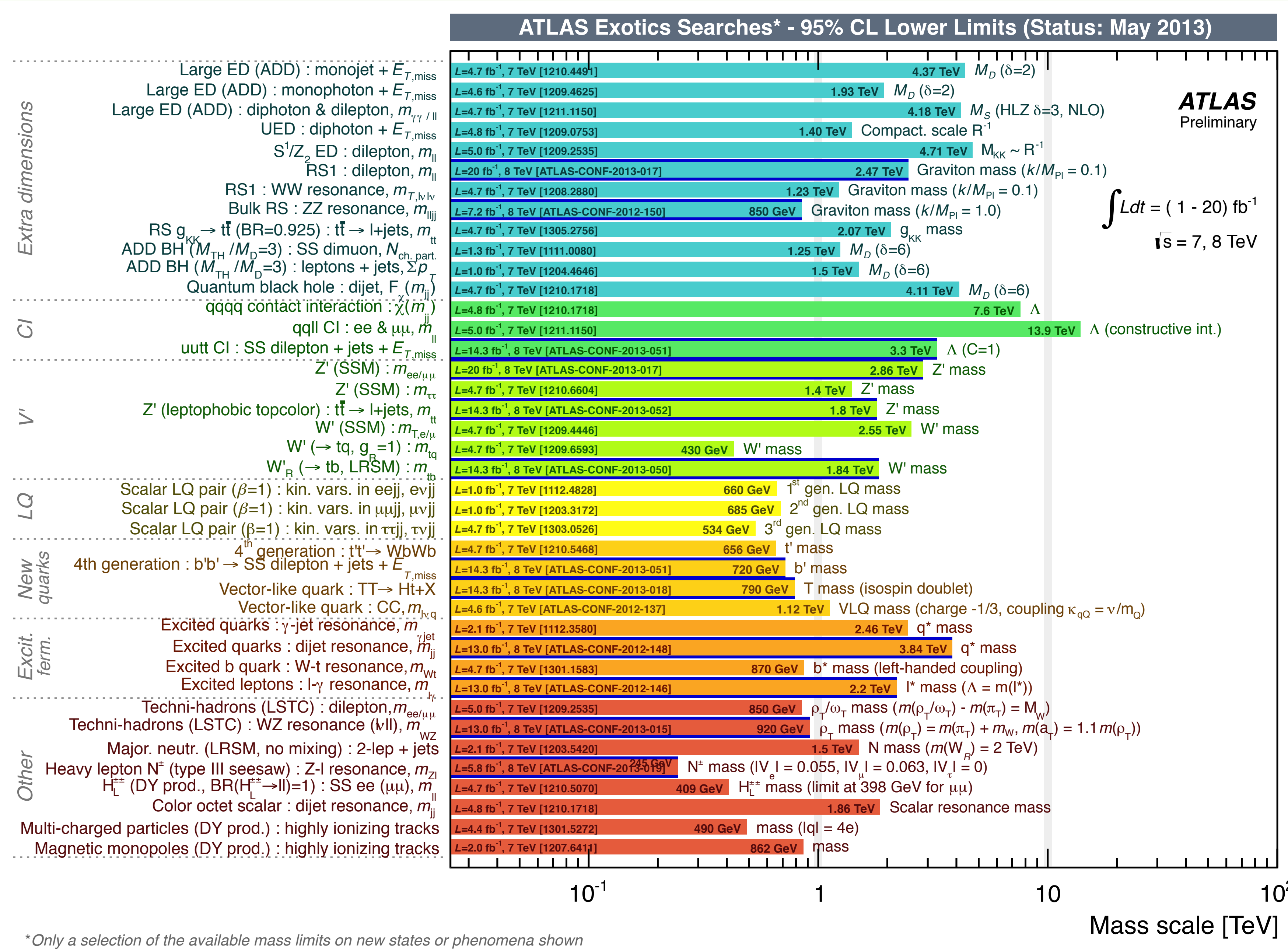






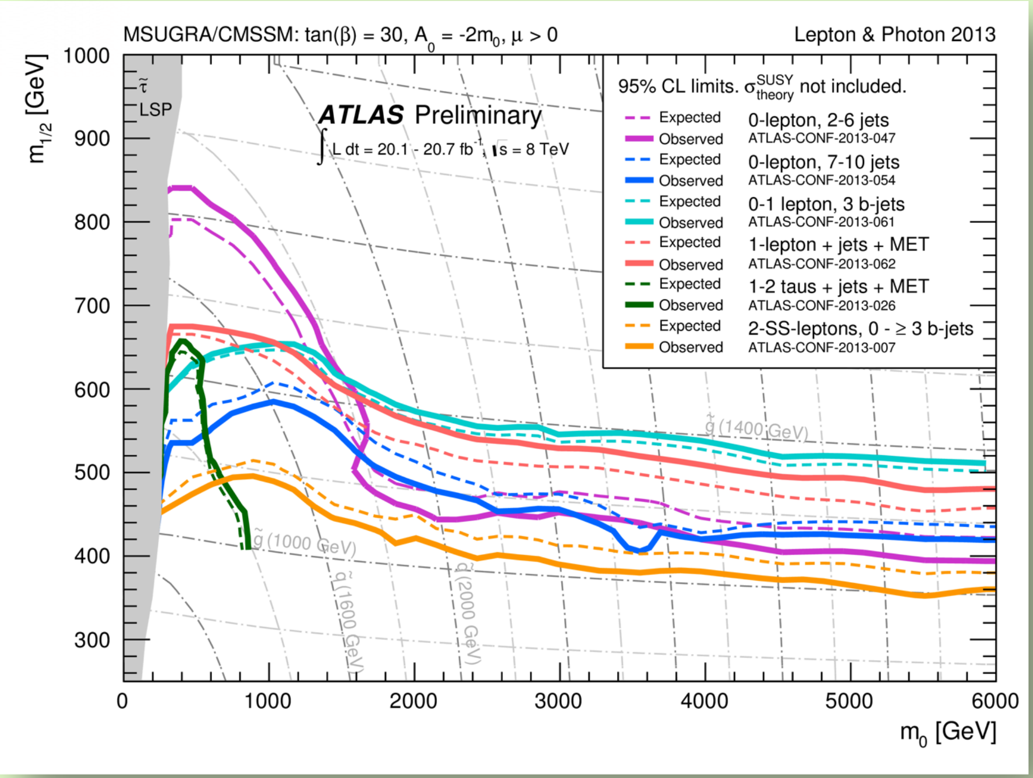
July 15, 2013 Invisibles13 Workshop Durham, UK J. Incandela UCSB/CERN

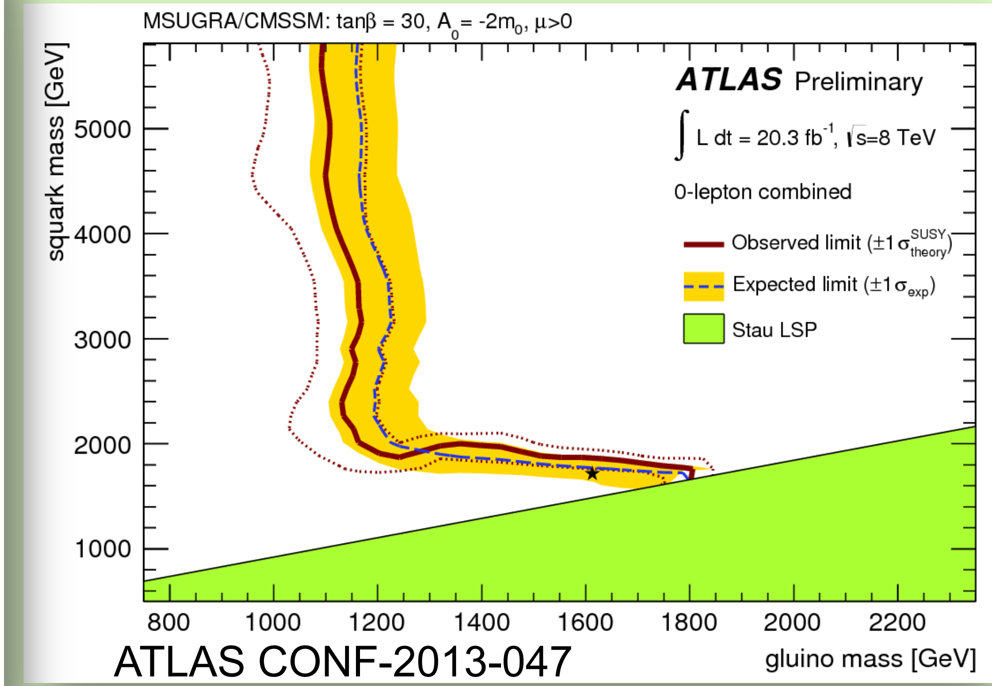
ATLAS EXOTICA



UCSB/CERN J. Incandela Durham, UK Invisibles13 Workshop July 15, 2013

MSUGRA/CMSSM

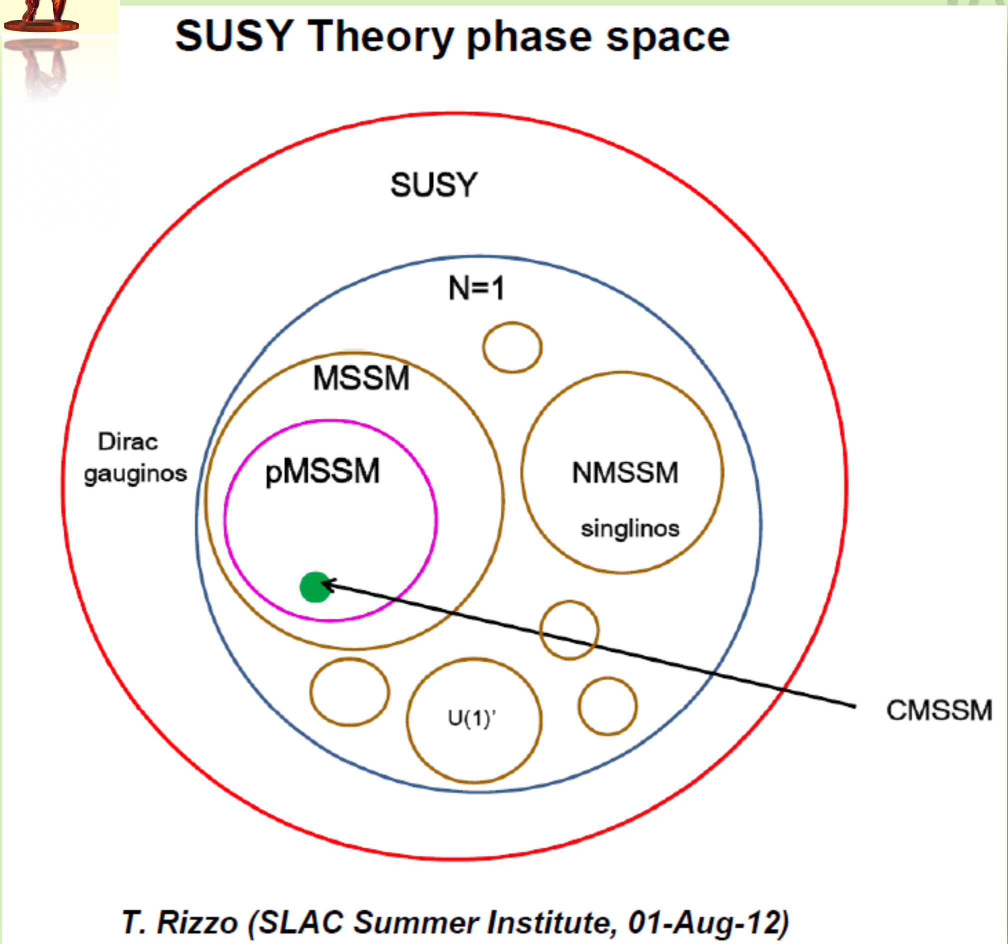


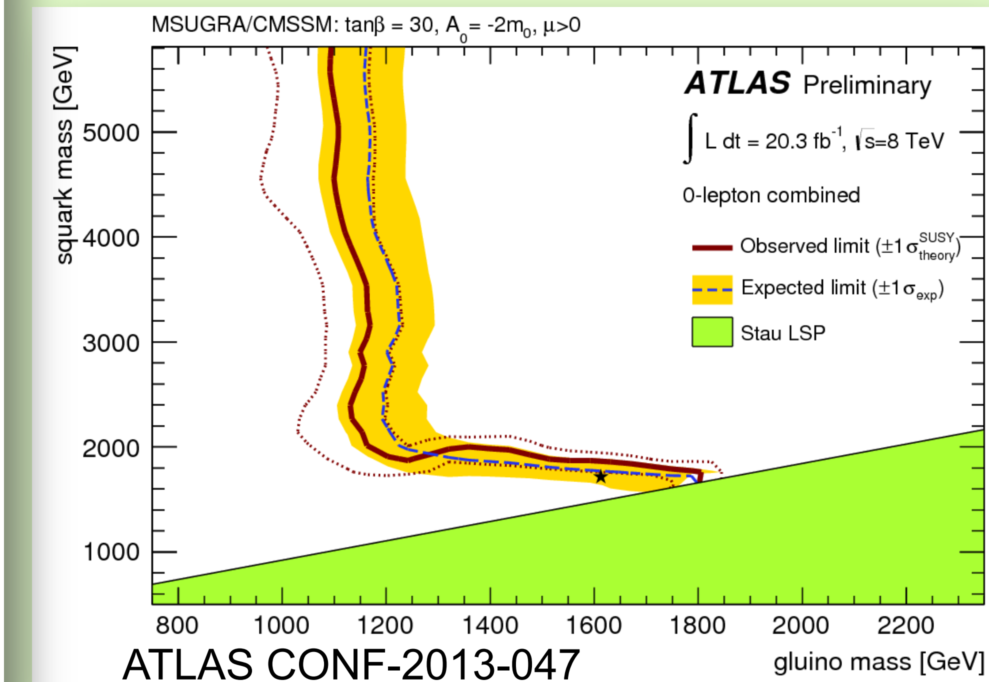


ATLAS CONF-2013-047

- MSUGRA/CMSSM
  - Exclude squarks and gluinos > 1 TeV and > 1.8 TeV respectively

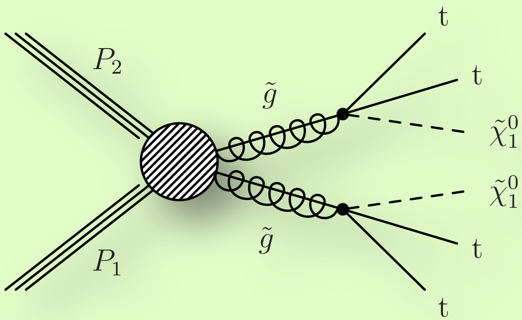
MSUGRA/CMSSM



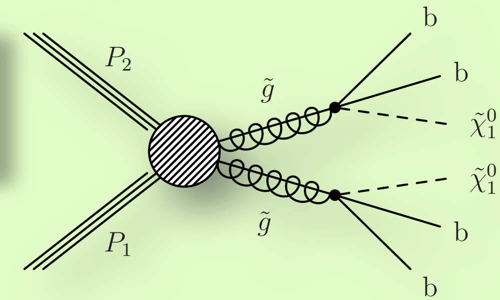


- MSUGRA/CMSSM
  - Exclude squarks and gluinos > 1 TeV and > 1.8 TeV respectively
- But, only really probing a tiny part of a very large parameter SUSY space

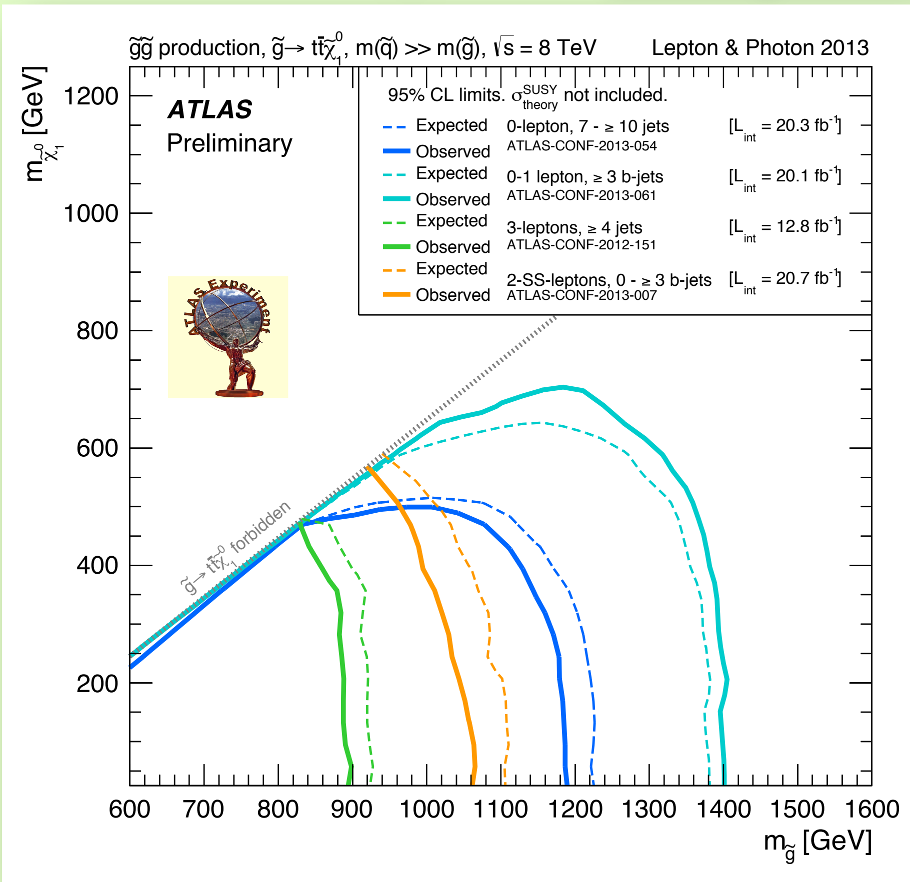
Onto more general SUSY searches

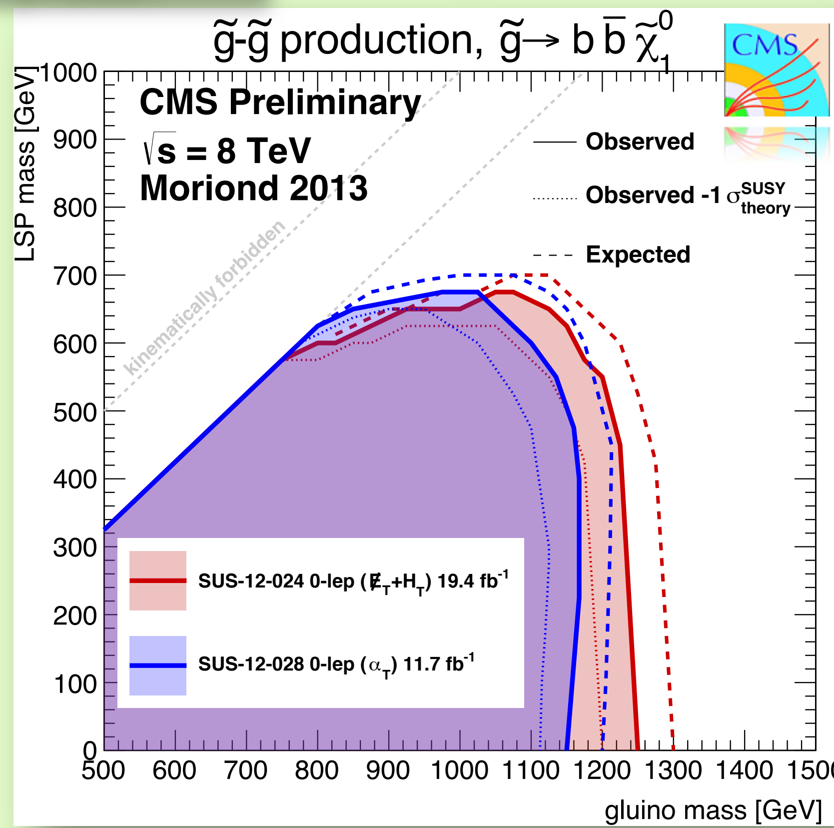


Gluinos decaying to stop or sbottom decaying to top or bottom + neutralino



Eliminating essentially all of the regions we can probe:

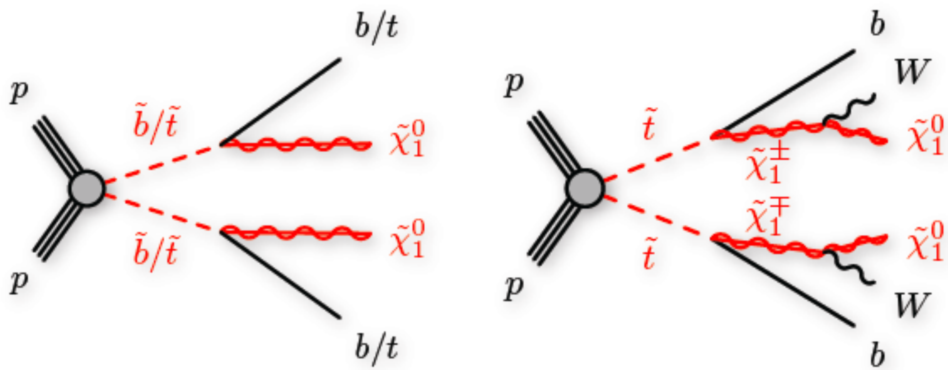


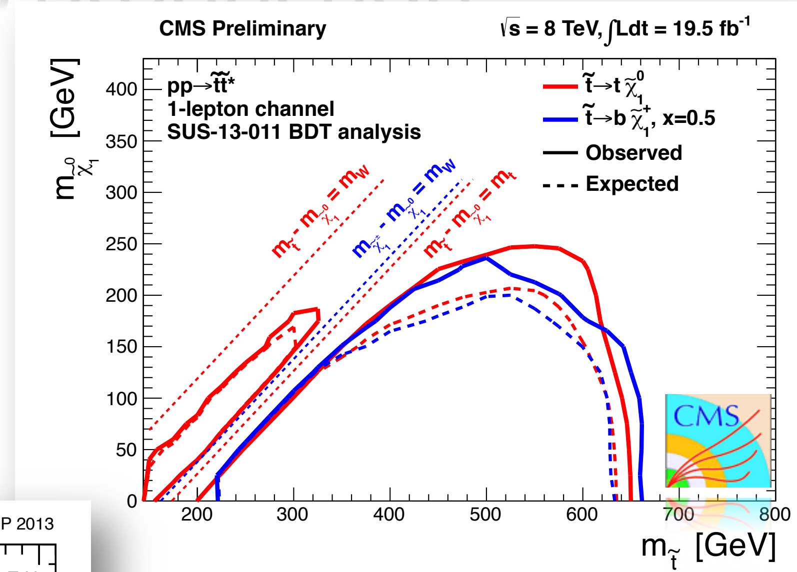


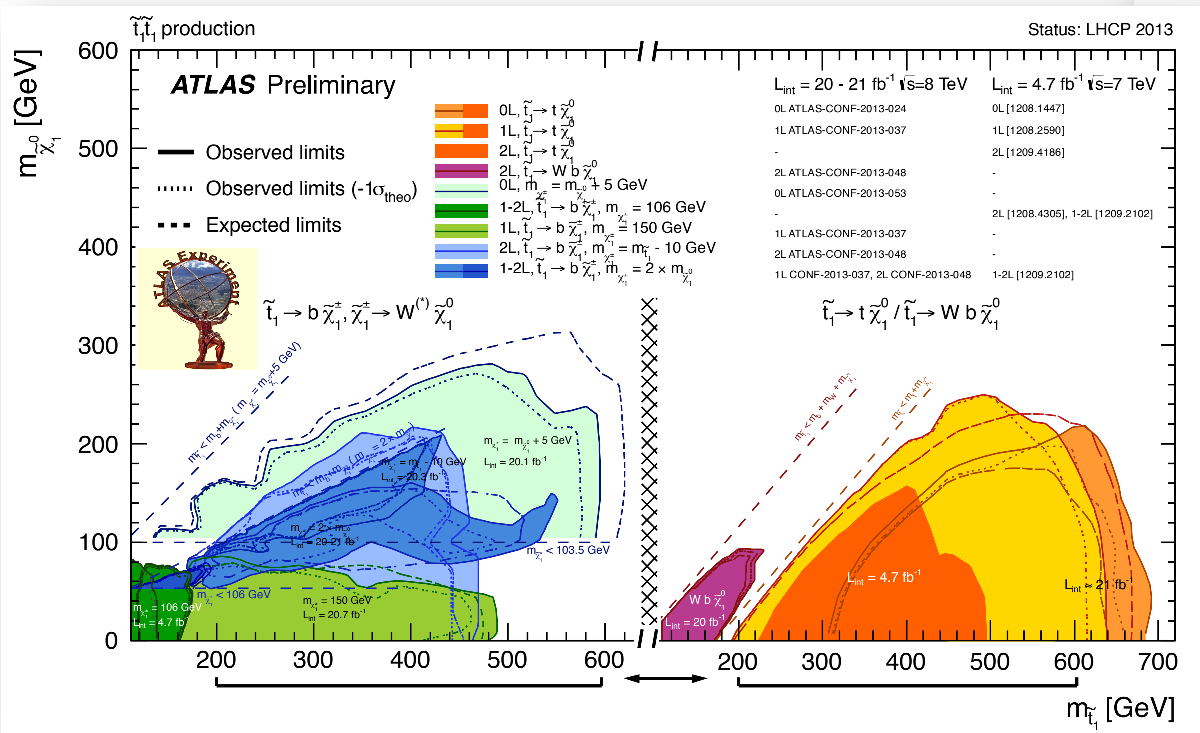
[CMS SUS-12-024](), [SUS-12-028]()

Direct 3rd generation production

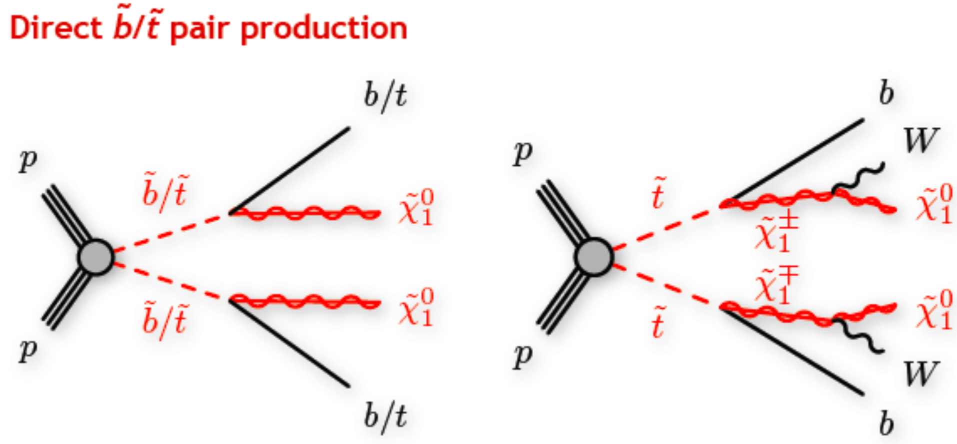
Direct $\tilde{b}/\tilde{t}$ pair production

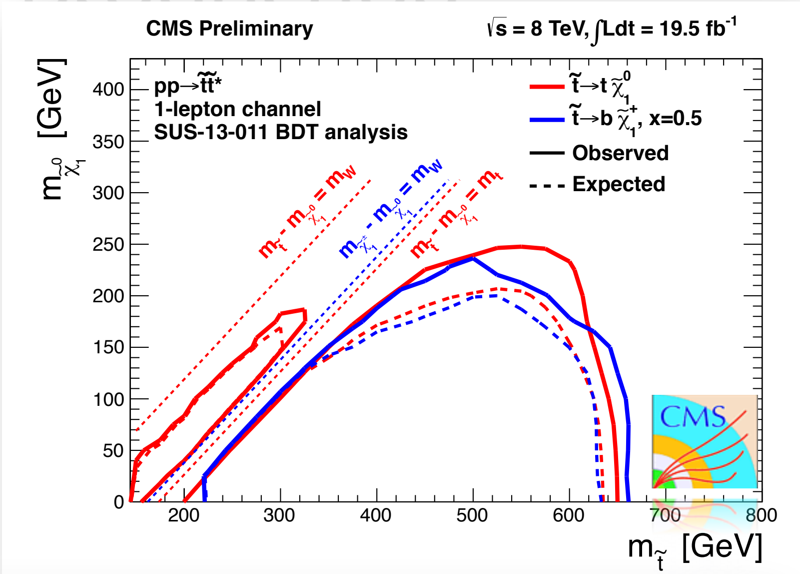




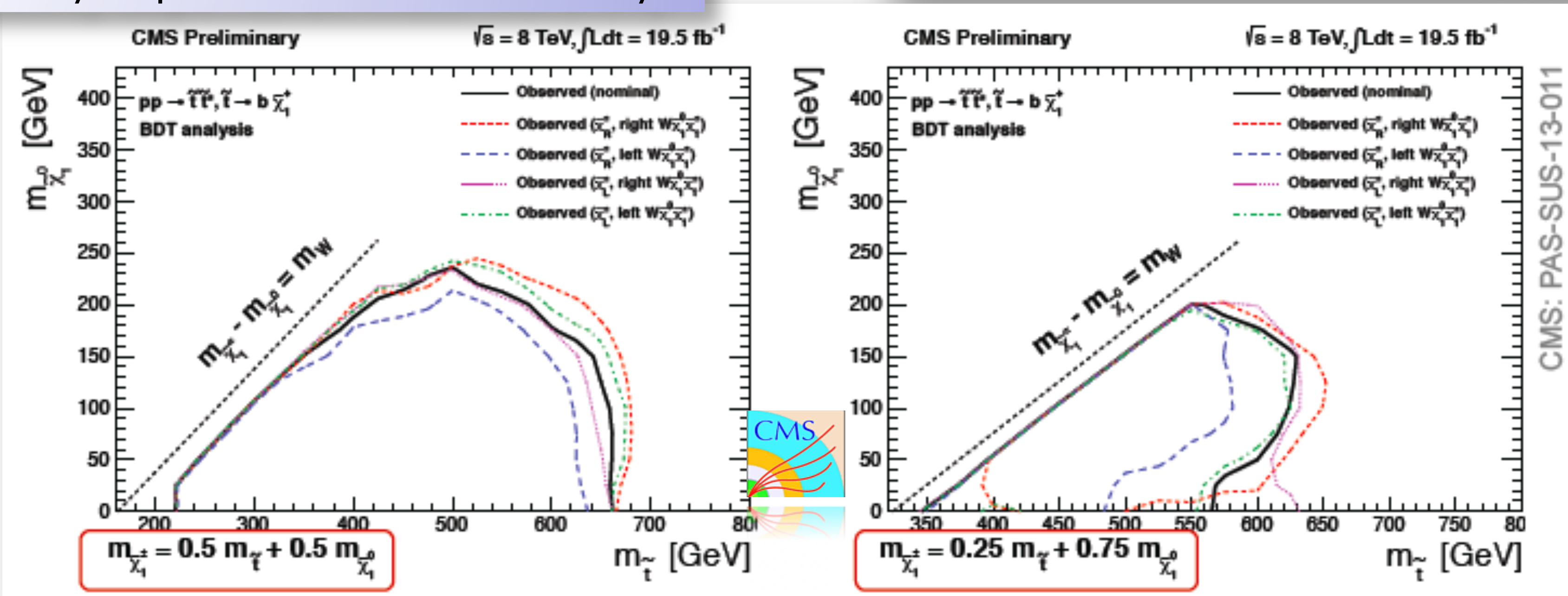


Direct 3rd generation production





Sensitivity depends on mass hierarchy



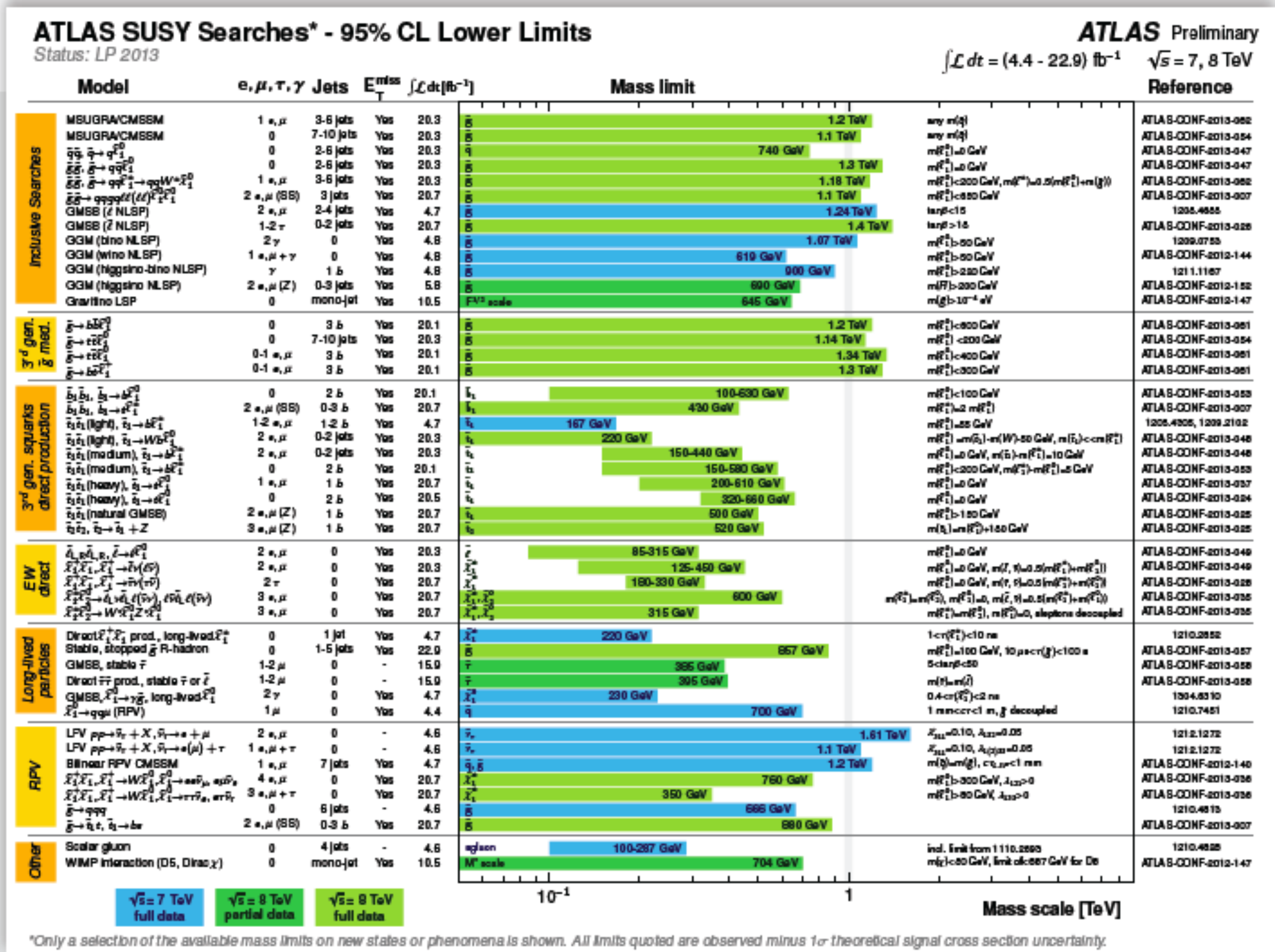
SUSY no show tables

Incl. searches

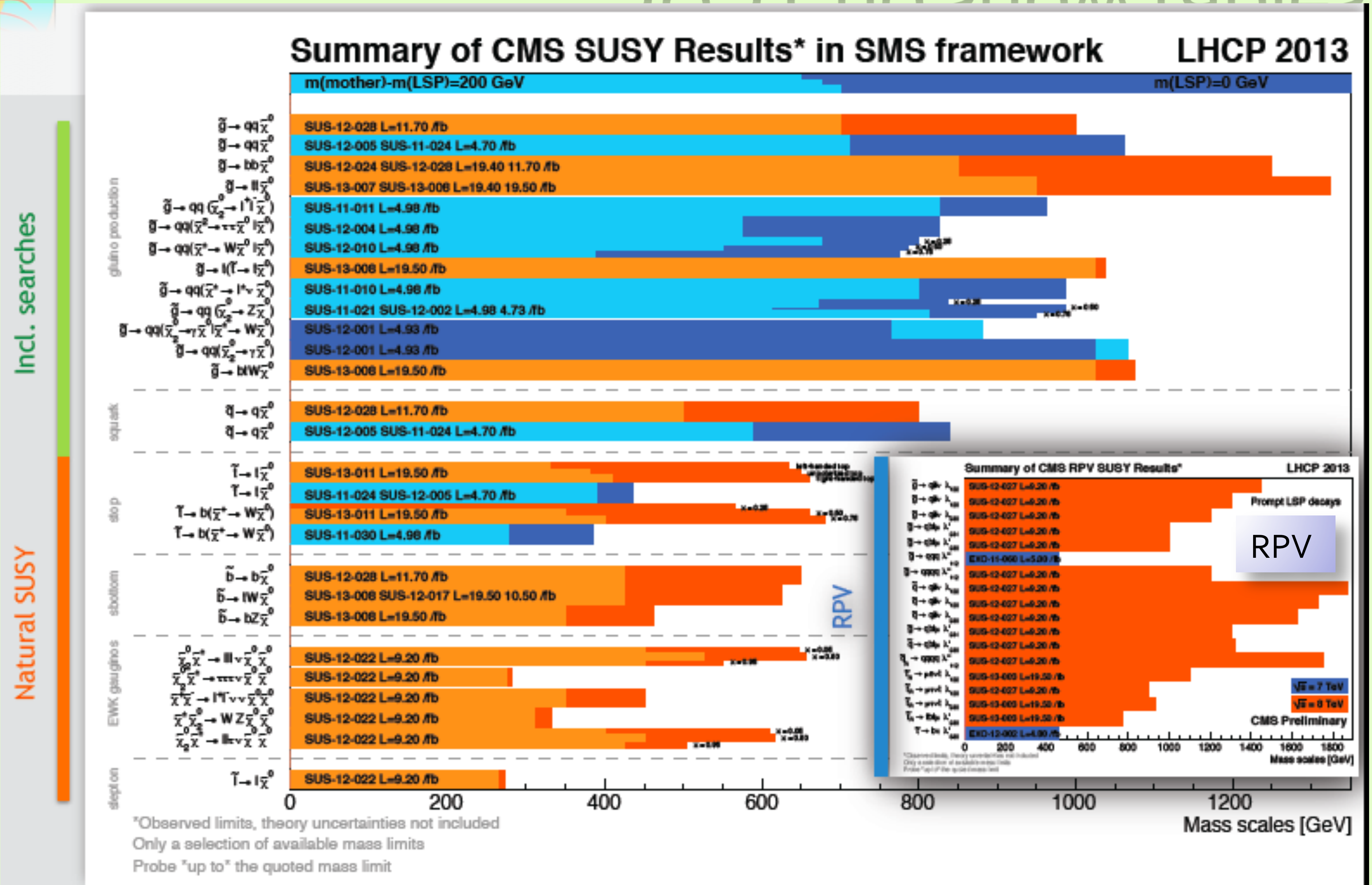
Natural SUSY

LLP + RPV

Extended MSSM



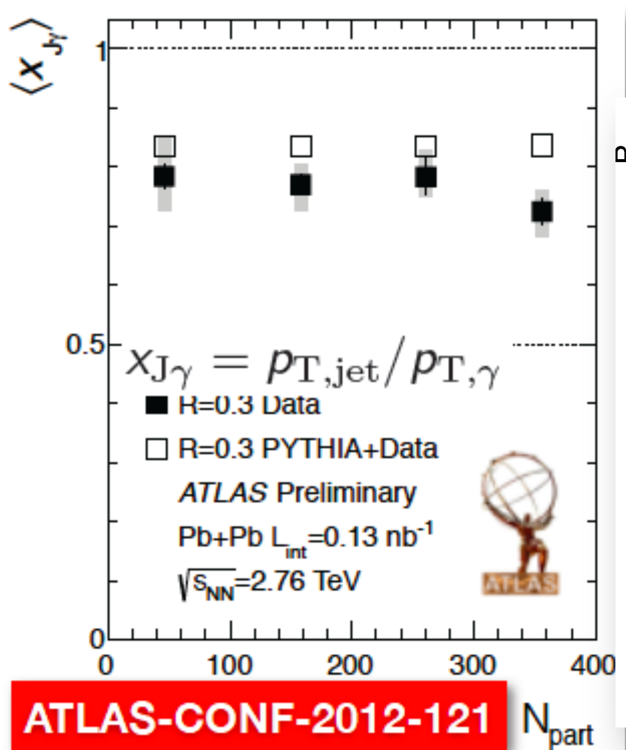
SUSY no show tables



Heavy Ions at LHC

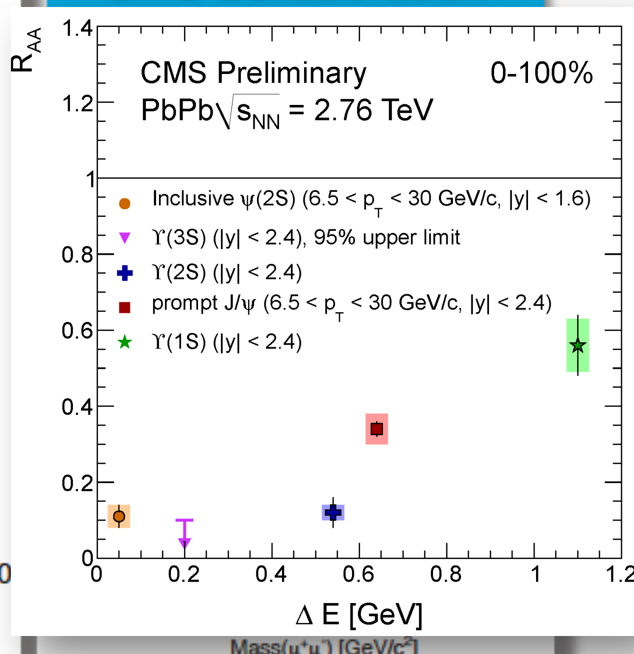
- Some of the many heavy-ion highlights from the LHC
- Plus many more results with exclusive strange and charm hadron identification,as well as beauty tagging, completely unique to the LHC experiments

j+γ nuclear modification factor

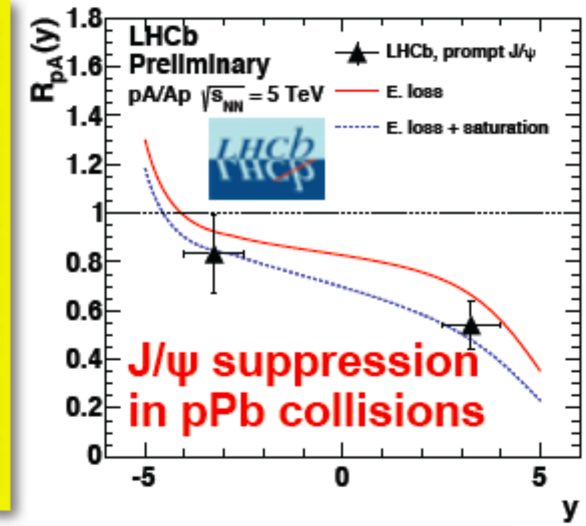


Suppression ordered by binding energy

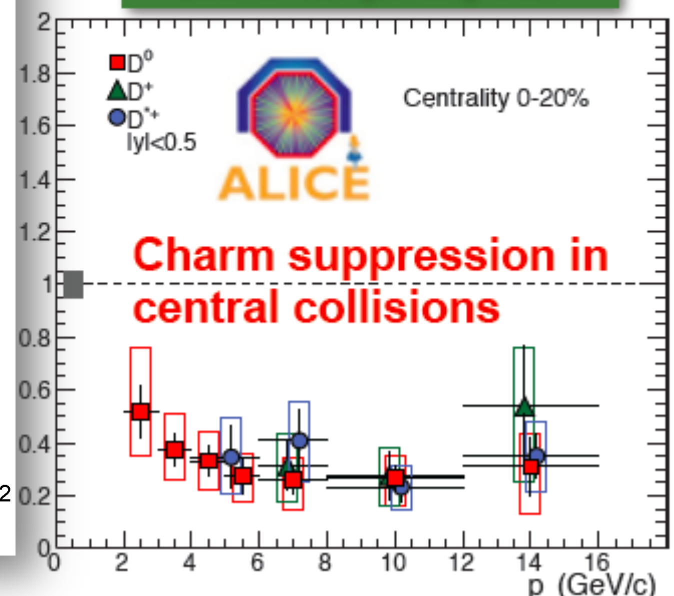
CMS Collaboration



LHCb-PAPER-2013-008



ALICE Collaboration JHEP 09 (2012) 112



The search for $B_{s(d)} \rightarrow \mu\,\mu$

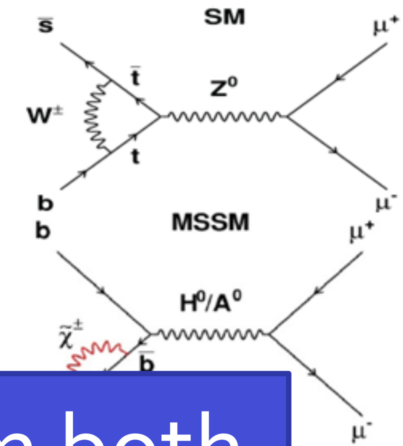
Predicted to be very rare in SM due to GIM & helicity suppression:

Precise predictions in SM:

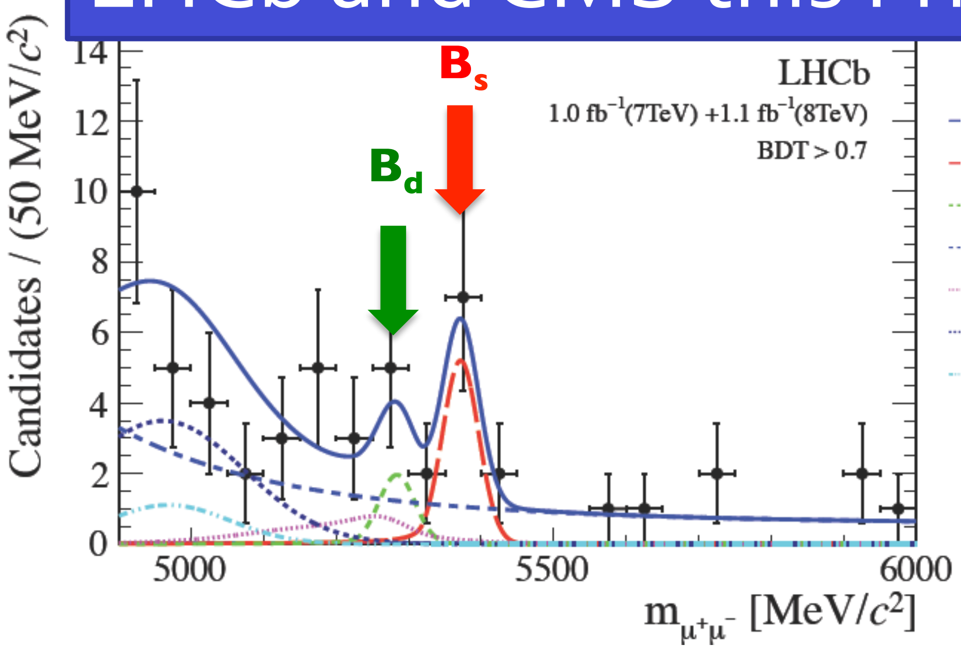
- $\mathcal{B}\,(B_s \rightarrow \mu\,\mu) = 3.5 \pm 0.2\ 10^{-9}$
- $\mathcal{B}\,(B_d \rightarrow \mu\,\mu) = 1.1 \pm 0.2\ 10^{-10}$

“G

(e.



New results with full dataset from both LHCb and CMS this Friday at EPS !!



…Cb has the first evidence of $B_s \rightarrow \mu\,\mu$ decay at ~ 3.5 σ

$$\mathcal{B}(B^0_s \rightarrow \mu^+\mu^-) = (3.2^{+1.5}_{-1.2}) \times 10^{-9}$$

in agreement with SM

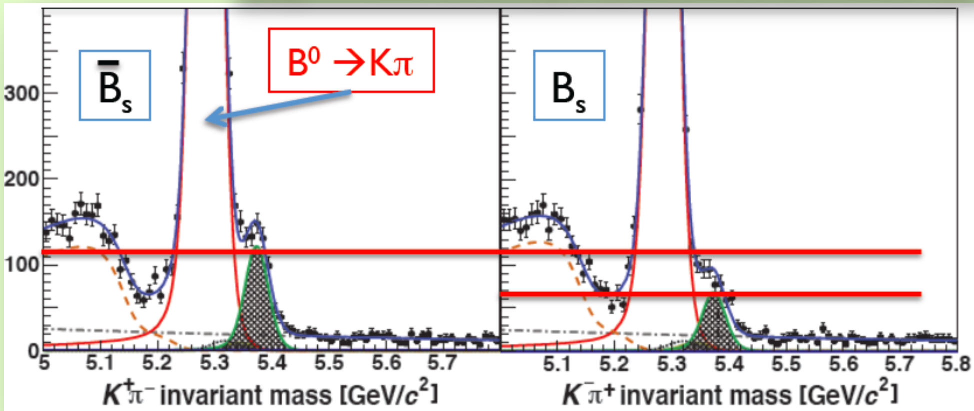
“Background only” p value ~ $5\ 10^{-4}$

Also best limit on $B_d \rightarrow \mu\,\mu$

$$\mathcal{B}(B^0 \rightarrow \mu^+\mu^-) < 9.4 \times 10^{-10} \text{ at 95\% CL}$$

CPV

First 5σ observation of CPV in $B_s \to K\pi$ decays (thanks to RICH)



Raw asymmetry is corrected for production and detector asymmetries (small: ~ 1%)

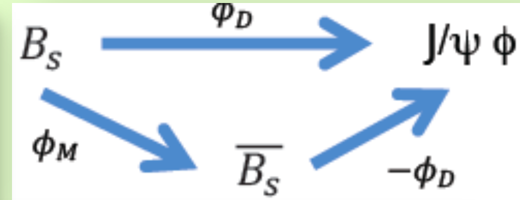
ACP = 0.27 ± 0.04 ± 0.01 (1 fb^{-1})

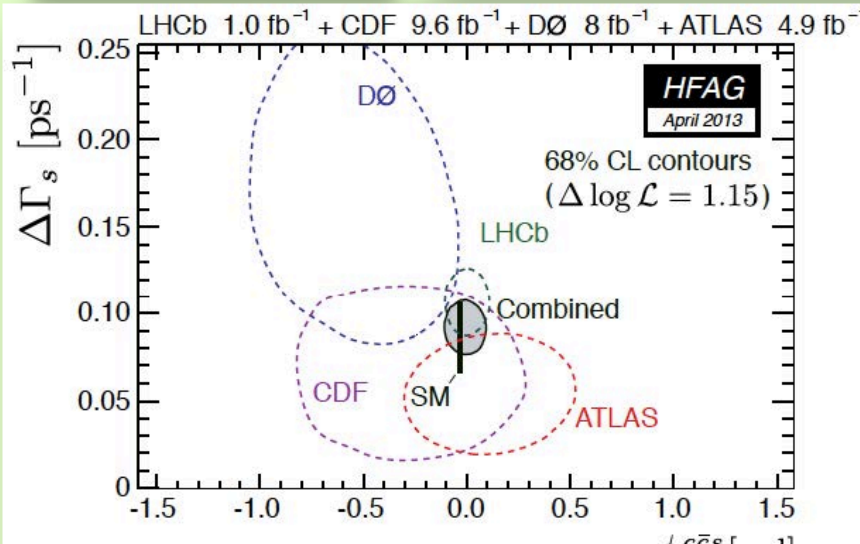
4^{th} particle exhibiting CP violation ($K^0_{[1964]}$, $B^0_{[2000]}$, $B\pm_{[2012]}$)

Previous evidence for CPV in charm D → ππ, KK decays is not confirmed either

CP violating phase $\phi_s = \phi_M - 2\,\phi_D$

If $\phi_s \neq 0$, New Physics in B_s oscillations ?





PRD 87 (2013) 112010

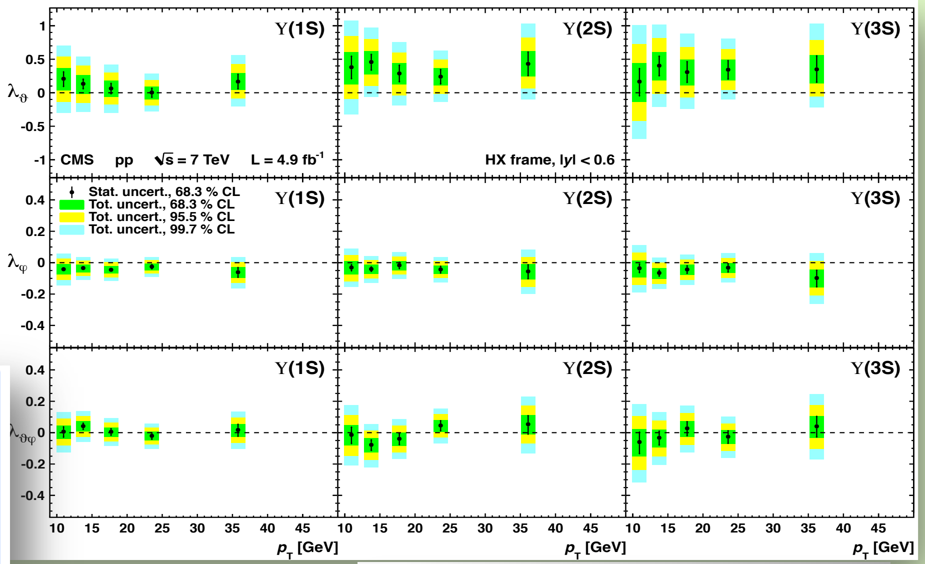
$\Phi_s = 0.01 \pm 0.07 \pm 0.01$ rad

$\Delta\Gamma_s = 0.106 \pm 0.011 \pm 0.007\ ps^{-1}$

LHCb: σ_t~44 fs – tagging εD^2~3.5%

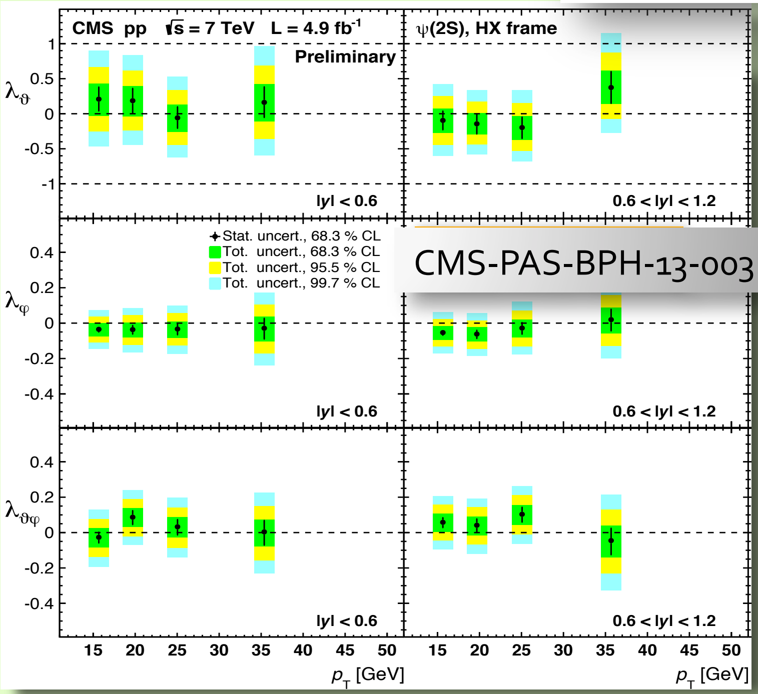
Ψ/Υ Polarization, Λ_b lifetime

- 1st meas. of Υ(nS) polarization at the LHC
  - Now extended to Ψ(2S) polarization measurement
- No evidence for large polarizations
  - An issue for NRQCD that needs to be resolved!

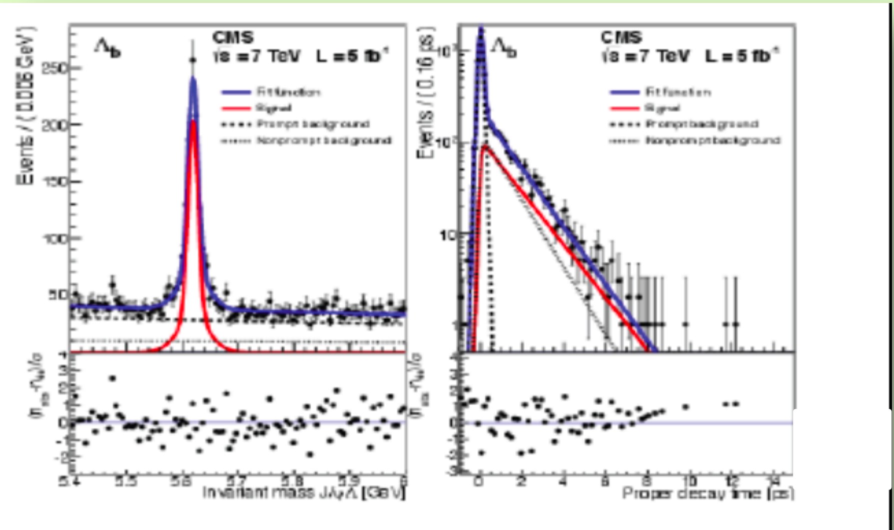


$$\frac{dN}{d\Omega} \propto 1 + \lambda_\theta \cos^2\theta + \lambda_\varphi \sin^2\theta \cos 2\varphi + \lambda_{\theta\varphi} \sin 2\theta \cos\varphi$$

PRL 110 (2013) 081802



CMS-PAS-BPH-13-003



$$\tau_{\Lambda_b} = 1.503 \pm 0.052(stat) \pm 0.031(syst)\ ps$$

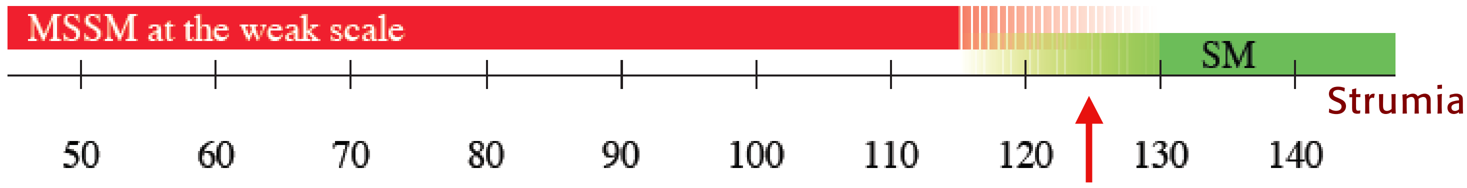
Where do we stand now?

The Higgs:
so simple yet so unnatural

Guido Altarelli

A malicious choice!

$m_H = 125.6 \pm 0.4$ GeV



*G. Altarelli: https://indico.cern.ch/conferenceDisplay.py?confId=239571

Implications

- 126 GeV Higgs boson
  - Important constraint on "simple" SUSY models
    - Especially if we require "naturalness" values of superpartner masses
      - i.e. avoiding non-fine-tuned solution to the hierarchy problem

"If not, we would be giving up at least one of the three SUSY 'miracles' " – Greg Landsberg (CMS Physics Coordinator)

- If 15% higher, we might have stopped considering MSSM scenarios…

- An interesting situation also in regard to SM
  - Vacuum stability ⇒ new physics must come in at ~10^{11} GeV
    - ~15% higher, the SM would be fine to the Planck scale

SUSY still fills an obvious gap !

Belief in Principles Paid Off

$0, \frac{1}{2}, 1, \frac{3}{2}, 2$

↑

Higgs is first "really new" particle we've seen

An Obvious Gap !

$\{0, \frac{1}{2}, 1, \frac{3}{2}, 2\}$

↑ POSSIBLE, VERY SPECIAL!

SUPERSYMMETRY

See talk by Nima Arkani-Hamed at Edinburgh Higgs Symposium, January 2013

What seems "so simple" may just be more complicated…

NMSSM as an example
(Talk by R. Barbieri)*

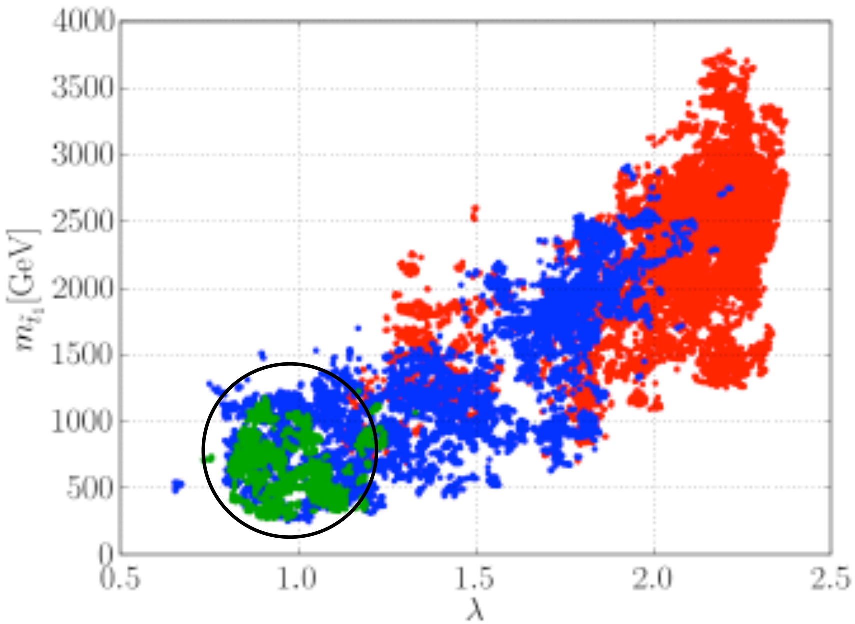
Fayet 1975

Two independent reasons to consider it:

1. Add an extra contribution to $m_{hh}^2 = m_Z^2 c_{2\beta}^2 + \Delta_t^2 + \lambda^2 v^2 s_{2\beta}^2$
   thus allowing for lighter stops

2. Alleviates fine tuning in v for $\lambda \gtrsim 1$ and moderate $\tan\beta$

$$\frac{dv^2}{dm_{H_u}^2}|_{NMSSM} \approx \frac{\kappa}{\lambda^3}\cot 2\beta \quad \text{versus} \quad \frac{dv^2}{dm_{H_u}^2}|_{MSSM} \approx \frac{4}{g^2}$$



green points have better than 5% "combined" fine-tuning and $\Lambda_{mess} = 20\ TeV$ in the scale invariant NMSSM

$$m_{\tilde{t}_1} < 1.2\ TeV$$

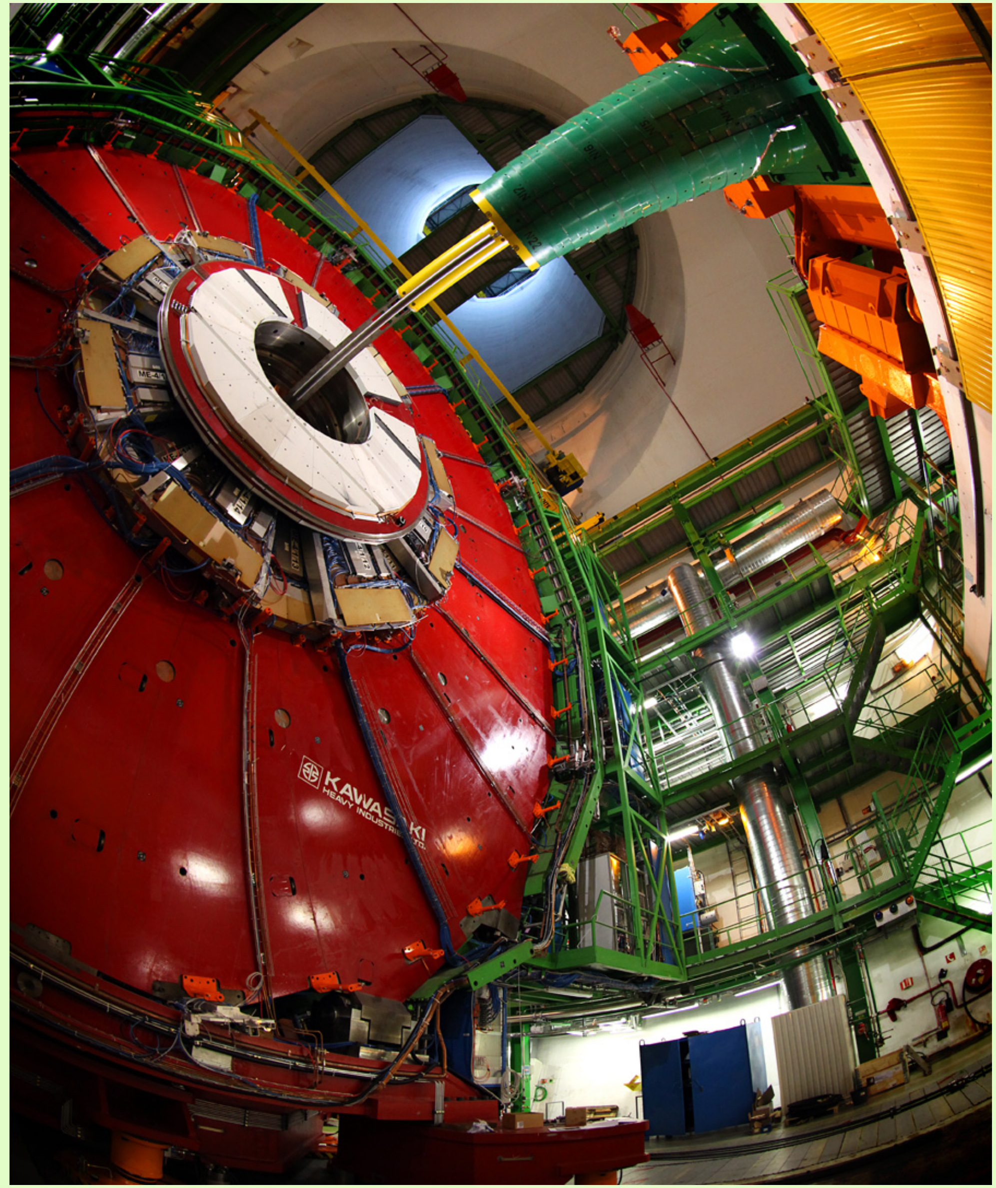
$$m_{\tilde{g}} < 3\ TeV$$

Gherghetta et al 2012

*R. Barbieri: https://indico.cern.ch/conferenceDisplay.py?confId=239571

What next?

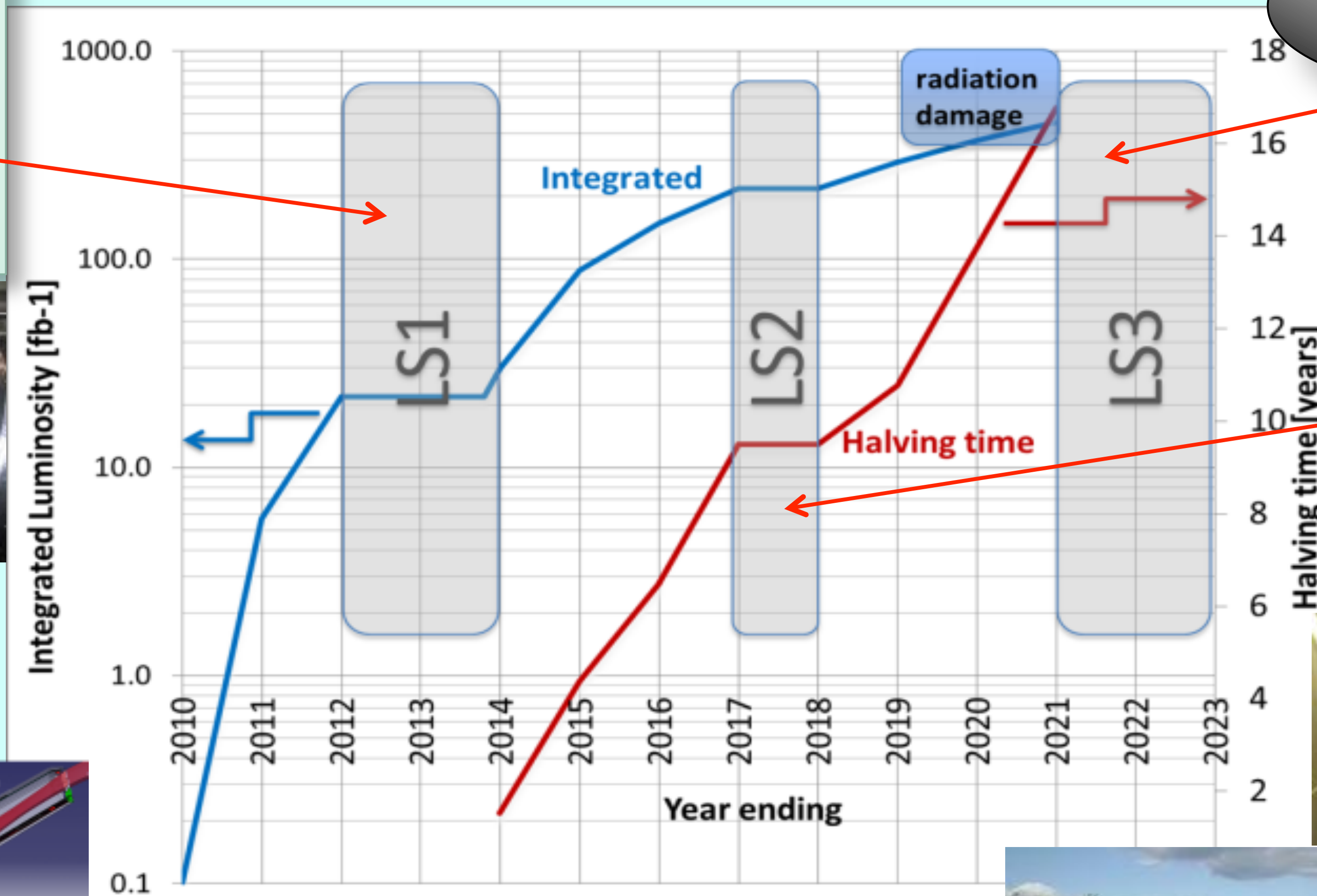
- Run 1 has been a success
  - But the LHC is in its childhood
- Run 2 and beyond
  - Extend searches, precision measurements - significantly
  - For the next 15+ years the LHC is the only Higgs (and top, W, Z …) factory we have!



CERN Plan for the next 10 years

Shut down to fix interconnects and overcome energy limitation (LHC incident of Sept 2008) and R2E

HiLumi LHC



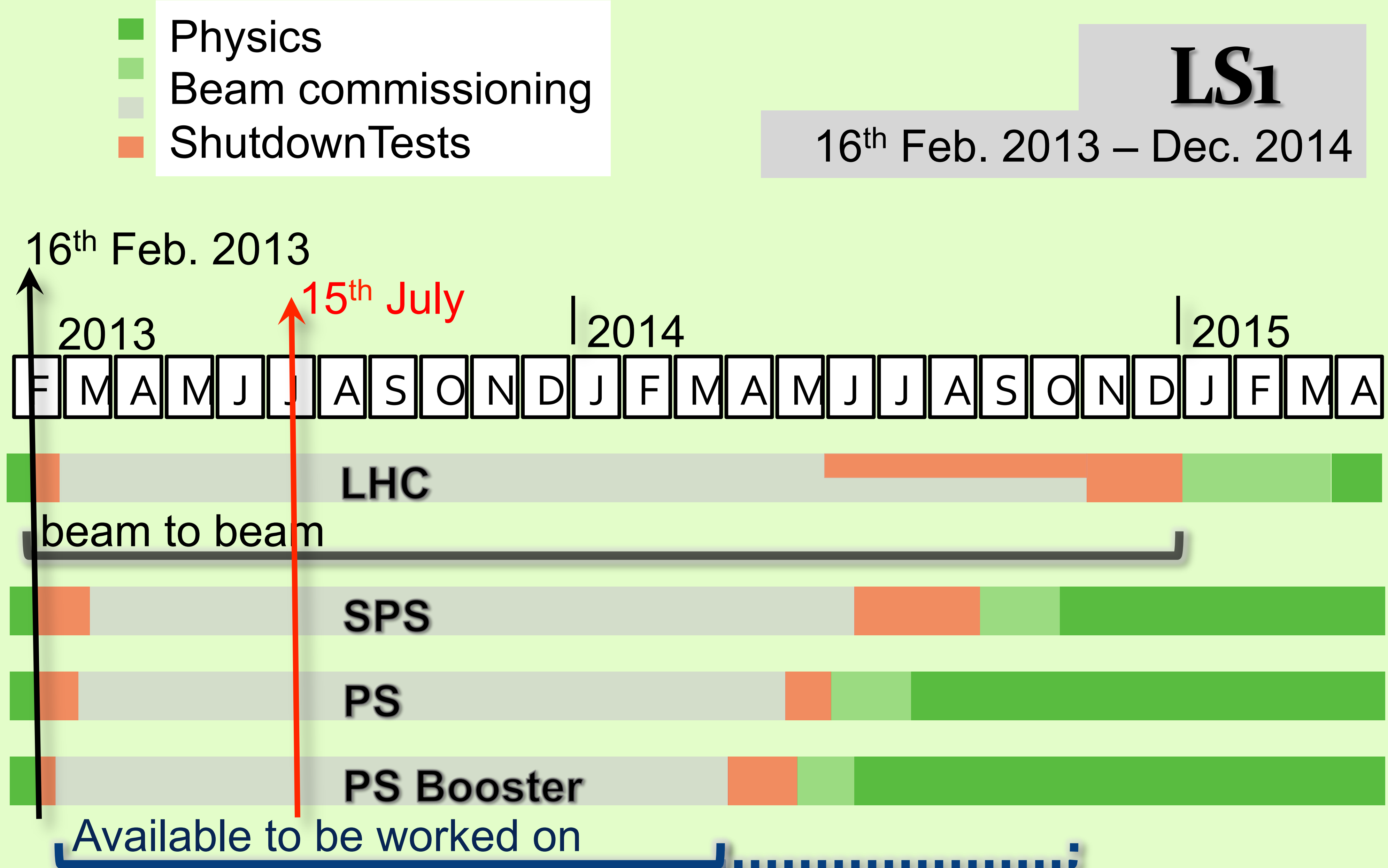
Shut down to overcome beam intensity limitation (Injectors, collimation and more…)

LHC Warm-UP 2013

Few perturbations (EL, CV, controls),
Few issues with HW (HX-Comp-Tu)

Done in 10 weeks !!!

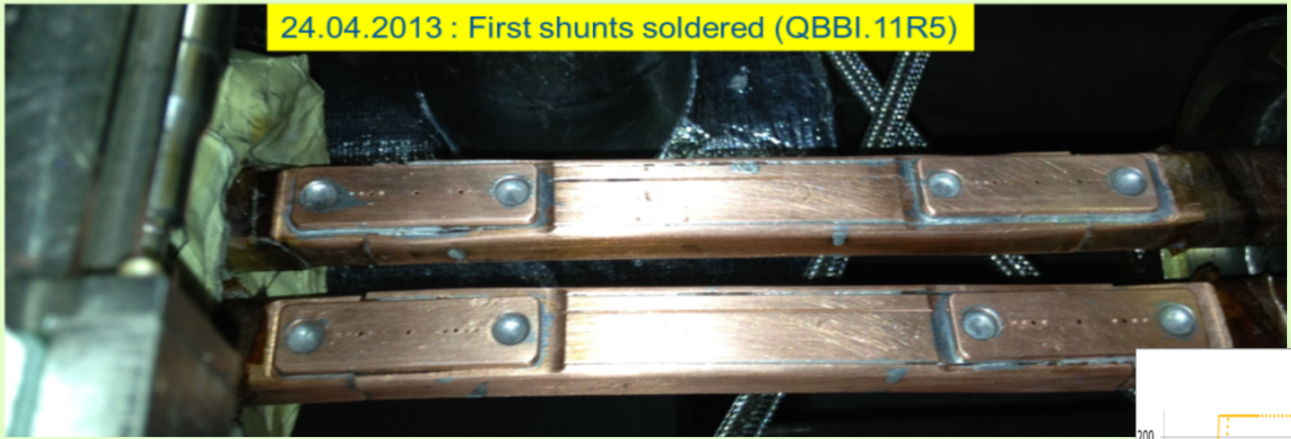
Courtesy F. Bordry



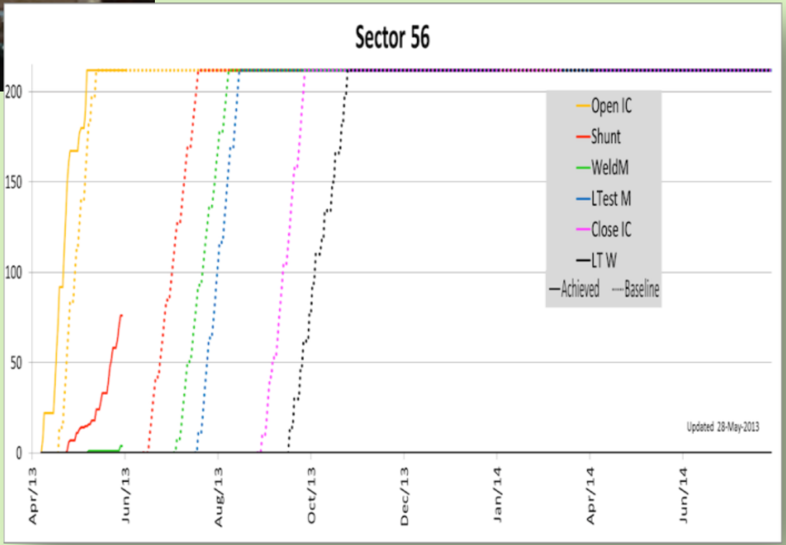
Courtesy F. Bordry

SMACC: Installation of shunts

- >160 IC in sector 56 (75% of one sector) are now equipped with shunts (almost 10% of the LHC, 2560 shunts)
- Started ahead of schedule, learning for critical activity

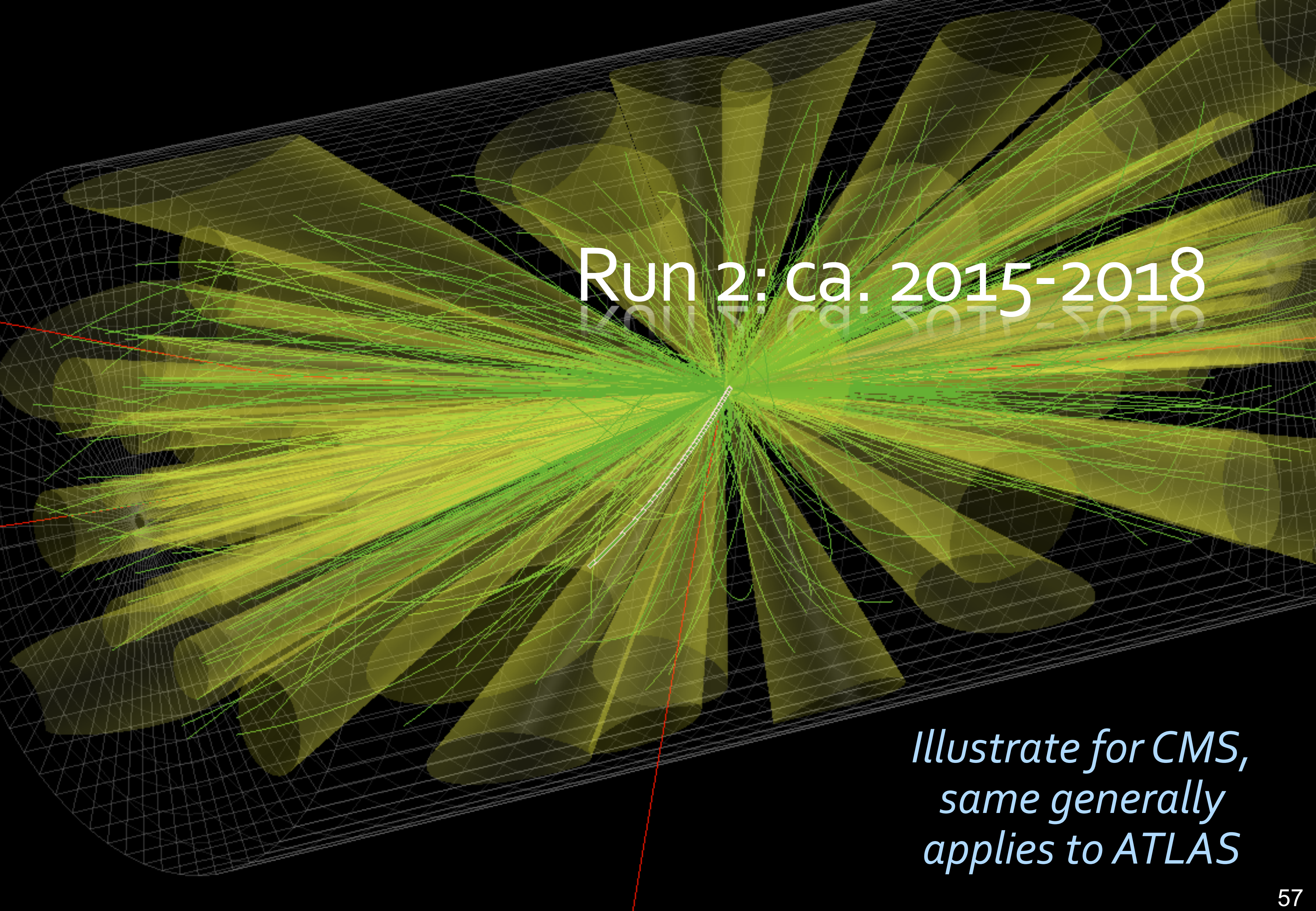


First shunt soldered on 24.04.2013



Courtesy F. Bordry

Run 2: ca. 2015-2018



Illustrate for CMS, same generally applies to ATLAS

Basically, life will not be easy…

Pileup~50 at 25 ns and L = $2x10^{34}$ $cm^{-2}s^{-1}$

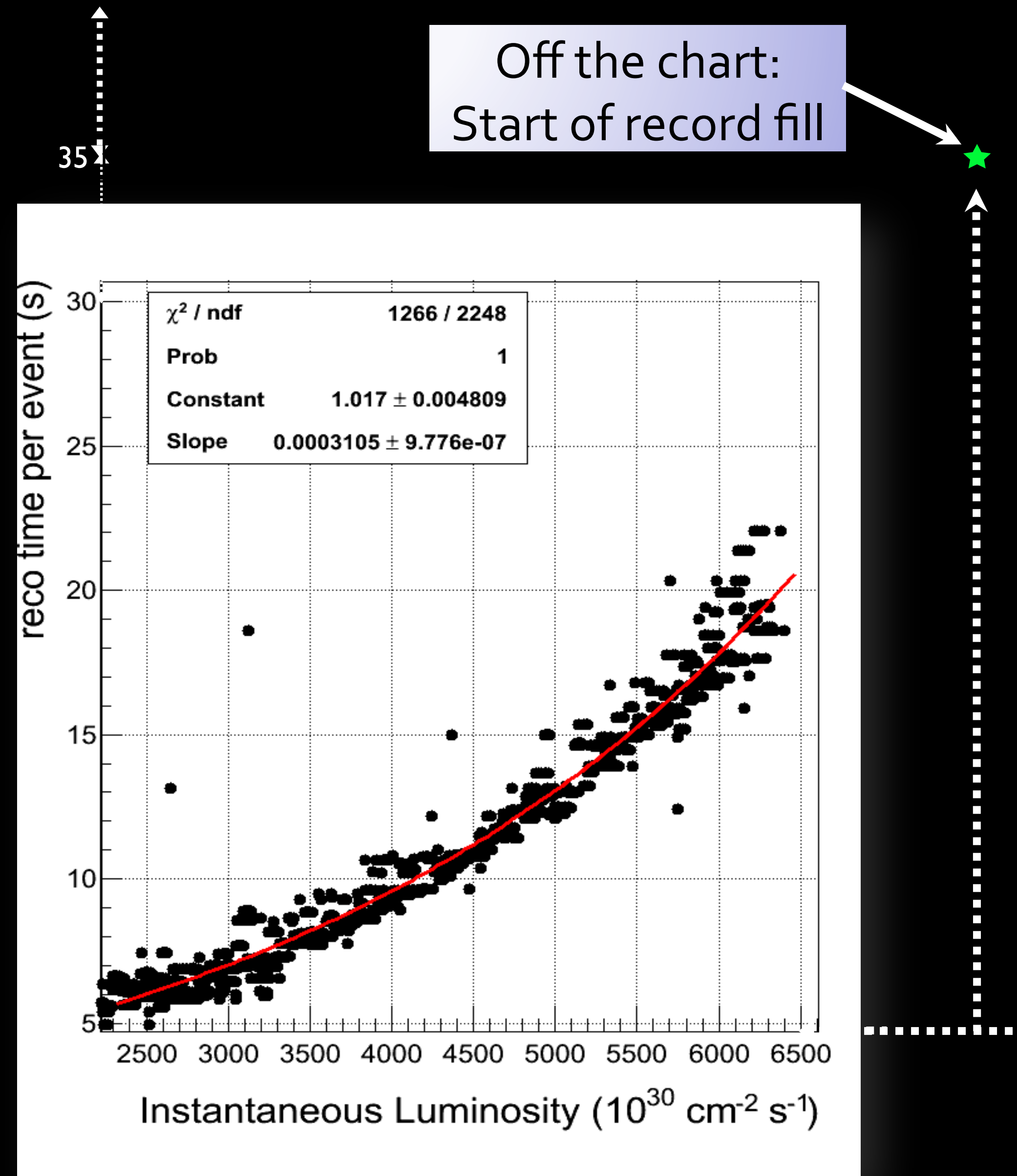
Looking Ahead to Run 2: Summary of Challenges

- CPU for 2015 (25 ns bunch spacing, L= 1.5E34 $cm^{-2}s^{-1}$):
  - x10 CPU required in 2015.

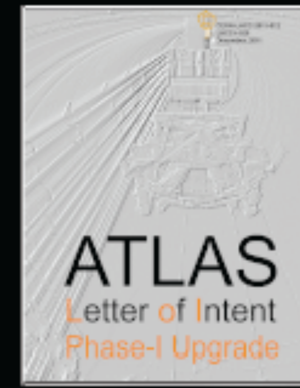
    x2 or more from trigger rate;
    x2.5 from in-time pile up;
    x2 from out of time pileup at 25 ns
    (worse for luminosity leveling at 50 ns)

- Improvements are *crucial*
  - Faster algorithms needed:
    - *A first example; increase tracking cluster charge thresholds*

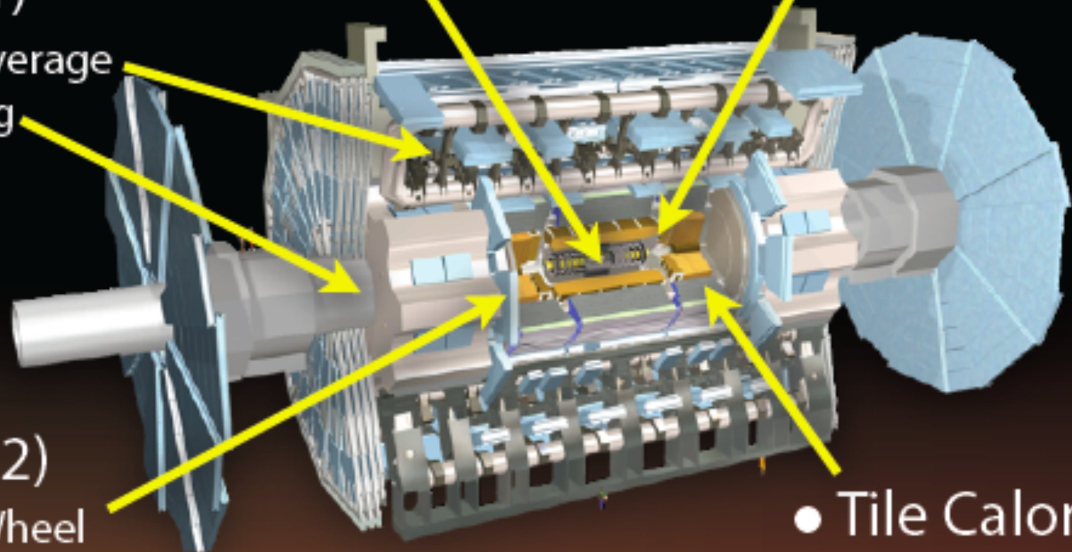
- A real challenge
  - Requires a lot of expertise.
    - *Work for next 2 years will be very challenging*



ATLAS Upgrades up to Phase-1

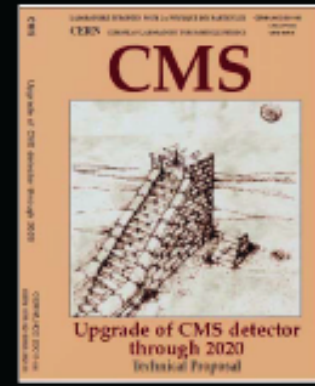


- Insertable B-Layer (LS1)
  - ➡ and new services for Pixels
- LAr Calorimeter (LS2)
  - ➡ fine granularity readout for Level-1
- Muons (LS1)
  - ➡ complete coverage
  - ➡ new shielding
- Level-1 Trigger
  - ➡ new electronics
  - ➡ topological trigger
  - (phased in before LS2)

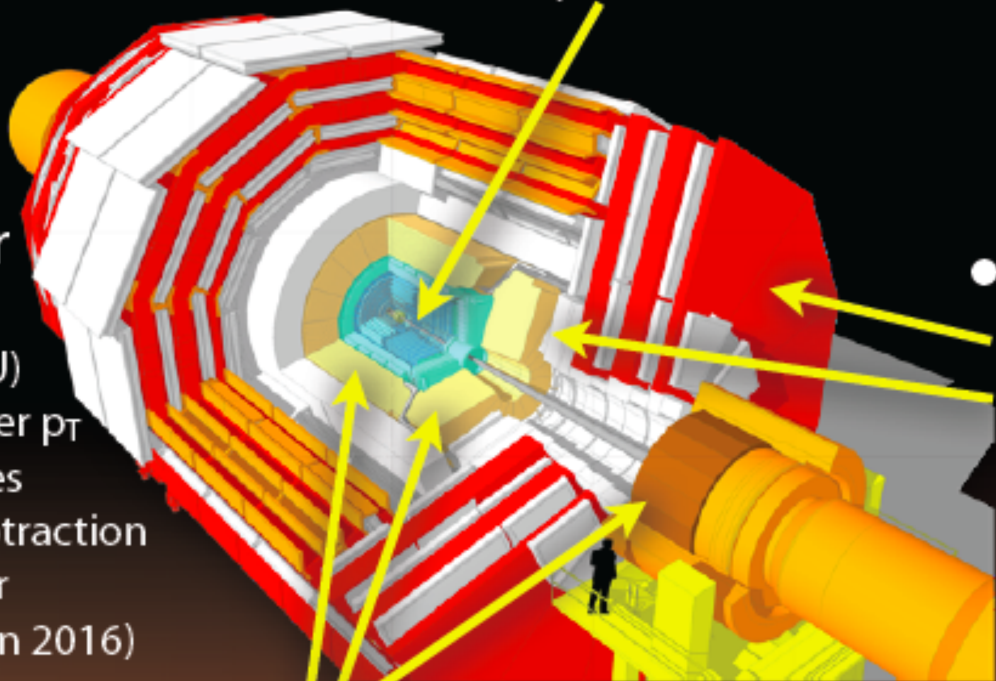


- High Level Trigger farm
  - (phased in before LS2)
- Muons (LS2)
  - ➡ New Small Wheel
- Tile Calorimeter (LS2)
  - ➡ new gap scintillators
  - ➡ new trigger electronics
- ATLAS Forward Physics AFP
  - ➡ 210m downstream from P1 (before LS2)
- Fast Track Trigger FTK (LS2)
  - ➡ HW tracking input to Level-2

CMS Upgrades up to Phase-1



- new Pixel detector
  - ➡ installation in 2016/17 in end of year shutdown



- Level-1 Trigger
  - ➡ new electronics
    - e, γ isolation (PU)
    - μ isolation, better p_T
    - narrower τ-cones
    - jets with PU subtraction
  - ➡ topological trigger

  (ready for operation in 2016)

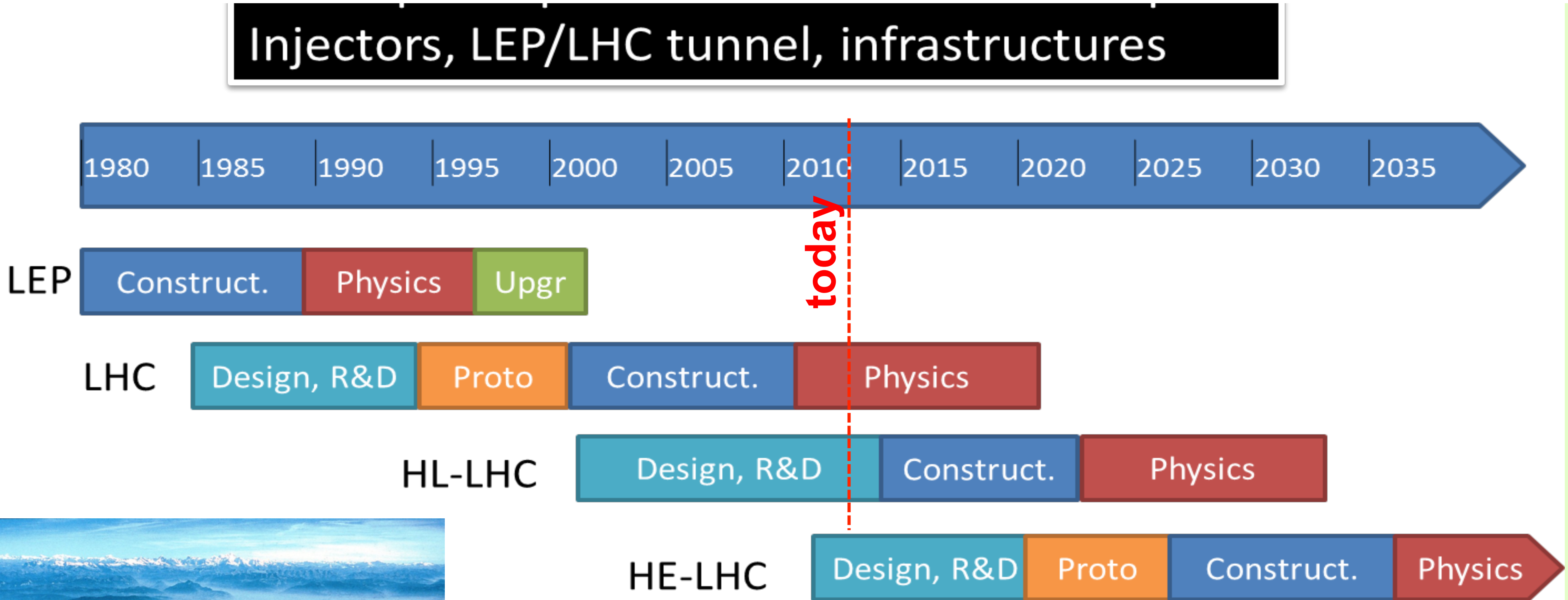
- Muons (LS1)
  - ➡ complete coverage
  - ➡ increase CSC readout granularity

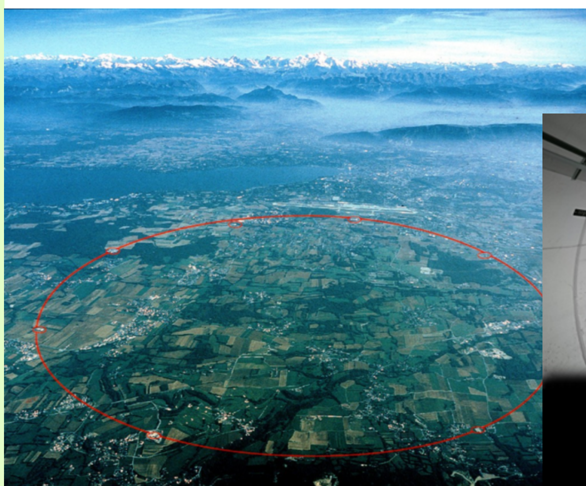
- Hadron Calorimeters (LS2)
  - ➡ new photodetectors, higher Level-1 granularity
    - better background rejection using timing
  - ➡ longitudinal segmentation (5 HB and 3 HE segments)

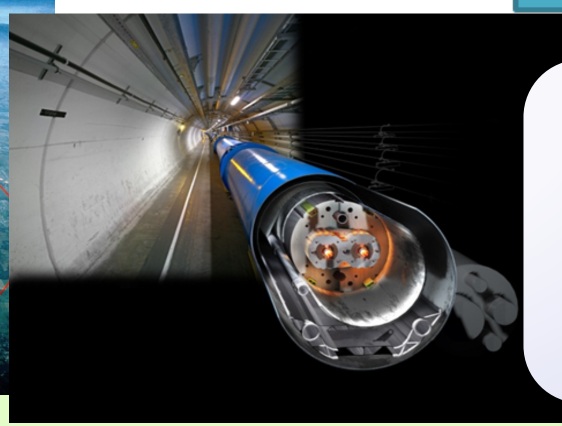
High Luminosity LHC (HL-LHC) and beyond

Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030

- European strategy update document: Approved by CERN Council in May



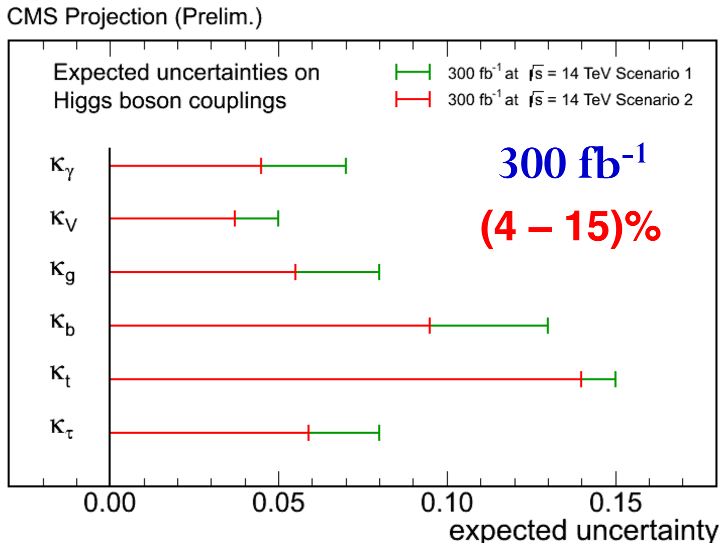


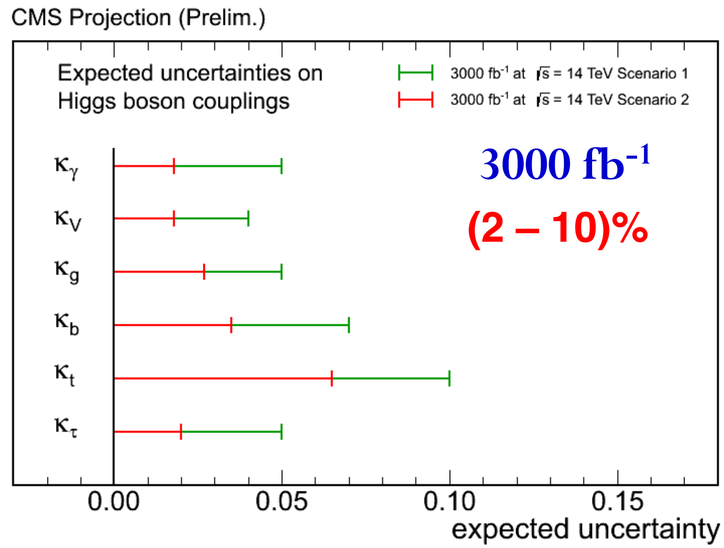


2000 large magnets of 15-20 T
1500 tons of HEP grade Nb3Sn
500 tons of HTS for magnets
100 tons of SC for Sc links

Courtesy L. Rossi

New CMS Higgs projections for 300(0) fb^{-1}





Numbers in brackets are % uncertainties on coupling deviations for [scenario 2, scenario 1]

L (fb^{-1})	κ_γ	κ_V	κ_g	κ_b	κ_t	κ_τ
300	[5, 7]	[4, 5]	[6, 8]	[10, 13]	[14, 15]	[6, 8]
3000	[2, 5]	[2, 3]	[3, 5]	[4, 7]	[7, 10]	[2, 5]

Goal: ultimate precision of ~5% or better

July 1, 2013 J. Olsen – Snowmass Energy Frontier Workshop 31

Bracket precision estimates

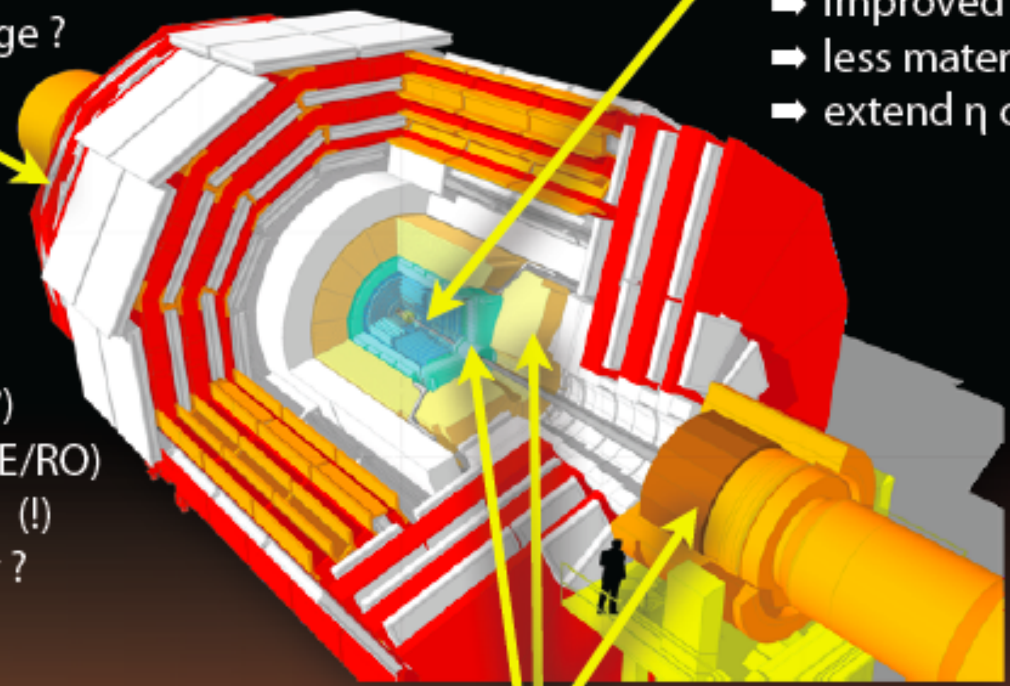
1. Systematics unchanged
2. Theory uncertainties reduced ½, all other systematics ~ $1/\sqrt{(\int L dt)}$

Upgrades target precision Higgs measurements with pileup ~140!! (25 ns and L = 5×10^{34} cm^{-2}s^{-1})

CMS Phase-2 Upgrades

- Muons
  - ➡ complete RPCs in forward region with new technology, GEM or GRPCs
  - ➡ extend η coverage ?

- new Inner Tracker
  - ➡ radiation hardness
  - ➡ better granularity and faster links
  - ➡ improved precision
  - ➡ less material
  - ➡ extend η coverage ?

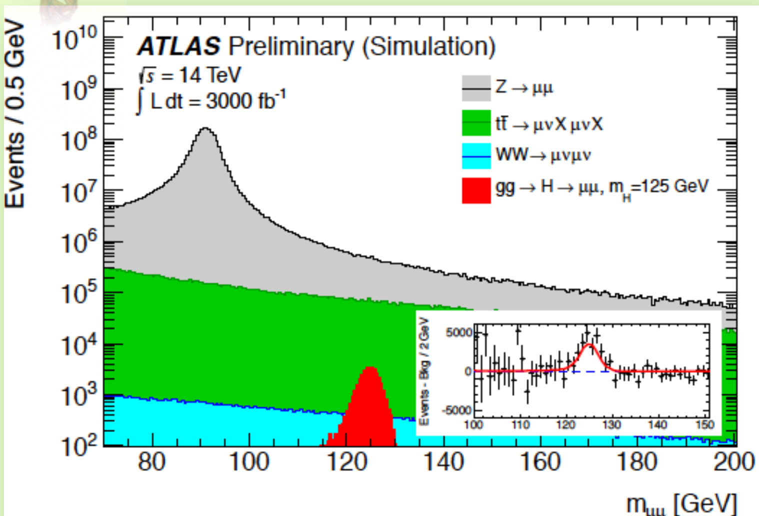


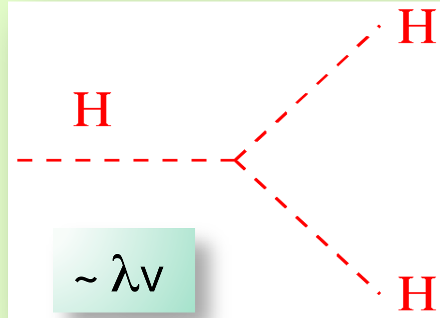
- T/DAQ
  - ➡ Level-1 at 1 *MHz* (?) (requires all new FE/RO)
  - ➡ Tracking at Level-1 (!)
  - ➡ HLT output 10 *kHz* ?

Technical Proposal in 2014

- upgrade/replace Forward Calorimeters
  - ➡ extend η coverage ?
  - ➡ mitigate pileup effects with tracking and precise timing

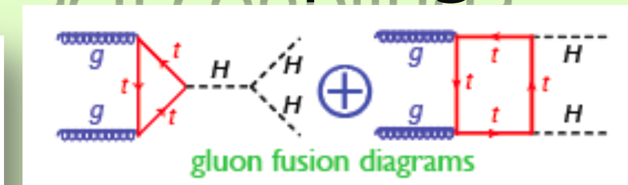
ATLAS Projections: rare decays, self couplings

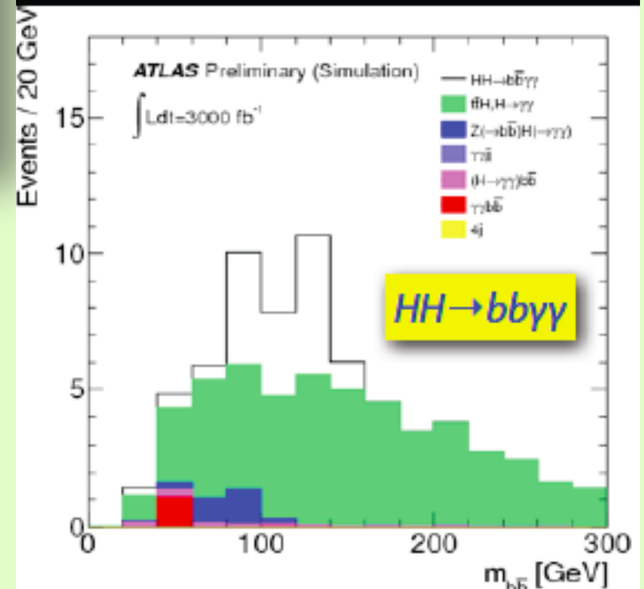




~ λv

$m_H^2 = 2 \lambda v^2$





Atlas-PHYS-PUB-2013-01

- H → μμ
  - Low rate and S/B only 0.2%

    > 6σ with 3000 fb⁻¹

- tt̄H, H → μμ
  - ~ 30 events at 3000 fb⁻¹

    ⇒ top- and μ-Yukawa couplings with a precision on total signal strength of 25%

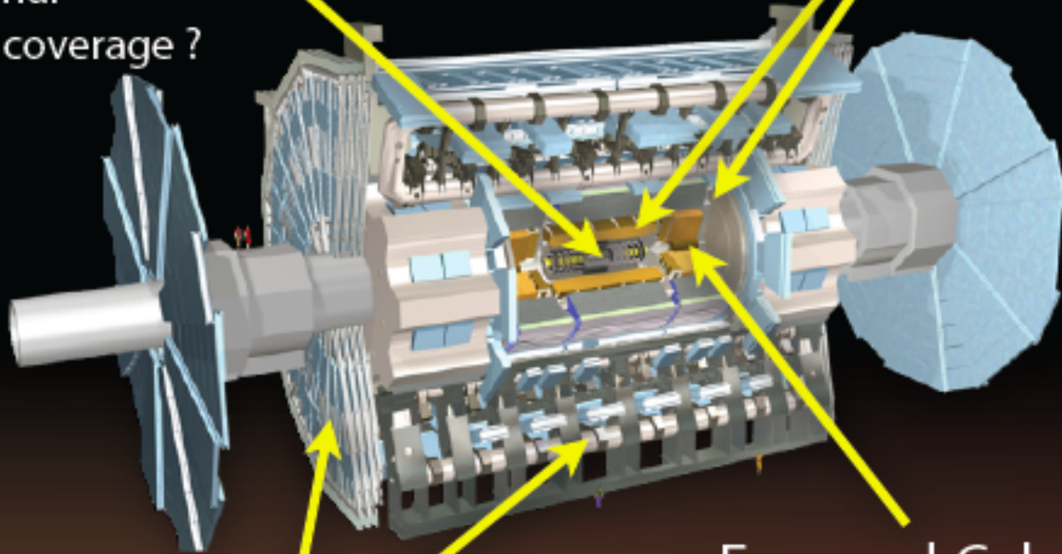
- Higgs self-couplings: ~ 3σ from
  - HH → bbγγ channel with 3000 fb⁻¹
    - HH→ bbττ also promising

  ±30% on λ/λ_{SM} may be achieved

ATLAS Phase-2 Upgrades

- new Inner Tracker
  - ➡ radiation hardness
  - ➡ better granularity and faster links
  - ➡ improved precision
  - ➡ less material
  - ➡ extend η coverage ?

- LAr and Tile Calorimeter
  - ➡ new FE and BE electronics

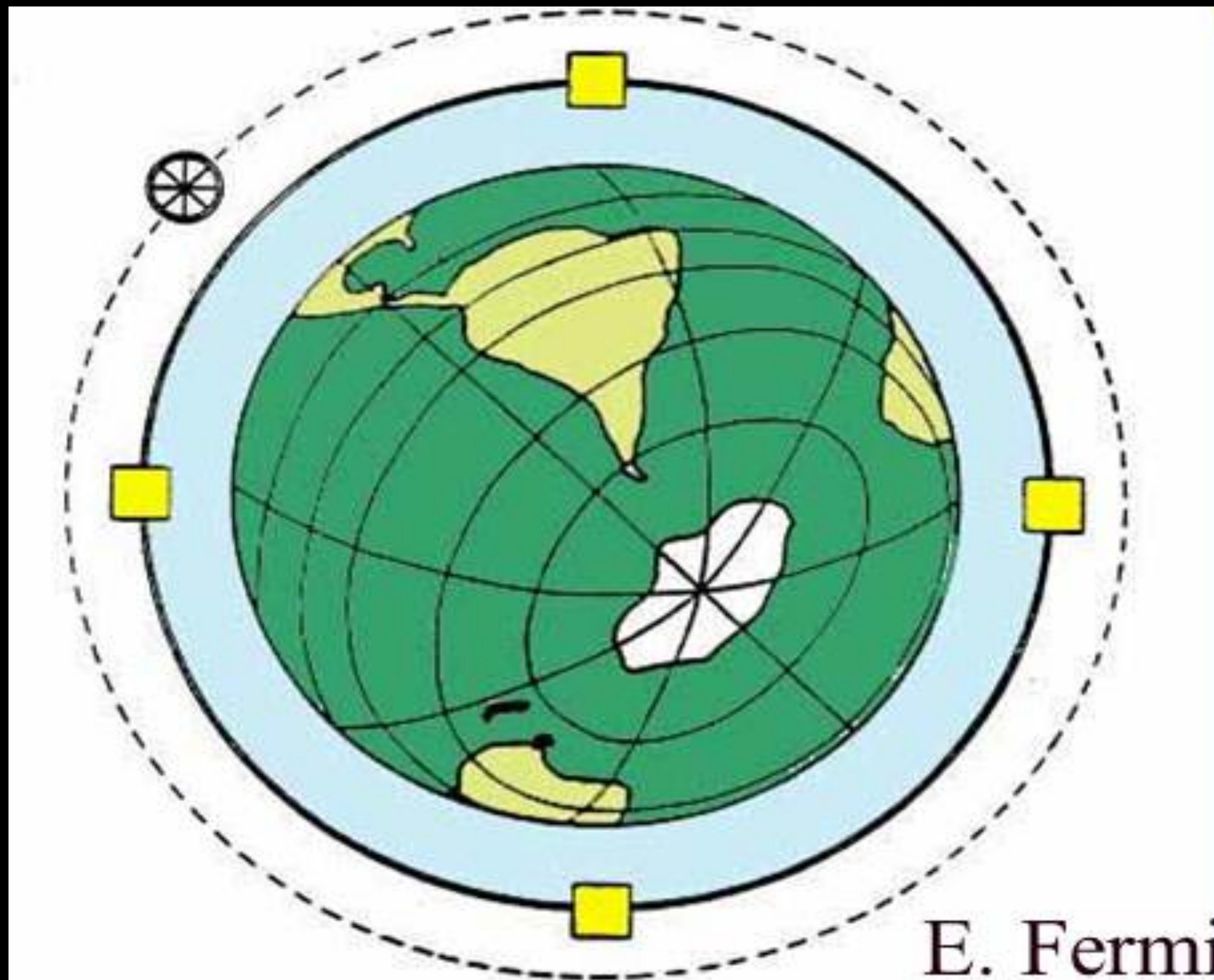


- T/DAQ
  - ➡ Level-0 at 500 *kHz*
  - ➡ Tracks at Level-1
  - ➡ 200 *kHz* input to HLT
  - ➡ output 5 *kHz* ?

- Forward Calorimeters
  - ➡ replace FCal ?
  - ➡ replace HEC cold electronics ?

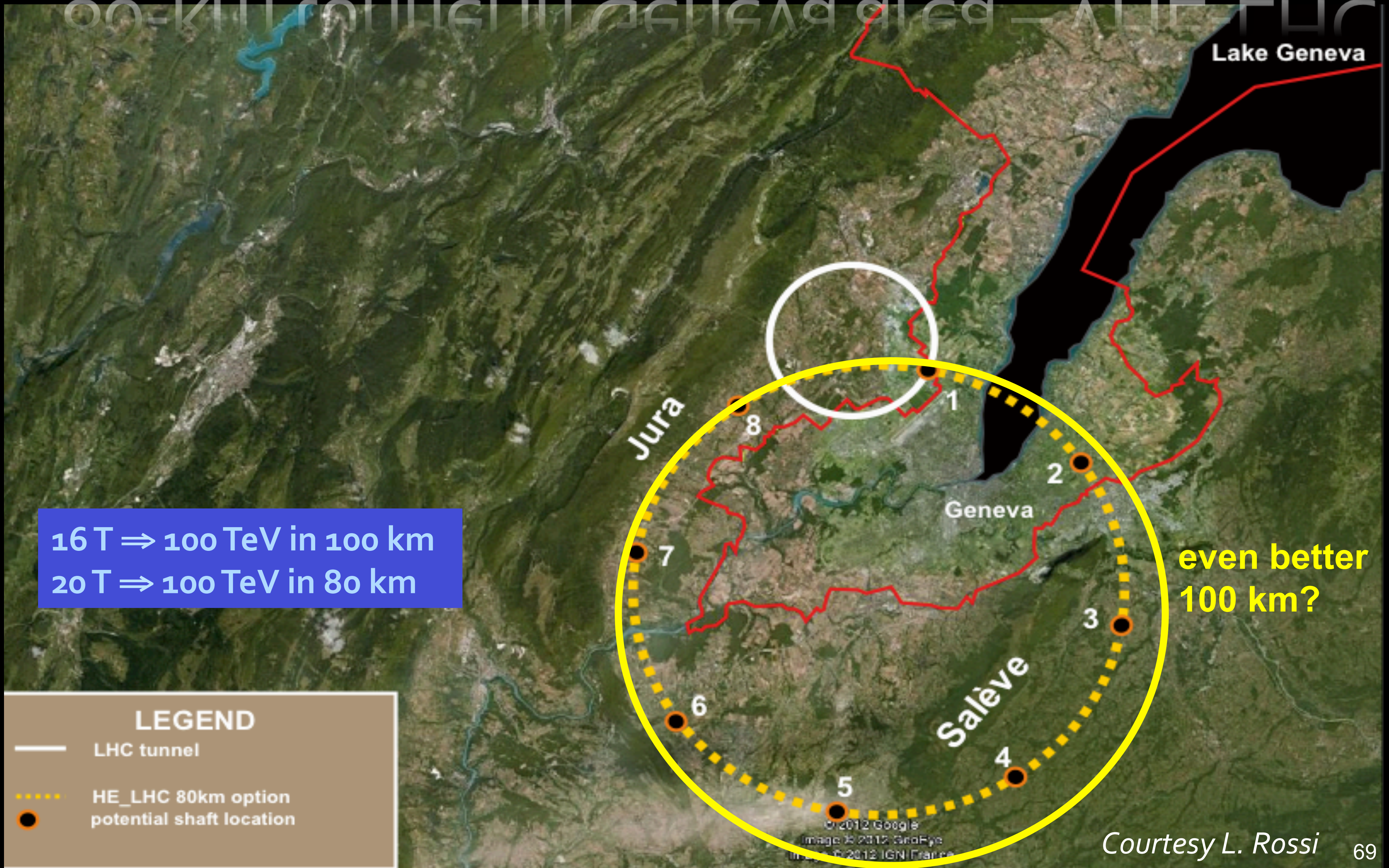
- Muons
  - ➡ new FE electronics
  - ➡ improved resolution

Further into the Future…



Well, maybe not quite this far forward…

80-km tunnel in Geneva area – VHE-LHC



Conclusion

Advancing on 5 fronts

1. *Run 1 Physics*
2. *LS1 consolidation*
3. *Phase 1 Upgrades*
4. *Run 2 preparation of detector, operations, computing, offline, trigger and simulations for physics*
5. *Phase 2 simulation studies to converge on cost, scope, possible baseline scenario(s) plus (staged) options*