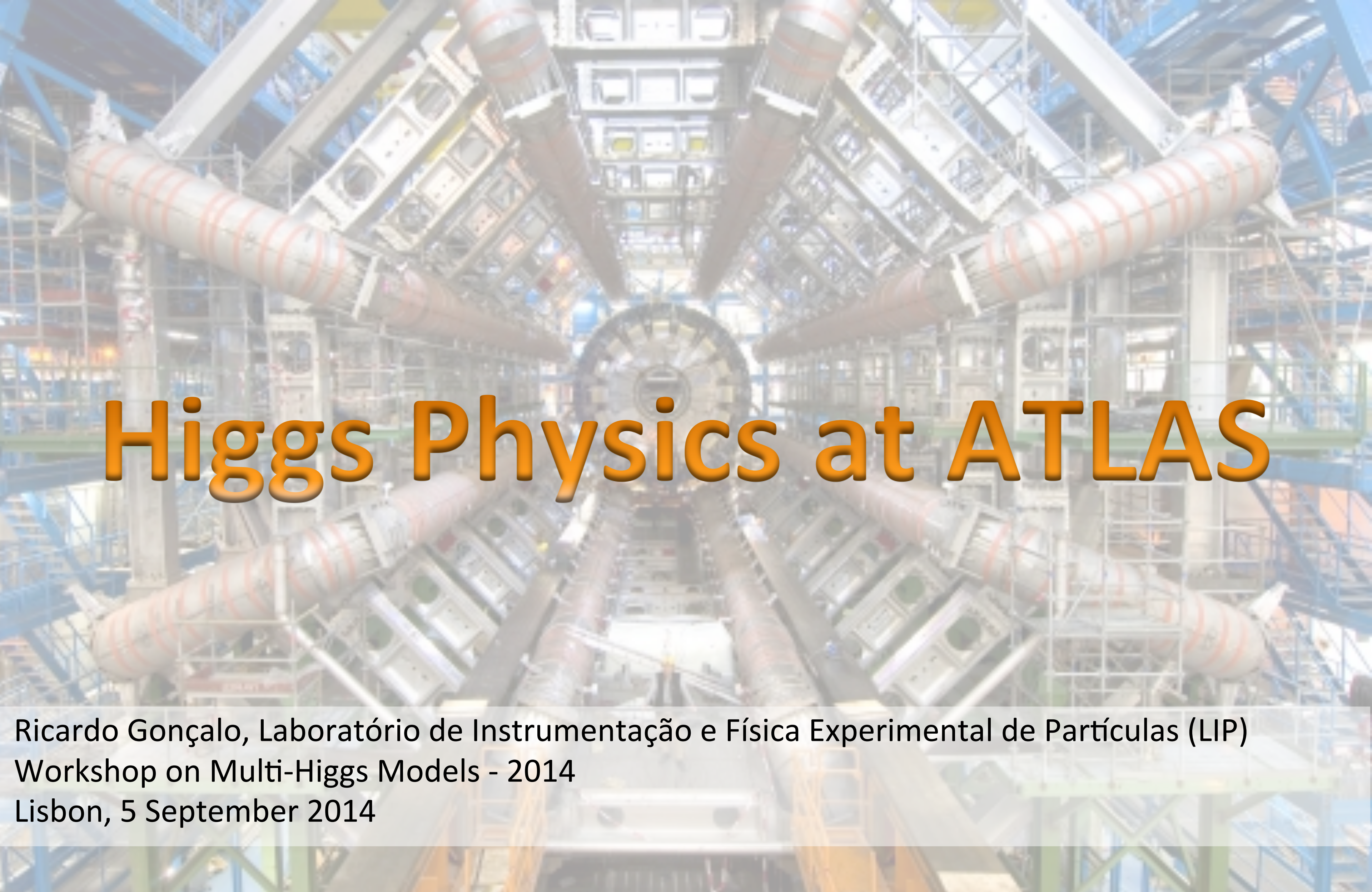

Higgs Physics at ATLAS

Ricardo Gonçalo, Laboratório de Instrumentação e Física Experimental de Partículas (LIP)
Workshop on Multi-Higgs Models - 2014
Lisbon, 5 September 2014

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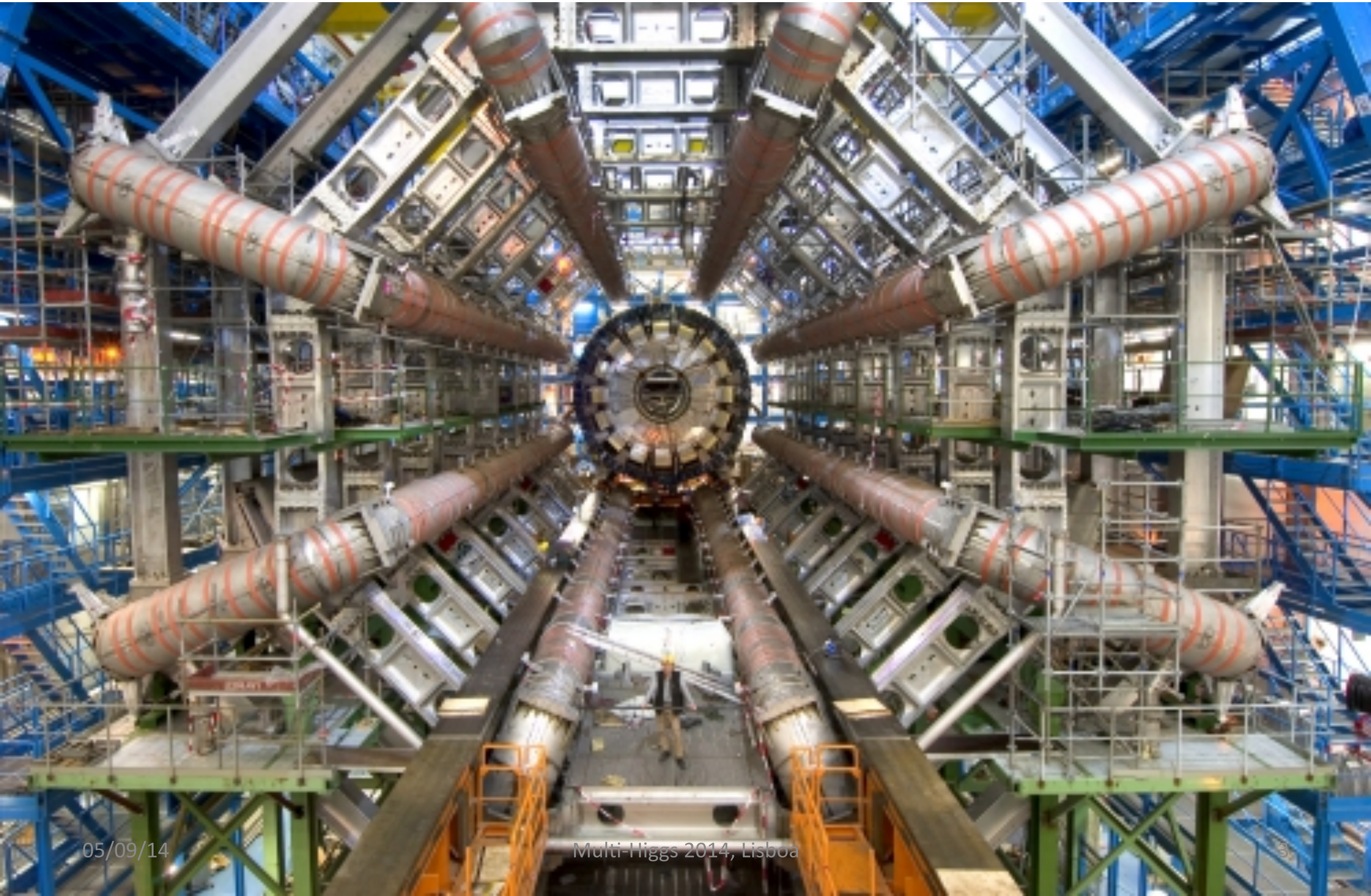
QUALIFICAR É CRESCER.
UNIÃO EUROPEIA
Fundo Social Europeu
QREN QUADRO DE REFERÊNCIA ESTRATÉGICO NACIONAL
ATLAS EXPERIMENT

Outline

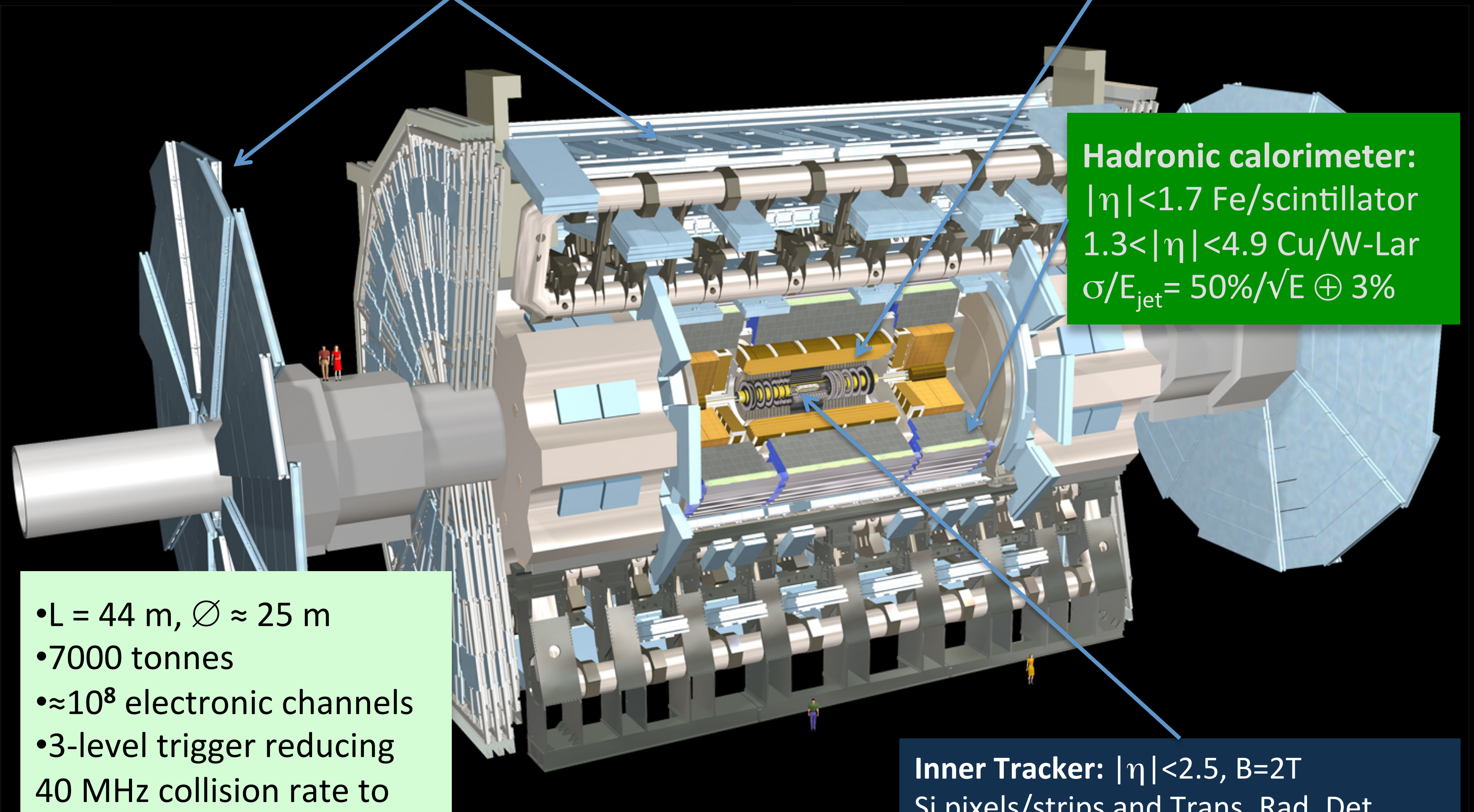
- The ATLAS detector and run-I performance
  - ATLAS vs CMS – strengths and weaknesses
- Higgs Boson Mass and Couplings
  - Recent ATLAS mass measurement
  - New coupling results – what changed?
- Higgs boson width
- Run 2 outlook

The ATLAS Detector



Muon Spectrometer: |η|<2.7
Air-core toroids and gas-based muon chambers
σ/p_T = 2% @ 50GeV to 10% @ 1TeV (ID+MS)

EM calorimeter: |η|<3.2
Pb-LAr Accordion
$\sigma/E = 10\%/\sqrt{E} \oplus 0.7\%$

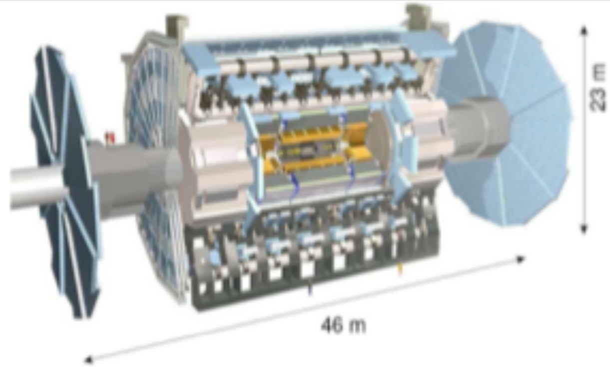
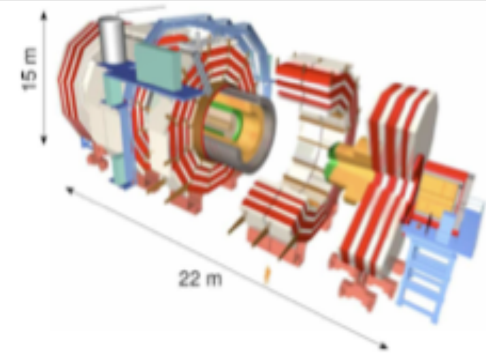


Hadronic calorimeter:
|η|<1.7 Fe/scintillator
1.3<|η|<4.9 Cu/W-Lar
$\sigma/E_{jet} = 50\%/\sqrt{E} \oplus 3\%$

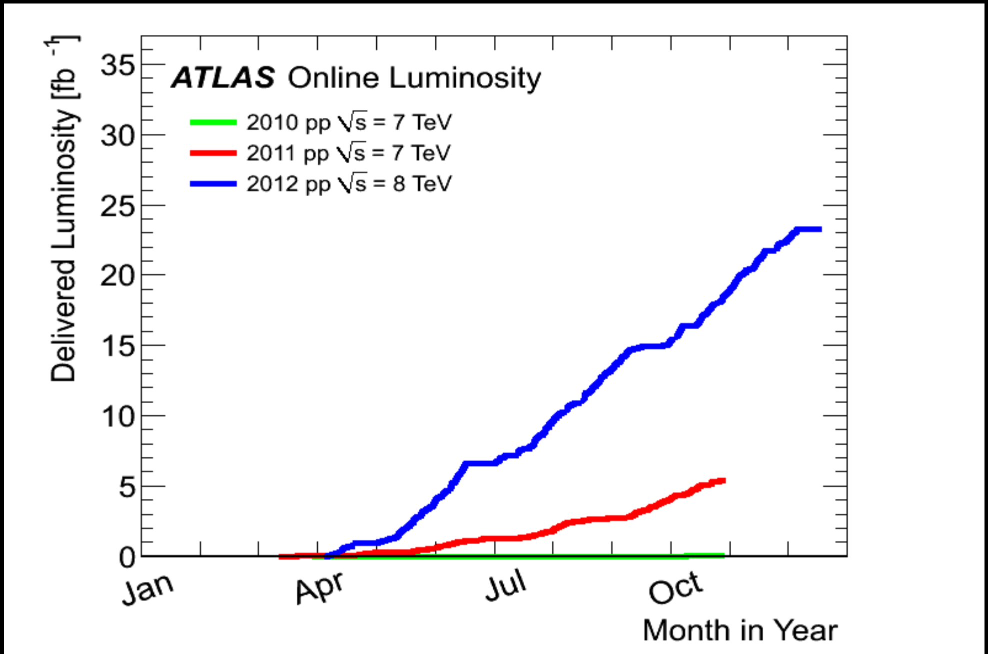
- L = 44 m, ∅ ≈ 25 m
- 7000 tonnes
- ≈10^8 electronic channels
- 3-level trigger reducing 40 MHz collision rate to 200 Hz of events to tape

Inner Tracker: |η|<2.5, B=2T
Si pixels/strips and Trans. Rad. Det.
$\sigma/p_T = 0.05\%\ p_T\ (\text{GeV}) \oplus 1\%$

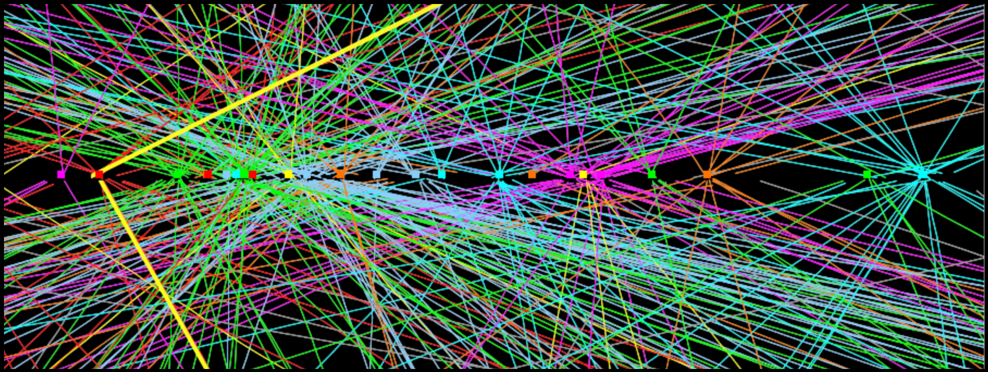
The ATLAS and CMS Detectors In a Nutshell

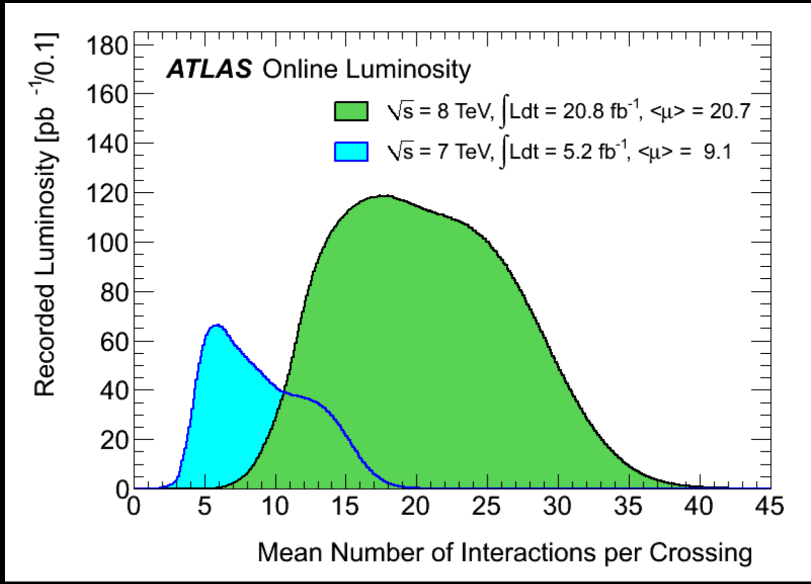
Sub System	ATLAS	CMS
Design		
Magnet(s)	Solenoid (within EM Calo) 2T 3 Air-core Toroids	Solenoid 3.8T Calorimeters Inside
Inner Tracking	Pixels, Si-strips, TRT PID w/ TRT and dE/dx $\sigma_{p_T}/p_T \sim 5 \times 10^{-4} p_T \oplus 0.01$	Pixels and Si-strips PID w/ dE/dx $\sigma_{p_T}/p_T \sim 1.5 \times 10^{-4} p_T \oplus 0.005$
EM Calorimeter	Lead-Larg Sampling w/ longitudinal segmentation $\sigma_E/E \sim 10\%/\sqrt{E} \oplus 0.007$	Lead-Tungstate Crys. Homogeneous w/o longitudinal segmentation $\sigma_E/E \sim 3\%/\sqrt{E} \oplus 0.5\%$
Hadronic Calorimeter	Fe-Scint. & Cu-Larg (fwd) $\gtrsim 11\lambda_0$ $\sigma_E/E \sim 50\%/\sqrt{E} \oplus 0.03$	Brass-scint. $\gtrsim 7\lambda_0$ Tail Catcher $\sigma_E/E \sim 100\%/\sqrt{E} \oplus 0.05$
Muon Spectrometer System Acc. ATLAS 2.7 & CMS 2.4	Instrumented Air Core (std. alone) $\sigma_{p_T}/p_T \sim 4\%$ (at 50 GeV) $\sim 11\%$ (at 1 TeV)	Instrumented Iron return yoke $\sigma_{p_T}/p_T \sim 1\%$ (at 50 GeV) $\sim 10\%$ (at 1 TeV)

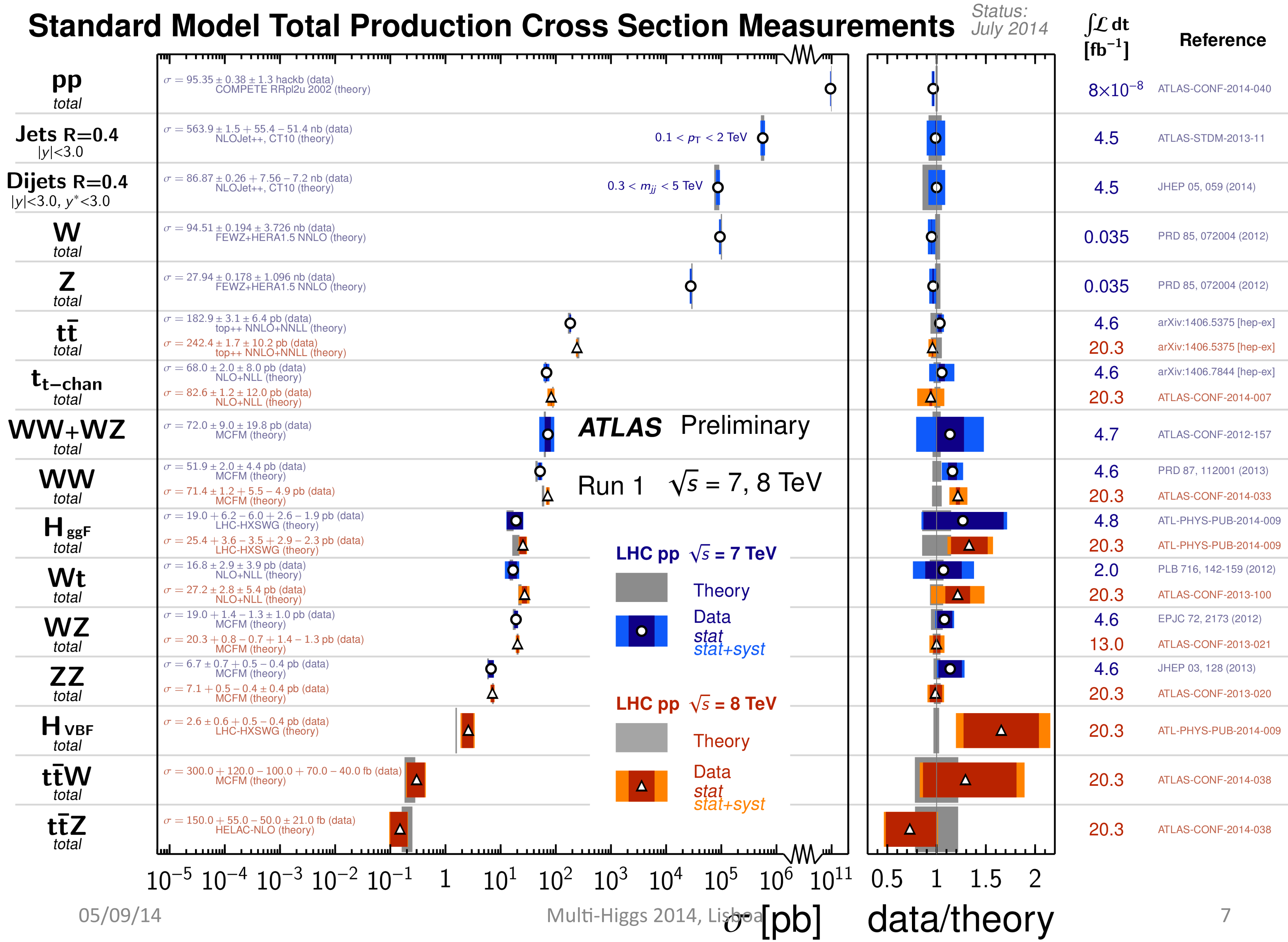
LHC and ATLAS Performance



- Outstanding performance of LHC and ATLAS detector!
- $7.7\times10^{33}cm^{-2}s^{-1}$ peak luminosity
- Up to ≈40 pileup interactions
- 95% efficiency after physics-quality data requirements
- 20.3 fb^{-1} at 8 TeV
- 4.7-4.9 fb^{-1} at 7 TeV



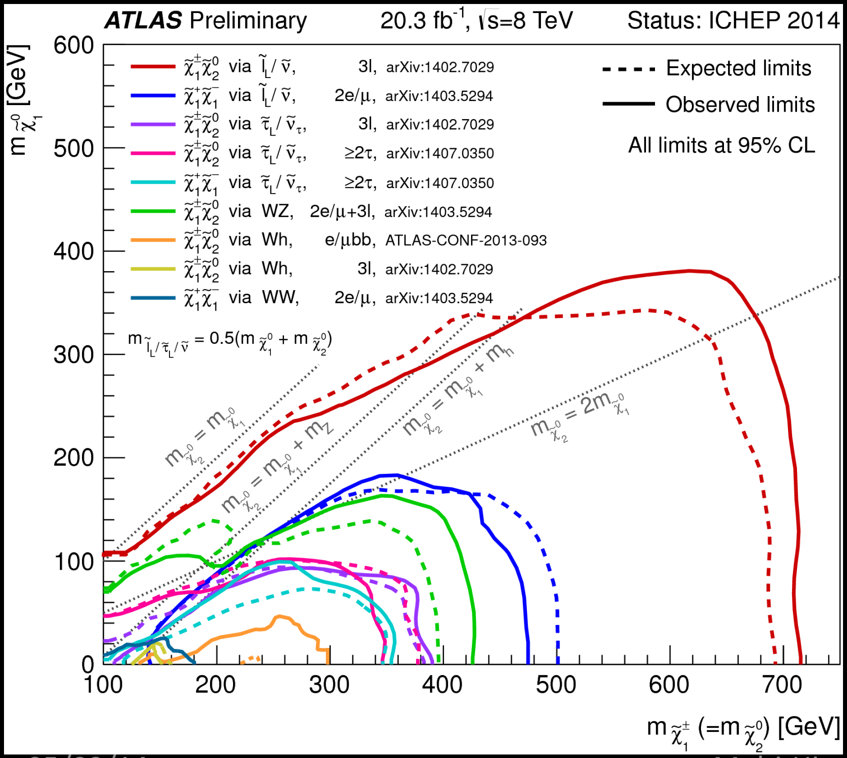


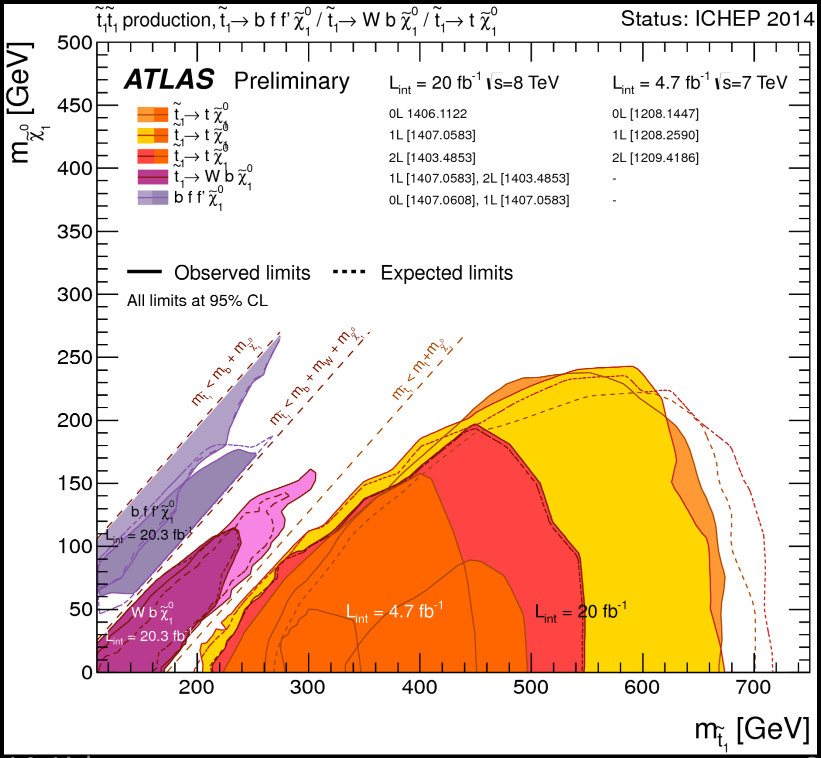


Standard Model Total Production Cross Section Measurements
Status: July 2014
∫ℒ dt [fb⁻¹]
Reference
pp total
σ = 95.35 ± 0.38 ± 1.3 mb (data)
COMPETE RRpl2u 2002 (theory)
8×10⁻⁸ ATLAS-CONF-2014-040
Jets R=0.4 |y|<3.0
σ = 563.9 ± 1.5 + 55.4 − 51.4 nb (data)
NLOJet++, CT10 (theory)
0.1 < pT < 2 TeV
4.5 ATLAS-STDM-2013-11
Dijets R=0.4 |y|<3.0, y*<3.0
σ = 86.87 ± 0.26 + 7.56 − 7.2 nb (data)
NLOJet++, CT10 (theory)
0.3 < mjj < 5 TeV
4.5 JHEP 05, 059 (2014)
W total
σ = 94.51 ± 0.194 ± 3.726 nb (data)
FEWZ+HERA1.5 NNLO (theory)
0.035 PRD 85, 072004 (2012)
Z total
σ = 27.94 ± 0.178 ± 1.096 nb (data)
FEWZ+HERA1.5 NNLO (theory)
0.035 PRD 85, 072004 (2012)
tt̄ total
σ = 182.9 ± 3.1 ± 6.4 pb (data)
top++ NNLO+NNLL (theory)
4.6 arXiv:1406.5375 [hep-ex]
σ = 242.4 ± 1.7 ± 10.2 pb (data)
top++ NNLO+NNLL (theory)
20.3 arXiv:1406.5375 [hep-ex]
tt−chan total
σ = 68.0 ± 2.0 ± 8.0 pb (data)
NLO+NLL (theory)
4.6 arXiv:1406.7844 [hep-ex]
σ = 82.6 ± 1.2 ± 12.0 pb (data)
NLO+NLL (theory)
20.3 ATLAS-CONF-2014-007
WW+WZ total
σ = 72.0 ± 9.0 ± 19.8 pb (data)
MCFM (theory)
4.7 ATLAS-CONF-2012-157
WW total
σ = 51.9 ± 2.0 ± 4.4 pb (data)
MCFM (theory)
4.6 PRD 87, 112001 (2013)
σ = 71.4 ± 1.2 + 5.5 − 4.9 pb (data)
MCFM (theory)
20.3 ATLAS-CONF-2014-033
H ggF total
σ = 19.0 + 6.2 − 6.0 + 2.6 − 1.9 pb (data)
LHC-HXSWG (theory)
4.8 ATL-PHYS-PUB-2014-009
σ = 25.4 + 3.6 − 3.5 + 2.9 − 2.3 pb (data)
LHC-HXSWG (theory)
20.3 ATL-PHYS-PUB-2014-009
Wt total
σ = 16.8 ± 2.9 ± 3.9 pb (data)
NLO+NLL (theory)
2.0 PLB 716, 142-159 (2012)
σ = 27.2 ± 2.8 ± 5.4 pb (data)
NLO+NLL (theory)
20.3 ATLAS-CONF-2013-100
WZ total
σ = 19.0 + 1.4 − 1.3 ± 1.0 pb (data)
MCFM (theory)
4.6 EPJC 72, 2173 (2012)
σ = 20.3 + 0.8 − 0.7 + 1.4 − 1.3 pb (data)
MCFM (theory)
13.0 ATLAS-CONF-2013-021
ZZ total
σ = 6.7 ± 0.7 + 0.5 − 0.4 pb (data)
MCFM (theory)
4.6 JHEP 03, 128 (2013)
σ = 7.1 + 0.5 − 0.4 ± 0.4 pb (data)
MCFM (theory)
20.3 ATLAS-CONF-2013-020
H VBF total
σ = 2.6 ± 0.6 + 0.5 − 0.4 pb (data)
LHC-HXSWG (theory)
20.3 ATL-PHYS-PUB-2014-009
tt̄W total
σ = 300.0 + 120.0 − 100.0 + 70.0 − 40.0 fb (data)
MCFM (theory)
20.3 ATLAS-CONF-2014-038
tt̄Z total
σ = 150.0 + 55.0 − 50.0 ± 21.0 fb (data)
HELAC-NLO (theory)
20.3 ATLAS-CONF-2014-038
ATLAS Preliminary
Run 1 √s = 7, 8 TeV
LHC pp √s = 7 TeV
Theory
Data
stat
stat+syst
LHC pp √s = 8 TeV
Theory
Data
stat
stat+syst
10⁻⁵ 10⁻⁴ 10⁻³ 10⁻² 10⁻¹ 1 10¹ 10² 10³ 10⁴ 10⁵ 10⁶ 10¹¹
σ [pb]
0.5 1 1.5 2
data/theory

Many BSM direct searches

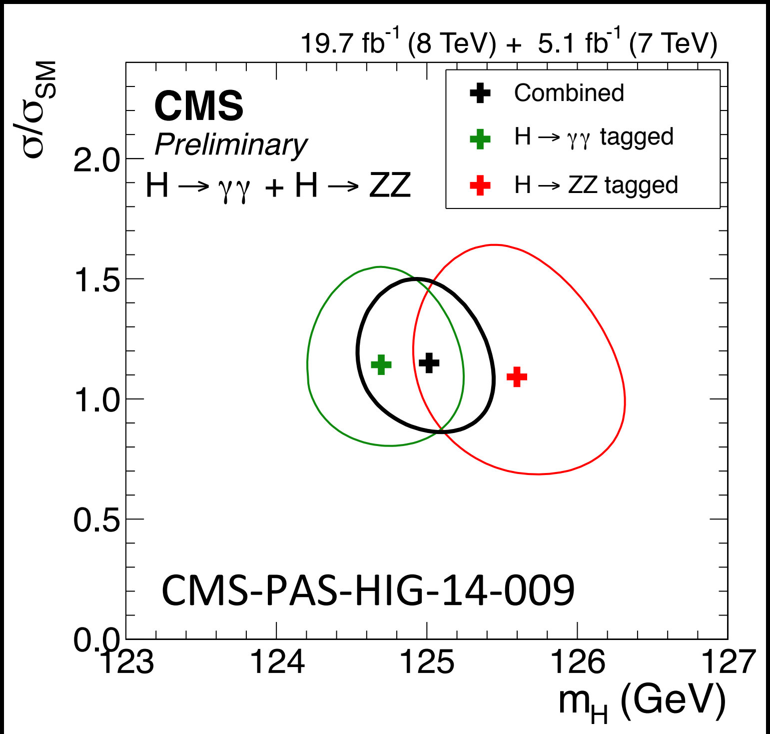
- SUSY spectrum explored to ≈TeV scale
- Many other scenarios explored up to ≈1 – ≈10 TeV: extra dimensions, new gauge bosons, Dark matter candidates, leptoquarks, fermion substructure, new heavy quarks, contact interactions, etc
- Nothing new… so far!

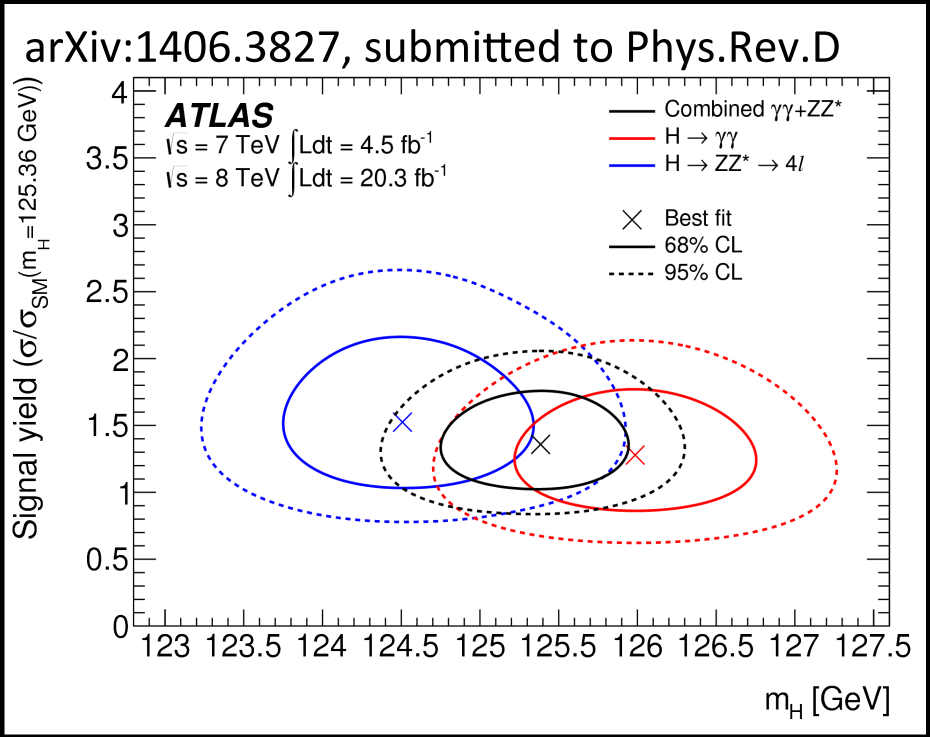




Higgs in ATLAS

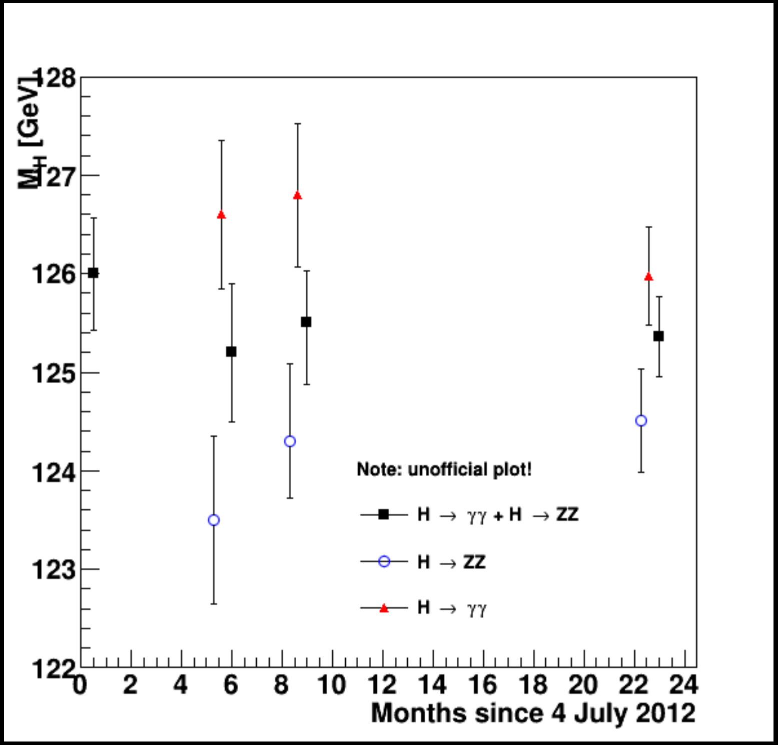
Higgs Boson Mass

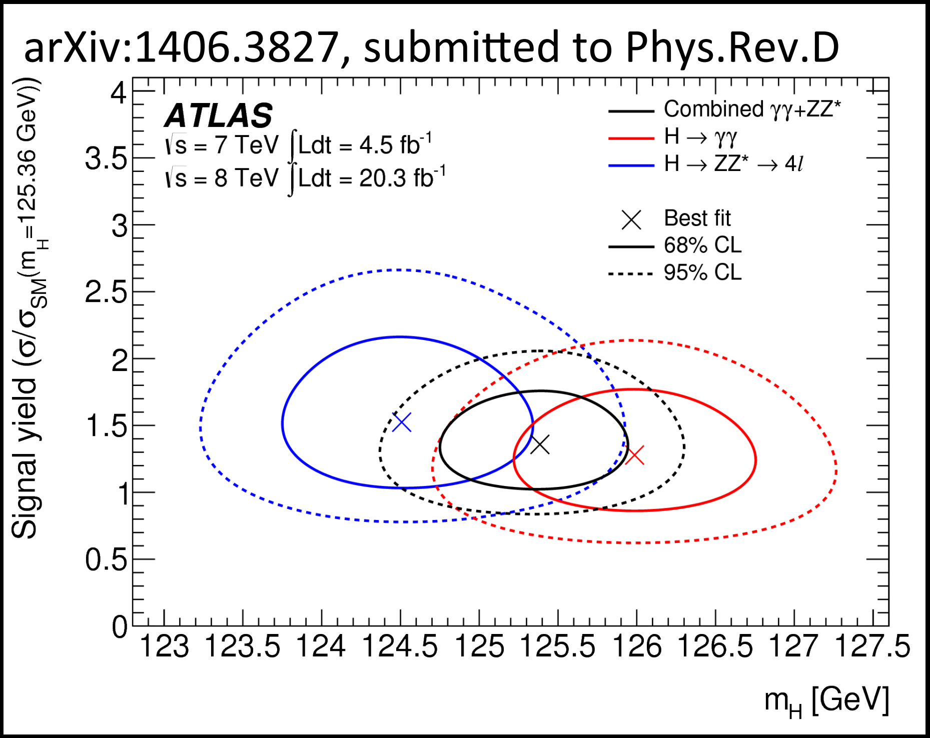




- New combined: m_H= 125.36 ± 0.37 (stat.) ± 0.18 (syst.) GeV
- $m_{\gamma\gamma}$=125.98 ± 0.42 (stat.) ± 0.28 (syst.) GeV
- m_{ZZ}=124.51 ± 0.52(stat.) ± 0.06(syst.) GeV
- CMS: m_H=125.03 $^{+0.26}_{-0.27}$ (stat.) $^{+0.13}_{-0.15}$ (syst.) GeV

Higgs Boson Mass

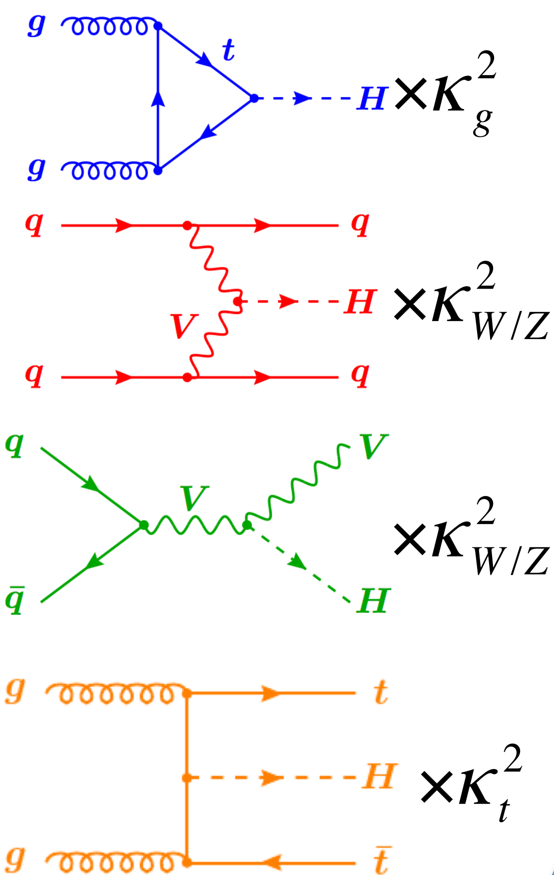




- New combined: m_H= 125.36 ± 0.37 (stat.) ± 0.18 (syst.) GeV
- $m_{\gamma\gamma}$ = 125.98 ± 0.42 (stat.) ± 0.28 (syst.) GeV
- m_{ZZ} = 124.51 ± 0.52(stat.) ± 0.06(syst.) GeV
- Old combination (PLB 726(2013)88): m_H= 125.5 ±0.2 (stat) ±0.6 (syst) GeV
- $m_{\gamma\gamma}$ = 126.8 ± 0.2 (stat.) ± 0.7 (syst.) GeV
- m_{ZZ} = 124.3 $\pm^{+0.6}_{-0.5}$ (stat.) $\pm^{+0.5}_{-0.3}$ (syst.) GeV

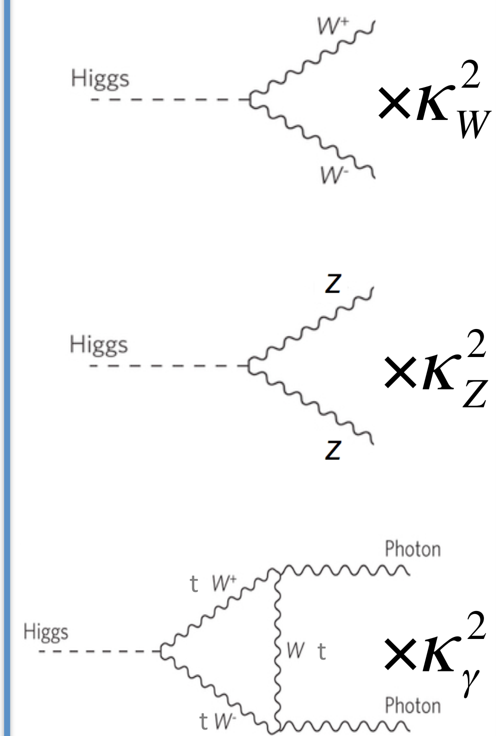
Combining Higgs Channels

Production



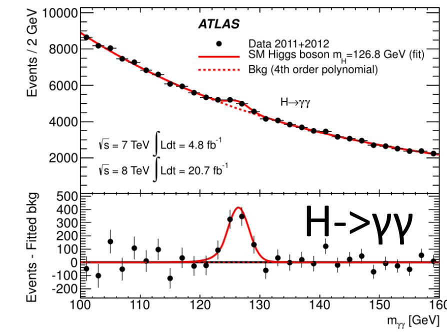
×

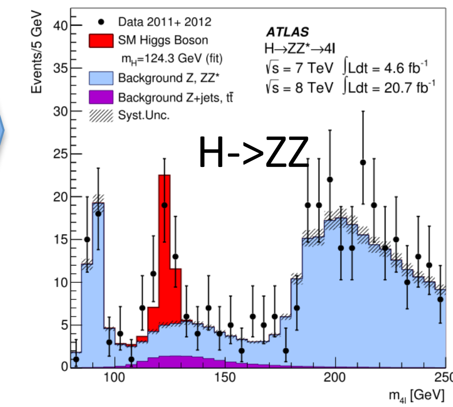
Decay

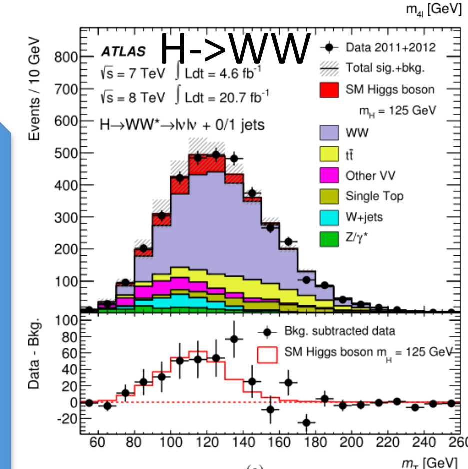


FIT

Backgrounds +







A bit more technically

- **Assumptions:**
  - Single resonance (at $m_H = 125.5$GeV)
  - No modification of tensor structure of SM Lagrangian:
    - i.e. H has $J^P = 0^+$
  - Narrow width approximation holds
    - i.e. rate for process i ➔ H ➔ f is: $\sigma \times BR = \frac{\sigma_{i \to H} \times \Gamma_{H \to f}}{\Gamma_H}$

- **Free parameters** in framework:
  - Coupling scale factors: κ_j^2
  - Total Higgs width: κ_H^2
  - Or ratios of coupling scale factors: $\lambda_{ij} = \kappa_i / \kappa_j$

$$\sigma_i = \kappa_i^2 \cdot \sigma_i^{SM}; \Gamma_f = \kappa_f^2 \cdot \Gamma_f^{SM}; \Gamma_H = \kappa_H^2 \cdot \Gamma_H^{SM}$$

- Tree-level motivated framework
  - Useful for **studying deviations** in data with respect to expectations
    - E.g. extract coupling scale factor to weak bosons κ_V by setting $\kappa_W = \kappa_Z = \kappa_V$
  - Not same thing as fitting a new model to the data

Higgs couplings: $H\rightarrow\gamma\gamma$ and $H\rightarrow ZZ$

- $H\rightarrow\gamma\gamma$ (arXiv: 1408.7084) : $\mu_{\gamma\gamma} = \sigma/\sigma_{SM} = 1.17 \pm 0.27$
- $H\rightarrow ZZ$ (arXiv: 1408.5191) : $\mu_{ZZ} = \sigma/\sigma_{SM} = 1.44^{+0.40}_{-0.33}$

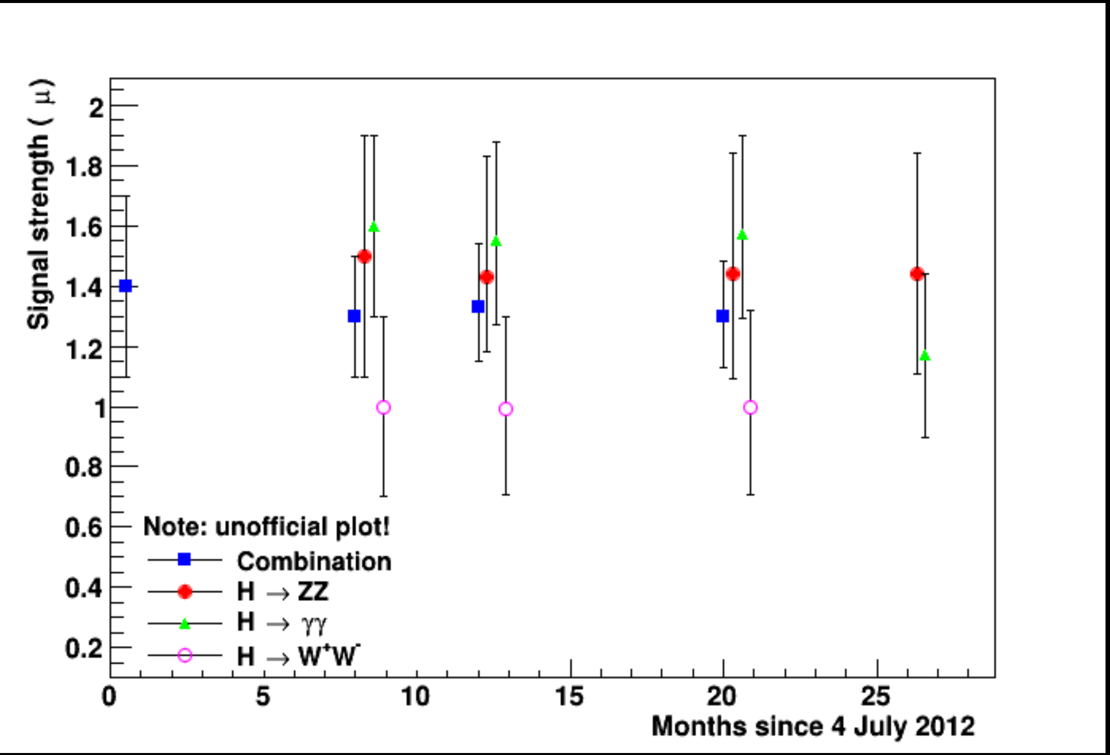
- Old combination (PLB 726 (2013) 88):
- $\mu_{\gamma\gamma} = \sigma/\sigma_{SM} = 1.55^{+0.33}_{-0.28}$
- $\mu_{ZZ} = \sigma/\sigma_{SM} = 1.43^{+0.40}_{-0.35}$

- Large change in $H\rightarrow\gamma\gamma$!!

- $\mu_{\gamma\gamma}$ now SM compatible

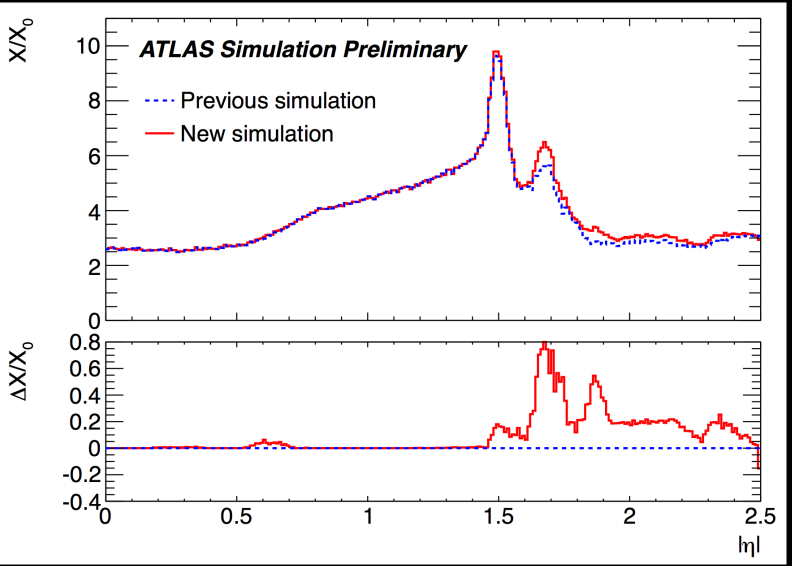
- $\mu_{\gamma\gamma}$ uncertainty increased !?

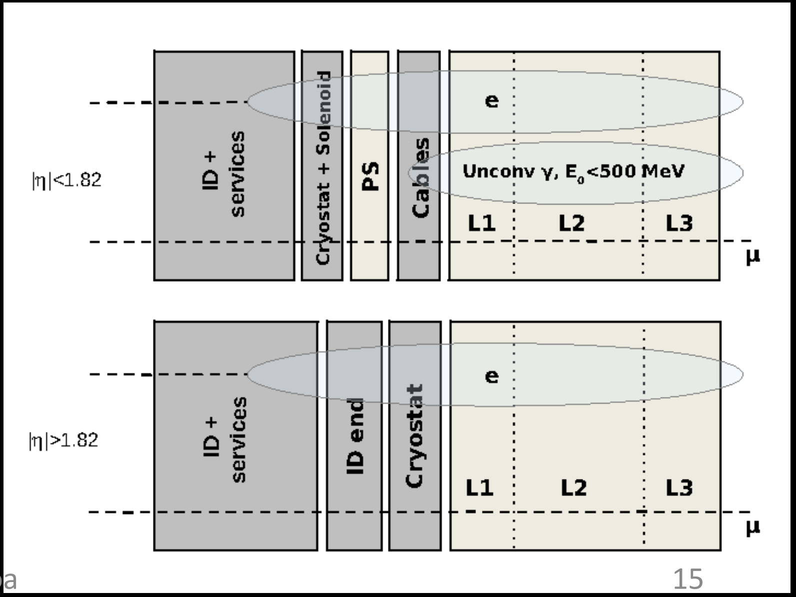
- $H\rightarrow ZZ$ unchanged



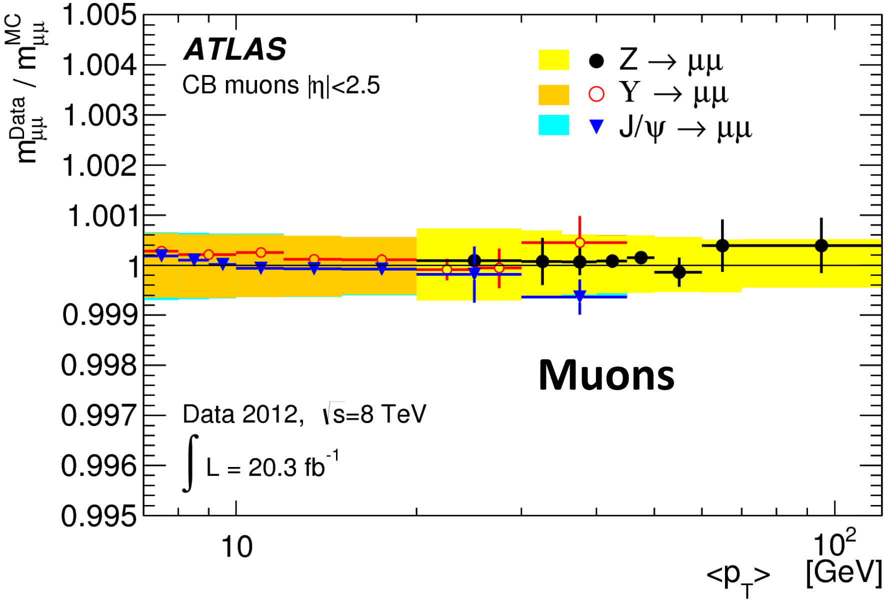
What happened?

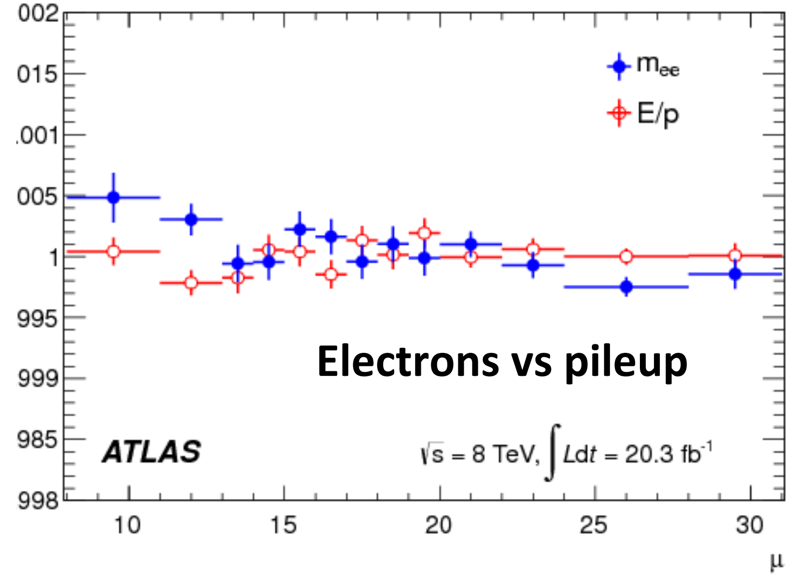
- New electron and photon energy calibrations
  - Intercalibration of calorimeter layers
  - New map of material in front of calorimeter
- Multivariate regression to calibrate e and γ
  - Inputs: cluster position, calorimeter related quantities (deposit per layer etc), tracks
- Improved muon momentum scale and resolution systematics
- Used large calibration samples accumulated during the run:
  - Z→ee (6.6M), Z→μμ (9M), J/ψ→μμ (6M) to determine calibration corrections
  - J/ψ→ee (0.3M), Z→eeγ (6.6M), ϒ→μμ (5M) to verify calibrations
- **Bottom line**: improved systematics from **ultimate Run-I detector calibration**
  - **10% improvement** on $m_{\gamma\gamma}$ resolution!
  - **≈x2 improvement** on γ resolution systematic uncertainty
  - **≈10% improvement** on μ(H→γγ) uncertainty

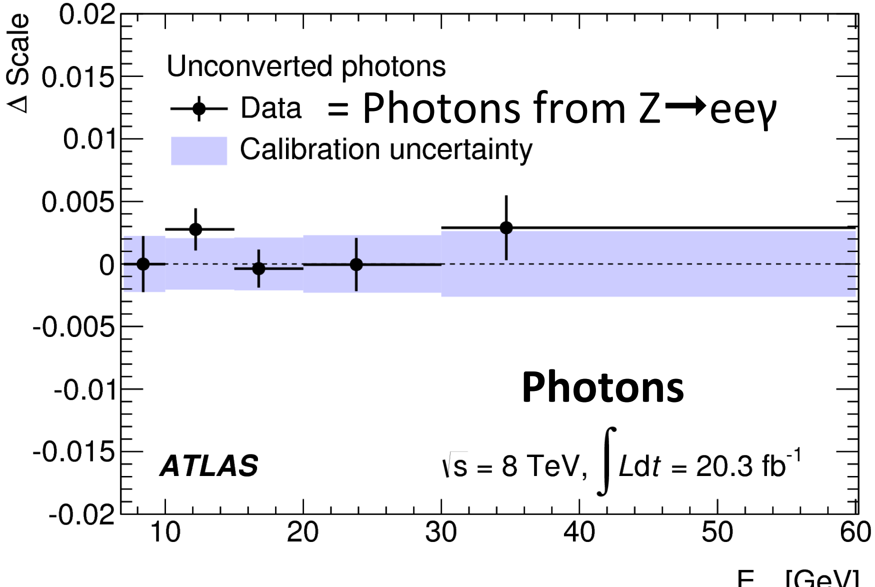


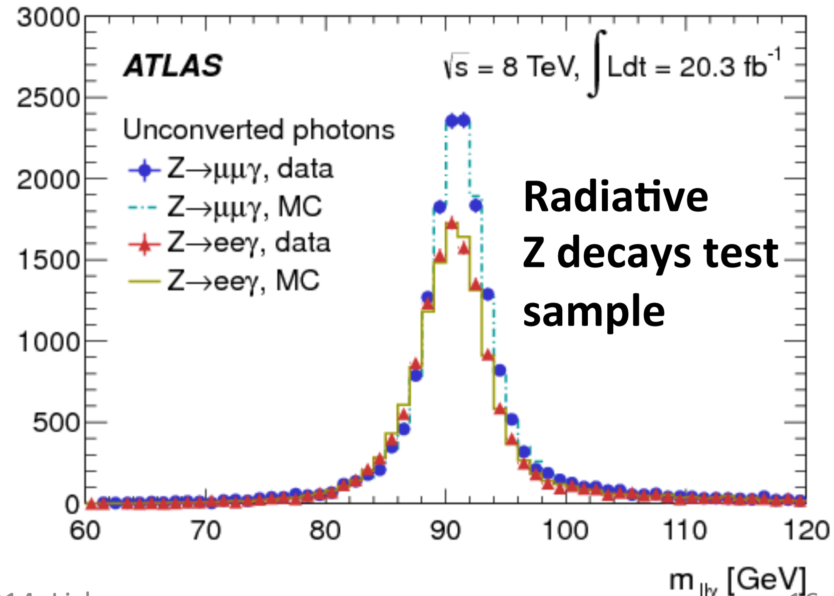


arXiv:1406.3827, CERN-PH-EP-2014-153

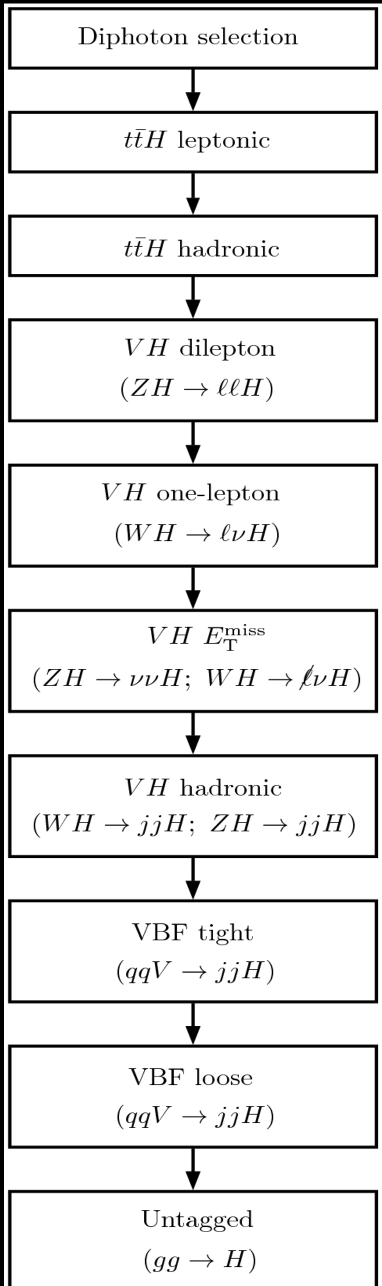








H→γγ Analysis



γγ, 105<$m_{\gamma\gamma}$<160GeV

1 e/μ and b-jets

No e/μ,
5-6 jets incl. b-jets

2 e/μ, $m_{ee/\mu\mu} \approx m_Z$

1 e/μ, E_t^{miss}

High E_t^{miss}

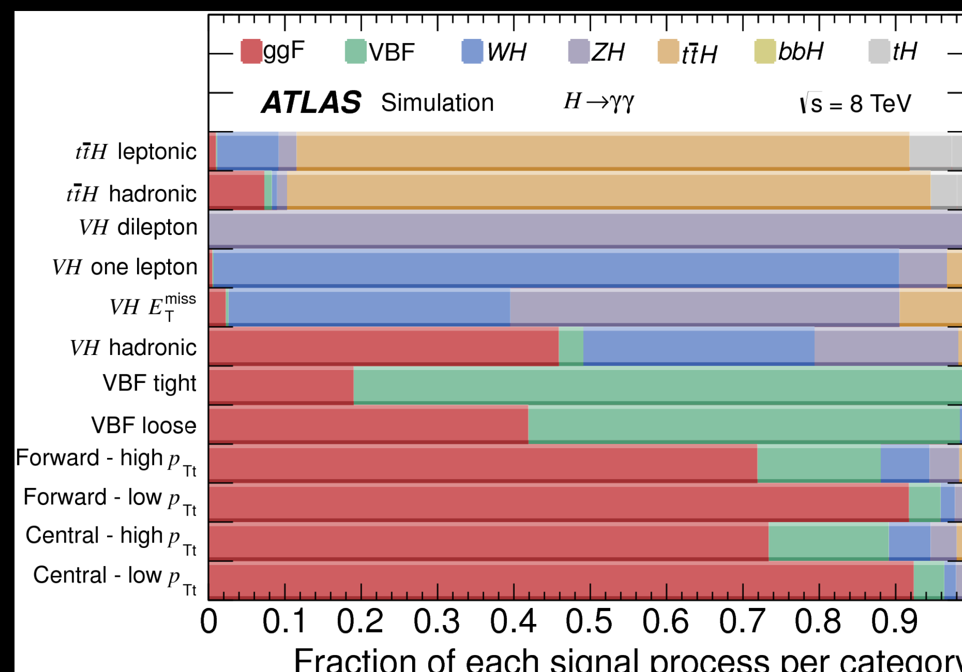
2 jets, $m_{jj} \approx m_{Z/W}$

|Δη(lead jets)|>2, BDT tight

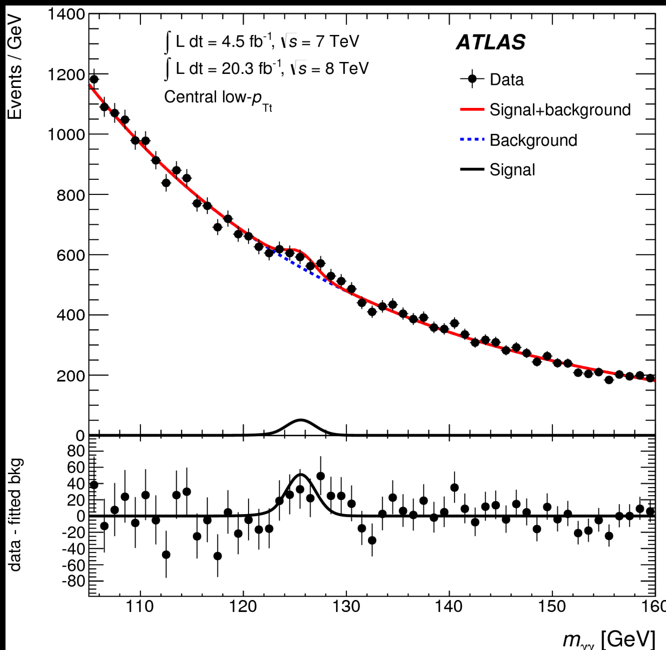
|Δη(lead jets)|>2, BDT loose

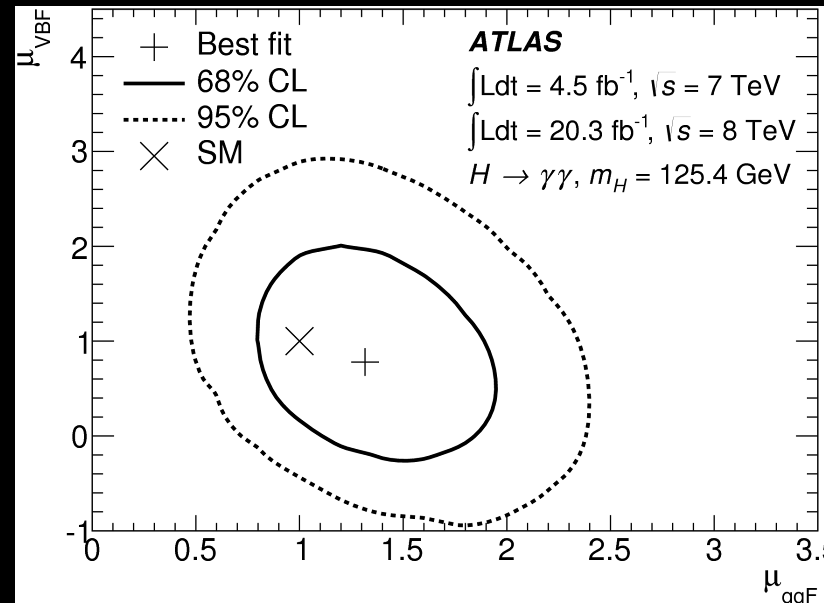
Untagged: 4 categories
Dominated by ggF

- Analysis categories optimized for measuring signal strength
- m_H set to 125.4 GeV, as determined in arXiv:1406.3827
- 20% reduction in total uncertainty with respect to an inclusive analysis



H→γγ Analysis (cont.)





$$\mu_{\text{ggF}} = 1.32 \ \pm 0.32 \text{ (stat.) } {}^{+0.13}_{-0.09} \text{ (syst.) } {}^{+0.19}_{-0.11} \text{ (theory)}$$
$$= 1.32 \pm 0.38,$$
$$\mu_{\text{VBF}} = 0.8 \ \pm 0.7 \text{ (stat.) } {}^{+0.2}_{-0.1} \text{ (syst.) } {}^{+0.2}_{-0.3} \text{ (theory)}$$
$$= 0.8 \pm 0.7,$$
$$\mu_{WH} = 1.0 \pm 1.5 \text{ (stat.) } {}^{+0.3}_{-0.2} \text{ (syst.) } {}^{+0.2}_{-0.1} \text{ (theory)}$$
$$= 1.0 \pm 1.6,$$
$$\mu_{ZH} = 0.1 \ {}^{+3.6}_{-0.1} \text{ (stat.) } {}^{+0.7}_{-0.0} \text{ (syst.) } {}^{+0.1}_{-0.0} \text{ (theory)}$$
$$= 0.1 \ {}^{+3.7}_{-0.1},$$
$$\mu_{t\bar{t}H} = 1.6 \ {}^{+2.6}_{-1.8} \text{ (stat.) } {}^{+0.6}_{-0.4} \text{ (syst.) } {}^{+0.5}_{-0.2} \text{ (theory)}$$
$$= 1.6 \ {}^{+2.7}_{-1.8}.$$

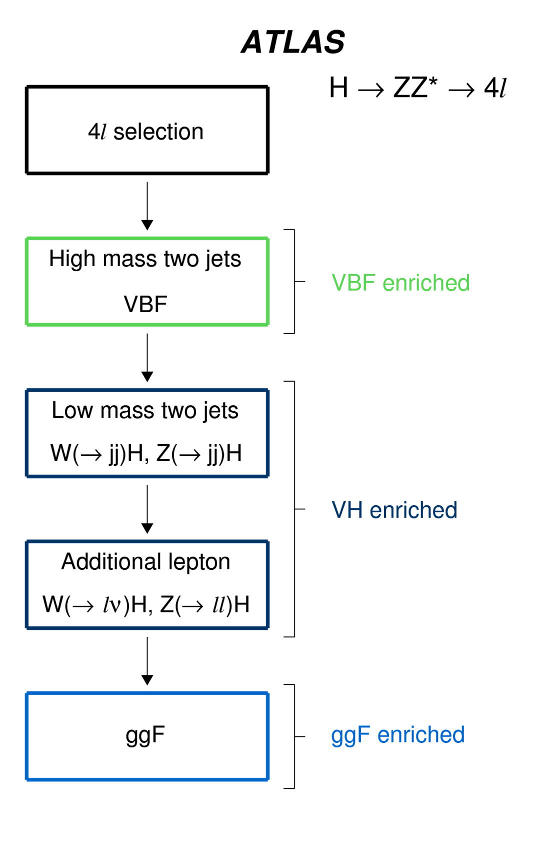
- m_H fixed at 125.4 GeV
- $\mu_{\gamma\gamma} = \sigma/\sigma_{SM} = 1.17 \pm 0.27 =$

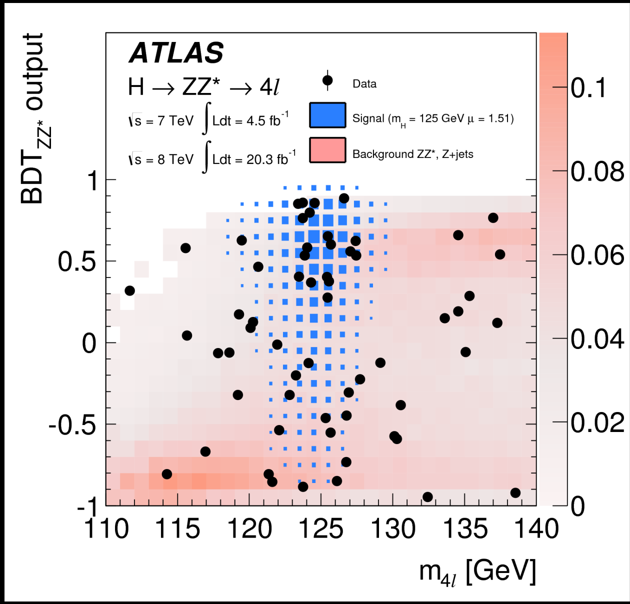
1.17 ± 0.23 (stat) ${}^{+0.10}_{-0.08}$ (syst) ${}^{+0.12}_{-0.08}$ (theory)

- Increased statistical uncertainty due to:
  - Lower signal rate
  - Fluctuation – expected uncertainty 0.35 GeV

H→ZZ Analysis

- Also benefits from improved:
  - Electron identification and energy measurement
  - Muon momentum scale
- Plus:
  - New VH category
  - Multivariate method to discriminate ZZ* (BDT_{ZZ*})
  - Improved treatment of FSR photons
  - 2D fit to m(4l) and BDT_{ZZ*}





- Signal strength: $\mu = \sigma/\sigma_{SM}$
- Inclusive:
  - $\mu_{ZZ} = 1.44\ ^{+0.34}_{-0.21}$ (stat) $^{+0.21}_{-0.11}$ (syst)
- ggF and VBF categories:
  - $\mu_{ggF} = 1.66\ ^{+0.45}_{-0.41}$ (stat) $^{+0.26}_{-0.16}$ (syst)
  - $\mu_{VBF} = 0.26\ ^{+1.60}_{-0.91}$ (stat) $^{+0.38}_{-0.23}$ (syst)

We've been keeping busy…

SM Higgs and its properties

- ***Mass and couplings (ZZ+WW+γγ):***
  - Phys. Lett. B 726 (2013), pp. 88-119
- ***(Updated Mass):*** arXiv:1406.3827
- ***(Updated Coupling γγ):*** arXiv:1408.3827
- ***(Updated Coupling ZZ):*** arXiv:1408.5191

- ***Spin and parity (ZZ+WW+γγ):***
- ***H → γγ:*** ATLAS-CONF-2013-012
- ***H → WW:*** ATLAS-CONF-2013-030
- ***H → Zγ:*** ATLAS-CONF-2013-009
- ***H → bb:*** ATLAS-CONF-2013-079
- ***H → ττ:*** ATLAS-CONF-2013-108
- ***H → μμ:*** ATLAS-HIGG-2013-07
- ***H → invisible:***
  Phys. Rev. Lett. 112, 201802 (2014)
- ***ttH(γγ):*** ATLAS-CONF-2014-043
- ***VH(WW):*** ATLAS-CONF-2013-075
- Phys. Lett. B 726 (2013), pp. 120-14
- ***H → ZZ (on-shell cross-section and pT):*** ATLAS-CONF-2014-044 ***(off-shell cross-section)*** ATLAS-CONF-2014-042

Additional Higgs Boson searches

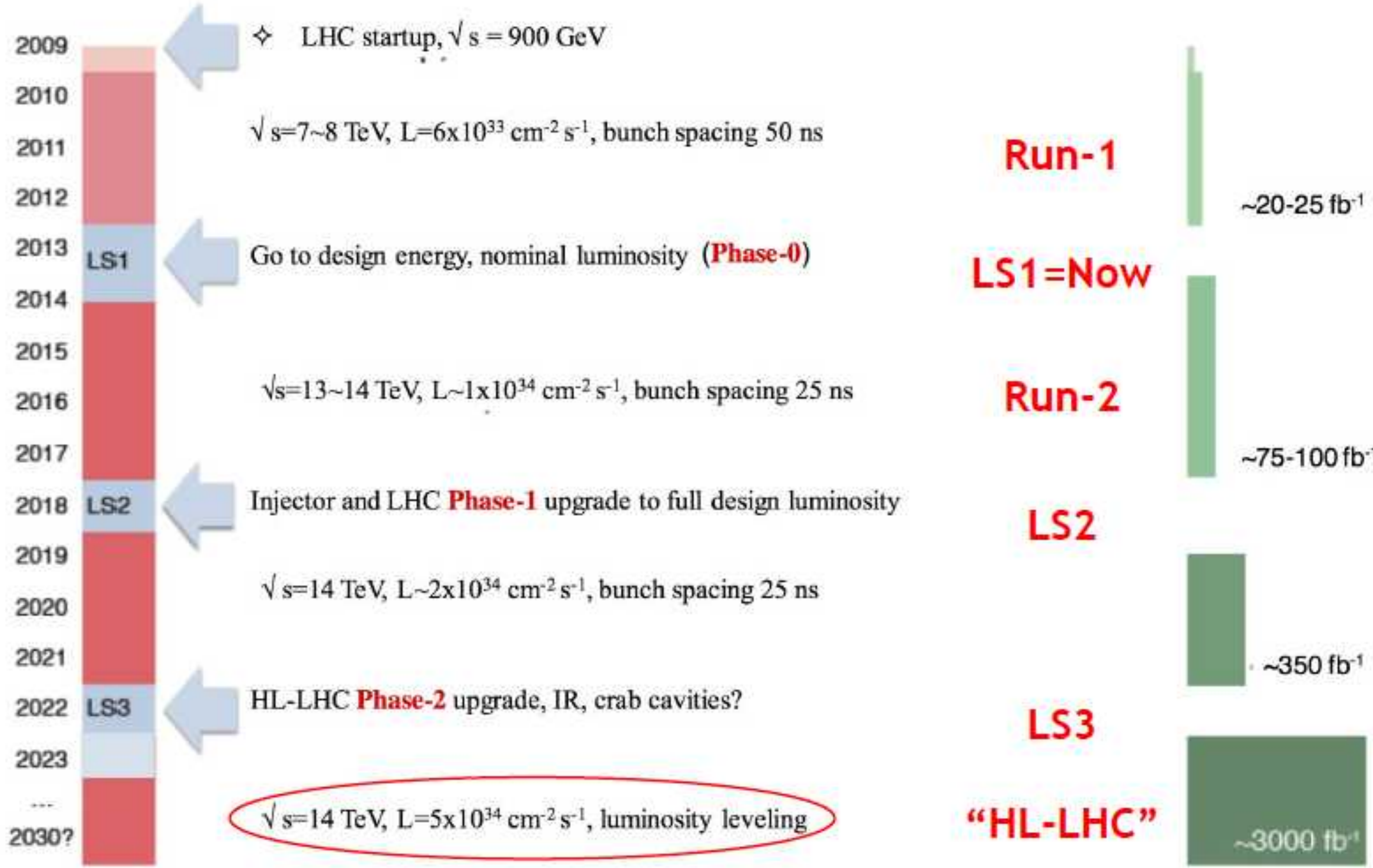
- ***H/h/A→ττ:***
  ATLAS-CONF-2014-049 **ATLAS-CONF-2014-005**
- ***X→hh→4b:***
- ***H+ → τ ν:*** ATLAS-CONF-2013-090, JHEP03(2013)076
- ***H+ → c $s\bar{s}$:***
  Eur. Phys. J. C, 73 6 (2013) 2465
- ***H → WW (2HDM):*** ATLAS-CONF-2013-027
- ***X→hh→γγbb:*** ATLAS-HIGG-2013-29
- ***Multi-higgs cascade:***
  Phys. Rev. D 89, 032002 (2014)
- ***SM Higgs Couplings and New Phenomena:***
- ATLAS-CONF-2014-010

It is an old maxim of mine that when you have excluded the impossible, whatever remains, however improbable, must be the truth.'

Sherlock Holmes

-The Beryl Coronet

The landscape in the next decade(s)

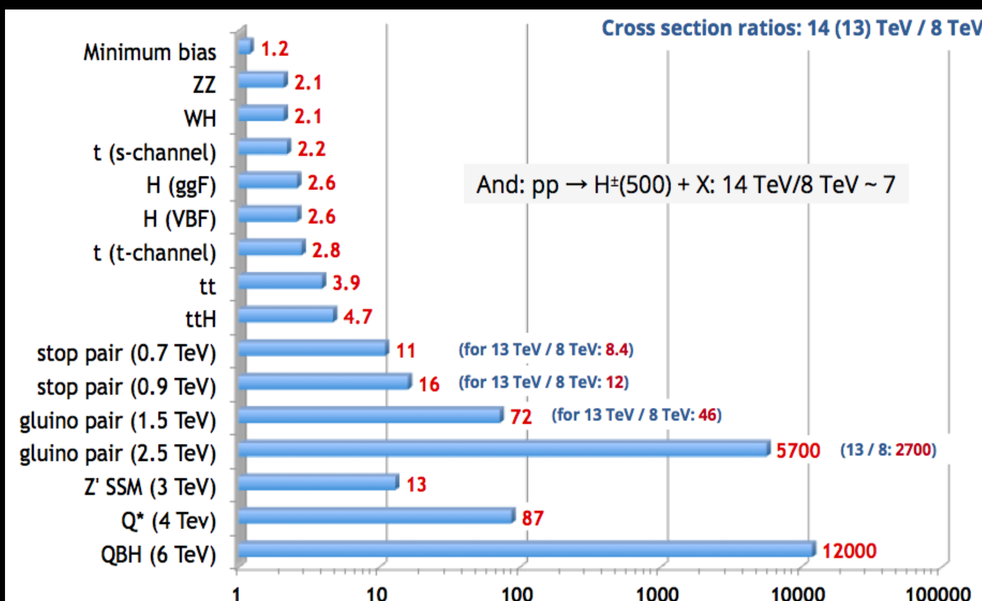


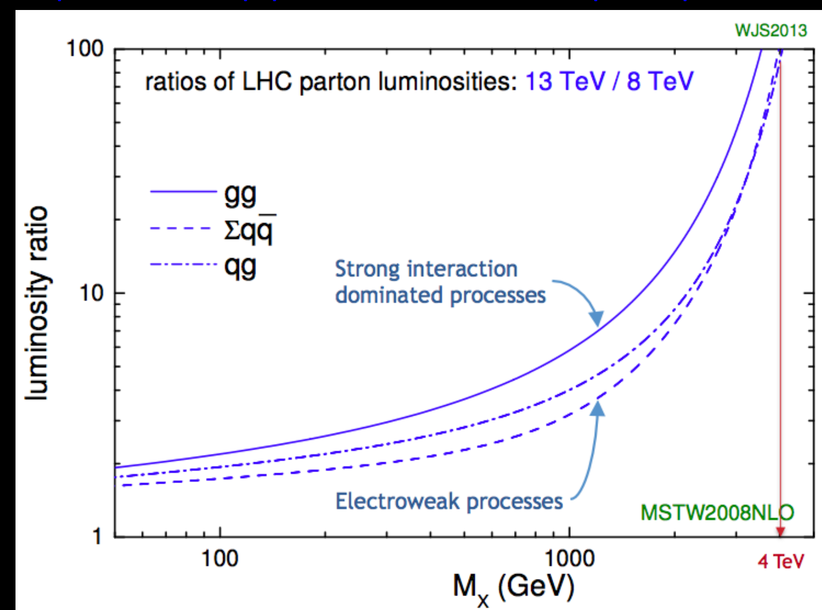
D Charlton / Birmingham - 12 August 2013, ICISE inauguration, Quy Nhon, Vietnam 43

Run II – Not only more luminosity

- Higher centre of mass energy gives access to higher masses
- Hugely improves potential for discovery of heavy particles
- Increases cross sections limited by phase space
  - E.g. ttH increases faster than background (factor 4)
- But may make life harder for light states
  - E.g. only factor 2 increase for WH/ZH, H→bb and more pileup
  - Could be compensated by use of boosted jet techniques (jet substructure)

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

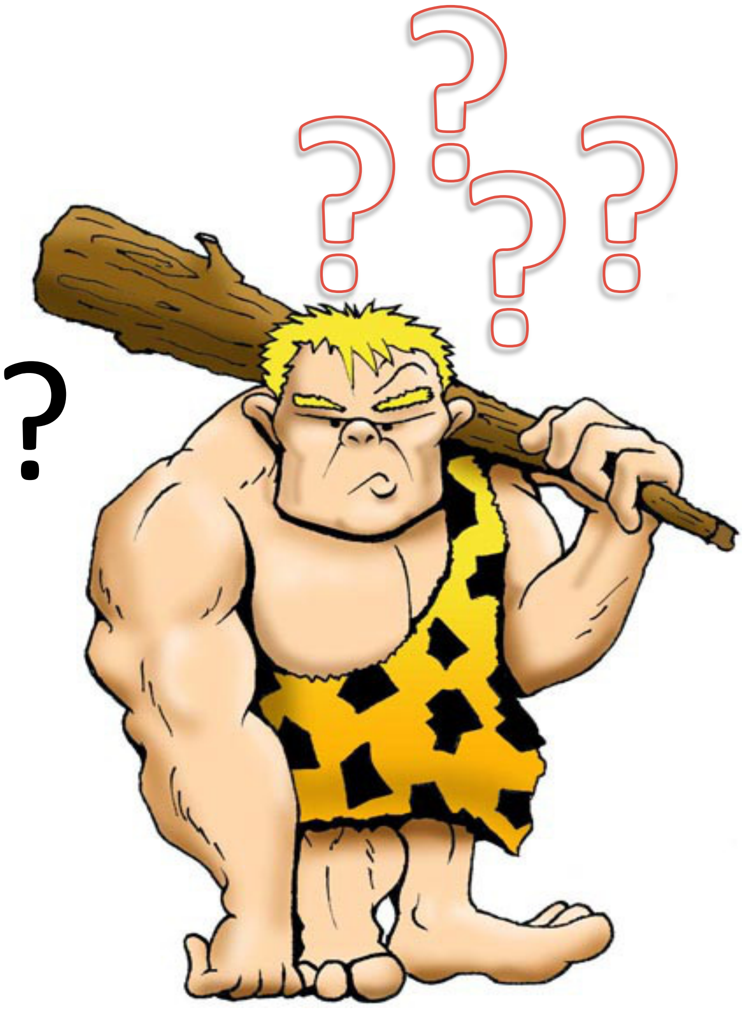




Conclusions

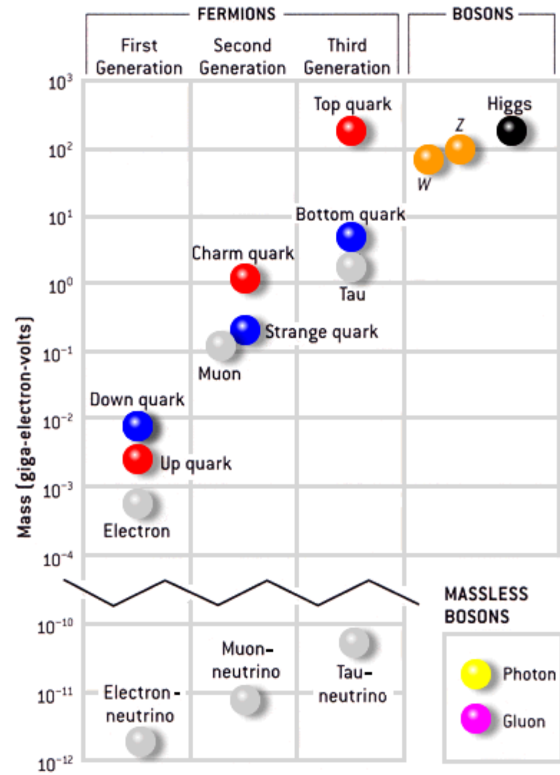
- Only a very short review of the latest diboson mass and coupling results (apologies)
- Looking forward to Run II
  - Improve further on the precision measurements that I mentioned (and all the ones I didn't)
  - But not all channels will become easier

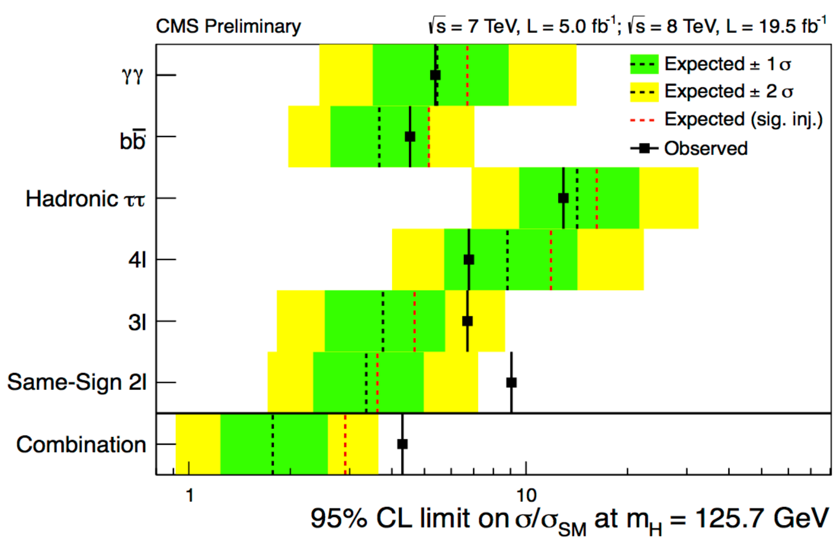
Any Questions?

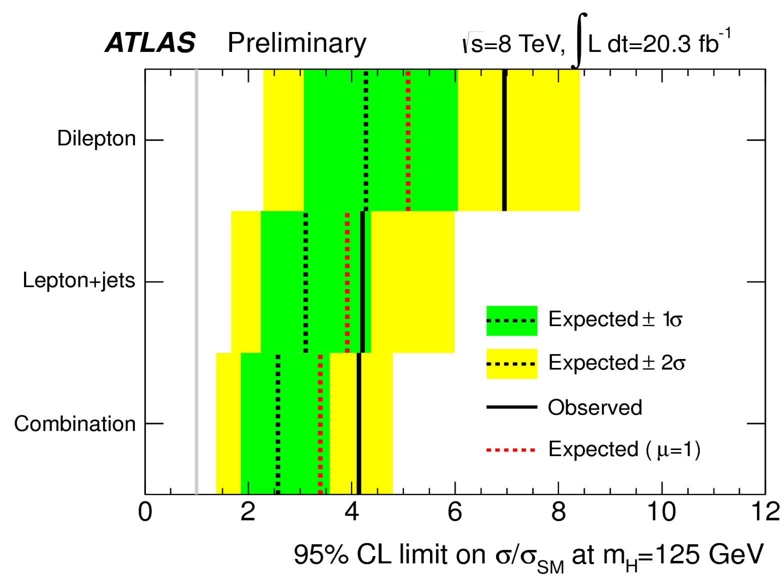


An example: ttH

- Indirect constraints on top-Higgs Yukawa coupling from loops in ggH and ttH vertices
  - Assumes no new particles contribute to loops
- Top-Higgs Yukawa coupling can be measured directly
  - Allows probing for New Physics contributions in the ggH and γγH vertices
- Top Yukawa coupling $Y_t = \sqrt{2}M_t/vev = 0.996 \pm 0.005$
  - Does this mean top plays a special role in EWSB?







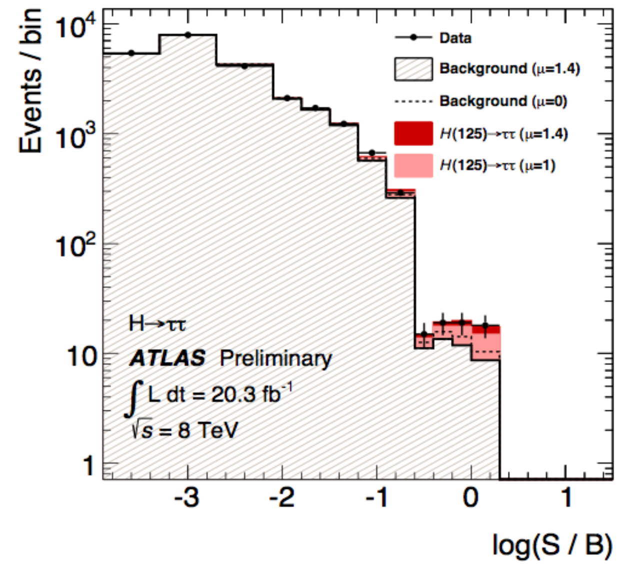
Direct Evidence of Fermion Couplings

- **Challenging** channels at the LHC!
  - Huge backgrounds (H->bb,H->ττ)
  - Or low rate: H->μμ

- ATLAS:

  4.1σ evidence of H->ττ decay 3.2σ exp.

  $\mu = \boldsymbol{\sigma_{obs.}/\sigma_{SM}} = 1.4 \pm 0.3(stat) \pm 0.4(sys)$



ATLAS-CONF-2013-108

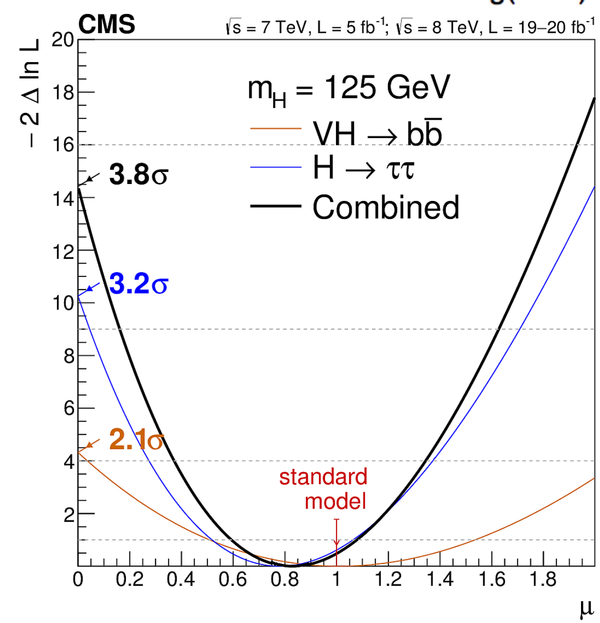
- CMS:
  - Combination of H->bb and H->ττ:

  3.8σ evidence (obs.) 4.4σ (expected)

  $\mu = \boldsymbol{\sigma_{obs.}/\sigma_{SM}} = 0.83 \pm 0.24$

CMS 1401.6527

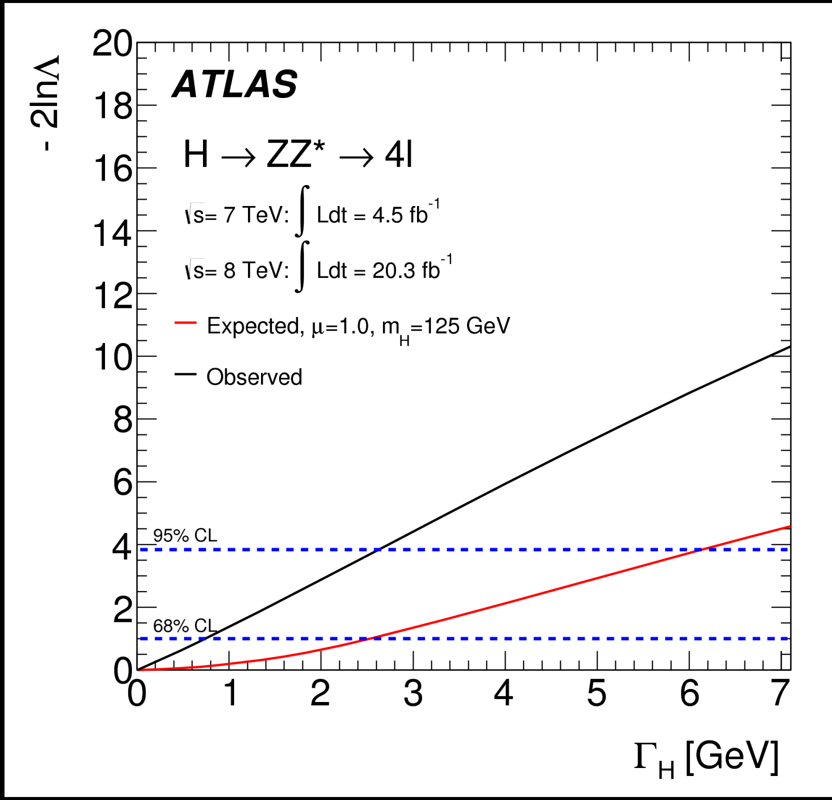
Channel ($m_H = 125\,GeV$)	Significance (σ) Expected	Significance (σ) Observed	Best-fit μ
$VH \to b\bar{b}$	2.3	2.1	1.0 ± 0.5
$H \to \tau\tau$	3.7	3.2	0.78 ± 0.27
Combined	4.4	3.8	0.83 ± 0.24



CMS 1401.6527

Direct Measure of Higgs Boson Width

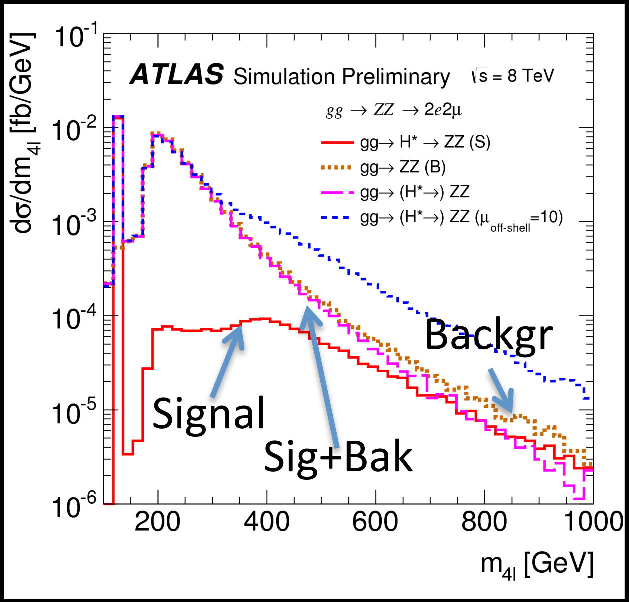
- Going back to latest ATLAS mass measurement
  - Combination of H➞γγ and H➞ZZ
  - arXiv:1406.3827
- Direct measurement assuming no interference between signal and backgrounds
- Mass peak is a convolution of natural Higgs width and detector resolution
  - SM: Γ = 4 MeV << resolution
- H➞ZZ➞4l :
  - Γ < 2.5 GeV @ 95% C.L.
  - Expect 6.2 for μ = 1
- H➞γγ:
  - Γ < 2.5 GeV @ 95% C.L.
  - Expect 6.2 for μ = 1



ATLAS-CONF-2014-042

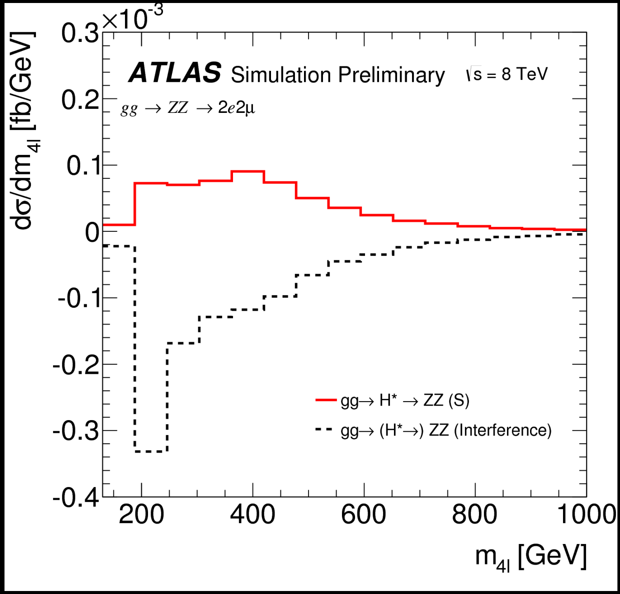
Indirect Measurement

- High-mass region in H→ZZ ($m_{ZZ} > 2\ m_Z$) provides access to total width
  - Kauer and Passarino, JHEP 1208 (2012) 116
  - Caola and Melnikov, PRD 88 (2013) 054024
  - Campbell, Ellis, and Williams, PRD 89 (2014) 053011
- Off-shell signal strength is independent of total width (depends only on couplings) – unlike on-shell
  - Assumes background is immune to any new physics affecting off-shell couplings (and so κ factors)
  - Assumes κi,off-shell = κi,on-shell



$$\frac{\sigma^{gg\to H^*\to ZZ}_{\text{off-shell}}}{\sigma^{gg\to H^*\to ZZ}_{\text{off-shell, SM}}} = \mu_{\text{off-shell}} = \kappa^2_{g,\text{off-shell}} \cdot \kappa^2_{V,\text{off-shell}}$$

$$\frac{\sigma^{gg\to H\to ZZ}_{\text{on-shell}}}{\sigma^{gg\to H\to ZZ}_{\text{on-shell, SM}}} = \mu_{\text{on-shell}} = \frac{\kappa^2_{g,\text{on-shell}} \cdot \kappa^2_{V,\text{on-shell}}}{\Gamma_H/\Gamma_H^{\text{SM}}}$$



Indirect Measurement

Combination of ZZ→4l and ZZ→2l2ν to fit $\mu_{off\text{-}shell}$

ZZ→4l

Off-shell region m_{4l}=[220,1000] GeV
Matrix element (ME) kinematic discriminant to separate gg→H→ZZ from gg→ZZ and qq→ZZ

ZZ→2l2ν
- E_t^{miss} > 150 GeV, 76 < m_{ll} < 106 GeV
- Main backgrounds: qq→ZZ + diboson

Off –shell signal region: m_{TZZ} > 350 GeV

- limit on $\mu_{off\text{-}shell}$
- Small dependence on the ratio between gg→ZZ and **gg→**H→ZZ **k-factors**
- **RHB is ~ 1 in the soA̋ collinear approxima4on Include low-mass region (4l) to fit μon-shell**

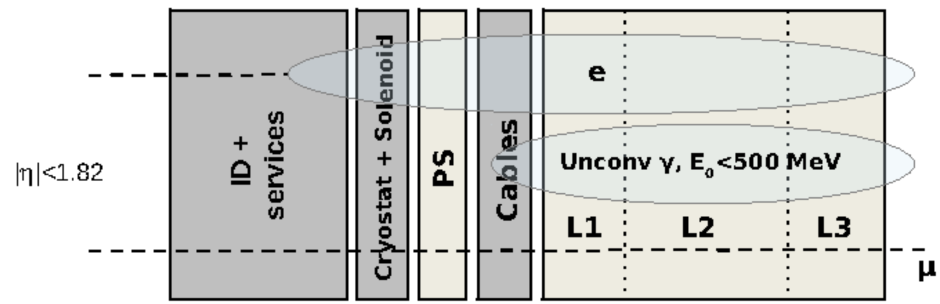
Ratio of μon-shell/μoff-shell gives ΓH

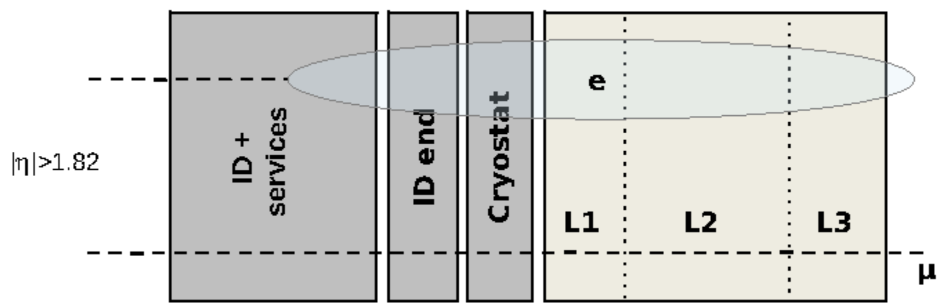
Off-shell signal strength is independent of total width (depends only on couplings) – unlike on-shell

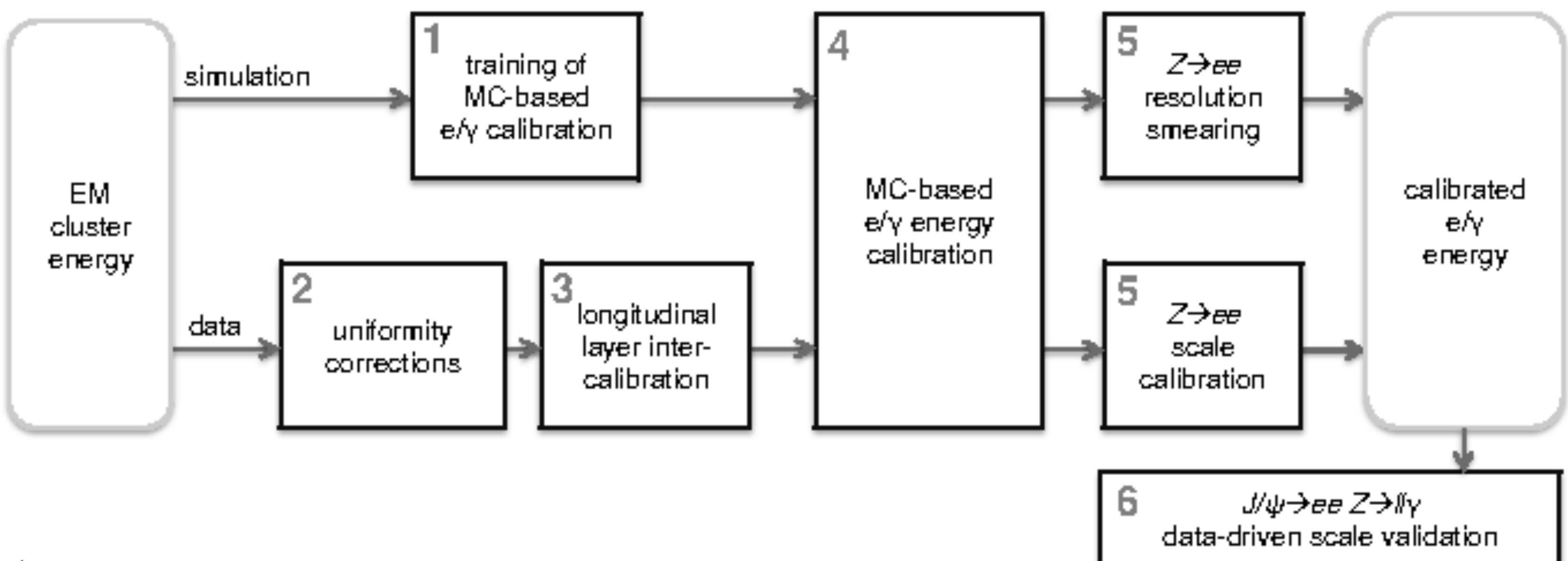
Assumes background is immune to any new physics affecting off-shell couplings (and so κ factors)

Assumes κi,off-shell = κi,on-shell

Higgs in ATLAS

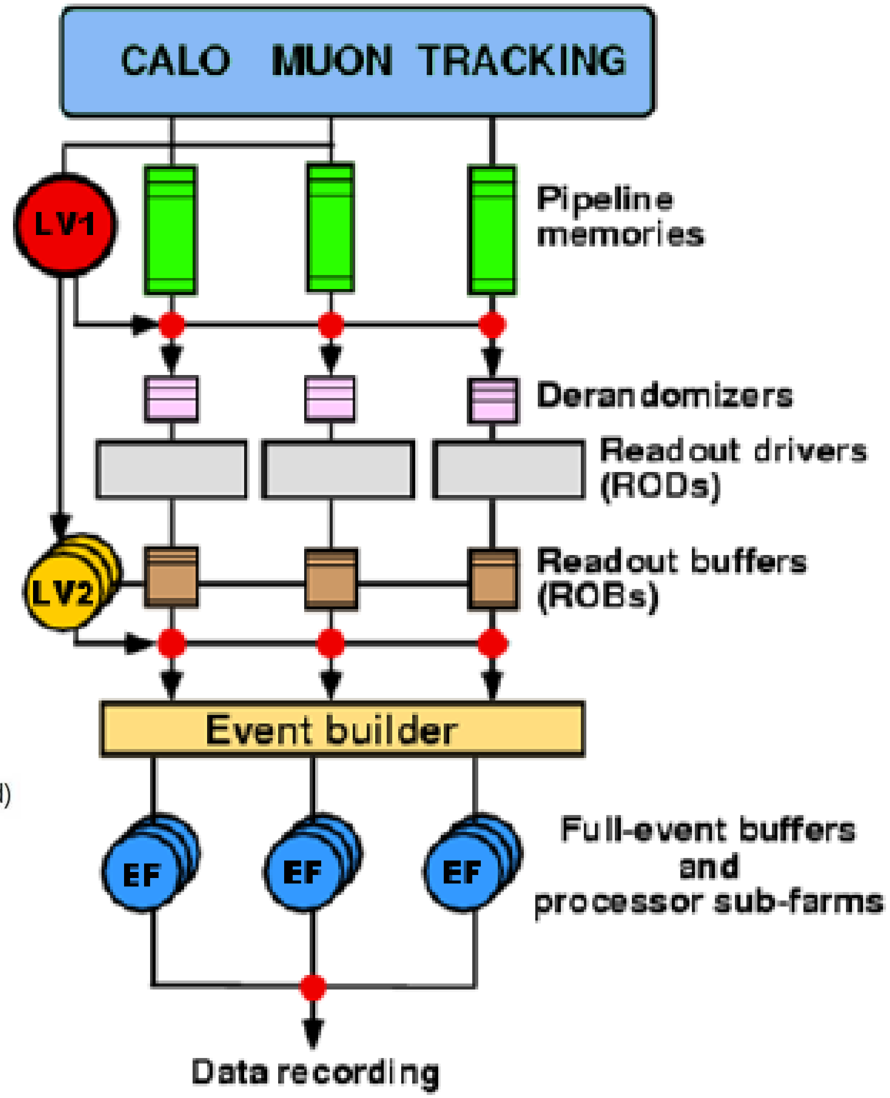

|η|<1.82
ID + services
Cryostat + Solenoid
PS
Cables
e
Unconv γ, E0<500 MeV
L1
L2
L3
μ

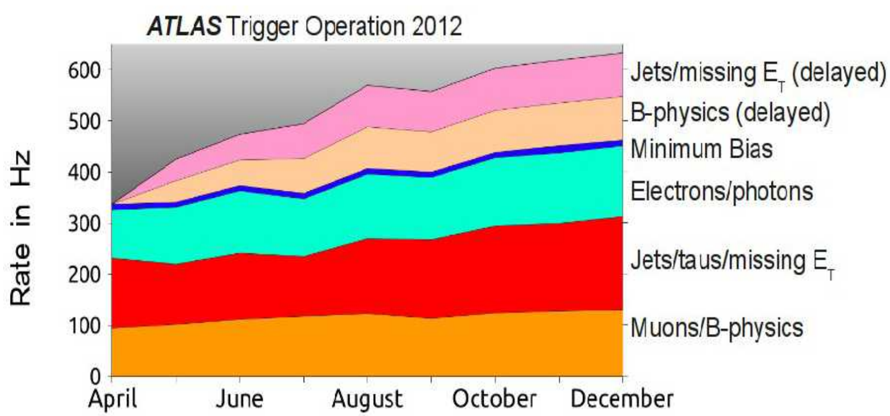

|η|>1.82
ID + services
ID end
Cryostat
e
L1
L2
L3
μ


EM cluster energy
simulation
data
1 training of MC-based e/γ calibration
2 uniformity corrections
3 longitudinal layer inter-calibration
4 MC-based e/γ energy calibration
5 Z→ee resolution smearing
5 Z→ee scale calibration
calibrated e/γ energy
6 J/ψ→ee Z→llγ data-driven scale validation

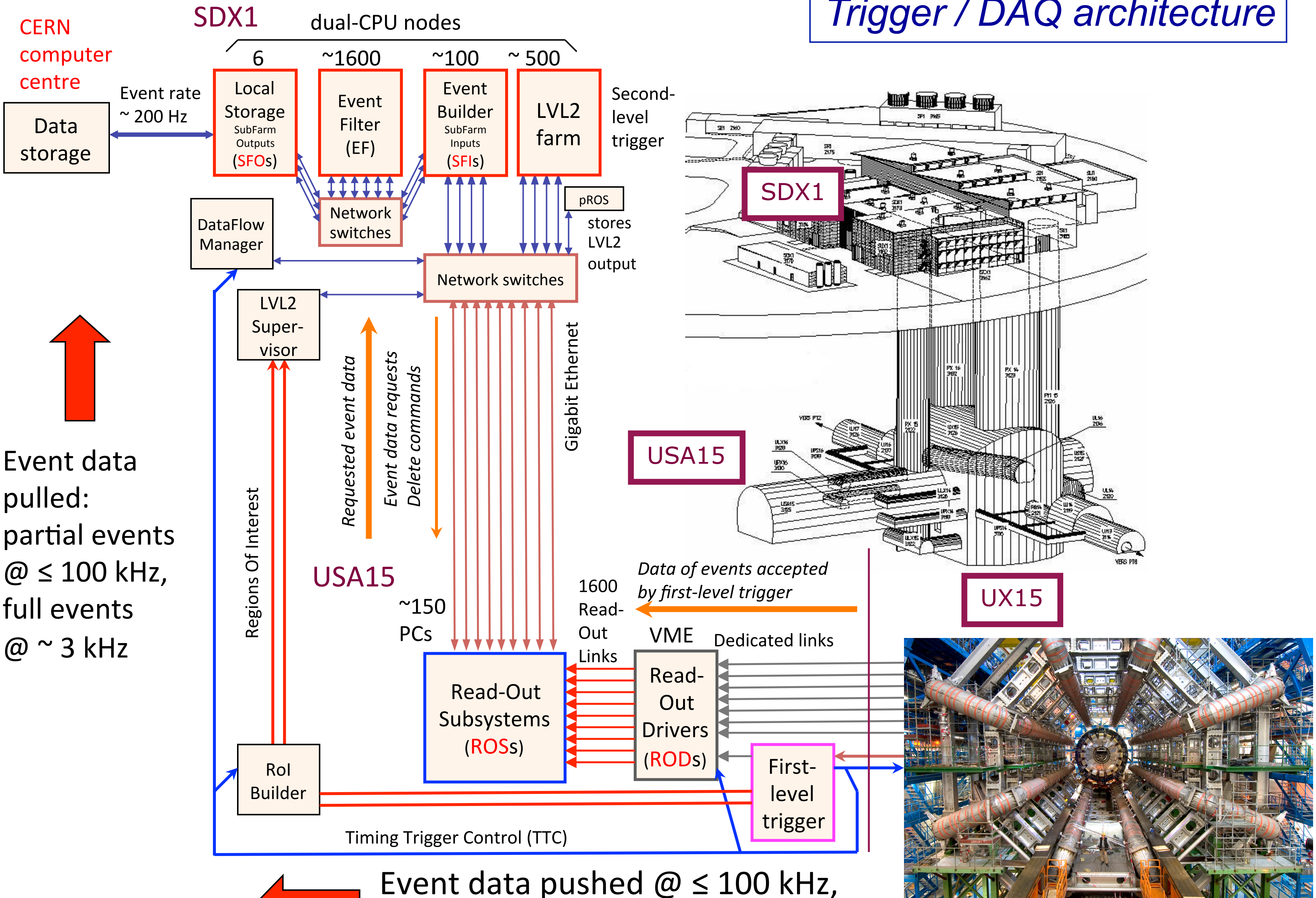
Trigger: sistema de seleção em tempo real

- 25 ns entre pacotes
  - (i.e. ≈7.5m à velocidade de *c*)
  - 40 milhões de cruzamentos de feixes por segundo
  - Cada colisão daria ≈1.5Mb
  - => 60Tb por segundo
- Impossível guardar todos os dados
  - E desnecessário!
  - A maioria das colisões é sem interesse
- O sistema de trigger guarda apenas ≈10-15 colisões por cada milhão
- Mas tem que decidir em 2,5µs!!





Trigger / DAQ architecture

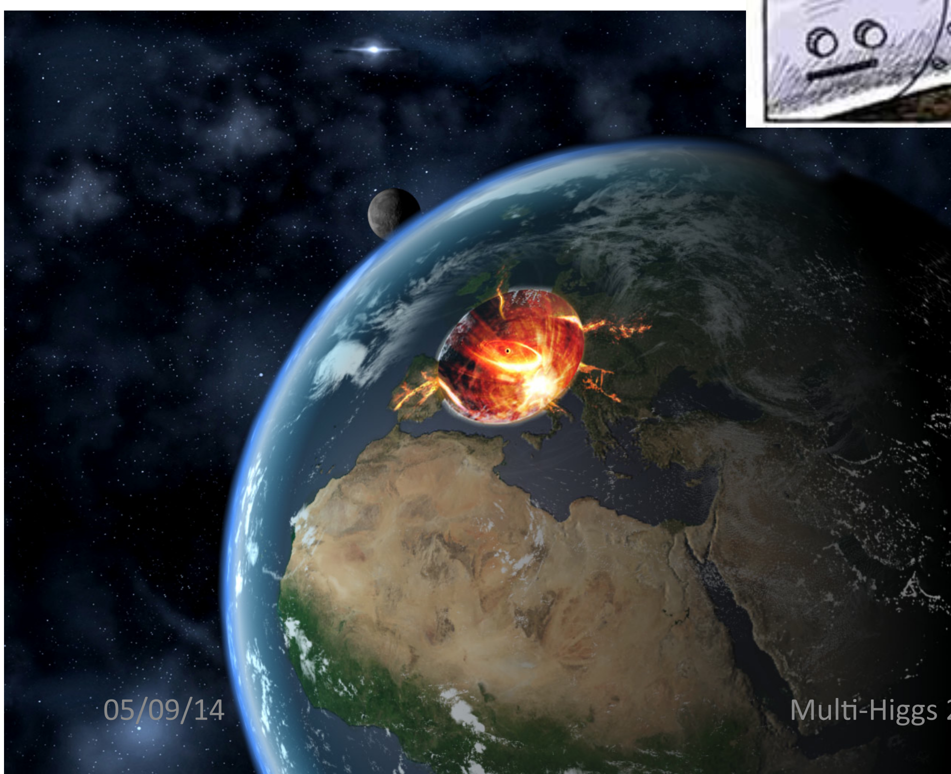


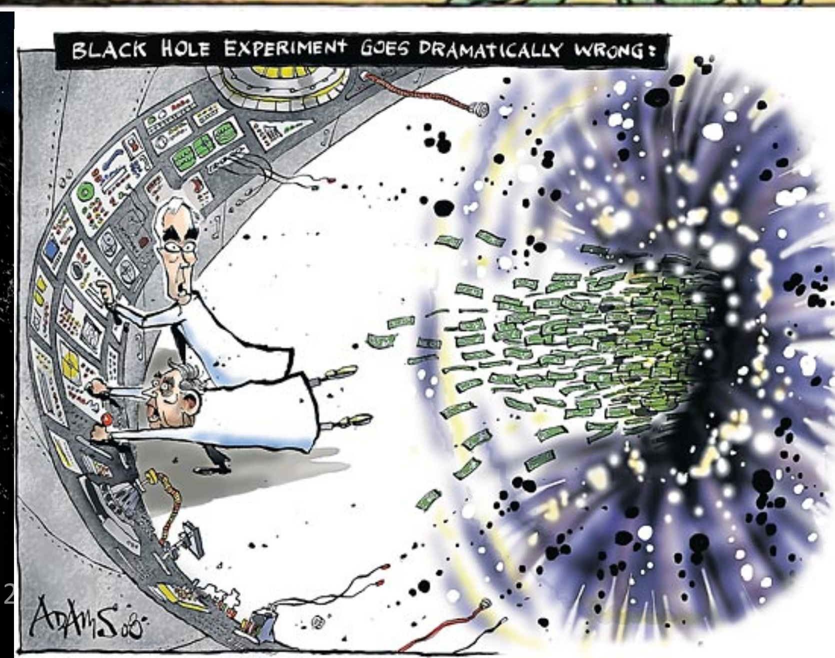
Event data pulled: partial events @ ≤ 100 kHz, full events @ ~ 3 kHz

Event data pushed @ ≤ 100 kHz, 1600 fragments of ~ 1 kByte each


QUI A PEUR
DU
TROU NOIR


13.8 BILLION YEARS AGO, A FEW SECONDS BEFORE THE CREATION OF OUR UNIVERSE...
All set. Let's fire up this Large Hadron Particle Collider and see what happens!




BLACK HOLE EXPERIMENT GOES DRAMATICALLY WRONG:

A Colaboração ATLAS

3000 cientistas
(1000 estudantes)
33 países
177 universidades
e laboratórios

Outline

- The ATLAS detector and run-I performance
  - ATLAS vs CMS – strengths and weaknesses
- Standard Model Higgs
  - Bosonic decay channels – γγ (incl., ttH), WW, ZZ, Zγ
    - Differential analyses – γγ, ZZ
    - ttH(H→γγ)
    - Couplings and Properties from Bosonic Channels – incl mass (ATLAS-CONF-2014-043)
  - Fermionic decay channels – ττ, bb (VH, ttH), μμ
    - H→ττ, VH(H→bb), ttH(H→bb)
    - Hcc access through H->J/Psi? http://arxiv.org/abs/1306.5770
  - Di-Higgs production – γγbb
- Beyond the Standard Model
  - Constraints from current measurements
  - Direct BSM Searches
    - Additional γγ resonances
    - Cascade decays
    - Invisible Higgs in ZH production
    - FCNC t→Hq
    - MSSM H→ττ (in circulation)
    - High Mass H→γγ
    - PROCURAR em exotics (e.g. H++) e SUSY