The Higgs boson discovery

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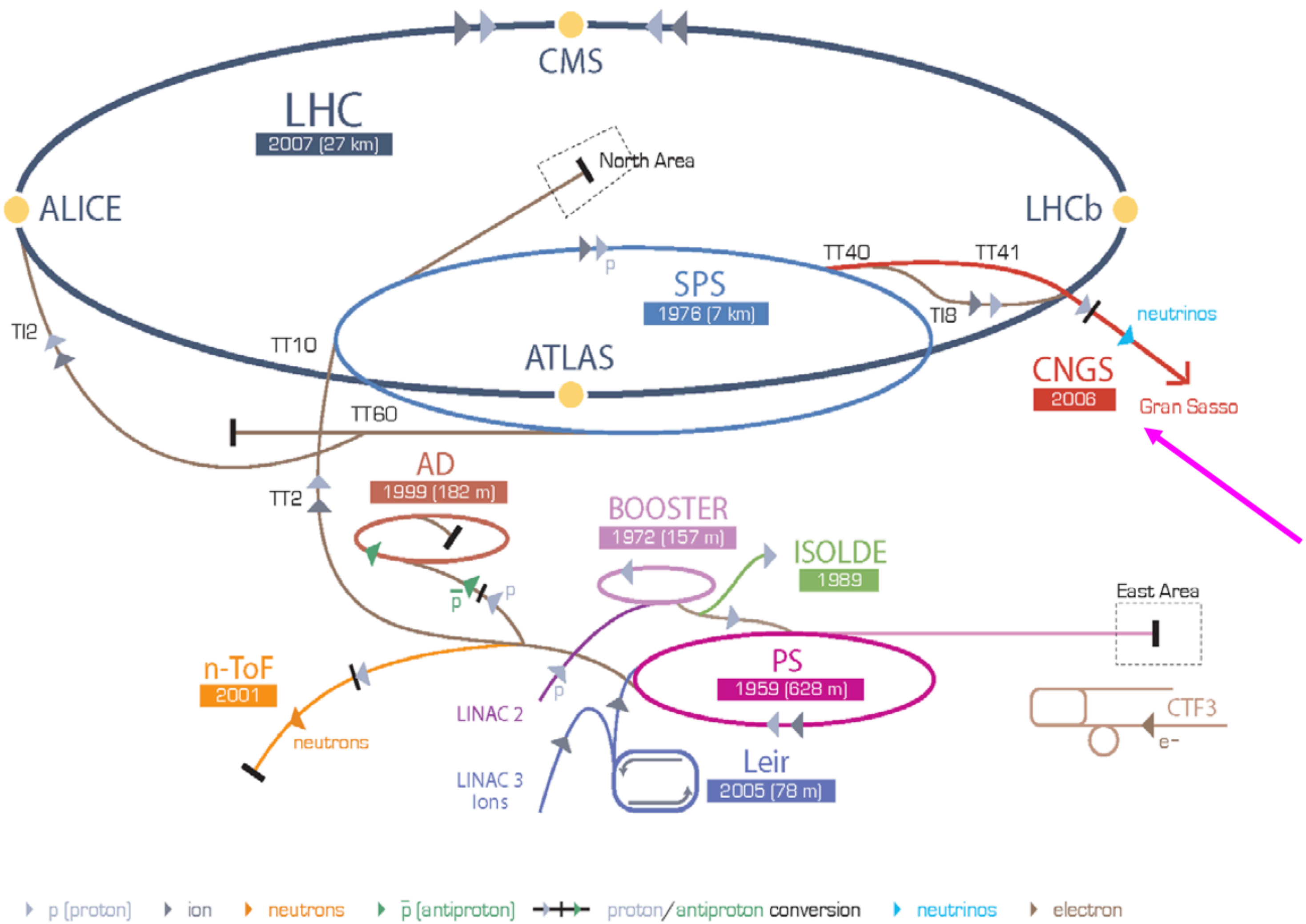
Overview

- CERN, the accelerator complex, the LHC machine
- Particle production and decay, the Standard Model, the Higgs mechanism
- General purpose detectors at LHC: ATLAS and CMS
- Particle production and LHC
- Higgs discovery
- Conclusions

The Large Hadron Collider

CERN Accelerator Complex



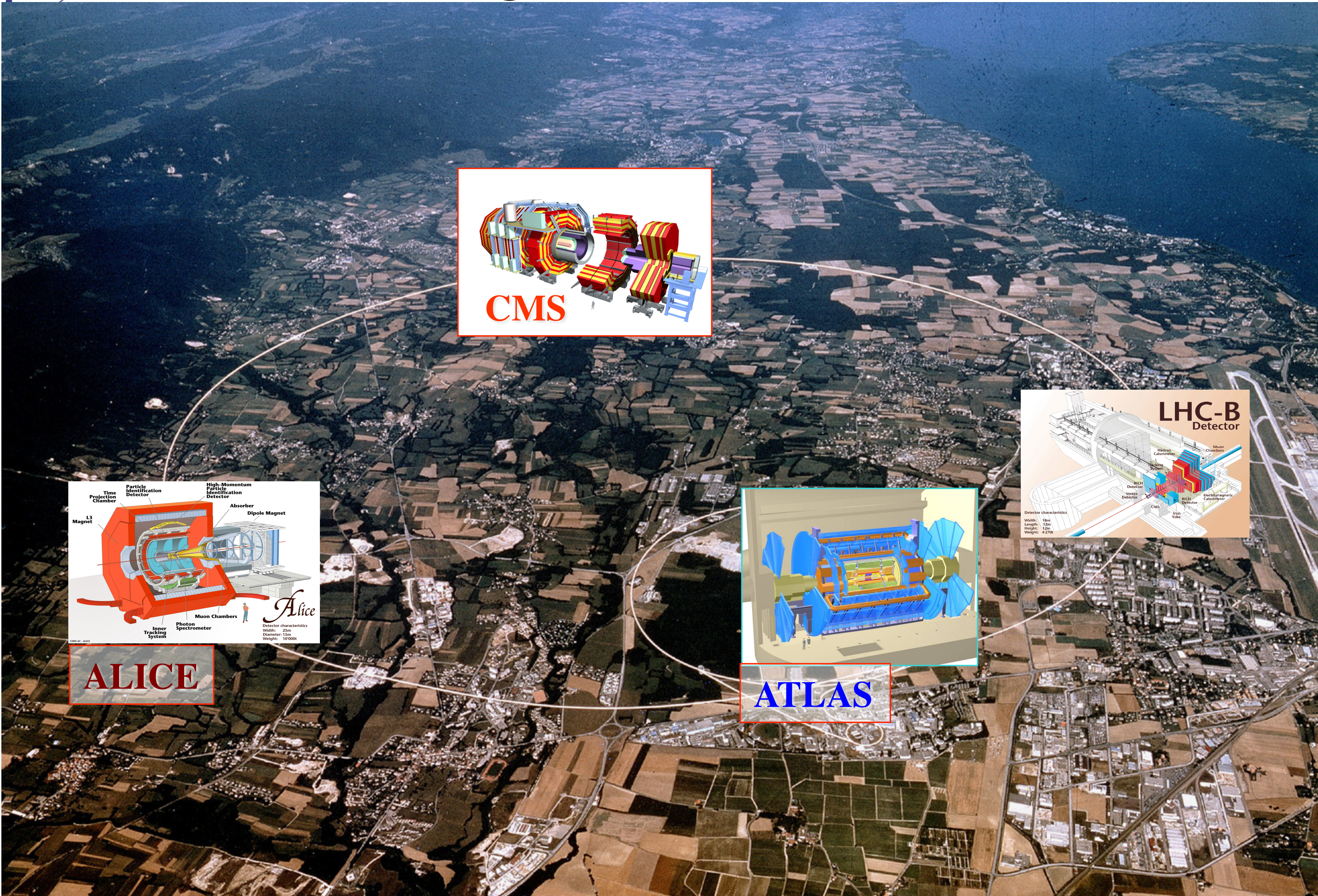
LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron

AD Antiproton Decelerator CTF3 Clic Test Facility CNGS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice

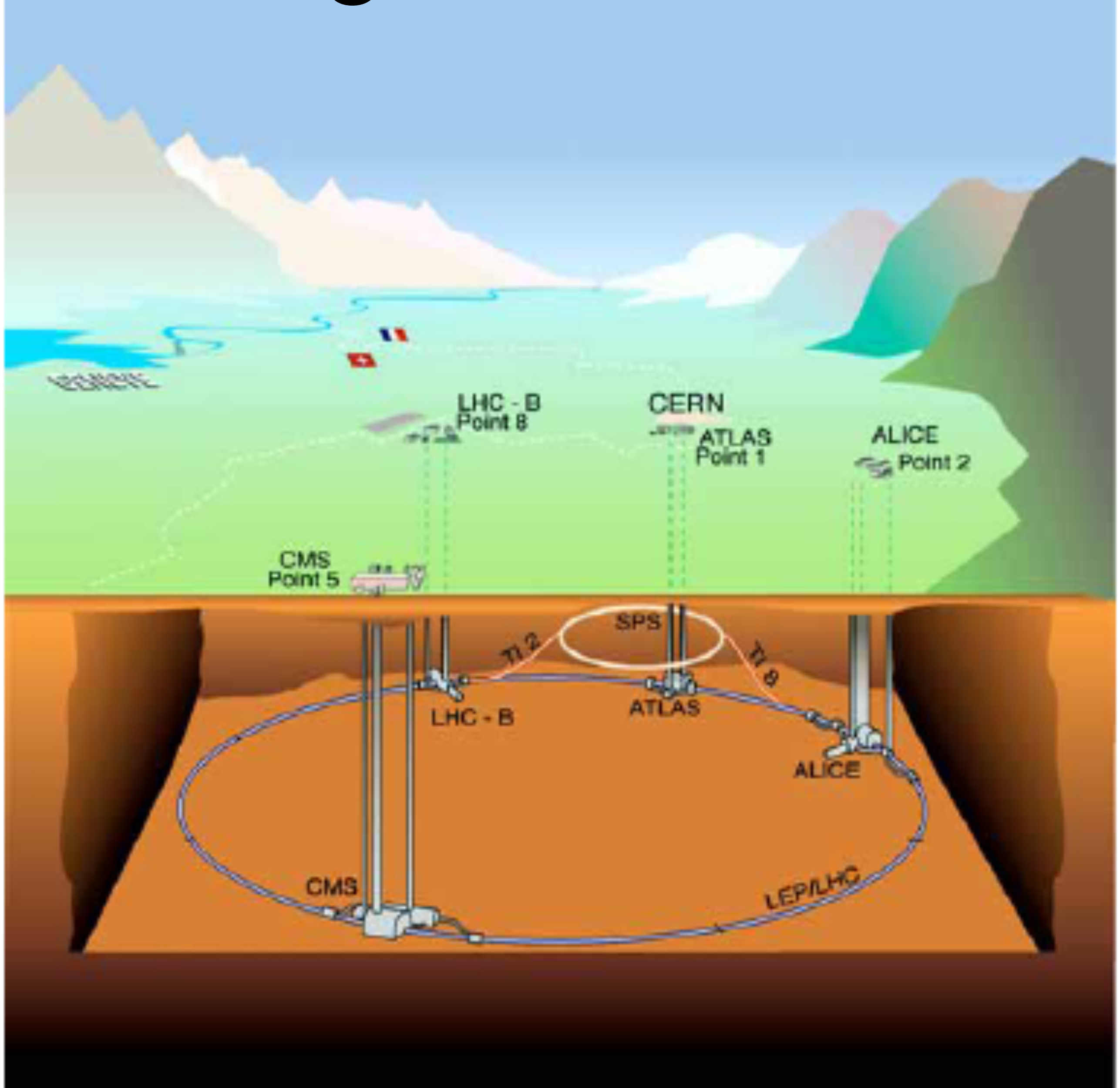
LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight

INFN

The Large Hadron Collider

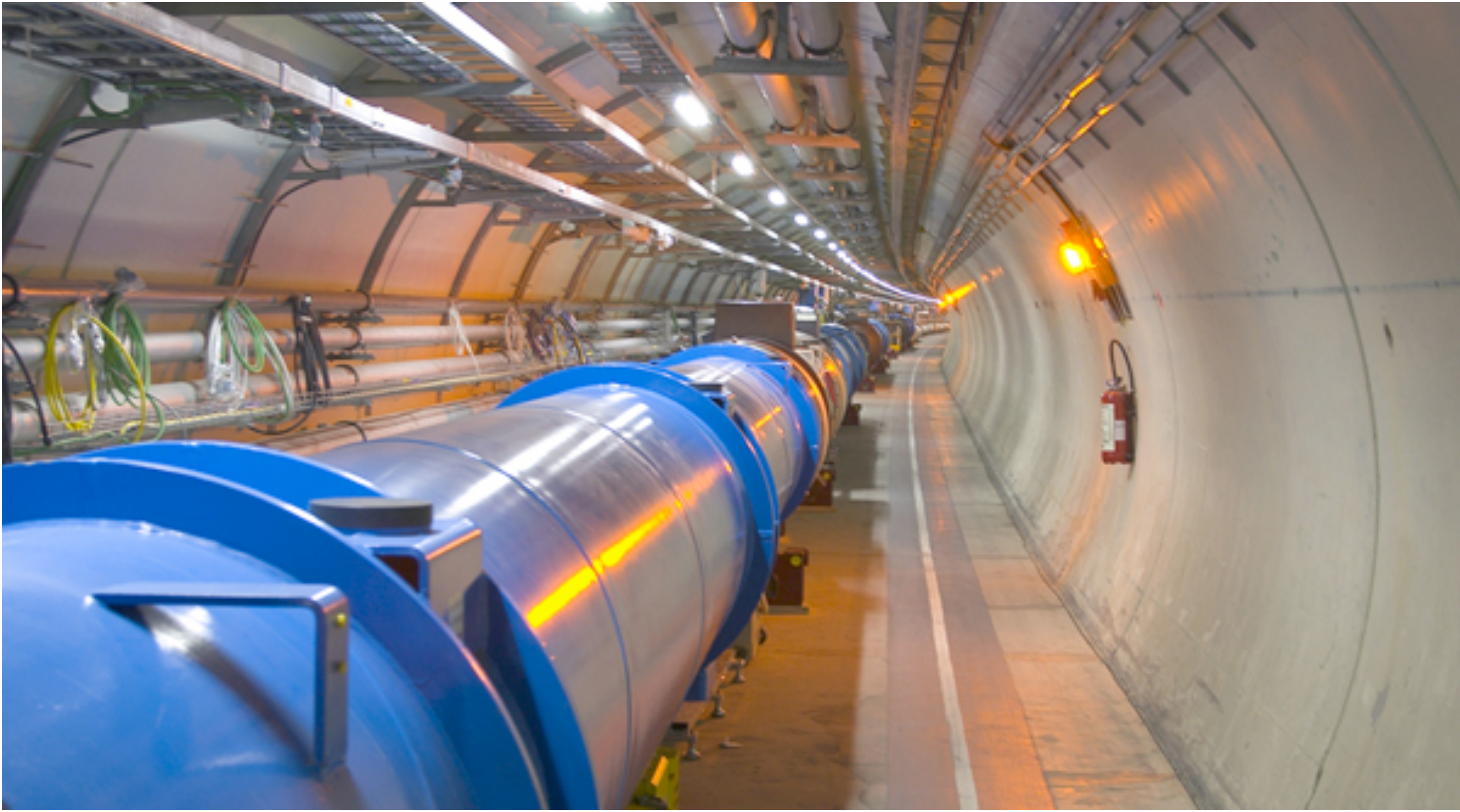


The Large Hadron Collider



The Large Hadron Collider

proton-proton collider √s=14 TeV (nominal). In 2010,2011: √s=7 TeV; 2012: √s=8 TeV



The Large Hadron Collider

proton-proton collider $\sqrt{s}$=14 TeV (nominal). In 2010,2011: $\sqrt{s}$=7 TeV; 2012: $\sqrt{s}$=8 TeV

Now upgrade on going to bring the center of mass energy to ~ 14 TeV

Nominal Luminosity $L = 10^{34}$ cm^{-2} s^{-1}

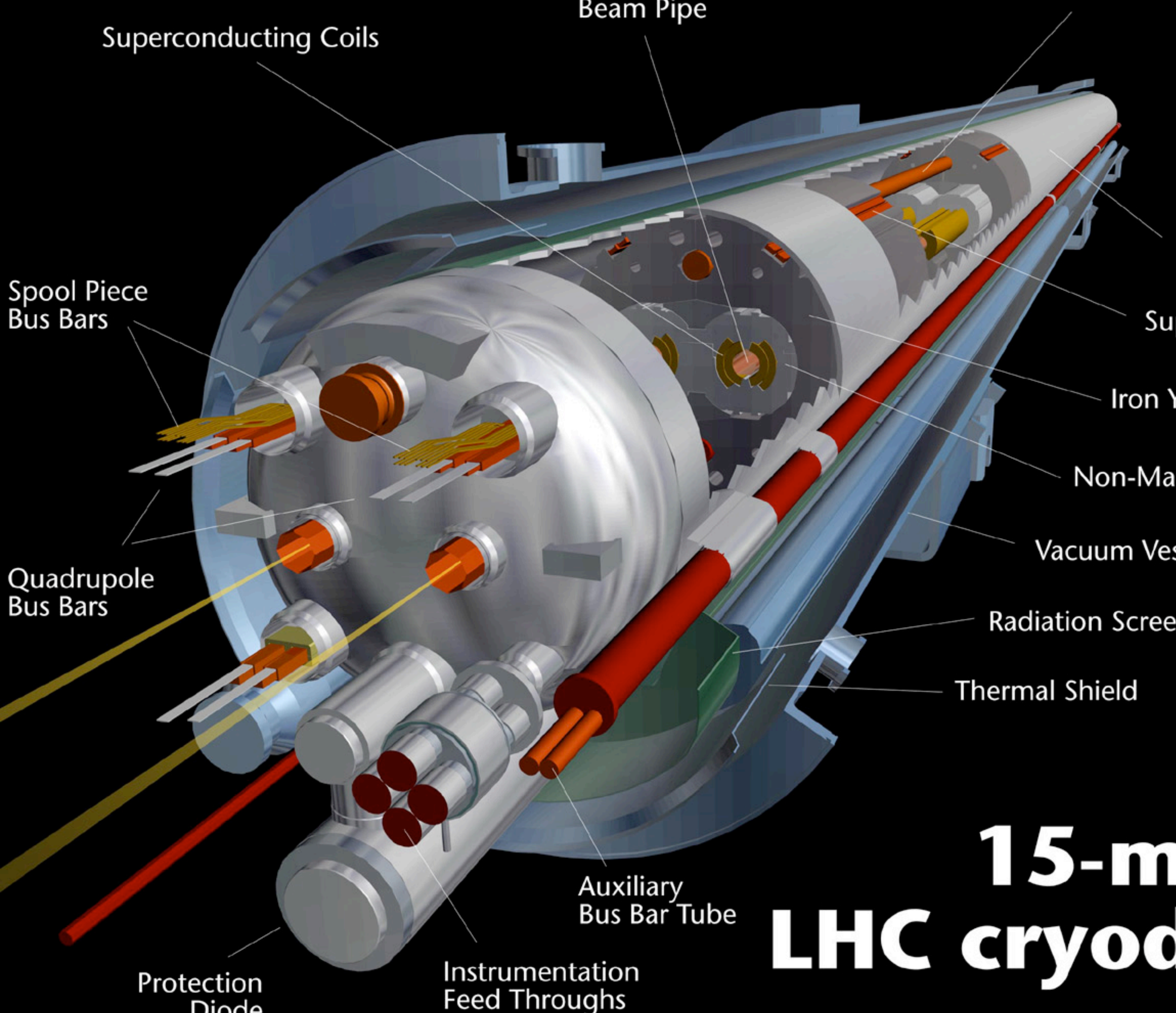
Superconducting magnets in LHC:

Dipoles: 1232

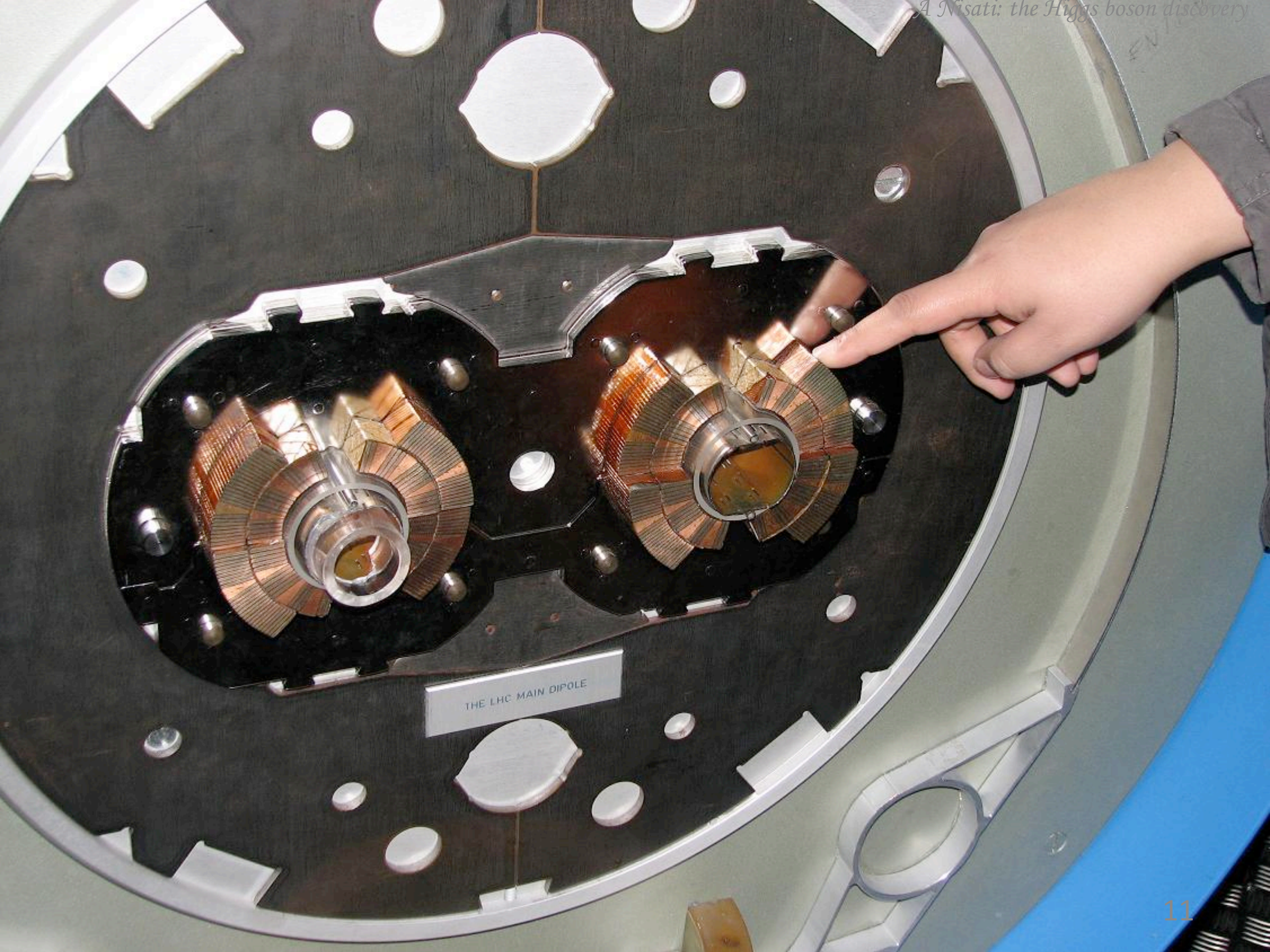
Total: >1800

Number of protons per bunch: **1.15×10^{11}**
(currently ~ 1.7×10^{11})

Number of bunches: 2808 (currently ~ 1400)



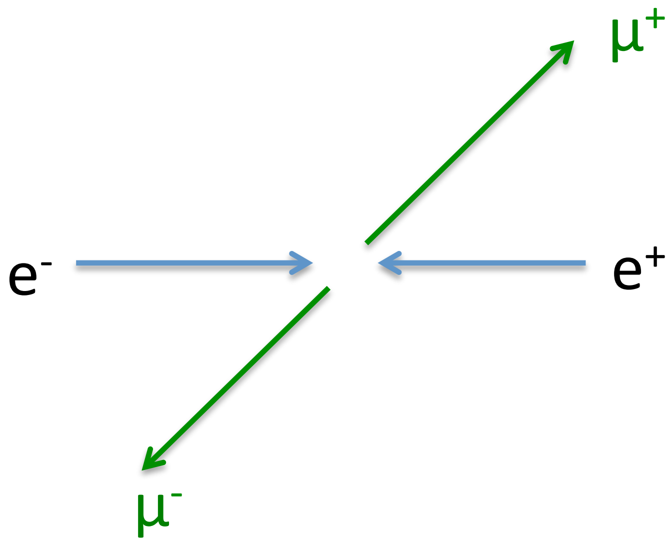
The 15-m long LHC cryodipole

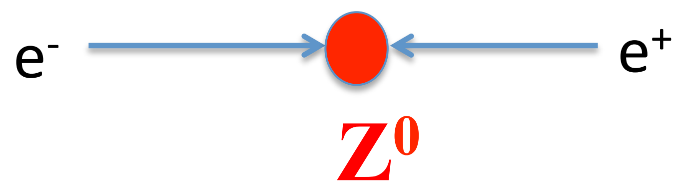

THE LHC MAIN DIPOLE

relativistic-quantum mechanics

- In relativistic quantum physics **we can create** particles (if realized in nature) that are not necessarily present in our Universe because their instability
- These particle can be composite objects, or more importantly, **elementary constituents or force carriers**
  - Electrons and photons are elementary particles
  - Protons and neutrons are composite particles
  - Muons, taus and quarks are elementary particles
- Particle creation obeys to conservation and symmetry laws

Particle creation



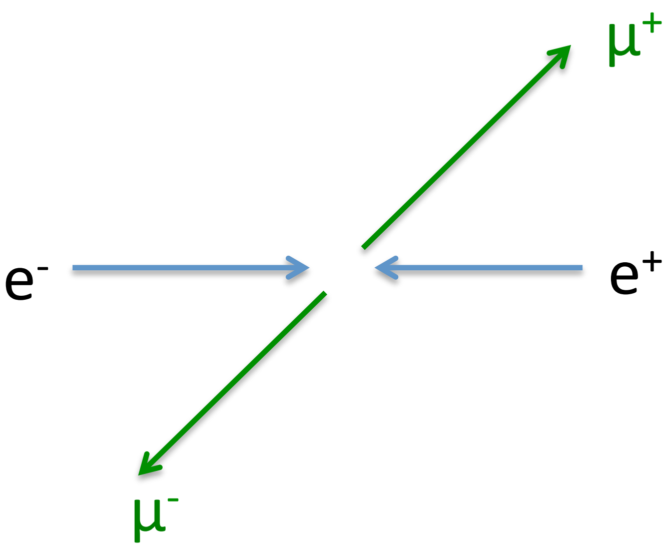


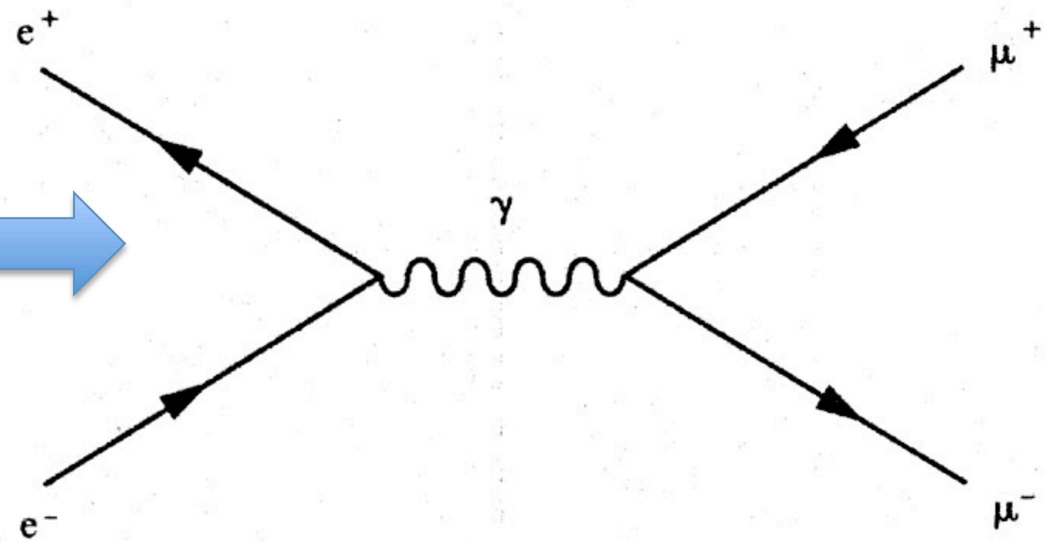
creation of a muon pair from a e+e- collision

creation of a Z^0 boson from a e+e- collision

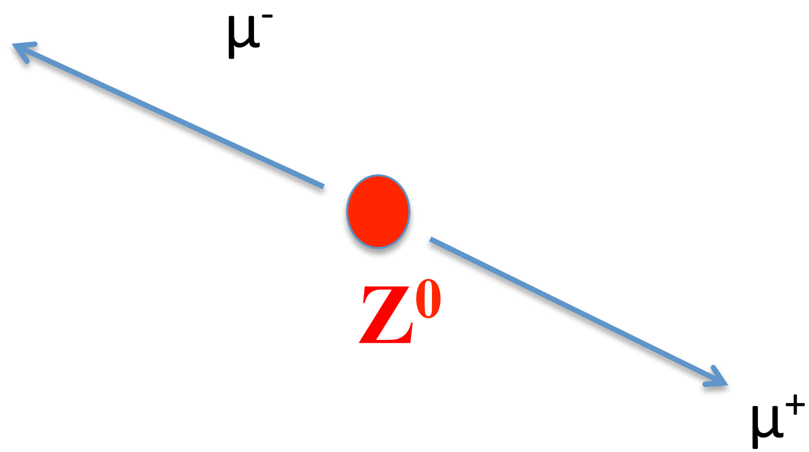
Energy and momentum of the particle system is conserved

Feynman diagrams





Particle decay

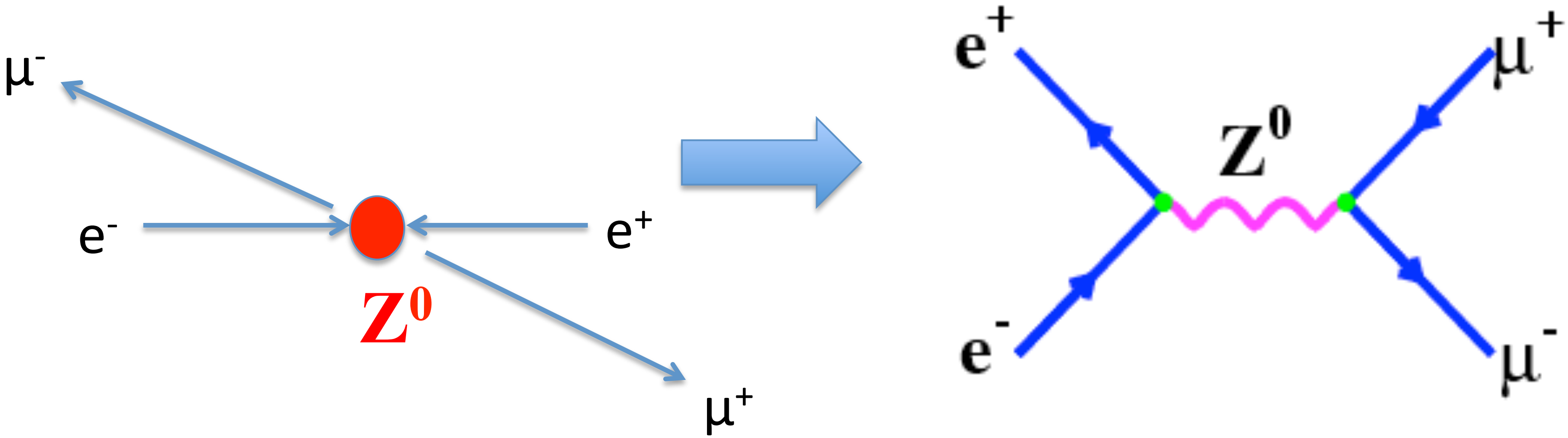


decay of a Z^0 boson to a $\mu^+\mu^-$ pair.
Several other final states are possible

Energy and momentum of the particle system is conserved

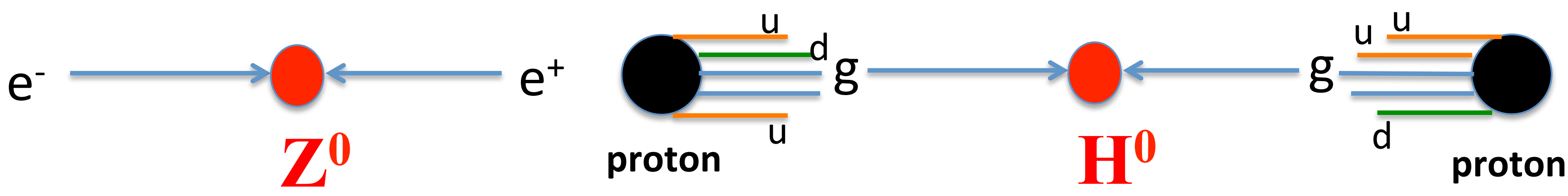
The *invariant mass* of the $\mu^+\mu^-$ pair gives the mass of the Z boson

Feynman diagrams



Particle creation

g = gluon
u,d = up quark, down quark

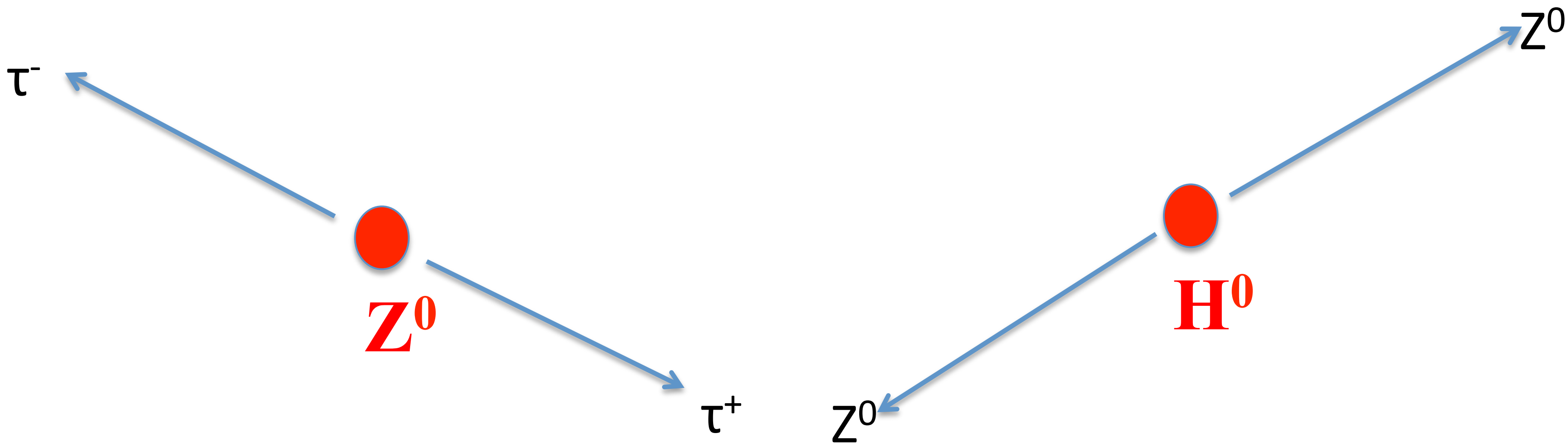


creation of a Z^0 boson from a e+e- collision

creation of a H^0 boson from a proton-proton **collision**

Energy and momentum of the particle system is conserved

Particle decay

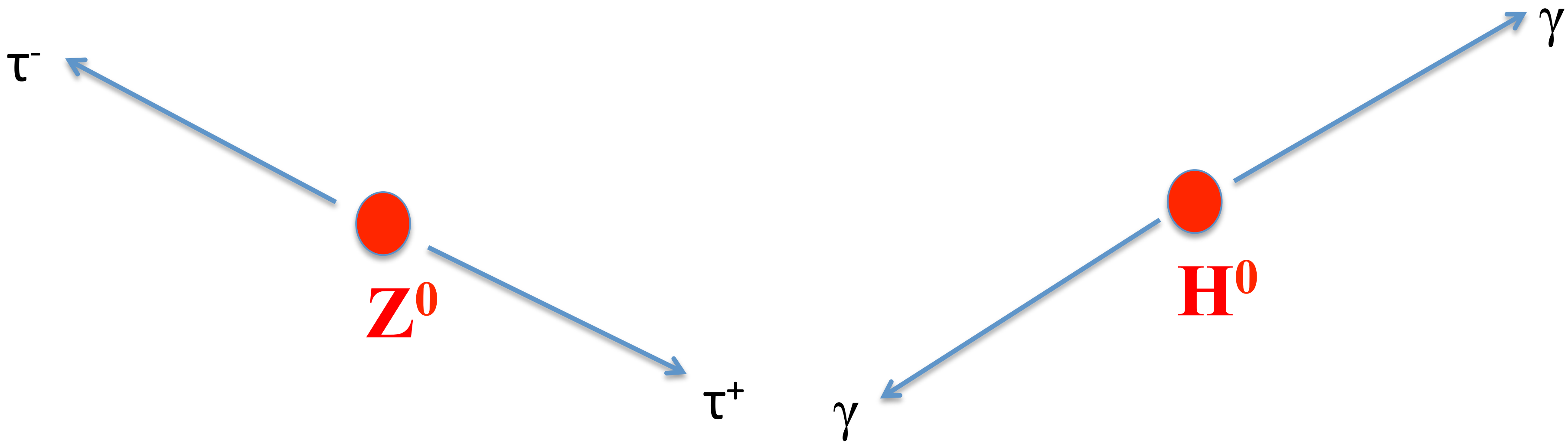


decay of a Z^0 boson to a $\tau^+\tau^-$ pair

decay of a H^0 boson to a Z^0Z^0 pair
Several other final states are possible

The invariant mass of the Z^0Z^0 pair gives the mass of the H boson

Particle decay

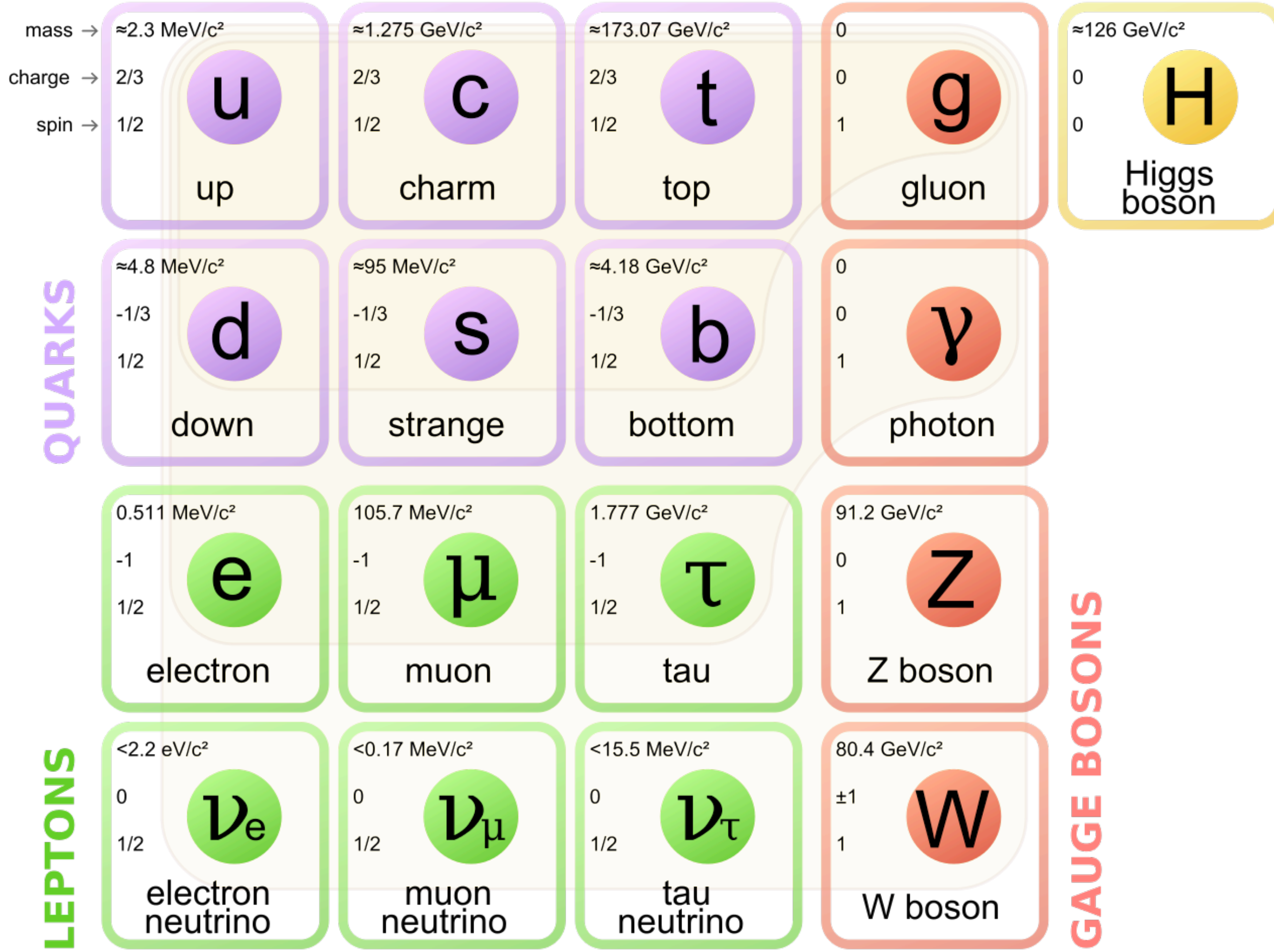


decay of a Z^0 boson to a $\tau^+\tau^-$ pair

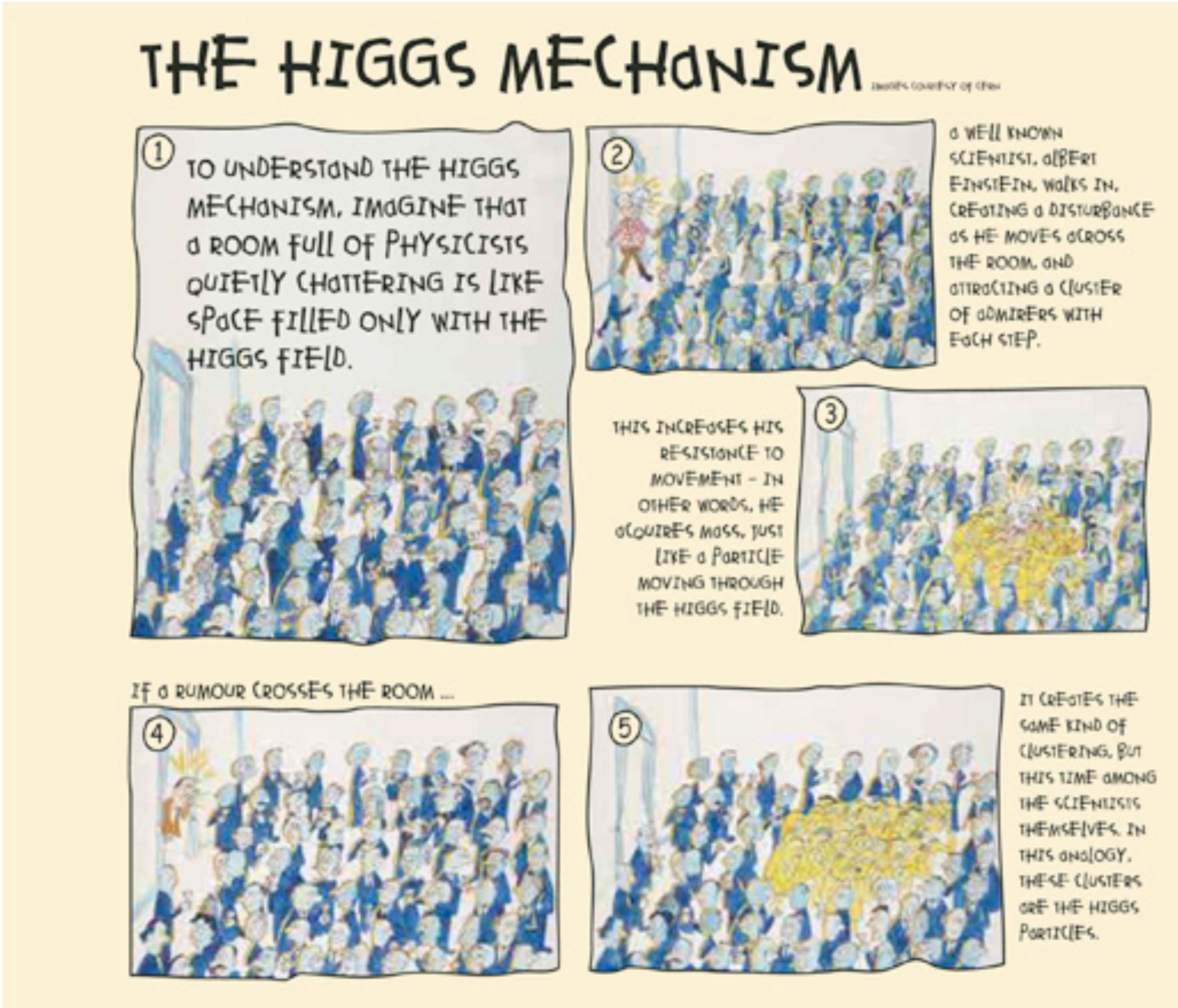
decay of a H^0 boson to a $\gamma\gamma$ pair
Several other final states are possible

The invariant mass of the Z^0Z^0 pair gives the mass of the H boson

The Standard Model

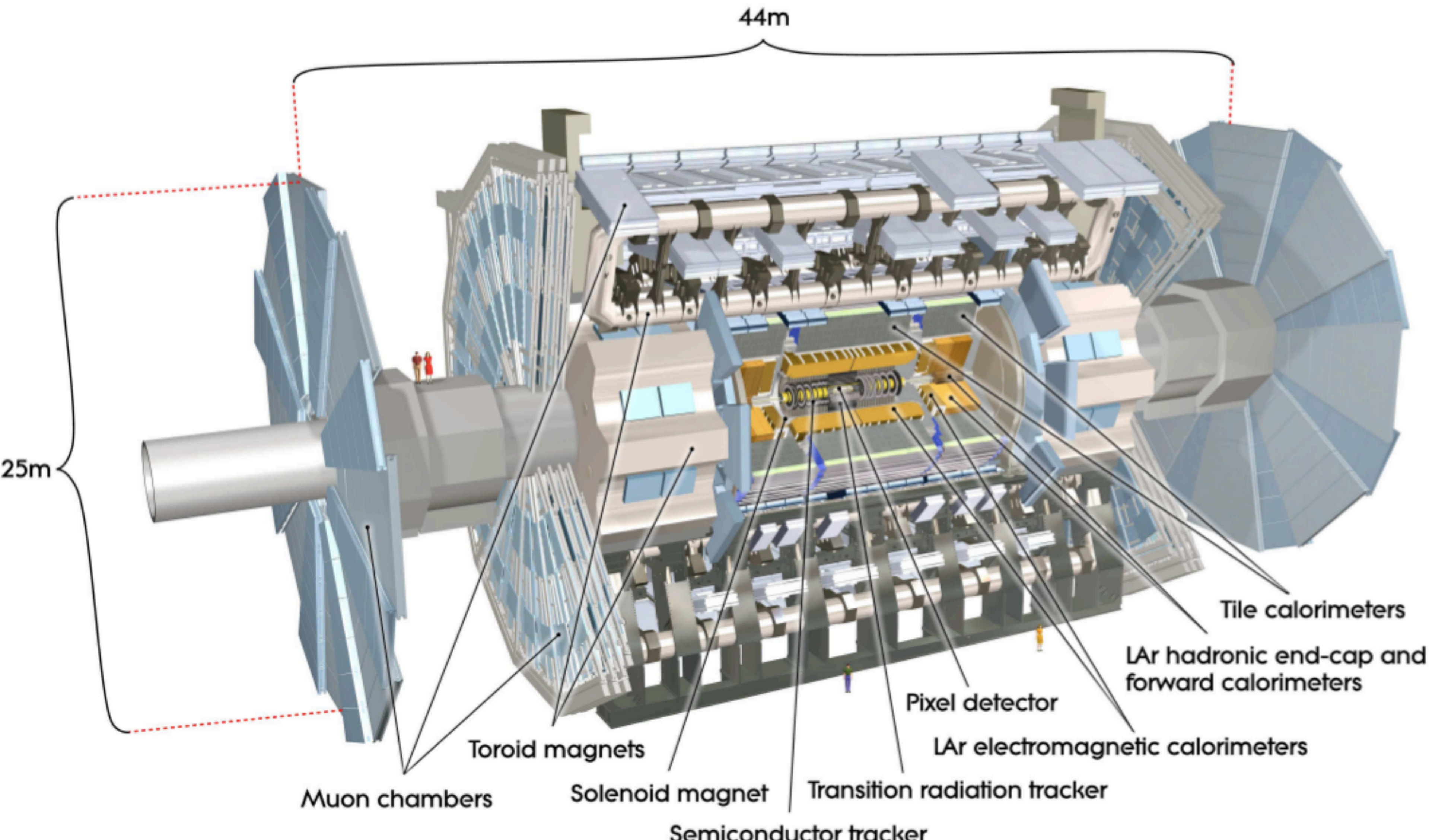


The Higgs mechanism

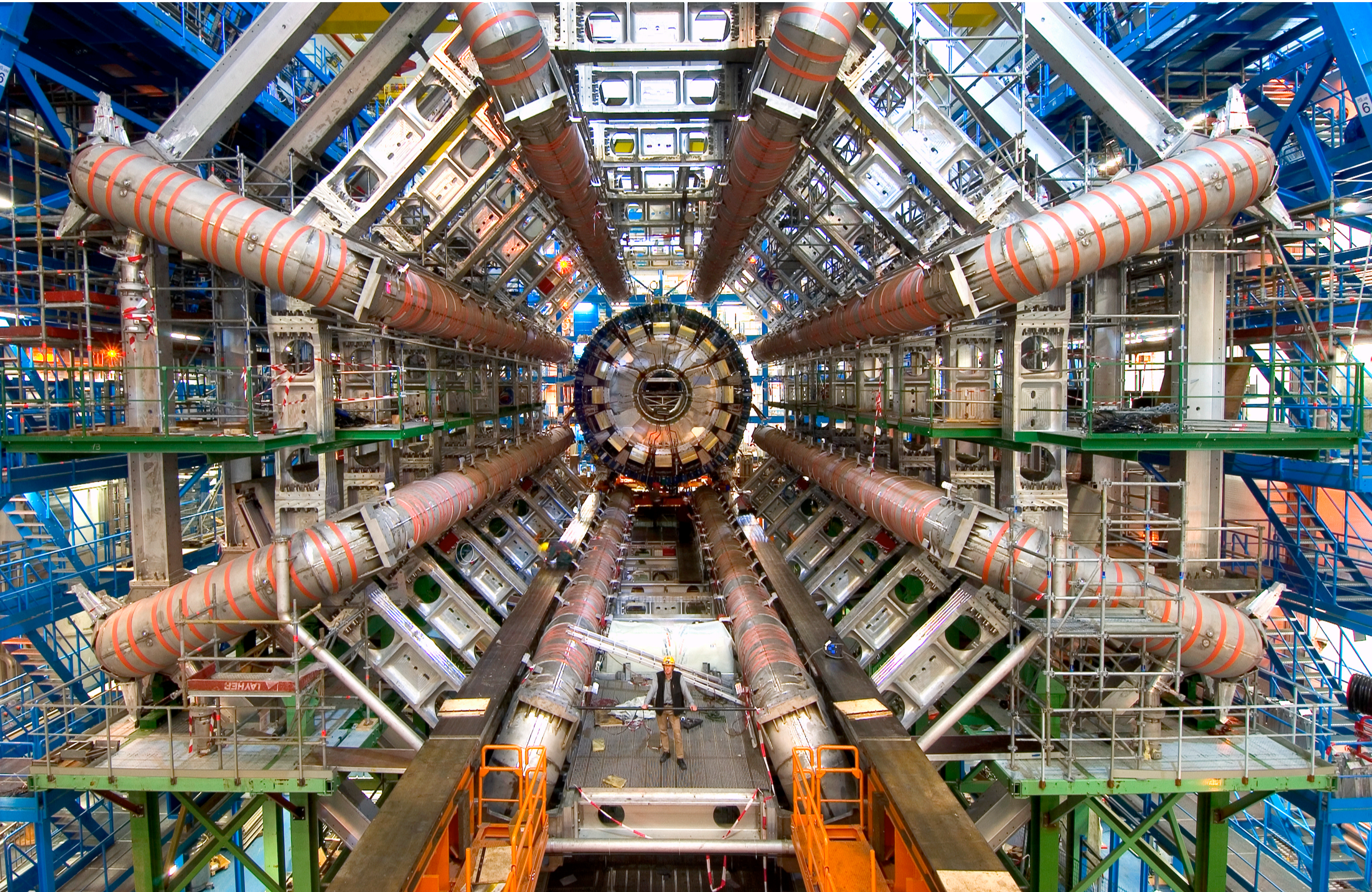


The ATLAS and CMS detectors

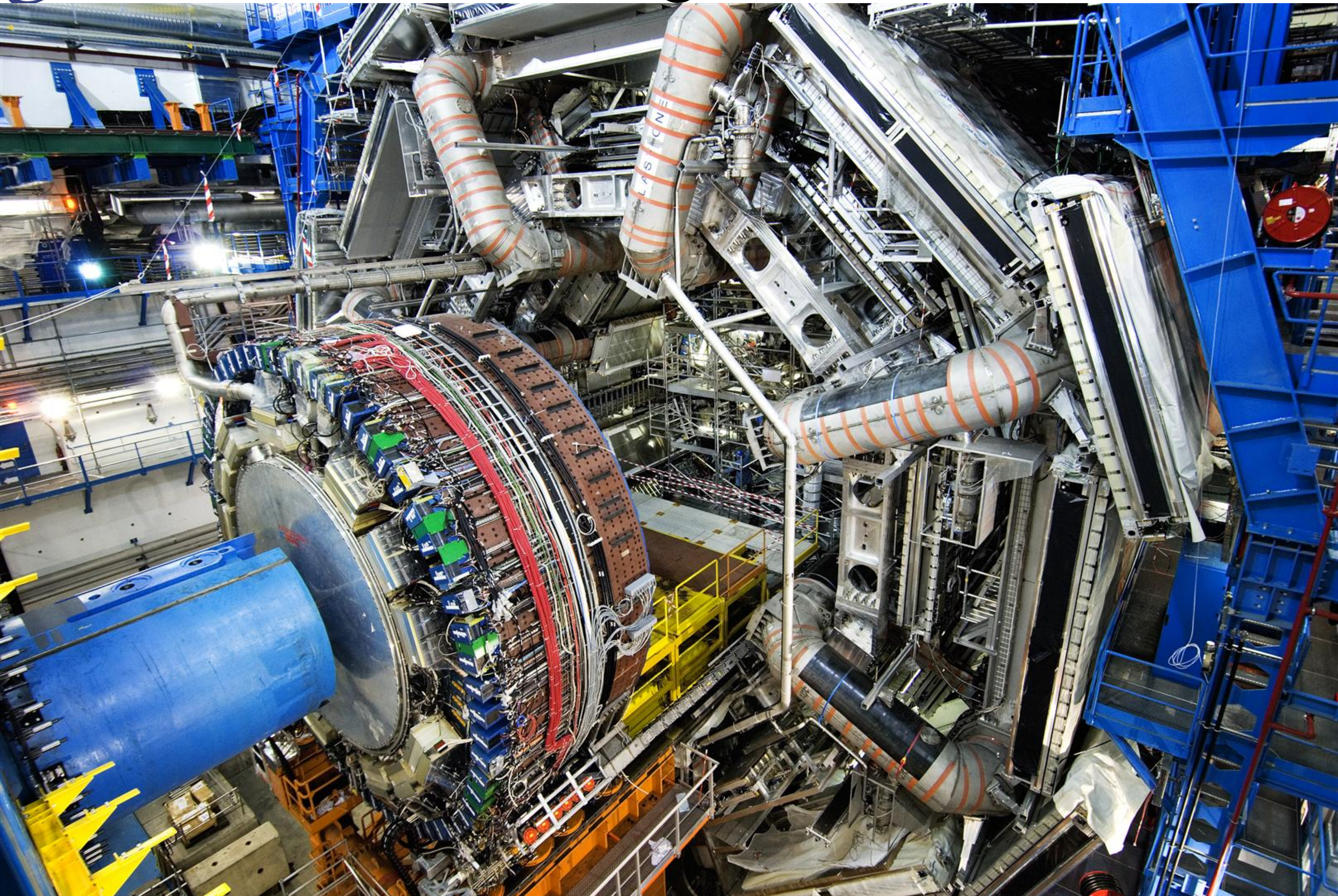
The ATLAS Detector - I



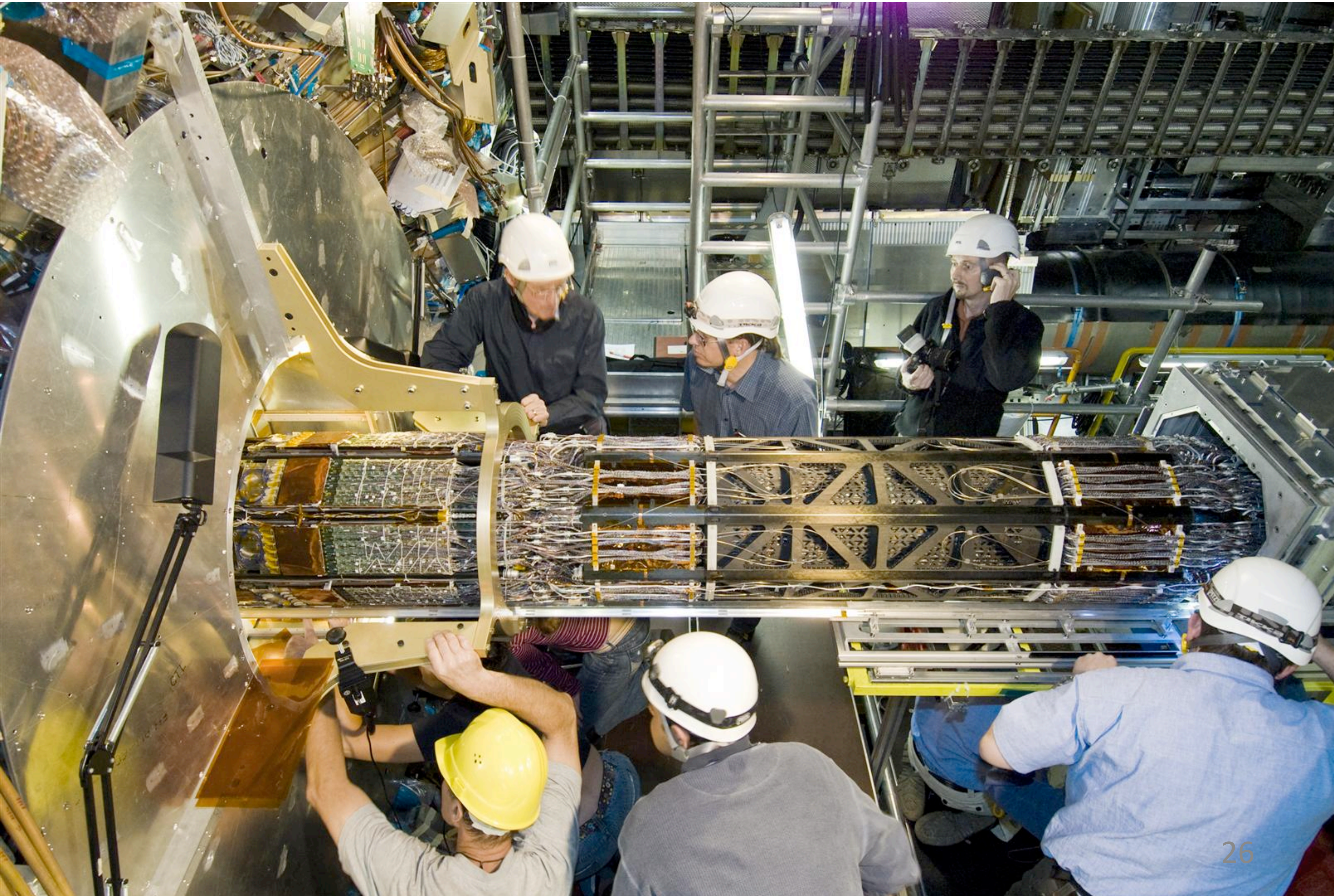
ATLAS during construction

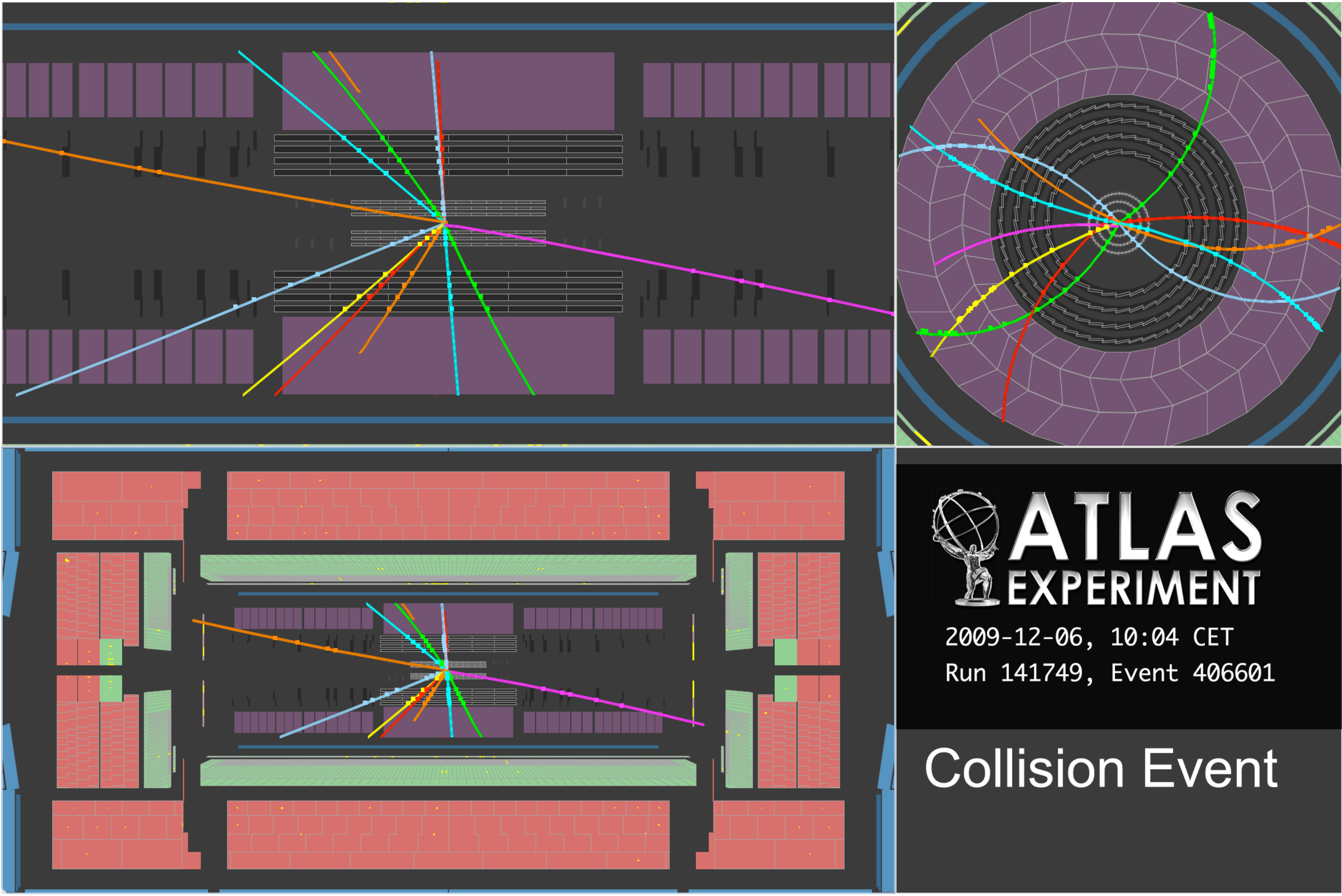


ATLAS during construction

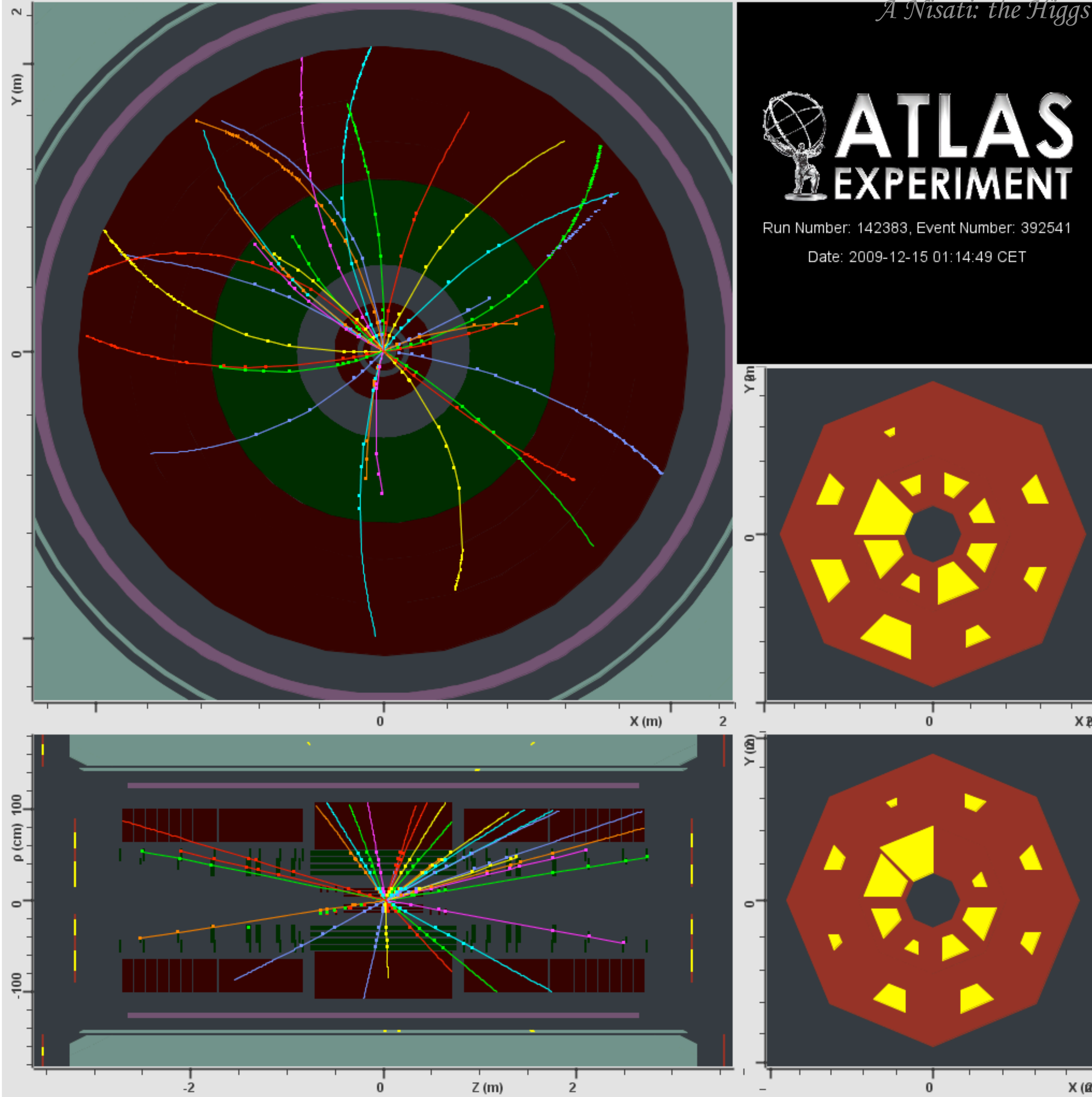


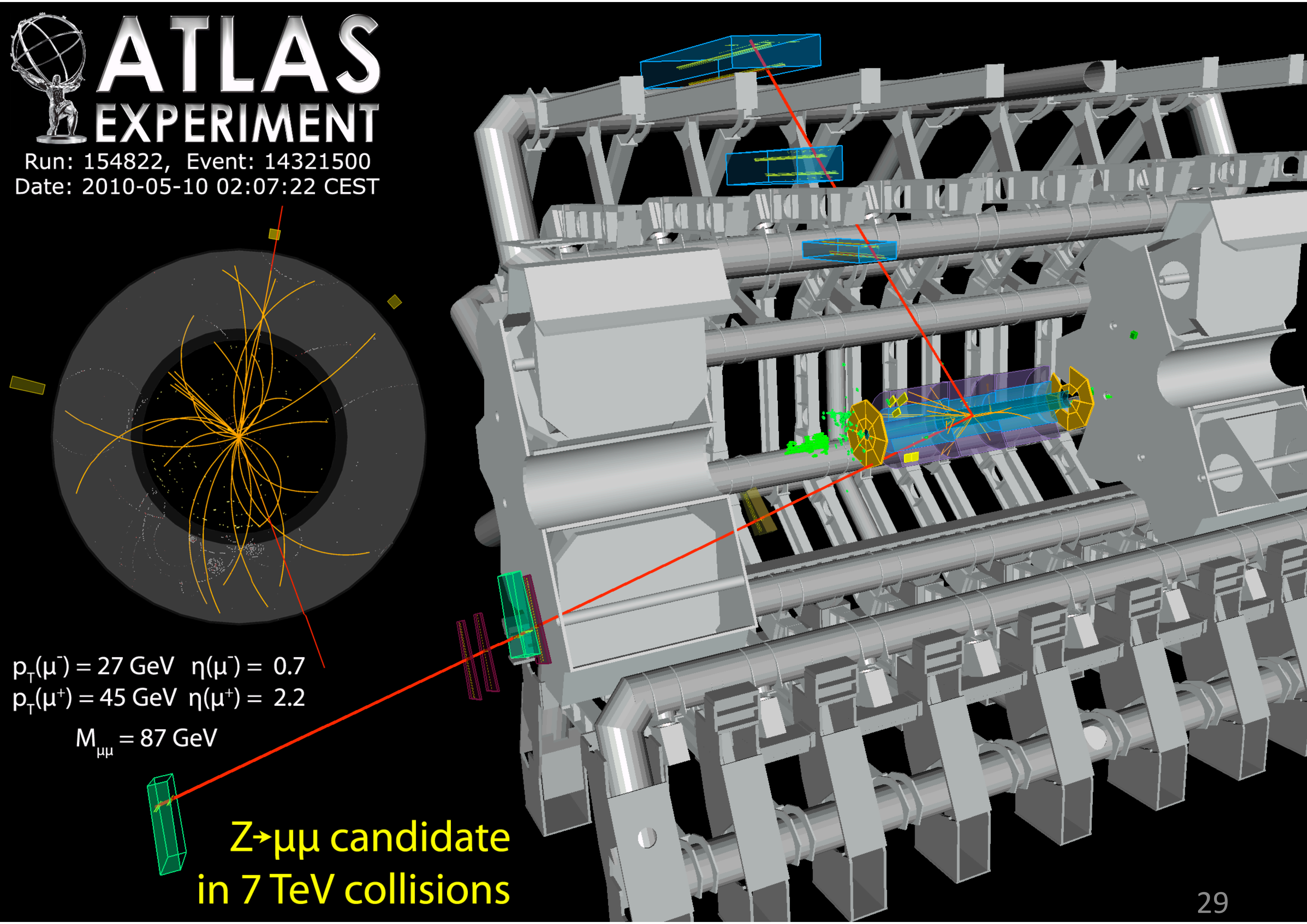
ATLAS during construction



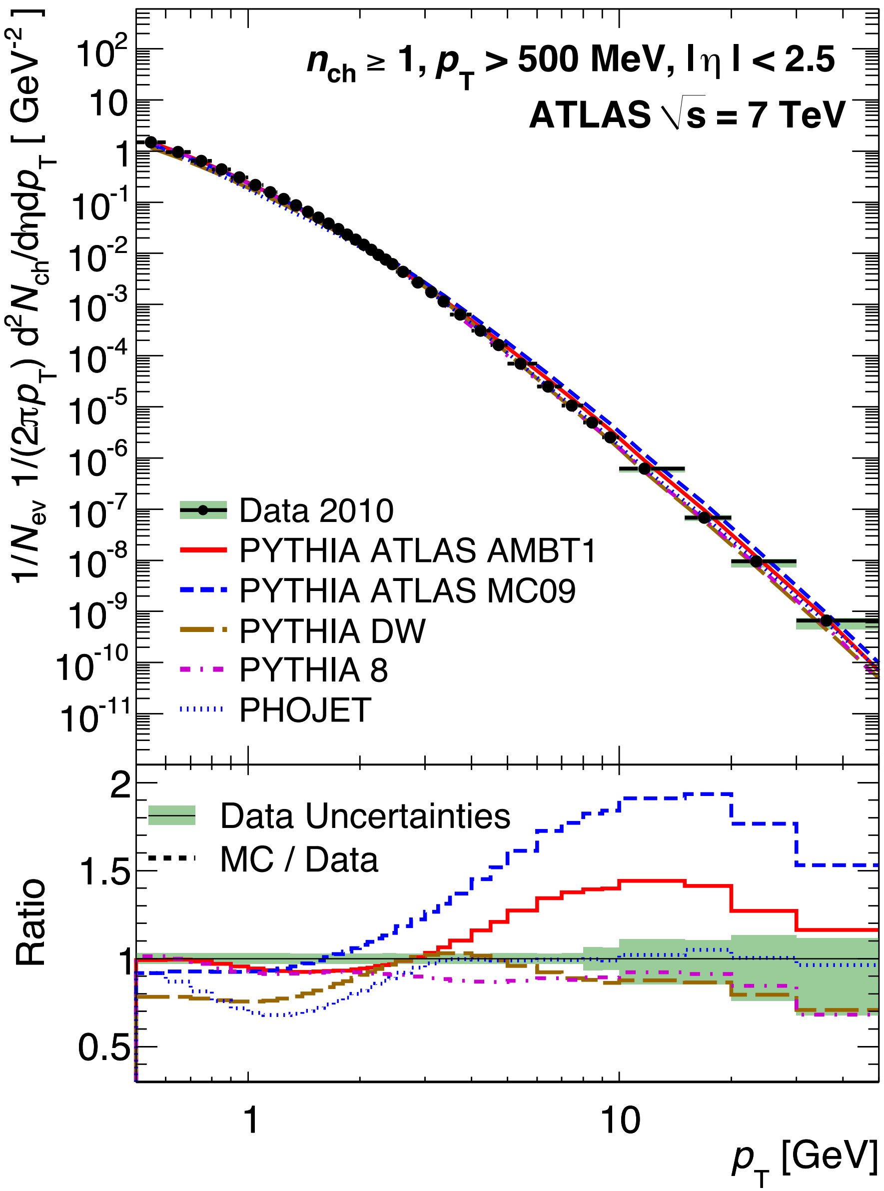


http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html


ATLAS EXPERIMENT
Run Number: 142383, Event Number: 392541
Date: 2009-12-15 01:14:49 CET
Y (m)
X (m)
ρ (cm)
Z (m)
2
0
-2
100
-100

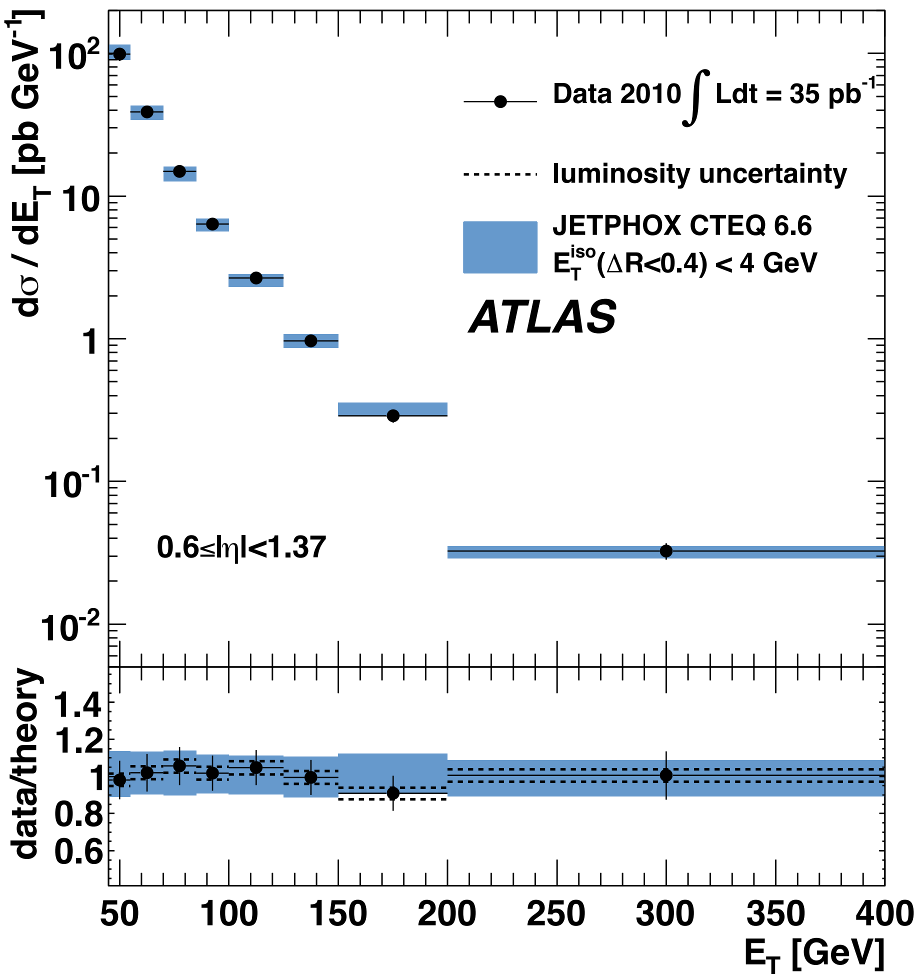

ATLAS EXPERIMENT
Run: 154822, Event: 14321500
Date: 2010-05-10 02:07:22 CEST
$p_T(\mu^-) = 27$ GeV $\eta(\mu^-) = 0.7$
$p_T(\mu^+) = 45$ GeV $\eta(\mu^+) = 2.2$
$M_{\mu\mu} = 87$ GeV
$Z \rightarrow \mu\mu$ candidate
in 7 TeV collisions

Charged particle production



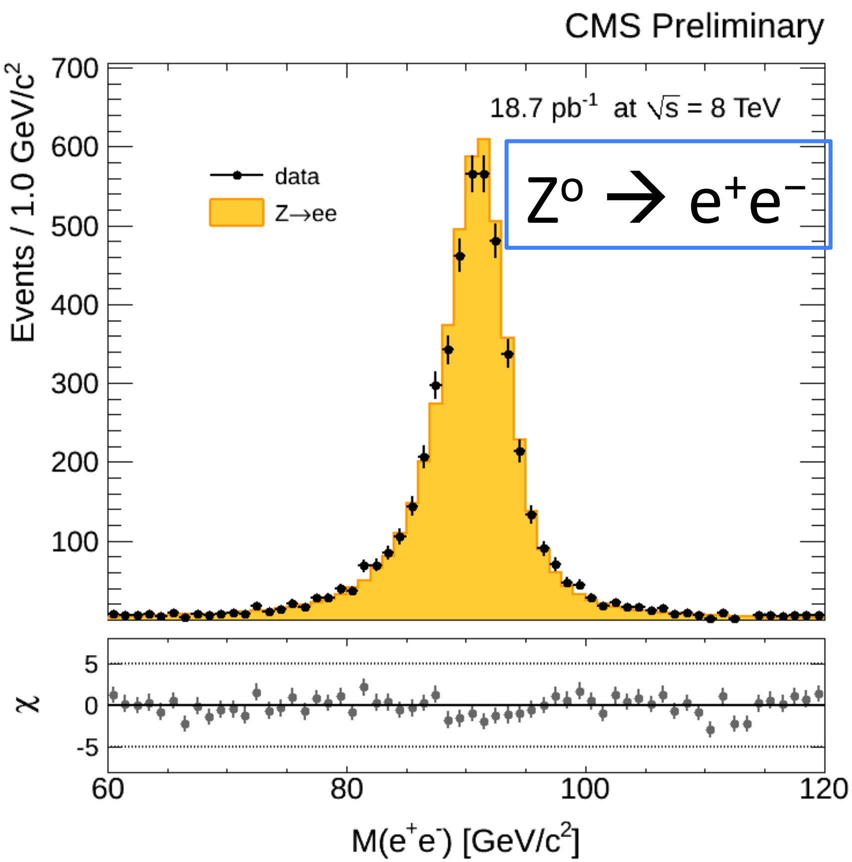
- Charged-particle multiplicities as a function of the transverse momentum, p_T, for events with nch >= 1, p_T > 500 MeV and $|\eta|$<2.5 at $\sqrt{s}$ = 7 TeV.
  - dots represent the data and the curves the predictions from different MC models.
  - vertical bars represent the statistical uncertainties
  - shaded areas show statistical and systematic uncertainties added in quadrature.
  - The bottom inserts show the ratio of the MC over the data. The values of the ratio histograms refer to the bin centroids.

Di-photon production

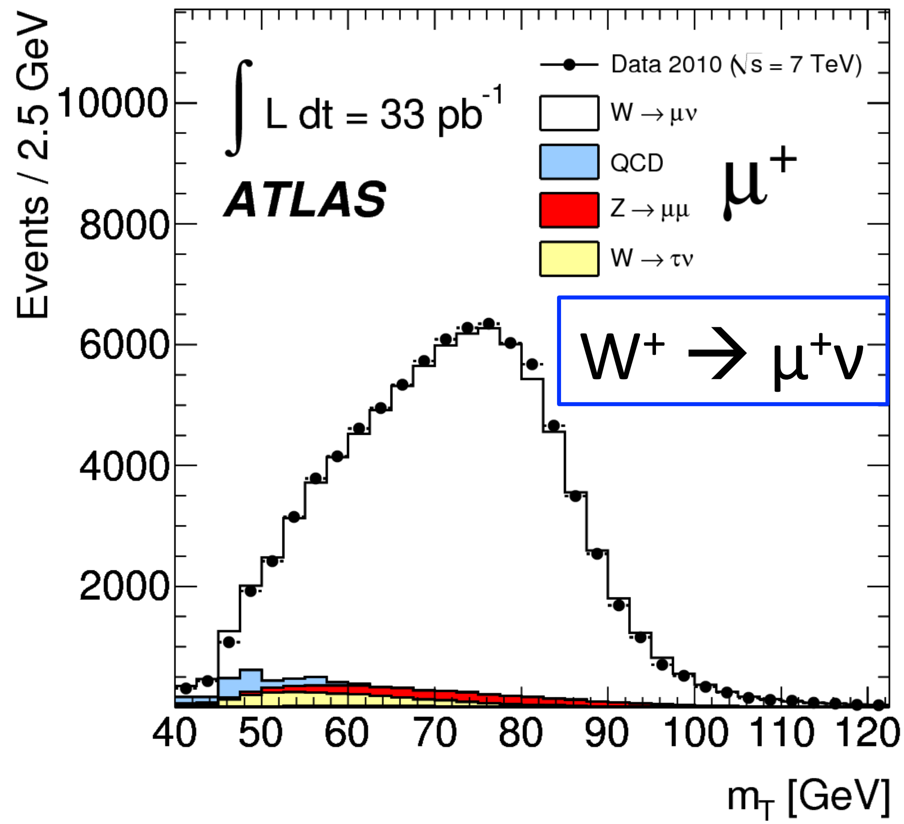


- Measured (dots) and expected (shaded area) inclusive prompt photon production cross-sections, and their ratio, as a function of the photon E_T and in the range $|\eta|<0.6$. The CTEQ 6.6 PDFs are used in the JETPHOX theoretical computation.

Production of $W^{\pm}$ and Z^0 bosons



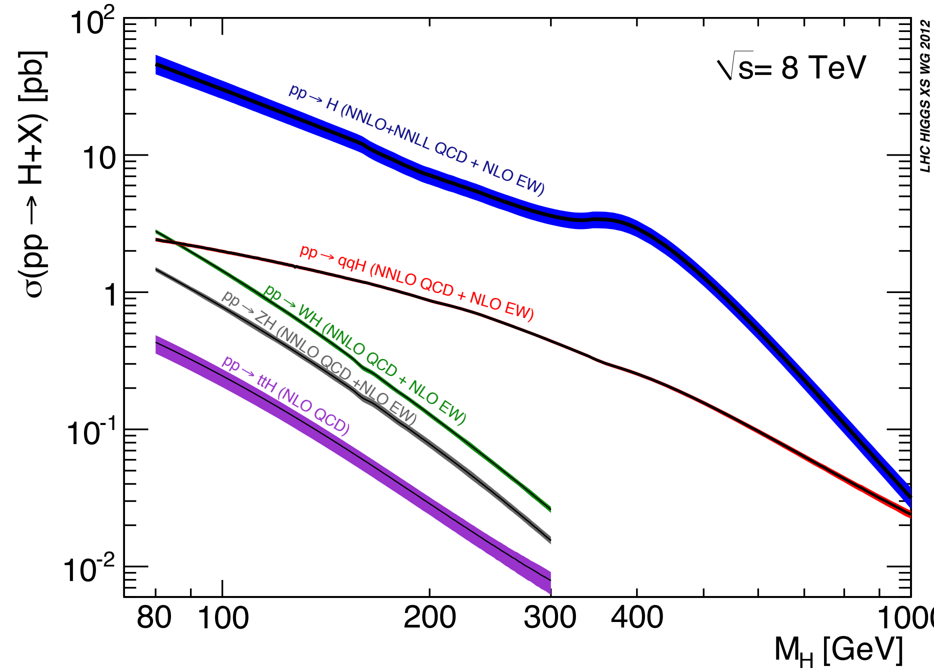
Invariant mass distribution of candidate Z^0 events in electron-positron final states.

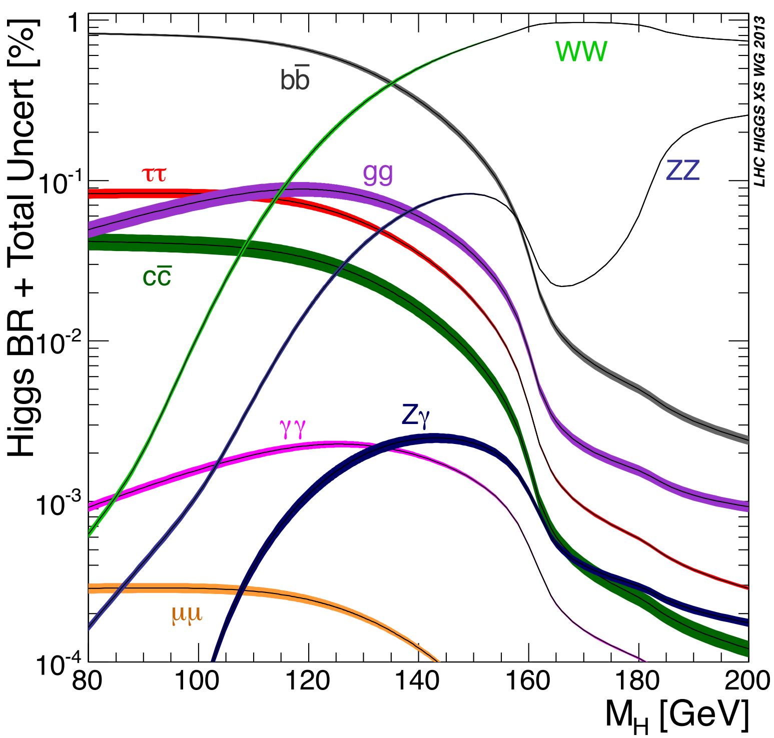


Transverse mass distribution of candidate W^+ events in muon-neutrino final states. The simulation is normalised to the data. The QCD background shape is taken from simulation and normalised to the number of QCD events measured from data.

Higgs boson production at LHC

- If realized in nature, also the Higgs boson predicted by Standard Model can be produced at the Large Hadron Collider





- The decay modes of the Higgs boson depends on its mass

Search for the Higgs boson

- Searches for the Higgs boson are based on experimental signatures that combine production rates and robustness of the measured final states

m_H, GeV	WW→ lνlν	ZZ→4l	γγ
120	3141	36	1061
150	10517	59	434
300	3053	119	1

no detector acceptance
no analysis cuts applied

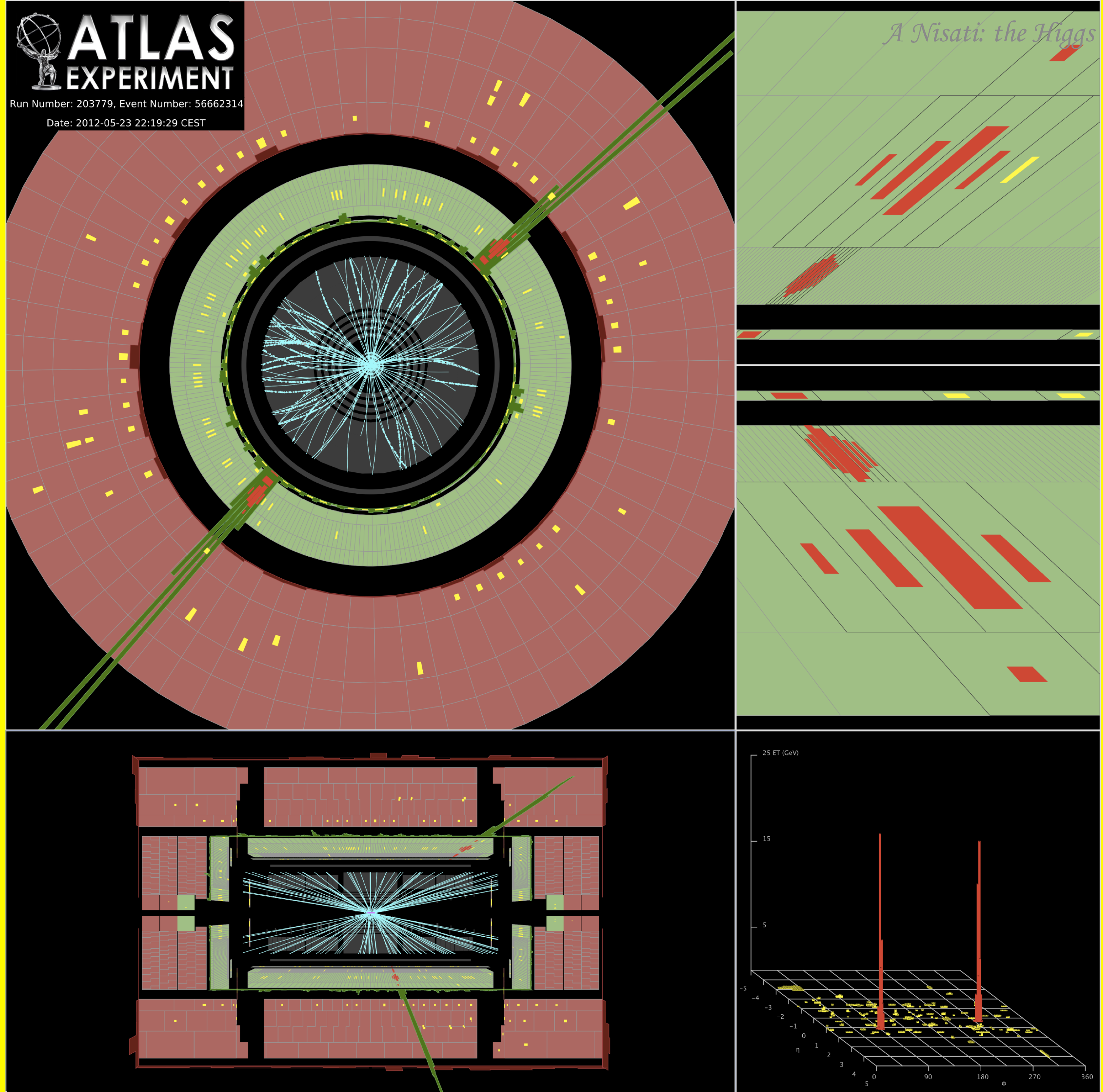
Higgs events, √s=8 TeV , L = 20 fb^{-1}

- **H→γγ**: rare channel, but the best for low mass
- **H→WW$^{(*)}$**:
  - →lνlν: very important in the intermediate mass range
  - → lνqq: highest rate, important at high mass
- **H→ZZ$^{(*)}$**:
  - **→ 4l: golden channel**
  - → llνν: good for high mass
  - → llbb: also high mass
- **H→ττ**: good signal/ background, important at low mass, rare
- Associated prod. **H→ bb-bar**
  - ttH, WH, ZH
  - It is useful for the discovery
  - It is very important for Higgs boson property studies

Instrumentation is crucial!

- ***Detector – Trigger – Computing – Theory*** have been all crucial to the discovery of the 125 GeV Higgs boson
- Not possible to cover in detail all the domains above cited, perhaps I can expand a bit on Detector:
  - High performance needed for reconstruction, identification and precise measurements of photons, electrons, muons, taus, jets, b-jets and missing transverse energy
  - High granularity detectors, longitudinal segmentation of electromagnetic and hadronic calorimeter

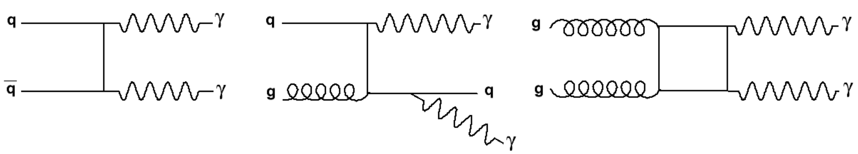
$H \rightarrow \gamma\gamma$


ATLAS EXPERIMENT
Run Number: 203779, Event Number: 56662314
Date: 2012-05-23 22:19:29 CEST

H→γγ

- small BR (about 0.002)
- decay due to W and top loops
- clean 2-γ signature

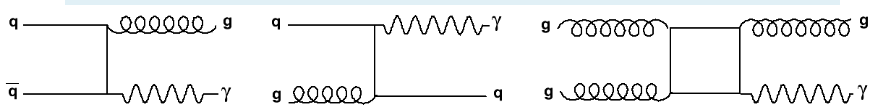
Irreducible background: pp→γγ + X



Born $O(\alpha^2)$ — Bremsstrahlung $O(\alpha_s\alpha^2)$ — Box diagram $O(\alpha^2_s\alpha^2)$

Theoretical uncertainty: ~ **25 %** (NLO: 20%)

Reducible background: pp→γj , jj+ X

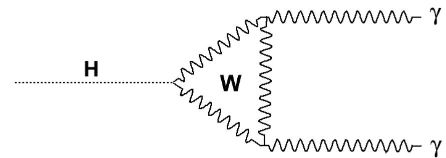


$O(\alpha_s\alpha)$ — $O(\alpha_s\alpha)$ — $O(\alpha^3_s\alpha)$

Theoretical uncertainty: ~ **30%** (dominated by NLO cross-section)

Higgs to 2γ decay

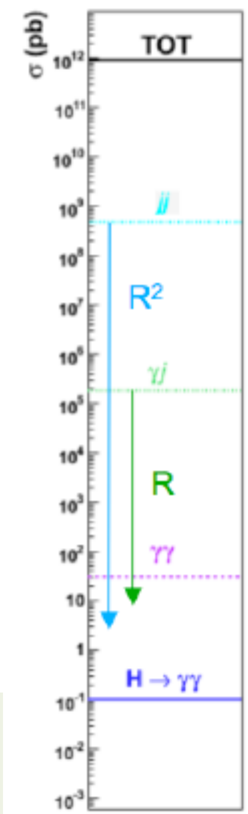
σ = 0.04 pb



qqbar, qg σ ≈ 21 pb
gg σ ≈ 8 pb

γ-jet σ ≈ 1.8 × 10^5 pb
jet-jet σ ≈ 4.8 × 10^8 pb

γ-jet need rejection R~O(10^4)
jet-jet need rejection R~O(10^7)

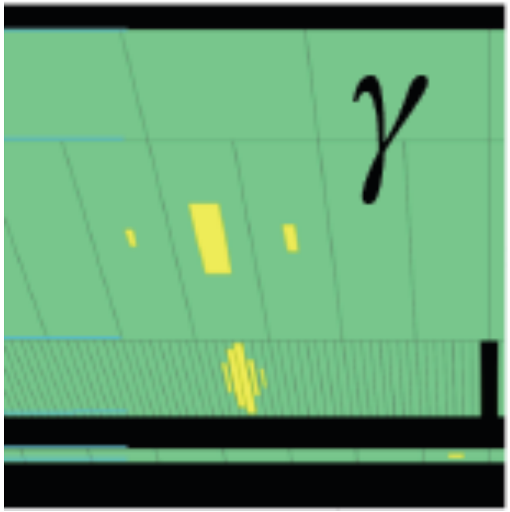


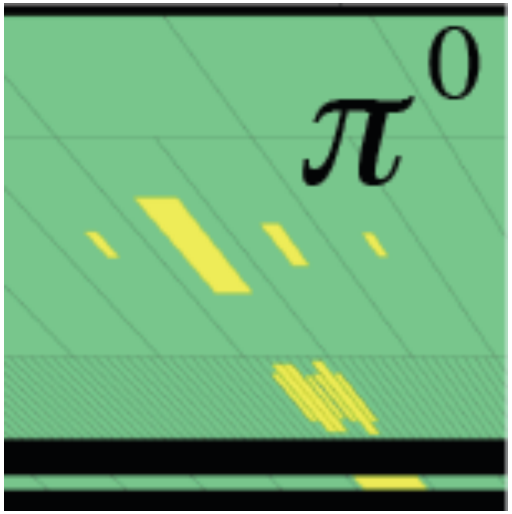
R ~ O(8000)

Main background is from leading π^0's

H→γγ

- Very simple signature (and analysis)
- Photon identification based both on lateral and longitudinal segmentation of the electromagnetic calorimeter
- Two high-quality isolated high-p_T photons
  - $p_{T1} > 40$ GeV; $p_{T2} > 25$ GeV
  - $|\eta_{12}| < 1.37$ and $1.52 < |\eta_{12}| < 2.37$





Spring 2011 data

H → γγ

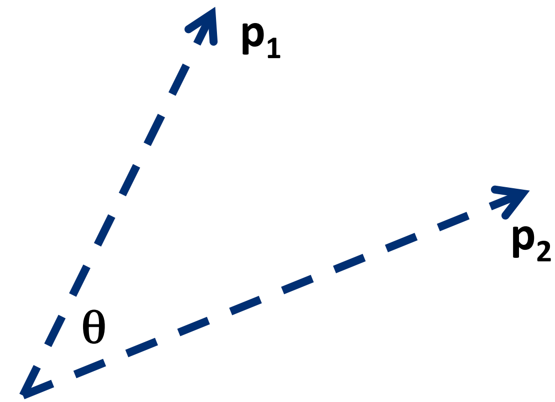
Mass reconstruction

$m^2 = 2\mathbf{P_1 P_2}(1-\cos\vartheta)$

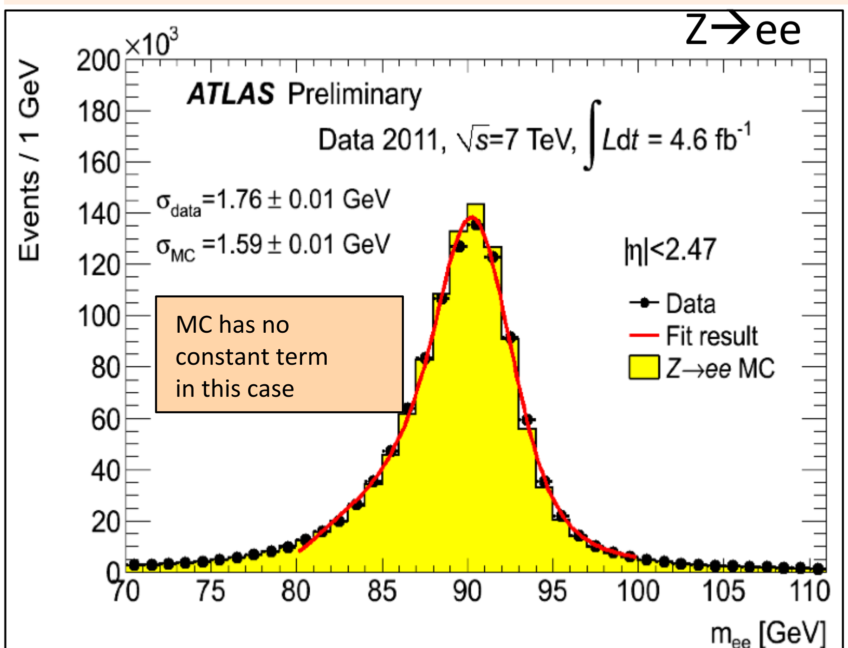
$\delta m/m = (1/\sqrt{2})(\delta P/P) \oplus (1/2)\ \delta\vartheta/(\tan\vartheta/2)$

It is important to measure the photon momentum in space with high resolution:

- → accurate measurement of the photon energy
- → accurate measurement of the photon direction of flight



Calorimeter calibration



Electron scale and resolution transported to photons using MC
(systematics few % from material effects)

Present understanding of calorimeter E response
(from Z, J/ψ → ee, W→ eν data and MC):

- **Energy scale at m_Z known to ~ 0.5%**
- **Linearity better than 1%** **(over few GeV-few 100 GeV)**
- **"Uniformity" (constant term of resolution):** 1% (barrel) -1.7 % (end-cap)

$H \rightarrow \gamma\gamma$

Mass reconstruction

$m^2 = 2P_1P_2(\mathbf{1-\cos\vartheta})$

$\delta m/m = (1/\sqrt{2})(\delta P/P) \oplus (1/2)\,\delta\vartheta/(\tan\vartheta/2)$

It is important to measure the photon momentum in space with high resolution:

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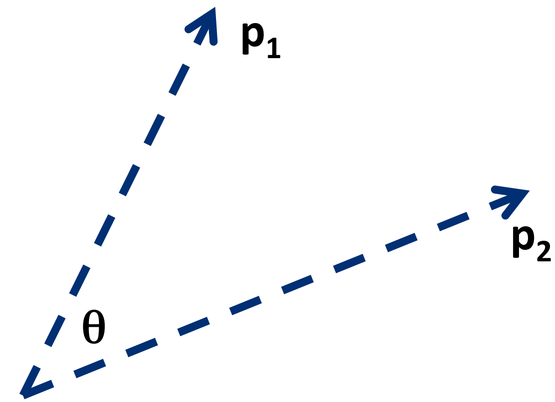
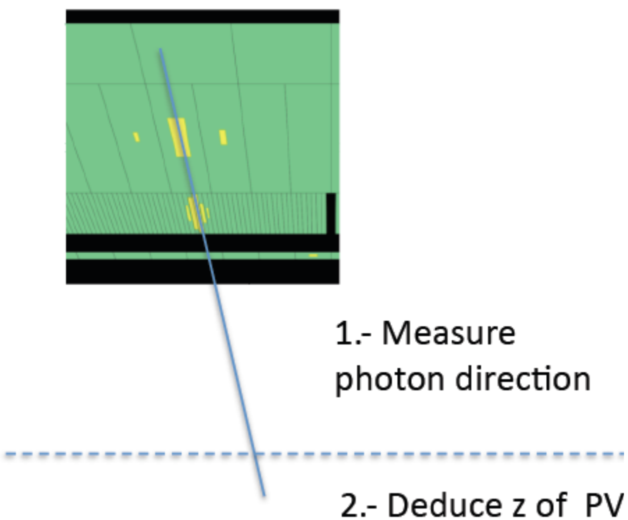


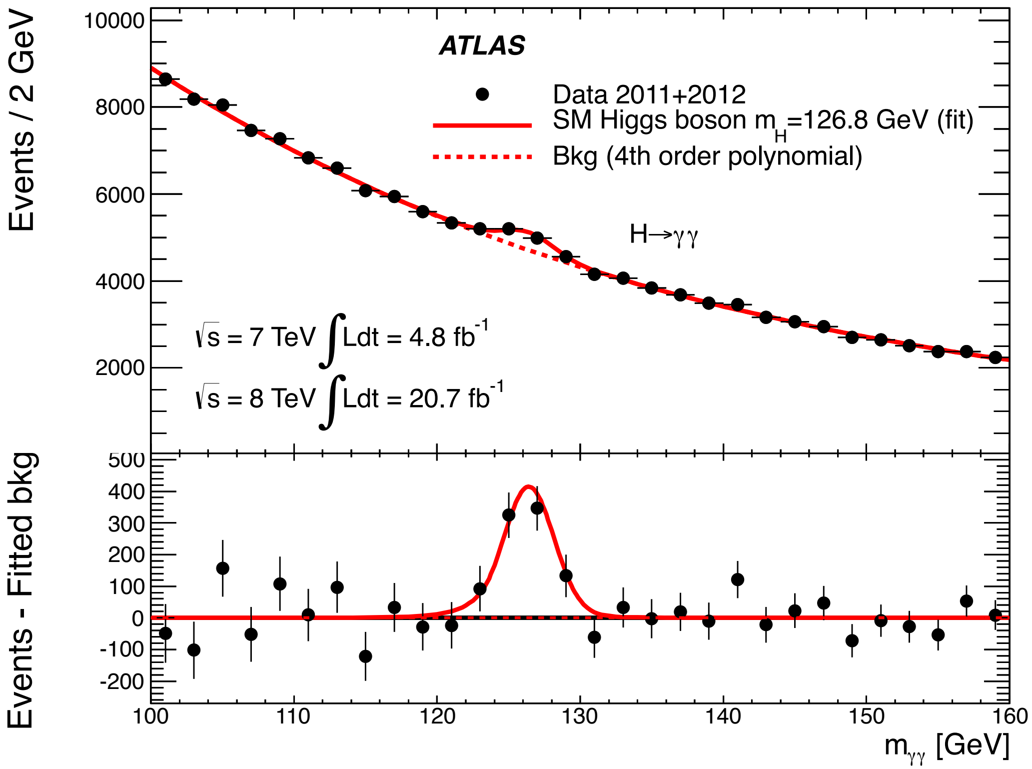
- CMS:
  - very high energy resolution
  - Measure the photon direction using the impact point measured by the crystal calorimeter, and the hard-scattering proton-proton vertex ➔ requires correct vertex identification in presence of large pile-up

- ATLAS:
  - high energy resolution
  - Measure the photon direction using the longitudinal segmentation of the LAr calorimeter, and fit the $\gamma\gamma$ production vertex using the pp beam line

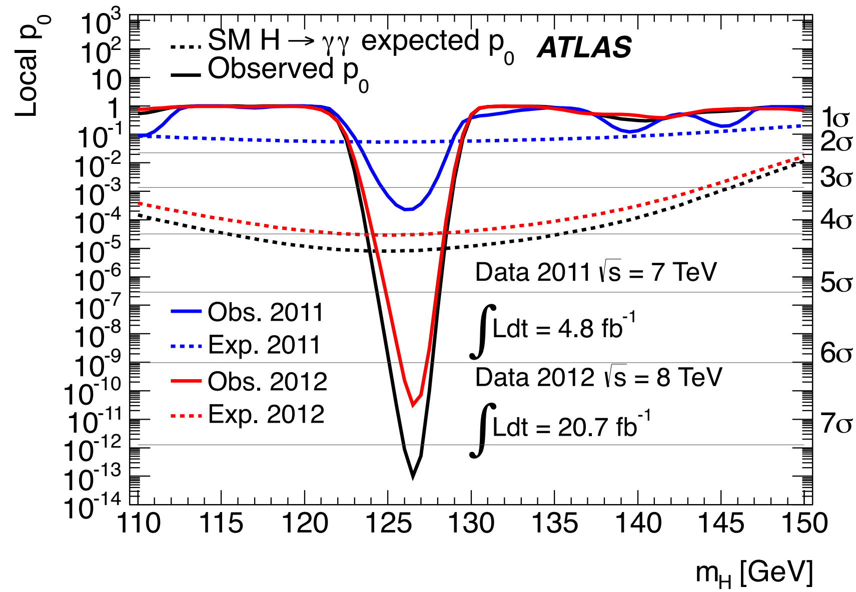


H→γγ

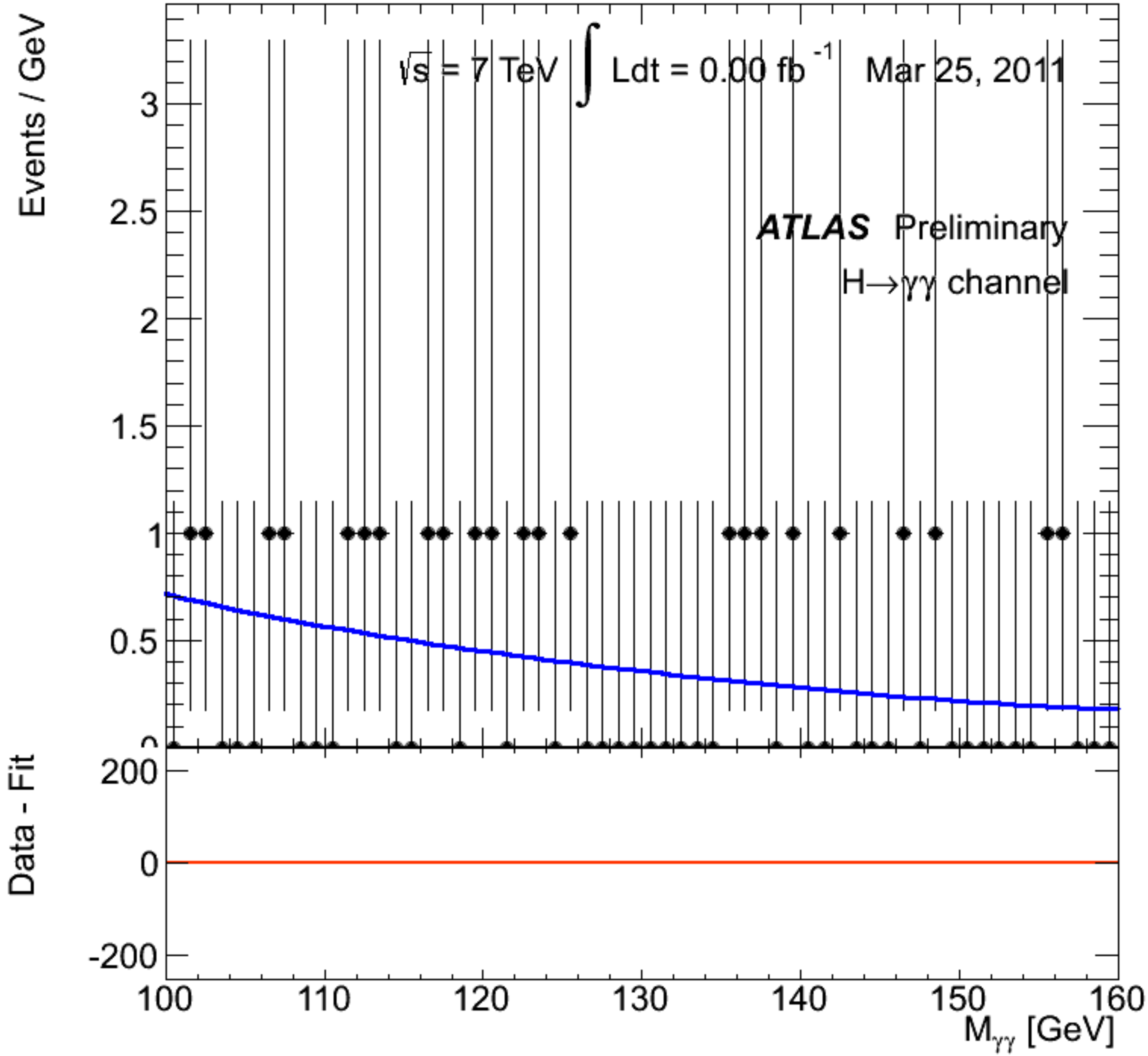
Phys. Lett. B 726 (2013), pp. 88-119



Invariant mass distribution of diphoton candidates after all selections of the inclusive analysis for the combined 7 TeV and 8 TeV data.

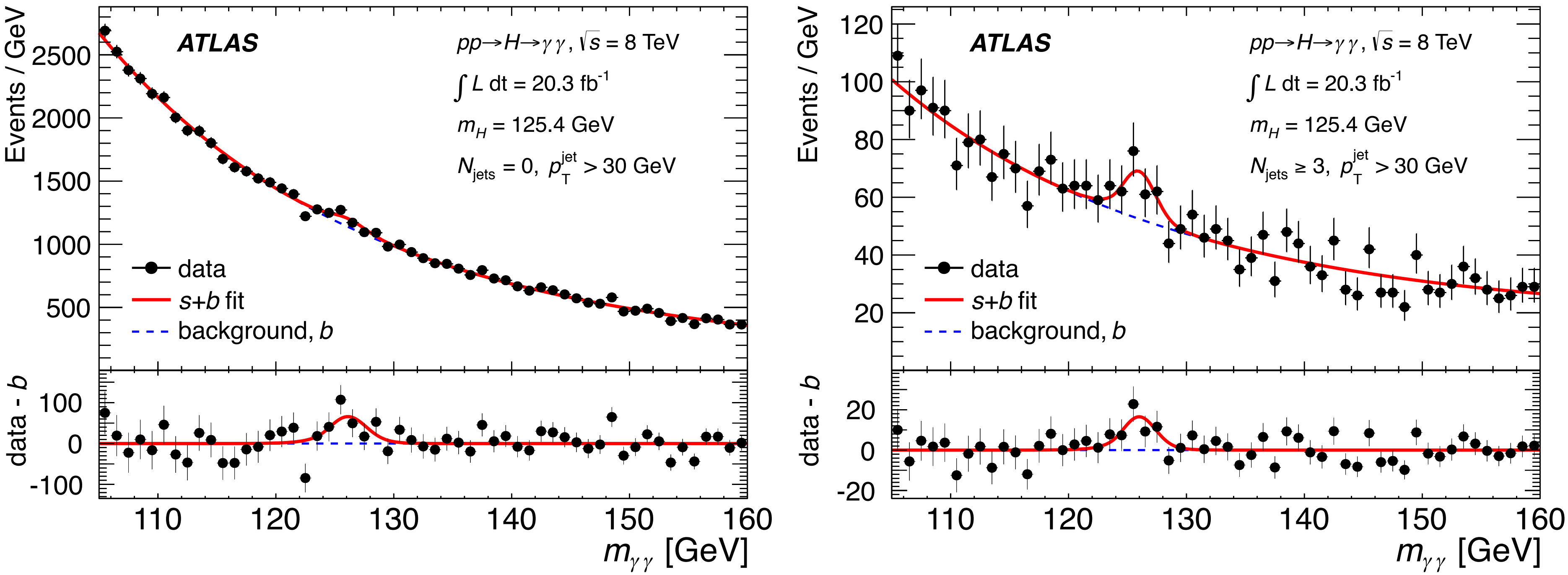


Observed local p_0 as a function of the Higgs boson mass mH for the $\sqrt{s}$ = 7TeV data(blue), the $\sqrt{s}$ = 8TeV data (red) and their combination (black).



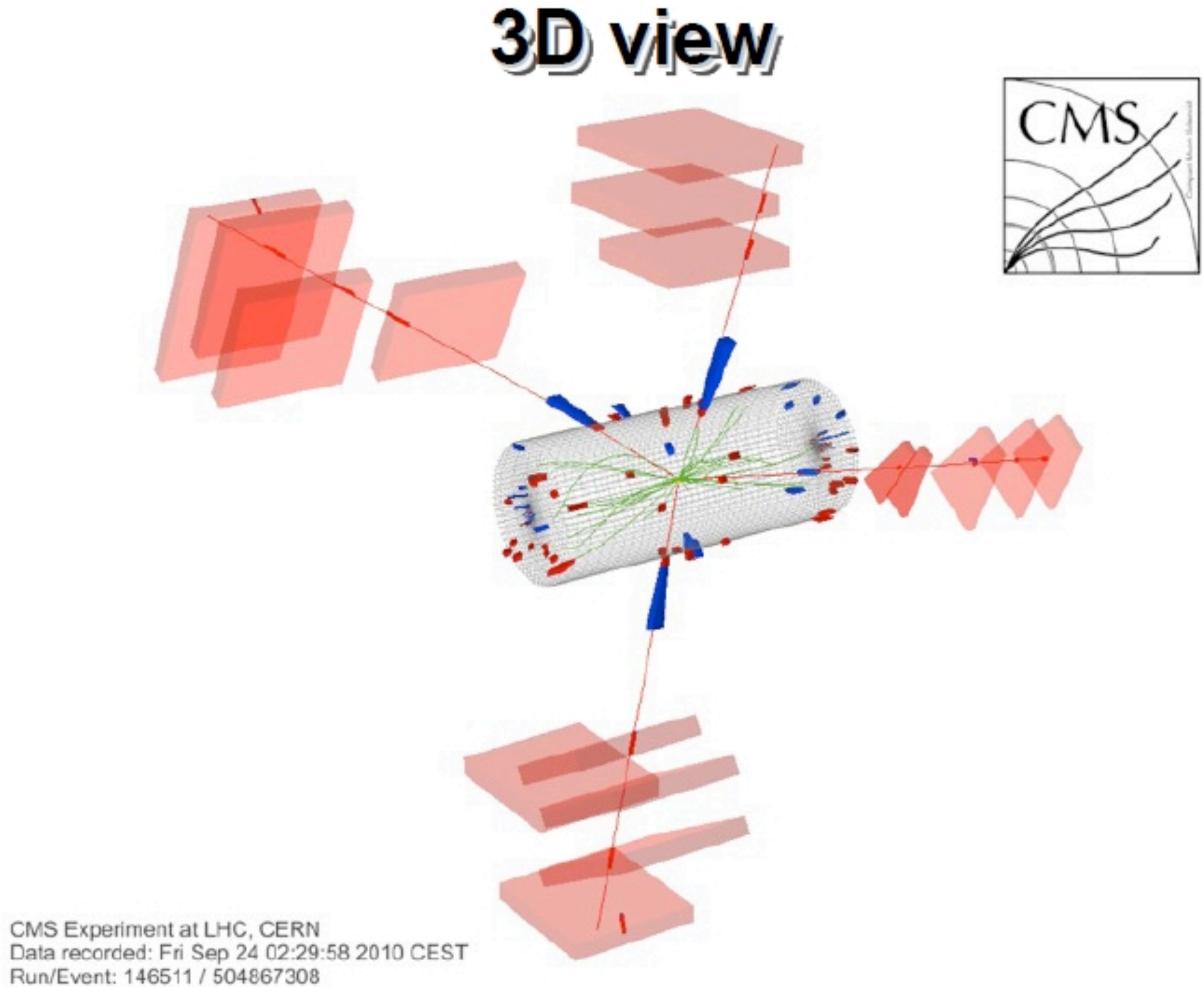
$\sqrt{s}$ = 7 TeV $\int$ Ldt = 0.00 fb^{-1} Mar 25, 2011
ATLAS Preliminary
H→γγ channel
Events / GeV
3
2.5
2
1.5
1
0.5
0
Data - Fit
200
0
-200
100
110
120
130
140
150
160
$M_{\gamma\gamma}$ [GeV]

Final H→γγ results (ATLAS)



The diphoton invariant mass spectrum for four bins of jet multiplicity. The curves show the results of the single simultaneous fit to data for all multiplicity bins, where the Higgs boson mass is fixed to be m_H = 125.4 GeV. The bottom inset displays the residuals of the data with respect to the fitted background component.

H→ZZ→4leptons

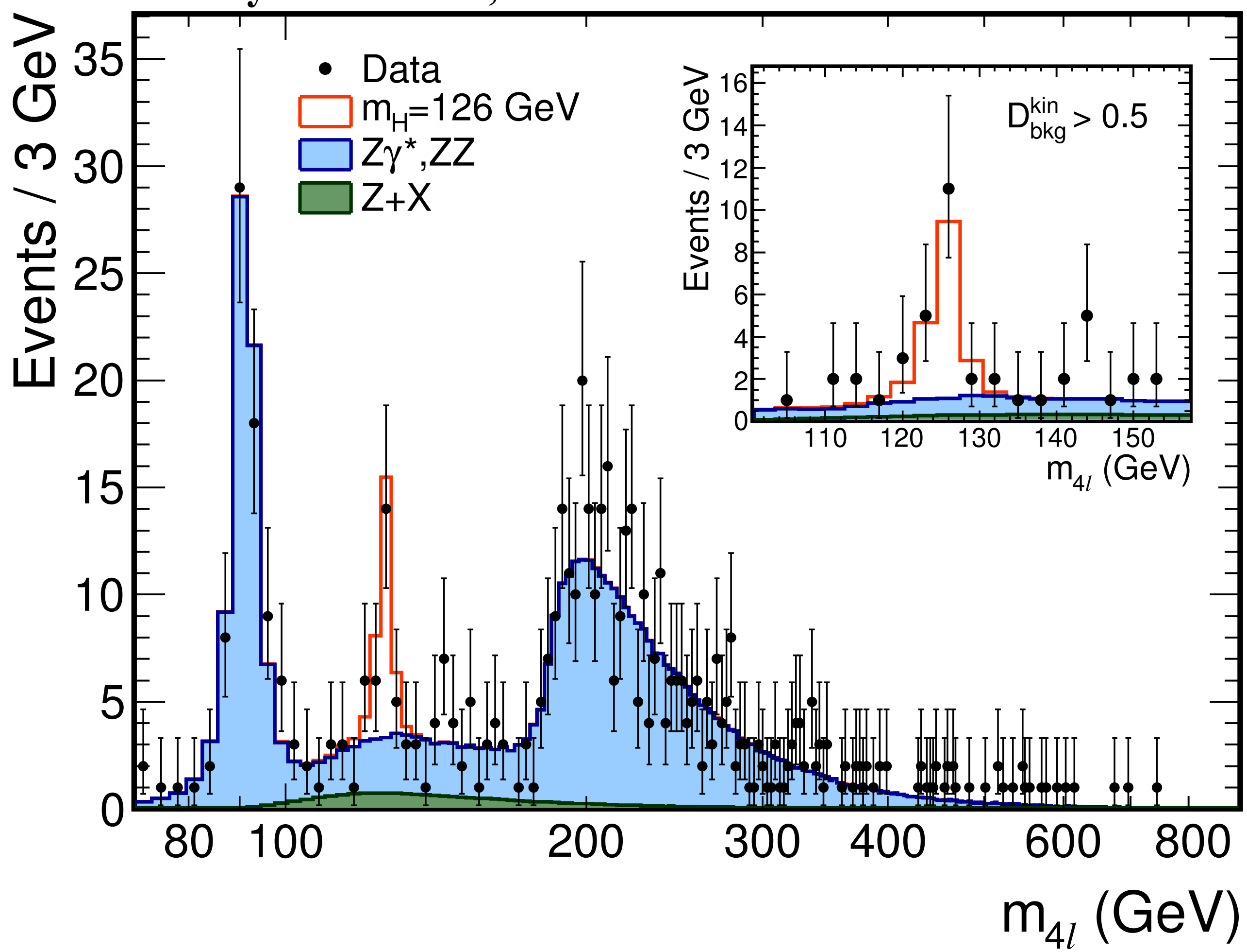


H→ZZ→4-lepton search

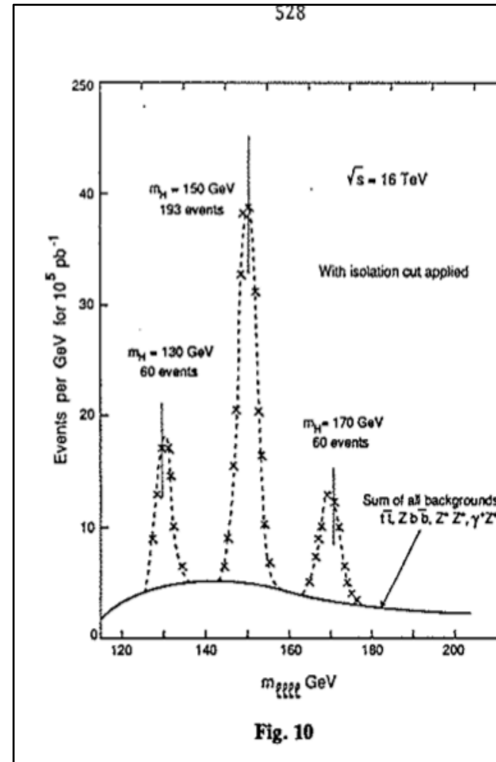
- Here we would like first to reconstruct the two Z-bosons through their decays $Z \to \mu^+\mu^-$ and $Z \to e^+e^-$
- Select events with **two pairs** **same-flavour** **opposite charge** **isolated** **high transverse momentum** leptons (e or μ)
  – Ask the pair with the highest pT leptons to have an invariant mass consistent within resolution with the Z boson mass

H→ZZ→4-lepton invariant mass

CMS **Phys. Rev. D 89, 092007** $\sqrt{s}$ = 7 TeV, L = 5.1 fb^{-1} ; $\sqrt{s}$ = 8 TeV, L = 19.7 fb^{-1}



Proceedings of LHC Workshop (Aachen, 1990): H→ 4l signals
m_H=130, 150, 170 GeV
$\sqrt{s}$ = 16 TeV, 100 fb^{-1}

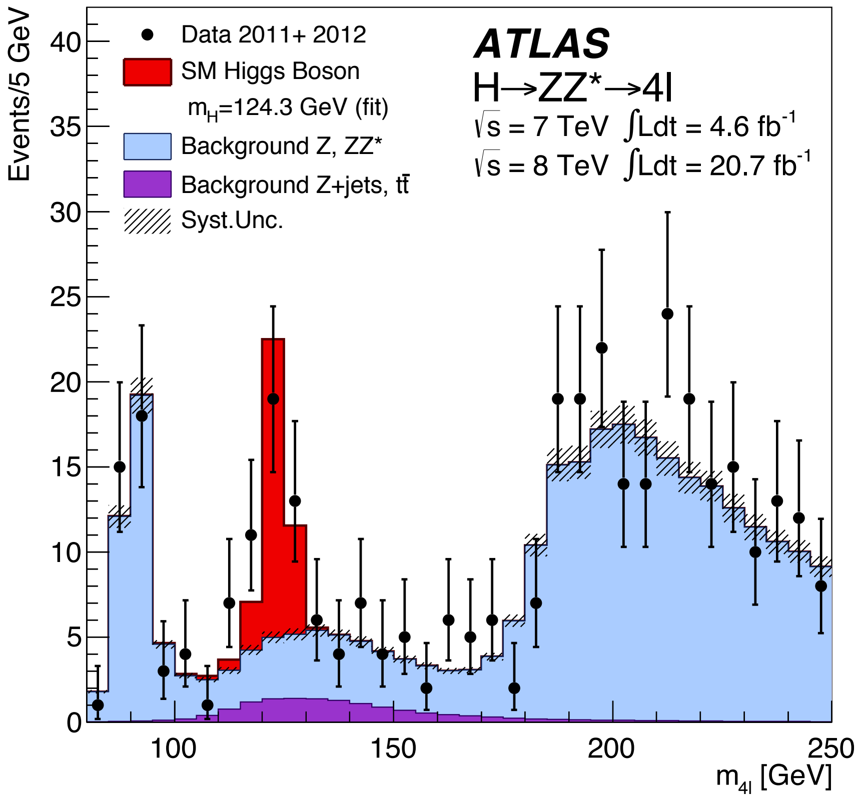


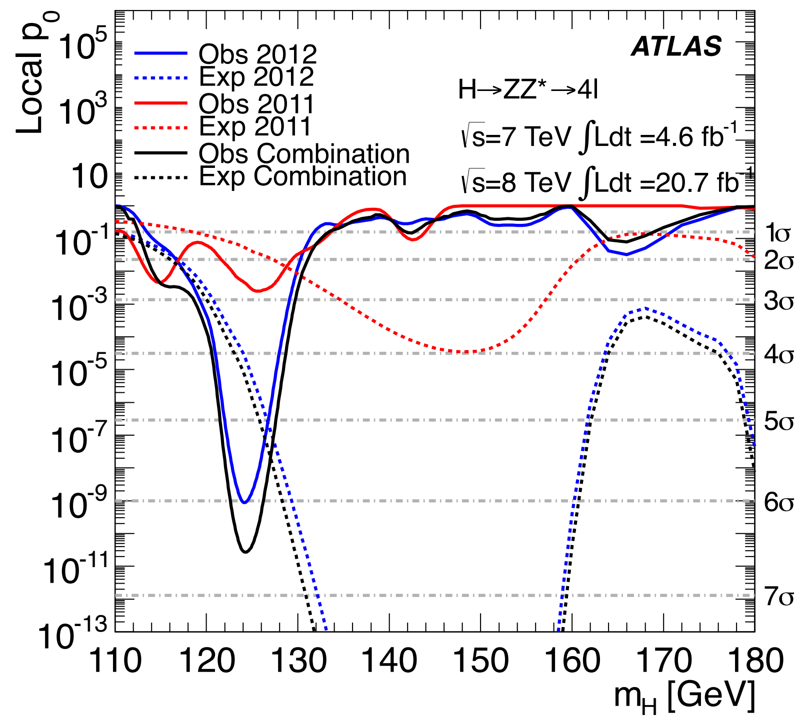
Continuum: ZZ (dominant) + Z+jets

Significance of the observed excess at m_H~ 125.6 GeV: 6.8σ (expected : 6.7σ)

H→ZZ→4l

arXiv:1408.5191 [hep-ex]

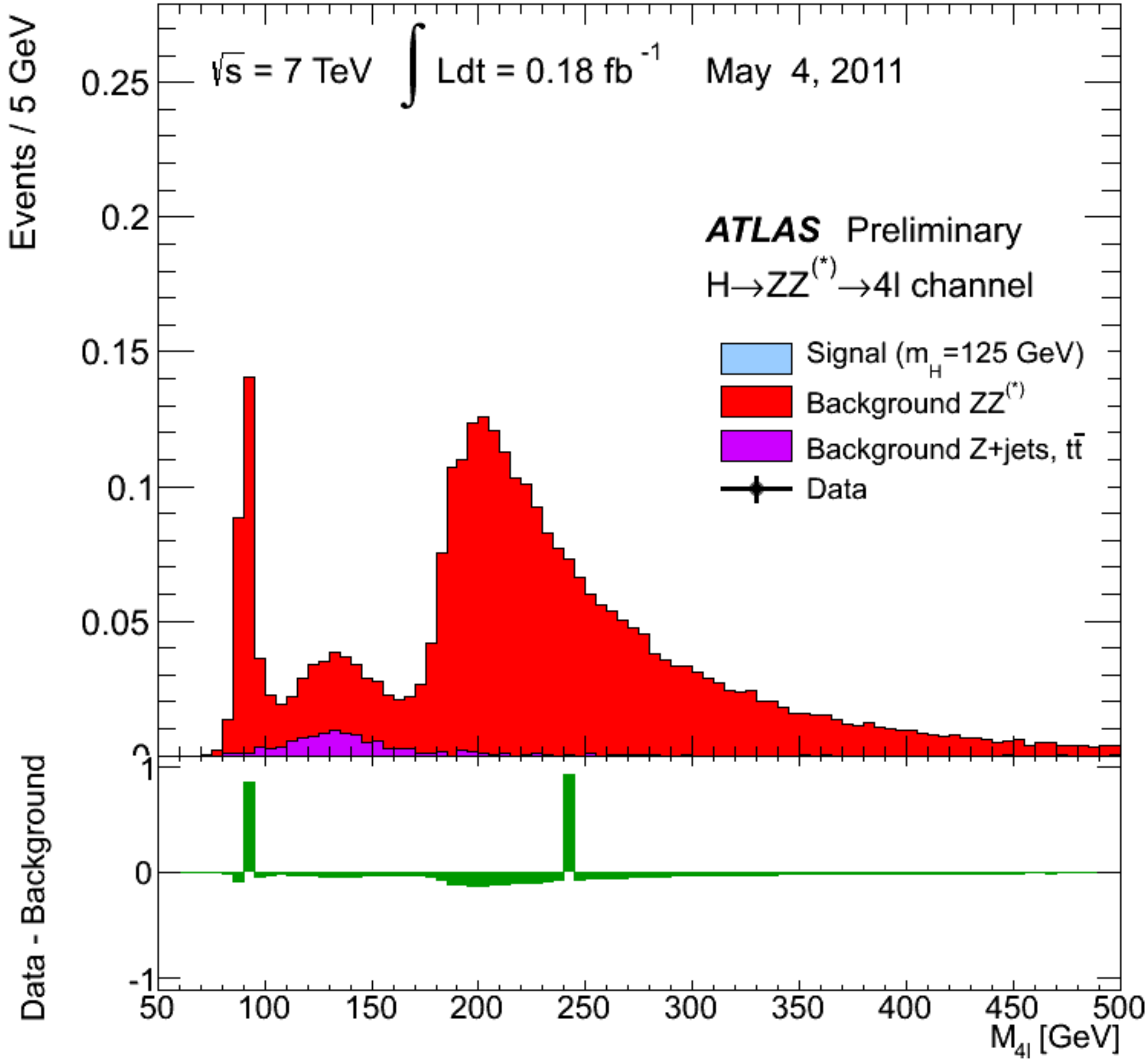




The distribution of the four-lepton invariant mass, m4l, for the selected candidates in the data. The single-resonant peak at m4l ~ 90 GeV includes contributions from s-channel Z/γ* and t-channel (Z*/γ*)(Z*/γ*) production.

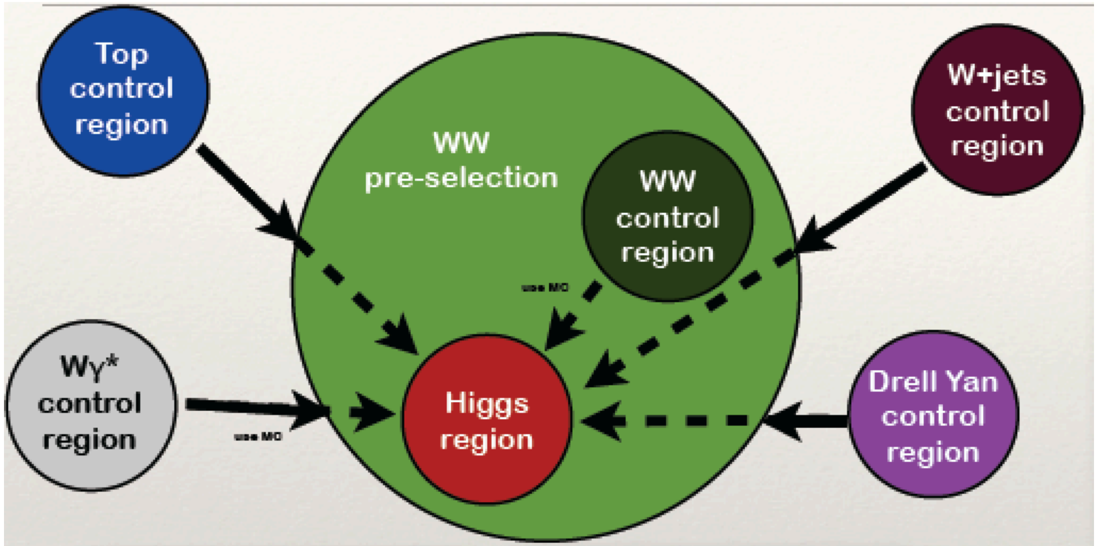
The observed local p_0 for the the sqrt(s) = 7 TeV data (red), the sqrt(s) = 8 TeV data (blue) and their combination (black). The dashed curves show the expected median local p0 for a SM Higgs boson hypothesis when tested at a given m_H.

SS

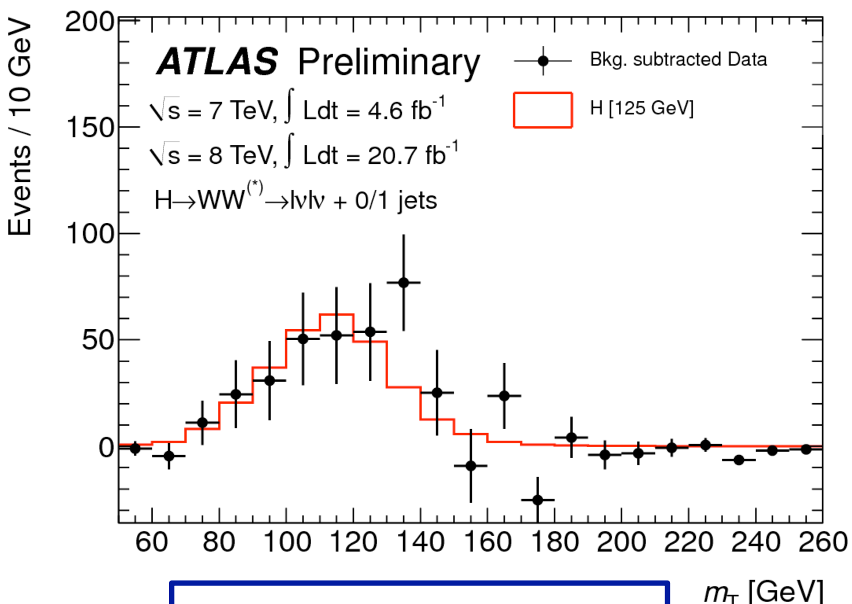


$\sqrt{s}$ = 7 TeV $\int$ Ldt = 0.18 fb^{-1} May 4, 2011
ATLAS Preliminary
H→ZZ$^{(*)}$→4l channel
Signal (m$_H$=125 GeV)
Background ZZ$^{(*)}$
Background Z+jets, $t\bar{t}$
Data
Events / 5 GeV
Data - Background
M$_{4l}$ [GeV]

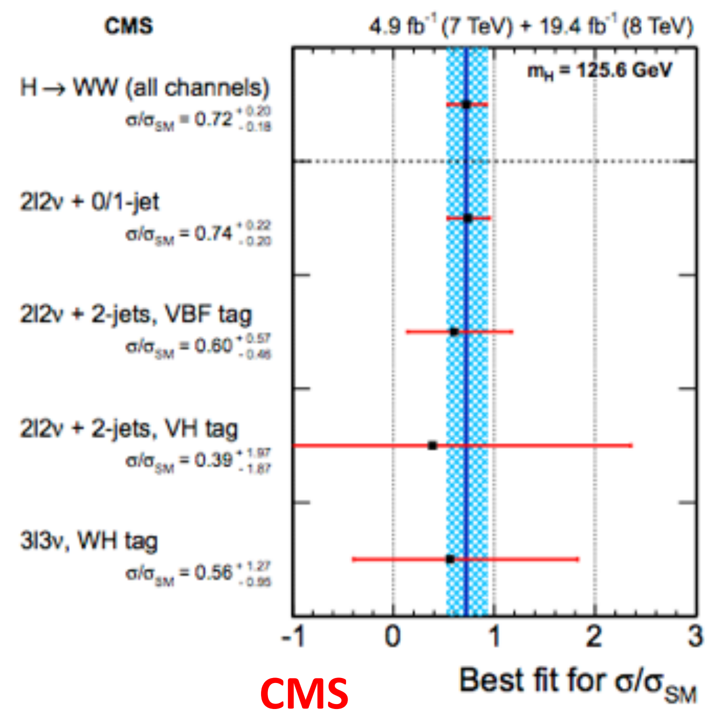
H→WW*→lνlν



Complex analysis: the challenge: determine as many background processes as possible directly from data



ATLAS: μ=1.01±0.31

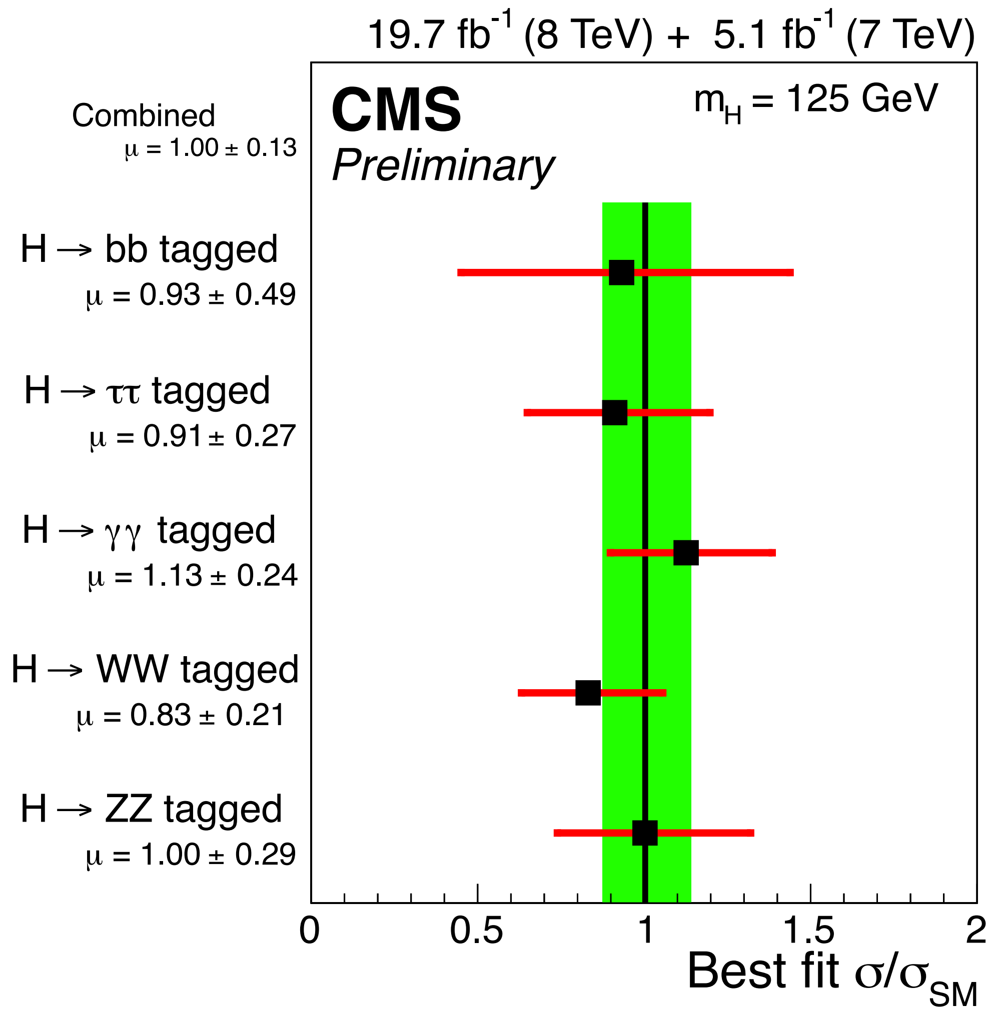


CMS

Evidence for H →WW → 2l2ν (4.3σ)

Latest results: Higgs combination

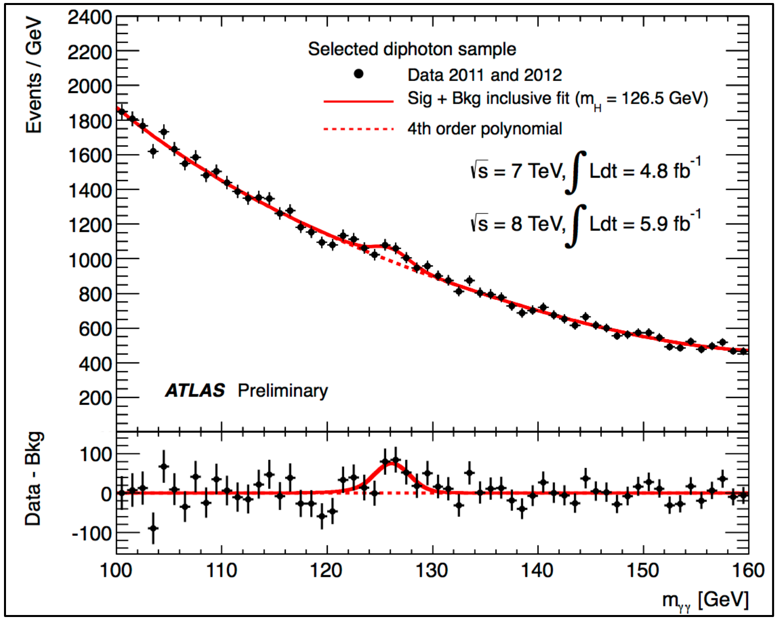
CMS-PAS-HIG-14-009



$\mu = \sigma/\sigma_{SM}$ ratio denotes the production cross section times the relevant branching fractions, relative to the SM expectation.

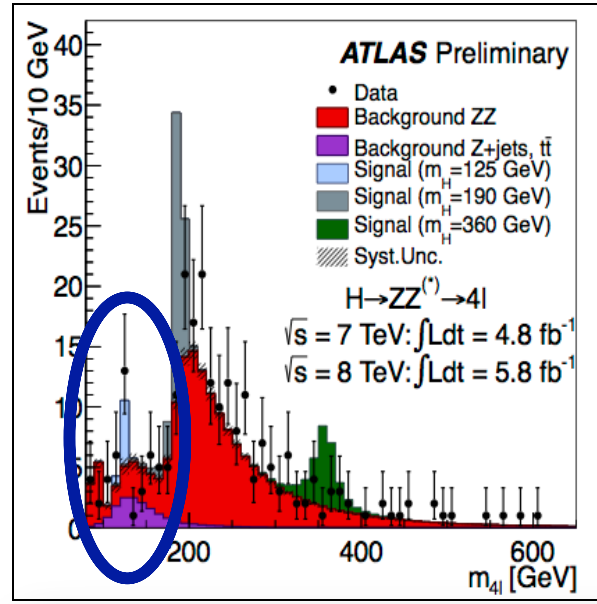
Values of the best-fit σ/σ_{SM} for the combination (solid vertical line), for individual channels. The vertical band shows the overall σ/σ_{SM} uncertainty. The horizontal bars indicate the ±1 standard deviation uncertainties in the best-fit σ/σ_{SM} values for the individual modes; they include both statistical and systematic uncertainties.

The “historical” results of July 4th, 2012

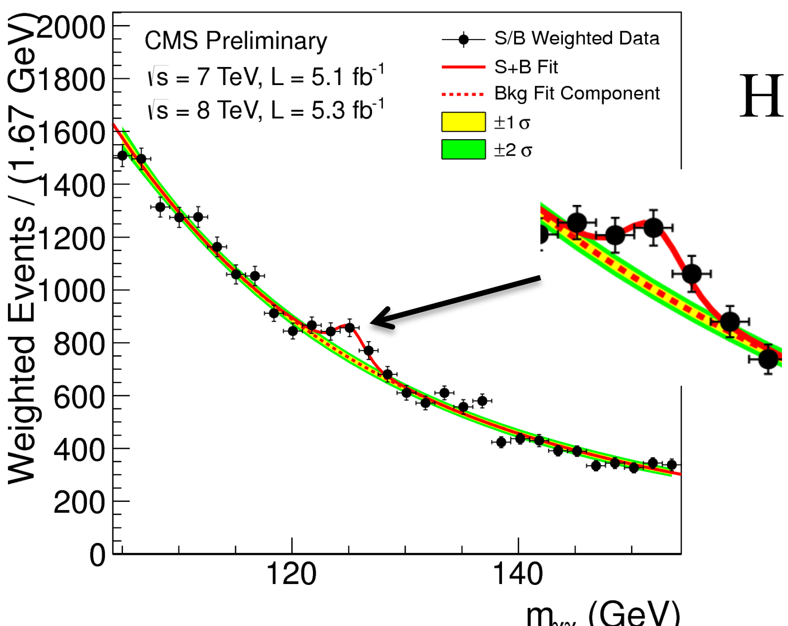


H→γγ

ATLAS

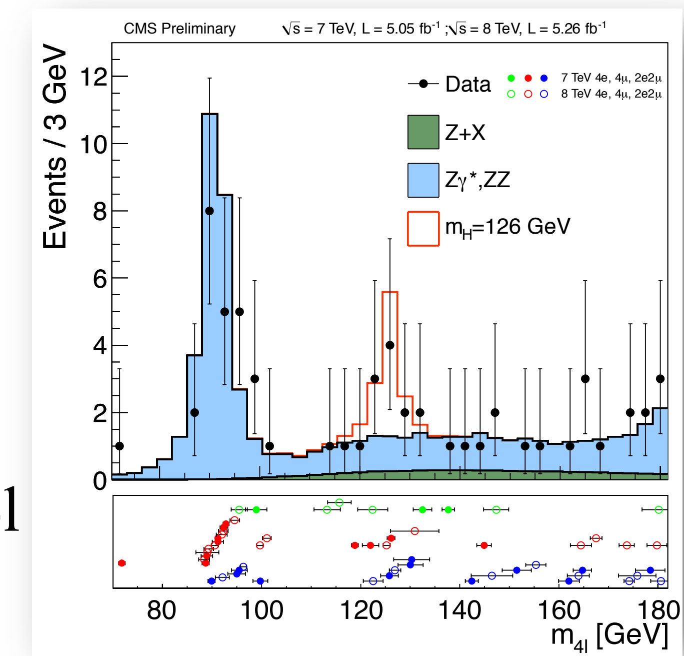


H→4l



H→γγ

CMS



H→4l

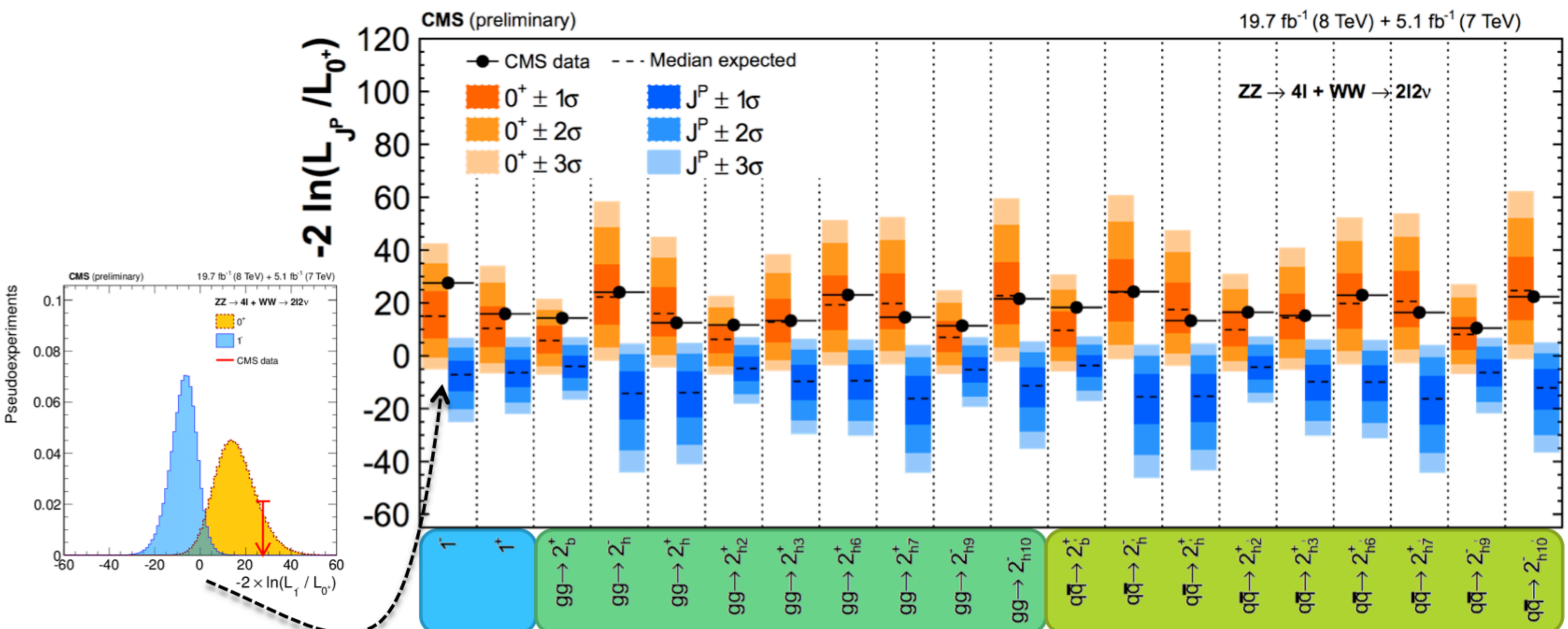

ALFR.
NOBEL
NAT.
MDCCC
XXXIII
OB.
MDCCC
XCVI

Higgs spin-parity

H→VV combination on J>0 states

168 [CMS-PAS-HIG-14-012] [CMS-PAS-HIG-14-014]

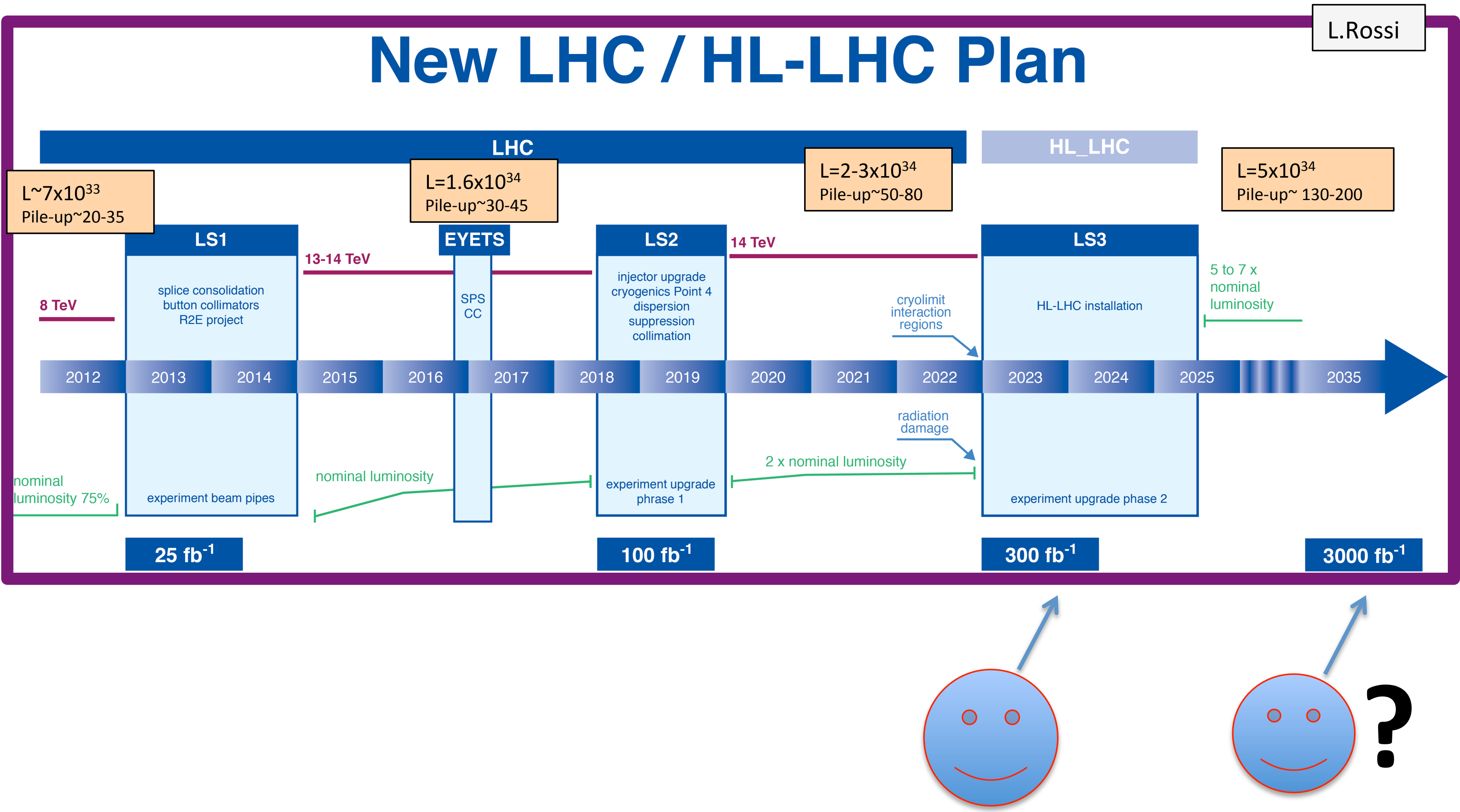
- Combination of H→WW→2ℓ2ν and H→ZZ→4ℓ.
- All tested hypotheses excluded at more than 99.9% CL_S.



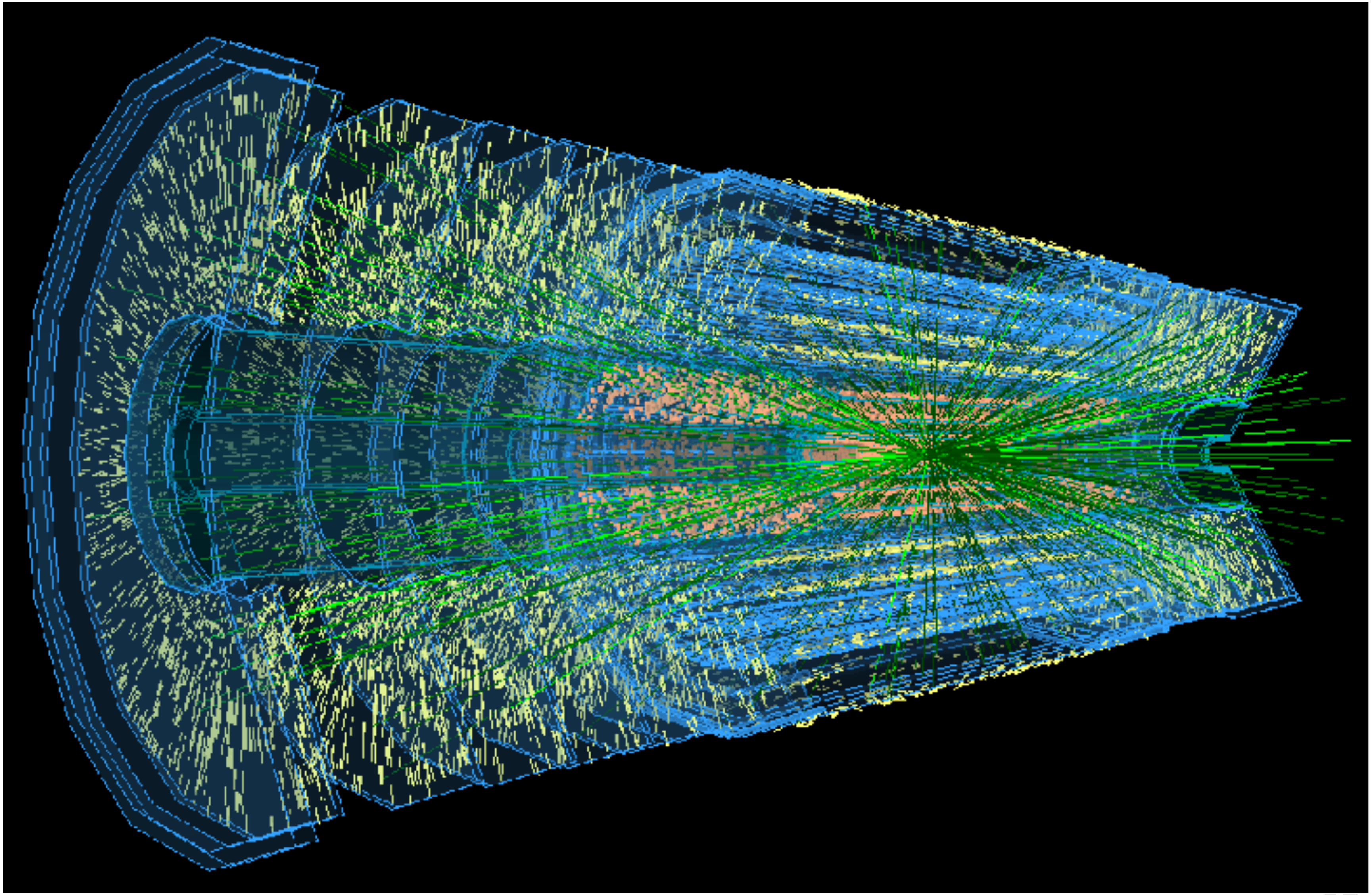
a.david@cern.ch @CMSexperiment @ICHEP2014

What next ?

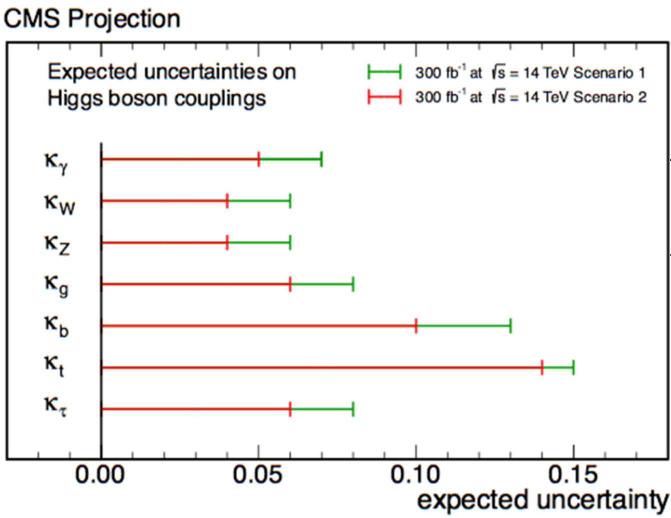
LHC roadmap beyond LS1

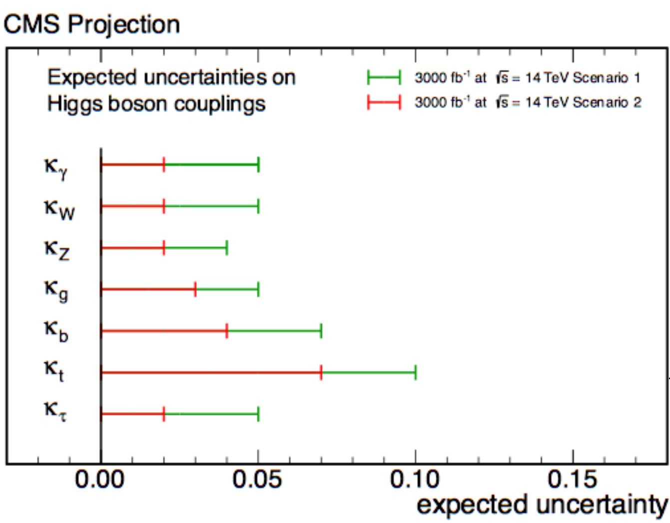


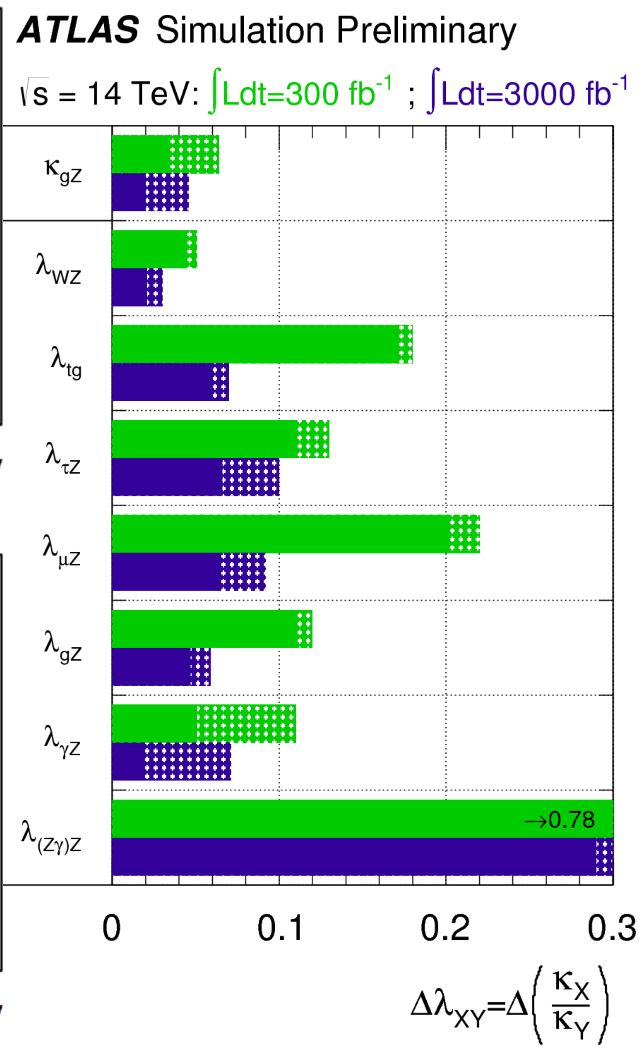
Typical event at HL-LHC <m>=140, reconstructed by ATLAS simulation



Higgs Couplings







300 fb^{-1}:
$k_X \sim$ 10-15%

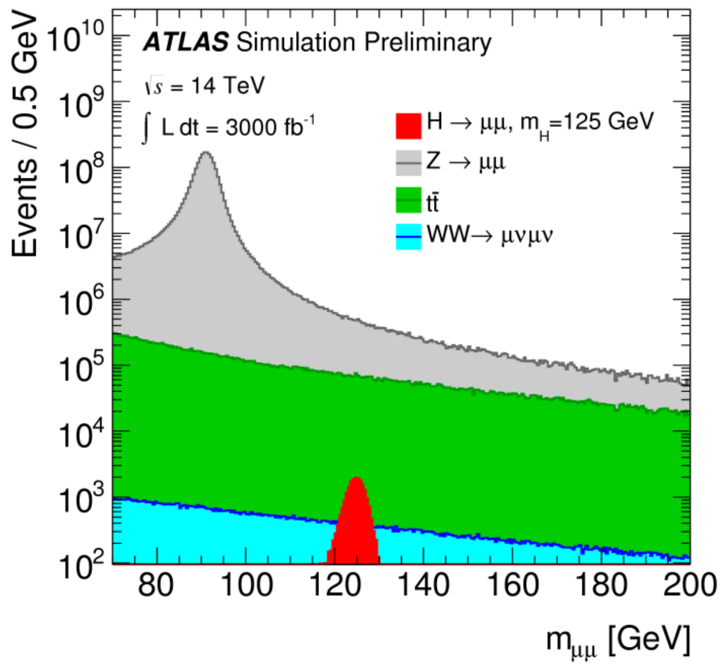
3000 fb^{-1}:
$k_X \sim$ few %

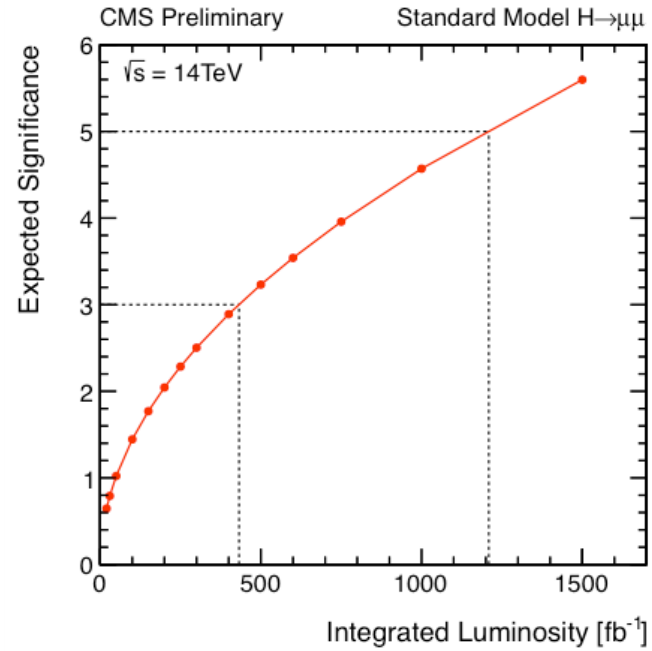
➔**Reduce exp. systematics**

➔**Reduce theory uncertainties**

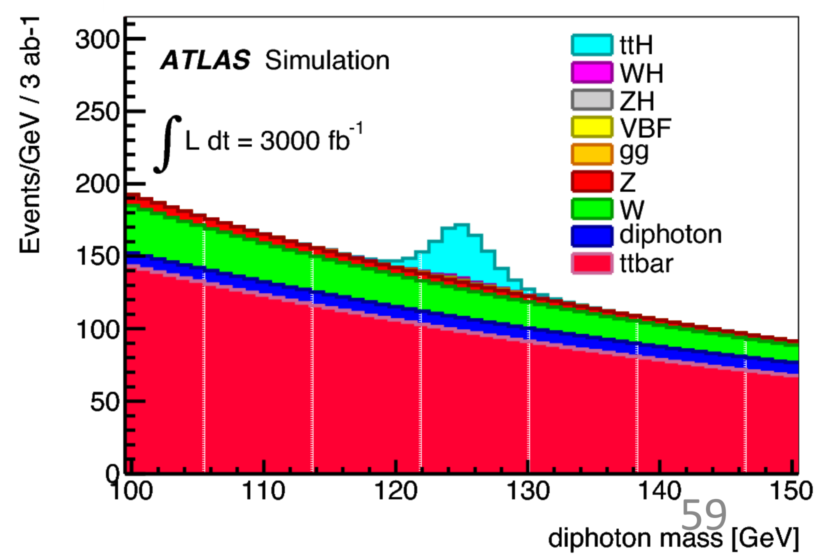
Rare Decays & Yukawa coupling

H→μμ



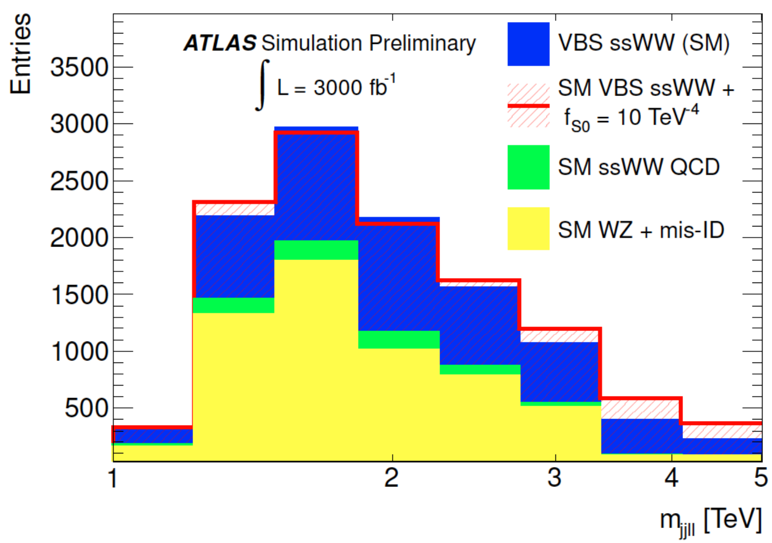


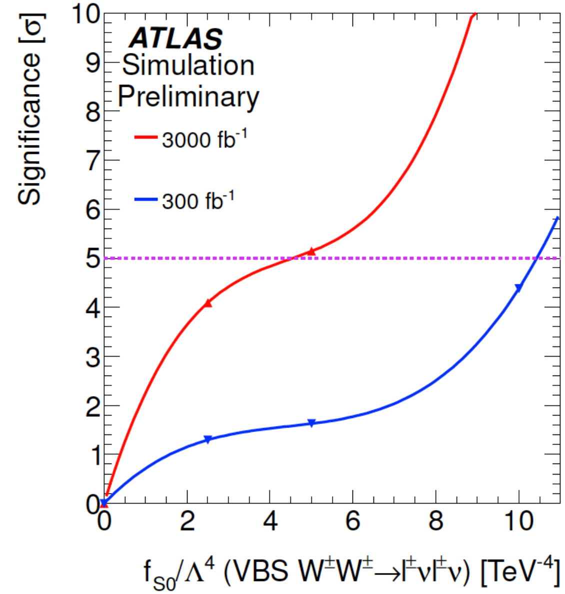
- Evidence at 300 fb^{-1}
- Observation of ttH, H→γγ at HL-LHC



High-lumi VBS sensitivity

- Simulation studies by ATLAS (ATLAS-PHYS-PUB-2013-006)
  - MADGRAPH for VBS production (k-factor ignored)





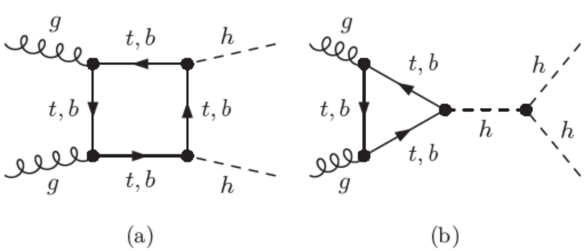
expected sensitivity at 14 TeV (5σ discovery value)

analysis	parameter	$300\ fb^{-1}$	$3000\ fb^{-1}$
VBS $WZjj \to \ell\nu\ell\ell jj$	$f_{T,1}/\Lambda^4\ TeV^{-4}$	1.3	0.6
VBS $W^\pm W^\pm jj \to \ell^\pm \nu \ell^\pm \nu jj$	$f_{S,0}/\Lambda^4\ TeV^{-4}$	10	4.5
$Z\gamma\gamma$	$f_{T,8}/\Lambda^4\ TeV^{-4}$	0.9	0.4
$Z\gamma\gamma$	$f_{T,9}/\Lambda^4\ TeV^{-4}$	2.0	0.7

Clear gain by increasing statistics

Higgs Boson Pair Production

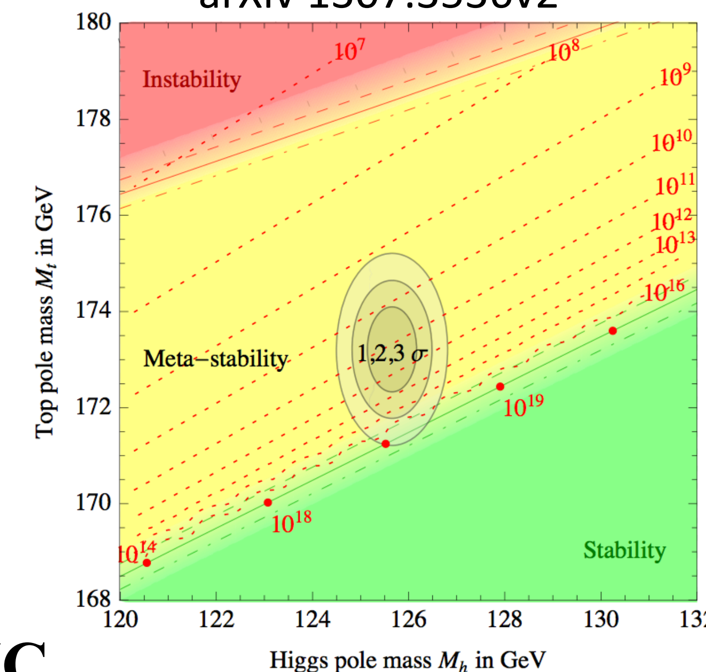
- One of the core physics programmes at HL-LHC, but very challenging in both experiment and theory.
- Is it feasible to measure Higgs boson pair production ~30% level at HL-LHC ?



bbWW	30000
bbττ	9000
WWWW	6000
γγbb	320
γγγγ	1

Expected events with L = 3000 fb^{-1}

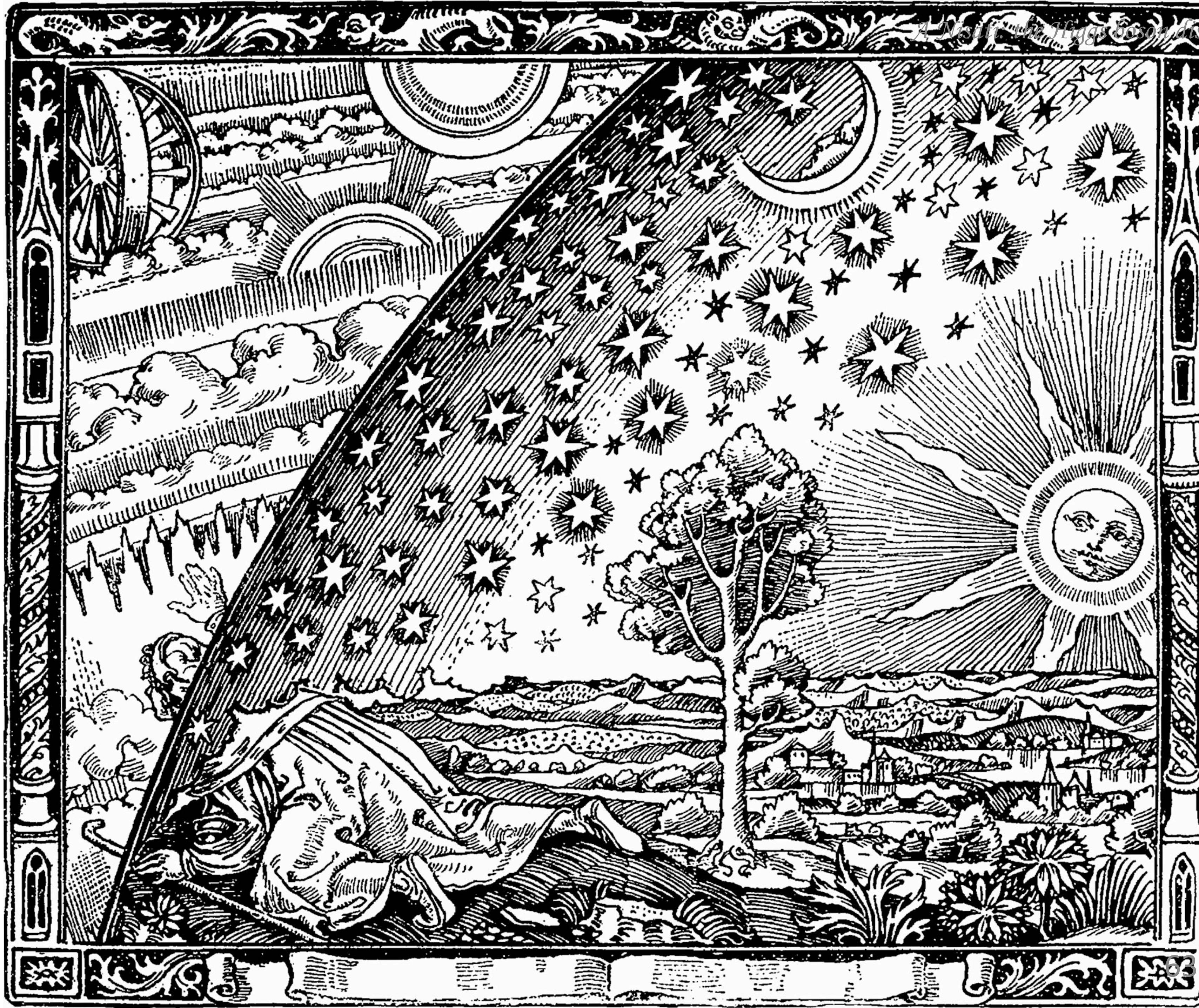
arXiv 1307.3536v2



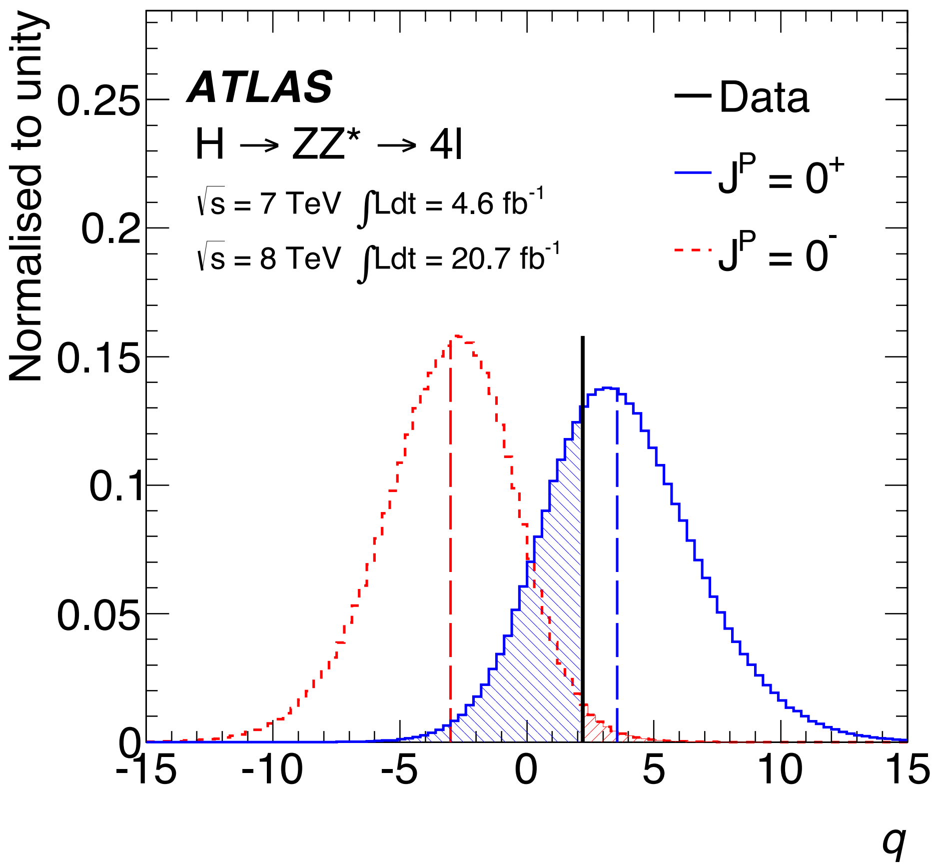
- **Challenging process, also at HL-LHC**
- **Promising final states are HH→bbγγ, bbττ, bbbb?, …**
- **Hopefully preliminary results @ HL-LHC ECFA 2014**

Conclusive Remarks

1. Outstanding performance of the Large Hadron Collider and associated detectors with Run-1, in particular ATLAS and CMS
2. Searches for a Standard Model Higgs has leaded to the exclusion at 99% Confidence Level in a wide mass region except $121.8 < m_H < 130.7$ GeV
3. An excess of events at $m_H \sim 125$ GeV has been observed by ATLAS and CMS with a significance **larger than 5 standard deviations**
4. collaboration with theory community important to this achievement, and essential to explain the level of understanding of current and future data
5. We have analysed <10% of the data expected from LHC, and <1% of the data HL-LHC can deliver; we will get collisions at ~twice the c.m. energy → big potential for new discoveries
6. ➔ we just entered a new era in HEP, with LHC as “portal” to a new world



Latest results: spin

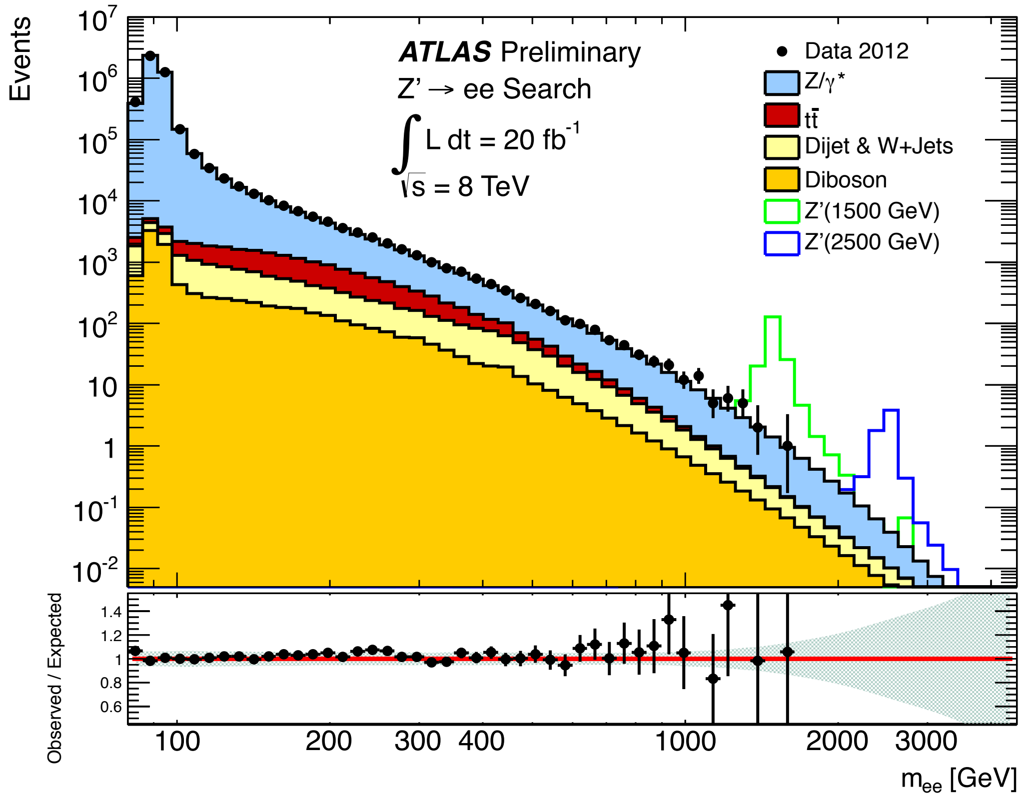


Expected distributions of q = log(L(0+)/L(0-)), the logarithm of the ratio of profiled likelihoods, under $J^P = 0^+$ hypotheses for the Standard Model $J^P = 0^+$ (blue/solid line distribution) or $J^P = 0^-$ (red/dashed line distribution) signals. The observed value is indicated by the vertical solid line and the expected medians by the dashed lines. The coloured areas correspond to the integrals of the expected distributions up to the observed value and are used to compute the p_0-values for the rejection of each hypothesis.

Exclusion of $J^P = 0^-$ at 97.8% confidence level

J^P values such as $J^P = 1^+$, 1^- and graviton-inspired $J^P = 2^+$ models with minimal couplings to Standard Model particles are also excluded at more than 99% confidence level combining H→γγ, H→ZZ*→4l and H→WW*→lνlν channels

New Physics beyond SM?



Dielectron invariant mass (mee) distribution with statistical uncertainties after final selection, compared to the stacked sum of all expected backgrounds, with two selected Z′ signals overlaid. The SSM bin width is constant in log mee. Bottom inset: The black points show the ratio of observed to expected events with statistical uncertainty, while the shaded band indicates the mass-dependent systematic uncertainty on the sum of the backgrounds.

no SUSY at LHC

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: SUSY 2013

ATLAS Preliminary

$\int \mathcal{L}\,dt = (4.6 - 22.9)\ \mathrm{fb}^{-1}$ $\sqrt{s}$ = 7, 8 TeV

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\,dt[\mathrm{fb}^{-1}]$	Mass limit			Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$	1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.2 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	any $m(\tilde{q})$	1308.1841
	$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$	740 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq\tilde{\chi}_1^{\pm}\to qqW^{\pm}\tilde{\chi}_1^0$	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.18 TeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}^{\pm})=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ	0-3 jets	-	20.3	$\tilde{g}$	1.12 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e,μ	2-4 jets	Yes	4.7	$\tilde{g}$	1.24 TeV	$\tan\beta$<15	1208.4688
	GMSB ($\tilde{\tau}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$	1.4 TeV	$\tan\beta$>18	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	-	Yes	4.8	$\tilde{g}$	1.07 TeV	$m(\tilde{\chi}_1^0)$>50 GeV	1209.0753
	GGM (wino NLSP)	1 $e,\mu+\gamma$	-	Yes	4.8	$\tilde{g}$	619 GeV	$m(\tilde{\chi}_1^0)$>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$	900 GeV	$m(\tilde{\chi}_1^0)$>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e,μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$	690 GeV	$m(\tilde{H})$>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale	645 GeV	$m(\tilde{g})>10^{-4}$ eV	ATLAS-CONF-2012-147
3rd gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$	1.2 TeV	$m(\tilde{\chi}_1^0)$<600 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	$m(\tilde{\chi}_1^0)$ <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$	1.34 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)$<300 GeV	ATLAS-CONF-2013-061
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$	100-620 GeV	$m(\tilde{\chi}_1^0)$<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to t\tilde{\chi}_1^{\pm}$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$	275-430 GeV	$m(\tilde{\chi}_1^{\pm})=2\,m(\tilde{\chi}_1^0)$	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}_1^{\pm}$	1-2 e,μ	1-2 b	Yes	4.7	$\tilde{t}_1$	110-167 GeV	$m(\tilde{\chi}_1^0)$=55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e,μ	0-2 jets	Yes	20.3	$\tilde{t}_1$	130-220 GeV	$m(\tilde{\chi}_1^0)=m(\tilde{t}_1)-m(W)$-50 GeV, $m(\tilde{t}_1)<<m(\tilde{\chi}_1^{\pm})$	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}_1^0$	2 e,μ	2 jets	Yes	20.3	$\tilde{t}_1$	225-525 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-065
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}_1^{\pm}$	0	2 b	Yes	20.1	$\tilde{t}_1$	150-580 GeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}_1^{\pm})-m(\tilde{\chi}_1^0)$=5 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e,μ	1 b	Yes	20.7	$\tilde{t}_1$	200-610 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.5	$\tilde{t}_1$	320-660 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$	90-200 GeV	$m(\tilde{t}_1)-m(\tilde{\chi}_1^0)$<85 GeV	ATLAS-CONF-2013-068
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e,μ (Z)	1 b	Yes	20.7	$\tilde{t}_1$	500 GeV	$m(\tilde{\chi}_1^0)$>150 GeV	ATLAS-CONF-2013-025
	$\tilde{t}_2\tilde{t}_2$, $\tilde{t}_2\to\tilde{t}_1+Z$	3 e,μ (Z)	1 b	Yes	20.7	$\tilde{t}_2$	271-520 GeV	$m(\tilde{t}_1)=m(\tilde{\chi}_1^0)$+180 GeV	ATLAS-CONF-2013-025
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}$, $\tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e,μ	0	Yes	20.3	$\tilde{\ell}$	85-315 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm}$	125-450 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^{\pm})+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.7	$\tilde{\chi}_1^{\pm}$	180-330 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}_1^{\pm})+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu)$, $\ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	20.7	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$	600 GeV	$m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^{\pm})+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	3 e,μ	0	Yes	20.7	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$	315 GeV	$m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 h\tilde{\chi}_1^0$	1 e,μ	2 b	Yes	20.3	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$	285 GeV	$m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	ATLAS-CONF-2013-093
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^{\pm}$	270 GeV	$m(\tilde{\chi}_1^{\pm})-m(\tilde{\chi}_1^0)$=160 MeV, $\tau(\tilde{\chi}_1^{\pm})$=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$	832 GeV	$m(\tilde{\chi}_1^0)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$	475 GeV	10<$\tan\beta$<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$	230 GeV	0.4<$\tau(\tilde{\chi}_1^0)$<2 ns	1304.6310
	$\tilde{q}\tilde{q}$, $\tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$	1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, $m(\tilde{\chi}_1^0)$=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau+X$, $\tilde{\nu}_\tau\to e+\mu$	2 e,μ	-	-	4.6	$\tilde{\nu}_\tau$	1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\to\tilde{\nu}_\tau+X$, $\tilde{\nu}_\tau\to e(\mu)+\tau$	1 $e,\mu+\tau$	-	-	4.6	$\tilde{\nu}_\tau$	1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	1 e,μ	7 jets	Yes	4.7	$\tilde{q}, \tilde{g}$	1.2 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}$<1 mm	ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e,μ	-	Yes	20.7	$\tilde{\chi}_1^{\pm}$	760 GeV	$m(\tilde{\chi}_1^0)$>300 GeV, λ_{121}>0	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e,\mu+\tau$	-	Yes	20.7	$\tilde{\chi}_1^{\pm}$	350 GeV	$m(\tilde{\chi}_1^0)$>80 GeV, λ_{133}>0	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$	916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1 t$, $\tilde{t}_1\to bs$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$	880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon pair, sgluon$\to q\bar{q}$	0	4 jets	-	4.6	sgluon	100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon$\to t\bar{t}$	2 e,μ (SS)	1 b	Yes	14.3	sgluon	800 GeV		ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale	704 GeV	$m(\chi)$<80 GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

10^{-1} 1   Mass scale [TeV]

$\sqrt{s}$ = 7 TeV full data $\sqrt{s}$ = 8 TeV partial data $\sqrt{s}$ = 8 TeV full data

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.