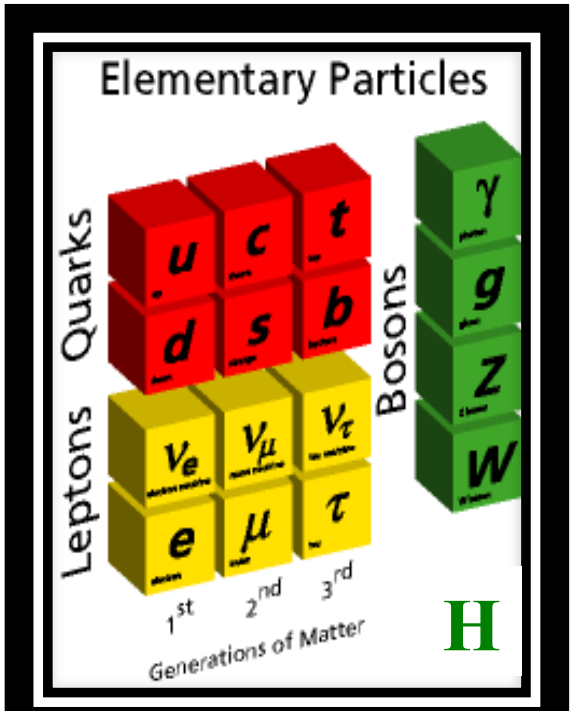
The Research Council of Norway

UiO : University of Oslo

ATLAS Experiment

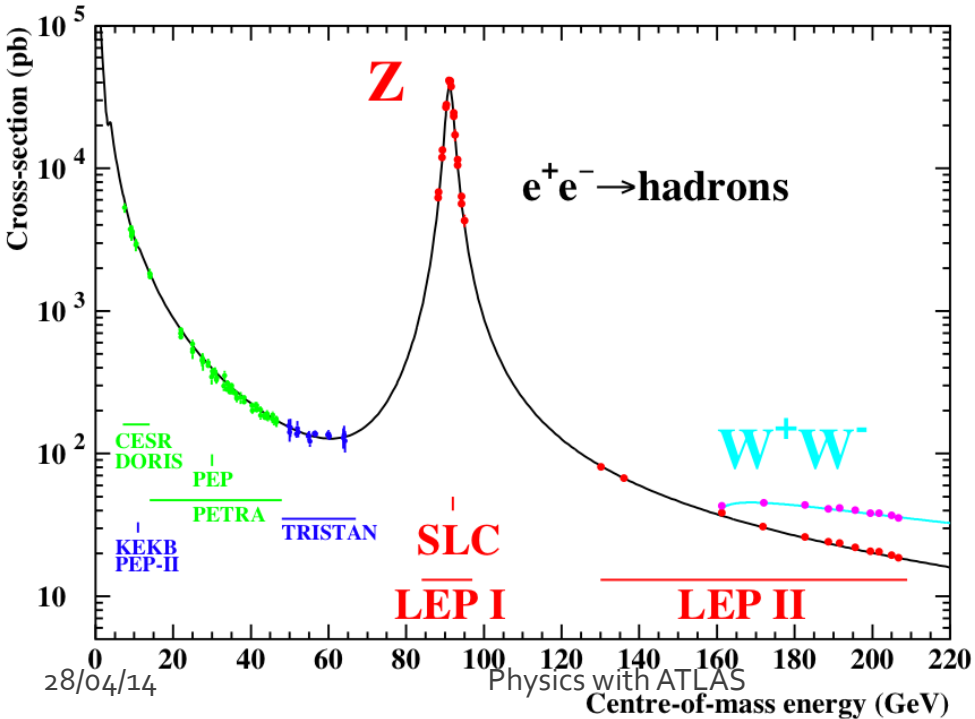
A trip through some ATLAS achievements

PHYSICS OF THE EARLY UNIVERSE

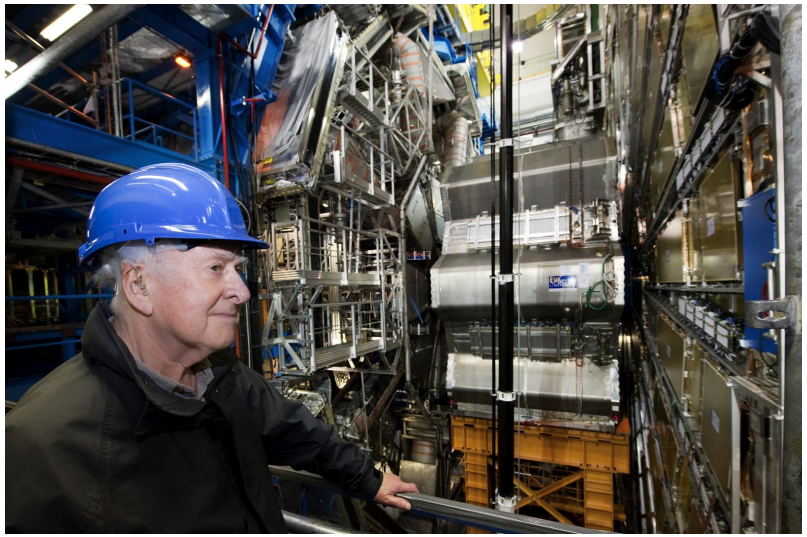


- All forces in nature obey a form of symmetry.
  - Gauge-symmetry
- The Standard Model (SM) describes interactions between elementary particles grouped in 3 families of quarks and leptons

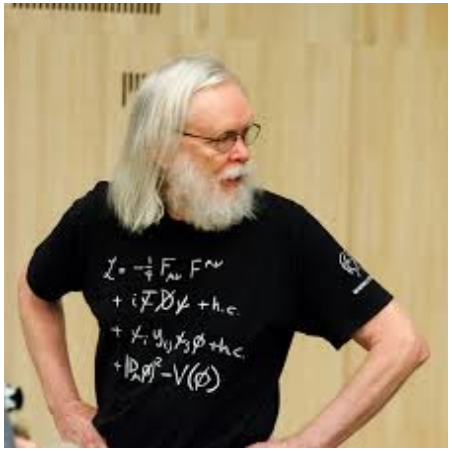
- The Standard Model
  - unifies Electromagnetism (long range, macroscopic, photon has no mass) and Weak force (short range, microscopic, W and Z are heavy) …at high energies
  - describes (almost) all current particle physics data



- The Electroweak symmetry must be broken at low energies in order to give the weak bosons (W,Z), as well as all matter particles, masses.
- A scalar field requiring a new particle, the Higgs Boson …



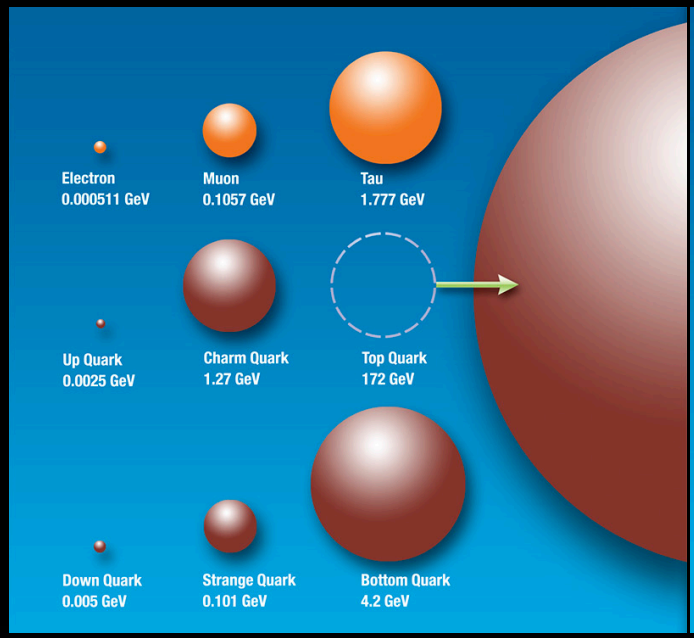
- Whole Universe swims in an invisible, cosmic field, Higgs-field, which acts on particles and provide them with what is called mass.
- All fields have associated boson. The Higgs-field has its Higgs-boson.

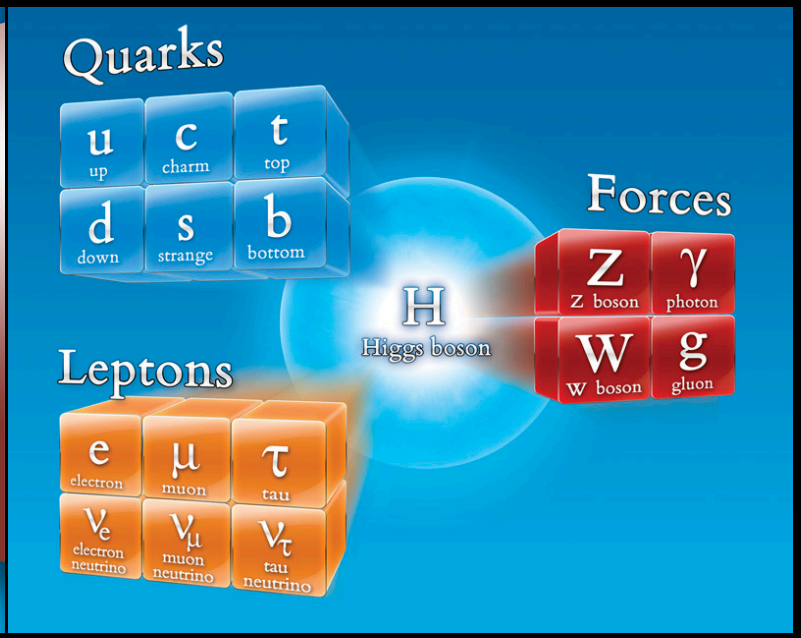


See Thursday's lecture: **The Higgs boson and beyond**

The Standard Theory of Particles and Forces

- Forces are dictated by (gauge) symmetries
  - Fermions in 3! = $SU(3)_C * [SU(2)_L * U(1)_Y]$ → QCD + Electroweak ("=" QED + Weak)





- Symmetries of laws do not necessarily lead to symmetries of outcomes
  - Electroweak symmetry spontaneously broken – Brout Englert Higgs mechanism
  - BEH "hides" EW symmetry, gives masses to weak gauge bosons and "approves" fermion masses, predicts couplings of particles to Higgs, and more
- Higgs boson mass is not predicted by the SM
- → Must be measured!

Origin of mass

http://www.atlas.ch/multimedia/4-muon-event.html#origin-of-mass

LHC Physics

- Particle collisions at LHC
  - proton + proton
    - Study Standard Model, including Higgs, in new energy domain
    - Search for new physics capable of explaining various mysteries
    - Be ready for surprises
  - LHC collides also heavy ions: pb-pb and p-pb
    - High energies and high densities
    - New state of matter, quark-gluon plasma, …

$$N_{\text{Physics}} = \sigma_{\text{Physics}} \left(\int \mathcal{L} dt \right)_{\text{Beams}}$$

- Sensitivity to rare phenomena
  - with small cross sections
  - depends on the luminosity

Number of collisions
$N = L \cdot \sigma(pp \rightarrow X)$

Luminosity L

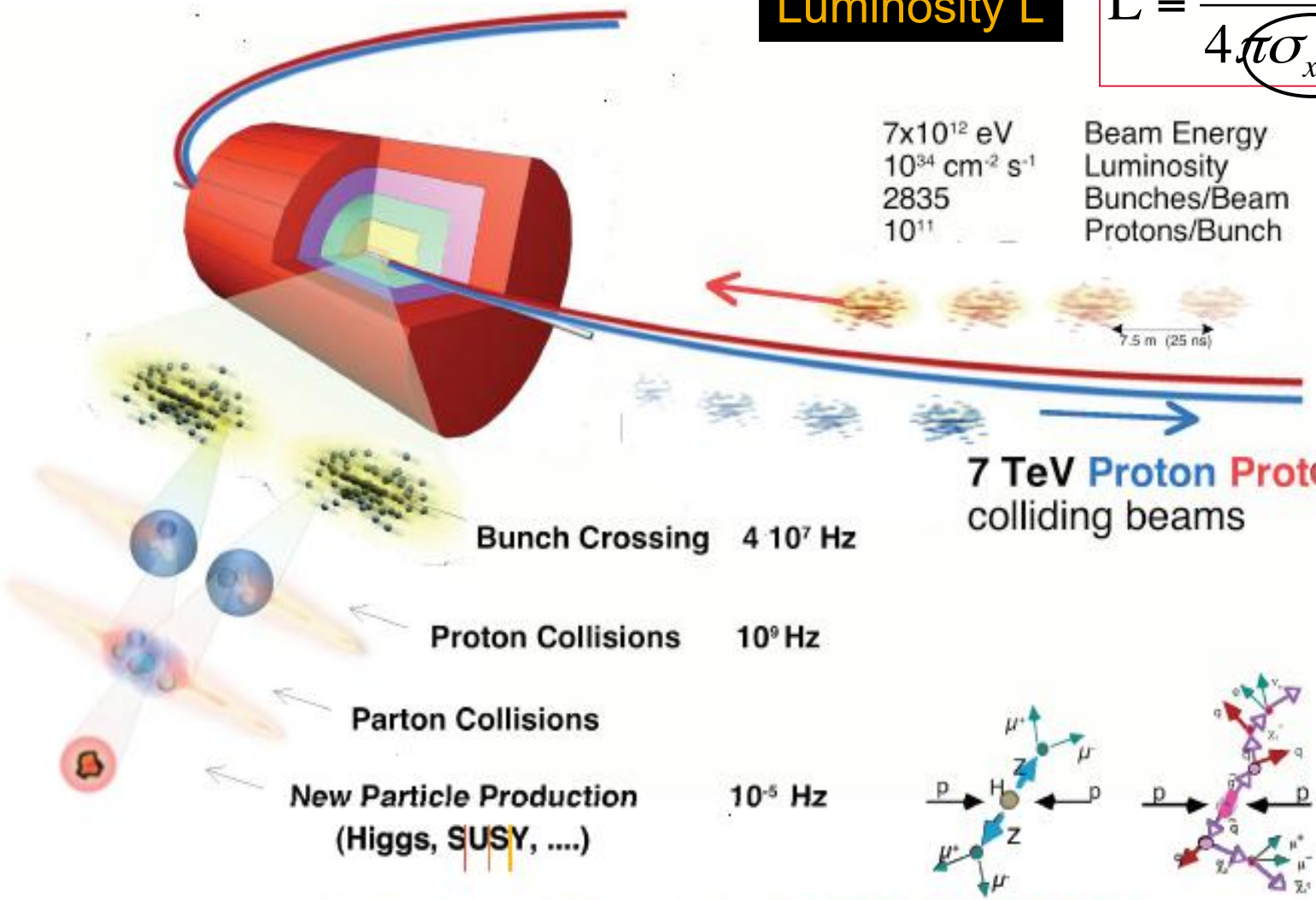
$$L = \frac{N^2 k_b f}{4\pi\sigma_x\sigma_y}$$

n. of protons per bunch

n. of bunches

n. of turns per second

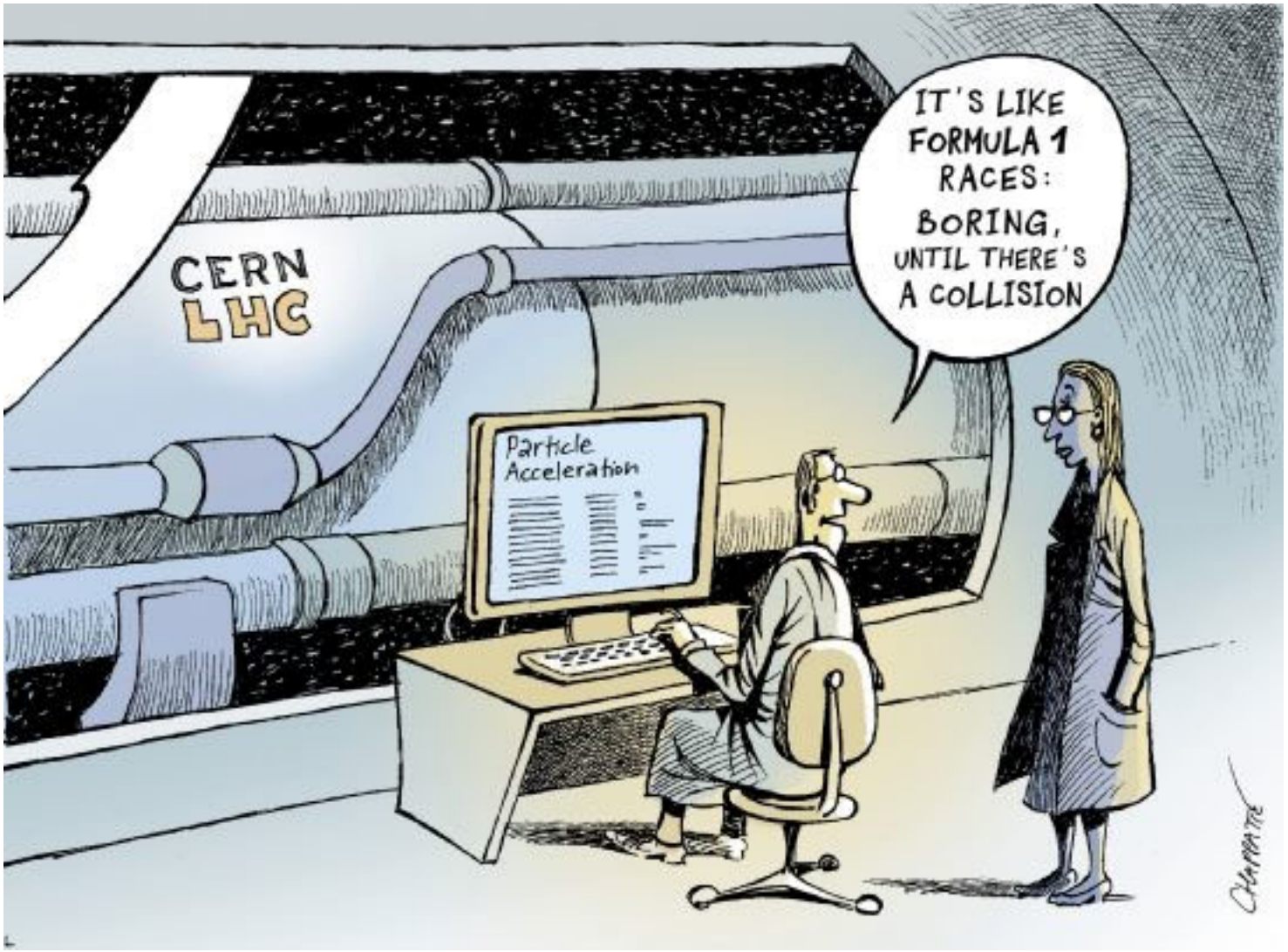
beam size at IP ($\sigma_{x,y}$ = 16 μm)



Cross-section σ

Very small for new processes

Selection of 1 event in 10,000,000,000,000

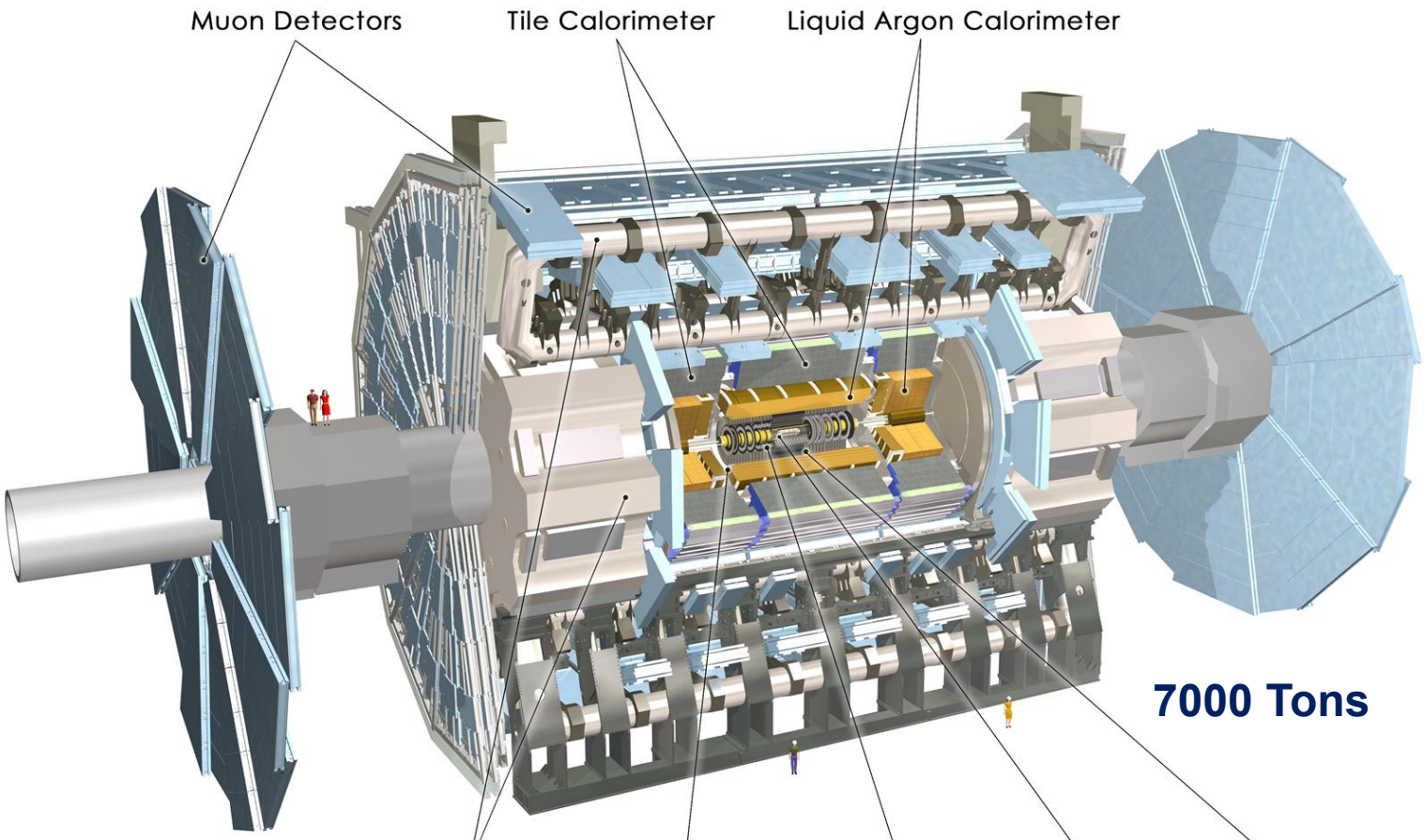

CERN
LHC
Particle
Acceleration
IT'S LIKE
FORMULA 1
RACES:
BORING,
UNTIL THERE'S
A COLLISION

ATLAS
Multipurpose Detector

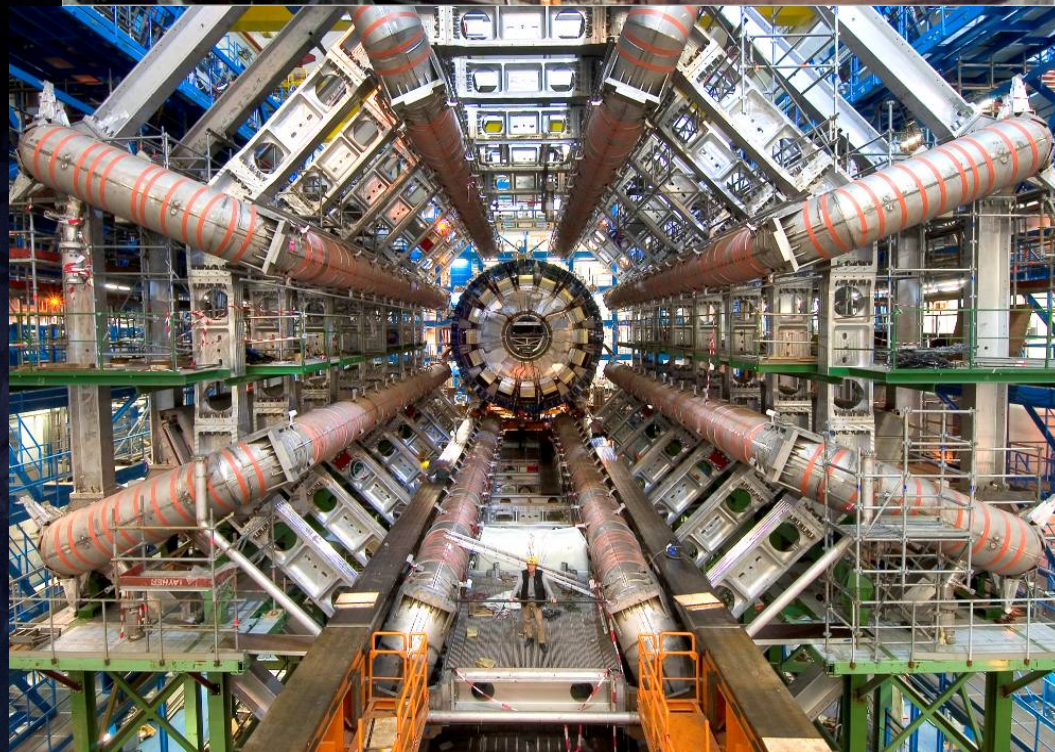
45 m

ATLAS superimposed to
the 5 floors of building 40

24 m

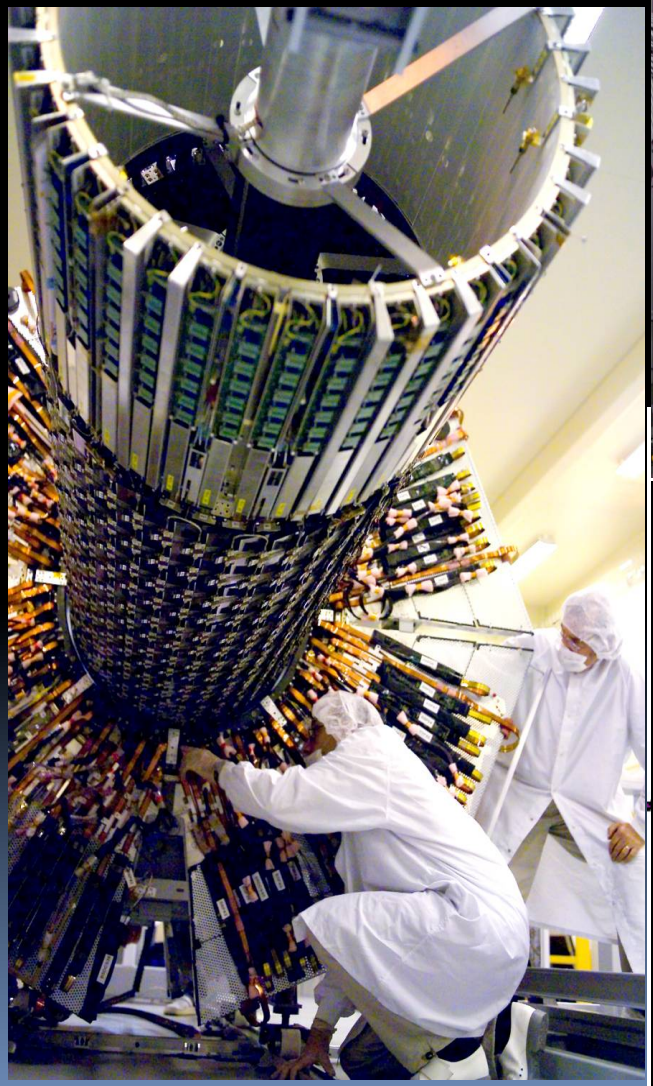


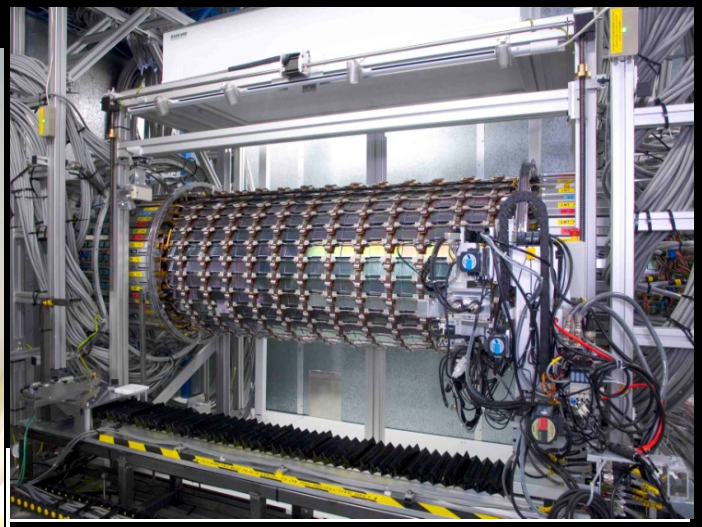
7000 Tons



Let’s build ATLAS in ~ 1 minute … or 3 or 5 http://www.atlas.ch/multimedia/4-muon-event.html#atlas-built-1-minute

One of the Norwegian contributions to ATLAS: "Semi Conductor Tracker" (SCT) – Oslo, Bergen, Uppsala made 320 silicon-modules ~ 15% of ATLAS needs

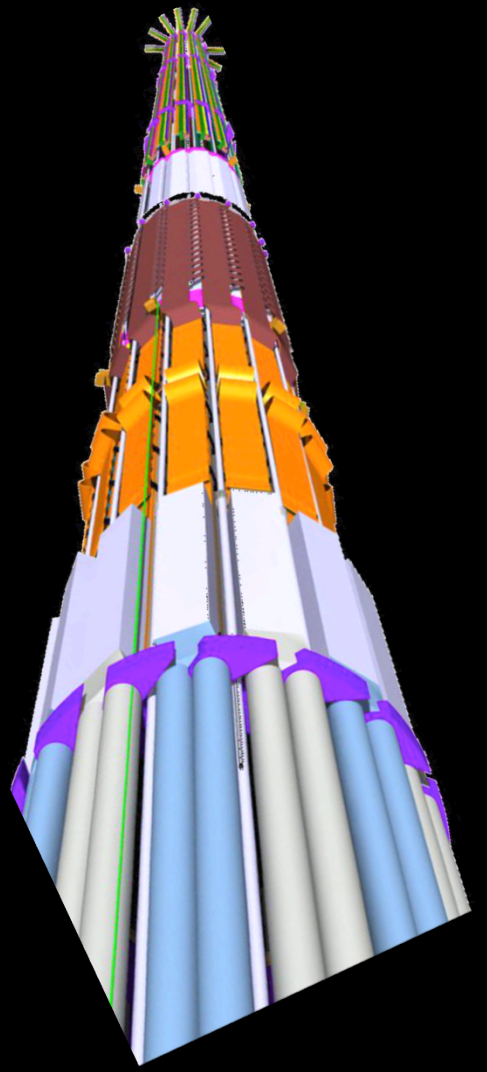




ATLAS upgrade

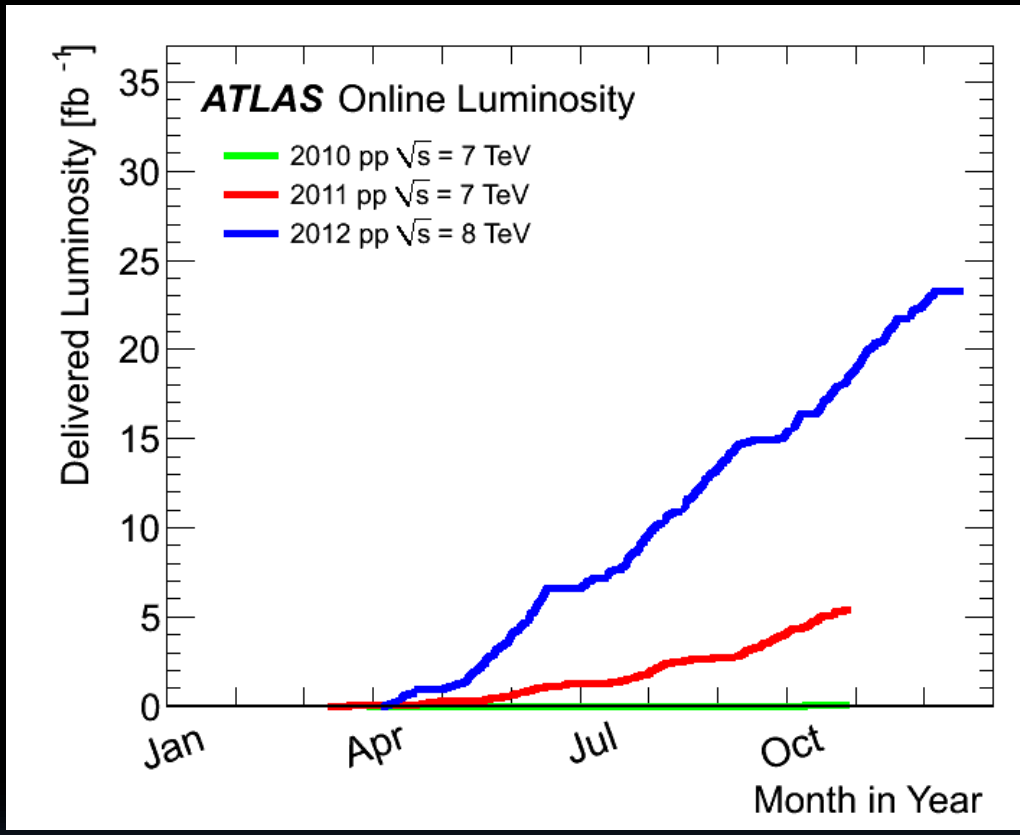
➔Insertable pixel B-Layer

➔ 3D-Pixel R&D



LHC and ATLAS performance

- Excellent LHC performance 12>11>10
  - Max luminosity already 80% of design value
  - 2010: 0.05 fb^{-1} at 7TeV
  - 2011: 5.6 fb^{-1} at 7TeV
  - 2012: 23 fb^{-1} at 8TeV
- ATLAS recorded 90% of luminosity delivered by LHC → ~25 fb^{-1}
- Excellent detector performance →



ATLAS p-p run: April-December 2012

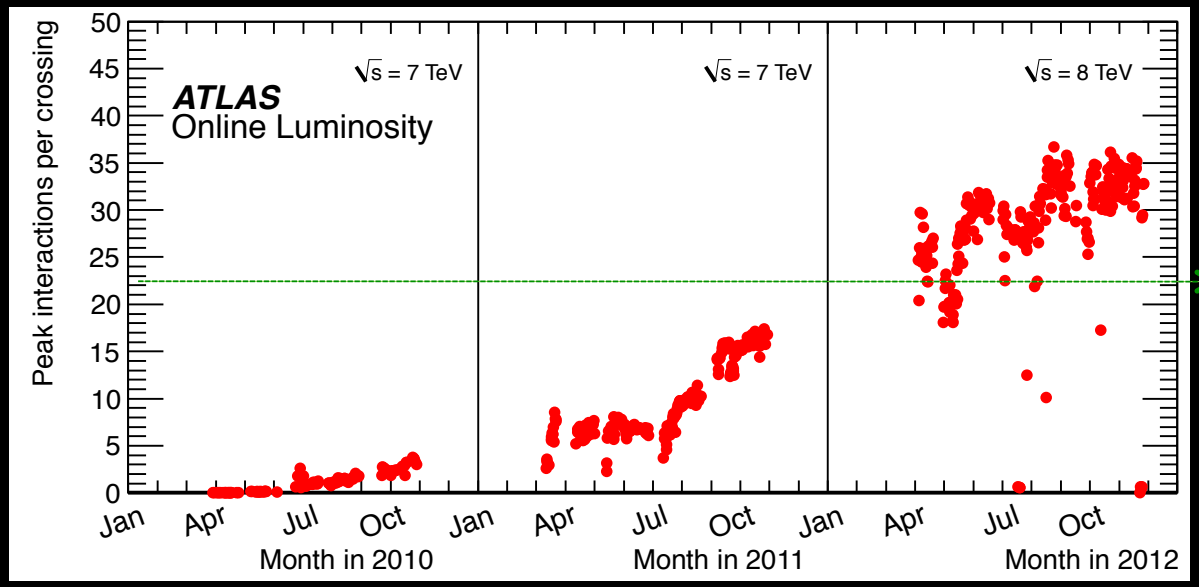
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.9	99.1	99.8	99.1	99.6	99.6	99.8	100.	99.6	99.8	99.5

All good for physics: 95.5%

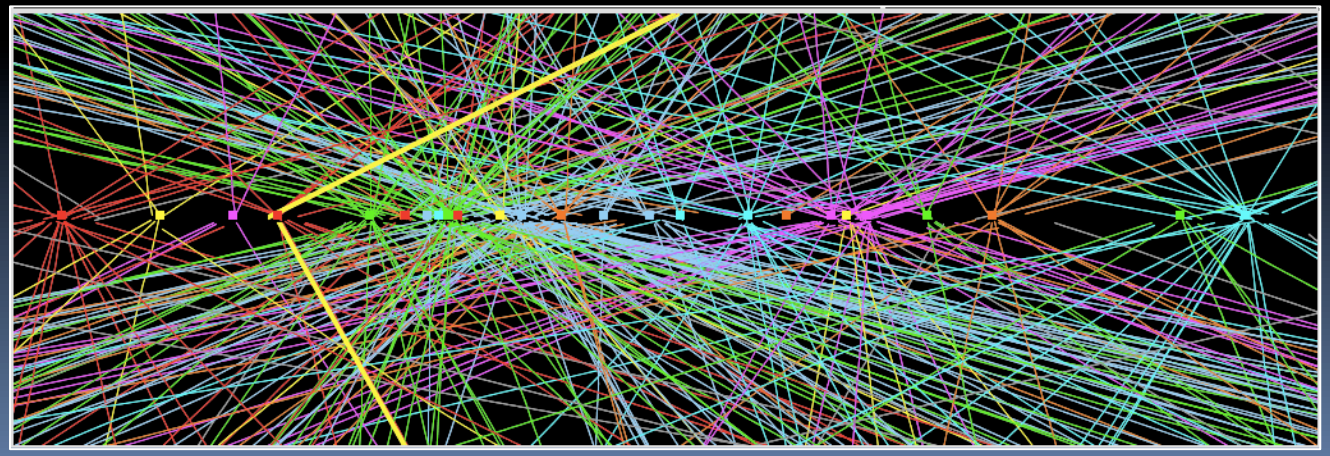
Luminosity weighted relative detector uptime and good quality data delivery during 2012 stable beams in pp collisions at $\sqrt{s}$=8 TeV between April 4th and December 6th (in %) – corresponding to 21.3 fb^{-1} of recorded data.

Tough conditions with many interactions per beam crossing

- ATLAS detector functioned well despite recording many interactions per collision
  - Due to increase in luminosity



- *Z* boson decay to μμ with many reconstructed vertices



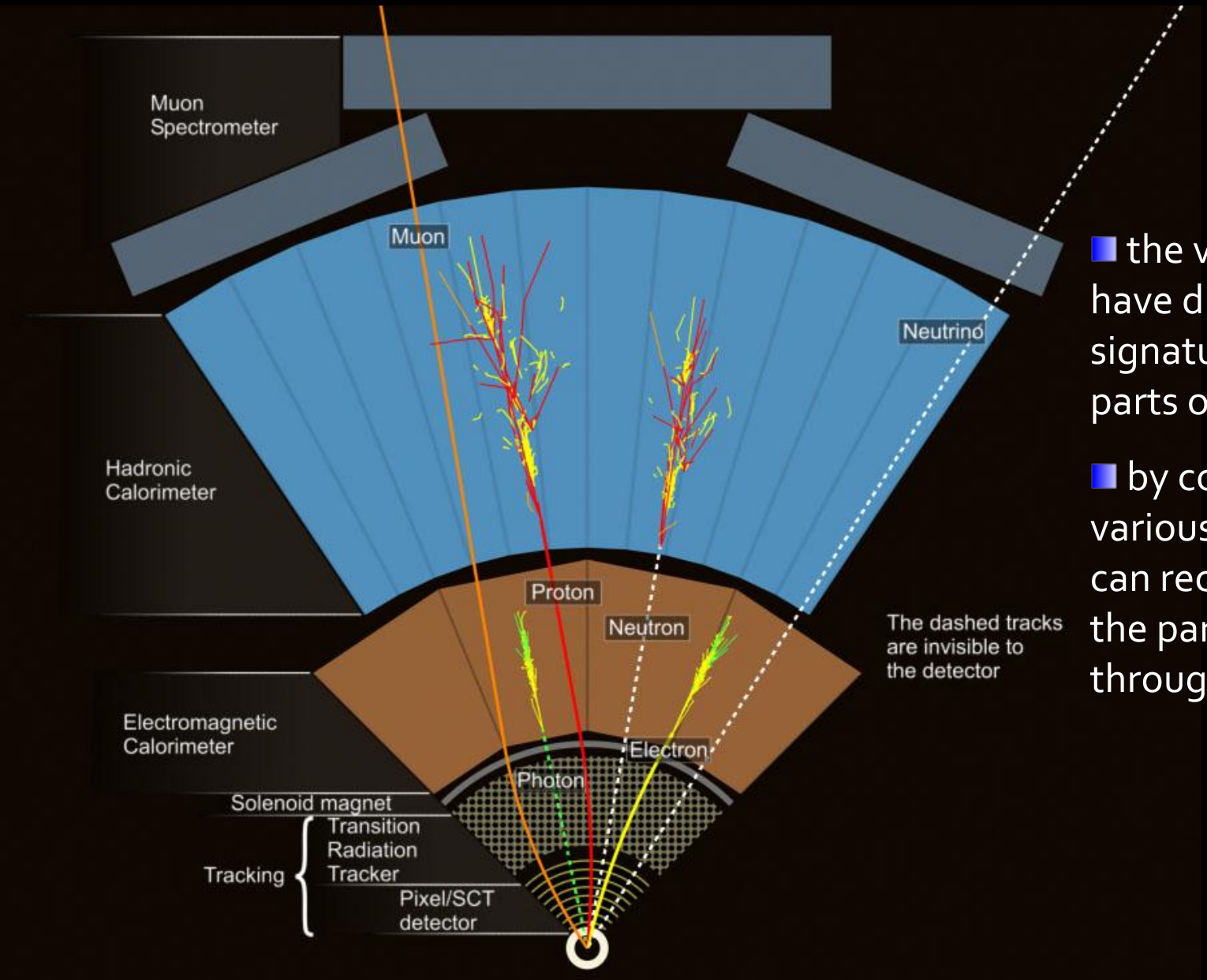
$ee\mu\mu$ event in p-p collisions

http://www.atlas.ch/multimedia/4-muon-event.html#2-electron-2-muon-event

Heavy Ion Collision

http://www.atlas.ch/multimedia/4-muon-event.html#heavy-ion-event

Particle detection



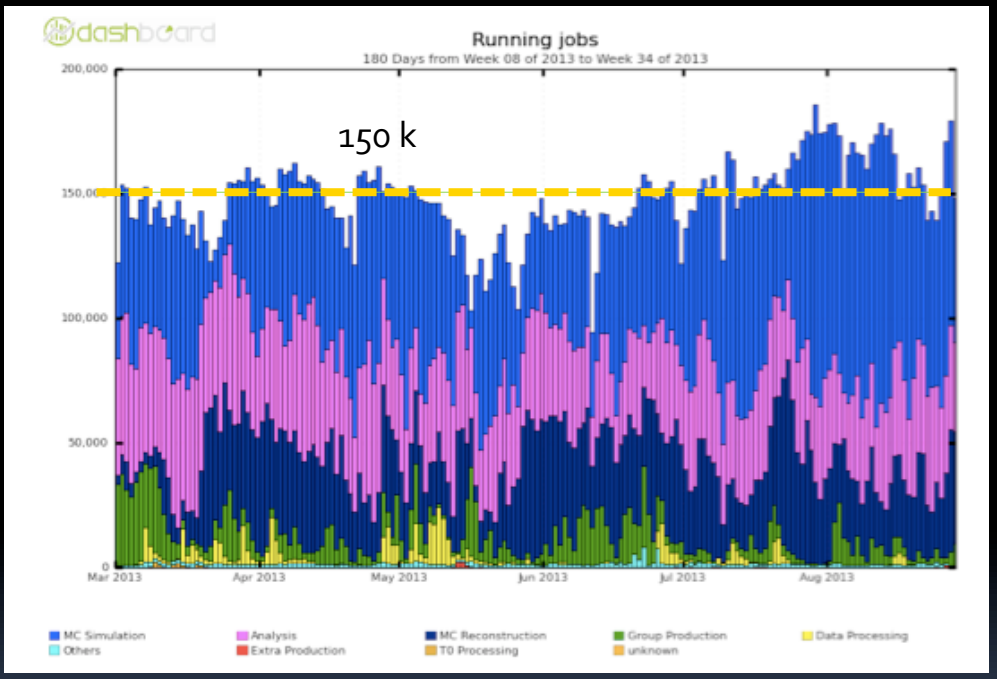
- the various particles have different signatures in different parts of the detector
- by combining the various signatures, we can reconstruct how the particle moved through the detector

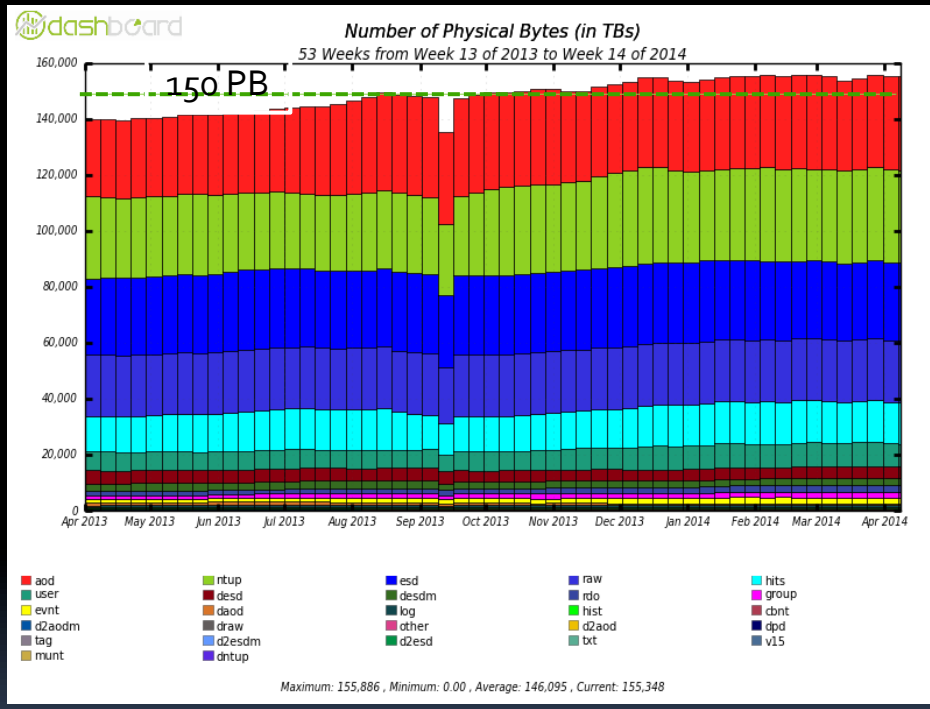
Particle identification

http://www.atlas.ch/multimedia/4-muon-event.html#episode-2

ATLAS Computing

- More than 150 000 concurrent jobs
- More than 150 PB of data on disk & tape



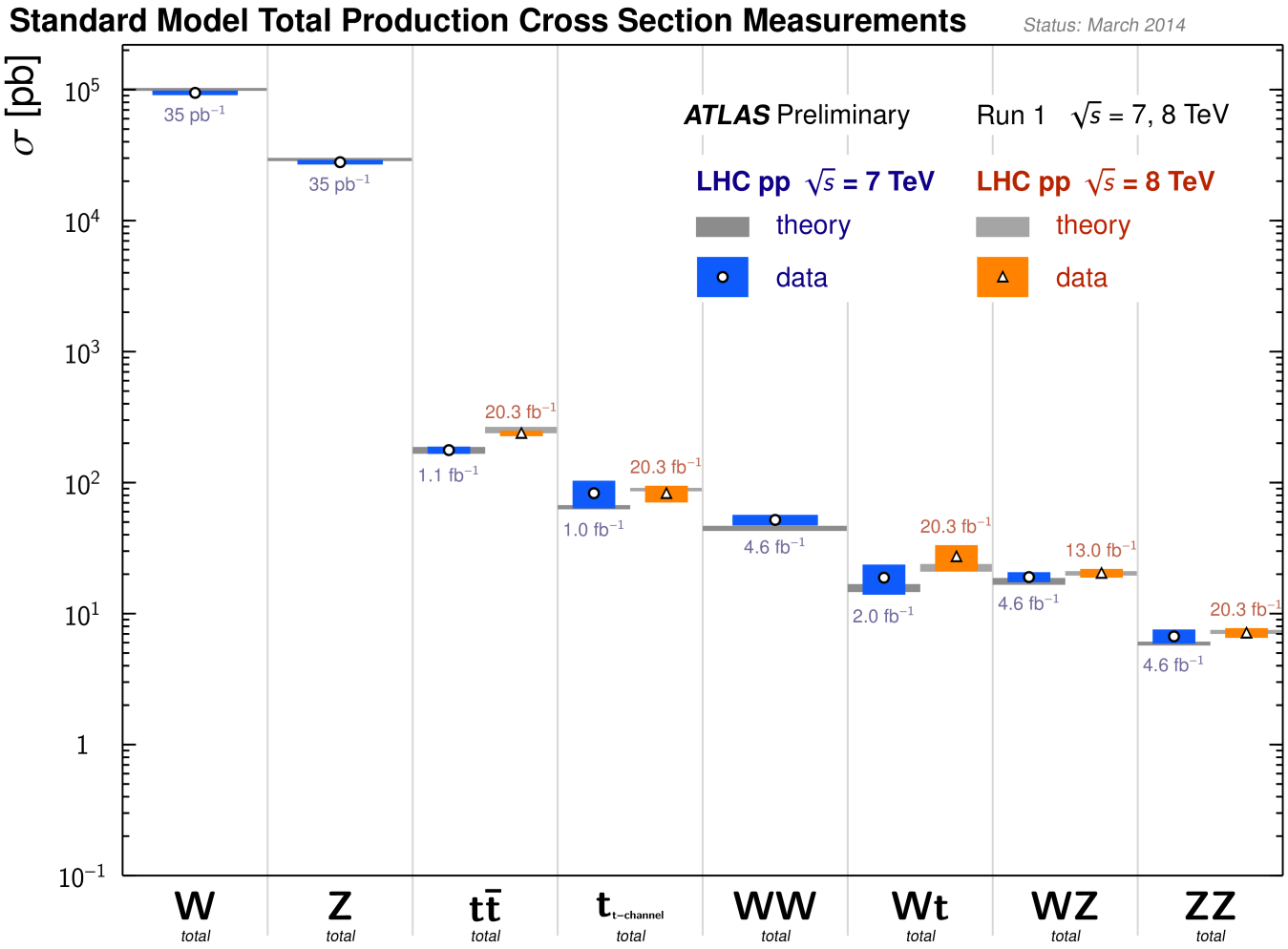


"It would have been impossible to release so many results so quickly without the outstanding performance of the Grid"

Access to physics

- Full dataset 2010-2012 after typical selection cuts ~25 fb^{-1}
  - W→lν ~100 M
  - Z→ll ~10 M
  - tt→l+X ~0.4M
  - >400 Higgs
- LHC is W, Z, top factory …
- ATLAS made discoveries,

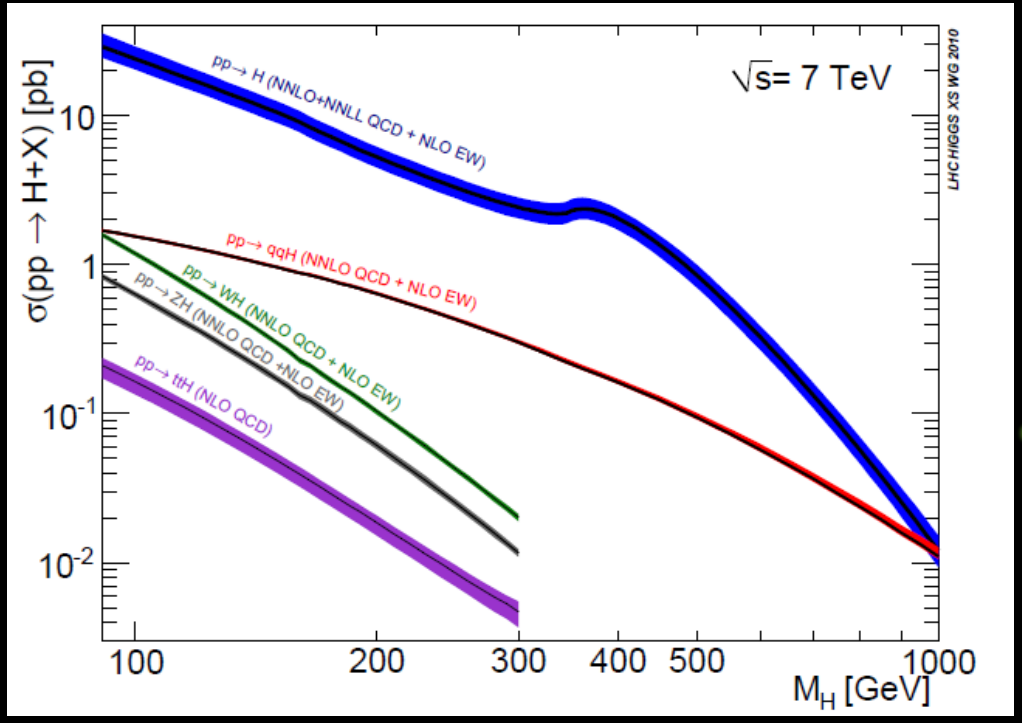
  one per year
  - 2010: Jet quenching
  - 2011: New B meson
  - 2012: Higgs

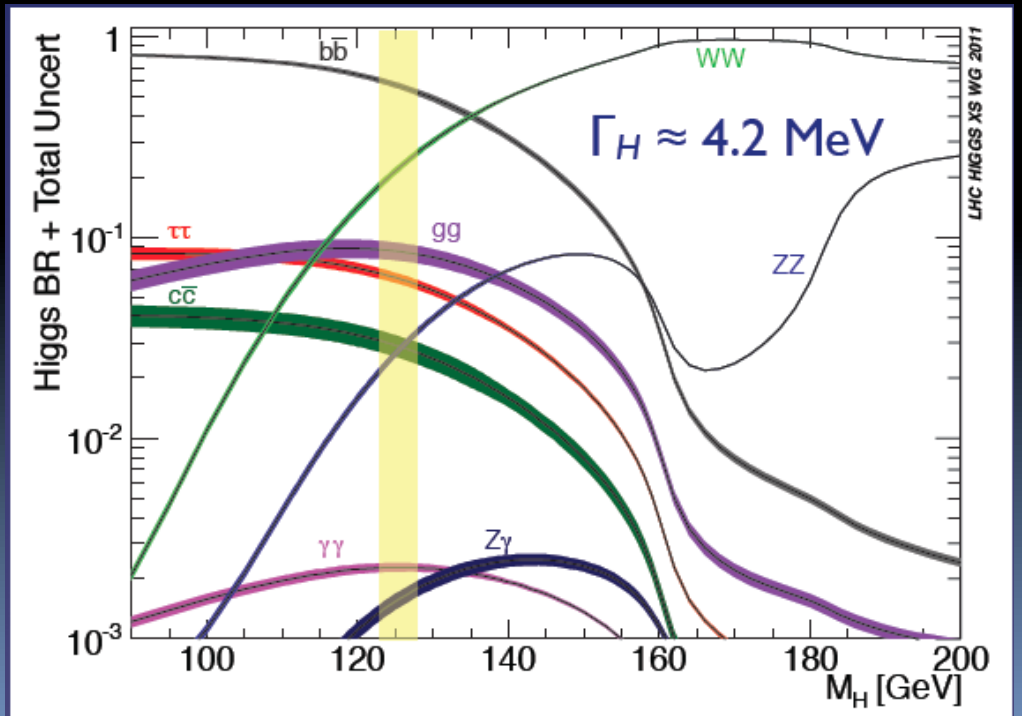


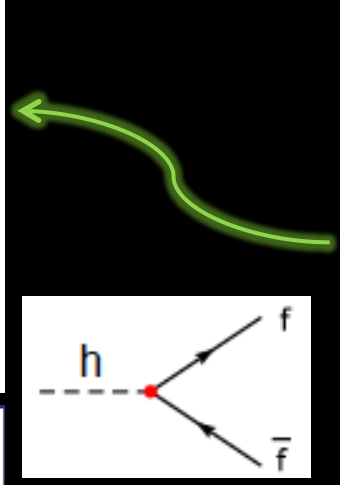
Why LHC

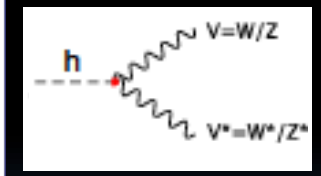
- Several accelerators / colliders built to discover (among others) the Higgs particle
- LHC was planned not to miss the Higgs

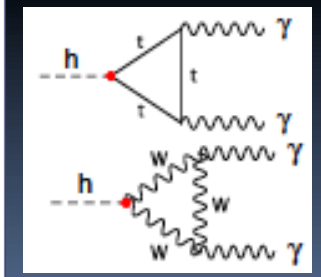
Higgs production and decay at LHC

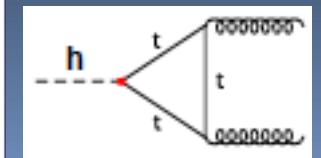






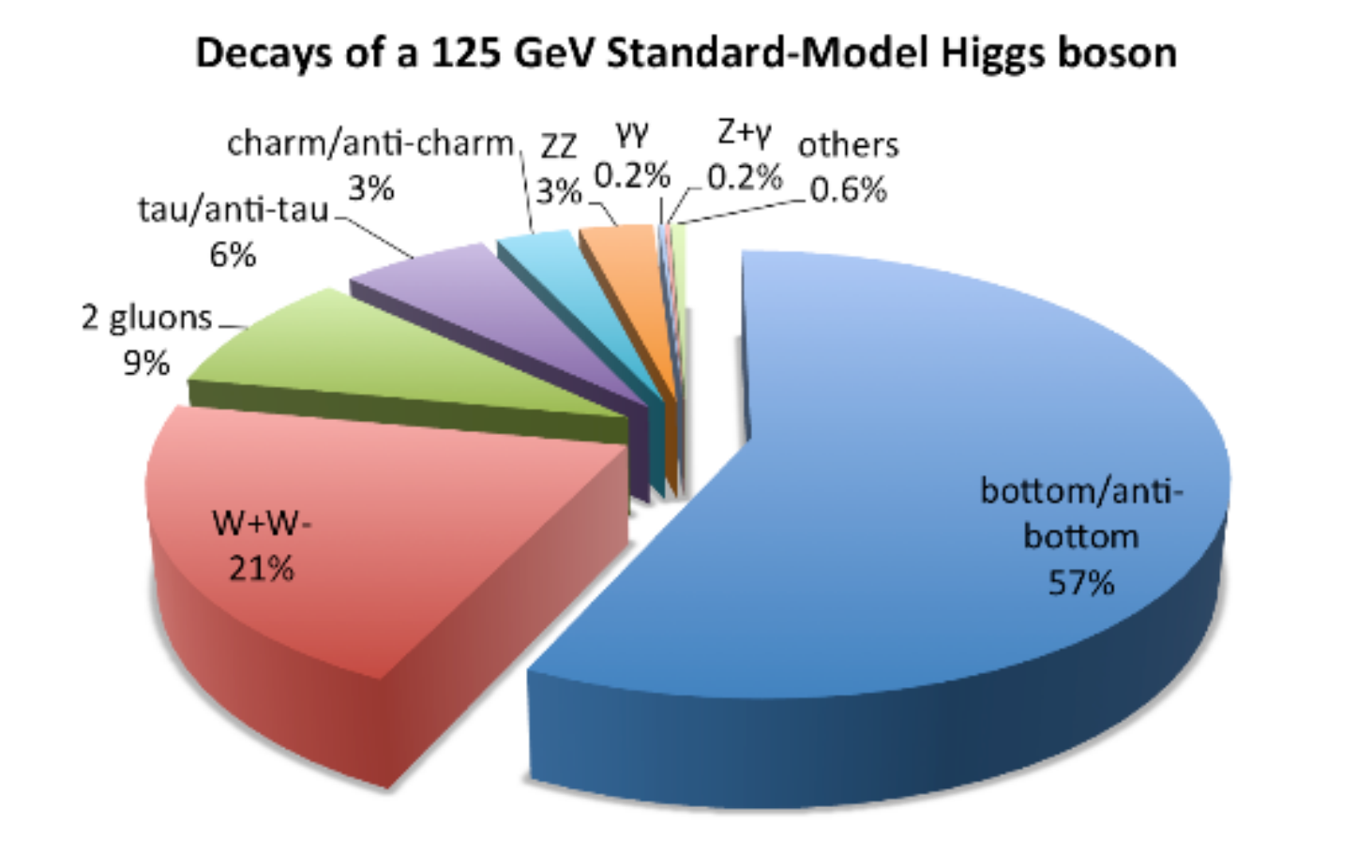




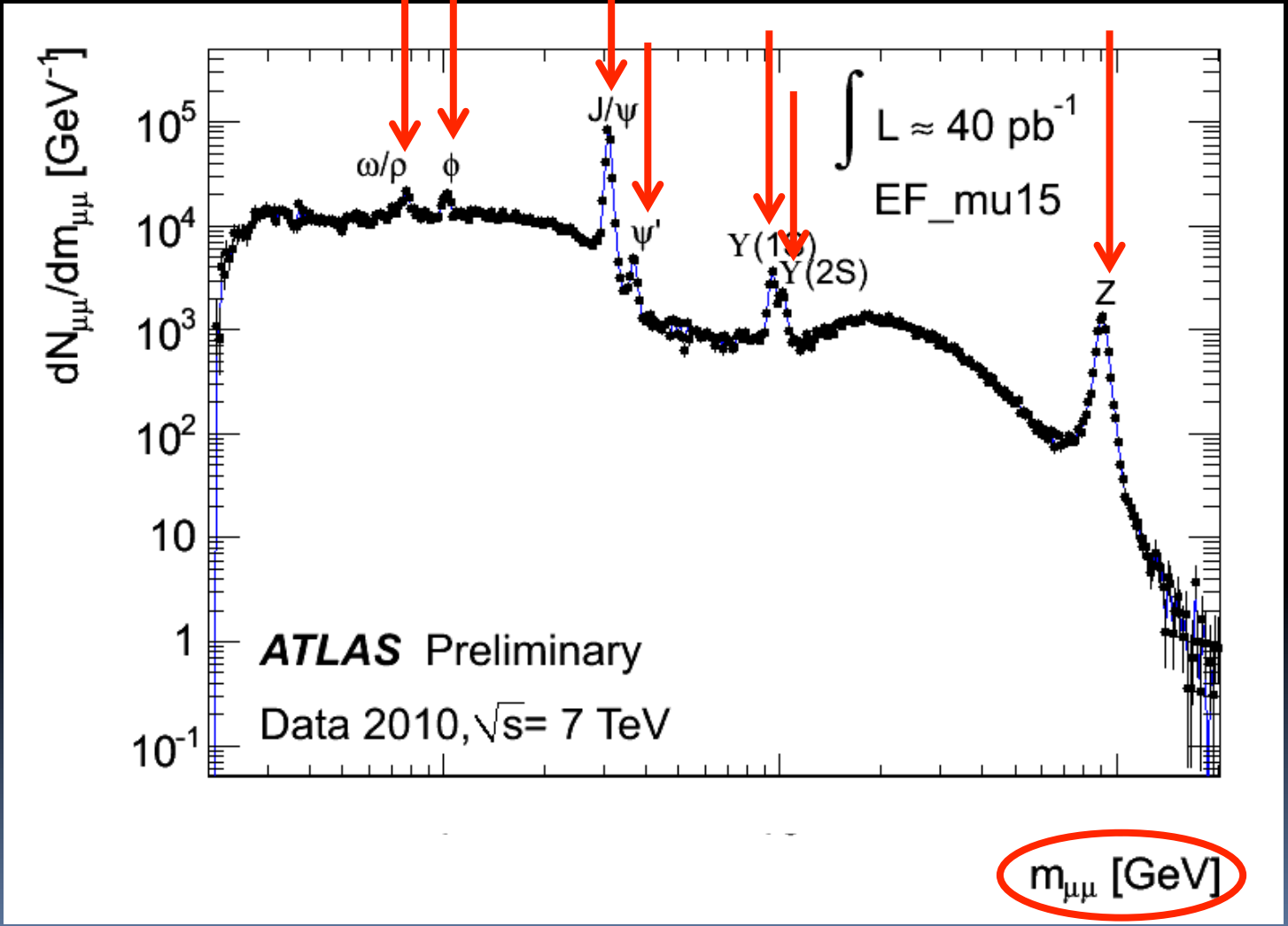


- 125 GeV … a rather good compromise
- 4/5 production processes
- ≥5 decay channels

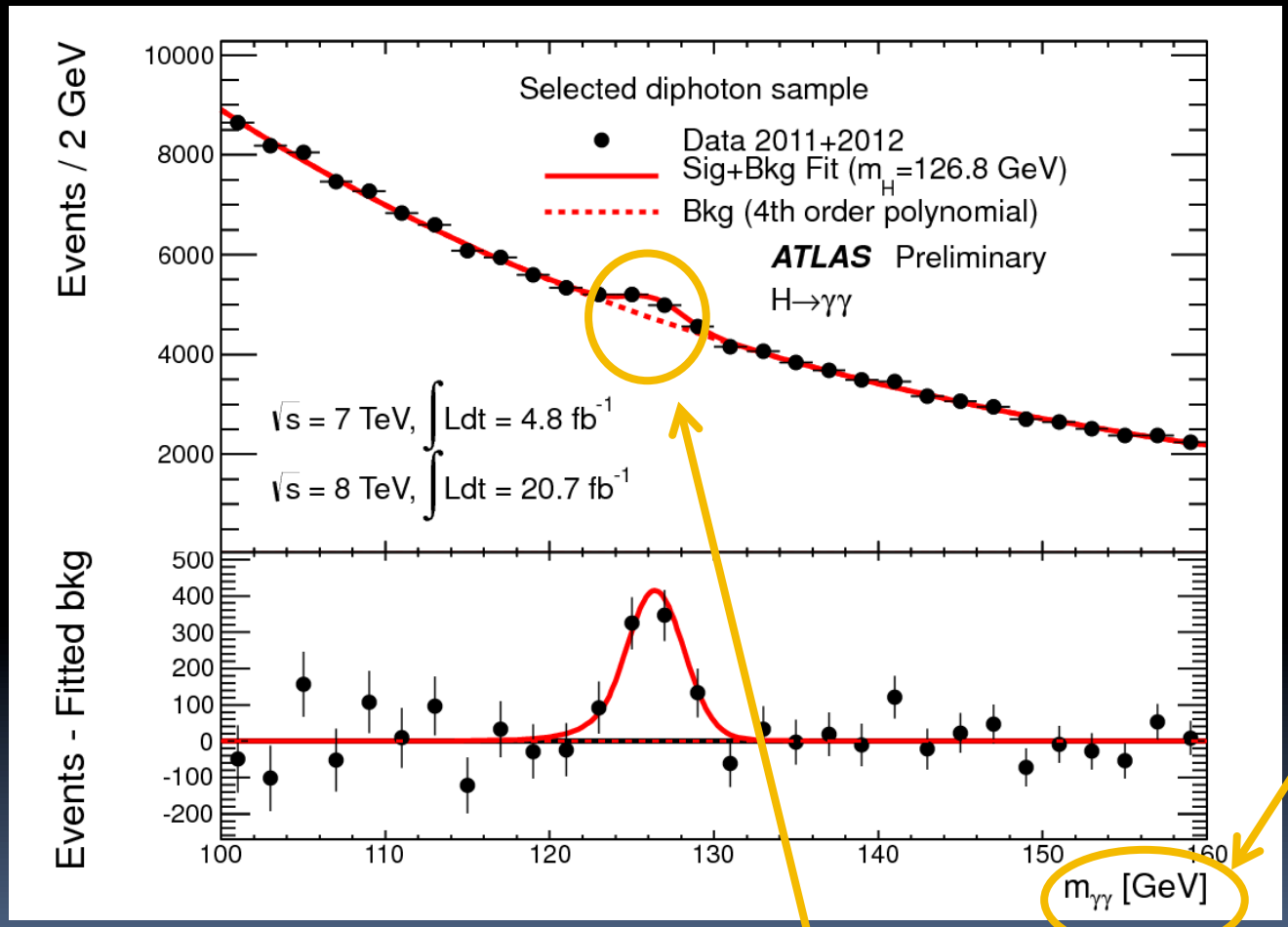
The 125 GeV Higgs cake …



Everything in place?



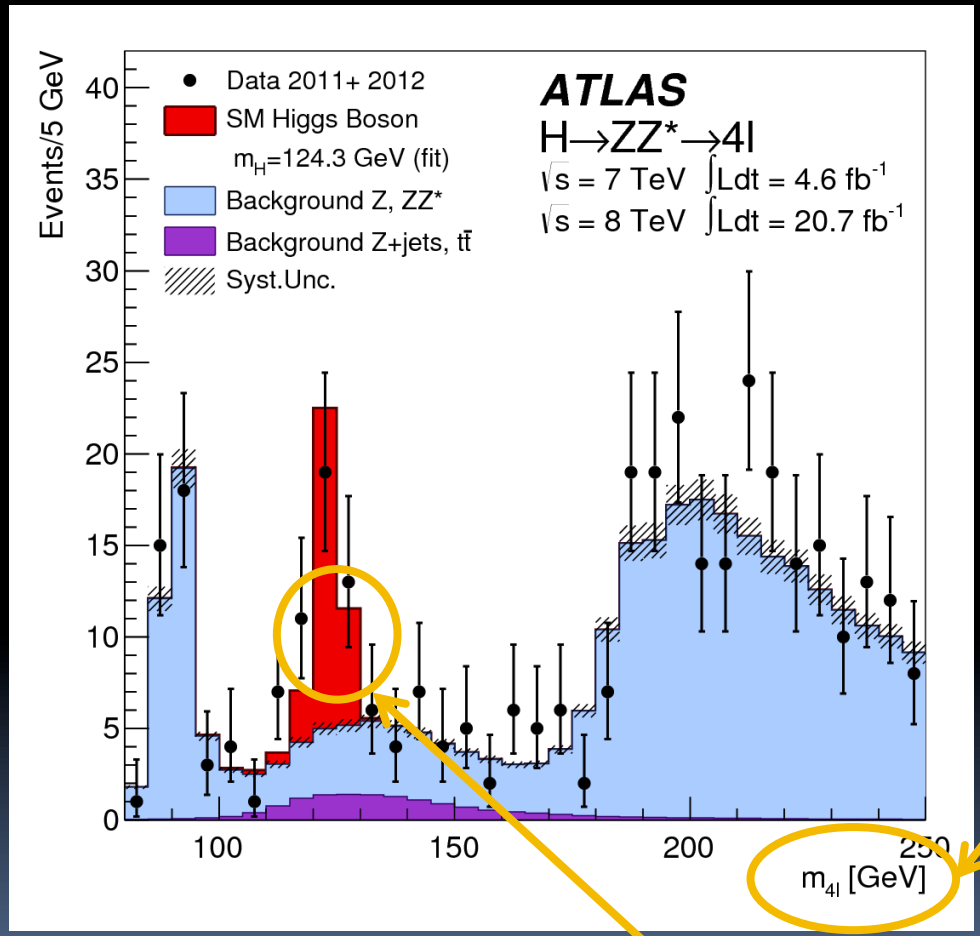
Anything new?



Invariant mass of photons

Higgs particle at 126 GeV!

Anything new?

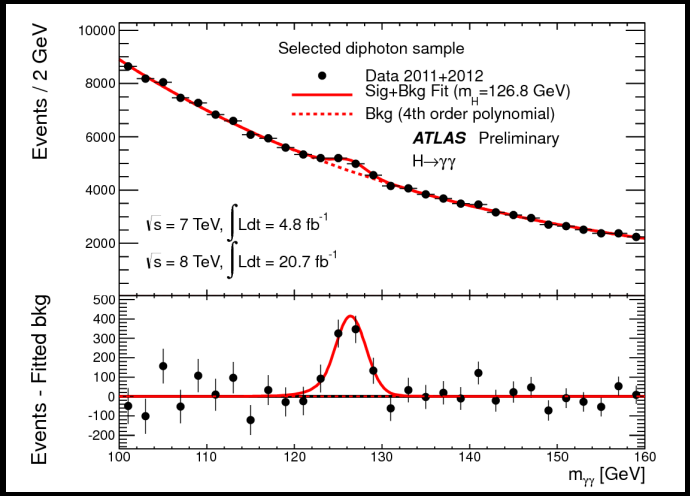


Invariant mass of 4 leptons

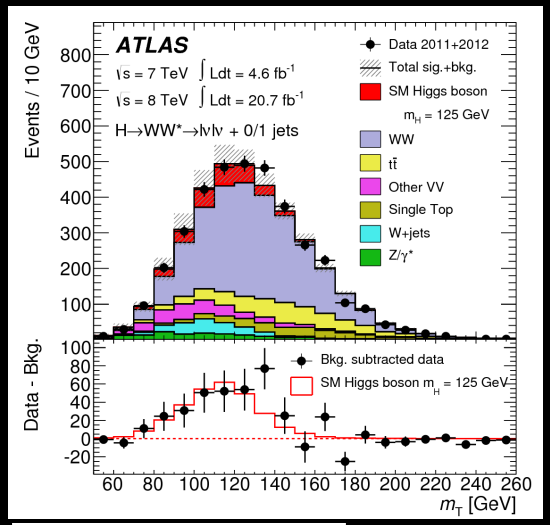
Higgs particle at 125 GeV

Higgs discovery?

H→γγ

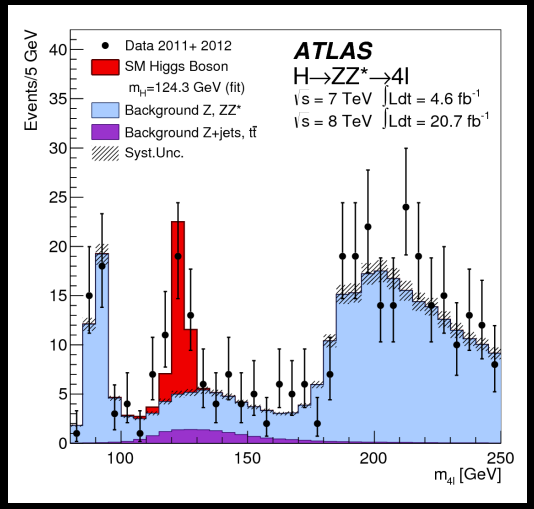


H→WW*→lνlν

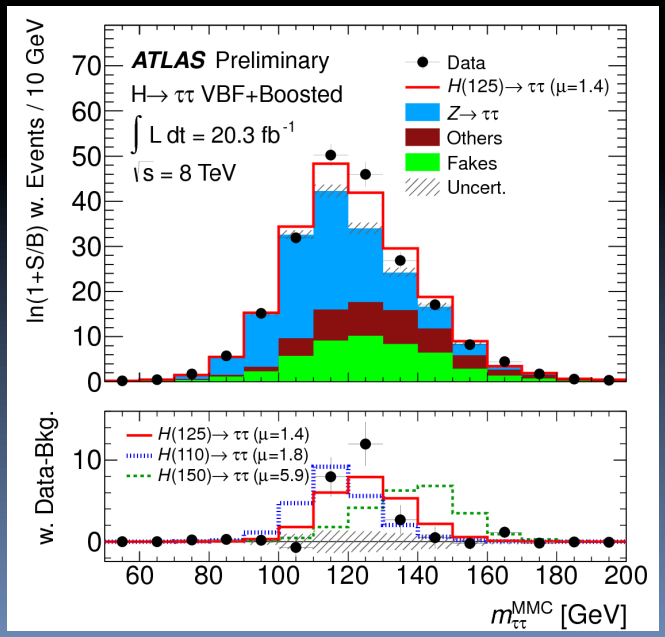


$$m_{\mathrm{T}} = \sqrt{(E_{\mathrm{T}}^{\ell\ell} + E_{\mathrm{T}}^{\mathrm{miss}})^2 - (\mathbf{P}_{\mathrm{T}}^{\ell\ell} + \mathbf{P}_{\mathrm{T}}^{\mathrm{miss}})^2}$$

H→ZZ*→llll

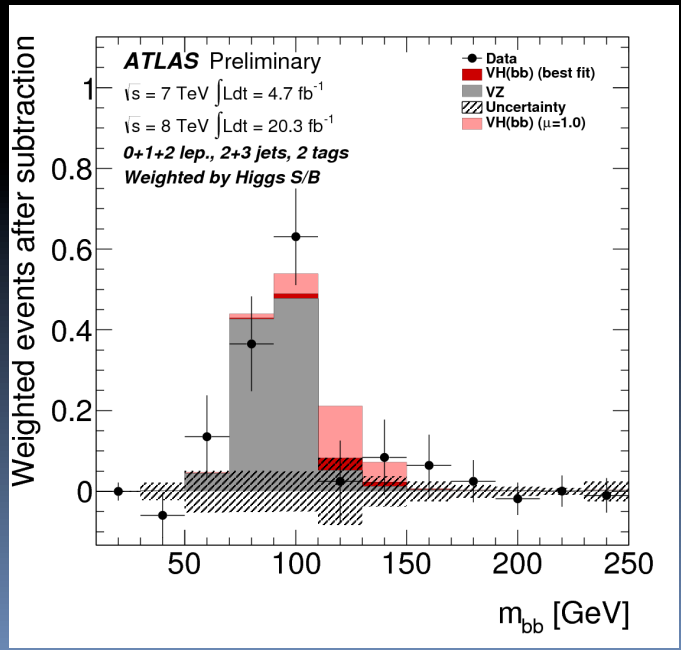


H→ττ



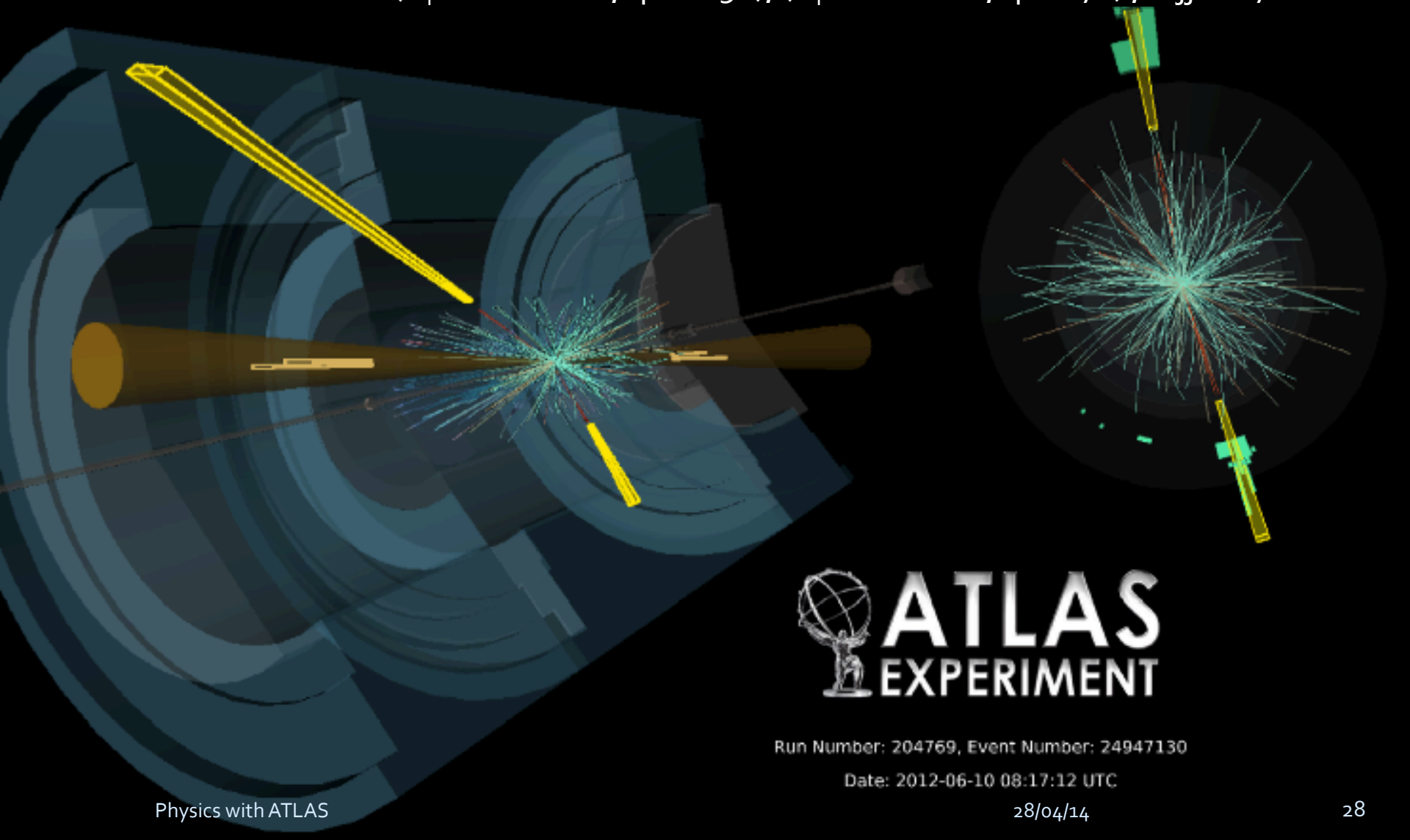
- Fermions
- Tau evidence 4σ
- Bottom decays still need be confirmed

H→bb



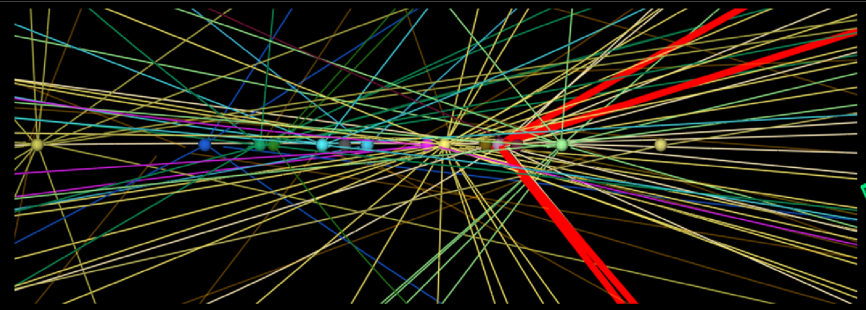
$H \rightarrow \gamma\gamma$

Vector Boson Fusion candidate at $\sqrt{s}$=8TeV
2 converted photons and two high-mass jets
- Photons: (E_T = 80.1 GeV, η = 1.01); (E_T = 36.2 GeV and η = −0.17)
- Measured di-photon mass = 126.9 GeV
- Jets: (E_T = 121.6 GeV, η = -2.90); (E_T = 82.8 GeV, η = 2.72) ; Mjj=1.67 TeV



$H \rightarrow ZZ^* \rightarrow \mu^+\mu^-\mu^+\mu^-$

m_4=127.4 GeV. m_{12}=86.6 GeV, m_{34}=31.6 GeV

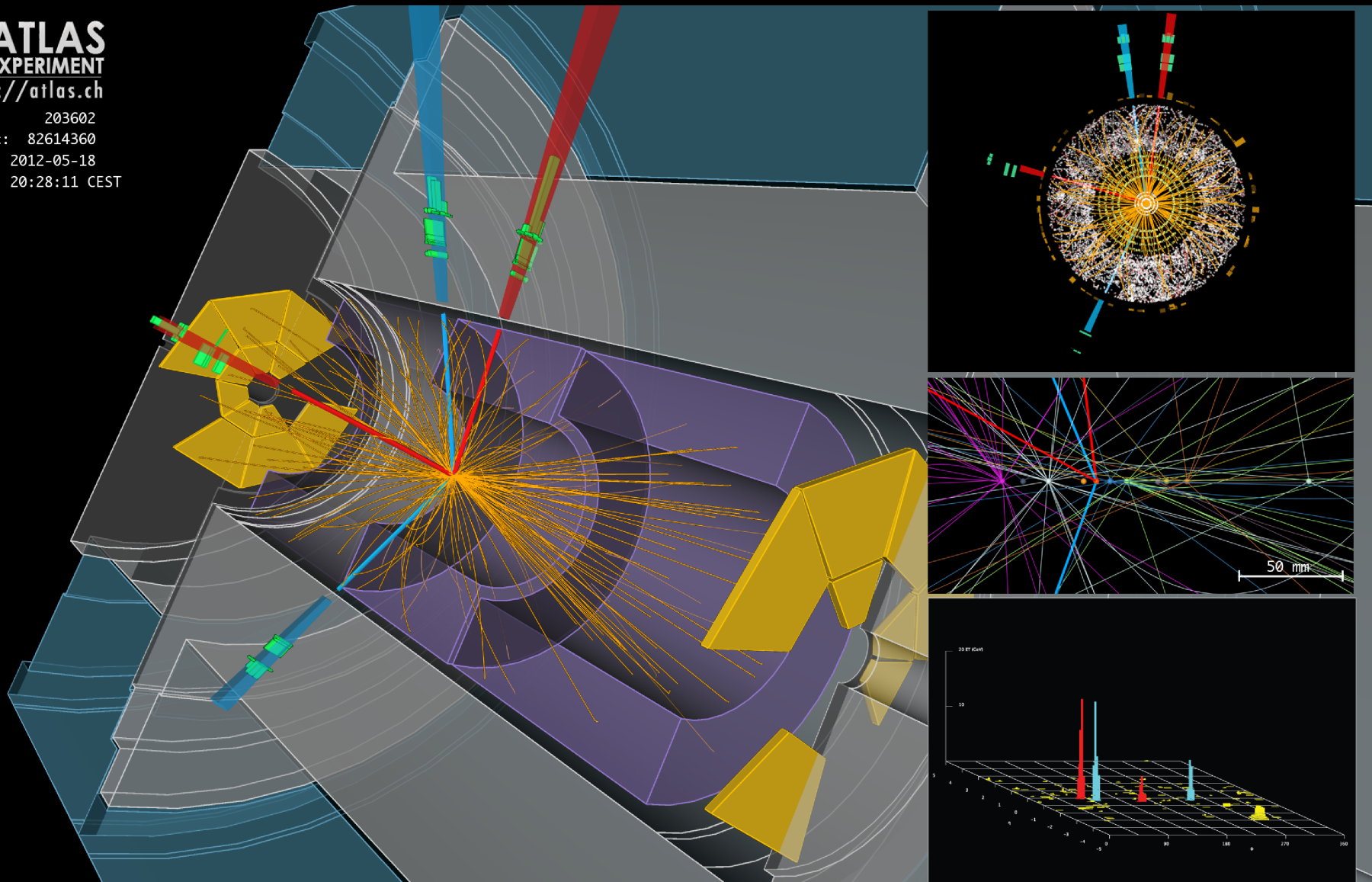


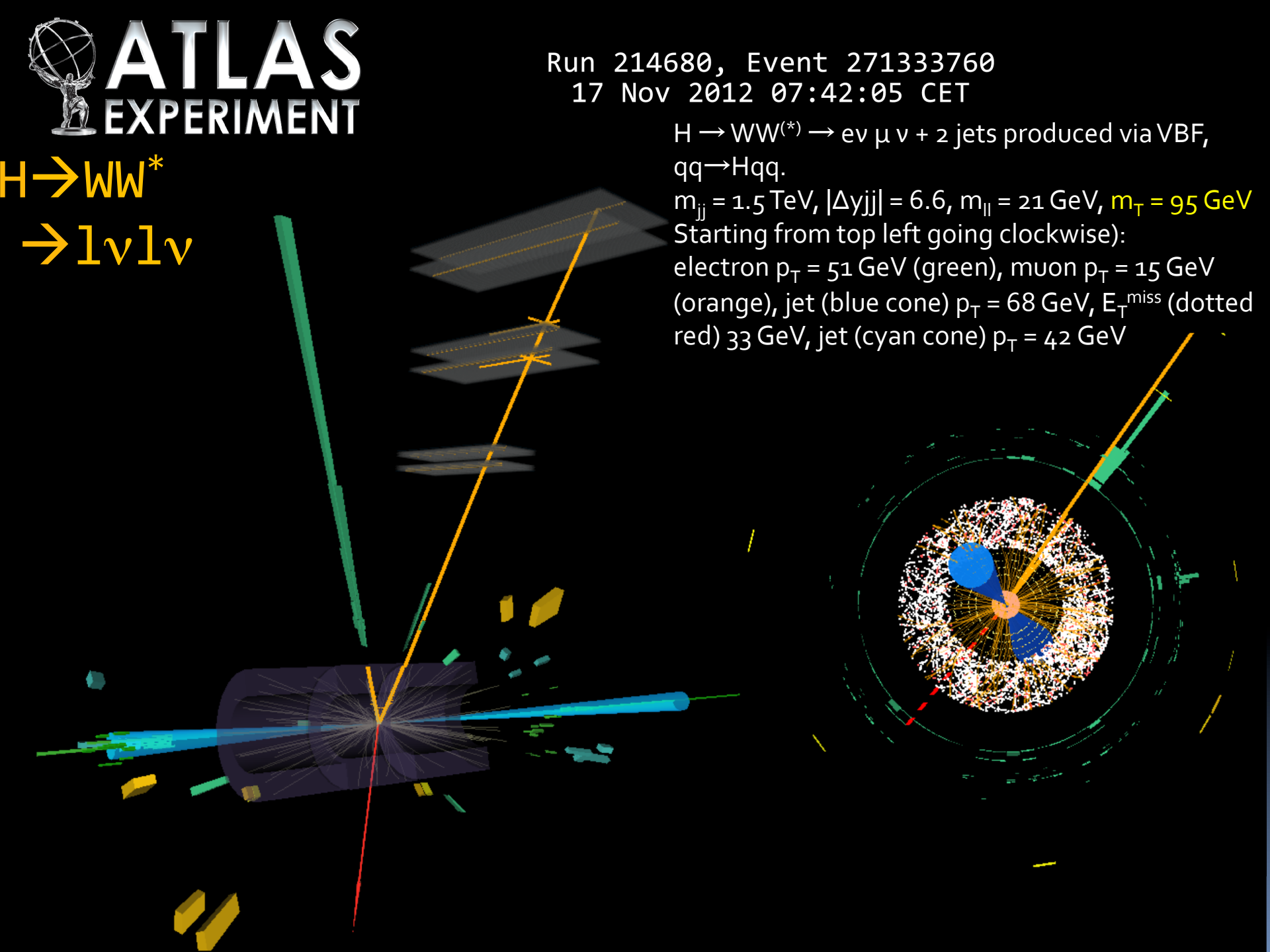
ATLAS EXPERIMENT
http://atlas.ch

Run: 204769
Event: 71902630
Date: 2012-06-10
Time: 13:24:31 CEST

$H \rightarrow ZZ^* \rightarrow e^+e^-e^+e^-$

m_4=124.6 GeV. m_{12}=70.6 GeV, m_{34}=44.7 GeV

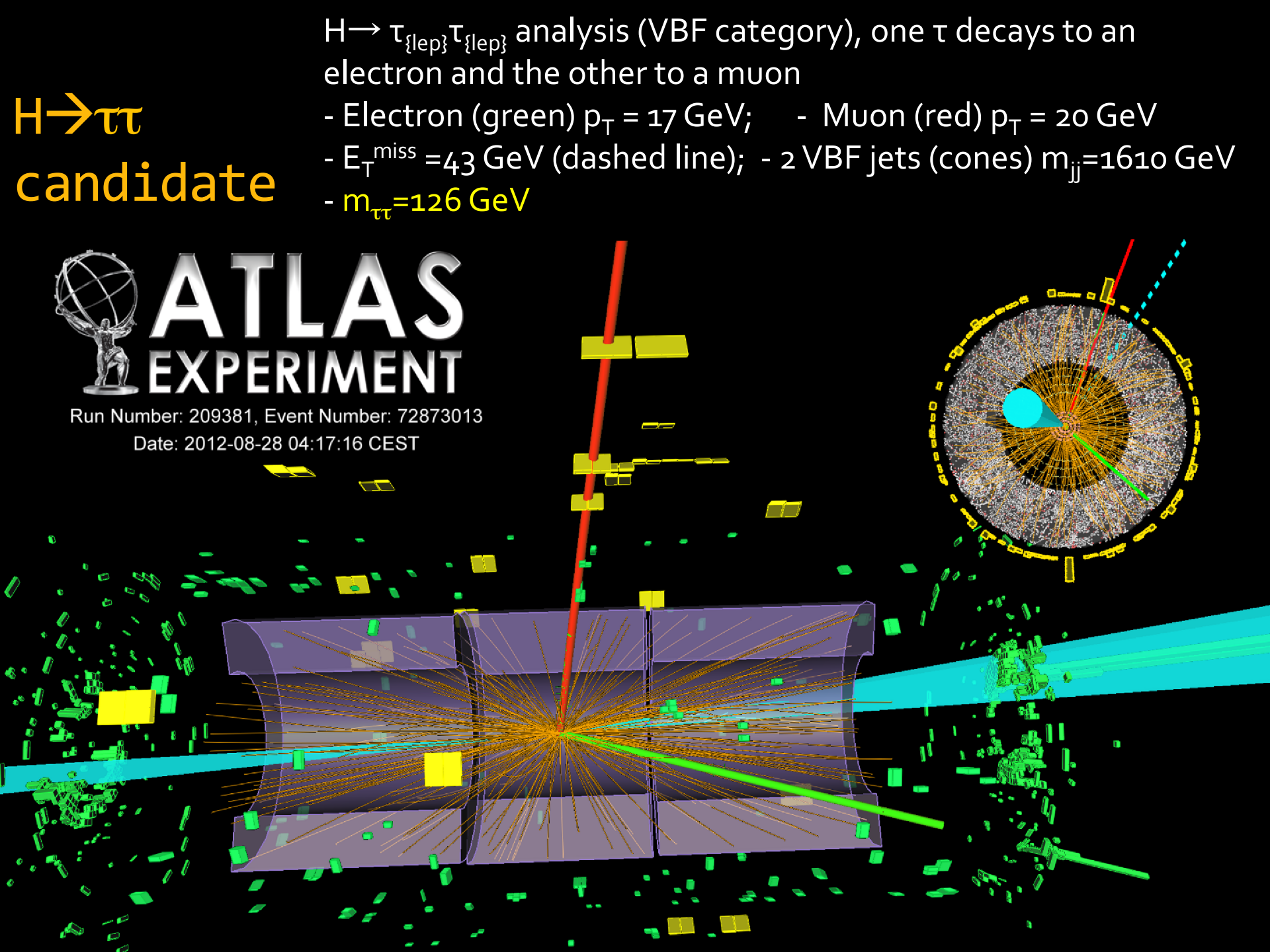



ATLAS
EXPERIMENT
Run 214680, Event 271333760
17 Nov 2012 07:42:05 CET
H→WW*
→lνlν
H → WW(*) → eν μ ν + 2 jets produced via VBF, qq→Hqq.
mjj = 1.5 TeV, |Δyjj| = 6.6, mll = 21 GeV, mT = 95 GeV
Starting from top left going clockwise):
electron pT = 51 GeV (green), muon pT = 15 GeV (orange), jet (blue cone) pT = 68 GeV, ETmiss (dotted red) 33 GeV, jet (cyan cone) pT = 42 GeV

H→ττ candidate

H→ $\tau_{\{lep\}}\tau_{\{lep\}}$ analysis (VBF category), one τ decays to an electron and the other to a muon

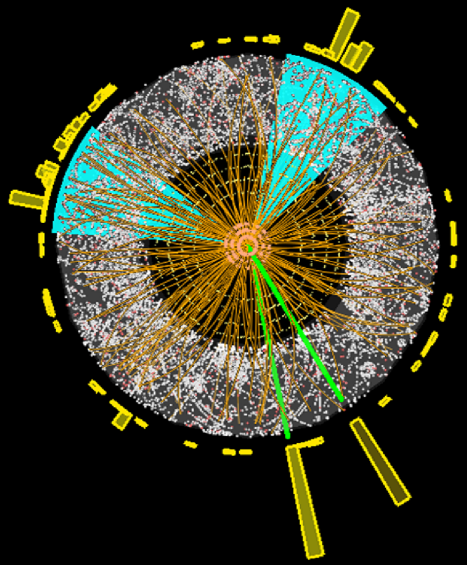
- Electron (green) p_T = 17 GeV;
- Muon (red) p_T = 20 GeV
- E_T^{miss} =43 GeV (dashed line);
- 2 VBF jets (cones) m_{jj}=1610 GeV
- $m_{\tau\tau}$=126 GeV

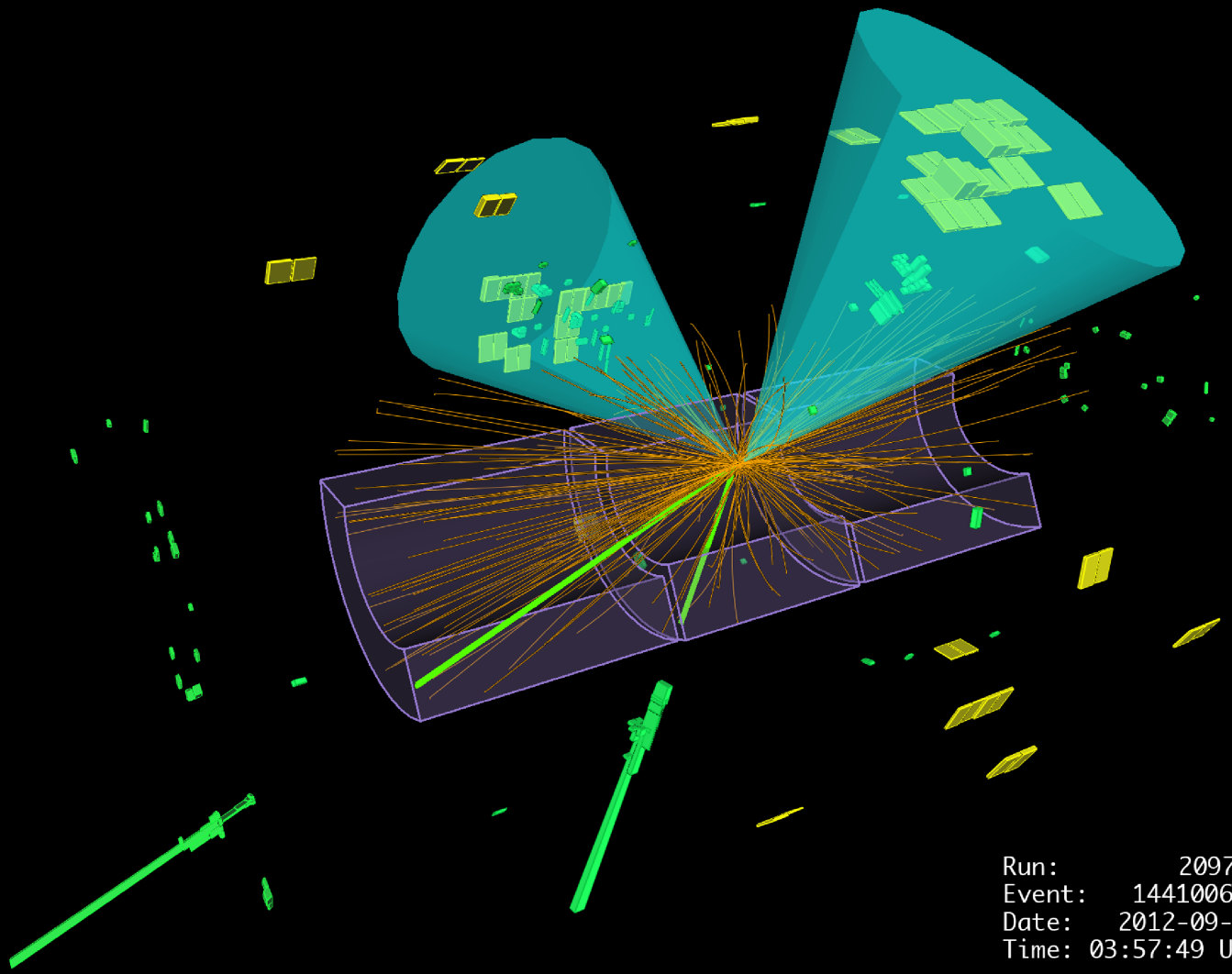


H→b-bbar candidate

- 2 identified b-jets (p_T=70 GeV, p_T=65 GeV, m_{bb}=122 GeV)
- 2 electrons (p_T=63 GeV, p_T=54 GeV).

ATLAS EXPERIMENT
http://atlas.ch





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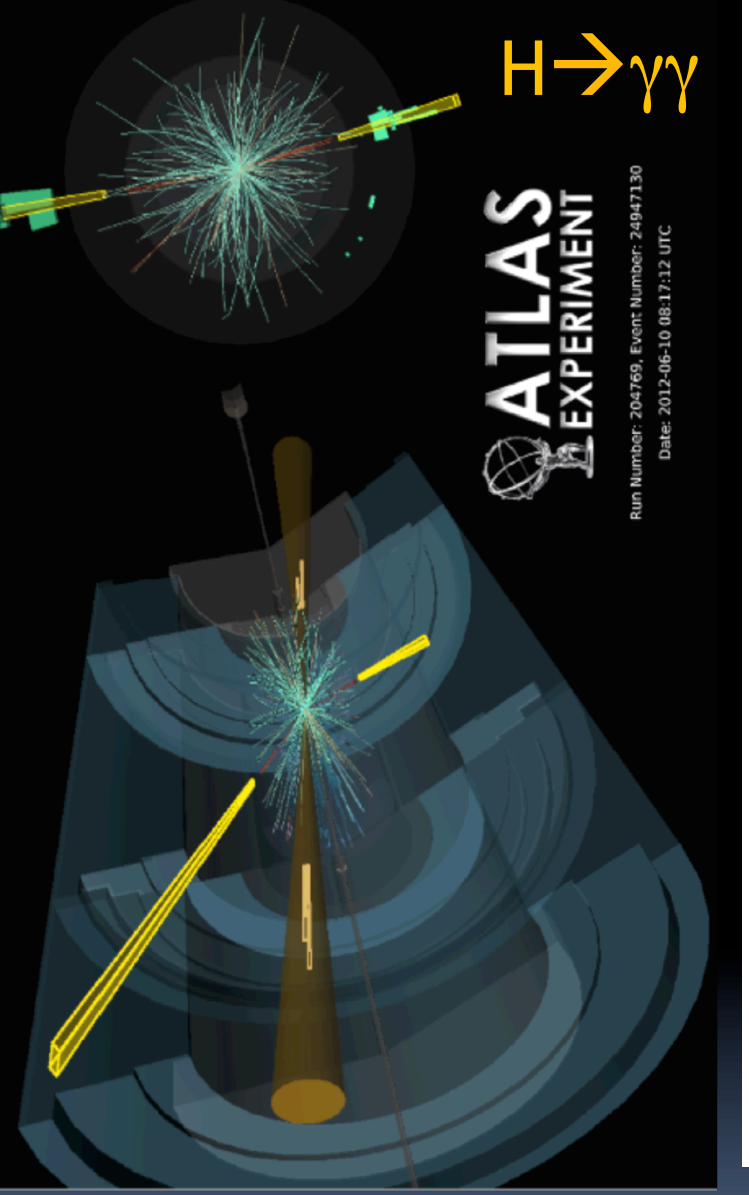
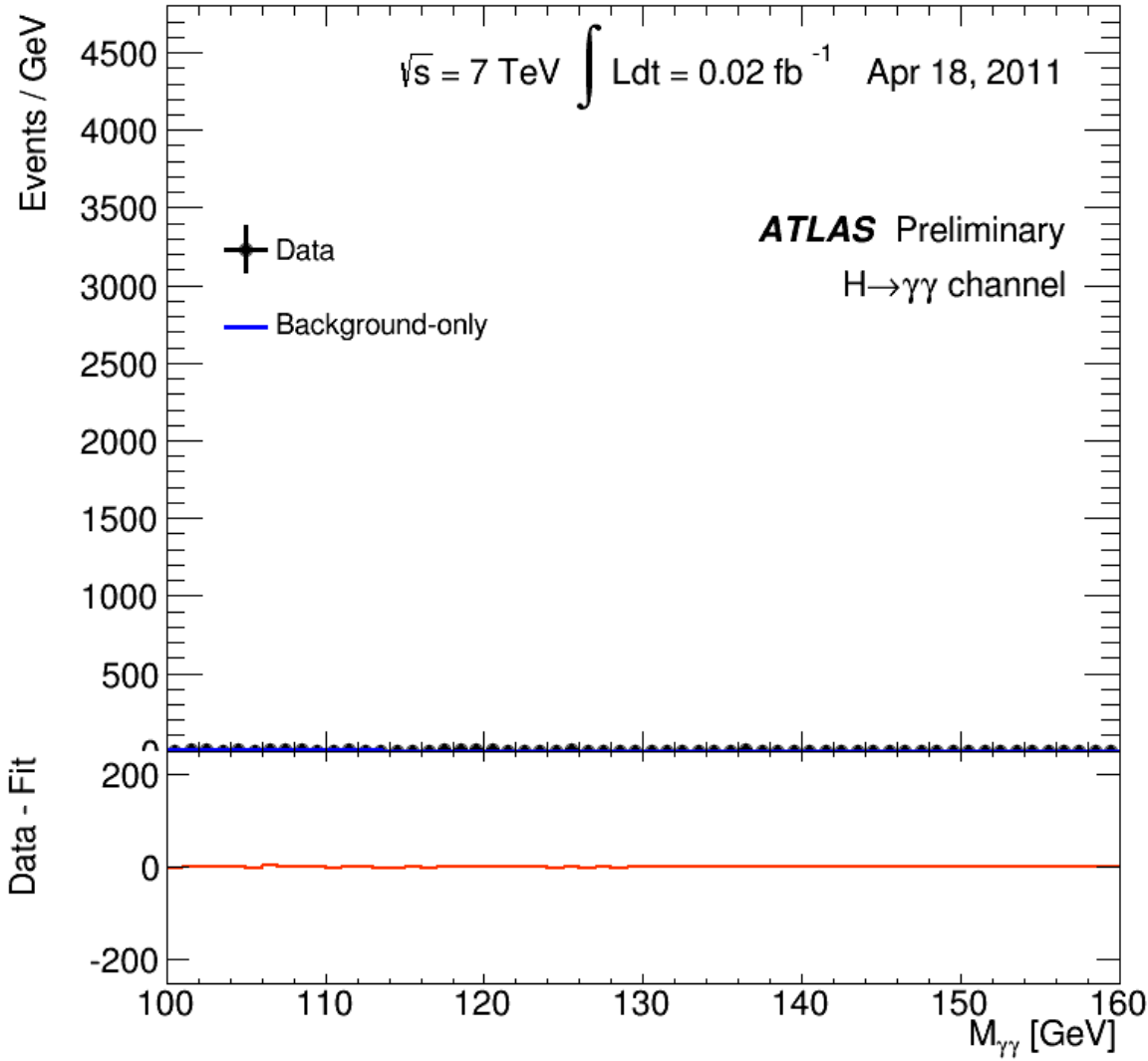
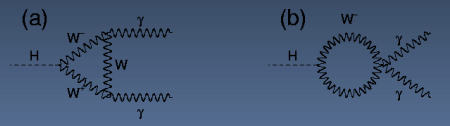
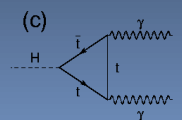
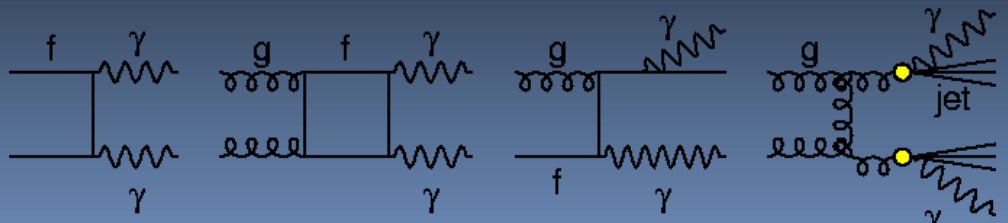
Time: 03:57:49 UTC


H→γγ
ATLAS EXPERIMENT
Run Number: 204769, Event Number: 24947130
Date: 2012-06-10 08:17:12 UTC

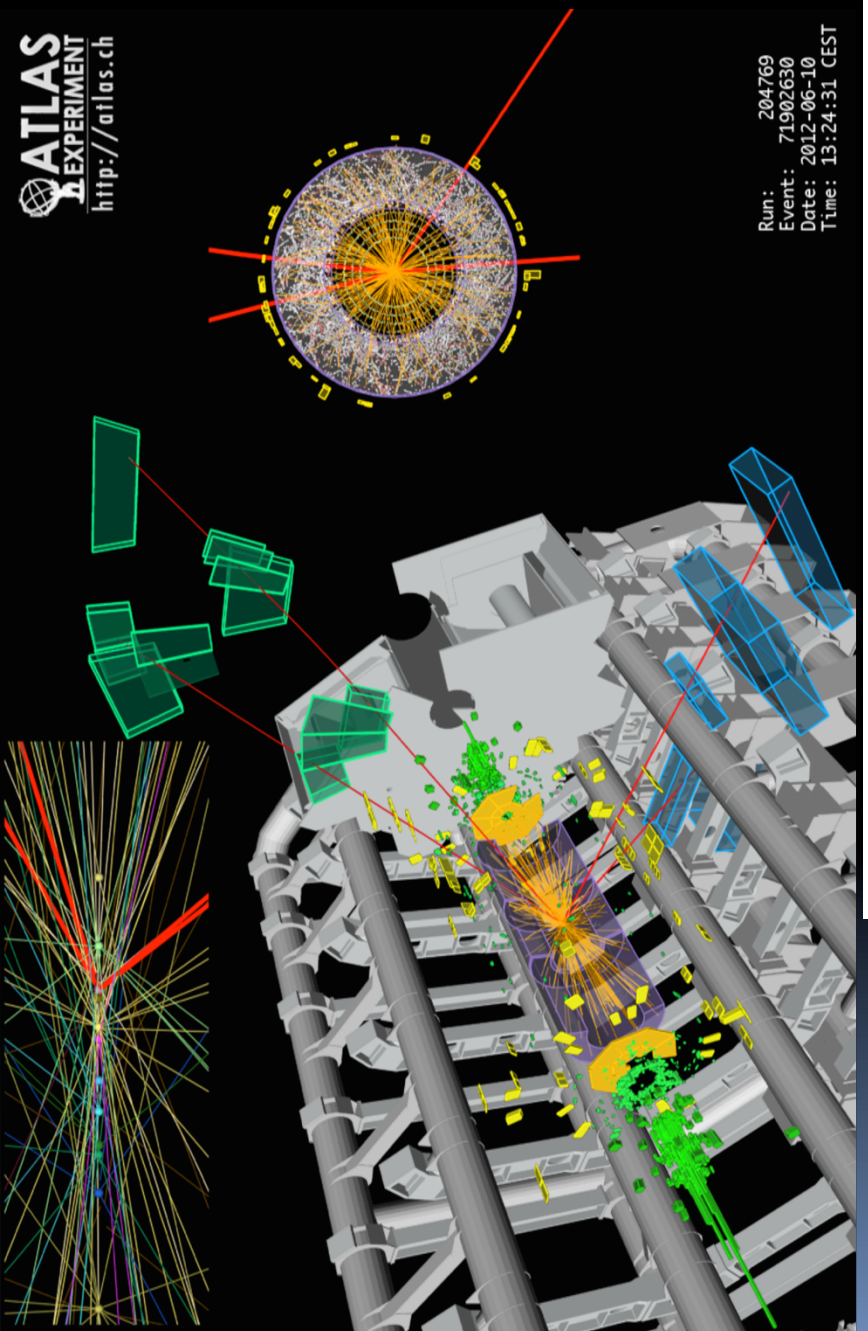

√s = 7 TeV ∫ Ldt = 0.02 fb⁻¹ Apr 18, 2011
ATLAS Preliminary
H→γγ channel
Data
Background-only
Events / GeV
Data - Fit
4500
4000
3500
3000
2500
2000
1500
1000
500
200
0
-200
100
110
120
130
140
150
160
M_γγ [GeV]

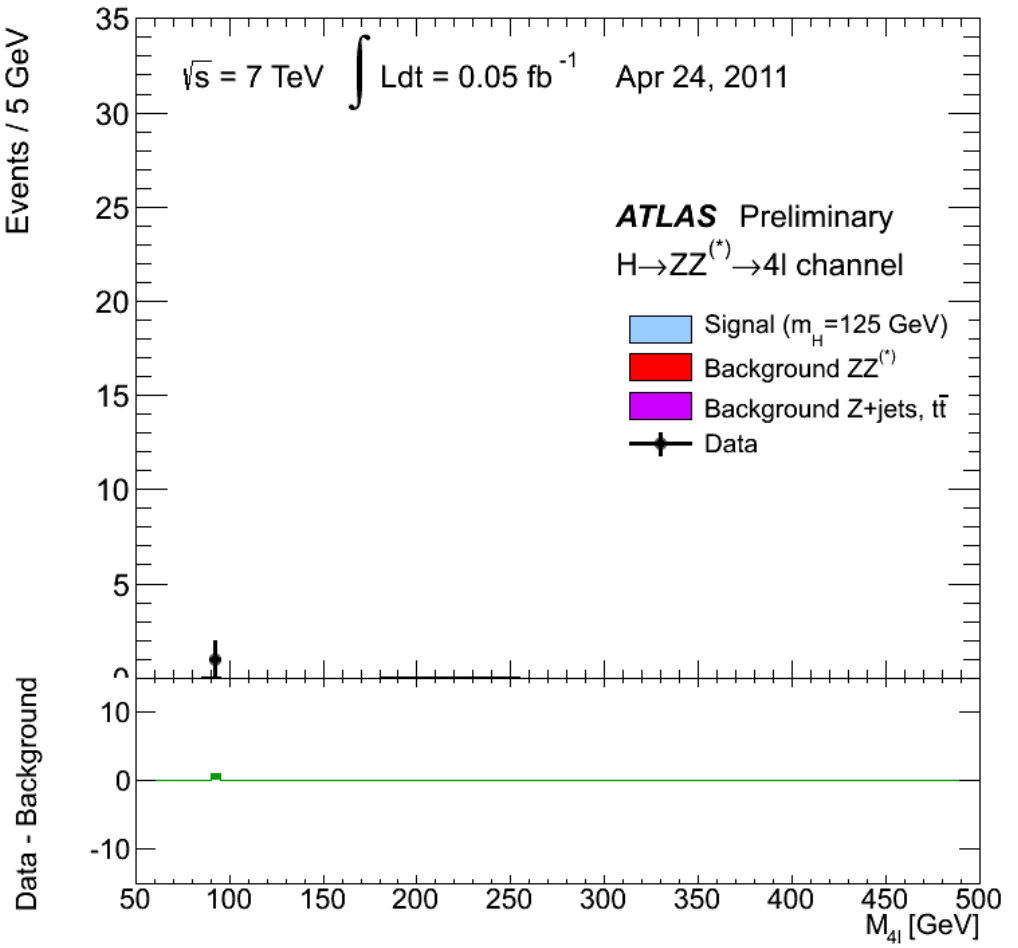

(a)
(b)
H
W
γ


(c)
H
t
γ


f
γ
g
jet

$H \rightarrow ZZ^* \rightarrow l^+l^-l^+l^-$

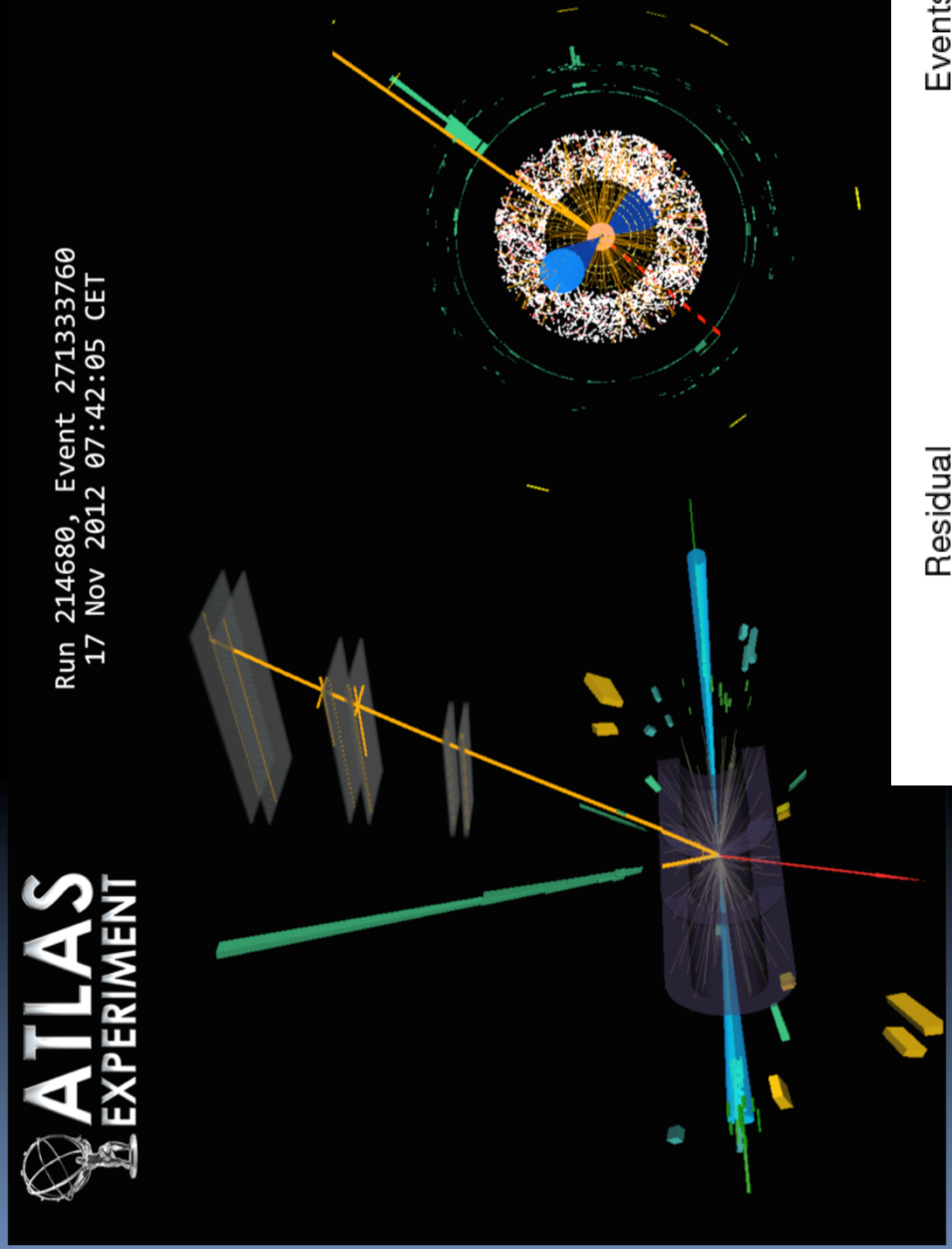


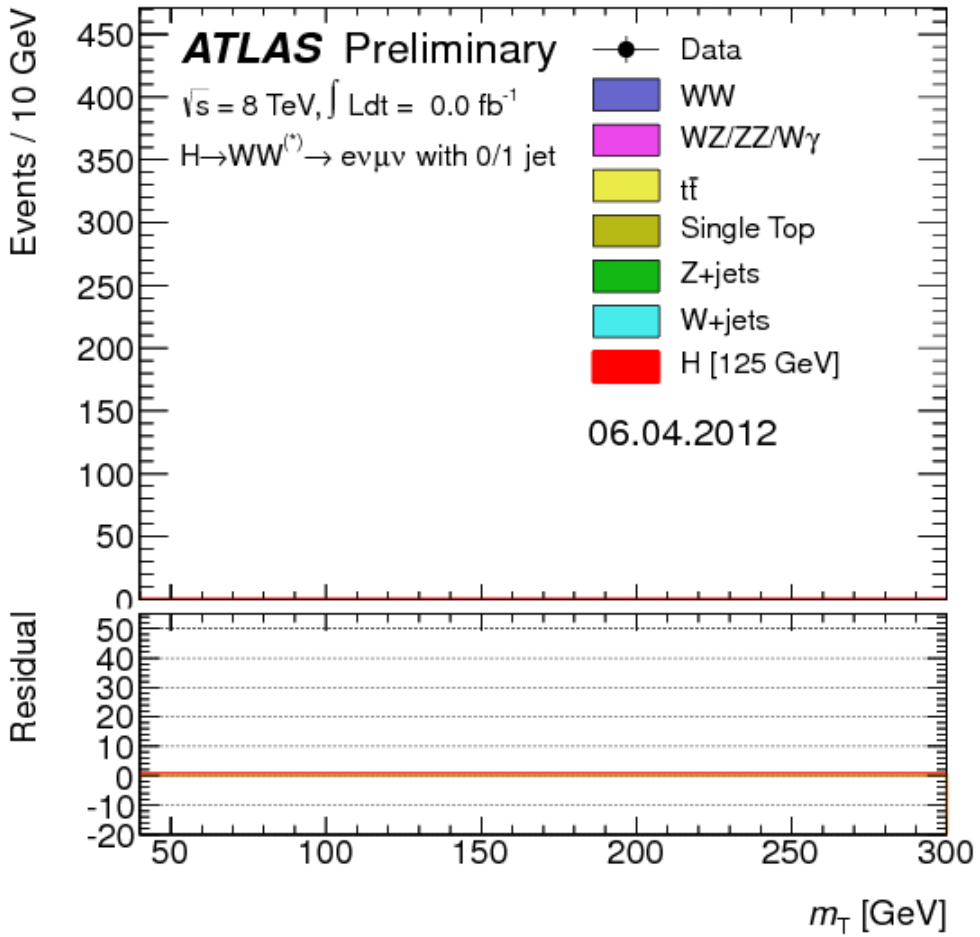


Understanding of "background" is important

- Most of which is due to important physics at the heart of the gauge structure / symmetry of electroweak interaction
- Higgs showed up between 2 relatively busy regions!

H→WW*→lνlν

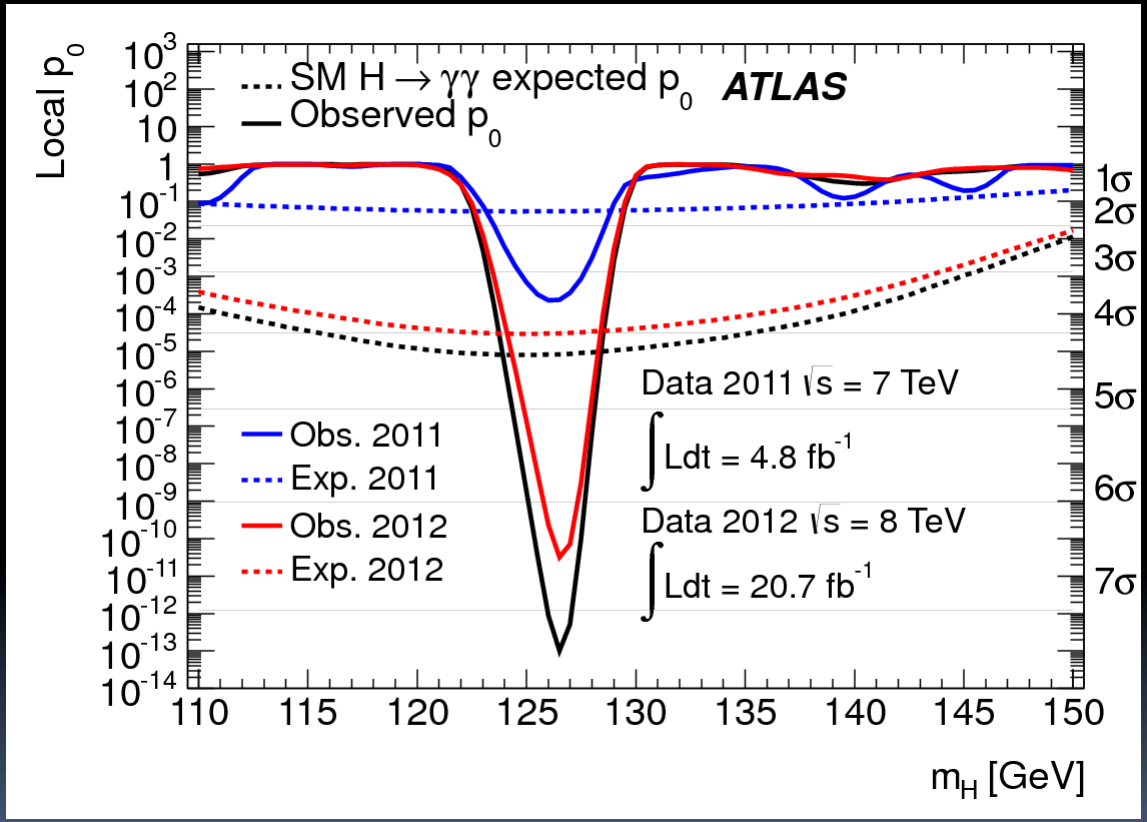




$$m_{\mathrm{T}} = \sqrt{(E_{\mathrm{T}}^{\ell\ell} + E_{\mathrm{T}}^{\mathrm{miss}})^2 - (\mathbf{P}_{\mathrm{T}}^{\ell\ell} + \mathbf{P}_{\mathrm{T}}^{\mathrm{miss}})^2}$$

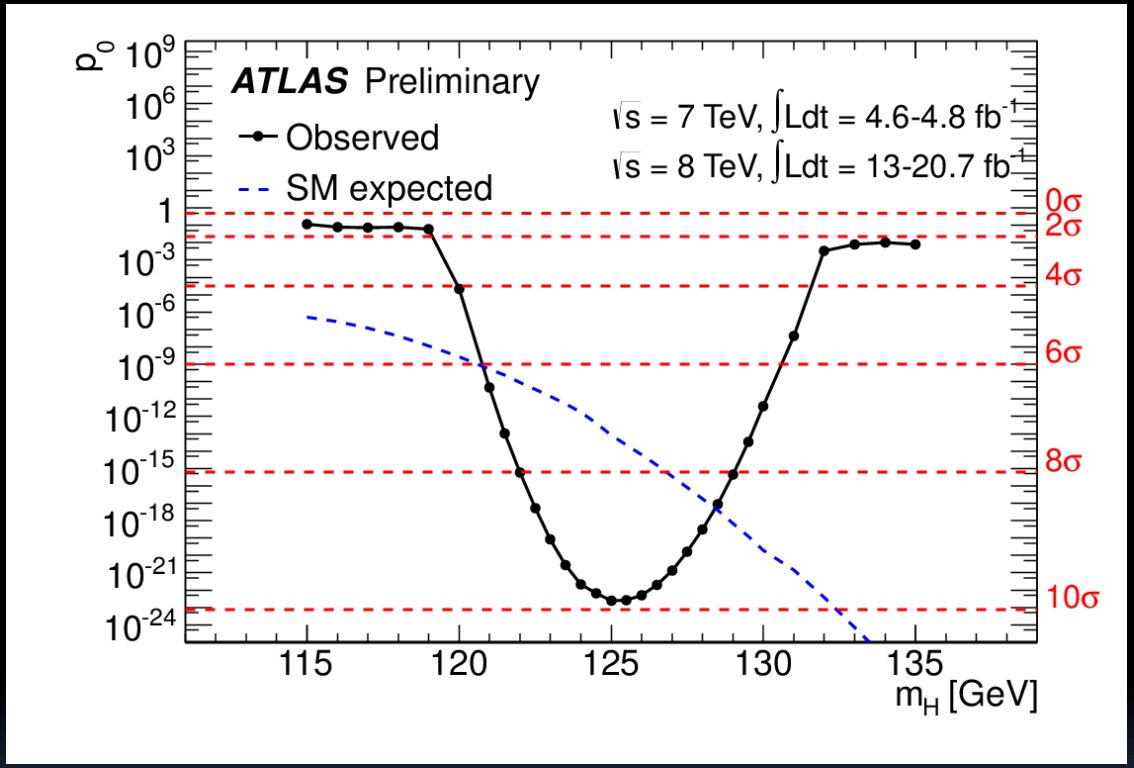
- Understanding of background is crucial
  - Most of which is due to important physics
  - at the heart of the gauge structure / symmetry of electroweak interaction

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



A new particle discovered

- Local probability p_0 for a background-only experiment to be more signal-like than the observation as a function of m_H
- Combination of all channels
  - $\tau\tau$ and bb not all included yet

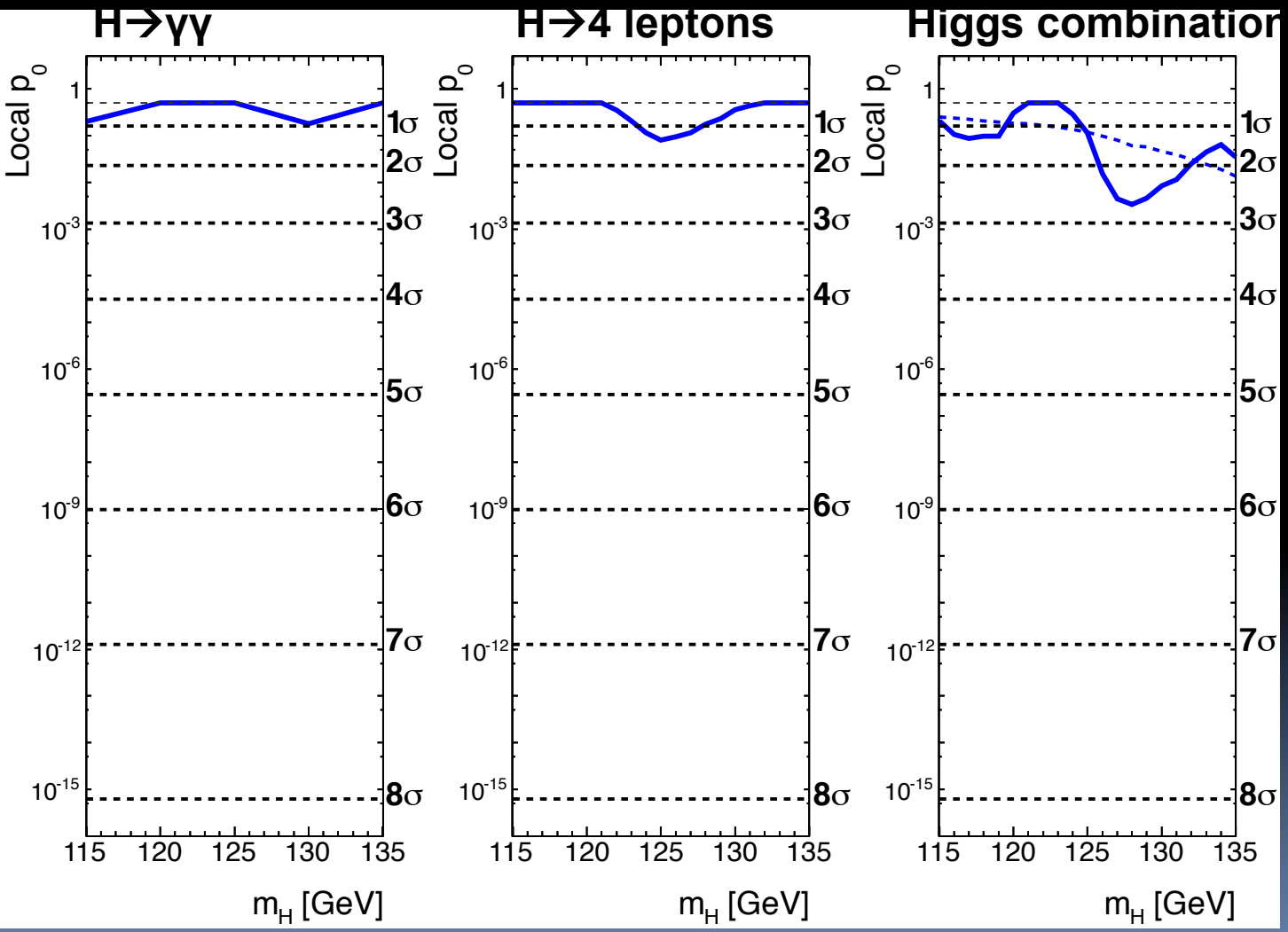


- 10σ signal @ M~125.5 GeV
- Probability of background fluctuation: ~10^{-23}

From excess to discovery (ATLAS)

progressive significance(p0) plots

Local p_0: probability that the background fluctuates to the observed data (or higher)

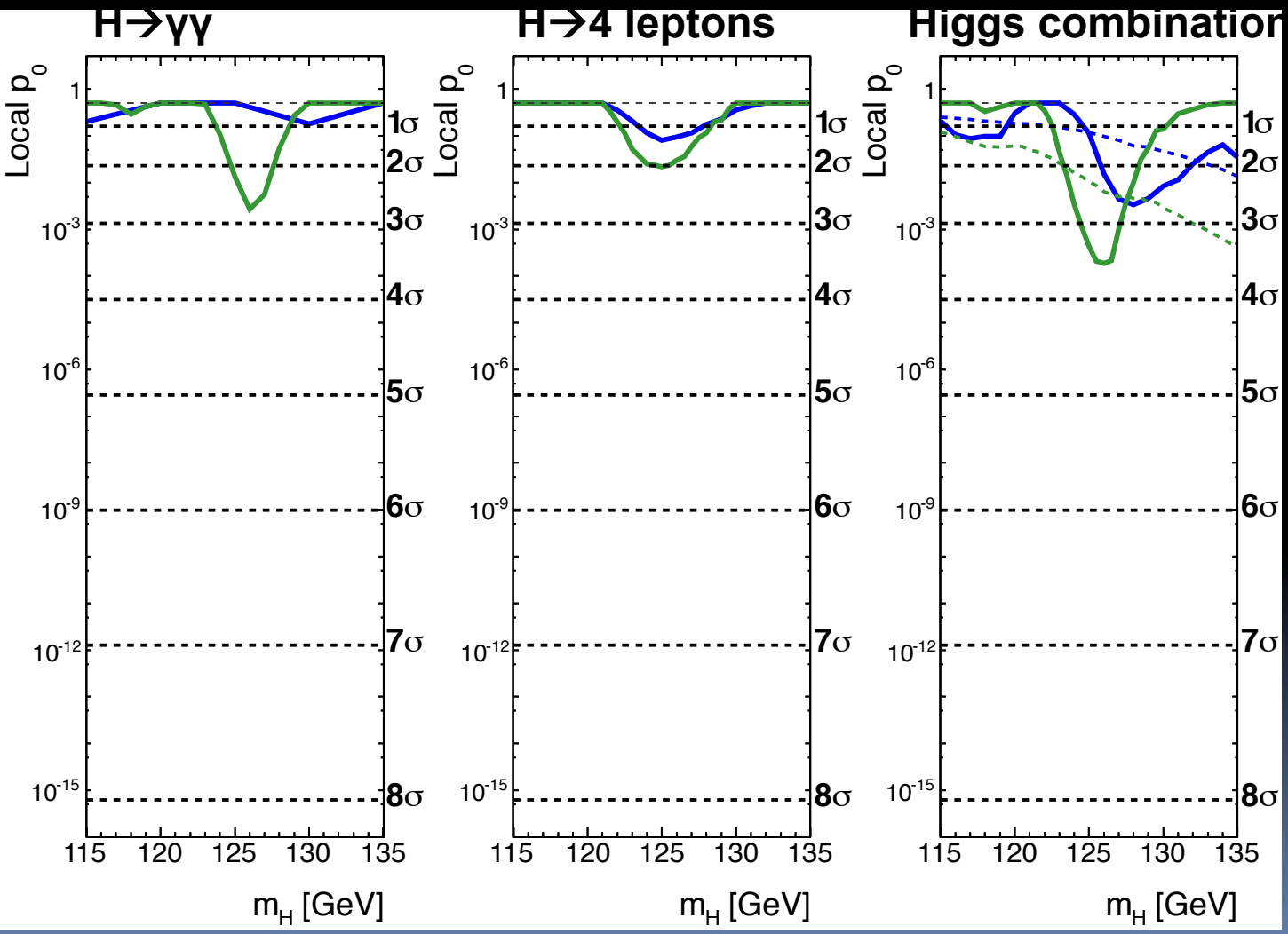


07/2011 EPS

From excess to discovery (ATLAS)

progressive significance(p0) plots

Local p_0: probability that the background fluctuates to the observed data (or higher)

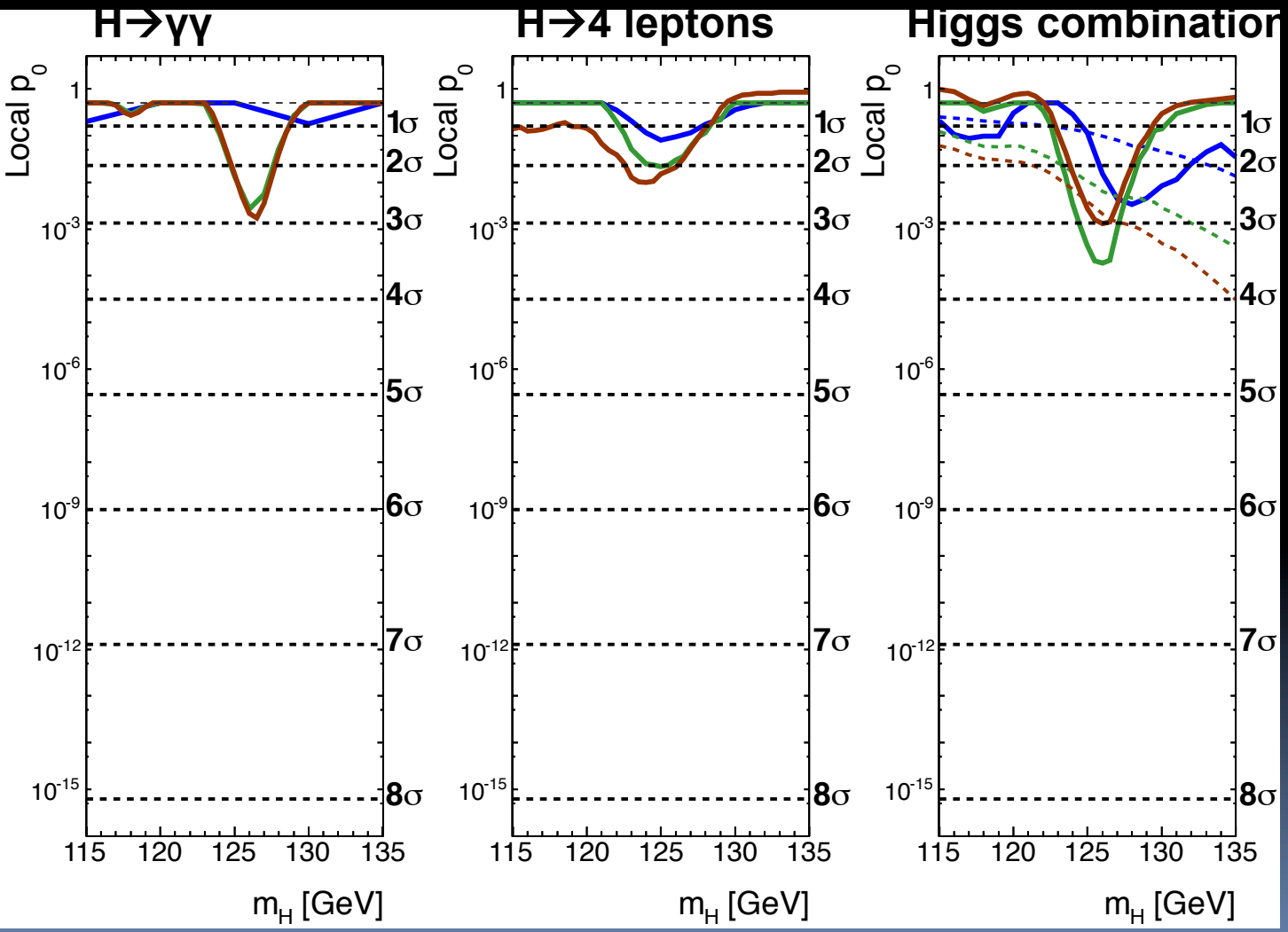


07/2011 EPS
12/2011 CERN

From excess to discovery (ATLAS)

progressive significance(p0) plots

Local p_0: probability that the background fluctuates to the observed data (or higher)

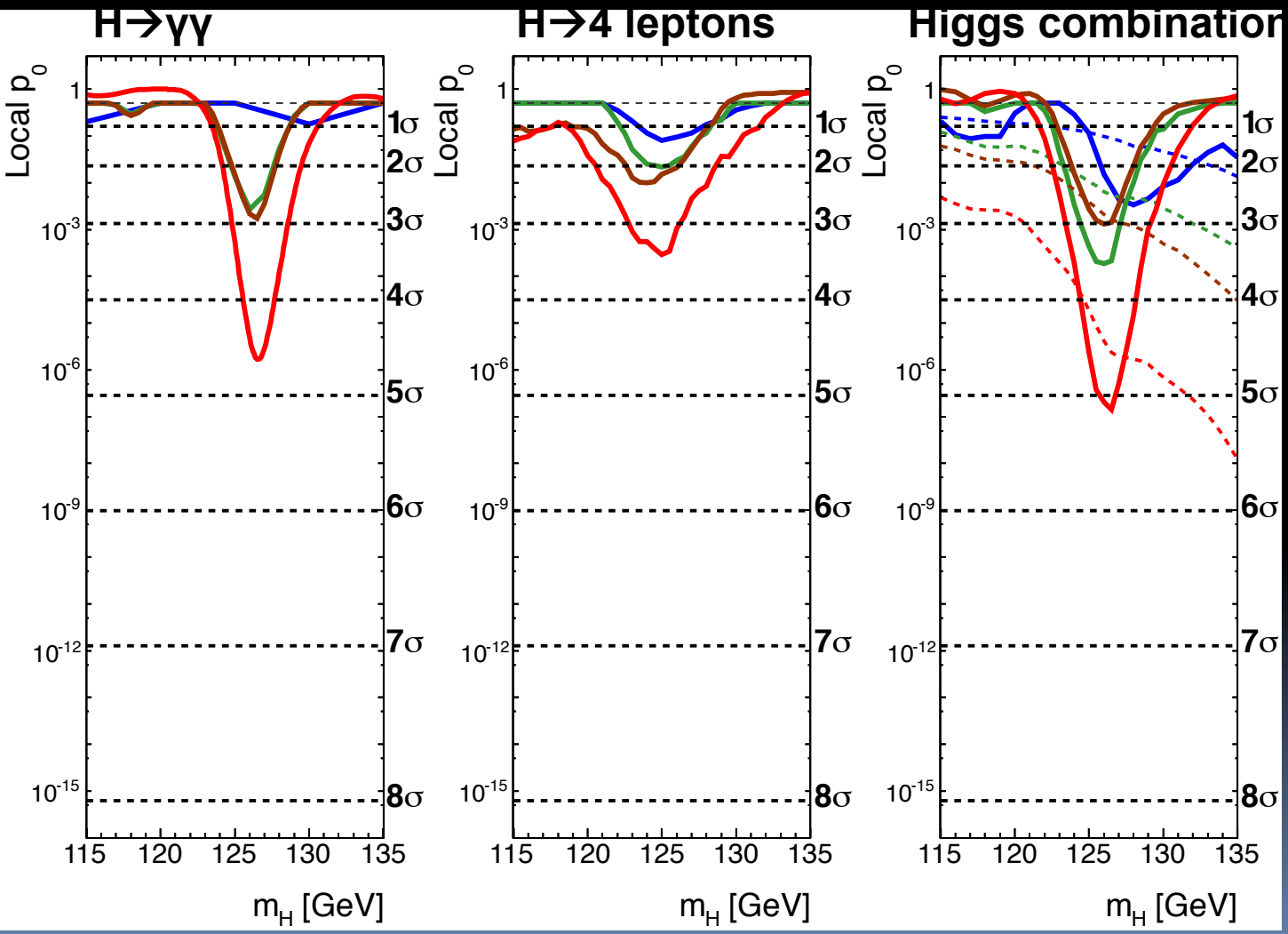


07/2011 EPS
12/2011 CERN
Spring 2012 PRD

From excess to discovery (ATLAS)

progressive significance(p0) plots

Local p_0: probability that the background fluctuates to the observed data (or higher)



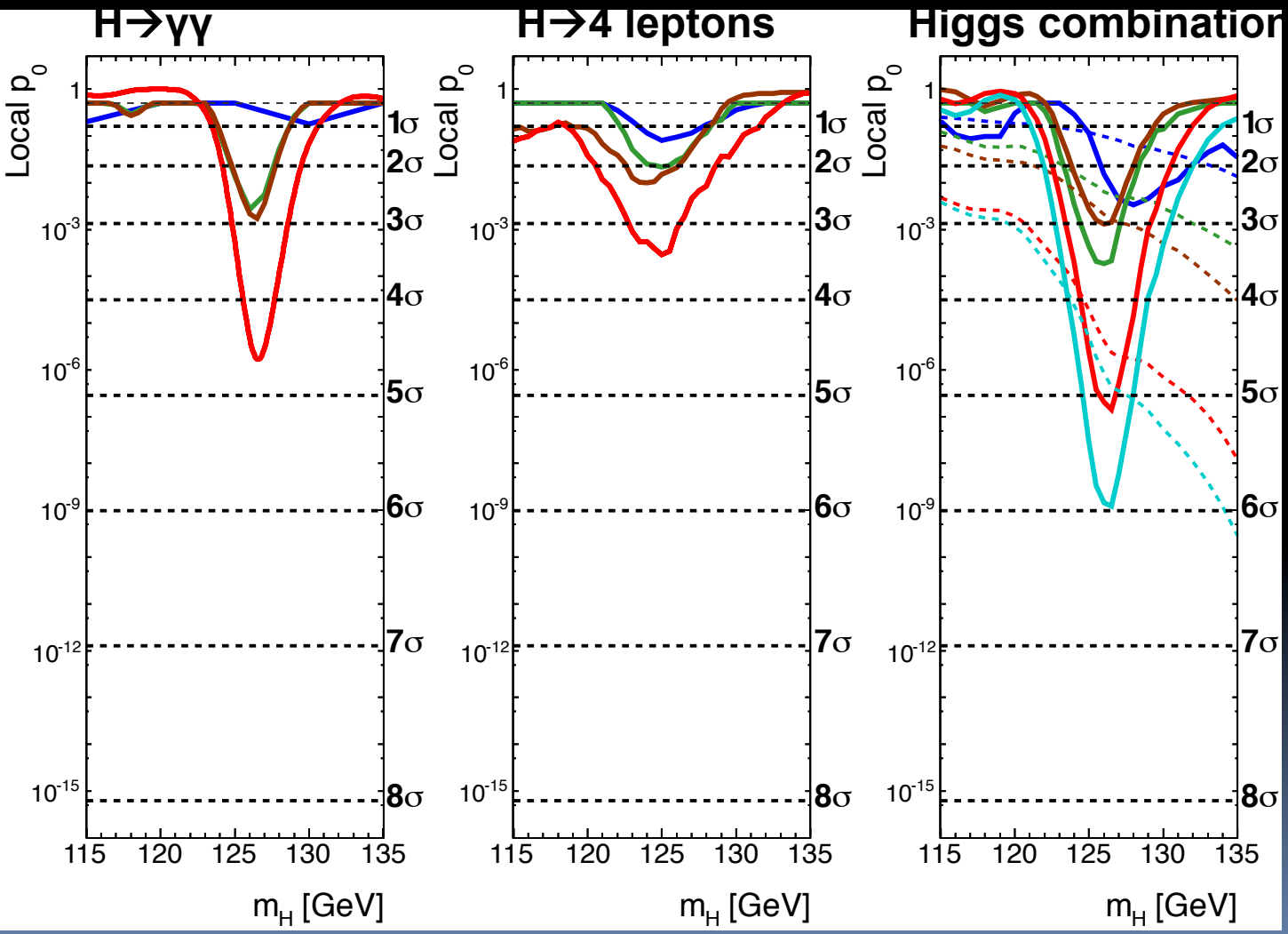
07/2011 EPS
12/2011 CERN
Spring 2012 PRD

07/2012 CERN

From excess to discovery (ATLAS)

progressive significance(p0) plots

Local p_0: probability that the background fluctuates to the observed data (or higher)



07/2011 EPS
12/2011 CERN
Spring 2012 PRD

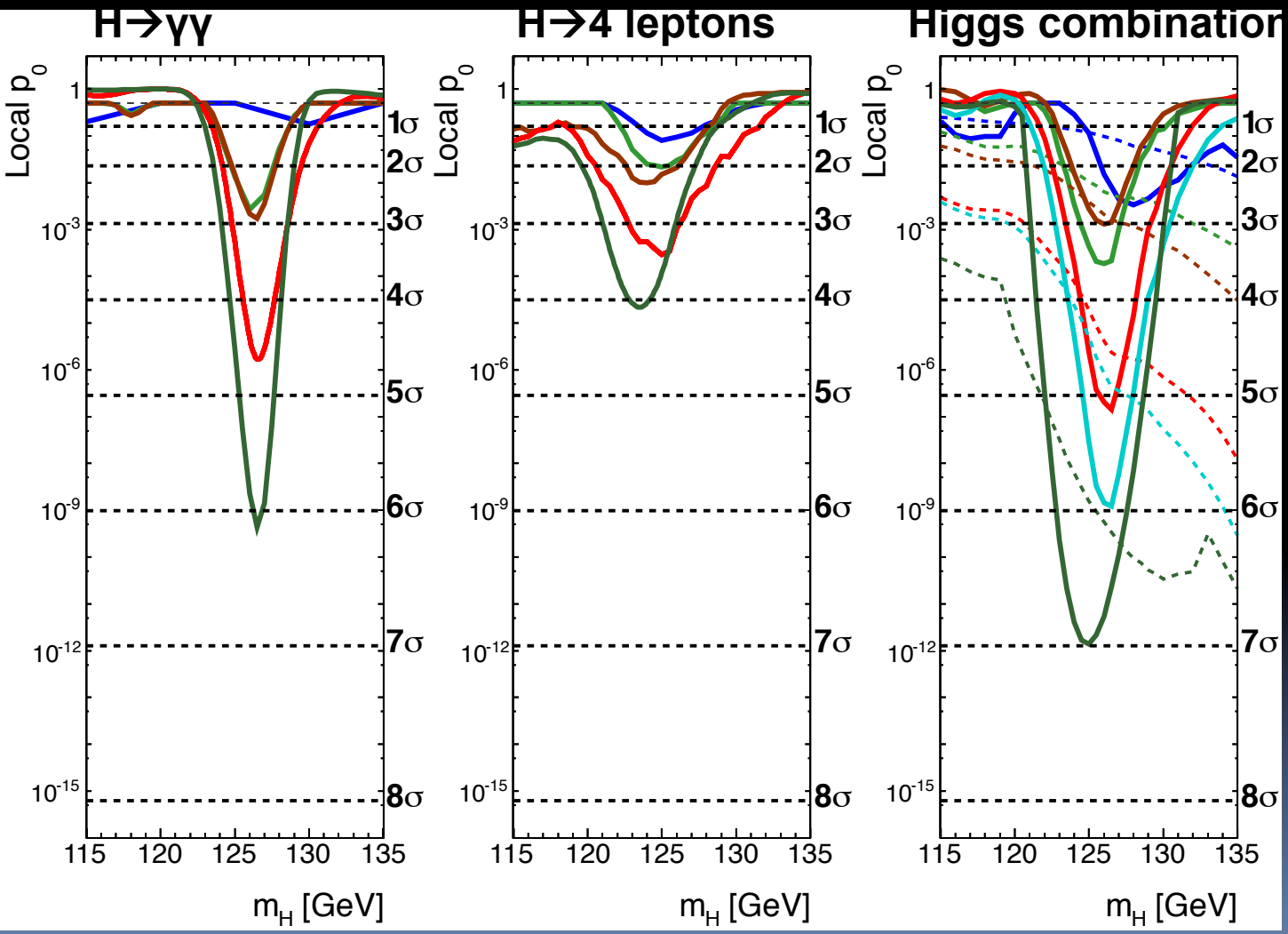
07/2012 CERN

PLB 07/2012

From excess to discovery (ATLAS)

progressive significance(p0) plots

Local p_0: probability that the background fluctuates to the observed data (or higher)



07/2011 EPS
12/2011 CERN
Spring 2012 PRD

07/2012 CERN

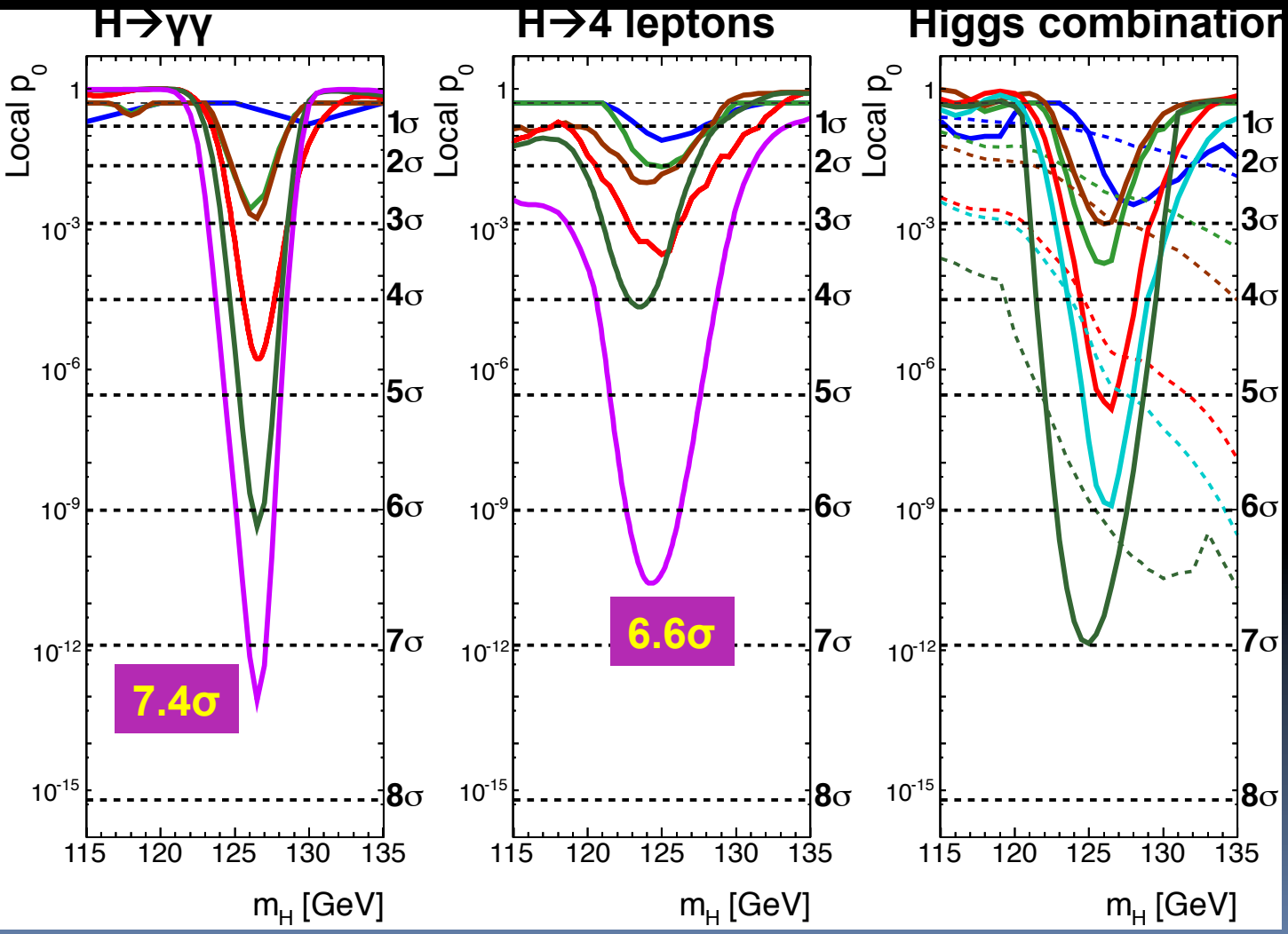
PLB 07/2012

12/2012 CERN

From excess to discovery (ATLAS)

progressive significance(p0) plots

Local p_0: probability that the background fluctuates to the observed data (or higher)



07/2011 EPS
12/2011 CERN
Spring 2012 PRD

07/2012 CERN

PLB 07/2012

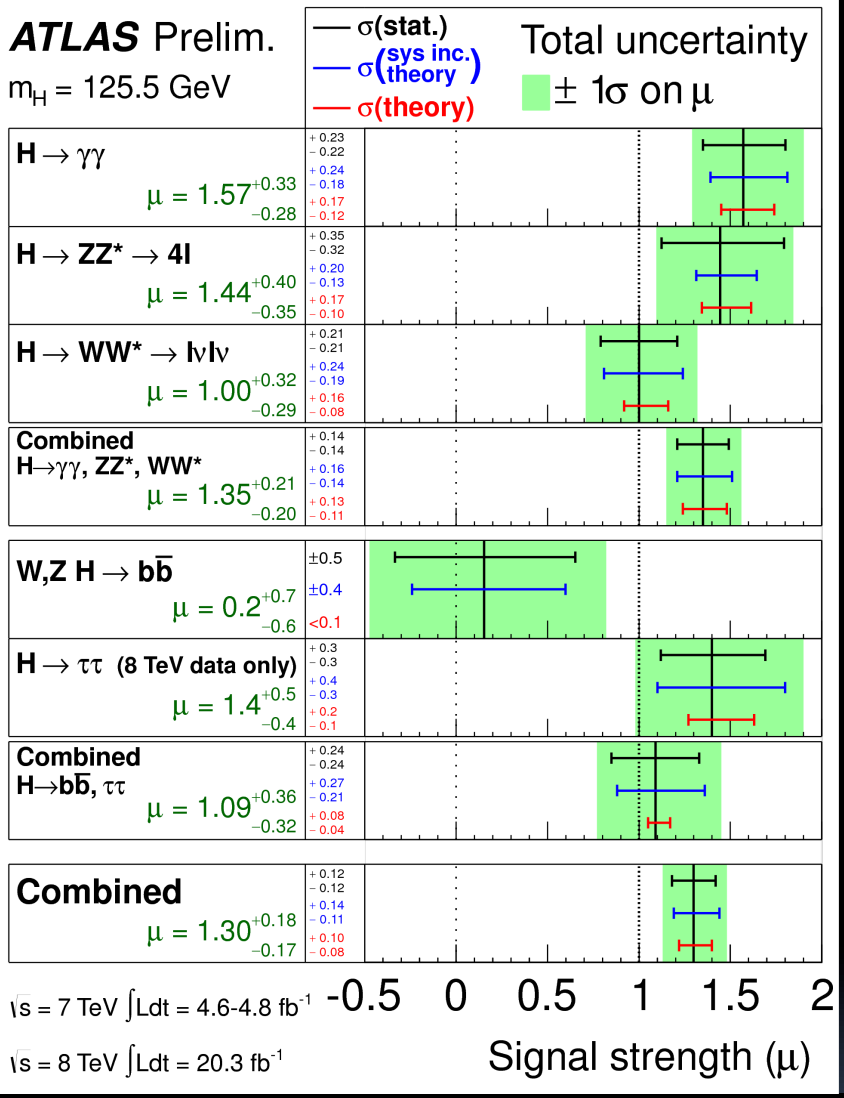
12/2012 CERN

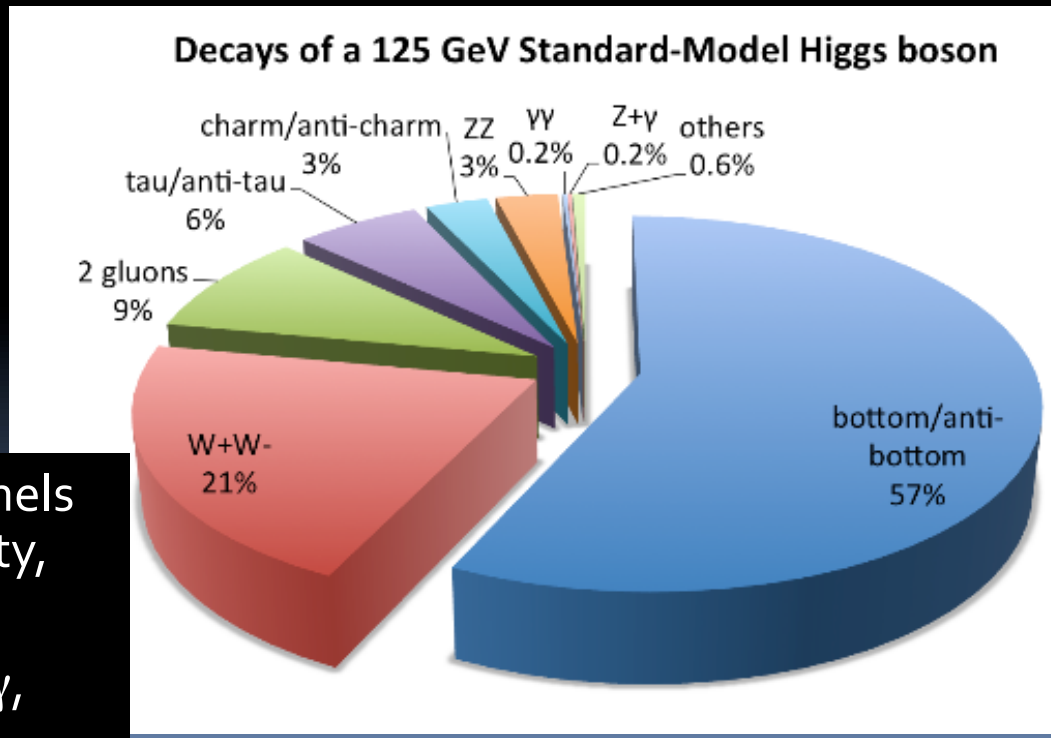
03/2013 Moriond EW

>9σ

Decays to bosons established, evidence for ττ, …

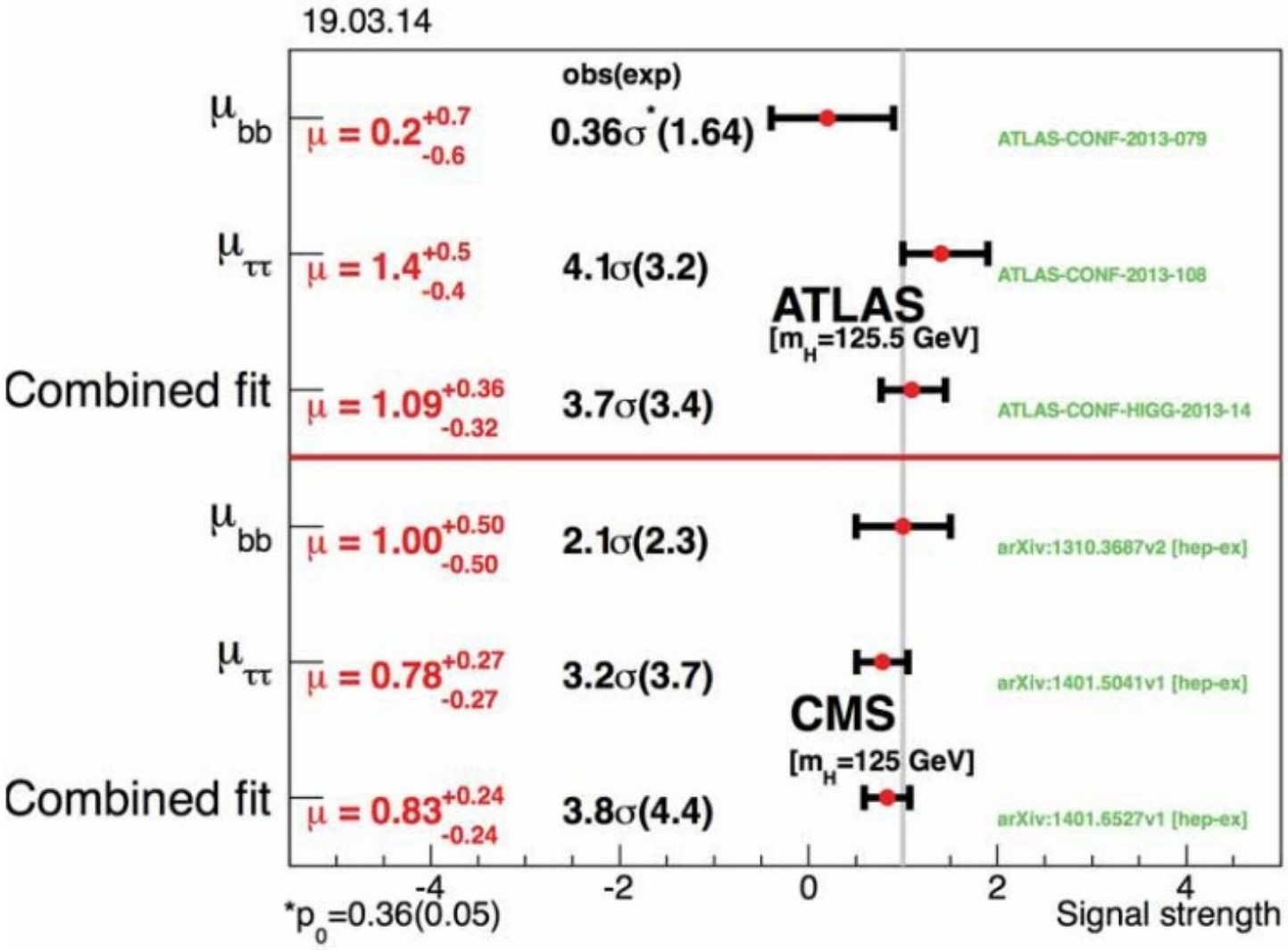
- Measurements of the signal strength parameter μ for m_H =125.5 GeV for the individual channels and their combination
- Combination of all channels
- Consistency with SM: 1.30±0.18





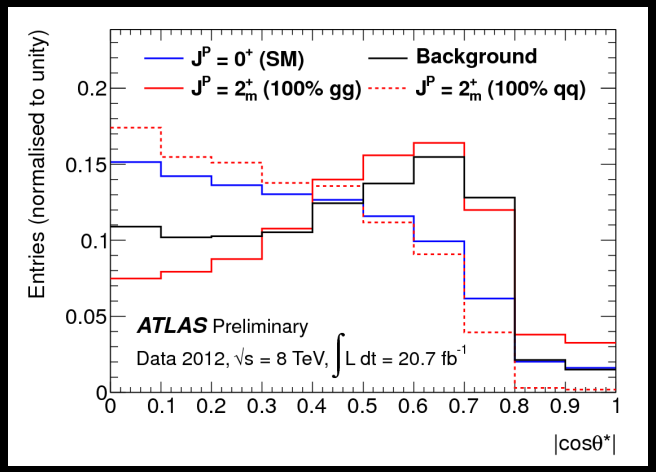
- Decays to fermions – difficult channels with high background – are a priority, especially bb (B~57%!)
- Searches for rare decays started: Zγ, μμ, …. Hidden decays, …

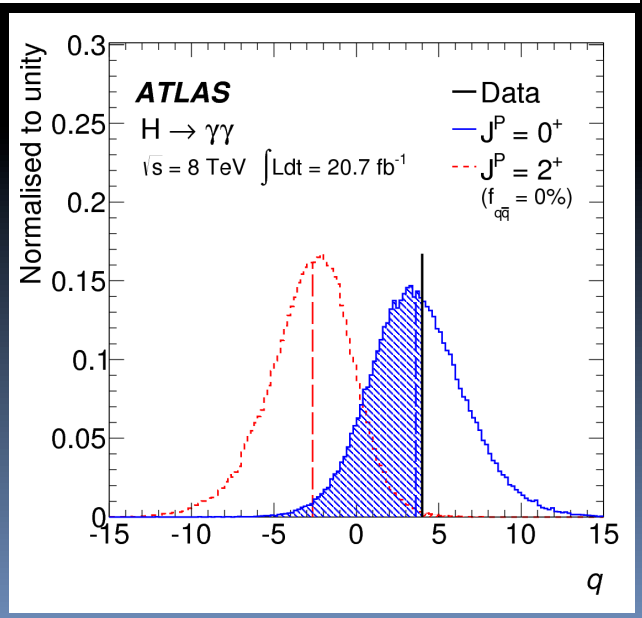
Higgs to Fermions



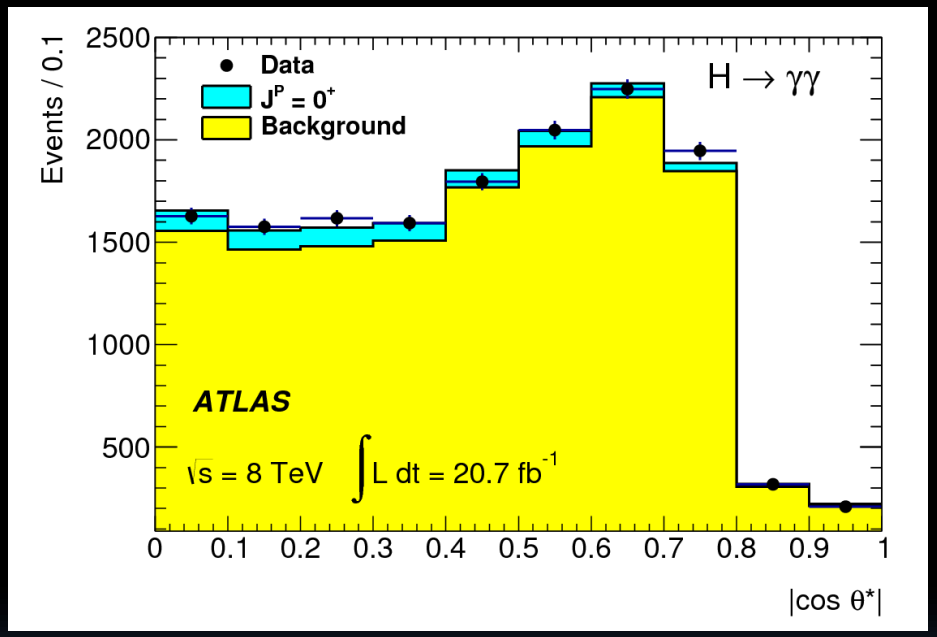
Is the new boson a Higgs?

- Measure its quantum numbers! Spin, parity, c-parity: J^{PC}=? If Higgs: 0^{++}
- Decay angle of H→γγ
  - Expected





data (background not subtracted)



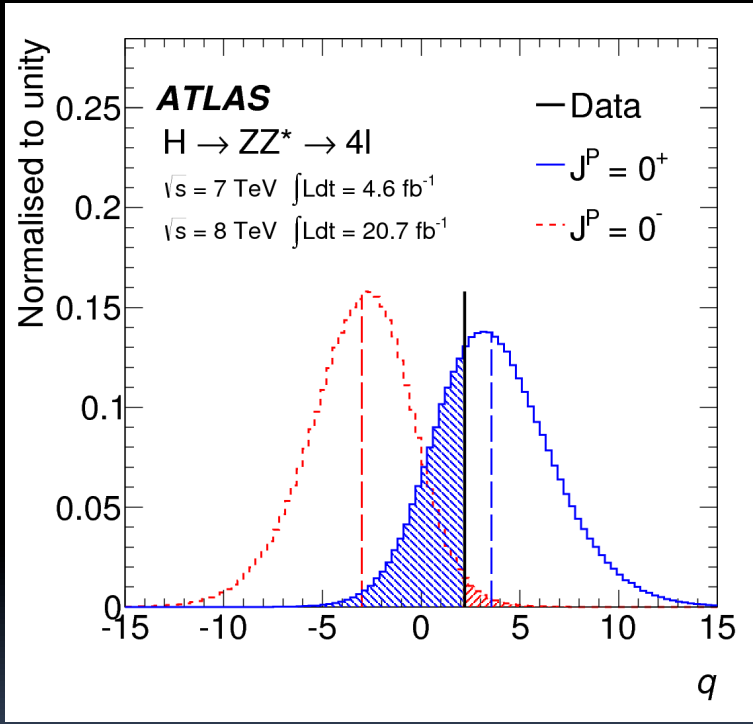
- "The hypothesis of a spin-2 particle (Graviton-like) produced by gluon fusion is excluded at 99% CL"

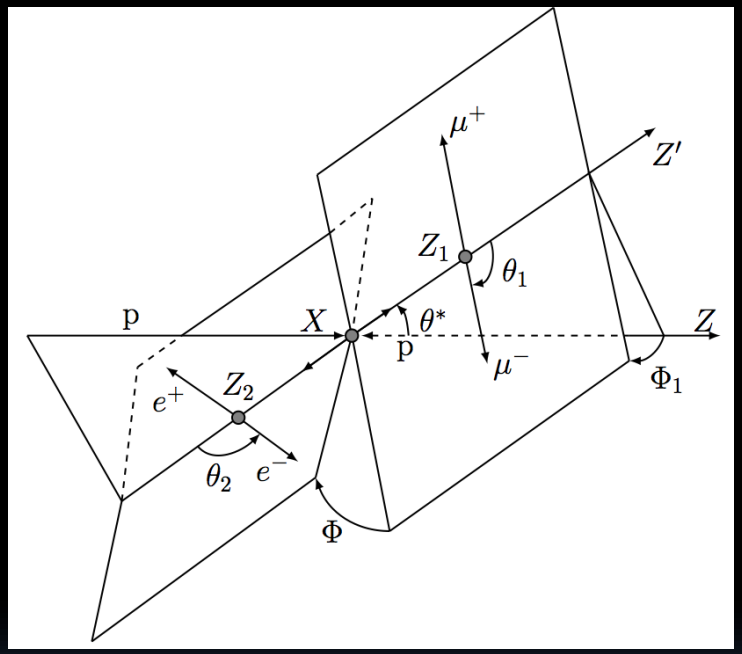
- Spin 1 cannot decay to γγ …

Is the new boson a Higgs?

- Define production & decay angle for H→ZZ→4l
  - Beam axis in the lab frame, the Z_1 and Z_2 in X rest frame and leptons in their corresponding parent rest frames

- Likelihood ratio for various hypotheses





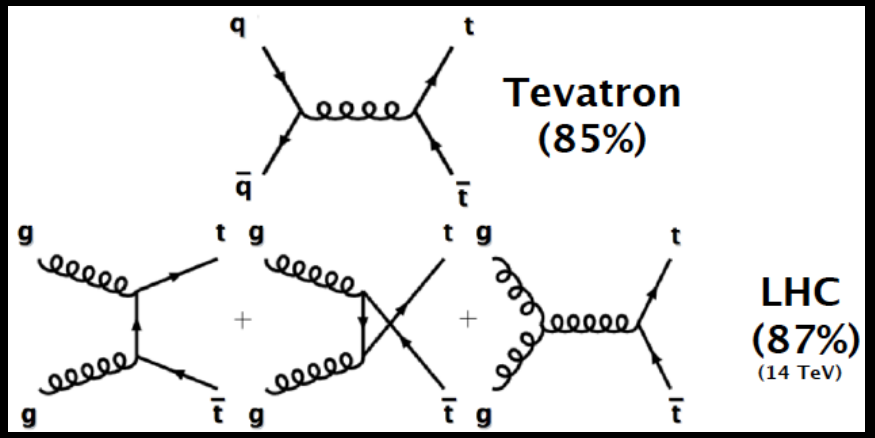
- Higgs-like boson found to be compatible with SM expectation of 0^+ when compared pair-wise with 0^- , 1^+ , 1^- , 2^+ , and 2^-
- 0^- and 1^+ states are excluded at the 97.8% C.L.
- WW analysis leads to similar conclusions

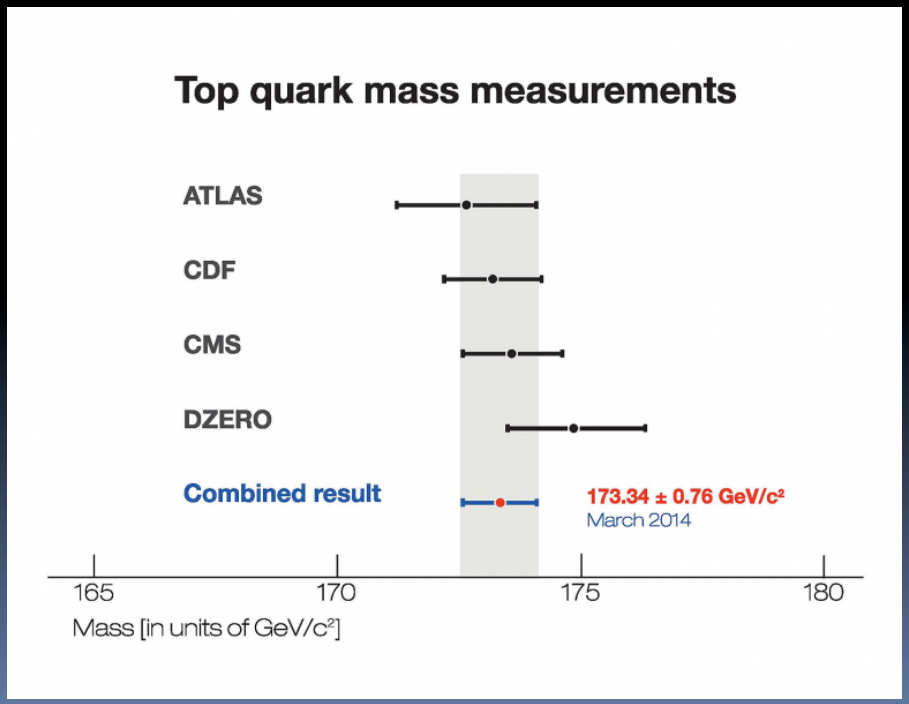
Standard Model: 3!=3*2*1

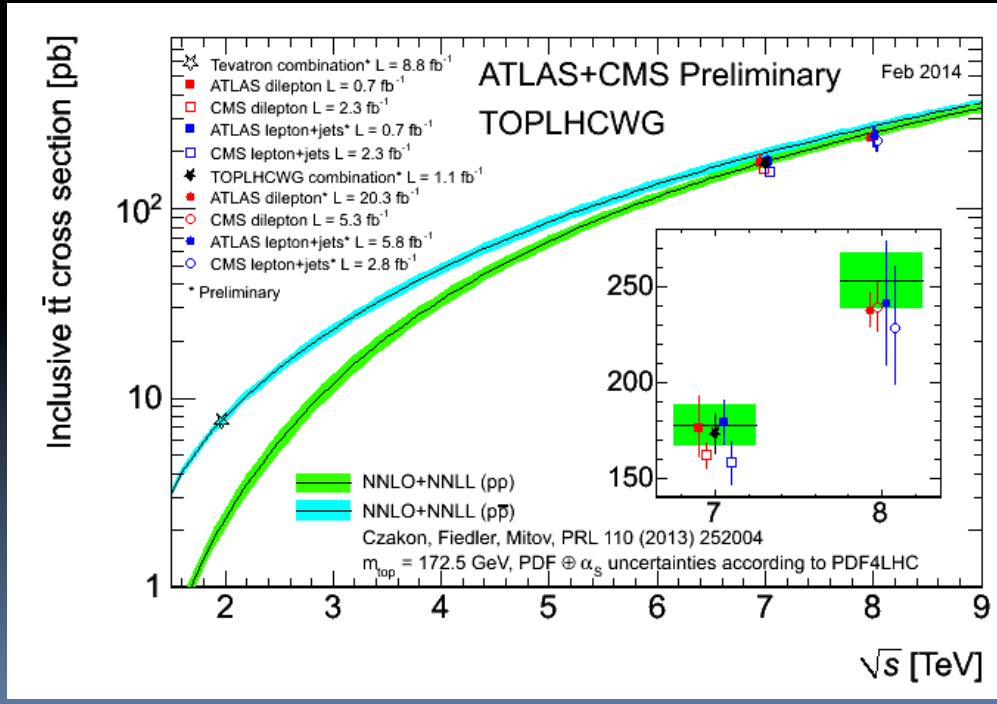
- SM very successful …
  - Higgs looks like Higgs and probably Standard & Minimal
    - (For good or for bad?)
  - LHC Top Laboratory
  - SU(2)*U(1) gauge structure
  - QCD works well …

Top quark @ ATLAS ++

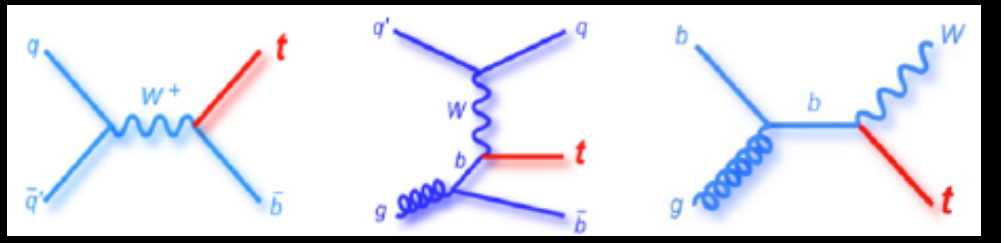
- Ttbar, single top cross sections
- Top mass, …

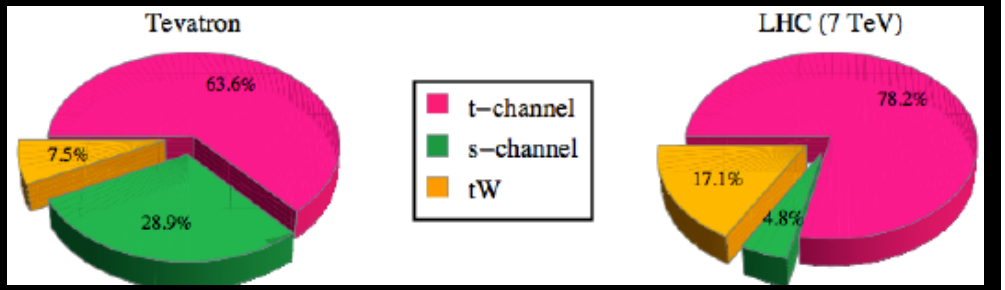


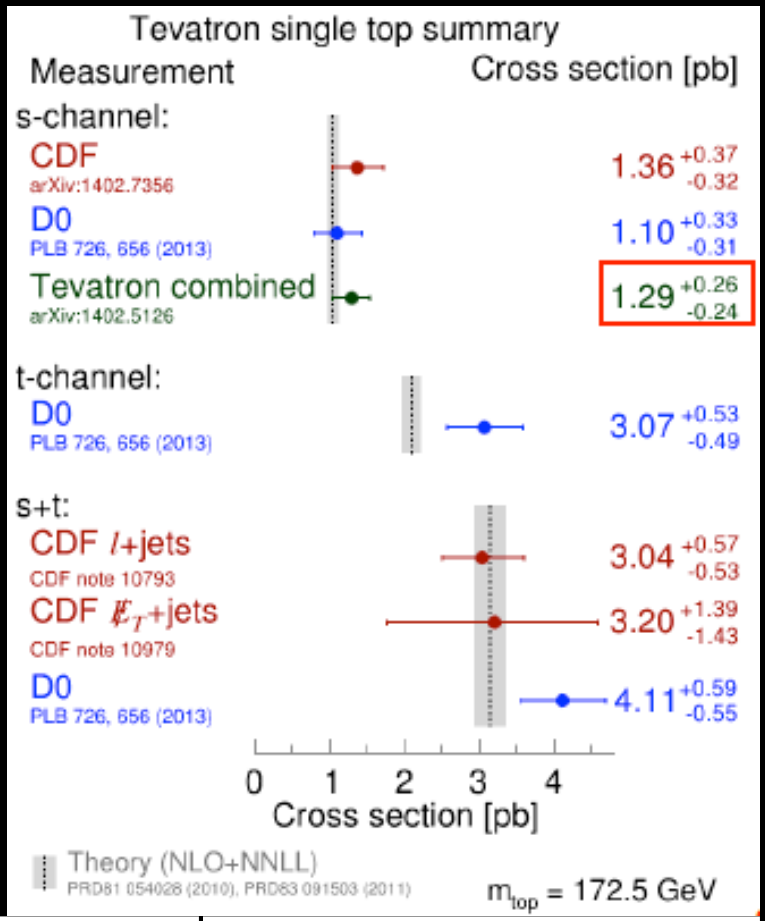


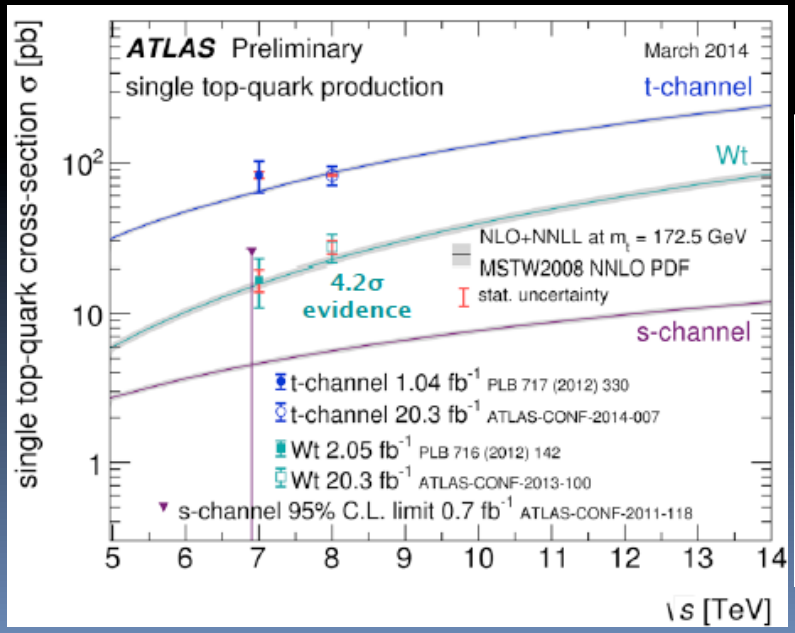


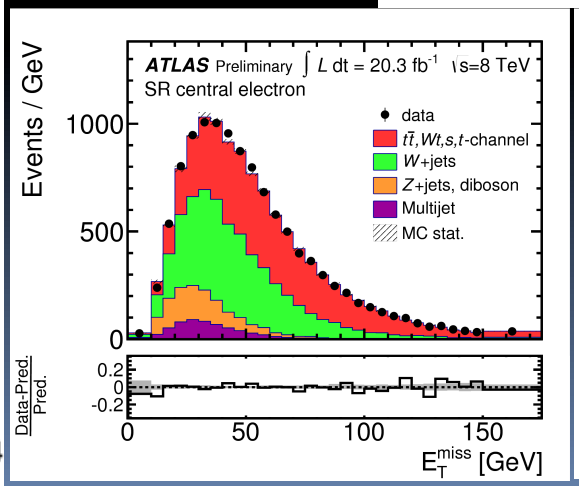
Single top @ ATLAS ++

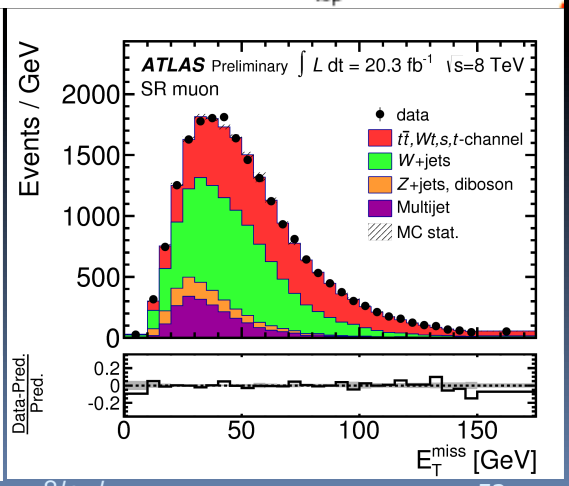






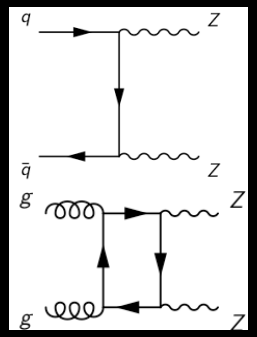






Electroweak symmetry validated at LHC

- ATLAS results
  - Triple Gauge Couplings investigated
  - Quartic couplings – next step
- Gauge boson self-coupling as predicted by SM
  - γWW, ZWW , Yes - No evidence of γZZ, ZZZ



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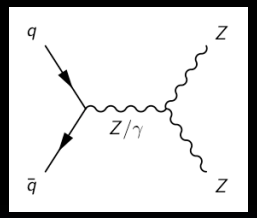

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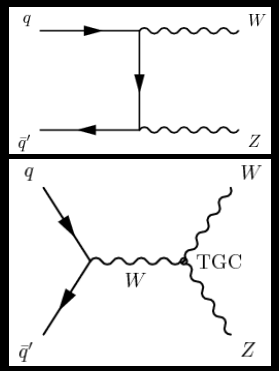

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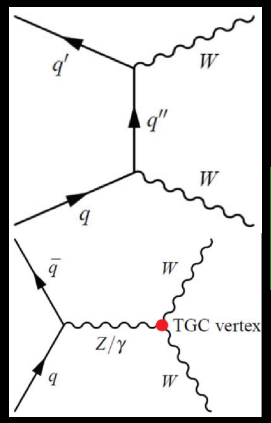

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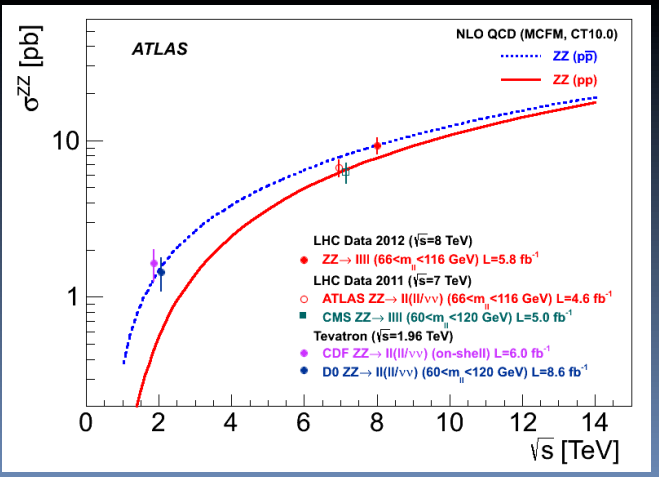
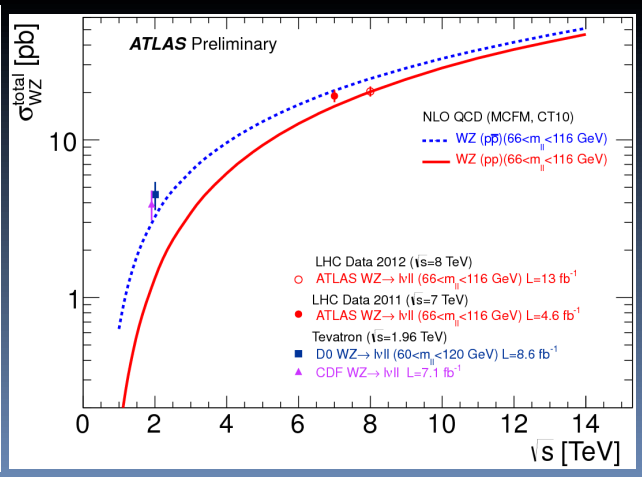
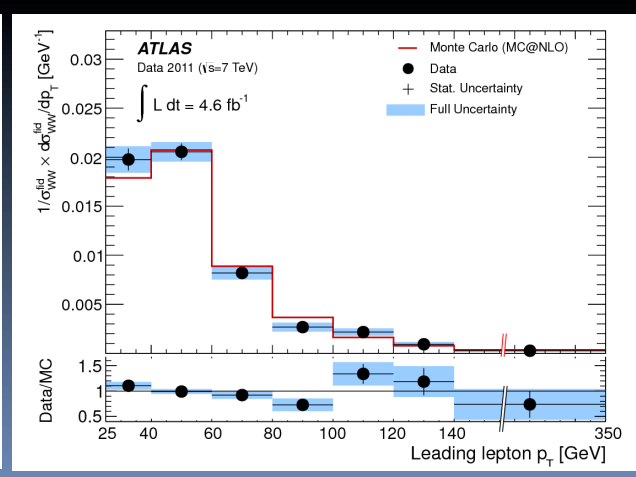
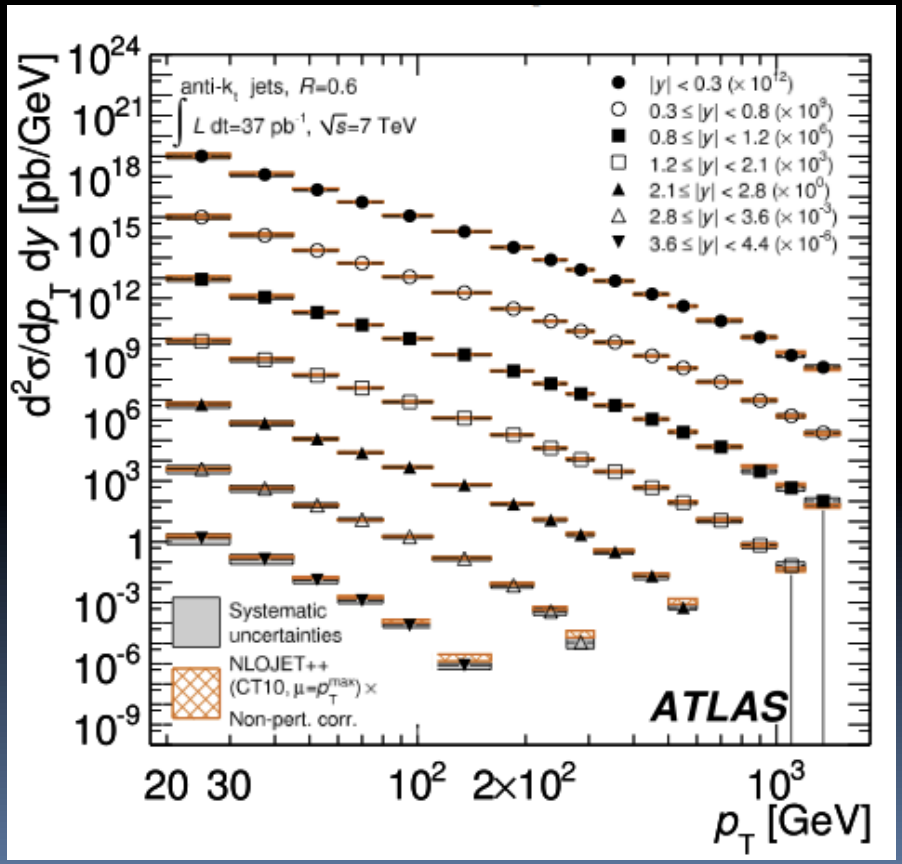


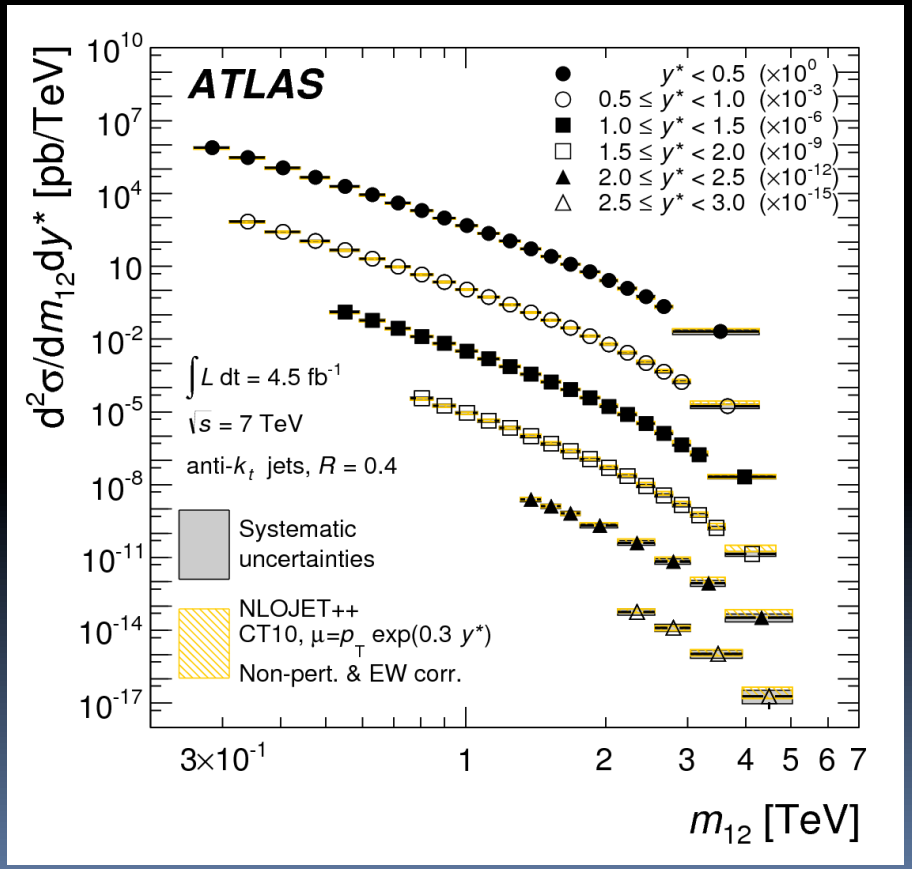




QCD Jets

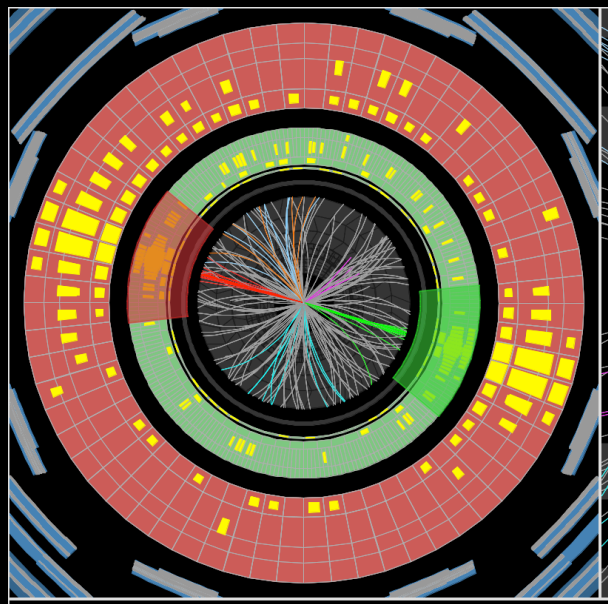
- Inclusive Jet cross sections
  - QCD works well and fits data over 10 orders of magnitude!

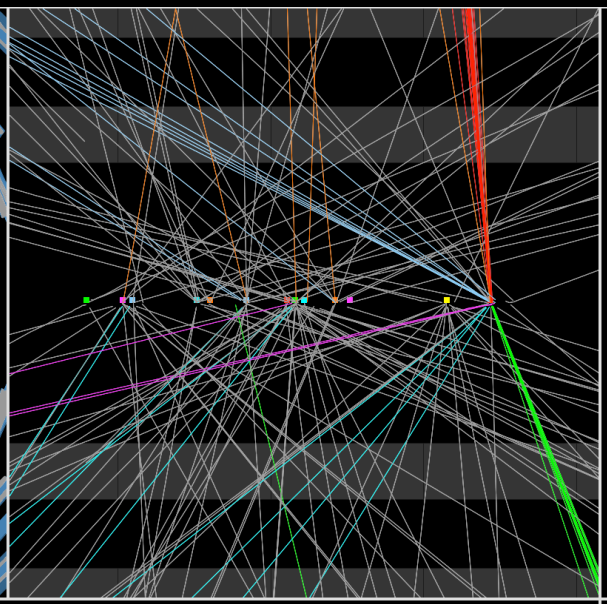




High-pT di-jet: M_{jj} = 4.7 TeV!

m_{jj} = 4.7 TeV
p_T^j = 2.3 TeV
E_T^{miss} = 47 GeV

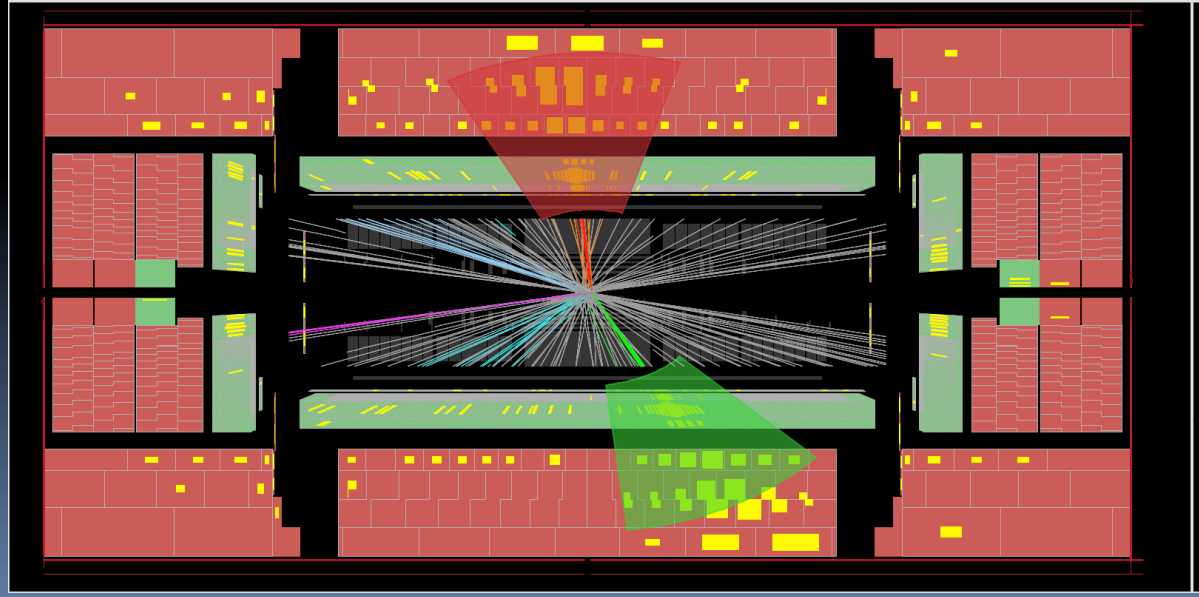


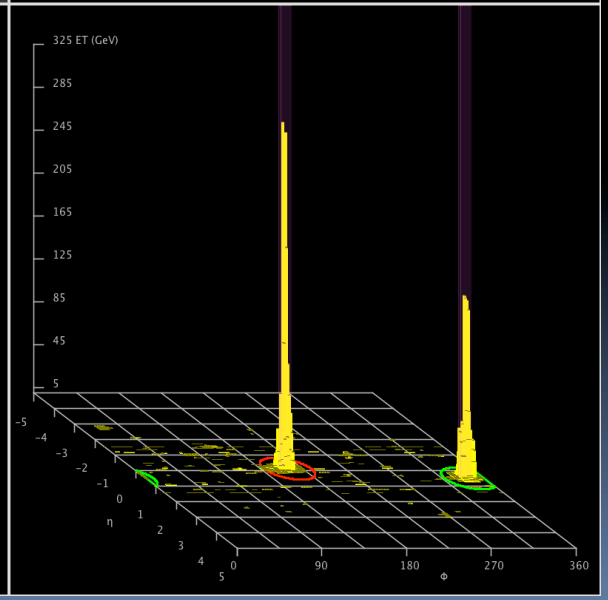


ATLAS EXPERIMENT

Run Number: 209580, Event Number: 179229707

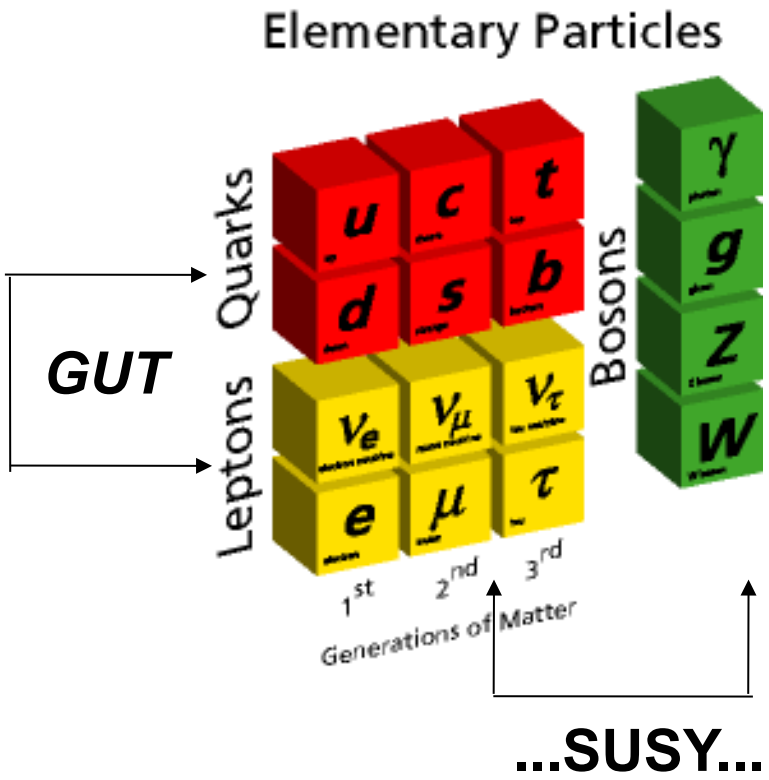
Date: 2012-08-31 20:24:29 CEST



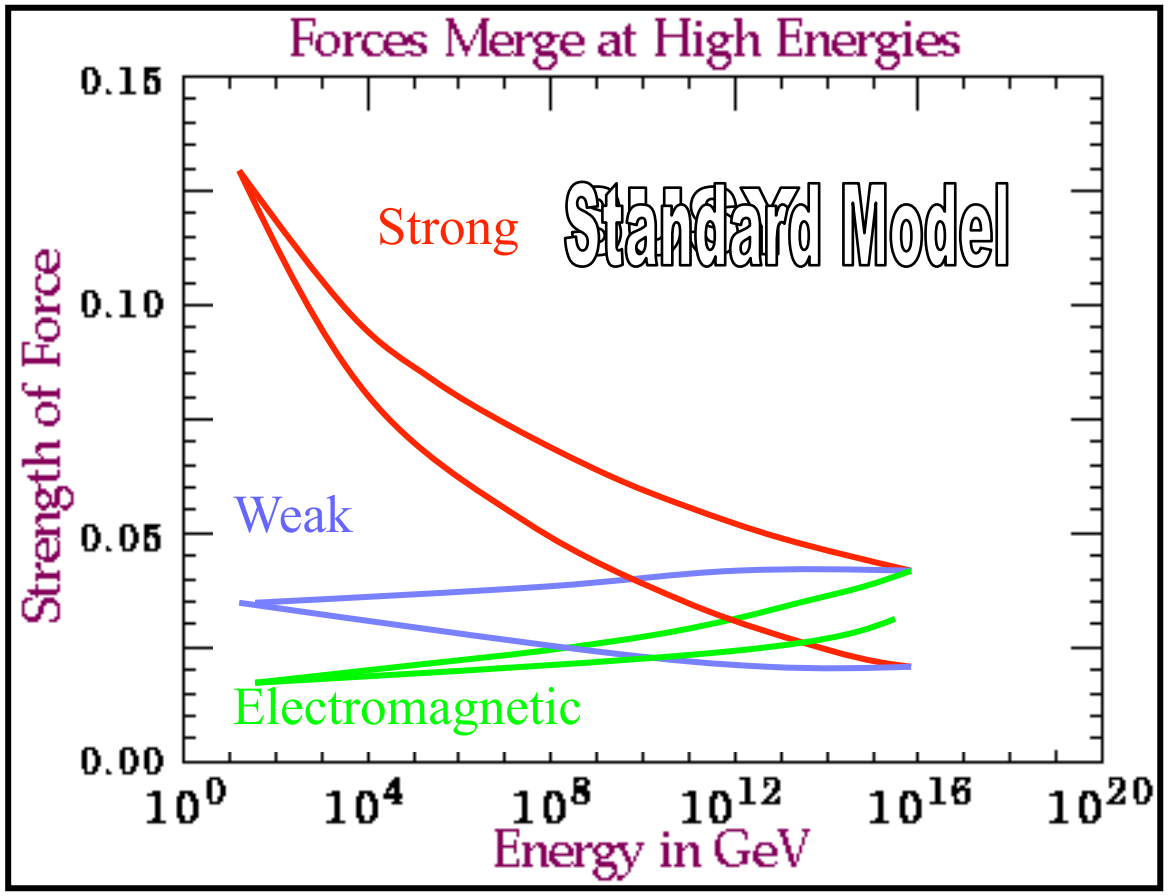


Grand Unification Theories (GUT) and SuperSymmetry (SUSY)

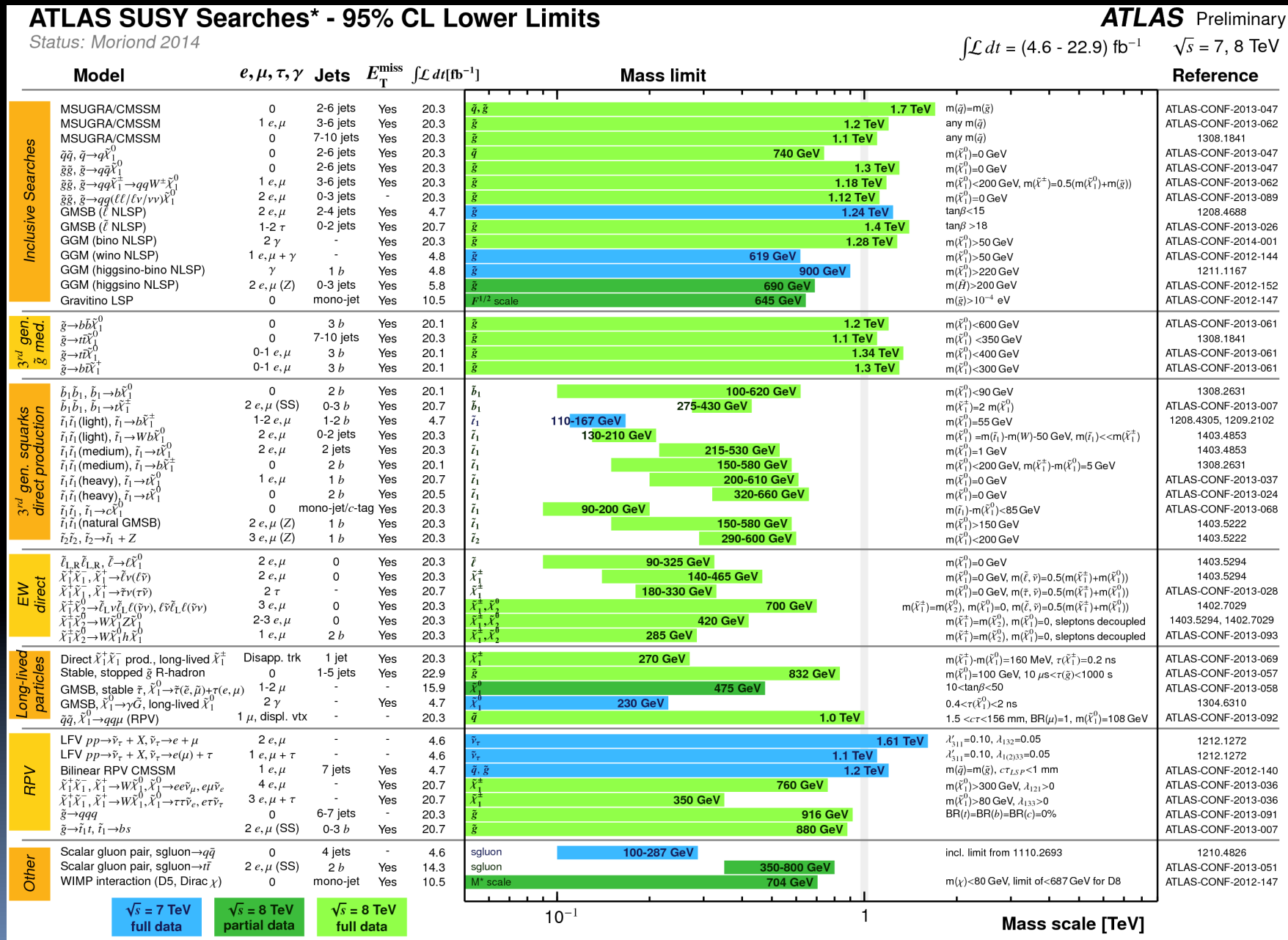
- Current data also hint at a unification between Strong and Electroweak forces … at much larger energies, GUT scale.
- GUT is a symmetry between Leptons and Quarks
  - unifies strong and electroweak forces
- SUSY unifies "matter and force particles": "matter-force duality"
  - relates particles of different spins: Fermions-Bosons
  - introduces super-partners to each SM particle
  - requires 5 Higgs particles
  - provides DM candidate



SUSY helps Grand Unification



ATLAS & Supersymmetry



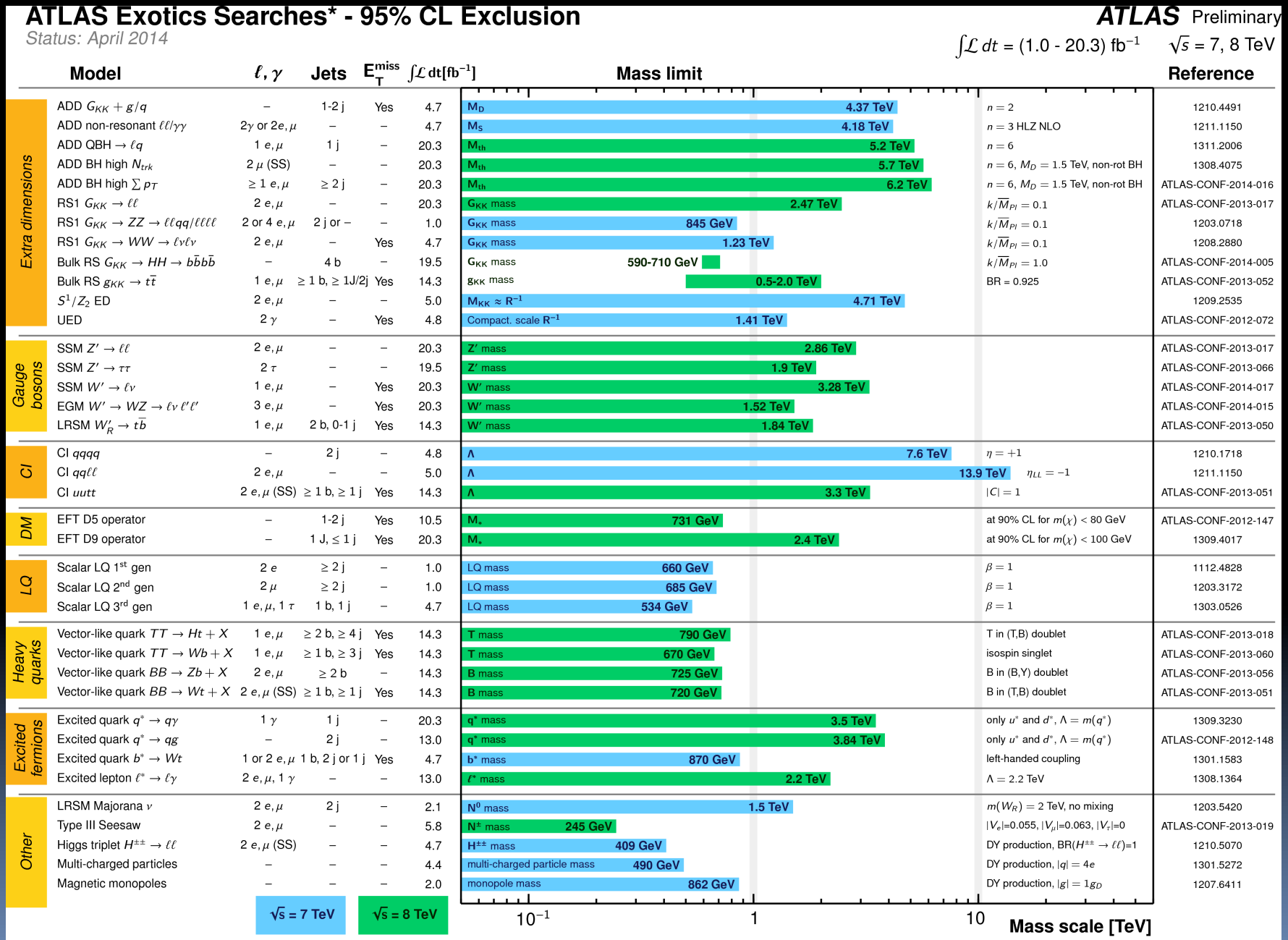
Other RPV LLP EW 3rd gen squarks squarks & gluinos

What & How?

- Heavy gauge bosons, Z′ and W′,
  - From higher symmetry (e.g. E6) breaking, and more
- Composite models for quarks, q^*, and leptons, l^*
  - with substructure scale Λ
- Randal-Sundrum gravitons, G^* and
- G^*_{bulk}, from warped extra dimensions
- Low-scale strings with large EDs,
  - and TeV^{-1} Kaluza-Klein excitations of γ/Z
- Technicolor, Chiral bosons (W^*/Z^*)
- Quantum black holes, ADD, CI (non res′) …

- "Simple"
  - ll
  - $\gamma\gamma$
  - ZZ, WW, …
  - …
- Traditional
  - Jets or Rutherford – Hammer method
  - Missing
- Mix
  - "Leptons-quarks-gauge bosons-missing"
- Innovate
  - "Lepton-jets"

ATLAS & Exotica



*Only a selection of the available mass limits on new states or phenomena is shown.

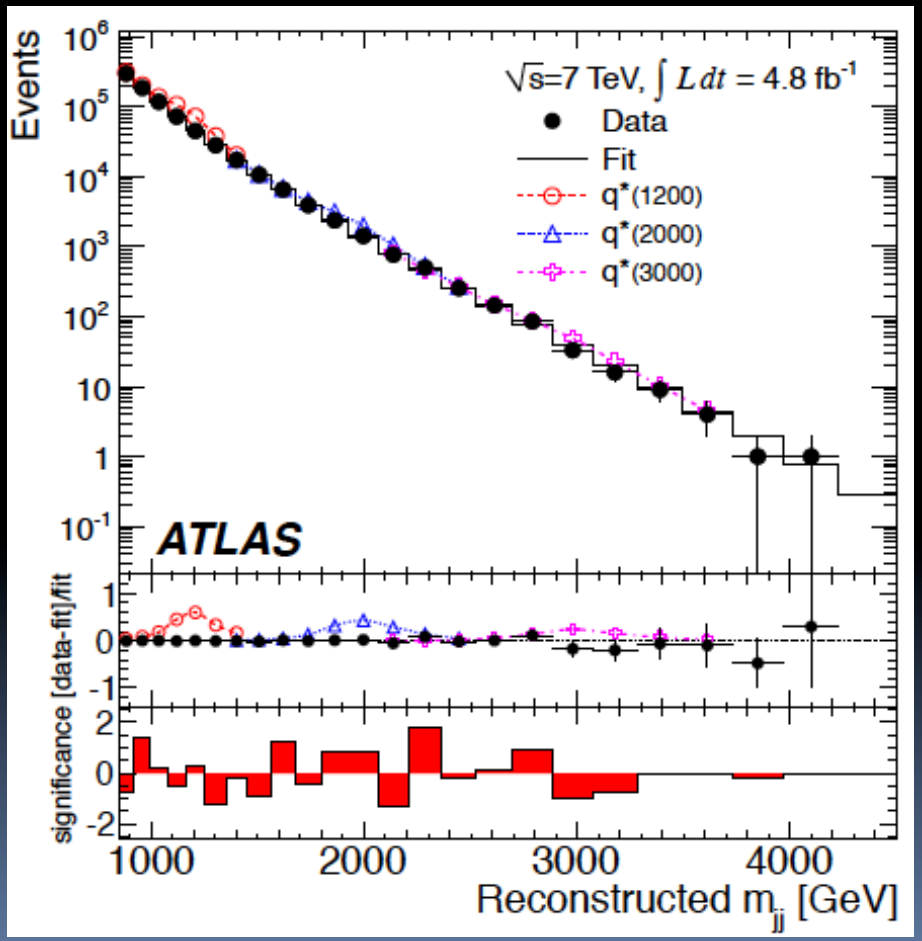
New phenomena in di-jets

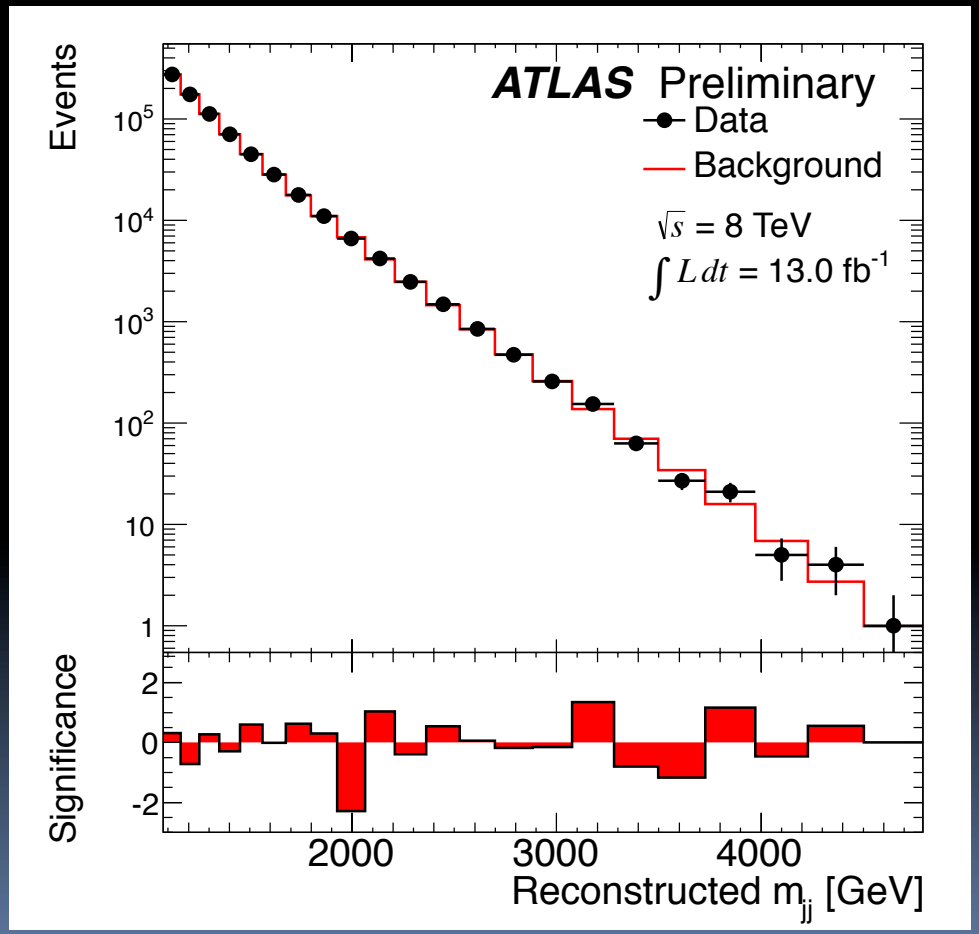
- New physics
  - new particles could be produced,
  - new interactions between particles could manifest themselves,
  - interactions resulting from the unification of SM with gravity could appear in the TeV range
  - probe the structure of the fundamental constituents of matter at the smallest distance scales
    - experimental test of the size of quarks.

Di-jet invariant mass

- Background fit

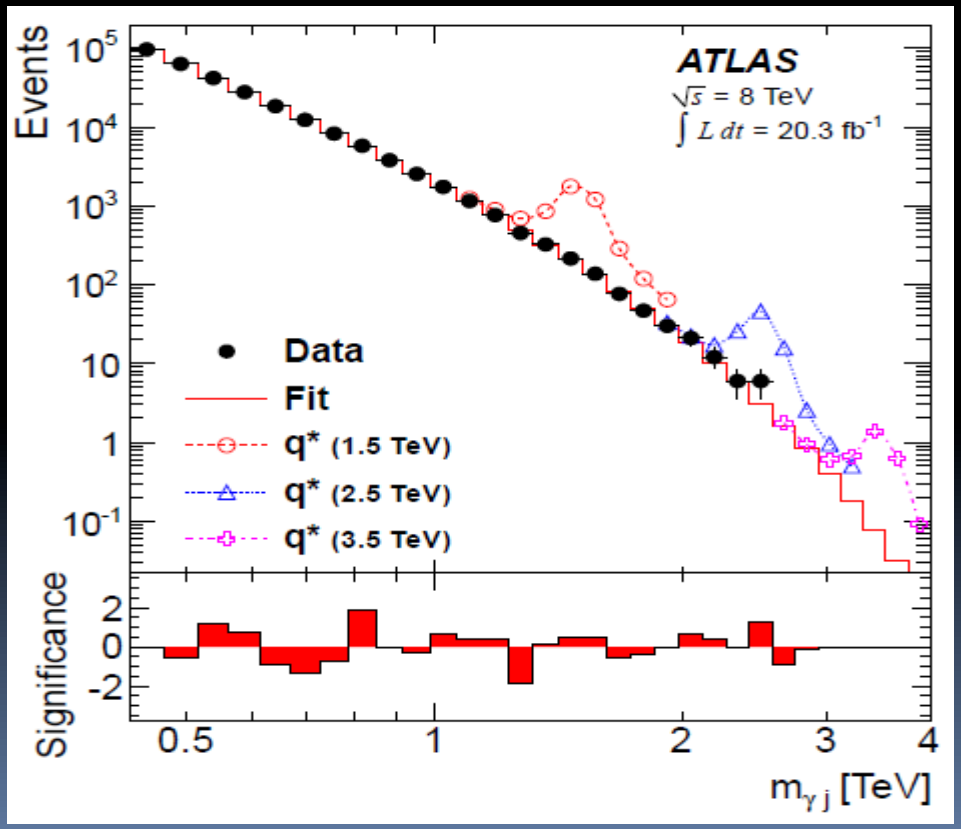
$$f(x) = p_1(1-x)^{p_2} x^{p_3 + p_4 \ln x}$$



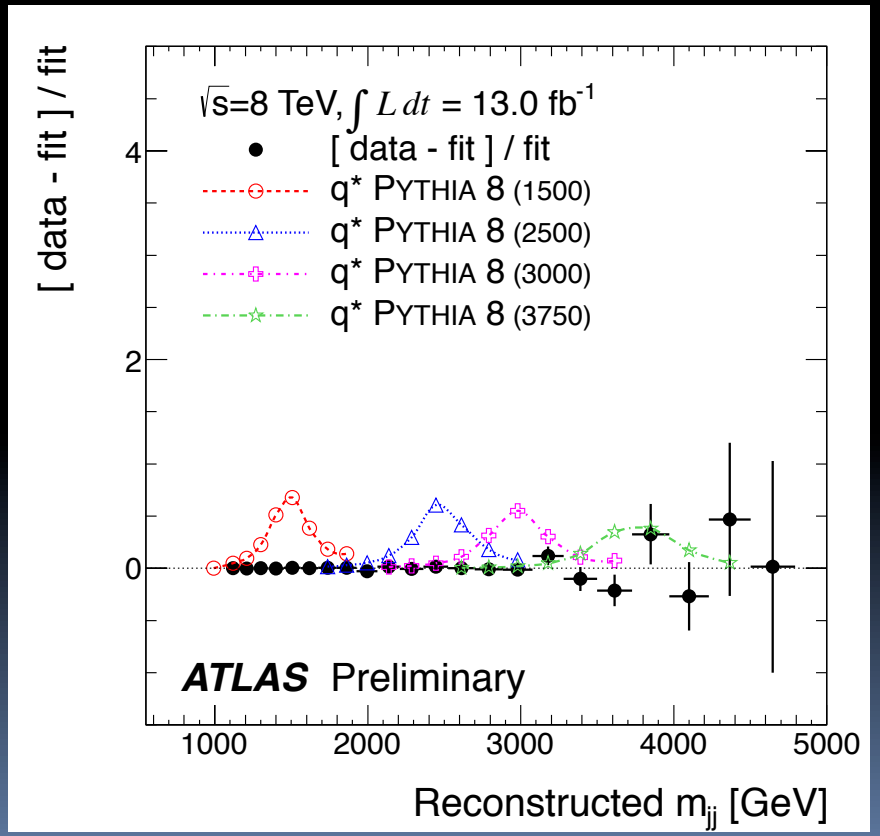


Excited quarks

- $q^* \rightarrow q\gamma$
  - Exclude $m(q^*) < 3.5$ TeV @ 95% CL

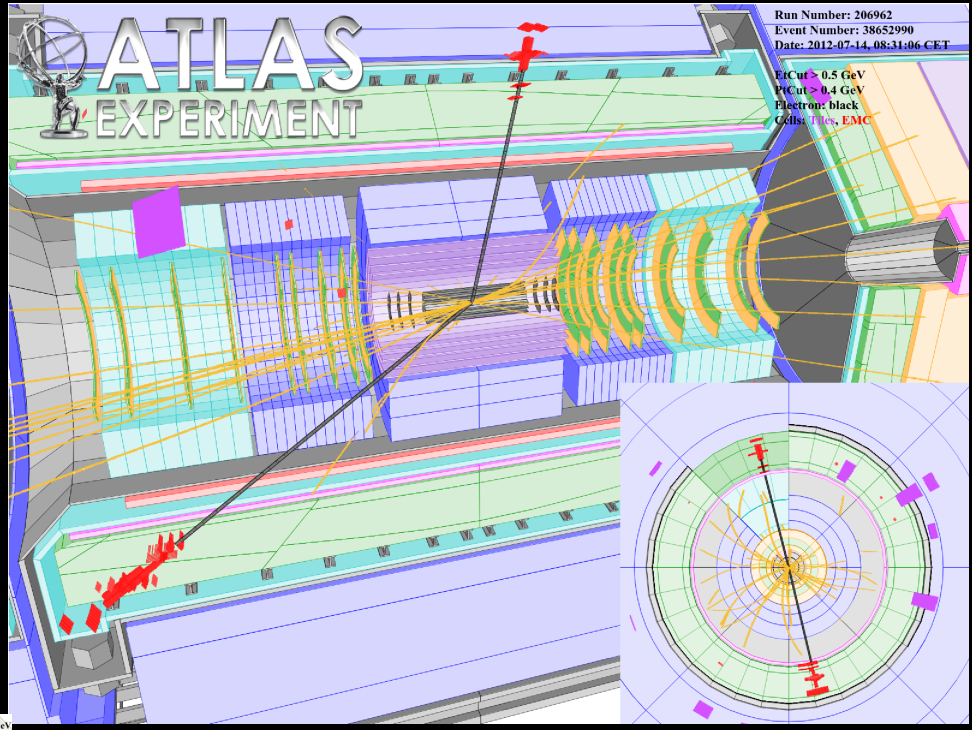


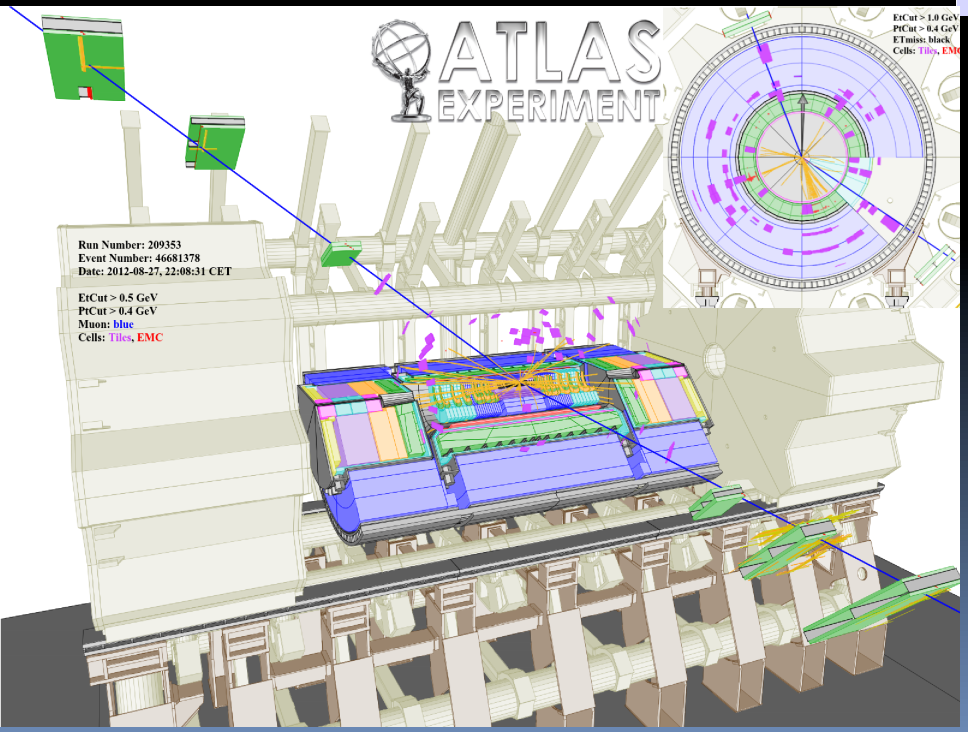
- Modification of di-jet mass and angular distributions
- Observed & fitted di-jet mass: 8TeV data
  - Comparison to 4 q^* models
  - $M_{q^*} > 3.84$ TeV (95% CL)



High p_T leptons

- Transverse momentum & rapidity:
  - Muon1: p_T = 653 GeV ; η = 0.99
  - Muon2: p_T = 646 GeV ; η = 0.85
- Invariant mass: $M_{\mu\mu}$=1844 GeV.

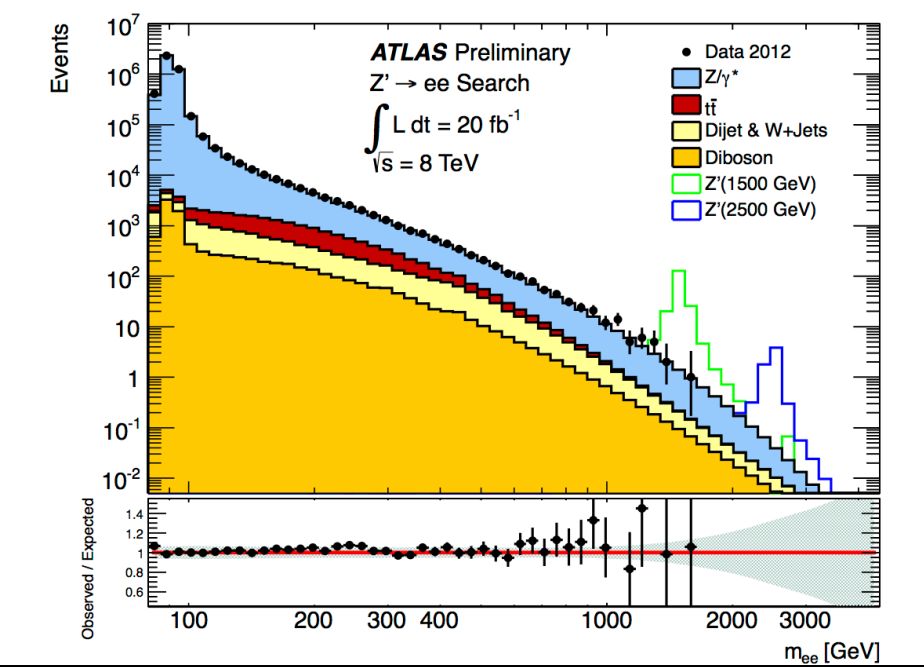




- Transverse momentum & rapidity:
  - Electron 1: p_T = 588 GeV ; η = 1.25
  - Electron 2: p_T = 584 GeV ; η = -0.29
- Invariant mass: M_{ee}=1541 GeV.

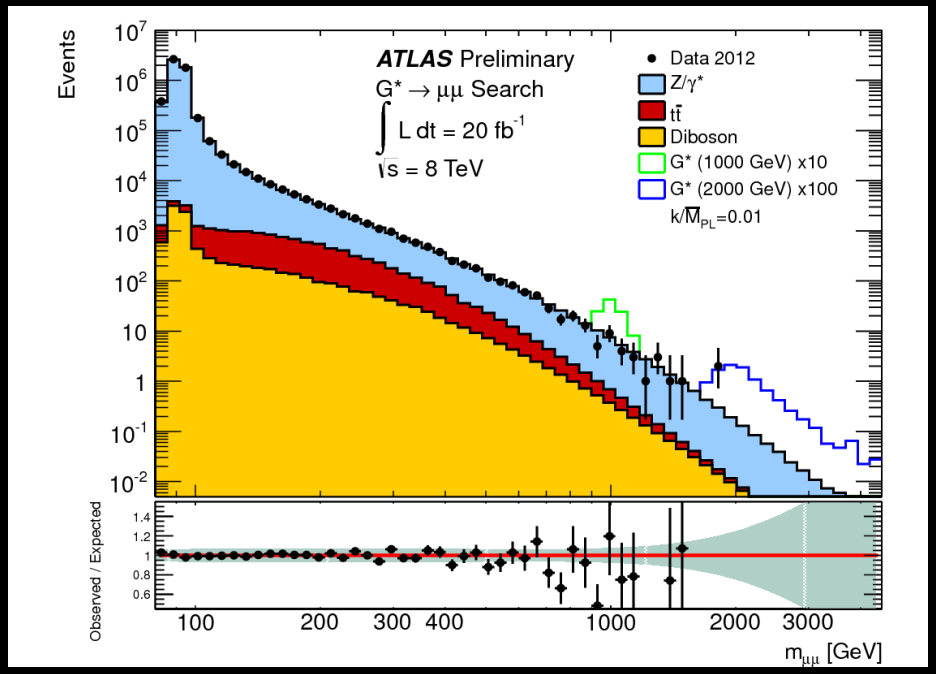
Search for Di-lepton resonances (ee, μμ)

– New gauge bosons Z’



- Sequential SM
  - $M_{Z'} > 2.86$ TeV
- (Superstring) E_6-inspired models
  - $M_{Z'} > 2.38 – 2.54$ TeV

– Graviton G*

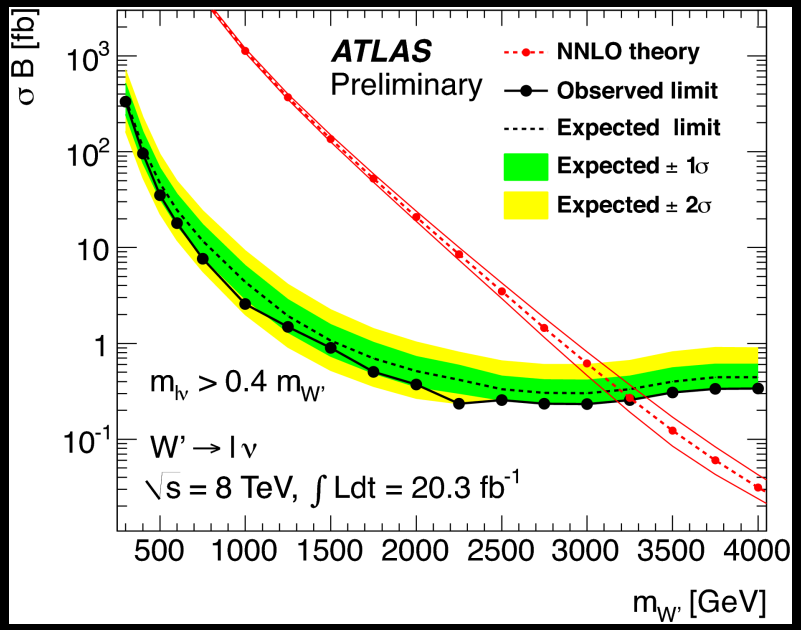


- Randall-Sundrum Graviton (extra space dimensions)
  - $M_{G^*} > 2.47$ TeV

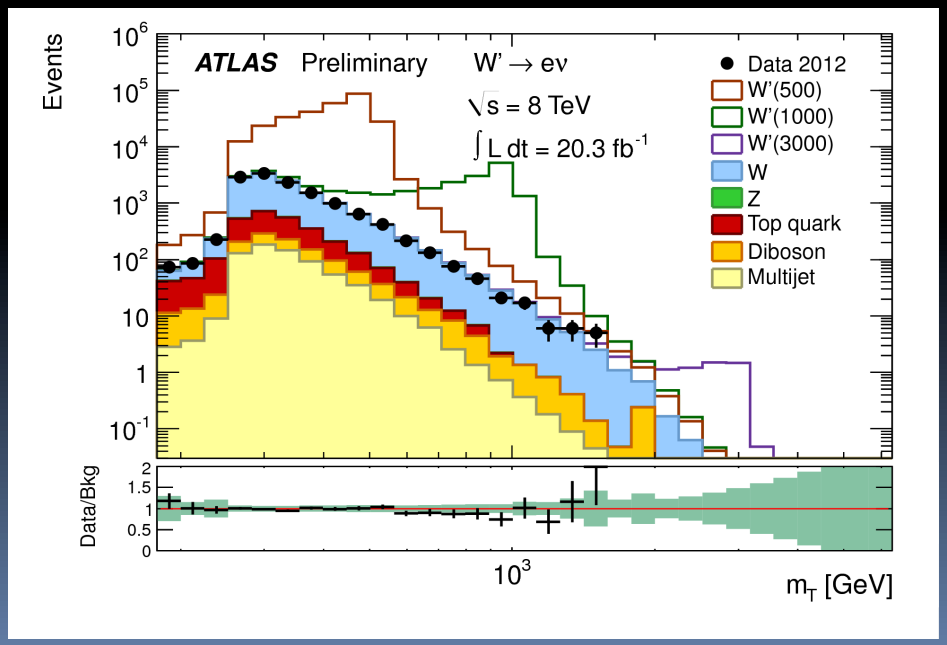
New gauge boson W'→lν

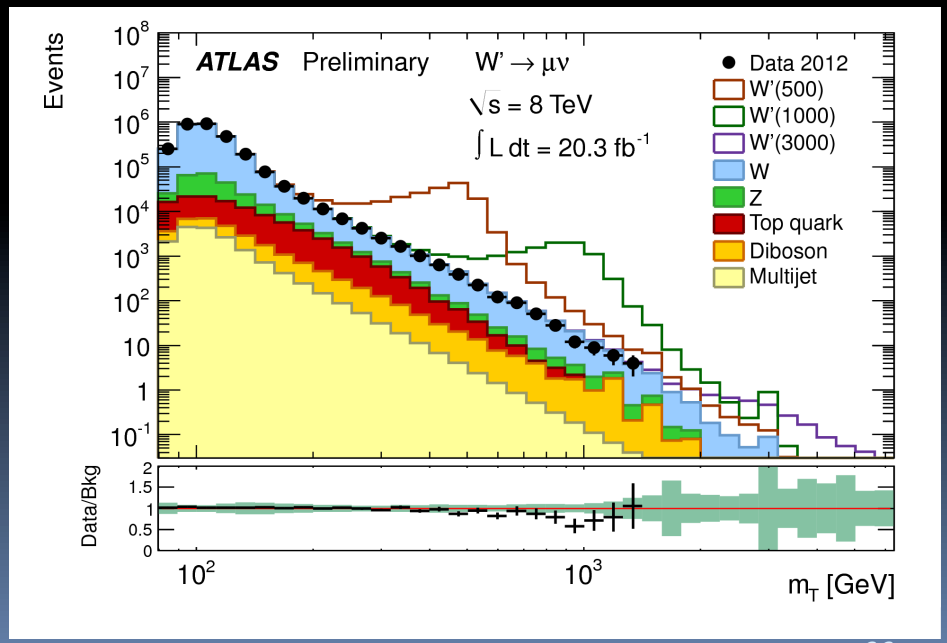
http://cds.cern.ch/record/1692660

- Limits on σB for W′ in the combination e,μ channels
- Transverse mass $m_T = \sqrt{2 p_T E_T^{miss} (1 - \cos \varphi_{\ell\nu})}$



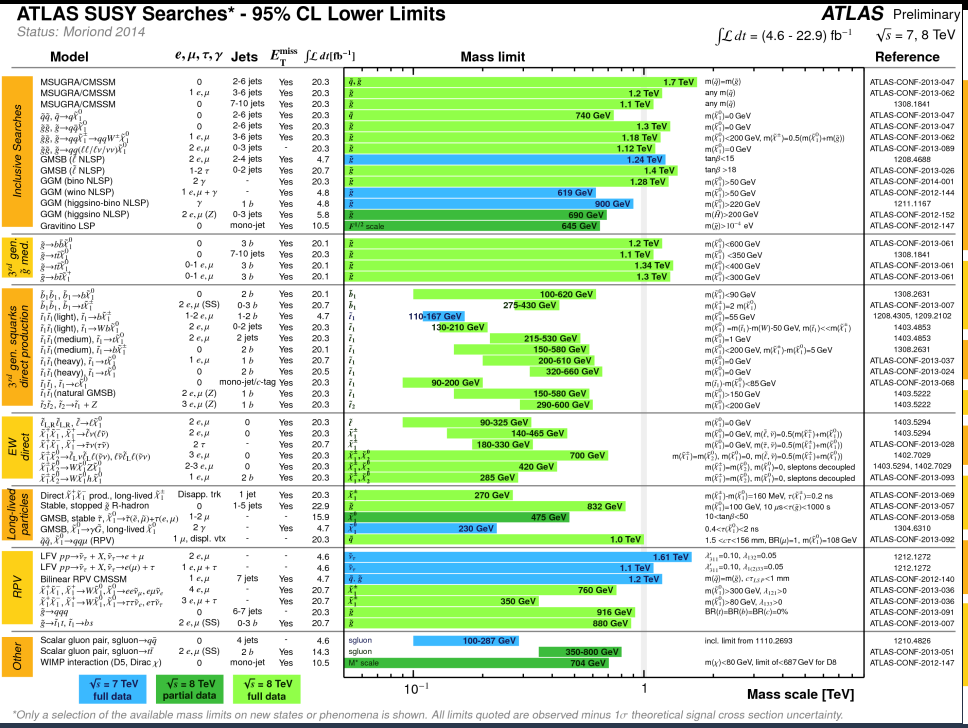
$M_{W'}$>3.27TeV M_{W*}>3.17TeV

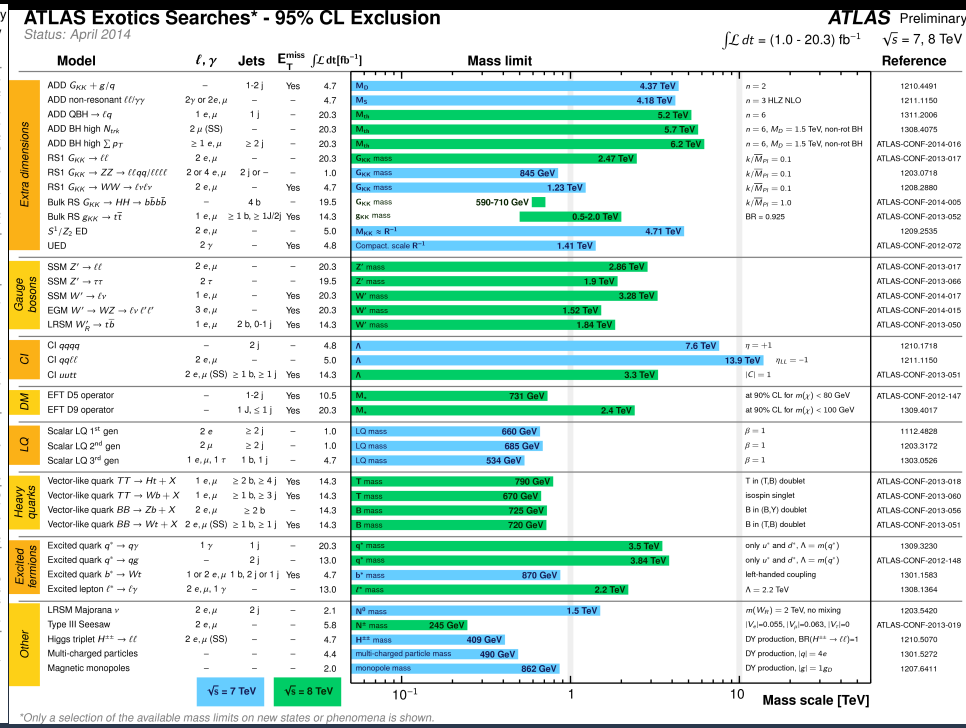




Physics of/beyond the Standard Model of EW+QCD

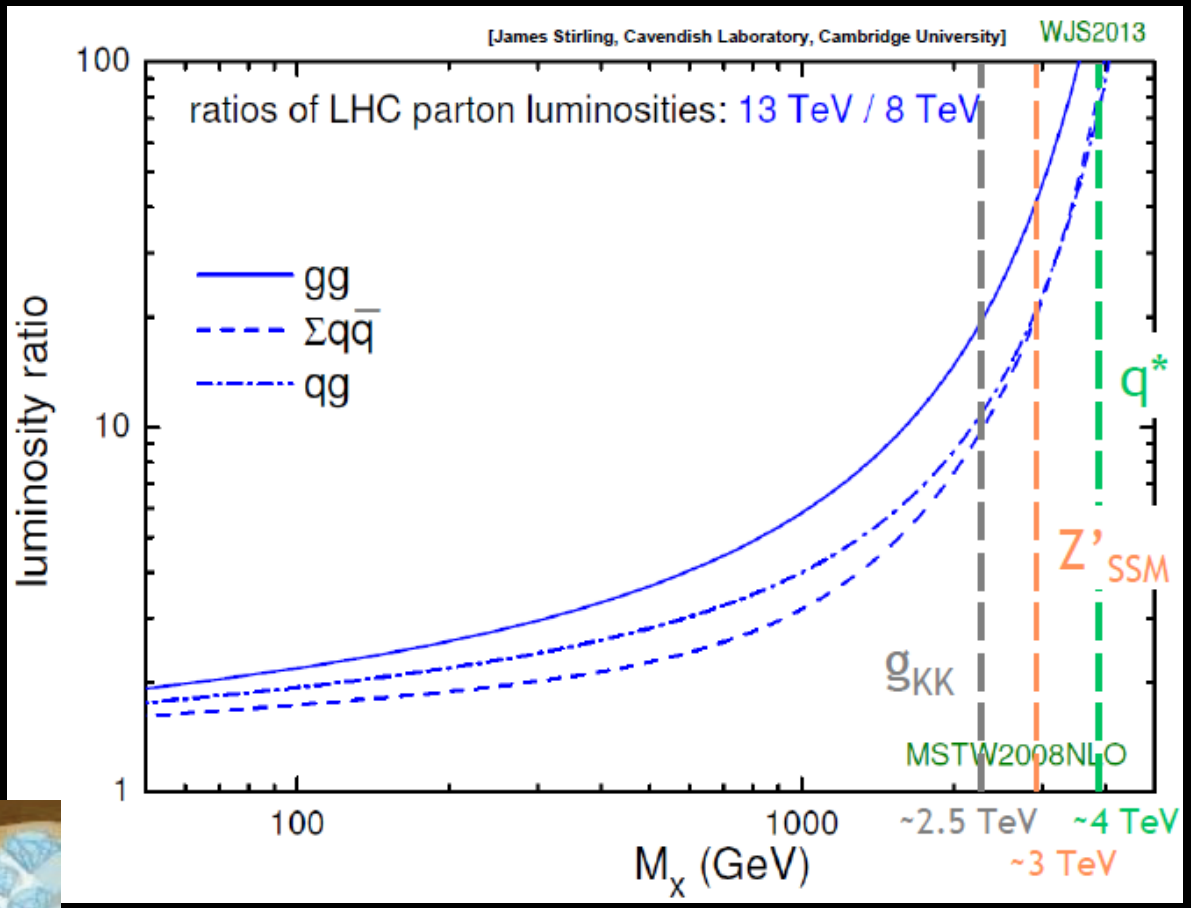
- Despite enormous gains in mass reach since the previous experiments, there is as yet no direct evidence for Supersymmetry or more exotic physics beyond the SM.

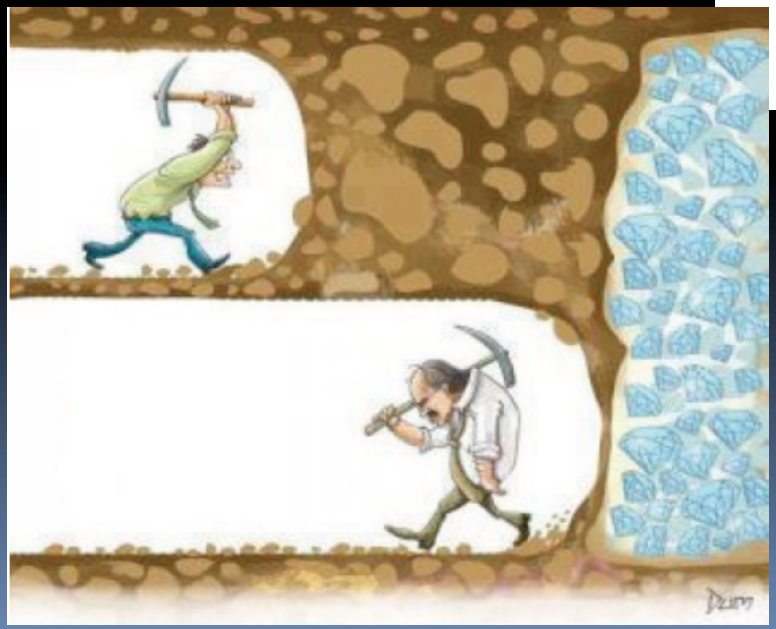




- However, we have collected only a few % of the data planned for the full LHC program and already in 2015 the doubling of the collision energy could yield some surprises … stay tuned

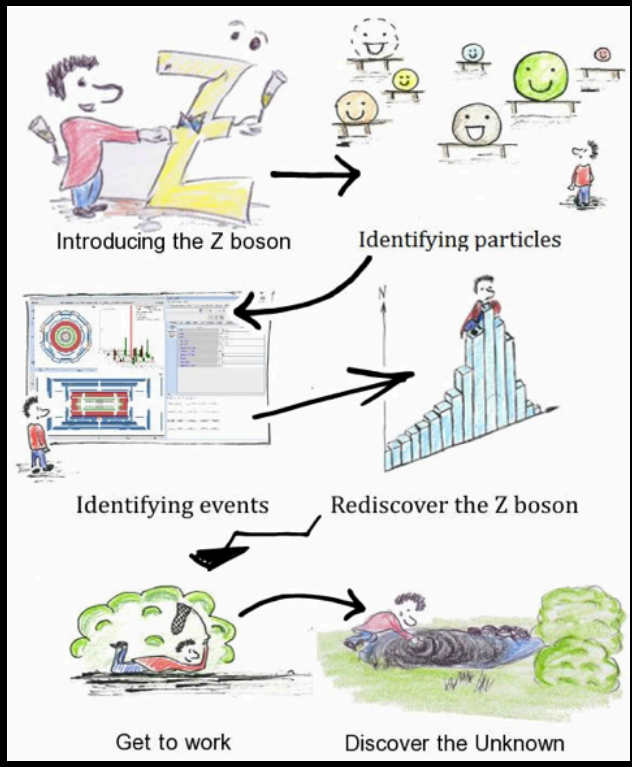
- Higher luminosities & energies from 2015





Don't give-up …

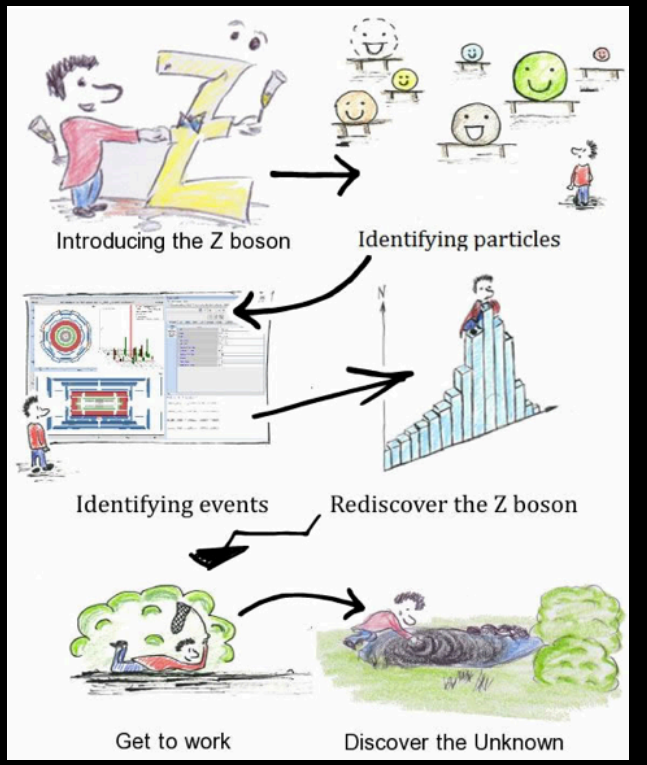
- You want to learn more?
- join LHC Masterclasses
  - 2011-12: J/ψ, Υ, Z,Z'
  - 2013: +Higgs-like
  - > 2014: + Whatever-like we will discover



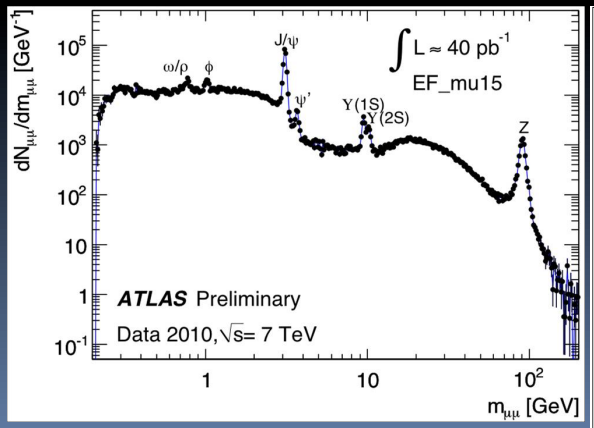
Outreach & Education

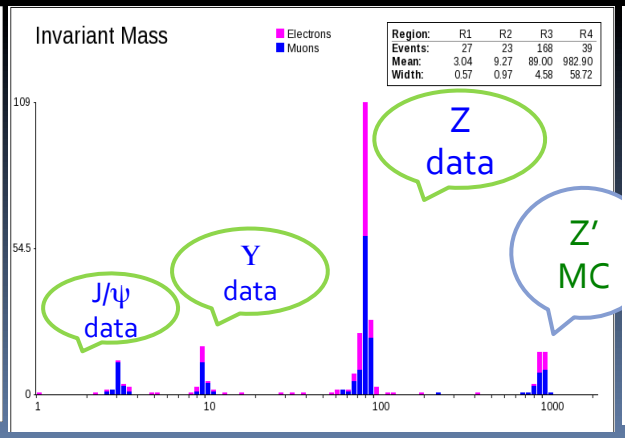
- UiO has been leading the development of educational material and methods based on fresh LHC data through the International Particle Physics Outreach Group (IPPOG).
- ATLAS Z^0 package, Invariant mass as a tool to identify known short-lived particles and discover new ones
  - allows high school students to work with real LHC data, is the most popular among all packages from LHC experiments.
  - Master classes 2012: 53 out of 143 institutes all over the world conducted the Z-path, were a great success.

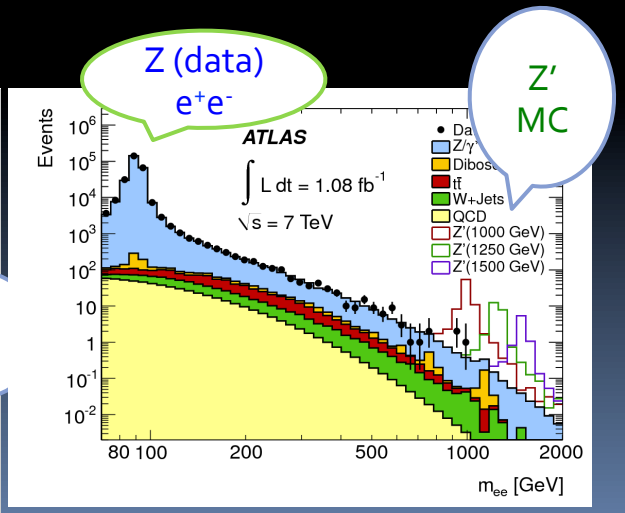
Link to Z-Path



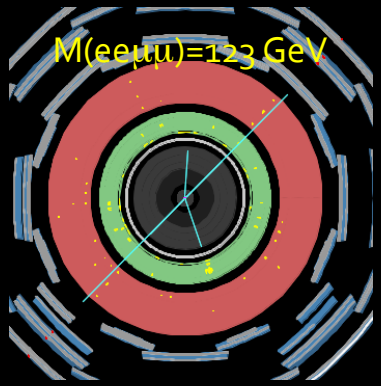
- Compare students results to ATLAS measurement





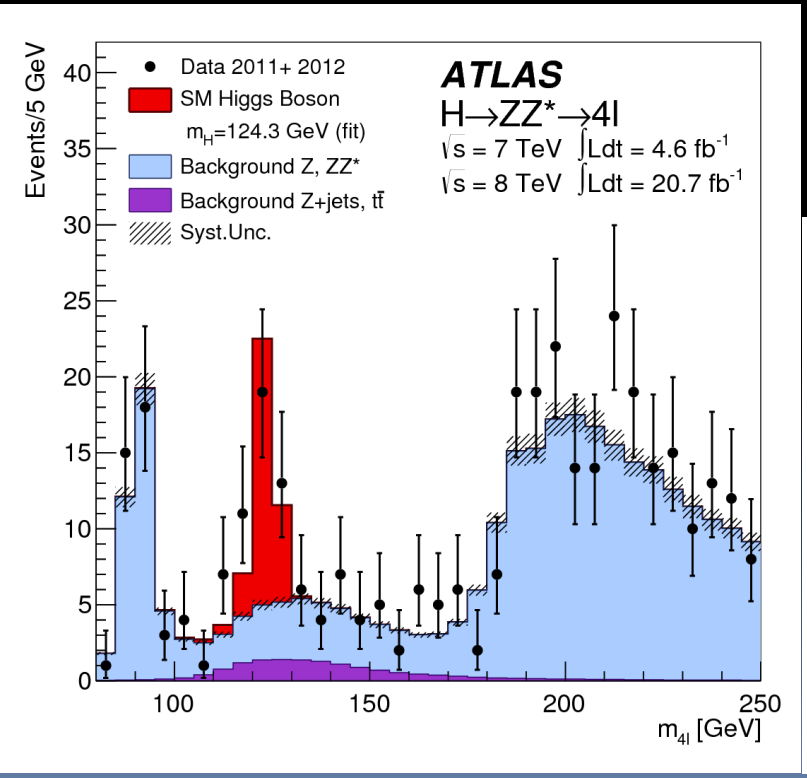


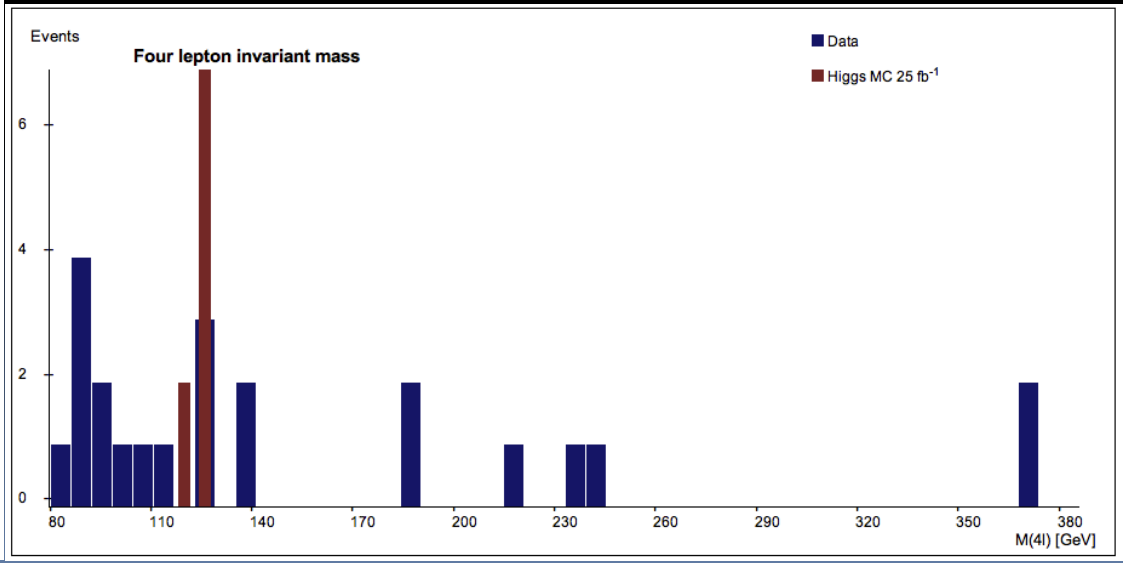
Higgs search H→4l
ATLAS vs IMC Students



- ATLAS results
  - H→ZZ*→llll
  - 25.3 fb-1

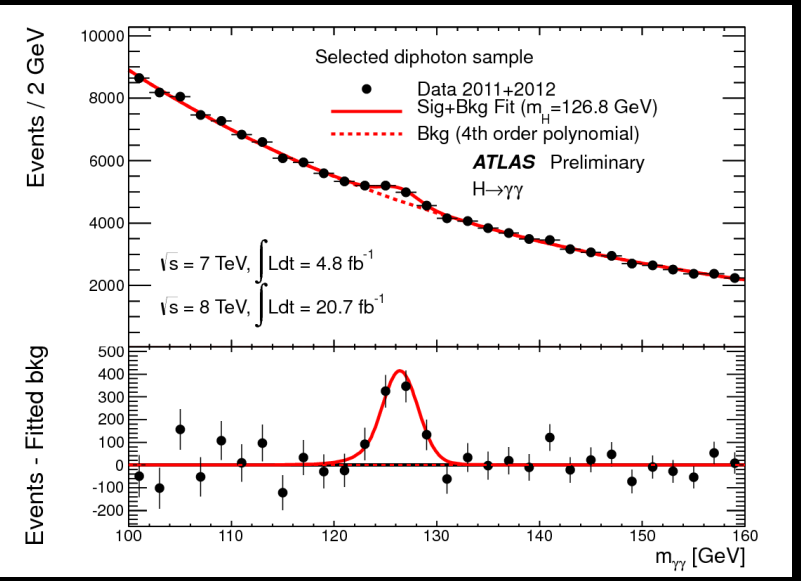
- You have searched for Higgs
  - H→llll with 1 fb-1
- You have 2 candidates at ~125 GeV
  - 1 compatible with what ATLAS has observed
  - The other event corresponds to ZJ/ψ→4l
  - With 25 fb-1, you would see ~10 events on top of very small background



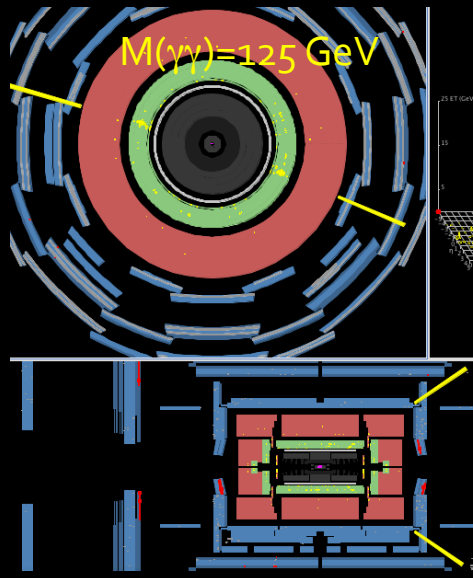


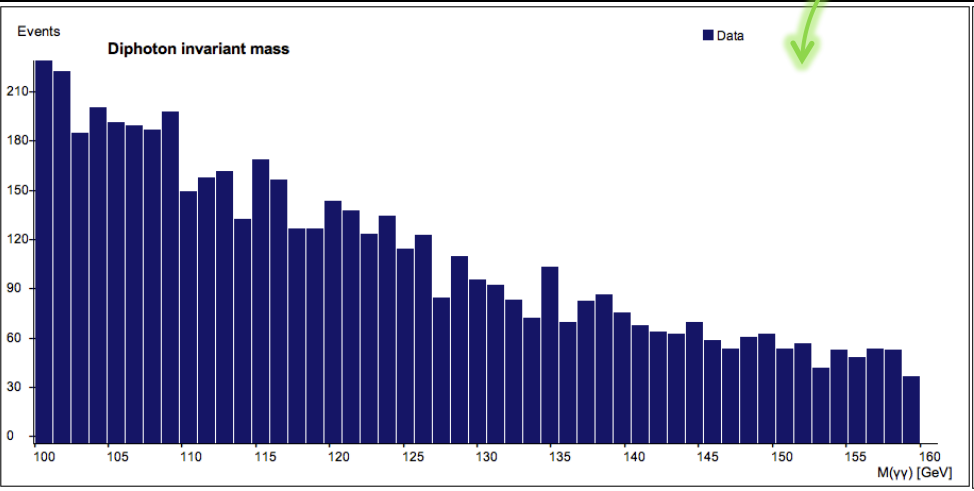
Higgs search H→γγ ATLAS vs Students

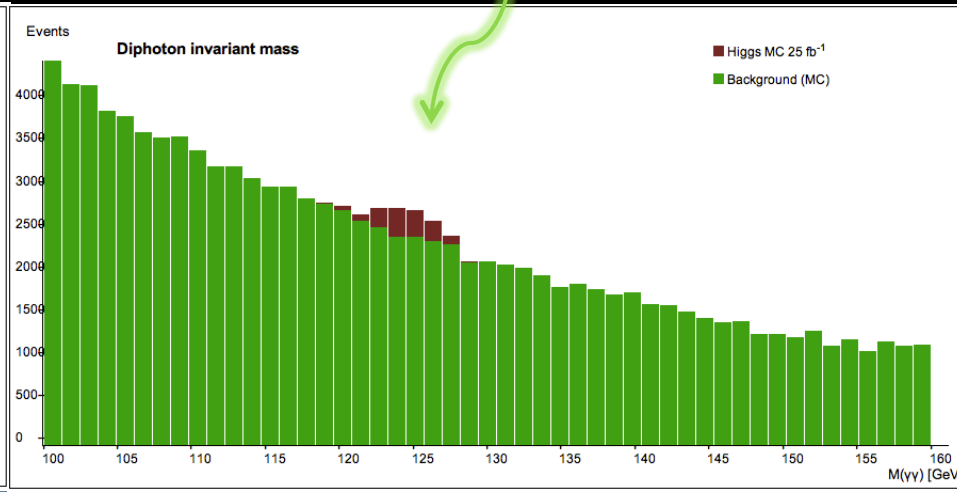
- ATLAS results: H→γγ
  - 25.5 fb-1 → clear signal



- You have searched for Higgs
  - H→γγ with 1 fb-1
- You have several candidates at ~125 GeV
  - You don't have enough statistics to reproduce the ATLAS result
  - With 25 fb-1, you would clearly observe a signal on top of a large background.





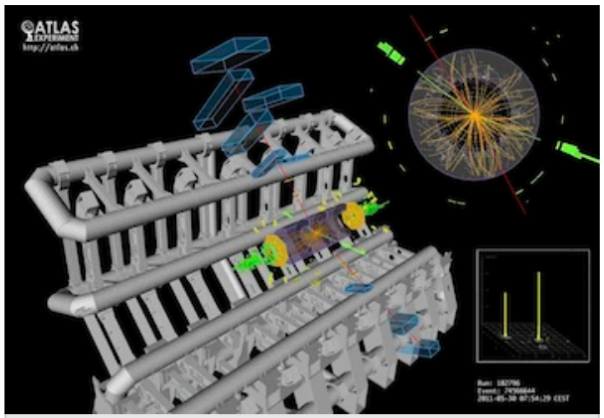


High Energy Particle Physics - HEPP - Project

The goal of HEPP is to extend the frontiers of physics knowledge using the advanced technology of the world's largest and highest energy particle accelerator, the LHC, and, among others, the world's largest particle detector, ATLAS, to discover the last missing building block of the Standard Model of elementary particles, the Higgs boson, and identify the new physics which may be expected in a previously unexplored energy regime, the TeV scale.

Latest Results from the ATLAS Experiment

The HEPP project is part of the Norwegian CERN-related program, funded by the Research Council (RCN). The 6-year period 2006-2011 came to an end in December 2011. Although the main activity has been the ATLAS experiment at the LHC, project members have also been involved in theoretical work related to and/or relevant for LHC physics, in Grid computing, in detector upgrade activities, in the BABAR detector at SLAC, as well as in a vast outreach program towards young students and media. The first 4-year period of the current program (2012-2019) started in January 2012 with main emphasis the ATLAS experiment. The partners UiO, UiB and HiG contribute with permanent staff members and PhD students. Post-docs are funded by RCN, as well as hardware, computing and operation of ATLAS.



Proton-proton collision leading to two Z particles: one Z decays to two muons, the other to two electrons. This is one of the Higgs candidates. *Photo ATLAS.*

Contact

Project leader: Prof. Farid Ould-Saada

Deputy: Prof Anna Lipniacka

Participants

- Farid Ould-Saada
- Alexander Lincoln Read
- Lars Bugge
- Steinar Stapnes
- Are Strandlie
- Are Raklev
- Jan Olav Eeg
- Torsten Bringmann

List all participants

Participants: UiB

Research activities

HEPP Twiki

- ATLAS Physics
- ATLAS Upgrade
- Computing
- Theory
- Outreach

Supersymmetry
Higgs
Exotics
Combined performance

Pixels
0- Insertable B-layer
1- Atlas Forward Protons
2- New Inner Tracker ITk

NorduGrid ARC
Atlas Tier-1, Tier-2
NeIC, USIT, Uninett
ATLAS computing, software, data management, operations, HPCs

IPPOG
IMC
Education material
Dissemination ...

UiO/HEPP @ ATLAS

- SCT, 3D-pixels, silison sensors
  - New pixel layer, 3D-pixel R&D in prep of New tracker
- Computing, Grid, New software developments
- Higgs
  - H→γγ channel
  - Charged Higgs search
  - Higgs for education
  - (H→ττ : UiB)
  - (H→ZZ*→llll: UiB)
- Super-symmetry
  - Sleptons: super partners of leptons
  - Gauginos: super partners of gauge bosons & Higgs
  - SUSY phenomenology
  - Supersymmetric Higgs
  - (SUSY with taus: UiB)
- Exotic particles
  - New gauge bosons, including superstring-inspired
  - : Z'→ll, W'→lν
  - New space dimensions: Graviton: G→ll, Blackholes
  - Independent search for new phenomena
  - SM and New physics for education
  - …
- Outreach & Education

Just in case you might be interested ☺