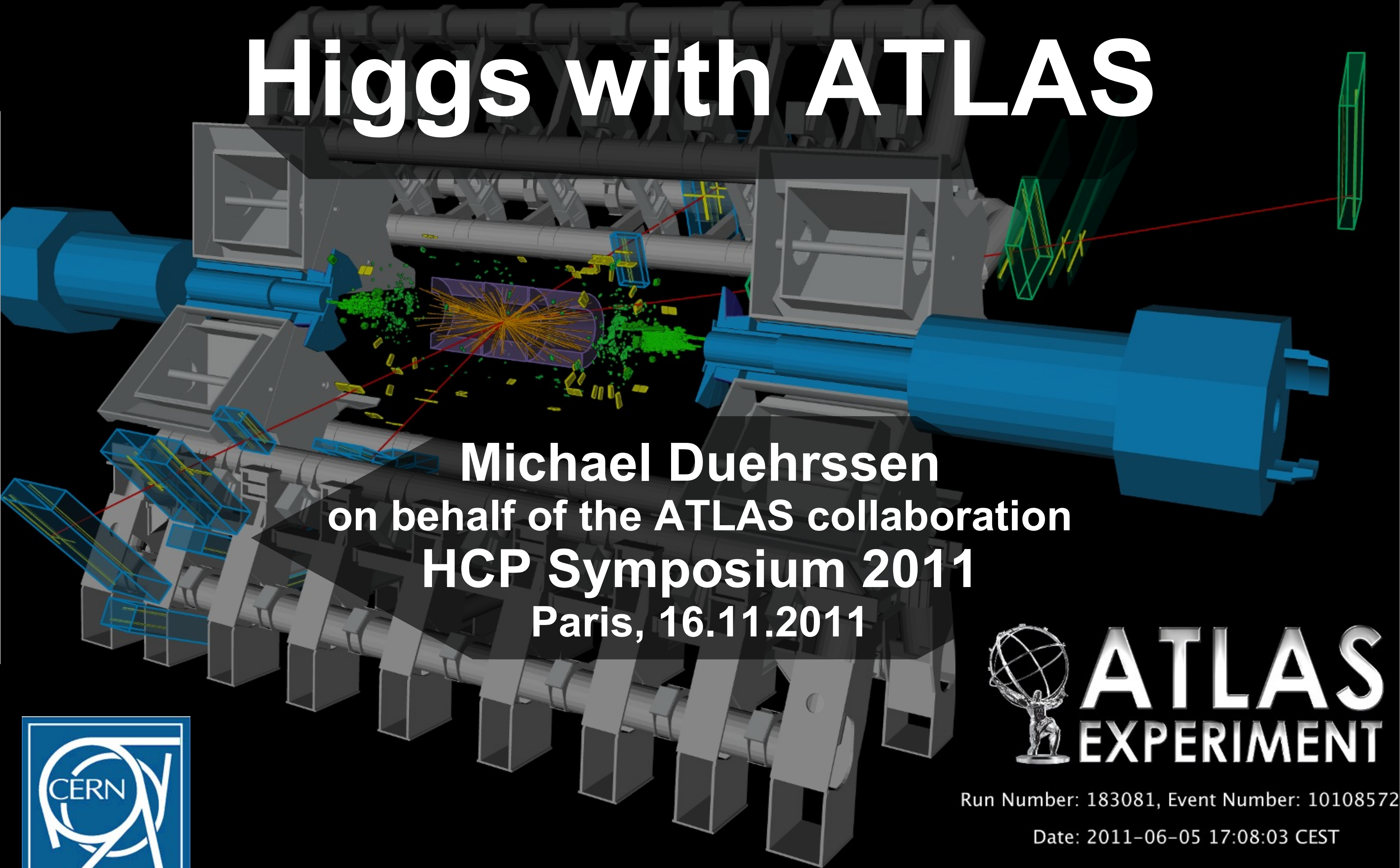
Searches for Low mass Higgs with ATLAS



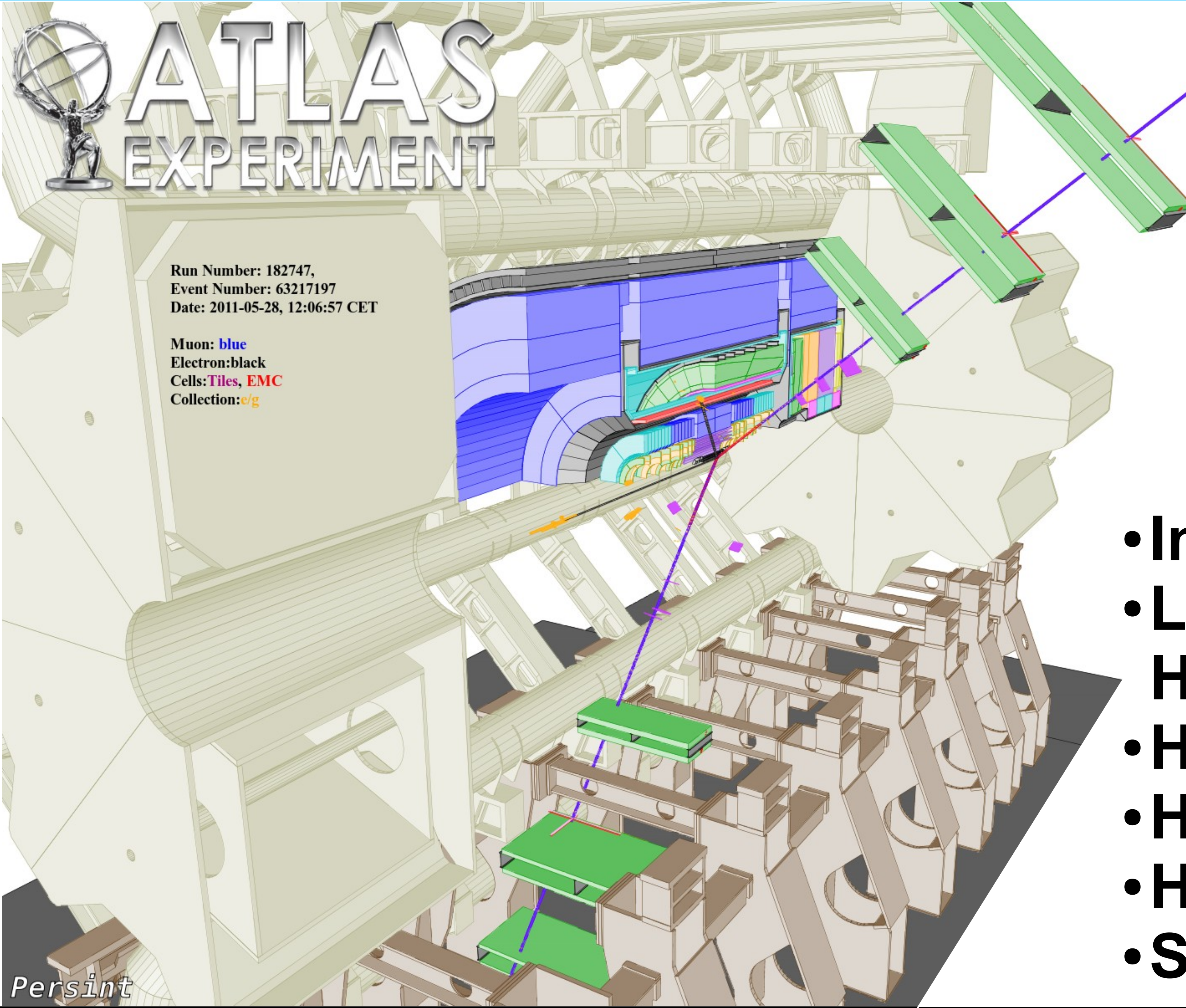
Michael Duehrssen
on behalf of the ATLAS collaboration

HCP Symposium 2011

Paris, 16.11.2011

CERN

Outline

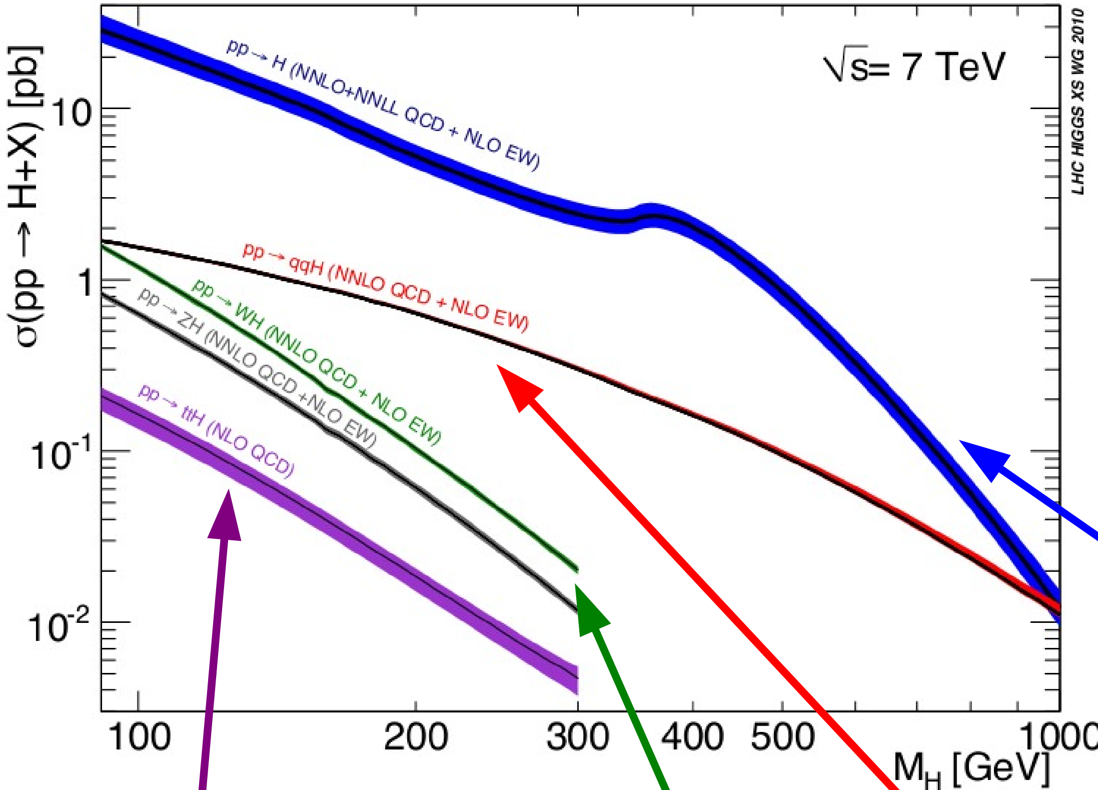


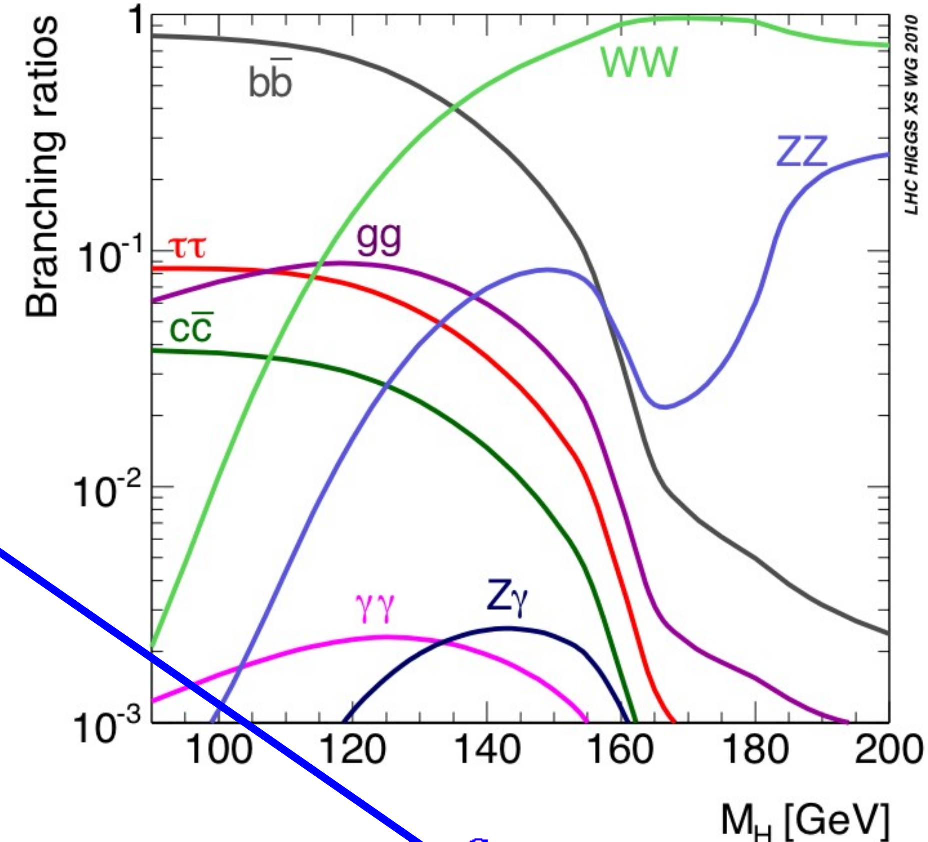
1[st] page: 4μ event
m_{4l} =143.5 GeV

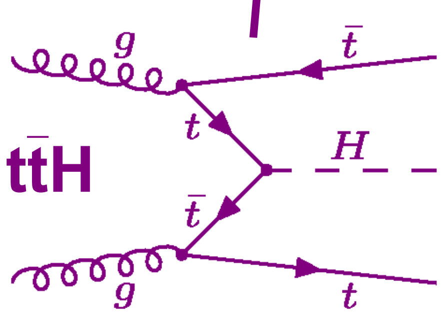
This event: $2e2\mu$
m_{4l} =209.7 GeV

- Introduction
- Low mass H→WW/ZZ
- $H\to\gamma\gamma$
- $H\to\tau\tau$
- H→bb
- Summary

Standard Model Higgs at the LHC

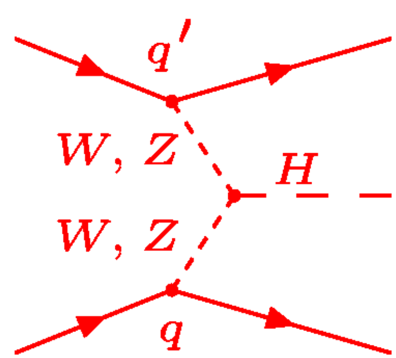




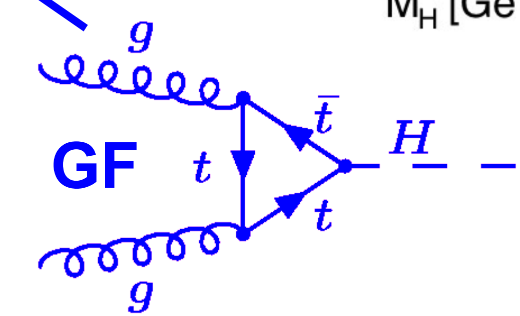


Not used as signature so far, but xsec is included

Used in WH/ZH ($H \to b\bar{b}$) **search**



Used in VBF $H \to \tau\tau$ **and** $H \to WW$ + 1 jet



Dominant: Gluon Fusion

$H \to \gamma\gamma$ (incl.)

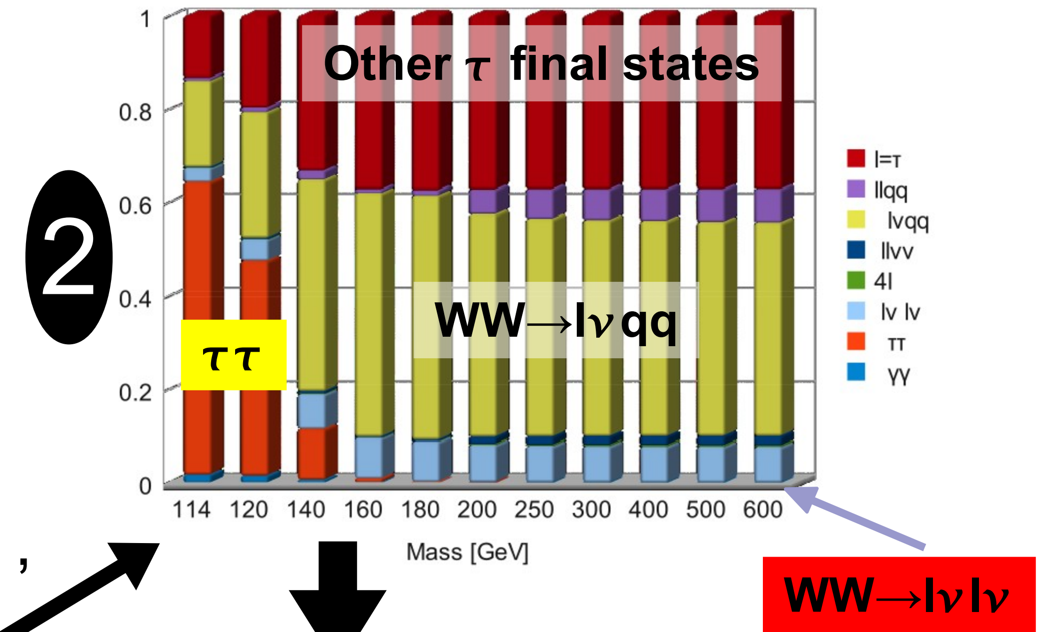
$H \to WW$ + 0/1 jet

$H \to ZZ$ (incl.)

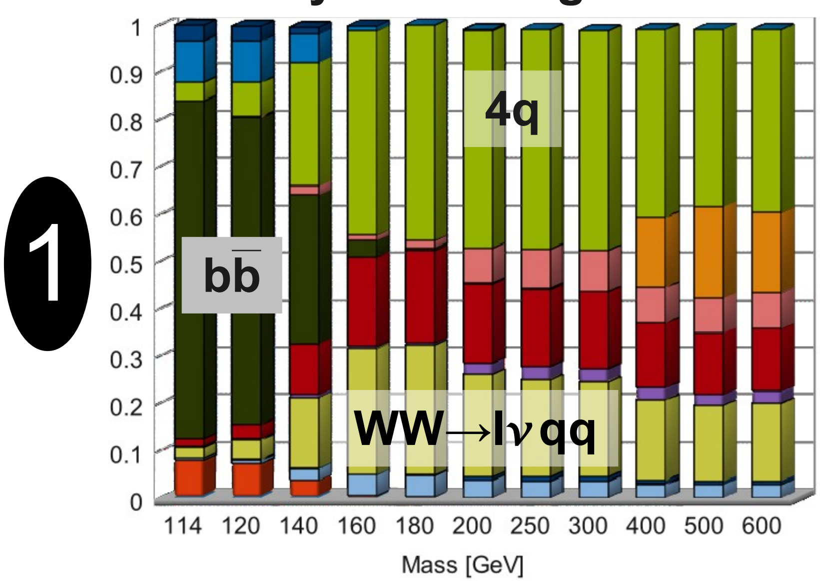
Searching for a low mass Higgs Boson

- So far, the integrated luminosity allows mainly for a Higgs search in gg→H production
- Viable channels need:
  (1) High branching ratio
  (2) Good trigger
  (3) Low background level
- Channels remaining in the end:
  H→WW→lνlν , H→ZZ→4l , H→γγ ,
  H→ττ and W/ZH(H→b$\bar{b}$)

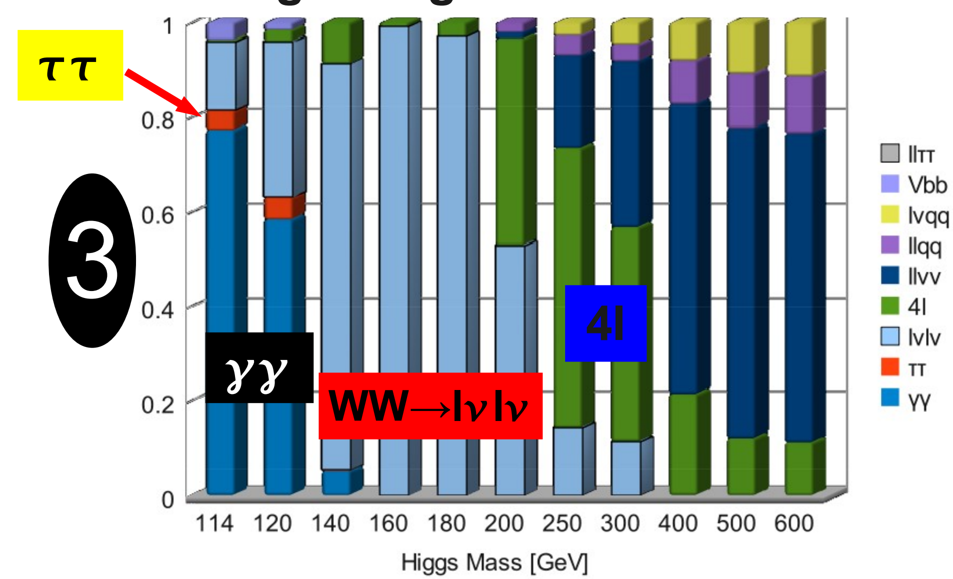
BR with trigger



Only Branching Ratios

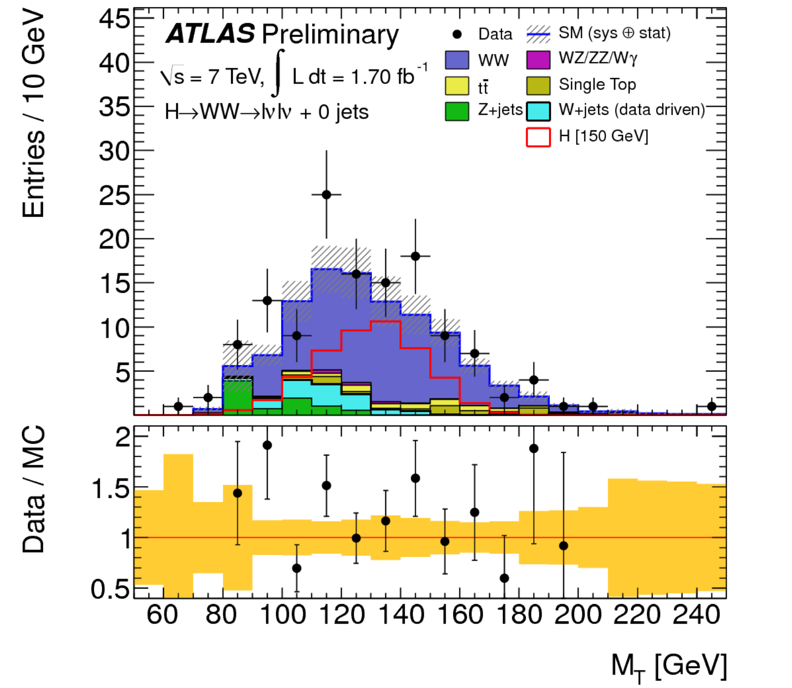


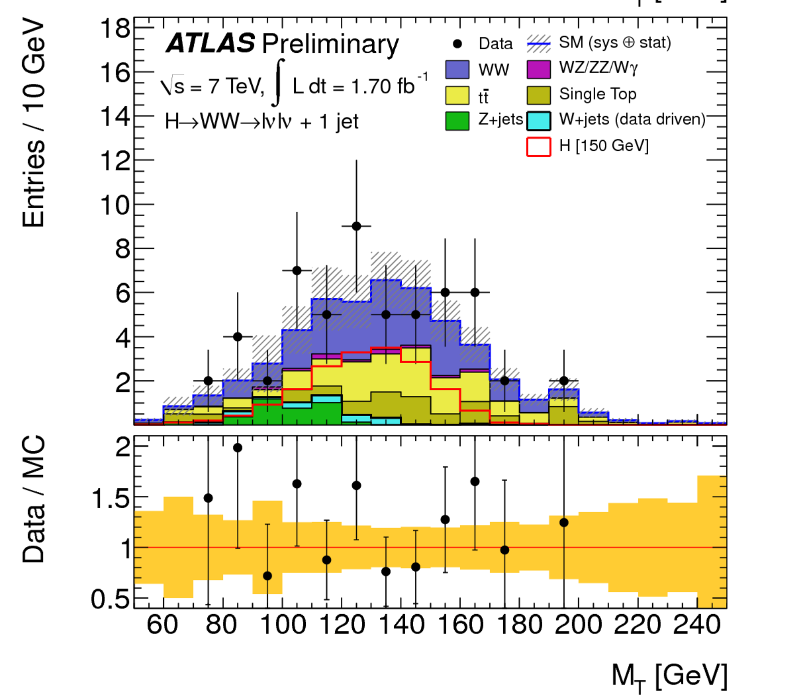
Taking backgrounds into account

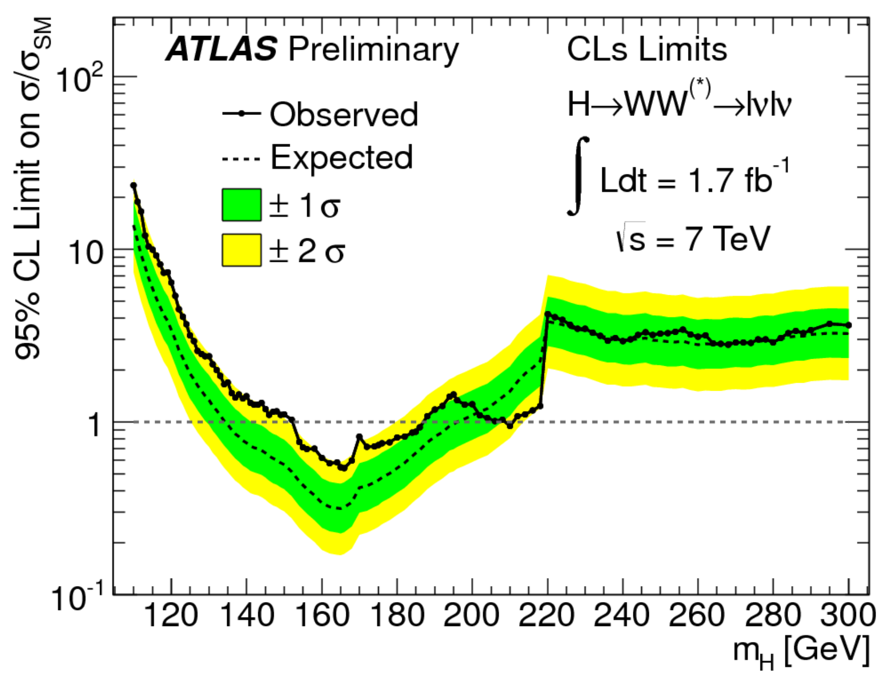


Search for H→WW with 0 or 1 jet

- Most promising channel with the current low integrated luminosity. Good S/B!
- But challenging: no mass peak, only M_T
- Analysis exploits the angular correlation in spin 0 H→WW decays: collinear leptons
- Main background: continuum QCD WW
- Separate into exclusive 0 and 1 jet analysis
- Analysis requires MET and a jet veto. High pileup conditions will hurt somehow

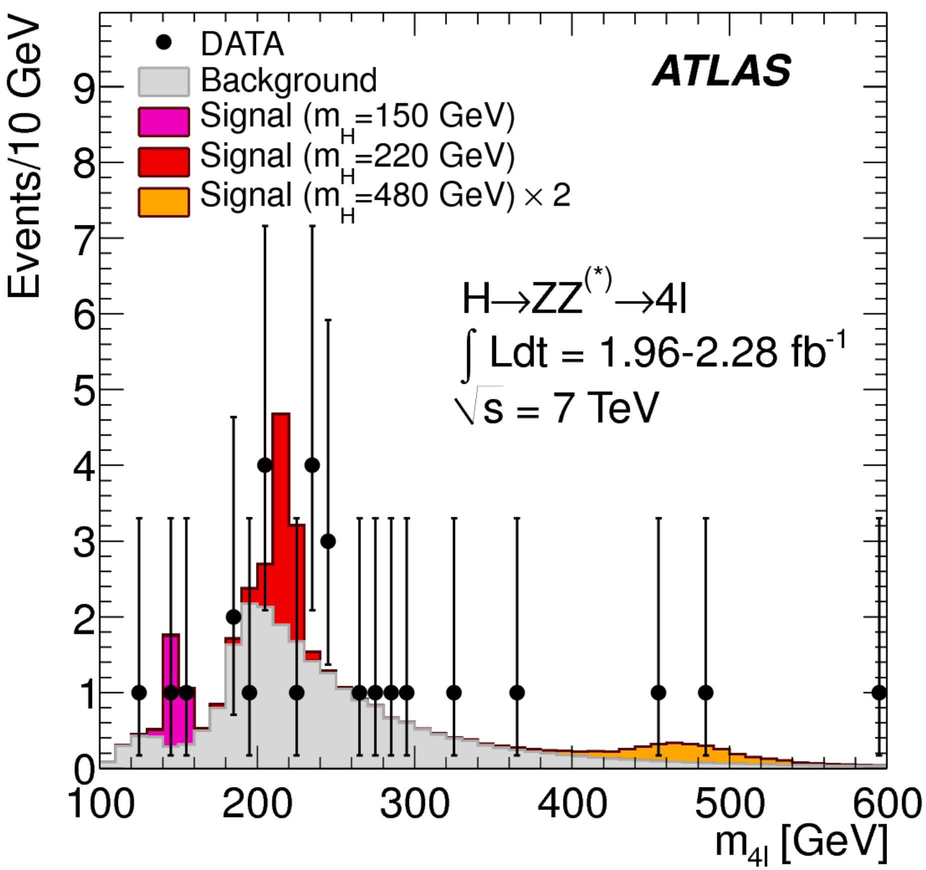


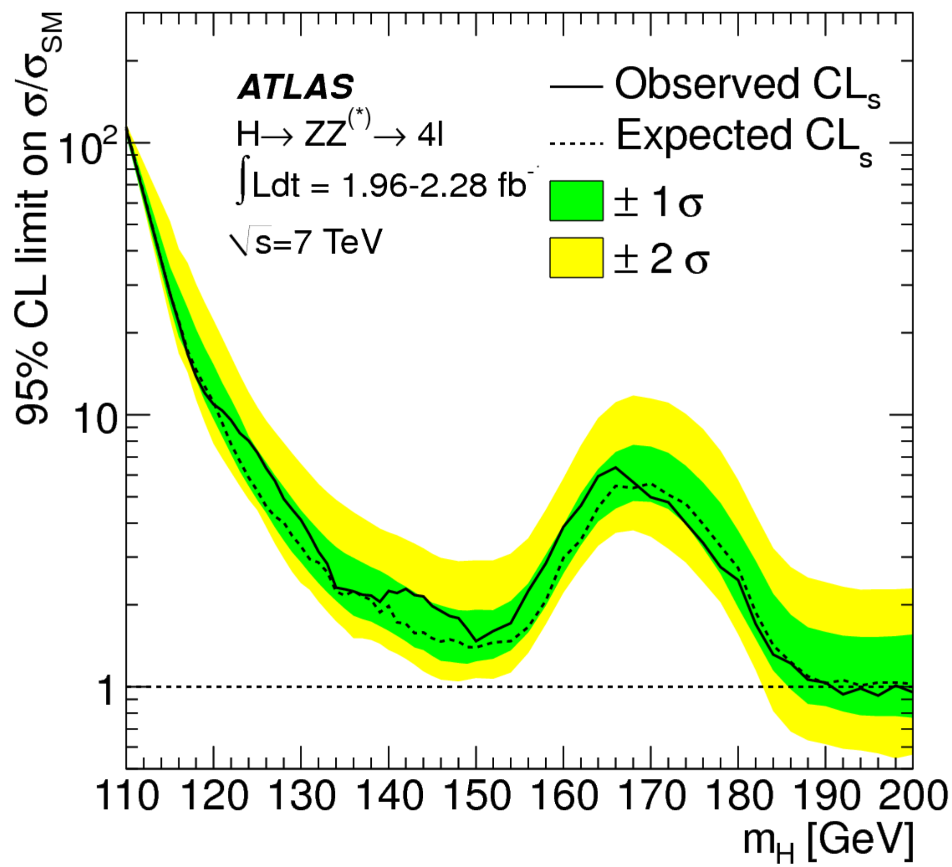




Inclusive search for H→ZZ→4l

- Golden channel
  - Expect to see a mass peak over a ~flat background (m_H<170 GeV)
  - Very good S/B
- But still limited by the available integrated luminosity
- Relative good stability with respect to high pileup conditions
- Improving m_H<130GeV is challenging as it requires very low p_T leptons

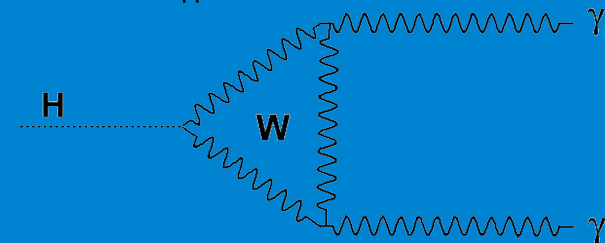


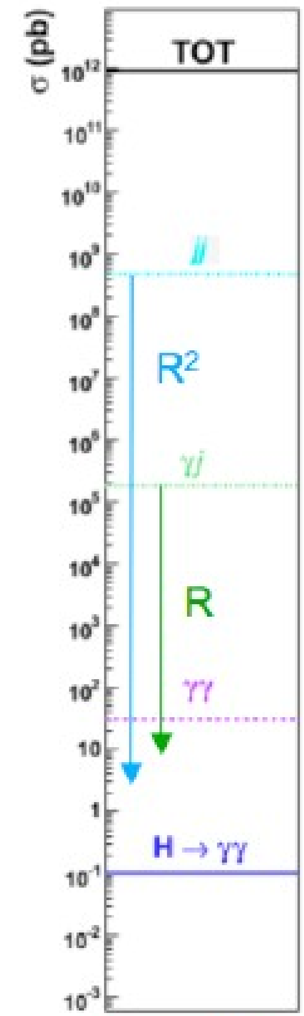


Inclusive search for $H \to \gamma\gamma$

- $H \to \gamma\gamma$ decay
- small direct BR (≈0.002)
- decay due to W and top loops
- BUT: clean 2γ signature

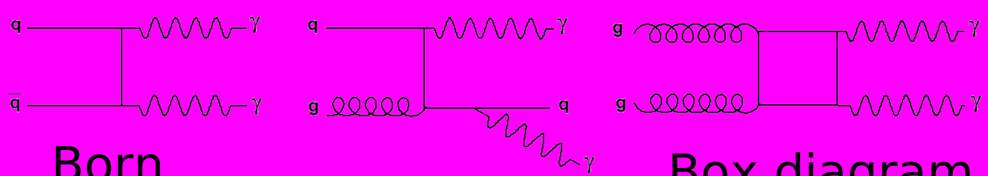
$\sigma * BR(m_H = 130\ \text{GeV}) \approx 0.04$ pb





R ~ O(8000)

Irreducible background: $pp \to \gamma\gamma + X$



Born $O(\alpha^2)$

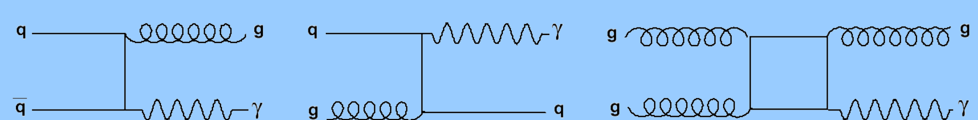
Bremsstrahlung $O(\alpha_s \alpha^2)$

Box diagram $O(\alpha_s^2 \alpha^2)$

$q\bar{q}$, qg	$\sigma \approx 21$ pb
gg	$\sigma \approx 8$ pb

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

Reducible background: $pp \to \gamma j$, jj+ X



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

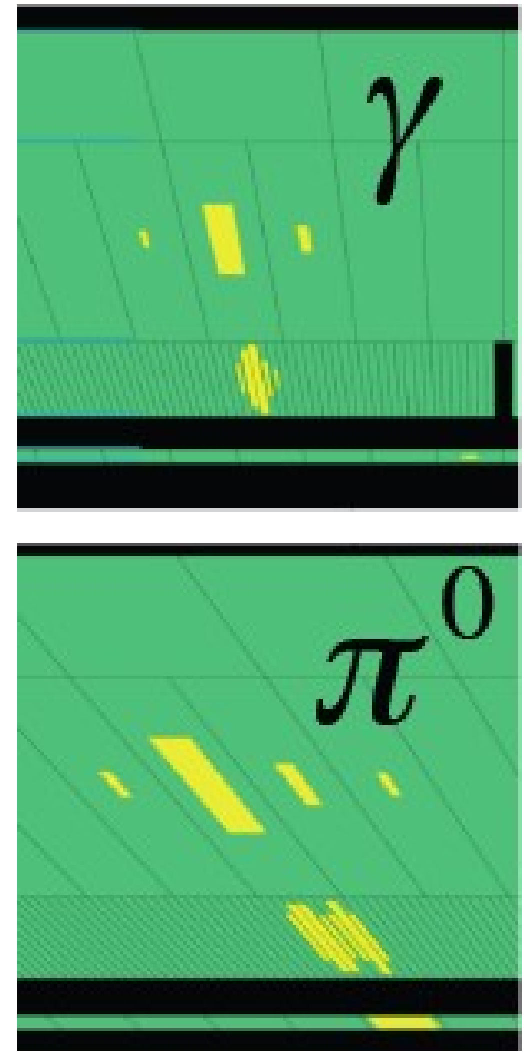
γ-jet	$\sigma \approx 1.8 * 10^5$ pb
jet-jet	$\sigma \approx 4.8 * 10^8$ pb

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

γ-jet need rejection R~O(10^4)
jet-jet need rejection R~O(10^7)
Main background is from leading π^0's

$H\rightarrow\gamma\gamma$ event selection

- Very simple signature (and analysis)
- Photon identification based on both lateral and longitudinal segmentation of the Electromagnetic calorimeter
- Two high-quality isolated high-p_T photons
- $p_T^1 > 40$ GeV; $p_T^2 > 25$ GeV
- $|\eta^{12}| < 1.37$ and $1.52 < |\eta^{12}| < 2.37$



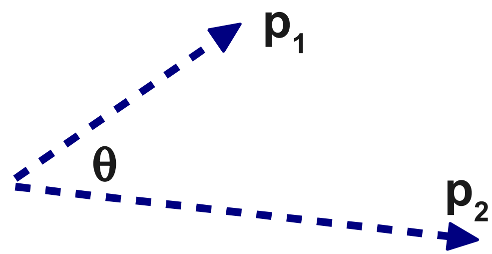
Spring 2011 data

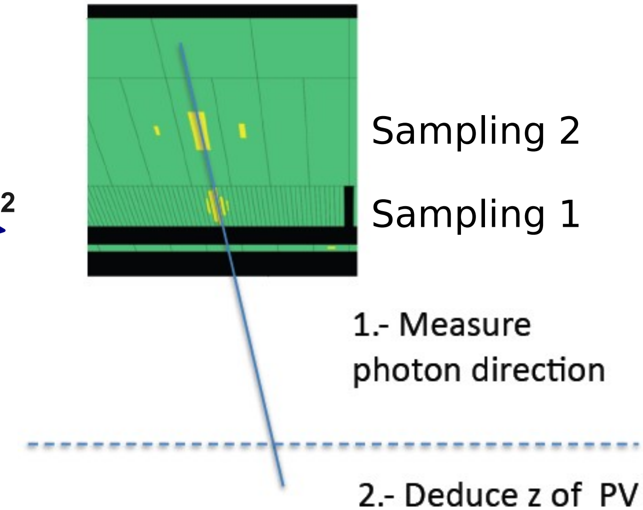
$H\rightarrow\gamma\gamma$ mass reconstruction

Mass reconstruction

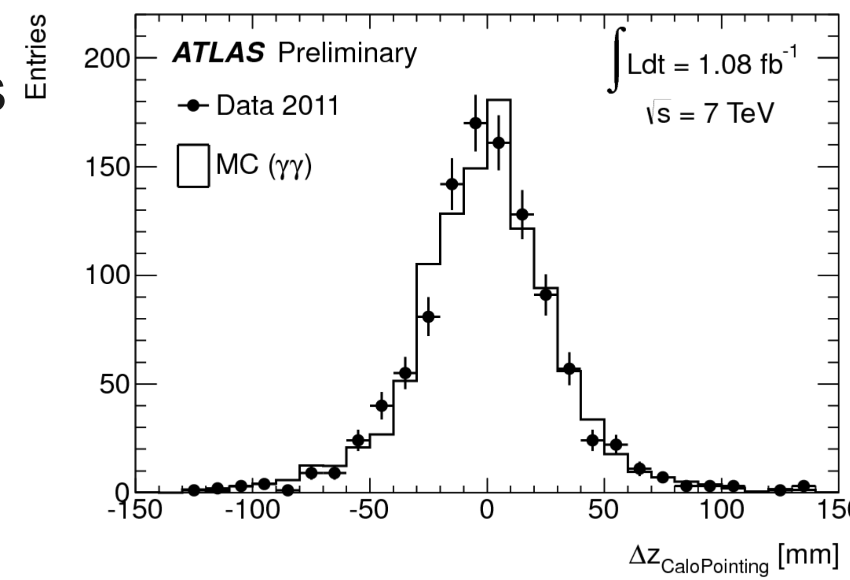
$$m^2 = 2p_1p_2(1-\cos\theta) \cong p_1p_2\,\theta^2$$

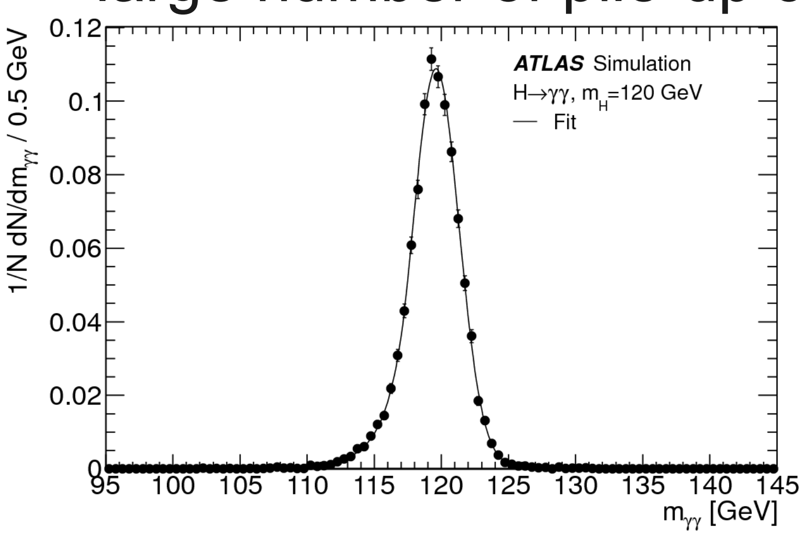
$$\delta m/m = (1/\sqrt{2})(\delta p/p) \oplus \delta\theta/\theta$$





- Energy resolution contribution $\delta p \approx 1.3$ GeV
  - Energy scale calibration from $Z\rightarrow e^+e^-$
- Interaction point spread: $\sigma(z) \approx 5.6$ cm $\rightarrow \delta m\,(\theta) \approx 1.4$ GeV
- Resolution with pointing: $\sigma(z) \approx 1.5$ cm
  - Improve by also using conversion tracks
  - Use of recoil tracks less effective with large number of pile-up collisions



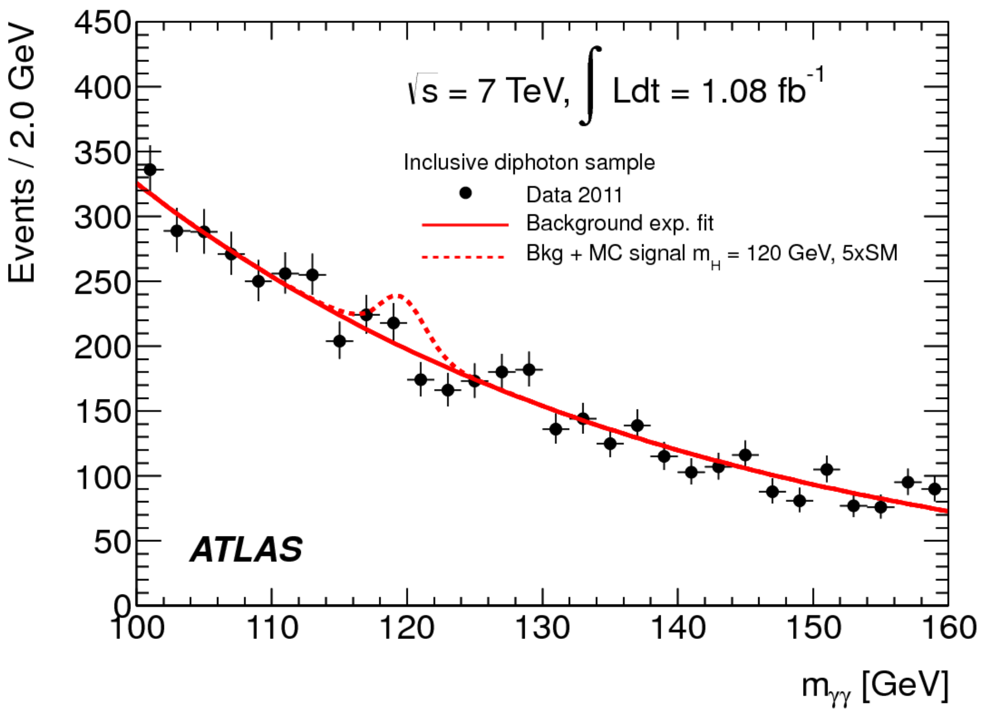


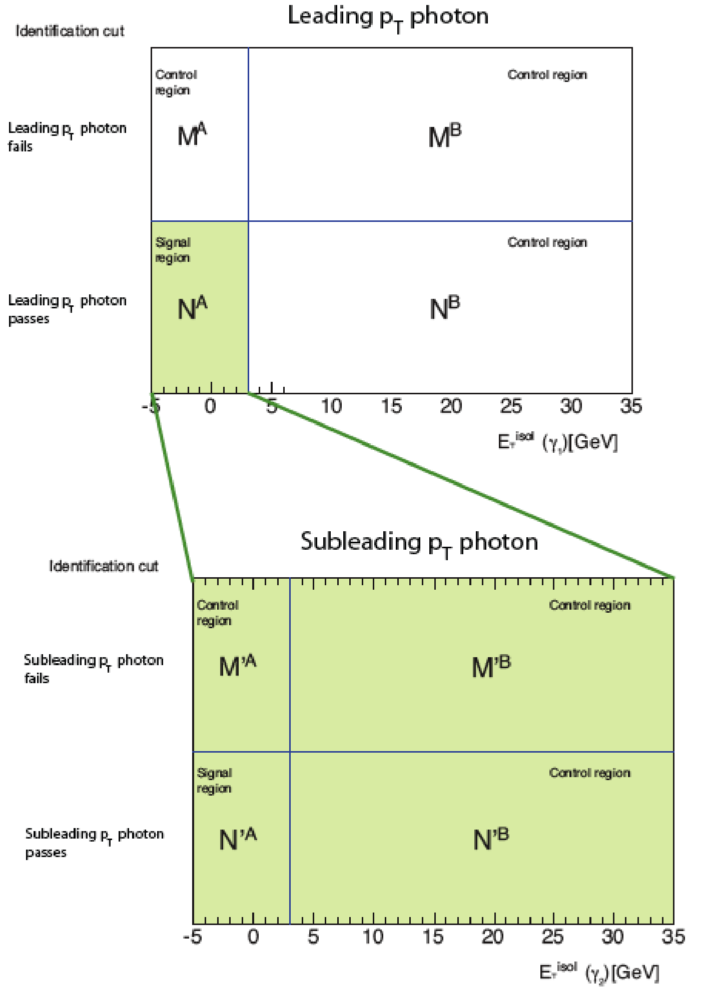
Distribution of simulated $m_H = 120$ GeV Higgs events; $\sigma(m) \sim 1.7$ GeV

$$\Delta z_{12} = z_{\gamma 1} - z_{\gamma 2} \approx 3\text{ cm}$$
$$\rightarrow \delta z_{\gamma\gamma} \approx 1.5\text{ cm}$$

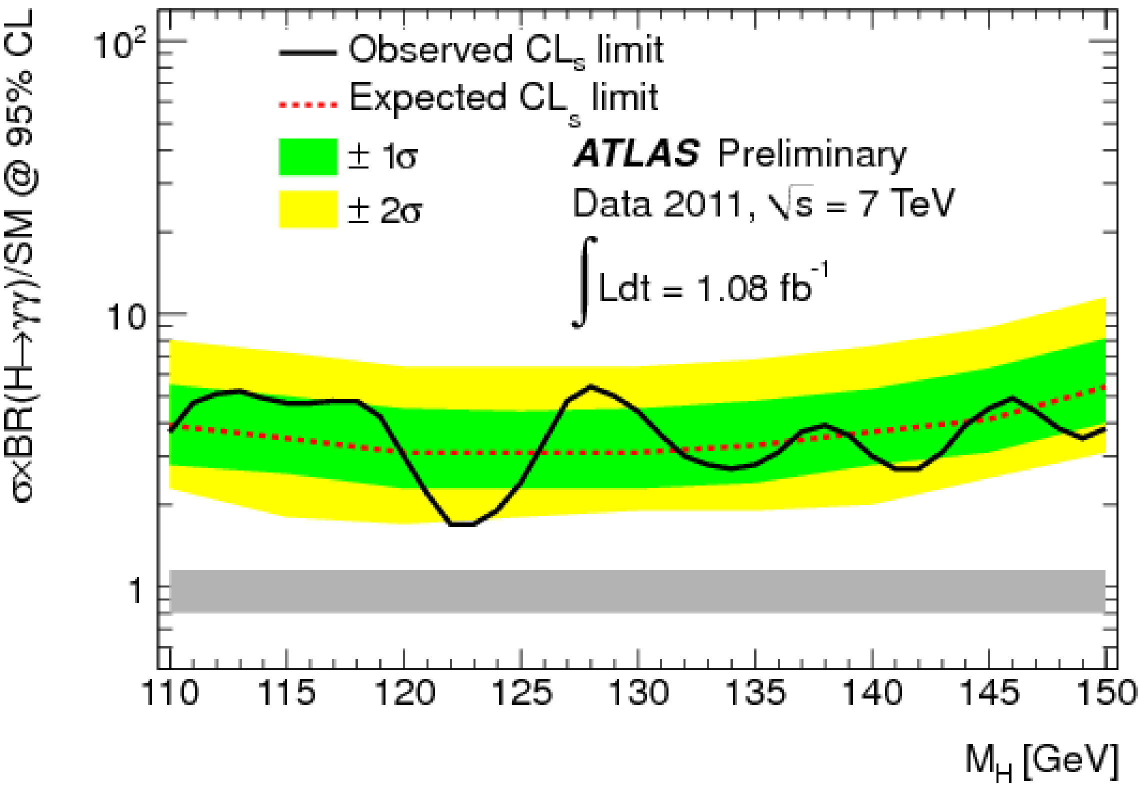
H→$\gamma\gamma$ results

- Measure the SM background using control samples
  - analyze photon isolation and identification criteria (loose-tight) to extract the $\gamma\gamma$, γj, and jj components
- Perform the analysis of the data classifying the events in 5 categories
  - these are based on the direction of the photons in η and on whether they are converted-unconverted
- Fit the data in each category with an exponential falling distribution plus a crystal-ball function to describe the signal





H→γγ limit



Systematic uncertainties	
Signal yield	±12%
Invariant mass resolution	±14%
Background modeling, $m_{\gamma\gamma}$ = 110(150) GeV	±5(±3) events

We exclude ~ 4 the SM production cross-section × BR

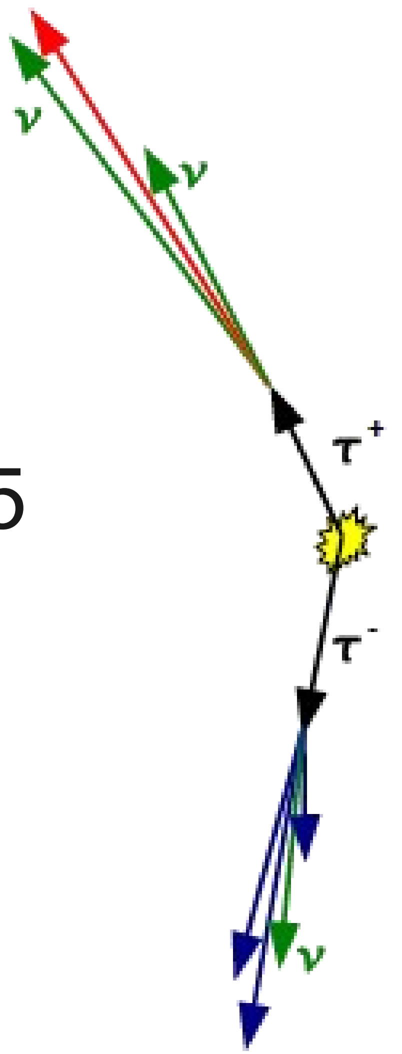
- 95% C.L. exclusion limits using the CLs method on the production cross-section relative to the SM cross-section
- Channel is currently statistical limited
- Relative good stability with respect to high pileup conditions
- Channel is not degrading rapidly for decreasing Higgs masses

Search for H$\rightarrow\tau\tau$

- Promising channel for SM Higgs searches in the mass range $110<m_H<140$ GeV
- The VBF production offer the advantage of a small background, at the price of a low signal production rate
- However, so far not sufficient events collected to fully exploit the VBF forward jet signature
- Three classes of final states, depending on the τ-decay:
    - lepton-lepton, *ll*
    - lepton-hadron, *lh*
    - hadron-hadron, *hh*
- ATLAS has studied the *ll* and *lh* final state
- Most important backgrounds:
    - $Z/\gamma^* \rightarrow$ ll + jets ($\rightarrow \tau\tau$ is largely irreducible)
    - $W \rightarrow l\nu$ + jets
    - dibosons, ttbar and single top, QCD jets

$H \to \tau\tau$ event selection

- Selection for ll
  - 2e, or 2μ or 1e1μ
  - p_{Te} > 15 GeV, $|\eta_e|<2.47$
  - $p_{T\mu}$ > 10 GeV $|\eta_\mu|<2.5$
- At least 1 jet with p_{Tj} > 40 GeV, $0.5<|\eta_j|<4.5$
- ETmiss > 30 GeV for 2e/2μ, > 20 for eμ
- $30<m_{ll}<75(100)$ GeV for 2e/2μ (eμ)
- $0.3<\Delta\Phi_{ll}<2.5(2.8)$ for 2e/2μ (eμ)
- reconstruct the tau momentum in the collinear approximation
  - good MET resolution is essential
- $m_{\tau\tau j}>225$ GeV

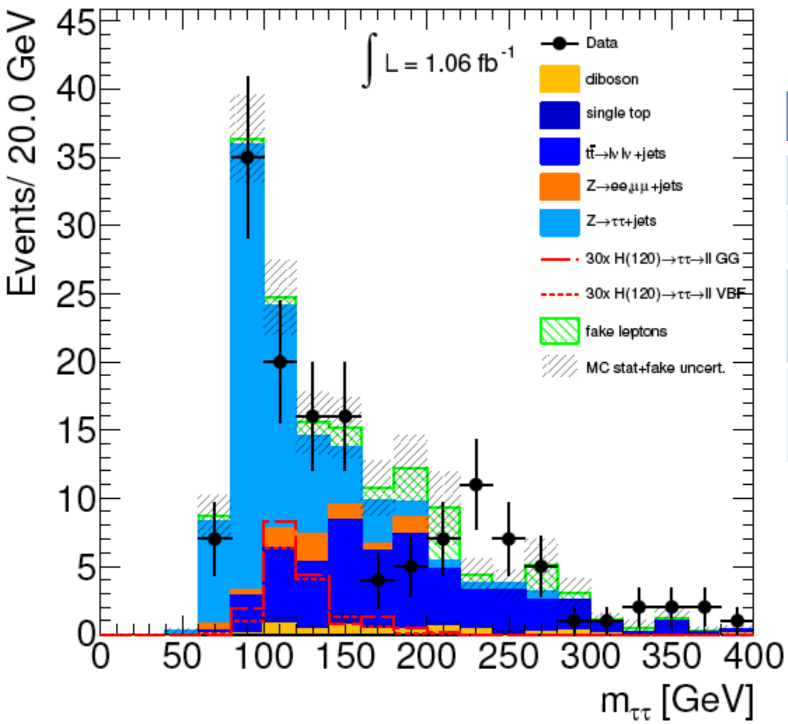


$$x_{1,2} = \frac{p_{vis1,2}}{(p_{vis1,2} + p_{mis1,2})}$$

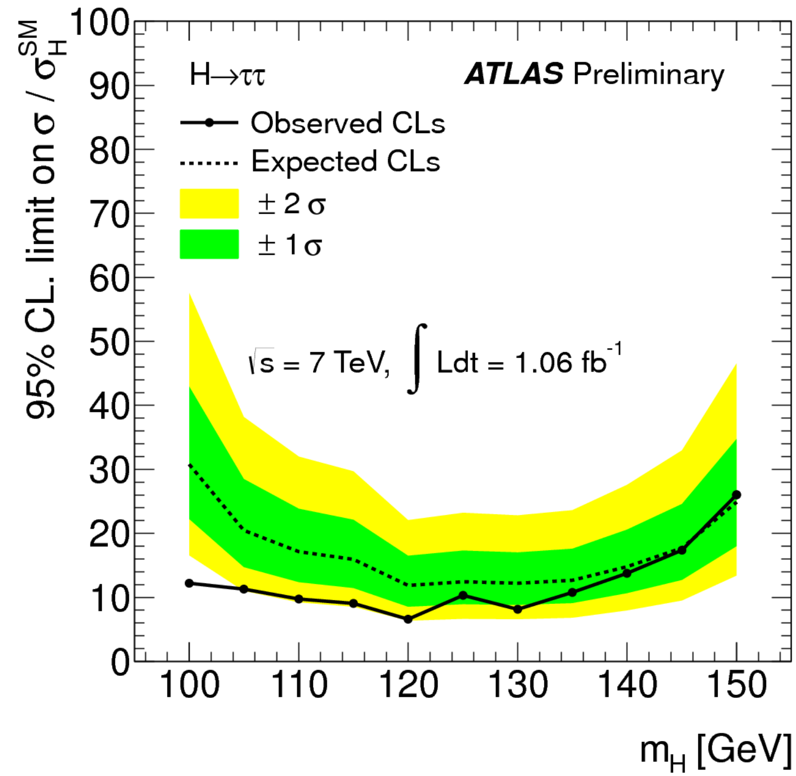
$$m_{\tau\tau} = \frac{m_{vis}}{\sqrt{x_1 x_2}}$$

Collinear approximation

H→ττ results



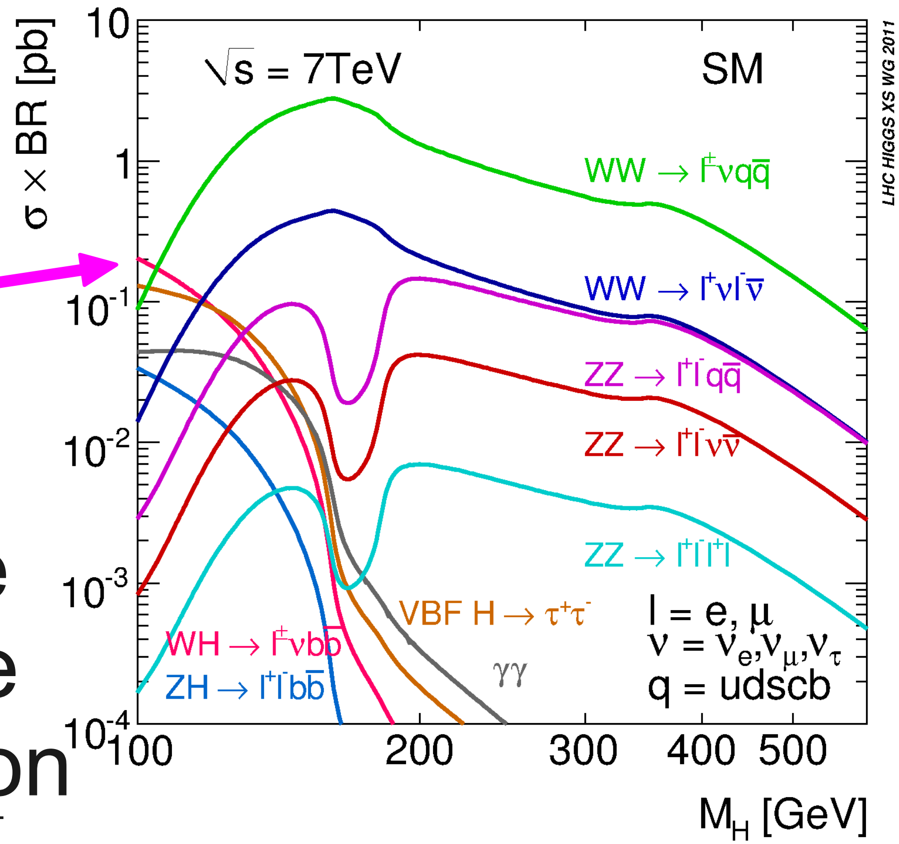
	yield
observed	**46**
expected	**47.4±3.9**
gg → H (120 GeV)	**0.44±0.05**
VBF H (120 GeV)	**0.38±0.02**



- **Systematic uncertainties**
  - Dominated by the jet energy scale: background: +7.0% -9.8%; Higgs(120 GeV) +7.8% -4.1%
  - Also important contribution from Etmiss
- **Analysis is limited by the available integrated luminosity**
  - Full potential only with VBF forward jet and central jet veto selection
- **Analysis depends critically on MET and jets**
  - High pileup conditions will hurt

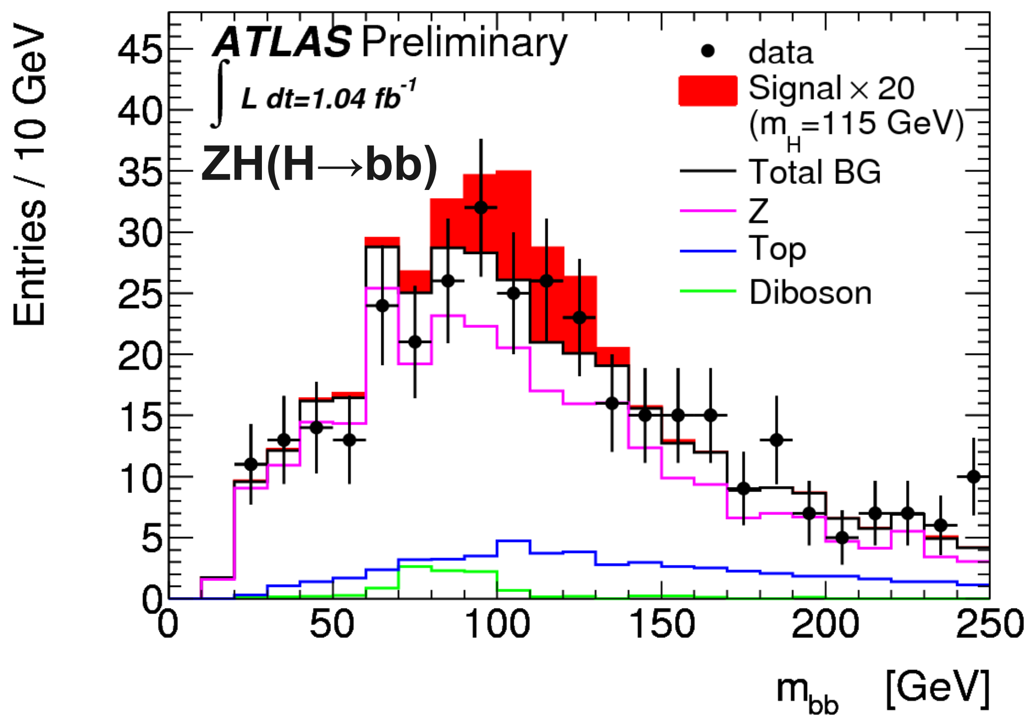
Search for $H \to b\bar{b}$

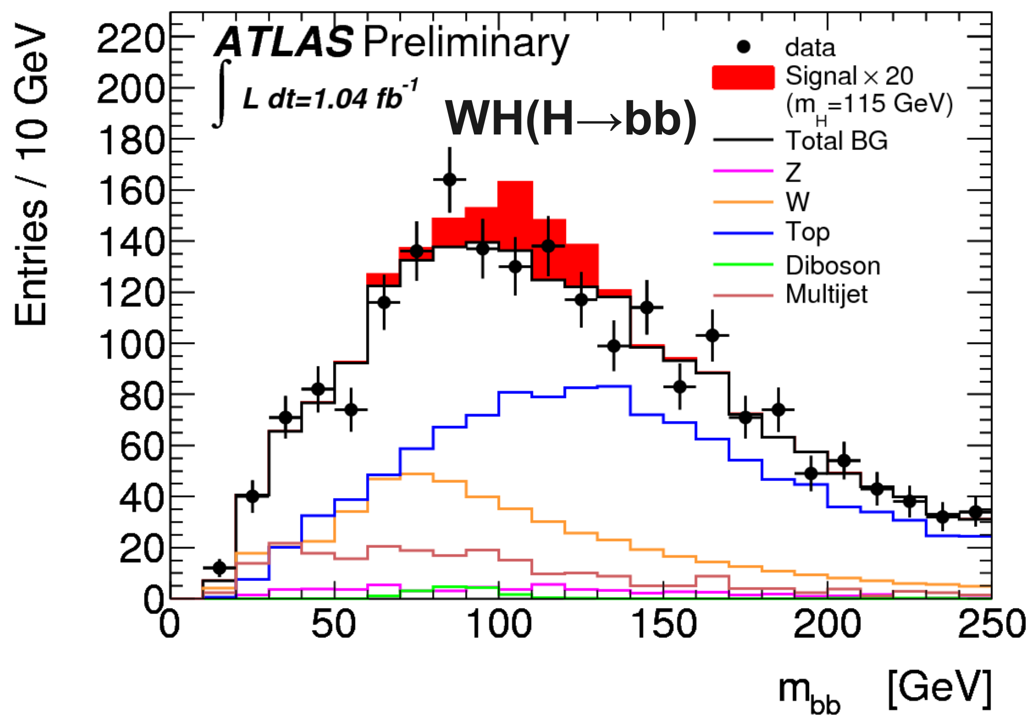
- The decay of the SM Higgs boson to $b\bar{b}$ is of particular importance as this is one of the few channels that offers experimentally the possibility of measuring directly Higgs to quark couplings
- It may also play an important role for the search in the low mass region
- $b\bar{b}$ is the dominant Higgs channel at low mass
- but the QCD jet background makes this search impossible in the inclusive channel, while it is promising in the production in association with W,Z and $t\bar{t}$



Search for $H \rightarrow b\bar{b}$

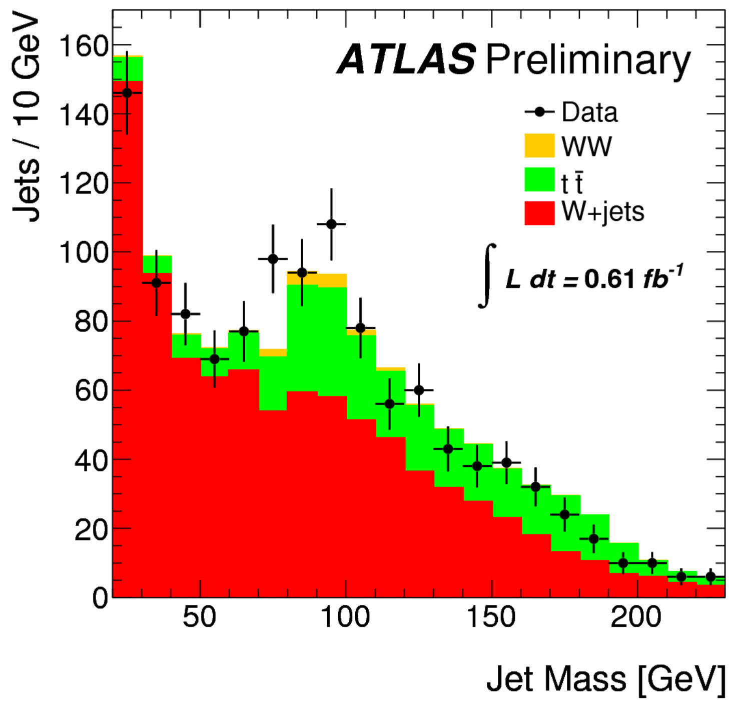
- Select events with a Z(W) boson in the leptonic final state
- The leptons are also used to trigger the event
- At least (exactly) two b-tagged jets with p_T>25 GeV
- Backgrounds: W+(b-)jets, Z+(b-)jets, top, QCD jets
- Background systematic uncertainties are crucial

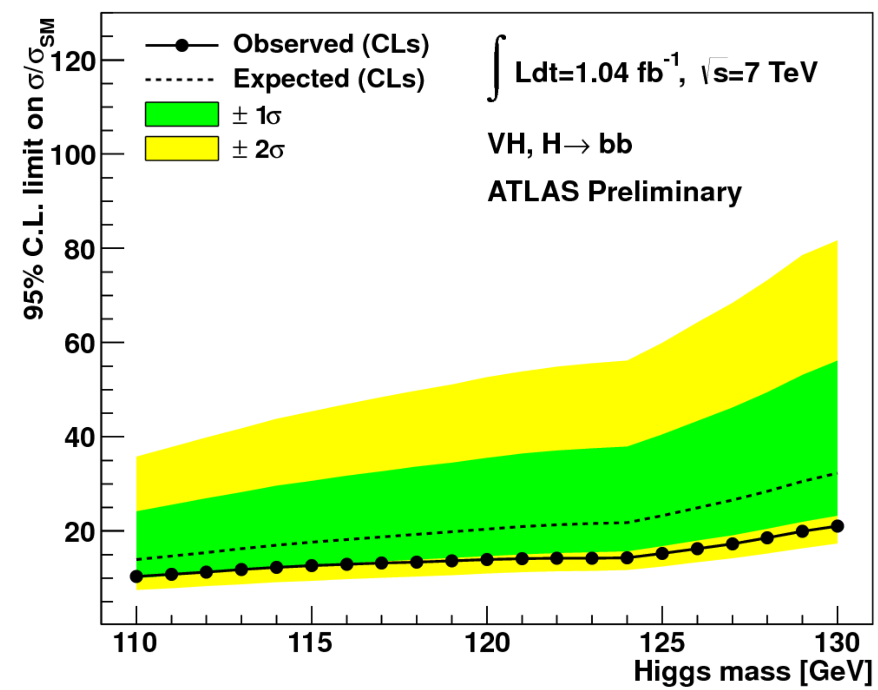




Search for $H \to b\bar{b}$

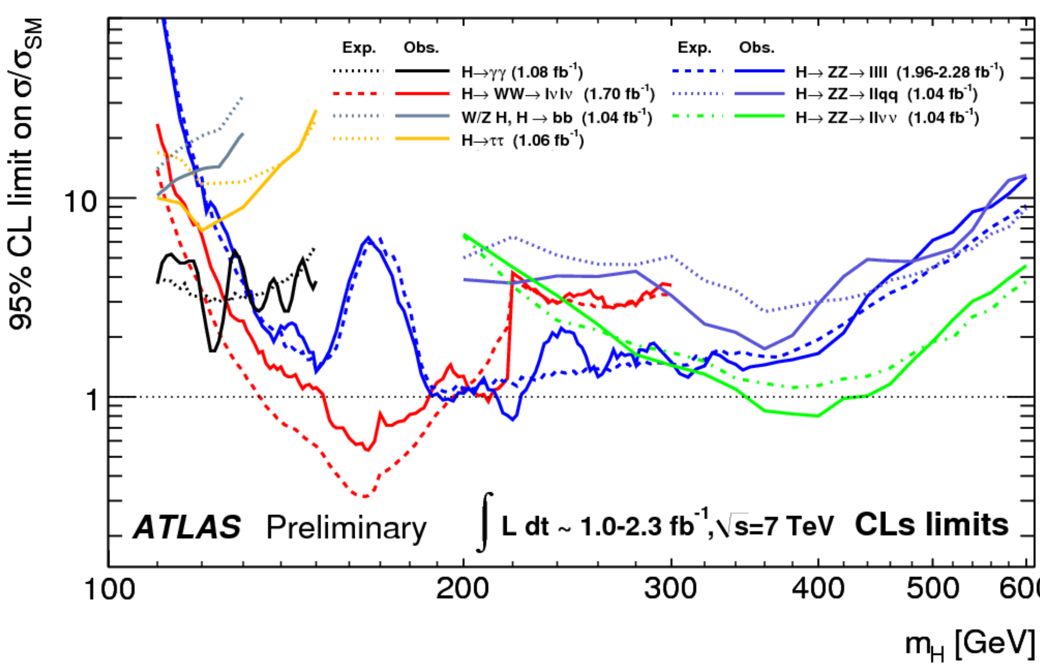
- Dominant systematic uncertainties
  - Jet energy scale/resolution, pileup, b-tagging
  - MC: cross sections and shapes
- Analysis is currently limited by the available integrated luminosity
  - However, systematics will be critical when approaching the SM
- Analysis depends critically on jets and b-tagging
  - High pileup conditions will hurt
- With more luminosity:
  Improve sensitivity with the boosted $H \to b\bar{b}$ topology

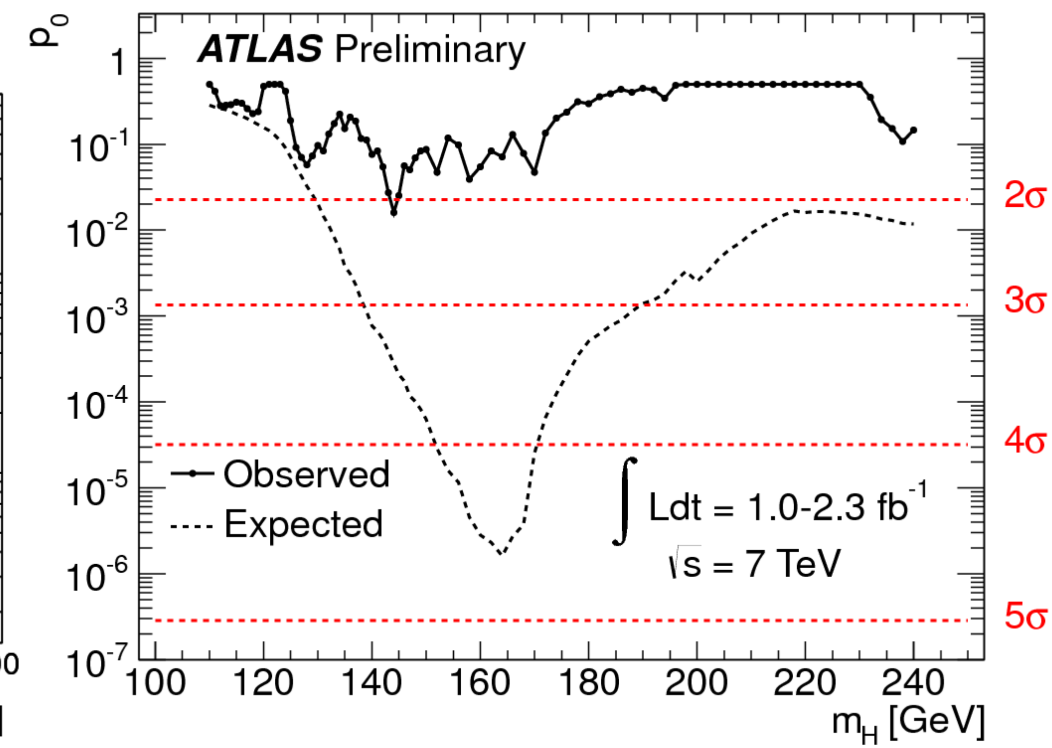




Summary

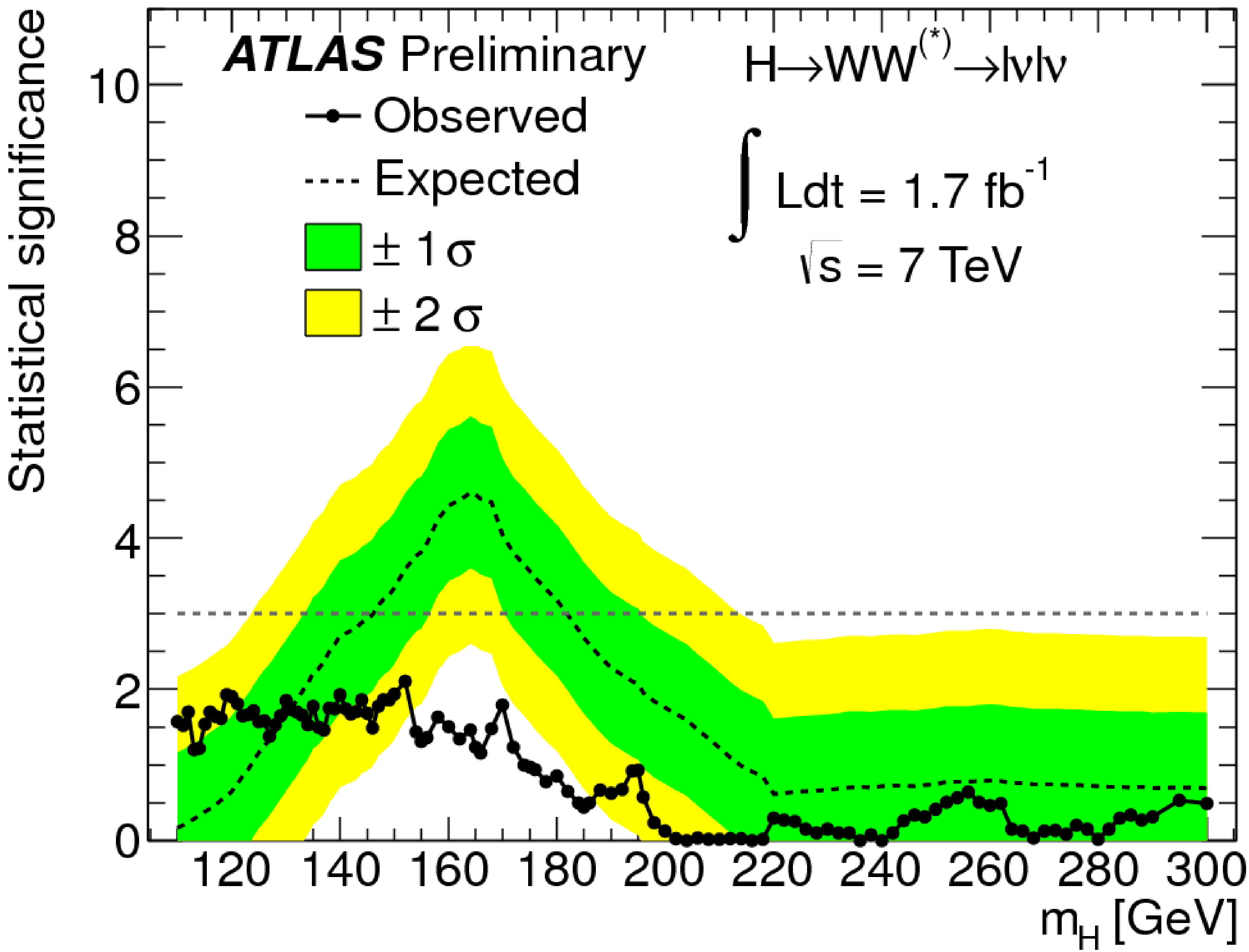
- Data with an integrated luminosity between 1 and 2.1 fb^{-1} have been analyzed by ATLAS in the SM Higgs searches for the WW, ZZ, $\gamma\gamma$, $\tau\tau$ and bb final states
- No significant excess seen so far
- See next session for the details of the ATLAS Higgs combination
- LHC 2011 run has ended: ATLAS recorded more than 5 fb^{-1} !
- 2012 will be very exciting for SM Higgs searches.
  Not much room left!



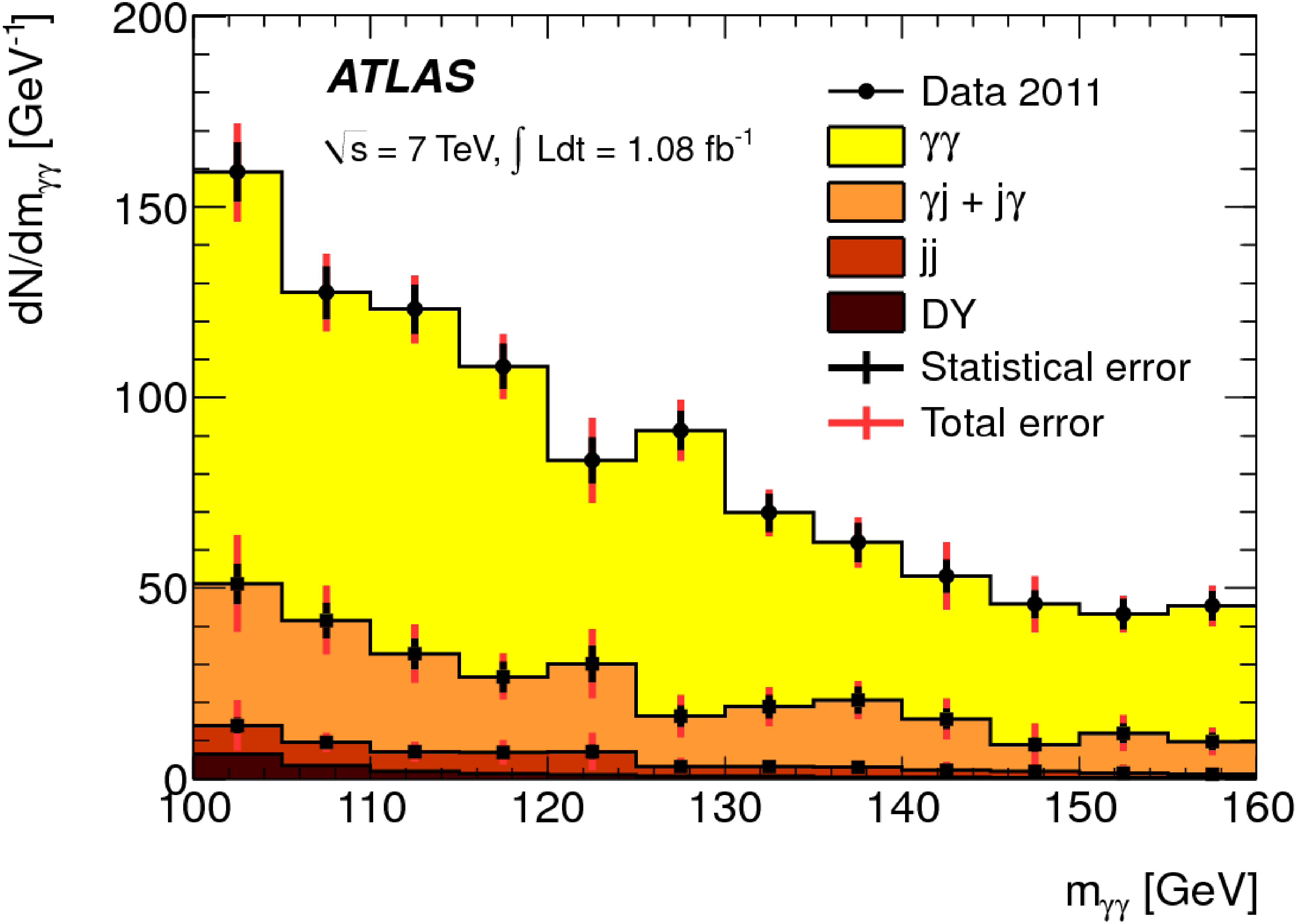


Backup

Search for H→WW with 0 or 1 jet

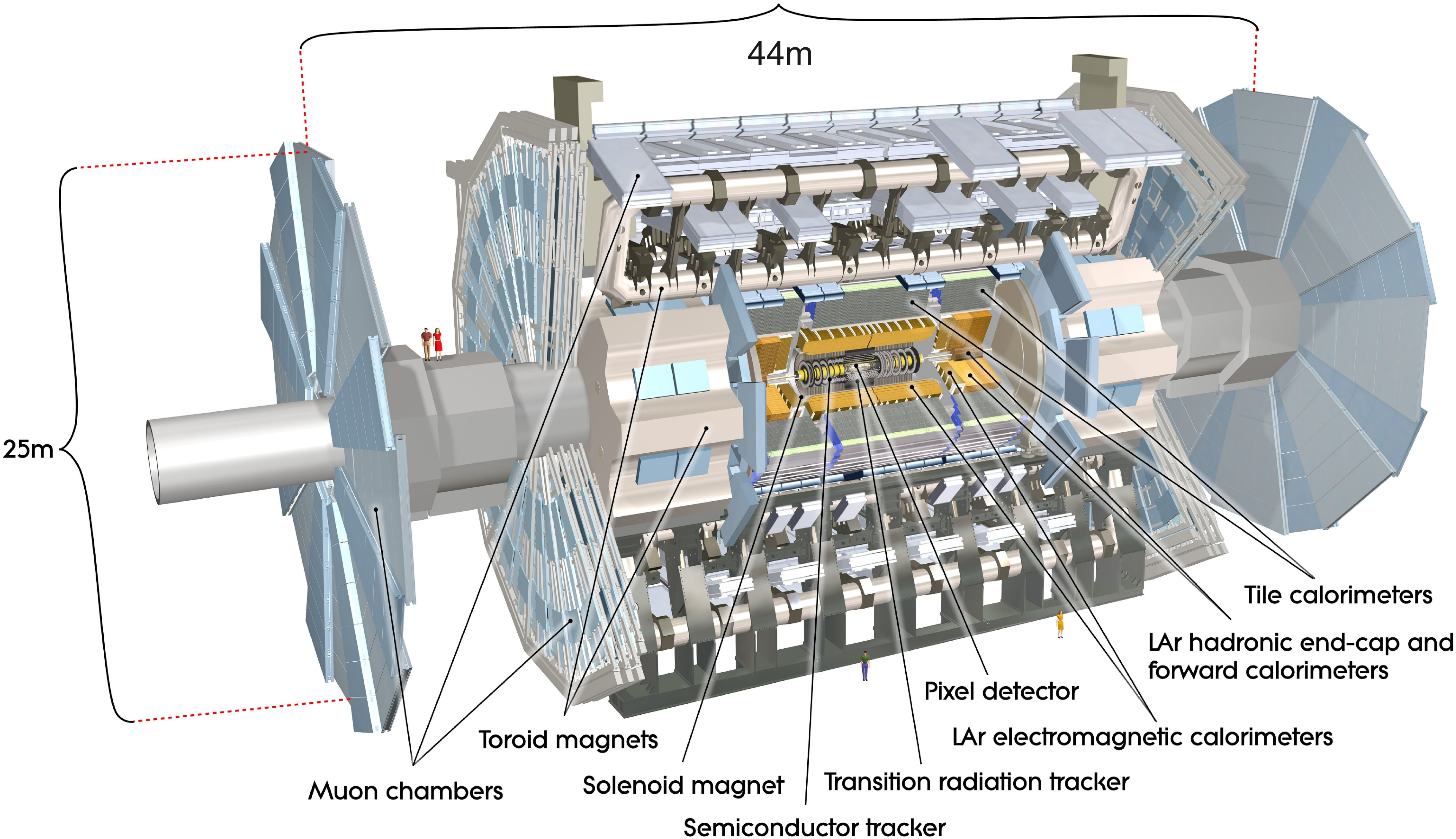


H→γγ background

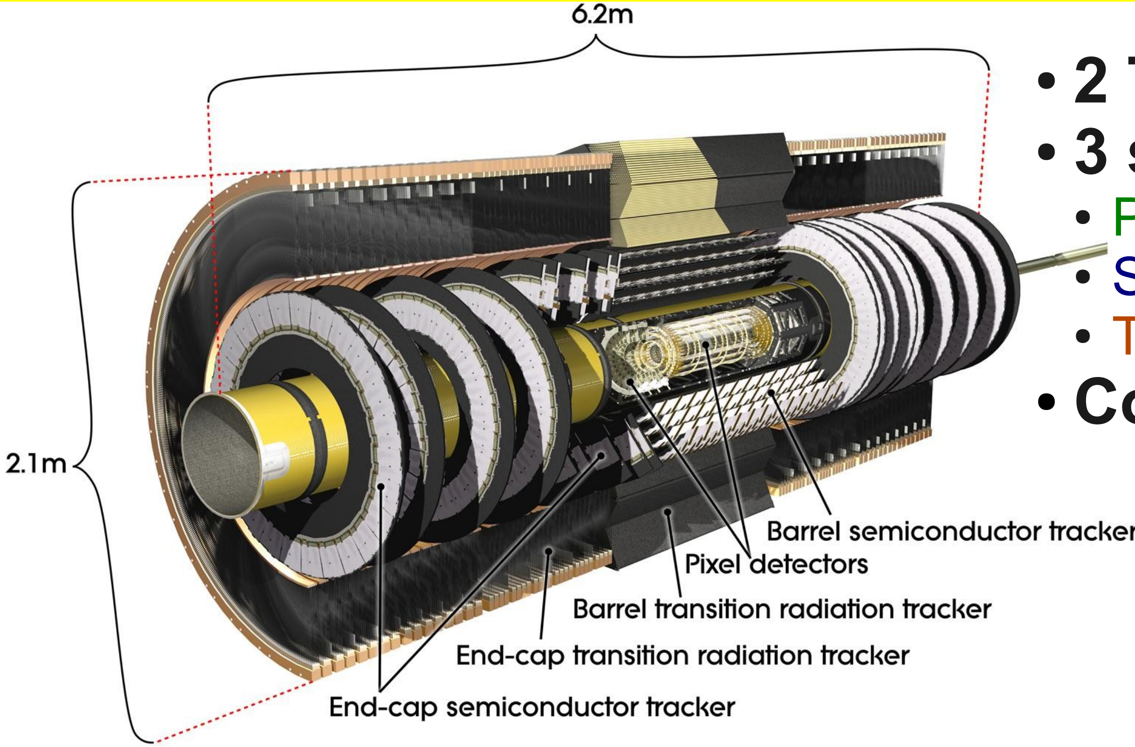


The ATLAS Detector

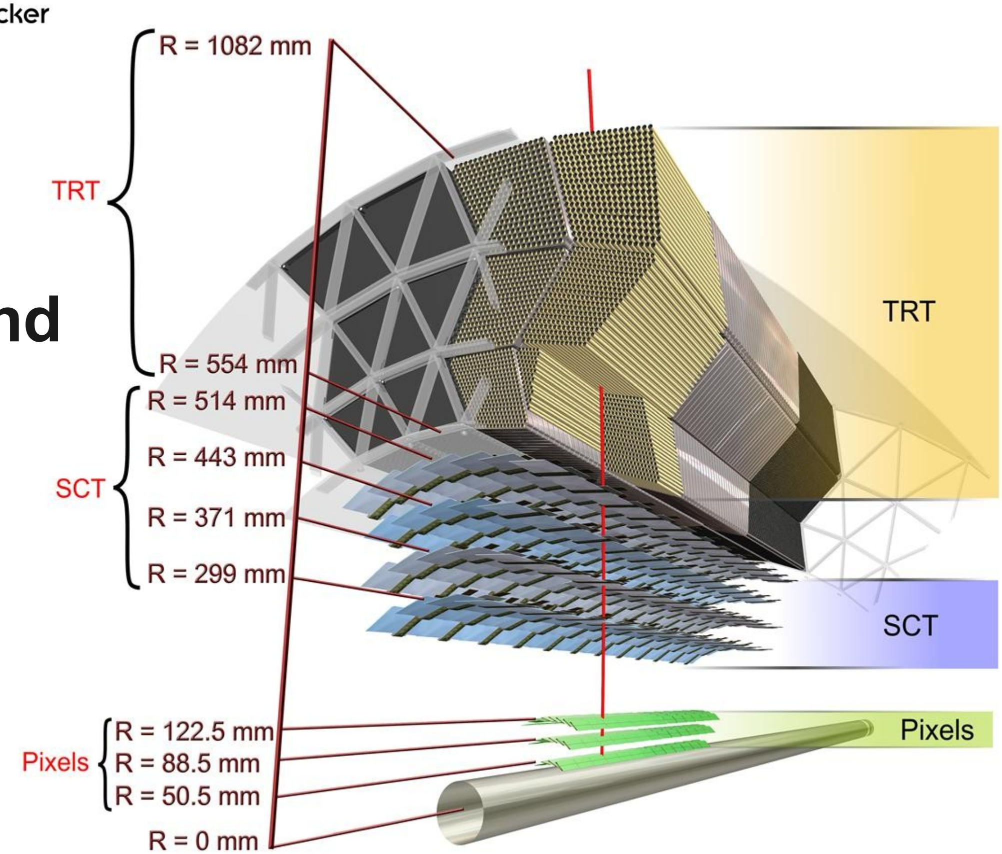
In parallel to physics with first data: Detector commissioning and understanding!



Inner Detector



- **2 Tesla solenoid field**
- **3 sub-detectors: (resolution)**
  - Pixel detector: 10/115 μm
  - Silicon strip detector (SCT): 17/580 μm
  - Transition radiation tracker (TRT): 130 μm
- **Coverage up to |η| < 2.5**

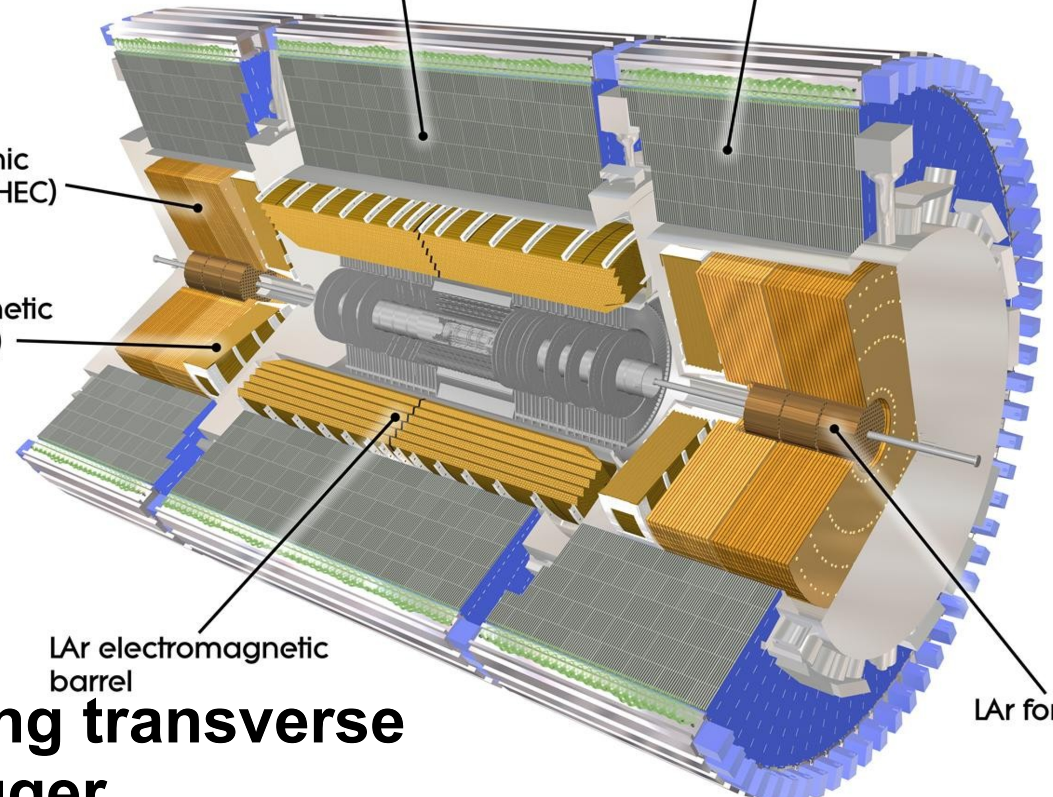


The Inner Detector (ID) gives around
- **3 Pixel**
- **4 SCT pairs**
- **36 TRT**

precision measurements per track and allows for accurate track and vertex reconstruction

Calorimeter system

- Electromagnetic accordion calorimeter (LAr)
  - Precision measurement of photons and electrons
  - $|\eta|<3.2$
  - Intrinsic resolution ~10%/√E
- Hadronic calorimeter
  - Scintillator Tile calorimeter $|\eta|<1.7$
  - Hadronic endcap (LAr) $1.5<|\eta|<3.2$
- Forward calorimeter (LAr)
  - $3.2<|\eta|<4.9$



- Altogether gives hermetic coverage up to $|\eta|<4.9$
- Essential for the reconstruction of jets, the missing transverse momentum and for the trigger

Muon Spectrometer

- Tracking and trigger
- 4 detector types :
  - Monitored drift tubes
  - Cathode drift chambers
  - Thin-gap chambers
  - Resistive plate chambers
- $|\eta|$ coverage up to 2.7
- Magnetic field produced by 3x8 large coils + End-cap toroids
- Up to 4T magnetic field