ATLAS group status report.

78th DESY Physics Research Committee meeting

Elisabeth Petit
on behalf of the ATLAS group
Zeuthen, 17th of October 2014

HELMHOLTZ GEMEINSCHAFT

ATLAS

DESY

General review of activities

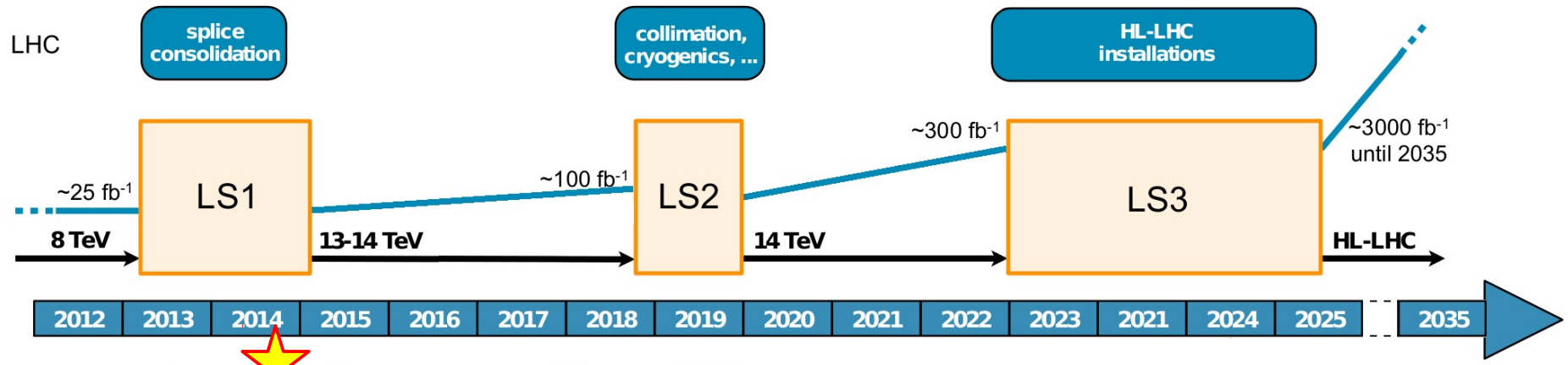
- Operation
  - Inner Detector Software
  - Current Semi Conductor Tracker (SCT)
  - Trigger
  - ALFA
- Detector upgrade
  - Insertable B-Layer IBL (Phase 0)
  - Fast Track Trigger (FTK, Phase 1)
  - Inner Tracker Upgrade (Phase 2)
  - Test Beam Telescope
- Computing
  - Tier 2, NAF, condition data base
- Physics objects performance
  - electron/photon
  - jet and missing energy
- Physics analyses
  - Standard Model: Z/DY production, WW production, jet production
  - Top: $t\bar{t}$ resonances, $t\bar{t}$+jets production, top properties, single-top FCNC
  - Higgs: SM $H \rightarrow \gamma\gamma$, BSM Higgs
  - Generator & PDFs: mass production and validation (HepMCAnalysis), new generators setups, generator tuning, derivation and impact studies of PDFs

People + responsibilities

- 65 members
  - 15 staff, 2 YIG, 16 fellows, 26 PhD students, 6 support staff
- Positions in the ATLAS collaboration:

General management and boards	Judith Katzy	Speakers committee
	Michael Medinnis	SCAB chair
	Klaus Mönig	Panel for Operation Task Sharing
Detector operation and upgrade	Ingo Bloch	Module activity coordinator
	Sergio Diez Cornell	Support structure coordinator
	Ingrid Gregor	ITk Strip project leader
	Karl-Heinz Hiller	ALFA project leader
	Marcel Stanitzki	ITk CMOS Sensors
Computing	Ewelina Lobodzinska	MC software manager
	David South	Reprocessing coordinator
	Nicholas Styles	Inner detector software coordinator
	Voica Radescu	Conditions Database Coordinator
Physics and performance	Stefano Camarda	MC tuning convener
	Stefano Camarda	PDF forum convener
	Cécile Deterre	Top properties subgroup convener
	Alexander Grohsjean	Top LHC MC contact
	Alexander Grohsjean	Top systematic convener
	Kristin Lohwasser	Electron ID subgroup convener
	Elisabeth Petit	Photon ID subgroup convener
	Voica Radescu	Convener of HERAFitter
	Kerstin Tackmann	egamma group convener

LHC timeline



SCT Operation
monitoring
calibration
digitisation

ALFA
commissioning
calibration
measurement

Phase 0 - IBL
test beam
fibre
installation
commissioning

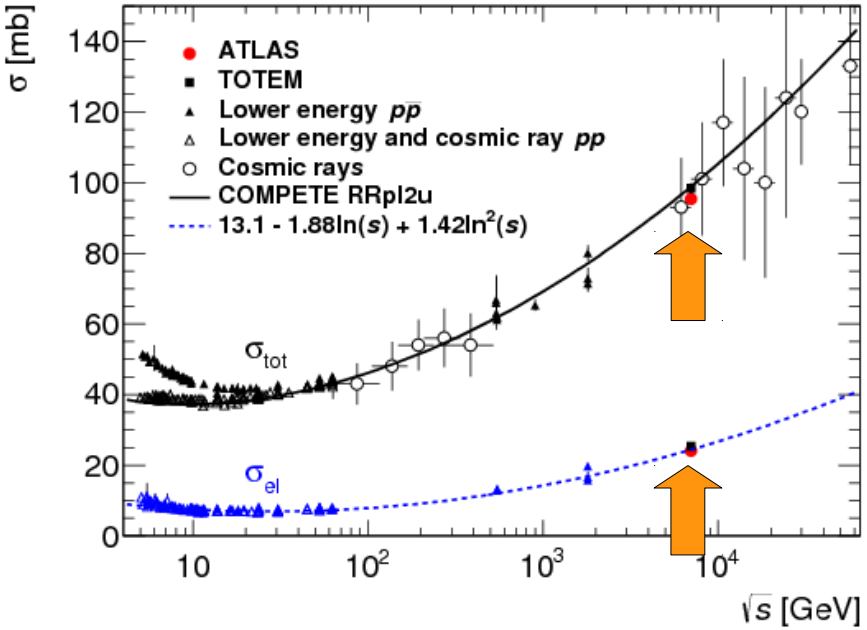
Phase 1 - FTK
simulation
optimisation

Phase 2 – Tracker Endcap
"PETAL2014"
Sensor studies
electronics
mechanics
upgrade simulation

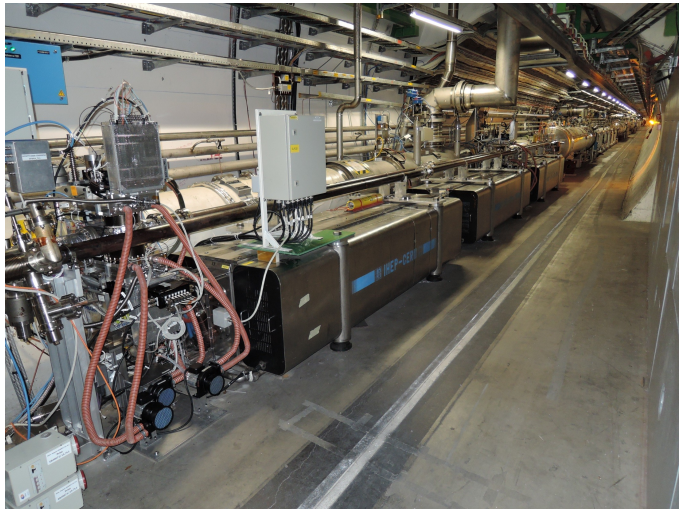
Detector and Operation

ALFA Roman pots stations

- Measurement of elastic and total cross sections analyzing elastic scatting using optical theorem
- Measurement at 7 TeV with best precision: σ_{tot} = 95.35 ± 1.36 mb
  - TOTEM error: 2.2 mb
- Work for 8 TeV in progress



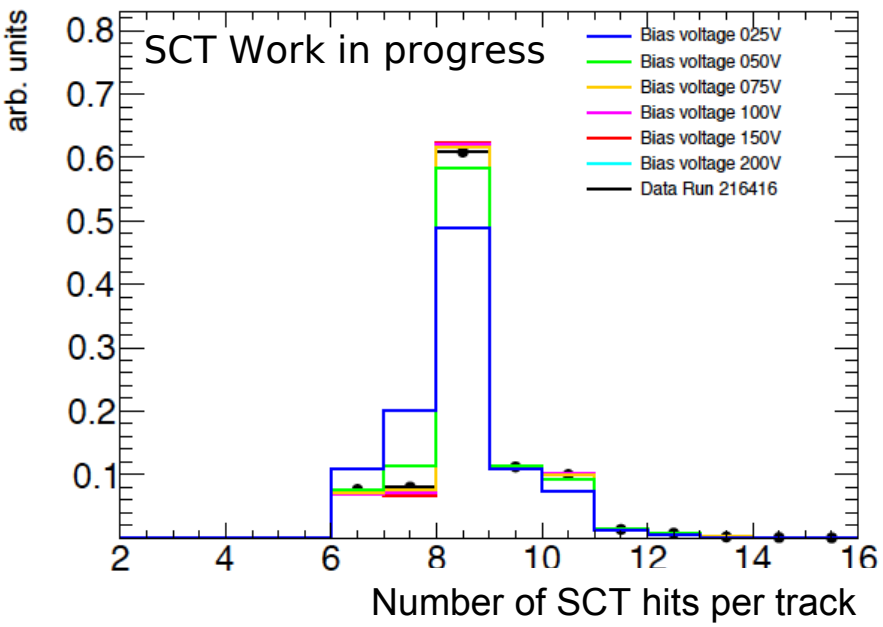
- In LS1 all Roman Pot stations at surface assembled to cope with heating at higher beam intensities
- All stations back in the tunnel, equipped with detectors and ready for run 2



SCT

- SCT being recommissioned for run 2
  - calibration loop working again
  - Sonar now being extended to the whole inner-detector

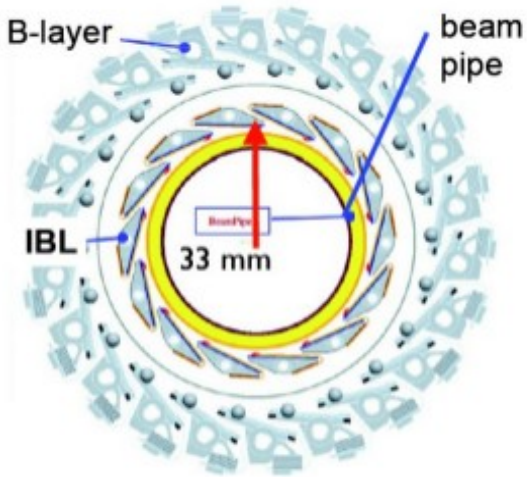
- Need realistic simulation of detector response, e.g. charge collection, crosstalk with increased radiation in run 2
  - software preparation for run 2 framework
  - study impact of sensor and readout parameters on tracking performance in digitization
  - comparison of SCT simulation with 8 TeV data using minimum bias events under similar pileup conditions



Pixels "Insertable B Layer"

> New Pixel layer, IBL

- Surrounding new, smaller radius beampipe
- 75% planar sensors, 25% 3D sensors
- Radiation levels: ~5x10^{15} neq/cm^2



> DESY ATLAS contributions

- Detailed test beam study of IBL sensors and modules
- Procurement of optical fibres for data transmission

> Status

- IBL successfully inserted by ATLAS in May!
- Commissioning ongoing

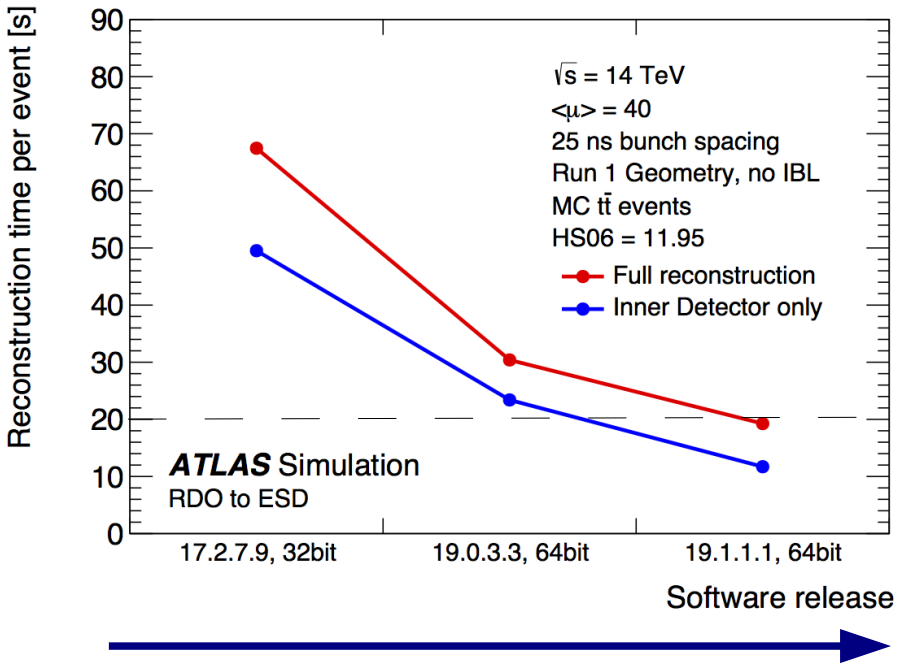
Computing

- DESY-IT provides vital resources to the ATLAS group at DESY and beyond
  - large Tier-2 resources, including 2 PB of dedicated Grid space for analysis
  - NAF-2 transition completed without problems; SL5 essentially also phased out now
  - NAF batch system and Sonas storage contribute to the success of DESY-ATLAS analysis

- DESY-ATLAS group played a key role in ATLAS LS1 activities, with responsibilities in data preparation and software development crucial to run 2
  - preparation of new conditions model to be deployed for new data taking
  - large scale reprocessing run 1 data samples during the summer
  - testing of new production system and analysis models for run 2

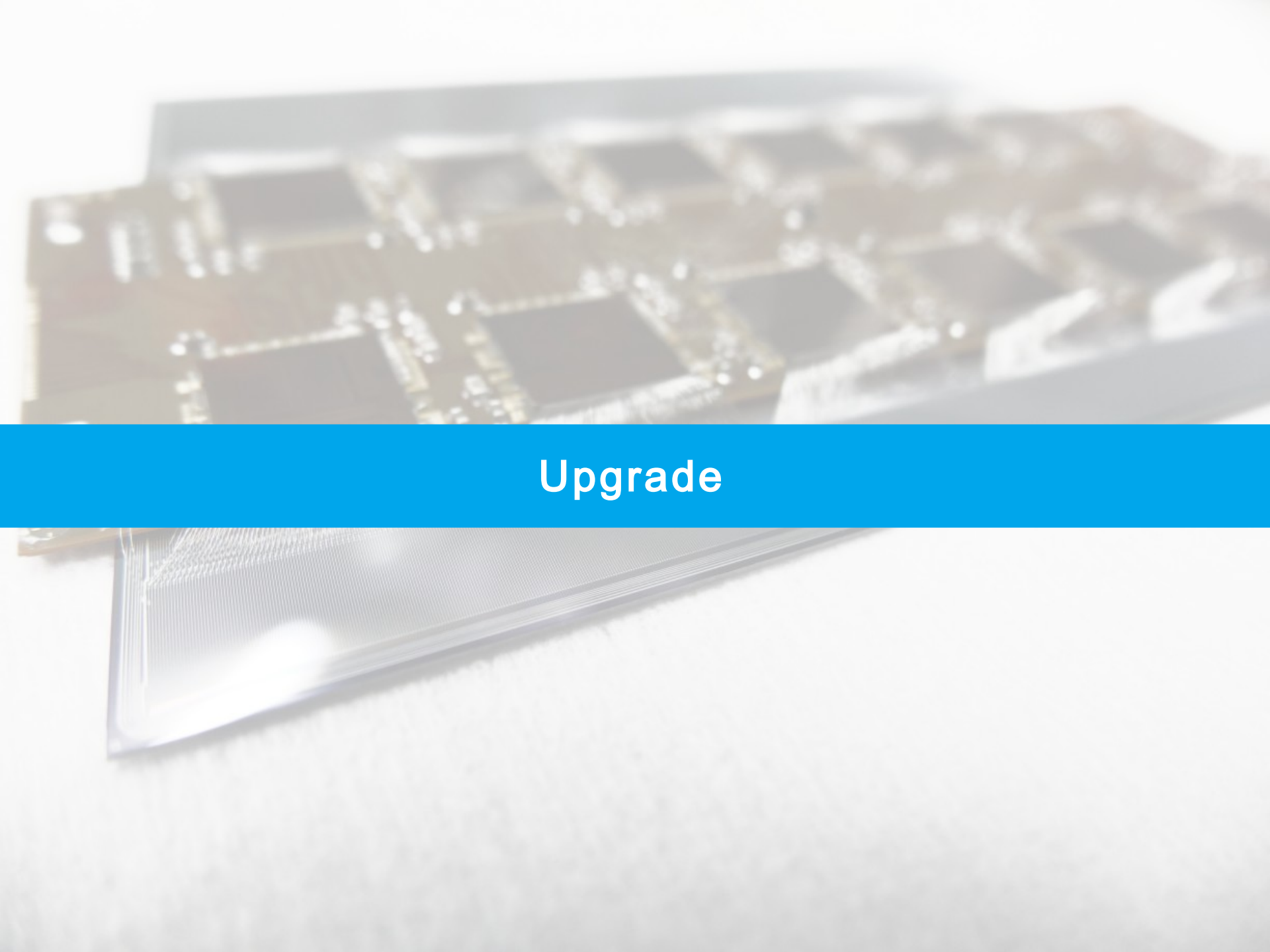
Tracking software improvements

- Inner Detector Tracking algorithms strongly affected by increased pile-up
  - reconstruction time x10 between 20 and 80 pile-up events
- Extensive process of software migrations and optimizations
  - changed maths library
  - optimized algorithm strategies
  - simplified Event Data Model (in conjunction with ATLAS-wide movement to new persistent output format, xAOD)
  - …



Software migrations and optimizations (starting from Run 1 software release)

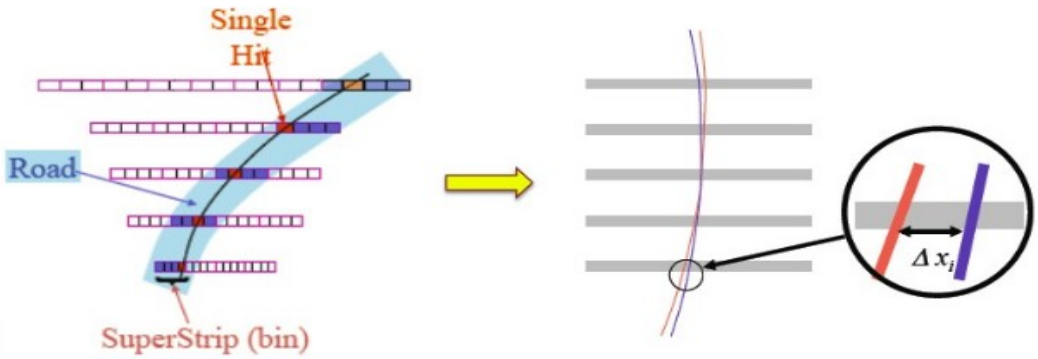
- Achieved > 3-fold improvement in reconstruction time
  - 20s per event average reconstruction time allows goal of 1 kHz prompt Tier-0 reconstruction at CERN Tier 0 to be met



Upgrade

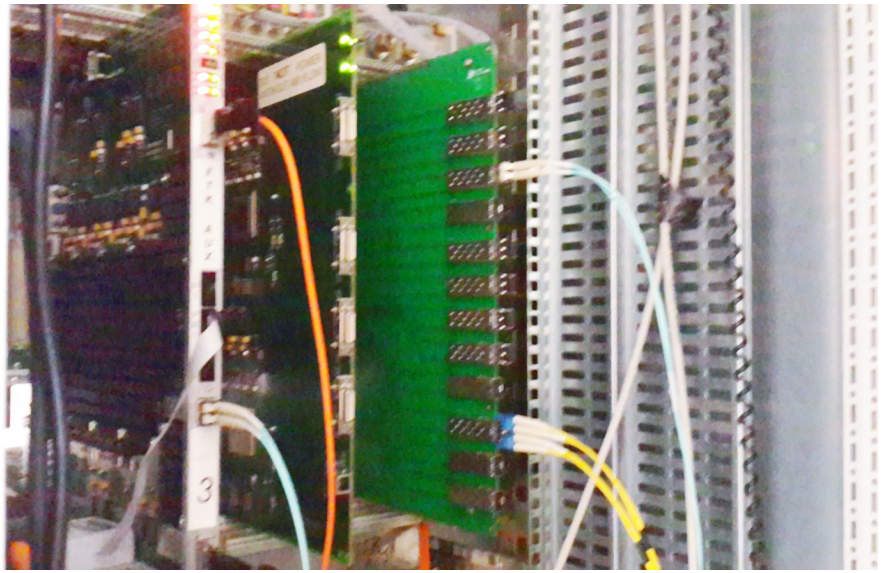
Phase I Upgrade – FTK

- Dedicated hardware-based track finder for silicon detector
  - runs after L1 trigger on additional Si-det readout links
  - tracking input for full event for L2 trigger
- Finds and fits tracks (25µs) in ID silicon layers with near offline precision



hit pattern matching to pre-stored patterns (coarse)

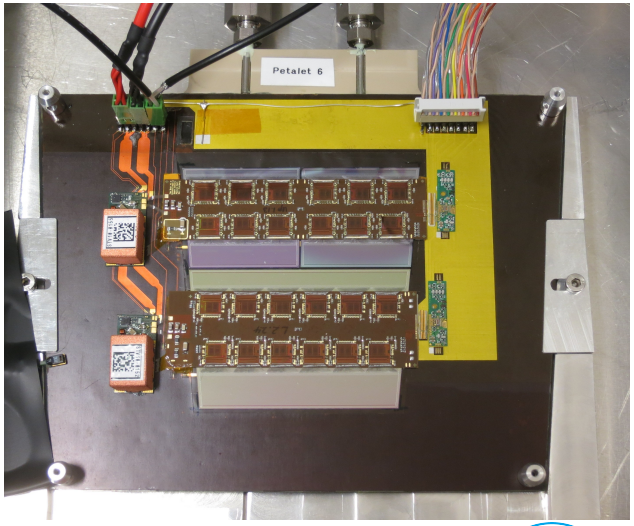
subsequent linear fitting in FPGAs (precise)



- DESY effort: 4 people
  - at CERN: hardware testing and installation (second stage board)
  - software for pattern banks
  - pattern Bank definition for 2015
  - FTK simulation
  - RDO&TP converters for FTK tracks

Phase II Upgrade – Si Strip Endcap @ DESY

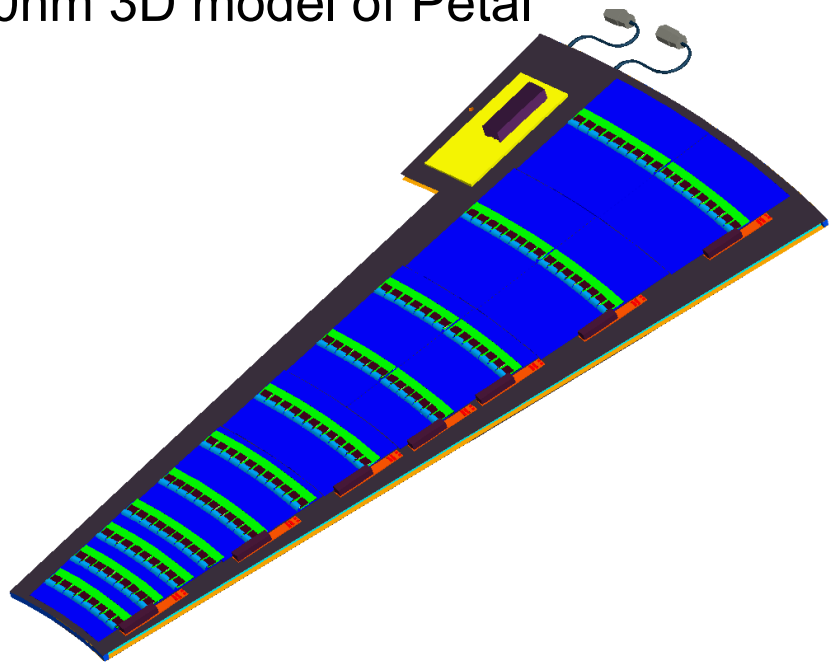
- Group target: assemble one of two Strip Endcaps
- R&D targets
  - construction and extensive tests of
    - electrical modules
    - small scale structures (PETALET)
    - full scale prototypes (PETAL ramping up effort here)
  - evaluation and HL-LHC qualification of current and alternative materials
  - integration of results obtained from R&D into detector design
  - begin of preproduction ~2017



- Petalets built as preliminary step towards petals
  - detailed tests of performance as function of voltage, temperature, shielding, etc.
  - to be wrapped up end of 2014/beginning 2015

Phase II Upgrade – Si Strip: new ASICs

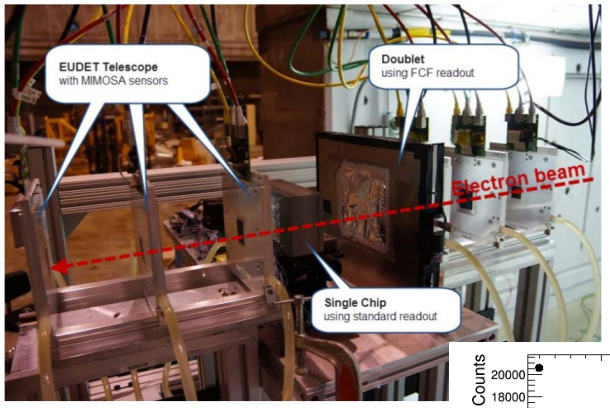
- Completing 250nm ASIC program
- Transition to 130nm ASIC + corresponding infrastructure
- Recently finished initial full 130nm 3D model of Petal
  - base model
    - integration / assembly studies
    - thermal and mechanical FEA

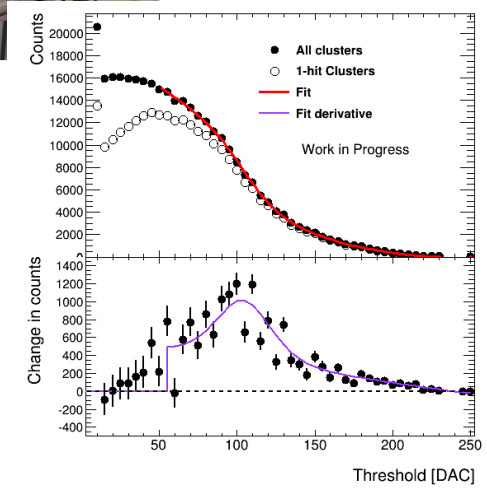


- Model provided basis for discussion and led to significant improvements in design, now being re-implemented in updated model

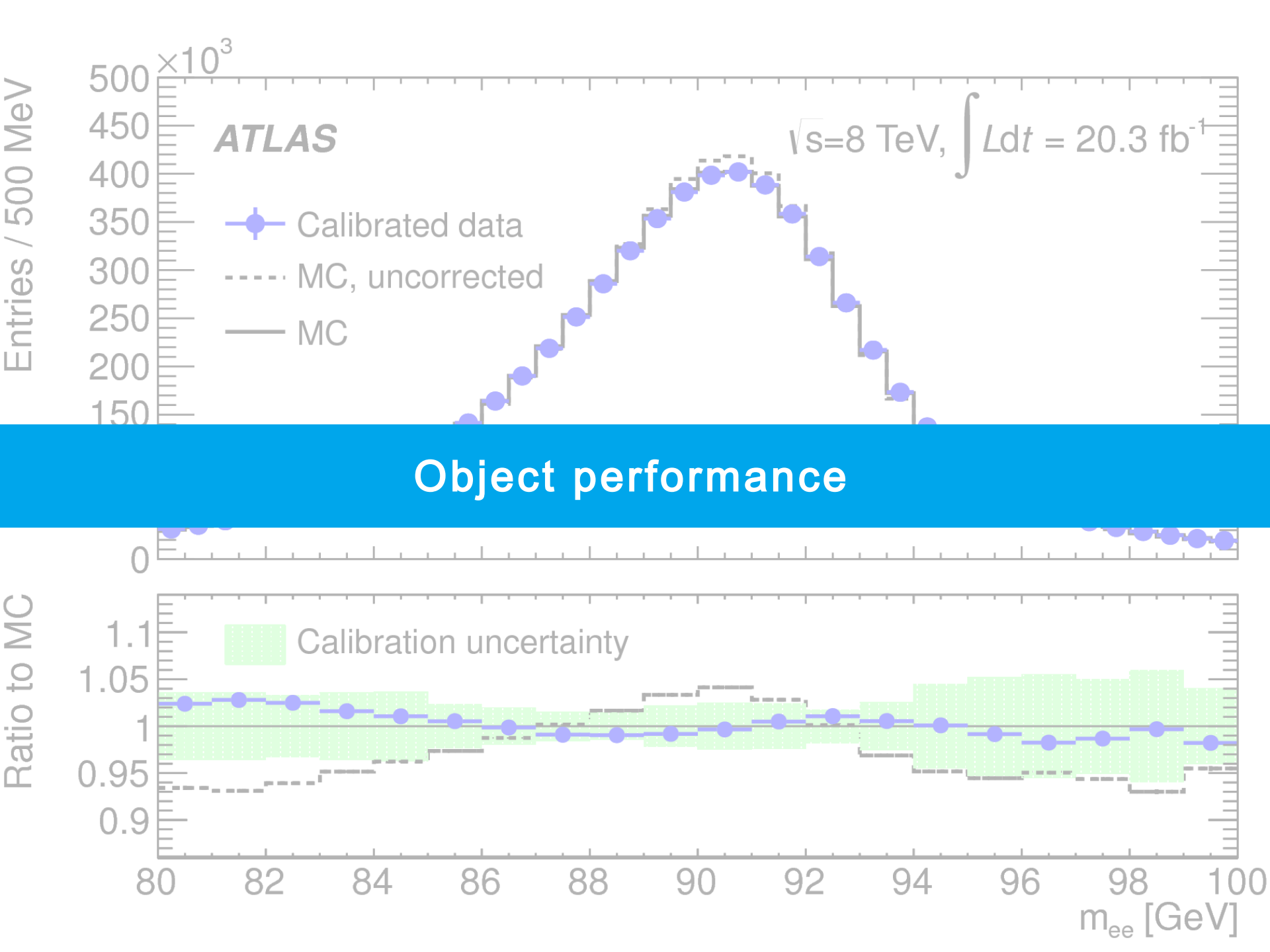
Phase II Upgrade – Si Strip Endcap

- New 130nm ASIC being studied, e.g. in test beam at SLAC
  - very good correlation between extrapolated beam position (from telescope) and measured hit in sensor
  - work in progress





- Studying CMOS as alternative to the baseline strip sensor
- Advantages
  - potential for savings in costs and material
- Technical implementation and radiation hardness to be understood
- Submissions for two CMOS processes made
  - studying performance and radiation hardness
  - first chips back in November 2014
- Currently preparing test setup at DESY

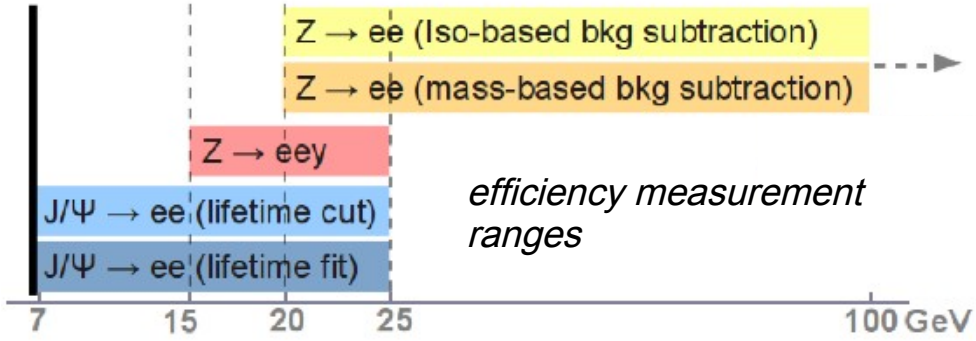


Object performance

Electron reconstruction and identification

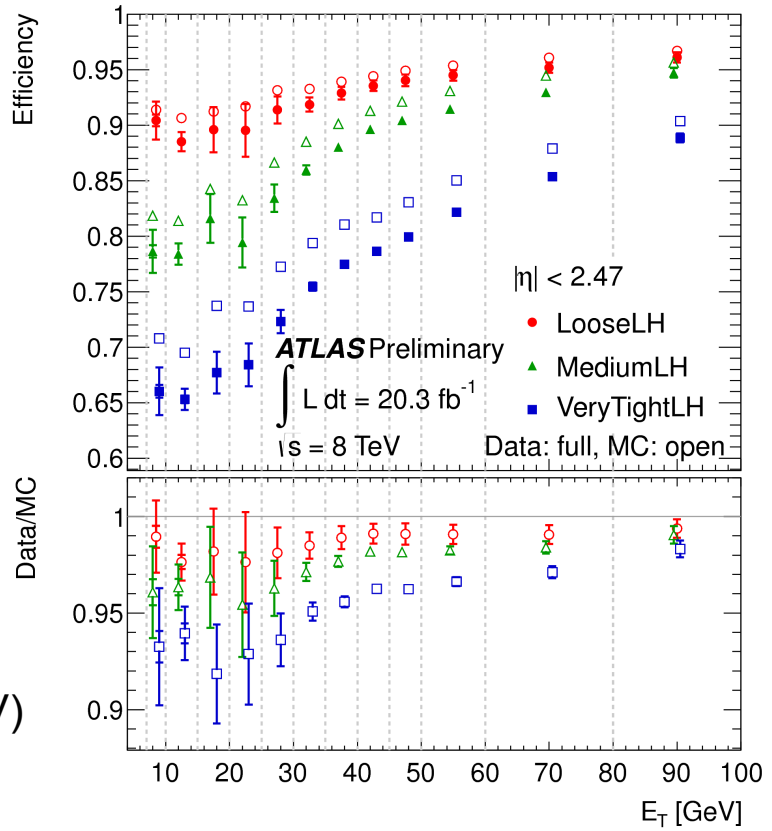
> Reconstruction

- large improvement for 2012 to recover electrons undergoing energy losses due to bremsstrahlung
- measured with Z → ee



> Identification

- cut-based + likelihood
- 4+3 working points
- 4 different measurements
- correction factors for MC

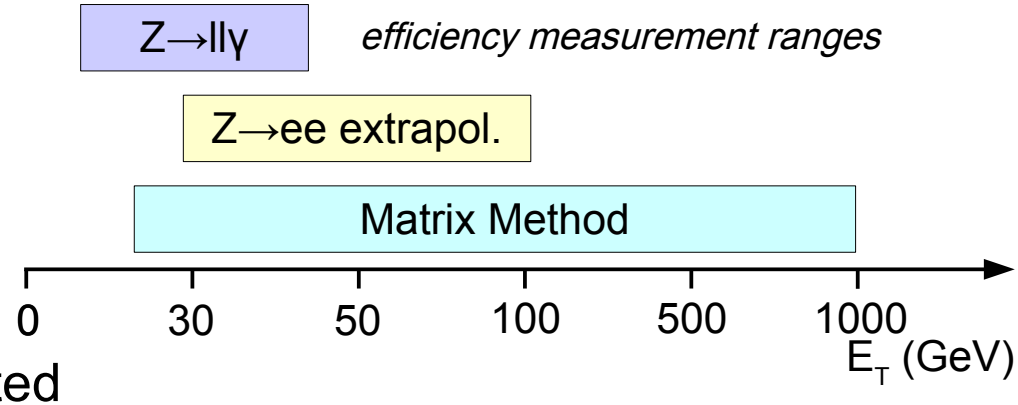


> Reco*ID efficiency uncertainties:

- ~3% (15-20 GeV)
- decreasing with E_T to 0.2% (35-40 GeV)

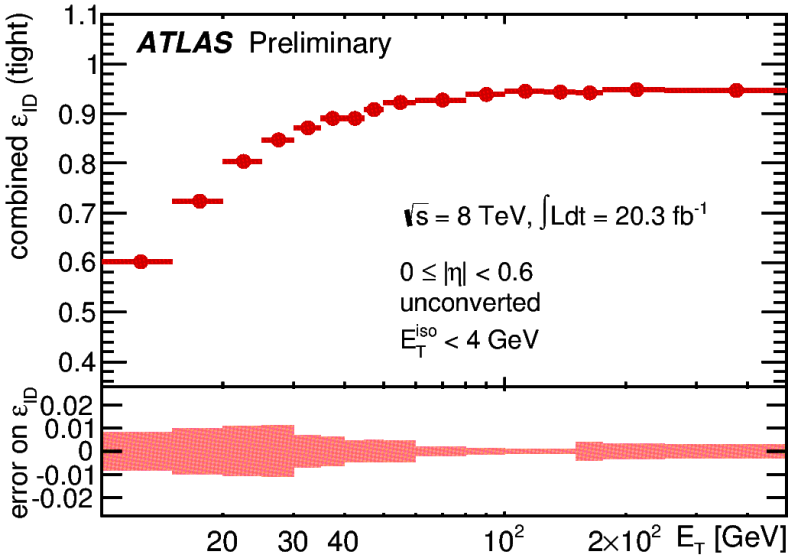
Photon identification

- Identification
  - 2 working points
  - 3 different measurements



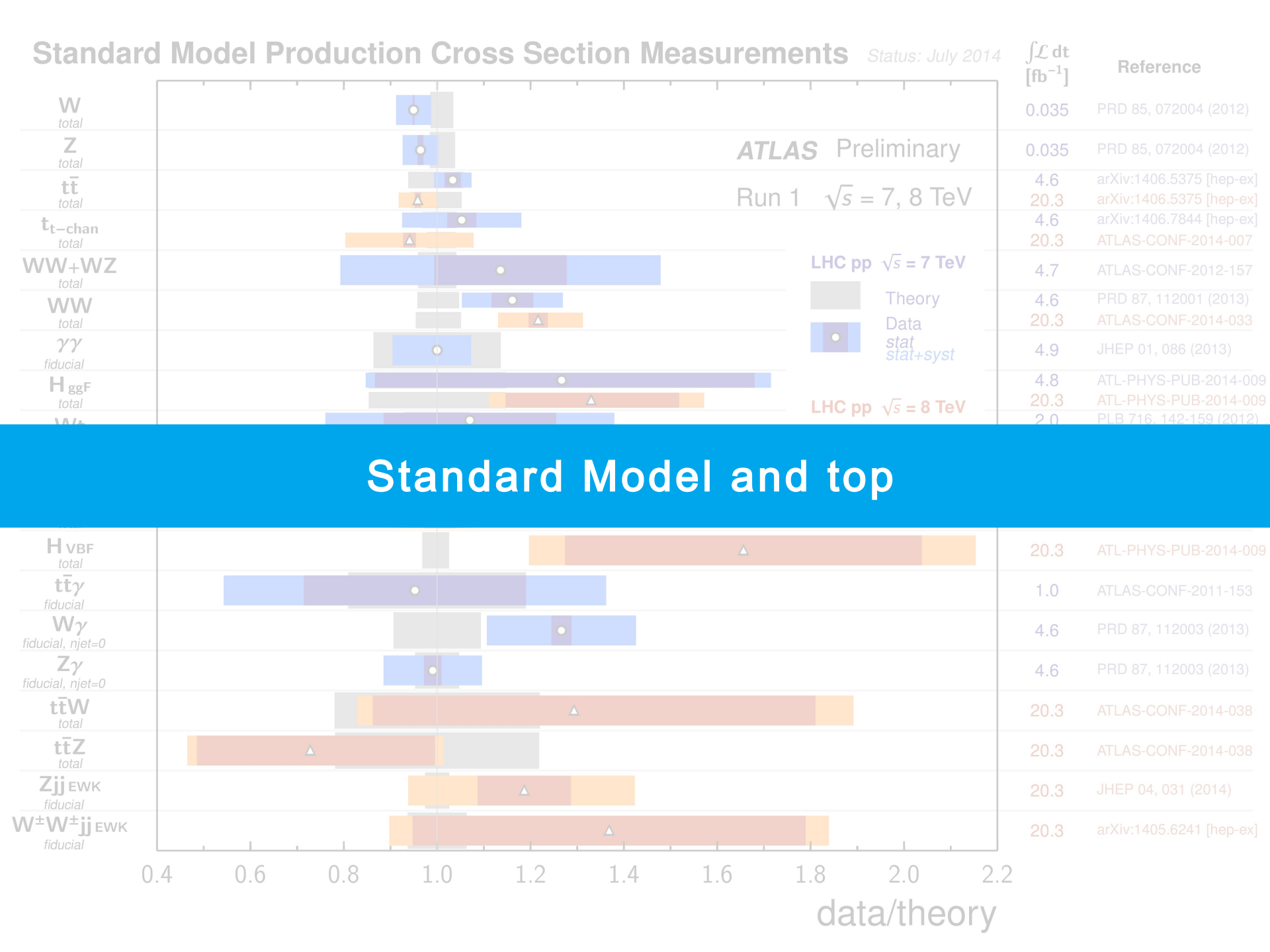
- Excellent identification of converted and unconverted photons

- Photon identification uncertainties:
  - 2-3% for E_T < 40 GeV
  - 0.5-1% above



- Uncertainties on H→γγ yield:

July 2012	December 2012	March 2013	June 2014
10.8%	5.3%	2.4%	1.0%



Standard Model and top

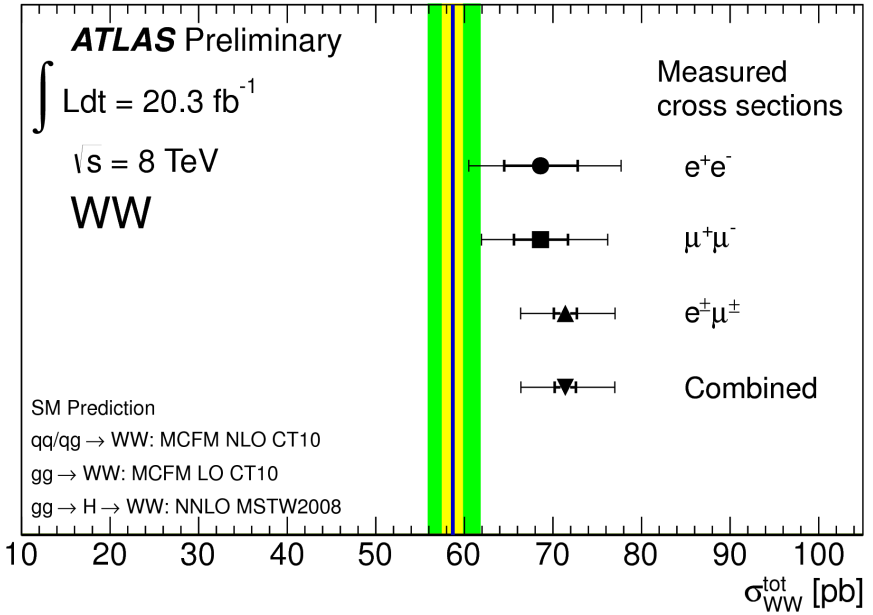
WW production

> Measurement of WW production with 8 TeV data

- non-abelian structure of electroweak interaction, important test of Standard Model
- sensitive to new physics (triple gauge couplings)
- slight data enhancement with 7 TeV data

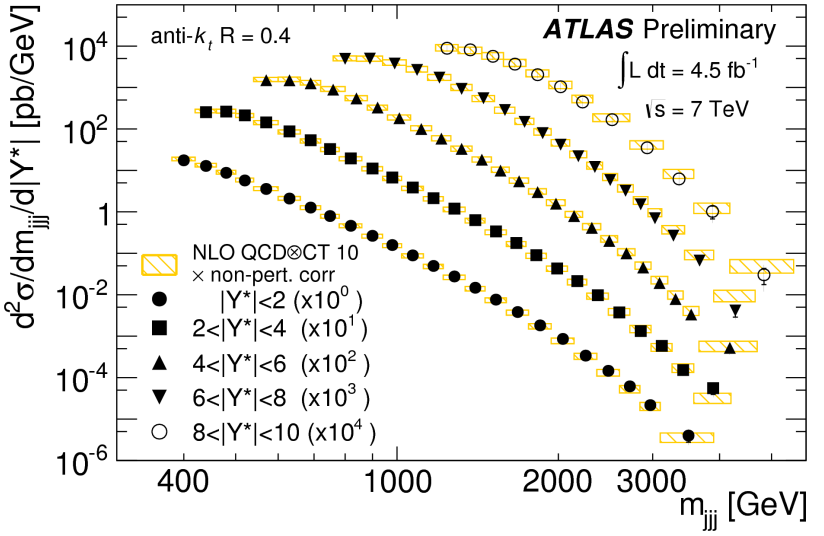
> Measured total cross-section:

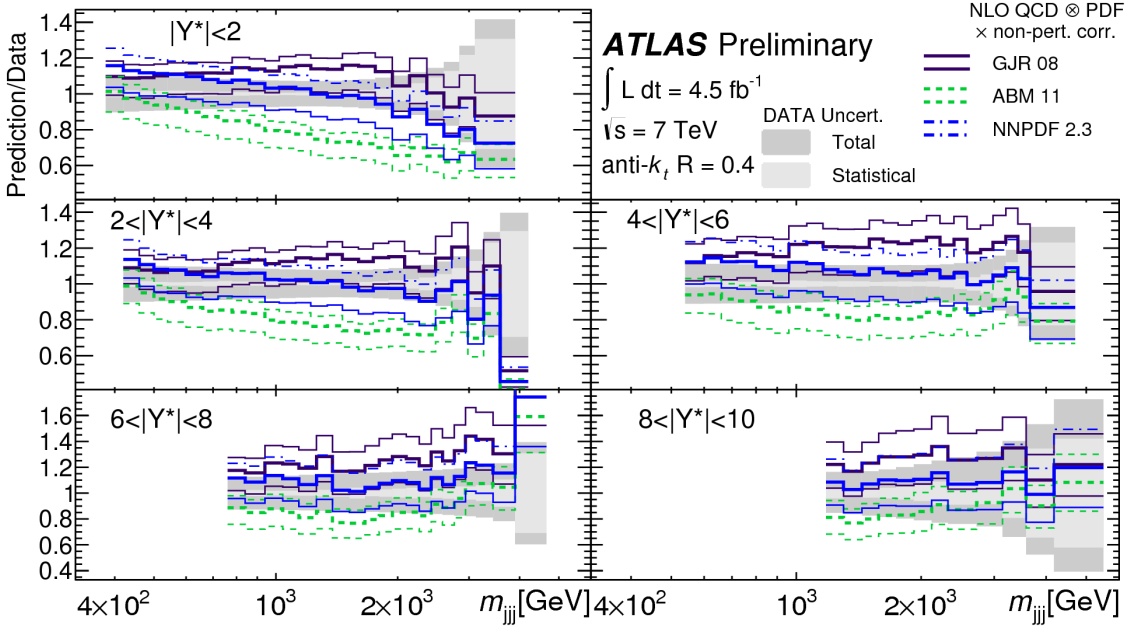
- $\sigma_{WW} = 71.4^{-1.2}_{-1.2}(\text{stat})^{+5.0}_{-4.4}(\text{syst})^{+2.2}_{-2.1}(\text{lumi})\,\text{pb}$
- predicted: $\sigma_{WW} = 58.7^{+3.1}_{-2.7}\,\text{pb}$
- 2.1σ excess wrt prediction
- slightly better agreement with a PDF using LHC + HERA data only



Jet cross-sections

- Double differential cross-section of events with ≥ 3 jets
- Test perturbative QCD at higher scales and larger jet multiplicities (mjjj → 5.5 TeV)
- Experimental uncertainties comparable (or smaller) than theoretical ones

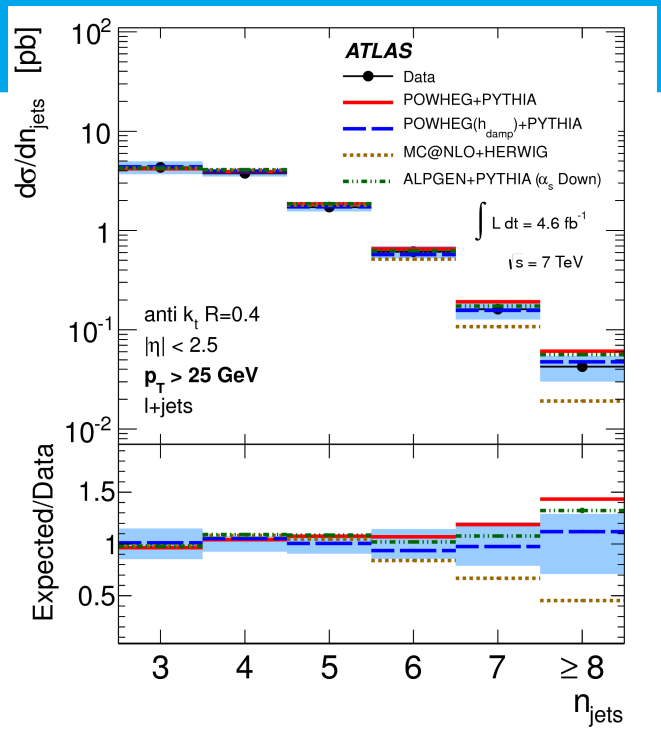




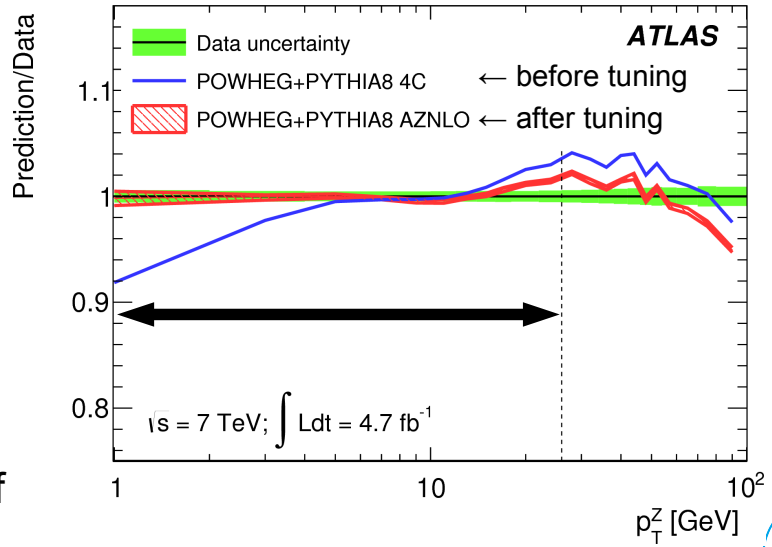
- Comparison of 2 → 3 NLO QCD predictions to data using different PDF sets
- Input to PDF fits

NLO MC tuning

- Measure effects of QCD radiation in top pair + jets production
  - soft scale preferred by data at high pT for jets from top and additional jets
- MC modelling of top pair data
  - adaptation of free parameters in NLO MC Powheg leads to good description



- Z p_T measurement and MC tuning
  - important for high precision W mass measurement
  - strategy: measure Z p_T with high precision and tune MCs to estimate uncertainties for W p_T
  - first step: publication of Z p_T including new MC tune to provide complete description of vector boson events



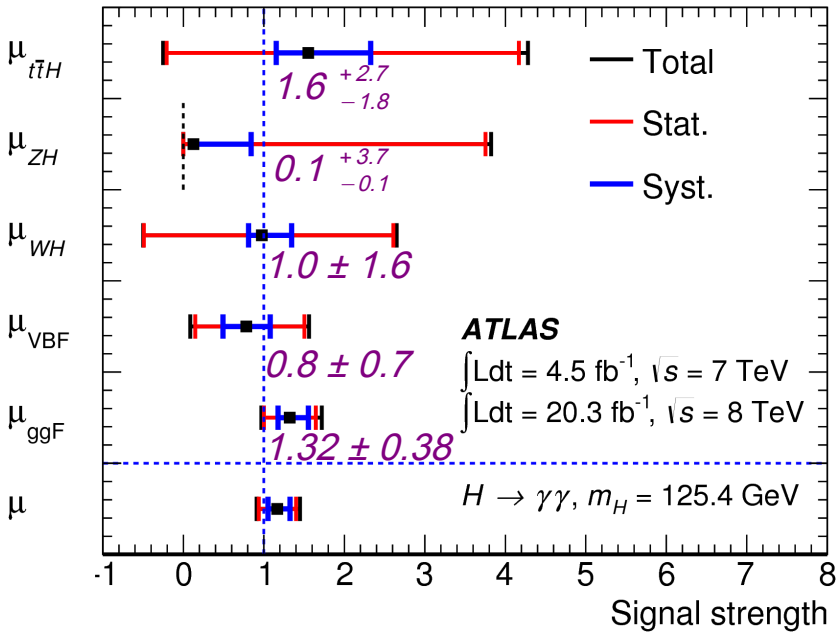
Higgs boson

Run Number: 204769, Event Number: 2494713

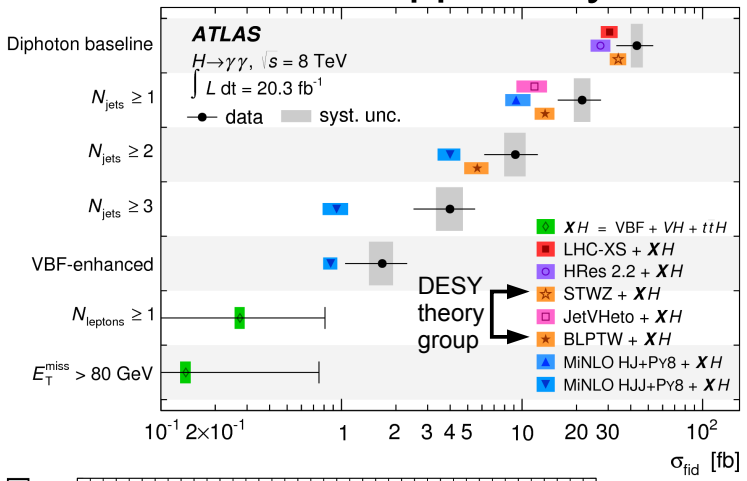
Date: 2012-06-10 08:17:12 UTC

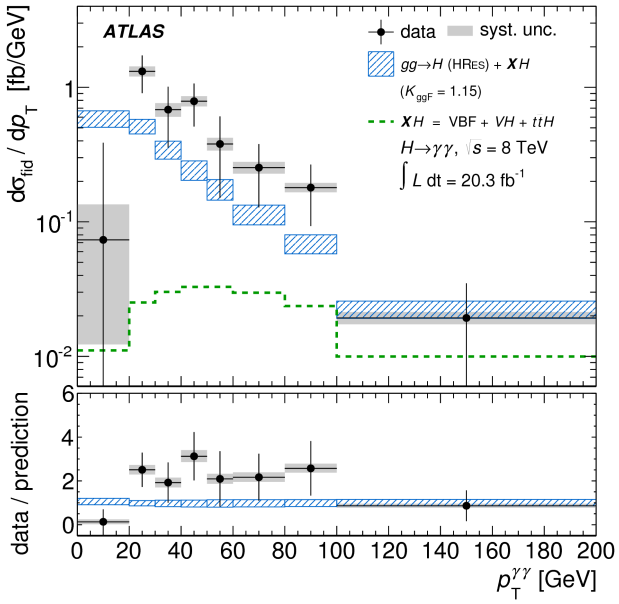
SM Higgs boson

- Discovery → precise measurements
- Benefits from final calibration, identification, ...
- H→γγ production and couplings
  - $\sigma/\sigma_{SM} = 1.17 \pm 0.23(\text{stat})\ ^{+0.10}_{-0.08}(\text{syst})\ ^{+0.12}_{-0.08}(\text{th})$
  - separate the different production modes:



- Fiducial and differential cross-section with H→γγ decays

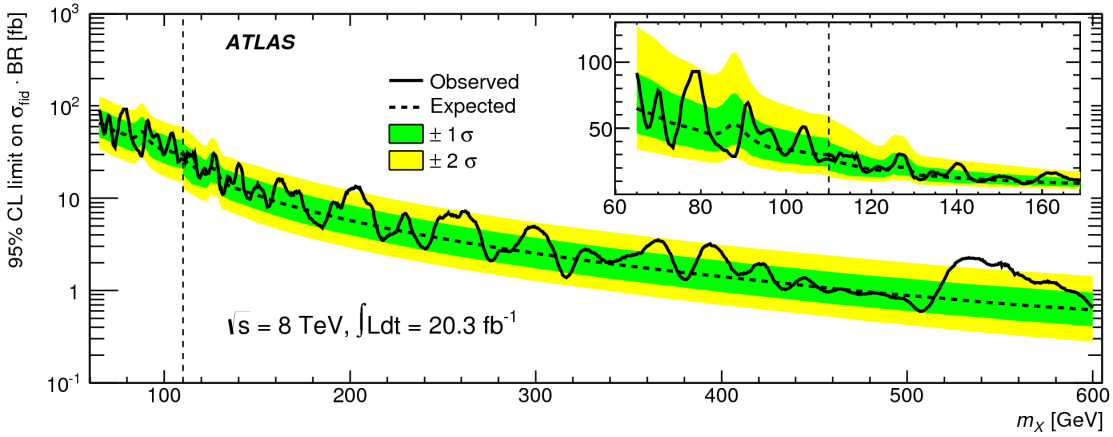




Beyond SM Higgs boson

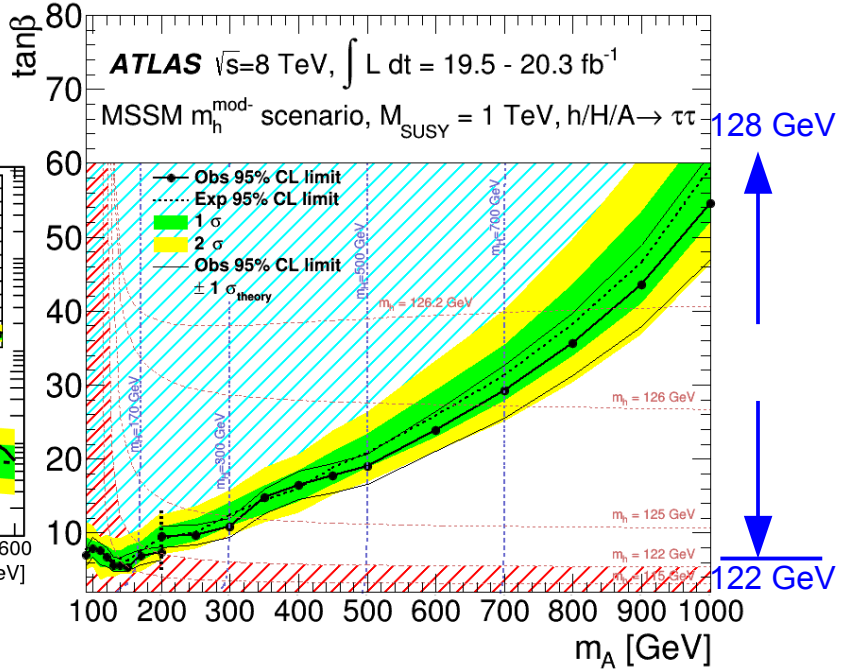
> Search for additional scalar γγ resonances:

- as model-independent as possible
- SM Higgs boson as background



> MSSM h/H/A→ττ

- enhanced branching ratios to tau pairs



> No excess seen over one order of magnitude in mass

- from 65 to 600 GeV

> No evidence for signal

- exclusion limits to highest masses yet
- low tanβ excluded by SM Higgs boson mass measurements

Recent public notes

> 4 public notes

- Electron efficiency measurements with the ATLAS detector using the 2012 LHC proton-proton collision data, ATLAS-CONF-2014-032
- Measurement of the W+W− production cross section in proton-proton collisions at $\sqrt{s}$=8 TeV with the ATLAS detector, ATLAS-CONF-2014-033
- Measurement of three-jet production cross-sections in pp collisions at 7 TeV centre-of-mass energy using the ATLAS detector, ATLAS-CONF-2014-045
- Measurement of the charge asymmetry in dileptonic decays of top quark pairs in pp collisions at $\sqrt{s}$ = 7 TeV using the ATLAS detector, TOPQ-2013-09

> 1 phenomenology paper

- Effects of color reconnection on $t\bar{t}$ final states at the LHC, accepted by JHEP

Recent papers

> 11 papers (out of 68 ATLAS papers)

- Measurement of the total cross section at the LHC at √s=7 TeV from elastic scattering with the ATLAS detector, submitted to Nuclear Physics B
- Electron reconstruction and identification efficiency measurements with the ATLAS detector using the 2011 LHC proton-proton collision data, Eur. Phys. J. C (2014) 74
- Electron and photon energy calibration with the ATLAS detector using LHC Run 1 data, accepted by Eur. Phys. J. C
- Measurements of spin correlation in top-antitop quark events from proton-proton collisions at s√=7 TeV using the ATLAS detector, submitted to PRD
- Measurement of the $t\bar{t}$ production cross-section as a function of jet multiplicity and jet transverse momentum in 7 TeV proton-proton collisions with the ATLAS detector, submitted to JHEP
- Measurement of the Z/gamma* boson transverse momentum distribution in pp collisions at √s = 7 TeV with the ATLAS detector, JHEP09(2014)145
- Simultaneous measurements of the tt, W+W-, and Z_>tautau production cross-sections in pp collisions at sqrt(s)=7 TeV with the ATLAS detector, submitted to Phys. Rev. D
- Measurement of Higgs boson production in the diphoton decay channel in pp collisions at center-of-mass energies of 7 and 8 TeV with the ATLAS detector, submitted to Phys. Rev. D
- Measurement of fiducial and differential cross sections for Higgs boson production in the diphoton channel at √s =8 TeV with the ATLAS detector, JHEP09(2014)112
- Search for Scalar Diphoton Resonances in the Mass Range 65-600 GeV with the ATLAS Detector in pp Collision Data at √s = 8 TeV, accepted by PRL
- Search for neutral Higgs bosons of the Minimal Supersymmetric Standard Model in pp collisions at √s = 8 TeV with the ATLAS detector, submitted to JHEP

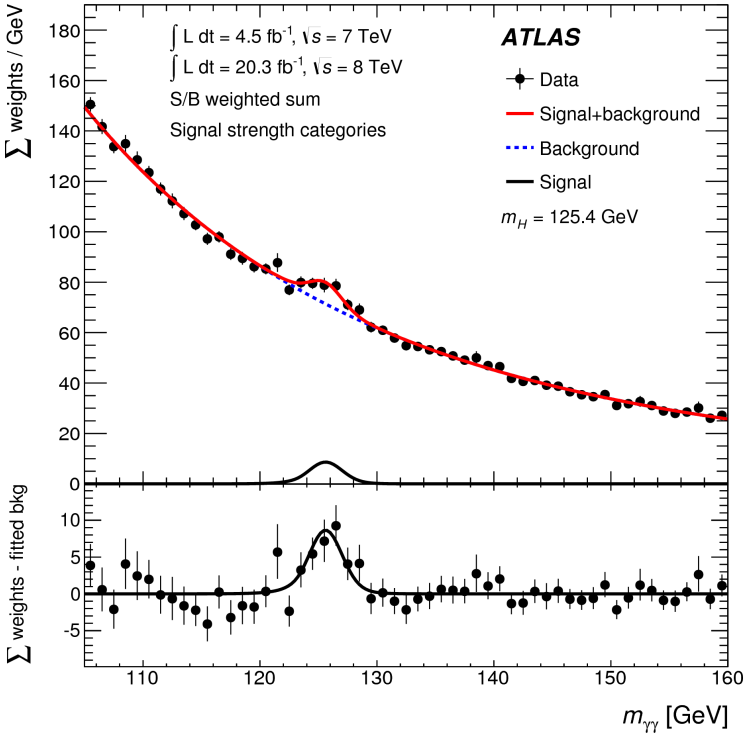
DESY

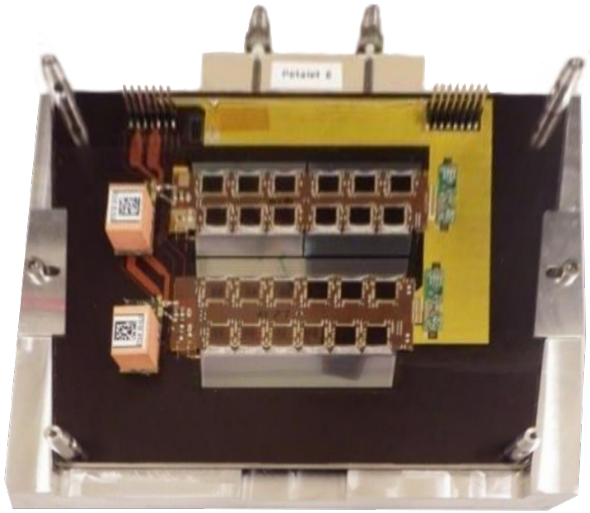
Summary

- DESY-ATLAS group involved in most parts of the ATLAS experiment

- Contributions to detector activities
  - preparing detector, software for run 2
  - upgrades for run 3 and HL-LHC

- Wrapping up analyses with run 1 data
  - final electron/photons performance
  - MC tuning, SM and Higgs boson measurements





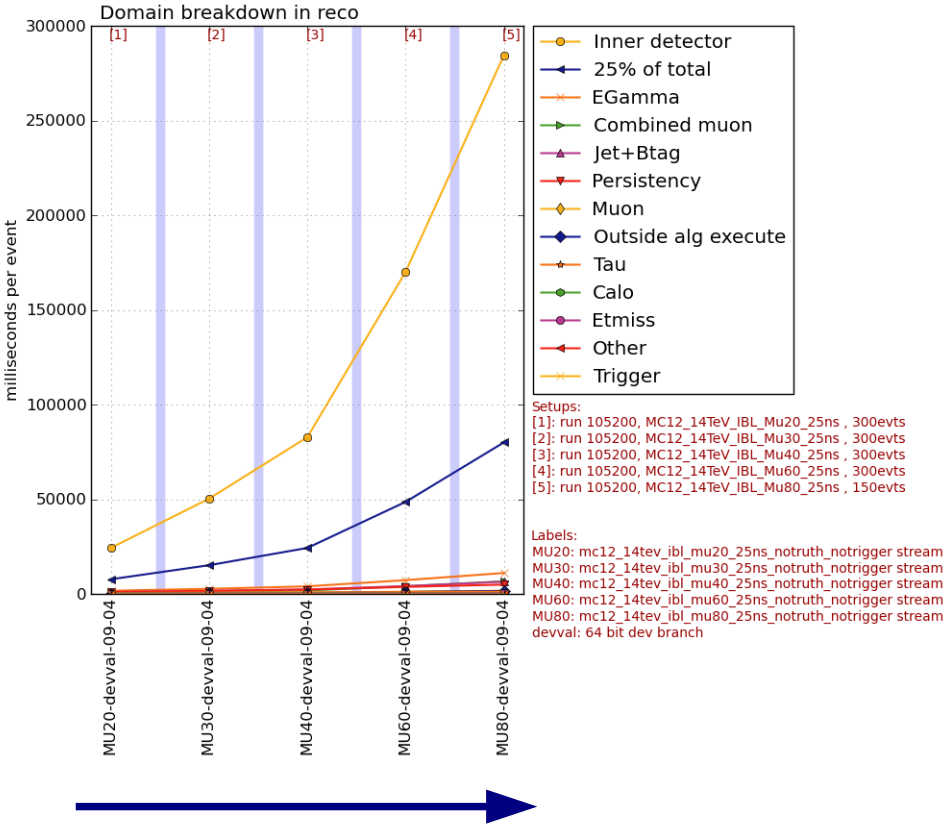
Additional slides

LHC start-up in 2015

- Main phases [F. Bordry, 6 Oct 2014]
- Low intensity commissioning (2 months)
  - Physics with a few isol . bunches in May
  - ATLAS: want > 10M min bias &vdM scan
- 50 ns operation, 21 days in June,
  - $L_{peak} < 5\times10^{33}$ cm^{-2}.s^{-1},$L_{int} < 1$ fb^{-1}, $\mu_{peak} < 25$
- 25 ns operation, 21 days in July
  - $L_{int} < 2$ fb^{-1}
- 25 ns operation + special runs
  - Total 2015: ~90 days between July-Nov
  - $L_{peak} \sim 1.3\times10^{34}$ cm^{-2}.s^{-1}($\beta^* = 80 \rightarrow 40$ cm ?)
  - $L_{int} \sim 10$ fb^{-1},$\mu_{peak} \sim 34$
- Ion run, 24 days in December

Inner Detector and Tracking Software Development

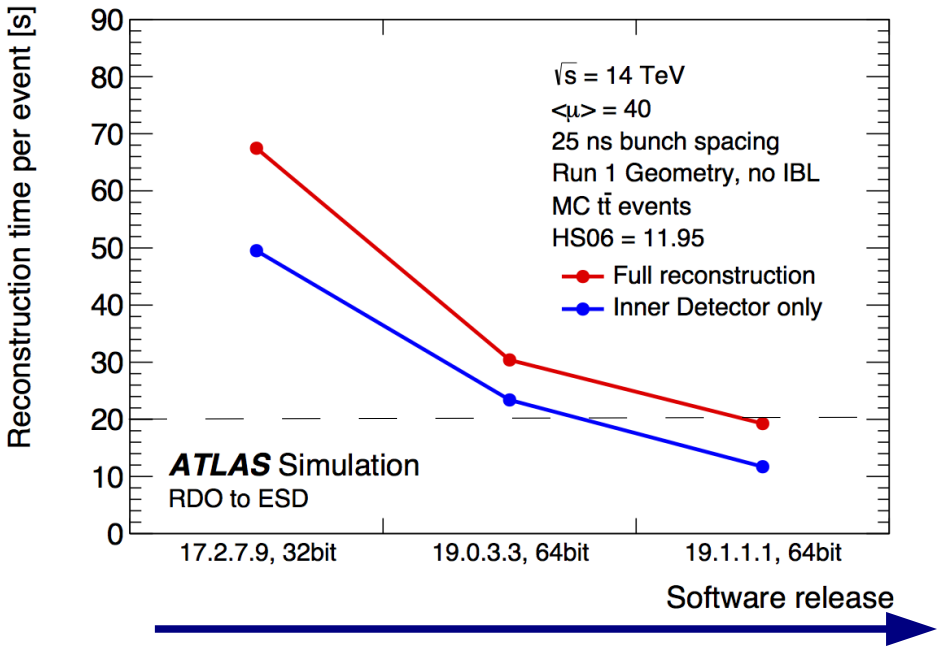
- Reconstruction of Run 2 data will bring new challenges for ATLAS Software
  - Increased multiplicity due to higher instantaneous luminosity (and centre-of-mass energy)
- Inner Detector Tracking algorithms strongly affected by increased pile-up
  - Combinatoric effects cause rapid increase in CPU consumption
- Work needed to mitigate this effect
  - Reconstruction must fit within available computing resources, or physics will be compromised



Increasing pile-up (20 to 80)

Inner Detector and Tracking Software Development

- Extensive process of software migrations and optimisations
  - Changed maths library used for linear algebra
  - Simplified Event Data Model (in conjunction with ATLAS-wide movemen to new persistent output format, xAOD)
  - Optimised algorithm strategies
  - Plus many other changes
- Achieved > 3-fold improvement in reconstruction time
  - 20s per event average reconstruction time allows goal of 1 kHz prompt Tier-0 reconstruction at CERN Tier 0 to be met

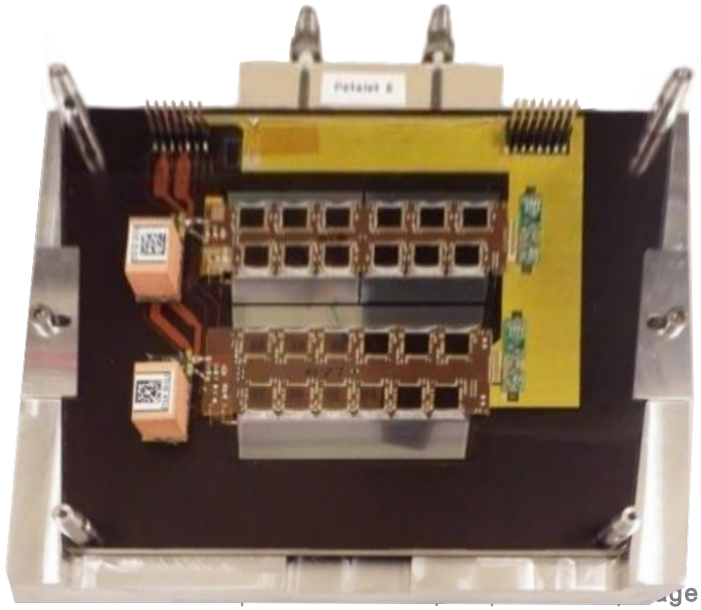


Software migrations and optimizations (starting from Run 1 software release)

Phase II Upgrade – Si Strip Endcap @ DESY

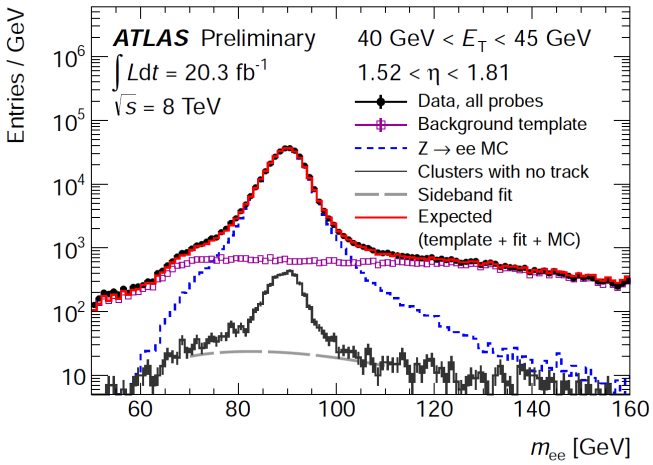
> Petalet program converging

- Spanish groups getting close to first full electrical modules with alternative design
- German groups built several Petalet prototypes, targeting to finish Petalet construction by end of 2014
- Prototypes used to determine
  - Powering scheme
  - Treatment of several sensors in one row
  - Cooling
  - DCDC powering placement
  - Noise behaviour
  - Sensor details
  - ...

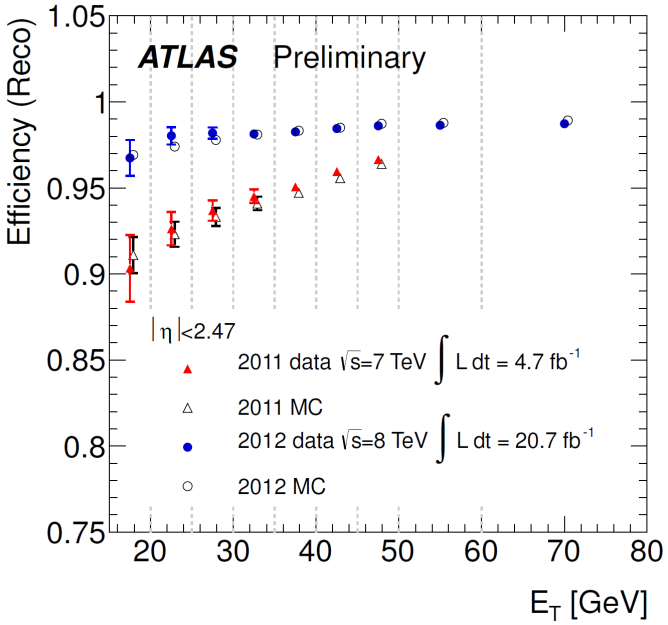


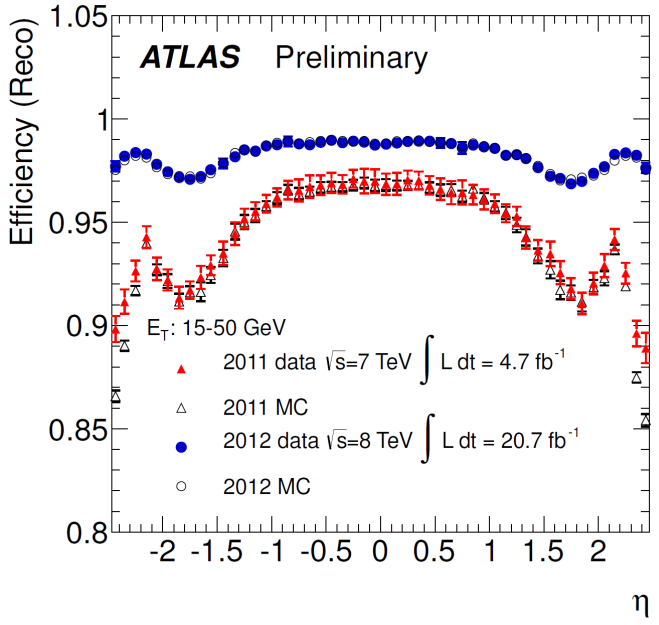
Electron reconstruction efficiency

- Large improvement for 2012 to recover electrons undergoing energy losses due to bremsstrahlung
  - Gaussian Sum Filter refits electron candidate tracks
  - more performant track – cluster matching



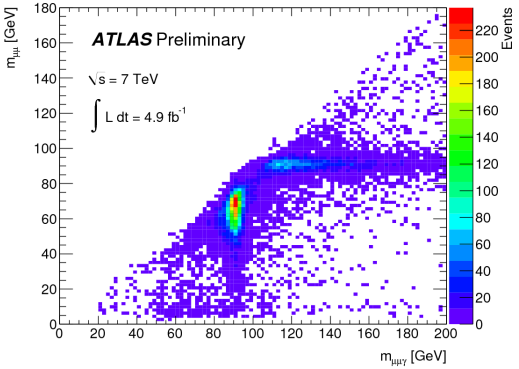
- Measured using Z → ee sample, need to account for electrons reconstructed without track



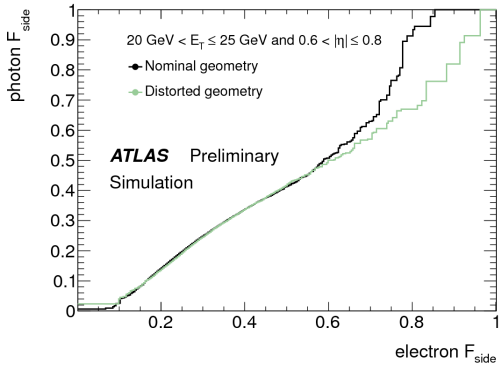


Photon identification efficiency

- Three data-driven methods
- Radiative Z method
  - $10 < E_T < 80$ GeV
  - use of $Z \rightarrow ll\gamma$ sample
  - limited by stat uncertainty above 40 GeV
- Electron Extrapolation
  - $30 < E_T < 100$ GeV
  - from $Z \rightarrow ee$ efficiencies
  - limited by uncertainty on MC description c shower-shapes
- Matrix Method
  - $20 < E_T < 1500$ GeV
  - use of track isolation as discriminant
  - limited by uncertainty on track isolation



Select pure photon sample by placing cut on 3-body inv mass

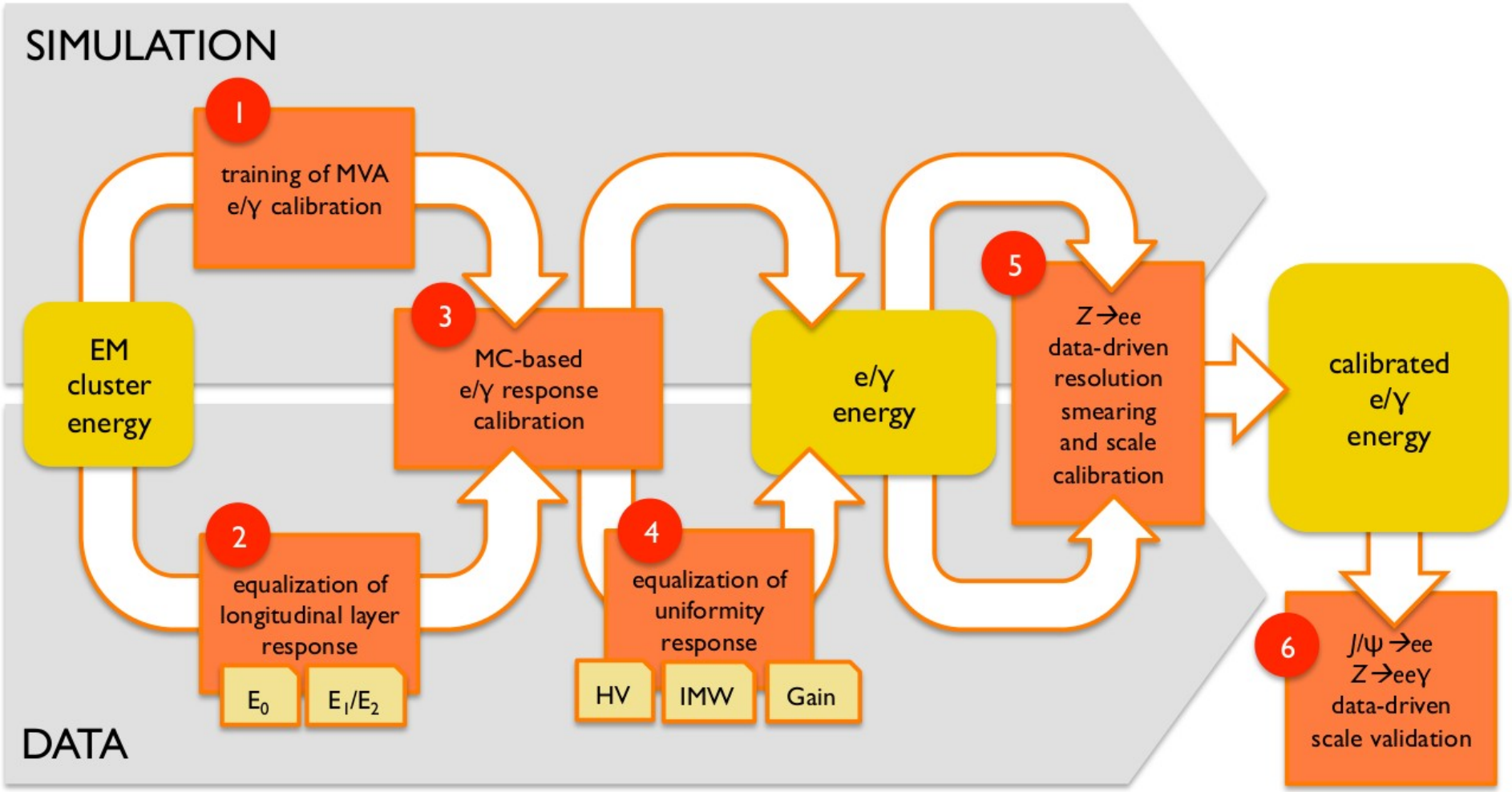


Transform electron to photon showers in MC and apply it to data $Z \rightarrow ee$

$$N^{TI}_{\text{pass}} = \varepsilon^S_p N^S_{\text{pass}} + \varepsilon^B_p N^B_{\text{pass}}$$
$$N^{TI}_{\text{fail}} = \varepsilon^S_f N^S_{\text{fail}} + \varepsilon^B_f N^B_{\text{fail}}$$

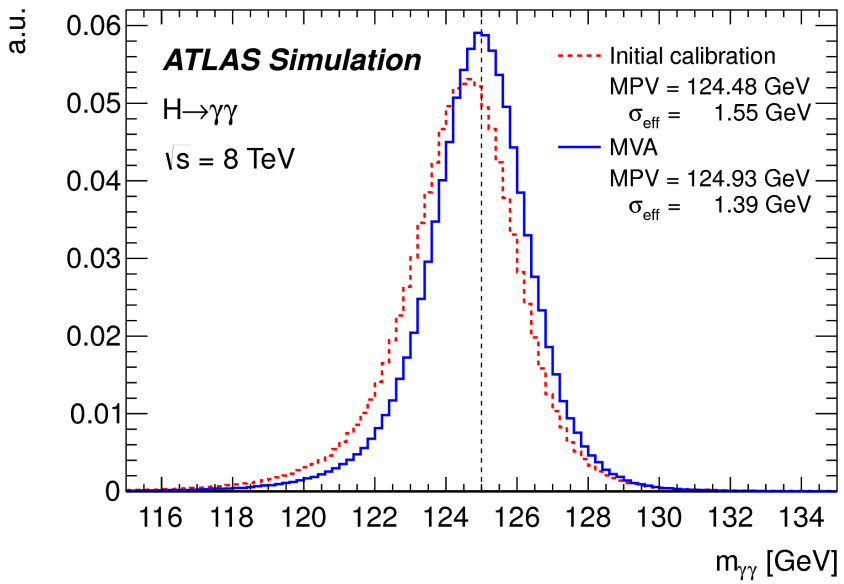
Find variable orthogonal to shower shapes to serve as discriminant

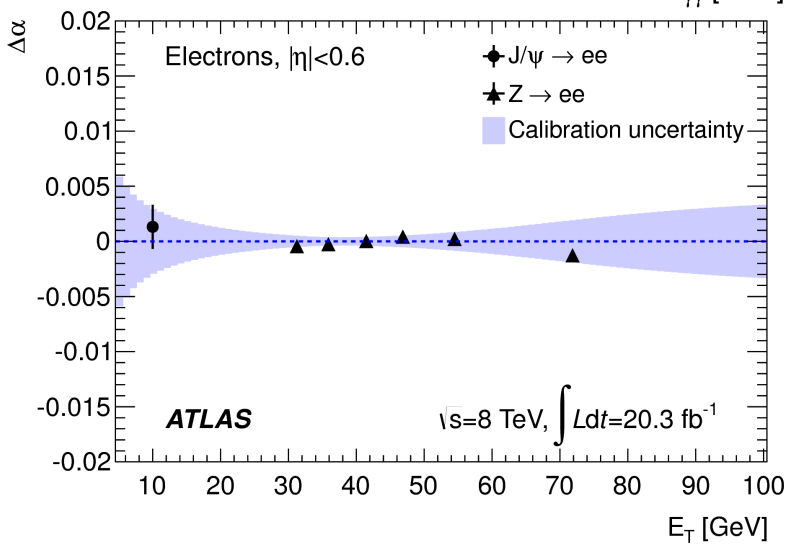
electron/photon calibration (1)



electron/photon calibration (2)

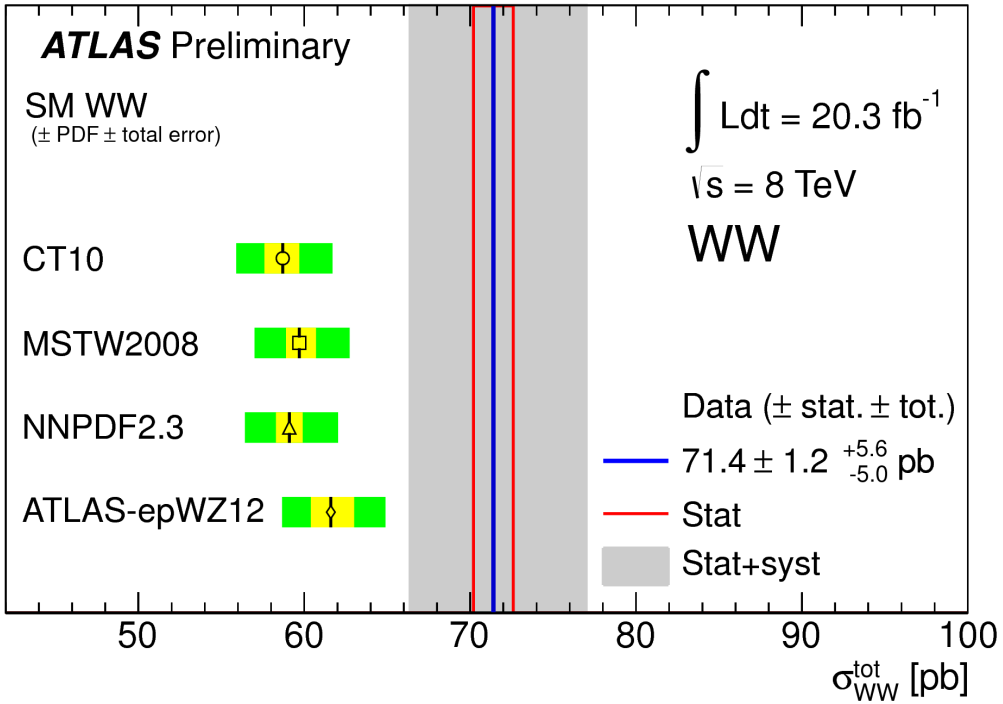
- Improvement of material description
- MVA MC-based calibration
  - Correlation between Etrue and reconstruction-level variables (E0...E3, η, φ, shower depth...) optimised using BDT
- Improvement of material description before the calorimeter
- Resulting uncertainties on energy scale
  - photons from Higgs decay: ~0.3% for most of acceptance
  - electrons 10 (45) GeV: 0.4 – 1 (~0.04) % for most of acceptance





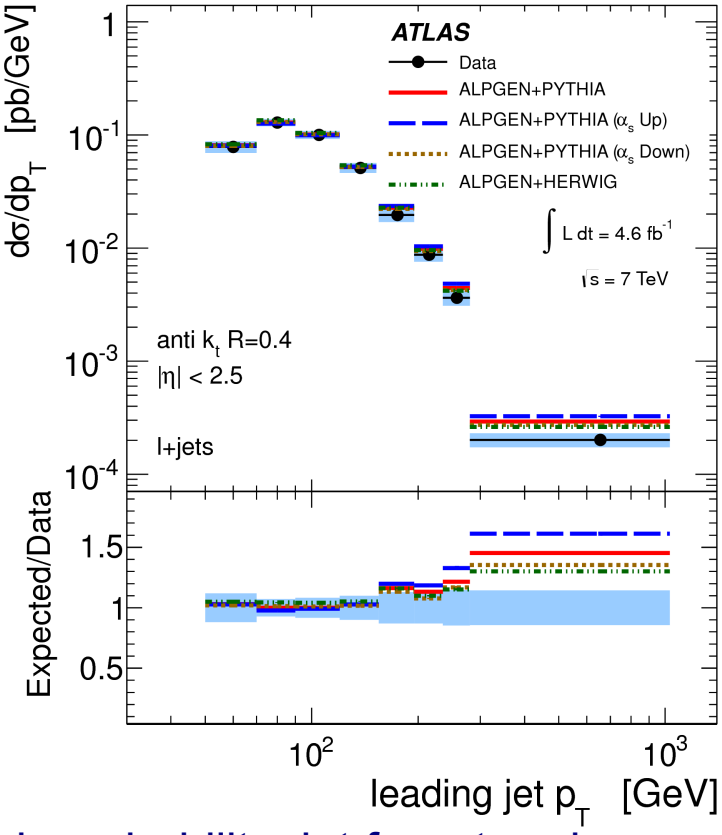
WW cross-section measurement

- Some variations observed for different PDF predictions
- Global data CT10 PDF chosen for its generally good agreement with other LHC data
- PDF using LHC + HERA data only gives slightly better agreement

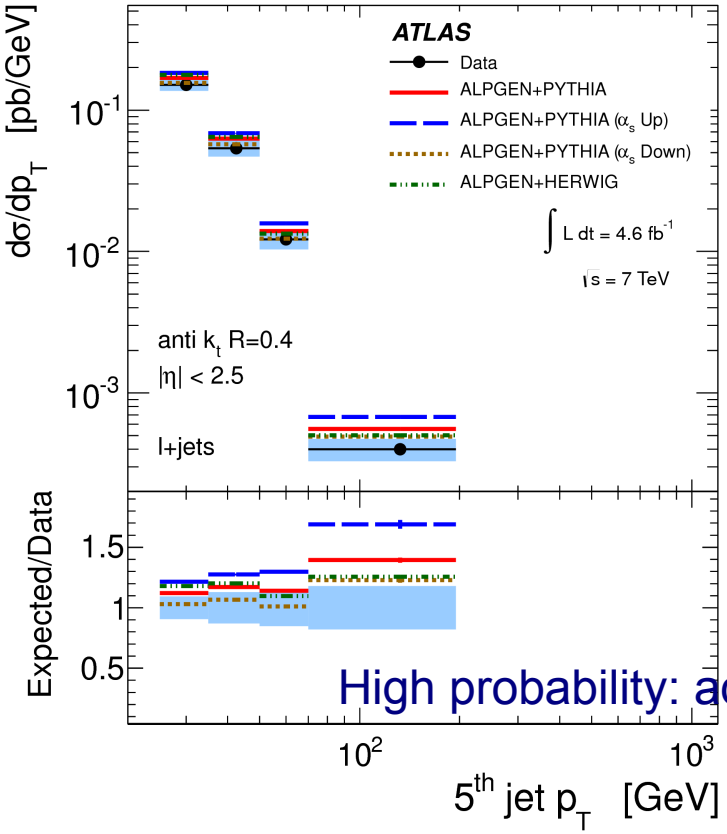


Effects of QCD radiation in top pair production

- Soft scale preferred by data @ high p_T of leading jet and p_T of 5th jet
- DESY contribution: data analysis (measurement) and model comparison



High probability: jet from top decay

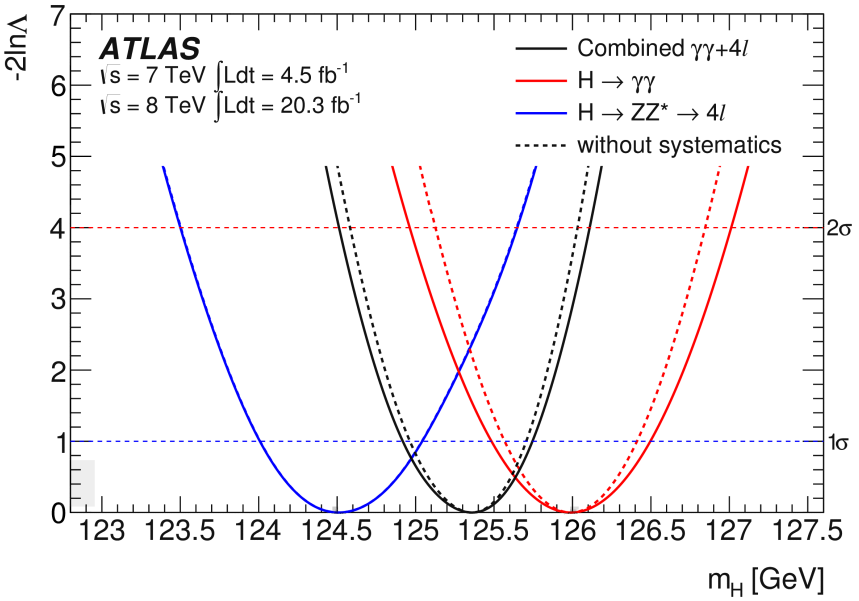


High probability: additional jet

Higgs boson mass

- Measurements:
  - $H \rightarrow \gamma\gamma$: m_H = 125.98 ± 0.42 (stat) ± 0.28 (syst) GeV
  - $H \rightarrow 4l$: m_H = 124.51 ± 0.52 (stat) ± 0.06 (syst) GeV
  - combined: m_H = 125.36 ± 0.37 (stat) ± 0.18 (syst) GeV

- Dominating systematic uncertainties:
  - electron/photon calibration ~150 MeV
  - $H \rightarrow \gamma\gamma$ background model ~ 40 MeV
  - primary vertex ($\gamma\gamma$) ~ 20 MeV
  - muon momentum scale ~ 10 MeV
- Reduction of systematic uncertainty by 60% wrt previous measurement



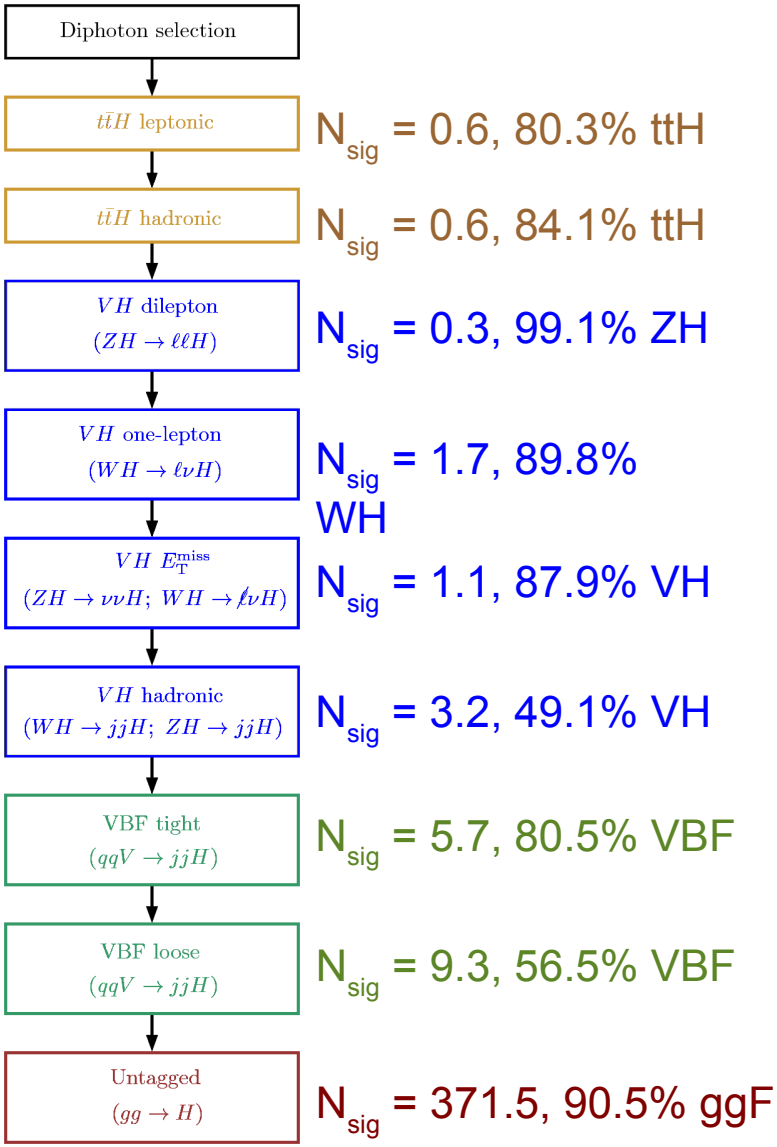
- Compatibility between measurements: 2σ

H→γγ production: changes wrt last paper

- First results on run-1 dataset published in Physics Letters B, Volume 734
- Improved material description
- Improved calibrations
  - mass resolution improved by 10%
  - resolution uncertainty reduced by factor 2
- Reduced uncertainties on photon ID and isolation
- New categories
  - added ttH leptonic, hadronic
  - split VH into 1-lepton (WH) and 2-lepton (ZH)

H→γγ production: categories

> Divide diphoton selection in sequential, exclusive categories



N_{sig} = 0.6, 80.3% ttH

N_{sig} = 0.6, 84.1% ttH

N_{sig} = 0.3, 99.1% ZH

N_{sig} = 1.7, 89.8% WH

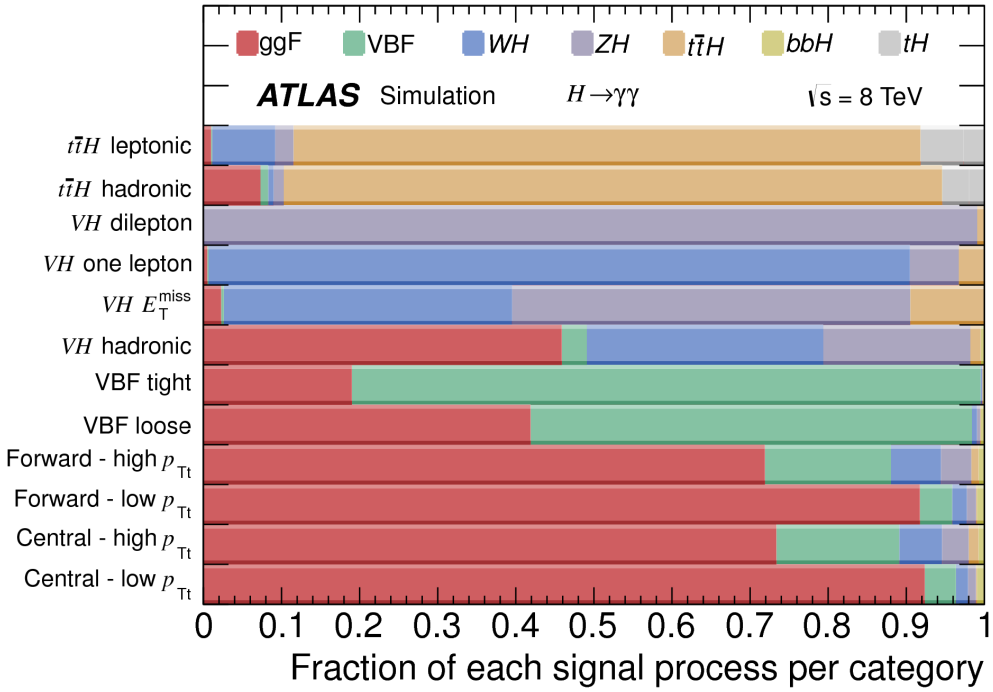
N_{sig} = 1.1, 87.9% VH

N_{sig} = 3.2, 49.1% VH

N_{sig} = 5.7, 80.5% VBF

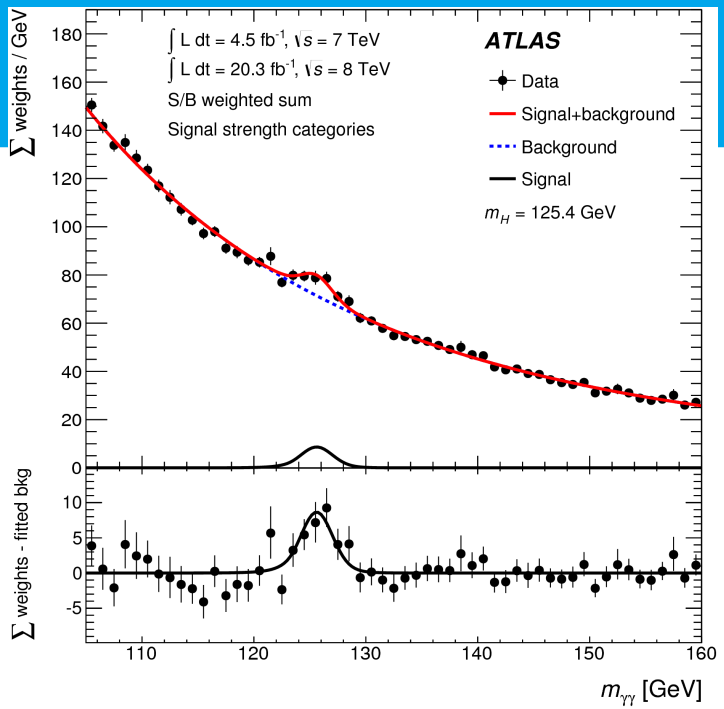
N_{sig} = 9.3, 56.5% VBF

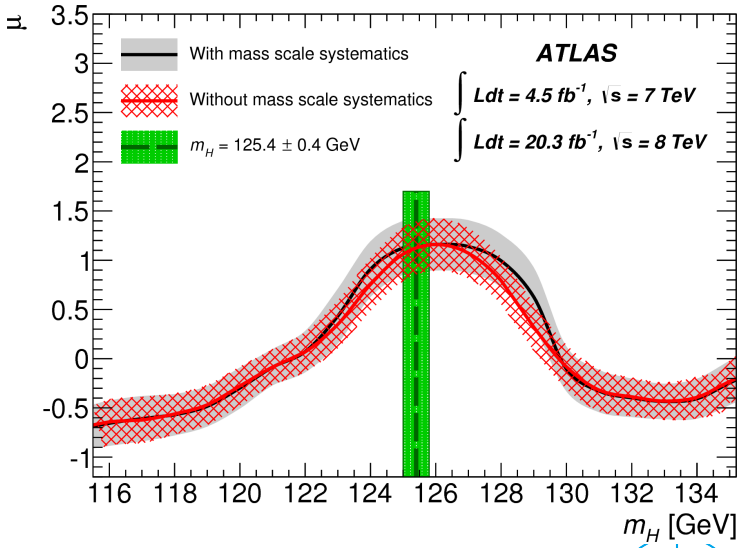
N_{sig} = 371.5, 90.5% ggF



H→γγ production: results

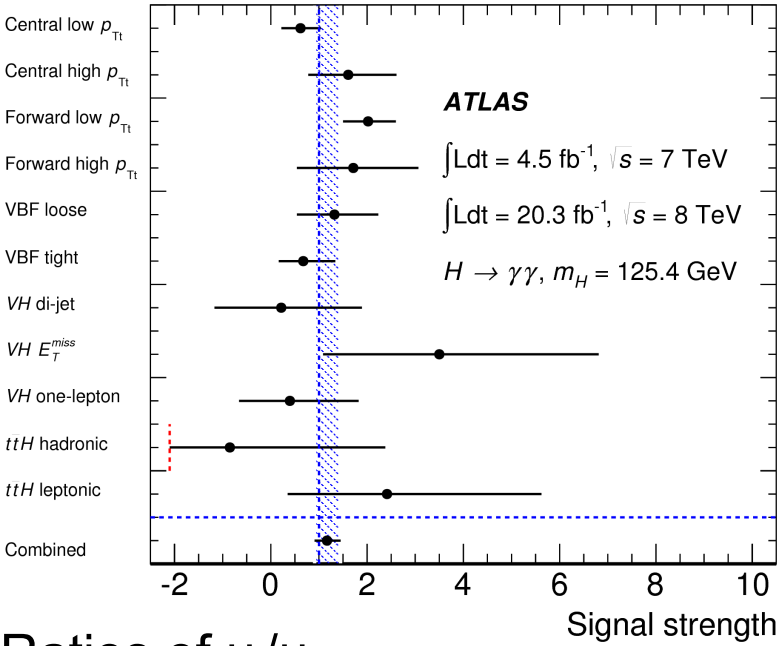
- Local significance at 125.4 GeV:
  - expected: 4.6σ
  - observed: 5.2σ
- Signal strength ($\sigma^{obs}/\sigma^{exp}$):
  - $\mu = 1.17 \pm 0.23(\text{stat})\ ^{+0.10}_{-0.08}(\text{syst})\ ^{+0.12}_{-0.08}(\text{th})$
  - 0.7σ compatibility with SM (μ=1)
- Compatibility with previous results
  - Phys. Lett. B 726, 88 (2013)
  - $\mu = 1.55\ ^{+0.33}_{-0.28}$
  - consistent with each other at the level of ~2.3 σ

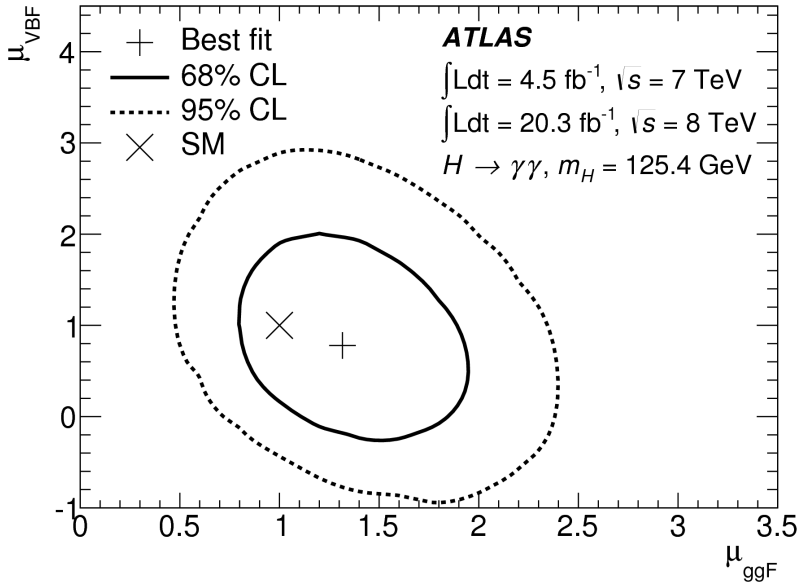




H→γγ production: signal strength /production mode

> Extracted from simultaneous fit on 12 categories



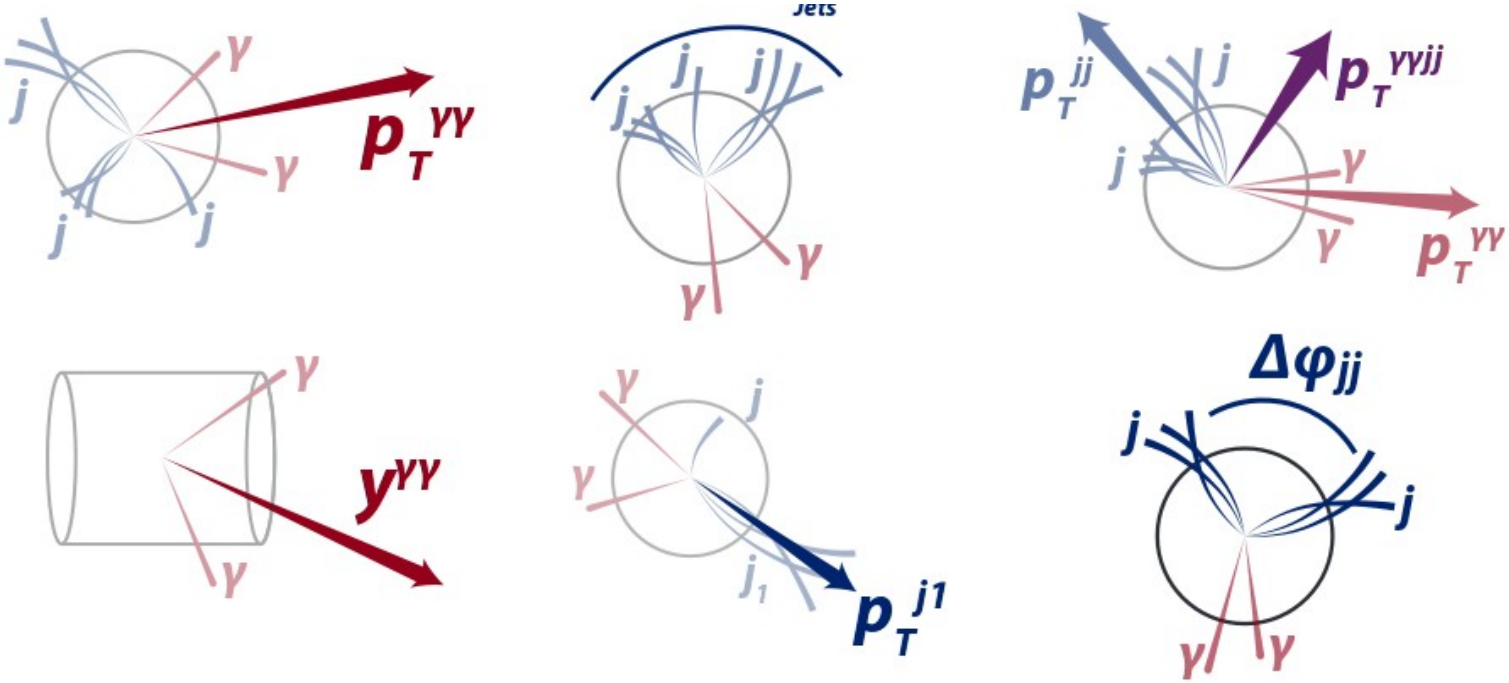


> Ratios of μ_i/μ_{ggF}

- test the production through VBF, VH and ttH independently of BR(H→γγ)
- $\mu_{VBF}/\mu_{ggF} = 0.6\ ^{+0.8}_{-0.5}$
- $\mu_{VH}/\mu_{ggF} = 0.6\ ^{+1.1}_{-0.6}$
- $\mu_{ttH}/\mu_{ggF} = 1.2\ ^{+2.2}_{-1.4}$
- not significantly different from 0, consistent with SM

H→γγ: differential cross-section (1)

> Four categories of kinematic variables with focus to probe different aspects of Higgs production:



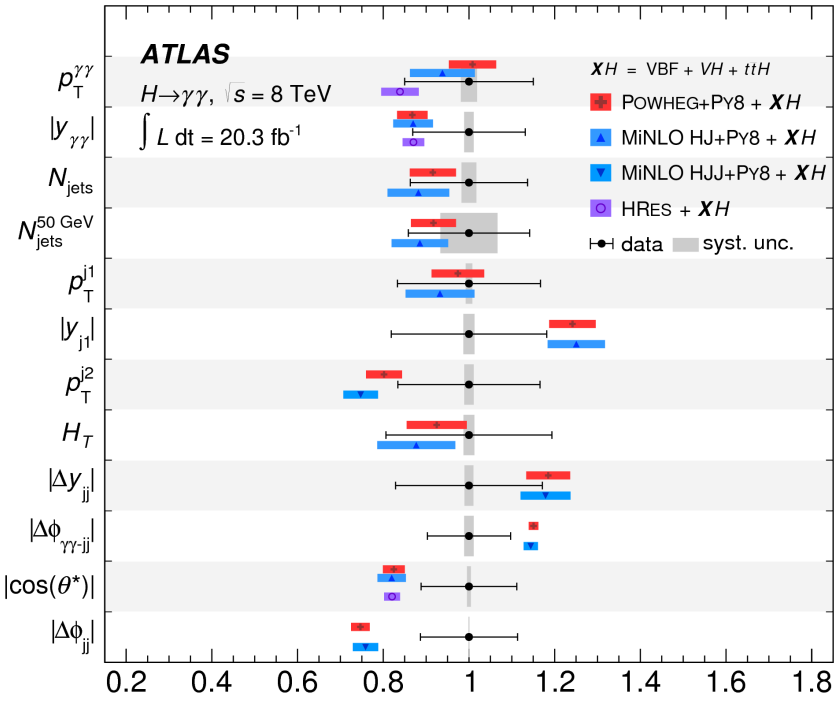
Category	*Variables*
Higgs boson kinematics	$p_T^{\gamma\gamma}$, $\lvert y^{\gamma\gamma}\rvert$
Jet activity	$N_{\text{jets}}^{30\text{ GeV}}$, $N_{\text{jets}}^{50\text{ GeV}}$, p_T^{j1}, $\lvert y_{j1}\rvert$, p_T^{j2}, H_T
Spin-CP	$\lvert\cos\,theta*\rvert$, $\Delta\phi_{jj}$
VBF-sensitive	$\lvert\Delta y_{jj}\rvert$, $\lvert\Delta\phi_{H-jj}\rvert$

H→γγ: differential cross-section (2)

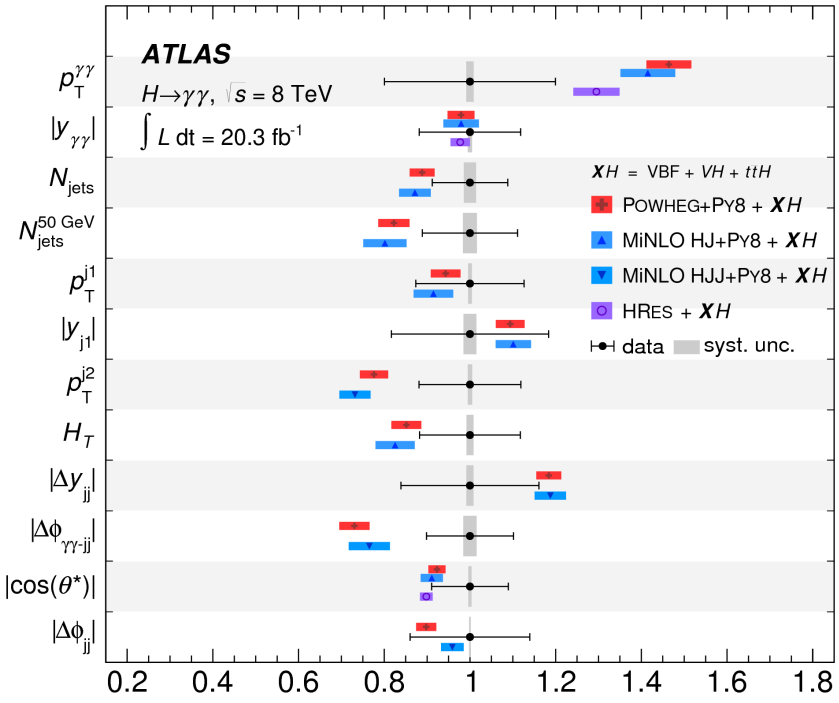
> Methodology

- signal extraction from fit to mγγ mass spectrum in bins of observable of interest
- unfold measured spectrum into cross section with correction factors

> Summary plots:



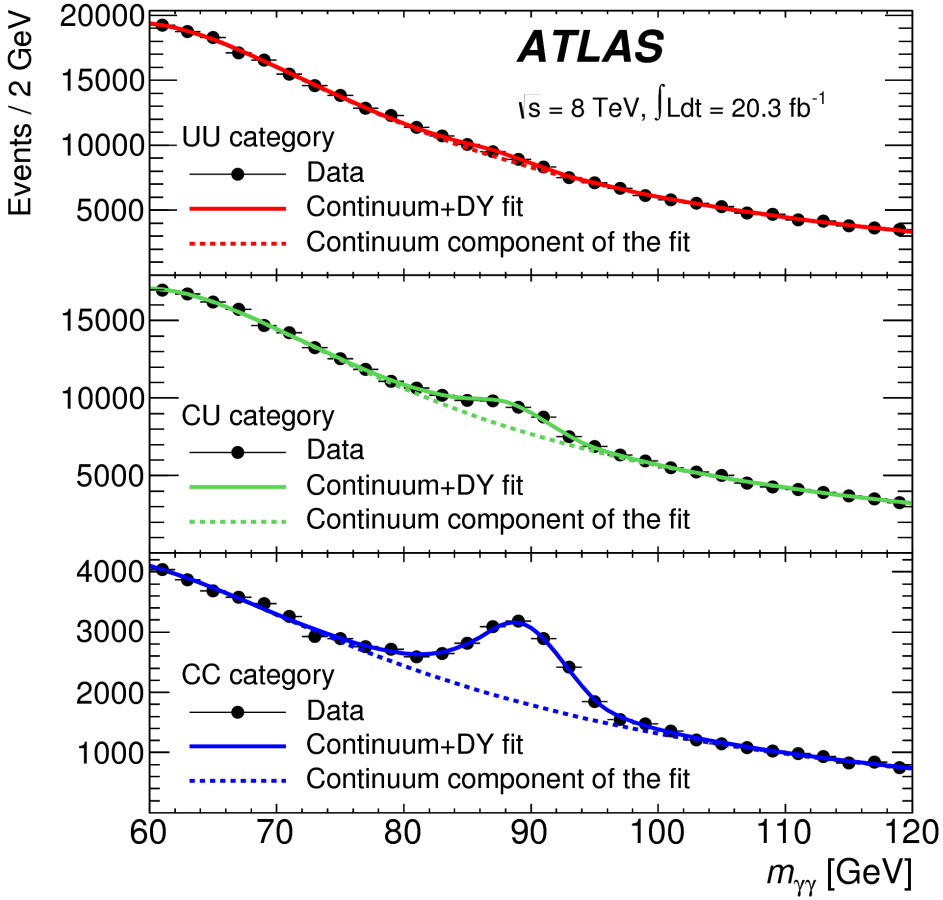
Ratio of 1st moment relative to data



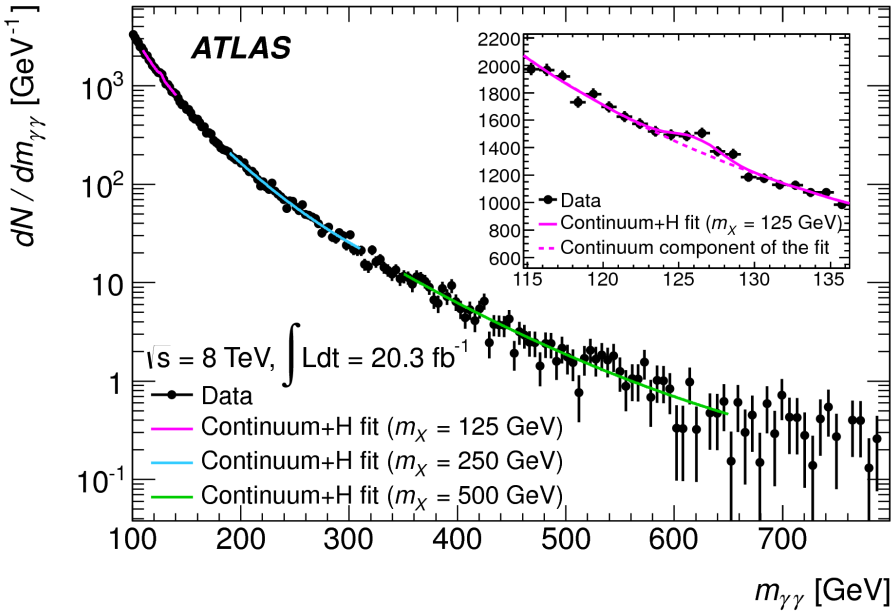
Ratio of 2nd moment relative to data

Search for γγ resonances: overview

- 60 < mγγ < 120 GeV
- Continuum background + Z→ee with e faking γ as background

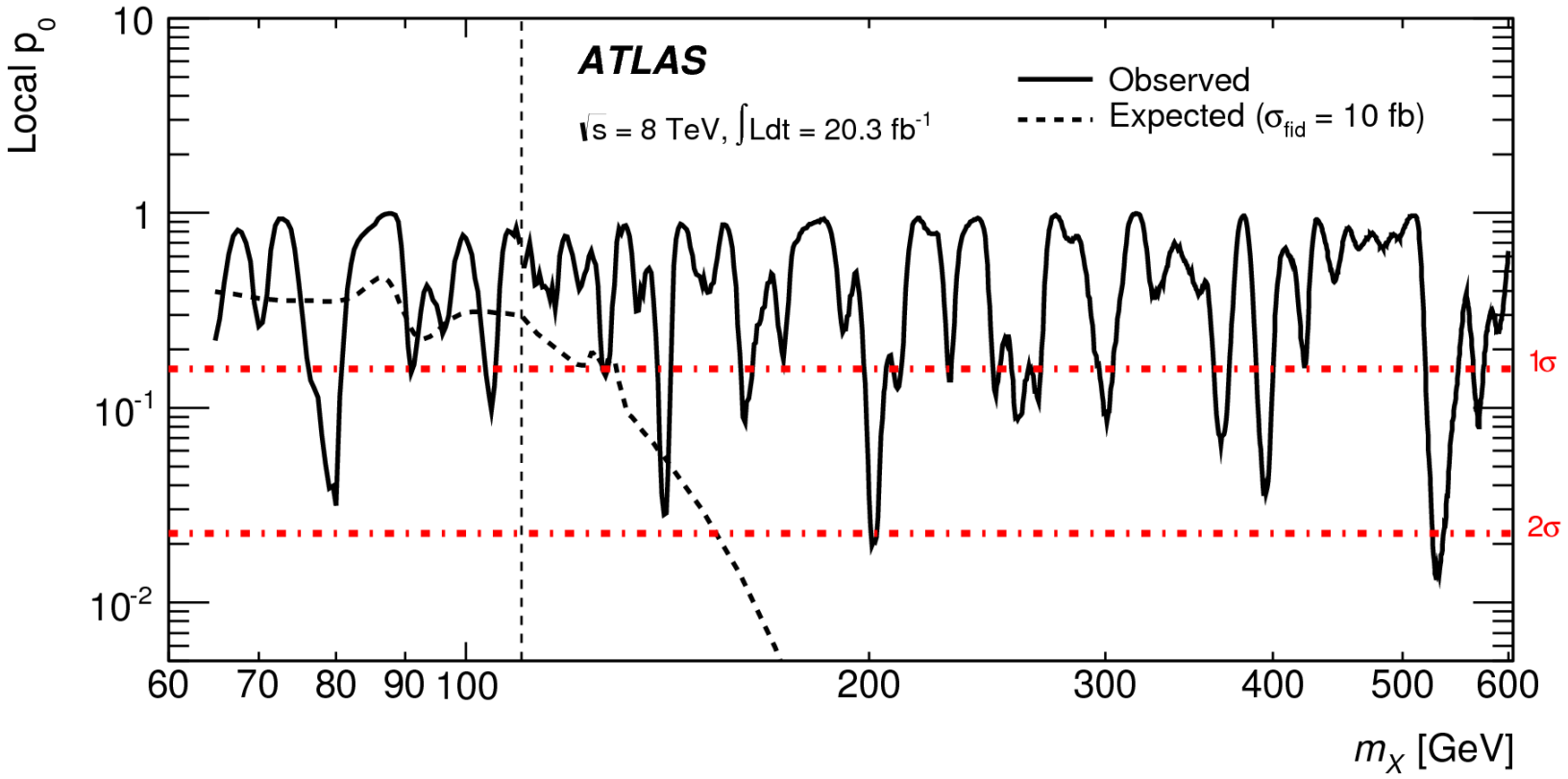


- 100 < mγγ < 800 GeV
- Fits in mass sliding windows around each tested mass
- H(125 GeV) as additional background (μ = 1)



Search for γγ resonances: p-values

> p0 (= probability that peak comes from background fluctuations)



> No significant excess over one order in magnitude in mass

> Two fluctuations around 2σ

MSSM Higgs →ττ

- Many theories predict that the discovered Higgs boson is just part of a larger Higgs sector: Supersymmetry a prominent example
- Additional neutral Higgs bosons have enhanced branching ratios to tau pairs across much of the parameter space
- New ATLAS result sees no evidence for signal, but pushes exclusion limits to highest masses yet