Status of ATLAS

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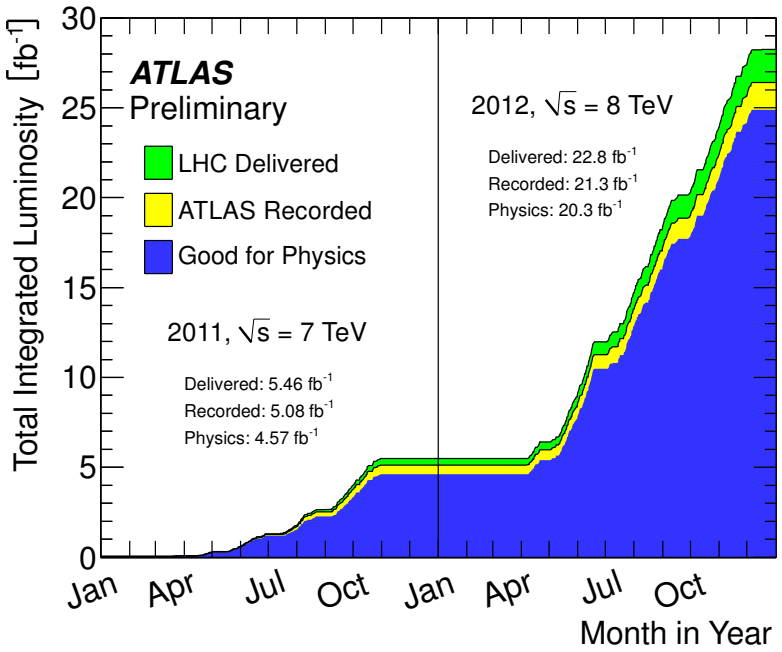
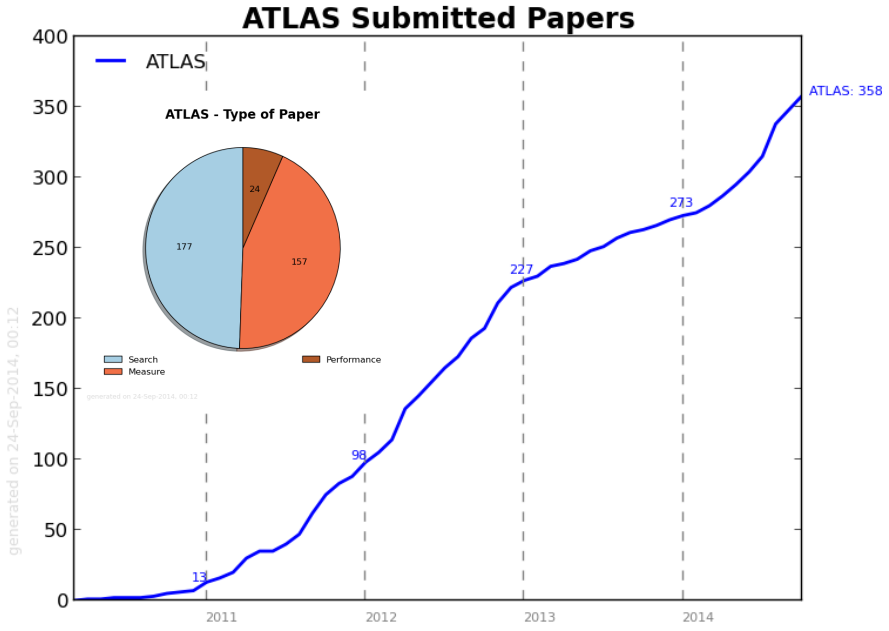
Very successful Run 1!

2010: $\sqrt{s} = 7$ TeV, 0.05 fb^{-1}
2011: $\sqrt{s} = 7$ TeV, 4.6 fb^{-1}
2012: $\sqrt{s} = 8$ TeV, 20.3 fb^{-1}

Big thanks to the LHC staff!



About 90% of delivered data usable for physics.



Over 350 submitted papers to date!

Over 2 papers/week in 2014.

Nearly 600 conference notes.

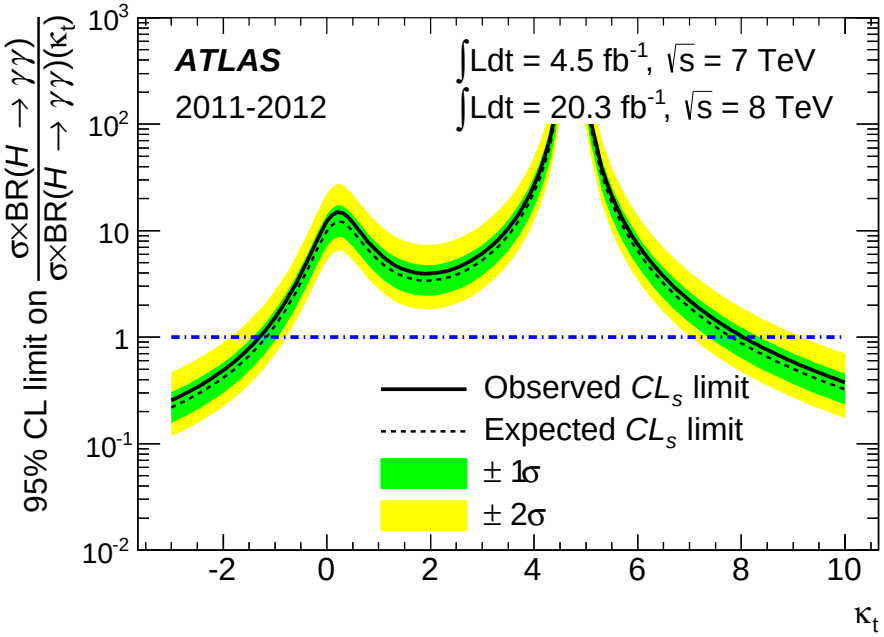
And still coming...

Recent physics results

Search for $t/t\bar{t} + H \to \gamma\gamma$

[arXiv:1409.3122]

- Direct measurement of t–H Yukawa coupling $\kappa_t = Y_t/Y_t^{SM}$.
- BSM models predict $\kappa_t \neq 1$ and even $\kappa_t < 0$.
- Using tH allows probing κ_t sign.

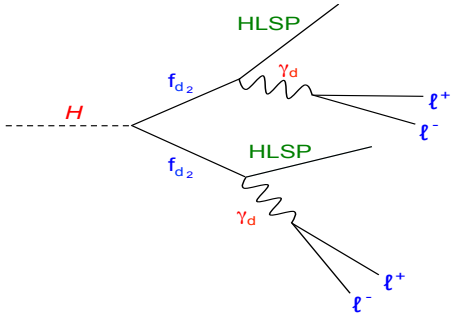


Exclude $\kappa_t < -1.3$ and $\kappa_t > 8.1$.

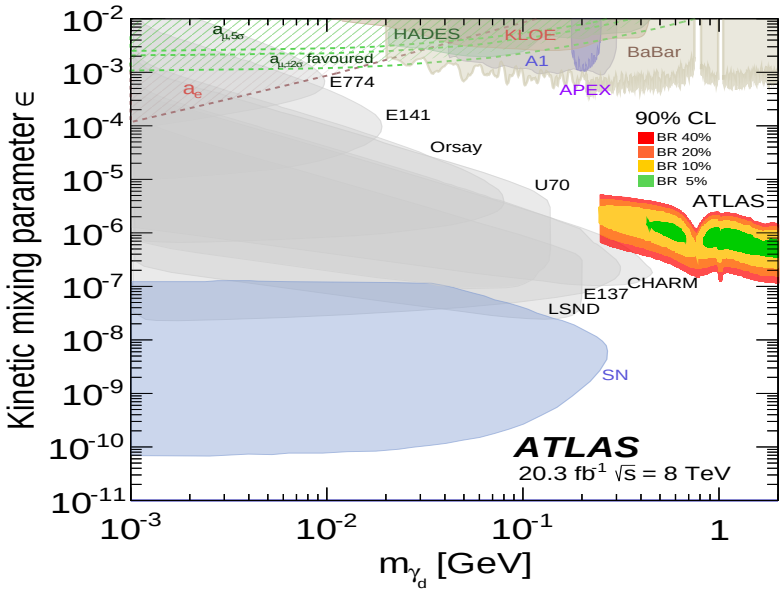
Search for long-lived particles decaying into lepton jets

[arXiv:1409.0746]

Hidden sector search: Higgs to dark photon $\gamma_d \to ee/\mu\mu/\pi\pi$.



Search for clusters of muons/jets

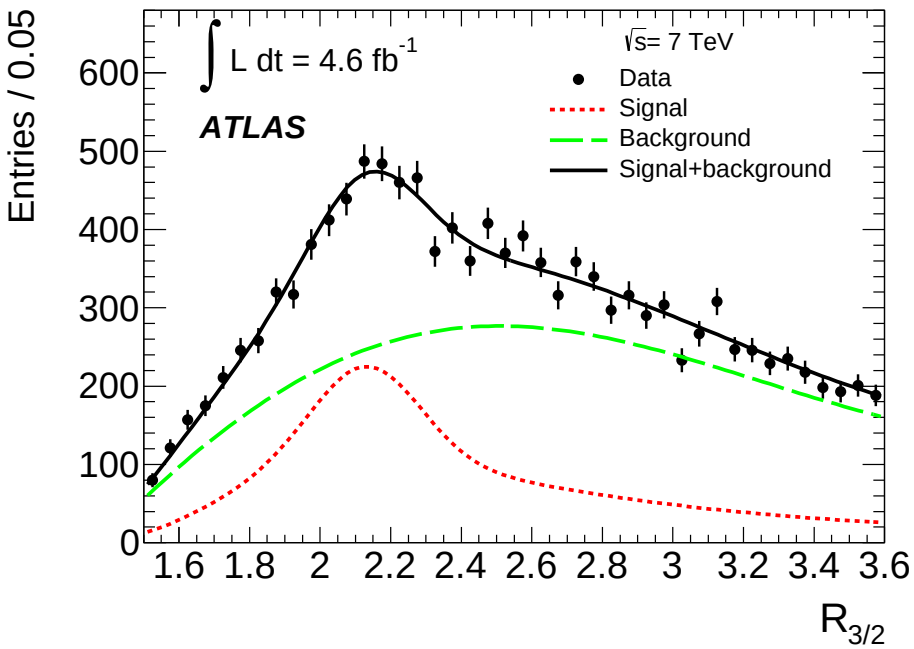


m_t in fully-hadronic channel

[arXiv:1409.0832]

Reduce uncertainty from jet scale by using observable $R_{3/2} = m_{jjj}/m_{jj}$.

Assign jets to partons with a kinematic fit. Fit $R_{3/2}$ with templates.



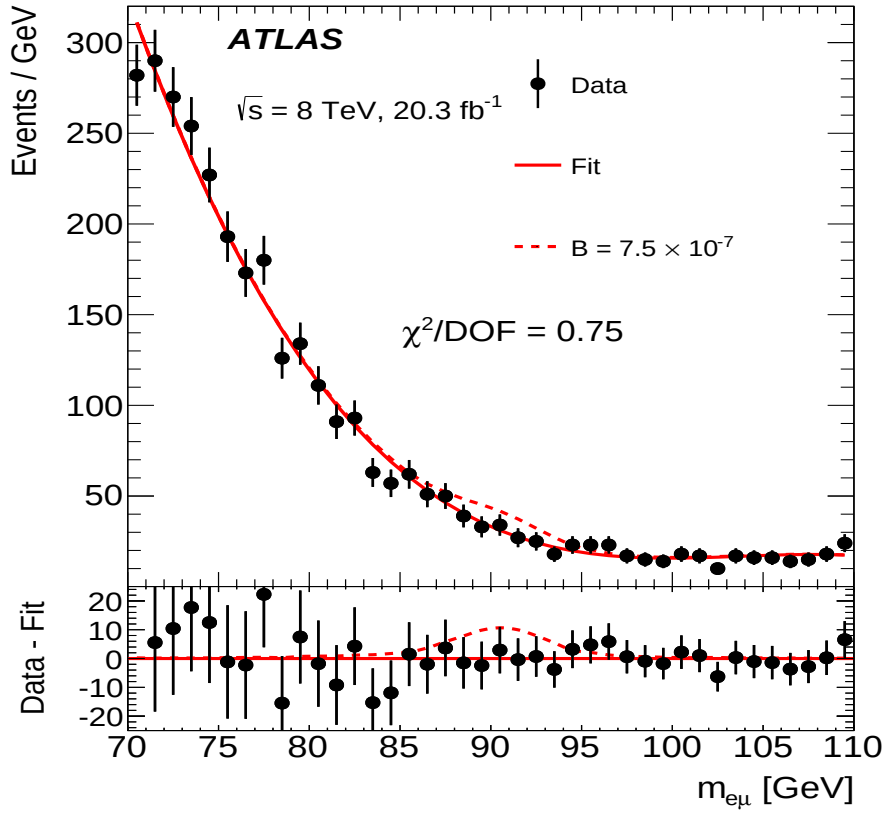
From 4.6 fb^{-1} (7 TeV)

$m_t = 175.1 \pm 1.4\,(\text{stat.}) \pm 1.2\,(\text{syst.})$ GeV

Search for $Z \to e\mu$

[arXiv:1408.5774]

Direct lepton flavor violation search.



From 20.3 fb^{-1} (8 TeV)

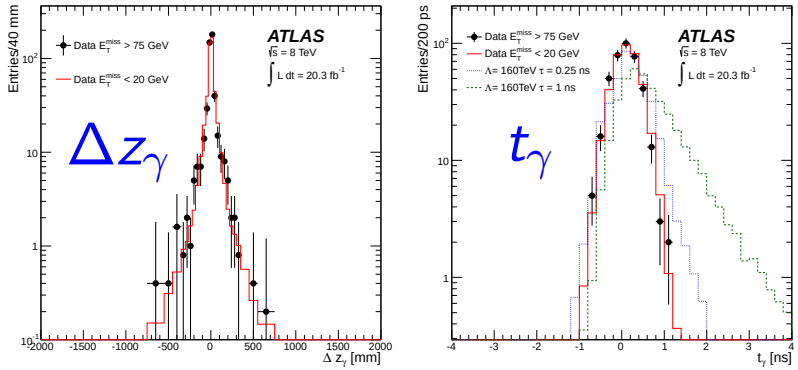
$\text{BR}(Z \to e\mu) < 7.5 \times 10^{-7}$ (95% CL)

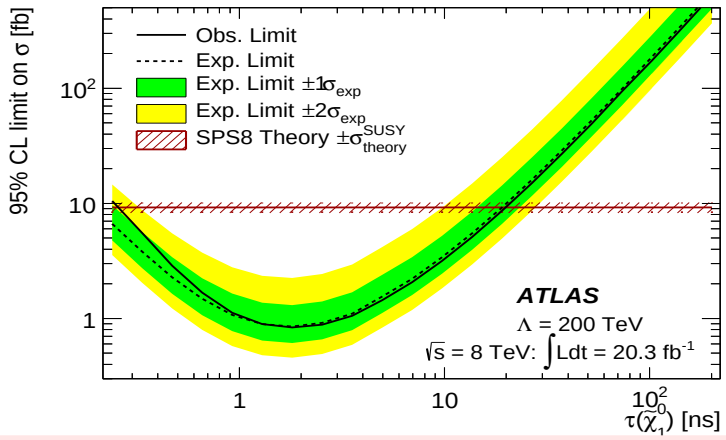
$\times 2$ better than prev. best limit (LEP)

SUSY search with displaced/delayed photons [arXiv:1409.5542]

Search for GMSB SUSY process $pp \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 \to \gamma\gamma \tilde{G}\tilde{G}$.

LAr EM calo can measure γ incident angle and TOF.



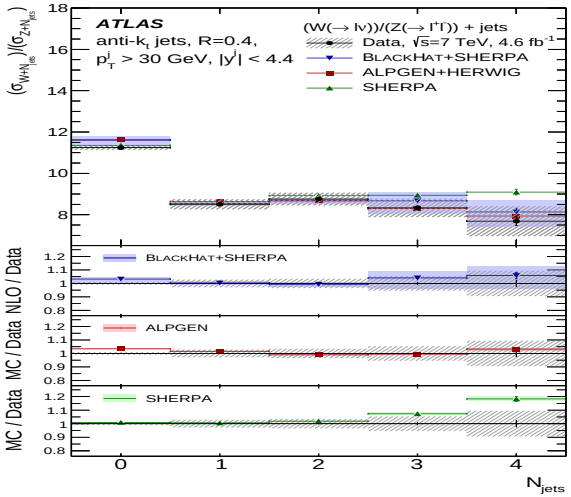


$\Lambda = 200$ TeV: exclude $0.3 < \tau < 20$ ns.

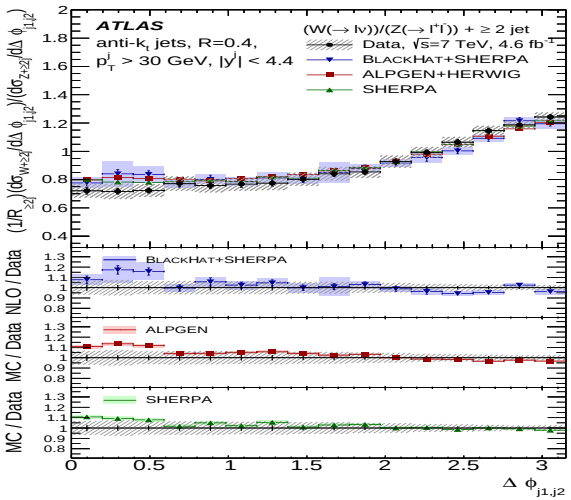
Measurement of $W + \text{jets}/Z + \text{jets}$ cross section ratio [arXiv:1408.6510]

$R_{\text{jets}} = \sigma(W + \text{jets})/\sigma(Z + \text{jets})$.

Sensitive test of pQCD.



R_{jets} vs. N_{jets} (exclusive)



R_{jets} vs. $\Delta\phi(j_1, j_2)$ ($N_{\text{jets}} \geq 2$)

Many other differential distributions in paper.

Detector upgrades

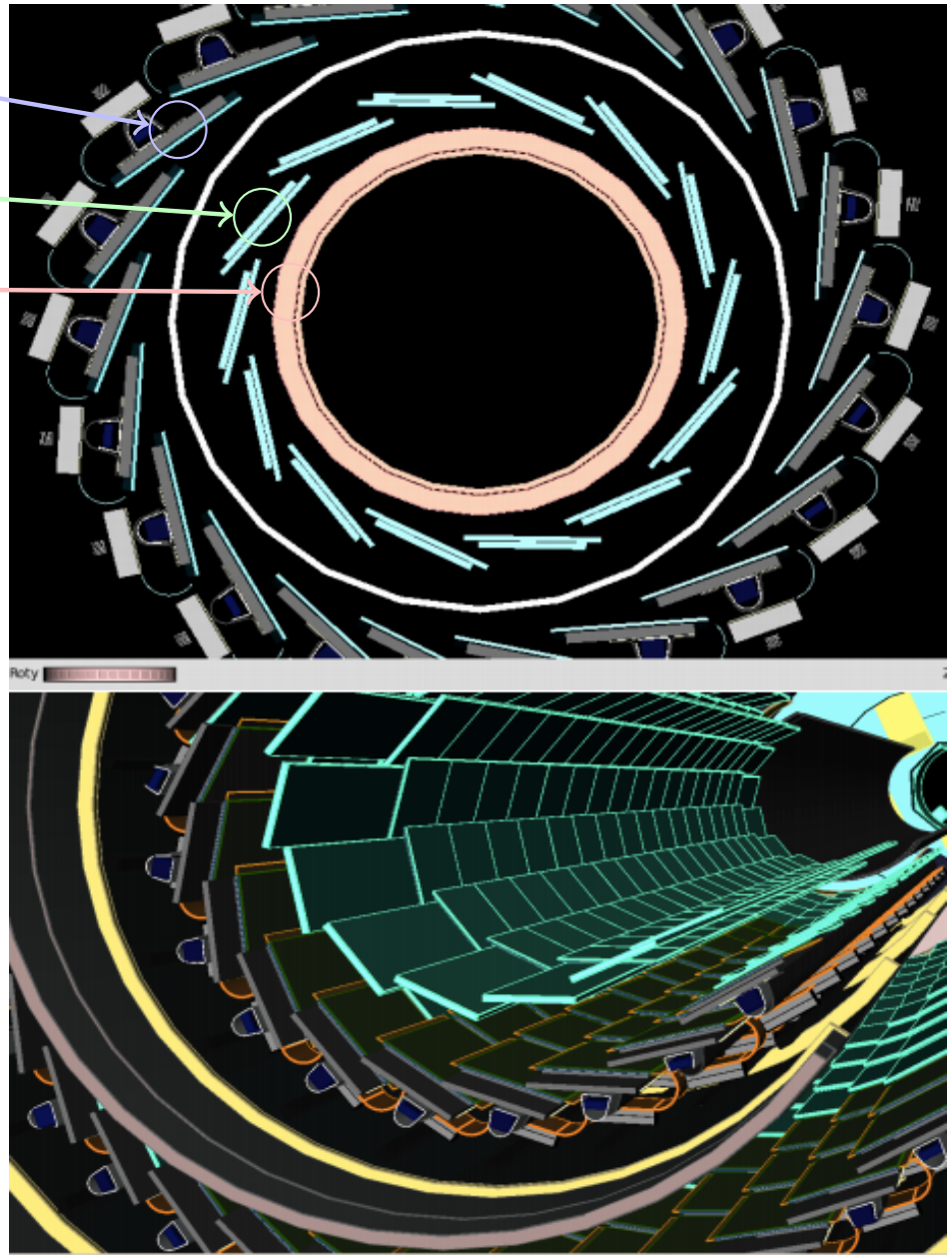
Insertable B Layer

Existing innermost ("B") layer

New innermost layer (IBL)

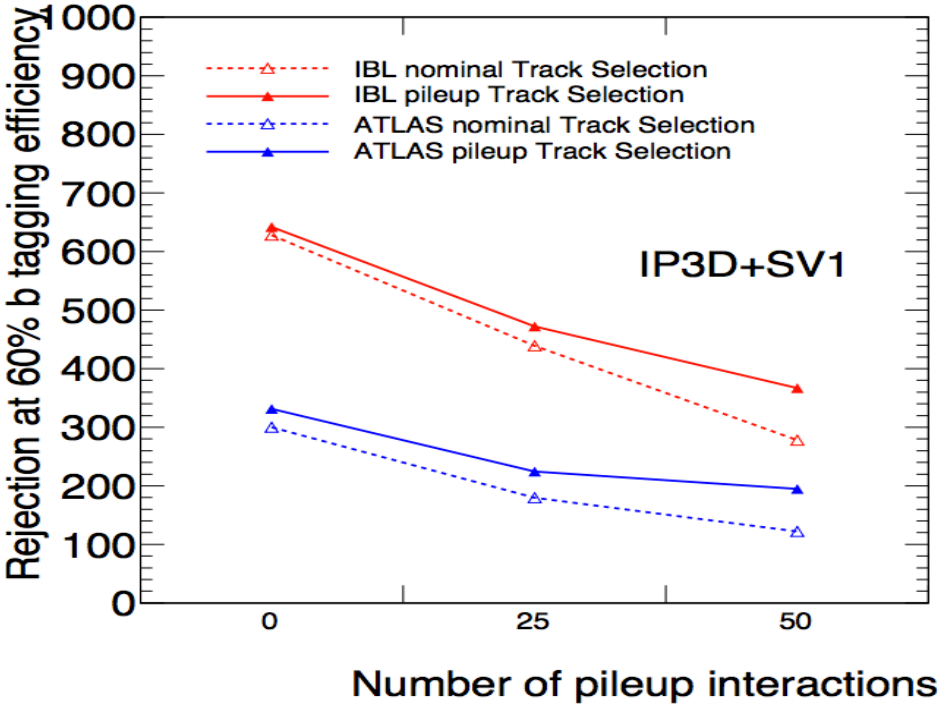
New smaller Be beampipe

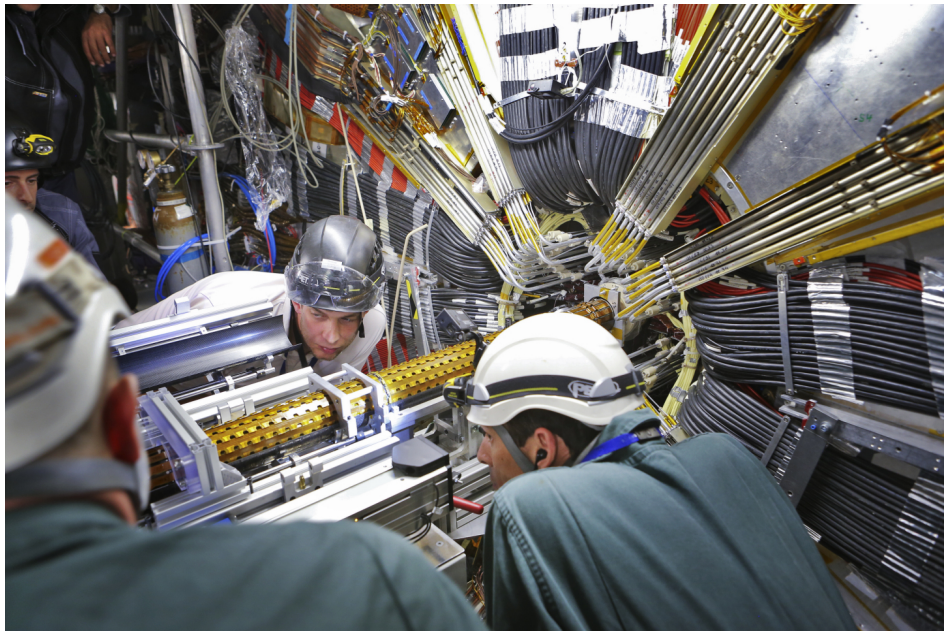
- Adding a 4th pixel layer.
- Closer to interaction point ($5.1 \rightarrow 3.3$ cm).
- Smaller pixels (50×250 μm).
- Better sensors, readout chip.



Insertable B Layer

- Improve impact resolution with additional point closer to origin;
- Improve light-jet rejection for *b*-tagging;
- Redundancy against inefficiency due to radiation damage.



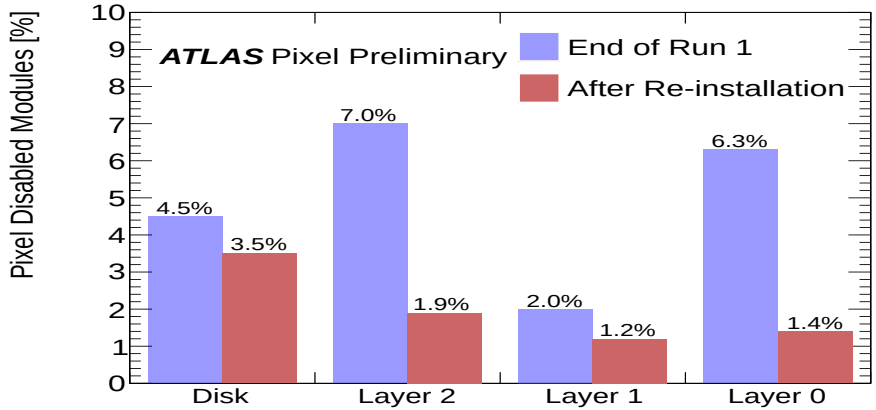


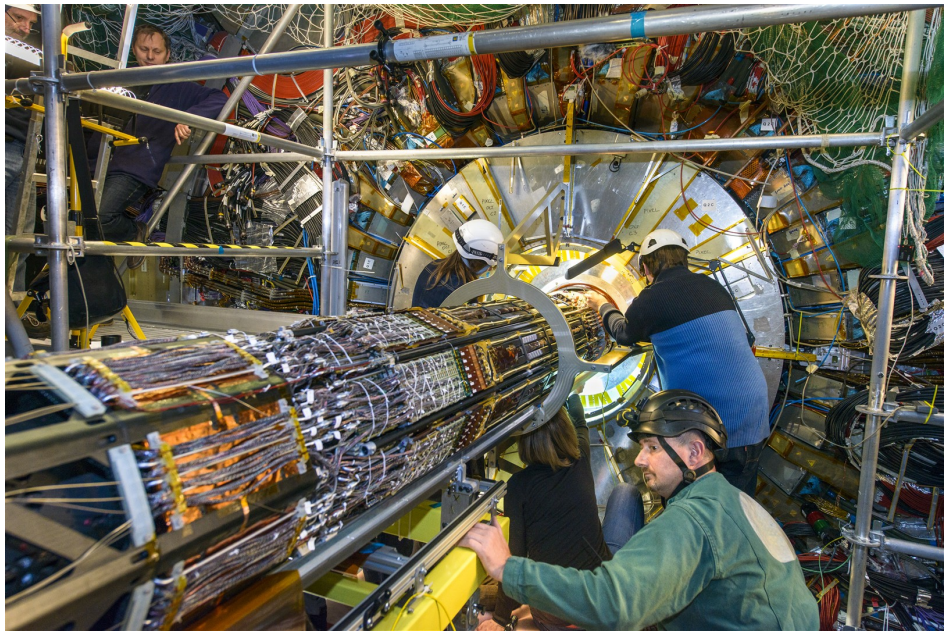
- 30 Apr: Assembly complete.
- 7 May: Installed in ATLAS.
- 27 Jun: Cabling complete.
- 10 Sep: One stave integrated into ATLAS readout.

No dead modules.
Dead pixels $< 0.1\%$ (goal: $< 1\%$).

Pixel detector

Pixel detector brought to surface.
Replaced detector services; allows higher readout bandwidth.
Optoelectronics moved off-detector.
Prepared for new inner layer.





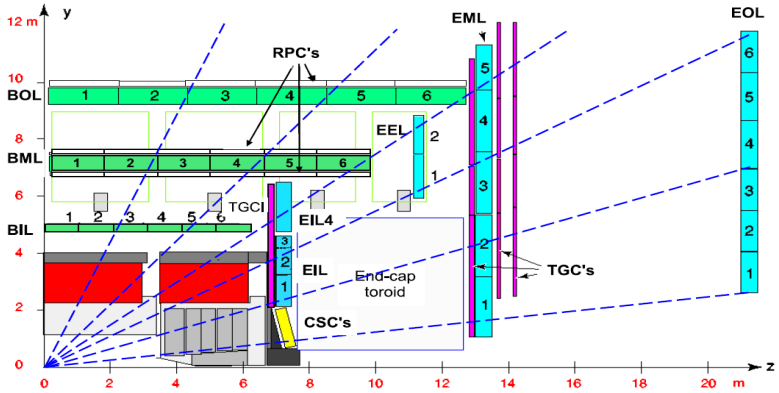
- New beam monitor for luminosity measurements. (6 diamond, 2 Si detectors.)
- Repaired dead modules.

Detector successfully reinstalled and tested.

Operational fraction: 95% → 98% .

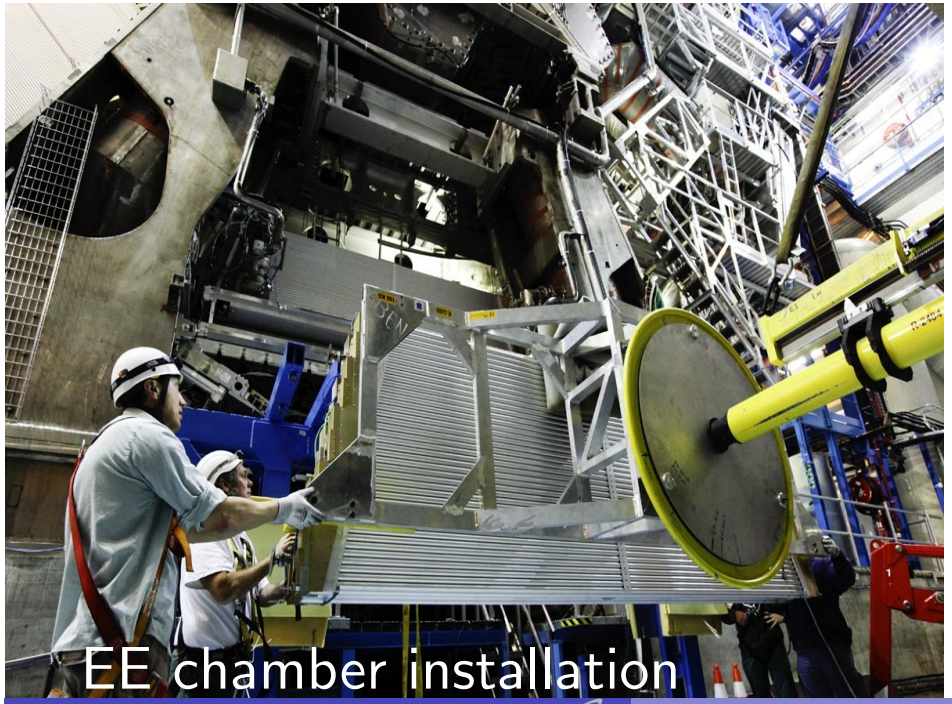
Muon systems

- Installed "EE" endcap chambers.
- Electronics for trigger chambers around detector feet.
  - Both staged from Run 1.



Full muon system as described in TDR now commissioned.

Additional chambers to recover acceptance around elevator shaft.



EE chamber installation

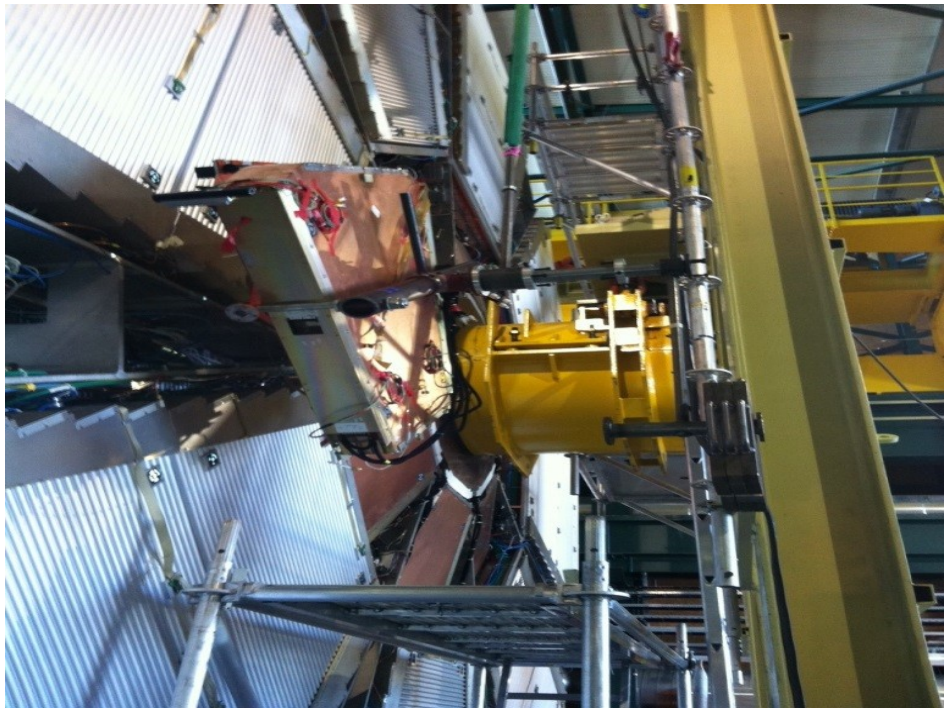
Elevator chamber installation

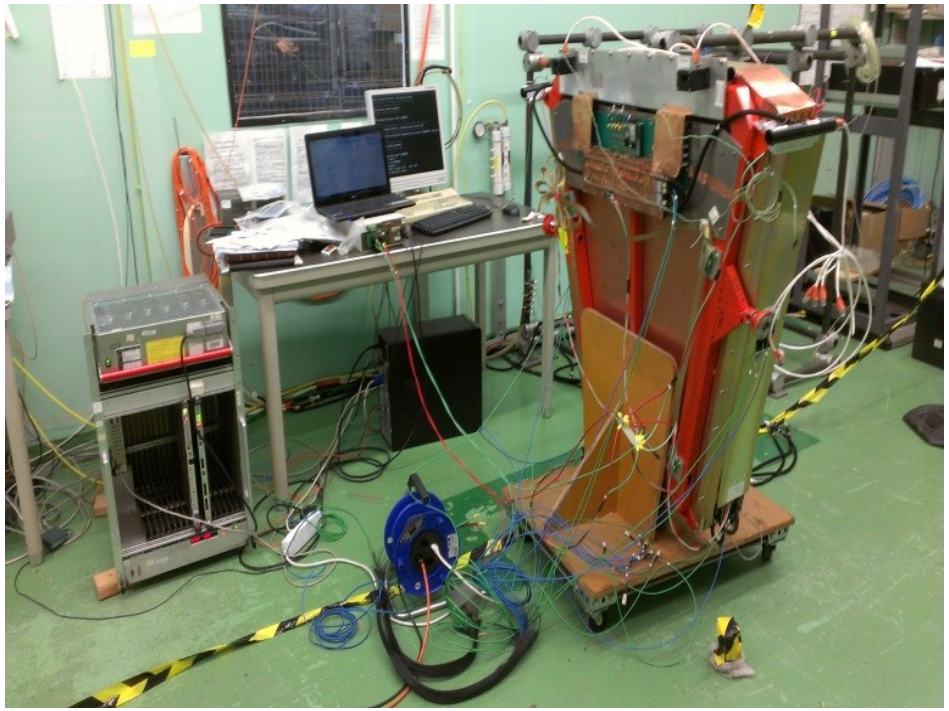
Muon systems

- New CSC readout system.
  - Was limiting overall ATLAS L1 trigger rate to 70 kHz.
  - Can now run at 100 kHz!
- Extracted broken CSC chambers. Repaired and reinstalled.

Also:

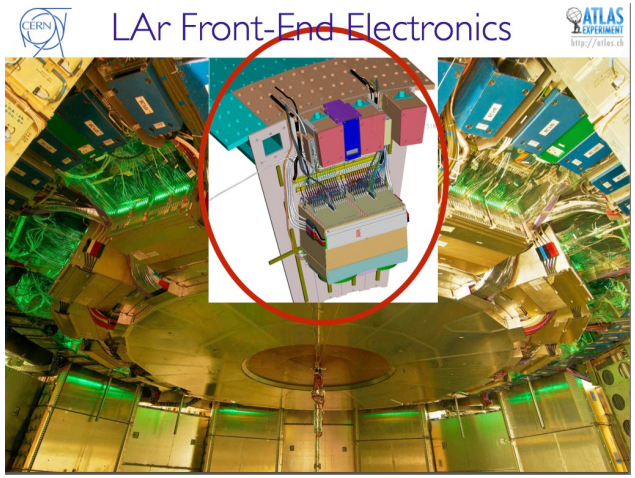
- RPC gas leak repairs.
- Readout stability improvements.
- Still need to replace some bad TGC chambers.



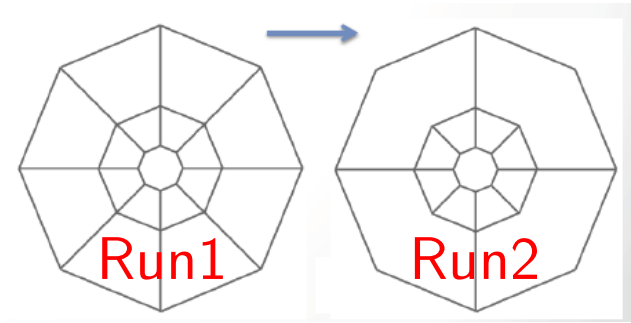


Calorimeters

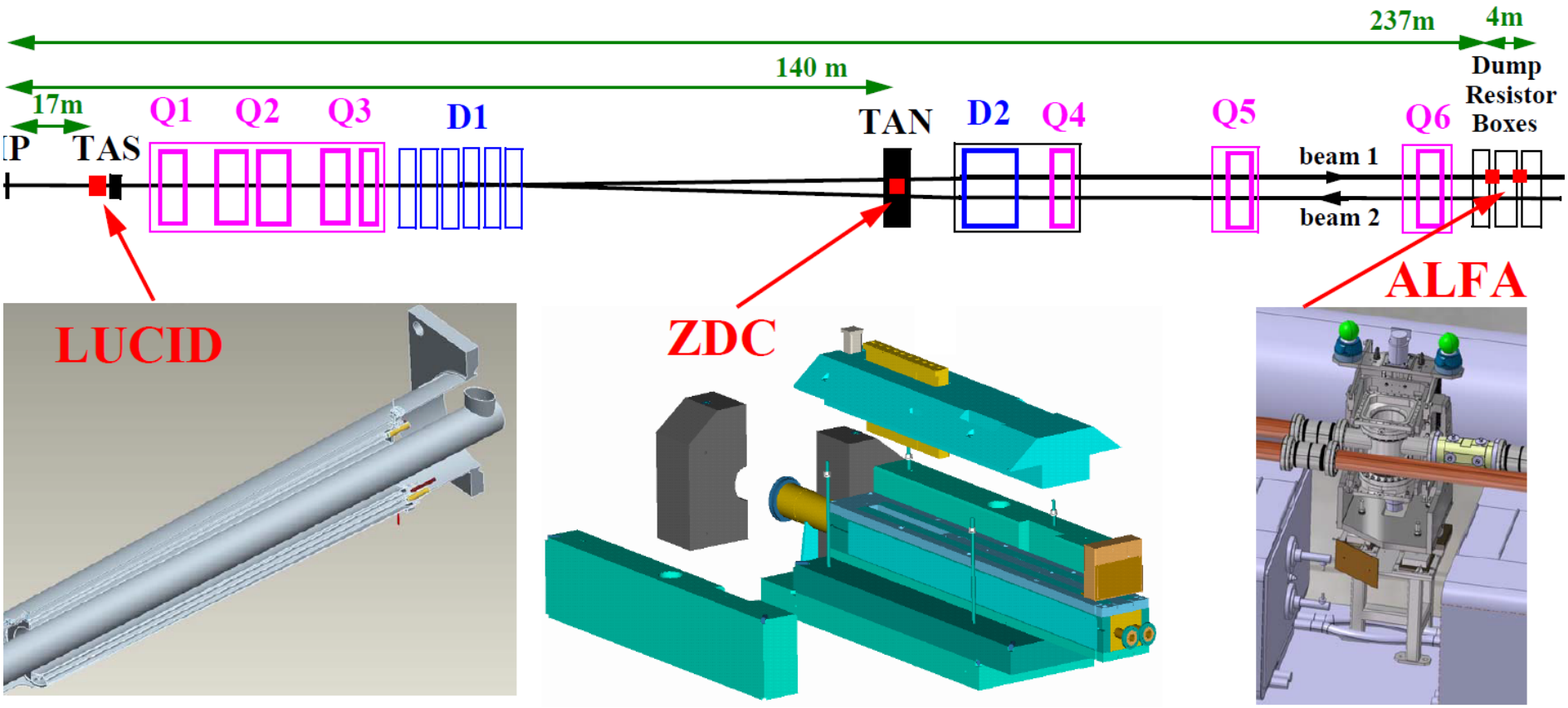
- Repaired LAr front-end boards.
- Replaced bad readout fibers.
- All new LAr LV power supplies.
  - Installed and operated in 2013.
  - Failures observed in Feb 2014 due to cracked capacitors.
  - Capacitors replaced Apr–Jun. All supplies working well since then.



- Tile FE electronics and LVPS repair.
- New minimum bias trigger scintillators.



Forward detectors



Lumi

New PMTs, electronics for 25 ns to avoid saturation.

Small θ neutrals (HI)

Radiation-damaged quartz fibers to be replaced for 2016 HI run.

Lumi, σ_{tot}, diff

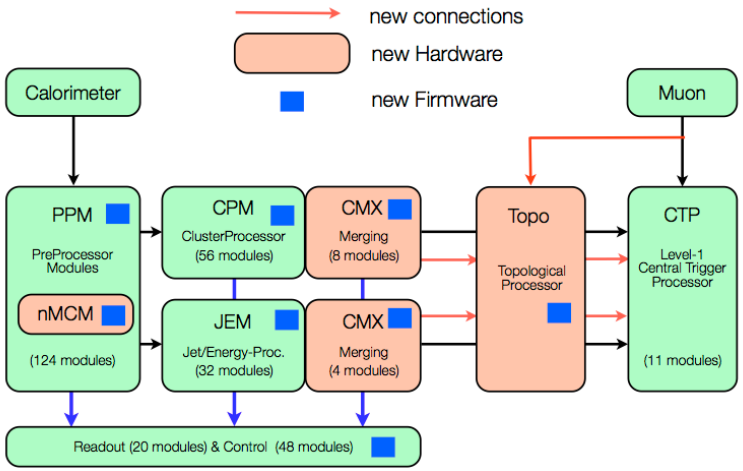
Reduce beam-induced heating with Roman Pot "fillers."

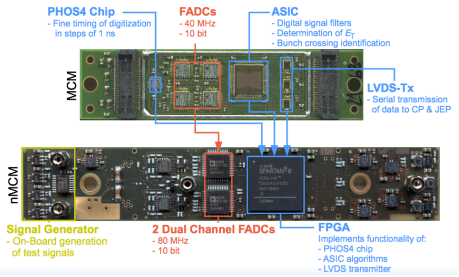
Move out 4m.

Trigger

L1 trigger upgrade:

- Overall L1 rate increased from 70 kHz to 100 kHz.
- New L1 calo preprocessors (nMCM): 80 MHz digitization, lower noise, better pileup handling.
- L1 topo processor allows trigging on relations between objects, e.g. $\Delta\phi(E_{\mathrm{T}}^{\mathrm{miss}}, j)$.
- Require coincidences between tile/inner muon endcap and outer muon endcap to reduce fakes.
- New central trigger processor hardware+software.
- Readout system upgrades.





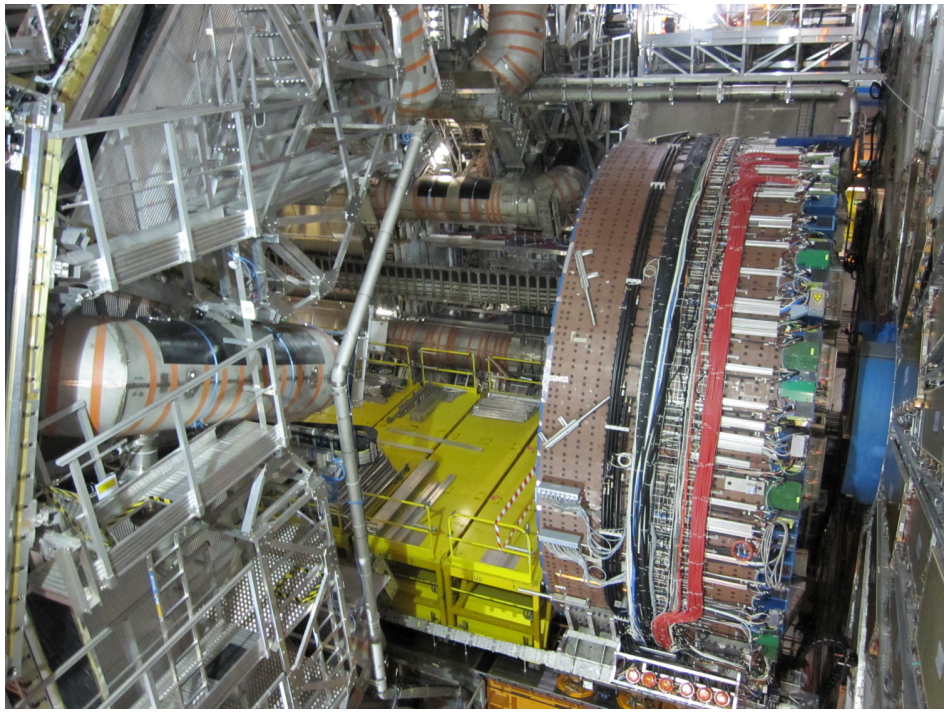
High-level trigger: significant speed increases; more use of offline algorithms to cope with pileup.

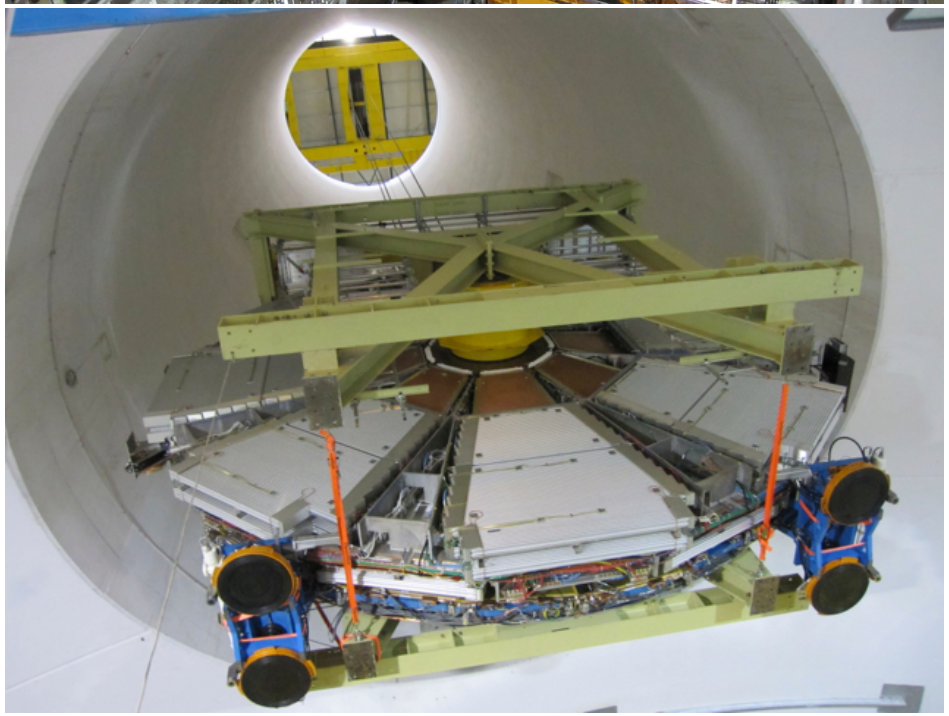
Installation/commissioning in progress!

Other detector work

Over 250 scheduled jobs, including:

- Replace SS beam pipes with Al.
  - Reduce cavern background.
- Magnet cryogenics consolidation.
- UPS to protect against power glitches.
- New inner detector cooling system.
- TRT Xe gas leak repair.
- SCT DAQ upgrade.



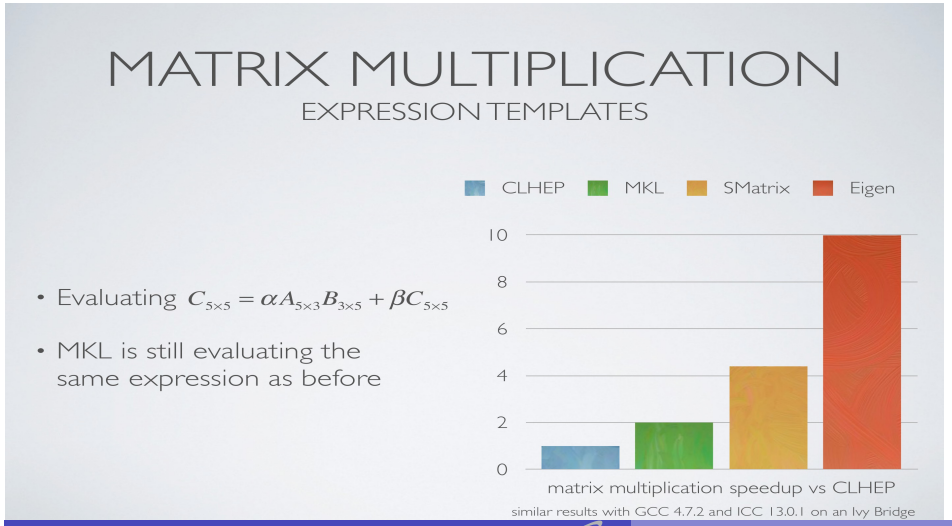


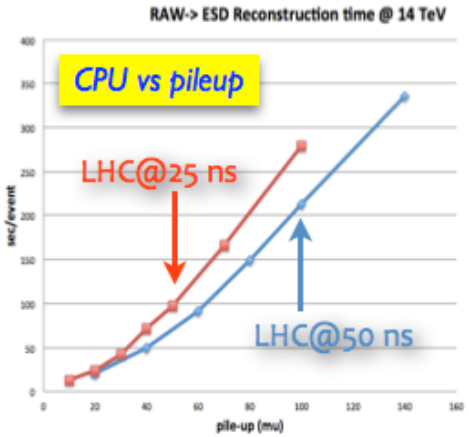
Offline computing

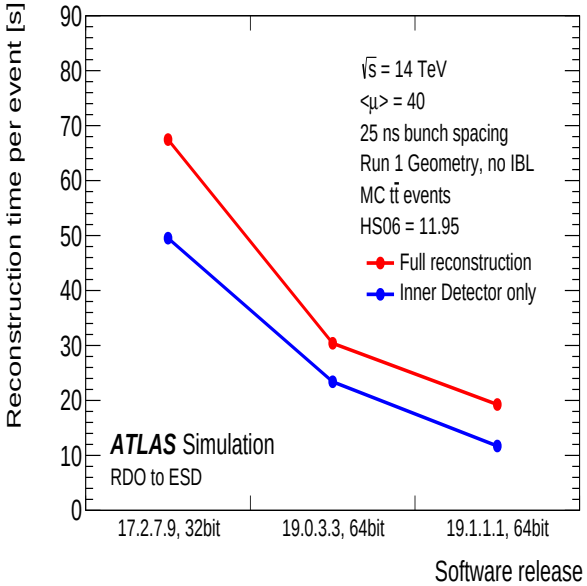
Reconstruction time increases with pileup (dominantly tracking).

Effort to speed up reconstruction:

- Algo. changes, esp. track seeding.
- CLHEP $\rightarrow$ Eigen for linear algebra.
- Use vectorized special functions.
- B-field management rewritten.
- Simplified tracking data model.



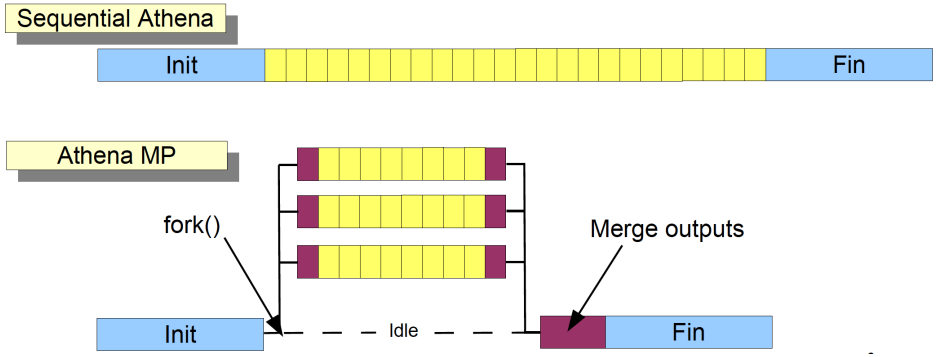




3× improvement in processing time!

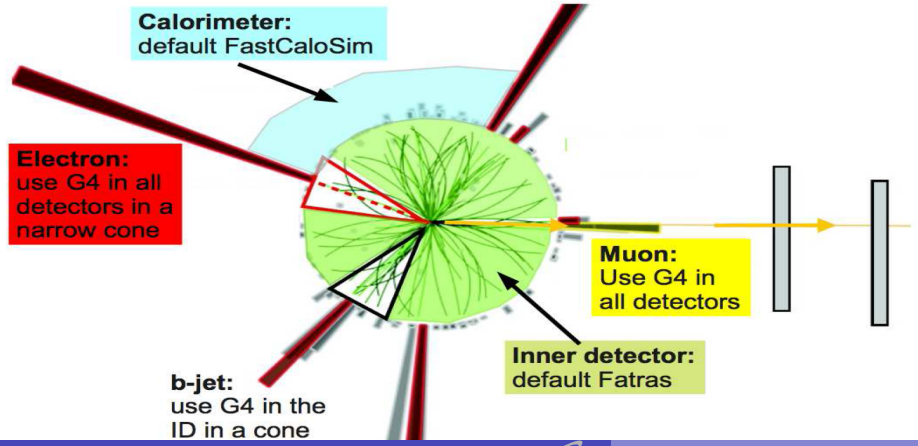
Offline computing

AthenaMP: Use `fork()` to share memory between parallel jobs.



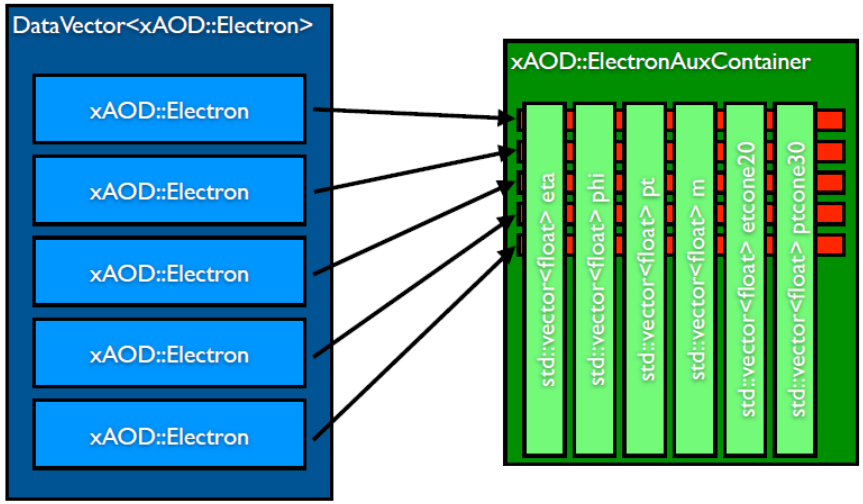
New Integrated Simulation Framework:

- Mix fast and full simulation within an event.



New analysis data model:

- Separate storage of object properties.
- Better locality.
- Allows partial object reading and user extension of objects.



Also big upgrades to data handling and production software!

Recommissioning for Run 2: Milestone weeks

Detector integration tests periodically scheduled through 2014.

Most recent: M5, week of 8 Sep.

- Most of ATLAS read out.
- At high rate (100 kHz).
- Including part of IBL.

Still a lot to do, but ATLAS is coming together again as an integrated experiment!

Future milestones:

- 13–17 Oct. Full IBL readout.
- 24 Nov – 7 Dec.
- Cosmics tests in Feb.
- Ready for first beams in March!

	M3	M4	M5	M6
	May19-May 23	Jul 7-Jul 11	Sep 8-Sep 12	Oct 13-Oct 17
PIX		X^1, X^2	X^2	
IBL		X^1	X^2	
SCT		X	X^2	
TRT				
LAR		X		
TIL		X		
MBTS		X		
L1Calo		X^2	X^3	X^4
CSC			X^2	X^2
MDT				
RPC	X^1			
TGC				X^2
BCM				
ALFA			X	
LUCID				X
Lumi			X	

ATLAS upgrades

LS1: Phase 0 (Now!)

$\sqrt{s} = 13$–14 TeV
25 ns bunch spacing
$\mathcal{L} = 10^{34}$ cm^{-2} s^{-1}

- Insertable B layer.
- Pixel repairs.
- Complete muon coverage.
- L1 calo trigger upgrade.
- L1 topo trigger.

LS2: Phase-I $\sim$ 2018

$\sqrt{s} = 14$ TeV
25 ns bunch spacing
$\mathcal{L} = 2 \times 10^{34}$ cm^{-2} s^{-1}

- New small wheels (muon endcap).
- Fast tracking trigger (L2).
- Higher-granularity information to calorimeter trigger.
- DAQ upgrades.

LS3: Phase-II $\sim$ 2022

$\sqrt{s} = 14$ TeV
25 ns bunch spacing
$\mathcal{L} = 5 \times 10^{34}$ cm^{-2} s^{-1}

- All-Si inner tracker.
- L1 track trigger.
- New LAr calorimeter electronics.
- Possible upgrades of forward calorimeters.
- Muon trigger/readout electronics.
- New trigger architecture.

See Weiming Yao's talk for more!

Summary

ATLAS had a very successful Run 1

- Technical goals exceeded.
- Hundreds of physics publications.
- More to come!

Huge efforts by many people to prepare for Run 2

- Higher energy, luminosity, pileup; reduced bunch spacing.
- Refurbished pixel detector with new innermost layer.
- Many other improvements.

Recommissioning ongoing.

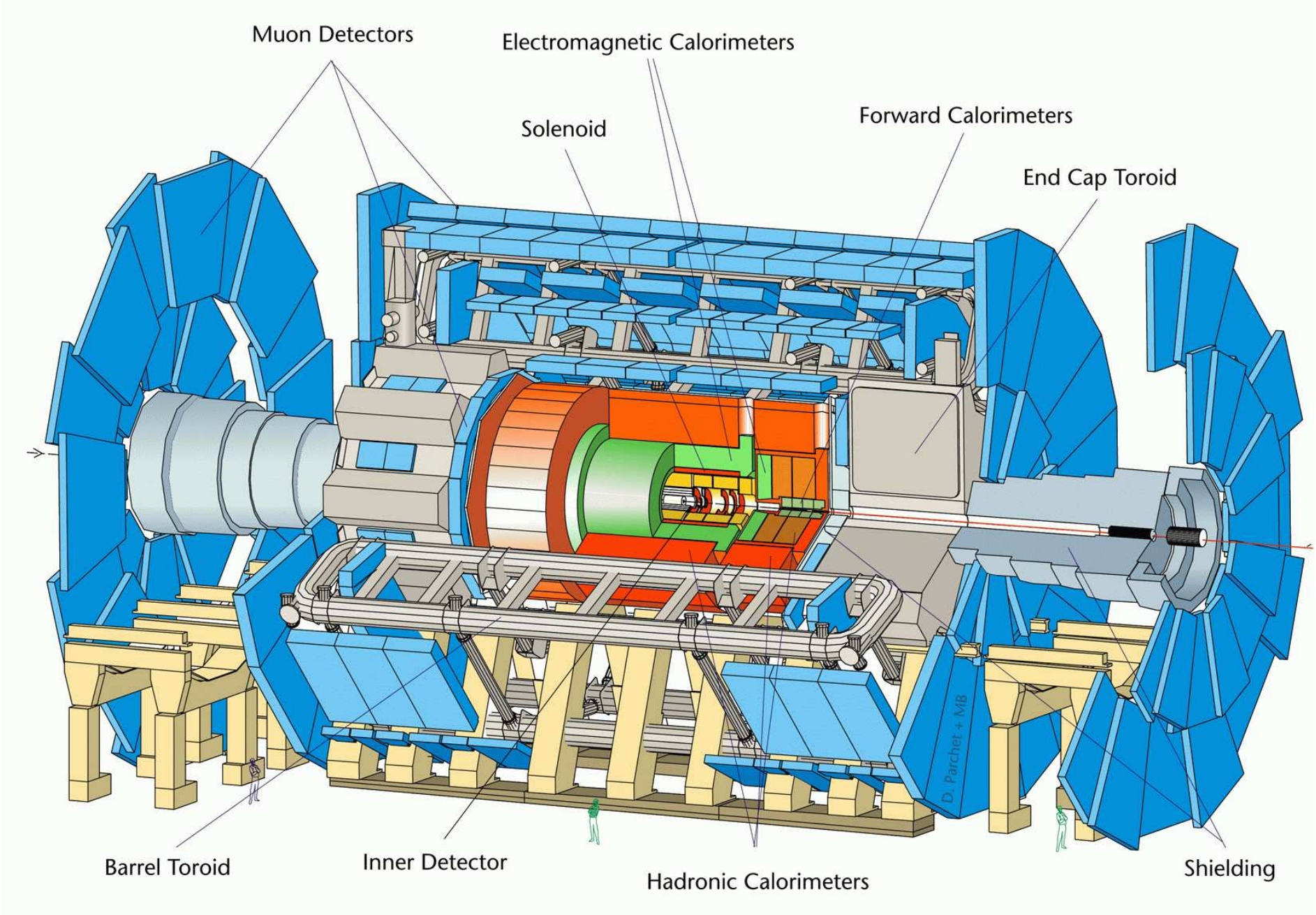
Other ATLAS talks this week:

- M. Backes: tb partner search
- M. Bugge: BSM with HL-LHC
- C. Guyot: SUSY/BSM
- A. Cerri: b physics
- D.B. Ta: t physics
- A. Buckley: QCD physics
- J. Ramos: EWK physics
- N. Berger: Higgs prod/decay
- N. Karastatis: Higgs properties
- X. Sun: BSM Higgs
- A. Dimitrievska: Muon performance
- S. Marsden: Diboson resonances
- W. Yao: Upgrade

On track to be ready for first physics in the spring!

Extra

ATLAS detector



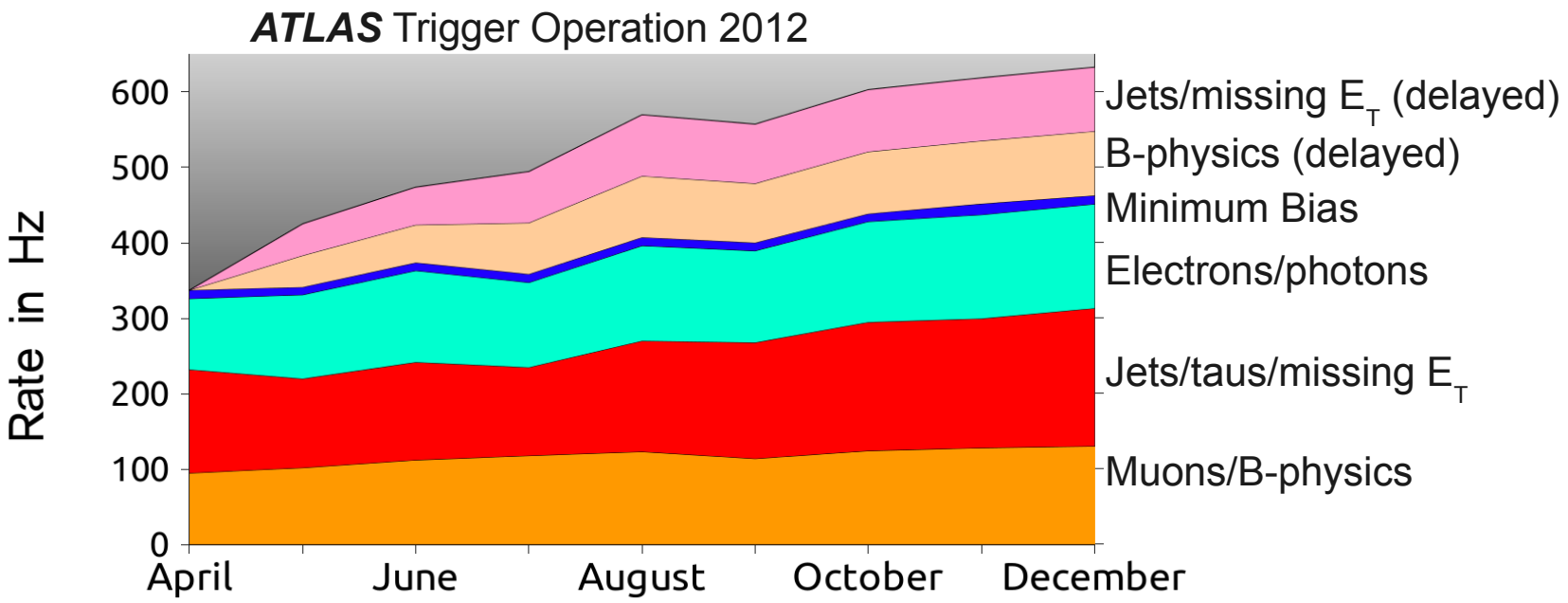
Run 1 data

Recorded data at up to 600 Hz (design 200 Hz).

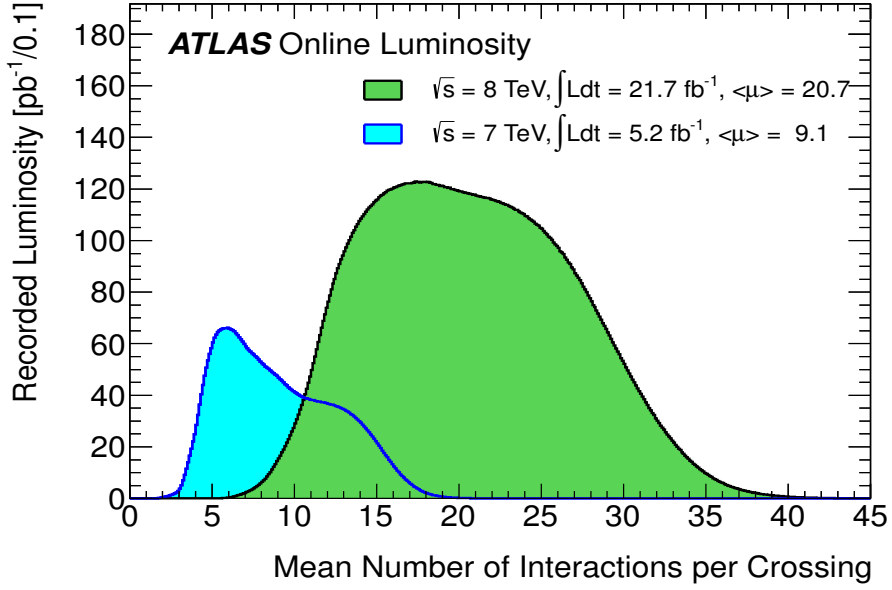
High fraction of good-quality data.

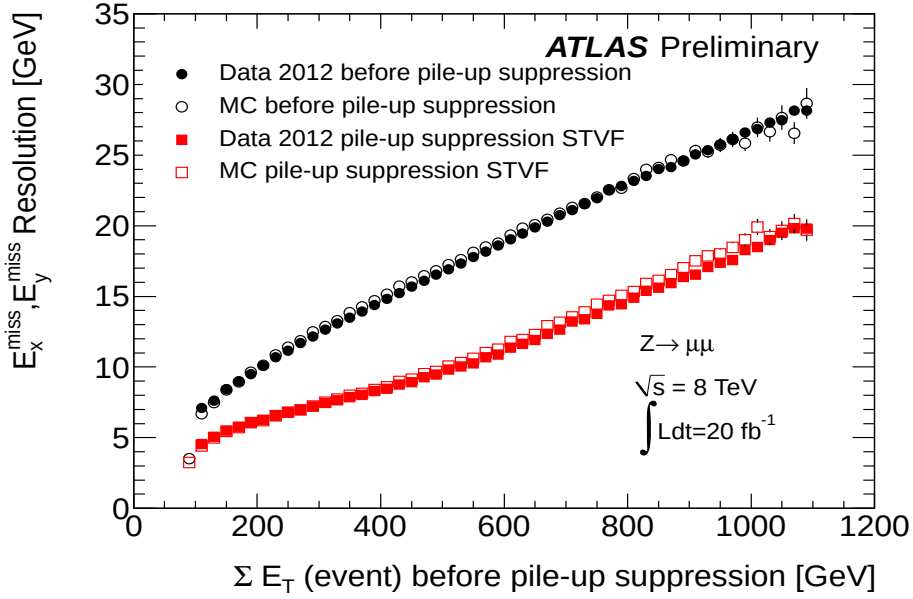
ATLAS p-p run: April-December 2012										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.9	99.1	99.8	99.1	99.6	99.6	99.8	100.	99.6	99.8	99.5
All good for physics: 95.5%										

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.

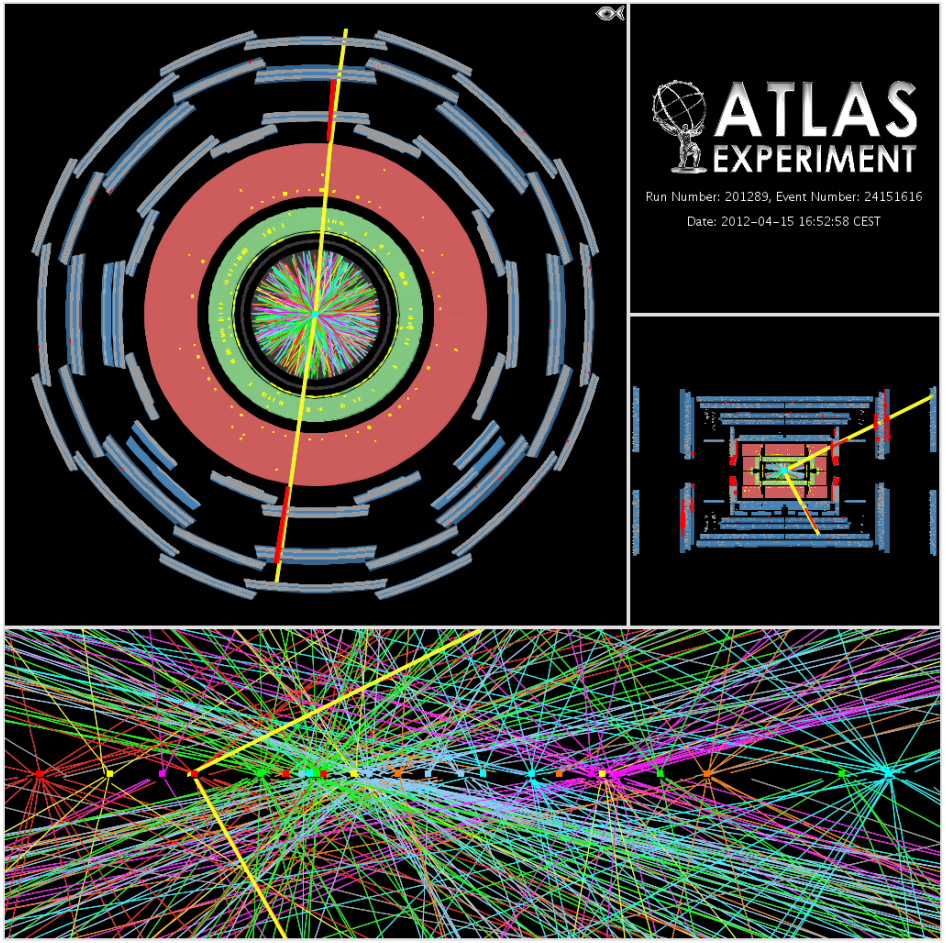


Pileup in Run 1





Routinely reached > 35 interactions per crossing. (Design < 25.)

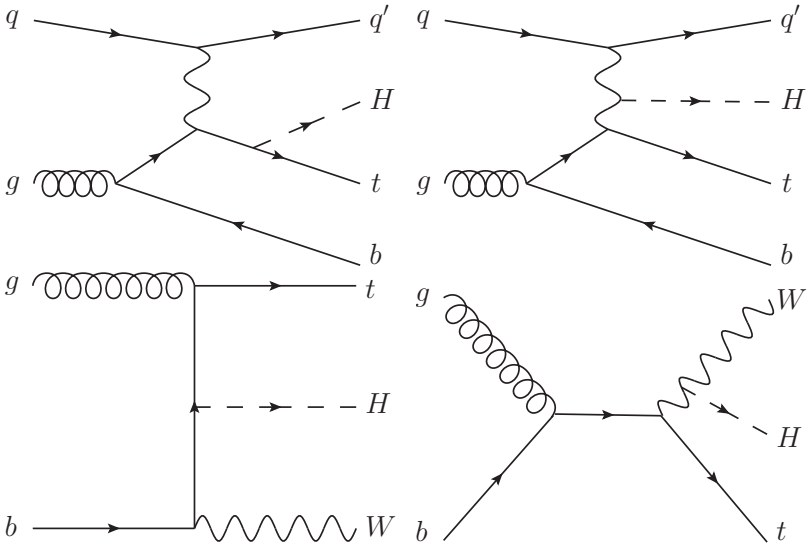


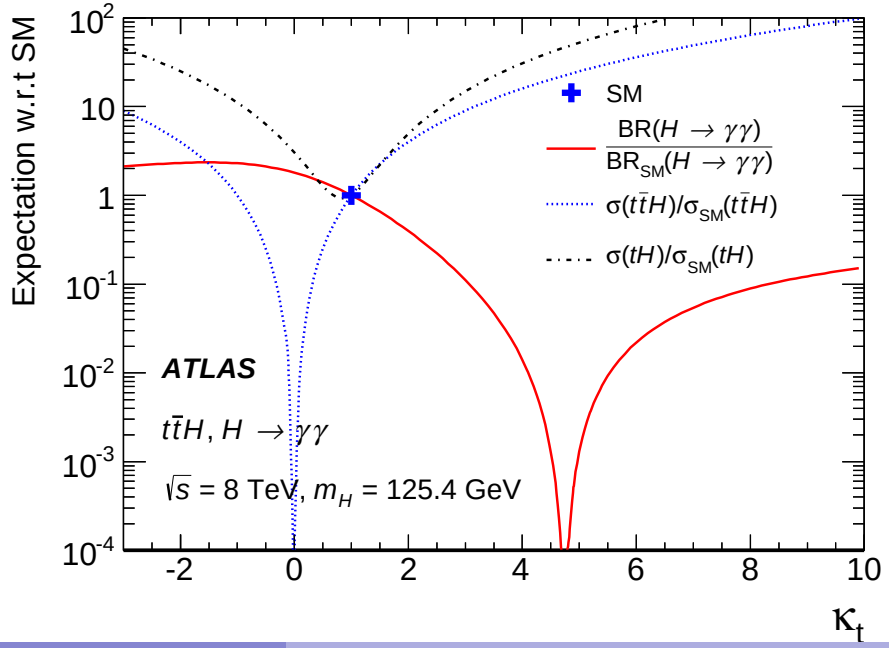
With hard work, effect of pileup was significantly reduced!

Search for $t/t\bar{t} + H \to \gamma\gamma$

[arXiv:1409.3122]

- Direct measurement of t–H Yukawa coupling Y_t.
  - Indirect measurements available through loop processes.
  - $\kappa_t = Y_t / Y_t^{SM}$
- BSM models predict $\kappa_t \neq 1$ and even $\kappa_t < 0$.
- SM $t + H$ processes too small to see in the current data set. But for κ_t far from 1, $t\bar{t}H$ and tH production are enhanced.
- If $\kappa_t < 0$ destructive interference in tH becomes constructive.
  - Including tH allows probing sign of κ_t.





Search for $t/t\bar{t} + H \to \gamma\gamma$ [arXiv:1409.3122]

Selection:

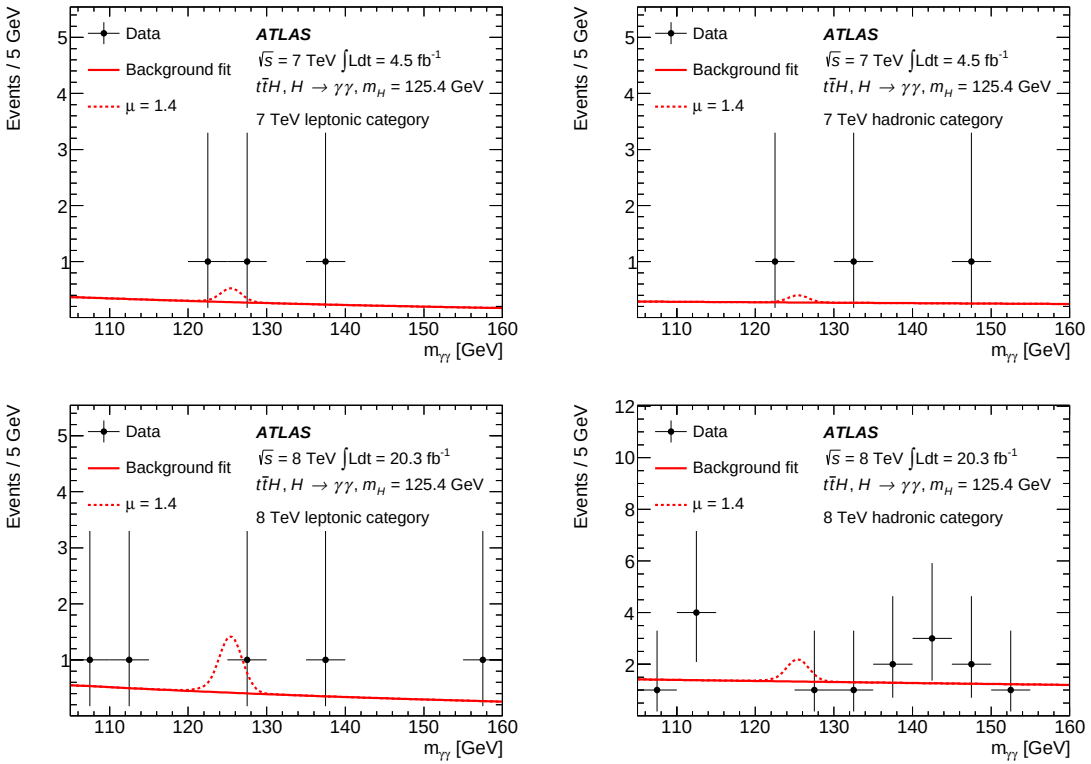
- Photon pair as in $H \to \gamma\gamma$ analysis.

Leptonic category ($t\bar{t}$ $\ell\ell$ and ℓj and single-top):

- e or μ
- Veto $84 < m_{\ell\gamma} < 94$.
- ≥ 1 b-tag.
- Either a second b-tagged jet or $E_T^{miss} > 20$ GeV.

Hadronic category ($t\bar{t}$ all-jet):

- No leptons.
- ≥ 6 jets and ≥ 2 b-tags.
- Additional selections on jet p_T and more stringent b-tagging.



BG fit with falling exponential, signal from MC.

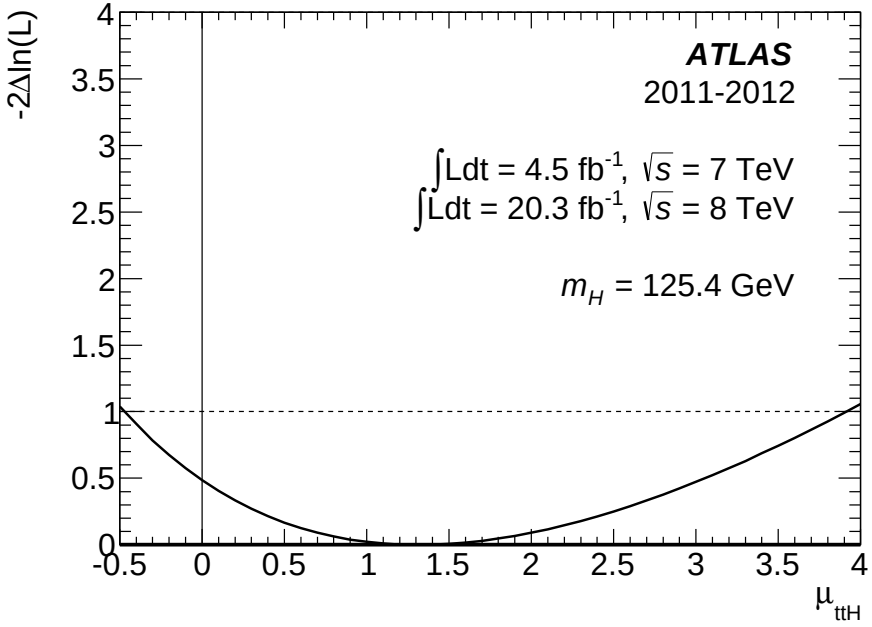
Full Run 1 data set: In 120–130 GeV, expect 1.3 Higgs events and $4.6^{+1.3}_{-0.9}$ BG; observe 5.

	7 TeV ℓ	7 TeV h	8 TeV ℓ	8 TeV h
N_H	0.10	0.07	0.58	0.49
N_B	$0.5^{+0.5}_{-0.3}$	$0.5^{+0.5}_{-0.3}$	$0.9^{+0.6}_{-0.4}$	$2.7^{+0.9}_{-0.7}$
N_{obs}	2	1	1	1

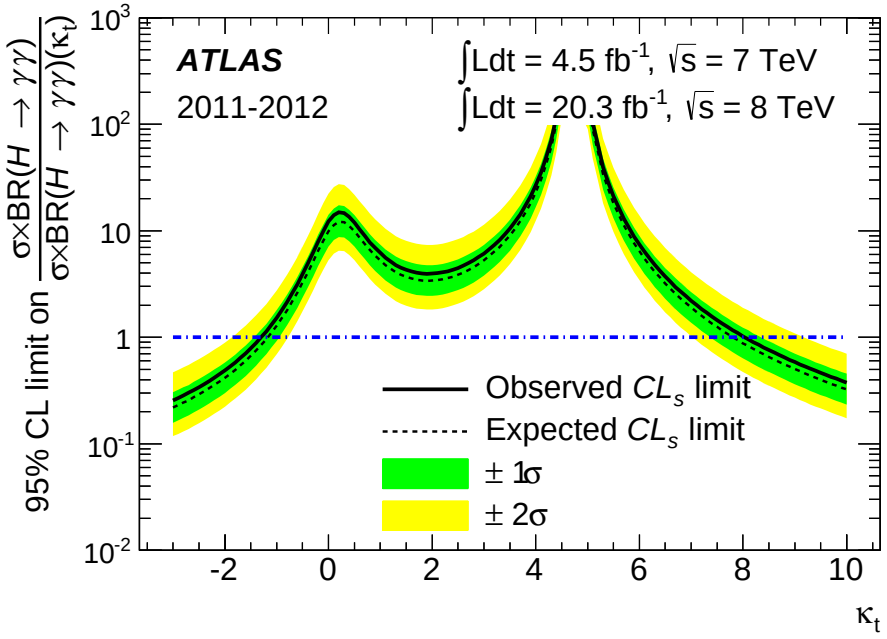
Search for $t/t\bar{t} + H \to \gamma\gamma$

[arXiv:1409.3122]

Likelihood for $\mu_{t\bar{t}H} = \sigma \times \mathrm{BR}(t\bar{t}H \to \gamma\gamma)$ relative to SM value.



Cross-section limit vs. κ_t:



Exclude $\kappa_t < -1.3$ and $\kappa_t > 8.1$.

$\mu_{t\bar{t}H} = 1.3^{+2.5}_{-1.7}(\text{stat.})^{+0.8}_{-0.4}(\text{syst.})$

Expect to be able to see a significant ttH signal in Run 2!

95% CL limit: $\mu_{t\bar{t}H} < 6.7$.

m_t in fully-hadronic channel

[arXiv:1409.0832]

Measure m_t from $t\bar{t} \to bbqqqq$.
Uses the 7 TeV sample of 4.6 fb^{-1}.

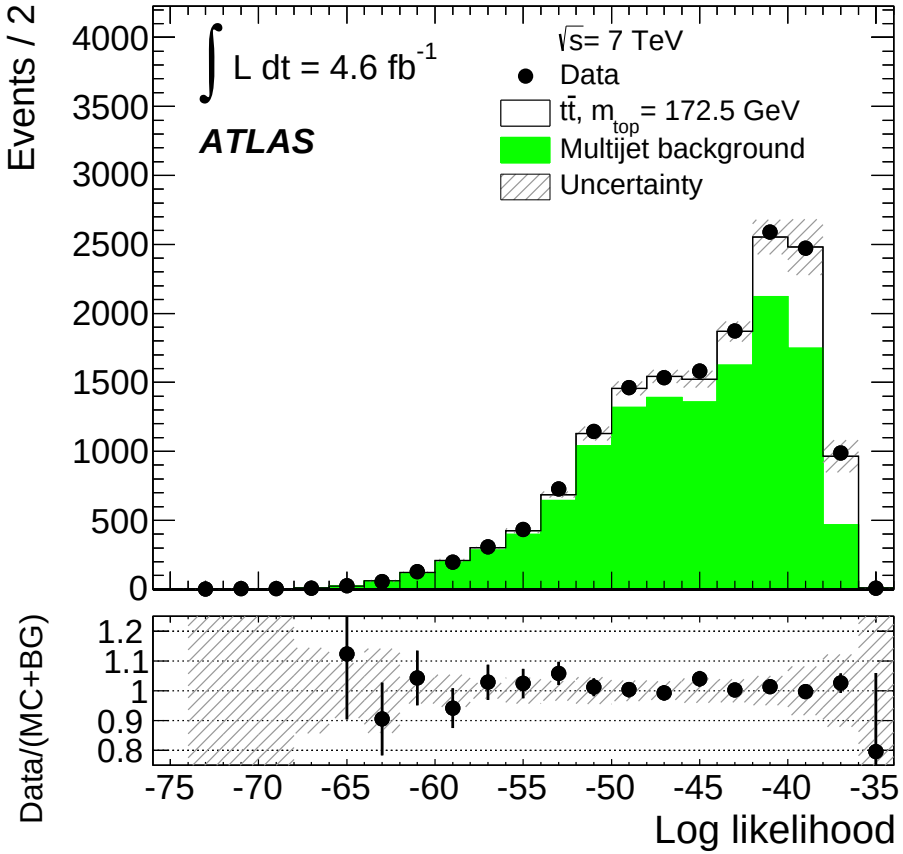
Reduce uncertainty from jet scale by using observable $R_{3/2} = m_{jjj}/m_{jj}$.

Selection:

- Jet-based trigger
- ≥ 6 jets with $p_{\mathrm{T}} > 30$ GeV and $|\eta| < 2.5$
- ≥ 5 jets with $p_{\mathrm{T}} > 55$ GeV and $|\eta| < 2.5$
- $\Delta R > 0.6$ between pairs of jets with $p_{\mathrm{T}} > 30$ GeV
- Jet vertex fraction JVF > 0.75
- Reject events w. isolated electrons with $E_{\mathrm{T}} > 25$ GeV
- Reject events w. isolated muons with $p_{\mathrm{T}} > 20$ GeV
- Exactly 2 b-tagged jets among the four leading jets
- Missing transverse momentum significance $E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}} < 3$ GeV$^{1/2}$
- Centrality $\mathcal{C} > 0.6$

Assign jets to partons with a kinematic fit.

- Based on $m_{jj} = M_W$, $m_{t1} = m_{t2}$, and proper b-jet assignment.



Require ln $L > -45$.

m_t in fully-hadronic channel

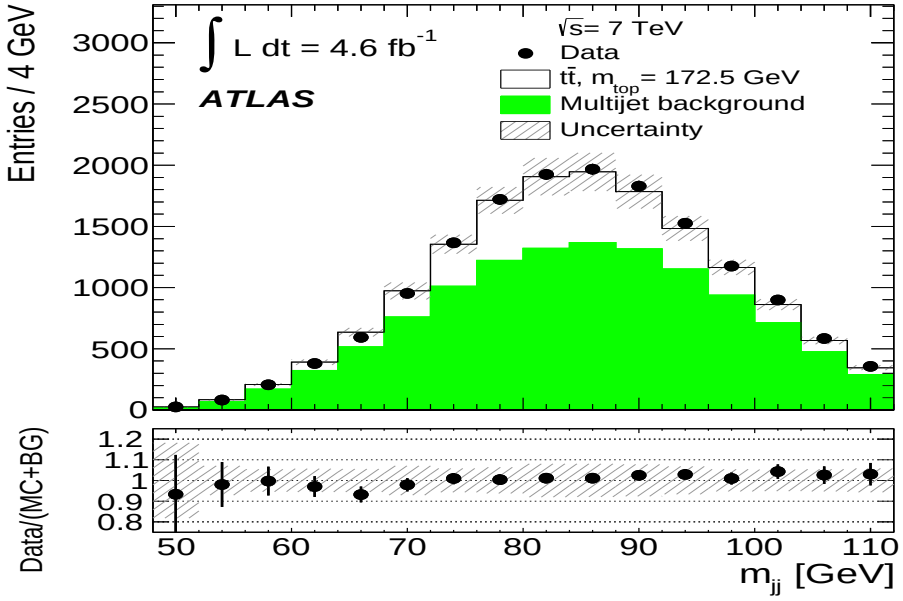
[arXiv:1409.0832]

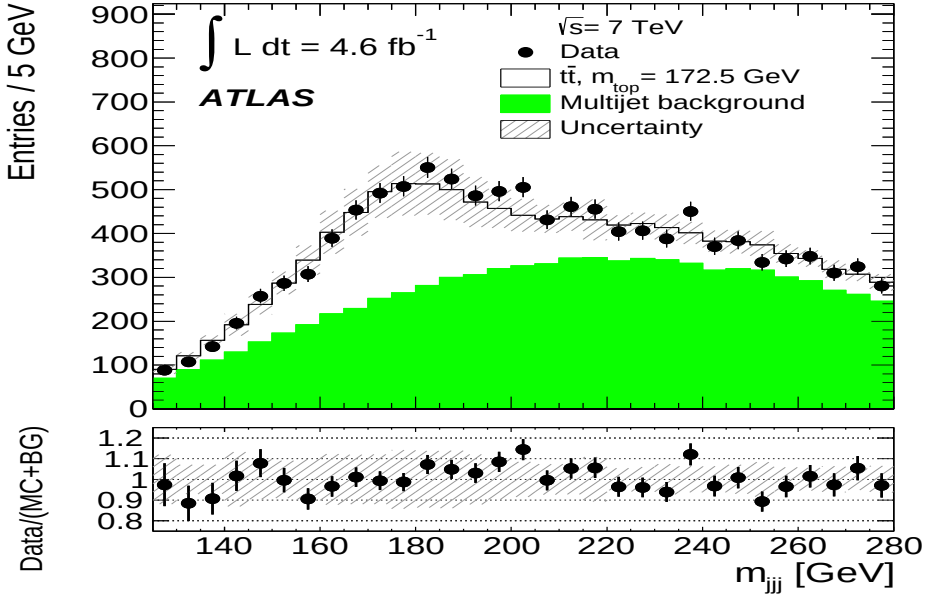
Background derived entirely from data ("ABCD" method).

Bin data in uncorrelated variables N_{tag} and $p_T{}^{\text{6th jet}}$.

	$p_T{}^{\text{6th jet}}$	
	< 30 GeV	> 30 GeV
$N_{\text{tag}} = 0$	A	B
$N_{\text{tag}} = 1$	C	D
$N_{\text{tag}} = 2$	E	F

Background in F can be estimated as either $E/A \times B$ or $E/C \times D$. Take average, and use difference for systematics.

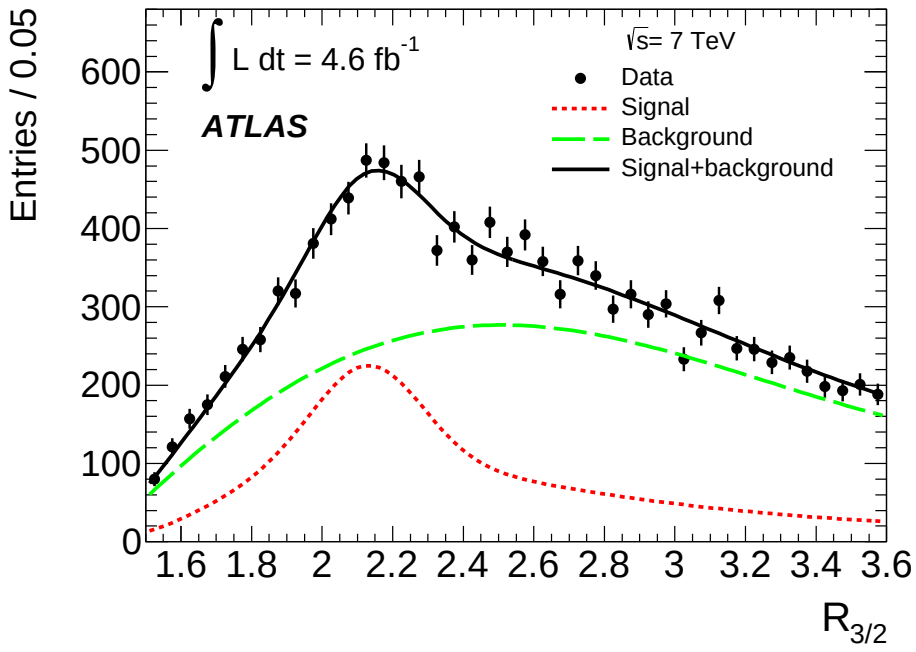




m_t in fully-hadronic channel

[arXiv:1409.0832]

Derive templates for $R_{3/2}$ vs. m_t.



From 4.6 fb^{-1}

$m_t =$

175.1 ± 1.4 (stat.) ± 1.2 (syst.) GeV

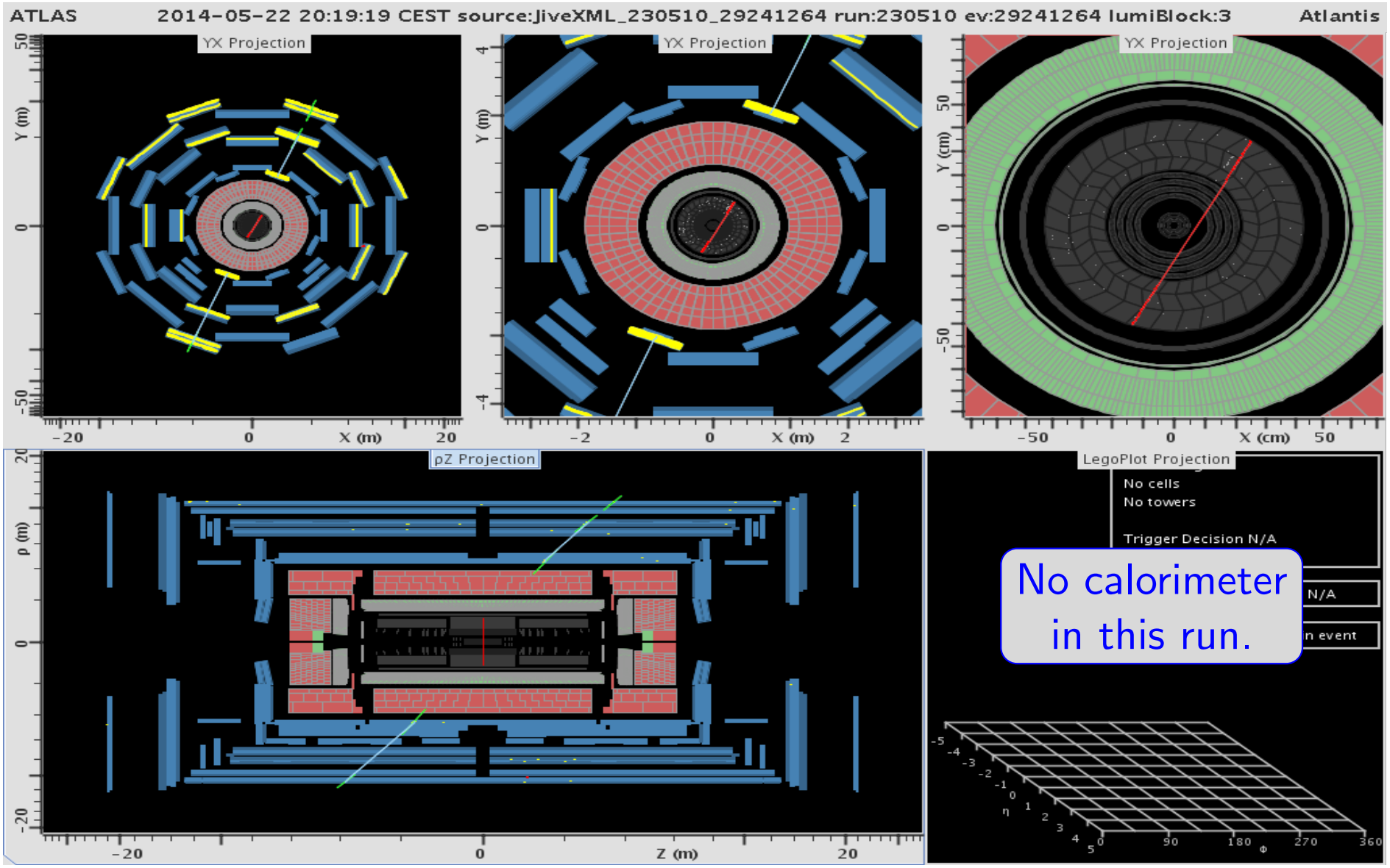
Statistical uncertainty consistent with MC expectations. Systematic uncertainty dominated by jet scale.

Signal modelling:	Δm_t [GeV]
Method calibration	0.42
Trigger	0.01
Signal MC generator	0.30
Hadronisation	0.50
Fast simulation	0.24
Colour reconnection	0.22
Underlying event	0.08
ISR and FSR	0.22
Proton PDF	0.09
Pile-up	0.02

Background modelling:	Δm_t [GeV]
Multijet background	0.35

Jet measurements:	Δm_t [GeV]
Jet energy scale (see Table **??**)	0.51
b-jet energy scale	0.62
Jet energy resolution	0.01
Jet reconstruction efficiency	0.01
b-tag efficiency and mistag rate	0.17
Soft contributions to missing energy	0.02
JVF scale factors	0.02

Total systematic uncertainty	1.22

Recommissioning for Run 2: Milestone weeks

From May milestone week: cosmic through ATLAS.