Status and Plans for the ATLAS Experiment

- Brief review of 7 & 8 TeV results
- Improvements to ATLAS for 13 TeV running
- Physics prospects for Run II
- Ultimate goals for ATLAS at the HL-LHC

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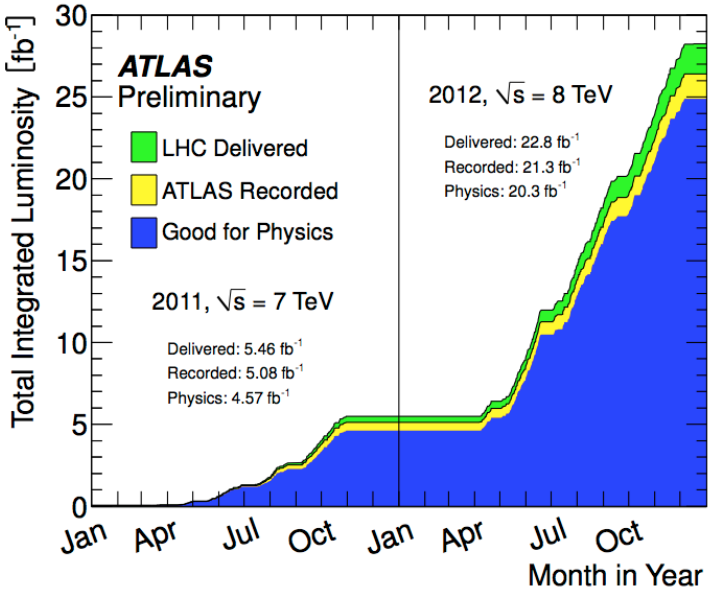
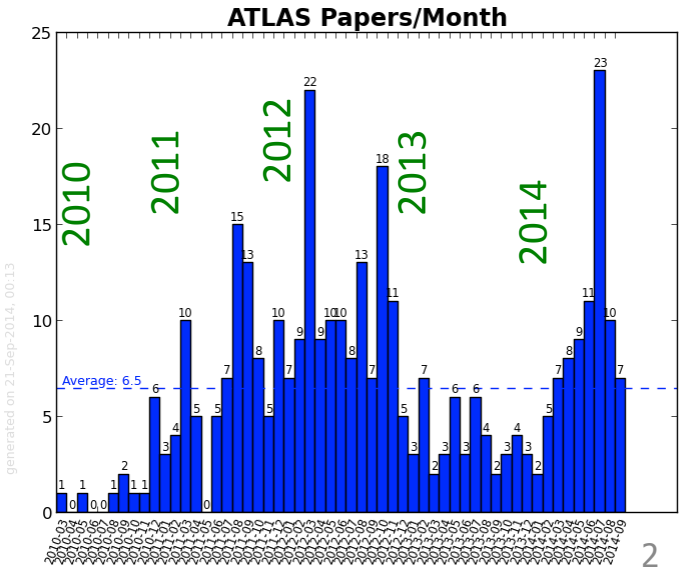
Miami2014

Run I in a Nutshell

- ATLAS recorded ~all collisions
- 90% end up in physics papers
  - 0.05 fb^{-1} (7 TeV, 2010)
  - 4.6 fb^{-1} (7 TeV, 2011)
  - 20.6 fb (8 TeV, 2012)
- Publications
  - 350 papers published (100+ in prep)
  - 600 conference notes
  - 660 conference talks (+ this one)



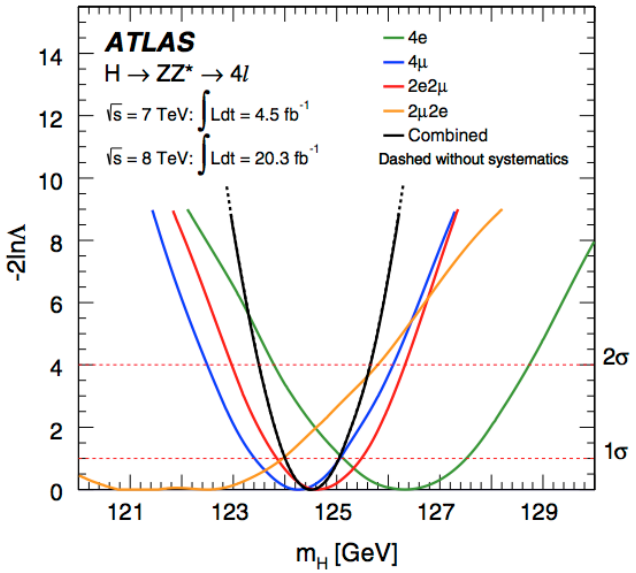


The ATLAS/LHC Physics program

- Understand the Higgs Boson
  - Mass, CP, Standard Model couplings, …
- Measure the properties of *t*, *W* and *Z*
  - They couple most strongly to the Higgs
- Search for new TeV-scale particles
  - What is the importance of this scale to SM?
- Find/understand any Standard Model anomalies

The Higgs Boson

- We hoped for discovery – and got more
  - Higgs mass ~125 GeV – as predicted (sigh..)
  - Higss mass = (125.4±0.4± 0.2) GeV (precise!)
  - Spin-parity properties consistent with 0^+ …



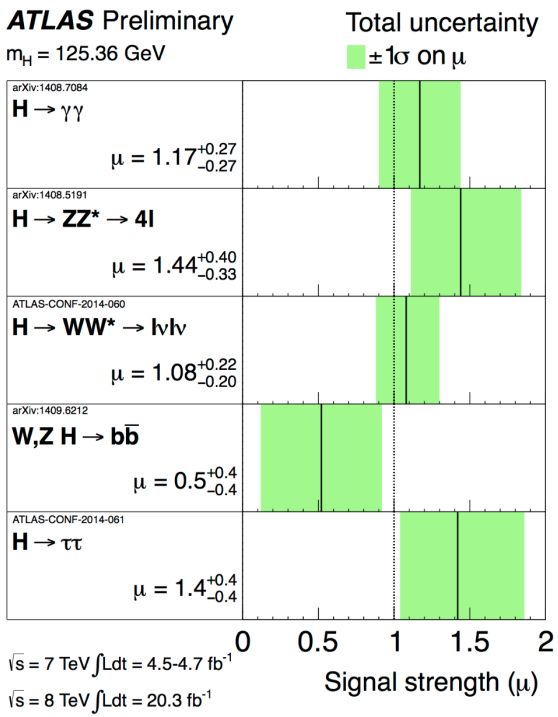
Currently 40 candidates/channel

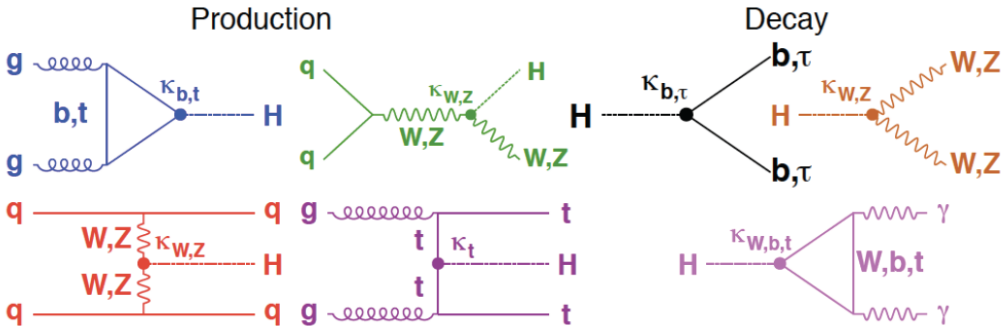
Run II expect ~500/channel

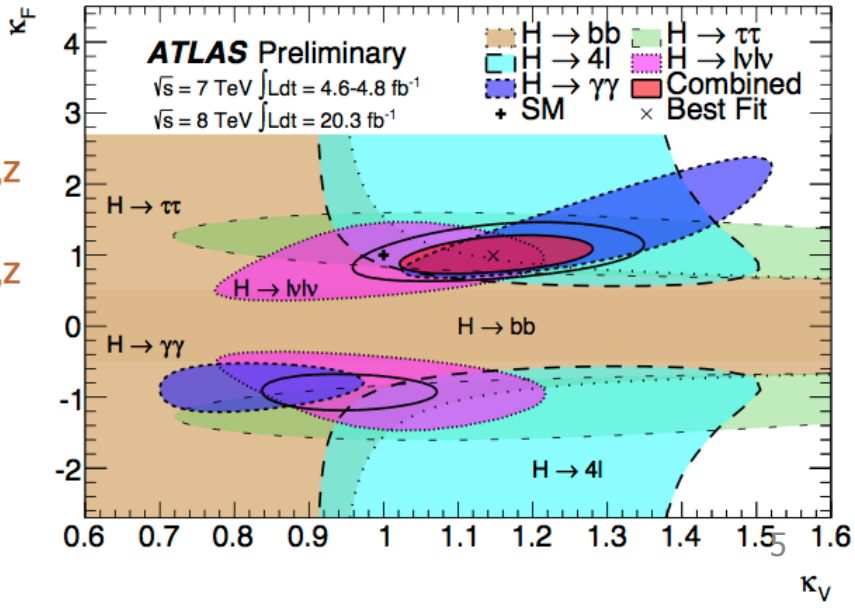
Physical Review D **90** 052004 (2014)

Higgs Couplings

- Higgs couplings falling into place
  - Model dependent ratios to the SM
  - Model independent global fits
- Reduce assumptions as get more data







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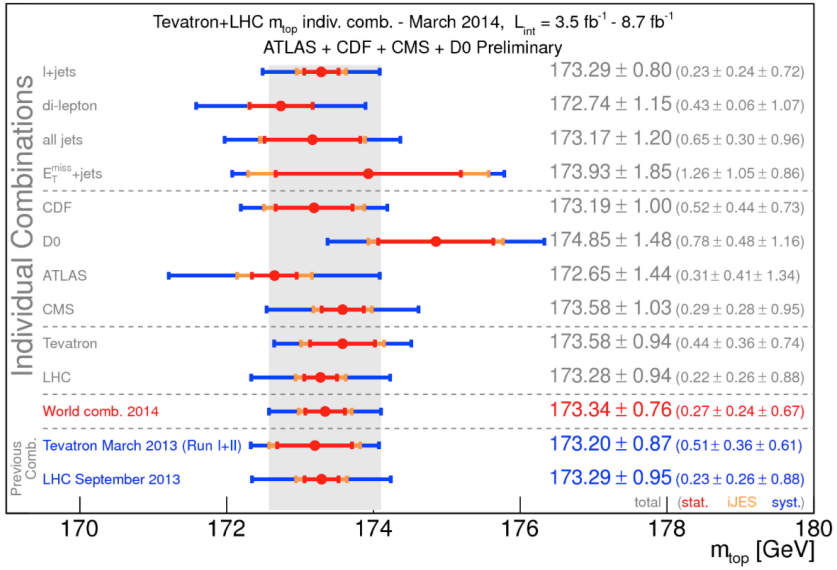
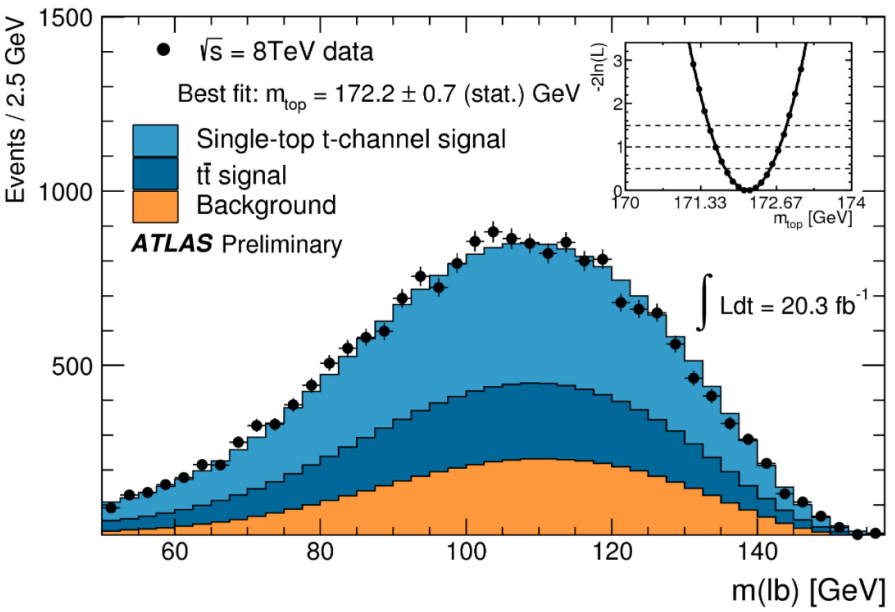
The Top Quark

- The LHC is the 'real' top factory
  - Production cross-sections teaching us about proton structure
- Top quark mass still an important SM ingredient even with m_H
  - Tour de force: measuring top mass in single-top final state
  - Systematics dominate, but also thy. (pole vs. QCD mass: Δ~0.3 GeV)





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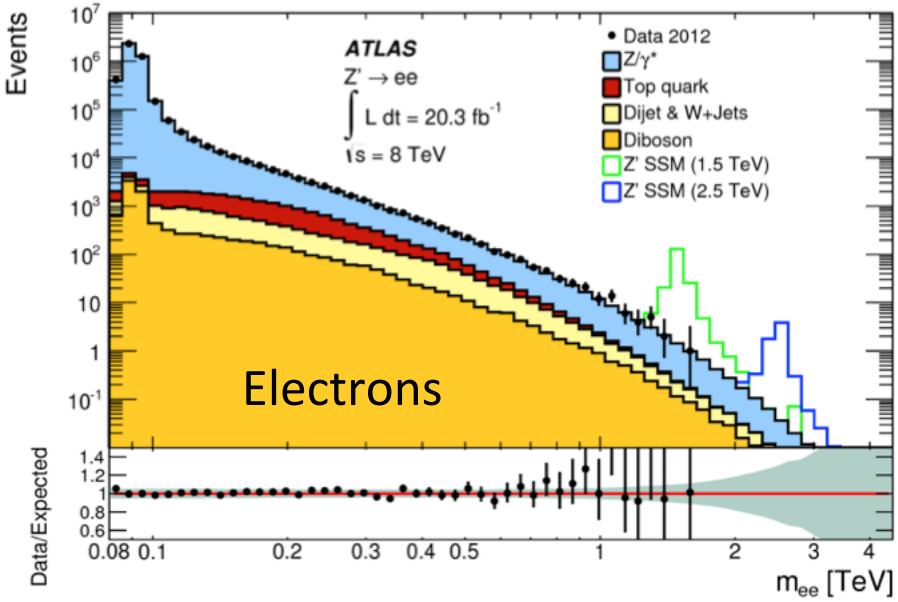
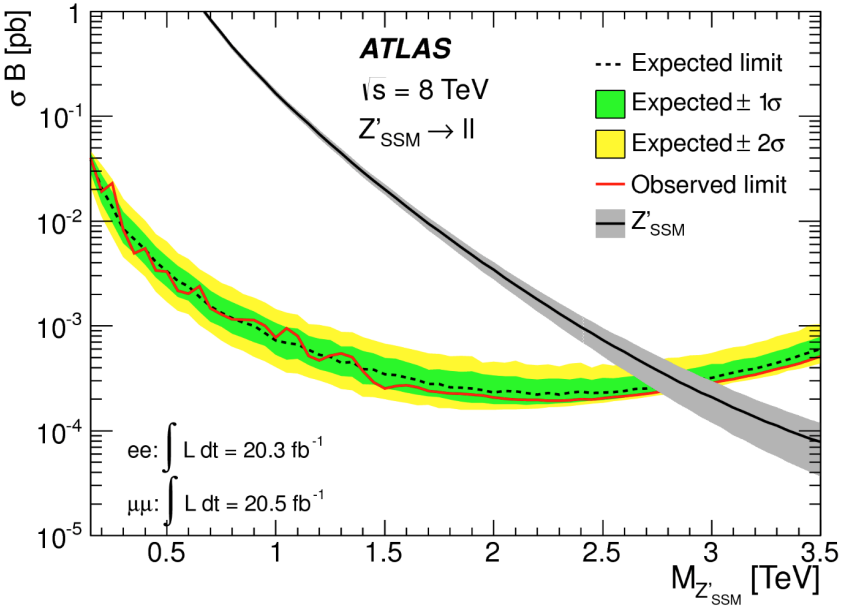
Z' Searches

- Electrons: E_T > 40,30 GeV ($|\eta|$<1.37, 1.52<$|\eta|$<2.47)
  - Acceptance * ε_{ID} = 72%
- Muons: E_T > 25,25 GeV ($|\eta|$<1, 1.3<$|\eta|$<2)
  - Acceptance * ε_{reco} = 46%



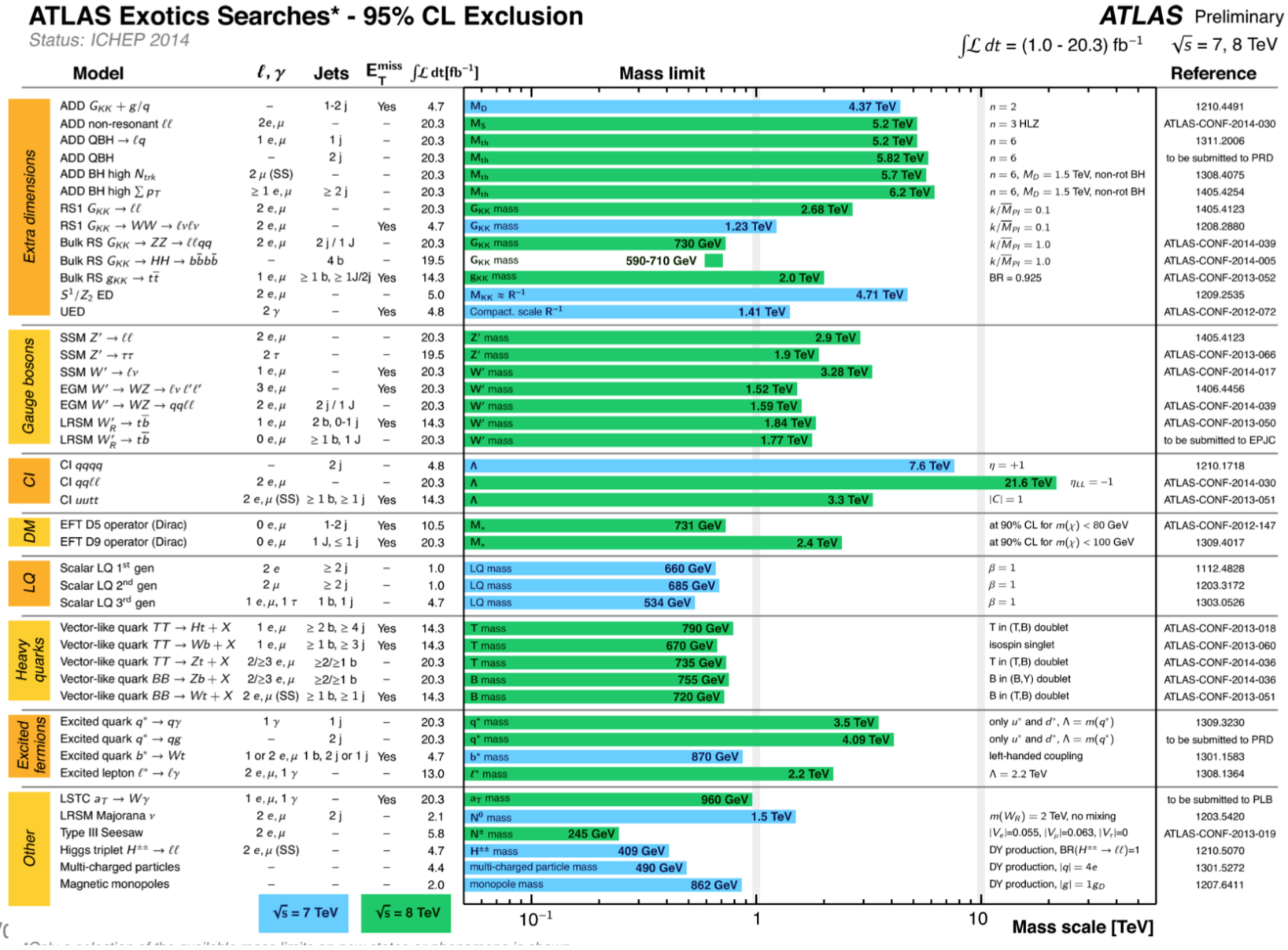


$m_{Z'}$ > 2.9 TeV

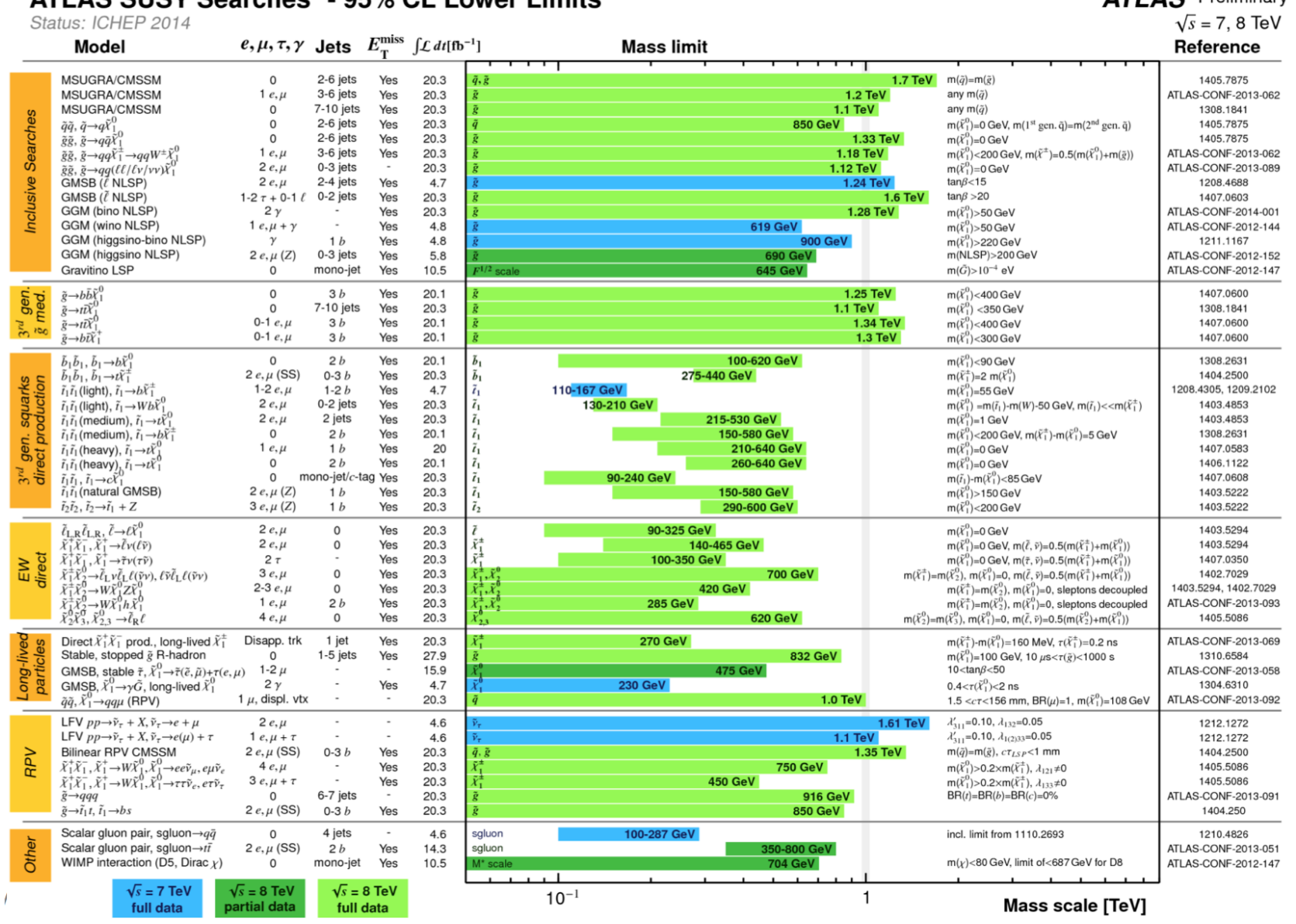
(also $m_{W'}$ > 3.2 TeV)

Phys Rev D **90** 052005 (2014)

Many Other Exotics Searches

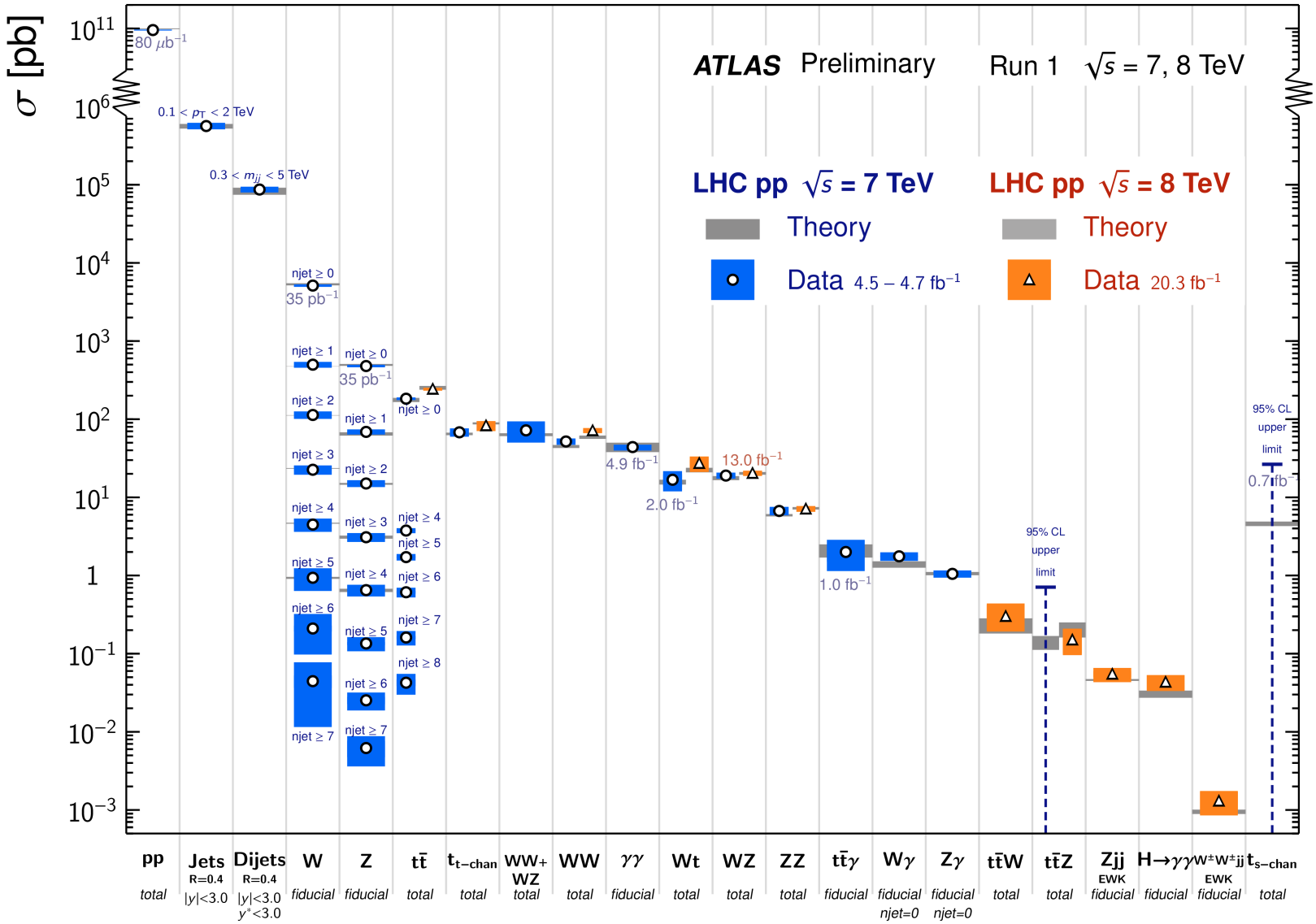


Summary of Supersymmetry Searches

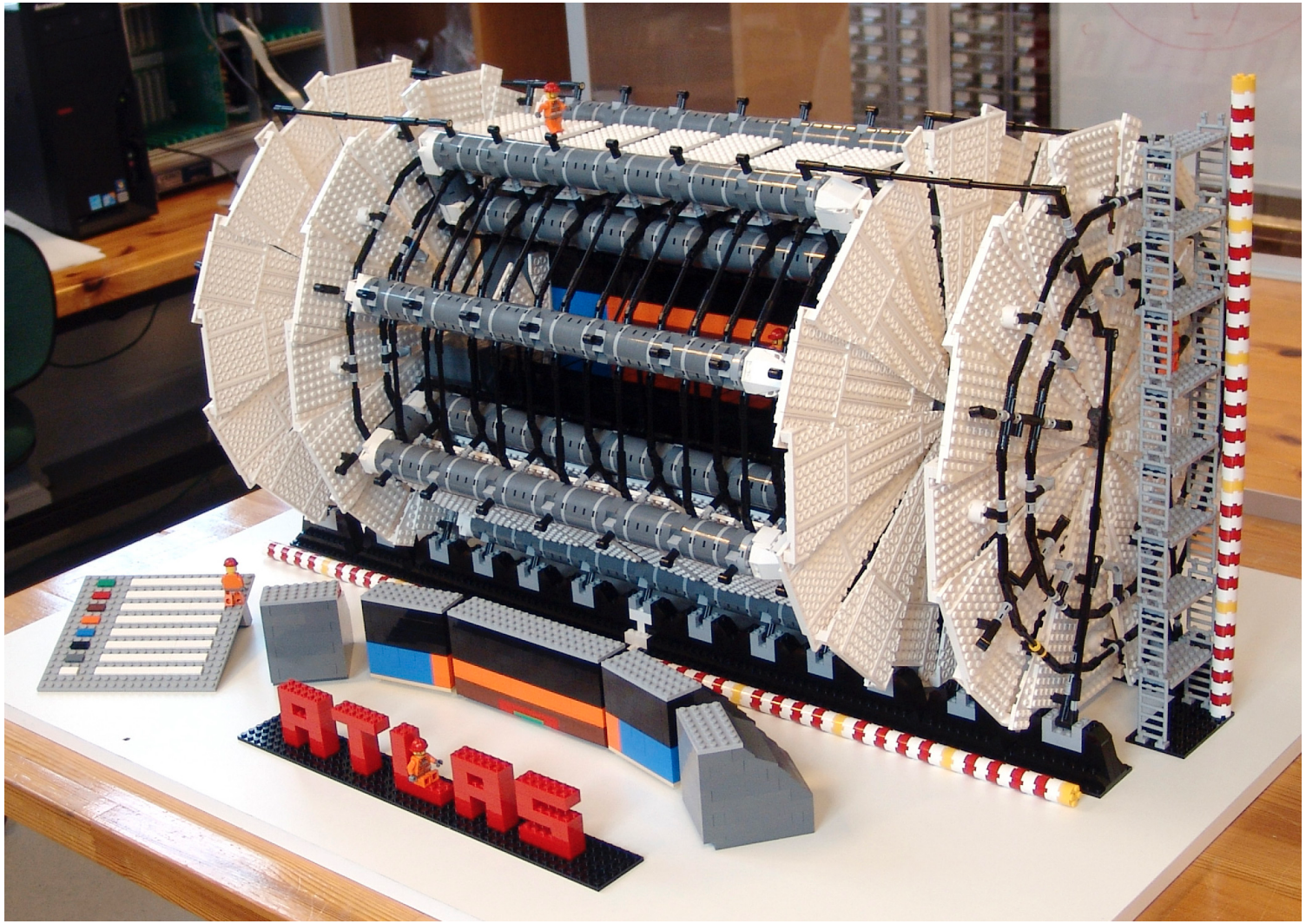


*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Not Least: Understand All Accessible SM Processes

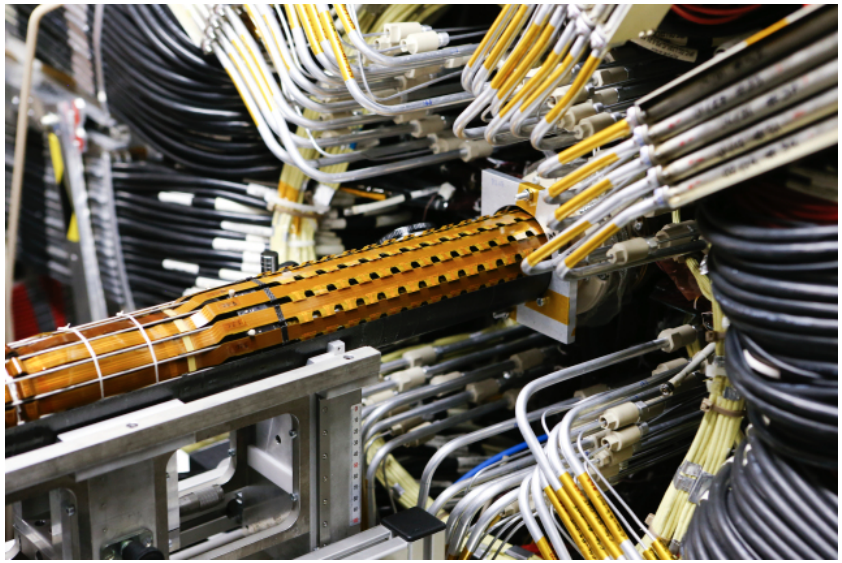


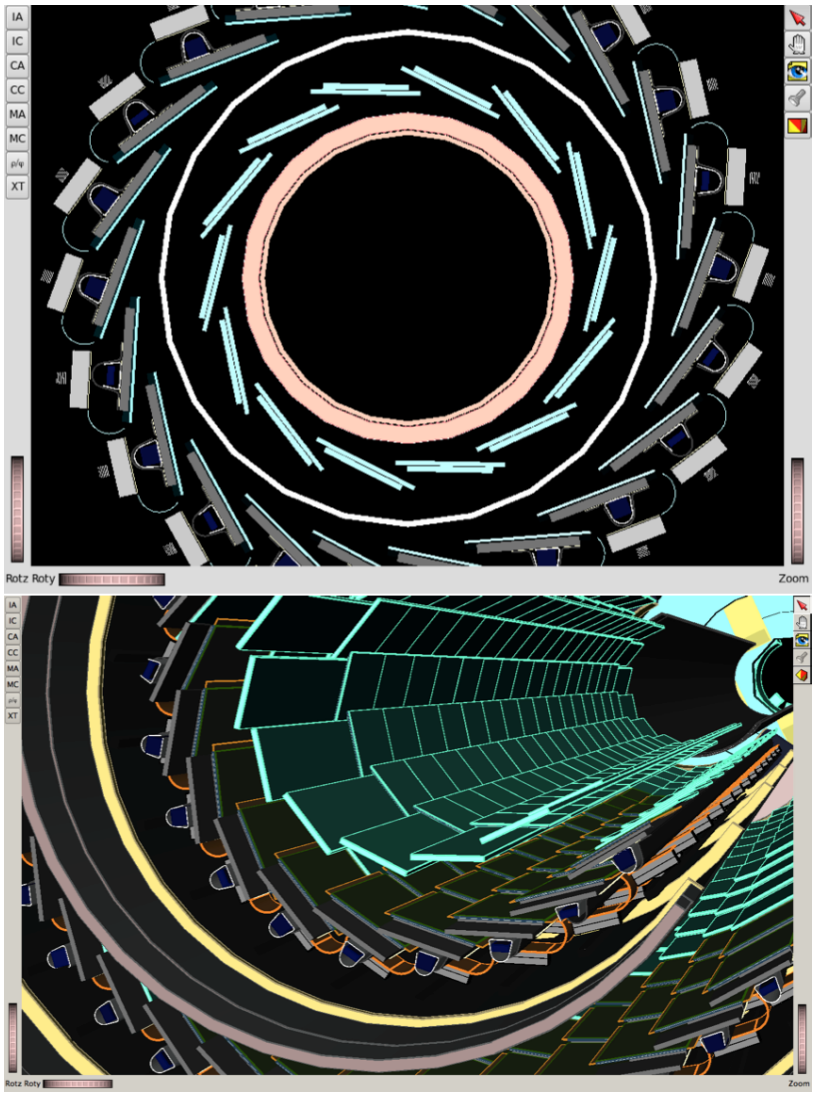
Preparing ATLAS for the Future



The ATLAS Insertible *B* Layer (IBL)

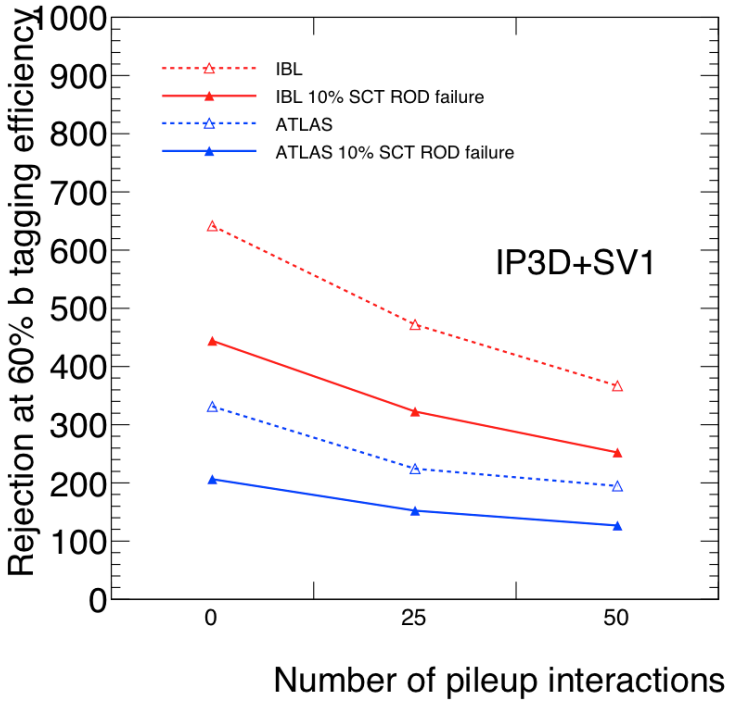
- Additional layer of pixels
- Built/installed during 2013-14
- Improved radiation tolerance
  - Will survive to 300 fb^{-1}





The ATLAS Insertible *B* Layer (IBL)

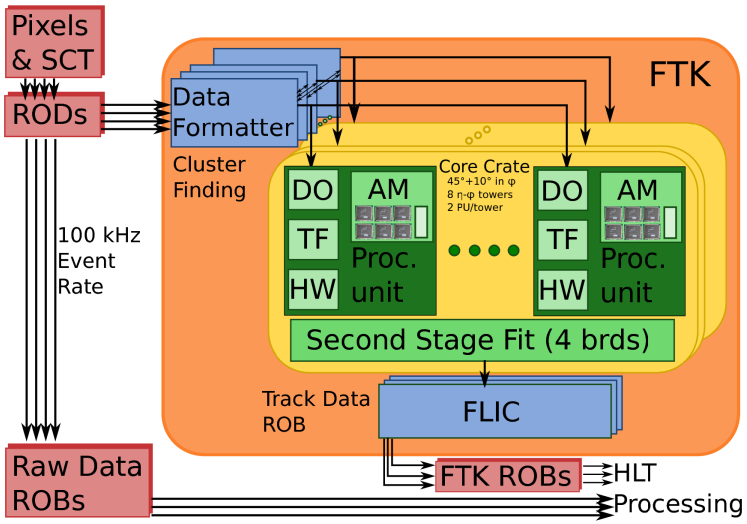
- IBL mission:
  - Improved impact parameters
  - Insurance against radiation damage in original pixel layers
  - More robust *B* tagging especially if remainder of tracking suffers
    - Failure of SCT/Pixel module gp.
    - High pileup → TRT saturation

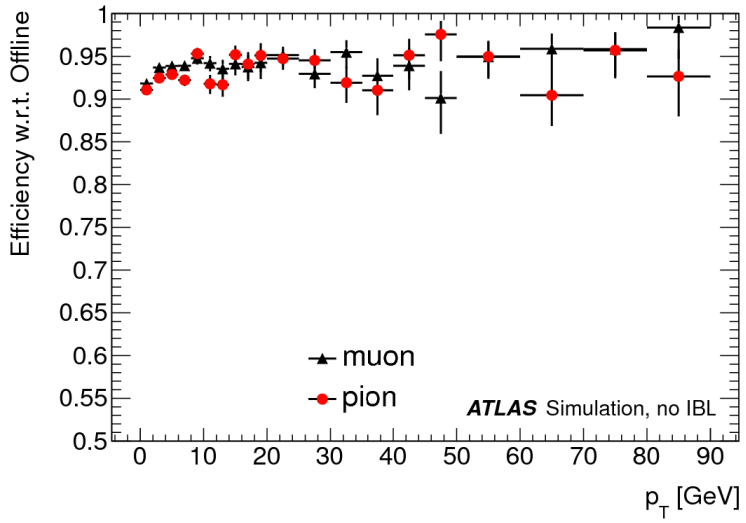


- Installed with > 99.9% live channels
- Routinely readout in cosmic ray running

Fast Track Trigger (FTK)

- As luminosity increases, trigger must become more selective
- Push global tracking to Level 1 (100 kHz and < 100μs)
  - Requires dedicated hardware track finder (FTK)
  - Receives all SCT/pixel hits
  - Computes helix parameters (lookup tables in associative memory)
  - Provides full track fit for electron, muon (other?) trigger decisions
- Implementation already well underway
  - Key to maintaining single lepton p_t thresholds
  - Does not require shutdown or (further) detector modifications





Milestone Commissioning Weeks

	M1 ✓	M2 ✓	M3 ✓	M4 ✓	M5 ✓	M6 ✓
	Feb 17–Feb 23	Mar 31-Apr 4	May19-May 23	Jul 7-Jul 11	Sep 8-Sep 12	Oct 13-Oct 17
PIX				X[1]	X[2]	
IBL				X	X[2]	
SCT				X	X[2]	
TRT		X				
LAR				X		
TIL				X		
MBTS				X		
L1Calo	X			X	X	X[2]
CSC	X				X	X
MDT	X					
RPC		X[1]	X[1]			
TGC	X					X[2]
BCM		X				
ALFA						X
LUCID						
Lumi					X	

M7 - Cosmic Run Nov 24th - Dec 8th

Full Shiftcrew; all detectors; B field ON from Dec 1st.

[1] TDAQ integration, using simulated events

[2] detector cooled to nominal operating temperature

[2] All staves in M6

[2] Barrel + Endcap in M6

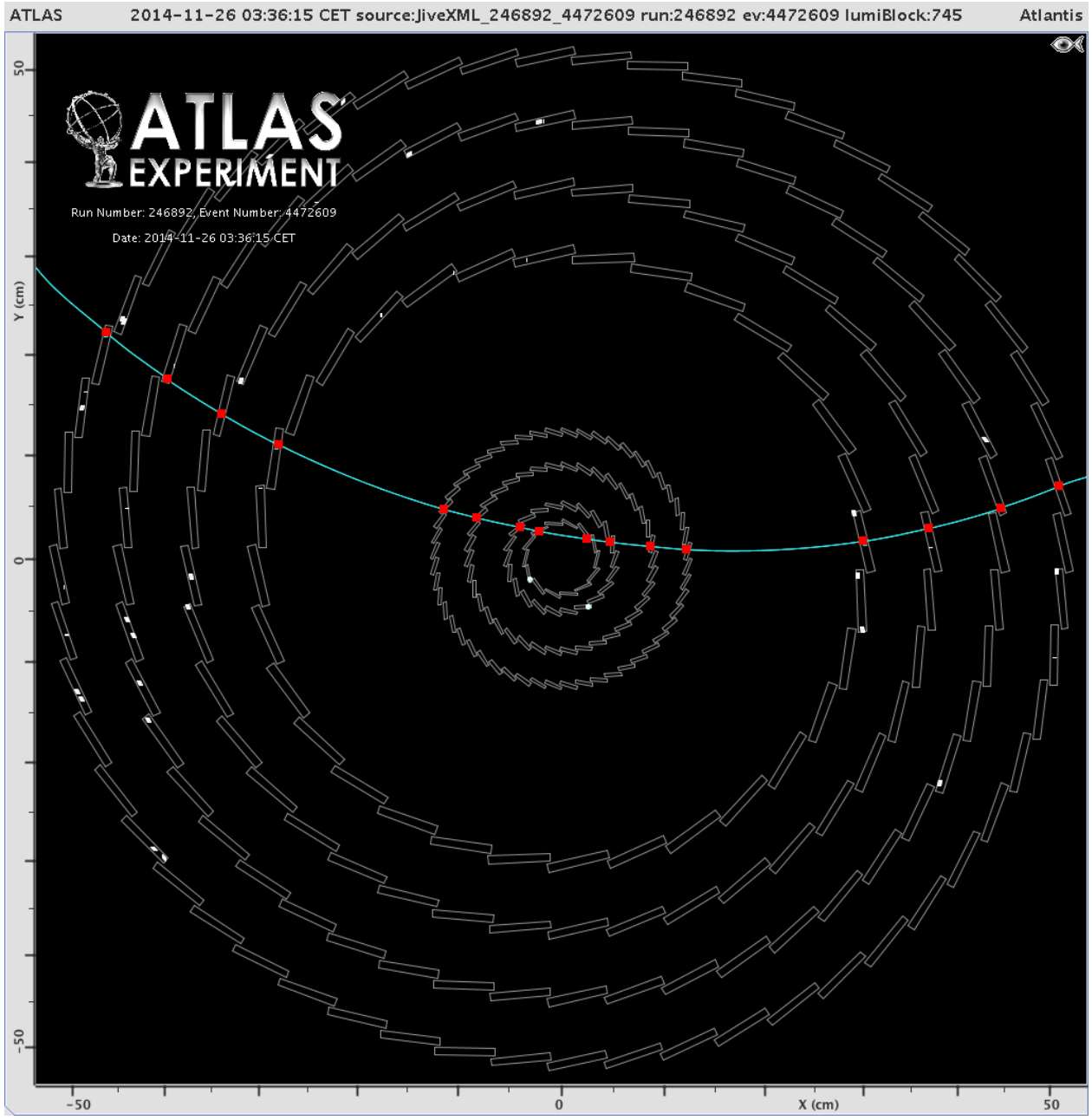
Both sides in M5

[2] L1Topo trigger commissioned fully in trigger system

[1] TDAQ integration. HV for ~ 1 sector

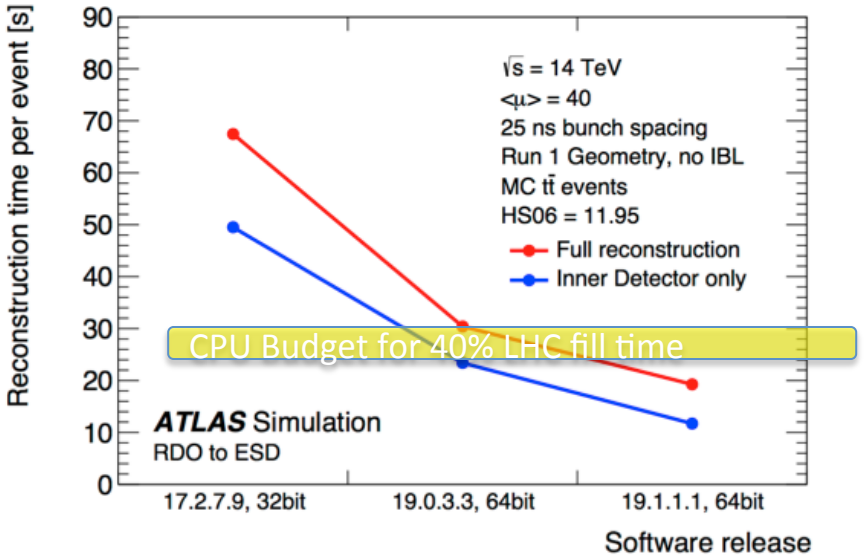
[2] Out for chamber replacements

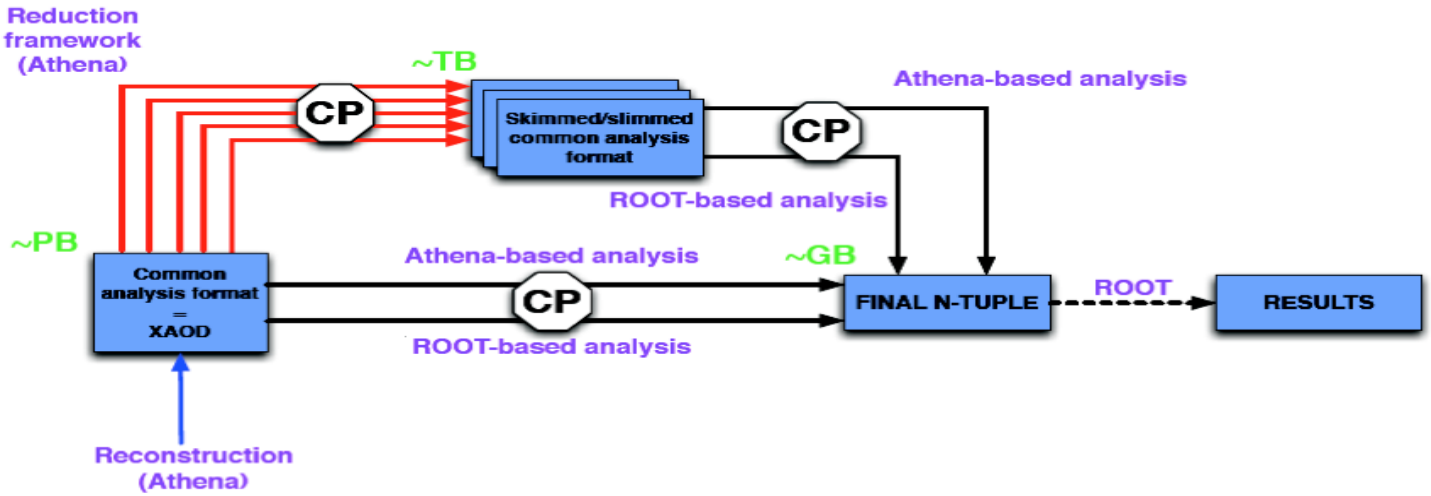
Cosmic Track Reconstructed with IBL



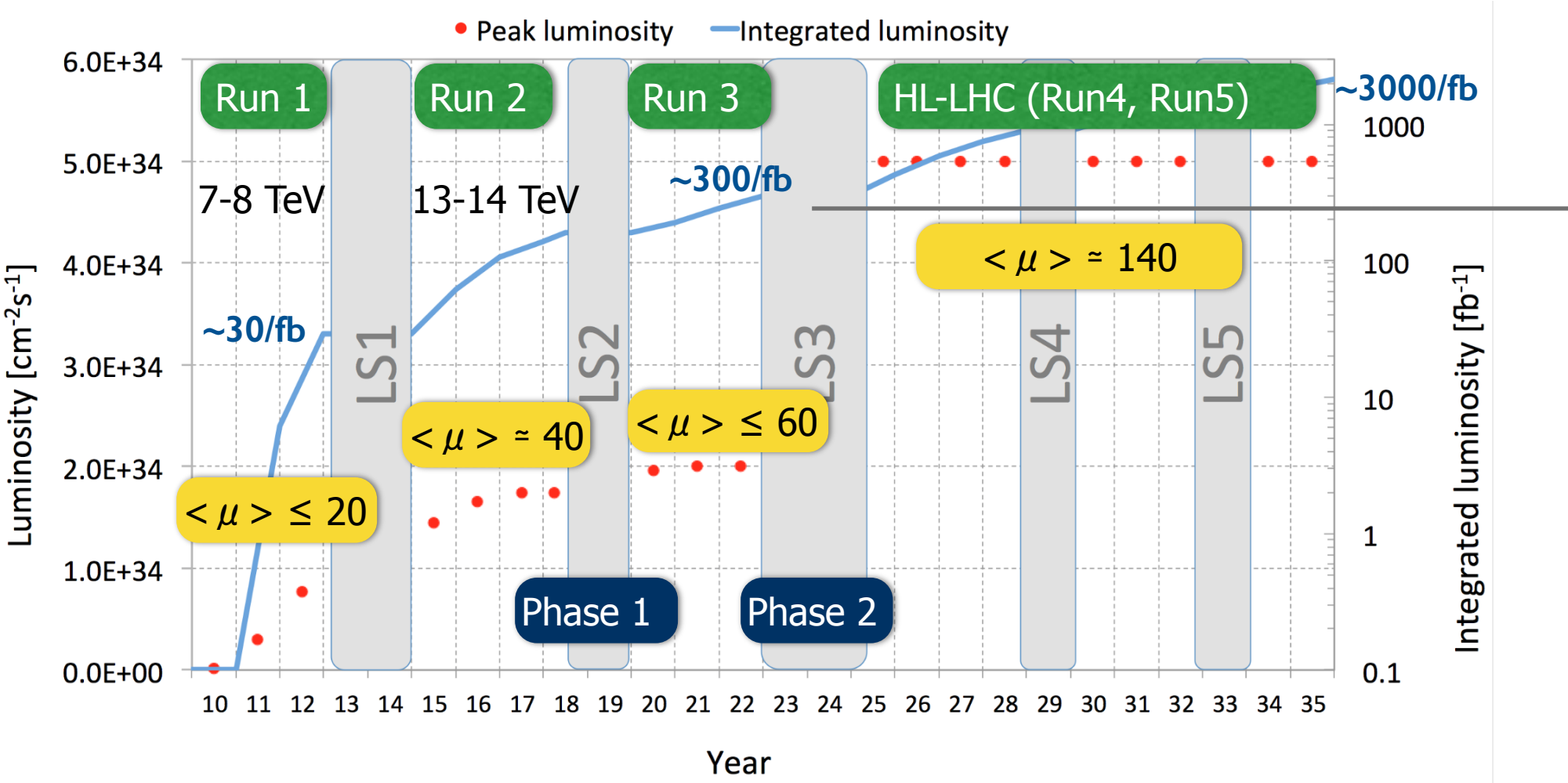
Computing, Software and Analysis

- Physics algorithm and mathematical fitting changes
  - Factors of 3+ improved speed
  - Robustness against pileup
- Root readable mini-DSTs
- Reducing disk usage
  - Computing may limit analysis





LHC Operating Parameters



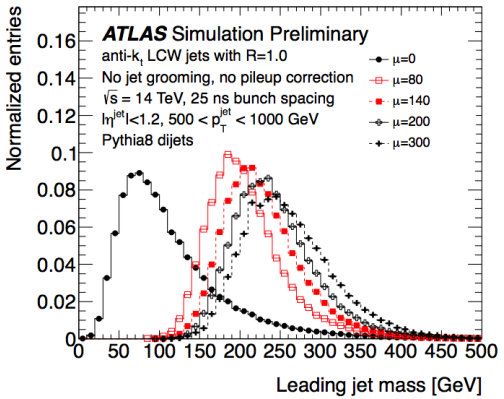
Jet Reconstruction Improvements

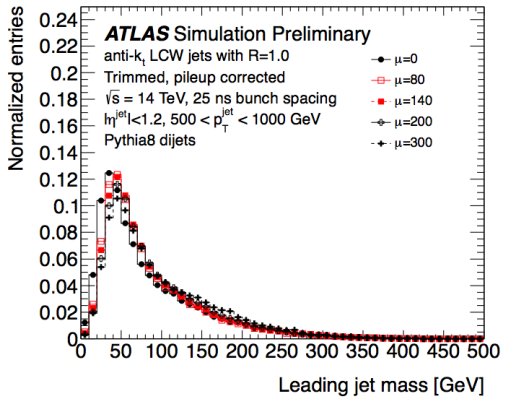
- Discriminate jets from hard-scatter and pile-up
  - Use tracking to remove jets from different primary collision points
  - Energy corrections restore scale and improve jet resolution

Uncorrected

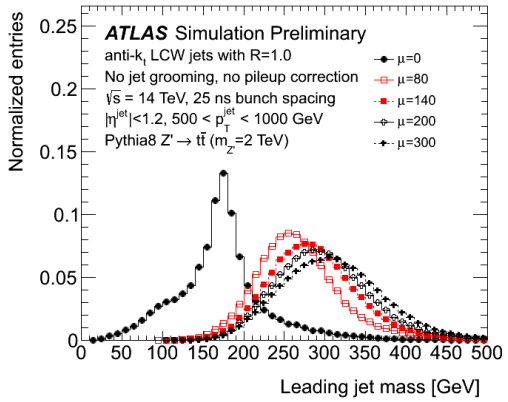
Corrected

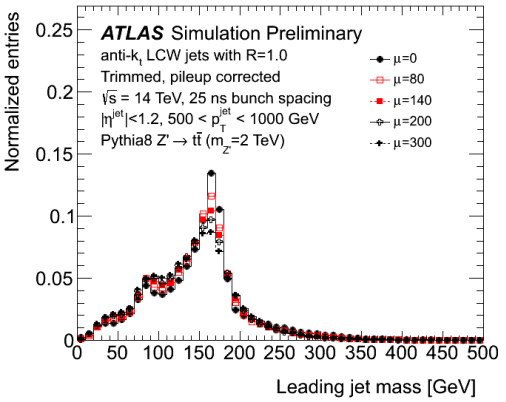
QCD background





$Z' \rightarrow t\bar{t}$

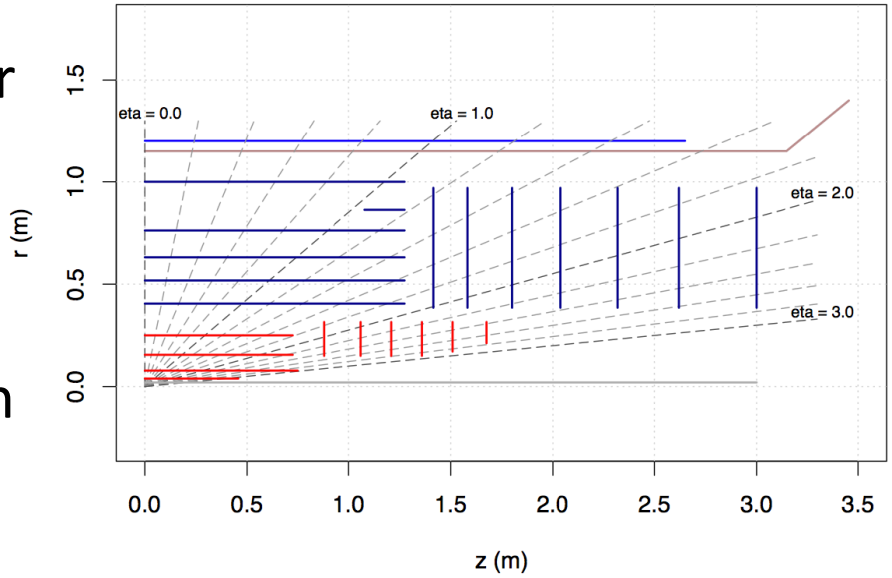




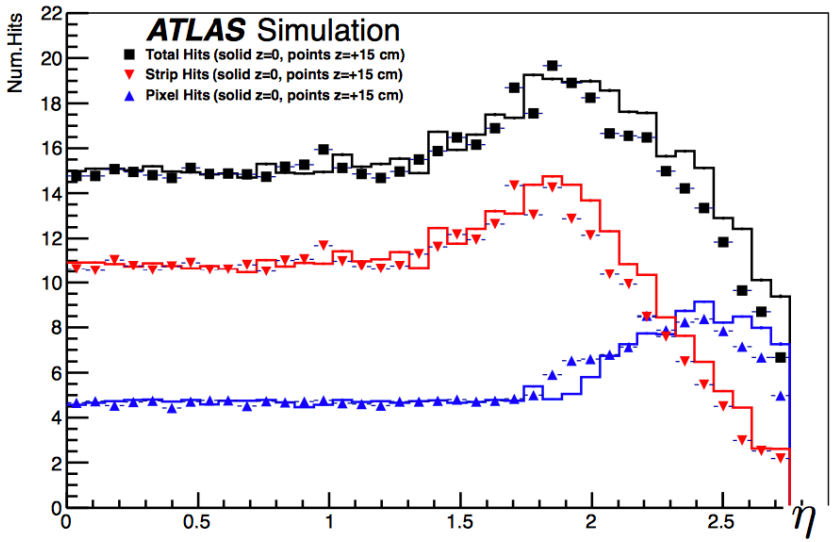
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/UpgradePhysicsStudies

The ATLAS Inner Tracker upgrade

- For HL-LHC replace full inner tracker
  - Design uses all solid-state sensors
    - 4 barrels of pixels
    - 6 barrels of strips
  - Full coverage to $|\eta|<2.5$
- Maintain tracking performance with increased pileup



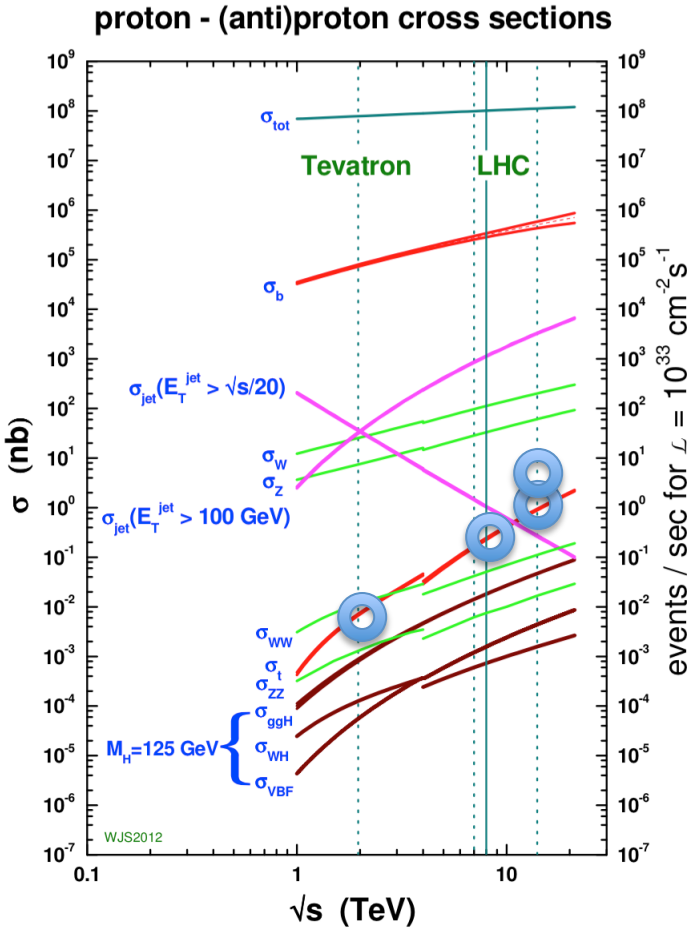
Track parameter $\lvert\eta\rvert < 0.5$	Existing ID with IBL no pile-up $\sigma_x(\infty)$	Phase-II tracker 200 events pile-up $\sigma_x(\infty)$
Inverse transverse momentum (q/p_T) [/TeV]	0.3	0.2
Transverse impact parameter (d_0) [μm]	8	8
Longitudinal impact parameter (z_0) [μm]	65	50



- Will take 7-8 years to build
  - Start soon if needed for 2023 installation

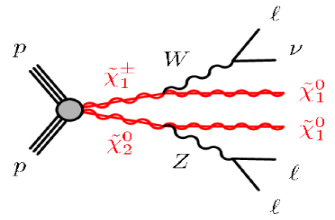
Physics Reach for Run-II and Beyond

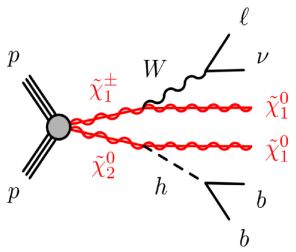
- Energy increase:
  - Tevatron → LHC-I: $\Delta \sqrt{s}$ = 6 TeV
  - LHC-I → LHC-II:: $\Delta \sqrt{s}$ = 5-6 TeV
- Luminosity increase:
  - Tevatron → LHC-I: x10 (to 7x 10^{33})
  - LHC-I → LHC-II: x2 (to 1.5 x 10^{34})
- LHC-I→LHC-II bigger jump than LHC-III
- From:
  - 1 $t\bar{t}$ events/s at Tevatron
  - 2 $t\bar{t}$ events/s at LHC-I
  - 13 $t\bar{t}$ events/s at LHC-II
  - 40 $t\bar{t}$ events/s at LHC-III

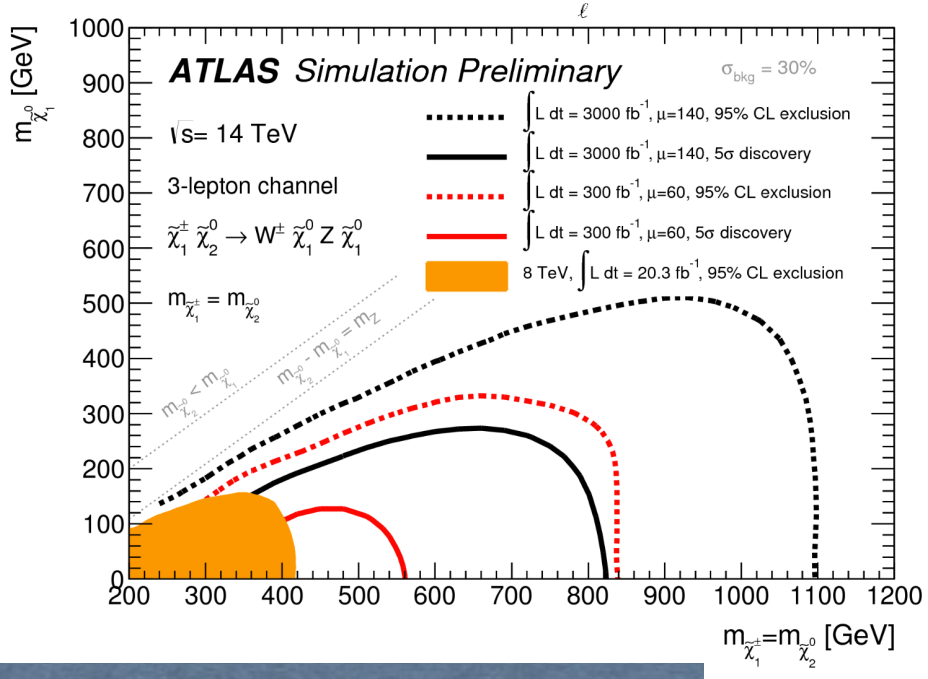


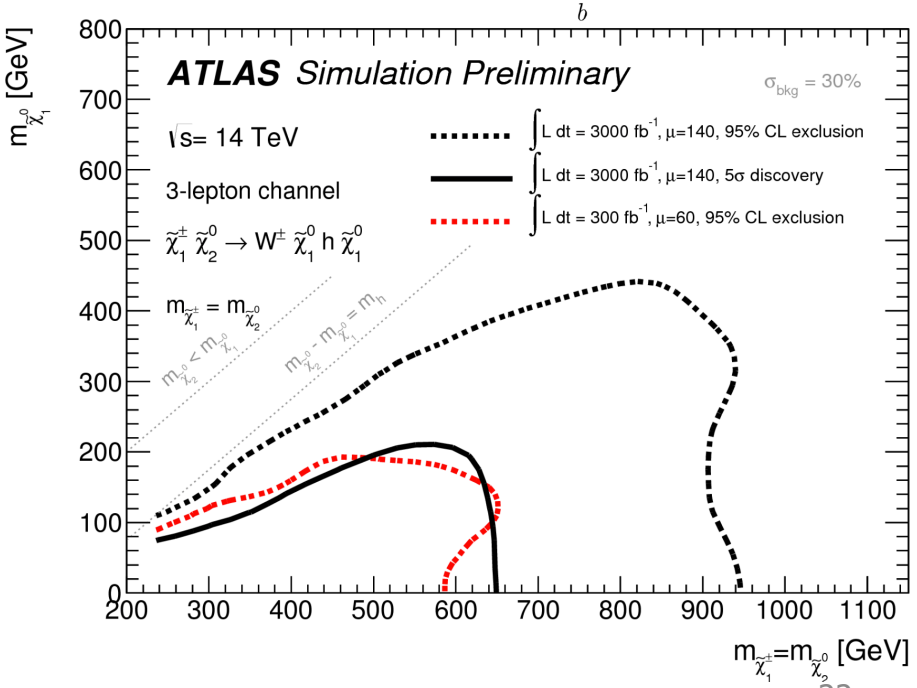
Electroweak SUSY at Run II and HL-LHC

- Strongly produced SUSY has all but priced itself out of the market
- Neutralinos could still explain the naturalness of the TeV scale
  - Run II ++ will cover the remaining phase space









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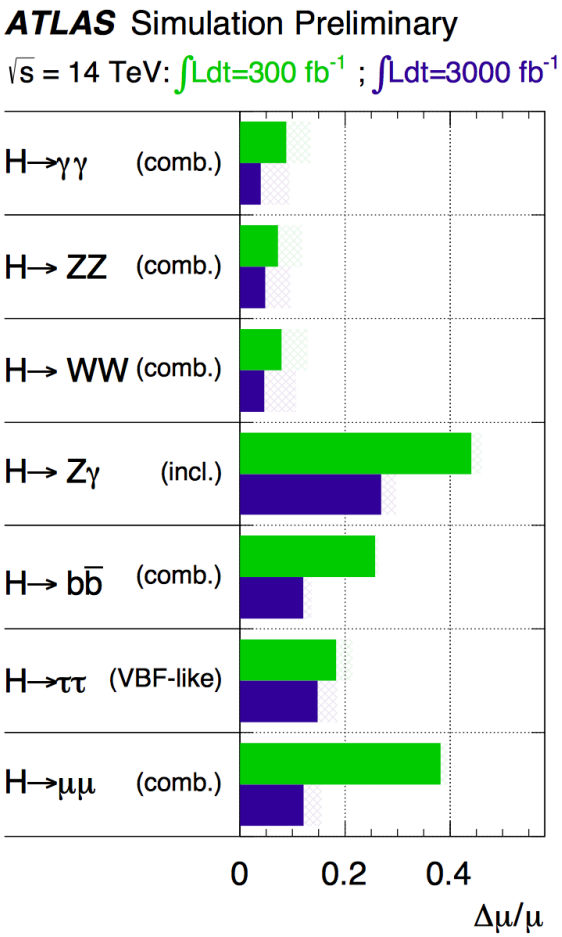
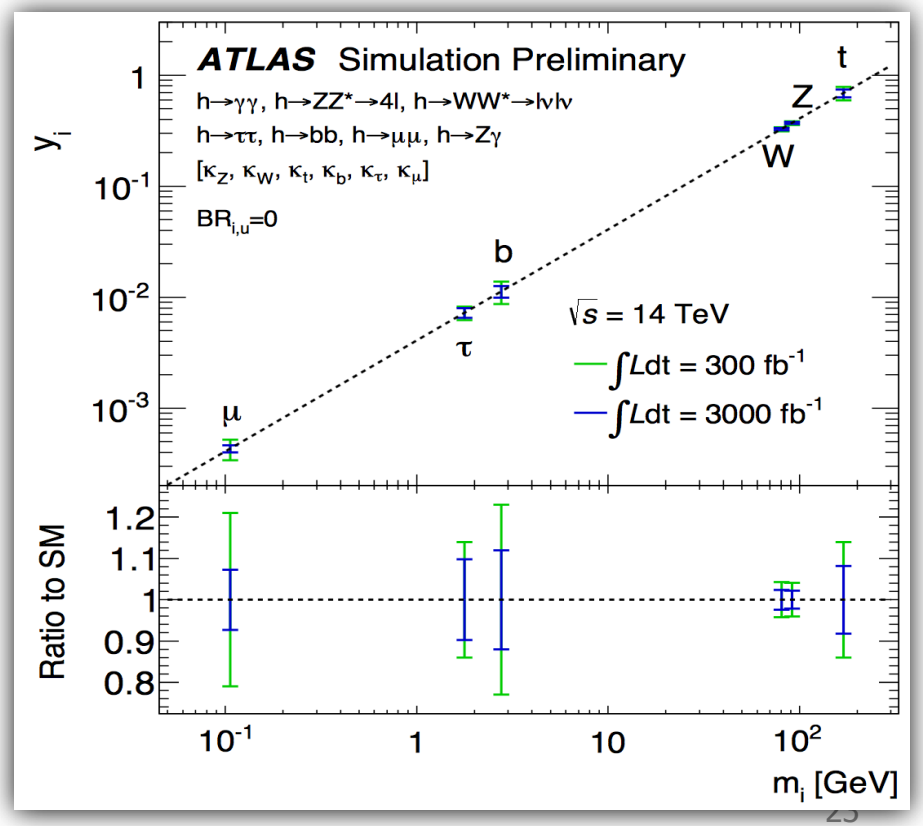
Prospects for Higgs Coupling Improvements

- Pin down SM couplings or reveal anomalies



$$\frac{\sigma \cdot B\,(gg \to H \to \gamma\gamma)}{\sigma_{SM}(gg \to H) \cdot B_{SM}(H \to \gamma\gamma)} = \frac{\kappa_g^2 \cdot \kappa_\gamma^2}{\kappa_H^2}$$



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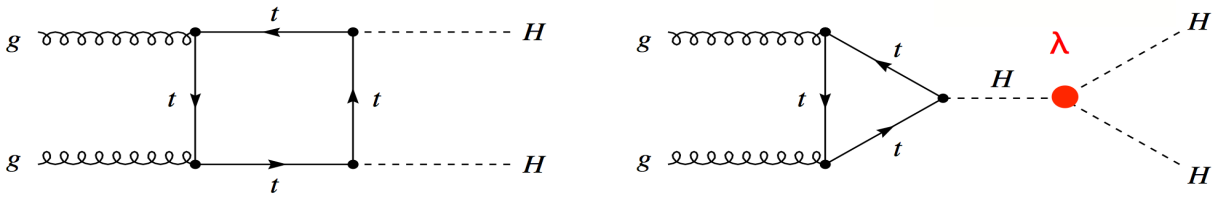
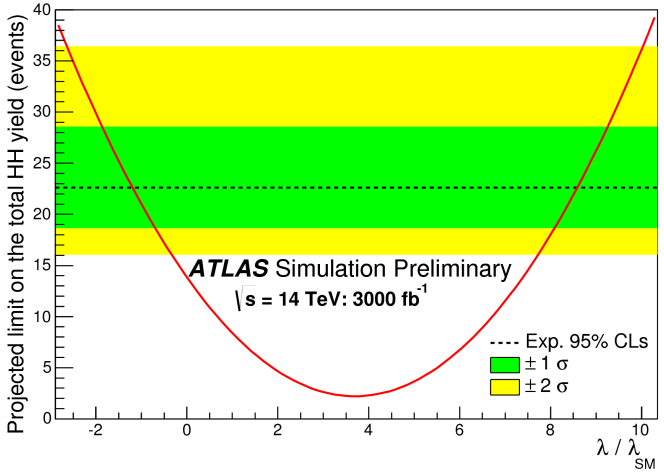
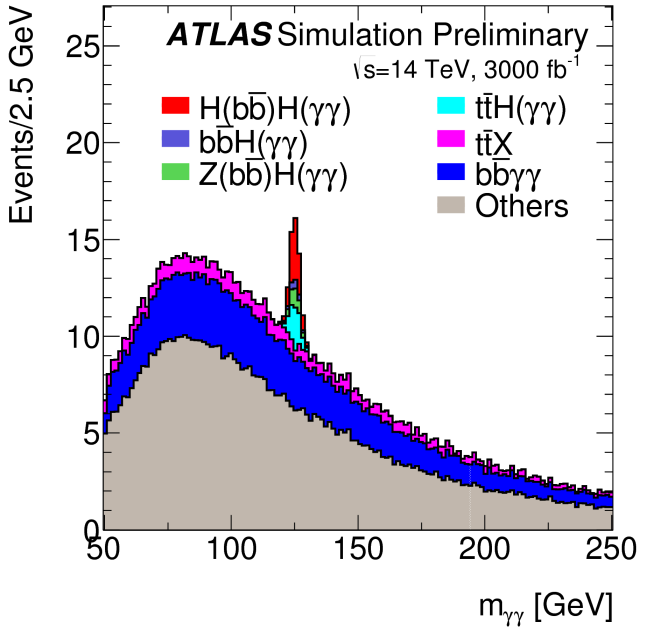
Higgs Pair Production

- Ultimate test of the Higgs potential (self-coupling)
  - Cancellation between box and triangle diagram doesn't help



- Simulation shows that it might not be hopeless
- Very challenging even for ILC





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Summary

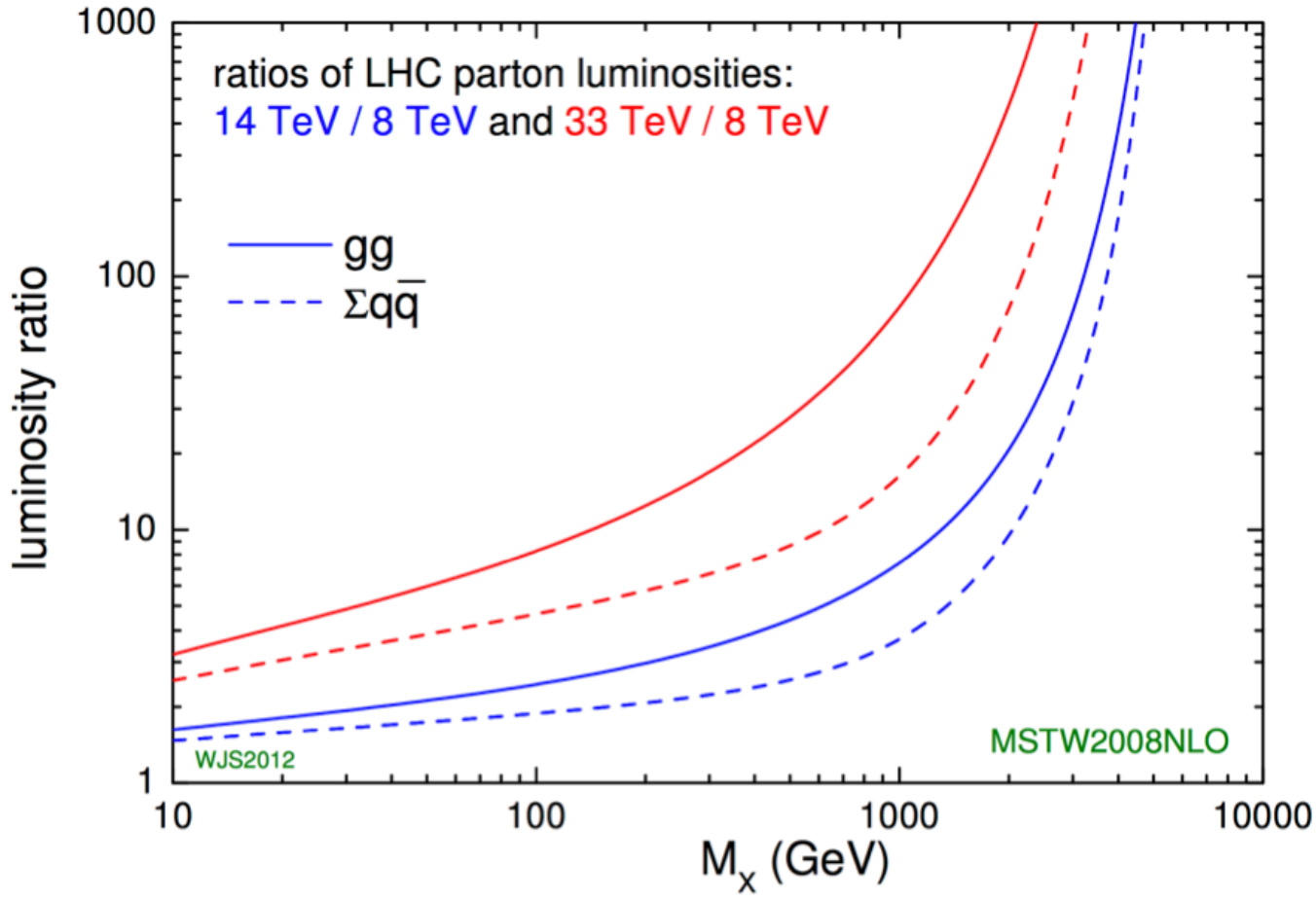
- ATLAS and the LHC have exceeded expectations during run I
- We have improved the experiment during LS1
  - Detector refurbishments and important additions
  - Building on physics alogrithm data processing lessons from Run I
- Expect factor of two in energy reach soon (end of 2015?)
- Ultimately factor of 10 in reach (lumi*energy) from Run II
- Further factor of 2-5 by the end of LHC era (2030++)

Next target not so clearly spelled out

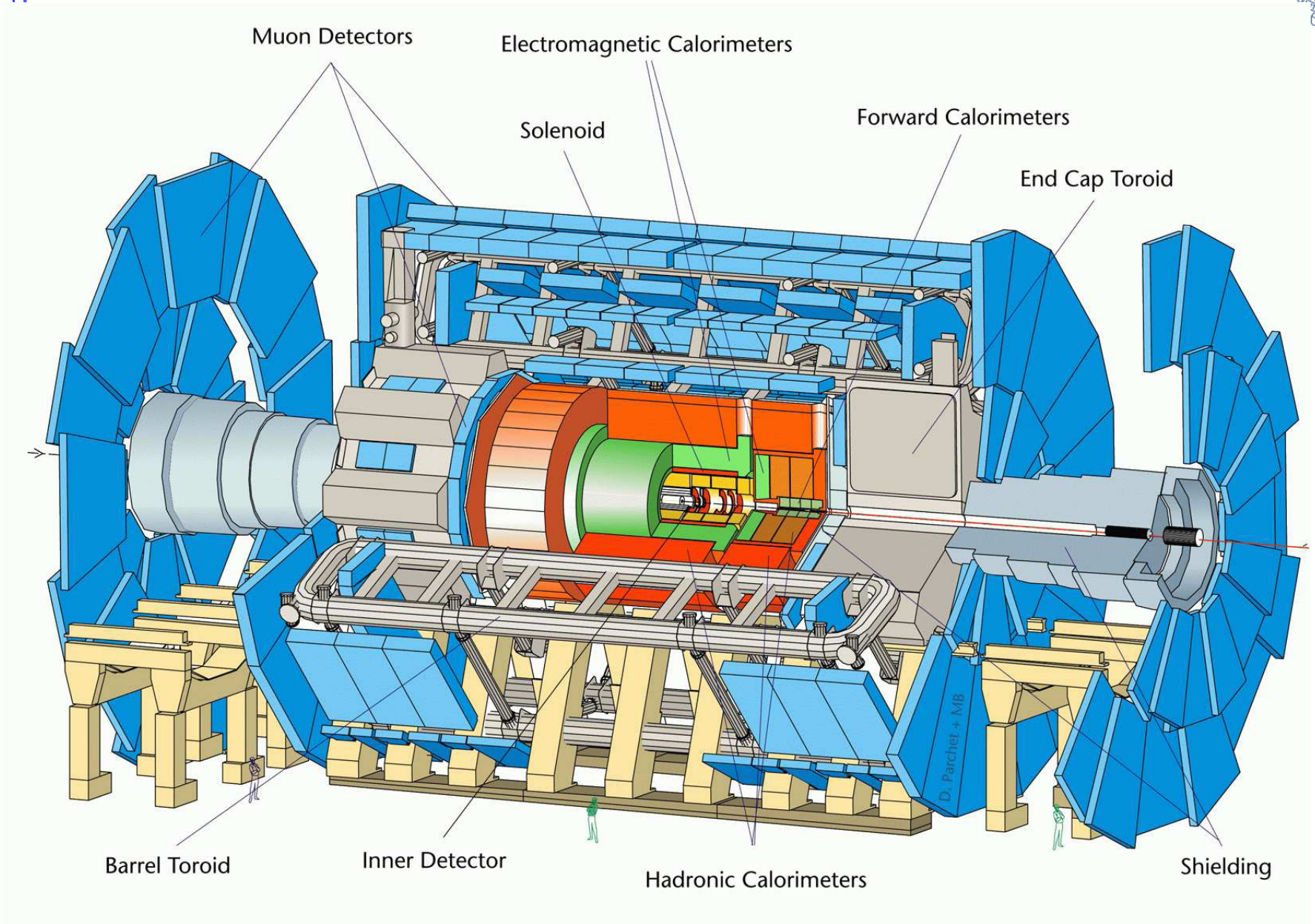
But if it is there we will hit it…

Backup

Parton Luminosity Scaling



The ATLAS Detector



The ATLAS Diamond Beam Monitor