UNIVERSITY OF ALBERTA DEPARTMENT OF PHYSICS

Review of Results from ATLAS

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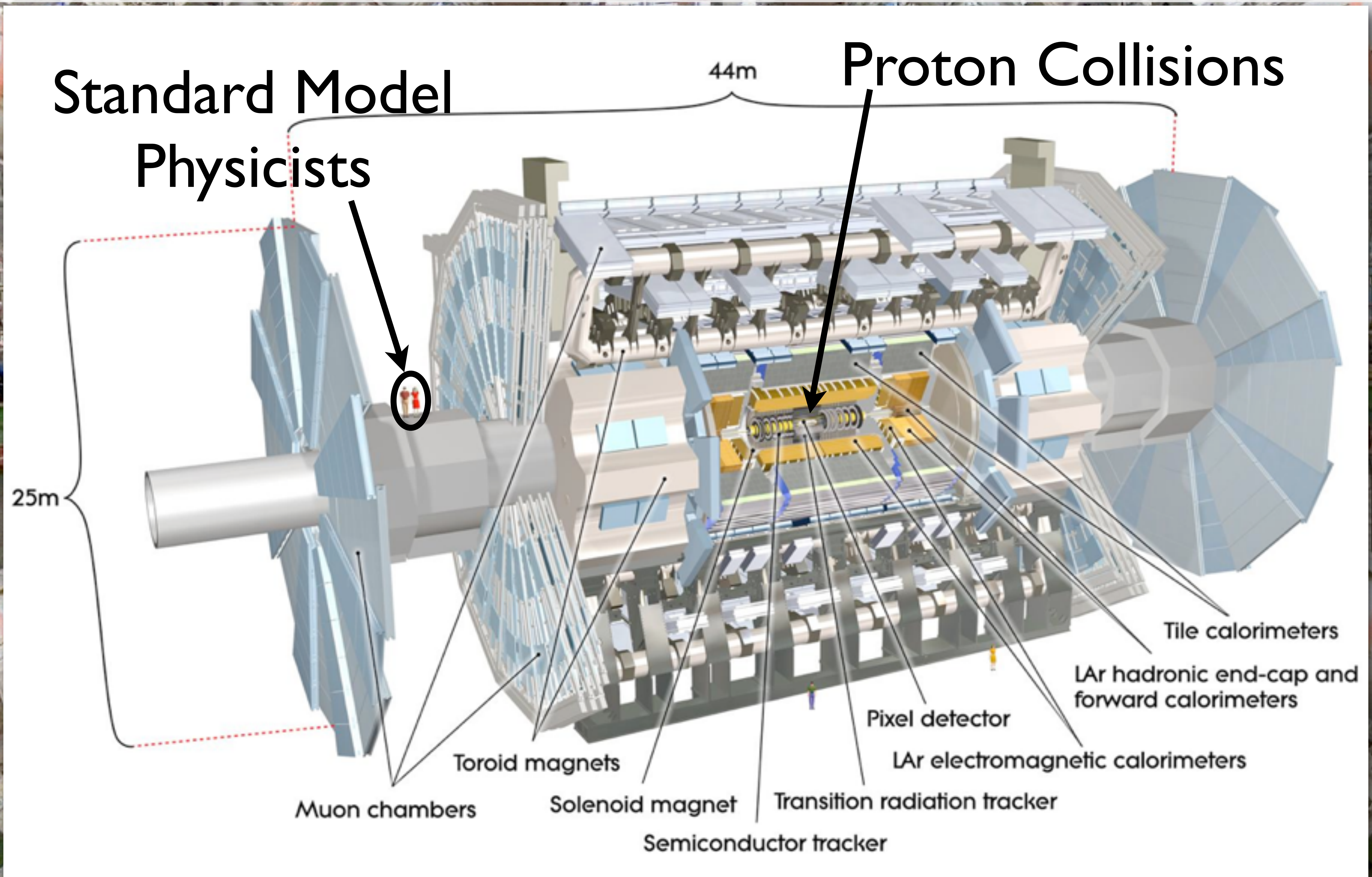
CERN

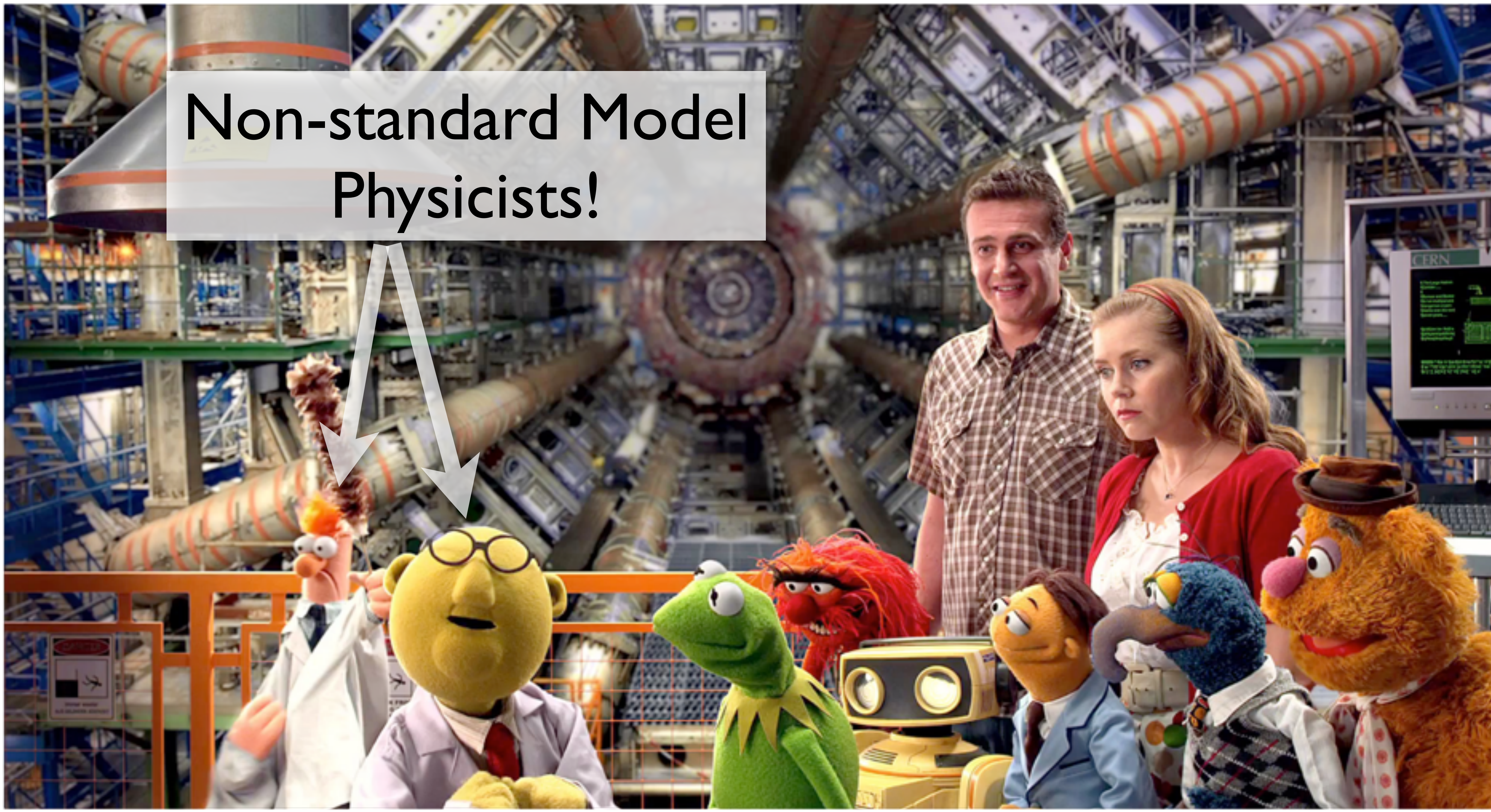
ATLAS EXPERIMENT
http://atlas.ch

ATLAS in Real Life



ATLAS in the Movies

from "The Muppets" (2011)

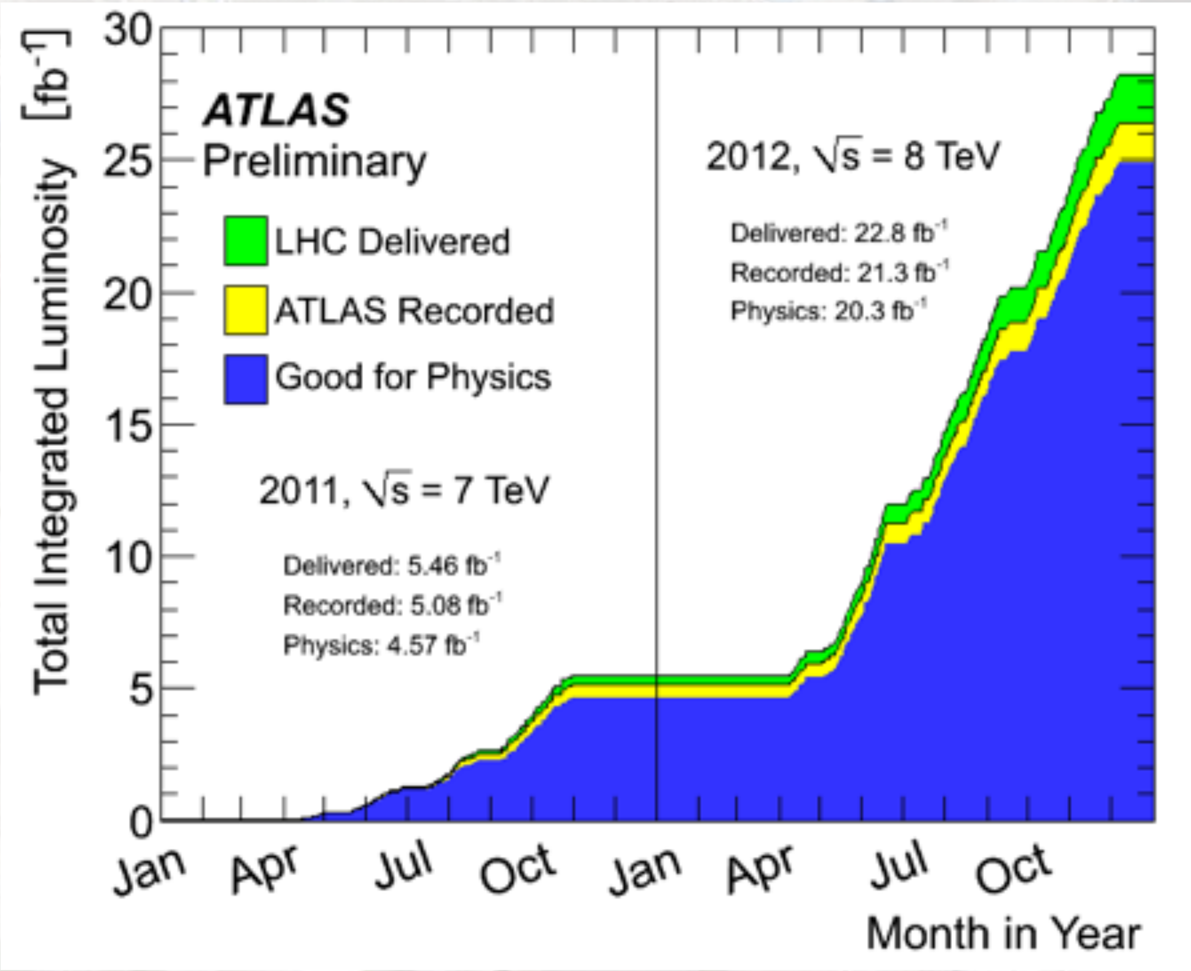


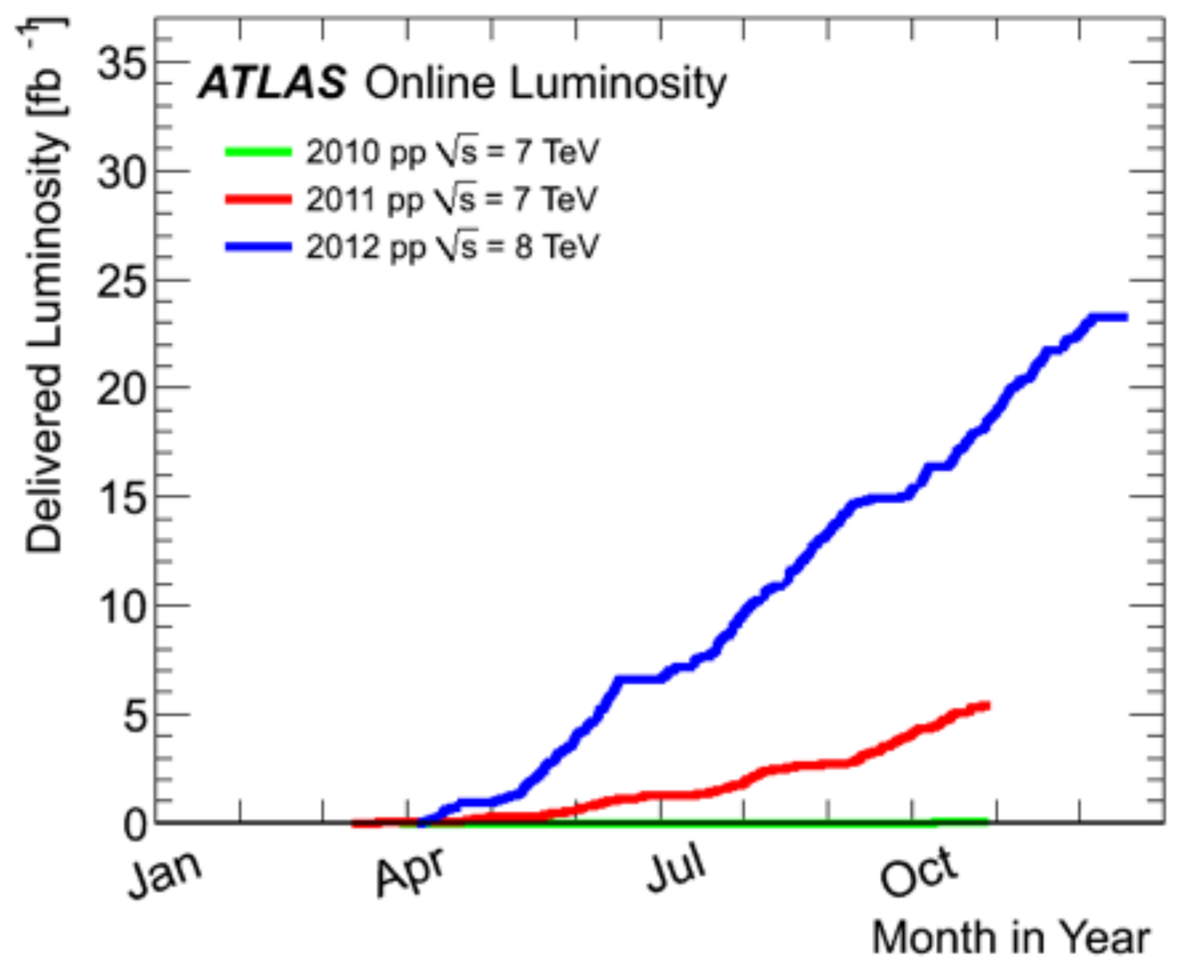
General Comments

- Detailed discussion of each analysis not possible in a summary talk like this
  - Concentrate on motivation for analysis and results rather than the details: references given for those interested
  - All public results available on the web, papers are all freely available (no expensive journal subscriptions required!)
    - https://twiki.cern.ch/twiki/bin/view/AtlasPublic
- Only possible to highlight recent and/or important results here
  - ATLAS has been producing ~100 papers/year!
  - Focus on top, Higgs, SUSY and recent exotics
- Generally analyses shown use the most recent data
  - 2012 data: 8TeV centre-of-mass with 20.3 fb^{-1} luminosity
  - Some summary results also include 2011 data: 7TeV; 4.57fb^{-1}

Run 1

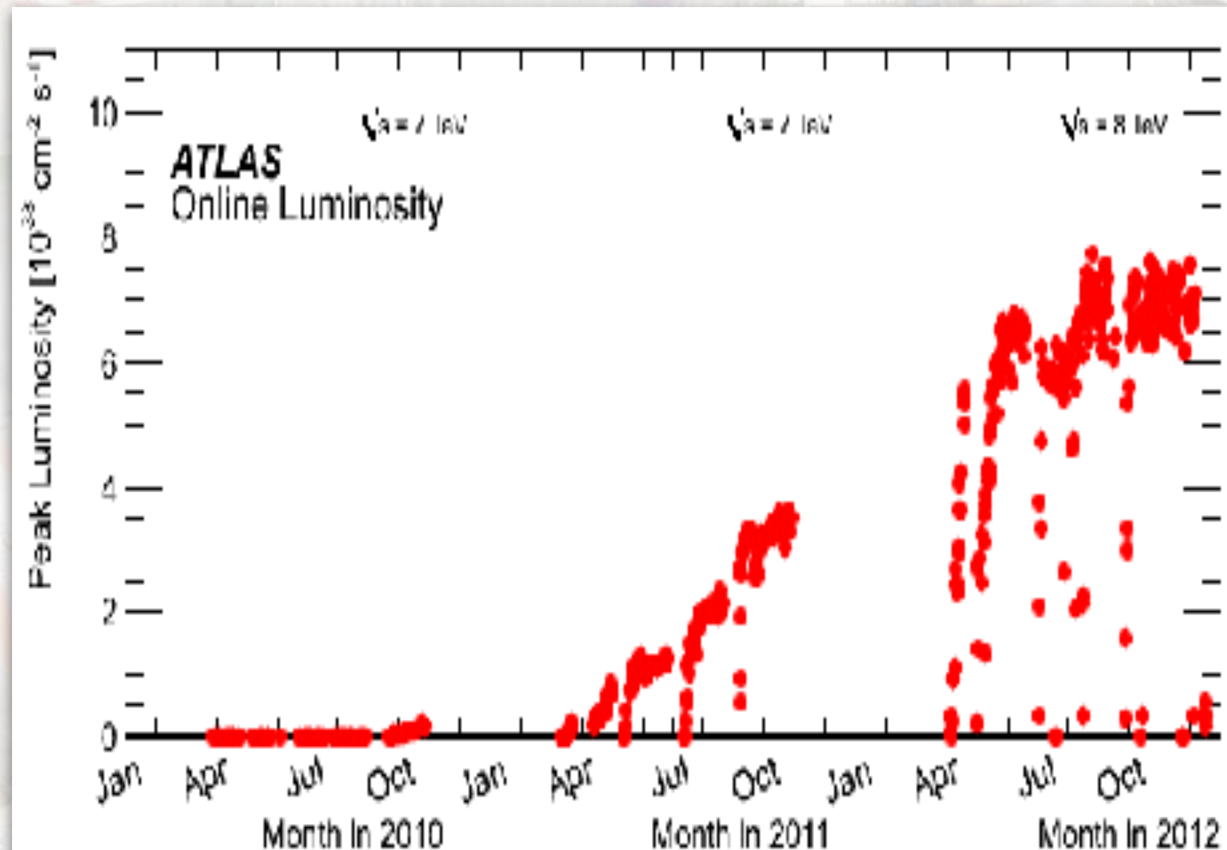
- First run of ATLAS has been extremely successful
  - Run from 2010-2012 and collected 25 fb^{-1} physics data
  - Data taking efficiency for 2011 and 2012
    - 93% recorded, 88% for physics

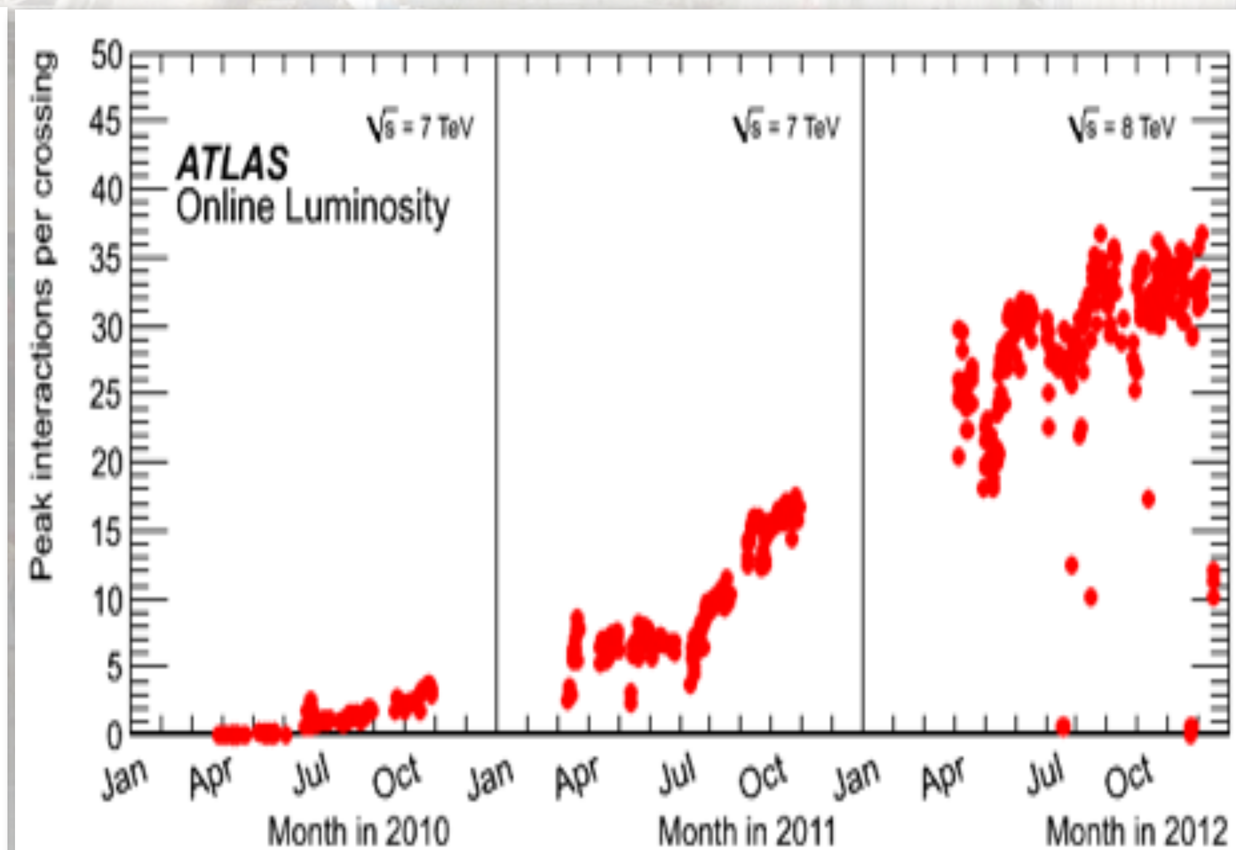




Run I

- Operating at 7 TeV (2010-11) and 8 TeV(2012) centre of mass
  - ~80% of data recorded at 8 TeV
- Instantaneous luminosity reached 8x10^{33} $cm^{-2}s^{-1}$ with 50 ns bunch spacing
  - Collisions per bunch crossing slightly above design

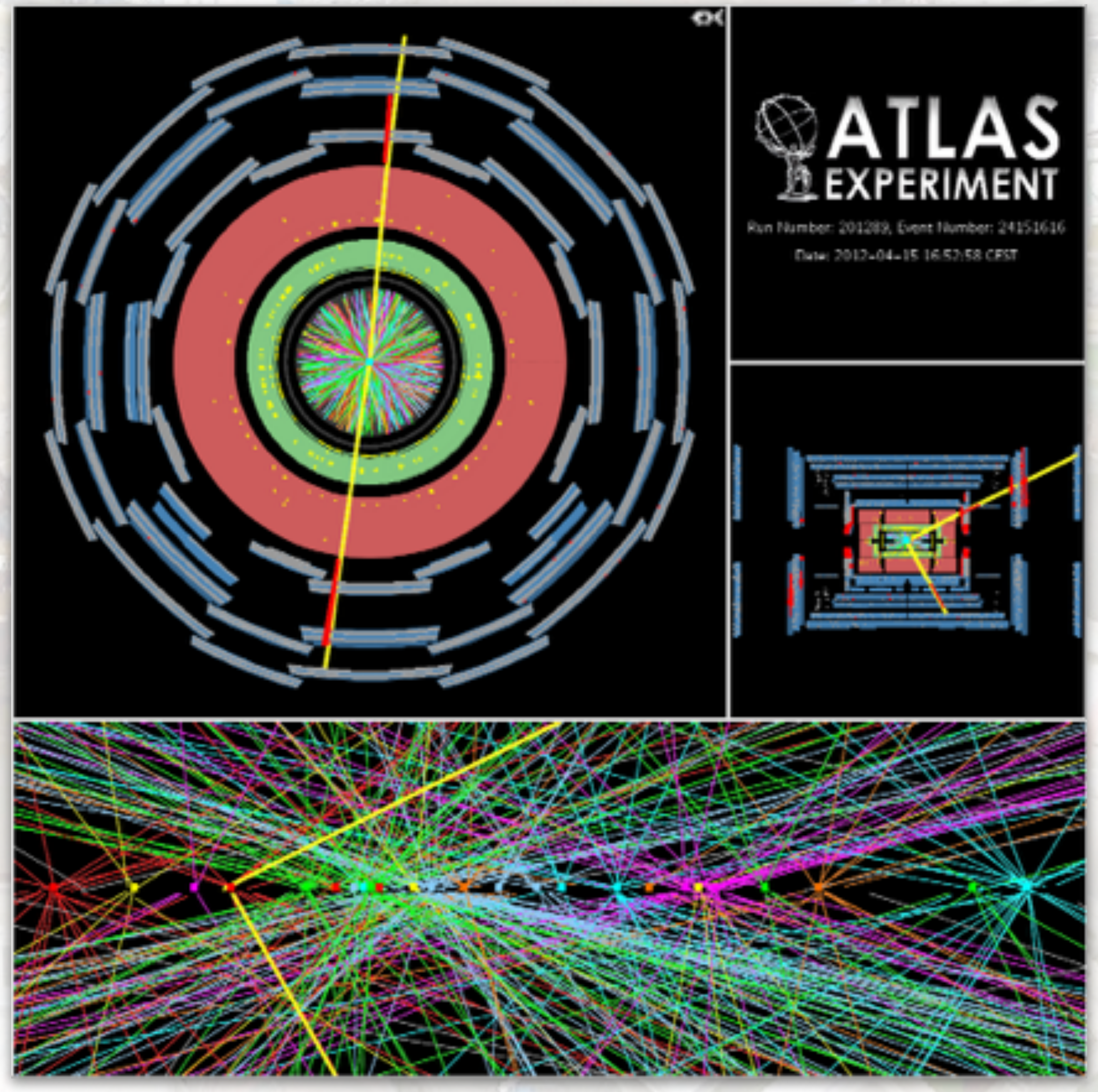




Challenging Environment

- This provides a very challenging environment for physics analyses!
  - Multiple proton-proton collisions in each beam crossing provides a lot of in-time background
  - Use vertices to separate collisions

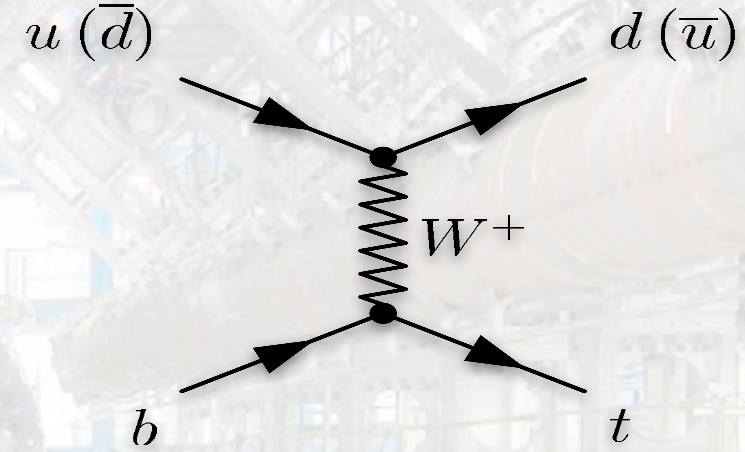
$Z \rightarrow \mu\mu$ with 25 vertices

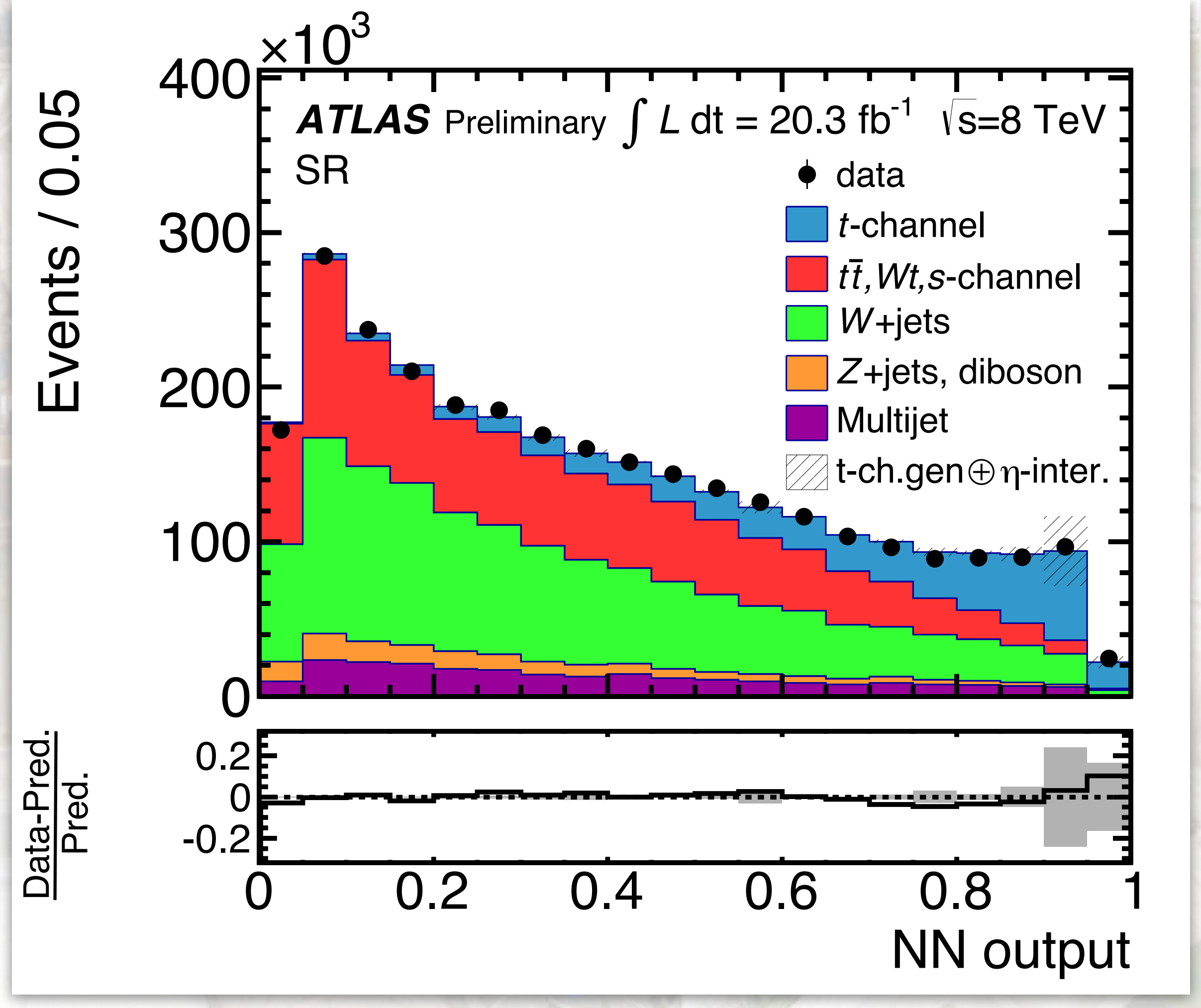


Single Top Production

- Single top production useful for measuring V_{tb}
  - Using t-channel production
- Select events with two jets (one b-tagged) plus isolated e/μ and MET
- Backgrounds significant
  - ttbar, W/Z+jets to NNLO
  - di-boson to NLO
  - Multi-jet with jet faking electron
- Analysis uses "NeuroBayes"
  - 3 layer neural network with complex input preprocessing
- Result assuming aMC@NLO in pb:

$$\sigma_t = 82.6 \pm 1.2(\text{stat.}) \pm 11.4(\text{syst.}) \pm 3.1(\text{PDF}) \pm 2.3(\text{lumi.})$$



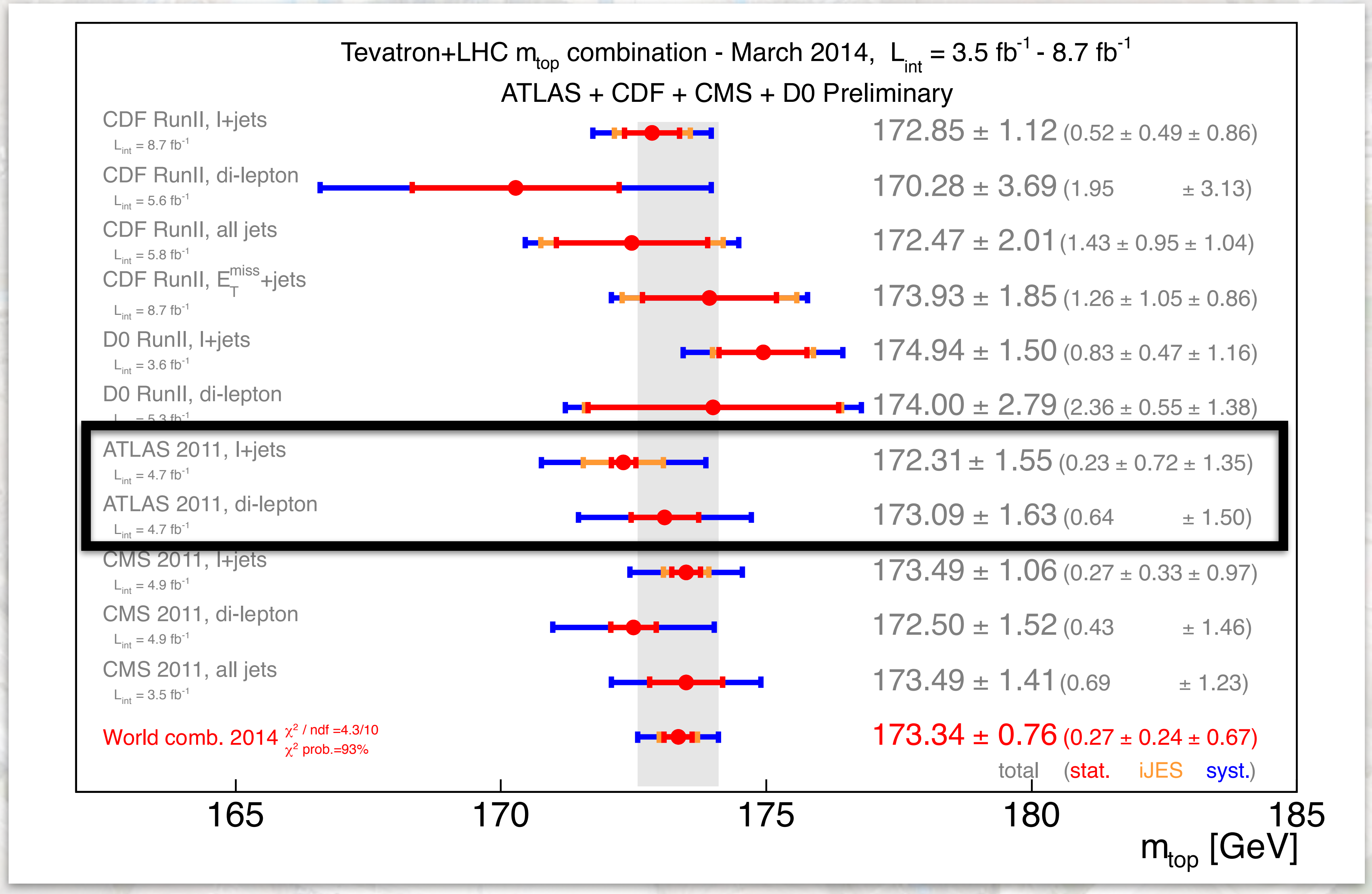


Top Mass

- Combination of ATLAS, CMS, DØ and CDF top mass measurements

arXiv:1403.4427

  - Tevatron:
    - 1.96 TeV
    - up to 8.7 fb^{-1}
  - LHC:
    - 7 TeV
    - up to 4.9 fb^{-1}
- Channels included:
  - lepton+jets
  - di-lepton
  - all jets
  - MET+jets

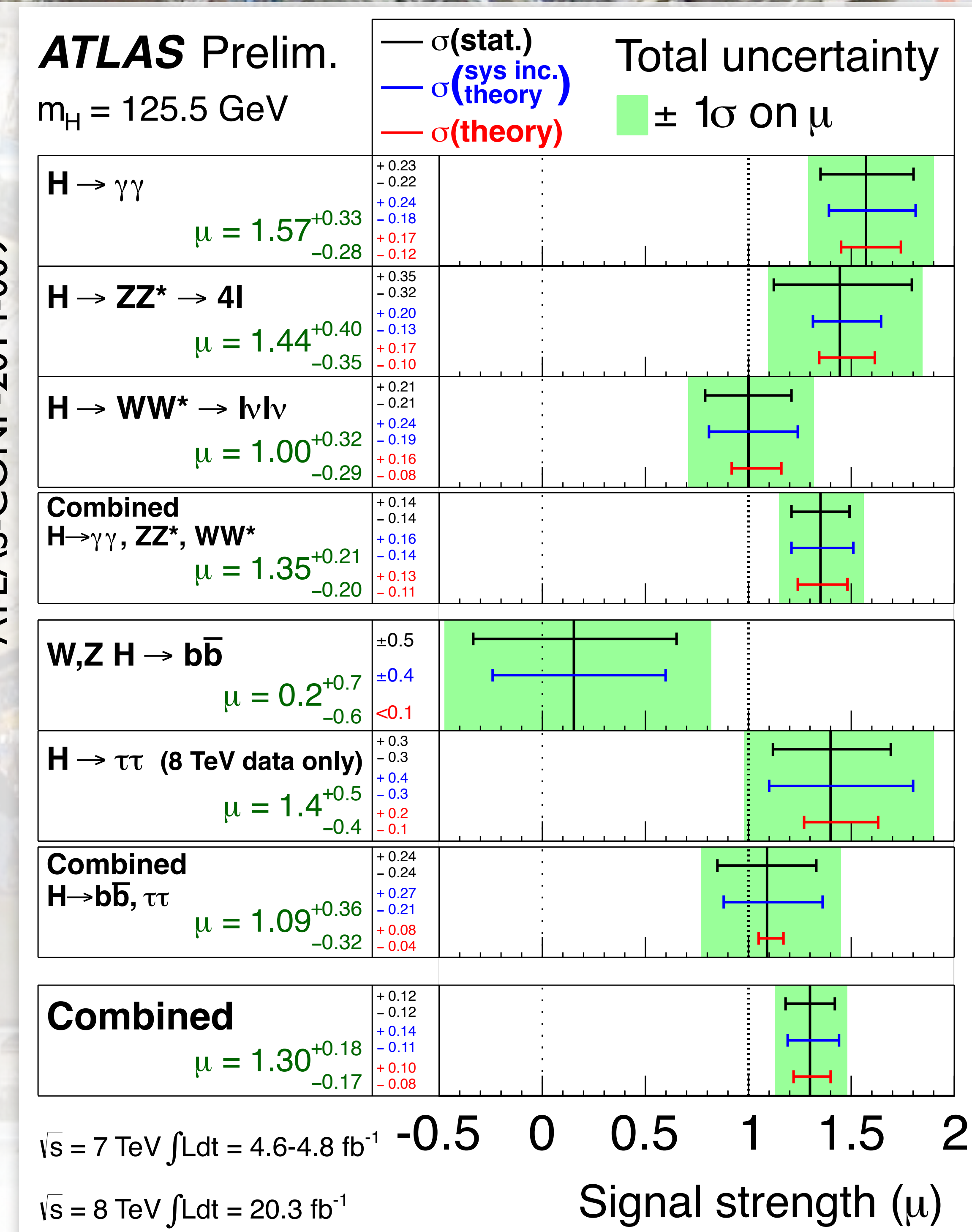


Higgs Physics

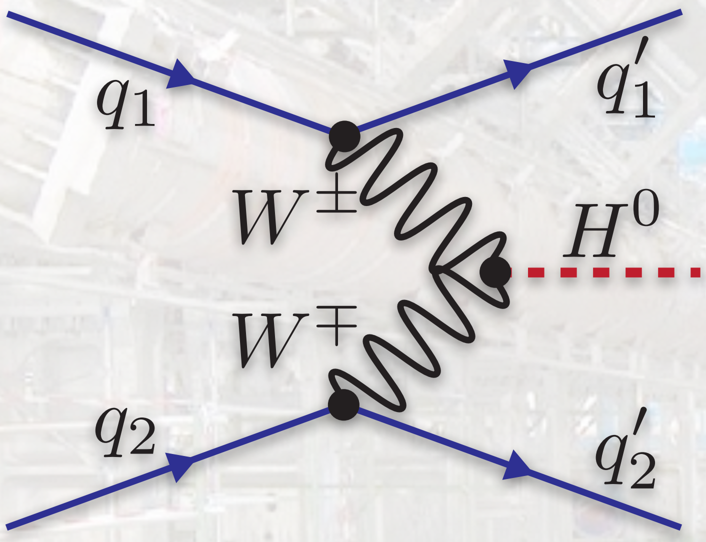
- Highlight of Run 1 was the discovery of the Higgs boson
  - Final Run 1 analyses still underway: expect completion later this year
- Recent results for Higgs decay channels
  - Boson decays well established, fermion channels less so
  - Slight excess in H signal
  - Not statistically significant

$$\mu = (\sigma \times BR)/(\sigma \times BR)_{SM}$$

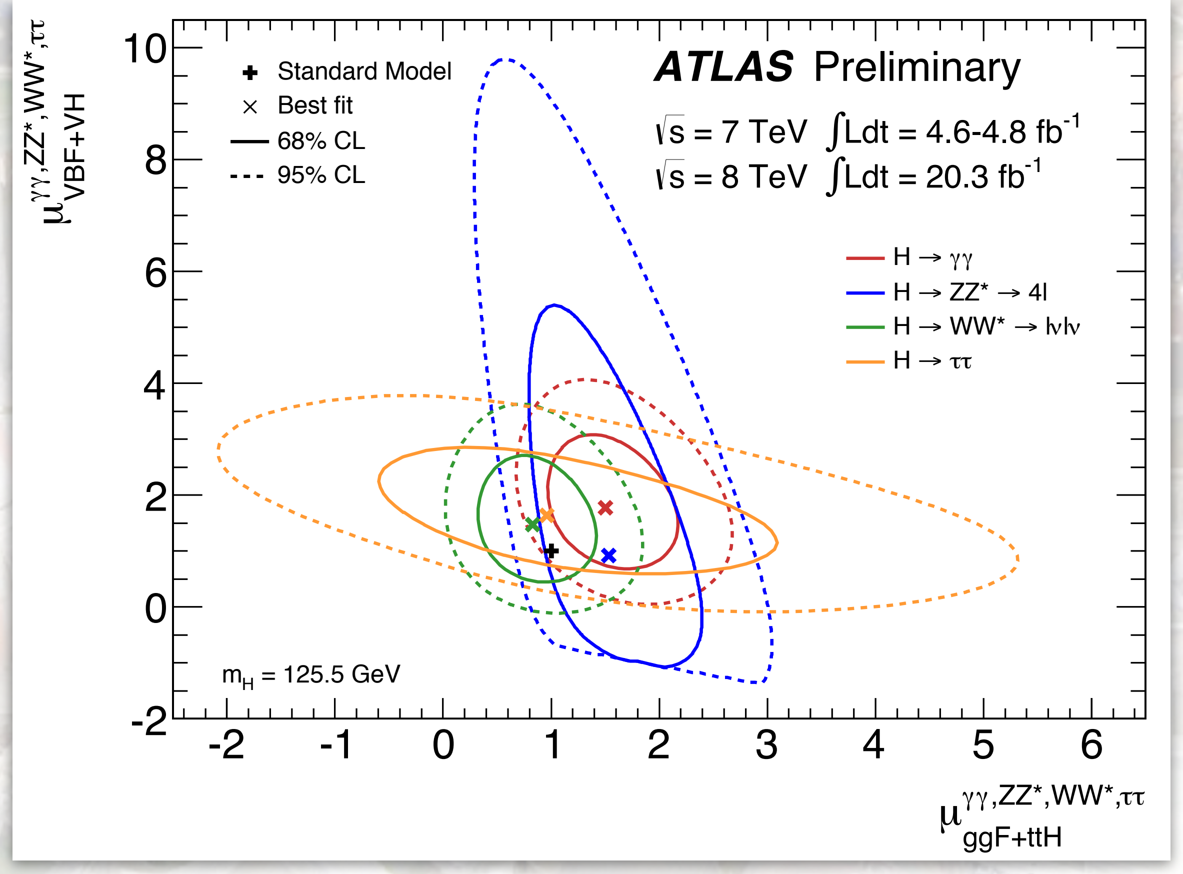
ATLAS-CONF-2014-009



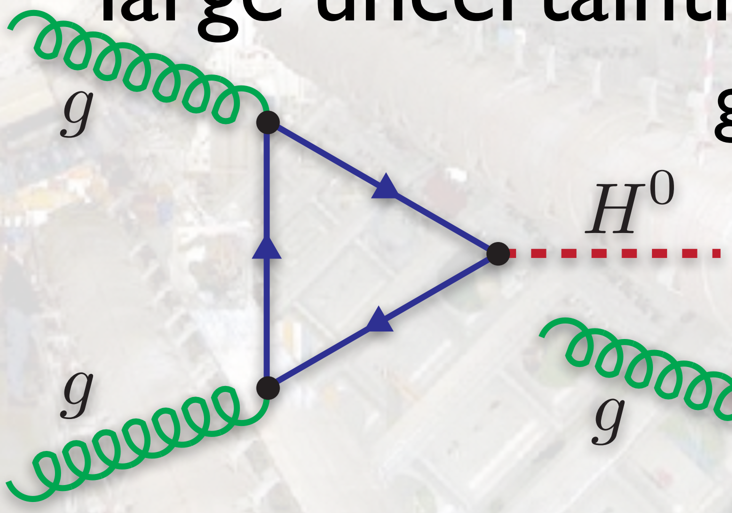
Higgs Physics



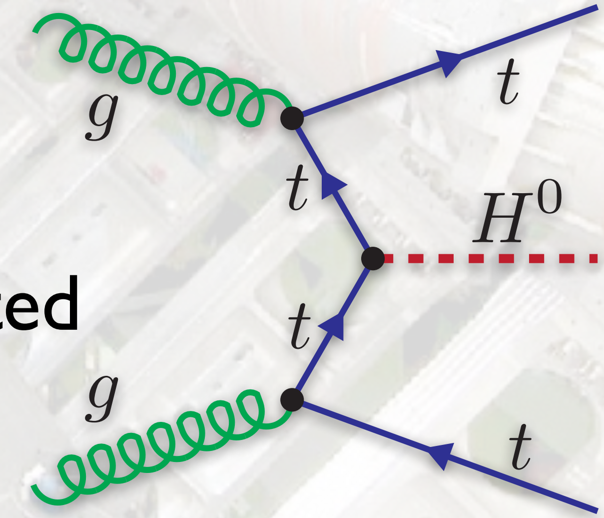
vector boson fusion



- Can also compare the signal from different production mechanisms
  - VBF vs. ggF+ttH
- Consistent with SM but large uncertainties



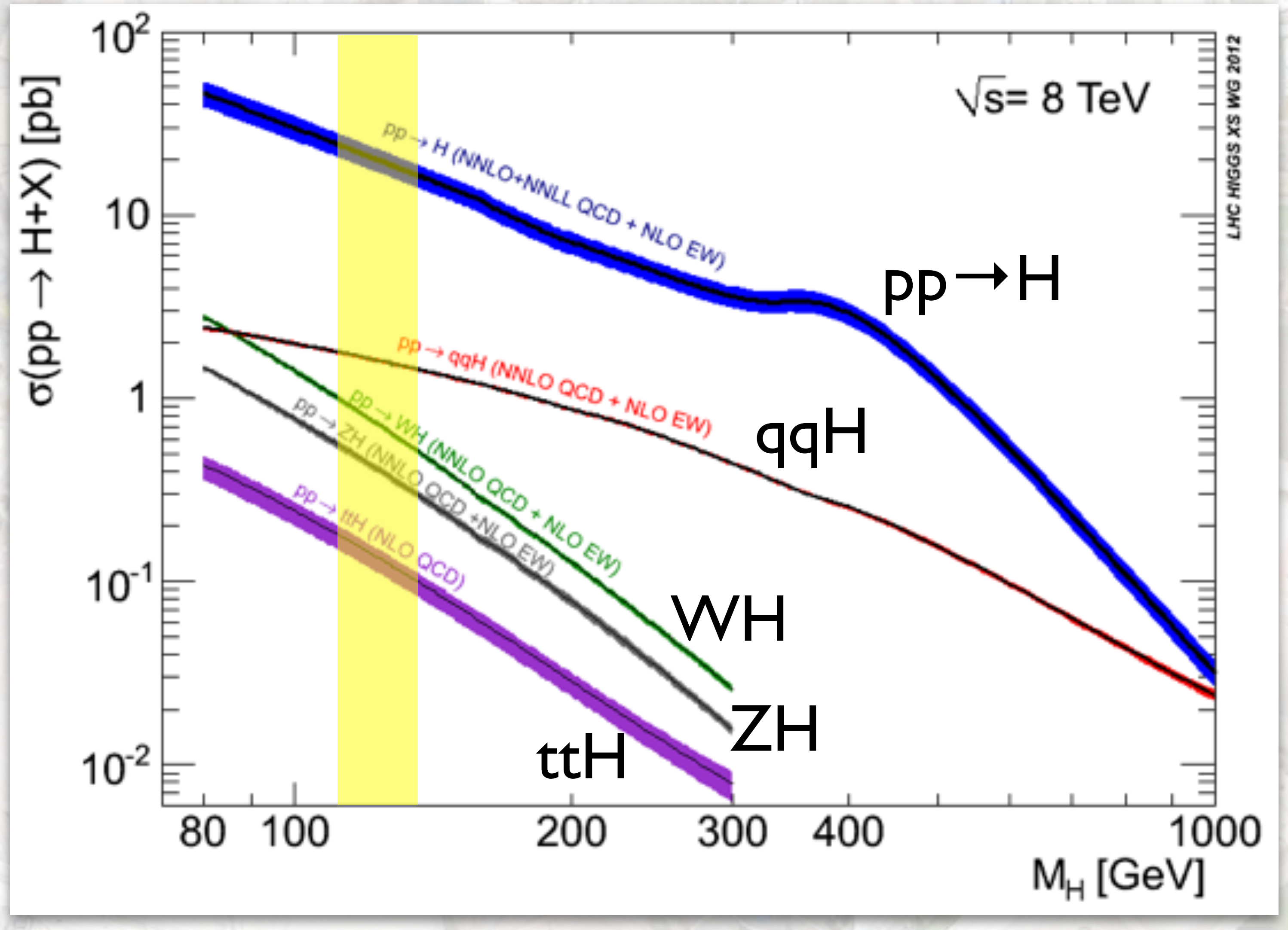
gluon-gluon fusion



ttbar associated production

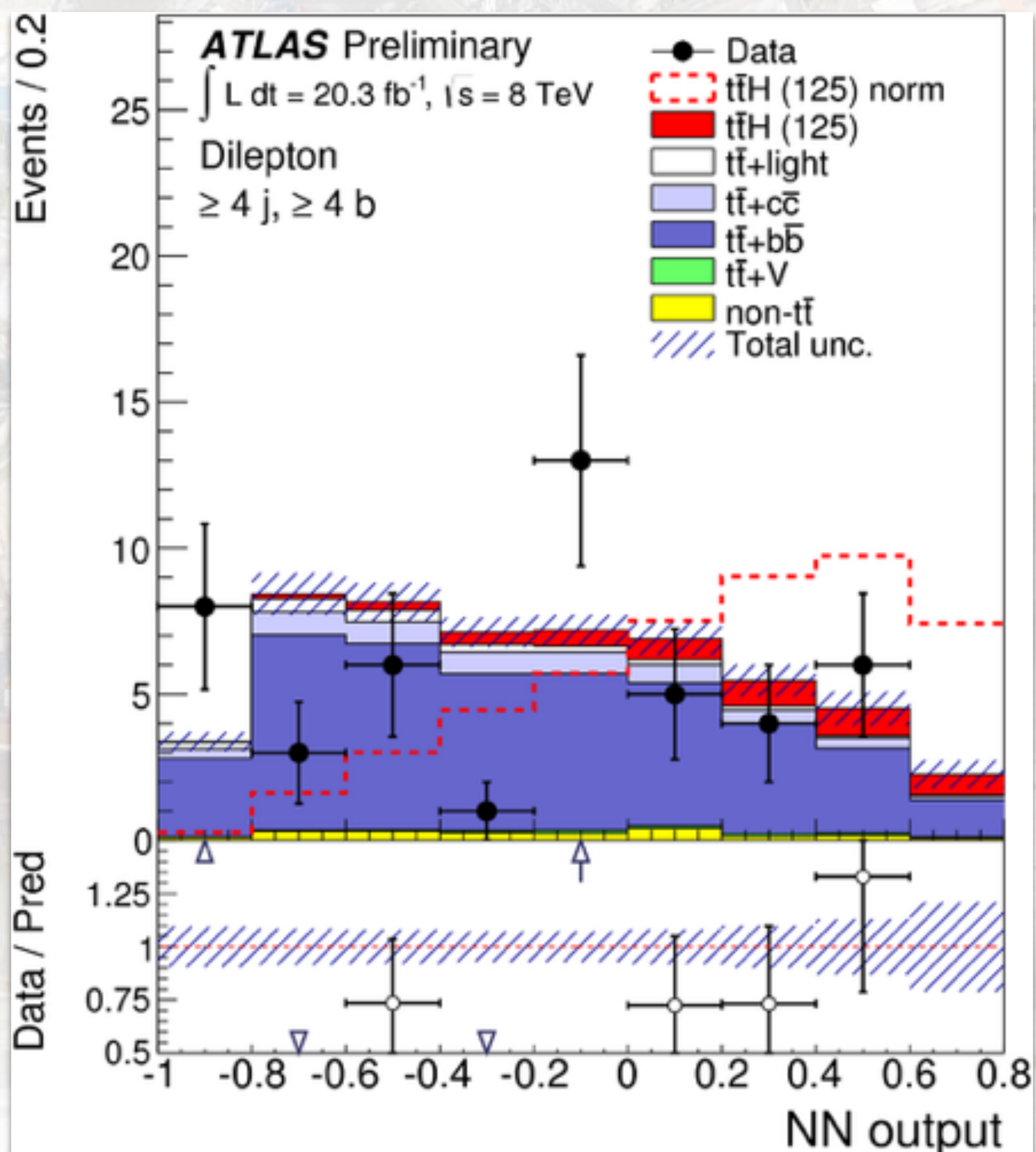
Higgs Fermion Couplings

- Coupling of Higgs to bosons well established
  - Discovery channels were γγ, ZZ and WW
- Coupling to fermions is the current challenge
  - Two approaches
    - associated production
    - direct fermion decays
- Both difficult
  - SM: σ(ttH) ~<0.2 pb
  - bb and ττ decays have large BRs but large backgrounds



Higgs Fermion Couplings

- New search from ATLAS
  - Look for ttH production with H→bb
- Require 1 or 2 semi-leptonic (e,μ) top quark decays
  - High pT leptons have low backgrounds
  - top mass large enough that lepton will be isolated
- Cut events where lepton invariant mass close to m_Z
  - Z+jet event background
  - No MET cuts required
  - Tag b-jets via displaced vertex
- Neural network used for analysis



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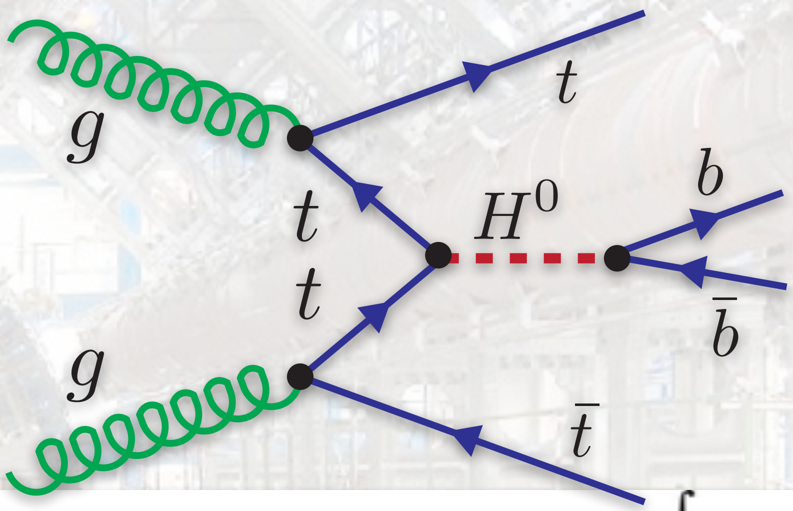
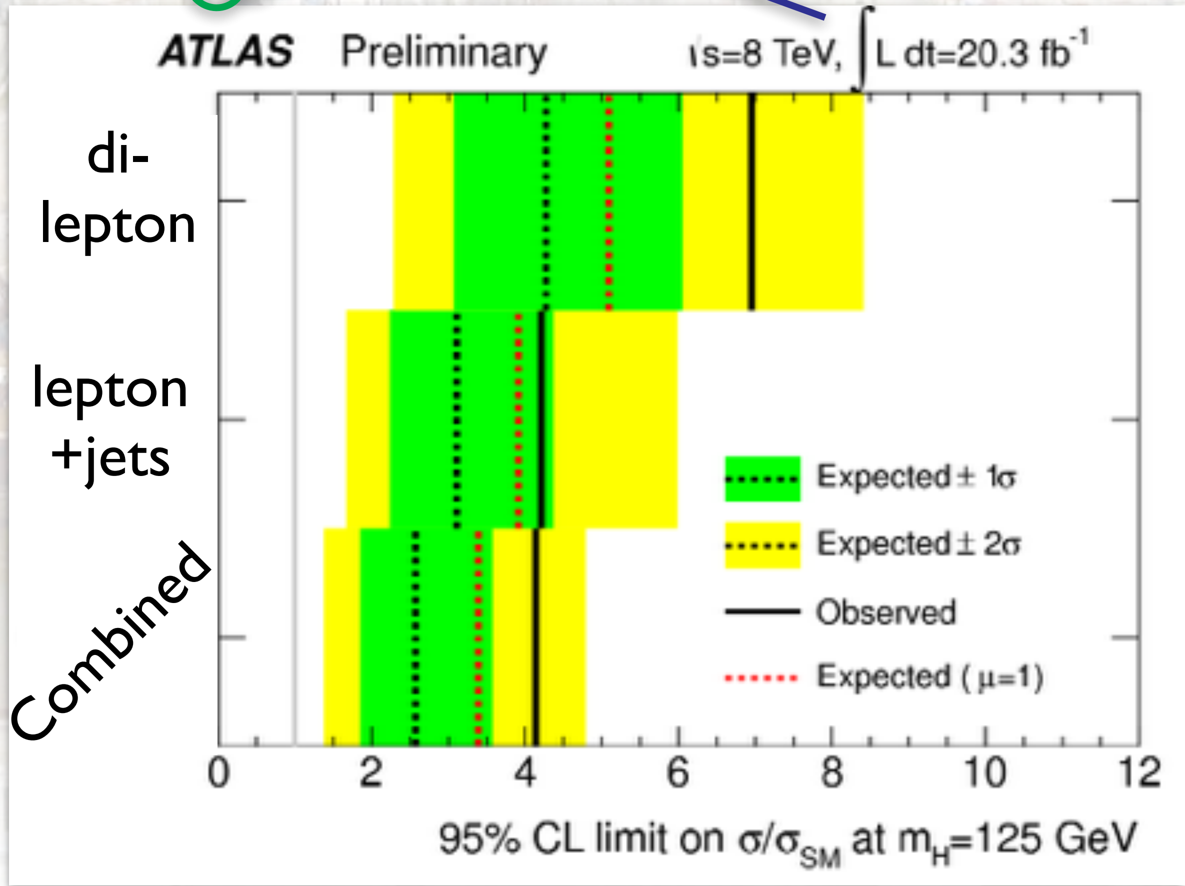
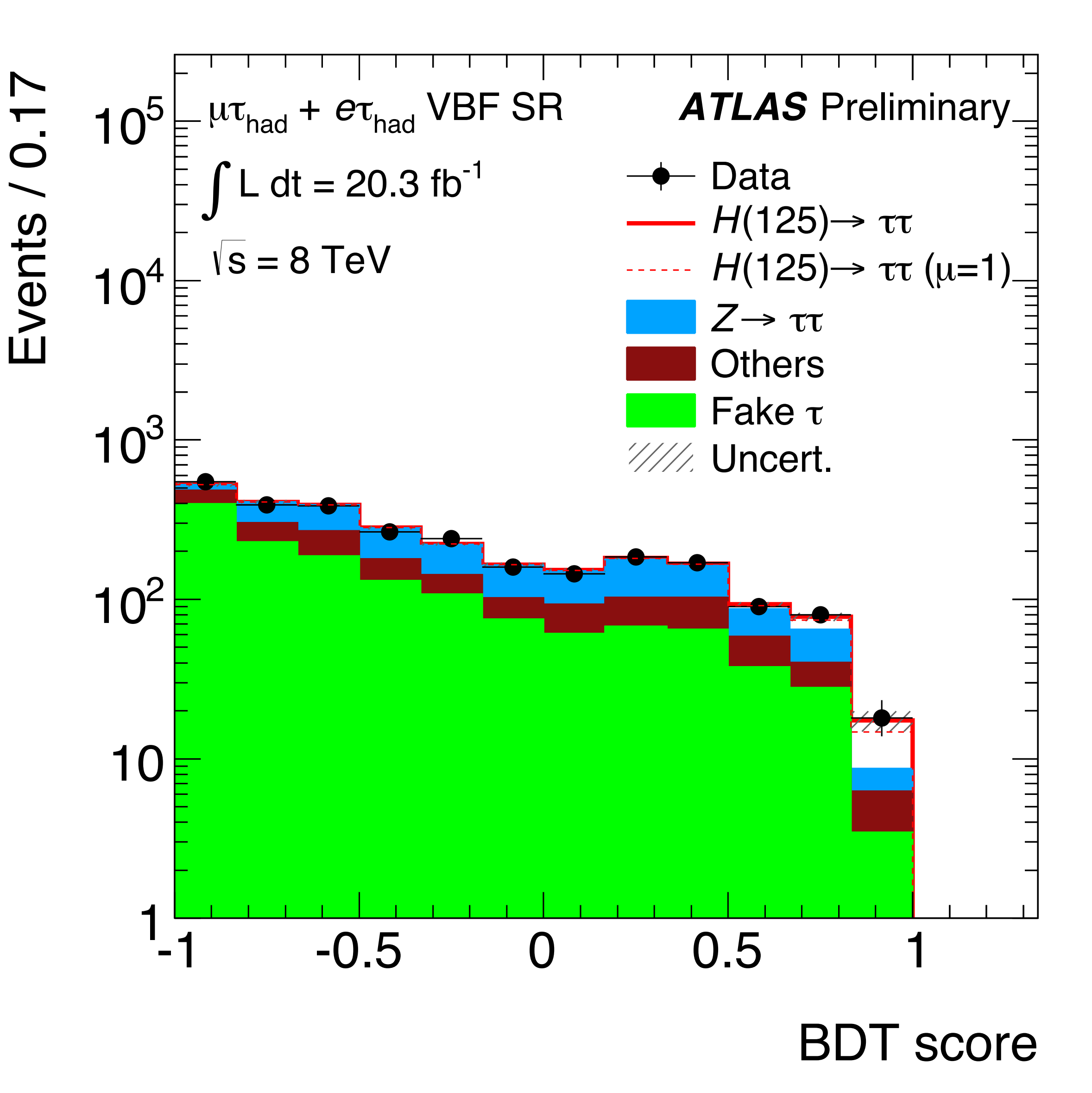




ATLAS-CONF-2014-011

Evidence of H→ττ

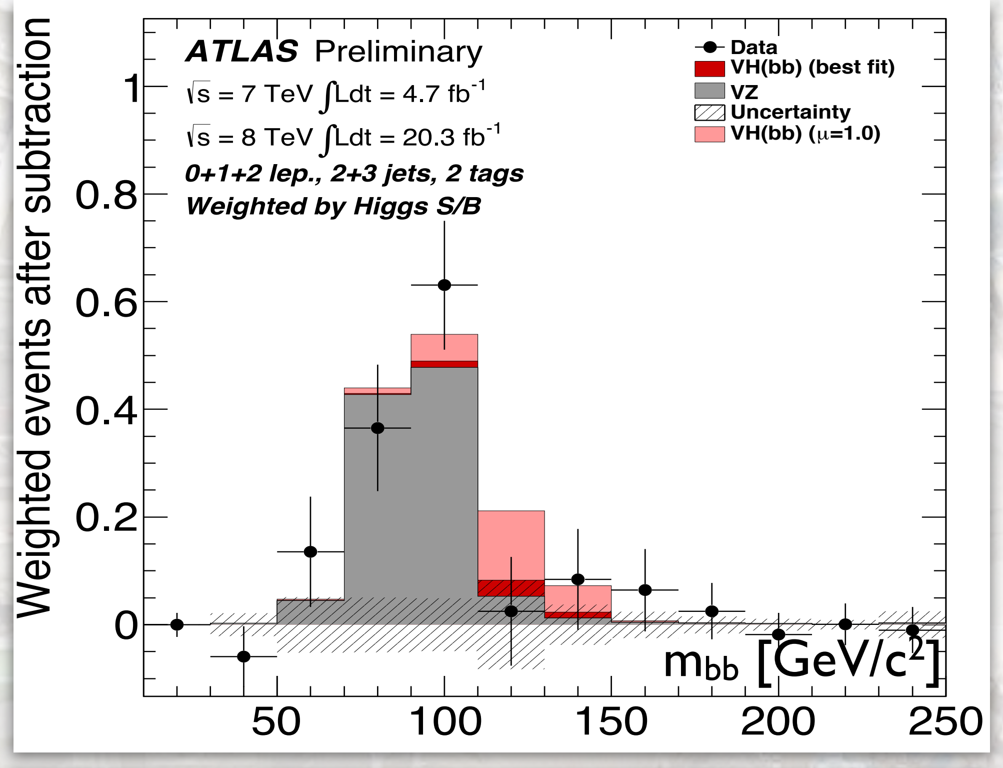
$\tau_{lep}\tau_{had}$, VBF Result

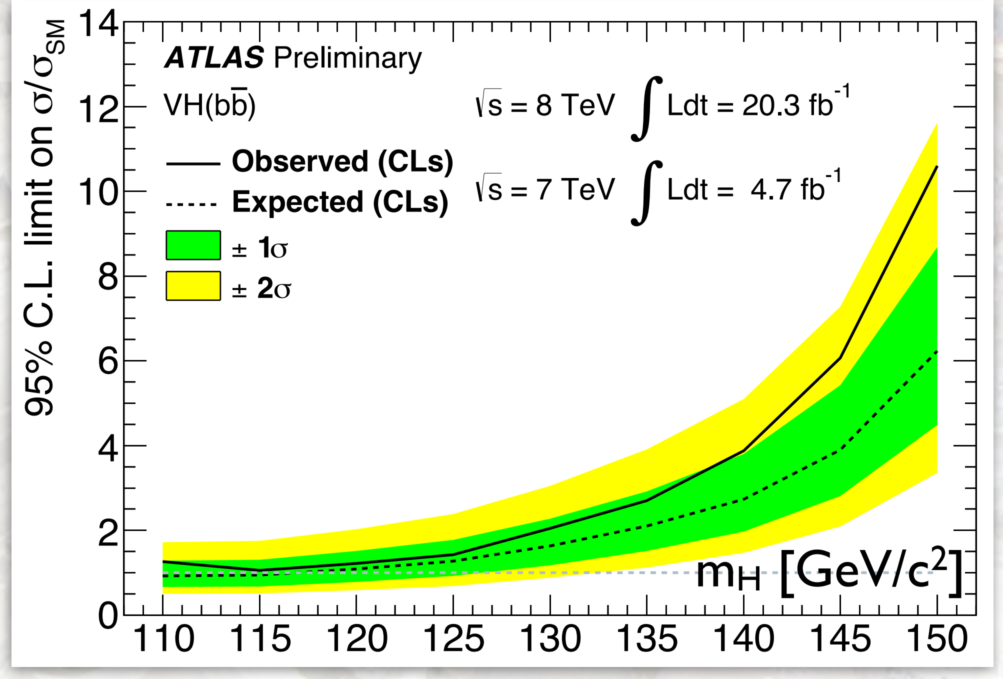


- Use both hadronic and leptonic tau decays in combinations
  - lep-lep, lep-had and had-had
- Two production types considered
  - gluon fusion & vector boson fusion
- Boosted Decision Trees
  - Same technique used for tau ID both offline and in the high level trigger
  - Largest backgrounds from Z, tt and jets faking taus
- Evidence at 4.1σ (3.2σ expected)
  - m_H=125 GeV/c^2 signal strength of full combination:

$$\mu = 1.43^{+0.31}_{-0.29}(\text{stat.})^{+0.41}_{-0.30}(\text{syst.})$$

Higgs Fermion Couplings

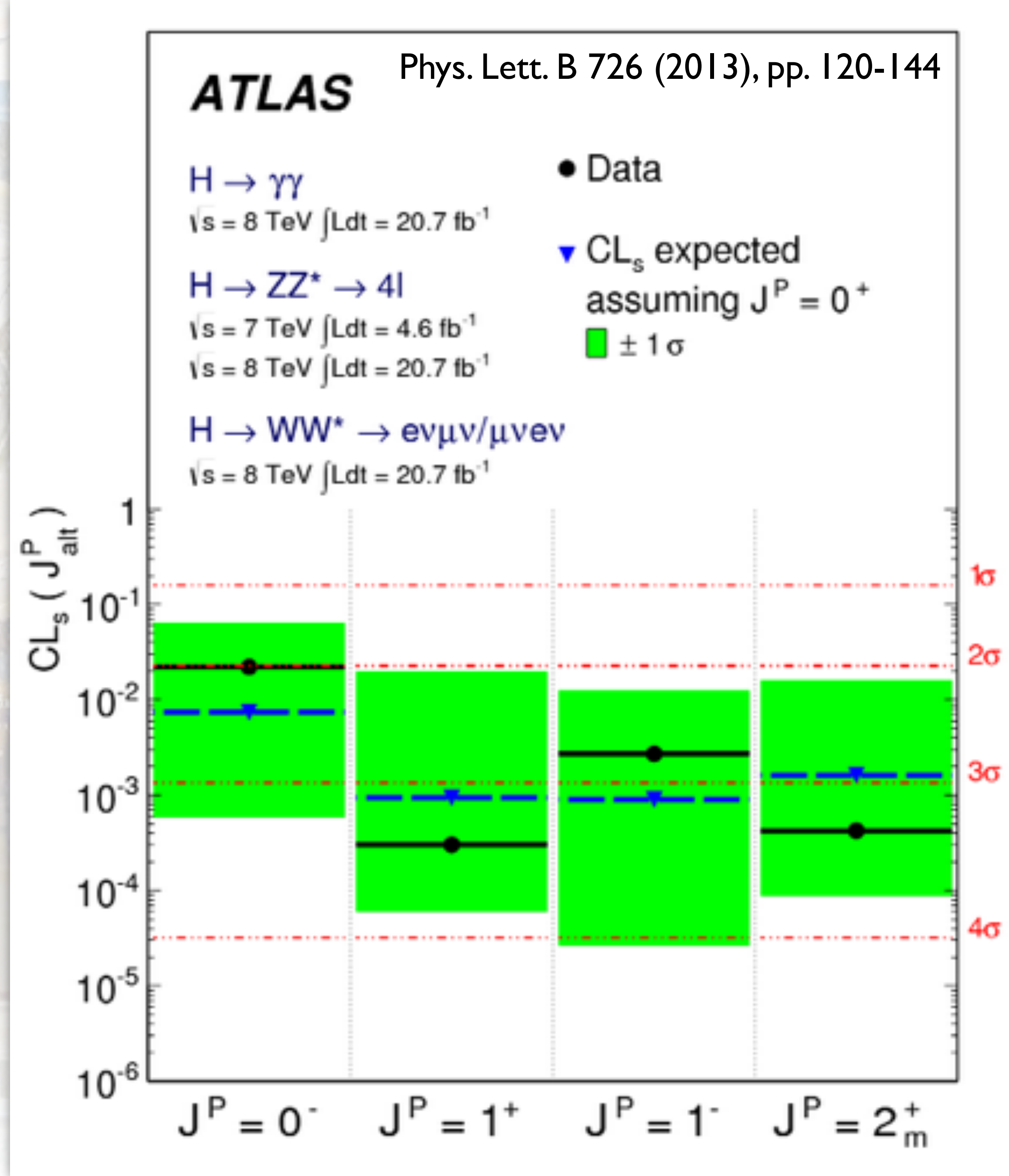




- $H \to bb$ has massive QCD background
  - Look for associated production with W/Z or ttbar
- Major backgrounds:
  - W/Z+bb, tt, di-boson
- Look at events with 2+3 jets, 0-2 leptons & 2 b-tags
  - $W \to l\nu$, $Z \to ll$, $Z \to \nu\nu$ [$l = e, \mu$]
- Result is 95% CL limit at 1.4 times SM expectation for $m_H = 125$ GeV/c^2

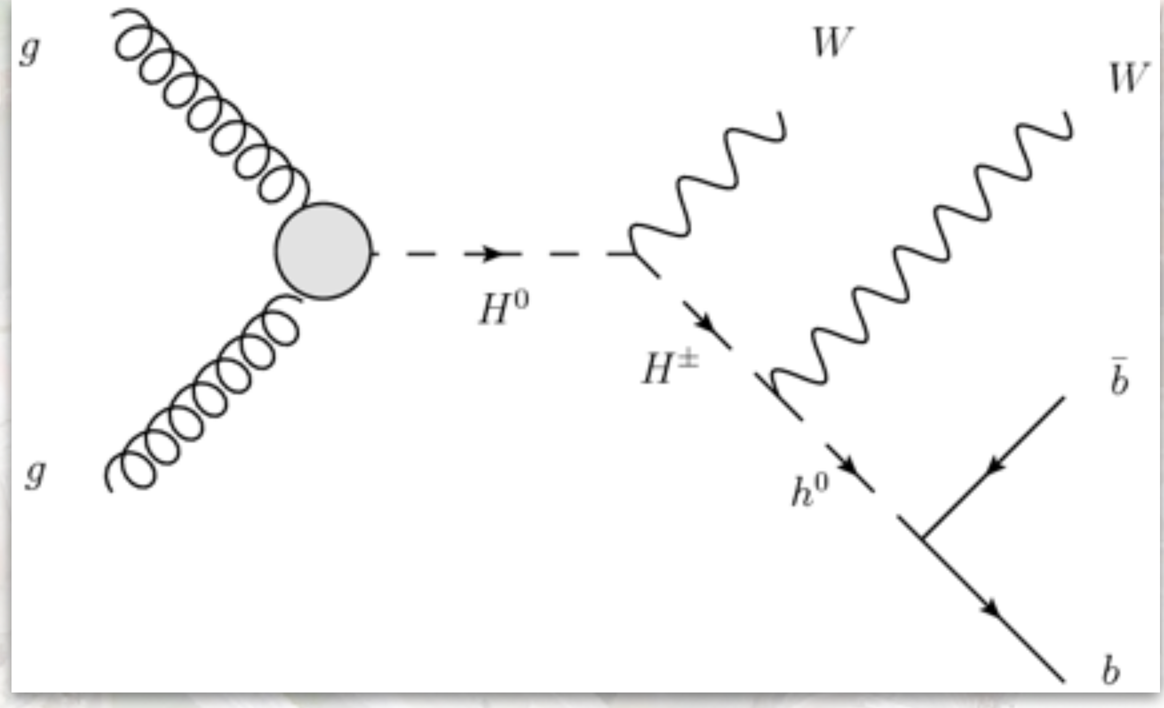
Higgs Spin

- Spin measurement uses a statistical approach
  - Assume only one particle contributes to resonance
- Compare different J^P possibilities
  - **0^+(ZZ*,WW*,γγ) [SM],** 0^-(ZZ*), $1^\pm$(ZZ*,WW*), 2^+(ZZ*,WW*,γγ)
  - Z/W decaying to e or μ
- Spin-1 strongly disfavoured by existence of γγ decay
- Result: exclude other spin-parity states at 2-3σ level



Supersymmetric Higgs

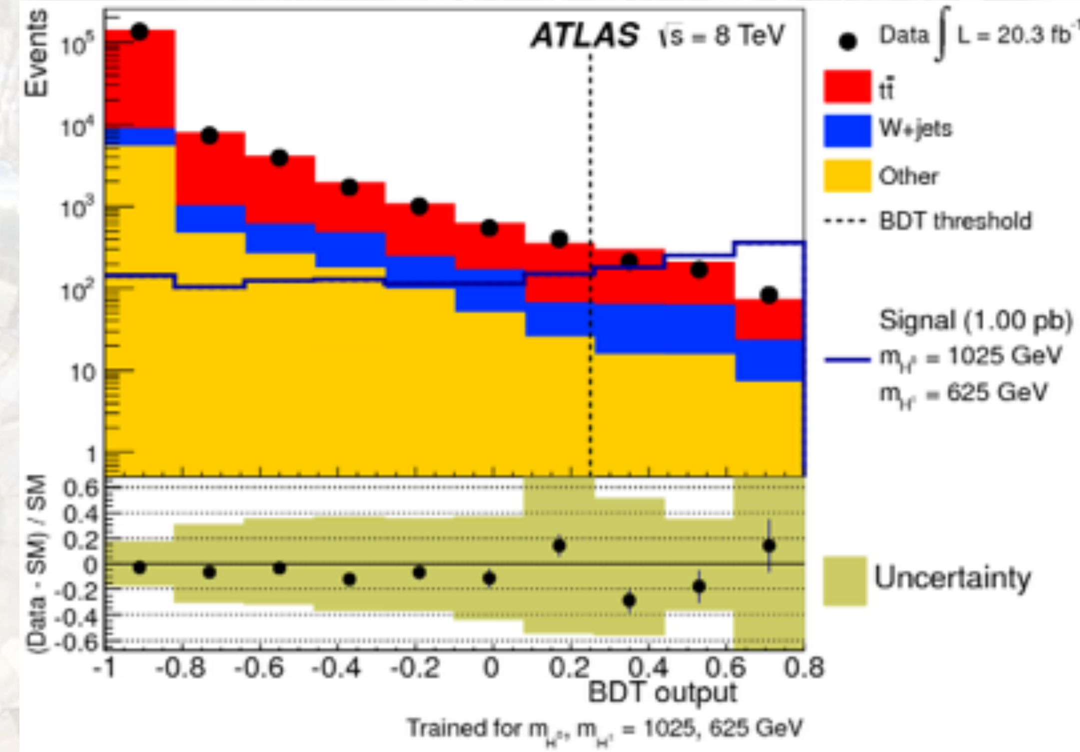
Higgs Cascade Decay Requires:
$m(H)>m(H^{\pm})>m(h)$
and that $\Delta m>m(W)$

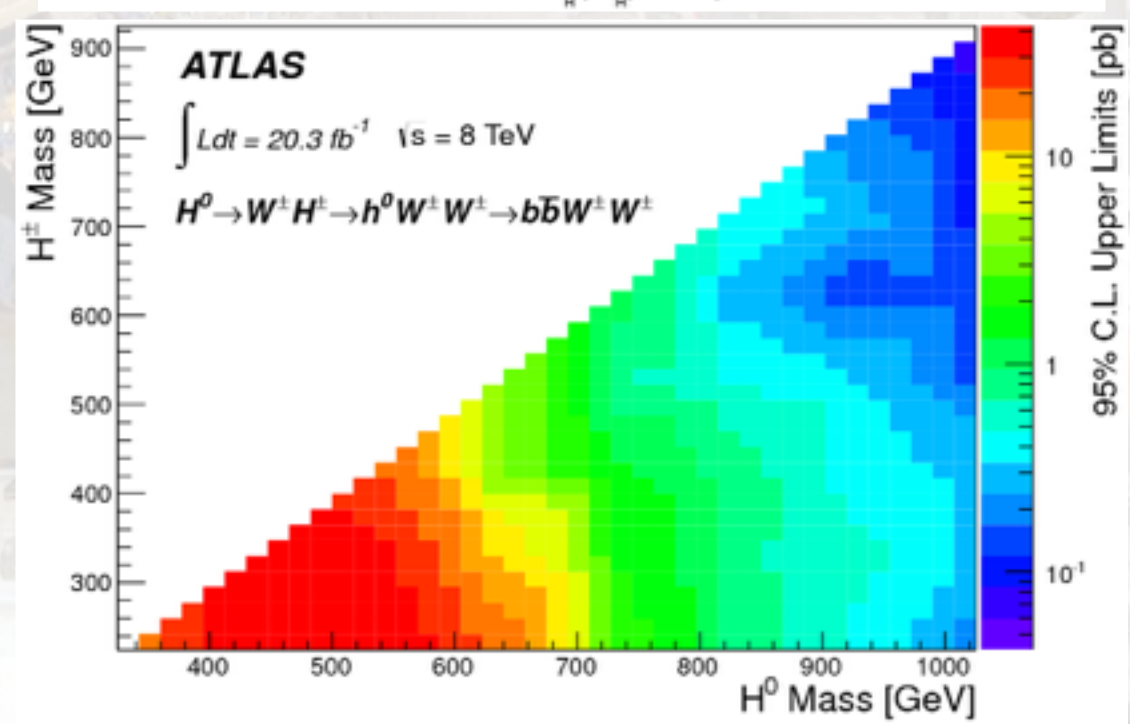


- SUSY requires at least 2 Higgs doublets
  - At least 5 Higgs bosons to find!
    - 3 neutral: h, H, A (CP odd)
    - 2 charged: $H^{\pm}$
- Even without SUSY 2 Higgs doublets possible
- Two main search methods
  - Direct production of a new Higgs particle
  - SM deviations due to $H^{\pm}$ participation in electroweak interactions
    - Different mass and couplings compared to $W^{\pm}$
- Higgs cascades even possible!

Higgs Cascade

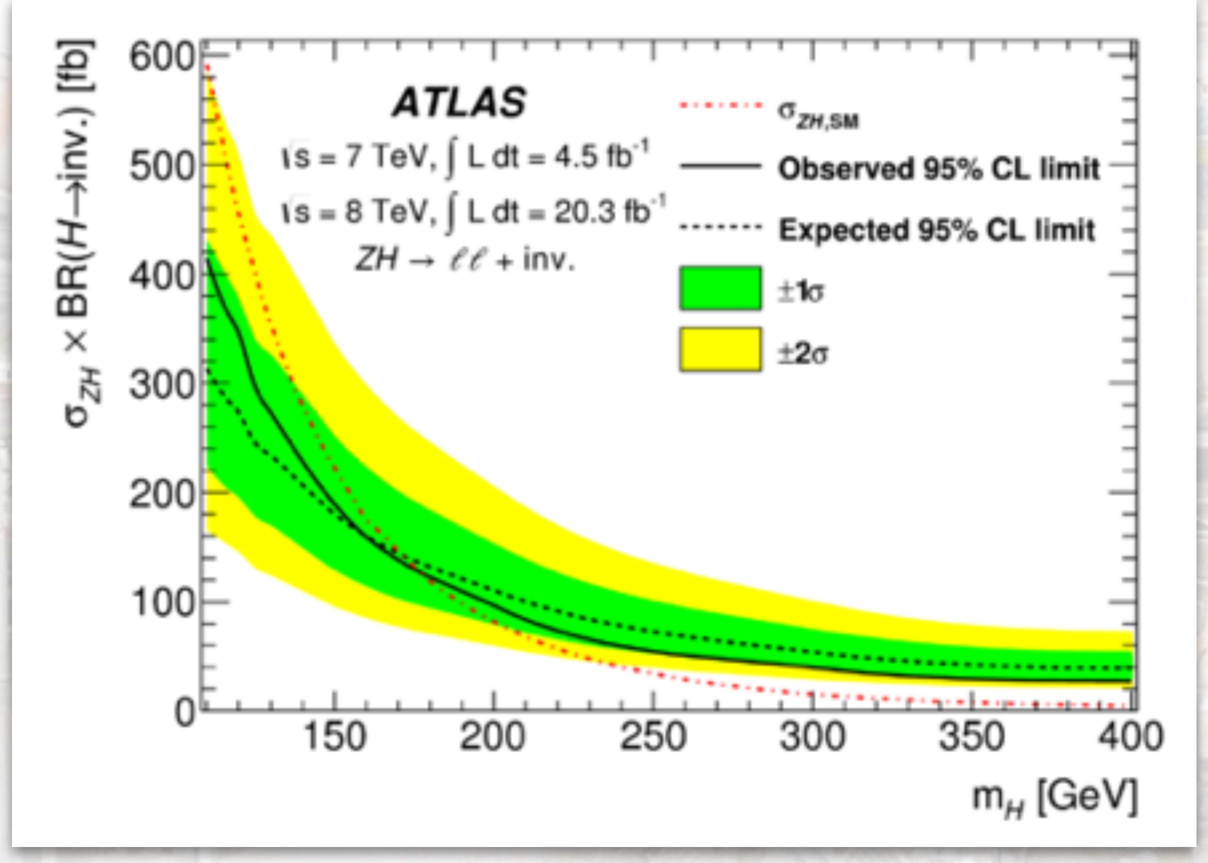
- Final state has 2 W bosons+2 b-jets
  - Require one W to decay leptonically (e/μ)
- SM Backgrounds
  - ttbar dominant SM background ($t\rightarrow Wb$)
- Use Boosted Decision Tree to separate signal and background
- No excess over SM backgrounds observed
  - Limits still above predicted σ but close in high $m_{H0}/M_{H\pm}$ area



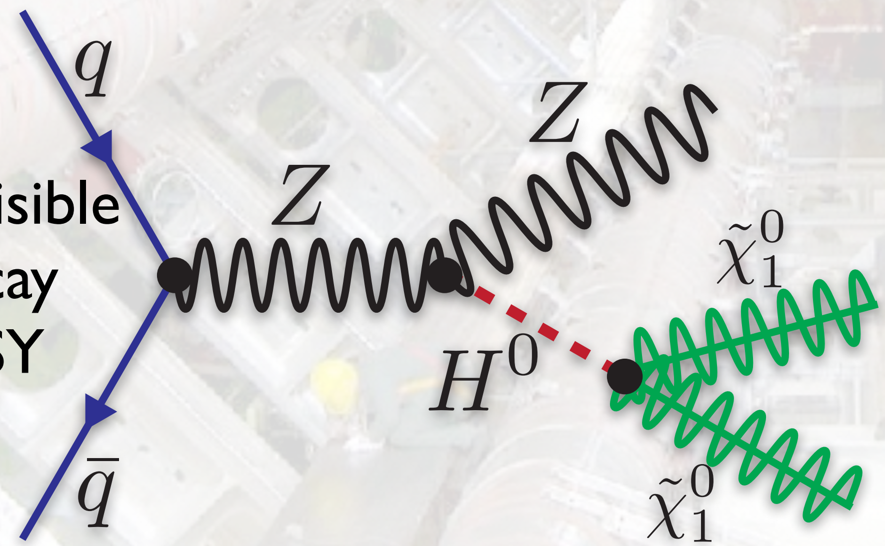


Phys. Rev. D 89, 032002 (2014)

Invisible Higgs



Possible invisible Higgs decay with SUSY

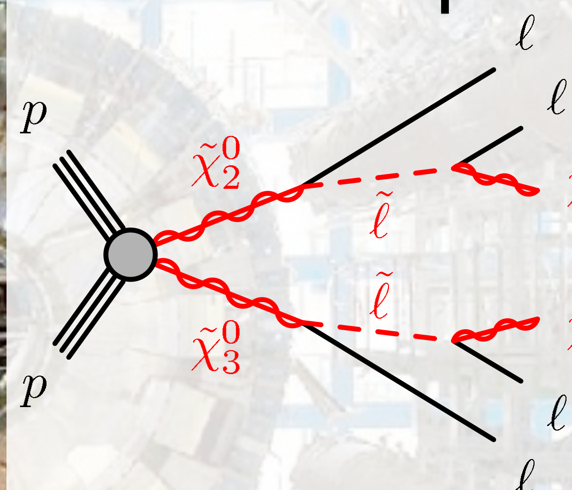


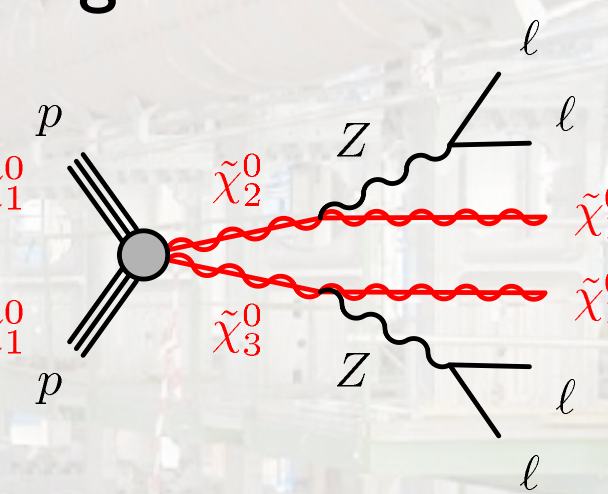
- New physics also offer the intriguing possibility of "invisible" Higgs decays
  - e.g if the SUSY LSP is light enough a Higgs can decay to it
    - LSP has weak cross-section so no detector interaction
- Need a production channel with other observables to see a recoil from the Higgs
  - ZH associated production (shown here)
  - but also VBF and ggH (monojet)
    - Coming soon…

Supersymmetry

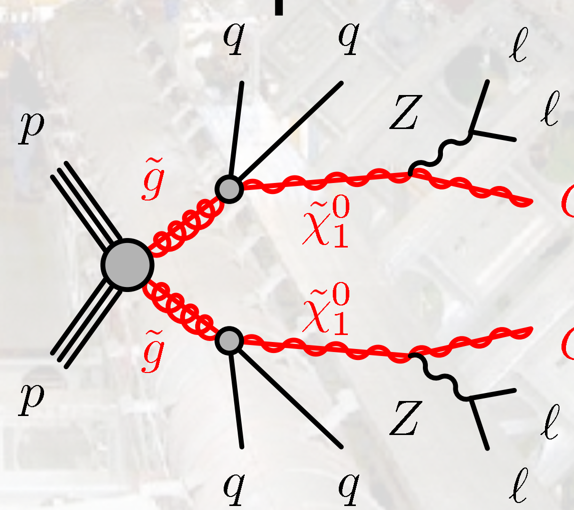
- ATLAS has also searched for production of other SUSY particles
- Two categories:
  - Strongly produced particles: squarks, gluinos
  - Weakly produced: charginos, neutralinos
- Searches complicated by huge size of SUSY parameter space
  - Decay of particles varies depending on the precise choice of parameters
  - Common feature is missing transverse energy in many models
    - R-parity conservation → LSP stable
  - R-parity violating models also considered
  - Also models with long-lived particles
- Recent search considered final states with 4 leptons [arXiv:1405.5086]
- Also a purely general search [ATLAS-CONF-2014-006]

Electroweak Neutralino 4-lepton signature

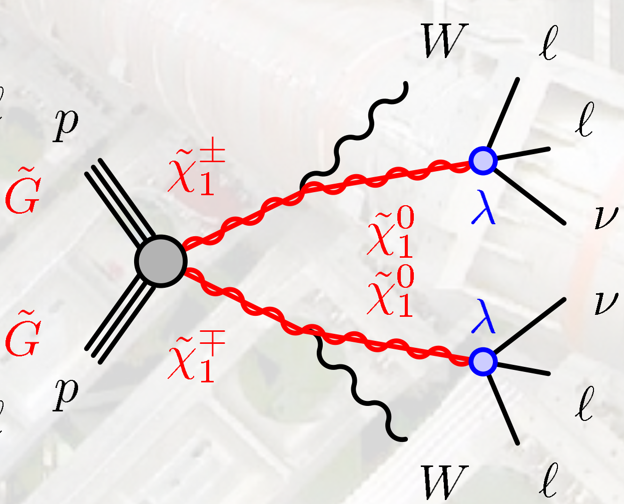




Strong, gluino 4-leptons



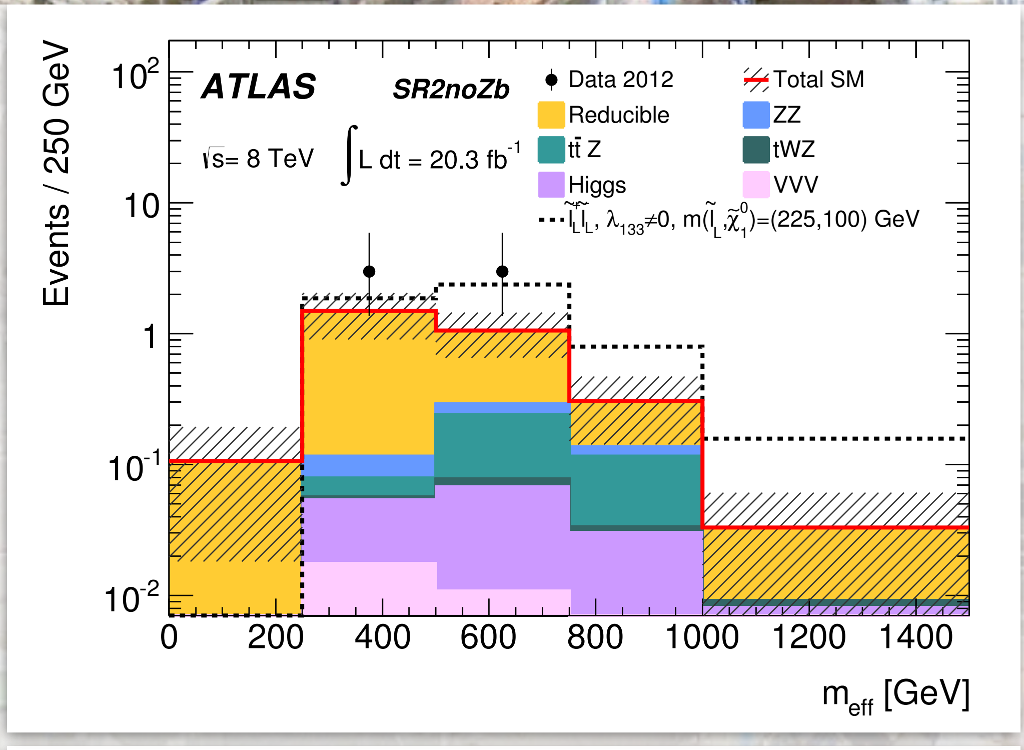
RPV, Lepton no. violation models



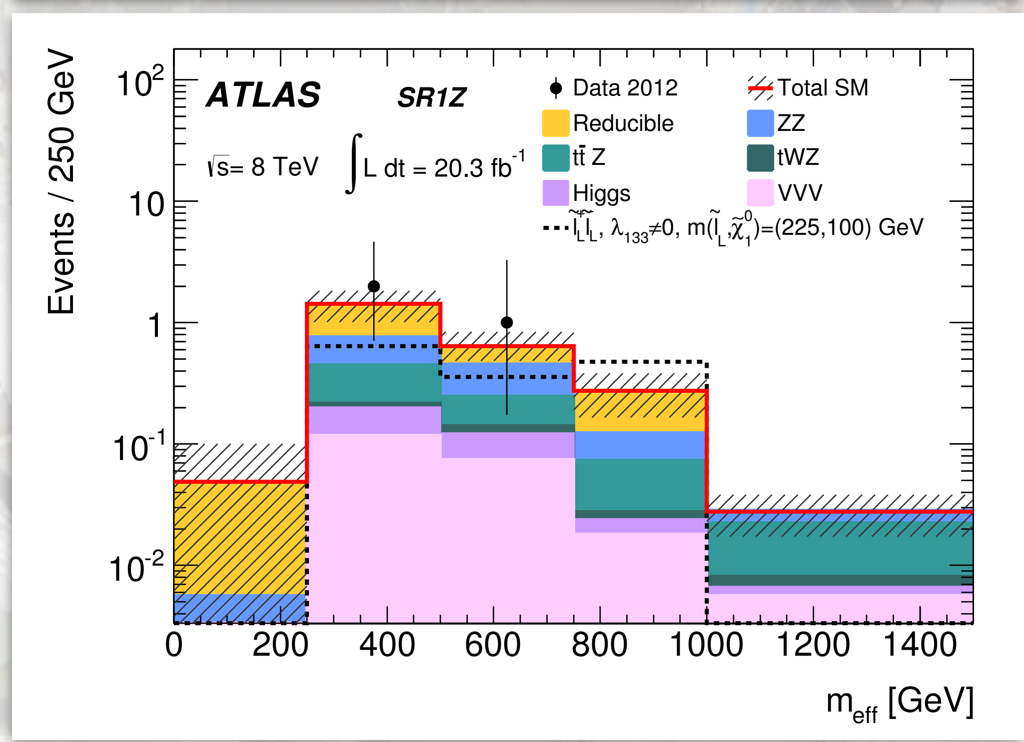
Plus other models…

NEW! 4-Lepton Search

2e/μ, 2+tau, no Z



3 e/μ, 1+ tau, Z

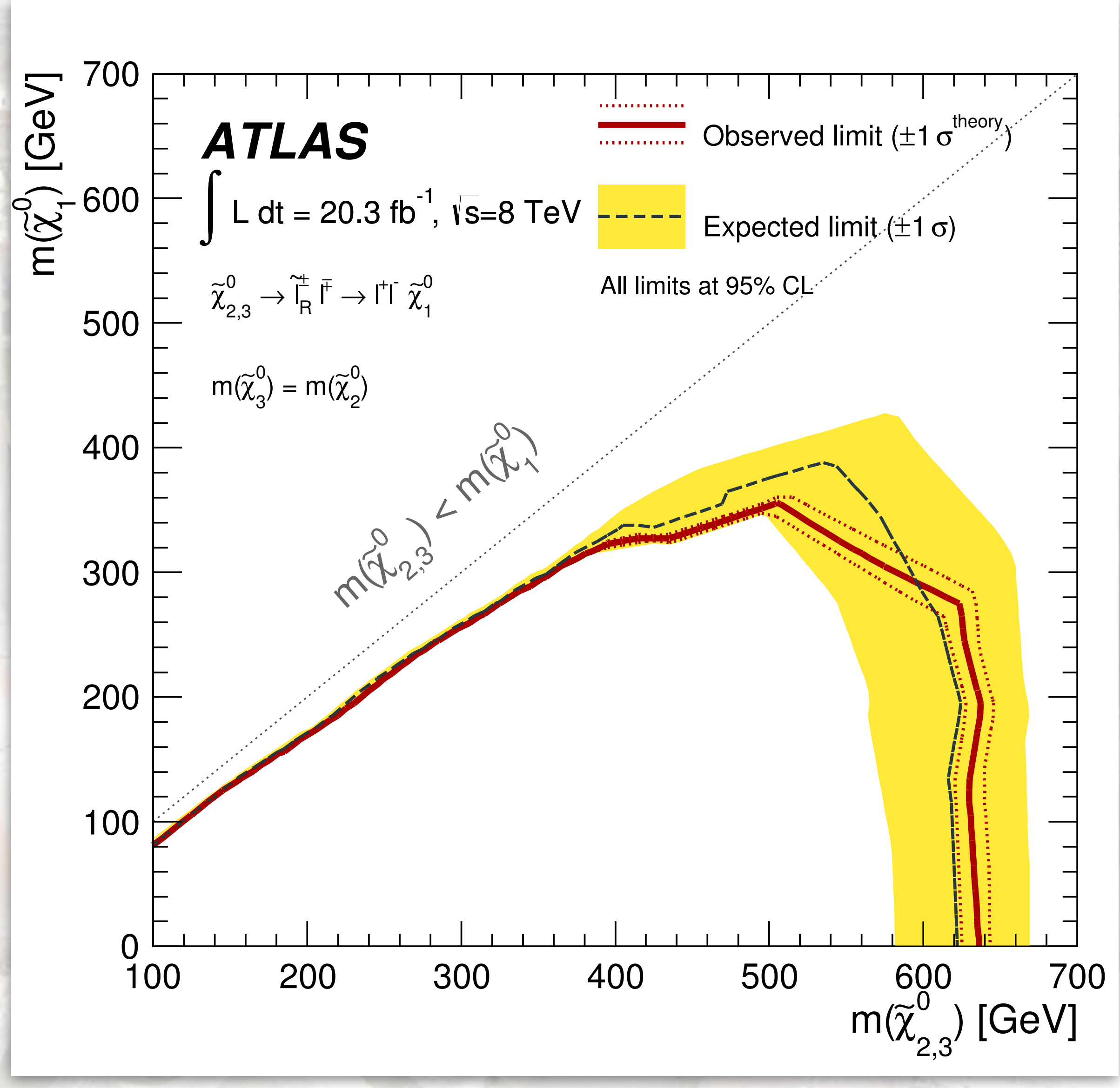


- Many possible SM backgrounds considered
  - diboson, triboson, Higgs, top +boson(s), ttbar, single top, W/Z +jets and multi-jet
  - Jets can fake electrons
- Nine signal regions defined based on:
  - Number of taus vs. e/μ
  - Missing ET
  - How the Z mass veto, or requirement, is applied
- As expected backgrounds are very small and in agreement with data

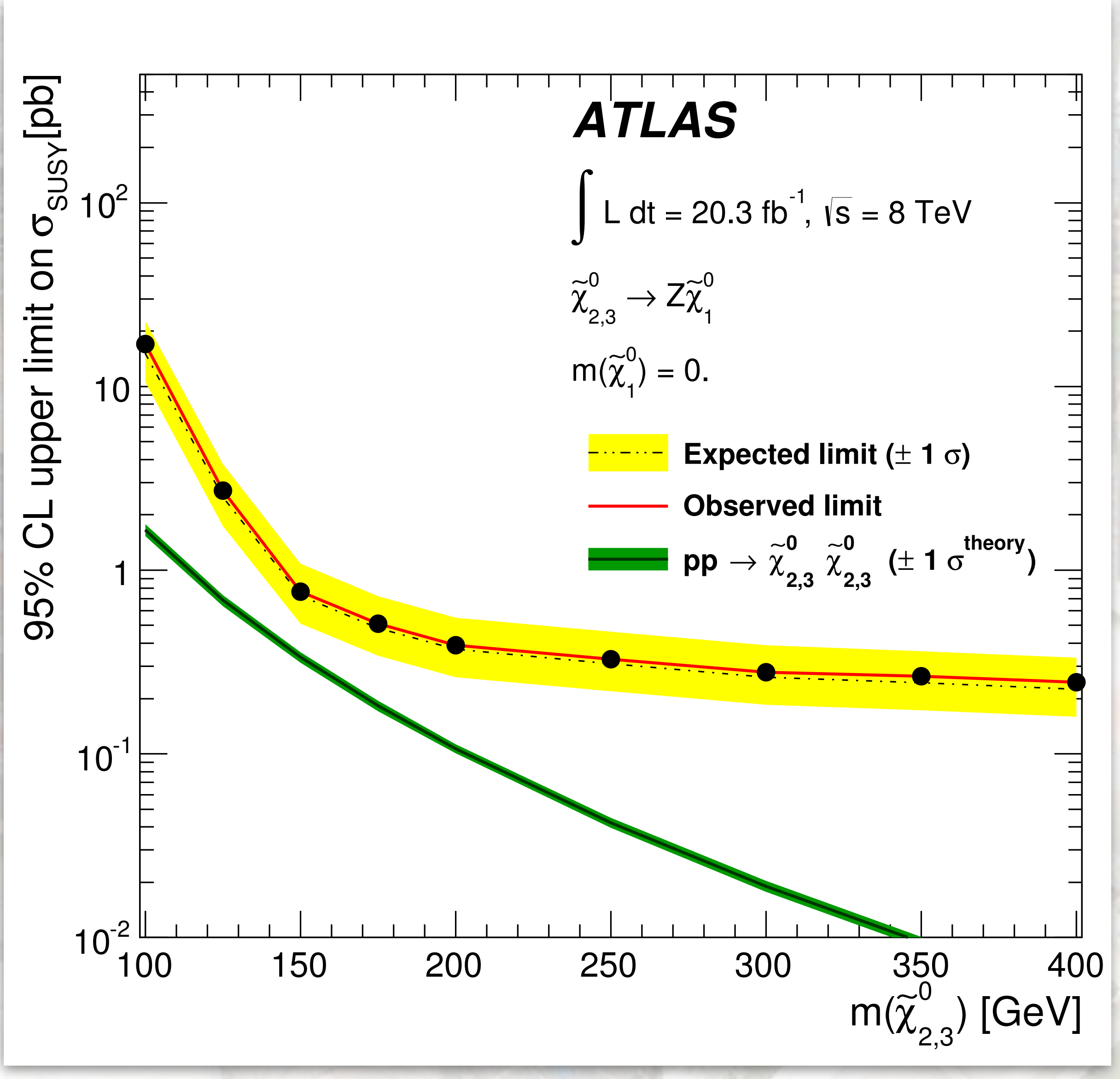
NEW! 4-Lepton Search

- No signal so set limits depending on model considered

RPC, sleptons



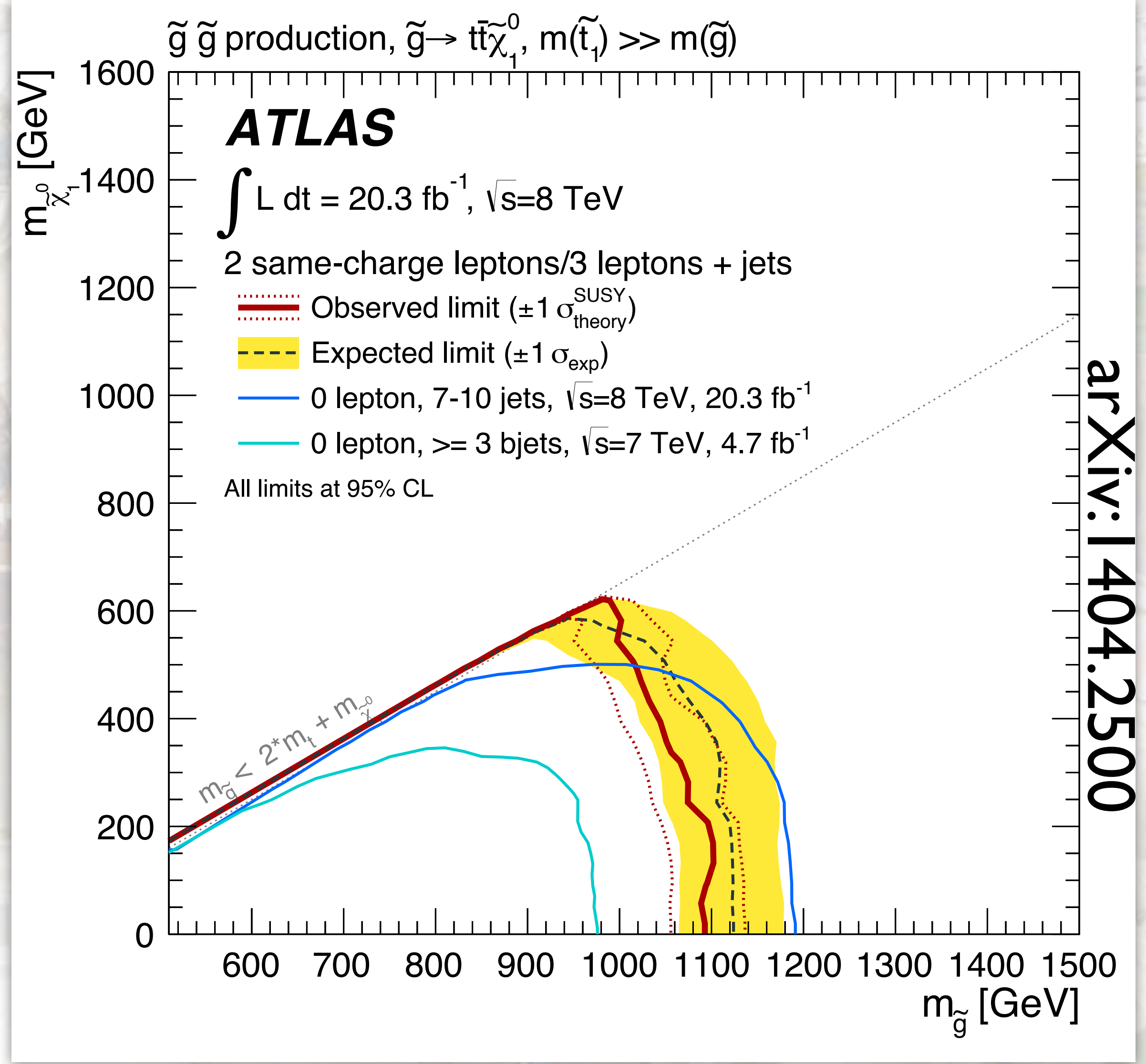
RPC, Z



NEW! Gluinos and Squarks

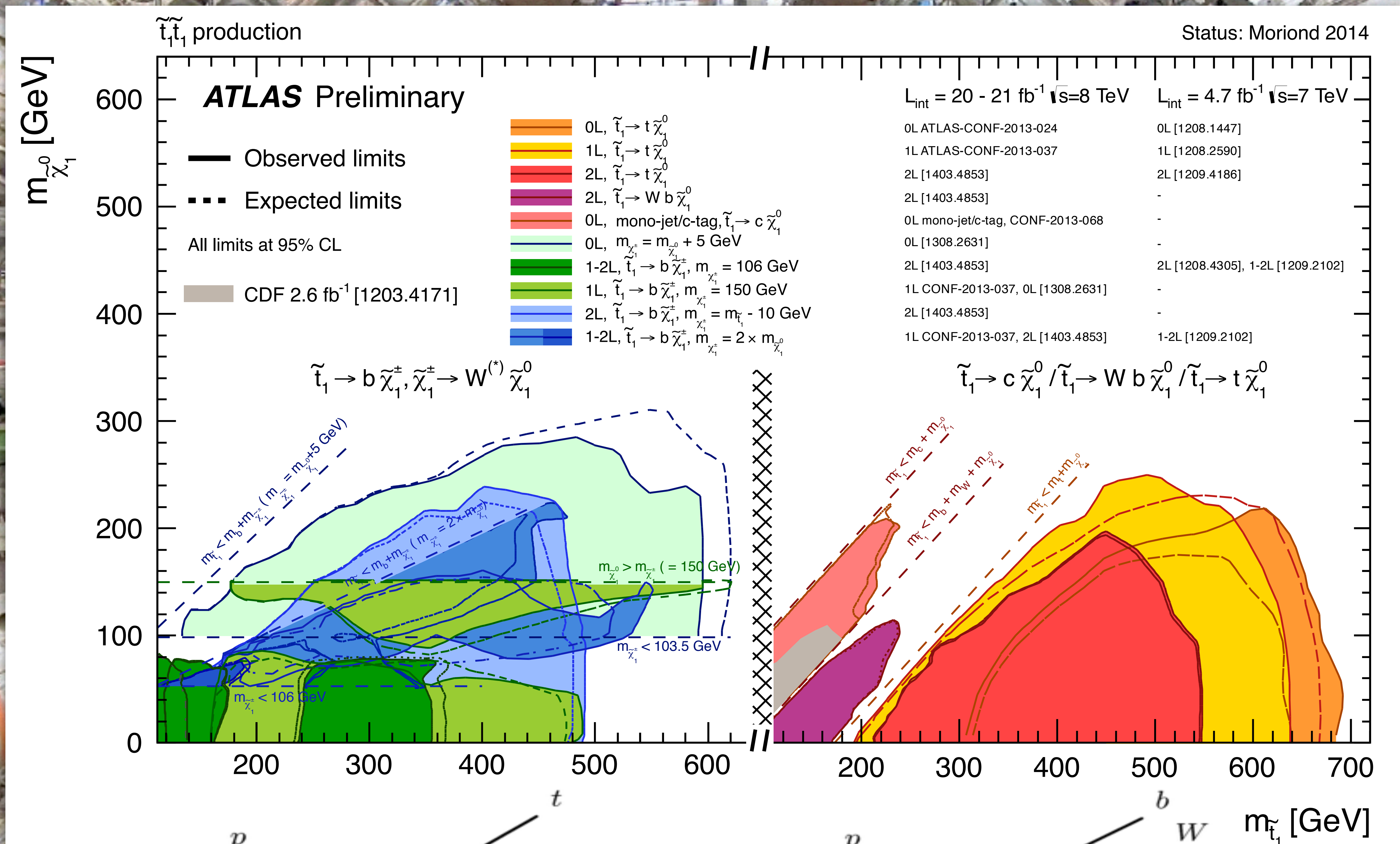
- Gluinos and squarks strongly produced
  - high cross-section if mass in reach
- Stop squark mass is a key ingredient to prevent Higgs mass floating high
  - Key motivation for SUSY
  - Expect stop mass to be close to electroweak breaking scale(≲400GeV/c^2)
- Decay chain depends strongly on model
  - Expect leptons from SUSY partners of W and Z
- Recent search
  - 2 same sign or 3 lepton events
  - No excess observed so set limits
- We can also look for direct stop pair production without gluinos
  - Many channels searched and summarized

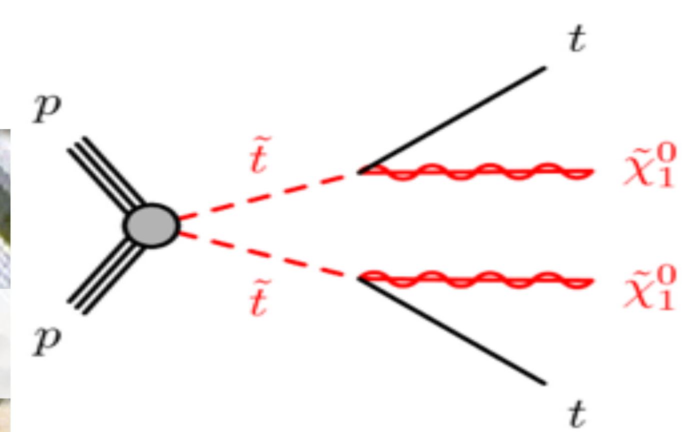
gluino mediated stop production limits

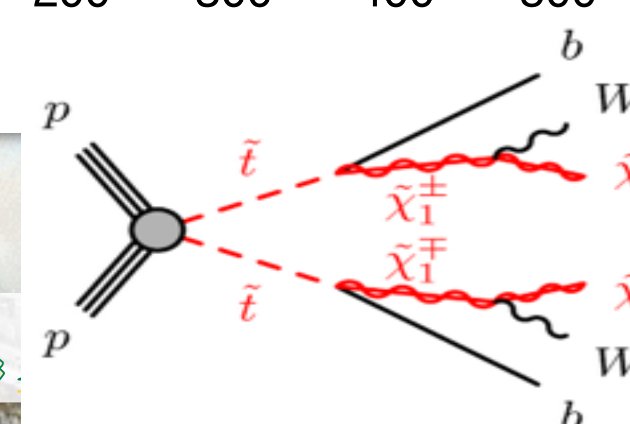


arXiv:1404.2500

Stop Pair Production

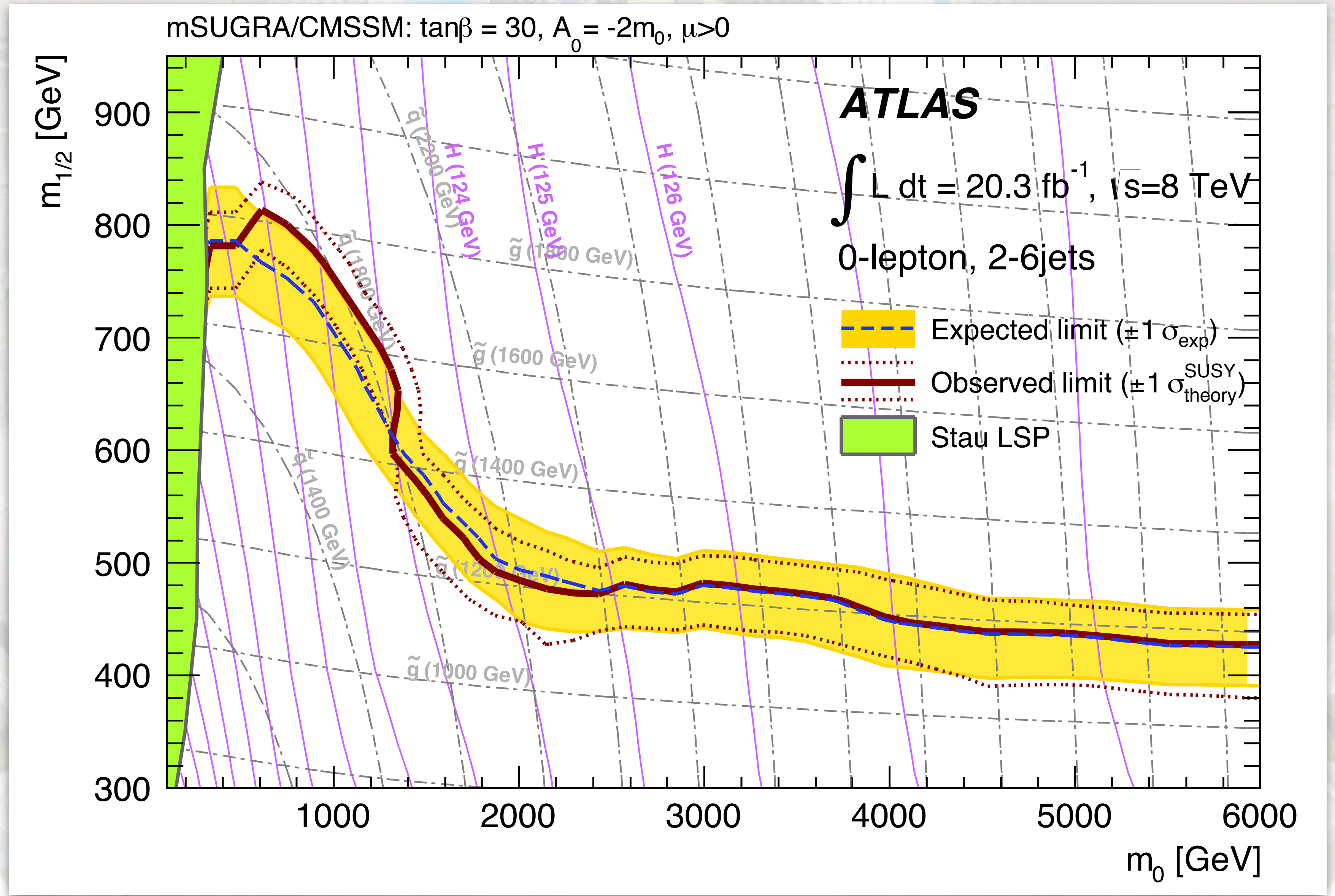






0-lepton Squark/Gluino Search

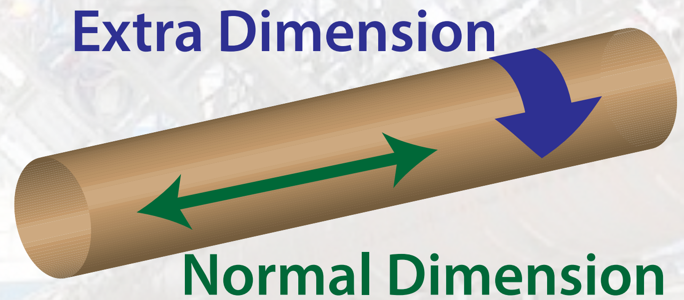
- Very new result for squark/gluino production with zero leptons and 2-6 jets + MET in final state
  - Limits shown for mSUGRA SUSY models

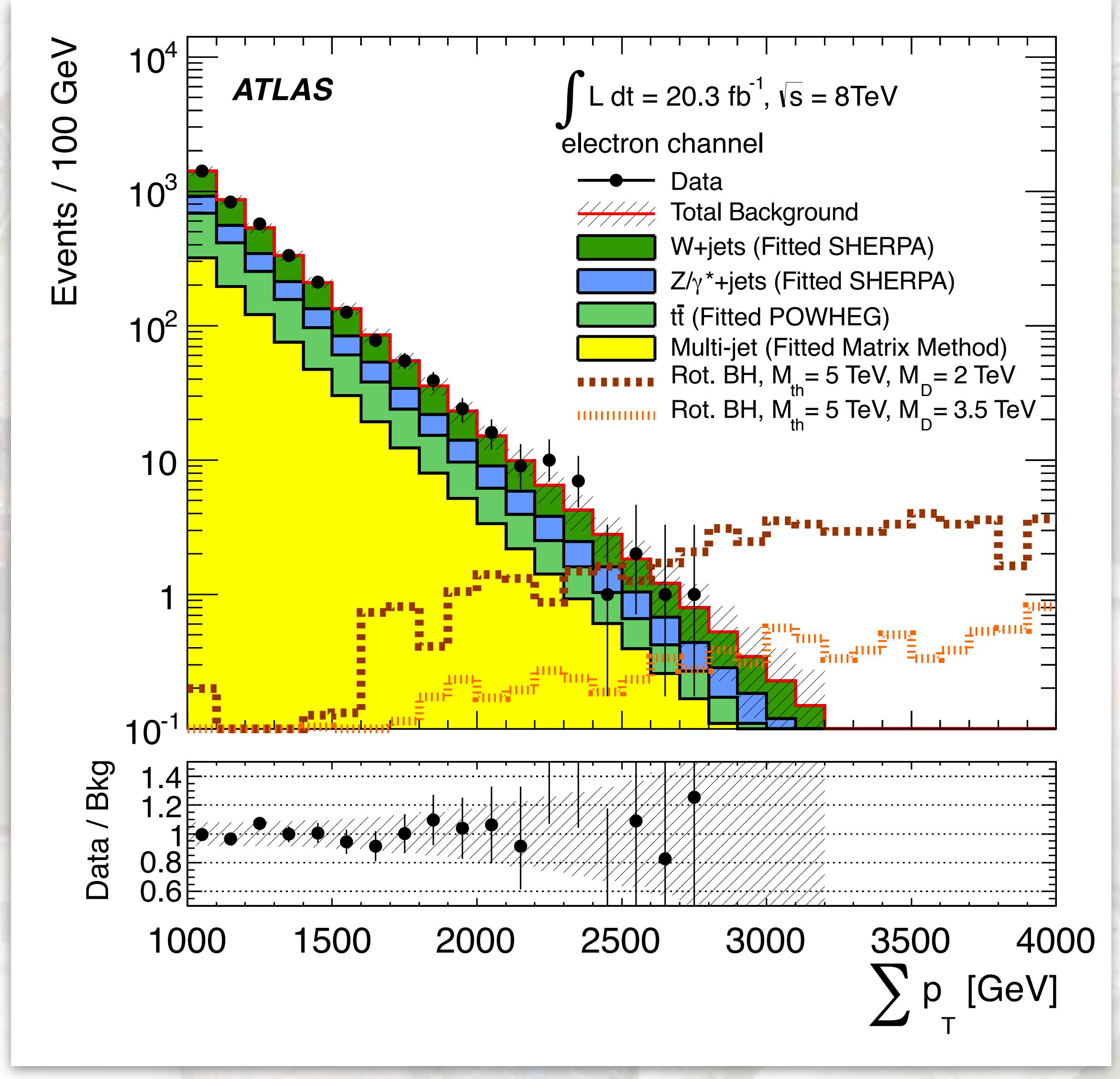


Black Holes

NEW!

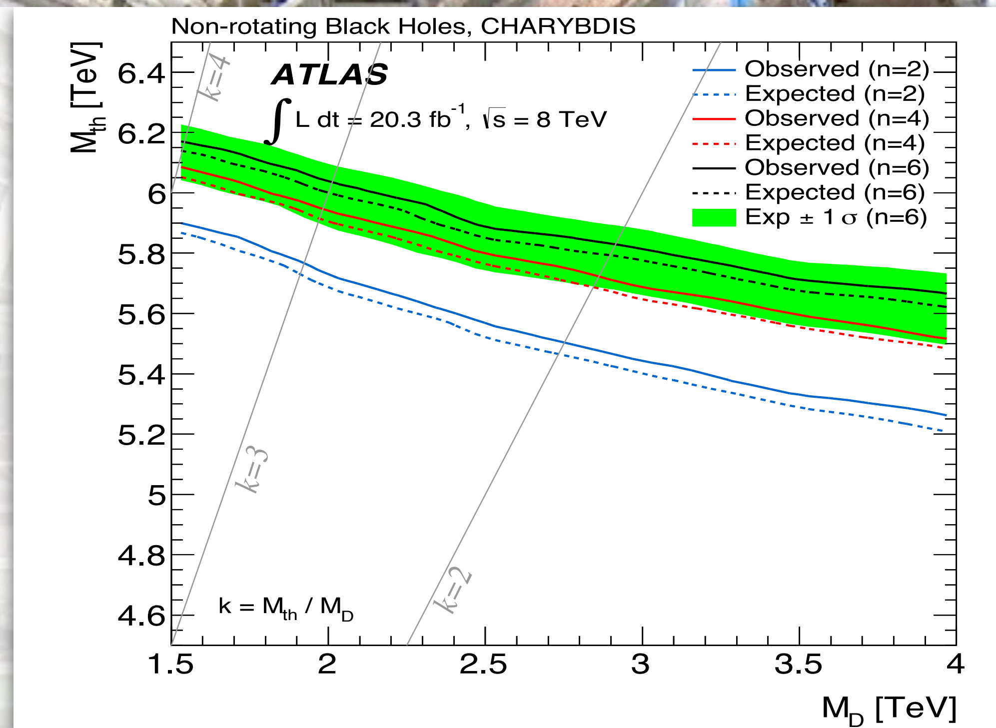
- Large Extra Dimension models predict possibility of Black Hole production at LHC
  - Alternative solution to hierarchy problem
    - Planck scale at ~TeV, gravity diluted by extra spacial dimensions
  - Disfavoured by BICEP2 results
    - gravity coupling at ~2x10^{16} GeV
  - Decay to all SM particles via Hawking radiation
    - Not black body: disfavour low energy emissions
- Trigger on one high pT e or μ
  - Look at scalar pT sum of all particles with pT>60GeV/c

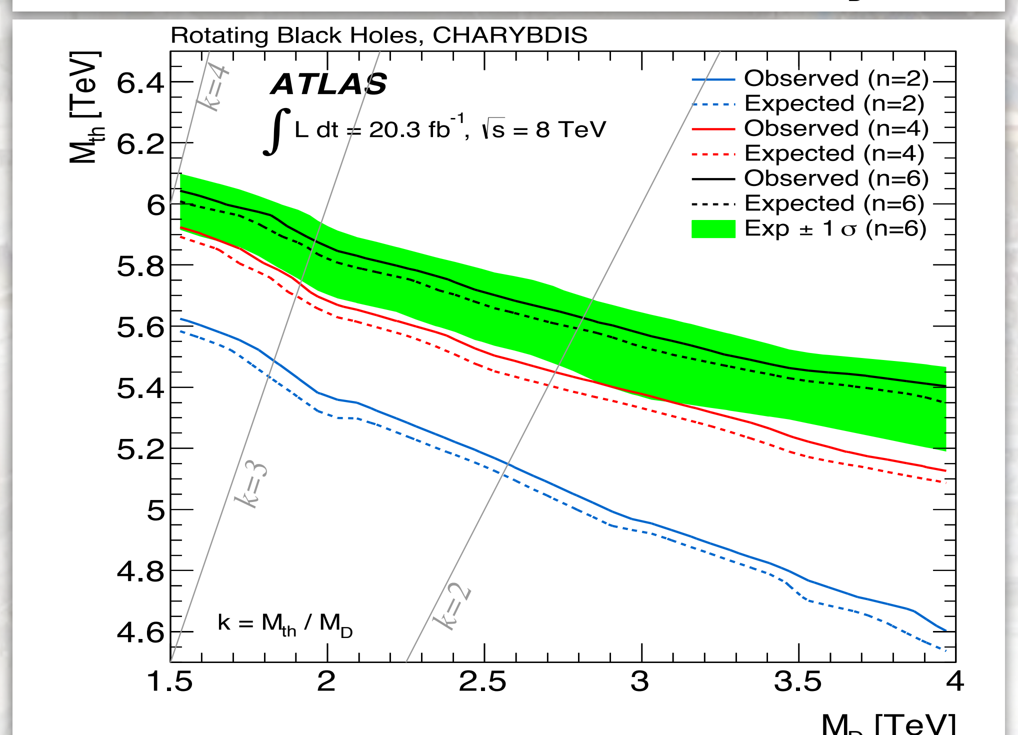




Black Holes

NEW!

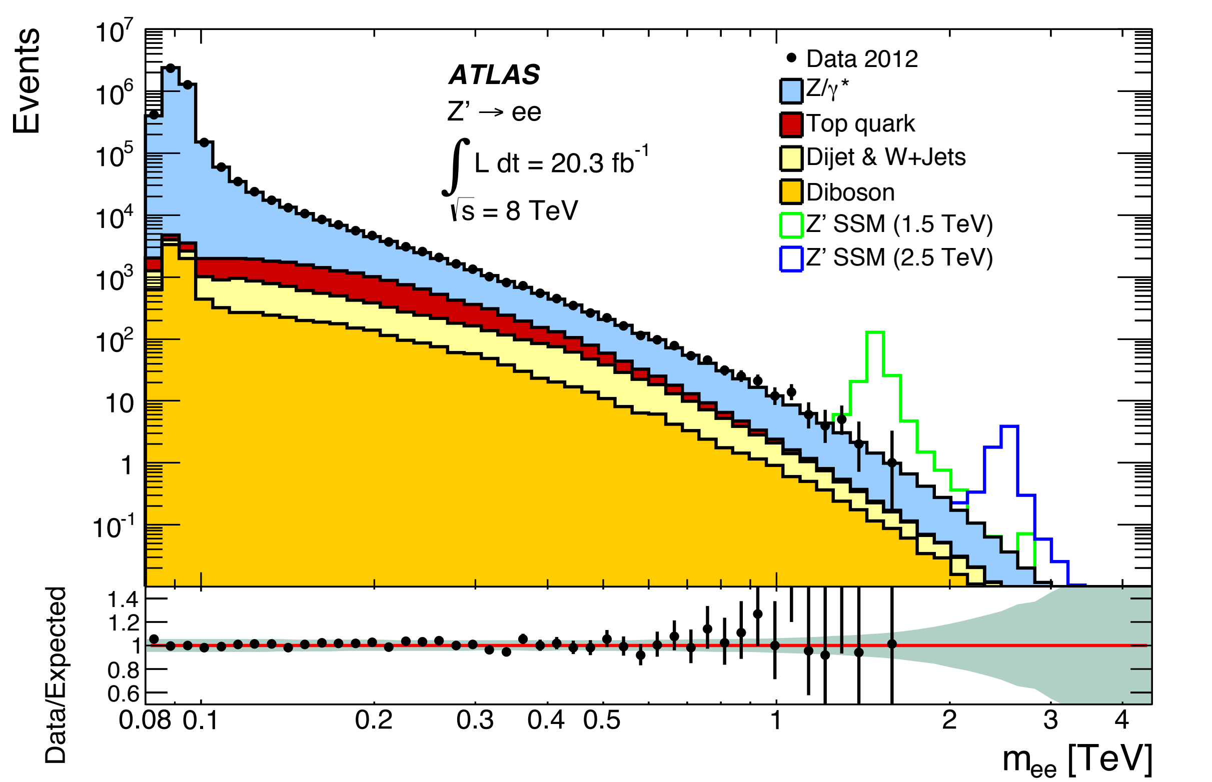


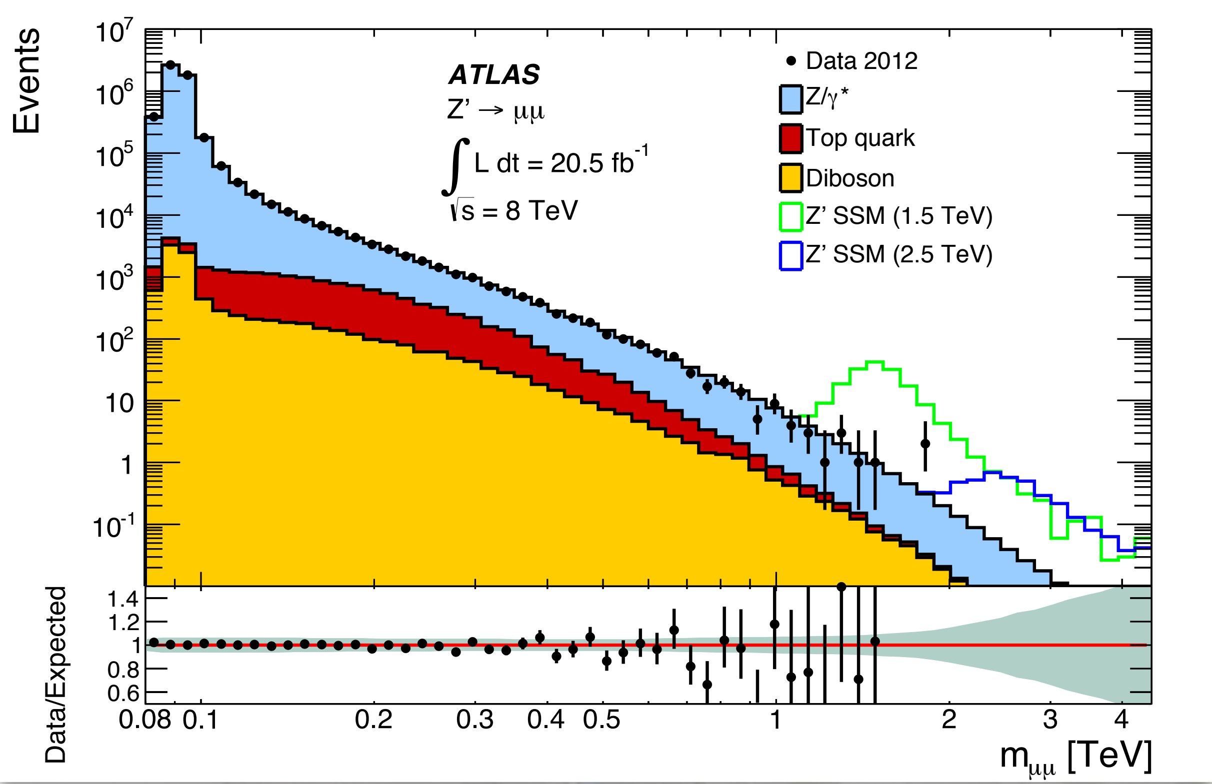


- No excess over SM backgrounds observed
  - Set limits using ADD models
- Three parameters
  - M_D: scale at which extra dimensions 'turn on'
  - M_{th}: threshold mass for 'classical' BH production
  - n: number of extra dimensions
- Set limits in M_D vs M_{th} plane
  - Different limits depending on whether BH is rotating
  - Comparable limits if invisible graviton emission is allowed
    - Gravitons propagate in ED and so are not seen in detector

NEW! High Mass Di-leptons

- Another recent exotics search is for high mass, di-lepton resonances [arXiv:1405.4123]
  - e.g. Z′ bosons, RS graviton excitations etc.
- Only consider electron and muons
  - Easy identification, low backgrounds
- Data consistent with SM backgrounds: Drell-Yan, top, diboson
  - Detector fake rates, e.g. jet→electron, measured from data

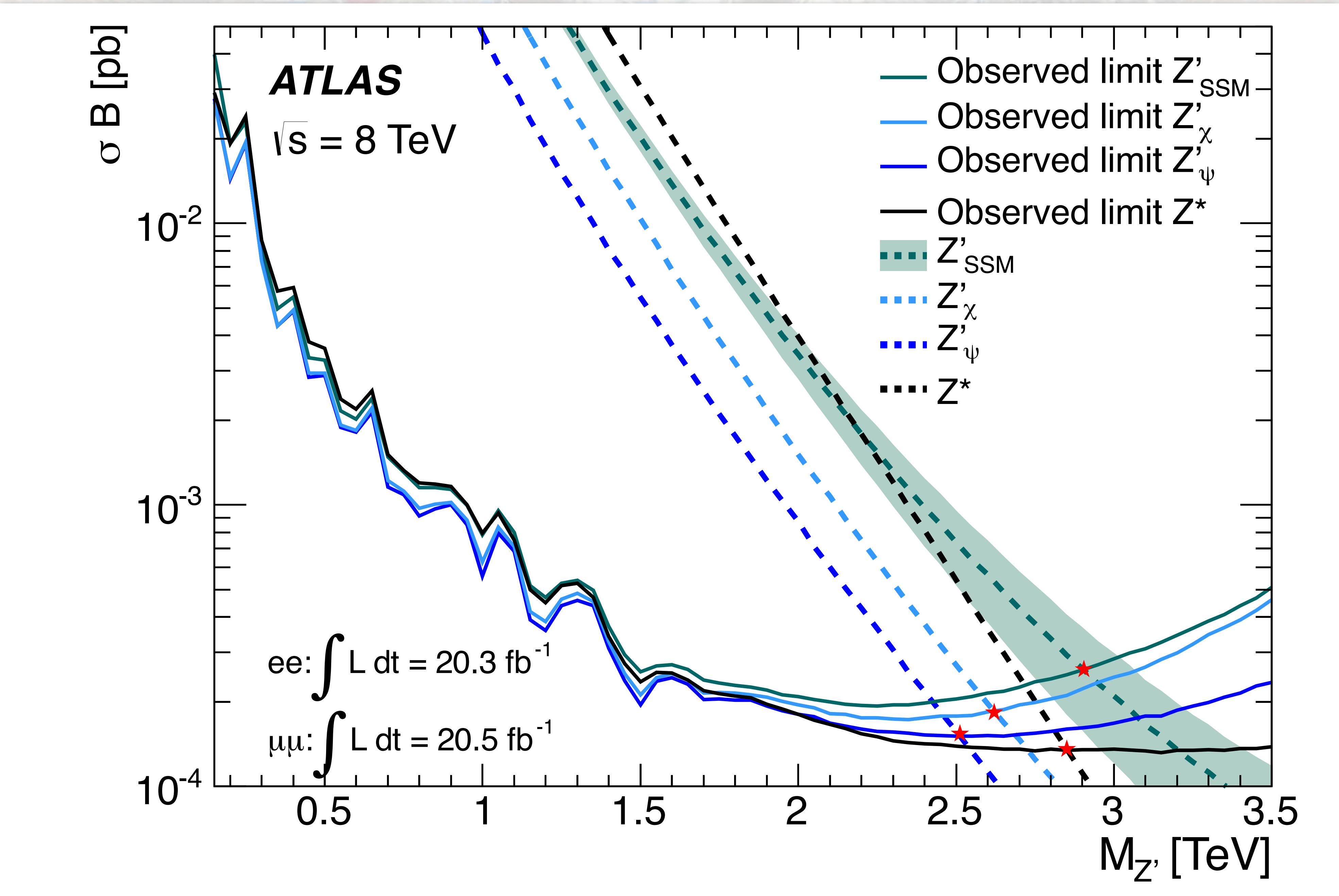




High Mass Di-leptons

NEW!

- Limits set depend on model

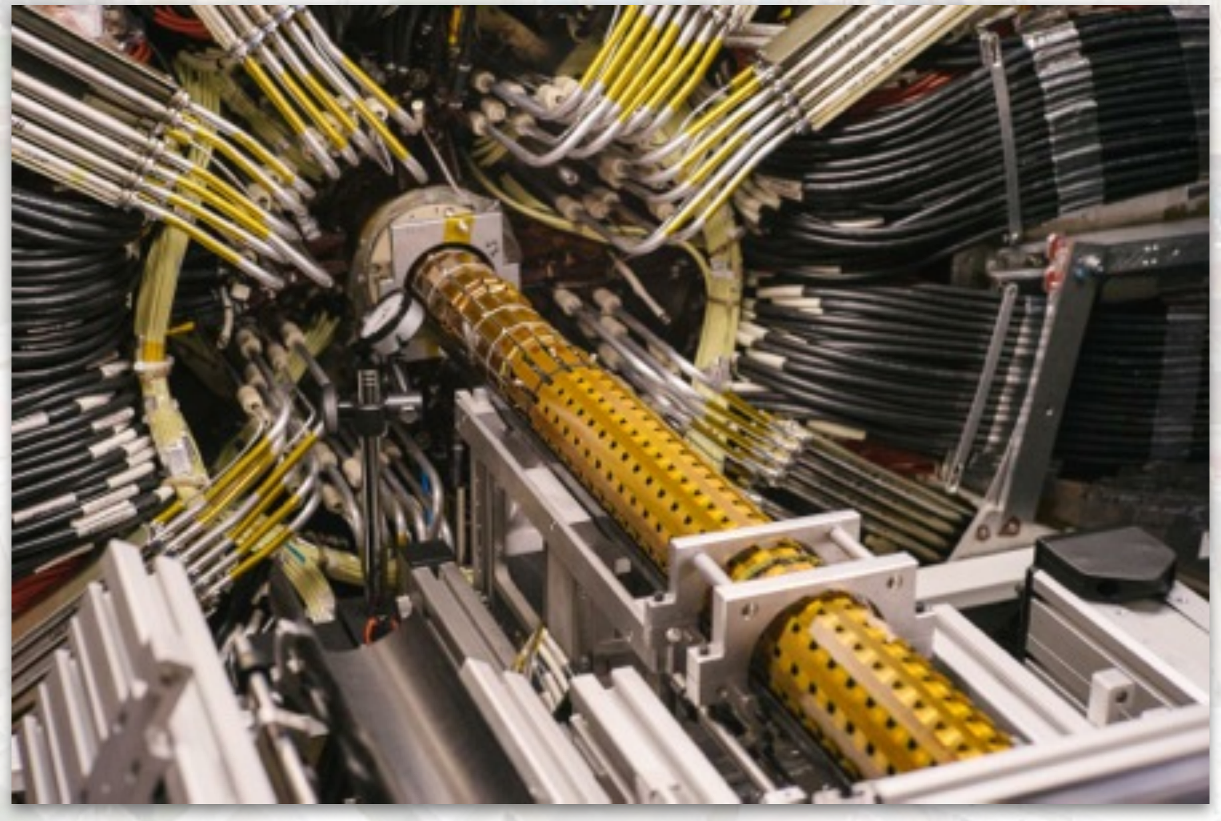


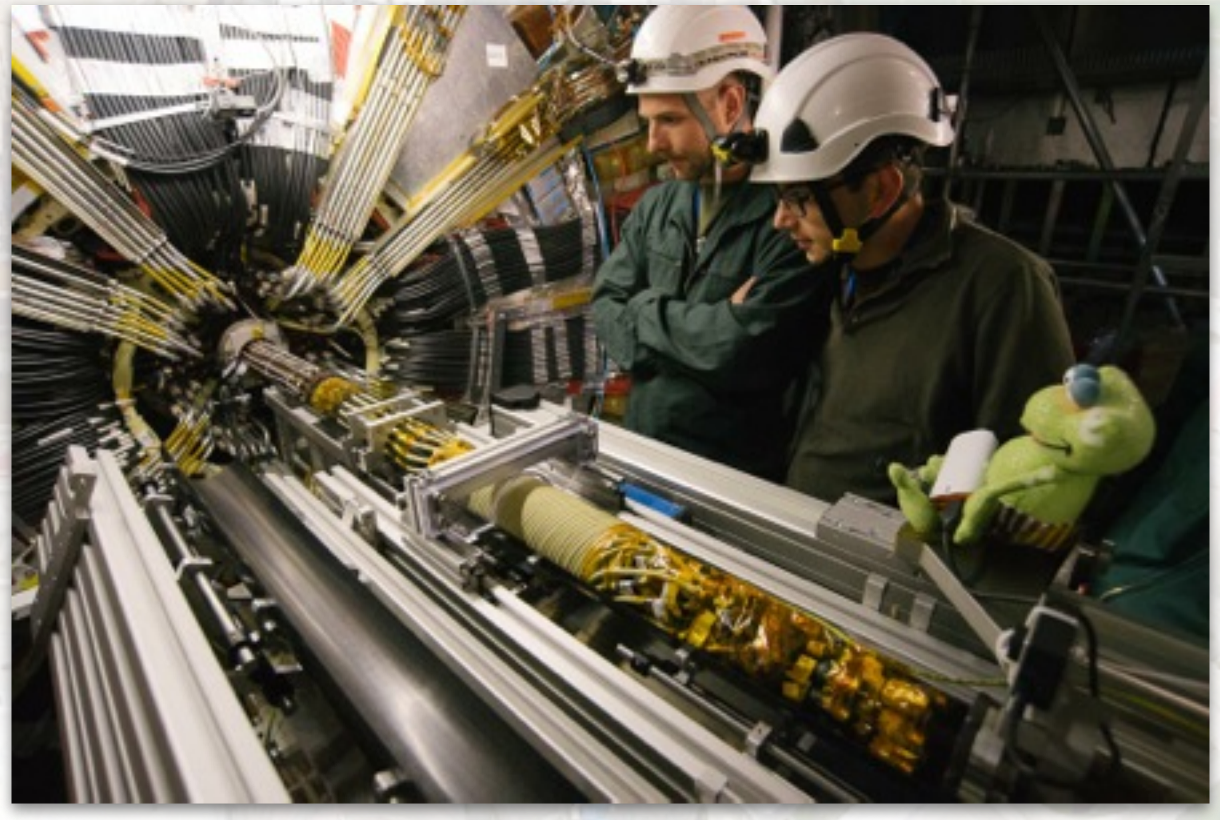
LHC Run 2

- Major work to upgrade machine in light of 2008 disaster
  - 3,000 splices reconstructed
  - 27,000 shunts installed
- Result will be that the machine will operate close to design specifications
  - 13-14 TeV centre of mass energy
  - 25 ns bunch spacing
- Run 2 will start in March 2015
  - Initially with 50 ns bunch spacing and high luminosity
    - Expect as many as ~80+ interactions/crossing
    - Move quickly to 25 ns spacing: fewer interactions/crossing but up to 3 crossings inside detector at the same time!

ATLAS Upgrades

- ATLAS upgrading to cope with new conditions!
- Pixel detector extracted, repaired and re-inserted
  - Readout fraction up to 98.8% from 95%
  - Insertable B Layer (IBL) inserted (8th May 2014)
    - Improves b-tagging and pileup performance





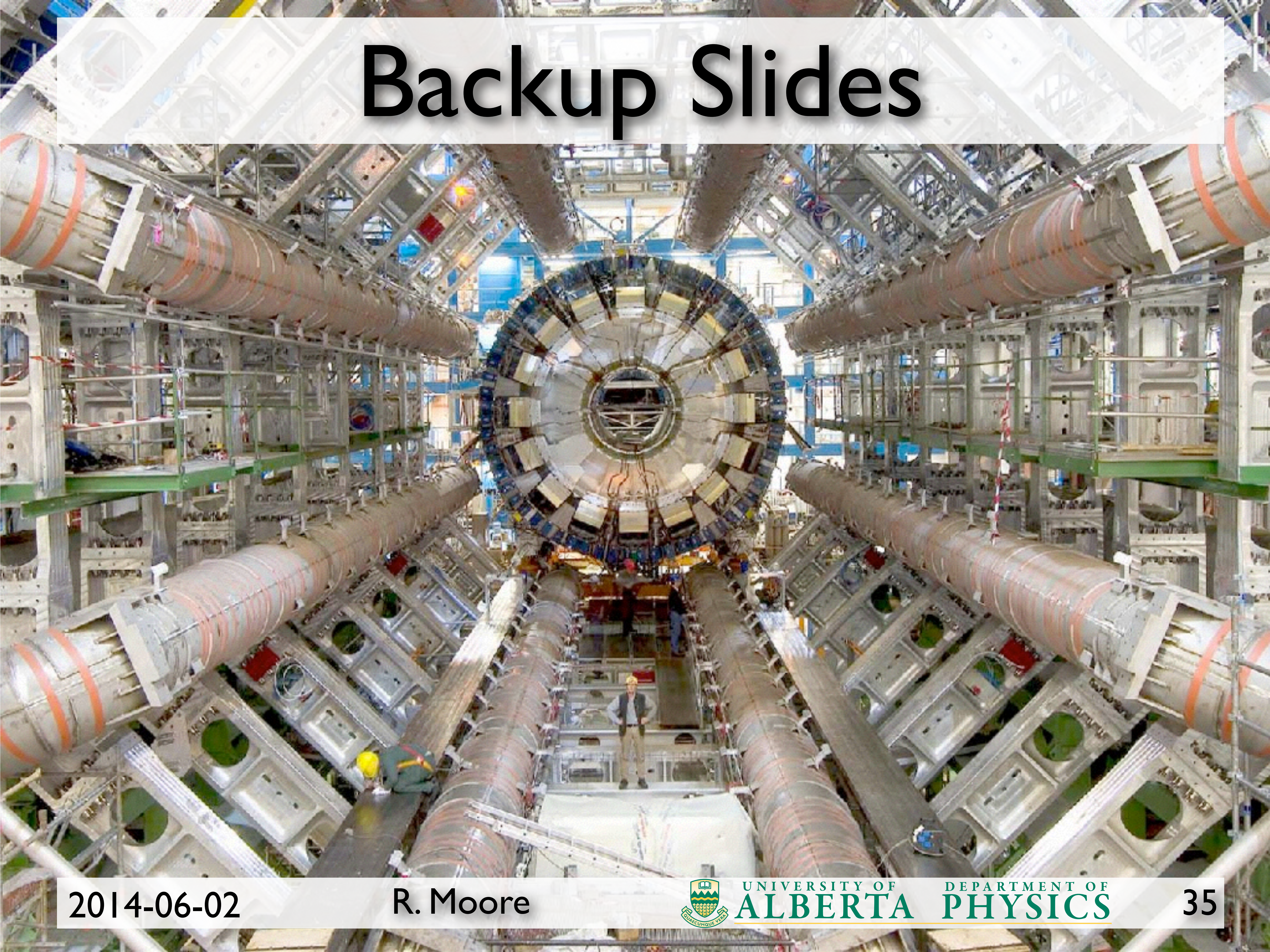
ATLAS Upgrades

- Significant trigger and DAQ upgrades
  - Expect factor 5 increase in rates from luminosity and energy!
- Upgrade trigger rates
  - L1 from 75 kHz to 100 kHz, essential for $2\times10^{34}cm^{-2}s^{-1}$
  - Total readout rate from 400 Hz to 500/1000 Hz
    - Puts a lot of pressure on offline computing to store and process a far larger data volume
  - Developing parallel algorithms to better utilize modern computing hardware: GPUs and hyperthreading
- New hardware based tracking trigger: FTK
  - Provide reconstructed tracks without large CPU overhead
  - Barrel initially, complete by ~2016

Conclusions

- Run 1 provided some amazing new physics
  - Discovery of the first fundamental scalar particle
  - …but no explanation as to why it is so light vs. M_{planck}
- Run 2 will effectively double our reach for new, high energy physics
  - Provides what will likely be the best chance for a major new discovery at the LHC
    - Future luminosity increases (HL-LHC) will only slowly improve our energy reach
- Tantalizing hints from BICEP2 (if confirmed!)
  - Gravity coupling scale roughly equal to SUSY GUT scale
- So watch this space…the Quarks-2016 ATLAS talk will hopefully contain some exciting discoveries!

Backup Slides

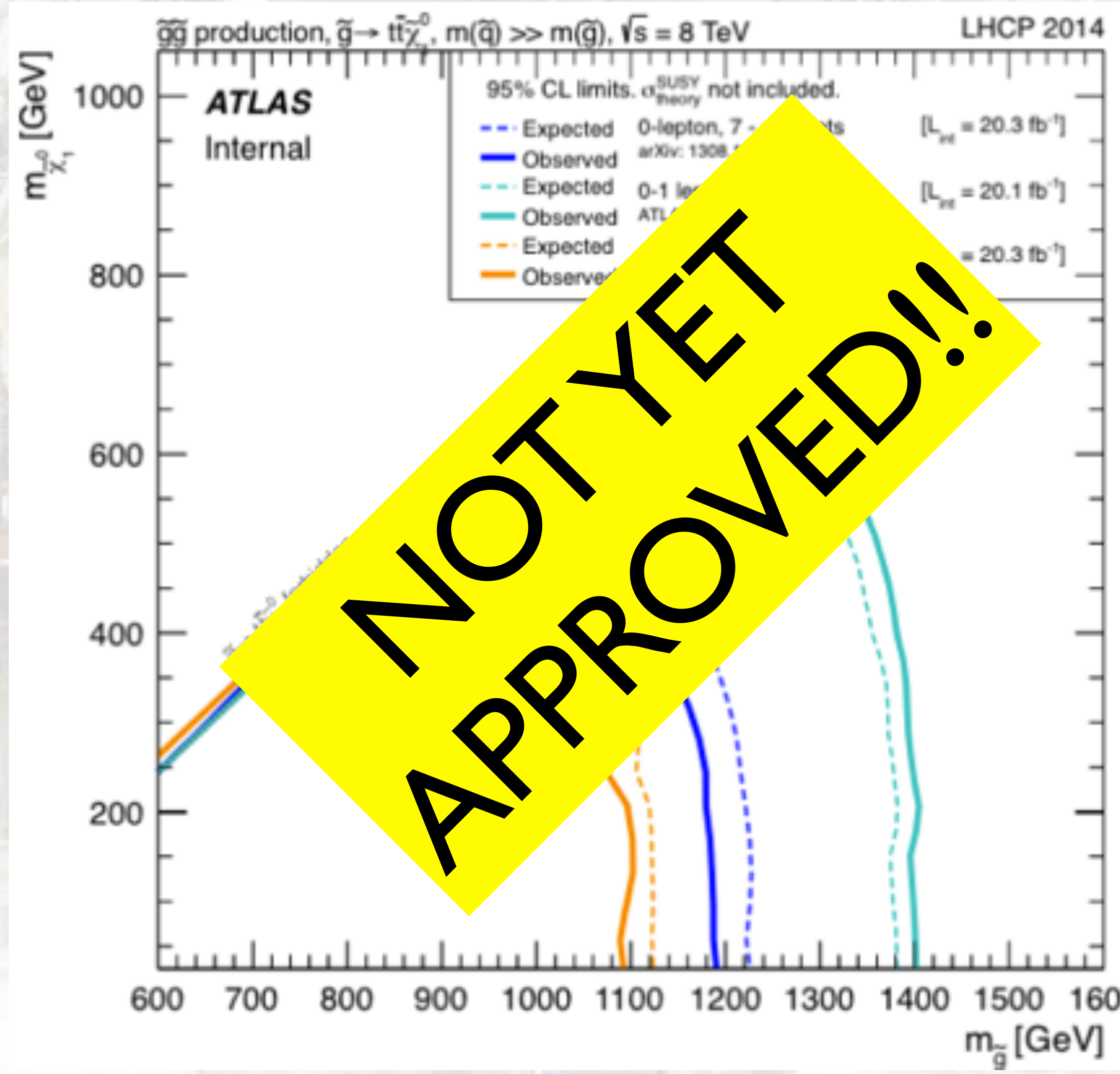


NEW!

Gluinos and Squarks

- Gluinos and squarks strongly produced
  - high cross-section if mass in reach
- Stop squark mass is a key ingredient to prevent Higgs mass floating high
  - Key motivation for SUSY
  - Expect stop mass to be close to electroweak breaking scale(≲400GeV/c^2)
- Decay chain depends strongly on model
  - Expect leptons from SUSY partners of W and Z
- Recent searches
  - 2 same sign or 3 lepton events
  - No excess observed so set limits
- We can also look for direct stop pair production without gluinos
  - Many channels searched and summarized

gluino mediated stop production limits



arXiv:???

SUSY Summary

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: Moriond 2014

ATLAS Preliminary

$\int \mathcal{L}\, dt = (4.6 - 22.9)$ fb^{-1} $\sqrt{s}$ = 7, 8 TeV

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt$[fb^{-1}]		Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$	1.7 TeV	m($\tilde{q}$)=m($\tilde{g}$)	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.2 TeV	any m($\tilde{q}$)	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	any m($\tilde{q}$)	1308.1841
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$	740 GeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$	1.3 TeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.18 TeV	m($\tilde{\chi}_1^0$)<200 GeV, m($\tilde{\chi}^\pm$)=0.5(m($\tilde{\chi}_1^0$)+m($\tilde{g}$))	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e, μ	0-3 jets	-	20.3	$\tilde{g}$	1.12 TeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e, μ	2-4 jets	Yes	4.7	$\tilde{g}$	1.24 TeV	tanβ<15	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$	1.4 TeV	tanβ >18	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	-	Yes	20.3	$\tilde{g}$	1.28 TeV	m($\tilde{\chi}_1^0$)>50 GeV	ATLAS-CONF-2014-001
	GGM (wino NLSP)	1 $e, \mu + \gamma$	-	Yes	4.8	$\tilde{g}$	619 GeV	m($\tilde{\chi}_1^0$)>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$	900 GeV	m($\tilde{\chi}_1^0$)>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e, μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$	690 GeV	m($\tilde{H}$)>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale	645 GeV	m($\tilde{g}$)>10^{-4} eV	ATLAS-CONF-2012-147
3rd gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$	1.2 TeV	m($\tilde{\chi}_1^0$)<600 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	m($\tilde{\chi}_1^0$) <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$	1.34 TeV	m($\tilde{\chi}_1^0$)<400 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$	1.3 TeV	m($\tilde{\chi}_1^0$)<300 GeV	ATLAS-CONF-2013-061
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$	100-620 GeV	m($\tilde{\chi}_1^0$)<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$	275-430 GeV	m($\tilde{\chi}_1^\pm$)=2 m($\tilde{\chi}_1^0$)	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	1-2 e, μ	1-2 b	Yes	4.7	$\tilde{t}_1$	110-167 GeV	m($\tilde{\chi}_1^0$)=55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e, μ	0-2 jets	Yes	20.3	$\tilde{t}_1$	130-210 GeV	m($\tilde{\chi}_1^0$) =m($\tilde{t}_1$)-m(W)-50 GeV, m($\tilde{t}_1$)<<m($\tilde{\chi}_1^\pm$)	1403.4853
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}_1^0$	2 e, μ	2 jets	Yes	20.3	$\tilde{t}_1$	215-530 GeV	m($\tilde{\chi}_1^0$)=1 GeV	1403.4853
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	0	2 b	Yes	20.1	$\tilde{t}_1$	150-580 GeV	m($\tilde{\chi}_1^0$)<200 GeV, m($\tilde{\chi}_1^\pm$)-m($\tilde{\chi}_1^0$)=5 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e, μ	1 b	Yes	20.7	$\tilde{t}_1$	200-610 GeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.5	$\tilde{t}_1$	320-660 GeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$	90-200 GeV	m($\tilde{t}_1$)-m($\tilde{\chi}_1^0$)<85 GeV	ATLAS-CONF-2013-068
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e, μ (Z)	1 b	Yes	20.3	$\tilde{t}_1$	150-580 GeV	m($\tilde{\chi}_1^0$)>150 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1 + Z$	3 e, μ (Z)	1 b	Yes	20.3	$\tilde{t}_2$	290-600 GeV	m($\tilde{\chi}_1^0$)<200 GeV	1403.5222
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e, μ	0	Yes	20.3	$\tilde{\ell}$	90-325 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm$	140-465 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{\ell}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$))	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.7	$\tilde{\chi}_1^\pm$	180-330 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{\tau}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$))	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	700 GeV	m($\tilde{\chi}_1^\pm$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, m($\tilde{\ell}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$))	1402.7029
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	2-3 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	420 GeV	m($\tilde{\chi}_1^\pm$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	1403.5294, 1402.7029
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 h\tilde{\chi}_1^0$	1 e, μ	2 b	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	285 GeV	m($\tilde{\chi}_1^\pm$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	ATLAS-CONF-2013-093
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^\pm$	270 GeV	m($\tilde{\chi}_1^\pm$)-m($\tilde{\chi}_1^0$)=160 MeV, τ($\tilde{\chi}_1^\pm$)=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$	832 GeV	m($\tilde{\chi}_1^0$)=100 GeV, 10 μs<τ($\tilde{g}$)<1000 s	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e}, \tilde{\mu})+\tau(e, \mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$	475 GeV	10<tanβ<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$	230 GeV	0.4<τ($\tilde{\chi}_1^0$)<2 ns	1304.6310
	$\tilde{q}\tilde{q}, \tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$	1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, m($\tilde{\chi}_1^0$)=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e + \mu$	2 e, μ	-	-	4.6	$\tilde{\nu}_\tau$	1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\to\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e(\mu) + \tau$	1 $e, \mu + \tau$	-	-	4.6	$\tilde{\nu}_\tau$	1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	1 e, μ	7 jets	Yes	4.7	$\tilde{q}, \tilde{g}$	1.2 TeV	m($\tilde{q}$)=m($\tilde{g}$), $c\tau_{LSP}$<1 mm	ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e, μ	-	Yes	20.7	$\tilde{\chi}_1^\pm$	760 GeV	m($\tilde{\chi}_1^0$)>300 GeV, λ_{121}>0	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e, \mu + \tau$	-	Yes	20.7	$\tilde{\chi}_1^\pm$	350 GeV	m($\tilde{\chi}_1^0$)>80 GeV, λ_{133}>0	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$	916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$	880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon pair, sgluon$\to q\bar{q}$	0	4 jets	-	4.6	sgluon	100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon$\to t\bar{t}$	2 e, μ (SS)	2 b	Yes	14.3	sgluon	350-800 GeV		ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale	704 GeV	m(χ)<80 GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

$\sqrt{s}$ = 7 TeV full data | $\sqrt{s}$ = 8 TeV partial data | $\sqrt{s}$ = 8 TeV full data

10^{-1} 1 **Mass scale [TeV]**

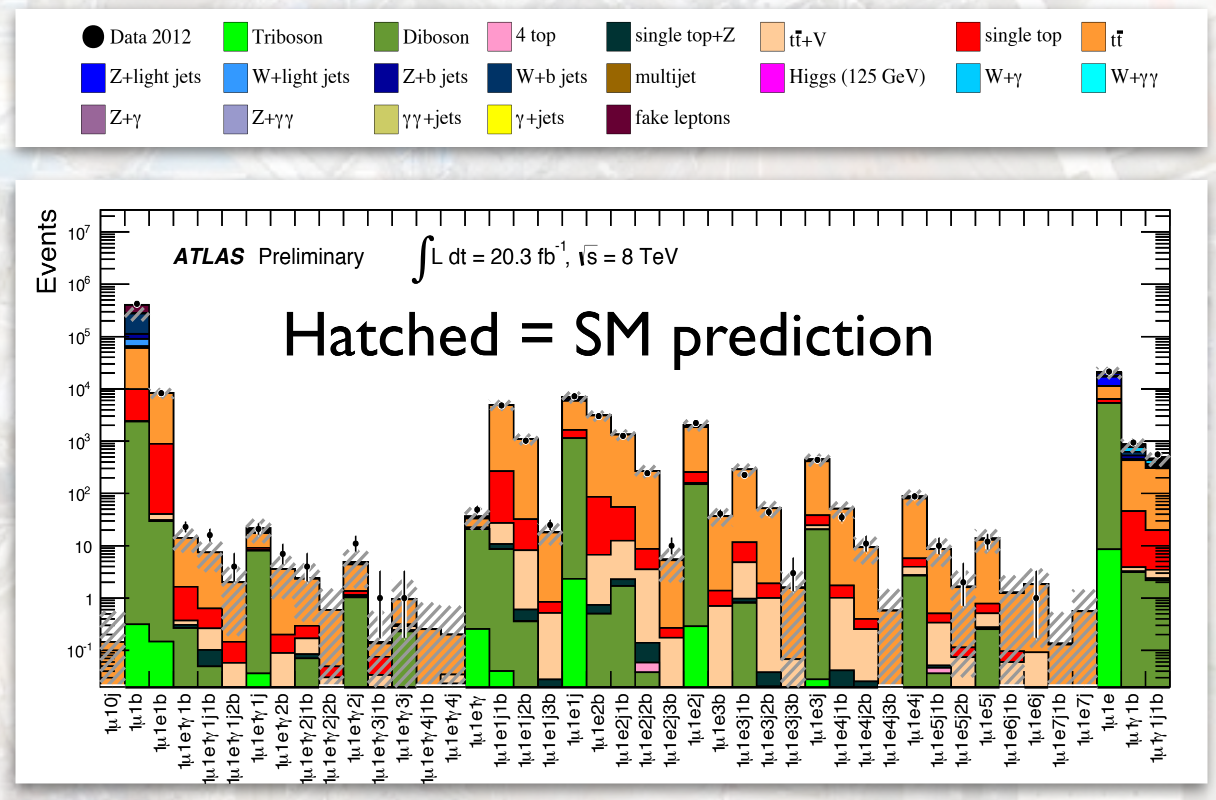
*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

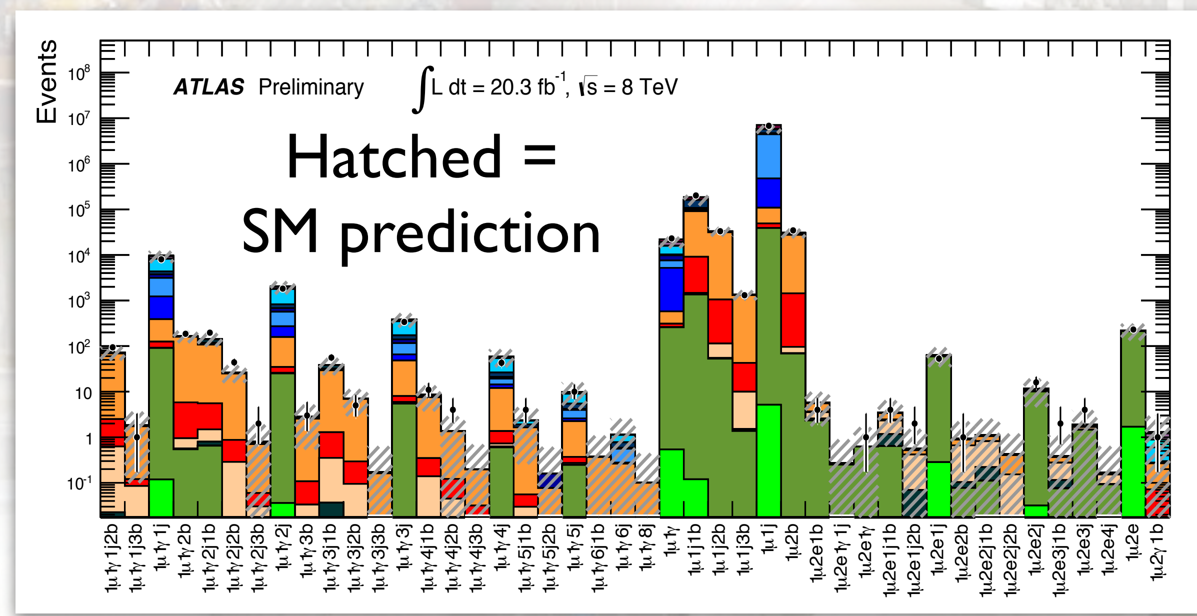
General SUSY Searches

- As well as specific SUSY searches ATLAS can perform more generic searches [ATLAS-CONF-2014-006]
  - Fewer assumptions possible about the final states so less sensitivity
  - Need an excellent understanding of the data: any misunderstood detector effect or background can give a signal
  - …but may catch a signal which nobody has thought to look for!
- Classify events according to the particles in final state
  - jet (j), b-jet (b), electron (e), muon (μ), photon (γ), MET (ν)
    - e.g. 1j1b2μ = 1 jet, 1 b-jet and 2 muons in the final state
  - pT thresholds for each object
    - e.g. jet p_T>50GeV/c, μ p_T>25 GeV/c and MET>150 GeV
- Only sees high pT physics: low pT phenomena or those with large SM backgrounds will not be seen
- Many different MC samples used to simulate SM backgrounds
  - multijet, Z/W+jets, γ and γγ+jets, W/Z+γ/γγ, top quark (pair and single), top +vector boson, diboson, triboson, higgs

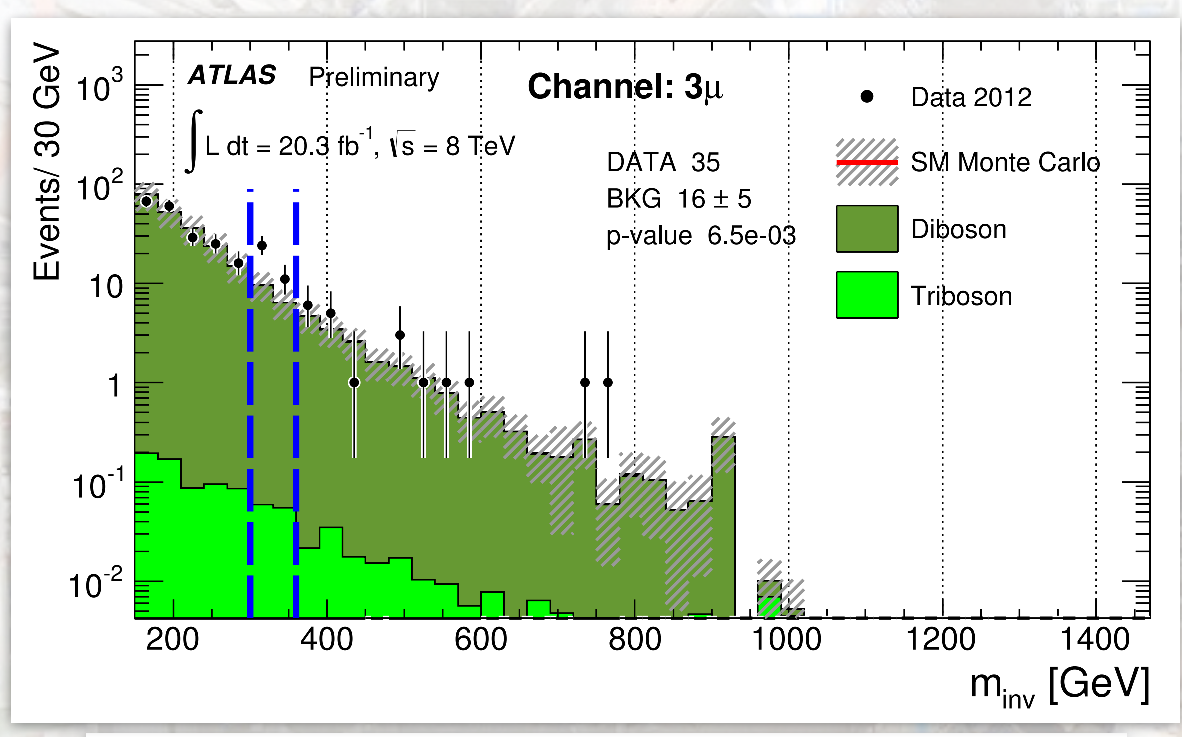
General SUSY Searches

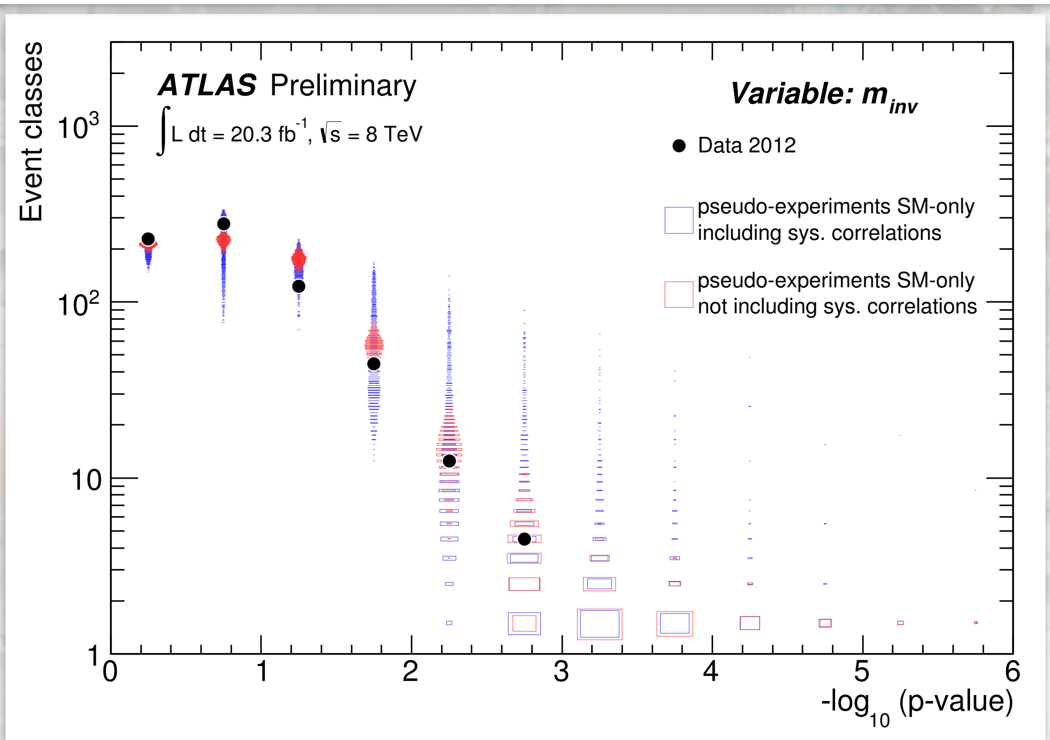
- SM expectation of >0.1 events in 697 event classes with 20.3 fb^{-1} data
  - Events observed in 573 classes
  - 16 event classes have SM prediction <0.1 but have at least 1 data event
    - 2 events in 2μ1e5j class
- Most event classes show agreement between SM prediction and observation
  - Observed deviations consistent with statistical expectation





General SUSY Searches

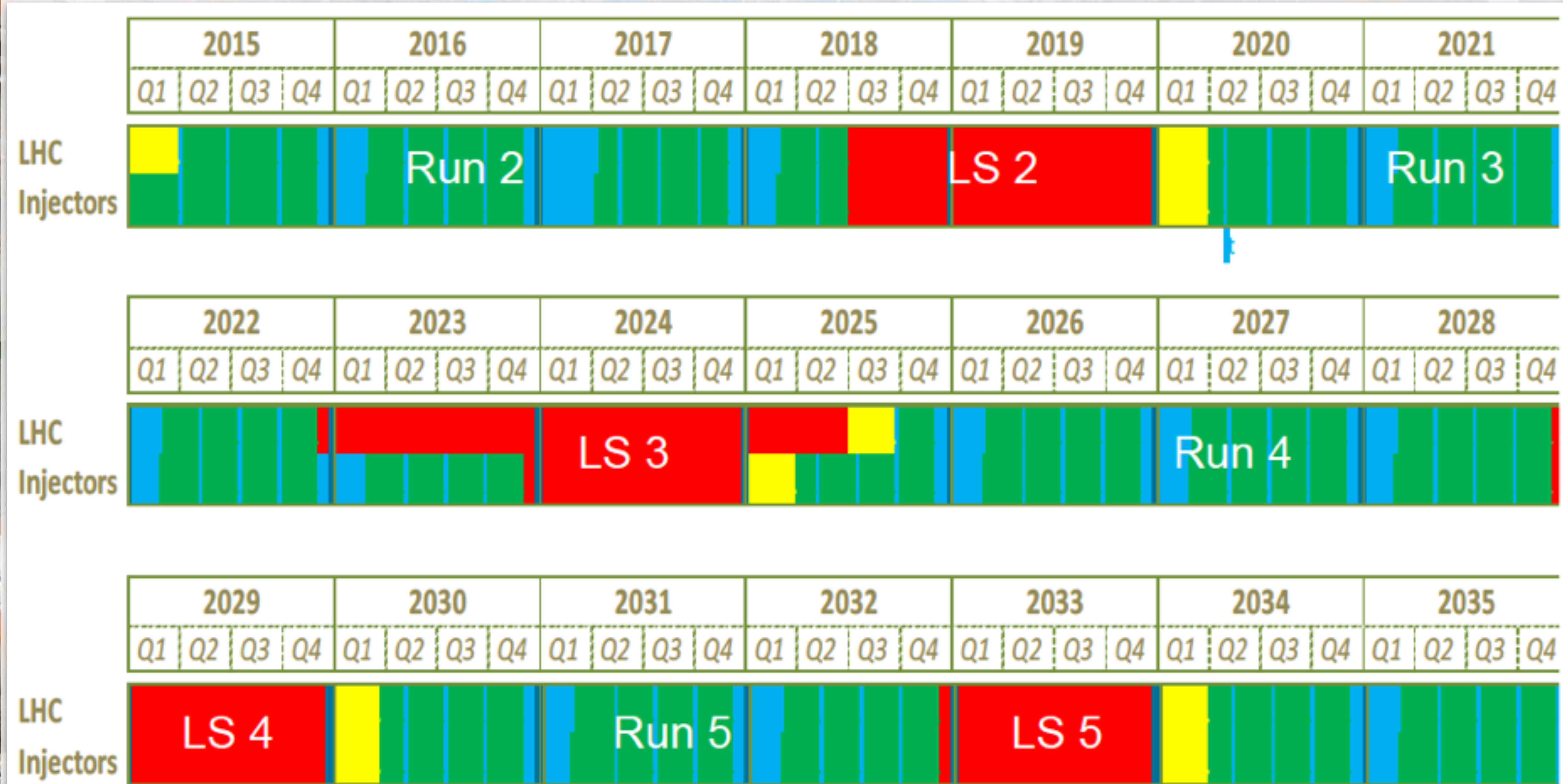




- Search event classes comparing 3 distributions
  - Scalar pT sum
  - Visible invariant mass
    - Defined as invariant mass of all object except MET
  - MET distribution
- Algorithm looks for region of largest deviation
  - Bin size based on expected resolution
  - Regions where background uncertainty is >100% are discarded
- Pseudo-experiments used to determine expected number of deviations with p-value
- Conclusion: data is consistent with SM predictions

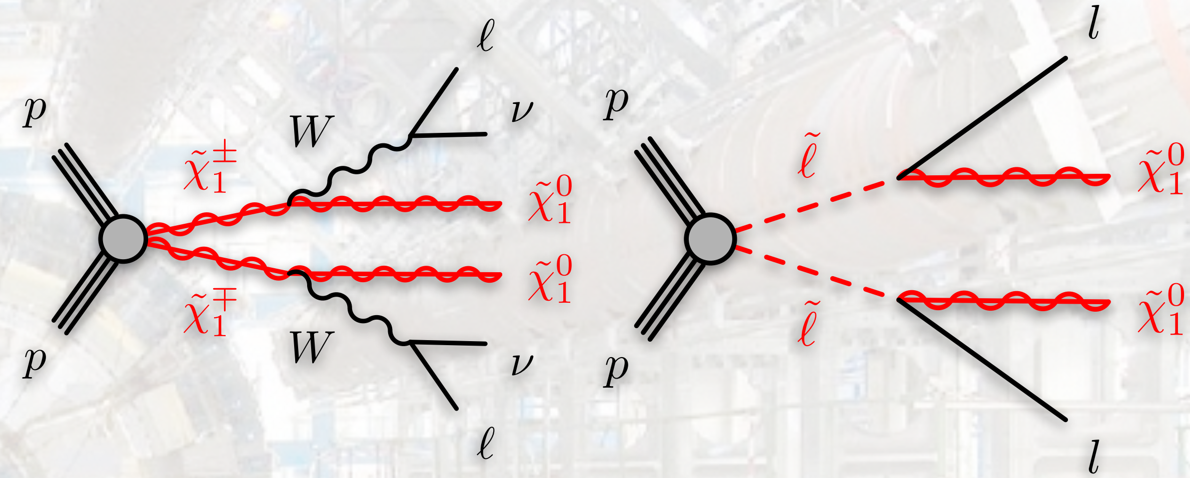
LHC Run Plan

- LHC currently preparing for Run 2 in March 2015

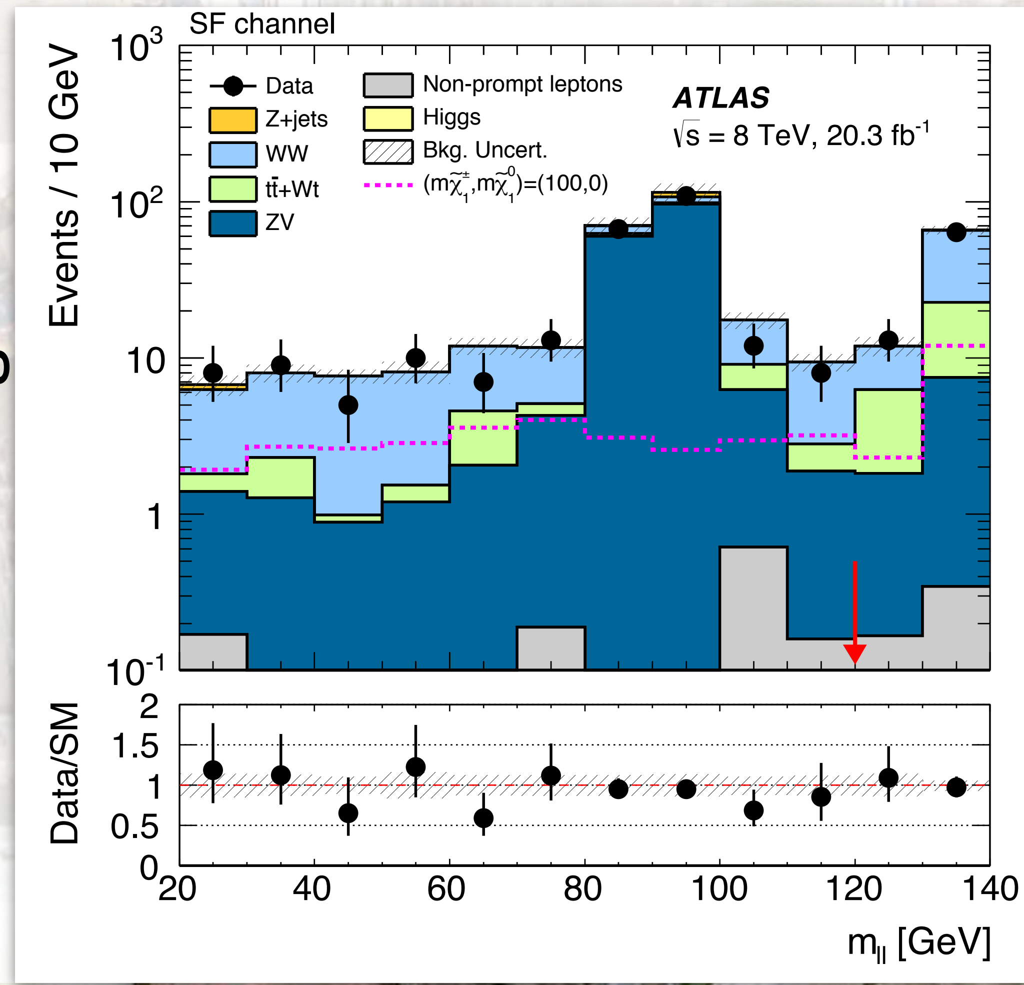


Electroweak SUSY

- EW SUSY events have lower cross-sections but produce leptons in final state
  - Lower backgrounds: ttbar, single top and diboson
- Events involve chargino, neutralino or sleptons
  - Decays model dependent but, like SM partners, will likely include leptons
- Recent search looked for 2 e/μ + MET in final state
  - 7 signal regions used: 3 slepton, 3 chargino+W(lν) and 1 chargino +neutralino(2) + W(qq), Z(ll)
  - Lepton flavour allowed to be the same (SF) or different (DF)
- MC backgrounds normalized to control regions and predicted in signal regions



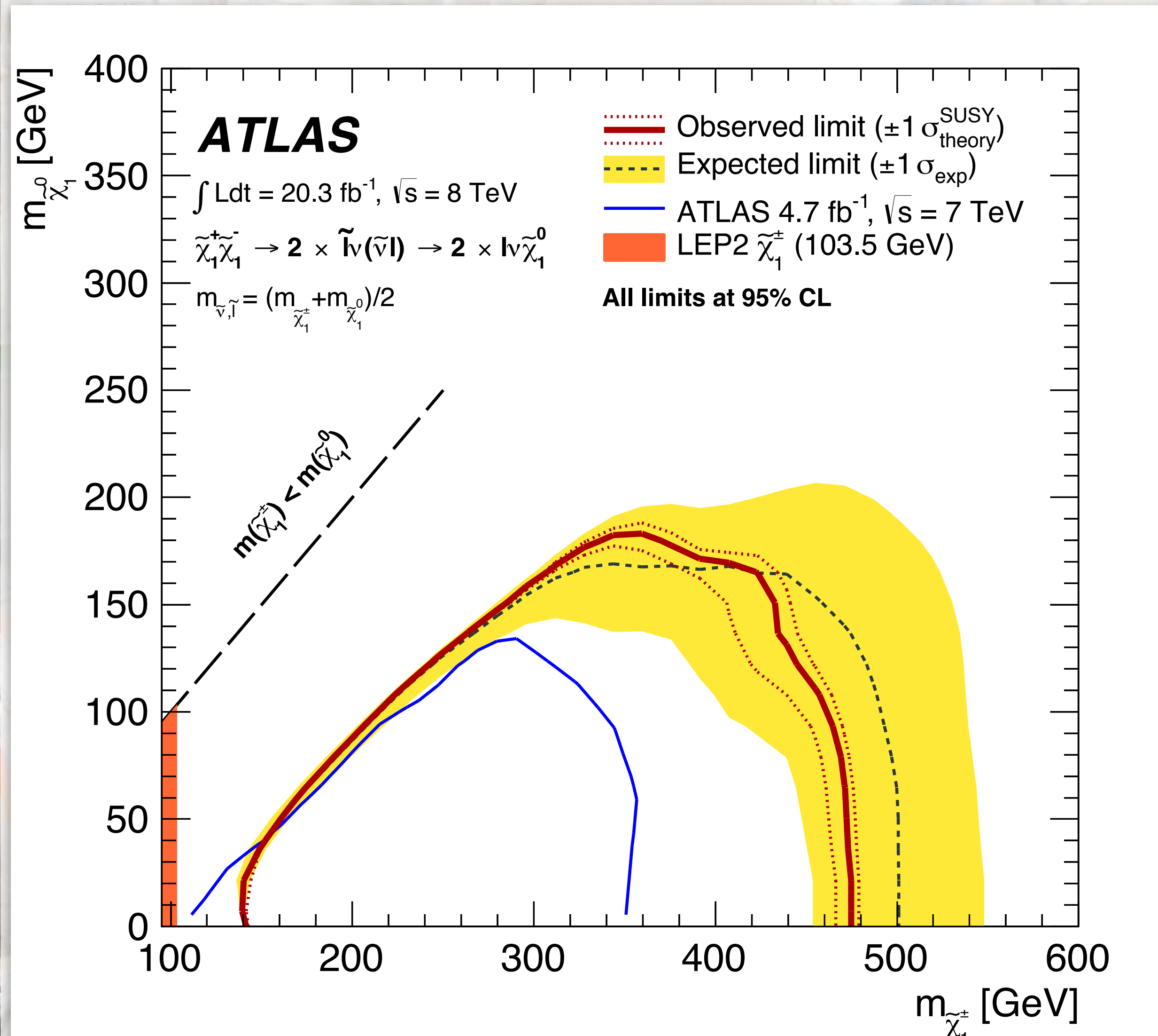
SR-WWa Backgrounds

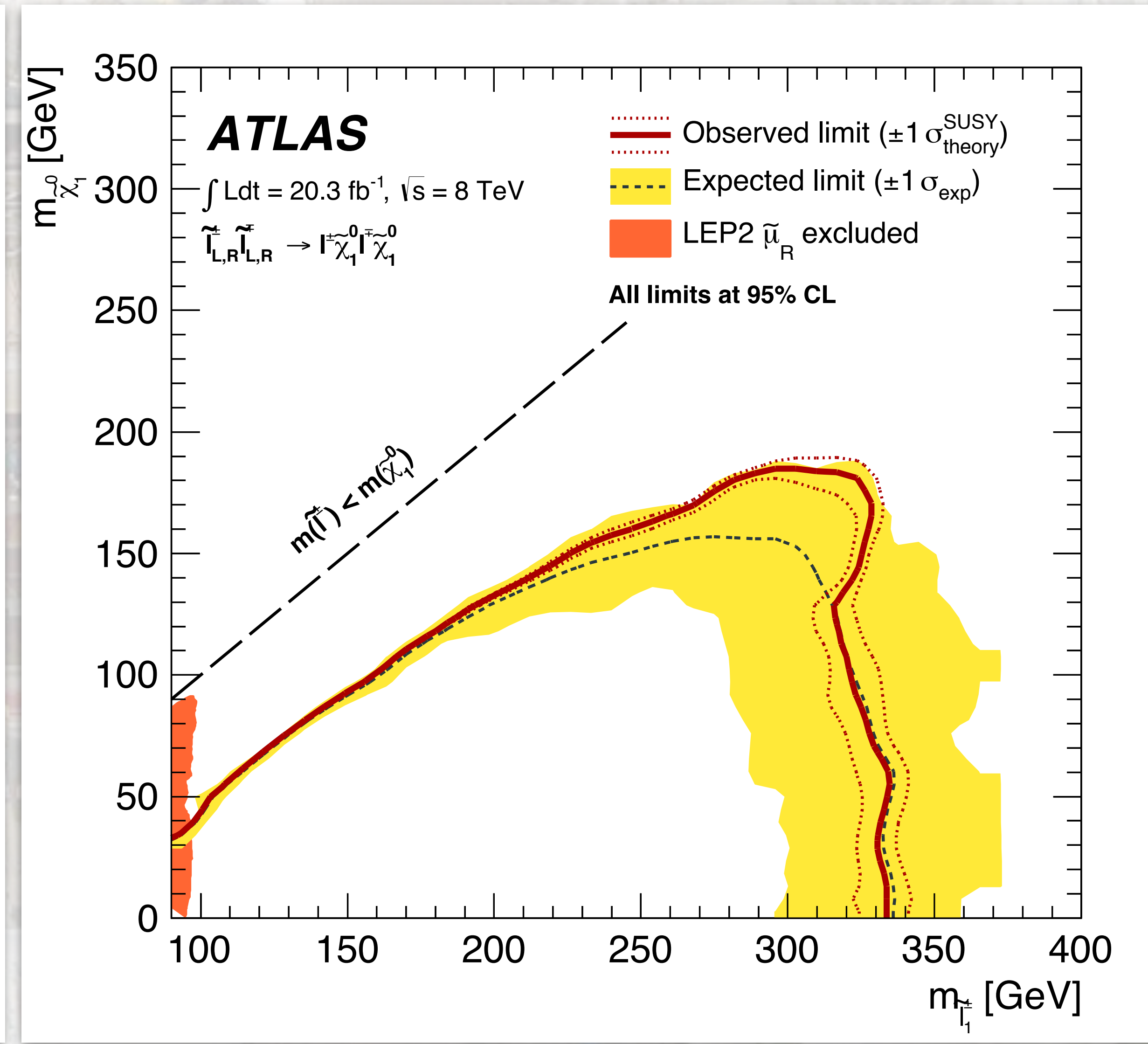


arXiv:1403.5294 (Accepted JHEP)

Electroweak SUSY

- Limits for chargino(1)+neutralino(1) and slepton channels
  - Simplified SUSY model: prompt decays, common slepton masses, chargino/neutralinos are winos





Electroweak SUSY

- Searches for chargino(1)+ neutralino(2) include taus in final state [JHEP 04 (2014)169+see plot]
  - Three leptons: even lower backgrounds
- Other searches include higgs in decays
- Combination
  - Assume m(chargino1)= m(neutralino2)