

ATLAS Highlights and Outlook

US LHC Users Association

Argonne National Laboratory

November 13, 2014

Chip Brock, for the ATLAS Collaboration

Michigan State University

24 October

Hello,

This is a talk for the U.S. LHC Users Organization at Argonne Lab scheduled for November 13.

<https://indico.hep.anl.gov/indico/conferenceDisplay.py?confId=410>

The assigned title is “ATLAS Highlights and Outlook” and I’ve chosen to interpret this as not just the most recent results, but as much as possible a look back at Run I as compared with what we might have expected. Also a quick run-through of preparations for Run 2 are included. I’ve not included heavy ion physics, pleading time, a lack of expertise, and an audience dominated by, if not exclusively, particle physicists.

What’s shown is a superset of what I can possibly include in a half-hour, but because I’ve got 2 talks in a couple of weeks, I hoped to get approval sooner rather than later so I can tweak during the first week of November.

In some cases, I’ve just included plots I might show without yet adding commentary. In some cases, I’ve still got some clips and notes to myself. My understanding for this review is that appropriate attribution and most recent results are the basic concern.

Thanks,

Chip Brock

brock@pa.msu.edu

1%

x2

ATLAS @work

efficient and productive

~90% usable data efficiency

2010: $\sqrt{s} = 7$ TeV, 0.05/fb

2011: $\sqrt{s} = 7$ TeV, 4.6/fb

2012: $\sqrt{s} = 8$ TeV, 20.3/fb

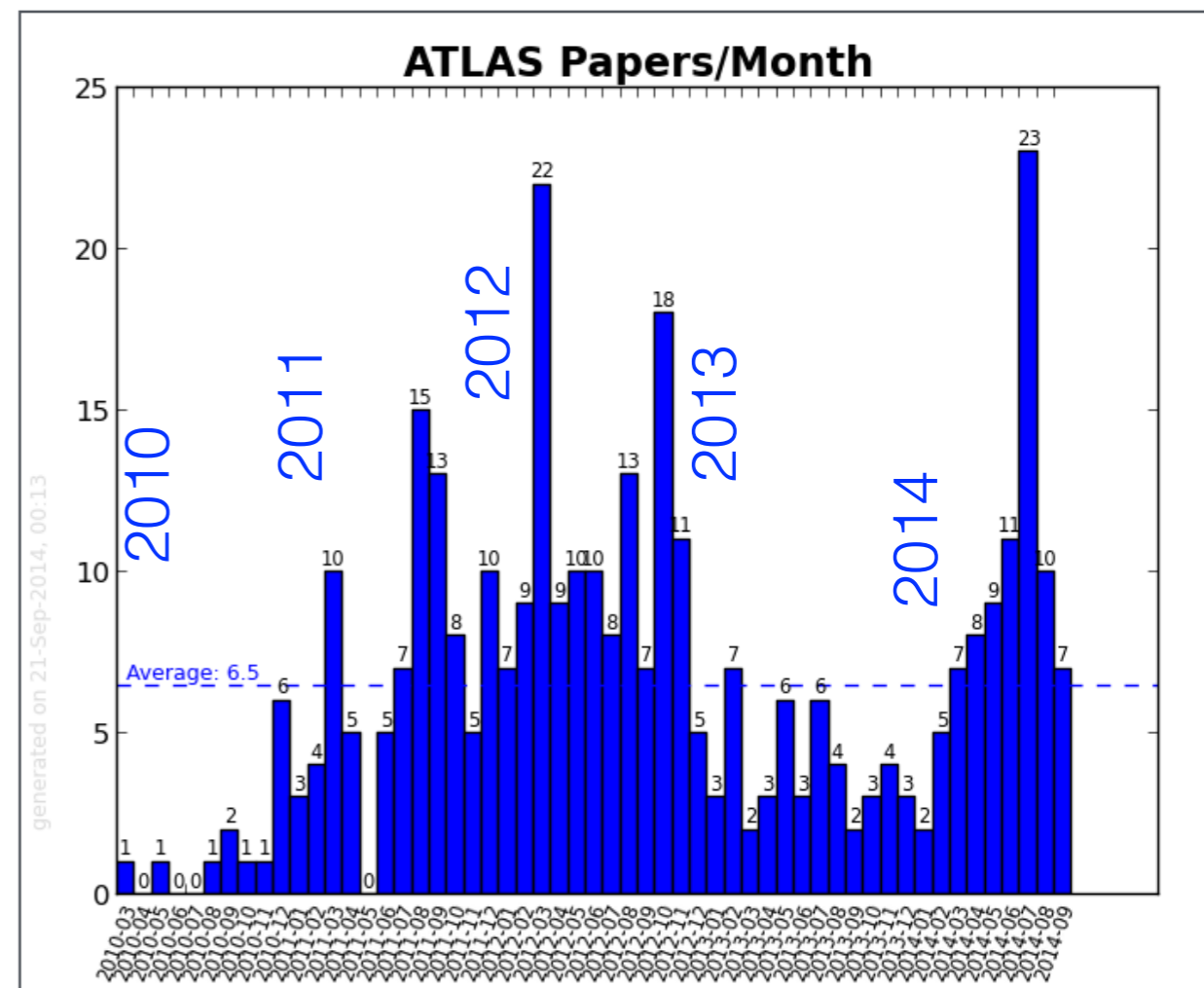
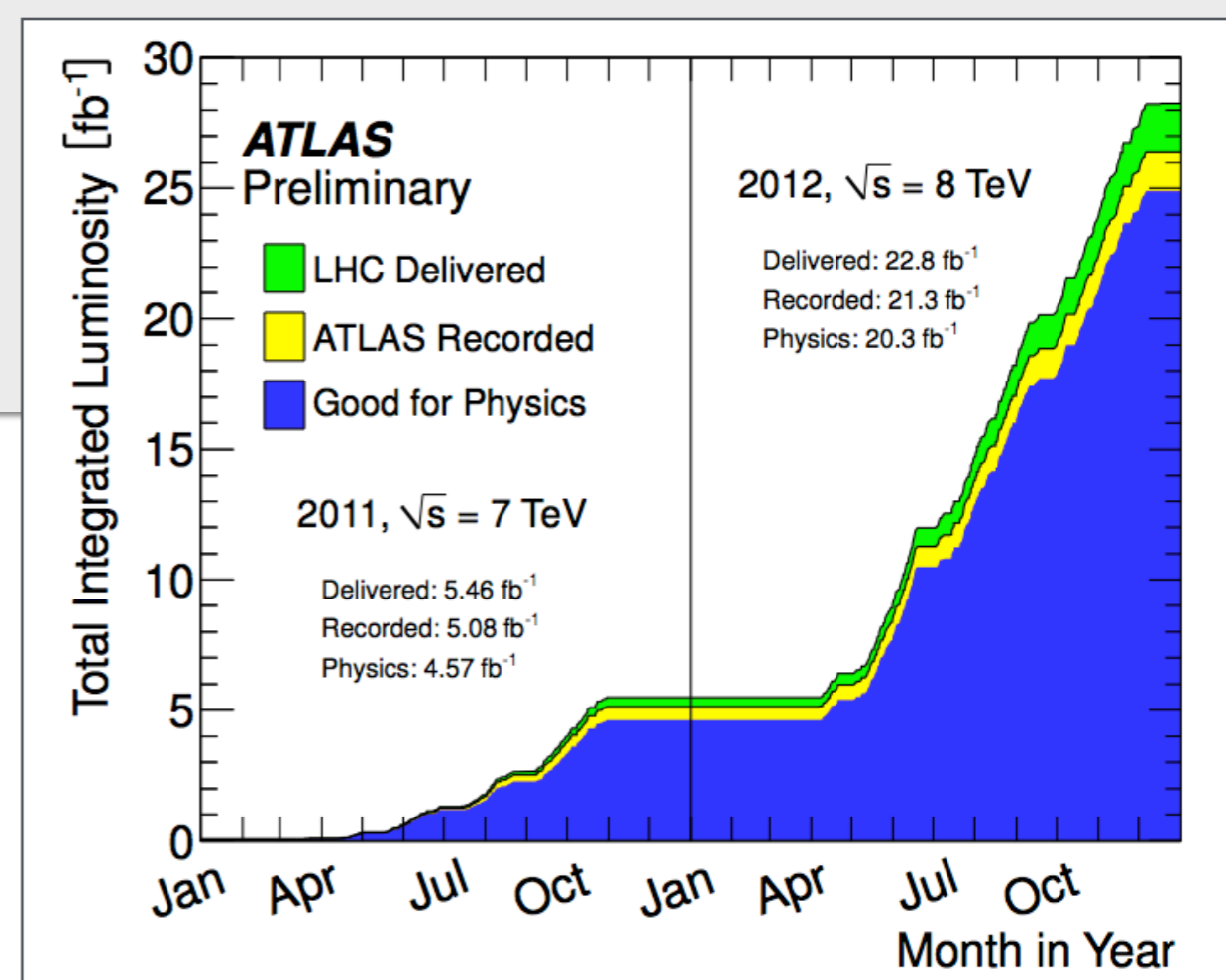
Run I results: a 2014 publication stream

350 publications, ~150 performance

~100 to come

600 CONF notes

660 conference talks



Snowmass Energy Frontier

Research Program:

1. Measure properties of the Higgs boson.

Including: mass, CP properties, and especially couplings

2. Measure properties of the: t, W, and Z

Because they talk “loudly” to the Higgs

3. Search for TeV-scale particles

A scale inspired by naturalness

Snowmass Energy Frontier

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A scale inspired by naturalness

I'll add:

4. Wrestle the Standard Model to the ground.

5. Search for kinematical anomalies wrt SM (see #4)

Is excitement about Run 2...

lost in the huge Phase 1 preparation?

a rule of  : a x10 increase in \mathcal{L} is like x2 in E_{cm}

and visa versa

Run 2 gives us:

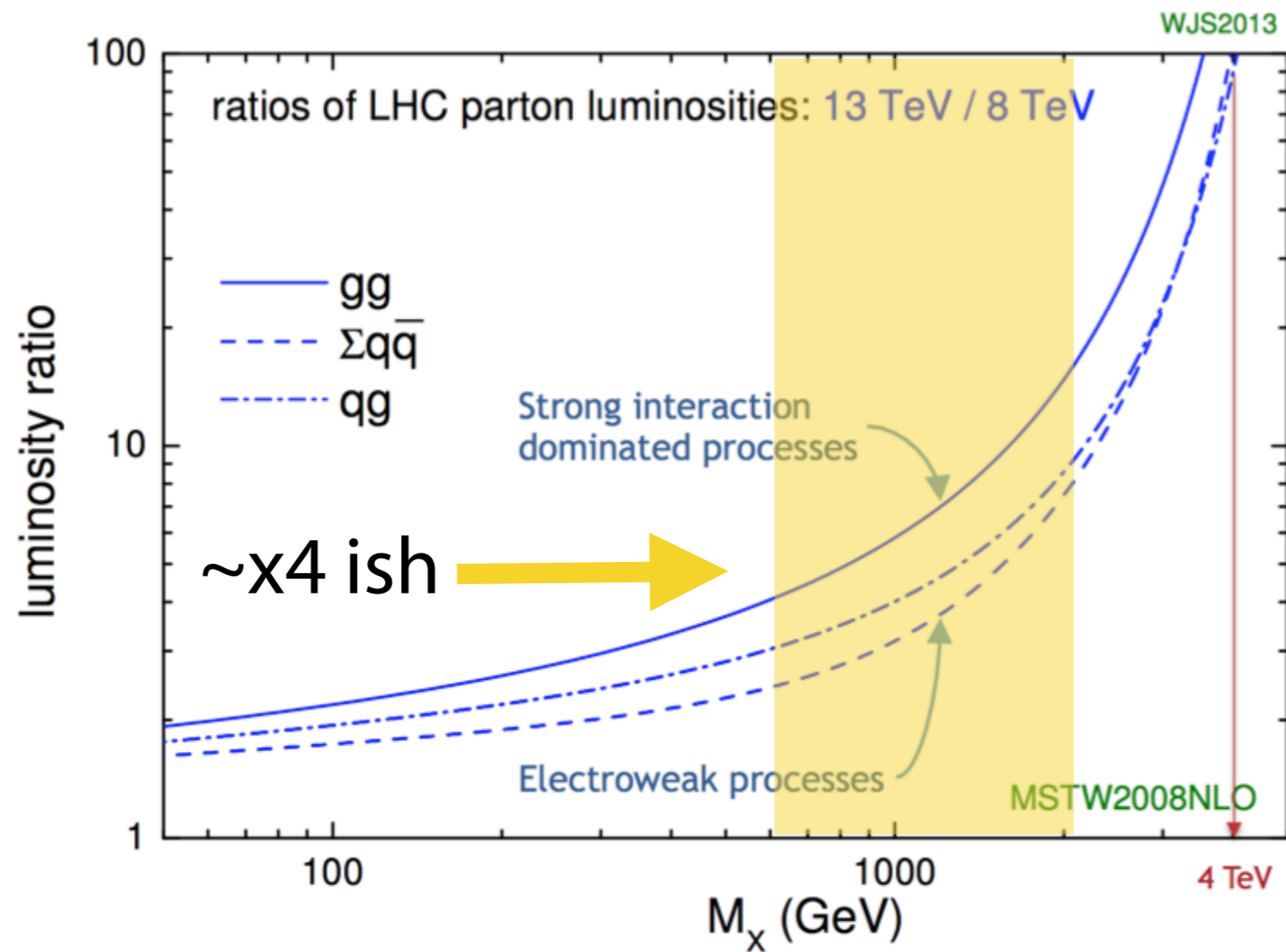
Unprecedented precision

W 's, tops, Higgs!, flavor, inclusive σ 's,

Enormous discovery reach

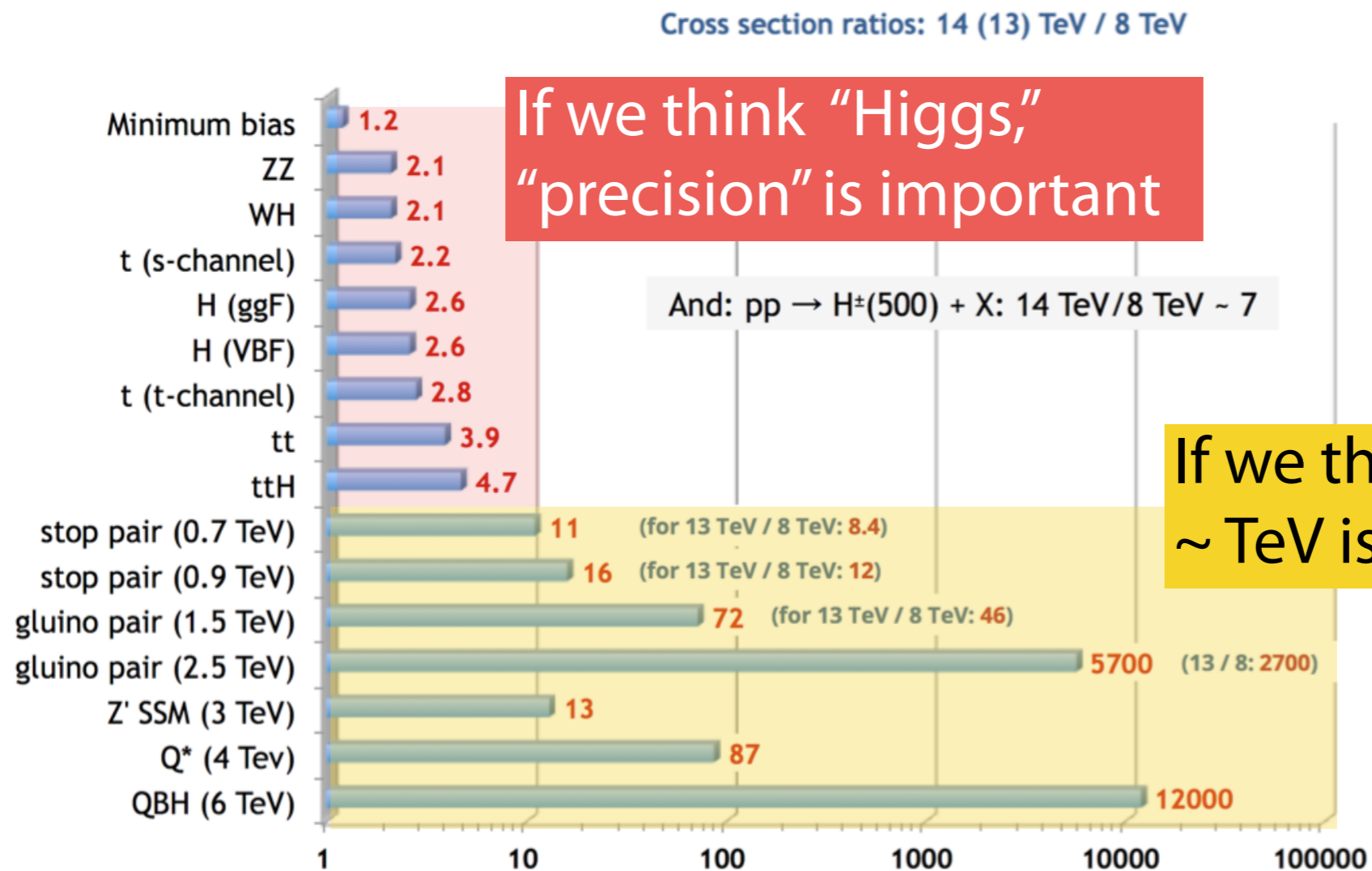
surpass the 1 TeV SUSY scale, Z'/W' , BSM Higgs

More parton luminosity



If we think "natural," then
~ TeV is interesting

+ Higher cross sections



If we think "Higgs,"
"precision" is important

And: $pp \rightarrow H^{\pm}(500) + X$: 14 TeV/8 TeV ~ 7

If we think "natural," then
~ TeV is interesting

Run 1 is essentially a wrap

Higgs Boson Physics

Notable results

from Run 1 we anticipated:

Discovery, first looks

from Run 1 we achieved:

Discovery, the beginnings of a precision Higgs program:

mass, couplings, important final states, differential distributions

in Run 2, we expect:

Cross sections 13/14 TeV, ttH, high mass BSM searches, combination
precision couplings, differential distributions

~x10 statistics

Higgs Boson mass

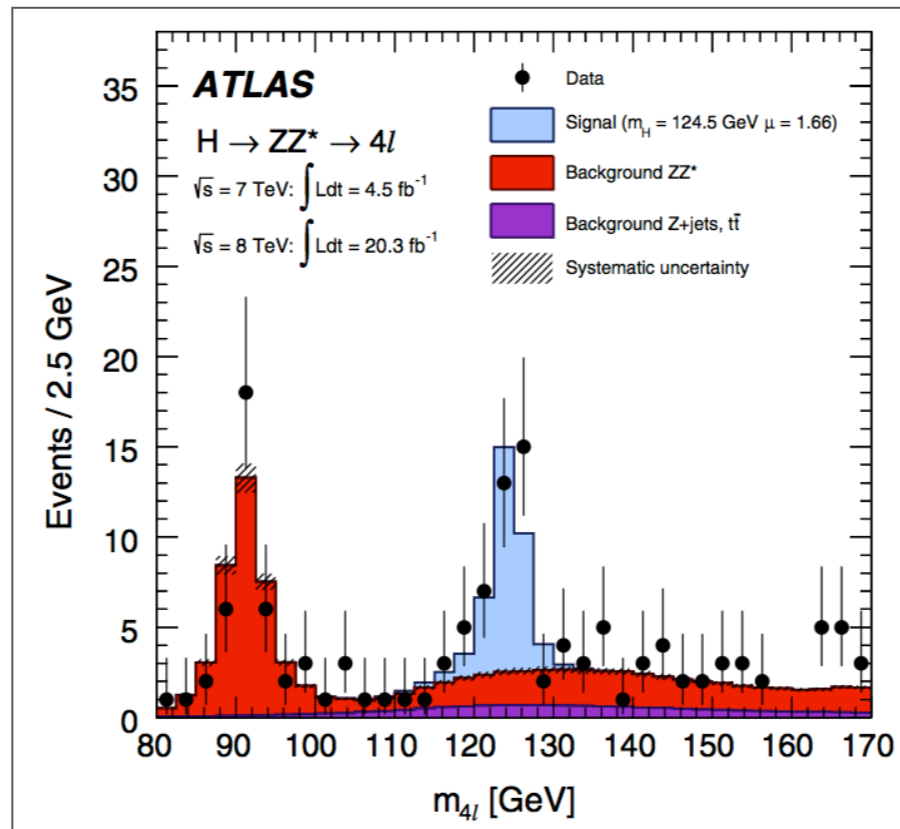
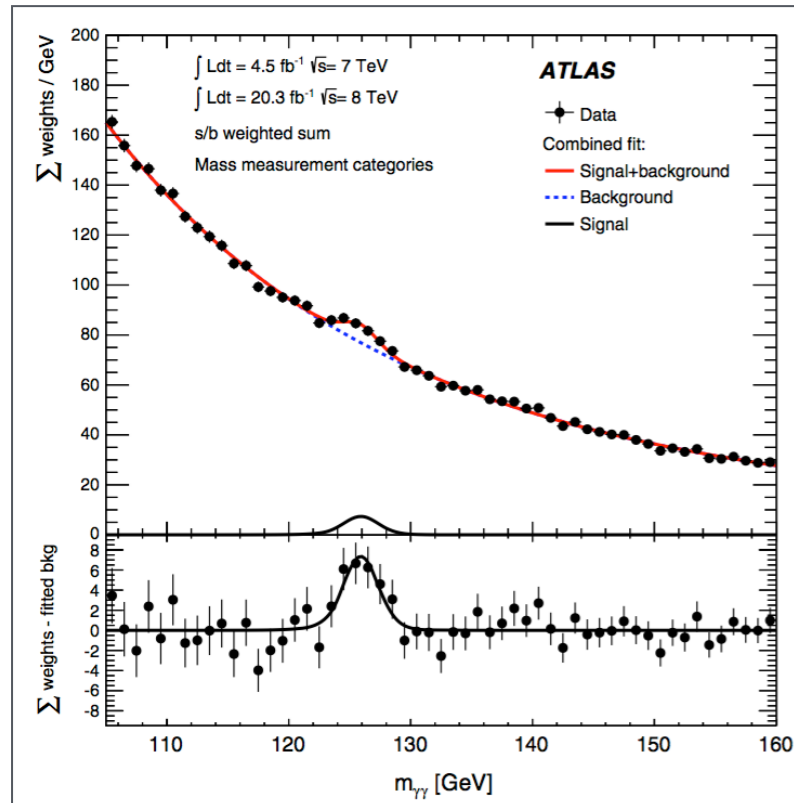
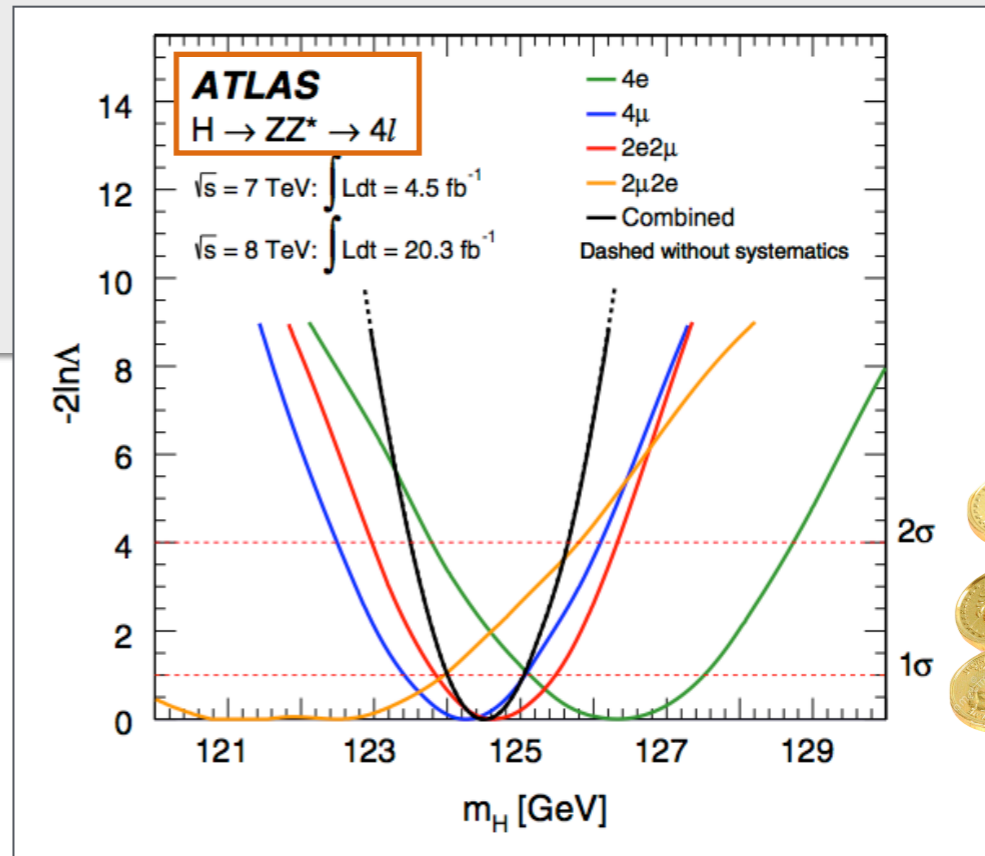
Agony and Ecstasy

Agony:

m_H only ~ 125 GeV

Ecstasy:

m_H precisely = $125.36 \pm 0.37 \pm 0.18$ GeV



~ 40 signal/channel

Run II: expect 400-500

PHYSICAL REVIEW D 90, 052004 (2014)

Higgs width?

smart ideas

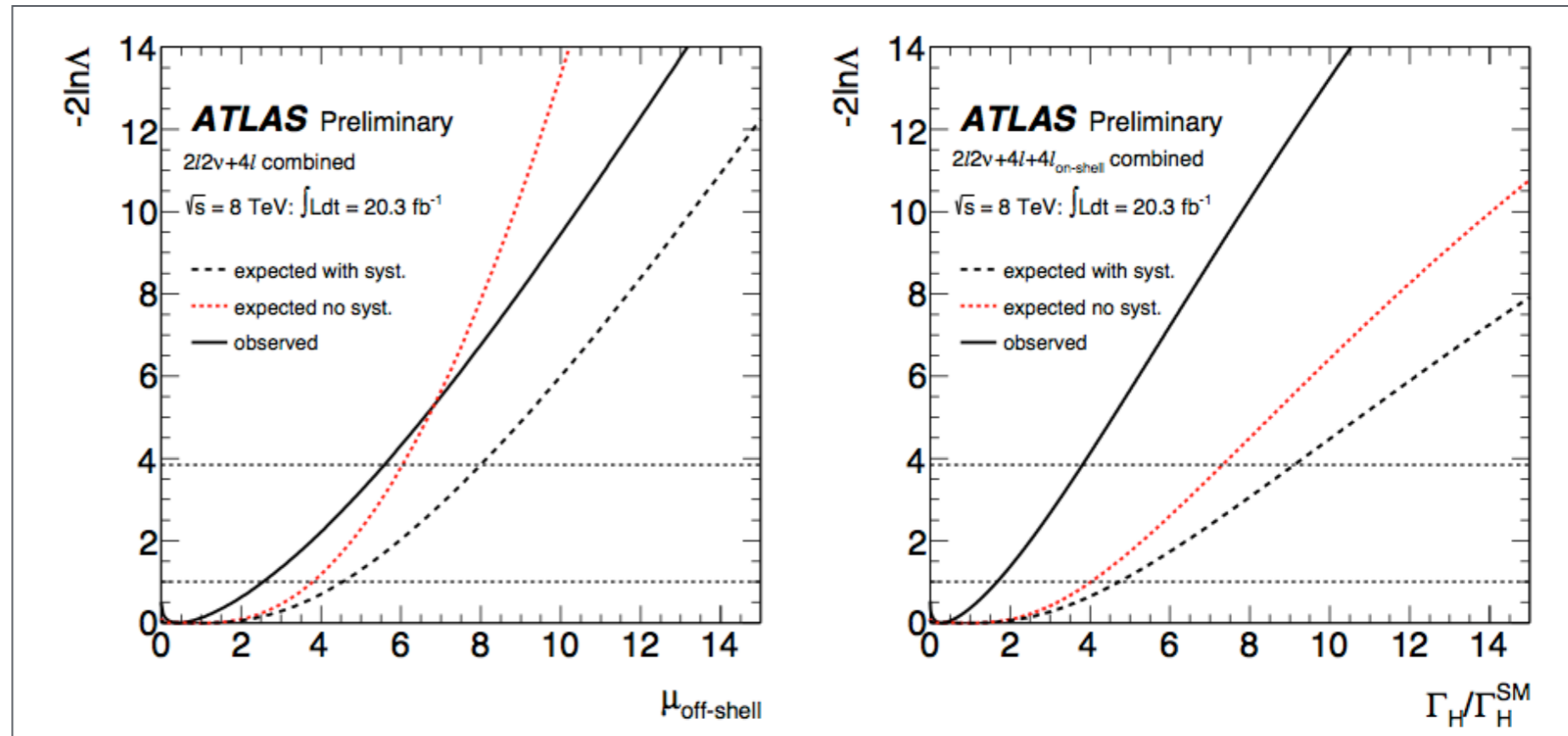
Infer

on-shell, vs off-shell

$$\mu_{\text{off-shell}} = \mu_{\text{on-shell}} \cdot \Gamma_H / \Gamma_H^{\text{SM}}$$

$$\frac{\Gamma_H}{\Gamma_H^{\text{SM}}} = 0.3^{+1.4}_{-0.3}$$

so far, 1 sd compatible



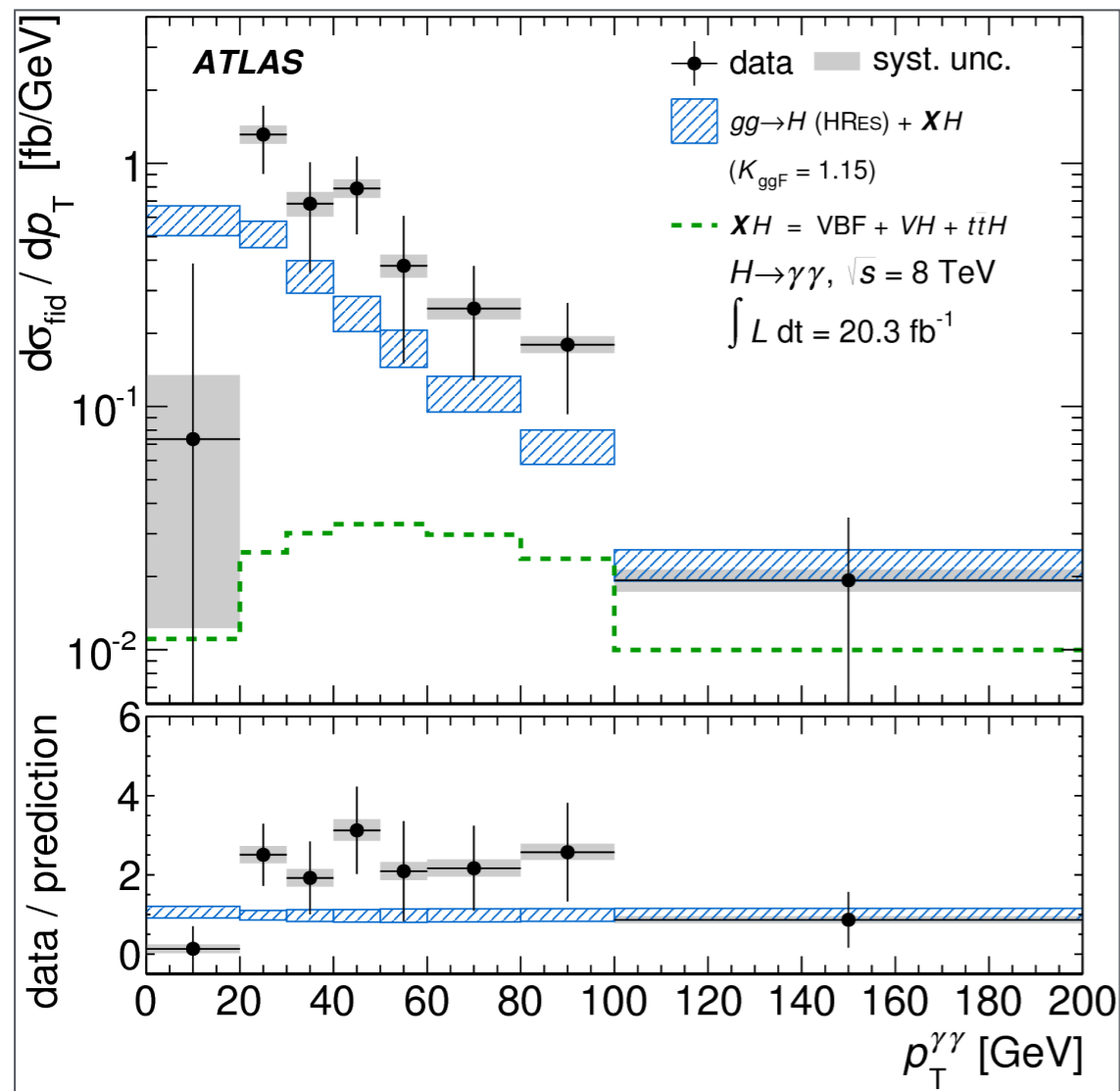
ATLAS-CONF-2014-042

Higgs in slices

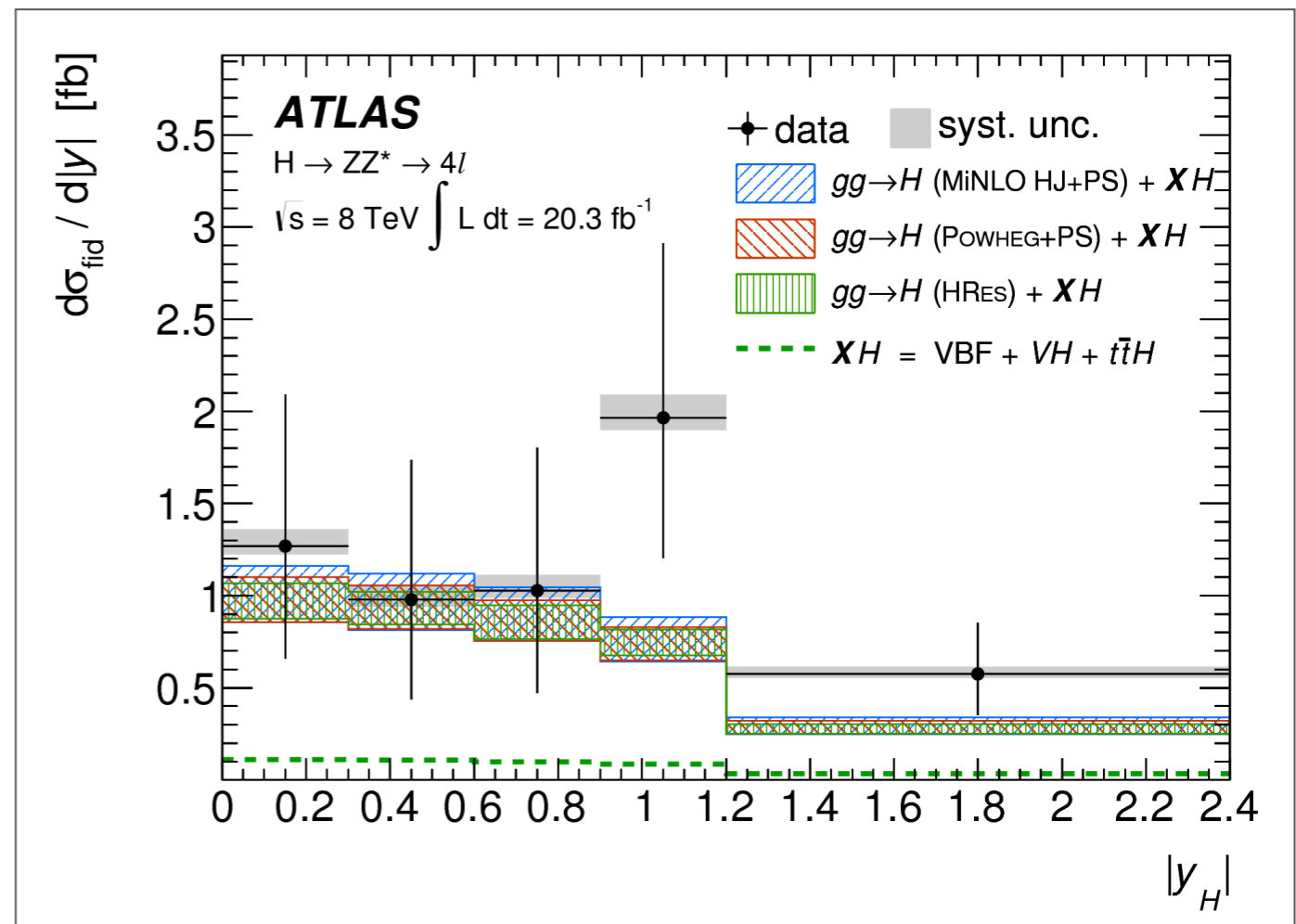
differential distributions



the details corrected to the particle level



arXiv:1407.4222



arXiv:1408.3226

Higgs couplings, 1

signal strengths, small, vibrant industry

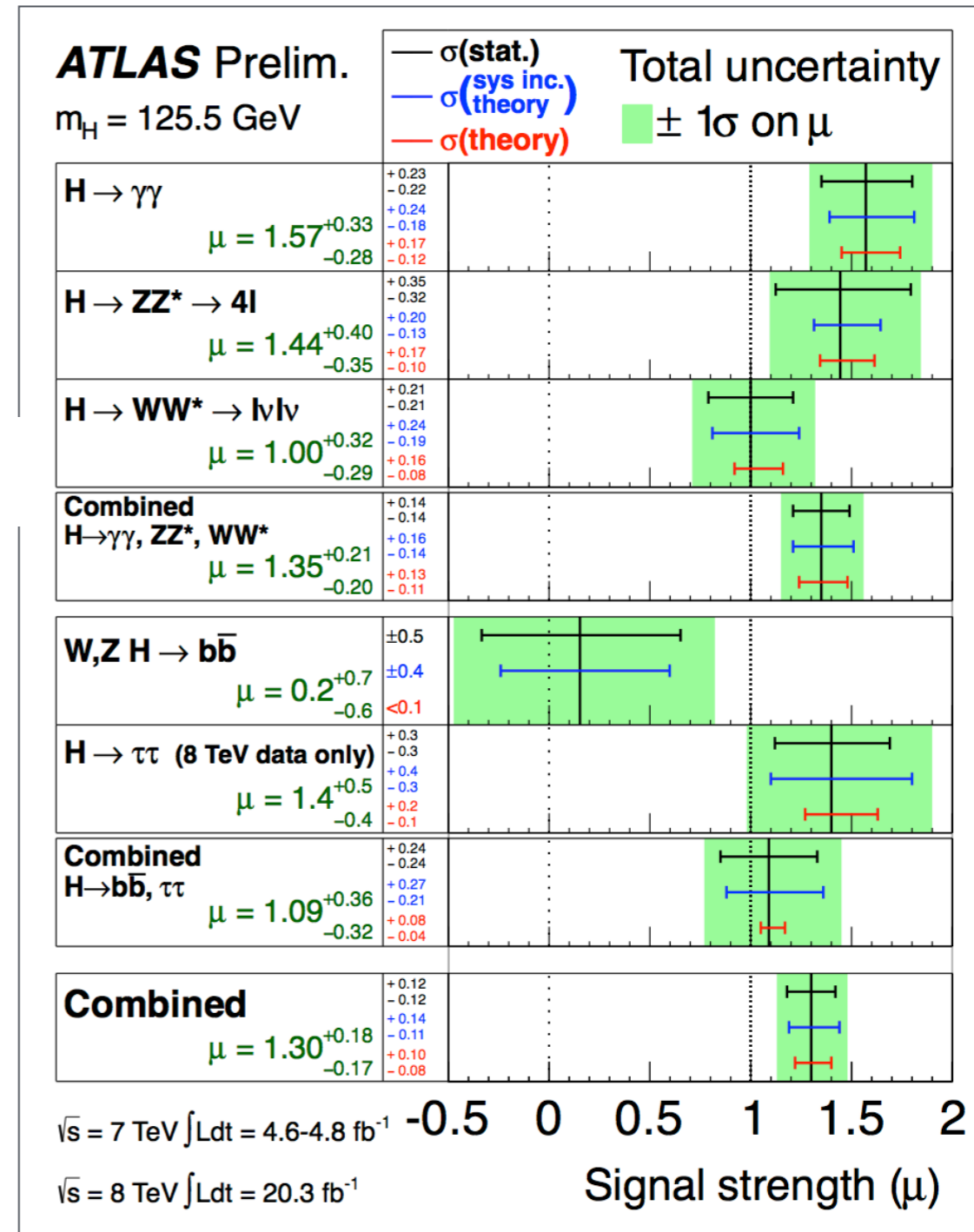
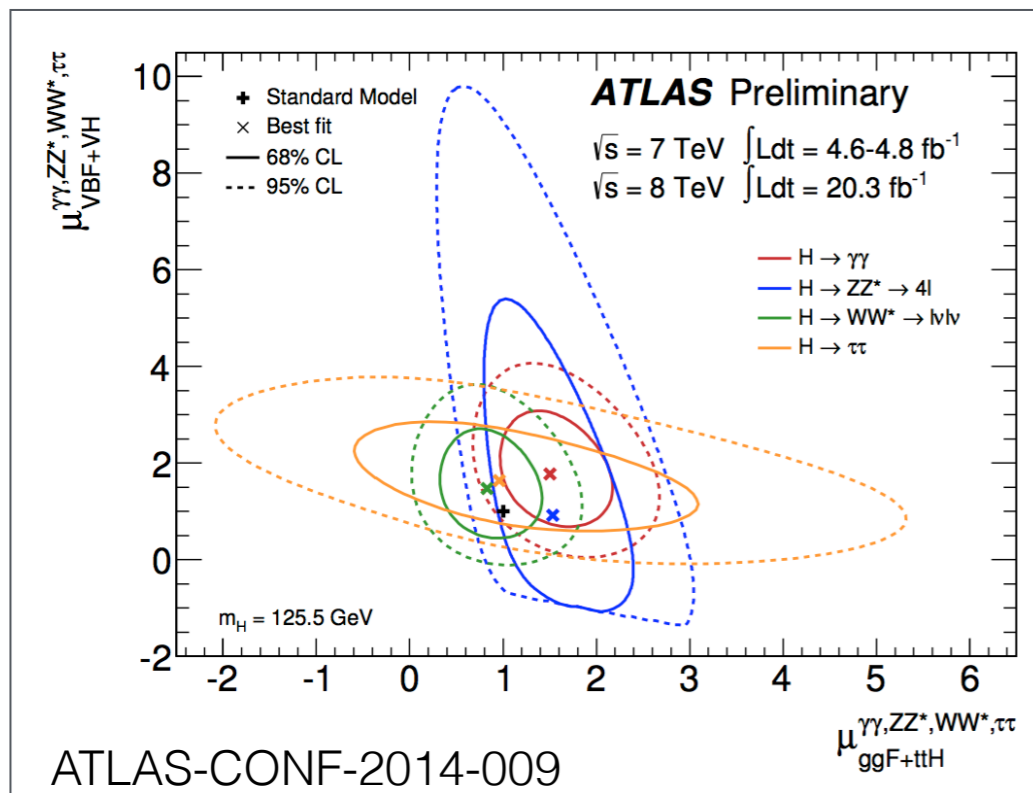


succession of assumptions

least constrained, signal strength:

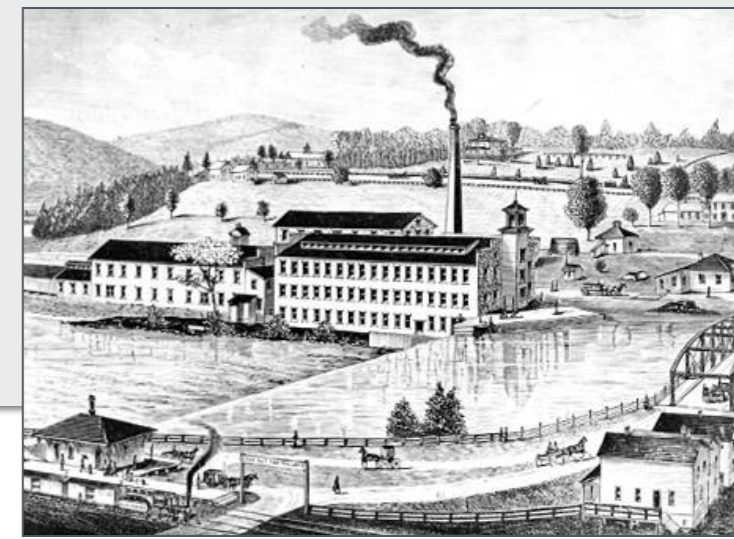
other fits with constraints

$$\mu_{VBF+VH} = \mu_{VBF} = \mu_{VH} \quad \mu_{ggf+ttH} = \mu_{ggf} = \mu_{tt}$$



Higgs couplings, 2

global fitting, big, growing industry



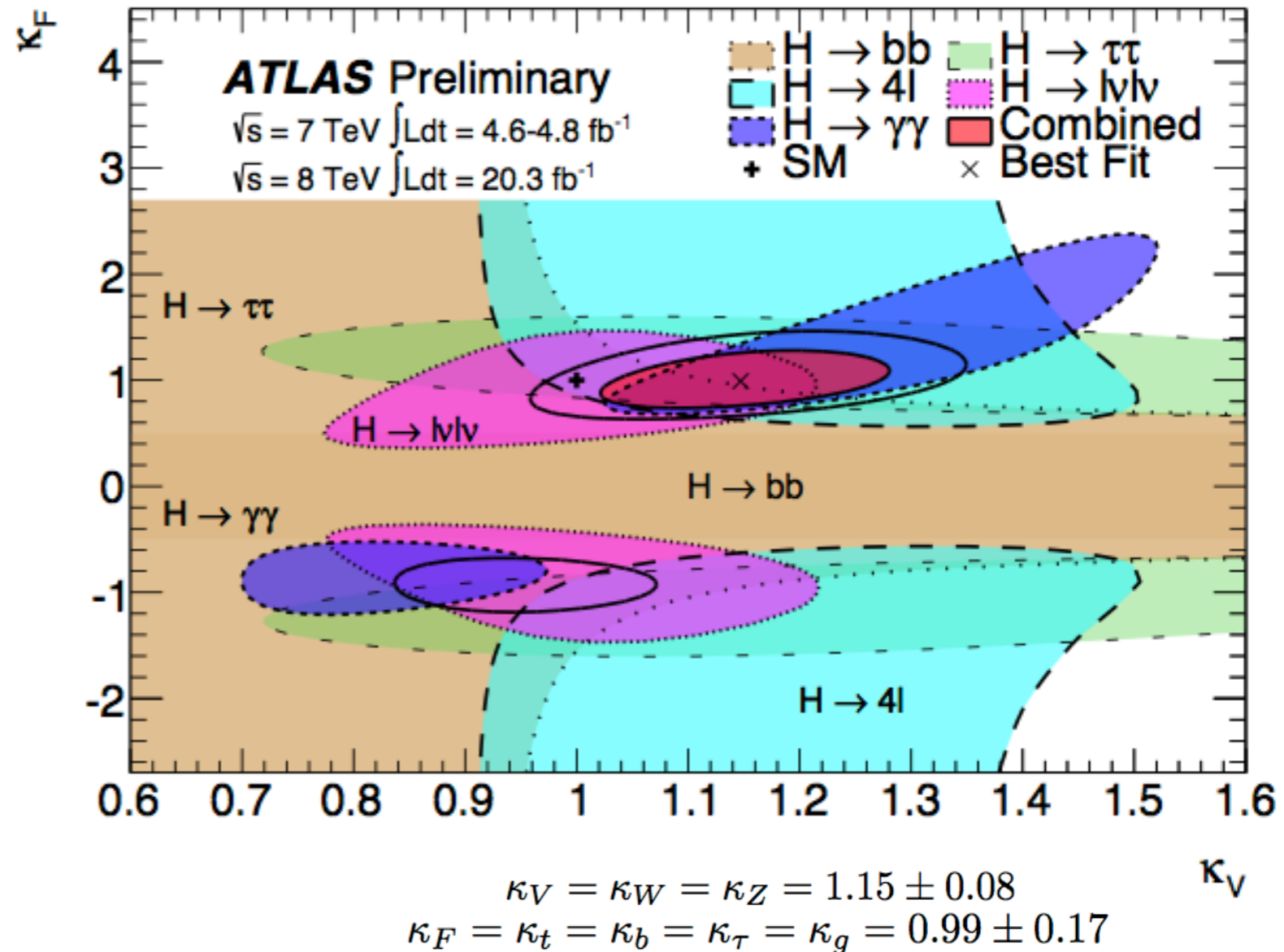
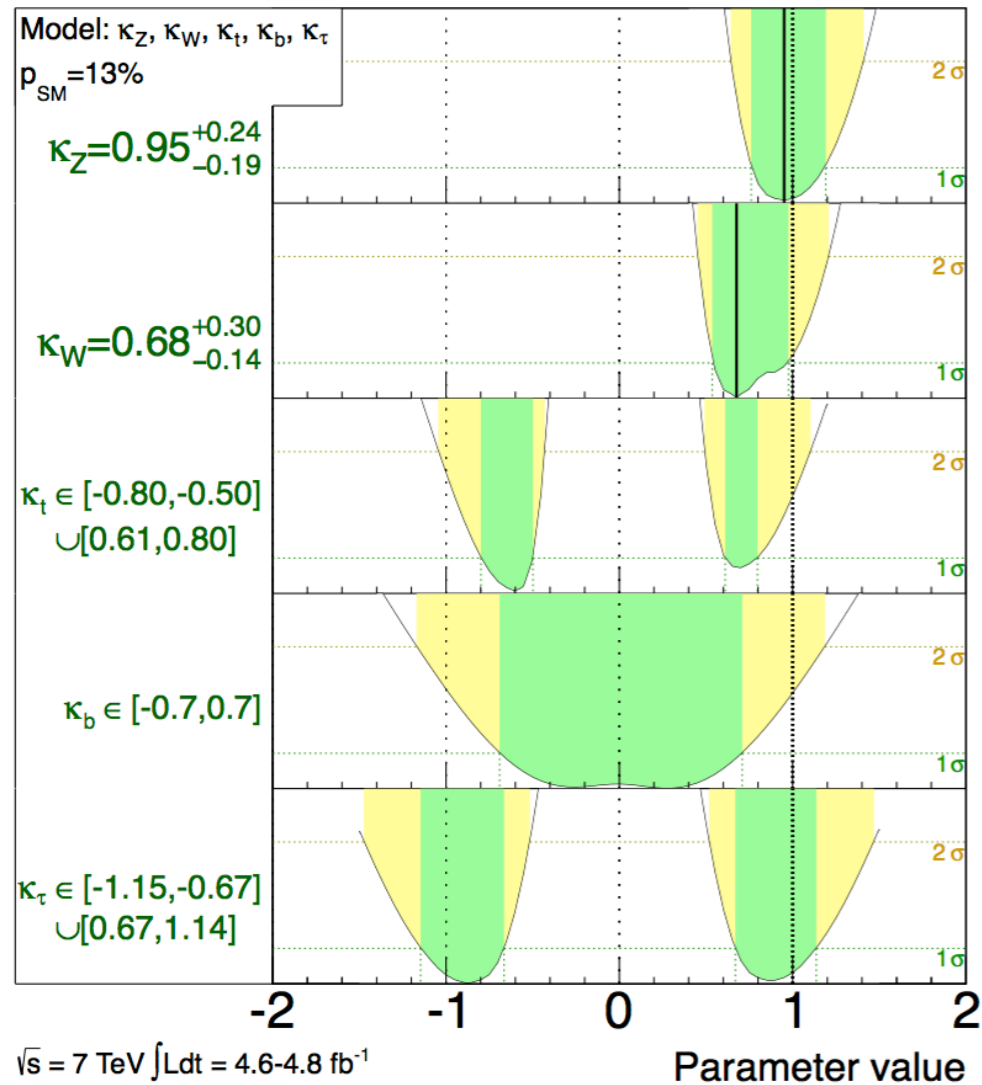
global fitting

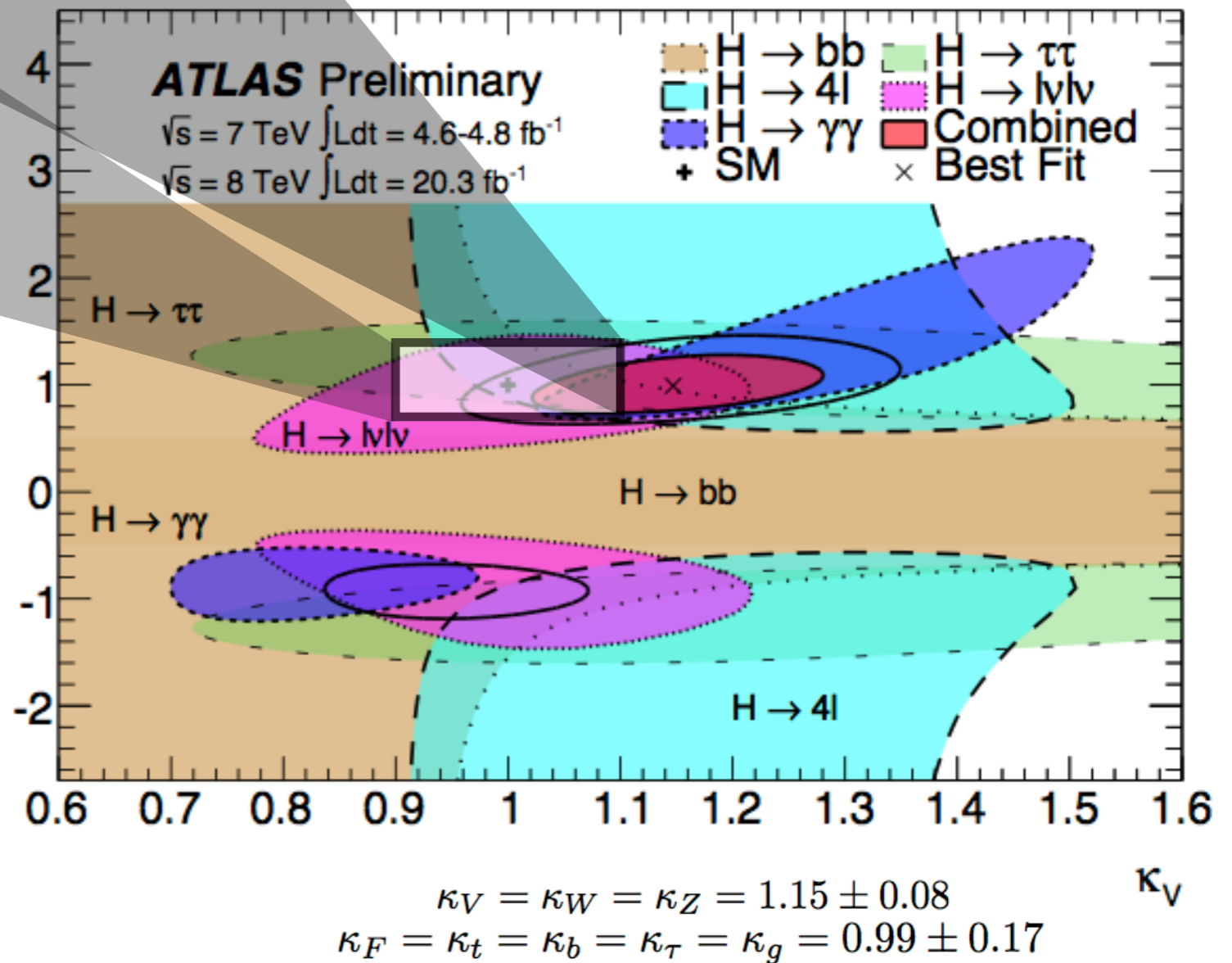
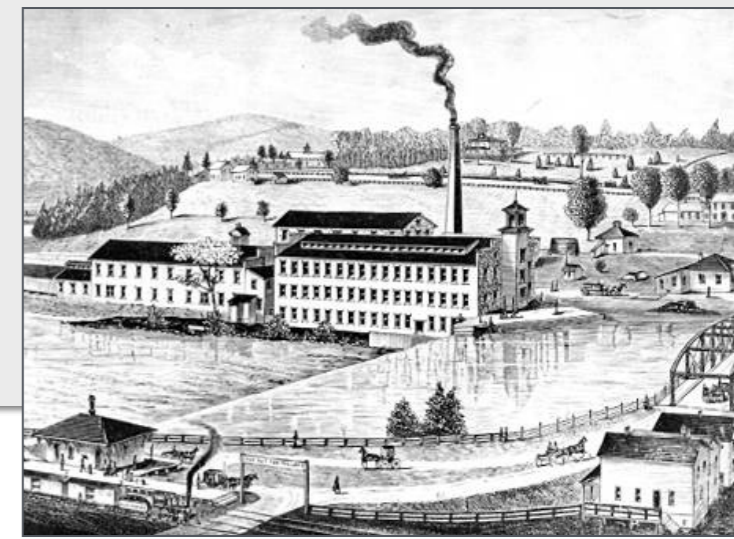
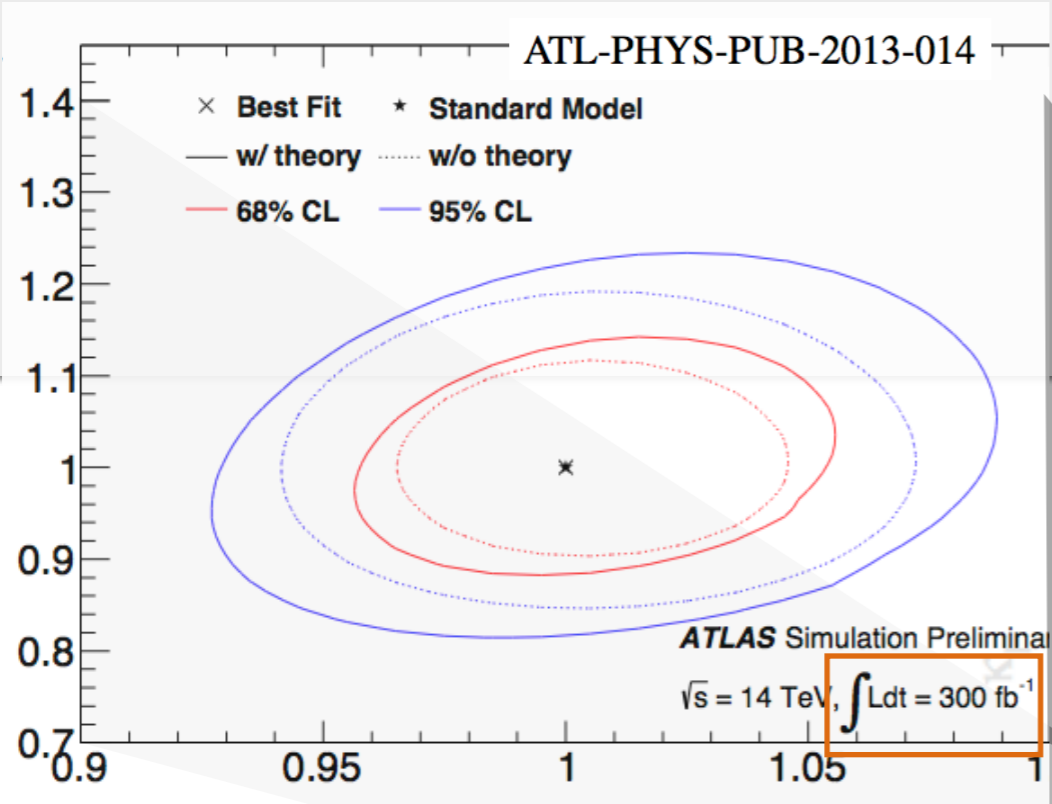
ATLAS Preliminary

$m_H = 125.5 \text{ GeV}$

Total uncertainty

■ $\pm 1\sigma$ ■ $\pm 2\sigma$





But Wait...
**THERE'S
MORE!**

higgs ww

higgs tau tau

VH bb

spin/CP gg, zz, ww,



Standard Model Physics

Notable results



from Run 1 we anticipated:

“Rediscovery”...Precision total & inclusive cross sections, VV studies, differential cross sections. Did we expect MW?

from Run 1 we achieved:

Rediscovery, indeed.

in Run 2, we expect:

Rerediscovery...Precision couplings, differential distributions, much pileup study.

First MW?

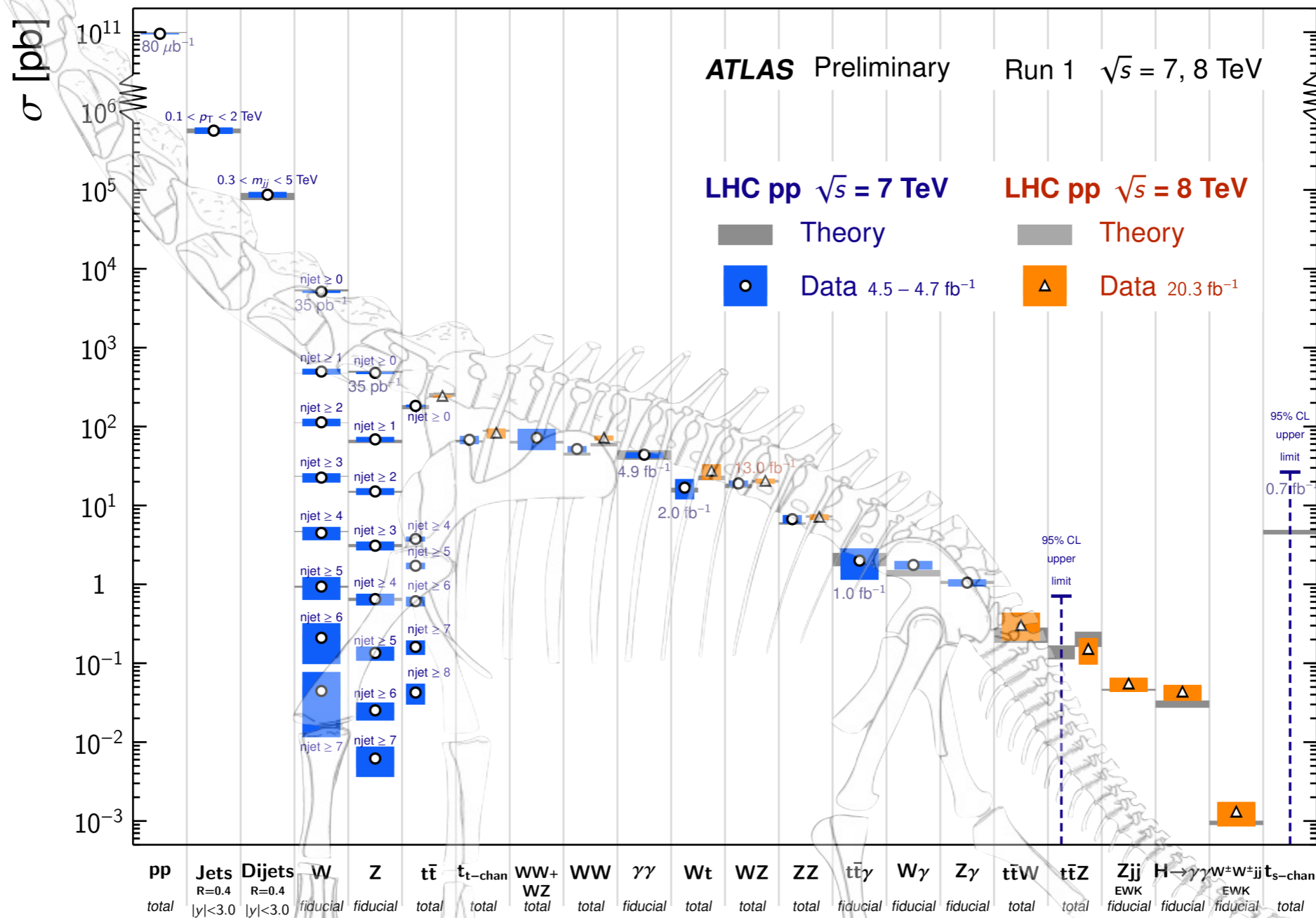
Standard Model Paleontology

pick your favorite dinosaur



Standard Model Production Cross Section Measurements

Status: July 2014

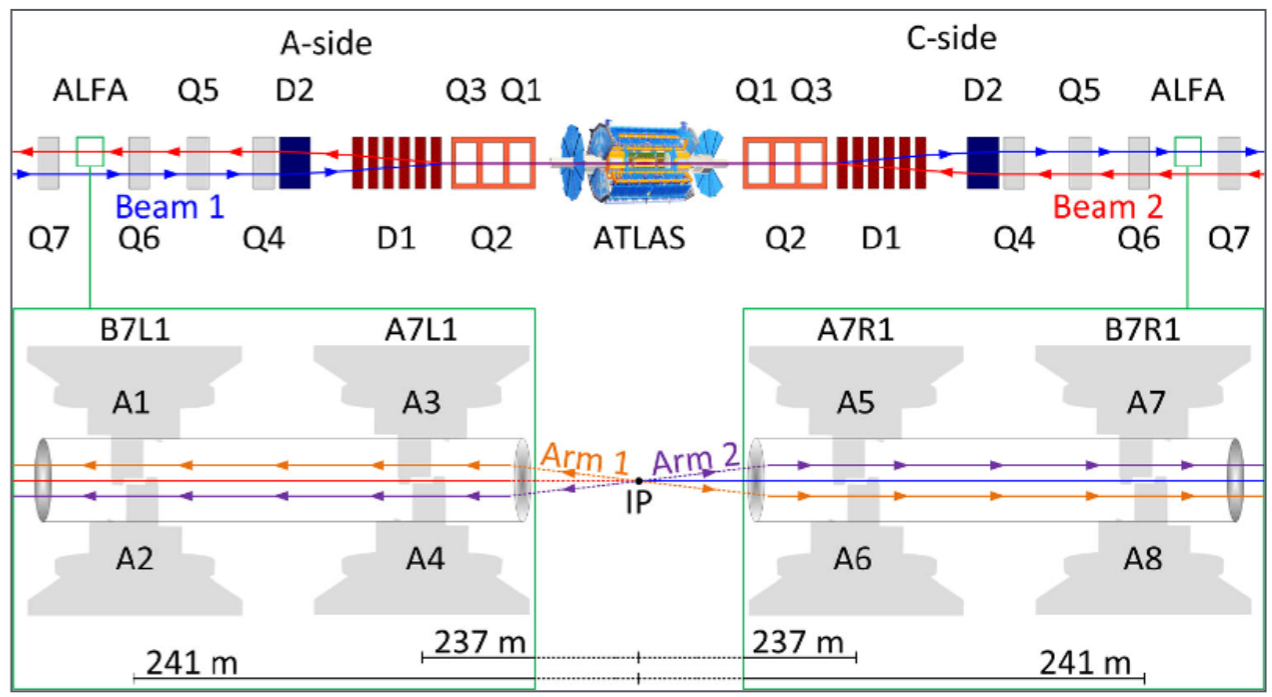
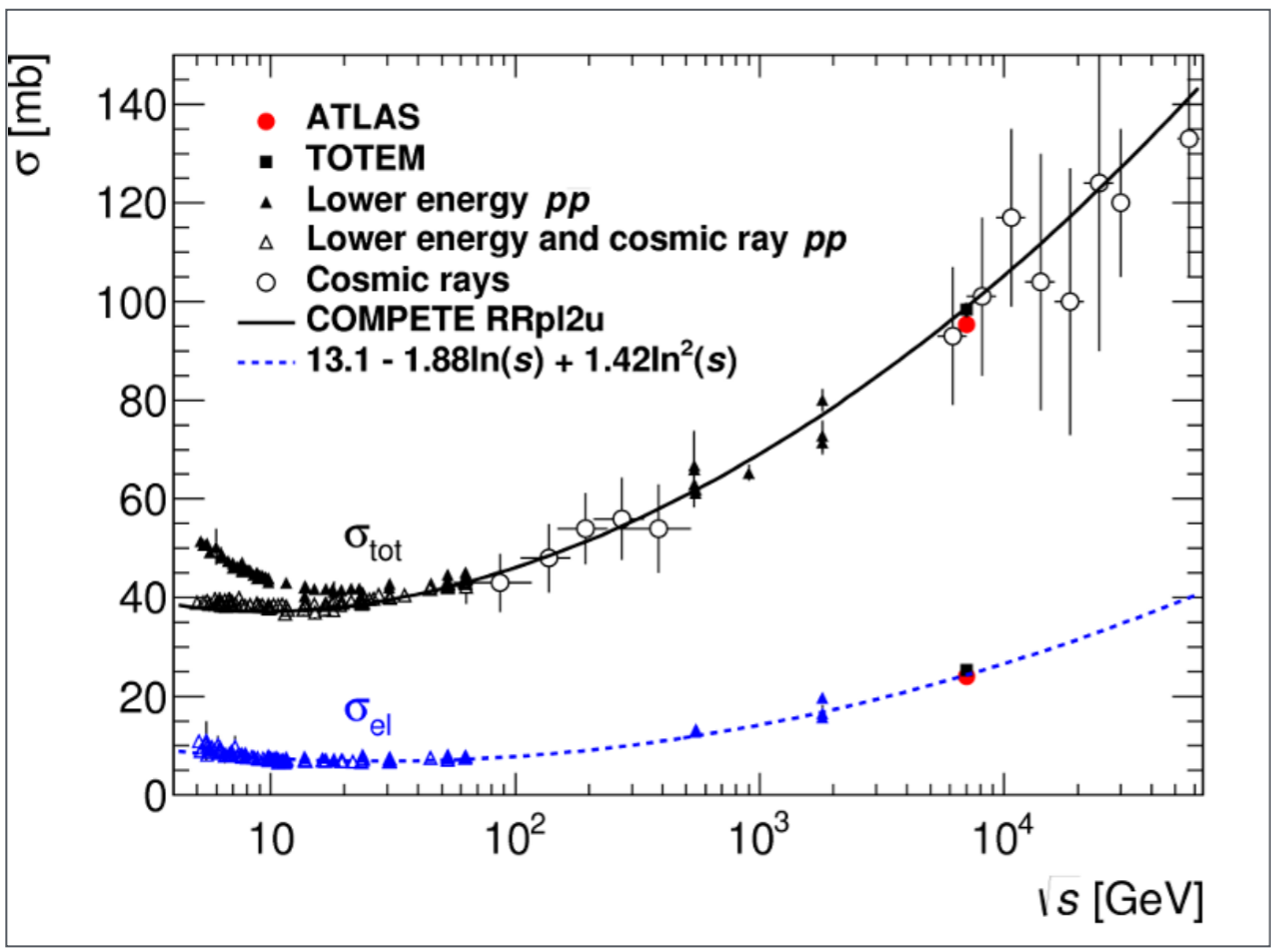


The basics

Elastic and total pp cross section

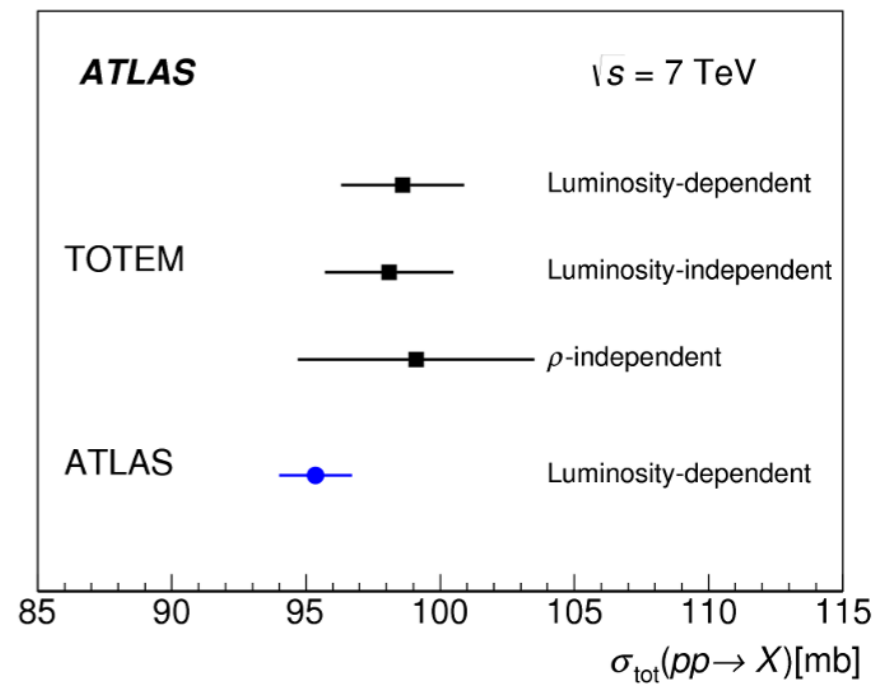


ALFA detectors at $\pm 240\text{m}$



arXiv:1408.5778

Result: $\sigma_{\text{tot}}(pp \rightarrow X) = 95.35 \pm 0.38 \text{ (stat)} \pm 1.25 \text{ (exp)} \pm 0.37 \text{ (extr)} \text{ mb}$
 and elastic slope $B = 19.73 \pm 0.14 \text{ (stat)} \pm 0.26 \text{ (syst)} \text{ GeV}^{-2}$



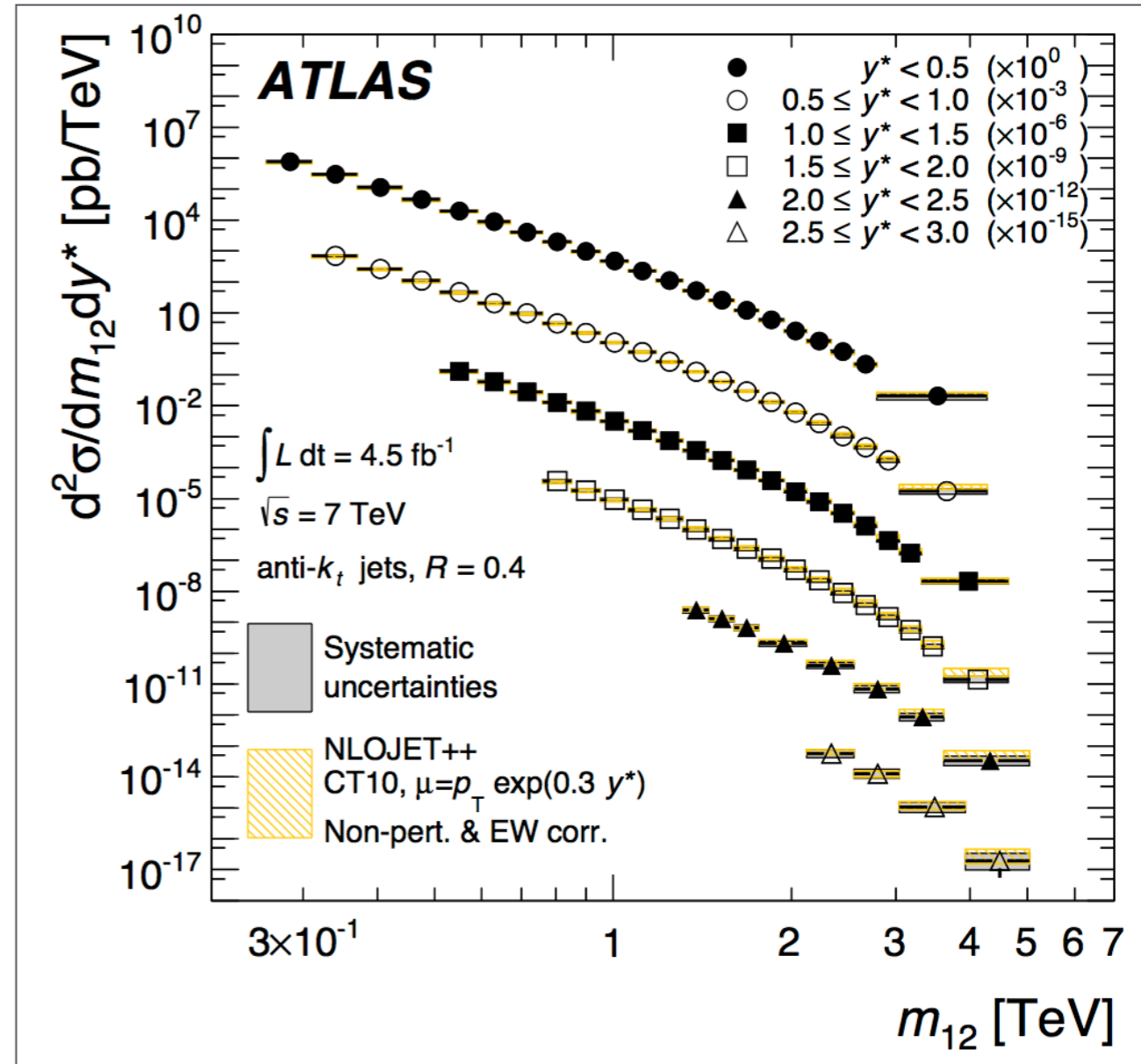
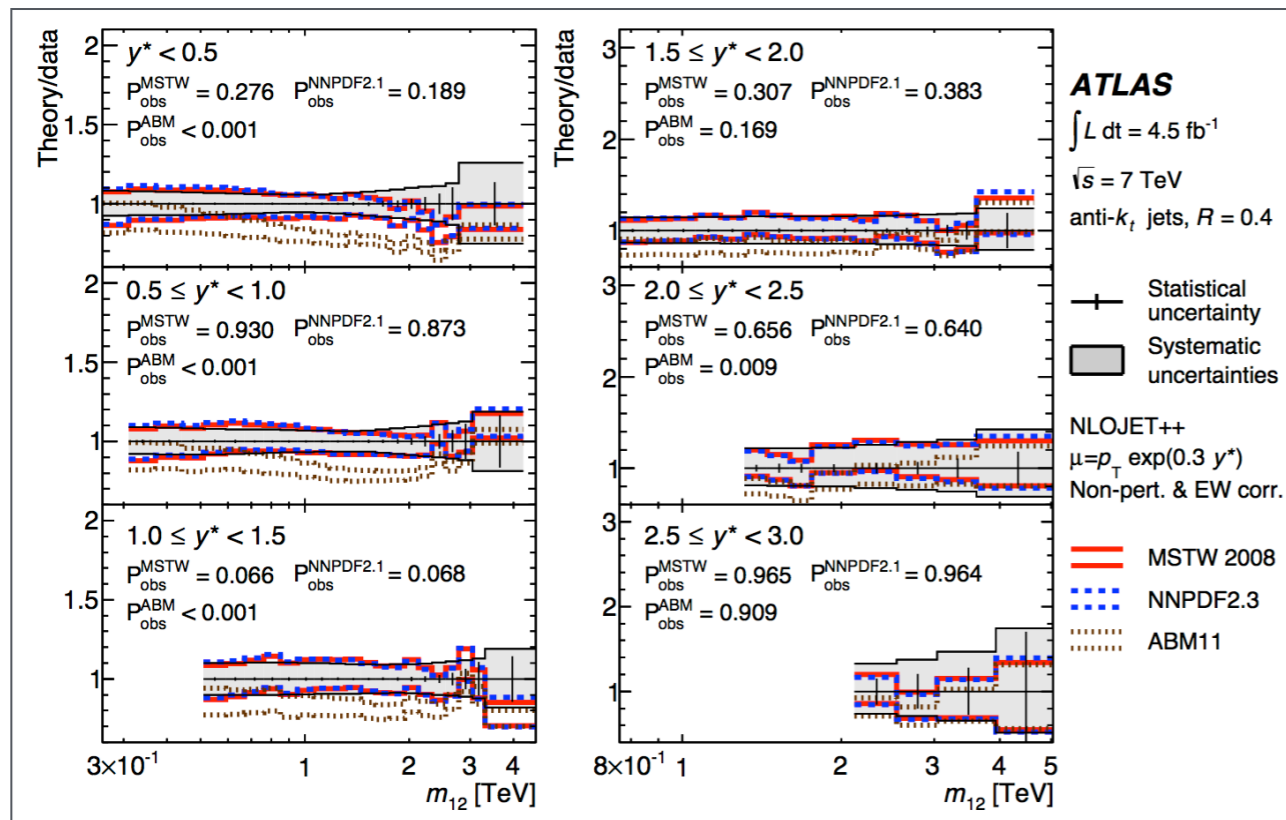
QCD jet physics

di-jet observables



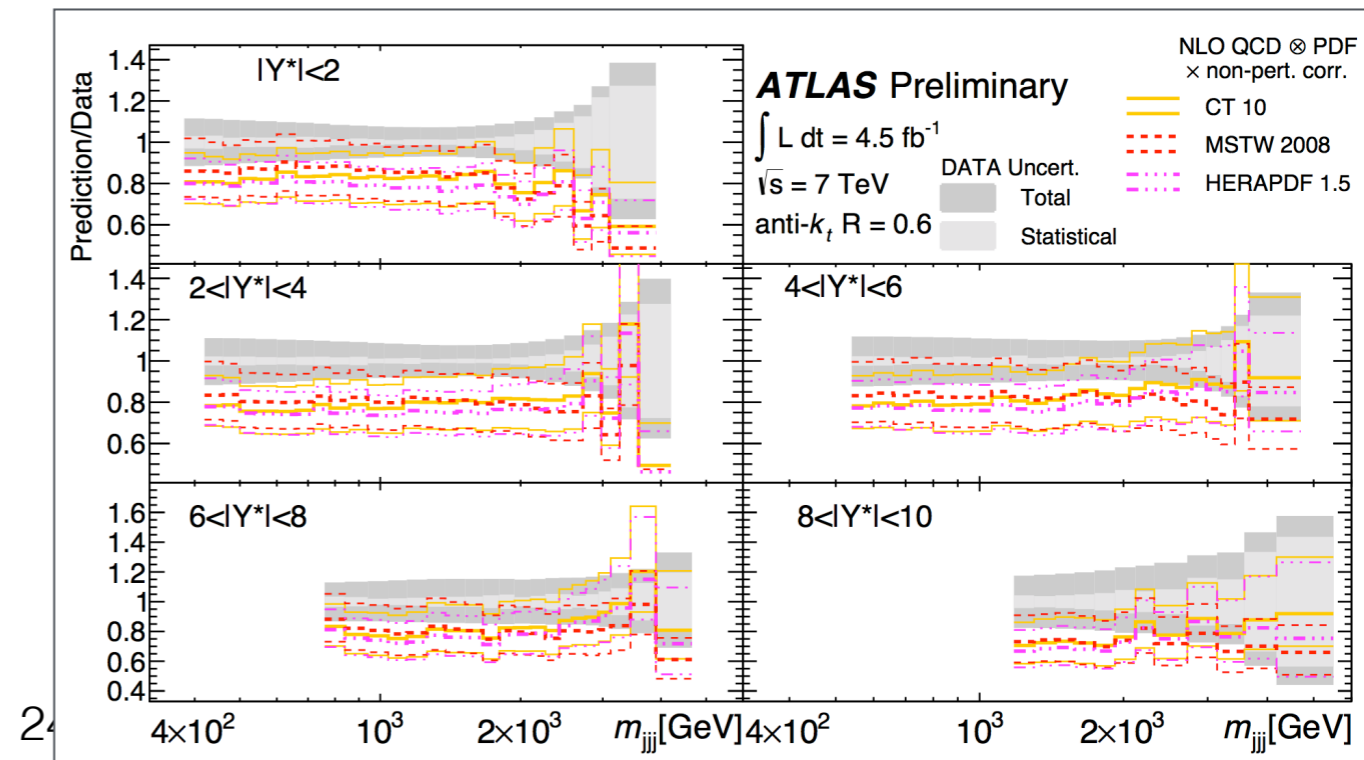
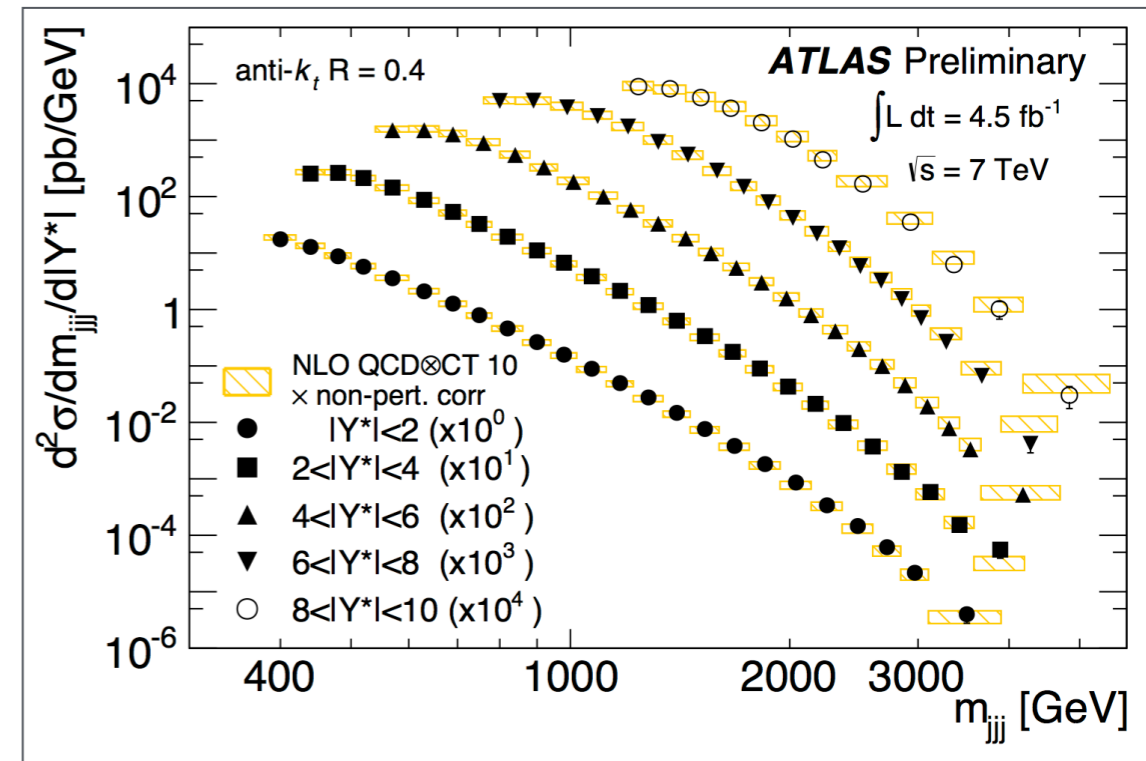
Bins of m_{12} and rapidity

Sensitive test of NLO and pdf predictions

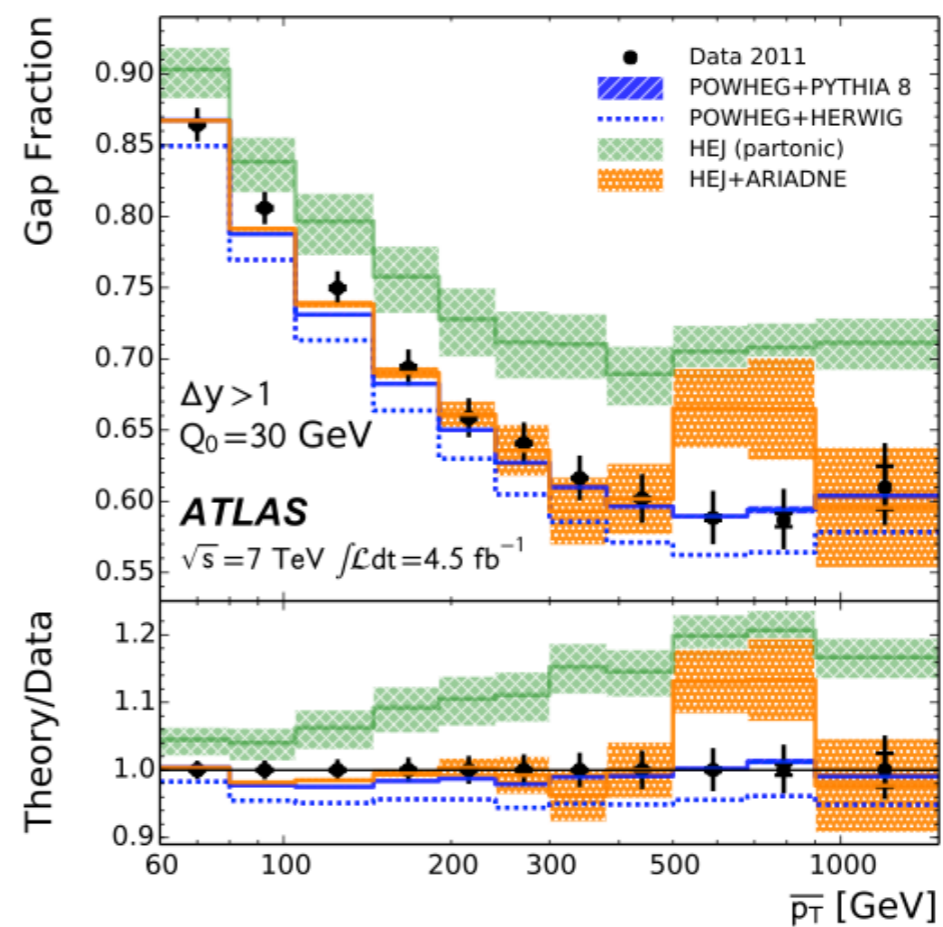
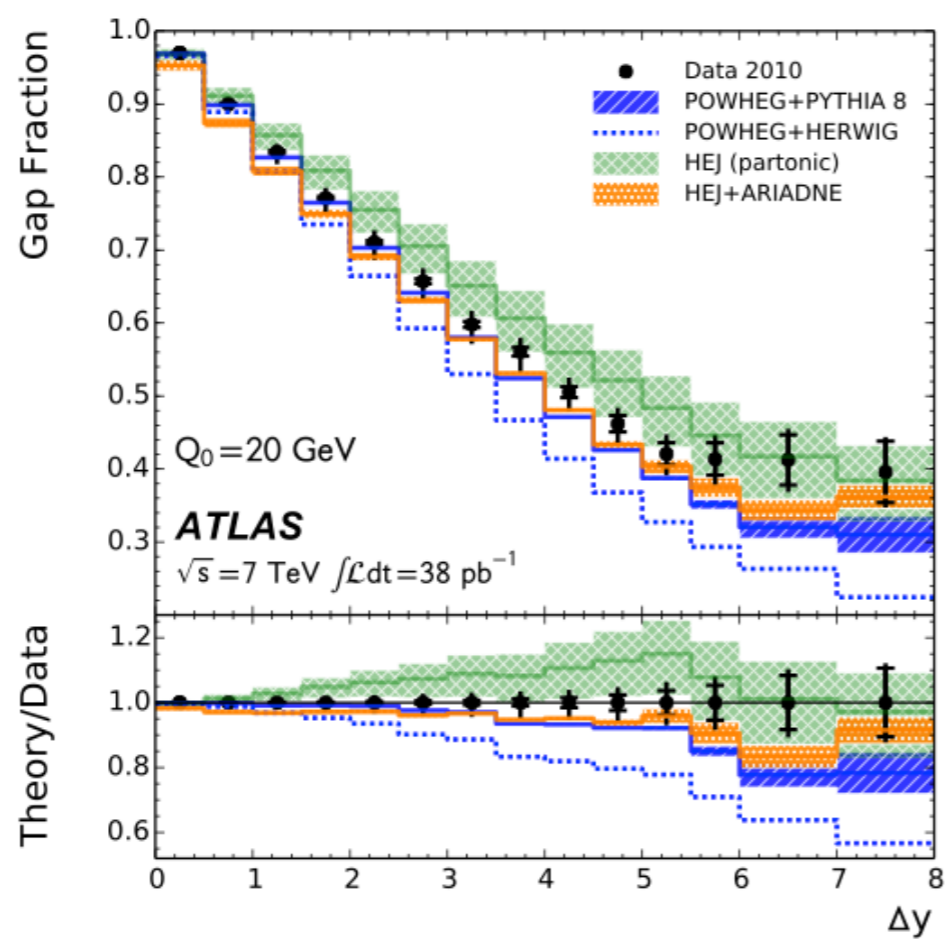


QCD jet physics

3 jet cross sections



jet gaps



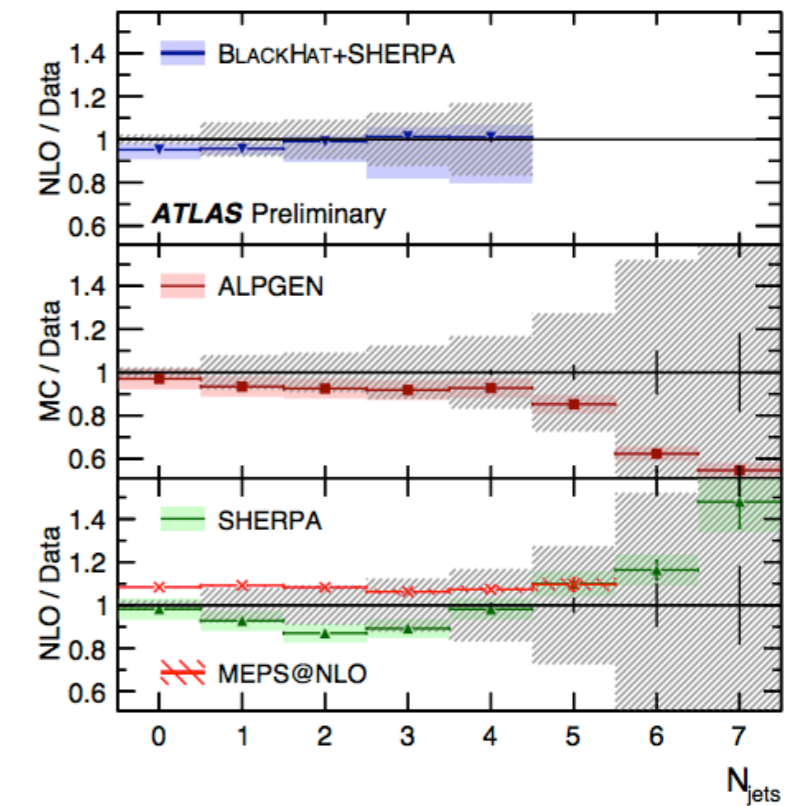
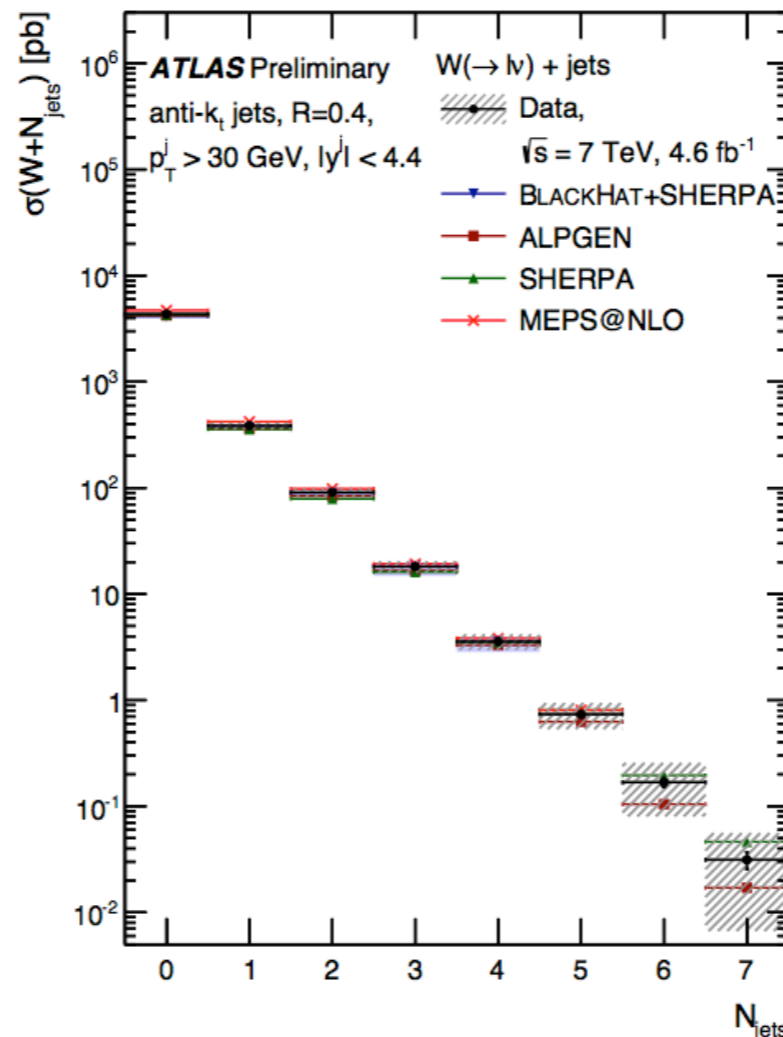
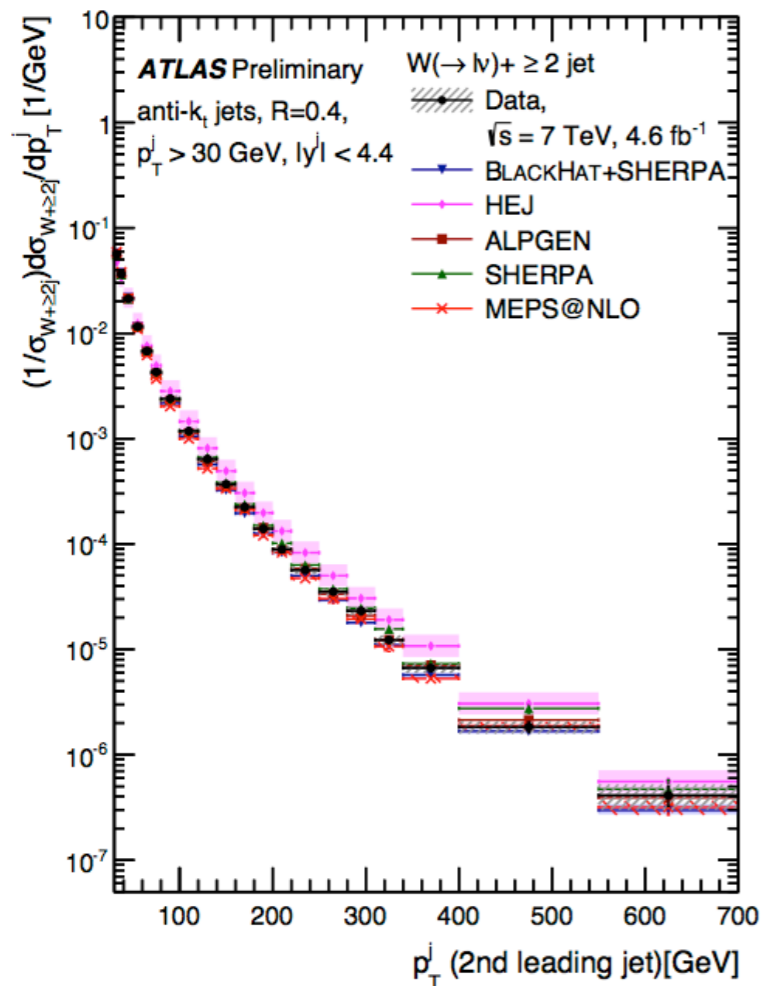
W+jets

up to 8!



leptonic decay modes

differential in many quantities, e.g.



Electroweak physics

multibosons



Standard Model processes

TCG for $Z/\gamma - WW$

QGC for $WWWW$

Non-standard (anomalous) couplings

$Z/\gamma - Z/\gamma - Z/\gamma$

Results on:

$W\gamma, Z\gamma$

ZZ

$W+W-$

$W\pm Z$, fully leptonic and semileptonic

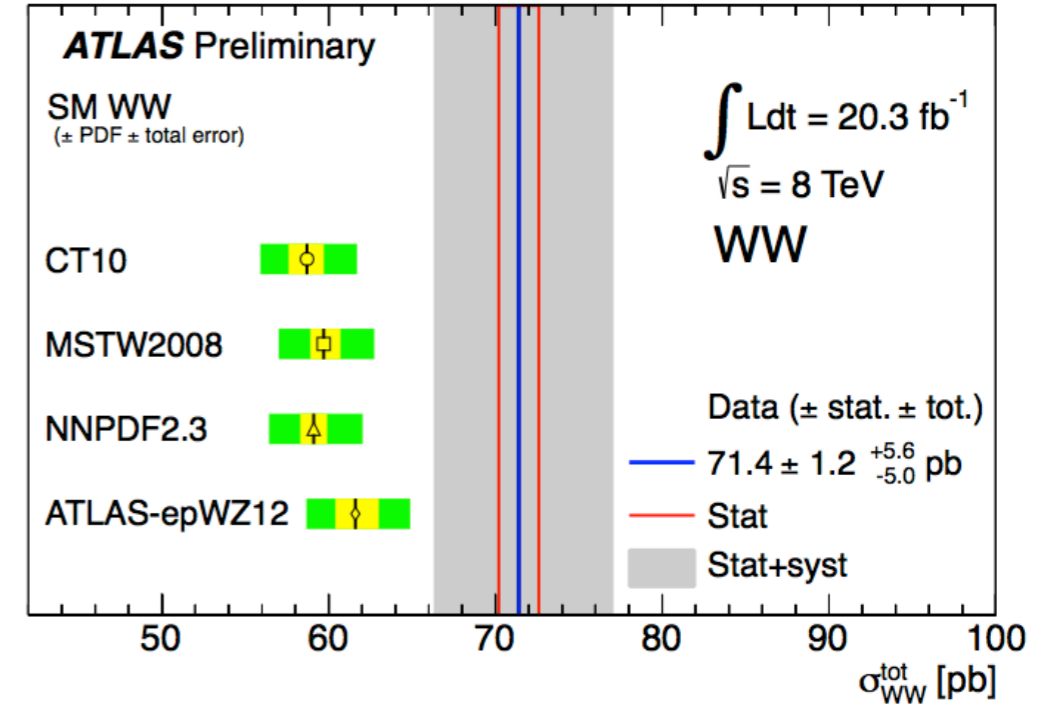
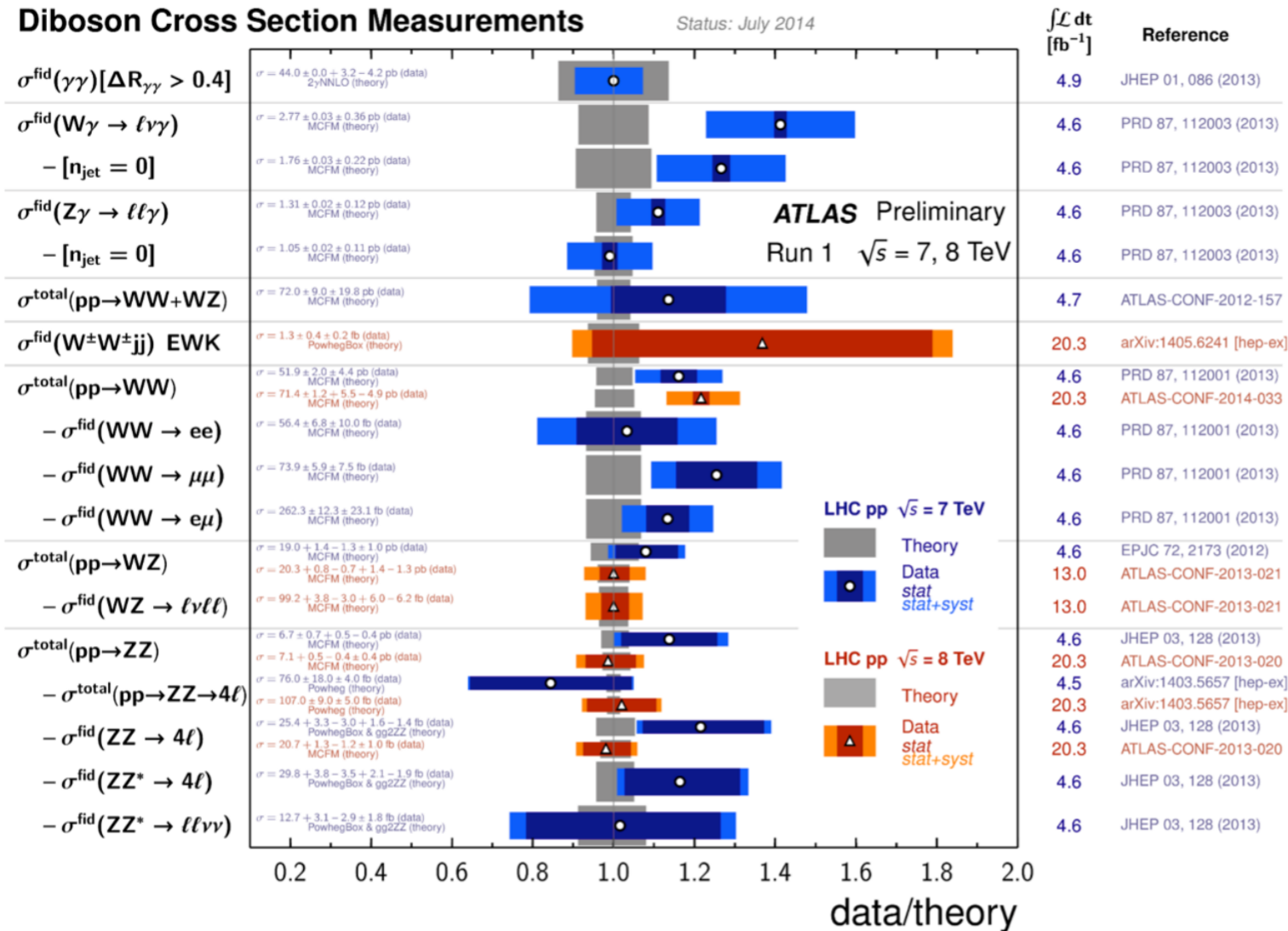
W+W-

continues to be interesting



Diboson Cross Section Measurements

Status: July 2014



ATLAS-CONF-2014-033

But Wait...
**THERE'S
MORE!**

Z production

heavy flavor: $W + c$ (arXiv:1402.6263) and $Z \rightarrow b\bar{b}$ (arXiv:1404.7042)

underlying event

ZpT

jet structure

boosted W/Zs

Multi-bosons

aQGCs

electroweak Zjj production

WWjj scattering



Top quark Physics

Notable results



from Run 1 we anticipated:

precision cross sections, precision mass of 1-3.5 GeV,
rediscovery of single top, single top W_t channel

from Run 1, we achieved:

precise cross sections, mass, distributions $t\bar{t}$ and single top

in Run 2, we expect:

20x statistics!

Top quark cross section

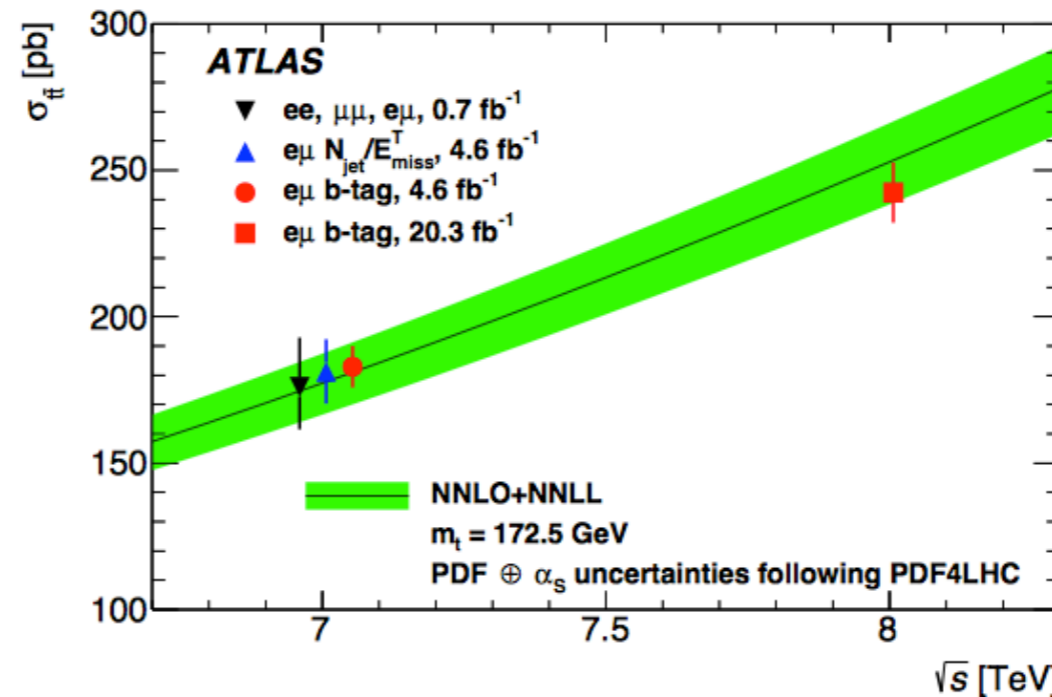
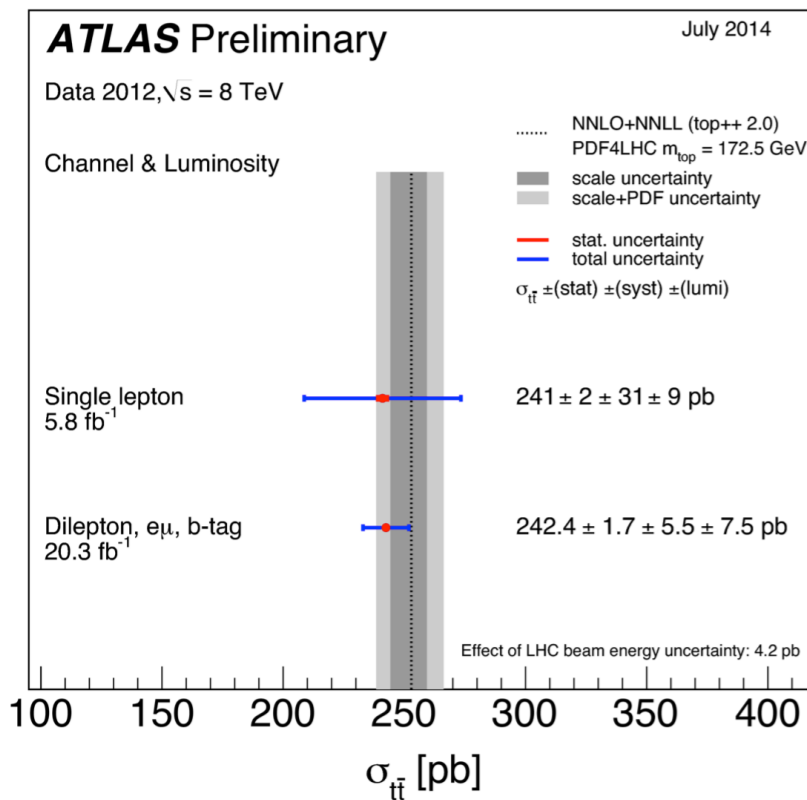
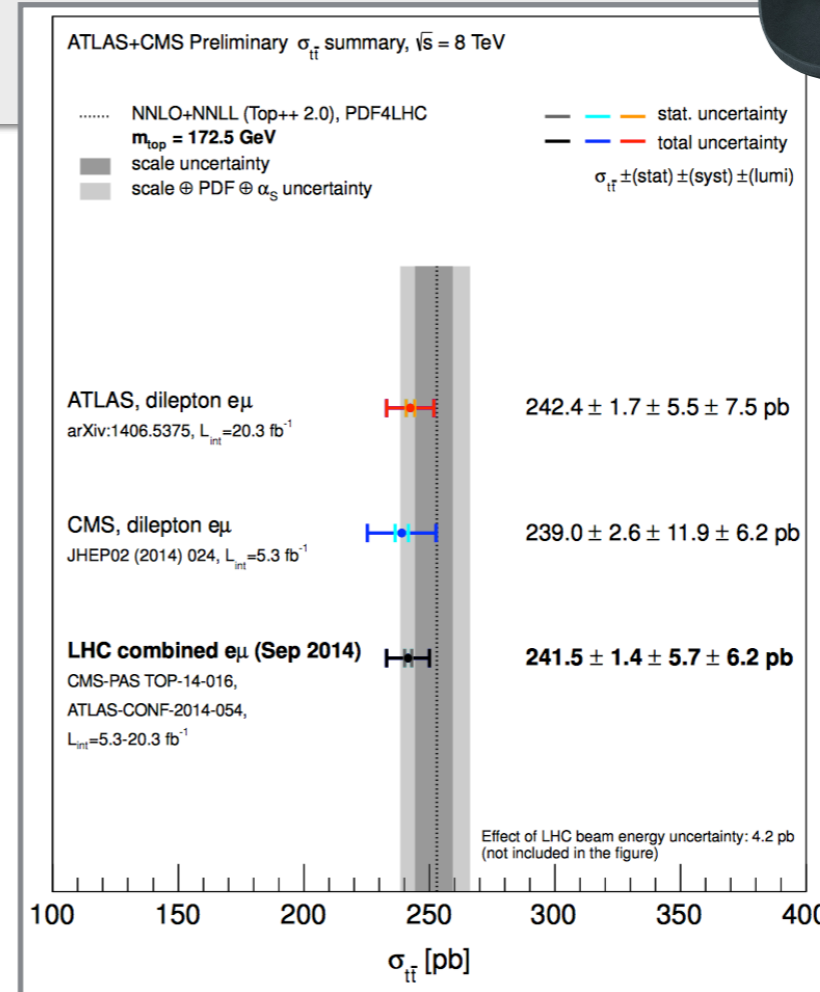
win-win



Combined ATLAS+CMS

$$\sigma_{t\bar{t}} = 242.4 \pm 1.7 \pm 5.5 \pm 7.5 \pm 4.2 \text{ pb (stat/syst/lumi/beam energy)}$$

$$\sigma_{t\bar{t}} = 241.4 \pm 1.4 \pm 5.7 \pm 6.2 \text{ pb @ } m_t = 172.5 \text{ GeV (stat/syst/lumi)}$$



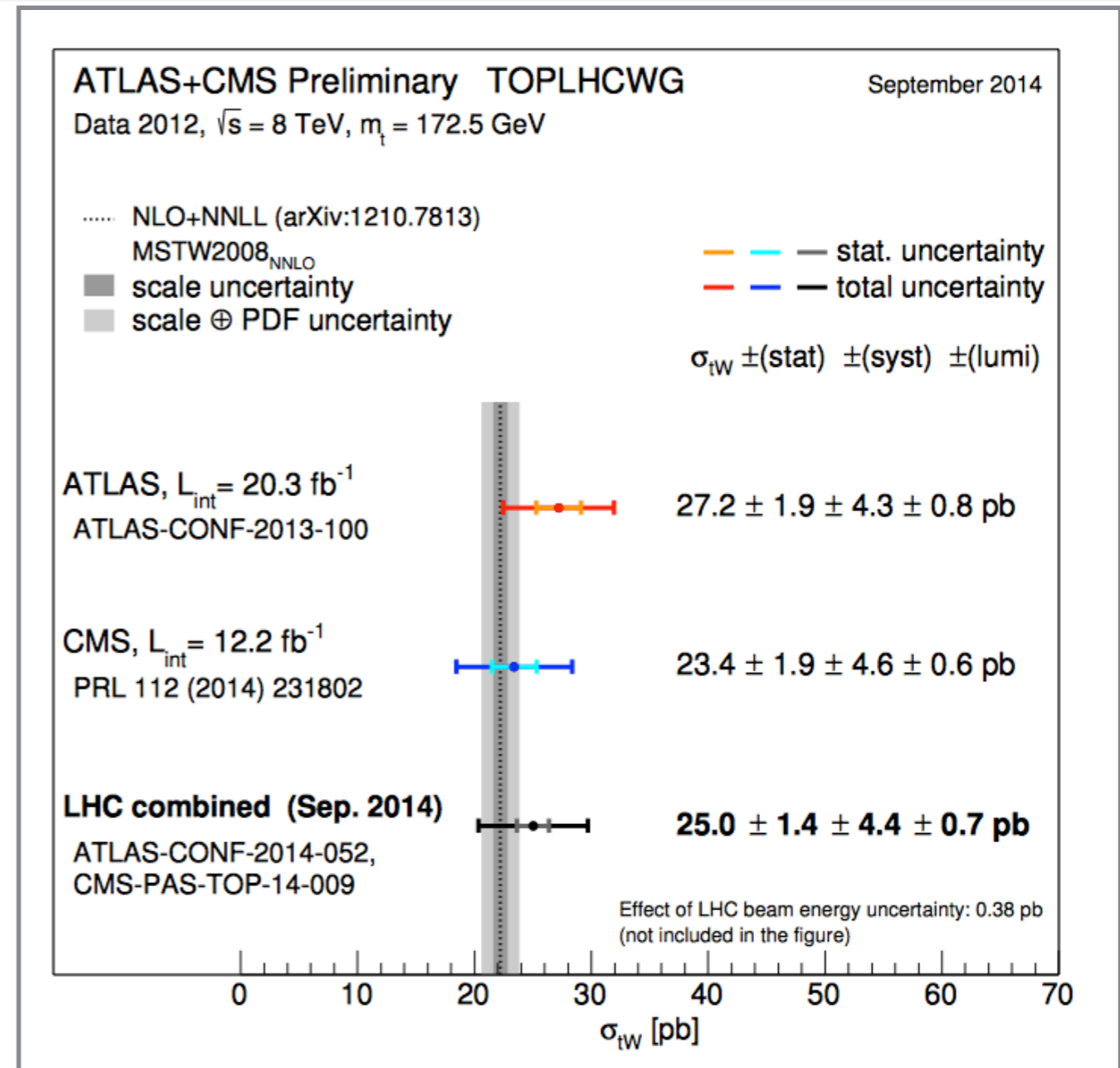
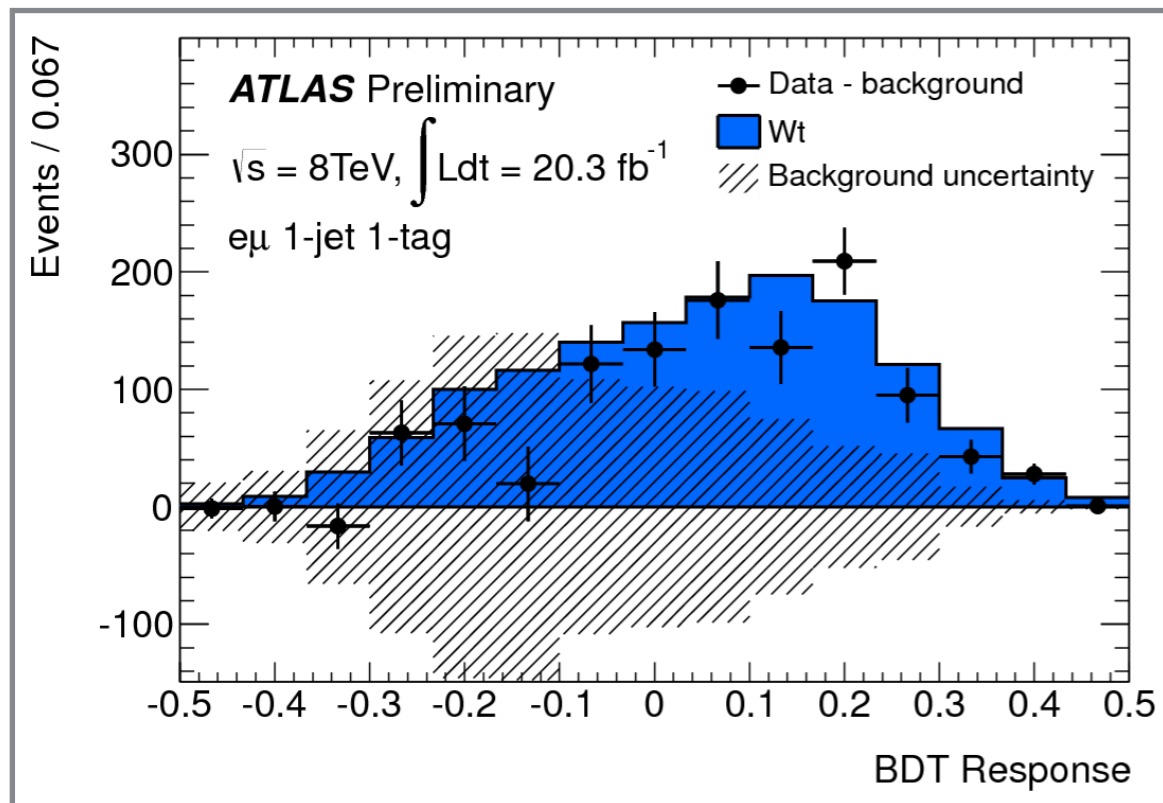
Single top, Wt

win-win



Evidence at 4.2 sigma

then ATLAS + CMS



ATLAS-CONF-2013-052

ATLAS-CONF-2013-100

Top quark mass

win-win-win

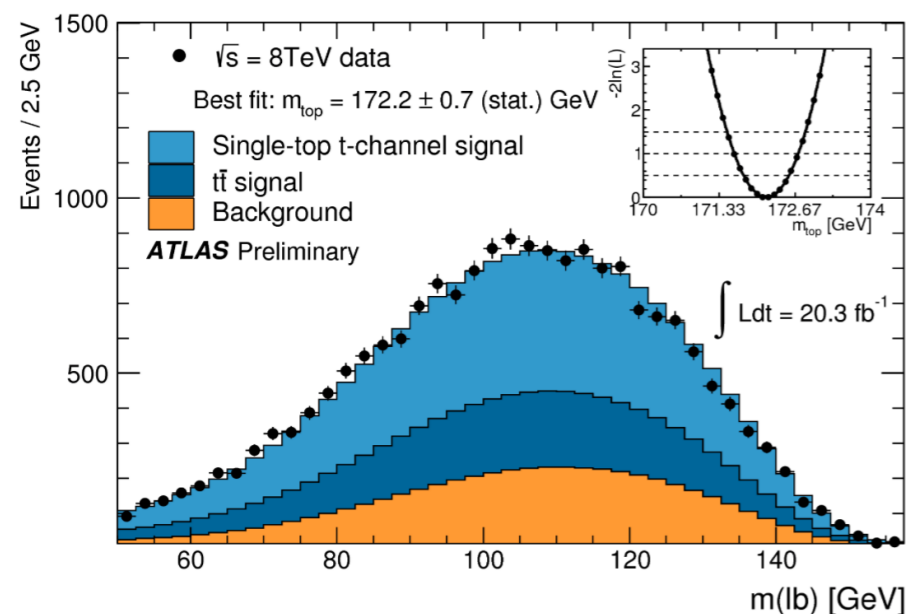


2008 estimates for 1/fb: $\pm 1-3.5$ GeV three channels

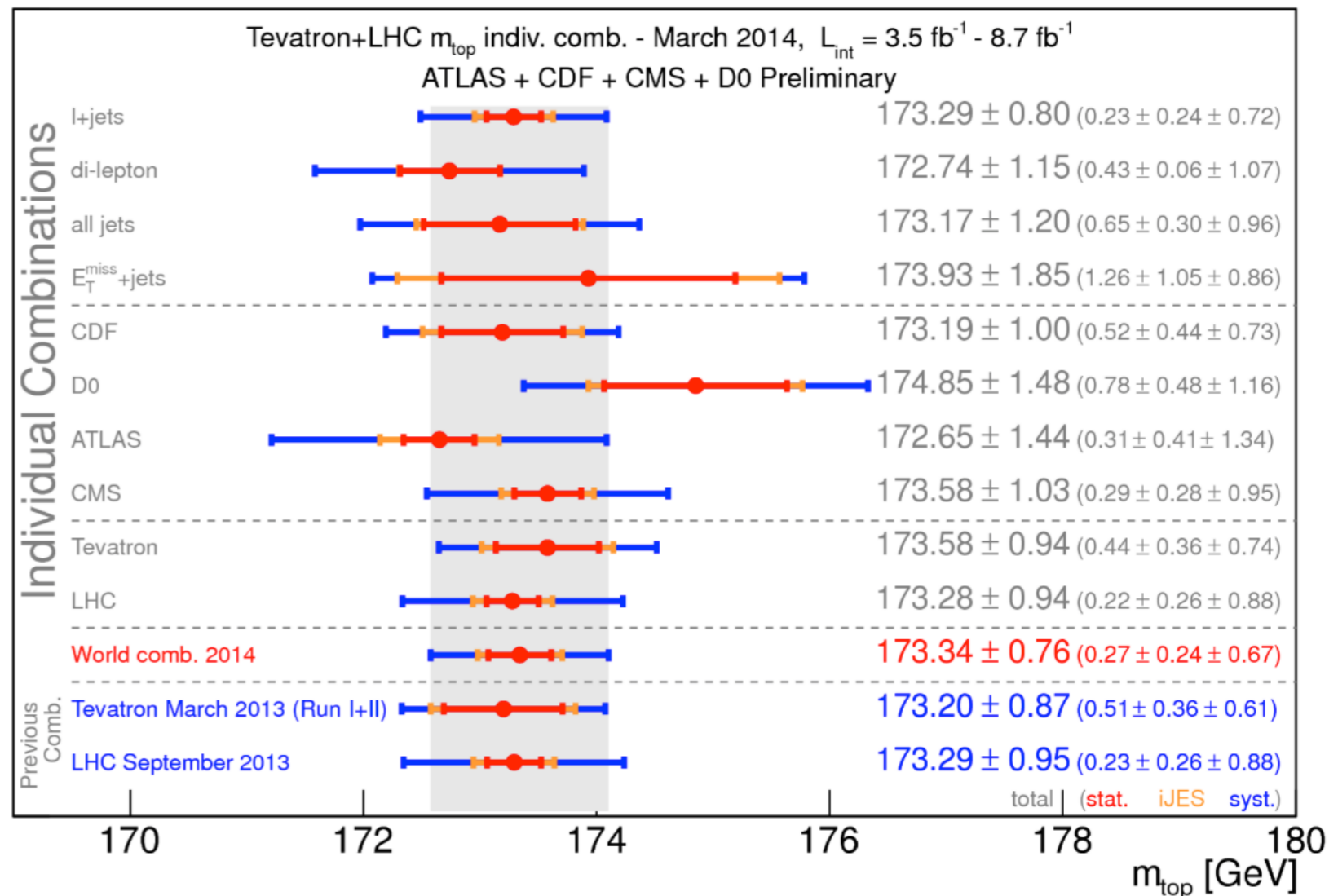
better than advertised

Single top

t channel template



ATLAS-CONF-2014-055



ATLAS-CONF-2014-008

But Wait...
**THERE'S
MORE!**



top cross sections

all hadronic final states, tau final states, $t\bar{t}$ /Z/WW

differential distributions: parton level, boosted $t\bar{t}$, associated production with jets and heavy flavor, W/Z, high p_t boosted

single top

CP violation

top mass

pole mass from cross section tail, t - T mass difference

top properties

charge, W polarization, FCNC searches, charge asymmetry, t polarization

Exotic Physics

Notable results



from Run 1 we anticipated:

supersymmetry discovery? no Higgs? Higgs? BSM Higgses (SP?),
extension of Tevatron IVB' searches by x2 or more,

from Run 1 we achieved:

supersymmetry limits! one Higgs, BSM Higgs searches, IVB' searches

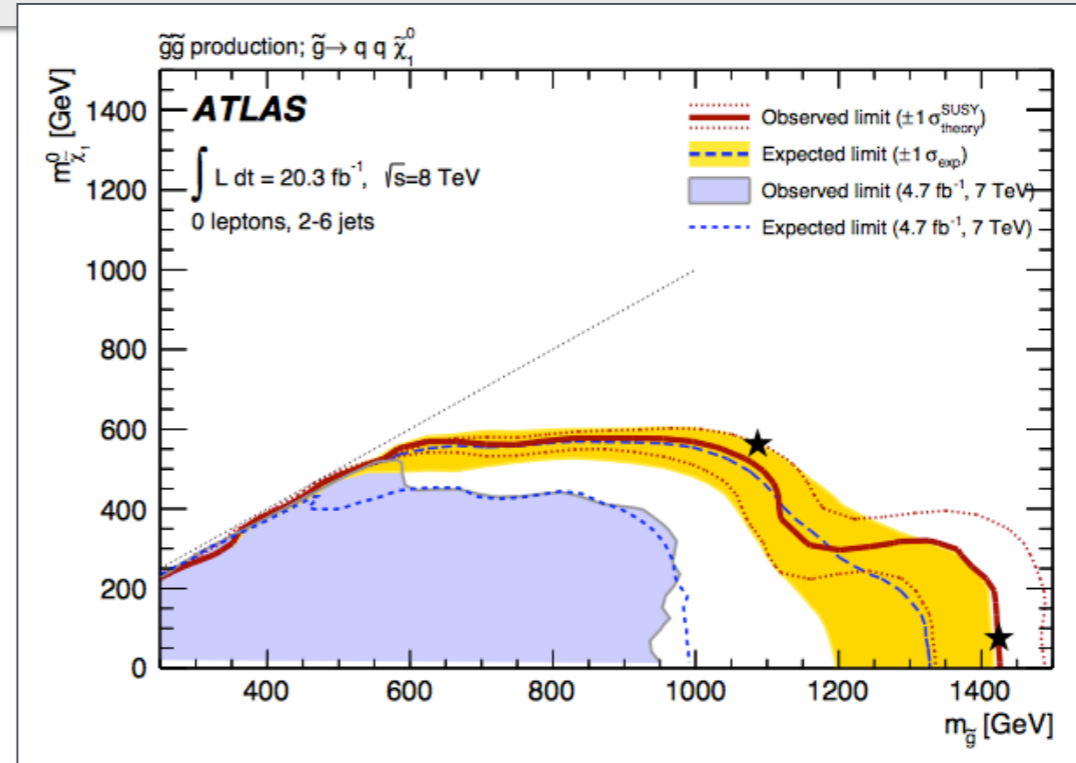
in Run 2, we expect:

supersymmetry discovery? BSM Higgs hints, additional IVB' searches

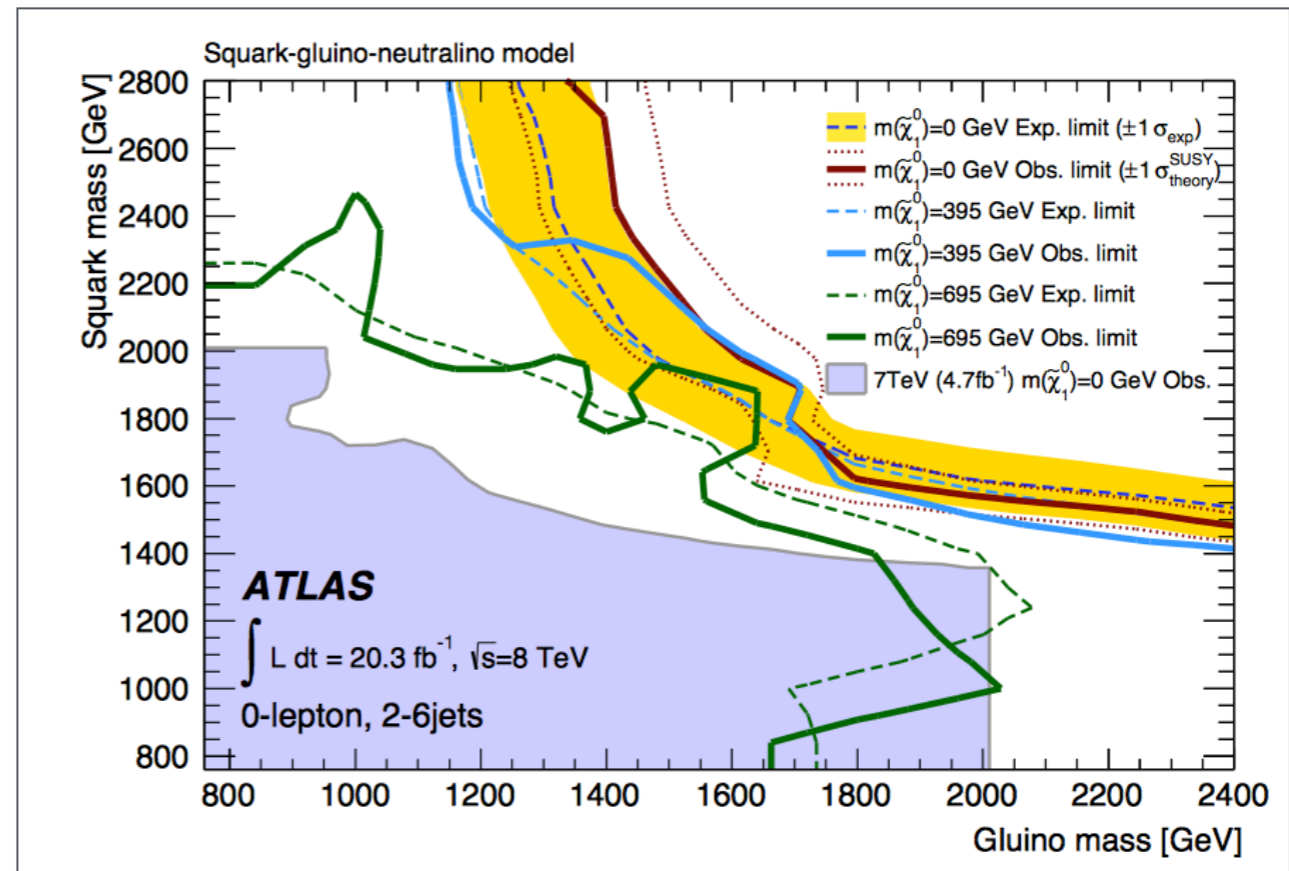
Supersymmetric Physics

squarks and gluinos

DESPERATELY
SEEKING SUSAN



arXiv:1405.7875



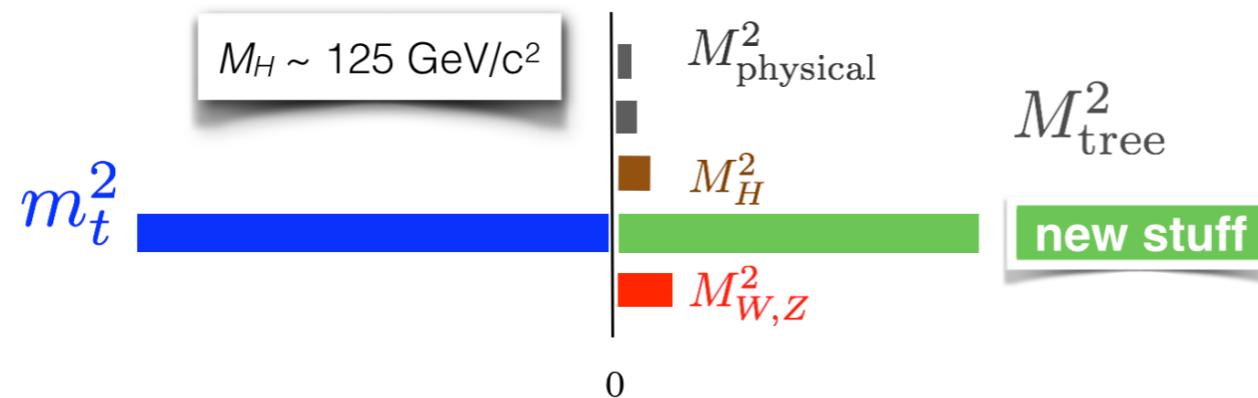
stop
stealthy stop?

STOP! IN THE NAME OF LOVE

I'M IN LOVE AGAIN



$$M_H^2 = M_{\text{tree}}^2 + \left(\text{Higgs self-energy loop} \right) + \left(\text{top quark loop} \right) + \left(\text{W/Z loop} \right) + \left(\text{BSM} \right)$$



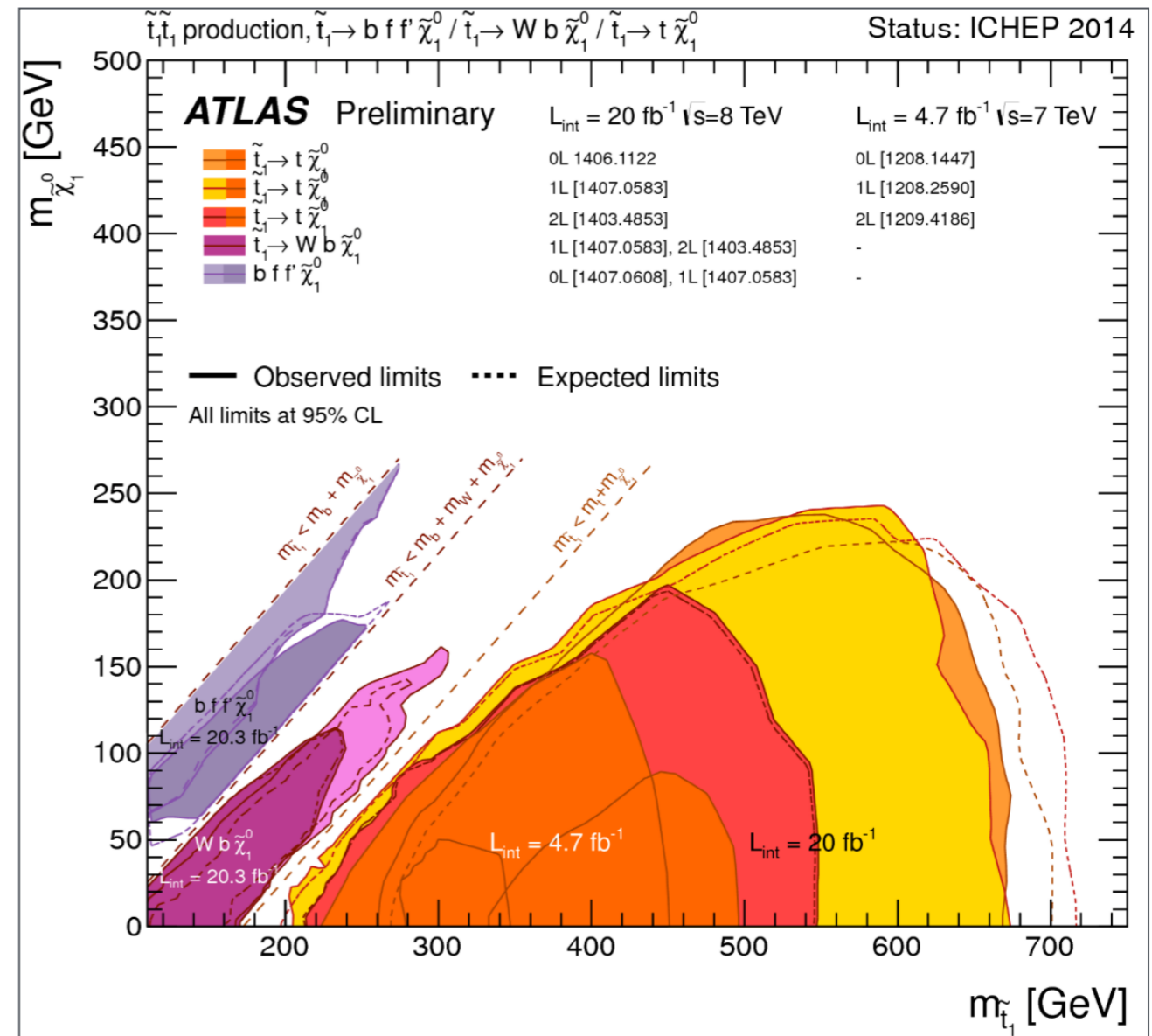
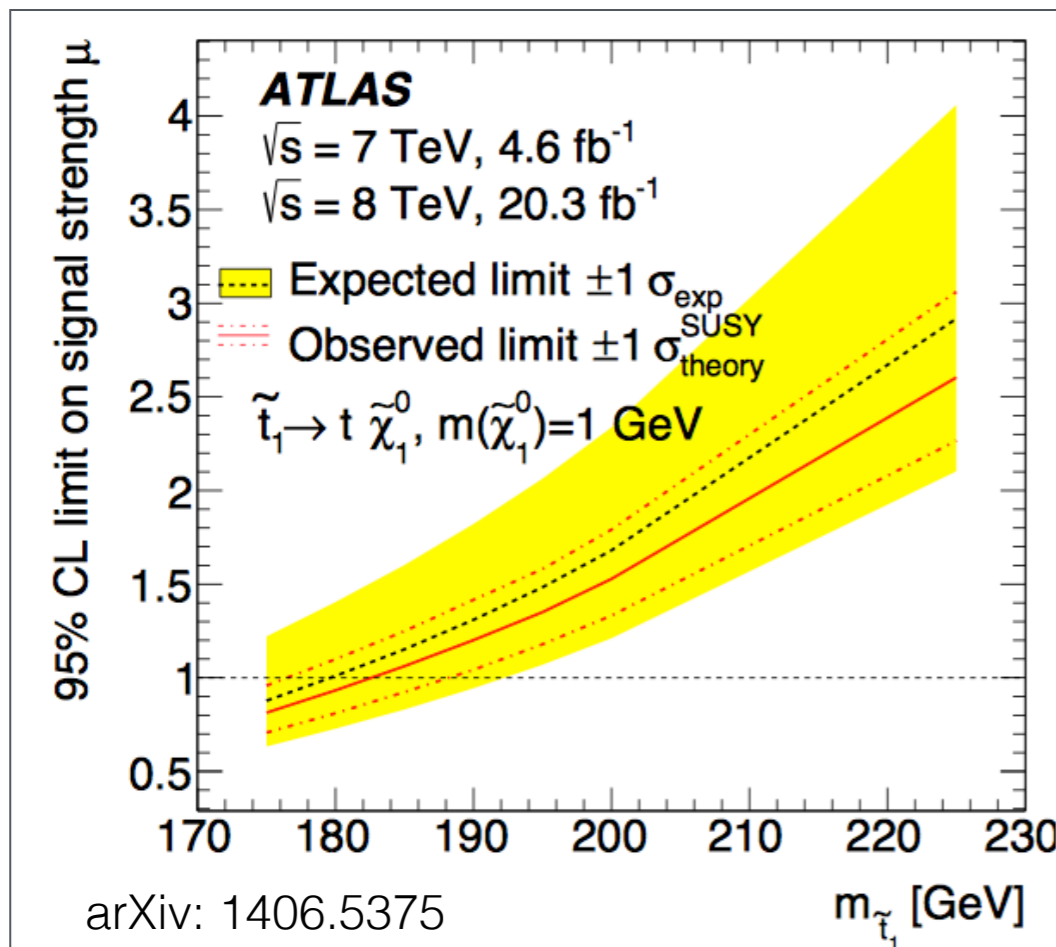

DON'T PANIC
ACT NATURAL

stop

stealthy stop?

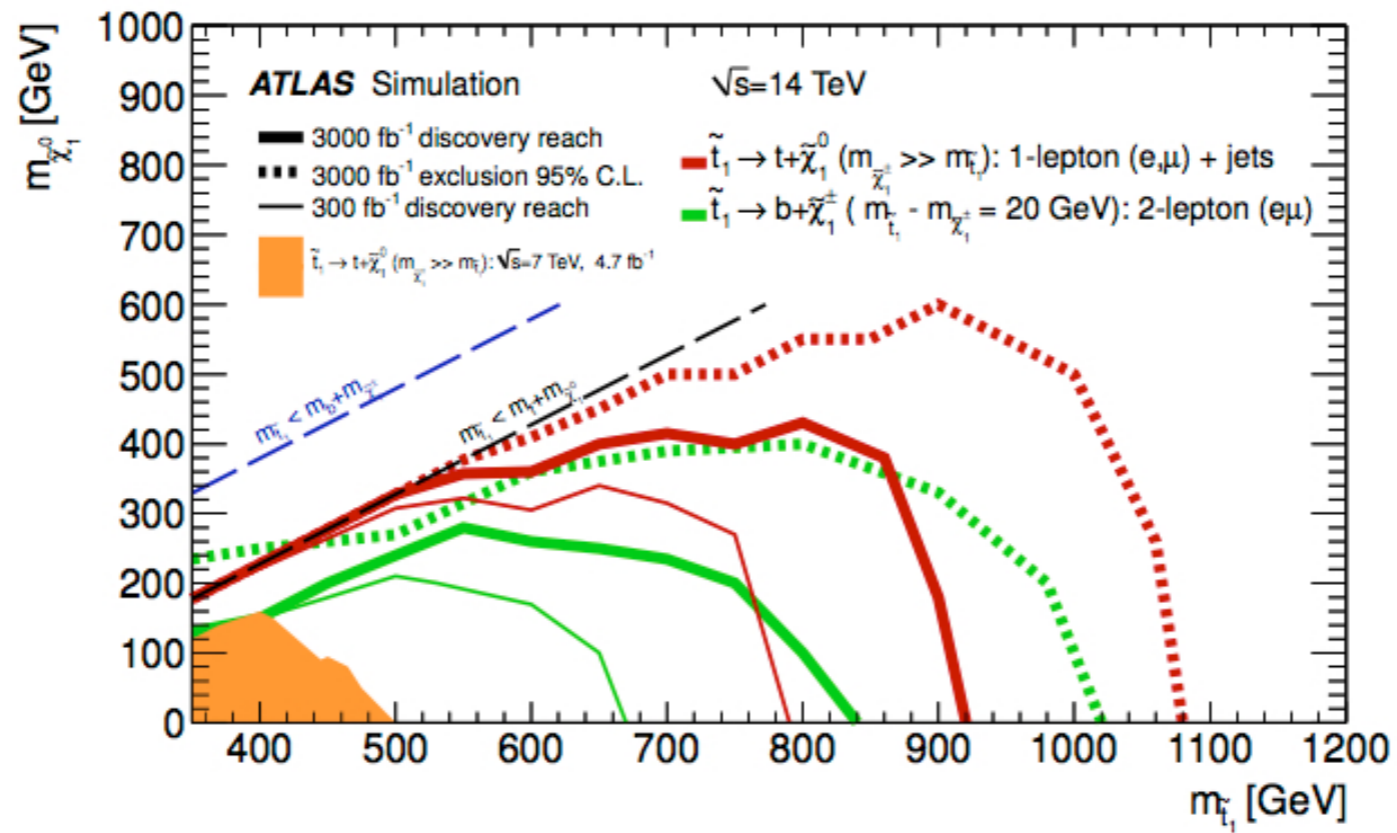


- arxiv:1208.1447 (0 lepton 7 TeV)
- arxiv:1208.2590 (1 lepton 7 TeV)
- arxiv:1209.4186 (2 leptons 7 TeV)
- arxiv:1407.0583 (1 lepton 8 TeV, 20/fb)
- arxiv:1406.1122 (0 lepton + 5/6 jets 8 TeV, 20/fb)
- arxiv:1403.4853 (2 lepton + jets+ MET 8 TeV, 20/fb)
- [7] arxiv:1407.0608 (0 lepton + jets (c-jets) + MET 8 TeV, 20/fb)



Run 2

cms Energy directly extends searches

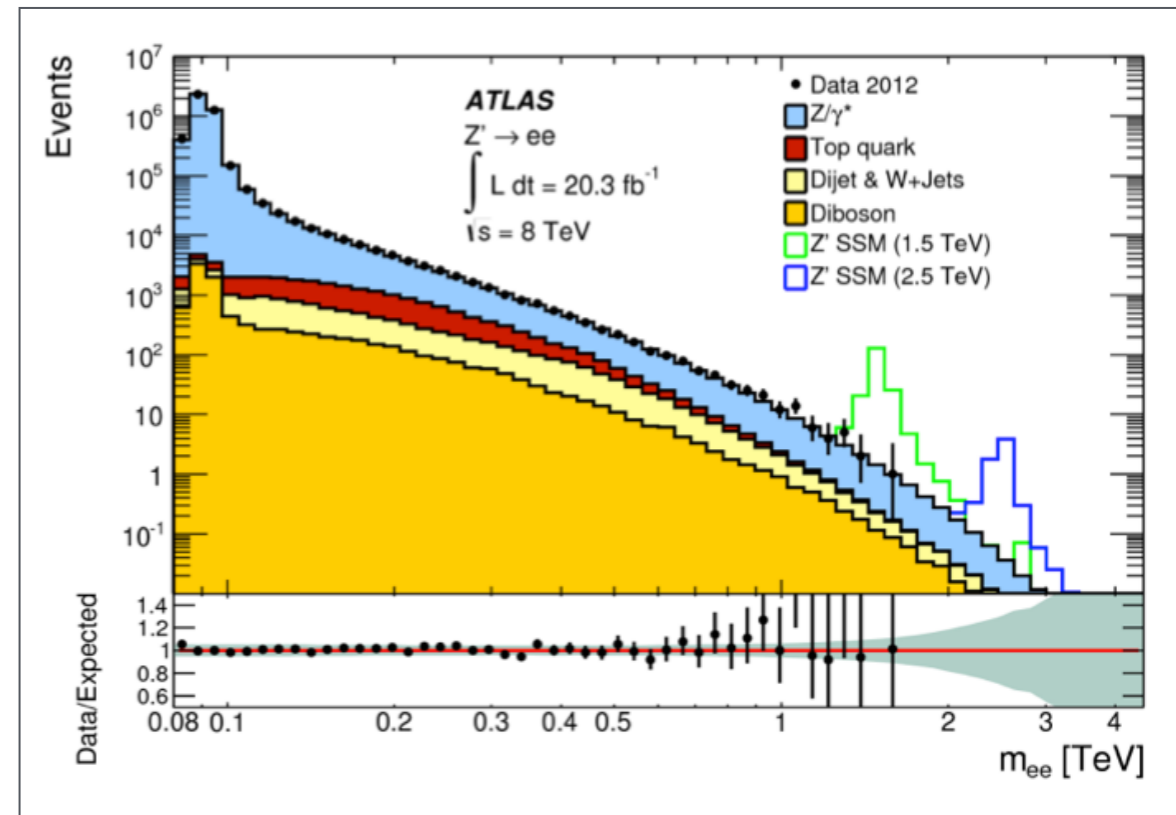
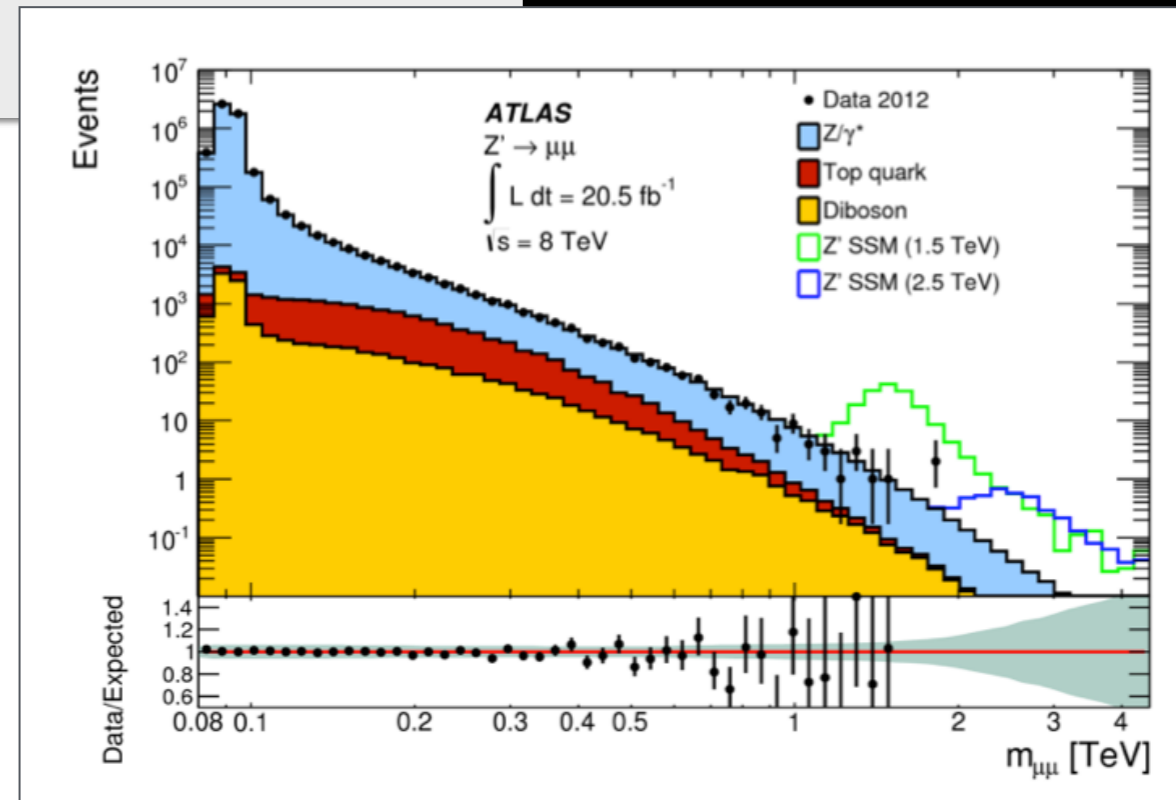
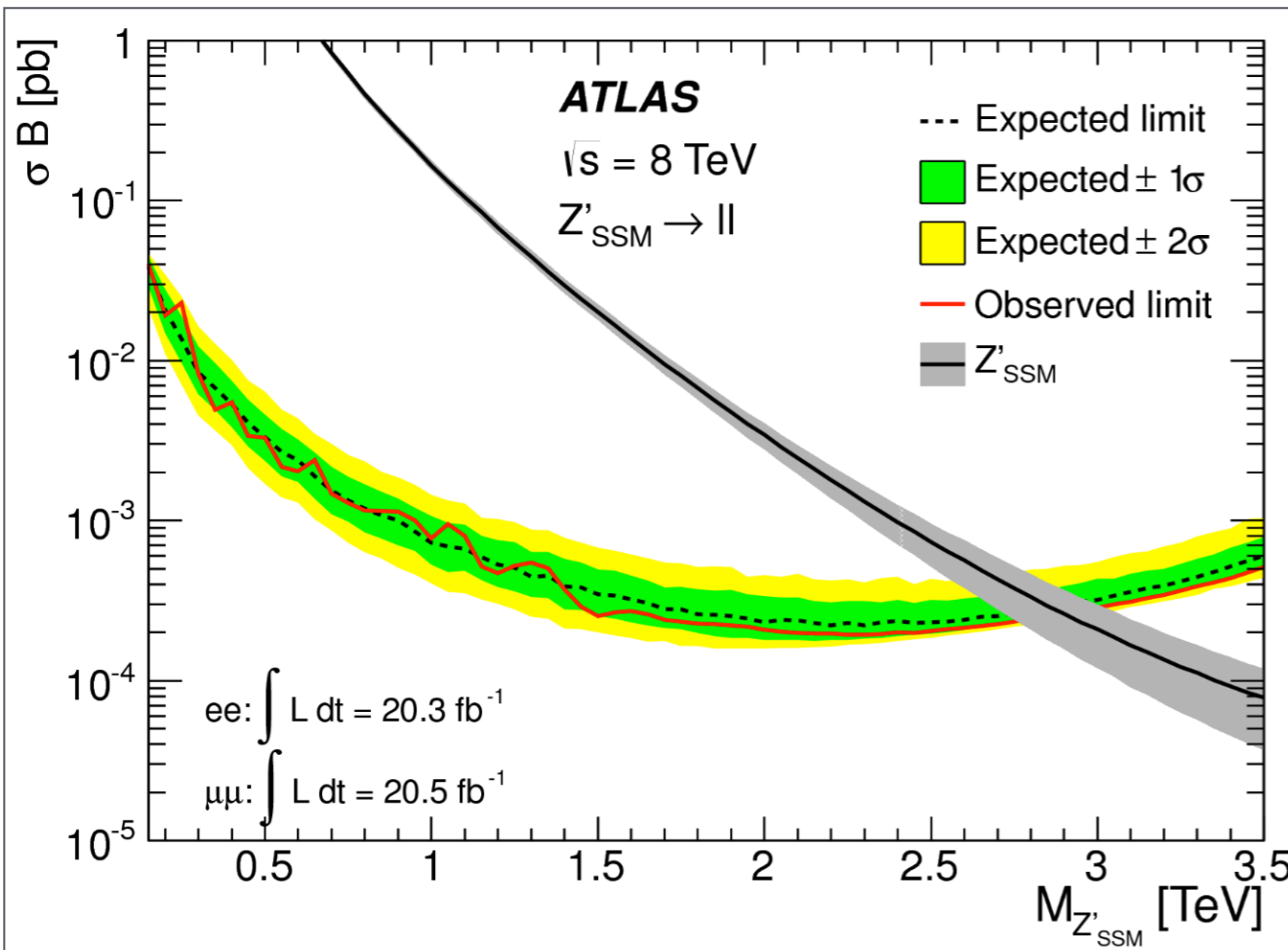


ATL-PHYS-PUB-2012-001

Z prime

electrons and muons

a standard way to extend the SM

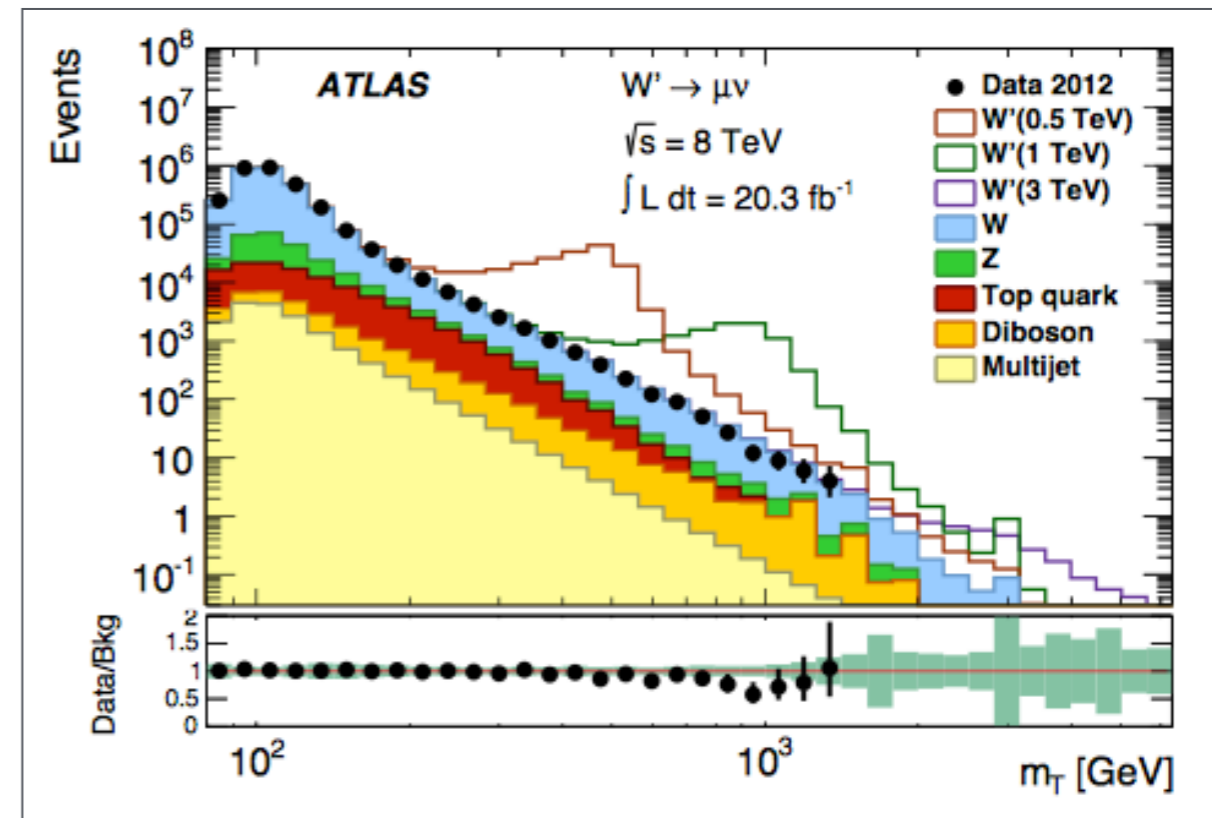
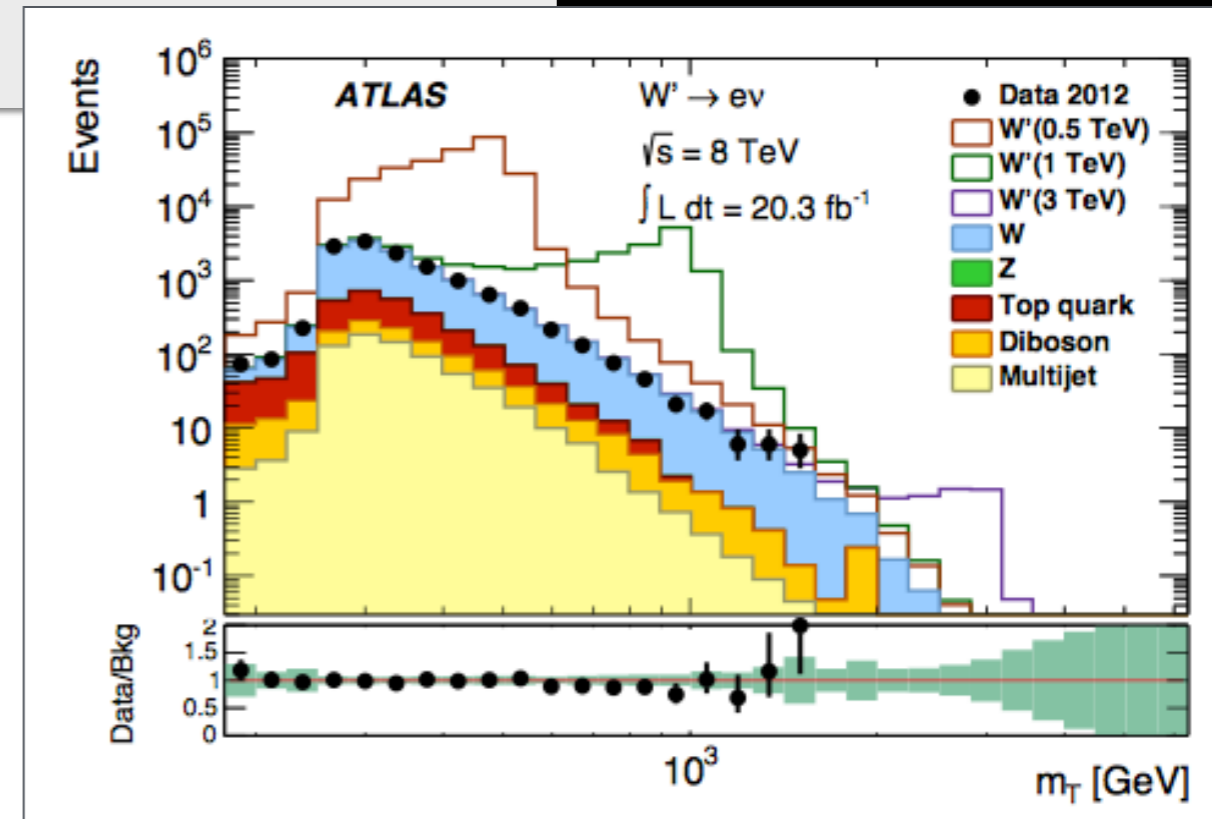
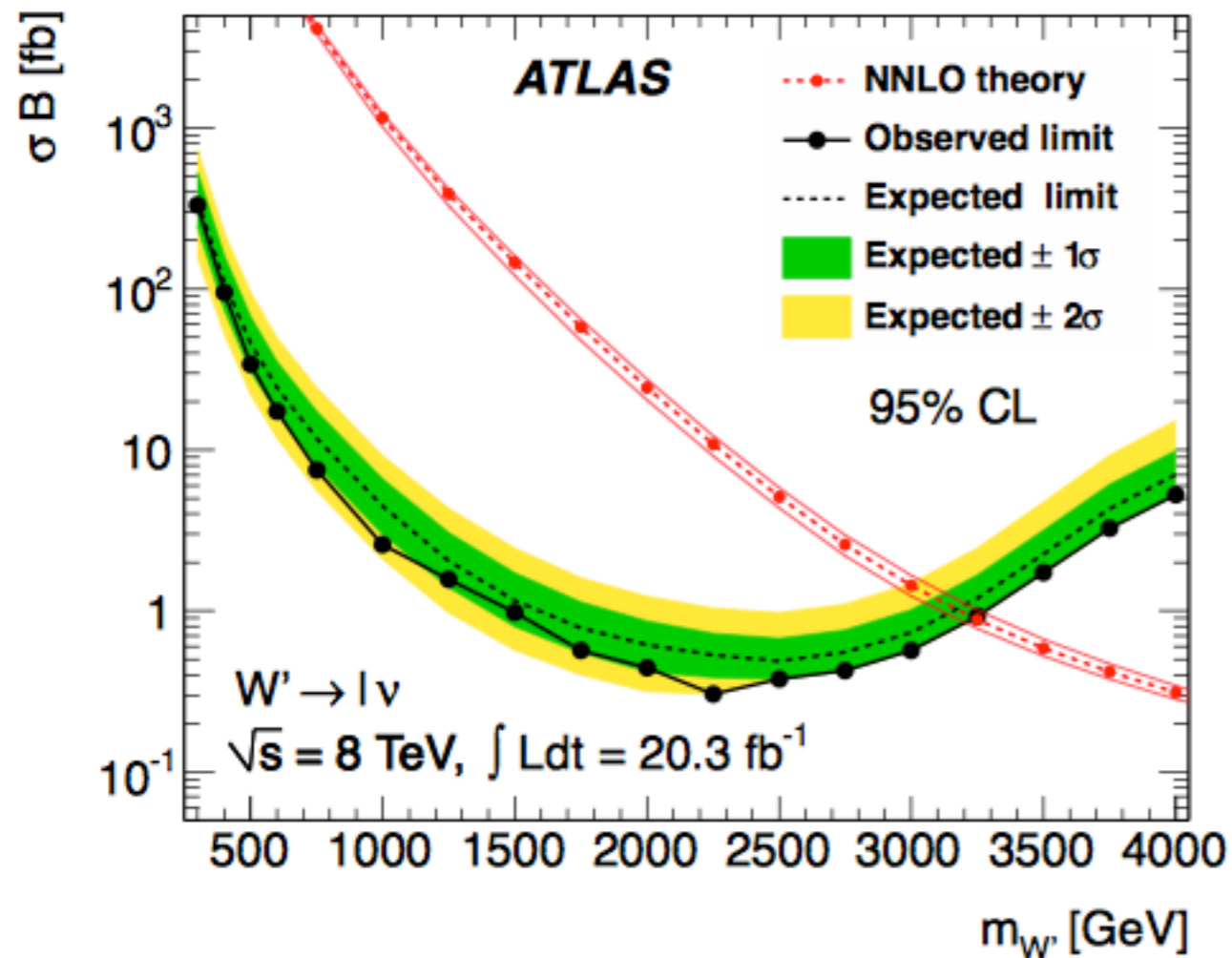


W prime

electrons and muons

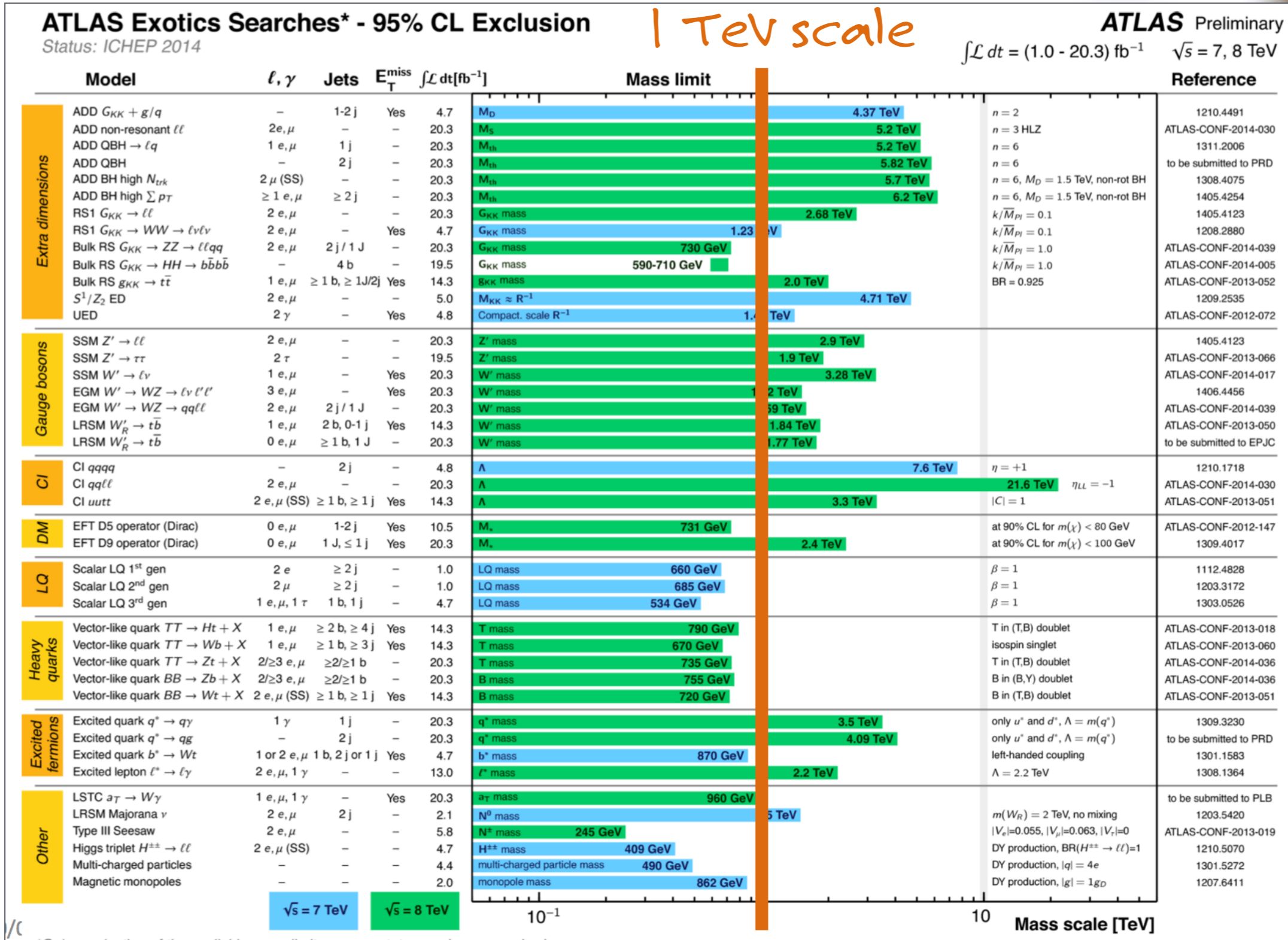
a partner

arXiv:1407.7494v1



Exotics in a nutshell

a big nutshell



SUSY in a nutshell



ATLAS SUSY Searches* - 95% CL Lower Limits

Status: ICHEP 2014

1 TeV scale

ATLAS Preliminary

$\sqrt{s} = 7, 8 \text{ TeV}$

Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L} d\mathcal{L} [\text{fb}^{-1}]$	Mass limit	Mass limit	Reference	
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	\tilde{q}, \tilde{g}	1.7 TeV	1405.7875
	MSUGRA/CMSSM	1 e, μ	3-6 jets	Yes	20.3	\tilde{g}	1.2 TeV	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	\tilde{g}	1.1 TeV	1308.1841
	$\tilde{q}\tilde{q}, \tilde{q} \rightarrow q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	\tilde{q}	850 GeV	1405.7875
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	\tilde{g}	1.3 TeV	1405.7875
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow qq\tilde{\chi}_1^0 \rightarrow qqW^\pm\tilde{\chi}_1^0$	1 e, μ	3-6 jets	Yes	20.3	\tilde{g}	1.18 TeV	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e, μ	0-3 jets	-	20.3	\tilde{g}	1.12 TeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e, μ	2-4 jets	Yes	4.7	\tilde{g}	1.2 TeV	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 $\tau + 0-1 \ell$	0-2 jets	Yes	20.3	\tilde{g}	1.6 TeV	1407.0603
	GGM (bino NLSP)	2 γ	-	Yes	20.3	\tilde{g}	1.2 TeV	ATLAS-CONF-2014-001
	GGM (wino NLSP)	1 $e, \mu + \gamma$	-	Yes	4.8	\tilde{g}	619 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	\tilde{g}	900 GeV	1211.1167
	GGM (higgsino NLSP)	2 e, μ (Z)	0-3 jets	Yes	5.8	\tilde{g}	690 GeV	ATLAS-CONF-2012-152
Gravitino LSP	0	mono-jet	Yes	10.5	$E_T^{1/2}$ scale	645 GeV	ATLAS-CONF-2012-147	
3^{rd} gen. \tilde{g} med.	$\tilde{g} \rightarrow b\tilde{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	\tilde{g}	1.2 TeV	1407.0600
	$\tilde{g} \rightarrow t\tilde{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	\tilde{g}	1.1 TeV	1308.1841
	$\tilde{g} \rightarrow t\tilde{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	20.1	\tilde{g}	1.4 TeV	1407.0600
	$\tilde{g} \rightarrow b\tilde{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	20.1	\tilde{g}	1.4 TeV	1407.0600
3^{rd} gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	\tilde{b}_1	100-620 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1 \rightarrow t\tilde{\chi}_1^0$	2 e, μ (SS)	0-3 b	Yes	20.3	\tilde{b}_1	275-440 GeV	1404.2500
	$\tilde{t}_1\tilde{t}_1$ (light), $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^0$	1-2 e, μ	1-2 b	Yes	4.7	\tilde{t}_1	110-167 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$ (light), $\tilde{t}_1 \rightarrow Wb\tilde{\chi}_1^0$	2 e, μ	0-2 jets	Yes	20.3	\tilde{t}_1	130-210 GeV	1403.4853
	$\tilde{t}_1\tilde{t}_1$ (medium), $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$	2 e, μ	2 jets	Yes	20.3	\tilde{t}_1	215-530 GeV	1403.4853
	$\tilde{t}_1\tilde{t}_1$ (medium), $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	\tilde{t}_1	150-580 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$ (heavy), $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$	1 e, μ	1 b	Yes	20	\tilde{t}_1	210-640 GeV	1407.0583
	$\tilde{t}_1\tilde{t}_1$ (heavy), $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$	0	2 b	Yes	20.1	\tilde{t}_1	260-640 GeV	1406.1122
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$	0	mono-jet/ c -tag	Yes	20.3	\tilde{t}_1	90-240 GeV	1407.0608
	$\tilde{t}_1\tilde{t}_1$ (natural GMSB)	2 e, μ (Z)	1 b	Yes	20.3	\tilde{t}_1	150-580 GeV	1403.5222
$\tilde{t}_2\tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + Z$	3 e, μ (Z)	1 b	Yes	20.3	\tilde{t}_2	290-600 GeV	1403.5222	
EW direct	$\tilde{\ell}_L\tilde{\ell}_L, \tilde{\ell} \rightarrow \ell\tilde{\chi}_1^0$	2 e, μ	0	Yes	20.3	$\tilde{\ell}$	90-325 GeV	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+ \rightarrow \tilde{\ell}\nu(\tilde{\ell}\bar{\nu})$	2 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm$	140-465 GeV	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+ \rightarrow \tilde{\tau}\nu(\tilde{\tau}\bar{\nu})$	2 τ	-	Yes	20.3	$\tilde{\chi}_1^\pm$	100-350 GeV	1407.0350
	$\tilde{\chi}_1^+\tilde{\chi}_2^0 \rightarrow \tilde{\ell}_L\nu\tilde{\ell}_L(\tilde{\nu}\bar{\nu}), \tilde{\ell}\nu\tilde{\ell}_L(\tilde{\nu}\bar{\nu})$	3 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	700 GeV	1402.7029
	$\tilde{\chi}_1^+\tilde{\chi}_2^0 \rightarrow W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	2-3 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	420 GeV	1403.5294, 1402.7029
	$\tilde{\chi}_1^+\tilde{\chi}_2^0 \rightarrow W\tilde{\chi}_1^0 h\tilde{\chi}_1^0$	1 e, μ	2 b	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	285 GeV	ATLAS-CONF-2013-093
	$\tilde{\chi}_2^0\tilde{\chi}_3^0, \tilde{\chi}_{2,3}^0 \rightarrow \tilde{\ell}_R\ell$	4 e, μ	0	Yes	20.3	$\tilde{\chi}_{2,3}^0$	620 GeV	1405.5086
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	ATLAS-CONF-2013-069
	Stable, stopped \tilde{g} R-hadron	0	1-5 jets	Yes	27.9	\tilde{g}	832 GeV	1310.6584
	GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0 \rightarrow \tilde{\tau}(\tilde{e}, \tilde{\mu}) + \tau(e, \mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$	475 GeV	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$	230 GeV	1304.6310
$\tilde{q}\tilde{q}, \tilde{\chi}_1^0 \rightarrow qq\mu$ (RPV)	1 μ , displ. vtx	-	-	20.3	\tilde{q}	1.0 TeV	ATLAS-CONF-2013-092	
RPV	LFV $pp \rightarrow \tilde{\nu}_\tau + X, \tilde{\nu}_\tau \rightarrow e + \mu$	2 e, μ	-	-	4.6	$\tilde{\nu}_\tau$	1.61 TeV	1212.1272
	LFV $pp \rightarrow \tilde{\nu}_\tau + X, \tilde{\nu}_\tau \rightarrow e(\mu) + \tau$	1 $e, \mu + \tau$	-	-	4.6	$\tilde{\nu}_\tau$	1.1 TeV	1212.1272
	Bilinear RPV CMSSM	2 e, μ (SS)	0-3 b	Yes	20.3	\tilde{q}, \tilde{g}	1.5 TeV	1404.2500
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+ \rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e, μ	-	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_1^0$	750 GeV	1405.5086
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+ \rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow \tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e, \mu + \tau$	-	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_1^0$	450 GeV	1405.5086
	$\tilde{g} \rightarrow qq\tilde{q}$	0	6-7 jets	-	20.3	\tilde{g}	916 GeV	ATLAS-CONF-2013-091
$\tilde{g} \rightarrow \tilde{t}_1 t, \tilde{t}_1 \rightarrow bs$	2 e, μ (SS)	0-3 b	Yes	20.3	\tilde{g}	850 GeV	1404.2500	
Other	Scalar gluon pair, sgluon $\rightarrow q\tilde{q}$	0	4 jets	-	4.6	sgluon	100-287 GeV	1210.4826
	Scalar gluon pair, sgluon $\rightarrow t\tilde{t}$	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	ATLAS-CONF-2012-147

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

But Wait...
**THERE'S
MORE!**

SUSY

spin correlations

Electroweak-ino production, many channels and assumptions

GSMB models, delayed and non-pointing photons

out of time events and disappearing tracks

R-parity violating final states

Additional searches

W' searches to hadronic final states

dijet, ZZ, ZW, $W\backslash\gamma$, $Z\backslash\gamma$ resonances

Vector like quarks

Mono jets, tT , b , t

LFV and long-lived neutral particles



Flavor Physics

Notable results



from Run 1 we anticipated:

measure: $bb \rightarrow J/\psi$, $pp \rightarrow J/\psi$, and $B^+ \rightarrow J/\psi + K^+$ cross section ratios
begin to contribute to world averages on B-hadron properties; start to
set limits on rare decays

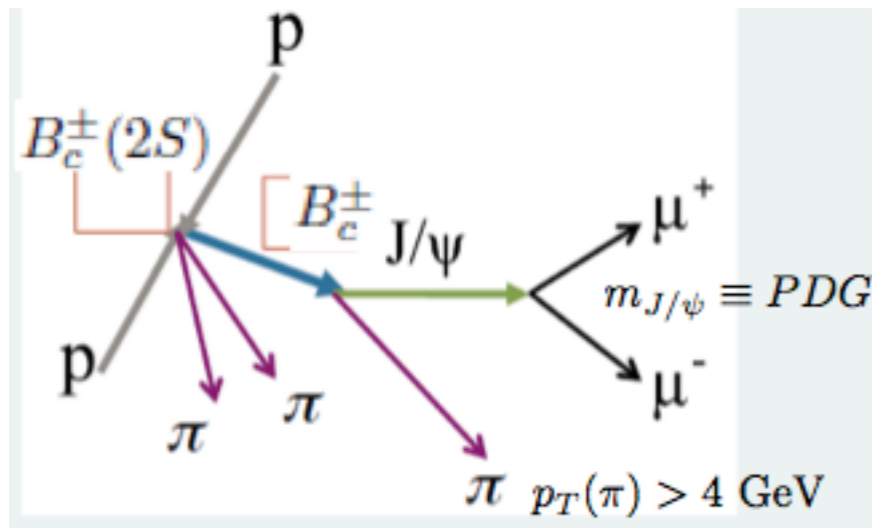
from Run 1 we achieved:

many production studies, χ , ψ studies, new physics searches, new b
states

in Run 2, we expect:

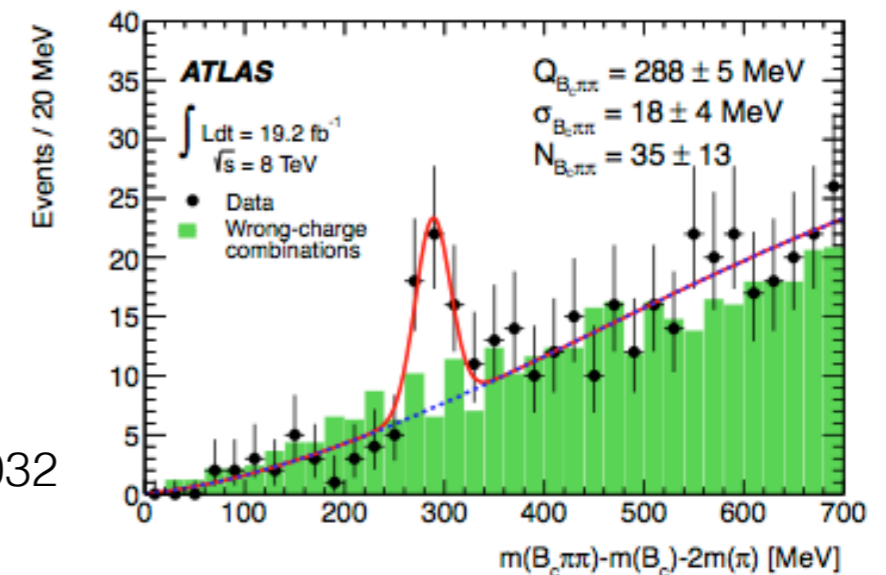
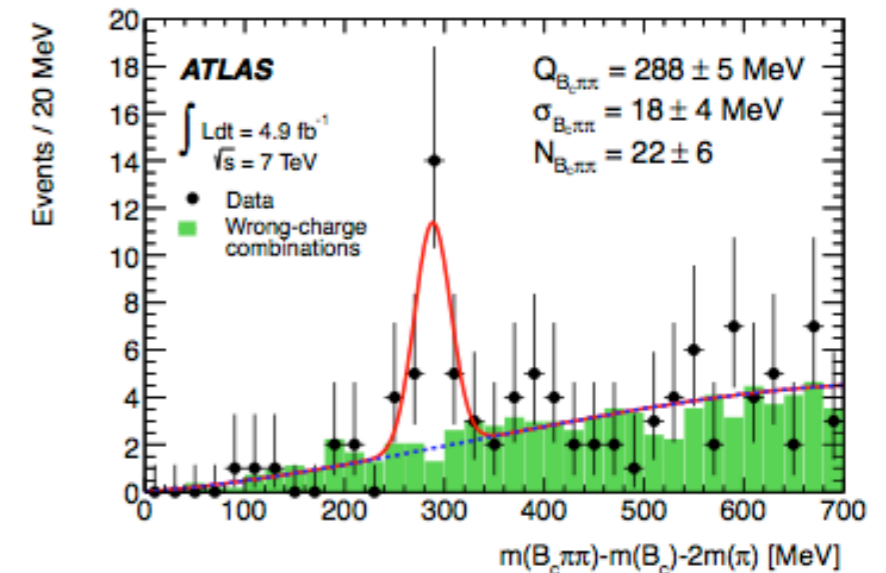
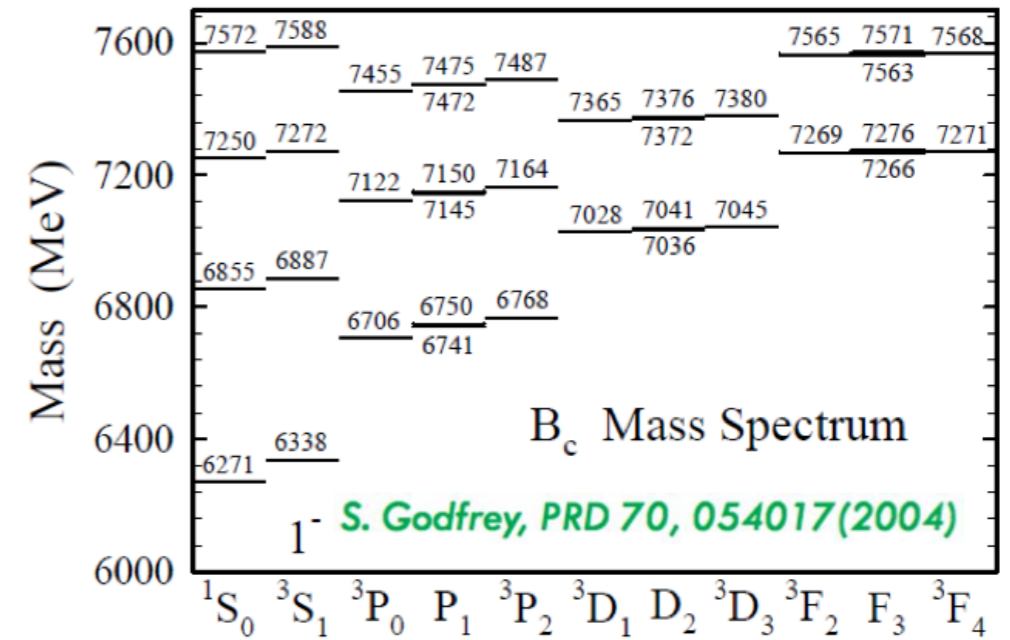
increased statistics, improved performance/triggers, robust against \mathcal{L}

First excited B_c open beauty discovery



$$2^1 S_0 \rightarrow 1^1 S_0 + \pi\pi$$

In conclusion, the distribution of the mass difference $Q = m(B_c^\pm \pi^+ \pi^-) - m(B_c^\pm) - 2m(\pi^\pm)$ for events with the B_c^\pm meson reconstructed in its decay to $J/\psi \pi^\pm$ has been investigated in pp collisions at the LHC using the ATLAS detector. The analysis is based on an integrated luminosity of 4.9 (19.2) fb^{-1} of pp collisions at a center-of-mass energy of 7 (8) TeV. A new state is observed at $Q = 288.3 \pm 3.5 \pm 4.1 \text{ MeV}$ (calculated as the error weighted mean of the 7 TeV and 8 TeV mass values) corresponding to a mass of $6842 \pm 4 \pm 5 \text{ MeV}$, where the first error is statistical and the second is systematic. The significance of the observation is 5.2σ with the “look



arXiv:1407.1032

But Wait...
**THERE'S
MORE!**



Production and Decays, incl

$\psi(2s)$ in many distributions, prompt and non-prompt

W^+ incl double parton scattering contribution

χ_c production, prompt?

$\Upsilon(1s, 2s, 3s)$ production

open charm/beauty, in jets, inclusive

Spectroscopy, incl

$\chi_b(3P)$ discovery, Λ_b mass, lifetime, PV in $\Lambda_b \rightarrow J/\psi \Lambda^0$, Rare Decays

Searches, incl

FCNC search for $B_{d/s} \rightarrow \mu^+ \mu^-$

Long Shutdown 1 Projects

Tracking system

Insertable B Layer, aka IBL

5.1 to 3.3 cm to IP

pixels reduced: 50 x 250 μm

new sensors and readout chip

May 7:

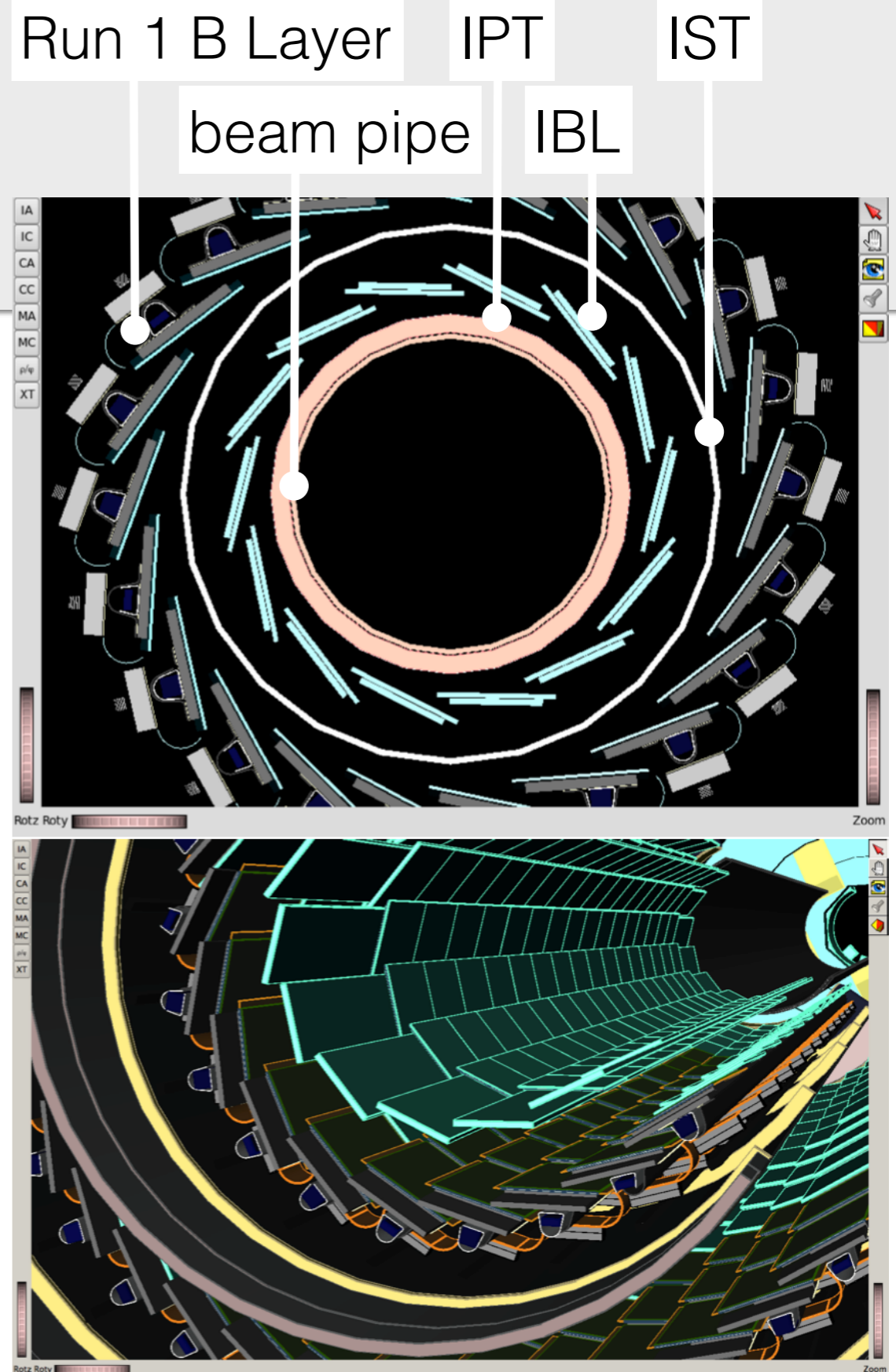
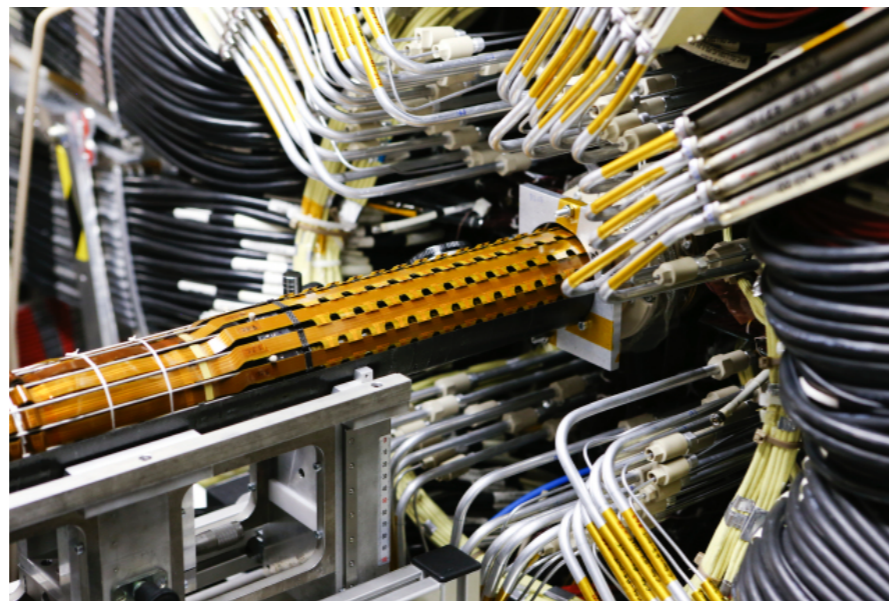
Gains:

impact param

light jet reject

redundancy

Status: live >99.9%



Tracking system

many other projects, "Consolidation"

SCT readout enhanced

high pileup and trigger rate mandates enhanced readout

90 -> 128 S links and compression

100 kHz @ $\mu = 87$

TRT

enhanced readout, data compression, different gating

104 KHz with 2% occupancy

gas studies

Pixel brought to surface, reinstalled

B layer, 6.3% to 1.4%; Layer 2, 7% to 1.9%; 98% functional of 1744

new diamond/Si beam monitors installed

Calorimeter system

LAr and Tile

LAr

LV power supplies replaced by manufacturer

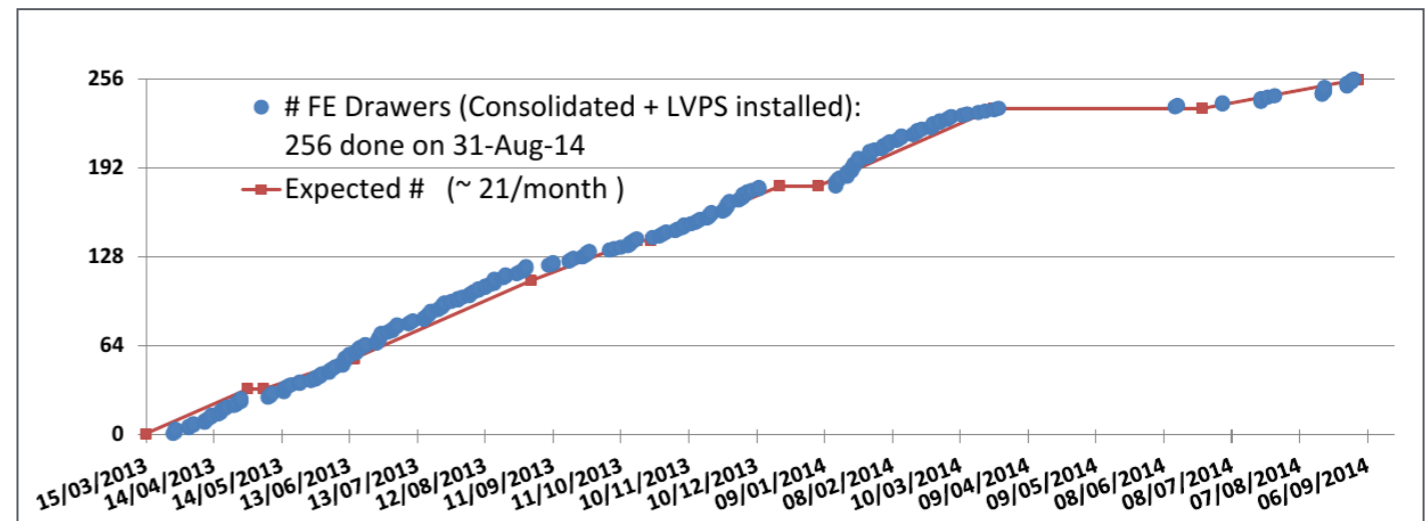
readout tested to more than 100 kHz

Phase 1 “demonstrator” installed

Tile

Power supply replacements

Min-bias trigger scintillators



Muon system

staged from Run 1

New ROD for CSC system

limited ATLAS L1 trigger rate to 70 kHz...now 100 kHz

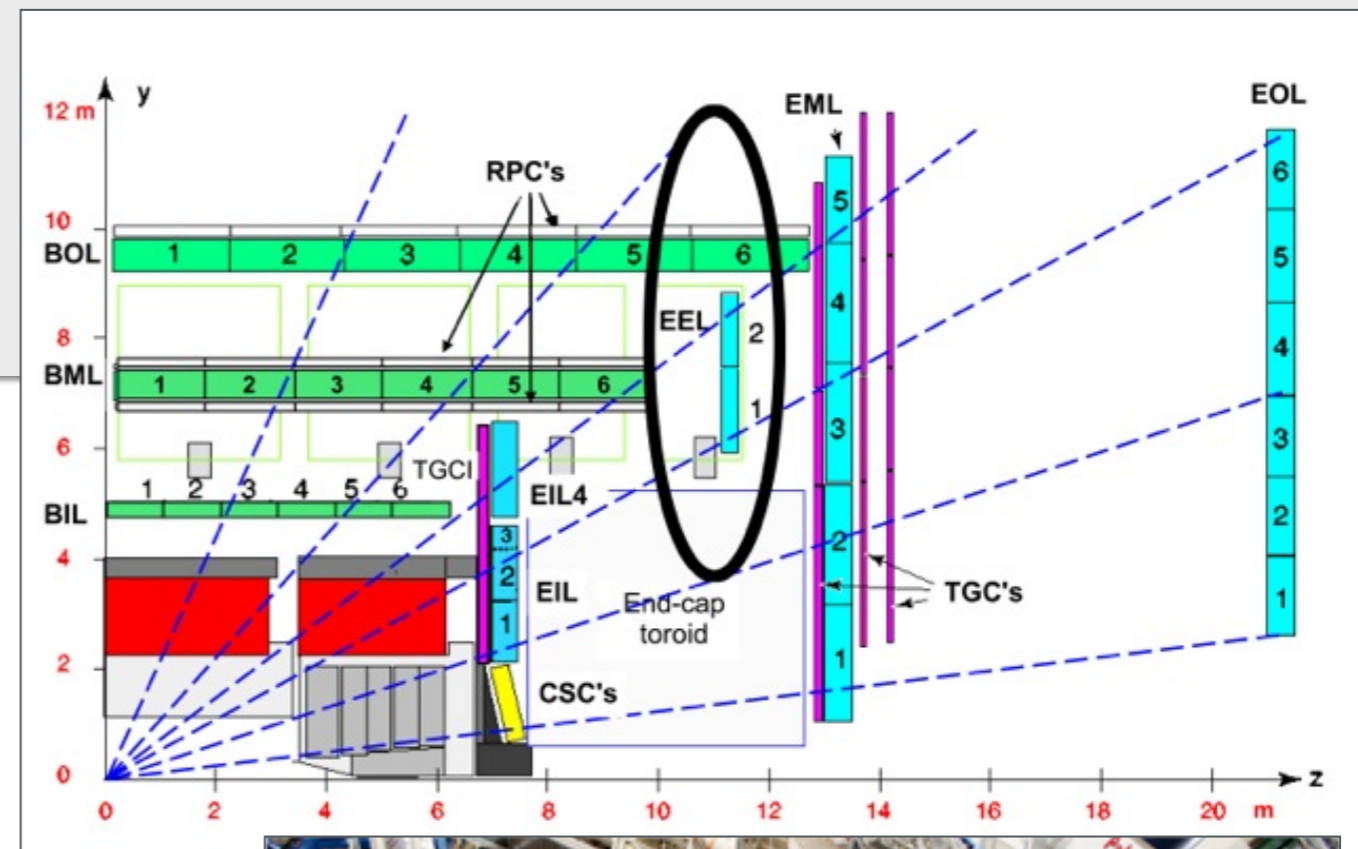
New EE endcap chambers

Repairs

Broken CSC chambers, repaired, reinstalled

RPC leak repairs

TGC chamber replacement requires detector to be closed



Trigger system

considerable enhancements

E_{CM} from 8 to 13 TeV (x2.5) +

\mathcal{L}_{peak} 0.8 to $1.6 \times 10^{34}/\text{cm}^2/\text{s}$

5x trigger rates from Run 1

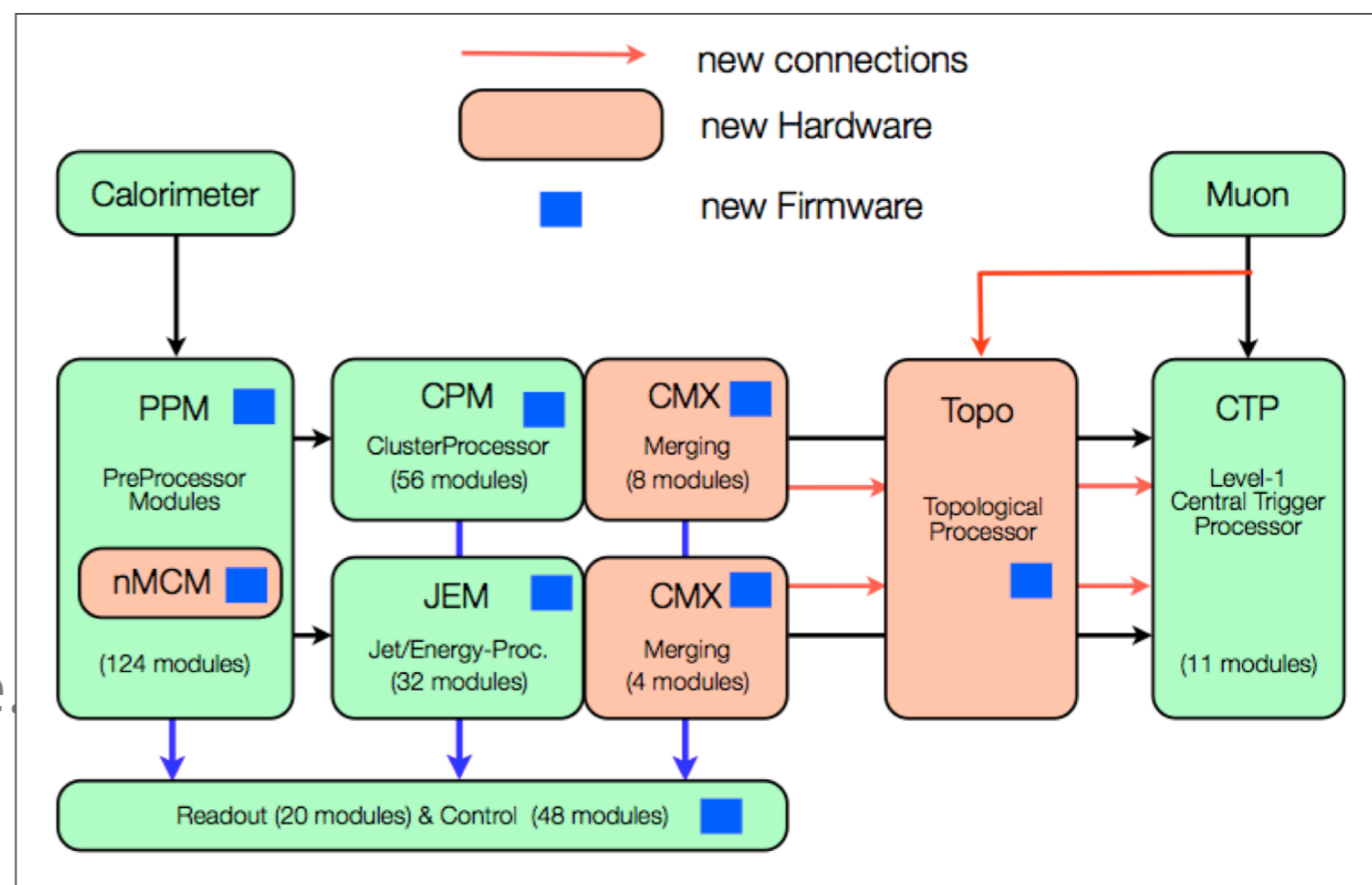
Upgrades to:

L1 rate, 70 kHz - 100 kHz
operation, factor 4/3 increase.

hardware

HLT rate, 400 Hz - ~1 kHz
operation, factor of ~2 increase.

algorithms



Trigger system hardware

New preprocessors (nMCM)

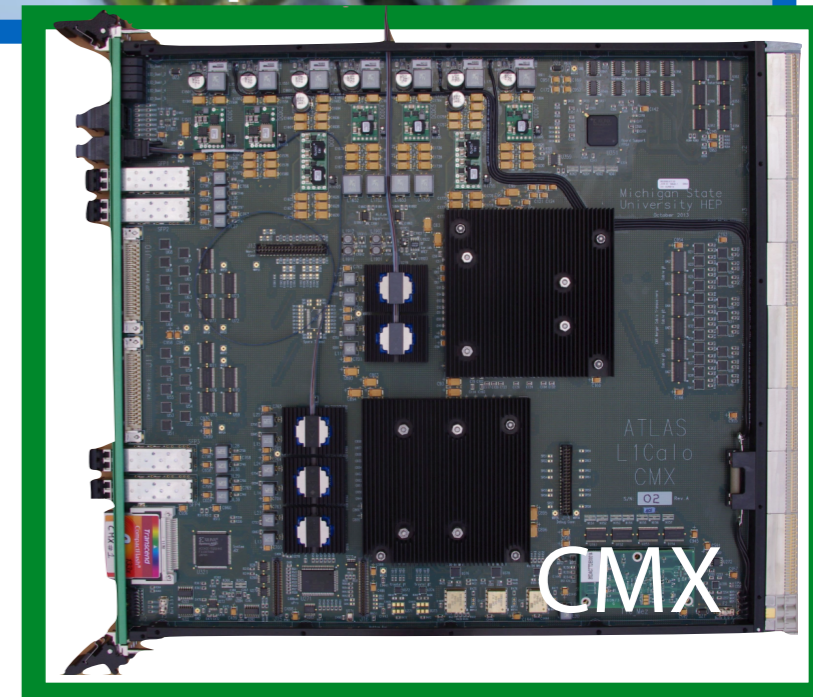
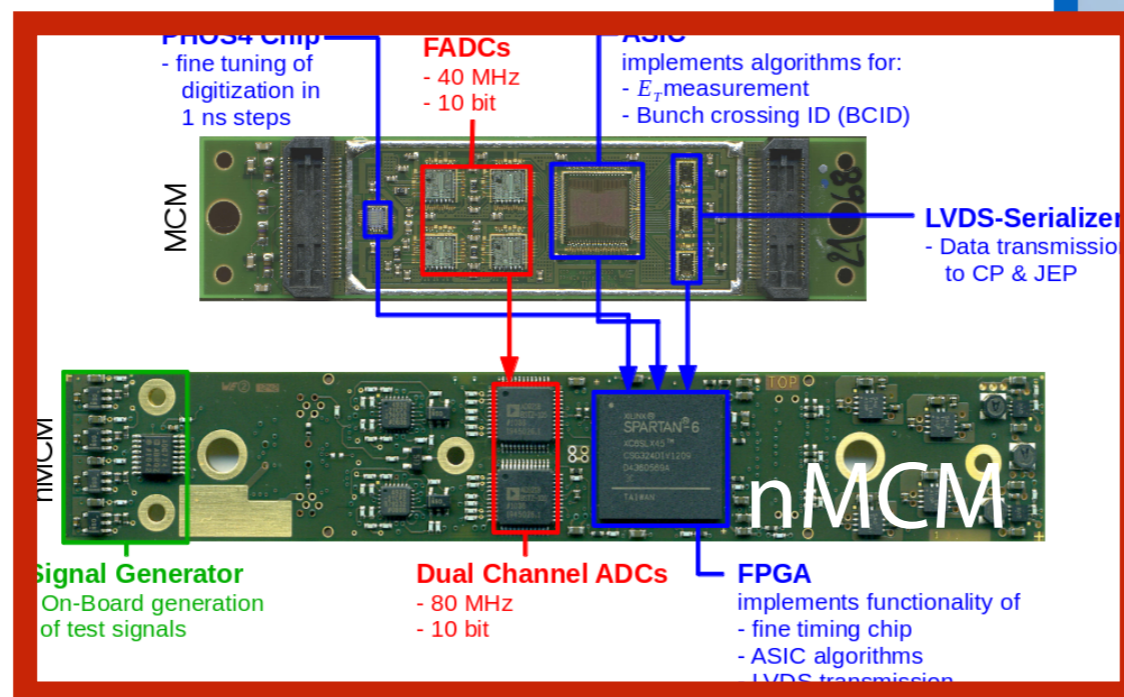
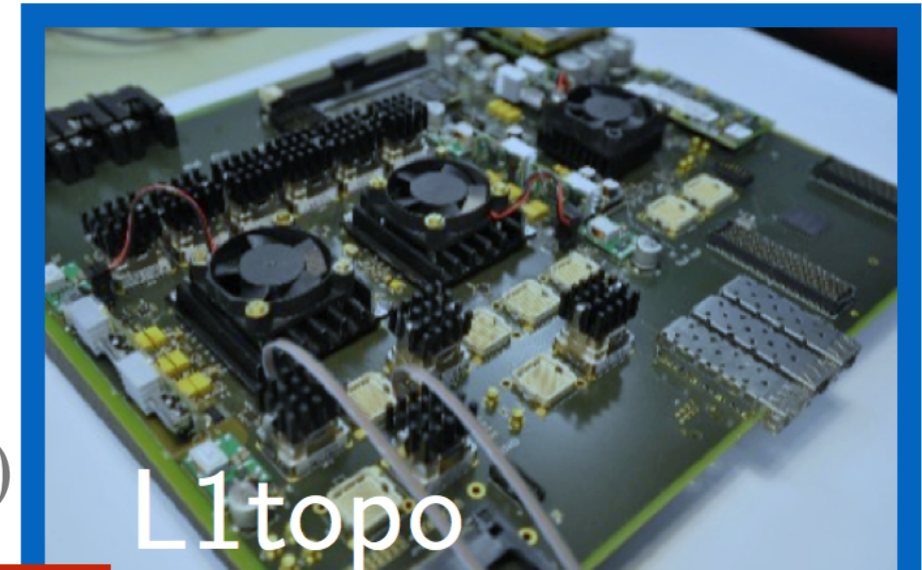
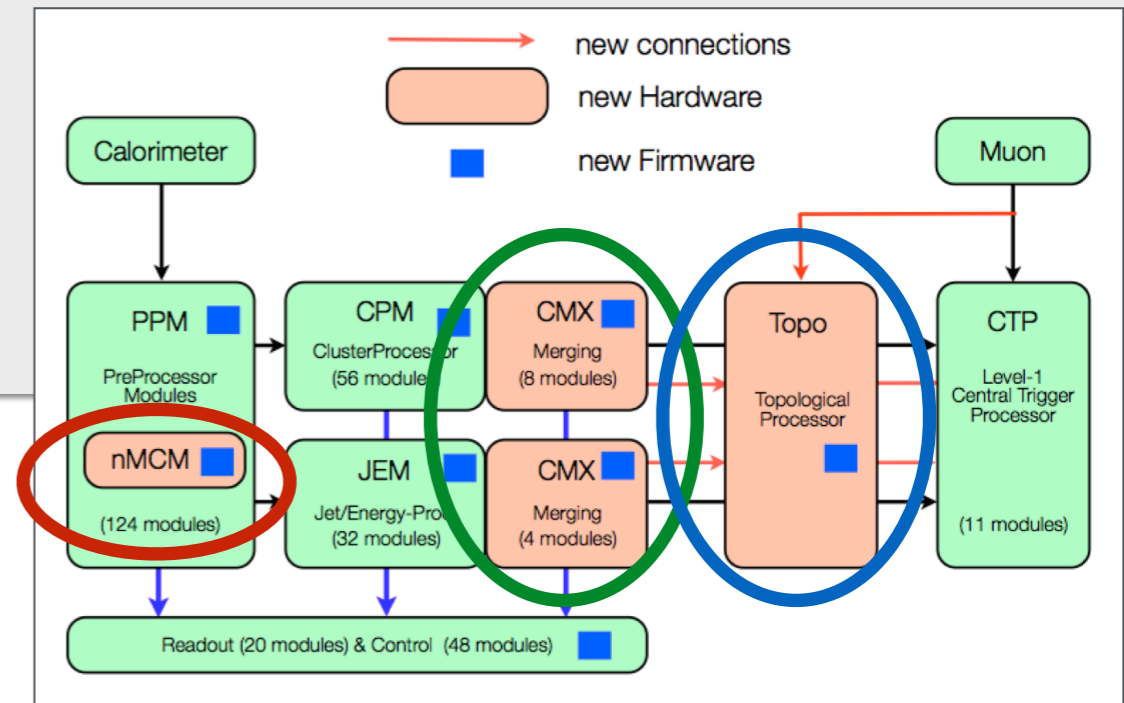
80 MHz digitization, lower noise

New merger modules (CMX)

x4 speed enhancement over CMM

L1 Topo processor

trigger on object relations at L1 e.g. $\Delta\phi(E^{miss}_T, j)$

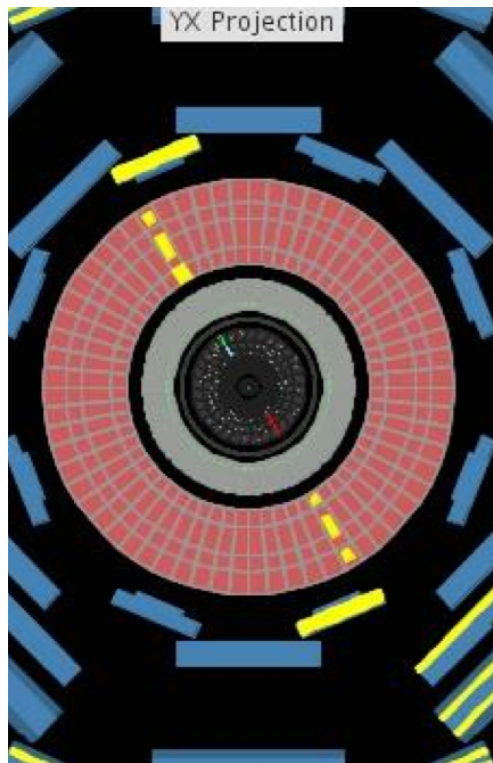


Commissioning underway in-situ

Commissioning

multiple "Milestone weeks"

24/5! M's cosmic rays HLT & reco'd Tier 0



	M3	M4	M5	M6	M7
	May19- May 23	Jul 7- Jul 11	Sep 8- Sep 12	Oct 13- Oct 17	Nov 24- Dec 08
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		

Commissioning

multiple "Milestone weeks"

24/5! M's cosmic rays HLT & reco'd Tier 0



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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 ⁴	
CSC			X ²	X ²	
MDT					
RPC	X ¹				
TGC				X ²	
BCM					
ALFA			X		
LUCID				X	
Lumi			X		

ATLAS
reading out
since "M5"

Computing & Software systems

speed/efficiency and pileup

Many algorithmic, mathematical, fitting changes

factor >3 gains

pileup robustness

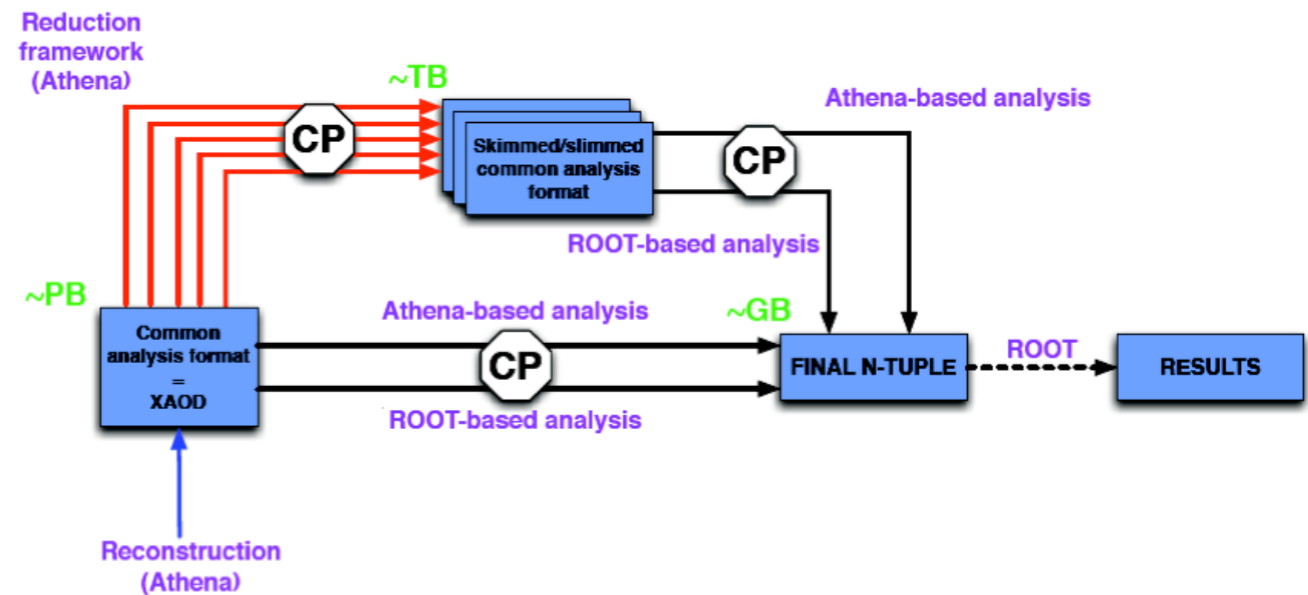
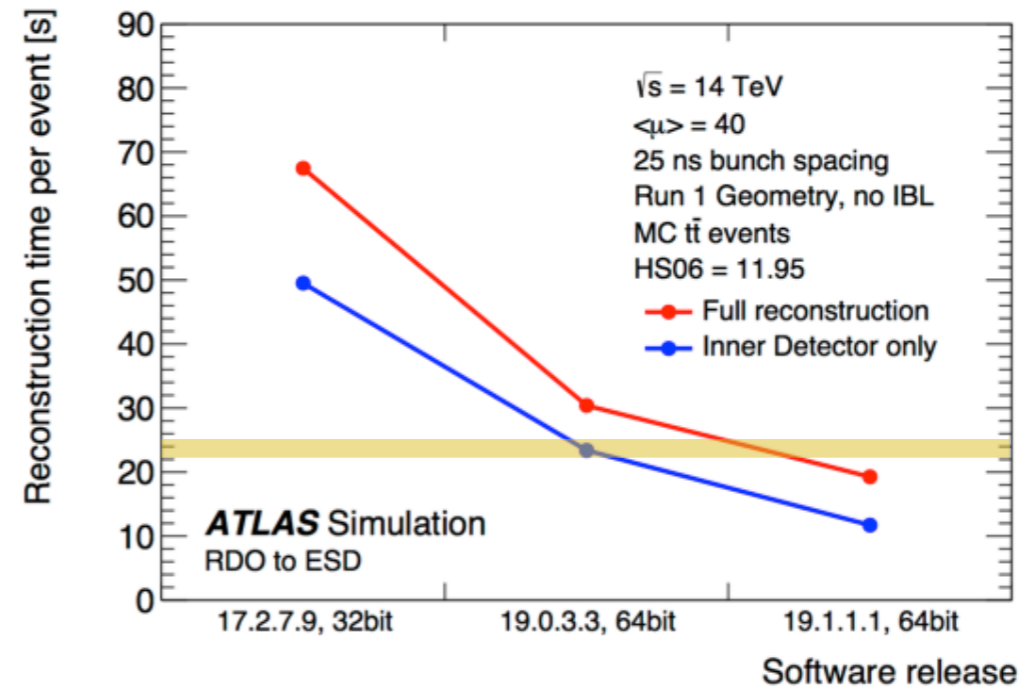
Completely redesigned analysis model

“xAOD” Athena reconstruction is ROOT-readable, tuning.

disk usage tight...working on xAOD sizes

memory usage gymnastics

CP tools mostly migrated



conclusion

nothing yet
