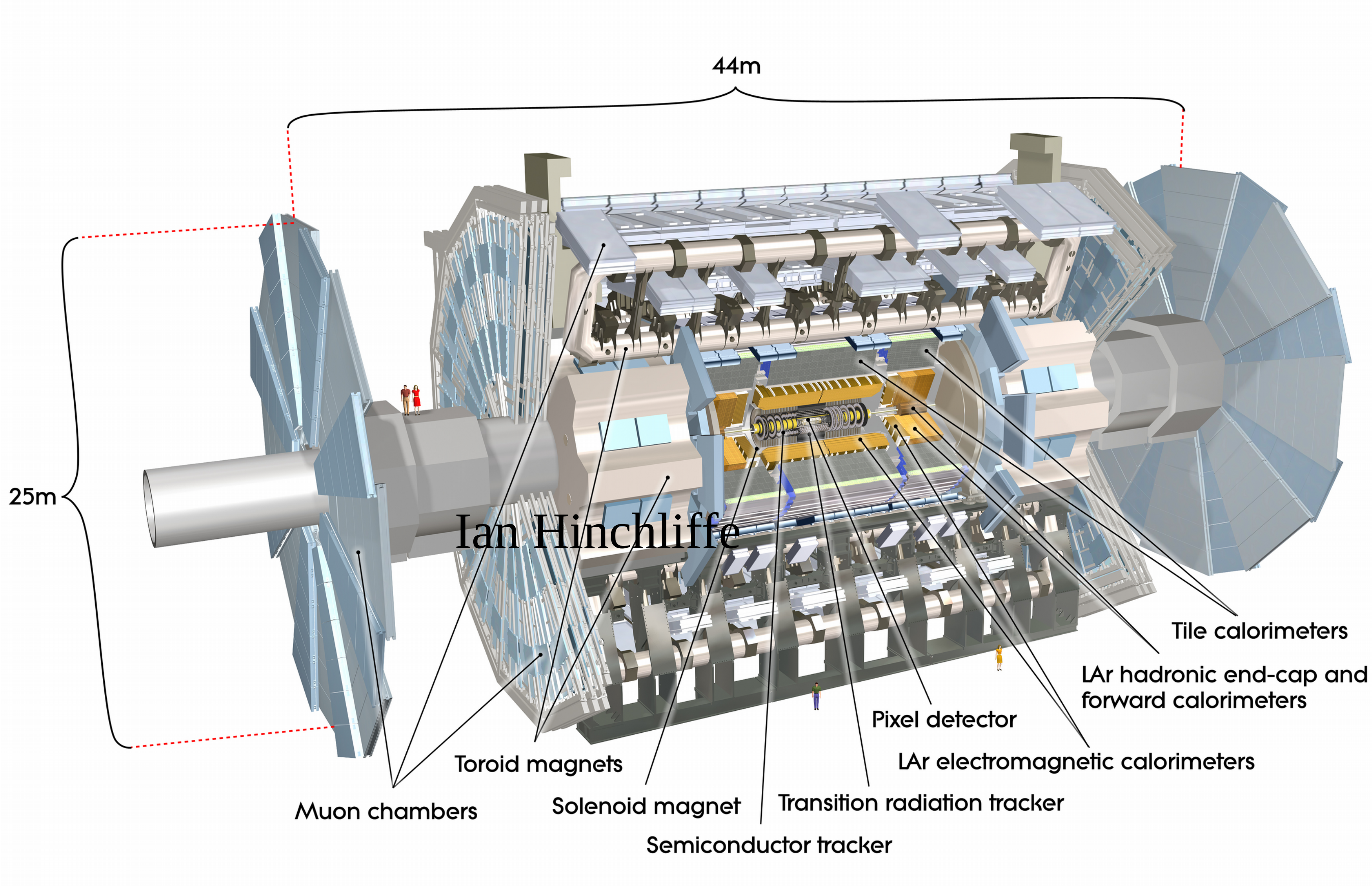
ATLAS:Status and plans



Ian Hinchliffe

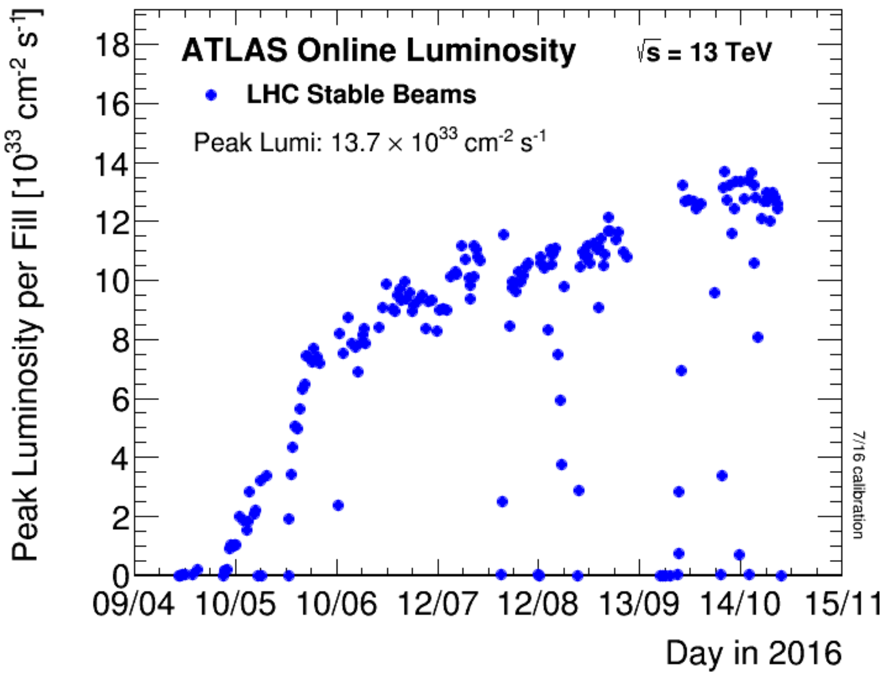
ATLAS Run-2

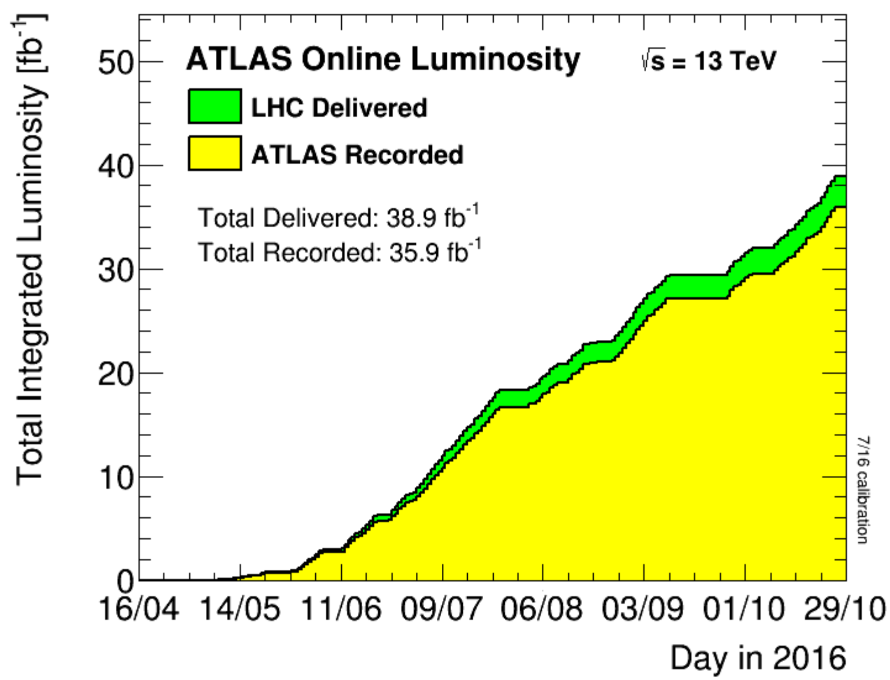
Proton proton data taking for 2016 ended last week

Very successful year – p-Pb collisions starting soon

LHC exceeded design luminosity ($10^{34}cm^{-2}\,sec^{-1}$)

More than 1/3 of promised Run-2 luminosity now delivered (3.9+35.9 fb^{-1})





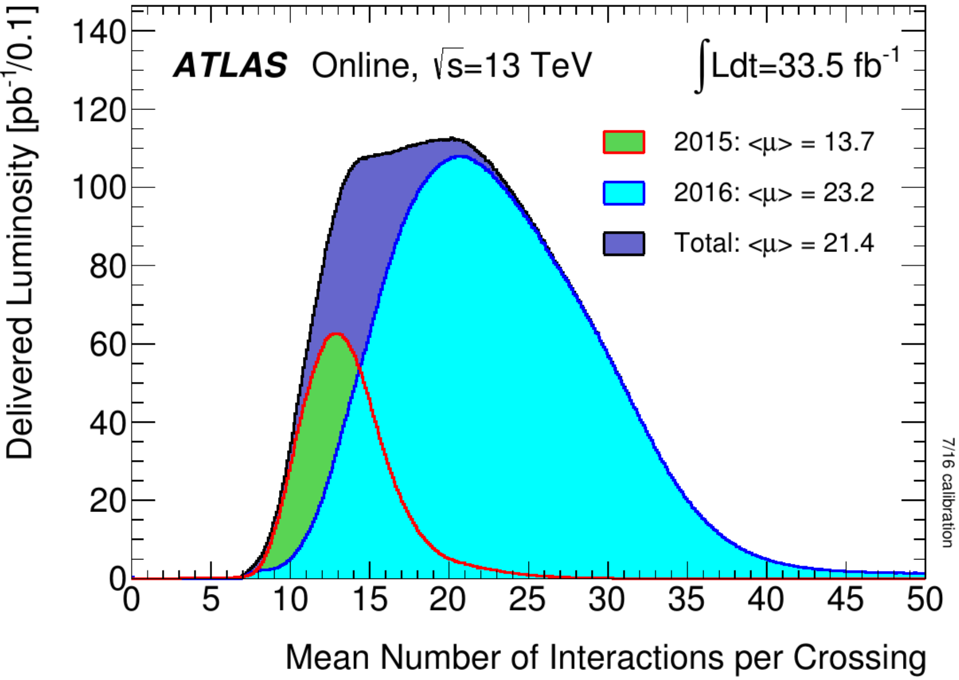
ATLAS Run-2

This superb LHC performance has a cost: But ATLAS data taking efficiency >92%

Higher pileup than expected: nominal max was 25.

>40 publications from Run-2: many more preliminary results

- >500 Run-1 papers
  - More Run-1 papers from SM measurements still pending



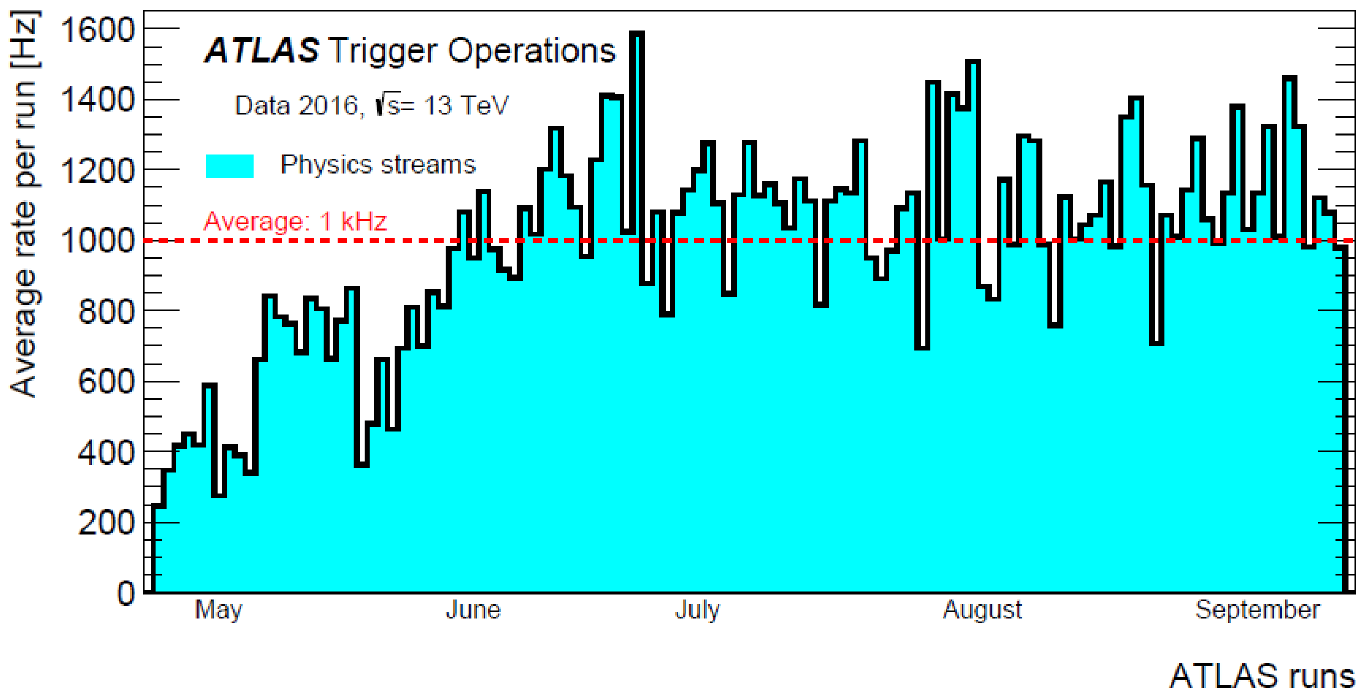
Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	92 M	98.0%
SCT Silicon Strips	6.3 M	98.6%
TRT Transition Radiation Tracker	350 k	97.2%
LAr EM Calorimeter	170 k	100%
Tile calorimeter	5200	99.0%
Hadronic endcap LAr calorimeter	5600	99.5%
Forward LAr calorimeter	3500	99.7%
LVL1 Calo trigger	7160	99.9%
LVL1 Muon RPC trigger	383 k	99.8%
LVL1 Muon TGC trigger	320 k	99.9%
MDT Muon Drift Tubes	357 k	99.7%
CSC Cathode Strip Chambers	31 k	97.7%
RPC Barrel Muon Chambers	383 k	96.6%
TGC Endcap Muon Chambers	320 k	99.6%
ALFA	10 k	99.9 %
AFP	188 k	98.8 %

ATLAS Run-2

Trigger menu stressed

Offline computing: where to put all the data?

- Tier 1 and Tier 2 disks full
- Computing costs in 2017/18 increase by ~20%



Physics comments

Most Run-2 results are searches as a new energy regime has opened up.

- Nothing has shown up yet.
- Note that some new excesses should be expected given the large number of ongoing searches
- The 2015 diphoton excess has not been confirmed
    - It appears to have been a statistical fluctuation.

More information in Sarah Demers talk later today and in the lightening talks

- She will try to cover SUSY:
- I'll show some exotics examples
- Look here for all references
- https://twiki.cern.ch/twiki/bin/view/AtlasPublic/WebHome

Physics comments II

Expect results, particularly searches, using full 2016 data set for Moriond 2017

If there are only limits, cannot expect discovery in Run-2 in same channel

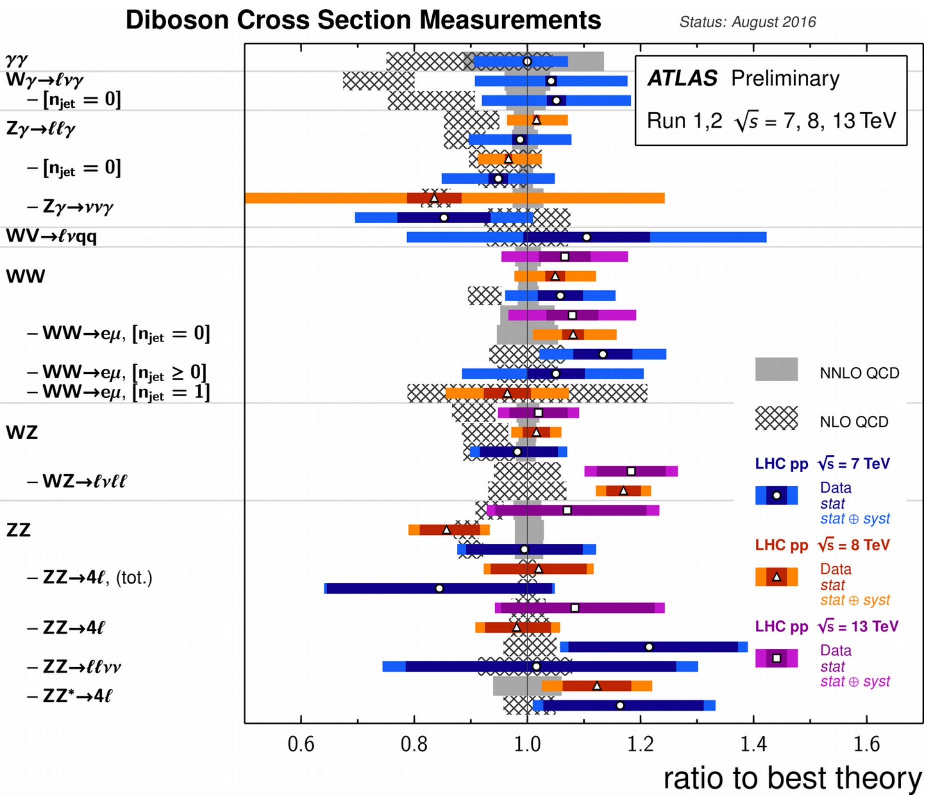
Expect searches to get more complicated

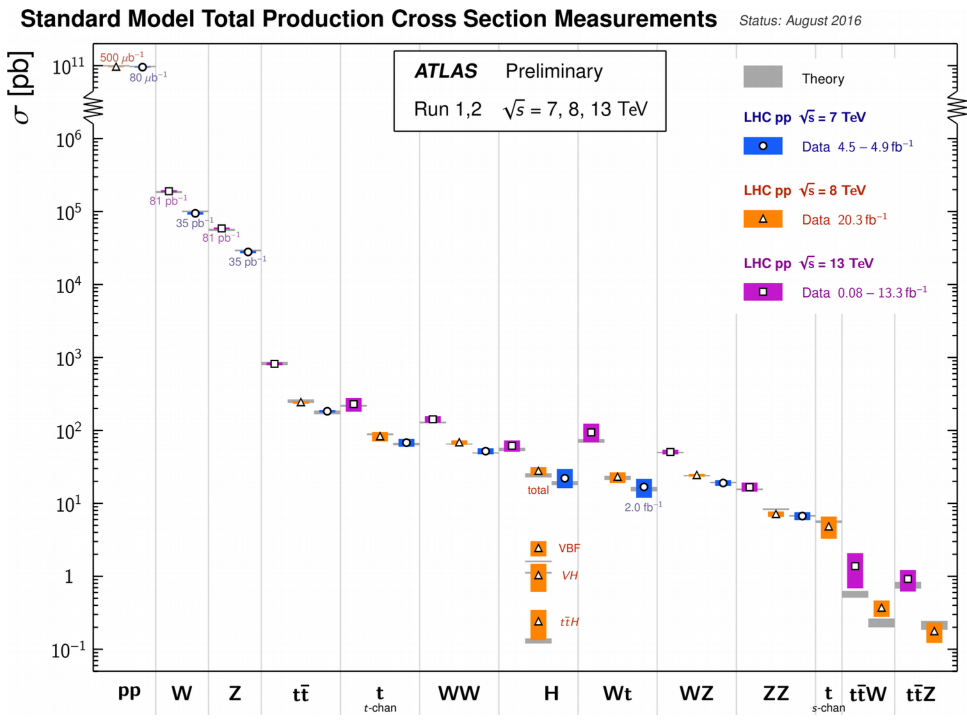
- Low cross section, low mass searches
  - Some may not use full detector
- Kinematically restricted phase space

Physics comments III

Spectacular agreement between data and theoretical models.

– Even in tails of distributions
– This has made some searches much easier





ATLAS Exotics Searches* - 95% CL Exclusion

Status: August 2016

ATLAS Preliminary

$\int \mathcal{L}\, dt = (3.2 - 20.3)\ \mathrm{fb}^{-1}$ $\sqrt{s} = 8, 13$ TeV

	Model	ℓ, γ	Jets†	E_T^{miss}	$\int \mathcal{L}\, dt[\mathrm{fb}^{-1}]$	Limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	–	≥ 1 j	Yes	3.2	M_D 6.58 TeV	$n = 2$	1604.07773
	ADD non-resonant $\ell\ell$	2 e, μ	–	–	20.3	M_S 4.7 TeV	$n = 3$ HLZ	1407.2410
	ADD QBH $\to \ell q$	1 e, μ	1 j	–	20.3	M_{th} 5.2 TeV	$n = 6$	1311.2006
	ADD QBH	–	2 j	–	15.7	M_{th} 8.7 TeV	$n = 6$	ATLAS-CONF-2016-069
	ADD BH high $\sum p_T$	≥ 1 e, μ	≥ 2 j	–	3.2	M_{th} 8.2 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1606.02265
	ADD BH multijet	–	≥ 3 j	–	3.6	M_{th} 9.55 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1512.02586
	RS1 $G_{KK} \to \ell\ell$	2 e, μ	–	–	20.3	G_{KK} mass 2.68 TeV	$k/\overline{M}_{Pl} = 0.1$	1405.4123
	RS1 $G_{KK} \to \gamma\gamma$	2 γ	–	–	3.2	G_{KK} mass 3.2 TeV	$k/\overline{M}_{Pl} = 0.1$	1606.03833
	Bulk RS $G_{KK} \to WW \to qq\ell\nu$	1 e, μ	1 J	Yes	13.2	G_{KK} mass 1.24 TeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2016-062
	Bulk RS $G_{KK} \to HH \to bbbb$	–	4 b	–	13.3	G_{KK} mass 360-860 GeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2016-049
	Bulk RS $g_{KK} \to tt$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	20.3	g_{KK} mass 2.2 TeV	BR = 0.925	1505.07018
	2UED / RPP	1 e, μ	≥ 2 b, ≥ 4 j	Yes	3.2	KK mass 1.46 TeV	Tier (1,1), BR($A^{(1,1)} \to tt$) = 1	ATLAS-CONF-2016-013
Gauge bosons	SSM $Z' \to \ell\ell$	2 e, μ	–	–	13.3	Z' mass 4.05 TeV		ATLAS-CONF-2016-045
	SSM $Z' \to \tau\tau$	2 τ	–	–	19.5	Z' mass 2.02 TeV		1502.07177
	Leptophobic $Z' \to bb$	–	2 b	–	3.2	Z' mass 1.5 TeV		1603.08791
	SSM $W' \to \ell\nu$	1 e, μ	–	Yes	13.3	W' mass 4.74 TeV		ATLAS-CONF-2016-061
	HVT $W' \to WZ \to qq\nu\nu$ model A	0 e, μ	1 J	Yes	13.2	W' mass 2.4 TeV	$g_V = 1$	ATLAS-CONF-2016-082
	HVT $W' \to WZ \to qqqq$ model B	–	2 J	–	15.5	W' mass 3.0 TeV	$g_V = 3$	ATLAS-CONF-2016-055
	HVT $V' \to WH/ZH$ model B	multi-channel			3.2	V' mass 2.31 TeV	$g_V = 3$	1607.05621
	LRSM $W'_R \to tb$	1 e, μ	2 b, 0-1 j	Yes	20.3	W' mass 1.92 TeV		1410.4103
	LRSM $W'_R \to tb$	0 e, μ	≥ 1 b, 1 J	–	20.3	W' mass 1.76 TeV		1408.0886
CI	CI $qqqq$	–	2 j	–	15.7	Λ 19.9 TeV	$\eta_{LL} = -1$	ATLAS-CONF-2016-069
	CI $\ell\ell qq$	2 e, μ	–	–	3.2	Λ 25.2 TeV	$\eta_{LL} = -1$	1607.03669
	CI $uutt$	2(SS)/≥ 3 e, μ	≥ 1 b, ≥ 1 j	Yes	20.3	Λ 4.9 TeV	$\lvert C_{RR} \rvert = 1$	1504.04605
DM	Axial-vector mediator (Dirac DM)	0 e, μ	≥ 1 j	Yes	3.2	m_A 1.0 TeV	g_q=0.25, g_χ=1.0, $m(\chi) < 250$ GeV	1604.07773
	Axial-vector mediator (Dirac DM)	0 e, μ, 1 γ	1 j	Yes	3.2	m_A 710 GeV	g_q=0.25, g_χ=1.0, $m(\chi) < 150$ GeV	1604.01306
	$ZZ\chi\chi$ EFT (Dirac DM)	0 e, μ	1 J, ≤ 1 j	Yes	3.2	M_* 550 GeV	$m(\chi) < 150$ GeV	ATLAS-CONF-2015-080
LQ	Scalar LQ 1st gen	2 e	≥ 2 j	–	3.2	LQ mass 1.1 TeV	$\beta = 1$	1605.06035
	Scalar LQ 2nd gen	2 μ	≥ 2 j	–	3.2	LQ mass 1.05 TeV	$\beta = 1$	1605.06035
	Scalar LQ 3rd gen	1 e, μ	≥ 1 b, ≥ 3 j	Yes	20.3	LQ mass 640 GeV	$\beta = 0$	1508.04735
Heavy quarks	VLQ $TT \to Ht + X$	1 e, μ	≥ 2 b, ≥ 3 j	Yes	20.3	T mass 855 GeV	T in (T,B) doublet	1505.04306
	VLQ $YY \to Wb + X$	1 e, μ	≥ 1 b, ≥ 3 j	Yes	20.3	Y mass 770 GeV	Y in (B,Y) doublet	1505.04306
	VLQ $BB \to Hb + X$	1 e, μ	≥ 2 b, ≥ 3 j	Yes	20.3	B mass 735 GeV	isospin singlet	1505.04306
	VLQ $BB \to Zb + X$	2/≥ 3 e, μ	≥ 2/≥ 1 b	–	20.3	B mass 755 GeV	B in (B,Y) doublet	1409.5500
	VLQ $QQ \to WqWq$	1 e, μ	≥ 4 j	Yes	20.3	Q mass 690 GeV		1509.04261
	VLQ $T_{5/3} T_{5/3} \to WtWt$	2(SS)/≥ 3 e, μ	≥ 1 b, ≥ 1 j	Yes	3.2	$T_{5/3}$ mass 990 GeV		ATLAS-CONF-2016-032
Excited fermions	Excited quark $q^* \to q\gamma$	1 γ	1 j	–	3.2	q^* mass 4.4 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1512.05910
	Excited quark $q^* \to qg$	–	2 j	–	15.7	q^* mass 5.6 TeV	only u^* and d^*, $\Lambda = m(q^*)$	ATLAS-CONF-2016-069
	Excited quark $b^* \to bg$	–	1 b, 1 j	–	8.8	b^* mass 2.3 TeV		ATLAS-CONF-2016-060
	Excited quark $b^* \to Wt$	1 or 2 e, μ	1 b, 2-0 j	Yes	20.3	b^* mass 1.5 TeV	$f_g = f_L = f_R = 1$	1510.02664
	Excited lepton ℓ^*	3 e, μ	–	–	20.3	ℓ^* mass 3.0 TeV	$\Lambda = 3.0$ TeV	1411.2921
	Excited lepton ν^*	3 e, μ, τ	–	–	20.3	ν^* mass 1.6 TeV	$\Lambda = 1.6$ TeV	1411.2921
Other	LSTC $a_T \to W\gamma$	1 e, μ, 1 γ	–	Yes	20.3	a_T mass 960 GeV		1407.8150
	LRSM Majorana ν	2 e, μ	2 j	–	20.3	N^0 mass 2.0 TeV	$m(W_R) = 2.4$ TeV, no mixing	1506.06020
	Higgs triplet $H^{\pm\pm} \to ee$	2 e (SS)	–	–	13.9	$H^{\pm\pm}$ mass 570 GeV	DY production, BR($H_L^{\pm\pm} \to ee$)=1	ATLAS-CONF-2016-051
	Higgs triplet $H^{\pm\pm} \to \ell\tau$	3 e, μ, τ	–	–	20.3	$H^{\pm\pm}$ mass 400 GeV	DY production, BR($H_L^{\pm\pm} \to \ell\tau$)=1	1411.2921
	Monotop (non-res prod)	1 e, μ	1 b	Yes	20.3	spin-1 invisible particle mass 657 GeV	$a_{\text{non-res}} = 0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	multi-charged particle mass 785 GeV	DY production, $\lvert q \rvert = 5e$	1504.04188
	Magnetic monopoles	–	–	–	7.0	monopole mass 1.34 TeV	DY production, $\lvert g \rvert = 1 g_D$, spin 1/2	1509.08059

$\sqrt{s} = 8$ TeV (green bars) $\sqrt{s} = 13$ TeV (yellow bars)

Mass scale [TeV] (axis: 10^{-1}, 1, 10)

*Only a selection of the available mass limits on new states or phenomena is shown. Lower bounds are specified only when explicitly not excluded.

†Small-radius (large-radius) jets are denoted by the letter j (J).

General remarks and examples

Single production of objects with strong couplings

- Excited quarks, microscopic black holes.....
- Good S/B
- Limits have reached 5-8 TeV.
- Further gains slow with luminosity

Single production with electro weak couplings

- New gauge bosons….
- Good S/B
- Limits have reached 3-6 TeV

Pair production of objects with strong couplings

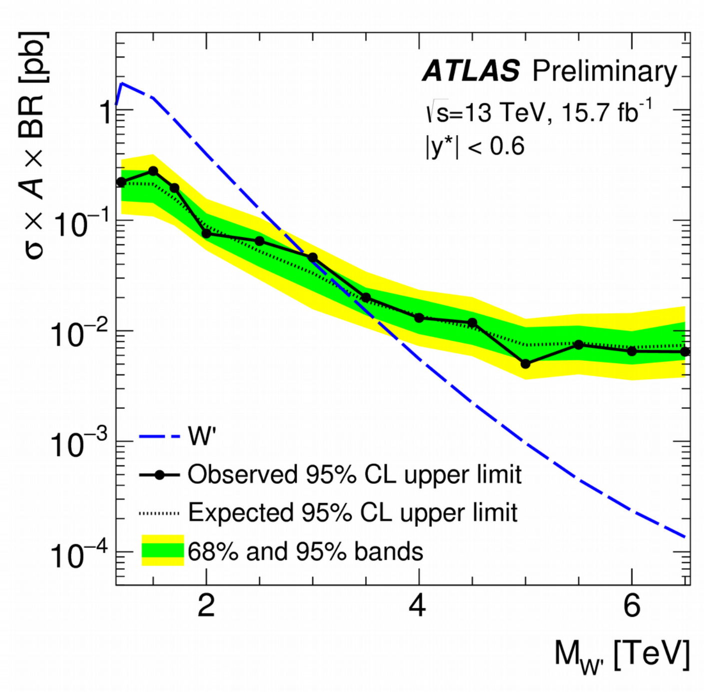
- Lepto-quarks. gluinis
- 1-2 TeV

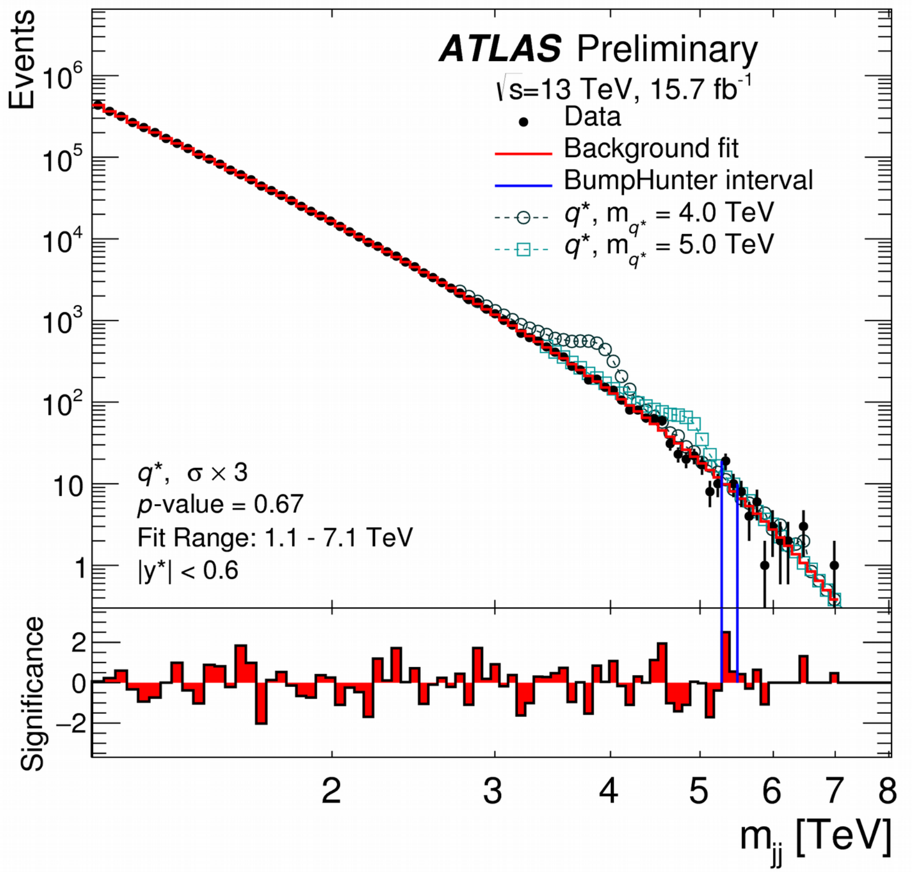
–

Dijet resonance search

Events selected with jet trigger

Search for structure in dijet mass: no Monte carlo needed, but data are consistent with expectations

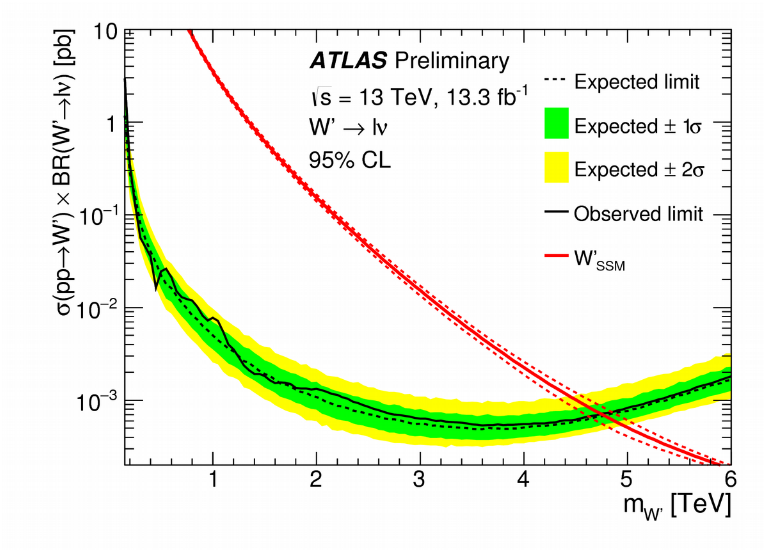


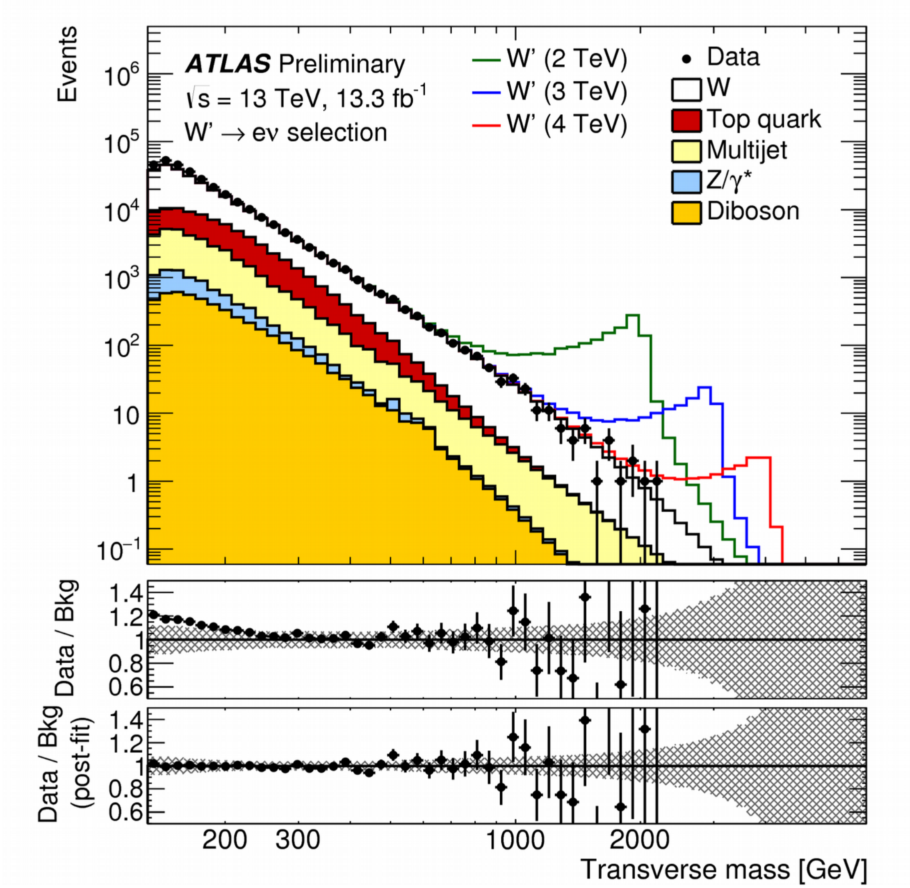


Charged Gauge boson search

Lepton trigger

Looks at transverse mass of lepton and etmiss (neutrino)

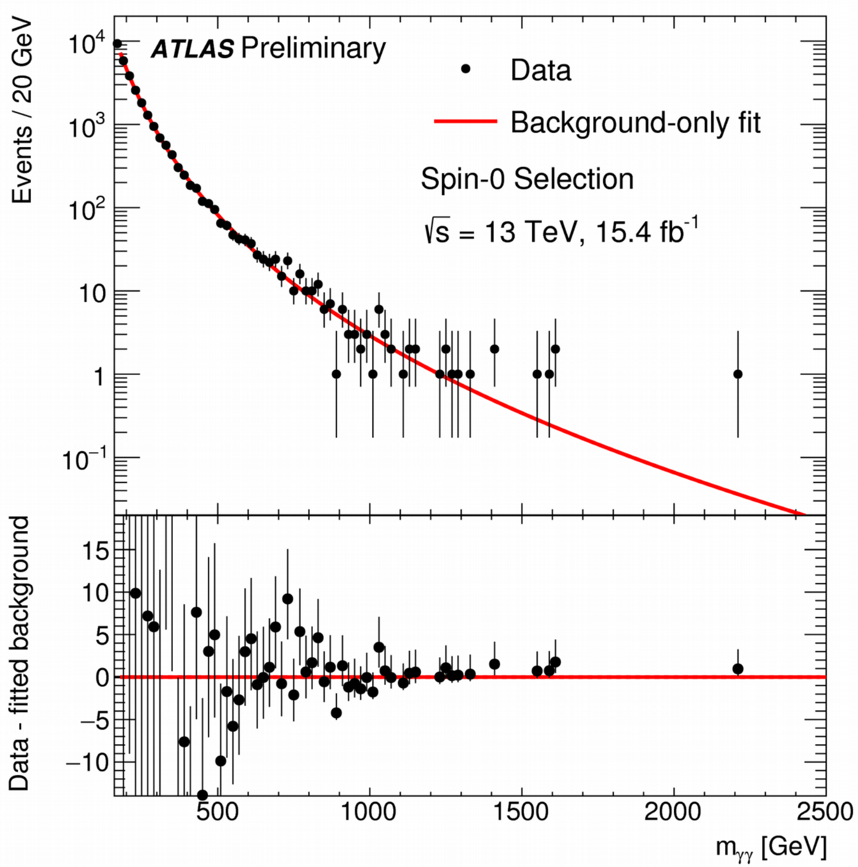




Diphoton search

Left over from 2015 excess:

- I recommend this as a use case in a class on how to interpret a result
- Can be interpreted as limit on new spin 0 particle



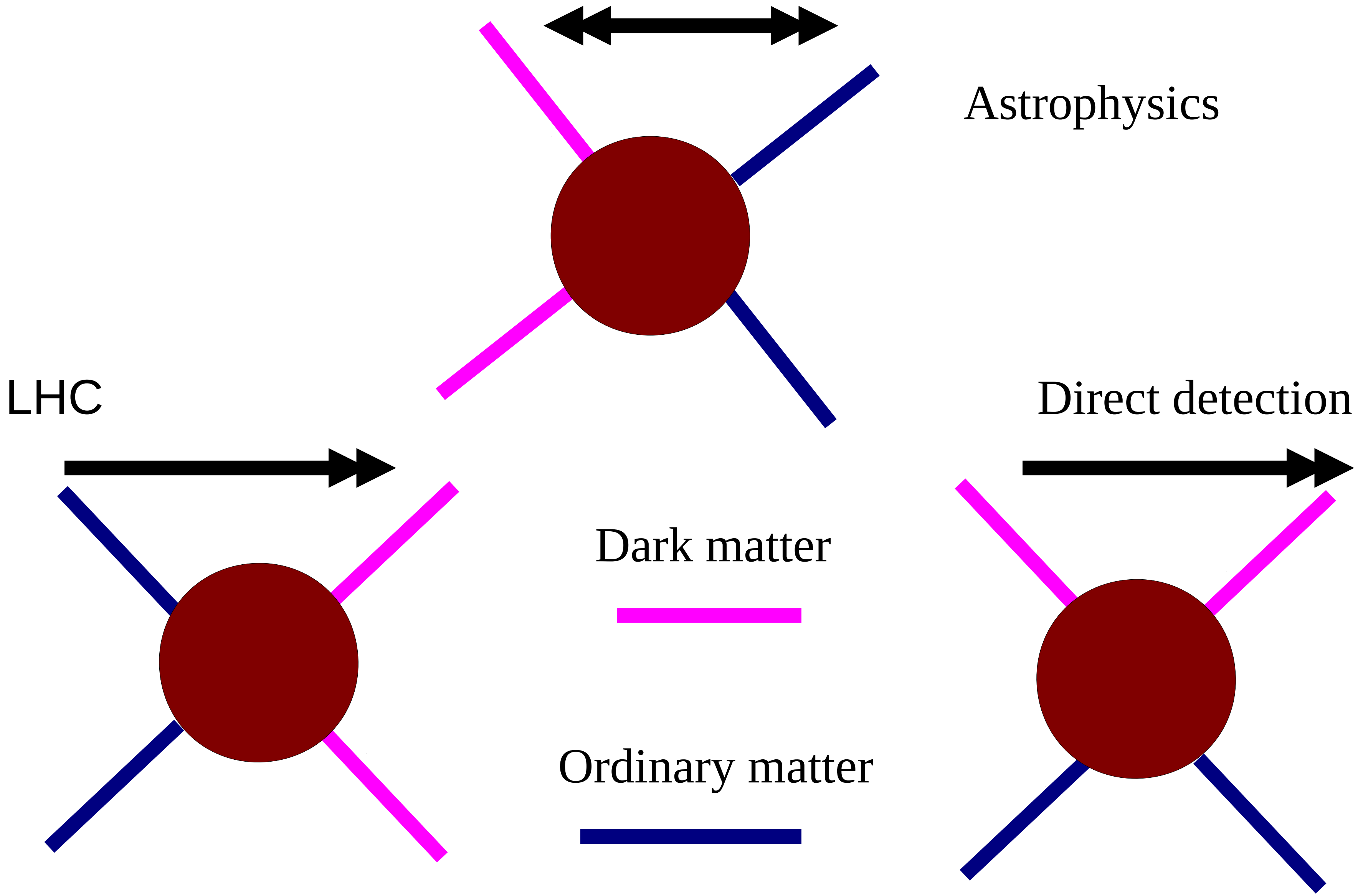
“Dark Matter” searches

These are all indirect and model dependent.

Basic idea

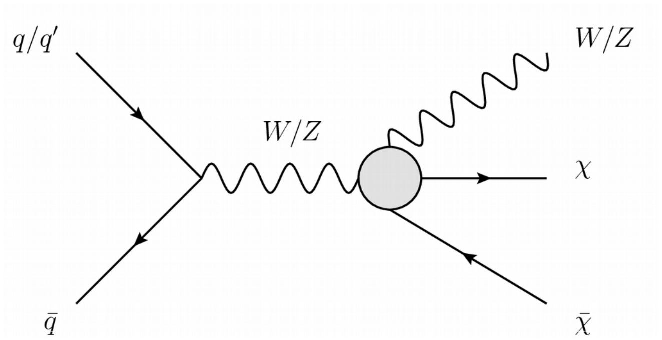
- Produce dark matter particle in pairs
  - Leaves no energy in detector: Missing ET signature
- Look for visible objects produced in association with DM
  - Any standard model object
    - Jets, photons, quarks, heavy quarks, Higgs
- Measuring something + missing energy
- Relies on proper understanding of
  - Standard model contributions
    - $Z \rightarrow \nu\nu$, $W \rightarrow \mu\nu$
      - » Validated from control regions
    - Lost jets, missing ET resolution
- Summary chart follows

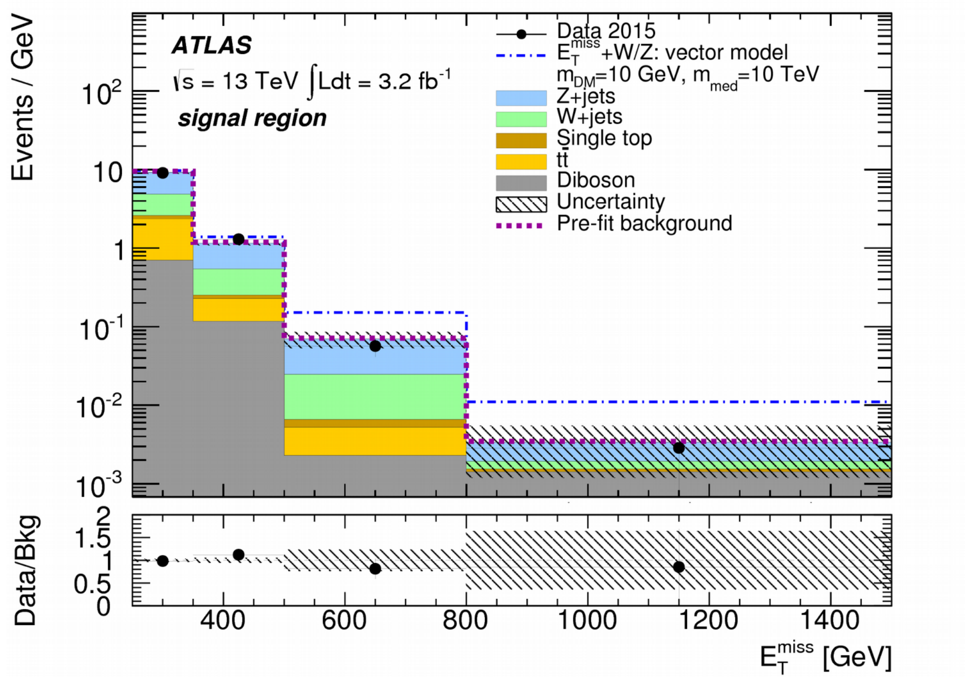
Generic approach



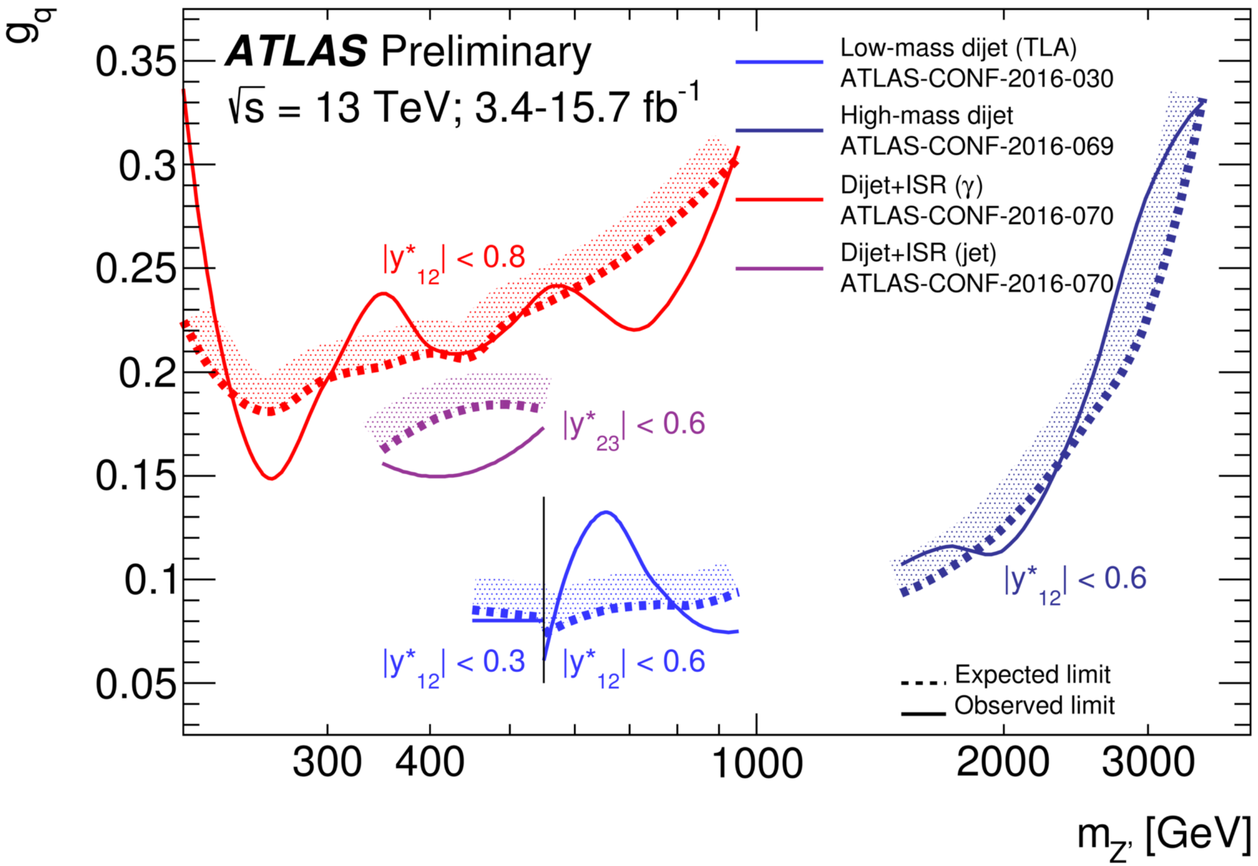
“Dark Matter”: new search

W/Z decaying to jets produced with DM candidate



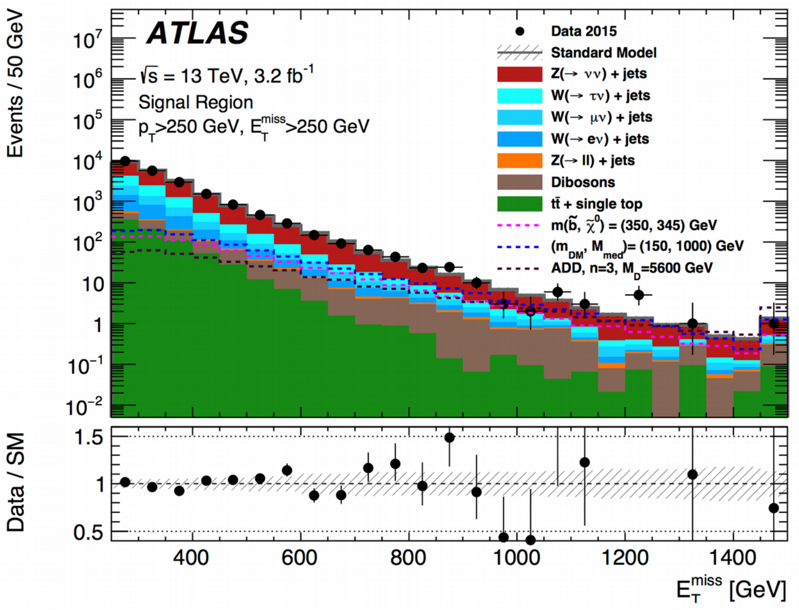


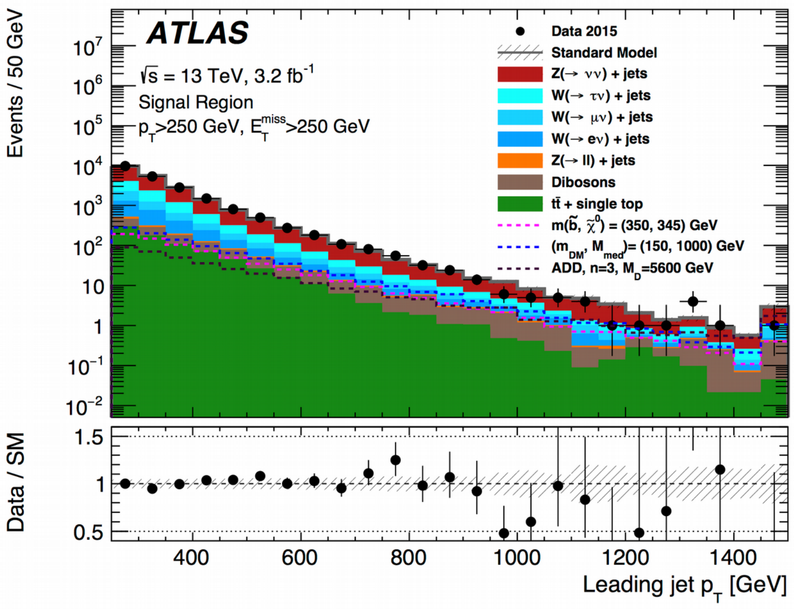
“Dark Matter”:”mediator model”



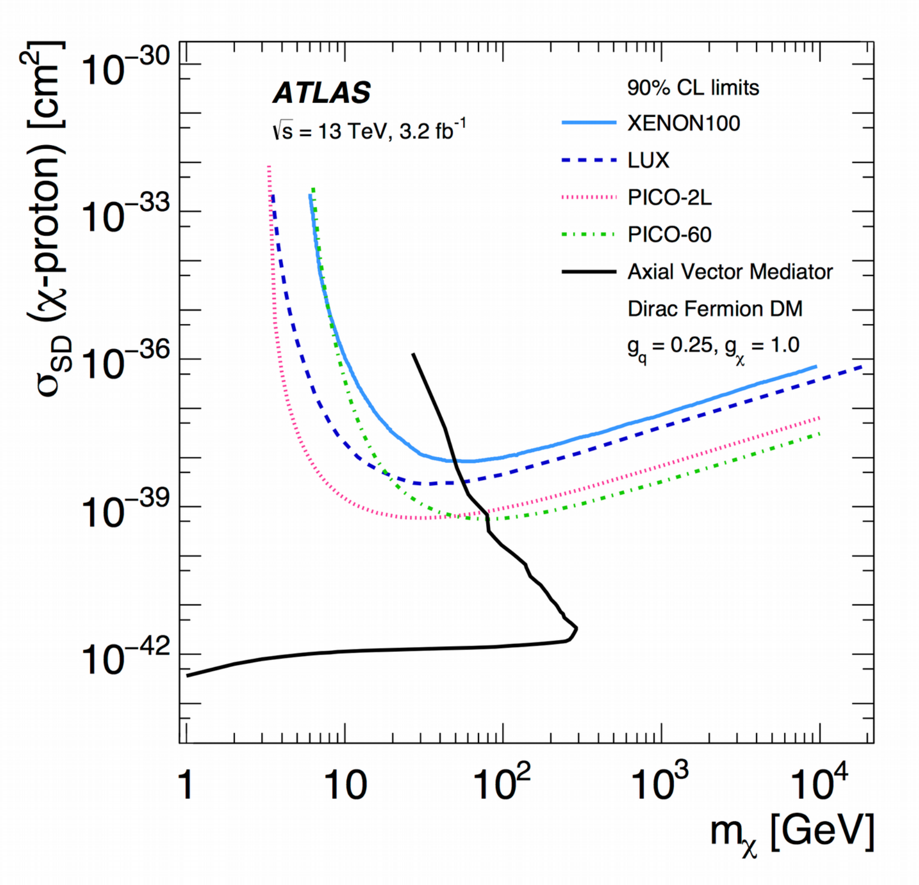
Jets+Met

- Dominant background is Z decay to neutrinos
- Validate using leptonic Z and W production





"Dark Matter": model dependent comparison to direct detection



Higgs as a search tool

New particles may decay to Higgs:

- Example of of X->HH
- Prototype for Higgs self coupling in Run-4+

Look for final state with largest Higgs Branching ratio

- 4 Jets with pairwise masses consistent with Higgs
  - B-tagging crucial to reduce QCD backgrounds
  - pt- threshold on jets crucial
  - QCD background is hard to computed
    - Use data driven method

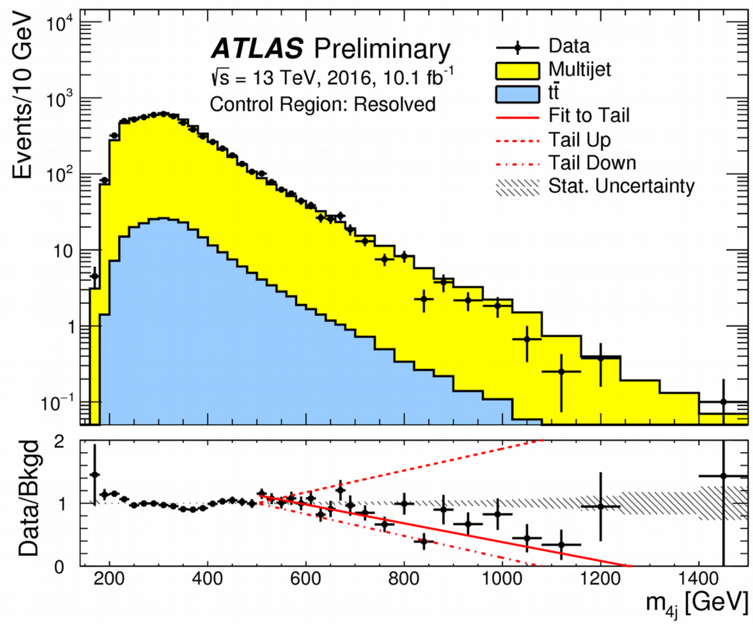
–

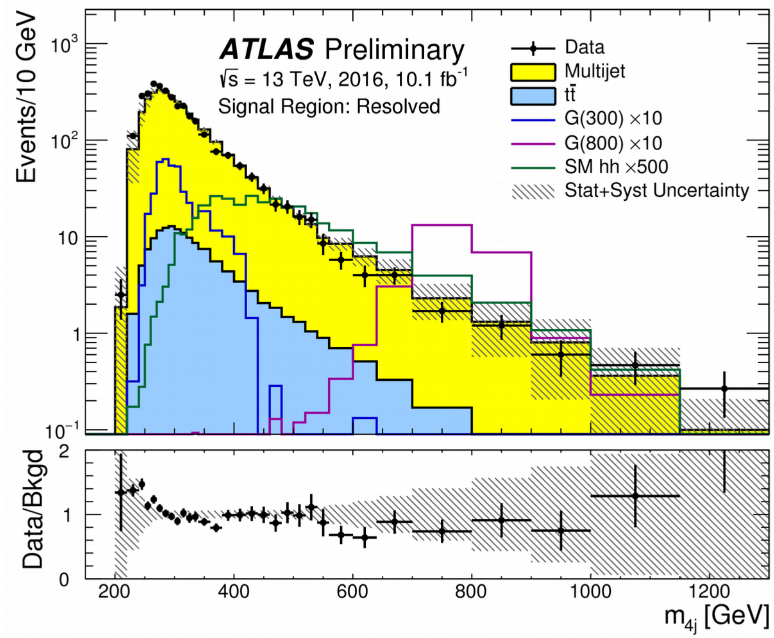
Higgs as a search tool

ATLAS-CONF-2016-049

4 Jets, 3 btagged,

- Consistent with two Higgs bosons
- Look for peak in HH mass
  - Background model from Higgs sidebands

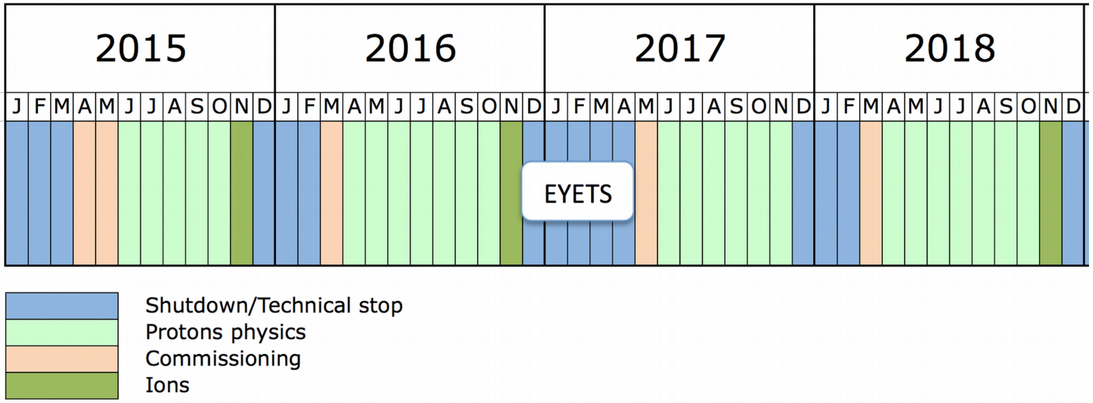




Looking forward

Details will evolve somewhat

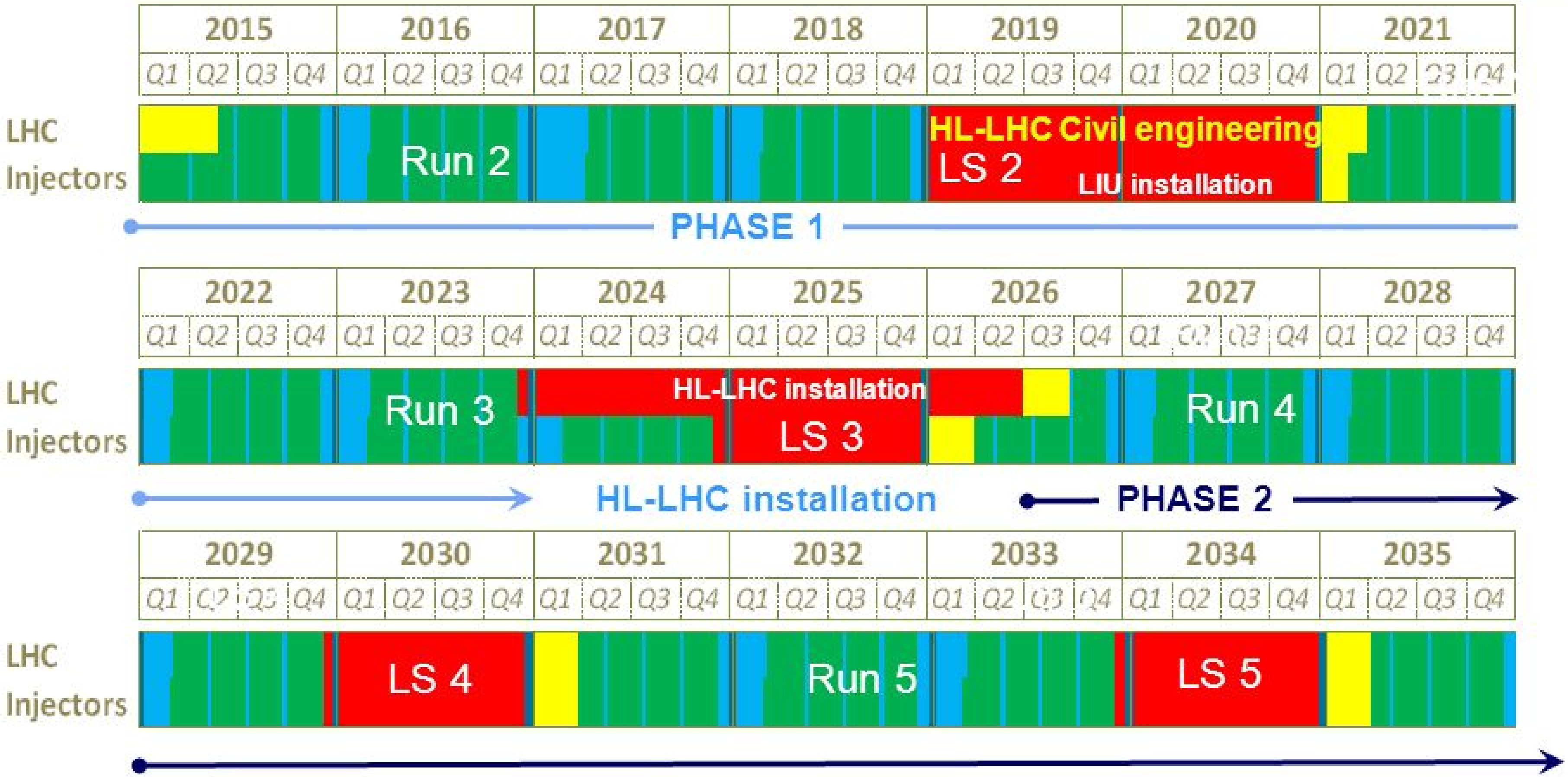
- Run-2 has two more years to go
- Notes for 2017
  - No Ion run
  - Later start for collisions than in 2016
  - Comparable integrated luminosity to 2016



LHC roadmap: according to MTP 2016-2020

LS2 starting in 2019 => 24 months + 3 months BC
LS3 LHC: starting in 2024 => 30 months + 3 months BC
Injectors: in 2025 => 13 months + 3 months BC

- Physics
- Shutdown
- Beam commissioning
- Technical stop



Longer term luminosity

Large increase in luminosity for Run-4 and later

- Goal is 3000 fb^{-1} integrated

Major detector upgrades needed to cope with consequent integrated luminosity

- Maintain thresholds at current values
  - Both at trigger and off-line
- Entirely new tracker
  - Layout not yet fully specified
-

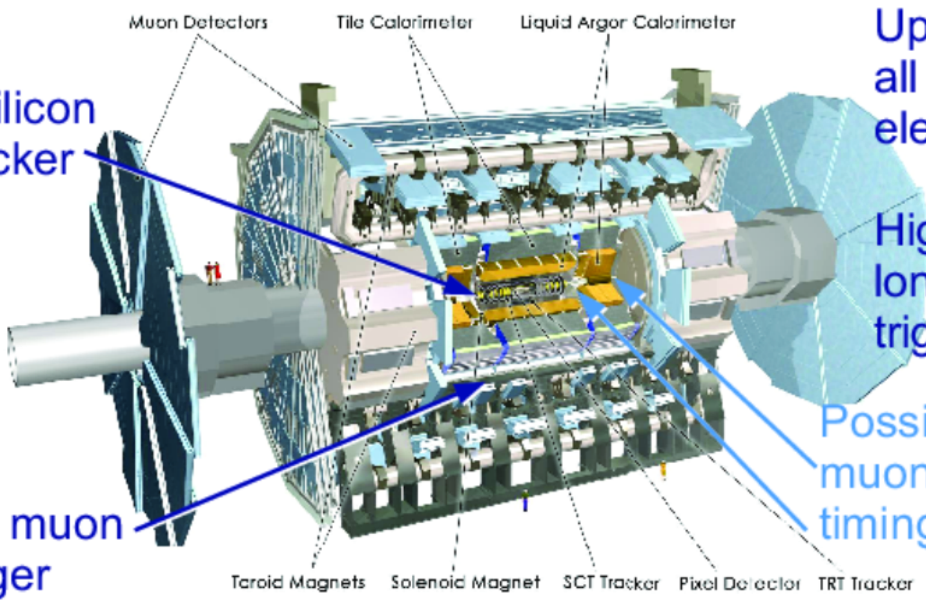
Longer term detector

Slide from Brian Peterson

Overview of Phase-II Upgrades

5

Overall scope of Phase-II upgrades is mostly settled



ew all-silicon
ıner Tracker

ew inner muon
ırrel trigger
ıambers

Upgrade
all front-end
electronics

Higher rate,
longer latency
trigger system

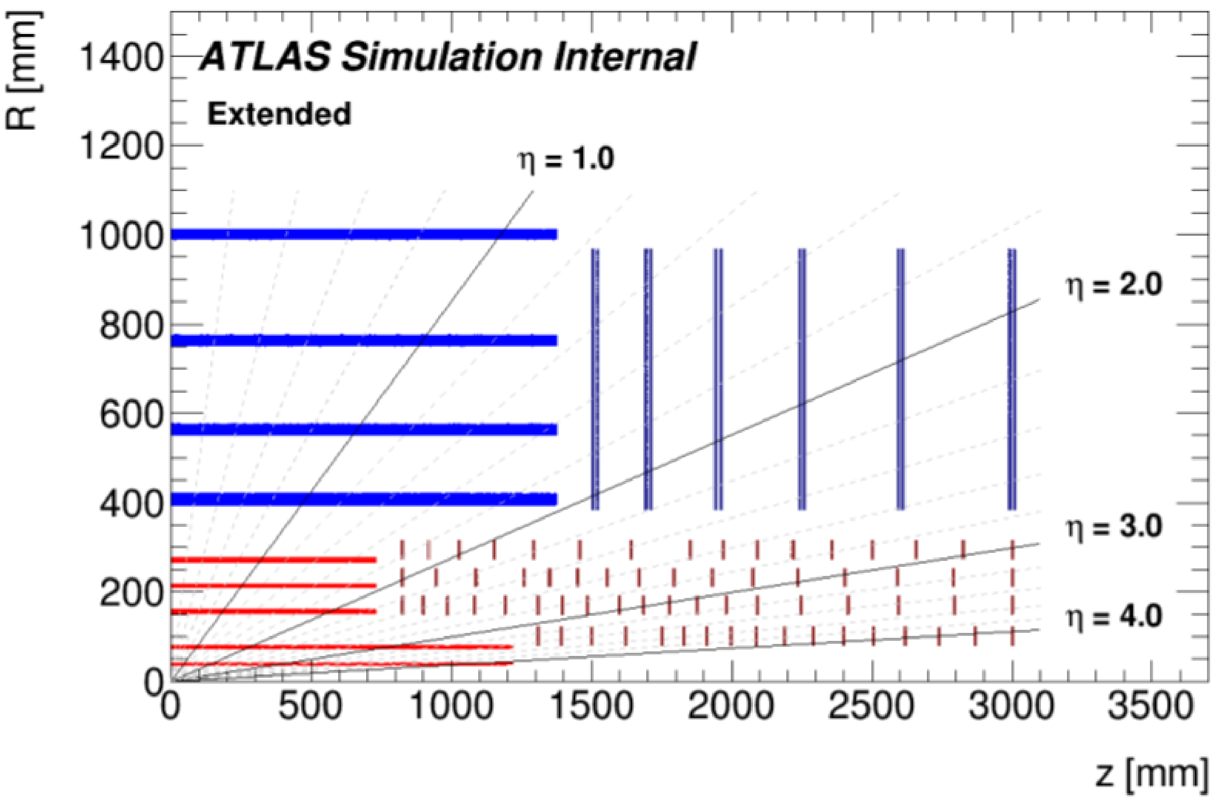
Possibly forward
muon tagger and
timing detector

Now evaluating different design/implementation options
towards submission of TDRs over next 15 months

ATLAS upgrade schedule

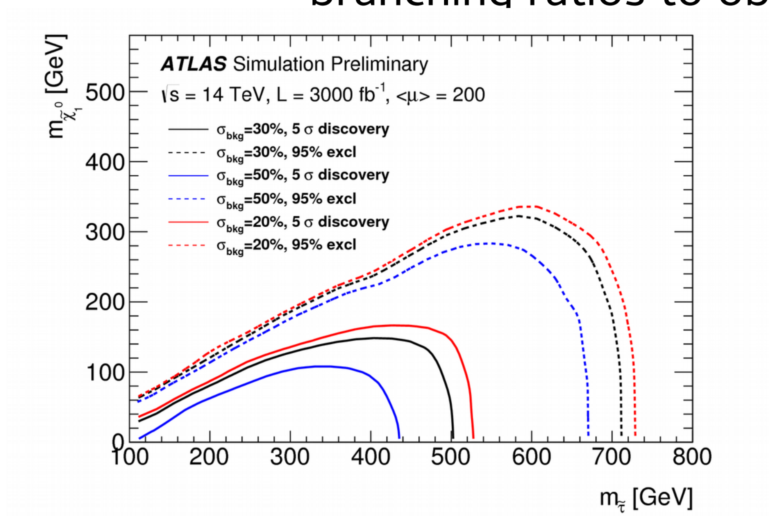
Tracker upgrade

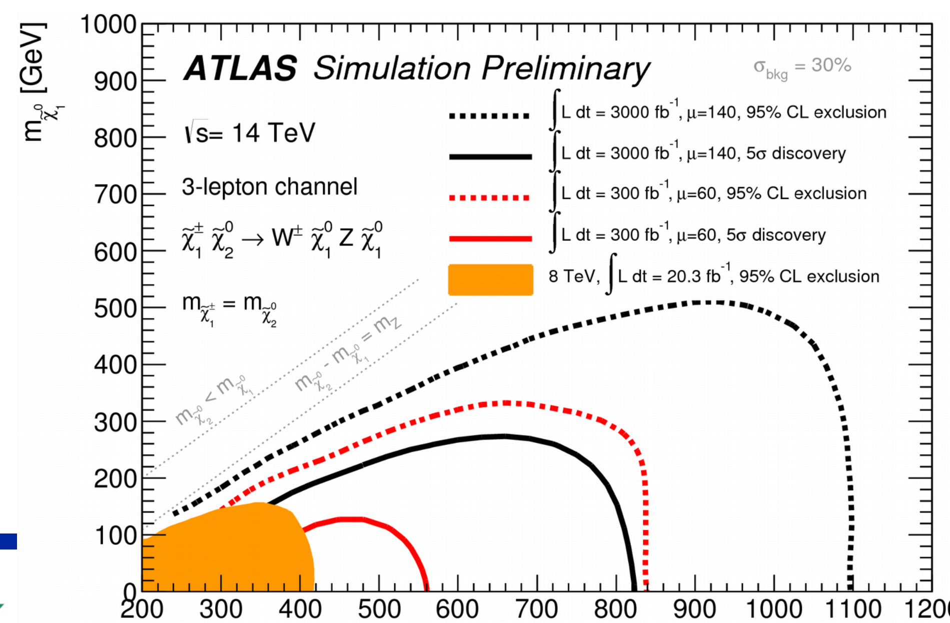
–



Physics goals: New physics

- Detailed Standard Model parameters and processes
  - Most important is Higgs (later)
- Measure properties on particles discovered in Run-2
  - Still waiting
- Extend searches.
  - Larger masses
  - Currently accessible masses, but lower production rates or small branching ratios to observable channels

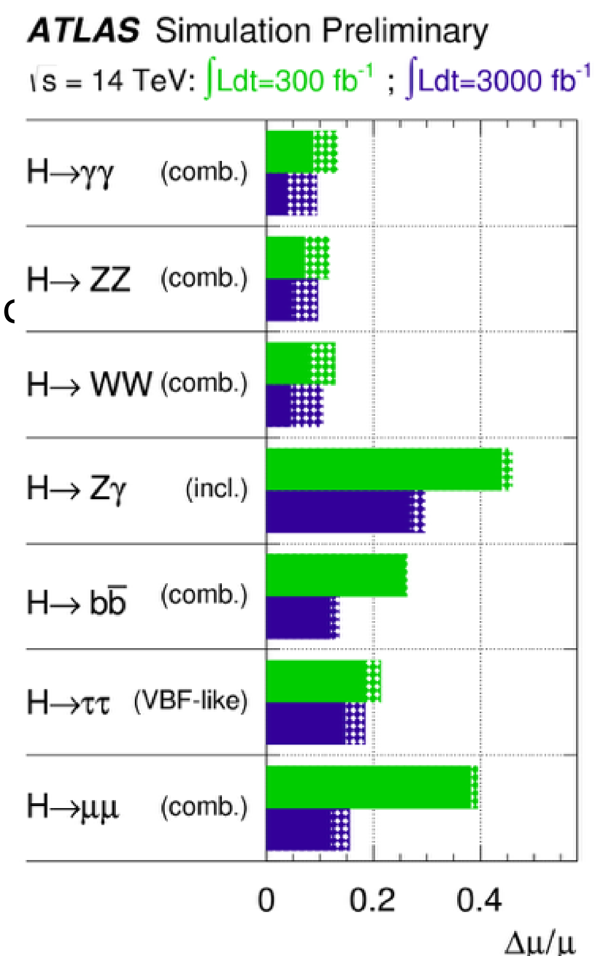




Long term Physics goals: Higgs

Well defined program

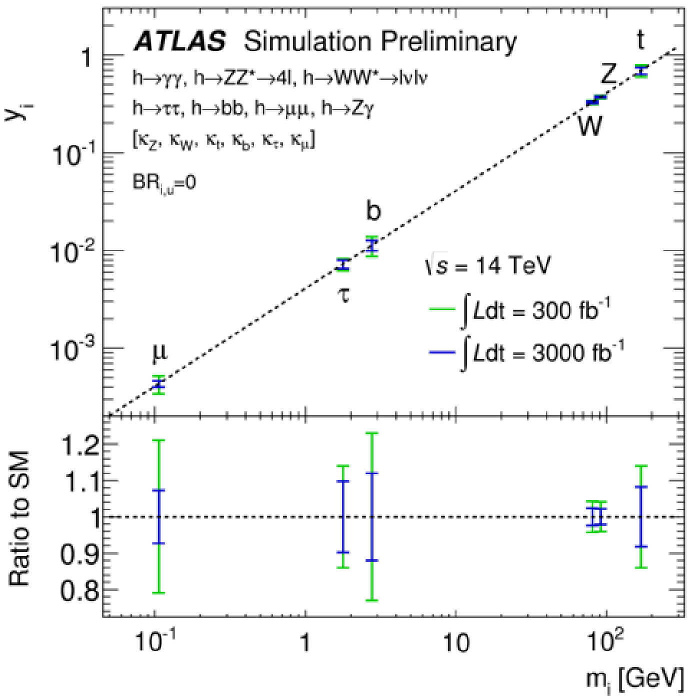
- Observe H μμ
  - Measure rates to μμ and ττ
- Other rare processes Zg
- Constrain Higgs width
- Constrain Higgs self coupling
  - Measure rate of Higgs pair produc



Higgs to μμ

Limited by background from Drell-Yan production.

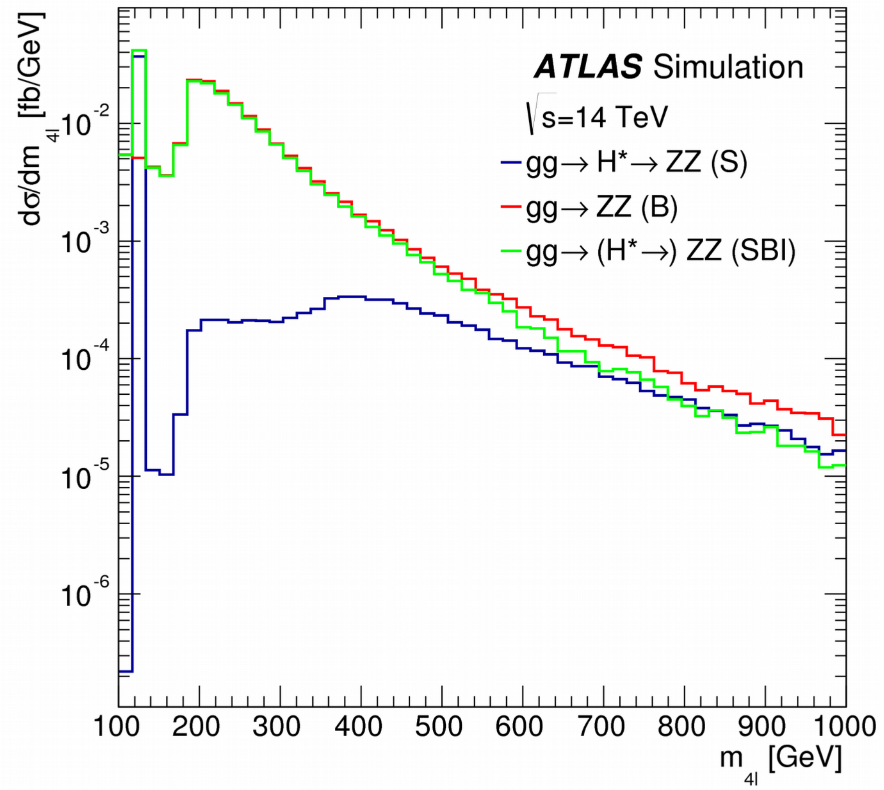
– Current limit: BR <



Higgs Width

Measure ZZ to 4l for m(4l)>220 GeV

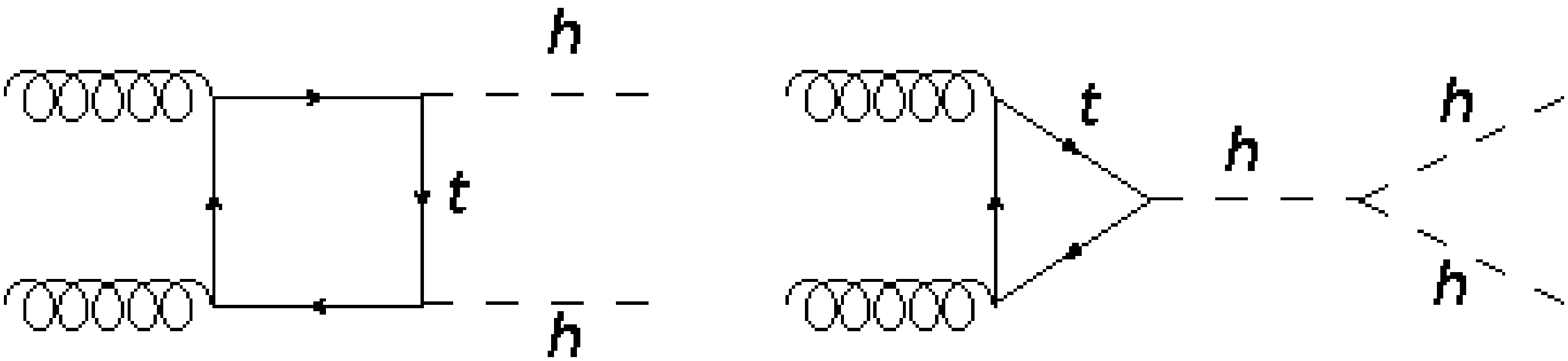
- Sensitive to interference and hence Higgs width
-



ATL-PHYS-PUB-2015-024

Higgs pair production

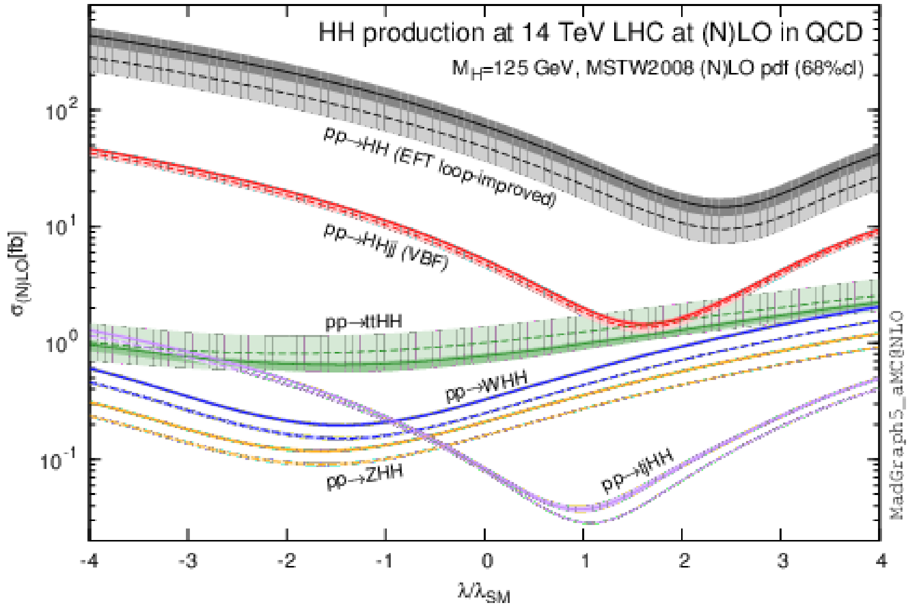
Destructive interference between production diagrams



- Rate is minimized for Higgs self coupling at Standard Model value
- Can begin to constrain coupling into a range as data is accumulated

http://xxx.lanl.gov/abs/1401.7340

Higgs pair production



- Rate is minimized for Higgs self coupling at Standard Model value
- Can begin to constrain coupling into a range as data is accumulate
- Note that total production rate is ~10 fb

http://xxx.lanl.gov/abs/1401.7340

Higgs pair production (bbbb)

Large backgrounds from

- QCD production of 4 bquarks
- Top pair production in association with bb
- (bbbb) mass distribution differs from signal

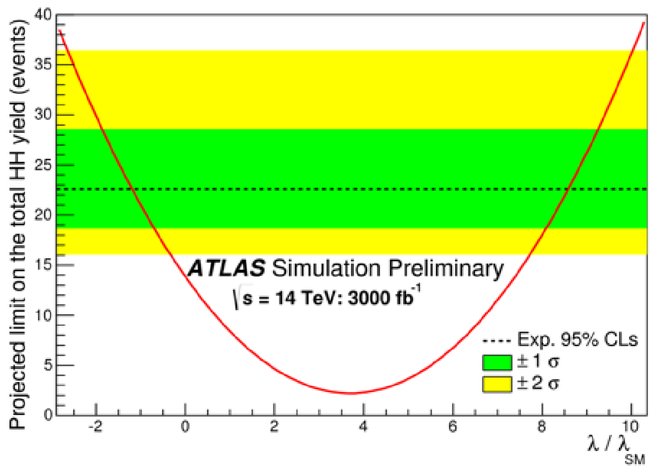
Channel with largest rates

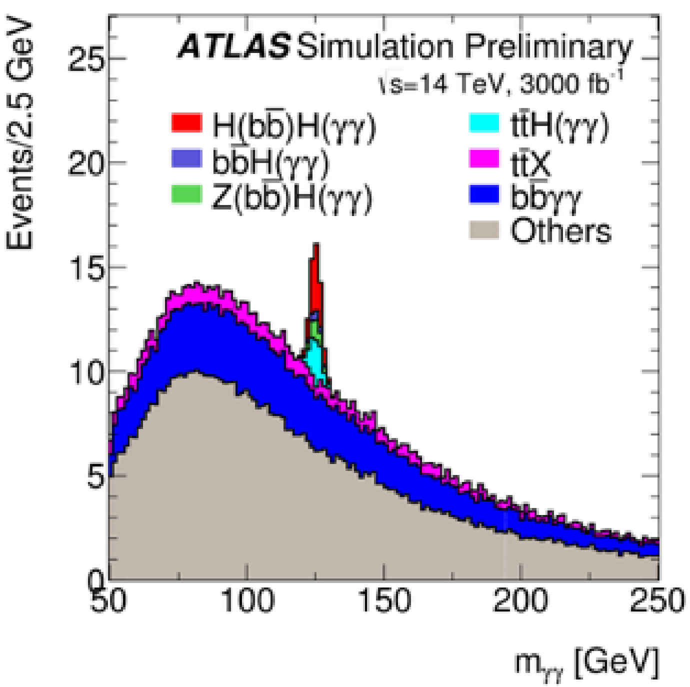
Challenges

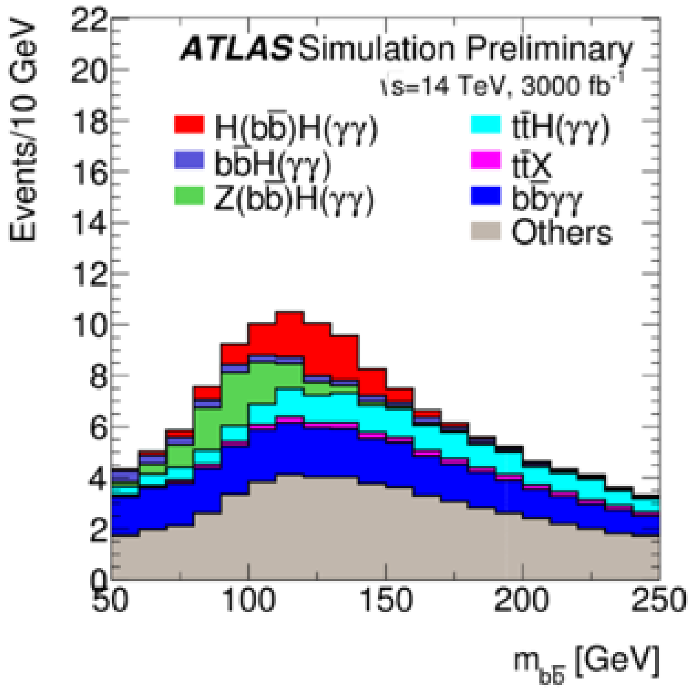
- Acceptance due to trigger thresholds
- Shape of (bbbb) mass distribution not very sensitive
- Systematic uncertainties very important

Higgs pair production (bbγγ)

- Rate limited
  - Small γγ branching ratio
- Much better S/B







Summary

Large backgrounds from

- QCD production of 4 bquarks
- Top pair production in association with bb
- (bbbb) mass distribution differs from signal

Channel with largest rates

Challenges

- Acceptance due to trigger thresholds
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