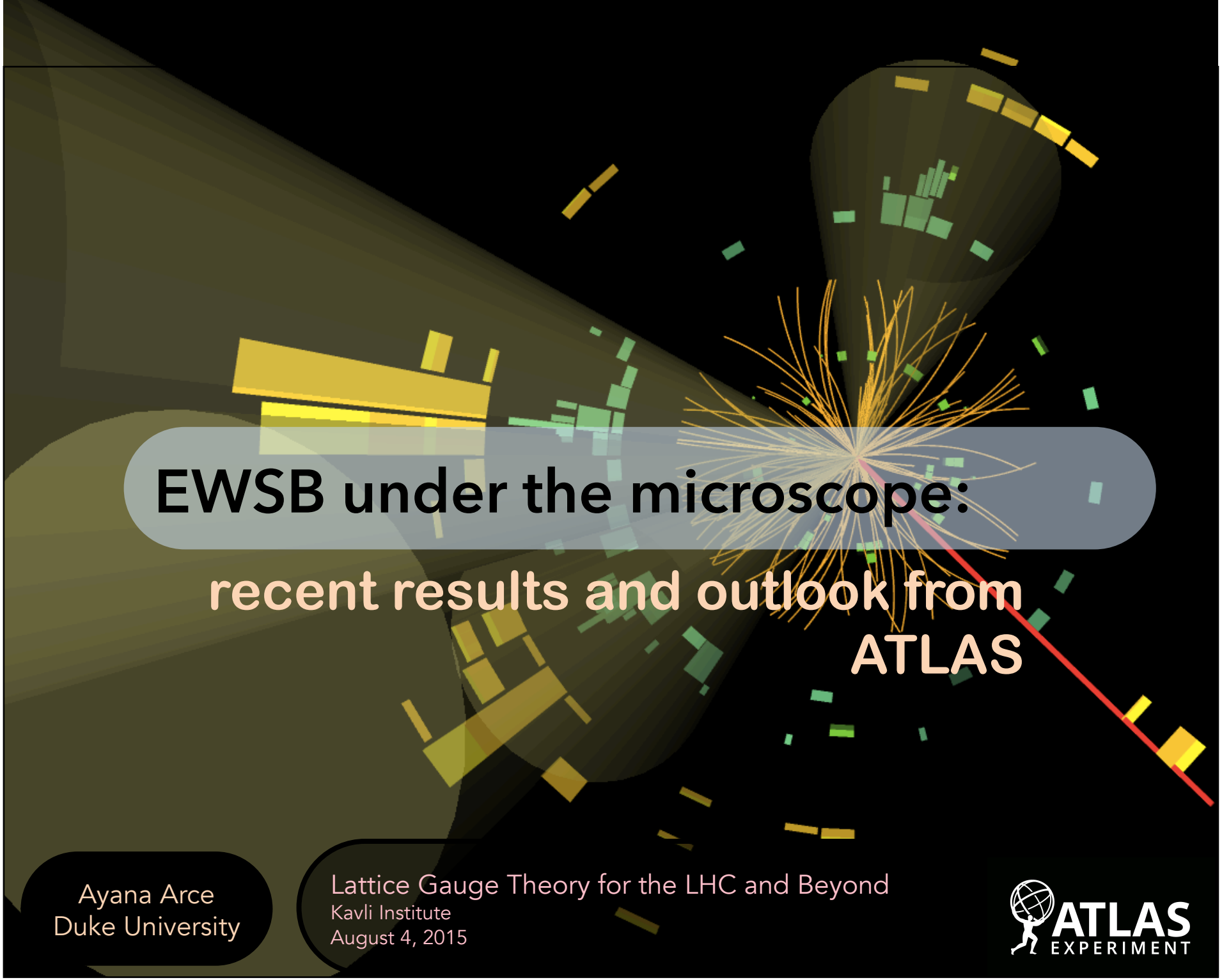


EWSB under the microscope:

recent results and outlook from ATLAS

Ayana Arce
Duke University

Lattice Gauge Theory for the LHC and Beyond
Kavli Institute
August 4, 2015

ATLAS EXPERIMENT

outline

some perspective on Run I results:

Run I measurement tools and techniques

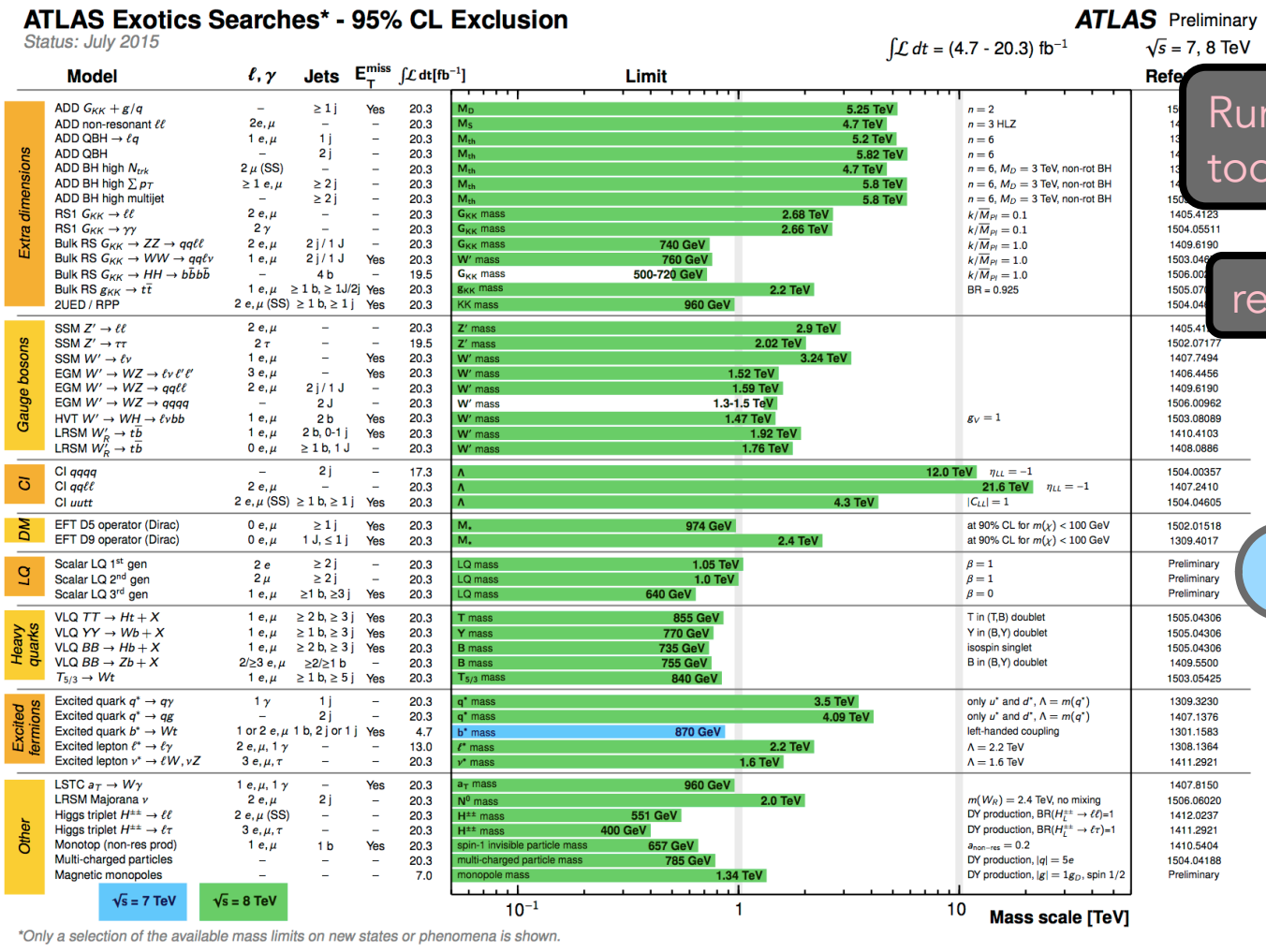
recent results:

new resonances

higgs couplings

t,b partners

Outlook on Run II and beyond



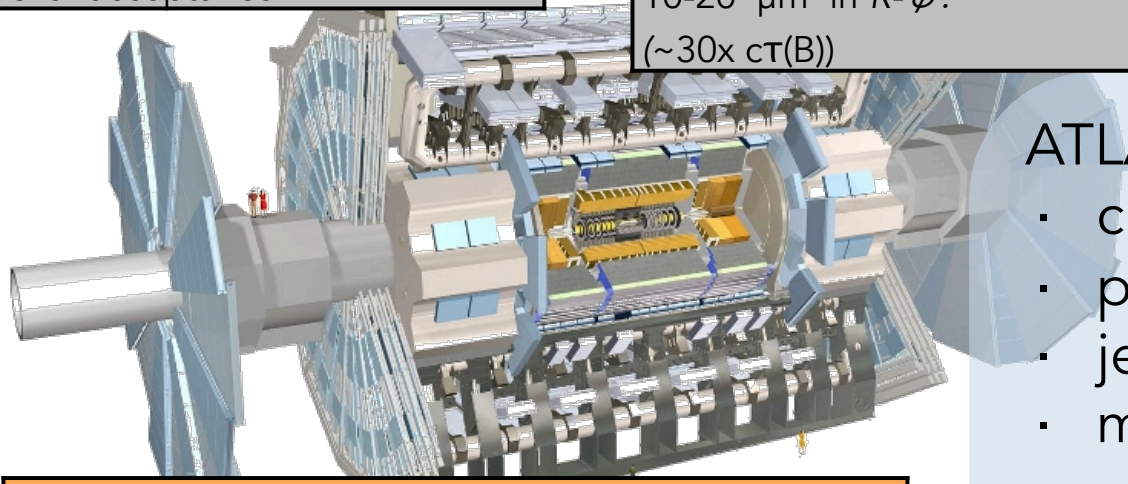
experimental

TOOLS

how to explore the attoscale

Muon drift tubes + cathode strips
μ-ID efficiency > 99% within tracker acceptance

Inner tracker: to |η|~ 2.5
10-20 μm in *R-ϕ:*
(~30x cτ(B))

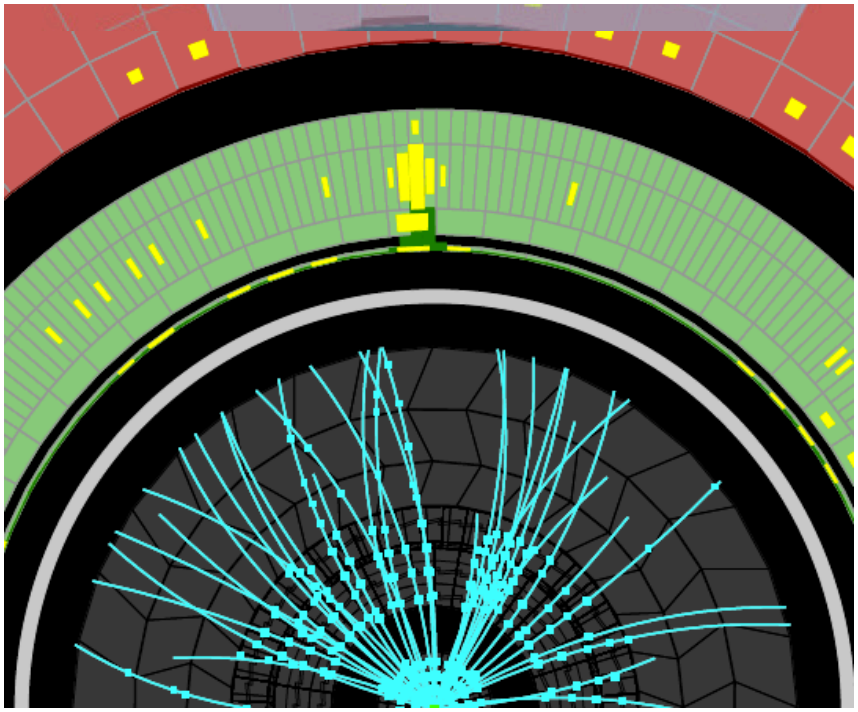


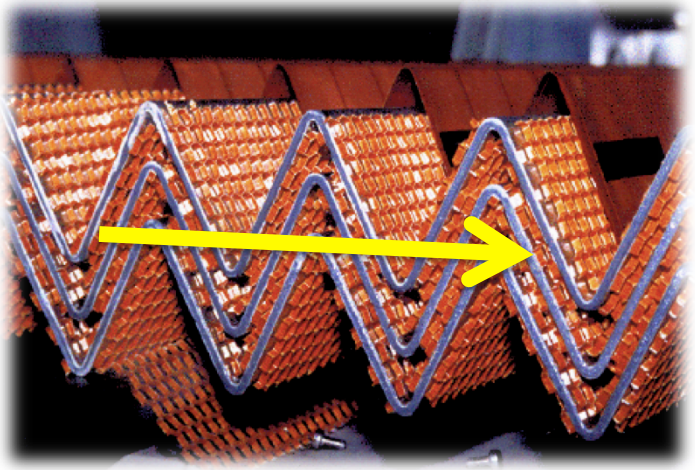
Central calorimeters (to |η|~2.5)
granularity ~ 0.025 (EM, LAr) to 0.1 (HAD, Tile):
- photon z_0 resolution ~15mm
- resolves Z^0 decay products at 1.8 TeV

ATLAS measures:
- charged particles
- photons/electrons
- jets
- muons

Key Run I **probes**:
- photons
- W/Z bosons
- τ leptons
- b-jets
- Higgs bosons (!)

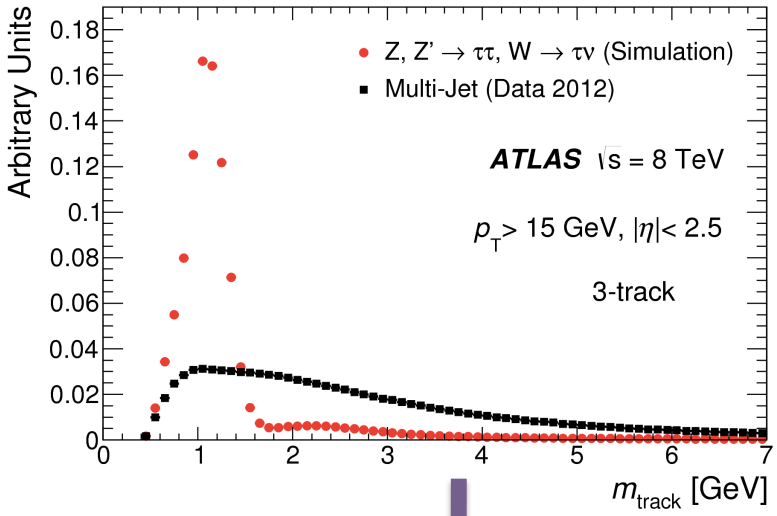
photons

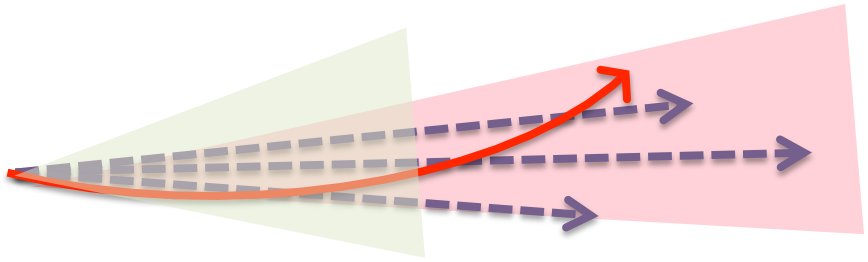




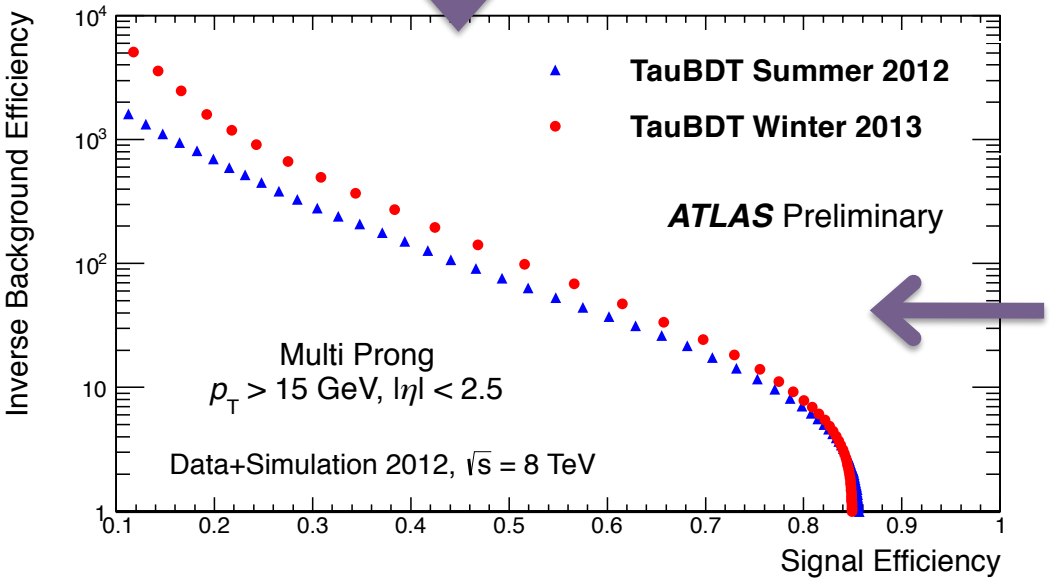
material in inner detector	up to 2.5 X_0(40% of photons are converted)
energy resolution	10%/√E (1% constant term in barrel)

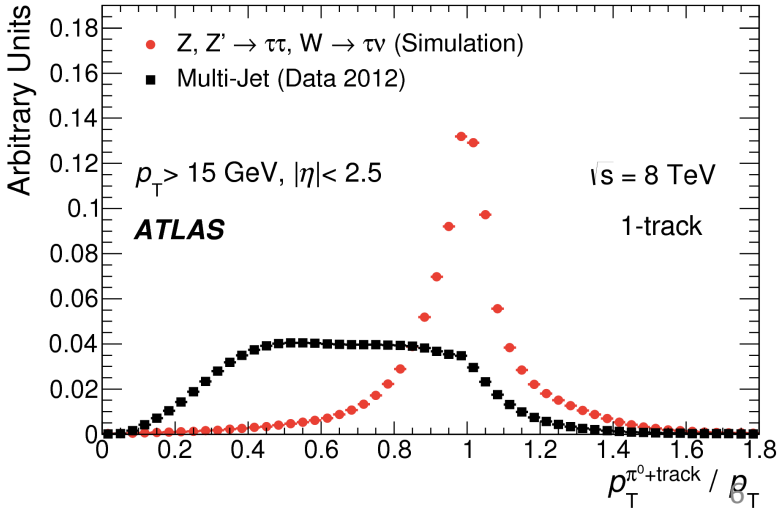
τ leptons



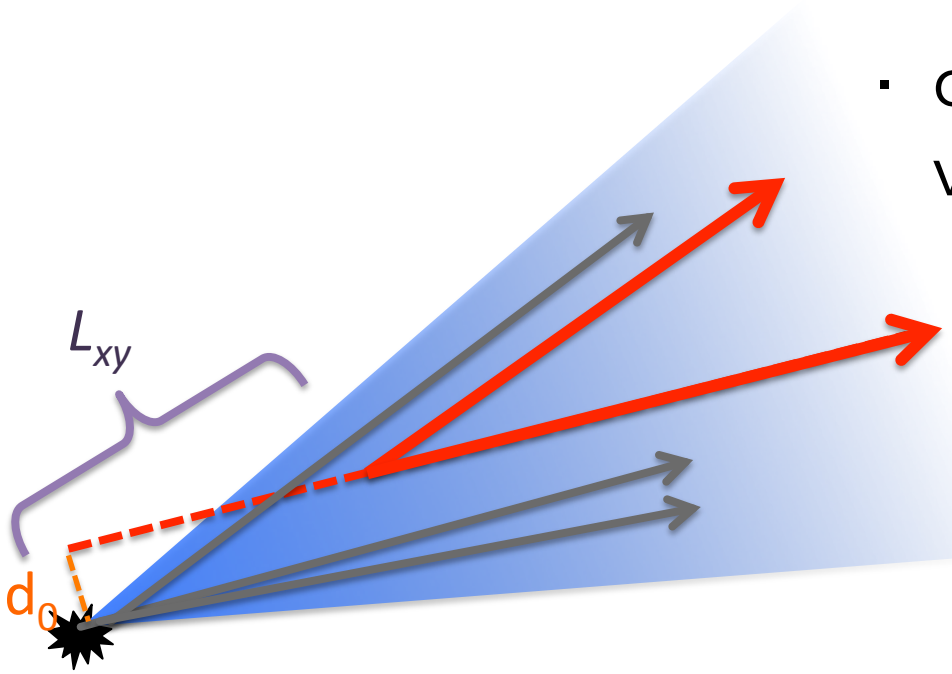


* τ_H trigger selects ~80% of offline "medium" candidates @ 40 GeV
* τ_H efficiency measured to < 4%





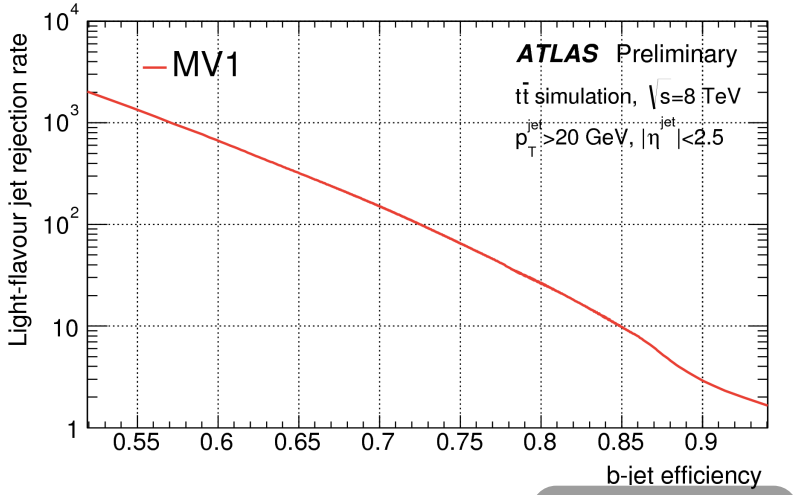
b-jets

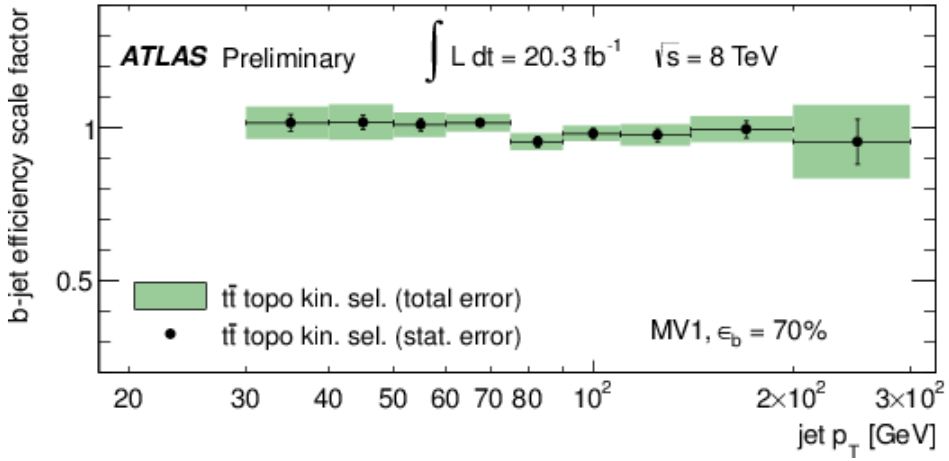


- combine discriminating variables:
  - N_{tracks}, m_{vertex}
  - vertex L_{xy} significance
  - track impact parameter d_0
  - vertex p_T ratio

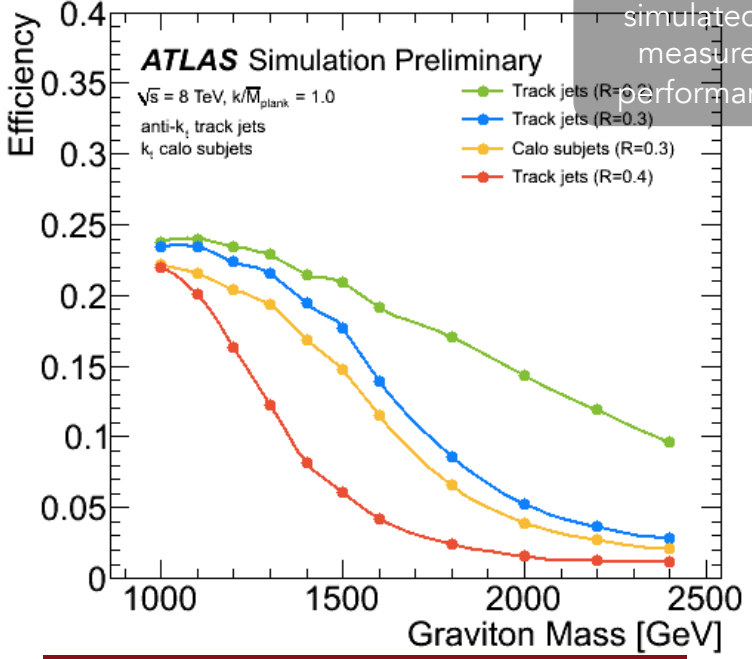
- b-jets identified by tracker properties: useful independence from calorimeter
  - muons, neutrinos in b-jets degrade jet energy response and resolution

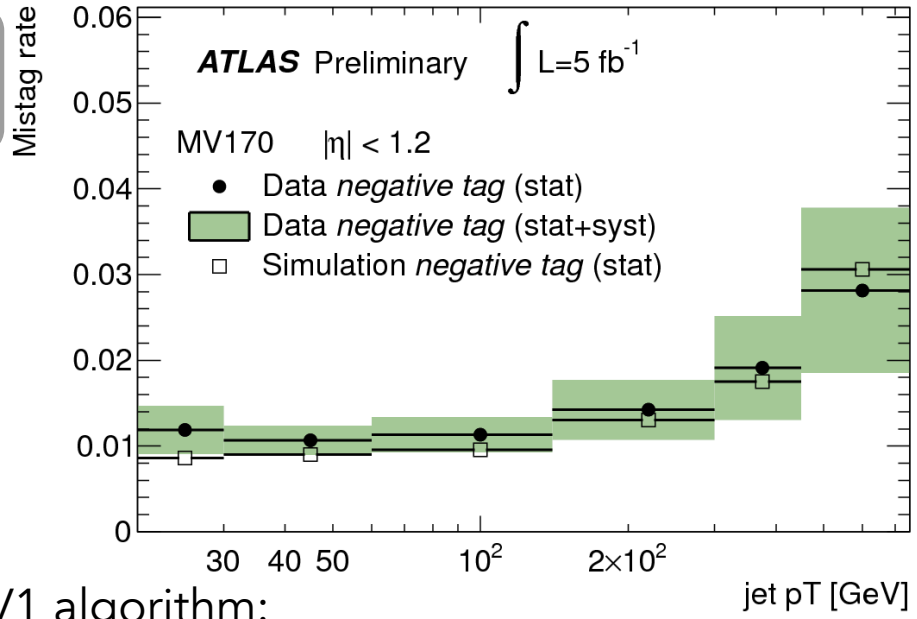
b (and $b\bar{b}$)-jets: performance





simulated & measured performance



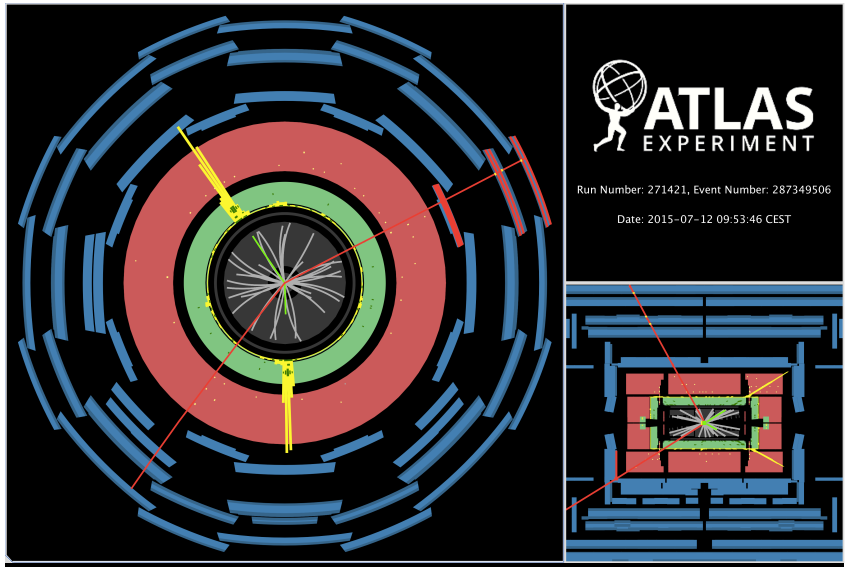


MV1 algorithm:

- neural network uses 3-d impact parameters and vertex reconstruction

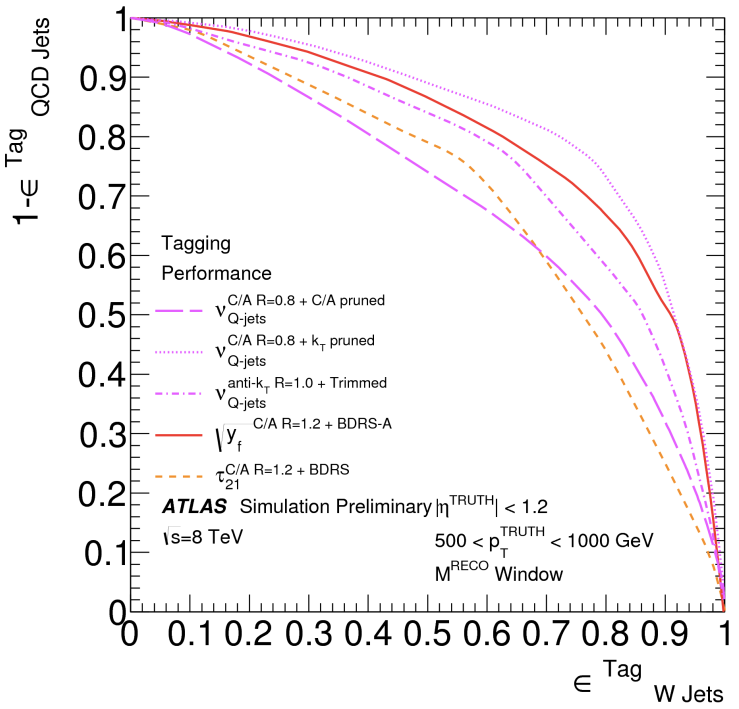
double b-tags in large-R jets

W/Z bosons



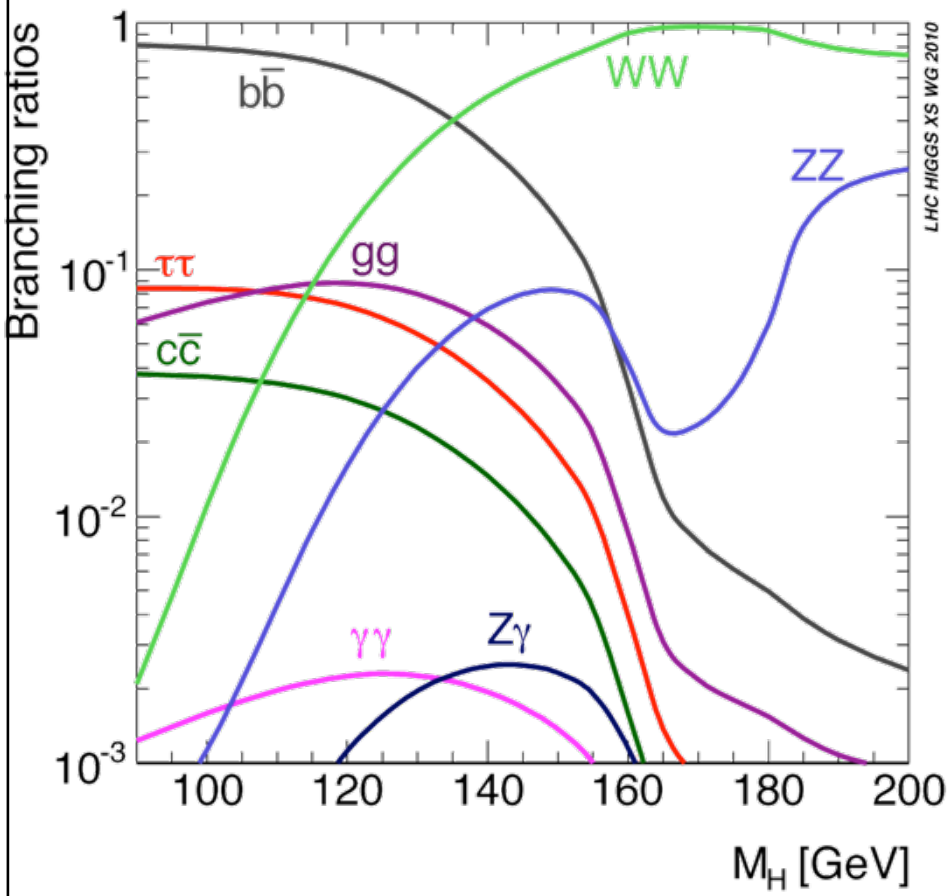
Pure: isolated electrons and muons and/or missing transverse energy

- Efficient: jet pairs or massive, large radius jets

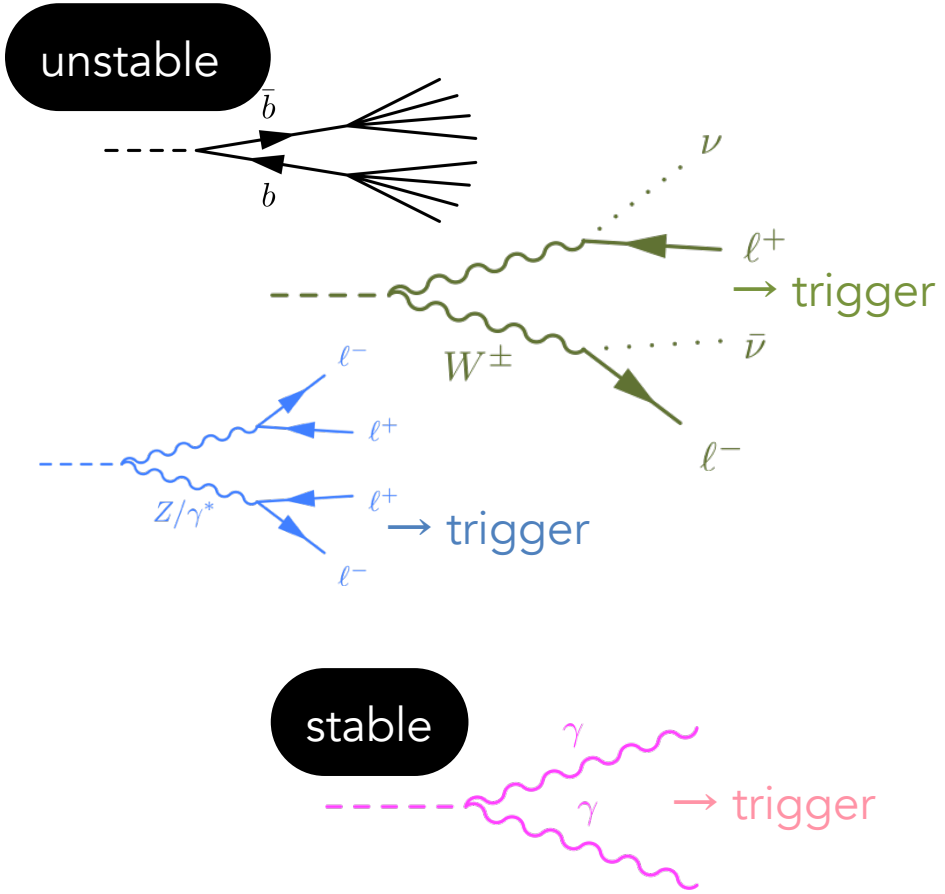


Higgs bosons

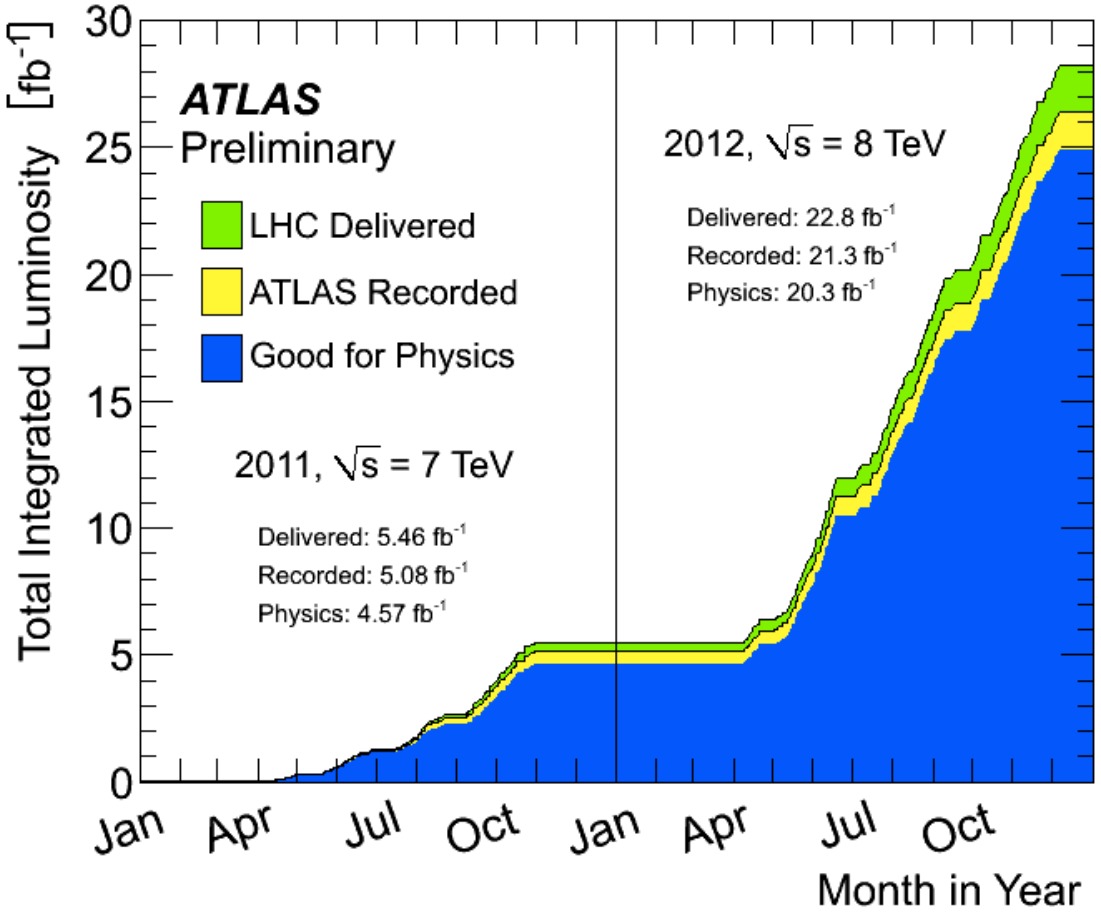
Higgs decay probabilities



Observable final states

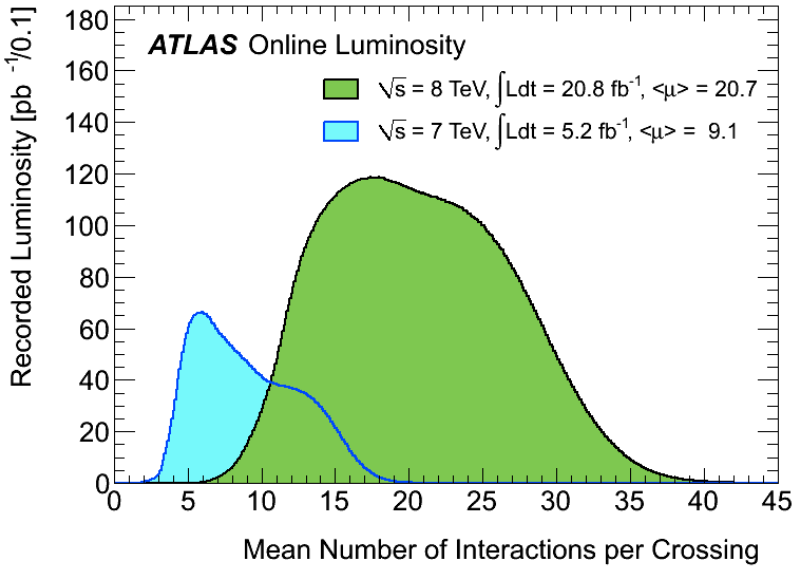


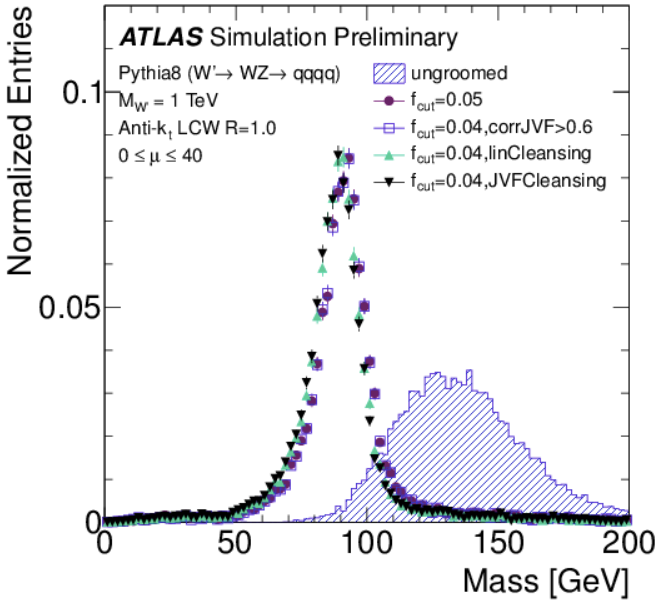
luminosity, 2011-2012

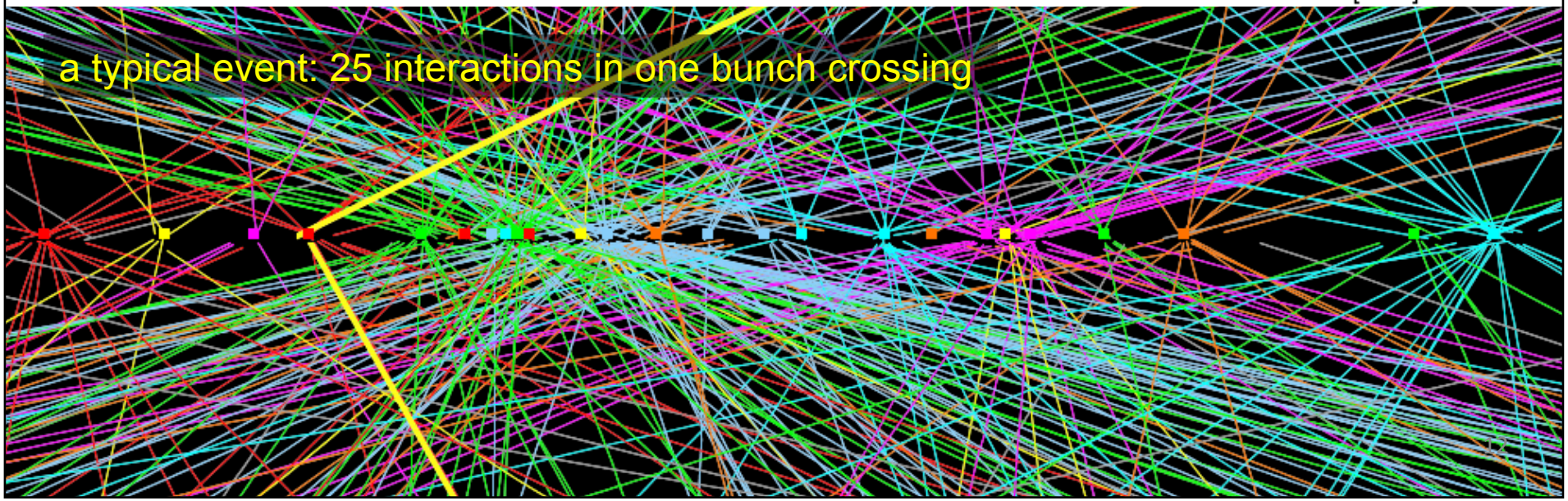


2012 uncertainty: 2.8%

luminosity, 2011-2012



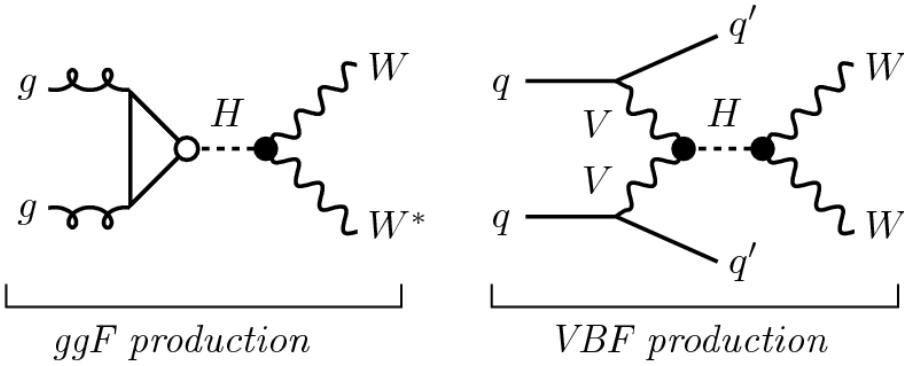


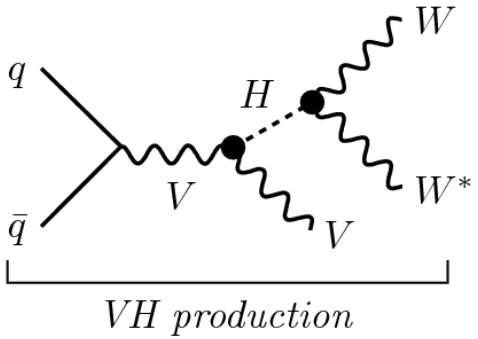


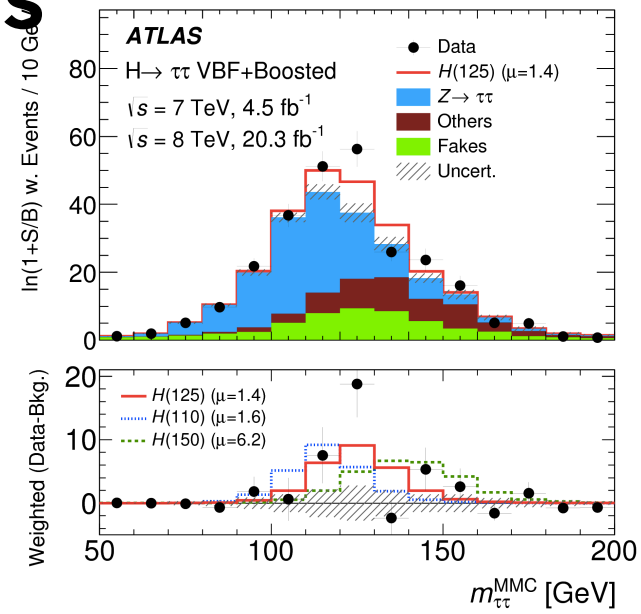
light higgs

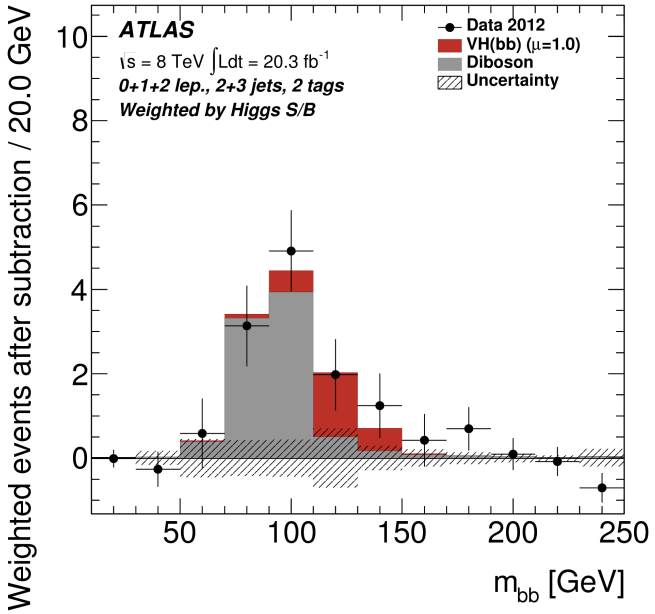
COUPLINGS

probing Higgs couplings

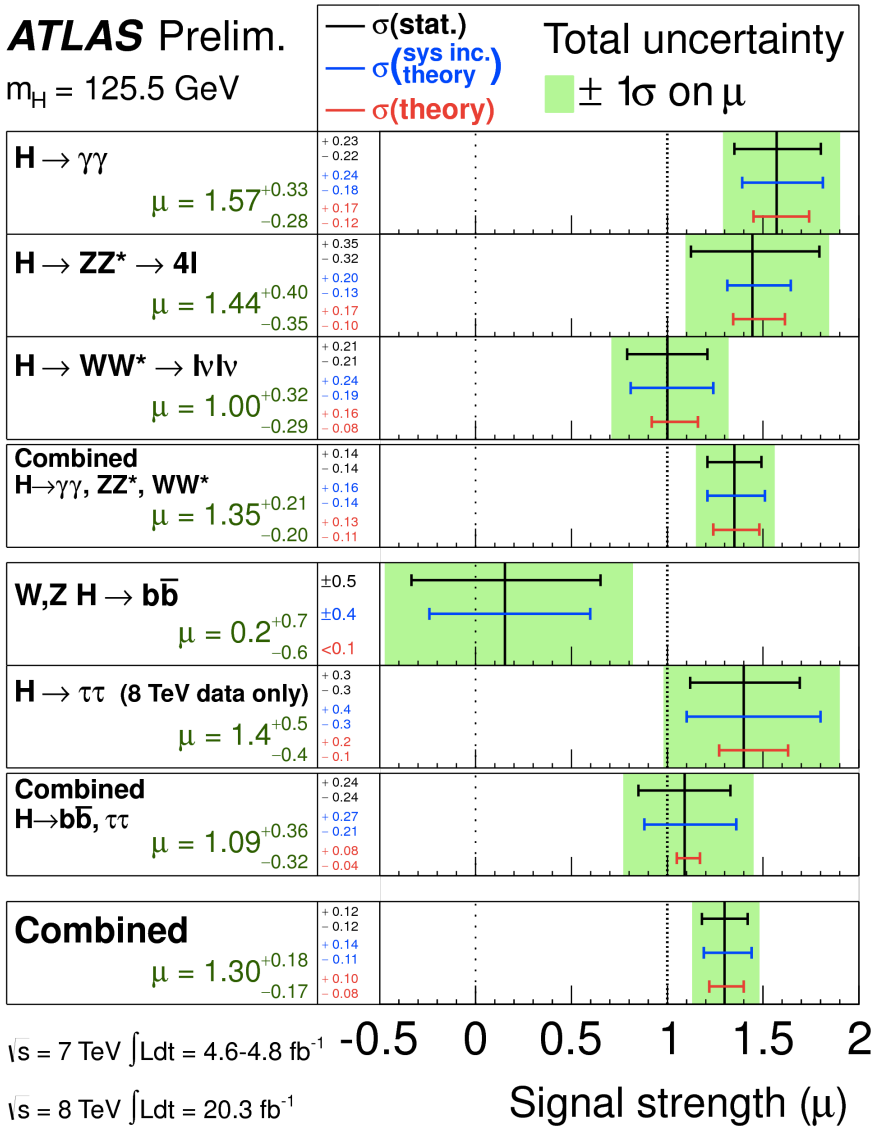






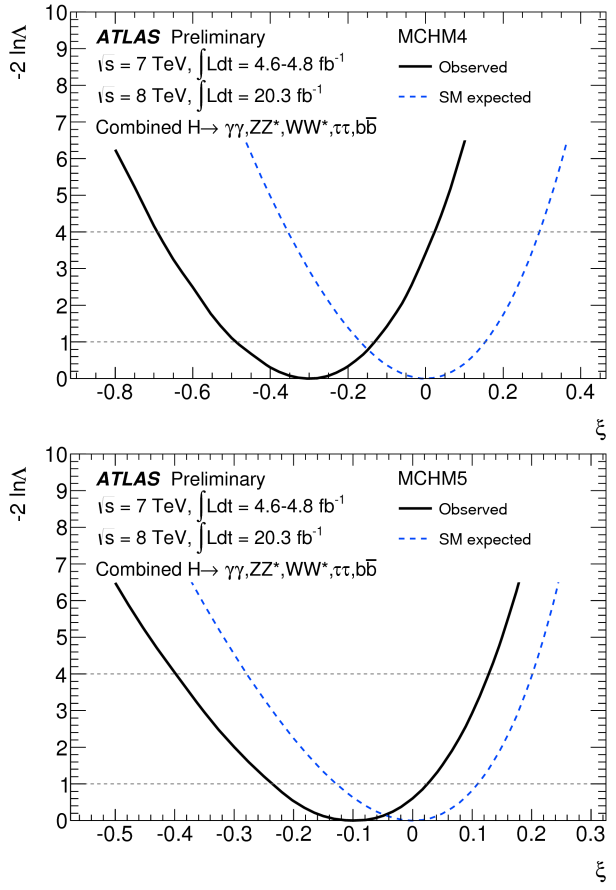


interpretation: MCHM



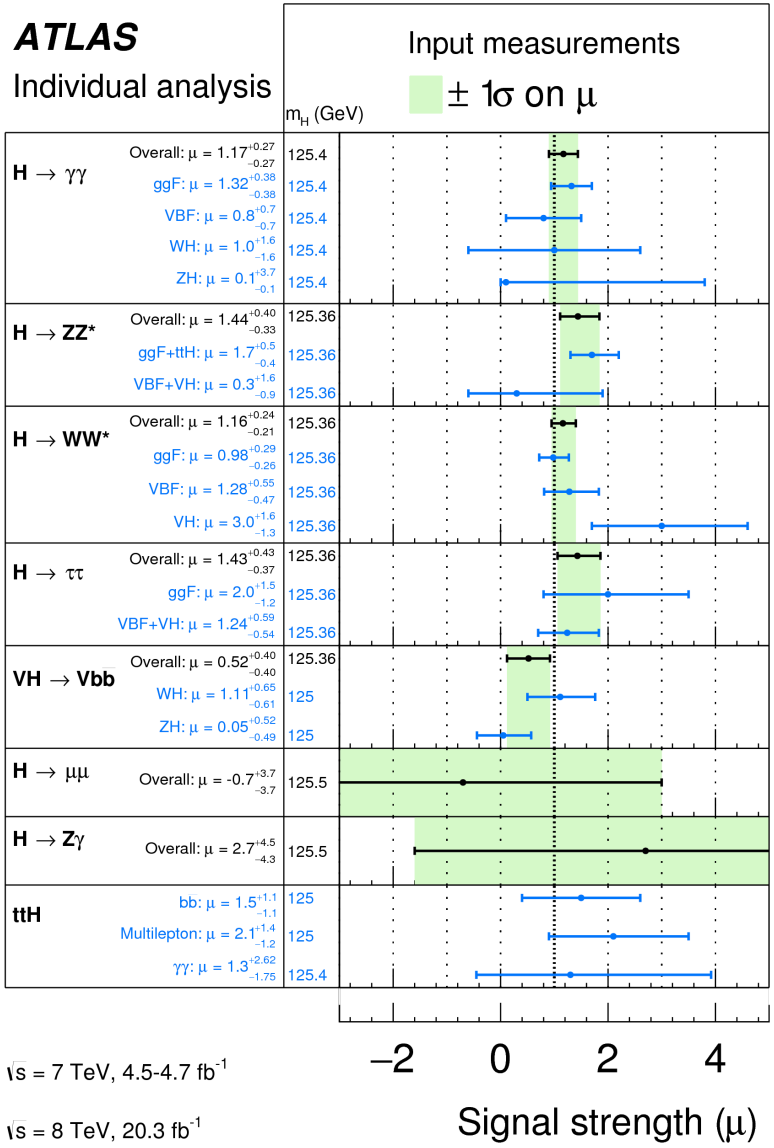
large SM coupling signal strengths:

compositeness scale fit prefers unphysical region



ATLAS-CONF-2014-010

interpretation: MCHM



large SM coupling signal strengths:

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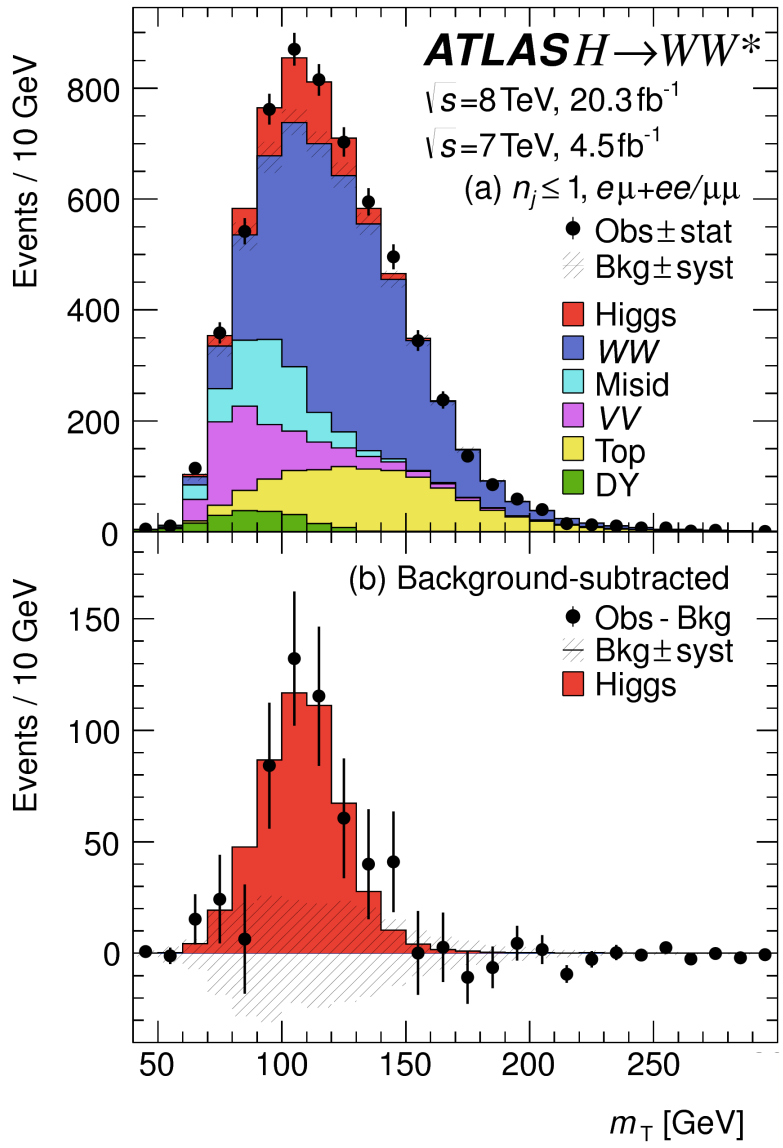
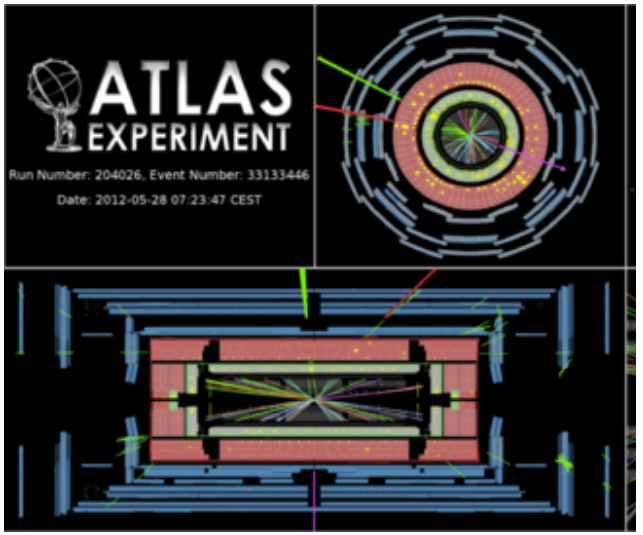
PRD 92 012006 (2015)

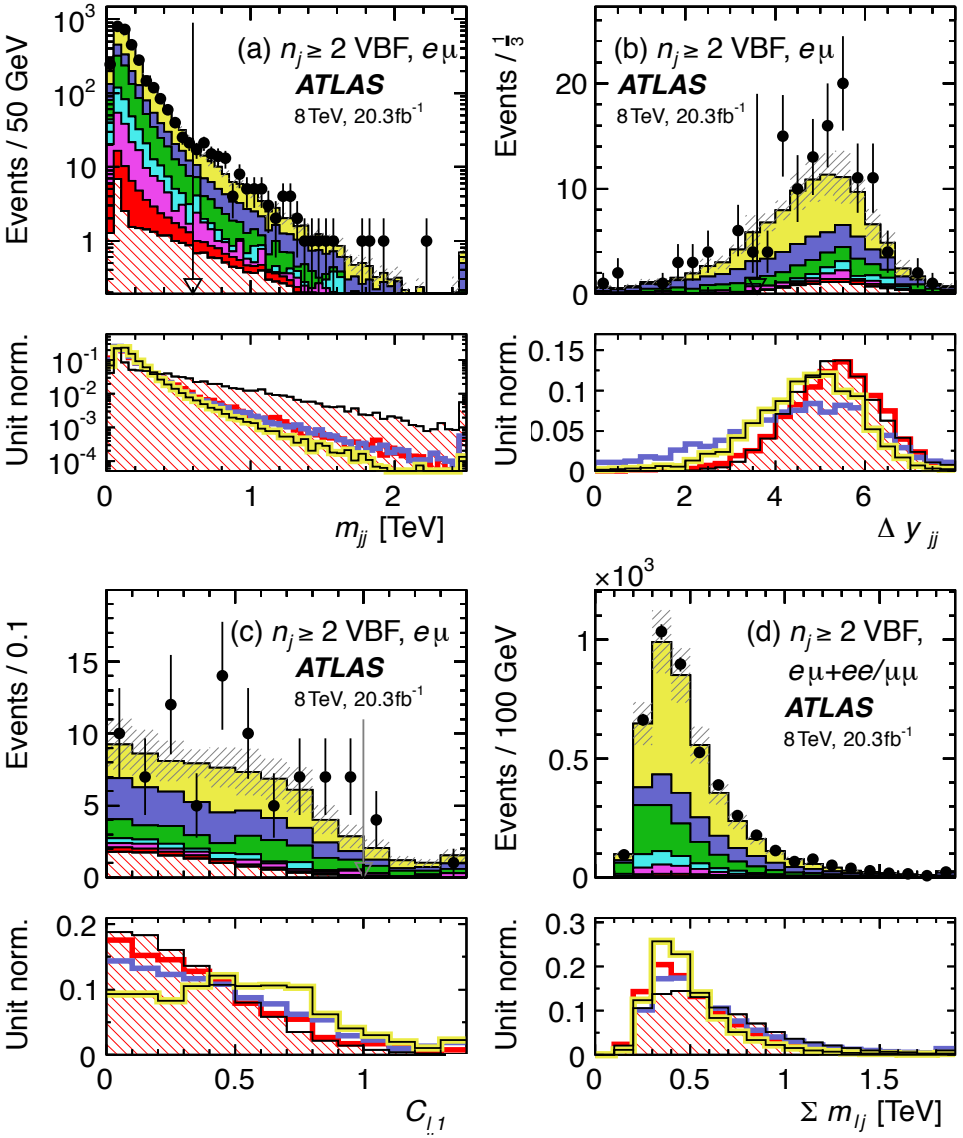
H → WW* measurements

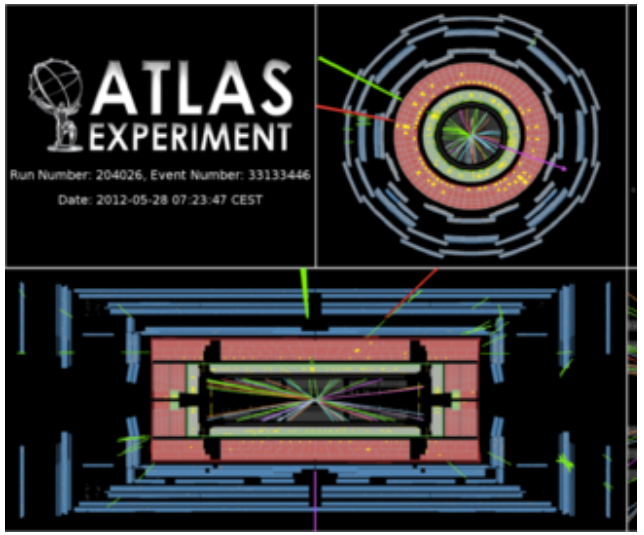


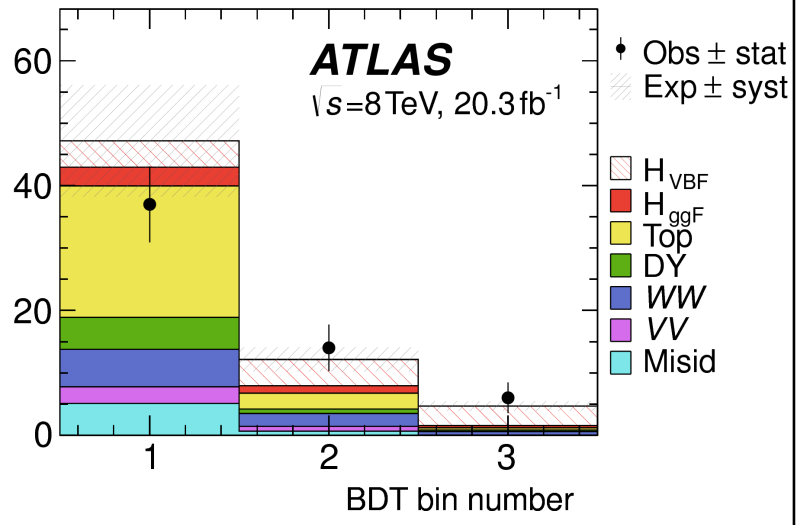


PRD 92 012006 (2015)

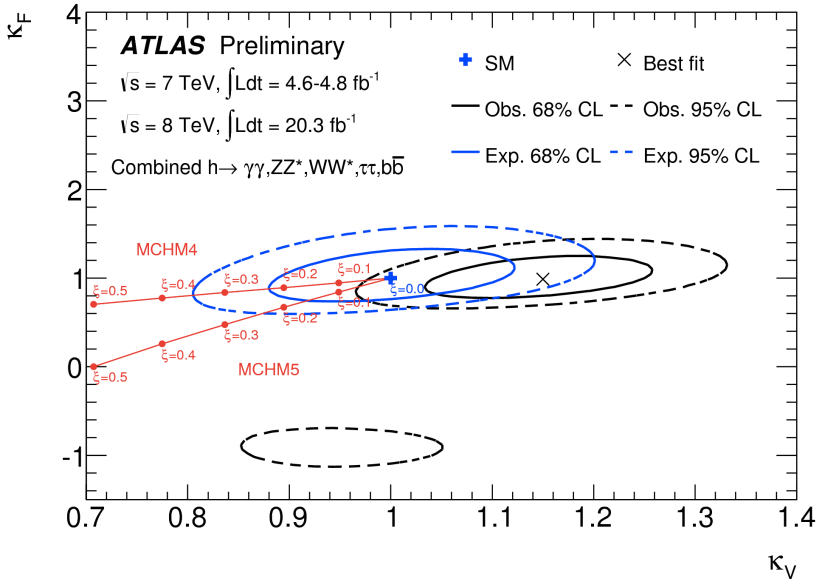
H → WW* measurements







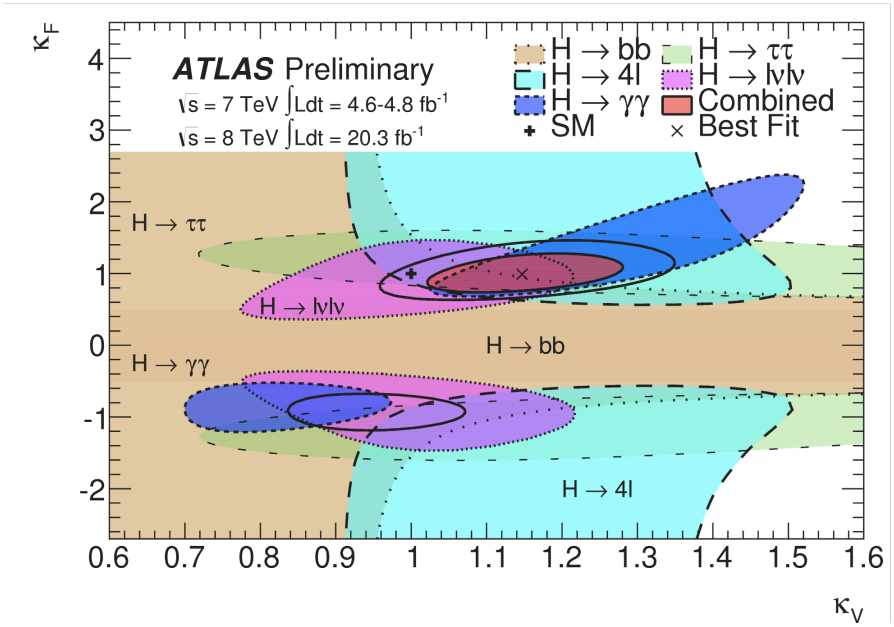
interpretation of coupling measurements



model constraints:

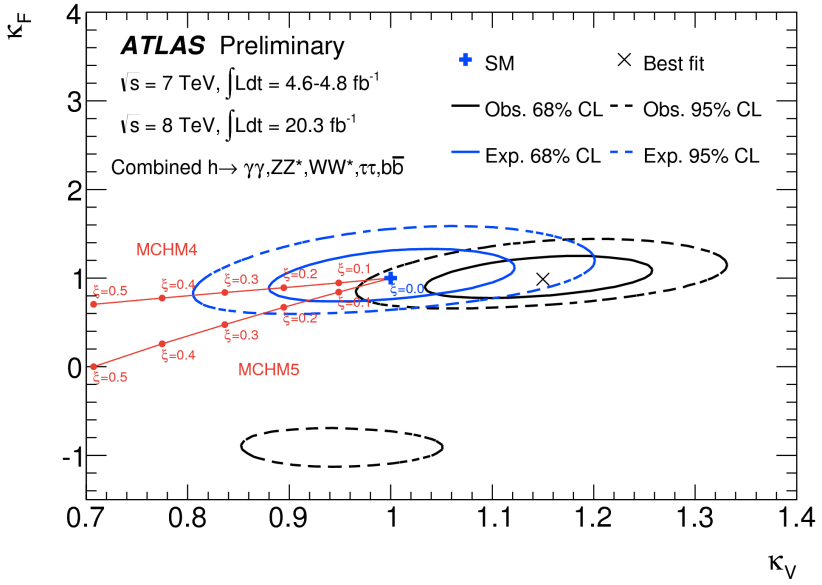
- no BSM invisible decays
- no new particles in loops
- all boson/fermion couplings modified in the same way

recent update: H → bb



ATLAS-CONF-2014-009

interpretation of coupling measurements



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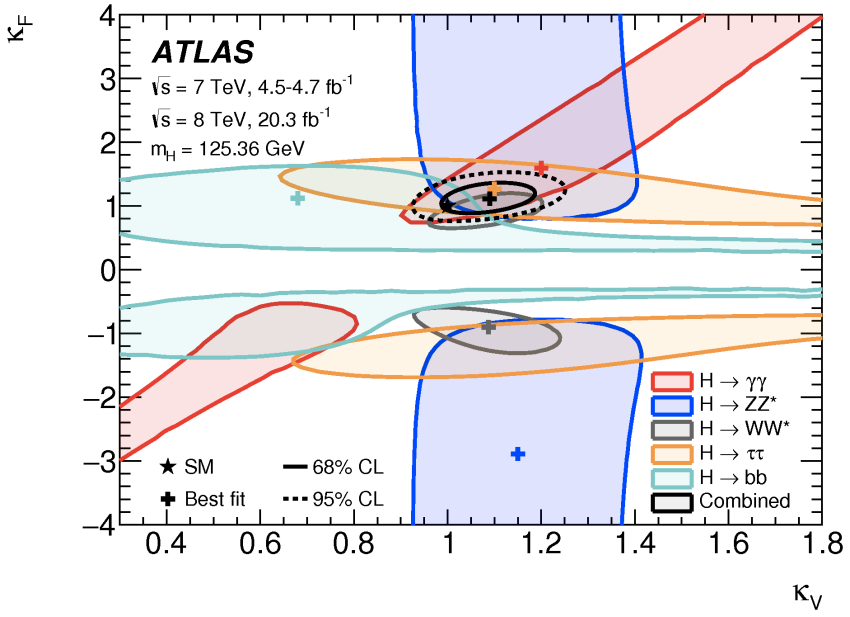
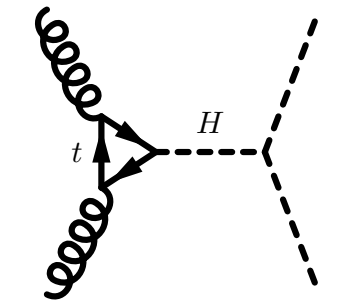


ATLAS-CONF-2015-007
ATLAS-CONF-2014-009

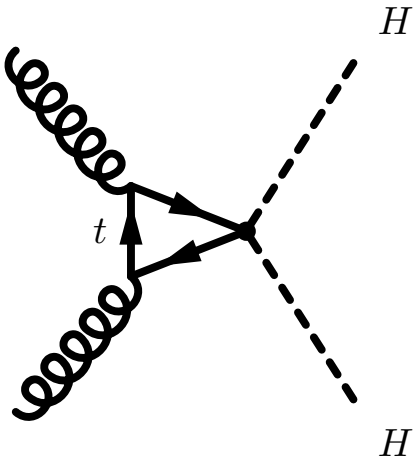
PRL 114.081802

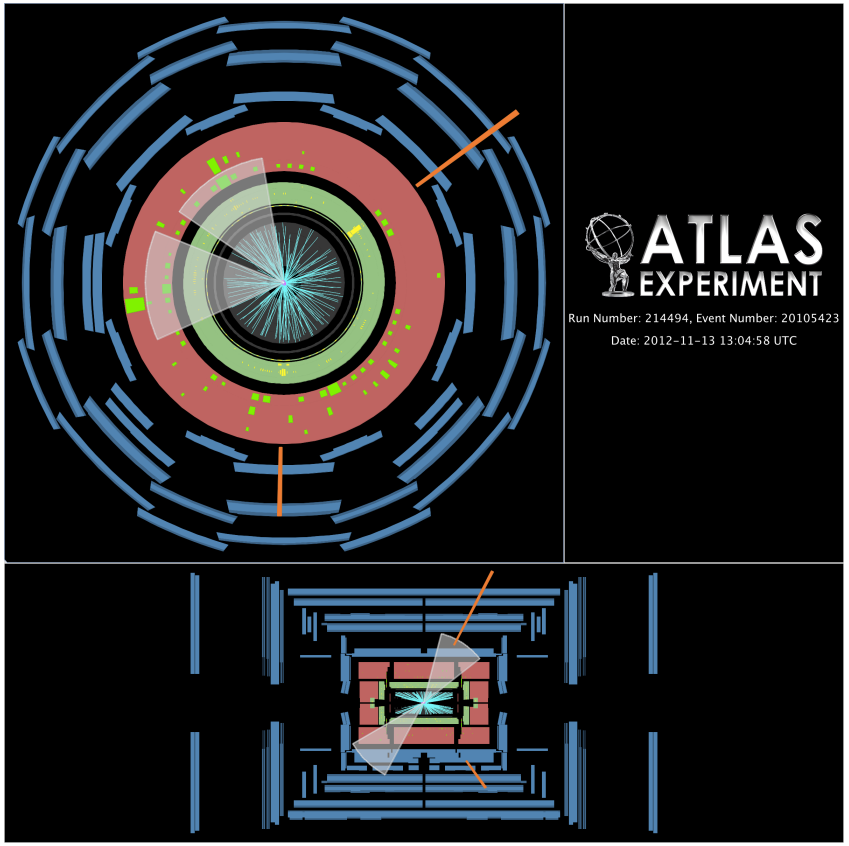
Higgs pair production search



$H \rightarrow \gamma\gamma$: diphoton trigger, sharp peak

$H \rightarrow$ b-jets (tagged)

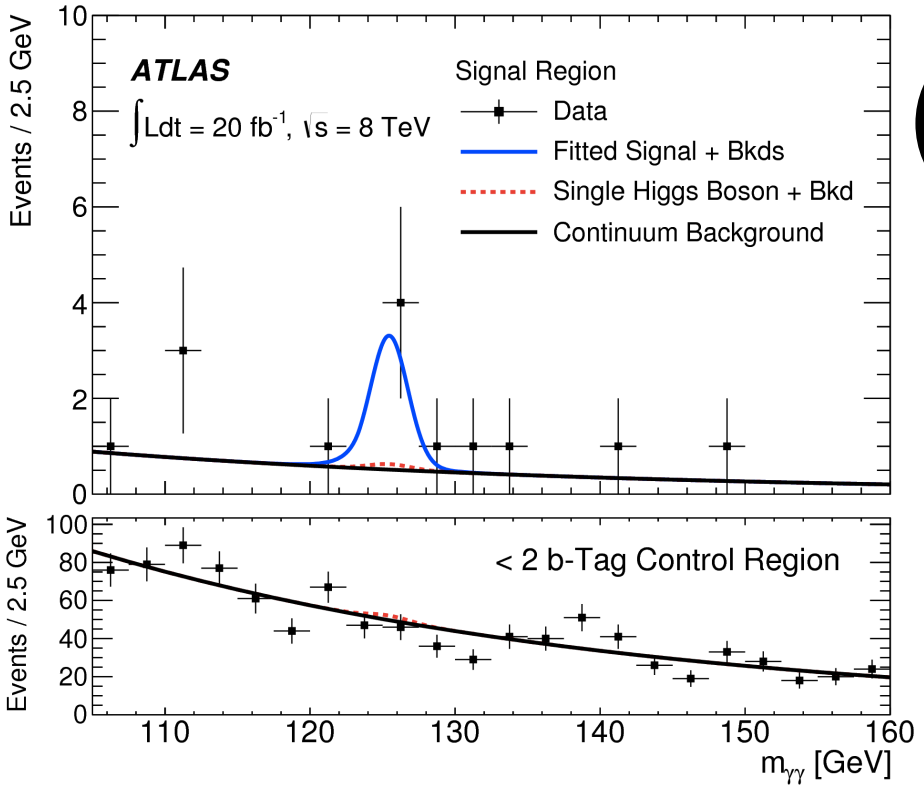




two-body invariant mass resolution: ~13 GeV (bb), ~1.6GeV (diphoton)

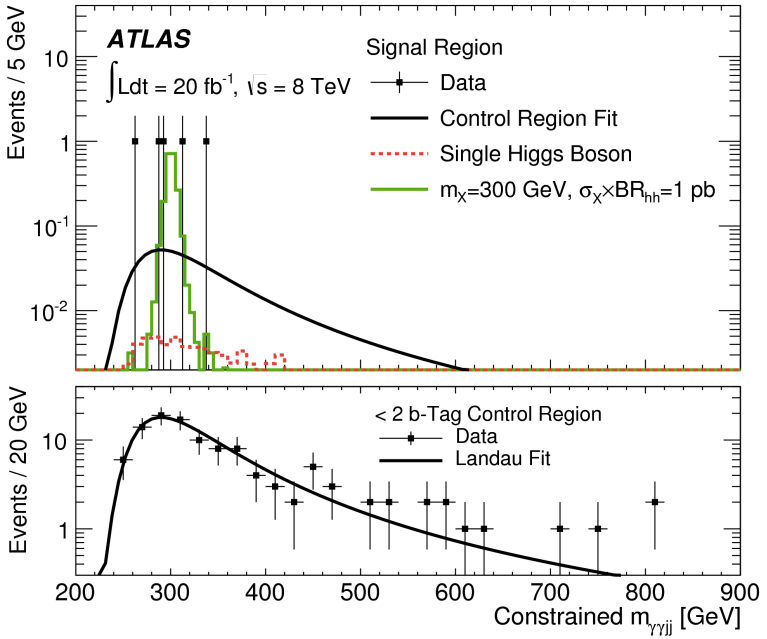
PRL 114.081802

pair production limits



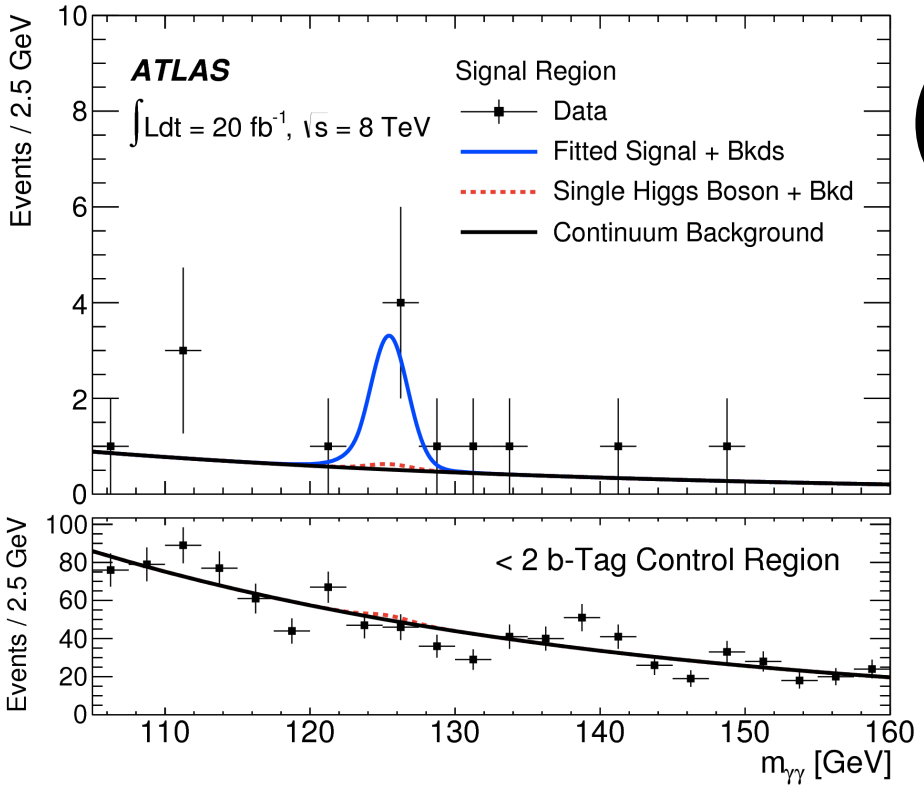
2.4 σ excess →
cross section limit: 2.2 pb

four-body mass distribution?



PRL 114.081802

pair production limits



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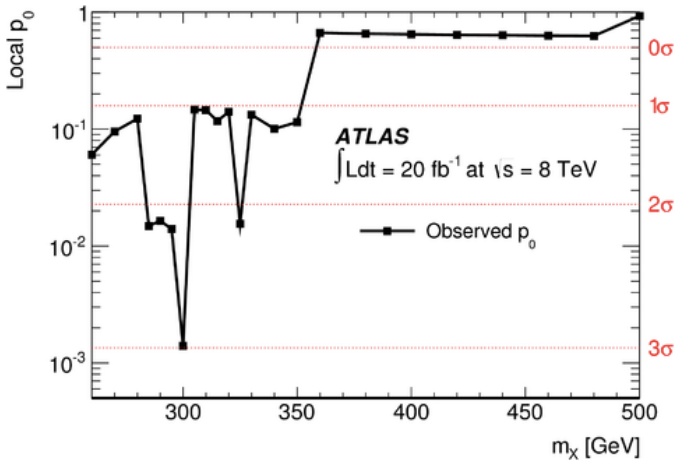
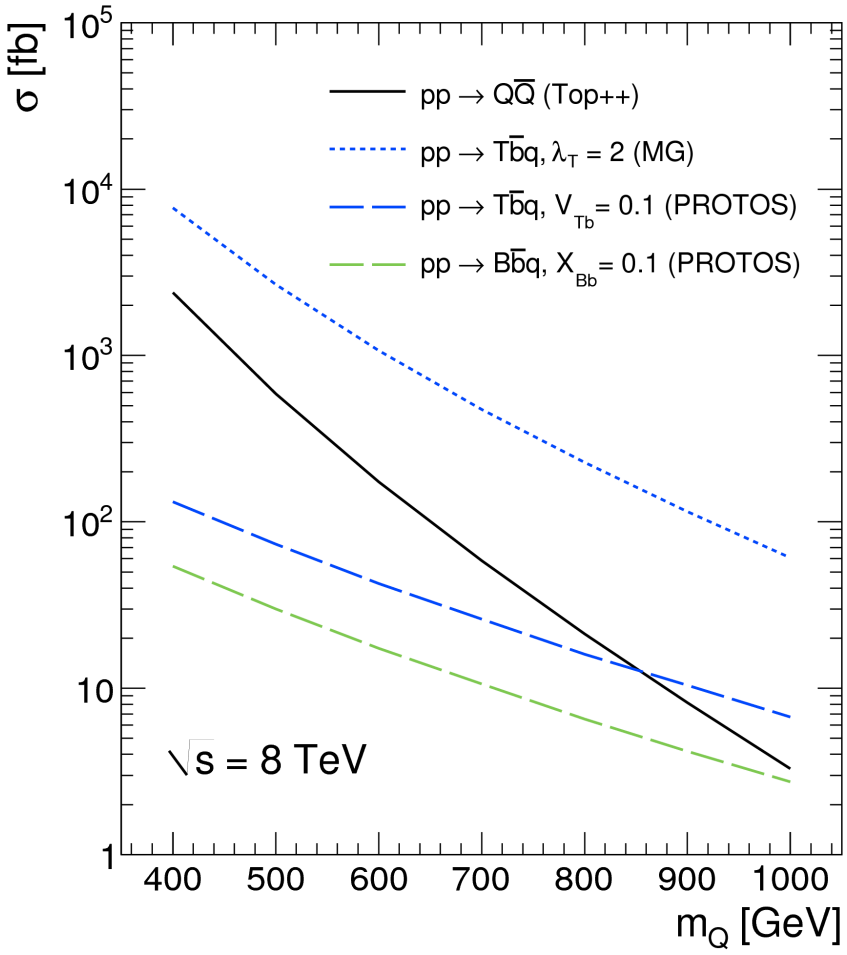


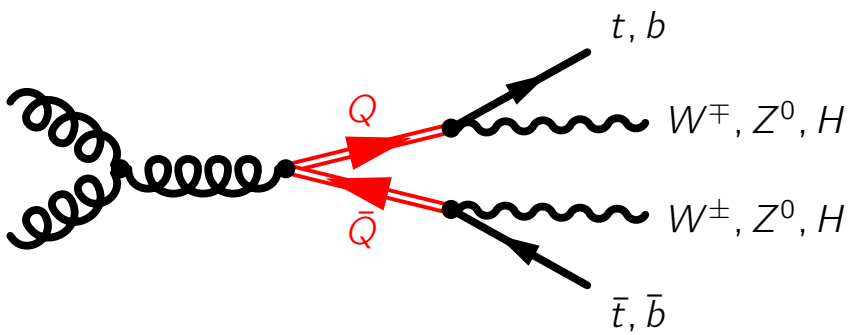
new particle

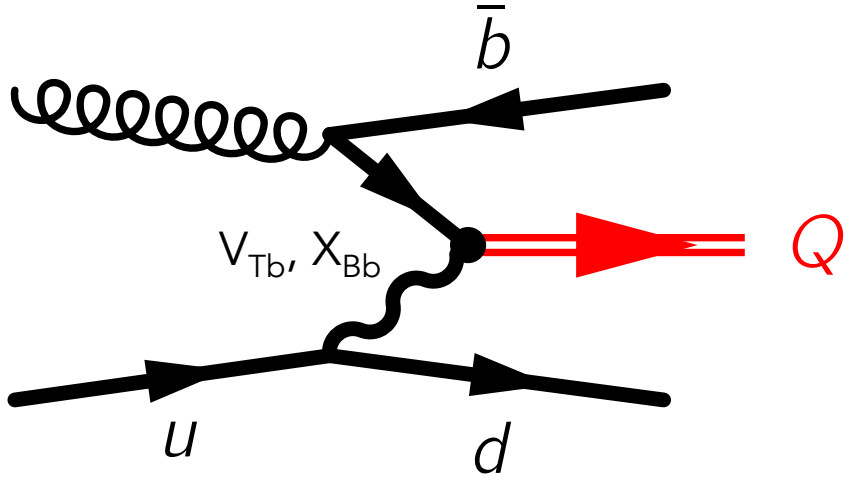
SEARCHES

searches for vector-like quarks



Run 1: pair production

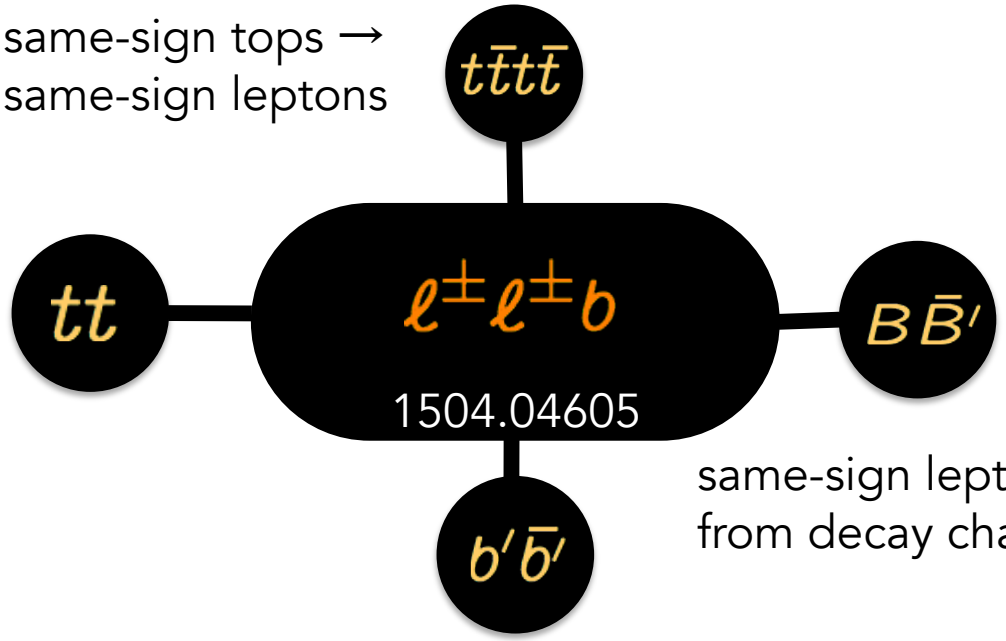




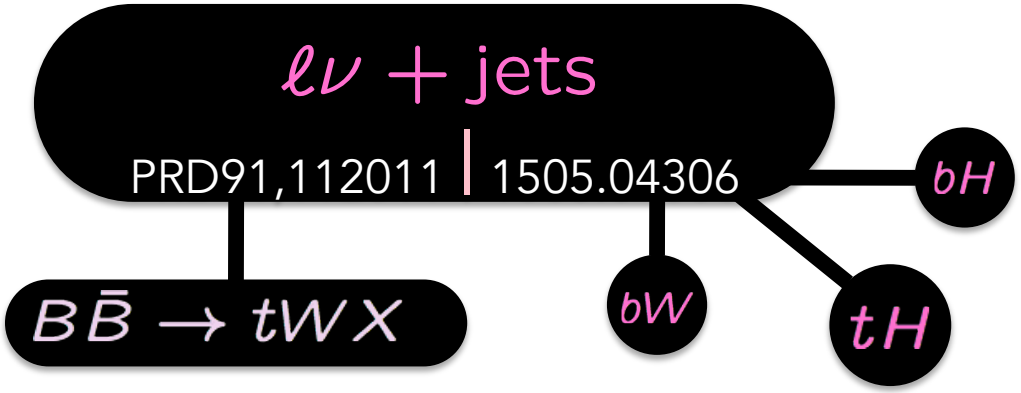
limits on single Q production: JHEP 11 (2014)104

recent signature-based searches

same-sign tops → same-sign leptons



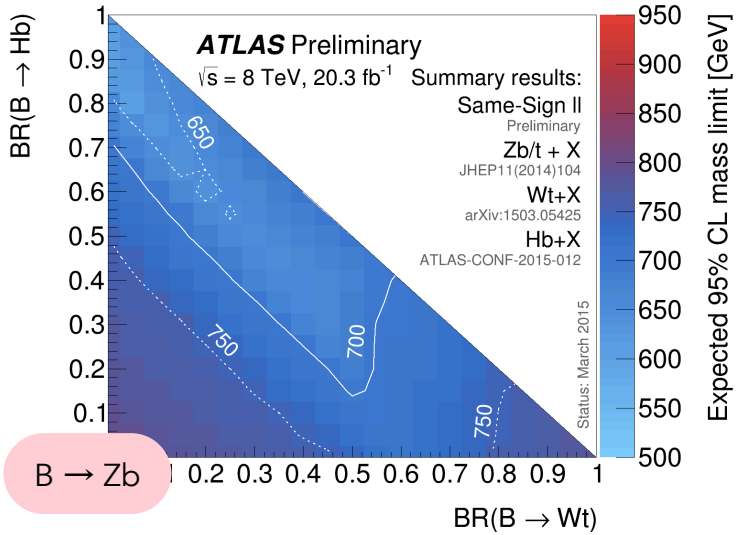
same-sign leptons from decay chains



Busy environments!
* lepton "mini-isolation"
* hadronic W/Z/H → bb

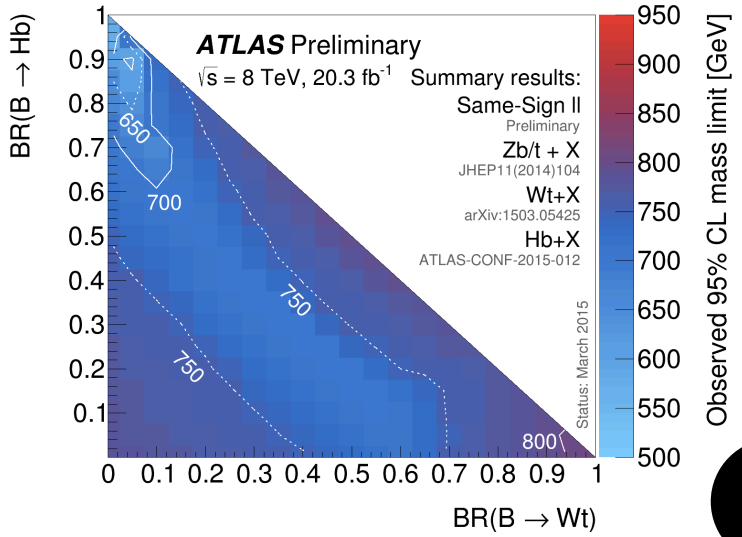
VLQ mass limits: summary

Expected

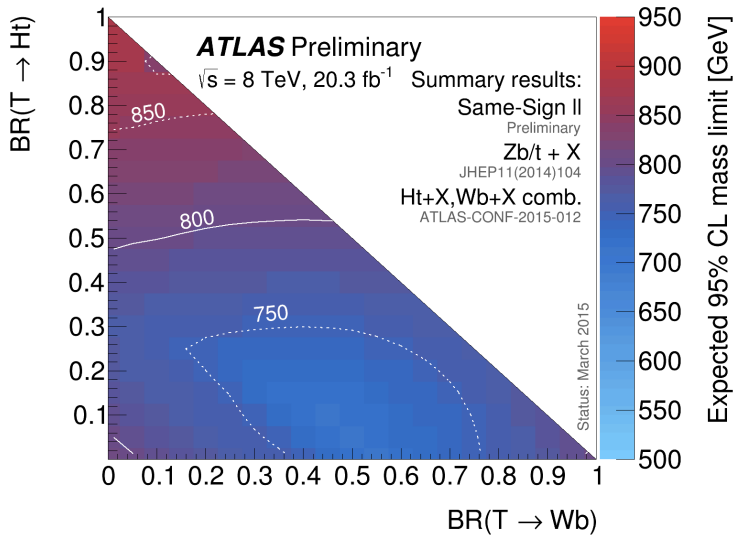


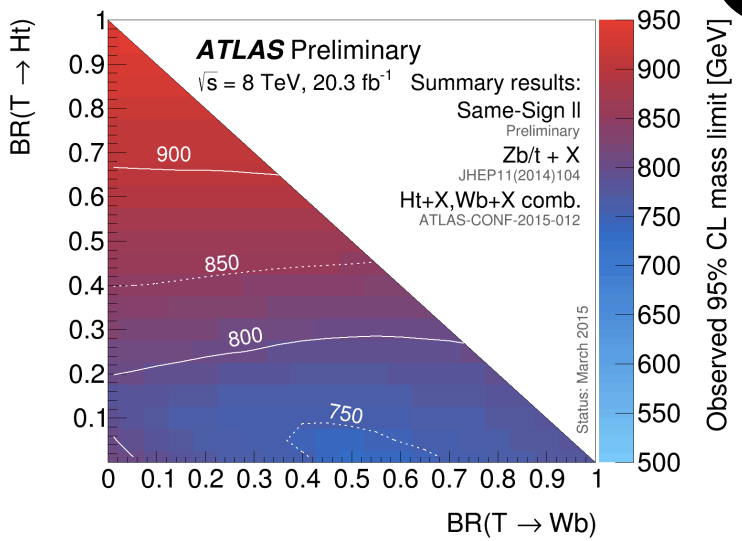
B → Zb

Observed



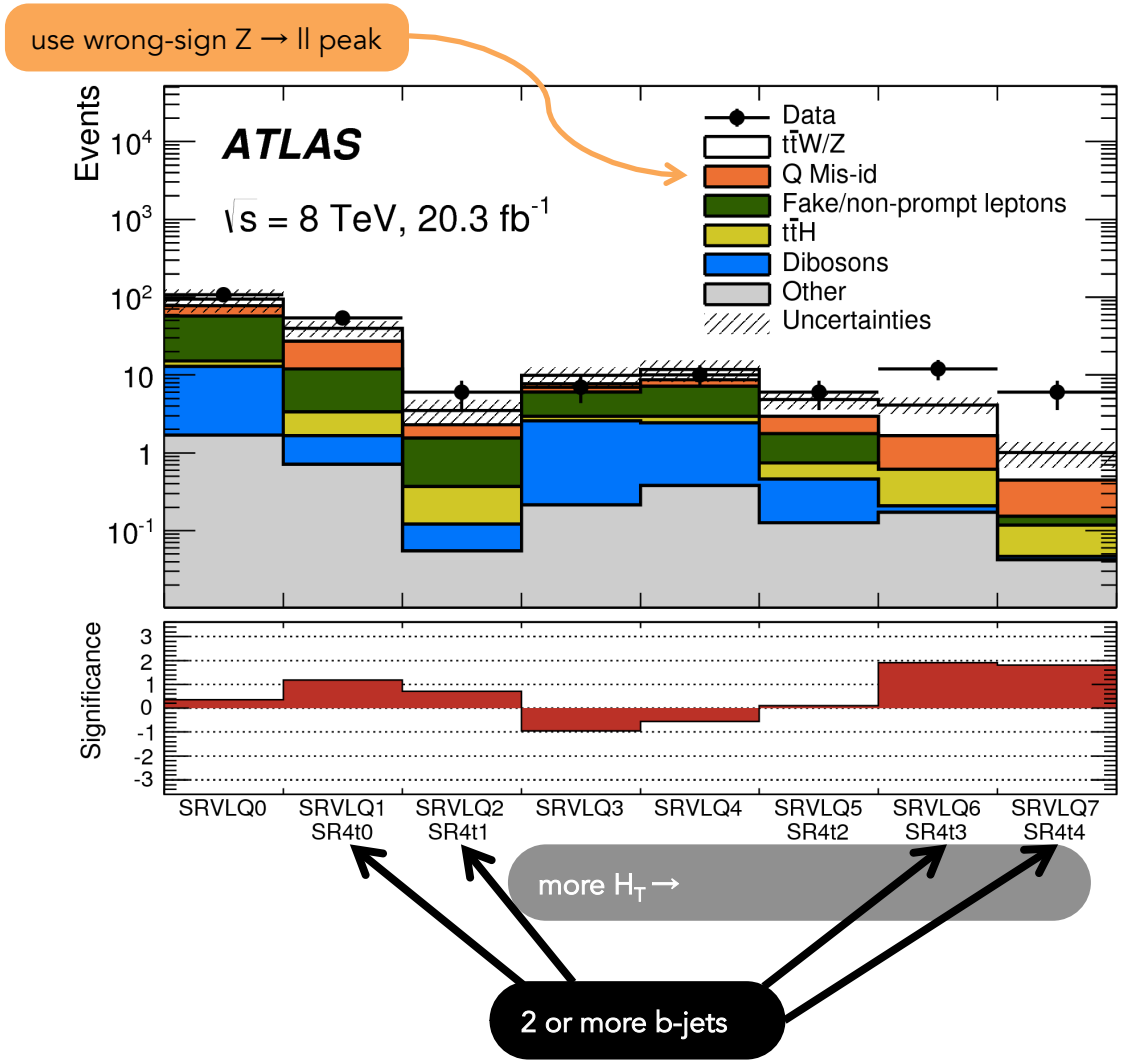
overlay of strongest mass limit at each point

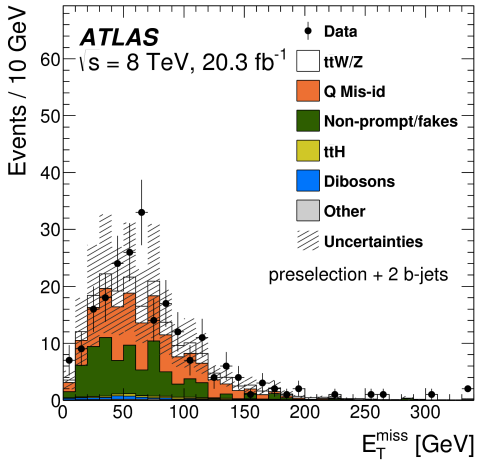




arxiv:1504.04605

same-sign leptons + *b* search





Good agreement with BG prediction in most signal regions (including tt, not shown)

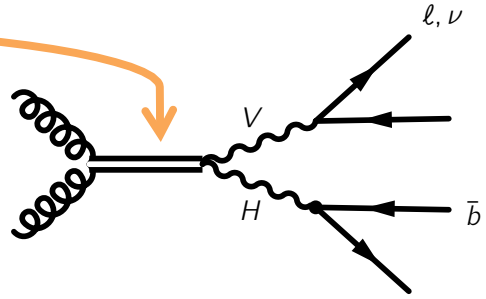
Excess in two:

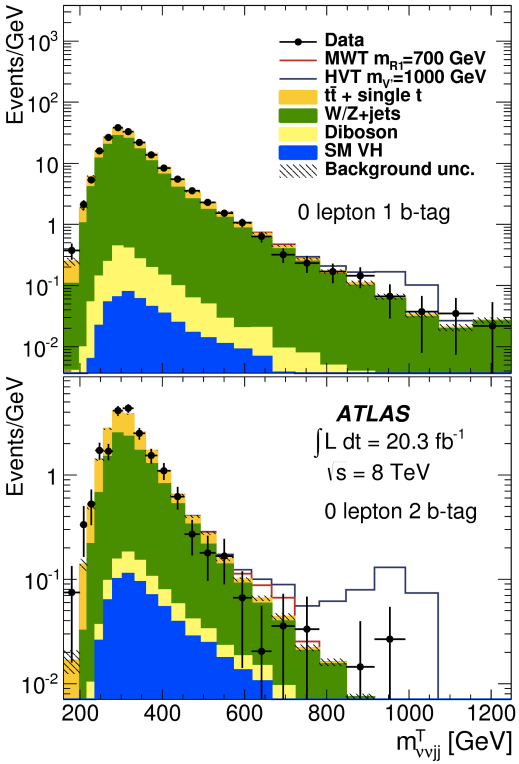
- dominant BG uncertainties here are SM *background cross section* and *charge mis-ID* rates

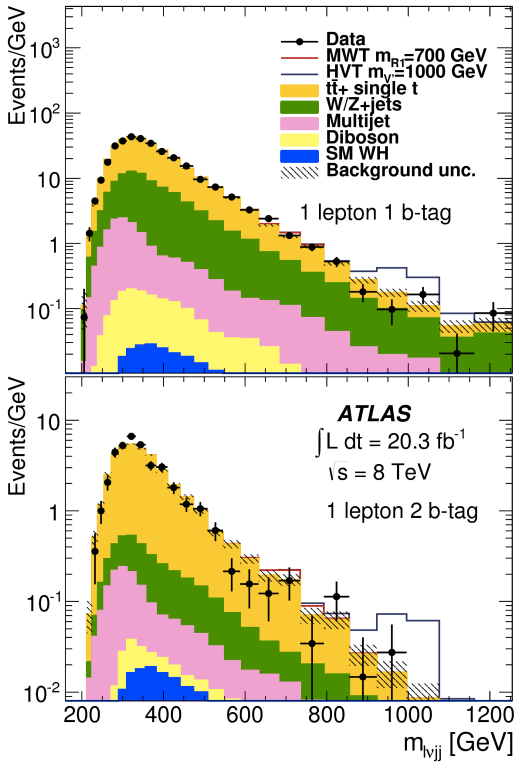
EPJC (2015) 75: 263

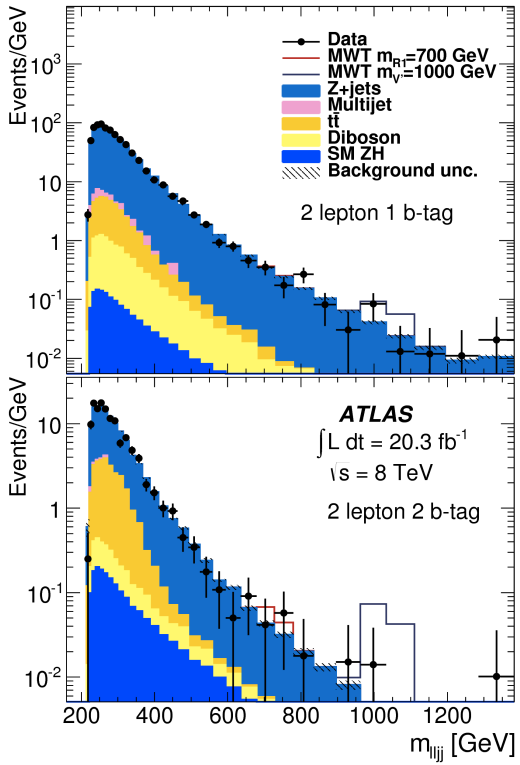
VH resonance search at ATLAS

interpret in HVT or MWT framework



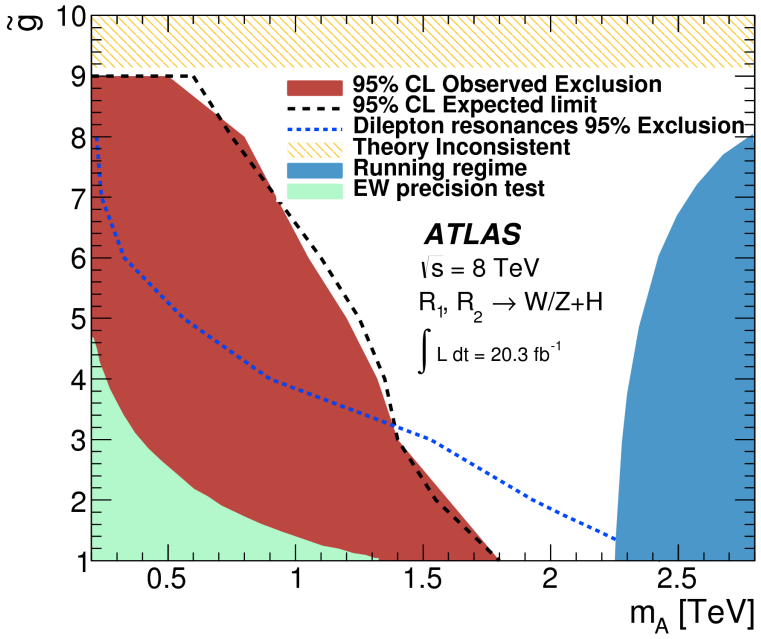


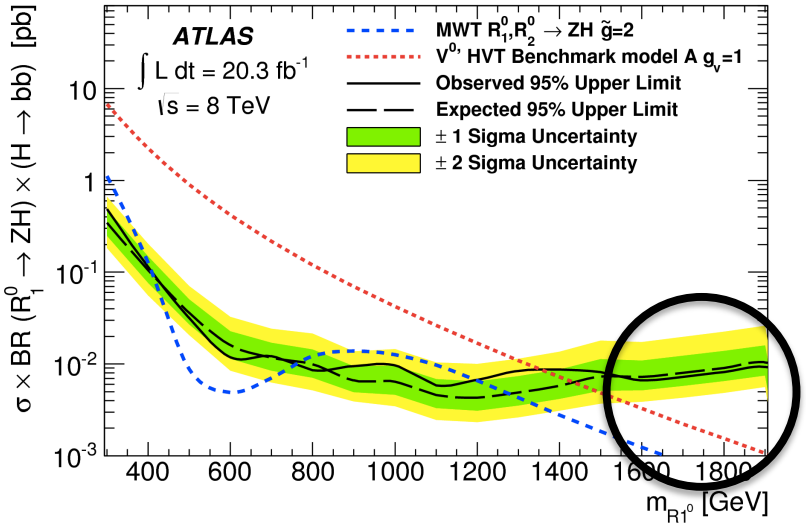




W/Z + jets predictions corrected to data in Higgs sidebands

VH resonance search at ATLAS

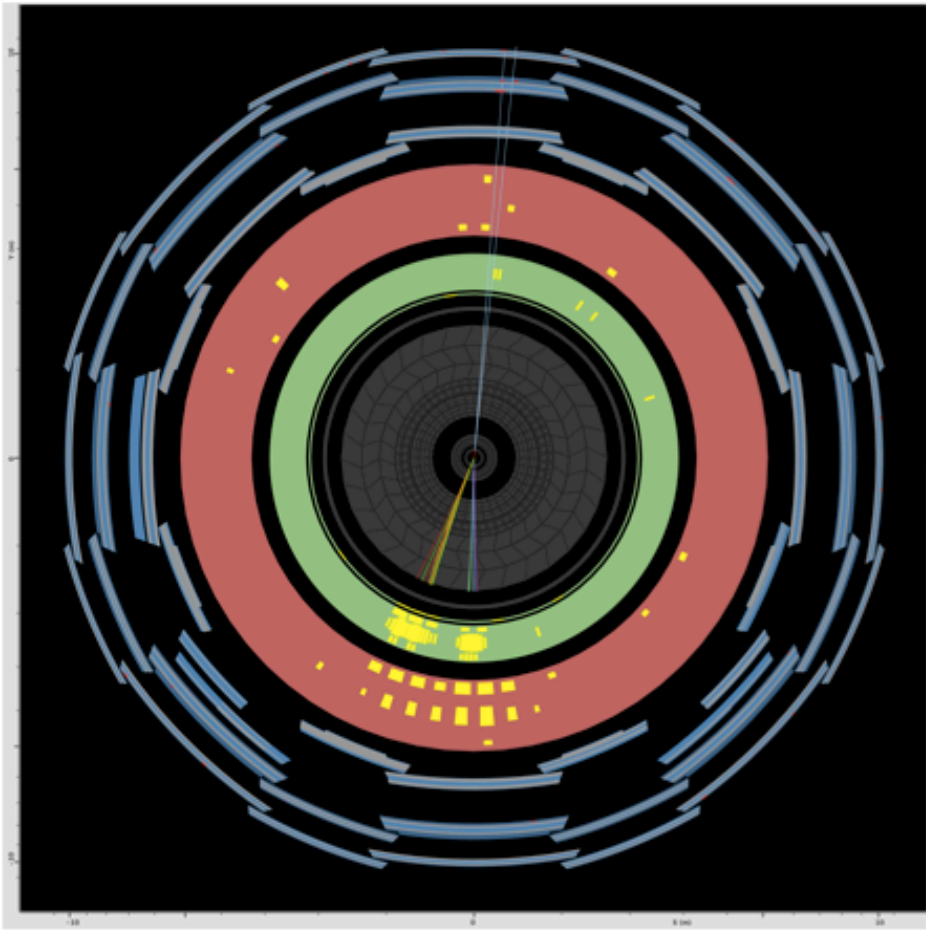




higgs candidate jets merge at high m_R

Massive diboson (W/Z) resonances

- Benchmarks: narrow resonances with enhanced diboson couplings
  - WZ: EGM W'
  - WW/ZZ: spin-2 G* in RS bulk model
  - HVT benchmarks (in some channels)

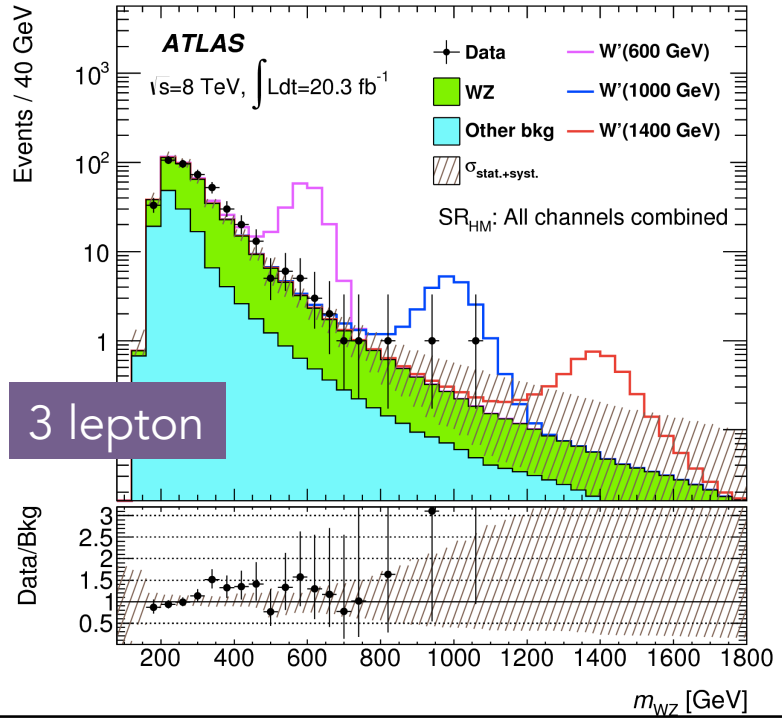


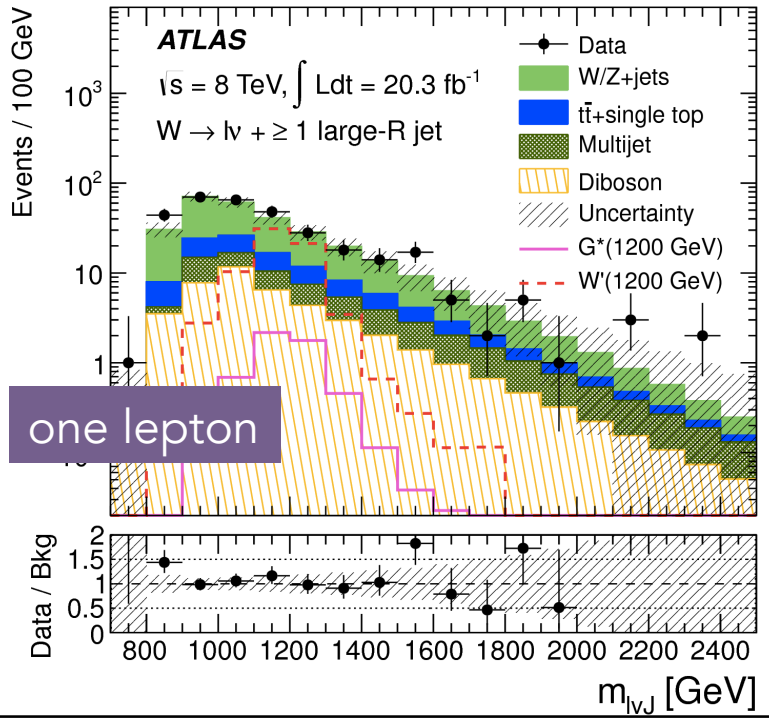
EPJC (2015) 75:69 and 209, 1506.00962v2

searching for diboson resonances

Channel	Branching Ratio (WZ)	Primary Backgrounds	WZ Signal efficiency @ 1 TeV
WZ→ 3 leptons	3%	WZ (<1 evt)	35%*
VZ → 2 leptons + jet(s)	7%	Z+jets	35% (1 Jet + 2 jets)
WV → 1 lepton + jet(s)	23%	W+jets, top	25%* (1 Jet + 2 jets)
VV → qqqq	47%	"multijet"	30%

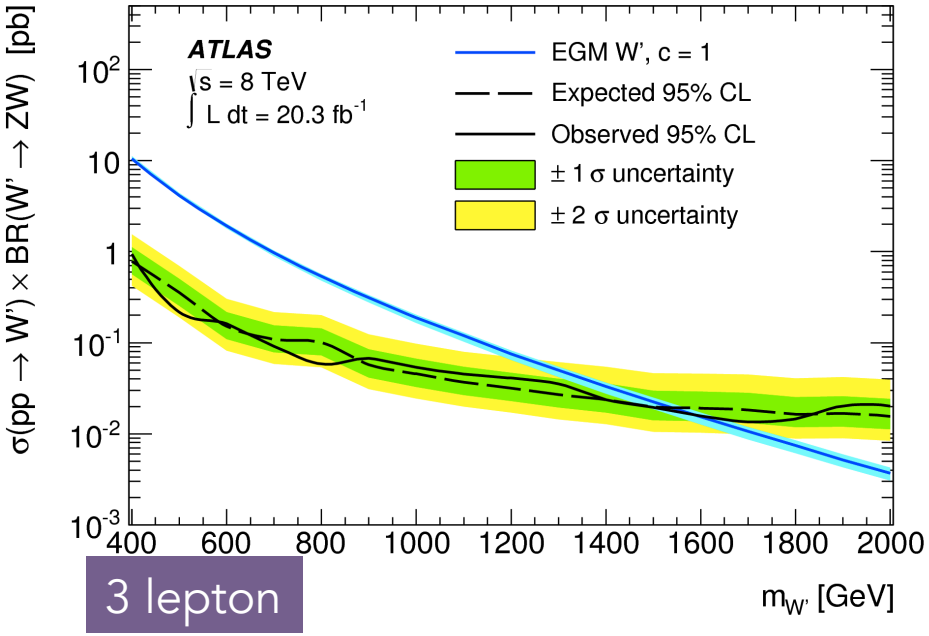
*(incl. W → tau)



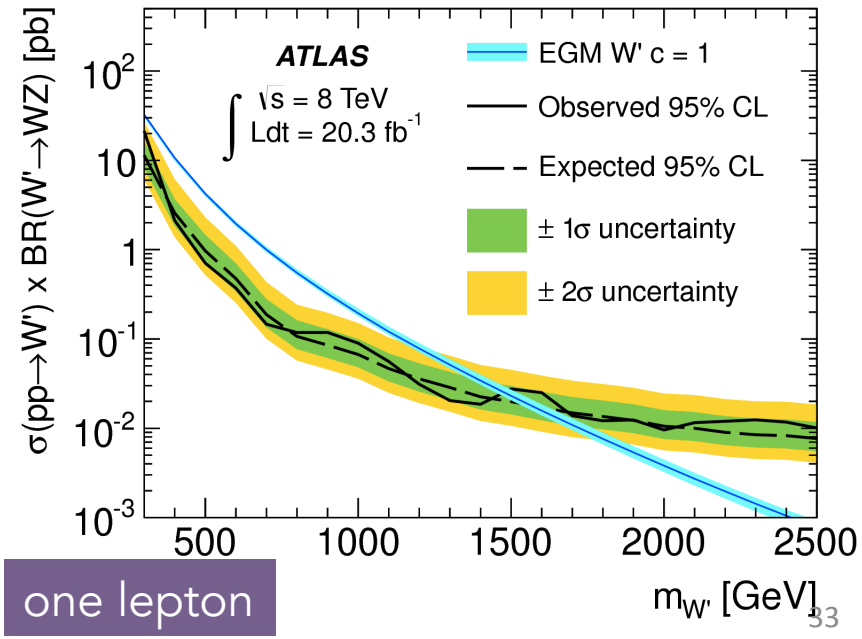


searching for diboson resonances

Channel	Branching Ratio (WZ)	Primary Backgrounds	Expected WZ limits @ 20 fb^{-1} & 2 TeV
WZ→ 3 leptons	3%	WZ (<1 evt)	38 fb
VZ → 2 leptons + jet(s)	7%	Z+jets	~20 fb
WV → 1 lepton + jet(s)	23%	W+jets, top	~10 fb
VV → qqqq	47%	"multijet"	12 fb



3 lepton



one lepton

High resonance mass strategy

hadronic decays

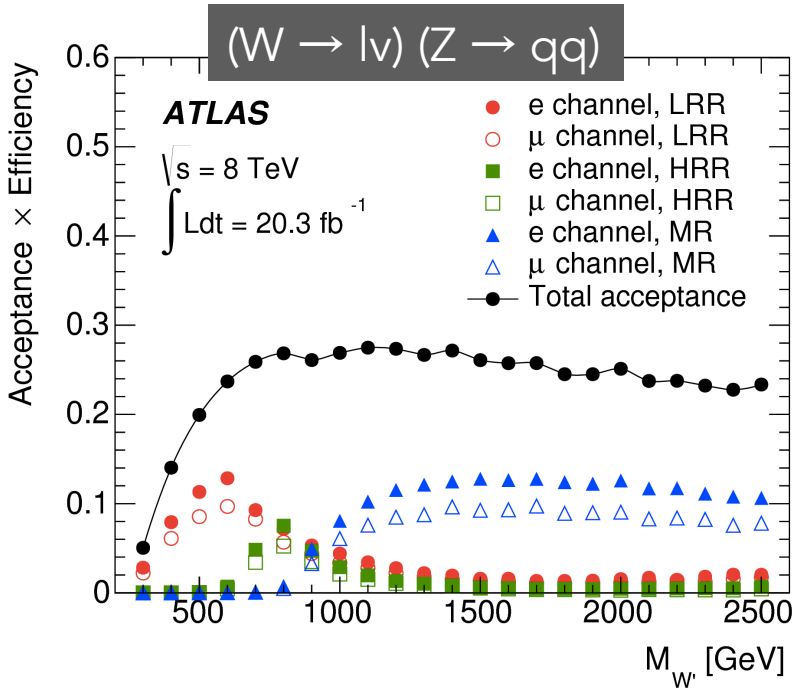
- larger branching ratio compensates for small signal cross section
- steeply falling nonresonant backgrounds: less multijet rejection required

→ first fully-hadronic searches!

modified reconstruction

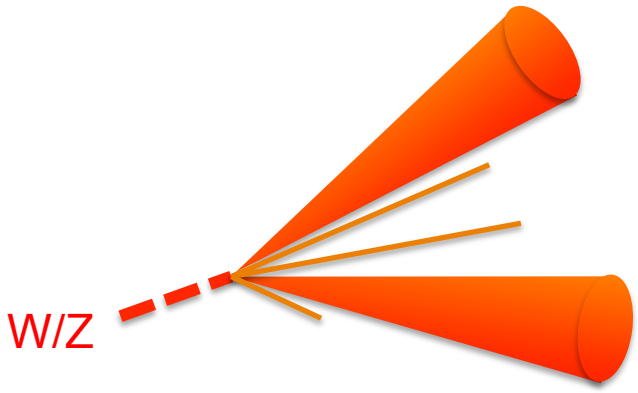
- isolation corrected for small-angle $Z \rightarrow \ell\ell$ decays
- overlapping jets from W/Z decays: use large-R jet reconstruction

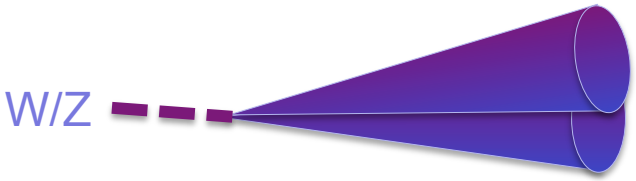
"merged" vs. "resolved"



Boson-jet tagging:

- "BDRS" [PRL100 242001 (2008)]-like mass-drop filtering algorithm
  - iteratively removes pileup, soft radiation, and U.E
- filtering criterion $\sqrt{y}$ is also tagging discriminant

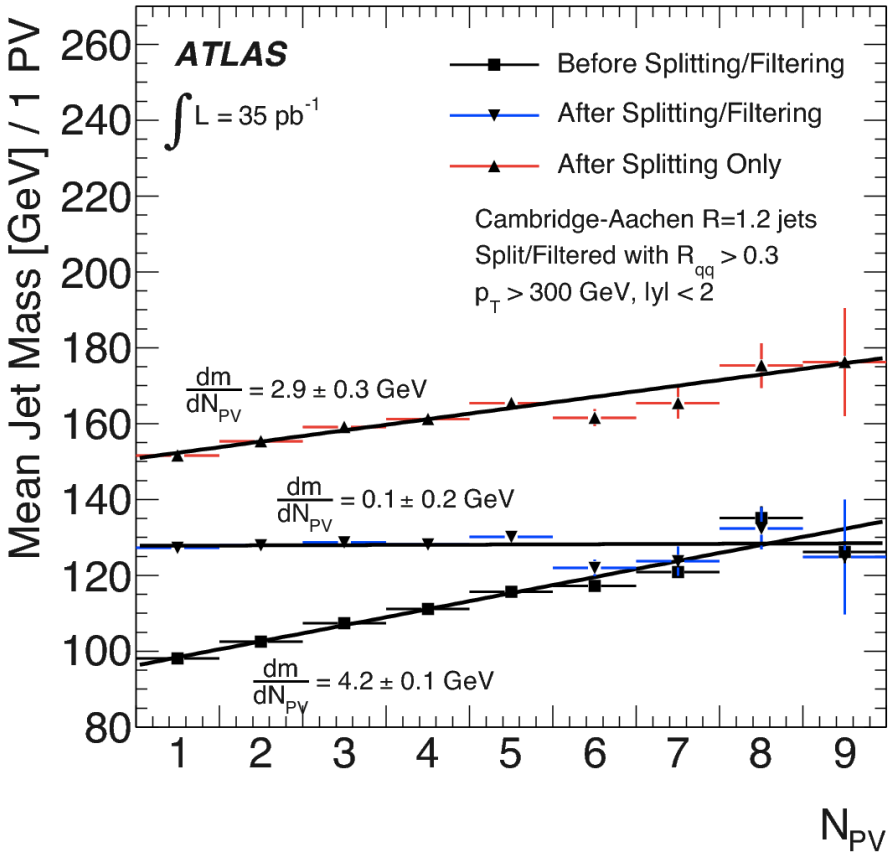


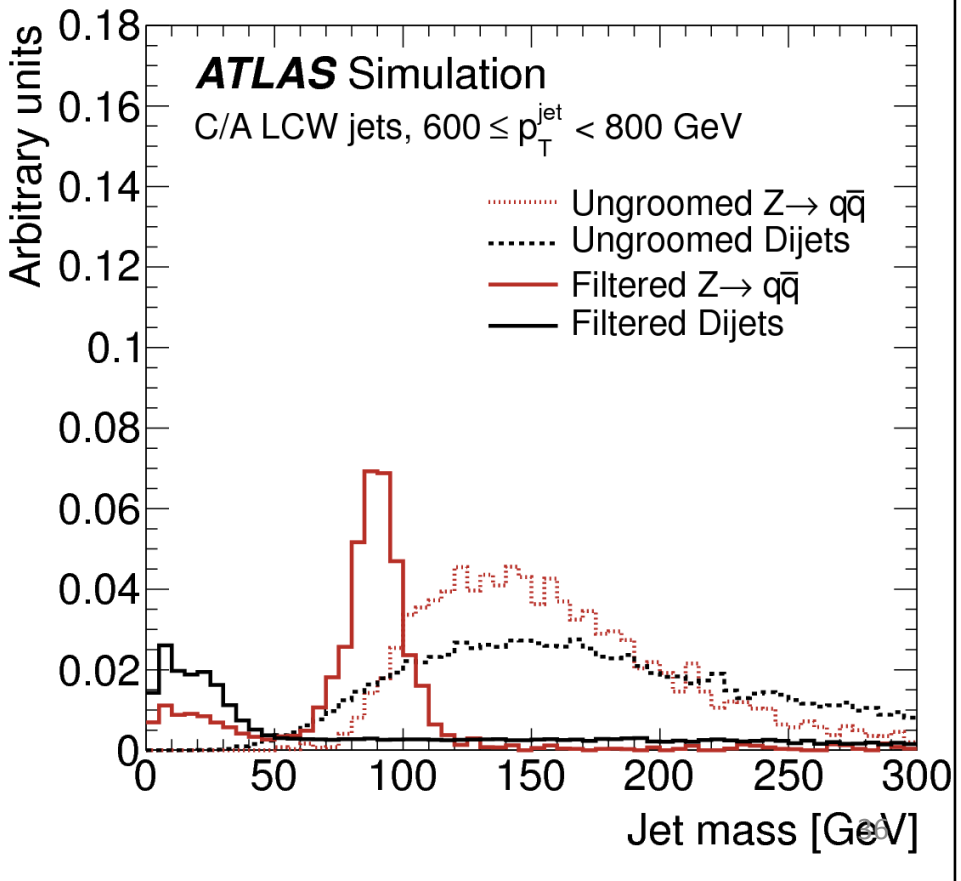


rejecting q/g jets with jet mass

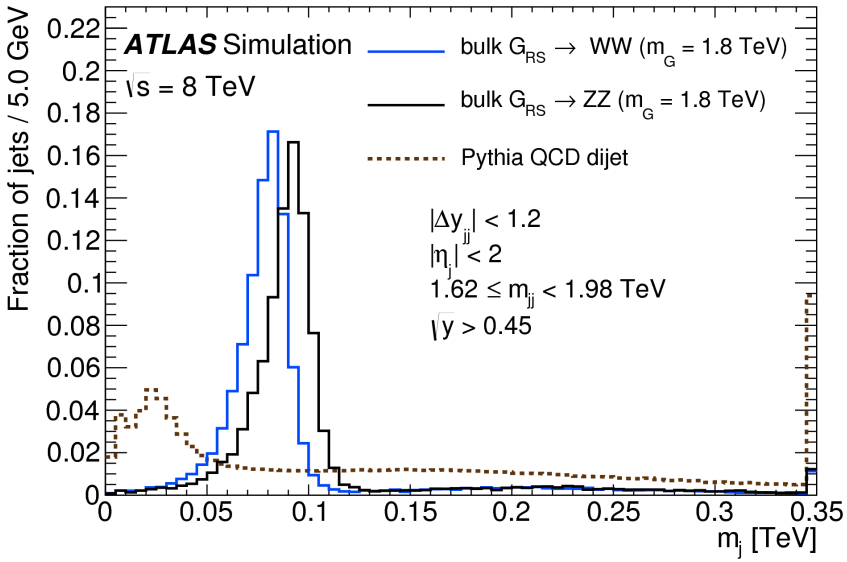
quark/gluon jet : average m^2 grows as $\alpha_s\ p_T^2\ R^2$

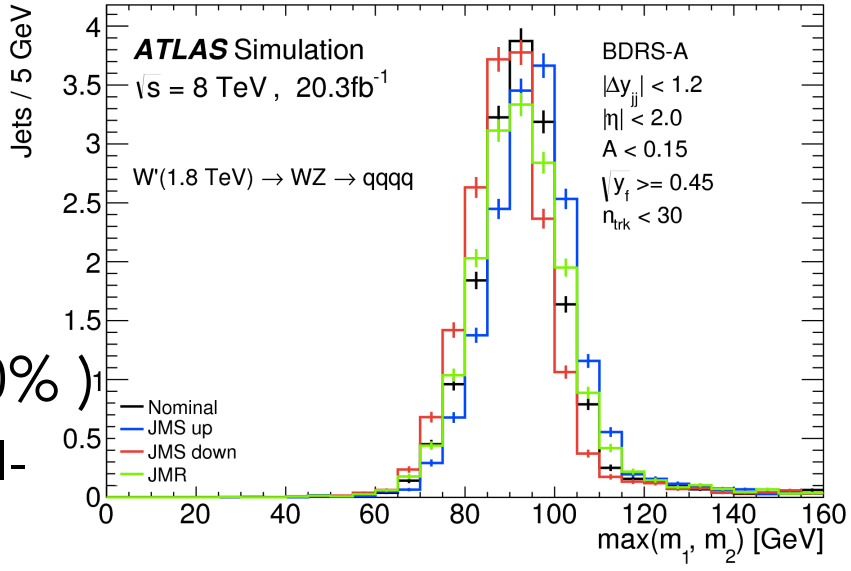
- pileup adds additional mass
- but filtering pushes QCD to lower mass scale





jet mass reconstruction uncertainties

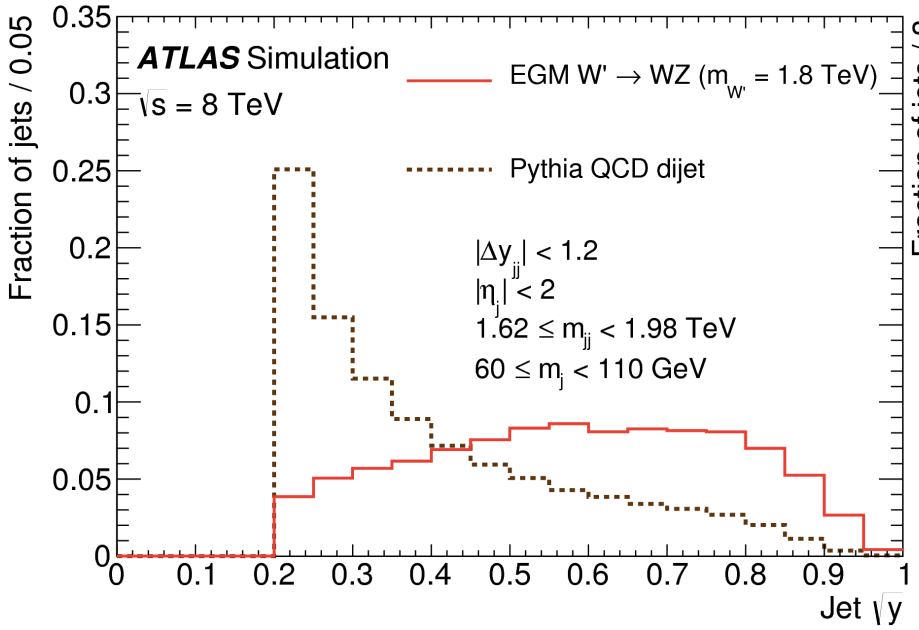




- jet mass scale uncertainty: ~3%
  (mass resolution uncertainty: 20%)
  - both have about a 5% effect on all-hadronic signal normalization

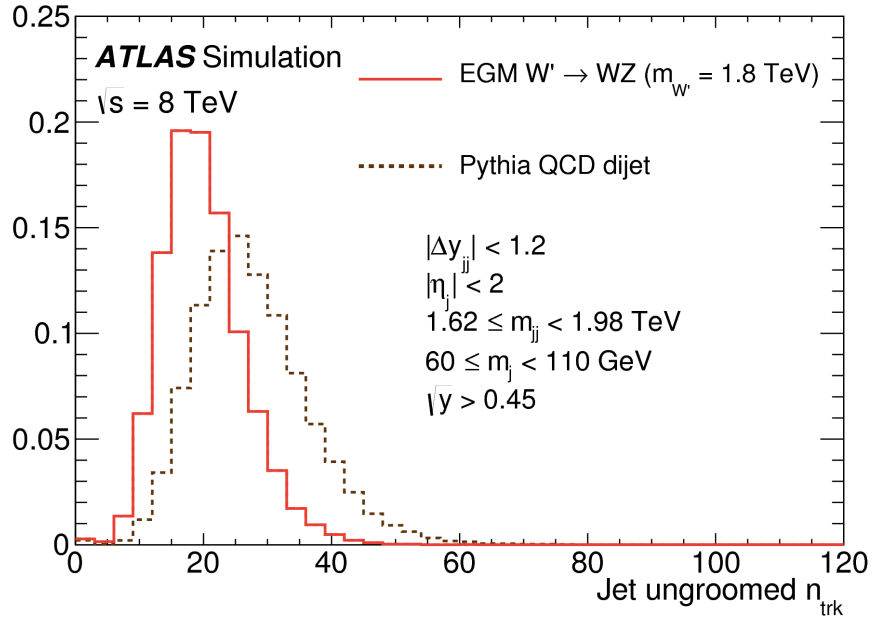
other boson-tagging tools

Subjet momentum balance



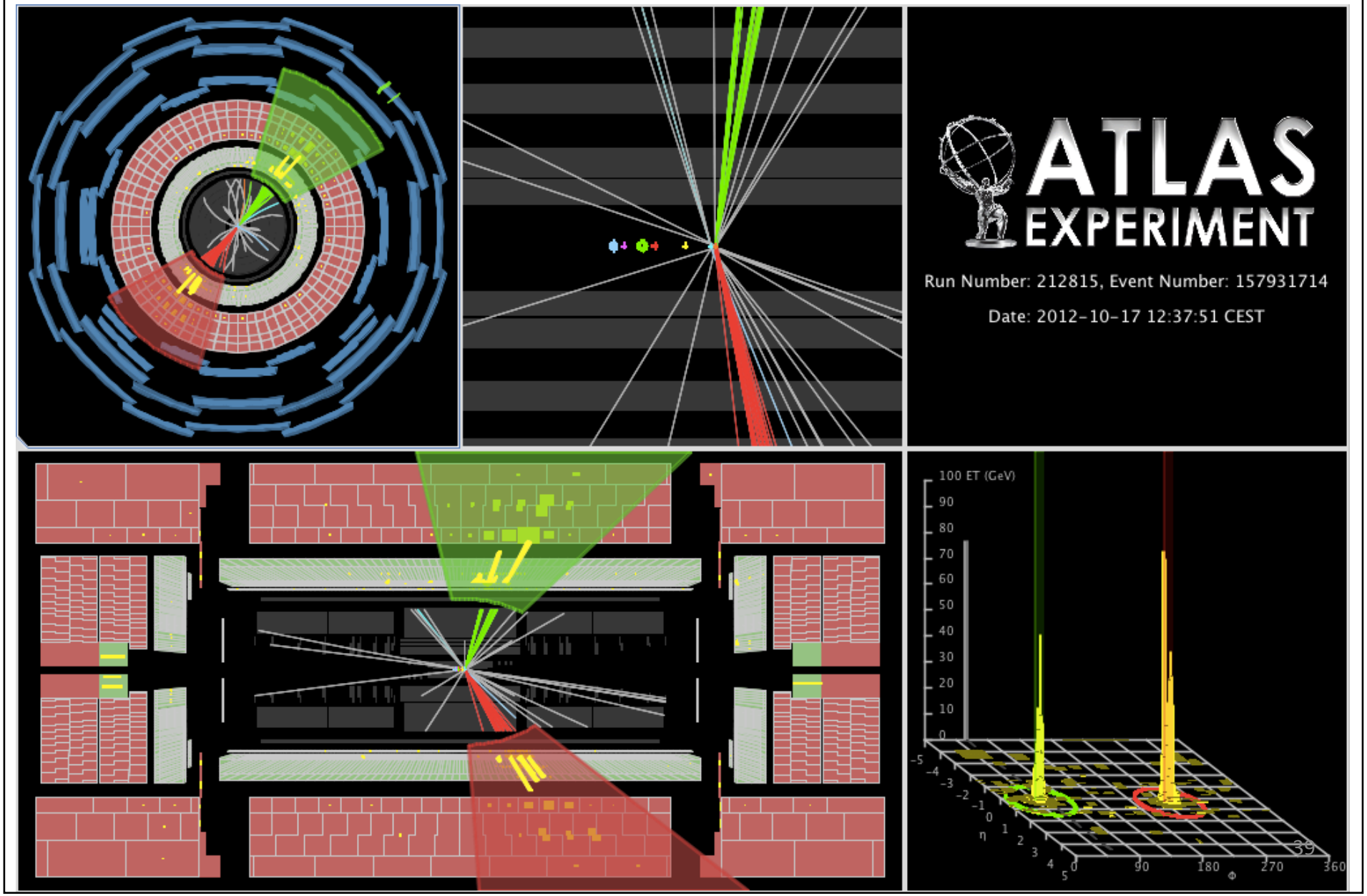
cuts against large m_J due to asymmetric, wide-angle emission

Track multiplicity

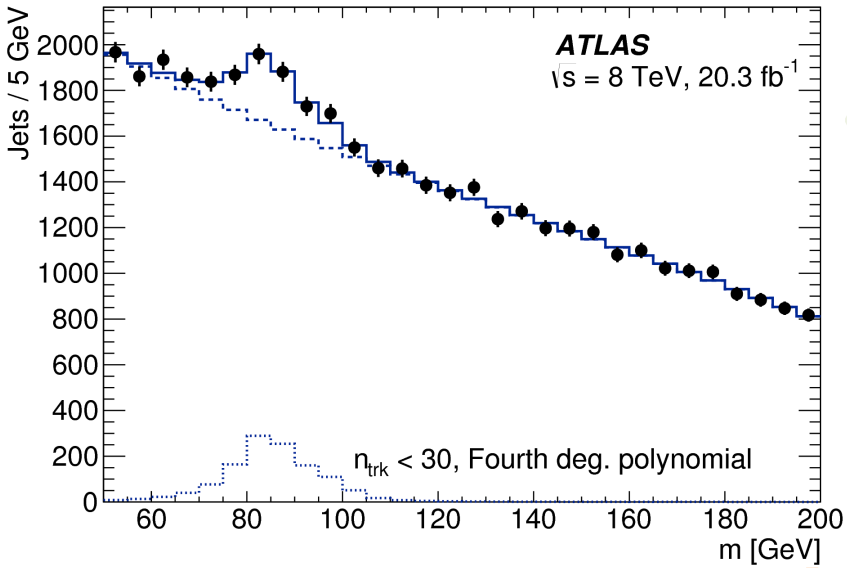


cuts against remaining QCD background (hard gluon emission)

selected event, 0-lepton channel

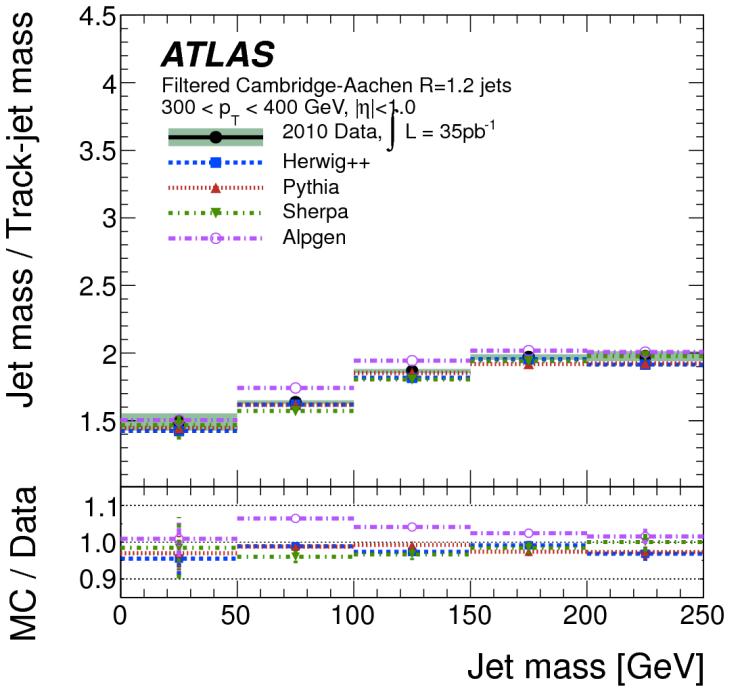


tagging efficiency uncertainties



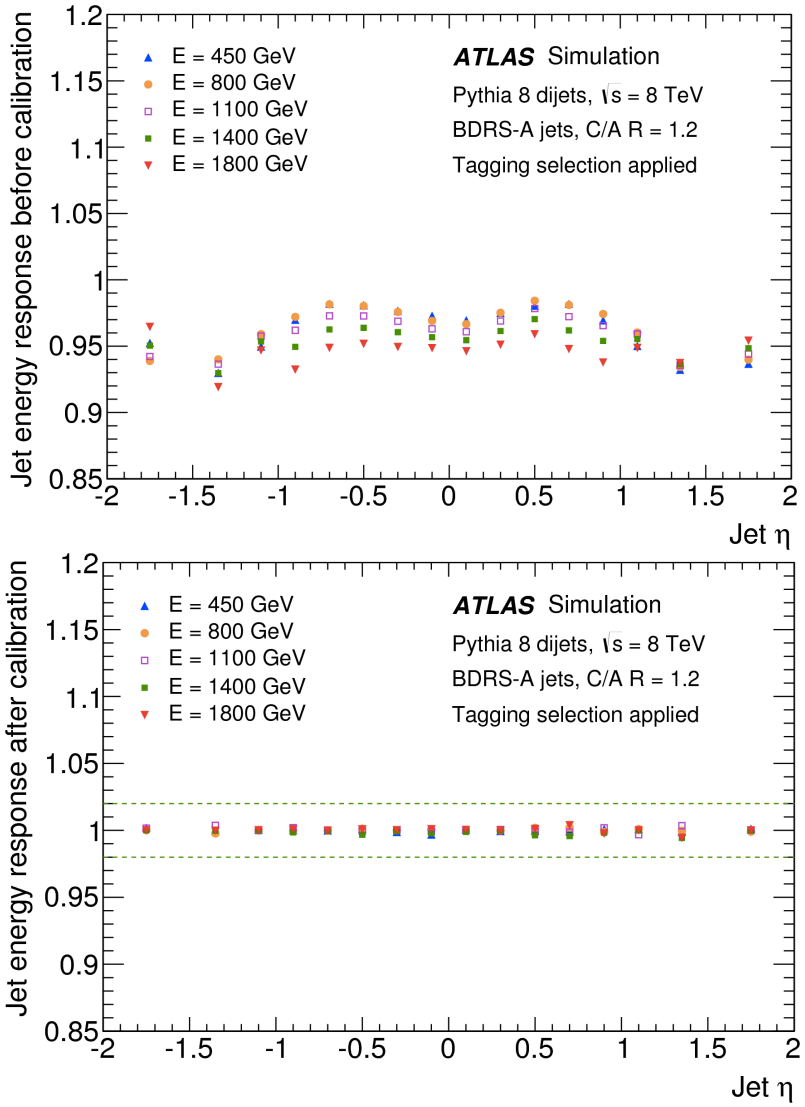
measure efficiency of track cut with hadronic W/Z + jets

compare track- and calo-based substructure variables to constrain calorimeter response

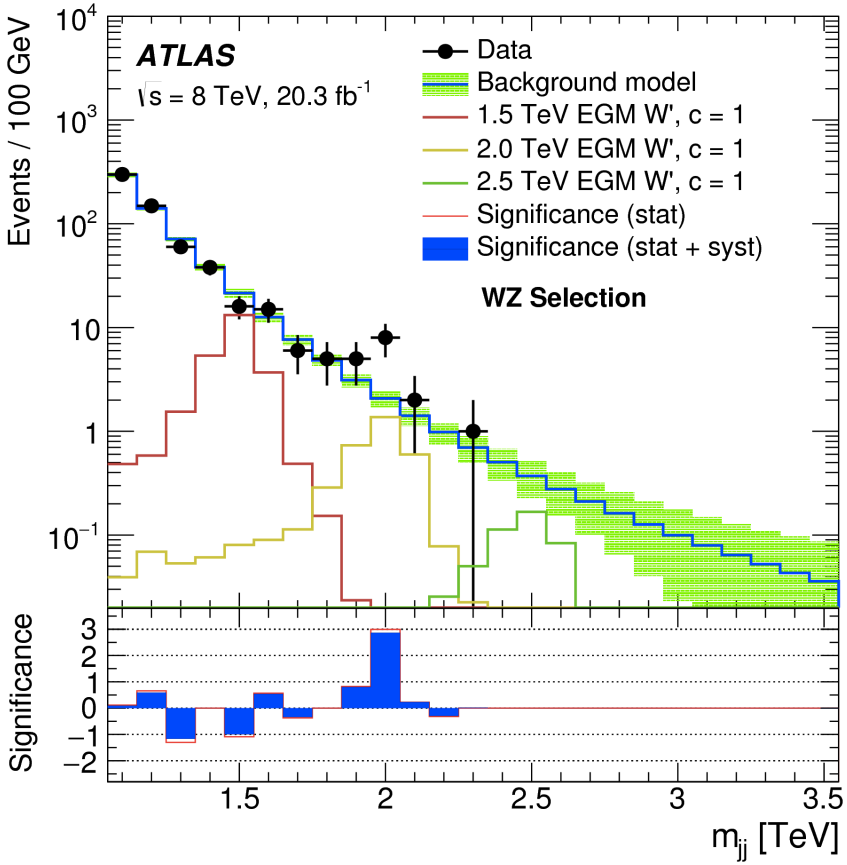


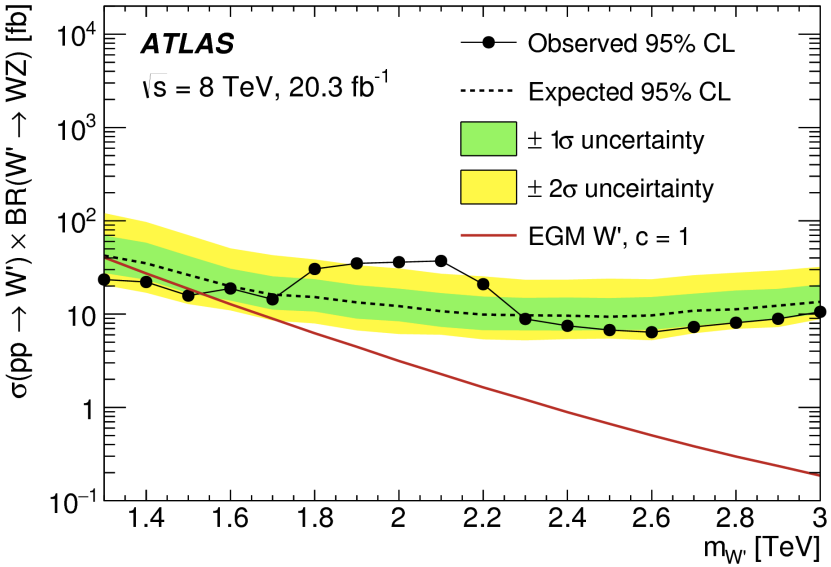
reconstructing a narrow resonance

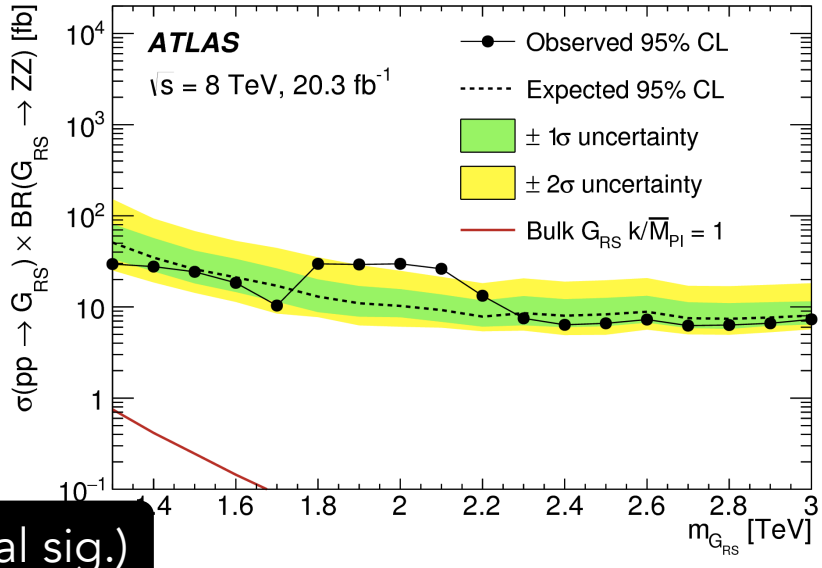
- MC-based energy and mass calibration
  - Uncertainty of energy scale: 3%
  - jet energy resolution uncertainty: 20%



0 lepton channel: result and limits



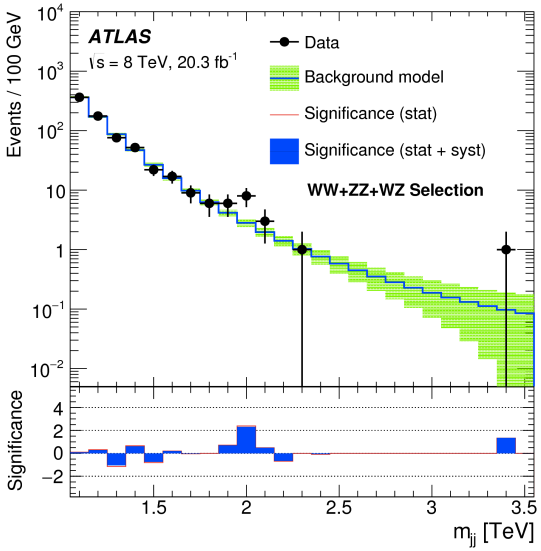


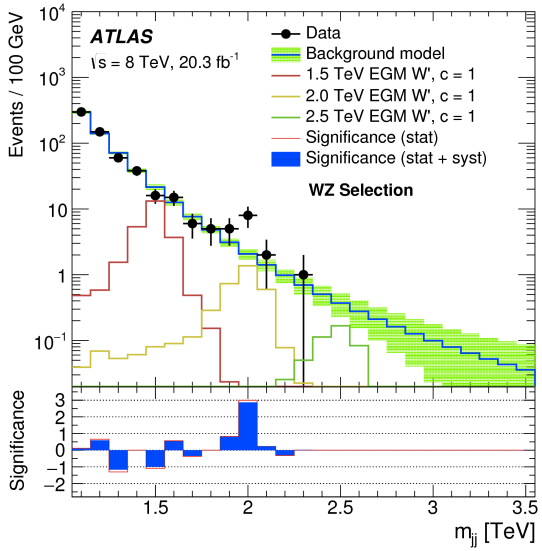


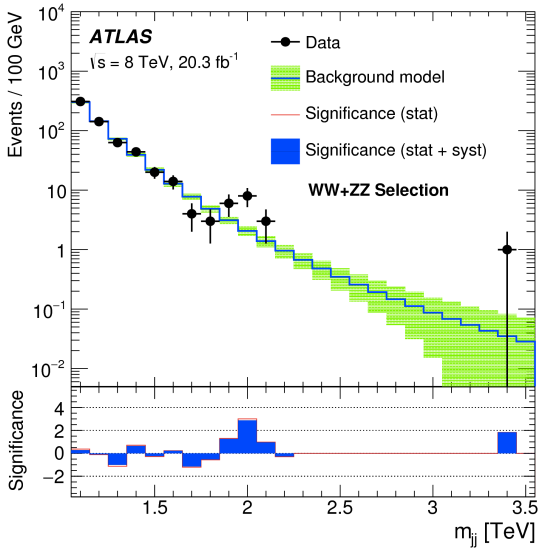
largest deviation: WZ channel (2.4 σ global sig.)

Note: overlapping selection!

mass windows are not exclusive (W: 69.4-95.4 GeV; Z: 79.8-105.8 GeV)
→ 20% of events appear in all three signal regions



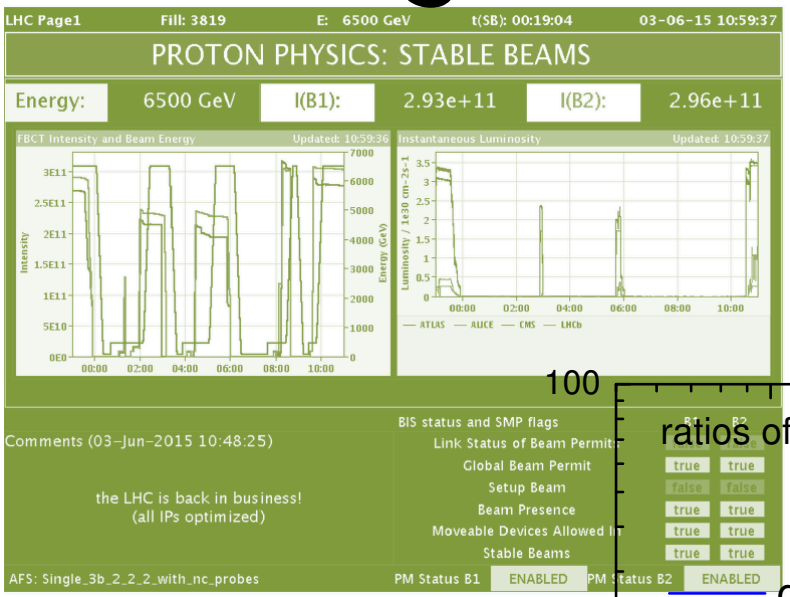


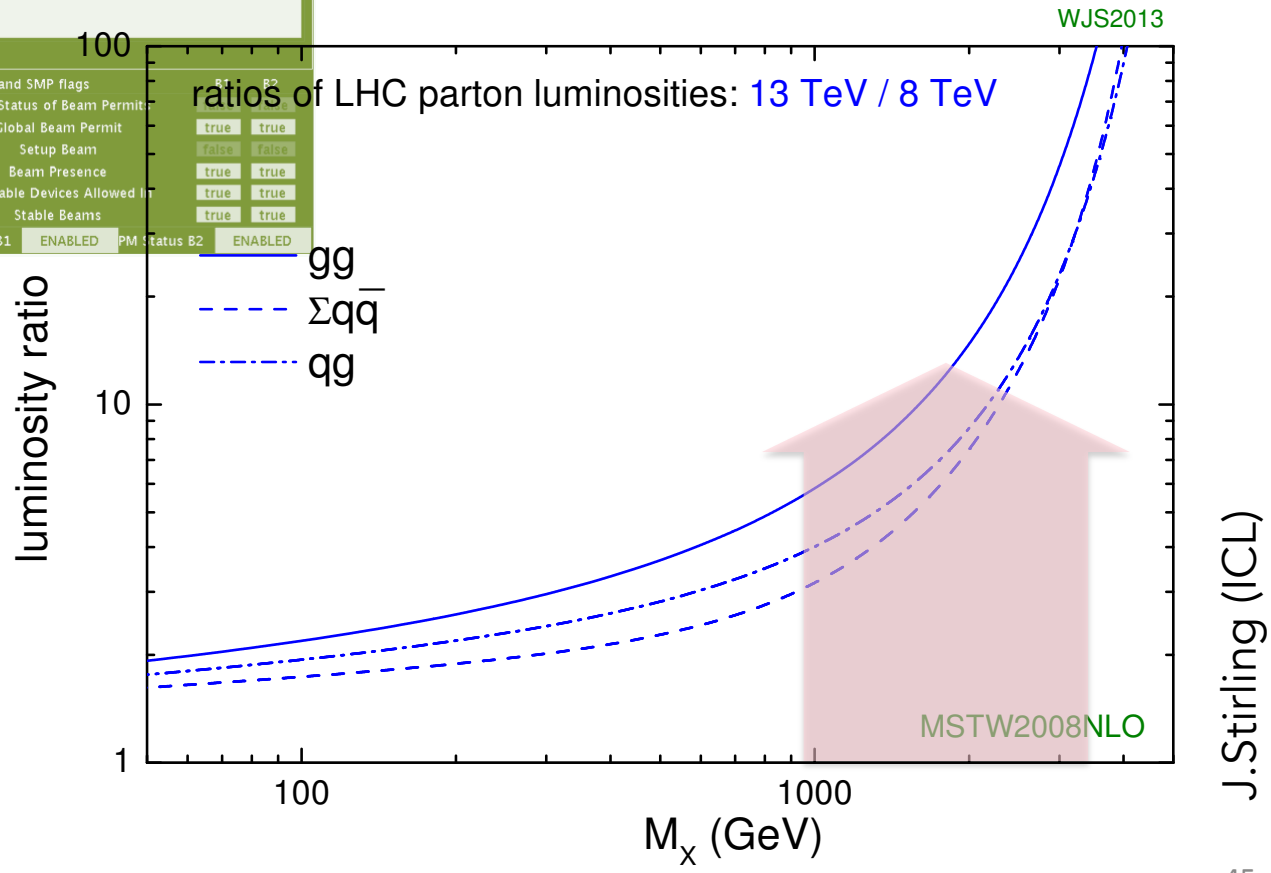


finally,

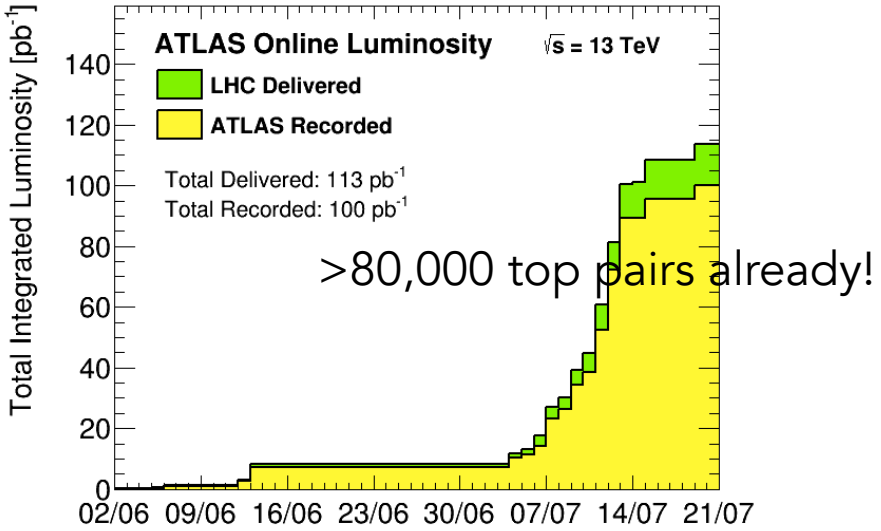
OUTLOOK

the training wheels are off!





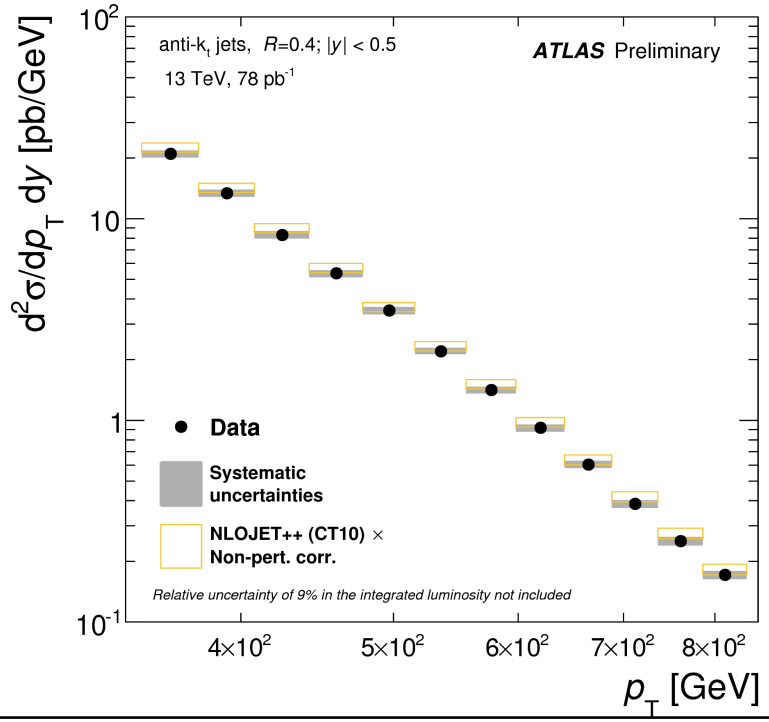
a first look at Run II

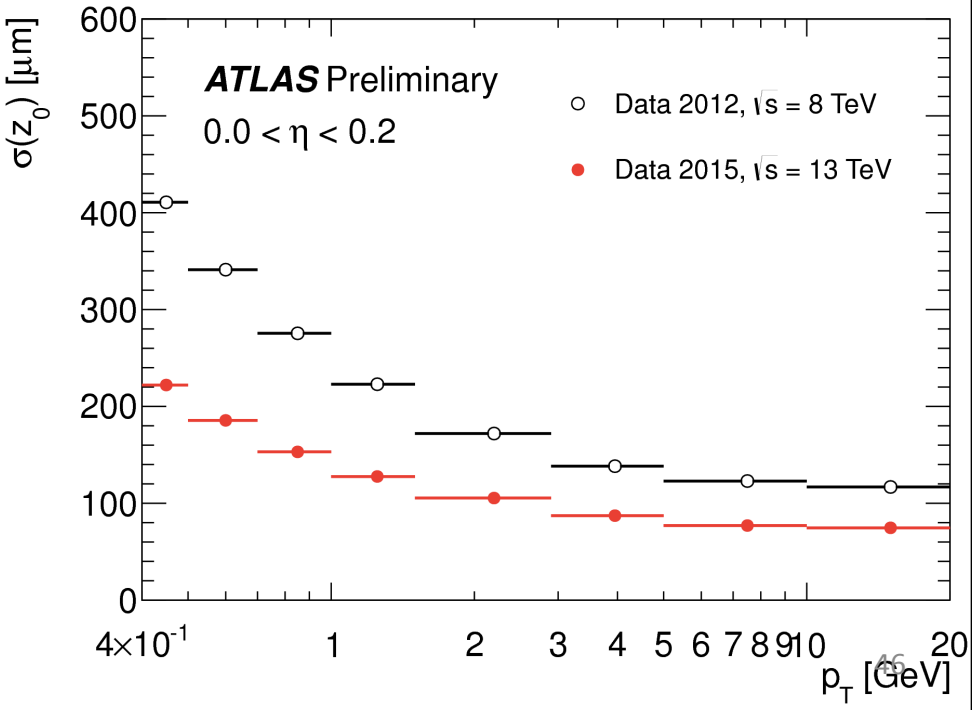


>80,000 top pairs already!

hardware highlights after the long shutdown:

- more muon acceptance
- more precision tracking hits
- more flexible triggering



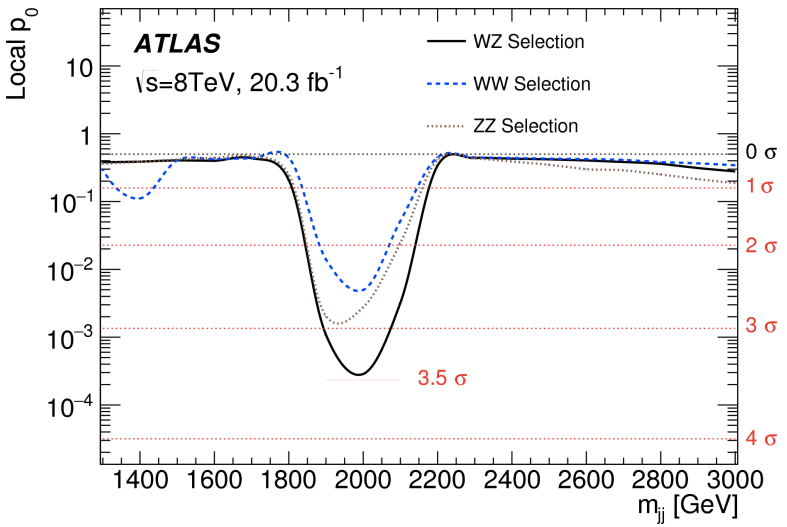


diboson resonances: expectations

Prospects

Expect signal and background enhancements of ~8 to 15 around 13 TeV

- Run 1 comparable datasets in a few fb^{-1}



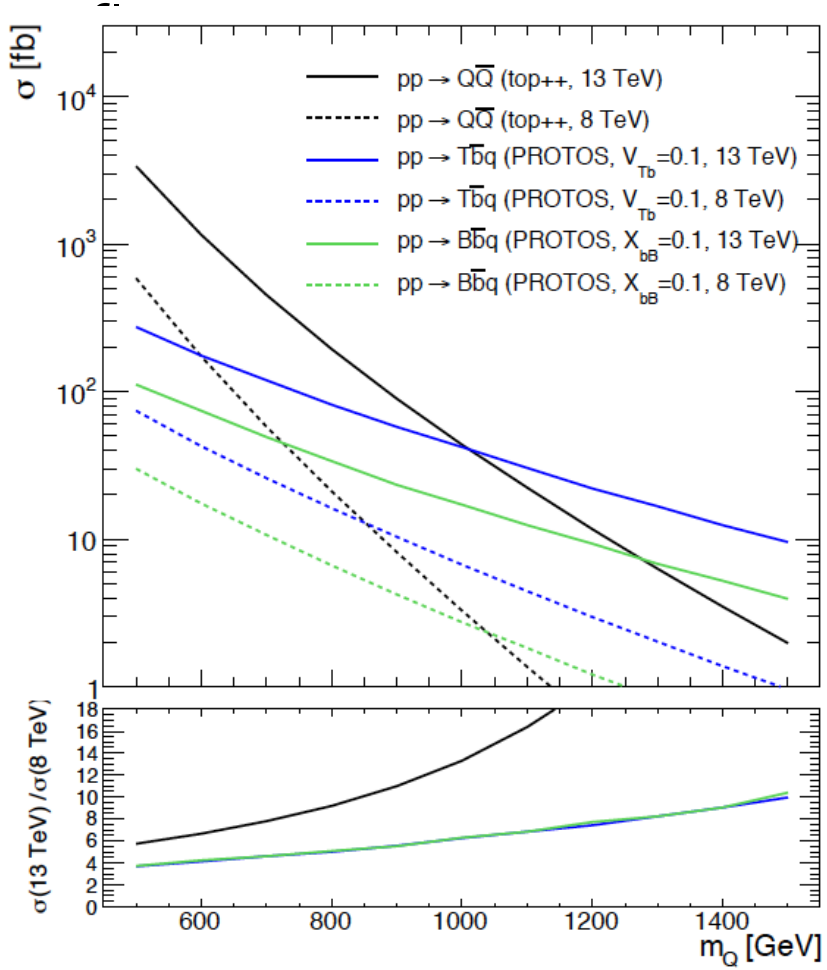
Activities

Changes in CM energy, inner detector material, tracking, simulation, pileup conditions and calo. reconstruction:

- recalibrate everything
- with data: repeat in-situ studies

Re-commissioning boson tagging (new variables, better algorithms)!

VLQ: Run II outlook



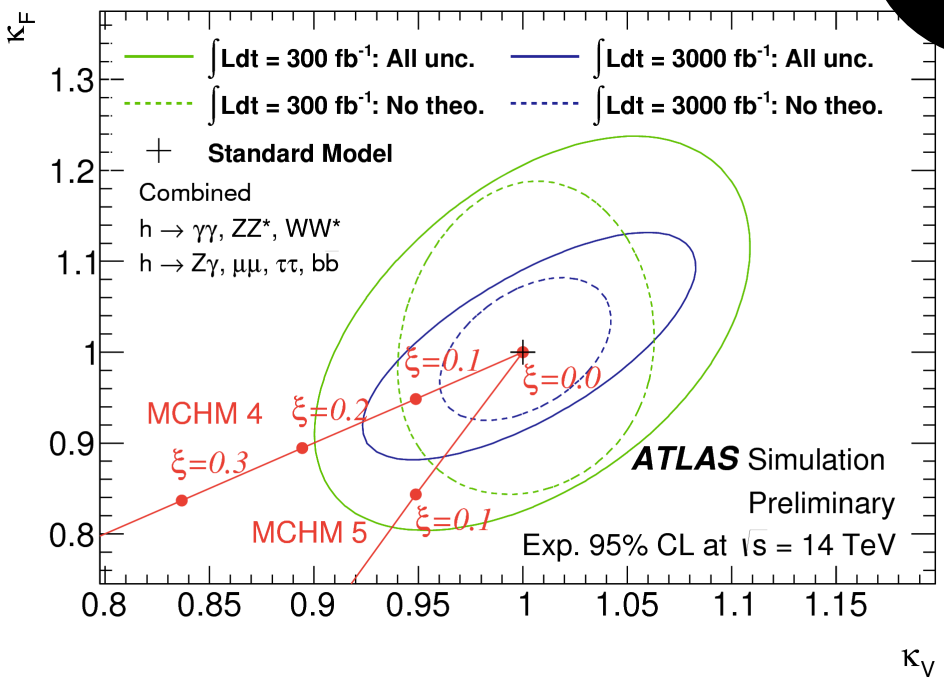
Large cross section enhancements – expect to match Run I sensitivities this year

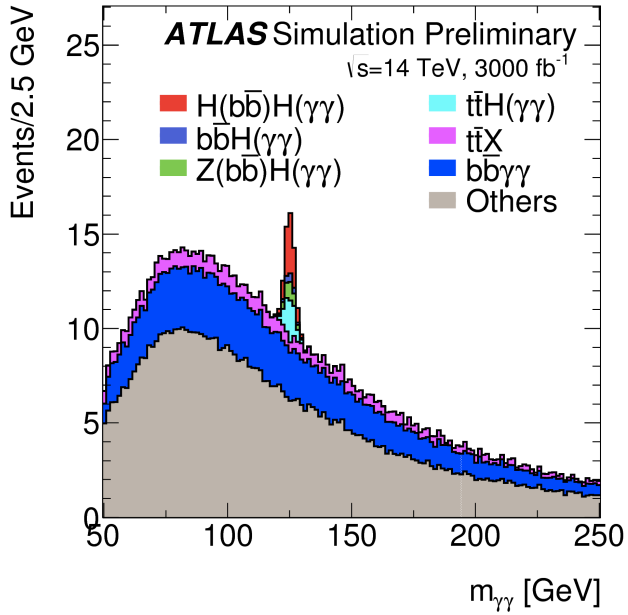
Look forward to:

- improved b-tagging (tracker + algorithms)
- more searches for single-VLQ and light quark couplings

after Run II: Higgs at the HL-LHC

Expected compositeness scale constraints (MCHM5) increase from 0.78 to 1 TeV with 3000 fb^{-1}





bbγγ sensitive to ~9x SM self-coupling

Conclusions

We're in an ideal scenario for starting Run II:

- Run I confirmed the SM prediction in a wide range of detailed measurements and searches
- Detectors and analysis techniques are more ready than ever for a discovery