Recent Results in Higgs and Exotics at ATLAS

NCTS Annual Theory Meeting 2016

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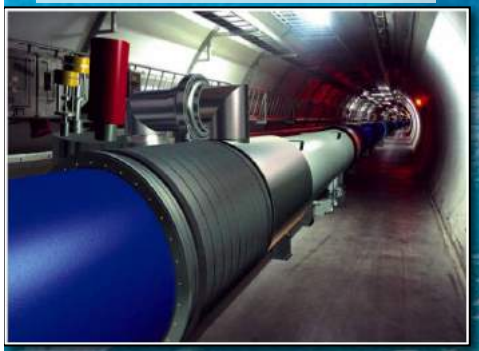
December 8th 2016

Outline

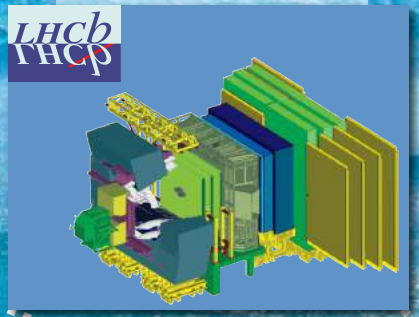
- LHC
- ATLAS
- Recent Results
  - SM Higgs
  - Exotics
- Summary

Large Hadron Collider (LHC)

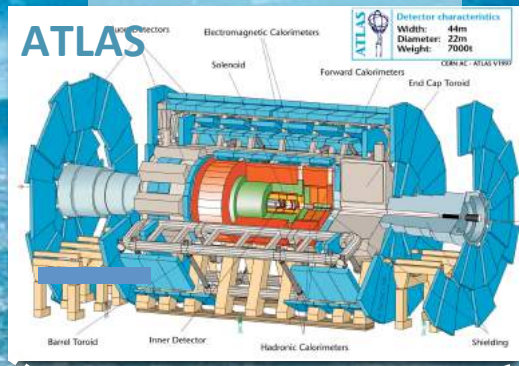
LHC : 27 km long
100m underground



pp, B-Physics,
CP Violation

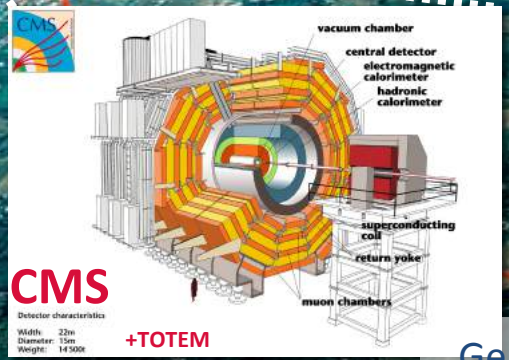


General Purpose,
pp, heavy ions



- **p-p collider**
- **Run1 operation (2010-2012):**
  - **√s = 7 , 8 TeV**
- **Run2 operation (2015, 2016):**
  - **√s = 13 TeV**

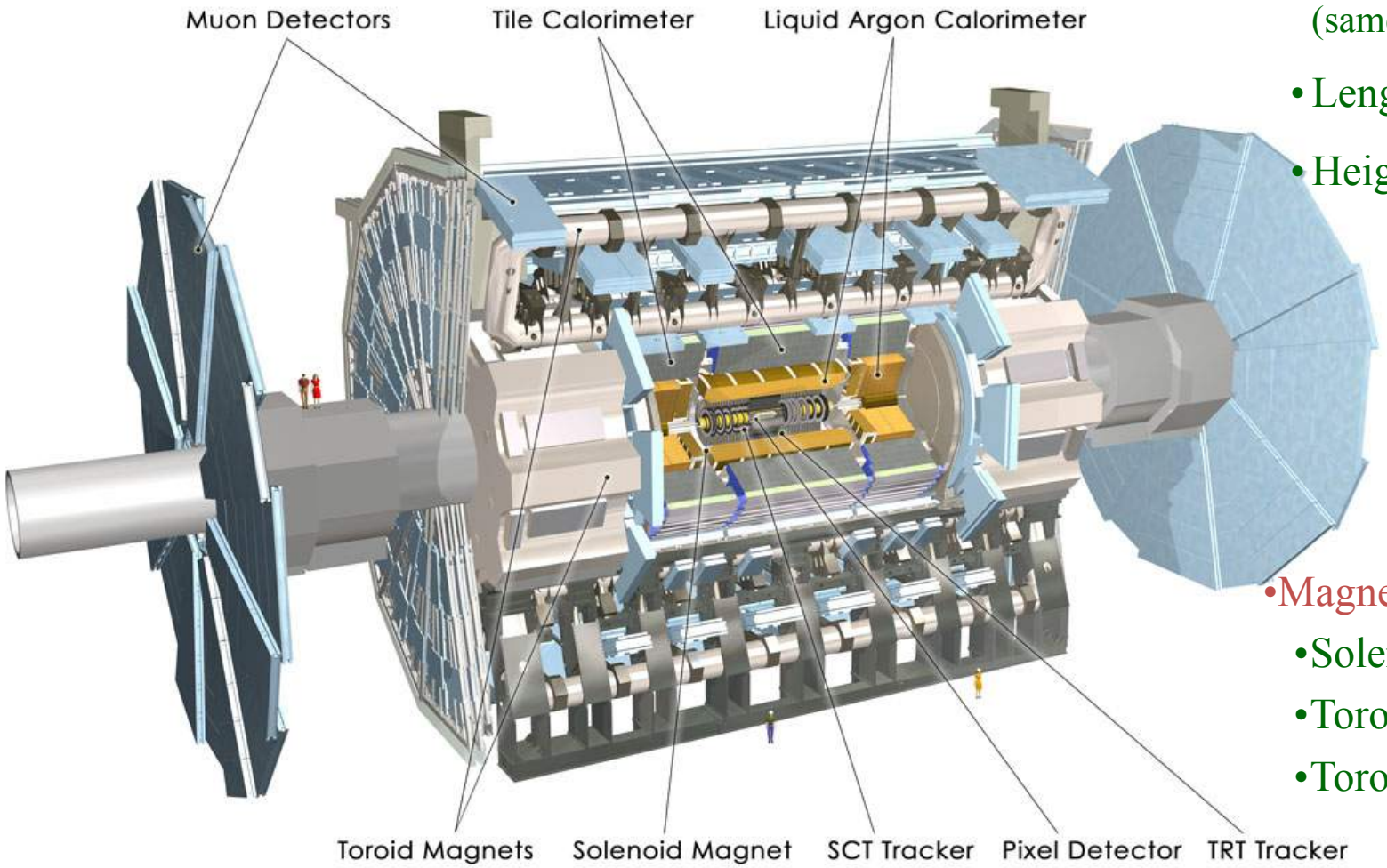
CERN



General Purpose,
pp, heavy ions

Heavy ions, pp

ATLAS Experiment



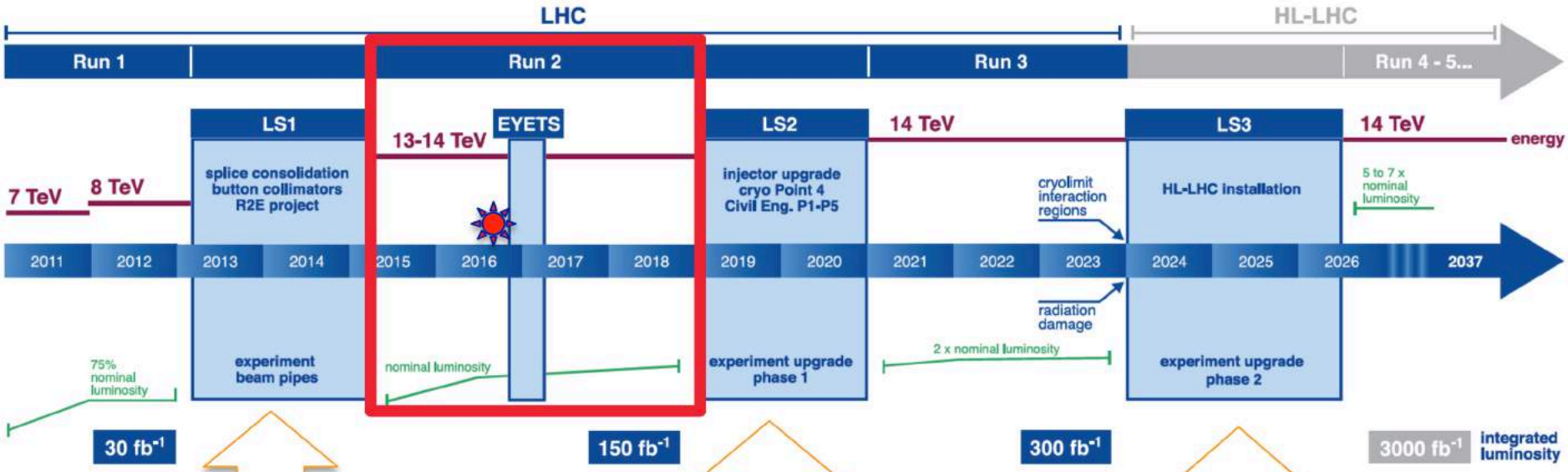
- Weight: 7000 ton (same as Eiffel tower)
- Length = ~46 m
- Height = ~25 m

- Magnets :
  - Solenoid : 2 T
  - Toroid (barrel) : 0.5 T
  - Toroid (endcap) : 1 T

- Tracker : $\sigma(p_T)/p_T \approx 0.05\%\ p_T \oplus 1\%$
- EM calorimeter : $\sigma(E)/E \approx 10\%/\sqrt{E} \oplus 0.7\%$
- Had calorimeter : $\sigma(E)/E \approx 50\%/\sqrt{E} \oplus 3\%$

- Muon Spectrometer
  - $\sigma(p_T)/p_T \approx 2\%$ @ 50 GeV
  - $\sigma(p_T)/p_T \approx 10\%$ @ 1 TeV

LHC and ATLAS Upgrades



Phase 0 upgrade

Be ready for:

- √s=**13** TeV
- Pile up ~**40**
- L ~ **1.6***10^{34} $cm^{-2}s^{-1}$
- Integral L ~ **100-150** fb^{-1}

What to improve:

- One more Pixel layer
- **70->100** kHz L1 trigger rate
- **400->1000** per sec recorded events
- Improve operation reliability of all detectors according to new challenges

Phase 1 upgrade

Be ready for:

- √s=**14** TeV
- Pile up ~**60-80**
- L up to **3***10^{34} $cm^{-2}s^{-1}$
- Integral L ~ **300** fb^{-1}

What to improve:

- New Muon Small Wheel (NSW)
- High precision Calorimeter L1 trigger
- Fast Track Trigger based on Si detectors
- Topological L1 trigger processor
- New forward diffractive physics detectors AFP

Phase 2 upgrade

Be ready for:

- √s=**14** TeV
- Pile up ~**200**
- L ~**7*** 10^{34} $cm^{-2}s^{-1}$
- Integral L ~ **3000** fb^{-1}

What to improve:

- New inner detector (Si)
- Calorimeter electronics upgrade
- Muon system upgrade
- Level-1 track trigger
- New forward calorimeters

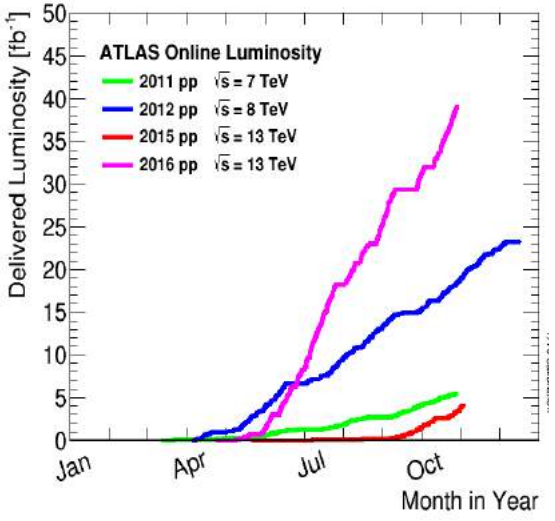
Slide from Sergei Smirnov, MEPhI, ICPPA 2016

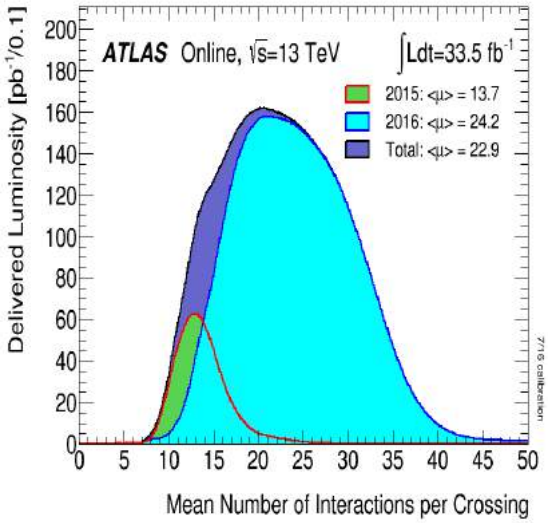
ATLAS During Run 2

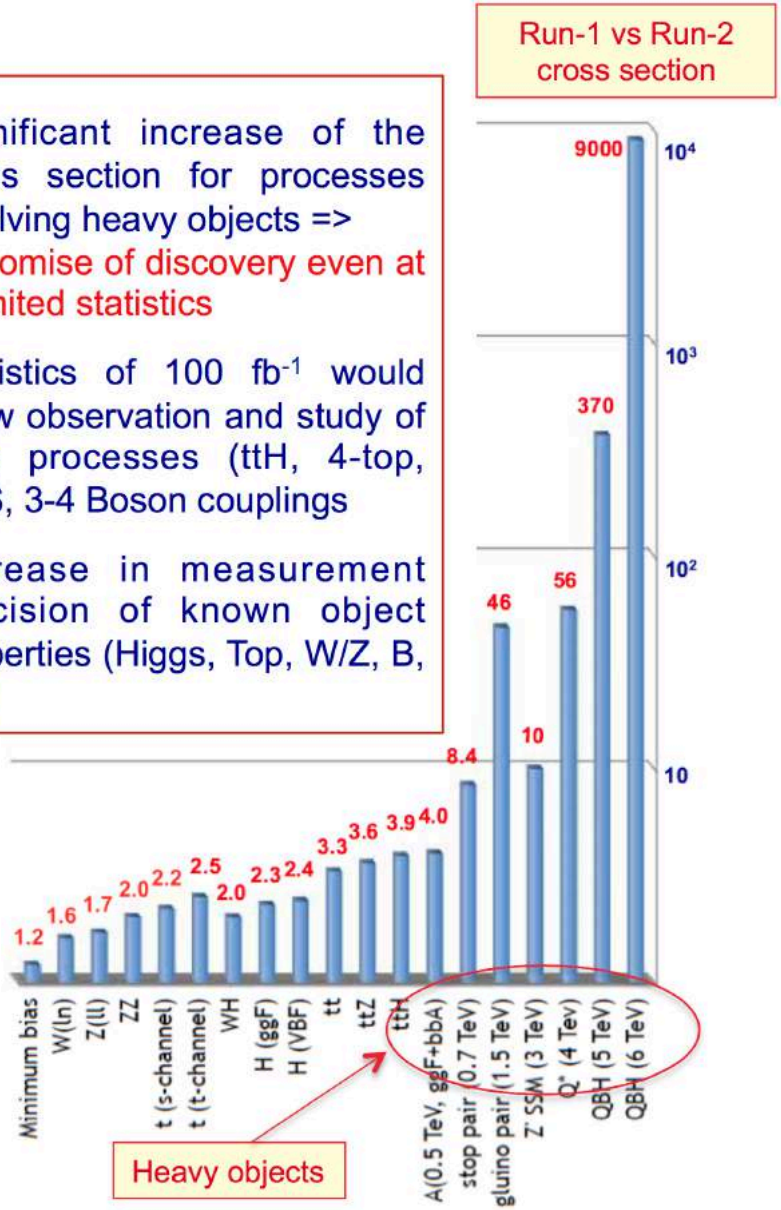
Parameter	Run-1	Run-2 (2015)	Run-2 (2016)
Peak Lumi. , 10^{34} cm^{-2}s^{-1}	0.77	0.51	1.37
Pile Up (<μ>)	20.7	13.7	24.2
Delivered Lumi. (fb^{-1})	28	4.2	39
Lumi. for physics (fb^{-1})	25	3.2	33.3

Lumi uncertainty (2016) ~4.1%

- Significant increase of the cross section for processes involving heavy objects => a promise of discovery even at a limited statistics
- Statistics of 100 fb^{-1} would allow observation and study of rare processes (ttH, 4-top, VBS, 3-4 Boson couplings
- Increase in measurement precision of known object properties (Higgs, Top, W/Z, B, ….)



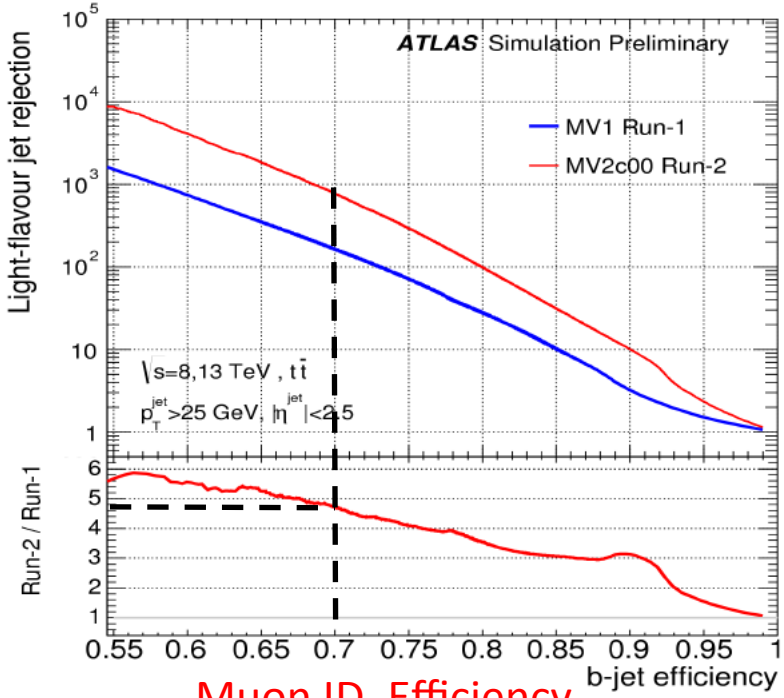




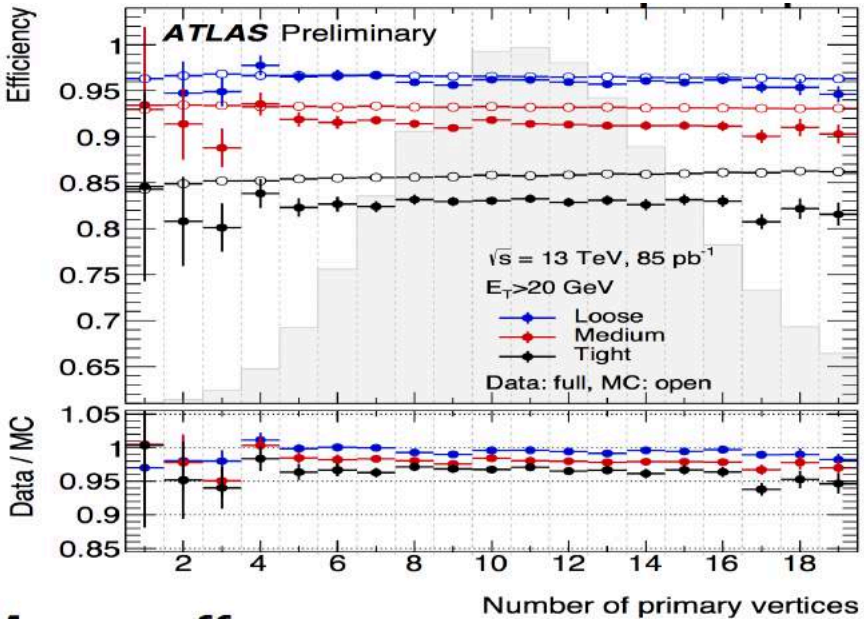
ATLAS Experiment

- Several upgrades during 2013-2014 shut down
- Add 4th silicon pixel layer
  - Significant tracking improvement
- Trigger :
  - From 3 levels => 2 levels
  - Level-1 output rate :
    - Improve from 75kHz to 100 kHz
  - HLT output rate :
    - Improve from hundreds Hz to ~1 kHz

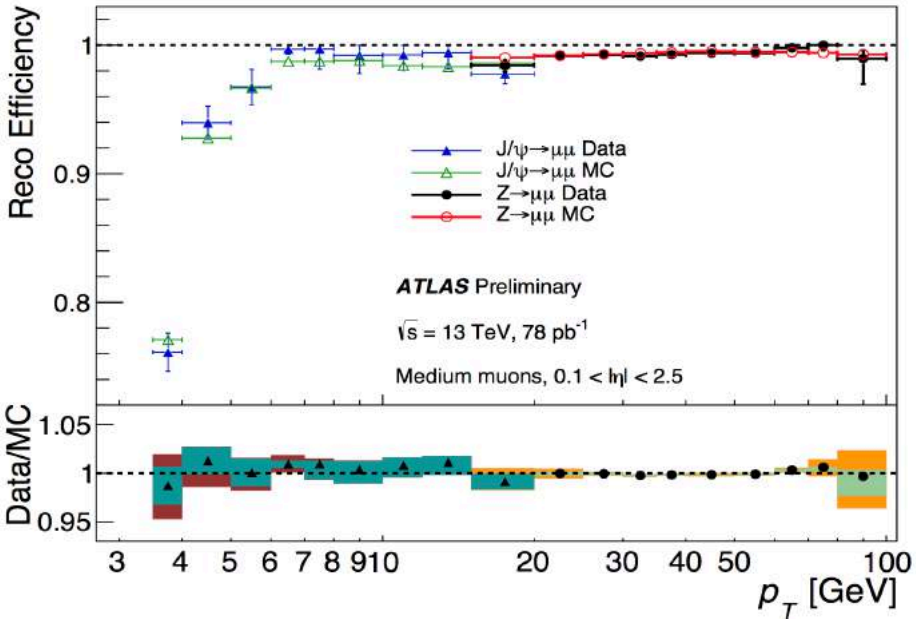
B-jet ID. Efficiency



Electron ID. Efficiency



Muon ID. Efficiency



Searches

- Try to answer fundamental questions in particle physics
  - E.g. origin of EWSB, matter, flavor, naturalness, unification, elementary vs composite, dark matter …
- Models :
  - Created to address the questions, and make predictions
  - Provide guidance to conduct search to test the model
  - Make use of unique signatures predicted by model
- Use benchmark models to interpret search results

Guiding models :

- Technicolor
- Warped Extra Dimensions
- Grand Unified Theories
- Heavy Vector Triplet
- Little Higgs
- Contact Interaction/Compositeness
- Leptoquarks
- …

One model with different signatures
One signature probing several models

Signatures :

- di-lepton, di-jet resonances
- di-boson resonances (γγ, Wγ, Zγ, WW, WZ, ZZ,…)
- Enhancement at high tail
- multiple leptons
- large missing energy
- long lived particles
- …

- Search as broad and general as possible

This Presentation

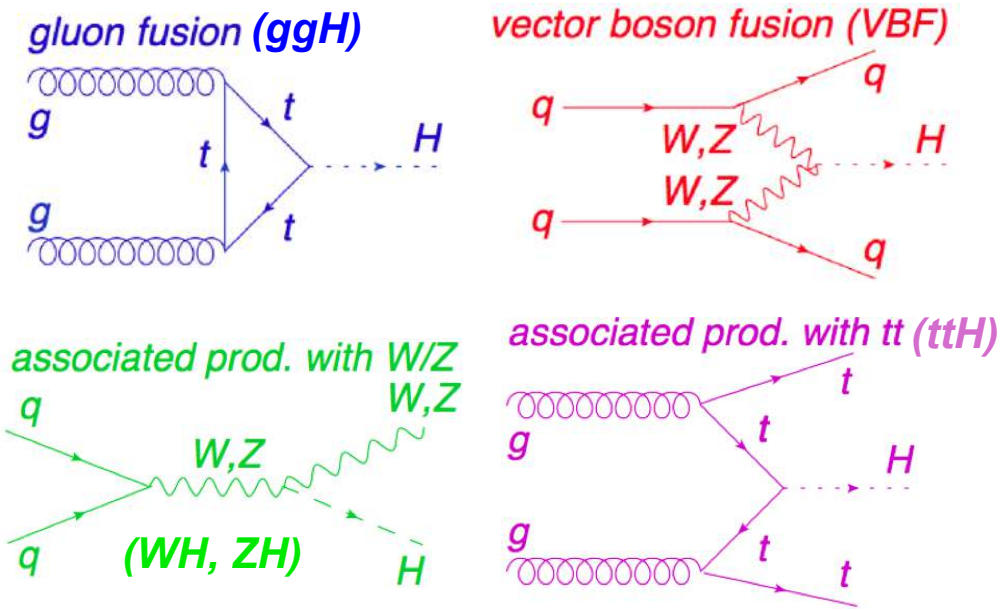
- Primarily results from :
  - "ICHEP 2016" (2015+2016 data, ~13-15 fb^{-1})
    - ~1/3 of collected Run2 data

- Will cover :
  - SM Higgs measurements / searches :
    - $\gamma\gamma$, ZZ, WW, bb, $\mu\mu$
  - Exotics (resonance search) :
    - di-lepton
    - di-photon
    - di-jet
    - di-boson

Standard Model Higgs Boson

Re-Establish SM Higgs Boson in Run 2

- Discovered a SM-like Higgs boson with Run1 data, with mass=125.09±0.21(stat)±0.11 GeV (ATLAS+CMS)



mH=125 GeV

process	σ (@13 TeV) pb
ggF	48.6
VBF	3.78
WH	1.37
ZH	0.884
ttH	0.507

Decay channel	BR (%)
bb	58.2
WW	21.4
gg	8.19
ττ	6.27
cc	2.89
ZZ	2.62
γγ	2.27
Zγ	0.153
μμ	0.0218

$H \to ZZ^* \to 4l$

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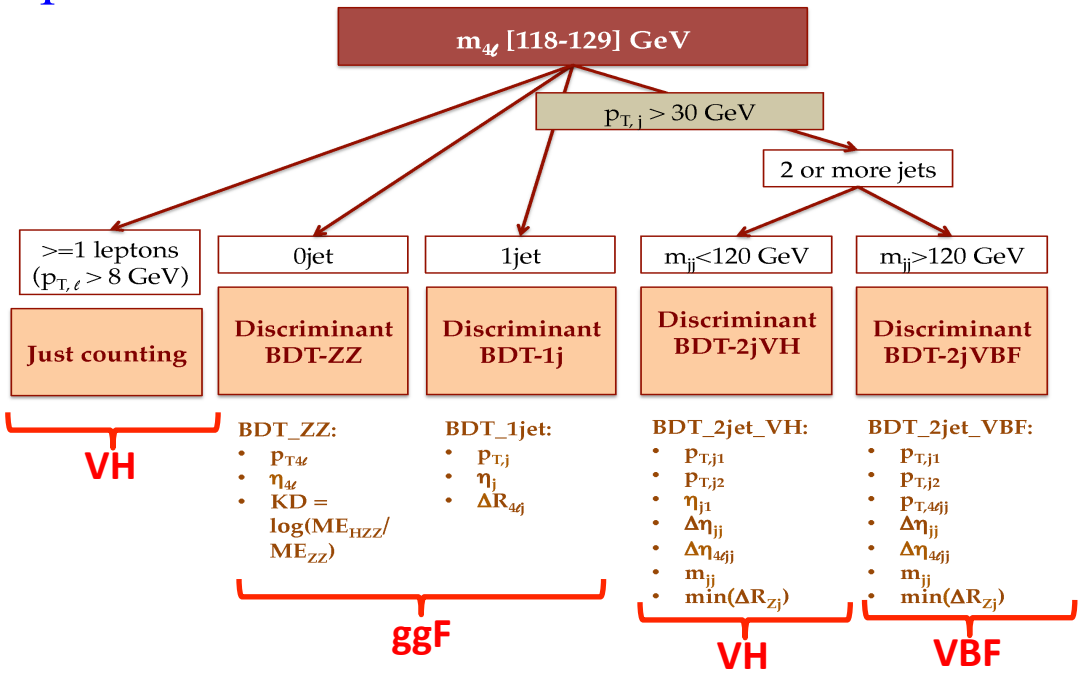
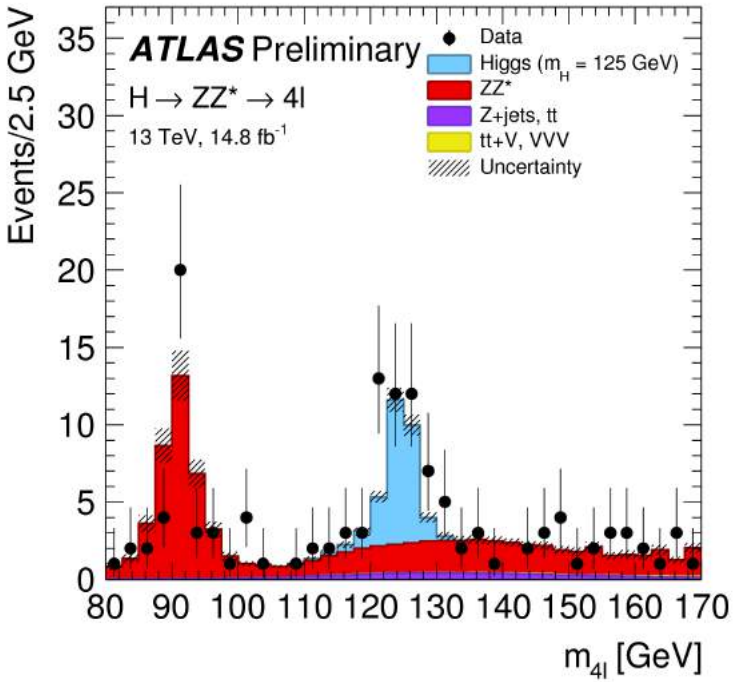
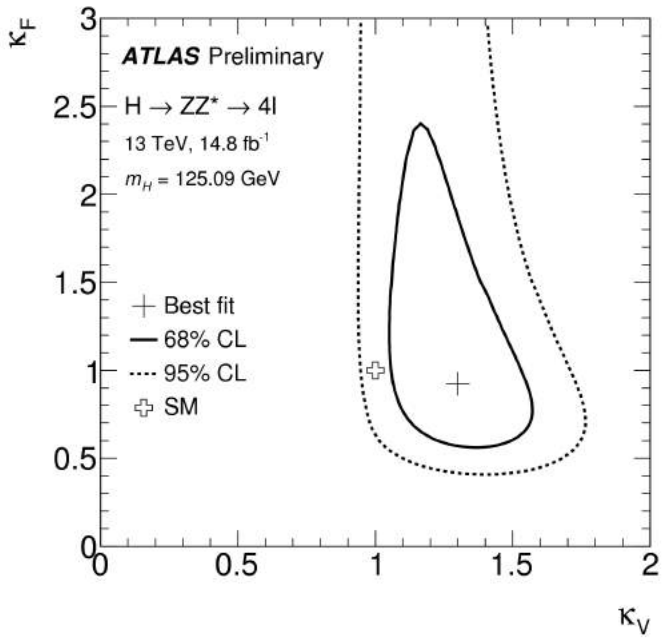
- Categorized selected events into different production channels:





- Observed 44 events in 118<m(4l)<129 GeV
  - Expect : 9.7±0.8 BG evt, 22.3 signal evt.
- σ(measured)=81^{+18}_{-16} pb
- σ(SM)=$55.5^{+3.8}_{-4.4}$ pb
- K_F (K_V) coupling strength to fermions (vector boson)
  - Observed more evt. in VBF enriched channel



H→γγ

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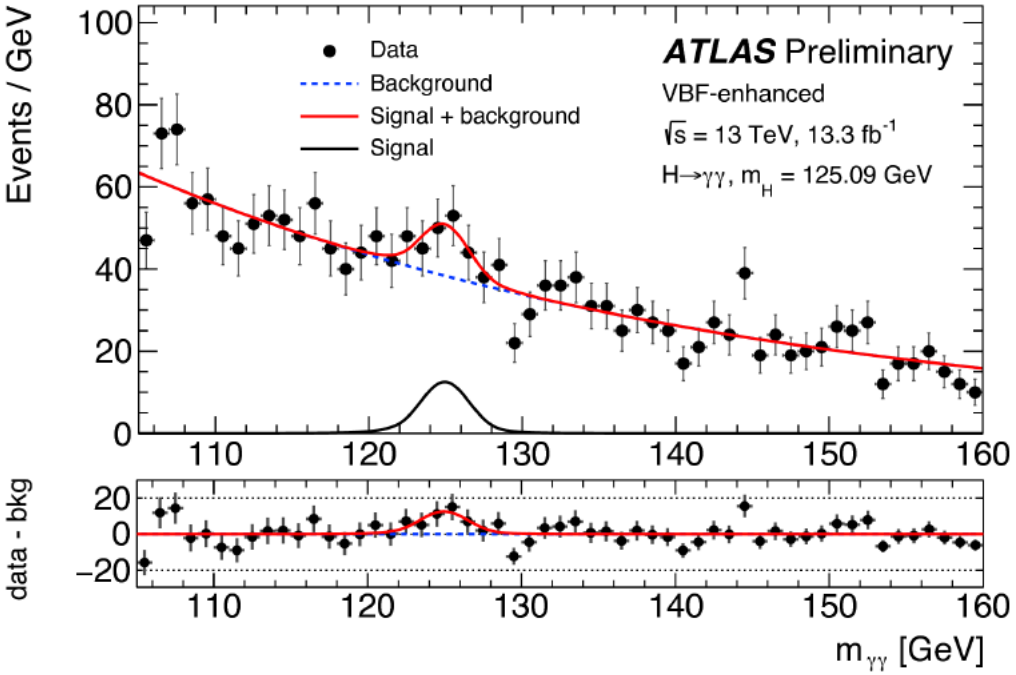
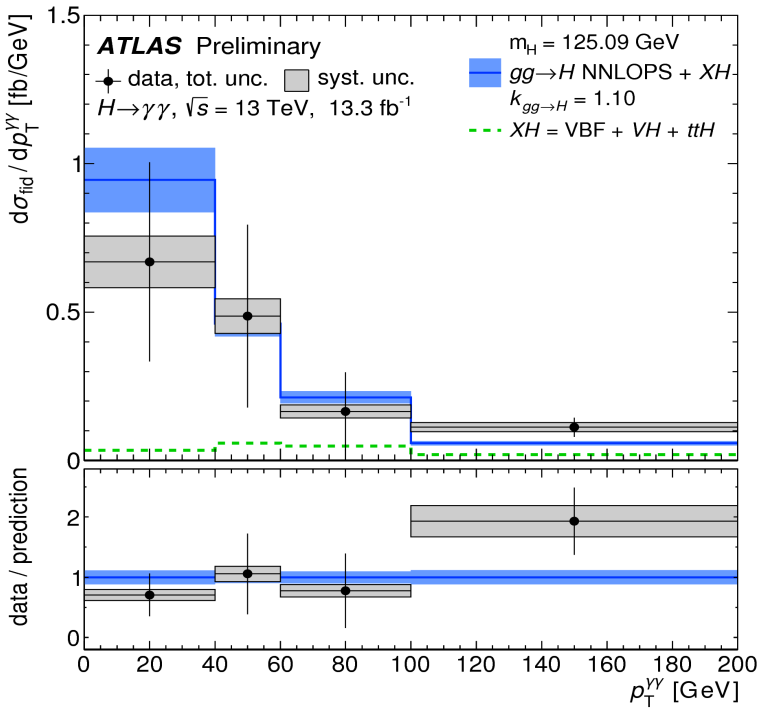
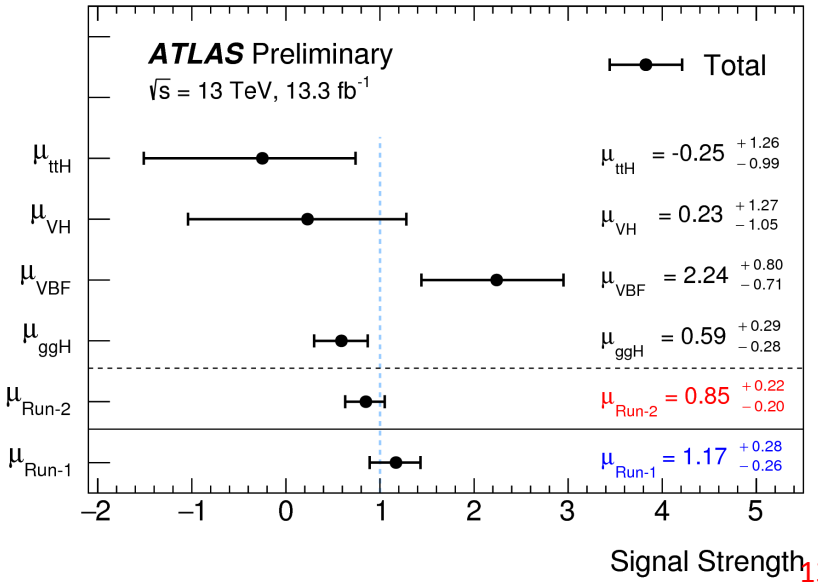
- Performed several measurements :
  - fiducial and differential cross sections
  - different production channels





- Fiducial cross section :
  - σ*BR(meas.)=43.2±14.9(stat)±4.9(syst) fb
  - σ*BR(SM)=$62.8^{+3.4}_{-4.4}$ fb
- Combined signal strength agree with SM
  - $\mu=\sigma_{meas.}/\sigma_{SM}=0.85\pm0.21$



Measurement of Higgs Cross Section

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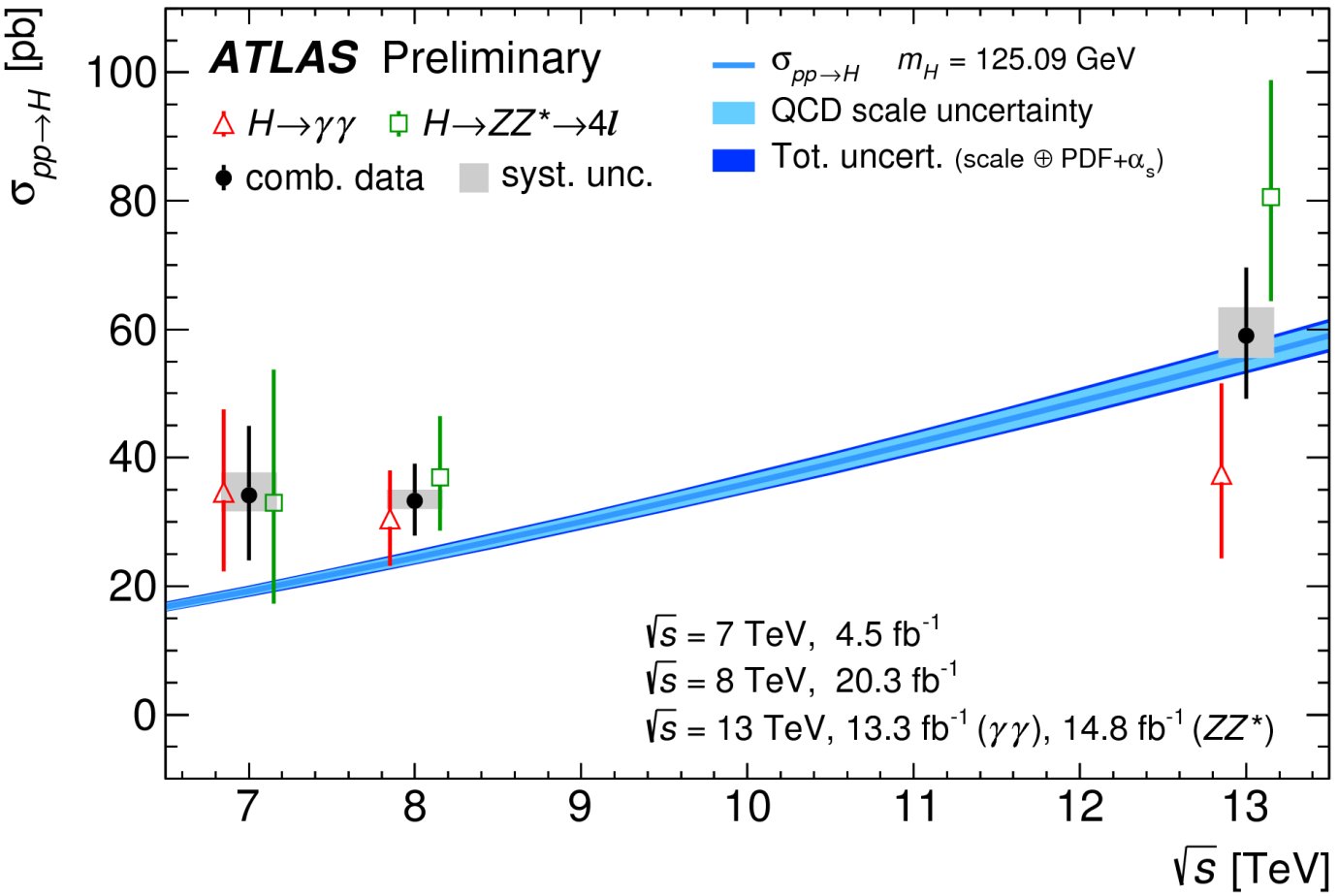
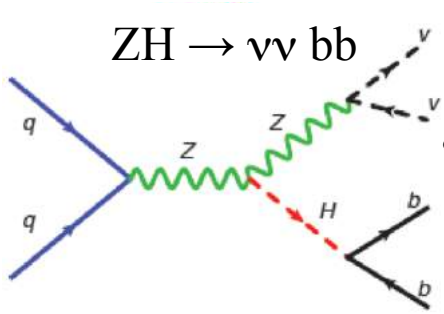


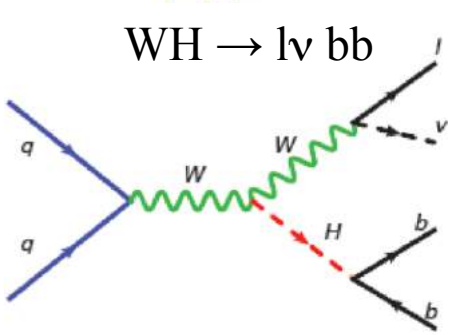
•Combined local significance = 10 σ (8.6 σ expected) for 13 TeV analysis

WH, ZH production with H→bb



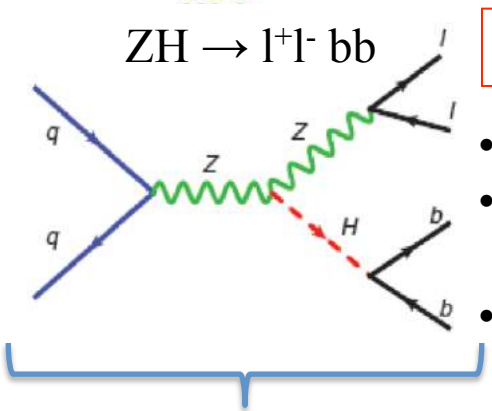
0-lepton

- Large missing energy
  - E_t^{miss}>150 GeV



1-lepton

- One isolated e,μ
- E_t^{miss}



2-lepton

- isolated ee or μμ
- m_{ll} compatible with m_Z
- no E_t^{miss}

2 b-jets

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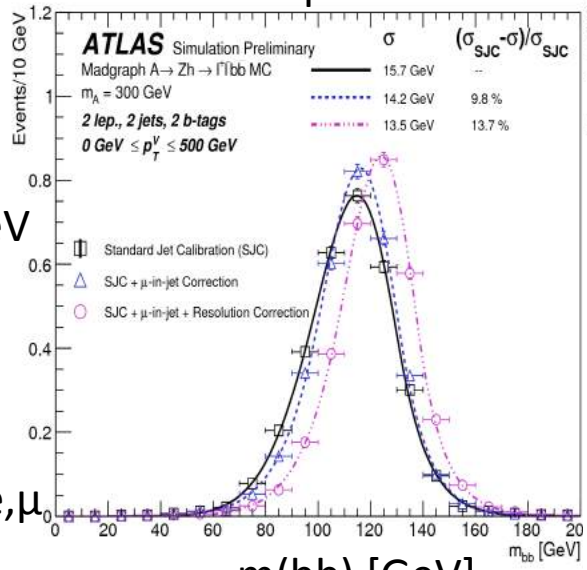
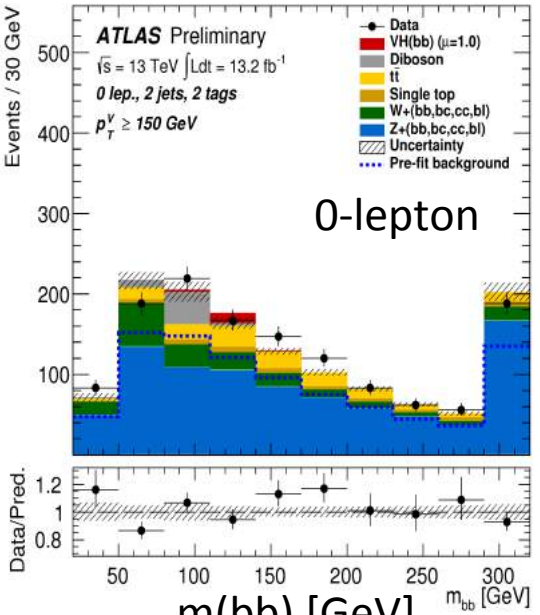
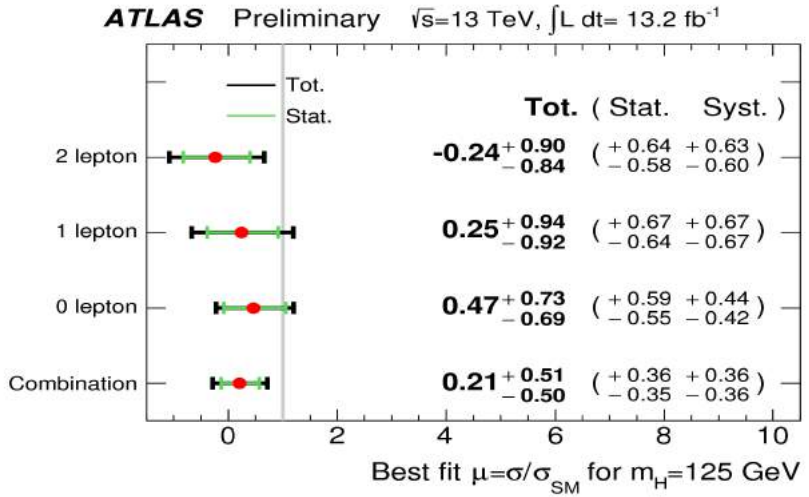
Mbb improvement



m(bb) [GeV]



m(bb) [GeV]



- **$\mu=\sigma_{meas}/\sigma_{SM}=0.21\pm0.51$**, corresponds to 0.42σ observed (1.94σ expected) sensitivity
- Run1 sensitivity : 1.4σ obs. (2.6σ expected)

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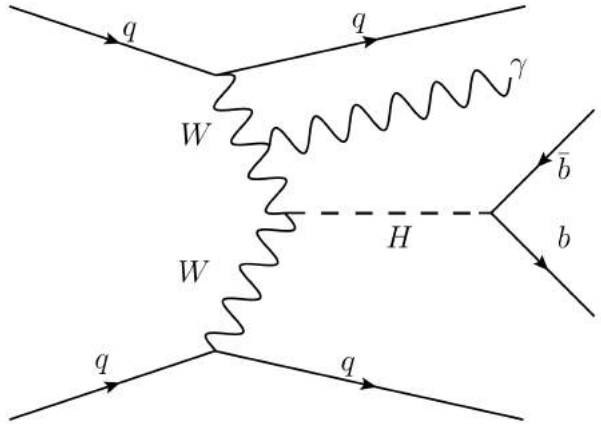
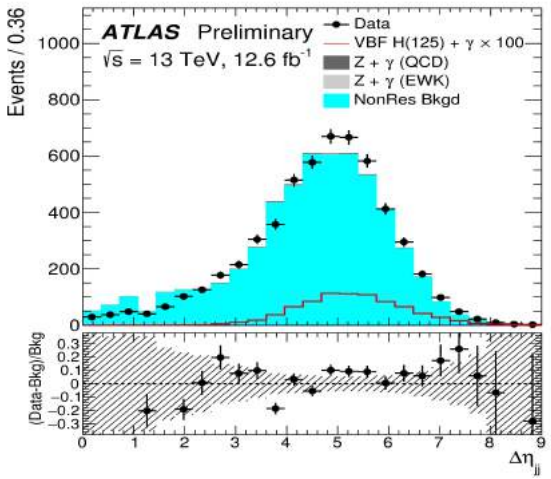
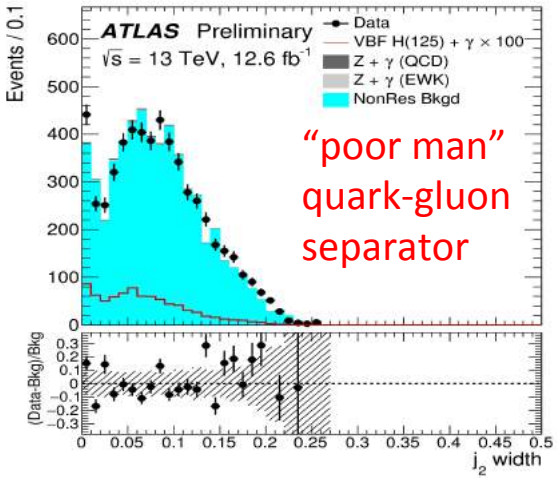
VBF(bb)+γ



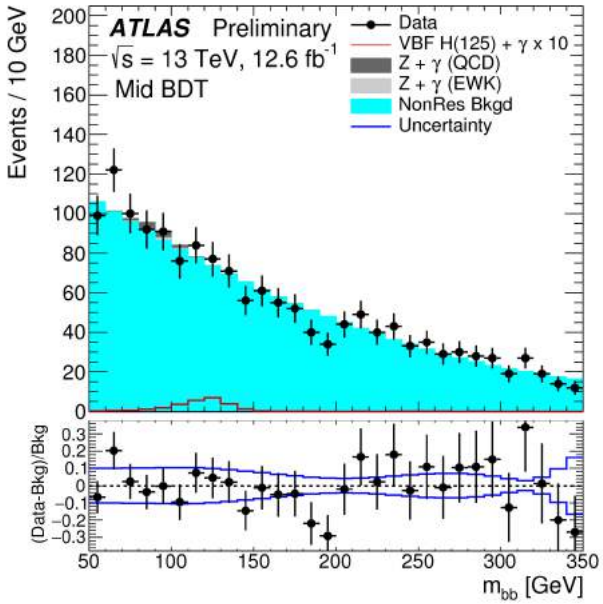
- Search for H->bb in VBF events with a γ
- High pT photon provides :
  - extra handle for trigger, suppress multijet background

- **Selection :** **First search at LHC**
  - 2 b-jets, 2 forward jets, 1 central γ
- **Separate signal from background**
  - use event kinematics
  - low jet activity between signal bb and forward jets
  - mostly quark jets in signal, mixture of quark and gluon jets in background
- **Results (95% CL limit):**
  - Expected : $6\ ^{+2.3}_{-1.7} \times$ SM
  - Observed : 4 × SM

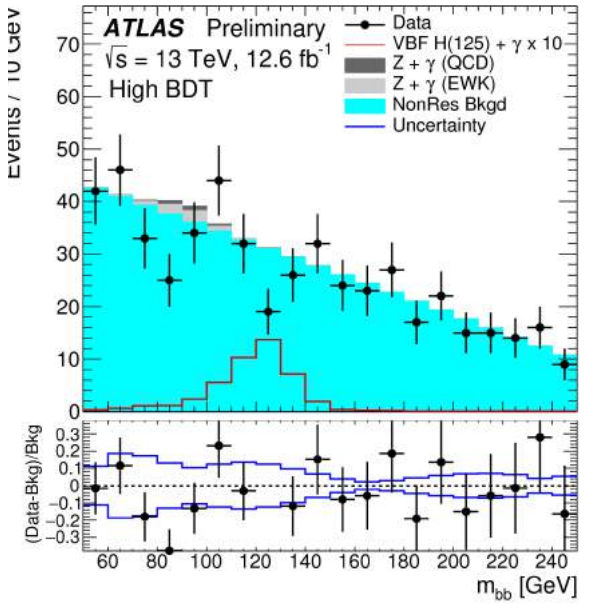




Low sensitivity category



High sensitivity category



ttH, H→bb

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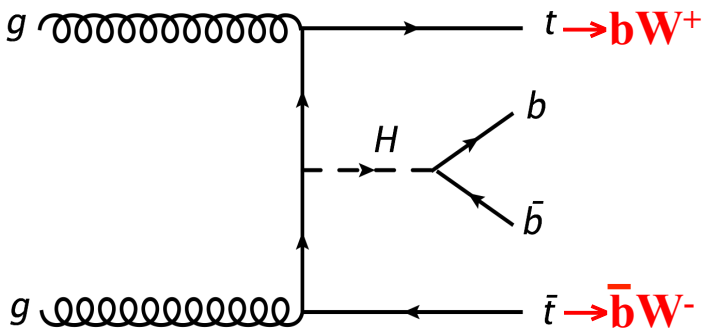
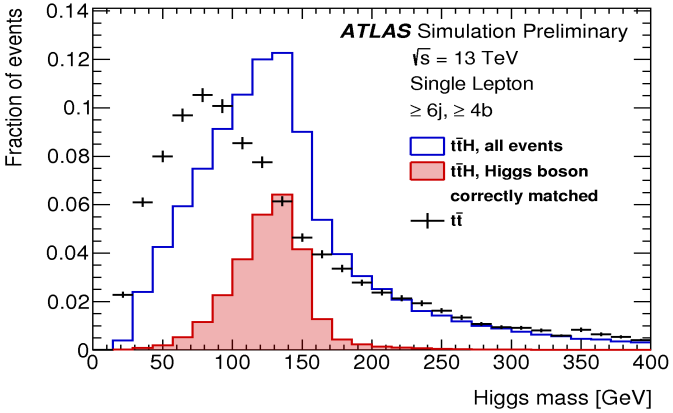
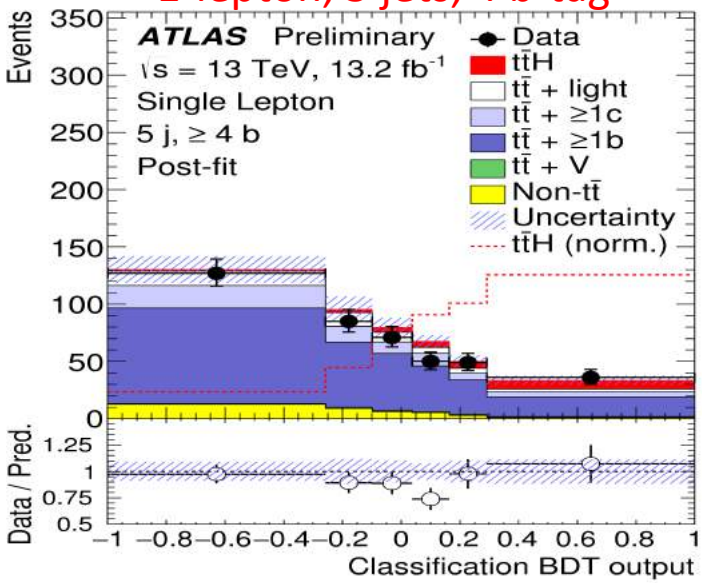


- Measure top Yukawa coupling
- Search in events with 1 W (1-lepton) or both W (2-lepton) decay leptonically
- Categorized search according to jet multiplicity and number of b-jets

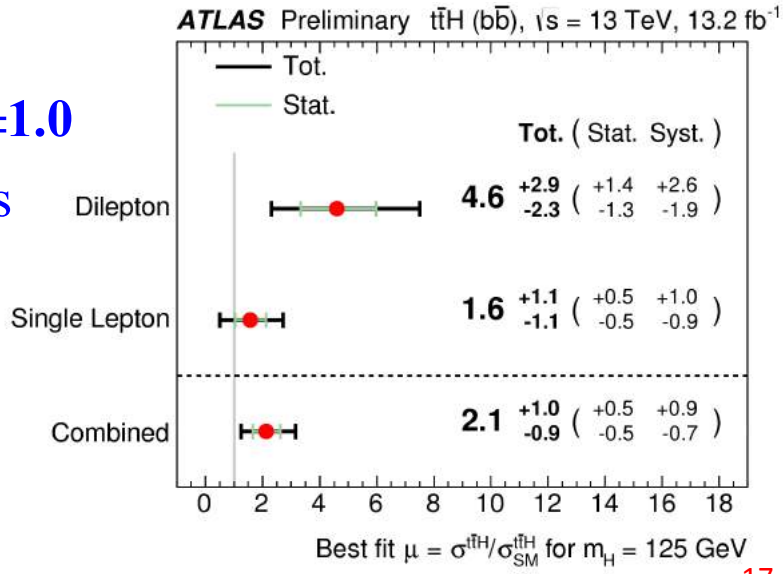
- Dominant background : tt+X
- 4 b-jets in final state, need to find right pair for H→bb
- Multivariate technique to discriminate signal from background



1-lepton, 5 jets, 4 b-tag



- $\mu=\sigma_{meas}/\sigma_{SM}=2.1\pm1.0$
- Sensitivity same as Run1 ($\mu=1.5\pm1.1$)!



Other New SM Higgs Results Not Covered

•H→μμ

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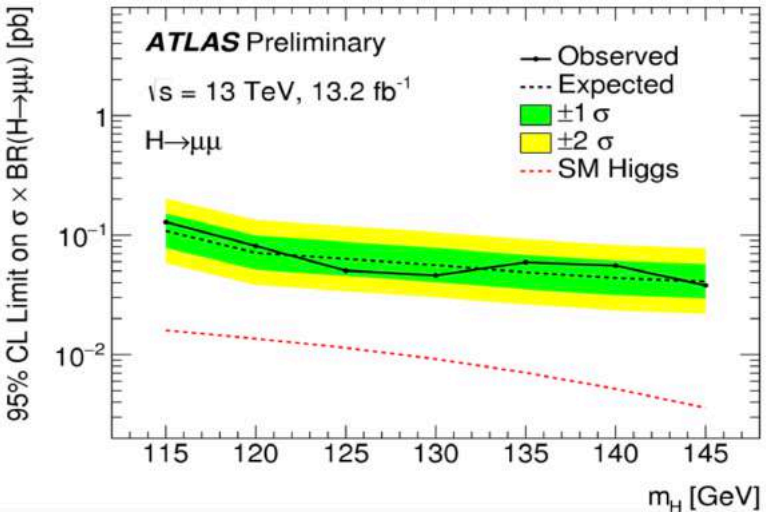

- Clean signature to measure H coupling to 2nd generation fermions

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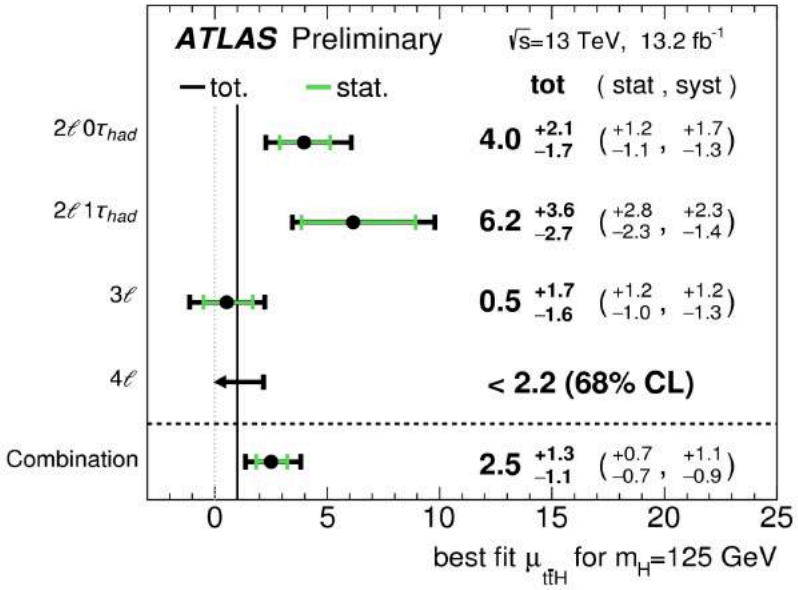
•ttH→multi-leptons (H→WW, ZZ, ττ)



•VBF, WH (H→WW)

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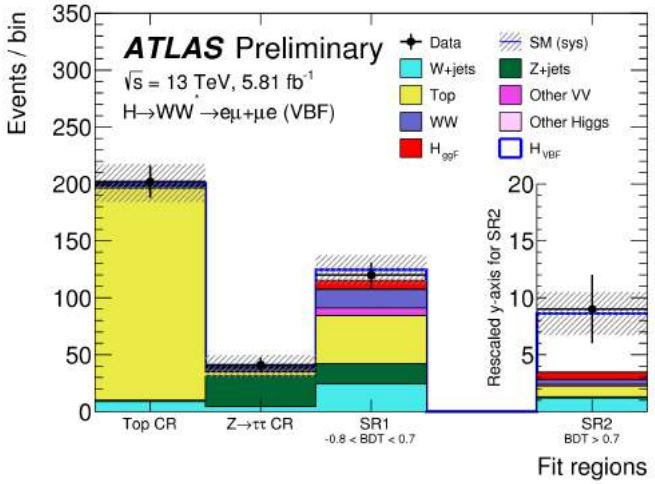
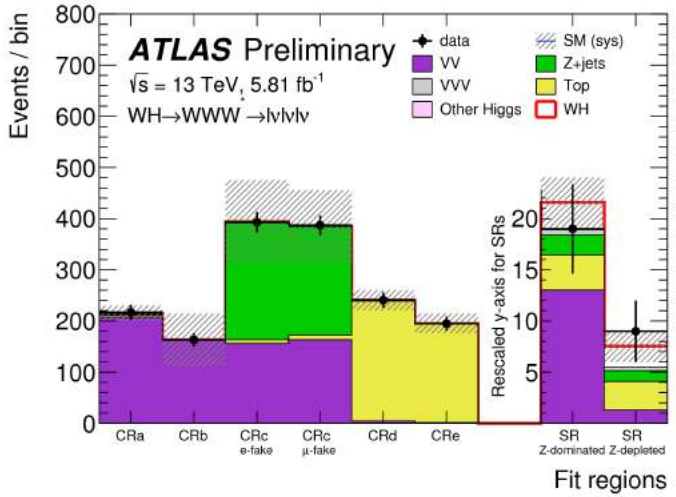


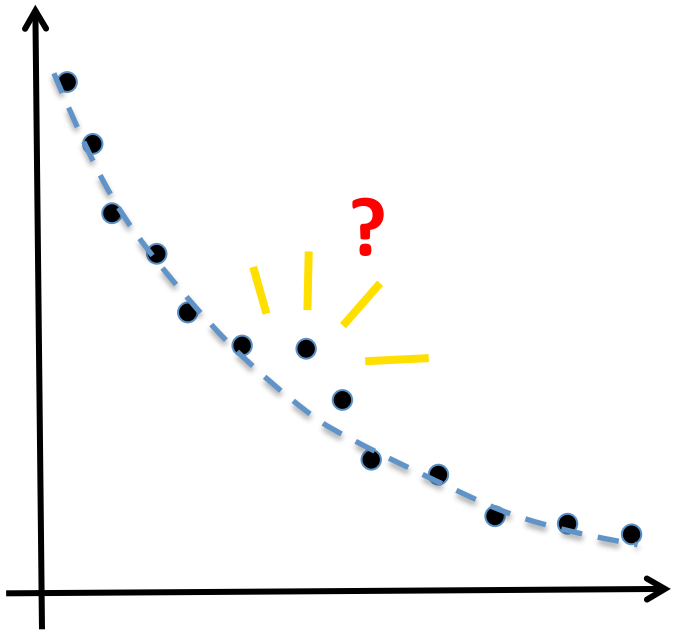


- $\mu(VBF)=1.7^{+1.1}_{-0.9}$
- $\mu(WH)=3.2^{+4.4}_{-4.2}$

Beyond Stand Model Searches

Resonances

- Perform model independent search for new physics processes
- IF an excess !!!
- Else , set limits for bench-mark processes



Lepton + Missing E_T

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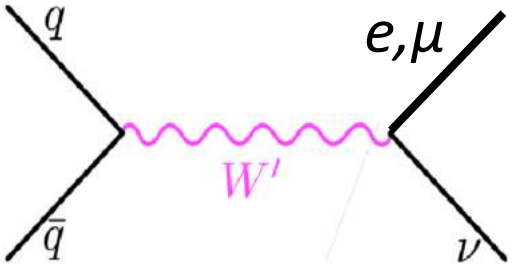
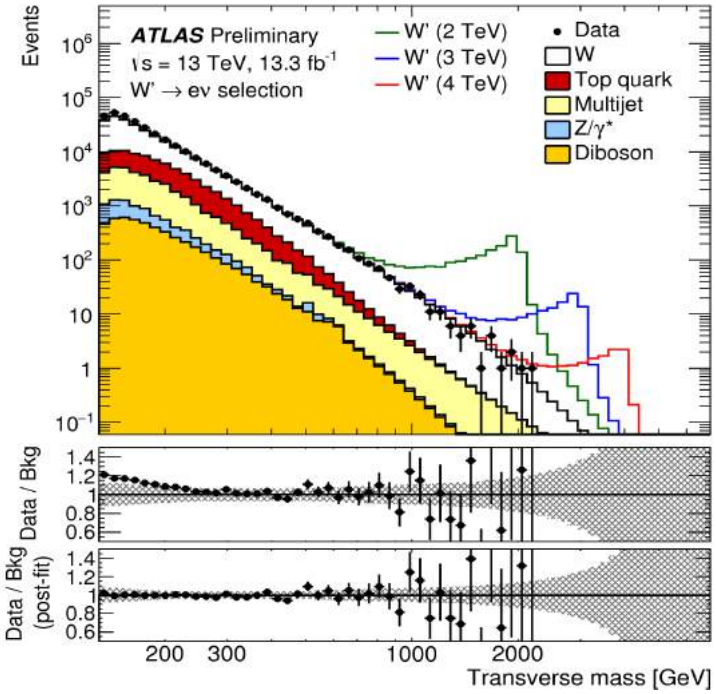
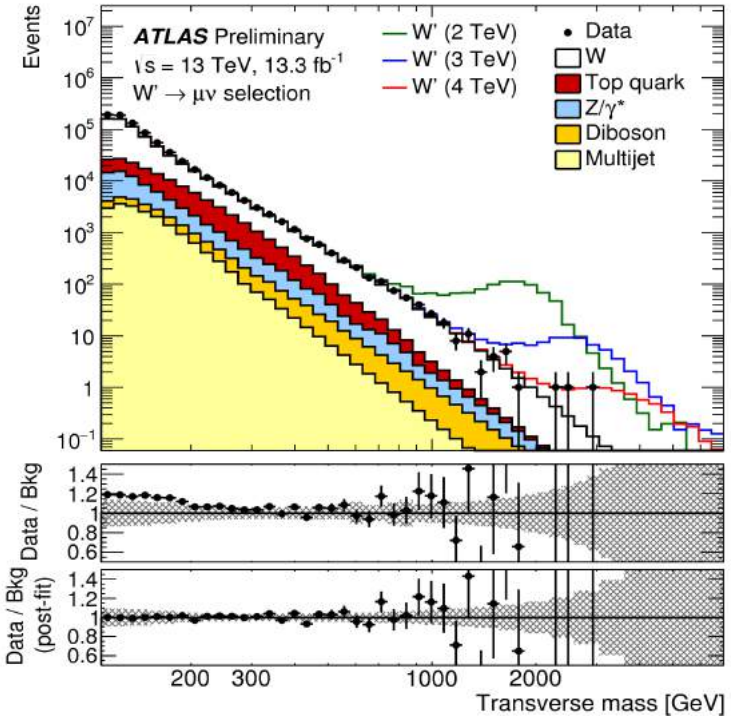


- New spin-1 gauge bosons predicted in many BSM
- Heavier version of SM W,Z => W', Z'
- Bench mark model : Sequential Standard Model (SSM)
  - W', Z' : couplings to fermions are same as SM W, Z

- Neutrino escapes detection
- Construct transverse mass : $m_T = \sqrt{2 p_T E_T^{miss} (1 - \cos\phi_{l\nu})}$

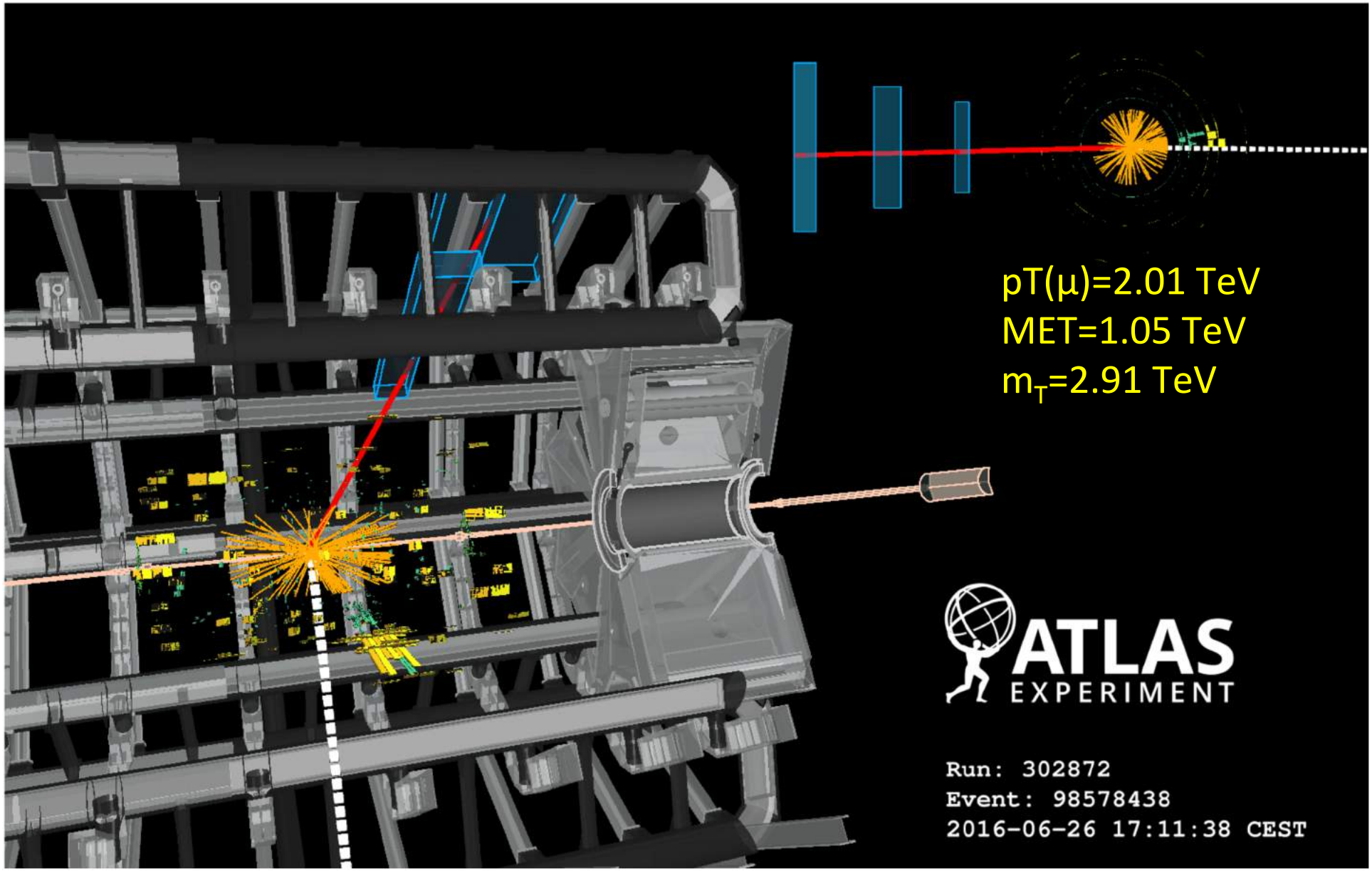




$W'_{SSM}(e) < 4.64$ TeV $W'_{SSM}(\mu) < 4.19$ TeV $W'_{SSM}(e+\mu) < 4.74$ TeV

$W'_{SSM}(e+\mu, \text{Run1}) < 3.24$ TeV

Highest $m_T(\mu,\nu)$ Event



Di-Lepton

•Search for heavy resonance decaying into same flavor di-lepton pair

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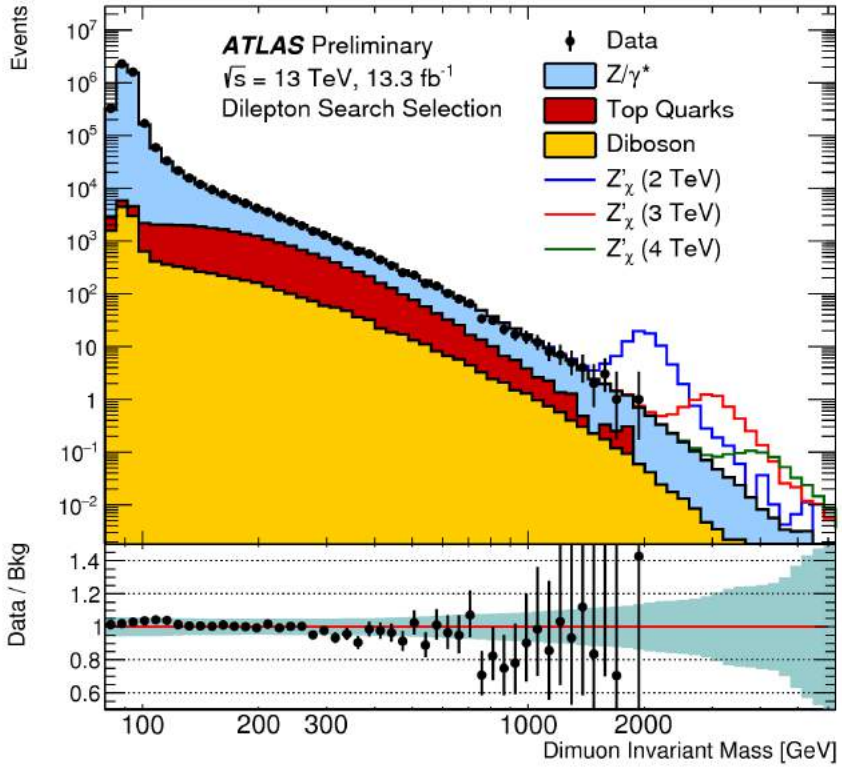
Opposite Sign Charged



Limits :

- Z'_{SSM} (3% width) < 4.05 TeV
- Z'_{Ψ} (0.5% width) < 3.36 TeV

Z'_{SSM} (Run1) < 2.9 TeV

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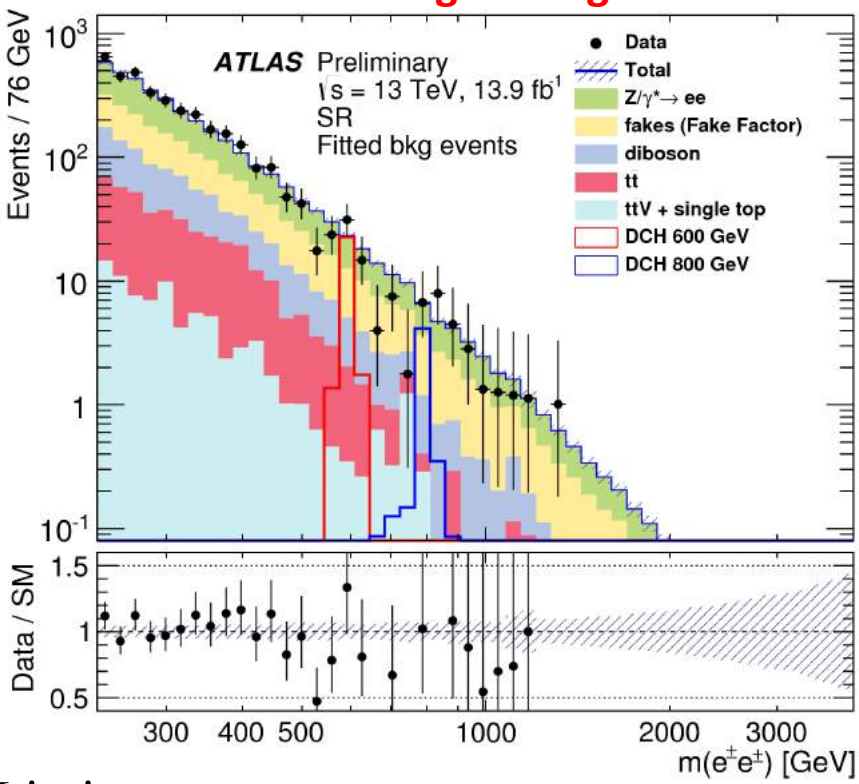
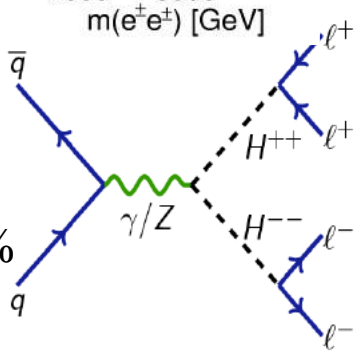
Same Sign Charged

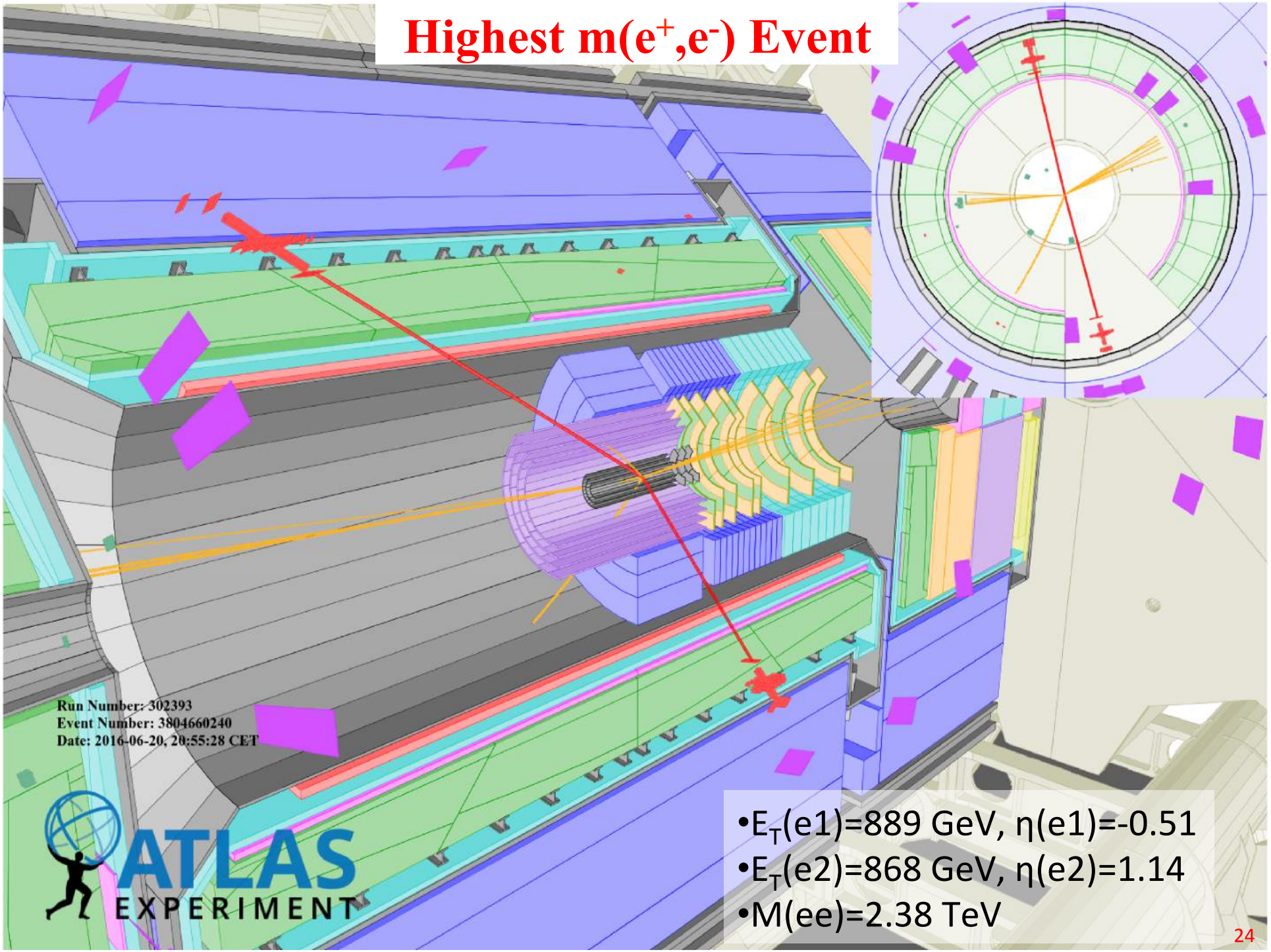


Limits :

- $H^{\pm\pm}_R$ < 420 GeV
- $H^{\pm\pm}_L$ < 570 GeV
- Assume BR($H^{\pm\pm} \rightarrow e^{\pm}e^{\pm}$)=100%



Highest m(e^+,e^-) Event



- E_T(e1)=889 GeV, η(e1)=-0.51
- E_T(e2)=868 GeV, η(e2)=1.14
- M(ee)=2.38 TeV

Di-Jet (high mass)

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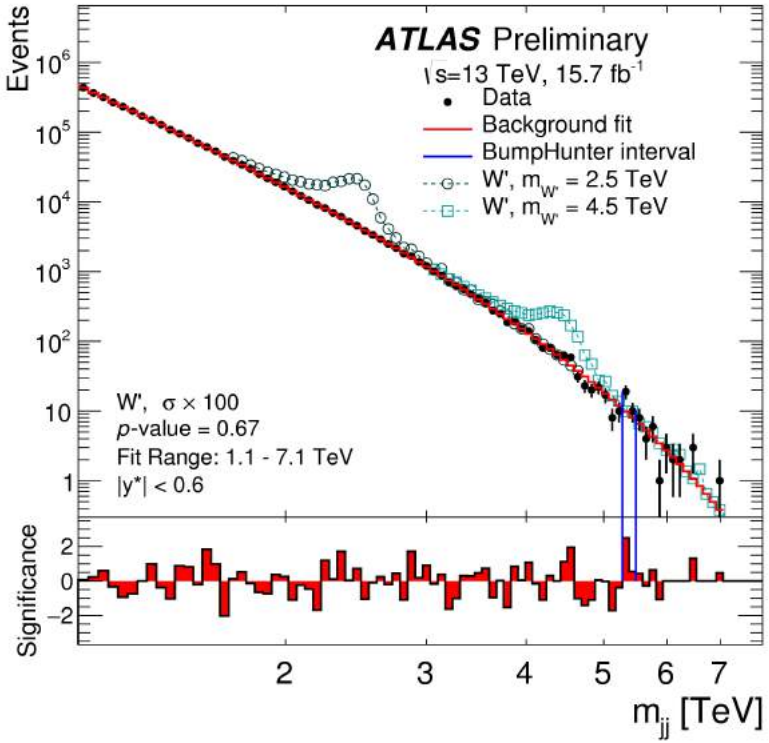
ATLAS-CONF-2016-060

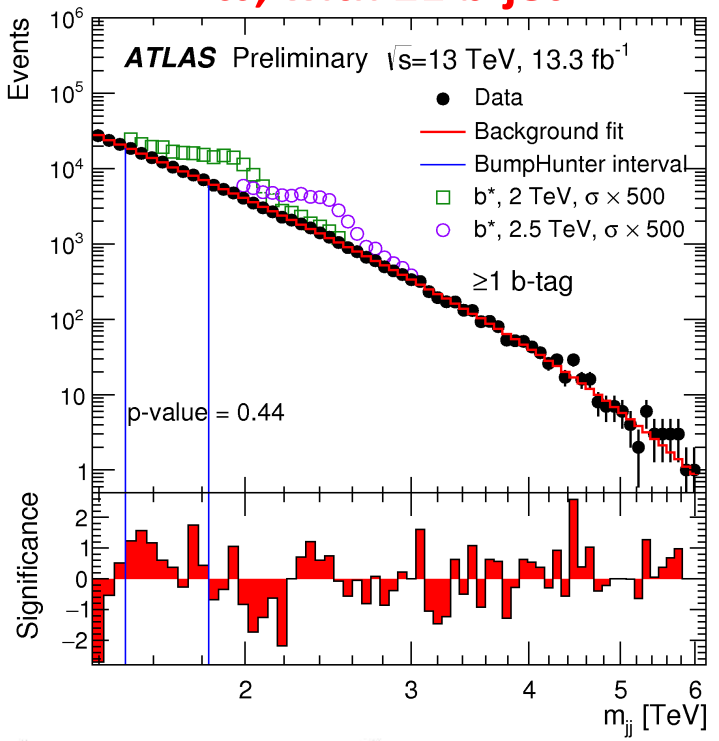
- QCD predicts smooth falling di-jet m_{JJ} spectrum
- New states decay to 2 jets may show up as local excess in m_{JJ}

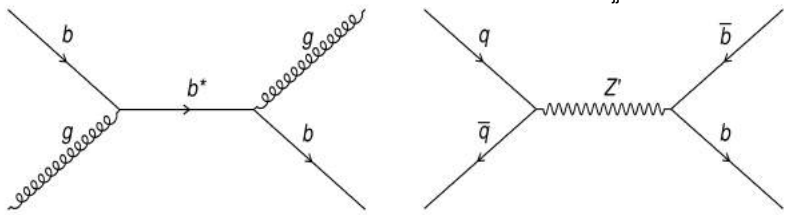
High m_{JJ} Search



- A pair of jets, leading jet pT>440 GeV
- Set limits on several bench mark models :
  - m(excited quark) < 5.6 TeV
  - m(W') < 2.9 TeV

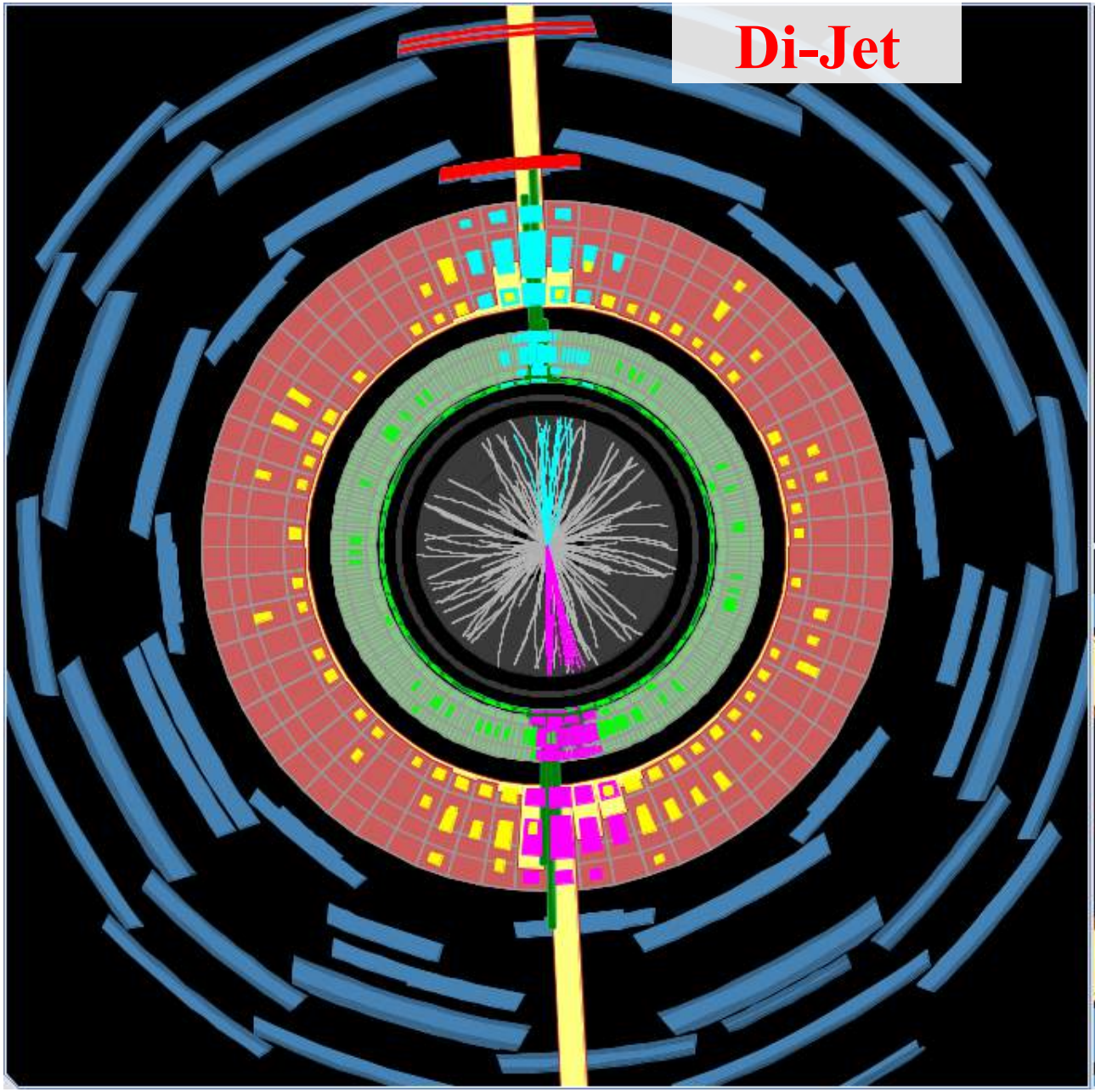
JJ, with ≥1 b-jet

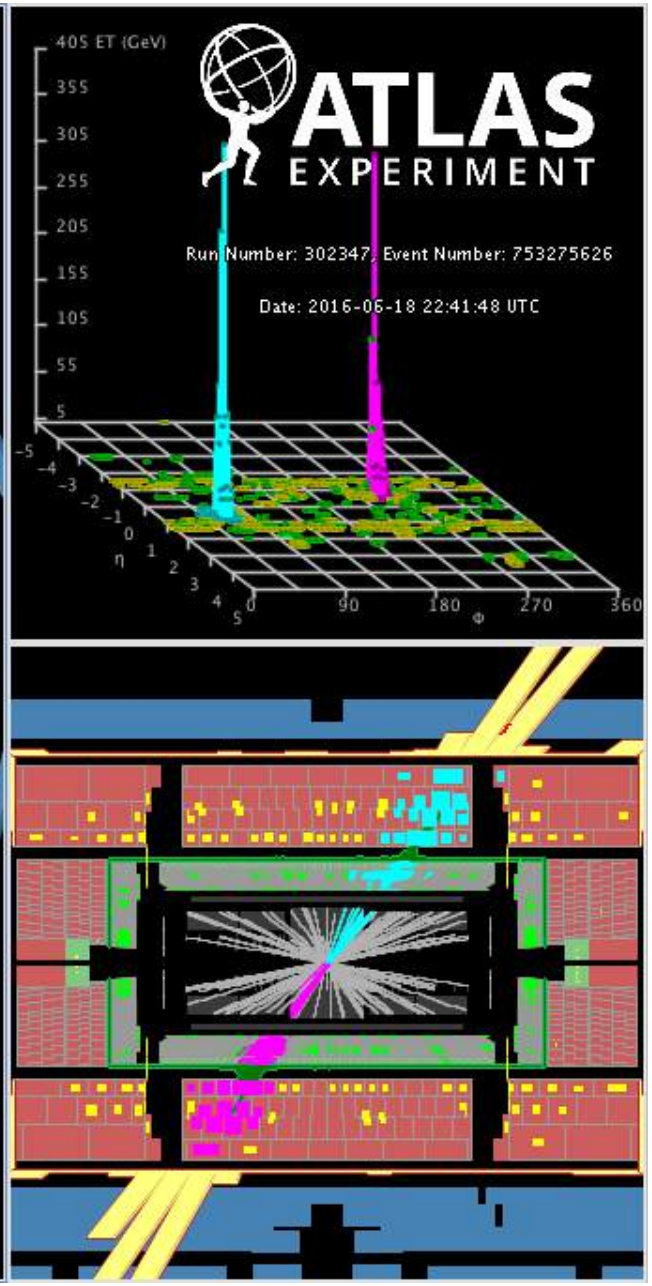




- Set limit :
  - excited b : <2.3 TeV (BR($b^* \rightarrow bg$)=0.85)

Di-Jet

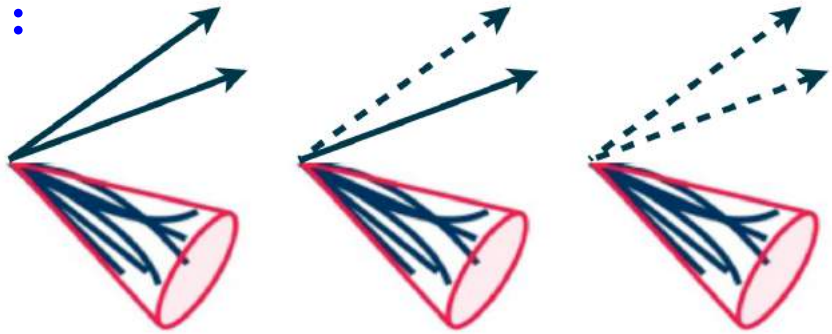




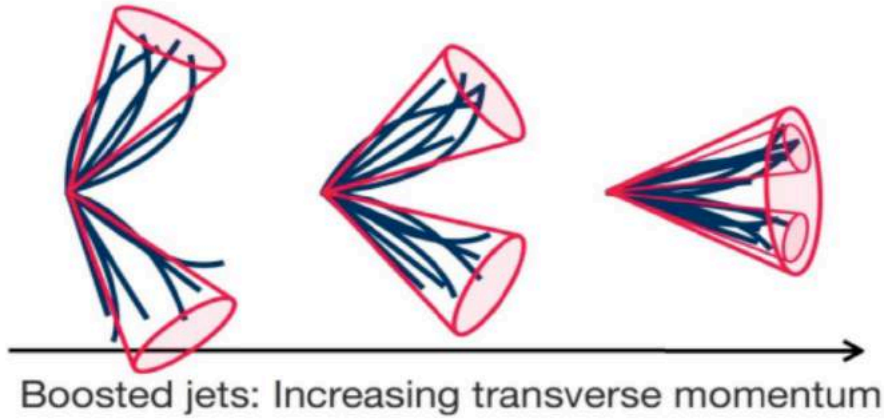
- pT(J1) = 3.13 TeV, pT(J2) = 2.98 TeV
- m(JJ) = 7.5 TeV

Di-Boson Searches

- **Many diboson decay channels and final states :**
  - $\gamma\gamma$
  - $W\gamma \rightarrow l\nu\gamma$, $qq\gamma$
  - $Z\gamma \rightarrow ll\gamma$, $qq\gamma$
  - $VV \rightarrow llll$, $ll\nu\nu$, $llqq$, $l\nu qq$, $\nu\nu qq$, $qqqq$
  - $Vh \rightarrow llbb$, $l\nu bb$, $\nu\nu bb$, $qqbb$
  - $hh \rightarrow \gamma\gamma bb$, $\gamma\gamma WW$, $bb\tau\tau$, $bbbb$



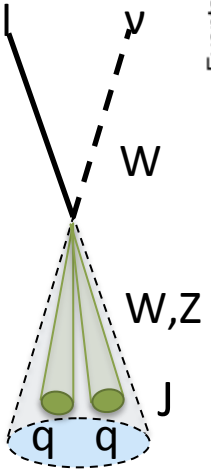
- **Wide range of boson pT :**
  - Resolved (low pT): 2 small cone jets
  - Boosted (high pT): 1 large cone jet
    - Analyze jet substructure to determine if it is due to merging of jets

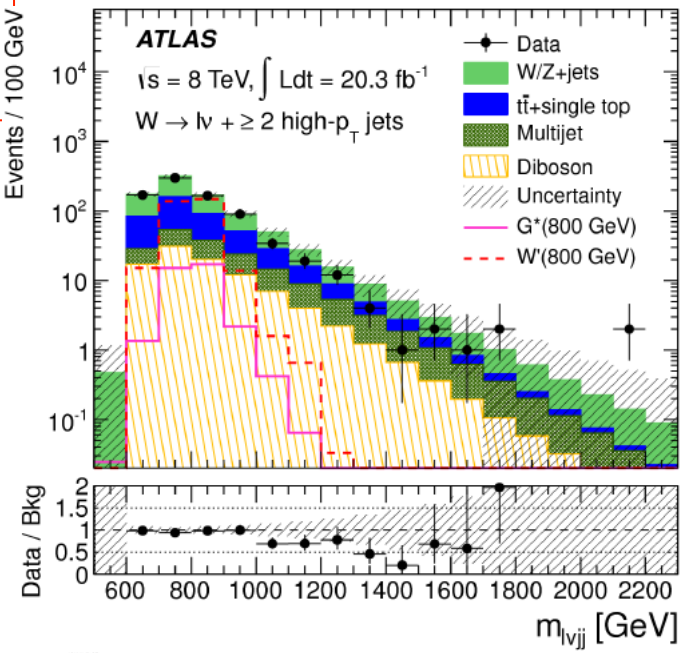


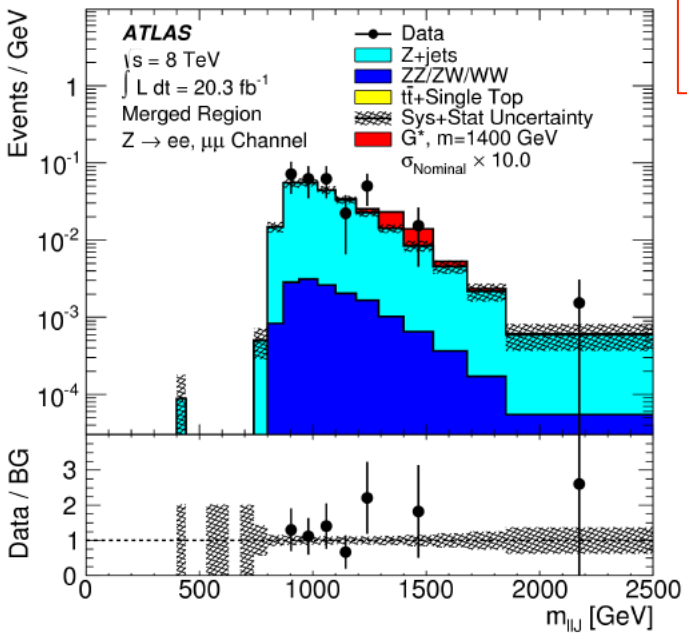
- **Diboson production predicted by many new physics models**
  - HVT (Heavy Vector Triplet), W', Z', bulk RS graviton, 2HDM, …
- If an excess is seen in one channel,
  - Measure the relative strengths in coupled channels : e.g. $Br(Z\gamma)/Br(\gamma\gamma)$
  - Understand the SU(2) structure of the underlying theory
- hh will lead to constraint of the Higgs self-coupling

Heavy Resonance in VV Final States (Run1)

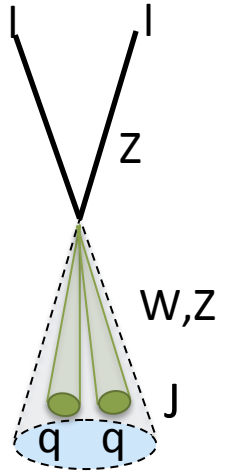
lνqq (WW/WZ)



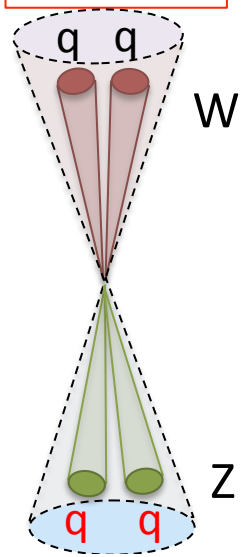


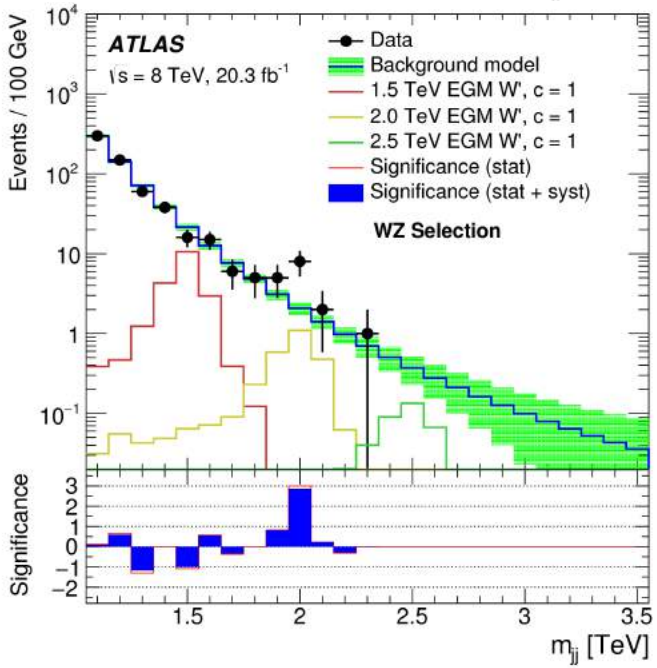


llqq (WZ/ZZ)



qqqq (WZ)





arXiv:1503:04677
arXiv:1409:6190
arXiv:1506:00962

- @ ~2TeV
- Local significance : 3.4 σ
- Consider entire mass range : 2.5σ
  - Check whether excess also in Run2 data

Heavy Resonance in VV Final States (Run2)

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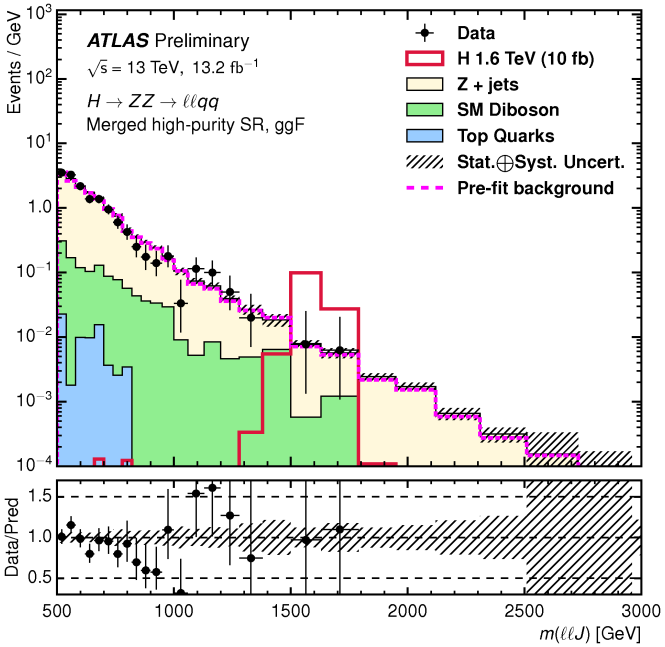
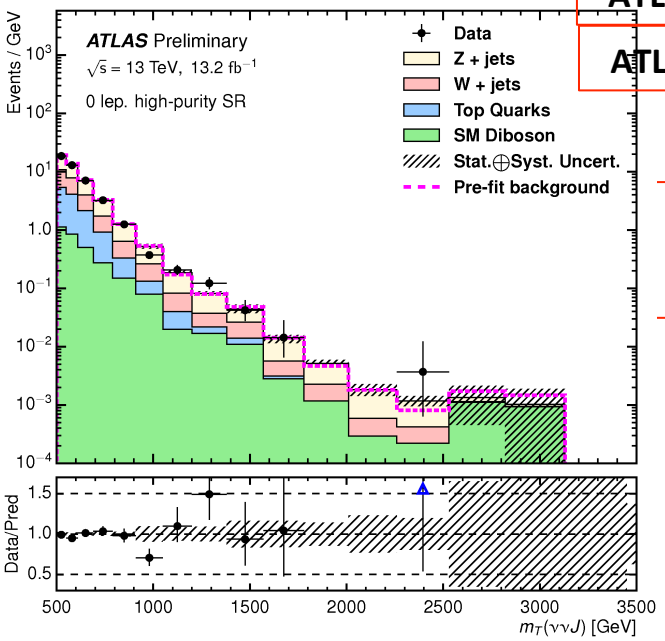
ATLAS-CONF-2016-082

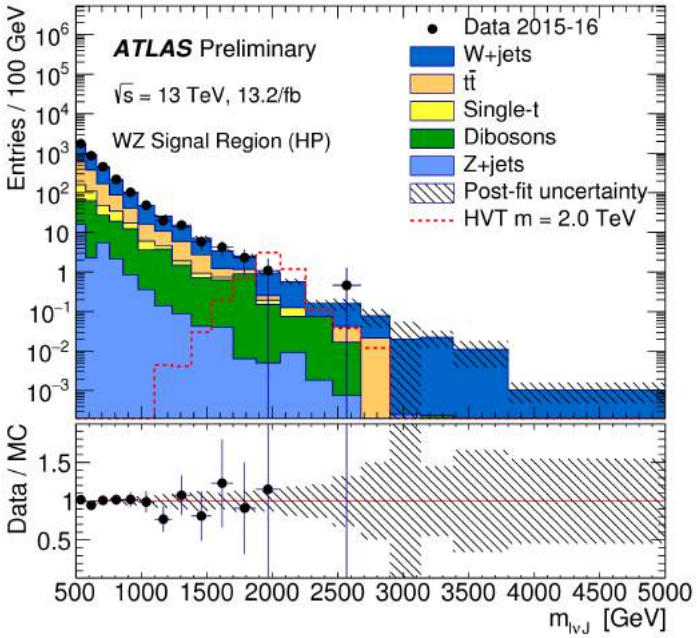
llqq (ZZ)



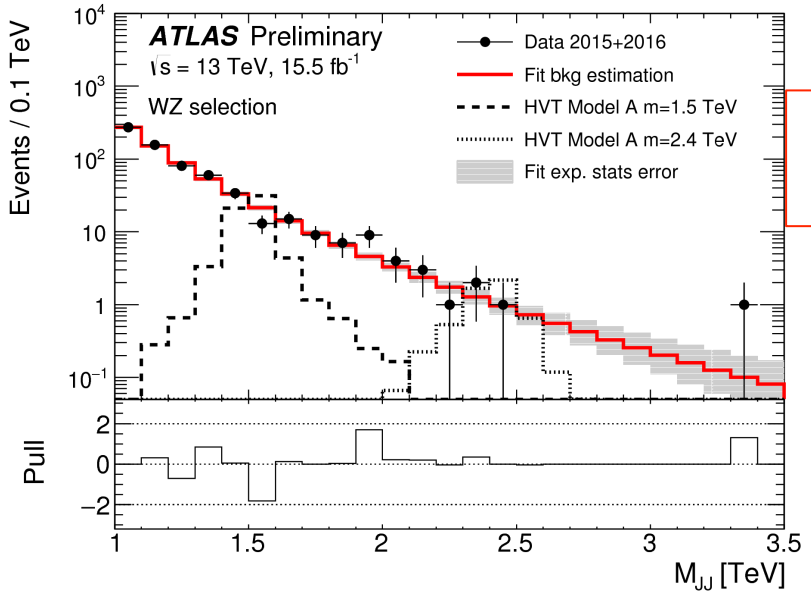
vvqq (WZ/ZZ)



lvqq (WW/ WZ)

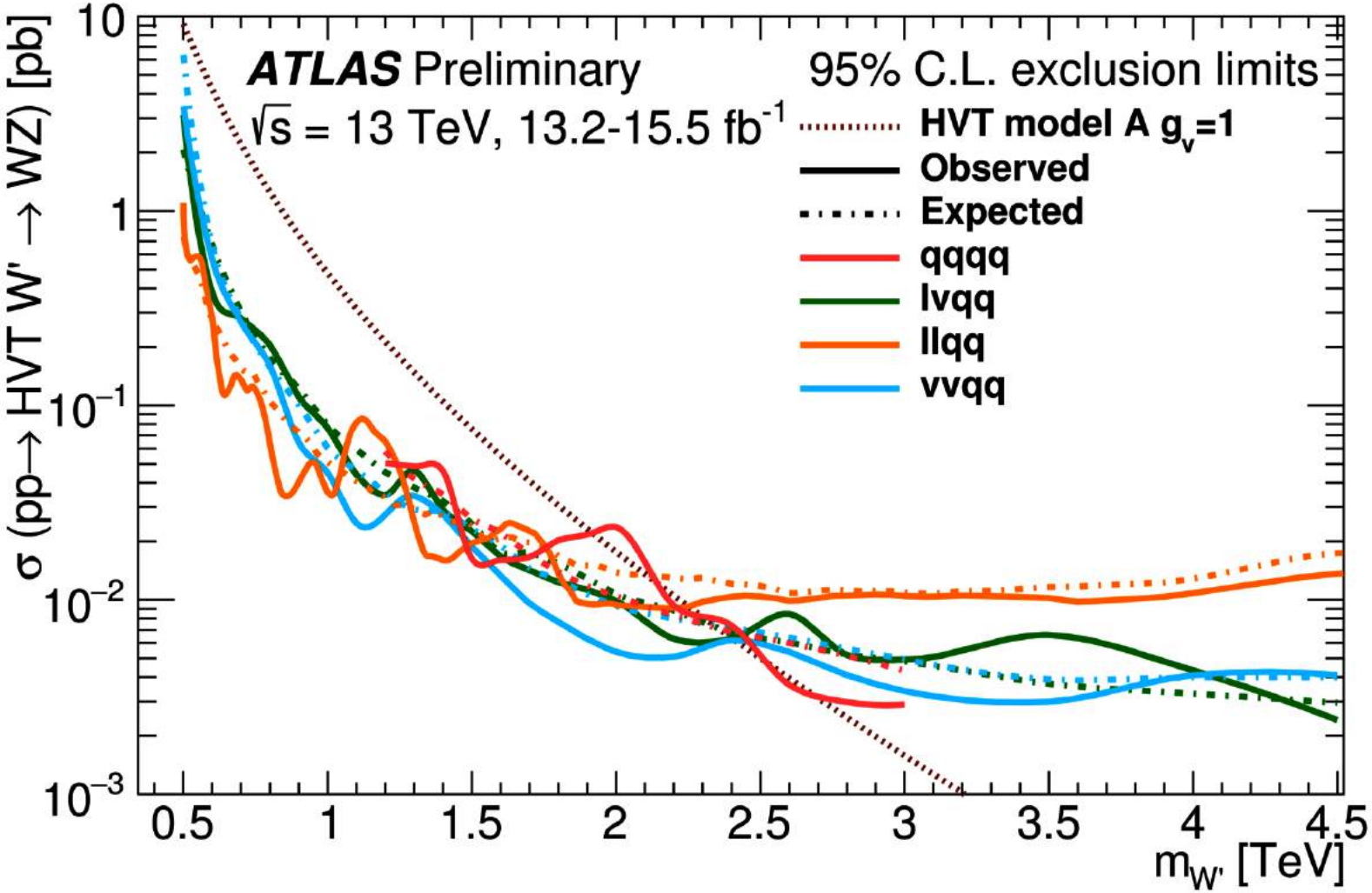


qqqq (WZ)



- Local significance : 1.9 σ (@ 1.9 TeV)

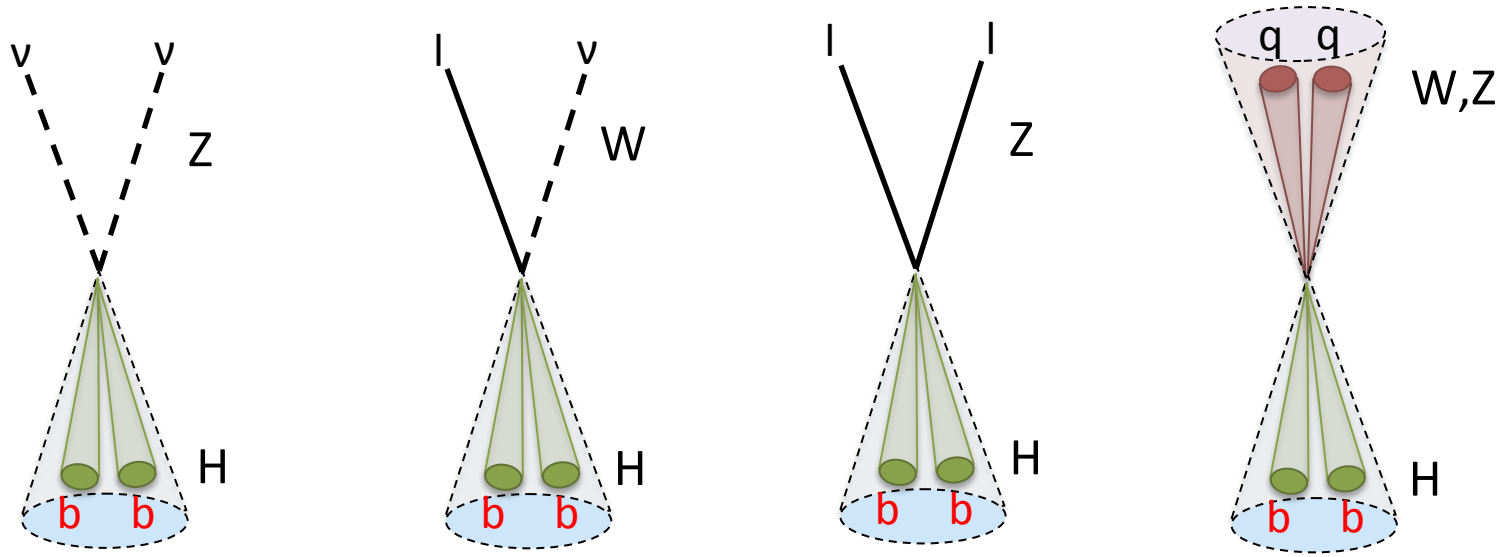
Heavy Resonance (VV) Limits (Run2)



- HVT W' mass limit up to ~2.4 TeV
- RS Graviton mass limit up to ~1.24 TeV

VH Final States (Run2)

- Search for heavy particle decays to WH, ZH
  - WH -> lvbb, qqbb
  - ZH -> llbb , vvbb, qqbb
- Mass regions :
  - Some analyses only focus in the boosted regime (>~1 TeV)
  - Other analyses combine both resolved and boosted (~200 GeV to 2 TeV)



- Interpret search results in :
  - Simplified model that incorporate Heavy Vector Triplet (HVT) , predicts W', Z'
  - Two Higgs Doublet Models (2HDM)
    - Predict a CP-odd scalar A , A->ZH

VH Final States (Run2)

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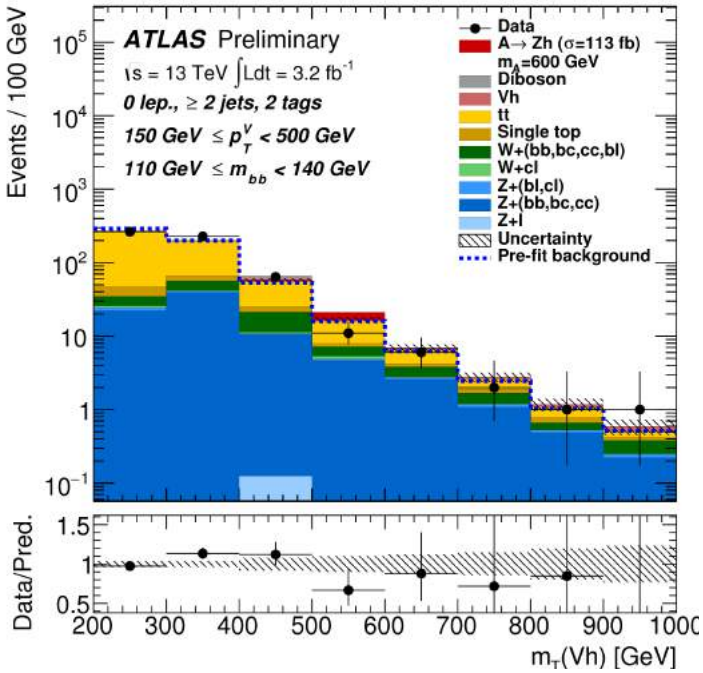
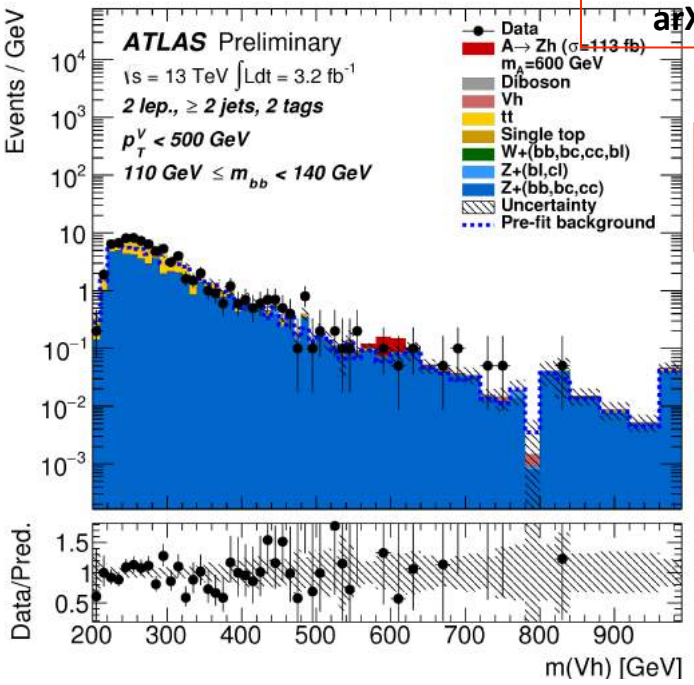
ATLAS-CONF-2016-083

arXiv:1607.05621

vvbb (resolved)

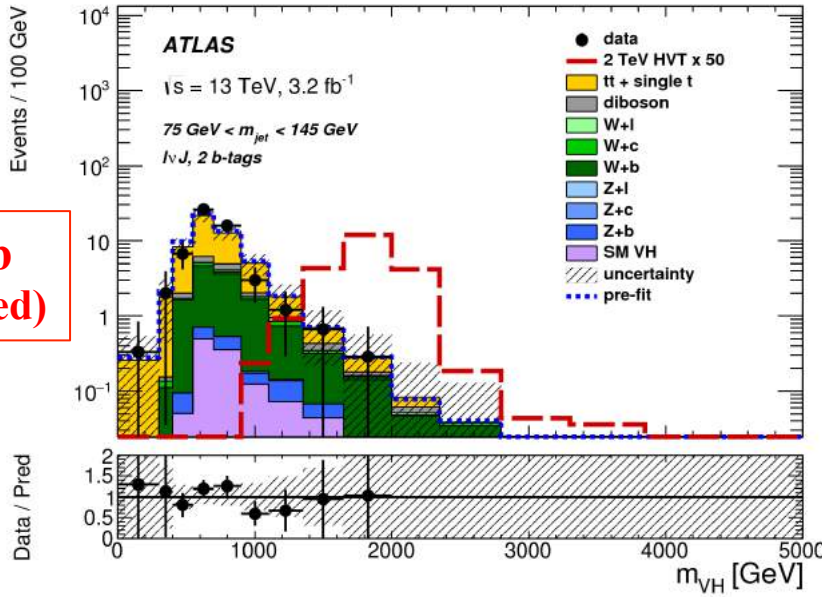


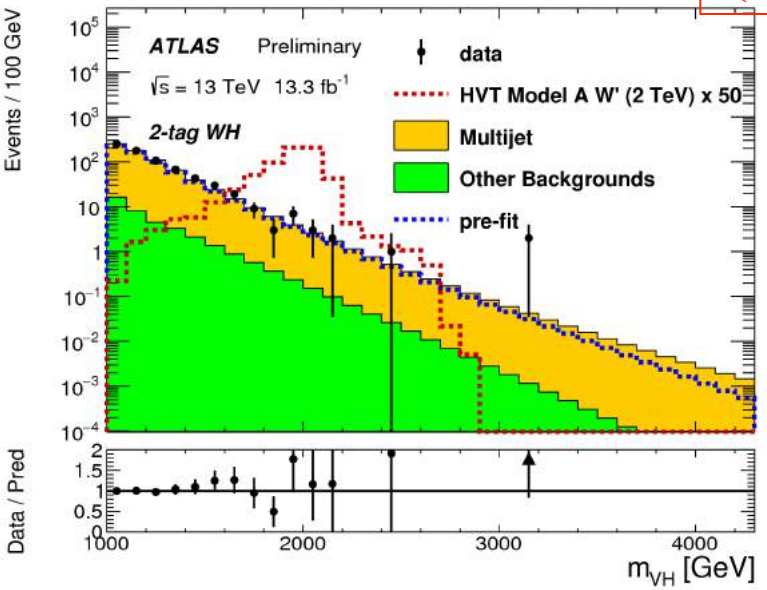
llbb (resolved)



qqbb (boosted)

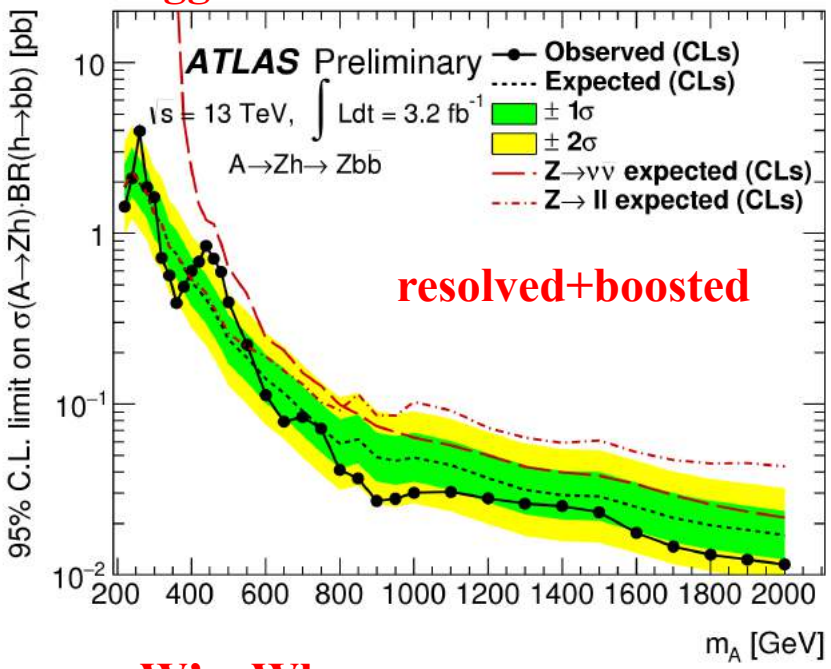
lvbb (boosted)



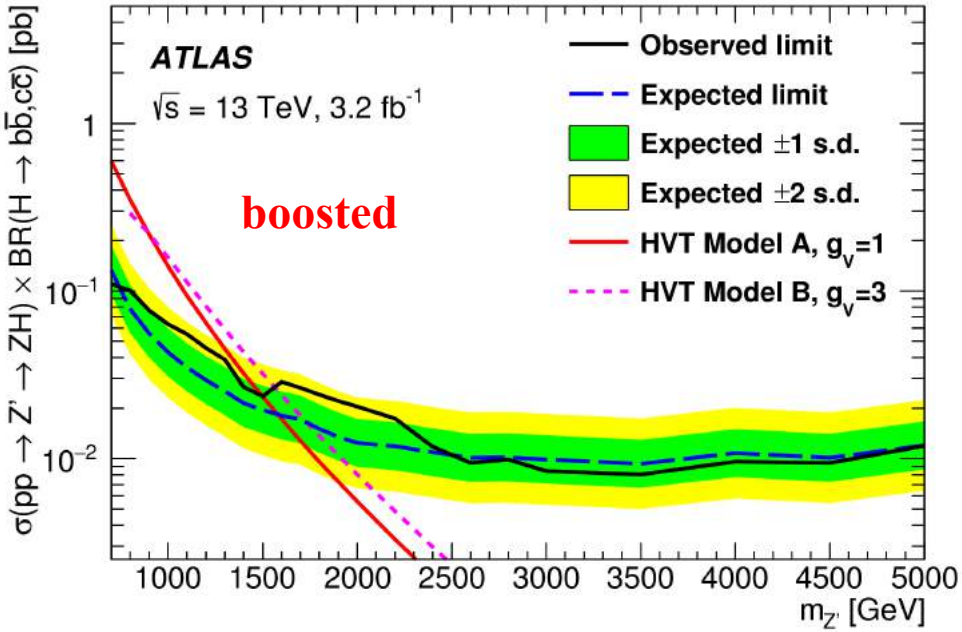


VH Final States (Run2)

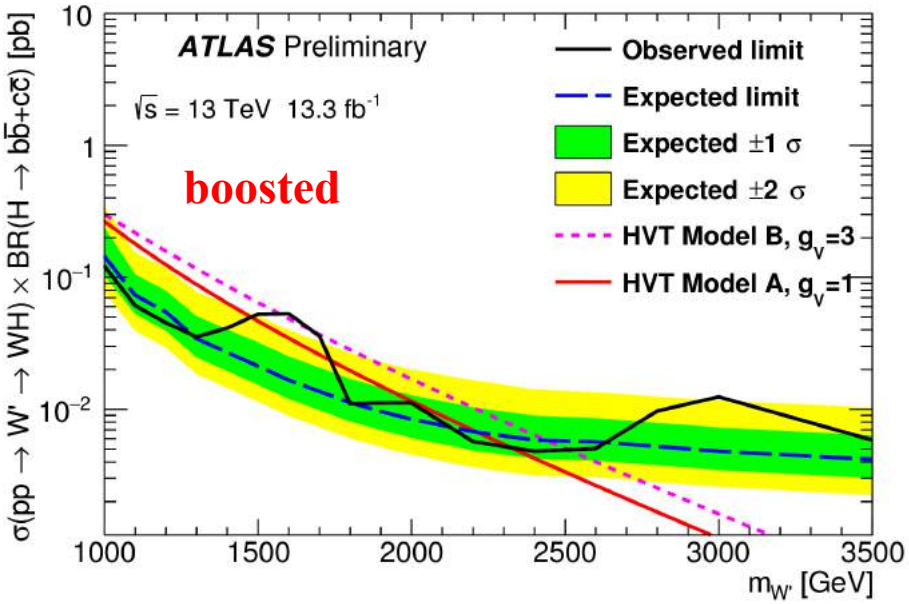
gg→A→Zh



Z'→Zh

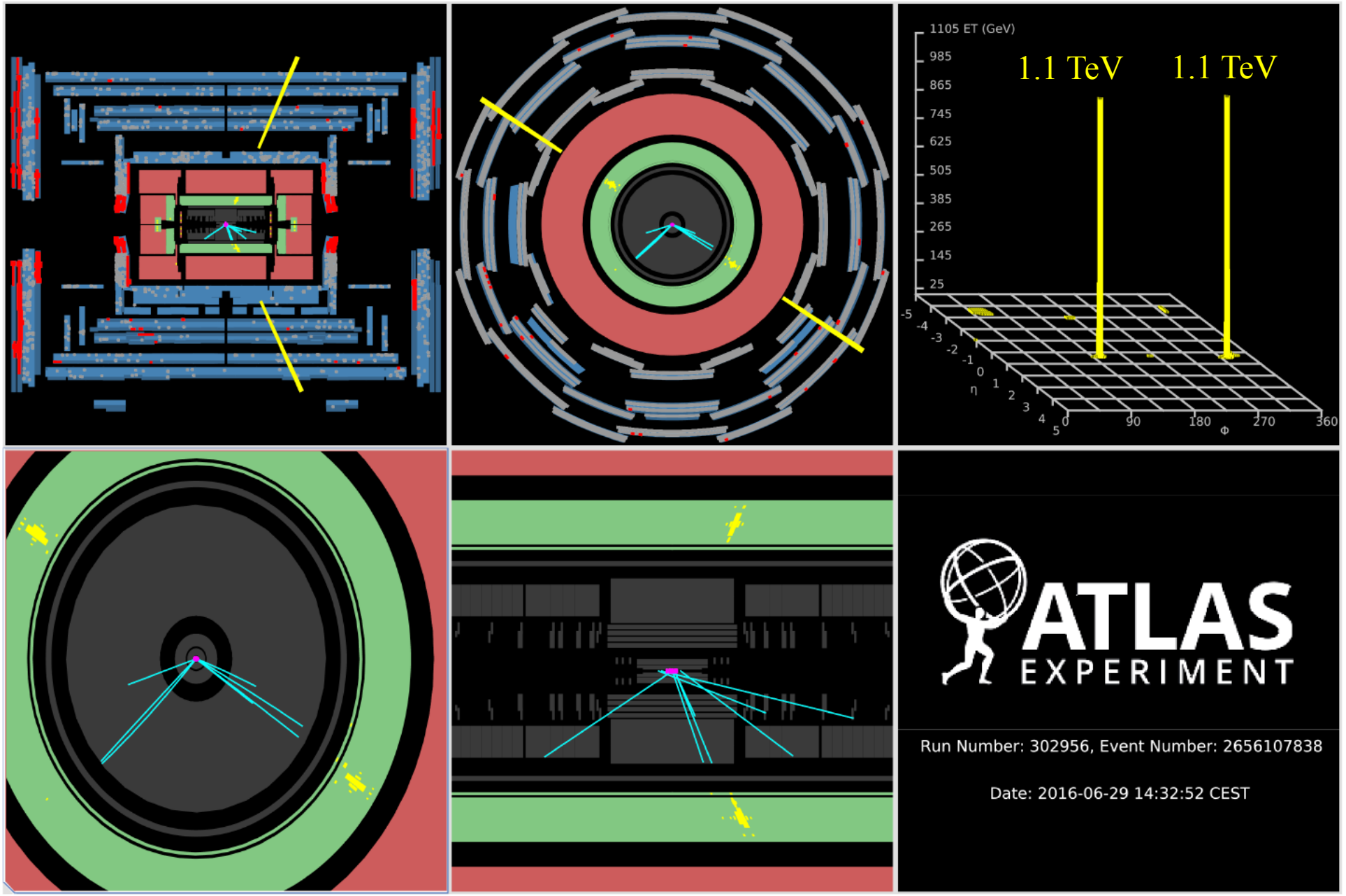


W'→Wh



- Slight excesses in Wh(qqbb)
  - at ~3TeV : 3.5σ (local), 2.5σ (global)
  - at ~1.6 TeV : 2.6σ (local)
- Should check again using the rest of 2016 data sample

Di-Photon



Highest Di-photon invariant mass event in 2016 : m(γγ)=2.2 TeV

Di-Photon

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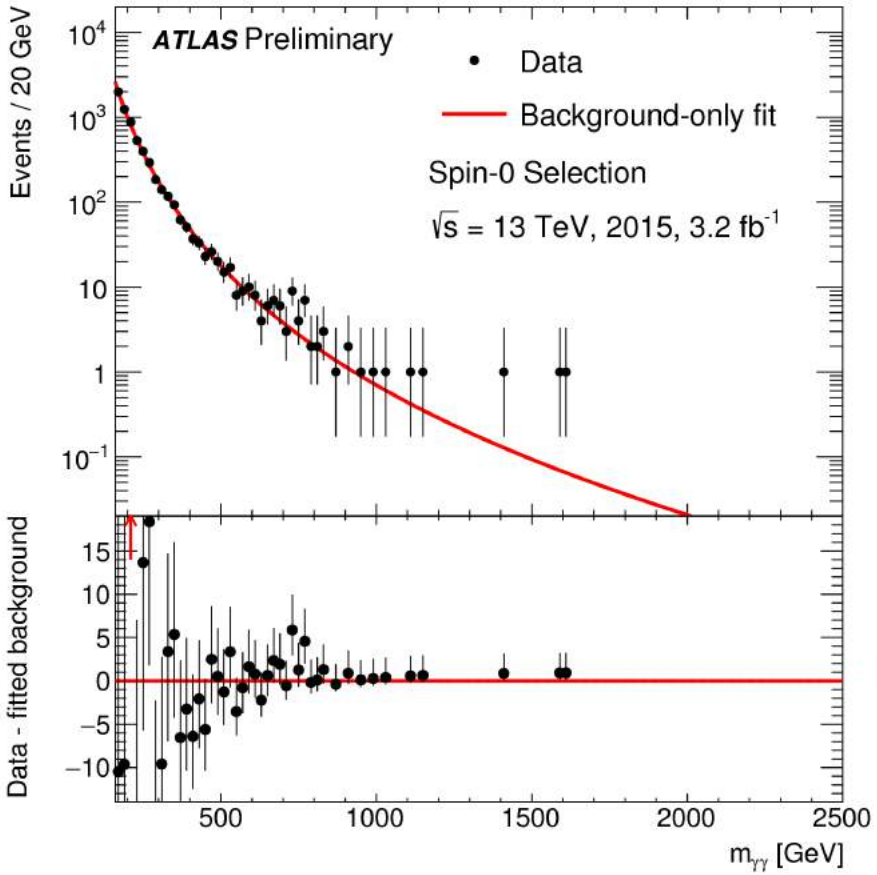
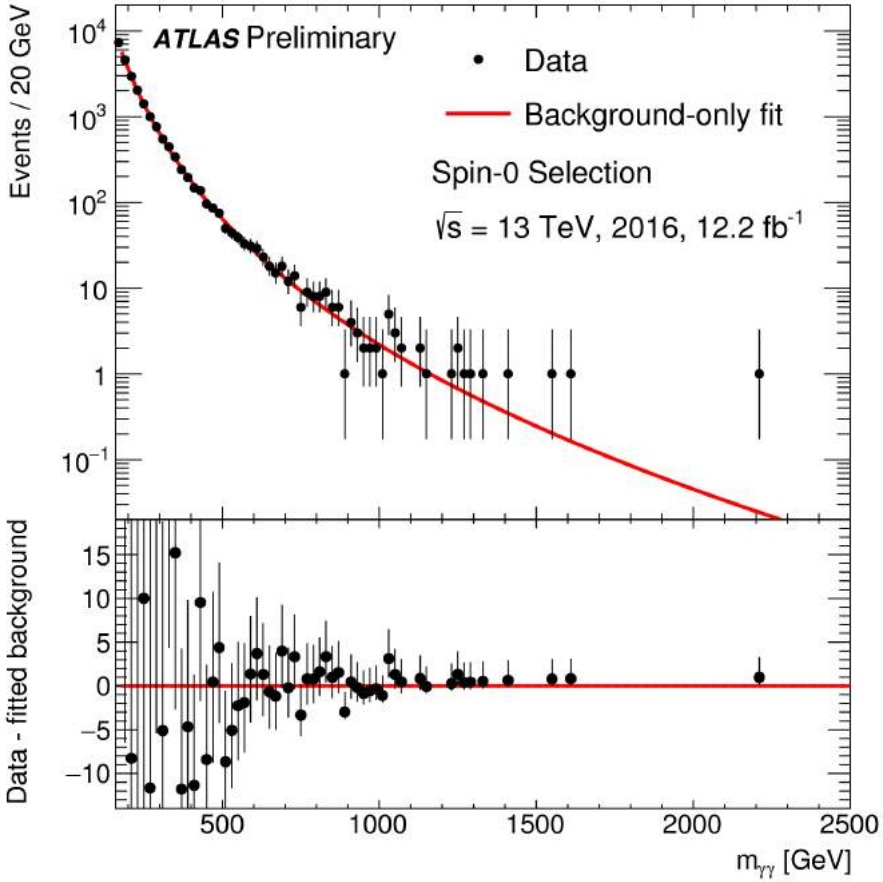
Re-processed 2015 data

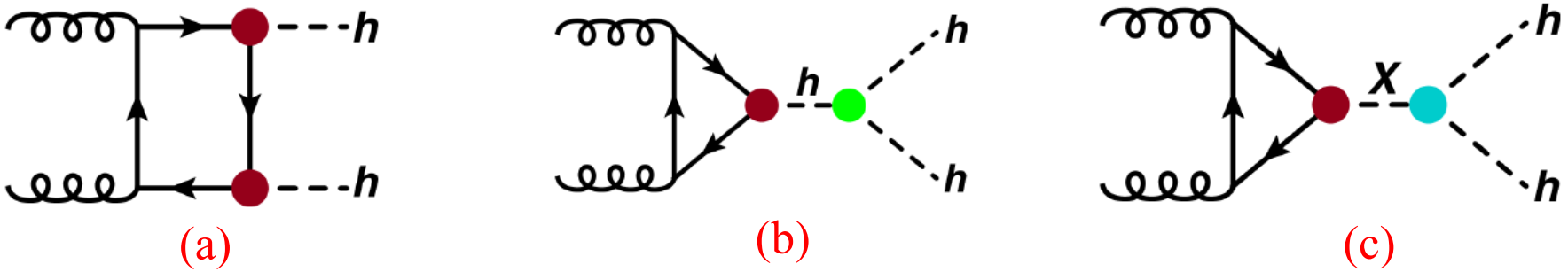


2016 data



- 2015 : excess of 3.9σ (local) at 750 GeV (relative width 6%)
  - After reprocessing : 3.4σ (local) at 730 GeV (relative width 8%)
  - One event migrate from 757 GeV to 722 GeV, one event removed due to isolation cut
- 2016 : No significant deviation from background, compatibility with 2015 ~2.7σ
- 2015+2016 : 2.3σ (local) at 710 GeV (relative with 10%)

hh



(a) (b) (c)

•SM predicts non-resonance hh pair production (a) and (b)
  •Destructive interference between them

•BSM also predict hh pair production :
  • **non-resonance** : production may be enhance by modifying the Higgs coupling constants
  • **resonance** : heavy particle (e.g. 2HDM : Heavy Higgs , Bulk RS model Graviton) can couple to 2 light SM-like Higgs boson

•ATLAS search for hh in various decay channels:
  • bbbb
  • bbττ
  • bbγγ
  • WWγγ

Decay Branching Fraction

	bb	WW	ττ	ZZ	γγ
bb	33%				
WW	25%	4.6%			
ττ	7.4%	2.5%	0.39%		
ZZ	3.1%	1.2%	0.34%	0.076%	
γγ	0.26%	0.10%	0.029%	0.013%	0.0053%

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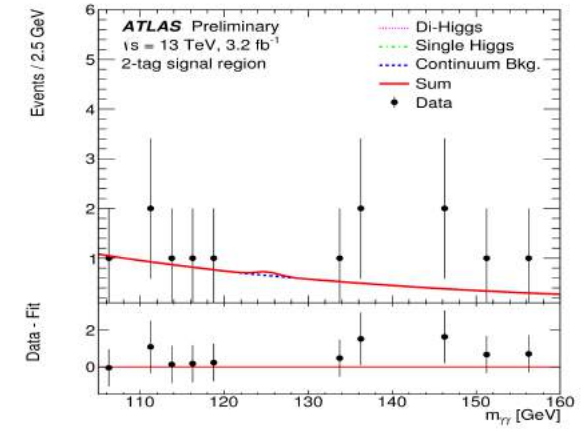
hh→bbγγ, WWγγ

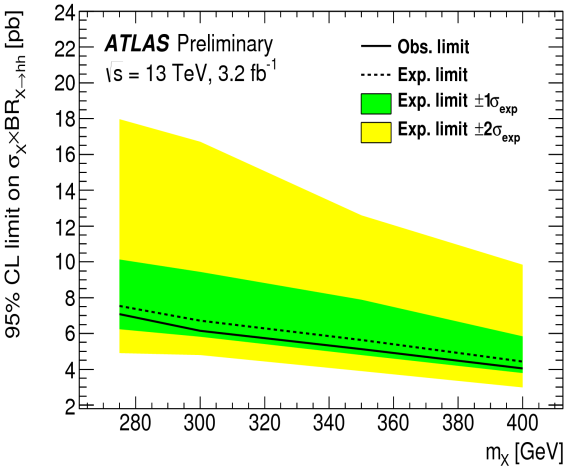
ATLAS-CONF-2016-071

bbγγ

- High BR(h→bb), clean γγ signal
- $95<m_{bb}<135$ GeV
- Non-resonance : search in $m_{\gamma\gamma}$
- Resonance : mass window cut on $m_{\gamma\gamma}$ and $m_{\gamma\gamma bb}$



- **Non-res:**
- Limit (95% CL)
- σ(hh):
  - **3.9 pb (obs)**
    - **~117xSM**
  - $5.4^{+2.8}_{-1.0}$ pb (exp)

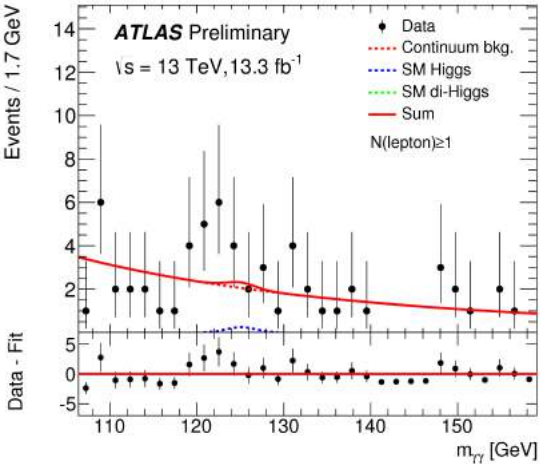


- **Resonance**:
- Limit (95% CL)
- σ(X)*BR(X→hh):
  - 7-4 pb (obs) for mX 275-400 GeV

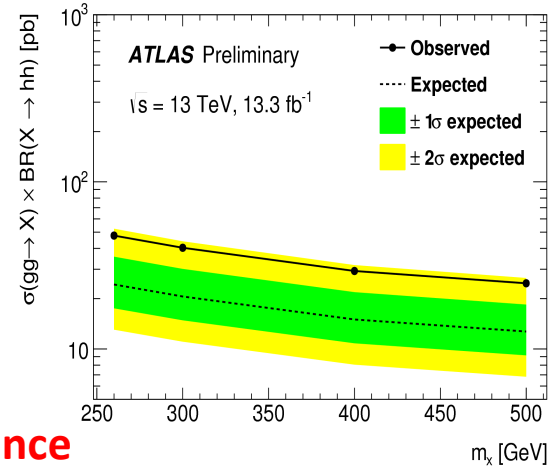
X : narrow resonance

WWγγ

- W→e/μ,ν , W→qq => γγlνjj
- Relative large BR(h→WW), clean γγ signal
- Perform non-res. & resonance search in $m_{\gamma\gamma}$ distribution



- **Non-res:**
- Slight excess ~120-125 GeV
- Limit (95% CL)
- σ(hh)
  - **25 pb (obs)**
    - **~750xSM**
  - 12.9 pb (exp)



- **Resonance**:
- Limit (95% CL)
- σ(X)*BR(X→hh):
  - 47.7-24.7 pb (obs) for mX 260-500 GeV

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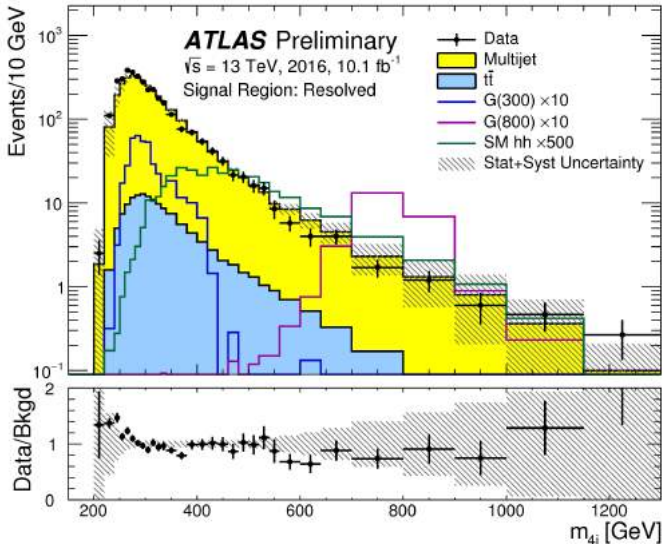
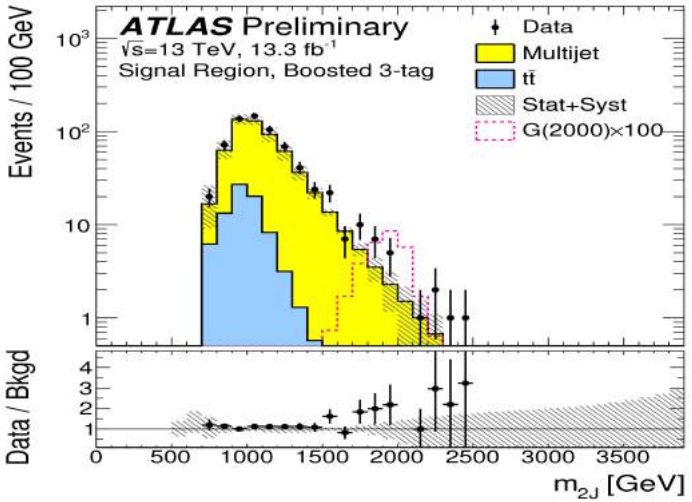
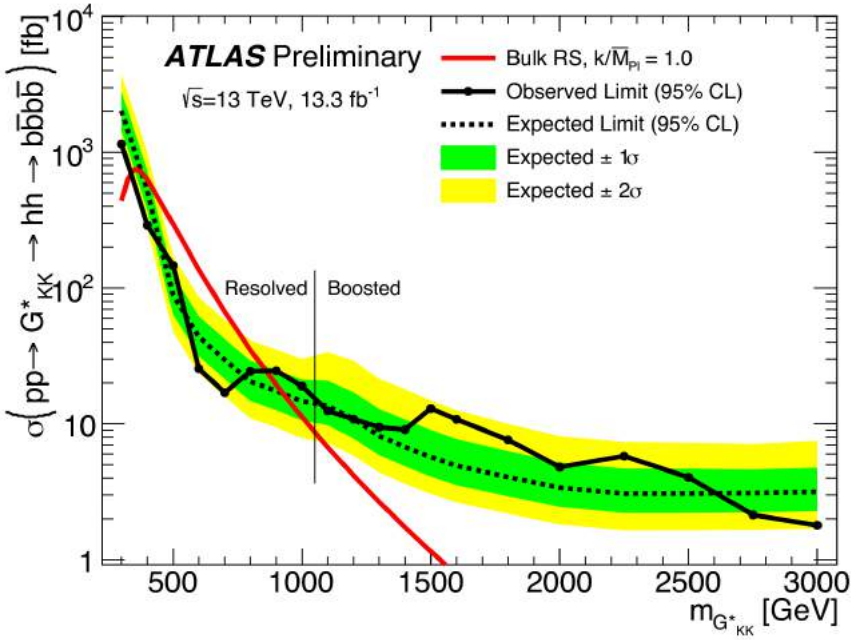
hh→bbbb

- Highest BR, but also largest background (mostly from multi-jet production)
- Search in wide mass range (~300 GeV to 3 TeV)
  - <1TeV : resolved analysis (non-resonance, resonance)
  - >1 TeV : boosted analysis (resonance)
- Need to choose the right pairs of bb to construct both h bosons





- **Limit (Non-resonance) :**
  - **σ(hh→bbbb) < 330 fb (~29xSM)**
  - $\sigma_{SM}(hh \to bbbb) = 11.3^{+0.9}_{-1.0}$ fb



- **Limit (resonance, RS graviton k/M_{pl}=1) :**
  - σ(hh→bbbb) : 1 pb → 2 fb (0.3-3 TeV) (obs.)
  - exclude mass :
    - 360-860 GeV (observed)
    - 380-910 GeV (expected)

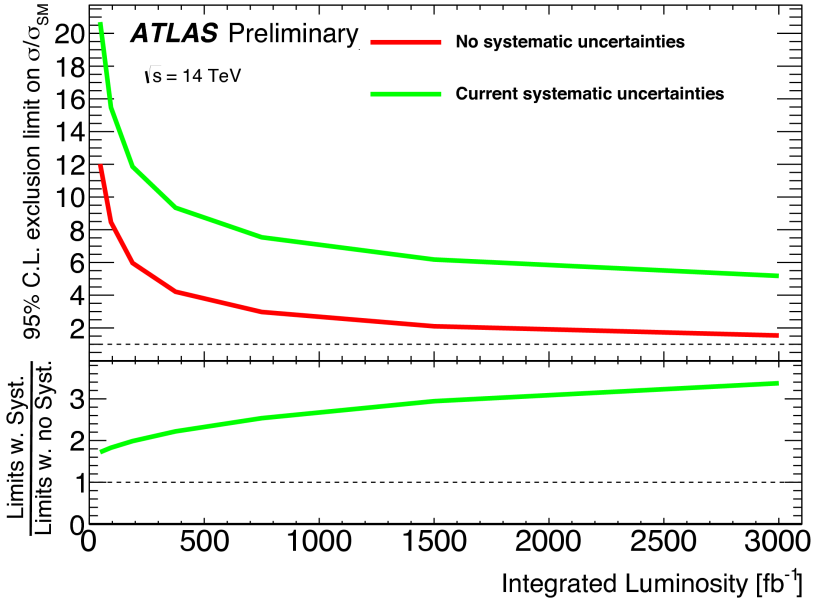
hh (HL-LHC)

•Expect to collect ~3000 fb^{-1} at $\sqrt{s}$=14 TeV during the high luminosity LHC run
•Estimated the sensitivities of the non-resonance hh search :

• bbγγ (ATL-PHYS-PUB-2014-019) :
  •Expected signal significance ~1.3σ (w/o systematic)

• bbττ (ATL-PHYS-PUB-2015-046) :
  •Expected upper limit on cross section (95% CL) ~4.3 x SM

• bbbb (ATL-PHYS-PUB-2016-024) :
  •Expected upper limit on cross section (95% CL) :
  • ~1.5xSM (w/o systematic)
  • ~5.2xSM (w/ systematic)



Summary

- ATLAS is re-establishing Higgs discovery in Run2 and is performing more measurements and searches in other channels

- Partial analyses of 2016 data samples have already reached or exceed the Run1 search sensitivities for new physics

- Unfortunately some exciting hints from Run1 and 2015 data samples are not confirmed in 2016

- Still have another ~20 fb^{-1} of 2016 data sample to analyze

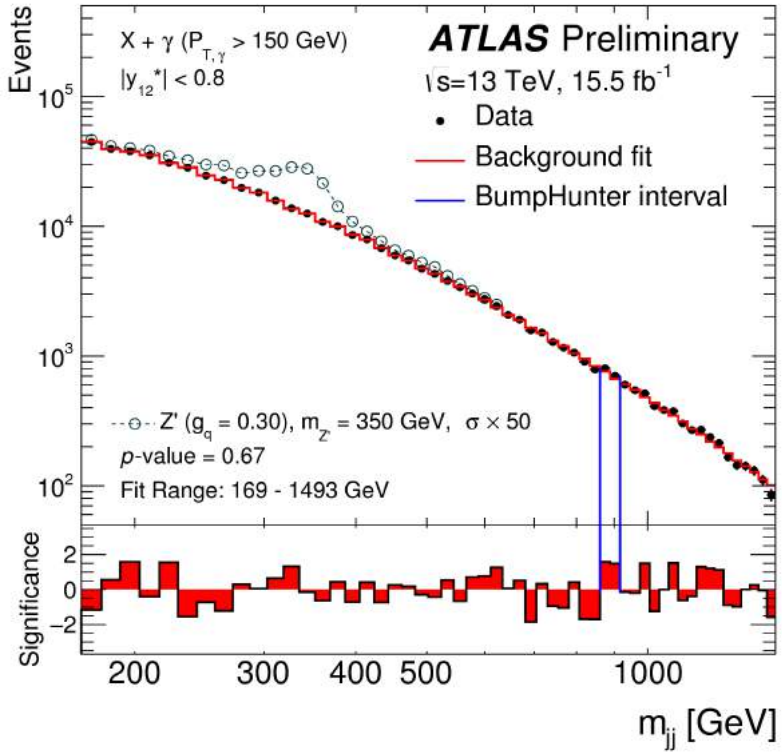
- Stay tuned for more new results in the coming few months.

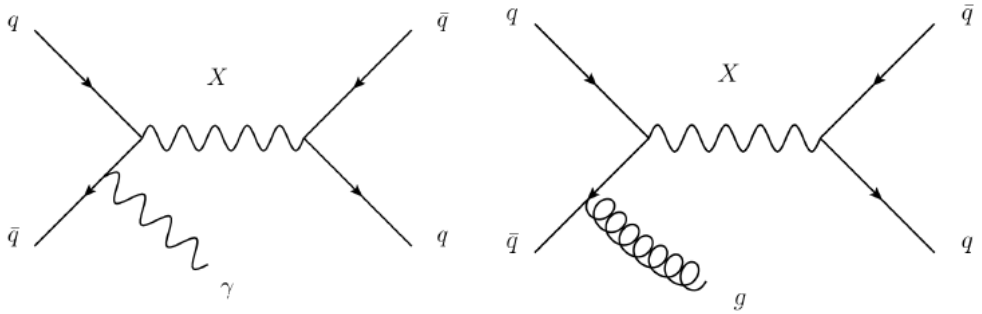
Back-Up

Di-Jet (lower mass)

- Rates too high to trigger on softer jets to search in lower mass region
- Explore low m_{JJ} by triggering on ISR objects (γ or g)

JJ + γ/J

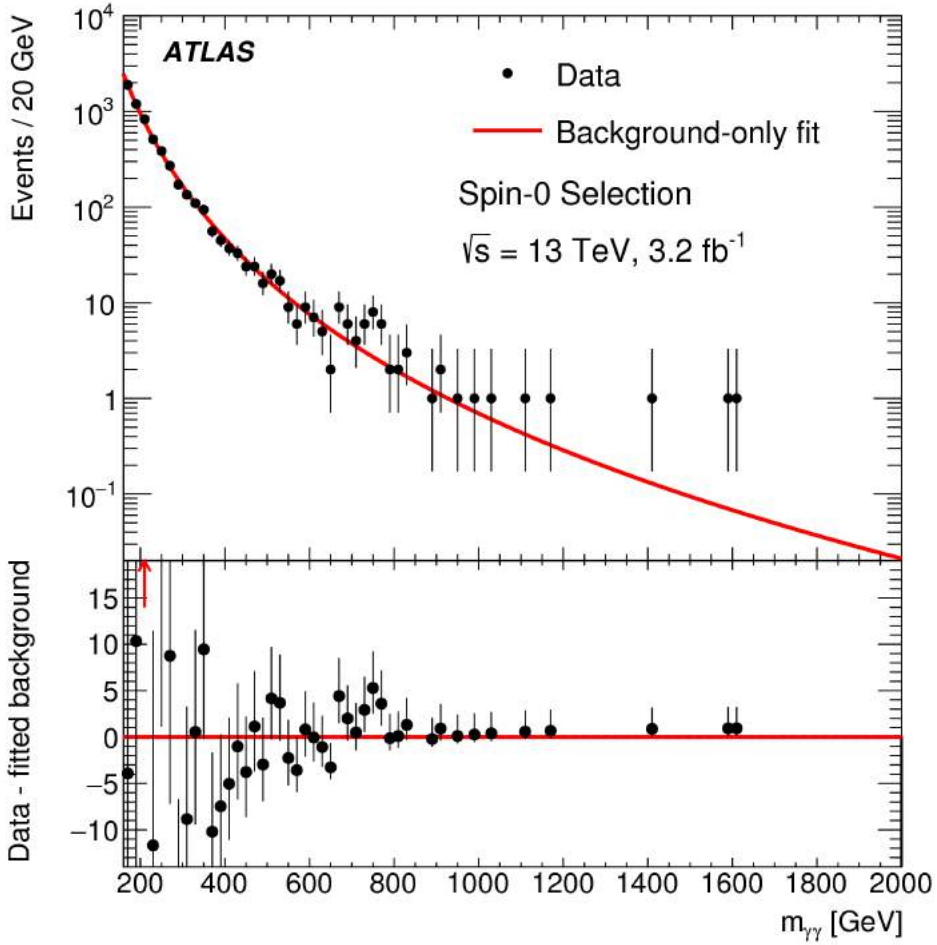




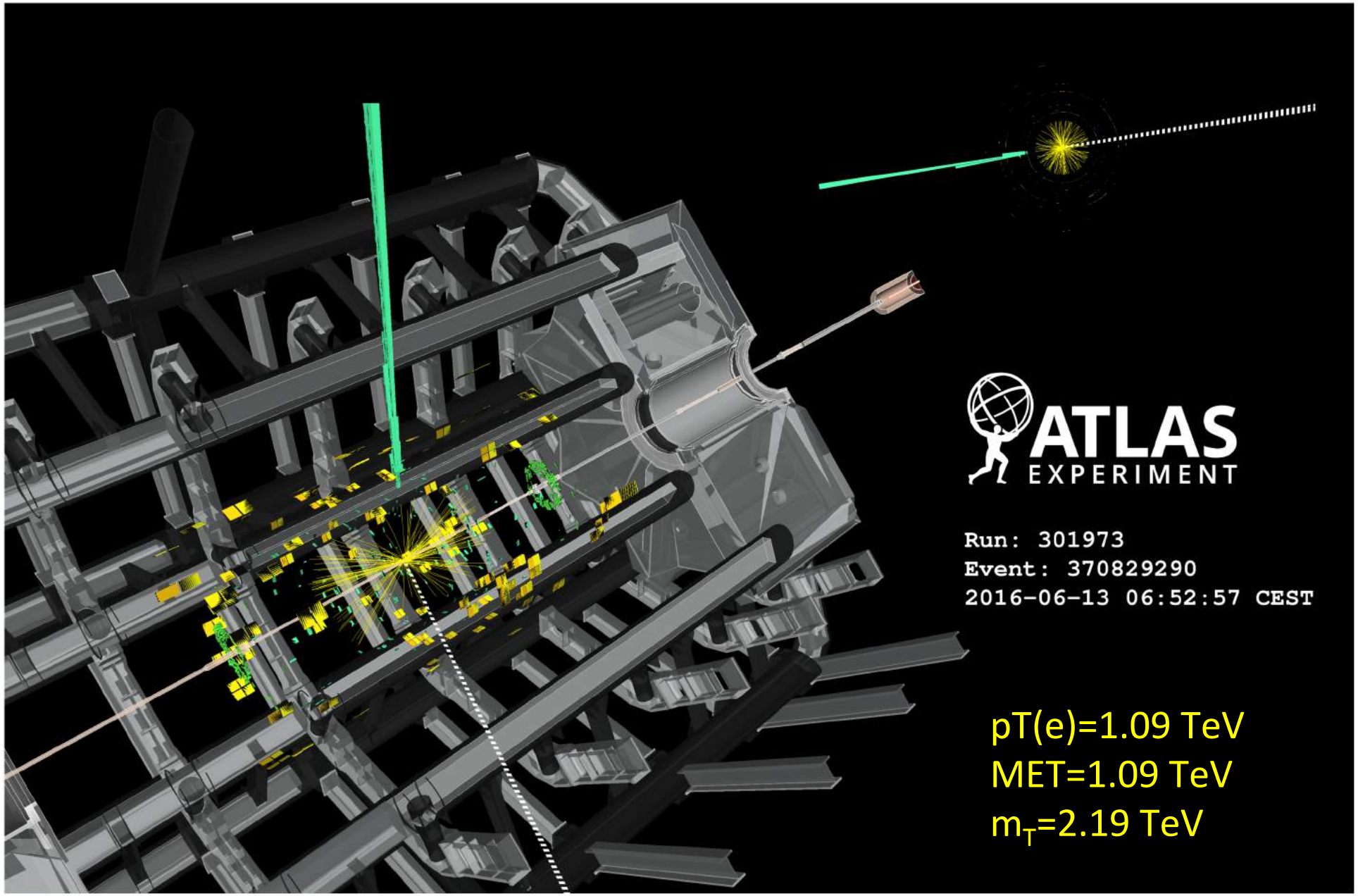
- Interpret results in lepto-phobic axial –vector Z' model
- Set limit in g_q vs m(Z')

ATLAS-CONF-2016-070

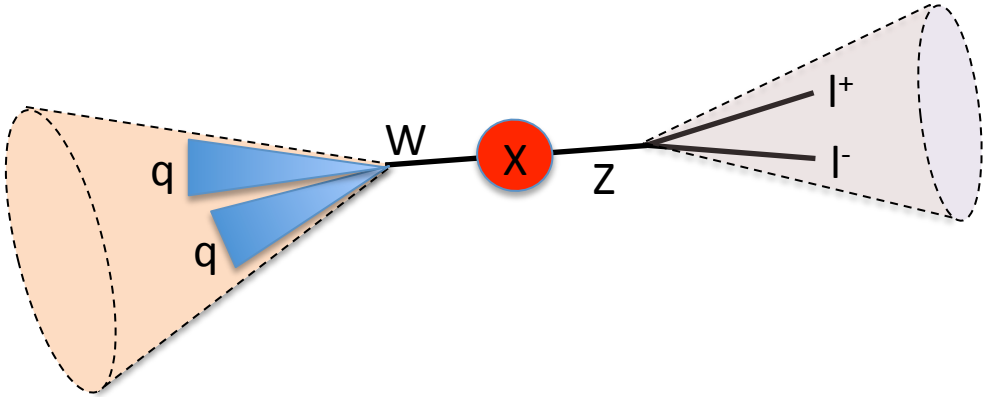
Di-Photon (Dec 2015)



Highest m_T(e,ν) Event

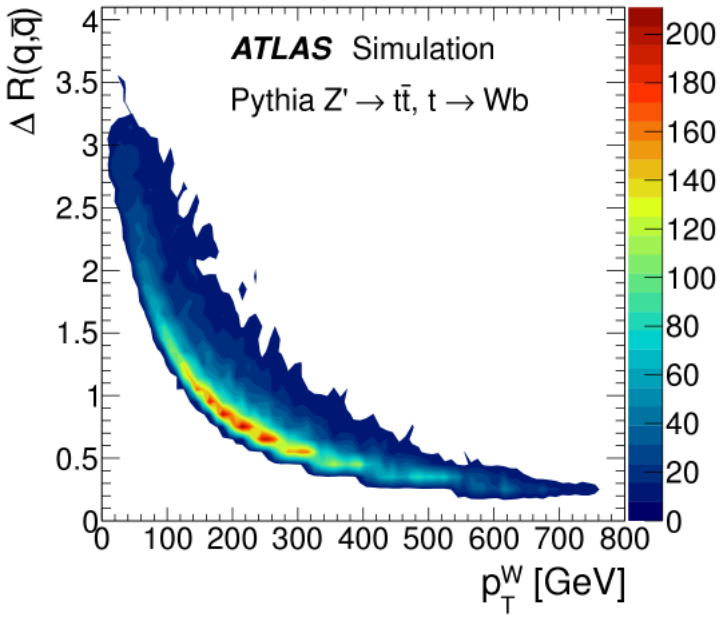


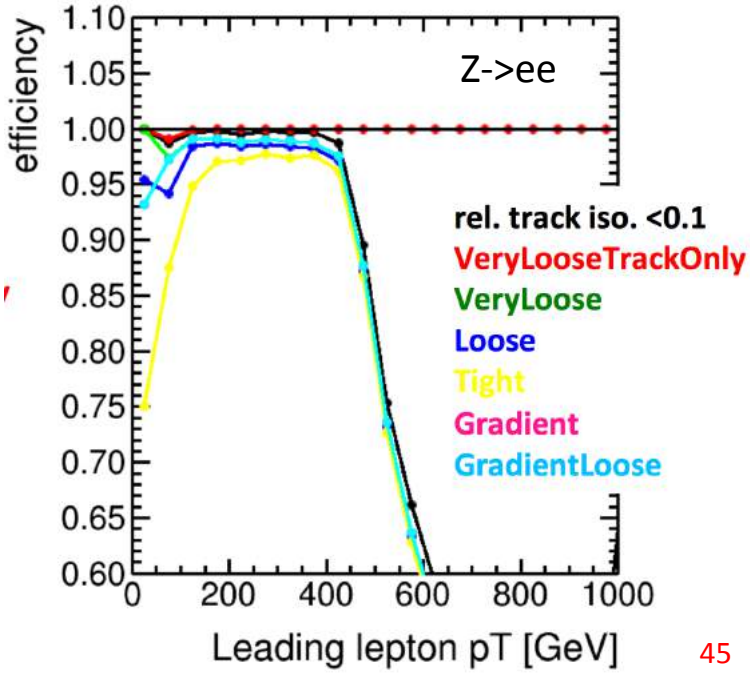
Experimental Techniques in Boosted Region



- $\Delta R \sim 2m/pT$
- Decay products from highly boosted objects:
  - Get very close
  - Can affect reconstruction

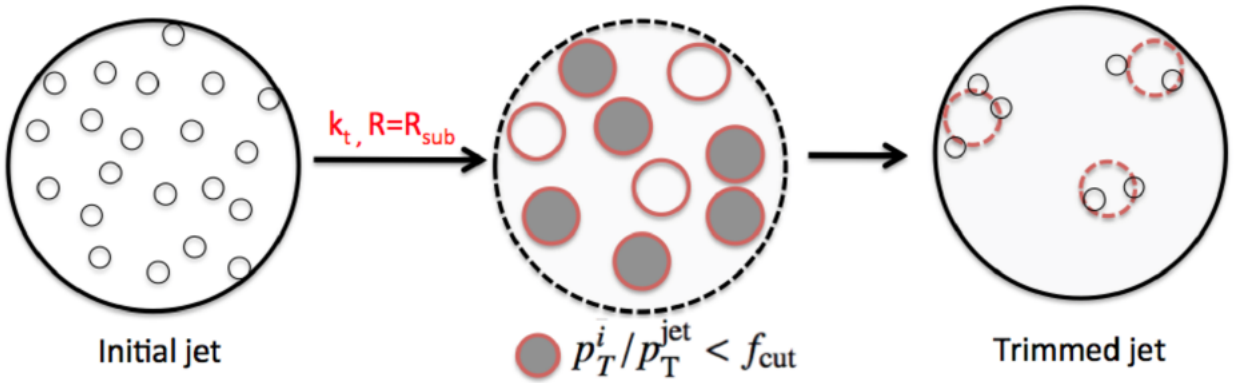
- **Leptons :**
- Identification requires isolation to reduce mis-identification (e.g. jet fakes as electron)
- Efficiency of reconstructing lepton pair from Z decay can degrade quickly for highly boosted Z boson due to isolation cut
- Design looser isolation requirement to re-gain efficiency at high pT



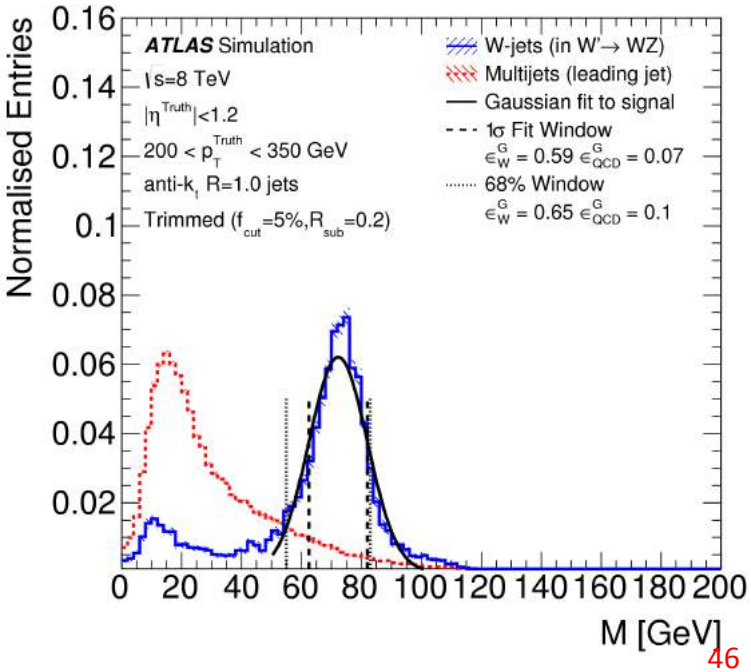


Large-R jets

- Jets from hadronic decay of a boosted W or Z can be merged
- To increase the reconstruction efficiency, instead of attempting to directly resolve the individual decay products, combine them into a single object and inspect its properties



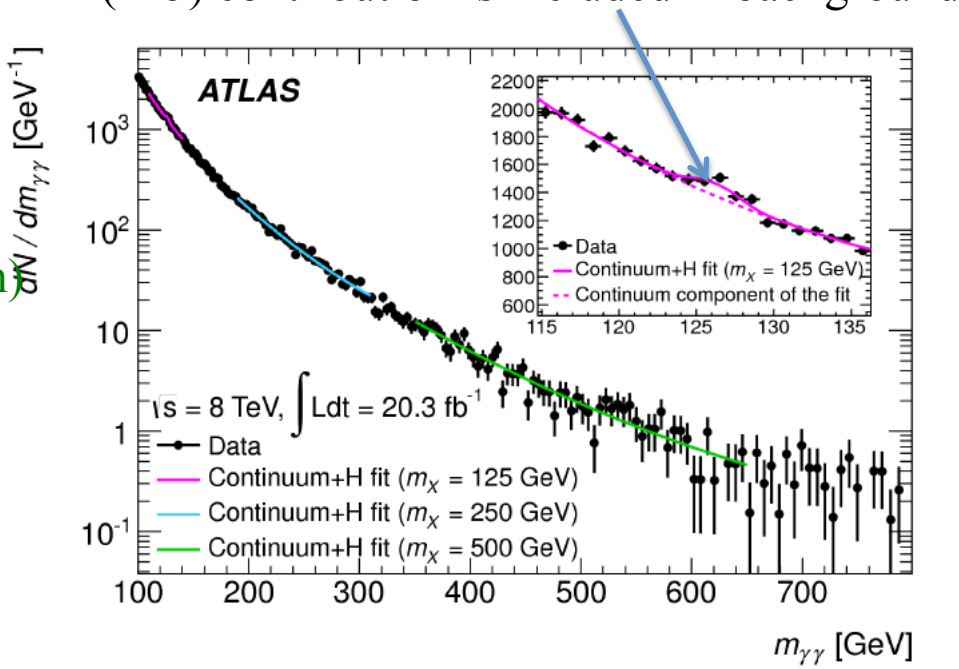
- Energy depositions in calorimeter are grouped into topological clusters, which are used to form large-R jet (R=1.0, anti-kt)
- Trim the large-R jets by forming smaller sub-jets (R_{sub}=0.2, anti-kt)
- Remove sub-jets whose pT fraction is less than f_{cut}=5% of large-R jet (suppress pile-up)
- Trimmed jet pt, mass from sub-jets



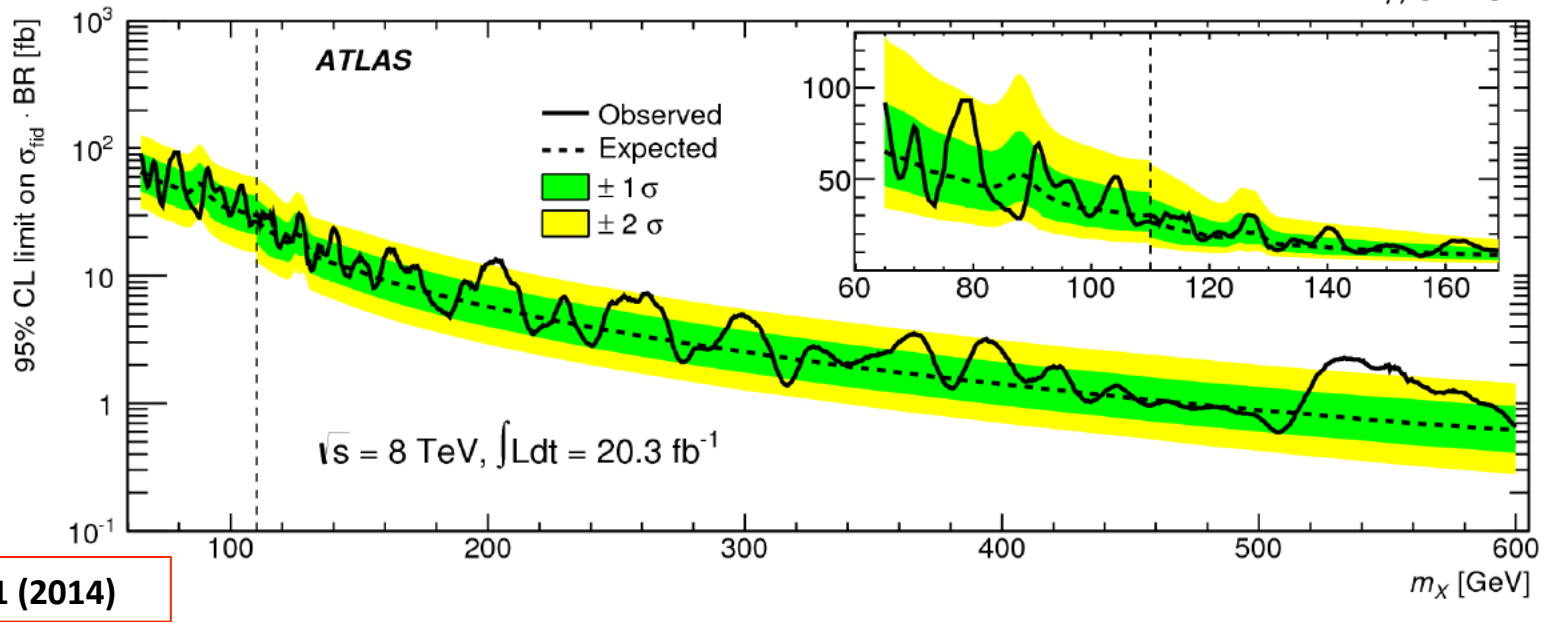
Heavy Resonance in γγ Final States (Run1)

- Select events with two isolated photons
- Main background :
  - di-photon continuum
  - γ+jet , di-jet (jet fakes photon)
  - Drell-Yan (γ^*/Z) (electron fakes photon)
- Search for a mass peak over a continuous $m_{\gamma\gamma}$ spectrum

h(125) contribution is included in background



- ATLAS : Search for narrow resonance (Γ_X=0.09 GeV + 0.01m_X)



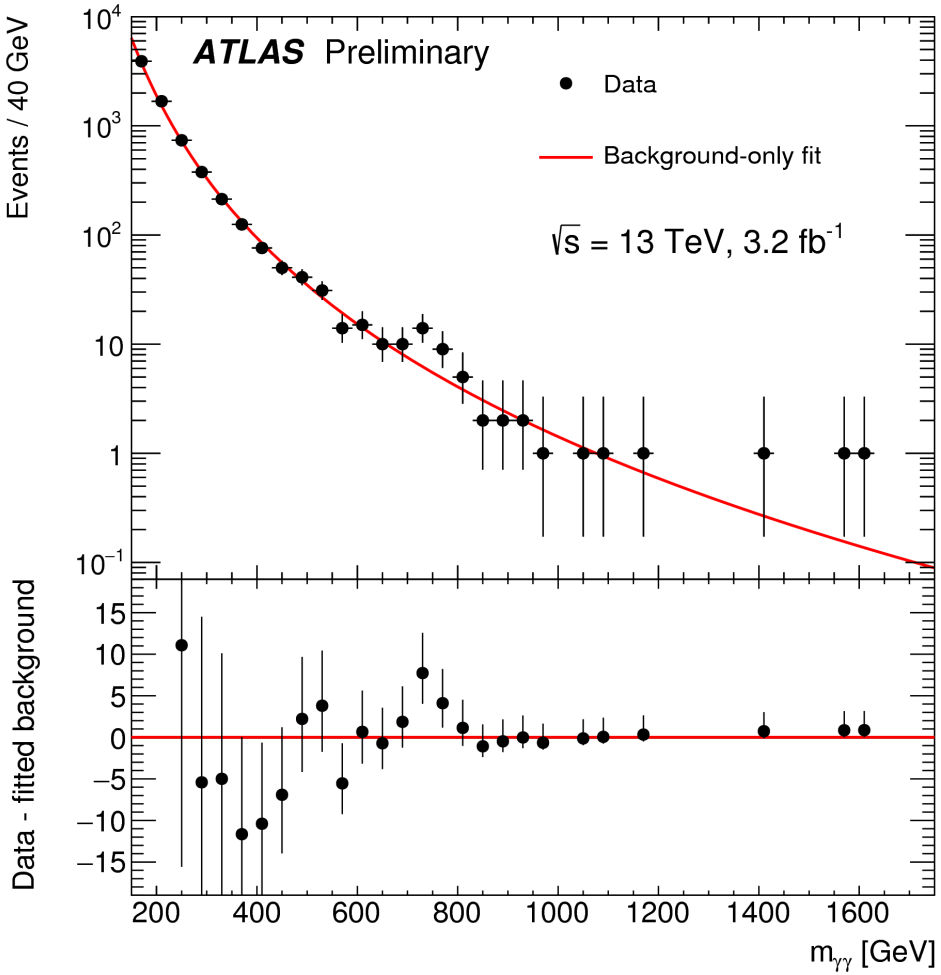
PRL 113, 171801 (2014)

Heavy Resonance in γγ Final States (Run2)

- Repeat similar search
- Two isolated photons: Et>0.4×$m_{\gamma\gamma}$ 0.3× $m_{\gamma\gamma}$
- γ ID eff = ~85% (@ 25 GeV) – 95% (@200 GeV)
- Signal Efficiency (ggF) ~30-40%
- Diphoton purity ~ 90%
- Search in range 200<mγγ<2000 GeV
  - σ($m_{\gamma\gamma}$)~2 GeV @ $m_{\gamma\gamma}$=200 GeV
  - σ($m_{\gamma\gamma}$)~13 GeV @ $m_{\gamma\gamma}$=2000 GeV

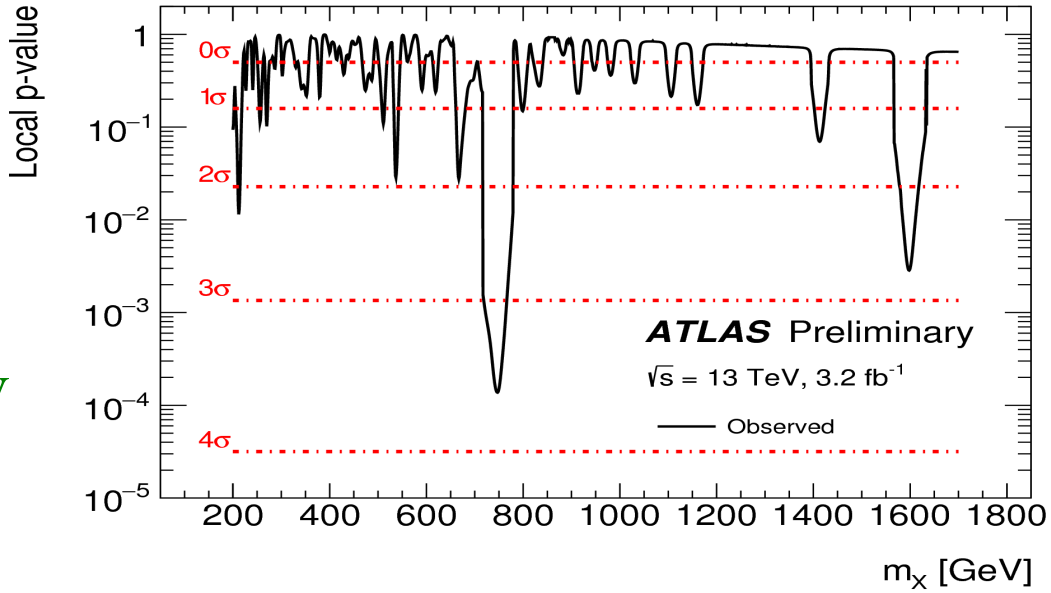
- Smooth functional form to model background
  - Validate function on simulated background samples (γγ, γ+jets => Sherpa)
- Dominant systematic uncertainty :
  - Background fit : ≤50-20% of the total signal yield uncertainty

ATLAS-CONF-2015-081



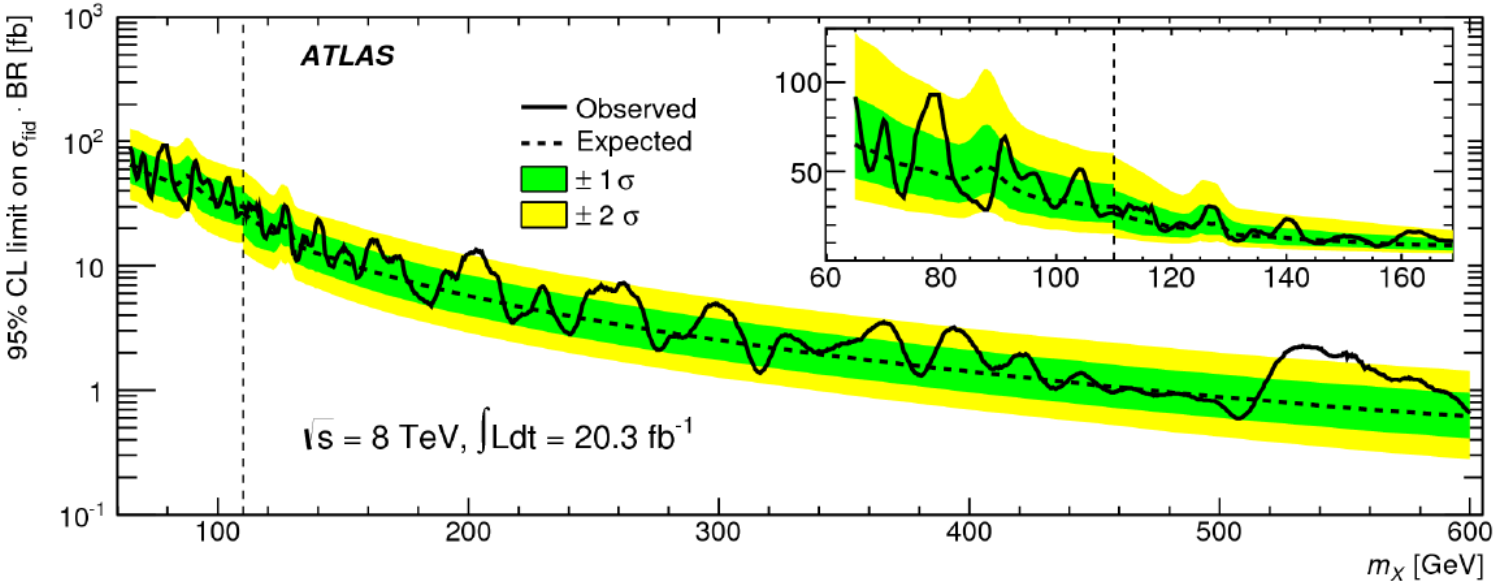
Heavy Resonance in γγ Final States (Run2)

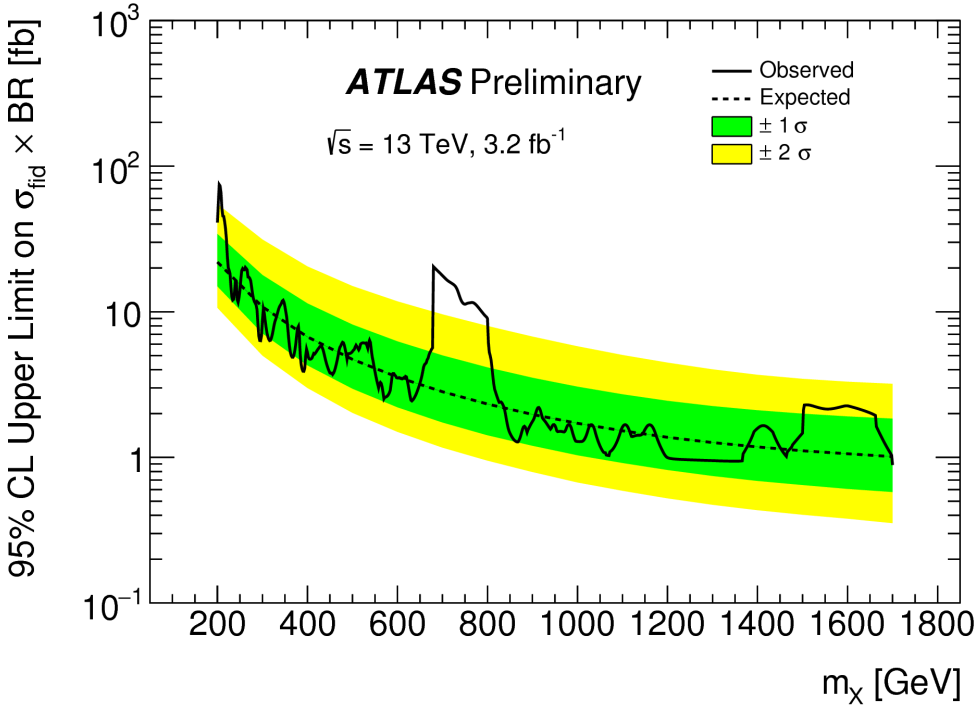
- Assume narrow width signal :
  - Local excess (@ 750 GeV) = 3.6σ
  - Global excess (0.2-2TeV) = 2.0σ
- Observed width is broader than experimental resolution
  - Expt. width ($m_{\gamma\gamma}$=750 GeV)=6 GeV
  - Observed width = ~45 GeV (~6%)
- Assume large width signal (6%) :
  - Local excess = 3.9σ
  - Global excess (0.2-2TeV) = 2.3σ



- Run 1 paper only up to to 600 GeV
- Extended the invariant mass beyond 600 GeV using similar background modeling technique as Run2
- Compare the measured cross sections
  - Assuming s-ch gluon initiated process
  - Scaled to same center-of-mass energy
- Compatibility between 8 and 13 TeV at mX=750 GeV:
  - Narrow width : 2.2 σ
  - Large width (6%) : 1.4 σ

Heavy Resonance in γγ Final States (Run2)



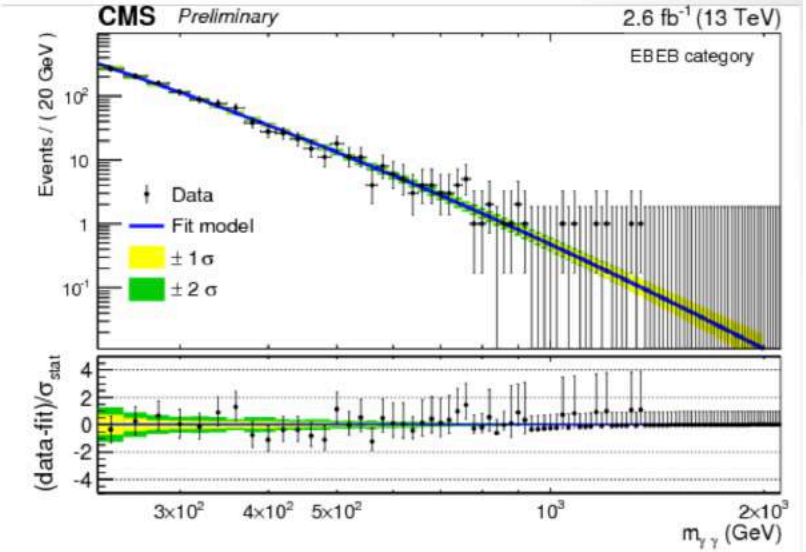


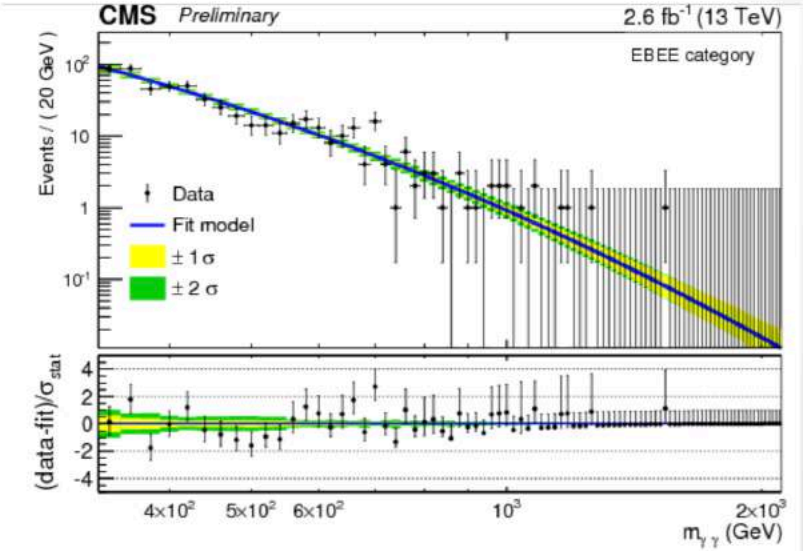
CMS Diphoton (Run2)

Search for diphoton resonances

EXO-15-004

- Two categories: barrel-barrel (EBEB), barrel-endcap (EBEE)
- $p_T(\gamma) > 75$ GeV, $I_{ch} < 5$ GeV (in 0.3 cone around photon direction)
- Efficiency, scale and resolution calibrated on $Z \rightarrow ee$ and high-mass DY events
- Search for RS graviton with three assumptions on coupling: $\tilde{\kappa} = 0.01$ (narrow), 0.1, 0.2 (wide)
- **Blind analysis, no changes have been made to the analysis since unblinding data in the signal region**





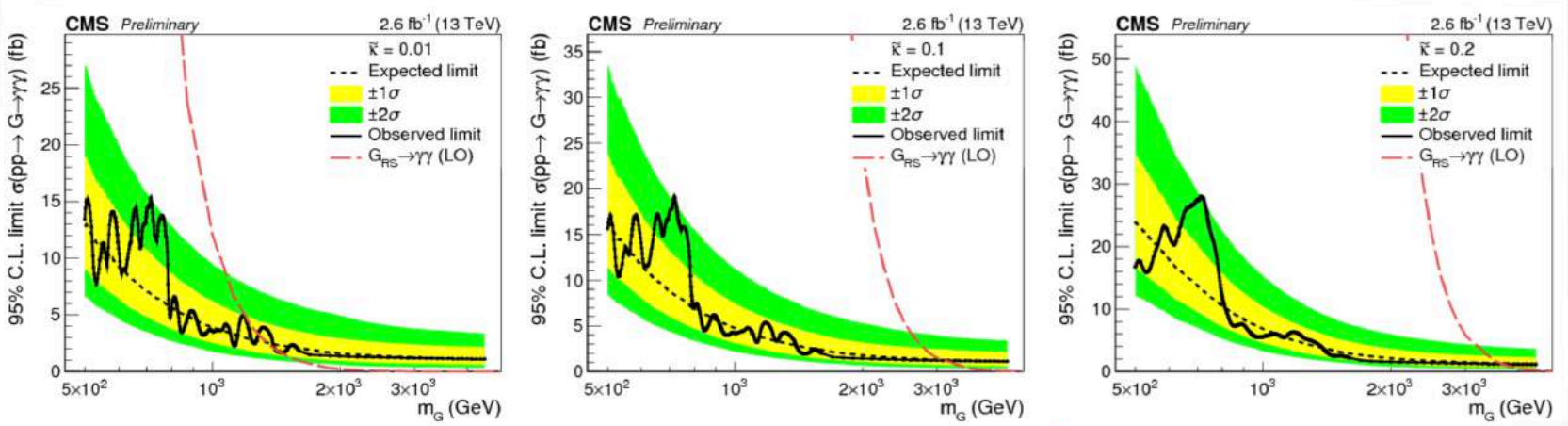
CERN LPCC special seminar
(Dec. 15th 2015, Jim Olsen)

CMS Diphoton (Run2)

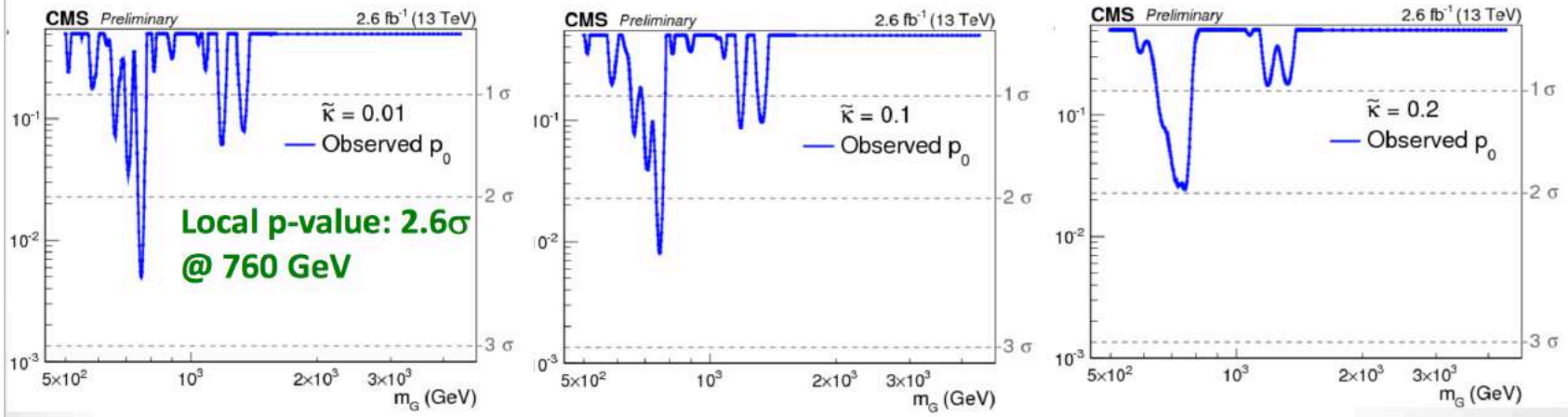
CERN LPCC special seminar
(Dec. 15th 2015, Jim Olsen)

EXO-15-004

Combined limits and p-values



Narrow Width → **Wide (6%) Width**

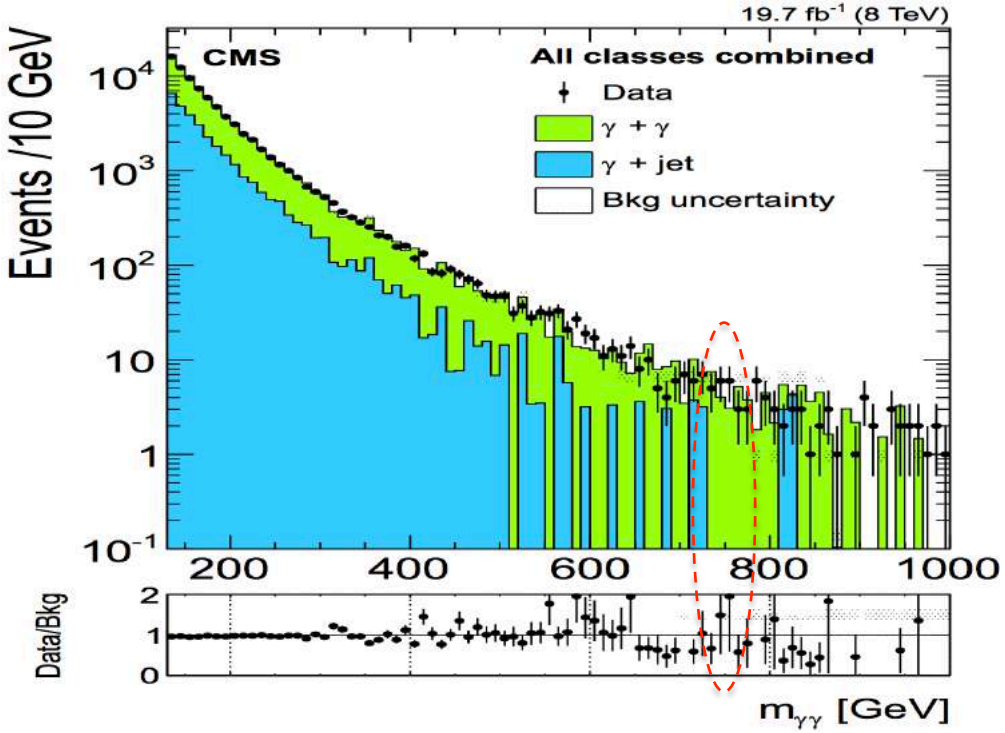


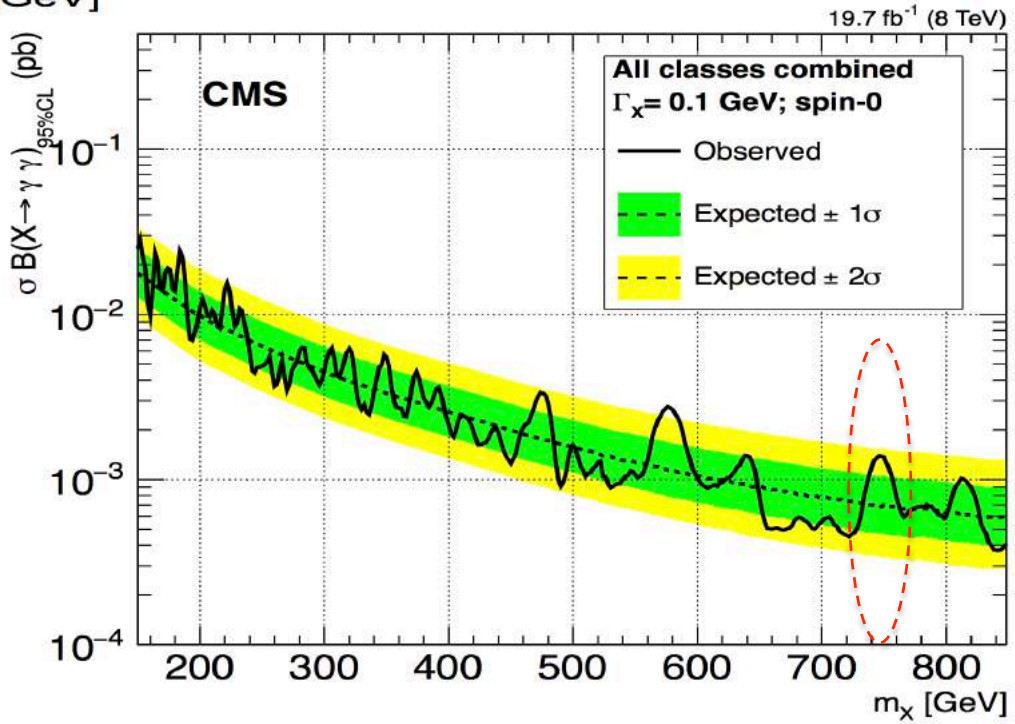
Including LEE (0.5 - 4.5 TeV; narrow width), global p-value < 1.2σ

CMS Collaboration - 13 TeV Results 15/12/2015

CMS Diphoton (Run1)

arXiv:1506.02301v2

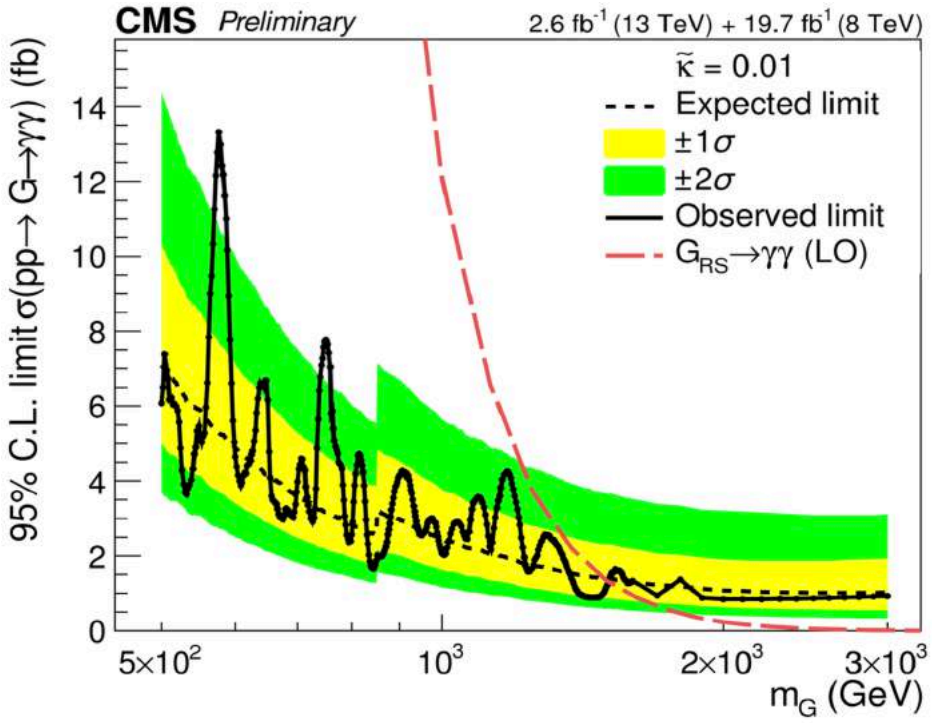


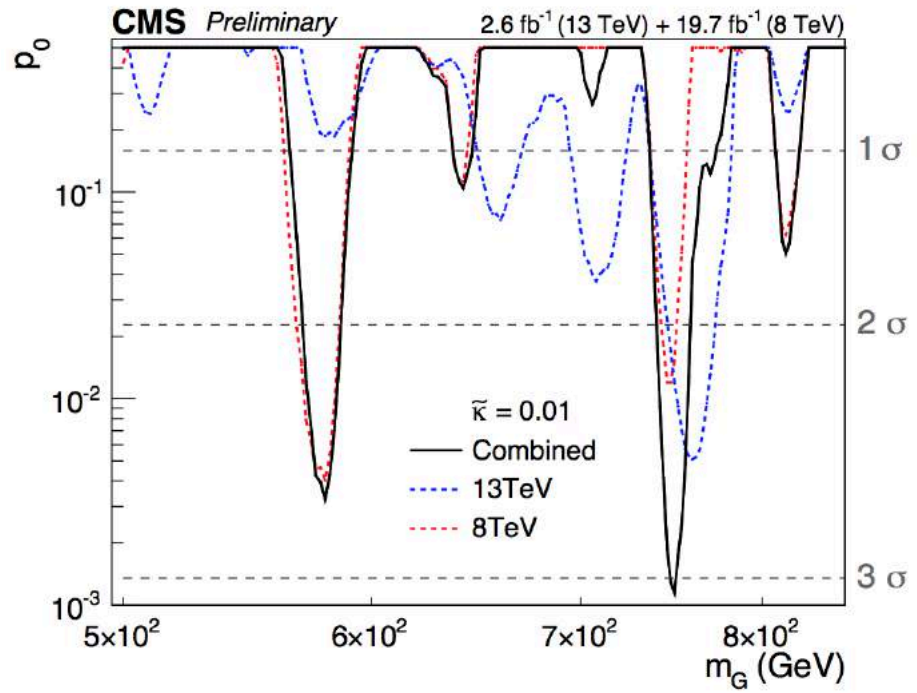


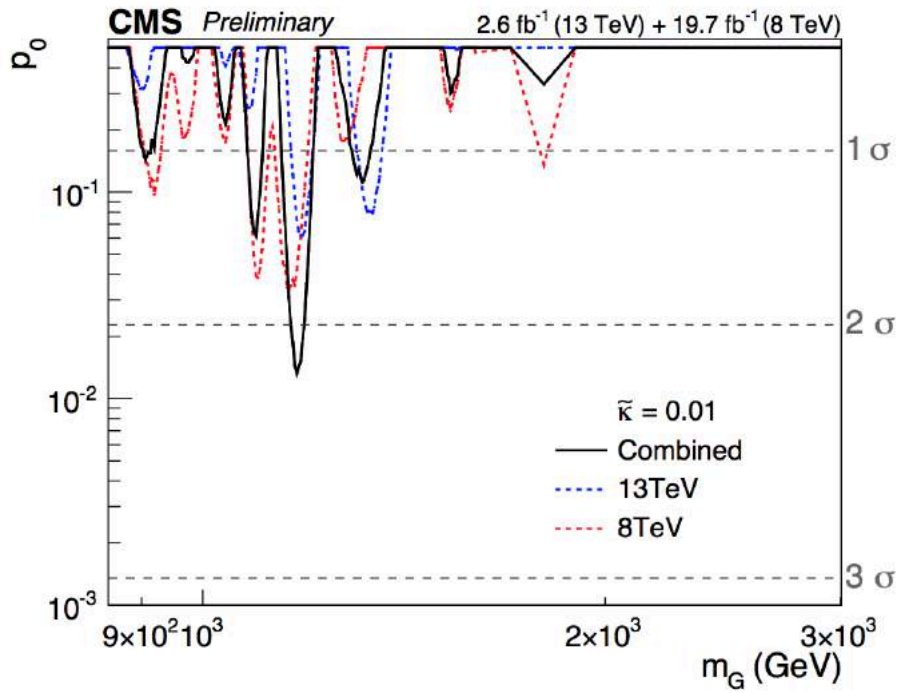
CMS Diphoton (Run1+Run2)

CMS PAS EXO-15-004

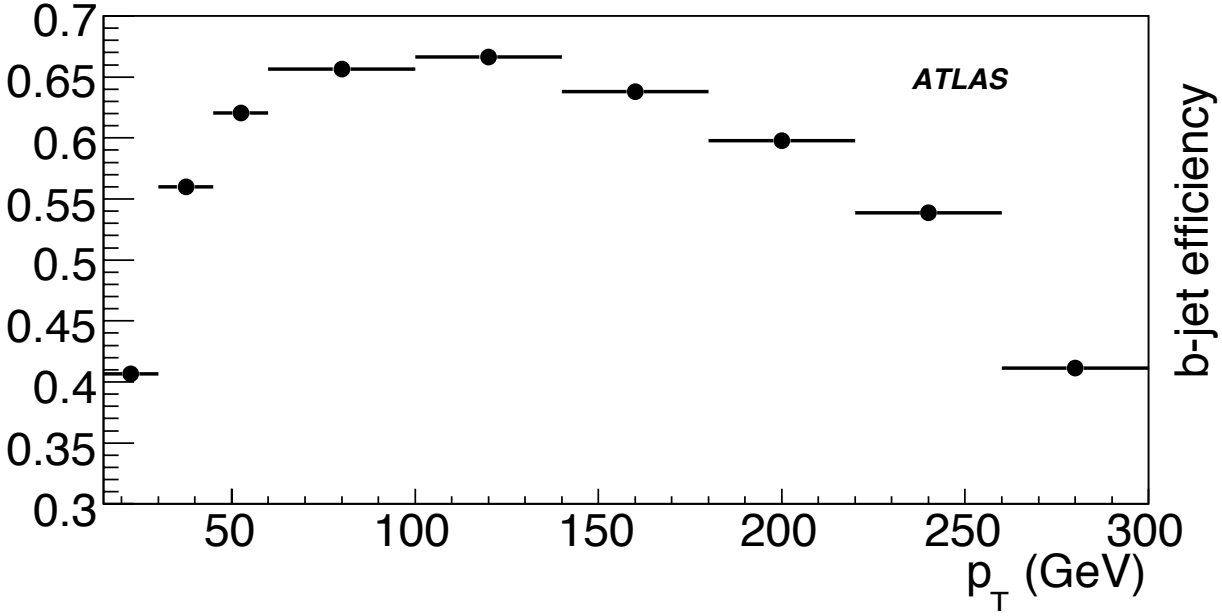
- Combined Run1 and Run2
- Assume narrow width :
  - Local excess : ~3σ
  - Global excess : ~1.7σ

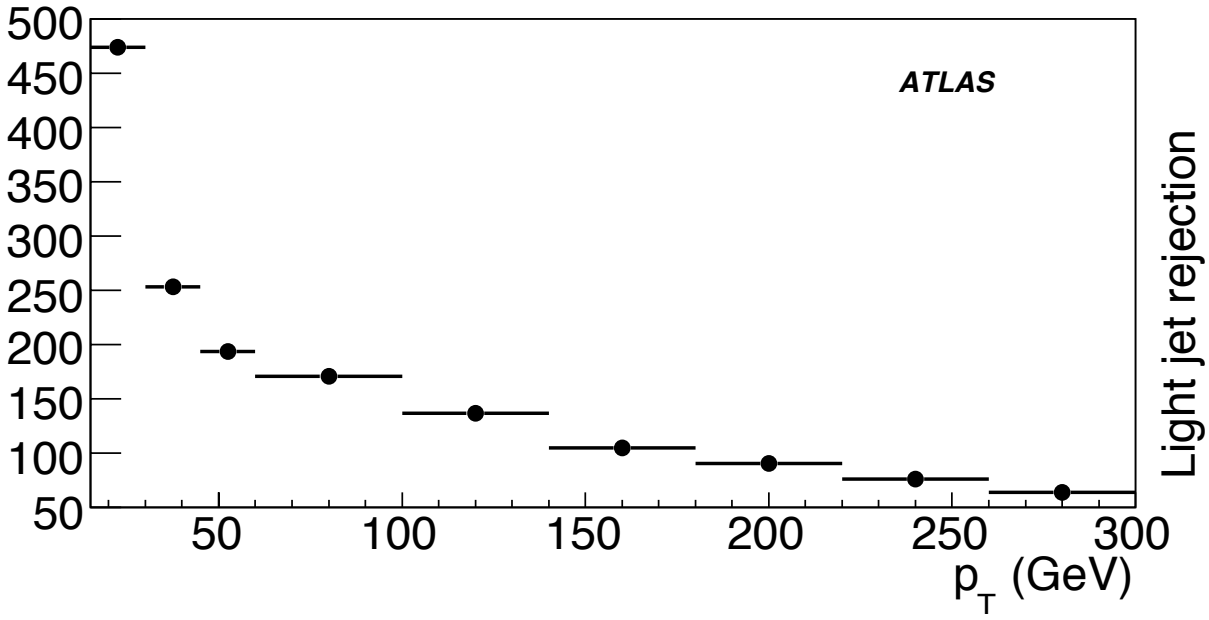






Btagging Efficiency





B-tagging in Phase2