Generic Search of Inclusive High pT Z Events Analysis with ATLAS detector

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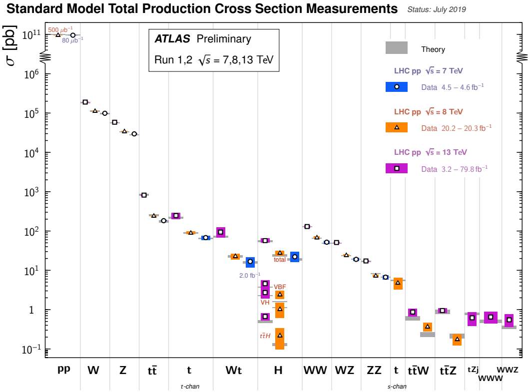
Outline

- Analysis Motivation
- Event reconstruction and classification
- Background estimation
- Kinematics of $Z + X$ system
- Kinematic variable in resonance search
- Challenge of the analysis
- Conclusion

Success and Challenges of the Standard Model

After the observation of Higgs boson in 2012 by ATLAS and CMS experiments, all the elementary particles predicted by the Standard Model have been observed.



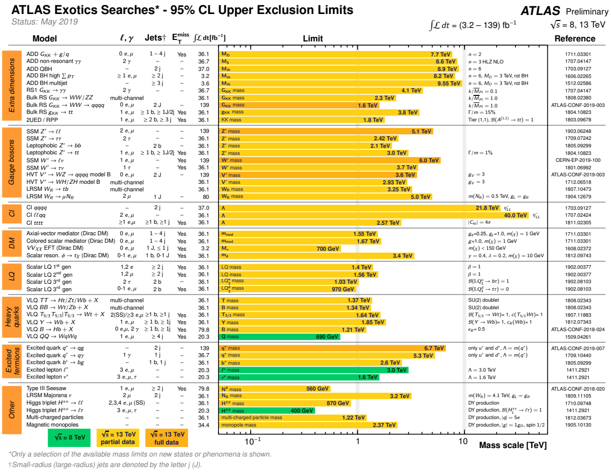
The SM works extremely well but...

Phenomena not explained

- Gravity
- Dark Matter & Dark Energy
- Neutrino mass
- ...

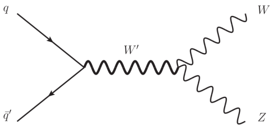
Beyond the Standard Model

Many theories beyond the Standard Model solving the challenges, predict new phenomena accessible by the LHC

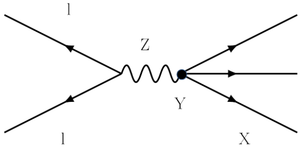


Motivation

- Model independent search for new resonances in high P_{T} Z events
- Leptonic Z decays provide a clean tag and fully triggered sample
- Signal process: $pp \to (\mathbf{Y}) \to Z + \mathbf{X}$, the resonances could be **X** or **Y**
- A generic search in the sense that X can have all possible final states.
- Relevant variables: m$_X$, m$_{ZX}$ or H$_{\mathrm{T}}$ (scalar sum of all objects)



Feynman diagrams for $W' \to WZ$ process



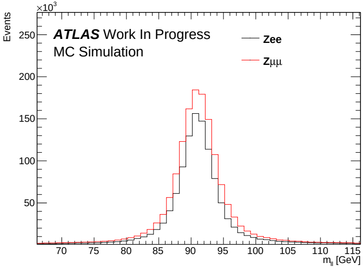
Event topology in Feynman diagrams' style

Event selections

Data sample:

- 2015+2016 (36.2 fb^{-1}) data and MC samples are used for defining the analysis
- Final analysis will use full Run2 data of about 140 fb^{-1}

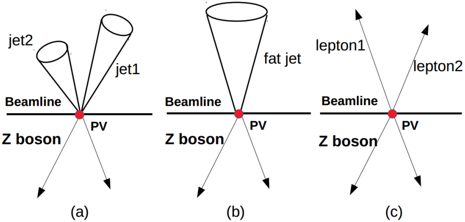
Event Selections	
Trigger selections	
$N_{e^+e^-} \geq 1\, or\, N_{\mu^+\mu^-} \geq 1$	
Select Z candidate, closest to PDG mass	
$p_{T,(sub)lead\ lepton} > 27\, GeV$	
$66\, GeV < m_{ll} < 116\, GeV$	
$p_{T,ll} > 50\, GeV$	
Low p_T Region	*High p_T Region*
$p_{T,ll} \leq 100\, GeV$	$p_{T,ll} > 100\, GeV$



m_{ll} after event selections

Analysis strategy

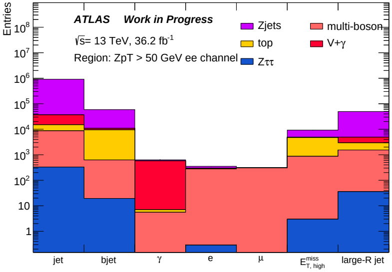
1. Identify leading p_{T} object in the remaining final state X
2. Define channels with the leading p_{T} object in the event:
    - leadJ: jet + ...
    - leadB: b-jet + ...
    - leadP: photon + ...
    - leadL: lepton(e/μ) + ...
    - leadFatJ: large-R jet + ...
    - leadMET: MissingET + ... ($MET/\sqrt{SumET} > 5.0$)
3. Study all kinematic distributions for every given channel



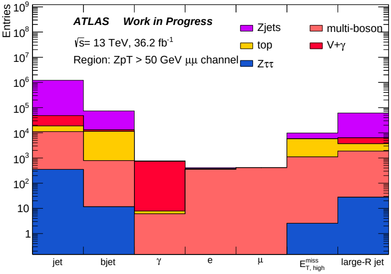
(a)Lead jet (b) lead large-R jet (c) lead lepton

Event yield of different channels

- The leading jet channel dominates in statistics
- The leading lepton channel is further separated in leading e and μ channels



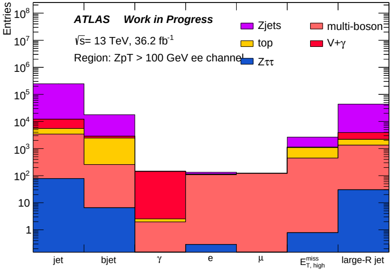
$Z \to ee$



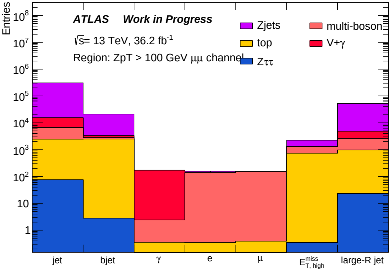
$Z \to \mu\mu$

Background estimation

- Dominant background process varies with different channels.
- Background from fake contribution is small and data-driven
- All other background is based on MC simulation



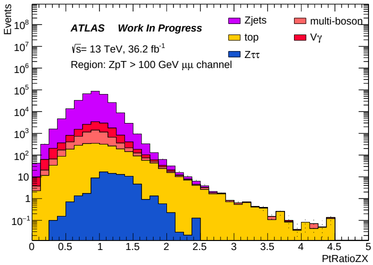
$Z \to ee$



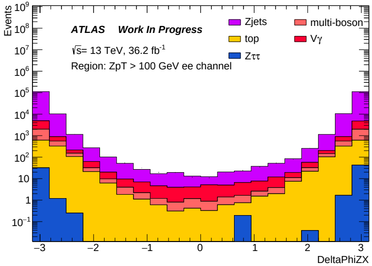
$Z \to \mu\mu$

Kinematics of $Z + X$ system

- At LO, p_{T}^{Z}=0, large p_{T}^{Z} implies QCD radiation in the SM or new resonance X production
- Expected $X - Z$ balance in p_{T} in e.g. the leading jet channel with $p_{\mathrm{T}}^{Z} > 100$ GeV
  - PtRatioZX: p_T^X / p_T^Z
  - DeltaPhiZX: $\phi_Z - \phi_X$



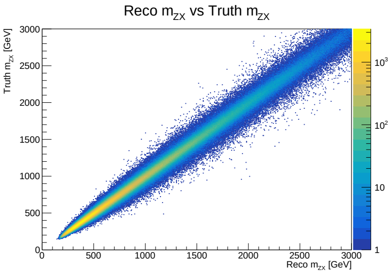
muon channel



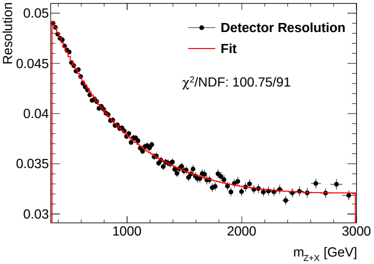
electron channel

Kinematic variables in resonance search

- The kinematic variables used for model-independent resonance search:
  - H_T: scalar sum of transverse momentum of all visible objects
  - m_X: invariant mass of visible objects in recoil system
  - m_{Z+X}: invariant mass of all final states
  - $m_{X'}$ and $m_{Z+X'}$: from only two leading p_T objects of the same type.
- The mass detector resolution is derived given by the difference between reconstruction and truth info.



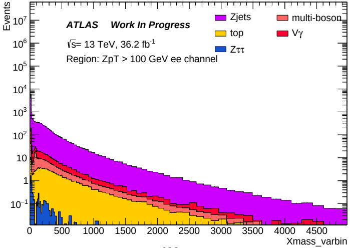
Reco m_{ZX} vs Truth m_{ZX}



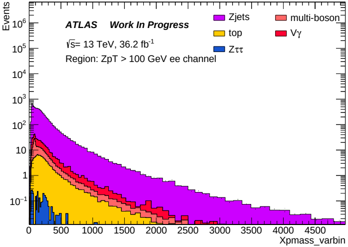
m_{ZX} resolution vs Truth m_{ZX}

Kinematic variables in resonance search

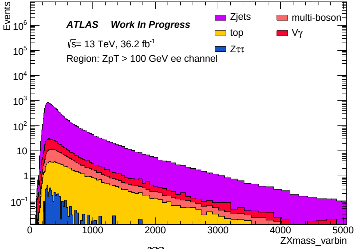
Plots taken from LeadJ category in highZPt100 region in Zee channel.



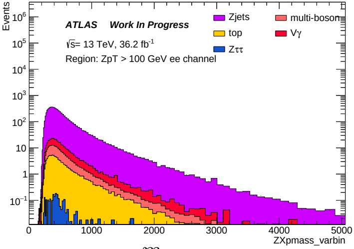
m_X



$m_{X'}$



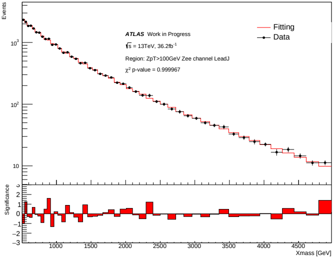
m_{Z+X}



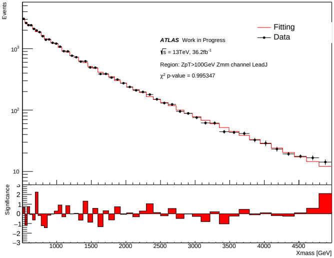
$m_{Z+X'}$

Fitting on mass spectrum

- Hard to model well in all categories using MC simulation.
- Assume the shape of background smoothly falling-down.
- Perform a fit to estimate the background contribution.



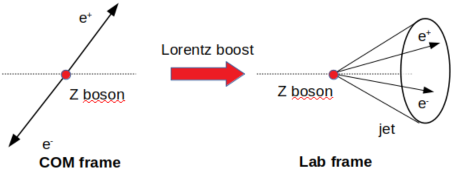
electron channel m_X

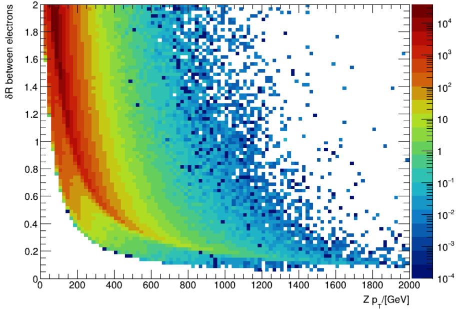


muon channel m_X

Challenge of the analysis

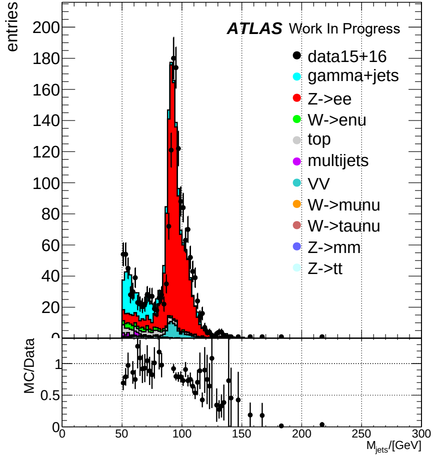
- The highly boosted Z bosons make the two decaying electrons non-isolated at high p_{T}
- Aim to gain efficiency by developing "fat-electron" identification
- Recover the events with small-R (0.4) jet instead of 2 ID-electrons.





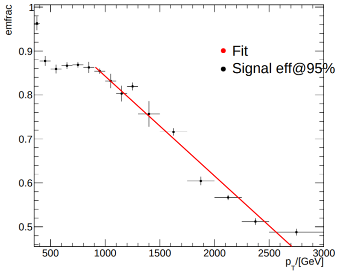
$\Delta R(e, e)$ vs p_T^Z in truth

"Fat-electron" candidates



Jets satisty:

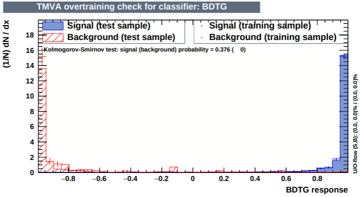
- $p_T > 450\,GeV$, $|\eta| < 2.5$
- $m_{jet} > 50\,GeV$
- $0 < N_{track,pT>500MeV} \leq 7$
- EMfrac: fraction of deposited energy in EM calorimeter, pT-dependent cut

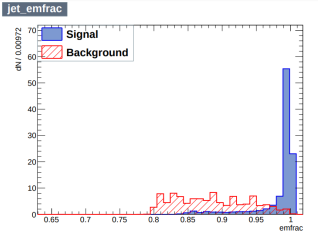


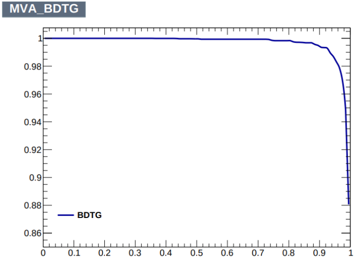
BDT selections

- The BDTG(Gradient Boost Decision Trees) model is trained to select fat-electrons.

- Trained signal from HVT VcWZ$\rightarrow llqq$ samples
- Background from $\gamma + jets$, W($e\nu$)jets and top processes

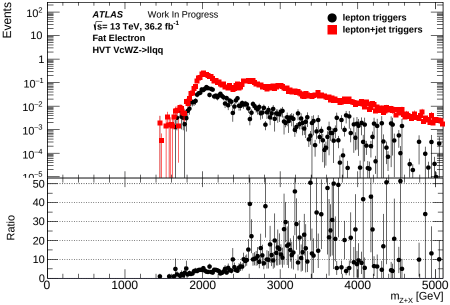




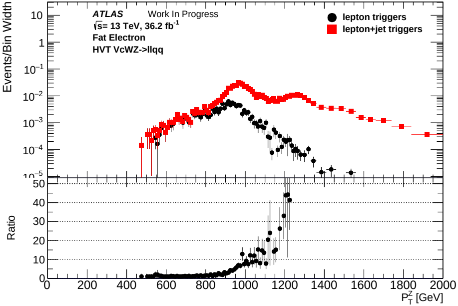


Inefficiency of lepton triggers

- In extremely high p_T^Z region of electron channel, the lepton triggers will also suffer from the boost issues.
- Jet triggers added to recover the efficiency loss.
- Plots below show the comparison of different trigger selections for signal MC samples.



m_{Z+X}



p_T^Z

Summary

- 2015+2016 data and MC samples are used to test the proposed analysis strategy.
- The search algorithm is defined and tested
- The fat-electron object and jet triggers increase statistics in extremely high p_{T} regions.
- The analysis is still ongoing and will include full Run2 ATLAS data

Thanks for your attention!

Backup