Model-independent search in multilepton final states

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Searches in the ATLAS detector

- ATLAS collected $> 150 fb^{-1}$ pp collision data in 2015-2018
- ... so far no conclusive evidence of new physics in model-based BSM physics regions
- Dedicated analyses carry the possibility of overlooking new physics if
  - it occurs in signal regions not being investigated
  - it is only seen in specific observables
- A new approach encourages large coverage of available phase space
- We want to probe more observables and final states at the cost of overall sensitivity
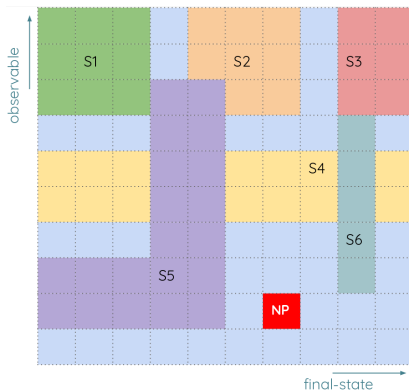
Benefits of the model-independent search

- Cover as much accessible phase space as possible
- Partition data into many smaller regions
- Test all selections and regions for excesses in data compared to Standard Model predictions
- Regions with a large enough deviation define possible new signal regions for a dedicated analysis
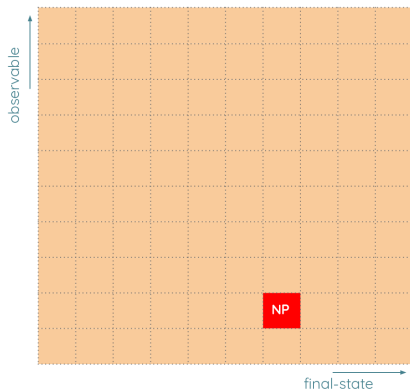
Multilepton search

	Low MET	High MET
1 lepton	**Electron Fakes:** loose triggers no isolation	**W+jet CR:** MET > 40 GeV || MET > 25 GeV && 60 < MT < 100 GeV
2 lepton	**dilepton (Z) CR:** opposite sign same-flavor Z-mass window	**ttbar CR:** opposite-sign opposite-flavor MET > 40 GeV
3 lepton	Signal	
4+ lepton		
	Color Scheme legend:	
	Validation	
	Signal	
	Fake Estimate	

- Final states consisting of 3 or more (light) leptons are potentially very interesting
- A lot of new physics models can potentially be found in this signature (H^{++}, excited leptons, heavy neutrinos)
- region with 1 or 2 leptons can be used as a control and validation for e.g. fake events.
- relatively few events in this region, but still a large phase space

Signal Region Selection

- Good Runs List
- Triggers (single light lepton)
- Removal of overlapping particle tracks + clusters
- Isolated leptons
- non-prompt MC subtraction
- At least 3 leptons (electrons and muons)

Jets
- $\eta < 2.8$
- $p_T > 30\,GeV$

Electron Selection
- $|\eta| < 2.47$ (+crack veto)
- $z_0 sin\theta < 0.5$
- $p_T > 30\,GeV$
- Tight ID
- $|d_0| < 5$

Muon Selection
- $|\eta| < 2.5$
- $z_0 sin\theta < 0.5$
- $p_T > 10\,GeV$
- veto bad muons
- medium ID
- $|d_0| < 5$

Multilepton Analysis: Signal Region Selection

- We want to separate our 3+ lepton region into (sensible) signal regions
- Good signal regions would target attractive BSM/exotics models without overcommitting
- Possible separations: Flavor Permutations, missing energy, bjets
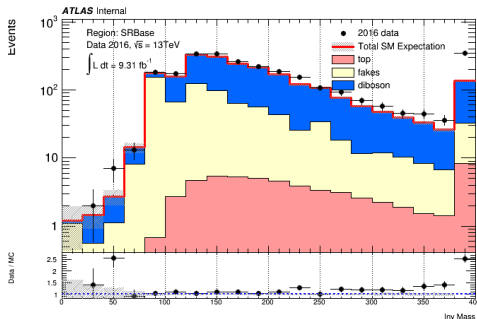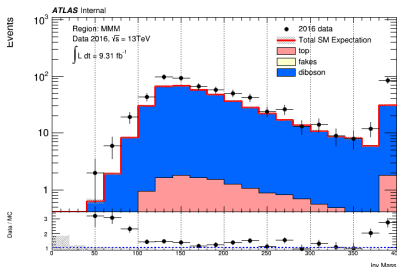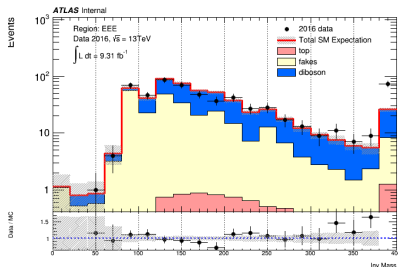- Also have to make a choice of observable(s) to investigate.

Figure: **Example of the event invariant mass of an inclusive 3+ lepton region with MC and fake backgrounds**

Multilepton Analysis: Signal Region Selection

- Example of possible signal regions being used
- EEE: 3 electrons (left); MMM: 3 muons (right)
- All plots use limited 2016 data and are work in progress

Fake Factors

Fake Events are caused by semileptonic heavy flavor decays or misidentified light hadrons "faking" an electron or muon. These events are hard to model with MC

- Data-driven background estimation is commonly used for undefined backgrounds by ATLAS
- In these cases, other methods (MC) are often inaccurate or time-consuming
- Different data-driven estimations exist, but we use the Fake Factor method

Calculating the fake factors

- fake factors extracted using a data-driven approach from a fake-enriched electron region
- Use **loose, single-electron** triggers
- Calculate the fake factor as the ratio between tight and non-tight electrons
- For muons use isolated and non-isolated muons
- due to momentum dependence of electron fake factors we bin accordingly
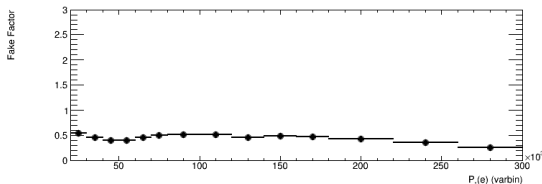
Further Fake Factor considerations

- Binning fake factors in 2 dimension: η or b-tagging?
- Different choices of binning must be motivated by physics
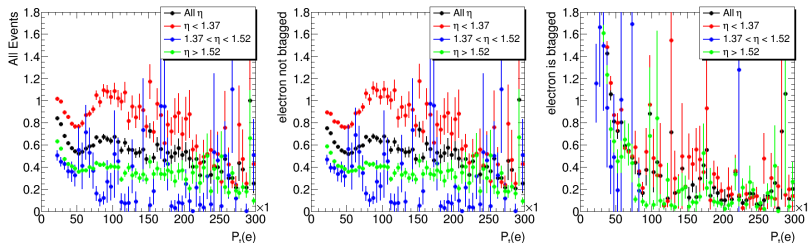- Is the presence of fake events dependent on a particular observable?

Figure: Example of fake factor calculations when taking eta and b-jet fraction into account seperately

Signal Regions: FF in action

- Apply calculated FF to fake-enriched sideband
- Subtract non-prompt MC events: these are now handled by data-driven estimations
- use small subsection of 2016 data to compare our estimate
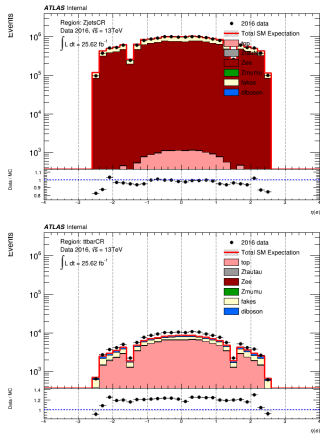- validate if the used fakes definition adequately describes our regions
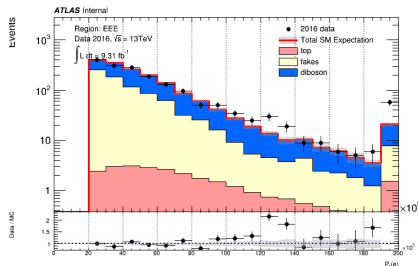
Control Regions

- Control Regions often used for MC normalisation corrections
- For our analysis, also gives the opportunity to verify the fake factor calculation as correct
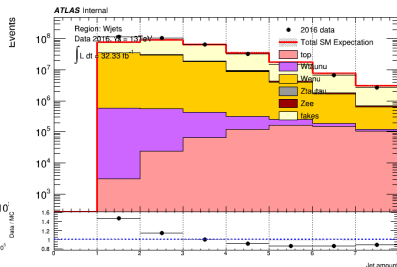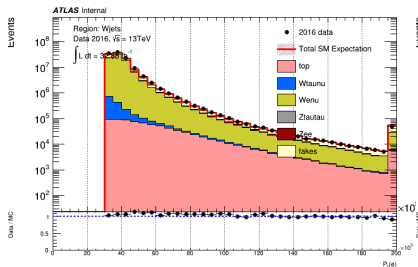
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Further Development

- Model-independent searches offer a great opportunity to cover large phase spaces.
- Use data-driven background estimation techniques to measure lepton fake contribution
- A full analysis would eventually also be able to probe tau signal regions
- New challenges are bound to arise