Search for di-boson resonances in the semileptonic final state

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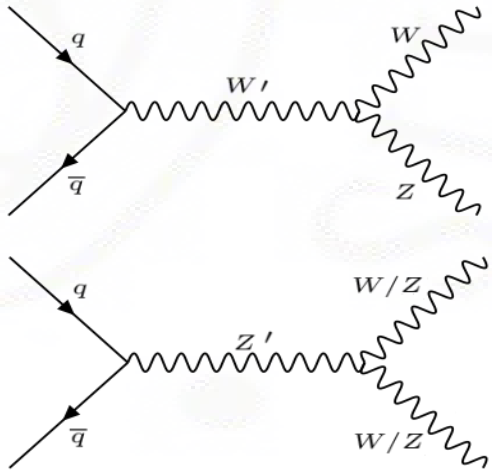
Overview

- Analysis Motivation;
- Previous results;
- Event selection;
- The $X \rightarrow WZ \rightarrow l\nu b\bar{b}$ category;
  - Motivation;
  - Expected performances;
- Statistical treatment;
- Conclusion.

Motivation for this analysis

- After the Higgs boson discovery, the goals of the ATLAS Collaboration is to search for hints on new physics beyond the standard model. These goals can be achieved through:
  - Deviation from Standard Model prediction (precision measurement of the Standard Model);
  - Search for direct production of new physics.
- SIGNAL: X→WV→lvqq, qqqq, llqq, vvqq;
- Many models can give rise to di-boson resonances:
  - Extended gauge models;
  - Heavy/composite Higgs;
  - Massive gravitons;
  - Technicolor
- Example: Heavy Vector Triplet:
  - Presence of three mass-degenerate spin-1 particles;
    - Two charged: W'$^{\pm}$;
    - One neutral Z'.



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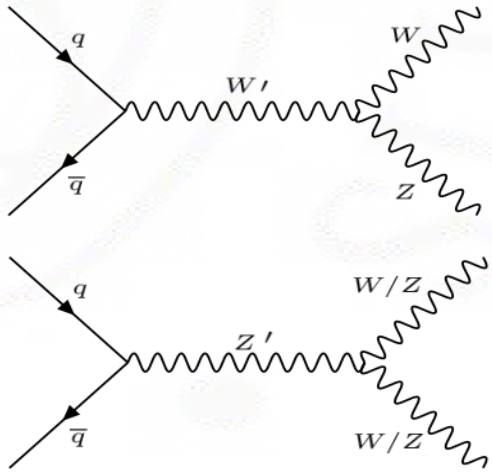

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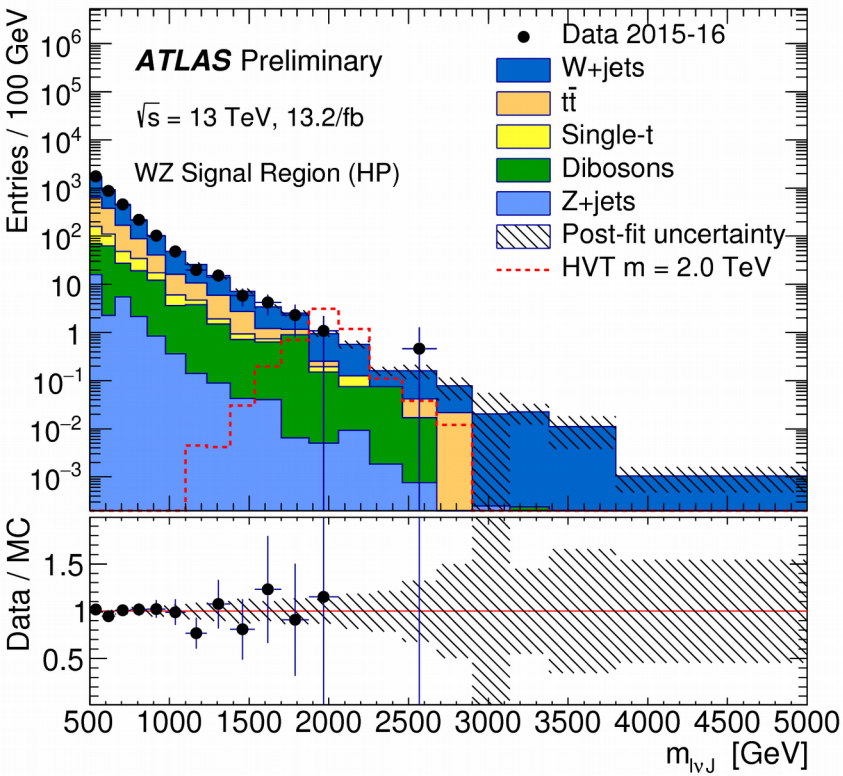
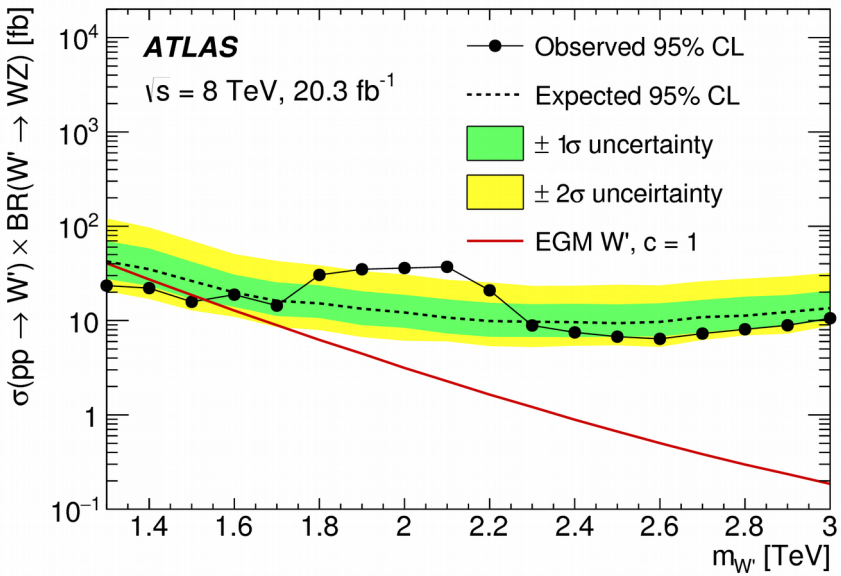


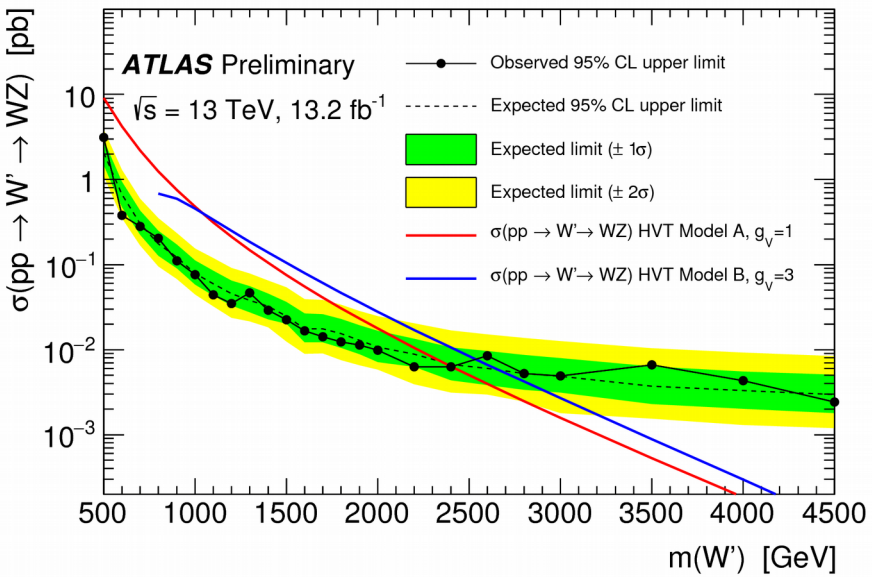
- Main observable is the invariant mass of the lvqq system:
  - We search for a peak.
- The standard model irreducible di-boson background is low:
  - Clear signature of the resonance;
- Main backgrounds:
  - Standard Model di-boson;
  - $t\bar{t}$;
  - W+jets;
- Many models can be checked with the same analysis.
  - No need of a model specific event selection;
  - We need to control not to be dependent on resonance peculiarities;
    - Spin;
    - Polarization of decay products, …
    - Check acceptance for different (simulated) models.

Previous results

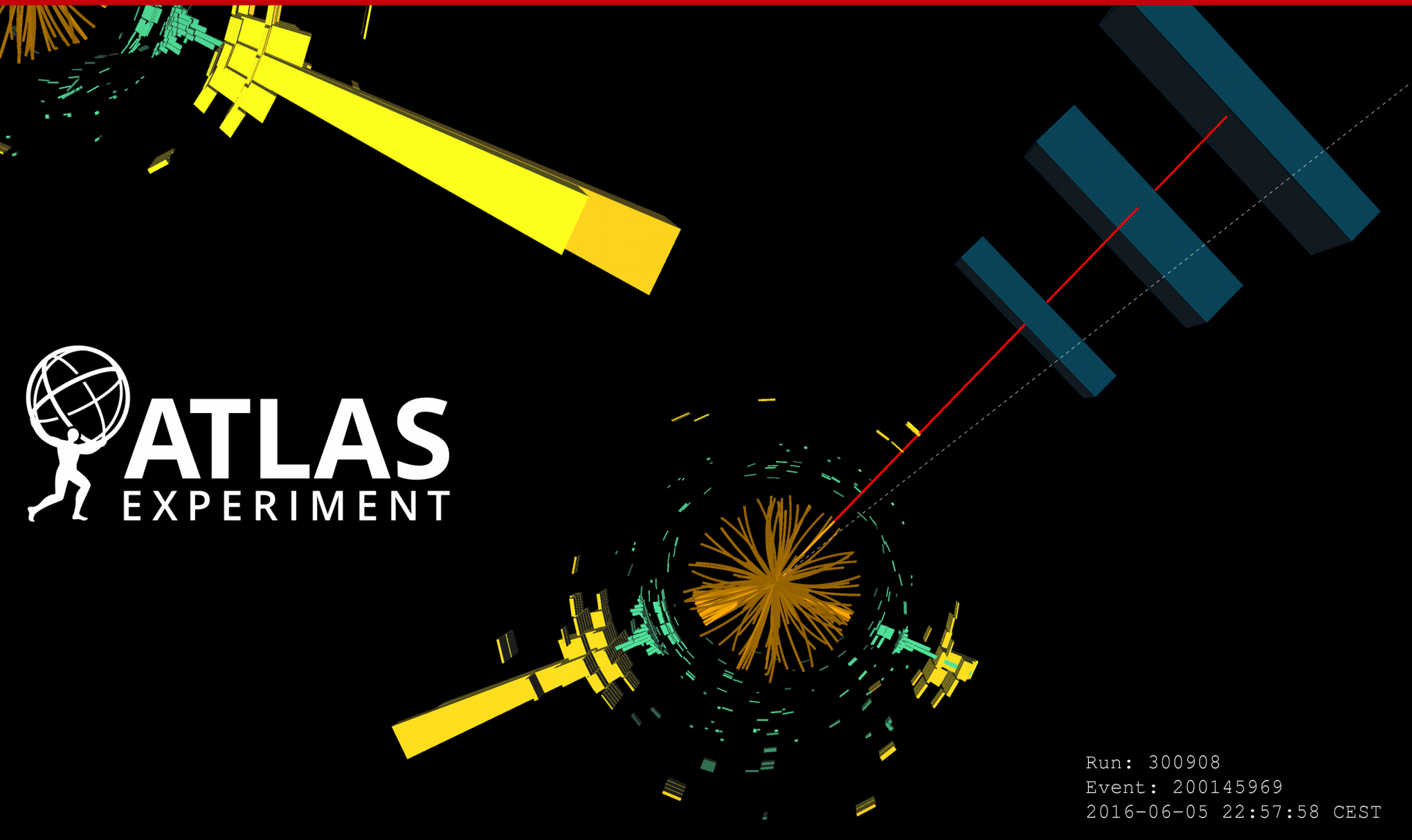
Data at $\sqrt{s}=8\,TeV$ combined over all diboson decay modes



Data at $\sqrt{s}=13\,TeV$ lvqq final state only



Signal event



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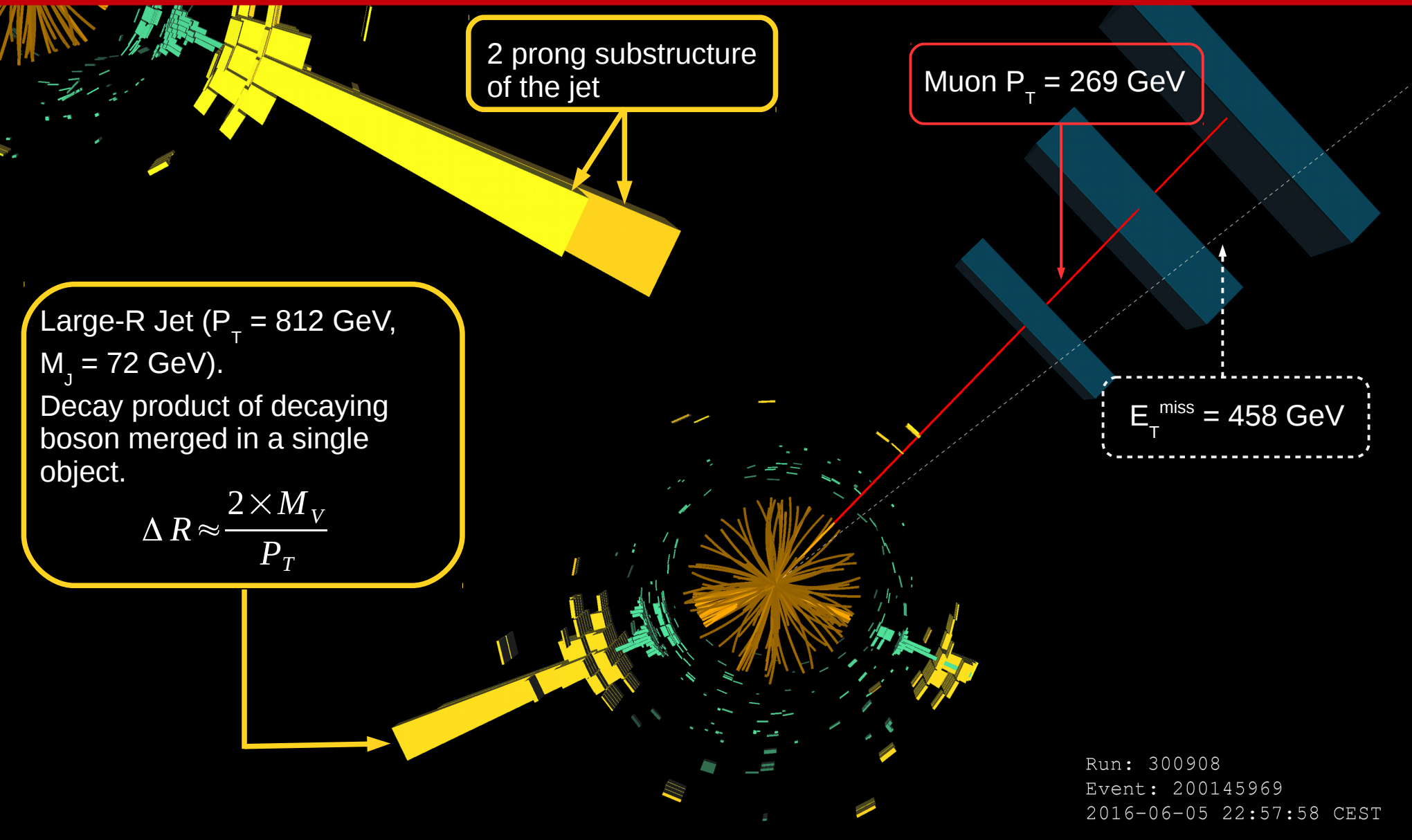
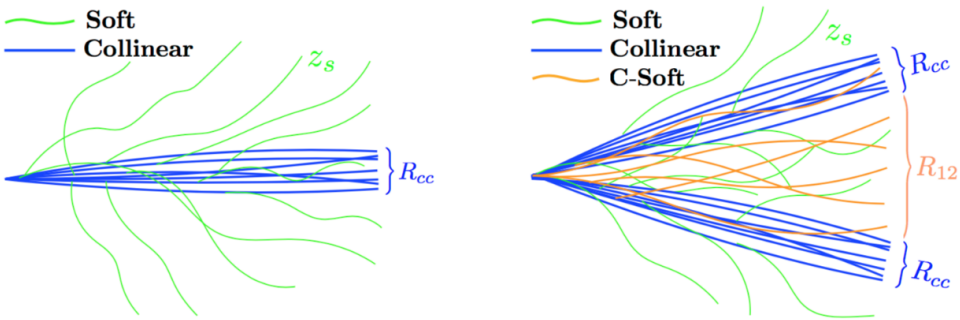


Boson tagging

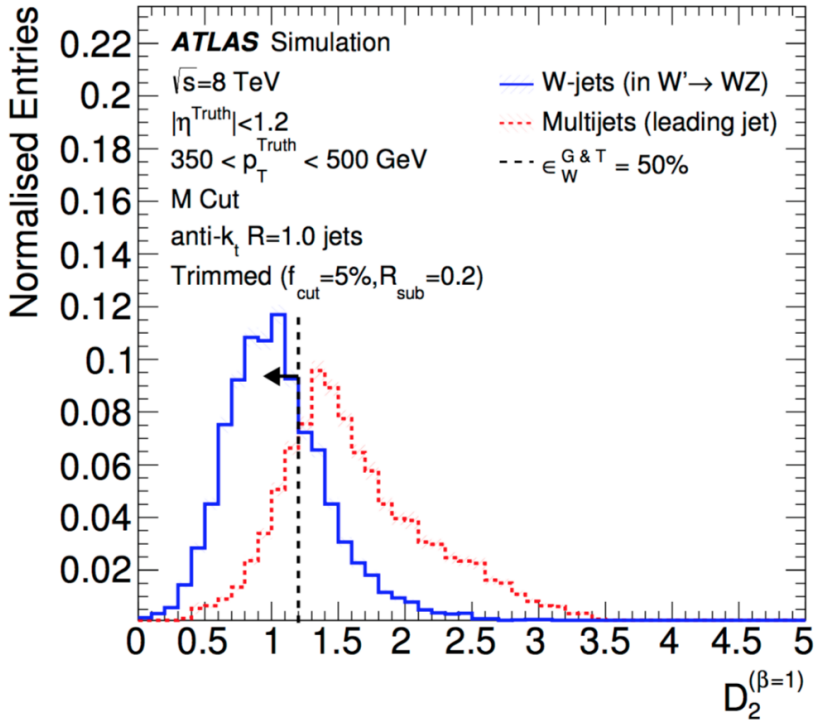
- Substructure for QCD jets (left) and Boson generated jets (right) is different;



- To exploit this difference we rely on correlation function between clusters:
  - The (normalized) ratio of the two is our tagger;

$$e_2^{(\beta)} = \frac{1}{p_{TJ}^2} \sum_{1 \le i < j \le n_{sub}} p_{Ti} p_{Tj} \Delta R_{ij}^{\beta}$$

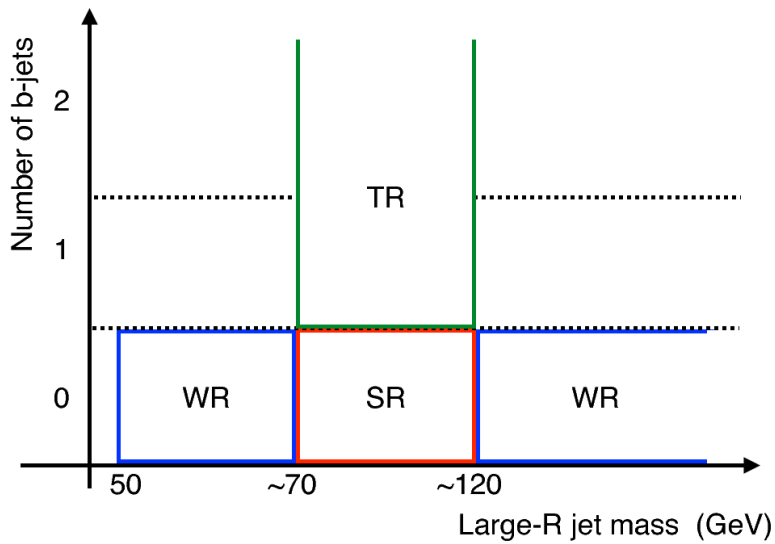
$$e_3^{(\beta)} = \frac{1}{p_{TJ}^3} \sum_{1 \le i < j < k \le n_{sub}} p_{Ti} p_{Tj} p_{Tj} \left(\Delta R_{ij} \Delta R_{ik} \Delta R_{jk} \right)^{\beta}$$



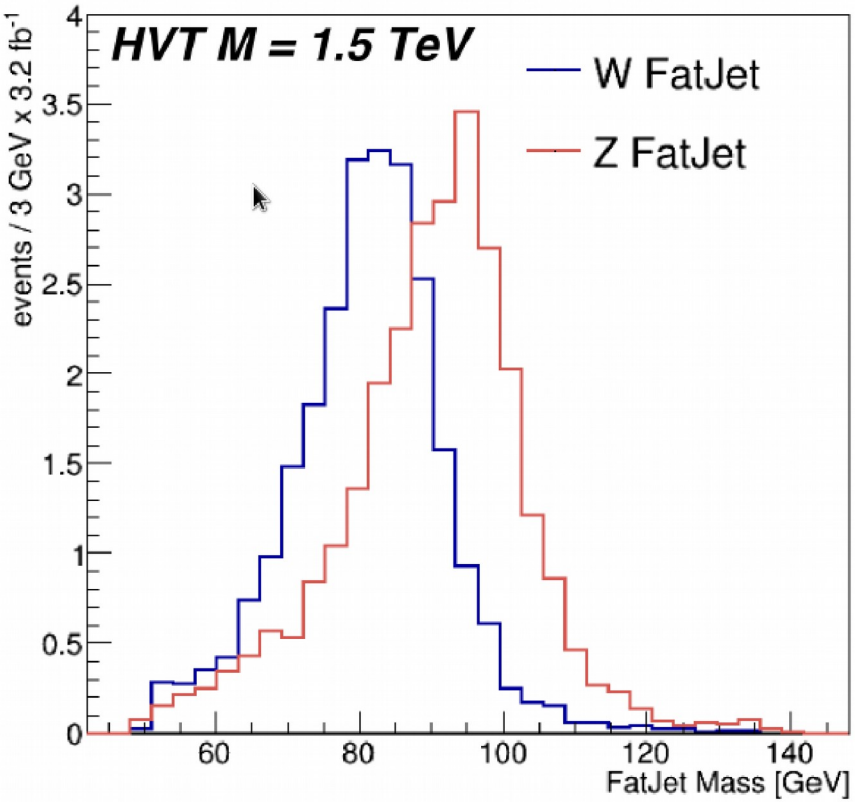
- D2 variable achieves:
  - 50% efficiency;
  - Rejection power 5.

Event selection

Phase	Cut
Event Cleaning	Good run list
	Bad jet veto
Pre-Selection	Exacly one "veto" lepton
	Exactly one "signal" lepton
	Single lepton trigger and trigger matching (electron only)
	Exactly one "signal" Large-R jet
	$E_{\mathrm{T}}^{\mathrm{miss}} > 100$ GeV
	W $p_{\mathrm{T}} > 200$ GeV
Momentum balance	W $p_{\mathrm{T}} > 0.4 \times M_{lvJ}$
	Large-R jet $p_{\mathrm{T}} > 0.4 \times M_{lvJ}$

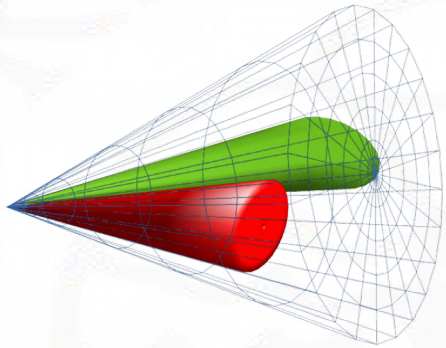


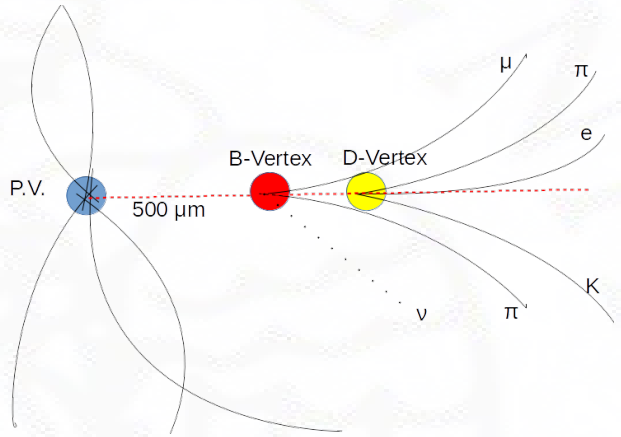
Mass cut



- Distinction between W and Z boson relies on a cut on Large-R jet mass
  - The mass distribution is broad due to high boost of the object;
  - Use 65% efficiency mass window;
    - $|M_J - M_v| < 15\,GeV$
  - W and Z mass windows overlap;
  - Distinction between neutral and charged signal done with a statistical method.
- Idea, exploit different decay modes!

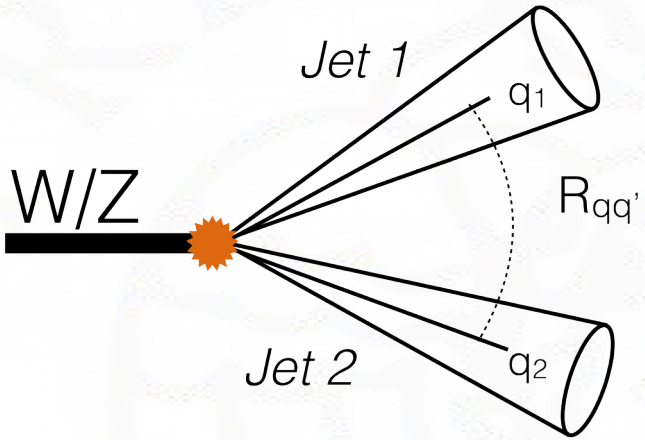
B-Tagging algorithm

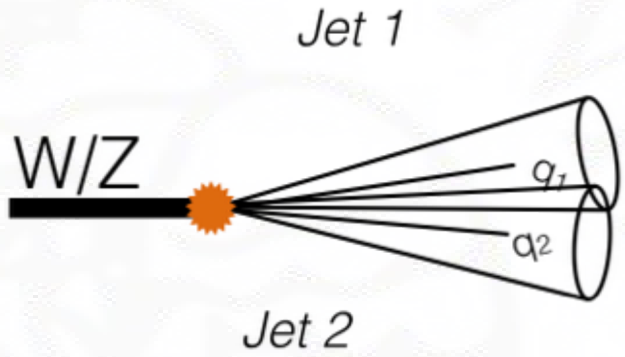




- The aim is to see large impact parameter of the jet;
  - Calorimetric jets have coarse information
  - We use trackjets (jets built using tracks) pointing to the region with high hadronic activity;
- Tracks associated to a Track-jet are collected;
- Tracks are used in three different secondary vertex reconstruction algorithms;
  - Tracks signed impact parameter;
  - Two vertex fitting;
  - Three vertex fitting.
- Those variables are used to train a BDT classifier.
- Different efficiency-rejection points are available

The algorithm





2 B-TAG category.

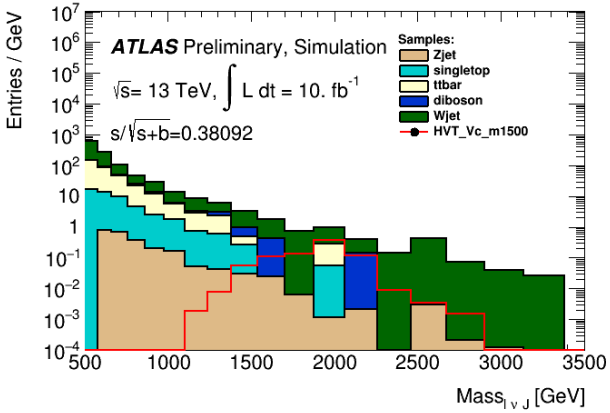
- **Mass** cut:
  - 65-107 GeV (90% mass window);
- **Leading AND subleading** trackjets must satisfy B-Tag.

1 B-TAG category.

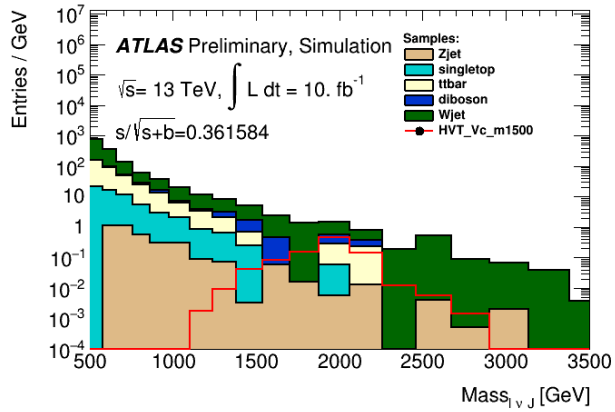
- **Mass** cut:
  - 65-107 GeV (90% mass window);
- **Leading XOR subleading** trackjet satisfy B-Tag.

Signal region 1-B vs MV2c20 w.p. for 2 TeV HVT_Vc

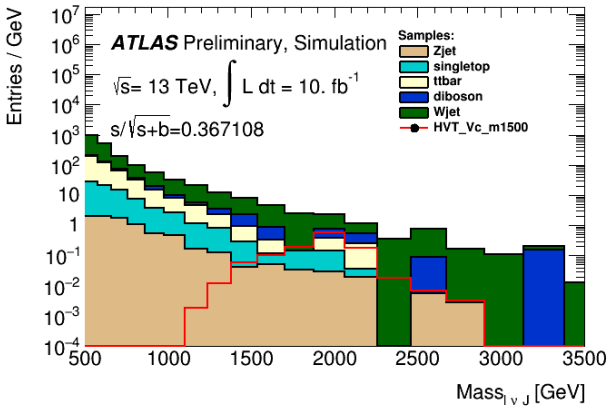
ε=70%



ε=77%

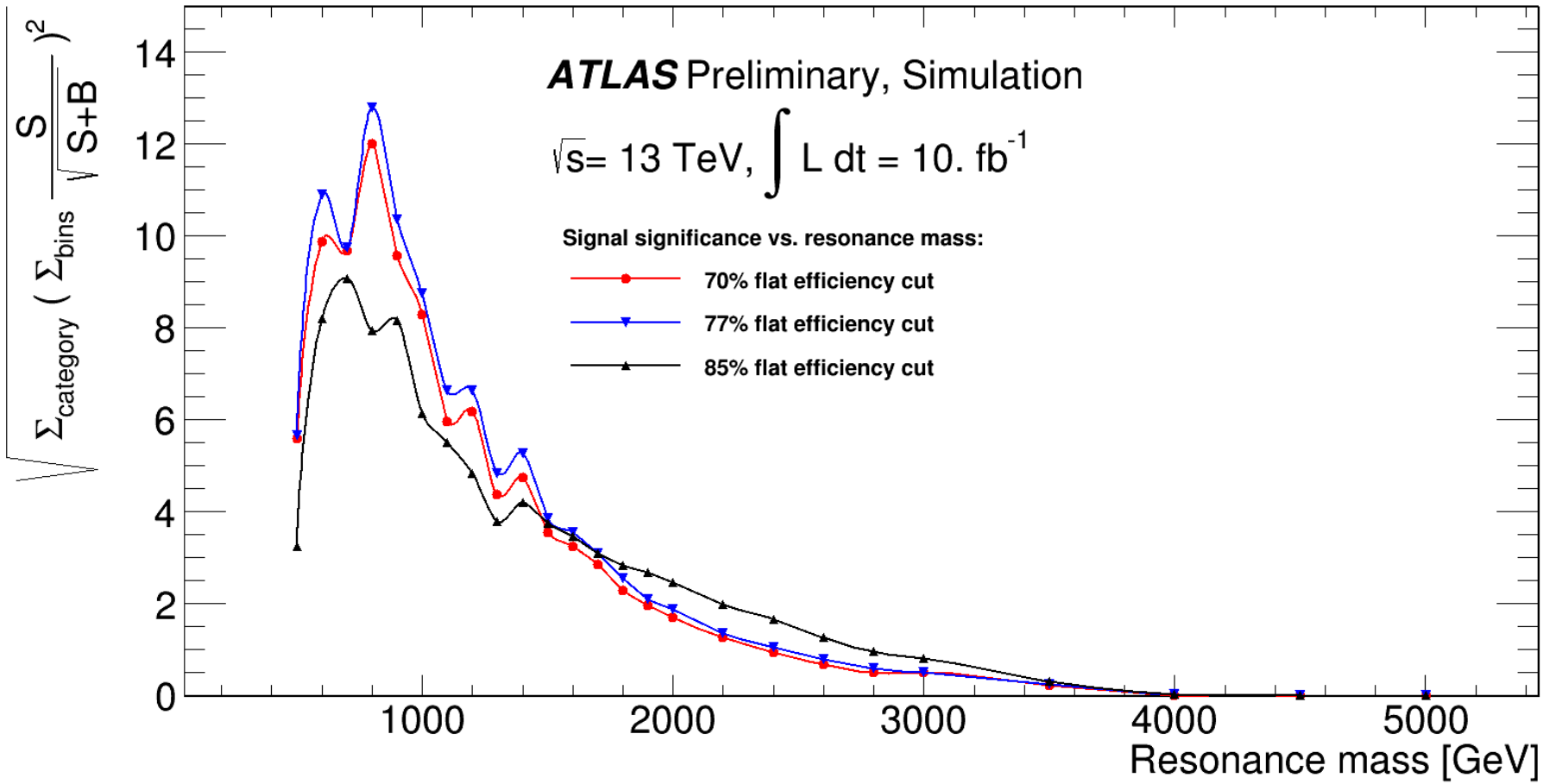


ε=85%

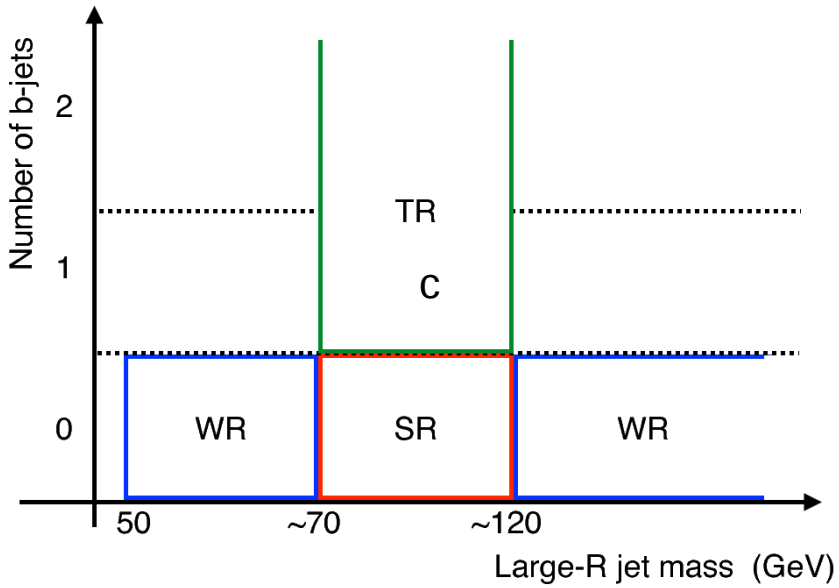


- Different efficiency points are available:
  - We have to choose one;
  - Reconstruct observable in simulated data;
  - Evaluate significance.

Signal significance



Statistical treatement



- Data belonging to different categories follow the same statistical treatement;
  - A simultaneous fit is performed in signal and background enriched regions;
  - We fit the shape extracted from simulated data to the real data;
  - The result is a likelihood function;
- The global likelihood is obtained as the product of likelihoods in different categories;
- The profiled likelihood ratio is used as a test statistic;
- If the best signal strength is 0, limits are then set on production cross section

Conclusion.

- ✔ Tagger optimization;
- ✔ Event Selection optimization;
- ✔ Included in analisys code;
- ✔ Fit using pre-existing code;
- ✗ Fit extrapolating normalization factors among categories:
  - ✗ Evaluate increase in signal sensitivity;
- ➢ Publish it!
  - ➢ Find the unexpected and win a Nobel prize!
  - ➢ Find the unexpected and win an Ig-Nobel prize!
- ➢ Combine with other search channels:
  - ➢ VH
  - ➢ $ZZ \rightarrow llqq$;
  - ➢ $WZ \rightarrow qqqq$;
  - ➢ $WW \rightarrow qqqq$,...

Thank you for the attention!