Boosted jets and jet substructure

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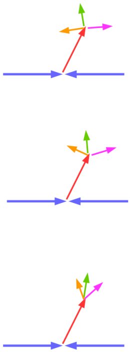
First year of PhD → enter the ATLAS collaboration.
Qualification work on jet mass scale (JMR) and resolution (JMR).
Goal: provide some reccomendations based on 2015 data.

When momentum increases:



arXiv:0910.5472

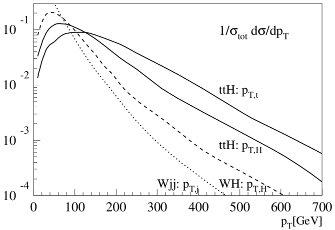
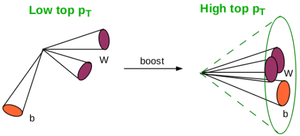


FIG. 1: Normalized top and Higgs transverse momentum spectra in $t\bar{t}H$ production (solid). We also show $p_{T,H}$ in W^-H production (dashed) and the p_T of the harder jet in W^-jj production with $p_{T,j} > 20$ GeV (dotted).

Motivations

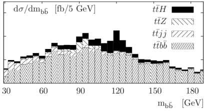
At RunI for the first time large samples of W, Z, t, H with $p_T >> m$, were produced. Much more are expected at RunII.

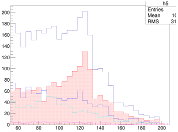
Inadequate one-to-one (jet-to-parton) reconstruction. Jets with a large radius (*fat jets*), to capture all decay products, can be used, studying their internal structure.
Techniques improve resolution of large jet substructure measurements.



Boosted analysis and jet substructure tecniques can be applied to Higgs Physics (and in general to many analysis...).

For instance: "Fat jets for a light Higgs ", *arXiv:0910.5472*.
→ 5σ ttH(bb) signal at 13Tev, 100 fb^{-1}.





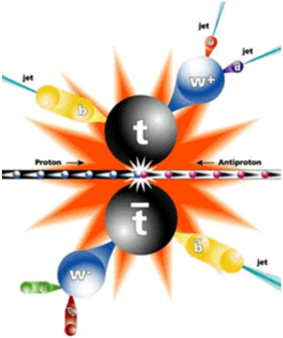
Hadronic top JMS/JMR in ttbar semileptonic decay

$$JMS = \frac{\mu_{\text{data}}}{\mu_{\text{MC}}} - 1$$

$$JMR = \frac{\sigma_{\text{data}}}{\sigma_{\text{MC}}} - 1$$

JMS and JMR show how accurately jet mass is measured. They are calculated from MCs and data mass peaks.

Large jet mass is one of the less known substructure observables, it has an uncertainty around 15%/20%.
An ATLAS group claimed to be able to measure it with around 5% (using RunI data).
Their work still is ongoing, but I am working to reproduce it for RunII.



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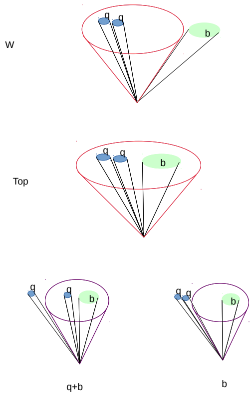

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The leading jet of each event can be classified.

Selections are made (with no MC information) to increase signal acceptance.

W-jets are selected if they have a near b-tagged jet.

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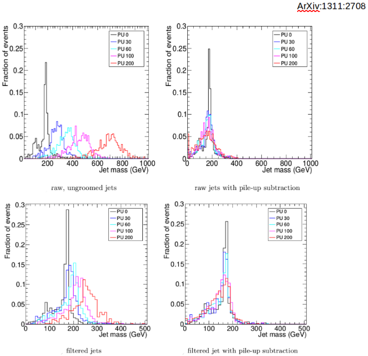
Pile-up

In RunII pile up is larger than at 8Tev. (At 8tev $\langle \mu \rangle = 20$).
This could decrease the resolution with which jet observables are measured.
Pile up manifests itself mostly in additional hadronic transverse momentum flow but it can also generate particle jets (pile-up jets).
A metod has been studied to reduce the impact of the pile up. *arXiv:1311:2708.*

(Following plots came from a $Z' \to t\bar{t}$ study)

Jet grooming works well in mantaining the JMS/JMR, provided it is applied together with pile-up subtraction.

Grooming= trimming/filtering and pruning
= cleaning the jet



Conclusions and outlook

Conclusions:

- Top JMS and JMR are important in every top-related analysis (ttH, H+t). An improvement on measuring large jets mass will reduce systematic uncertainties.
- Increasing pile-up will not affect too much JMS/JMR, if treated properly.

Notice:

- Code still is under development and lot of things have not be implemented yet.
- The RunI analysis is having some problems on fitting the mass peaks.
- Usable data from RunII will not be available in a short term.

This work will be an useful experience for my PhD subject and is going to be used when performing ttH analysis in ATLAS.

Thanks for your attention!

Back-up: Theoretical state of art

Goal: to predict jet substructure by first-principle QCD calculations (and compare results to data in meaningful way...).
ATLAS and CMS performed measurements on largeR jets and their substructure. (example: boosted hadronic W jets mass uncertainty $\approx 1\%$)

Fixed order NLO (qcd) calculations are available for jet substructure observables. But:

- When multiple scales (p_T, m) are involved, predictions contain logarithms like $L = \ln(p_T)$ which strongly affect jet shapes.

To perform accurate predictions, resummation is needed.

$$\sigma(L(p_T)) = \sum_{config\,\delta} \sigma_0^{(\delta)} g_0^{(\delta)}(\alpha_s) e^{L g_1^{(\delta)}(\alpha_s L) + g_2^{(\delta)}(\alpha_s L) + \alpha_s g_3^{(\delta)}(\alpha_s L) + \ldots}$$

$N^k LL \longrightarrow$ resummation of $\alpha_s^n \ln^m N$,with $2(n-k)+1 \leq m \leq 2n$

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State of the calculations:

- MCs are correct to LL, some observables NLL.
  Analytical calculations commonly at NLL, but also NNLLand NNNLL.
- NGLs resummed recently. arXiv:1304.6930
- CLs for *Kt* and *CA* clustering studied. arXiv:1207.4528