Comparison of event structures in W / Z + jets events

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June 3rd 2008

Contents

Introduction and Motivation

→ Measure W+jets cross section

→ especially: ratio W+0j : W+1j : W+2j : W+3j : W+4j : W+5j

- use Z+jets as tool to learn more about jet production in W+jets events
- get the ratio of jet multiplicities in W+jets events from ratio in Z+jets events
- **assumption**: $\frac{inclusiveZ}{inclusiveW} = \frac{Z+njets}{W+njets}$ **or** $\frac{Z+(n-1)jets}{W+(n-1)jets} = \frac{Z+njets}{W+njets}$ ("Multijet production in W,Z events at p$\bar{\text{p}}$ colliders", F.A. Berends, W.T. Giele, H. Kuijf, R. Kleiss, W.J. Stirling)
- σ_W=c*σ_Z → event shapes for W and Z events should be compatible!

Long term goal of analysis:
Measure ratio of different jet multiplicities in W+jets event for top analysis

Predictions for W/Z + jets cross section

Used datasets generated with Alpgen/Herwig (note additional cuts!!):

$N_{partons}$	σ_{Z+jets}/pb	σ_{W+jets}/pb	$\frac{\sigma_{W+jets}}{\sigma_{Z+jets}}$
0	149	1760	11.8
1	138	1650	12.0
2	50.5	587	11.6
3	16.2	177	10.9
4	4.57	49.3	10.8
5	1.69	18.0	10.7

Cuts in these datasets:

- $\geq$ 1 electron (W)/ 2 electrons (Z) with $p_T \geq 10$ GeV and $|\eta| < 2.7$
- $\geq$ 1 truth jet (Cone $\Delta R = 0.4$) with $p_T \geq 20$ GeV and $|\eta| < 5.0$

The search for observables

Look for observables with the following features:

- comparable distributions for W and Z
- (as much different from top as possible)

Main differences expected because of
mass difference and **neutrino** $\Longleftrightarrow$ **electron**

Start with observables, which

- are based on jets
- do not depend on decay products of vector bosons

differences also expected from:

- additional graphs in Z production
- different flavour content for heavy flavours

Studies on TRUTH level

First step:
Are event structures in W/Z+jets events compatible at truth level?

- Electrons are reconstructed as jets
- Overlap removal (electron,jet) on truth level not optimal for this analysis
- One electron less in W+jets events than in Z+jets events

$\rightarrow$ count **neutrino** from W decay **as an additional jet**

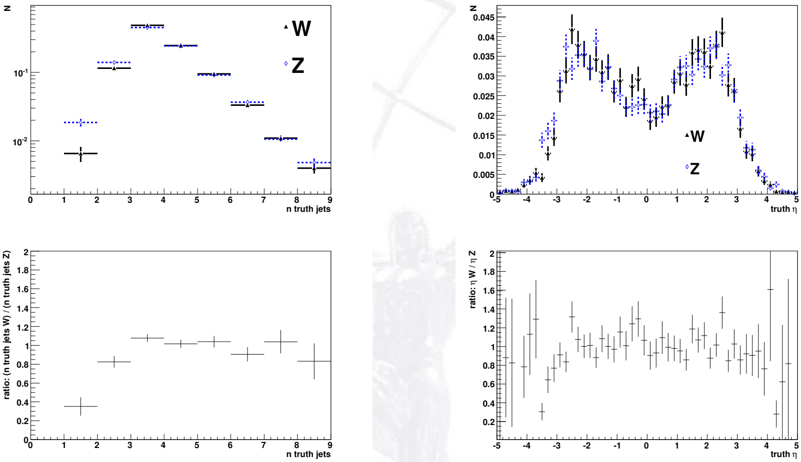
(it´s truth level ;-))

Cut on truth jets:

- $p_T > 15$ GeV
- $|\eta| < 2.5$

TRUTH: η of W/Z and N_{jets}

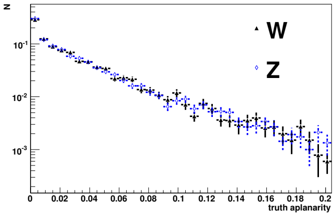
Top: Distributions of **W** and **Z** superimposed (both normalized to 1)
Bottom: Distribution W / Distribution Z

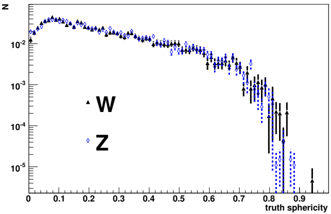


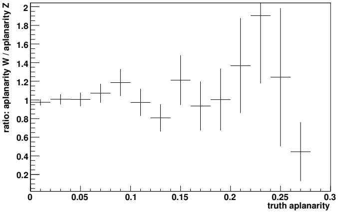
Deviations in N_{jets} in small jet bins arising from cuts in MC?

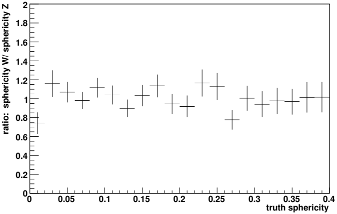
TRUTH: Aplanarity ($= \frac{3}{2}\lambda_3$) and Sphericity ($= \frac{3}{2}(\lambda_2 + \lambda_3)$)

Top: Distributions of **W** and **Z** superimposed (both normalized to 1)
Bottom: Distribution W / Distribution Z









Good agreement between W and Z!

Studies on detector level

Truth level looks good, now proceed to detector level!

still one electron more in Z events!
→ overlap removal (jet,electron) important
→ twice the electron reconstruction efficiency for Z events

→ **important**: all leptons have to be reconstructed!

- require exactly 1 electron in W+jets events
- require exactly 2 electrons in Z+jets events

different constraints for W and Z events:

- ν **from W**
  - can fly wherever it likes to
- **corresponding e from Z**
  - has to be inside certain η range to be reconstructed
  - is rejected if too close to another object (e.g. jet)

Event Selection

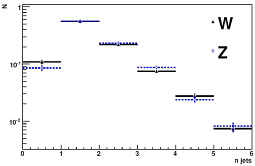
Find the "best" event selection!

Find a way to replace the 2^{nd} electron in Z events
by the missing E_T in W+jets (and top events) (**to do!**)

Try different cuts on jets besides required reconstruction of leptons:

$\geq$ 4 jets with $|\eta| < 2.5$ and

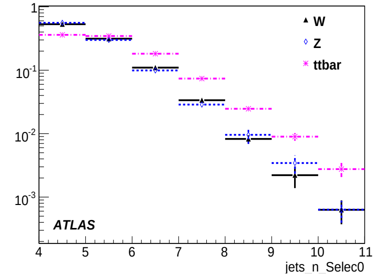
- "Selec0": 20/20/20/20 GeV
- "Selec1": 40/40/30/20 GeV
- "Selec2": 40/40/40/20 GeV



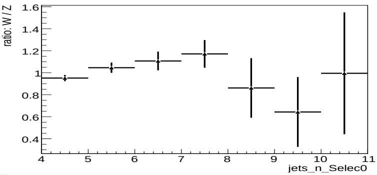
	Selec0/%	**Selec1/%**	**Selec2/%**
ttbar	11.6	10.2	8.3
W+jets	3.9	2.8	2.0
Z+jets	3.1	2.2	1.6

Number of reconstructed jets

- first thing to do:
  check if jet multiplicities agree
  for W / Z events for ≥ 4 jets
- cut improves agreement



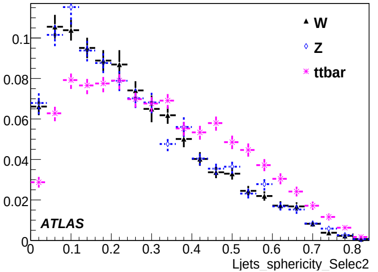
- deviations,
  slope in ratio visible
- reason?
  cuts? statistics? physics?



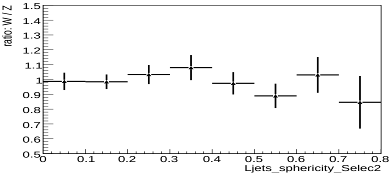
Sphericity I - Distributions and ratio of distributions

Sphericity $= \frac{3}{2}(\lambda_2 + \lambda_3)$

- compare sphericity distributions of W+jets, Z+jets and top
- all distribution normalized to 1



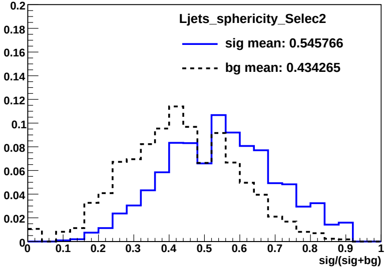
- plot ratio: distribution of W+jets divided by Z+jets
- ratio is 1 if W/Z+jets are compatible



Sphericity II - Add-on: Separate top events from W events

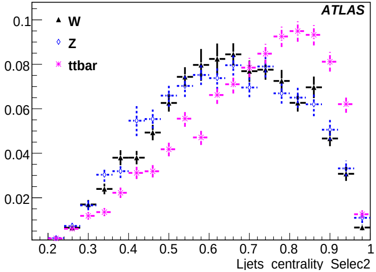
- compare distribution of top events to W+jets events
- calculate a "One Variable Likelihood":
- scan through distributions and fill a histogram with: N_{sig}, N_{bg} against $\frac{N_{sig}}{N_{sig}+N_{bg}}$

Calculate separation power: $\frac{1}{2}\sum_y \frac{(sig(y)-bg(y))^2}{sig(y)+bg(y)}$

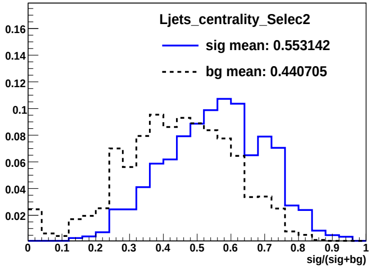


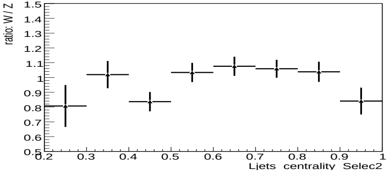
Separation power: 0.131

Centrality $= \mathrm{H}_T \;/\; \mathrm{H}_E = \sum_{jet=1}^{4} E_T(jet) \;/\; \sum_{jet=1}^{4} E(jet)$



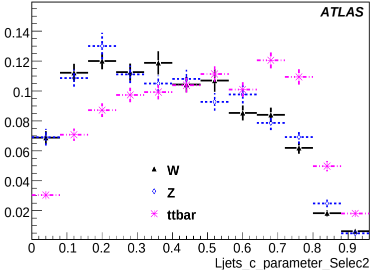
Separation power: 0.119

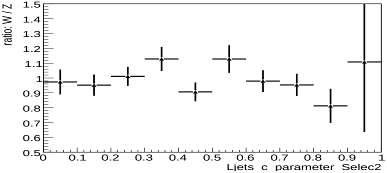




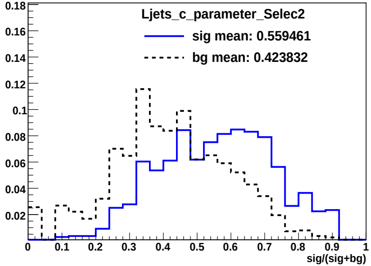
- good agreement of W and Z
- good separation power

C Parameter $= 3(\lambda_1\lambda_2 + \lambda_1\lambda_3 + \lambda_2\lambda_3)$



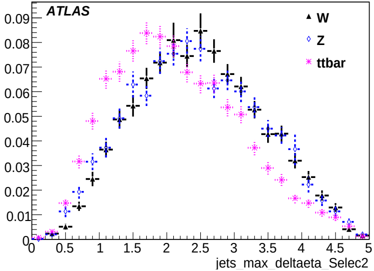


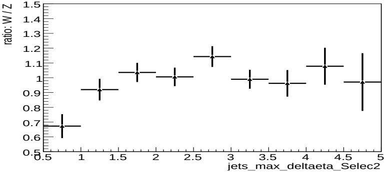
Separation power: 0.152



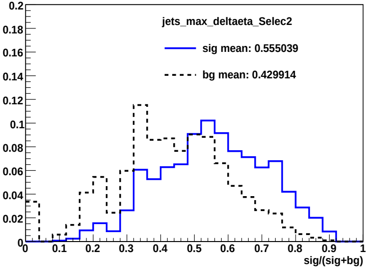
- good agreement of W and Z
- good separation power

$\Delta\eta^{max}$





Separation power: 0.140

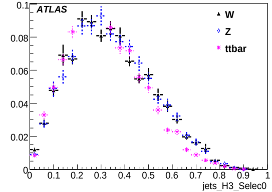


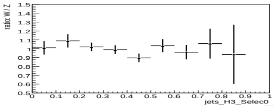
- deviations between W and Z: statistical?

Fox-Wolfram-Moment No 3

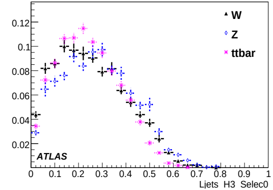
$$H_l = \sum_{i,j} \frac{|\vec{p}_i||\vec{p}_j| P_l(\hat{p}_i \hat{p}_j)}{(\sum_{i,j} |\vec{p}_i|)^2}, \ P_l = \text{Legendre-Polynome}$$

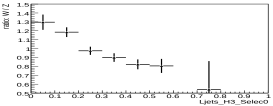
Laboratory frame:





Rest frame:





Shapes of W/Z+ jets get different after boost to rest frame! Why??

Conclusion & Outlook

idea $\sigma_Z \rightarrow \sigma_W$ could work!
considered observables show good agreement!

- understand the cause of (small) differences between W / Z + jets events
- use alternative generators (SHERPA)
- include W(Z) $\rightarrow \mu\nu(\mu\mu)$

Optimize event selections in view of biases and Xsection:

- 2nd lepton in Z→ee events $\Longleftrightarrow$ neutrino in W→eν events
- measure W+jets background for top analysis
  $\rightarrow$ cuts should be similar to top event selection
  but of course should not reject Z+jets

BACKUP

Fox-Wolfram-Moments:
$H_l = \sum_{i,j} |\vec{p}_i||\vec{p}_j| P_l(\hat{p}_i \hat{p}_j) / (\sum_{i,j} |\vec{p}_i|)^2$, P_l = Legendre-Polynome

$\mathrm{H}_T = \sum_{jet=1}^{4} E_T(jet)$
$\mathrm{H}_T^3 = \mathrm{H}_T$ - E_T(jet1) - E_T(jet2)

centrality = H_T / $\mathrm{H}_E = \sum_{jet=1}^{4} E_T(jet)$ / $\sum_{jet=1}^{4} E(jet)$

Momentum Tensor:

$\mathrm{M}_{ij} = \frac{\sum_{jet=1}^{4} p_i^{jet} p_j^{jet}}{\sum_{jet=1}^{4} |p^{jet}|^2}$ (λ_i = Eigenvalues of M)

sphericity $= \frac{3}{2}(\lambda_2 + \lambda_3)$
aplanarity $= \frac{3}{2}\lambda_3$
circularity $= 2 \, \frac{min(\lambda_1,\lambda_2)}{\lambda_1+\lambda_2}$
c parameter $= 3(\lambda_1\lambda_2 + \lambda_1\lambda_3 + \lambda_2\lambda_3)$
d parameter $= 27(\lambda_1\lambda_2\lambda_3)$