Determination of the jet energy resolution in QCD dijet events using an unbinned maximum likelihood method

CMS Jet Algorithms Meeting

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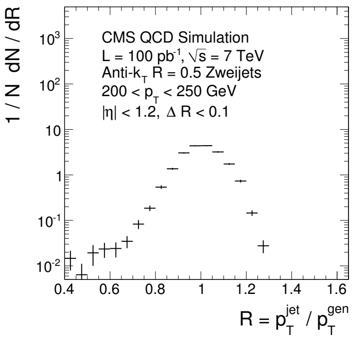
Motivation

- Presented studies within context of all-hadronic SUSY search
- $\not{E}_T$ from QCD background to signatures
- Data driven estimation: smearing of well-measured QCD jets with resolution
- Here: determination of jet resolution from dijet events
  - Large QCD cross section
  - Early sensitivity to non-gaussian tails
  - Independent from signal sample ($\geq$ 3 jets)



Definition of dijet likelihood

- Description of selection biases
- Description of tails in response
- Inclusion of other data types e.g. γ-jet

Overview

1. Technique
   - Definition of the likelihood
   - Description of the resolution bias
2. Conceptual study with Toy MC
3. Event selection
   - Dataset and selection cuts
   - η binning and MC truth resolution
4. Influence of a 3rd jet
5. Resolution in Spring10 QCD MC
   - Results for Gaussian resolution
   - Results for Crystal Ball resolution

Approach to determine the resolution

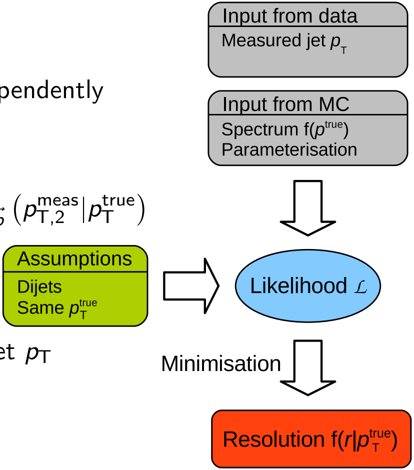
- Assumption: dijets
  - One $p_{\mathrm{T}}^{\mathrm{true}}$ for both jets
  - Measured jet $p_{\mathrm{T},i}^{\mathrm{meas}}$ fluctuate independently
- Probability density $f_{\vec{b}}(p_{\mathrm{T},1}^{\mathrm{meas}}, p_{\mathrm{T},2}^{\mathrm{meas}})$

$$\propto \int_0^{\infty} \mathrm{d}p_{\mathrm{T}}^{\mathrm{true}}\, f\left(p_{\mathrm{T}}^{\mathrm{true}}\right) \cdot f_{\vec{b}}\left(p_{\mathrm{T},1}^{\mathrm{meas}} | p_{\mathrm{T}}^{\mathrm{true}}\right) \cdot f_{\vec{b}}\left(p_{\mathrm{T},2}^{\mathrm{meas}} | p_{\mathrm{T}}^{\mathrm{true}}\right)$$

with parameterised pdfs

  - $f(p_{\mathrm{T}}^{\mathrm{true}})$: of the true jet p_{T}
  - $f_{\vec{b}}(p_{\mathrm{T},i}^{\mathrm{meas}} | p_{\mathrm{T}}^{\mathrm{true}})$: of the measured jet p_{T}
- Likelihood for N dijet events

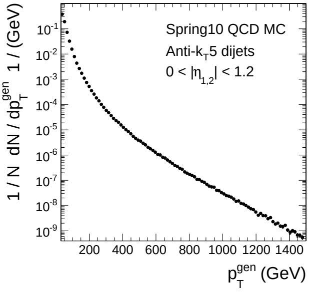
$$\mathcal{L} = \prod_{k=1}^{N} f_{\vec{b}}\left(p_{\mathrm{T},1}^{\mathrm{meas}}, p_{\mathrm{T},2}^{\mathrm{meas}}\right)$$

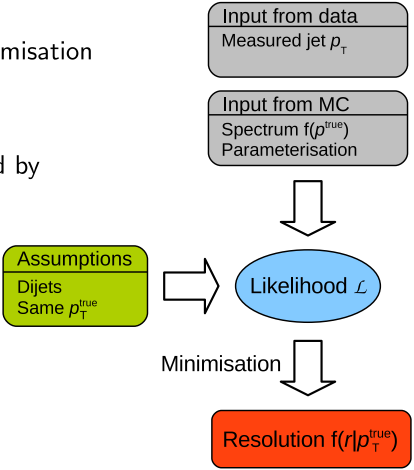


- Max($\mathcal{L}$): parameters $\vec{b} \longrightarrow f_{\vec{b}}(p_{\mathrm{T},i}^{\mathrm{meas}} | p_{\mathrm{T}}^{\mathrm{true}}) \longrightarrow$ resolution $f_{\vec{b}}(r | p_{\mathrm{T}}^{\mathrm{true}})$

Parameterisation of pdfs

1. Resolution $f_{\vec{b}}(r|p_{\mathrm{T}}^{\mathrm{true}})$
   1. Gaussian
   2. Crystal Ball function
   - Parameters $\vec{b}$ determined by maximisation
2. Spectrum $f(p_{\mathrm{T}}^{\mathrm{true}})$ from MC
   - Fixed during maximisation
   - Uncertainty on resolution replaced by uncertainty on spectrum





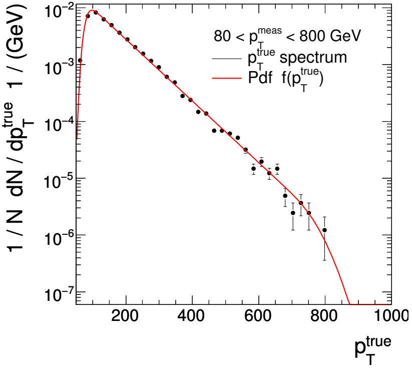
Description of the resolution bias

- Cuts on measured p_T: $p_T^{min} < p_T^{meas} < p_T^{max}$
  - Resolution bias: migration effects due to finite resolution
- Each event considered twice, cuts on 1. or 2. jet
  - Avoidance of *additional* bias by p_T ordering

Inclusion of resolution bias in $f(p_T^{true})$[1]

$$f(p_T^{true}) \rightarrow f(p_T^{true}) \int_{p_T^{min}}^{p_T^{max}} dx' \, f_{MC}(x'|p_T^{true})$$

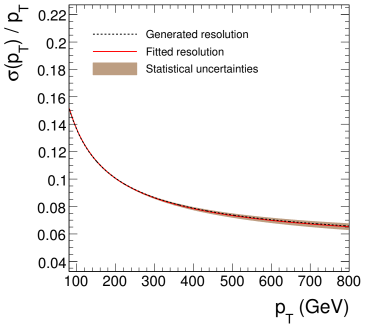
- $f_{MC}(x'|p_T^{true})$: MC truth resolution
- Additional uncertainty

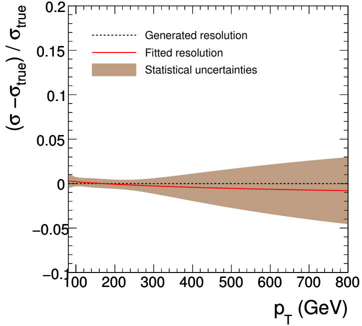


Resolution bias considered in fit

[1] And normalisation of response pdf

Conceptual study with Toy MC simulation





- Dijets with Gaussian resolution

$$\frac{\sigma}{p_T} = \frac{b_0 \text{ GeV}}{p_T} \oplus \frac{b_1 \sqrt{\text{GeV}}}{\sqrt{p_T}} \oplus b_2$$

b_i	True value	Fit result
0	4	4 ± 1
1	1.2	1.20 ± 0.07
2	0.05	0.049 ± 0.005

Method is consistent for ideal dijet events

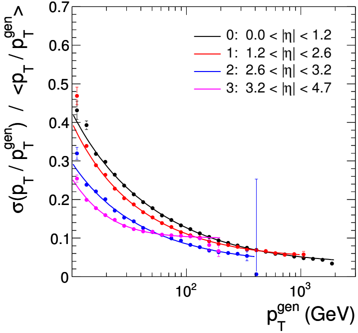
Dataset and selection cuts

- /QCDFlat_Pt15to3000/Spring10-START3X_V26_S09-v1/GEN-SIM-RECO
- Event weights for $L = 50\ \mathrm{pb}^{-1}$ and QCD spectrum
- L2L3 corrected anti-k_T5 calo jets
- Dijet selection
  - 2 jets leading in p_T, *here:* L2L3 corrected p_T(caloJet)
  - Both jets in same $|\eta|$ bin
  - $p^3_{\mathrm{T,rel}} < 0.1$ with $p^3_{\mathrm{T,rel}} = \frac{2p^3_\mathrm{T}}{p^1_\mathrm{T}+p^2_\mathrm{T}}$
  - $f_\mathrm{em} > 0.01$

η binning and MC truth resolution

- Response distributions p_T/p_T^{gen} in p_T^{gen} bins
- Gaussian fits with

$$\frac{\sigma}{p_T} = \frac{b_0}{p_T} \oplus \frac{b_1}{\sqrt{p_T}} \oplus b_2$$



	η_{min}	η_{max}	b_0 (GeV)	b_1 ($\sqrt{\text{GeV}}$)	b_2
0	0	1.2	1.9 ± 0.2	1.205 ± 0.006	0.0342 ± 0.0007
1	1.2	2.6	to be added...		
...					

Influence of a 3rd jet

- Assumption of method

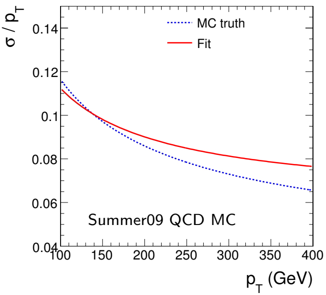
  2 jets with equal p_T^{true}

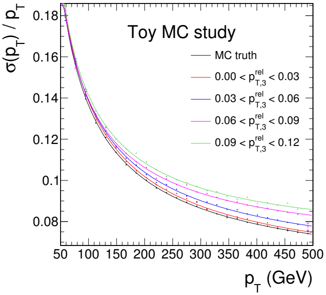
- p_T-imbalance by additional jet

→ Fitted resolution too large

Solutions

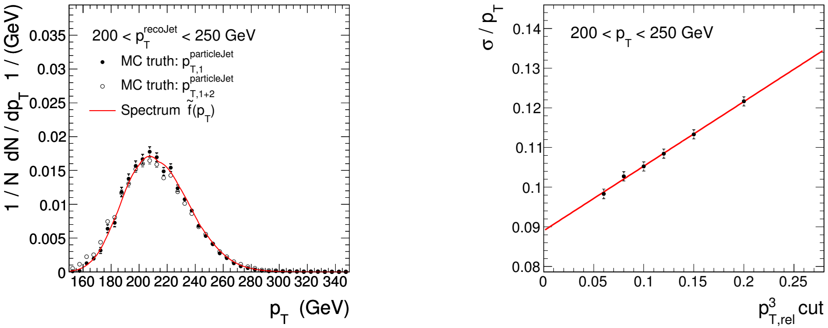
1. Inclusion of 3rd jet into dijet pdf
   - Work in progress
2. Variation of $p^3_{T,rel}$ cut and extrapolation $p^3_{T,rel} \to 0$
   - ? How to extrapolate 3 higly correlated parameters in $\sigma(p_T)$
   - → **Fit of mean $\bar{\sigma}$ in bins of p_T**





Resolution in Spring10 QCD MC

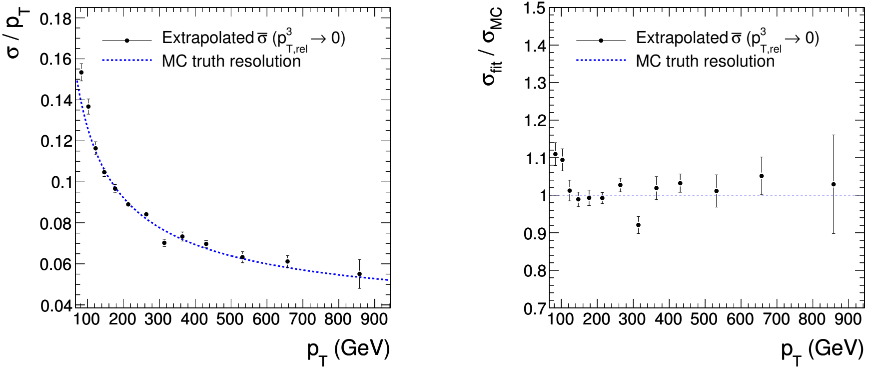
- Selection of dijet events in bins of p_{T} and η
- Description of resolution bias in pdf
- Fit of p_{T} independent $\bar{\sigma}$ in Gaussian resolution
- Variation of cut on $p^3_{\mathrm{T,rel}}$



- Linear extrapolation of $\bar{\sigma}$ to ideal dijet configuration

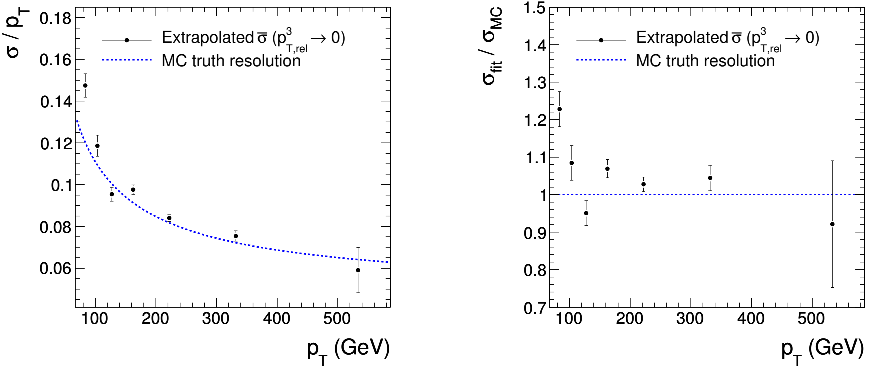
Extrapolated resolution for $0 < |\eta| < 1.2$

- p_T is mean of assumed spectrum $f(p_T^{true})$



- Agreement of fitted and MC truth resolution within statistical uncertainties
- Excess at low p_T due to incorrect jet ordering (*to be confirmed*, maybe different dijet selection?)

Extrapolated resolution for $1.2 < |\eta| < 2.6$



- Significant fluctuations
- Again excess at low pt

Extrapolated resolution for $2.6 < |\eta| <?$

To be added. . .

Example fit

To be added...

Summary & Outlook

- Presentation of a method to determine the jet energy resolution in QCD dijets using an unbinned maximum likelihood fit
- Resolution bias in event selection considered in fit
- Sensitivity to non-gaussian tails in response: example fit of Crystal Ball function shown
- p_{T}-imbalance due to 3. jet biases result
- Gaussian resolution in Spring10 MC fitted in bins of p_{T} and η
  - Extrapolation to dijet configuration
  - Reasonable agreement to MC truth
  - Excess at low p_{T} to be studied
- To be studied: direct description of p_{T}-imbalance in pdf $\longrightarrow$ fit of p_{T} dependent resolution

Backup

Konzeptstudie: Parameterkorrelationen

- Simulation von idealen Zweijetereignissen
- Exponentielles Spektrum $\propto e^{-x/100}$
- Gaußsche Auflösung

$$\frac{\sigma}{p_T} = \frac{b_0 \text{ GeV}}{p_T} \oplus \frac{b_1 \sqrt{\text{GeV}}}{\sqrt{p_T}} \oplus b_2$$

- Fitergebnis

b_i	Wahrer Wert	Fitergebnis
0	4	5 ± 1
1	1.2	1.18 ± 0.07
2	0.05	0.051 ± 0.006