Constrained Fitting for Semileptonic $t\bar{t}$-Events

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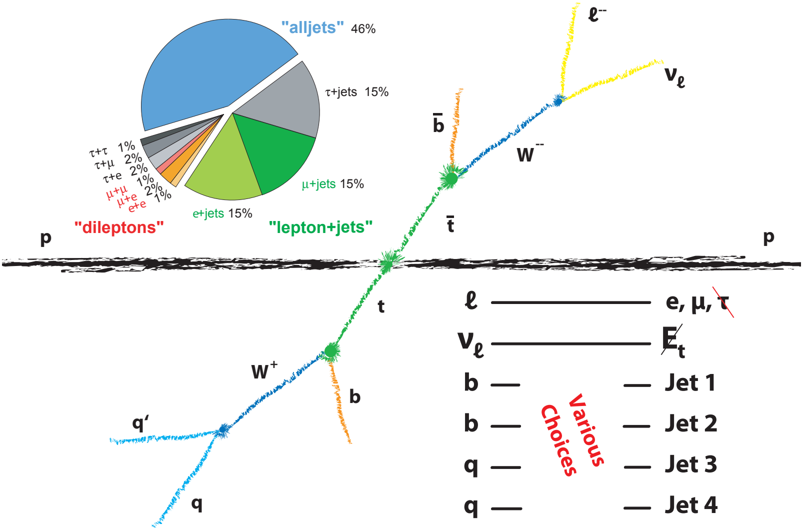
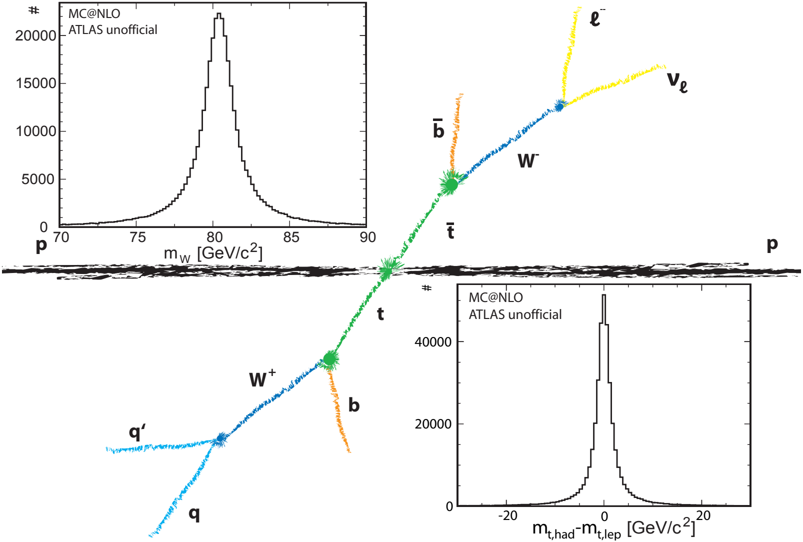
Semileptonic Channel



World average W mass: 80.398 GeV/c^2



Fit Variables and Constraints

Invariant Masses

- $m_{W,\ell} = \sqrt{(p_\ell + p_\nu)^2} = \sqrt{(E_\ell + E_\nu)^2 - (\vec{p}_\ell + \vec{p}_\nu)^2}$
- $m_{W,\text{had}} = \sqrt{(p_{q_1} + p_{q_2})^2} = \sqrt{(E_{q_1} + E_{q_2})^2 - (\vec{p}_{q_1} + \vec{p}_{q_2})^2}$
- $m_{t,\ell} = \sqrt{(p_\ell + p_\nu + p_{b,\ell})^2} = \sqrt{(E_\ell + E_\nu + E_{b,\ell})^2 - (\vec{p}_\ell + \vec{p}_\nu + \vec{p}_{b_\ell})^2}$
- $m_{t,\text{had}} = \sqrt{(p_{q_1} + p_{q_2} + p_{b,\text{had}})^2} = \sqrt{(E_{q_1} + E_{q_2} + E_{b,\text{had}})^2 - (\vec{p}_{q_1} + \vec{p}_{q_2} + \vec{p}_{b,\text{had}})^2}$

Constraints (loose)

		Initial value	Uncertainty
$m_{W,\ell} - X_1 = 0$	X_1	$80.4\,\text{GeV}/\text{c}^2$	$6\,\text{GeV}/\text{c}^2$
$m_{W,\text{had}} - X_2 = 0$	X_2	$80.4\,\text{GeV}/\text{c}^2$	$6\,\text{GeV}/\text{c}^2$
$m_{t,\ell} - m_{t,\text{had}} - X_3 = 0$	X_3	$0\,\text{GeV}/\text{c}^2$	$5\,\text{GeV}/\text{c}^2$

Fit Variables and Constraints

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- $m_{t,\ell} = \sqrt{(p_\ell + p_\nu + p_{b,\ell})^2} = \sqrt{(E_\ell + E_\nu + E_{b,\ell})^2 - (\vec{p}_\ell + (p_{\nu,x}, p_{\nu,y}, p_{\nu,z})^T + \vec{p}_{b_\ell})^2}$
- $m_{t,\text{had}} = \sqrt{(p_{q_1} + p_{q_2} + p_{b,\text{had}})^2} = \sqrt{(E_{q_1} + E_{q_2} + E_{b,\text{had}})^2 - (\vec{p}_{q_1} + \vec{p}_{q_2} + \vec{p}_{b,\text{had}})^2}$

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Recovering the Neutrino p_z

The four vector of the neutrino is unmeasured!
There are several approaches to recover it.

p_x and p_y We will take the misssing transverse energy as an estimate.

p_z

1. Set $p_z = 0$
2. Calculate p_z from the leptonic W constraint

From $\sqrt{(p_\ell + p_\nu)^2} - m_{W,\ell} = 0$ derrive

$$p_{\nu,z}^{(1,2)} \approx \frac{a}{p_{\ell,t}^2} p_{\ell,z} \pm \frac{E_\ell}{p_{\ell,t}^2} \sqrt{a^2 - p_{\ell,t}^2 (p_{\nu,x}^2 + p_{\nu,y}^2)}$$

- $a := \frac{m_W^2}{2} + p_{\ell,x} p_{\nu,x} + p_{\ell,y} p_{\nu,y}$
- $p_{\ell,t}$ is the transverse momentum of the lepton

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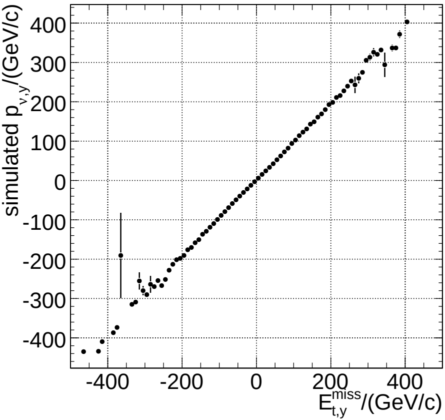
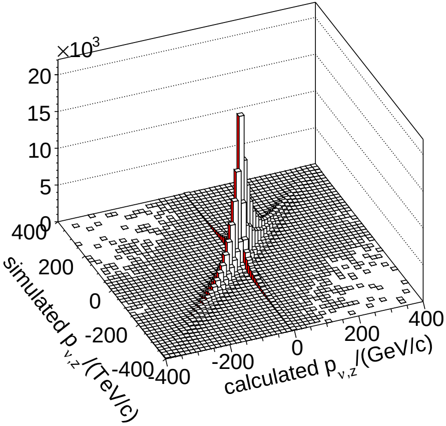
with

- $a := \frac{m_W^2}{2} + p_{\ell,x} p_{\nu,x} + p_{\ell,y} p_{\nu,y}$
- $p_{\ell,t}$ is the transverse momentum of the lepton

If discrimant < 0 use $p_z = 0$ as a fallback solution.

p_y and p_z


simulated p_{ν,y}/(GeV/c)
400
300
200
100
0
-100
-200
-300
-400
-400
-200
0
200
400
E_{t,y}^{miss}/(GeV/c)


×10^3
20
15
10
5
0
400
200
0
-200
-400
simulated p_{ν,z}/(TeV/c)
-400
-200
0
200
400
calculated p_{ν,z}/(GeV/c)

Used Data Sets

Parton Level

Aim	Well defined grounds to test method
Generator	MC@NLO
Statistics	1 000 000 lepton + jets events
Phase Space	Full

Caveat

Gluon in ttg is not treated as extra jet `today`

Full Simulation

Used Data Sets

Parton Level

Aim	Well defined grounds to test method
Generator	MC@NLO
Statistics	1 000 000 lepton + jets events
Phase Space	Full

Caveat

Gluon in *ttg* is not treated as extra jet `today`

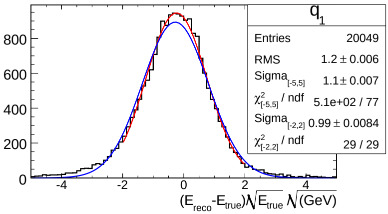
Full Simulation

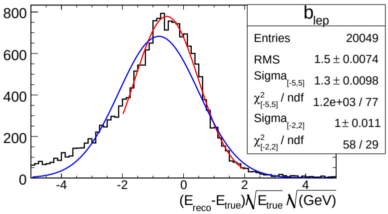
Aim	Best achievable approxiamtion of reality
Generator	MC@NLO + Herwig/Jimmy + Geant
Statistics	20049 = 8479 (e) + 11570 (μ)
Phase Space	Reconstructed Jets with • $E > 20$ GeV • $\eta > 2.5$ • $\Delta R < 0.1$ Match

Smearing of Parton Level

To simulate a detector resolution, the energies of the partons are smeared acording to the following resolution assumption:

$$\frac{\sigma(E)}{E} = \frac{\alpha_i}{\sqrt{E}} \qquad [E] = \mathrm{GeV}$$



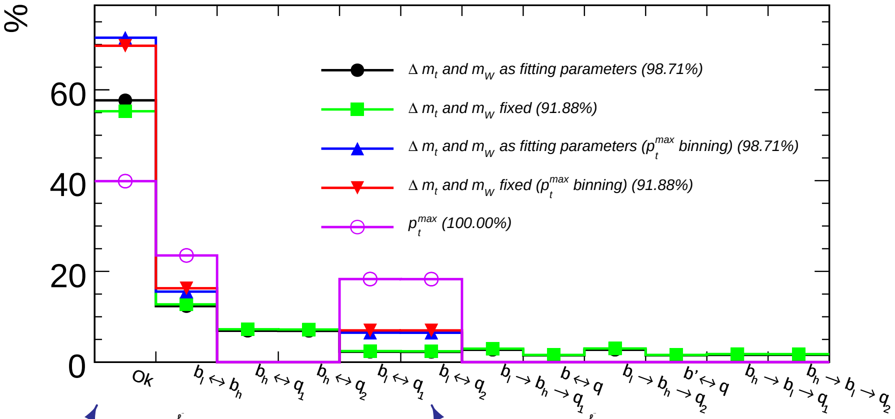


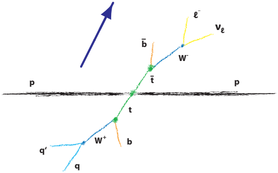
	b quarks	light quarks	leptons
α_1	75 %	60 %	15 %
α_4	140 %	105 %	22 %

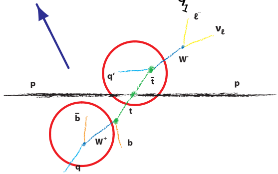
Selection Recipe

1. Take an event
2. Assign each jet to all possible roles $\Rightarrow$ e. g. 12 Permutations for 4 jets
3. Do the fit for both neutrino p_z solutions
4. Select the permutation with the smallest χ^2

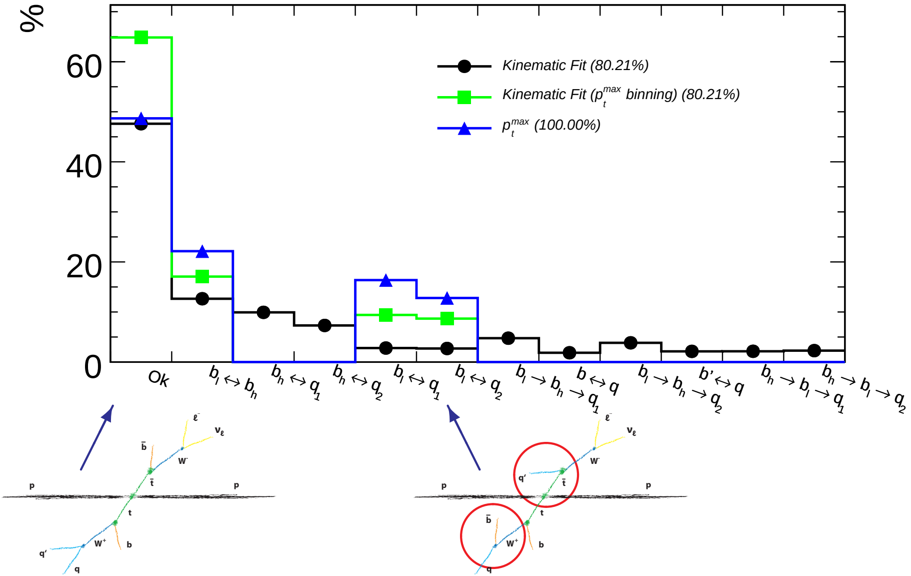
Distribution of Selected Permutation (Parton Level)





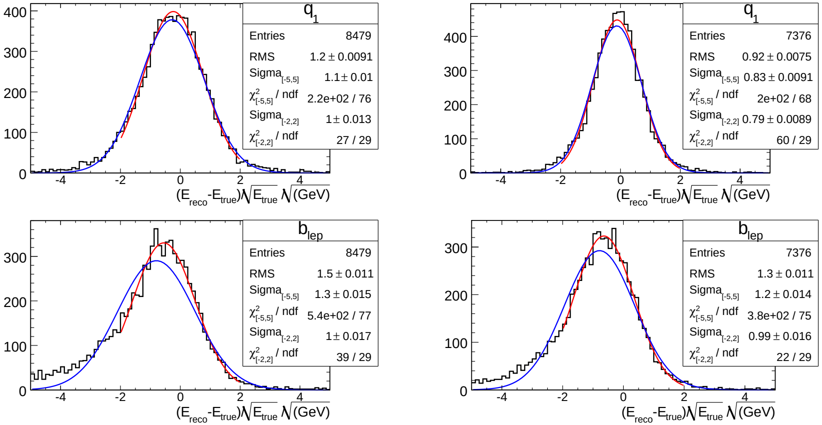


Distribution of Selected Permutation (Reco Level)



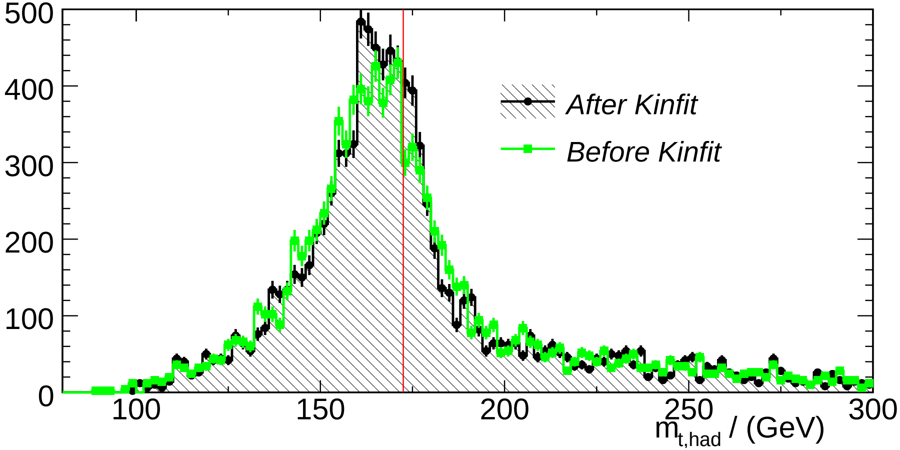
Improvement of Resolution (Reco Level)

The constraints should improve the resolution:



And they do!

Improvement of Resolution (Reco Level)



Conclusions and Outlook

Conclusions

- Kinematic fit selects correct configuration in about 65 % for reco objects
- In comparison: $p_{t,max}$ only in 47 %
- Constraints (m_W, ...) improve resolution

Plans

- Port to unmatched events (finished probably by end of this week)
- Quantisation of resolution improvement
- Background studies (already working, promising)

BACKUP

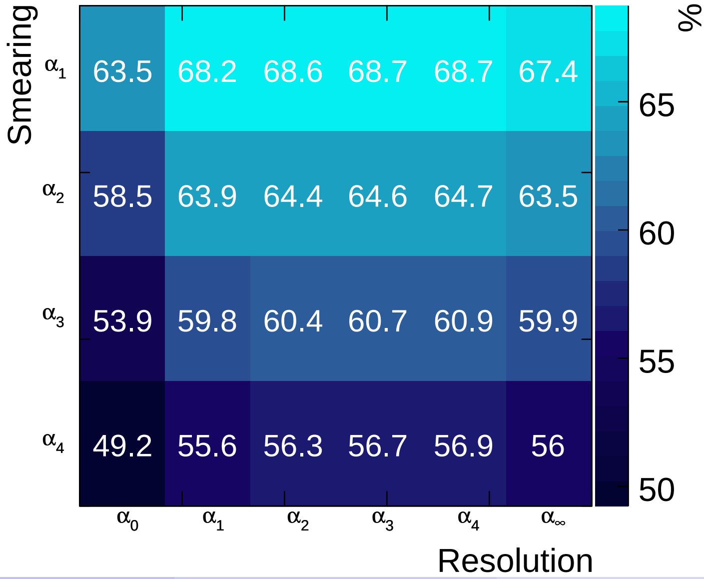
Dependence on the Assumed Resolution

Since in data one cannot use Monte Carlo `truth` to determine the `correct` energy resolution the method should be in certain boundaries robust against misestimated uncertainties.

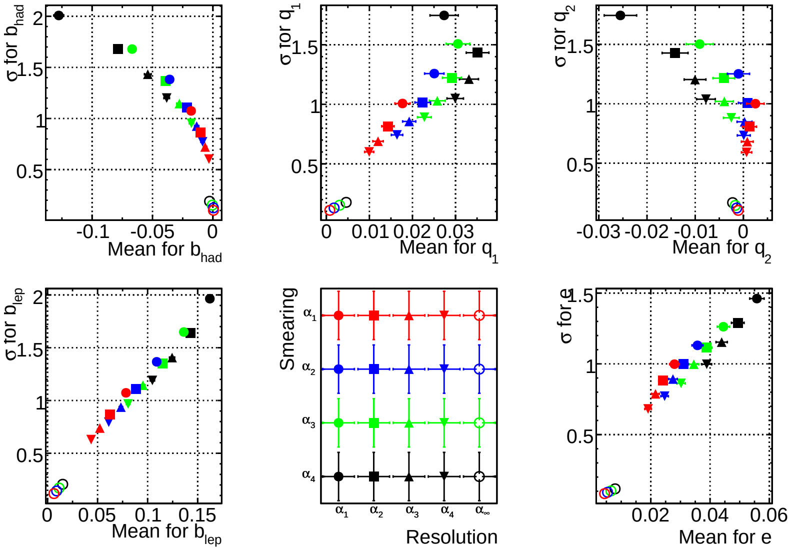
$$\frac{\sigma(E)}{E} = \frac{\alpha_i}{\sqrt{E}} \qquad [E] = \mathrm{GeV}$$

	b quarks	light quarks	leptons
α_0	10	5	2
α_1	75	60	15
α_2	95	75	17
α_3	115	90	19
α_4	140	105	22
α_∞	1000	800	200

Dependence on Resolution - Correct convergence



Dependence on Resolution - Pull Distributions



Influence of Gaussian Assumption