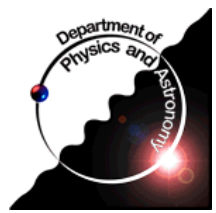
top mass in t-tbar → 6jets
Status Report

Top meeting
CERN, 21 Feb 2007
Michel Lefebvre

Keith Edmonds M.Sc. project
Much help from Rolf Seuster

Physics and Astronomy
University of Victoria
British Columbia, Canada



Introduction and goals

- Fully hadronic t-tbar decays
  - Attempt at measuring the top mass
  - First see how far one can go without b-tagging
    - only calorimetry
  - Huge combinatorics and QCD backgrounds

Samples

- Signal sample
  - 5204, athena 11.0.5 AOD
    - 270k events
    - Cone4TowerParticleJets
- Background samples
  - QCD multijet, alpgen 2.06, atlfast, athena 12.0.31
    - home production
      - generation: p_{Tmin}=25 GeV and R_{min}=0.5
      - matching: E_{Tmin}=25 GeV and R_{jet}=0.5
    - 2, 3, 4, 5, 6(inc.) jets

Selections

- Event selection
  - at least 6 jets in $|\eta| < 3$
  - at least 6 jets satisfying graded p_T cuts
    - 85, 65, 50, 40, 40, 40 GeV
- Hypotheses for each event
  - only consider the 6 highest p_T jets
  - consider all 90 combinations for t-tbar topology
    - 10 distinct triplet pairs, each triplet with 3 possible W
      - assumes one cannot distinguish charges and quark types

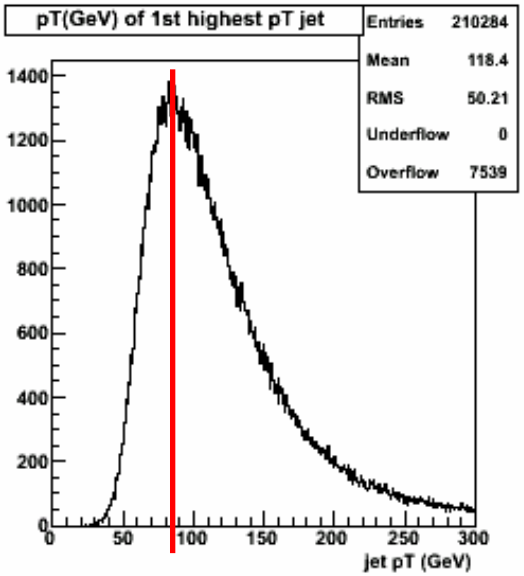
Selections

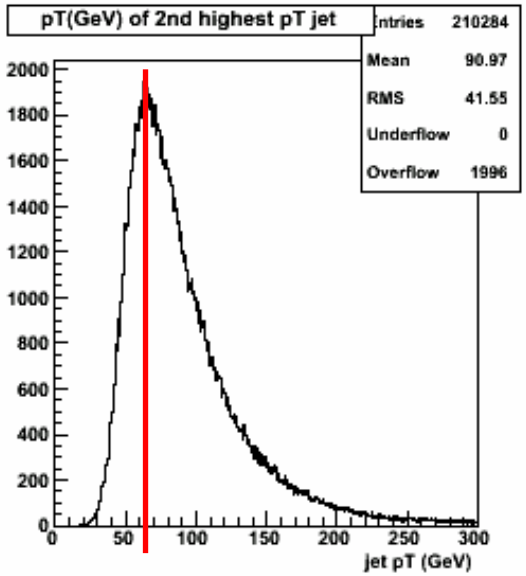
- Hypotheses treatment

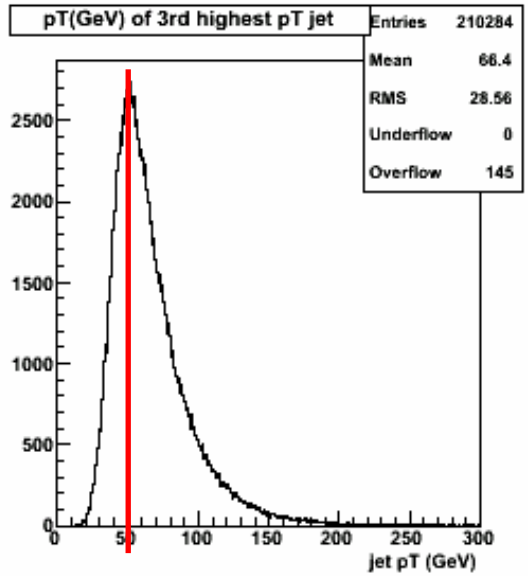
  build both W and top 4-vectors from jets

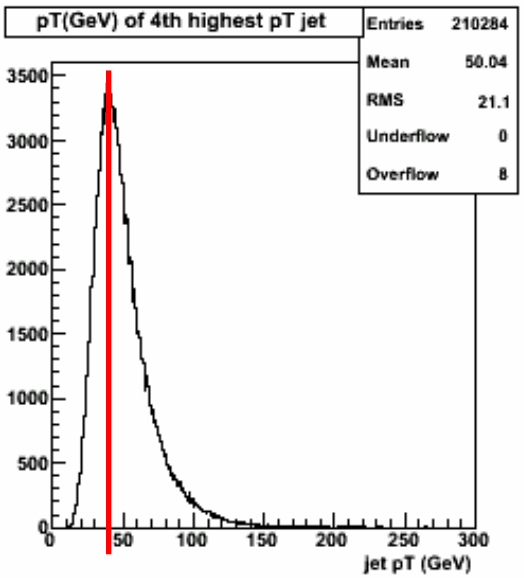
- Hypotheses selection
  - M_W window cut: $40 < M_W < 120$ GeV
  - ΔM_{top} window cut: $|\Delta M_{top}| < 100$ GeV
  - top p_T cut: $p_T > 100$ GeV
- Perform kinematic fit
- Hypotheses selection
  - valid kinematic fit: full accurate cov matrix
  - kinematic fit χ^2 cut: $\chi^2 < 10$

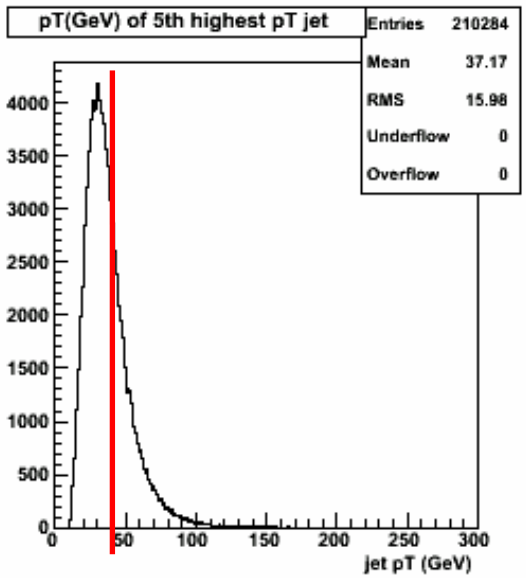
P_T distribution: signal

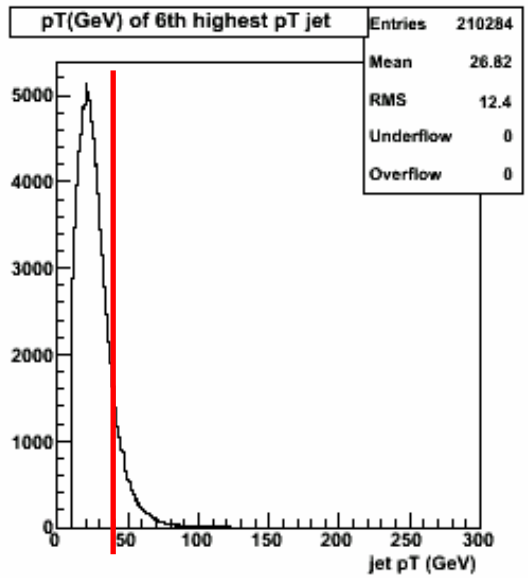




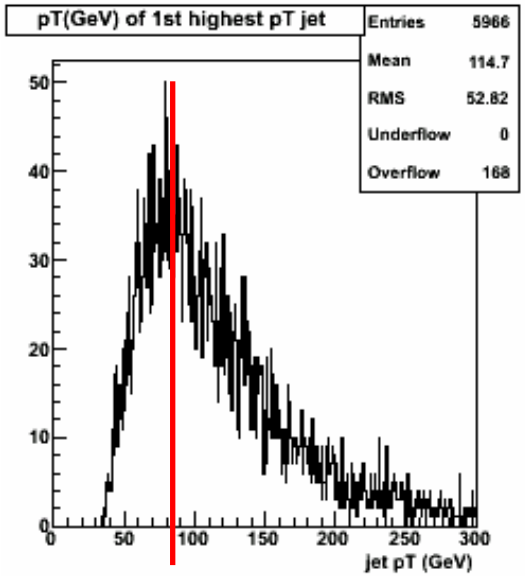


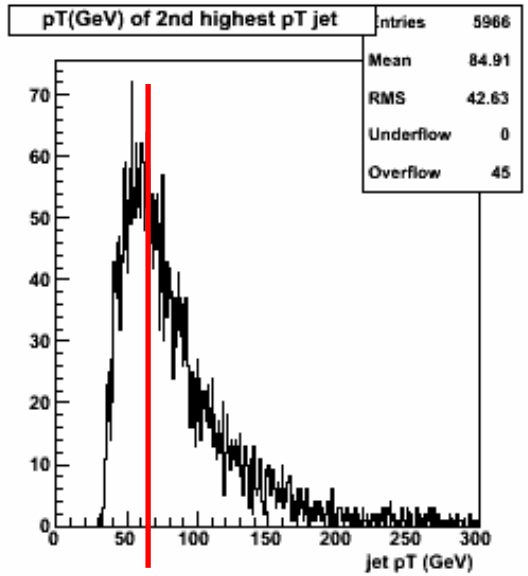


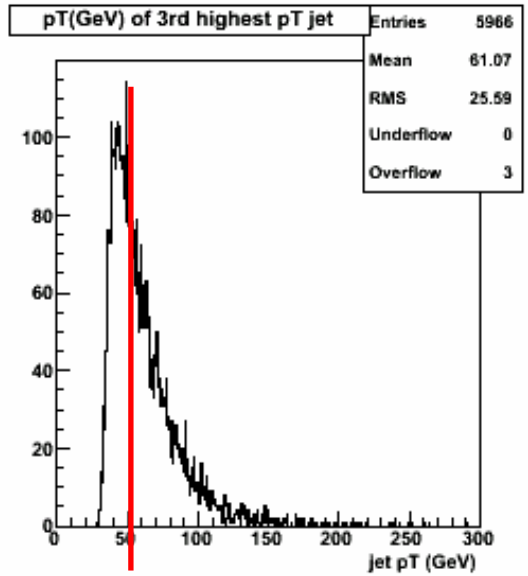


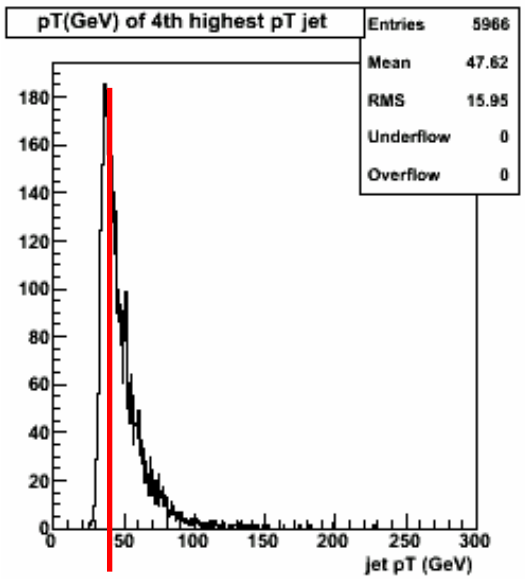


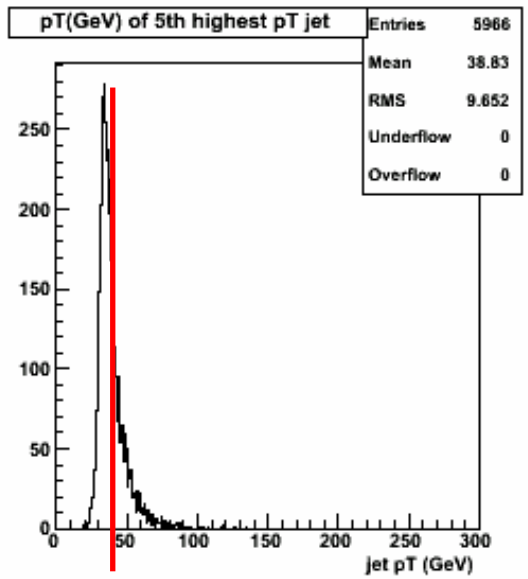
P_T distribution: 6 partons background

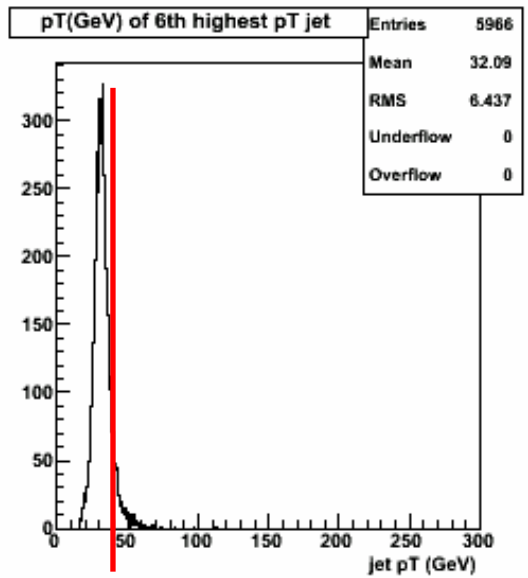












Kinematic fit: input parameters

- Experimental jets
  - initial 4-vectors $p_j^m = \left(E_j^m, \vec{p}_j^{\,m}\right) \quad j = 0,1...5$
  - we set $m_j^m \equiv 0$
    - should not do this when considering merged partons
  - each jet therefore characterized by the triplet

$$\left(E_j^m, \eta_j^m, \varphi_j^m\right) \qquad \left|\vec{p}_j^{\,m}\right| = E_j^m$$

    - for now assume no b-jet tagging

Kinematic fit: simple chi2

- consider a simple chi2 fit
  - assume jet direction exact
  - constraint both W masses
  - demand that both tops have the same mass
  - consider Gaussian for W and top masses
    - easy to improve to likelihood and Breit-Wigner if needed
  - for a given jet hypothesis consider the chi2

$$\chi^2 = \sum_{j=0}^{5} \left(\frac{E_j^m - E'_j}{\sigma_{Ej}} \right)^2 + \left(\frac{M'_{W^+} - M_W}{\Gamma_W} \right)^2 + \left(\frac{M'_{W^-} - M_W}{\Gamma_W} \right)^2 + \left(\frac{M'_t - M'_{tbar}}{\sqrt{2}\Gamma_t} \right)^2$$

    - the free parameters are the six fit jet energies E'

Kinematic fit

- start each fit with $E'_j = E^m_j$
- in the fit use $p'_j = \left(E'_j,\ E'_j \hat{p}^m_j \right)$

$$M'_{\mathrm{W}^+} = \sqrt{\left(p'_0 + p'_1 \right)^2} \qquad M'_{\mathrm{W}^-} = \sqrt{\left(p'_2 + p'_3 \right)^2}$$

$$M'_{\mathrm{t}} = \sqrt{\left(p'_0 + p'_1 + p'_4 \right)^2} \qquad M'_{\mathrm{tbar}} = \sqrt{\left(p'_2 + p'_3 + p'_5 \right)^2}$$

- for $M_{\mathrm{W}},\ \Gamma_{\mathrm{W}},\ \Gamma_{\mathrm{t}}$ use the same values as used in the generation
- use the best possible estimate of the jet energy error $\sigma_{Ej}\left(E_j, \eta_j \right)$
  - Here just use $\dfrac{100\%}{\sqrt{E(\mathrm{GeV})}} \oplus 10\%$

Cut flow

sample	signal	signal with truth matching	6 partons	5 partons	4 partons
cross section (pb)	369	369	34334	173852	986113
events	270784	270784	7364	28339	28166
at least 6 jets in |eta| < 3	210341	210341	5966	15333	7214
at least 6 jets with enough pt	23727	23727	294	76	3
efficiency	0.088	0.088	0.040	0.0027	0.00011
hypotheses	2135430	23727	26460	6840	270
matched jet-parton 1to1		6484			
all highest pt jets		1104			
after W mass cut	292236	1073	2648	658	10
after delta top mass cut	83993	1069	540	97	5
after top pt cut	49906	1038	323	50	5
attempted kinematic fit	49906	1038	323	50	5
valid fits	46214	1038	286	39	4
final: after chi2 cut	12599	896	49	3	0
efficiency	0.0059	0.038	0.0019	0.00044	0

Jet-parton matching

- Study events with “true” jet hypothesis
- Matching criteria
  - For each parton, look for a matching jet
    - restrict search in a region limited by $\Delta R_{max} = 0.2$
    - keep the closest jet in this region
  - Demand that a jet be matched only once
    - matching efficiencies depends on interparton distances
      - same top combinations

$\langle \Delta R(u\text{-}b) \rangle$	$= 2.220 \pm 0.002$	$\langle \Delta R(ubar\text{-}bbar) \rangle$	$= 2.219 \pm 0.002$
$\langle \Delta R(u\text{-}dbar) \rangle$	$= 2.008 \pm 0.002$	$\langle \Delta R(ubar\text{-}d) \rangle$	$= 2.010 \pm 0.002$
$\langle \Delta R(dbar\text{-}b) \rangle$	$= 2.037 \pm 0.002$	$\langle \Delta R(d\text{-}bbar) \rangle$	$= 2.036 \pm 0.002$

      - other 9 combinations

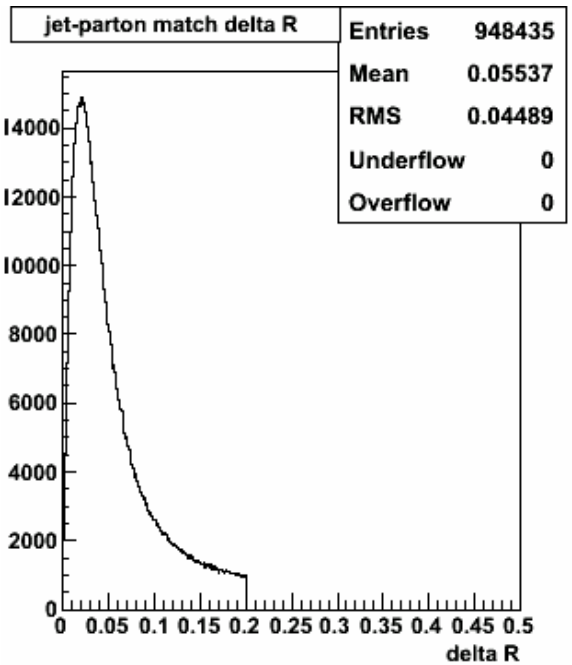
$\langle \Delta R \rangle \approx 2.40$

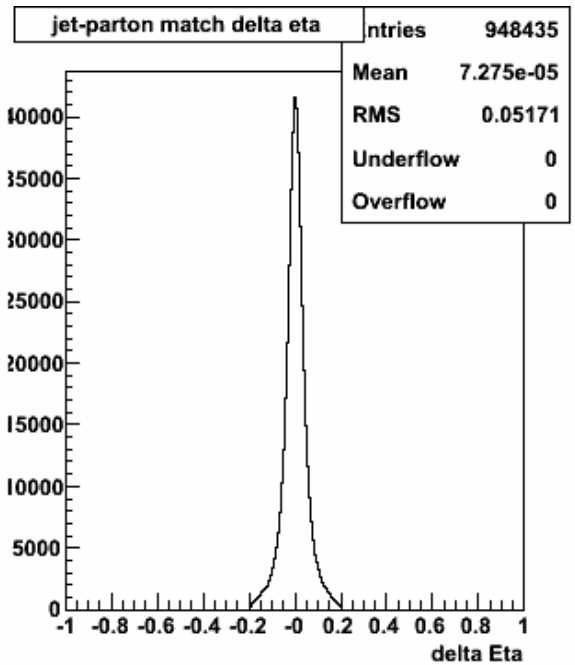
Jet-parton matching

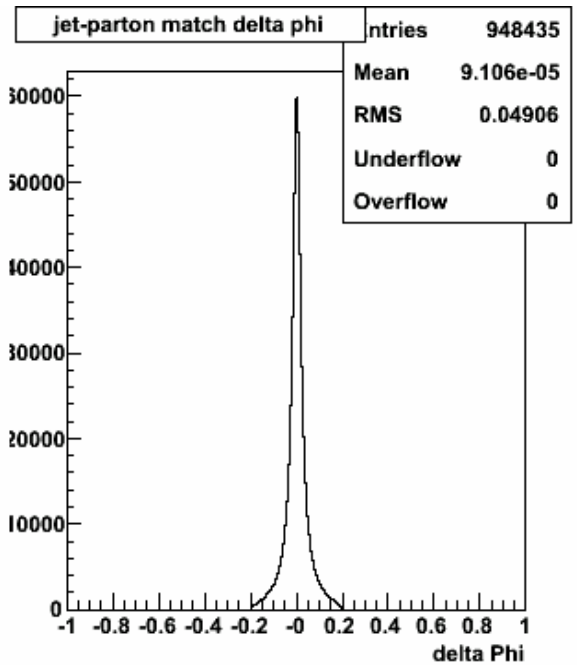
Matching efficiencies

• u	76.1%	± 0.1%	ubar	76.2%	± 0.1%
• dbar	70.2%	± 0.1%	d	70.2%	± 0.1%
• b	79.1%	± 0.1%	bbar	79.2%	± 0.1%

Jet-parton distances







- $\Delta R < 0.2$ is a reasonable criteria

Jet kinematics uncertainties

- Need to characterize kinematics uncertainties
  - required for the kinematic fit
- Consider 1-to-1 matched jet-parton pairs
  - study the quantities

$$\Delta E \equiv E^m - E$$

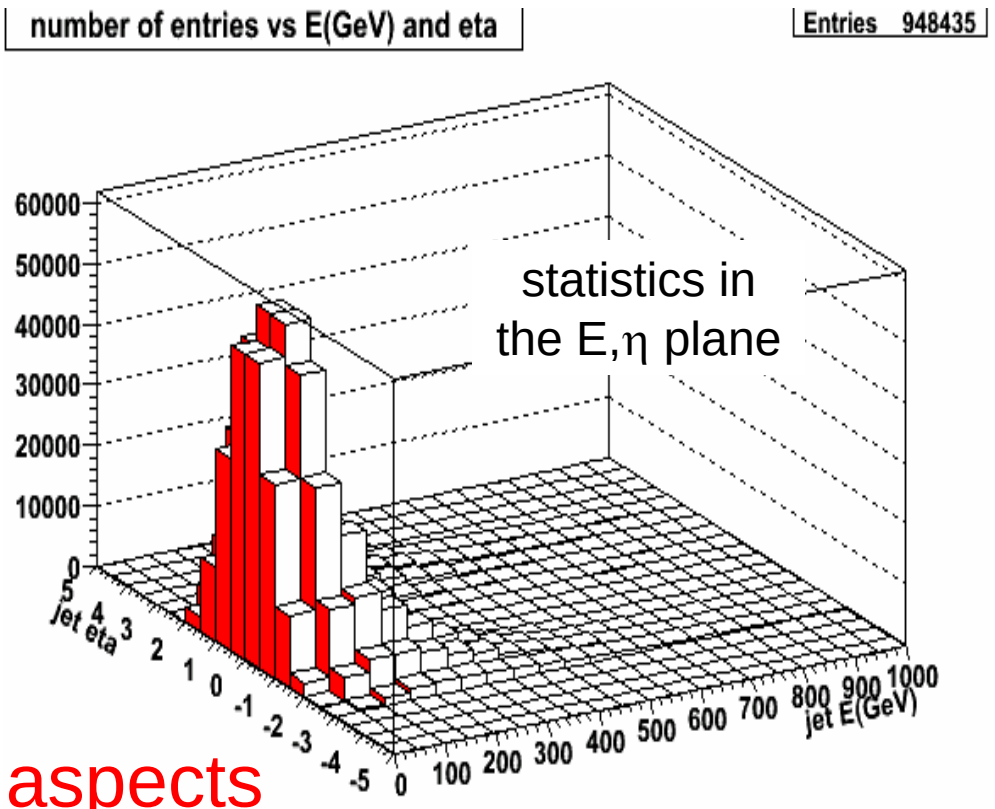
$$\langle \Delta E \rangle \qquad \sigma_E \equiv \mathrm{rms}(\Delta E)$$

$$\Delta\eta \equiv \eta^m - \eta$$

$$\langle \Delta\eta \rangle \qquad \sigma_\eta \equiv \mathrm{rms}(\Delta\eta)$$

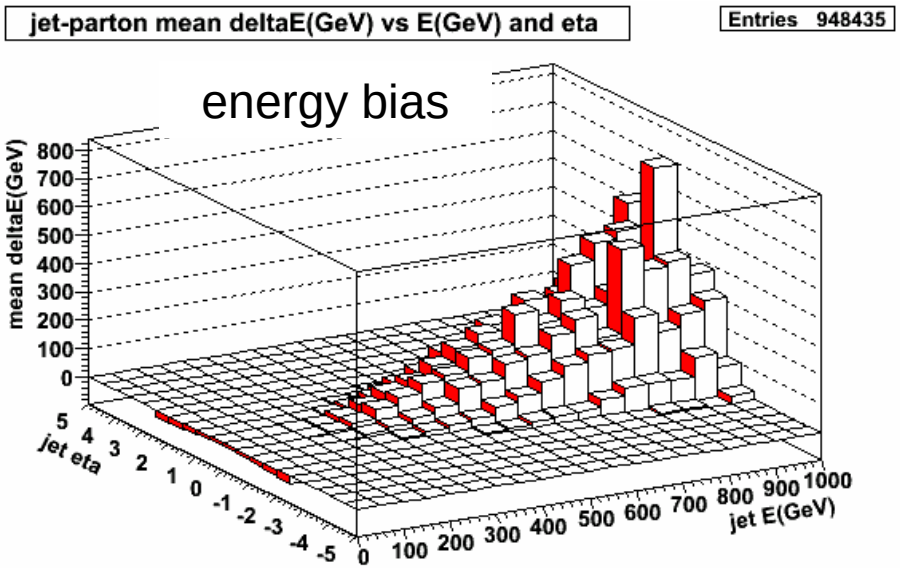
$$\Delta\varphi \equiv \varphi^m - \varphi$$

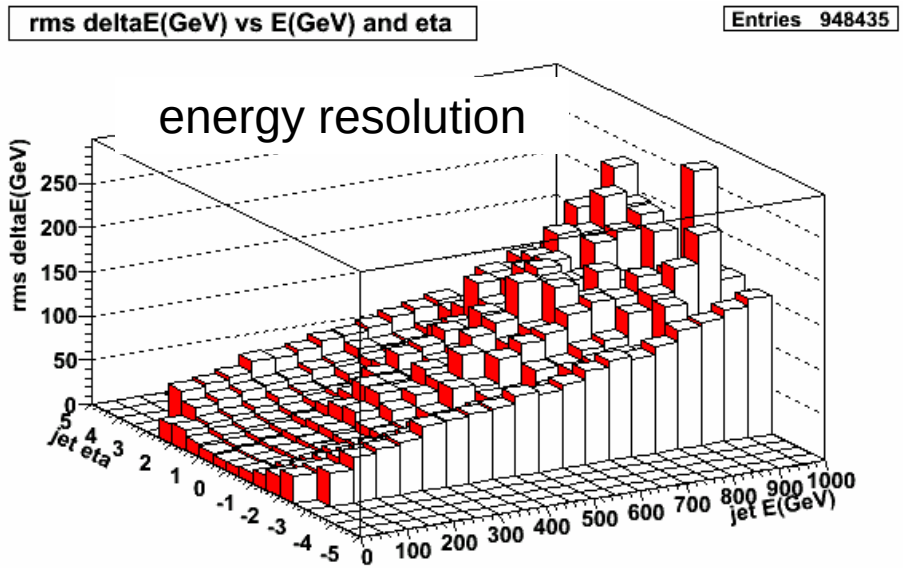
$$\langle \Delta\varphi \rangle \qquad \sigma_\varphi \equiv \mathrm{rms}(\Delta\varphi)$$

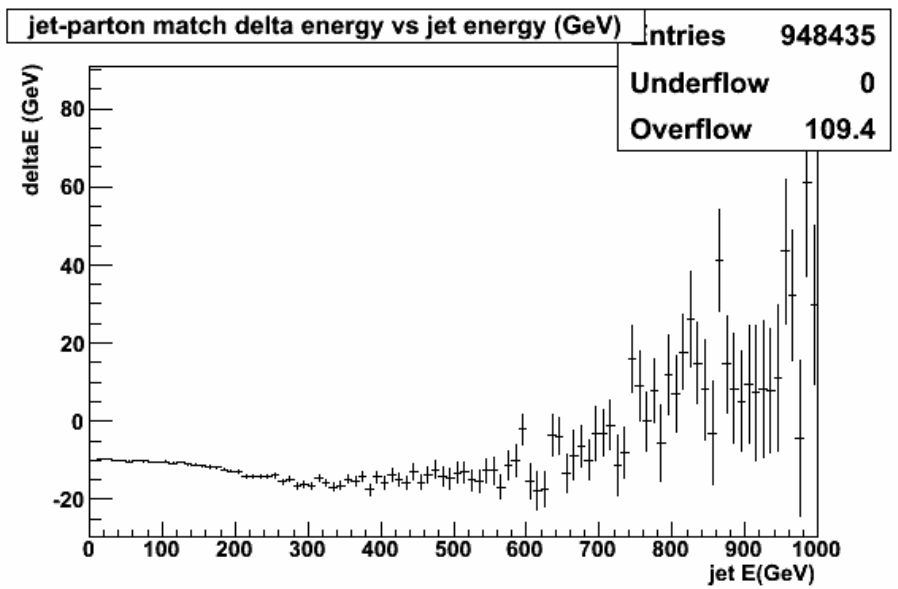


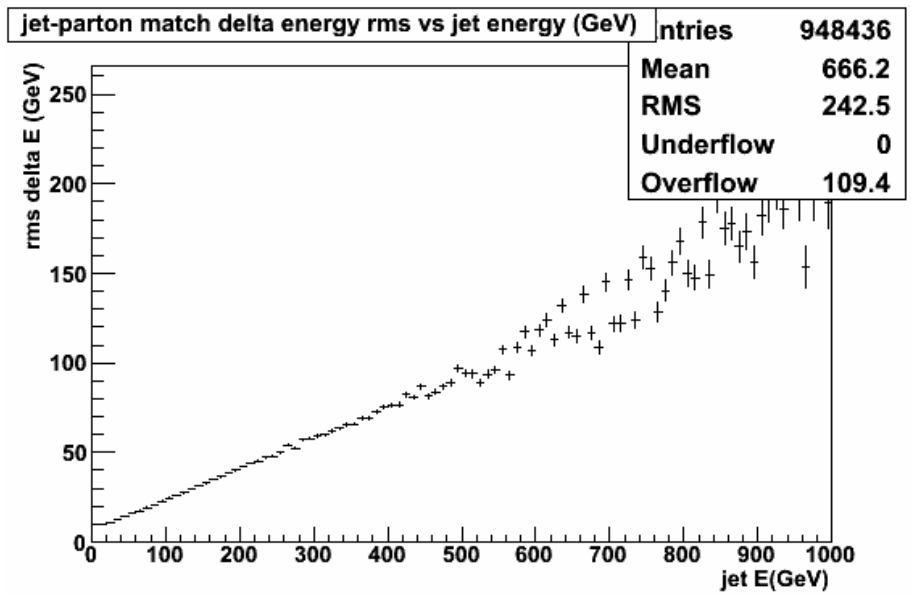
  - here focus on a few aspects

Jet kinematics: energy

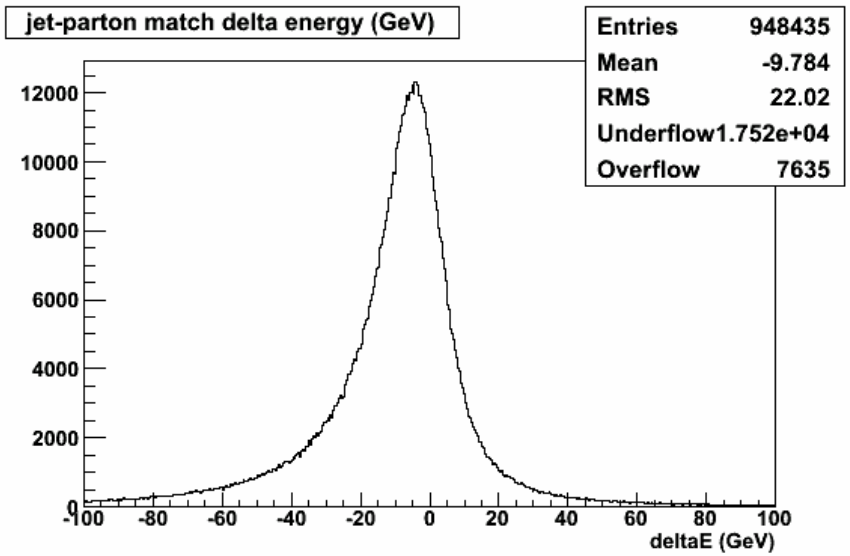


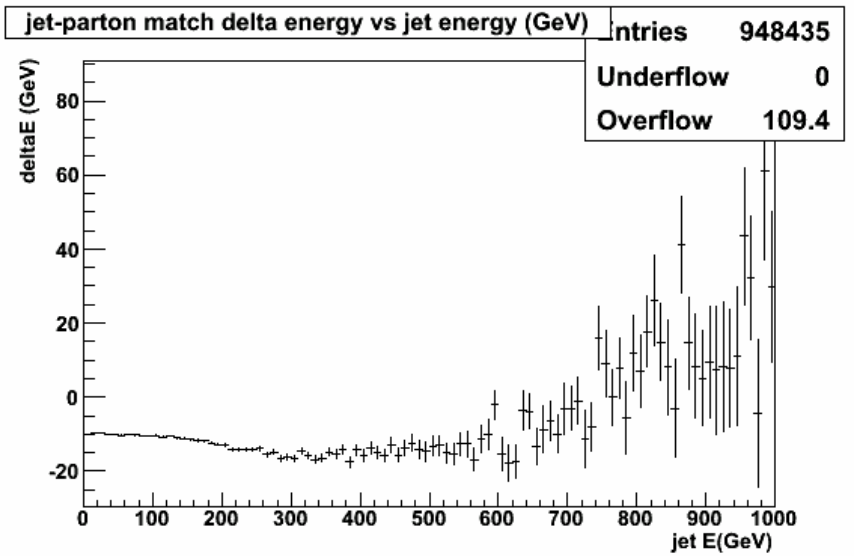


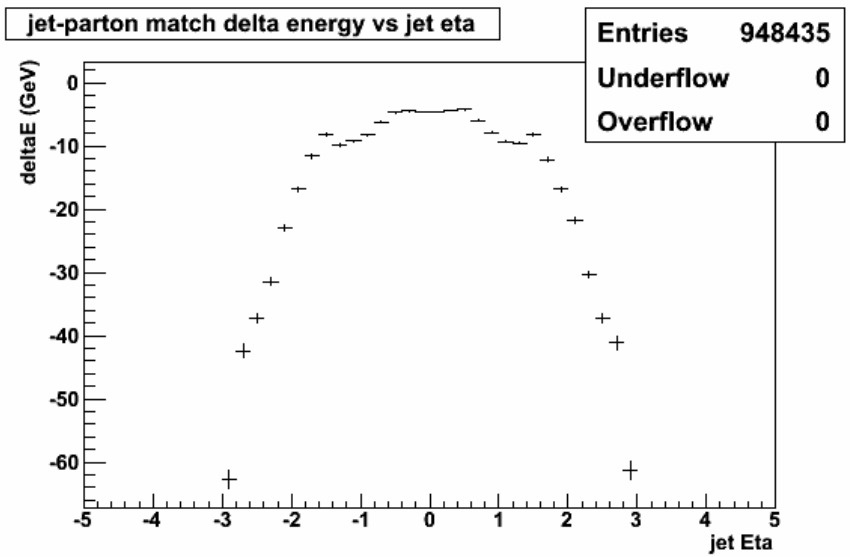


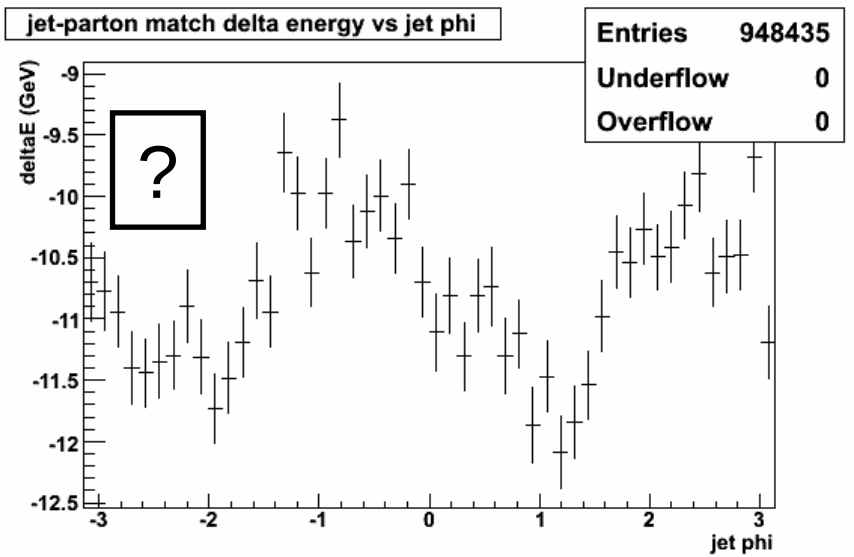


Jet kinematics: energy bias

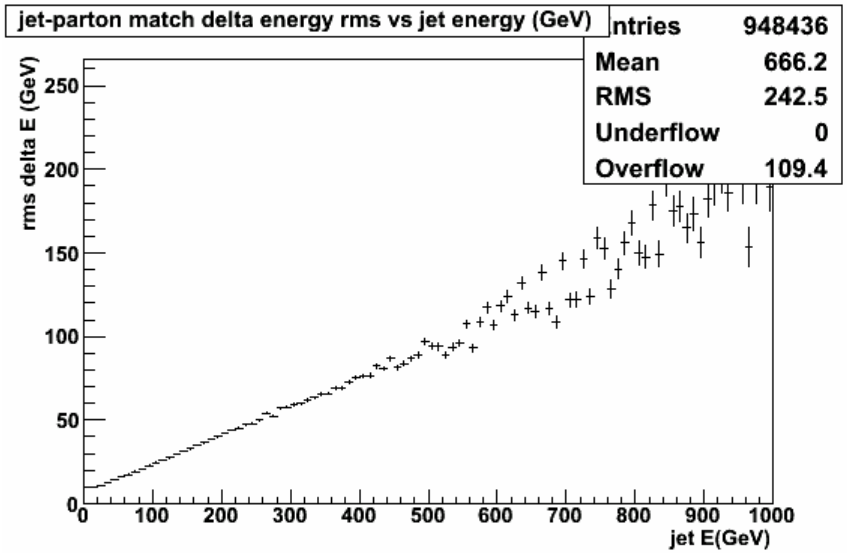


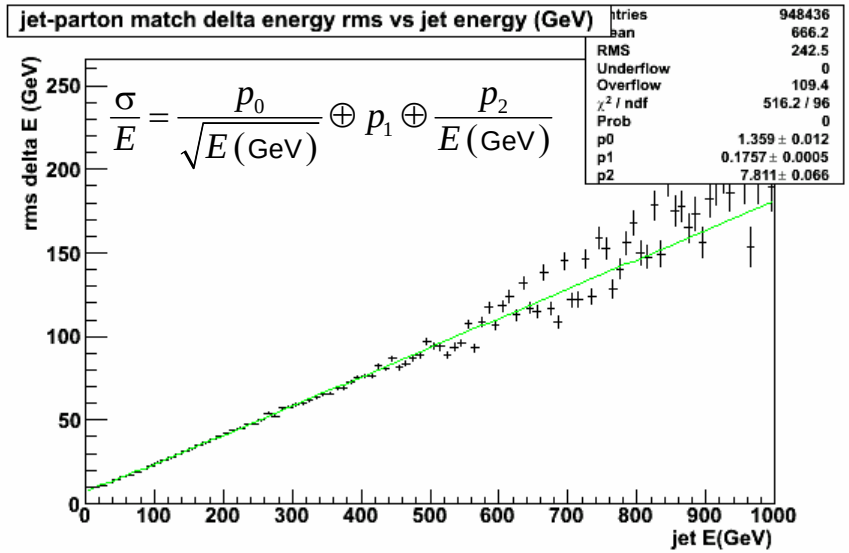


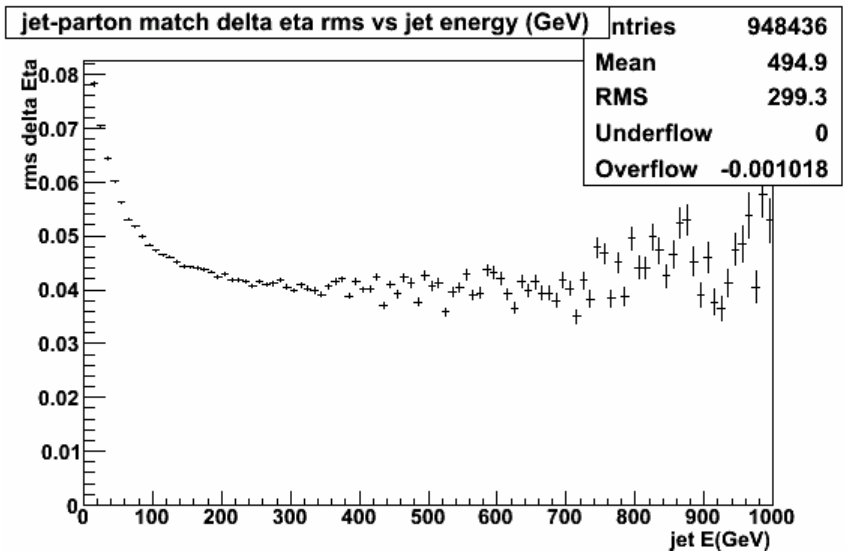


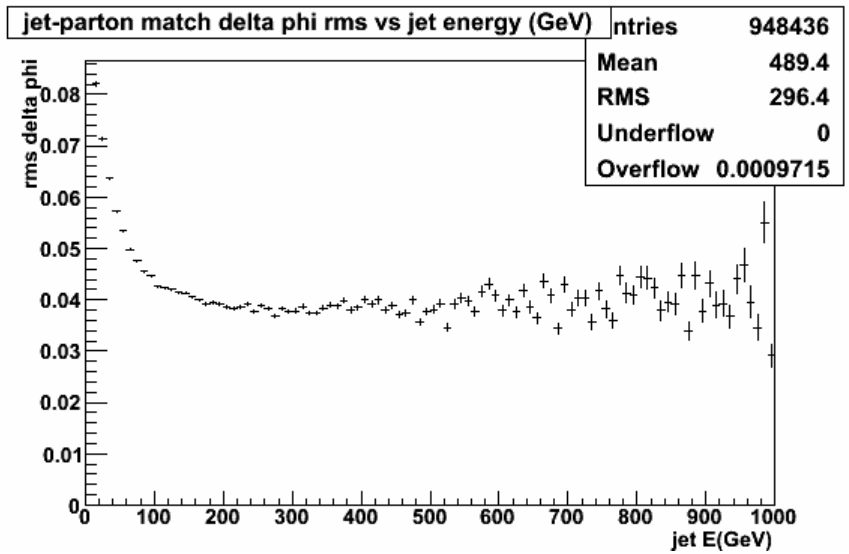


Jet kinematics: resolution

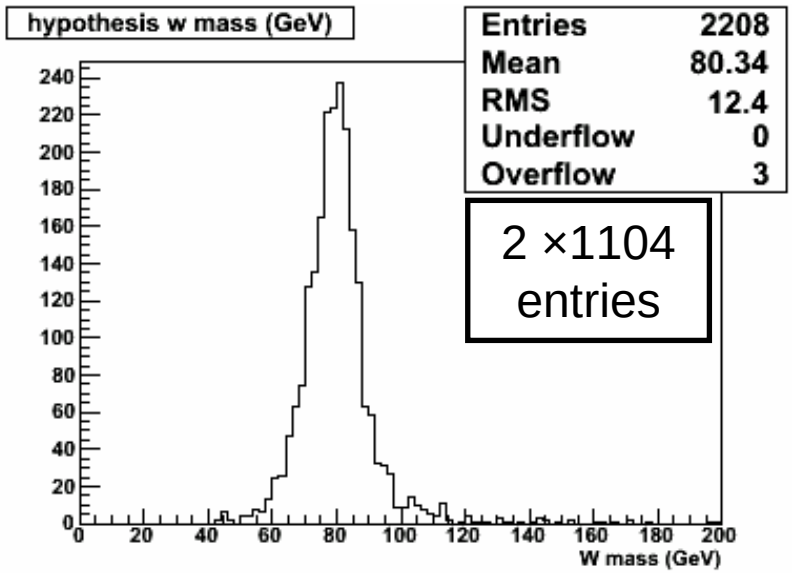


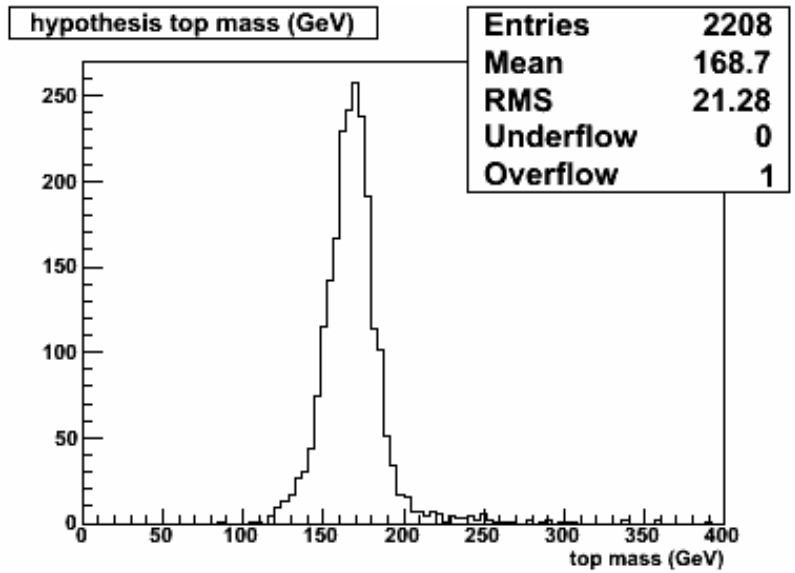


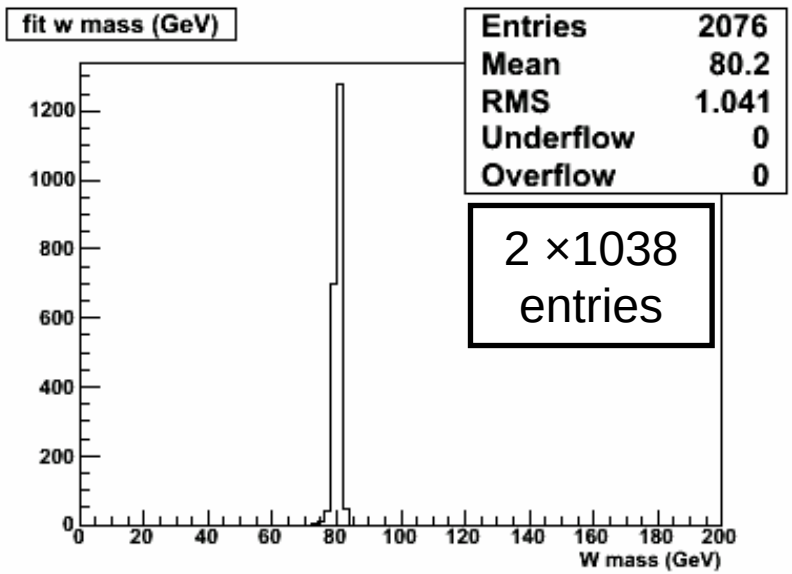


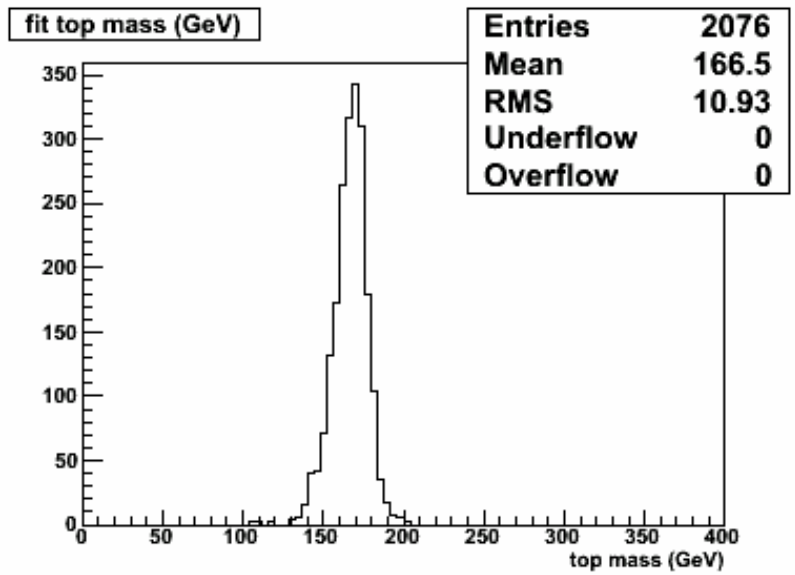


Signal truth kinematic fit results

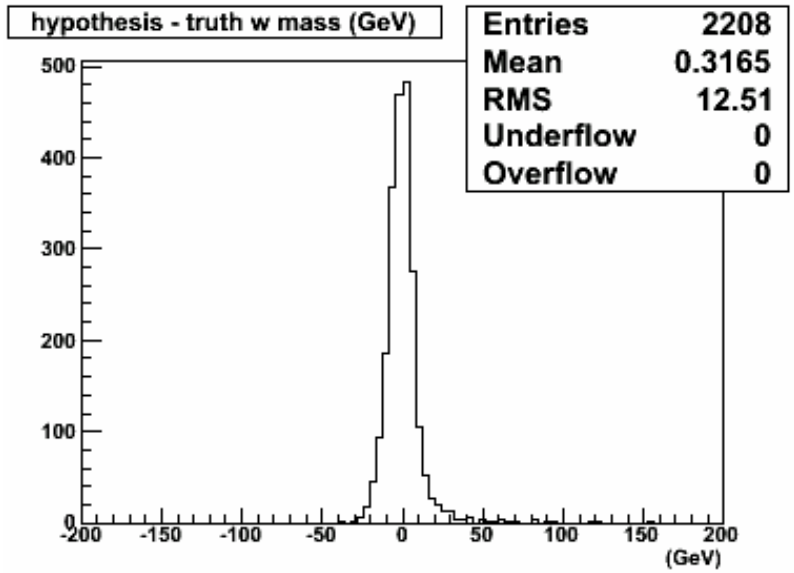


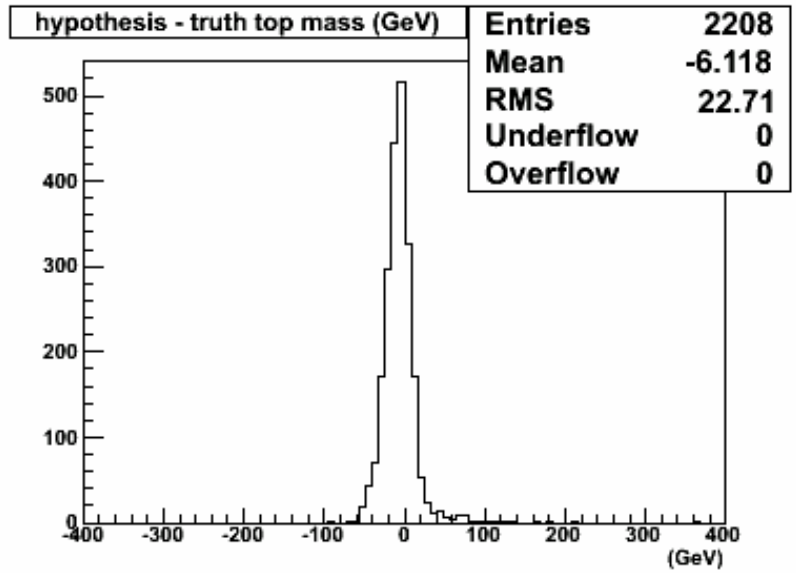


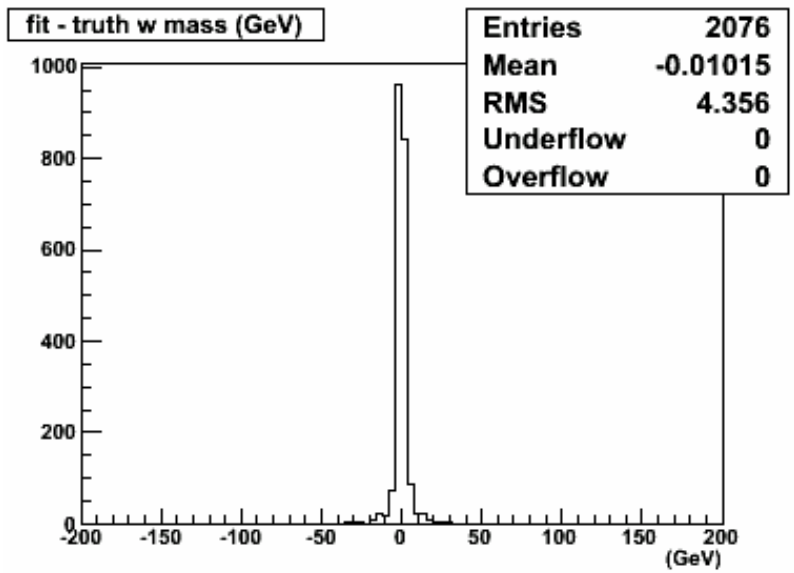


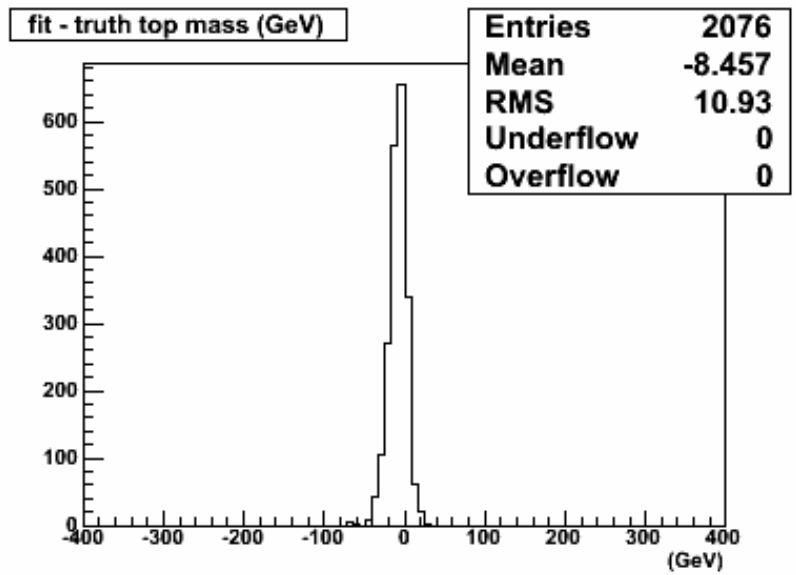


Signal truth kinematic fit results







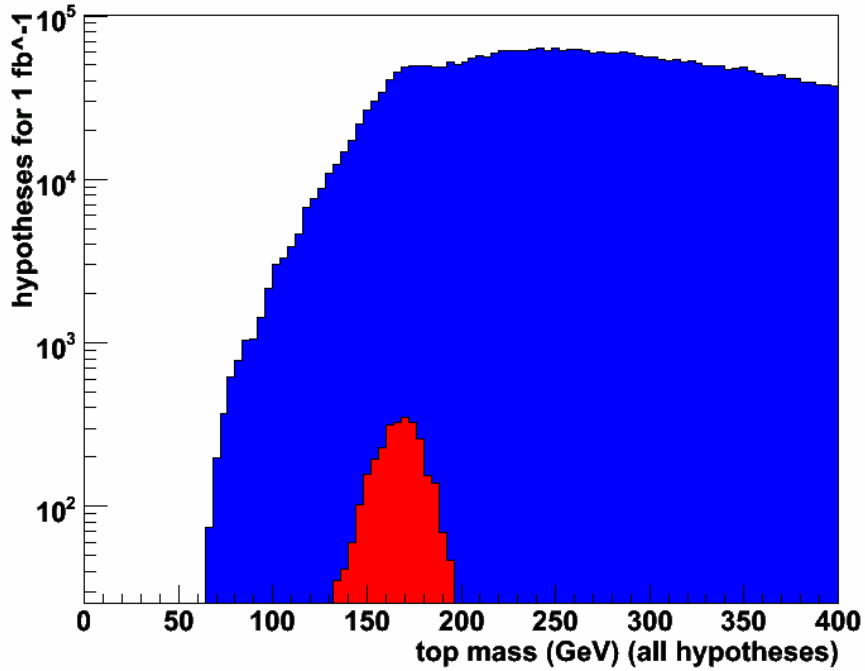


Cut flow: signal

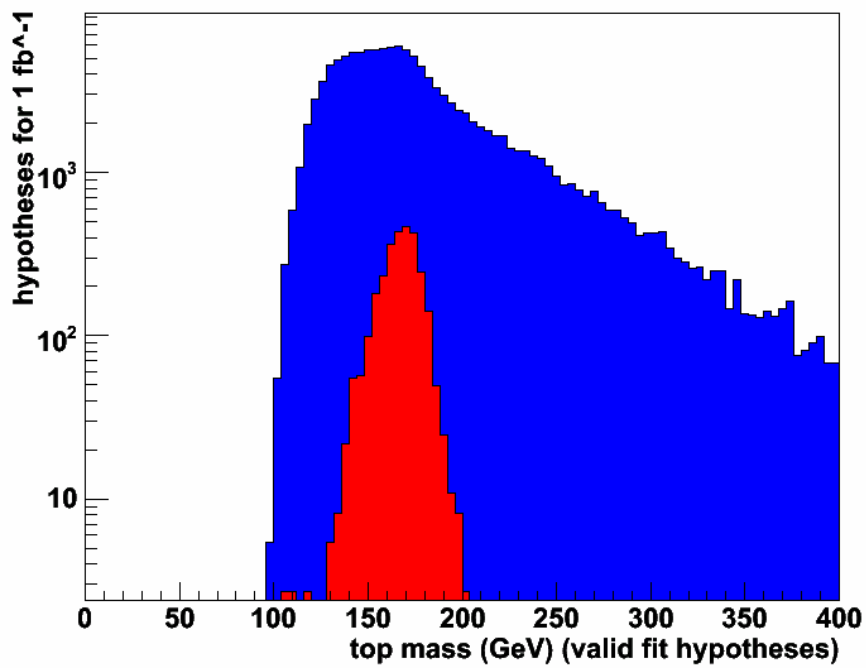
sample	signal	signal with truth matching	6 partons	5 partons	4 partons
cross section (pb)	369	369	34334	173852	986113
events	270784	270784	7364	28339	28166
at least 6 jets in |eta| < 3	210341	210341	5966	15333	7214
at least 6 jets with enough pt	23727	23727	294	76	3
efficiency	0.088	0.088	0.040	0.0027	0.00011
hypotheses	2135430	23727	26460	6840	270
matched jet-parton 1to1		6484			
all highest pt jets		1104			
after W mass cut	292236	1073	2648	658	10
after delta top mass cut	83993	1069	540	97	5
after top pt cut	49906	1038	323	50	5
attempted kinematic fit	49906	1038	323	50	5
valid fits	46214	1038	286	39	4
final: after chi2 cut	12599	896	49	3	0
efficiency	0.0059	0.038	0.0019	0.00044	0

Selections: signal top mass

all hypotheses

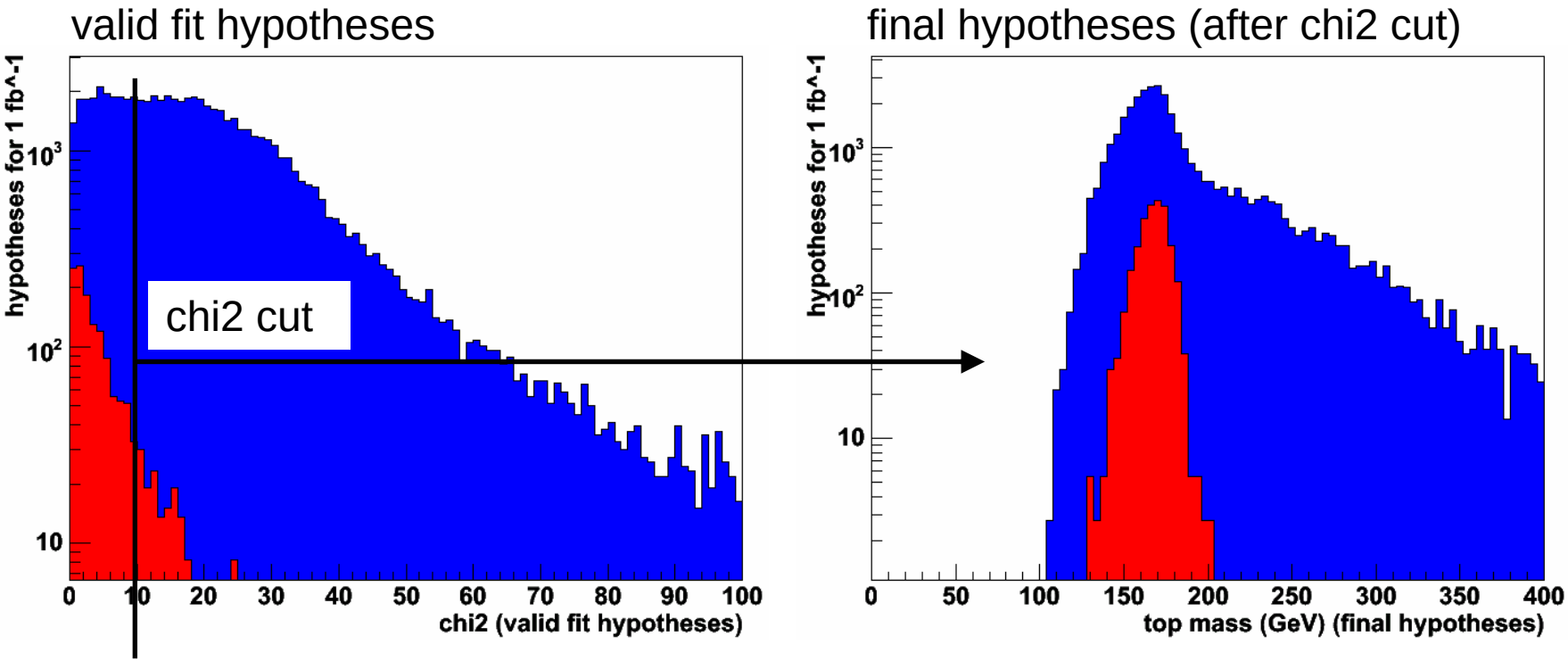


valid fit hypotheses



- 1-to-1 matched jet-parton pairs (overlaid, not stacked)
- with combinatorics
  - recall that 10% of all hypotheses combinatorics have correct top triplets

Selections: signal top mass



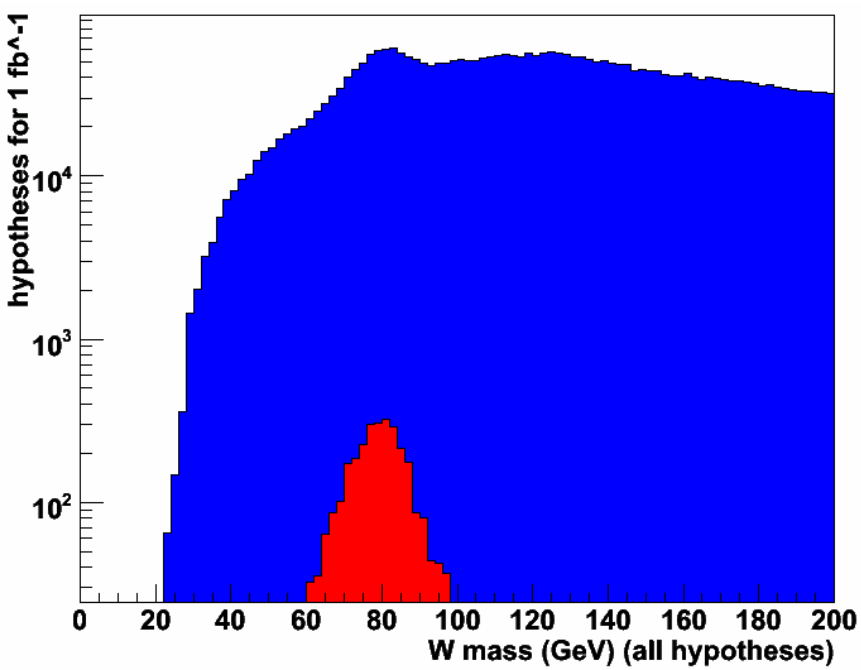
- 1-to-1 matched jet-parton pairs (overlaid, not stacked)
- with combinatorics

Need to revisit combinatorics strategy

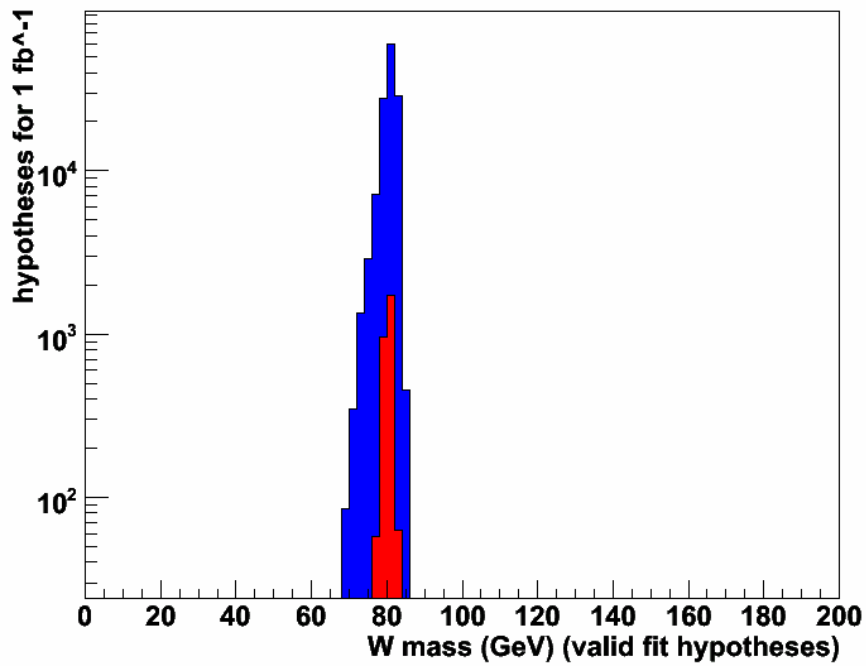
perhaps keep only one (best?) combination per event?

Selections: signal W mass

all hypotheses



valid fit hypotheses



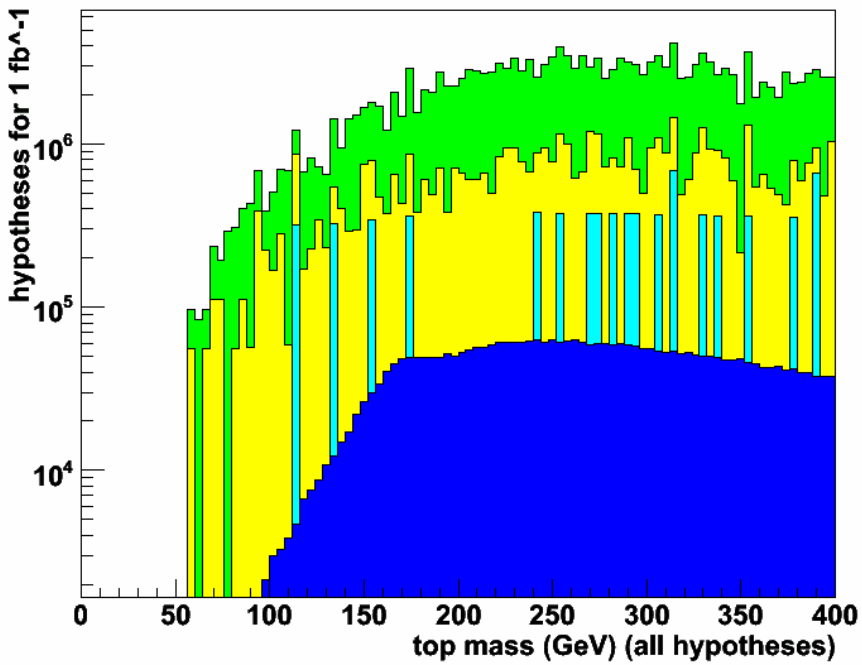
- 1-to-1 matched jet-parton pairs (overlaid, not stacked)
- with combinatorics
  - recall that 10% of all hypotheses combinatorics has correct top triplets

Cut flow: all samples

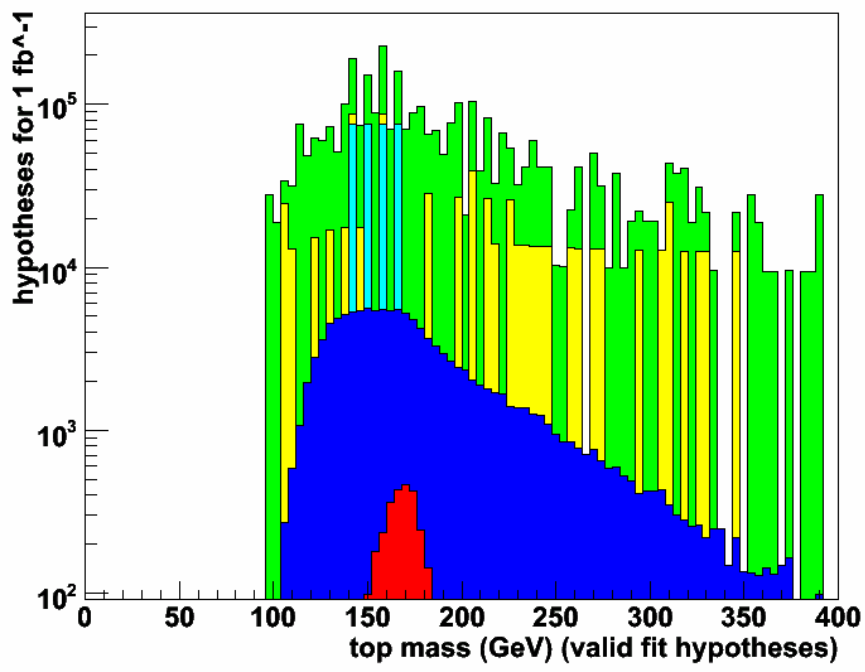
sample	signal	signal with truth matching	6 partons	5 partons	4 partons
cross section (pb)	369	369	34334	173852	986113
events	270784	270784	7364	28339	28166
at least 6 jets in |eta| < 3	210341	210341	5966	15333	7214
at least 6 jets with enough pt	23727	23727	294	76	3
efficiency	0.088	0.088	0.040	0.0027	0.00011
hypotheses	2135430	23727	26460	6840	270
matched jet-parton 1to1		6484			
all highest pt jets		1104			
after W mass cut	292236	1073	2648	658	10
after delta top mass cut	83993	1069	540	97	5
after top pt cut	49906	1038	323	50	5
attempted kinematic fit	49906	1038	323	50	5
valid fits	46214	1038	286	39	4
final: after chi2 cut	12599	896	49	3	0
efficiency	0.0059	0.038	0.0019	0.00044	0

Selections: top mass

all hypotheses



valid fit hypotheses

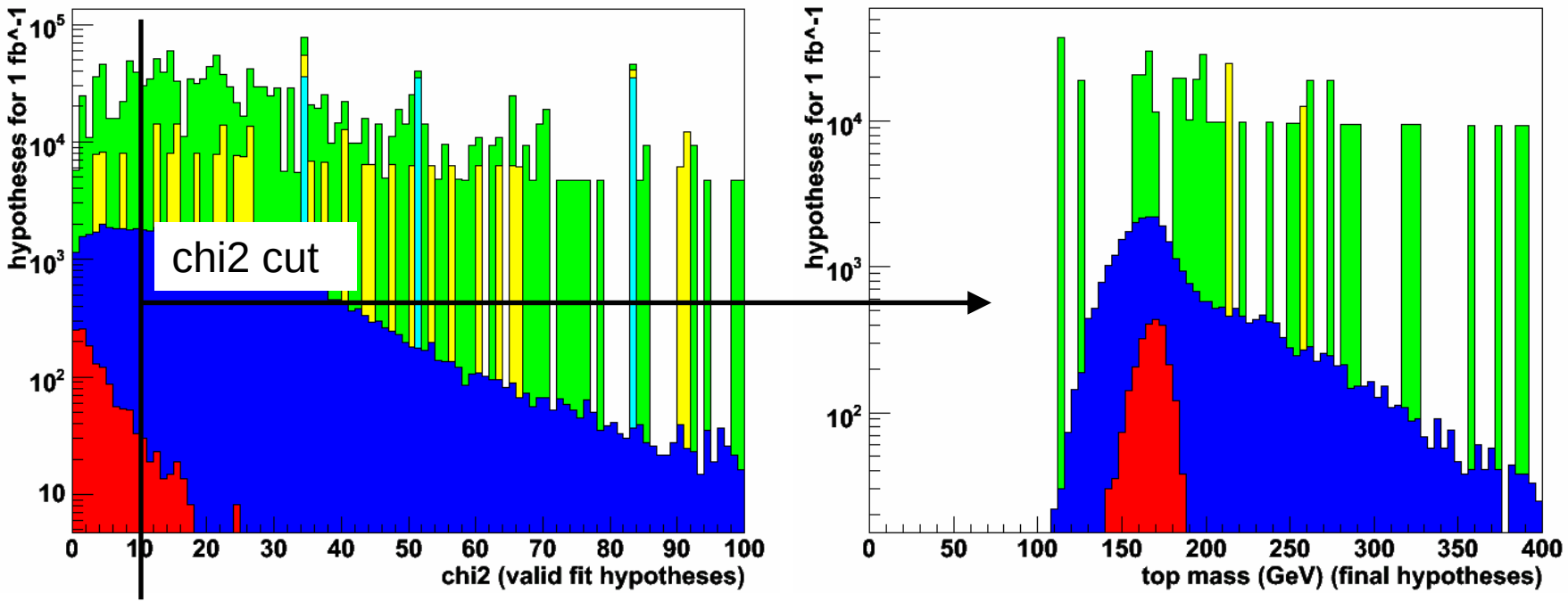


- signal 1-to-1 matched jet-parton pairs (overlaid, not stacked)
- signal with combinatorics
- QCD 6 partons
- QCD 5 partons
- QCD 4 partons

Selections: top mass

valid fit hypotheses

final hypotheses (after chi2 cut)

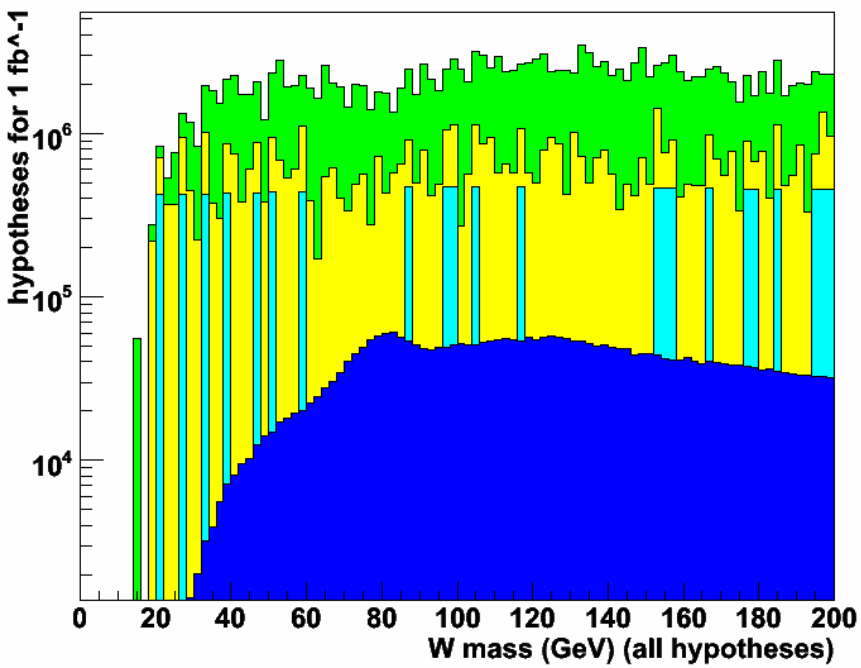


- signal 1-to-1 matched jet-parton pairs (overlaid, not stacked)
- signal with combinatorics
- QCD 6 partons
- QCD 5 partons
- QCD 4 partons

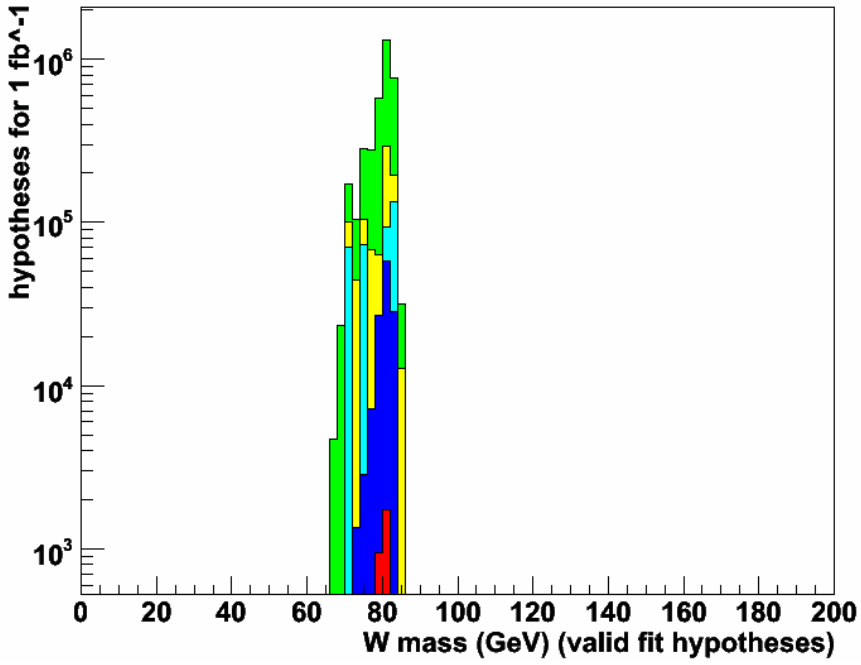
Need larger background samples!!

Selections: W mass

all hypotheses



valid fit hypotheses



- signal 1-to-1 matched jet-parton pairs (overlaid, not stacked)
- signal with combinatorics
- QCD 6 partons
- QCD 5 partons
- QCD 4 partons

Possible way forward...

- need b-tagging
- explore existing background samples
  - SUSY samples?
- revisit jet-parton hypotheses strategy
- study energy biases
  - can they be extracted from the study of semileptonic decays?
  - how do they affect the kinematic fits?
- improve kinematic fit
  - better energy resolution parameterization
    - obtain this in situ?
  - allow jets direction to vary
  - move to likelihood with Breit-Wigner
- tackle b-jet energy scale
  - obtain this in situ?