ATLAS実験初期における損失エネルギー・ジェットの測定能力の理解とその改善

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Outline (we focus on missET today…)

1) Introduction
2) W's transverse mass
3) Determination of missET performance with W events
4) Results with 30^{-1}pb data

Introduction

Jets/missET appear in most of physics processes at LHC: neutrinos in ttbar and Higgs production, LSP's in SUSY cascade decays…

- ✓ Jet energy scale could be a dominant systematic uncertainty at measurements (Tevatron experiences)
- ✓ MissET is more complicated object…(observed as an imbalance of energy against visible objects in an event)

Both are calorimeter based objects and <u>understanding calorimeter performances and calibration are crucial</u>. (Especially for early SUSY searches, we should validate missET reconstruction, whether our baseline performances are achieved or not..)

We here propose a method for in-situ missET resolution determination using W decays and perform a feasibility study

W's transverse mass

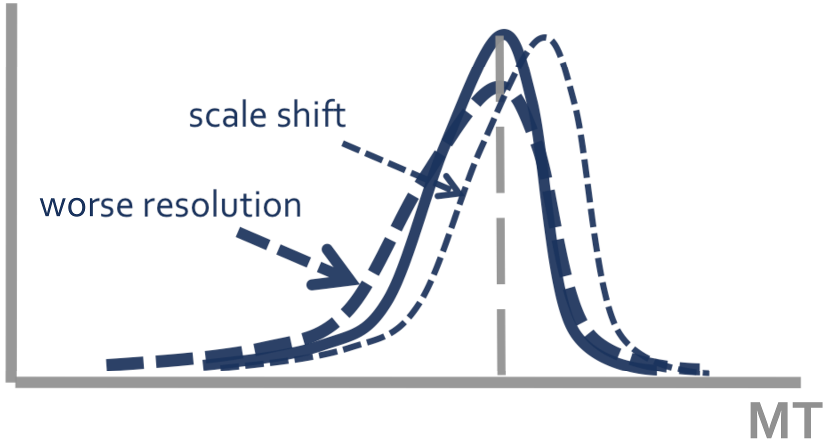
Use W→μν events

- Promising performances for muon reconstruction
- Less fake rate compared to electrons.
- Enough signal yield at the early stage: σxBr~10nb (sqrt(s)=10TeV, p_T^{muon}>15GeV/c)

For W's decaying into leptons, the shape of transverse mass (MT) distribution is sensitive to missET resolution/scale:

"**spread**"	⇔ missET resolution
"**Jacobian peak**"	⇔ missET scale

Comparing with MC incorporating various resolution parameters, we can evaluate missET reconstruction performances.



$$m_T = 2 p_T^l E_T^{miss} (1 - \cos \Delta\phi)$$

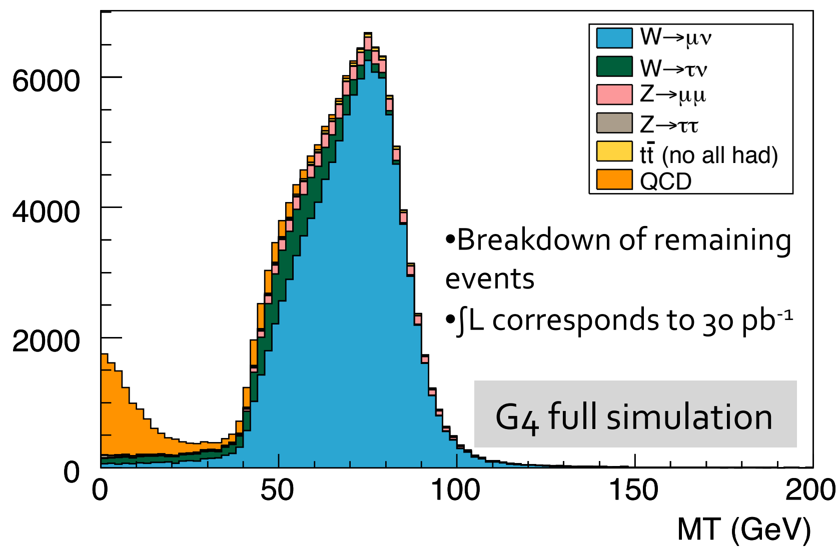
p_T^l: transverse momentum of lepton
E_T^{miss}: transverse missing energy
Δϕ: ϕ angular difference between lepton and missET vector

W→μν candidates and MT

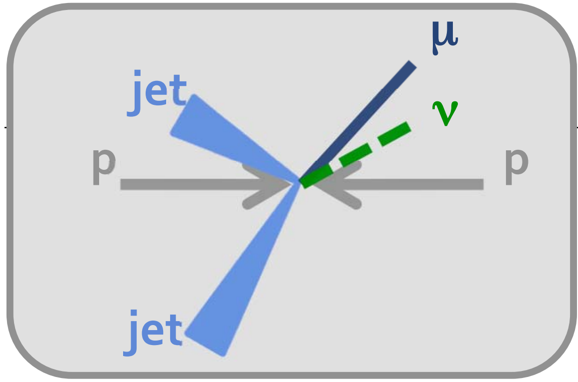
- Selection cuts
  1. Fire single muon trigger (p_T>15GeV/c)
  2. One isolated muon with p_T > 20GeV/c
  3. No tight electron above 20GeV/c
  4. missET>20GeV (suppress QCD)
- Signal purity ~84%

process	#events
W→μν	122498
W→τν	13169
Z→μμ (one μ lost)	5748
QCD (heavy flavor decays)	2940
ttbar (w in decays)	725
Z→ττ	405

- Shape of W's MT is smeared due to the contamination of backgrounds (W→τν, W→μν, QCD b-jets, ttbar, Z→ττ).
- To extract missET reconstruction performances correctly, we need to know these contamination effects simultaneously.



General description of missET performance



missET (p_T of neutrinos) is measured as the energy imbalance with "calorimeter activities (hadronic recoils) + muons"

- The resolutions are mainly described as the stochastic effect of visible calorimeter energy sum. (αxsumET$^{1/2}$)
- The scale shift is caused by
    - Difference between true hadronic energy sum(sumET$_{truth}$) and visible one.
    - Muons also affect the scale when undetected.
- Thus missEx resolution described as $\sigma(E_x^{miss}) = \alpha \cdot \Sigma E_T^{calo} \oplus \sigma(\mu \text{ inefficiency})$
- To confirm our baseline performance of α=0.52 (according to Geant4 full simulation), we need to check MT in each sumET slice. But MC sumET is uncertain. (instrumental effects, fragmentation/underlying event models alter sumET predictions)

→ Fit α and sumET scale β simultaneously with "MT-sumEt" 2-D distributions

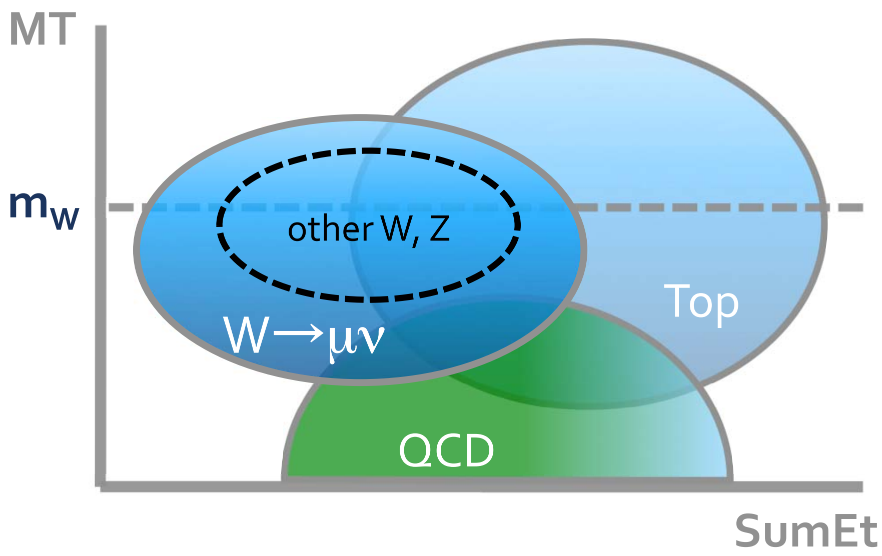
missET-sumET 2-D distribution

- Looking into 2D-distribution of "MT-sumEt", <u>we can separate BG's.</u>
  - QCD events cluster in the region of large SumEt after selection cuts and show small MT. (due to small $\Delta\phi$ for heavy flavor decays)
  - ttbar's also have large SumEt (emit multiple jets), but W's in ttbar gives higher MT.

  - Remaining W/Z backgrounds cannot be separated,

    but their fractions to signal are determined by MC with small uncertainties.

    — given only by branching fractions and muon ID eff.



Analysis overview

Signal/BG MC templates

PDF(sumET,MT; α, β)

Inputs from measurements

— Muon ID efficiencies (currently based on MC)

Compare

MT-sumEt distribution of $W \rightarrow \mu\nu$ candidates

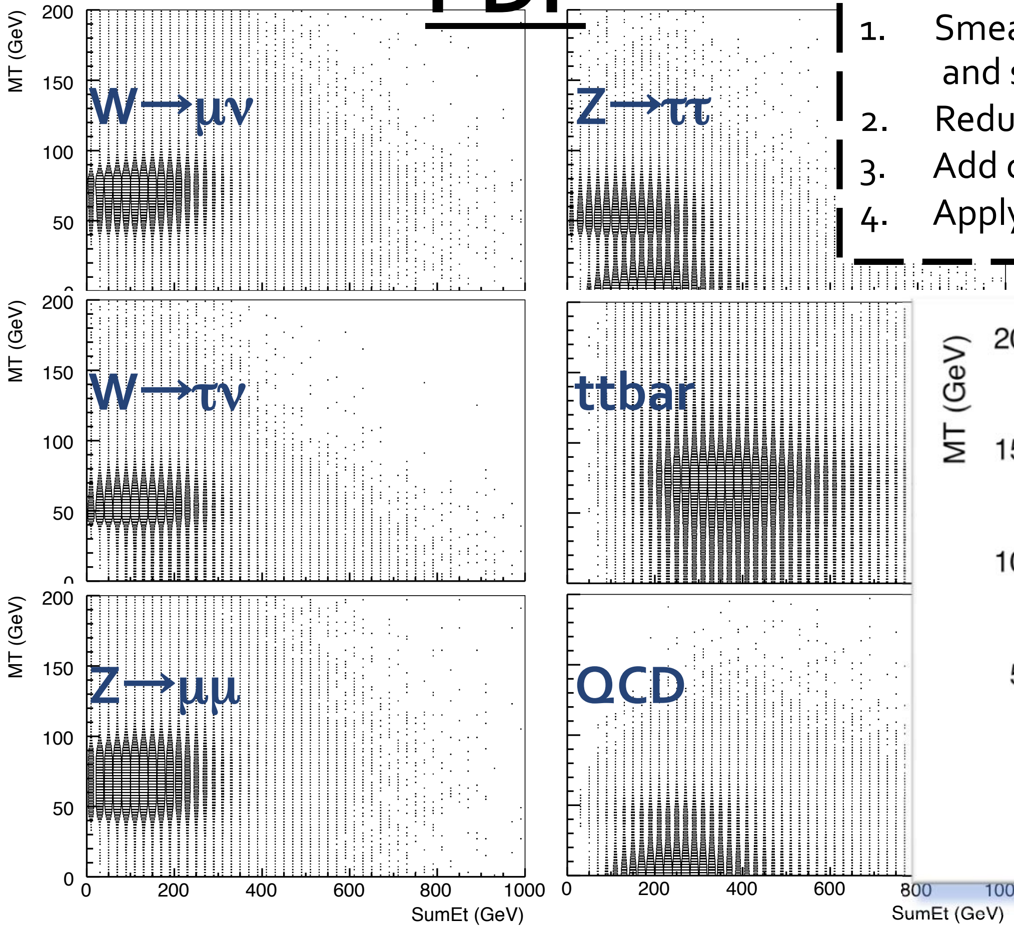
Fit MC templates to data using the maximum likelihood method (shape only) with 4 free parameters:

- **coefficient of stochastic term "α"**
- **sumET scale "β"**
- **2 background fractions of QCD and ttbar**

(SumEt shows non-linear response for small calo. activity events due to noise, then the fitting range of SumEt is set to be >100GeV.)

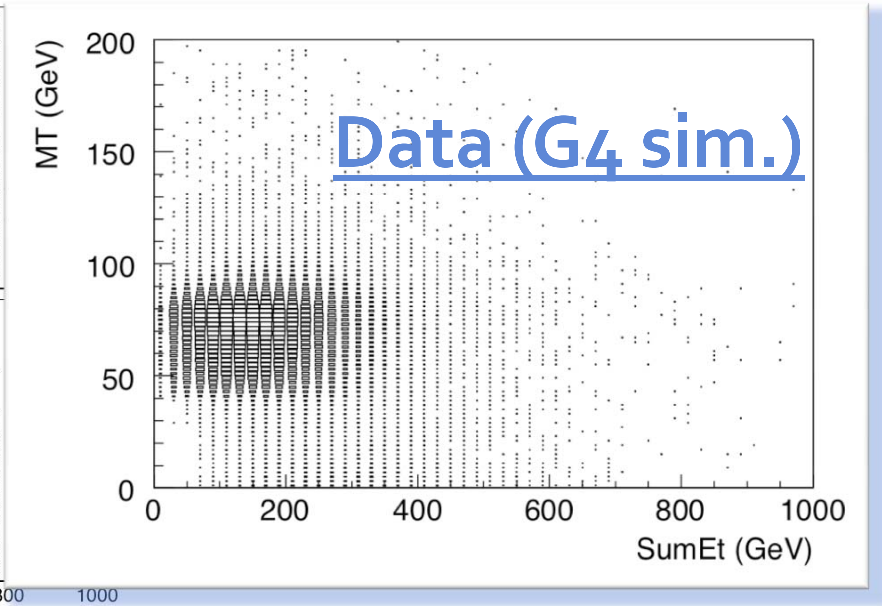
Preparation of PDF's

PDF

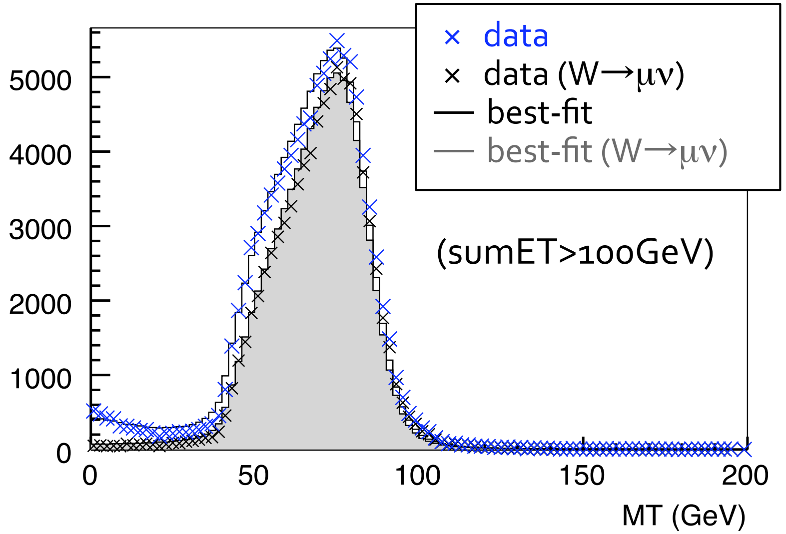


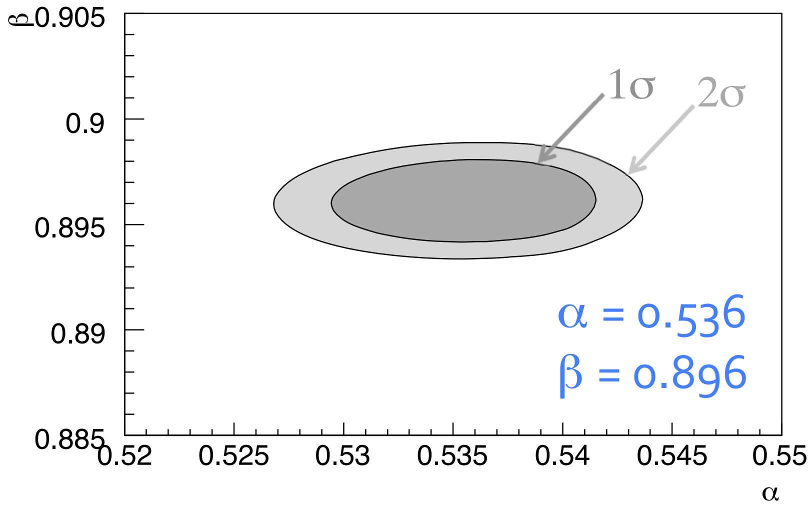
PDF's are given by toy MC:

1. Smear true missEx/y according to $\alpha(\beta \times SumET_{truth})^{1/2}$ and scale $sumET_{truth}$ by β
2. Reduce muons according to their ID eff.
3. Add contributions of reduced muons into missEx/y
4. Apply offline selection cuts

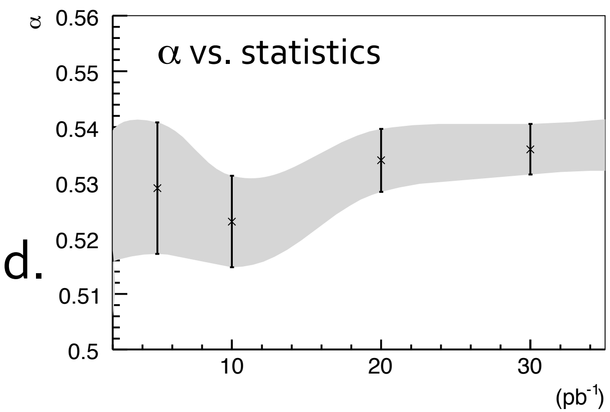


Result (30 pb^{-1})





- σ_{Exmiss} = 0.536× $SumEt_{rec}^{1/2} \oplus \sigma_{muon}$
  = 0.536× (0.896 × $SumEt_{truth})^{1/2} \oplus \sigma_{muon}$
  Consistent with the performances G4 sim. says. (α~0.52)
- Almost no correlation between α and β, as expected.
- missEx resolution can be determined with an accuracy of <1% using a few 10 pb^{-1} data.

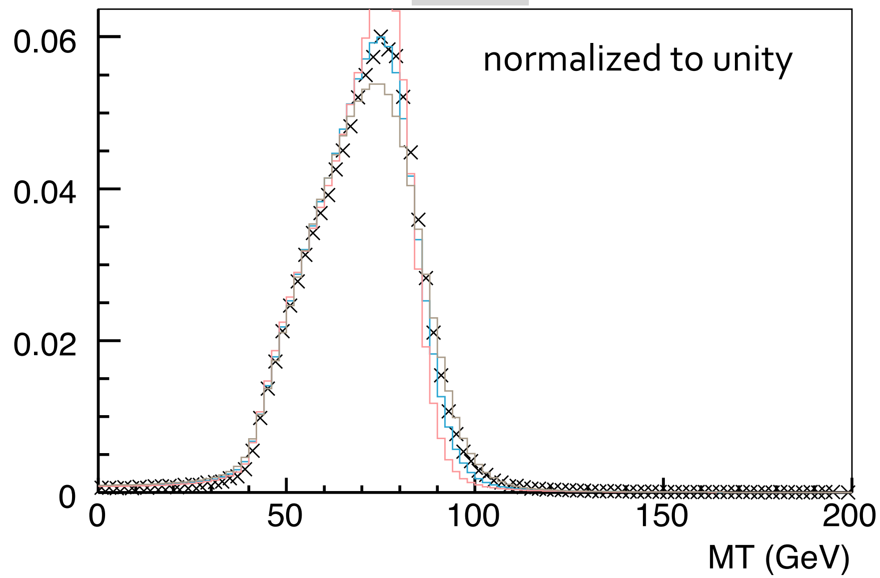


MT/missET resolution of W→μν

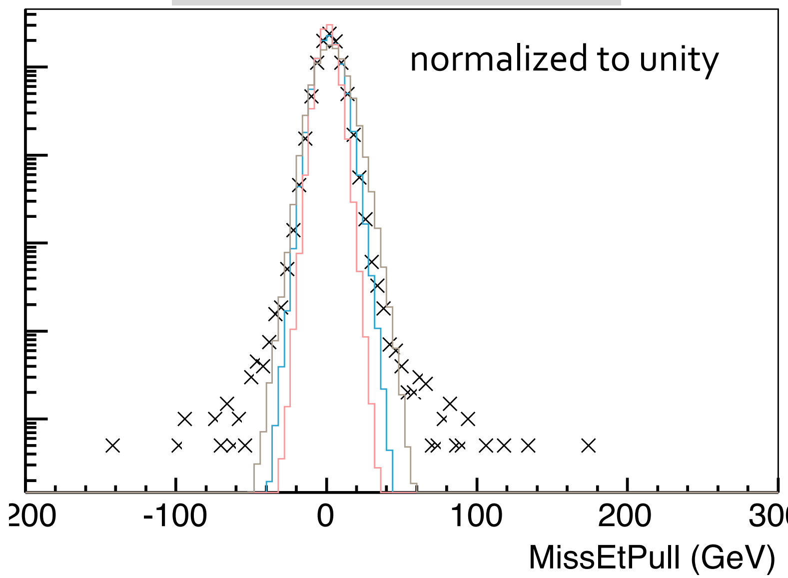
missET reconstruction performances can be extracted correctly.

- × data (G4 full sim.)
- — α=0.536 (best-fit)
- — α=0.3
- — α=0.7

MT



missET resolution



Concerning systematics

- Muon p_T resolution, ID efficiencies
  - Muon p_T resolution could be quite better than calorimeter objects and small effect on missET resolution
  - ID efficiency just alters the fraction of BG, so we can obtain stable fitting results. (if we keep high : $W\rightarrow\mu\nu$ signal purity)

- p_T of recoil W alters the MT shape and could be a dominant systematic uncertainty of MT-sumET templates, but can be reduced by using measured Z's p_T ($Z\rightarrow\mu\mu$)

Summary

- We performed a practical analysis using W decays to give general descriptions of missET performances.
  - Maximum likelihood fit with “MT-SumEt” 2-D distributions
- We examined the feasibility including possible background processes, and showed it works as expected.
- The fitting gives correct answers for missET performances; consistent with G4 full simulation says (baseline performance).
  - $\sigma_{MEX/Y} = 0.536 \times \mathrm{sumET(rec)}^{1/2} \oplus \sigma_{\mathrm{muon\ ineff}}$
  - Can achieve an accuracy of <1% using a few 10 pb^{-1} data

backup

Object definition

Muon:

- Staco combined
- |eta| < 2.5
- Isolation requirement of EtCone(ΔR=0.2)<10GeV

Electron:

- Tight ID
- |eta| < 2.5
- EtCone(ΔR=0.2)<10GeV

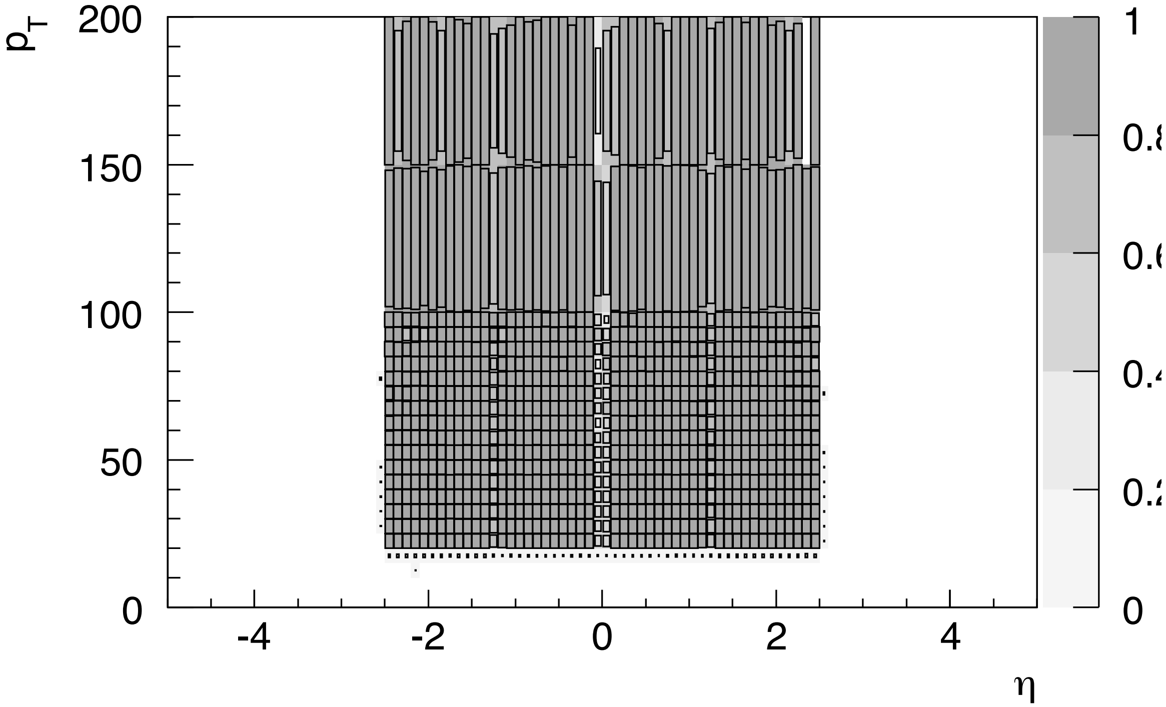
Etmiss/SumEt:

- RefinedMETFinal algorithm

Muon ID efficiency

ID requirement:

- Staco combined muon
- p_T > 20GeV/c
- |eta| < 2.5



trigger eff. included

Fitting procedure

maximum likelihood fit using 2D binned data of "MT-SumEt"

- 4 free parameters
  - Exmiss resolution parameter (α), visible Etsum scale (β) and two BG fractions of QCD (f_{QCD}) and ttbar (f_{top})
- Signal and background PDF's for parameters α and β
- Convolute PDF's
  - $\Sigma f_i \times PDF_i (\alpha,\beta)$; i=$W\rightarrow\mu\nu$,$W\rightarrow\tau\nu$, $Z\rightarrow\mu\mu$, $Z\rightarrow\tau\tau$, Top, QCD
  - $\Sigma f_i = 1$
  - $f_{W\rightarrow\tau\nu}/f_{W\rightarrow\mu\nu}$, $f_Z/f_{W\rightarrow\mu\nu}$: constant
- Fit PDF to data (using shape only) by Minuit
  - Fitting region: SumEt > 100 GeV, MT>0

Preparation of PDF's

1. Generate a signal/BG MC event and suppose a certain set of resolution α and scale β.

2. Smear truth Ex(y)miss with a given resolution in Gaussian regime.
   - Resolution = α (β × EtSumTruth)$^{1/2}$

     (Truth Ex(y)miss is calculated by all interacting particles other than muons, with |eta<5|)

3. Reduce muons according to the ID efficiencies $\varepsilon(p_T$, eta) and set Ex(y)miss:
   - Exmiss = (smeared truth Exmiss) - Σrandom_binary(ε) × p_x^{μ}
   - $\varepsilon(p_T$, eta) is based on fullsim data for the moment

4. Apply the selection cuts on the event. If passed, we fill it in "MT-SumEt" histogram.
   - SumEt = β × EtSumTruth

5. Repeat the toy event generation described above and make "MT-SumEt" histograms for various parameters .