# A physics benchmarking study using top pair production at $E_{cm}$=500GeV for the ILD-LOI

Katsumasa Ikematsu (KEK)

ILD Workshop at Seoul (16/Feb/'09 @Ewha Womans Univ.)

# A benchmark process: $e^+e^-$ -> ttbar

**Benchmark Reactions for the ILC LOI process**

The WWOC Software panel:
Ties Behnke, DESY, Norman Graf, SLAC. Akiya Miyamoto, KEK

5. **$e^+e^- \rightarrow tt$, $t \rightarrow bW$, $W \rightarrow qq'$ (Mtop=175GeV, Ecm=500 GeV)**
   a. multi jet final states, dense jet environment
   b. particle flow
   c. b-tagging inside a jet
   d. maybe lepton tagging in hadronic events (b-ID)
   e. tracking in a high multiplicity environment

   Top reconstruction is an excellent test for the performance of the reconstruction in very busy events. At the moment it is not yet clear how critical ultimate particle flow performance is for this reaction.
   Physical observables are $\sigma$, $A_{fb}$, and $m_{top}$

### *Signal Samples*

For each reaction we indicate the main detector parameters which are to be tested with this reaction. Performances for $250 fb^{-1}$ for Ecm=250GeV and $500\ fb^{-1}$ for 500 GeV should be presented.

The background events will be based on the SM sample generated at SLAC. It has been generated with beam polarisation for the electrons of 80%, for the positrons of 30%. It is based on the Whizard event generator. The notation 2f, 4f, 6f should be understood in the context of this generator.( two-photon processes and low Q2 events are not categolized in 4f and 6f processes). Depending on the physics benchmark processes, events which are obviously outside signal phase space could be rejected prior to a detector simulation

# My analysis flow

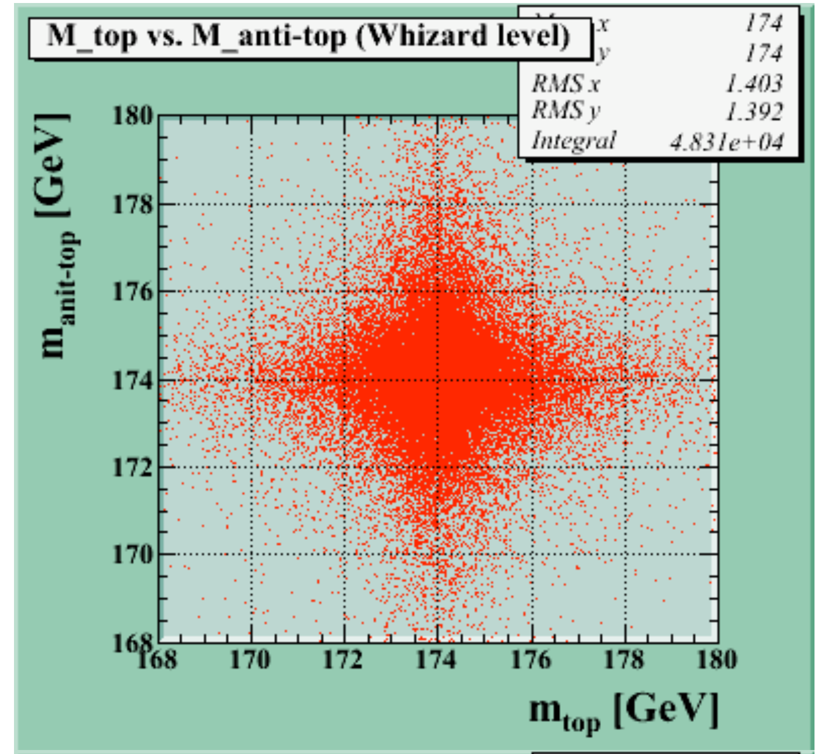
- Starts from ILD-DST files for both signal and background processes
  - Tagged w/ `DST01-06_ppr004_<process id>_<IDRUPLH>500_ILD_00_LCP_<Pol. combination>_Slac_SM_<# file>.slcio`
    - Complete SM StdHep samples for 500fb$^{-1}$ at all 4 polarization combinations were produced using Whizard + PYTHIA (includes both incoming LINAC energy spread and beamstrahlung) at SLAC
  - All information I used are in `Durham_6Jets` of `LCCollection`
- 6-jet paring w/ double b-tagging and $\chi^2$ best selection
- Kinematical fitting for the best solution (by using my original TT6JKinematicalFitter)
- BG rejection w/ cut bases analysis (using event profiles and kinematically reconstructed variables)
- Refill histograms w/ weights to 500fb$^{-1}$ and (Pol_e$^-$, Pol_e$^+$) = (-80%, +30%) by using ntuple for (±100%, ±100%)

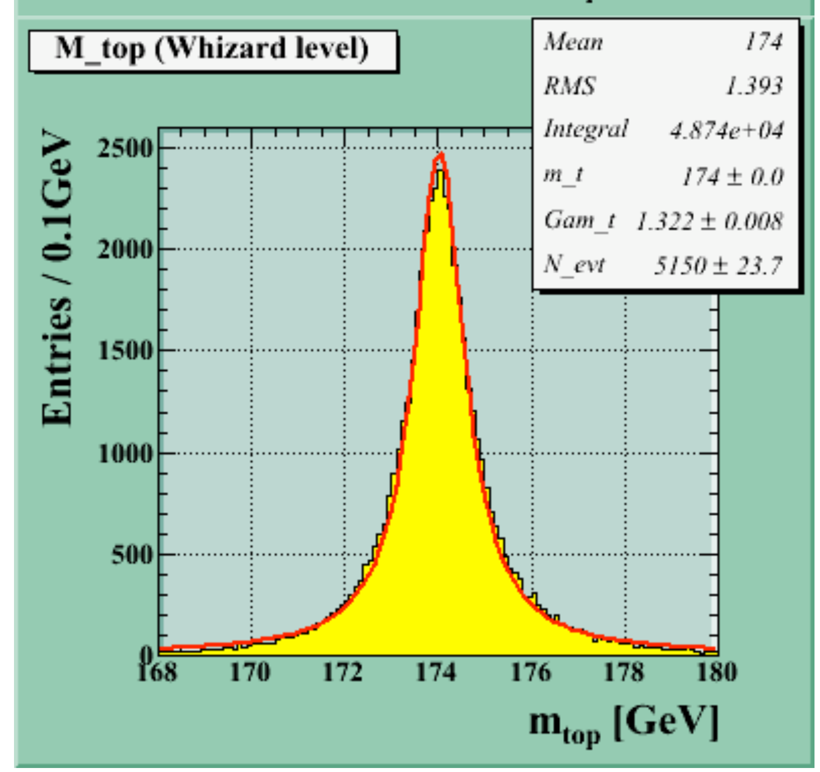
# Signal sample

- Common input: SLAC SM StdHep
  - All analyses used in the context of the detector optimization and LoI process need an inclusive sample of the SM Background => SLAC team
- ttbar -> 6-jets samples are included in bbqqqq of 6-fermion SM samples
- bbqqqq samaples also contain no ttbar mediated events: ($e^+e^-$ -> bb with $\gamma$ ->WW) and ($e^+e^-$ -> WW with Z -> bb) etc.

| IDRUPLH | Process | Pol(e-) | Pol(e+) | Xsec (fb) |
|---|---|---|---|---|
| w17765 | bbuddu | -1.0 | 1.0 | 166.3 |
| w17766 | bbuddu | 1.0 | -1.0 | 66.0 |
| w17769 | bbudsc | -1.0 | 1.0 | 164.7 |
| w17770 | bbudsc | 1.0 | -1.0 | 65.7 |
| w17785 | bbcsdu | -1.0 | 1.0 | 164.7 |
| w17786 | bbcsdu | 1.0 | -1.0 | 66.0 |
| w17789 | bbcssc | -1.0 | 1.0 | 165.1 |
| w17790 | bbcssc | 1.0 | -1.0 | 66.0 |

Extract generator info:
on-shell tops from bbqqqq
(w17765 StdHep)



# ttbar -> 6jets reconstruction

I) Force 6-jets clustering

II) Confirm Max_cos $\theta_{jet}$ should be less than 0.99

III) Choose all the 15-possible pairs out of 6-jets => $W_1$ candidate

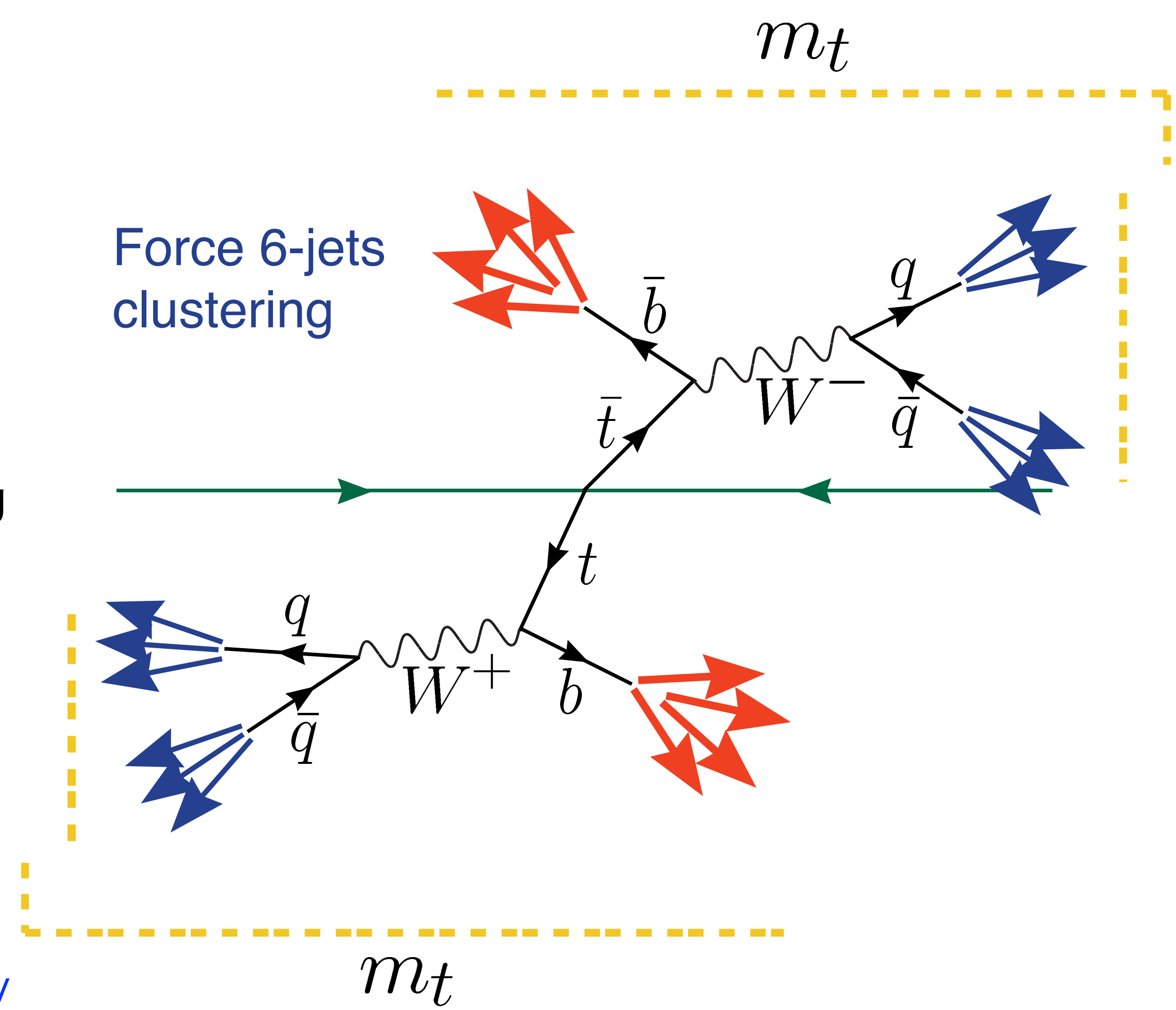
IV) Choose all the 6-possible paris out of remaining 4-jets => $W_2$ candidate

V) Remaining 2-jets should be b-jets: flavor tagging (charm/bottom tagging) is very important to eliminate both combinatorial and process BGs

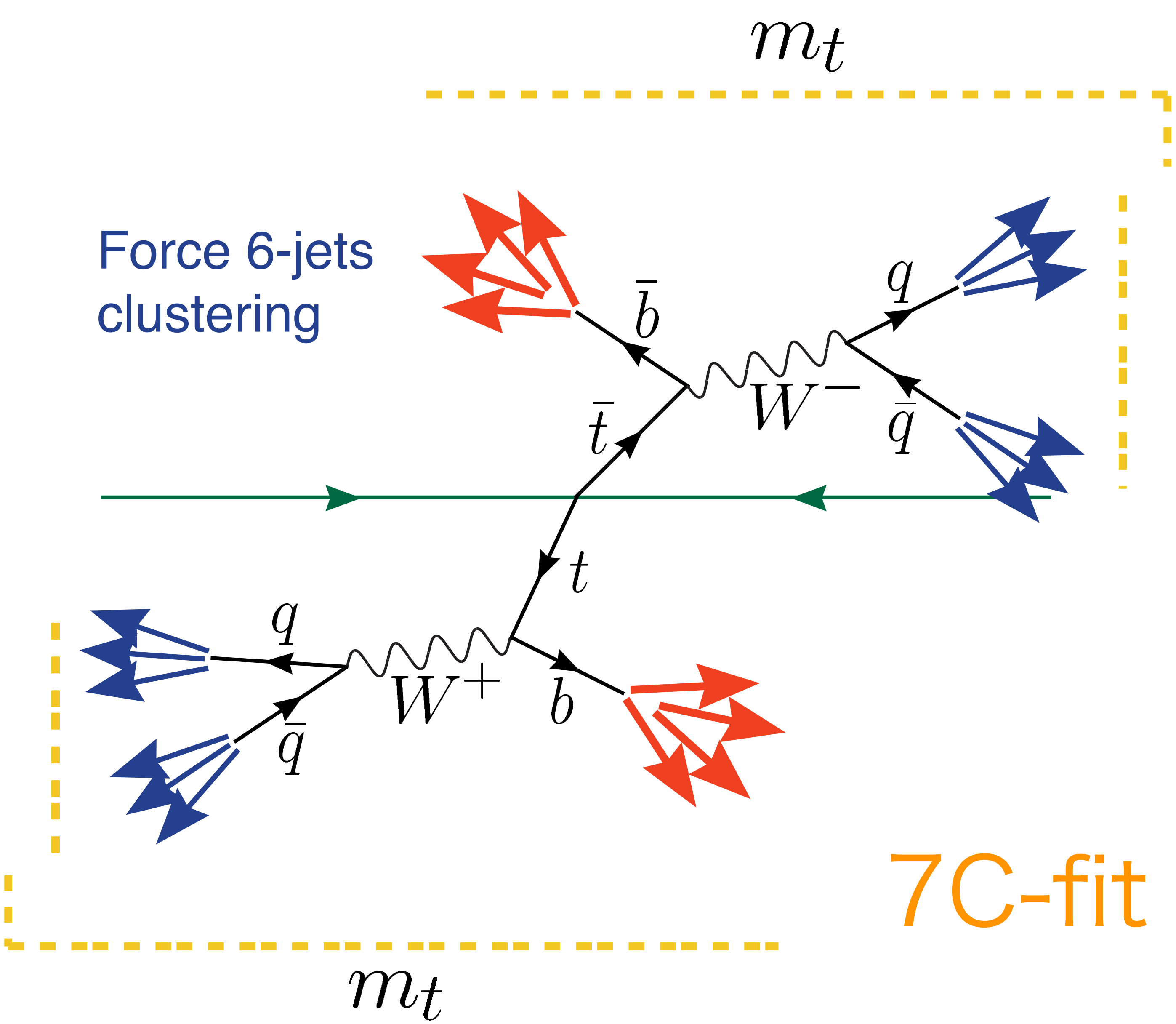
VI) There are 2 possibilities to attach a b-jet to $W_1$ and $W_2$ candidates

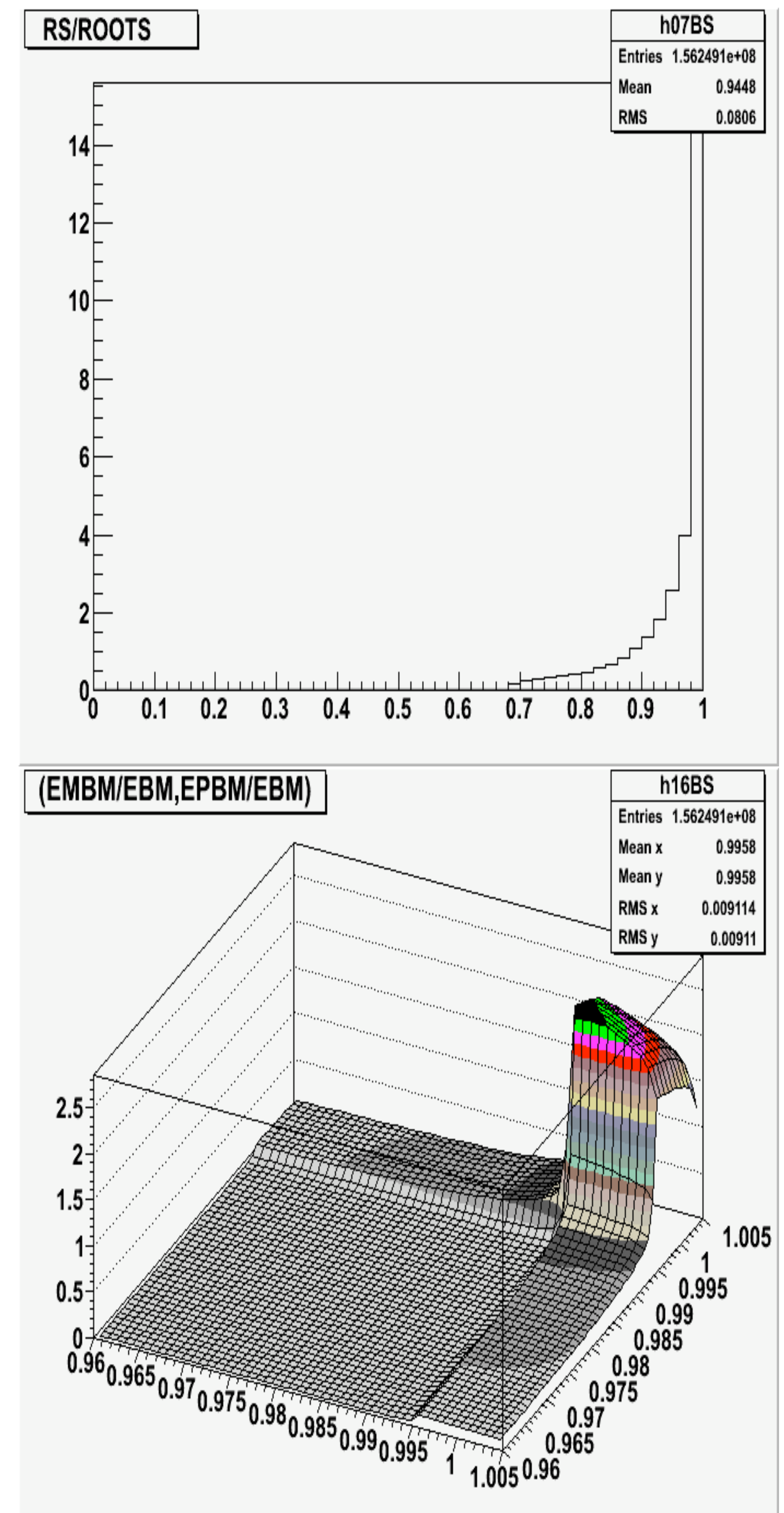
VII) Store all solutions w/ $\chi^2 = (m_{w1} - m_w)^2/\sigma^2_{mw} + (m_{w2} - m_w)^2/\sigma^2_{mw} + (m_{t1} - m_t)^2/\sigma^2_{mt} + (m_{t2} - m_t)^2/\sigma^2_{mt}$

VIII) Sort solutions according to $\chi^2$: choose the best solution



# Kinematical fitting in ttbar -> 6jets



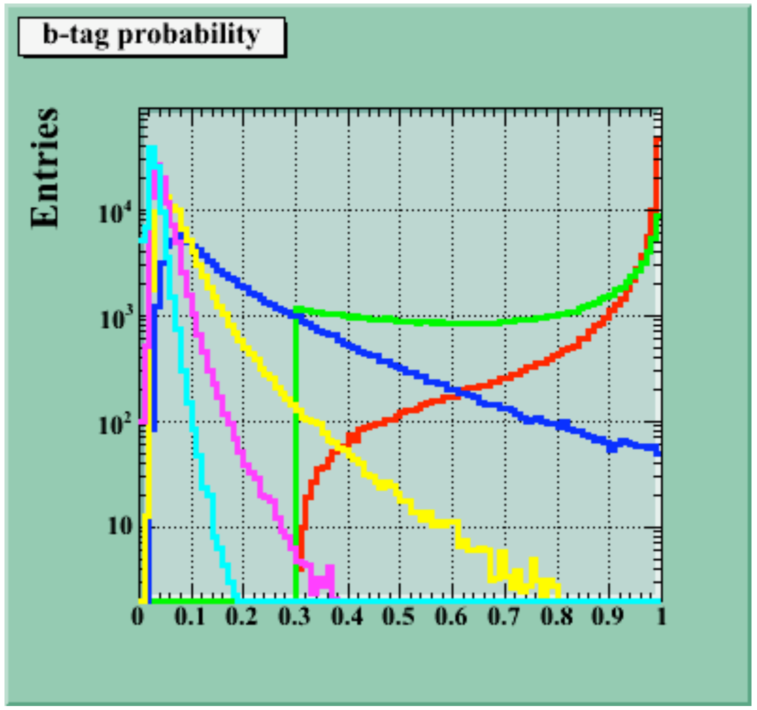




I) Energy of 6 jets should be fitted (6 free parameters)

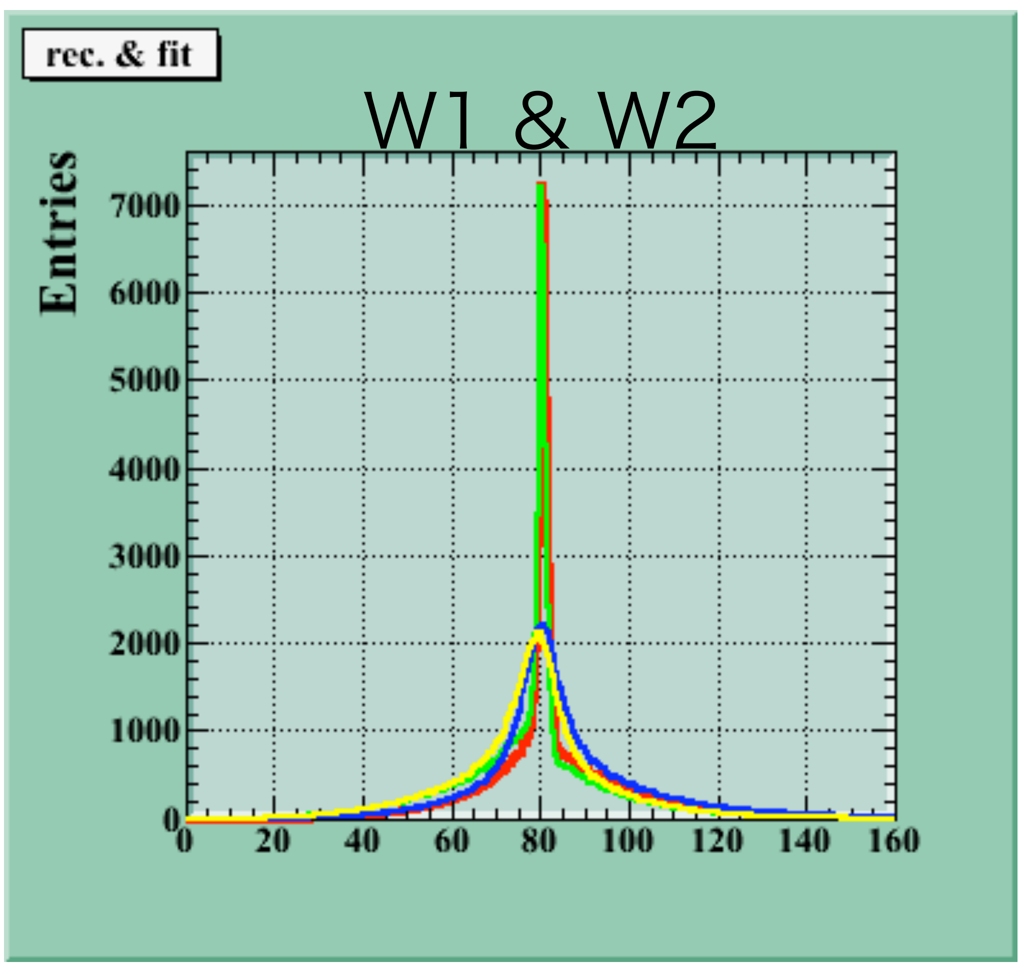
II) Consider ISR/Beamstrahlung

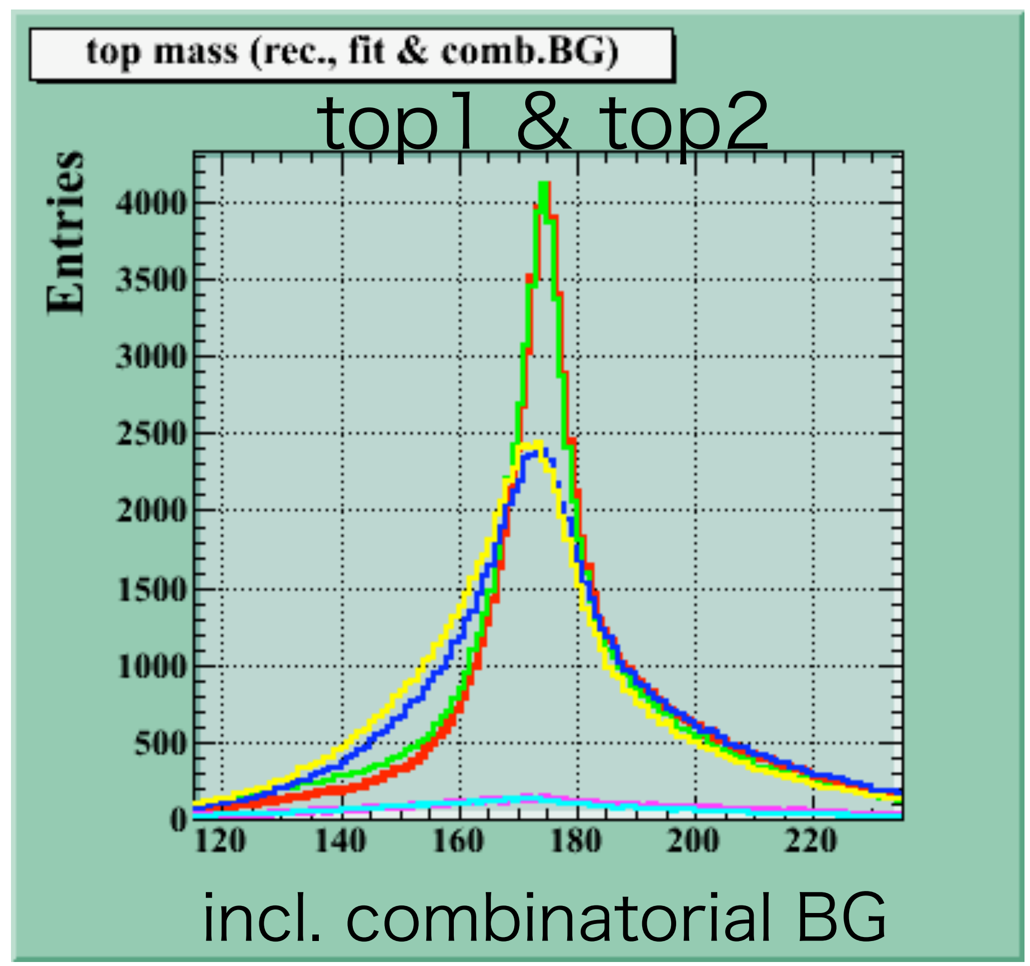
III) Include neutrino emission from b-jets (empirical formulation)

# Kinematically reconst'd bbqqqq




- Relatively loose double b-tagging (B-tag value > 0.3) => Eff(sel) ~ 68%
- Choose $\chi^2$ best solution => Kinematical fit
- W mass constraint of Breit-Wigner
- Improve 3-jet invariant mass resol.



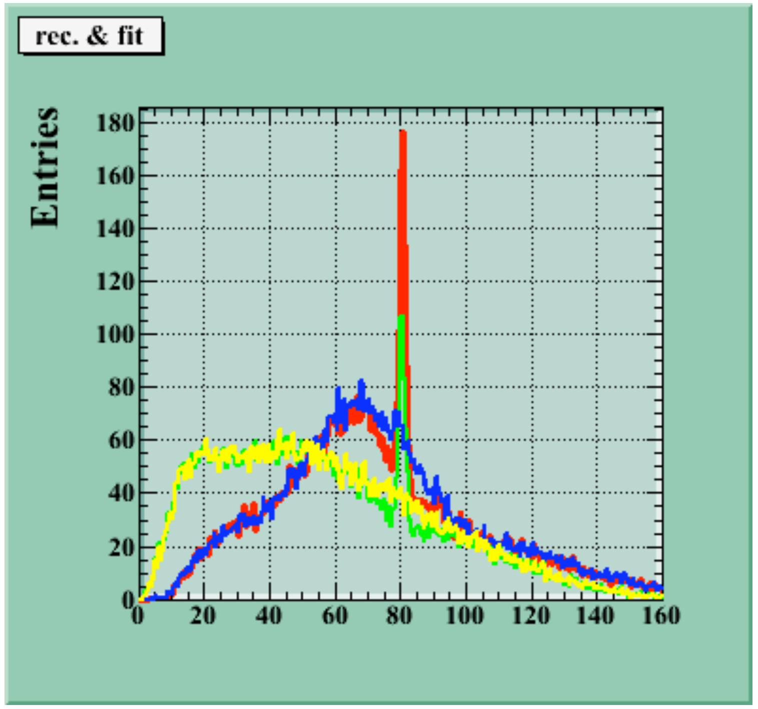
# BG reduction: cut summary

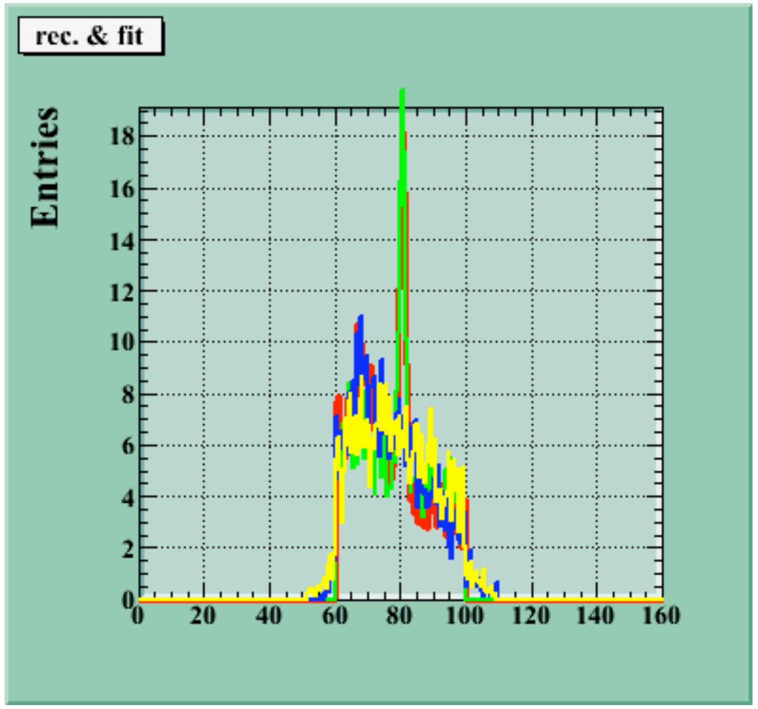
6 category for both signal and background processes

| Processes | Double b-tagging (B-tag value > 0.3) | Cuts by event profile, chi2 value & masses (w1, w2, w1fit, w2fit) | No. of final events |
|---|---|---|---|
| bbqqqq (incl. no ttbar mediated ~ 30%) | 68.0% | 96% | 91.75k |
| ffffbb | 64.1% | 16% | 35 |
| All 4F & 6F (w/o ffffbb) | 4.36% | 4.9% | 479 |
| 2F (bb) | 47.7% | 0.91% | 4789 |
| 2F (cc) | 5.2% | 1.6% | 670 |
| 2F (uu, dd & ss) | 0.8% | - | negligible |

S/B~10 can be achieved by cutting on fitted $M_W$

Cut on W1 & W2



# Define line-shape, then fit $M_{3j}$

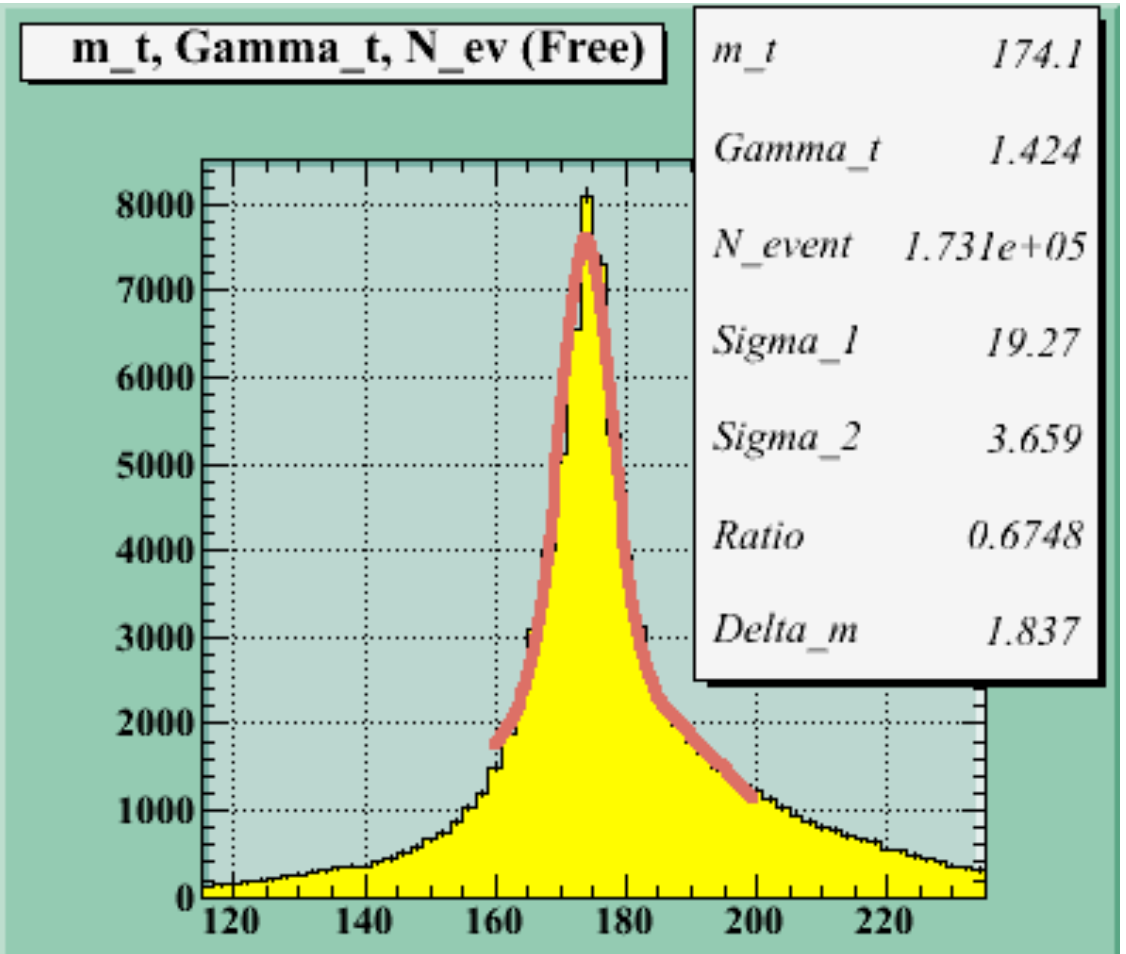
- Line-shape function: convoluted Breit-Wigner w/ detector resolution
  - Assume detector resolution function as double Gaussian w/ a mean shift and a weight (4 parameters)
  - Decide resolution functions using hight statistics samples w/ fixed top mass (174GeV) and top width (1.32GeV) which were obtained from input SLAC StdHep files.
- M3j fit w/ above line-shape
  - Free 3 parameter ($m_t$, $\Gamma_t$, $N_{event}$)
  - 500 $fb^{-1}$
  - (Pol_e-, Pol_e+) = (-80%, +30%)

$m_t$ = 174.1 ± 0.04 (stat. only)

Preliminary

$\Gamma_t$ = 1.42 ± 0.10 (stat. only)

BGs from other processes are not yet overlaid



Signal + Combinatorial BG

# Summary

- Double b-tagging and kinematical fitting are very powerful for both kinematical top-pair reconstruction and background (combinatorial & other processes) rejection
- S/B~10 can be achieved w/ relatively loose double b-tagging and loose cuts on kinematically reconstructed variables (e.g. fitted W mass)

| $E_{cm}$ | Integ. lumi. | ($Pol\_e^-$, $Pol\_e^+$) | Generator file | Detector | DST / LCCollection |
|---|---|---|---|---|---|
| 500 GeV | 500 $fb^{-1}$ | (-80%, 30%) | SLAC SM StdHep | ILD_00 | Durham_6Jets |

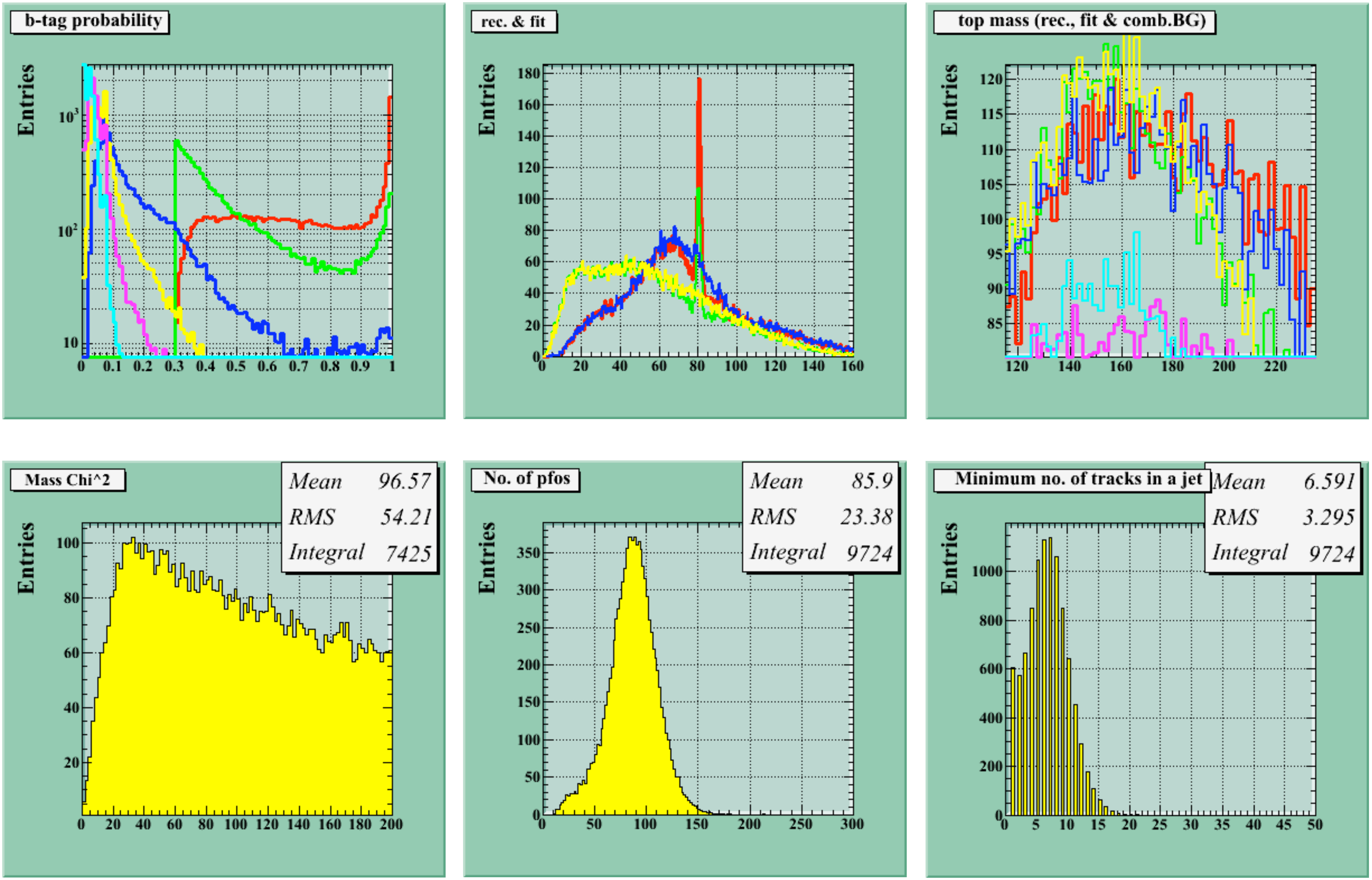
$m_t = 174.1 \pm 0.04$ (stat.)    $\Gamma_t = 1.42 \pm 0.10$ (stat.)

Preliminary

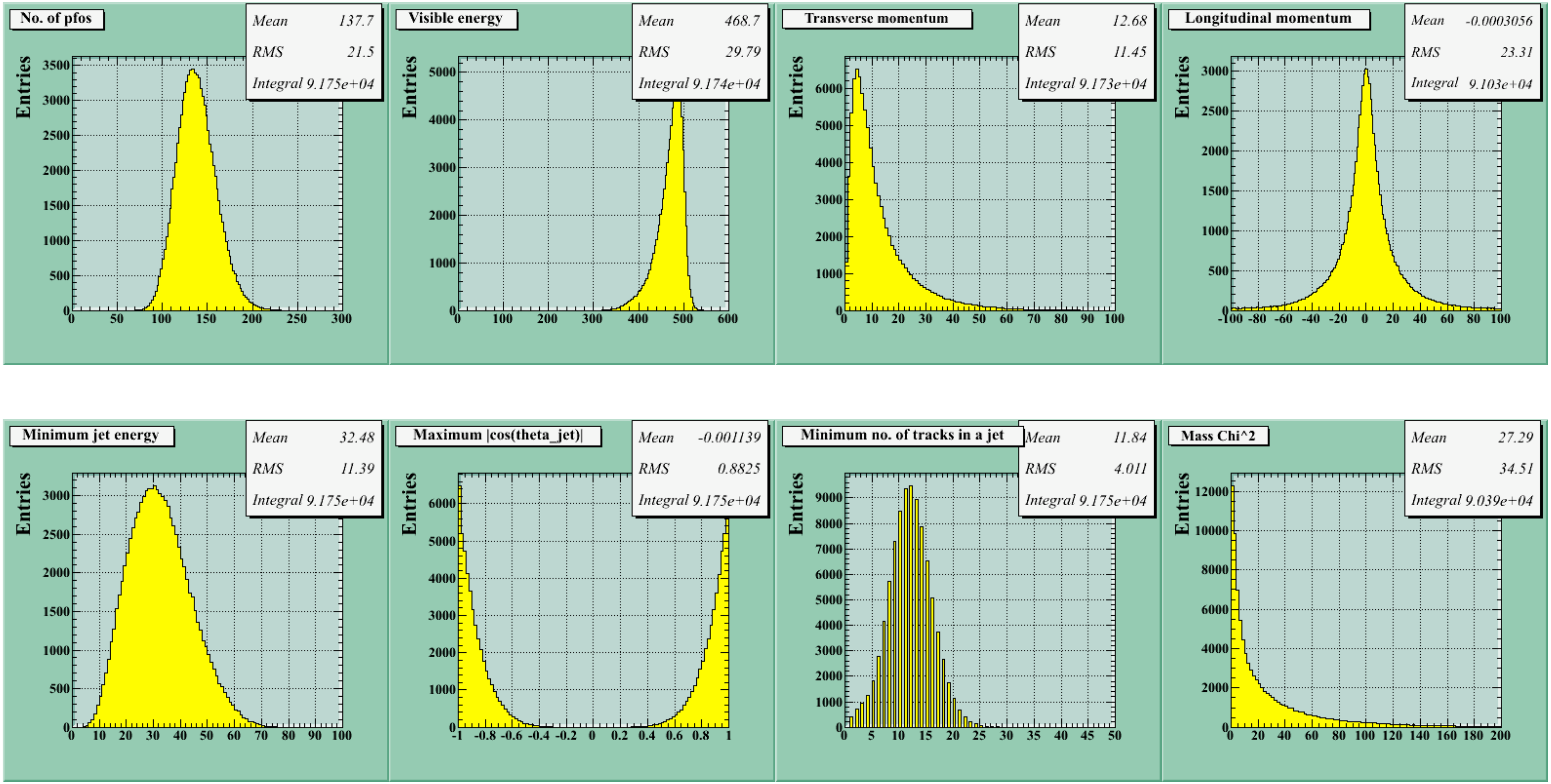
- Need to evaluate systematic errors!! => different $m_t$ sample?
- Precision for the $\sigma_{tt}$ mesurement

# Backup slides

# 4F-6F (w/o ffffbb) distribution



# bbqqqq event profile



# $M_{3j}$ fitting line-shape

convolution of Breit-Wigner and resolution fucnctions

```
Double_t convfun(Double_t *xp, Double_t *parm)
{
   Double_t x       = *xp;
   Double_t mt      = parm[0];
   Double_t gamt    = parm[1];
   Double_t m3j     = parm[2];
   Double_t sigmt1  = parm[3];
   Double_t sigmt2  = parm[4];
   Double_t weight1 = parm[5];
   Double_t delm1   = parm[6];

   return TMath::BreitWigner(x, mt, gamt)
          *(weight1 * TMath::Gaus(m3j, x + delm1, sigmt1, kTRUE)
            + (1 - weight1) * TMath::Gaus(m3j, x, sigmt2, kTRUE));
}

Double_t lineshape(Double_t *m3jp, Double_t *x)
{
   Double_t m3j     = *m3jp;
   Double_t mt      = x[0];
   Double_t gamt    = x[1];
   Double_t norm    = x[2];
   Double_t sigmt1  = x[3];
   Double_t sigmt2  = x[4];
   Double_t weight1 = x[5];
   Double_t delm1   = x[6];

   TF1 func("convfun", convfun, mmin, mmax, 7);
   fun.SetParameters(mt, gamt, m3j, sigmt1, sigmt2, weight1, delm1);
   Double_t val = fun.Integral(mmin, mmax);
   return norm*val;
}
```

Detector resolution:

Asymmetric double Gaussian