Status of SiD Benchmarking

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Benchmark Reactions for the ILC LOI process

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Signal Samples

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

1. **$e^+e^- \rightarrow ZH$, $H \rightarrow e^+e^-X$, $\mu\mu X$ (M_H=120 GeV, E_{cms}=250 GeV)**
   a. momentum resolution
   b. material distribution in the detector, in particular in the tracker
   c. photon ID

   The electron channel is particularly challenging and sensitive to the material in the detector. The reconstruction of events with significant bremsstrahlung will demonstrate the ability to find and associate photons with the tracks. Physical measurements are the Higgs mass and the cross section.

2. **$e^+e^- \rightarrow ZH$, $H \rightarrow cc$, $\mu\mu$. $Z \rightarrow \nu\nu$ (M_H=120GeV, Ecm=250GeV)**
   a. heavy flavour tagging, secondary vertex reconstruction
   b. multi jet final state, c-tagging in jets, uds anti-tagging (particle ID)
   c. Anti-tagging can be tested by studying the $H \rightarrow gg$ channel.

   Selecting the neutrino final state for the Z makes the results from this study less sensitive to confusion in the event. Charm tagging is particularly challenging, and more sensitive to detector parameters than b-tagging. Physical observables are the BR(h->cc) and the BR(h->mu mu).

3. **$e^+e^- \rightarrow ZH$, $H \rightarrow cc$, $\mu\mu$, $Z \rightarrow qq$ (M_H=120GeV, Ecm=250GeV)**
    a. **in addition to the charm tagging, this final state tests the confusion resolution capability**

    Physical observables are the BR(h->cc) and the BR(h->mu mu).

4. **$e^+e^- \rightarrow Z \rightarrow \tau^+\tau^-$ (Ecm=500 GeV)**
    a. tau reconstruction, aspects of particle flow
    b. π^0 reconstruction
    c. tracking of very close-by tracks

    Tau reconstruction is a very challenging topic at the ILC. It will stress the tracking system and the clustering in the calorimeter. In addition selecting π^0 mesons will probe the photon reconstruction ability of the detector.
    Physical observables are σ, A_{FB} and tau decay mode efficiency and purity.

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 σ, A_{fb}, and m_{top}

6. **$e^+e^- \rightarrow \chi^+\chi^- / \chi_2^0\chi_2^0$ at Ecm=500 GeV**
    a. particle flow (WW, ZZ separation)
    b. multi-jet final states
    c. c. SUSY parameter is point 5 of Table 1 of hep-ex/0603010

    Physical observables are σ and masses

$\sqrt{s} = 500$ GeV SM Bgnd (similar set of events for $\sqrt{s} = 250$ GeV)

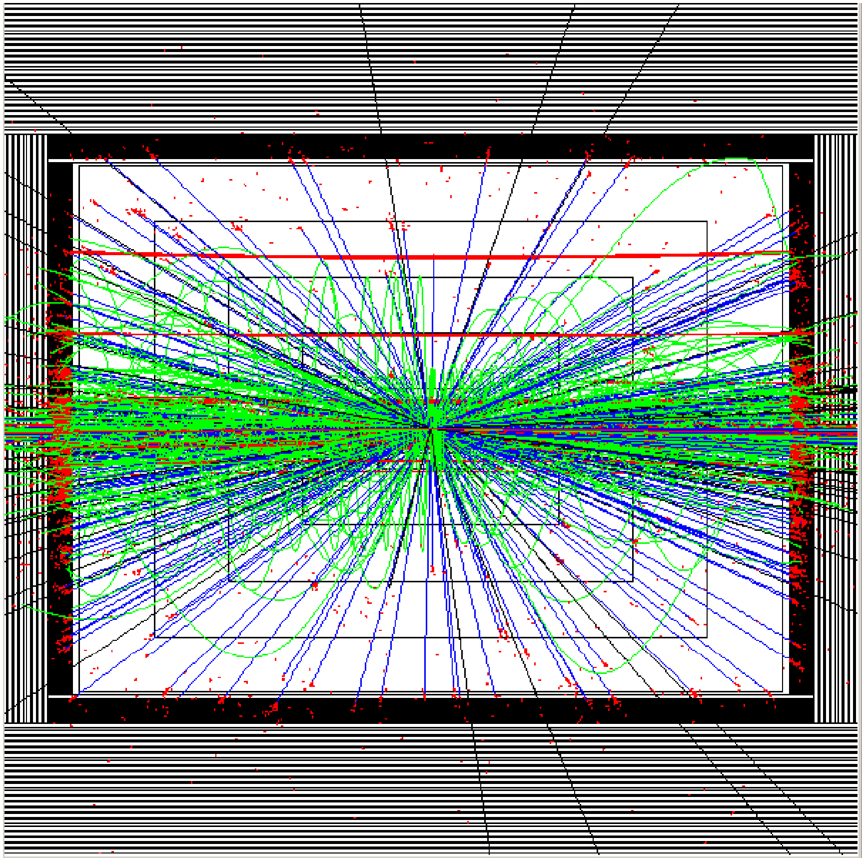
stdhep files for background and signal are shared by all detector concept groups

Process	σ(fb)	Lumi (fb^{-1})	# Events
	$pol_{e^-/e^+} = \mp 80/\pm 30\%$		
$e^+e^- \to e^+e^-$	1.74×10^7	0.04	696435
$\gamma\gamma \to f\,\bar{f}$	5.55×10^6	0.10	554700
$e\gamma \to e\gamma$	1.74×10^6	0.10	172119
$e\gamma \to e\,f\,\bar{f}, \nu\,f\,\bar{f}$	2.59×10^5	4.00	1034034
$e^+e^- \to \gamma\gamma$	2.60×10^4	2.00	51974
$e^+e^- \to f\,\bar{f}\,f\,\bar{f}$	1.90×10^4	140.00	2665962
$e^+e^- \to \mu^+\mu^-, \tau^+\tau^-, q\bar{q}$	1.85×10^4	50.00	924384
$e^+e^- \to \nu\bar{\nu} + n\gamma$	1.31×10^4	40.00	522449
$e^+e^- \to \gamma\gamma, \gamma\gamma\gamma$	1.46×10^3	20.00	29166
$e^+e^- \to f\,\bar{f}\,f\,\bar{f}\,f\,\bar{f}$	7.32×10^2	500.00	366070
$\gamma\gamma \to f\,\bar{f}\,f\,\bar{f}$	2.32×10^2	500.00	115914
$e\gamma \to f\,f\,\bar{f}\,f\,\bar{f}$	1.14×10^2	500.00	56875
$\gamma\gamma \to tt, e\gamma \to \nu bt, ett$	2.56×10^0	500.00	1282
Total			7191364

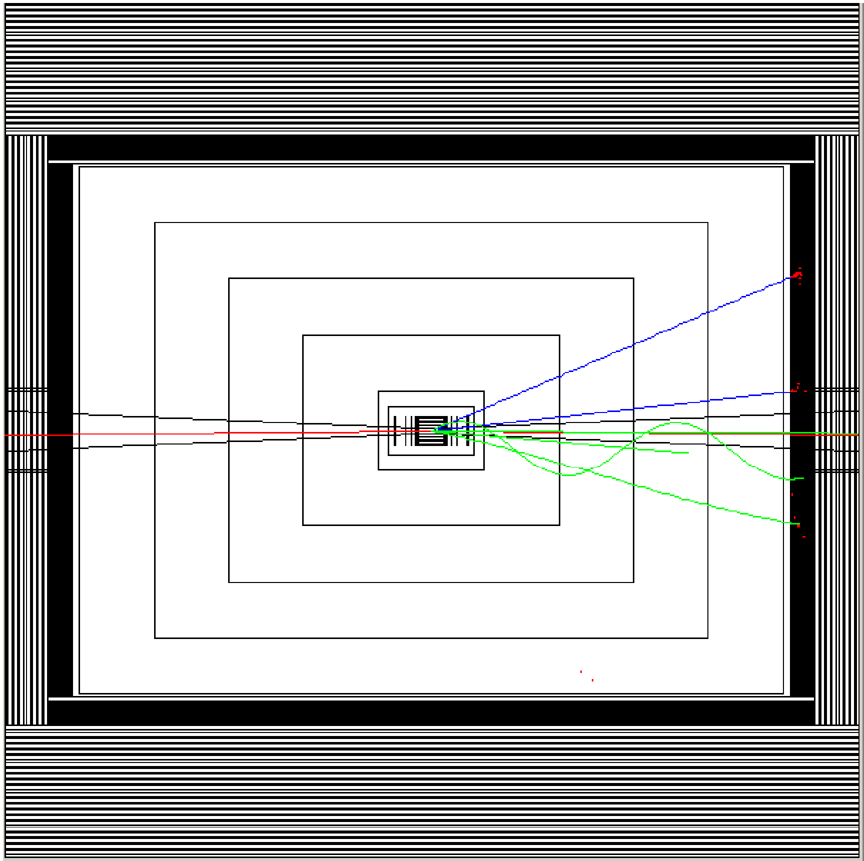
http://confluence.slac.stanford.edu/display/ilc/Standard+Model+Data+Samples

Beam-Beam Background

Process	$\gamma\gamma \to e^+e^-$ $pT > 115$ MeV	$\gamma\gamma \to \mu^+\mu^-$ $pT > 115$ MeV	$\gamma\gamma \to hadrons$
σ(fb)	1.10×10^9	1.36×10^9	4.61×10^8



Yellow = muons   Red = electrons   Green = charged hadrons
Black = Neutral Hadrons   Blue = photons with E > 100 MeV
150 bunch crossings (5% of train)



1 bunch crossing

Current benchmarking plan: Include this background in analysis of $e^+e^- \to t\bar{t}$ only. Integrate over just 1 bunch crossing.

Status of SiD Benchmarking for LOI

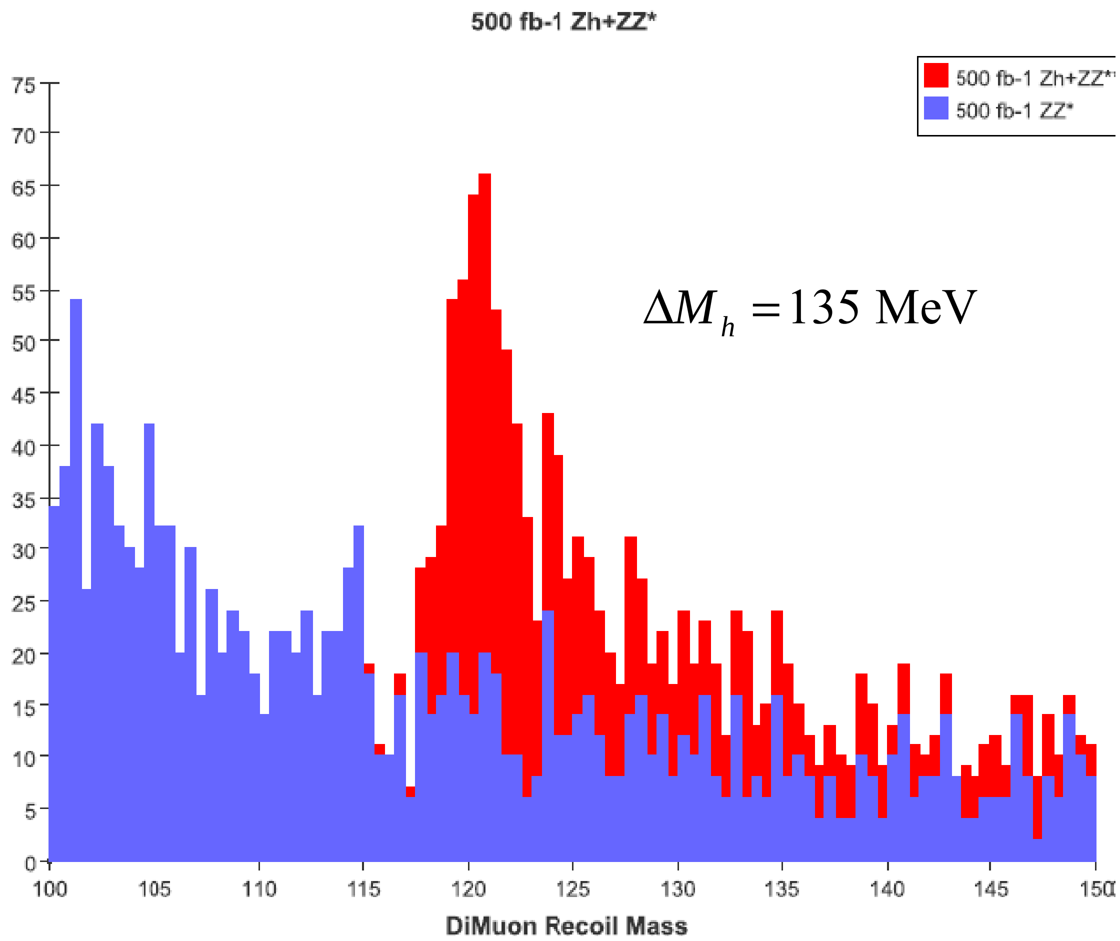
#	$\sqrt{s}$ (GeV)	Final State	Institution		Fraction of Work Completed			
			Stdhep	Analysis	Stdhep	Geant4	Reco	Analysis
1	250	e^+e^-H	SLAC	SLAC	0.3	0.3	0.3	0.9
1	250	$\mu^+\mu^-H$	SLAC	SLAC	0.3	0.3	0.3	0.9
2	250	$\nu\nu H \to \nu\nu c\bar{c}$	SLAC	Oxford	1.0	1.0	1.0	0.4
3	250	$qqH \to qqc\bar{c}$	SLAC	Oxford	1.0	1.0	1.0	0.2
2	250	$\nu\nu H \to \nu\nu\mu^+\mu^-$	SLAC	RAL	1.0	1.0	1.0	0.6
3	250	$qqH \to qq\mu^+\mu^-$	SLAC	RAL	1.0	1.0	1.0	0.6
4	500	$\tau^+\tau^-$	DESY	Stonybrook	1.0	1.0	1.0	0.1
5	500	$t\bar{t}$	SLAC	Oxford	1.0	1.0	1.0	0.9
6	500	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_2^0\tilde{\chi}_2^0$	DESY	Oxford	0.9	0.0	0.0	0.2
–	250	SM bkgd	SLAC	–	1.0	1.0	1.0	–
–	500	SM bkgd	SLAC	–	1.0	1.0	1.0	–

1. $e^+e^- \rightarrow ZH \rightarrow e^+e^-X$, $\mu\mu X$ (M_H=120 GeV, E_{cms}=250 GeV)

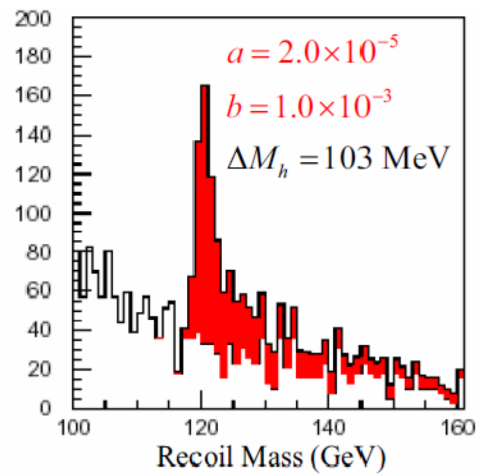
- General analysis algorithm and error calculation for mass measurement are in good shape due to previous fast MC study
- Still must develop algorithm for cross section calculation
- Need to establish muon id algorithm
- First results for eeX now available

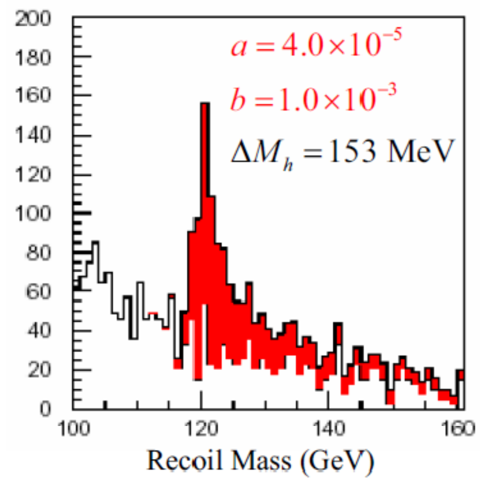
Old Full MC Detector Simulation and Event Reconstruction of $e^+e^- \rightarrow ZH \rightarrow \mu^+\mu^- X$ by Norm Graf Using Cheated Tracks & SiD01

$\sqrt{s} = 350\, GeV \quad L = 500\ fb^{-1}$



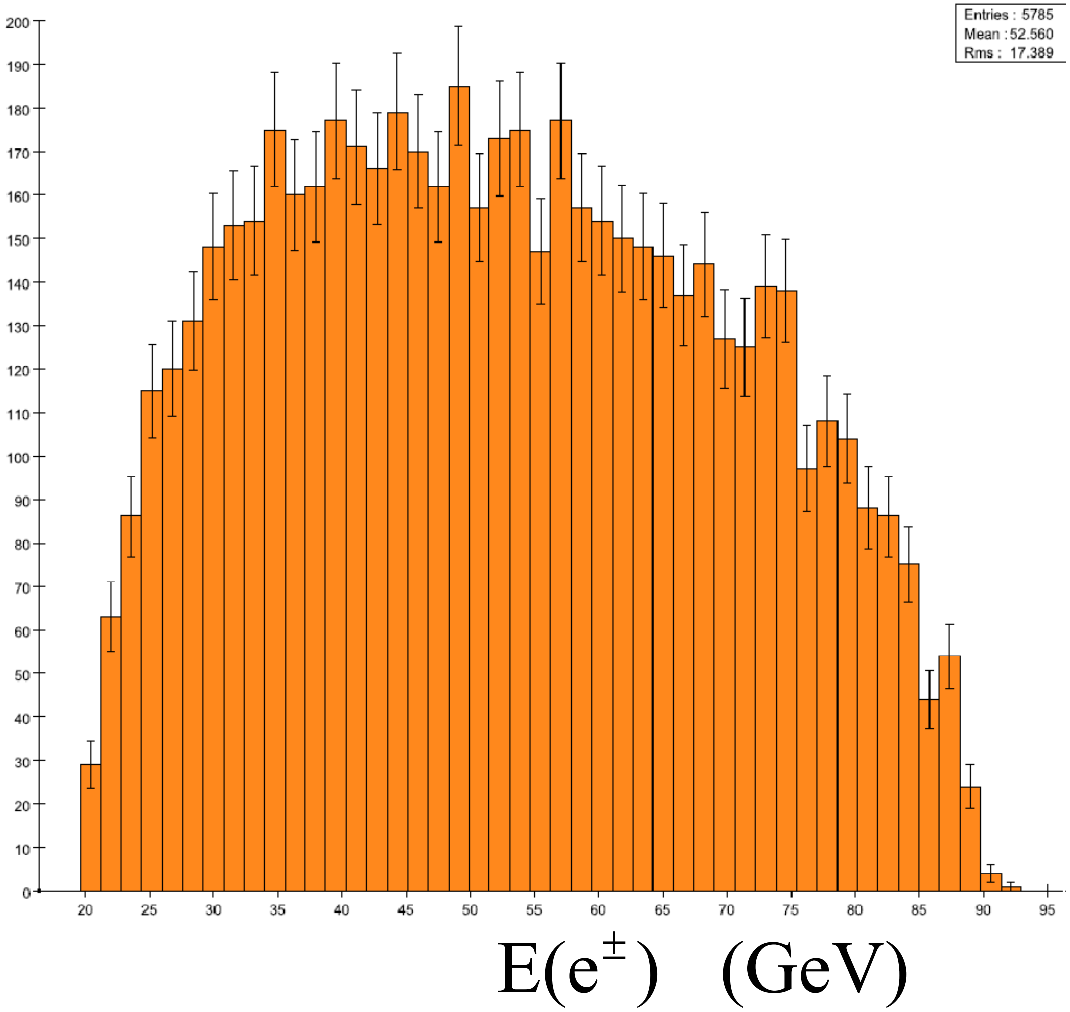
FASTMC study:





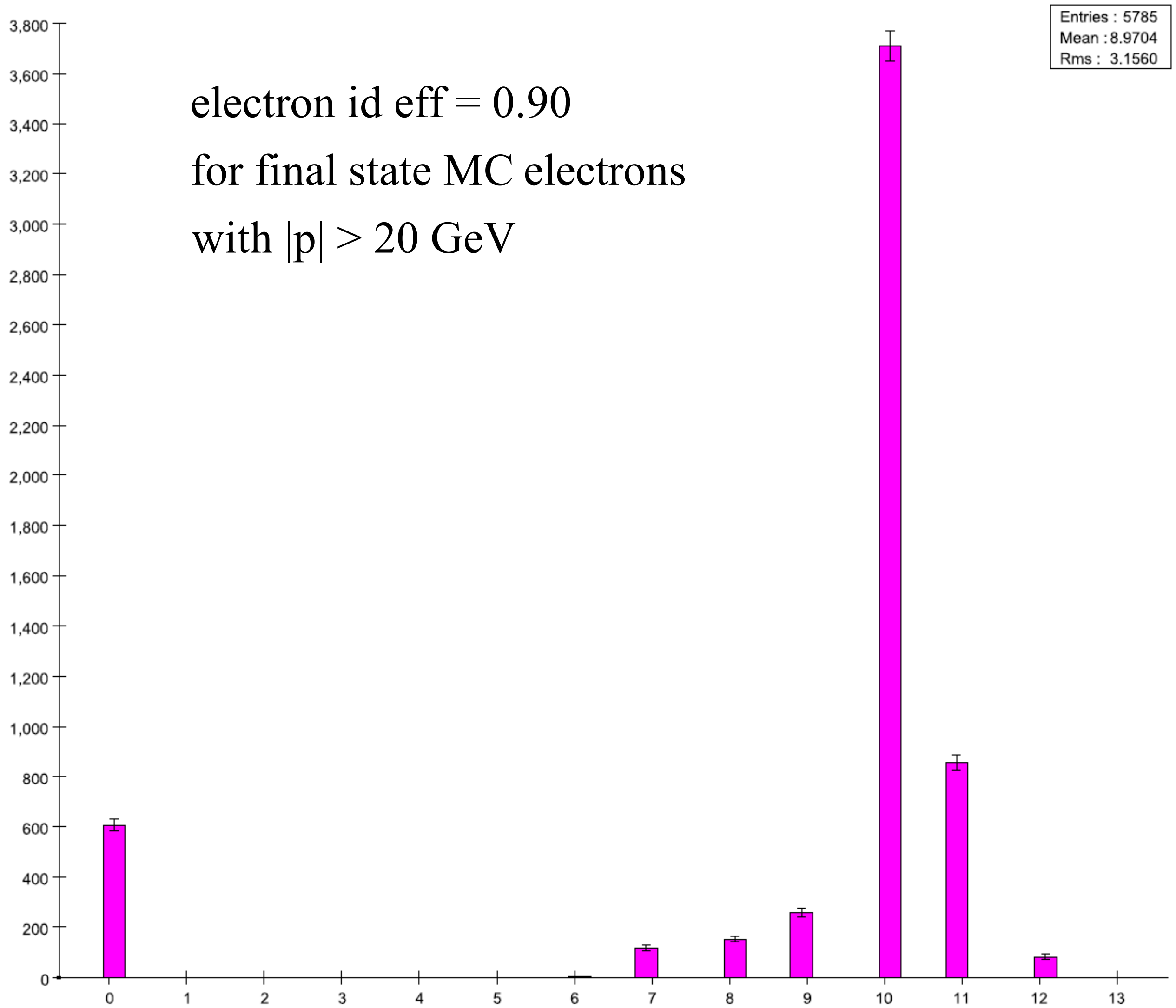
Electron ID is important for the Higgs recoil mass measurement in $e^+e^- \to ZH \to e^+e^- X$

At $\sqrt{s} = 250$ GeV the energies of the electrons from the Z decay range from 20 to 90 GeV:



Efficiency of Electron ID algorithm is currently 90%

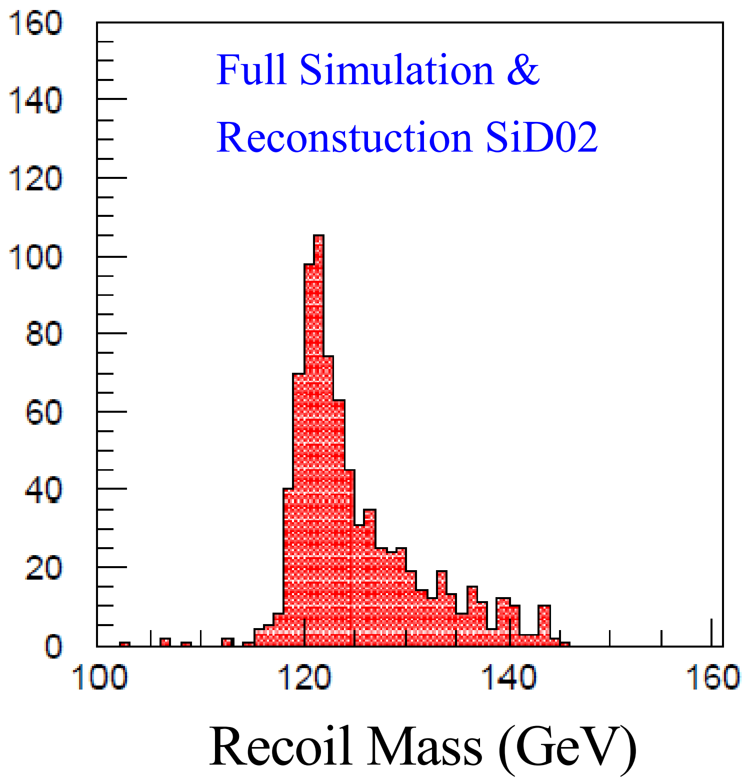
Mis-ID rate is currently 0.5% for $E_{\pi^+} > 20$ GeV

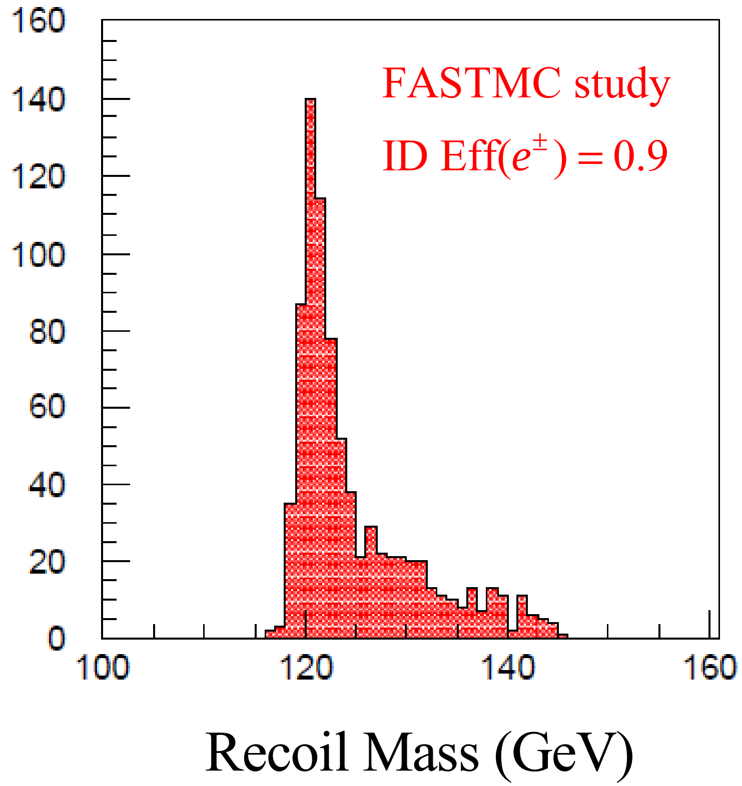


\# Reco electron tracker hits associated with the final state MC electron

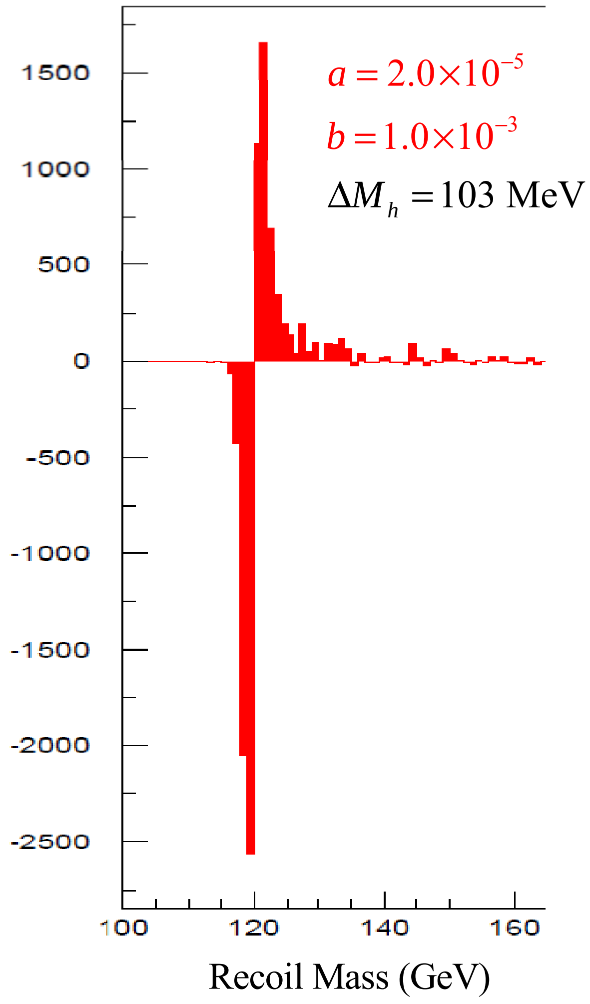
First plots from Full Sim/Reco SiD02 $e^+e^- \to ZH \to e^+e^- X$

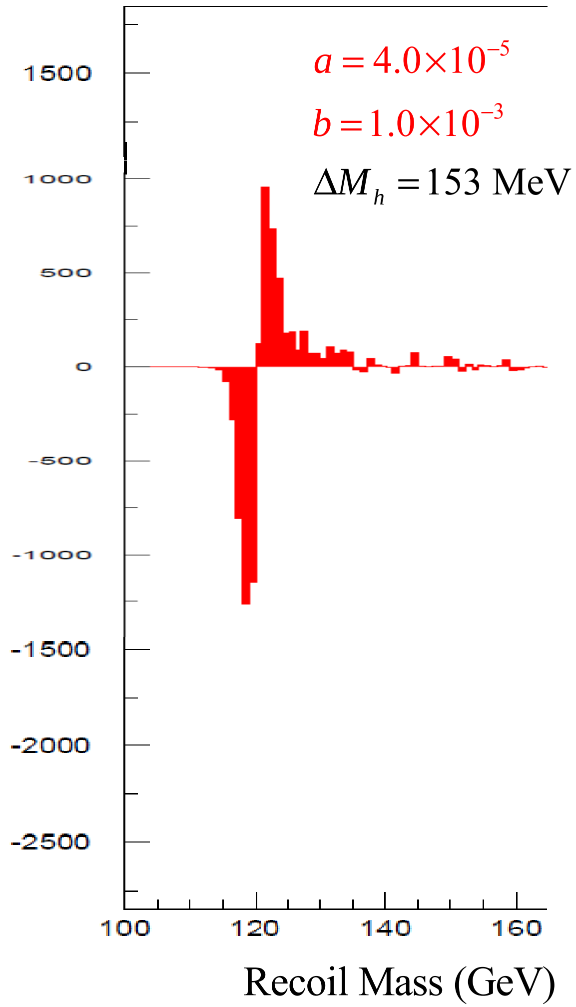
$$\sqrt{s} = 250\ GeV$$





$$\left.\frac{d\hat{N}_{bin}}{dM_h}\right|_{Mh=120\,GeV}$$





$$\hat{N}_i(M_h) = \hat{N}_{i\,bkdg} + \hat{N}_{i\,signal} + \frac{\partial \hat{N}_i}{\partial M_h}(M_h - 120)$$

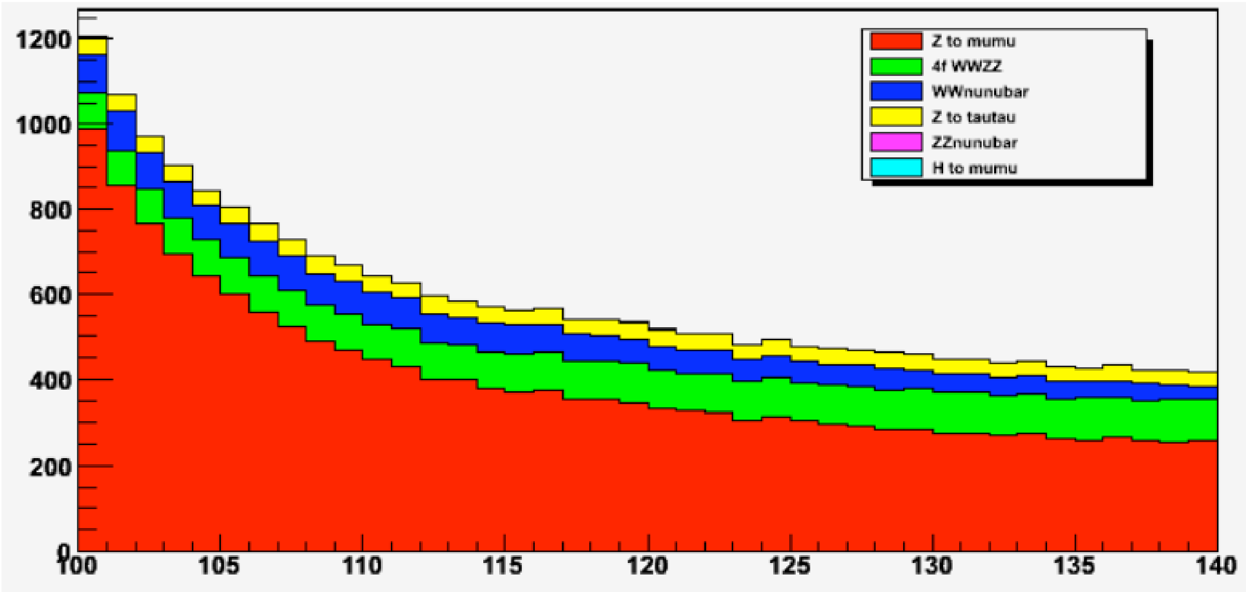
$$\chi^2(M_h) = \sum_i \frac{(N_i - \hat{N}_i(M_h))^2}{\sigma_i^2} \quad , \quad \sigma_i = \sqrt{\hat{N}_{i\,bkdg} + \hat{N}_{i\,signal}}$$

2. $e^+e^- \to ZH, H \to cc, \mu\mu$. $Z \to \nu\nu$ (M_H=120GeV, Ecm=250GeV)

- Yambazi Banda (Oxford) is working on the decay H→cc using the LCFI vertexing package. First estimate of BR(H→cc) expected next month.
- Jan Strube (RAL) is doing H→ μμ.

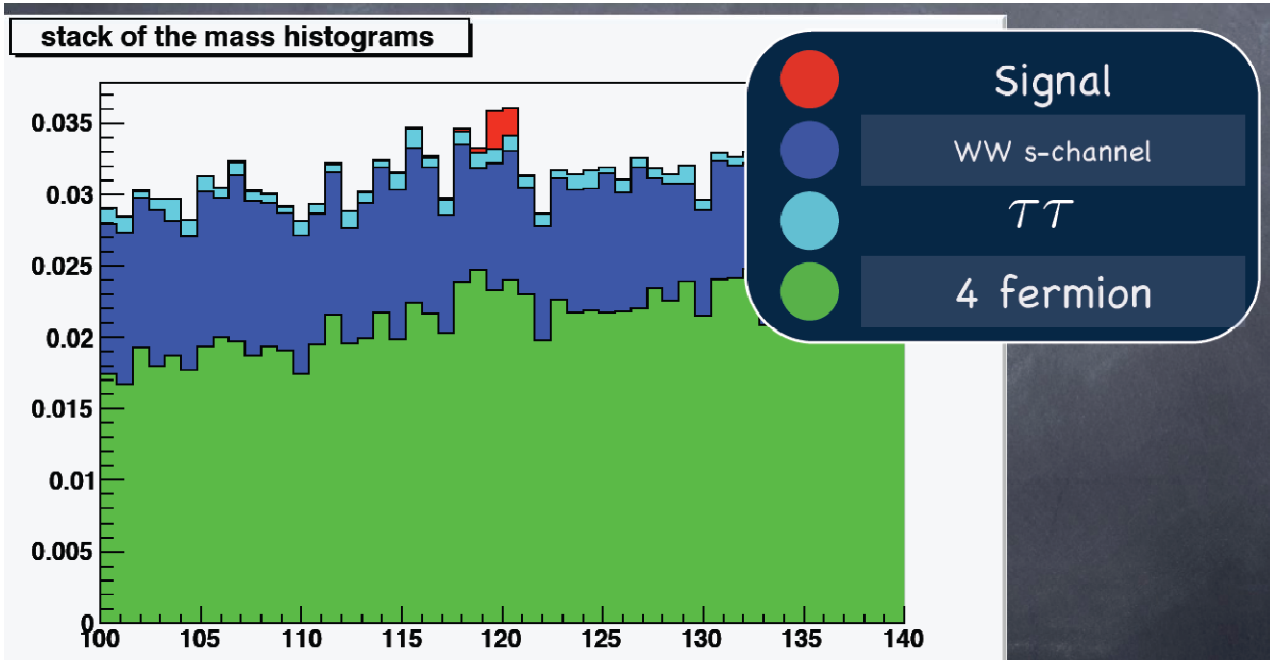
$e^+e^- \to ZH \to \nu\bar{\nu}\mu^+\mu^-$ Jan Strube (RAL)

Before Cuts



After Cuts and Boosted Decision Tree Analysis of FastMC events

Signal 1.8σ



Outlook and plans

- The analysis strategy seems to make sense
  - applicable to 250 GeV events
  - use ReconstructedParticles instead of FastMC
- Still need some dedicated background samples to understand differences between FastMC and full simulation
- Add Z->qq to gain statistics

3. $e^+e^- \to ZH$, $H \to cc$, $\mu\mu$, $Z \to qq$ (M_H=120GeV, Ecm=250GeV)

- Yambazi is concentrating at the moment on H→ cc with Z→ νν . A large fraction of that analysis will carryover to Z→qq.
- Same comments apply to H→μμ

4. $e^+e^- \rightarrow Z \rightarrow \tau^+\tau^-$ (Ecm=500 GeV)

- This analysis is being done by Subhendu Chakrabarti and Paul Grannis. They are currently getting started but expect to come up to speed quickly in the coming weeks.

5. $e^+e^- \to tt$, $t \to bW$, $W \to qq'$ (Mtop=175GeV, Ecm=500 GeV)

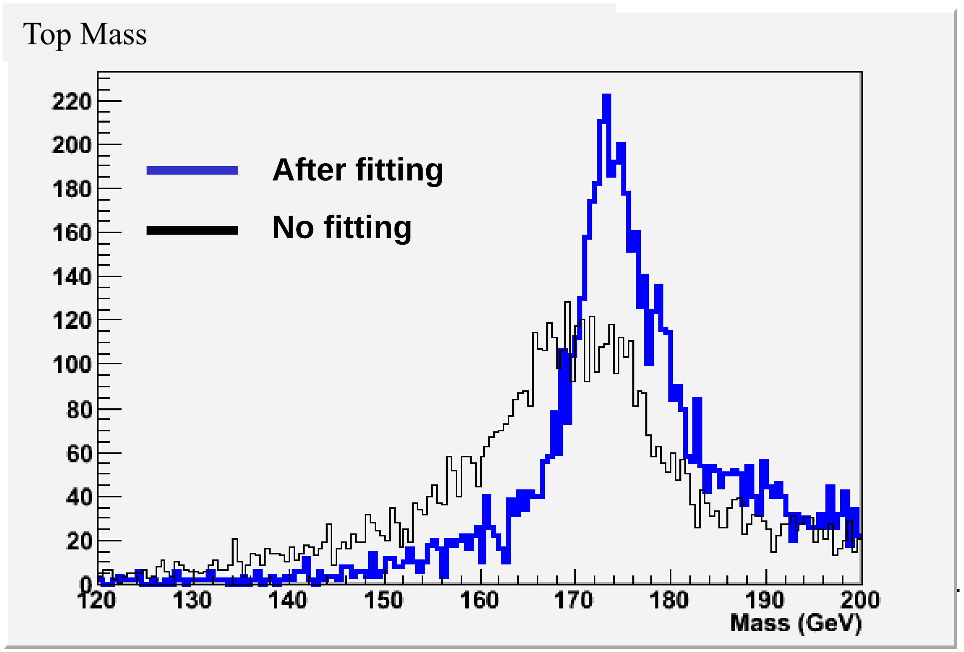
- Algorithm and error calculation for mass measurement are in very good shape thanks to the work of Erik Devetak (Oxford).
- This analysis has also been used to test the Reconstructed Particle output of the PFA algorithm

TOOLS 2: Kinematic Fitting

- Kinematic fitter performed after b tagging.
- 2 jets with highest b-tag treated a b jets others as jets from W.

- Use hard constraints:

	#constraints
Total energy 500GeV	1
Total momentum (x,y,z direction) =0	3
W_1mass = W_2mass = 80.4	2
top_1mass = top_2mass	1

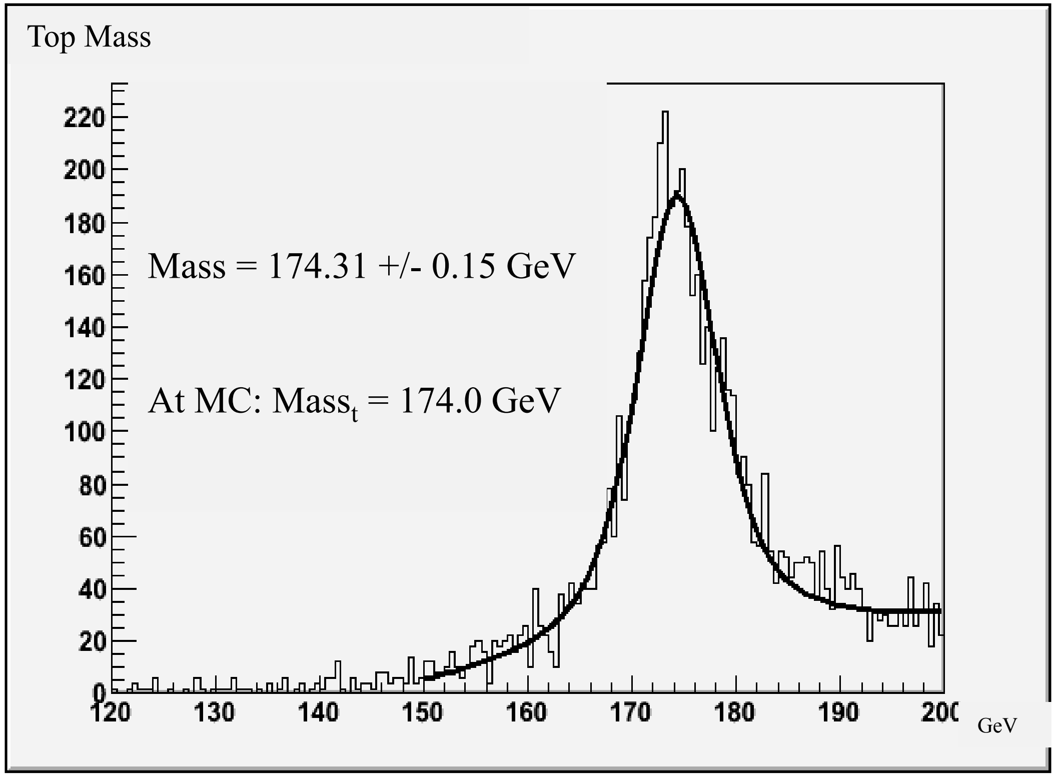


- Attempted also different constrains-combinatorics:
  - Not use b tagging
  - Not use W mass constrain
  - Use only W_1mass =W_2mass

- Very useful tool

Top Mass – Simple fitting

- Function fitted:
  - gauss (detector smearing)
  - convoluted BW (intrinsic width)
  - add tanh (good model for additional background, empirical) from combinatorics?
- Purity: 97%,
- Efficiency: 33%
- Both values can improve:
  - by using e, μ ID
  - optimize cuts!



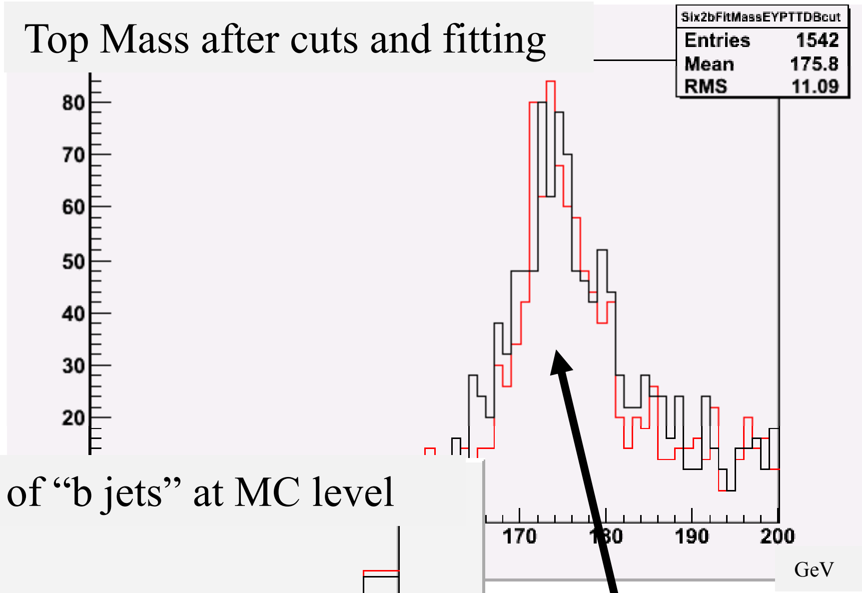
- Can now extrapolate results to $500 fb^{-1}$: σ_m = 46MeV (statistical error)

NOTES

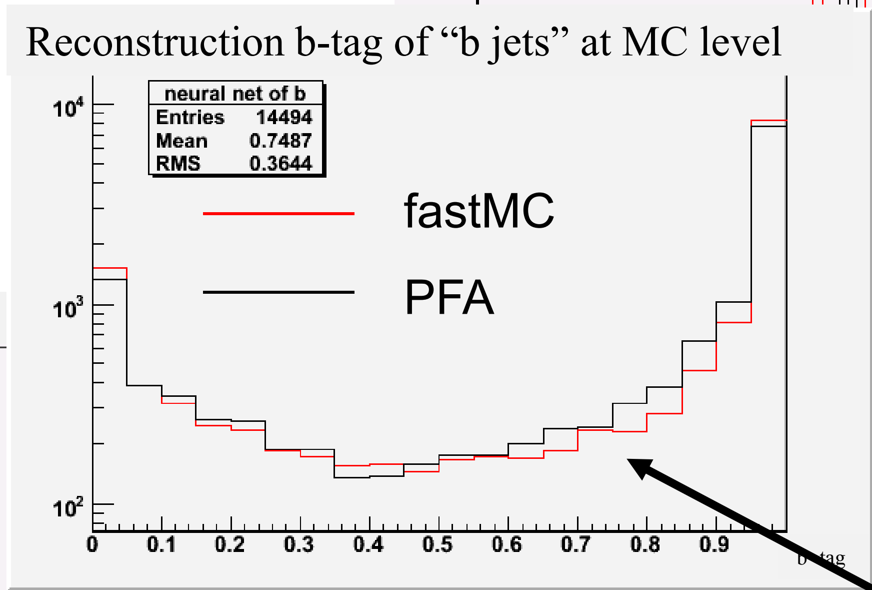
- FastMC study; smaller statistics studies with full reconstruction suggest no significant degradation
- Sample is bbffff and not tt – no way of separating the two with the produced sample (so includes WWZ, Z→bb + ….)

From fastMC to SiD PFA

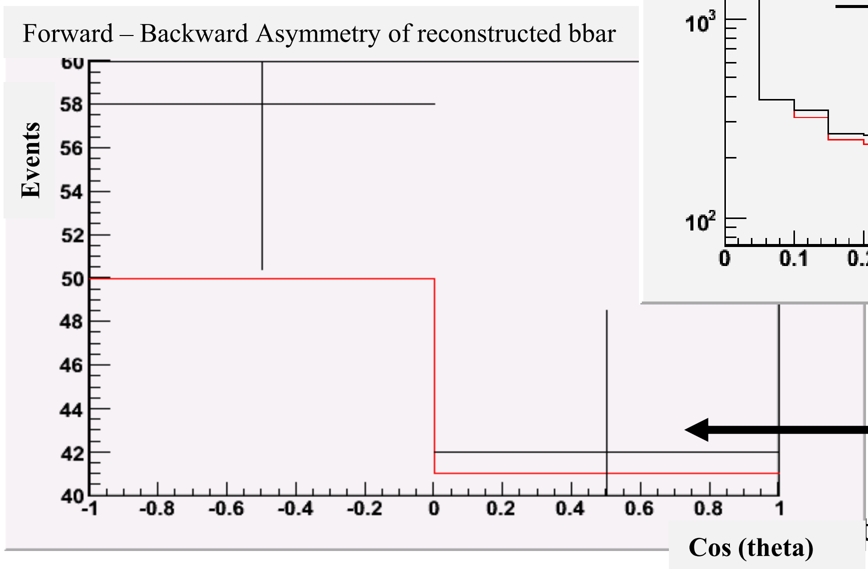
- Started move to more realistic simulation
- Step one move to SiD PFA
- Test performance (at low statistics)



NO MAJOR DIFFERENCE



Increase in σ, very small, expect ≈5%



Comparable, some issues from V0s, need finder

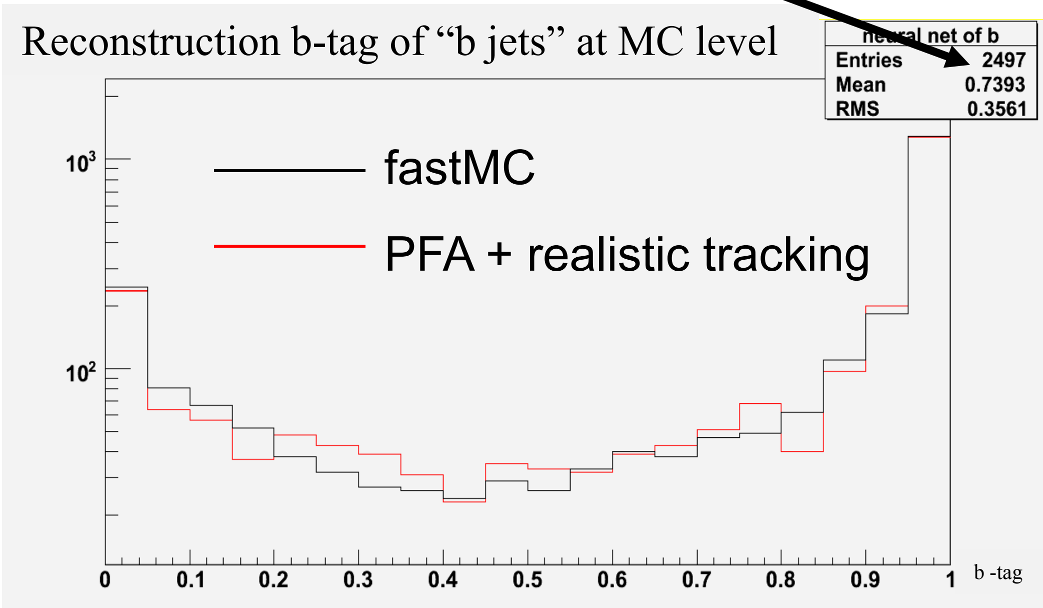
Better statistics with PFA, no difference in mis-tag

… + realistic tracking

- Step two move to realistic tracking
- Again test performance (here statistics very very low statistics)
- At first glance…

NO SURPRISE

REPEAT WITH MORE STATISTICS AND NEW ALGORITHM



- Additionally algorithm improved substantially since plot…
- Test show: no major difference in results expected from full reconstruction
- Moving very quickly to full reconstruction and to higher statistics!

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Benchmarking LoI #5

AIM: in the all hadronic channel (**e+e-→tt, t→bW, W→qq'**) calculate:

- Top total cross – section ≈
- Calculate mass of top quark ✓
- Top forwards backwards asymmetry ✓

GOOD PROGRESS!

First draft analysis!

Clearly some algorithms need tuning/improvements!

TOOLS:

- b tagging (LCFI) ✓
- charge reconstruction (LCFI + ad hoc) ✓
- Kinematic Fitting (MarlinKinfit) ✓

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6. $e^+e^- \rightarrow \chi^+\chi^- / \chi_2^0\chi_2^0$ at Ecm=500 GeV

- Analysis is being developed by Andrei Nomerotski et al. at Oxford. In the initial stages of development.
- Geant4 simulation of SiD02 has not yet started for these processes, but stdhep events are available for algorithm development with FastMC

Summary

- Full simulation and reconstruction are in good shape from the viewpoint of the people doing the physics benchmarking.
- We are not as far along as we would like with analysis algorithm development for some of the benchmarks. We have recently added some new people. Also, as event generation , simulation and reconstruction near completion some resources can be shifted from that work to physics analysis.