Benchmarking Status

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Outline

- LOI Benchmarks
- Event Samples
- Strategy for LOI Studies
- PFA vs. FastMC Comparisons
- Physics Algorithms

Benchmark Reactions for the ILC LOI process

February 28. 2008

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

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

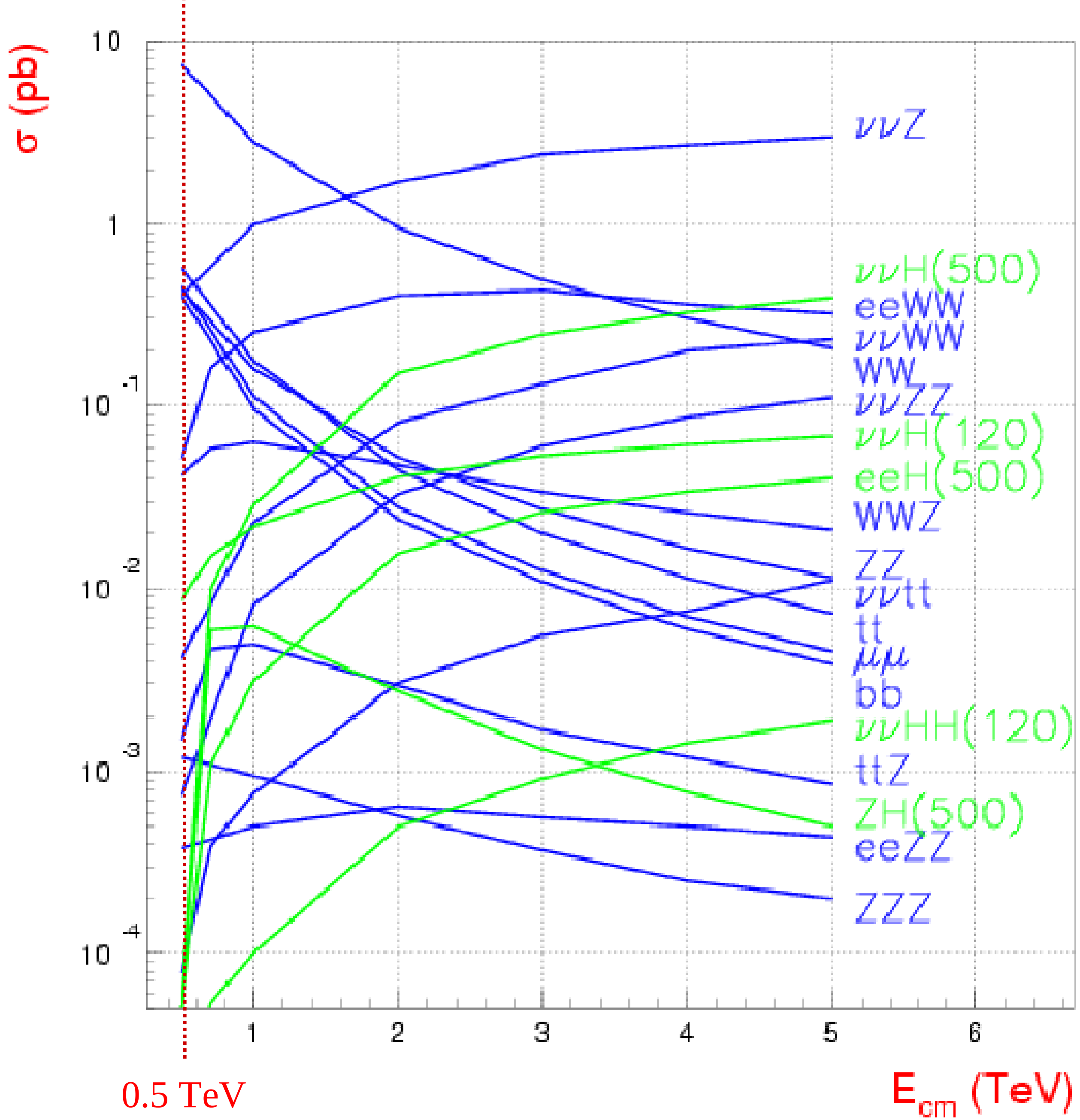
    Top reconstruction is an excellent test for the performance of the reconstruction in very busy events. At the moment it is not yet clear how critical ultimate particle flow performance is for this reaction.
    Physical observables are σ, A_{fb}, and m_{top}

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

Event Samples

- Generation of 2 ab^{-1}SM Event Samples (parton generation +FSR+fragmentation+decays) is completed for E_{cm} = 500 & 250 GeV
- Still must generate beam-beam background sample at E_{cm} = 250 GeV . Ongoing physics analyses dictate additional signal event generation and generation of specialized backgrounds.
- Cannot perform full simulation/reconstruction on all of these events. Which events are fully simulated?


σ (pb)
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
1
2
3
4
5
6
ννZ
ννH(500)
eeWW
ννWW
WW
ννZZ
ννH(120)
eeH(500)
WWZ
ZZ
ννtt
tt
μμ
bb
ννHH(120)
ttZ
ZH(500)
eeZZ
ZZZ
0.5 TeV
E_{cm} (TeV)

Standard Model Sample (background sample)

WWOC Software Panel

For realistic estimation of detector performances, analysis should include the study of appropriate background processes. It is unrealistic to expect that at the moment a full unbiased production of SM samples is possible. We therefore suggest the following list of reactions and luminosities as a minimum set to be simulated for the basis of the background studies:

e^+e^-	→	2f (f=μ, τ,u,d,s,c,b,ν,e) 4f 6f	50 fb^{-1} 20 fb^{-1} 20 fb^{-1}
$e^+e^- \to \gamma^*\gamma^*$	→	X (X=paris of μ, τ, u,d,s,c,b	1 fb^{-1}
e^+e^-	→	γγ (nγ)	10 fb^{-1}
		νν (nγ)	20 fb^{-1}
		e^+e^-	0.1 fb^{-1}
		e γ	0.1 fb^{-1}
e+e- → γ(nγ)2f			??fb-1
Calibration samples			According to need
Single particle samples			According to need

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

ILD E_{cm} = 500 GeV

Process	σ(fb)	Lumi (fb^{-1})	# Events
	pol_{e^-/e^+} = 0/0%		
$e^+e^- \to e^+e^-$	1.74×10^7	0.4	6953514
$\gamma\gamma \to f\bar{f}$	5.55×10^6	0.1	554769
$e\gamma \to e\gamma$	1.72×10^6	0.2	344268
$e\gamma \to ef\bar{f}, \nu f\bar{f}$	2.59×10^5	2.0	517124
$e^+e^- \to \gamma\gamma$	2.60×10^4	10.0	259895
$e^+e^- \to f\bar{f}f\bar{f}$	1.68×10^4	200.0	3358060
$e^+e^- \to \mu^+\mu^-, \tau^+\tau^-, q\bar{q}$	1.48×10^4	80.0	1182788
$e^+e^- \to \nu\bar{\nu} + n\gamma$	1.05×10^4	80.0	842752
$e^+e^- \to \gamma\gamma\gamma, \gamma\gamma\gamma\gamma$	1.18×10^3	40.0	47057
$e^+e^- \to f\bar{f}f\bar{f}f\bar{f}$	5.89×10^2	2000.0	1177372
$\gamma\gamma \to f\bar{f}f\bar{f}$		varies	2280
$e\gamma \to ff\bar{f}f\bar{f}$		varies	7440
$\gamma\gamma \to tt, e\gamma \to \nu bt, ett,$ & $e^+e^- \to t\bar{t}f\bar{f}$	2.43×10^0	200.0	485
Total			15247804

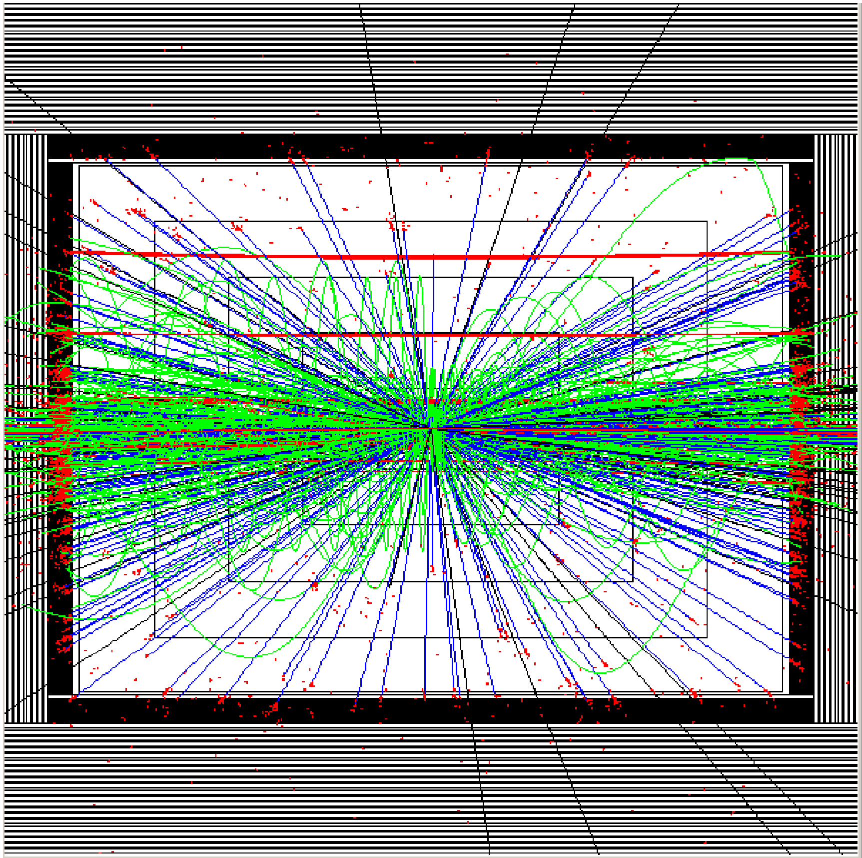
SiD E_{cm} = 500 GeV

$pol_{e^-/e^+} = \mp 80/\pm 30\%$

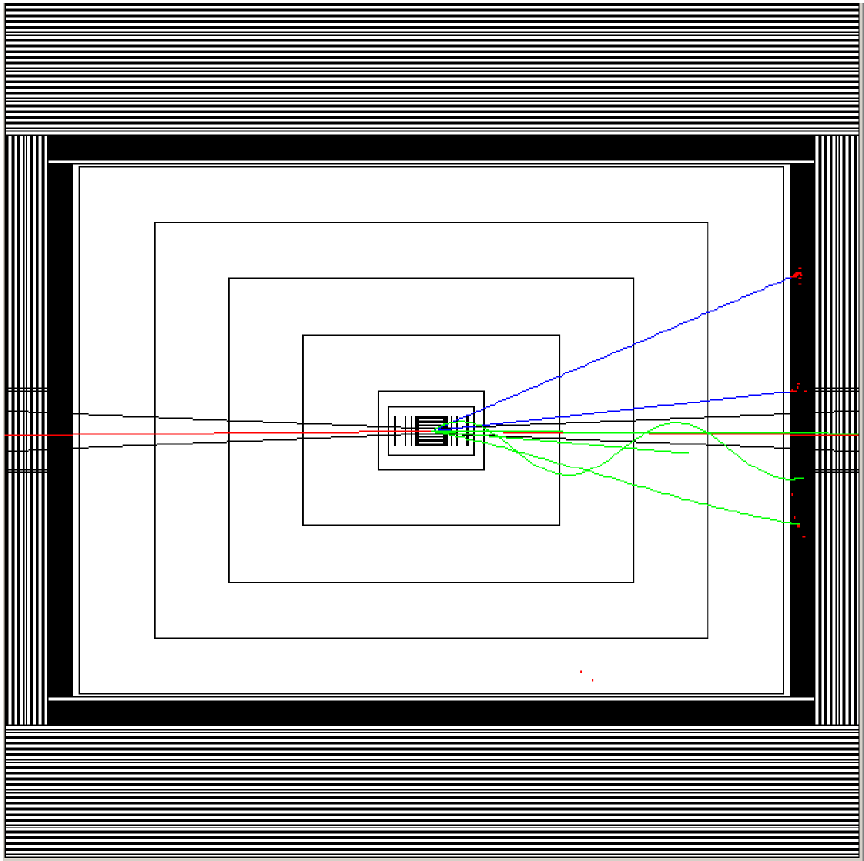
Process	σ(fb)	Lumi (fb^{-1})	# Events
$e^+e^- \to e^+e^-$	1.74×10^7	0.04	696435
$\gamma\gamma \to f\bar{f}$	5.55×10^6	0.10	554700
$e\gamma \to e\gamma$	1.74×10^6	0.10	172119
$e\gamma \to ef\bar{f}, \nu f\bar{f}$	2.59×10^5	4.00	1034034
$e^+e^- \to \gamma\gamma$	2.60×10^4	2.00	51974
$e^+e^- \to f\bar{f}f\bar{f}$	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
$e^+e^- \to \gamma\gamma\gamma, \gamma\gamma\gamma\gamma$	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
$e\gamma \to ff\bar{f}f\bar{f}$	1.14×10^2	500.00	56875
$\gamma\gamma \to tt, e\gamma \to \nu bt, ett,$ & $e^+e^- \to t\bar{t}f\bar{f}$	2.56×10^0	500.00	1282
Total			7191364

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.

Strategy for LOI Studies

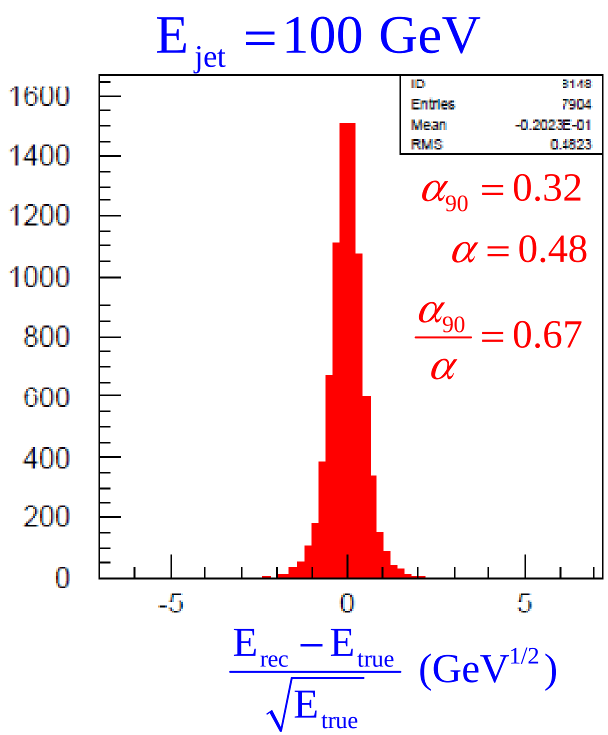
- Develop analysis algorithms using FastMC reconstructed particle LCIO output
- When full simulation/reconstruction data sets are ready run same analysis algorithms on the reconstructed particle LCIO output of the PFA
- FastMC based analyses are also used to estimate the number of signal events and specialized background events that require full simulation

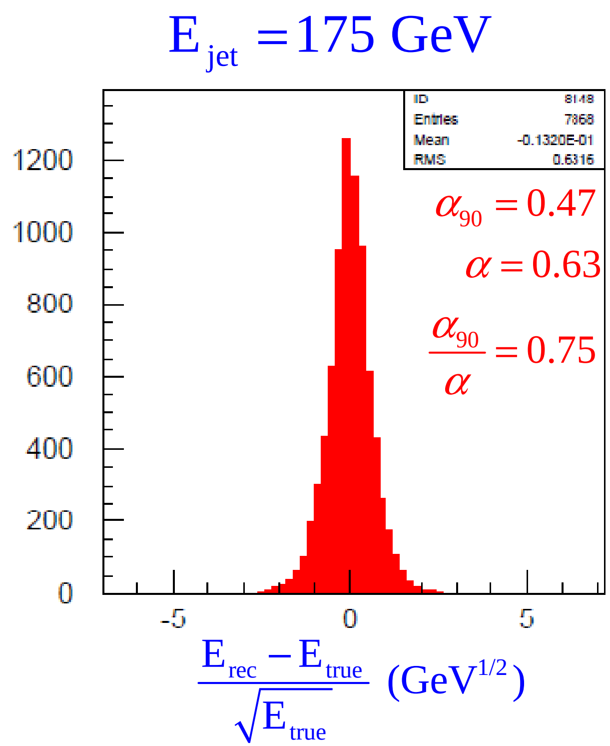
Use the following single particle calorimeter resolutions in FASTMC to mimick PFA jet energy resolution versus jet energy for jet energies 50 GeV < E_{jet} < 250 GeV

$$\frac{\Delta E_\gamma}{E_\gamma} = \frac{0.19}{\sqrt{E_\gamma}}$$

$$\frac{\Delta E_{\pi^+, K^+, p, n, K_L^0}}{E_{\pi^+, K^+, p, n, K_L^0}} = 0.10$$

Tracker used for π^+, K^+, p angles.

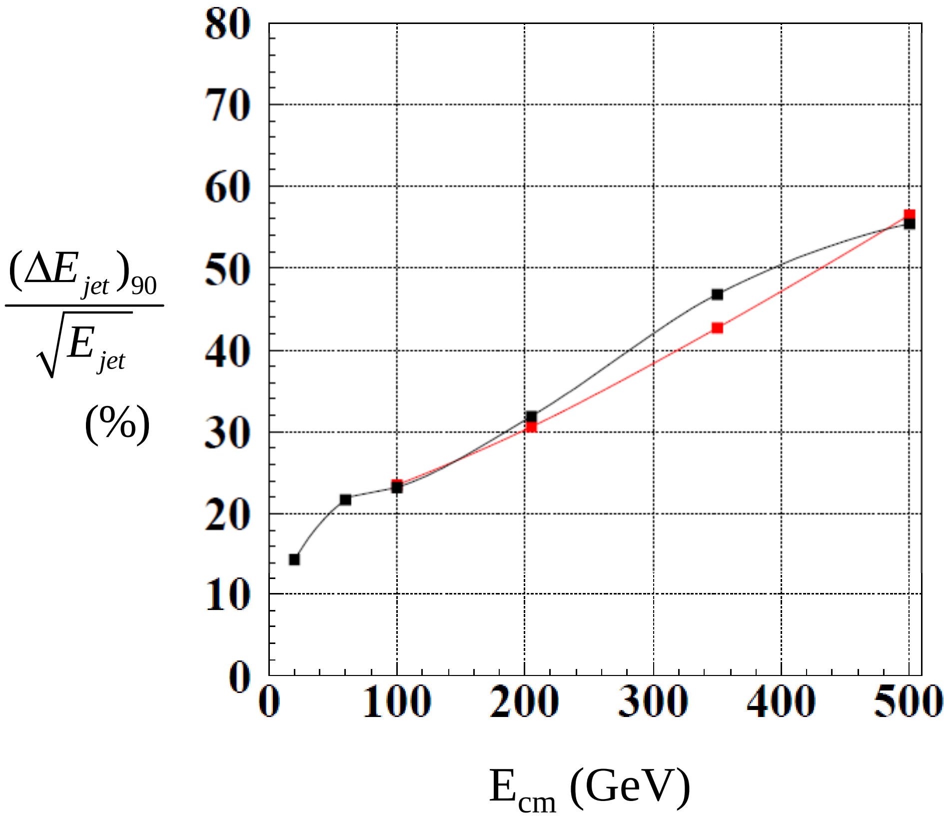


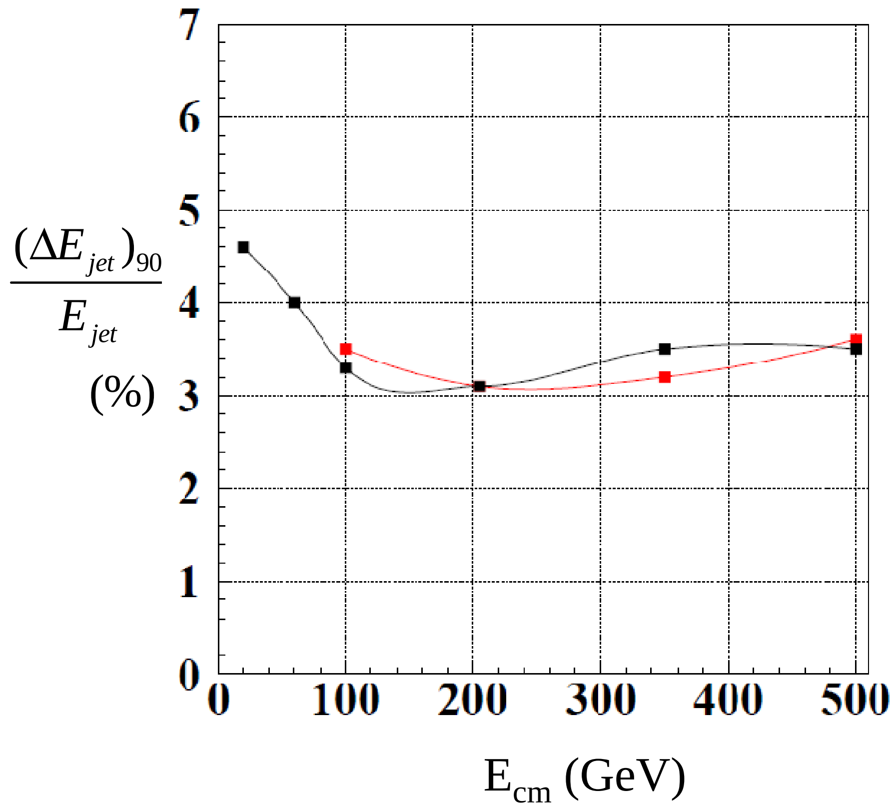


Light quark jets ee→qq

PandoraPFA v02-01 (red line) — FASTMC with (black line)

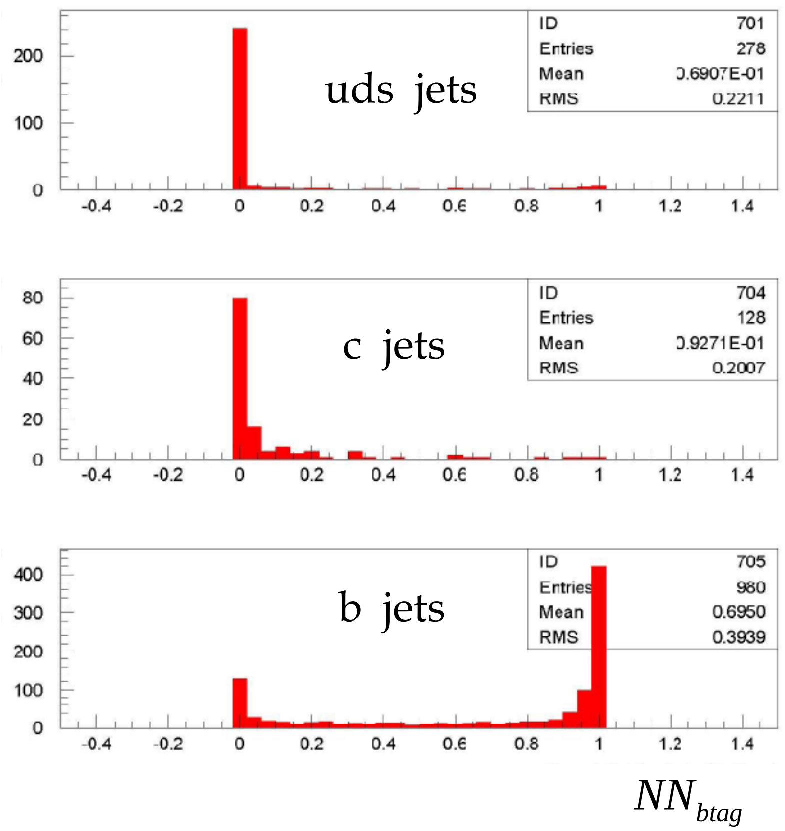
$$\frac{\Delta E_\gamma}{E_\gamma} = \frac{0.19}{\sqrt{E_\gamma}} \qquad \frac{\Delta E_{\pi^+, K^+, p, n, K_L^0}}{E_{\pi^+, K^+, p, n, K_L^0}} = 0.10$$



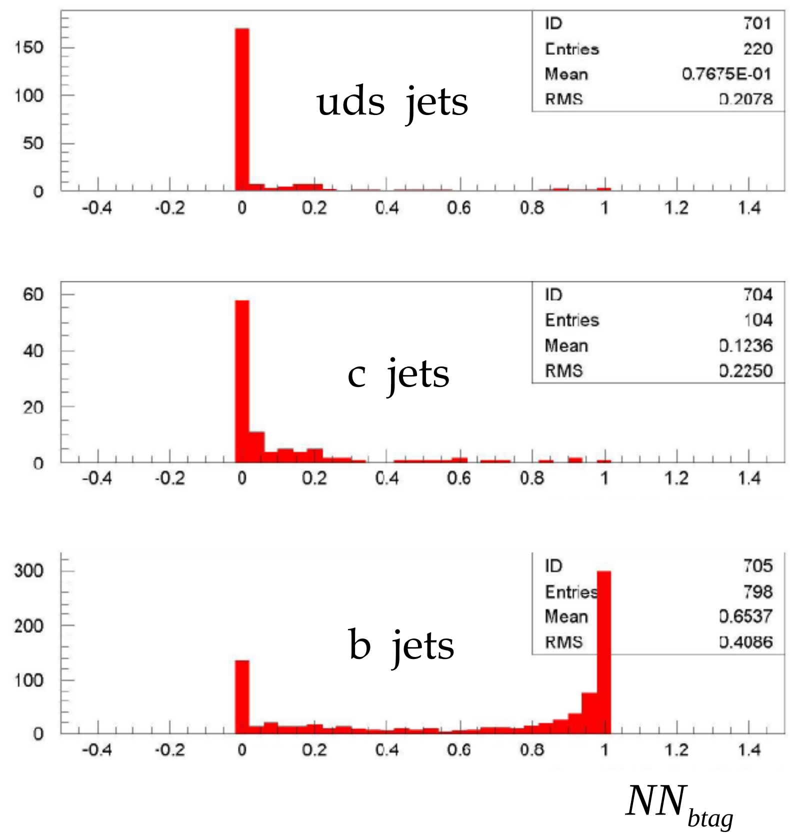


Comparison of FastMC and Ron’s PPR PFA

FastMC



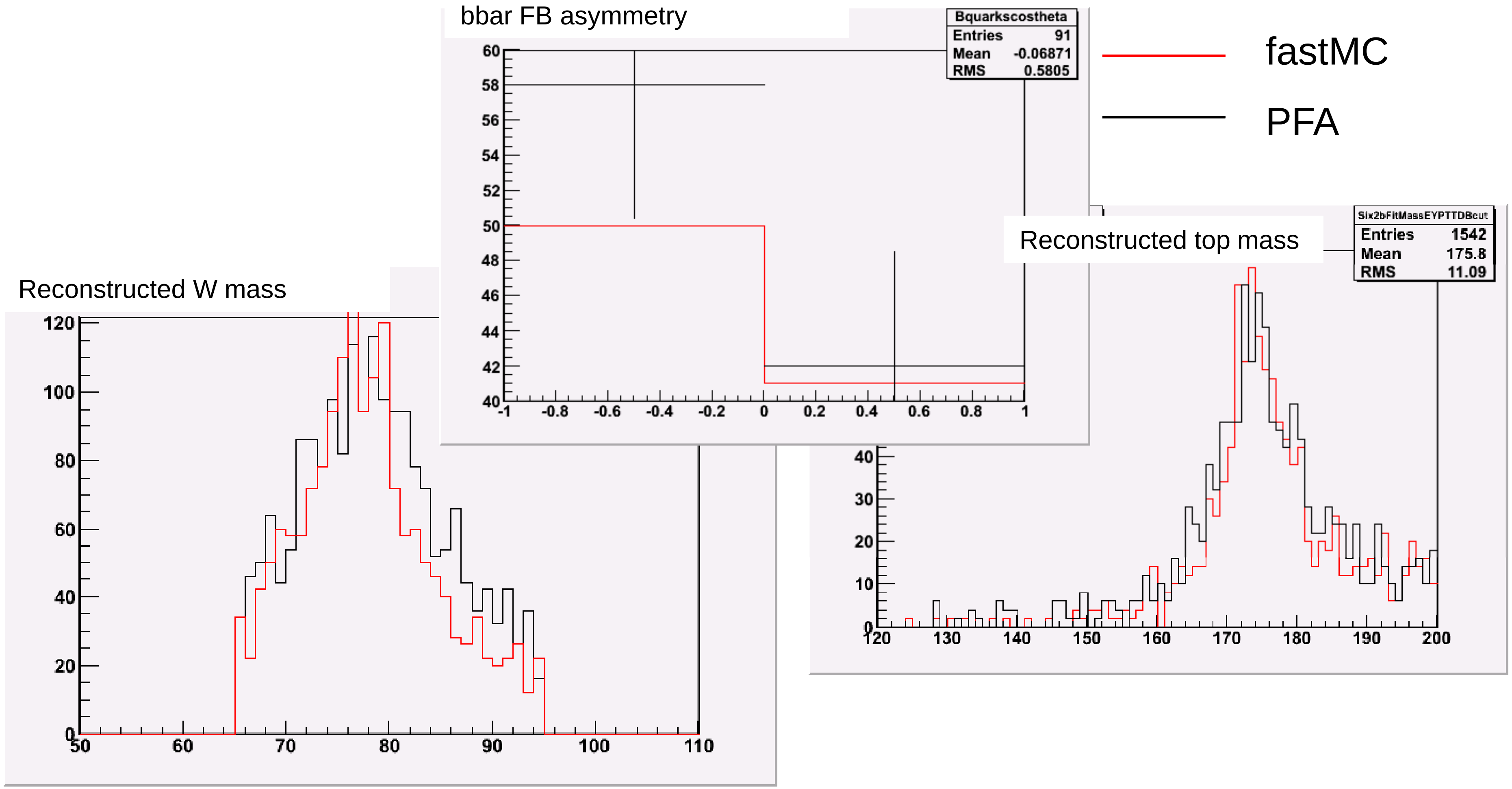
PPR PFA



ZHH events LCFI btag NN

Comparison of FastMC and Matt's PFA Using ttbar Events

(Erik Devetak, Oxford)



LOI Benchmark Responsibilities

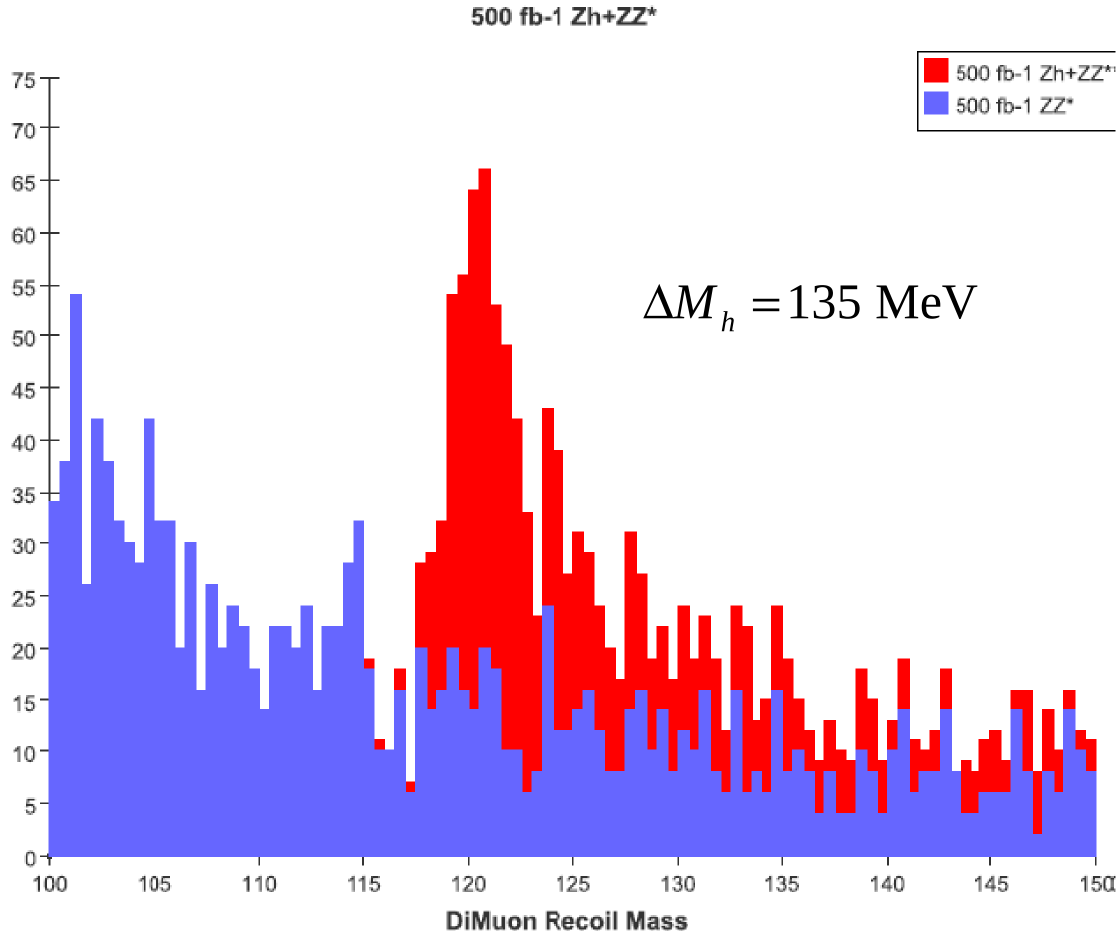
1. $e^+e^- \to Zh, \to \ell^+\ell^- X,\ l - e, \mu;\ m_h - 120$ GeV at $\sqrt{s}$–0.25 TeV — SLAC
2. $e^+e^- \to Zh,\ Z \to q\bar{q}, \nu\bar{\nu};\ h \to c\bar{c},\ \mu^+\mu^-;\ \ m_h = 120$ GeV at $\sqrt{s}$=0.25 TeV — Michigan/Oxford
3. $e^+e^- \to \tau^+\tau^-$, at $\sqrt{s}$=0.5 TeV — ?
4. $e^+e^- \to t\bar{t}$ at $\sqrt{s}$=0.5 TeV — Oxford (Eric Devetak)
5. $e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^- / \tilde{\chi}_2^0\tilde{\chi}_2^0 \to W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0$ / $ZZ\tilde{\chi}_1^0\tilde{\chi}_1^0$ at $\sqrt{s}$=0.5 TeV — Oxford (Andrei N./Yiming Li)

Full MC Detector Simulation and Event Reconstruction of

$$e^+e^- \to ZH \to \mu^+\mu^- X$$

by Norm Graf

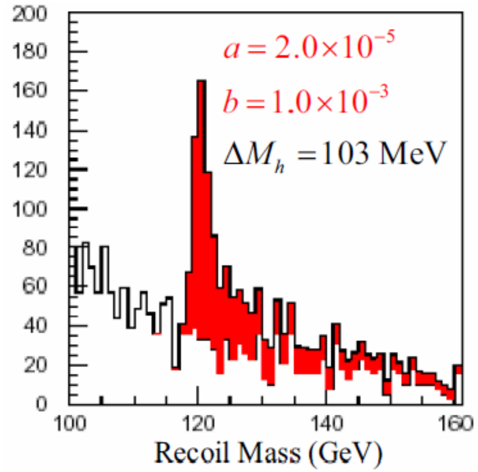
$$\sqrt{s} = 350\ GeV \quad L = 500\ fb^{-1}$$

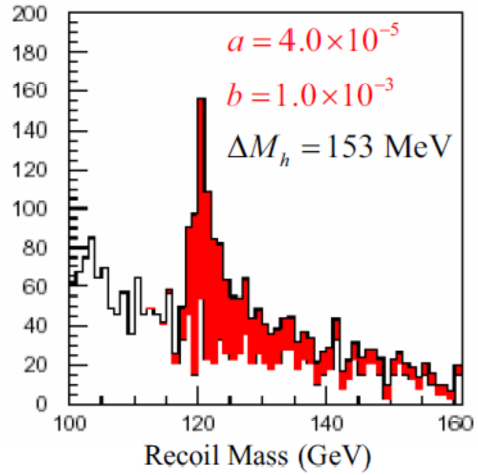


Still to Do:

$$e^+e^- \to ZH \to e^+e^- X$$

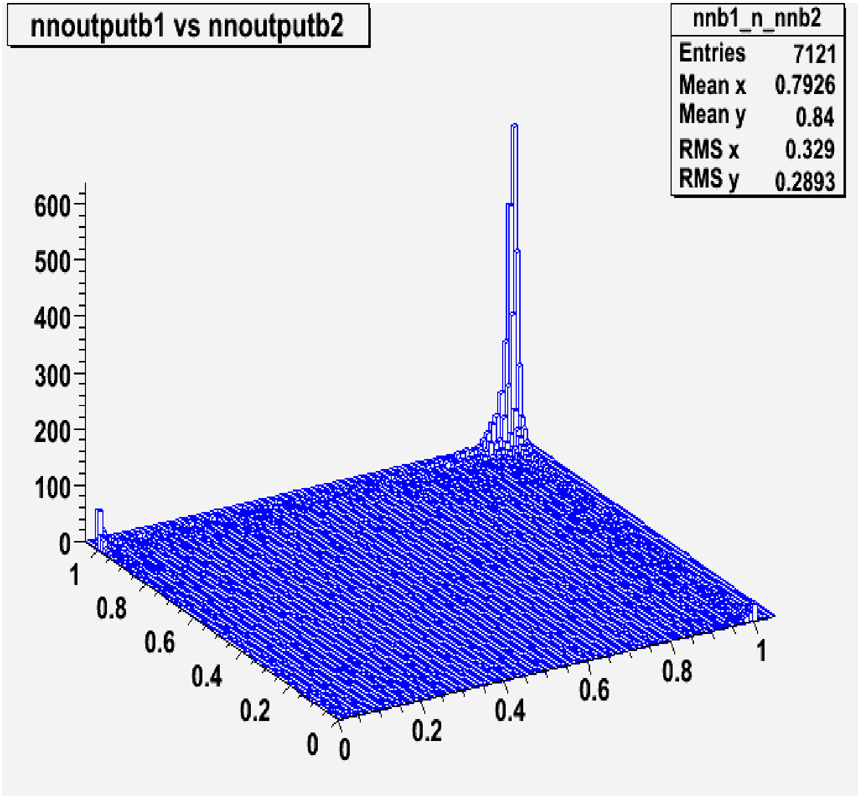
Old FASTMC study:



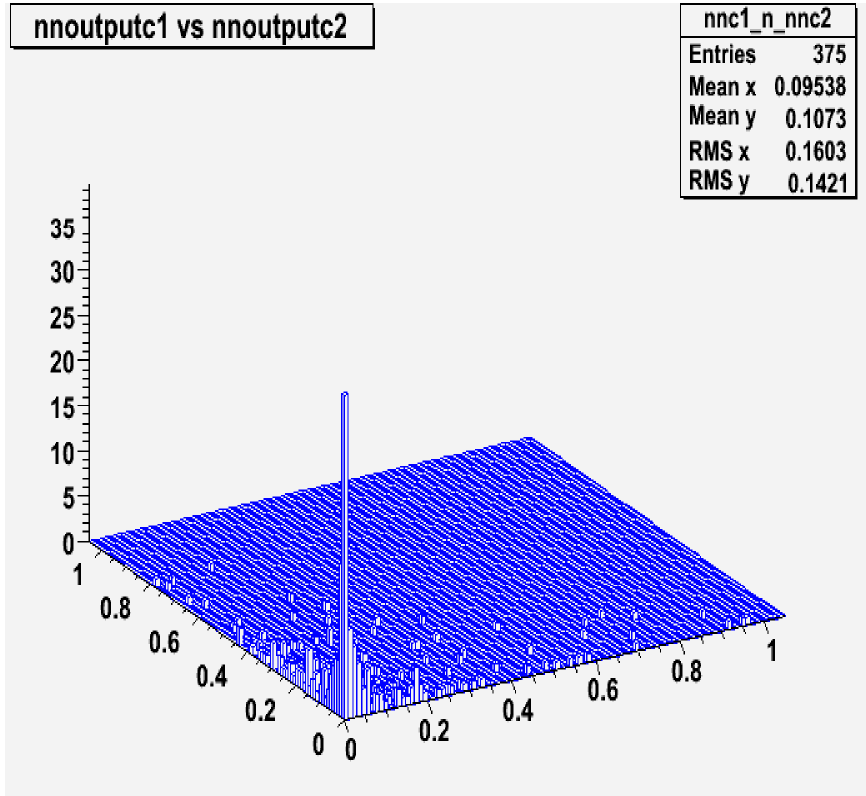


Study of ZH→ννcc
by Yambazi Banda (Oxford)

Jet1 b NN output vs Jet2 b NN output for H→bb

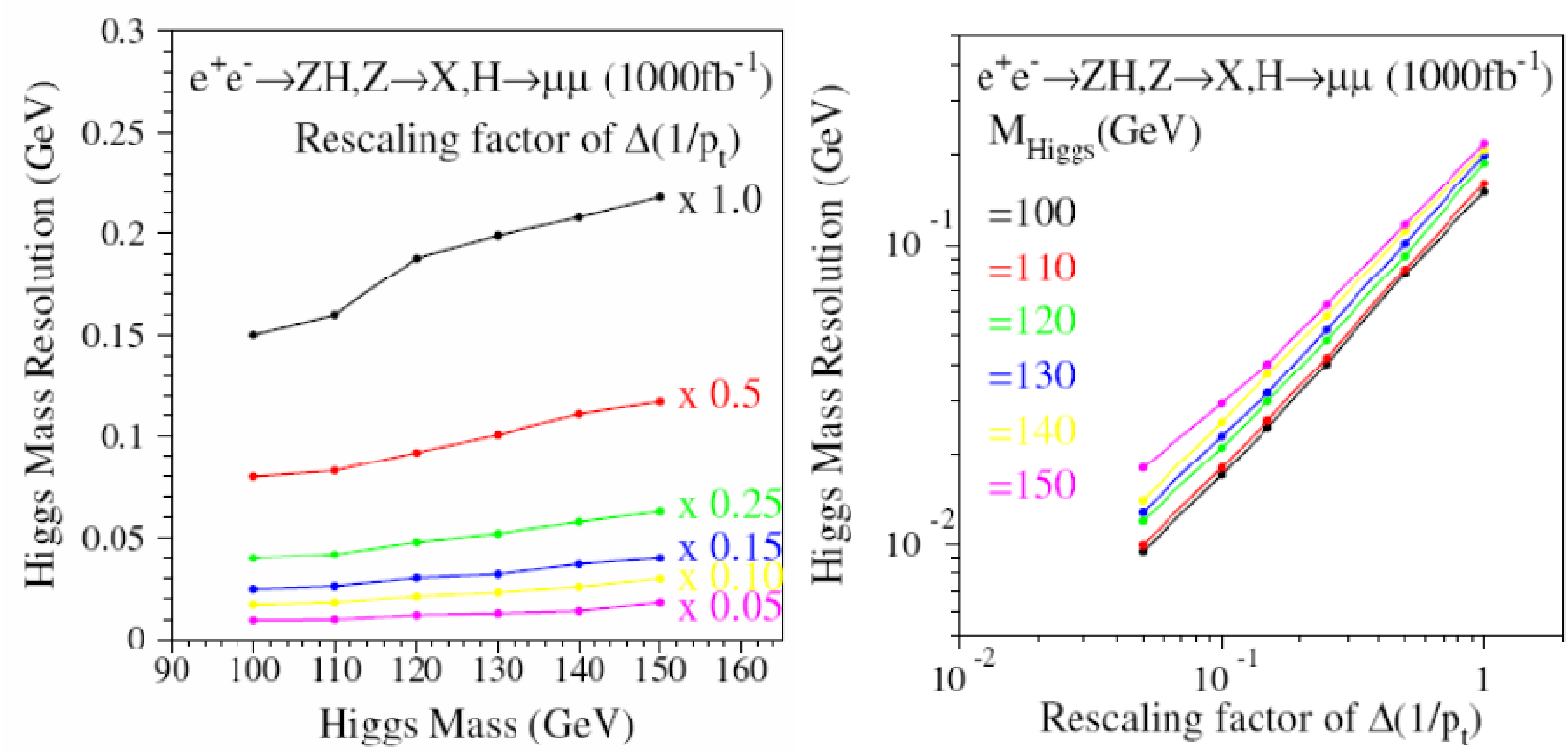


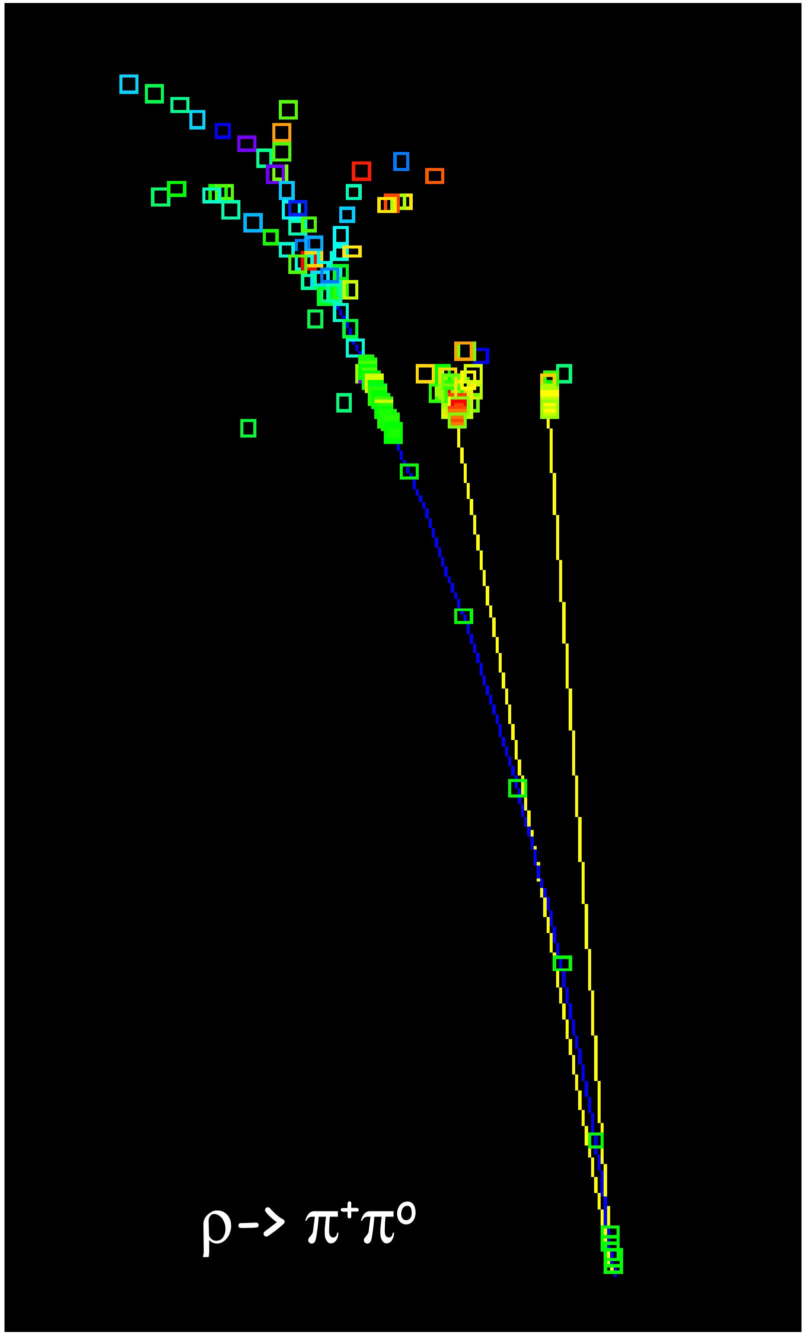
Jet1 c NN output vs Jet2 c NN output for H→cc



Impact of ILC Tracker Design on $e^+e^- \rightarrow H^0Z^0 \rightarrow \mu^+\mu^- X$ Analysis

Hai-Jun Yang & Keith Riles
University of Michigan, Ann Arbor





Study of tau decay mode efficiency and purity for 250 GeV tau's is still needed for the $\tau^+\tau^-$ benchmark

Summary

- Parton event generation for the LOI is completed with the exception of as needed signal and specialized background events.
- We have chosen a subset of events to fully simulate; it is similar in composition to the set simulated by ILD.
- The processing chain from parton event generation to GEANT4 simulation to reconstruction to physics analysis has been exercised and gives results comparable to FastMC analyses
- Physics analysis algorithms have now become a critical path item. The benchmarking group will be focusing heavily on developing these algorithms in the coming weeks