Overview of Benchmarking Tools

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SLAC
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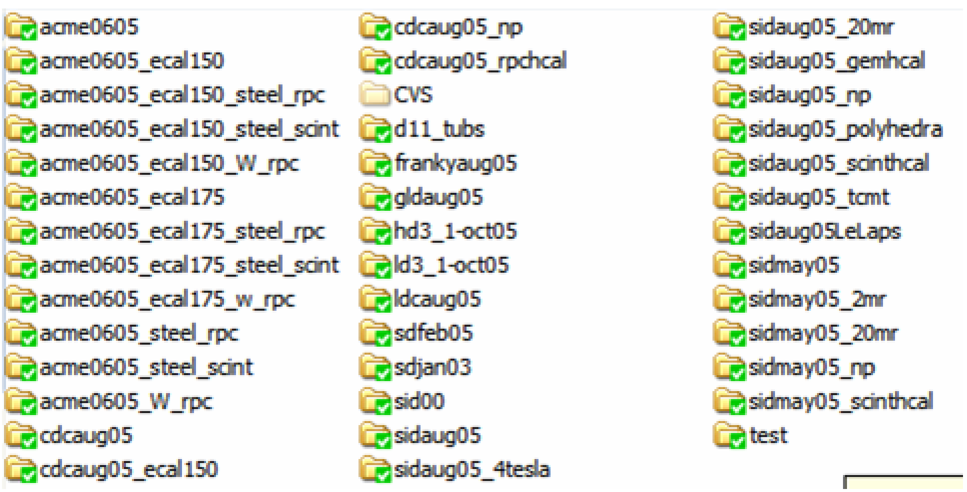
org.lcsim Goals

- "Second generation" ILC reconstruction/analysis framework
  - Builds on hep.lcd framework used since 1999
  - Full suite of reconstruction and analysis tools
- Uses LCIO for IO and as basis for simulation, raw data and reconstruction event formats
  - Isolate users from raw LCIO structures
  - Maintain full interoperability with other LCIO based packages
- Detector Independence
  - Make package independent of detector, geometry assumptions so can work with any detector
  - Read properties of detectors at runtime
- Written using Java (1.5)
  - High-performance but simple, easy to learn, OO language
  - Enables us last 10 years of software developments in the "real world"
- Ability to run standalone (command line or batch) or in JAS3 or IDE such as Netbeans, Eclipse

Available Detector Descriptions

- Although detector descriptions can live anywhere we maintain a CVS repository of detector descriptions
  - Exported to org.lcsim web site for automatic download
- 40 detector variants as of July 2006
- Many SiD variants, but also some gld, ldc



- You are welcome to contribute more

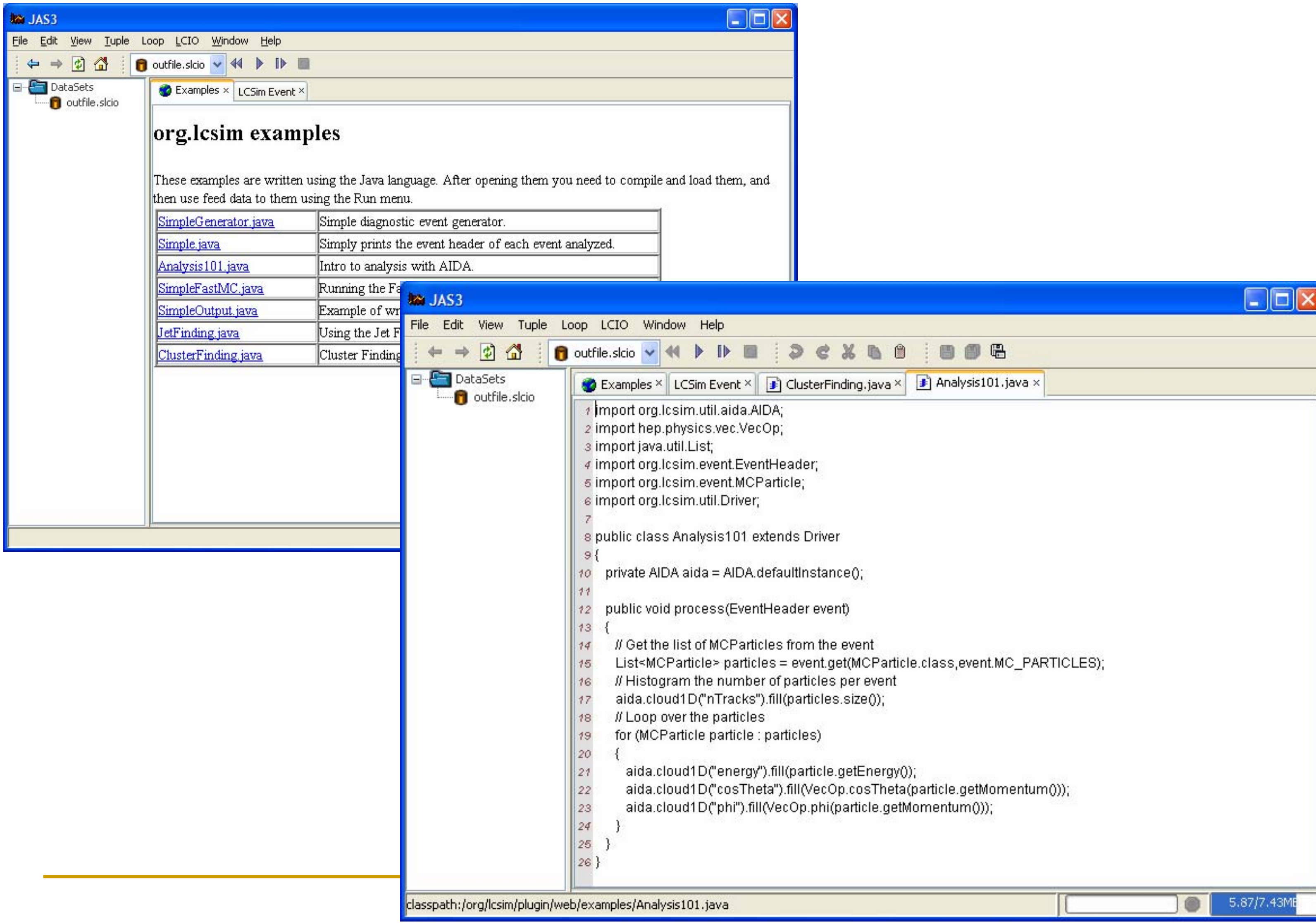
Org.lcsim Reconstruction

- Reconstruction package includes:
  - Physics utilities:
    - **Jet finders, event shape routines**
    - **Diagnostic event generator, stdhep reader/translator**
    - Histogramming/Fitting/Plotting (AIDA based)
    - Event Display
    - **Processor/Driver infrastructure**
  - **Fast MC**
    - **Track/Cluster smearing**
  - Reconstruction
    - Cheaters (perfect reconstruction)
    - Detector Response
      - CCDSim, Digisim
    - Clustering Algorithms
      - Cheater, DirectedTree, NearestNeighbour, Cone
    - Tracking Finding/Fitting Algorithms
      - TRF,
    - Muon Finding, Swiming
    - **Vertex Finding (ZvTop)**

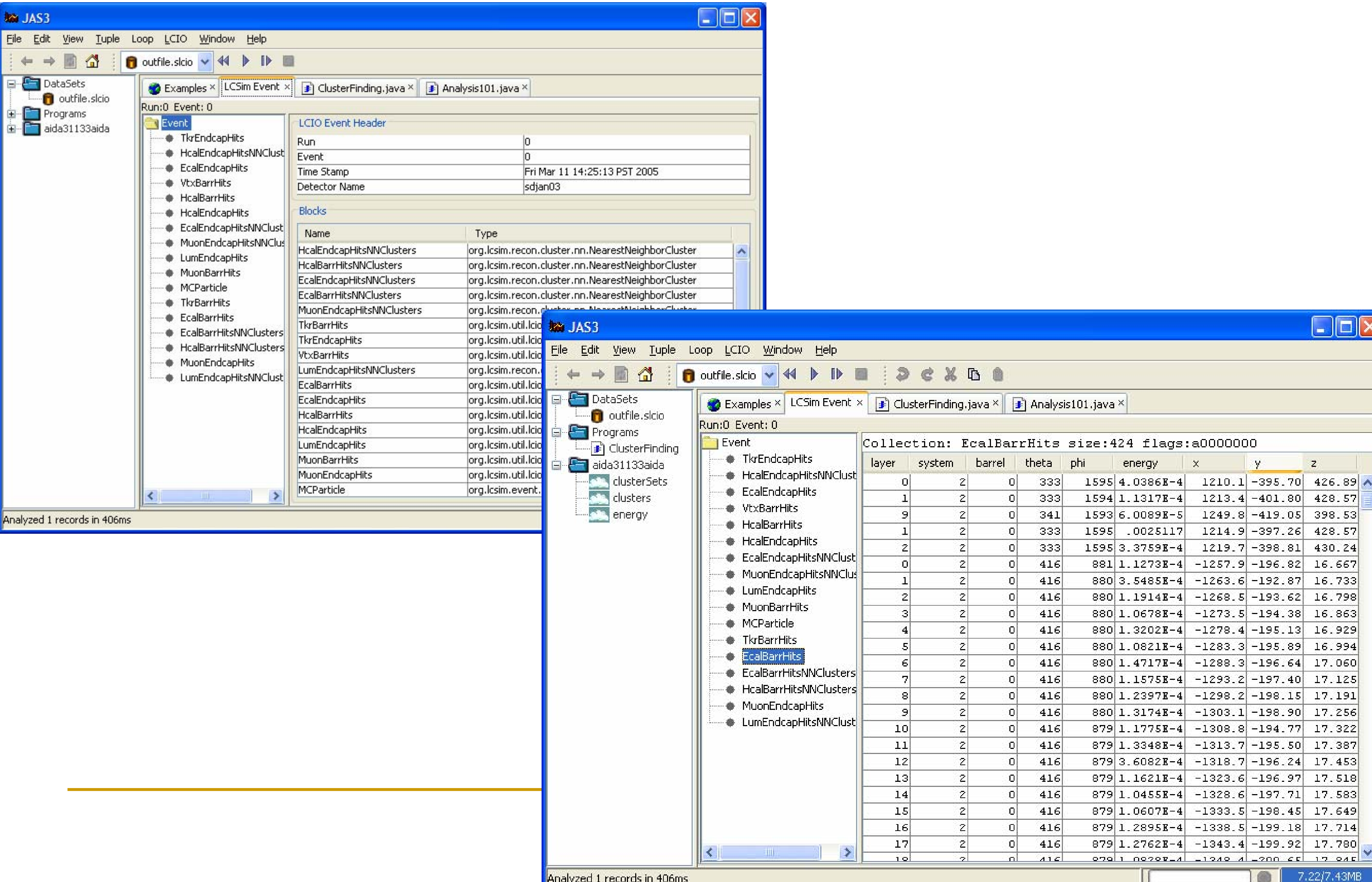
Using org.lcsim with JAS3

- The org.lcsim can be used standalone, withan IDE, or inside JAS3. Same code can be used in all modes, so easy to move back and forth
  - E.g. develop in IDE and run in JAS3
  - E.g. develop in JAS3 and run in batch
- JAS3 org.lcsim plugin adds:
  - Example Analysis Code
  - org.lcim Event browser
  - Easy viewing of analysis plots
  - WIRED event display integration

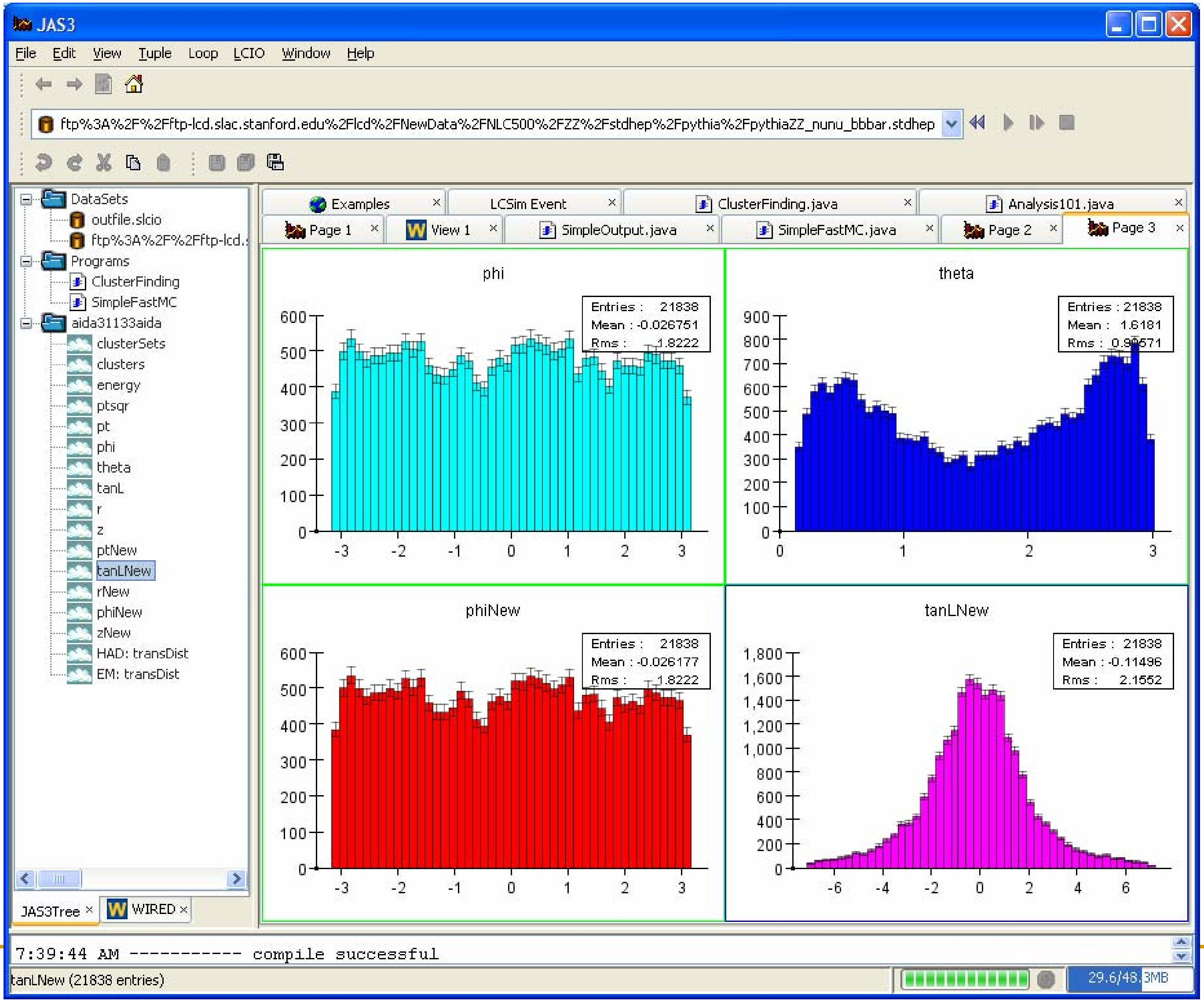
org.lcsim: Examples



org.lcsim: Examples

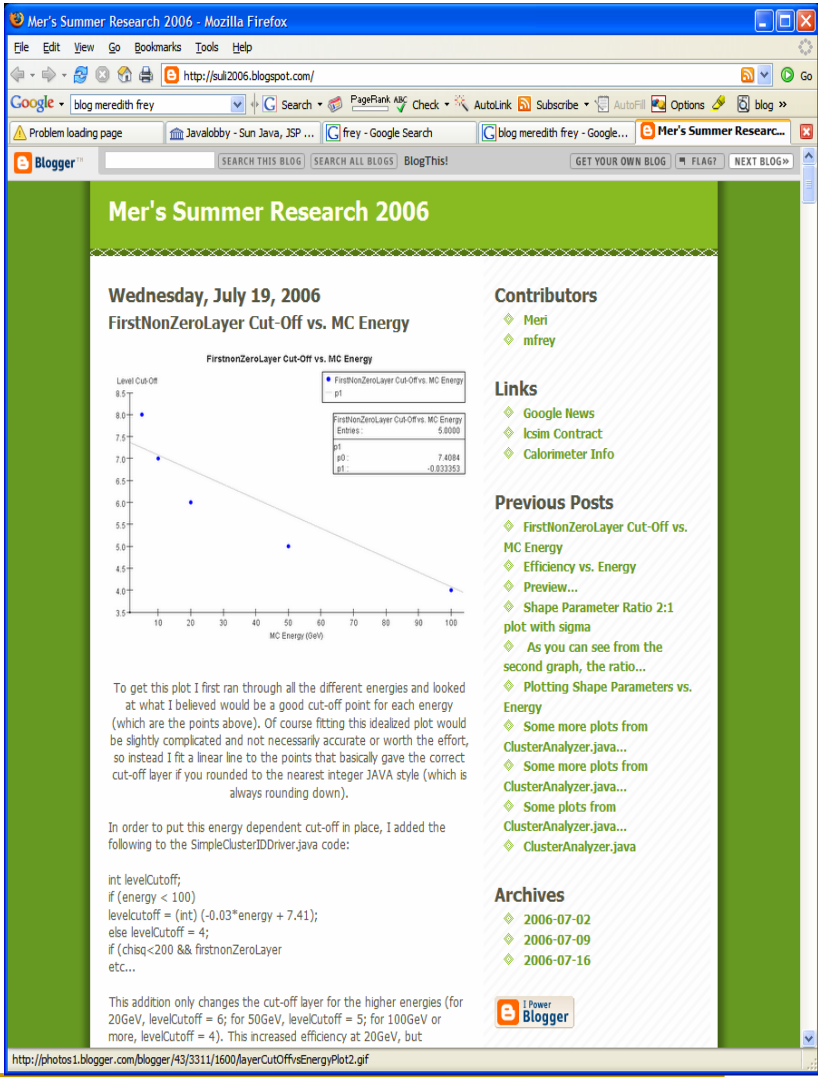


org.lcsim: Plot Viewing



How hard is it to get started with org.lcsim?

- Works on Linux, MacOSX, Windows
  - Should take about 15 minutes to install JAS3 and org.lcsim plugin.
- Case Study: SLAC Summer student
  - 2 semesters of Java experience
    - (no C++, Fortran *etc*)
  - Using tutorial on lcsim.org Wiki; installed software, downloaded data, and got useful results in one day (and fixed a few errors in the documentation along the way).
  - Regular analysis updates have been appearing on her blog ever since!
- Even if you don't have Java experience you can get started almost as fast
  - (the only thing you will miss is the core dumps)
- Start here:
  - https://confluence.slac.stanford.edu/display/ilc/lcsim+Getting+Started
  - Problems? Attend Tuesday afternoon "Simulation" phone meeting or use discussion forum at http://forum.linearcollider.org/



SiD Benchmarking Tools

- MC Data sets (stdhep files) of all SM processes at Ecm=500 GeV assuming nominal ILC machine parameters
  - About 50 fb^{-1} with e- pol=+/- 90% available at
    - **ftp://ftp-glast.slac.stanford.edu/glast.u32/simdet_output/simd401xx/whizdata.stdhep (-90% e- pol)**
    - **ftp://ftp-glast.slac.stanford.edu/glast.u32/simdet_output/simd402xx/whizdata.stdhep (+90% e- pol)**
  - 1 ab^{-1} on SLAC mass storage with all initial e+,e- polarization states
- Many Monte Carlos (Pythia, Whizard) for producing additional stdhep files
- Fast MC which takes stdhep files as input and outputs the same kind of reconstructed particle LCIO objects that full event reconstruction software produces (LCIO bindings exist for C++, JAVA, FORTRAN). For old SIMDET users there exists software to transfer reconstructed particle LCIO data to SIMDET common blocks.

Fast MC Detector Simulation (I)

- In the context of SiD benchmarking the Fast Monte Carlo should be considered a ***Fast Physics Object Monte Carlo.*** It emulates the bottom line performance of the event reconstruction software in producing the electron, muon, charged hadron, photon and neutral hadron physics objects.
- Status of Fast MC used by SiD:
  - Tracker simulation uses parameterized covariance matrices based on tracker geometry and material
  - Electron and muon id given by min energy + overall efficiency
  - Photon and neutral hadron energies & angles smeared using single particle EM & hadronic energy & angle resolutions. Photons and neutral hadrons also have min energy and overall efficiency within detector volume.

Fast MC Detector Simulation (II)

- Fast MC with nominal single particle calorimeter response gives 17%/sqrt(E) jet energy resolution. This can be tuned to any value by varying the single particle EM & hadronic calorimeter energy resolutions and by replacing charged particle tracker momentum with calorimeter energy a certain fraction of the time.
- Will improve the parameterization of calorimeter response as we learn more from the particle flow algorithm studies.

Perfect PFA : What theory predicts

- Jet energy resolution
  $\sigma^2(E_{jet}) = \sigma^2(ch.) + \sigma^2(\gamma) + \sigma^2(h^0) + \sigma^2(conf.)$
- Excellent tracker :
  $\sigma^2(ch.) << \sigma^2(\gamma) + \sigma^2(h^0) + \sigma^2(conf.)$
- Perfect PFA : $\sigma^2(conf.) = 0$
- $\sigma^2(E_{jet}) = A_\gamma^2 E_\gamma + A_h^2 E_{h0} = w_\gamma A_\gamma^2 E_{jet} + w_{h0} A_h^2 E_{jet}$
  $\sigma(E_{\gamma,h})/E_{\gamma,h} = A_{\gamma,h}/\sqrt{E_{\gamma,h}}$

Typically $w_\gamma = 25\%$; $w_{h0} = 13\%$

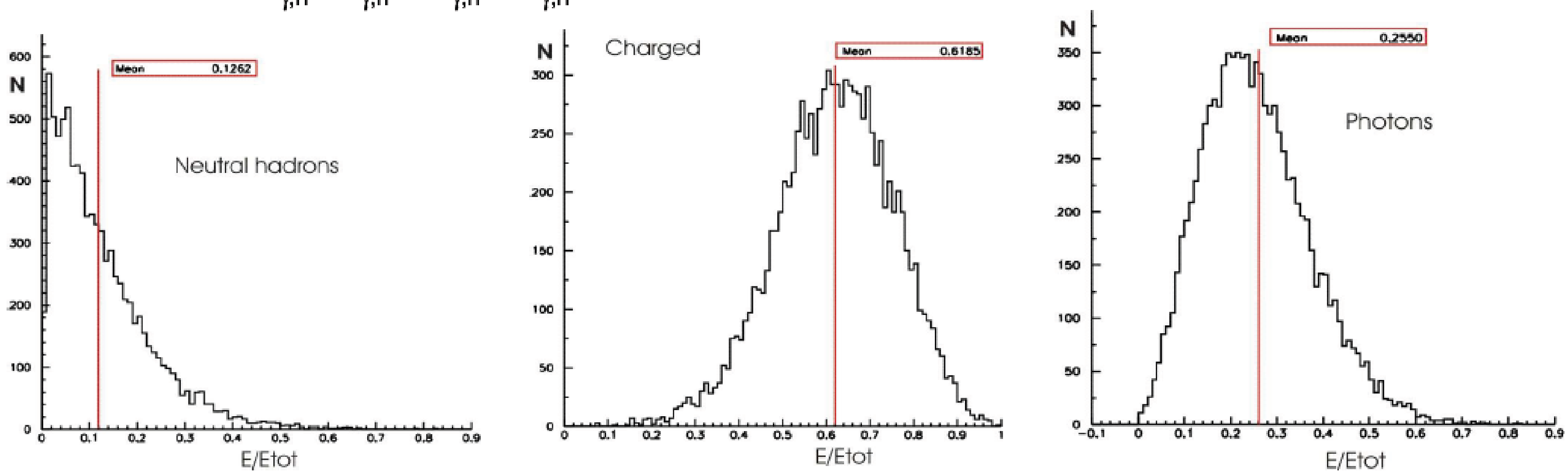
I find $w_\gamma=28\%$; $w_{h0}=10\%$

$A_\gamma = 11\%$; $A_{h0} = 34\%$

=> $\sigma(E_{jet})/E_{jet} = 12\%/\sqrt{E_{jet}}$

$A_\gamma = 11\%$; $A_{h0} = 50\%$

=> $\sigma(E_{jet})/E_{jet} = 17\%/\sqrt{E_{jet}}$



Alexei Raspereza, DESY, ILC Workshop, Snowmass, August 26, 2005

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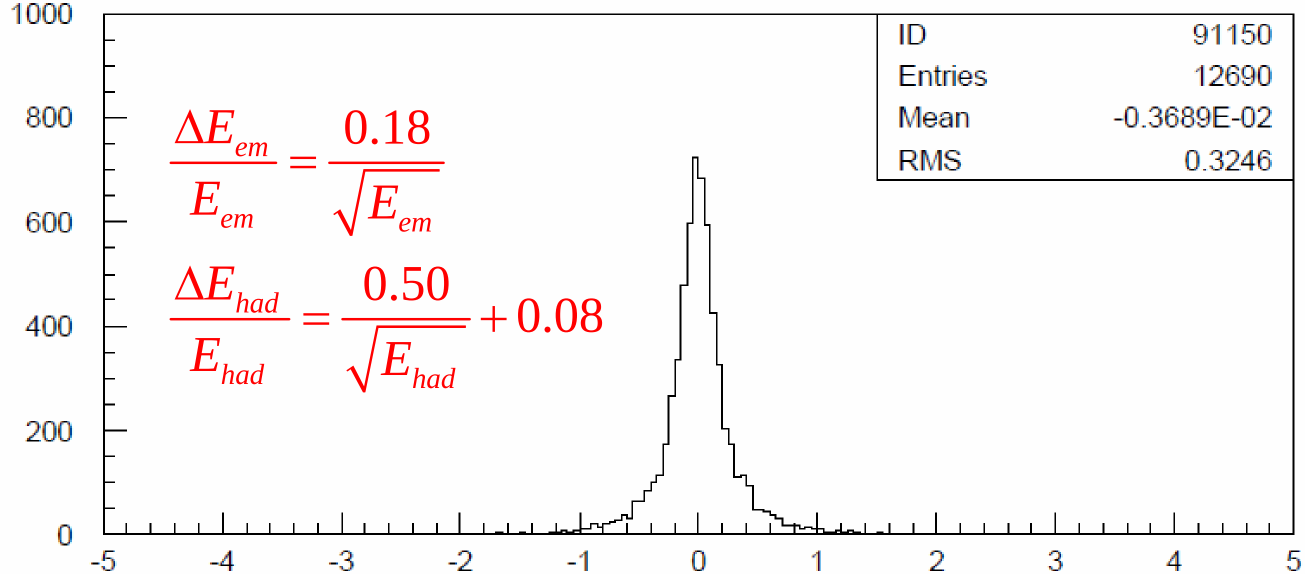
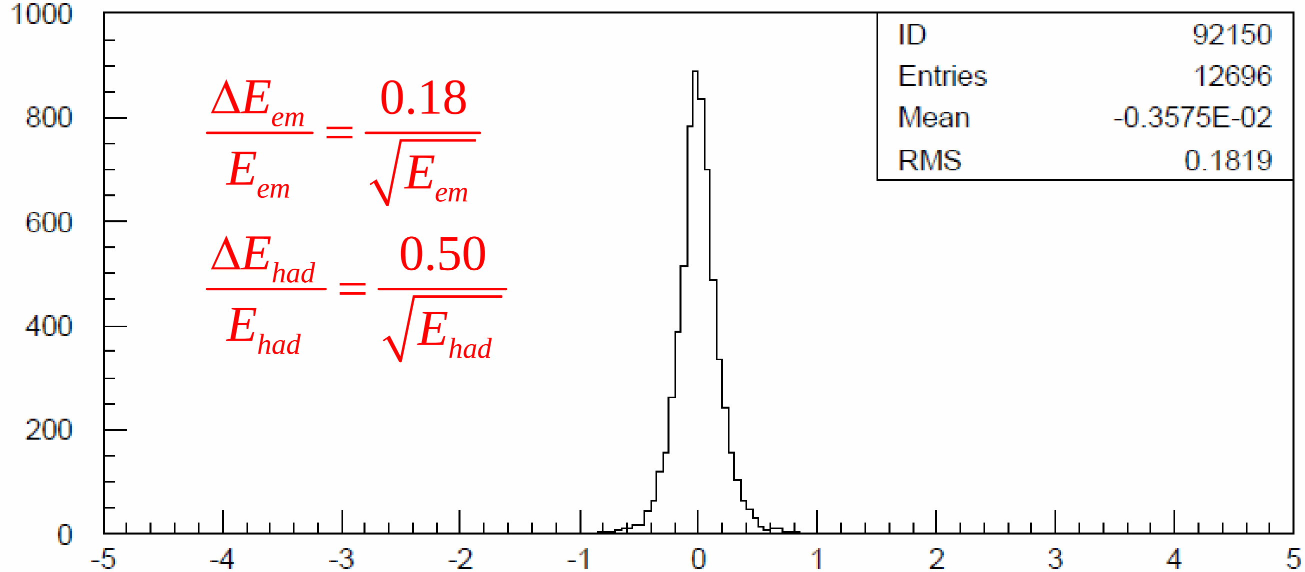
$\sqrt{s} = 500$ GeV

$e^+e^- \to u\bar{u}$

E_{true} is adjusted for neutrinos and particles outside detector acceptance





$$\Delta E_{jet} = (E_{rec} - E_{true}) / \sqrt{E_{true}}$$

Drop constant term in single particle resolution for now. Assume negligible contribution from charged particles to jet energy resolution and write

$$\sigma^2 = (1+\lambda(1-r))A_\gamma^2 w_\gamma E_{jet} + (1+\lambda r)A_h^2 w_h E_{jet} = c^2 E_{jet}$$

where $c = 0.3, 0.4, 0.5, 0.6$

$r =$ hadronic resolution degradation fraction

($r = 1$ to only degrade hadronic resolution

$r = 0$ to only degrade em resolution)

$A_\gamma = 0.18 \quad A_h = 0.50 \quad w_\gamma = 0.28 \quad w_h = 0.10$

Given a desired jet energy resolution c the parameter λ is given by

$$\lambda = \frac{c^2 - A_\gamma^2 w_\gamma - A_h^2 w_h}{(1-r)A_\gamma^2 w_\gamma + rA_h^2 w_h}$$

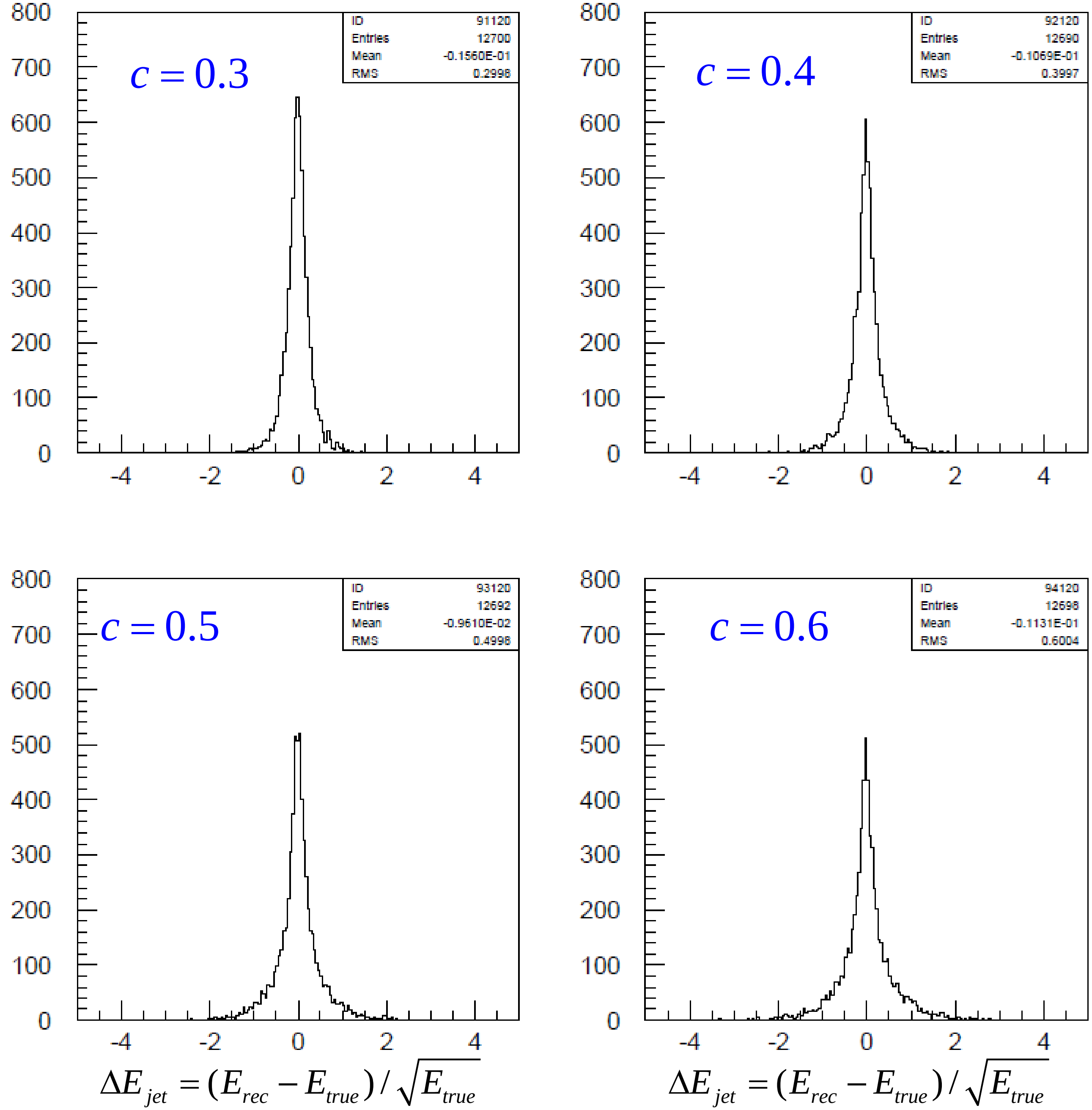
$e^+e^- \to u\bar{u}$

$\sqrt{s} = 500$ GeV

$r = 1.0$

(only degrade had resolution)

call this the "non-Gaussian parameterization"



$\sqrt{s} =$ 500 GeV

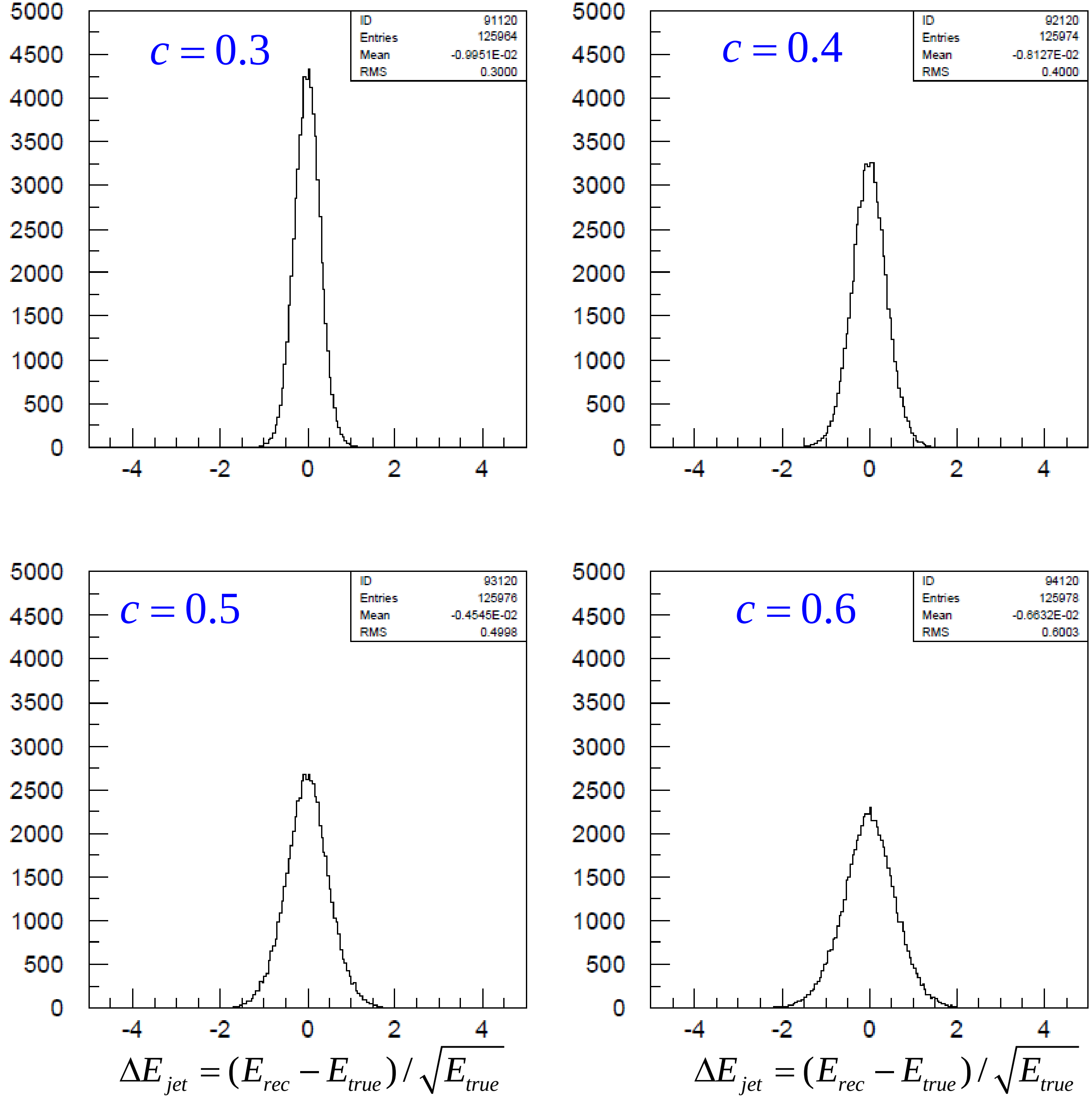
$e^+e^- \rightarrow u\bar{u}$

$r = 1.0$

but use calor E

for all chg had

=> $w_h = 0.71$



call this the

"Gaussian

parameterization"

Monte Carlo Production

- WHIZARD Monte Carlo is used to generate all 0,2,4,6-fermion and t quark dominated 8-fermion processes.
- 1 ab^{-1} @ 0.5 TeV & 2 ab^{-1} @ 1.0 TeV using ILC & NLC params respectively have been generated so far.
- 100% electron and positron polarization is assumed in all event generation. Arbitrary electron, positron polarization is simulated by properly combining data sets.
- Fully fragmented MC data sets are produced. PYTHIA is used for final state QED & QCD parton showering, fragmentation, particle decay.

SM Final States

0-fermion

$e^+e^- \to$	$\gamma\gamma$	
	$\gamma\gamma\gamma$	
	$\gamma\gamma\gamma\gamma$	
	$\gamma\gamma\gamma\gamma\gamma$	

2-fermion

$e^+e^- \to$	ff	$f \neq \nu$
	$\nu\nu\gamma$	
	$\nu\nu\gamma\gamma$	
	$\nu\nu\gamma\gamma\gamma$	
$e^-\gamma \to$	$e^-\gamma$	
$\gamma e^+ \to$	$e^+\gamma$	

4-fermion

$e^+e^- \to$	$\nu\nu\nu\nu\gamma$	6 total
	$u_j\overline{d}_j d_k\overline{u}_k$	25 total
		$\nu_e e^+ e^- \overline{\nu}_e$
		$\nu_e e^+ \mu^- \overline{\nu}_\mu$
		$\nu_e e^+ \tau^- \overline{\nu}_\tau$
		$\nu_e e^+ d\overline{u}$
		.
		.
		$c\overline{s}s\overline{c}$
	$u_j\overline{u}_j u_k\overline{u}_k$	9 total
	$u_j\overline{u}_j d_k\overline{d}_k$	25 total
	$d_j\overline{d}_j d_k\overline{d}_k$	21 total
$\gamma\gamma \to$	$f\overline{f}$	8 total
$e_L^-\gamma \to$	$\nu_e d_k\overline{u}_k$	5 total
$e^-\gamma \to$	$e^- f\overline{f}$	10 total
$\gamma e_R^+ \to$	$\overline{\nu}_e u_k\overline{d}_k$	5 total
$\gamma e^+ \to$	$e^+ f\overline{f}$	10 total

6-fermion

$e^+e^- \to$	$u_i\overline{u}_i u_j\overline{d}_j d_k\overline{u}_k$	125 total
	$d_i\overline{d}_i u_j\overline{d}_j d_k\overline{u}_k$	150 total
	$u_i\overline{u}_i u_j\overline{u}_j u_k\overline{u}_k$	25 total
	$u_i\overline{u}_i u_j\overline{u}_j d_k\overline{d}_k$	65 total
	$u_i\overline{u}_i d_j\overline{d}_j d_k\overline{d}_k$	75 total
	$d_i\overline{d}_i d_j\overline{d}_j d_k\overline{d}_k$	56 total
$\gamma\gamma \to$	$u_j\overline{d}_j d_k\overline{u}_k$	25 total
	$u_j\overline{u}_j u_k\overline{u}_k$	9 total
	$u_j\overline{u}_j d_k\overline{d}_k$	25 total
	$d_j\overline{d}_j d_k\overline{d}_k$	21 total
$e_L^-\gamma \to$	$\nu_e u_j\overline{u}_j d_k\overline{u}_k$	25 total
	$\nu_e d_j\overline{d}_j d_k\overline{u}_k$	30 total
$e^-\gamma \to$	$e^- u_j\overline{d}_j d_k\overline{u}_k$	20 total
	$e^- u_j\overline{u}_j u_k\overline{u}_k$	10 total
	$e^- u_j\overline{u}_j d_k\overline{d}_k$	20 total
	$e^- d_j\overline{d}_j d_k\overline{d}_k$	21 total
$\gamma e_R^+ \to$	$\overline{\nu}_e u_j\overline{d}_j u_k\overline{u}_k$	25 total
	$\overline{\nu}_e u_j\overline{d}_j d_k\overline{d}_k$	30 total
$\gamma e^+ \to$	$e^+ u_j\overline{d}_j d_k\overline{u}_k$	20 total
	$e^+ u_j\overline{u}_j u_k\overline{u}_k$	10 total
	$e^+ u_j\overline{u}_j d_k\overline{d}_k$	20 total
	$e^+ d_j\overline{d}_j d_k\overline{d}_k$	21 total

8-fermion

$e^+e^- \to$	$f\overline{f}t\overline{t}$
$\gamma\gamma \to$	$t\overline{t}$
$e^-\gamma \to$	$e^- t\overline{t}$
	$\nu_e b\overline{t}$
$\gamma e^+ \to$	$e^+ t\overline{t}$
	$\overline{\nu}_e t\overline{b}$

There are currently 14 MC production groups:

- 0-2-4-fermion
- 6-fermion/ddi-udj-duk
- 6-fermion/eminus-gamma
- 6-fermion/gamma-eplus
- 6-fermion/gamma-gamma
- 6-fermion/uui-udj-duk
- 6-fermion/zzz_1
- 6-fermion/zzz_2
- 8-fermion/
- bench-point-5
- ffh
- ffhh
- tesla_bosons
- tth

The production group directories are located in

/afs/slac/g/nld/whizard/xxxx

where xxxx=0-2-4-fermion e.g.

(xxxx will stand for a production group from here on)

For each Production Group There are 5 Steps Needed to Produce MC Data Sets: (corresponding shell script is shown in italics)

1. Generate Executable*
   /afs/slac/g/nld/fa/whizard-1.50/remake_process_class
2. Submit MC Integration Jobs
   /afs/slac/g/nld/whizard/ILC/multiple_whiz_ini
3. Repair MC Integration Jobs
   /afs/slac/g/nld/whizard/ILC/multiple_whiz_ini_cleanup
4. Submit MC Event Generation Jobs
   /afs/slac/g/nld/whizard/ILC/multiple_whiz_run
5. Repair MC Event Generation Jobs
   /afs/slac/g/nld/whizard/ILC/multiple_whiz_run_repair

*Event generation at E_{cm}=500 GeV used an older whizard version
/nfs/slac/g/lcd/mc/prj/sw/dist/whizard/v1r4p0/whizard-v1r4p0/remake_process_class

Data Analysis

- Hundreds of stdhep files are produced with 100% initial state polarization. For data analysis a subset of these files have to be combined in the proper proportion according to the processes to be analyzed and the desired initial state polarization.
- Software has been written to read out stdhep files according to user-specified processes and initial state polarization using the SLAC mstore mass storage facility and the SLAC LINUX batch system. The Makefile for an executable that uses this software can be found at
~timb/grace/six_fermion/a6f/analysis/lcio/Makefile
- Examples of analysis job output can be found at
/afs/slac/g/nld/fa/lcio_physics_analysis/
- When running over all SM processes 78 batch jobs are submitted simultaneously. Template input files for the 78 batch jobs can be found at
~timb/grace/six_fermion/a6f/analysis/lcio/whizdata_sm_xx.in ,xx=01,02,...,78
The script that submits the 78 batch jobs is
/afs/slac/g/nld/whizard/ILC/multiple_lcio_ini
The 78 process classes are described in
http://www.slac.stanford.edu/~timb/ilc_2ab_mc_data_set/process_classes.pdf

Polarization, $\sqrt{s}$, and specific processes are defined in whizdata.in:

```
&whizdata_input
path_root = '/afs/slac.stanford.edu/g/nld/whizard/'
data_root = '/nfs/mstore/g/lcddata/'
i_sqrts = 1000
luminosity = 2000.
n_events_max=120000
mbyte_max = 200.
pol_eminus = -1.0
pol_eplus  =  1.0
seed = 520027
output_events = F
process =
  "e1,E1    q,q,q,q"
  "e1,E1    l,q,l,q"
  "e1,E1    l,v,l,v,q,q"
  "e1,A     f,l,l,q,q"
  "e1,A     e1,e1,E1,e2,E2"
/
```

where q,l,v,f,x are defined as:

```
q=u,d,s,c,b,U,D,S,C,B
l=e1,e2,e3,E1,E2,E3
v=n1,n2,n3,N1,N2,N3
f=q,l,v
x=f,A
e3=e3,E3
E3=E3
```

Access to 1 ab^{-1} Standard Model Monte Carlo Data Sets

- Stdhep files are on SLAC MSTORE Mass Storage
- We have tried in the past to put a subset of this data on permament disk; we now believe that for SiD Benchmarking studies it is better to have users of this data obtain SLAC computing accounts. We will post info on obtaining SLAC accounts on the Benchmarking web site.
- We will endeavor to improve the user-friendliness of the software that reads out the mstore stdhep files according to user-specified processes and initial state polarization

Appendix:
WHIZARD Event Generation Details

1. Generate Executable

remake_process_class copies the file **`xxxx/whizard.prc`** to WHIZARD's conf directory, does 'make prg', and then copies the results of the make to **`xxxx/results.`**

2. Submit MC Integration Jobs

multiple_whiz_ini loops through the processes in **`xxxx/results/whizard.prc`** and submits 4 batch jobs for each process (1 job for each initial state $e^{+}e^{-}$ helicity combination).

For each job a directory **`/afs/slac/g/nld/fa/mmmm/whizyyyyy`** is created where **`mmmm`** is the center-of-mass energy in GeV and **`yyyyy`** is a unique 5-digit job number.

multiple_whiz_ini uses the file
`xxxx/results/multiple_cardswhiz_in`
to build the batch job's **`whizard.in`** file

multiple_whiz_ini uses the file
`/afs/slac/g/nld/whizard/ILC/iniwhiz`
to build the batch job's executable script.

3. Repair MC Integration Jobs

multiple_whiz_ini_cleanup loops through the job output in the directories **`/afs/slac/g/nld/fa/mmmm/whizttttt`** through **`/afs/slac/g/nld/fa/mmmm/whizyyyyy`** and verifies that the integration was completed successfully. Here **`mmmm`**, **`ttttt`**, **`yyyyy`** are input arguments to the script.

If the integration failed then ***multiple_whiz_ini_cleanup*** resubmits the job. WHIZARD saves intermediate integration results, so the new job essentially picks up where the old one left off.

4. Submit MC Event Generation Jobs

multiple_whiz_run loops through the MC integration job output directories **`/afs/slac/g/nld/fa/mmmm/whizttttt`** through **`/afs/slac/g/nld/fa/mmmm/whizyyyyy`** and submits a run job for every MC integration job which had a cross-section above some minimum value.

For each run job a directory **`/afs/slac/g/nld/fa/mmmm/run_output/wkkkkk/run_01`** is created where **`mmmm`** is the center-of-mass energy in GeV and **`kkkkk`** is the 5-digit MC integration job number.

multiple_whiz_run copies most of the files in the directory **`/afs/slac/g/nld/fa/mmmm/whizkkkkk`** into the directory **`/afs/slac/g/nld/fa/mmmm/run_output/wkkkkk/run_01`**. Parameters specific to event generation are added to the **`whizard.in`** file before it is copied to **`/afs/slac/g/nld/fa/mmmm/run_output/wkkkkk/run_01.`**

multiple_whiz_run uses the file **`/afs/slac/g/nld/whizard/ILC/runwhiz`** to build the batch job’s executable script.

5. Repair Event Generation Jobs

multiple_whiz_run_repair loops through the MC run job output directories **`/afs/slac/g/nld/fa/mmmm/run_output/wttttt/run_01`** through **`/afs/slac/g/nld/fa/mmmm/run_output/wyyyyy/run_01`** and verifies that the jobs completed successfully. If the job failed ***multiple_whiz_run_repair*** resubmits the job. If the job completed successfully but additional runs are required it will submit new run jobs after creating directories of the form

`nfs/slac/g/lcd/mc/mmmm/run_output/wkkkkk/run_02`
`nfs/slac/g/lcd/mc/mmmm/run_output/wkkkkk/run_03`

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`nfs/slac/g/lcd/mc/mmmm/run_output/wkkkkk/run_nn`