

# Summary of Simulation / Detector Performance / Reconstruction

Tomohiko Tanabe (ICEPP, U. of Tokyo)

September 30, 2011

LCWS11

Granada, Spain

ilcsoft  
(F. Gaede)

Icsim  
(N. Graf)

Clupatra  
(F. Gaede)

Forward  
tracking in ILD  
(R. Glattauer)

Samples for  
CLIC CDR  
(S. Poss)

Samples  
for DBD  
(A. Miyamoto)

ILD  
Tracking  
(S. Aplin)

Non-prompt  
tracks in SiD  
(B. Schumm)

SGV:  
fast simulation  
(M. Berggren)

SiD-Iowa  
PFA  
(R. Zaidan)

PandoraPFA  
(J. Marshall)

Pixel sensor  
simulation  
(N. Sinev)

PFA  
performance at CLIC  
(A. Muennich)

Lepton ID  
at CLIC  
(J. Marshall)

Electron reco.  
in BeamCal  
(A. Rosca)

FPCCD  
digitization and reco.  
(D. Kamai)

Flavor  
tagging at CLIC  
(J. Strube)

W/Z  
separation at 1 TeV  
(T. Barklow)

Beam  
backgrounds at CLIC  
(A. Sailer)

LCFIVertex+  
(T. Tanabe)

Jet energy res.  
with  $\pi^0$  fit  
(B. van Doren)

Photon with  
shower fitting  
(G. Wilson)

Muon  
background at CLIC  
(M. Thomson)

- core software
- event generation / simulation
- backgrounds
- detector models
- tracking
- PFA
- flavor tagging
- particle reconstruction

# core software

N. Graf

F. Gaede

## Simulation & Reconstruction

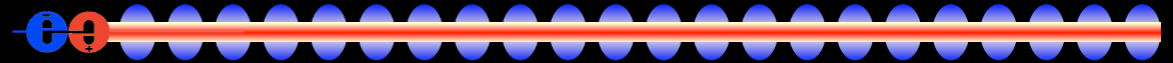
### iLCSoft release v01-12

<a href="#">CED</a>	v01-03	<a href="#">Overlay</a>	v00-11
<a href="#">CEDViewer</a>	v01-03	<a href="#">PandoraPFANew</a>	v00-07
<a href="#">CLHEP</a>	2.0.4.5	<a href="#">QT</a>	4.2.2
<a href="#">CondDBMySQL</a>	ILC-0-9-5	<a href="#">RAIDA</a>	v01-06-01
<a href="#">Druid</a>	1.8	<a href="#">StandardConfig</a>	v03-00
<a href="#">Eutelescope</a>	v00-06-03	<a href="#">cernlib</a>	2006
<a href="#">KalTest</a>	v01-02	<a href="#">dcap</a>	1.9.5-5
<a href="#">KalDet</a>	v01-02	<a href="#">gear</a>	v01-00
<a href="#">LCFIVertex</a>	v00-06	<a href="#">gsl</a>	1.14
<a href="#">LCFI_MokkaBasedNets</a>	v00-01	<a href="#">lccd</a>	v01-02
<a href="#">Marlin</a>	v01-01	<a href="#">lcio</a>	v02-00
<a href="#">MarlinPandora</a>	v00-06	<a href="#">mysql</a>	5.0.45
<a href="#">MarlinReco</a>	v00-30	<a href="#">root</a>	5.28.00f
<a href="#">MarlinTPC</a>	v00-06	<a href="#">ilcutil</a>	v00-02
<a href="#">MarlinUtil</a>	v01-04	<a href="#">MarlinTrk</a>	v01-00
<a href="#">Mokka</a>	mokka-07-07	<a href="#">MarlinKinFit</a>	v00-01
<a href="#">MokkaDBConfig</a>	v03-02	<a href="#">MarlinFastJet</a>	v00-02

updated  
new  
this talk

development release targeted at getting the software into shape for the DBD

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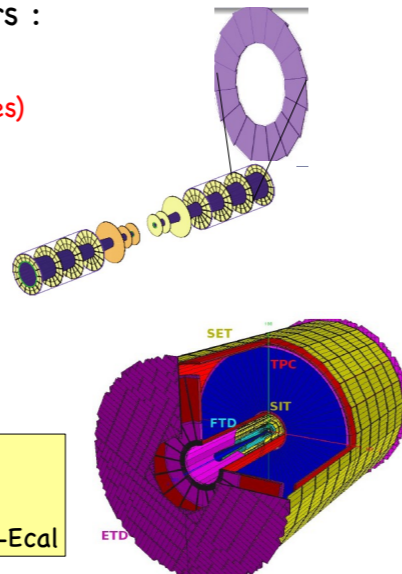
- **SLIC provides full detector simulation in Geant4**
  - runtime detector description in XML
  - stdhep input
  - standard LCIO output
- **org.lcsim reconstruction/analysis suite**
  - Java-based reconstruction & analysis framework
  - full, *ab initio* signal digitization, track finding & fitting, calorimeter cluster finding and association (PFA)
  - LCIO provides access to global LC code base
    - flavor-tagging via LCFI
    - PFA via Pandora
  - AIDA histogramming and fitting
  - WIRED 3-D event display

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### recent developments in Mokka

- major rewrite of some sub detector drivers :
  - SIT, SET, ETD - FTD - Muon
  - **increased level of detail and realism (incl. services)**
- made existing drivers more realistic:
  - TPC, AHCal, Ecal
- new drivers (technology options):
  - SDHCal, SciEcal
- **added overall services and cables**
- new models under development:
 

ILD_01_pre02	- AHCal and Si-Ecal
ILD_01_SDH_pre00	- SDHCal and Si-Ecal
ILD_01_SciW_pre00	- AHCal and Scintillator-Ecal
- next steps:
  - finalize and debug these models
  - adopt new Gear materials



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Continued improvement in core software tools used by ILC & CLIC.  
More realistic detector models.

# event generation

S. Poss

A. Miyamoto

Introduction

## Introduction

- 6 benchmark analysis:
  - $e^+e^- \rightarrow h\nu_e\bar{\nu}_e$ ,
  - $e^+e^- \rightarrow H^+H^-$ ,  $e^+e^- \rightarrow H^0A$ ,
  - $e^+e^- \rightarrow \tilde{q}_R\tilde{q}_R$ ,
  - $e^+e^- \rightarrow \tilde{\ell}\tilde{\ell}$  ( $\ell = e, \mu$ ),
  - $e^+e^- \rightarrow \tilde{\chi}^\pm_i\tilde{\chi}^\mp_j$ ,  $e^+e^- \rightarrow \tilde{\chi}^0_i\tilde{\chi}^0_j$ ,
  - $e^+e^- \rightarrow t\bar{t}$  (500 GeV).
- Plus all the backgrounds (Standard Model)
- 2 detector models

Number of events processed in the last 9 months:  $17 \cdot 10^6 \times 3$  processed.

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## Task for DBD study

- Benchmark processes for the DBD studies
  - ◆  $E_{cm}=1\text{TeV}$ 
    - $e^+e^- \rightarrow \nu\bar{\nu}h^0$
    - $e^+e^- \rightarrow W^+W^-$
    - $e^+e^- \rightarrow t\bar{t}h^0$
  - ◆ One of LOI benchmark processes at  $E_{cm}=500\text{ GeV}$
- Backgrounds
  - ◆ Relevant SM processes, up to 8 fermions final states for  $t\bar{t}h$
  - ◆ Machine backgrounds and same-bunch crossing  $\gamma\gamma$  events should be overlaid in some way...

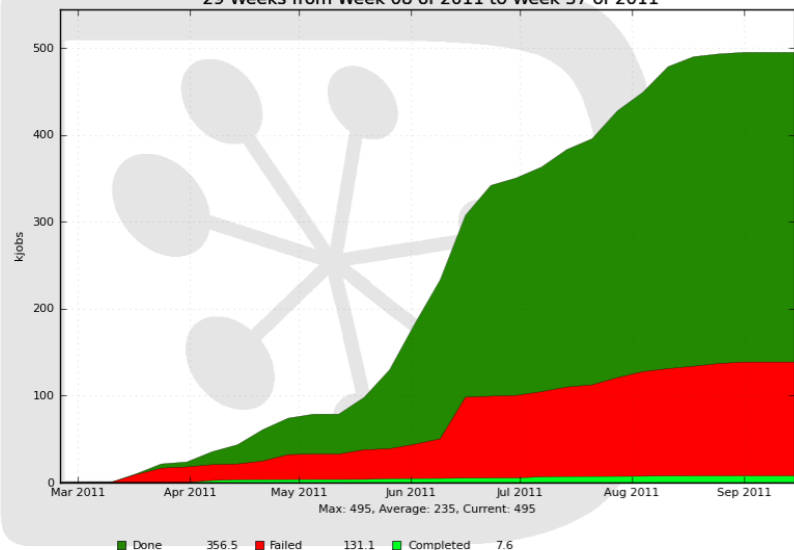
27 September 2011

Akiya Miyamoto, LCWS2011

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Reconstruction (no overlay) jobs' final statuses

29 Weeks from Week 08 of 2011 to Week 37 of 2011



Over 50 million events generated & reconstructed for CLIC CDR.

Test samples for DBD available.

# fast event simulation

M. Berggren

The need for fast simulation

## The need for fast simulation

- We have very good full simulation now.
- So why bother about fast simulation ?
- Answer:
  - R. Heuer yesterday: *We need to update the physics case continuously.*
  - Light-weight: run anywhere, no need to read tons of manuals and doxygen pages.
  - Anyhow, the LOI exercise showed that for **physics**, the fastSim studies were good enough.

But most of all:

Fast simulation is **Fast** !

So...

Why do we need speed ?

Mikael Berggren (DESY-HH)

SGV 3.0 - a fast detector simulation

LCWS, Granada, 2011

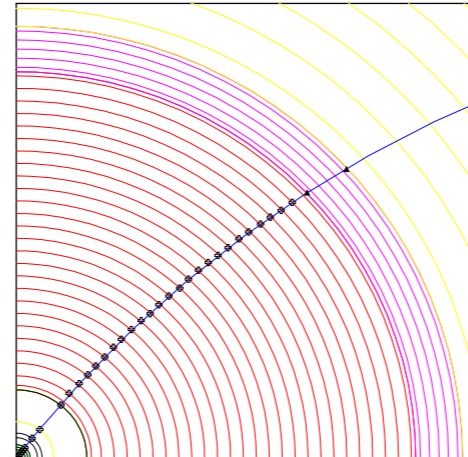
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Fast simulation

## SGV: How it works

SGV is a **machine to calculate covariance matrices**

**Tracking:** Follow track-helix through the detector, to find what layers are hit by the particle.



- From this, calculate cov. mat. at perigee, including effects of material, measurement errors and extrapolation. **NB: this is exactly what Your track fit does!**
- **Smear perigee parameters** accordingly, with Choleski decomposition (takes all correlations into account)
- Information on hit-pattern accessible to analysis. Co-ordinates of hits accessible.

Mikael Berggren (DESY-HH)

SGV 3.0 - a fast detector simulation


LCWS, Granada, 2011

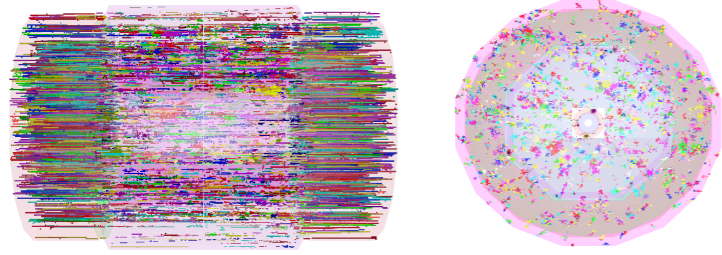
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SGV: new fast event simulator based on covariance matrix calculation.

# Beam halo muon background at CLIC

M. Thomson






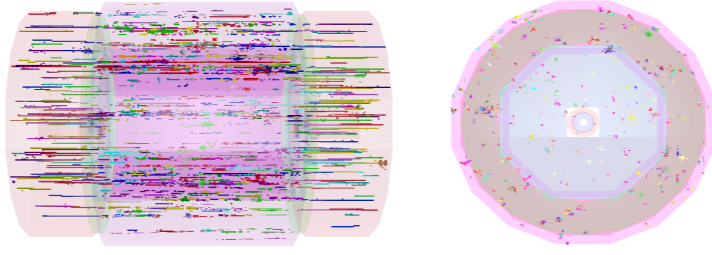
★ From **entire bunch train**, 5 muons per BX  
Average energy deposition (per bunch train):

**13.2 TeV**

Mark Thomson LCWS 2011, Granada 5



### In-time Energy Deposit




★ Only hits in calorimeter readout windows:

- ECAL integrates over 10 ns
- HCAL endcap integrates over 10 ns
- HCAL barrel (Tungsten) integrates over **50 ns**

★ 5 muons per BX in time with assumed calorimeter readout

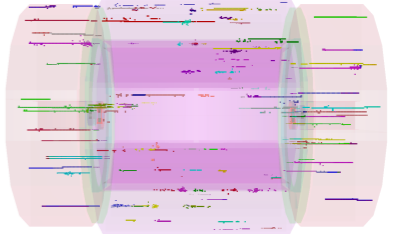
**2.2 TeV**

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### Offline timing cuts


- ★ Apply timing cuts to “offline” reconstructed clusters
  - “Tight” PFO Selection
  - Time cuts: require cluster within **1 - 2 ns** of physics BX



★ 5 muons per BX in time with  $O(1-2 \text{ ns})$  time cuts

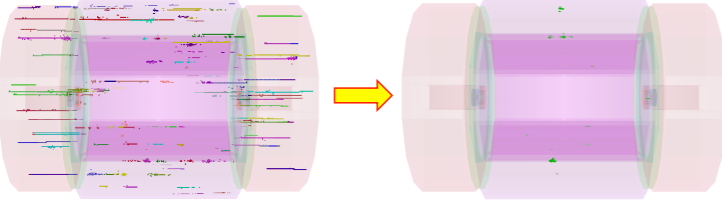
**420 GeV**

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### 3 Software Mitigation


- ★ Implement algorithms in Particle Flow Reconstruction to remove “clusters” consistent with being from beam halo muons
  - Only uses shape information
  - Algorithm is run deep down in reconstruction chain
  - Quite sophisticated – approximation to realistic pattern recognition



**420 GeV**

**30 GeV**

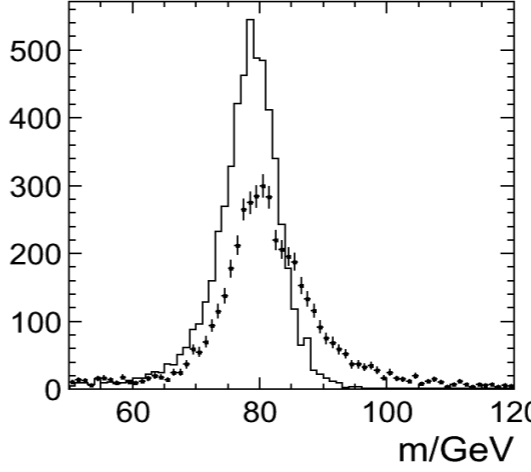
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### Impact on W Reconstruction

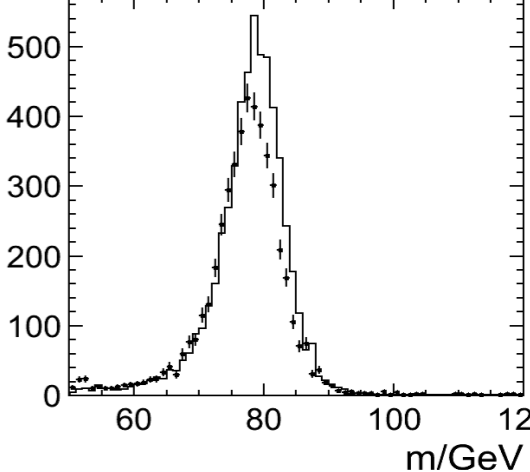
- ★ Compare impact of 5/BX to 1/BX
  - Beam halo background at level of 1 muon/BX is acceptable
  - “Safety-margin” of 5/BX is **not safe** from point of view of physics
  - PatRec could be improved but already quite sophisticated

**muon halo (5/BX)**



m/GeV

**muon halo (1/BX)**



m/GeV

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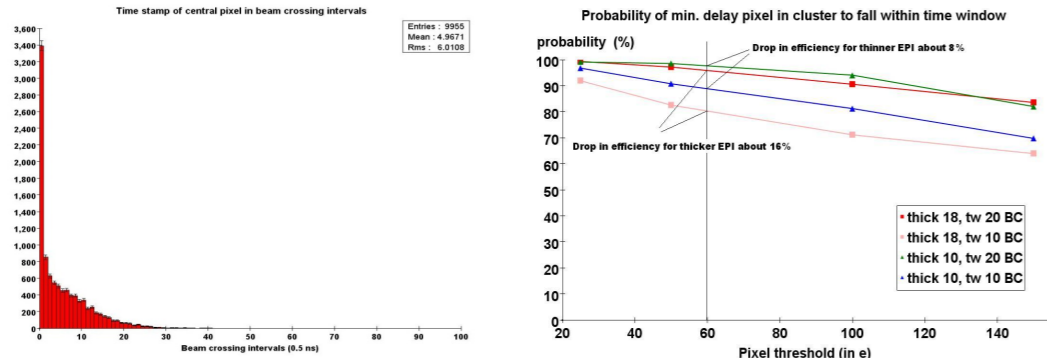
Beam halo background of 1/BX is manageable.  
5/BX degrades physics performance.

# vertex detectors

N. Sinev

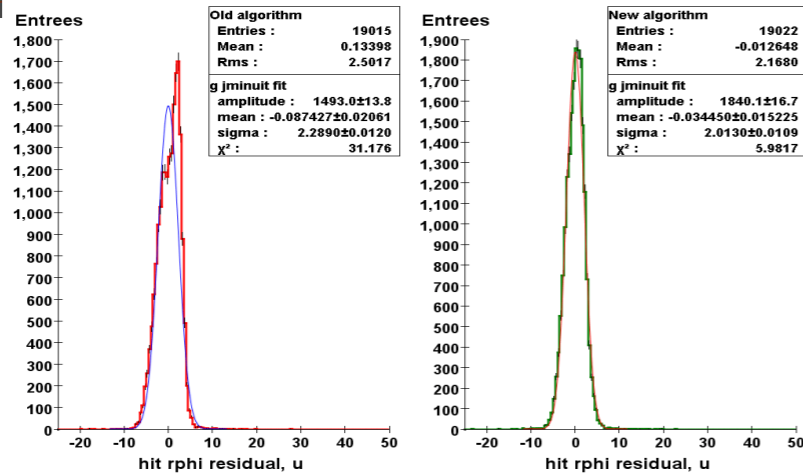
D. Kamai

## Some results of simulation for CLIC



- On the left picture you can see time stamps (time of the threshold crossing by the signal) distribution for fastest in the cluster pixel.
- On the right plot shown the probability that time stamp of the fastest signal in the cluster falls within the time window for different pixel thresholds.

## Results with new algorithm



Covariance matrix does not affect hit position. But, because I have added the position correction, which depends on the cluster shape, into the same tables, which I made for covariance matrix, I have used this corrections to improve accuracy of hit position finding.

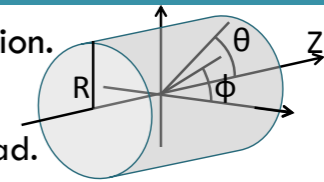
Nick Sinev, LCWS11, Granada, Spain, September 28, 2011

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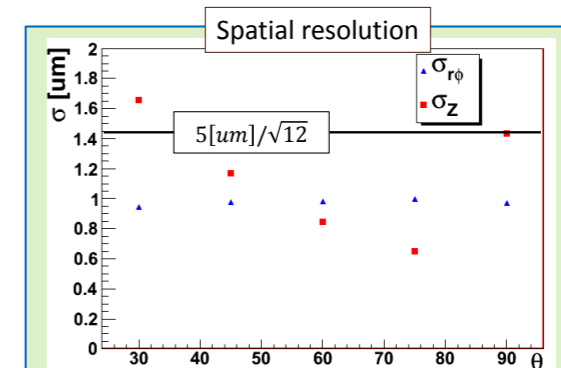
## Spatial resolution

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- The  $\theta$  dependency of the spatial resolution.
  - The Z resolution is worse at forward.
  - The Z resolution of the vertical track is bad.
  - The R- $\Phi$  resolution is better than 1  $\mu\text{m}$ .

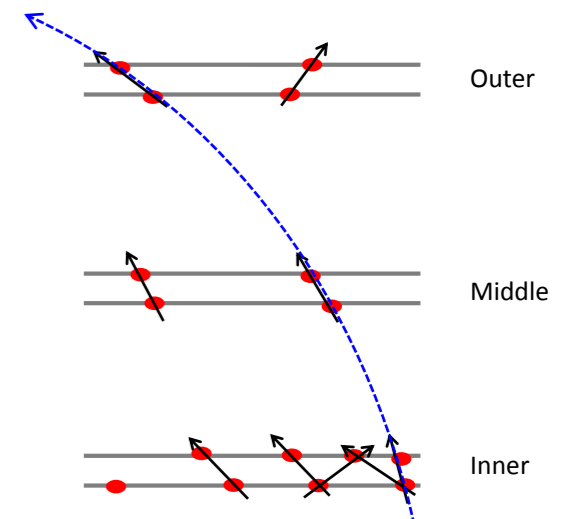
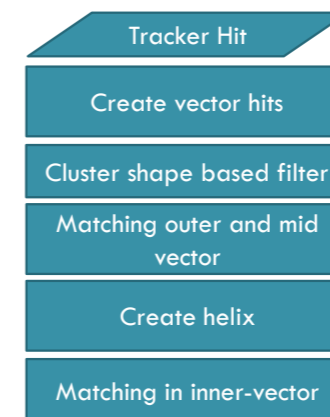


$\theta$	$\sigma_z$	$\sigma_{R-\phi}$
90°	1.5 $\mu\text{m}$	0.94 $\mu\text{m}$
75°	0.64 $\mu\text{m}$	0.96 $\mu\text{m}$
60°	0.83 $\mu\text{m}$	0.96 $\mu\text{m}$
45°	1.2 $\mu\text{m}$	0.96 $\mu\text{m}$
30°	1.6 $\mu\text{m}$	0.98 $\mu\text{m}$
LOI	2.8 $\mu\text{m}$	2.8 $\mu\text{m}$



International Workshop on Future Linear Colliders 2011 at Granada September 26-30, 2011

- Extrapolate the helix into inner layers and determine the track.



International Workshop on Future Linear Colliders 2011 at Granada September 26-30, 2011

New PixSim drivers for CLIC.  
Improvements in reconstruction.

FPCCD: good spatial resolution.  
Si tracking based on mini-vectors.



# tracking

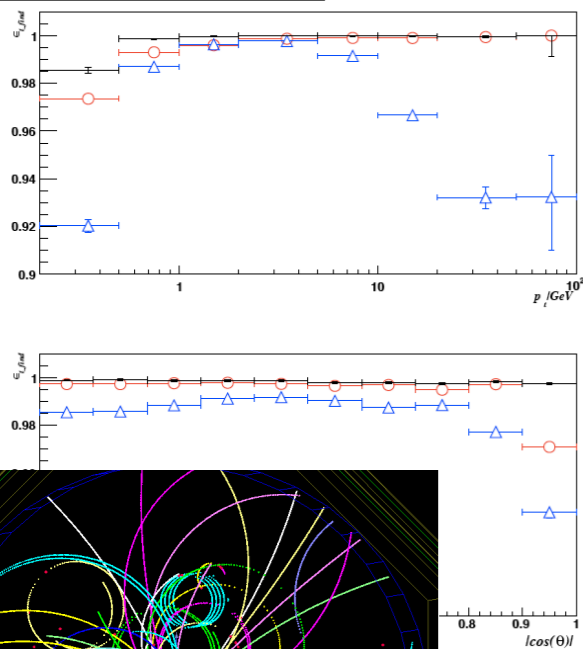
F. Gaede

S. Aplin

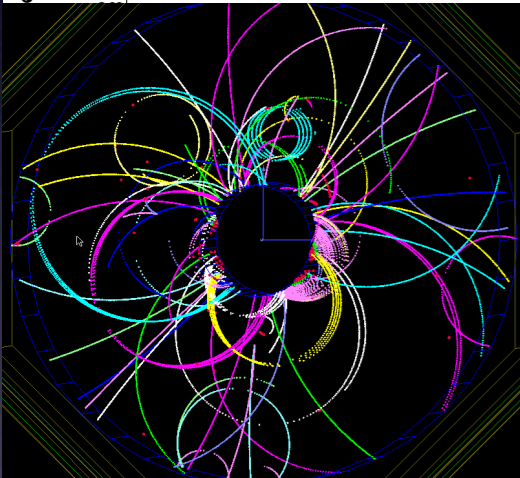
Gaede, LCWS11, Granada, Sep 26-30, 2011

## track finding efficiency I

TPC track finding efficiency - ttbar @ 500 GeV



- prompt tracks PCA(IP)<10cm
- > 5 TPC Hits
  - (  $p_T > 100$  MeV )
  - (  $|\cos(\theta)| > .99$  )
- comparison to LEP tracking pattern recognition
- NB: Clupatra has no fully reconstructed tracks yet and no quality cuts are applied
- high efficiency demonstrates that algorithm works and could replace old f77 code soon



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Improved patrec for ILD tracking (clupatra).  
Use Kalman filter library (KalTest).  
ILD tracking without F77!

## KalTest

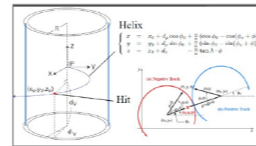
Kalman Filter fitting library (Keisuke Fuji et al)

Based on Root

Structured in sub-libraries

- geomlib -- geometry
- kallib -- Kalman filter
- kaltracklib -- Kalman tracker
- utils -- utilities

Built into one libKalTest.so



Example 2 - Tracking in HEP Experiments

$$d_k = \begin{pmatrix} d_x \\ d_y \\ d_z \\ \lambda \end{pmatrix}$$

Helix parameter vector at  $(k)$

Multiple scattering between  $(k-1)$  and  $(k)$

Measured hit point at  $(k)$

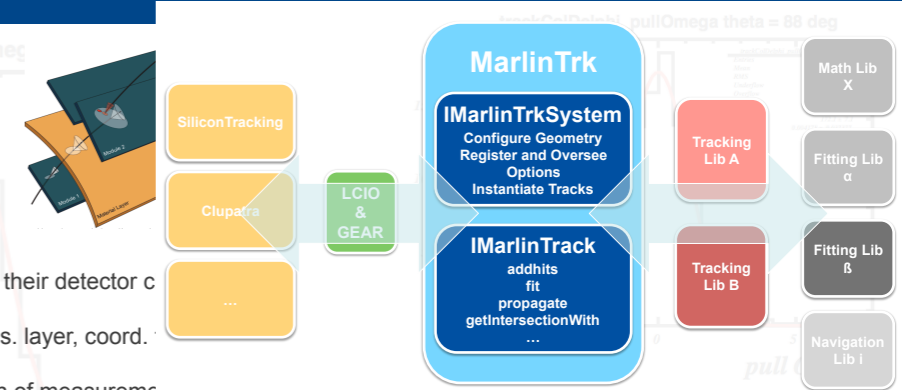
random detector noise

- User needs to define their detector class (**KalDet**)
- TVMeasLayer: meas. layer, coord. state transformation
  - TVDetector: position of measurement and material properties
  - Since ALCPG treatment of rotated planes have been done by Daisuke Kamai.

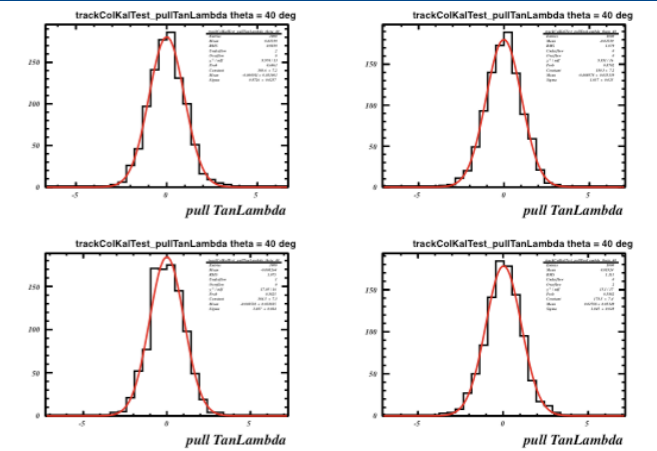
Steve Aplin ILD Tracking LCWS 2011

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## IMarlinTrack and IMarlinTrkSystem

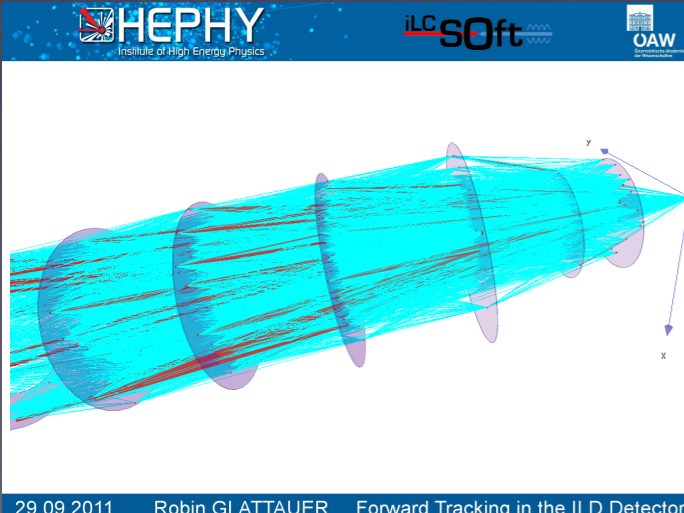


## Track Parameter Pull Distributions

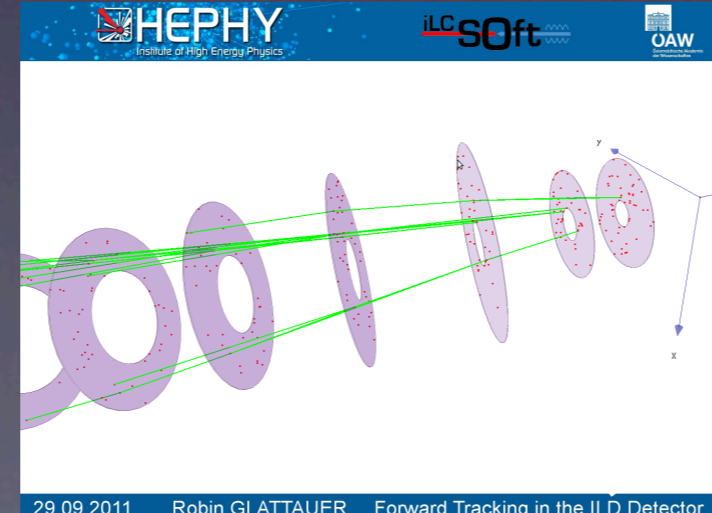


Steve Aplin ILD Tracking LCWS 2011

28 September 2011 30



29.09.2011 Robin GLATTAUER Forward Tracking in the ILD Detector



29.09.2011 Robin GLATTAUER Forward Tracking in the ILD Detector

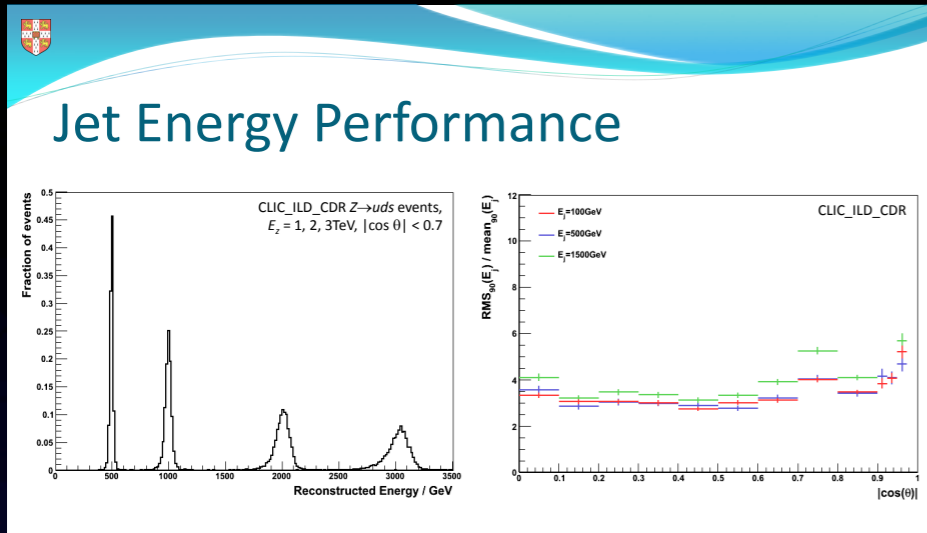
R. Glattauer

Forward tracking based on cellular automaton, Kalman filter, neural network.  
Standalone tracking to deal with beam-related background.

# PFA

J. Marshall

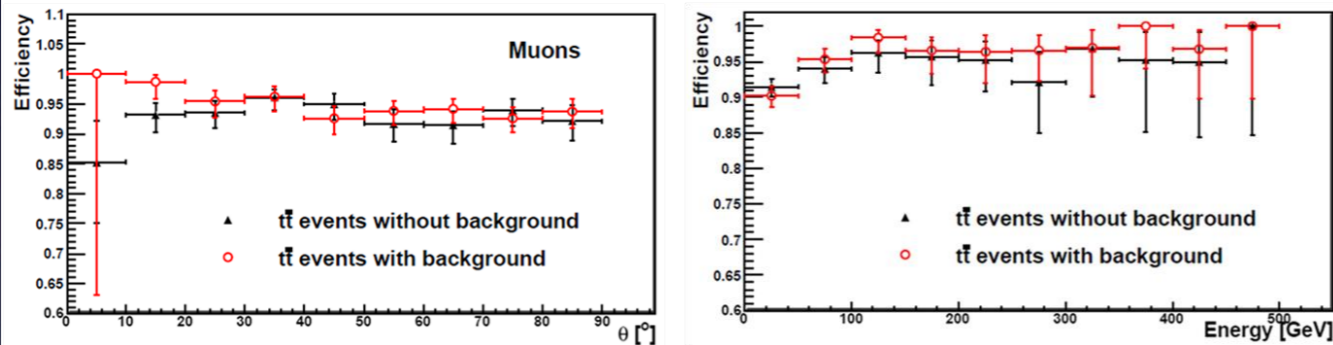
G. Halladjian



CLIC\_ILD\_CDR,  $E_s = 1, 2, 3\text{TeV}$

- No Photon Clustering
- Photon Clustering

## CLIC ILD: Particle Id in Jets



- For the CLIC ILD detector model, the events considered are  $e^+e^- \rightarrow t\bar{t}$  at  $\sqrt{s} = 3\text{TeV}$ .
- The simulated samples included both fully-hadronic and semi-leptonic final states:  $t\bar{t} \rightarrow b(q\bar{q})\bar{b}(q\bar{q})$  (six jets) and  $t\bar{t} \rightarrow b(q\bar{q})\bar{b}(l\nu)$  (four jets, lepton and missing energy).

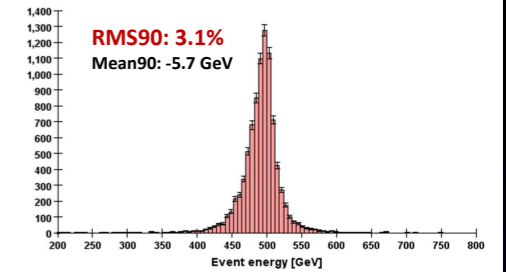
Mean efficiency without background: **94%  $\pm$  1%**  
 Mean efficiency with background: **94%  $\pm$  1%**

John Marshall, 18

## Event energy resolution



- Event energy resolution of low  $\alpha$  PFA with the modifications described = 3.1%
- Confusion between the charged and neutral sub-clusters is correlated



	Charged	Neutral	Photon	Purity
Reco as Charged	51.56	3.97	1.59	0.90
Reco as Neutral	6.69	7.81	1.55	0.49
Reco as Photons	3.12	0.79	22.91	0.85
Efficiency	0.84	0.62	0.88	

Sep 28, 2011

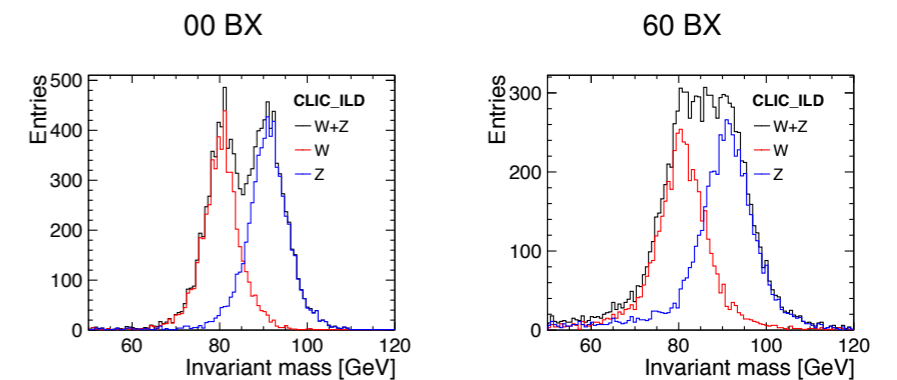
LCWS11 - G. Halladjian

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A. Muennich

## WZ Separation: Mass Distributions

W from  $e^+e^- \rightarrow WW \rightarrow \mu\nu qq$   
 Z from  $e^+e^- \rightarrow ZZ \rightarrow \nu\nu qq$   
 same reconstruction and analysis as for W.



Mass distribution of the reconstructed W and Z for CLIC\_ILD at  $E_{W,Z} = 500\text{ GeV}$

A. Muennich

PFA Performance at CLIC

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Improvements in PFA algorithms; lepton ID. Performance studies for CLIC.

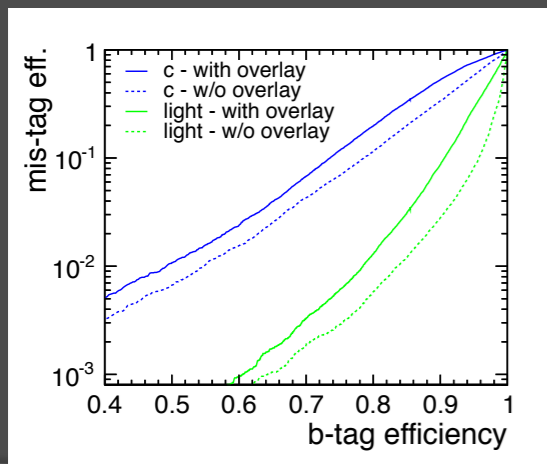
# flavor tagging

J. Strube

T. Tanabe

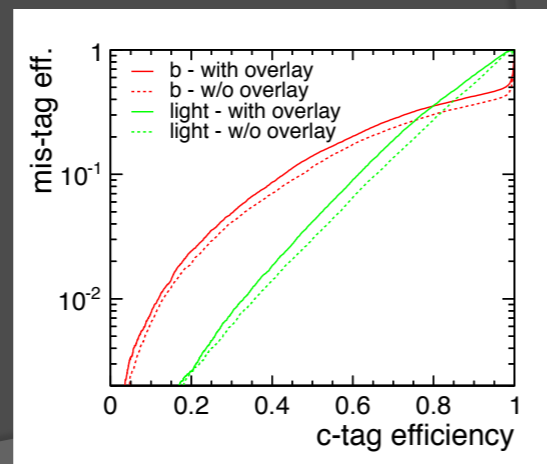
## Light Higgs decays to bottom and charm

- Mean energy of Jets 130 GeV
- Using FastNN for training
- Additional track-based variables used in additional step
- b and c(!) tagging



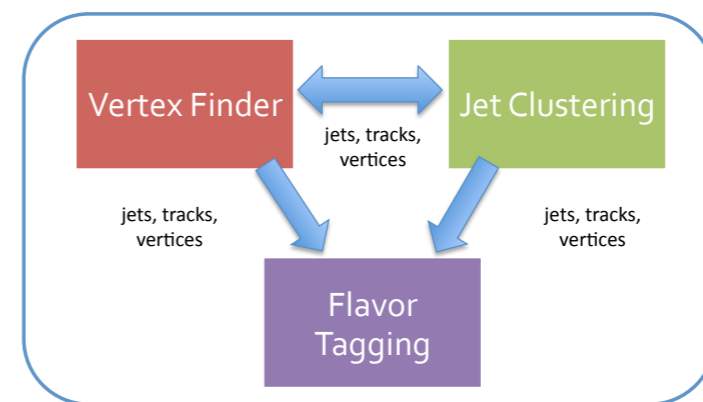
Jan Strube - LCWS2011

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## LCFIVertex framework

- improvements in **vertex finding, jet clustering, flavor tagging** in a unified way
  - creation of a new framework suited to this task
    - data types: event, track, neutral, mcparticle, jet, vertex
    - algorithms: vertex finding, jet clustering, flavor tagging



T. Tanabe

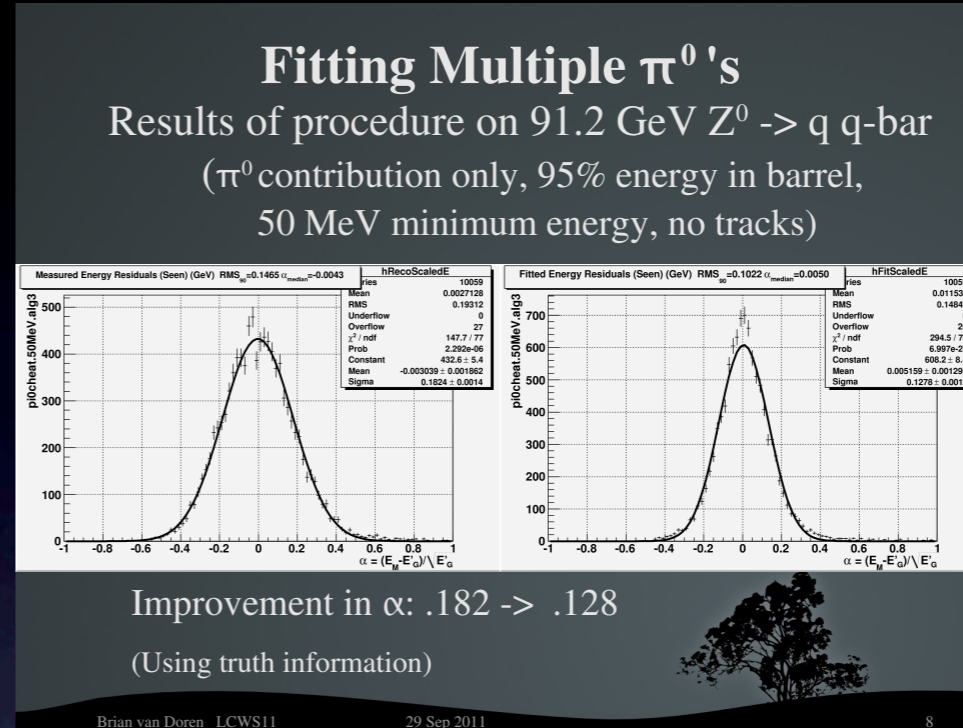
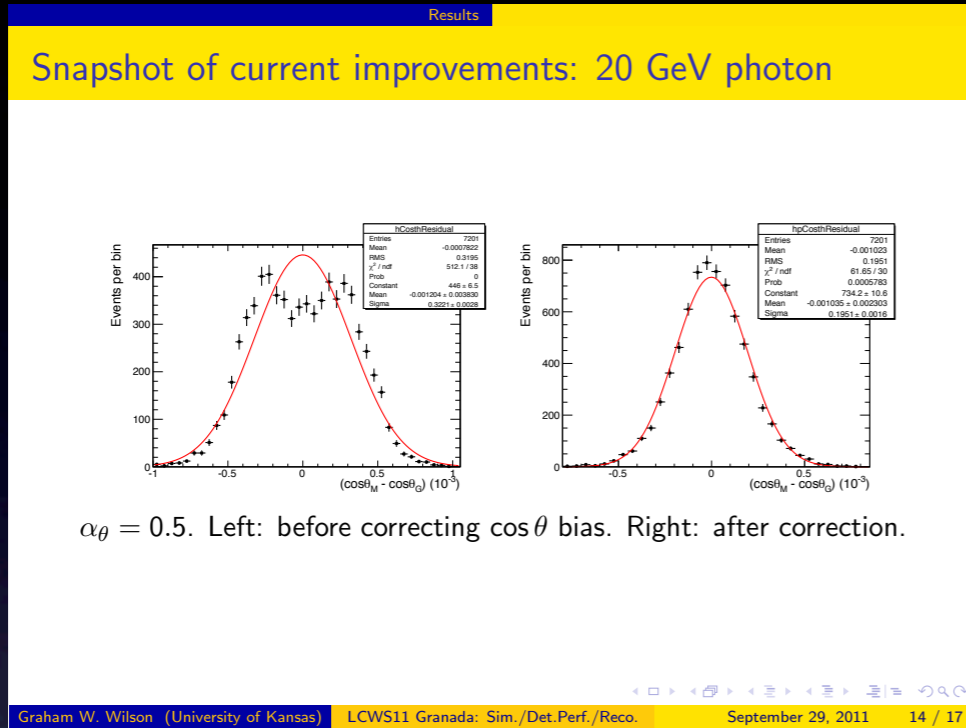
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On-going effort to improve flavor tagging.

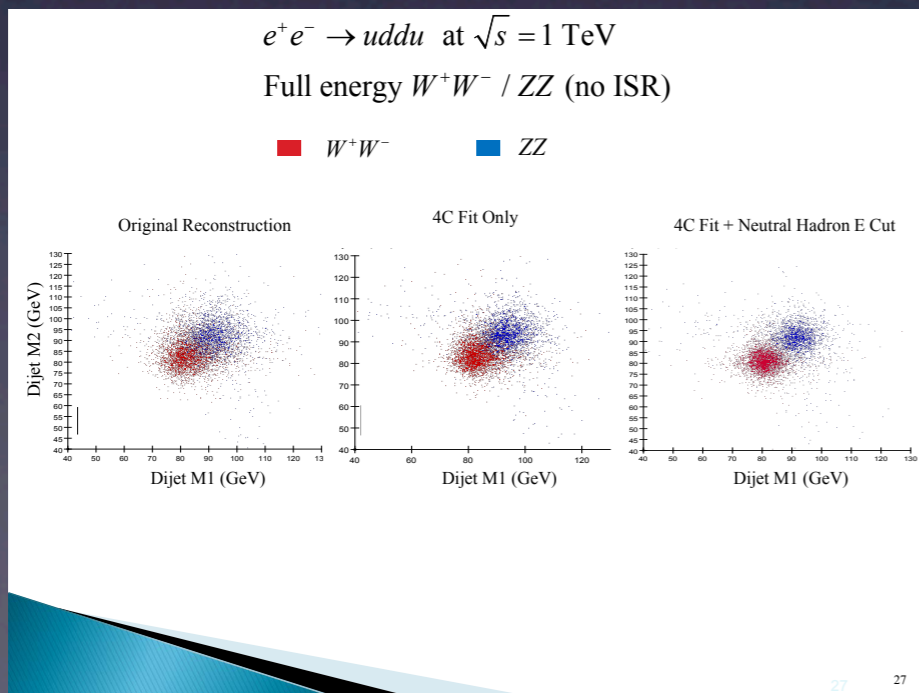
# particle reconstruction

G. Wilson

B. van Doren



T. Barklow



Shower fitting improves calorimeter measurements.  
 Constrained fits improve  $\pi^0, W/Z$  resolution.

- Tremendous amount of progress made (mostly) driven by
  - CLIC CDR
  - DBD for ILD & SiD
- Keep up the good work!