Status of
Full-Simulation Calorimeter Study

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In this talk, I’ll report

1. New features in LCDROOT Cluster
   - Change the cluster position definition (from V3.4)
   - Modify clustering algorithm (for the next version V3.5)

2. Photon reconstruction study in EM calorimeter
   - Separation of scattered particle clusters
   - $\gamma$ selection by transverse information
   - $\gamma$ selection by longitudinal energy deposit information
   - SD vs LD
1-1) Change of cluster position definition

So far we define cluster position as energy weighted mean of associated Cal-Hits.

→ To see cluster-tracker matching, we should see cluster starting position.
From LCDROOT V3.4 we have changed the definition of cluster position.
Seeing cluster starting position, we get better particle-cluster association.
1-2) Modify clustering algorithm

So far we used cheater algorithm to form clusters
→ gather all CalHits associated to the same particle

Even there are scattering particles
… Make 1 cluster by gathering these CalHits
In real experiments, we cannot associate the hits from scattered particles to the original particle

→ Cheater algorithm is not a realistic clustering method

We introduce modified clustering algorithm:
1) Form a cluster by Cheater algorithm
2) Make cluster(s) from grouping CalHits

1. At 1st layer, gather the neighboring hits
2. Calculate energy-weight mean ← reference position
3. Go to the next layer
4. Gathering hits within a cone from the reference position
5. Repeat 2 to 4

cone width:

$\Delta \theta$ 50mrad $\Delta \phi$ 40mrad (SD)
140mrad 110mrad (LD)
$\Delta\theta$ and $\Delta\phi$ between the near calhit in the same particles
Now we have more realistic clustering

... This will be available from LCDROOT V3.5
2. Photon reconstruction study in EM calorimeter

In energy flow analysis, we use

Tracker for Charged particles
Calorimeters Neutral particles

EM calorimeter \( \cdots \) \( \gamma \)
HAD calorimeter \( \cdots \) Neutral hadron

At first, the \( \gamma \) reconstruction studies in EM is important
2-1) Separation of scattered particle clusters

As we showed, there are one or more clusters from one particle

Average # of clusters in a particle ... 1.7
Scattered particles carry 20% of total event energy
I don’t know how to treat the clusters from scattered particles yet. But if we want to have correct jet direction, for example, we want to reject such clusters.

Nearest clusters to the particles

Scattering particle clusters

Scattered clusters have less energy… apply a cut $E_{cls} > 0.35 \text{GeV}$
Cluster Energy (GeV)

**Photon**
- $E_{cls\_gam}$
- Nent = 6310
- Mean = 0.8583
- RMS = 0.4401

**Electron**
- $E_{cls\_ele}$
- Nent = 361
- Mean = 0.8888
- RMS = 0.4324

**Hadron**
- $E_{cls\_had}$
- Nent = 7791
- Mean = 0.4747
- RMS = 0.431

**Muon**
- $E_{cls\_mu}$
- Nent = 163
- Mean = 0.0282
- RMS = 0.0288

Graphs showing the distribution of cluster energy for different particle types.
Nearest clusters to the initial particles start from surface of EM CAL

apply clus. starting depth < 2 cm

<table>
<thead>
<tr>
<th>#particle</th>
<th>#cluster</th>
<th>purity</th>
</tr>
</thead>
<tbody>
<tr>
<td>9163</td>
<td>14988</td>
<td>61%</td>
</tr>
<tr>
<td>Ecls &gt; 0.35 GeV</td>
<td>7487</td>
<td>9405</td>
</tr>
<tr>
<td>depth &lt; 2cm</td>
<td>6864</td>
<td>7702</td>
</tr>
</tbody>
</table>
Cluster Starting depth (cm)

**Photon**
- Depth: 7.603 cm
- Mean: 7.303 cm
- RMS: 2.489 cm

**Electron**
- Depth: 28.33 cm
- Mean: 28.33 cm
- RMS: 3.907 cm

**Hadron**
- Depth: 3.839 cm
- Mean: 3.839 cm
- RMS: 4.888 cm

**Muon**
- Depth: 30.77 cm
- Mean: 30.77 cm
- RMS: 2.07 cm
2-2) γ selection by transverse information

To separate Charged/Neutral Clusters we see track-cluster matching

1) Extrapolate Charged tracks to the Cluster radius,
2) Associate the nearest track to the cluster

Apply a cut: Track-cluster distance > 2.5 cm

→ γ selection π 70% ε 88% (for Ecls>0.35GeV clusters: SDMar01)
2-3) γ selection by longitudinal information

It is useful to separate EM particles / hadron by seeing longitudinal Edeposit information

**Longitudinal energy deposit shape**

**Photon**

![Graph showing photon energy deposit shape]

- Distance from CAL surface (cm)
- Mean: 3.981
- RMS: 1.814

**Electron**

![Graph showing electron energy deposit shape]

- Distance from CAL surface (cm)
- Mean: 3.107
- RMS: 2.338

**Hadron**

![Graph showing hadron energy deposit shape]

- Distance from CAL surface (cm)
- Mean: 6.09
- RMS: 4.284

**Muon**

![Graph showing muon energy deposit shape]

- Distance from CAL surface (cm)
- Mean: 3.85
- RMS: 4.161
Depth where CALHit Energy > min-I

**photon**

Depth (cm)

**electron**

Depth (cm)

**hadron**

Depth (cm)

**muon**

Depth (cm)

**scattered particle**

Depth (cm)

Apply a cut: depth < 2 cm
Cluster starting layer - max Edeposit layer distance

 photon

 electron

 hadron

 muon

 scattered particle

Apply a cut: 0.5 < distance < 7 cm
## Summary of $\gamma$ selection (SDMar01 detector)

<table>
<thead>
<tr>
<th>Condition</th>
<th>$N(\gamma)$</th>
<th>$N$ (not $\gamma$)</th>
<th>$N$ (scattered)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{\text{cls}} &gt; 0.35$ GeV</td>
<td>3665</td>
<td>3822</td>
<td>1918</td>
</tr>
<tr>
<td>Cluster depth $&lt; 2$ cm</td>
<td>3331</td>
<td>3533</td>
<td>838</td>
</tr>
<tr>
<td>Track-cluster cut</td>
<td>3243</td>
<td>648</td>
<td>742</td>
</tr>
<tr>
<td>Longitudinal cuts</td>
<td>3036</td>
<td>274</td>
<td>376</td>
</tr>
</tbody>
</table>

→ Longitudinal energy deposit information is effective to reject both hadrons and scattered clusters.
2-4) SD vs LD detectors

... Currently we have several detector designs

**SD(Mar01)** : W-Si EM cal
- granularity: 7.5 mrad
- # layers: 30 layer
- inner radius: 127 cm

**LD(Mar01)** : Pb-scint EM cal
- granularity: 40 mrad
- # layers: 10 layer
- inner radius: 196 cm
Apply a cut: Track-cluster distance > 6 cm
→ γ selection π 48% ε 79% (for Ecls>0.35GeV clusters: LDMar01)
Longitudinal energy deposit shape

**Photon**
- Nent = 1140
- Mean = 1.08
- RMS = 0.308

**Electron**
- Nent = 2717
- Mean = 3.614
- RMS = 4.415

**Hadron**
- Nent = 6141
- Mean = 5.721
- RMS = 4.439

**Muon**
- Nent = 423
- Mean = 9.184
- RMS = 6.899

Distance from CAL surface (cm)
Depth where CALHit Energy > min-I

 photon

 LD (Mar01)

 electron

 hadron

 muon

 scattered particle

Apply a cut: depth < 2.4 cm
Cluster starting layer - max Edeposit layer distance

Photon

LD (Mar01)

Electron

Hadron

Muon

Scattered particle

Apply a cut: distance < 7.2 cm
## SD vs LD

### SD (Mar01)

<table>
<thead>
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<td>376</td>
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### LD (Mar01)

<table>
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<th>Condition</th>
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<th>N (not γ)</th>
<th>N(scattered)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecls &gt; 0.35 GeV</td>
<td>3043</td>
<td>4932</td>
<td>2659</td>
</tr>
<tr>
<td>Cluster depth &lt; 2.4 cm</td>
<td>2667</td>
<td>4207</td>
<td>1119</td>
</tr>
<tr>
<td>Track-cluster cut</td>
<td>2398</td>
<td>1645</td>
<td>913</td>
</tr>
<tr>
<td>Longitudinal cuts</td>
<td>2361</td>
<td>1138</td>
<td>566</td>
</tr>
</tbody>
</table>

Too bad??
... Do we have some bug in LD Full simulation??

Cluster-Initial particle distance (cm)

Cluster-Initial particle distance
Electron generation (LD)

...???
Summary

1) We update the clustering algorithm for more realistic simulation studies

2) Photon reconstruction in EMCal
   Longitudinal information is very useful
   $\chi^2$ fit or Neural Network?
   Need to check the LD data set…

3) Future plan
   GEANT4 (now in progress)
   HAD Cal study
   Tune FastMC parameters