Photon Reconstruction Status

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• Framework

• Approaches
  - TOWER
  - VICINITY
  - Photon FinDer
  - EMILE

• Tests
  - Isolated Photons
  - $\pi^+/\gamma$

• Conclusions
- GEANT 4
- Projective Geometry (LINEAIRE)
- Non-projective Geometry (MOKKA)

- Interface of the CODES with the non-projective geometry is on progress and no difficulty is foreseen

- The informations are centralized on the Web Site http://lc-ecal.in2p3.fr
• Projective Geometry
• **Clusterisation** is the collection of every pads in a 5x5x40 (θ, φ, layer) tower around the most energetic pad if such a pad is not-isolated.
If no not-isolated pad exits, the zone is reduced to a 3x3X40 tower around the most energetic pad.

• **Test**
Isolated Photons from 250 MeV up to 30 GeV

Resolution obtained as a function of $E_\gamma$

$$\frac{\Delta E}{E} = (10.3 \pm 0.3)\% \bigg/ \sqrt{E} + (1.1 \pm 0.1)\%$$

• Acts as a benchmark
• Indicates the intrinsic performances of the Si/W ecal
• Projective Geometry
• **Clusterisation** is based on vicinity rule between the pads

**Rule**: 2 pads with at least a corner or/and a side in common are connected

i) Clustering begins on the most energetic pad not already involved
ii) A cluster is the collection of all pads linked by the vicinity rule after iterative loop on all the pads already collected.
iii) goto i)

• **Tests**
Isolated Photons from 250 MeV up to 15 GeV

Fraction of collected energy as a function of $E_\gamma$
• Projective Geometry
• Isolated Photons from 250 MeV up to 15 GeV

Fraction of collected energy as a function of the energy

![Graph showing fraction of collected energy vs. root of energy in GeV]

The cluster under consideration should have more than 5 pads involved.

The fraction of collected energy is less than 80% @ 250 MeV while it decreases to 60% when only the most energetic cluster is taken into account.

• A rule to connect the clusters has to be defined
Which pads to use?

1 - reject from the list of pads, all pads within some distance to the extrapolation of a charged track (1cm)

VIRTUAL STACK 1

1 - Create a \textit{virtual stack} by summing the first 10 layers
2 - order by energy the \textit{virtual pad(s)} of the virtual stack
3 - Start a new \textit{virtual cluster(s)} as soon as a pad is not a neighbour of the previous virtual pad in the energy ordered list.

\textit{(GAMPEX - ALEPH photon package)}

CLUSTERING kernel

1 - Start from the \textit{virtual cluster(s)} as entry point to clustering for all \textit{real pad(s)}
2 - Use “equivalent distance” at the ECAL entry to declare 2 pads are neighbours
3 - Recover unassociated pads by the angle between the “direction” of a cluster and the “direction” of a pad.

see next transparency for the definition of the direction
• **What is ’direction’**
  
  for a cluster
  
  Vertex to COG of the cluster
  
  for a pad
  
  projected COG to entrance of the ECAL to Pad position
  
• **Tests**
  
  - Use of MOKKA
  
  - Simulate photons from 0.15 to 100 GeV
PHOTON simulated with GEANT4 and MOKKA

Clustering efficiency %

<table>
<thead>
<tr>
<th>Photon energy (GeV)</th>
<th>Clustering efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>99</td>
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<tr>
<td>0.5</td>
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<td>2</td>
<td>92</td>
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\[ \frac{E_{\text{cl}}}{E_{\text{gen}}} \]

- PFD efficiency to find photon in the low energy region:
  - About 99% above 0.25 GeV

- Rate of fake electromagnetic cluster (created from fluctuation of an electromagnetic shower):
  - About few per mill - $4 \times 10^{-3}$ at 0.5 to $9 \times 10^{-3}$ at 100 GeV

- Fraction of the total energy in the cluster:
  - Stable and about 95% up to 4 GeV then slowly going to 99.5% at 100 GeV
PHOTON simulated with GEANT4 and MOKKA

\( \chi^2/\text{ndf} \quad 0.2098 \quad / \quad 2 \)

A0 \quad .2394E-01 \quad \pm \quad .8991E-02

A1 \quad .1085 \quad \pm \quad .6312E-02

\[ \Delta E/E \]

\[ \delta \theta \text{ (mrad)} \]

PHOTON simulated with GEANT4 and MOKKA

\( \chi^2/\text{ndf} \quad 0.7118 \quad / \quad 3 \)

A0 \quad .4783E-02 \quad \pm \quad .1256E-02

A1 \quad .1367 \quad \pm \quad .5804E-02

\[ \Delta E/E \]

\[ \delta \theta \text{ (mrad)} \]

4 - Energy and angular resolution

AFTER CLUSTERING

the stochastic term is \( 11.4\%/\sqrt{E} \)

up to few GeV then about

\( 13.7\%/\sqrt{E} \)

\[ \delta \theta \text{ (mrad)} = 0.63/\sqrt{E} + 0.24 \text{ down} \]

to few hundred MeV
Beside the Standard approaches, new one is developed:

**Energy Measurement Intended for Low Em showers**

**Main Directions**

- 3D
- Democratic
- Physical insight
- No seed
- Long range
- Two pads \((i \text{ and } j)\) are connected according a link strength \(d_{ij}\) defined by terms which reflects the basic process \((e \rightarrow \gamma, \gamma \rightarrow e)\)

\[
\text{Energy relation: } E_i/E_j \\
\text{Angular dependence: } 1/(1-\beta \cos \theta_{ij})
\]

\(\rho_{ij}\) is the 3D distance between the pads \(i\) and \(j\), 
\(X_o\) is the interaction length, 
\(\theta_{ij}\) is the angle between the pad \(i\) and \(j\), 
\(\beta = .99\)

Thus \(d_{ij}\) is defined as

\[
d_{ij} = e^{-\rho_{ij}/X_o} \times E_i/E_j \times 1/(1-\beta \cos \theta_{ij})
\]
Energy Measurement Intended for Low E\textsubscript{m} showers

- $d_{ij}$
  - The $d_{ij}$ terms are determined between every pair of pads in the event but pad $j$ should be on a layer outer than the pad $i$ i.e. follows the development of the e.m. shower
  - All pads are connected without any initiate pad (in contrast with maximal energy pad rule)
  - The energy from a pad could be shared by many objects

- An internal cut is applied

*preliminary Version!*

**Cuts have to be tuned (or replaced by continuous function)**
**Clustering**

- **def**: Each pad $j$ with $d_{ij} = 0$ whatever $i$ is a terminal pad.
- **Rule**: From the outer layer (i.e. 40th) the energy is distributed on each pad according to $d_{ij}$ down to each terminal pad.

- A terminal pad defines a cluster
- Every characteristic of the cluster is built through the $d_{ij}$ weighting from the 40th layer to the terminal pad.

Examples: Energy, terminal pad coordinates, core cluster coordinates...
• **Cluster association**

Two clusters \((a\) and \(b\)) are merged if
\[
\|D_{\text{entry}}^a - D_{\text{entry}}^b\| \leq 1.73 \text{ or } \|D_{\text{core}}^{a,b}\| \leq 0.5
\]

where \(D_{\text{entry}}\) stands for the Distance from the center of the detector and the terminal pad point, and \(D_{\text{core}}^{a,b}\) is the distance between the barycenter of the cluster \(a\) and \(b\).

Cuts have been tuned to ensure the best recovering of photon energy

• **Tests**

Projective Geometry
Isolated Photons from 100 MeV up to 15 GeV
EMILE: Low Photons

$E_\gamma = 100$ MeV

$E_{\text{meas}} / E_{\text{expected}}$

$E_\gamma = 250$ MeV

$E_{\text{meas}} / E_{\text{true}}$
\[ \frac{\Delta E}{E} = (11.0 \pm 0.3)\% \sqrt{E} + (1.4 \pm 0.2)\% \]

Fraction of collected energy is never less than 92\% even when only the most energetic cluster is taken into account.
• **Tests**
• Photons with noise coming from $\pi^+$

Samples with different distances between the $\gamma$ and the $\pi^+$

Typically $E_\gamma=1$ GeV and $E_\pi=10$ GeV
Distance is 4, 3 and 2 cm

The clusters matching the MC photon direction are considered as photons

@ 4 cm
The clusters matching the MC photon direction are considered as photons.
Photon with Pions

@ 4 cm

to Simulate the Photon-Id a cut on \((E_{\text{e.m.}}/E_{\text{meas}})_{\text{cluster}}\) is applied.

The cut is 'tuned'\(^{(1)}\) to render the distribution gaussian

\(^{(1)}\) typically .75
Photons With Pions

Display @ 3 cm

knevt=36 dist=3cm

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<th>$E_{\gamma}$</th>
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Photon with Pions
@ 3 cm

With such assumptions Preliminary Results are

@ 4 cm $\epsilon_\gamma = 80\%$
@ 3 cm $\epsilon_\gamma = 50\%$
@ 2 cm $\epsilon_\gamma = 22\%$

**NB.** No rejection of the $\pi^+$ shower nor Mip reconstruction

More realistic numbers will come with Photon-Id
Conclusion

1 Standard approaches
   – Photon FinDer is an efficient photon finder
   – It is a good starting point for photon
   – Could play the Benchmark rôle, already interfaced w/ MOKKA

2 New approach with EMILE
   – (3D, democratic, Physical insight, no seed, long range)
   – Preliminary version
   – Many switches have to be tuned

Next
   • New Codes will be available from the Web Site
   • interfaced w/ MOKKA very soon
   • Included in BRAHMS
   • More investigation with noisy situation
   • Test the algorithms with jets, $\tau$ decays, etc.

– Regular meeting are forseen (last one 13th April 2000)
– KEK people are interested (F. Le Diberder will visit them on july)