Status of E-Flow Optimization of HCAL at ANL

Steve Magill
for
S. Chekanov, G. Drake, S. Kuhlmann, B. Musgrave, J. Proudfoot,
J. Repond, R. Stanek, R. Yoshida
Argonne National Laboratory

- Motivation - E-Flow Implications for Calorimetry
- ECAL Requirements
- Towards HCAL Optimization
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Motivation

How to design and build future calorimeters for optimal jet reconstruction/resolution?

- Physics Requirements
  - Multi-jet final states require separation of WW, ZZ, and Zh
    - \( \sim \text{few GeV mass resolution at 100 GeV} \)
    - \( \sim 30\% / \sqrt{E} \) jet energy resolution as well as good angular resolution
  - Missing energy \( \rightarrow \) hermiticity
  - Heavy q tags \( \rightarrow \) lepton ID + jet reconstruction

- Process/Machine Requirements
  - Signal/BACKGROUNDS (both machine and process)
  - High B-fields \( \rightarrow \) 4 T, \( \sim 2 \text{ m R to ECAL} \) \( \rightarrow \) \( \sim 1 \text{ GeV min charged particle momentum to get to calorimeter} \) \( \rightarrow \) need for excellent tracking
E-Flow Implications for Calorimetry

Traditional Standards
- Hermeticity
- Uniformity
- Compensation
- Single Particle E measurement
- Outside “thin” magnet (~1 T)

Optimized for best single particle E resolution

E-Flow Modification
- Hermeticity
- Optimize ECAL/HCAL separately
- Longitudinal Segmentation
- Particle shower reconstruction
- Inside “thick” coil (~4 T)

Optimized for best particle shower separation/reconstruction
ECAL Requirements

For electromagnetic showers in a dense calorimeter, the transverse size is small
- small $r_M$ (Moliere radius)
- If the transverse segmentation is of size $r_M$, get optimal transverse separation of electromagnetic clusters.

If $X_0/\lambda_I$ is small, then the longitudinal separation between starting points of electromagnetic and hadronic showers is large

Some examples:

<table>
<thead>
<tr>
<th>Material</th>
<th>$Z$</th>
<th>$A$</th>
<th>$X_0/\lambda_I$</th>
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<tbody>
<tr>
<td>Fe</td>
<td>26</td>
<td>56</td>
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<tr>
<td>Cu</td>
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<td>W</td>
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<td>Pb</td>
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<td>207</td>
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<tr>
<td>U</td>
<td>92</td>
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</table>
A dense ECAL with high granularity (small transverse size cells) and with $X_0/\lambda_I$ small is optimal for E-Flow.

$\rightarrow$ good 3-D shower reconstruction.

TESLA/NLC SD solution $\rightarrow$ Tungsten absorber/Silicon pad sandwich construction with 1 X 1 cm$^2$ transverse pad size.
Towards Optimization of HCAL

To optimize the HCAL for E-Flow requires:

- full containment of (neutral) hadronic showers.
- good precision on energy measurement.
- high segmentation in transverse and longitudinal directions in order to separate in 3-D close-by clusters in jets.

Requires integrated approach which includes other detector sub-components in the design phase and incorporating E-Flow algorithm.

- Assume a tracking system optimized for, e.g., di-lepton measurements.
- Assume an ECAL optimized for photon reconstruction.
- Vary HCAL parameters, e.g., absorber material, thickness, size of readout cells in both transverse and longitudinal directions, to determine optimal performance in an E-Flow Algorithm.
HCAL Design Choices

Z decay in ANL GEANT program (based on TESLA TDR)

Z decay in NLC SD Detector, JAS

HCAL in LD Detector also?
Example - HCAL Absorber Choices

Tungsten

Copper

Uranium

Iron

$4\,\gamma$s, $2\,K_0^L$, $\pi^+$, $\pi^-$
**Conclusions**

- Future calorimeters will be required to measure jet energies at unprecedented precisions.
- This will require an Energy Flow approach to jet reconstruction.
- E-Flow implies an integrated approach to calorimeter design, unlike traditional methods.
- Radical departures from current calorimetric methods may be needed -> Digital Hadronic Calorimetry.