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FE electronics for PFA driven scintillator strip EM calorimeter

EBU
photo
front/back
view
e+e- collider exp.

- next generation e+e- detector is designed to match Particle Flow Algorithm (PFA)

- PFA will achieve ~3% jet energy reso. so as to separate W from Z, e+e-→WW/ZZ ν ν event

![Graph showing 3% resolution](image)

![Graph showing mjj and e+e](image)
Fine segmentation requirements for calorimeter

**ECAL Conclusions:**
- Ability to resolve photons in current PandoraPFA algorithm strongly dependent on transverse cell size
- Require at least as fine as $10 \times 10 \, \text{mm}^2$ to achieve 4.0% jet $E$ resolution
- Significant advantages in going to $5 \times 5 \, \text{mm}^2$

**HCAL Conclusions:**
- For current PandoraPFA algorithm and for Scintillator HCAL, a tile size of $3 \times 3 \, \text{cm}^2$ looks optimal
- May be different for a digital/semi-digital RPC based HCAL
PFA-ECAL

- requirements to incorporate PFA
- fine granularity ~ 5mmx5mm (2D)
- as well as longitudinal segmentation +1D=3D)

<table>
<thead>
<tr>
<th>segmentaion</th>
<th>ECAL</th>
<th>HCAL</th>
<th>EJet resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHC</td>
<td>5cm</td>
<td>20cm</td>
<td>60% /\sqrt{E}</td>
</tr>
<tr>
<td></td>
<td>$10^5$ ch.</td>
<td>$10^5$ ch.</td>
<td>6% @100GeV</td>
</tr>
<tr>
<td>ILC</td>
<td>0.5cm</td>
<td>3cm</td>
<td>30% /\sqrt{E}</td>
</tr>
<tr>
<td></td>
<td>$10^8$ ch.</td>
<td>$10^7$ ch.</td>
<td>3% @100GeV</td>
</tr>
</tbody>
</table>
Want to resolve structure in hadronic showers

Require long and transverse segmentation

Want to fully contain hadronic showers

Require small 'I

HCAL will be large, so absorber cost & structural properties will be important

Material

<table>
<thead>
<tr>
<th>absorber</th>
<th>X0 (cm)</th>
<th>ρ (g/cm³)</th>
<th>R_M (cm)</th>
<th>total X0=25X0 (cm)</th>
<th>λ_I (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>tungsten</td>
<td>0.35</td>
<td>19.9</td>
<td>~1</td>
<td>9</td>
<td>9.94</td>
</tr>
</tbody>
</table>
ILD ECAL

- Large Detector for PFA
- $R_{\text{ECAL}} \sim 1.8\text{m} = R_{\text{tracker}}$
- $\text{ECAL} \sim 5\times 5\text{mm}^2 \sim 10^8\text{ch.}$
- Front End read out Electronics in each layers
- together with sensitive layer in between absorber (2mm)
- 30 layers in 20cm including FE elex.
scintillator strip 5x45x2 mm³
reduce number of R/O ch.
with a very small photo-sensor
with orthogonal arrangement
to achieve 5x5mm²
front end electronics (EBU) embedded
good timing resolution <1ns.
robust and low cost
scintillator strip

- scintillation light detected
- photo-sensor: MPPC
- how to read out
  - side read out: better uniformity & Light Yield
  - bottom read out: easy implementation on EBU

scintillator strip for bottom read out
Ecal Base Unit = EBU

- minimum R/O unit of sc-ECAL
- 18cmx18cm with 144 sc-strips
- FE electronics: 4SPIROCs ASIC + IF
- amp, shaper, digitizer
- self-trigger
- bias voltage control
photo-sensor

> small & low power consumption sensor: MPPC
> Geiger mode device
> counts number of pixels as output
> dynamic range must be large for EM shower
> increase # of pixel

keeping the size, smaller pixel

> 10/15um pitch are available

Hamamatsu

photo 10um 15um
**dynamic range**

Maximum energy: Bhabha max energy/strip \( \sim <800 \) MIPs

MPPC-output is limited with # of pixels

800x7=5600 pix: 10kpix is good enough, 15um sufficient

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**Figure:**

- **Graph 1:**
  - Title: photon250GeV
  - Data: Entries 4691899
  - Statistics: Mean 0.0526, RMS 0.2754

- **Graph 2:**
  - Title: Comparison of RC_scaled
  - Data: 10000 pixel
  - Annotation: (Scintillation)

- **Graph 3:**
  - Title: Kuraray-scsn38:rect.
  - Data: SCSN38
  - Annotation: 7p.e./MIP

- **Graph 4:**
  - Title: CAMAC ADC
  - Data: ADCCount [0.25pC]

- **Graph 5:**
  - Title: T. Honda
  - Data: 1600 pixel
  - Annotation: (Scintillation)
Light yield of different producers are examined to optimize to sc-strip ECAL. SCSN38: Kuraray, EJ204: ELJEN. LY (EJ) ~ LY (SCSN) * 1.4.
sensor coupling

- side read out
- bottom read out
LY (Side) ~
LY (Bottom) * 1.4
another light readout

> double sided read out
> reduce noise of MPPCs
> by taking coincidence
> with position resolution

LY sum is twice

45mm

90mm

EJ212~BC400

LY>20p.e.  dV+5.5V

MPPC1

Strip (L=90mm)

MPPC2

Sr-90
EBU with 25um

tested at DEDY electrons

with 25um pitch on an EBU

successful

blue indicates “good” separation of mip from ped.
EBU with 10um

current SPIROC2b is optimized for 25um pitch MPPC

with 10um pitch, encountered difficulty small signal

signal is too small

SPIROC is tuned to have max. amp and ...

ADC dist. for beta rays

increasing gain as well as noises, separation is difficult
EBU with 15um

> 15um pitch MPPC larger than 10um
> higher gain and PDE
> bench test for comparison
> one channel test with EBU
> possible operation of 15um pitch with EBU
> further tests
further EBU test

> EM shower test will be performed at ELPH-Tohoku university
> 100-800MeV electrons
> in preparation for 2017

EBU with 10um pitch MPPC was tested

Terada’s talk

2016 beam test
Summary & outlook

- Strip scintillator ECAL is under development, moving into realistic phase

- EBU: combination of sensors and embedded FE electrics including MPPC is being examined

- Optimization of each parts are under investigation

- EM shower test is planned
Jet energy resolution in terms of strip length is insensitive to the length when SSA. Strip Splitting Algorithm.

![Graph showing jet energy resolution vs. strip length for ScECAL with and without SSA.]

- ScECAL w/o SSA
- ScECAL w/ SSA

Length of strip (mm): 0 20 40 60 80 100

RMS90(Ej) / mean(Ej) (%)

100 GeV jets