Electromagnetic calorimeter of the Belle II detector

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KEKB SuperKEKB Background

Belle II

e\pm 3.6 \text{ A}
e^- 2.6 \text{ A}

E^- = 3.5 \text{ Gev}
E^+ = 8 \text{ GeV}
I^+ = 1.5 \text{ A}
I^- = 1.2 \text{ A}
L = 2.1 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}

E^- = 4 \text{ Gev}
E^+ = 7 \text{ GeV}
I^+ = 3.6 \text{ A}
I^- = 2.6 \text{ A}
L = 8 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}

\begin{equation}
L = \frac{\gamma e^\pm}{2 e r_e} \left(1 + \frac{\sigma_y^\pm}{\sigma_x^\pm}\right) \left(\frac{I_{e^\pm} \cdot \xi_{y,e^\pm}}{\beta_y^\pm}\right) \left(\frac{R_L}{R_{\xi_y}}\right)
\end{equation}
The Belle II detector

**EM Calorimeter:**
Csl(Tl), waveform sampling (baseline) 
(opt.) Pure Csl for end-caps

**K_\pi and muon detector:**
Resistive Plate Counter (barrel outer layers) 
Scintillator + WLSF + MPPC (end-caps, inner 2 barrel layers)

**Particle Identification**
Time-of-Propagation counter (barrel) 
Prox. focusing Aerogel RICH (fwd)

**Central Drift Chamber**
He(50%):C_2H_6(50%), Small cells, long lever arm, fast electronics

**Vertex Detector**
2 layers DEPFET + 4 layers DSSD

**Beryllium beam pipe**
2cm diameter

**Electron (7GeV)**

**Positron (4GeV)**
Upgrade to give optimum performance under \times20 beam background!
Electromagnetic calorimeter of the Belle II detector

- Construction, crystals, preamps are from Belle
- New readout electronics $\tau = 1\,\mu s \rightarrow 0.5\,\mu s$
- Encap preamplifiers are modernized to withstand high dark current

8736 CsI(Tl) crystals in total

Belle II 1152 crystals
960 crystals
6624 crystals

CsI(Tl) crystal
30 cm
16.1 $X_0$

Casing
2 x Preamplifier
2 x PIN diode

PIN diode
2 x Preamplifier

Belle
2MHz, 18-bit digitization
Waveform analysis

unit (mm)

2.0 m
1.0 m
0.0 m
1.0 m
2.0 m
3.0 m

6250
3825
1961.6
1021.6

Preamp + PIN diode

Backward Endcap Calorimeter
Forward Endcap Calorimeter
Barrel Calorimeter
Calorimeter electronics

- 576 ShaperDSP modules were produced, tested and installed on detector
- 52 VME crates - 52 EclCollector modules
Status

- Encaps were dismounted for the period of modernization
- In January 2017 backward endcap has been mounted
- For barrel and backward encap section all electronics are installed cabling is done
- Installation of forward endcap section is scheduled on September 2017
**Electronics status**

**Шумы электроники**

**Загрузка до 30 кГц**

**Временное разрешение по космике**

**Калибровка с генератором импульсов**

**Калибровка формы сигнала по космике**

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**Noise**

Entries: 5568  
Mean: 5.704  
RMS: 0.2777

**50 keV/channel**

**coherent noise ADC channels**

**E = 50MeV**

\[ \sigma_t = \frac{A}{E^{(MeV)}} + B \]

\[ A = 370 \pm 10 \text{ ns-MeV} \]

\[ B = 1.0 \pm 0.2 \text{ ns} \]

**x 1/\sqrt{2}**

**Амплитуда**

**Загрузка до 30 кГц**

**ADC channels**

50 keV/channel

**Шумы электроники**
ECL trigger system

Peaking time of TC | 700
---|---
ADC pipeline | 100
Peak finding process | 300~400
Programmable delay | 300
Gbit transfer(200bits) | 100
Optical cable length | 200~300

Bridge delay | 200~300
Gbit transfer(~ 1100bits) | 400
Input alignment | 100
Trigger decision | 200~300

* Total latency = 2600 ~ 3000 ns
** TMM FPGA = XC6VLX130T-1FF1156C
Test cosmic runs

- Runs for ECL-ECLTRG consistency tests
- Comparison of signal amplitudes measured by FAM modules and by ShaperDSP modules
- ECL-CDC runs (CDC)
- Tuning of DAQ
Reconstruction

- New procedure for cluster building
- Number of crystals in the cluster depends on its energy
- Clusters with improper time are rejected

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Use only digits with $E>0.5\text{MeV}$.

Overlapping CRs are merged.

Optimal number of crystals ($E > 0.5\text{ MeV}$, $\alpha_t / t < 5$)

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![Graph](image_url)

- Background rejection $FWD$ vs $E_{rec}^{raw}$ [MeV]

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Significant improvement of the resolution for maximum background level in comparison with old procedure.
Calorimeter electronics is installed on detector
All electronics channels are alive
DAQ of ECL is able to work at up to 30 kHz trigger rate
Backward endcap section is mounted. Installation of forward section scheduled on Sep. 2017
Test cosmic runs of simultaneous ECL-ECLTRG and ECL-CDC data taking were performed
Calorimeter is regularly calibrated with pulse generator, pulse shape is calibrated with cosmic
Software development for data acquisition, reconstruction, and calibration procedures (cosmic, Bhabha, γγ etc.) is in progress
Thank you for attention!
**FPGA algorithm**

- Fit of several measurements to response function taking into account correlation between measurements -> A, T, Quality
- Correlation matrix is obtained from the data

**Algorithm details**

\[
\chi^2(A, p, t_0) = \sum_{i,j} (y_{ij} - Af(t_i - t_0) - p)^2 S_\theta^{-1}(y_{ij} - Af(t_i - t_0) - p) \rightarrow \min
\]

\[
S_\theta = [y_{ij} - \bar{y}_{ij}][y_{ij} - \bar{y}_{ij}]
\]

\[
f(t) - \text{counter response}
\]

Af\(t_i - t_0 - \Delta t\) = Af\(t_i - t_0\) - A\(\Delta t f'(t_i - t_0)\)

where \(t_0\) – initial time (trigger time)

\[
\sum_{i,j} f S_\theta^{-1}(y_{ij} - Af_j - Bf'_j - p) = 0
\]

\[
A = \sum_i \alpha_i y_i
\]

\[
\sum_{i,j} f S_\theta^{-1}(y_{ij} - Af_j - Bf'_j - p) = 0
\]

\[
B = \sum_i \beta_i y_i \Rightarrow \Delta t = -B / A
\]

\[
\sum_{i,j} S_\theta^{-1}(y_{ij} - Af_j - Bf'_j - p) = 0
\]

\[
p = \sum_i y_i
\]

- For some fraction of data both input and output informations are sent to DAQ for test
Noise and shape

Noise: Incoherent noise - 6.6 bins (~300 keV)
Coherent noise - 0.45 bins (~20 keV)
Environment monitor

- Temperature & humidity monitor for barrel: All cables of the barrel calorimeter are connected. PC setup and software will be prepared in coming months.
- Temperature & humidity monitor for endcaps: is ready and running for backward endcap
- Temperature & voltages monitor for VME electronics is working.
- Isolation amplifiers for current measurement have been ordered and will be delivered at the end of this FY.
On-line Luminosity monitor

The main aim of the LOM is (quasi)independent from Belle II DAQ on-line luminosity measurement for a cross-check as well as providing luminosity when the Belle II is not running.

Coincidence:
\[ C_1 = (SF_1 > T_f) \land (SB_{1+8} > T_b) \]

Bhabha signal:
\[ BH_i = C_1 \land G_f \land G_b , \quad G_f, G_b = 1, \text{ if only 3 serial sectors are hitted} \]
The module has been produced. Hardware test has been done. Firmware, software development and emulation of the algorithm are going on.
Pure CsI

- Pure CsI is a good candidate for fast scintillator in endcap
  - It has relatively high light output, short decay component
- There are several producers who can provide crystal production

- Radiation hardness of 14 pure CsI crystals were tested up to 14 krad (expected dose less than 10 krad)
- In most of the crystals the drop of the light output is less than 20%