Electromagnetic calorimeter of the Belle II detector

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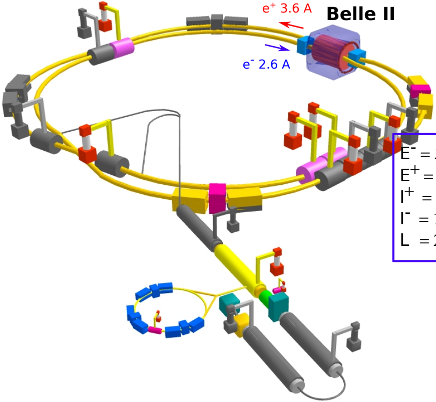
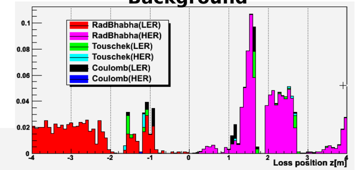
KEK, Tsukuba, Japan



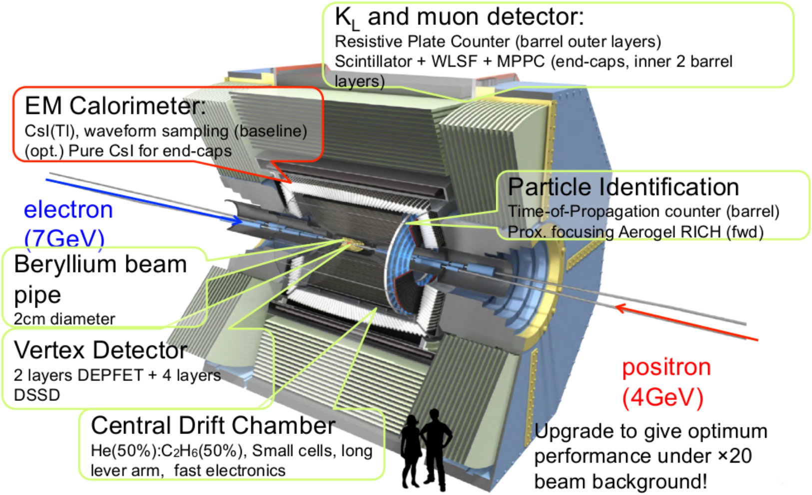
$$L = \frac{\gamma_{e\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_{e\pm}\cdot\xi_{y,e\pm}}{\beta_y^*}\right)\left(\frac{R_L}{R_{\xi_y}}\right)$$

KEKB		SuperKEKB
E^- = 3.5 Gev E^+ = 8 GeV I^+ = 1.5A I^- = 1.2 A L = 2.1x10^{34} cm^{-2}s^{-1}	→	E^- = 4 Gev E^+ = 7 GeV I^+ = 3.6A I^- = 2.6 A L = 8x10^{35} cm^{-2}s^{-1}

Background

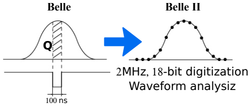


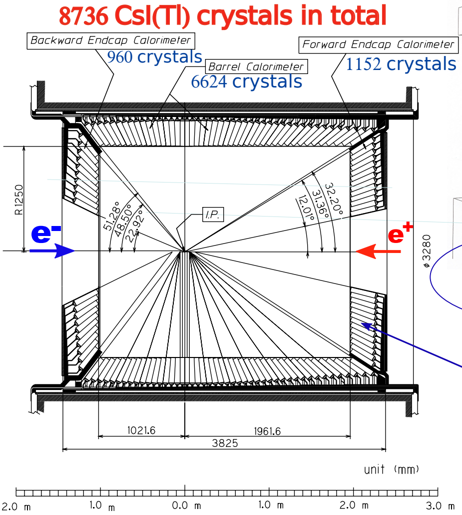
The Belle II detector

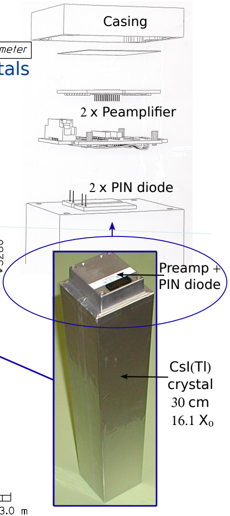


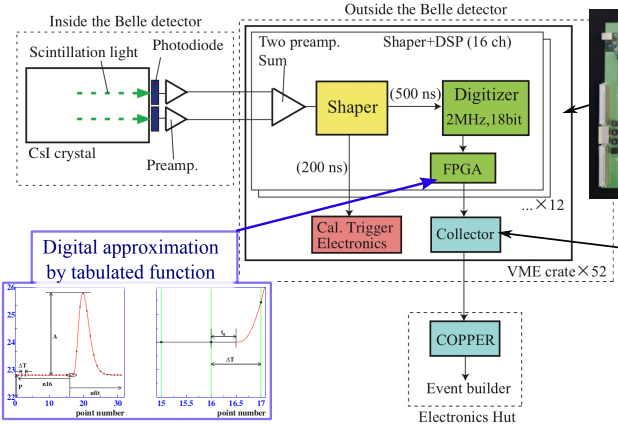
Ecctromagnetic calorimeter of the Belle II detector

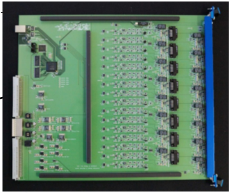
- Construction, crystals, preamps are from Belle
- New readout electronics $\tau = 1\mu s \rightarrow 0.5\mu s$
- Encap preamplifiers are moderinized to withstand high dark current







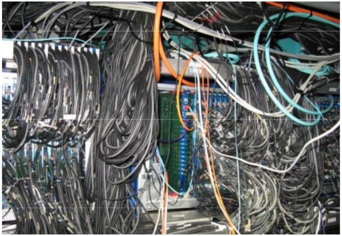




- 576 ShaperDSP modules were produced, tested and installed on detector
- 52 VME crates - 52 EclCollector modules

Status

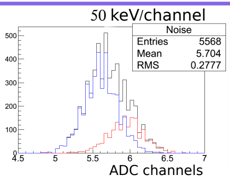
- Encaps were dismounted for the period of modernization
- In January 2017 backward andcap has been mounted
- For barrel and backward encap section all electronics are installed cabling is done
- Installation of forward endcap section is scheduled on September 2017

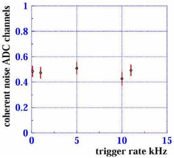


Electronics status

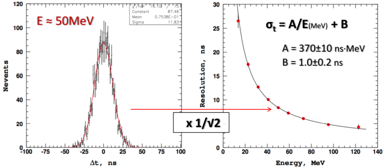
Шумы электроники

Загрузка до 30 кГц

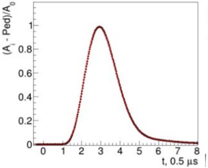


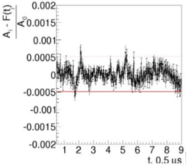


Временное разрешение по космике

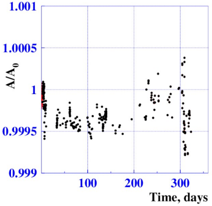


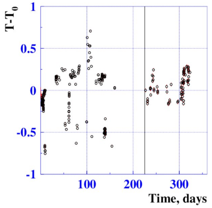
Калибровка формы сигнала по космике



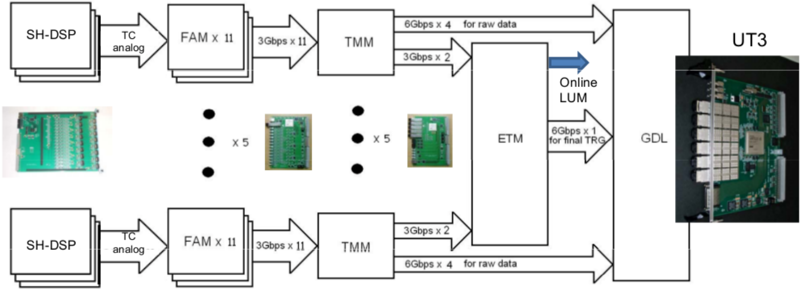


Калибровка с генератором импульсов





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

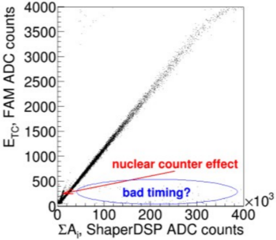
Bridge delay	200~300
Gbit transfer(~ 1100bits)	400

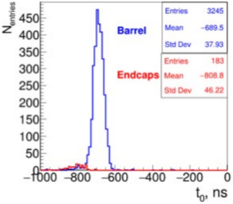
Input alignment	100
Trigger decision	200~300

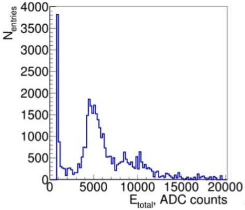
* Total latency = 2600 ~ 3000 ns

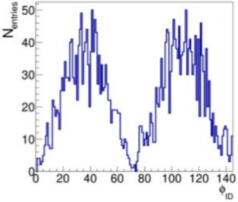
** TMM FPGA = XC6VLX130T-1FF1156C

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

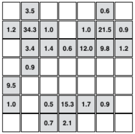




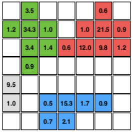




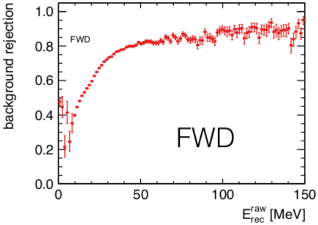
- New procedure for cluster building
- Number of crystals in the cluster depends of its energy
- Clusters with unproper time are rejected

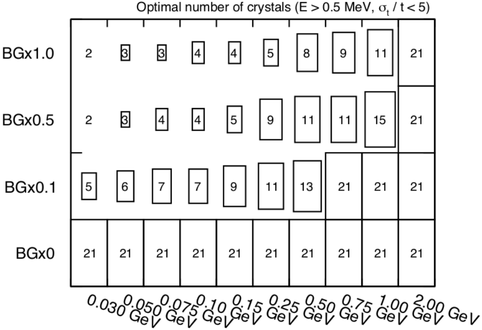


Use only digits with E>0.5MeV.



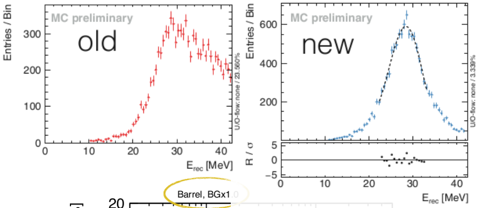
Overlapping CRs are merged.

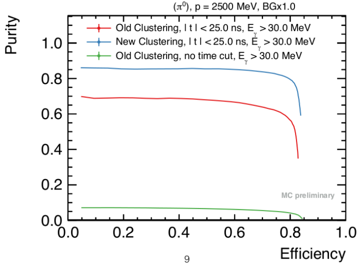


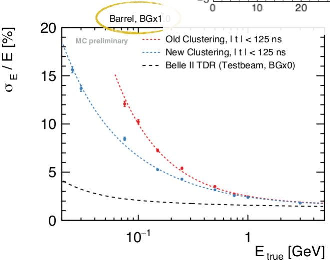


- Significant improvement of the resolution for maximum background level in comparison with old procedure

e.g. 30 MeV







Conclusion

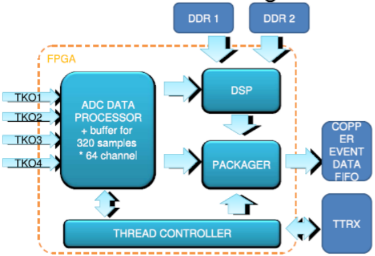
- Calorimeter electronics is installed on detector
- All electronics channels are alive
- DAQ of ECL is able to work at upto 30 kHz trigger rate
- Backward endcap section is mounted. Installation of forward section scheduled on Sep. 2017
- Test cosmic runs of simultaneous ECL-ECLTRG and ECL-CDC data taking were performed
- Calorimeter is regulary calibrated with pulse generator, pulse shape is calibrated with cosmic
- Software developement for data acqusiton, reconstruction, and calibration procedures (cosmic, Bhabha, $\gamma\gamma$ 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**

FPGA overall design

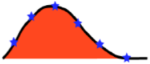


Algorithm details

$$\chi^2(A,p,t_0)=\sum_{i,j}\left(y_i-Af(t_i-t_0)-p\right)S_{ij}^{-1}\left(y_j-Af(t_j-t_0)-p\right)\to \min$$

$$S_{ij}=\overline{\left(y_i-\overline{y}\right)\left(y_j-\overline{y}\right)}$$

$f(t)$ — counter response



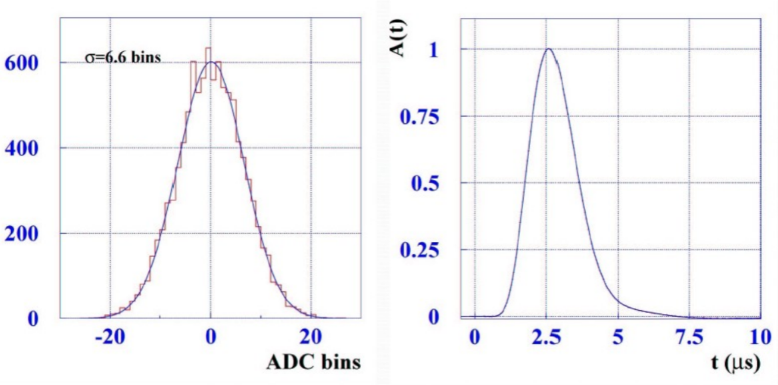
$$Af\left(t_i-t_1-\Delta t\right)=Af\left(t_i-t_1\right)-A\Delta t f'\left(t_i-t_1\right)=Af\left(t_i-t_1\right)+Bf'\left(t_i-t_1\right)$$

where t_1 — initial time (trigger time)

$$\begin{cases}\sum_{i,j} f_i S_{ij}^{-1}\left(y_j-Af_j-Bf'_j-p\right)=0\\ \sum_{i,j} f'_i S_{ij}^{-1}\left(y_j-Af_j-Bf'_j-p\right)=0\\ \sum_{i,j} S_{ij}^{-1}\left(y_j-Af_j-Bf'_j-p\right)=0\end{cases}\Rightarrow\quad \begin{aligned}A&=\sum_i \alpha_i y_i\\ B&=\sum_i \beta_i y_i \Rightarrow \Delta t=-B/A\\ p&=\sum_i \gamma_i y_i\end{aligned}$$

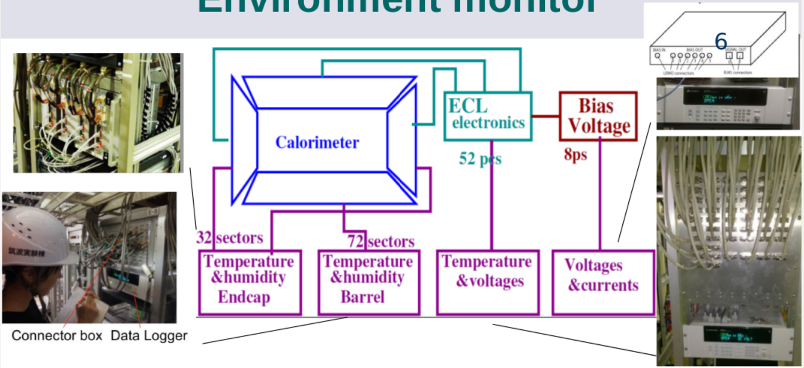
- **For some fraction of data both input and output informations are sent to DAQ for test**

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.

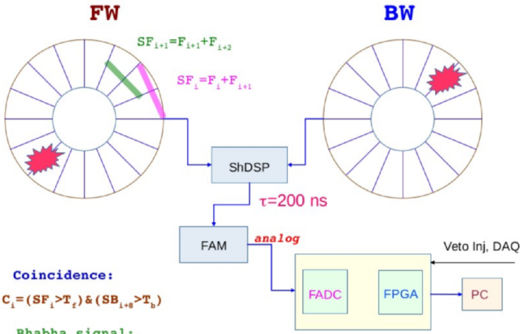
-Temperature&humidity monitor for endcaps: is ready and running for backward endcap

-Temperature&voltages monitor for VME electronics is working.

-Isolation amplifiers for current measurement have been ordered and will be deliverd 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

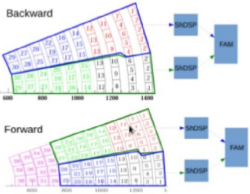


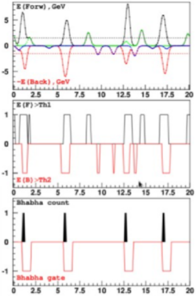
Coincidence:

$C_i=(SF_i>T_f)\&(SB_{i+8}>T_b)$

Bhabha signal:

$BH_i=C_i\&G_f\&G_b$, $G_f,G_b=1$, if only 3 serial sectors are hitted





Characteristics

- 16 inputs for 32 endcap sector signals
- Four 12-bit 8-channel AD9637 ADC with 40 MHz sampling rate
- Spartan-6 FPGA
- FTSW, JTAG, VETO inputs
- Ethernet interface for PC

The module has been produced
Hardware test has been done
Firmware, software development and emulation of the algorithm are going on

Pure CsI

crystal	ρ, g/cm^3	X_0, cm	λ_{em}, nm	n	N_{ph}/MeV	τ, ns
CsI(Tl)	4.51	1.86	550	1.8	52000	1000
CsI	4.51	1.86	305/400	2	5000	30/1000
BaF_2	4.89	2.03	220/310	1.56	2500/6500	0.6/620
CeF_3	6.16	1.65	310	1.62	600	3
$PbWO_4$	8.28	0.89	430	2.2	25	10
$LuAlO_3$(Ce)	8.34	1.08	365	1.94	20500	18
$Lu_3Al_5O_{12}$(Ce)	7.13	1.37	510	1.8	5600	60
Lu_2SiO_5(Ce)	7.41	1.2	420	1.82	26000	12/40

- **Pure CsI is a good candidate for fast scintillator in endcap**
  It has relatively high lightoutput, 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%**