Electromagnetic calorimeter.

Open meeting for proto-collaboration, March 20, 2008

A.Kuzmin

Outline:

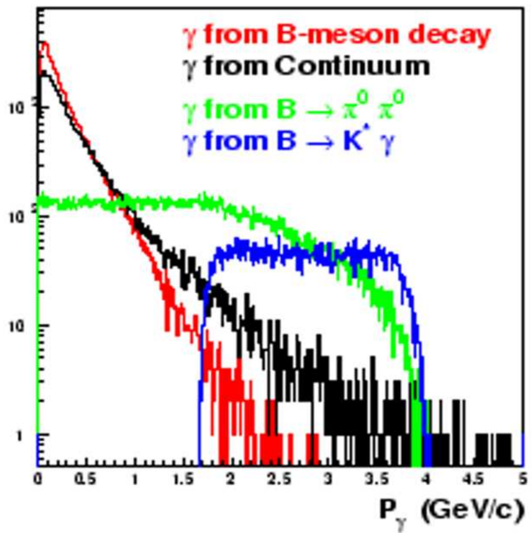
- Calorimeter tasks
- Belle ECL
- Upgrade scheme
- Barrel upgrade
- Trigger upgrade
- Endcap upgrade to pure CsI
- Summary

Calorimeter tasks

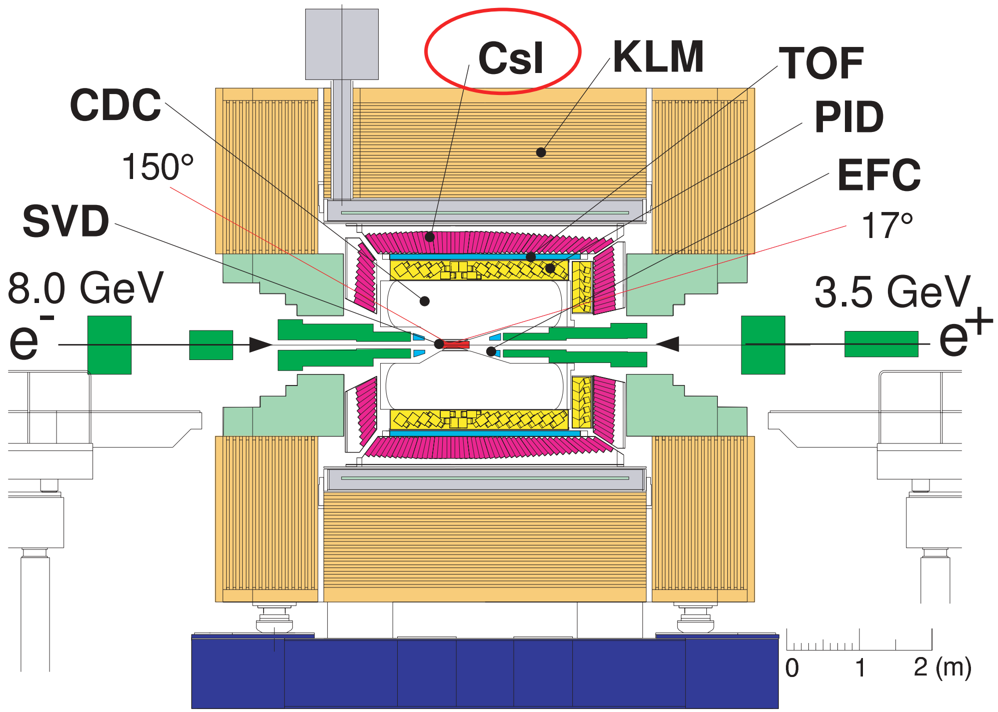
- To detect photons and measure their energy and angles
- e/hadron-separation
- K_L identification (together with KLM)
- Neutral trigger
- Luminosity measurement

Photons of what energy?

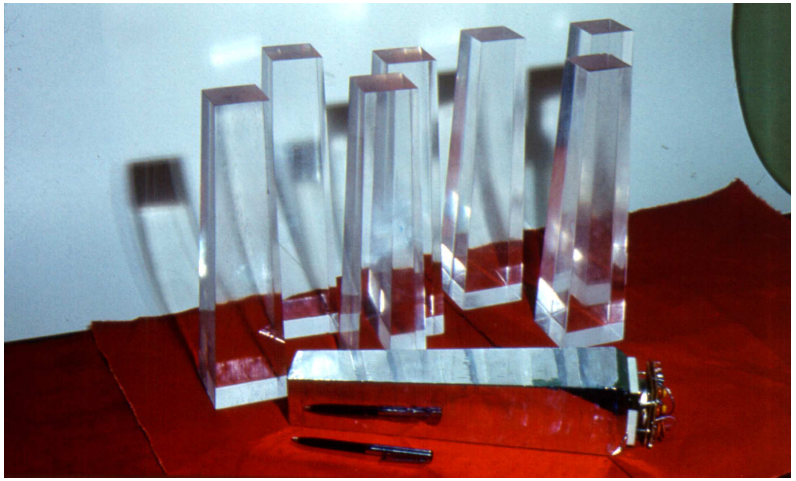
- Radiative transitions of mesons: $D^* \to D\gamma,\ B^* \to B\gamma,\ \chi_c \to J/\psi\gamma,\ \phi \to \eta'\gamma$ ...(50 – 500 MeV)
- π^0 decays (10 MeV– 3 GeV)
- QED: $ee \to ee\gamma,\ ee \to \gamma\gamma(1 - 9$ GeV)



Belle ECL

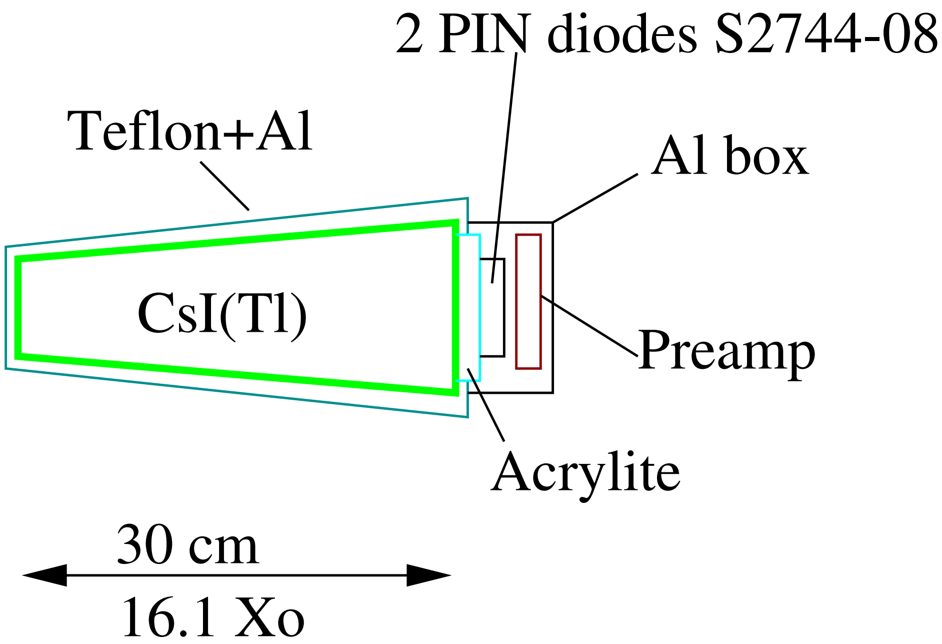


- Calorimeter based on CsI(Tl) scintillating crystals



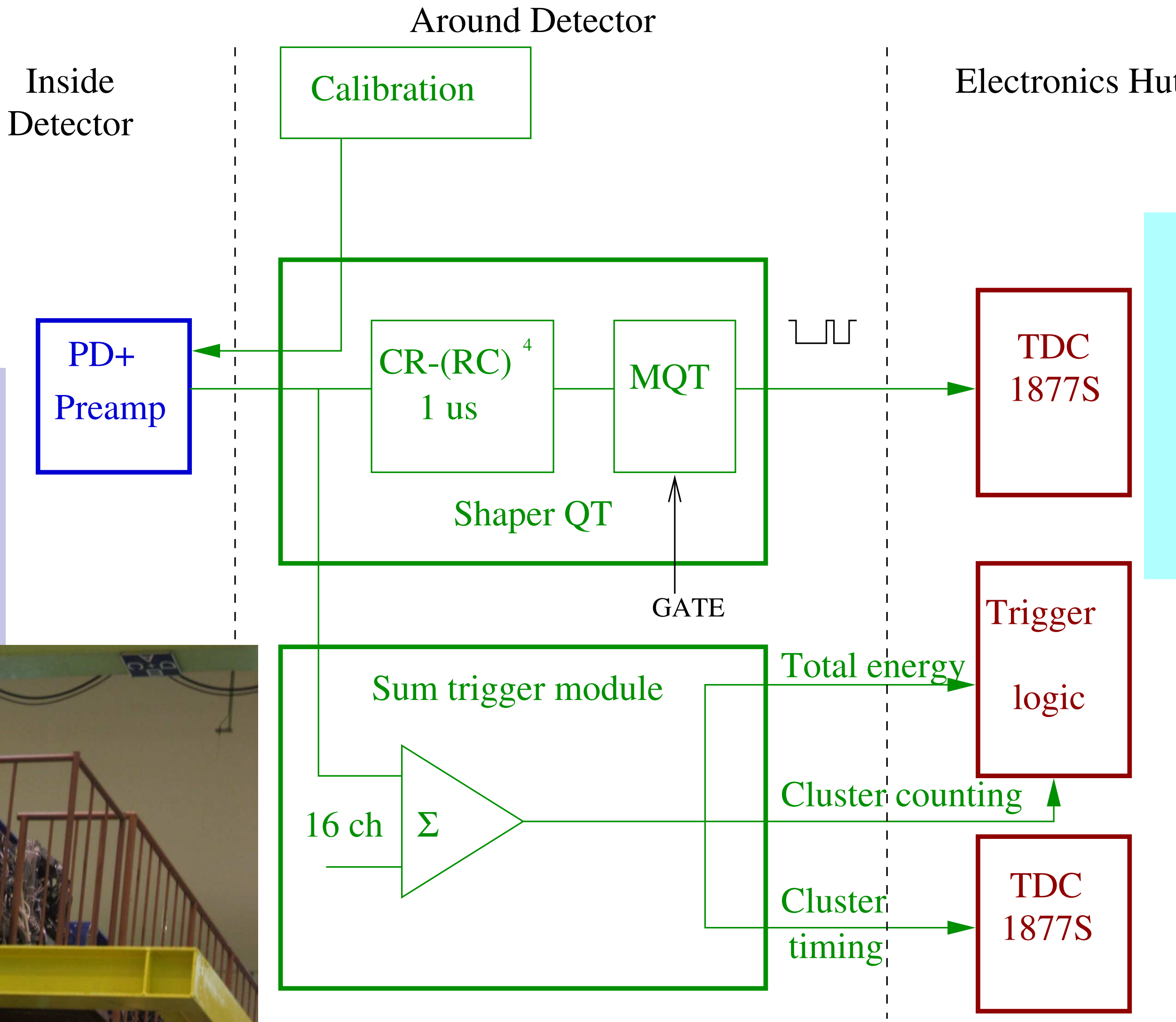
- Thickness – 16.1 X_0(30 cm)
- Calorimeter is inside magnetic coil
- CDC+ACC is about 0.3 X_0
- 8736 counters (40 tons of CsI(Tl))

ECL counter



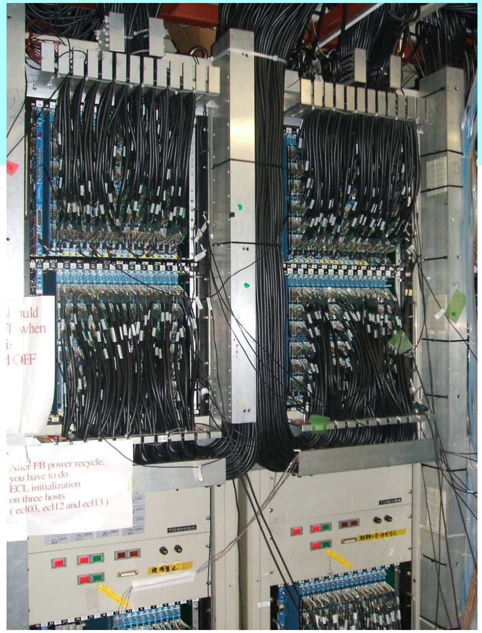
- Crystals 300x(50-80)x(50-80) mm
- Wrapping 200μm teflon+50 μm Al mylar
- Readout 2 10x20 mm PIN diodes
- 2 charge sensitive preamplifiers
- Shaper CR-(RC)^4, τ=1μs
- Lightoutput 5000 p.e./MeV
- Electronic noise 1000$e \approx$ 200 keV

Calorimeter electronics



- 52 TKO crates
- 576 Shaper-QT
- 288 STM

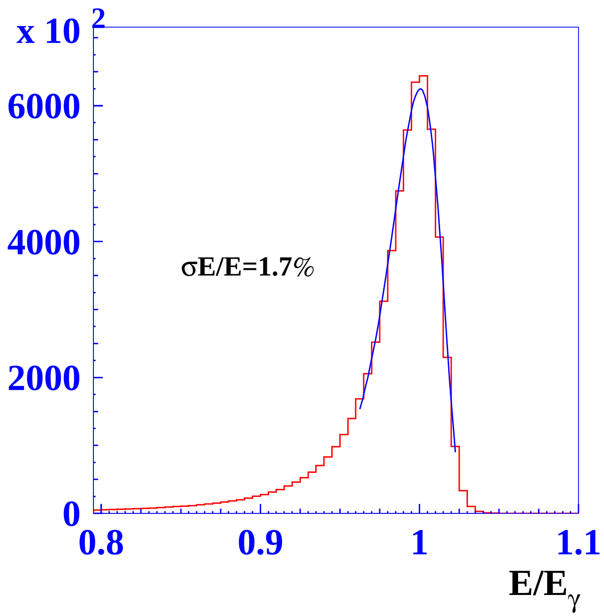
- 6 FASTBUS crates
- 108 LeCroy TDC(96)
- Trigger VME crate

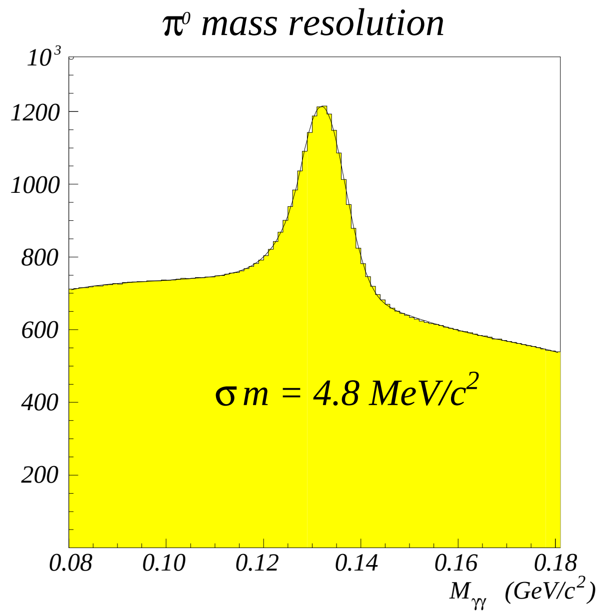


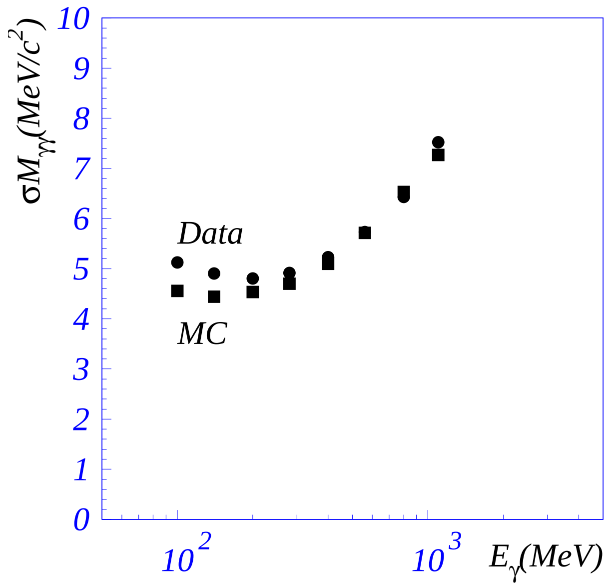
Calorimeter performance

- **One of the best calorimeter;**
- **Energy noise equivalent 200 keV;**
- **Good energy and angle resolution for photons:**

$e + e^- \to \gamma\gamma$



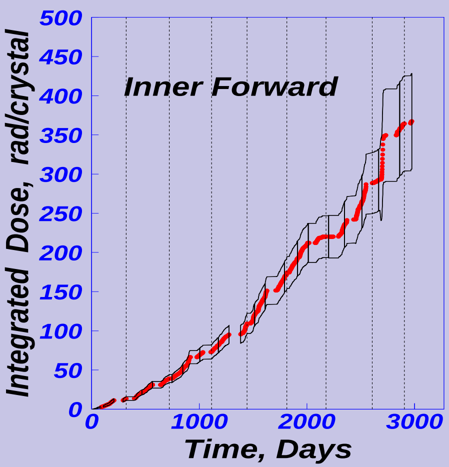


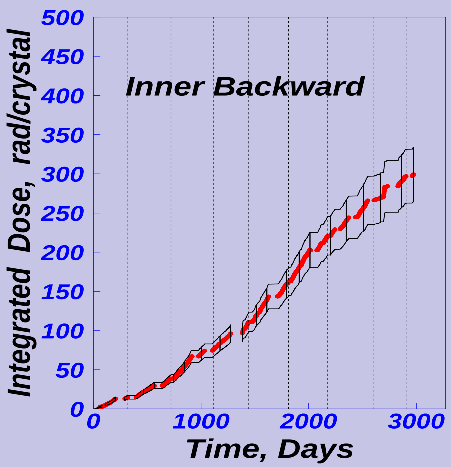


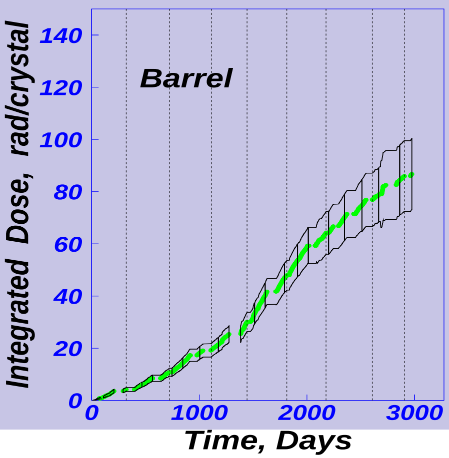
Problems with the present calorimeter

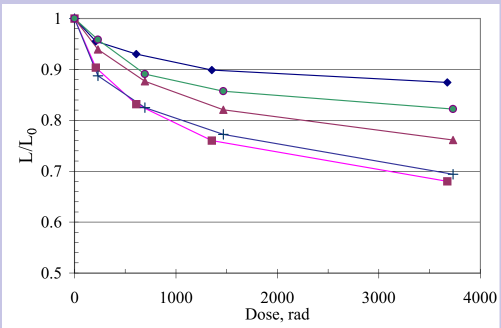
Now $L \approx 10^{34} s^{-1} cm^{-2}$, $I \approx 1.5\ A$ => Upgraded $L > 10^{35} s^{-1} cm^{-2}$, $I \approx 10\ A$.

Radiation damages of the crystals



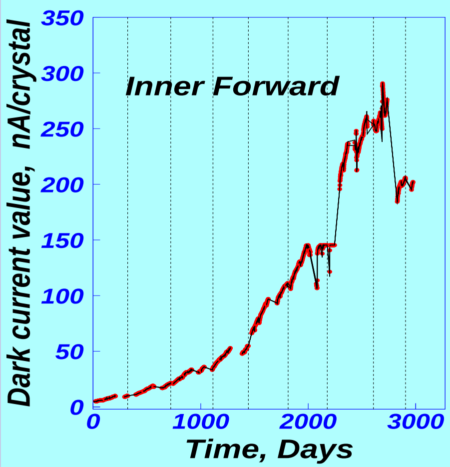


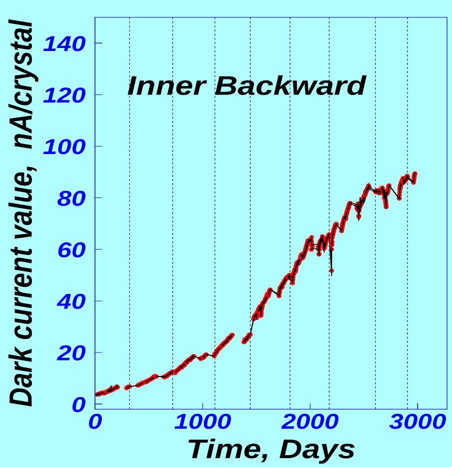


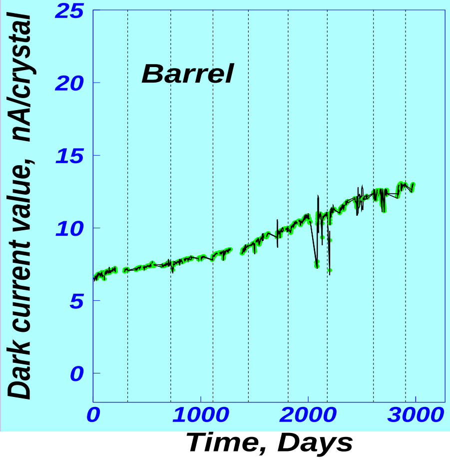


No big problems

Radiation damages of PIN photodiodes







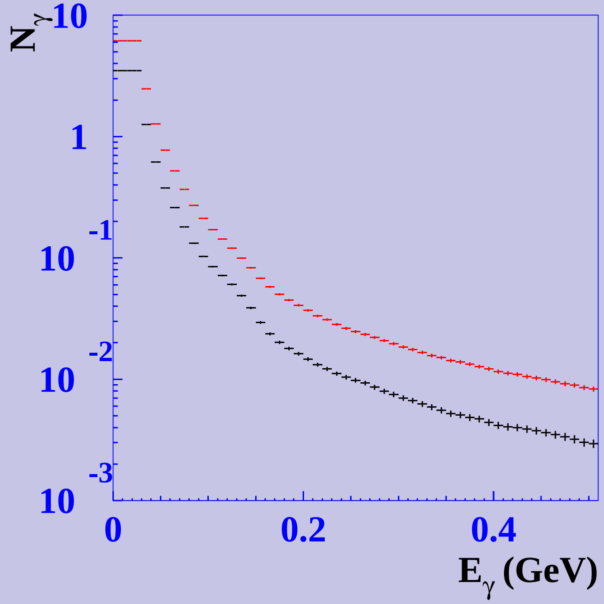
Small increase of the dark current in barrel

Essential increase of the dark current in endcaps

Caused by neutrons flux

Calorimeter performance degradation

Fake clusters

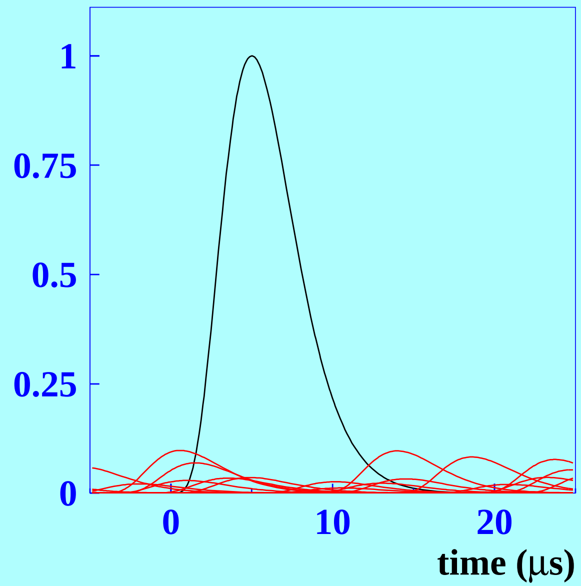


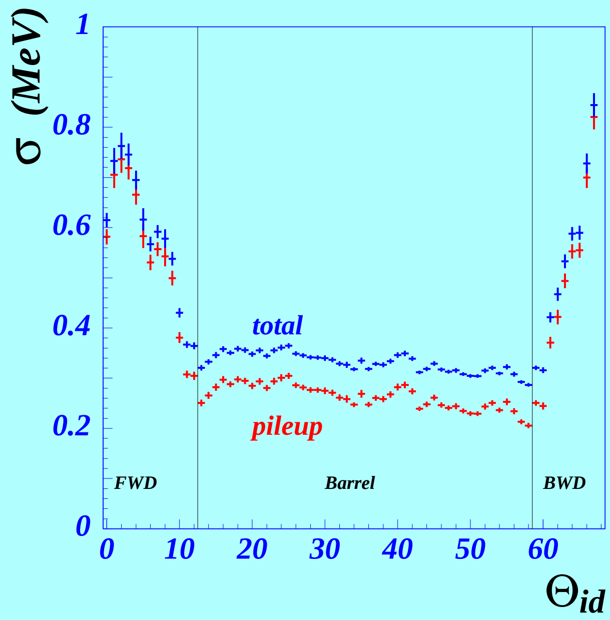
(E>20 MeV) 6 fake clusters,
3 in barrel 3 in endcaps

$\sim background$

Pileup noise

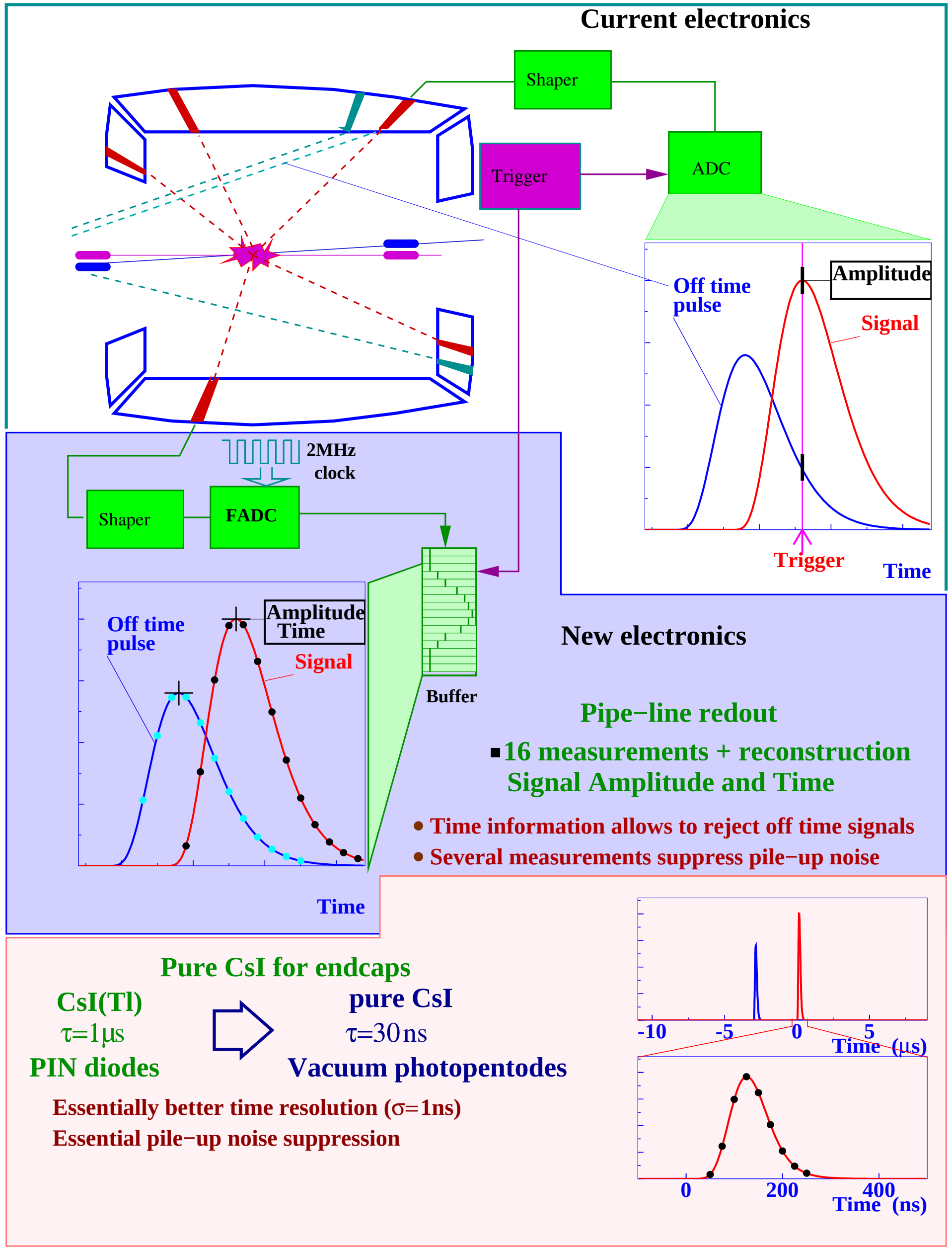
$$\sigma = \overline{E_\gamma}\sqrt{\nu\tau_{eff}} \sim \sqrt{IP}$$





$$\sim \sqrt{background}$$

One of the way to solve problems of the fake clusters and pileup noise is to reduce decay time of the scintillator and electronics shaping time.



- Modify electronics for the barrel.
- Pipe-line readout with waveform analysis:
- Replace the CsI(Tl) by the pure CsI crystals in endcaps.
- 16 points within the signal are fitted by the signal function $F(t)$:

$$F(t) = A\ f(t - t_0)$$

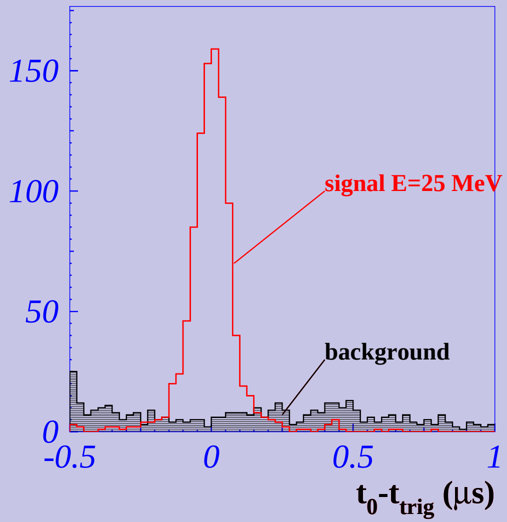
A - amplitude of the signal and

t_0 – time of the signal,

$$\chi^2 = \sum (y_i - A\ f(t_i - t_0)) S_{ij}^{-1} (y_j - A\ f(t_j - t_0))$$

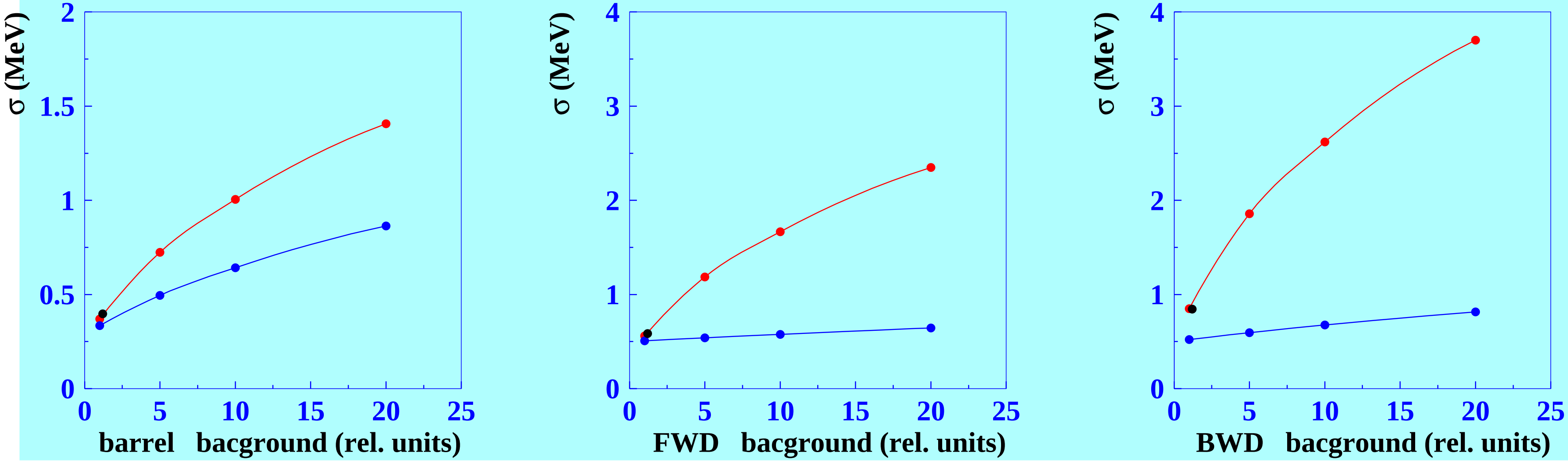
- Both amplitude and time information is reconstructed:

Expected improvement

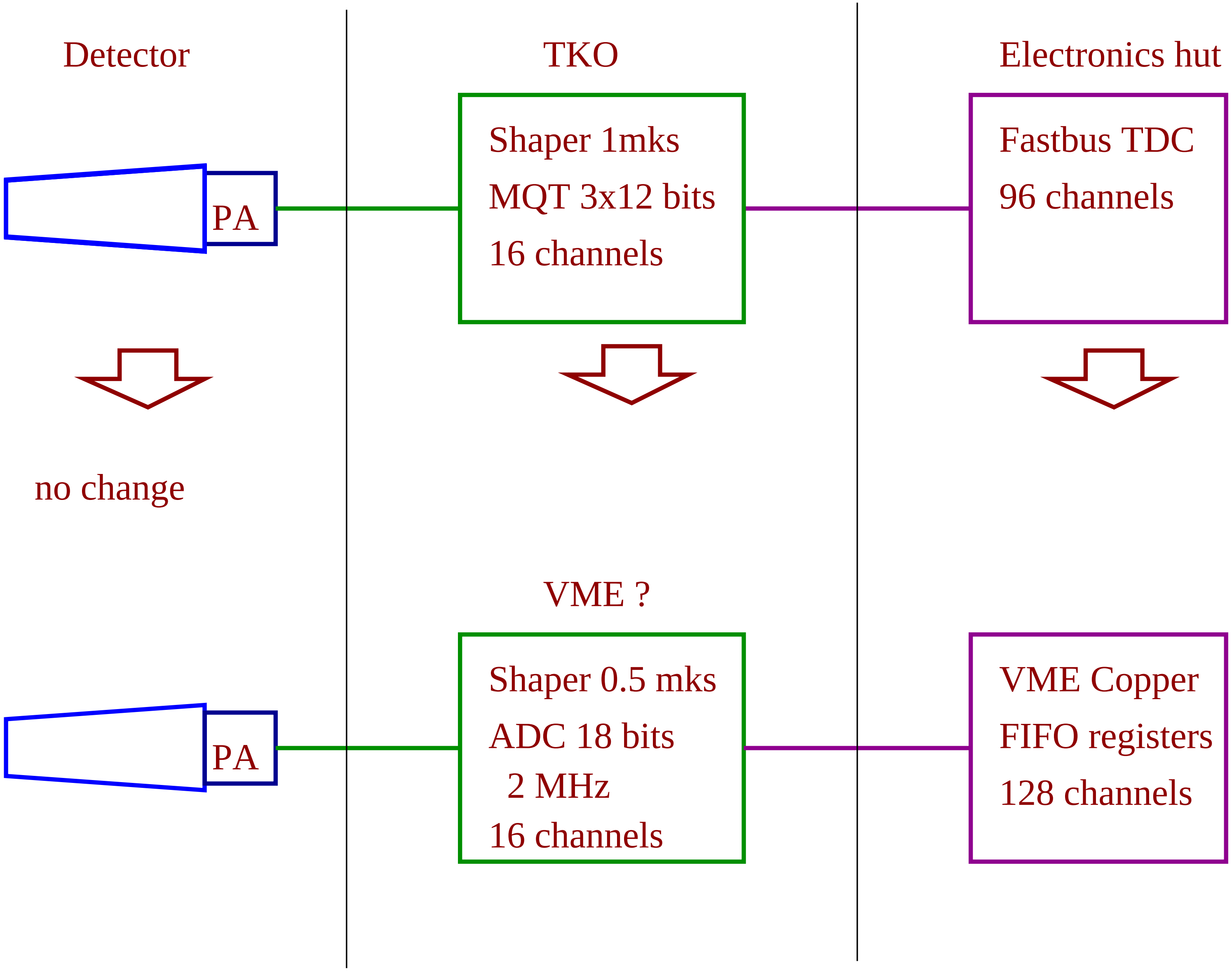


- Time information allows to suppress the fake clusters 7 times for the barrel by rejecting wrong time clusters.
- For endcaps the suppression factor is $7 \times 30 \approx 200$ due to shorter decay time of the pure CsI

- The pileup noise will be reduced factor ~ 1.5 for barrel and factor 5 for endcaps:

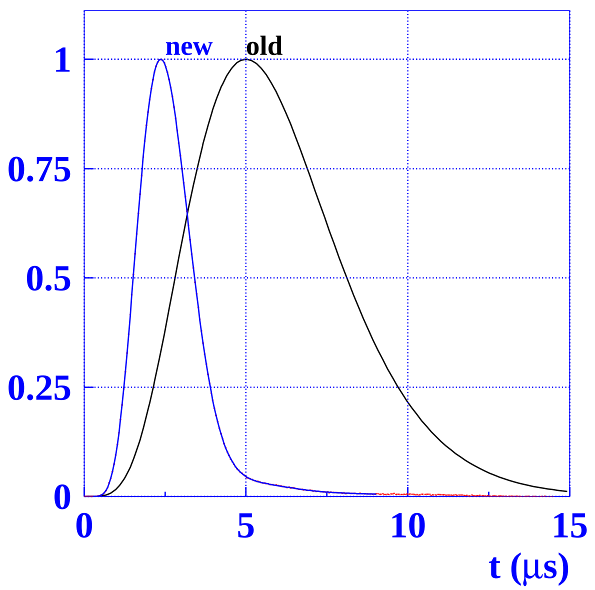


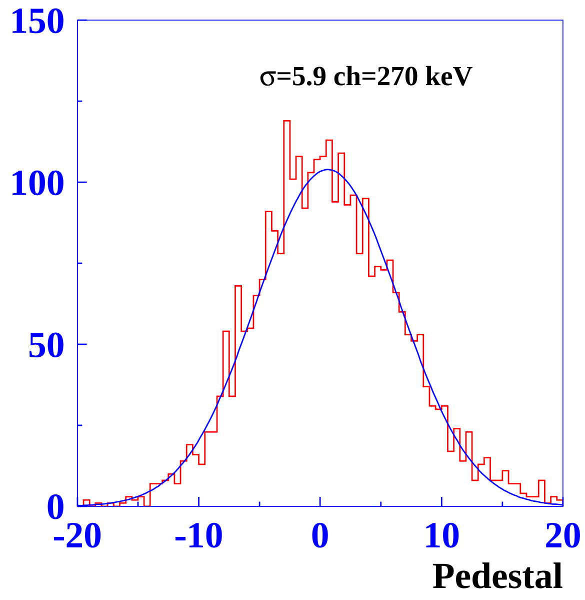
Electronics modification(barrel)

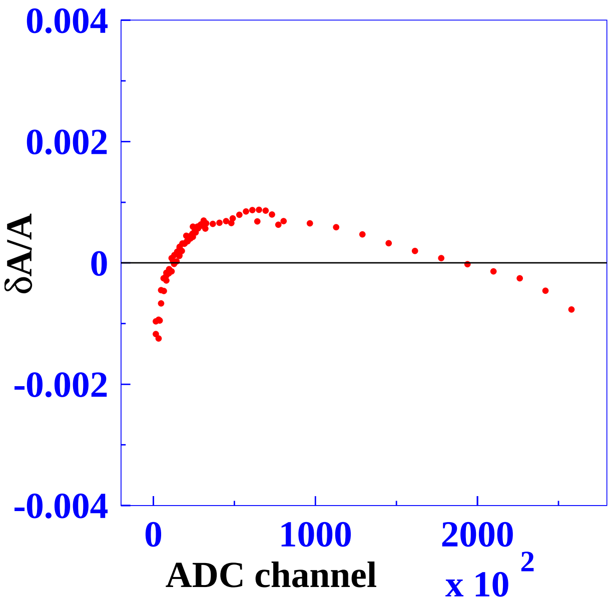


Shaper status

- Two TKO modules (containing 18-bits ADC) were produced in HOSHIN on April 2007.
- They have been tested in May-September. It has shown expected parameters.
- Eight TKO modules with small corrections have been produced beginning of October and are being tested now.

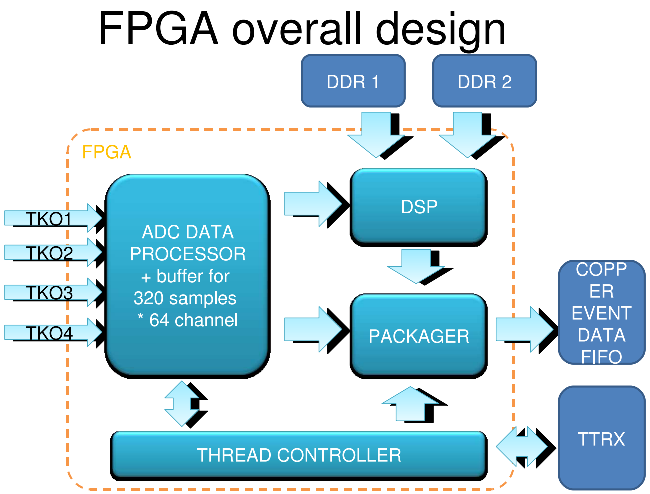


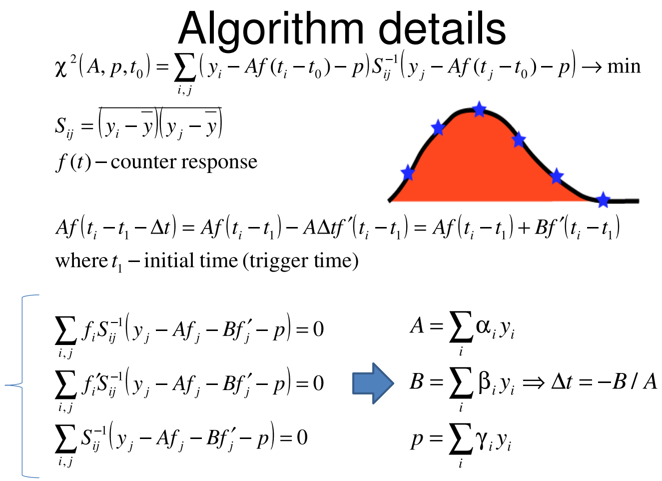


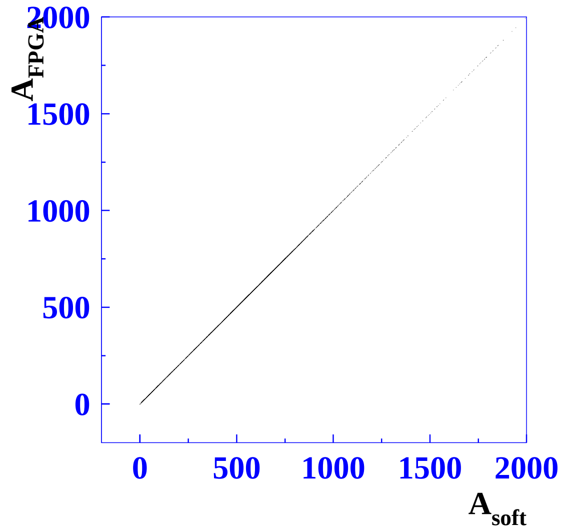


FINESSE status

- HOSHIN produced 16-channel FINNESE in March 2006.
- Tandem 64-channel FINNESE was developed and two modules has been produced in HOSHIN.
- The algorithm of energy and time reconstruction was implemented.

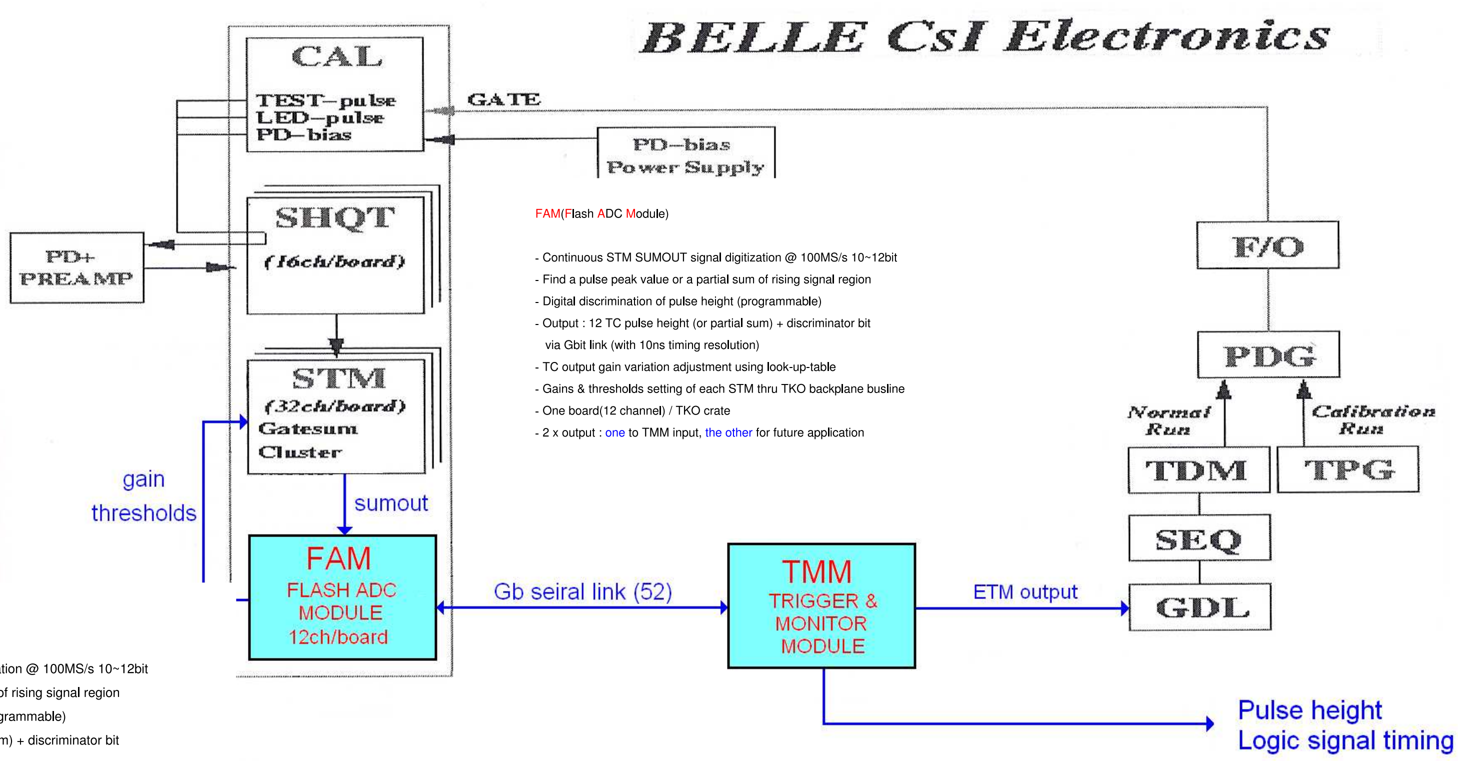






- The algorithm gives the same results as software calculations

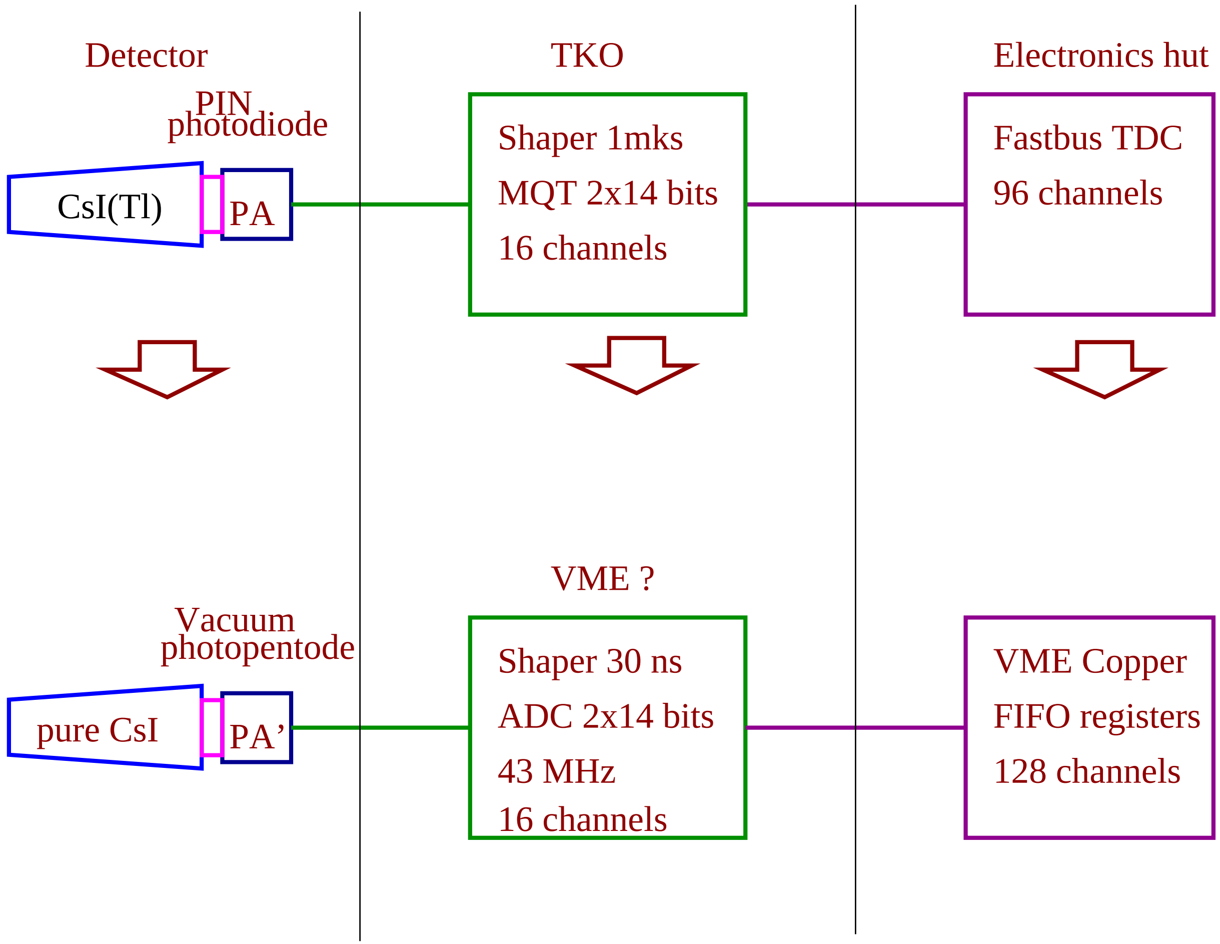
New implementation into current ECL trigger system



FAM(Flash ADC Module)

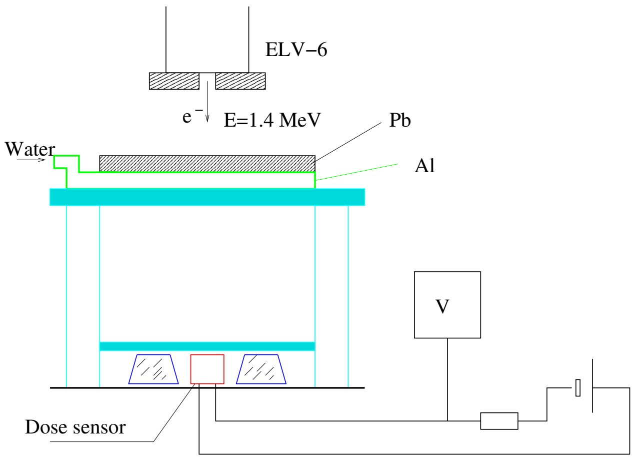
- Continuous STM SUMOUT signal digitization @ 100MS/s 10~12bit
- Find a pulse peak value or a partial sum of rising signal region
- Digital discrimination of pulse height (programmable)
- Output : 12 TC pulse height (or partial sum) + discriminator bit
  via Gbit link (with 10ns timing resolution)
- TC output gain variation adjustment using look-up-table
- Gains & thresholds setting of each STM thru TKO backplane busline
- One board(12 channel) / TKO crate
- 2 x output : one to TMM input, the other for future application

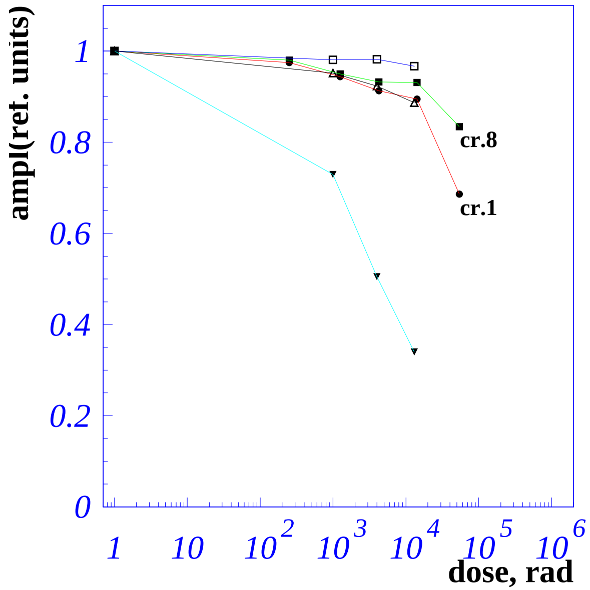
Electronics modification(endcap)

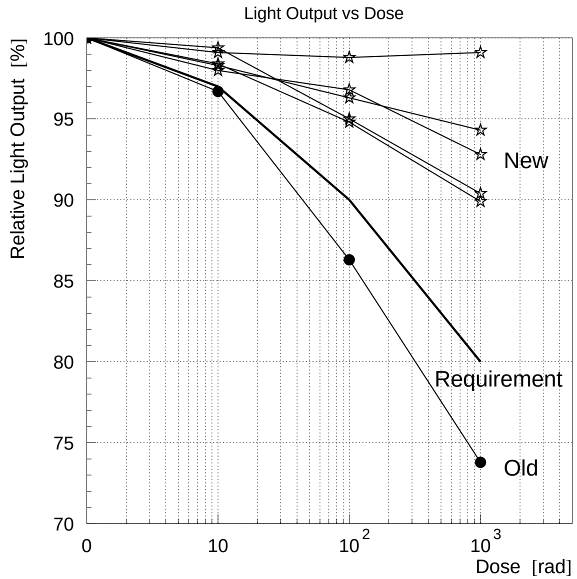


Radiatio hardness test with photons.

- Radiation hardness of 4 pure CsI crystals(Kharkov) and one counter (pure CsI crystal+ photopentode) were tested with γ-quantum irradiation.
- For 15 krad dose the degradation of the lightoutput for 3 crystals and counter was less than 10%, but one counter lightoutput reduction was about 60%.





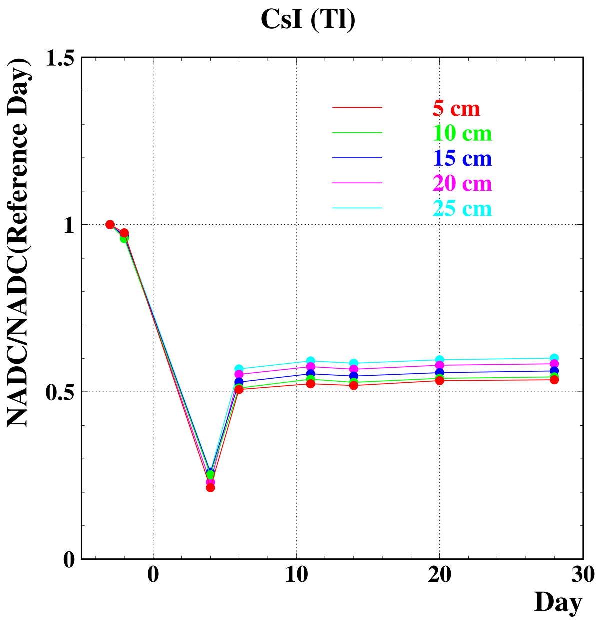


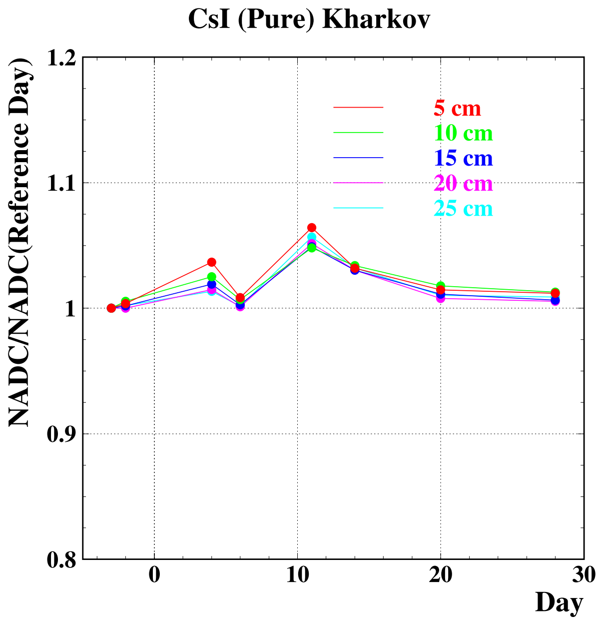
Bremsstrahlung γ ($E_\gamma = 0 - 1400\ keV$)

Dose 0.250, 1 , 4 , 10 , 30 krad

Radiatio hardness test with neutrons.

- Radiation hardness of CsI(Tl) and 3 pure CsI crystals(Kharkov, Shanghai, Sanit Gobain) were tested with neutron $n = 10^{12} cm^{-}2$.





- Ligtoutput of CsI(Tl) was decreased about two times.
- All 3 pure CsI crystalls showed change of lightoutput less than 5%.

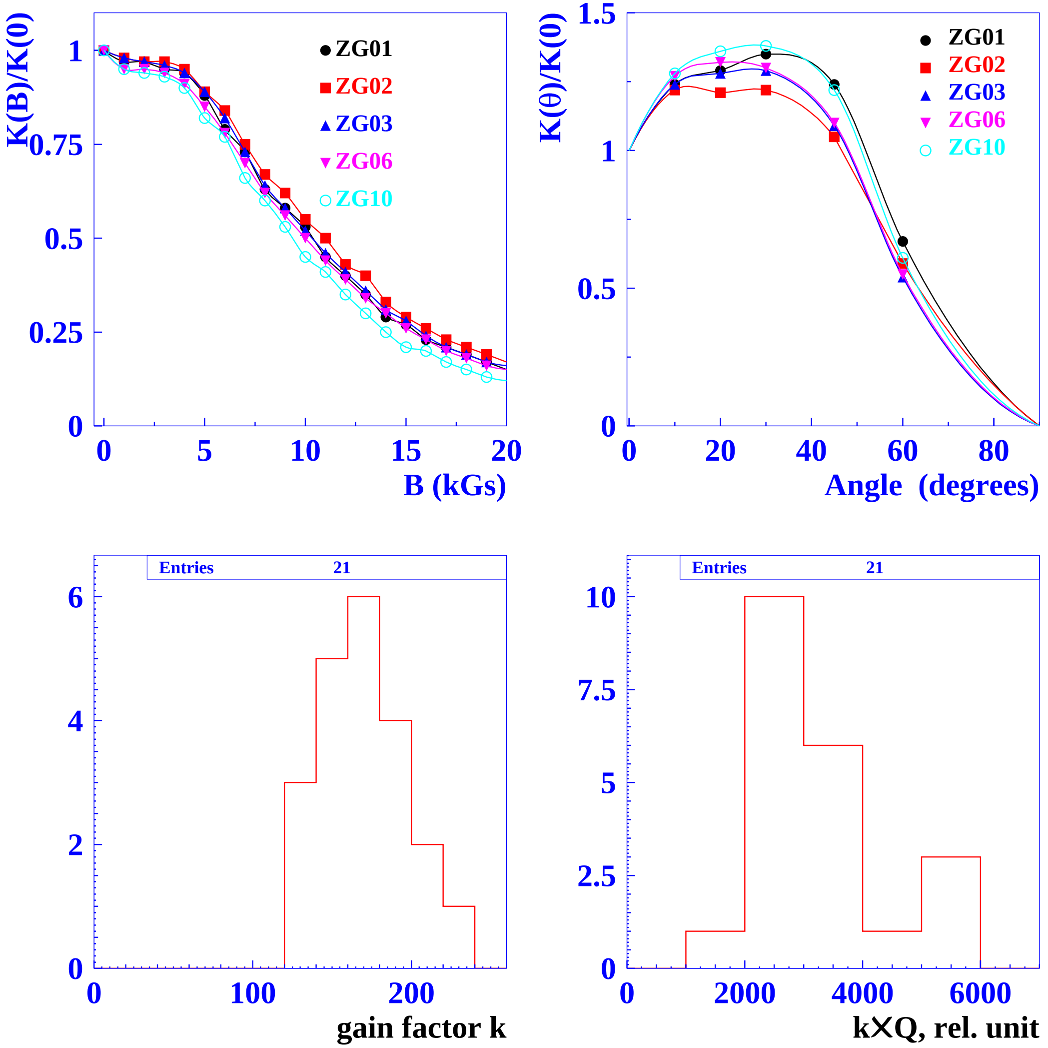
Photodetector

Hamamatsu developed the 2' UV sensitive photopentods(PP)

$C \approx 10\ pF$.

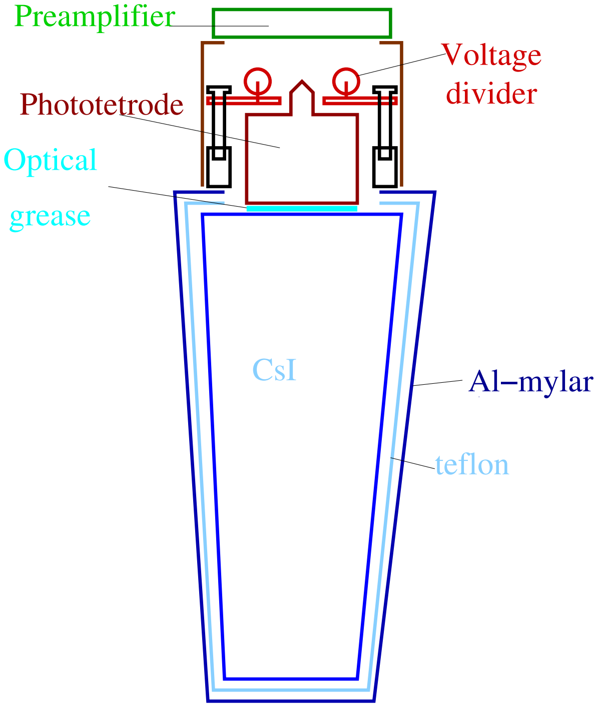
PP gain factor 120-240.

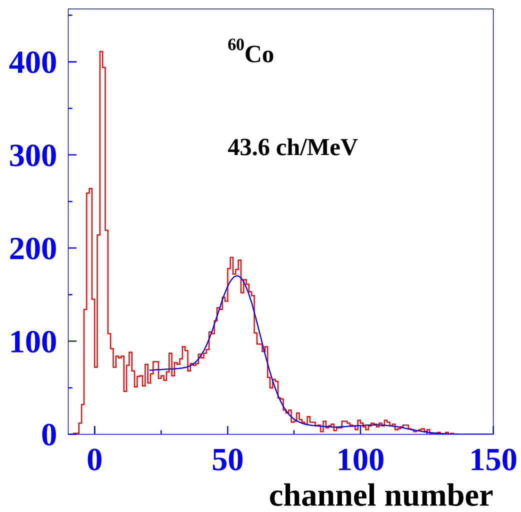
(we need > 30 in mag.field)

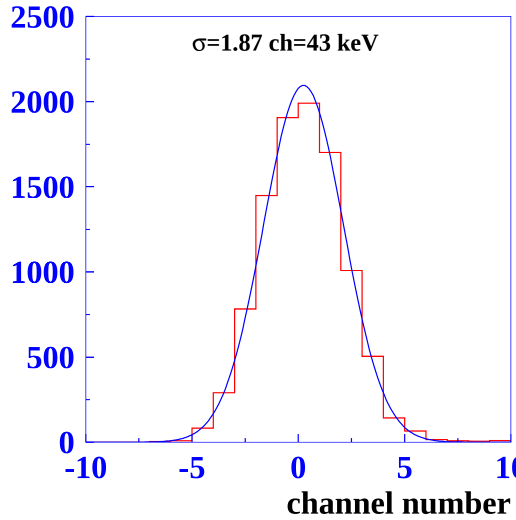


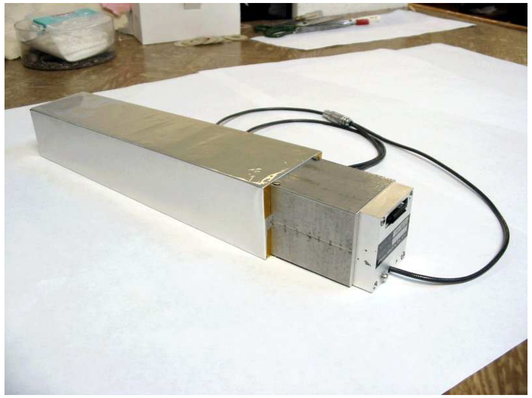
- The gain factor drops down ∼3.5 times for B=15 kGs
- About 20-30 % improvement for angle 20-45°

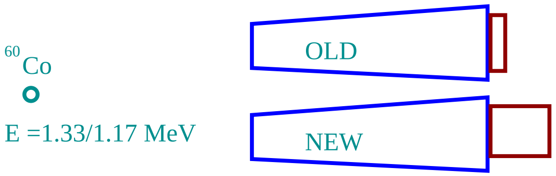
Counters design



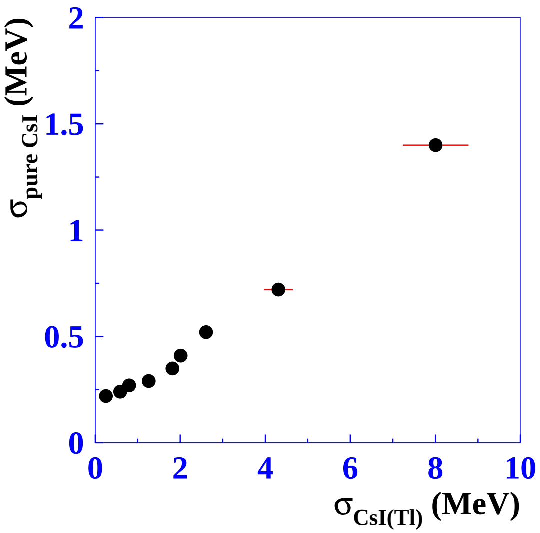




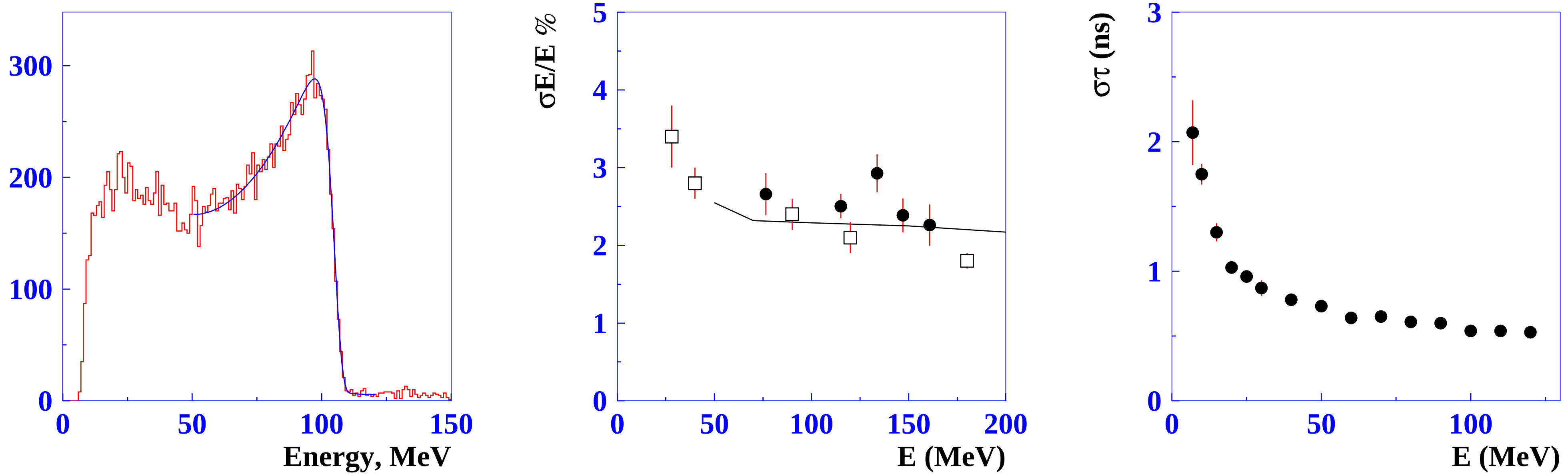




- Pile-up noise imitated by $^{60}Co(E_\gamma = 1.17/1.33\ MeV)$



Energy and time resolution results.



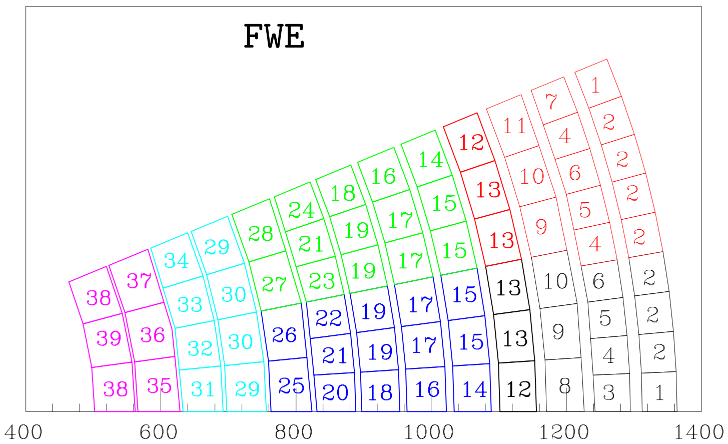
Trigger with TS Trigger with CsI

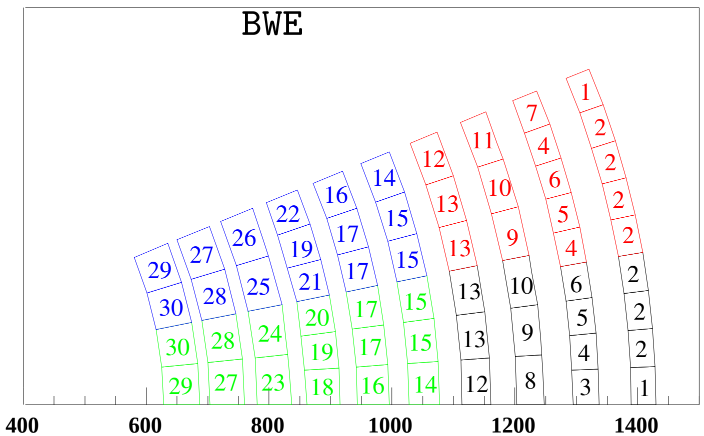
The distributions are fitted by convolution of the Compton spectrum and logarithmic-Gaussian.

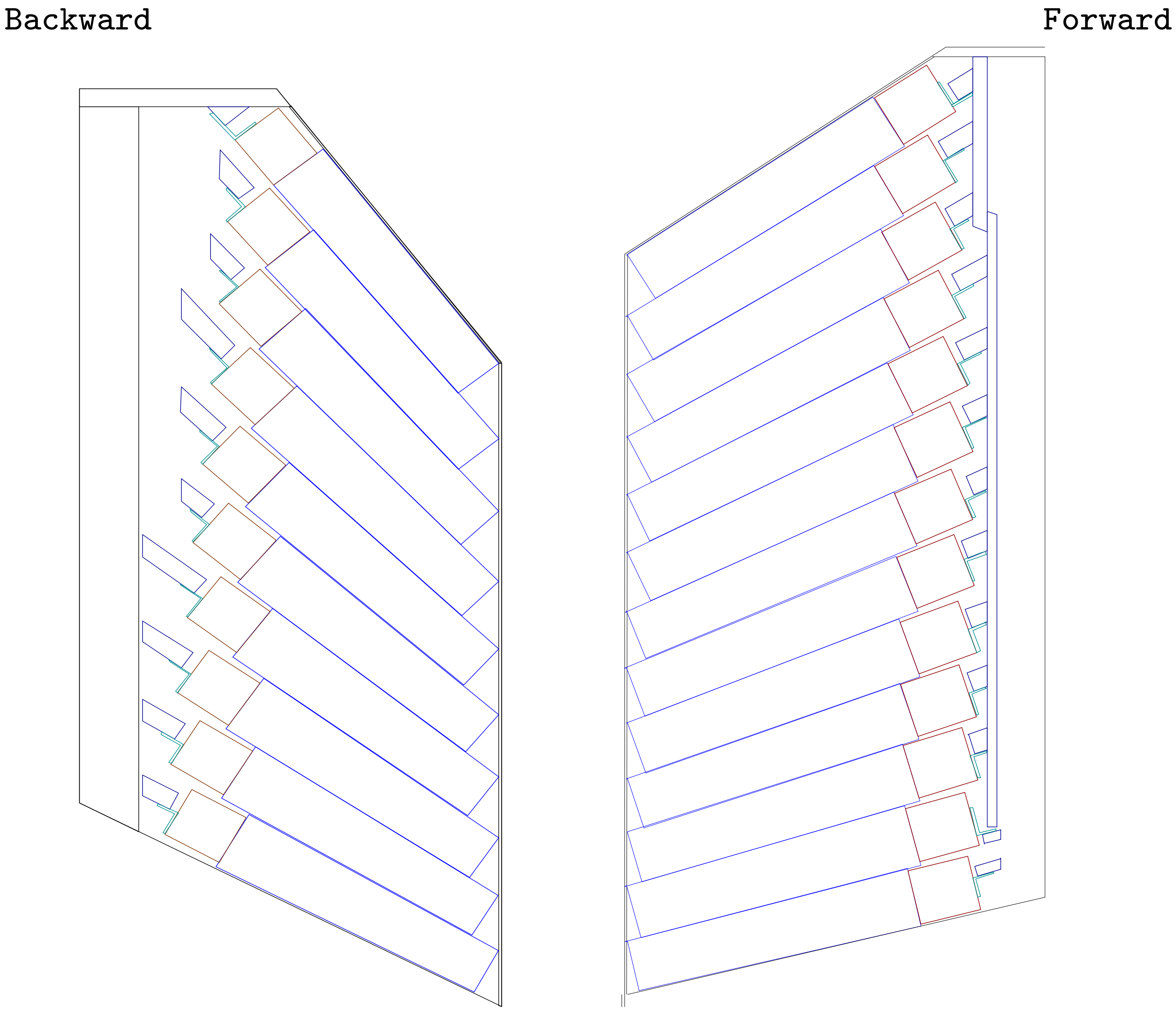
$$f(E) = N\{(E - \frac{E_C}{2})^2 + \frac{E_C^2}{4}\};$$

-round points pure CsI
-solid line MC
-rectangles CsI(Tl) beam test

$$\phi(E) = N \exp(-\frac{1}{2\sigma_0^2} \ln^2(1 - \frac{E - E_p}{\sigma_E}\eta) - \frac{\sigma_0^2}{2})$$


FWE
400
600
800
1000
1200
1400


BWE
400
600
800
1000
1200
1400


Backward
Forward

General statistics

options	3/5FWD	1/2BWD	1/2 Full	FWE	BBWE	Full
Number of crystals	672	480	1 152	1 152	960	2 112
Number geom.types	26	17	43	39	30	69
Weight of CsI, 10^3kg	3.5	2.4	5.9	5.8	4.7	10.5
Price, k$	2 600	1 900	4 500	4 500	3 700	8 200
Number of PP	672	480	1 152	1 152	960	2 112
Price, k$	400	300	700	700	600	1 300
Preamplifier+box	672	480	1 152	1 152	960	2 112
Price, k$	70	50	120	110	100	210
Number of Shaper boards	48+32	32+32	80+64	80	64	144
Number of COPPER boards	6+4	4+4	10+8	10	8	18
Number of HV	16	16	32	16	16	32
Price, k$	490	410	900	490	410	900
Mechanical modification						
Price, k$	200	200	400	200	200	400
Total price, k$	3 750	2 850	6 600	6 000	5 000	11 000

Preliminary Time table

		2008		2009				2010				2011				2012	
		III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II
Crystal	preperation	x	x	x	x												
	production					x	x	x	x	x	x	x	x				
PP	preperation	x	x														
	production	x	x	x	x	x	x	x	x								
	test		x	x	x	x	x	x	x	x							
PA	design	x	x	x	x												
	production					x	x										
Counter box	design	x	x	x	x												
	production					x	x										
Counter	production							x	x	x	x	x	x	x			
	test							x	x	x	x	x	x	x	x		
Mechanical structure	design				x	x											
	production						x	x									
Assembling	mechanical															x	
	test															x	x
installation into Belle																	x
Shaper-digitizer(slow)	design	x	x	x	x	x	x										
	production						x	x					x				
	test						x	x		x	x			x	x		
Shaper-digitizer(fast)	design	x	x	x	x	x	x										
	production						x				x				x		
test							x	x			x	x			x	x	
System test																x	x

Summary

- **Calorimeter is one of the main part of detector which serves many important functions of particle detection and identification.**
- **The Belle calorimeter have been showing good performance and relibility.**
- **To keep good performance of the calorimeter for high background conditions we definetly need to upgrade the electronics for the barrel and to replace both crystals and electronics in the endcaps .**
- **The work for barrel electronics upgrade are going on. The working version of the electronics has been developed. We need to perform test of the elctronics integrated to DAQ of the Belle detector.**
- **The endcap calorimeter based pure CsI counters with modified electronics provides essential pile-up noise suppression.**
- **There are many task to solve to provide fast and efficient work towards new calorimeter construction.**