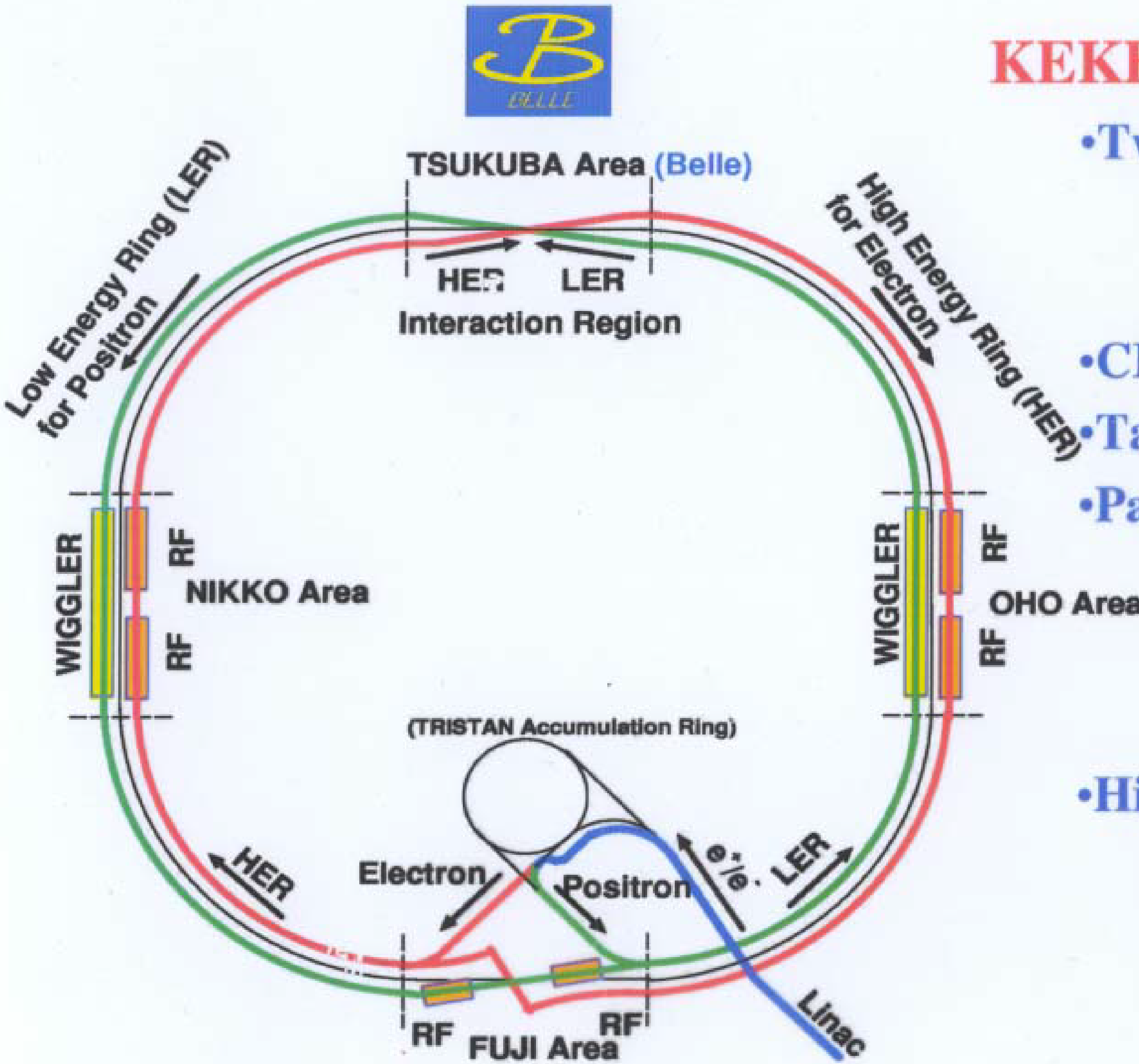
Status and performance of the BELLE electromagnetic calorimeter

BELLE collaboration
Presented by A.Kuzmin(BINP)



KEKB : Asymmetric e^+e^- collider

- Two separates rings
  - e^+ (LER) : 3.5 GeV
  - e^- (HER) : 8.0 GeV
- CM energy : 10.580 GeV at Υ(4S)
- Target luminosity : $10^{34}\ cm^{-2}s^{-1}$
- Parameters
  - 3016 m circumference
  - ±11 mrad crossing angle
  - 5120 RF buckets
- History
  - First collision : Jan. 1999
  - Physics run : since June 1999

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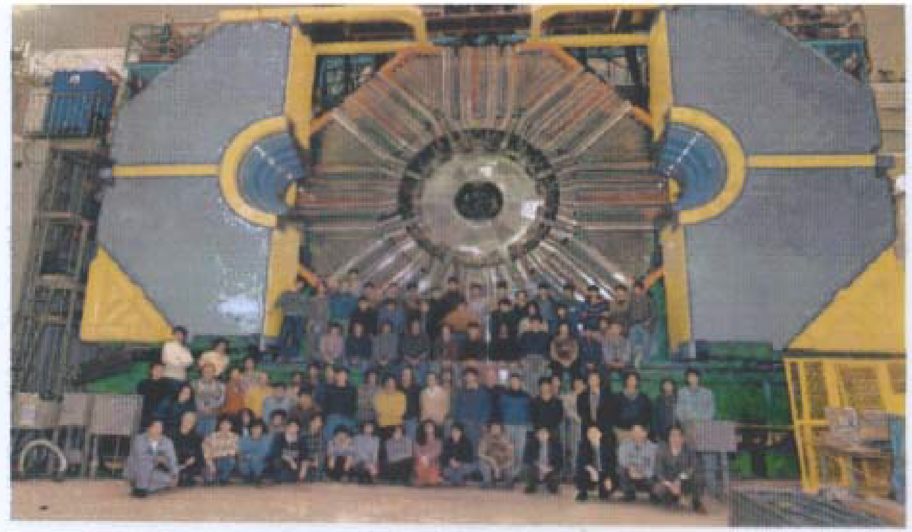
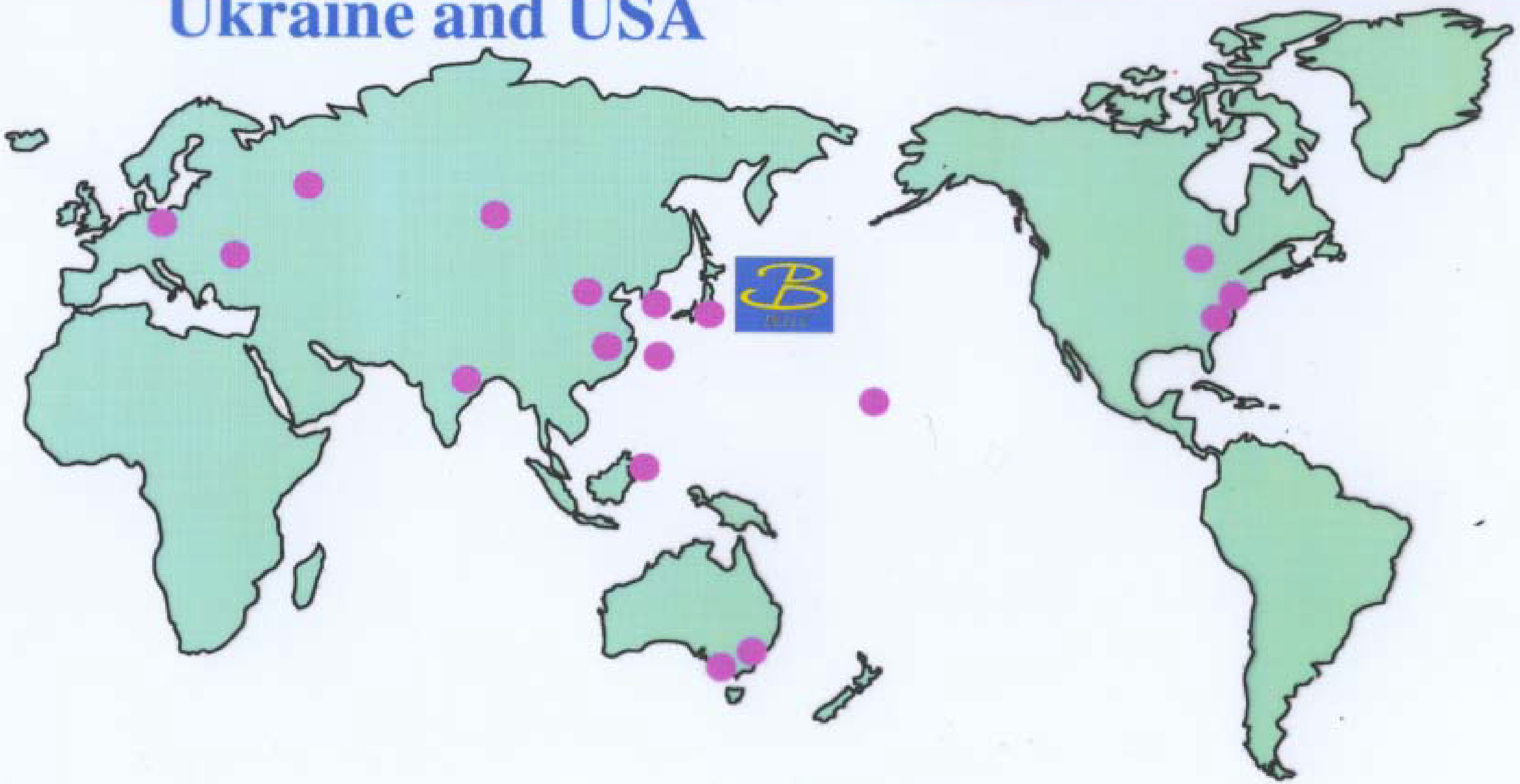
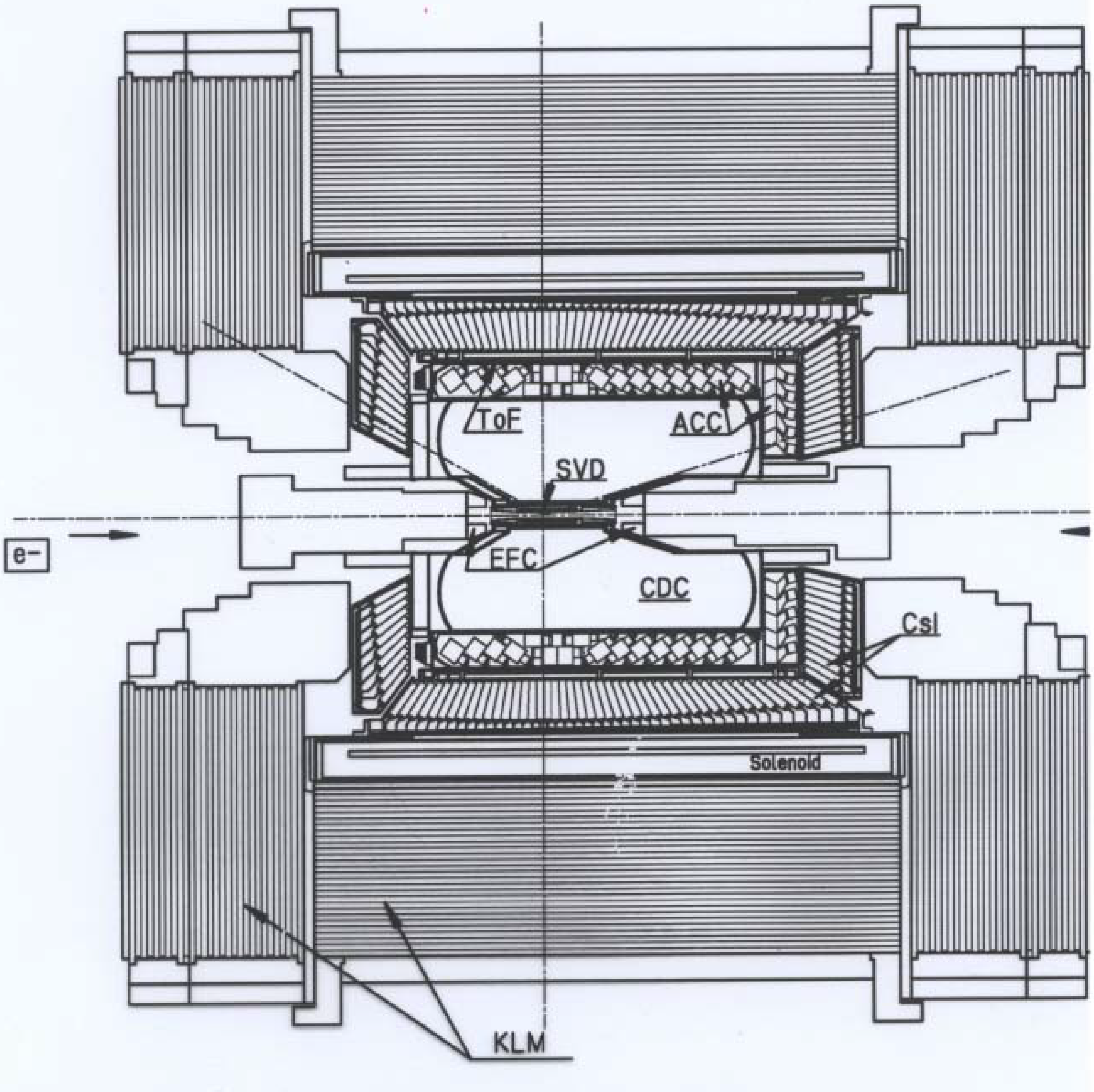


~300 researchers
(50 institutes) **from**
Australia, China, India,
Germany, Korea, Japan, Philippines,
Poland, Russia, Taiwan,
Ukraine and USA

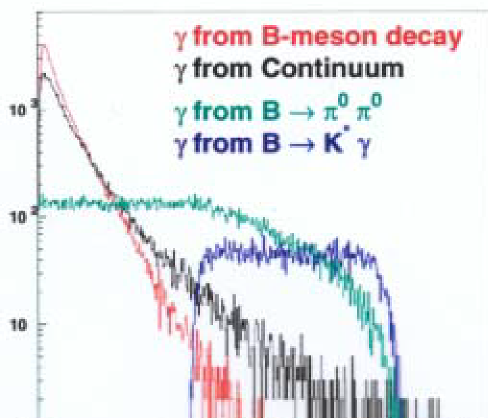




Beam Pipe	double wall of 0.5mm beryllium, He-gas cooled
SVD	3 layers of double-sided 300μ-silicon sensors
CDC	50 anode layers (18 stereo), 3 cathode layers
ACC	960+228 aerogel cells, n = 1.01 - 1.03
ToF	4cm-thick scintillator, 128 ϕ segmentation
CsI	6624 + 1152 + 960 CsI(Tl) crystals, 30cm long
Solenoid	1.5 Tesla
KLM	14 layers of RPC superlayer and 4.7cm iron
EFC	160 (13.7cm) + 160 (12.4cm) BGO crystals

Belle CsI Calorimeter

- The primary goal of BELLE detector at KEK asymmetric e^+e^- B-factory is the systematic study of CP asymmetry and rare decays of B-meson.
  - For typical B-meson decays about one third of the final state particles are π^0's.
  - Physics goals require γ detection of high efficiency and good resolution over the wide energy range from 20 MeV to 4 GeV.



- The detection of $ee \to ee$ and $ee \to \gamma\gamma$ are also important for detector calibration and luminosity measurements. ($\leadsto$ 8 GeV)

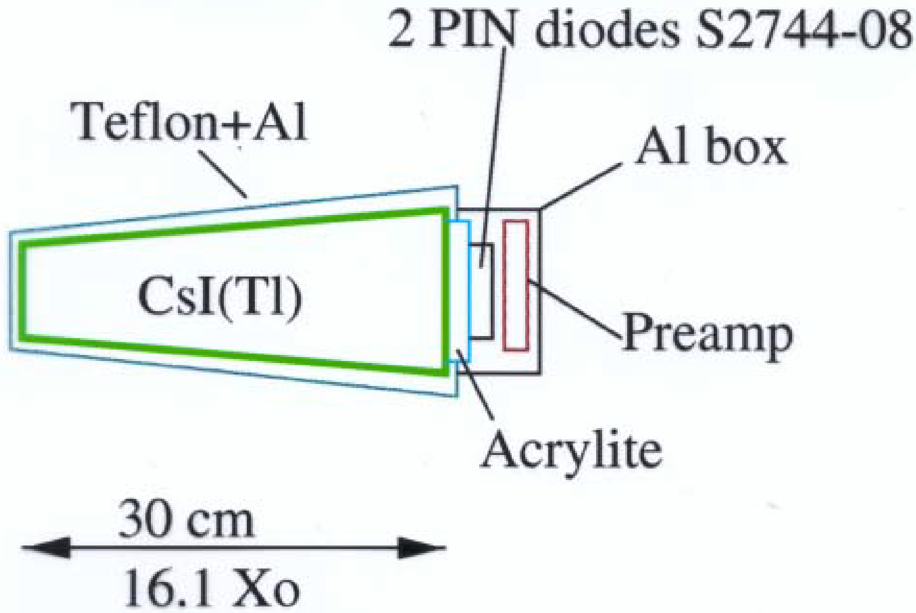
Calorimeter includes barrel and 2 endcaps.

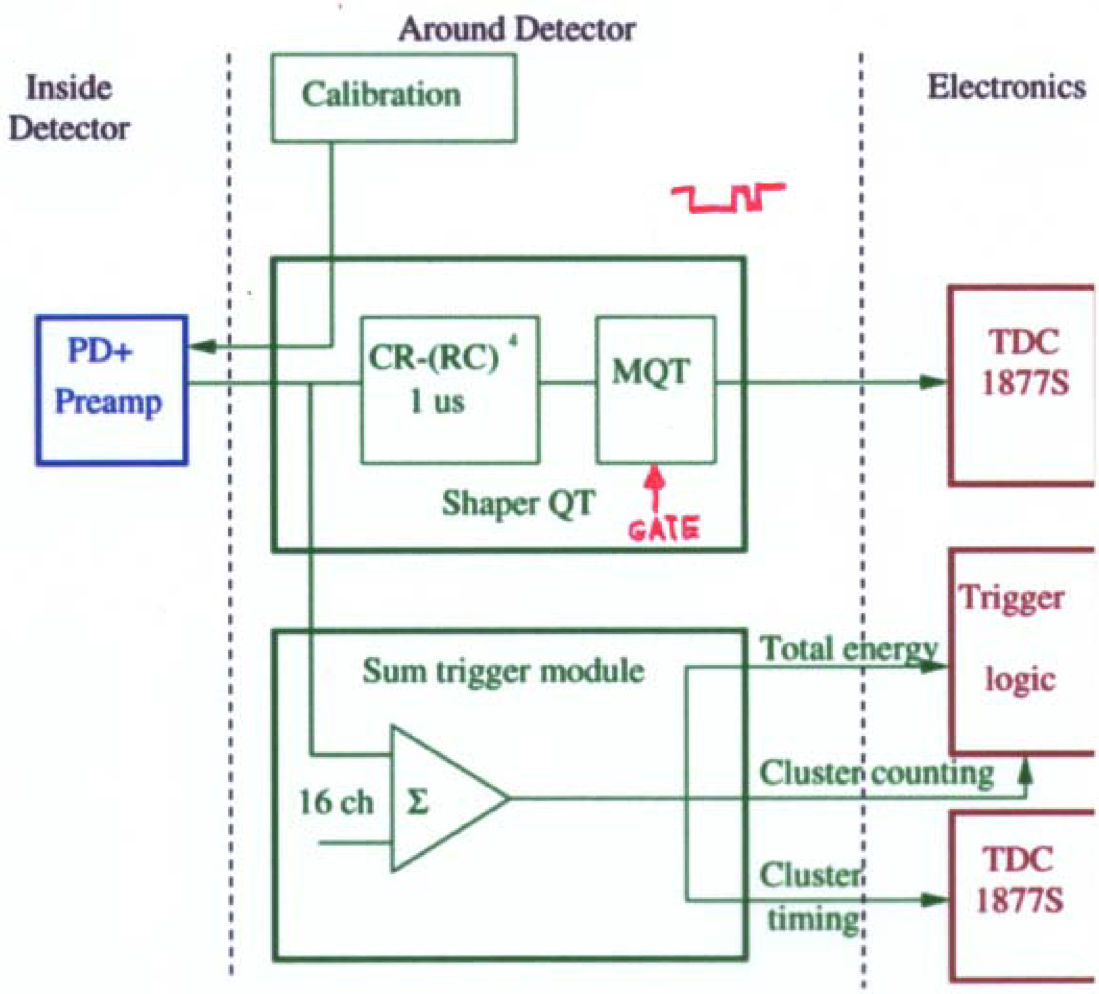
Covered solid angle $91\% 4\pi$

8736 CsI(Tl) crystals of 30 cm length.

Size of crystals front end $\sim 5.5 \times 5.5$ **cm**

Total weight about 43 tons.





- low range ~ 0.06 MeV/bin
- middle range ~ 0.5 MeV/bin
- high range ~ 4 MeV/bin
- Channels with energy deposition more than sparsification threshold(0.5 MeV) are read out(hardwa level)

- Calorimeter was assembled in autumn of 1998.
- Since June 1999 BELLE detector has been operating with beam
- All counters are alive
- Noise per counter 200 keV
- Pile-up effect from beam background contributes to counter noise
- Pile-up noise $\sim$ 200 - 300 keV for barrel counters, 200 - 800 keV for endcaps.

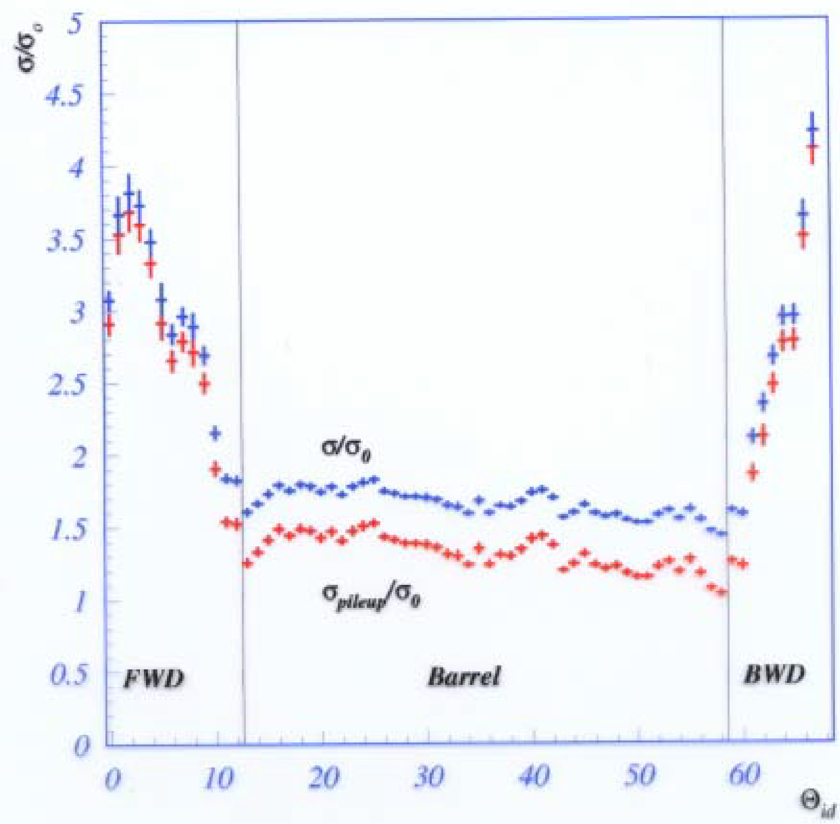
Pile-up effect

Signal overlapping with randomly distributed signals of background photons.

Can be estimated from pedestal width.

$$\sigma_{pil} \sim \sqrt{N_{bg\gamma}} \sim \sqrt{Dose} \sim \sqrt{IP}$$

$$\sigma_0 \approx 200 \textbf{ keV}; \ \sigma_{pileup} = \sqrt{\sigma^2 - \sigma_0^2}$$



$$I_+ = 360 \textbf{ mA}, \ I_- = 360 \textbf{ mA}$$

Photon energy reconstruction

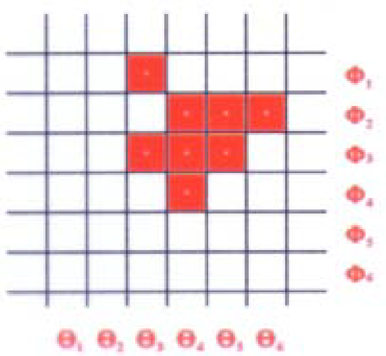
- **TDC counts to energy deposition**

$$E_i = c_i(TDC_i - Ped_i)$$

- **Cluster reconstruction within 5×5 matrix of the seed crystals**

$$E_{cl} = \sum E_i$$

$$(\theta_g, \phi_g) = \frac{\sum E_i \times (\Theta_i, \Phi_i)}{E_{cl}}$$



- **Reconstruction of the most probable photon energy and angles based on MC simulation.**

$$E_\gamma = F_e(E_{cl}, \theta_g); (\theta_\gamma, \phi_\gamma)_\gamma = F_{\theta,\phi}(E_{cl}, \theta_g, \phi_g)$$

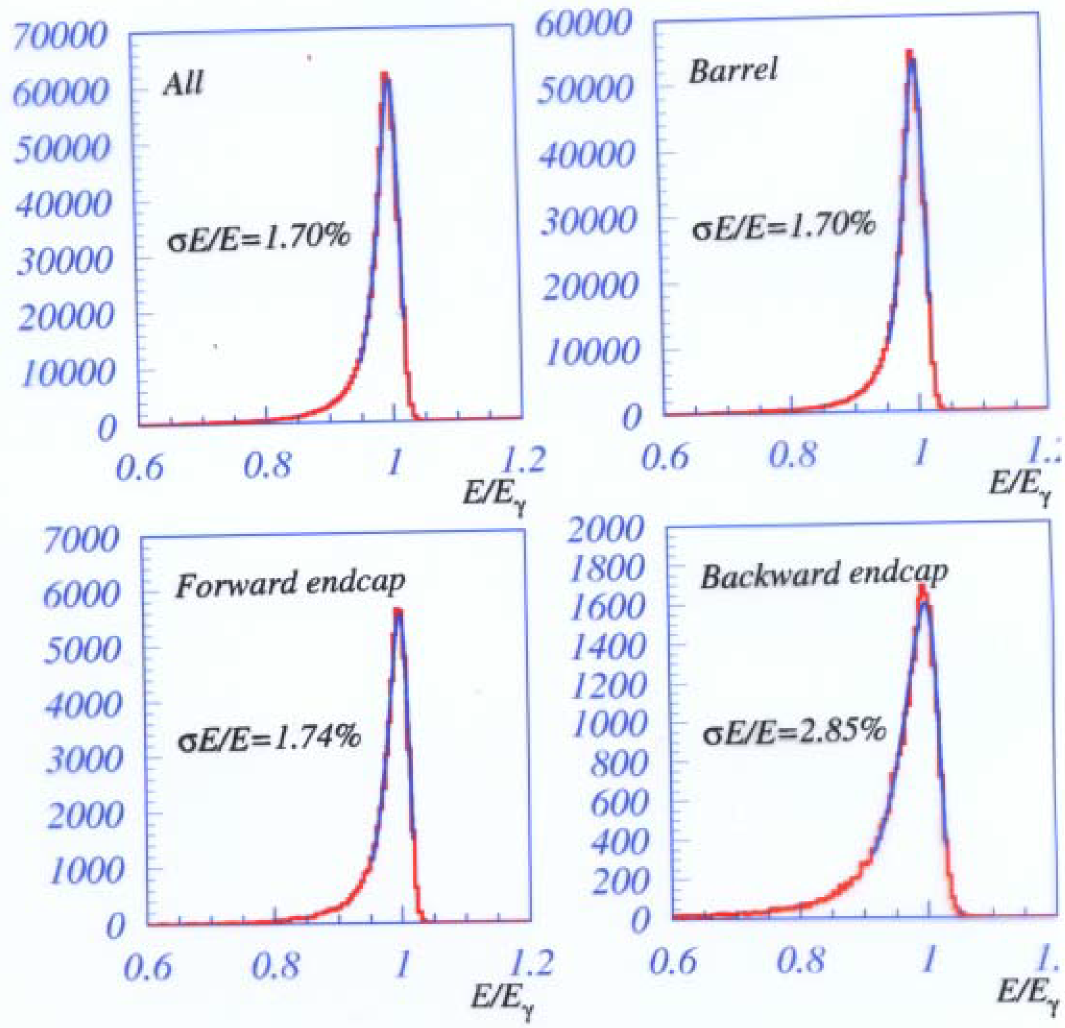
Calibration

- **Electronics calibration**
  - **Pedestals**
  - **Electronics gain**
  - **LED**
- **Cosmic calibration**
- **Absolute calibration using Bhabha and** $e^+e^- \to \gamma\gamma$

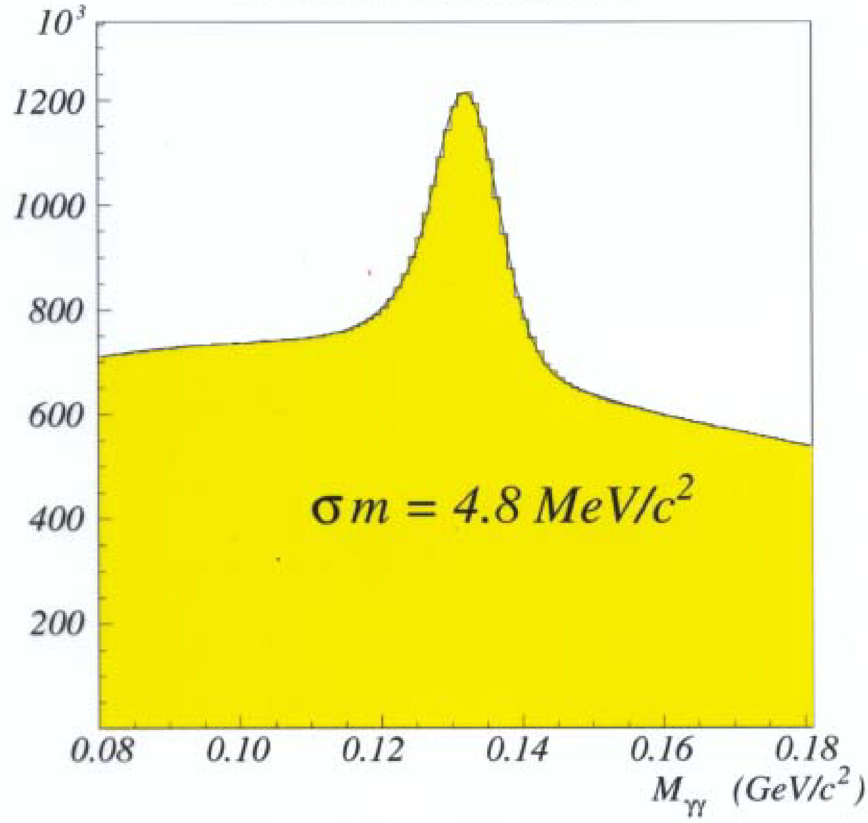
$$\sum \frac{(\sum c_i A_i - E_{calc}(\theta,\phi))^2}{\sigma^2(\theta)} \to min$$

- **Nonlinearity estimation using** $\pi^0 \to \gamma\gamma$ **and** $e^+e^- \to e^+e^-\gamma (< 2\%)$

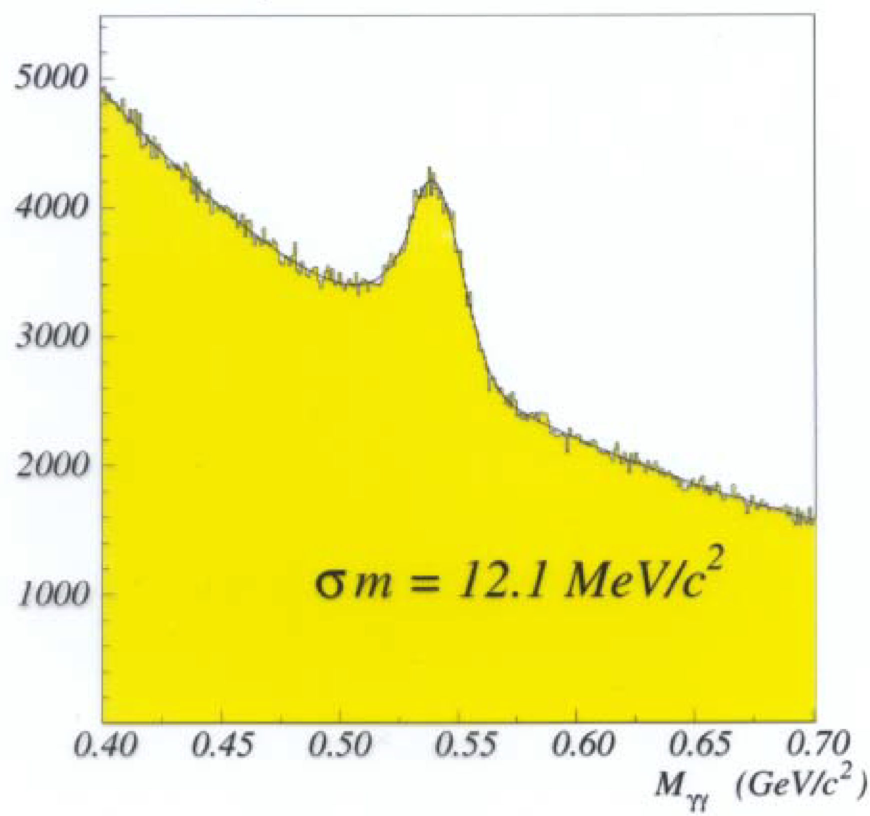
$e^+e^- \to \gamma\gamma$



π^0 mass resolution

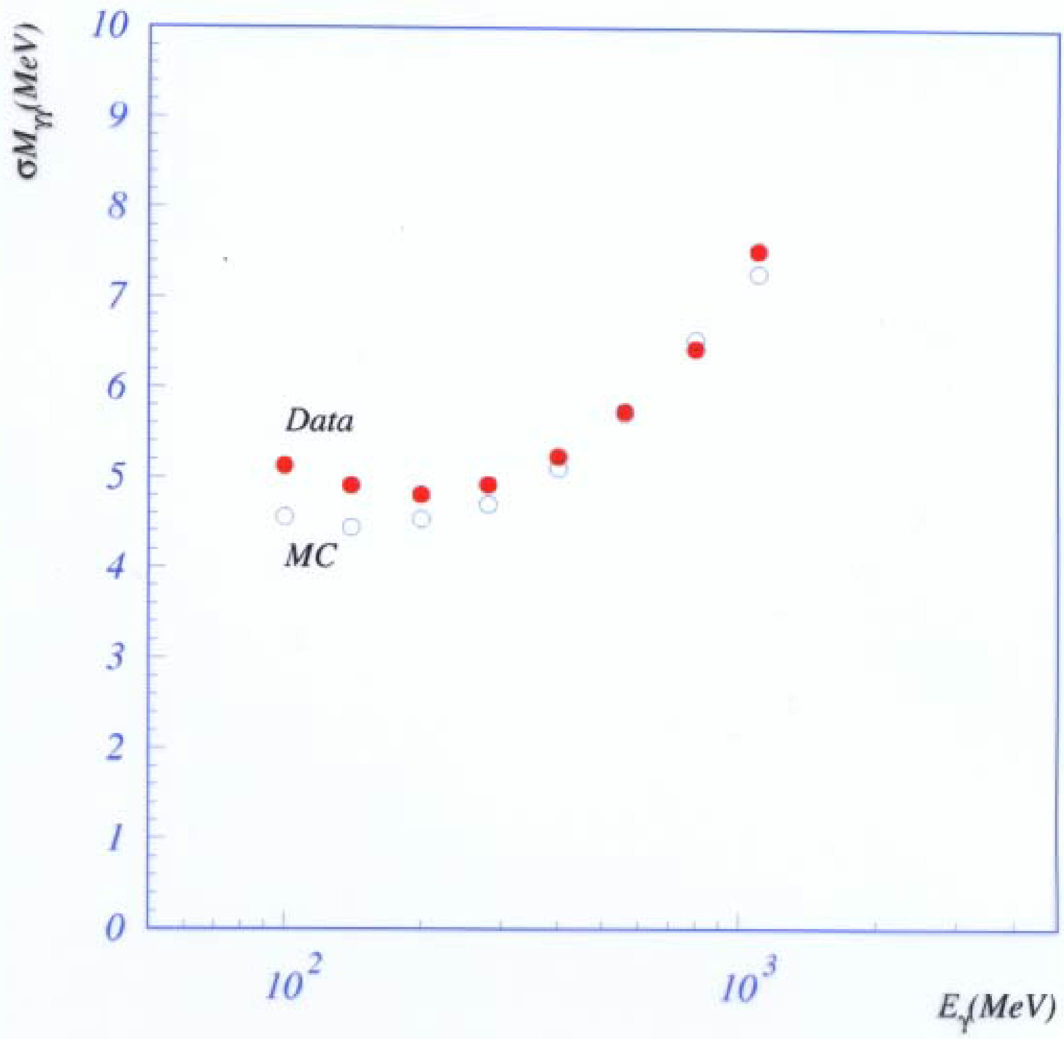


η mass resolution



π^0 mass resolution

Symmetrical case: $\pi^0 \to \gamma\gamma$, $E_{\gamma 1} \approx E_{\gamma 2}$.

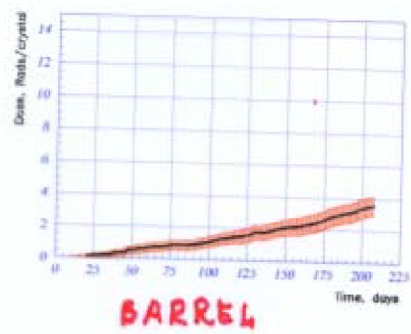


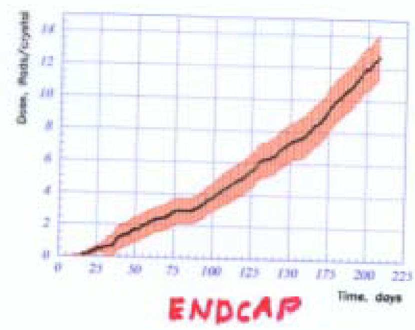
Radiation dose

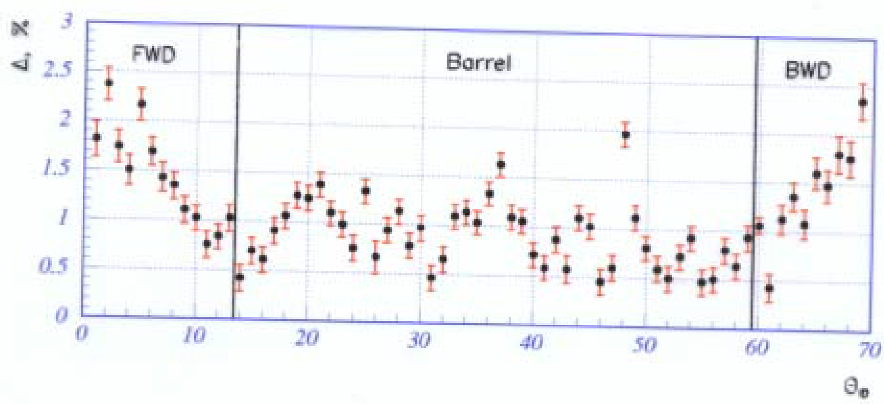
- The instantaneous radiation dose is proportional to the energy deposited in the crystal in unit of time.

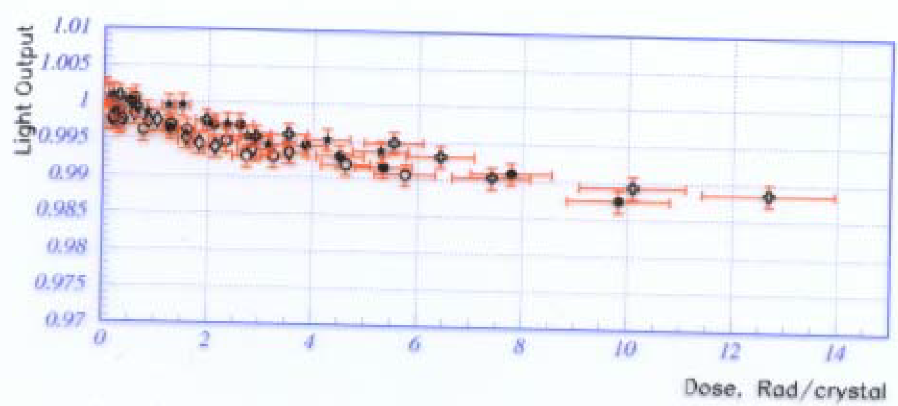
$$Dose \sim E \sim \int I dt$$

- Leakage current $\approx$ 5 nA/crystal
- Increase of 2.5 nA/crystal $\sim$ 100 Rad/(10^7sec)
- Detector subdivided in 16 groups. Total current of each group is monitored and radiation dose accumulated is estimated.


Dose, Rads/crystal
Time, days
BARREL


Dose, Rads/crystal
Time, days
ENDCAP


Δ, %
FWD
Barrel
BWD


Light Output
Dose, Rad/crystal

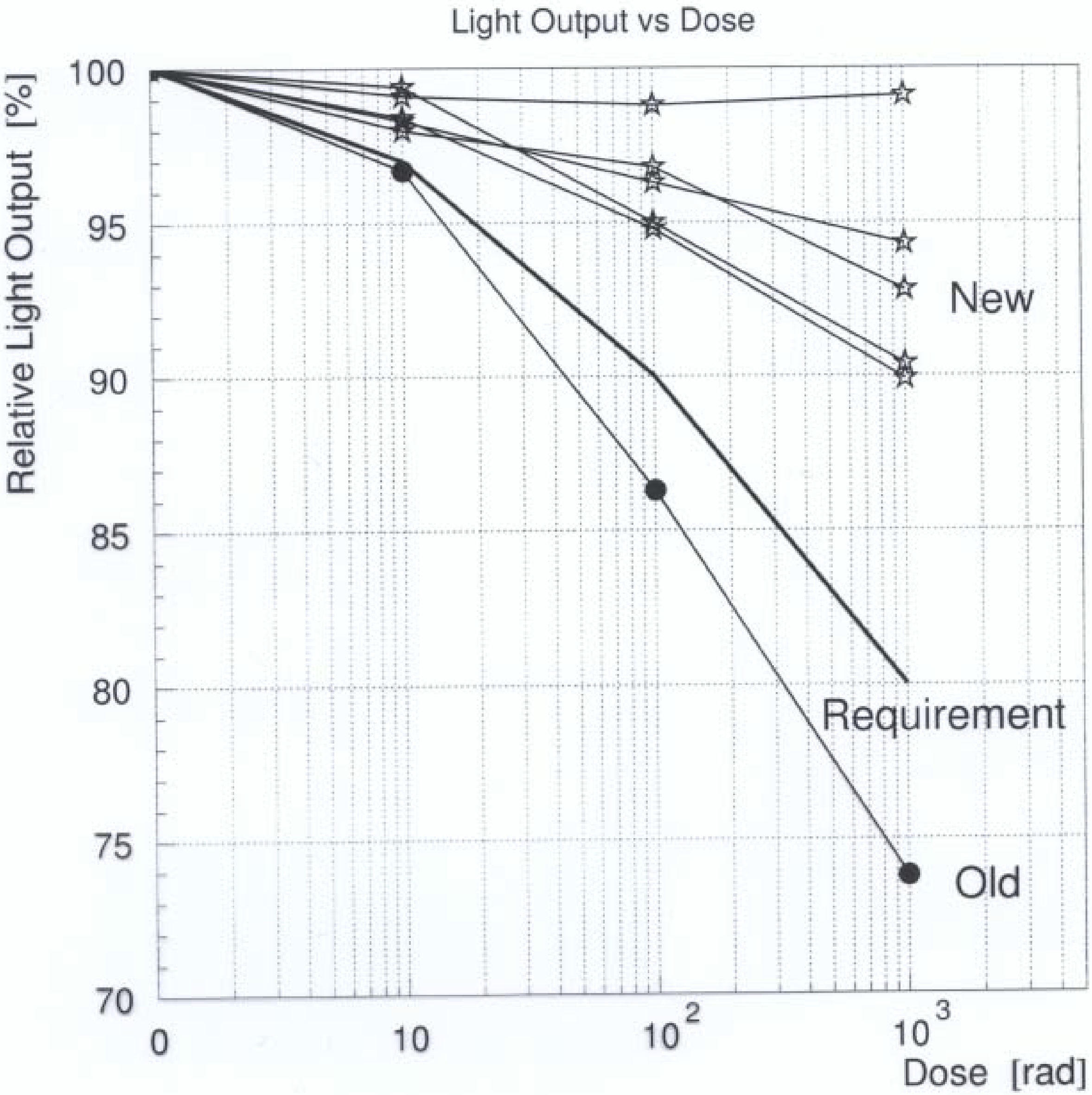


Figure 13: Light output of new SIC crystals vs dose (front-face irradiation).

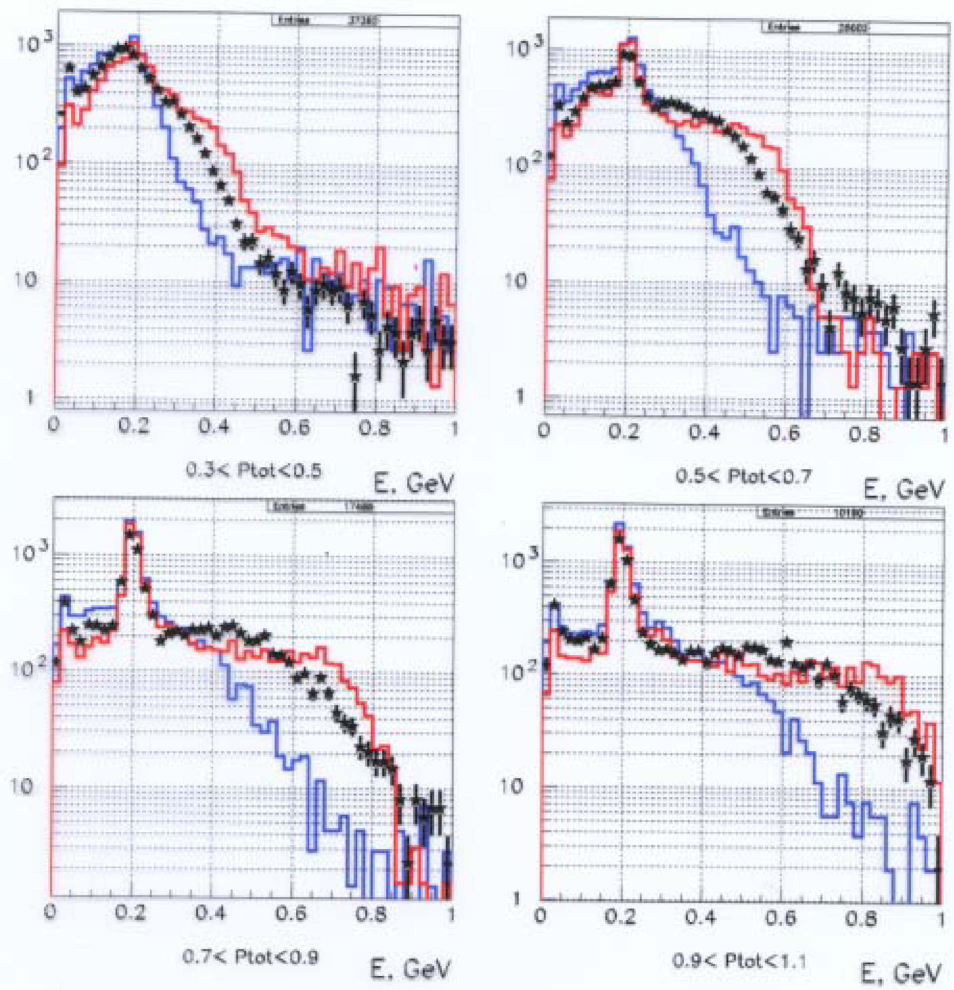


Figure 2: **Response for hadrons (π^+). Dots – data;Blue – GEISHA;Red – FLUKA(Updated version).**

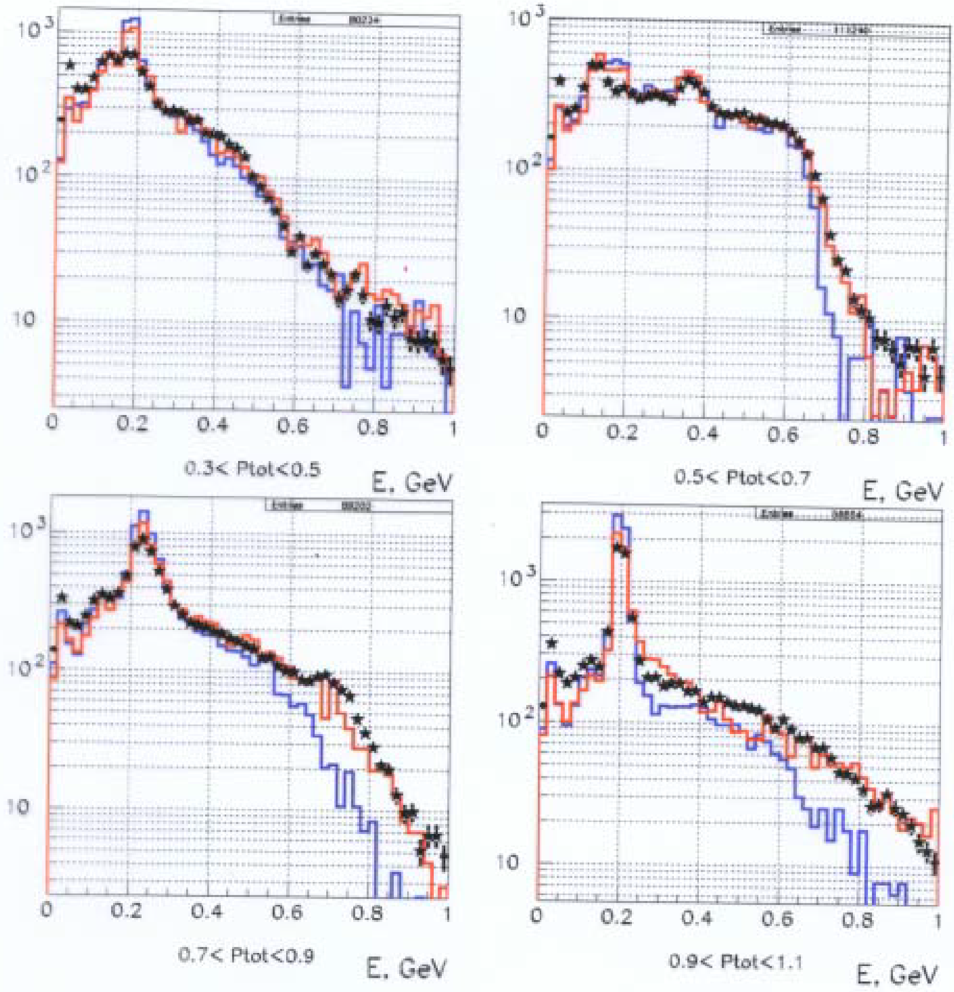


Figure 1: **Response for hadrons (K^+). Dots – data;Blue – GEISHA;Red – FLUKA(Updated version).**

Conclusion

- CsI calorimeter of BELLE detector has been working for more than one year.
- All counters are alive, electronics noise is consistent with expected one.
- Pile-up noise is comparable with electronics noise in barrel and 2-3 times larger in endcaps for present background conditions.
- The energy resolution for high energy photons is consistent with MC expectation (about 1.7 %). The π^0 mass resolution for pions from B-decay is about 4.8 MeV.
- The radiation dose obtained by the crystals during one year is $5 - 12$ Rads. Lightoutput degradation is about 0.5-1 % for barrel crystals and about 2 % for most inner crystals of endcaps which is consistent with radiation dose.
- Good PID together with calorimeter provide valuable information about hadron-nucleus interaction.