ECL calibration (*)

Elisa Manoni for the PG group
INFN Sezione di Perugia

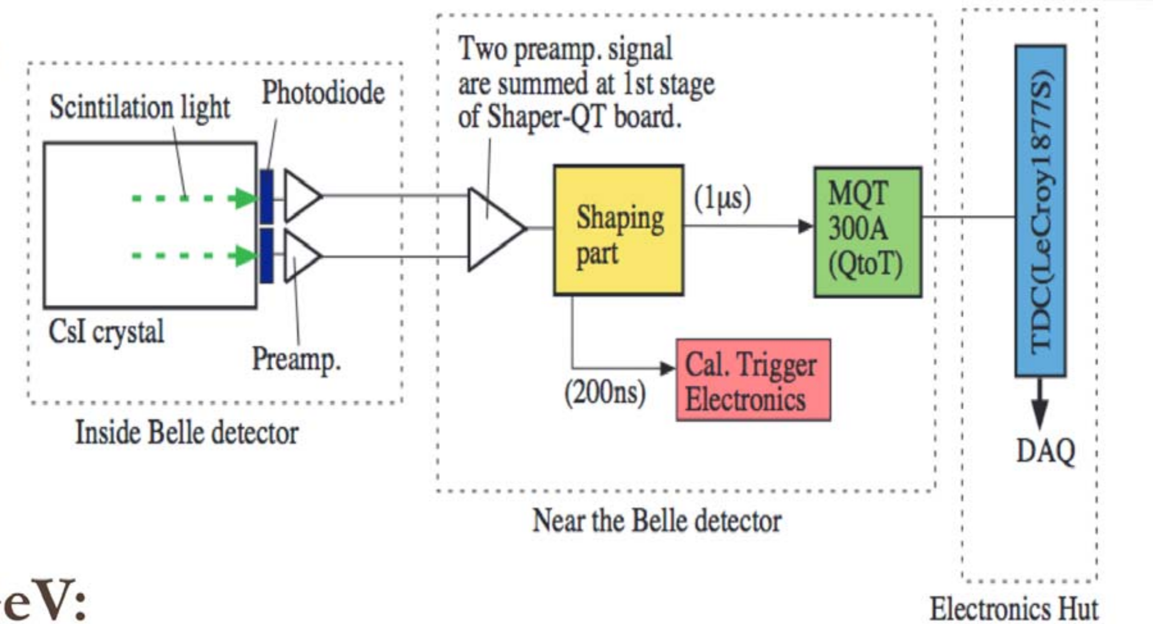
1st Belle-II Italian collaboration meeting
9-10 June 2014, Rome

(*) most of the material presented at the Camogli computing workshop

BELLE & BELLE-II ECL CALIBRATION

ECL calibration in Belle (I)

- **Read-out chain:**



- **From TDC to GeV:**

$$E_i = \frac{TDC_i - PED_i}{e_i \times c_i}$$

pedestal for i^{th} channel

electronic calibration constant, daily computed

energy conversion constant measured via cosmic ray

ECL calibration in Belle (II)

- Steps to compute c_i:

$$E_i = \frac{TDC_i - PED_i}{e_i \times c_i}$$

1. initial input values from cosmic rays
   - only method to calibrate innermost FWD xtals

2. calibration constant g_i computed by using BhaBha events, minimizing

$$\chi^2 = \sum_{k=1}^{N} \left(\frac{E_{exp} - \sum_i^{5x5} g_i E_i}{\sigma} \right)$$

measured energy in i^{th} xtal

$$E_{exp} = E(\theta, \phi) \cdot f(\theta)$$

$e^{\pm}$ kinematic energy

ratio of clus energy before and after energy leakage correction (from MC)

3. constant refinement by using $e^+e^- \to \gamma\gamma$ events
   - smaller syst due to effect of dead material

ECL calibration in Belle (III)

From Belle note 308, on Bhabha calibration

- Calibration sample selection:
  - (at least) 2 energetic clusters in the calorimeter
  - high ECL E_{tot}
  - acollinearity of e^+e^- tracks
  - $E(e^+e^-)$ ~ 80% total energy

select 2-body final state (e^+e^-) — applies to the first two criteria

reject 3-body final state ($e^+e^-\gamma$) — applies to the last two criteria

- Calibration history, as of April 2000:

#Exp	3	5	7
sample	Bhabha	CalQED	CalQED
Matrix order	8352	8448	8448
#event	2.4×10^5	7.2×10^5	7.0×10^5
#used runs	424(46~469)	78(142~220)	100(330~429)
$\int L \cdot dt(Pb^{-1})$	27.0	42.6	136.8
Data taking days	70	9	4
#version	1	2	3
Date	Aug.1999	Dec.1999	Mar.2000

Table 6. The history of Bhabha calibration

ECL calibration in Belle (IV)

- Kenkichi Miyabayashi @ Calor2002

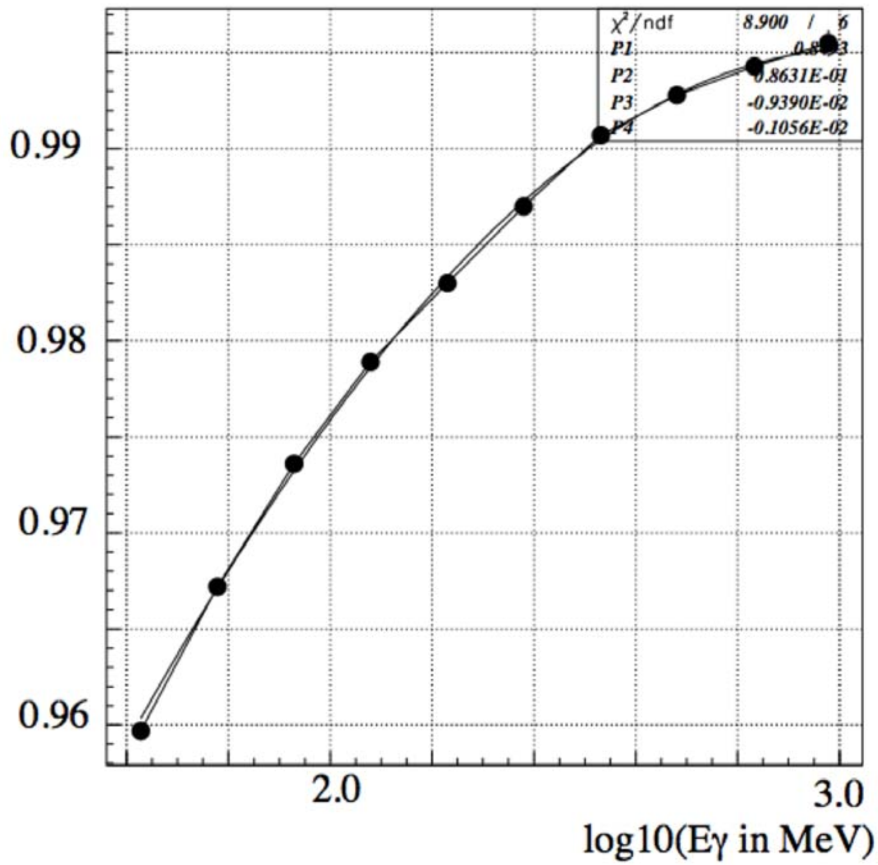
Non-linearity correction by π^0

- Bhabha, $\gamma\gamma$ calib. at highest E. point.
- Interpolation in low energy region needs verification.

$M_{\gamma\gamma} = \{ E_1 E_2 (1-\cos\alpha) \}^{1/2}$

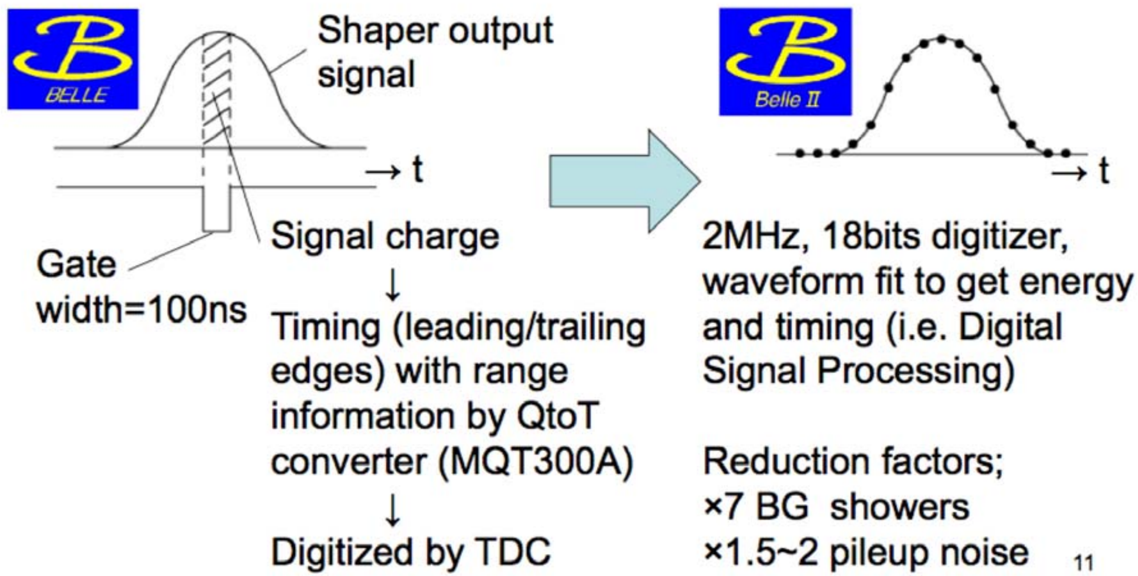
→ π^0 mass peak gives information in low ene. region(< 1GeV), because EM shower is well predicable by sim.

Non-linearity correction
(applied by div. for Exp. Data)



ECL calibration in Belle II

- **Upgraded electronics:**



- **Energy in GeV:**

$$E_i = \frac{A_i}{e_i \times c_i}$$

A_i: pulse height

e_i: electronic calib. constant

c_i: energy conversion constant

- **Non-linearity correction for the reconstructed shower energy to be checked and applied.**

ANSWERS TO THOMAS QUESTIONNAIRE

Which quantities have to be calibrated?

- Calibration constant c_i/g_i
  - for shaper+DSP output amplitude (A_i) to single crystal energy (E_i) conversion
- Energy-non-linearity correction.

What are the prerequisites (e.g. alignment/ calibration of other detectors)?

- For Bhabha calibration, angular info from tracking system are used (comparison between crystals' energy deposit and expected e^+/e^- energy as a function of polar angle theta)
- e^+/e^- tracks' polar angle should be reconstructed with a reasonable precision (~ few mrad). Some effort needed to confirm this is ok.

How often do the calibration constants change?

- In normal condition of the machine operation, calibration constant should not change during short period of data taking (some months?)
- Monitoring of the constants is mandatory, since xtal response may vary because of radiation damage, pressure of the structure,…

- During Belle, calibration was performed exp.-by-exp., i.e. a few - a few * 10 /fb
- In Belle II, one day-/few day- run to accumulate such stats: frequent calibration which requires automated procedure.

What kind and how much data is needed?

- Bhabha and $e^+e^- \to \gamma\gamma$ for single xtal calibration
  - ~ 10^6 Bhabha events, (in Belle, first calibration cycles with ~ 7×10^5 evts), corresponding integrated luminosity depends on prescale factor used in calorimeter trigger system
  - assuming a 10 xtal hit for e^+ or e^- from Bhabha, ~ 10^6 Bhabha events → 2×10^7 crystal hits
  - assume theta-dependent prescaling factor → uniform # of Bhabha evts in different theta bins
  - considering 8448 xtal → ~ 2000 evts per-xtal
  - $O(10^{-3})$ accuracy for c_i

- hadronic events for π^0 mass peak study
  - at least few fb^{-1}

- $e^+e^- \to \mu\mu\gamma$ for high energy photon deposit study
  - at least few tens of fb^{-1}.

Are multiple passes needed?

- Assuming that we adopt a calibration procedure similar to the Belle one, several steps are needed.

(form Belle Note 308)

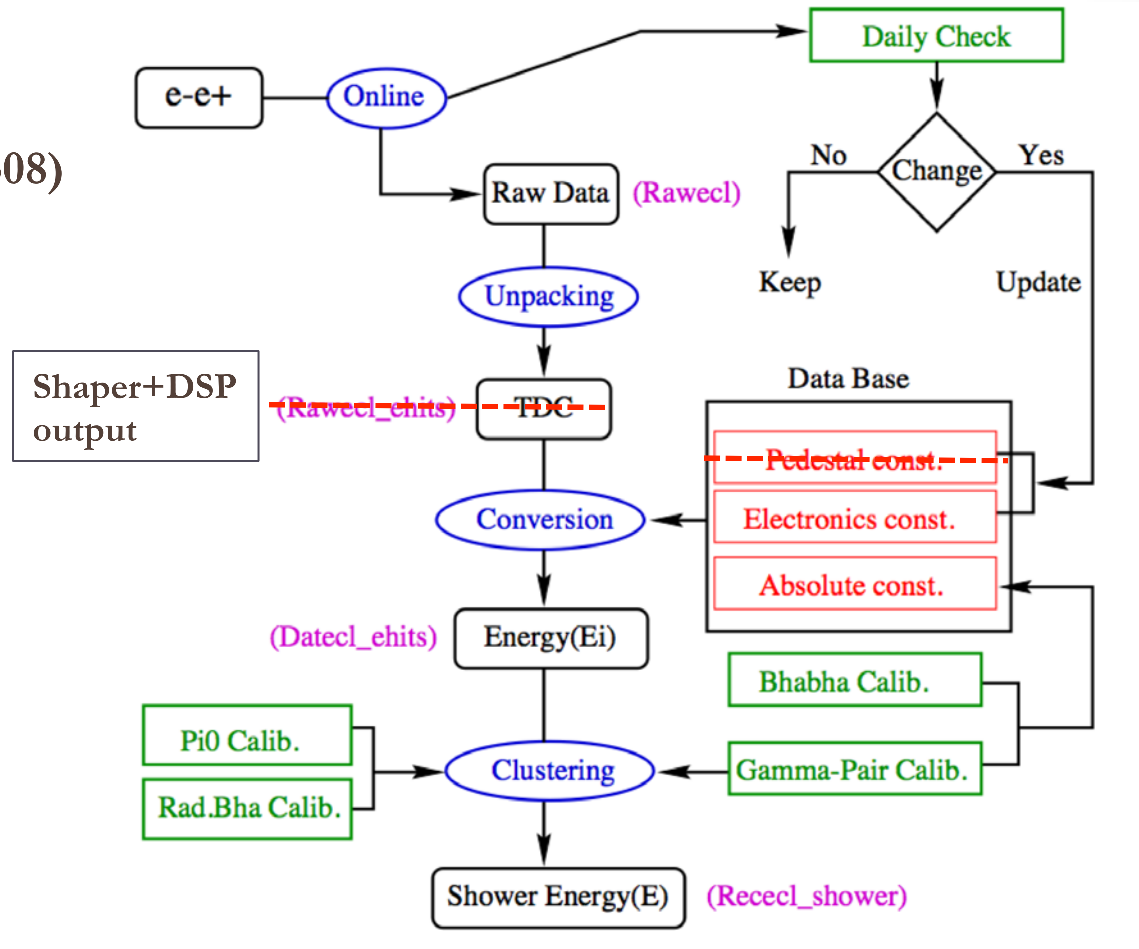


Figure 1. ECL calibration flow chart.

Is it sufficient to collect data in form of histograms or are ntuples needed?

- calibration constant and correction factors stored in database
- data form Bhabha and $e^+e^- \rightarrow \gamma\gamma$ for analysis to be stored in ntuples
- for energy non-linearity correction, histograms should be sufficient
  - 2-photon's invariant mass for π^0 in hadronic events
  - reconstructed shower energy by ECL
  - estimated photon energy by tracks in radiative di-μ events.

Which obstacles have to be overcome to automatize the determination of alignment/calibration constants?

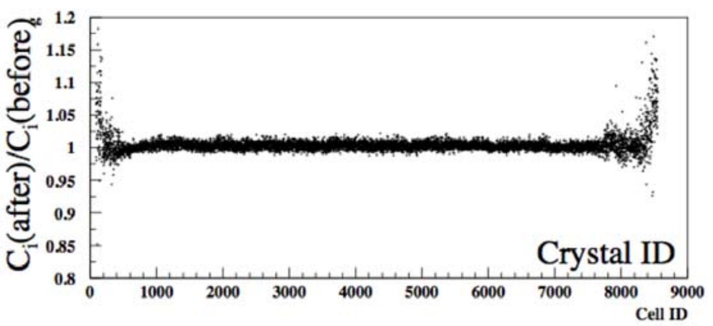
- Automatized tools are mandatory to frequently compute calib. const.
- Details on obstacles to this are not known at the moment since the calibration code has been not finalized yet.

Belle II

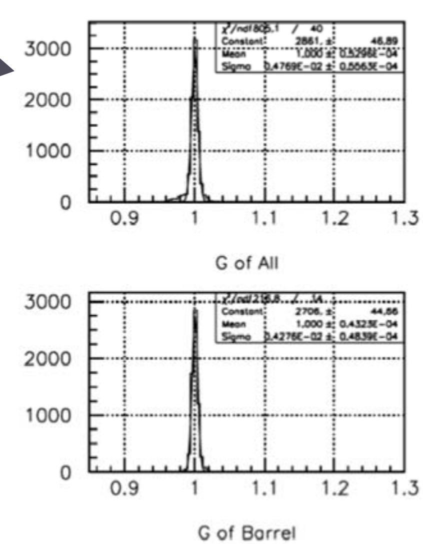
INFN

Can one define monitoring plots that would allow a shifter to decide whether an alignment/calibration was successful or not?

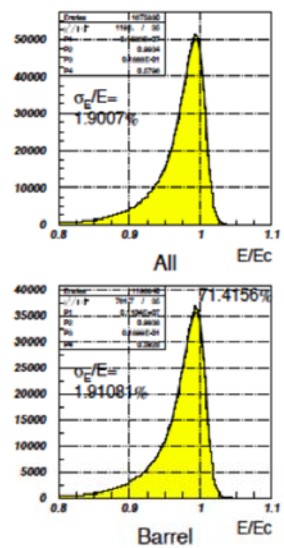
- change in calibration constants wrt previous calibration



- calib. constant distribution



- linearity and resolution check for $e^+e^- \rightarrow \gamma\gamma$ events



- 2-γ's invariant mass distribution in energy- and theta- bins for π^0 mass resolution check.

examples from Belle calibration

BHABHA CALIBRATION: ACTIVITY IN PG

Algorithm in brief (Belle note 308)

- **From TDC to GeV:** $E_i = \frac{A_i}{e_i \times c_i}$
- **Skim and selection**

of cluster ≥ 2
The two most energetic cluster energy ≥ 1 GeV
Sum of the two most energetic cluster energy ≤ 14 GeV
Total energy observed in ECL ≥ 5 GeV
Third shower energy ≤ 500 MeV

Table 2. Selection criteria of CalQED skimmed data

$\lvert\Delta_\phi - \pi\rvert > 0.087$
$\lvert\theta_1 + \theta_2 - \pi\rvert < 0.05$
of CR(energy ≥ 2 GeV) ≤ 4

Table 3. Cuts to select Bhabha from CalQED

of cluster (energy ≥ 800 MeV) ≤ 2
Acollinearity angle $\leq 1.5°$
Third shower energy ≤ 100 MeV
$\lvert E_{e^\pm}/E(\theta,\phi) - 1\rvert < 0.2$

Table 4. Cuts to select good Bhabha

- **χ^2 minimization**

$$\chi^2 = \sum_{k=1}^{N} \left(\frac{E_{exp} - \sum_i^{5x5} g_i E_i}{\sigma} \right)$$

Bhabha calib constant

$$E_{exp} = E(\theta, \phi) \cdot f(\theta)$$

$e^{\pm}$ kinematic energy

ratio of clus energy before and after energy leakage correction (from MC)

measured energy in i^{th} xtal

$$\sum_j g_j Q_{ij} = R_i$$

$$Q_{ij} = \sum_{k=1}^{N} \frac{E_{ik} E_{jk}}{\sigma^2}$$

$$R_i = \sum_{k=1}^{N} \frac{E_{ik} E_{exp}}{\sigma^2}$$

compute **R** and **Q** from measured quantities and invert matrices to have **g**

Code flow

1) generate Bhabha events with BHWide
2) from BHWide output produce reduced ntuples
3) apply preselection and selection
4) compute corrected energy
5) compute Q and R matrices
6) invert matrices to compute g
7) store g in database……

Code flow

1) generate Bhabha events with BHWide

2) from BHWide output produce reduced ntuples

generator tested and code to produce reduced ntuples in place; some sanity checks with latest releases needed

3) apply preselection and selection

first tests on event selection variables performed, to be repeated with latest release

4) compute corrected energy

5) compute Q and R matrices

to be implemented

6) invert matrices to compute g

Fortran routine was used in Belle, found and tested C++ routine which performs matrix inversion with reasonable time consumption

7) store g in database……

integration with Belle-II software to be agreed on with other sub-systems and with computing team

Conclusions and outlook

- ECL calibration requires several steps and samples
- Detailed discussion started at the Camogli computing workshop

- Perugia's group has the responsibility of xtal-by-xtal ECL calibration with Bhabha events
  - first tests on generator, ntuple code, selection variables, and inversion algorithm performed
  - other pieces of code (e.g. corrected energy computation) to be implemented
  - discussion on integration of calibration code with Belle-II software started at the Camogli computing workshop

EXTRA SLIDES