

BEPC-II c. m. s. energy studies (2012)

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Abstract

The study of BEPC-II beam energy in the 2011-2012 run period was performed. The aim of the study was an attempt to understand the problem of wrong determination of the BEPC-II c.m.s. energy. This problem had appeared after J/Ψ scan in June 2012. Each section in the text below describes a certain check results or questions.

1 BEPC-II set energy.

BEMS operation principle implies that during one measurement¹ at least two conditions must be fulfilled: 1) the average beam particle energy does not change; 2) the energy distribution of beam particles obey Gaussian distribution.

That's why BEMS requires an information about the beam energy from the BEPC-II control system. BEMS gets this information requesting “BER:PMO” and “BPR:PMO” parameters. These requests are performed every 30 s and the data is saved in parallel with every spectra measured by BEMS HPGe spectrometer.

What are these “BER:PMO” and “BPR:PMO”? BEPC people have not explained much details about it. Our assumption is that the beam energy is calculated on the basis of the following simple formulae:

$$E_{PMO} = \frac{c}{2\pi} \int_0^{c\tau_r} B(s)ds . \quad (1)$$

Here E_{PMO} is the beam energy, c is the speed of light, τ_r is a beam revolution time², s is the longitudinal coordinate along the beam orbit, $B(s)$ is the bending field at certain position s . Practically, the energy calculation should be something like:

$$E_{PMO} = \frac{c}{2\pi} \sum_{i=0}^N n_i B_i l_i = \frac{c}{2\pi} \sum_{i=0}^N n_i K_i I_i , \quad (2)$$

where summing is performed over the similar sets of magnetic elements, n_i is the number of elements of type i , and $B_i l_i$ is the “magnetic length” of a given element.

One can calculate “magnetic length” as $B_i l_i \simeq K_i I_i$, where I_i are the coils currents (measurements) and K_i are the calibration coefficients, based on the collider design and pre-installation tests of equipment. The typical accuracy for the absolute beam energy determination by this procedure $\Delta E/E \simeq 1\%$. However, if the exact beam energy is measured by some another approach (e. g. J/ψ scan), K_i can be adjusted to improve the accuracy.

Fig. 1 shows the history of BEPC energies in 2012.

Fig. 2 shows the difference $E_{PMO} - E_{BEMS}$ for the same time range.

Fig. 3 shows E_{PMO} readings for one cycle of BEMS operation: one can see that the fluctuations of E_{PMO} for electron and positron rings have strong anti-correlation, so that

$$\bar{E} = (E_{PMO}^{BER} + E_{PMO}^{BPR})/2 \quad (3)$$

value is much more stable than either E_{PMO}^{BER} or E_{PMO}^{BPR} . Fig. 3, b) and c) are (in addition) the demonstration of two technical problems in BEMS operation in June 2012: 1) BEMS did not stop measurements when the BEPC collision energy was changed; 2) there are some time gaps in E_{PMO} readings.

On Fig. 4 the values of $(E_{PMO}^{BER} - \bar{E})$ and $(E_{PMO}^{BPR} - \bar{E})$ were put into the 1-D histograms with 10 keV bin width. This was done for the time interval ($\simeq 10$ h) when the beam energy was not changed.

On Fig. 5 the values of $(E_{PMO}^{BER} - \bar{E})$ and $(E_{PMO}^{BPR} - \bar{E})$ were put into the profile histogram with 20 keV bin width.

¹one measurement means one BEMS data acquisition period. Typically 30-60 min.

² $c\tau_r$ is the length of the beam orbit which is fixed by RF frequency

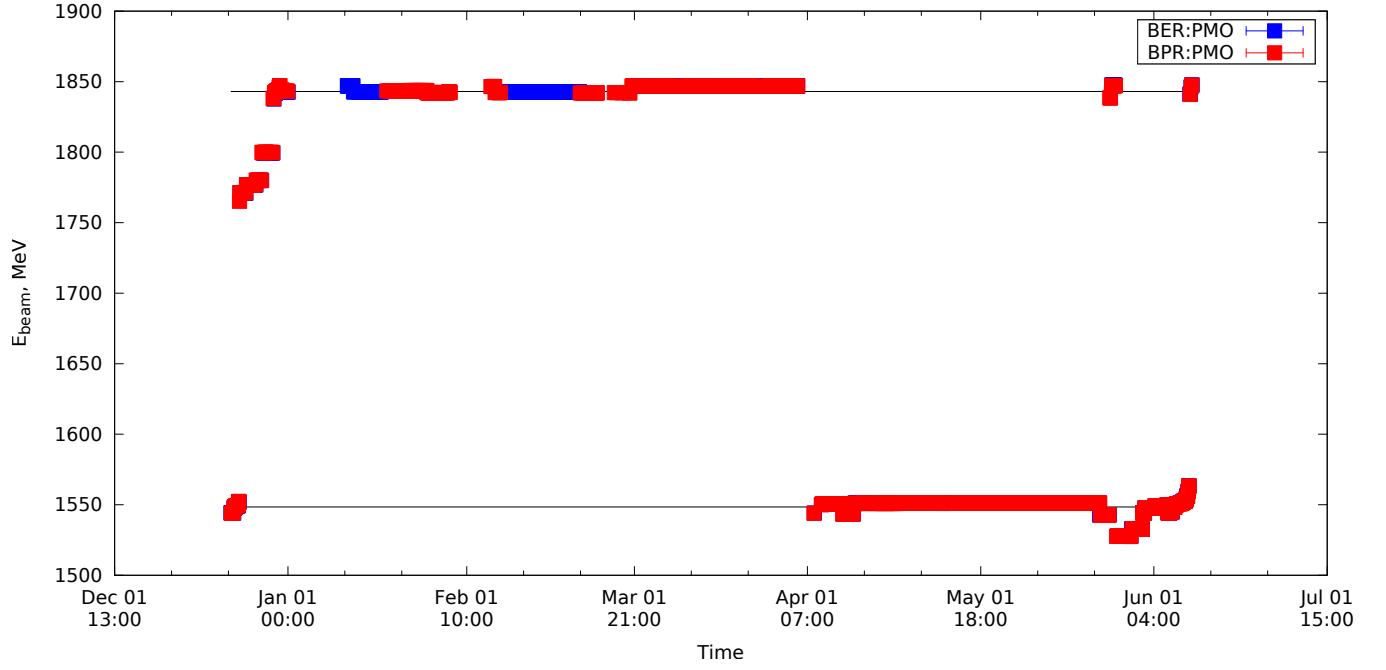


Figure 1: BEPC operation energies (E_{PMO}) in 2012. Horizontal lines are the J/ψ and $\psi(2s)$ half masses.

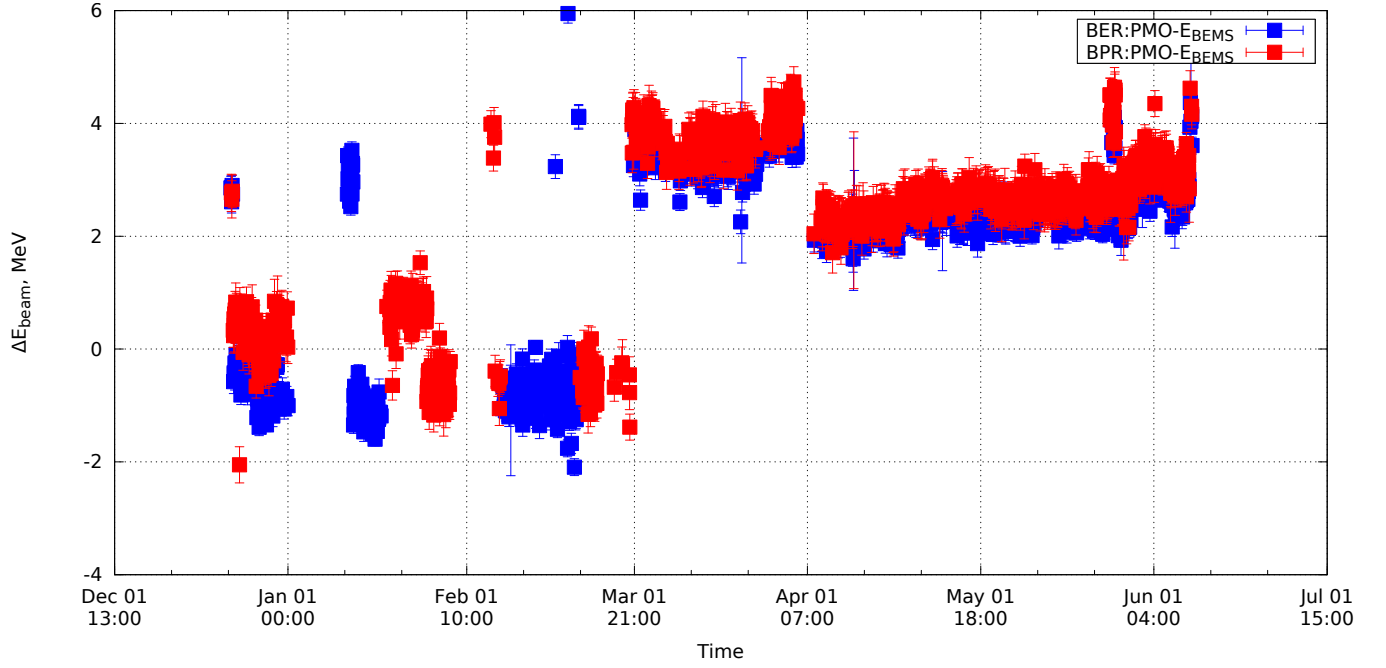


Figure 2: The difference $E_{PMO} - E_{BEMS}$. One can see “jumps” and “drifts”, probably caused by BEPC tuning. In June 2012, the J/ψ mass based on E_{PMO} is about 6 MeV higher than the PDG value, while in December 2011 there were almost no difference.

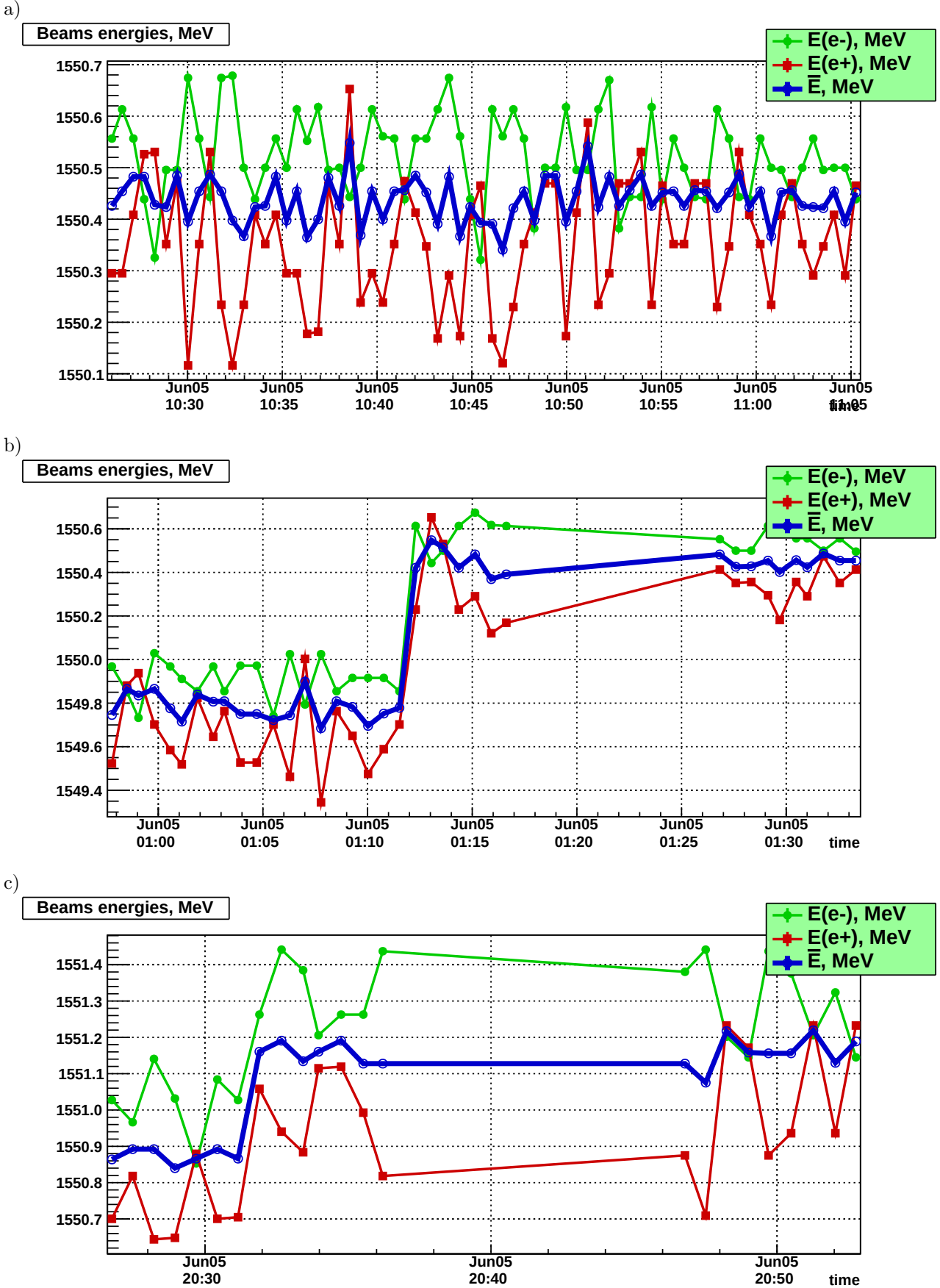


Figure 3: E_{PMO}^{BER} , E_{PMO}^{BPR} and $\bar{E} = (E_{PMO}^{BER} + E_{PMO}^{BPR})/2$ during one BEMS data acquisition cycle.

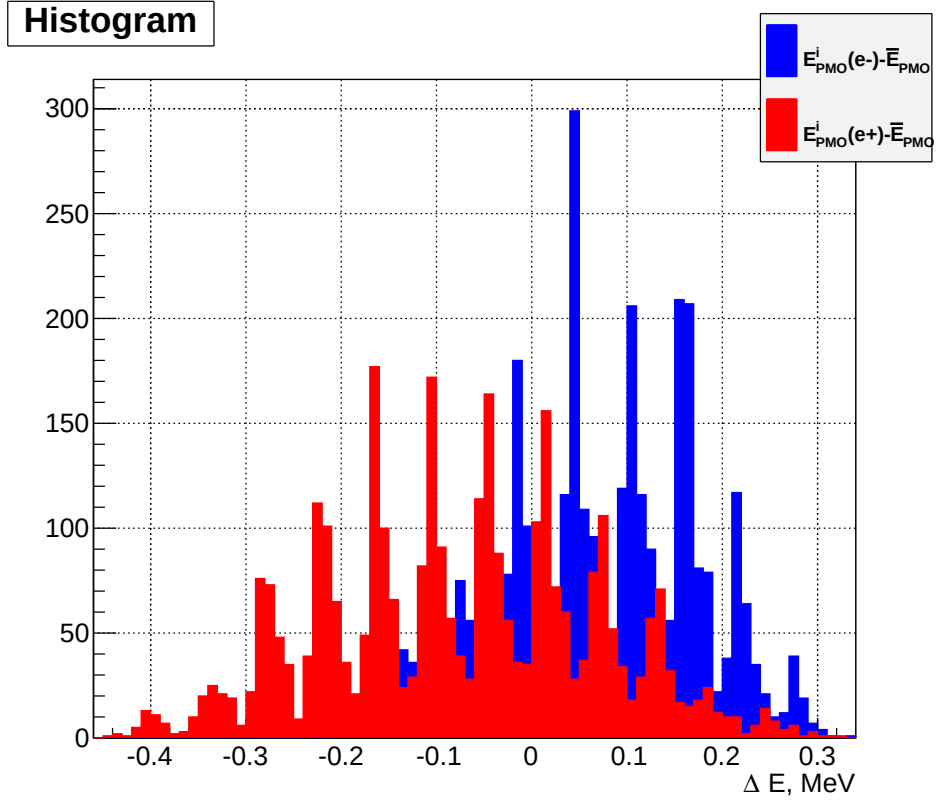


Figure 4: 1-D histograms shows the distributions of E_{PMO}^{BER} and E_{PMO}^{BPR} near their average value. One bin equals 10 keV. The discrete step of E_{PMO} determination is about 50 keV. Shapes and widths of the distributions are different.

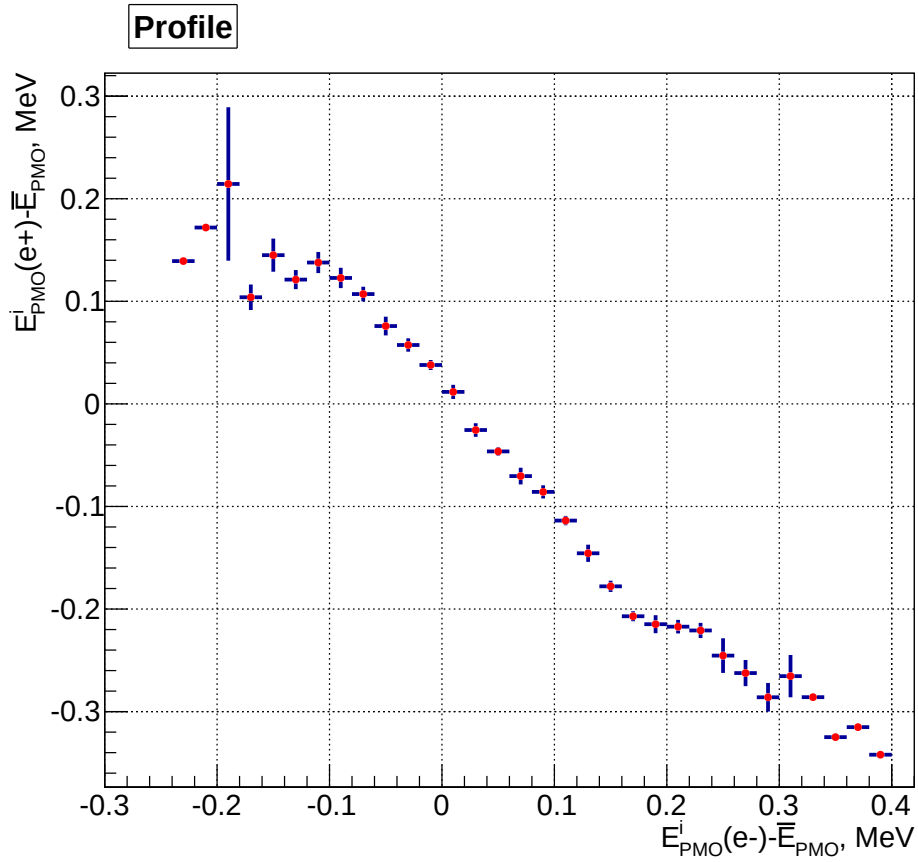


Figure 5: Profile histogram shows strong anti-correlation between E_{PMO}^{BER} and E_{PMO}^{BPR} .

1.1 Conclusion

If one believes that

- E_{PMO}^{BER} and E_{PMO}^{BPR} are determined by the similar but independent algorithms;
- the correlations shown in Fig. 3 and Fig. 5 really exist and are not the result of some bug,

it means that

- BEPC rings beams energies have some jitters/fluctuations with now unclear reason, amplitude and period;
- energy distributions of electrons/positrons, measured by BEMS, and those in the c.m.s. are essentially different;
- therefore, mean energy values of electrons/positrons, measured by BEMS, may be shifted from those in c.m.s.

It's better to understand all possible behaviours of the beam energy before and independently from the BEMS usage and data analysis. BEPC accelerator team should present the results of the stability tests of magnet currents for bending elements. If there are some kind of feedback systems³, e. g. for luminosity optimisation, we should understand the level of their possible influence to the beam orbits and corresponding $\int B(s)ds$ variations. We should be sure that the beam energy, that we're trying to measure, obey the requirements stated in the first sentence of this section with sufficient and understandable accuracy.

2 BES-III i. p. angle

We've performed an i. p. angle reconstruction by the BPMs records in the BES-III database and the i. p. design parameters. The results of these studies have shown, that the difference between the design collision angle $\alpha = 22$ mrad and its real value is in any case less than 5 mrad. This is too small to explain the observed shift in J/ψ mass, measured with BEMS. So this question seems to be closed.

3 BEMS scale calibration

Figure 6 shows the HPGe scale (top-right) and resolution (bottom-left) calibration results while BEPC is off. Blue points on the resolution plot are obtained by pulser peaks fitting. Their widths (σ) are well a constant, which is defined by the combination of HPGe preamp noise and pulser jitter. The widths of the isotopes peaks (red points) are fitted by

$$\sigma(E_\gamma) = \sqrt{N^2 + 2.96 \cdot 10^{-3} \cdot F \cdot E_\gamma},$$

where E_γ is in [keV], N is “noise” in [keV] and F is “Fano” factor. Therefore “noise” is the peak width for $E_\gamma = 0$. One can see that it is smaller than the pulser “noise”, cause the pulser has its own jitter and this should be so.

Figure 7 is the same, but the calibrations were done when there were currents in BEPC. One can see that the pulser peaks widths are no longer a constant as it should be. This seems due to some problem. The reason is that the isotope peaks are completely random in time, while the pulser peaks are not – according to the present version of pulser control program. The pulser stays on one peak for some seconds, than change the pulse amplitude, than another some seconds, etc. This means that the *HPGe spectrometer scale is not stable in a time period of one BEMS measurement*. Most probably this is due to some “occasionally happening” external influence to the HPGe spectrometer.

If we plot the “noise”, defined from pulser and from isotopes calibration for each BEMS measurement, as a function of time one can see the behaviour presented on Fig. 8. The expected behaviour should be constant (or slow drift due to environmental reasons) and practically it is not. This situation is typical for all times of BEMS running with BEPC in operation. On all other “Compton energy meters”⁴ we did not met such an effect.

This effect need to be studied and understood. The HPGe energy resolution is used as a well defined parameter while fitting the edge of the spectrum. If this parameter was not correctly measured during calibration procedure, it may lead to wrong beam energy determination.

³ especially radial orbit corrections

⁴ in Novosibirsk, with low-currents colliders and small amount of beam background

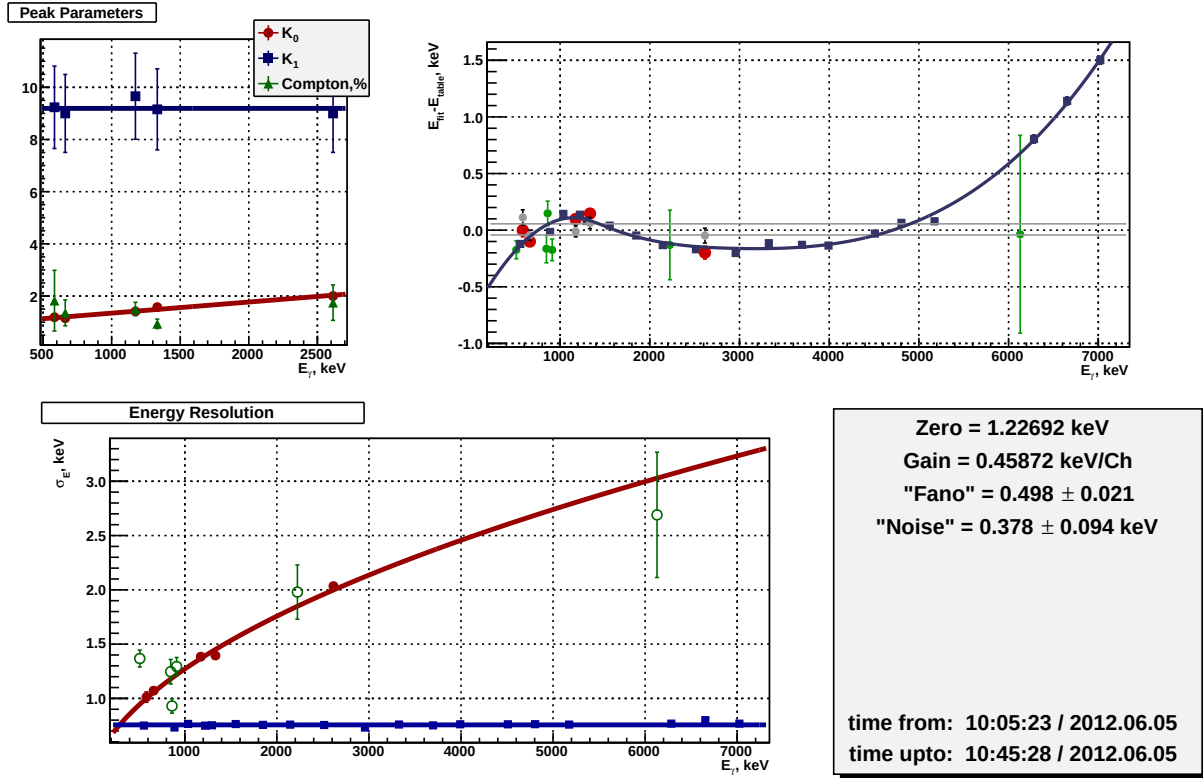


Figure 6: Calibration results example for “BEPC off” status

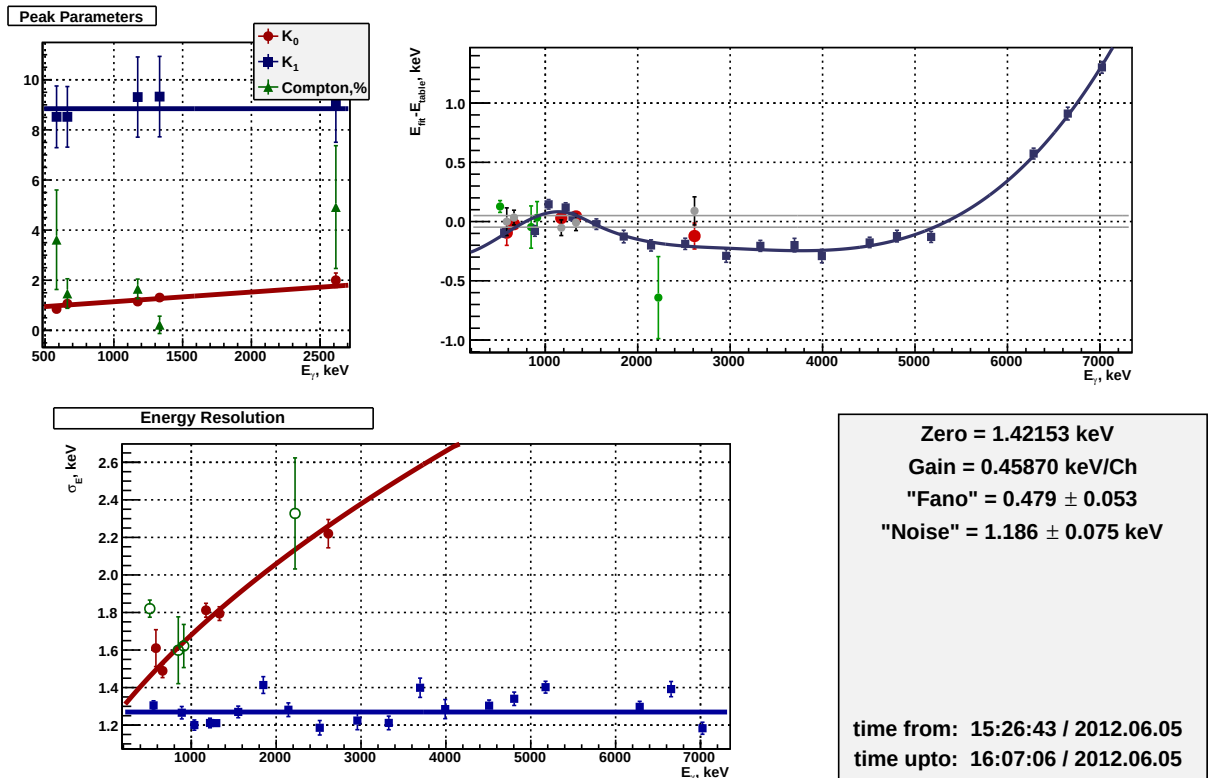


Figure 7: Calibration results example for “BEPC on” status

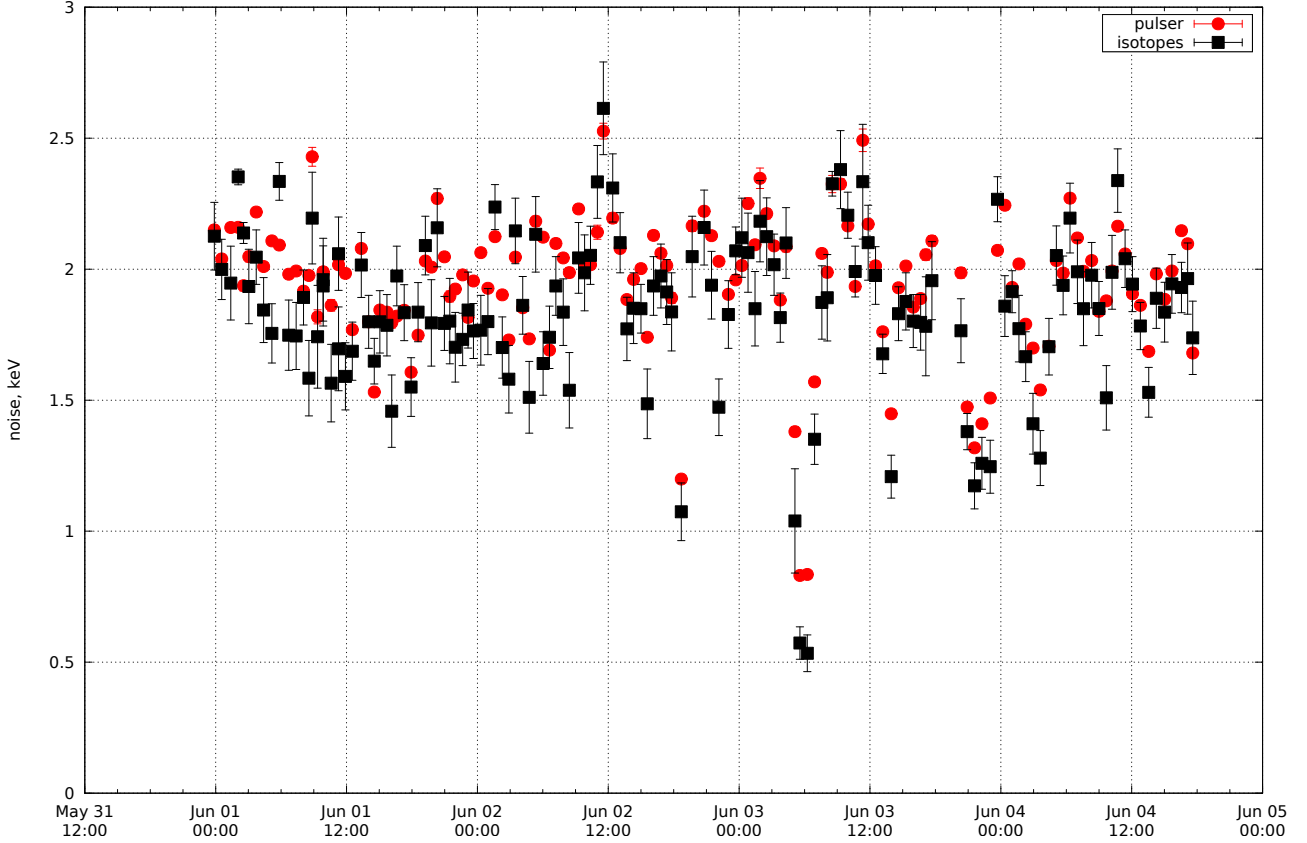


Figure 8: The “noise”, defined from pulser and from isotopes calibration, as a function of time

4 Conclusions

One can fit the J/ψ resonance shape using the beam energies from either E_{BEMS} or E_{PMO} (eq. 3). The results (draft) are presented on Fig. 9 and Fig. 10 correspondingly. Fig. 9 shows that the J/ψ mass is shifted for about 0.5 MeV above its PDG value, and the shape of the resonance is “not good”. Fig. 10 shows that the J/ψ mass is shifted for about 6 MeV above its PDG value, and the shape of the resonance is “much better”.

- E_{BEMS} shows the relative systematic error of about $2 \cdot 10^{-4}$ for absolute beams energy determination. The shape of the J/ψ resonance, obtained with BEMS measurements, indicate some problems with the stability of BEMS results in the narrow energy range.
- E_{PMO} shows the relative systematic error of about $2 \cdot 10^{-3}$ for absolute beams energy determination in 2012 BES run period. However, the differential non-linearity of these measurements in the narrow energy range is better than for BEMS measurements.
- an indication was found for strange behaviour of beams energies, which should be clarified by BEPC team. If this behaviour really exists, it may contribute to the BEMS systematic error in c.m.s. energy determination;
- an issue about “occasionally happening external influence” or “coherent noise” of the HPGe spectrometer does not allow us to be sure in the correctness and stability of HPGe calibration procedure. This should be studied (experimentally) by BEMS team. This may contribute to the uncontrolled “jitter” of BEMS results when BEPC operates in a certain energy point;
- in a whole, it is clear that in case when BES-III experiment requires accurate absolute beam energy measurements, additional time/efforts/checks should be devoted for understanding the situation. Just like we did this in the tau-mass experiment. BEPC-II is historically a first collider with two independent rings where the laser backscattering approach is used for beam energy measurement. So far the situation with BEMS is at least two times more complex than on the earlier facilities.

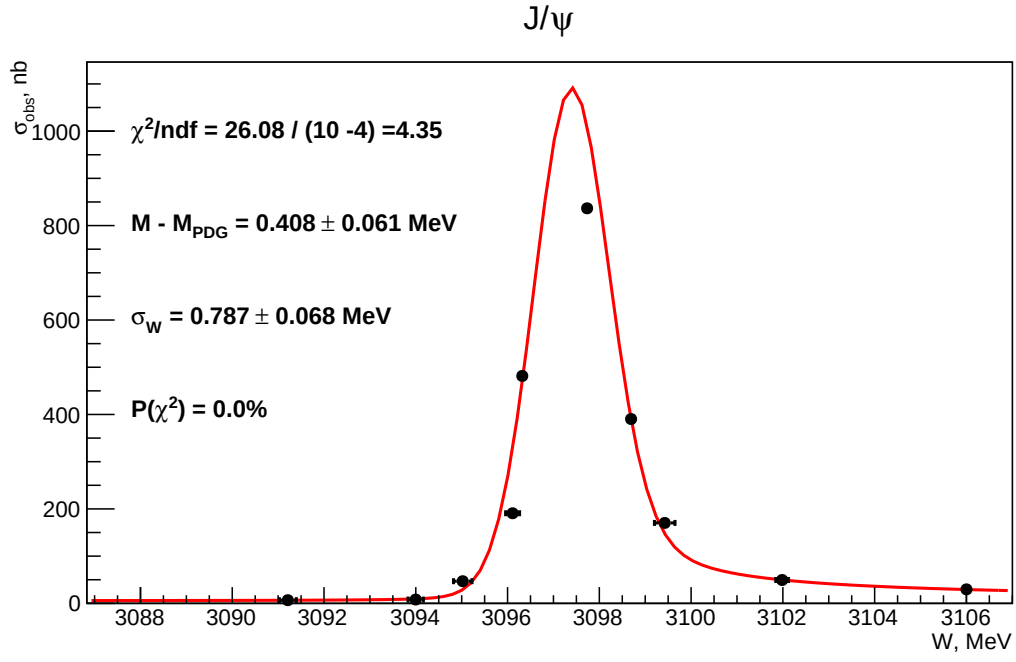


Figure 9: J/ψ scan (June, 2012) with BEMS

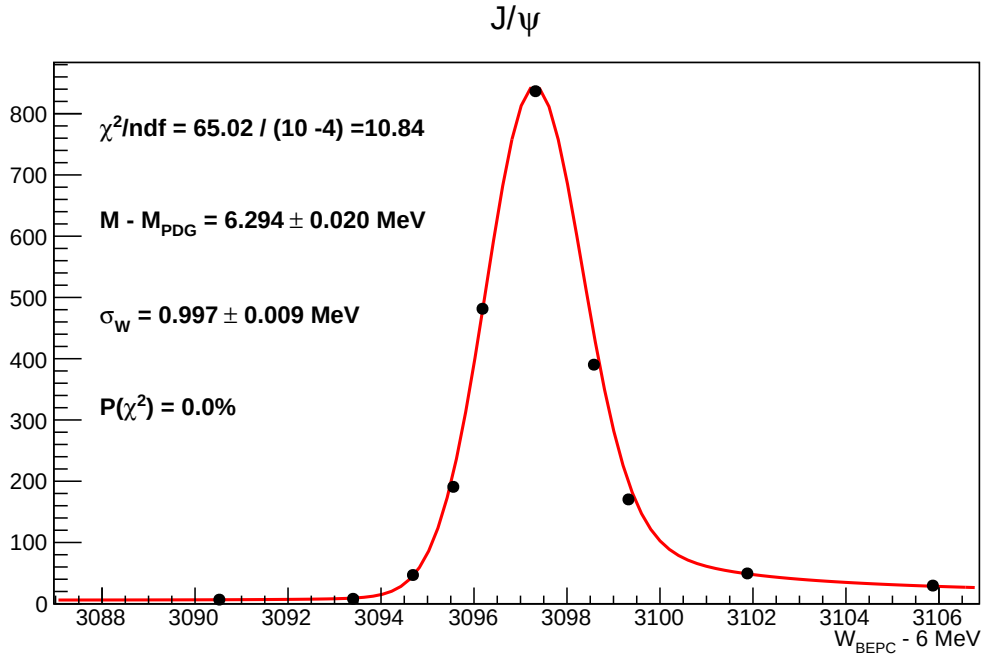


Figure 10: J/ψ scan (June, 2012) with BEPC $\bar{E} = (E_{\text{PMO}}^{\text{BER}} + E_{\text{PMO}}^{\text{BPR}})/2$