# '99 Data Calibration and Quality

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**Abstract**

The new features of BES software V101 is introduced, the calibration status of '99 data is described. Both the detector performance deduced from offline data calibration and data stablity indicate that the data quality can meet needs from $R$ physics analysis.

## 1 Introduction

BES finished its first $R$ scan in last year, the detector, the offline data processing software, the physics analysis codes have all been well tuned. Since then the reconstruction software is greatly improved and fixed as version 101 before the finer $R$ scan in this year. The main new features are

- VC tracks are extrapolated to MDC, it can be turned off by a user card **VCFTNODC** in the `drkcard` file.
- VC tracks are matched to ESC clusters
- MDC tracks may be extrapolated to VC, but this has to be turned on by **RVCMDC=2** in `besior`
- Unformatted VC track dictionaries which can be applied on multi platforms are generated and checked into BESLIB by CODEMAN.
- VC reconstruction is carried out immediatelly after MDC reconstruction, and the VC tracks are merged into MDC tracks.
- Constants are stored under separate directory `~bes/share/const2/v101`. This is true for subsequent BES software versions.
- Endcap TOF is calibrated

A draft documentation for trklst based on that of BESI is available by web at

`http://hpws1.ihep.ac.cn/~bes/trklst2.html`

Version V101 was frozen on Feburary 14 of 1999 by many efforts from both US ans Sino sides, but it's too short a period to check all the codes, and as a result this version has a patch of 34 codes to ensure the reconstruction quality.

'99 data taking with 1505 runs in total this year was started on Jan.11 and stopped on Jun.8. The data can be classfied as three types:

- 221 runs of $J/\psi$ data for offline data calibration and special purposes.
- 130 runs of $\psi'$ data for energy scale and fine scan.
- 1154 runs of $R$ scandata, they are distributed among 85 points in total.

Data status can be consulted by web at

`http://hpws1.ihep.ac.cn/~bescal/v101/v101data.html`

# 2 Calibration

Offline data calibration is a key step at BES offline data analysis. The variation of working conditions of all subdetectors may affect their responses, and hence corrections are necessary to achieve the optimized performances.

## 2.1 Main Drift Chamber

The Main Drift Chamber (MDC) is the main subdetector at BES to measure the trajectories and momenta of charged particles, and hence it plays an important rule in $R$ physics analysis to count on charged particles in $e^+e^-$ final states.

The MDC is composed of array of signal wires which record information on particle tracks. Before the MDC reconstruction, one has to find out two stuffs for each MDC wire: does it work? and how does it work?

To answer the first question, one has to find out MDC dead wires which are not involved in reconstruction. MDC dead wires are defined as those with hits less than 3% of layer average. Tens of cells in layers 7-10 have their HV on field wires turned off due to broken wires, and as a result about 130 dead wires are found this year.

Even though a wire works, one has to find some relevent parameters so that it can work well in reconstruction. TDCs and geometric positions are insufficient in MDC reconstruction, $t_0$'s, drift velocities, and true surveys are needed:

$$\left\{\begin{array}{rcl} t & = & 1.8182\cdot(\mathrm{TDC}-T_0-t_0-t_0^{Qt})-\mathrm{TOF}, \\ d^{exp} & = & \left\{\begin{array}{ll} v_n(t-t_{off}), & \text{near} \\ v_c(t-t_n)\cos\Theta+v_n(t_n-t_{off}), & \text{constant field} \\ +v_n(t-t_n)^2, & \text{far} \end{array}\right. \\ d^{cal} & = & d(\mathrm{trkParameter},\mathrm{survey}), \end{array}\right.$$

where $t$, $d$, and $v$ are drift time, distance, and velocity separatelly.

In the MDC calibration this year,

- `bb` data of $J/\psi$ Runs 11971-12035 are used.
- 2 files of constants are generated:
  - `dcsurvey.newbes` is the constant file to store MDC wire surveys.
  - `dcc12035.offcons` is the constant fire to store MDC wire $t_0$ shifts, drift velocities etc.

In Fig. 1 are shown the momentum ans residual distributions of MDC.

## 2.2 Vertex Chamber

Similar to MDC, what one can obtain from Vertex Chamber (VC) rawdata are its TDC's of fired wires. The VC reconstruction is to fit the helix track by calculating the drift distances from both TDCs and survey parameters:

$$\begin{cases} t &= 2\cdot(\mathrm{TDC}-T_0-t_0), \\ d^{exp} &= vt, \\ d^{cal} &= d(\mathrm{trkParameter},\mathrm{survey}). \end{cases}$$

From formulas above one can see that it's important to get the $t_0$ shifts, the drift velocities $v$'s, and the true surveys.

In VC calibration this year,

- `bb` data of $J/\psi$ Runs 11971-11999 are used.
- Two files of constants are generated: `vcsurvey.bes, vcc11999.offcons`.

In Fig. 2 are shown the residual distributions from `bb` data of $J/\psi$. For VC tracks, matched MDC hits are involved in final helix fit in V101, this gives a larger spatial resolution. If MDC hits are taken away, however, a better spatial resolution can be achieved.

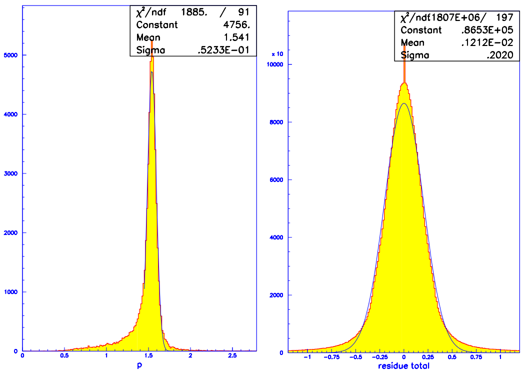


Figure 1: Momentum and spatial resolutions of MDC from $J/\psi$ data.

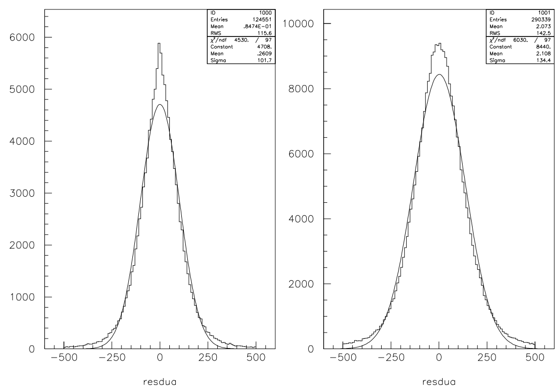


Figure 2: Spatial resolution of VC. MDC hits are not involved on left.

## 2.3 Muon Chamber

The $\phi$-position of $\mu$ hit is determined geometricly, and the $z$-position is calculated by charge division method which has an accuracy of 1% of the effective length, namely,

$$\begin{cases} Z = \alpha R + \beta, \\ R = \dfrac{Q_{big}}{Q_{big} + \gamma Q_{small}}, \end{cases}$$

where $Q$ is the pulse height of $\mu$ hit, $\alpha$ and $\beta$ are coefficients of charge division which are calibrated, $\gamma$ is the scale factor of pulse heights from two ends of a wire pair which is provided by online.

To calibrate the muon chamber this year,

- `mu` data of $J/\psi$ Runs 11971-12057 are used.
- One file of constants `muz12057.offcons` is generated.

In Fig. 3 are shown the $z$ resolutions for three layers of muon chamber. They are worse than those of BESI, but similar to BESII data in last year. A possible solution to improve the $z$ resolutions is to calibrate the coefficients $\gamma$.

## 2.4 Barrel Shower Counter

The energy response of shower counter changes with gas compositions, working HV, and temperature as well, and hence the scale factors have to be calibrated in each short period, suppose that the statistics is high enough. For the Barrel Shower Counter (BSC), one has

$$\begin{cases} E_{\text{REC}} = \dfrac{E_{\text{RAW}}}{C_\phi C_Z}, \\ Z_{\text{REC}} = C_1 \cdot Z_{\text{RAW}} + C_2. \end{cases}$$

For all data taken this year,

- BSC is calibrated once for each 20-30 runs, `bb` data are used.
- 83 files of BSC calibration constants like `bsc13475.offcons` are produced.

In Fig. 4 are shown the energy distributions of BSC clusters before and after the calibration.

## 2.5 Endcap Shower Counter

The calibration of Endcap Shower Counter (ESC) is much similar to that of BSC, but the scale factors are in 2-dimensional:

$$E_{\text{REC}} = C_{\phi\theta} \cdot E_{\text{RAW}}.$$

ESC is also sensitive to working environment, hence

- it's calibrated once for each 20-30 runs, `nu` data are used here, and
- 78 ESC calibration constant files are generated, the last one is `esc13475.offcons`.

The comparisom of energy distributions of ESC clusters before and after calibratoion can be seen from Fig. 5.

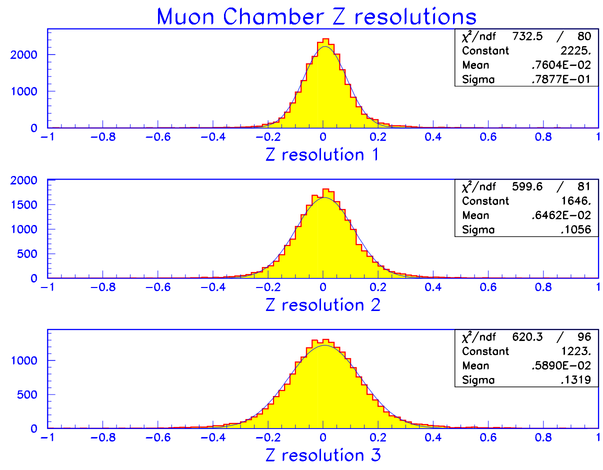


Figure 3: $z$ resolutions of muon chamber layers.

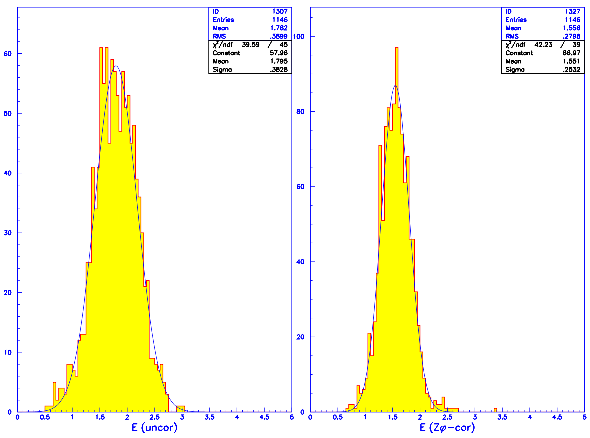


Figure 4: BSC energy distributions before and after corrections.

## 2.6 Barrel TOF

To achieve the optmized time resolution of TOF counter, the time of flight which is calculated from measured TDC, is corrected according to its ADC, hit position, and $T_0$ offset etc.:

$$\begin{cases} \mathrm{TOF}^{exp} &= \dfrac{\mathrm{TDC}}{70} - - \left(b_1 + \dfrac{b_2 + b_3 Z}{\sqrt{Q}} + b_4 Q + b_5 Q^2 \right. \\ & \quad \left. + b_6 Q^3 + \dfrac{b_7}{R^2 + Z^2} + b_8 Z + b_9 Z^2 + b_{10} Z^3 + T_0 \right), \\ \mathrm{TOF}^{cal} &= \dfrac{\mathrm{PATH}}{p/\sqrt{m^2+p^2}}, \\ Z &= \dfrac{\mathrm{TOF}^{\mathrm{east}} - \mathrm{TOF}^{\mathrm{west}}}{\dfrac{b_3^{\mathrm{east}}}{\sqrt{Q^{\mathrm{east}}}} + \dfrac{b_3^{\mathrm{west}}}{\sqrt{Q^{\mathrm{west}}}} + b_8^{\mathrm{east}} + b_8^{\mathrm{west}}}. \end{cases}$$

The calculation of time of flight depends on $T_0$, and the working of the counter is sensitive to HV etc., hence

- it's calibrated once for each 30-100 runs, `bb` data are used,
- 32 files of TOF constants like `tof13475.offcons` are produced.

The time resolution and $z$ resolution of BTOF are shown in Fig. 6.

## 2.7 Endcap TOF

Calibration of Endcap TOF (ETOF) is similar to that of BTOF:

$$\mathrm{ETOF} = \frac{\mathrm{TDC}}{70} - \left(e_1 + \frac{e_2 + e_3 R}{\sqrt{Q}} + \frac{e_5 + e_6 R}{Q} + e_8 R + e_9 R^2 + e_{10} R^3 + T_0\right)$$

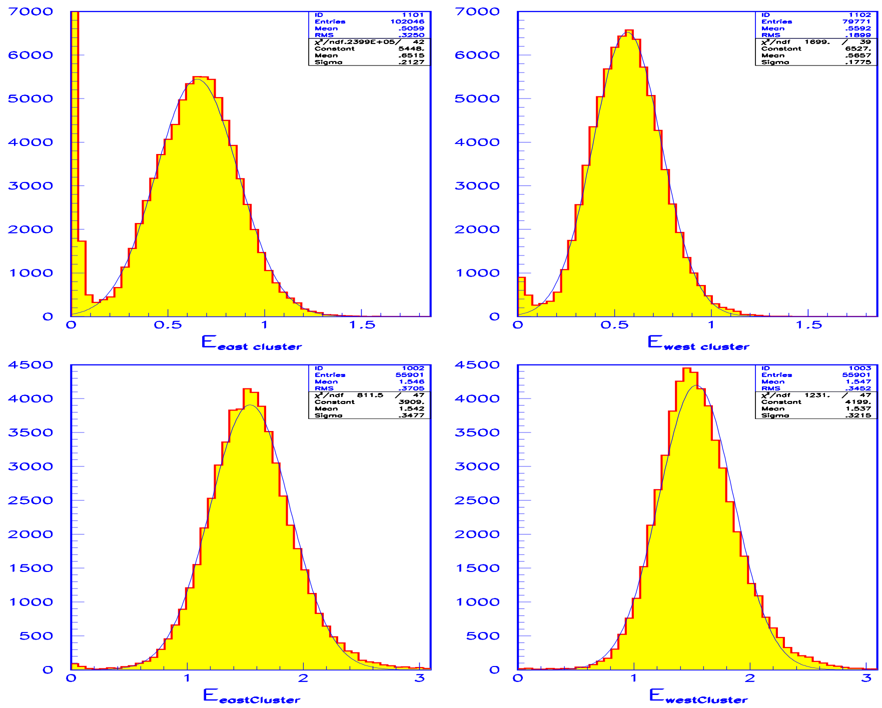


Figure 5: ESC energy distribution before and after corrections.

- Tt's calibrated once for each 30-100 runs,**nu** data are used.
- Constants of ETOF are stored in the same files as BTOF.

In Fig. 7 is shown the time resolution of ETOF.

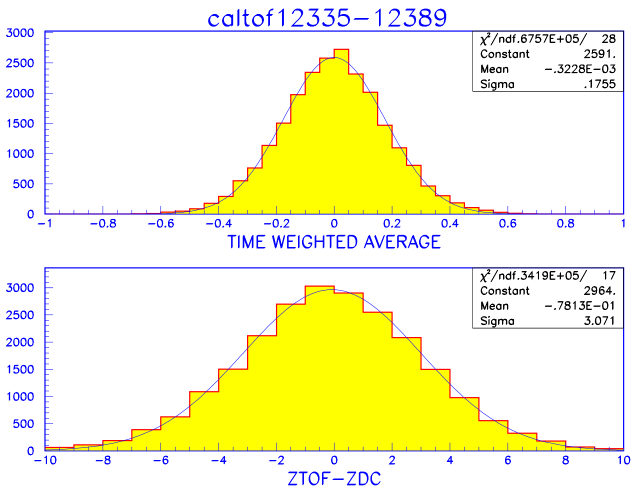


Figure 6: Resolutions of time and $z$ for BTOF.

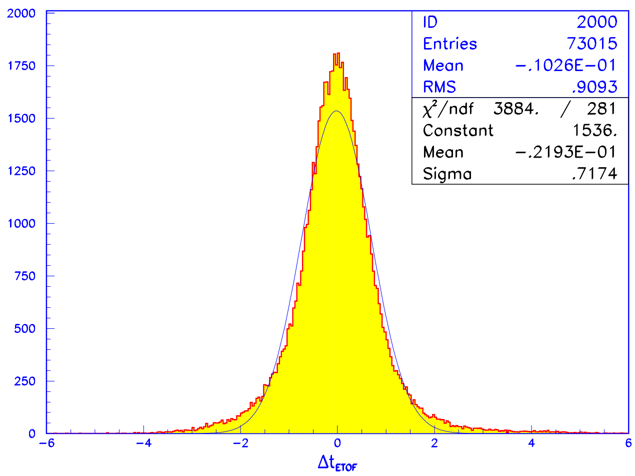


Figure 7: ETOF time resolution.

## 2.8 dE/dX

dE/dX is very important to particle identification, the raw pulse height has to be corrected by wire gains, left-right asymmetry, space charge saturation, and the attachment effect etc.:

$$\begin{cases} Q & = \dfrac{\mathrm{Q_{raw}} \cdot \sin\theta}{G_W G_L}(1+NF) \times \dfrac{f_S(40)}{f_S(\theta)} \times \dfrac{f_a(5)}{f_a(d)}, \\ f_S(\theta) & = s_0 + s_1\theta + s_2\theta^2 + s_3\theta^3, \\ f_a(d) & = a_0 + a_1 d + a_2 d^2 + a_3 d^3, \\ dE/dX & = 1286.6\dfrac{< Q >_{\mathrm{trk}}}{< Q >_{\mathrm{run}}}. \end{cases}$$

For the calibration of dE/dX,

- the systematic correction constants are obtained first by `bb` data of $J/\psi$,
- and then the run depedent quantity $< Q >_{\mathrm{run}}$ is calculated for each run by using `bb` data.
- 10 files of dE/dX run-by-run calibration constants like `dex13475.offcons` are produced.

In Fig. 8 are shown the dE/dX distributions with $\cos\theta$ for both before and after the correction.

# 3 Data quality

The noise problem was succesfully solved before data taken this year, this can be seen from the distribution of the averaged number of hits per event with run number. From Fig. 9 one can see that the number of signals in Q channel is smaller than that in T channel.

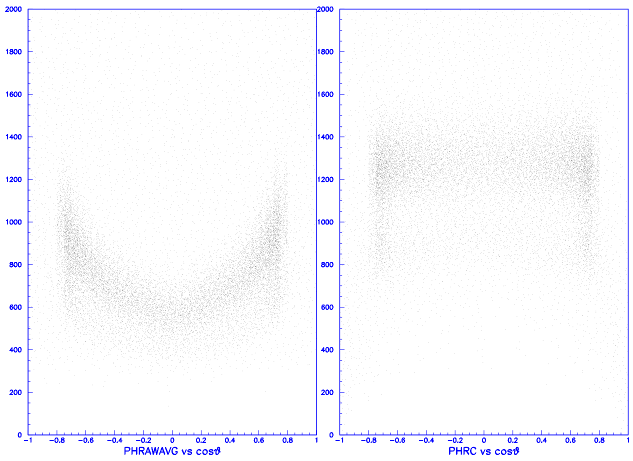


Figure 8: $\cos\theta$ distribution of dE/dX before and after correction.

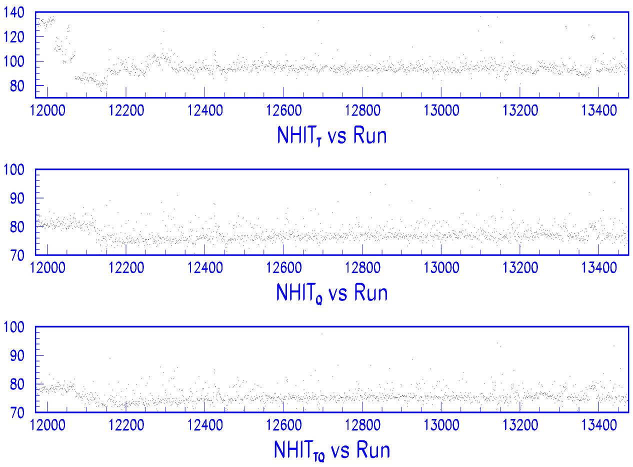


Figure 9: Variation of averaged number of hits per event with time.

As seen from MDC dead channel calibration, the MDC has "missing" cells in layers 7-10 at a $\phi$ angle of about 125°. Due to the decreasment of sampling times, the tracking efficiency in this region is a little bit lower than those in other regions, and the momentum resolution is worse as being expected (Fig. 10). However, such tracks can still pass the selection for $R$ physics analysis.

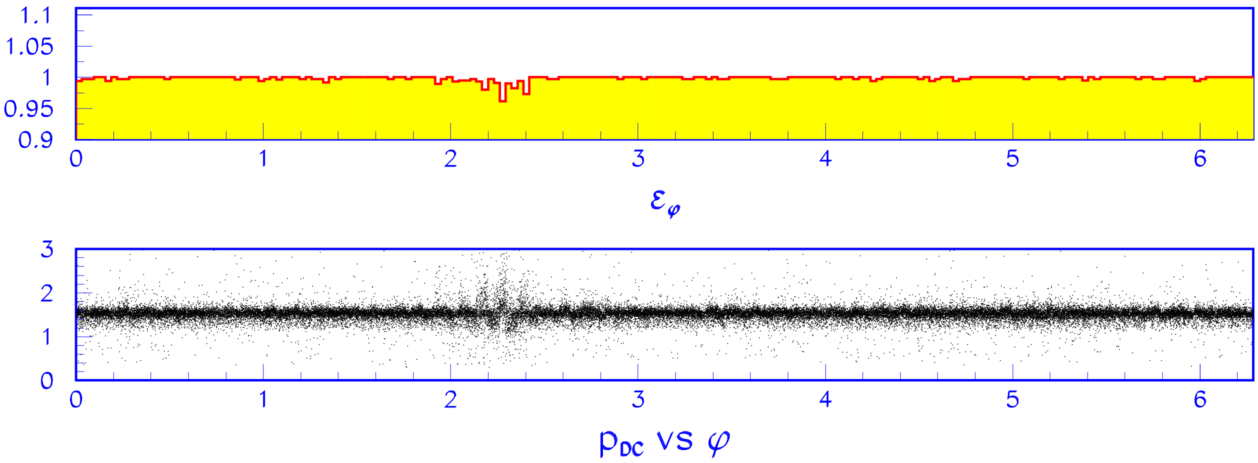


Figure 10: Effection on tracking efficiency and momentum resolution by "missing" cells.

The $R$ scan this year lasted for five months, the timing system varies very often, this can be seen from the MDC $T_0$ variation with time shown in Fig. 11, and it affects the MDC momentum resolution by a factor of 1.5. The reason is that MDC wire $t_0$ shifts are not calibrated run-by-run, the better solution is to get the run-dependent global $T_0$ and subtract it from TDC in each run. The run-by-run calibrated subdetectors like the dE/dX, though the pulse height changes very often, the dE/dX resolution keeps flat with time as can be seen in Fig. 12. This is true for SC (Fig. 13) and TOF (Fig. 14).

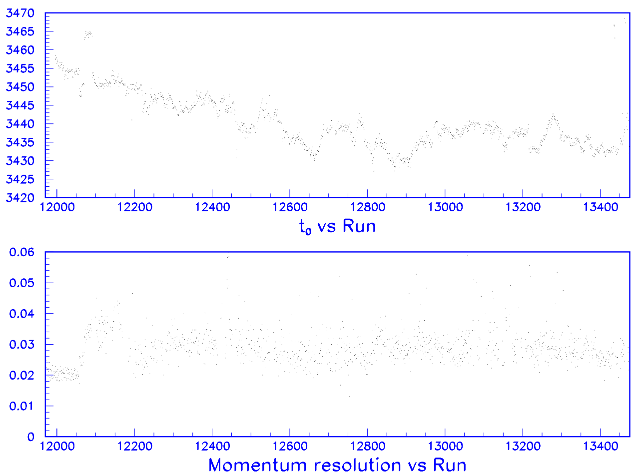


Figure 11: Variation of MDC global $T_0$ with time and it's effection on MDC momentum resolution.

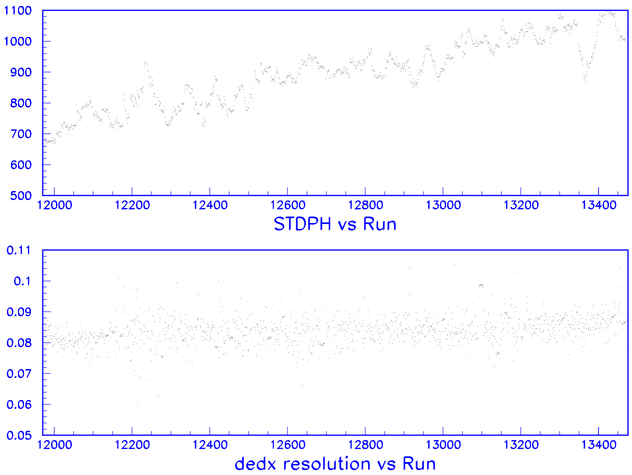


Figure 12: Variation of dE/dX before run correction with time, and dE/dX resolution with time.

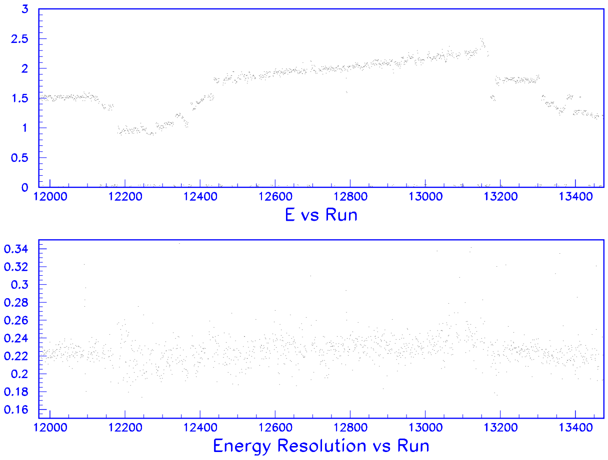


Figure 13: Variation of BSC energy and energy resolution with time.

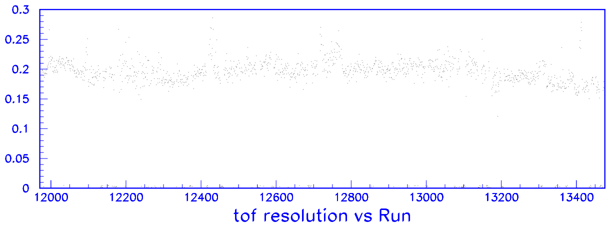


Figure 14: Variation of TOF time resolution with time.

# 4 Detector Performance

In Tab. 1 are shown the detector performance from offline data calibration by $J/\psi$ data.

Table 1: Detector Performance

| Subdetector | Performance |
|---|---|
| VC | $\sigma = \begin{cases} 100\mu\text{m}, & \text{VC only} \\ 133\mu\text{m}, & \text{With DC} \end{cases}$ |
| DC | $\begin{cases} \sigma_p = 52\text{MeV} \\ \sigma_{sp} = 202\mu\text{m} \end{cases}$ |
| TOF | $\begin{cases} \sigma_T = 175.5\text{ps} \\ \sigma_Z = 3.1\text{cm} \end{cases}$ |
| ETOF | $\sigma_T = 717.0\text{ps}$ |
| BSC | $\begin{cases} \frac{\sigma_E}{E} = \frac{21\%}{\sqrt{E}} \\ \sigma_Z = 2.5\text{cm} \end{cases}$ |
| ESC | $\frac{\sigma_E}{E} = \begin{cases} \frac{24.6\%}{\sqrt{E}}, & \text{East} \\ \frac{23.8\%}{\sqrt{E}}, & \text{West} \end{cases}$ |
| $\mu$ | $\sigma_Z = \begin{cases} 7.9\text{cm}, & \text{Layer 1} \\ 10.6\text{cm}, & \text{Layer 2} \\ 13.2\text{cm}, & \text{Layer 3} \end{cases}$ |

# 5 Conclusion

All runs this year have been calibrated three days after BES data taking stopped.

- MDC survey and $t_0$, dE/dX systematic correction, VC survey and $t_0$, Muon chamber are calibrated only once.
- MDC dead channels were calibrated several times.
- BSC/ESC, BTOF/ETOF, and dE/dX run-dependent correction are calibrated very often.

From the data quality, one can see that the run-by-run calibrated subdetectors can have stable performance, otherwise the optimized performances are not achieved. BES reconstruction software development and offline data calibration group may have to improve the calibration, and hence reconstructed data in good quality can be obtained at any time period. This is very important to the $J/\psi$ data taking in next two to three years.

However, the detector performance from calibration this year still satisfies requirements from $R$ physics analysis in general.

The calibration group has also spent much time to improve the quality of BES endcap tracks. This includes the track match between the vertex chamber and the endcap shower counter, the detailed calibration of both endcap shower counter and endcap time of flight counter. This is very useful to enlarge the accepatance in physics analysis.