Luminosity measurement at AMY

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Abstract

A precise measurement of a luminosity is required by experiments with high statistics. The largest sources of a systematic error of a luminosity measurement are an alignment of the tube chambers which measure a polar angle of Bhabha events and a higher order correction for the Bhabha cross section calculation. We describe a resent study for these uncertainties and how to reduce the systematic errors from these sources. The total systematic error of the luminosity measurement of 1.8% can be reduced to 1.0% by this study.

1 Introduction

The luminosity of the AMY experiment is measured by the Endcap Shower Counter (ESC) by counting the number of Bhabha events. A structure and performance of the ESC is reported at a last TRISTAN Workshop[1]. Details of the luminosity measurement and its systematic errors are also summarized in ref.[1]. For the precise study of the standard model of the electro-weak and strong interactions by the AMY experiment with high statistics, the precise measurement of the luminosity to 1% level is required. Sources of the systematic error of the luminosity are summarized in a table-1. The largest contributions come from alignment of the ESC and from a higher order correction for the Bhabha cross section calculation.

The ESC has resistive tube chambers between front- and rear-calorimeters. A polar angle of the Bhabha event is measured by this chamber with 0.2 degree accuracy. The angular distribution of the Bhabha scattering has a steep forward peak, $d\sigma/d\cos\theta \propto 1/\theta^4$. Then uncertainty of the position of the ESC chamber is very important.

The measured event rate is compared with the theoretical calculation and translated into the luminosity. Since the theoretical calculation of the cross section is performed perturbatively, a contribution from higher order terms is always a source of the systematic error. We discussed these two sources in this report.

2 ESC chamber alignment

2.1 Survey of the ESC

For the precise measurement of the luminosity, we should know the precise location of the θ-pad boards of the ESC with respect to a interaction point. θ-pad boards have cross-hair lines as fiducial points at 1112mm of radius and every 15 degree in azimuth. As the reference points on the ESC iron we use the corner of the notch which is cut at every 7.5 degree in azimuth on the outer edge of the iron. We have measured distance between the cross-hair line and the corner of the nearest notch along the radius (r), azimuth (ϕ) and perpendicular-to-the-iron (z) directions by rulers. Three points on each θ-pad board were measured. To estimate the accuracy of the survey and to get the most probable position of the board, we have used a fitting method under the constraint that distance between two measured points on one board should be the nominal value. From χ^2-distribution on the fitting, a 64% C.L. error of the survey is estimated to be 0.8mm on the board plane and 0.6mm for a z-direction. A dimension of the endcap iron is measured by Mitsui-zosen company with accuracy of 0.01mm. A deviation from an original design is around 0.1mm.

2.2 Location of the endcap iron

The x- and y-position of the interaction point, which is not the center of the detector, is surveied with respect to the AMY detector by A. Sill. The z-position is estimated by a TRISTAN alignment group taking into account the arc length difference along the accelerator magnets. The location of the endcap iron is determined by the location of the end-ring. A deviation of the end-ring location from the nominal one is surveied by A. Sill[2]. We estimate the deviation of the location of the endcap iron from the nominal location to be $(x, y, z) = (-0.7 \pm 0.4, -0.8 \pm 0.4, +2.6 \pm 1.3)$mm.

Finally we estimate the location of the θ-pad board with accuracy of 0.9mm in x- and y-direction and 1.5mm in z-direction.

2.3 Bhabha-event based alignment

The position of the θ-pad board is obtained by the optical survey of the detector and the accelerator magnet. That is very indirect method. Moreover after the survey by the TRISTAN alignment group final Q-magnets have been replaced by the superconducting ones. We have to keep a large safety factor to estimate the systematic error. The systematic error of 1.22% for the luminosity measurement is estimated based on the result of the survey with safety factor of 2. We need an independent measurement of the θ-pad board to estimate a reliable value of the systematic error. we used 'Bhabha-event based alignment' for this purpose.

If the ESC is located at the nominal position, polar-angle difference between two sides(so called Fuji-side and Tsukuba-side), $|\theta_{Fuji} - \theta_{Tsukuba}|$, should distribute around zero. We fitted the chamber position to make those distribute around zero. The ESC chamber at one side is divided into two parts, wall- and hat-parts. There are four independent chambers, Fuji-wall Fuji-hat, Tsukuba-wall, and Tsukuba-hat. Then there are 11 free parameters, a x-y position of each chamber and a x-y-z position of the interaction point.

At first we fix all chamber positions and fit the interaction point for three different run period. The interaction point also can be measured by the central drift chamber. The result of the fitting is summarized in Fig.1 for x-y direction and in Fig.2 for z-direction. The result of the optical survey is also plotted in figures. All results are consistent each other as shown in figures. We have estimated the uncertainty of the interaction point is 1mm in x-y plane and 2mm in z-direction.

Next we fix the position of three chambers and the interaction point and fit the position of one chamber. We only get a relative position of the chamber with respect to the opposite chamber by fixing the interaction point. Results are summarized in a table-2. We conclude that Tsukuba-wall or Fuji-hat chamber moved down to 1.9mm. The error of this fitting is estimated to be 1mm for Tsukuba-hat and Fuji-wall and 2mm for Tsukuba-wall and Fuji-hat.

We estimated the systematic error of the luminosity measurement based on this fitting to be 0.65%.

3 Higher order correction

To calculate the cross section of the Bhabha process, we use the program developed by Tobimatsu and Shimizu(T-S)[3], which includes a full $O(\alpha)$ collection. To estimate a contribution from higher order corrections, we compare the result with ALIBABA developed by Beenekker et al.[4] and QEDPS developed by Munehisa et al.[5]. ALIBABA includes full correction at $O(\alpha)$ and a leading-log correction at all orders, but it is not a event generator. QEDPS includes a leading-log correction at all orders and can generate weight-one events. Cross sections with two angular range are summarized in a table-3.

ALIBABA is using the scheme, $\sigma = \sigma_0(1+\delta_W)(1+\delta_\gamma)$, where σ_0 is the Born cross section and δ_W is a weak correction and δ_W is a photonic correction. On the other hand the T-S is using, $\sigma = \sigma_0(1+\delta_W+\delta_\gamma)$. To compare theses results, we reconfigure the ALIBABA result to the T-S scheme. At the $O(\alpha)$ correction T-S results are consistent with ALIBABA's within a statistical error of a Monte Carlo integration after reconfiguring the correction scheme. The QEDPS gave consistent results with ALIBABA, if we remove the non-log correction from ALIBABA. We can conclude that the *technical error* is negligible.

If we compare the T-S result with the full-corrected ALIBABA, we can see the contribution from the higher order correction is 0.5% for our angular region. It should be assigned to the systematic error of the luminosity measurement.

4 Summary

We have estimated the systematic error of the luminosity measurement due to the alignment of the ESC chamber and due to the higher order correction. For the alignment error, 'Bhabha event based alignment' gave a independent information of the ESC chamber position and can reduce a systematic error to 0.65%. The detailed comparison among the T-S program, ALIBABA, and QEDPS gave the contribution from the higher order correction to be 0.5%. New systematic error is 1.0% in total.

References

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Source	Systematic Error (%)
(1) Acceptance Estimation	**0.48**
numerical integration	0.05
MC statistics	0.25
angular resolution	0.39
energy resolution	0.03
beam spread	0.13
(2) Background Correction	**0.04**
Alignment	**1.22***
x,y-direction	0.90
z -direction	0.72
beam position	0.40
(4) Higher Order Correction	**1.1****
Miscellaneous	**0.4**
chamber efficiency	0.05
trigger efficiency	negligible
Lorents angle	0.4
Total	**1.8*****

Table 1: The systematic errors of the luminosity at the AMY detector. After this study, newvalues are *) 0.65, **) 0.5, ***) 1.0.

Chamber	x (mm)	y (mm)
Tsukuba-Hat	+0.2	-0.5
Tsukuba-Wall	-0.2	-1.9
Fuji-Hat	-0.3	-1.9
Fuji-Wall	+0.3	-0.6

Table 2: Fitted potision of the ESC chambers from their nominal position.

σ(pb)	a $16° < \theta < 164°$	b $34° < \theta < 146°$	a-b
T-S	3.477 ± 0.003	0.5859 ± 0.0004	2.891
QEDPS	3.4952 ± 0.0035	0.5965 ± 0.0006	2.8987
ALIBABA (full)	3.4946 ± 0.0082	0.5890 ± 0.0007	2.9056
ALIBABA (w/o non-log)	3.4981	0.5955	2.8963
ALIBABA ($O(\alpha)$)	3.54558 ± 0.0096	0.5790 ± 0.0007	2.8768
ALIBABA ($O(\alpha)$*)	3.4824	0.5850	2.8974

Table 3: Bhabha cross sections of three independent programs.
*) Reconfigured for T-S scheme.

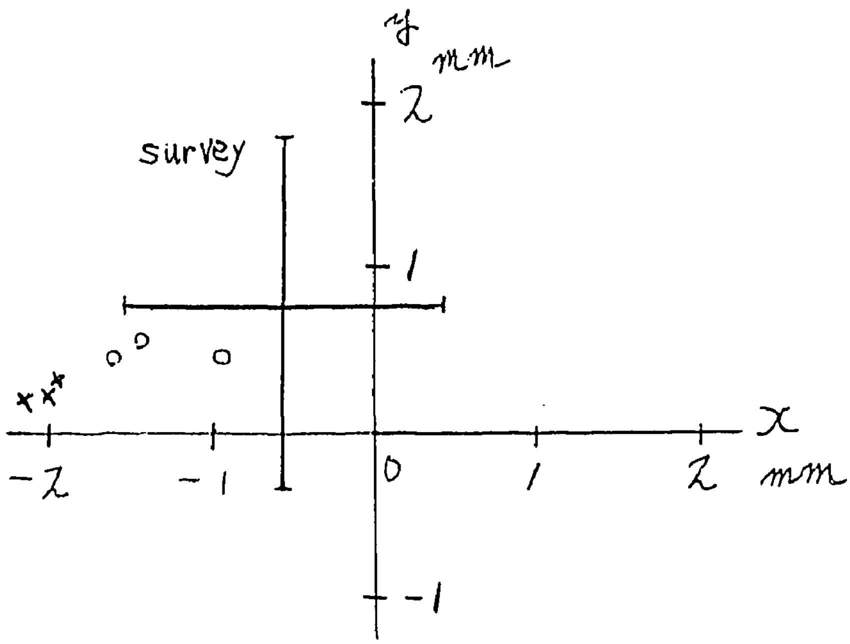

figure 1: Fitted x-y positions of the interaction point for tree run-periods. Circlrs show potisions measured by the ESC and crosses by the CDC. The result of the optical survey is also shown.

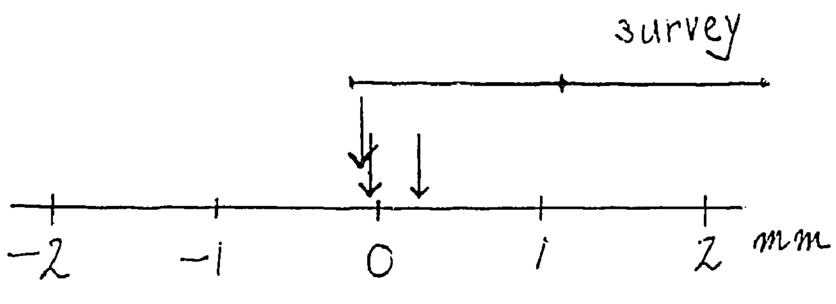

figure 2: Fitted z positions of the interaction point for tree run-periods by the ESC. The result of the optical survey is also shown.