Luminosity Determination for 99 R-scan Data

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June 15th, 1999

1 Introduction

In the determination of R value at IHEP [1], the following formula is used to calculate R,

$$R = \frac{N_{had}^{obs} - N_{bg} - \sum_l N_{ll} - N_{\gamma\gamma}}{\sigma^0_{\mu\mu} \cdot L \cdot \epsilon_{had} \cdot \epsilon_{trg} \cdot (1+\delta)}, \tag{1}$$

where L is the luminosity. In general, we calculate L via:

$$L = \frac{N_{evt}}{\sigma \cdot \epsilon \cdot \epsilon_{trg}}, \tag{2}$$

where N_{evt} is the number of real events in the particular channel being studied (Bhabha, $\mu^+\mu^-$, etc), σ is the cross-section of the process, ϵ is the detection efficiency of the process, and ϵ_{trg} is the trigger efficiency for the process (taken to be ≈ 1 for these studies).

2 Methods

A number of different channels and analysis methods are used to obtain the luminosity for a few initial data points in the 1999 run. They are:

1. Find Bhabhas via BSC info only ("Changzheng's method");
2. Find Bhabhas via BSC info only ("Zhiyong's method");
3. Find Bhabhas using both dE/dx and BSC ("Derrick's method");
4. Using dimuons;
5. Using $e^+e^- \to \gamma\gamma$ events.

In the following sections, we review each method and then compare the results.

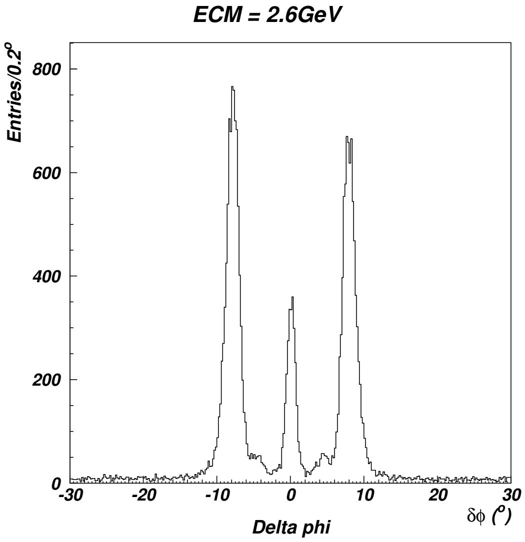

Figure 1: Plot of events vs phi angle, taken from Ref [2]. The region from 16 to 30 degrees is taken as background and subtracted from the region between 2 and 16 degrees to obtain the final number of events.

3 BSC info: "Changzheng's method"

This method was the "official" method for the 98 R-scan data.[2] The basic plan is to look for Bhabha events using BSC info only, then reject $e^+e^- \to \gamma\gamma$ events. The event selection used is:

- Find two clusters with largest BSC energy.
- Each must be > cutoff (1.0 GeV for 3.55 GeV data, scaled for rest).
- Both have $|\cos\theta| < 0.55$.
- Remove events directly back-to-back (2γ events): $|\delta\phi| = ||\phi_1 - \phi_2| - 180| > 2$ degrees.
- Further subtraction of flat background (see Fig 1)

To determine the efficiency of the cuts, a Bhabha sample is selected from the same data set without any information/systems used in the event selection. Then, the event selection criteria were used on this independent sample. Cuts used for the independent sample are:

- NCHRG = 2;
- MFIT = 2 for both tracks;
- $\left|\frac{Z_{sc}}{\sqrt{Z_{sc}^2+1.283^2}}\right| < 0.55$ for both tracks with Z_{sc} from subtype 11;
- $\Sigma dE/dx > 2400$;
- $\sqrt{p_+^2 + p_-^2} > 0.35E_{cm}$;
- TQL= 1 for both tracks;
- $|TOF_+ - TOF_-| < 1.0$ ns;

- $|VR_+ + VR_-| < 0.01$m ($R - \phi$ vertex);
- $|VZ_+ + VZ_-| < 0.20$m (Z vertex).

The resulting selection efficiencies are generally in the 80-90% range.
For the Monte Carlo sample, the radee generator is used, with $|\cos\theta| < 0.85$.

4 BSC info: "Zhiyong's method"

This method is a variant of Changzheng's method. The same cuts and method are used, except:

- $|\cos\theta| < 0.71$;
- Rib regions of the barrel shower counter (BSC) ($|Z| < 0.1$m, $0.8 < |Z| < 1.05$m) are cut because information in that region cannot be modelled via the Monte Carlo properly.

5 Derrick's method

This method [3] involves selecting Bhabha events using either BSC info or dE/dx info based on whether BSC info is good (rib regions). Two types of cuts are used in event selection; geometric cuts and PID cuts. The geometric cuts used are:

- NCHRG = 2, $\Sigma Q = 0$;
- MFIT = 2 for both tracks;
- $|Z_{sc}| < 1.5$m;
- $\theta_{acoll} < 0.05$ rad;
- $|\Delta TOF| < 4.0$ ns;

We further define rib regions (as in Zhiyong's method) of the BSC to be $|Z| < 0.04$m, $0.8 < |Z| < 1.0$m where shower counter information is not used.

The efficiency for geometric cuts is determined by applying above cuts to the Monte Carlo generator radee, using a cut of $|\cos\theta| < 0.85$. The efficiency is approx 40% for the listed cuts.

Further particle ID cuts (PID) are then applied based on whether the events tracks are in the rib or non-rib regions. For non-rib regions, the cuts are

- $(E/p)_1 > 0.5$ and $(E/p)_2 > 1.0$ OR
- $(E/p)_1 > 1.0$ and $(E/p)_2 > 0.5$ OR
- $\sqrt{((E/p)_1 - 1.0)^2 + ((E/p)_2 - 1.0)^2} < 0.7$.

For the rib regions, the cuts are

- $XSE_1 > 0.0$ OR
- $XSE_2 > 0.0$ OR

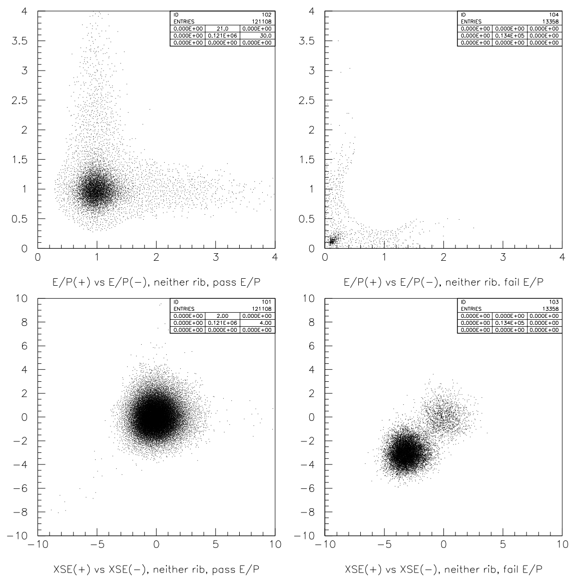

Figure 2: Derrick's method, taken from Ref [3]. Top graphs show E/p cut; events on left pass cut, events on right fail cut. Lower graphs show XSE values corresponding to events in the graphs above. In lower right, events clustered around (0,0) are good events removed by E/p cut, indicating efficiency.

- $\sqrt{XSE_1^2 + XSE_2^2} < 2.83$.

where

$$XSE = \frac{dE/dx(meas) - dE/dx(calc)}{\sigma(dE/dx(calc))}. \tag{3}$$

Here, the efficiencies are determined by examining cuts made via the shower counter info vs the dE/dx info and vice versa. See Fig 2. Overall, PID efficiencies fall in the 95-99% range.

6 Dimuon method

In addition to the Bhabha channel, two other channels were used as cross-checks to determine the luminosity. In one, we select muon tracks to look for dimuon events.[4, 5]

Previous analysis has shown that the selection algorithm must be limited to single muons as back-to-back matching is poor. Thus, the single muon track selection criteria are

- $N_{\mu hits} \geq 3$;
- $|\cos\theta| < 0.67$;
- $3 < TOF < 6$ ns;
- $|TOF_{meas} - TOF_{calc}| < 1$ ns;

- $p < 1.4p_{beam}$;
- $V_r < 1.5$ cm;
- $V_z < 50$ cm.

The above cuts are looped over all tracks in an event until a track passes; this event is then considered to be a diumon event. Cosmics are then removed via fit to V_z distribution. Hadrons are removed via the application of the above cuts to predetermined hadron sample (obtained via the hadronic selection mechanism) and then scaling the feedthrough rate appropriately.

The selection efficiency for these cuts is determined via comparison via a Monte Carlo, in this case the radmu generator. Efficiencies are in the 65-70% range.

7 Two photon method

The final channel used is the process $e^+e^- \to \gamma\gamma$. Selection cuts for this method are:

- Total tracks ≥ 2, NCHRG $= 0$;
- Rib region removed ($|Z| < 0.11$m, $0.835 < |Z| < 1.075$m);
- Find 2 or 3 tracks with largest energy, where:
  - $E_1 > 0.6E_{beam}$;
  - $E_2(+E_3) > 0.45E_{beam}$;
  - $\Sigma E > 1.15E_{beam}$;
- Back to back cut:
  - $|\theta_1 + \theta_2 - 180°| < 10°$;
  - $||\phi_1 - \phi_2| - 180°| < 3°$.

Again, a MC generator (radgg) is used to determine the acceptance which is approximately 3%.

8 Comparison of Results

The results presented here are preliminary, but stable. More detailed analysis (larger MC sets, etc) will be conducted over the next few months.

The initial comparison of results shows good agreement between methods that use Bhabha events for determination of L. However, methods using other channels (muons, photons) show some discrepancies. Note that both these latter channels have order of magnitude fewer statistics. See Fig 3 for a graphical comparison.

Furthermore a comparison between v100 and v101 BES reconstruction software shows differences of around 2-2.5% for most methods as seen in Fig 4. The source of this difference was not known at the time, but improved Monte Carlo realizations have resolved the discrepancy.[6]

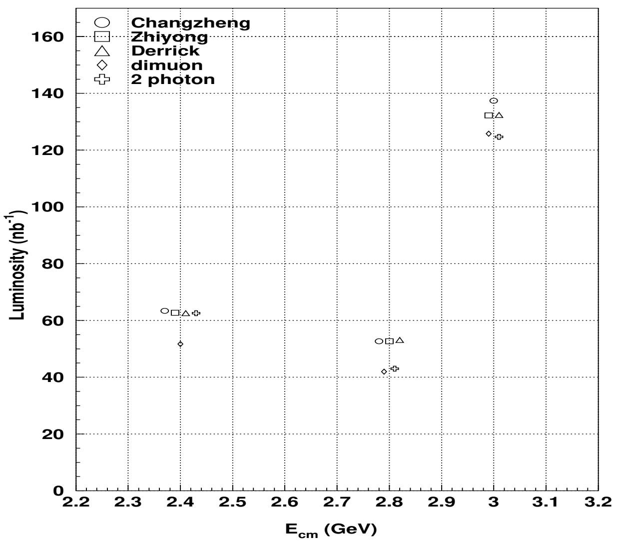

Figure 3: Comparison of luminosity values obtained via the five methods for 2.4, 2.8 and 3.0 GeV data points. The markers are spread along the horizontal axis to facilitate reading the graph and do not represent actual energy differences.

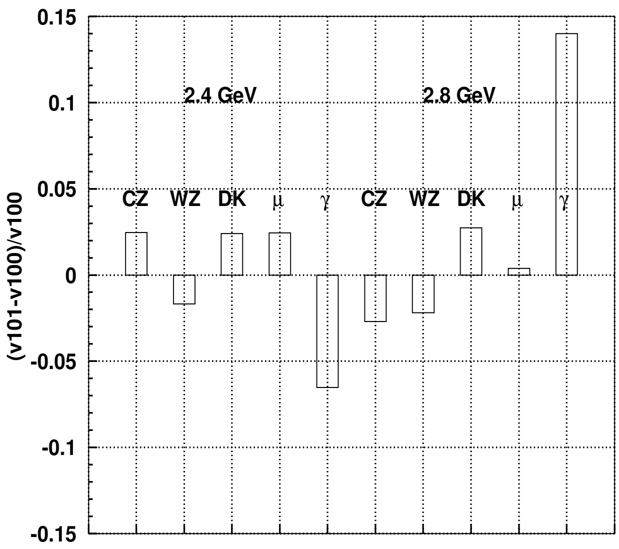

Figure 4: A comparison of luminosities determined in v100 vs v101 reconstruction of 2.4 and 2.8 GeV data. The vertical axis is scaled in percentage difference of v101 from v100. The first five bars are Changzheng's, Zhiyong's, Derrick's, dimuon, and two photon method results, respectively, for the 2.4 GeV data point. The second five are the same for the 2.8 GeV data point.

9 Conclusions

The determination of luminosity via wide-angle Bhabhas appears to be the preferred method. While the exact details on cuts and methodology are yet to be settled, any differences can be factored into the systematics.

We note that the systematic errors for L for the 98 R-scan data were 2-3% (and were not the dominant source of error). It seems reasonable that a similar precision can be achieved for the 1999 data set.

10 Acknowledgements

The work presented above was done by Chen Baosen, Huang Guangshun, Wang Zhiyong, Yuan Changzheng, and Derrick Kong.

11 References

References

[1] J.Z. Bai *et al.*, submitted to Phys. Rev. Lett.

[2] Y. Changzheng, BES memo, "Luminosity determination for R project," July 13, 1998.

[3] D. Kong and C Xiangzong, BES memo "Integrated Luminosity of Ψ' Data," Nov 27th, 1998.

[4] H. Guangshun, BES memo "Luminosity Determination from $e^+e^- \rightarrow \mu^+\mu^-$ at 3.55 GeV," Jan. 13, 1999.

[5] H. Guangshun, BES memo "Luminosity Determination from $e^+e^- \rightarrow \mu^+\mu^-$ for R Measurement," Jan. 14, 1999.

[6] Z. Zhengguo, private communication.