FINUDA Internal Note
December 20, 2000

# Bhabha Trigger Study

G. Gómez, S. Marcello, A. Zenoni

## 1 Generator

FINUDA uses the same Bhabha Monte Carlo generator as KLOE. Details of this generator can be found in [?]. The DAPHNE $e^+e^-$ beam crossing angle of 25 mrad is taken into account. We have verified that all Monte Carlo distributions for Bhabha events generated with electron/positron polar angles between $1^o$ and $179^o$ are similar to those reported by KLOE in the note cited above. Figure **??** shows a typical Monte Carlo Bhabha event.

## 2 Trigger

### 2.1 Hardware

The Bhabha trigger is a hardware trigger that uses only the internal and external scintillator detectors, tofino (ITOF) and tofone (ETOF). The tofino is made up of 12 scintillator slabs (ISLB), while the tofone is made up of 72 scintillator slabs (ESLB). At this level, event selection is based on the ITOF and ETOF multiplicity, topology, and time-of-flight.

### 2.2 Characteristic Signature

Bhabha events usually have an ITOF multiplicity of 2, an ITOF topology which is exactly back-to-back, an ETOF multiplicity between 2 and 4, an ETOF "angle" between the $e^+$ and $e^-$ of 16 to 32 slabs, and a time difference between ETOF and ITOF of about 4.5 to 6.5 ns. In addition, there is a strong geometrical correlation between the ITOF and ETOF slabs hit by the $e^+, e^-$ owing to their characteristic momenta. ¿From Figure **??** one would expect two preferred ESLB clusters for each ISLB hit: one when the ISLB is hit by a positron and one when the ISLB is hit by an electron.

These characteristic signatures must therefore be used to select Bhabha events and to reject other events such as Touschek, $e^+e^- \to \phi \to K^+K^-$, and $e^+e^- \to \phi \to K_sK_l$. Figures **??** and **??** show the relevant Monte Carlo ITOF/ETOF distributions for Bhabha events generated between $45^o$ and $60^o$, for $K^+K^-$, for $K_sK_l$, and for Touschek events (the normalization is relatively arbitrary: one thousand events of each type were generated for these figures). Hypernucleus formation and decay was not simulated for $K^+K^-$ events, since the $\Lambda^0$ capture rate is of order $10^{-3}$, and therefore constitutes a negligible fraction of the $K^+K^-$ background. The Touschek generator used was optimized for the DAPHNE accelerator conditions of 1997, and therefore a more realistic generator is needed to obtain more reliable estimates of this background. The $\Delta\mathrm{N}_{\mathrm{eslb}}$ distribution shown is only for ETOF slabs hit by electrons or positrons, and this is why there are very few events other than Bhabha in this histogram. Clearly, the trigger cut applied is independent of the particle type hitting the ETOF slabs. The ITOF/ETOF correlation plots for Bhabha events show, for each ISLB, two clear peaks corresponding to the preferred ESLB clusters. The ESLBs hit outside these peaks correspond to electrons or positrons coming from electromagnetic interactions such as photoconversions or scattering.

## 2.3 Trigger Conditions

In view of the distributions in Figures **??** and **??**, we consider the conditions listed in Table **??** for the Bhabha trigger under study. The *tof* and *tof'* cuts are 10 ns wide because this is the smallest time gate achievable. From the time-of-flight distribution in Figure **??**, we expect these cuts to be close to 100% efficient for Bhabhas. Two different ETOF multiplicity cuts are studied to see which one gives the best compromise between high Bhabha efficiency and low background contamination. The *energy* cut is aimed at reducing the $K^+K^-$ background, since electrons and positrons deposit much less energy on the ISLBs; it should therefore be close to 100% efficient for Bhabhas. Any event with any two ELSBs separated by 16 to 32 (20 to 26) slabs will pass the *tofgeo* (*tofgeo'*) cut. For the ITOF/ETOF correlation cuts, the correlation peaks chosen are 12 ELSBs wide and correspond to those shown in Figure **??** obtained from Bhabha Monte Carlo.

Table 1: Possible trigger conditions for Bhabha events.

| name | trigger condition |
|---|---|
| **imult** | ITOF multiplicity = 2 |
| **back** | ITOF slabs exactly back-to-back |
| **emult** | ETOF multiplicity = 1 to 7 |
| **emult′** | ETOF multiplicity = 2 to 7 |
| **tof** | 4 ns $\leq t_{ETOF} - t_{ITOF} \leq$ 14 ns |
| **tof′** | 0 ns $\leq t_{ETOF} - t_{ITOF} \leq$ 10 ns |
| **energy** | $<$ 2 ISLB with $\mathrm{E_{loss}} >$ 2.5 MeV |
| **tofgeo** | $\Delta\mathrm{N_{eslb}}$ = 16..32 |
| **tofgeo′** | $\Delta\mathrm{N_{eslb}}$ = 20..26 |
| **iecorr** | at least 1 ISLB with correlated ESLB |
| **iecorr′** | at least 2 ISLB with correlated ESLB |

## 2.4 Trigger Acceptance and Background Rejection

We have generated Monte Carlo events of the following types:

- Bhabha (between $45^o$ and $60^o$), $10^3$ events
- $e^+e^- \rightarrow \phi \rightarrow K^+K^-$, $10^3$ events
- $e^+e^- \rightarrow \phi \rightarrow K_sK_l$, $10^3$ events
- Touschek, $10^5$ events

Larger statistics are needed for Touschek events owing to the huge rejection of the Bhabha trigger for Touscheks. Table **??** shows the number of events of each type which survive as each single cut is applied. The effect of cuts applied in sequence will be studied shortly, but we use this first approximation to choose among the various possible combinations. The *imult* and *back* cuts give a large acceptance for Bhabha and very good background rejection, especially for Touschek. We choose the *emult, tofgeo* and *iecorr* cuts in order to keep the Bhabha acceptance as high as possible. These cuts accept a larger background fraction, but this is not a problem since the overall selection has very good background rejection. As expected, the time-of-flight cuts are highly efficient for Bhabhas, while they help reduce the backgrounds. The energy cut is $\approx 100\%$ efficient for Bhabha,

Table 2: Number of events of each type surviving after each single cut is applied.

| cut | Bhabha | $K^+K^-$ | $K_sK_l$ | Touschek |
|---|---|---|---|---|
| **none** | 1000 | 1000 | 1000 | 100000 |
| **imult** | 981 | 523 | 368 | 2327 |
| **back** | 871 | 595 | 92 | 105 |
| **emult** | 856 | 535 | 516 | 590 |
| **emult′** | 666 | 464 | 363 | 26 |
| **tof** | 947 | 458 | 229 | 3022 |
| **tof′** | 946 | 432 | 383 | 86367 |
| **energy** | 999 | 267 | 1000 | 98501 |
| **tofgeo** | 718 | 90 | 173 | 805 |
| **tofgeo′** | 544 | 45 | 101 | 378 |
| **iecorr** | 710 | 270 | 137 | 1392 |
| **iecorr′** | 454 | 209 | 91 | 184 |

$K_sK_l$ and Touschek, but reduces greatly the $K^+K^-$ background. We choose the *tof* cut because it has better rejection for Touschek and $K_sK_l$. This cut has a higher acceptance for $K^+K^-$, but this problem is solved applying the complementary *energy* cut. This combination gives the best overall rejection while keeping a high Bhabha acceptance.
Table **??** shows the number of events of each type which survive as the chosen selection cuts are applied in sequence. A very conservative upper limit for the Touschek acceptance is calculated by assuming a 100% correlation between the ITOF conditions (*imult, back*) and between the ETOF conditions (*emult, tofgeo*), and assuming that events which pass the ITOF and ETOF cuts have a 100% efficiency for the *energy* and *iecorr* cuts. The upper limit reported in Table **??** is therefore the product of the single cut efficiencies for *back, emult* and *tof* reported in Table **??**.

## 2.5 Trigger Rates

The Bhabha differential cross section for polar angles $\theta \gg 0$ is given by [**?**]:

$$\frac{d\sigma}{d\Omega} = \left(\frac{\alpha^2}{4s}\right)\left[(1+z^2) - 2\frac{(1+z)^2}{1-z} + 2\frac{4+(1+z)^2}{(1-z)^2}\right] = \left(\frac{\alpha^2}{4s}\right)\left(\frac{3+z^2}{z-1}\right)^2$$

Table 3: Number of events of each type surviving after cuts are sequentially applied.

| cut | Bhabha | $K^+K^-$ | $K_sK_l$ | Touschek |
|---|---|---|---|---|
| **none** | 1000 | 1000 | 1000 | 100000 |
| **imult** | 981 | 523 | 368 | 2327 |
| **back** | 864 | 306 | 84 | 2 |
| **emult** | 739 | 171 | 60 | 0 |
| **tof** | 739 | 138 | 55 | 0 |
| **energy** | 739 | 18 | 55 | 0 |
| **tofgeo** | 611 | 5 | 10 | 0 |
| **iecorr** | 510 | 3 | 8 | 0 |
| **acceptance** | 0.510 | 0.003 | 0.008 | $< 1.9 \times 10^{-7}$ |

where $z = \cos\theta$, $s = 1.0404$ GeV$^2$ is the square of the center-of-mass energy at DAPHNE and $\alpha$ is the fine structure constant, giving $\alpha^2/4s = 4.98$ nb. The total Bhabha cross section for FINUDA, which has a TOFINO polar angular acceptance of $45^o < \theta < 135^o$, is therefore given by

$$\begin{aligned}\int_0^{2\pi} d\phi \int_0^{1/\sqrt{2}} dz \frac{d\sigma}{d\Omega} &= 2\pi \left(\frac{\alpha^2}{4s}\right) \left[\frac{16}{1-z} + 9z + z^2 + \frac{z^3}{3} + 16\ln(1-z)\right]_0^{1/\sqrt{2}} \\ &= 810 \text{ nb} = 81 \times 10^{-32}\text{cm}^2\end{aligned}$$

With a DAPHNE luminosity of $\mathcal{L} = 10^{32}$ cm$^{-2}$s$^{-1}$ and a trigger efficiency of 0.510, this gives a Bhabha trigger rate of 41 Hz.
The phi production ($e^+e^- \to \phi$) rate at $\mathcal{L} = 10^{32}$ cm$^{-2}$s$^{-1}$ is approximately [?] 440 Hz. Taking into account the branching ratios and the trigger efficiencies for $K^+K^-$ and $K_sK_l$, we expect a trigger rate of $440 \times 0.491 \times 0.003 = 0.65$ Hz for $K^+K^-$ and $440 \times 0.340 \times 0.008 = 1.2$ Hz for $K_sK_l$.
The rate of lost $e^+e^-$ (Touschek) at $\mathcal{L} = 10^{32}$ cm$^{-2}$s$^{-1}$ is approximately [?] $2 \times 10^5$ Hz. Taking into account the upper limit on the trigger efficiency, we expect a trigger rate of $2 \times 10^5 \times (< 1.9 \times 10^{-7}) < 0.04$ Hz. Table **??** summarizes the results for all trigger rates.

Table 4: Expected trigger rates.

| physics process | expected trigger rate |
|---|---|
| Bhabha | 41 Hz |
| $K^+K^-$ | 0.65 Hz |
| $K_sK_l$ | 1.2 Hz |
| Touschek | $<$ 0.04 Hz |

# 3 Conclusions

A reasonably good Bhabha trigger seems to be:

- **imult** + **back** + **emult** + **tof** + **energy** + **tofgeo** + **iecorr**

This combination of cuts gives an acceptance of 51.0% for Bhabha events, 0.3% for $K^+K^-$ events, 0.8% for $K_sK_l$ events, and $< 1.9 \times 10^{-7}$ for Touschek events. At a machine luminosity of $\mathcal{L} = 10^{32}$ cm$^{-2}$s$^{-1}$, we expect a trigger rate of 41 Hz for Bhabha, 0.65 Hz for $K^+K^-$, 1.2 Hz for $K_sK_l$ and $<$ 0.04 Hz for Touschek. These results are preliminary for Touschek events, since a more realistic Touschek generator is needed to simulate current machine conditions.

# References


[1] V. Glagolev, M. Incagli, G. Venanzoni, *BHABHA generator for GEANFI code*, KLOE note n$^o$ 156, (1996).

[2] Get reference for Bhabha x-section expression

[3] The FINUDA Collaboration, *FINUDA TECHNICAL REPORT*, LNF-95/024 (IR), (1995).

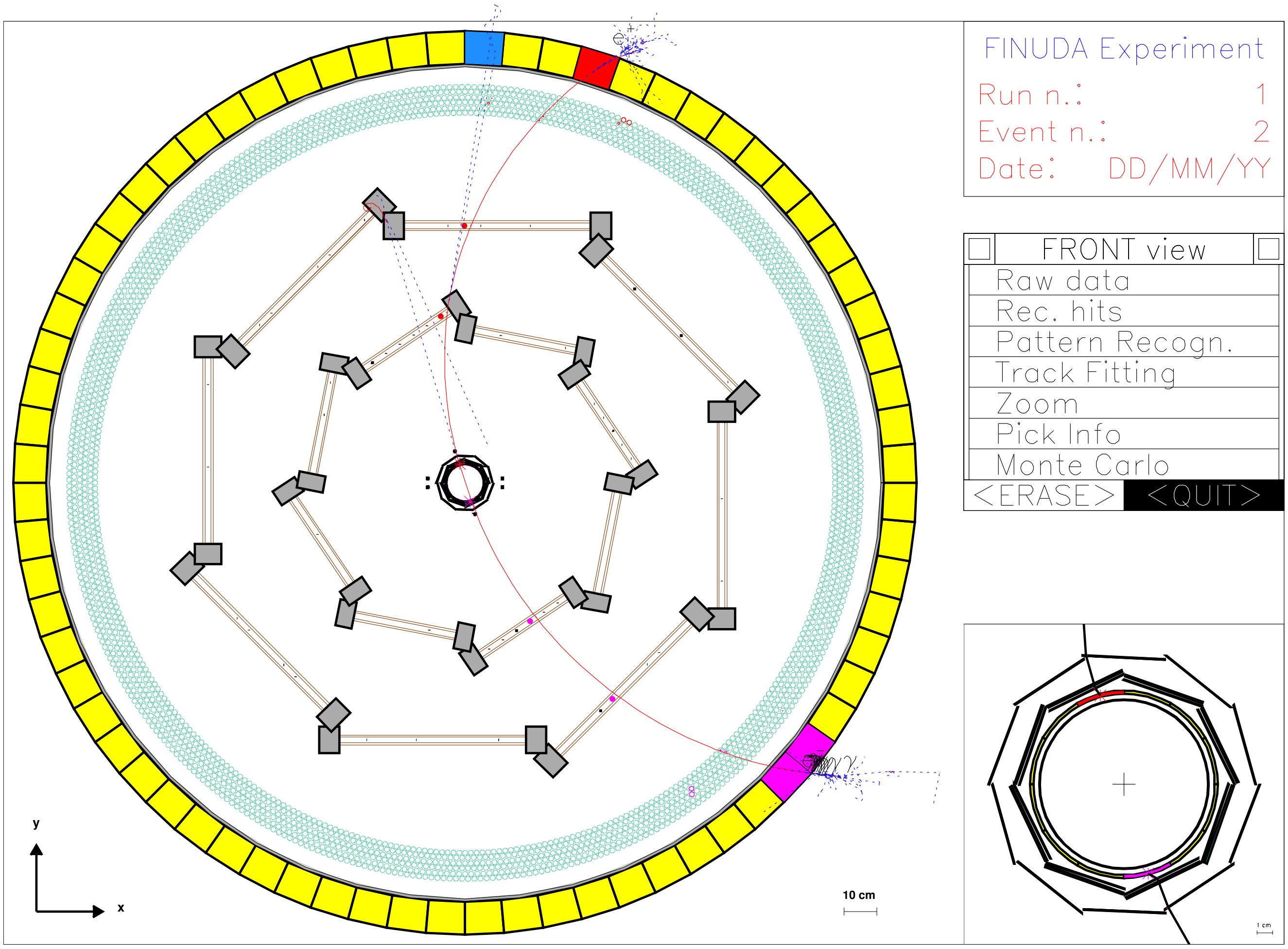


Figure 1: A typical MC Bhabha event.

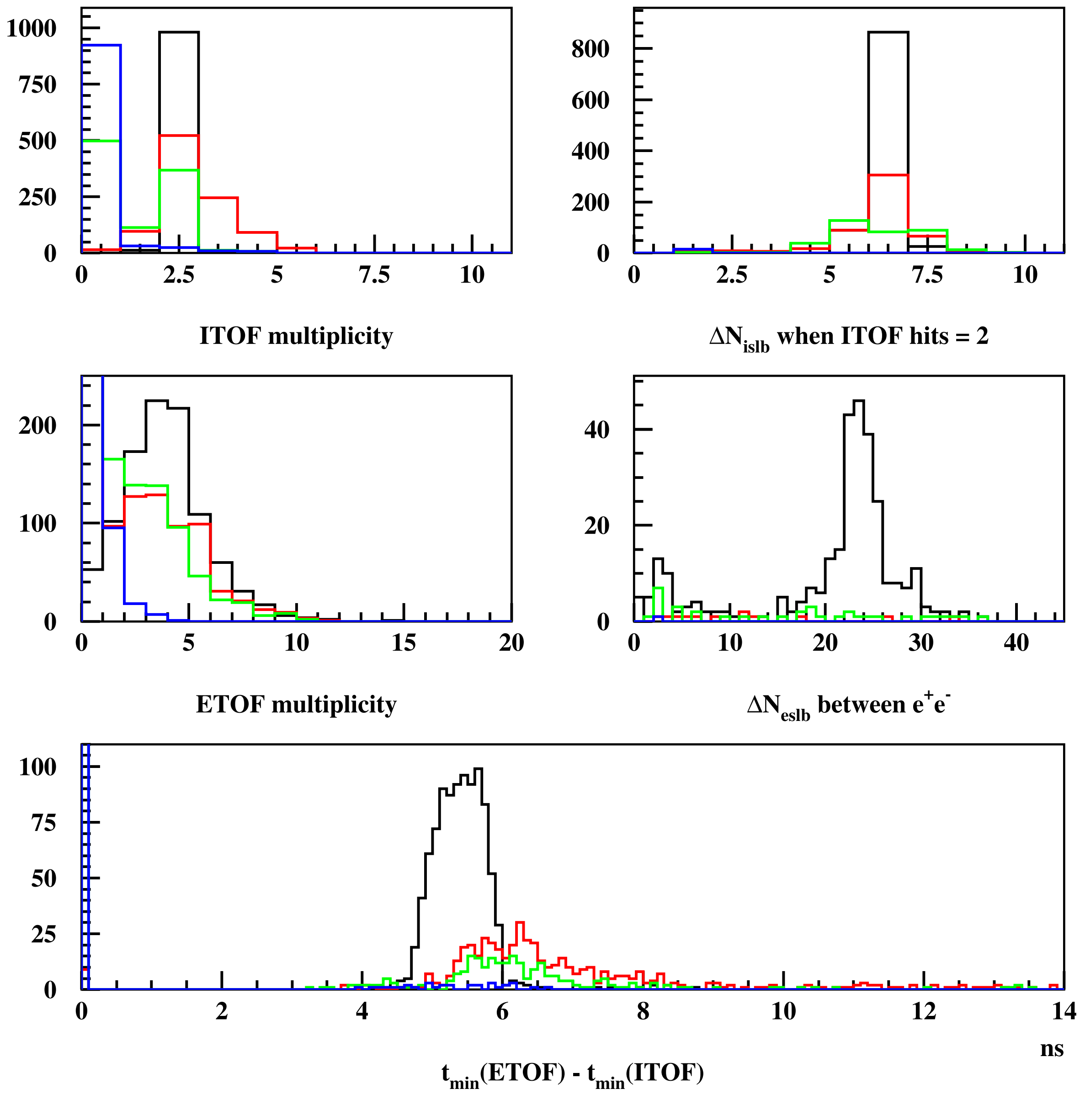


Figure 2: ITOF/ETOF multiplicity, topology and time-of-flight for Bhabha (black), $K^+K^-$ (red), $K_sK_l$ (green), and Touschek (blue).

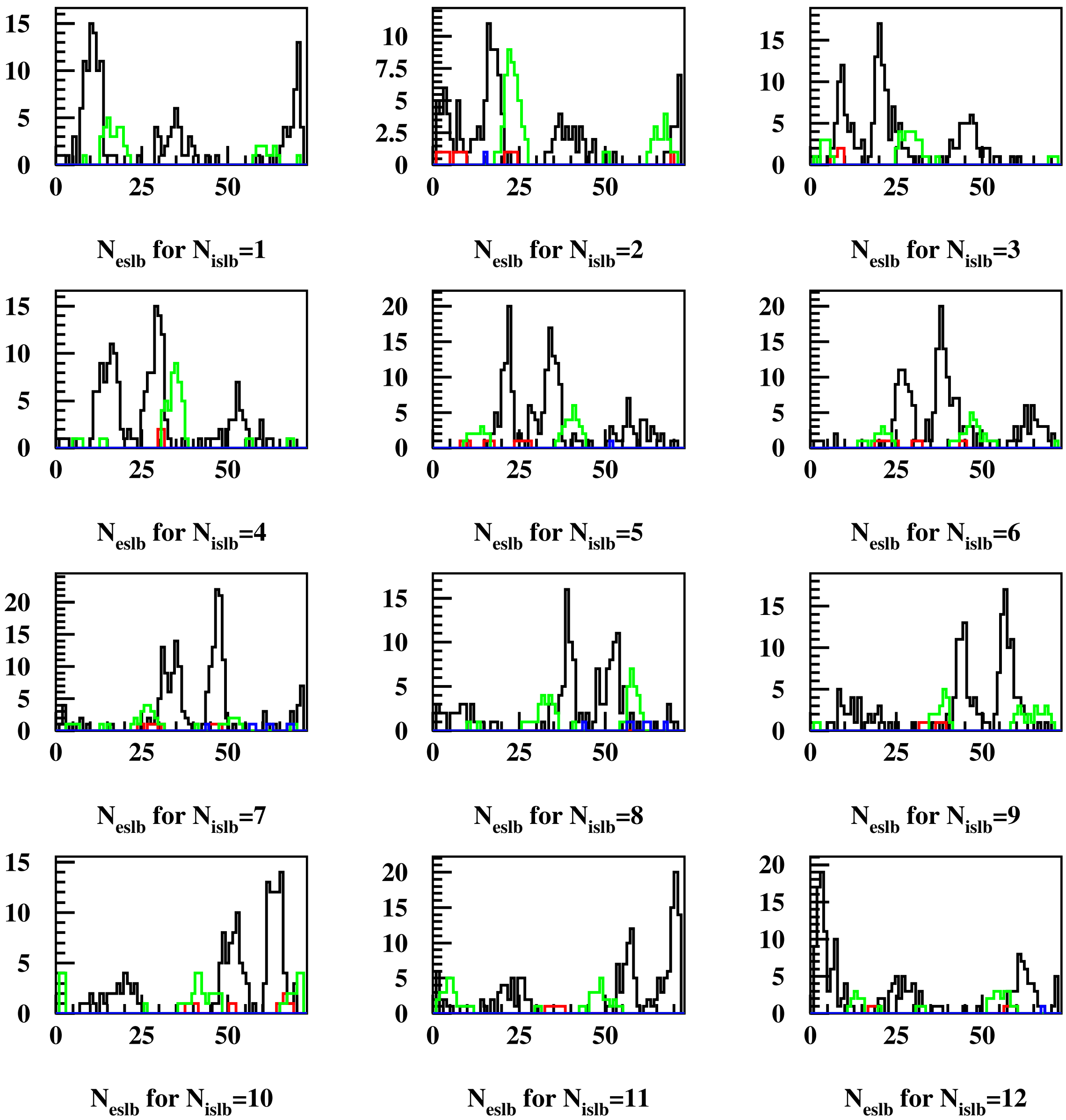


Figure 3: ITOF/ETOF correlation: number of ESLB hit for each possible back-to-back ITOF topology for Bhabha (black), $K^+K^-$ (red), $K_sK_l$ (green), and Touschek (blue).