STRANGE PAIR PRODUCTION IN HIGH ENERGY ELECTRON POSITRON COLLISIONS

Yuichi Okugawa*, Adrian Irles, François Richard, Hitoshi Yamamoto, Roman Pöschl
*yuichi.okugawa@ijclab.in2p3.fr

Introduction

A key physics topic anticipated at electron-positron colliders is the detailed investigation of Electroweak (EW) symmetry breaking. There are theories beyond the standard model that explain this mechanism, which requires modification in fermion coupling to weak bosons. ILC can play a central role in such investigation, as it can measure its coupling with higher precision than ever before.

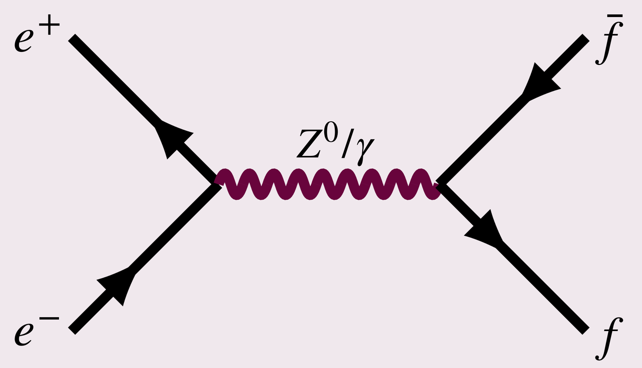

Figure 1 *Feynman diagram for fermion pair production at e+e- collision through Z^0/γ at Leading Order. Studies of tt/bb/cc pair production are being conducted.*

Theory

Differential Cross Section

The differential cross section of $e^+e^- \to f\bar{f}$ [1]:

$$\frac{d\sigma_{f\bar{f}}}{d\cos\theta} = \frac{3}{8}\sigma_{f\bar{f}}^{tot}(1-\mathcal{P}_e\mathcal{A}_e)(1+\cos^2\theta) + 2(\mathcal{A}_e - \mathcal{P}_e)\mathcal{A}_f\cos\theta \quad (1)$$

where

- θ : The production angle of the fermion
- $\sigma_{f\bar{f}}^{tot}$: Total cross section of $e^+e^- \to f\bar{f}$
- $\mathcal{P}_e$: Electron beam helicity (Left: negative, Right: positive)

Asymmetry parameters $\mathcal{A}_f$ are defined as:

$$\mathcal{A}_f = 2 \cdot \frac{g_{Vf}/g_{Af}}{1+(g_{Vf}/g_{Af})^2} \quad (2)$$

with g_{Vf}, g_{Af} being vector and axial vector coupling constants, respectively.

ILC & ILD

International Linear Collider (ILC)

- Center of mass energy: 250 GeV, 500 GeV, 1TeV (to be extended)
- Well defined initial states with controllable beam polarization (L:80%, R:30%)
- Clean events with less backgrounds compared to hadron colliders

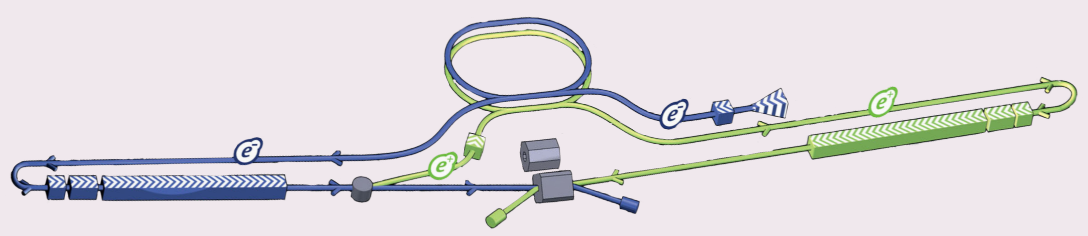

Figure 2 Schematic view of ILC. Planned to be constructed along the Kitakami mountains, Tohoku. [2]

International Large Detector (ILD)

- Capable of reconstructing every particle inside the detector and store them as objects, called Particle Flow Objects (PFOs)
- High tracking efficiencies.
- Time projection chamber facilitates the particle identification through dE/dx measurements

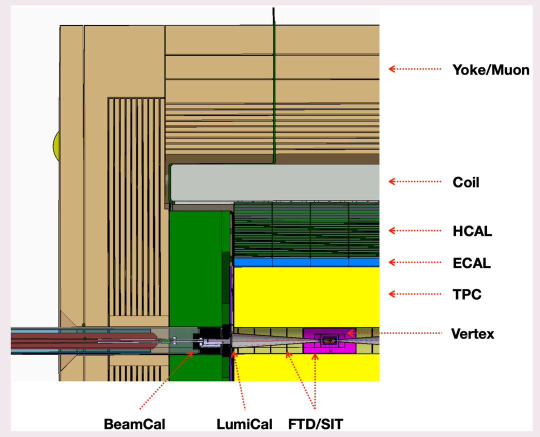

Figure 3 *The cross sectional view of the ILD. TPC is highlighted in yellow. [3]*

TPC

The time projection chamber (TPC) is the central detector in ILD.

- When a charged particle crosses the chamber, the ionized gas will create a thread of electrons which drift to the TPC endplate.
- The time and charge of each hit are recorded.
- From these, the track parameters and ionization energy loss (dE/dx) can be measured.

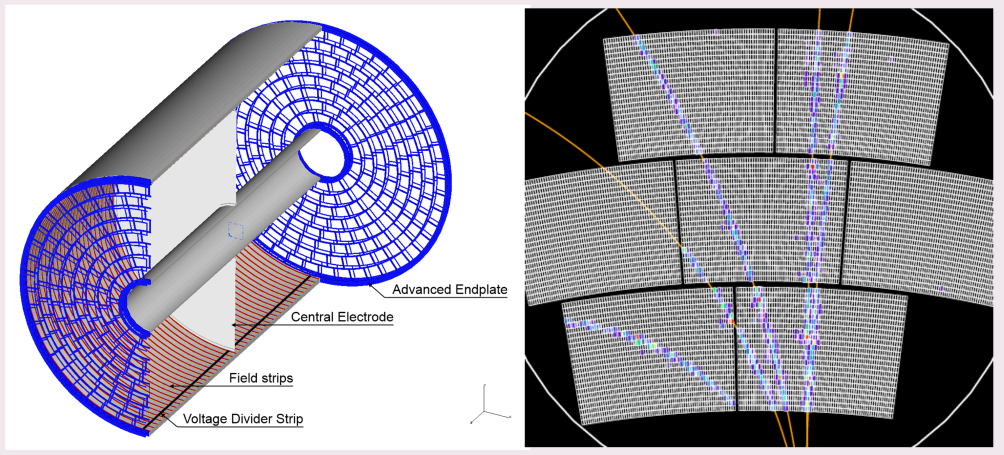

Figure 4 *Schematic view of TPC (left) and track reconstruction performed by the Endplate equipped with micromegas at test beam (right). The endplate in the current ILD TPC design has 220 pad rows and micromegas is one of the technical options.*

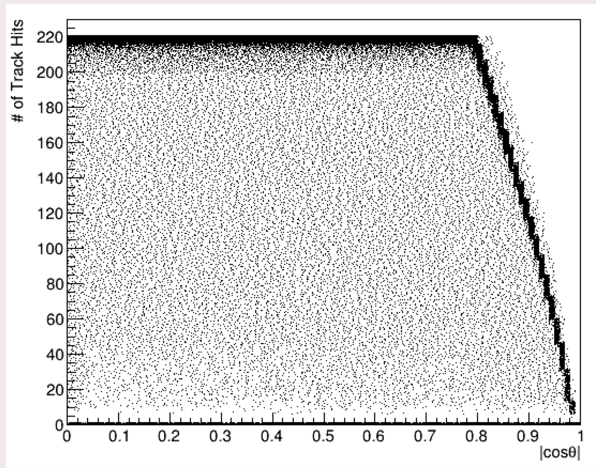

Figure 5 *Number of TPC hits are plotted against $\cos\theta$. Due to the short distance in projection for forward emitted particles, number of endplate hits in the forward region is low, causing larger statistical uncertainties in dE/dx measurements.*

Process

The analysis focuses on $e^+e^- \to s\bar{s}$ production at high effective centre-of-mass energy.

- $E_{CM} = 250$ GeV
- Integrated Luminosity $\int \mathcal{L}dt = 100$ fb^{-1}
- Full Geant4 simulation of ILD.

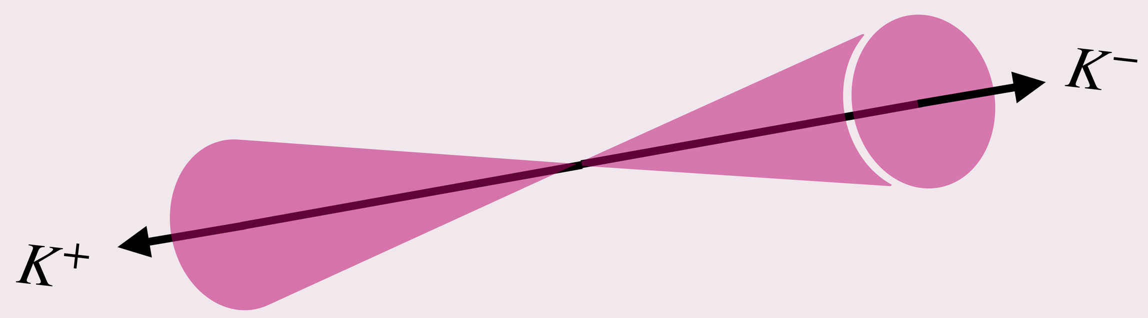

Figure 7 *Schematic diagram of $s\bar{s}$ production after its hadronization. Neutral kaons are being ignored for the time being. In reality, these jets will include mixture of pion and proton even in the pure $s\bar{s}$ events.*

Particle ID

dE/dx vs track momentum can be approximated by the Bethe-Bloch formula [4], which is unique to different particles.
dE/dx distance is also calculated as following:

$$\text{signed}\left[\left(\frac{(dE/dx - dE/dx_{exp-kaon})}{\Delta_{dE/dx}}\right)^2\right] \quad (3)$$

where

$dE/dx_{exp-kaon}$: dE/dx value expected from kaon Bethe-Bloch formula.
$\Delta_{dE/dx}$: Statistical error for dE/dx measurements.

The +/- sign that was lost upon squaring the quantity will be retained afterwards (thus "signed")

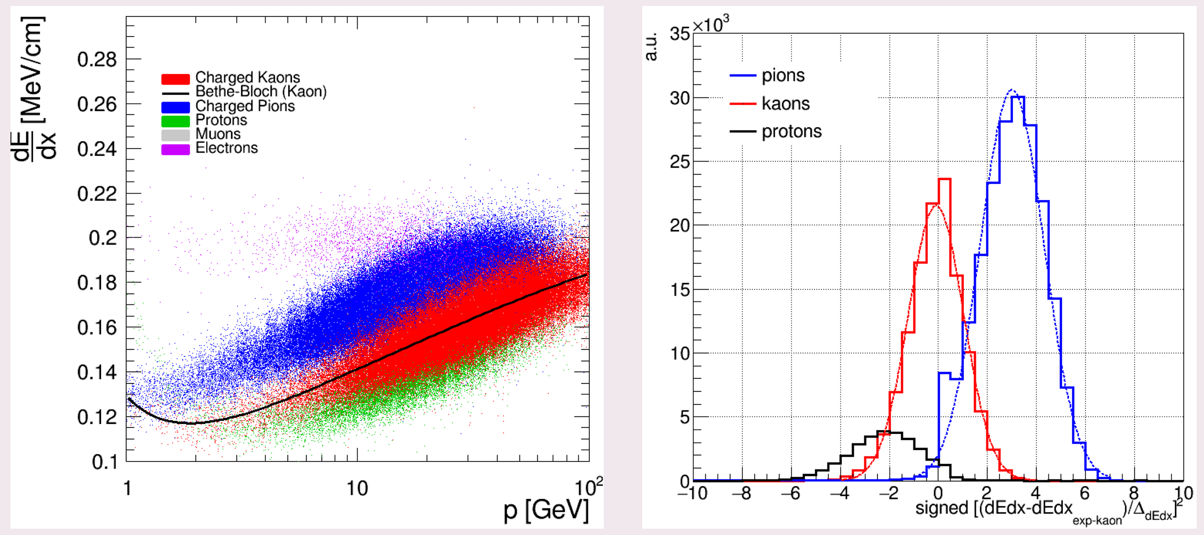

Figure 6 *dE/dx vs p distribution (left) and dE/dx distance calculated by eq (2) for $e^+e^- \to s\bar{s}$ process. The dominant backgrounds are pions and protons.*

Analysis

Selection

- Choose PFOs with the highest momentum within each jet, calling it "Leading PFOs" (LPFO).
- Both LPFOs should satisfy:
  - Momentum: $20 < p_{LPFO} < 60$ GeV
  - LPFOs have non-zero and opposite charge.
  - ≥ 210 TPC hits to ensure good dedx measurement
  - Impact parameter < 0.1 cm to remove proton backgrounds.
  - dE/dx distance from kaon Bethe-Bloch formula is smaller compared to the ones for pions and protons.

Results for $e^+e^- \to s\bar{s}$

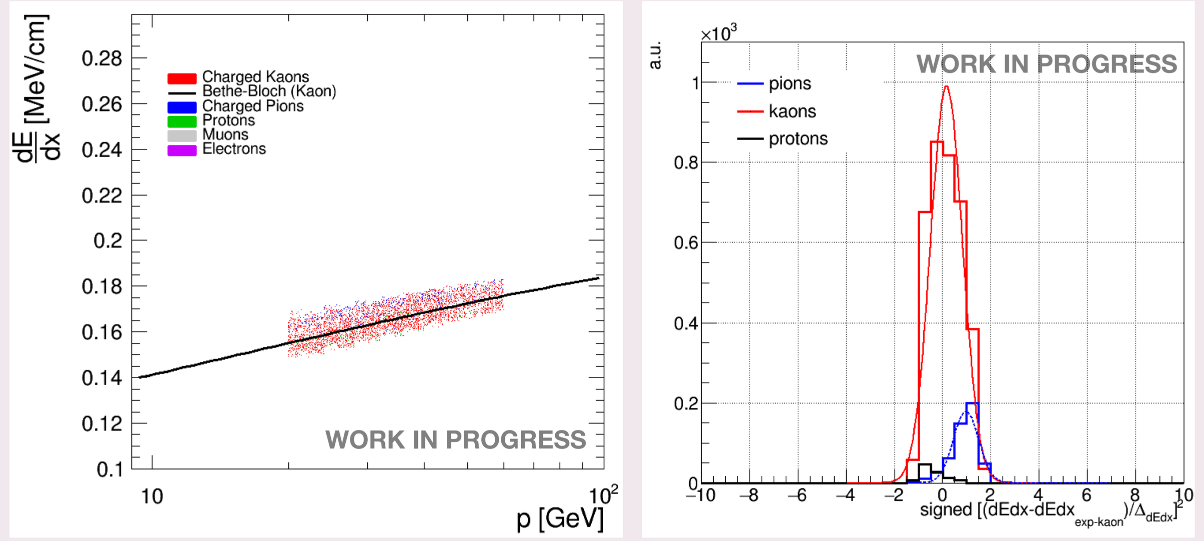

Figure 8 *dE/dx vs p distribution (left) and dE/dx distance (right) for selected LPFOs in $e^+e^- \to s\bar{s}$ events. Two major backgrounds pions and protons were drastically removed with the selection.*

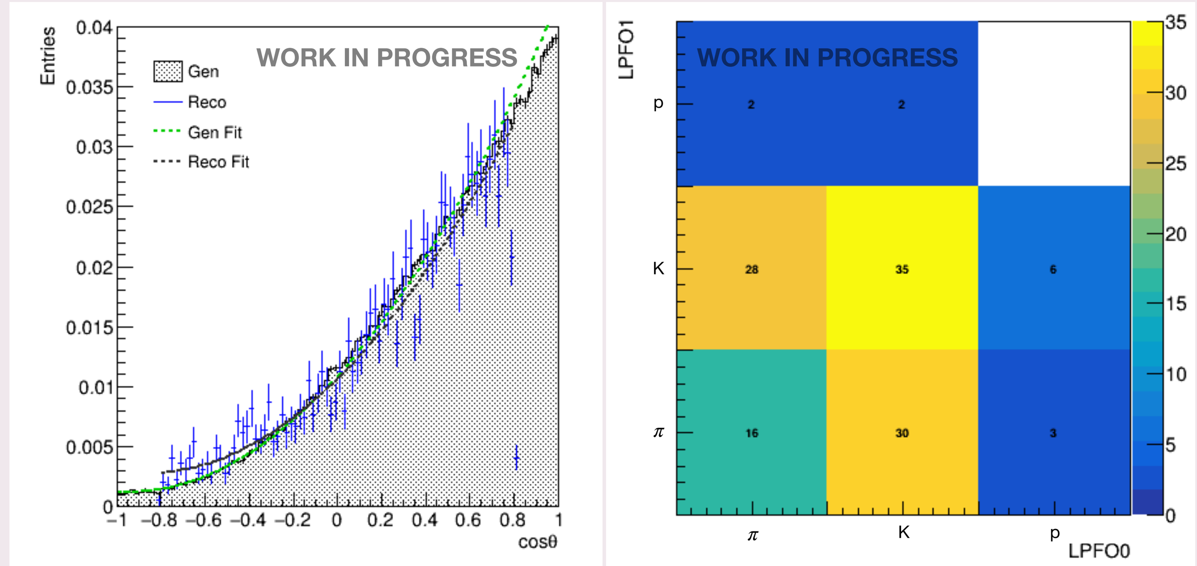

Figure 9 *Polar angle distribution of LPFOs after the selection (left) and true PDG information of LPFO with wrongly reconstructed charge (right). Note that due to the TPC detector acceptance (# of hits), there is little to no sensitivity at the forward region ($|\cos\theta| > 0.8$)*

Conclusion & Outlook

Conclusion

Reconstruction of strange quark pair charges at ILC for both 250 GeV scenario was examined. Such process requires precise selection in Kaons using dE/dx information. For this analysis, we were able to achieve **~ 85 % purity** for the kaon identification in **pure $s\bar{s}$ samples**.

Outlook

Prospects include of full background samples (u,d,c) and optimization of kaon selection as currently sacrifice efficiencies in exchange of purity.

References

(1) Electroweak, The SLD, et al. "Precision electroweak measurements on the Z resonance." Physics Reports 427.5-6 (2006): 257-454.
(2) Behnke, Ties, et al. "The international linear collider technical design report-volume 1: Executive summary." arXiv preprint arXiv:1306.6327 (2013).
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(4) K. Nakamura. Review of particle physics. Journal of Physics G: Nuclear and Particle Physics, 37:075021, 2010.

On behalf of the ILD Concept Group