# ILD Meeting

## June 23, 2021

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# Leading Kaons

# 1. Introduction

## First Look on SSbar samples @ C.M.E. 250GeV

- We use samples stored in:
  - /group/ilc/grid/storm/prod/ilc/mc-2020/ild/dst-merged/250-SetA/2f_hadronic_eL_pR/ILD_l5_o1_v02/v02-02/00015162/000/
  - ILCSoft v02-01-02
- As we'll be focusing on the light quark (u/d/s) separation, heavy quarks (c/b/t) were skipped in this analysis as for the first step.
- The ultimate goal is to be able to measure forward-backward asymmetry from ss process.
  - We first need separate s and sbar
    - Leading Kaon
    - Closer look on PFO associated to its origin quarks.

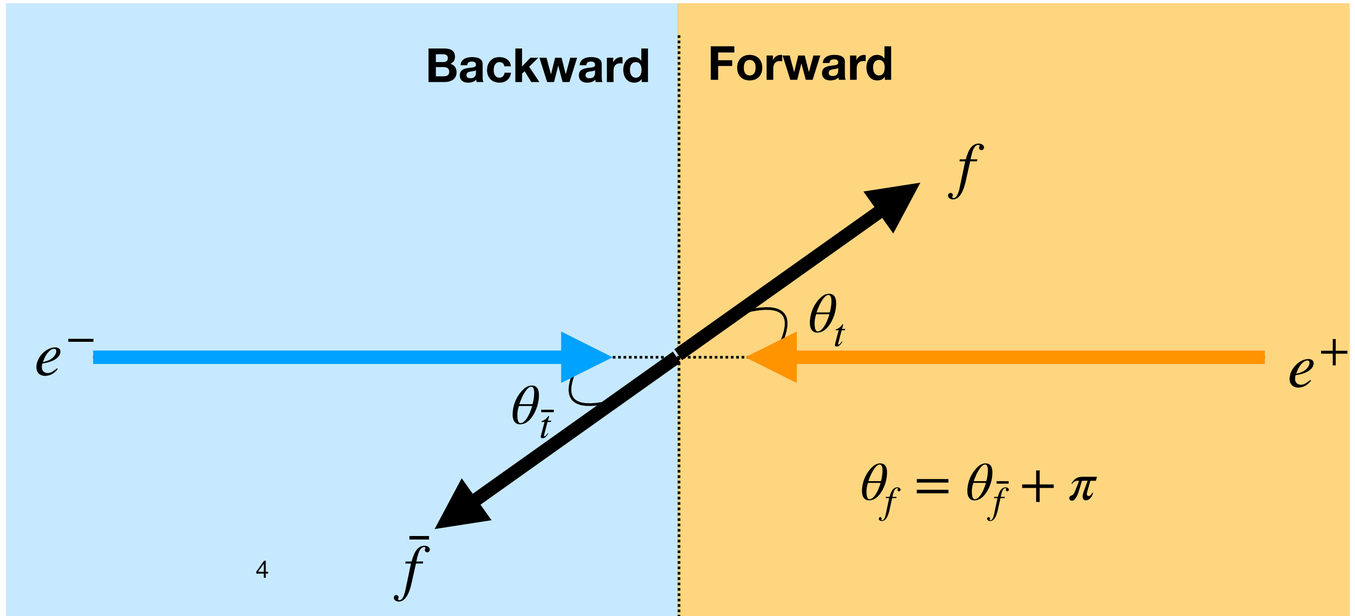
# 2. Set Up

## Polar Angle Distribution

- Distinguish ssbar using leading $K^{\pm}$ charges
  - Leading PFO identified as $K^{\pm}$ (Leading K)
  - Leading K momentum $p_{K^{\pm}_{Lead}} > 10$ GeV
  - Charges of Lead K from two jets should have opposite charges $(Q_{K_0} \times Q_{K_1} < 0)$
  - $\cos\theta_{K^{+}_{Lead}} = -\cos\theta_{K^{-}_{Lead}}$

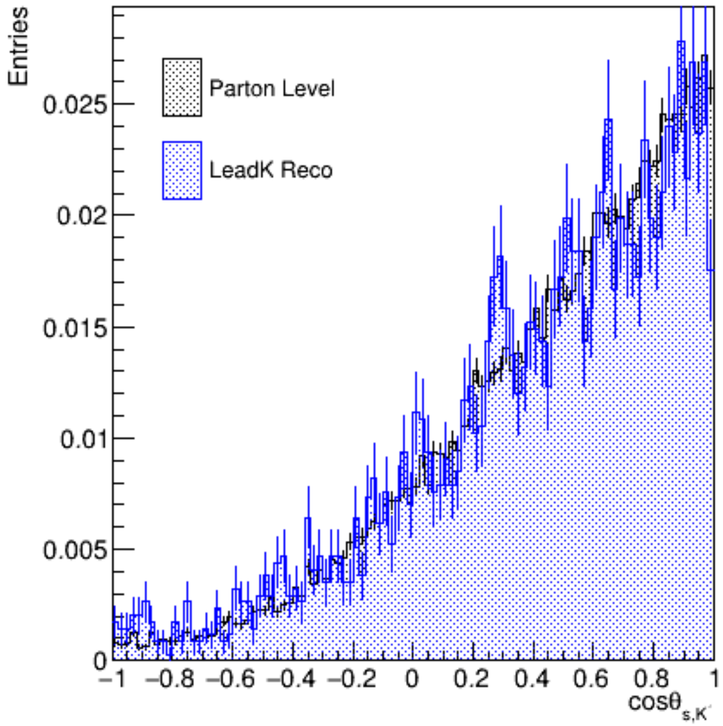
## Selection (to reject ISR/Gamma radiation)

- $\cos\theta_{QQsep} > 0.9$ (back-to-back)
- $120 < p_q, p_{\bar{q}} < 127$

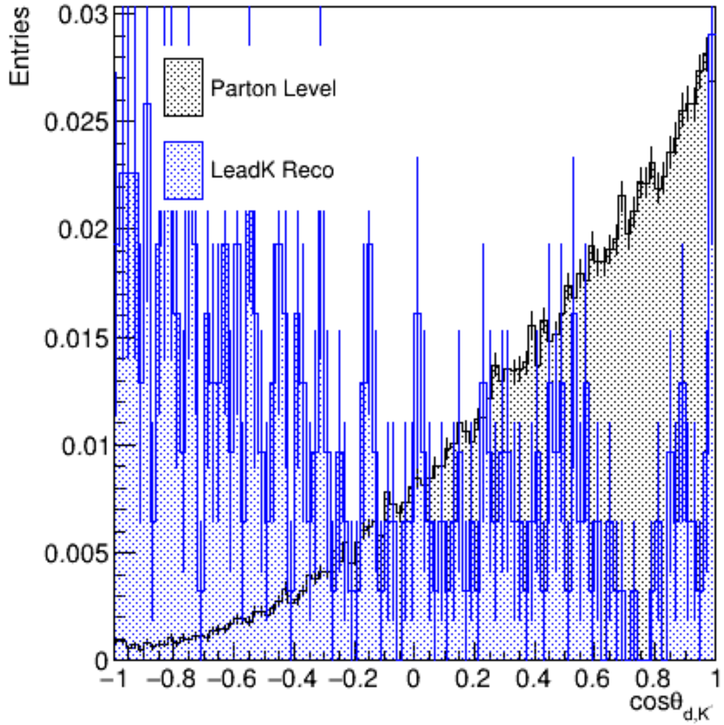


# 3. Leading K Polar Angle

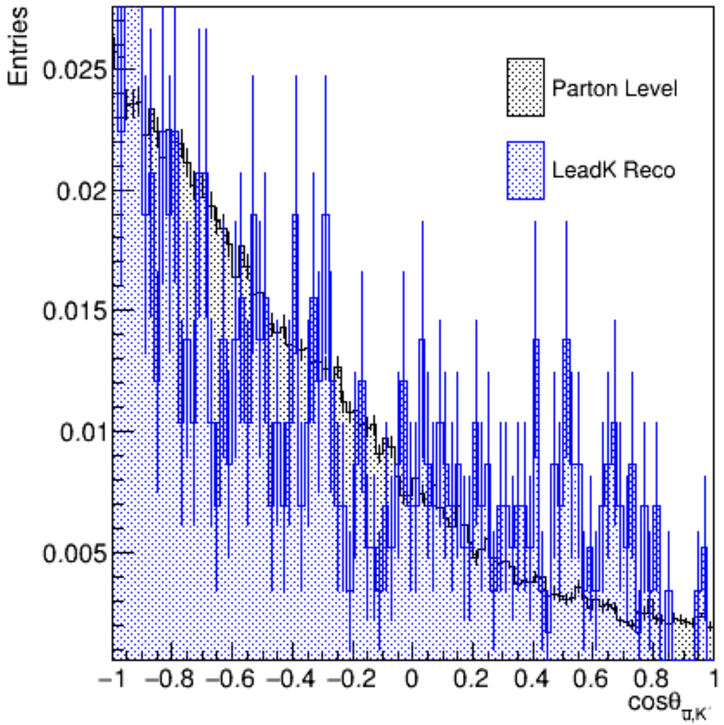
## Leading K Polar Angle Distribution




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




$e^+e^- \to d\bar{d}$

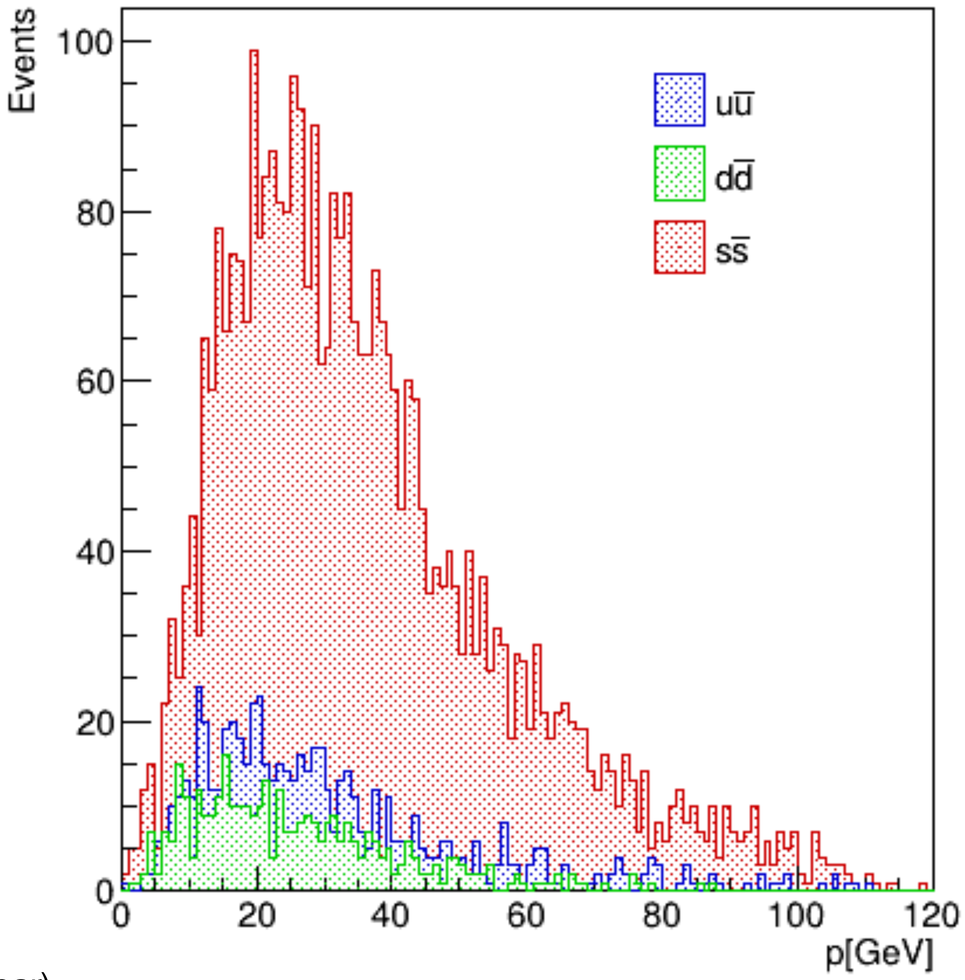



$e^+e^- \to u\bar{u}$

* Polar angle is flipped for anti-fermions ($\cos\theta_{K^+_{Lead}} = -\cos\theta_{K^-_{Lead}}$). In the reconstruction level, we distinguish $f\bar{f}$ by its charge thus the distribution of up-type and down-type quarks are flipped.

# Leading K momentum

- Majority of uu and dd events were suppressed from very strict requirement. (i.e. both jets should contain Kaon as leading PFO and should have opposite charges)
- The leading kaon distribution on the right signifies that from the u/d/s event sample, ss analysis can benefit from huge signal to background ratio.
- Leading Kaon purity:
  - uu: 0.852
  - dd: 0.287
  - ss: 0.967

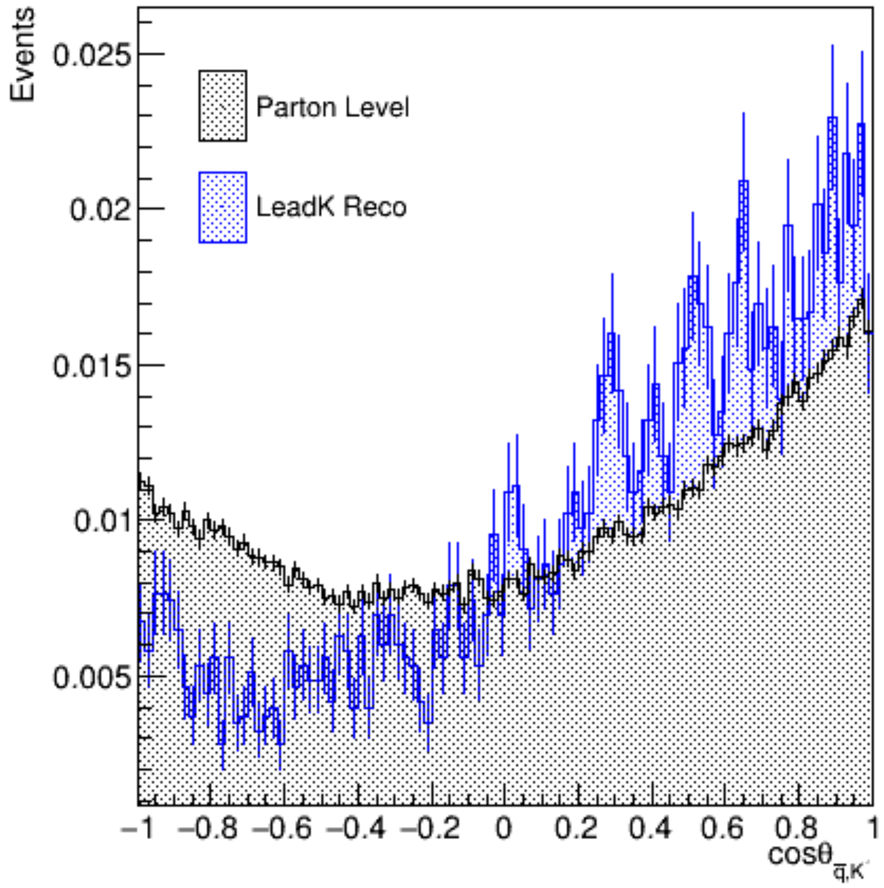



$$\text{purity} = \frac{\text{\# of Leading K-(+) going to same direction as q (qbar)}}{\text{Total \# of Leading Kaon}}$$

# 5. Over all Polar Angle

## Leading K Polar Angle Distribution

- Plot shows the polar angle of lead K for uu/dd/ss combined sample.
  - Reconstructed distribution reflects ss events as uu and dd events were surpassed by our requirement, while parton level still contains those events.
- dd contribution being uniform throughout the distribution?
  - One can possibly further attenuate it by tighten the lead K momentum cut. (currently 10GeV)

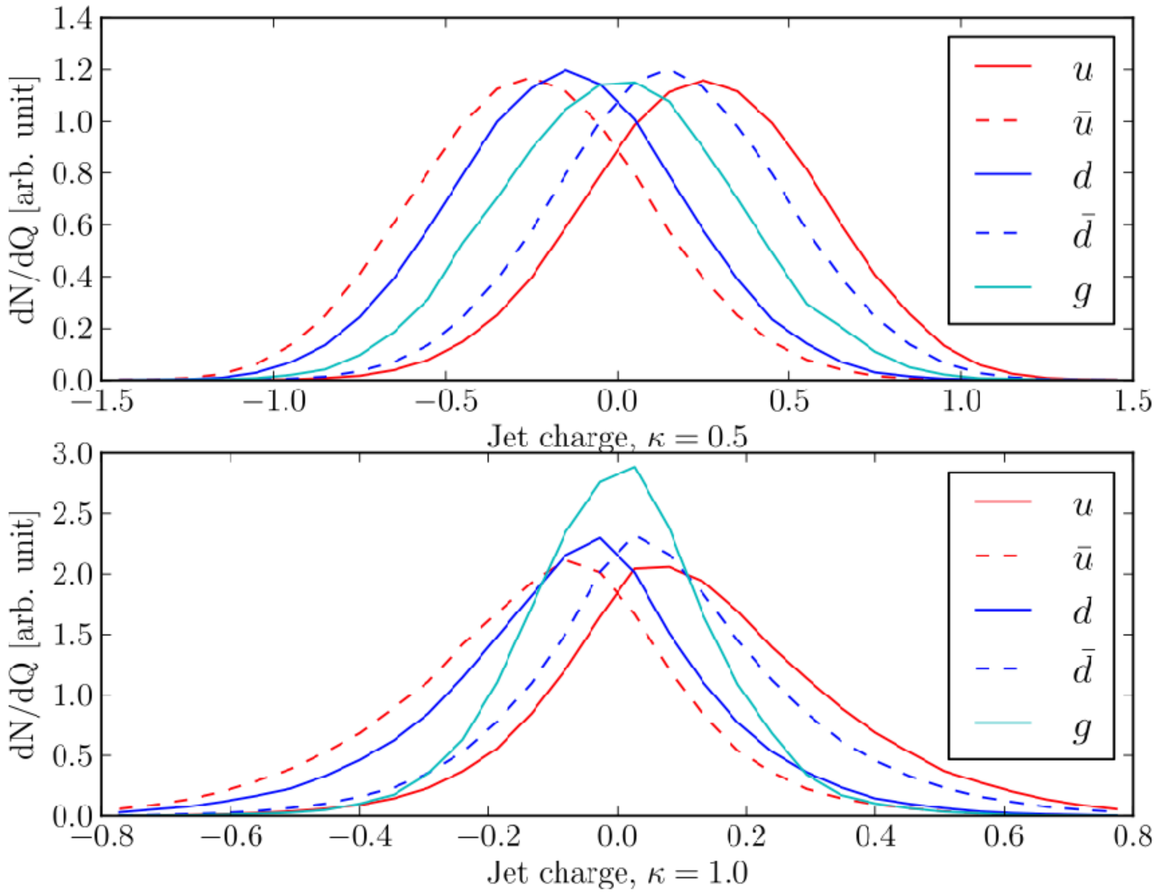



$e^+e^- \to u\bar{u}/d\bar{d}/s\bar{s}/$

# Jet Charges

# 6. Introduction to Jet Charge

- Charge separation power was suggested to be different amongst different flavors of quarks.
- Together with great statistics we can achieve with ILC, it is expected that great charge separation for lighter quarks can be achieved.
- We first need to optimize the selection to prepare for the jet charge measurements.




## Formula

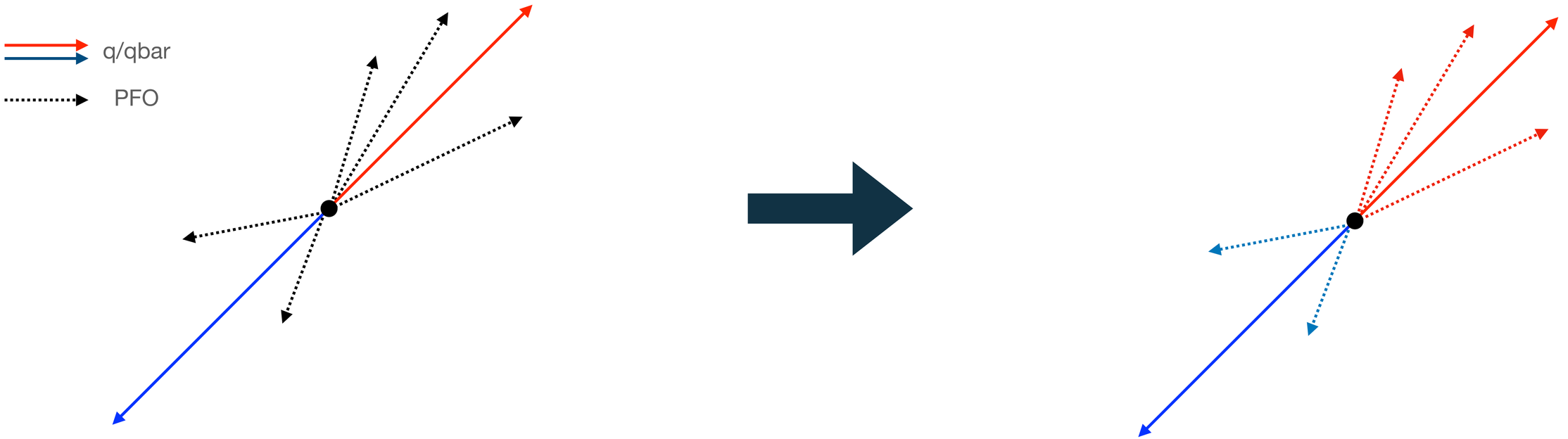
$$Q = \frac{\sum_i Q_i \cdot p_{z_i}^{\kappa}}{\sum_i p_{z_i}^{\kappa}}$$

Q: Jet charge
Qi: Charge of jet constituent
pzi: Momentum of jet constituent projected against thrust axis
K: weighting factor

arXiv:1209.2421

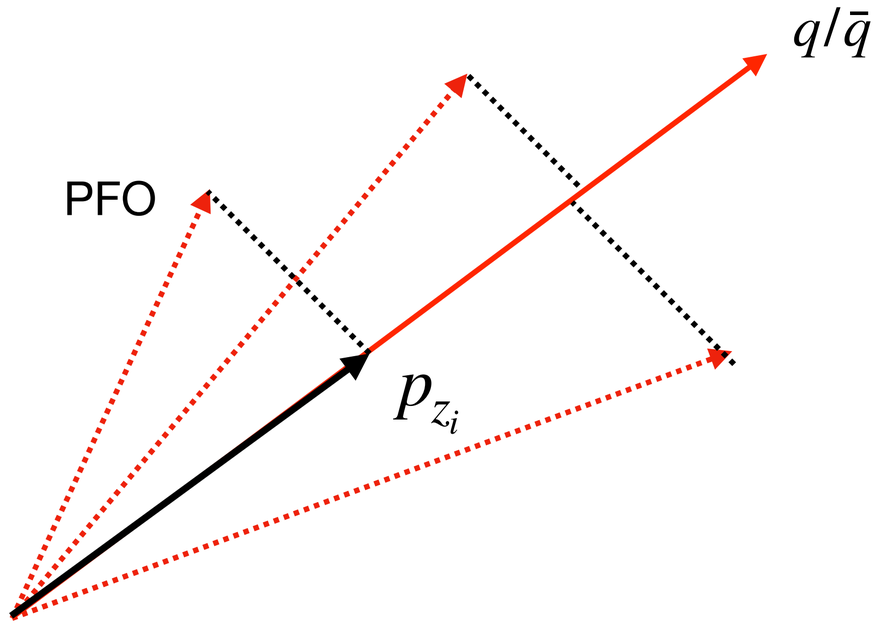
# 7. Jet Charge Definition

- We want to separate PFO depending on whether it is coming from q or qbar.
- We first compare PFO angle and Gen qqbar flight direction. We'll then associate each PFO with corresponding gen particle.
  - Later, we'd like to replace qqbar flight direction with thrust direction.



# 7. Jet Charge Definition

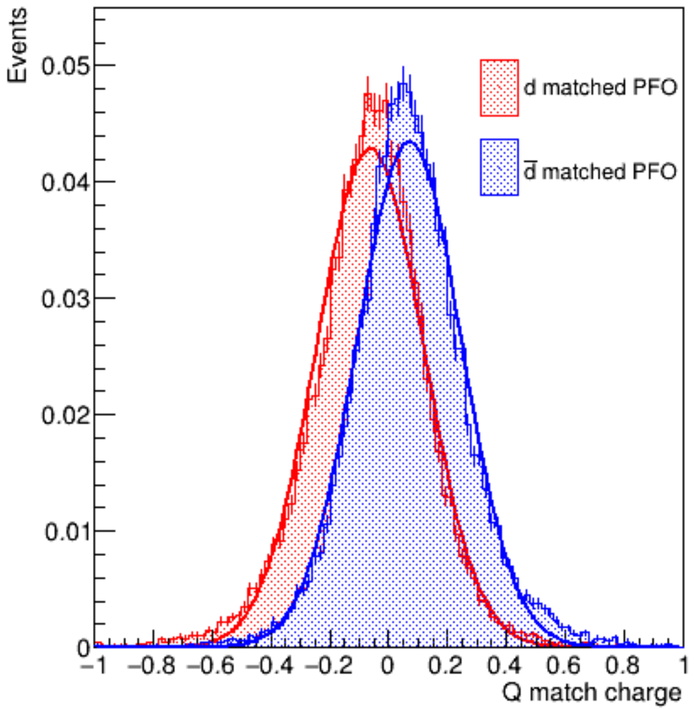
- Calculate pzi (= PFO momentum projected to uubar direction)
- Q is then calculated only for charged PFOs.
- K = 1.0 for now. (can be varied to see the optimal separation)



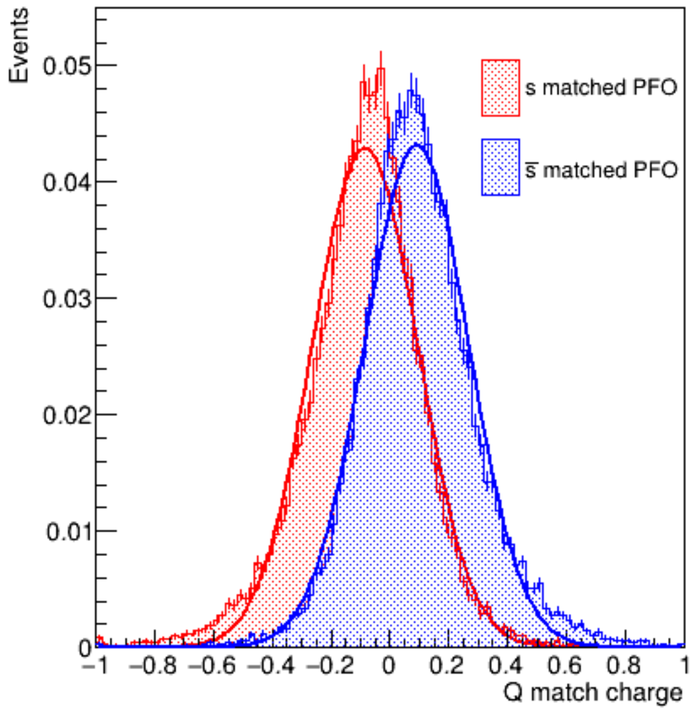

**Formula**

$$Q = \frac{\sum_i Q_i \cdot p_{z_i}^{\kappa}}{\sum_i p_{z_i}^{\kappa}}$$

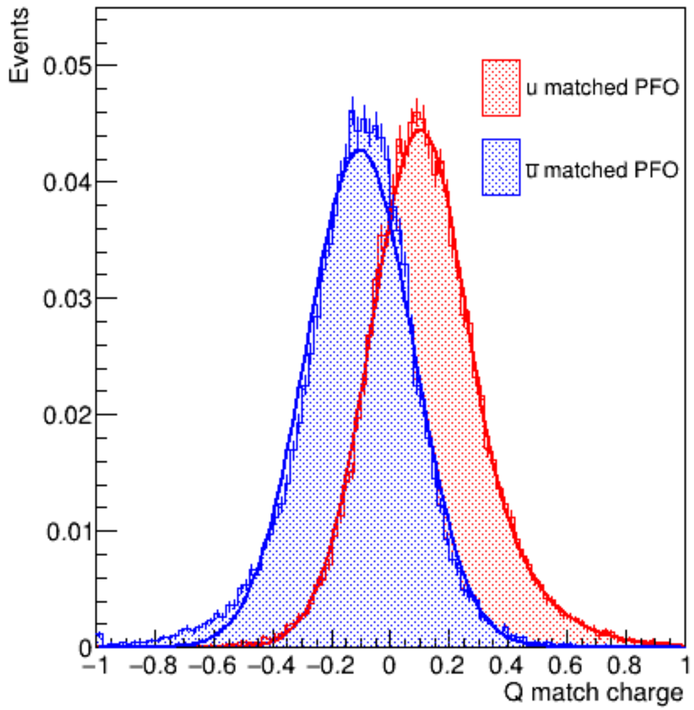
# 8. Jet Charges




| | dbar | d |
|---|---|---|
| Mean | 0.070 | -0.063 |
| Sigma | 0.178 | 0.181 |




| | sbar | s |
|---|---|---|
| Mean | 0.091 | -0.085 |
| Sigma | 0.178 | 0.178 |




| | ubar | u |
|---|---|---|
| Mean | -0.104 | 0.114 |
| Sigma | 0.183 | 0.181 |

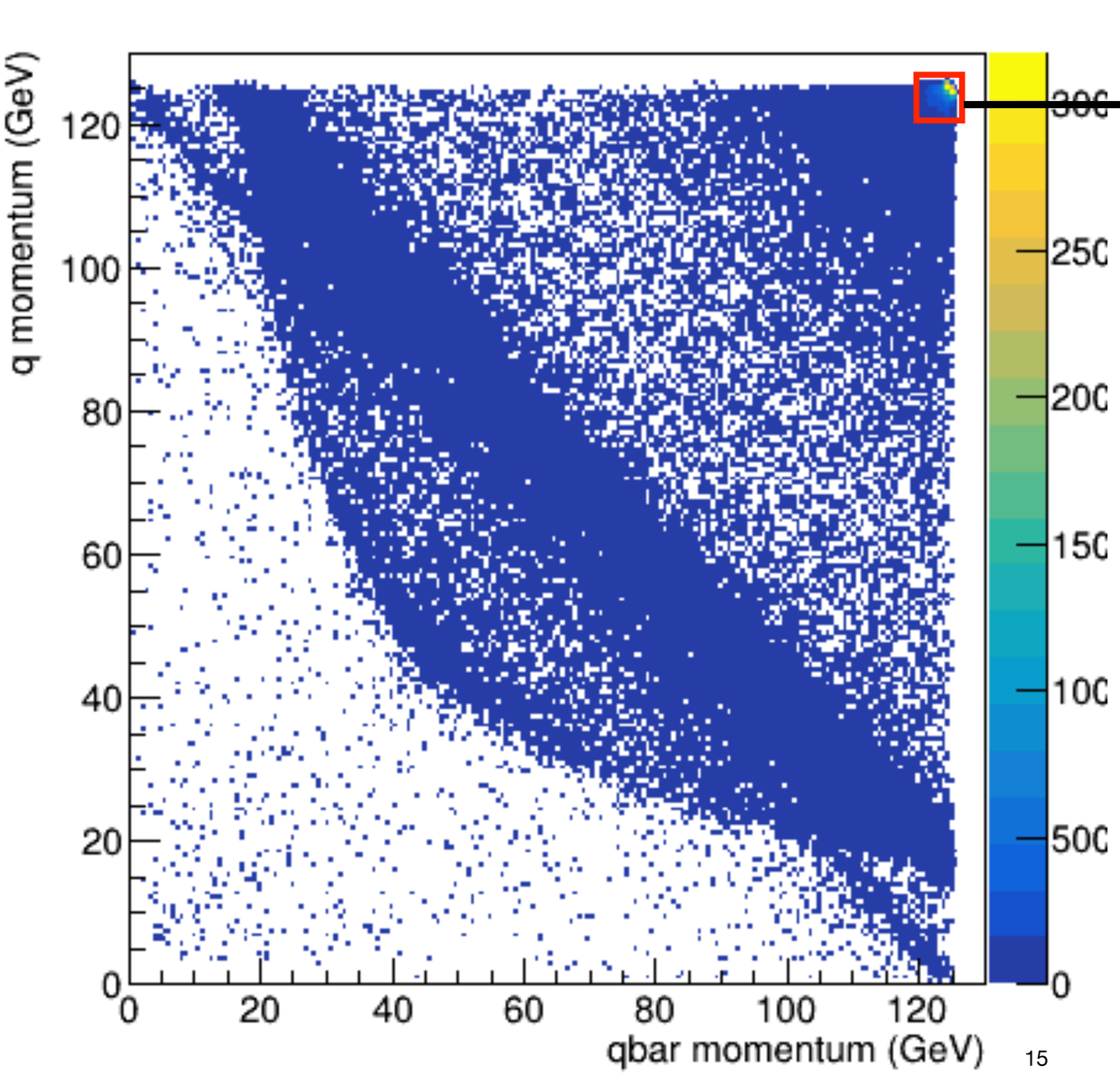
# 9. Summary & Outlook

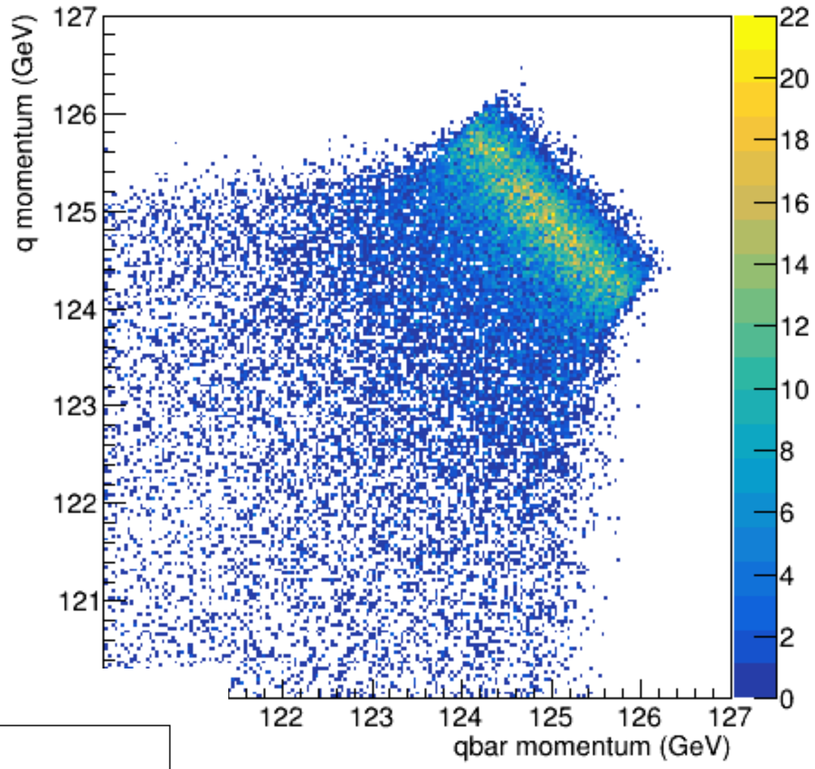
- For this analysis, generator information was used to determine whether leading PFOs are from Kaons.
  - This is to evaluate the true nature of u/d/s events and how can we maximally extract ss events from there.
  - Leading kaon distribution showed that this can be achieved with **excellent signal-to-noise ratio** throughout most of phase-space region.

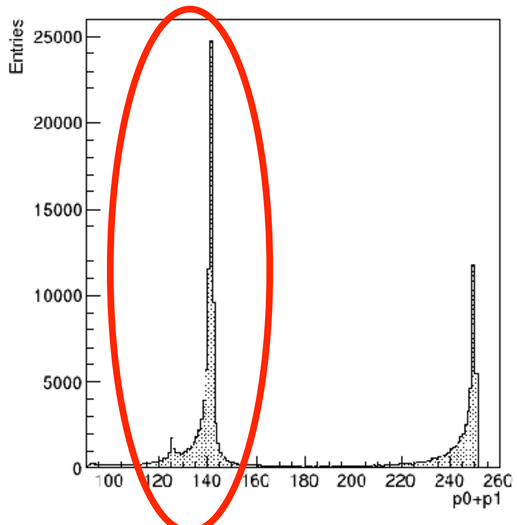
    ➡ One can quantify how this S/N would propagate through different leading Kaon momentum region.
  - Polar angle plot also showed that ss events can be reconstructed without worrying too much of contamination from uu/dd.
- Study of jet charge measurement was also done to separate qqbar charges.
  - Clear separation of charges for all events were observed.
  - It was also seen that there's greater charge separation for uubar.
  - Study is purely academic, and it gives first impression on charge separation when nice likelihood PID does not exist.

# Backup

# 1. Slide Title



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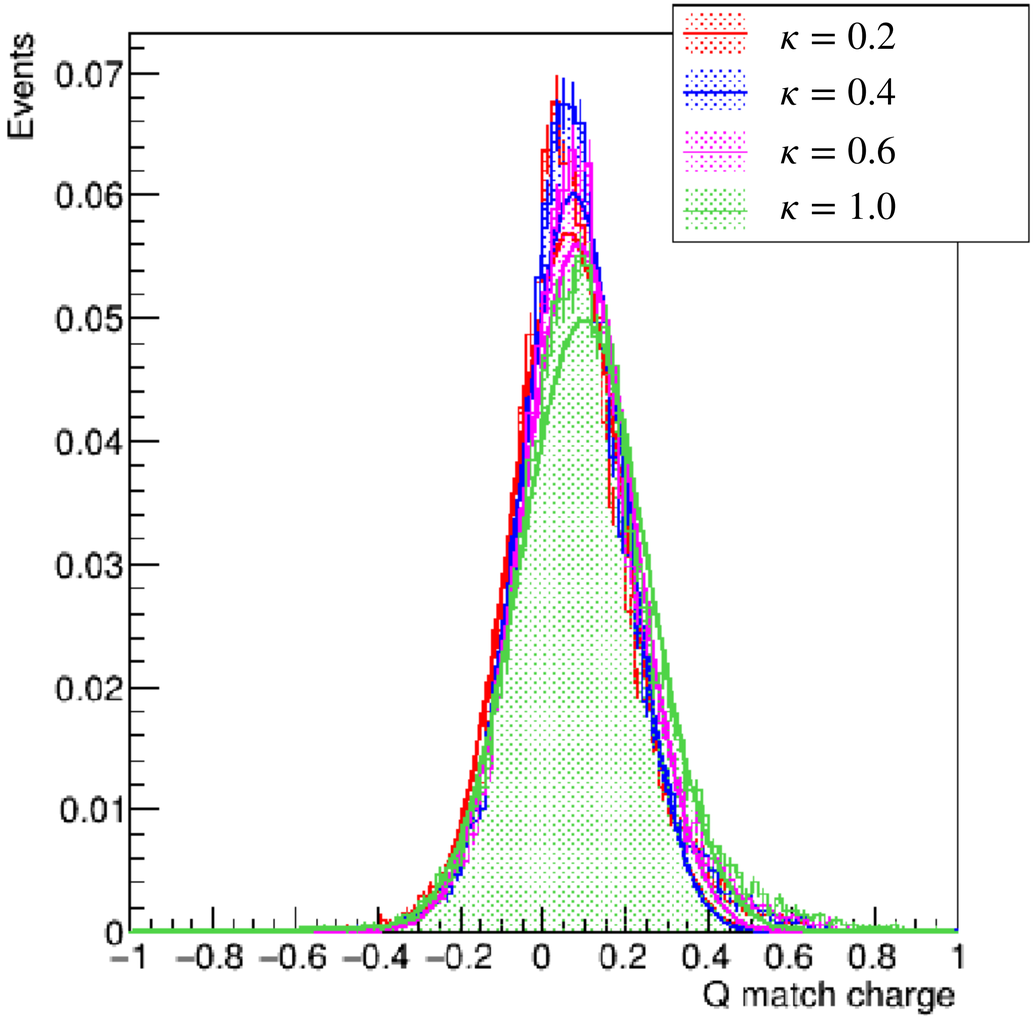


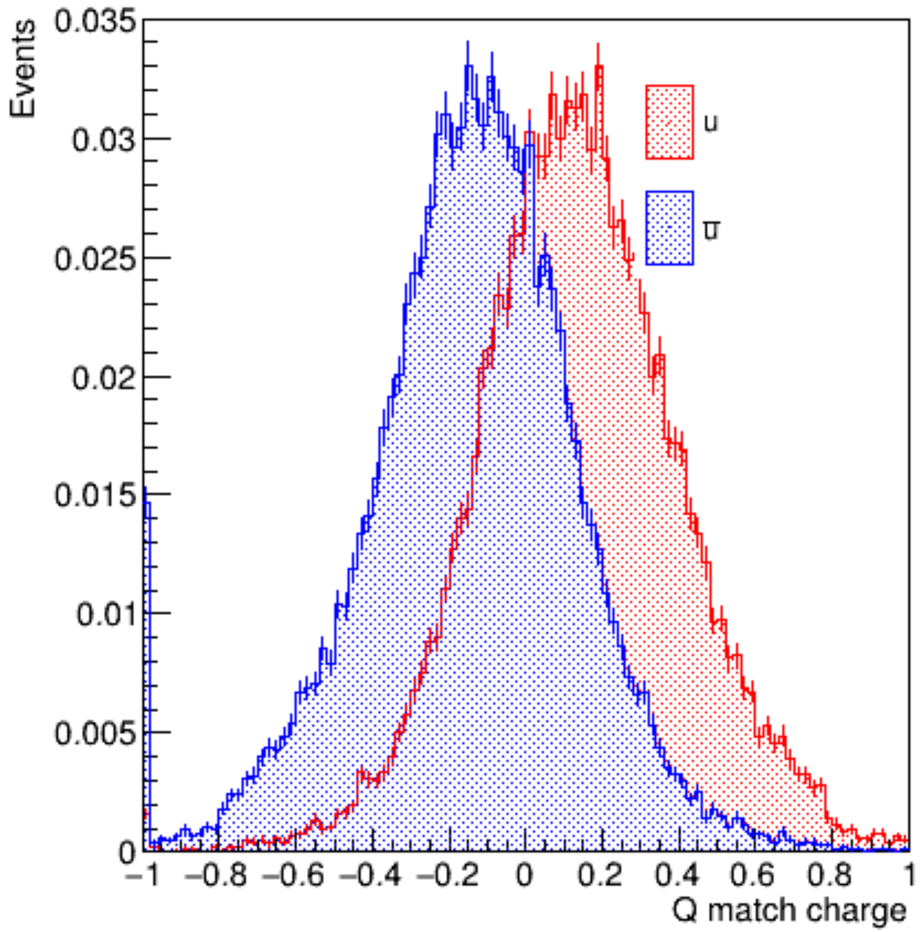


Charge separation when PFO momentum cut > 2 GeV