Kinematic fitting for ParticleFlow Detectors at Future Higgs Factories

Yasser Radkhorrami on behalf of the ILD collaboration, yasser.radkhorrami@desy.de
Deutsches Elektronen-Synchrotron DESY

1- Motivation

\[ \frac{N_{H,LD}}{N_{C,LD}} = 0.4 \% N_{C,LD} = 1 \% N_{H,LD} = 2 \%
\]

of H → bb/\bar{c}c events have at least one semi-leptonic b- or c-decay
⇒ degrade the invariant di-jet mass (important to separate ZH/ZZ and ZHH/ZZH) [1]

signal peak gets sharper

avoid by:
1. a better neutrino correction
2. a better parametrisation of the jet uncertainties

2- \( \nu \)-correction

1. identify b- or c- jets → flavour tagging
2. find the semi-leptonic decay(s) in the jet → find and tag leptons in jets
3. estimate neutrino momentum from kinematic of the semi-leptonic decay

\[
E_\nu = E_X - E_{vis} = \frac{E_{vis} - \vec{p}_{vis}}{m_X + \vec{p}_{vis}} m_X - E_{vis}
\]

2-fold ambiguity in the solution for neutrino energy (momentum)!

Use kinematic fit to decide!

As proof of principle: cheat input to \( \nu \)-correction

3- Kinematic fitting

Mathematical tool that adjusts measured quantities within their uncertainties to fulfill certain constraints [2] [3]

- E & \( \bar{p} \) conservation: clean collision environment at lepton colliders
- Invariant mass of known particles (e.g. \( m_Z \)) as soft constraint
- Minimize \( \chi^2 \):

\[
\chi^2(a, \xi, f) = (\eta - a)^TV^{-1}(\eta - a) - 2\lambda^T f(a, \xi)
\]

\( \eta \): vector of measured kinematic variables
\( V \): covariance matrix
\( a \): vector of fitted quantities
\( \lambda \): Lagrange multipliers
\( \xi \): vector of unmeasured kinematic variables
\( f(a, \xi) \): vector of constraints

4- PFA paradigm and jet error parametrization

ErrorFlow [4]

- \( \sigma_{det} \): detector resolution
- \( \sigma_{conf} \): effects of confusion in the PFA
- \( \sigma_{clus} \): mistakes in the jet clustering
- \( \sigma_{overlap} \): uncertainties of \( \gamma \gamma \rightarrow \text{low} p_T \) hadron overlay removal
- \( \sigma_{\nu} \): uncertainties of \( \nu \)-correction for semi-leptonic b- and c-decays

5- Fit performance

- Flat-most fit probability ever seen!
- Significantly improved pull distributions

6- Higgs mass reconstruction

ISR and Beamstrahlung included

Fully cheated \( \nu \)-correction

ErrorFlow: jet error estimation

Drastically improved reco. \( m_H \):

\( \nu \)-correction + Kinfit ⇒ together

Add backgrounds:

- low \( p_T \) hadron overlay
- background not pulled towards signal

potentially large improvement eg for Higgs self-coupling prospects

ongoing: perform \( \nu \)-correction based on reconstructed information only