A PID Framework for FHFs

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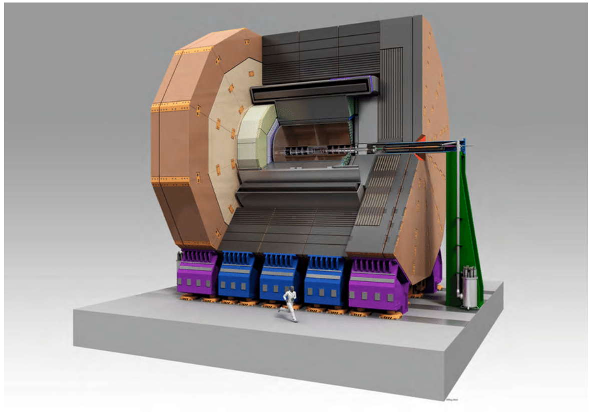
HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

ILD

DESY.

PID at Future Higgs Factories

- Increasing understanding that PID, in particular charged hadron PID, is a very valuable observable at a FHF
- Recent studies focus on 90-250 GeV and precision flavour physics instead of direct (BSM) detection at at TeV range
  → PID is more effective and more relevant in these studies



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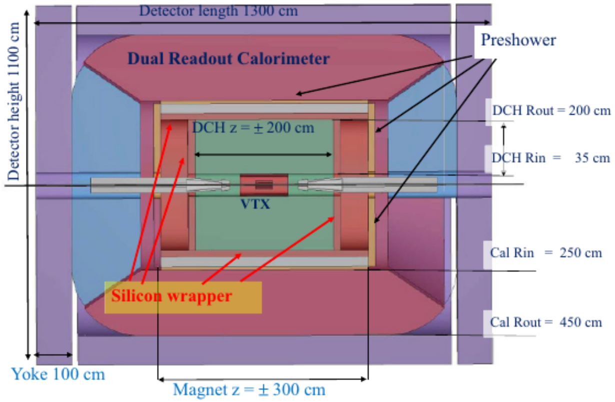
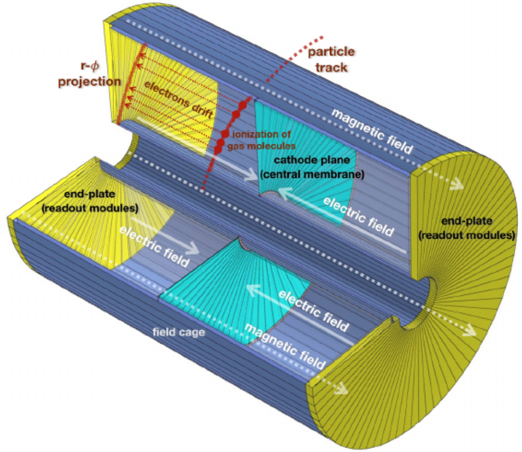


IDEA



CEPC-det

Examples for charged-hadron PID applications at ILD

- Z and W hadronic decay branching fractions via flavour tagging: P. Malek, UE
- Forward-backward asymmetry in $e^+e^- \to q\bar{q}$: R. Pöschl, F. Richard, S. Bilokin, A. Irles, Y. Okugawa, J. Marquez, e.a.
- $H \to s\bar{s}$ with s-tagging: M. Basso, V. Cairo
- Kaon mass with TOF: UE
- Track refit with correct particle mass: Y. Radkhorrami, B. Dudar

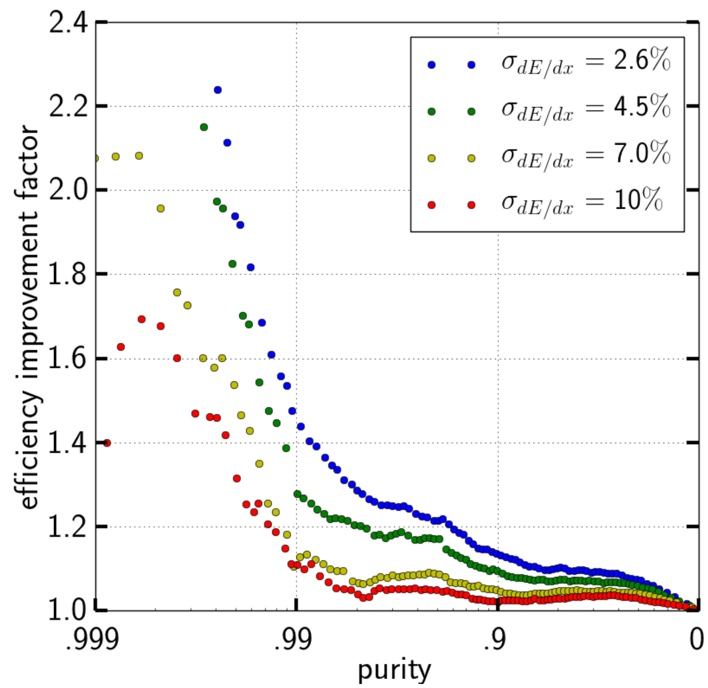
- All these show the effectiveness of PID, but can we quantify this?

* references in backup!

How do we evaluate the impact of PID?

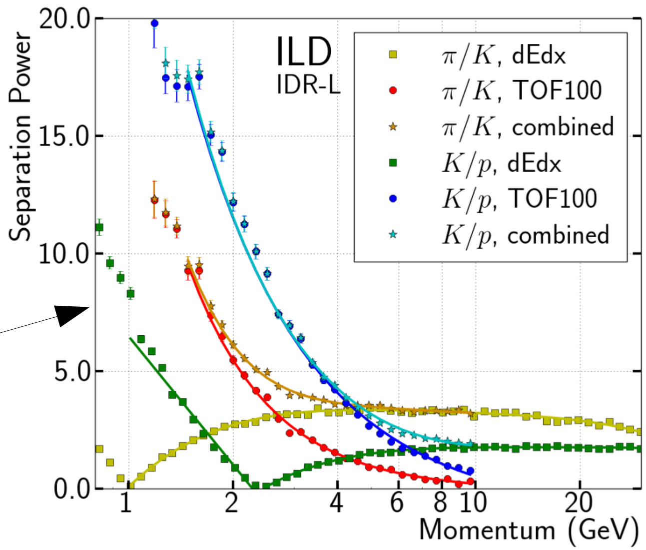
- Plot: for a particular flavour tagging analysis (separation of d/u vs. s/c decays of Ws), what is the improvement in efficiency over purity when adding dE/dx information, depending on the dE/dx resolution?
- Very specific case: one channel, one set of PID observables, one metric

  → How can we create a more general assessment of PID performance?
- Optimise detectors and compare them
  - Is Silicon dE/dx worth considering?
  - At what timing resolution starts TOF to be relevant for flavour tagging?
  - How does **my** physics result depend on the dE/dx resolution?
  - What if we add a RICH to SiD?



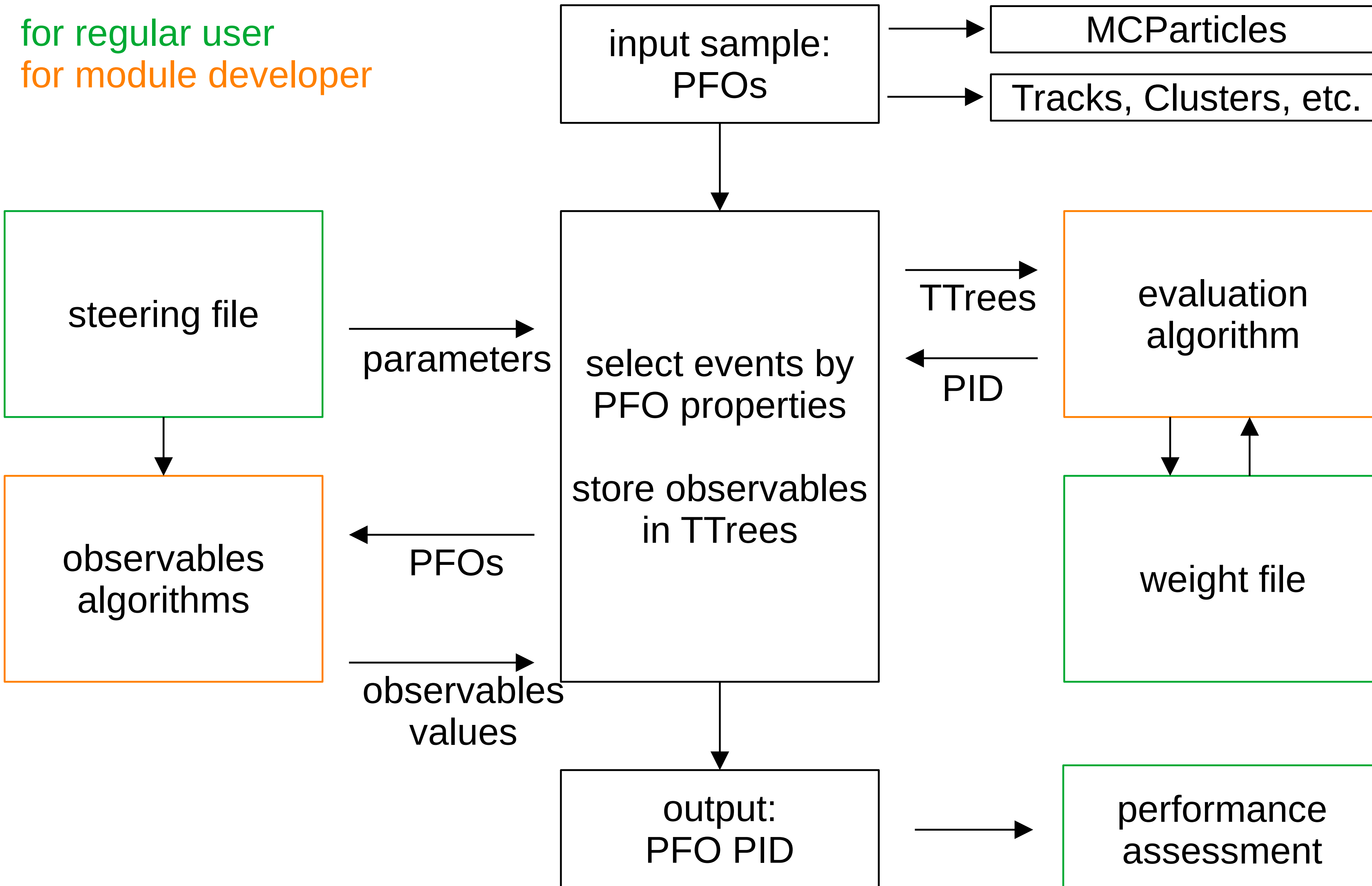
Status Quo in iLCSoft

- LikelihoodPIDProcessor
  - dE/dx (TPC)
  - Cluster shapes (calorimeter)
  - Low momentum muon ID (forward system)
- Rigid, complicated to adapt, needs work on core code
- Complicated to train → training done by experts once per MC production with calibration sample
- Time-of-flight newly added to ILD, not to LikelihoodPID → left to analysers to use, combination done 'by hand'



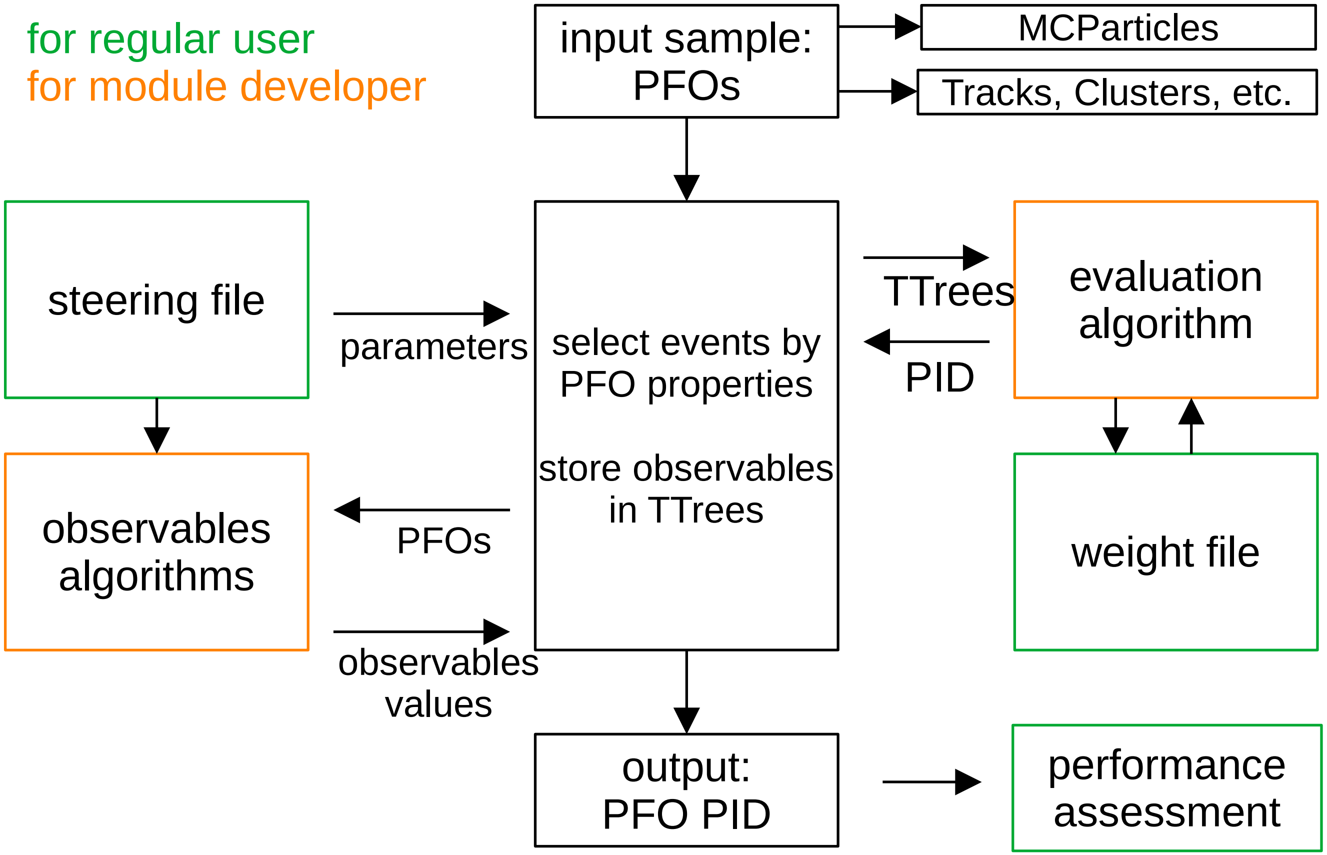
Proposal

- ‘Comprehensive PID Processor’
- For now, being implemented in LCIO / Marlin
  - immediately usable in Key4HEP via ‘Marlin wrapper’
  - target: implement in EDM4HEP, make available to whole FHFs community
- Modular:
  - observables algorithms
  - training methods / evaluation algorithms
- Core code takes care of book keeping
  - simple, well defined data structures for storage (TTree) and interfaces (std::vector)


for regular user
for module developer
input sample:
PFOs
MCParticles
Tracks, Clusters, etc.
steering file
parameters
select events by
PFO properties
store observables
in TTrees
TTrees
evaluation
algorithm
PID
observables
algorithms
PFOs
weight file
observables
values
output:
PFO PID
performance
assessment

Proposal

- Steering file
  - input sample
  - observables algorithms
  - signal categories PDGs
  - evaluation algorithm
  - weight file
  - sample cuts etc.
- Possibility to store observables and do training separately (python etc.)
- Separate performance assessment for various plots incl. eff./pur. MC PDG vs. Reco PDG and separation power



Examples

- Use cluster shapes, dE/dx and TOF for generic separation of electrons, muons, pions, kaons and protons

  → train multi class TMVA on calibration sample, output general likelihood values for general analysis purposes

- Use cluster shapes, dE/dx and low-momentum muon ID to select only muons, based on a pre-selected sample in the very forward region

  → train simple signal/background on 10% of specific sample, use weights for 90% fof sample for analysis

- Develop new observable module for RICH readout, match with novel neural network

  → train on SM sample, generate separation power plots to check overall effect of adding RICH

Questions to Community

- Would this be useful to you?
- What observables are you using and what value types do they contribute?
- What training methods are you using / do you want to use?

→ How do the interfaces need to look?

→ Let’s talk at coffee / poster session / via email!

Thanks!

Questions / Suggestions?

Backup - References

- Hadronic Z decay: P. Malek PhD thesis https://ediss.sub.uni-hamburg.de/handle/ediss/9634
- Hadronic W decay: U. Einhaus PhD thesis (in prep.), talk https://agenda.linearcollider.org/event/8437/
- Forward-backward asymmetry in $e^+e^- \to q\bar{q}$:
  - S. Bilokin PhD thesis https://tel.archives-ouvertes.fr/tel-01826535
  - $e^+e^- \to$ bb, 2019 https://agenda.linearcollider.org/event/8147
  - $e^+e^- \to$ tt, bb 2019 https://confluence.desy.de/download/attachments/42357928/ILD-PHYS-PUB-2019-007.pdf
  - $e^+e^- \to$ cc, 2020 https://arxiv.org/abs/2002.05805
  - $e^+e^- \to$ bb/cc, ss 2021 https://agenda.linearcollider.org/event/9440 https://agenda.linearcollider.org/event/9285
  - $e^+e^- \to$ bb/cc 2021 https://agenda.linearcollider.org/event/9211/contributions/49358/
- $H \to s\bar{s}$ with s-tagging: M. Basso, V. Cairo e.a. https://arxiv.org/abs/2203.07535
- Kaon mass with TOF: U. Einhaus https://pos.sissa.it/380/115/
- Track refit with correct particle mass: Y. Radkhorrami, B. Dudar https://agenda.linearcollider.org/event/8498/