MVA Track Quality Estimation for the Belle II Experiment

Tracking Meeting

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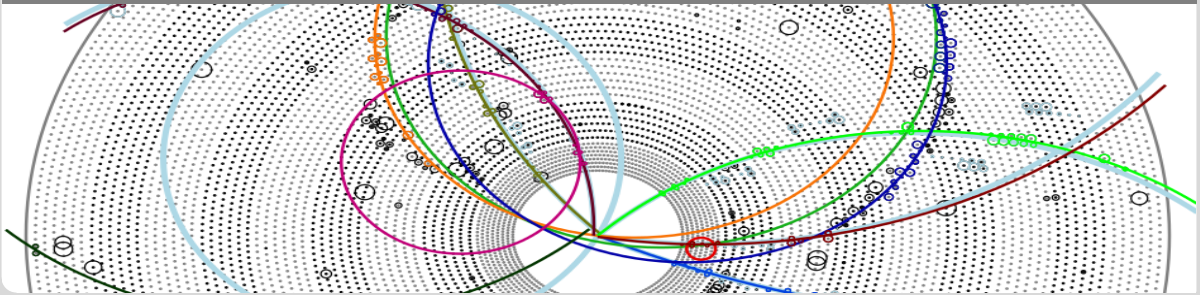
INSTITUT FÜR EXPERIMENTELLE TEILCHENPHYSIK (ETP) – KIT



Track Quality Indicator

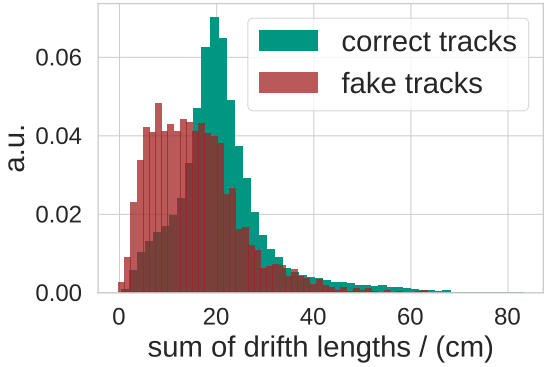
- Goal: Enable physics analysts to **choose working point** on the efficiency vs. purity receiver operating curve (ROC)
- assign a **quality indicator (QI)** to the final tracks
- include low-level **tracking information** in addition to already existing information from the fit (e.g. χ^2),
- Solution: Train an multivariate (MVA) classifier $=$ **track quality estimator**

Features for Training the Quality Estimator

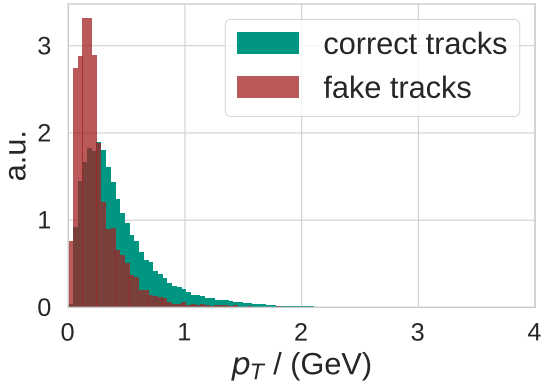
- training target: MC truth to discriminate fake (and clone) from correct tracks in training
- input variables: use all information available during the reconstruction
- intermediate quality estimators: **CDC QE, VXDTF QE**
  - many features only available to the tracking algorithms in the subdetectors, e.g.
  - CDC: drift lengths, ADC signals, . . .
  - SVD: charge, energy loss, triplet fit . . .
- hit patterns and hit weights from the **track fit**
- momentum and positional information (**four-vectors**)
- timing information
- **merger information**: χ^2 and differences in track parameters
- **event-level** variables: bias?

Example Feature Distributions

From CDC tracking: e.g. drift lengths



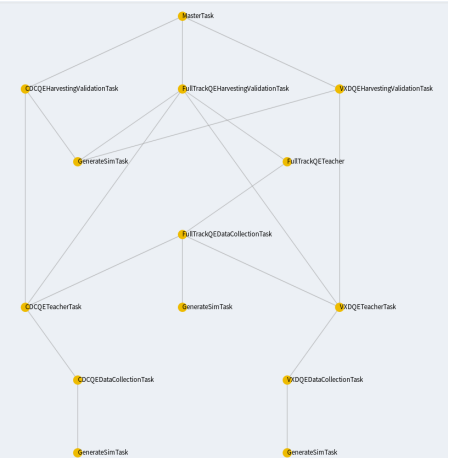
From fit: e.g. track-parameters



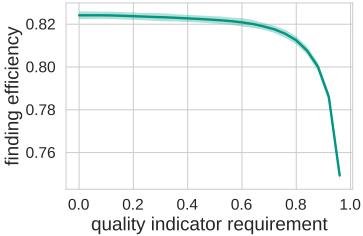
- these are not the most important ones, just examples
- heavily correlated with other variables: FastBDT can learn that

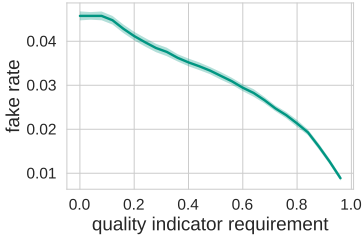
Training and Validation

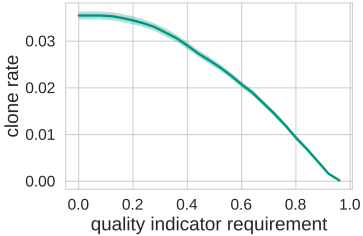
- use single steering file with b2luigi
  - combined training and validation of all three classifiers: CDC QE, VXDTF QE and Combined Track QE
  - easy to iterate over different parameter combinations (e.g. grid search)
- 5000 events ($\sim$ 50 000 tracks) for each training and separate dataset for validation
- currently used background: `15th_overlay_phase3_Feb2018`

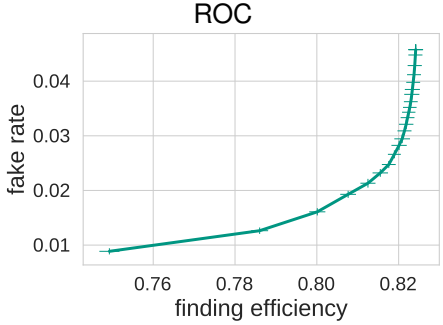


CDC Quality Estimator Performance



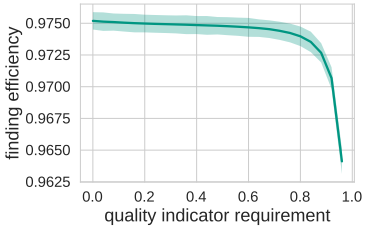


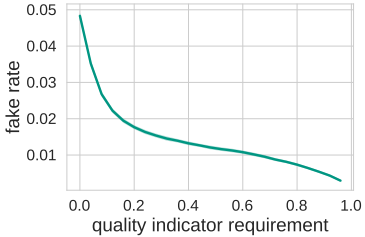


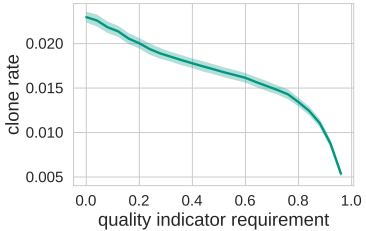


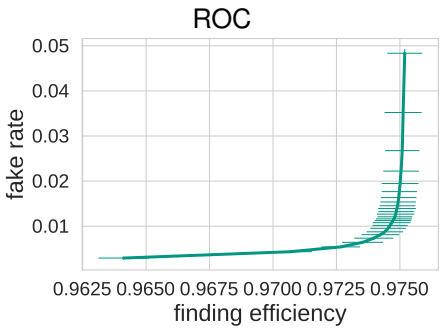
- CDC-only tracking with background
- normalized to tracks findable in the CDC
- currently trained with clones as background
  $\rightarrow$ study?

VXDTF2 Quality Estimator Performance



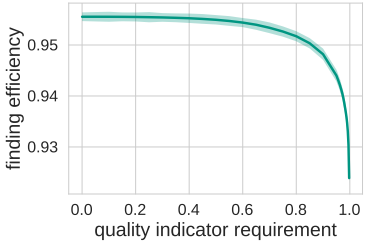


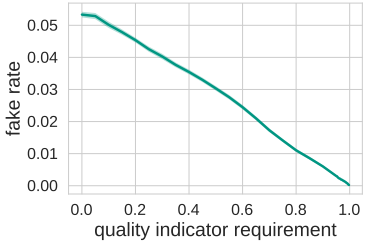


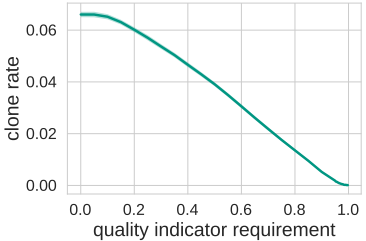


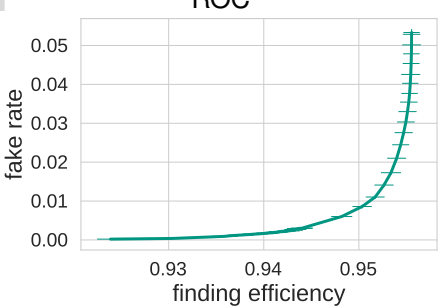
- VXD-only tracking with background
- normalized to tracks findable in the VXD
- trained with fakes as background class only
- in contrast to CDC QE, fake rate falls very steeply at low QI

Combined Quality Estimation









- combining features of all track finders yields good fake suppression with only small finding efficiency losses
- no impact on fitted parameter resolutions in correct PR track seen (plots in backup)

Current Status and ToDo's

- CDC and VXDTF quality estimators merged, combined quality indicator on branch `feature/BII-2127-General-MVA-QI`
- currently finalizing (refactoring) branch, e.g. warnings during training
- want to compare training with fake-only background in CDC
- train without event-level variables?
  $\Rightarrow$ easy with luigi
- create final payloads
- will create (TUPPR) PR soon so that discussions can happen in the comments

Backup

MVA Training Parameters

- train on 5000 events ($\sim$50 000 tracks) each for training and testing
- number of input features for combined QE: 96
  - CDC QE: 20
  - SVD QE: 27
- FastBDT parameters
  - 200 trees
  - 8 levels
  - size of random sample: 50 %
  - shrinkage: 0.1

Input Features for the SVD and CDC Quality Estimators

CDC QE input features

`adc_max`, `adc_mean`, `adc_min`, `adc_sum`, `adc_variance`, `drift_length_max`, `drift_length_mean`, `drift_length_min`, `drift_length_sum`, `drift_length_variance`, `empty_s_max`, `empty_s_mean`, `empty_s_min`, `empty_s_sum`, `empty_s_variance`, `has_matching_segment`, `pt`, `s_range`, `size`, `sz_slope`

SVD QE input features

`NSpacePoints`, `charge_max`, `charge_mean`, `charge_min`, `charge_std`, `energyLoss_max`, `energyLoss_mean`, `energyLoss_min`, `energyLoss_std`, `seedCharge_max`, `seedCharge_mean`, `seedCharge_min`, `seedCharge_std`, `size_max`, `size_mean`, `size_min`, `size_std`, `tripletFit_Chi2`, `tripletFit_PMag`, `tripletFit_P_Eta`, `tripletFit_P_Mag`, `tripletFit_P_Phi`, `tripletFit_P_X`, `tripletFit_P_Y`, `tripletFit_P_Z`, `tripletFit_Pt`, `tripletFit_QI`

Input Features for the Combined Quality Estimator

CDC_FitSuccessful, CDC_QI, Fit_Charge, Fit_Chi2, Fit_NFailedPoints, Fit_Ndf, Fit_PVal, Fit_Successful, N_CDCRecoTracks, N_CDC_hits, N_PXDRecoTracks, N_PXD_hits, N_RecoTracks, N_SVDRecoTracks, N_SVD_hits, N_TP_noKalmanFitterInfo, N_diff_PXD_SVD_RecoTracks, N_diff_SVD_CDC_RecoTracks, N_no_TrackPoint, N_total_hits, POCA_Mom_Mag, POCA_Mom_Phi, POCA_Mom_Pt, POCA_Mom_Theta, POCA_Mom_Z, POCA_Pos_Mag, POCA_Pos_Phi, POCA_Pos_Pt, POCA_Pos_Theta, POCA_Pos_Z, PXD_QI, RTs_Min_Mom_diff_Mag, RTs_Min_Mom_diff_Mag_idx, RTs_Min_Mom_diff_Pt, RTs_Min_Mom_diff_Pt_idx, RTs_Min_Pos_diff_Phi, RTs_Min_Pos_diff_Phi_idx, RTs_Min_Pos_diff_Theta, RTs_Min_Pos_diff_Theta_idx, SVD_CDC_CDCwall_Chi2, SVD_CDC_CDCwall_Mom_diff_Eta, SVD_CDC_CDCwall_Mom_diff_Mag, SVD_CDC_CDCwall_Mom_diff_Phi, SVD_CDC_CDCwall_Mom_diff_Pt, SVD_CDC_CDCwall_Mom_diff_Theta, SVD_CDC_CDCwall_Mom_diff_Z, SVD_CDC_CDCwall_Pos_diff_Eta, SVD_CDC_CDCwall_Pos_diff_Mag, SVD_CDC_CDCwall_Pos_diff_Phi, SVD_CDC_CDCwall_Pos_diff_Pt, SVD_CDC_CDCwall_Pos_diff_Theta, SVD_CDC_CDCwall_Pos_diff_Z, SVD_CDC_POCA_Mom_diff_Eta, SVD_CDC_POCA_Mom_diff_Mag, SVD_CDC_POCA_Mom_diff_Phi, SVD_CDC_POCA_Mom_diff_Pt, SVD_CDC_POCA_Mom_diff_Theta, SVD_CDC_POCA_Mom_diff_Z, SVD_CDC_POCA_Pos_diff_Eta, SVD_CDC_POCA_Pos_diff_Mag, SVD_CDC_POCA_Pos_diff_Phi, SVD_CDC_POCA_Pos_diff_Pt, SVD_CDC_POCA_Pos_diff_Theta, SVD_CDC_POCA_Pos_diff_Z, SVD_FitSuccessful,

Nonexistent Impact on Resolutions?