Machine Learning Assisted Track Finding in the Belle II SVD

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Connecting the Dots 2016 - Vienna

23.02.2016

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Some Information on Belle II

... can be found in talks given by

- Sebastian Skambraks: *The NeuroZ-Vertex Trigger of the Belle II Experiment*
- Oliver Frost: *Tracking in the Belle II Drift Chamber*
- Jakob Lettenbichler: *Tracking in the Belle II Vertex Detector*

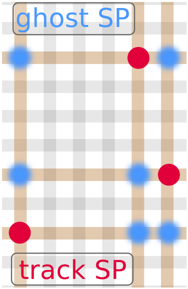
Challenges and Short Recap of SectorMap

Goal:

low momentum track finding down to $p_T \approx 50\,\mathrm{MeV}/c$

Main Challenges:

- Energy loss and multiple scattering influence particle trajectory
- Limited reconstruction time
- Ghost SpacePoints on strip detectors



SectorMap:[a]

- divide detector into small sectors
- use relations between sectors to define cut-off filters for hit combinations

[a] see talk by Jakob Lettenbichler

Bringing Machine Learning into play

Advantages and Challenges of the SectorMap:

+ Fast filtering with high efficiency
– Tuning of a large number of filters and sector relations
– Training very resource demanding

Hopes in Supervised Machine Learning:

+ Exploit generalization capabilities
    + Less sectors required
    + Less training data required
+ Improved signal and background separation

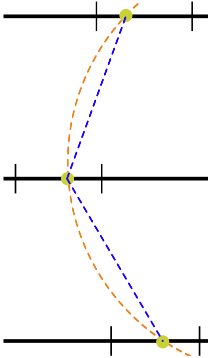
? Is it possible to exchange a large number of simple filters by a small number of ML filters ?

The Approach and Training

Combine SectorMap and Machine Learning:

2-SpacePoint combinations processed by SectorMap

Use a Boosted Decision Tree (BDT) to filter 3-SpacePoint combinations:



- inputs: $x \in \mathbb{R}^9$ - (3×3) spatial coordinates of SpacePoints
- outputs: $y \in \mathbb{R}$ - use cut to decide signal/background
- label: from full detector simulation
  - $\rightarrow$ signal if all SpacePoints from same MC particle

Some words on the simulation

Simulation setup:

- limited θ-range: $60^\circ \leq \theta \leq 85^\circ$
- particle gun: 10 μ tracks per event
- low momentum range: $100\,\mathrm{MeV/c} \leq p_T \leq 145\,\mathrm{MeV/c}$
- no additional background

Results in:

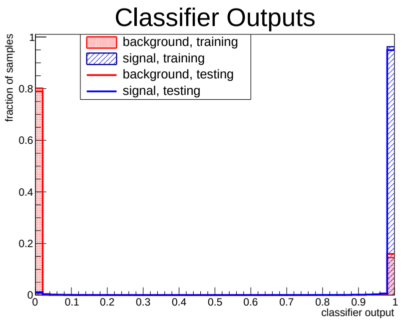
- TODO: ghost hits / track hits
- signal / background samples $\approx$ 0.08

Expected in experiment:

- $\Upsilon(4S)$-events: on average $\approx$ 10 tracks per event
- TODO: expected ghost / track hits[1]

[1] how to compute this?

Classifier Performance



- good separation of signal and background
- cut is defined to reach 99 % signal efficiency
- performance only slightly worse for test data set
  - cut (training): 0.072 → 81 % bg rejected
  - cut (testing): 0.011 → 78 % bg rejected

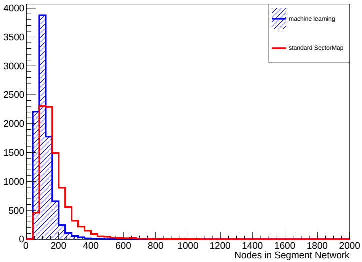
TODO: ROC + finer binned, zoomed, logscale of outputs

TODO: correct plots!!!

→ training a classifier for the task is possible

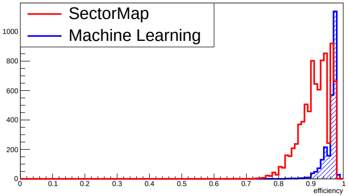
Comparison with Angle3d filter

Both approaches used same events (for training and for testing)



- Network size = number of Segments that passed three hit filters
- indicator for bg rejection
- ML yield smaller Networks

- TODO: efficiency definition
- ML with better efficiency



Conclusion & Outlook

Conclusions:

- Machine Learning Approach with promising results
- BUT Tests not done on full detector and momentum range
  - $\rightarrow$ SectorMap only slightly affected
  - $\rightarrow$ ML could degrade significantly

Outlook and ToDo's:

- Test on full detector and momentum range
- Test feasibility of different ML classifiers for different detector regions

TODO: what else?