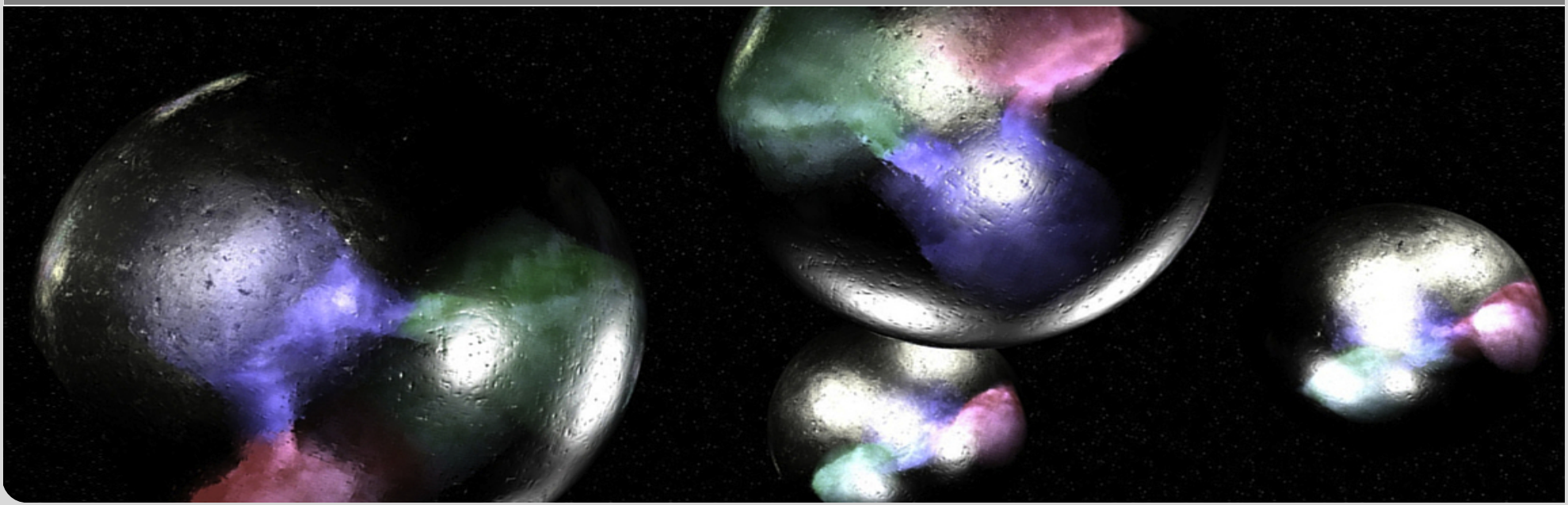
Karlsruhe Institute of Technology

Belle II

VXDTF2 Status Report from Karlsruhe

Felix Metzner | 18th September 2017

INSTITUT FÜR EXPERIMENTELLE TEILCHENPHYSIK (ETP)

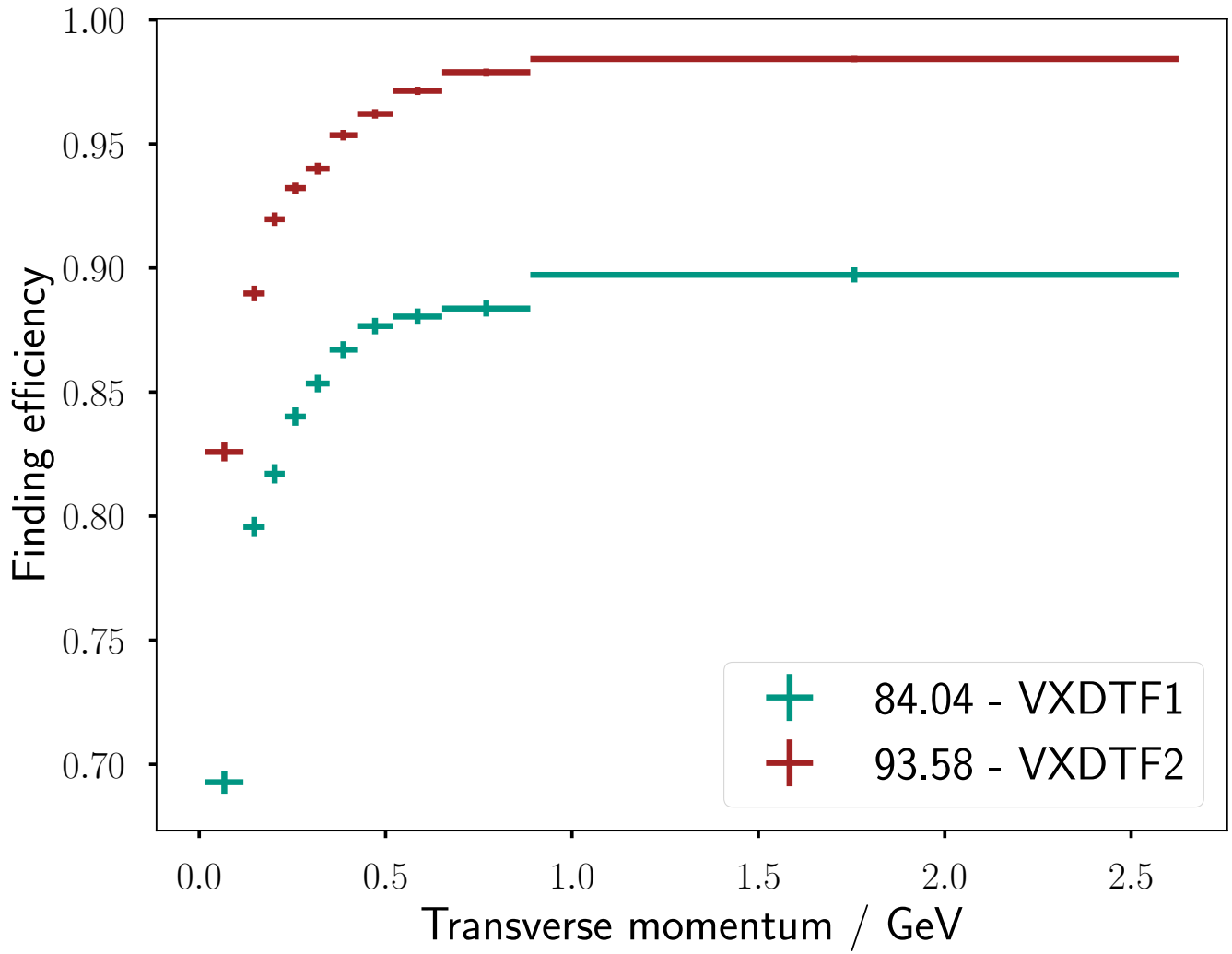


Overview

1. VXDTF2 Status Report
   - Current VXDTF2 Performance
   - New Feature: 2-Staged Overlap Resolving
   - Overlap SpacePoint Exclusion
   - Subpath Evaluation
   - MVA Track Quality Estimators
2. Study of Effects of Reduced PXD Integration Time
   - Study Description
   - Results

Current Performance of the VXDTF2

	Finding Eff.	Fake Rate	Clone Rate	Runtime / Event
VXDTF1	84.04	**18.07**	**0.41**	32.7 ms
VXDTF2	**93.58**	20.62	0.43	**16.3 ms**



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10-Moun SectorMap was used

Runtime of VXDTF2 can still be improved by

- removing unnecessary SpacePoint relations (already merged)
- replacing Sector-ID **strings** by Sector-ID **integers** (already merged)

Fake Rate can still be reduced by

- the application of the DAF for the final fit
- a cut on the Quality Index

Finding Efficiency loss of 1-2 %-points due to MC tracks sharing clusters

New Feature: 2-Staged Overlap Resolving

Current problem: Memory usage due to number of candidates.

New 2-step ansatz for Overlap Resolution:

Step 1 — During Path Finding

- 2 Tracks compete only if they share at least 2 SpacePoints
- All competing Track Candidates are part of a Family

$\Rightarrow$ Resolve overlap for each Family separately

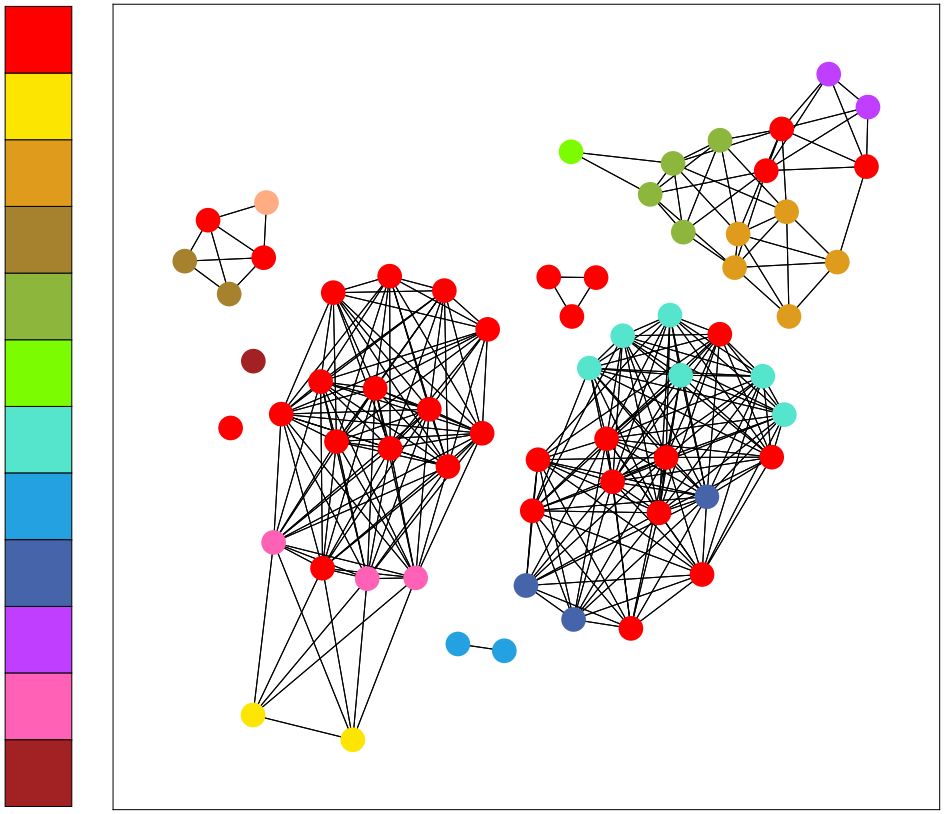
$\Rightarrow$ **Smaller overlap matrices and less candidates**

Step 2 — As usual . . .

- NEW: Add subpaths of Track Candidates
- Estimate Track Candidate quality
- Resolve cluster overlap as usual . . .

New Feature: 2-Staged Overlap Resolving

Before Step 1: All Cluster Overlaps of an Example Event

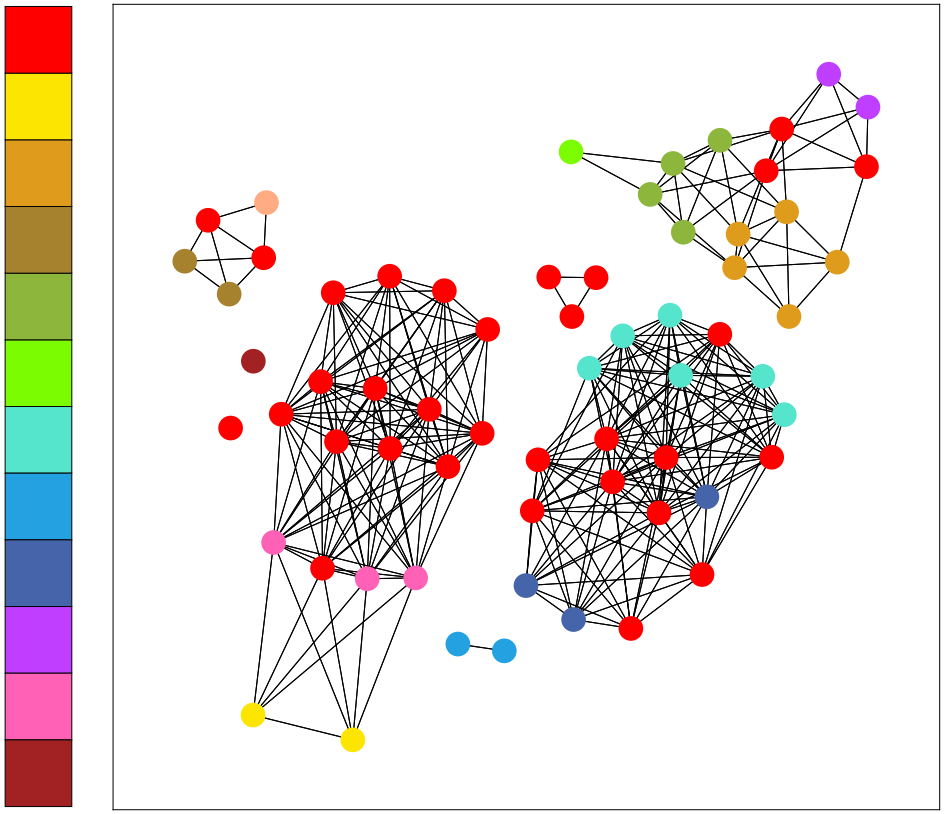


Cluster Overlap

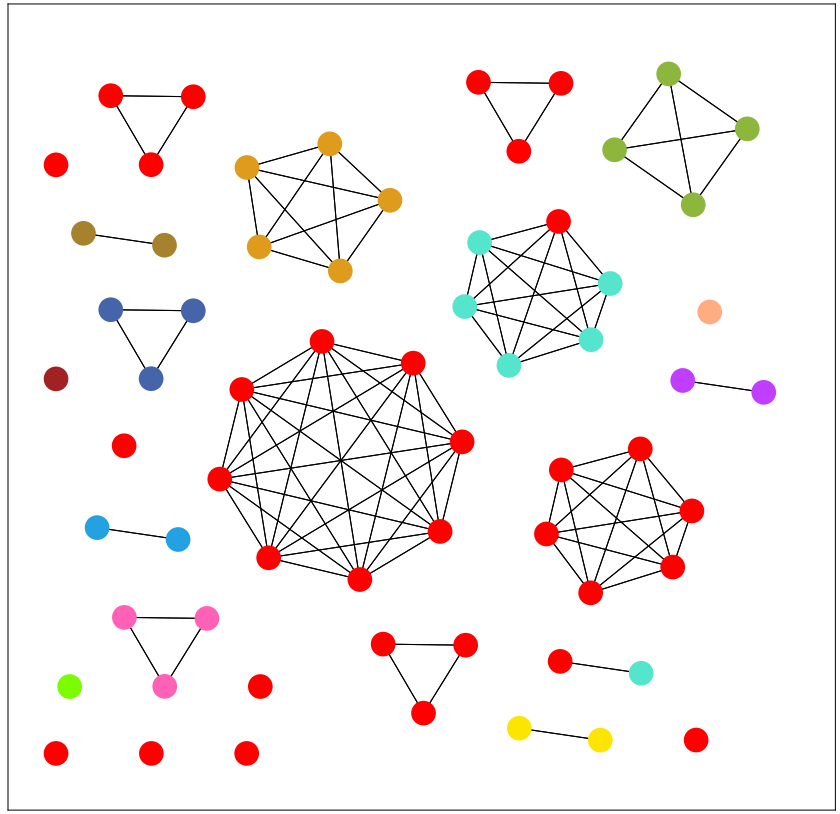
- Each Node represents a candidate
- Two Nodes are connected if they are overlapping
- The colors represent the matched MC Tracks
- Bright RED represents no match $\Rightarrow$ a Fake!

New Feature: 2-Staged Overlap Resolving

Before Step 1: All Cluster and 2-SP Overlaps of an Example Event



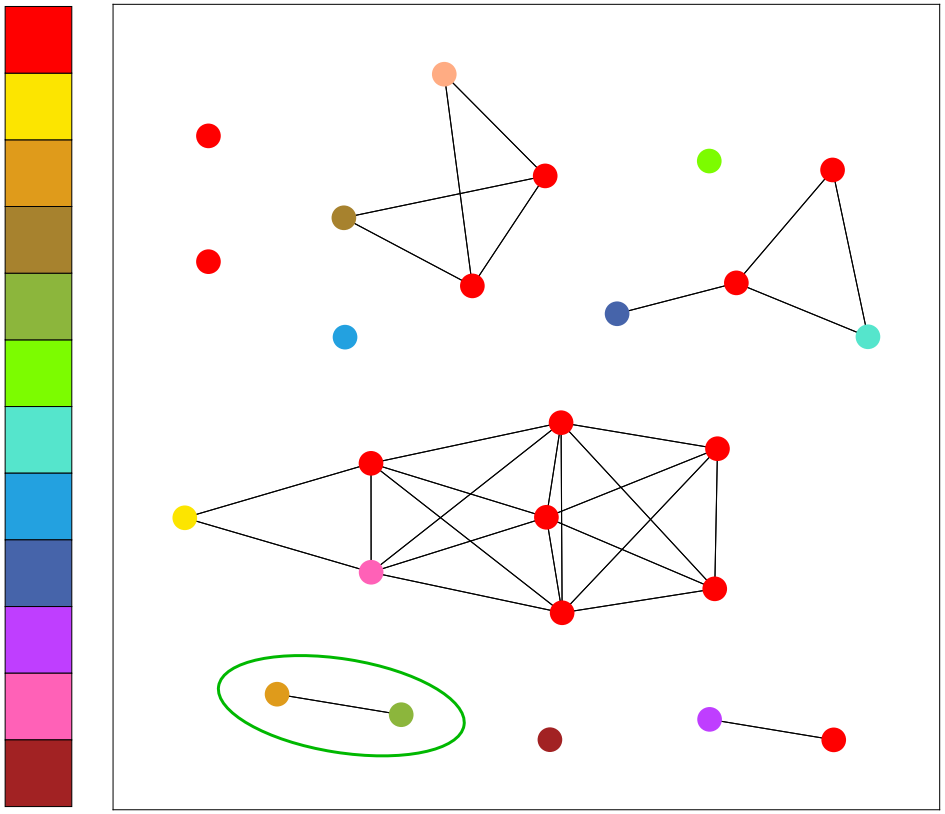
Cluster Overlap



2 SpacePoint Overlap

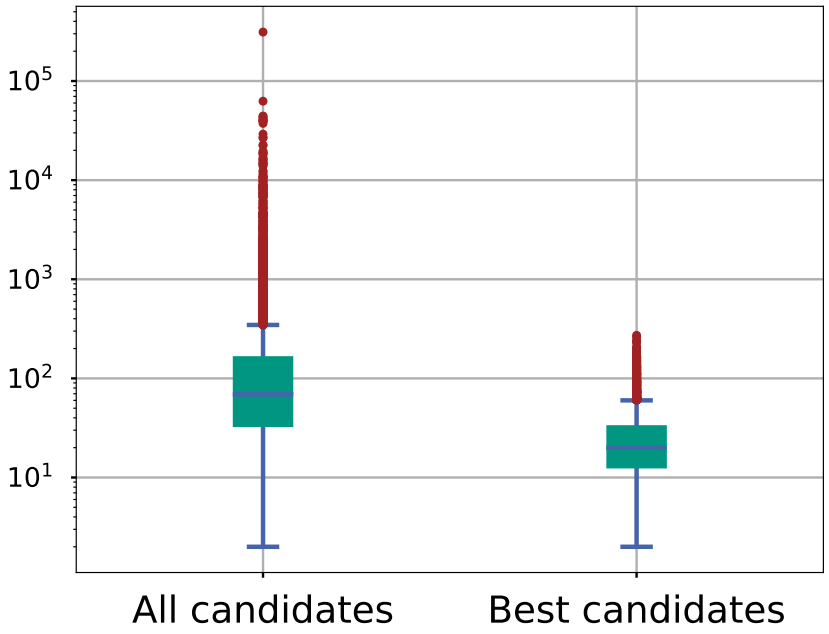
New Feature: 2-Staged Overlap Resolving

After Step 1: Cluster Overlaps after resolving 2-SP Overlap



Cluster Overlap after 2-SpacePoint Overlaps are resolved

	All candidates	Best candidates
Avg. Clones	31.35±0.05	2.81±0.02
Avg. Fakes	294.41±0.06	15.18±0.03
Finding Eff.	96.24±0.06	95.94±0.06
Hit Eff.	97.13±0.03	97.11±0.03
Hit Purity	83.78±0.02	93.02±0.04



New Feature: 2-Staged Overlap Resolving

Application of Step 1

Evaluation of 2-SP Overlaps and generation of Families

- based on SegmentNetwork
- during Cellular Automaton

Resolving **after** PathFinding

- ✓ 2-SP Overlap resolved for each Familiy separately via highest QI
- ✓ Implementation on Stash
- ✗ Does not solve Memory Problem . . .

Resolving **during** PathFinding

- ✓ Only the best Candidate of a Family is created
- ✓ Solves Memory Issue
- ✗ Not yet on Stash . . .

All results shown in the following were obtained with Resolving after PathFinding!

New Feature: 2-Staged Overlap Resolving

Current problem: Memory usage due to number of candidates.

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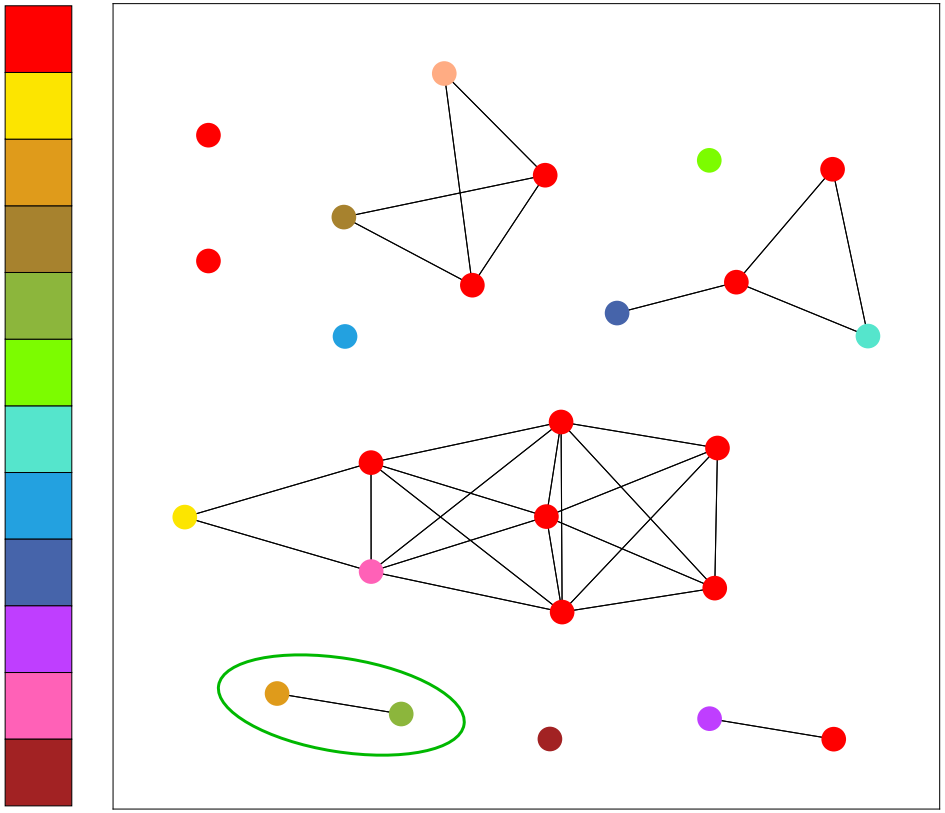
Step 2 — As usual . . .

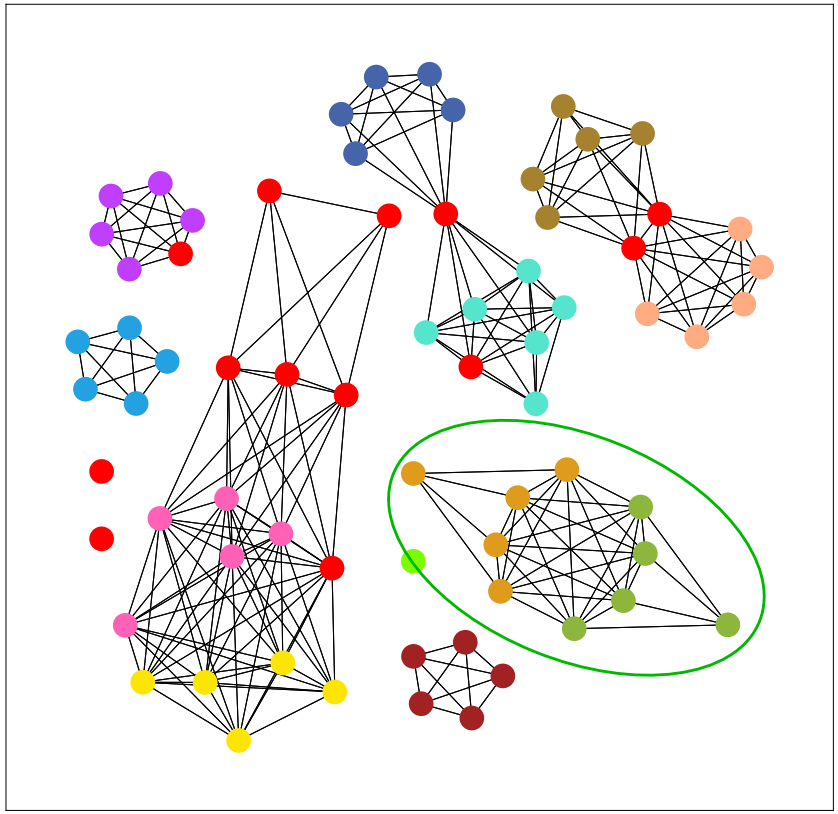
- NEW: Add subpaths of Track Candidates
- Estimate Track Candidate quality
- Resolve cluster overlap as usual . . .

New Feature: 2-Staged Overlap Resolving

Step 2: Add Subpaths of remaining Chains as new Candidates

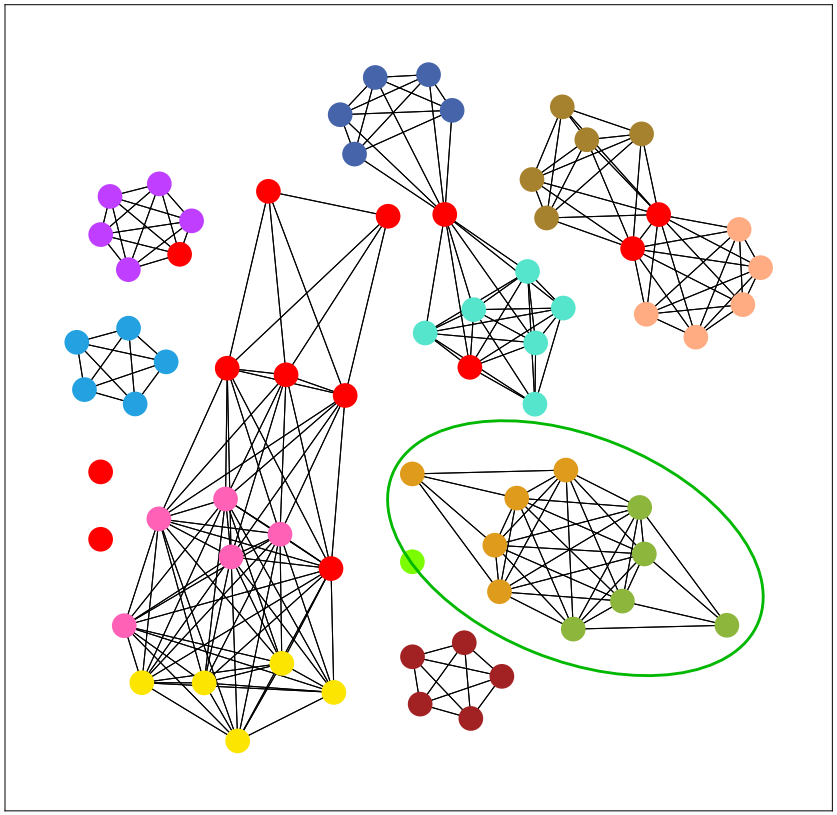


Cluster Overlap after 2-SpacePoint Overlaps are resolved



Cluster Overlap with new Subpath Candidates

New Feature: 2-Staged Overlap Resolving



Cluster Overlap with new Subpath Candidates

- Step 1 reduces number of candidates significantly.
- This allows for creation of new candidates from Subpaths in Step 2
- Inclusion of subpaths enables the VXDTF2 to retain previously incompatible candidates!

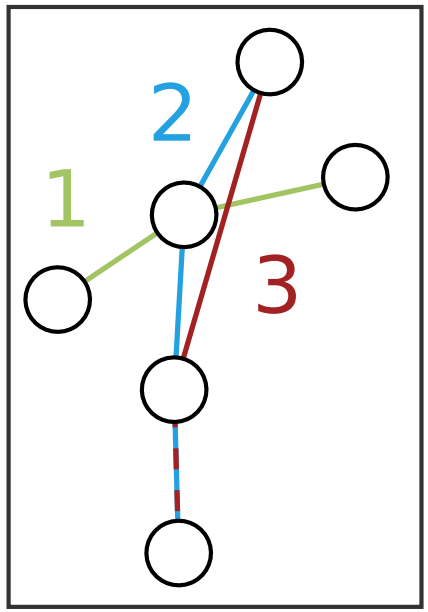
Benefit: Overlap SpacePoint Exclusion

Resolving Overlap between 2 valid Track Candidates:

- ⇒ Add Subpaths without problematic SP
- ⇒ Estimate quality of new candidates
- ⇒ Keep best combination

Why new Candidates? Because otherwise . . .

- special method to estimate quality necessary;
- special treatment in Greedy/Hopfield needed.

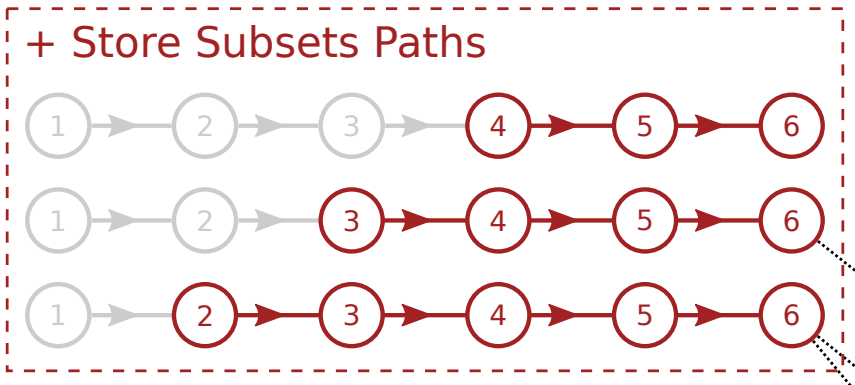


More candidates are no problem thanks to 2-Staged Overlap Resolving!

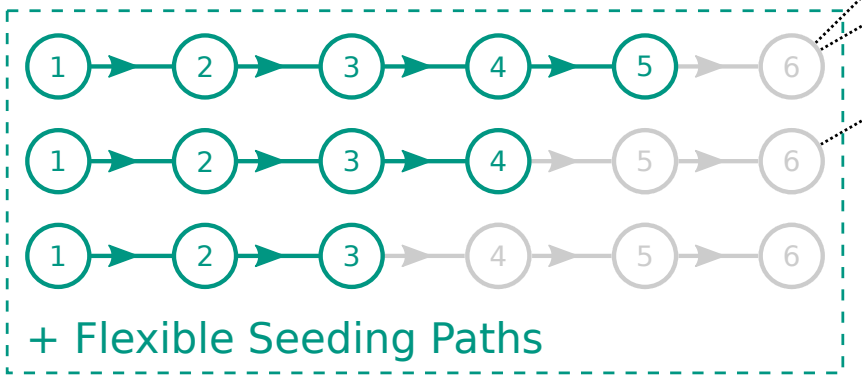
	Finding Eff.	Fake Rate	Clone Rate	Runtime / Event
VXDTF2 Original	93.58	20.62	0.43	16.3 ms
VXDTF2 w/ 2-Stage	**94.01**	**20.03**	**0.40**	**14.5 ms**

Hit-Efficiency drops from 96.4 to 95.4 due to missing SP for one Track . . .

Benefit: Subpath Evaluation

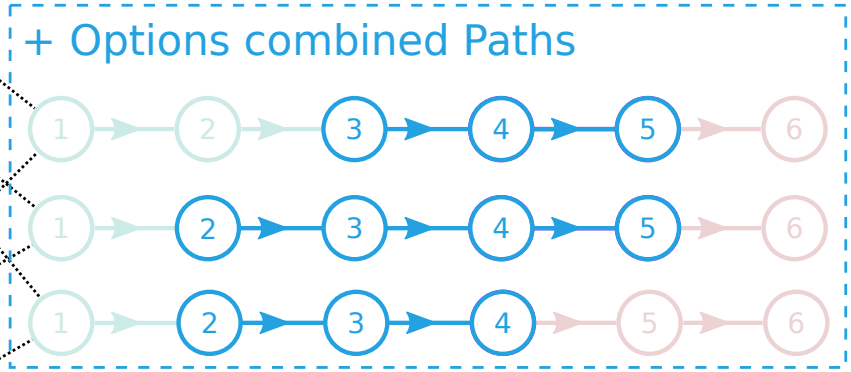


Original Path



Reduced memory footprint

⇒ Creation of new candidates form subsets of a track



⇒ Best candidate is chosen based on QI during Cluster-Overlap resolution

Has yet to be studied to determine influence on FoM and runtime!

⇒ Could improve Hit Purity

MVA Track Quality Estimators

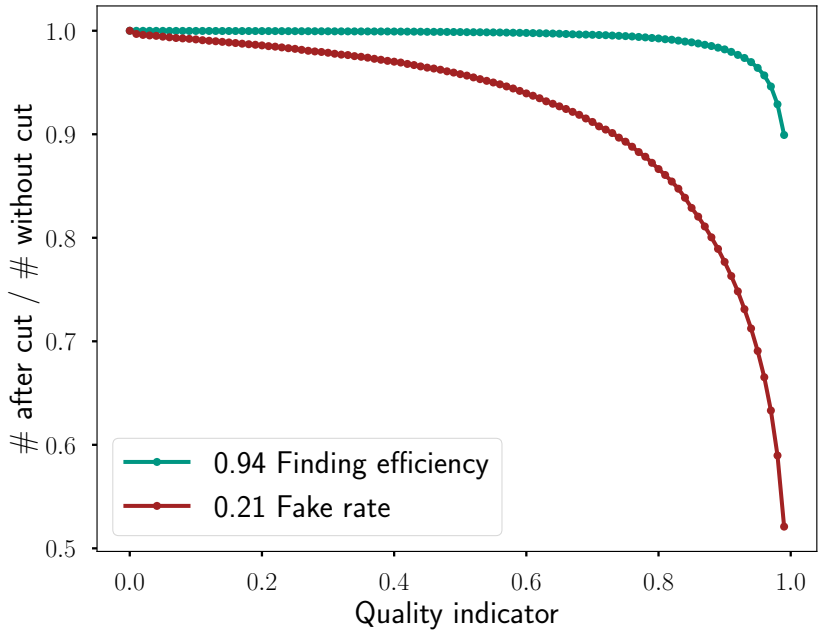
Improvement of Quality Estimation by

- Combining regular QIs with additional variables
- via **Boosted Decision Tree**
- trained with MC-QI as target

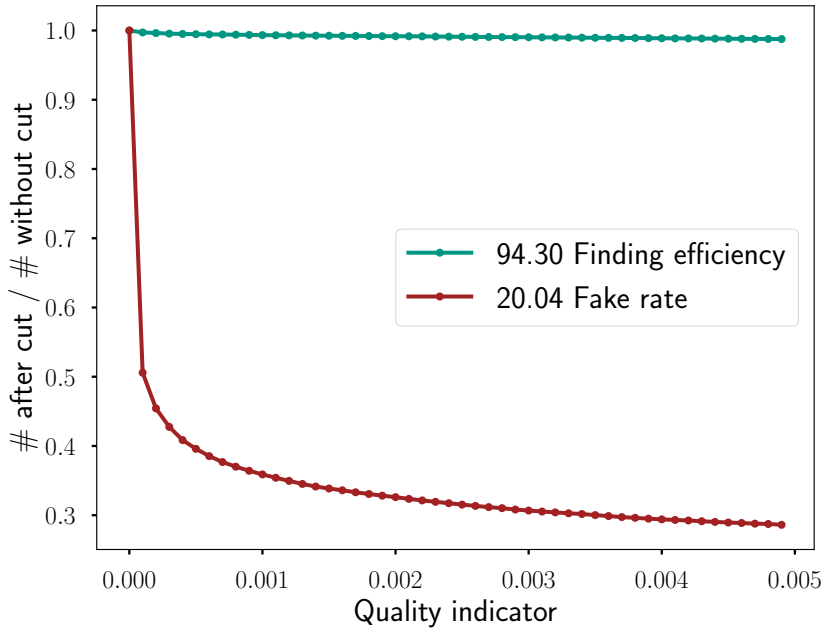
$\Rightarrow$ Output behaves like a probability

Variables:

- QI and χ^2 of respective fit
- Number of SpacePoints
- Momentum Estimation from fit
- Charge and maxCharge of Cluster
- Cluster size
- Cluster timing (not yet available)



Cut on Default Triplet QI



Cut on MVA Triplet QI

MVA Track Quality Estimators

Improved MVA QIs

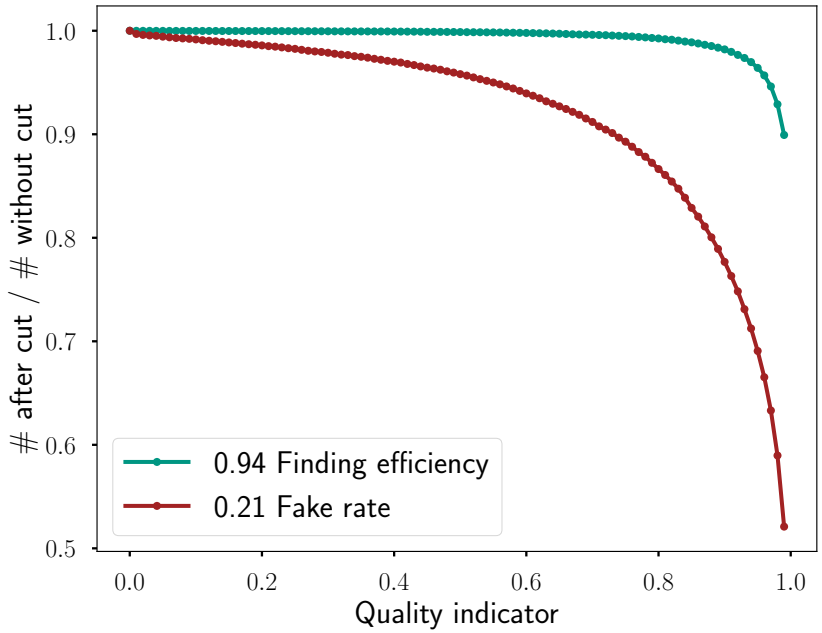
- can reduce Fake Rate efficiently

$\Rightarrow$ Cut on QI to reduce Fakes

- slightly increase Finding Efficiency
- are affordable regarding runtime

Further Plans:

- Not yet on Stash (underway)
- Promising Cluster Timing variable not yet used . . .
- Thorough study necessary to evaluate full potential
- MVA-QI estimation online or offline?



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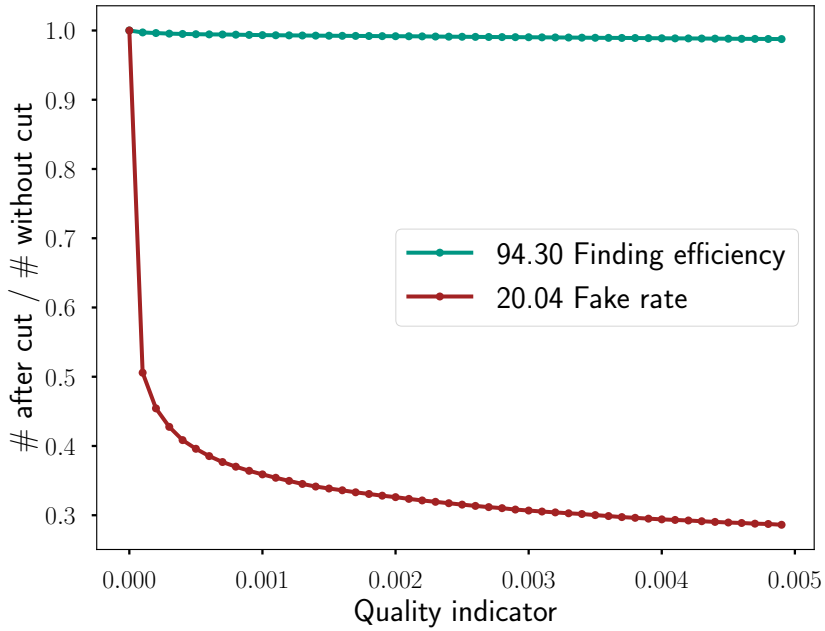


Cut on MVA Triplet QI

Study of Effects of Reduced PXD Integration Time Study

Evaluation of the influence of the integration time of the PXD with the cases

- 100 ns integration time
- 20 μs integration time

on 6–Layer VXD–Tracking with VXDTF2 also used for the PXD Data Reduction (DR).

$\Longrightarrow$ Analysis Quantitative Effects on the Figures of Merit

In all cases at least 3 SVD Space Points are required for a candidate.

Study of Effects of Reduced PXD Integration Time Study

Simulation of $\Upsilon(4S)$ events with background from campaign 15.2 with

1000 events per sample

PXD time window in the BeamBkgMixerModule of

- 20 μs: minTimePXD = -10000 ns; maxTimePXD = $+10000$ ns
- 100 ns: minTimePXD = -50 ns; maxTimePXD = $+50$ ns

Data Reduction turned

- on
- off

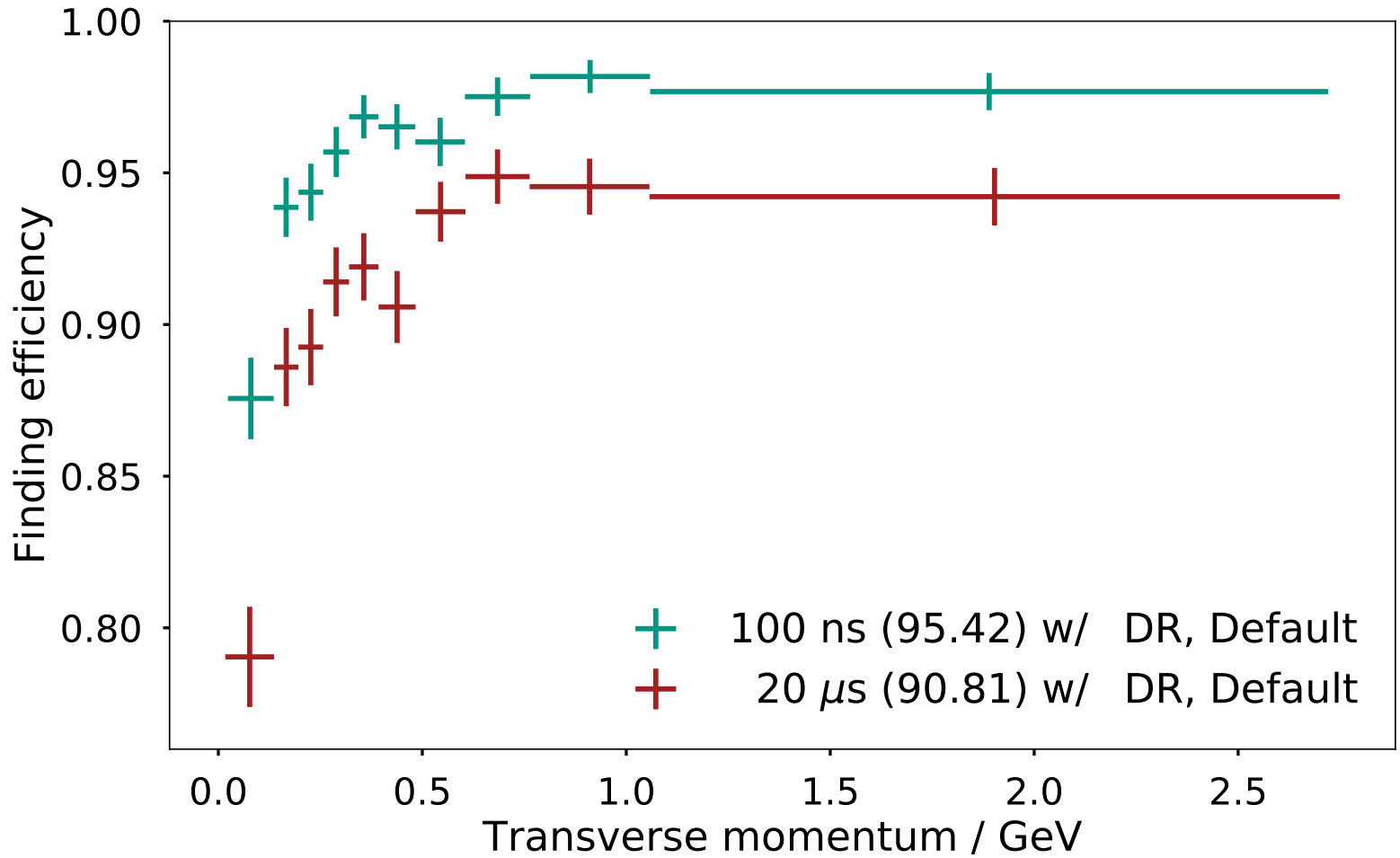
Evaluated with 6-Layer-SectorMap

- from Database (Default)
- trained on 10–Moun Sample (Custom)

Study of Effects of Reduced PXD Integration Time

Results

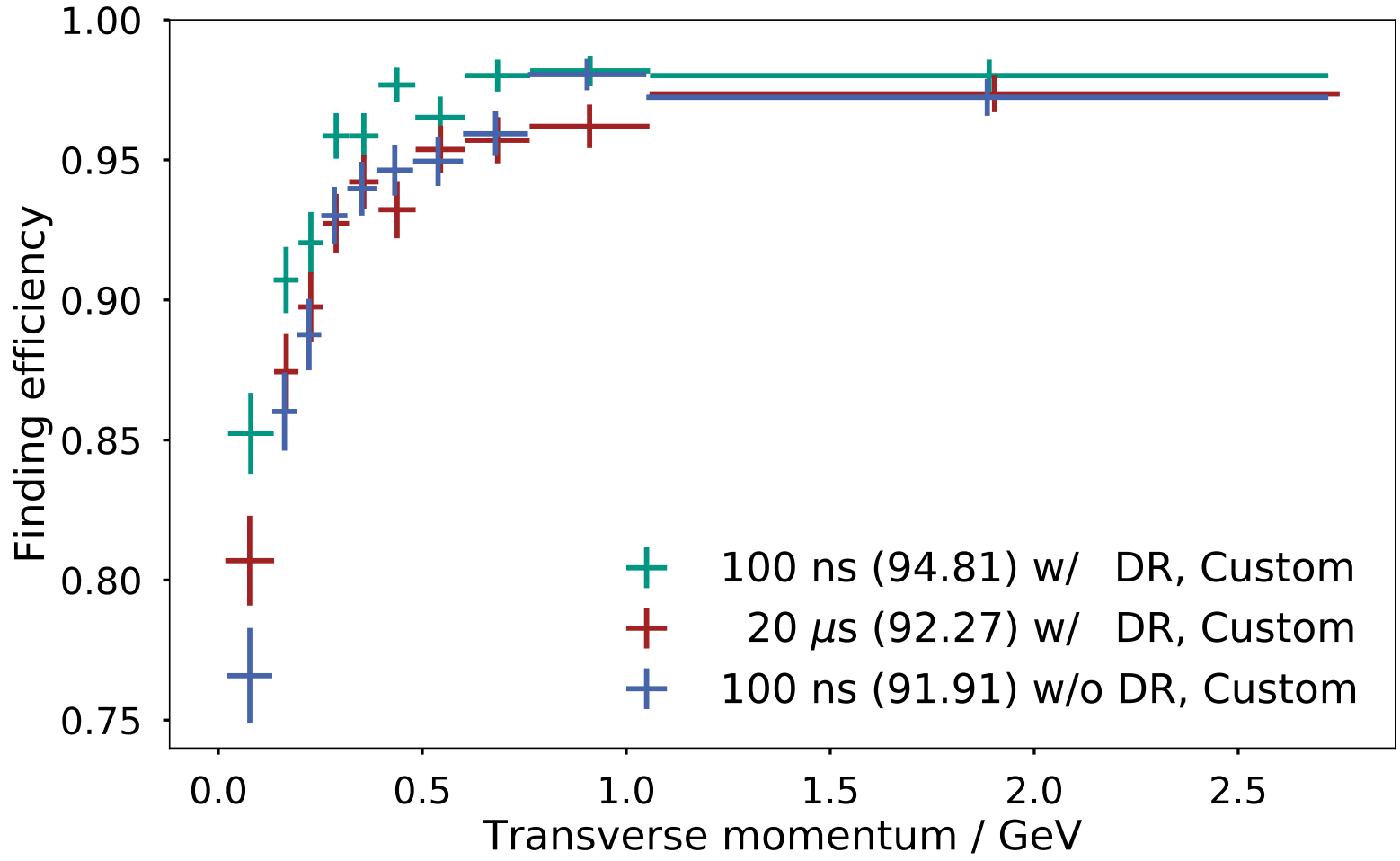
	Finding Eff.	Fake Rate	Clone Rate
100 ns	**95.42**	36.65	1.35
20 μs	90.81	**33.61**	**1.29**



Study of Effects of Reduced PXD Integration Time

Results

	Finding Eff.	Fake Rate	Clone Rate
100 ns	**94.81**	30.43	0.63
20 μs	92.27	29.09	0.68
100 ns w/o DR	91.91	**28.12**	**0.49**



Study of Effects of Reduced PXD Integration Time
Overview of Results

Integration Time		100 ns			20 μs
Sector Map	Default	Custom	Custom	Default	Custom
Data Reduction	✓	✓	✗	✓	✓
Finding Efficiency	**95.42**	94.81	91.91	90.81	92.27
Clone Rate	1.35	0.63	**0.49**	1.29	0.68
Fake Rate	36.65	30.43	**28.12**	33.61	29.09
Mean #Fakes	2.37	1.51	**1.22**	1.82	1.30
Hit efficiency	**96.16**	95.84	95.82	94.74	94.73
Hit Purity	**98.47**	98.47	98.55	96.45	96.82
PXD Hit Efficiency	91.91	91.62	**94.04**	85.40	85.90
PXD Hit Purity	90.10	91.13	**94.00**	82.94	84.48
SPTCs / Event in 10^3	1.4	**0.5**	2.1	9.8	2.5

Résumé:

- Lower Integration Time $\Rightarrow$ increased Finding and PXD Hit Efficiency
- SectorMap choice strongly affects Fake Rate