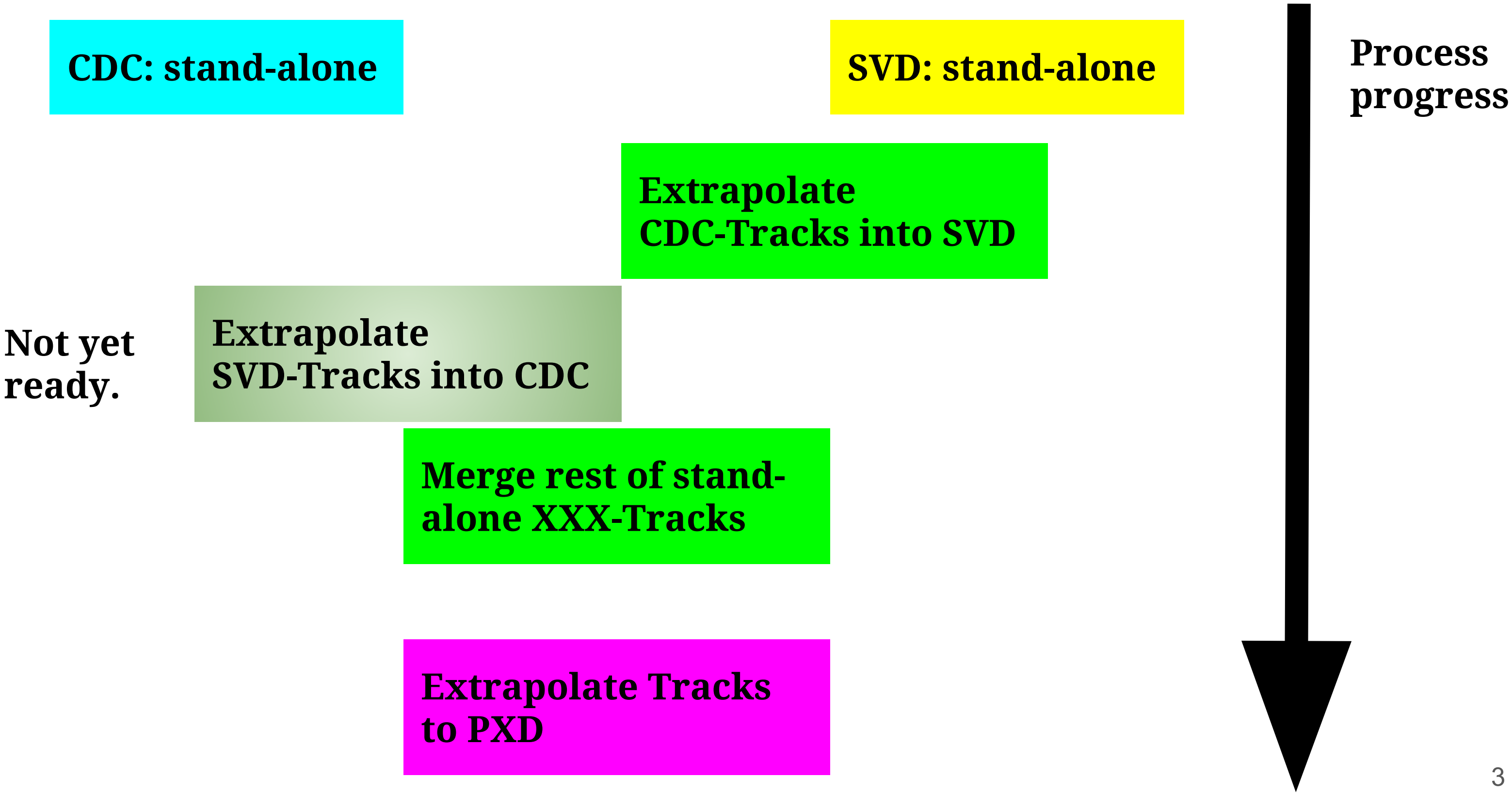
Tracking Overview

BPAC, February 2018

Overview

- Start with highlights of recent changes and concepts
- A little bit of organizational mentions
- Performance

Current Tracking Concept



CDC: stand-alone

SVD: stand-alone

Extrapolate CDC-Tracks into SVD

Not yet ready.

Extrapolate SVD-Tracks into CDC

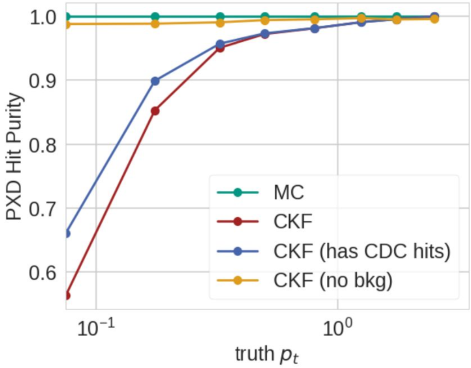
Merge rest of stand-alone XXX-Tracks

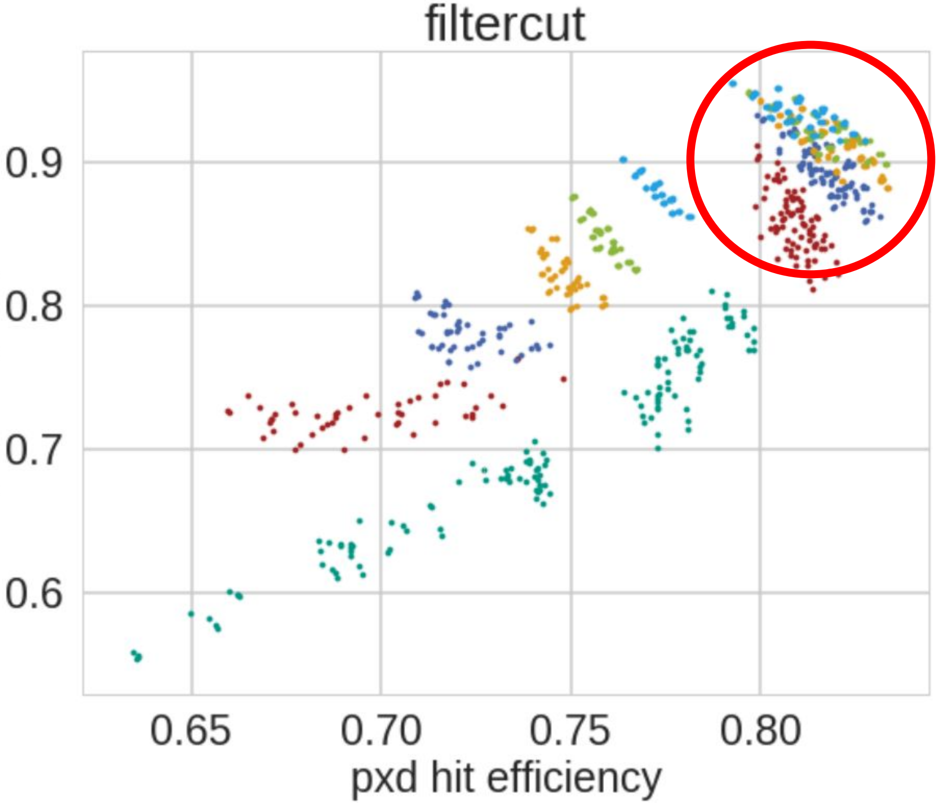
Extrapolate Tracks to PXD

Process progress

Why moving from VXD stand-alone to SVD stand-alone?

- **Purity too low**, if one doesn't start with a reasonably good track from the beginning
- Even using a combinatorial Kalman-filter (CKF), serious trade-off between purity & efficiency remains
  - to be further optimized…
- **Work under assumption of Full Phase III background!**





Alternative Concept

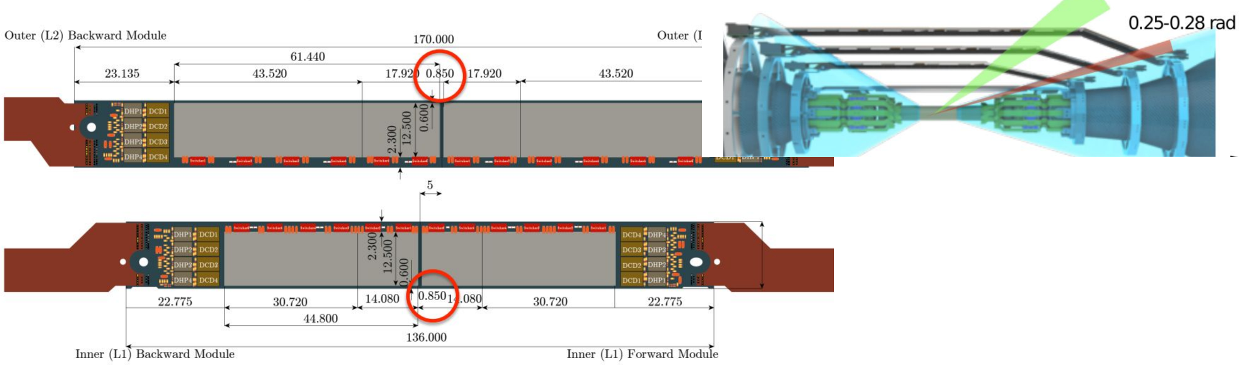
- Change format of mdst::Track to fitted without PXD hits; PXD hits saved in addition + filter value; added to the track dependent on the analysis;
    - advanced vertexing possible (e.g. PXD depending on if the PXD hit makes the track a far outlier or not, the hit is used);
    - analysis specific trade-offs possible (systematics vs. statistics);
    - substantial rework of event data model;
    - somewhat increased size of TrackFitResults;

  ⇒ Not in the near future

PXD Dead Zone Handling

- Extrapolation to L1 only performed, if hit in L2 is found, **otherwise purity too low**
- Most real tracks do have hit in L2, when hit in L1

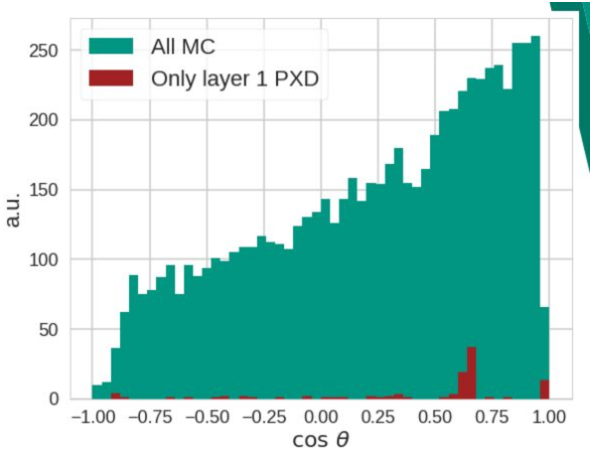
Geometry of PXD1 and PXD2

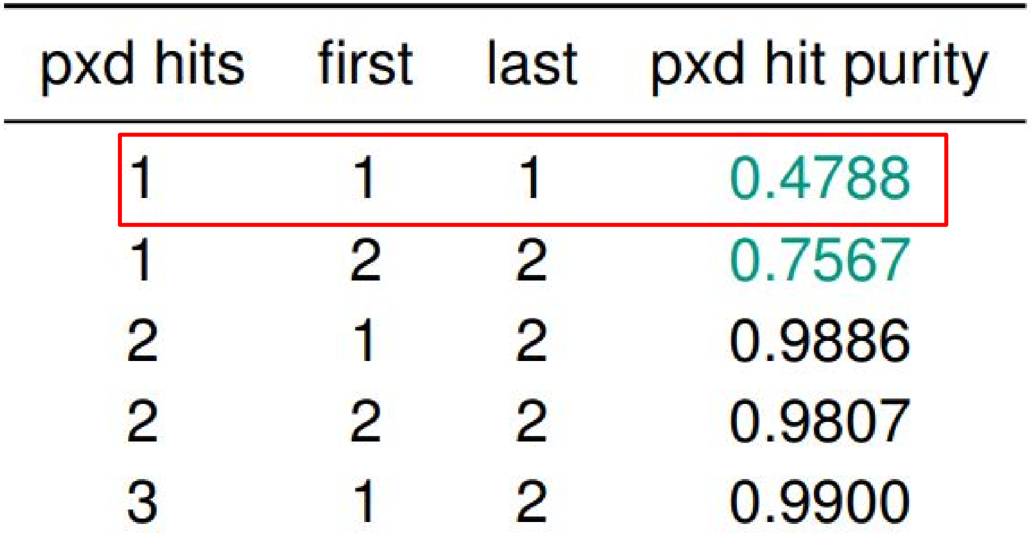


Geometry description in pxd/data/PXD-Components.xml

PXD1: gap 0.850mm between active areas from z=13.5755 to z=14.4255 mm

PXD2: gap 0.821mm between active areas from z=18.5895 to z=19.4105 mm





pxd hits	first	last	pxd hit purity
1	1	1	0.4788
1	2	2	0.7567
2	1	2	0.9886
2	2	2	0.9807
3	1	2	0.9900

PXD Dead Zone Handling [2]

- If parts of L2 become insensitive, reoptimization is necessary
- Currently, we stick with the strict requirement of needing an L2 hit

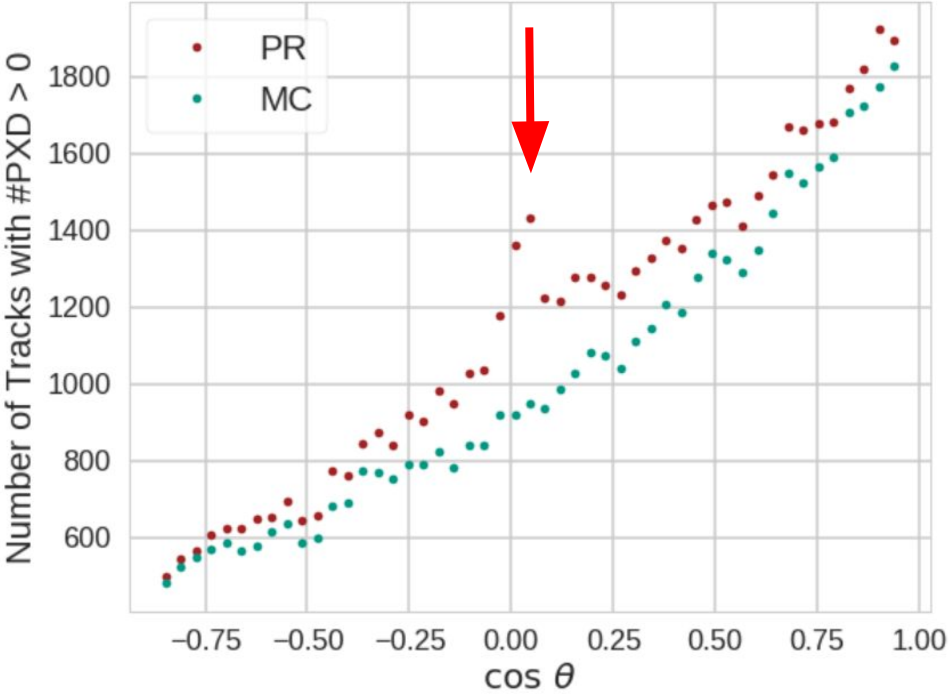
⇒ Not in the near future

- Better Tracks to start with are as well helpful (ongoing work):
    - Finalize SVD-Track extrapolation to CDC for hit pick-up
    - Extrapolate SVD-Tracks, that are “outgoing arm”, to pick up more hits in the SVD

Cave Clonem

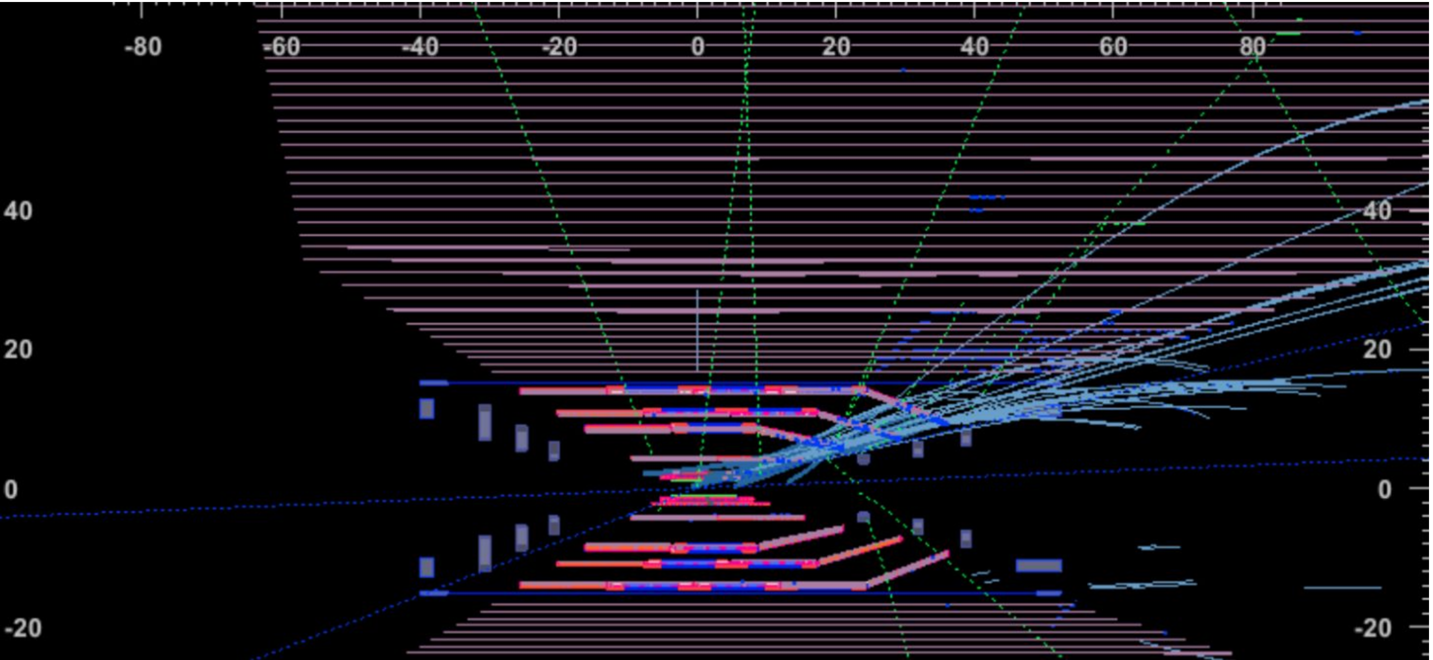
- Around cos(θ) == 0, the number of clones is fairly large.
- Strategy to tackle clones strongly dependent on what information, we get in future from SVD timing
  Promised in the past:
  2 - 4 ns resolution depending on n/p-side (small radius → usually large dE/dx)

  ⇒ Not exactly clear, what to assume, e.g. optimize with current SVD info or assume better timing in near future.



Developments in SVD Stand-Alone Tracking

- Last BPAC: new VXD stand-alone tracking can’t run on GRID, as it doesn’t stay within hard 2 GB bound…
  - We found the problematic events typically to be of this type:



Jet-like hit distributions from electrons hitting the magnets producing a shower of particles.

Mitigation of Shower Events on Memory Consumption

- Hard cut on the size of the offending vector
  → SVD stand-alone tracking is foregone for the event
  Obviously, we want that to happen as rarely as possible…

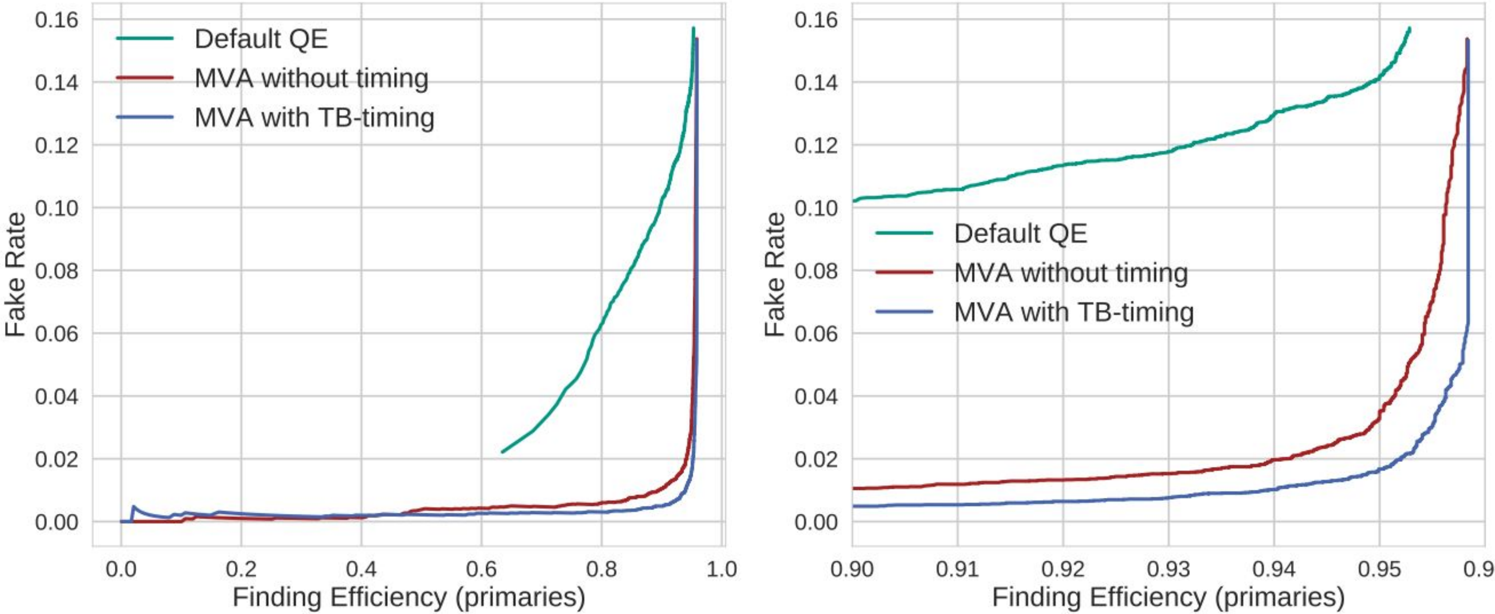
- Cut on the available timing in the SVD
  → Clusters, that clearly have happened before T0 aren't used

- More restrictive "SectorMaps", that don't take simulated tracks with strong scattering as viable pattern to search for (usefulness proven, not finally optimized)
  → Less combinations in the early stages of track finding

- 2-step track-candidate creation, where a full track-candidate is only build for a limited number of track-candidates, that overlap in two consecutive SpacePoints

Improved Track Quality Estimation for SVD stand-alone tracking

- Using FastBDT with a variety of information (spacial fit [Chi2, |p|, p_t], Cluster information [energy, shape, timing (6-sample-based)], #SpacePoints), we get a better Quality indicator (QI) on which even an analysis cut is possible [combined post-fit QI is under construction]:



Efficiency is normed to MCParticles with at least 5 connected SVD clusters,
fake rate to number of found tracks.

Estimate of Effects of Potential SVD Damage

- So far SVD stand-alone tracking strictly requires SpacePoints made from two SVDClusters (u-side + v-side).
- We believe, that in areas, where one side of the sensor fails, SpacePoints using only a single cluster can be used.
- Further studies about this are ongoing, we consider aligning the sector division (currently 3x3 on each sensor) closer to the division done by the APV25 servicing.

CDC Tracking

- Not many recent developments, working well in the cosmic ray setup.

Merging Options

- A number of different merging options for tracks from SVD + CDC have been developed.
- Currently active:
  - based on closeness of track parameters when extrapolated to CDC inner wall.
  - There are reasons to assume in tricky cases, something better can be done…

    … a CKF based method gives somewhat better results, but more often merges tracks (especially from pions), that contain CDCHits from a muon stemming from a decay in flight.

    How dangerous are them?

      Depends on what you measure as “efficiency”...

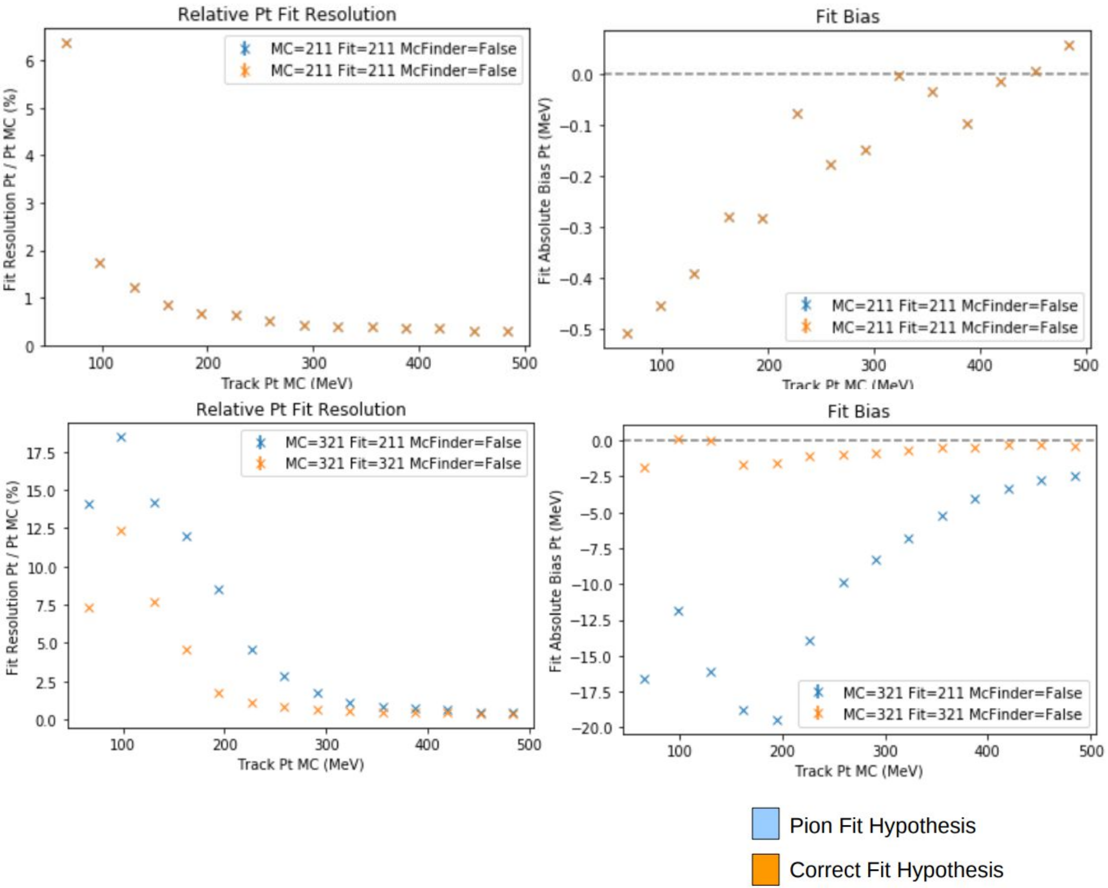
MC Truth Matching

- Truth matching is currently done based on number of hits/clusters assigned to a Track, that are connected to an MCParticle.
  Issues:
  - many wrong CDCHits in the outer region (e.g. from a decay-in-flight-muon) mark a Track as fake, even if the Track parameters are very close to the one of the real MCParticle
  - a smaller number wrong hits/clusters in the inner region might change the Track parameters substantially without causing the Track to be marked as fake

  ⇒ TO DO (not necessarily by the tracking group): check MC matching based on fitted parameters, especially momentum

  This influences as well machine learning methods used in tracking as it defines the target!

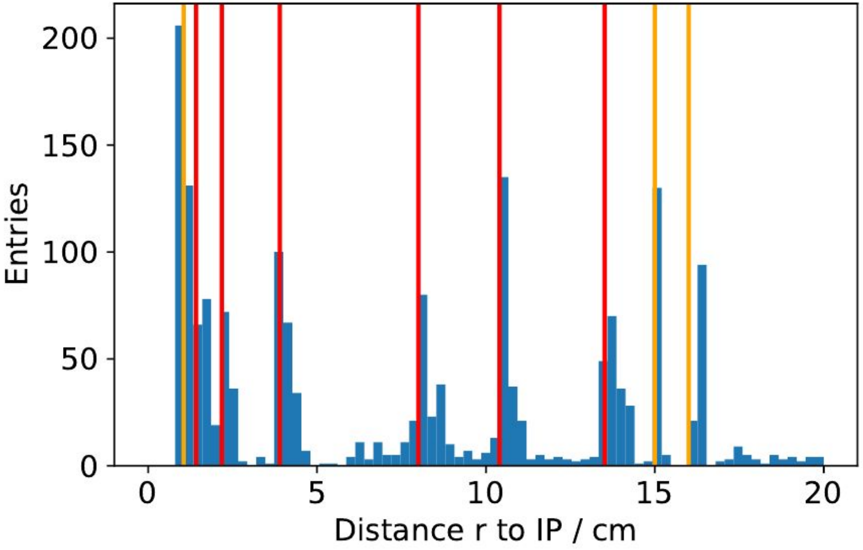
Fitting - Multiple Hypotheses Available

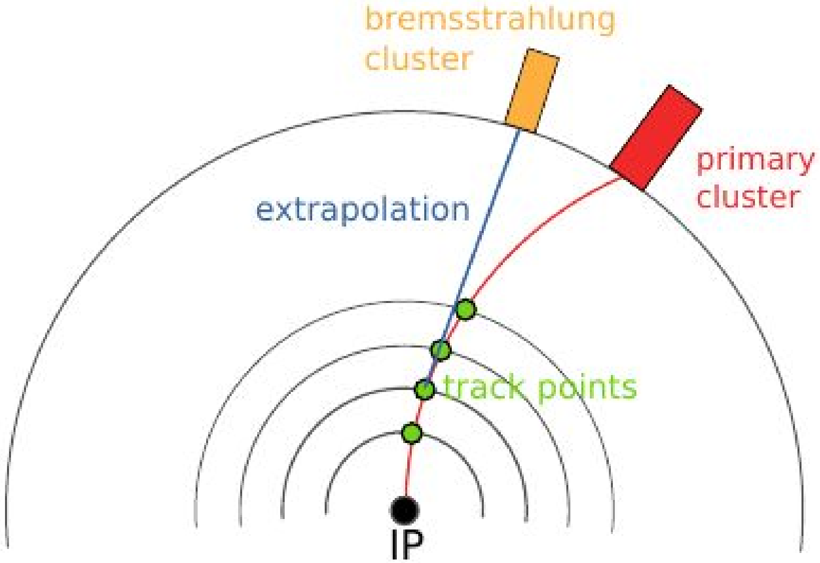


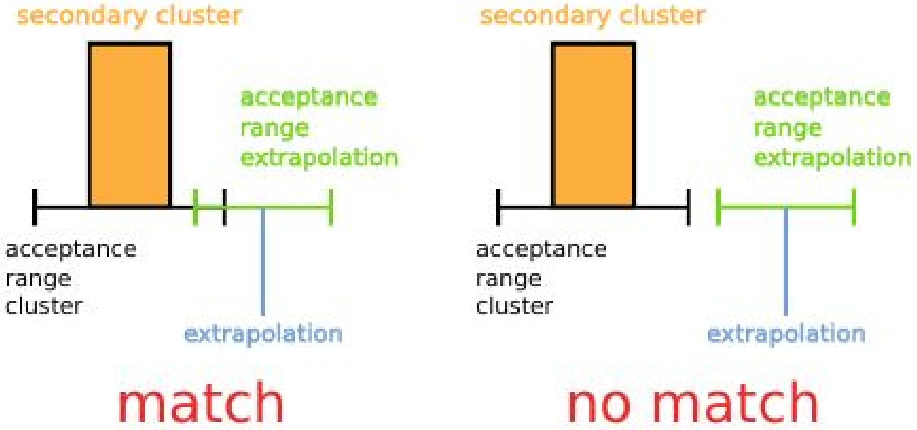
- Negligible bias, when using correct fit hypothesis
- Fitting with correct fit hypothesis yields better resolution than using pion hypothesis for kaons, protons (and at ~ < 100 MeV for muons), electrons remain a bit tricky…
- Current status:
  - pion, kaon, proton fit is performed and saved
  - muons ignored, because low momentum muons are boring
  - electron fit is foreseen for the future

Fitting - Bremsstrahlung Recovery Ansatz

- [Belle Ansatz:] take cone around initial perigee momentum direction as Bremsstrahlung
- New Ansatz: Extrapolate tangent at specific radii with high material







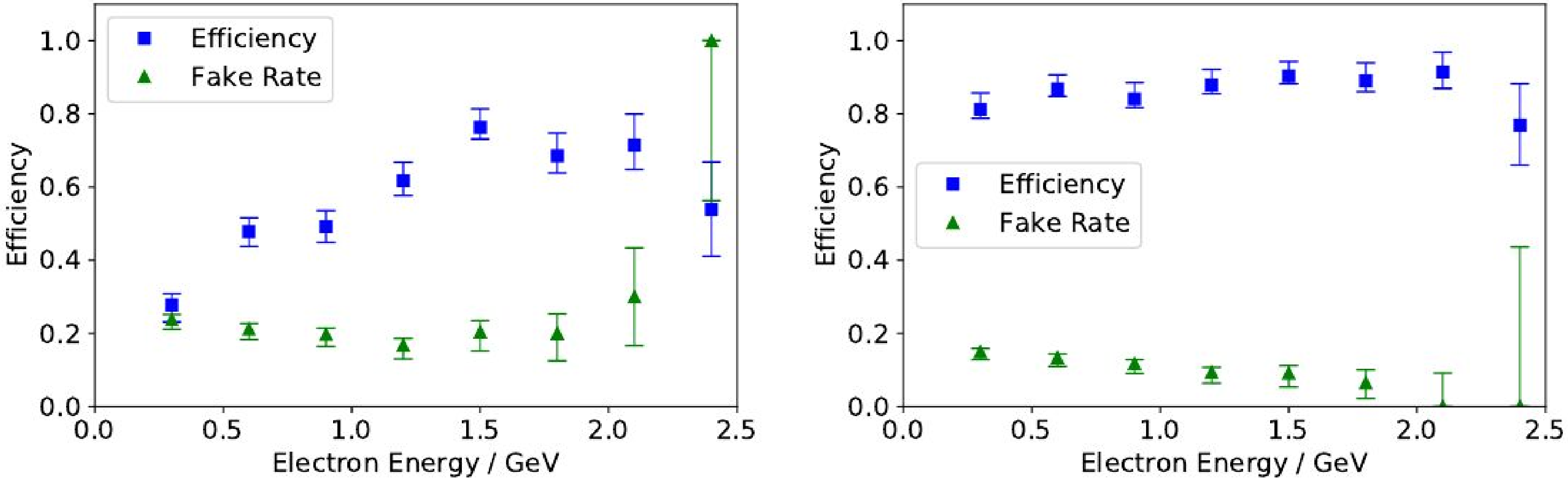


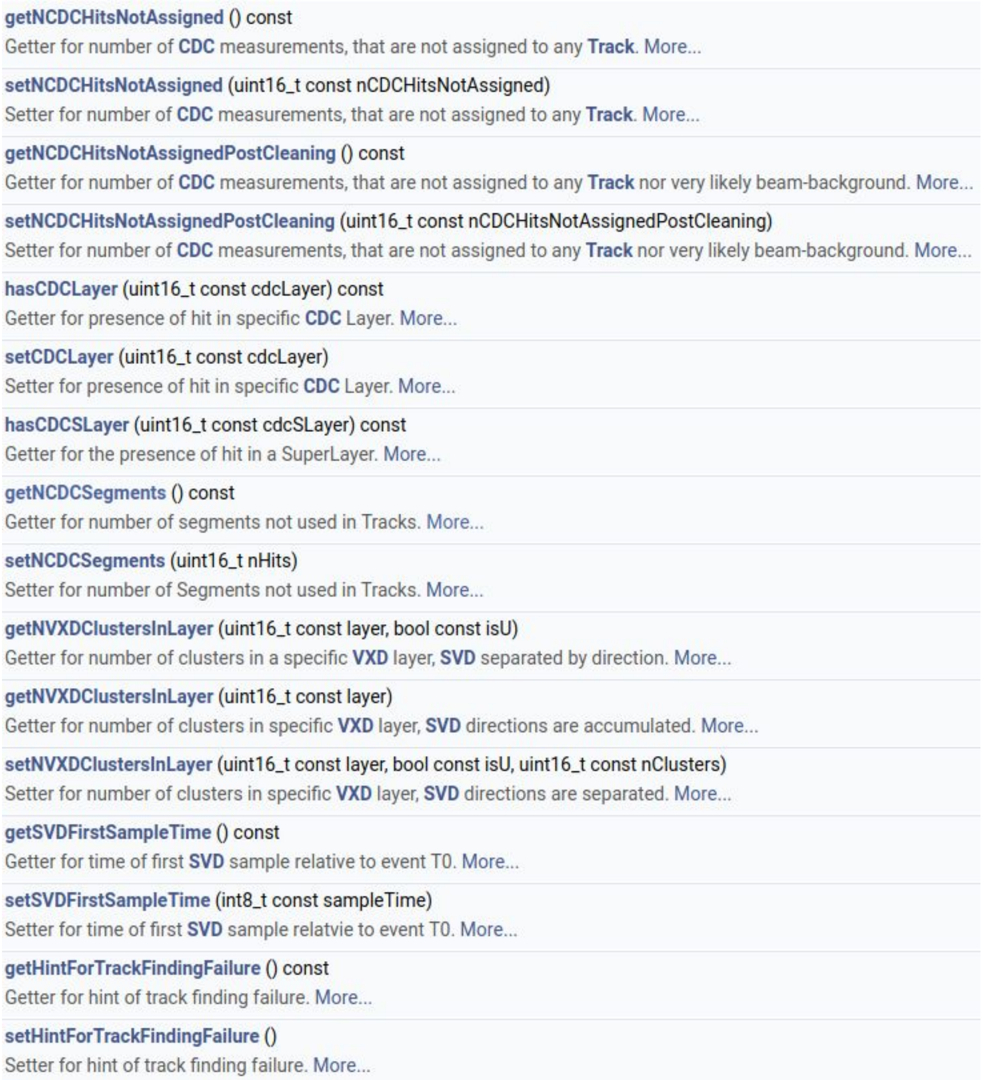
Figure 5.7: Comparison of the bremsstrahlung finding efficiency and fake rate, depending on the energy of the primary electron, between the new approach for Belle II and the Belle method. Left side: Belle method with a cone angle of 5 °. Right side: Belle II approach with an acceptance factor of 3.0.

Special Handling Issues in Phase II

- Mainly:
  - CKF allows to jump over 3 out of 4 SVD layers, when extrapolating CDC tracks (this was mainly a demand of the alignment group)

Event Level Tracking Information

- Various Information helping to understand background conditions on mdst level



getNCDCHitsNotAssigned () const
Getter for number of CDC measurements, that are not assigned to any Track. More...

setNCDCHitsNotAssigned (uint16_t const nCDCHitsNotAssigned)
Setter for number of CDC measurements, that are not assigned to any Track. More...

getNCDCHitsNotAssignedPostCleaning () const
Getter for number of CDC measurements, that are not assigned to any Track nor very likely beam-background. More...

setNCDCHitsNotAssignedPostCleaning (uint16_t const nCDCHitsNotAssignedPostCleaning)
Setter for number of CDC measurements, that are not assigned to any Track nor very likely beam-background. More...

hasCDCLayer (uint16_t const cdcLayer) const
Getter for presence of hit in specific CDC Layer. More...

setCDCLayer (uint16_t const cdcLayer)
Setter for presence of hit in specific CDC Layer. More...

hasCDCSLayer (uint16_t const cdcSLayer) const
Getter for the presence of hit in a SuperLayer. More...

getNCDCSegments () const
Getter for number of segments not used in Tracks. More...

setNCDCSegments (uint16_t nHits)
Setter for number of Segments not used in Tracks. More...

getNVXDClustersInLayer (uint16_t const layer, bool const isU)
Getter for number of clusters in a specific VXD layer, SVD separated by direction. More...

getNVXDClustersInLayer (uint16_t const layer)
Getter for number of clusters in specific VXD layer, SVD directions are accumulated. More...

setNVXDClustersInLayer (uint16_t const layer, bool const isU, uint16_t const nClusters)
Setter for number of clusters in specific VXD layer, SVD directions are separated. More...

getSVDFirstSampleTime () const
Getter for time of first SVD sample relative to event T0. More...

setSVDFirstSampleTime (int8_t const sampleTime)
Setter for time of first SVD sample relatvie to event T0. More...

getHintForTrackFindingFailure () const
Getter for hint of track finding failure. More...

setHintForTrackFindingFailure ()
Setter for hint of track finding failure. More...

Human Resources Situation

- Substantial long-term contributors to core of tracking code remain only active in development @KIT, Pisa
  - Vienna, Munich lost completely, DESY exchanged developers
- Increasing number of people at DESY active
- Starting contributions from LAL/Orsay (fitting CPU performance)
- Some maintenance work in Mainz (physics performance studies, RoI business) and Torino (multiple hypothesis performance)

Personal impression:
current level of activity appropriate, but further loss of development capacity should be avoided (see as well “not in the near future” comments above)

Tracking & Service Tasks

- Useful tracking development for further improvements, mitigation of potential sensor/wire failures, tuning to background conditions etc. can have beneficial impact on physics performance well beyond the start of the experiment.
  ⇒ will development be a service task?
  ⇒ if yes, how much/ how many points are available to the tracking convenors to distribute?

- More obvious tasks:
  - Efficiency and fake rate studies…
  - Resolution studies - for some aspects like vertexing resolution TCPV convenors might feel more responsible
  - …

Performance of Tracking under Phase III Conditions

- Here, I would like to show some of the usual performance plots from Bianca, or something similar (even if not all the features mentioned before are switched in the current head, much less the last release)