Karlsruhe Institute of Technology

Bremsstrahlungsfinding with Calorimeter Information

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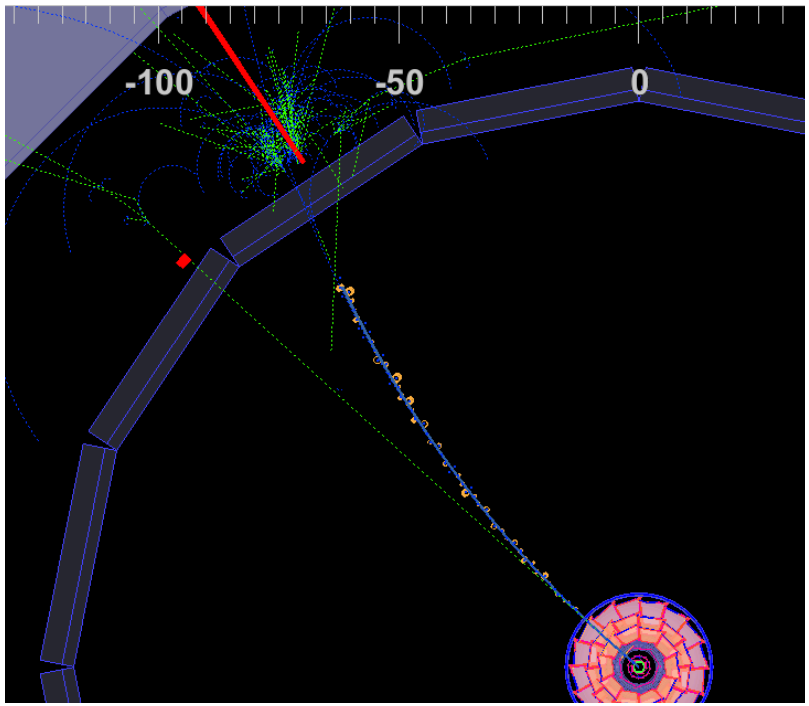
INSTITUT OF EXPERIMENTAL NUCLEAR PHYSICS (IEKP)

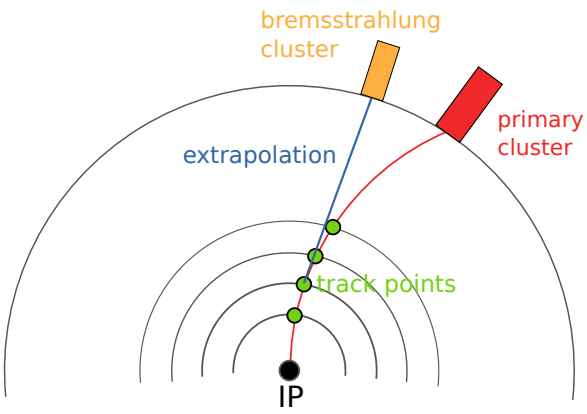
Goal of the Module

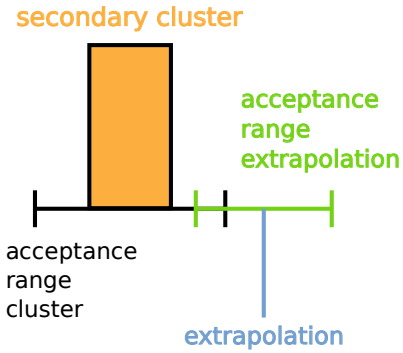
- Search for bremsstrahlung photons emitted in the inner part of the detector (Beampipe, VXD, CDC Wall)
- Get information about the position of bremsstrahlung radiation
- Save the collected information so the lost energy can be added later and the track fit can be improved



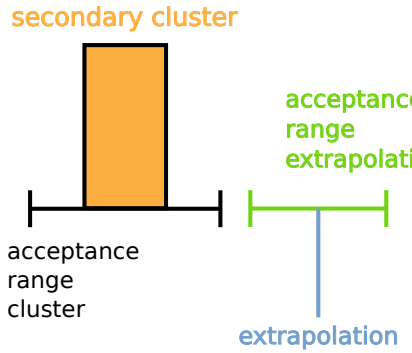
The Idea

Belle Method: photons lying in a 5 degree cone around the electron trajectory are added to the 4-vector of the electron





match

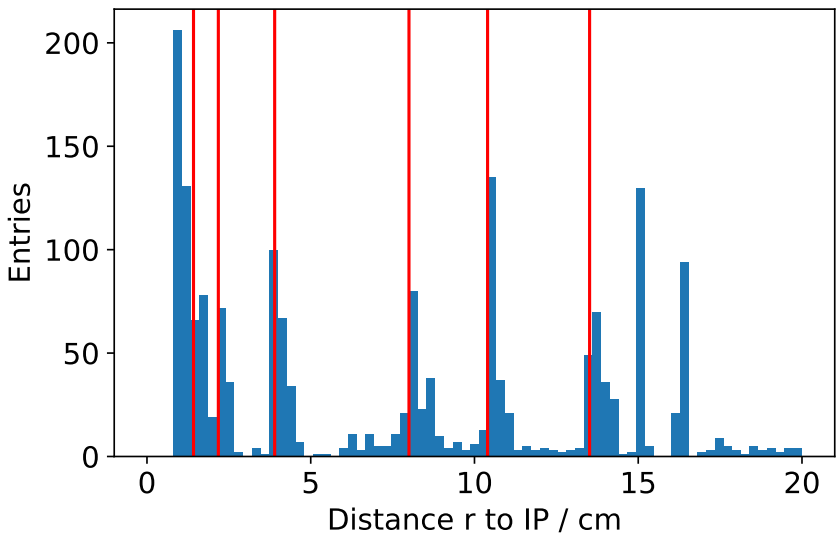


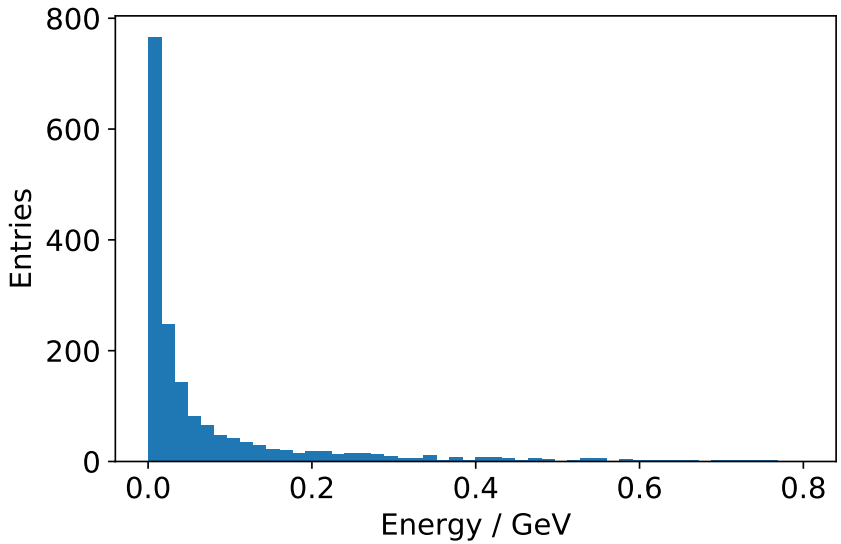
no match

- Extrapolate from the trackpoint to the ECL
- Check if the acceptance range of the cluster position and the extraplation overlap
- Acceptancerange:

$$\text{acceptance range} = \text{acceptanceFactor} \cdot \text{position uncertainty}$$

Bremsstrahlung Characteristics





- Most of the bremsstrahlung photons were emitted in the inner part of the detector (VXD)
- Most of the photons have an energy below 0.2 GeV

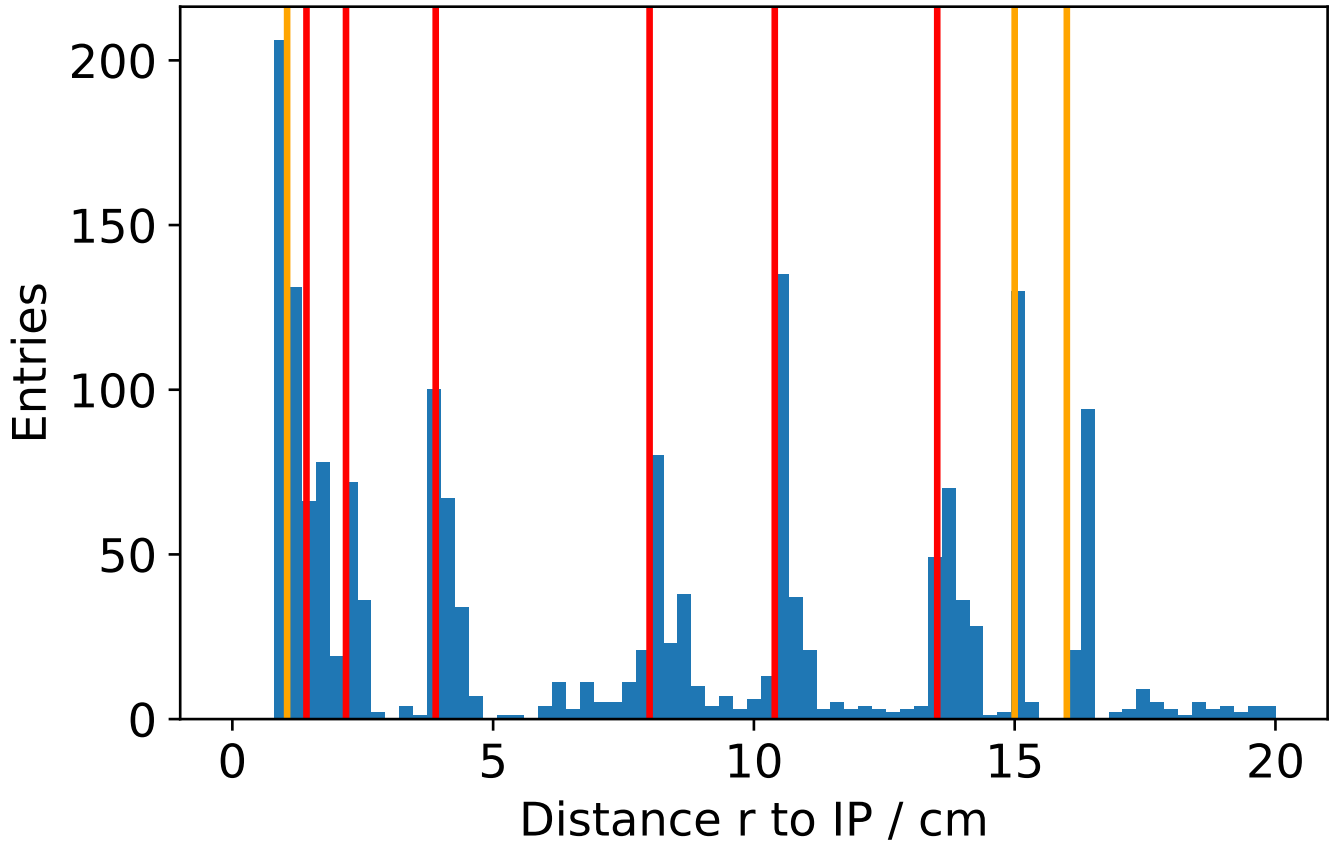
The Algorithm

Loop over all tracks

1. Get the primary cluster for each track and the related RecoTrack
2. Loop over all ECL clusters in the event
   - Check if cluster is secondary (e.g. not related to track)
   - Loop over all VXD track points
     - Extrapolate from each trackpoint to the ECL and check if the extrapolation matches the cluster position
     - If a match is found with a given acceptance factor, save this match
   - Get the best match from all matches
   - Set a relation from primary cluster to the expected bremsstrahlungcluster
   - Save the Sorting Parameter of the track point to get information about the expected position on which the bremsstrahlung emission happened

The Algorithm

Additionally to the VXD hits, three virtual hits are added. One at the edge of the beampipe at $r = 1.05\,\mathrm{cm}$ and the others at the CDC wall at $r = 15\,\mathrm{cm}$ and $r = 16\,\mathrm{cm}$.



Efficiency and Fake Rate

$$\text{Efficiency} = \frac{\#\text{ secondary cluster with correct relation}}{\#\text{ bremsstrahlung photons with cluster}}$$

$$\text{Fake Rate} = \frac{\#\text{ secondary cluster with wrong relation}}{\#\text{ secondary cluster with relation}}$$

Bremsstrahlungsphotons, which do not reach the ECL or do not have enough energy to generate a cluster there, are not considered in the efficiency calculation

Efficiency and Fake Rate depending on Acceptance Factor

Table: Efficiency and Fake Rate of the bremsstrahlungfinding module depending on the Acceptance Factor. Results are based on 10,000 Y(4S)-Events without considering background.

Acceptance Factor	Efficiency [%]		Fake Rate [%]	
1.0	50.32	$^{+1.78}_{-1,77}$	8.70	$^{+0.90}_{-2.24}$
2.0	78.00	$^{+2.08}_{-1.06}$	13.76	$^{+0.85}_{-2.02}$
3.0	86.47	$^{+1.94}_{-0.80}$	17.87	$^{+0.90}_{-1.97}$
4.0	89.00	$^{+1.85}_{-0.72}$	21.21	$^{+0.97}_{-1.94}$
5.0	89.63	$^{+1.82}_{-0.70}$	24.37	$^{+1.03}_{-1.90}$
6.0	90.52	$^{+1.77}_{-0.66}$	26.97	$^{+1.07}_{-1.86}$

Efficiency and Fake Rate depending on Acceptance Factor

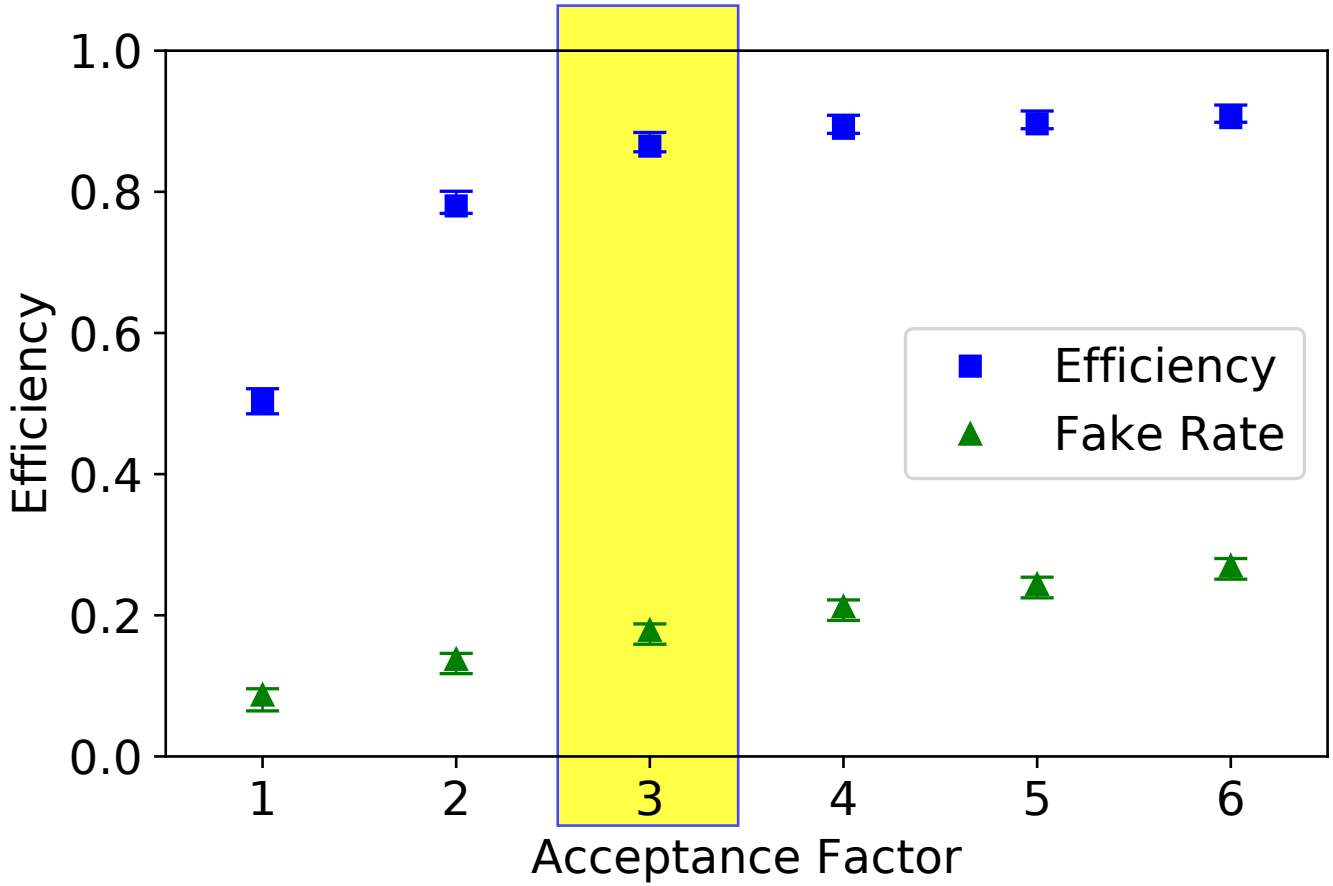
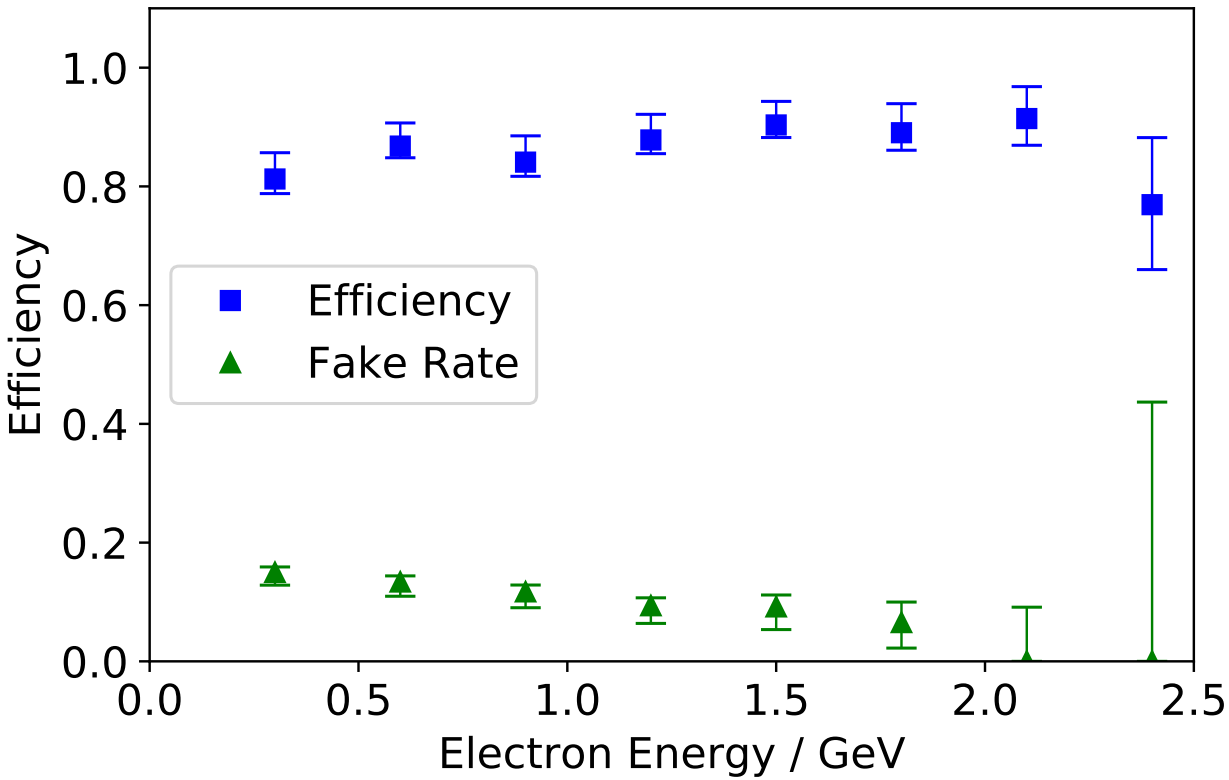


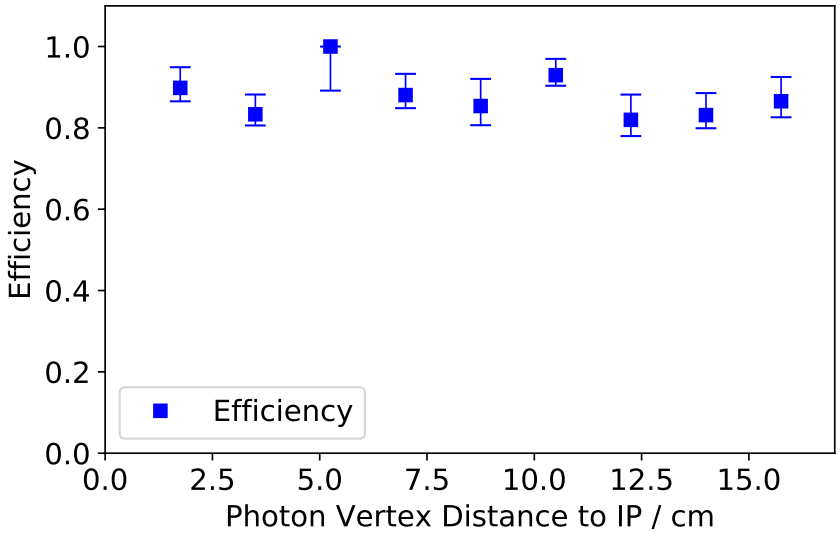
Figure: Efficiency and Fake Rate of the module depending on the Acceptance Factor, based on 10,000 Y(4S)-Events

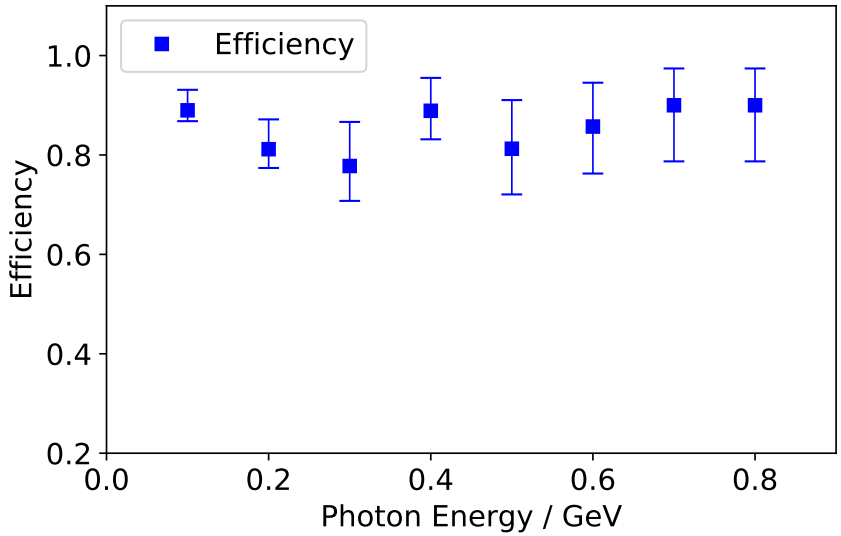
Efficiency and Fake Rate depending on Electron Energy

- Efficiency is slightly increasing with higher energy of the primary electron $\Rightarrow$ reason is the lower curvature of the track
- Fakre rate is slightly falling with increasing electron energy



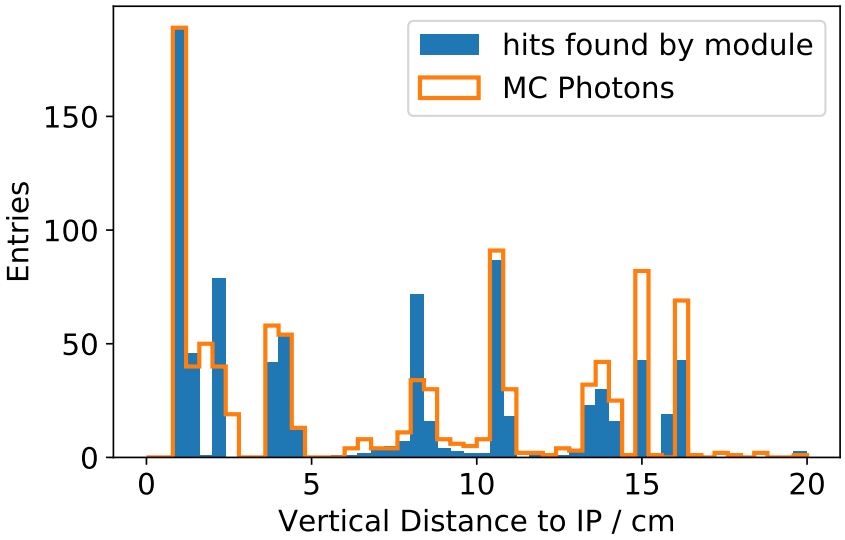
Efficiency over Photon Characteristics

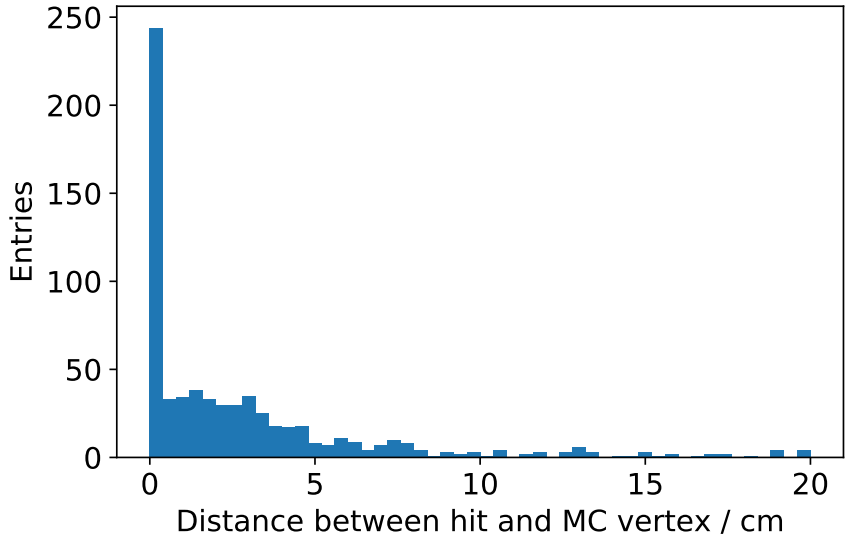




- Efficiency not dependig on production vertex of the bremstrahlungsphotons
- Also not depending on the bremstrahlungphotons energy

Reconstructed photon vertex

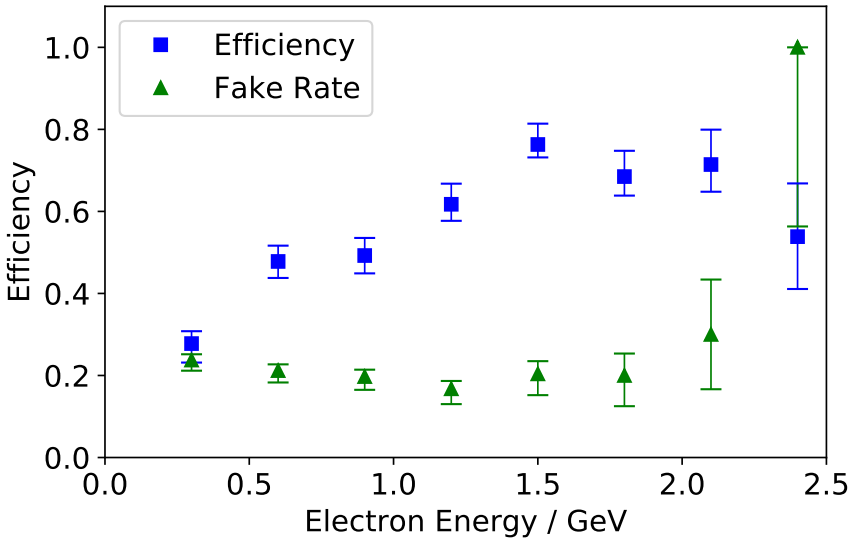




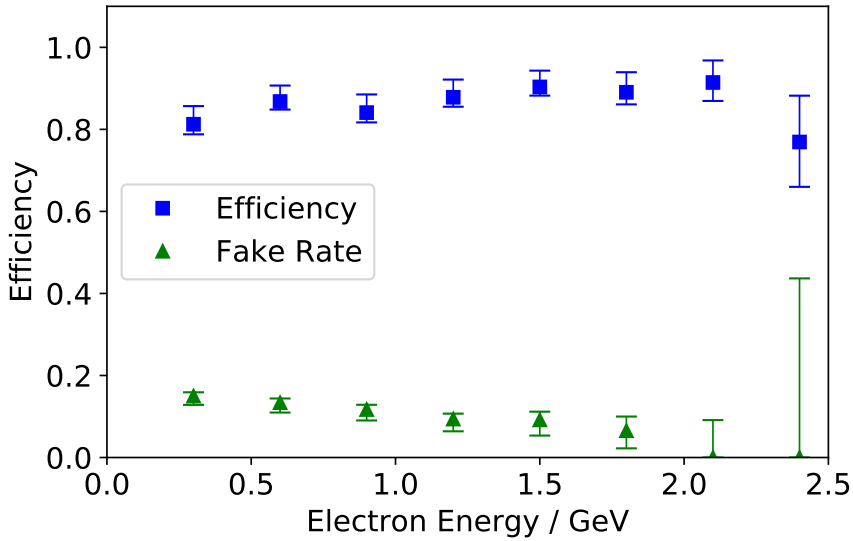
- Distribution of the found bremsstrahlung photon vertex positions matches the distribution obtained MC information quite good
- In most cases the reconstructed bremstrahlung photon vertex is in short range to the MC vertex

Comparison to the Belle Method

Belle Method



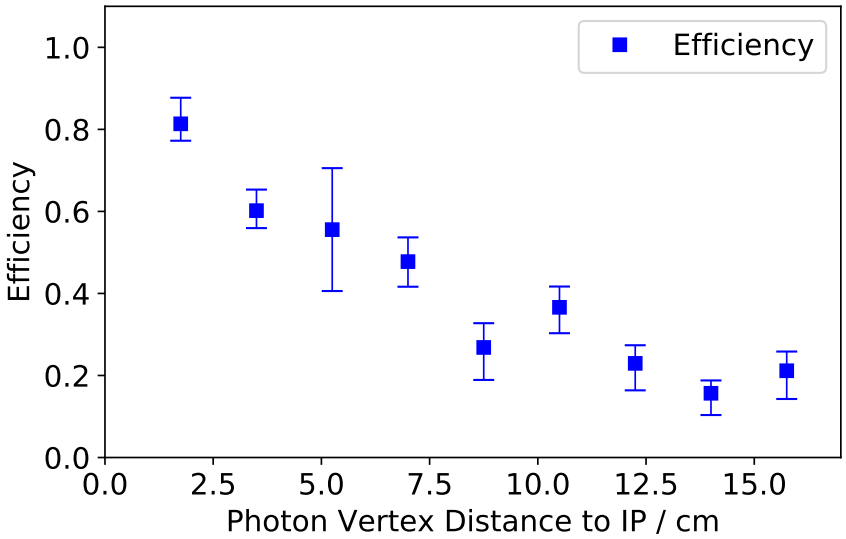
Our Method



- Belle method with a cone angle of 5 °
- Belle II approach with an acceptance factor of 3.0
- New method is better in efficiency and fake rate over the whole energy range

Comparison to the Belle Method

Belle Method



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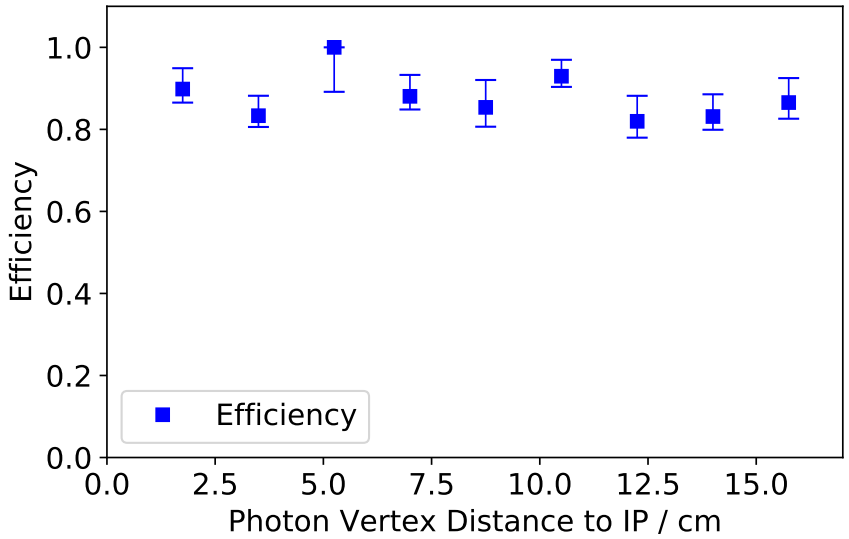


- Belle method with a cone angle of 5 °
- Belle II approach with an acceptance factor of 3.0
- Belle method is strongly depending on photon vertex ⇒ New method has good efficiency over the whole range

Summary

- Module works and is quite fast ($< 25\,\mathrm{ms}$)
- Good efficiency on Y4S-Events without background
- No dependency on bremsstrahlung photons energy or vertex position
- Good assigment to correct radiation vertex (68% $<$ 5 cm)
- Much better finding efficiency than the Belle method

Outlook

- Commit code to basf2 master (short-term)
- Check the efficiency and fake rate in Y4S-Events with background (mid-term)
- Incorporate the module into the electron-Track Fit and check if the resolution improves (mid-term)

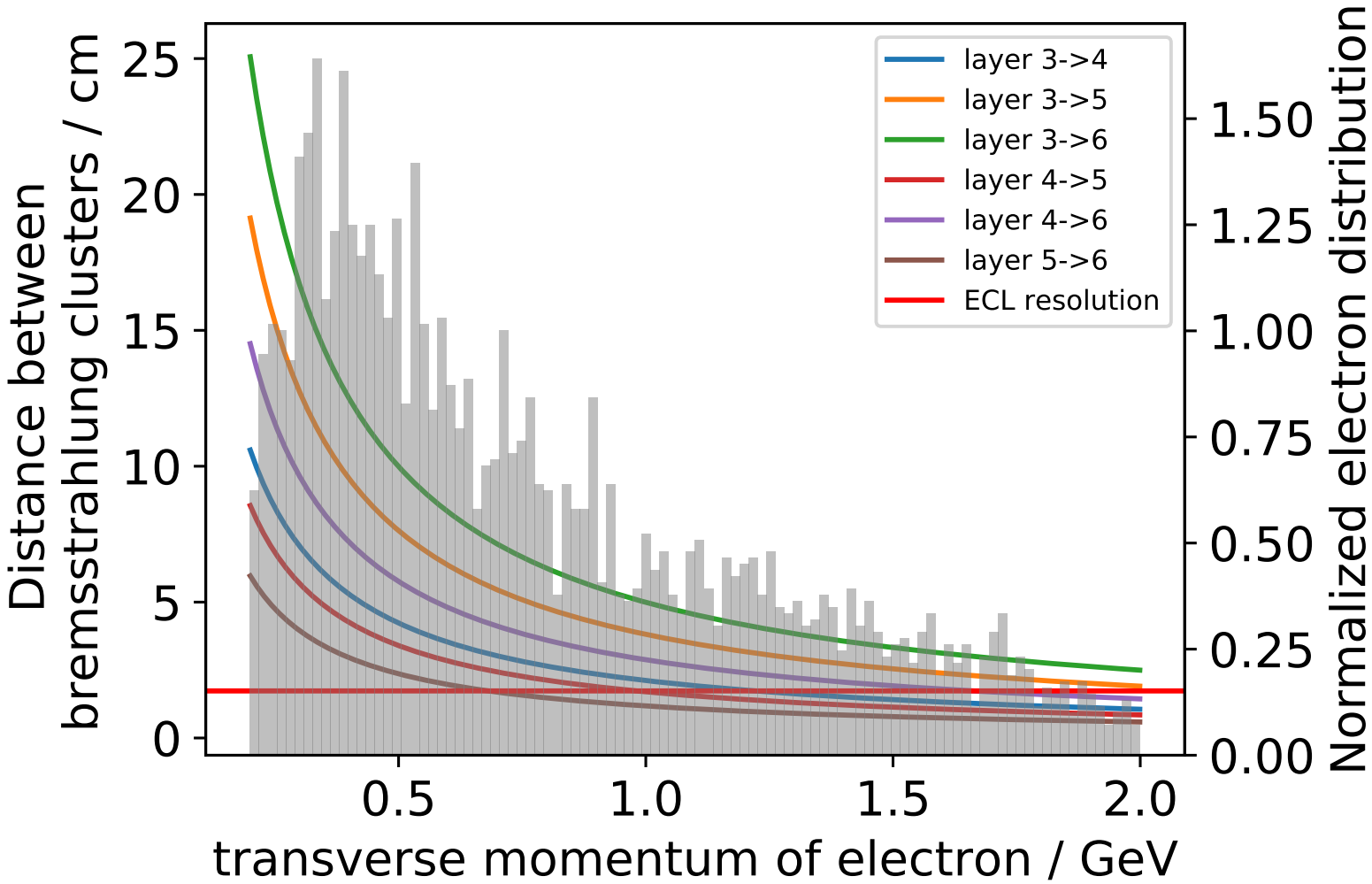
Backup

ECL Position Resolution

- Is the position resolution of the ECL good enough, so we can match the photon emission with the right VXD layer?
- The distance between two bremstrahlung cluster which were emitted on different VXD layers is approximately given by

$$d \approx f_1(r_{l1}, r_{l2}) \cdot \omega + f_2(r_{l1}, r_{l2}) \cdot \omega^3$$

where $\omega \sim \frac{1}{p_T}$ is the curvature of the track and f_1,f_2 are functions depending on the radii of the VXD layers



- for momenta where the curve lies under the red line we cannot differentiate between the two layers when assigning the cluster to a hit