Documentation of my work during the Projektpraktikum

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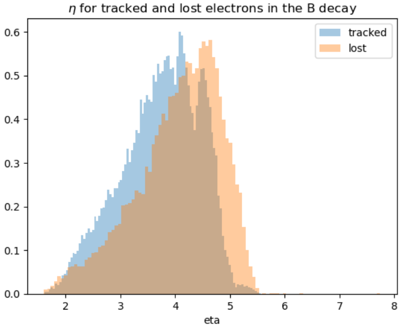
Overview

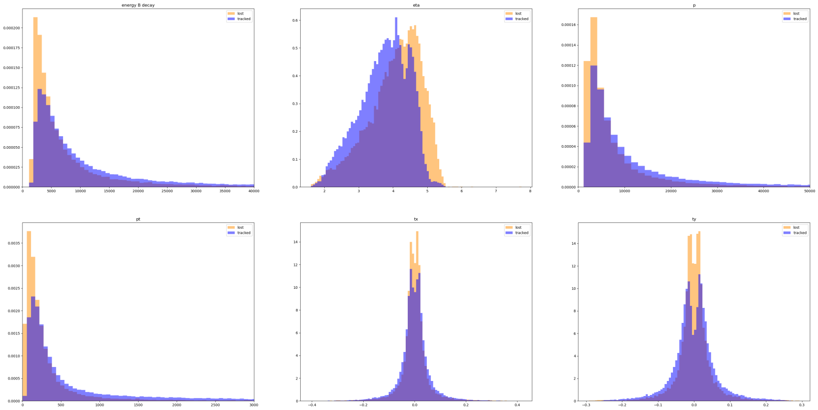
initial attempts to understand MC sims

Working with MC simulations of the two decays: $B^0 \longrightarrow K^{*0} e^+ e^-$ and $D^{*0} \longrightarrow D^0 e^+ e^-$.
Main focus on $e^{\pm}$ particles, especially the differences between those that are found and lost. Initial attempt to understand the data:

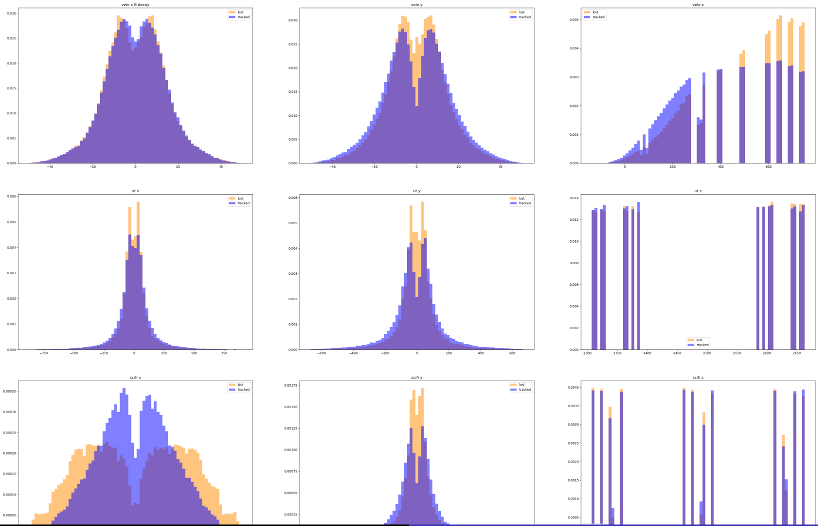
- plotted energy, η, p, p_T, tx (x slope), and ty (y slope)
- plotted tracking station hits to get an overview of what the data means



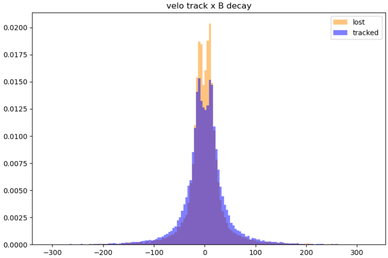
Particle Properties



Tracker hits



velo tracks


velo track x B decay
lost
tracked
0.0200
0.0175
0.0150
0.0125
0.0100
0.0075
0.0050
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−300
−200
−100
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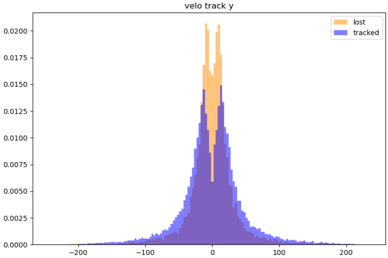
100
200
300


velo track y
lost
tracked
0.0200
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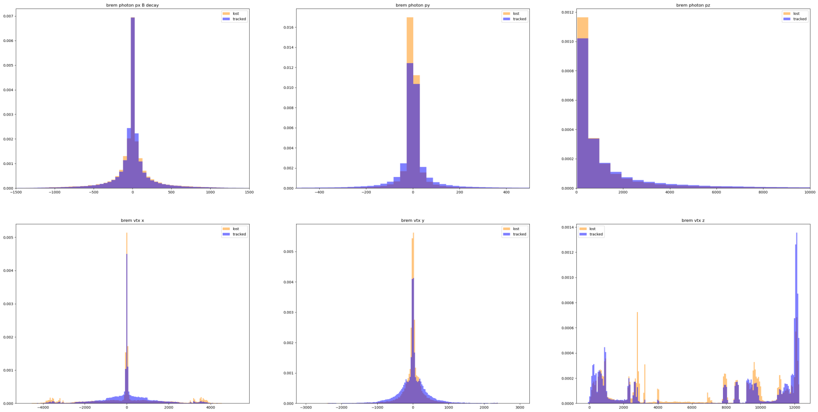
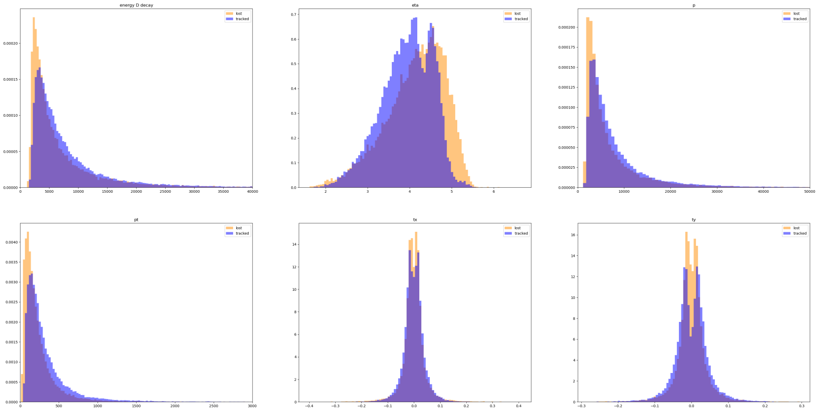
100
200

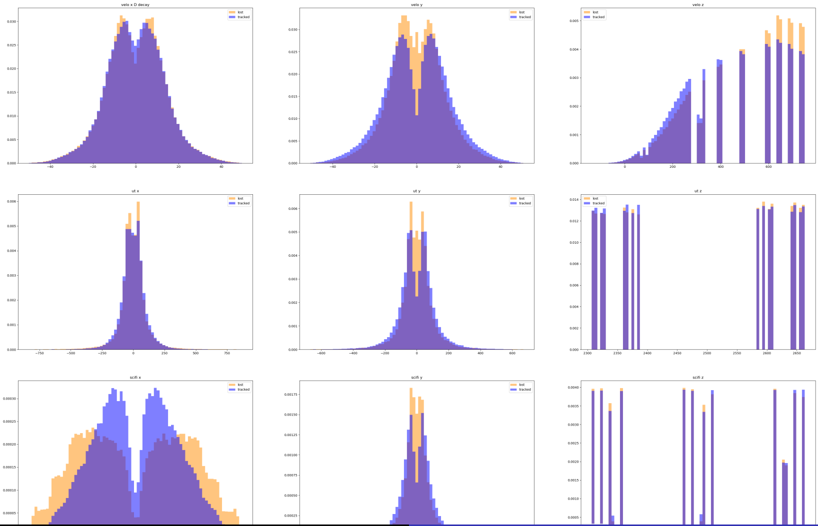
Brem photons



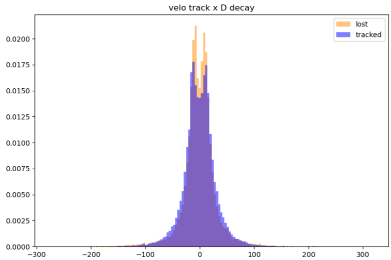
Particle Properties



Tracker hits



velo tracks


velo track x D decay
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0.0200
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0.0075
0.0050
0.0025
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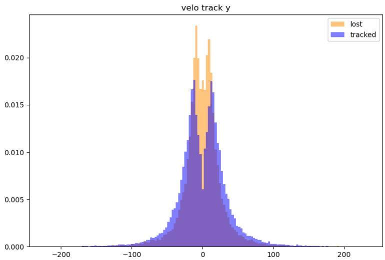
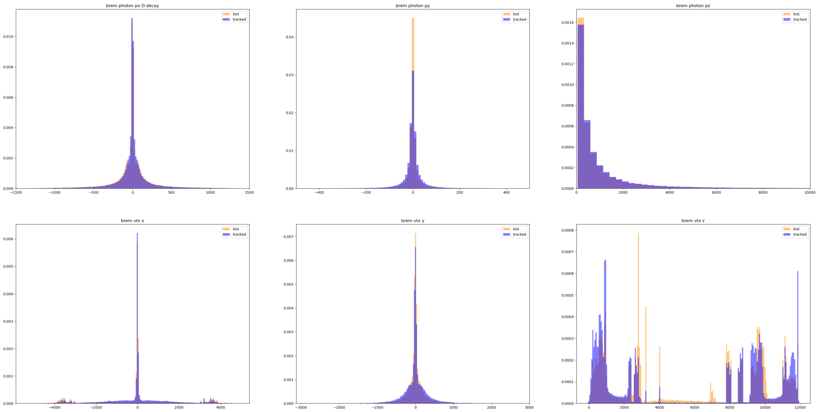
−300
−200
−100
0
100
200
300


velo track y
lost
tracked
0.020
0.015
0.010
0.005
0.000
−200
−100
0
100
200

Brem photons

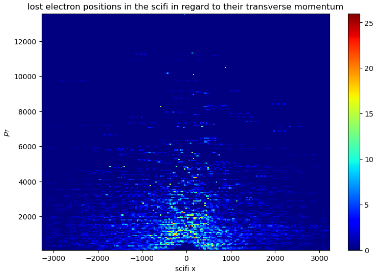


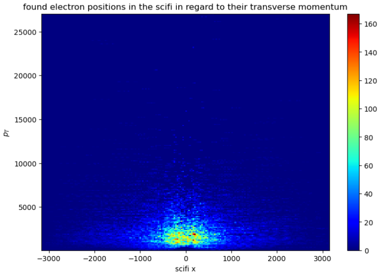
motivation

- For the B decay, we only look at $e^{\pm}$ with $E > 5\text{GeV}$, and for the D decay only $E < 5\text{GeV}$
- tried to plot some 2d histograms from the root files to look for connections between system parameters
- took a look at energyloss due to bremsstrahlung
- fitted first trajectories to singular particles

electron pos in scifi

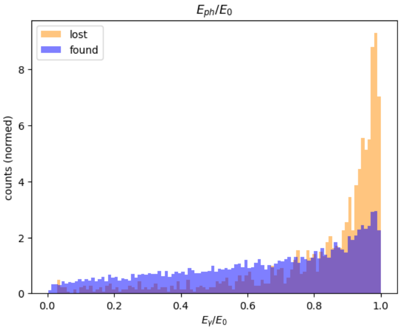
Noticed that lost electrons hit the scifi in much broader spread than found particles. Took a look at the relation of the x pos of the particles in the scifi and their transverse momentum



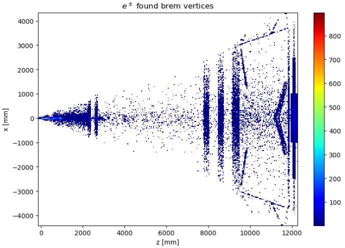


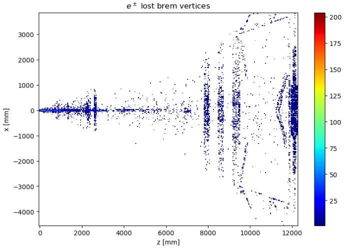
E_{ph}/E_0

we can clearly see that
lost electrons are responsible
for higher energy photons.



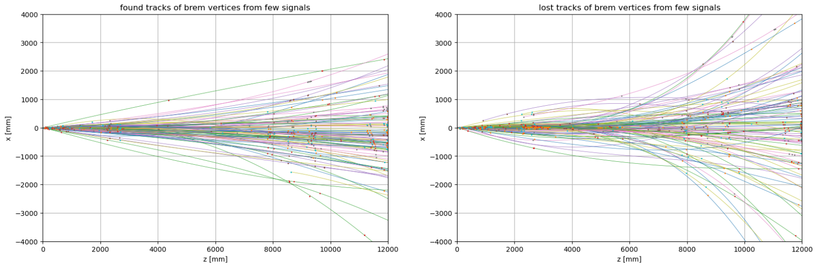
Brem Vertices xz-plane





vertices of lost e photons are more densely concentrated around the beampipe, especially in the z range of the magnet
found: vertices are densely located @ or around the detectors, while there are no real clusters in the z range of the magnet

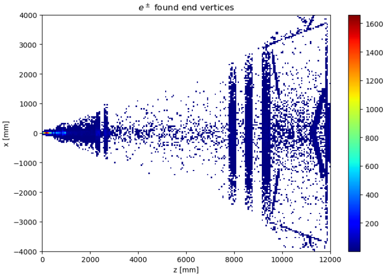
tracks from brem vertices

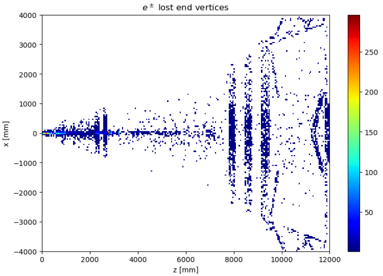


we can see that of the lost brem vertices, many trajectory fits seem illogical and not plausible

found: most seem like reasonable tracks

end vertices xz-plane





vertices of lost e photons are more densely concentrated around the beampipe, especially in the z range of the magnet found: vertices are densely located @ or around the detectors, while there are no clusters in the z range of the magnet

tracks from detector hits

electrons and photons will be stopped by the ECAL which serves to measure the particles energy

B:

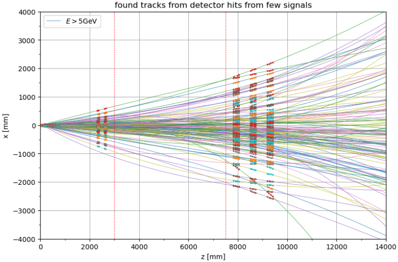
the trajectories between the velo and tt should be linear, which cannot be plotted accurately using a single fit.

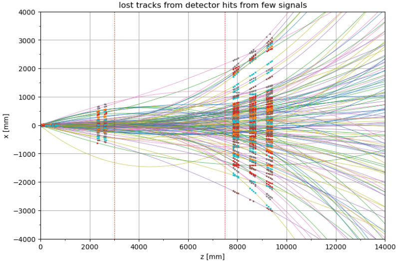
lost tracks diverge more severely.

most higher energy particles maintain a trajectory closer to the beamdirection ie a larger pseudorapidity, and show less bending in their trajectory, especially upstream.

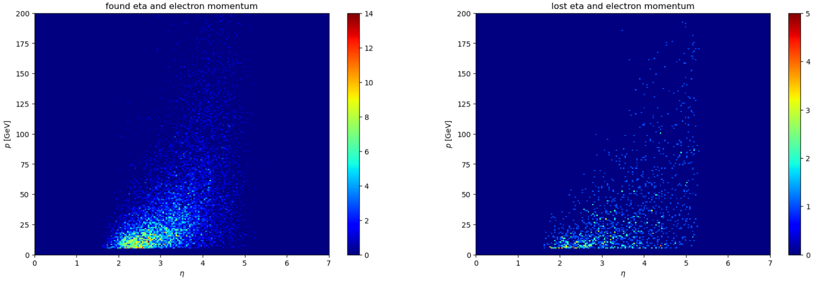
found: higher energy: very compact trajectory, less bending wrt lower energy particles

tracks from detector hits





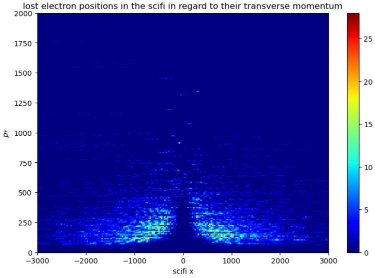
eta and momentum connection

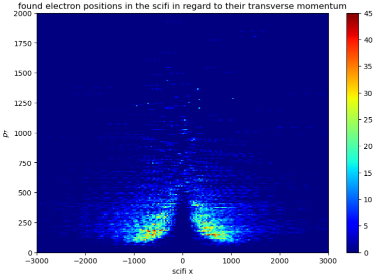


particles with lower momentum appear to have lower rapidity as well, ie a larger angle to the beam axis.

electron pos in scifi

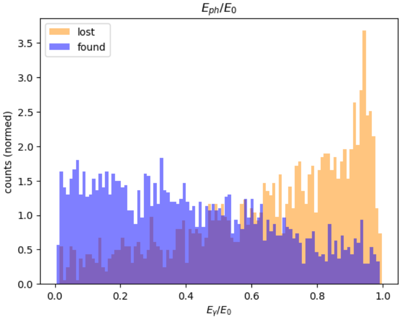
heatmaps look fairly similar. lost e are more densely located between $x \in [1000,2000]$. found e between $x \in [200,1500]$.
we can see a near empty space around the x origin in both. lost seem to have less pt.



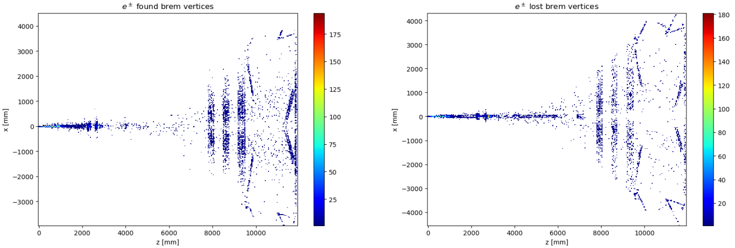


E_{ph}/E_0

still able to see a trend that most electrons that give up all of their energy to photons are lost e. but nowhere near as extreme as for the B decay. both energies are much smaller than in the B decay. otherwise similar pattern.

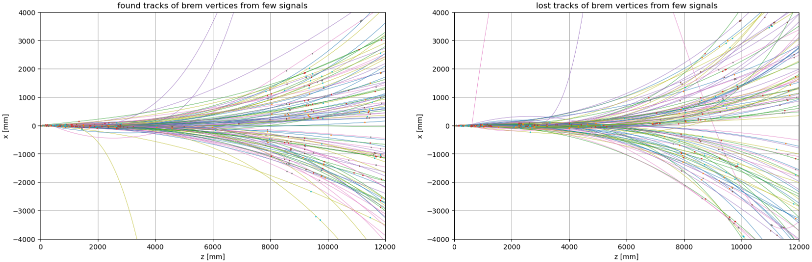


Brem Vertices xz-plane



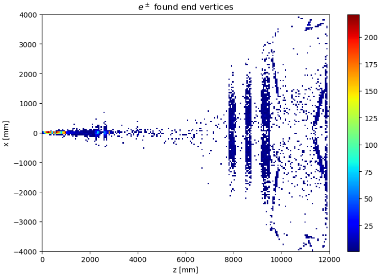
lost brem vertices: we can very clearly see the concentration of vertices @ the beampipe
both: less statistics in general, can still make out the tracking stations but not as well as in the B decay

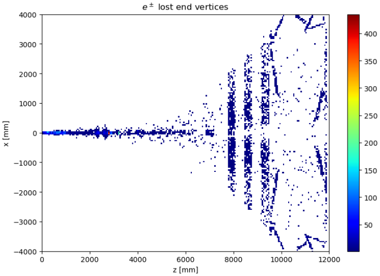
tracks from brem vertices



both: many tracks arent good fits and are unusable

end vertices xz-plane

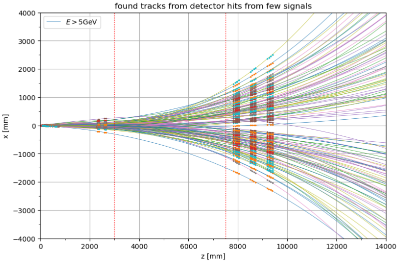


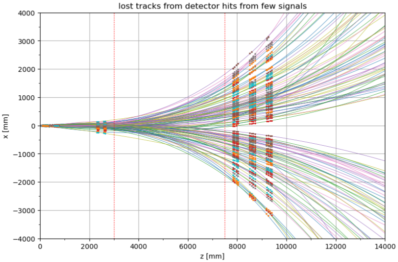


lost: densely located @ the beampipe.
both: almost cant make out the velo or ut

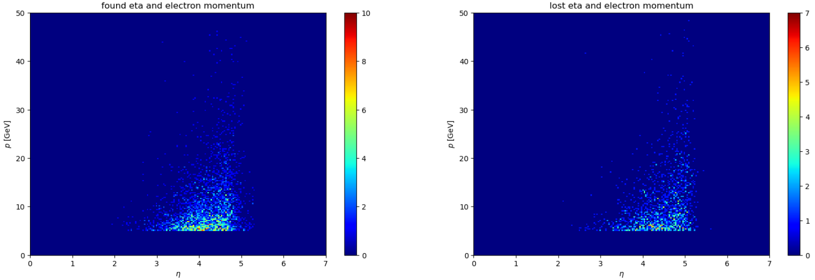
tracks from detector hits

E<10GeV: almost all diverge from the x origin (almost no hit for x<1500)
E>10GeV: much more densely clustered. however still a noticeable empty space around the x origin





eta and momentum connection



both: clustered between $3 < \eta < 5$ and $0 < p < 10$GeV. it seems that most particles had a higher rapidity

Tasks

Only select electrons from the B decay with $p > 5$GeV. Note the differences between lost and found.

- do we find the electrons that do not engage in bremsstrahlung with a high efficiency?
- how much energy relative to the initial energy do electrons lose through bremsstrahlung, and does that effect our finding the $e^{\pm}$?
- are there differences in the shape of the partial trajectory in the SciFi? (can be determined by comparing the fit parameters - cf Andre Thesis)
- does z_{mag} (parameter of the optical model) deviate significantly for $e^{\pm}$?

Tasks

Then do the same for the D decay for $e^{\pm}$ with $E < 5\text{GeV}$, and ascertain how many electrons share a velo track. Determine how many electrons from Photon Conversions (PairProd) share a velo track. The K^* decays further into a K and π. Take a look at the respective values for the K and π, and compare them to the electron. The efficiencies for K and π are very well.

- B decay: $\Delta m \sim 4.39\text{GeV}$
- D decay: $\Delta m \sim 0.14\text{GeV}$

$e^\pm$ with no bremsstrahlung

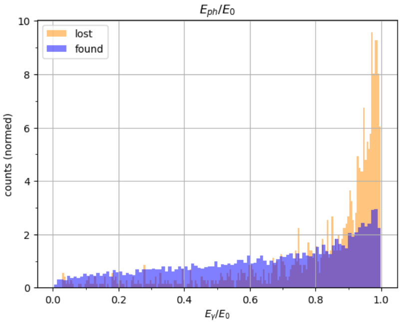
The general efficiency with which we find $e^\pm$ ($E > 5$GeV) is $\epsilon = 0.8607$, which can be calculated via

$$\epsilon = \frac{N_{\text{found}}}{N_{\text{gen.}}}.$$

The efficiency for $e^\pm$ with no bremsstrahlung is significantly higher with $\epsilon = 0.9688$, but this value has low statistics (< 100 particles). For Kaons and Pions (>5GeV) the efficiency is high $\epsilon = 0.9520$, for Kaons $\epsilon = 0.9629$, and for Pions $\epsilon = 0.9385$.

brem $e^{\pm}$ - energyloss

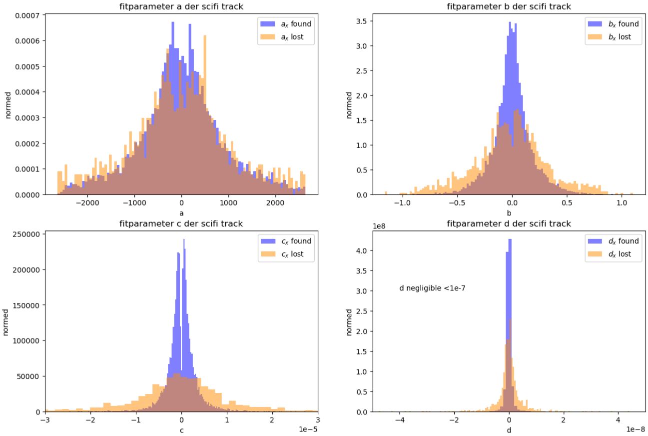
$\epsilon = 0.8603$
$\bar{q}_{\text{found}} = 0.6475$
$\bar{q}_{\text{lost}} = 0.8241$
Lost $e^{\pm}$ lose significantly more energy than found particles. Most lost $e^{\pm}$ lose more than 0.8 of their initial energy. But in both distributions we can observe an increase in density for E_γ/E_0 nearing 1.



Fit tracks in the SciFi

Fit polynomial for the SciFi tracks ($z_{\text{ref}} = 8520$ mm):

$$\text{SciFi\_track} = a_x + b_x(z - z_{\text{ref}}) + c_x(z - z_{\text{ref}})^2 + d_x(z - z_{\text{ref}})^3$$



Fit tracks in the SciFi

electrons:

found: $a = -0.6718$, $b = 0.001378$, $c = 3.3127 \cdot 10^{-8}$, $d = -1.0331 \cdot 10^{-10}$.

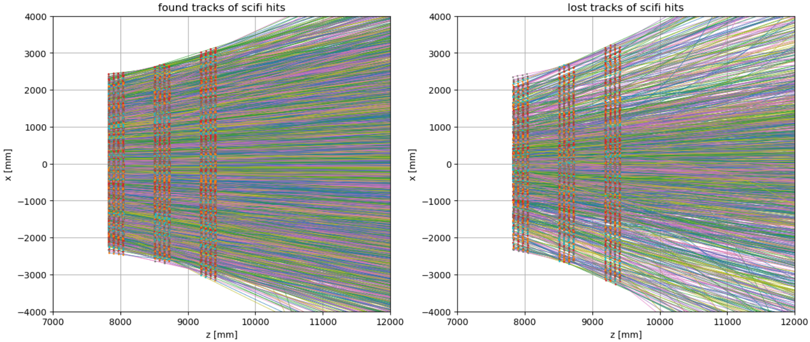
lost: $a = -36.9876$, $b = -0.0157$, $c = -8.2659 \cdot 10^{-7}$, $d = -1.5415 \cdot 10^{-11}$.

Kaon and Pions:

found: $a = 1.3759$, $b = 1.4867 \cdot 10^{-5}$, $c = 1.0612 \cdot 10^{-9}$, $d = 2.5243 \cdot 10^{-12}$.

lost: $a = 19.6555$, $b = -0.0007972$, $c = -1.6114 \cdot 10^{-7}$, $d = 8.0749 \cdot 10^{-11}$.

all fitted tracks

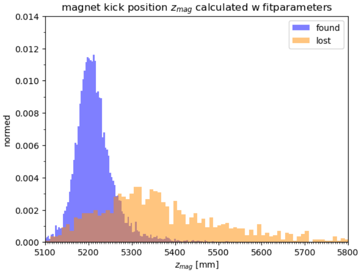


studying z_{mag}

The optical centre of the magnet z_{mag} is defined as the intersection between the trajectory tangents before and after the magnet:

$$z_{\mathrm{mag}} = \frac{x_v - t_x \cdot z_v - a_x + b_x \cdot z_{\mathrm{ref}}}{b_x - t_x},$$

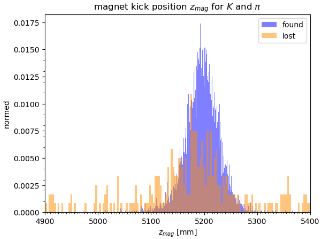
where x_v is the Velo x track, z_v the Velo z track, t_x the Velo x slope, a_x, and b_x fit parameters. There is a radical difference between the z_{mag} values for found and lost $e^{\pm}$. We see the peak for found $e^{\pm}$ at values between 5150mm and 5300mm. There is however no such dense concentration for lost $e^{\pm}$, we see a weak peak at around 5300mm.



studying z_{mag}

electrons:
found: $\bar{z}_{mag} = 5215.564$,
lost: $\bar{z}_{mag} = 5450.4847$.
Kaons and Pions:
found: $\bar{z}_{mag} = 5196.312$,
lost: $\bar{z}_{mag} = 5200.7103$.

the distribution for lost K and pi has a peak at around the same zmag value as found but its less compact and seems chaotic outside the range of the peak. the distribution for found particles appears compact around the peak.

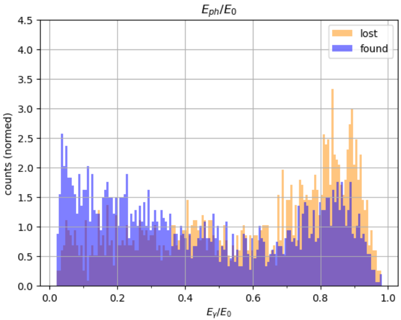


$e^{\pm}$ with no bremsstrahlung

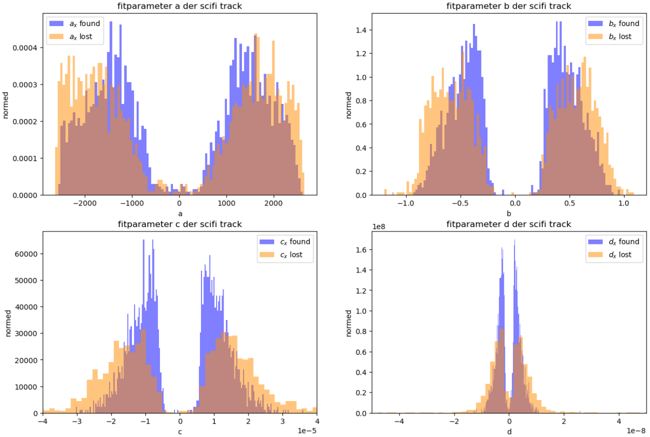
general $\epsilon(E < 5GeV) = 0.5759$
efficiency for $e^{\pm}$ with no bremsstrahlung is higher with $\epsilon = 0.7961$, but nowhere near good, (sample size 350).

brem $e^{\pm}$ - energyloss

$\epsilon = 0.5569$
$\bar{q}_{\text{found}} = 0.4422$
$\bar{q}_{\text{lost}} = 0.5885$
almost no trend noticeable at all for found. for lost there is a slight peak at E_γ/E_0 1. lost electrons lose slightly more energy than found electrons. This is however nowhere near as extreme as for the B decay. This is a lower energy decay, so the electrons themselves are of lower energy.



Fit tracks in the SciFi

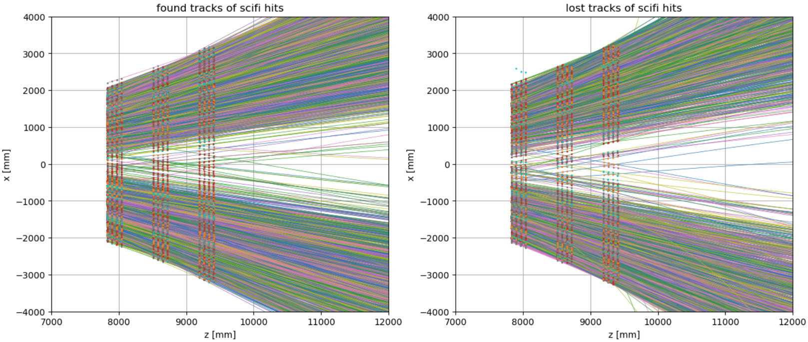


Fit tracks in the SciFi

found: $a = 18.0418$, $b = 0.005765$, $c = 9.4803 \cdot 10^{-8}$, $d = -4.4520 \cdot 10^{-11}$.

lost: $a = -35.4837$, $b = -0.01038$, $c = -6.2083 \cdot 10^{-7}$, $d = 9.5809 \cdot 10^{-11}$.

all fitted tracks



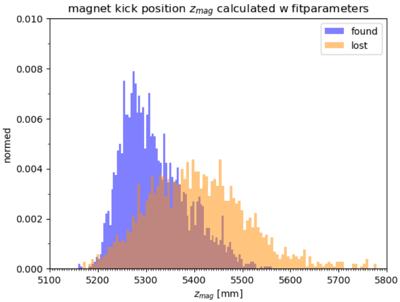
almost all tracks (found and lost) diverge from the beam axis

studying z_{mag}

There is a difference between the z_{mag} values for found and lost $e^{\pm}$. For found, we see a peak between 5250mm and 5350mm. For lost we notice a peak of a much broader distribution between 5350mm and 5450mm. Its less pronounced. Further there are significant outliers for lost particles that are outside the observed range.

found: $z_{mag} = 5318.4527$,

lost: $z_{mag} = 5425.1374$.



$e^{\pm}$ pairs that share a velo track

Looking for electron pairs that share a velo track, we could find one such pair when looking through both, lost and found. $e^{\pm}$ that share a track w.r.t. all selected decay electrons: 0.0445%. We also took a look at $e^{\pm}$ with the same `velo_track_idx` regardless of the `event_count`, which does not work, tho.

```
#events w/ shared track electrons from found and lost: 1
event_count: [2822, 2822]
velo idx: [146, 146]
mcp_index: [5806, 5829]

velo x: [-75.1, -75.1]
velo y: [5.88, 5.88]

velo tx: [-0.0908, -0.0908]
velo ty: [0.00703, 0.00703]
```

```
#velo_track_idx in all events: 217
velo idx: [0, 0, 0]
mcp_index: [1066, 1251, 666]
event_count: [5735, 7049, 7378]

velo x: [-2.21, 9.45, -18.5]
velo y: [-21.6, -33.4, 17.4]

velo tx: [-0.0022, 0.0153, -0.0224]
velo ty: [-0.0263, -0.0469, 0.0212]
```

$e^\pm$ pairs that share a velo track

Looked
for $e^\pm$ pairs in found and lost
with no momentum constraints
and found 35 events, ie
70 electrons that shared a track.

```
#events w/ shared track electrons from found and lost: 35
event_count: [359, 359]
velo idx: [25, 25]
mcp_index: [2926, 2936]

velo x: [5.89, 5.89]
velo y: [9.81, 9.81]

velo tx: [0.00824, 0.00824]
velo ty: [0.0135, 0.0135]
percentage of e with shared tracks: 0.7488
```

$e^\pm$ pairs from Photon Conversions that share a velo track

Also looked at electron pairs from Photon Conversion that shared a velo track. Found 951 events with $e^\pm$ pairs with shared velo tracks. $e^\pm$ that share a velo track w.r.t. all electrons from Photon Conversions: 5.59%.

```
#events w/ shared track electrons from Photon Conversions: 951
shared_idx: 0
event_count: [11, 11]
velo idx: [27, 27]
mcp_index: [1211, 1215]

velo x: [-20.4, -20.4]
velo y: [-24.4, -24.4]

velo tx: [-0.0234, -0.0234]
velo ty: [-0.028, -0.028]
```

calculate uncertainties for efficiencies

The uncertainty for the efficiency ϵ is calculated as follows:

$$\delta\epsilon = \frac{1}{N} \cdot \sqrt{k\left(1 - \frac{k}{N}\right)}.$$

The number of events passing the cut k, number of all events N.
Also: made a cut st all vertices @ $z > 9500$mm are disregarded, since thats where the ECAL is located, and the electrons lose their energy there anyway.

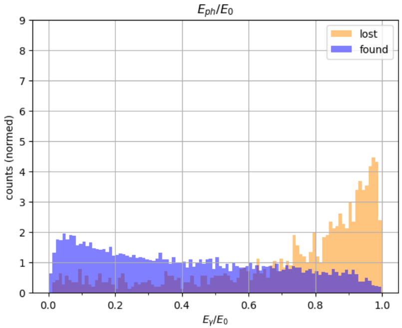
select cutoff energy for brem photons

We selected a cutoff energy for the sum of the brem photons of each $e^{\pm}$, st all electrons with photons of total energy below 350MeV are considered to be nobrem electrons. The efficiency of the electrons with no bremsstrahlung is 0.9481 ± 0.0084, and of those that emit bremsstrahlung photons that are relevant is 0.8545 ± 0.0036.

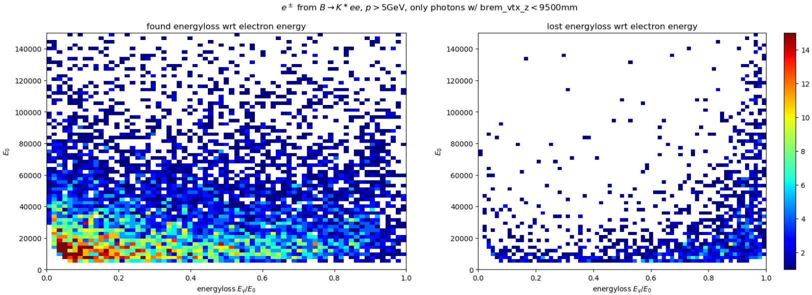
```
cutoff = 100 MeV, sample size: 322
eff = 0.9379 +/- 0.0135
cutoff = 200 MeV, sample size: 481
eff = 0.948 +/- 0.0101
cutoff = 300 MeV, sample size: 627
eff = 0.949 +/- 0.0088
cutoff = 400 MeV, sample size: 739
eff = 0.9513 +/- 0.0079
cutoff = 500 MeV, sample size: 860
eff = 0.9477 +/- 0.0076
cutoff = 600 MeV, sample size: 973
eff = 0.9424 +/- 0.0075
cutoff = 700 MeV, sample size: 1106
eff = 0.9412 +/- 0.0071
cutoff = 800 MeV, sample size: 1188
eff = 0.9411 +/- 0.0068
cutoff = 900 MeV, sample size: 1288
eff = 0.9387 +/- 0.0067
cutoff = 1000 MeV, sample size: 1387
eff = 0.9416 +/- 0.0063

cutoff energy = 350MeV, sample size: 693
eff = 0.9481 +/- 0.0084
```

energyloss due to bremphotons

mean energyloss relative to initial energy:
found: 0.4046,
lost: 0.7245.



energyloss wrt electron energy

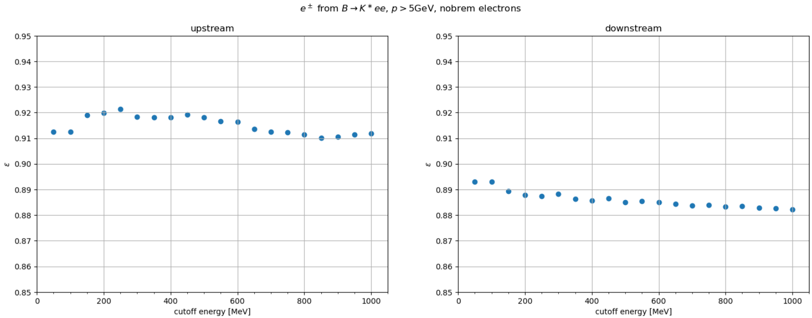


Then i looked at Up and Downstream vertices separately.

split into upstream and downstream vertices ($z \approx 5000$mm)

applied a cut st all vertices @ $z > 9500$mm are disregarded since thats where the ECAL is, where the electrons lose all their energy anyway. then i looked at upstream and downstream photon conversions separately to determine where the electrons lose their energy. electrons that lose most of their energy downstream should in theory be easier to find than upstream.
we used a cutoff energy of 350MeV

eff nobrem

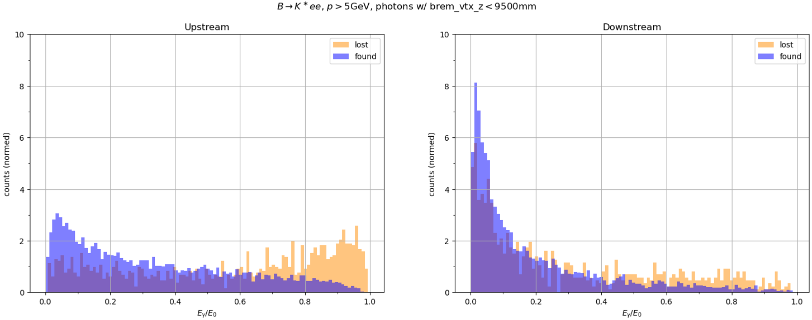

$e^\pm$ from $B \to K^* ee$, $p > 5$GeV, nobrem electrons
upstream
downstream
ε
cutoff energy [MeV]
0.95
0.94
0.93
0.92
0.91
0.90
0.89
0.88
0.87
0.86
0.85
0
200
400
600
800
1000

eff brem

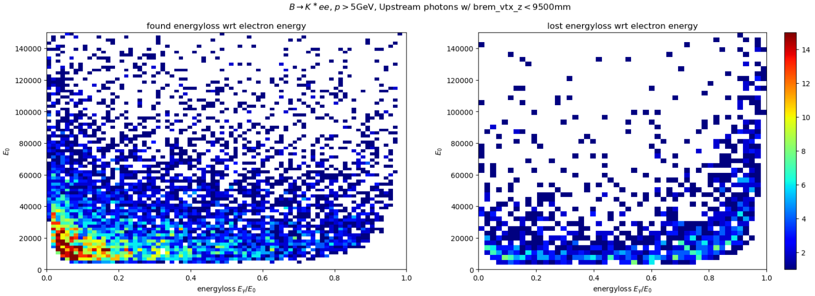
upstream $\epsilon = 0.851 \pm 0.004$, downstream $\epsilon = 0.836 \pm 0.005$

```
upstream:
mean energyloss relative to initial energy (found): 0.33078325542598164
mean energyloss relative to initial energy (lost): 0.5708618852236069
downstream:
mean energyloss relative to initial energy (found): 0.19104090843883118
mean energyloss relative to initial energy (lost): 0.3051594568487781
```

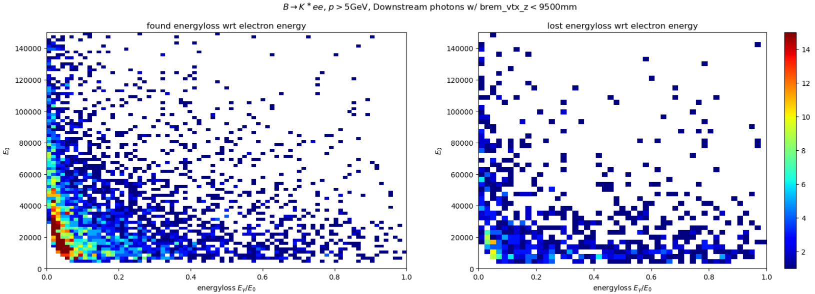
E_γ/E_0 updown



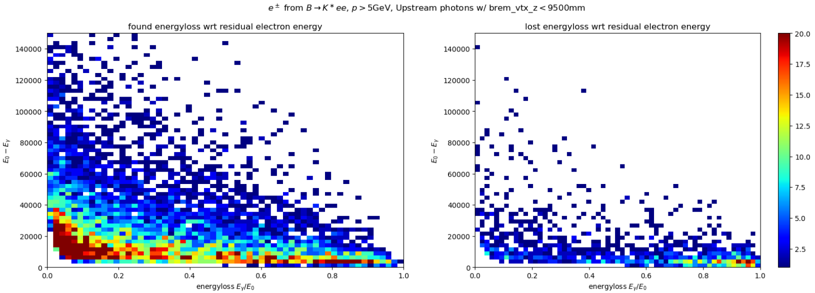
energyloss wrt E_0 upstream



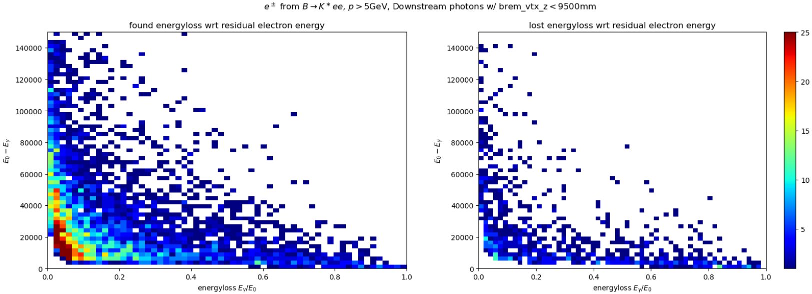
energyloss wrt E_0 downstream



energyloss wrt $E_0 - E_\gamma$ upstream



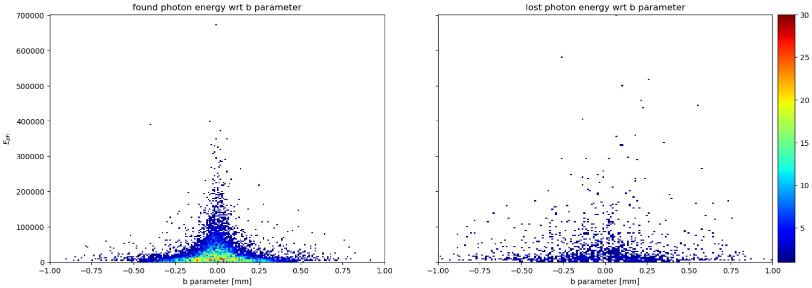
energyloss wrt $E_0 - E_\gamma$ downstream



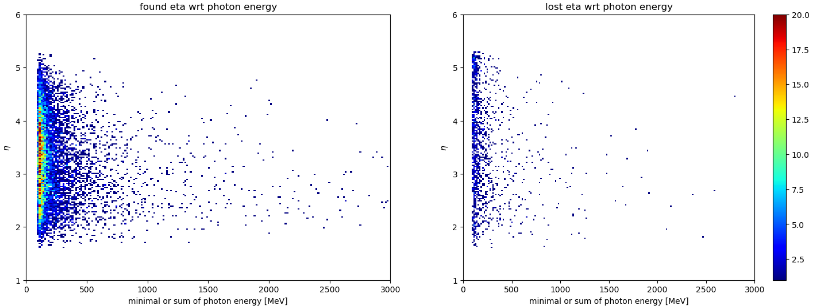
–

b parameter

tried to find the reason why the b parameter distribution in the scifi track-fit was broader for lost particles. i could not determine a singular cause, but i looked at the photon energies wrt b, at the vertex types of the photons, and excluded the reason that the particles may have entered the magnet at a skewed angle (η-dependency).

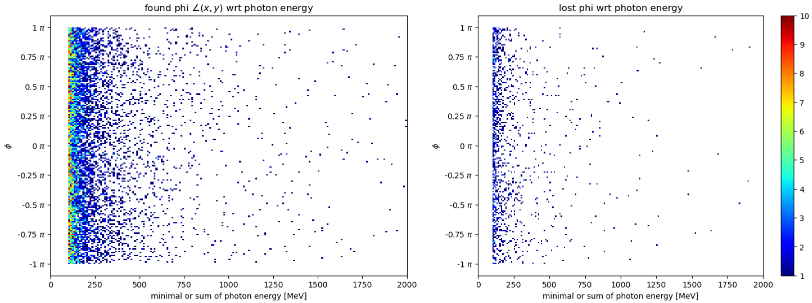


η wrt photon energy



lost: perhaps slightly more hits at larger eta but not really significant

ϕ wrt photon energy

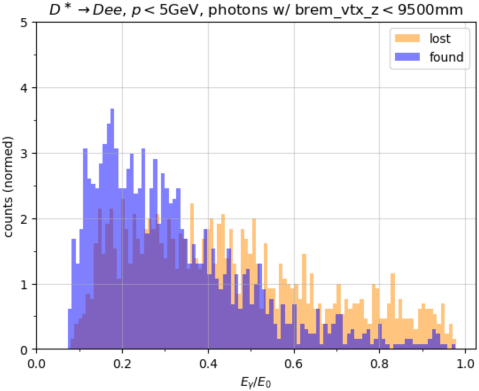


Cannot really make out any patterns that might explain lost and found differences. See no materialpeak.

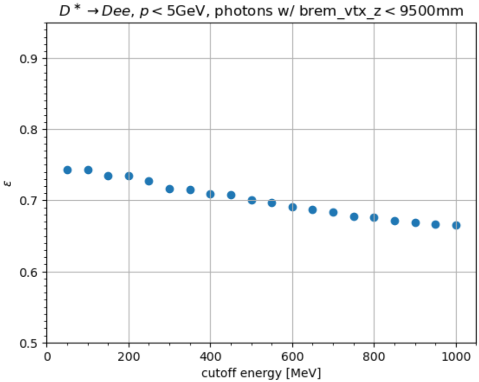
cut st ECAL does not interfere with results

We cut all brem vertices that originate @ $z > 9500$ and looked at the Energyloss again. We only look at electrons < 5GeV.
we set a cutoff energy at 350MeV which results in an efficiency of $\epsilon = 0.7148 \pm 0.0113$, and a sample size of 1600, for the electrons that do not emit photons whose total energy exceeds the cutoff.
For the bremsstrahlung electrons, we get $\epsilon = 0.4993 \pm 0.0093$.
mean $\Delta E/E_0$ (found): 0.3135,
mean $\Delta E/E_0$ (lost): 0.4443.

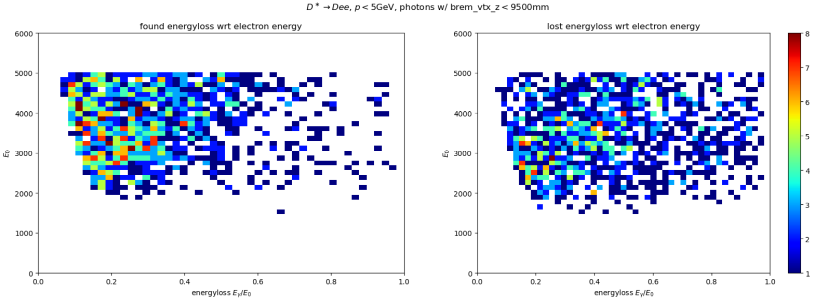
relative energyloss E_γ / E_0



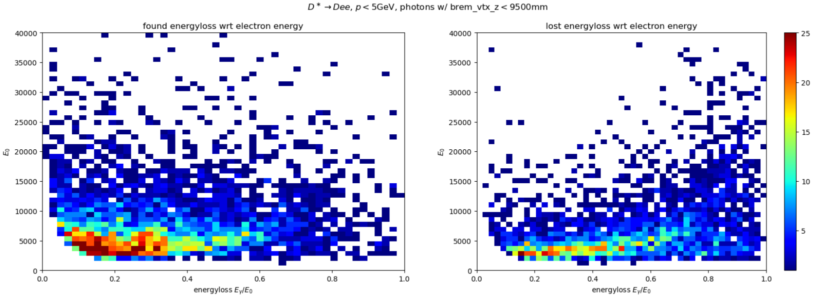
efficiency wrt cutoff energy



energyloss wrt E_0, for $e^\pm$ $p < 5\text{GeV}$



energyloss wrt E_0, for $e^\pm$ with no p cut



LHCb software stack

After building the LHCb software stack from a git repo, I loaded a repo to adjust the tracking of $e^{\pm}$.
Continues in Projektpraktikum Documentation 2.