Parameter Exploration for Realistic Seeding

Emma Yeats

Introduction/Recap

Continuing from Rey's studies from a few weeks ago on parameter optimization for the realistic seeder.

Two main results are discussed: a quick update on the bug found in EICrecon, and also my studies on varying parameters for realistic seeding and how they were changed by the bug.

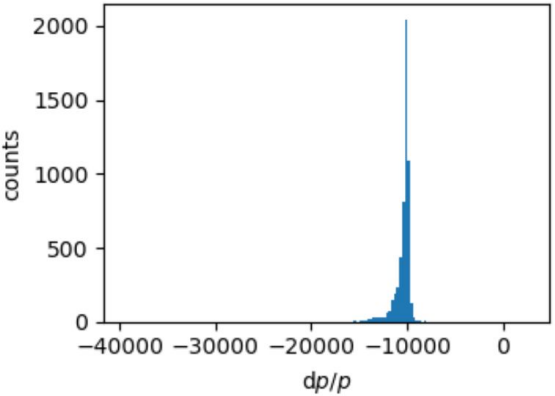
For all plots shown, the sample had 10k single pions with $p \in [0,10]$ GeV/c and $\eta \in [-4,4]$ (Brycecanyon, ACTS 21.1)

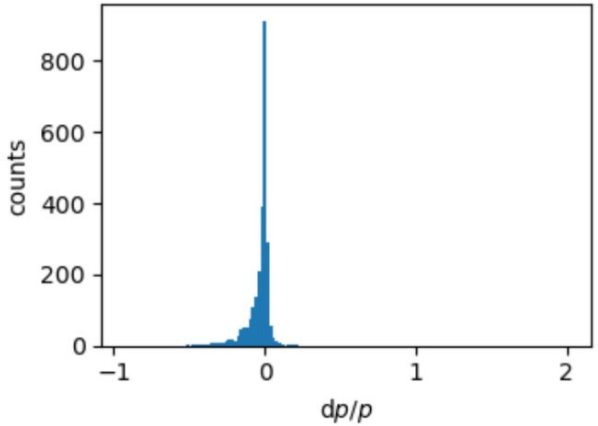
Update on EICRecon Bug

EICRecon recently updated the pt calculation:

```
97        float pt = 0.3 * R * (m_cfg.m_bFieldInZ * 1000) / 100.;
```

```
97        float pt = R * m_cfg.m_bFieldInZ; // pt[GeV] = R[mm] * B[GeV/mm]
```





The only other change is we found that ACTS units passed at the command line level do not get properly interpreted by ACTS. Now, only the number is read in, and the attached unit gets ignored.

We now obtain better momentum resolutions! The resolution is centered at zero, but we still need to investigate why it favors one side (future work).

Parameter Exploration

Parameter Descriptions

Parameter	Description	EICrecon default	Y.S. Lai's default
bFieldInZ	z component of magnetic field	1.7 T	1.7 T
rMax	Maximum r value to look for seeds	500 mm	440 mm
rMin	Minimum r value to look for seeds	33 mm	33 mm
zMin	Minimum z value to look for seeds	-800 mm	-1500 mm
zMax	Maximum z value to look for seeds	800 mm	1700 mm
beamPosX	Beam offset in x	0	0
beamPosY	Beam offset in y	0	0
deltaRMinTopSP	Min distance in r between middle and top SP in one seed	1 mm	50 mm
deltaRMinBottomSP	Min distance in r between middle and bottom SP in one seed	1 mm	50 mm
deltaRMaxTopSP	Max distance in r between middle and top SP in one seed	400 mm	220 mm
deltaRMaxBottomSP	Max distance in r between middle and top SP in one seed	400 mm	220 mm
collisionRegionMin	Min z for primary vertex	-300 mm	-250 mm
collisionRegionMax	Max z for primary vertex	300 mm	250 mm
cotThetaMax	Cotangent of max theta angle	16	16.54
minPt	Min transverse momentum	100	100 MeV/cotThetaMax
maxSeedsPerSpM	Max number of seeds a single middle space point can belong to - 1	1	0
sigmaScattering	How many standard devs of scattering angles to consider	5	5
radLengthPerSeed	Average radiation lengths of material on the length of a seed	0.1	0.1
impactMax	Max transverse PCA allowed	20 mm	3 mm
rMinMiddle	Min R for middle space point	20 mm	—
rMaxMiddle	Max R for middle space point	400 mm	—
bFieldMin	min B field	—	0.1 T

Parameters fixed based on the geometry

Parameter Descriptions

Parameter	Description	EICrecon default	Y.S. Lai's default
bFieldInZ	z component of magnetic field	1.7 T	1.7 T
rMax	Maximum r value to look for seeds	500 mm	440 mm
rMin	Minimum r value to look for seeds	33 mm	33 mm
zMin	Minimum z value to look for seeds	-800 mm	-1500 mm
zMax	Maximum z value to look for seeds	800 mm	1700 mm
beamPosX	Beam offset in x	0	0
beamPosY	Beam offset in y	0	0
deltaRMinTopSP	Min distance in r between middle and top SP in one seed	1 mm	50 mm
deltaRMinBottomSP	Min distance in r between middle and bottom SP in one seed	1 mm	50 mm
deltaRMaxTopSP	Max distance in r between middle and top SP in one seed	400 mm	220 mm
deltaRMaxBottomSP	Max distance in r between middle and top SP in one seed	400 mm	220 mm
collisionRegionMin	Min z for primary vertex	-300 mm	-250 mm
collisionRegionMax	Max z for primary vertex	300 mm	250 mm
cotThetaMax	Cotangent of max theta angle	16	16.54
minPt	Min transverse momentum	100	100 MeV/cotThetaMax
maxSeedsPerSpM	Max number of seeds a single middle space point can belong to - 1	1	0
sigmaScattering	How many standard devs of scattering angles to consider	5	5
radLengthPerSeed	Average radiation lengths of material on the length of a seed	0.1	0.1
impactMax	Max transverse PCA allowed	20 mm	3 mm
rMinMiddle	Min R for middle space point	20 mm	—
rMaxMiddle	Max R for middle space point	400 mm	—
bFieldMin	min B field	—	0.1 T

Parameters I studied

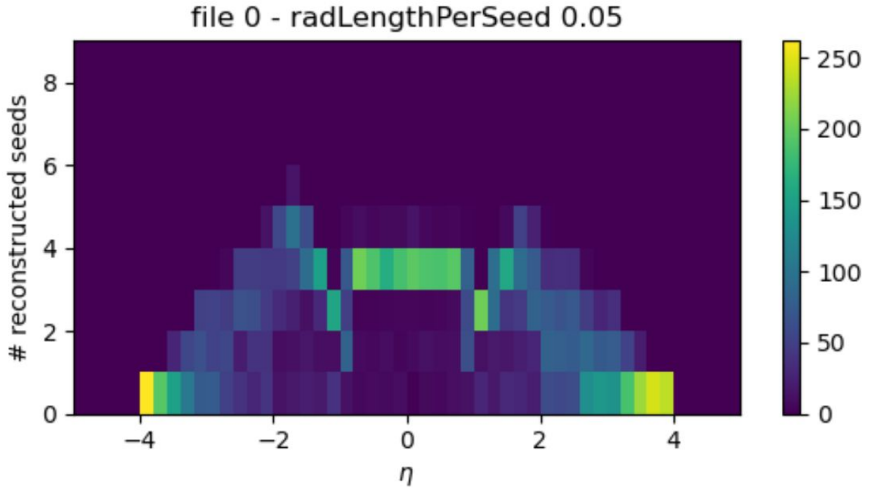
Parameters Chosen For Discussion

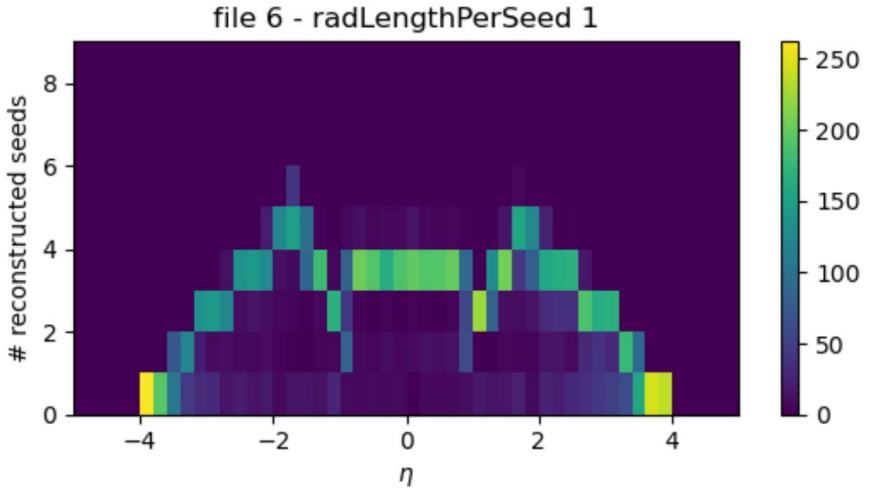
Before this bug, I found one parameter in particular that was responsible for increasing the efficiency in the far eta regime (radLengthPerSeed). I will discuss it's behavior briefly just to explain the sudden efficiency jump you'll see in that region.

Several of the parameters' behavior did not change after the bug was fixed, like deltaRMinSP, deltaRMaxSP, cotThetaMax, and more. However some changed after the fix, including radLengthPerSeed and sigmaScattering, that once had a larger impact on the efficiency and now do not.

radLengthPerSeed (pre-Bug)

Old Plot!



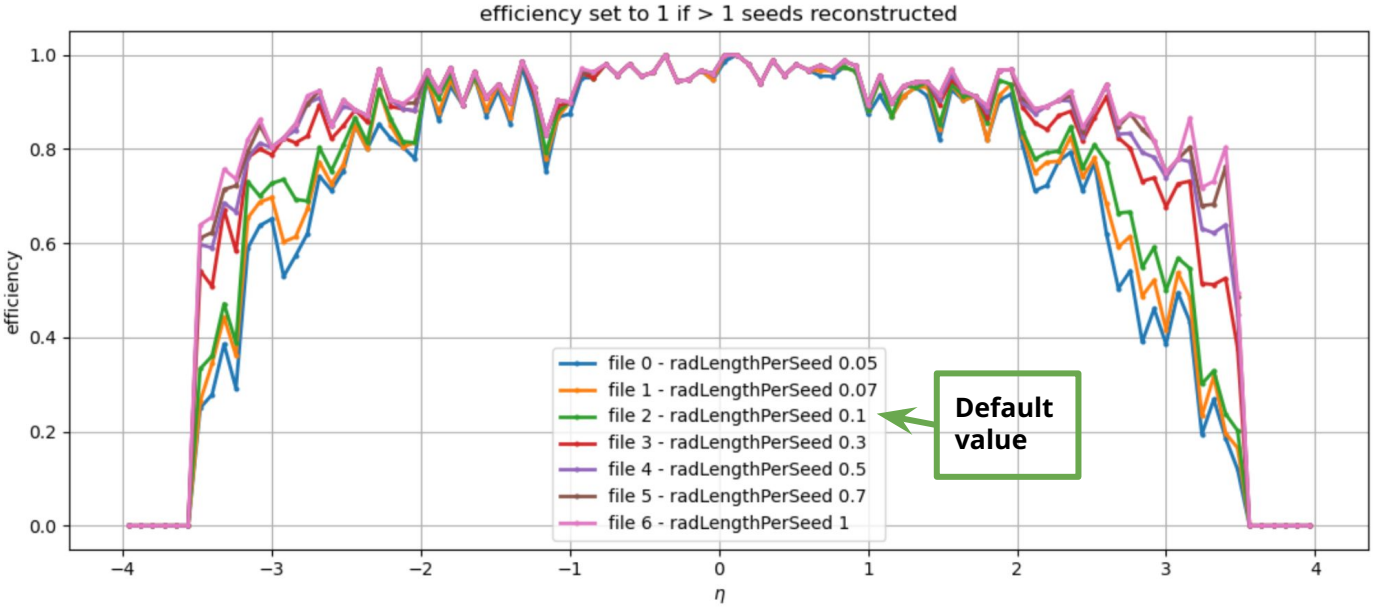


Average radiation lengths of material on the length of a seed.

I initially varied this parameter from 0.01 to 1 (assumed mm, but need to check). The number of reconstructed seeds and the efficiency both increase in the far eta regimes.

radLengthPerSeed (pre-Bug)

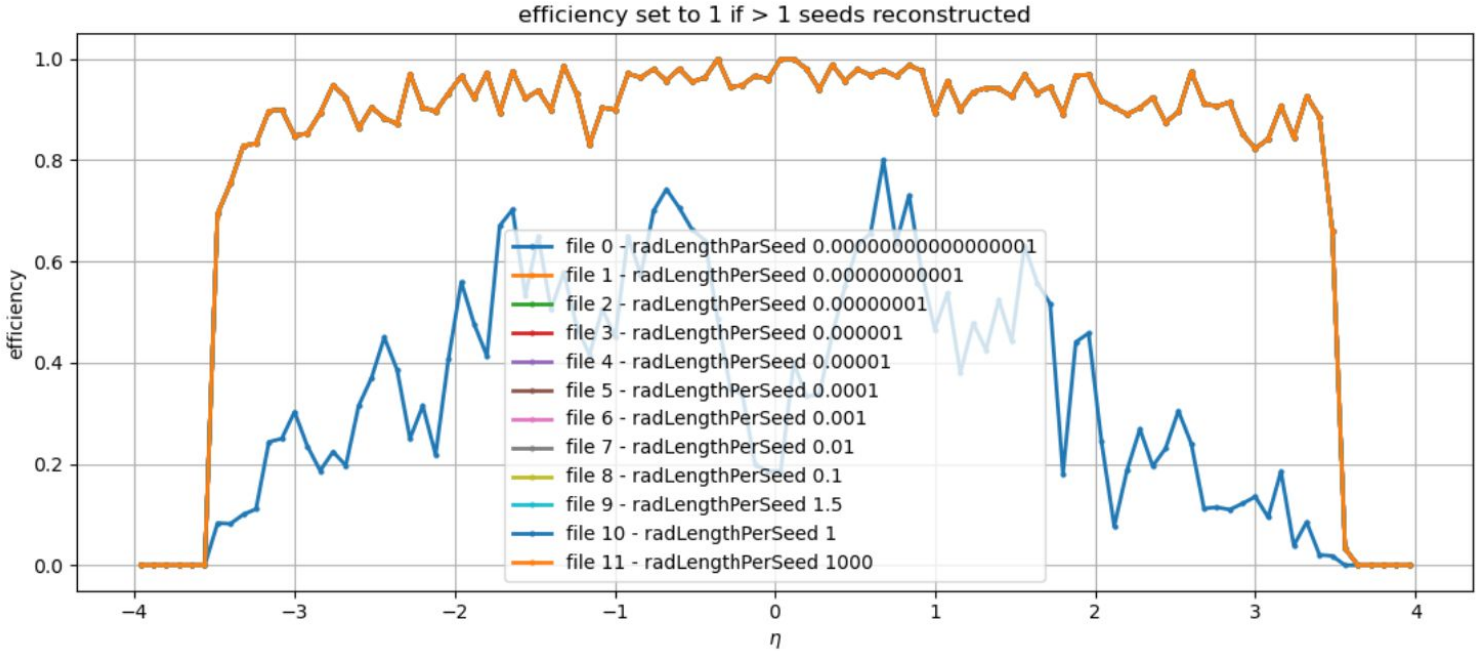
Old Plot!



Above was calculated before the bug was fixed, to show where the sudden increases in efficiency come from. It is less sensitive post-Bug, and I found that this increase in efficiency now happens around ~1e-16 mm.

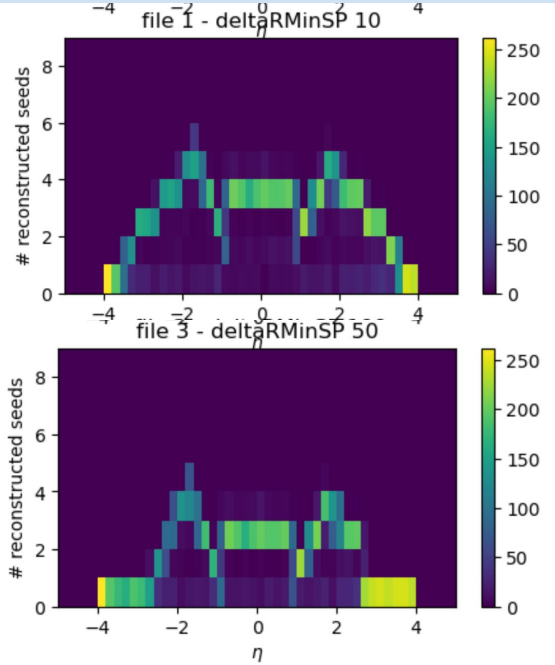
radLengthPerSeed (post-Bug)

(we can see it no longer really has an effect, and we can revert to the default, radLengthPerSeed==0.1)



Now we look at the parameters that remained sensitive.

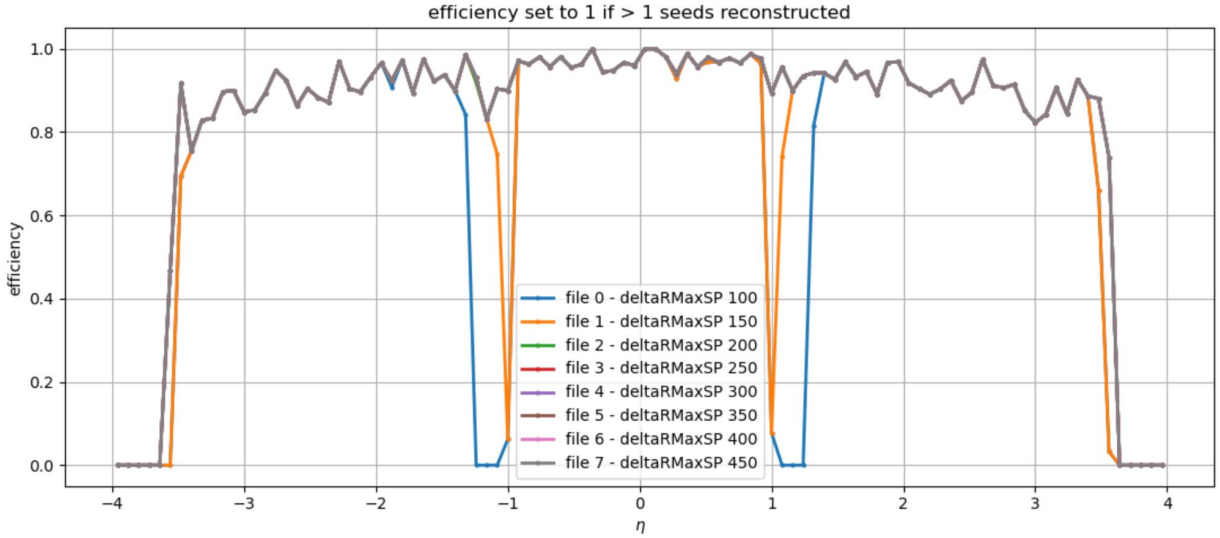
DeltaRMinTop/BottomSP (post-Bug)

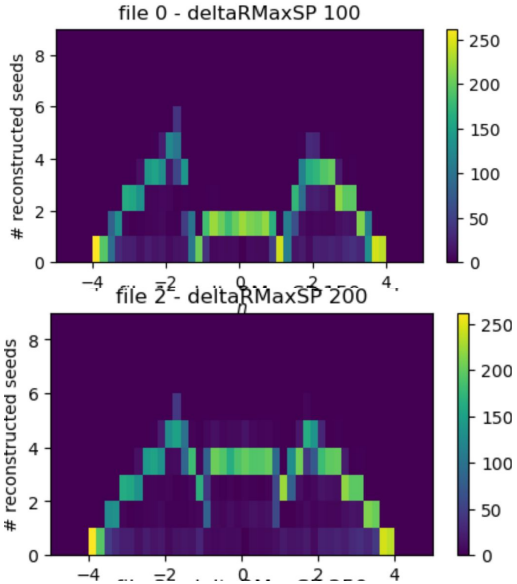


Minimum distance in r between Middle and Top/Bottom SP in one seed.

We see that 10 mm is ideal, and also doesn't increase the number of reconstructed seeds too much.

deltaRMaxTop/BottomSP (post-Bug)

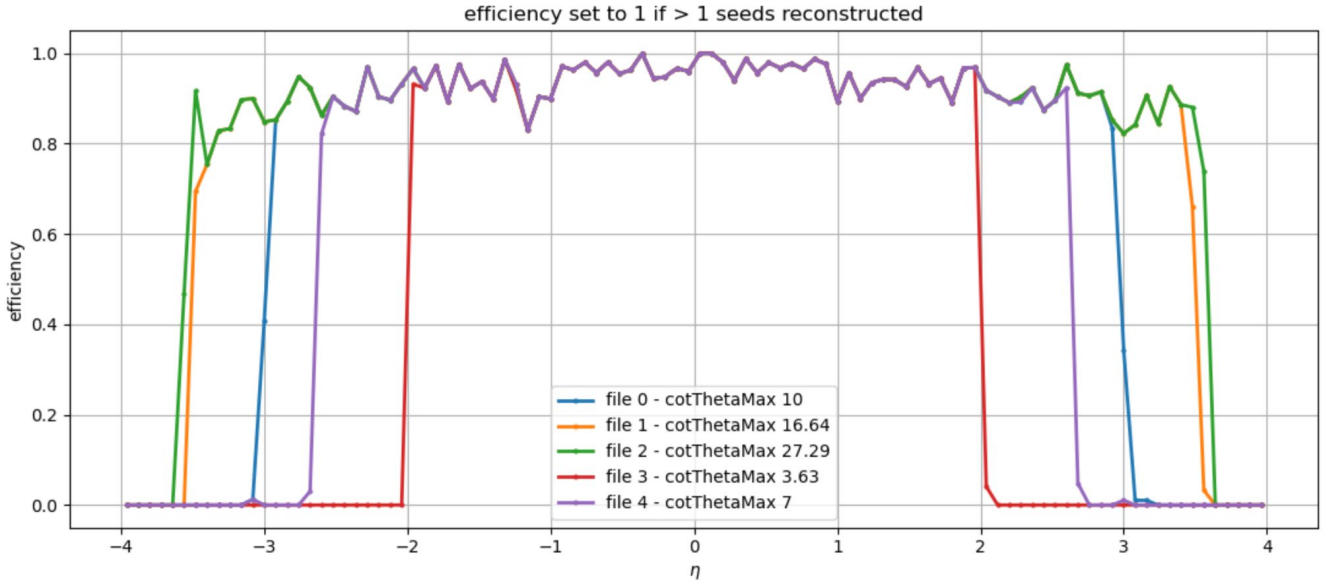




Maximum distance in r between Middle and Top/Bottom SP in one seed.

We see this should be set ≥200 mm.

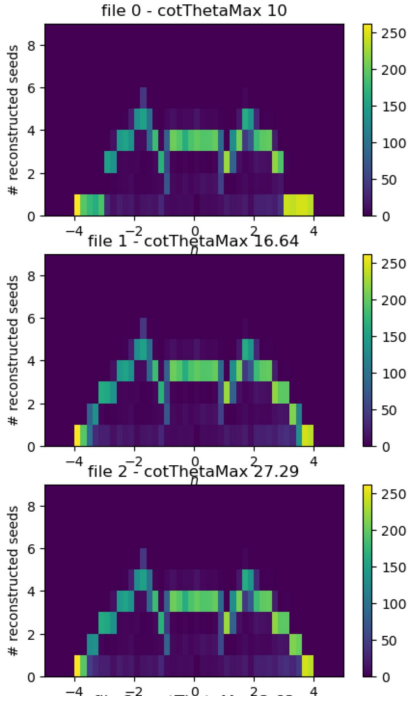
cotThetaMax (post-Bug)



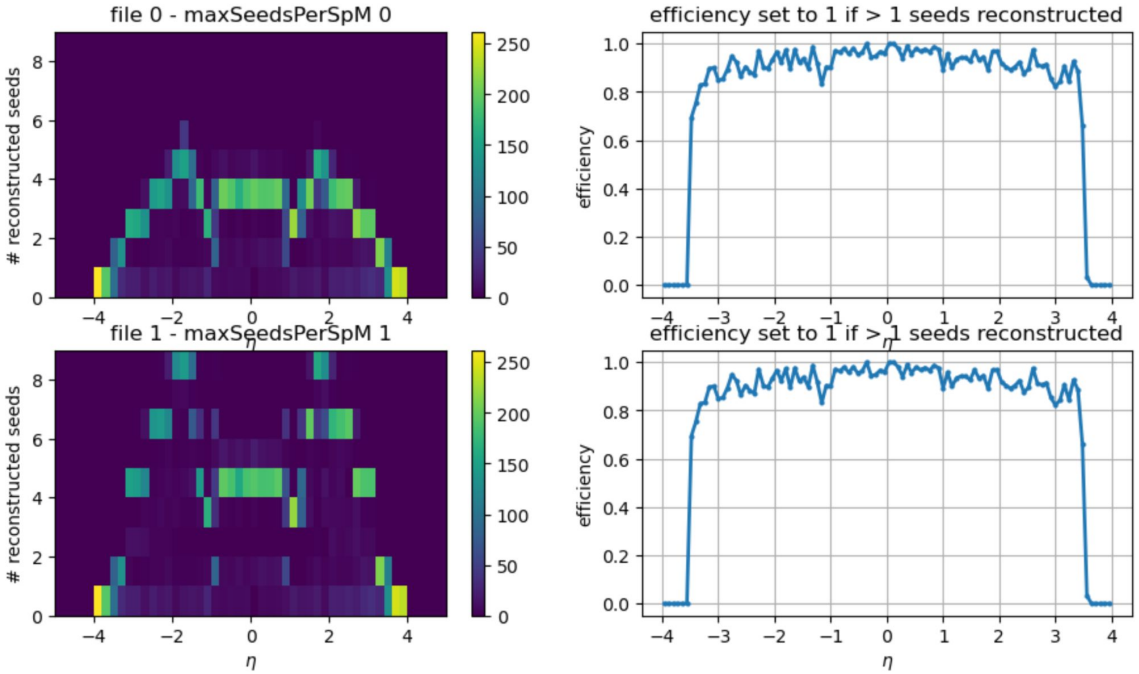
$\cot(\theta_{max})$	θ_{max} [°]	η_{max}
0.52	62.5	0.5
1.18	40.4	1
3.63	15.4	2
10.02	5.70	3
16.54	3.46	3.5
27.29	2.10	4

Cotangent of the maximum theta angle.

27.29 is best, but I am still working on trying to cover the entire eta regime (future work).



maxSeedsPerSpM (post-Bug)



The max number of seeds a single middle spacepoint can belong to (-1)

Efficiency is consistent, but the number of reconstructed seeds doubles after 0.

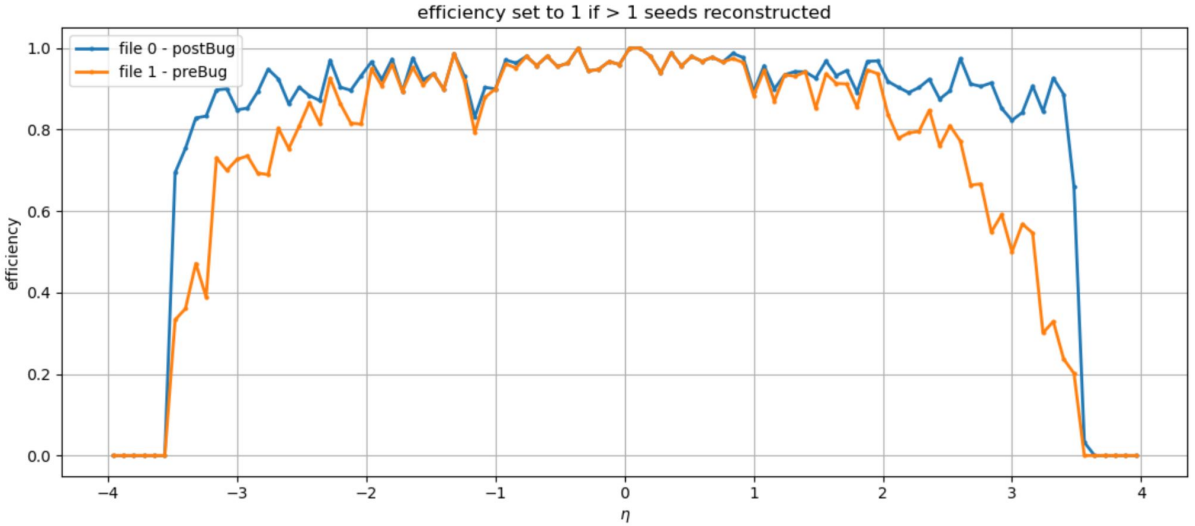
Updated Parameters

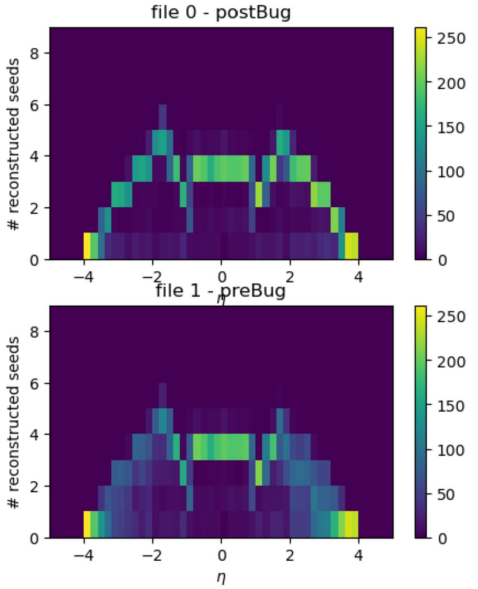
Parameter	Description	EICrecon default	Y.S. Lai's default	My New Default
bFieldInZ	z component of magnetic field	1.7 T	1.7 T	1.7 T
rMax	Maximum r value to look for seeds	500 mm	440 mm	440 mm
rMin	Minimum r value to look for seeds	33 mm	33 mm	33 mm
zMin	Minimum z value to look for seeds	-800 mm	-1500 mm	-1500 mm
zMax	Maximum z value to look for seeds	800 mm	1700 mm	1700 mm
beamPosX	Beam offset in x	0	0	0
beamPosY	Beam offset in y	0	0	0
deltaRMinTopSP	Min distance in r between middle and top SP in one seed	1 mm	50 mm	10 mm
deltaRMinBottomSP	Min distance in r between middle and bottom SP in one seed	1 mm	50 mm	10 mm
deltaRMaxTopSP	Max distance in r between middle and top SP in one seed	400 mm	220 mm	200 mm
deltaRMaxBottomSP	Max distance in r between middle and top SP in one seed	400 mm	220 mm	200 mm
collisionRegionMin	Min z for primary vertex	-300 mm	-250 mm	-250 mm
collisionRegionMax	Max z for primary vertex	300 mm	250 mm	250 mm
cotThetaMax	Cotangent of max theta angle	16	16.54	27.29
minPt	Min transverse momentum	100	100 MeV/cotThetaMax	100 MeV/cotThetaMax
maxSeedsPerSpM	Max number of seeds a single middle space point can belong to - 1	1	0	0
sigmaScattering	How many standard devs of scattering angles to consider	5	5	5
radLengthPerSeed	Average radiation lengths of material on the length of a seed	0.1	0.1	0.1 (mm)
impactMax	Max transverse PCA allowed	20 mm	3 mm	3 mm
rMinMiddle	Min R for middle space point	20 mm	—	-
rMaxMiddle	Max R for middle space point	400 mm	—	-
bFieldMin	min B field	—	0.1 T	0.1

Summary + Future Work

-Study produced an overall efficient setup! There are a few more parameters I can look at, especially after the recent units change in the pt calculation. But fixing the bug itself increased the efficiency by a ton.

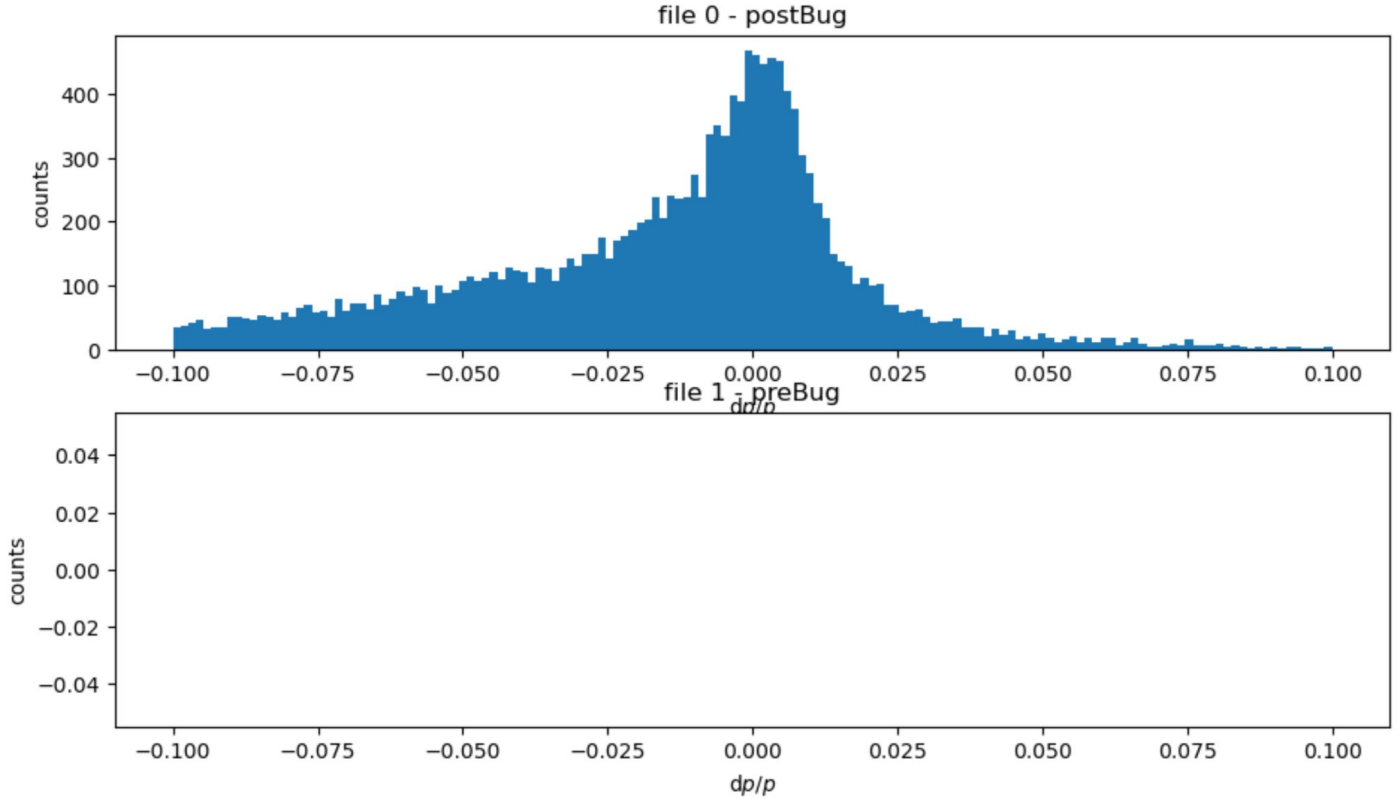
-Including other resolution plots like dΘ/Θ, dΦ/Φ.





backup

Momentum Resolutions in Greater Detail



Figuring Out the Units

Pt is calculated by equating lorentz and centripetal forces.

$$m\frac{v^2}{R} = q_e\,(v \times B) \longrightarrow p[GeV/c] = 0.3 * R[m] * B[T]$$

This is where pt is calculated in EICRecon - two bugs here!

```
97        float pt = 0.3 * R * (m_cfg.m_bFieldInZ * 1000) / 100.;
```

Overcompensating for a factor of 1000 and 0.3 (already included in acts)

constexpr double **Acts::UnitConstants::T** = 0.000299792458

$$\frac{0.3}{1000} = T \longrightarrow \frac{0.3}{1000} * \frac{1}{1000} = kT$$

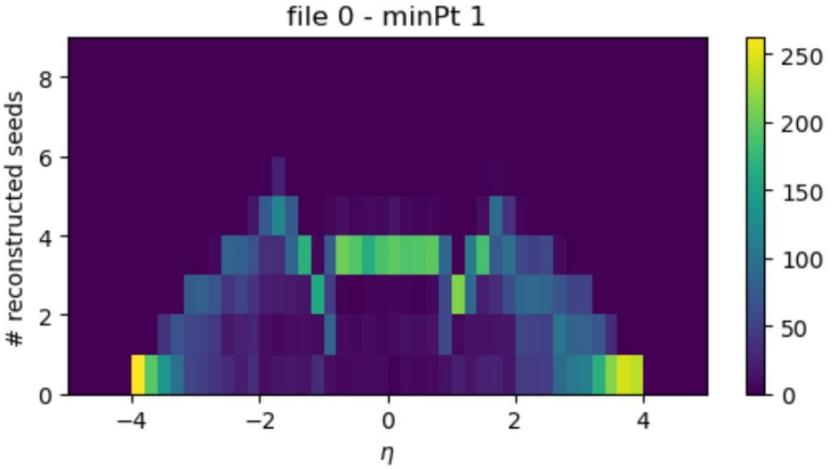
R is expected in cm (but acts default is mm)

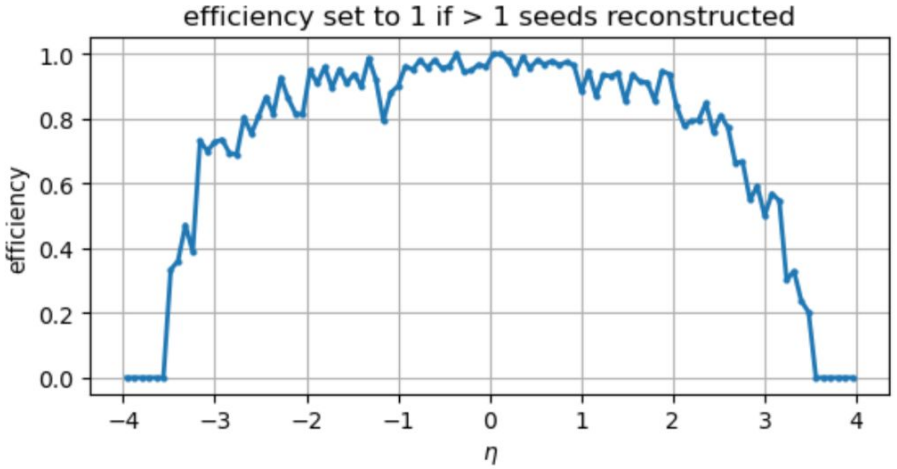
constexpr double **Acts::UnitConstants::mm** = 1.0

constexpr double **Acts::UnitConstants::GeV** = 1.0

So this pt definition is currently taking in R[cm] and B[kT]

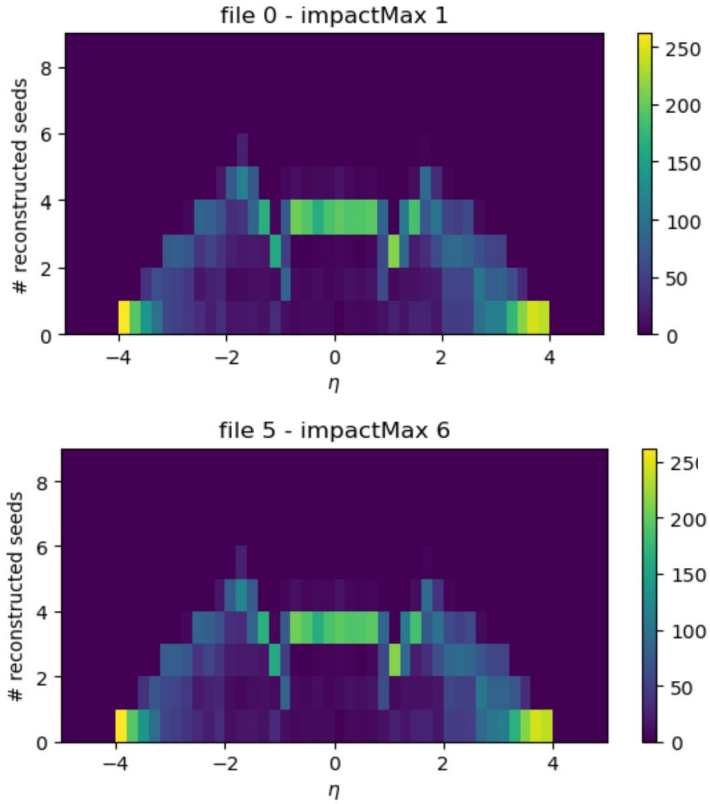
minPt

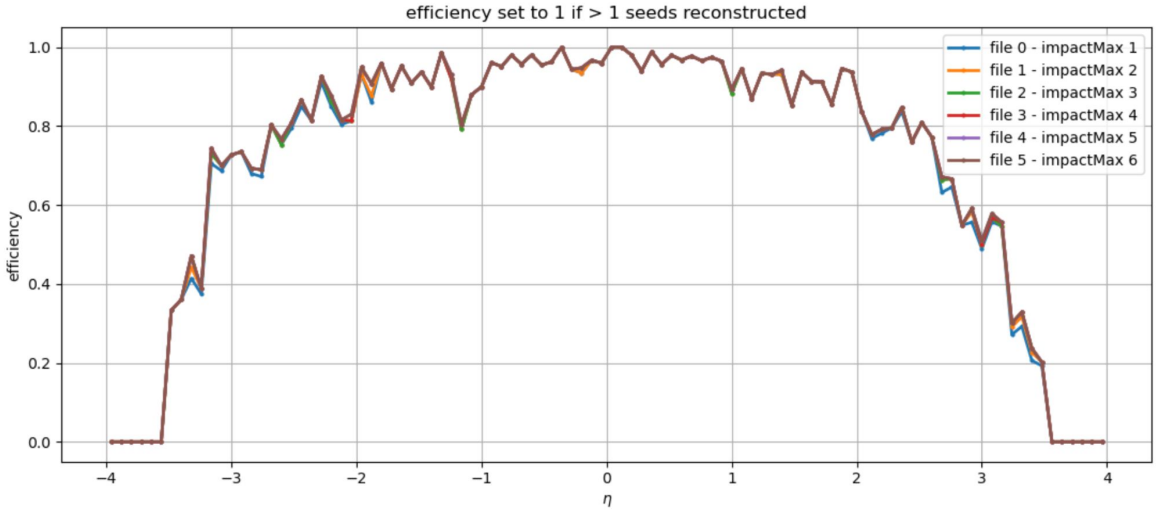




Parameter Values: 1,5,6,8,10 (default ==5). No effect on efficiency or #reconstructed seeds in the region varied, could increase values further move to backup

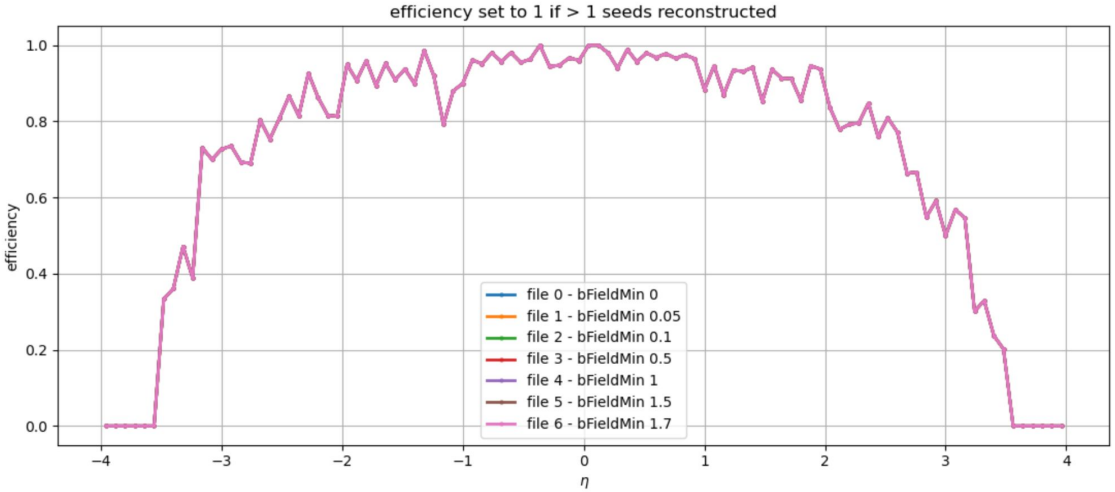
impactMax

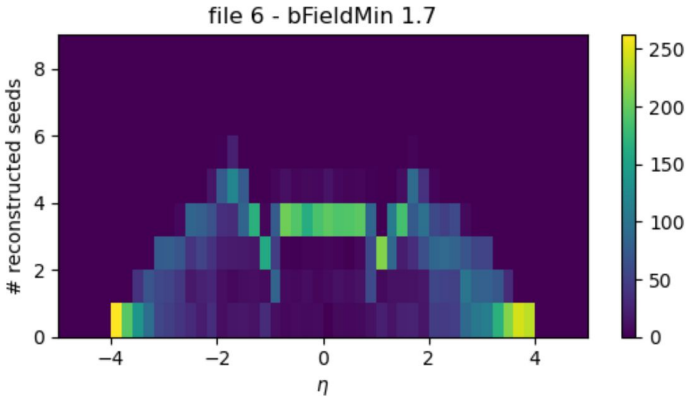




Values = 1,2,3,4,5,6. No notable differences in efficiency or #reconstructed seeds

bFieldMin

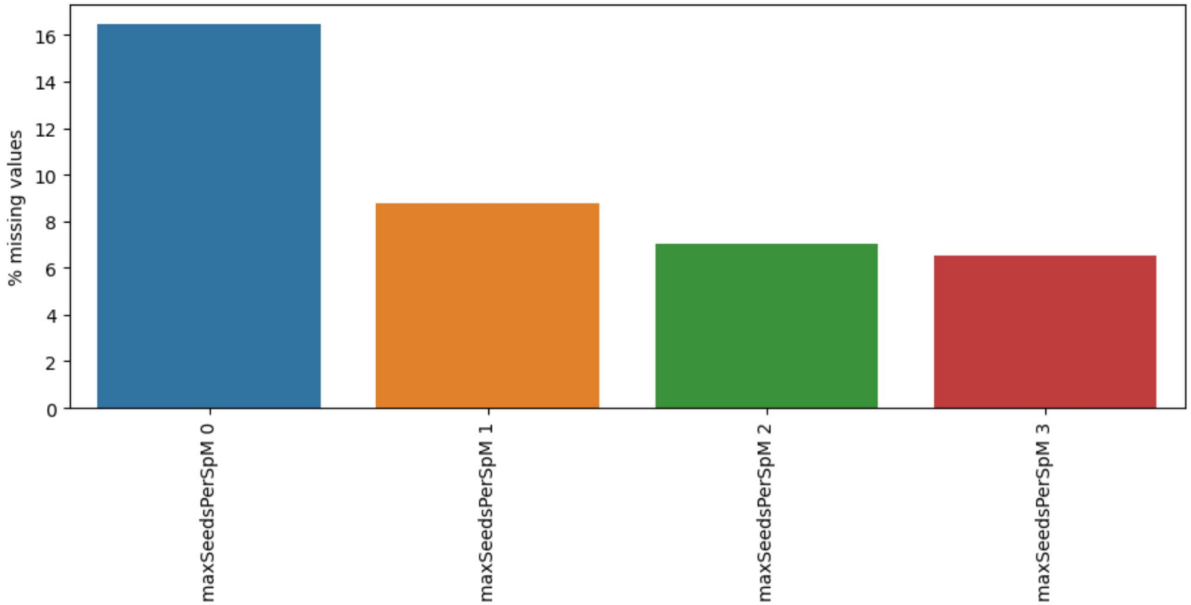




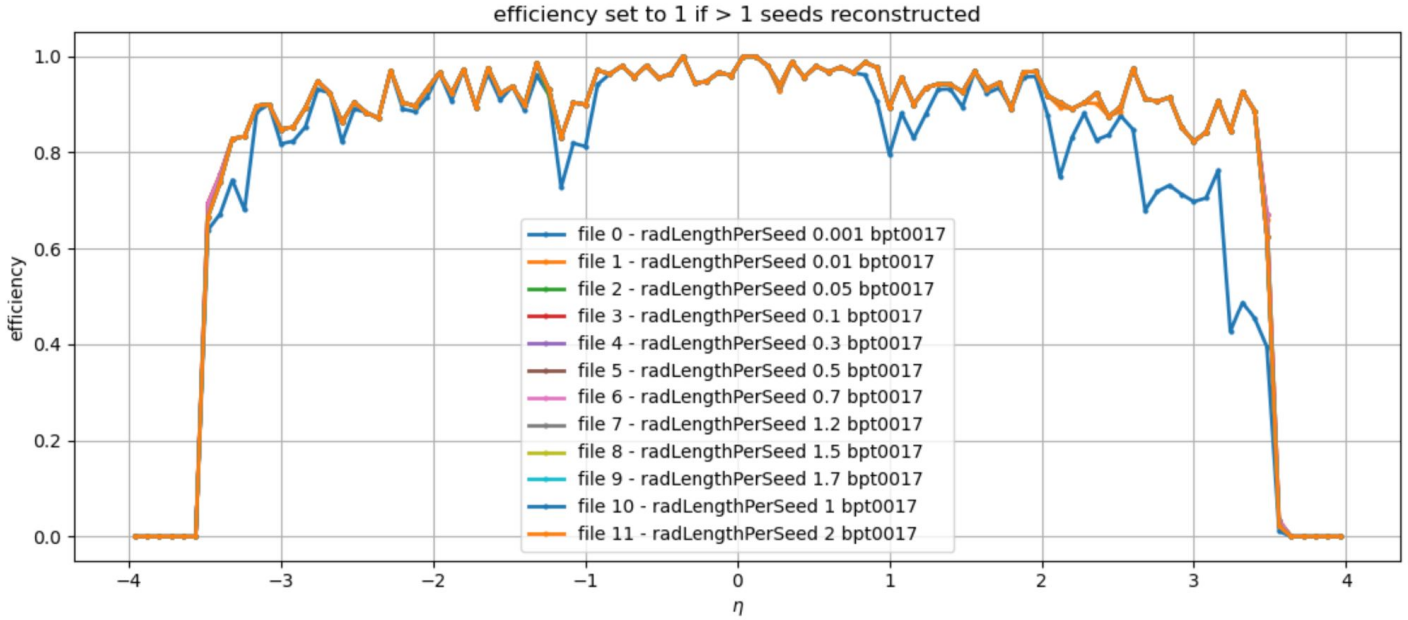
values=0,0.05,0.1,0.5,1,1.5,1.7 T … seemed to have no effect at all on efficiency or reconstructed seeds.

Number of Missing Values

Number of missing values - **the number of non-null entries in the generated branches can be larger than that in the reconstructed ones. These are cases in which no seed was reconstructed. Let's visualize this as the percentage of missing values**

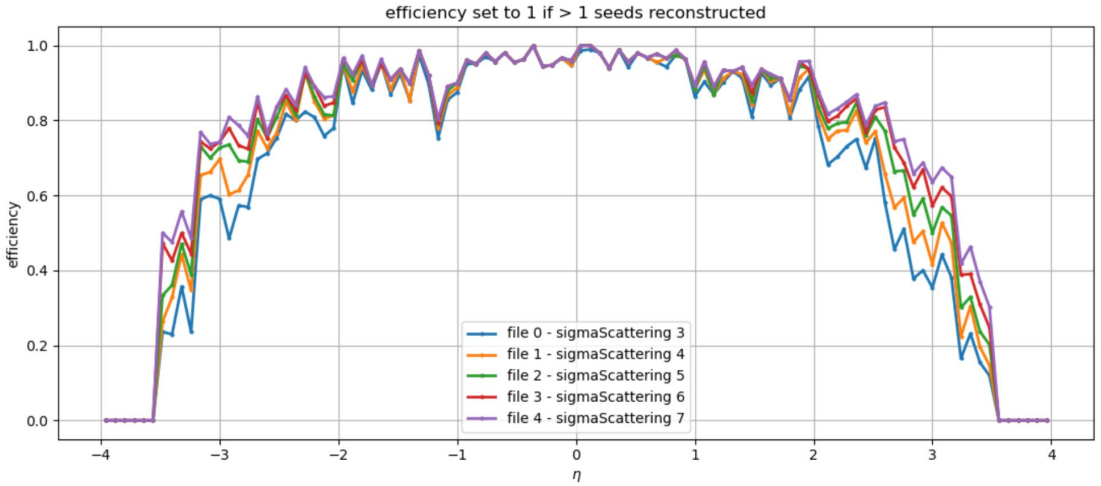


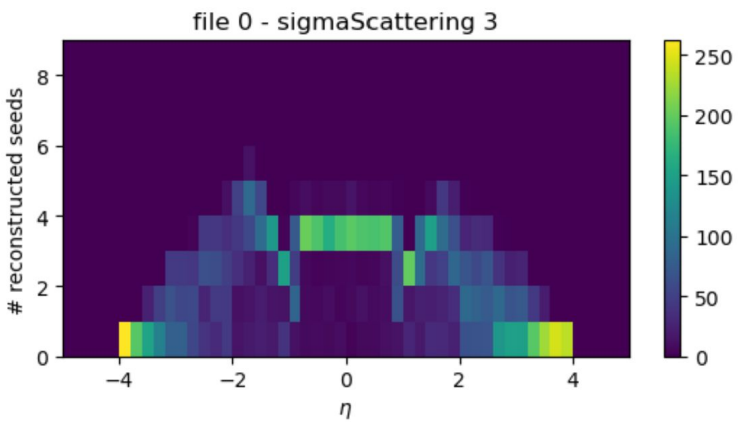
Varying rad length per seed after bField change



sigmaScattering

Old Plots





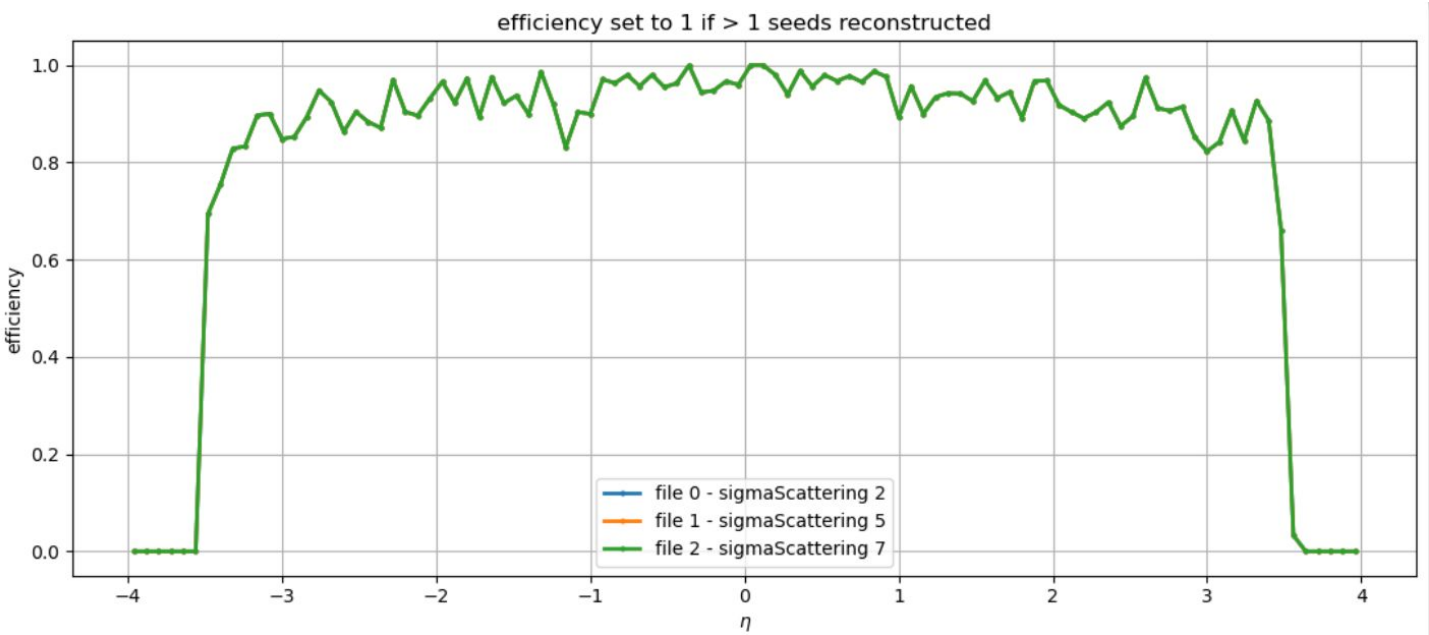
How many standard deviations in scattering angle are considered?

Overall we see that efficiency increases with increasing Sigma, with no effect on the number of reconstructed seeds.

This is important to keep in mind once a standard deviation is chosen for the detector later, that I have just kept my default at 5σ. Efficiency will decrease if a smaller σ is chosen.

sigmaScattering

No longer influences efficiency much post-Bug



radLengthPerSeed (post-Bug)