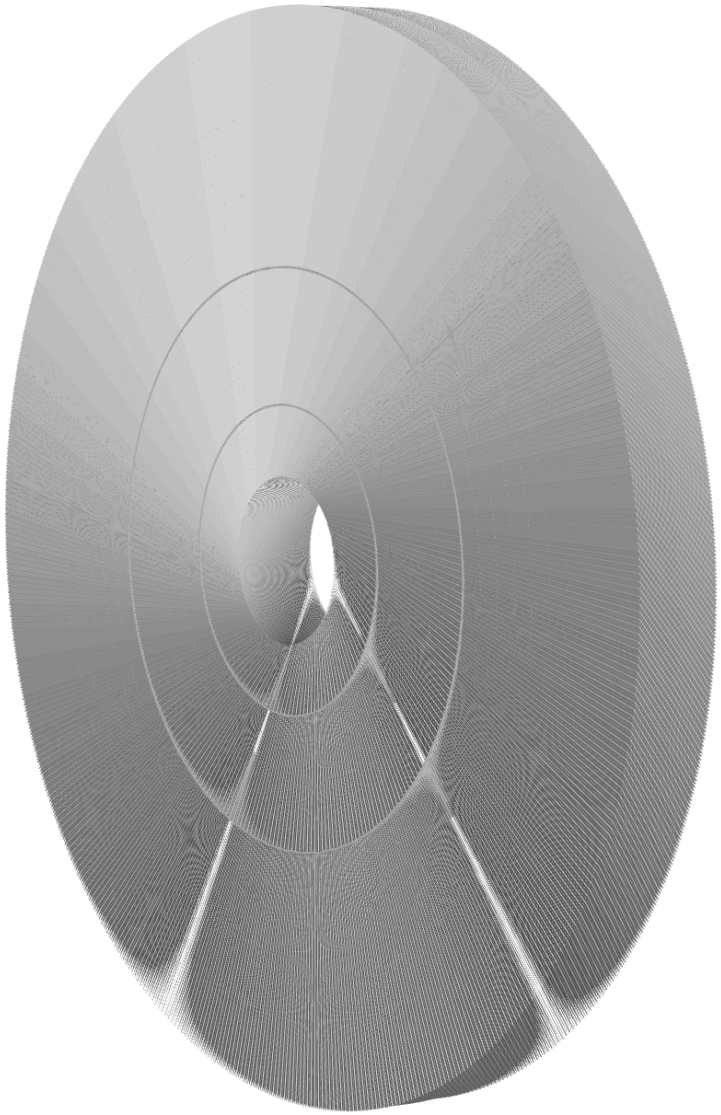
Status of "Turbine" Endcap EM Calorimeter in Full ALLEGRO Simulation

E. Varnes, J. Rutherfoord, R. Walker
University of Arizona
October 16, 2024

Reminder of Previous Status (~July)

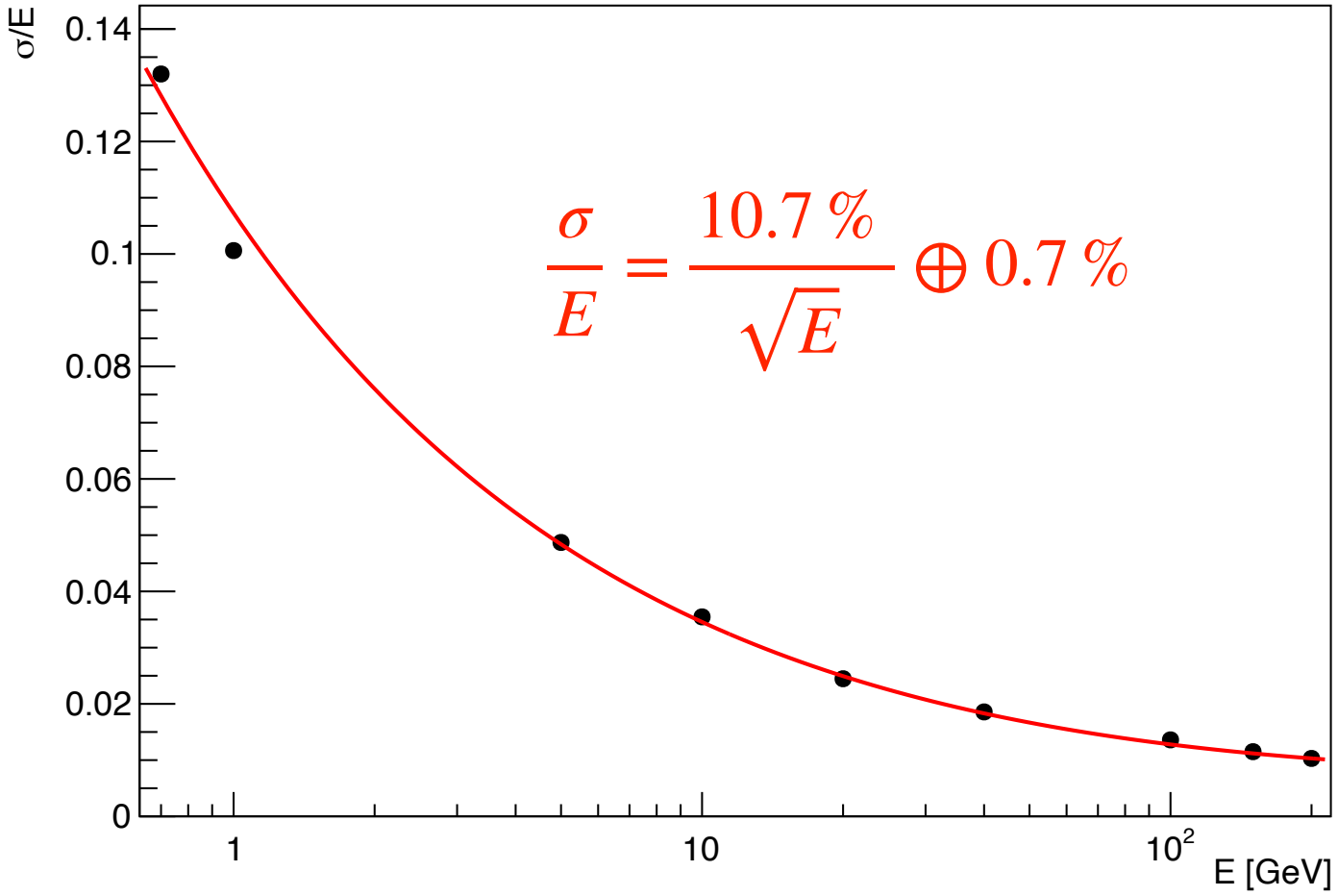
- Implemented initial pass of “turbine” geometry in k4geo and k4RecCalorimeter:

- Separated into three wheels
- Limited flexibility in the parameters
  - e.g. the angle of the blades required to be the same for all three wheels
- Sliding-window cluster reconstruction algorithm implemented



Performance

- Single electrons:



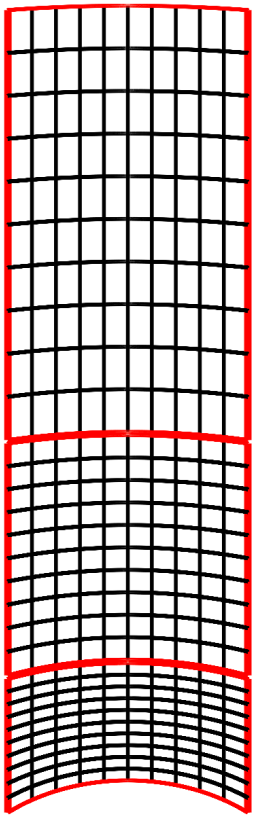
Caveats

- In addition to the limited flexibility, the detector segmentation (and associated translation from cellID to physical location) was a bit clunky/redundant:

```
system:4,cryo:1,type:3,subtype:3,side:-2,wheel:3,layer:8,module:17,rho:8,z:8
```

represents physical detector element (i.e. for hit collection or calibration)

represents logical detector element (for cell positioning)



Face-on view of readout electrode

Cells in an “arc” could be represented by layer or rho index

Implementation Version 2

- The lack of flexibility and sub-optimal segmentation have both been addressed in version 2 of the geometry
- Revised segmentation:

```
system:4,cryo:1,type:3,subtype:3,side:-2,wheel:3,layer:8,module:11,z:8
```

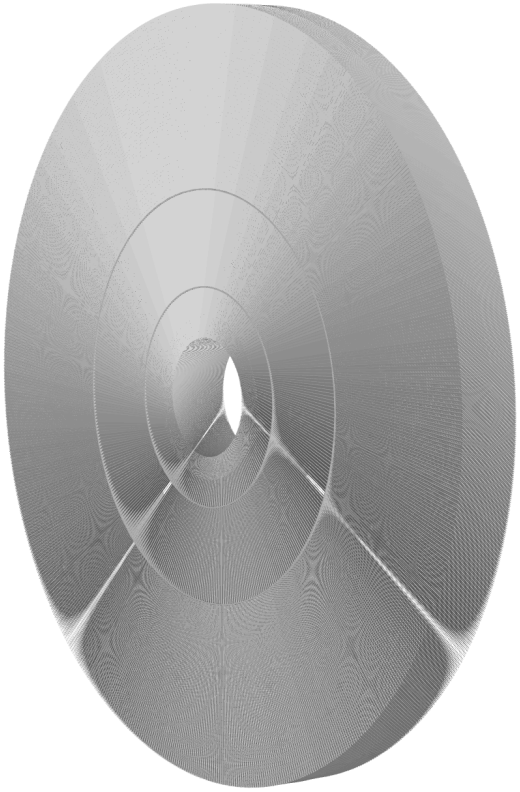
- No more “rho” field
  - position of “layer” physical element used in setting the cell position
- Also increased the number of calibration layers from 10 per wheel to 50 per wheel

Optimizing the geometry

- As before, a parameterized tool is used to select promising configurations
  - this adjusts parameters so that the sampling fraction is maximized, subject to some constraints:
    - minimum depth of 22 X_o
    - at least 15 absorbers crossed
    - variation in LAr gap width across z < 25%
    - number of absorbers in each wheel is a multiple of 16

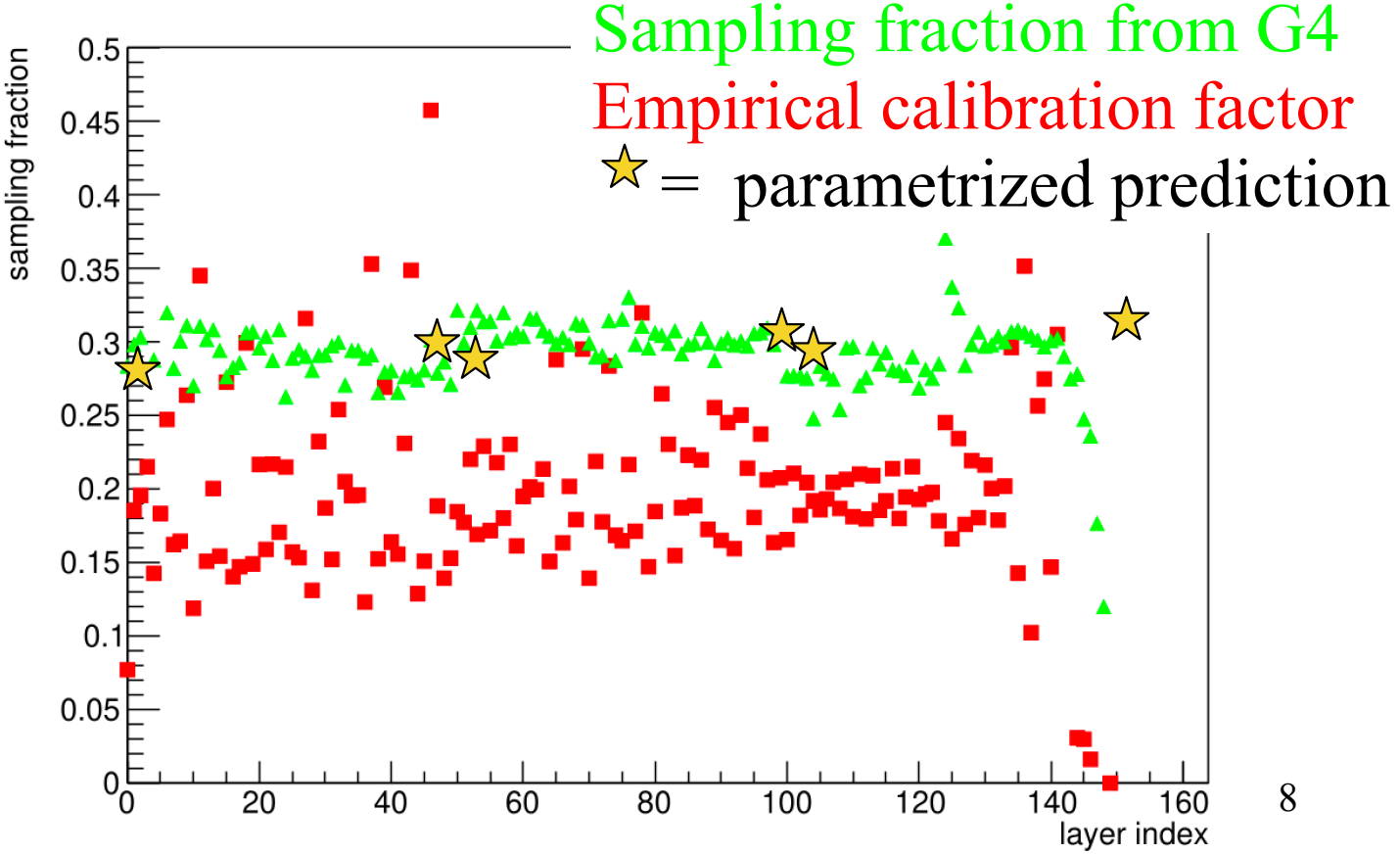
Optimization Result

Wheel	Blade Angle degrees	Blade width mm	Number of unit cells	Readout Board thick mm	Radius mm	Unit Cell Separation mm	No. of Samples	LAr Gap Mid mm	LAr Gap Front mm	Absorber thickness mm	Module thickness X0	MIP Sampling fraction
Wheel 0	44.0	648	160	1.3000	420	11.4573	29.9497	3.7286	3.0158	2.7000	22.30	0.2800
					786	21.4342	15.3327	7.4240	7.0669	5.2863	22.40	0.3031
Wheel 1	27.0	991	160	1.3000	796	14.1865	29.9615	4.7933	3.9059	3.3000	22.09	0.2941
					1489	26.5402	15.3382	9.3896	8.9451	6.4610	22.17	0.3123
Wheel 2	20.0	1316	208	1.3000	1499	15.4836	28.1508	5.2418	4.7337	3.7000	22.06	0.2972
					2750	28.4119	15.0115	10.0068	9.7388	7.0983	22.54	0.3080

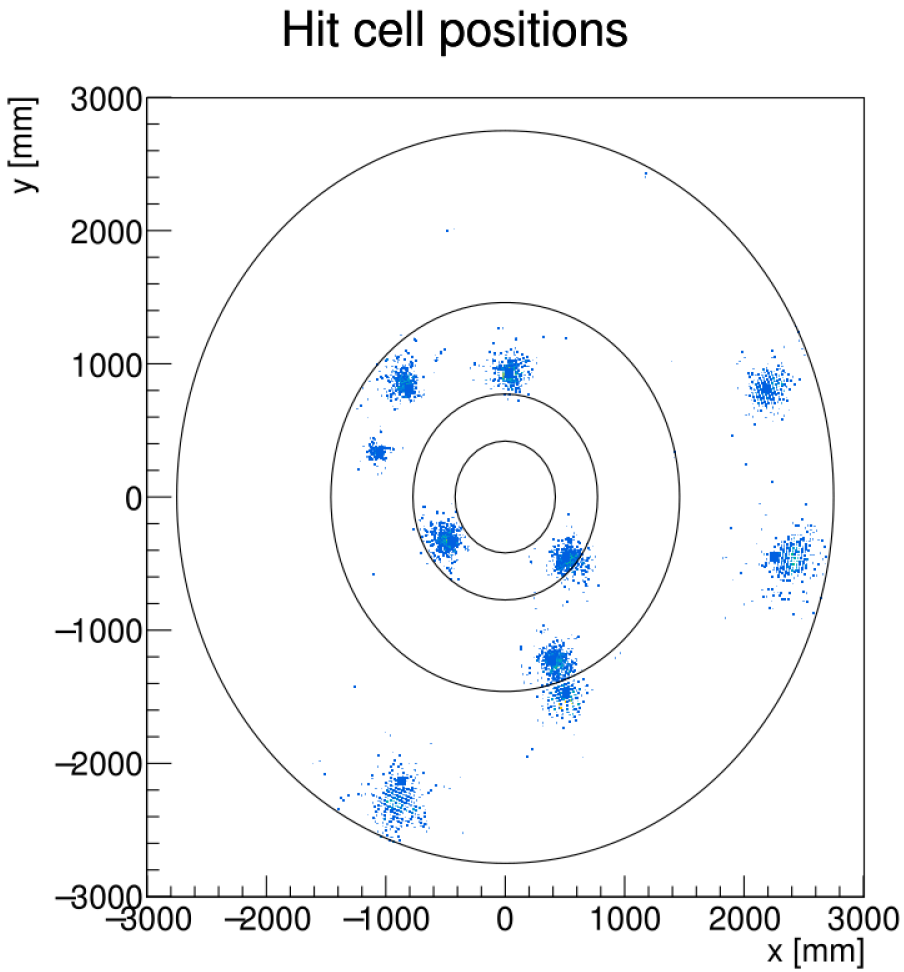


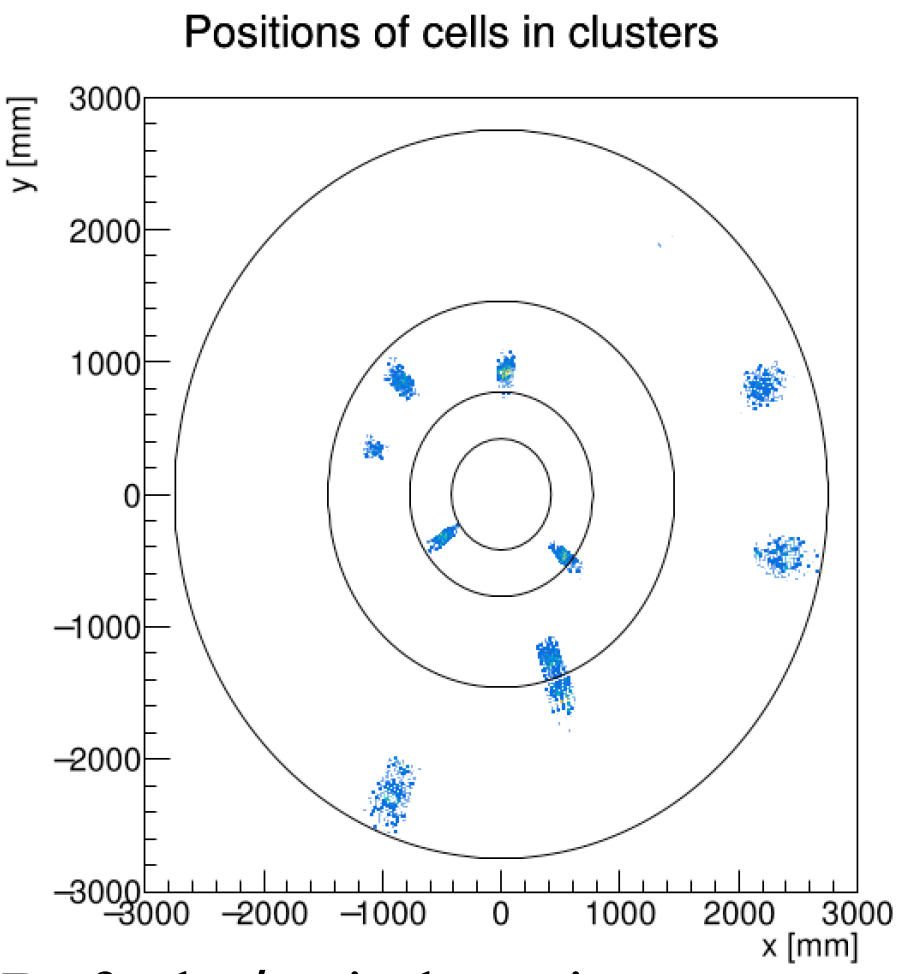
Sampling Fraction

- Sampling fraction estimated in two ways:
  - directly from G4 (fraction of energy deposited in LAr vs (LAr + absorber+glue+cladding+electrode)
  - empirically to bring clusters to the correct energy on average
- Results are substantially different:



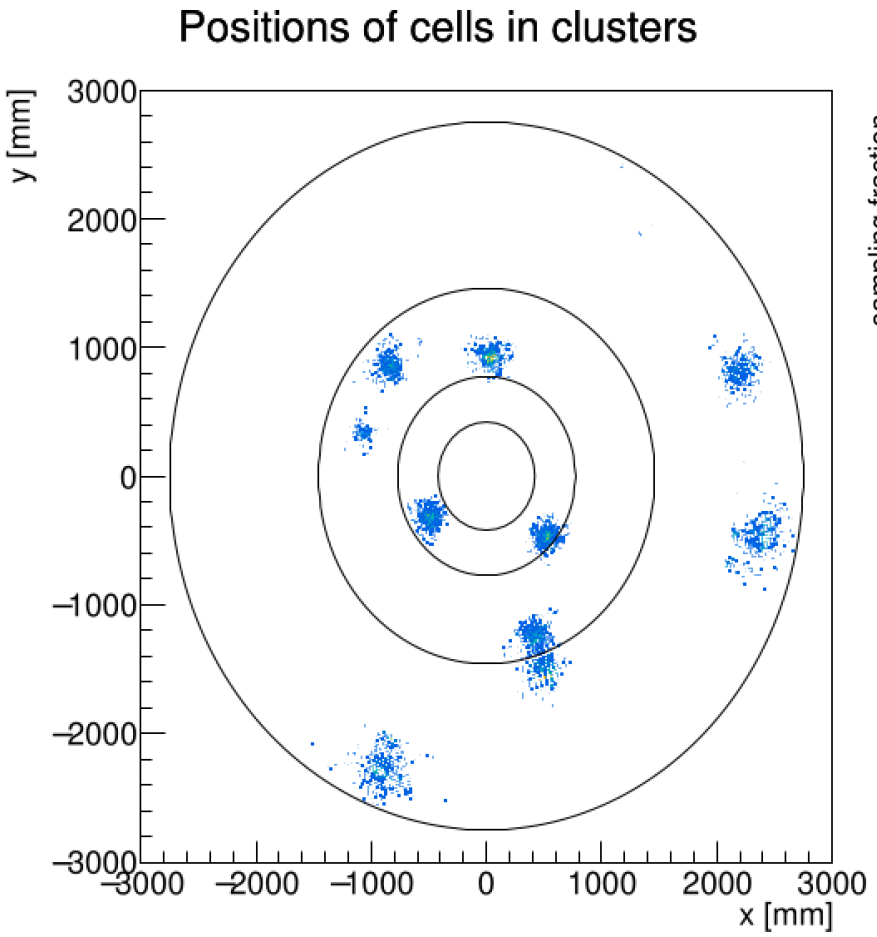
- Initial guess: may be related to non-optimal clustering:



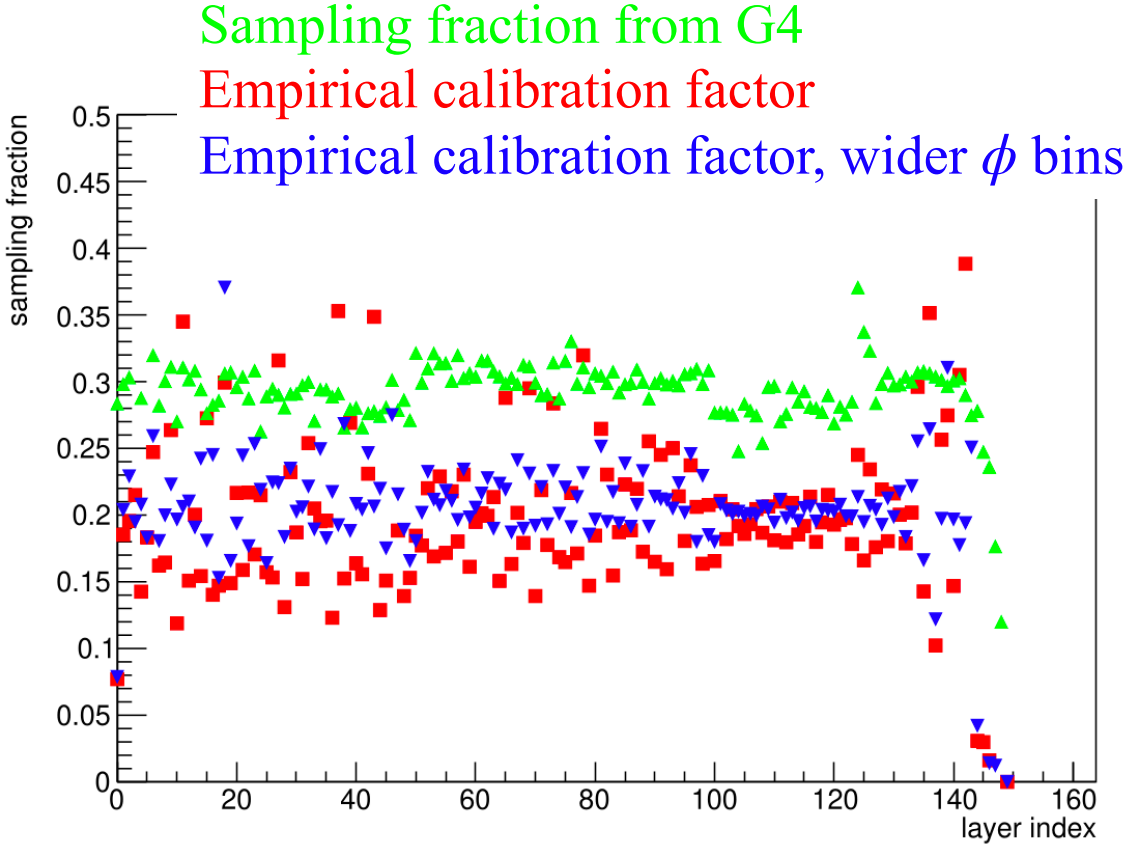


Default ϕ window size too small, especially at inner radii

- Increase the phi window size by a factor of 4:



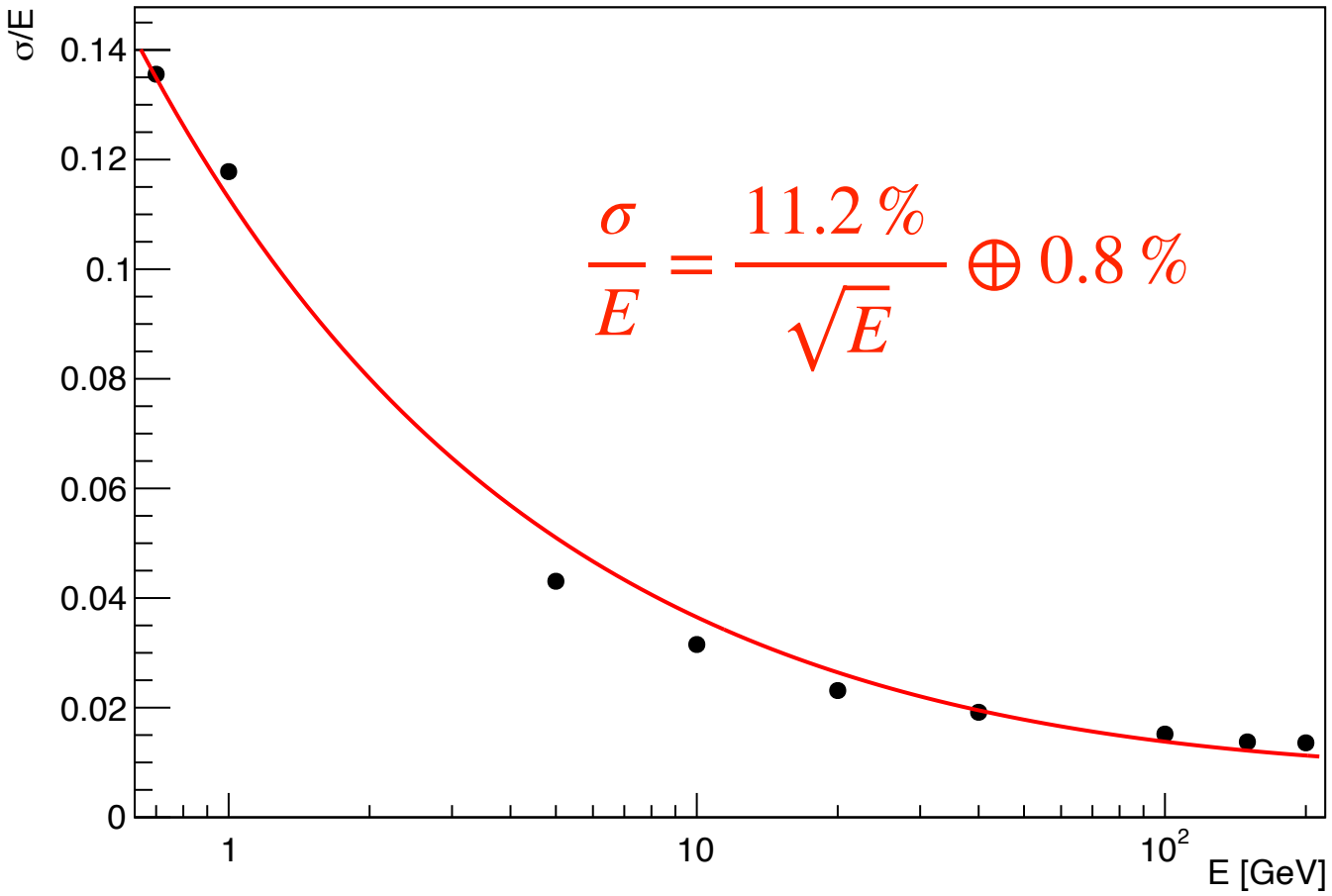
Looks better!



But does not explain most of the effect

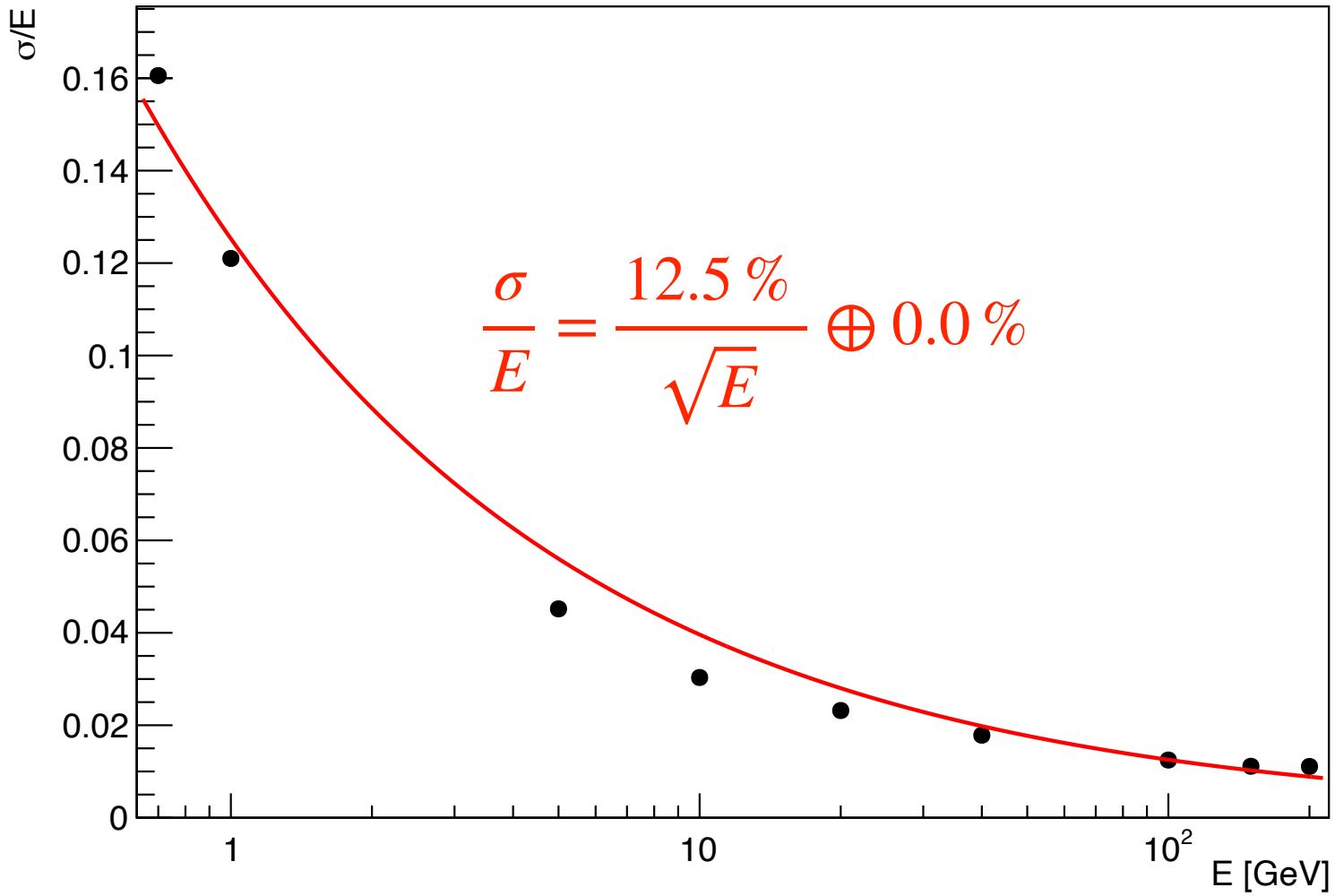
Performance of re-Optimized Turbine

- Single electrons:

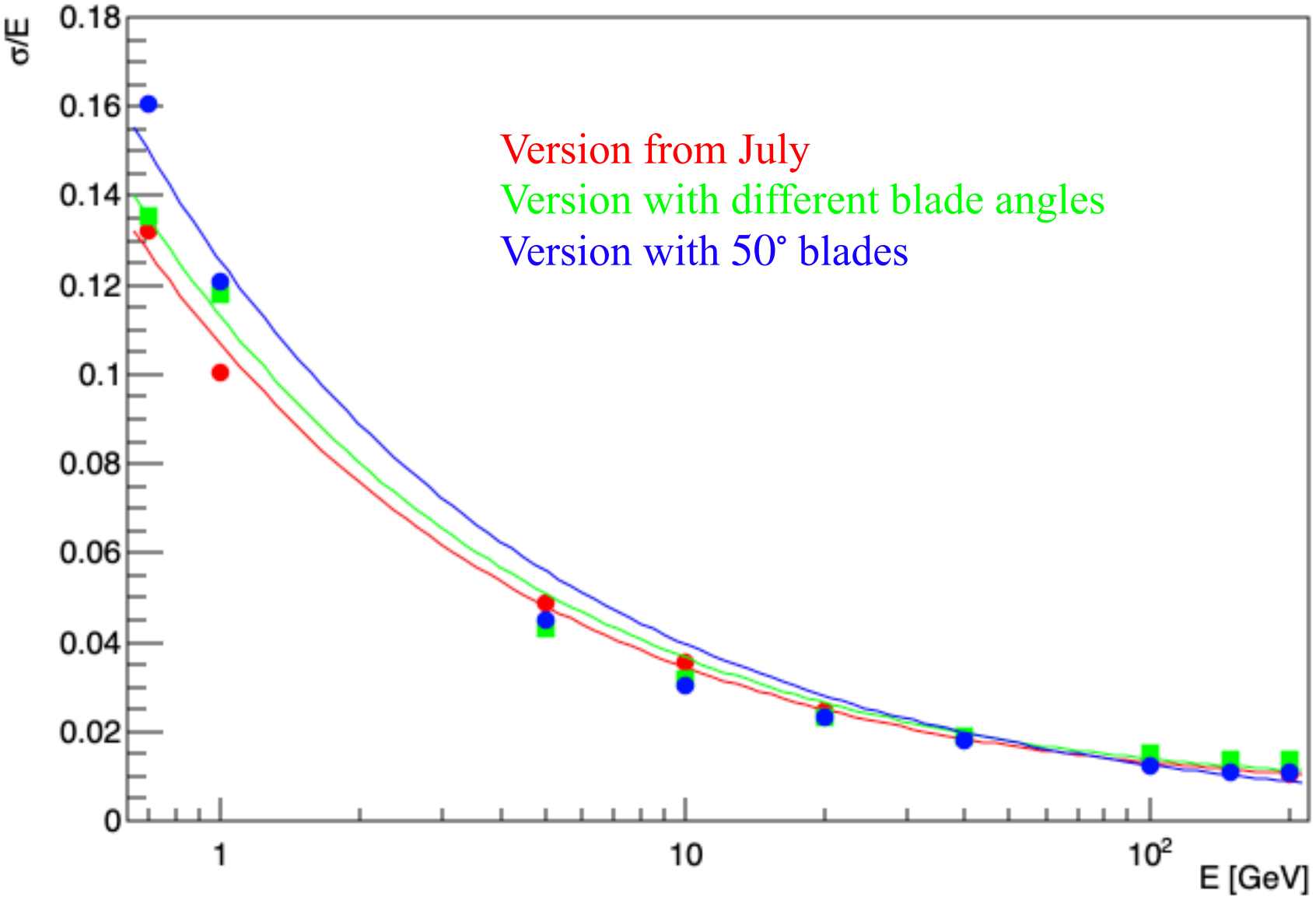


  - a little worse than the previous version
    - and values don't fit the function as well…

- Parametrized optimization tends to favor blades that are as perpendicular to the beam direction as possible
  - maybe there are details that make this incorrect?
- Try fixing the blade angles to ~50°:



- Comparison of all three designs:



Next Steps

- Continue to investigate difference between “first-principles” and “empirical” sampling fractions
- Implement topological clustering
  - to avoid the problem with ϕ window size
  - should be straightforward with the new segmentation
- Continue exploration of geometry parameters