Resolution of the CLAS12 Reconstruction Software

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Overview

- Aim is to measure in simulation the resolution of the reconstruction software and provide benchmarks for software and hardware developers.
- Investigated effects of particle energy, species, torus polarity, and upgrades to *gemc*.
- Resolutions obtained by swimming particle tracks using their simulated and reconstructed track parameters and then comparing the results in the CLAS12 subsystems.

Method

1. Start from the simulated and reconstructed vertex state vector of each event from MC::Particle and REC::Particle banks.
2. The two sets of vertex positions and initial momenta are rotated to the tilted sector coordinate system (TSCS).
3. The two tracks are swum from their vertex. Track points are collected at the surfaces of subsystems: HTCC, DCs R1, R2, R3, the FTOF, and the ECAL.
4. Differences $\Delta x, \Delta y, \Delta z, \Delta\theta, \Delta\varphi, b$ are obtained in CLAS12 lab coordinates, the distance between points on the detector surfaces ($\sqrt{\Delta x^2 + \Delta y^2}$) is obtained in the TSCS.
5. Widths of the histograms of $\Delta x, \Delta y, \Delta z, \Delta\theta, \Delta\varphi, b$ give the reconstruction resolution.

Additional details on Swimming

- HTCC swimmer swims in Lab coordinates (not TSCS), stops at fixed radial distance away from the origin (175 cm) and uses a fixed integration step size.
- DC, FTOF and ECAL swimmers swim in tilted sector coordinate system using the sectorSwim() method to a fixed distance along z axis in the tilted frame, use an adaptive step size.
- Layers where swimming terminates match the points stored in the REC::Traj bank for each track.
- DC swimmer swims to each region: superlayers 1, 2, 3, 5, sixth layer of wires in each of the superlayers.
- FTOF swimmer swims to Panel 1a.
- ECAL swimmer swims to fourth layer of the ECal inner detector.

Histogram Fitting

- Some of the distributions of differences have tails with a narrow peak that the Gaussian fitter struggled to fit (most fits had reduced χ > 2).
- To guide the fitting we first fit the full distribution to locate the central peak. Then we performed a second fit in the range $\mu \pm 1.5\,\sigma$ and starting with the parameters of the first fit. Did a second iteration of this step.
- The effective variance can be calculated from the fit parameters.

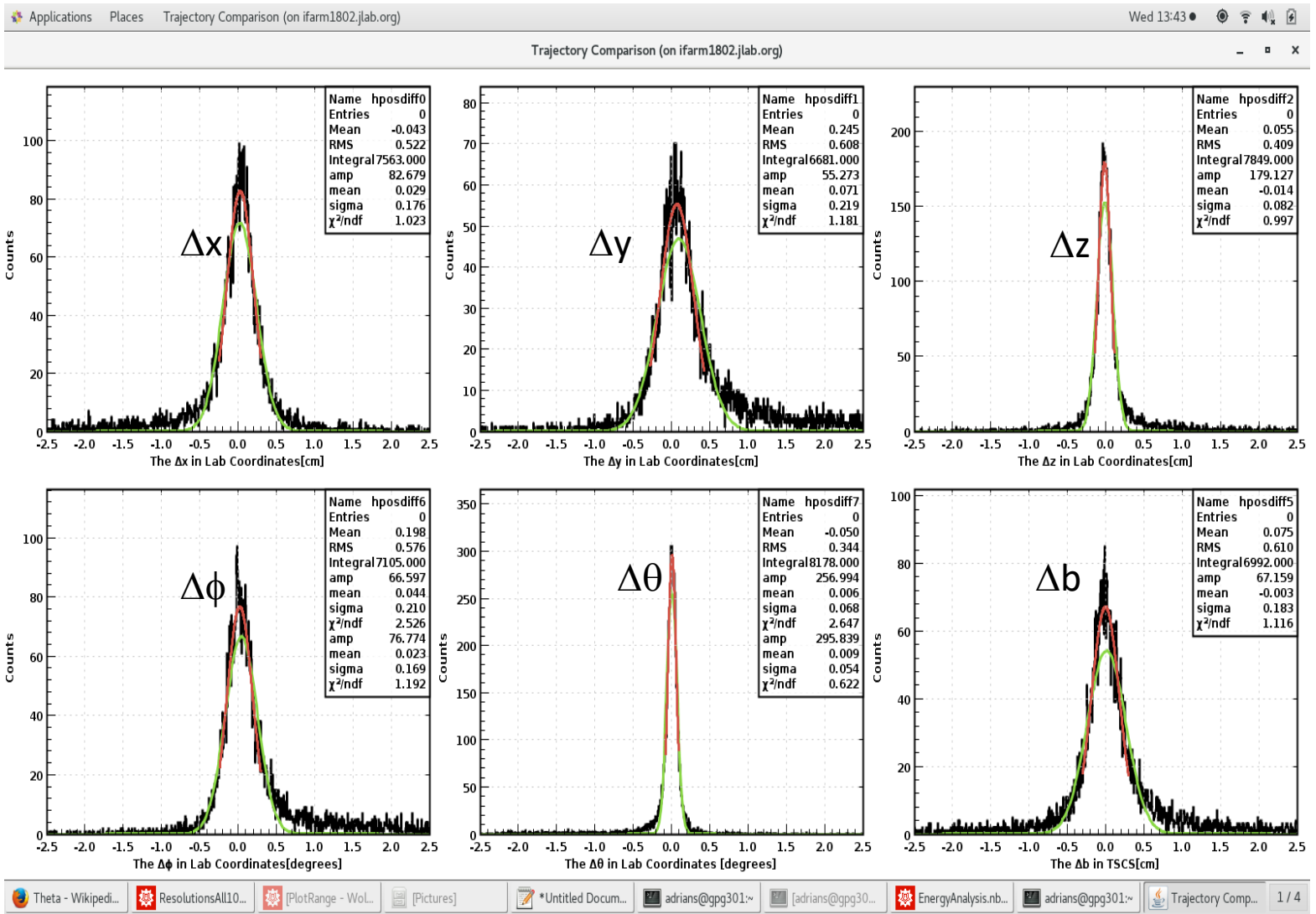
$$\sigma_\delta^2 = \langle \delta^2 \rangle - \langle \delta \rangle^2$$

$$\langle \delta^2 \rangle = \frac{A_0}{A_0 + A_2} \left(\mu_0^2 + \sigma_0^2 \right) + \frac{A_2}{A_0 + A_2} \left(\mu_2^2 + \sigma_2^2 \right)$$

$$\langle \delta \rangle = \frac{A_0}{A_0 + A_2} \mu_0 + \frac{A_2}{A_0 + A_2} \mu_2 \quad .$$

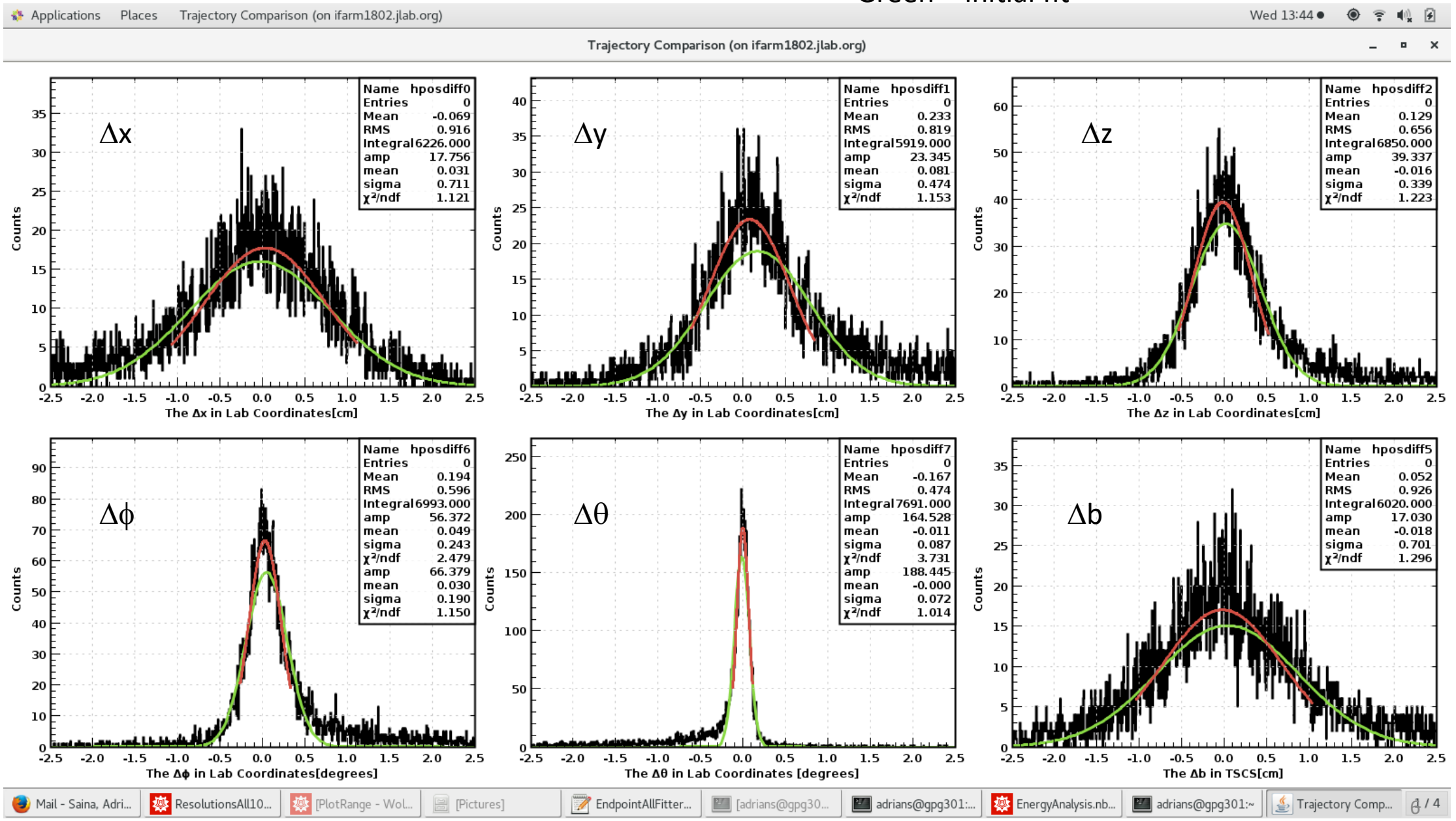
- The uncertainties in the resolutions were obtained as uncertainties in the standard deviation: $\Delta\sigma = \frac{\sigma}{\sqrt{2N-2}}$

- Plots below show the differences at track points for a 6 GeV e^- beam in the range $-30 < \varphi < 30$ and $5 < \theta < 35$.
- Fits to the entire distribution are green, the central peak fits are red.
- Distributions are centered close to zero in all observ-ables.

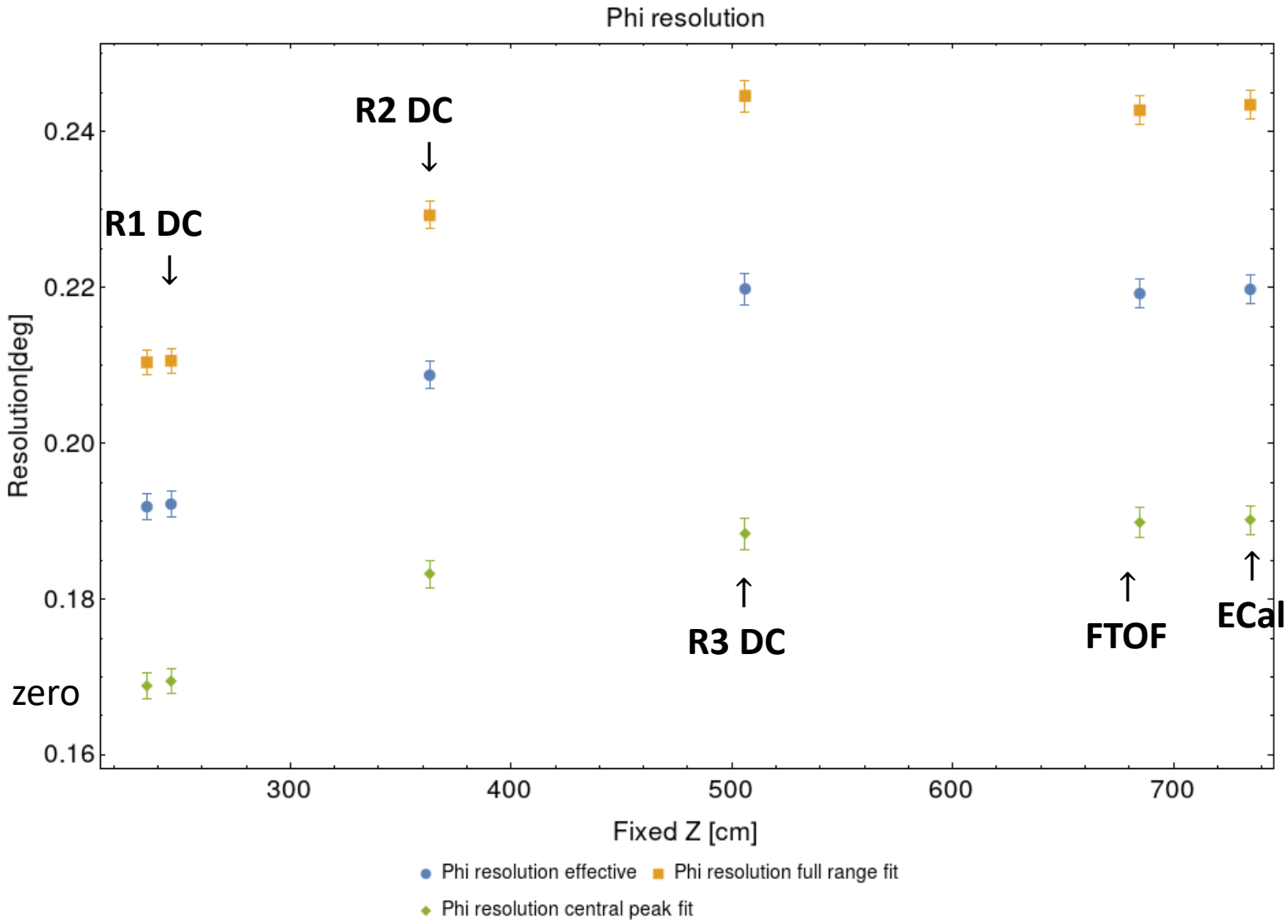


The effective fits- ECAL

Red – final fit
Green – initial fit



Effects of fitting procedure- ϕ resolution as a function of the z axis distance of track point in TSCS



Full range fits

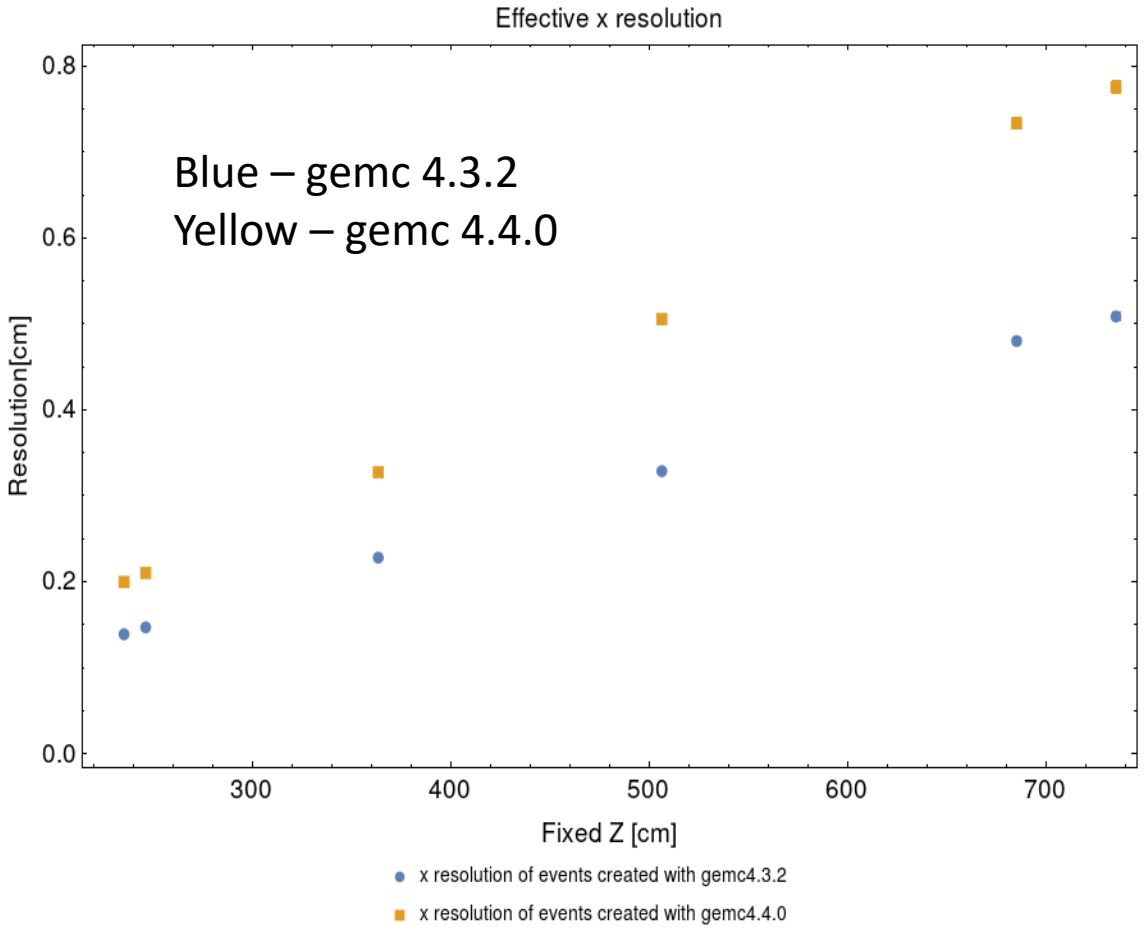
effective

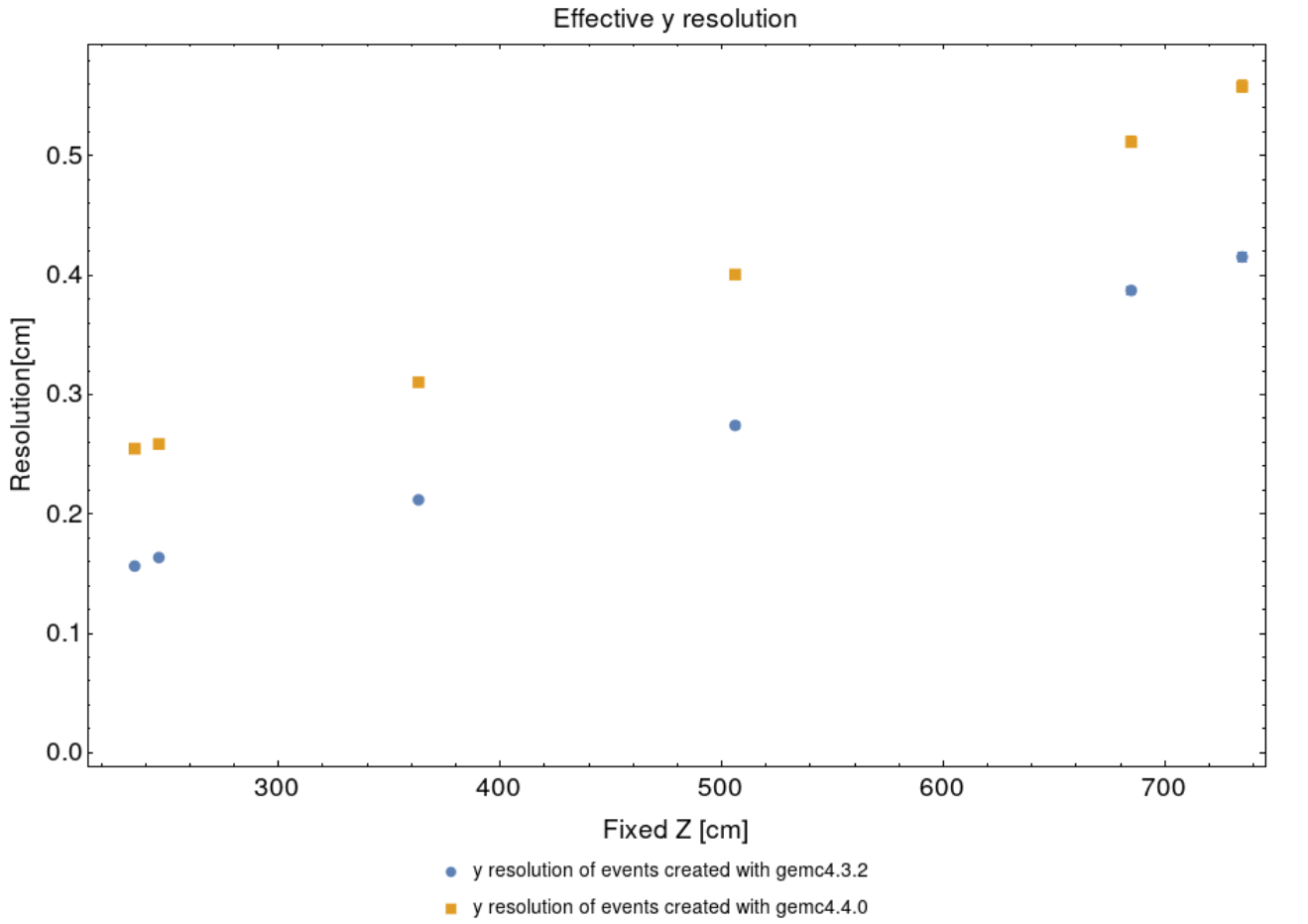
Central peak fits

Note suppressed zero on y-axis →

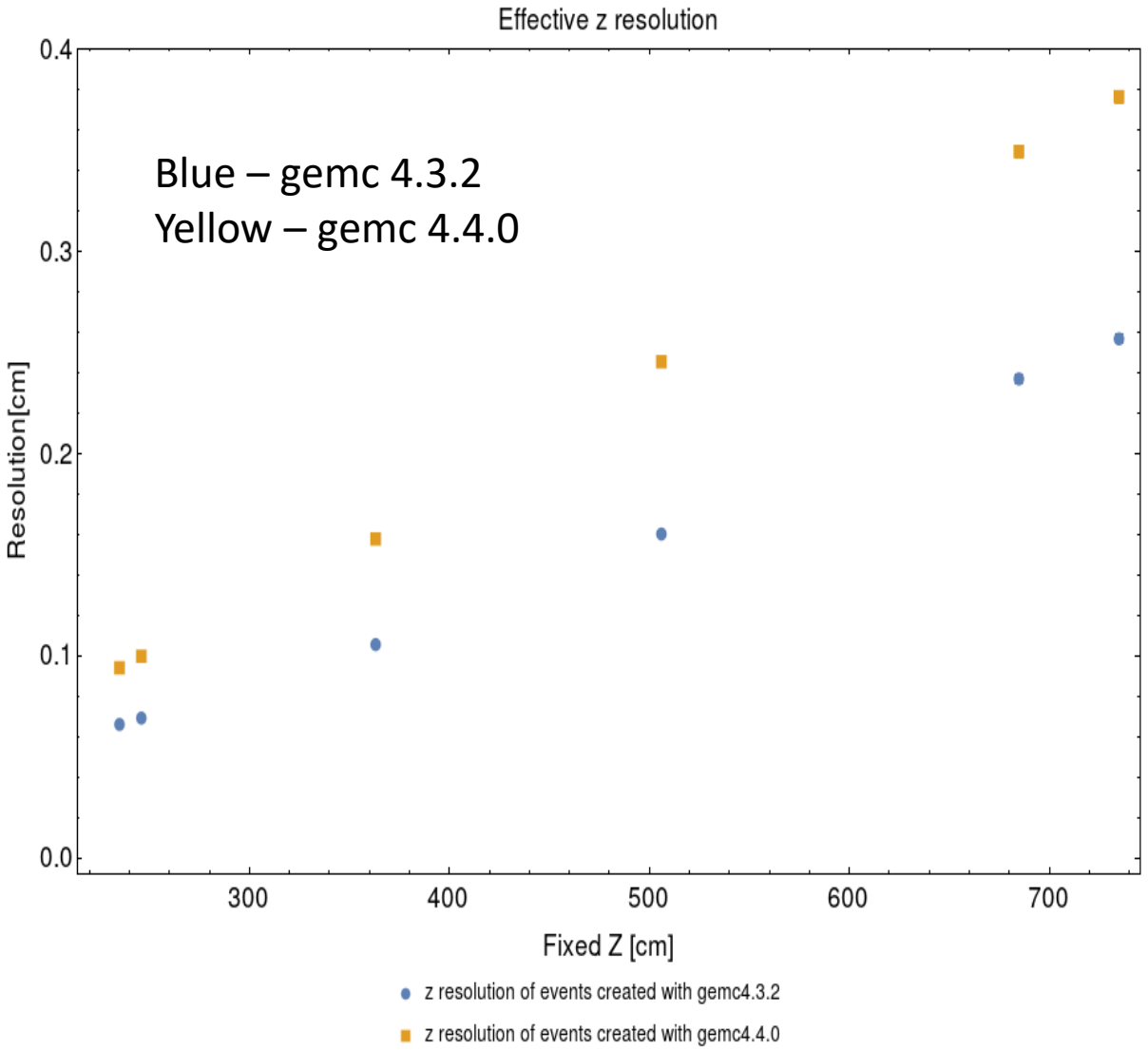
Effects of new version of GEMC on resolution

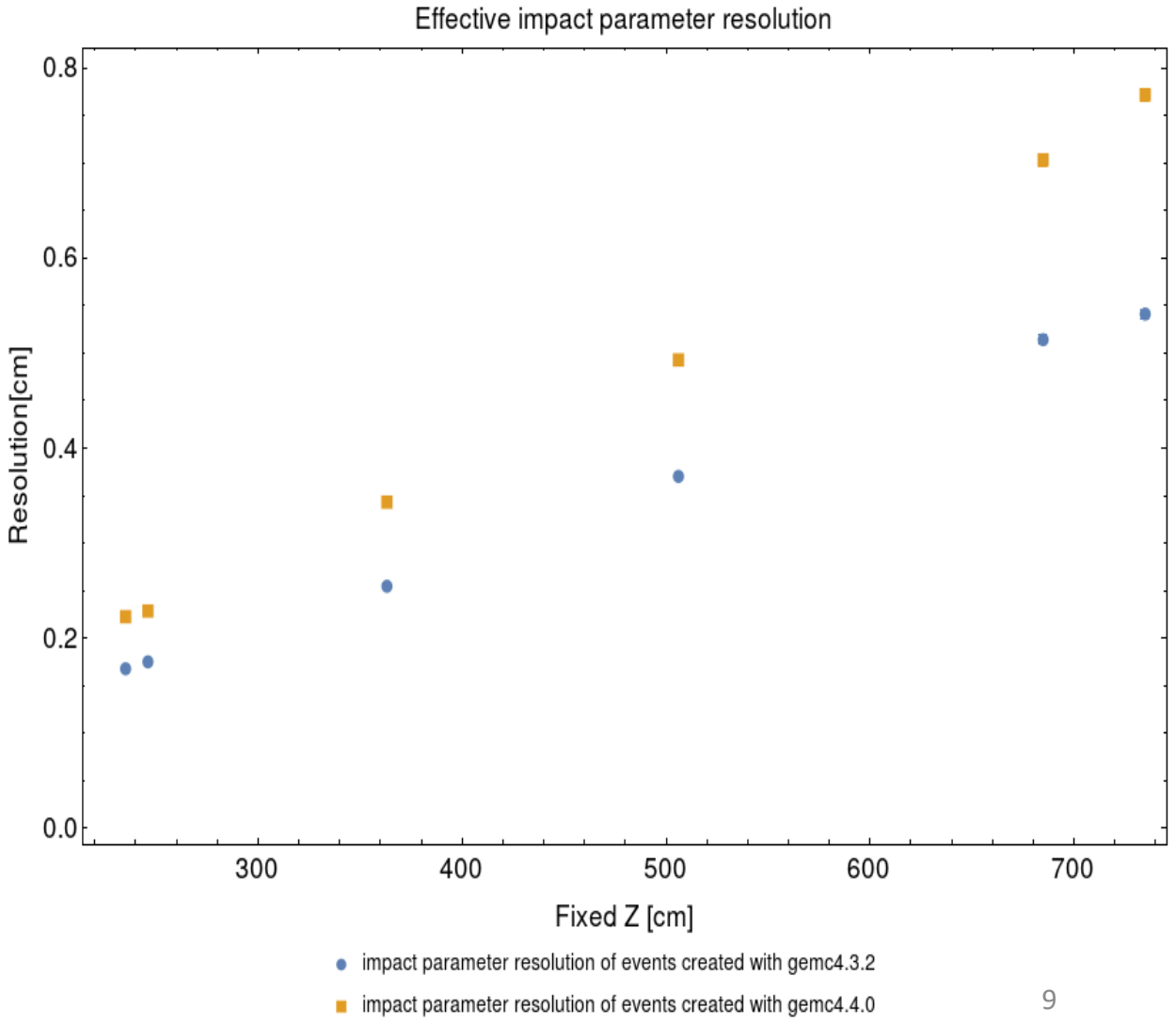
- New version of GEMC (4.4.0) introduced changes to digitizations to make them more realistic – this effected the resolutions significantly
- Plots here compare the Δx and Δy resolutions with events made with the previous version of GEMC, 4.3.2



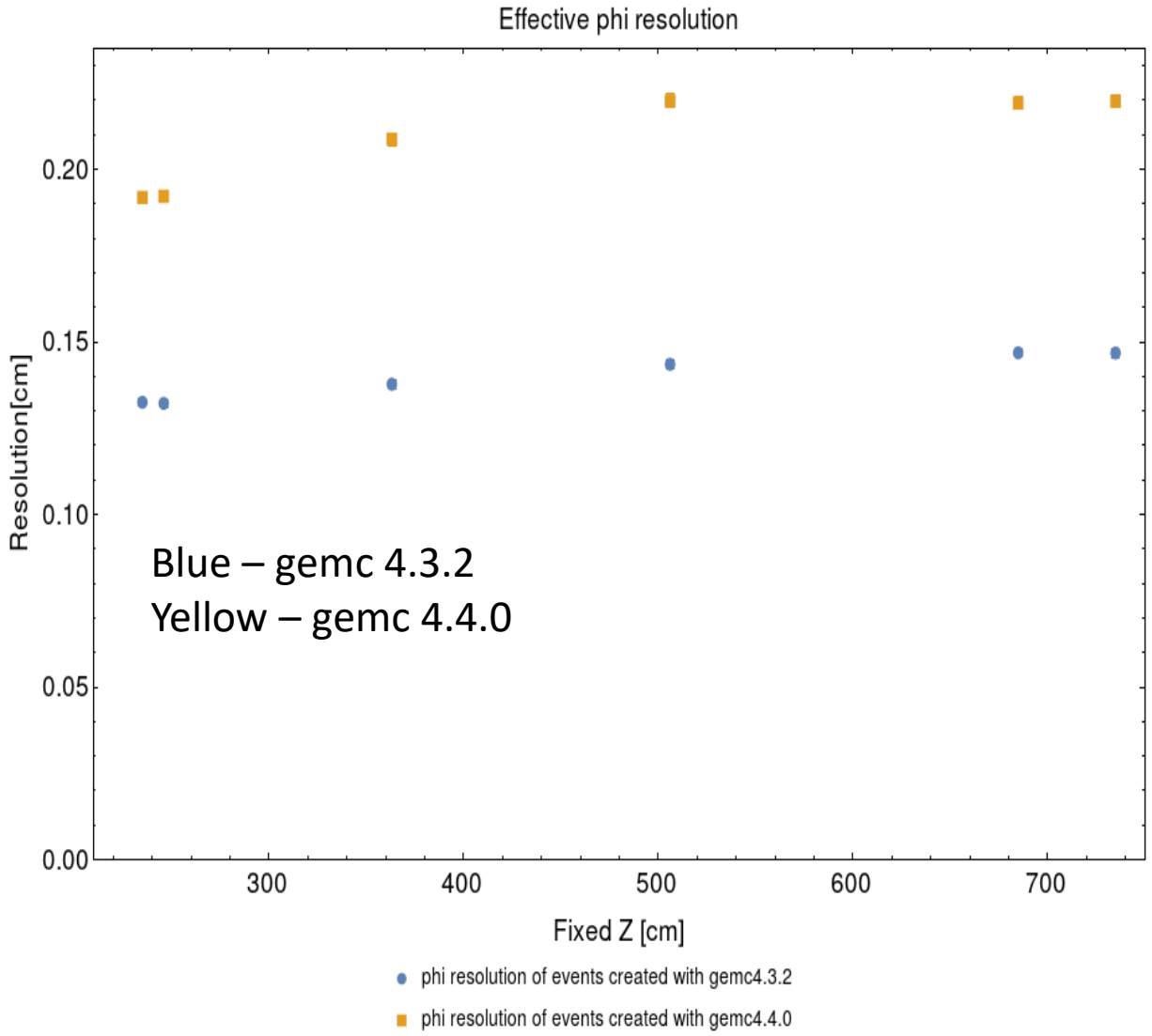


Effects of new version of GEMC on Δz and impact parameter resolution

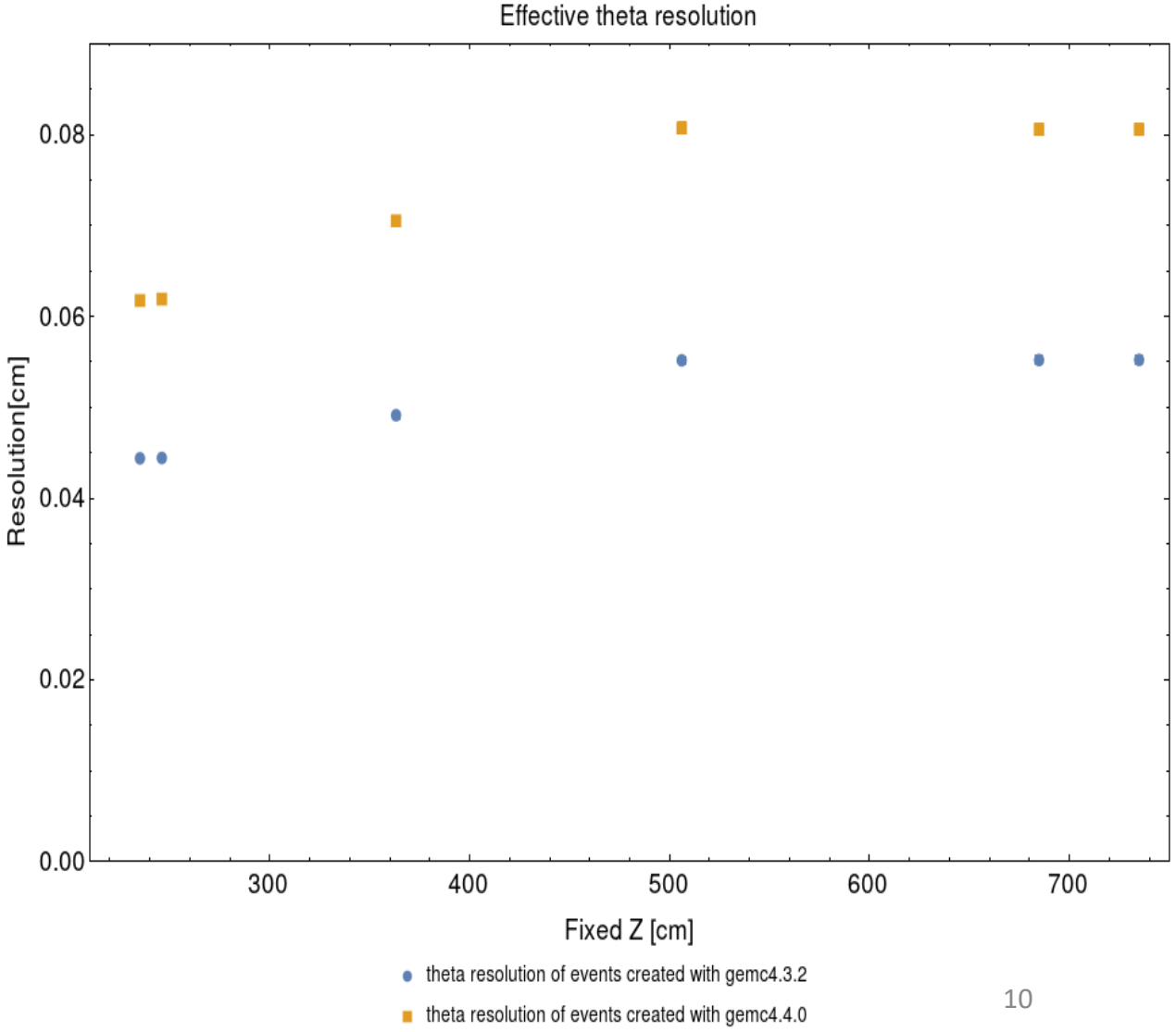




Effects of new version of GEMC on $\Delta\varphi$ and $\Delta\theta$ resolutions

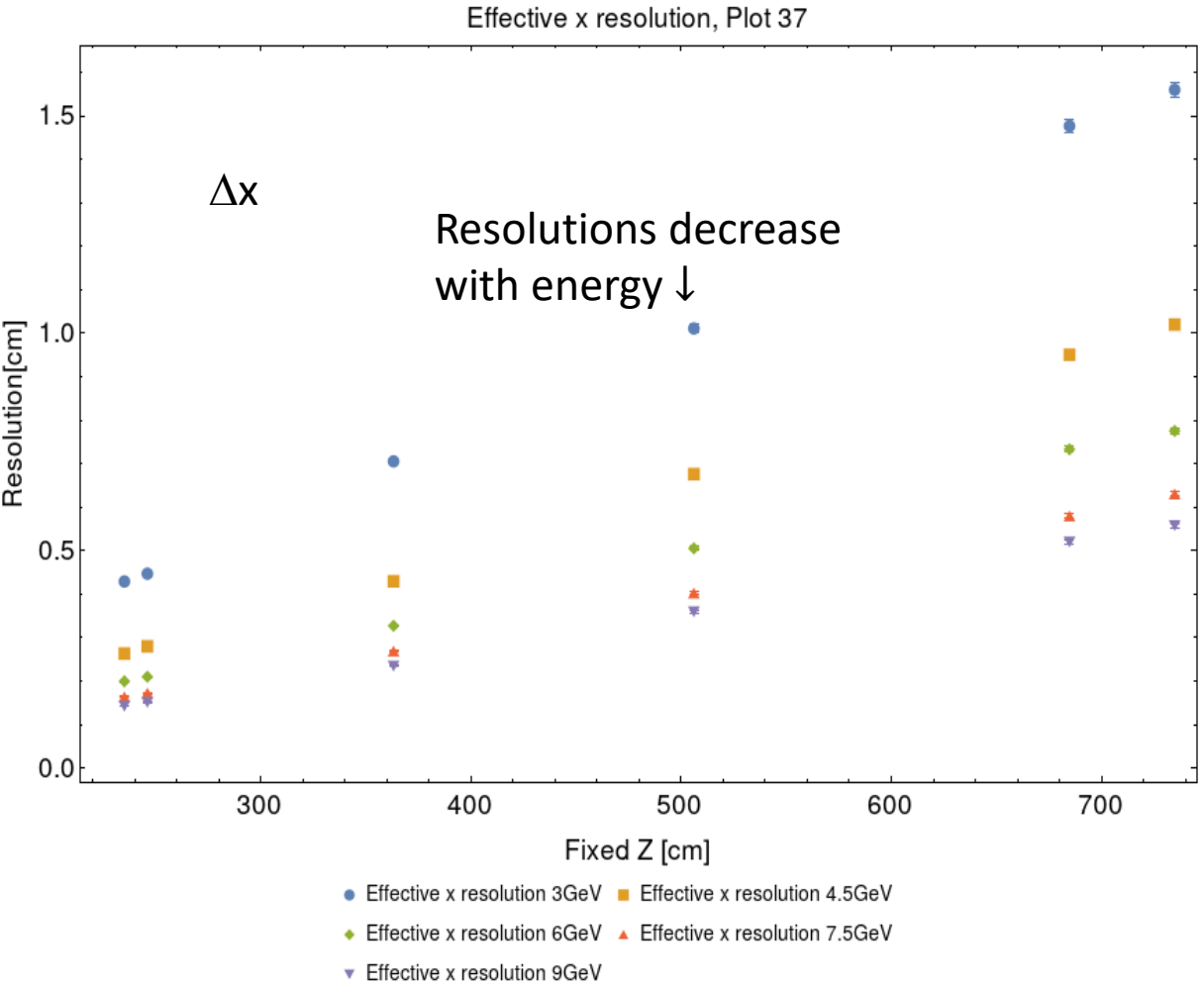


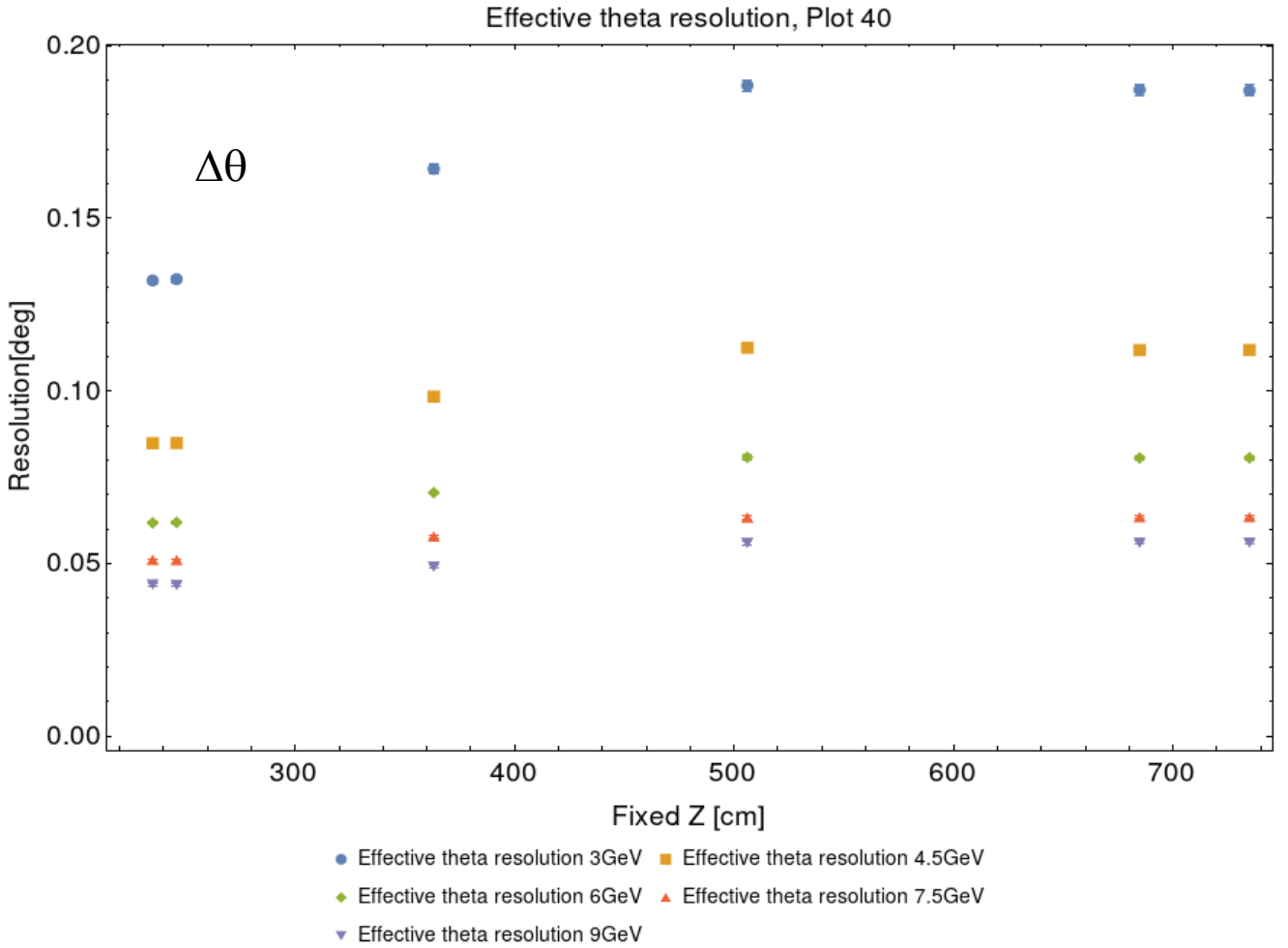
Blue – gemc 4.3.2
Yellow – gemc 4.4.0



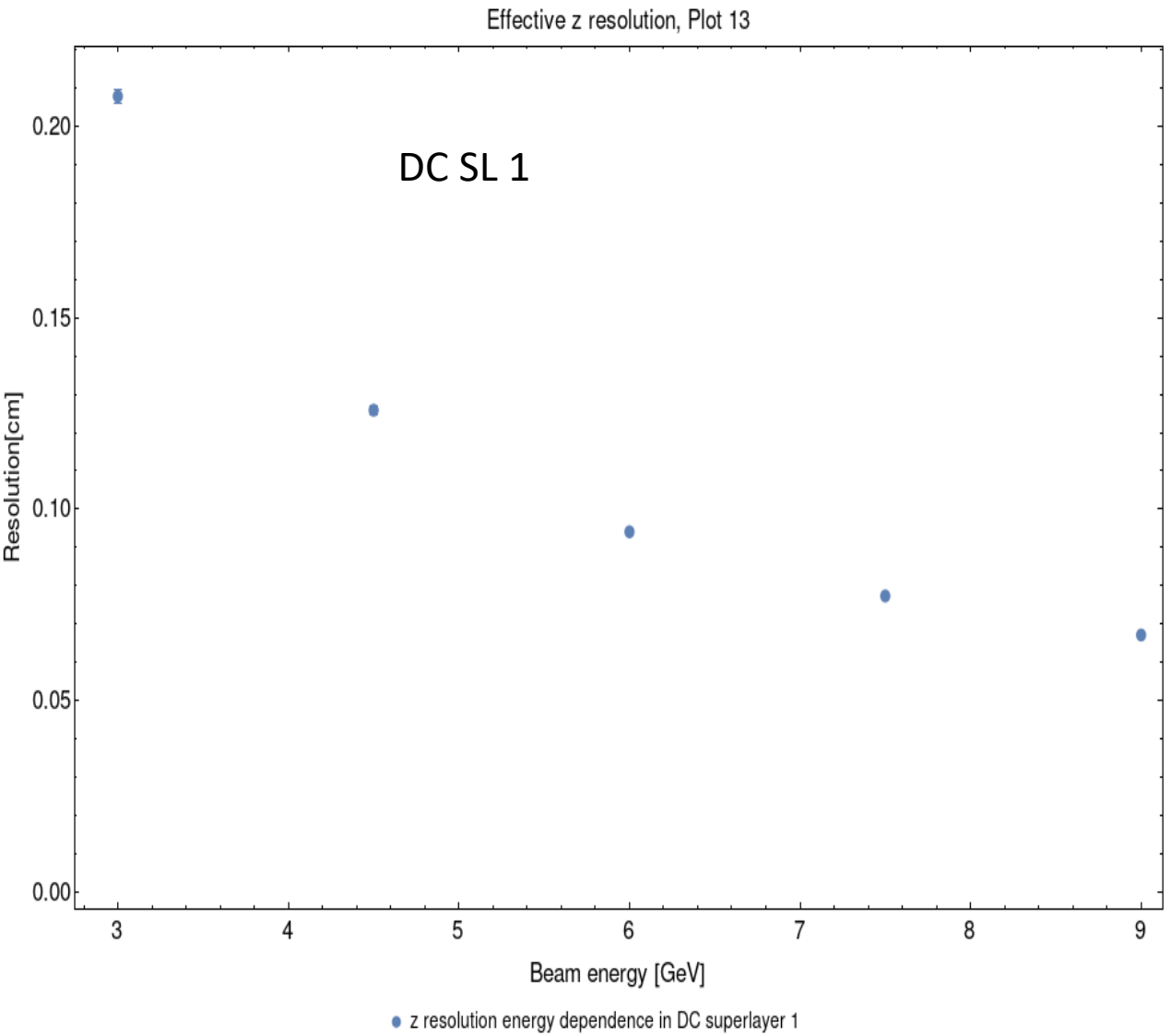
Results for varying energy

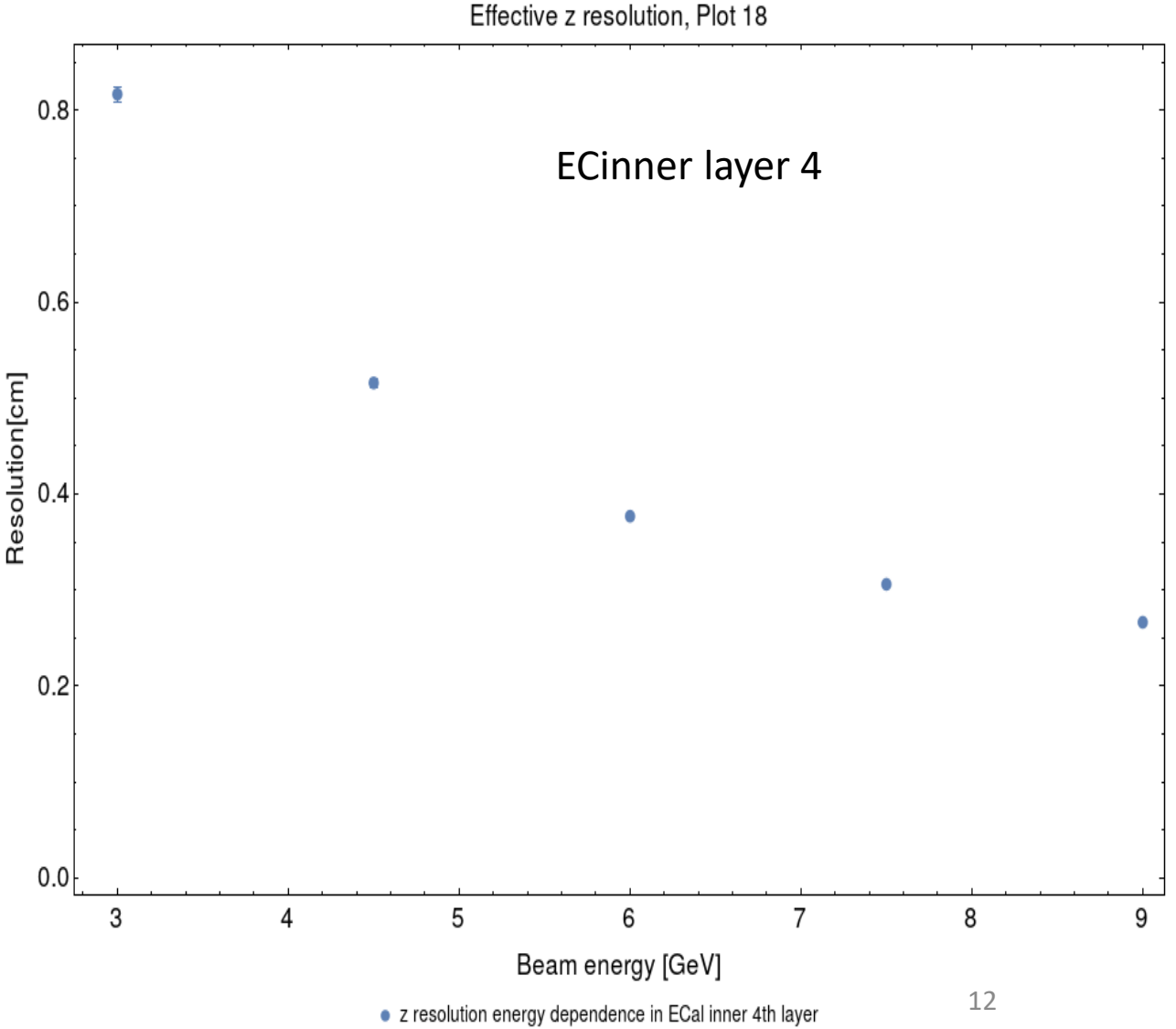
- Resolutions for Δx and $\Delta\theta$ plotted against the z axis distance of the endpoint to the origin of the TSCS.



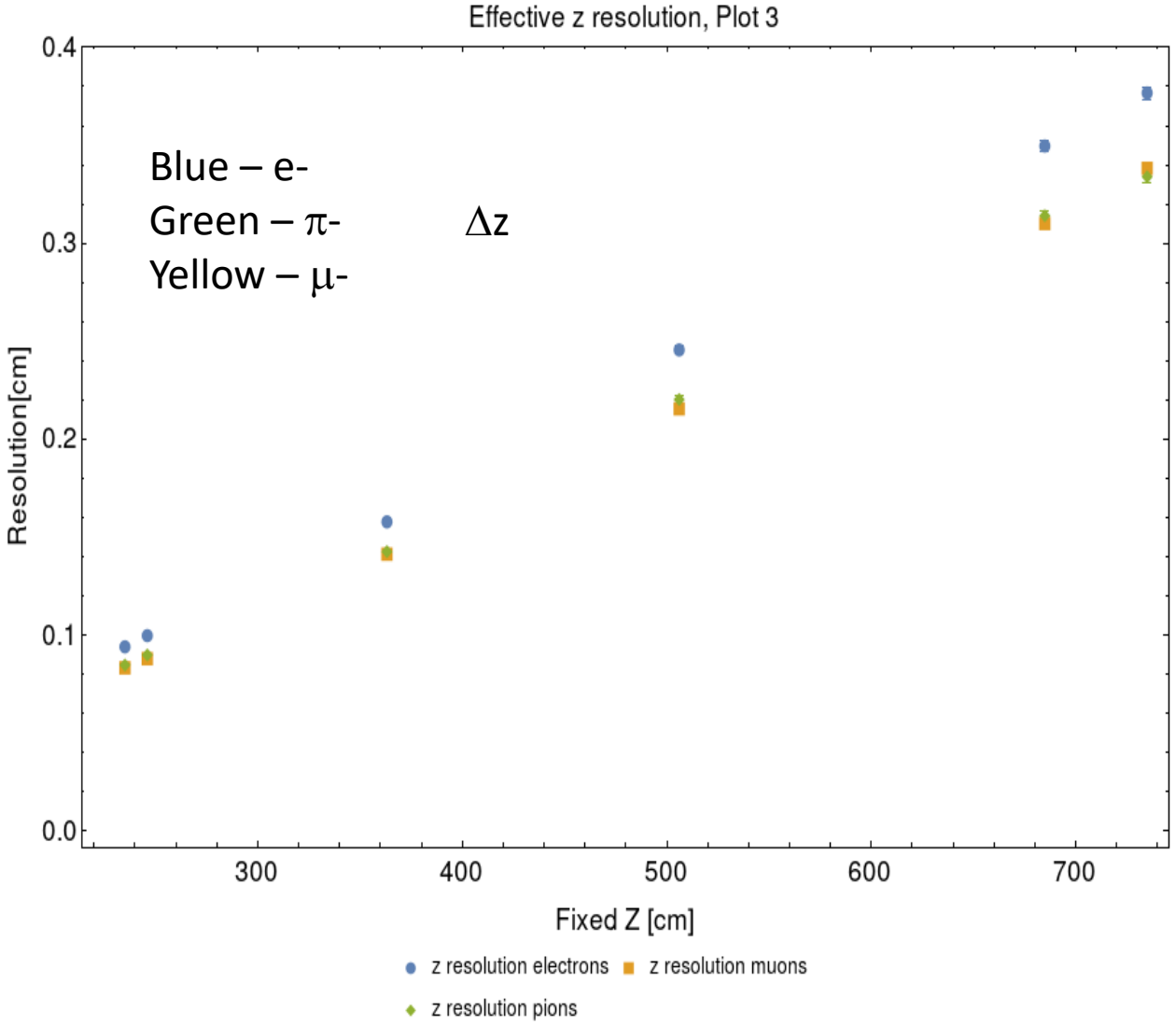


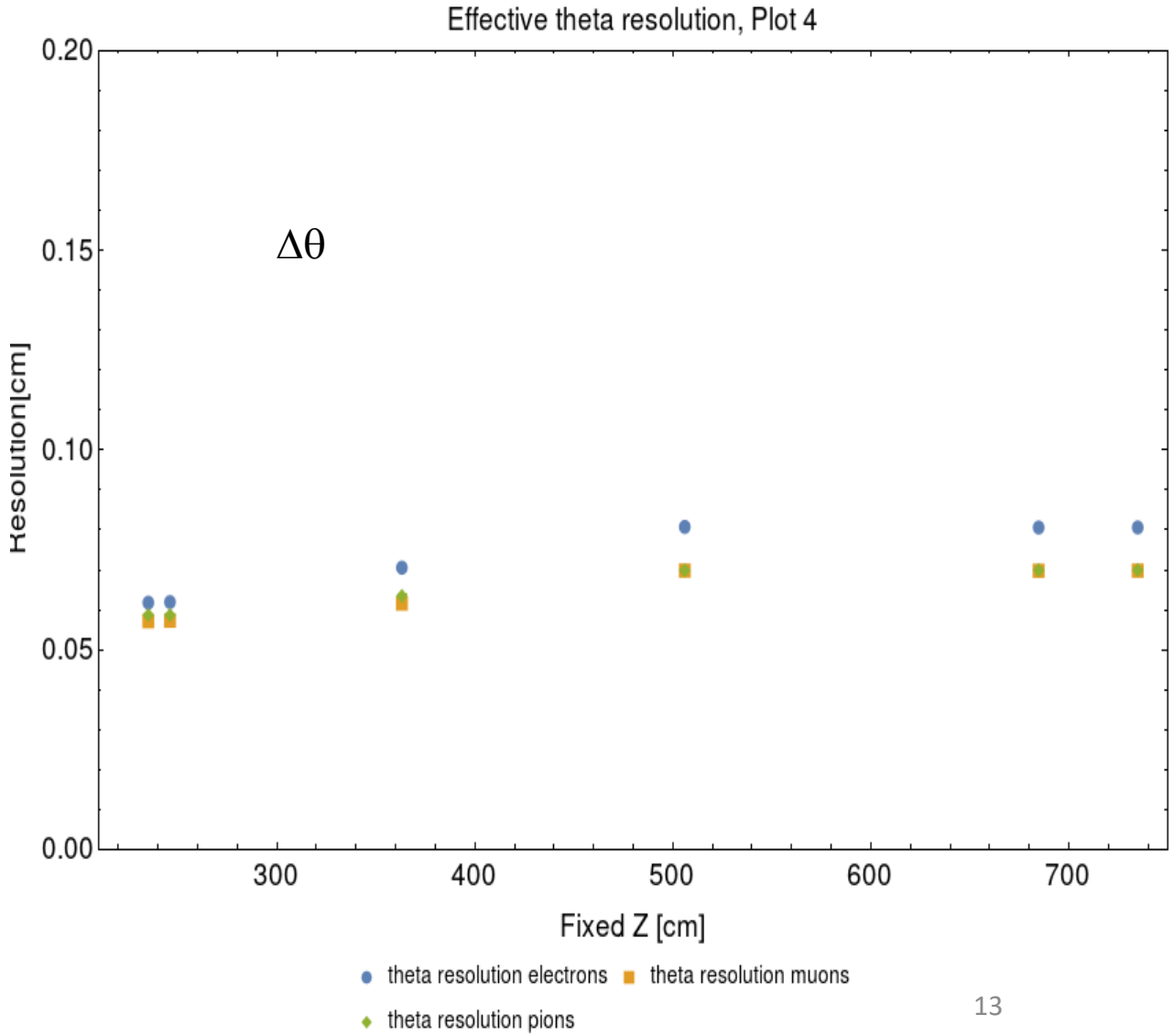
Energy dependence of Δz resolution



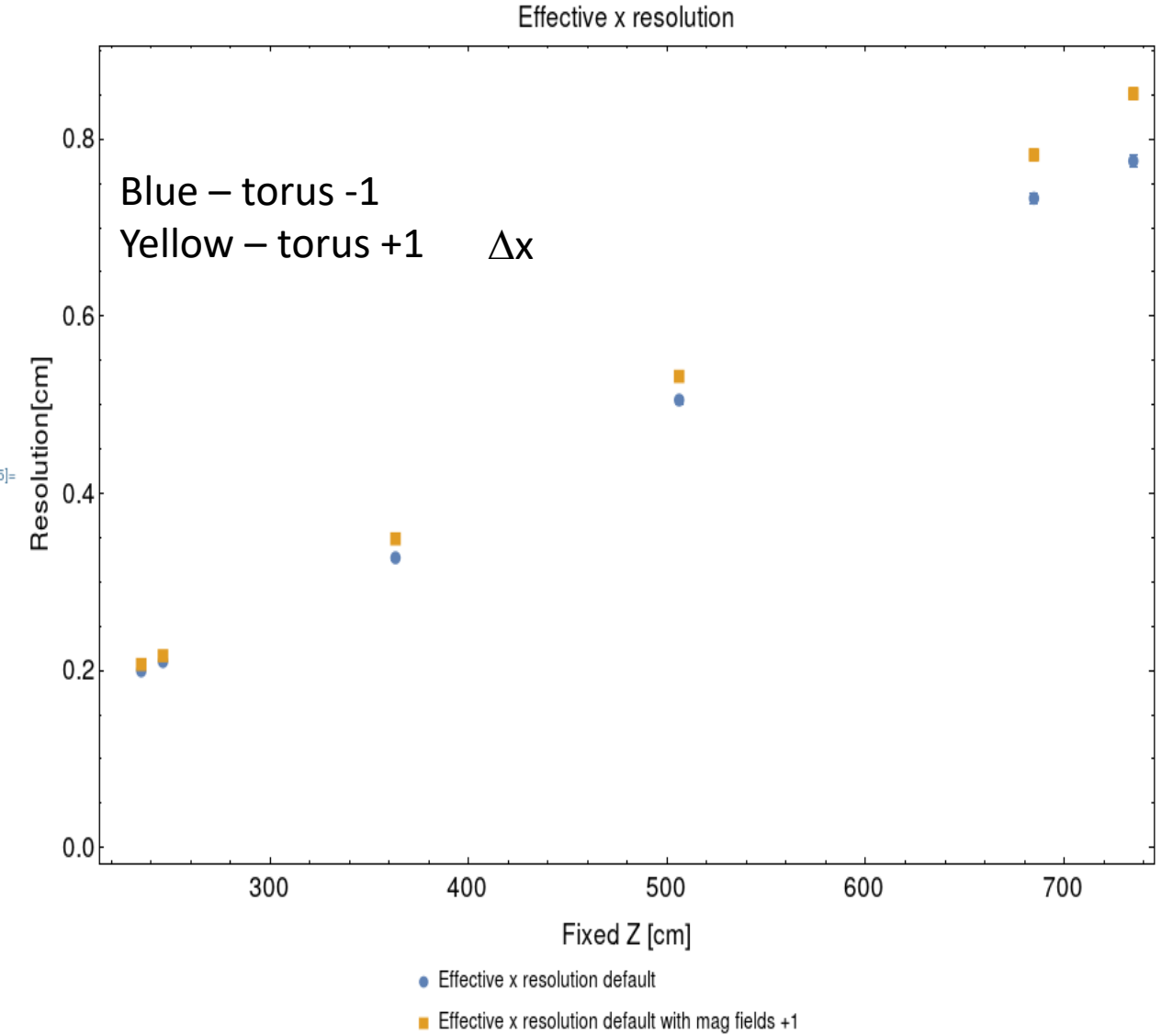


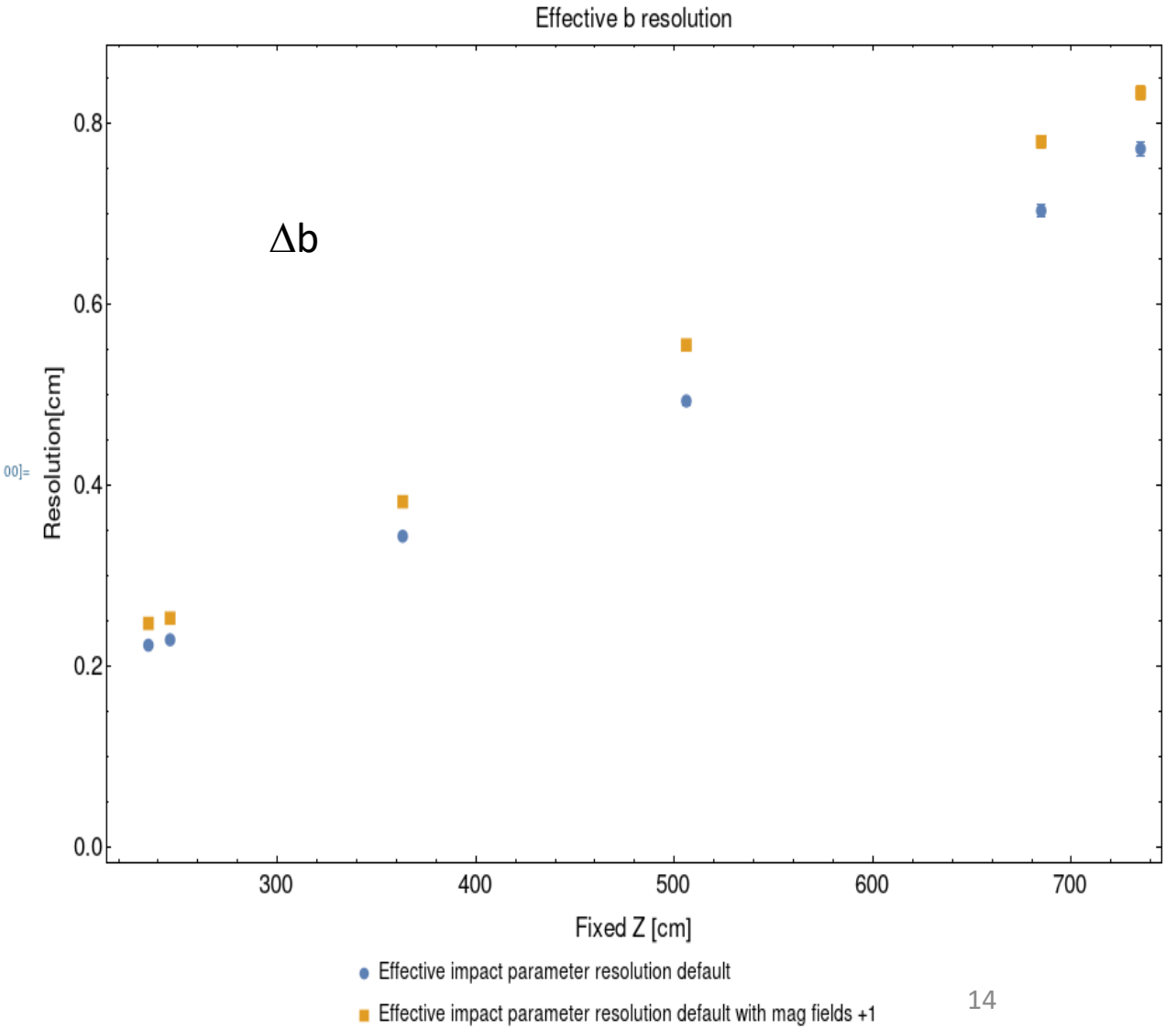
Resolutions for different particle species (e^-, π^-, μ^-) Δz and $\Delta\theta$ results





Resolutions for reversed torus polarity, Δx and Δb results





Conclusions

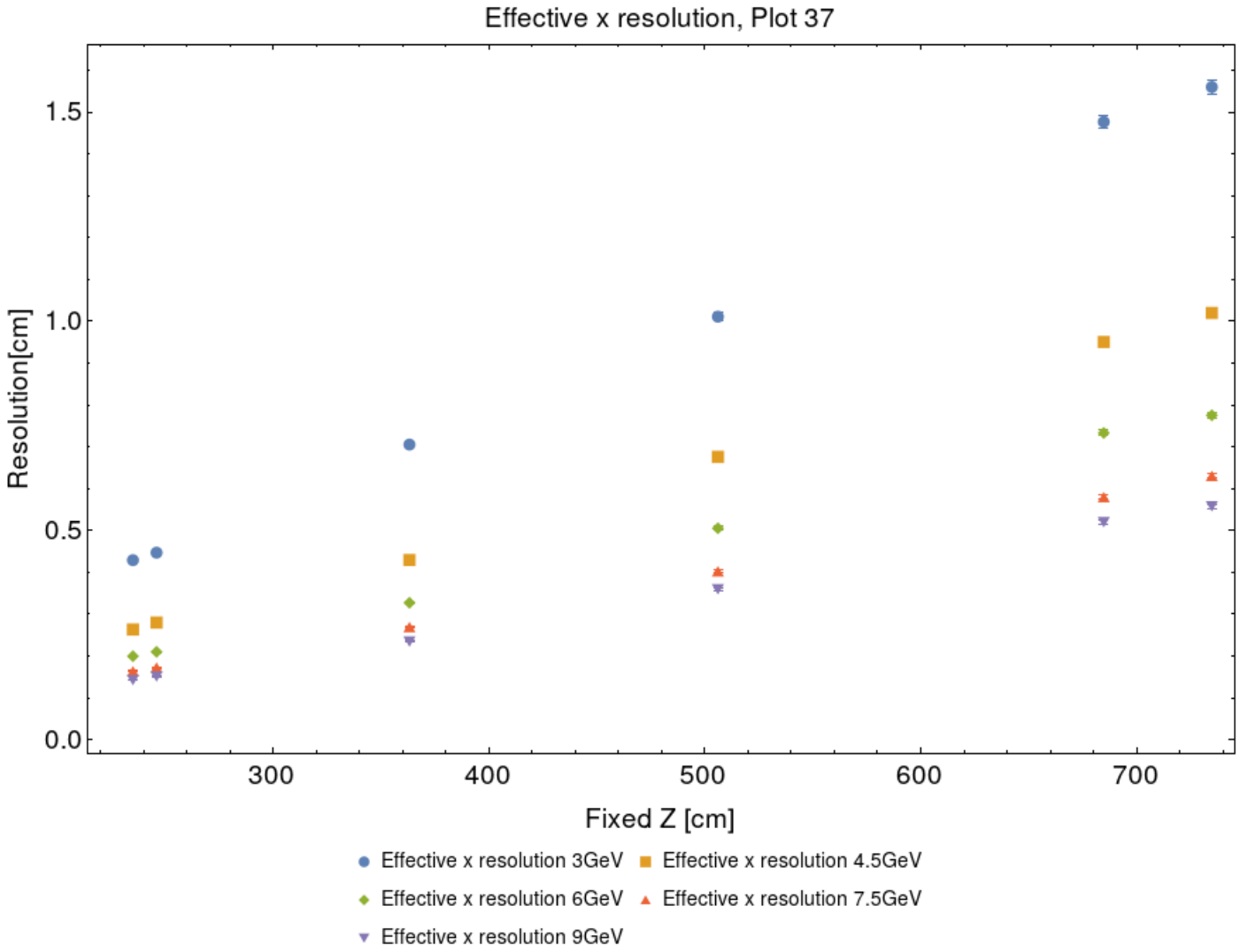
- Studied reconstruction resolution on simulated events
- A significant increase is seen in the resolution of all observables with events created with new version of GEMC
- Resolutions improve with increasing particle energy
- The resolutions of electron events higher than resolutions of μ^-, π^-
- The reconstruction performs worse for events with outbending torus field

Appendix

Remaining plots produced during this study

NB plots ordered as following: $\Delta x, \Delta y, \Delta z, \Delta\theta, \Delta\varphi, b$ with energy dependence shown first, followed by species, detector geometries, and sector dependence

Appendix: Resolutions energy dependence



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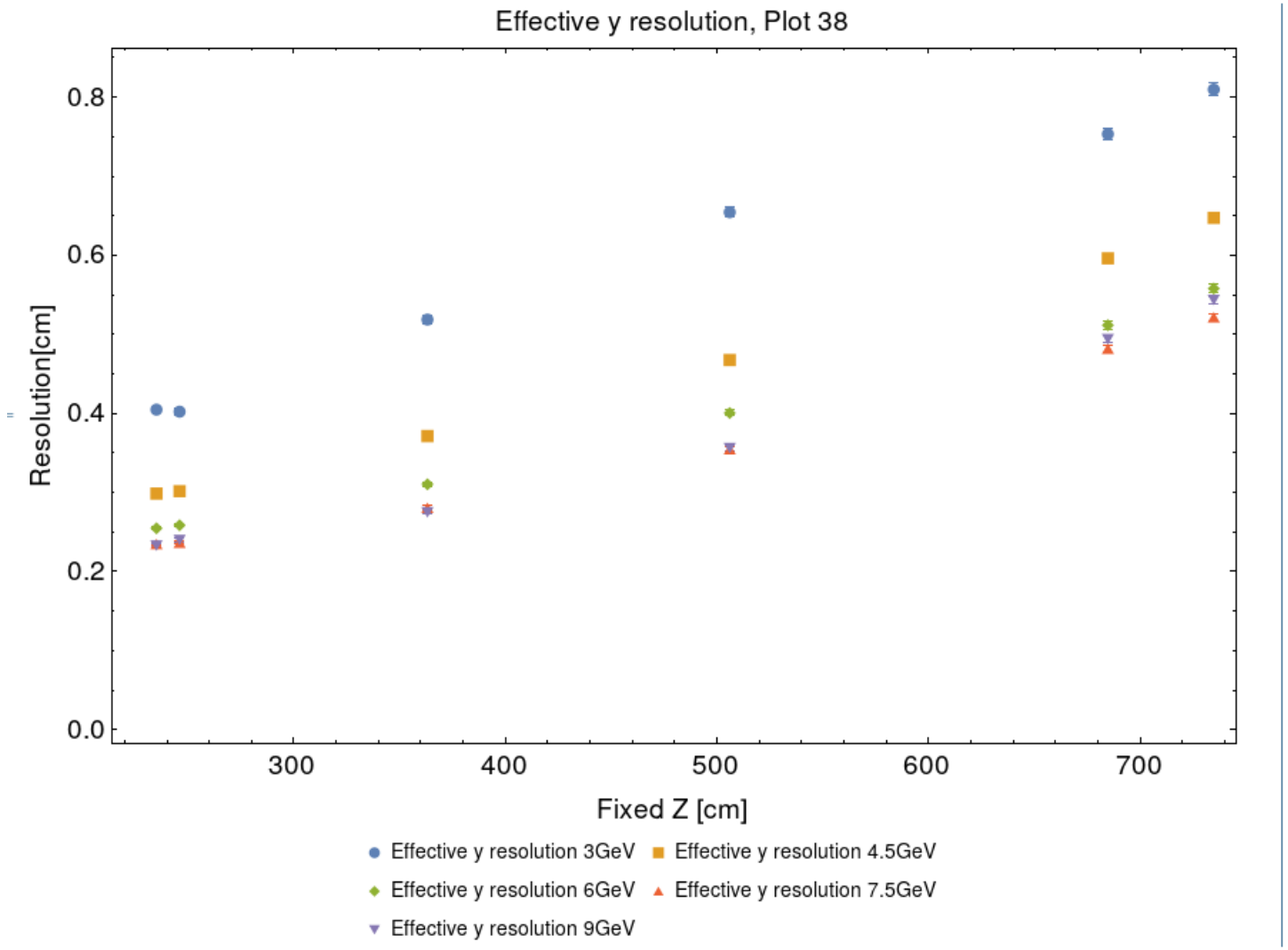

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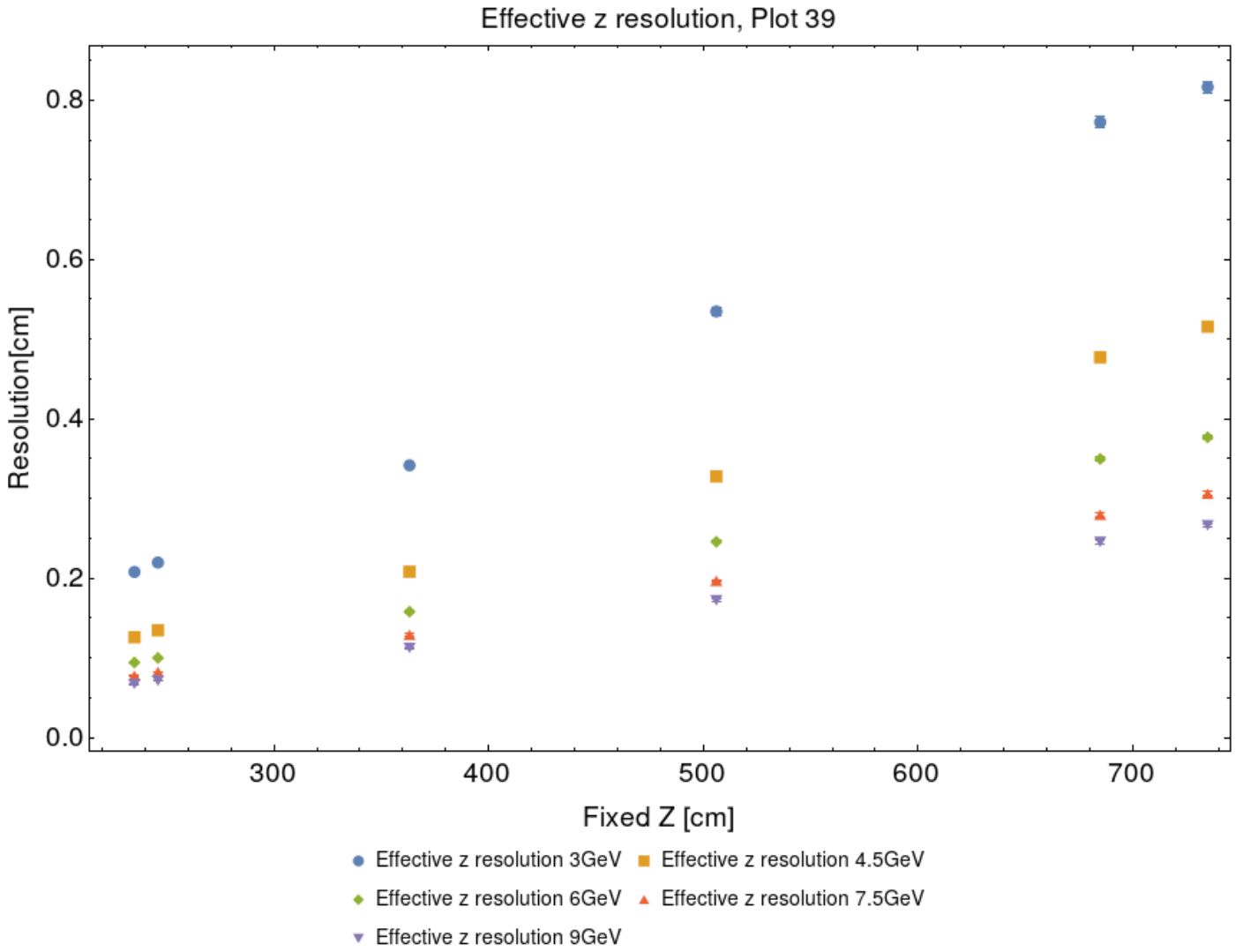

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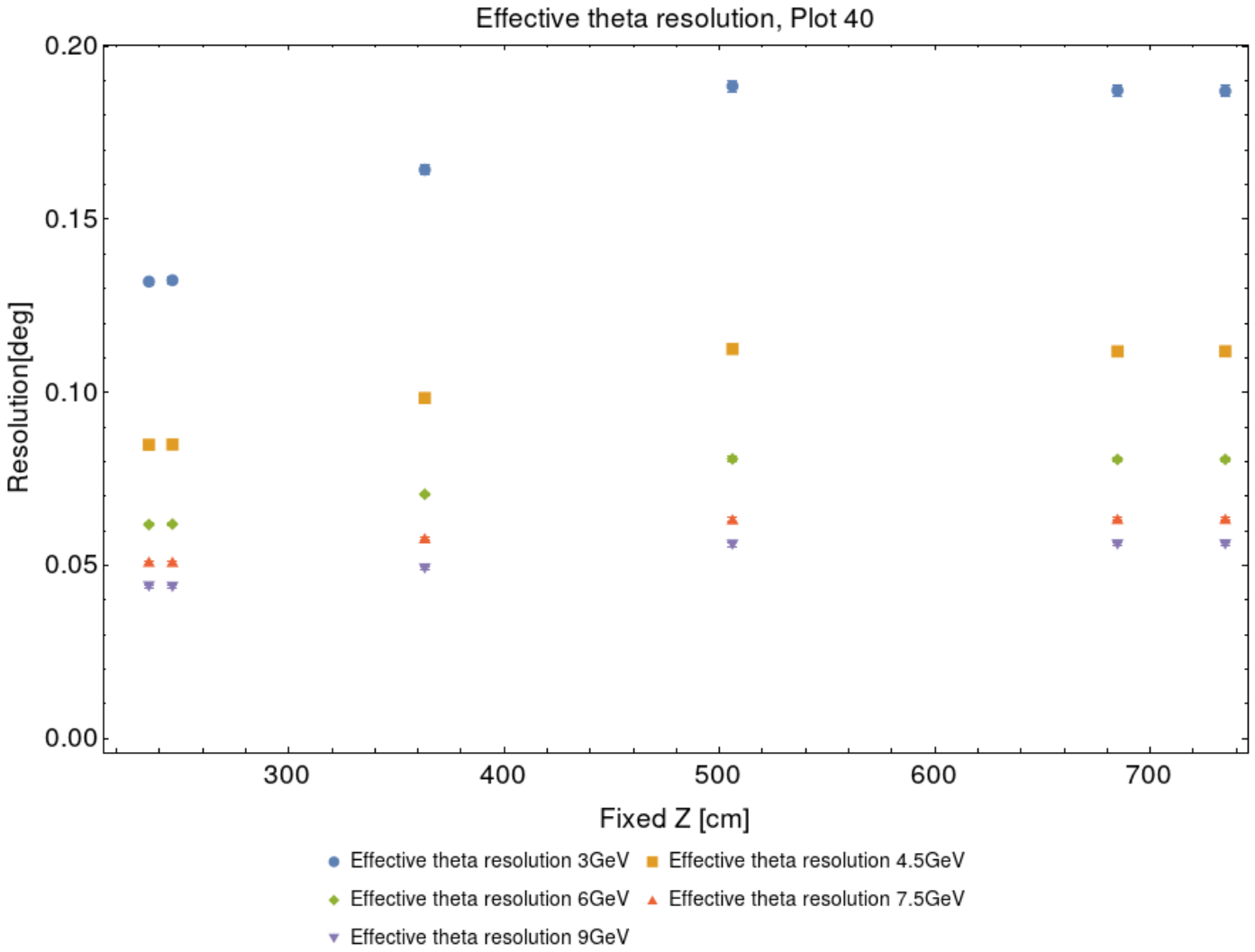

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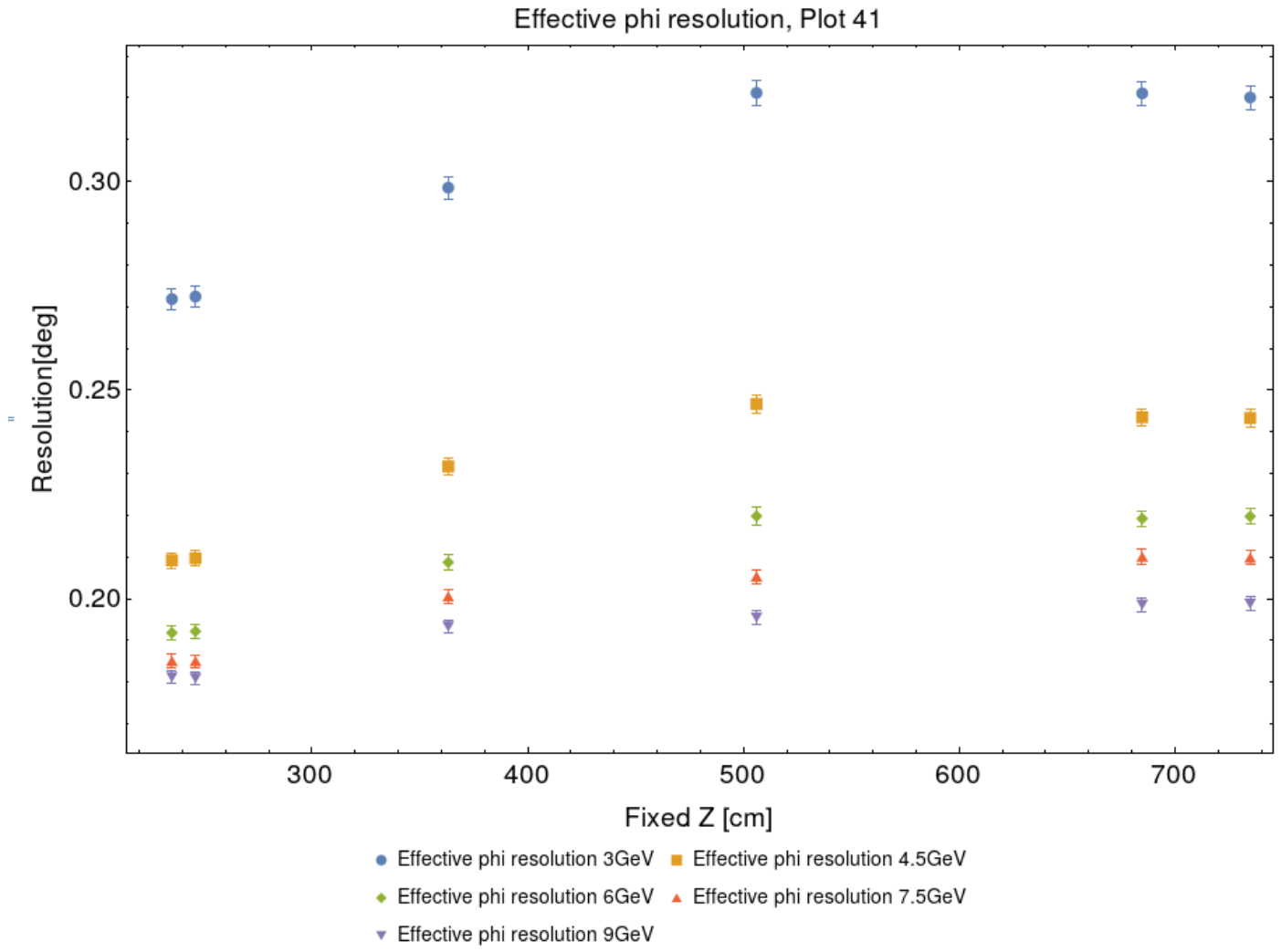

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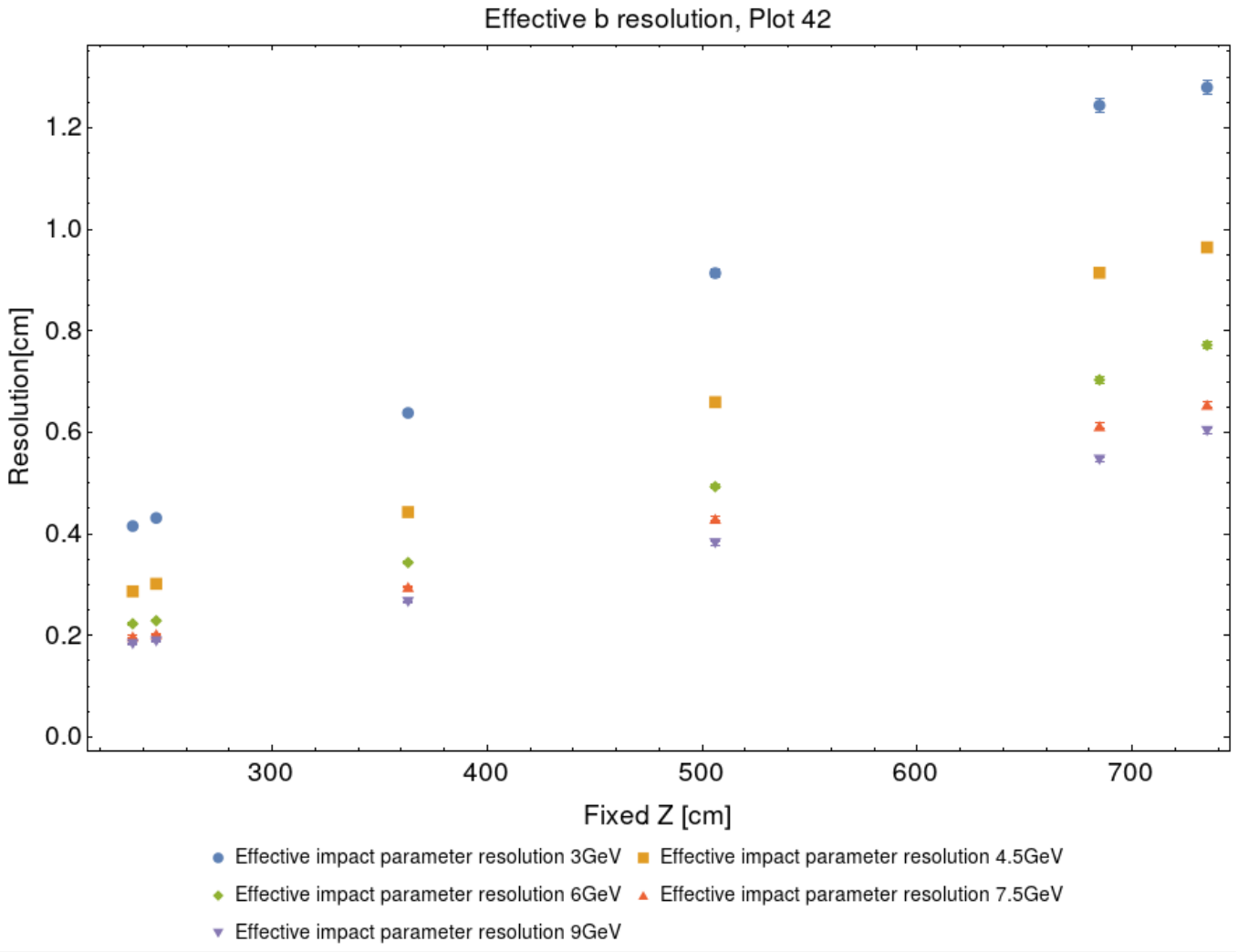
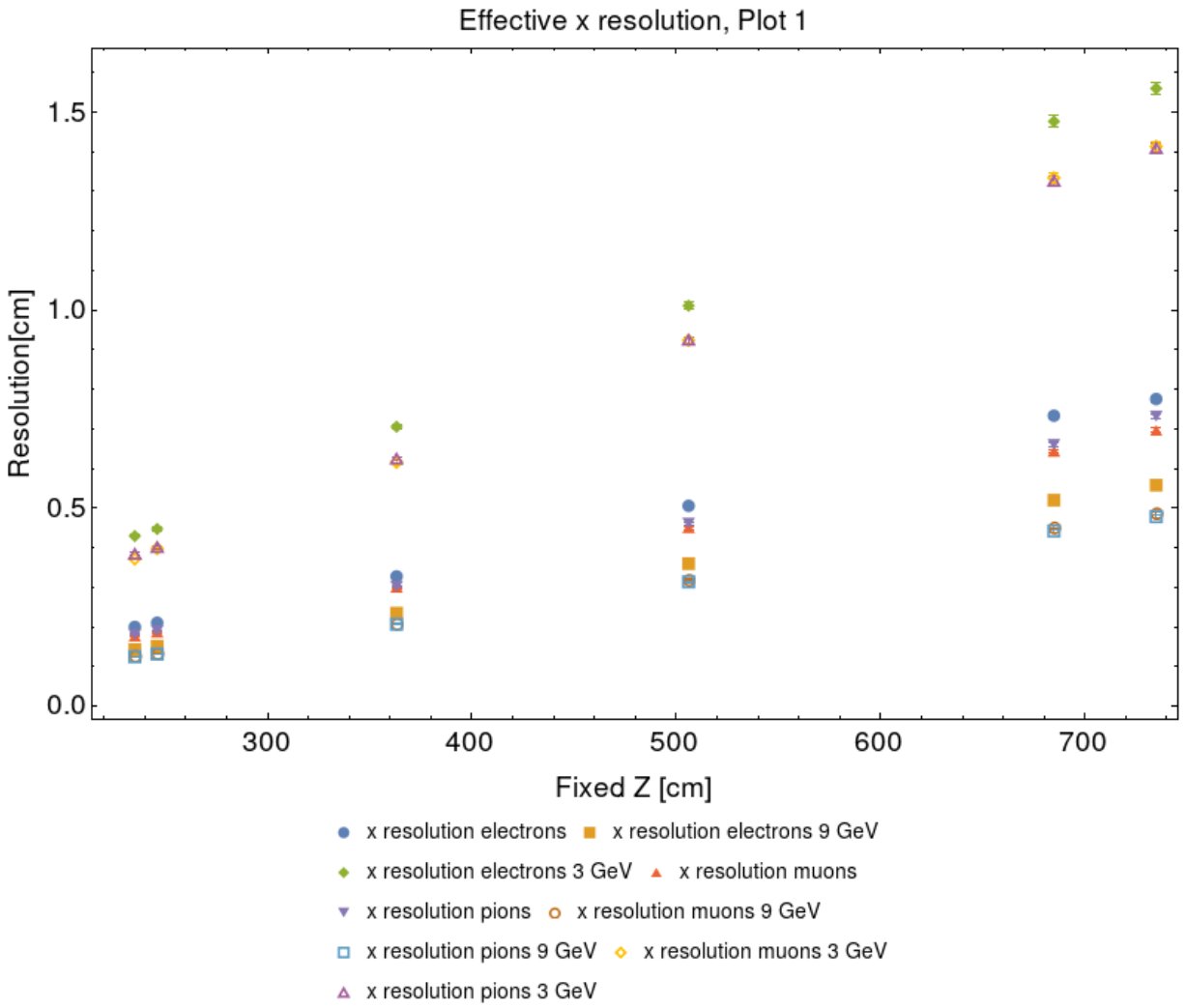


Appendix: Resolutions species dependence



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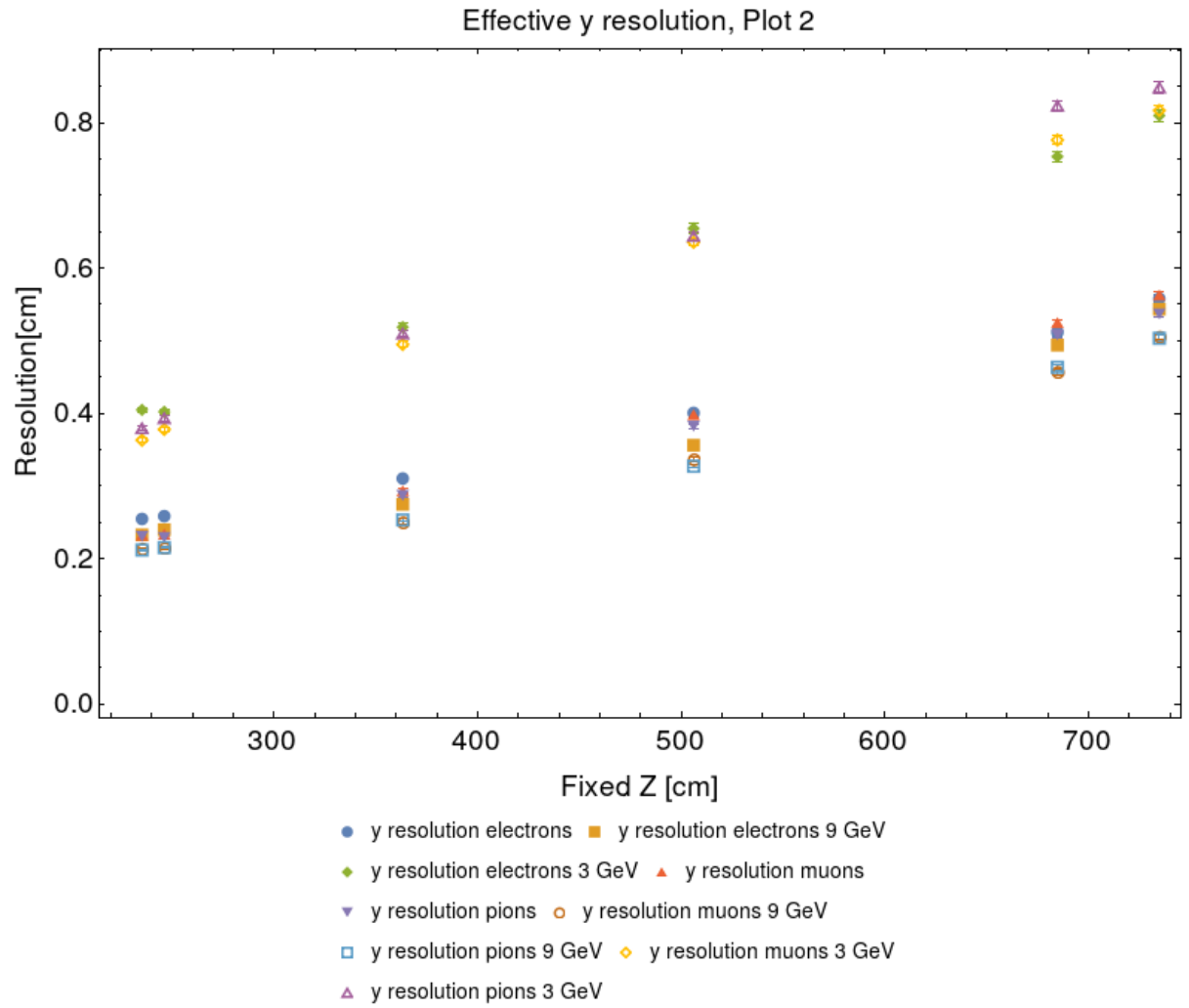

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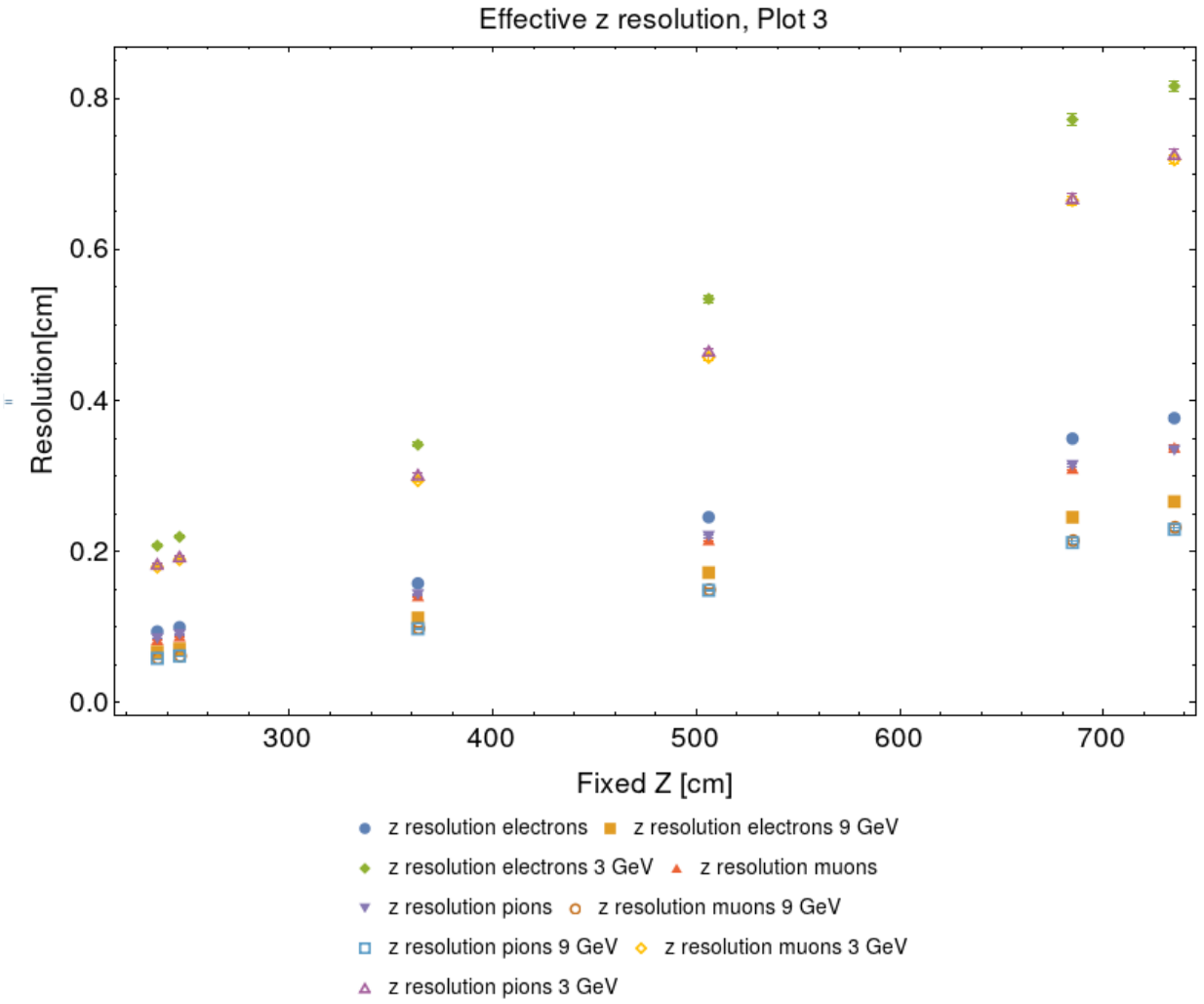

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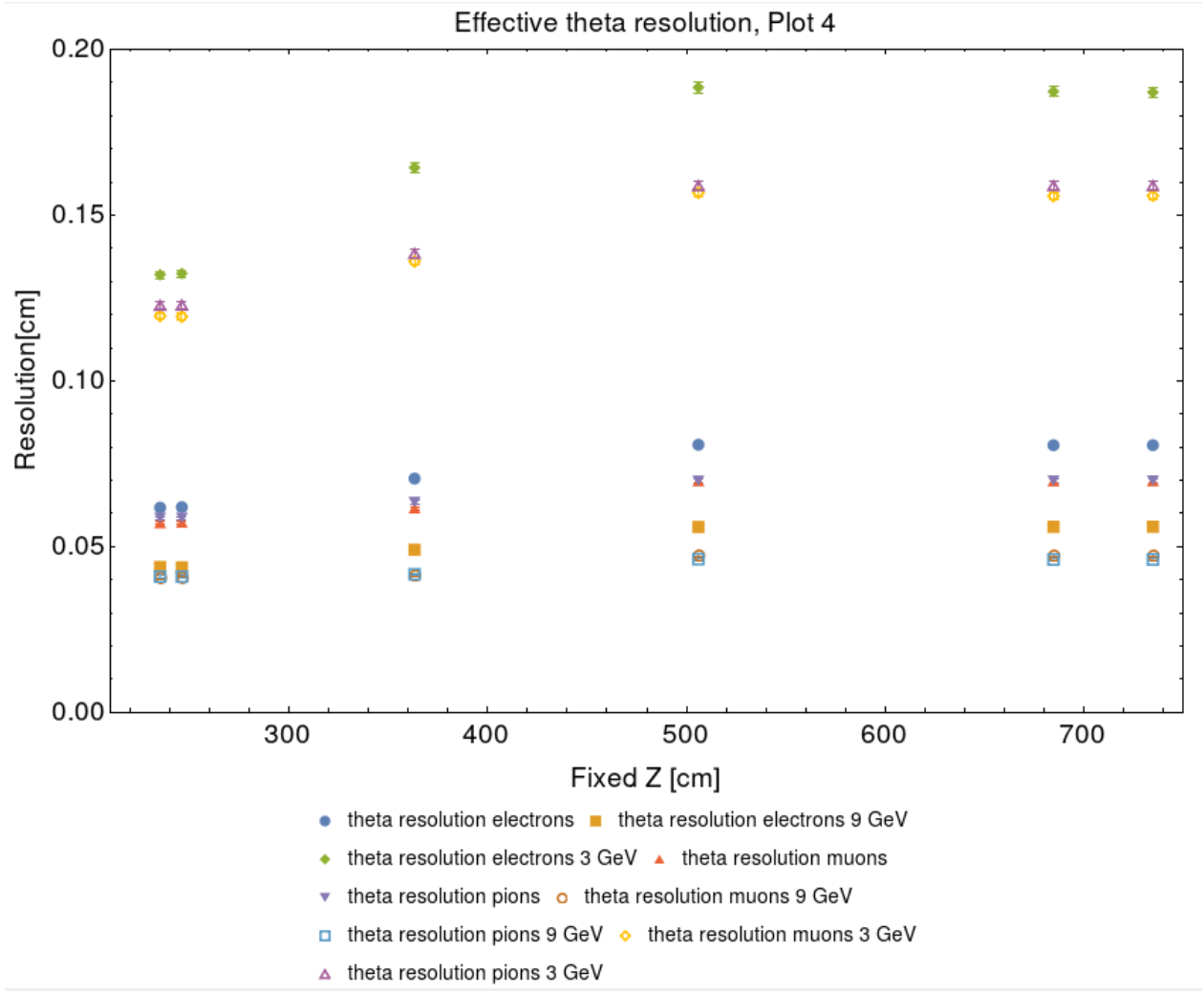

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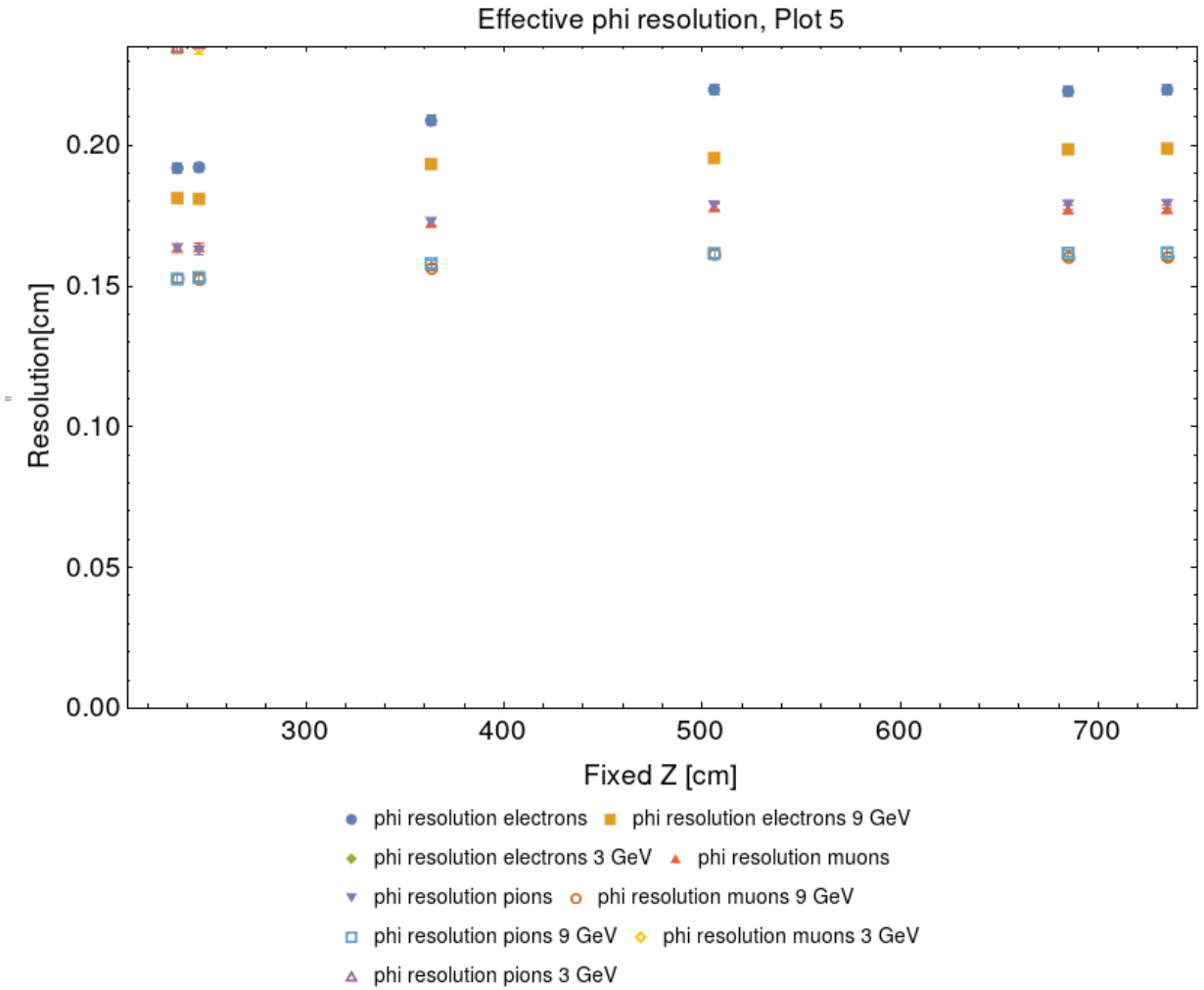

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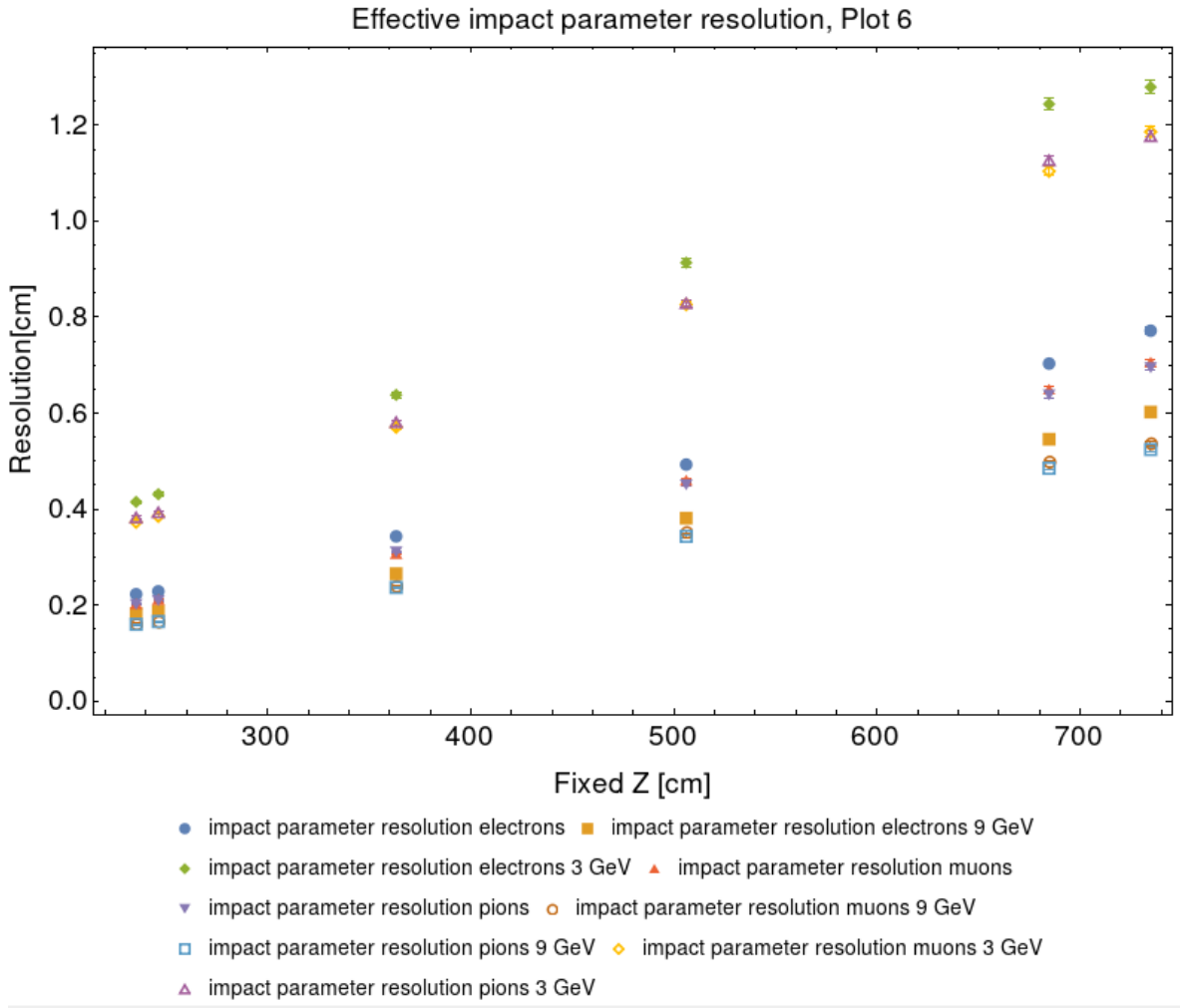
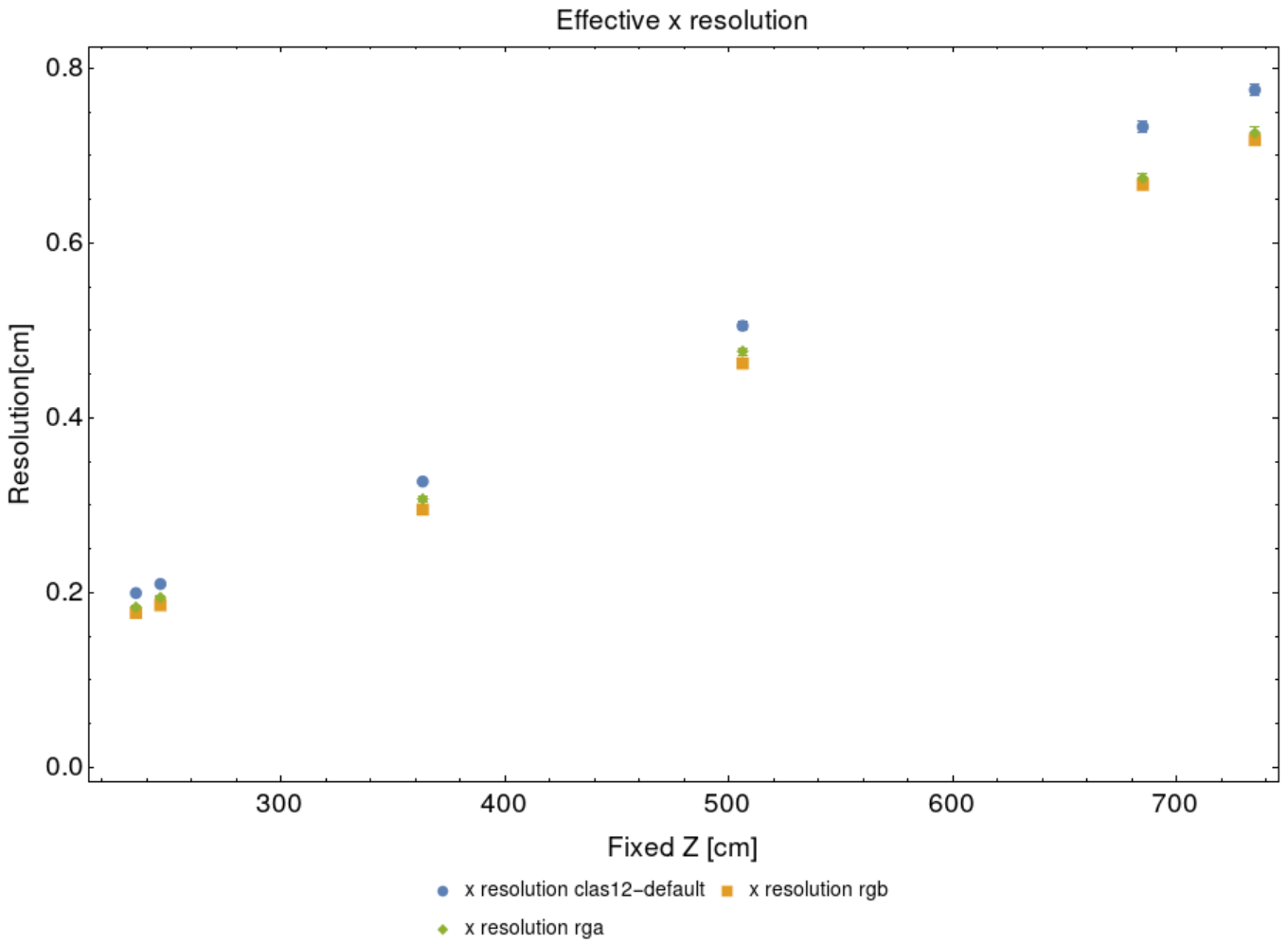


Appendix: Resolutions for different geometries



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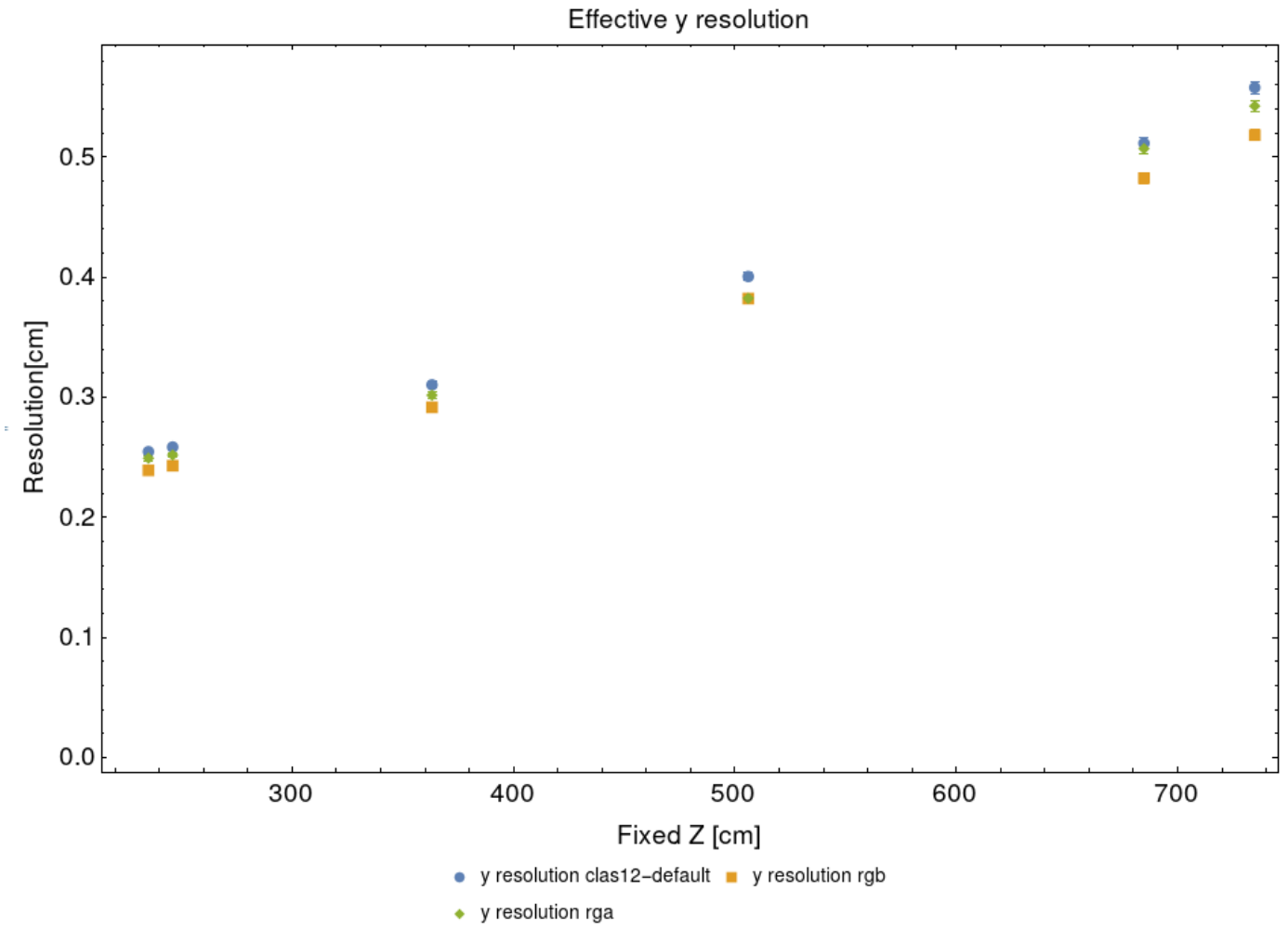

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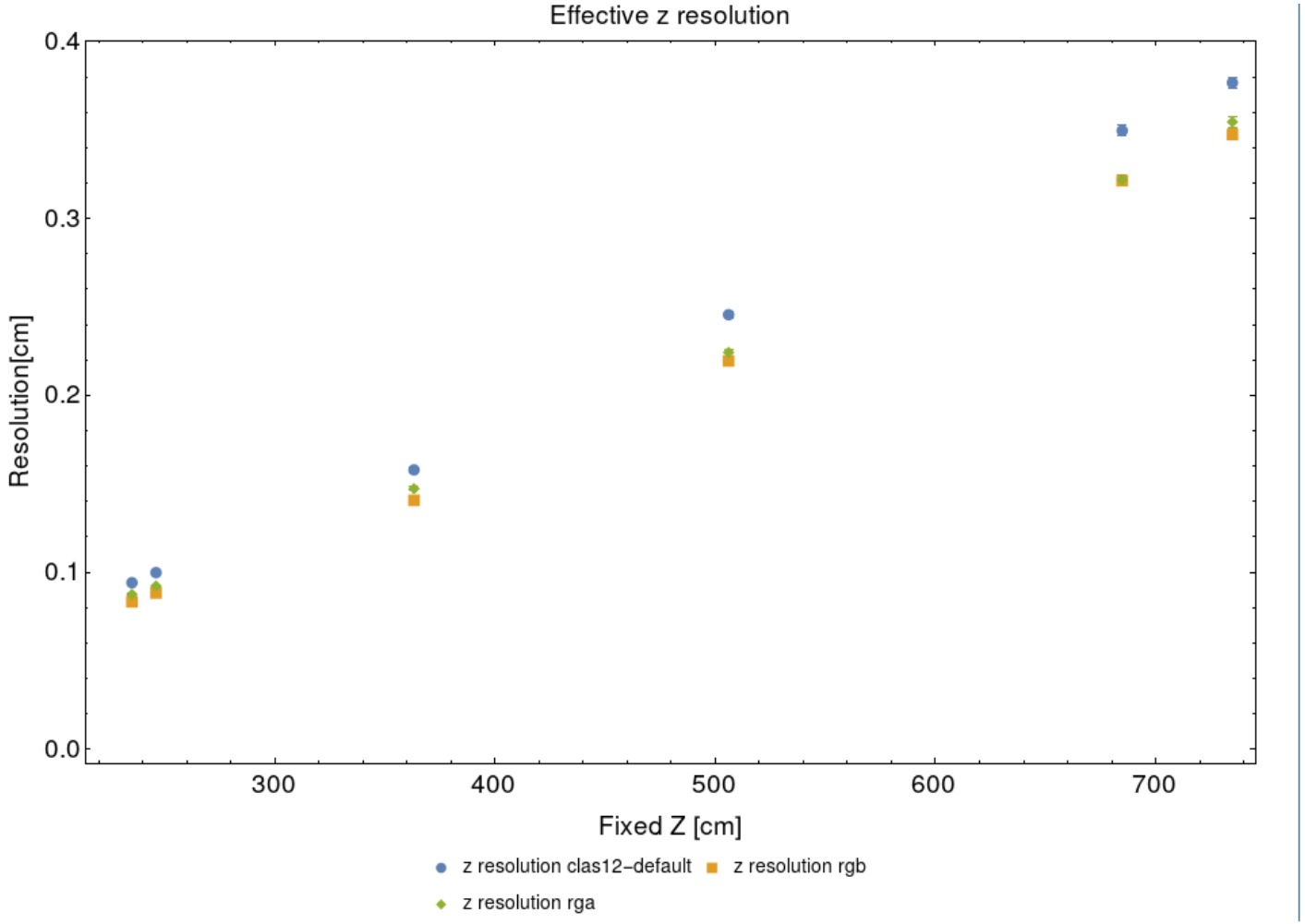

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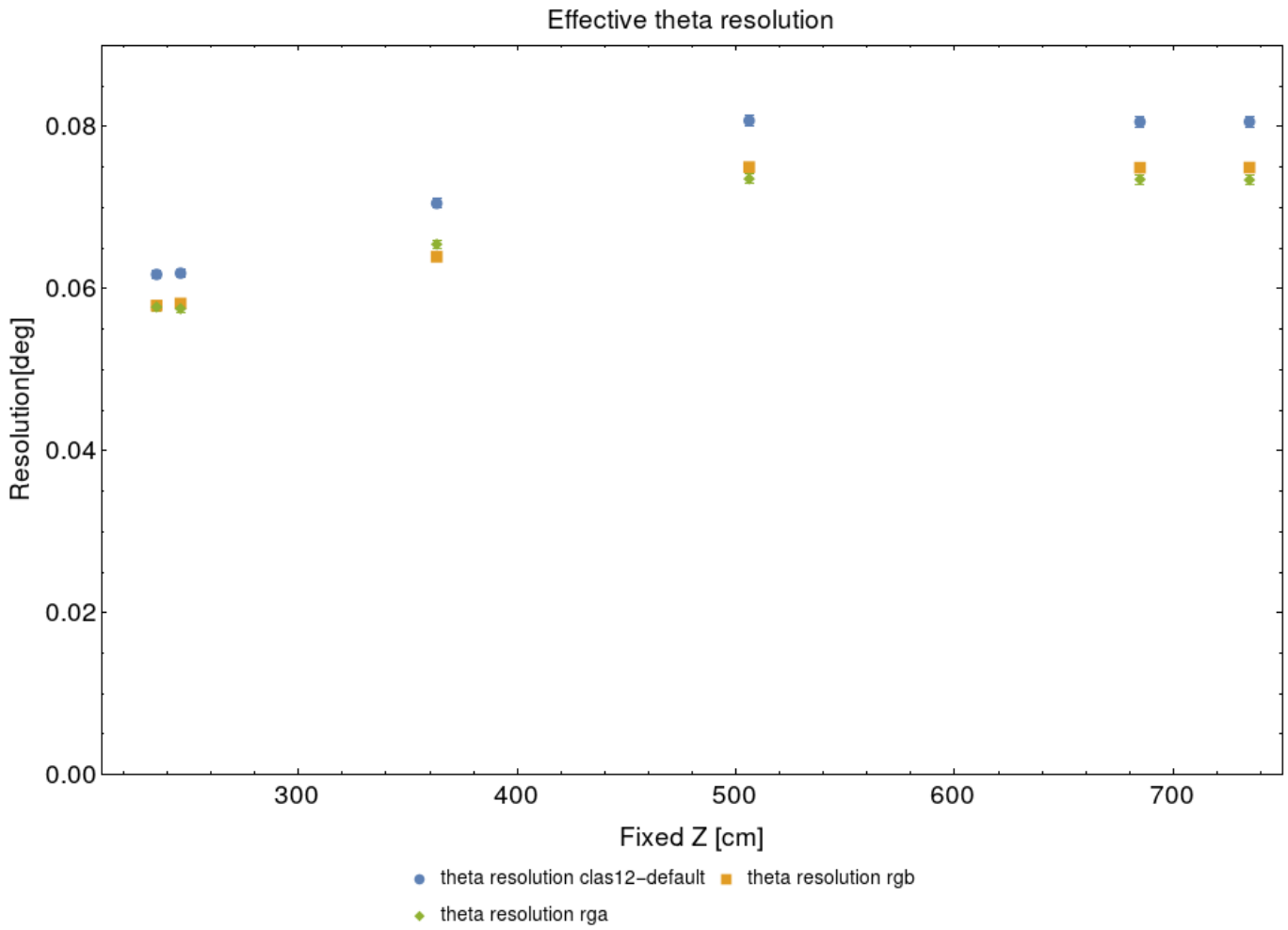

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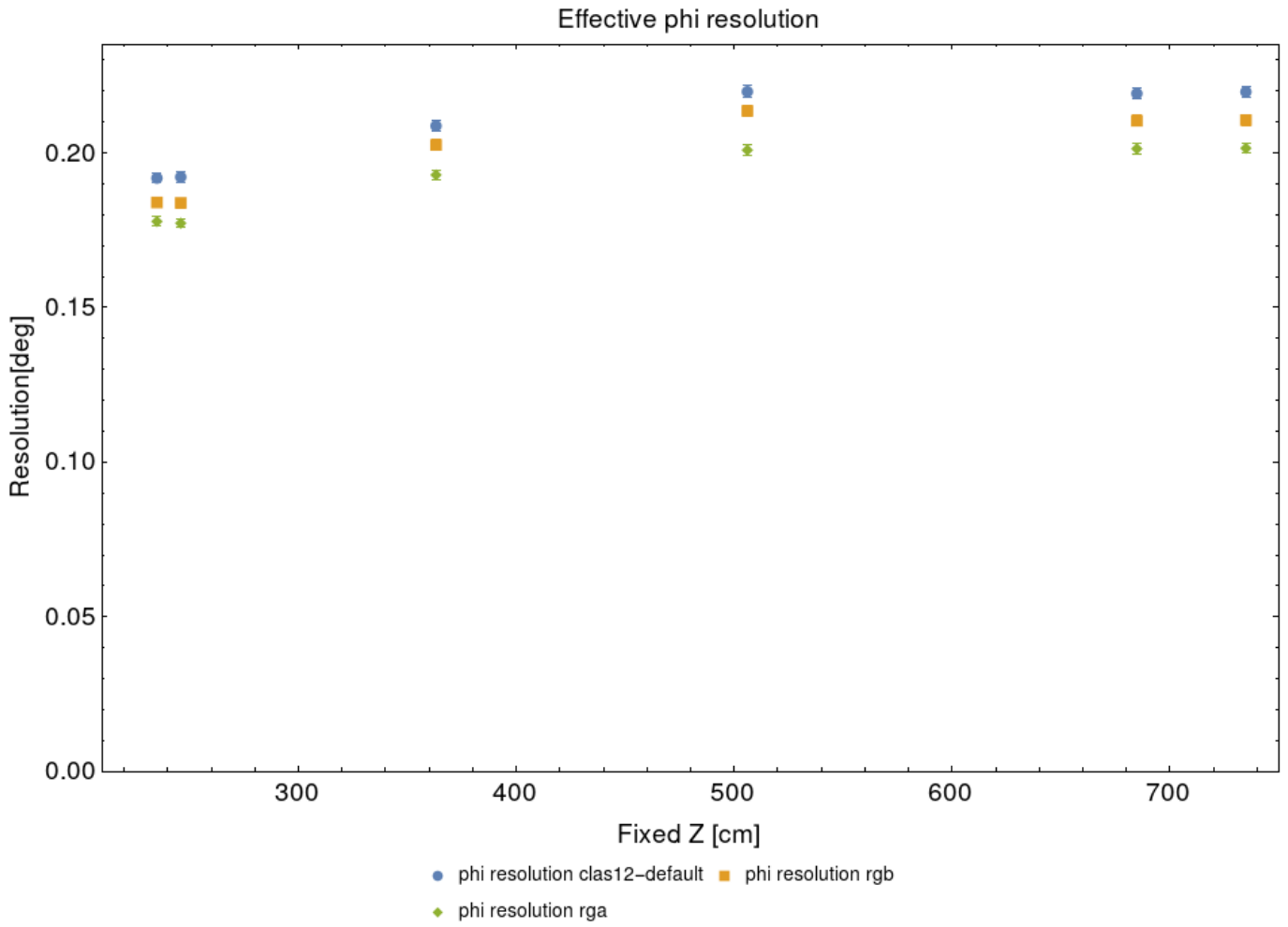

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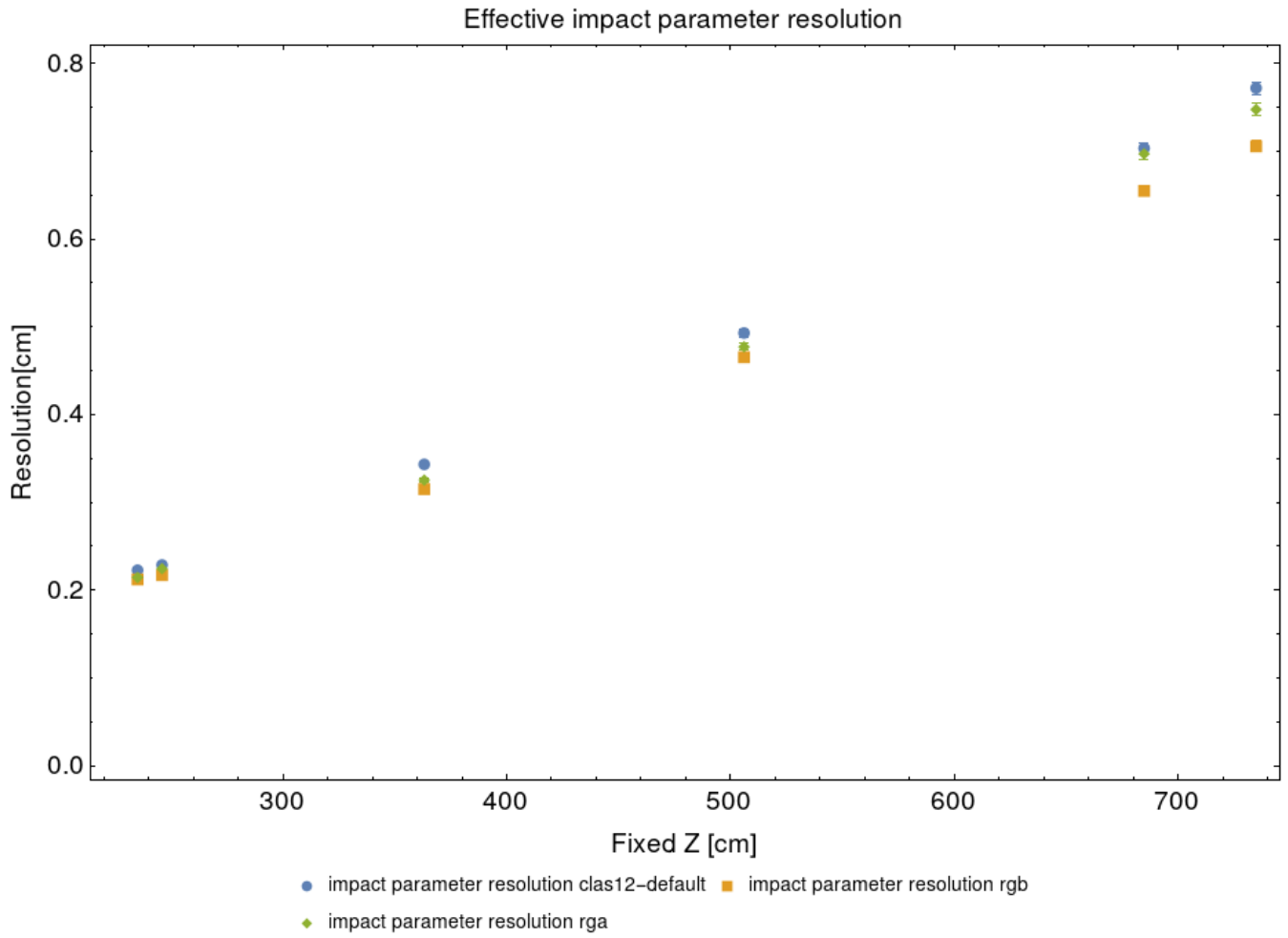
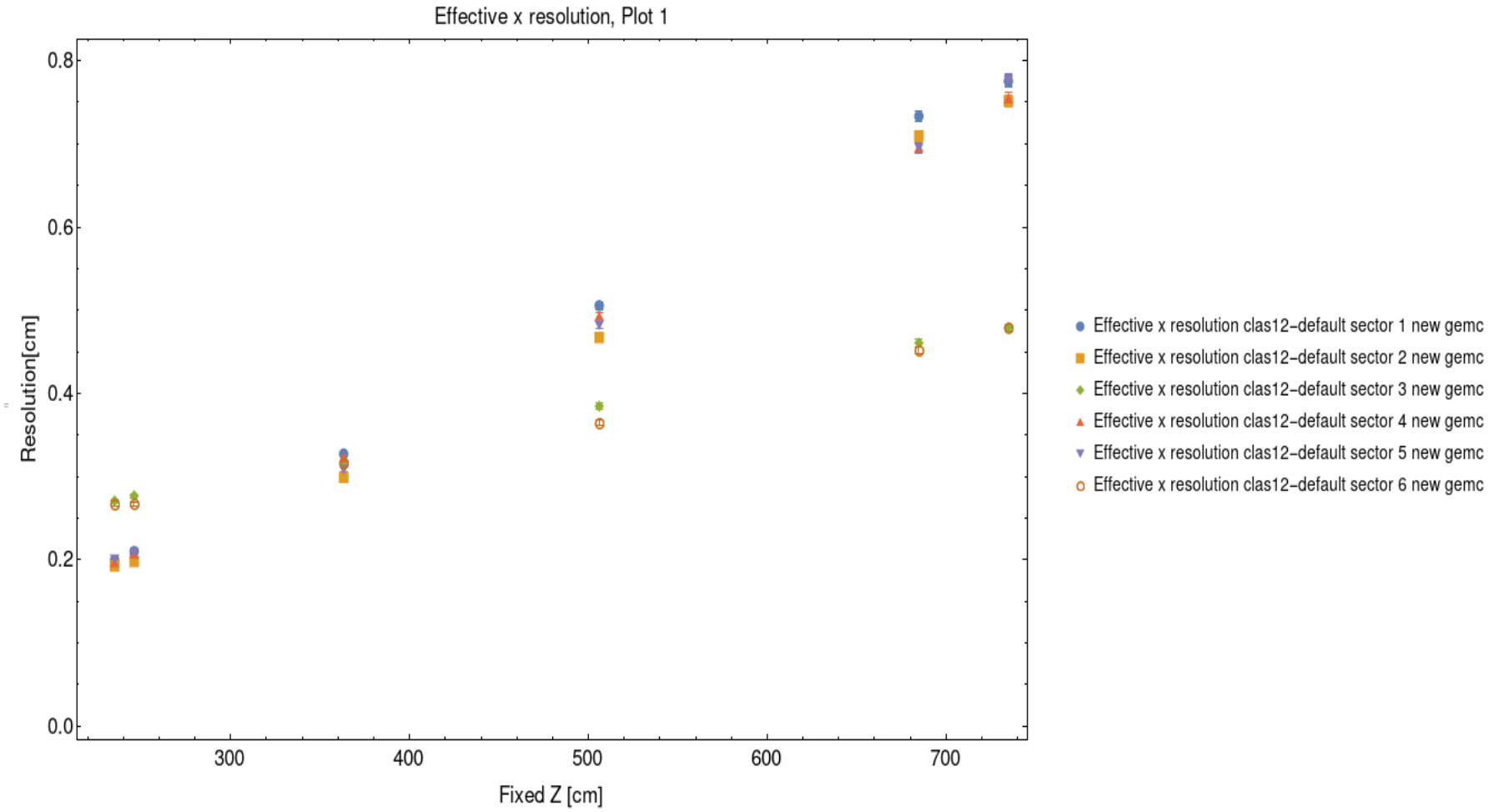


Appendix: Resolution sector dependence



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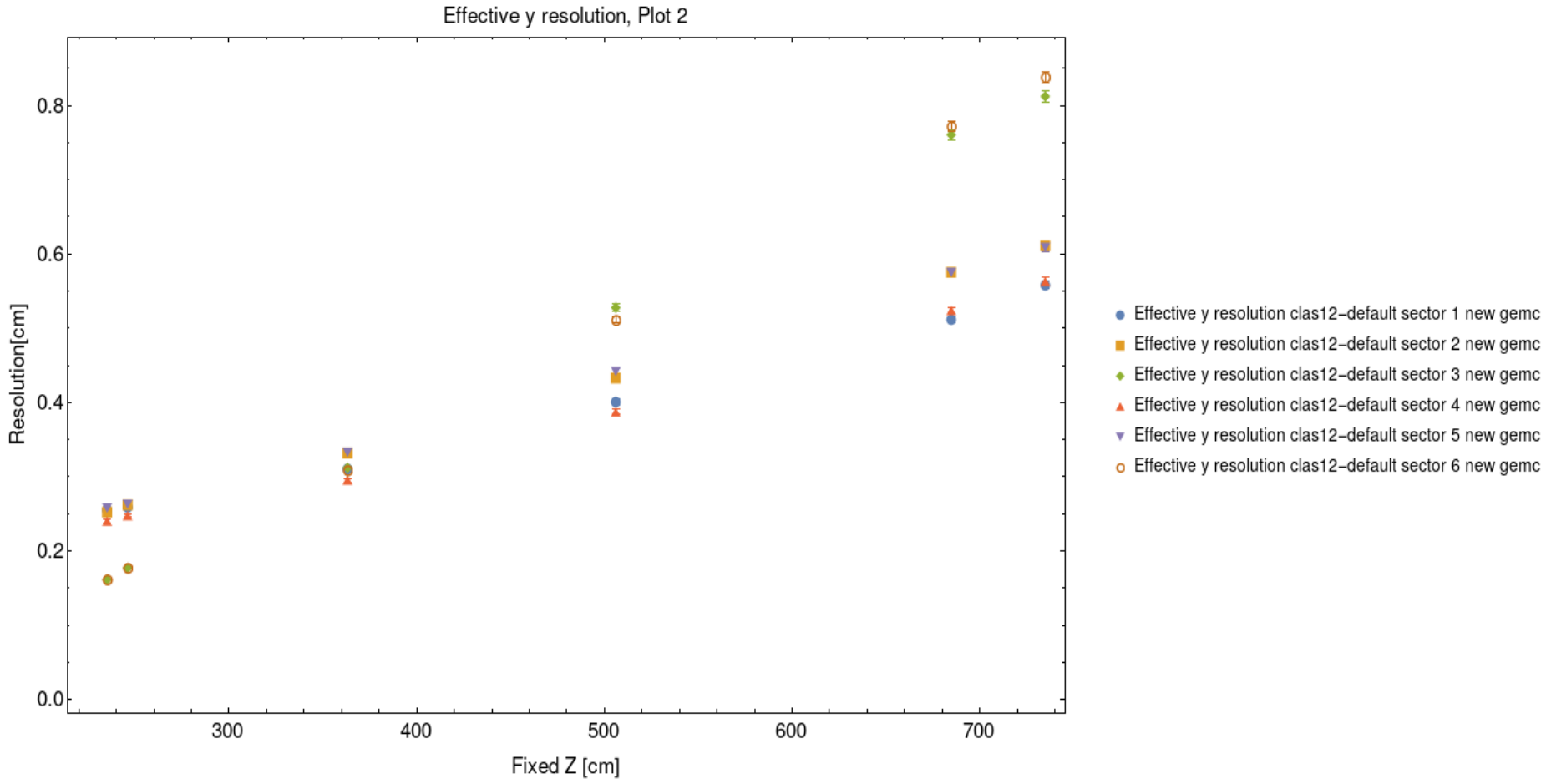

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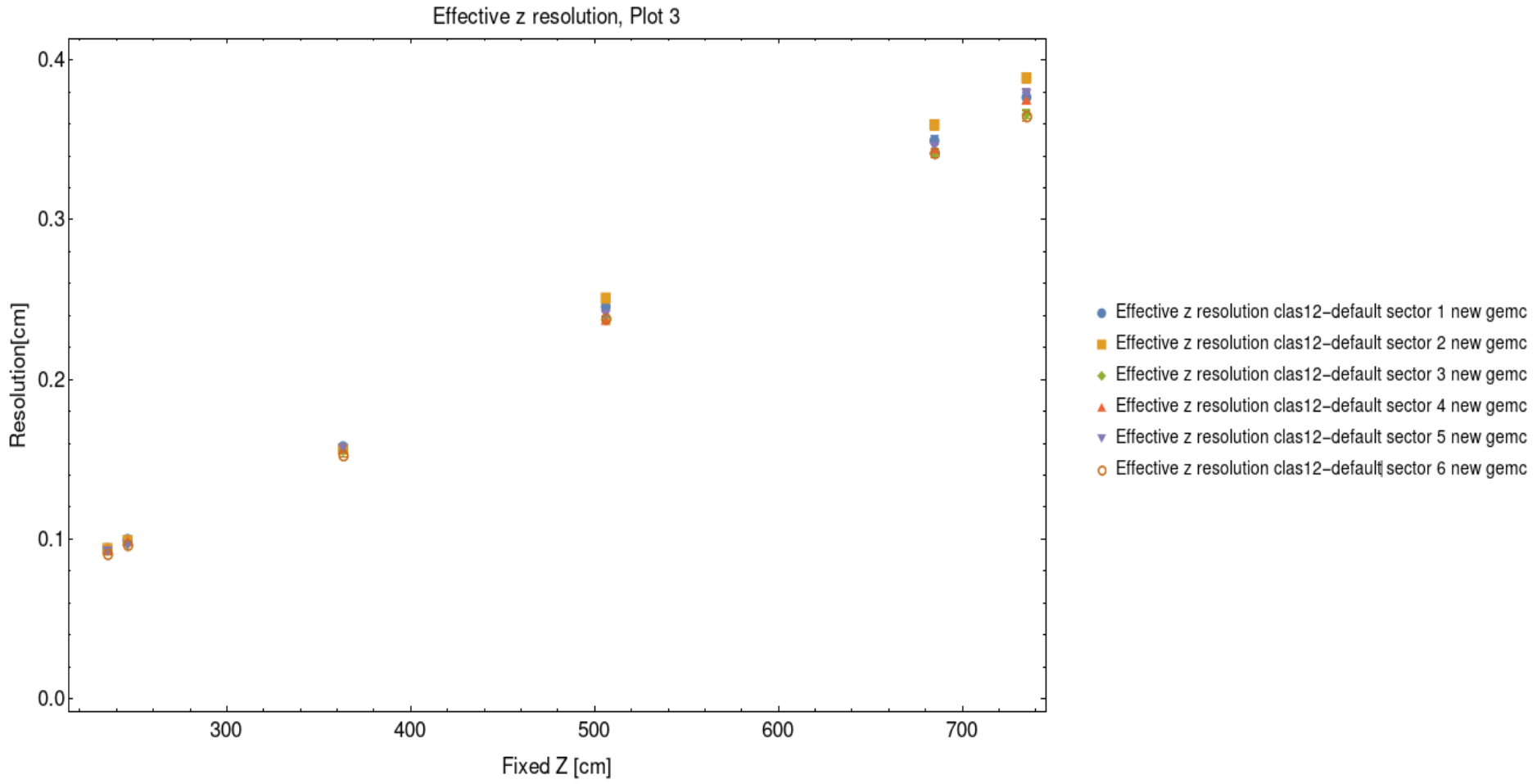

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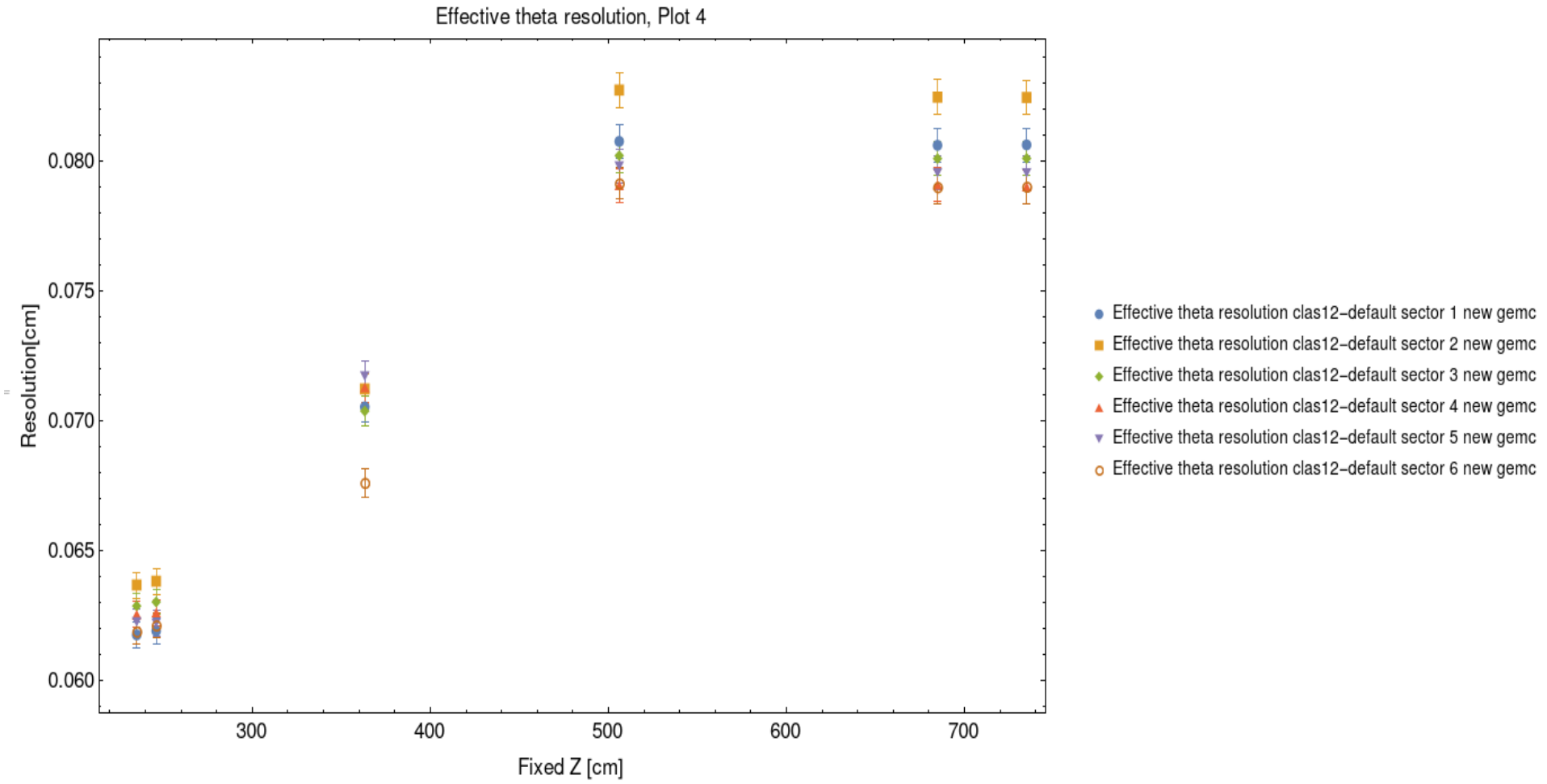

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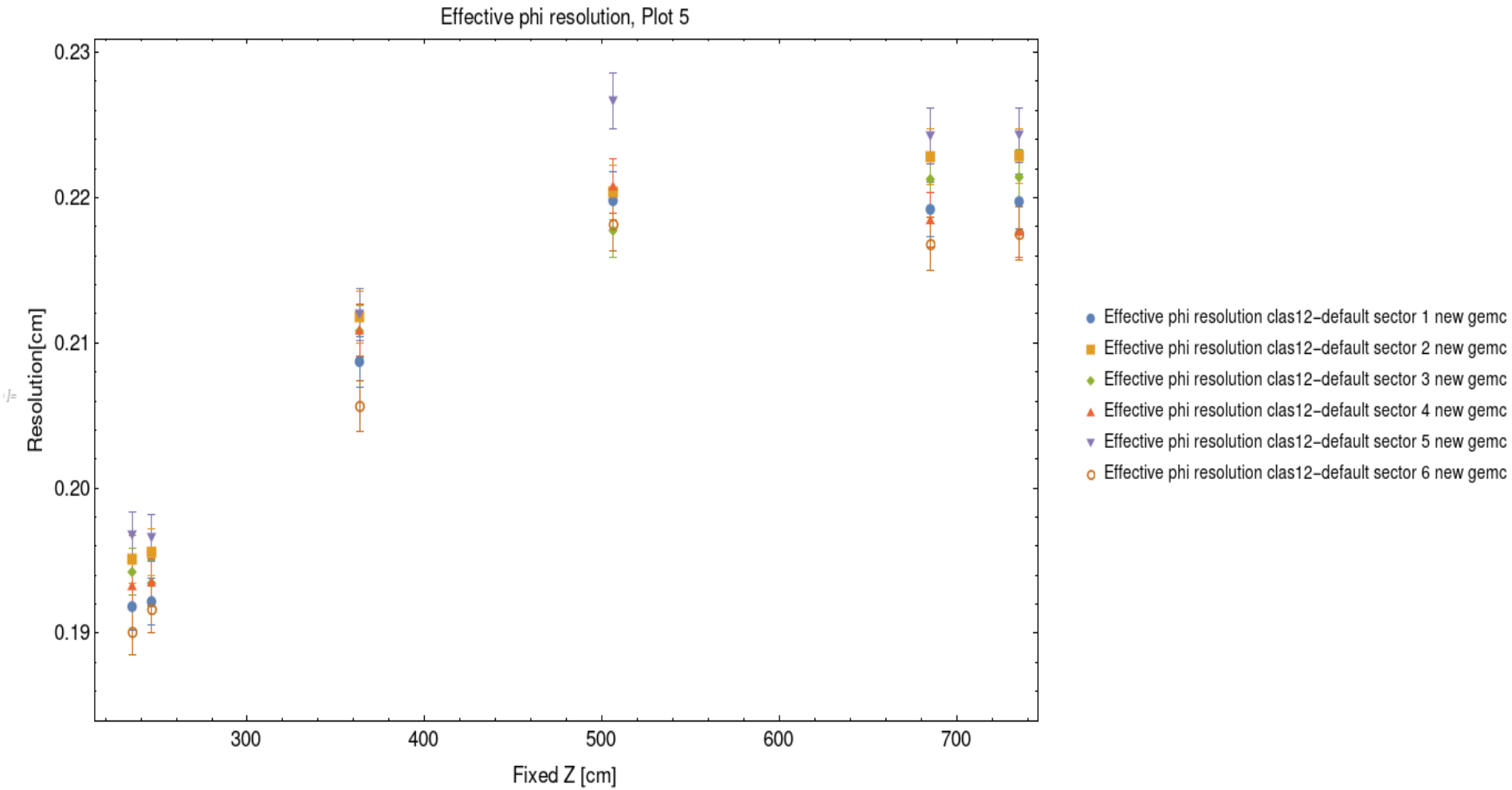

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