Locating quench origin by second sound detection

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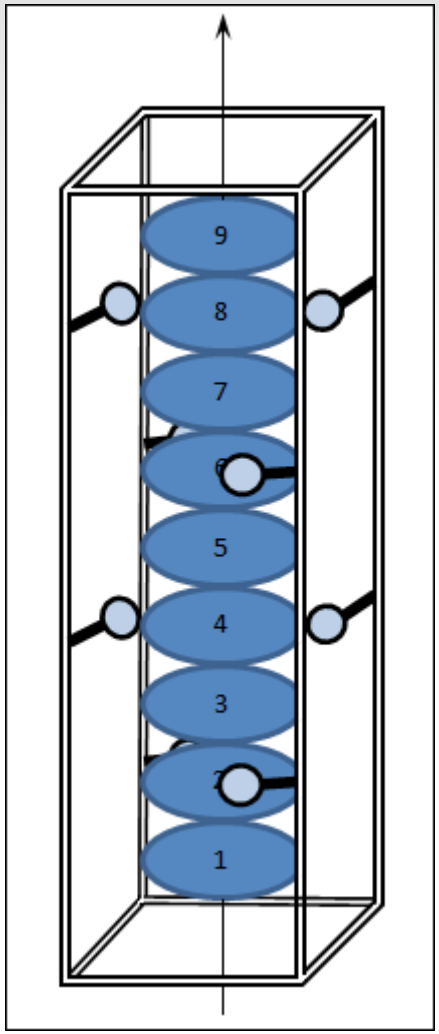
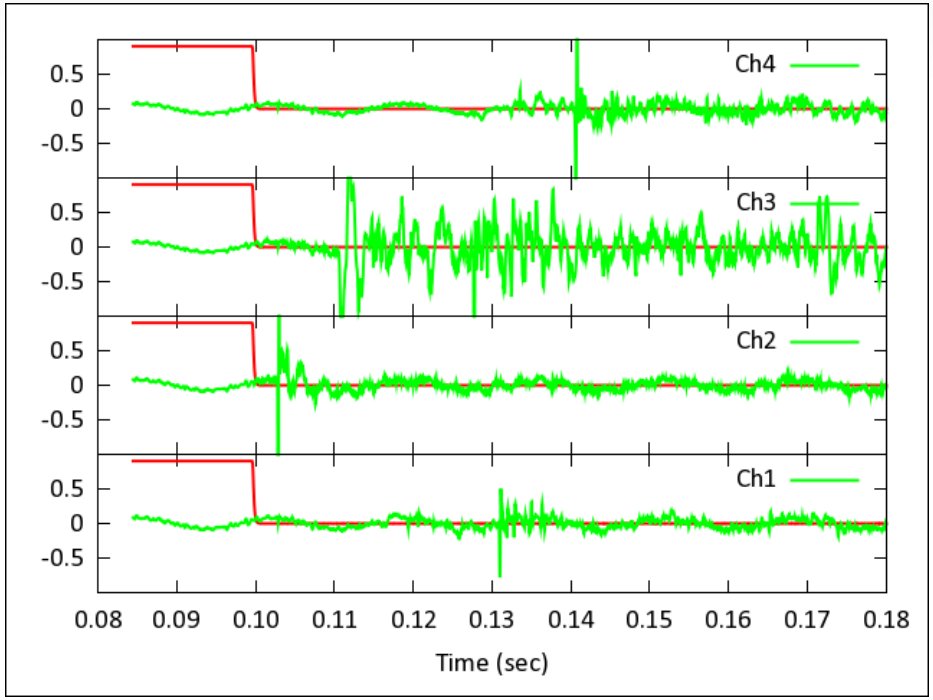
Inverse problem to locate quench origin



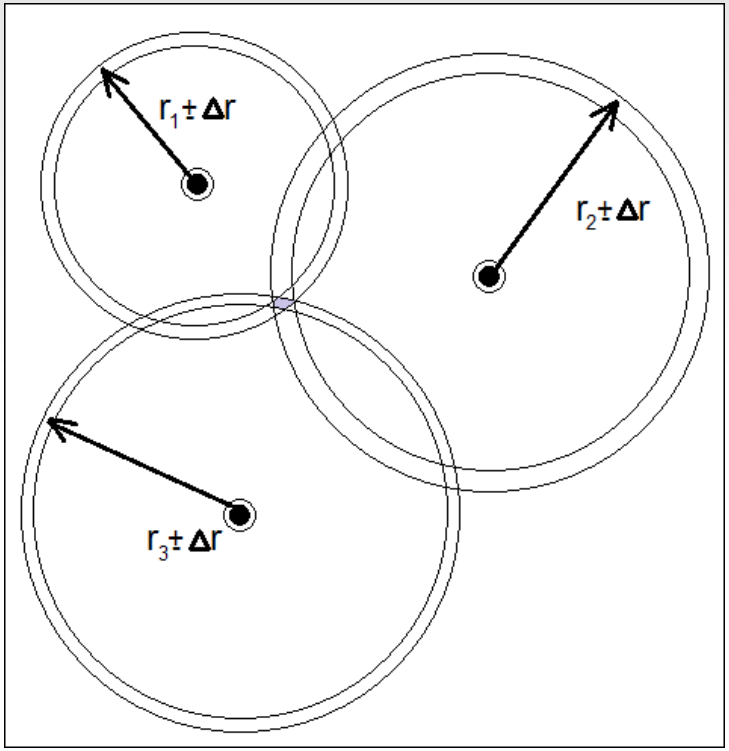
Measured times $t_i \rightarrow r_i \rightarrow$ quench origin coordinates.



Solution

Overdetermined system of nonlinear equations:

$$(x_0 - x_i)^2 + (y_0 - y_i)^2 + (z_0 - z_i)^2 = C^2 \cdot t_i^2, i = \overline{1,n}$$



C – second sound velocity
n – number of ss-transducers
(x_i, y_i, z_i) – i-transducer coordinates
(x_0, y_0, z_0) – quench origin, variables

$\Rightarrow$ Minimum norm solution.

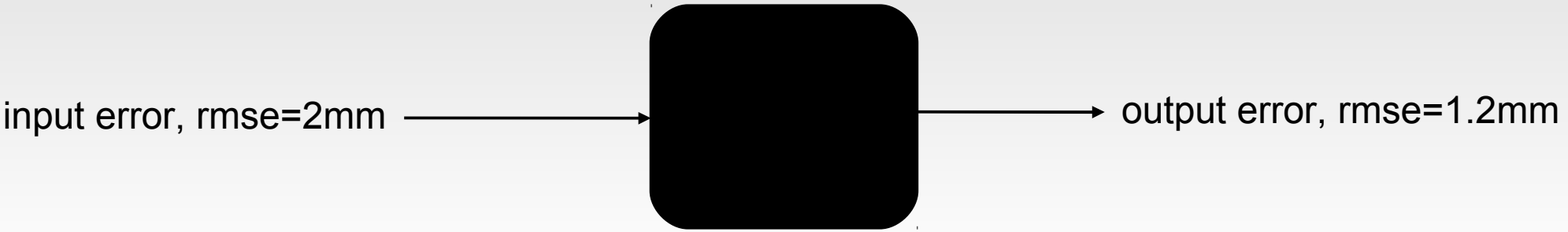
Function to minimize:

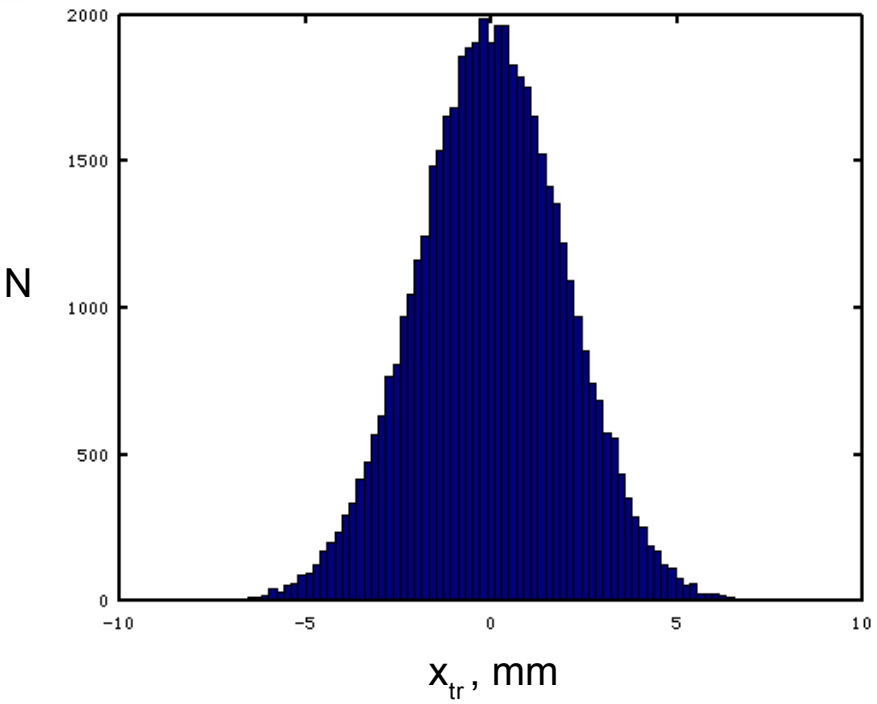
$$f(x_0, y_0, z_0) = \sum_{i=1}^{n} \left[(x_0 - x_i)^2 + (y_0 - y_i)^2 + (z_0 - z_i)^2 - C^2 \cdot t_i^2 \right]^2$$

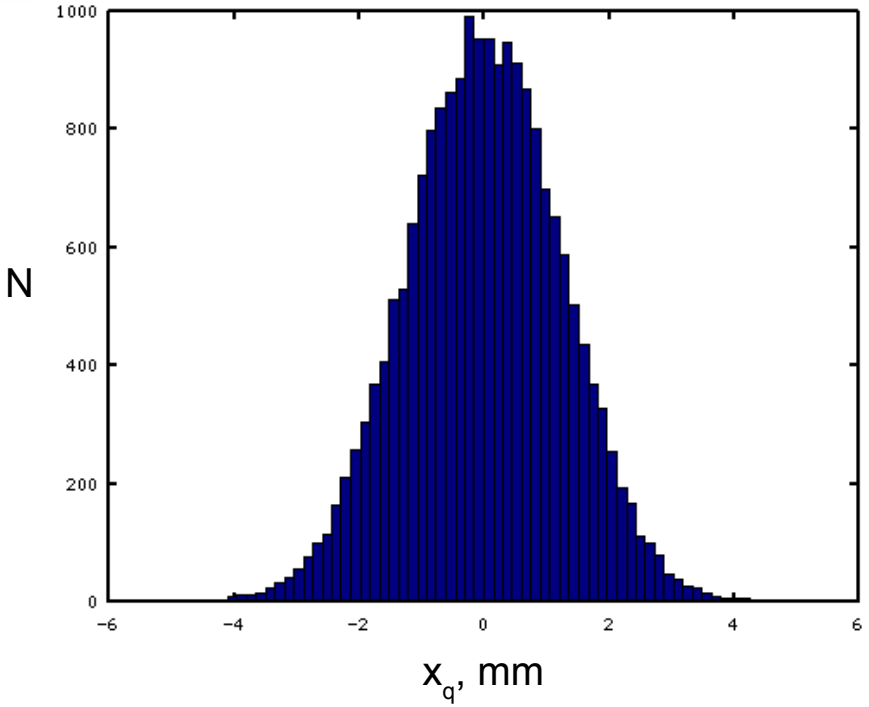
The method of minimization is Nelder-Mead Algorithm, i.e. downhill simplex method, GNU Octave implementation.

RMS error analysis

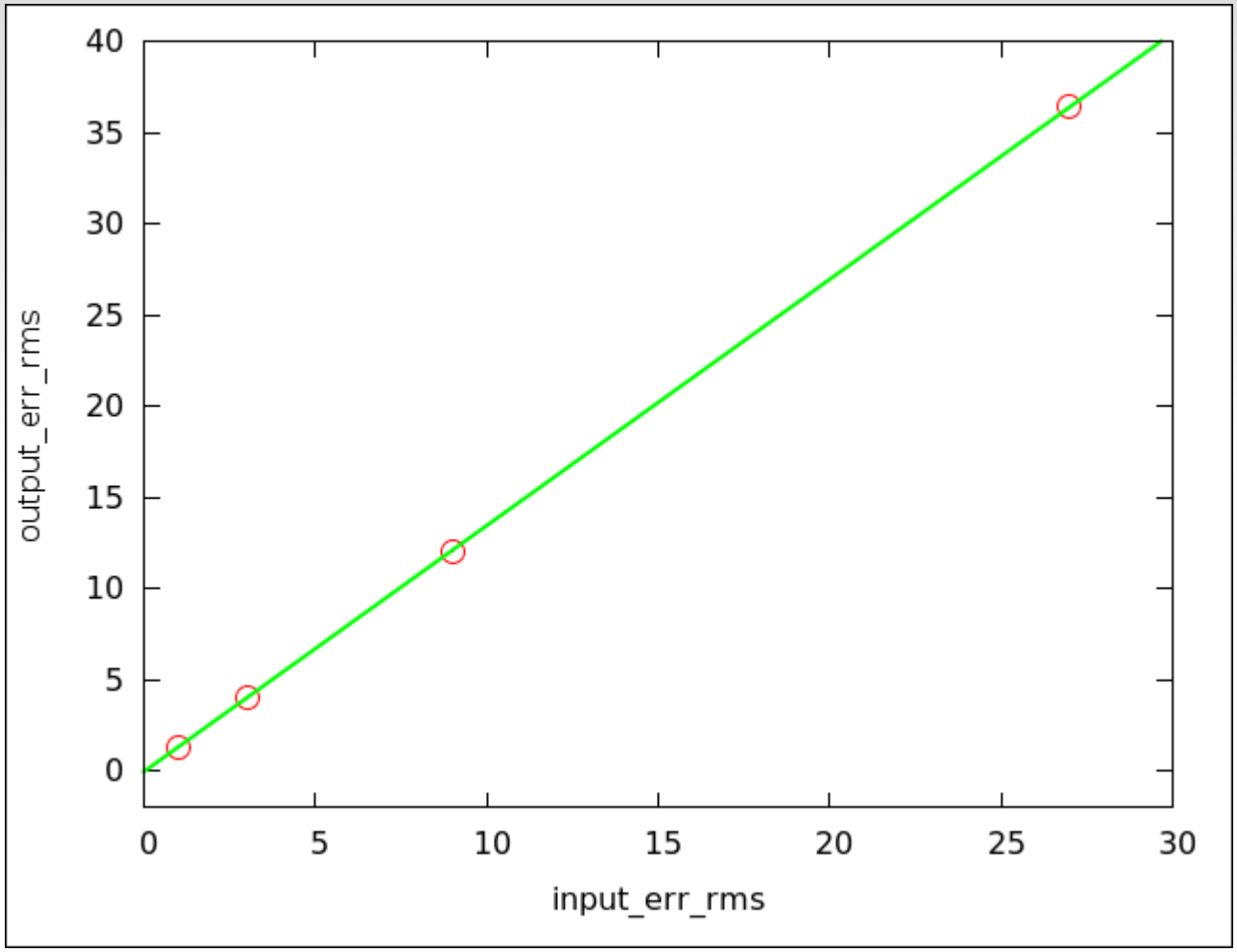
Monte Carlo Simulation







RMS error analysis

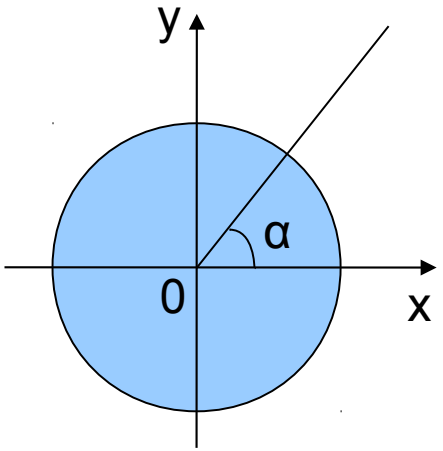


$O(x_0,y_0,z_0)$ – quench origin

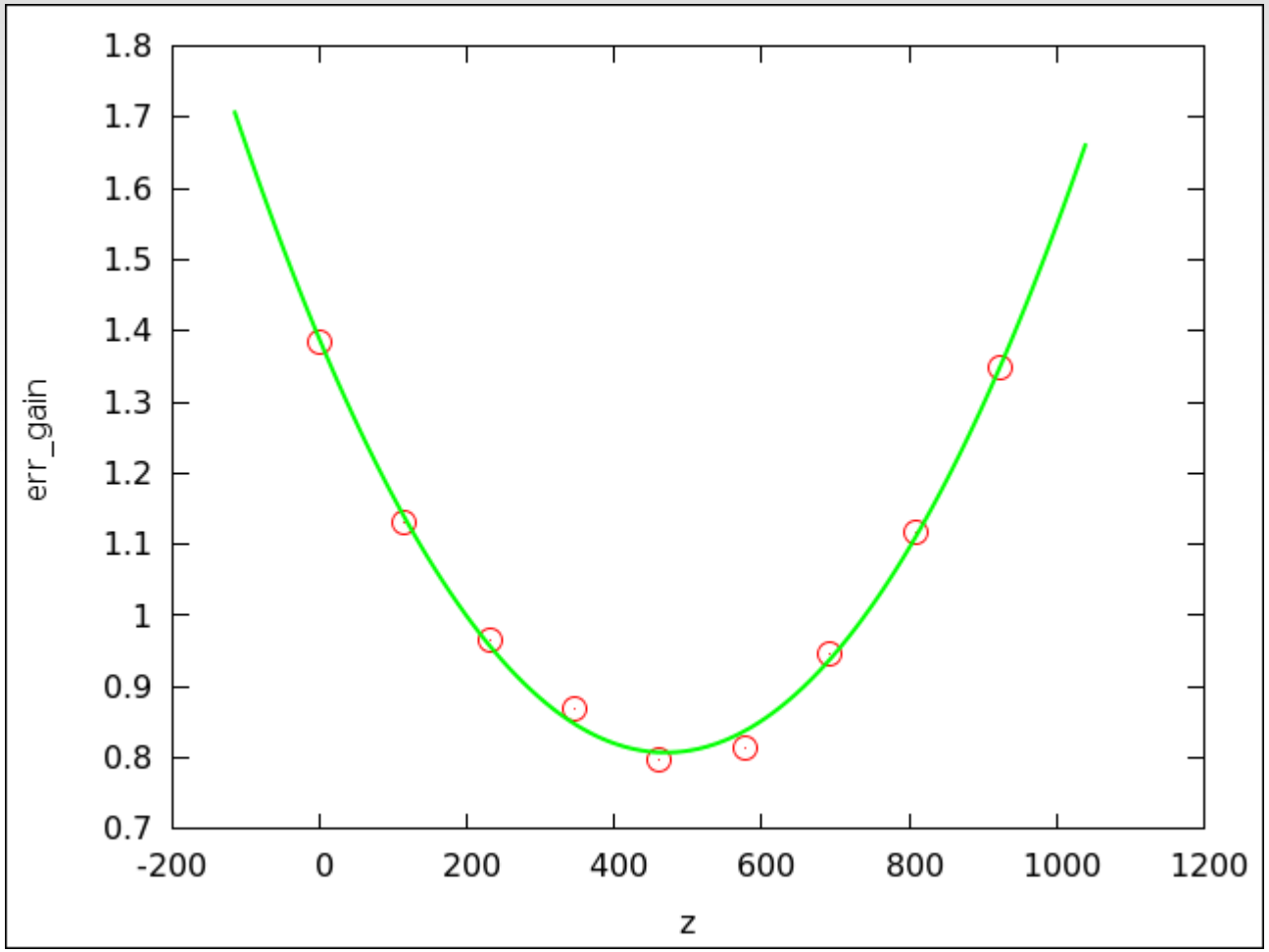
$$\sin(\alpha) = \frac{y_0}{r_0}$$

$$tg(\alpha) = \frac{y_0}{x_0}$$

Z_0=0, first cell



RMS error analysis

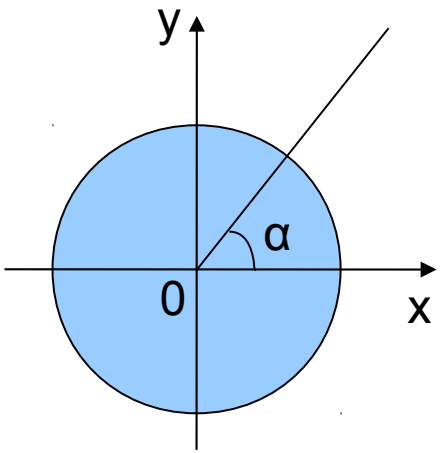


$O(x_0,y_0,z_0)$ – quench origin

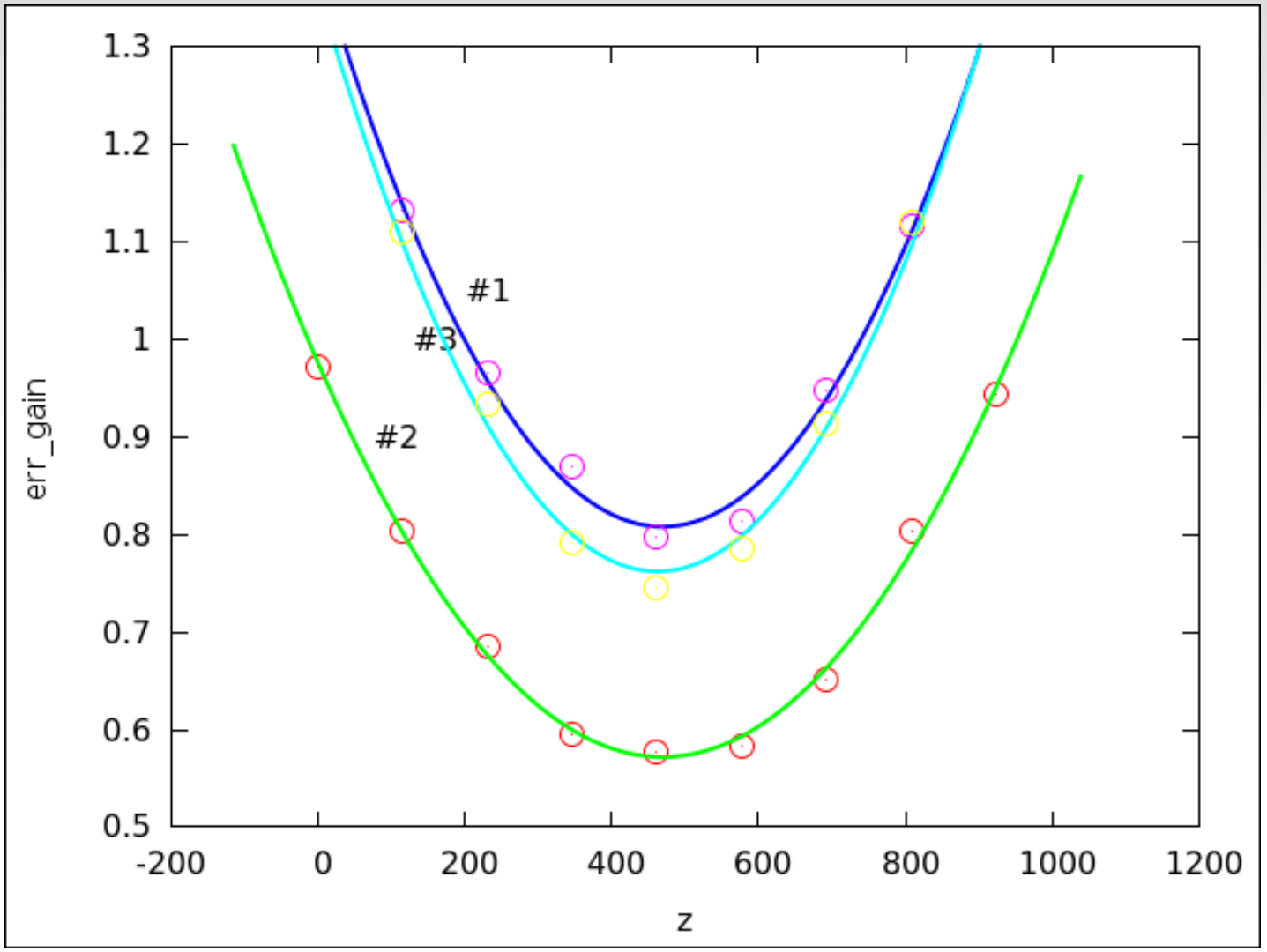
$$\sin(\alpha)=\frac{1}{2}$$

$$tg(\alpha)=\frac{y_0}{x_0}$$

Fix α, vary z_0.



Different detectors configuration

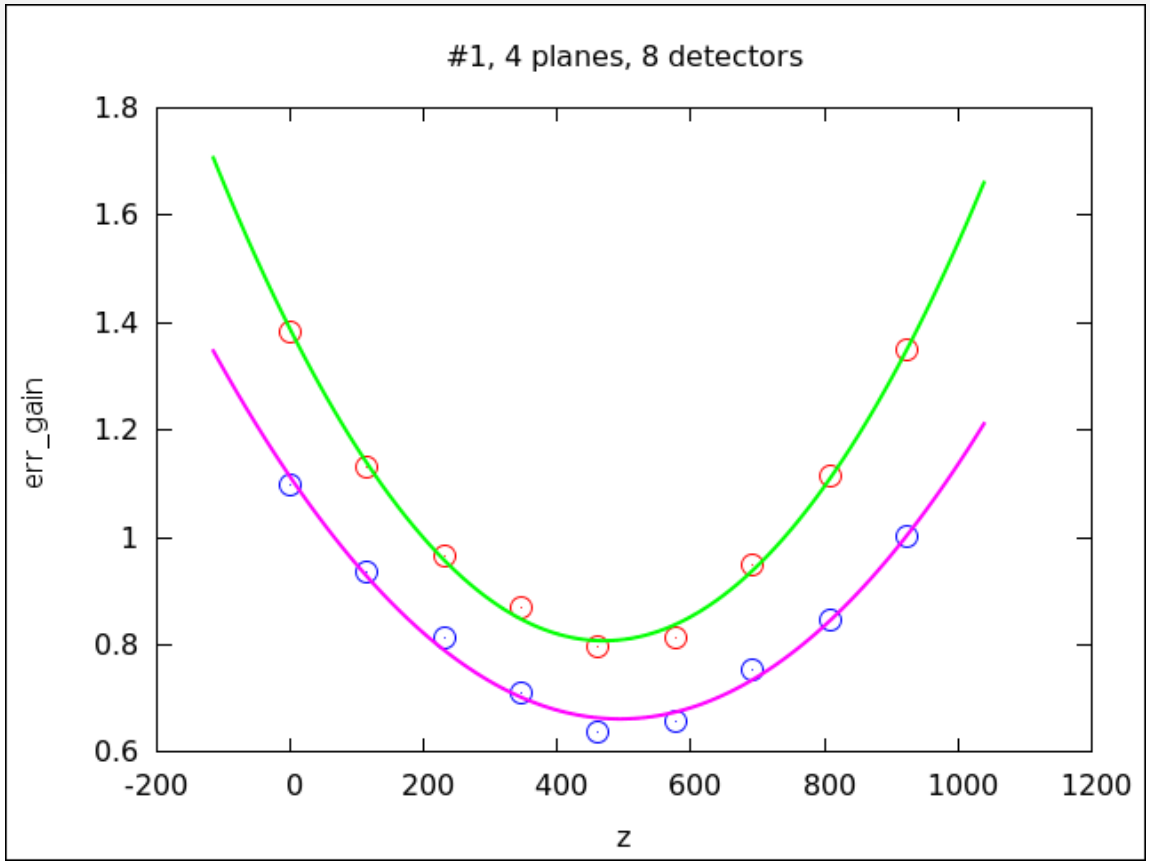


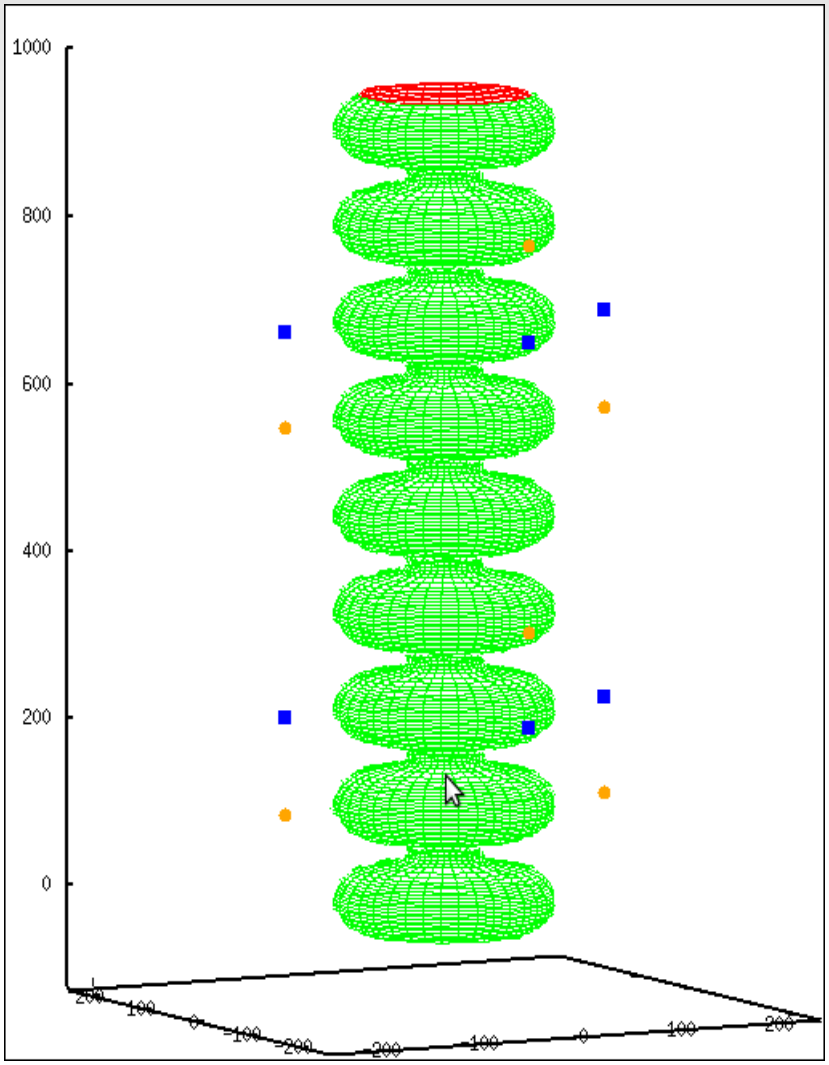
#1 – 4 planes, 8 detectors; #2 – 4 planes, 16 detectors; #3 – 2 planes, 8 detectors

Cavity surface restriction

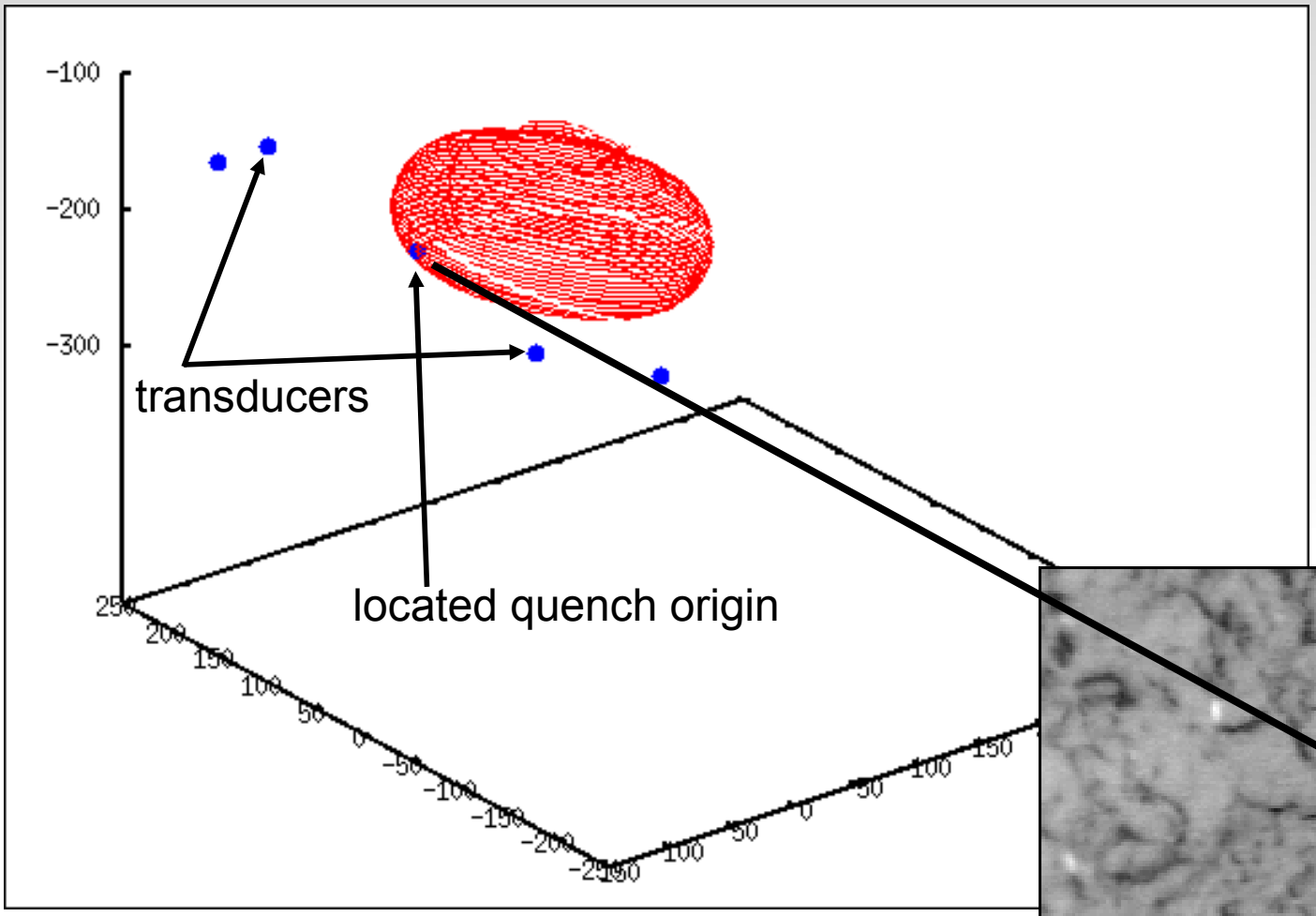
Variables number reduction in the error function:

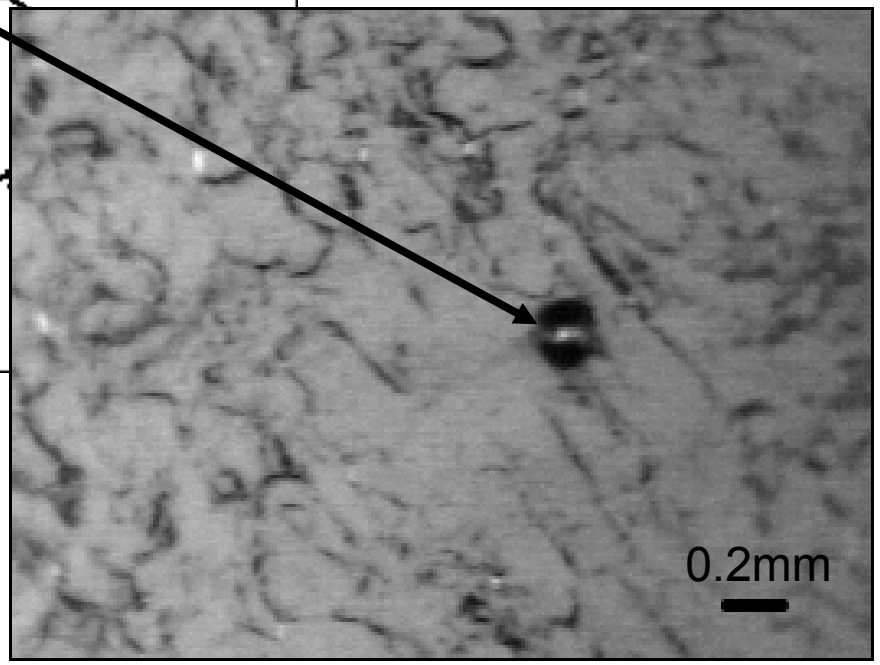
$$(x_0, y_0, z_0) \rightarrow (\alpha_0, z_0)$$





Single cell experiment





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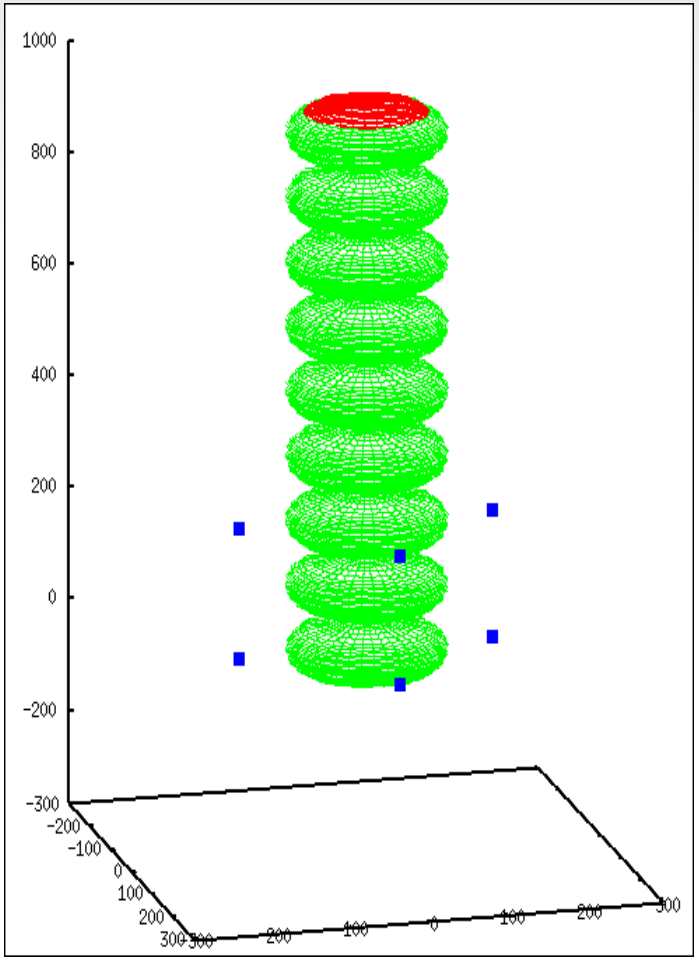
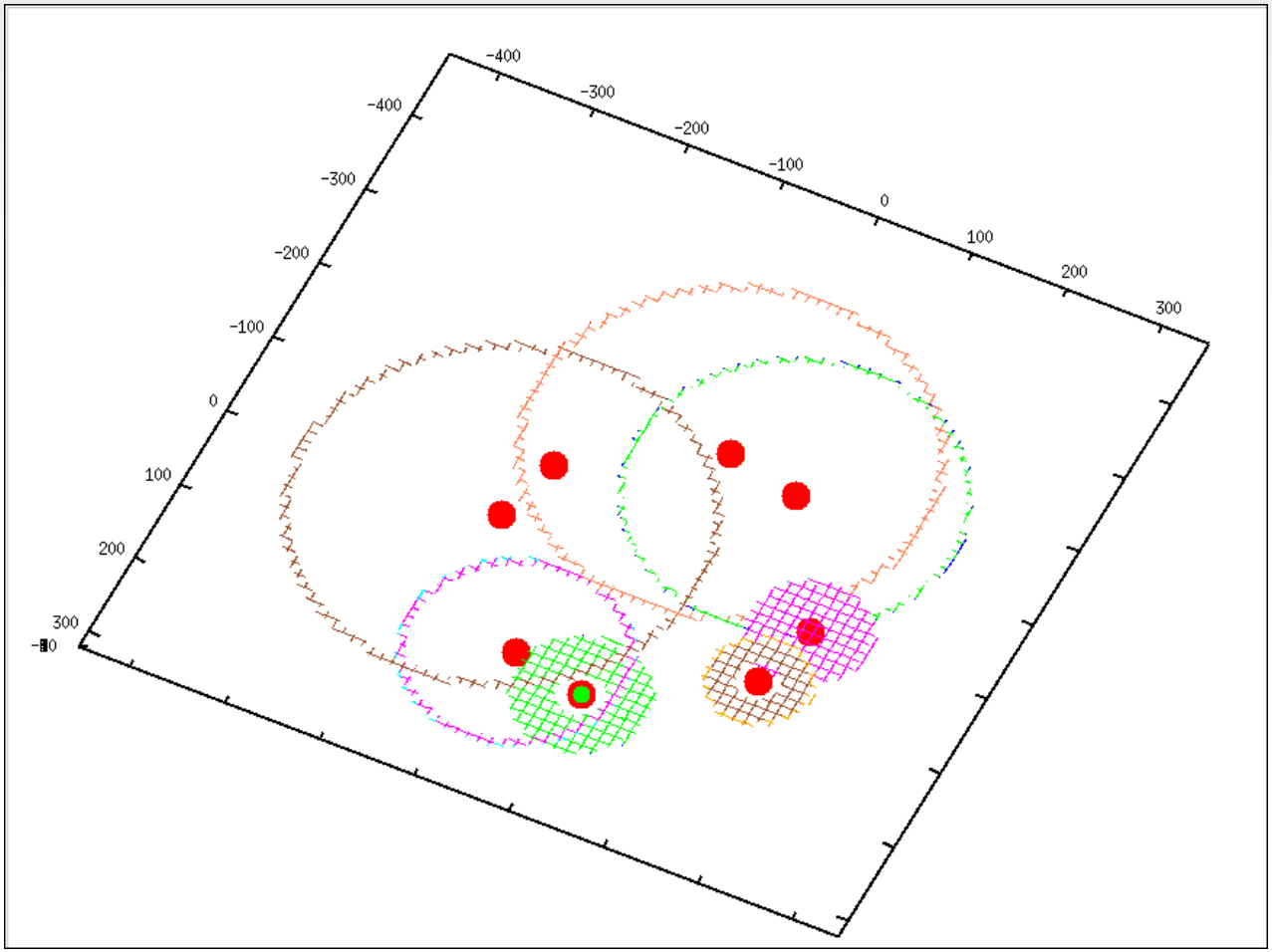
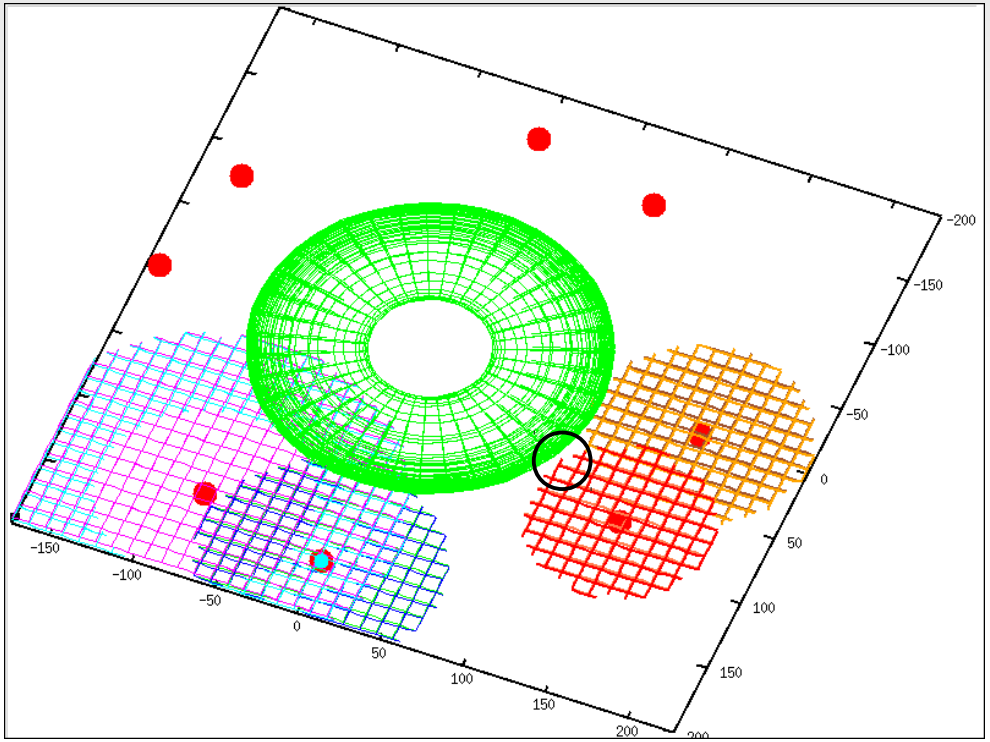
9-cell experiment

Inconsistent readings: $r_{i\_msr} < r_{i\_true}$

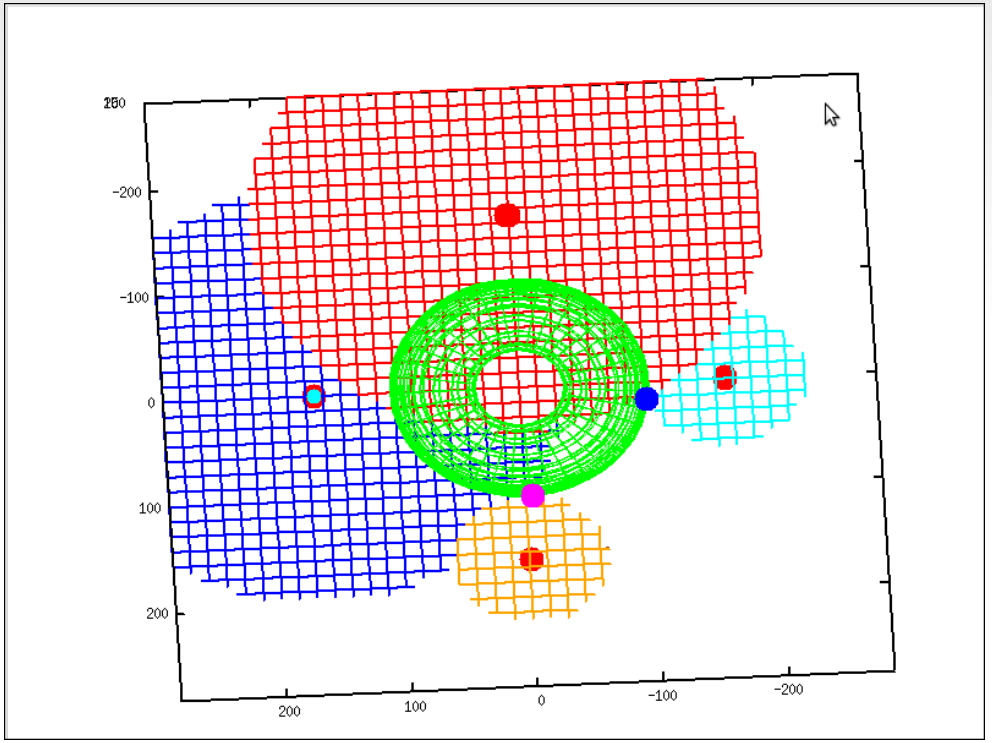




Helium blob



Hot spot



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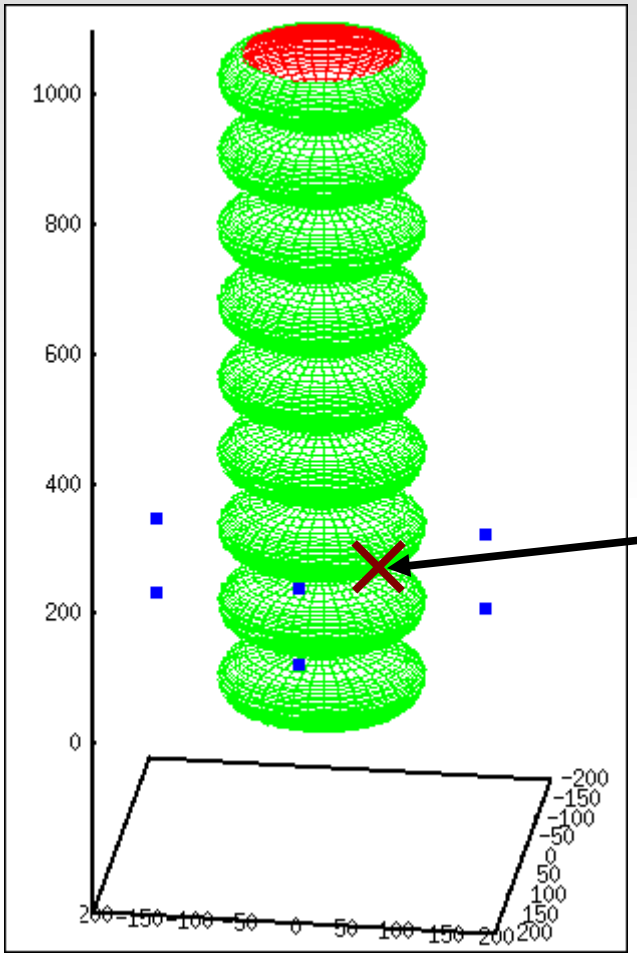
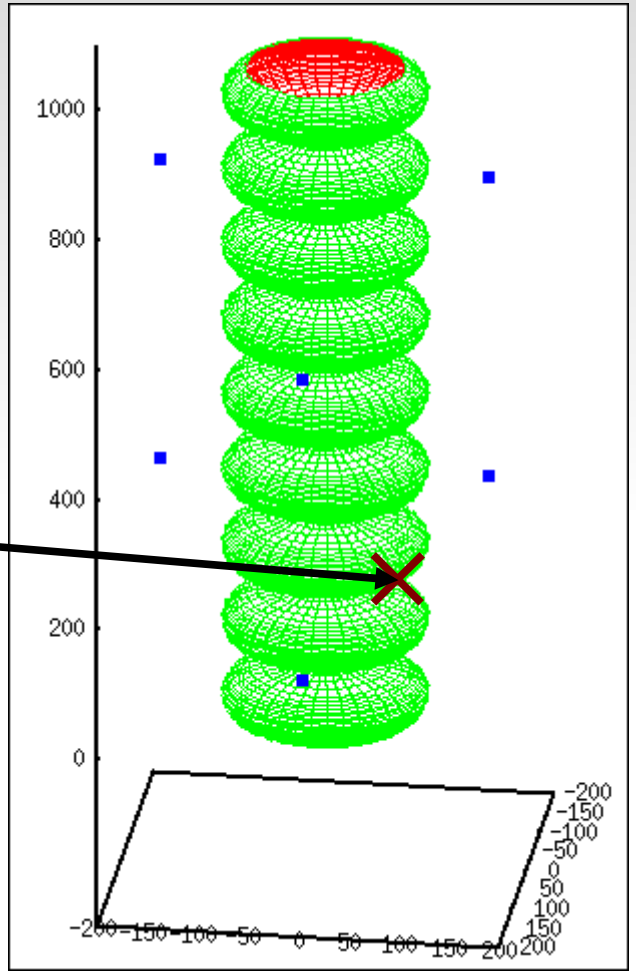


same answer



Δr = 3mm

Thank you for your attention!