PSA uncertainties estimation via bootstrap technique

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BOOTSTRAP

The **bootstrap** is a statistical technique based on resampling used to estimate statistical properties (e.g. average, standard deviation, etc.) of a population, when the statistical distribution trend is unknown.

It can be used for constructing hypothesis tests, in particular when parametric inference is impossible or requires complicated formulas for the calculation of standard errors.

➢ Estimate some properties of AGATA Pulse-Shape Analysis

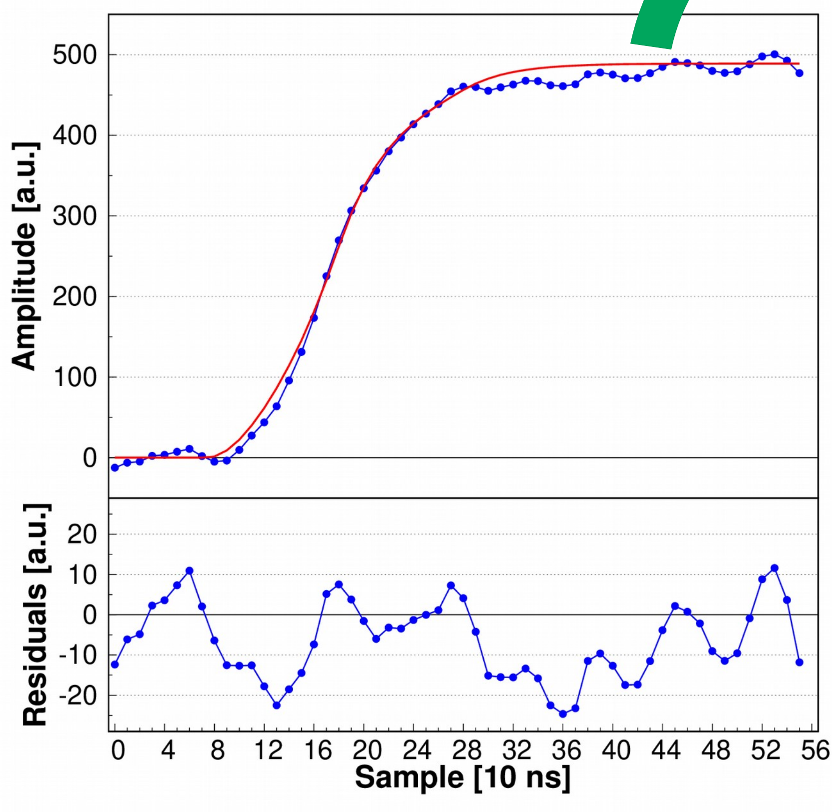
- ✔ Simplicity
- ✔ Verify stability of the results
- ✔ Asymptotic convergence of the estimators

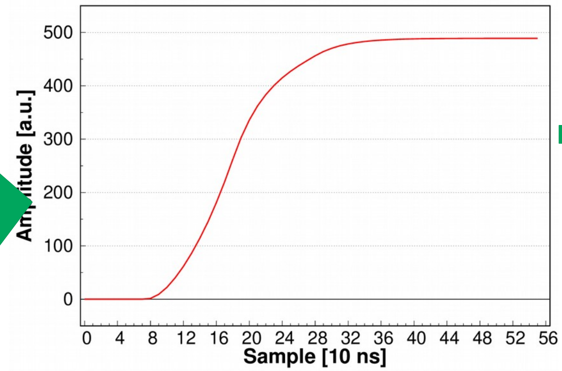
- ✗ Large resampling iterations to guarantee convergence
- ✗ Resources demanding

BOOTSTRAP WITH AGATA

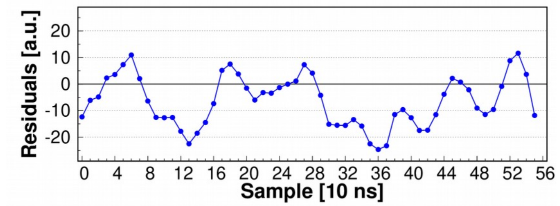
By comparing the original (short) trace with those from the database, the γ-ray interaction point position is identified inside the segment.

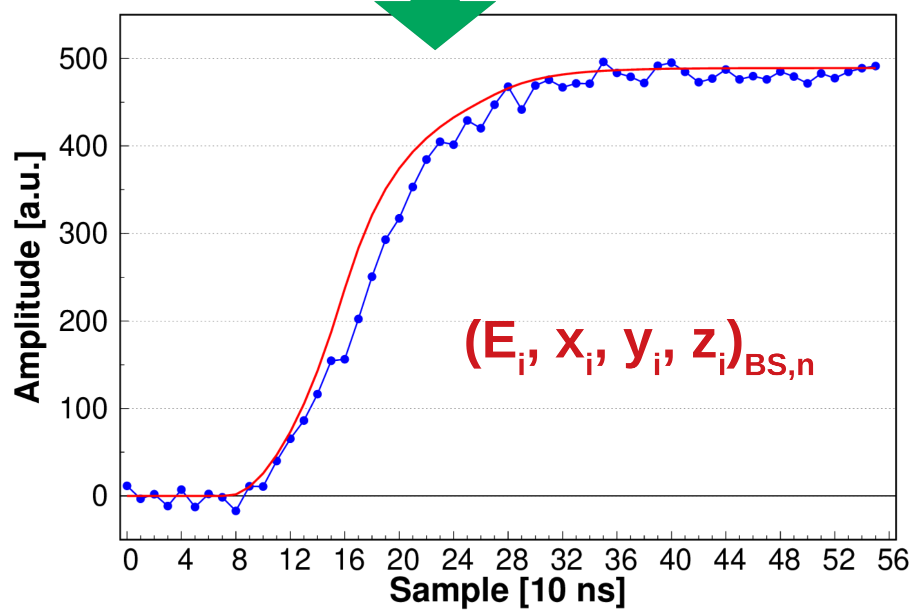
$(E_i, x_i, y_i, z_i)_{OR}$





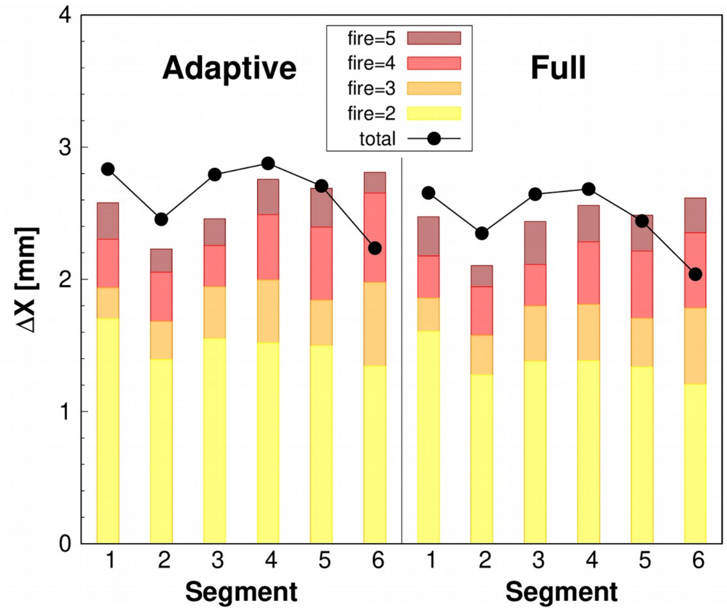
+ (RANDOM)

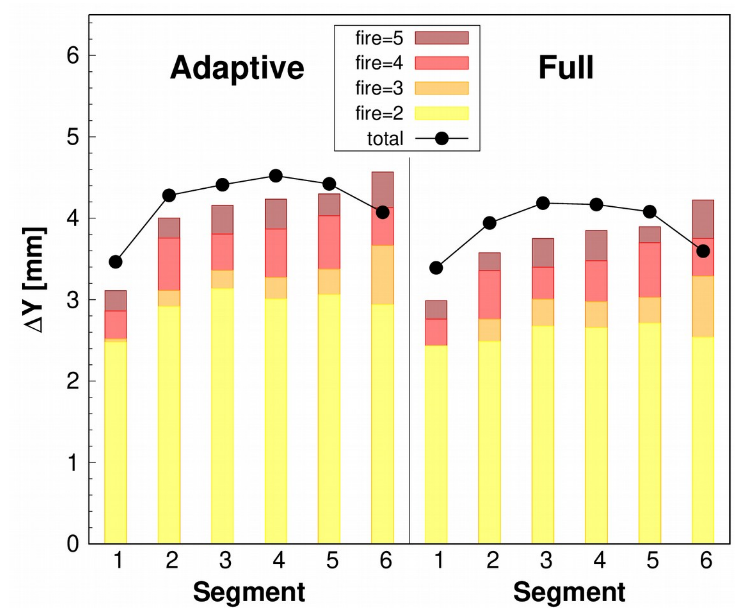




$(E_i, x_i, y_i, z_i)_{BS,n}$

RESULTS
PSA error vs Geometry

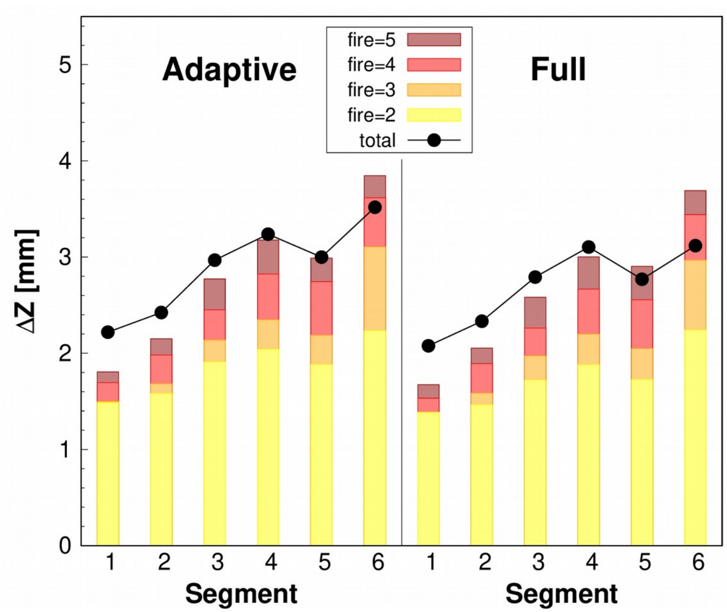


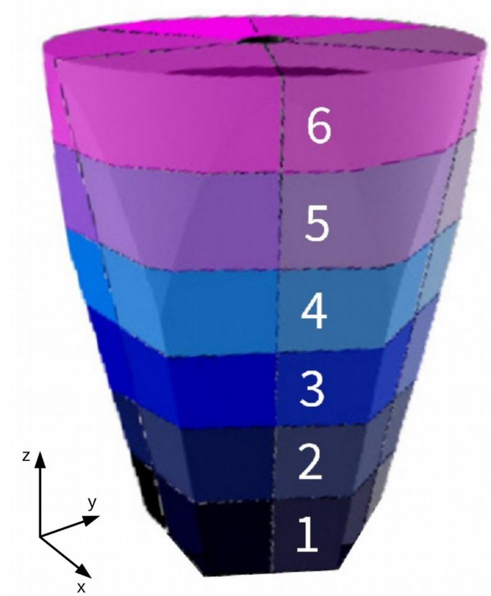


Along the X and Y directions the uncertainty is almost constant (σ~3mm)

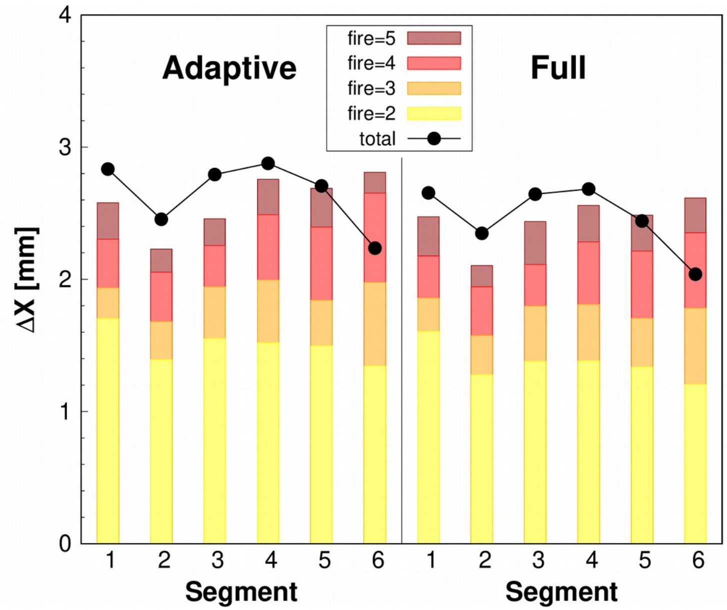
Along the Z direction the uncertainty increases with the crystal depth

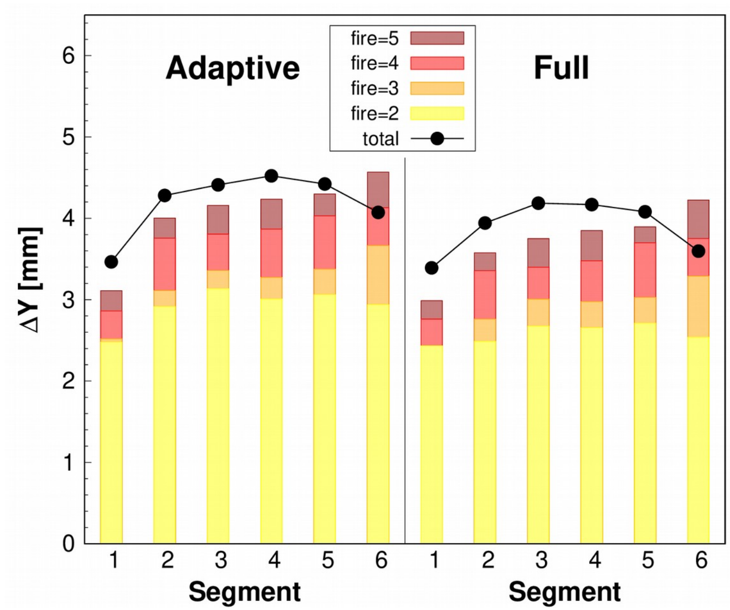
- Increasing size of the segments
- Higher-energy γ rays reach the bottom of the detector

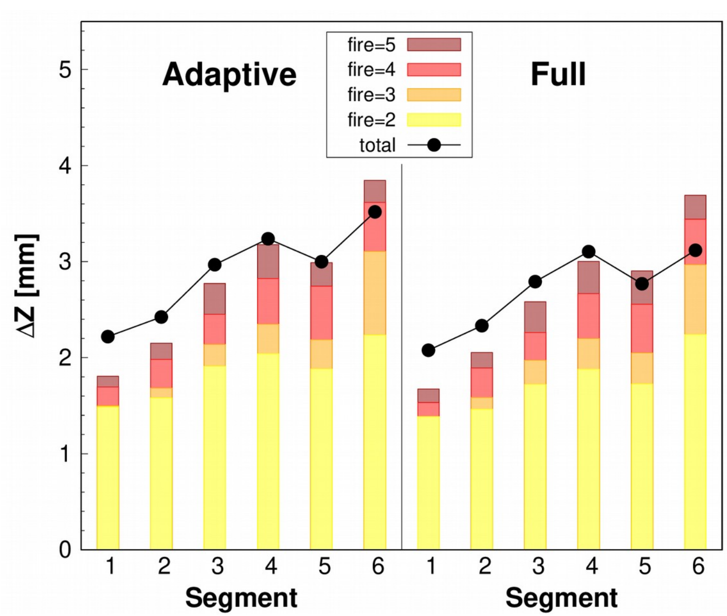


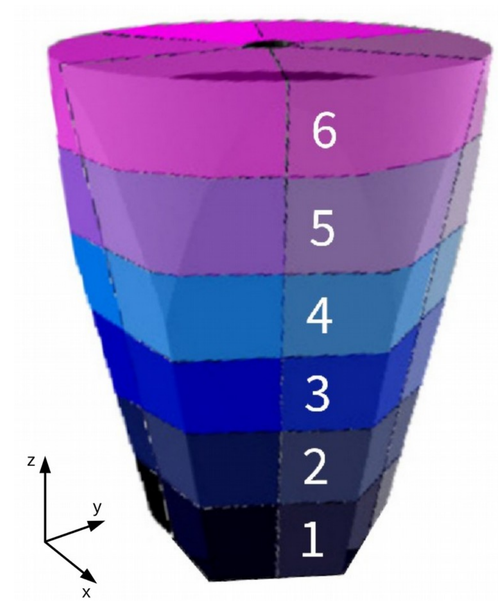


RESULTS
PSA error vs Fire









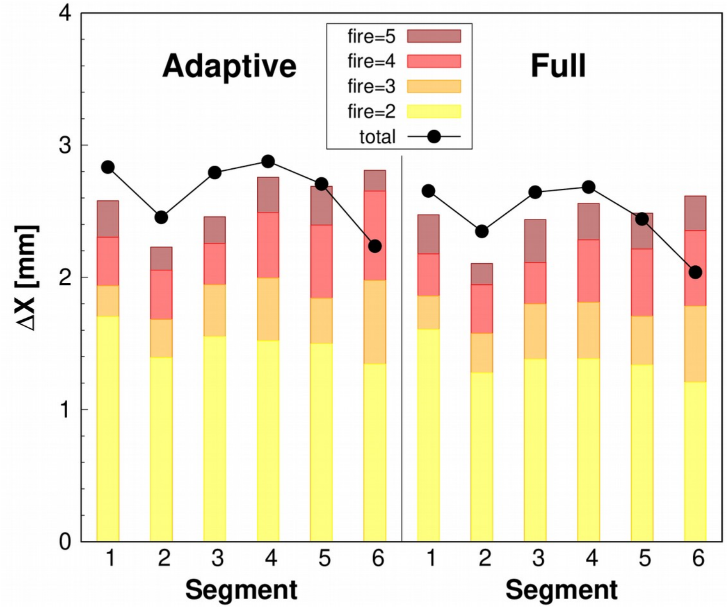
For fire=1 the bootstrap position is always equal to the original one

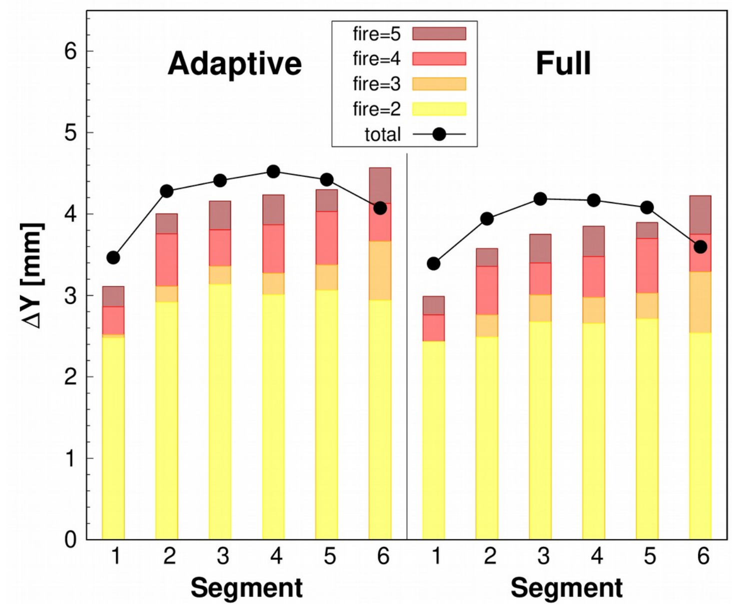
- The FoM is very deep and the bootstrap-related fluctuations are negligible

The uncertainty increases with the number of firing segments within the same crystal

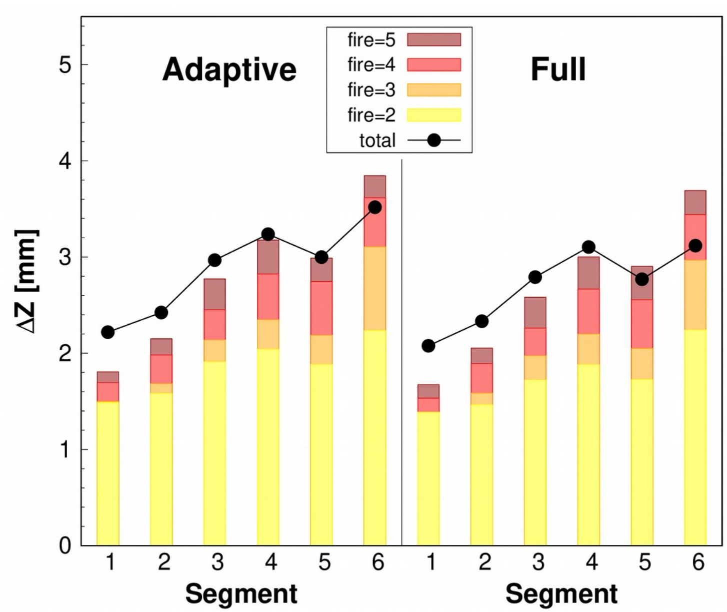
- PSA compares the one-hit signals-database with experimental overlapping signals

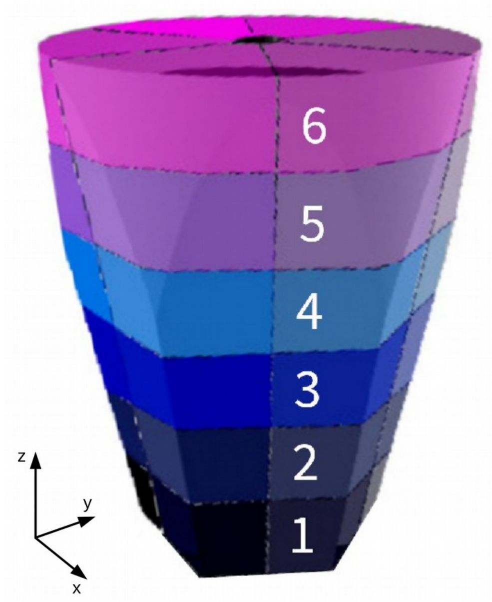
RESULTS
PSA error vs GridSearch





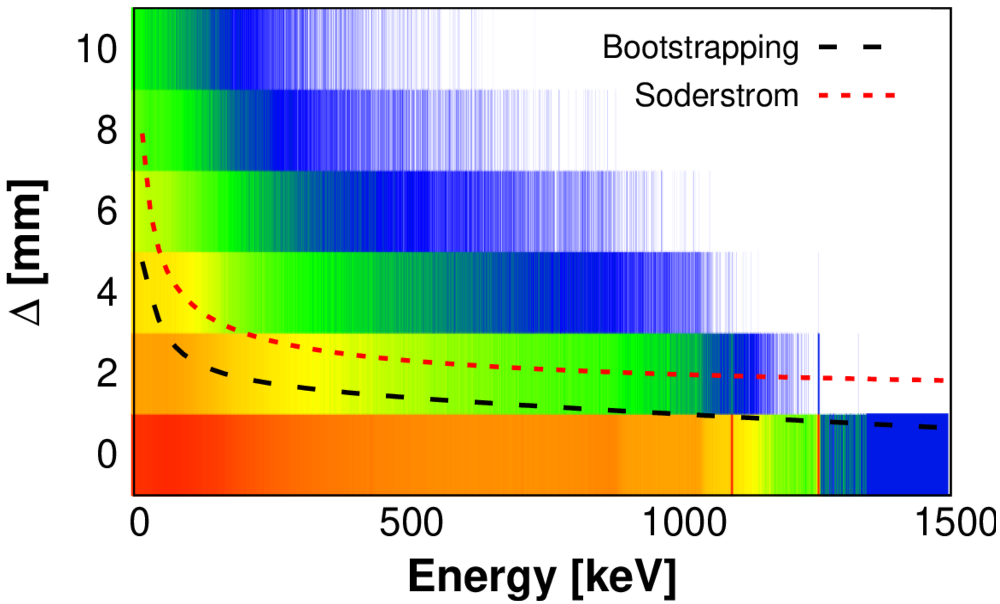
- ✔ The uncertainty of the “Full” grid search is 10% lower than the “Adaptive” mode





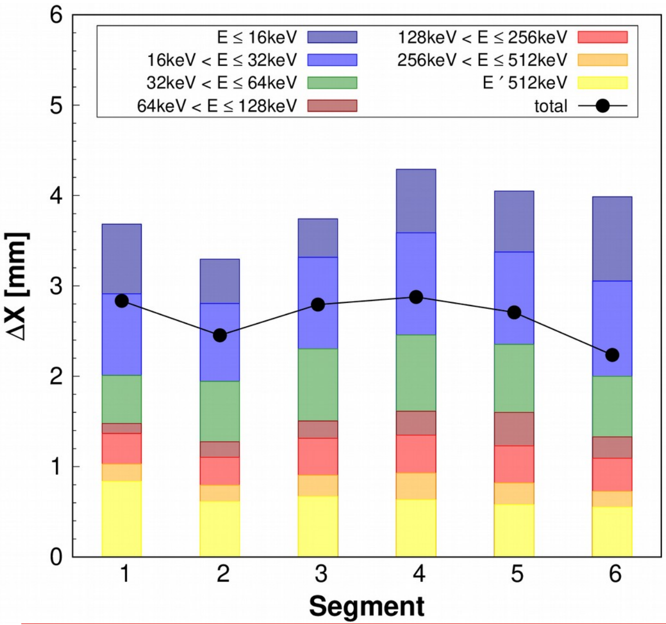
- ✗ “Full” grid search takes 10 times much more time than “Adaptive”

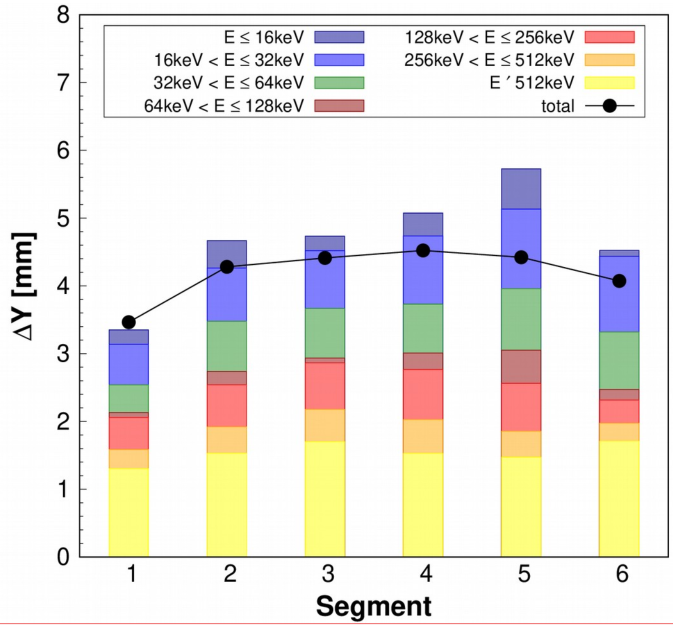
RESULTS
PSA error vs Energy

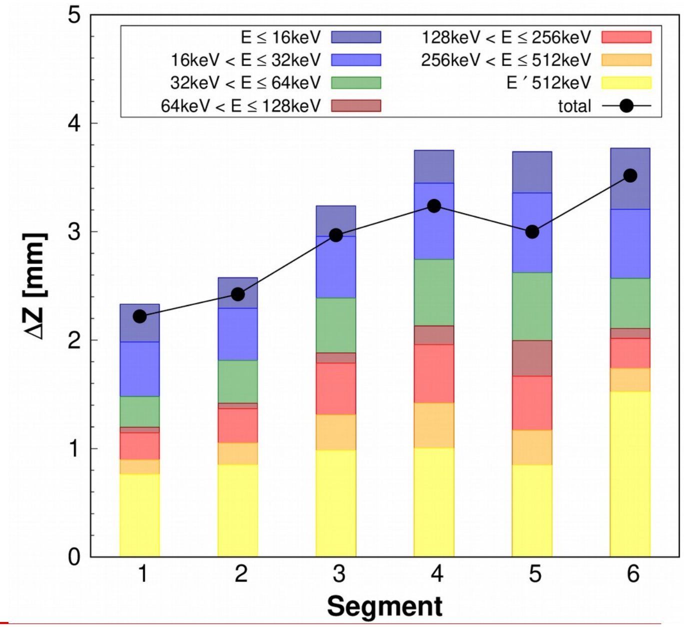


"Overall" uncertainty is define as the standard deviation of the quadratic sum the different distributions.

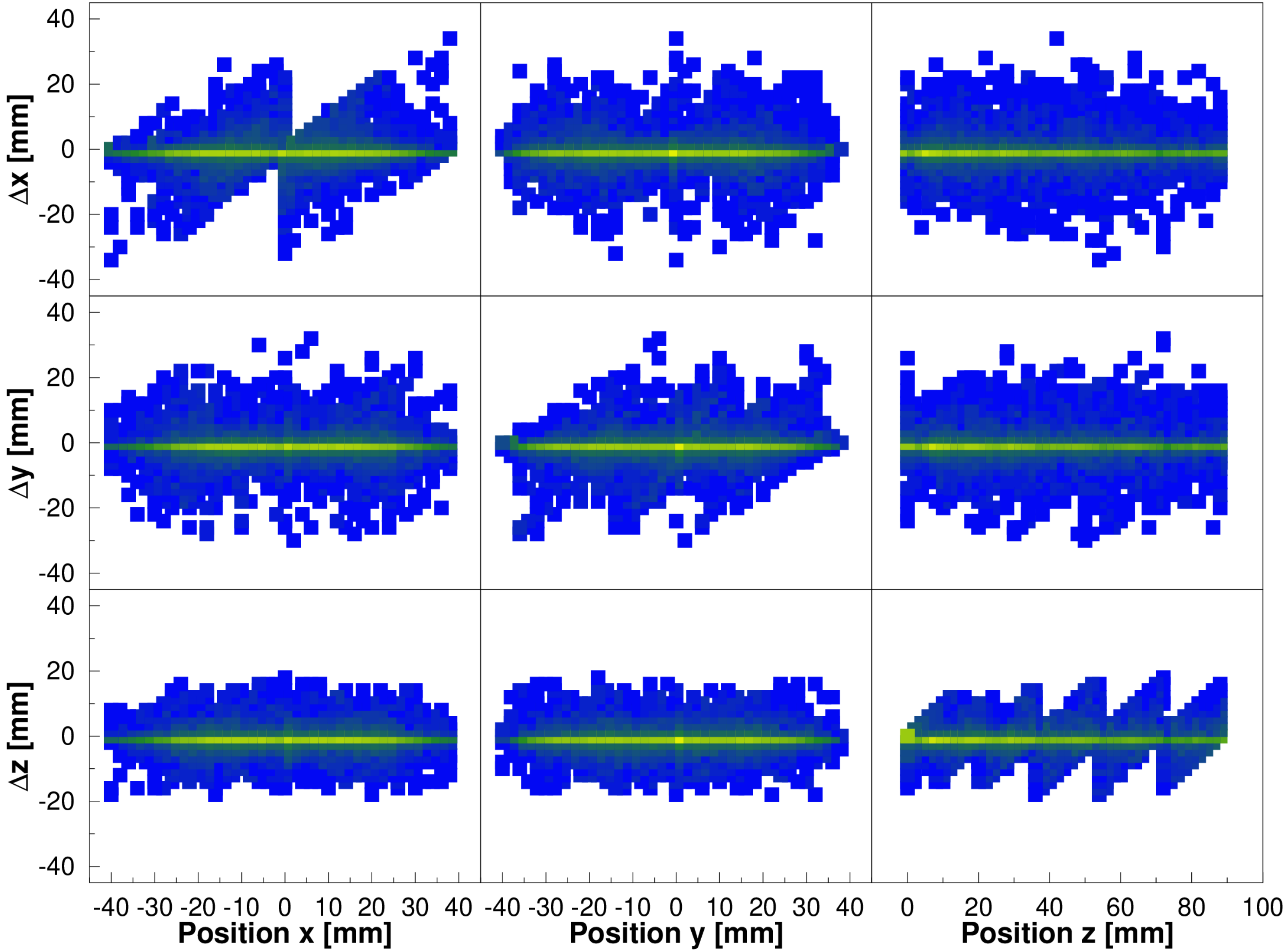
- Similar trend of the estimation of Soderstrom
- Position uncertainty is systematically ~1.1mm smaller than Soderstrom estimation





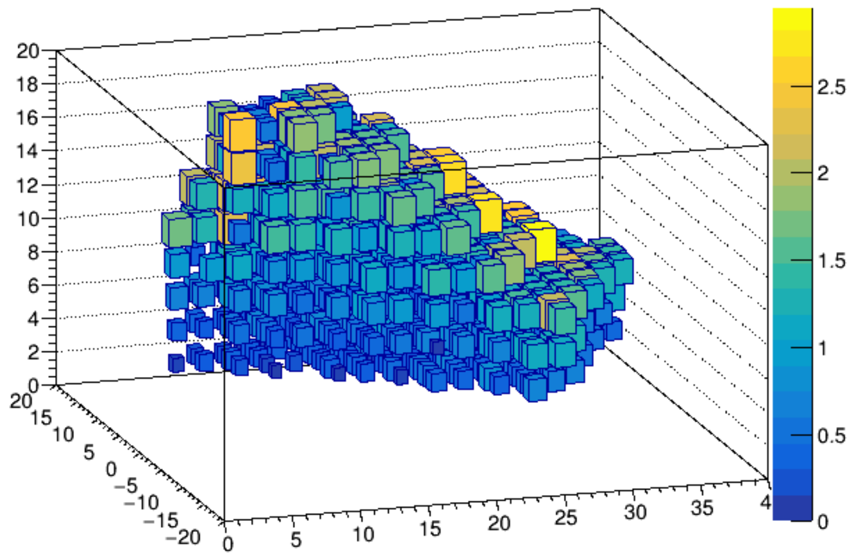


RESULTS
PSA error vs Position

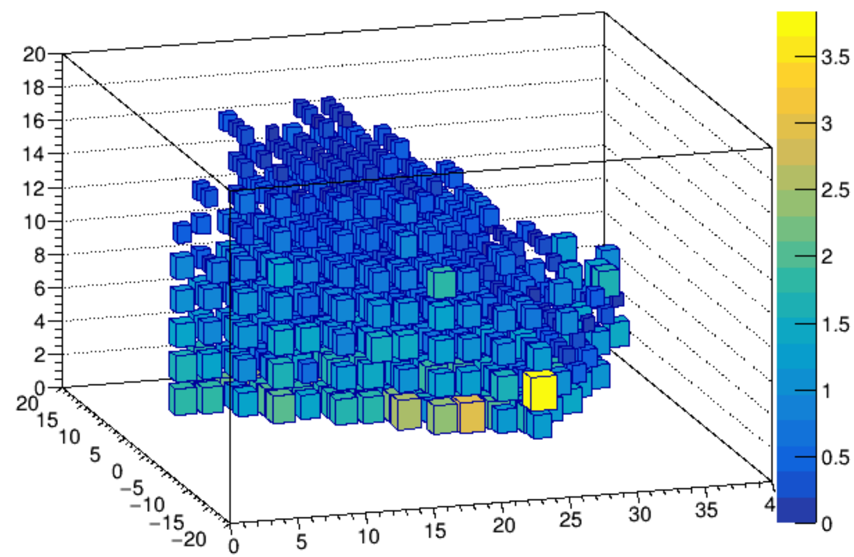


RESULTS
PSA error vs Position

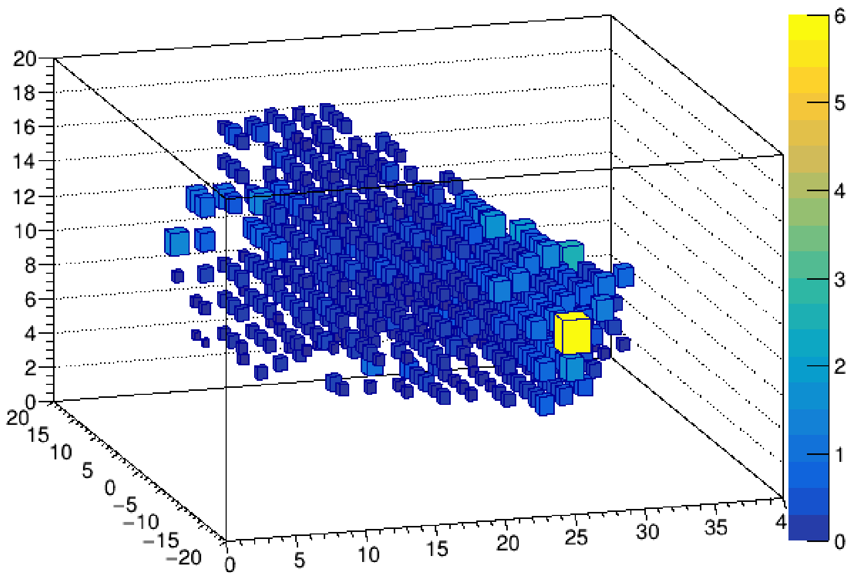
Position-dependent dZ distribution (left st.dev.) at 64keV



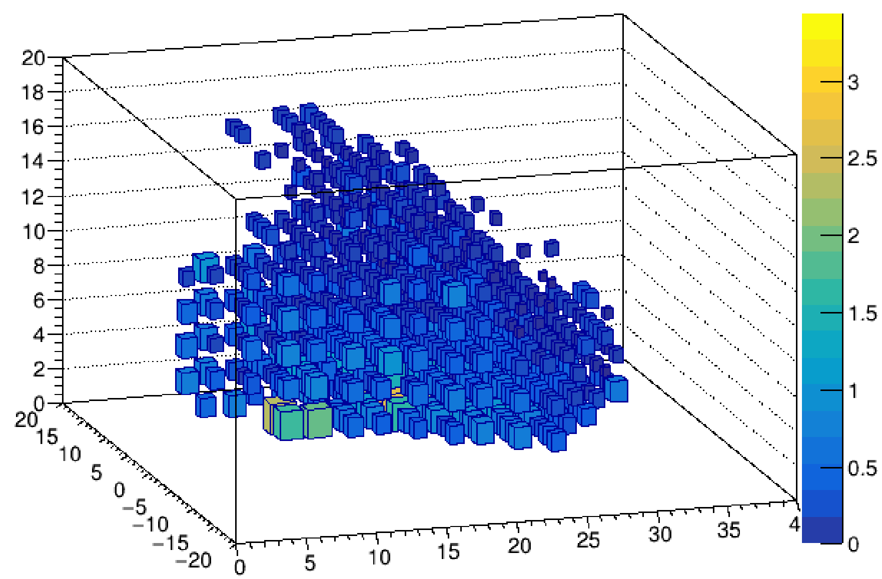
Position-dependent dZ distribution (right st.dev.) at 64keV



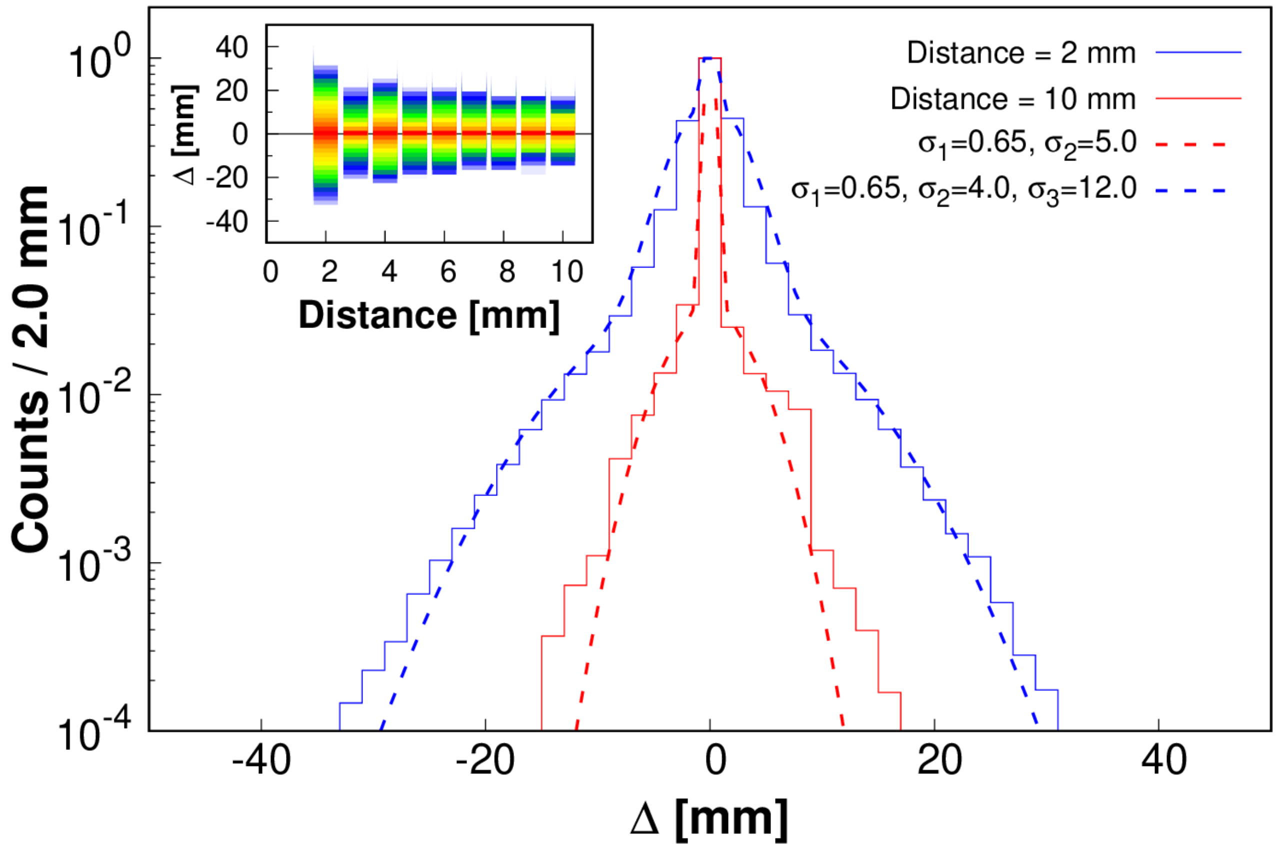
Position-dependent dZ distribution (left st.dev.) at 1024keV

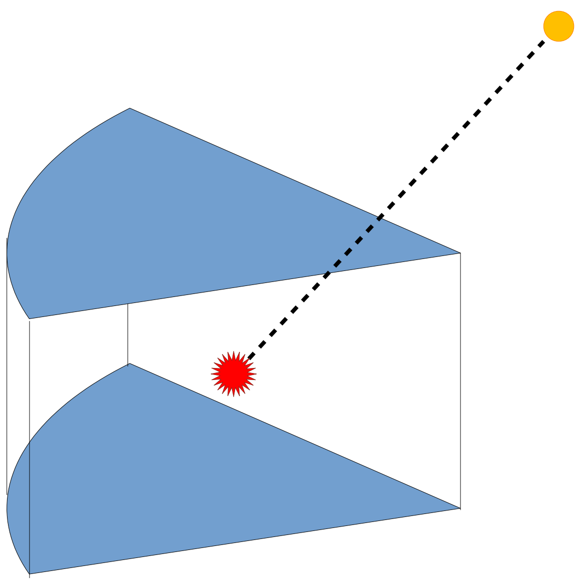


Position-dependent dZ distribution (right st.dev.) at 1024keV



RESULTS
PSA error vs Distance-to-the-edge





- Accumulation points on the edge of the segments
- Large Δ=0 bin for the inner segments positions: the bootstrap-related fluctuations are similar to the noise, so PSA interprets the traces in the same way
- For the points on the edge of the segments, the uncertainty has an additional “long-range” contribution: in addition to boundary issues, the traces rapidly change so small differences on the traces can lead to large position variation