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

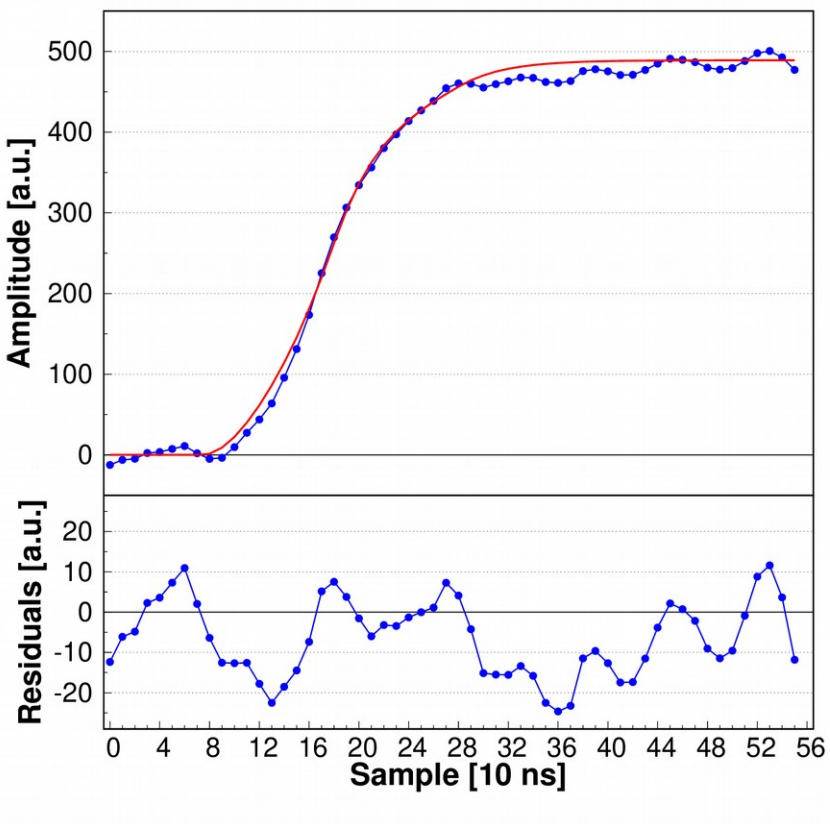
  - ✔ Simplicity
  - ✔ Verify stability of the results
  - ✔ Asymptotic convergence of the estimators

  - ✗ 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.

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



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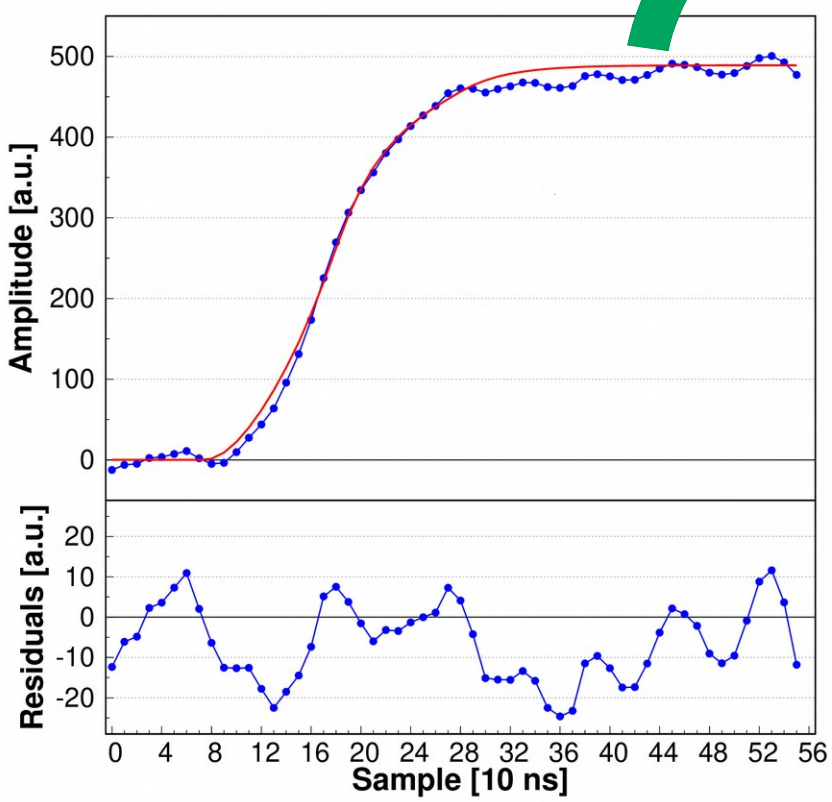

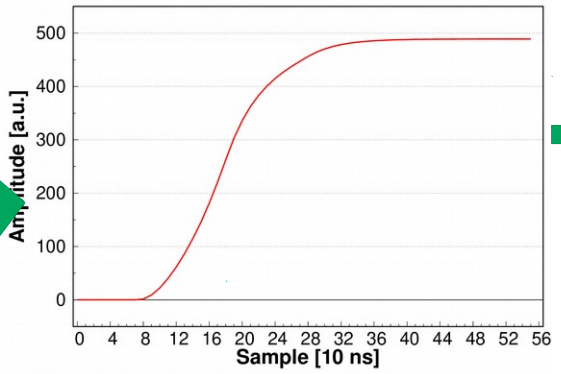

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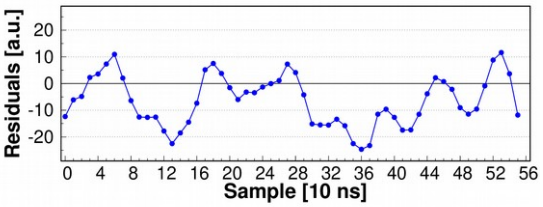
(RANDOM)



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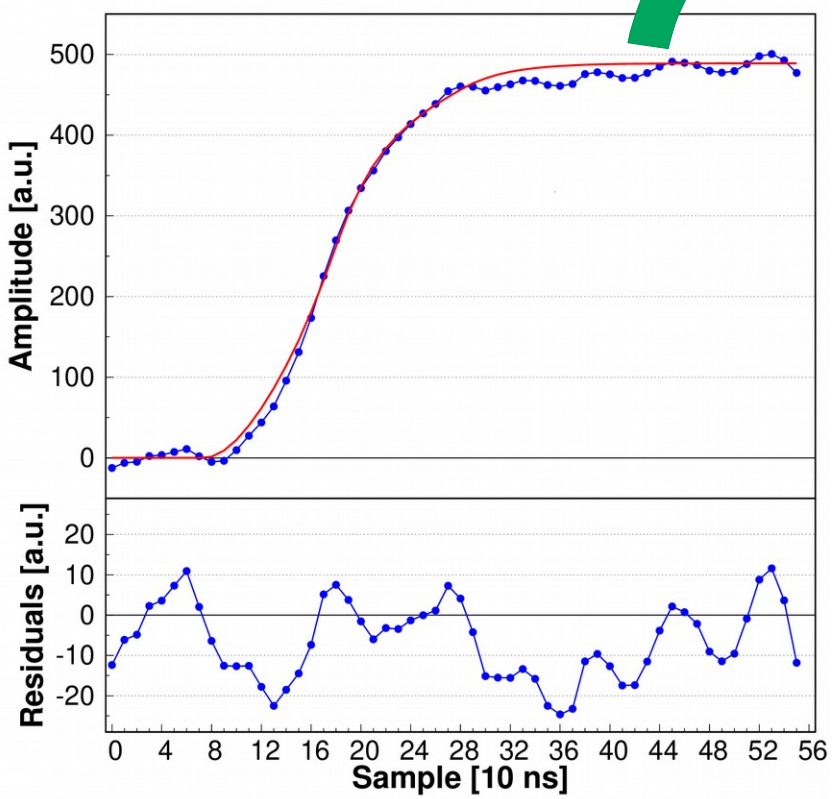

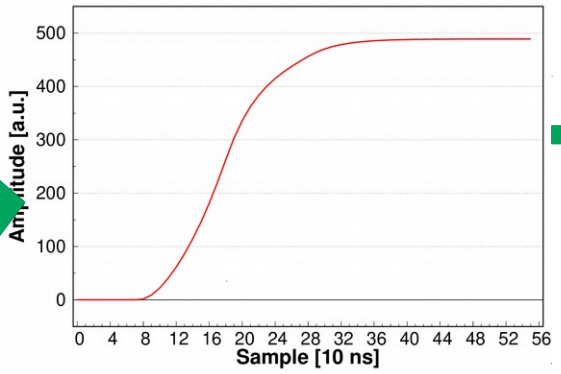

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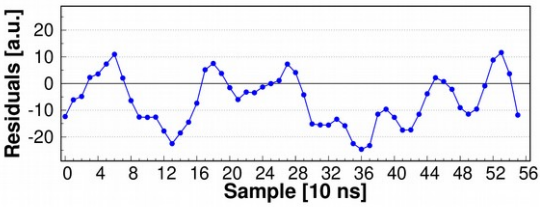
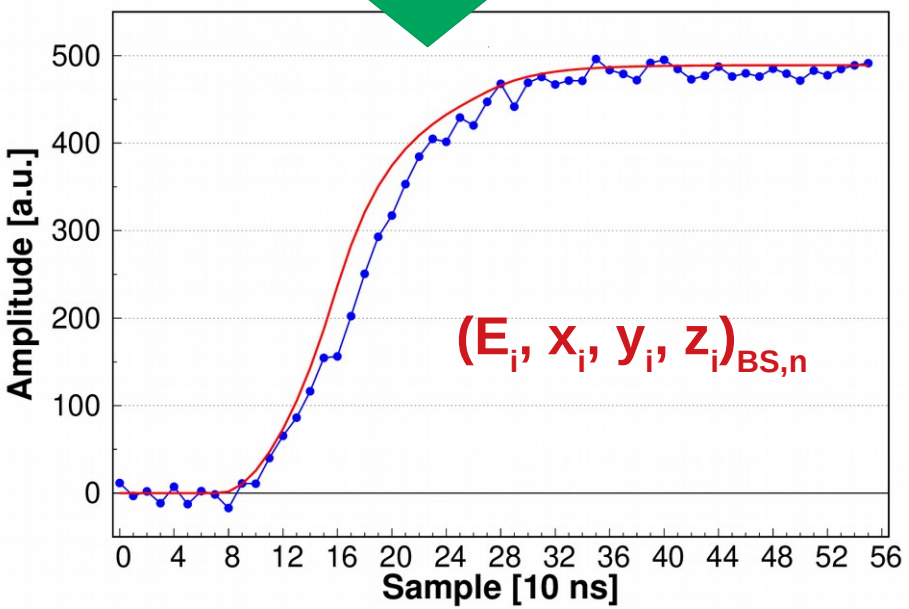
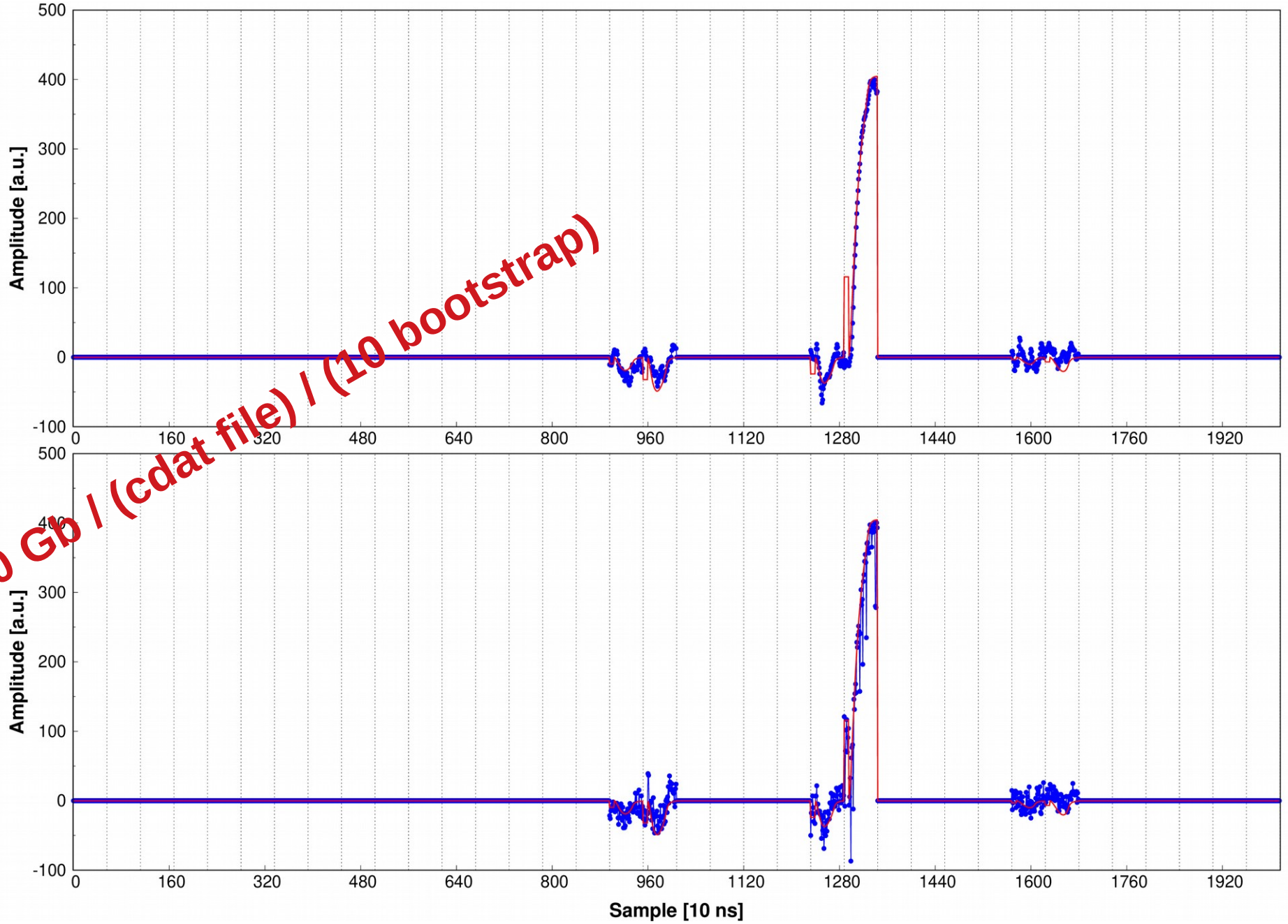




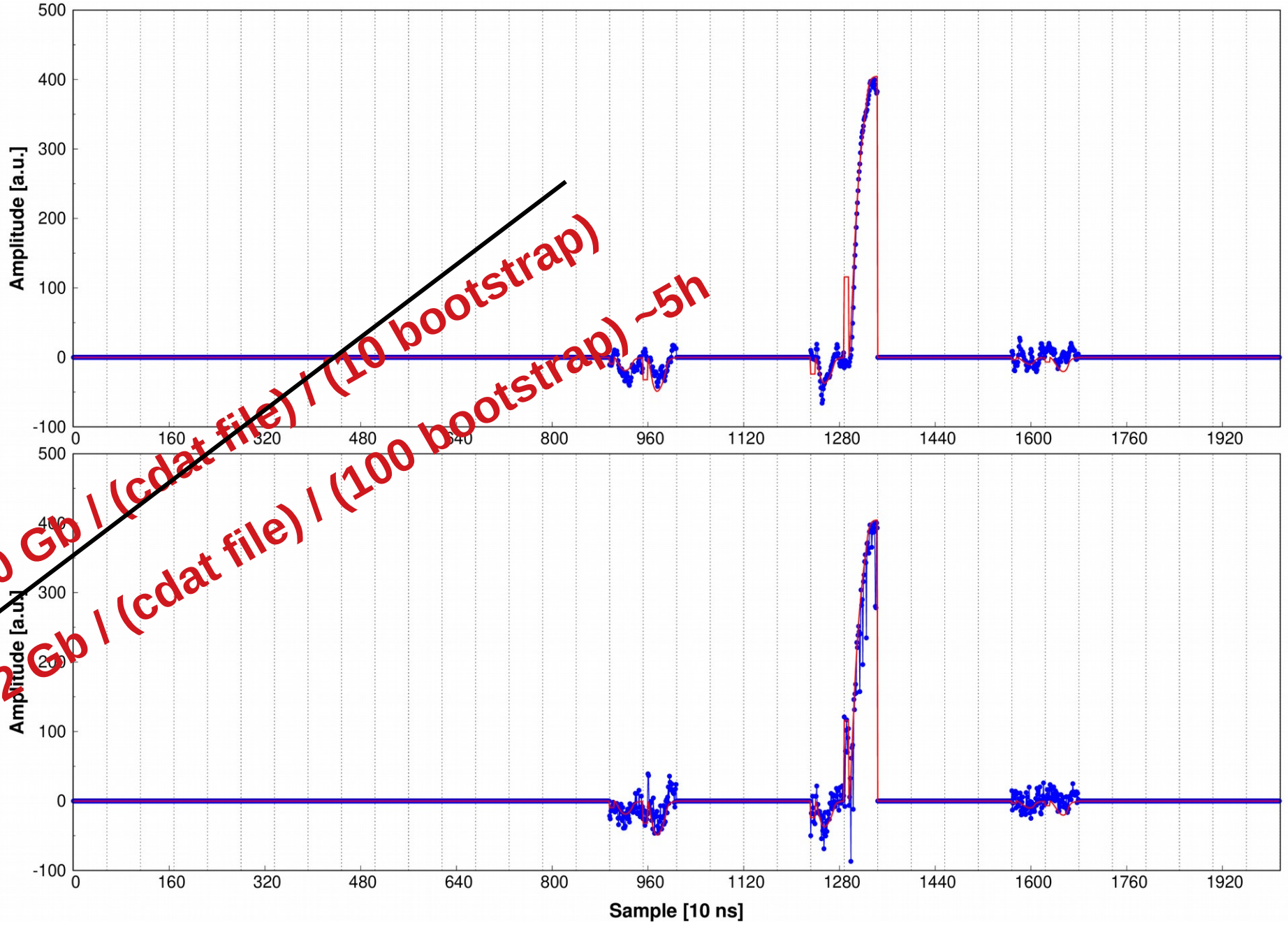
$(E_i, x_i, y_i, z_i)_{BS,n}$

BOOTSTRAP WITH AGATA

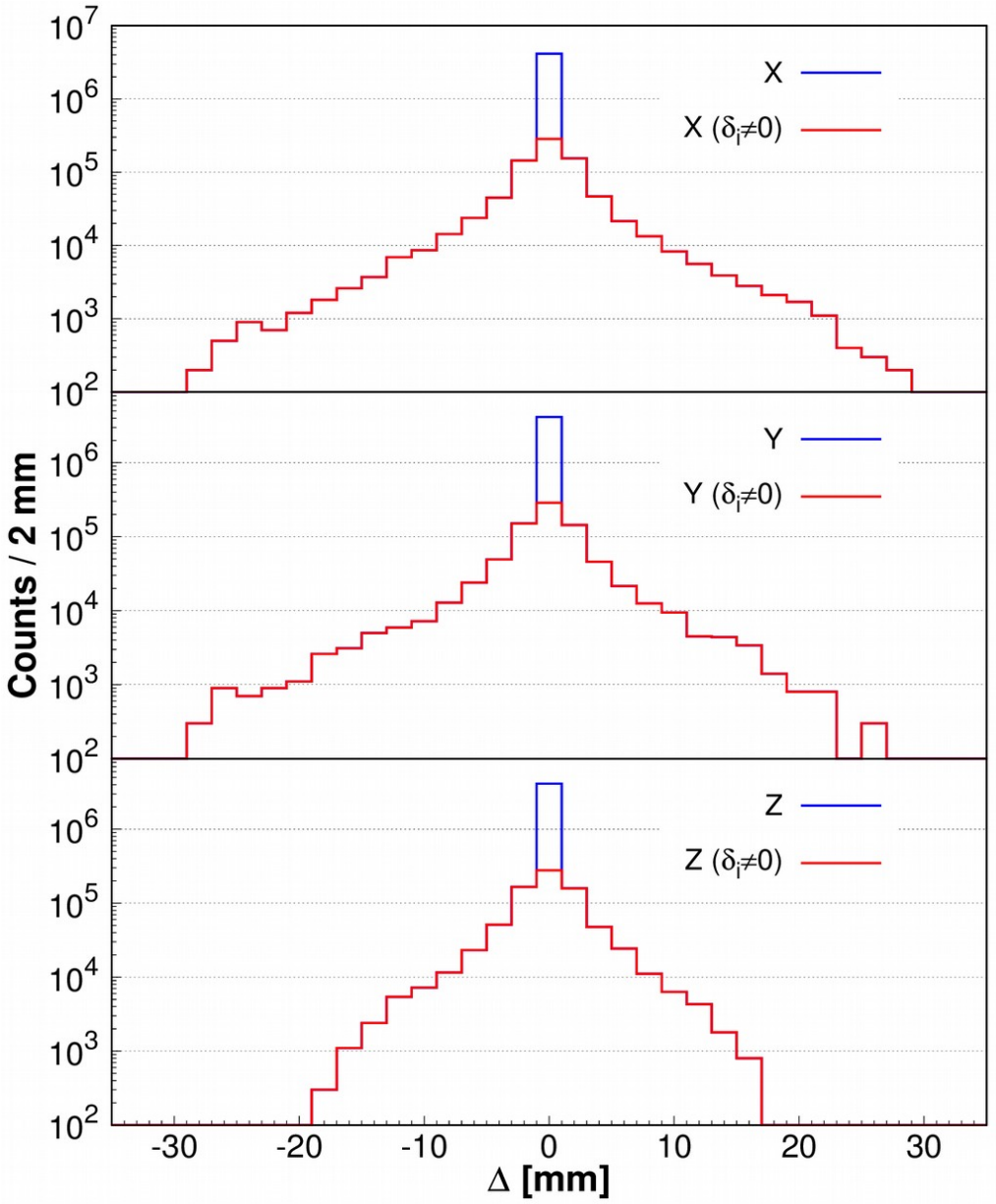


100 Gb / (cdat file) / (10 bootstrap)

BOOTSTRAP WITH AGATA



RESULTS
PSA error



- In adaptive grid search, the PSA distinguishes the bootstrapped traces 17%
- Asymmetric distribution requires the definition of positive/negative error
  - Fluctuations distribution is position dependent
  - Fluctuations distribution is energy dependent

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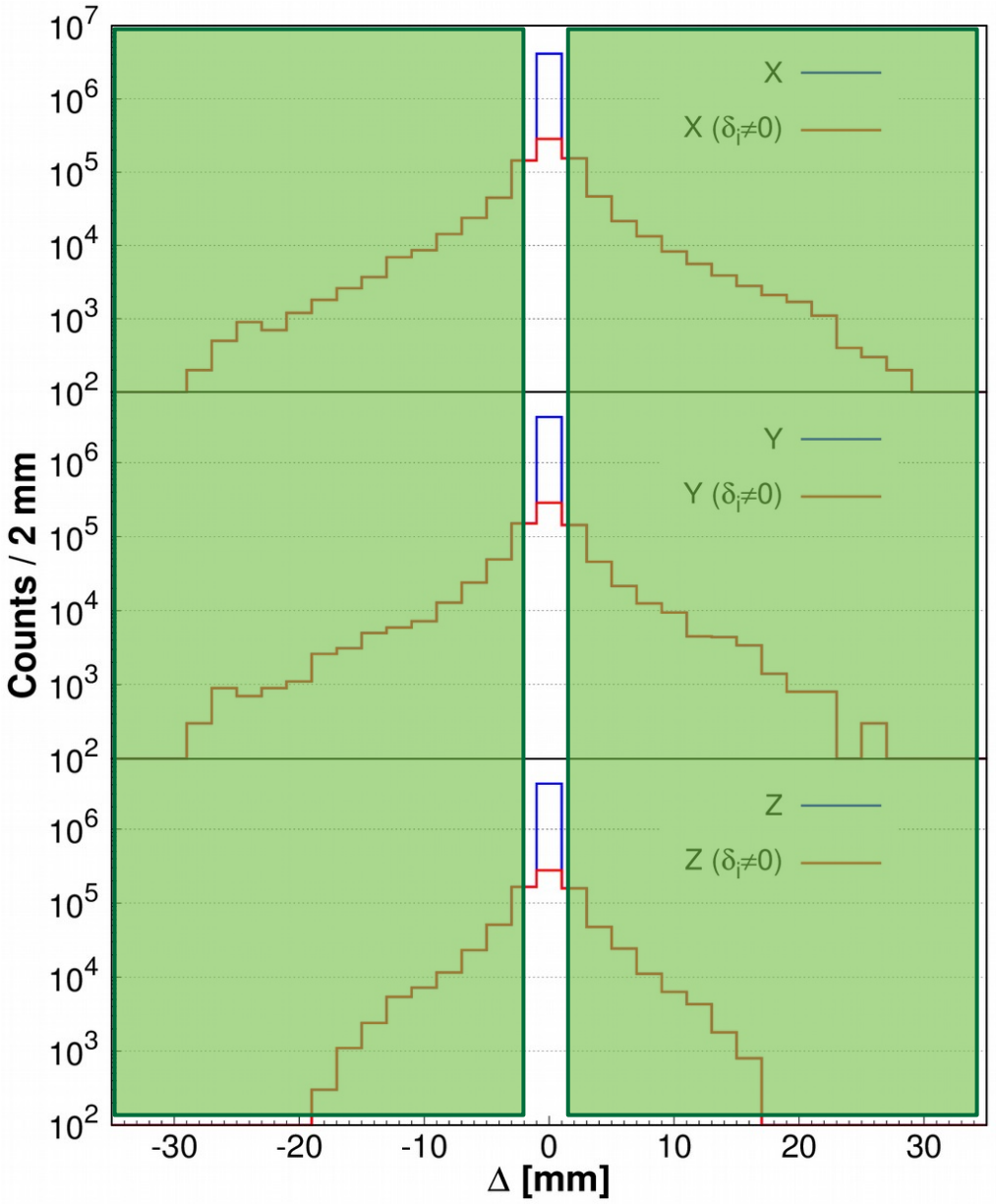
PSA error



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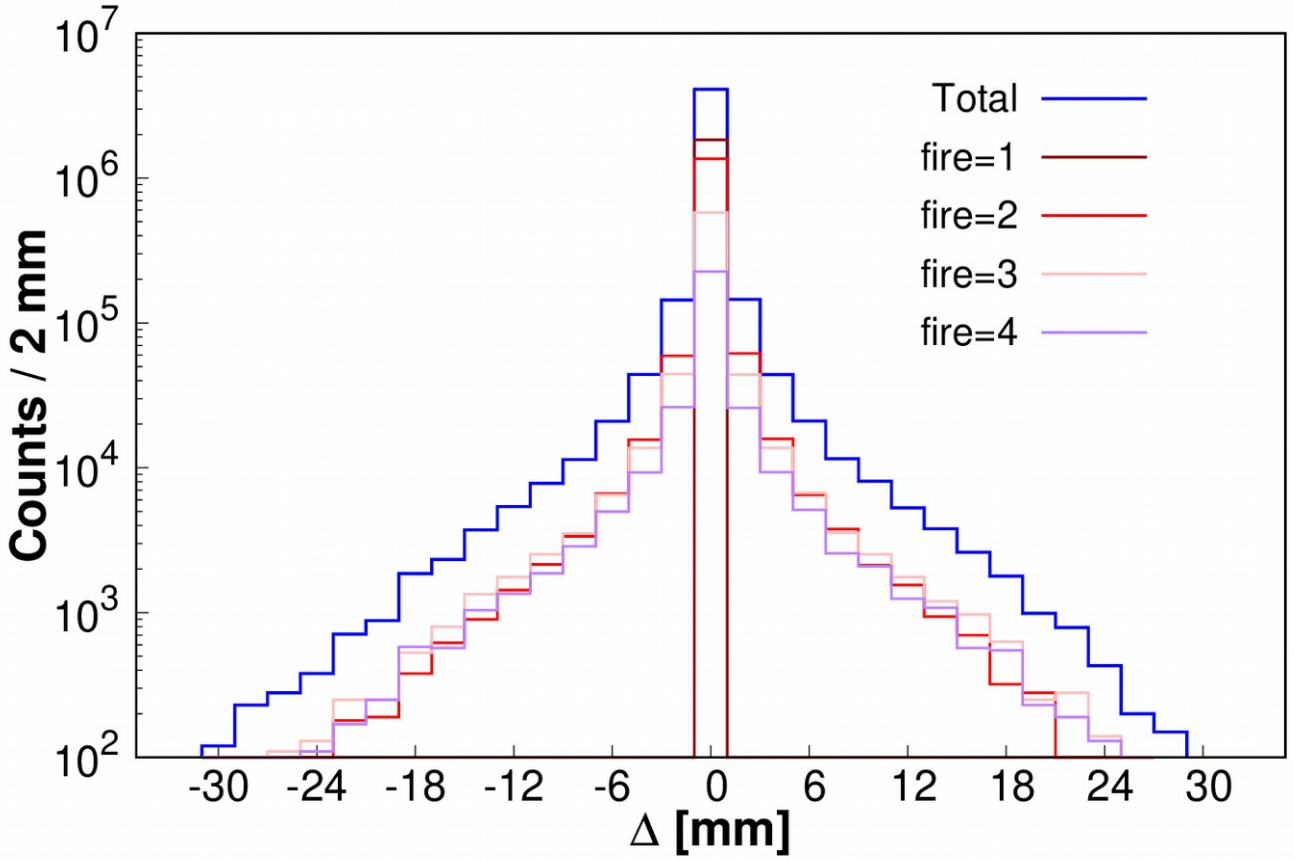
How do we define the error on PSA position?

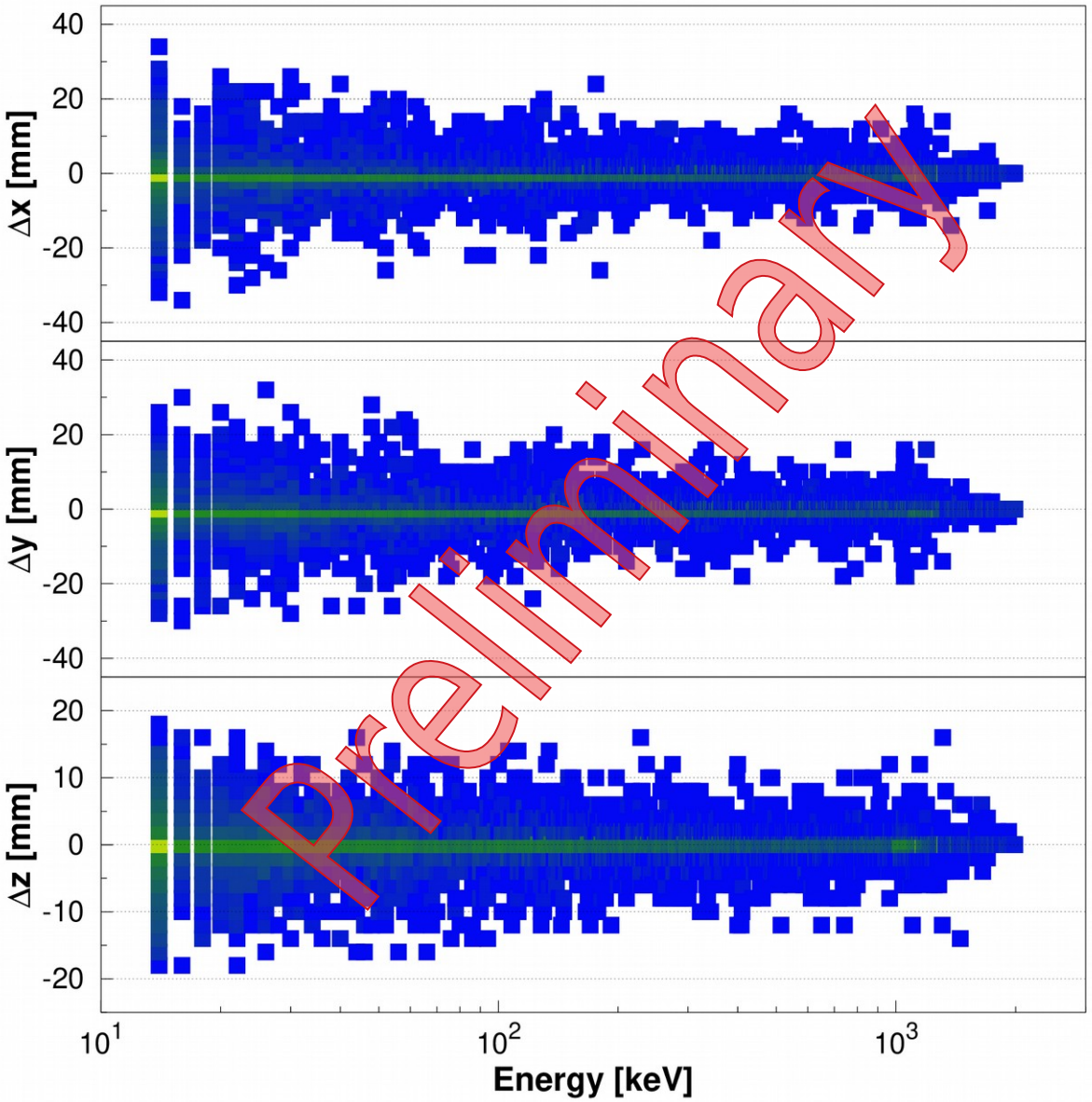
RESULTS
PSA error



- When only one segment is firing (~40%), PSA does not distinguish the bootstrap traces
  - Neighboring positions χ^2 largely different?
- Overall standard deviation 1.85 mm (2.36 mm for *fire>1* condition)
- Standard deviation increasing (from 1.6 to 4.4 mm) as a function of the number of firing segments

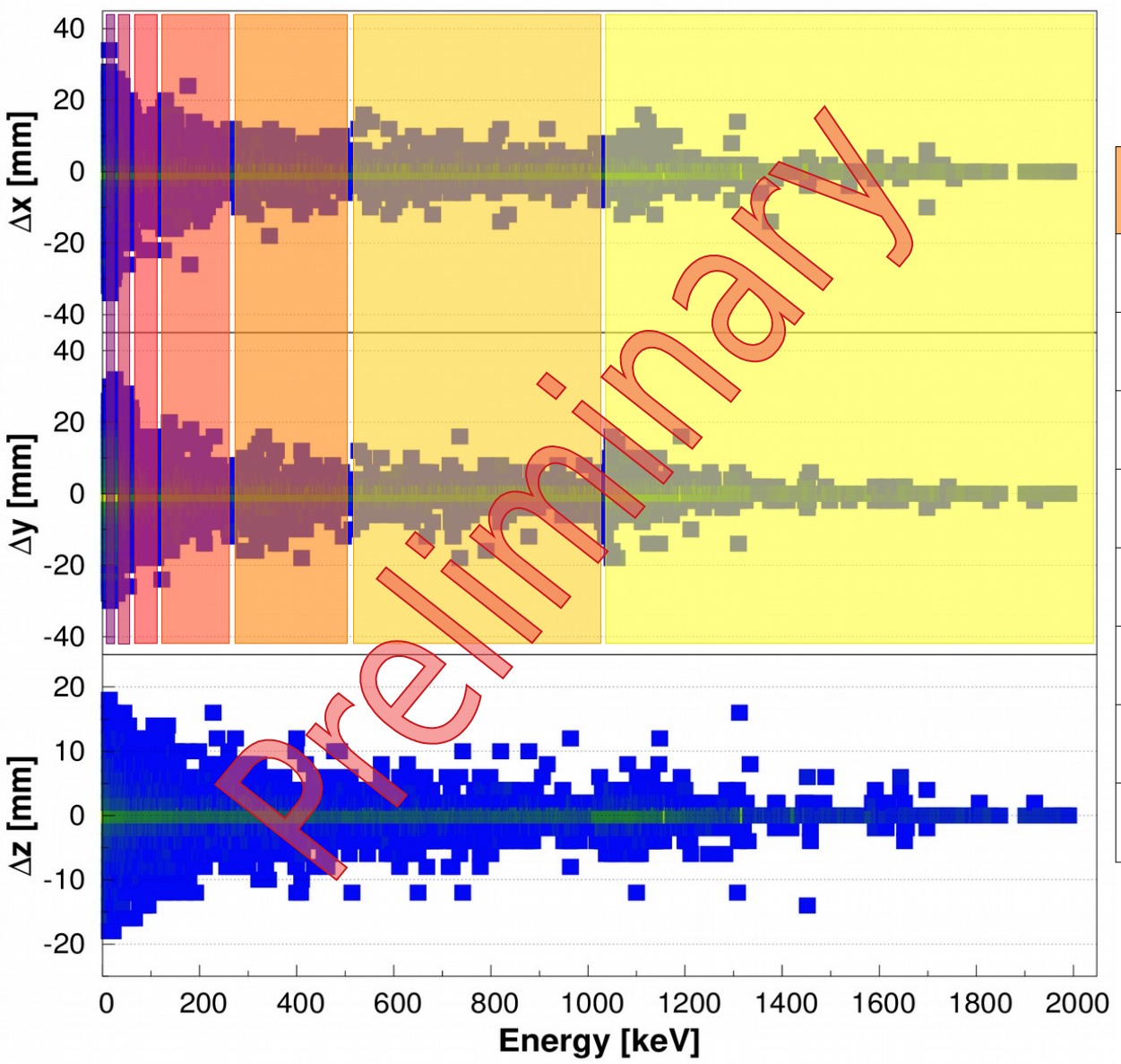
Comparison between overlapping and single-hit signals traces

RESULTS
PSA error vs Energy



- Fluctuations decrease with the increasing gamma-ray energy
- Fluctuations are almost symmetric with respect to 0
- PSA defines the interaction-point position withing the firing segment, so the coordinates are limited
  - For *x* and *y* coordinates, fluctuations have similar trend
  - For *z* coordinate, fluctuations distribution is narrower

RESULTS
PSA error vs Energy



PSA position error for *x* and *y* coordinates as a function of the energy:

Energy range [keV]	-Δ [mm]	+Δ [mm]
8-16	6	8
16-32	6	6
32-64	4	6
64-128	4	4
128-256	4	4
256-512	4	2
512-1024	2	2
1024-2048	2	2

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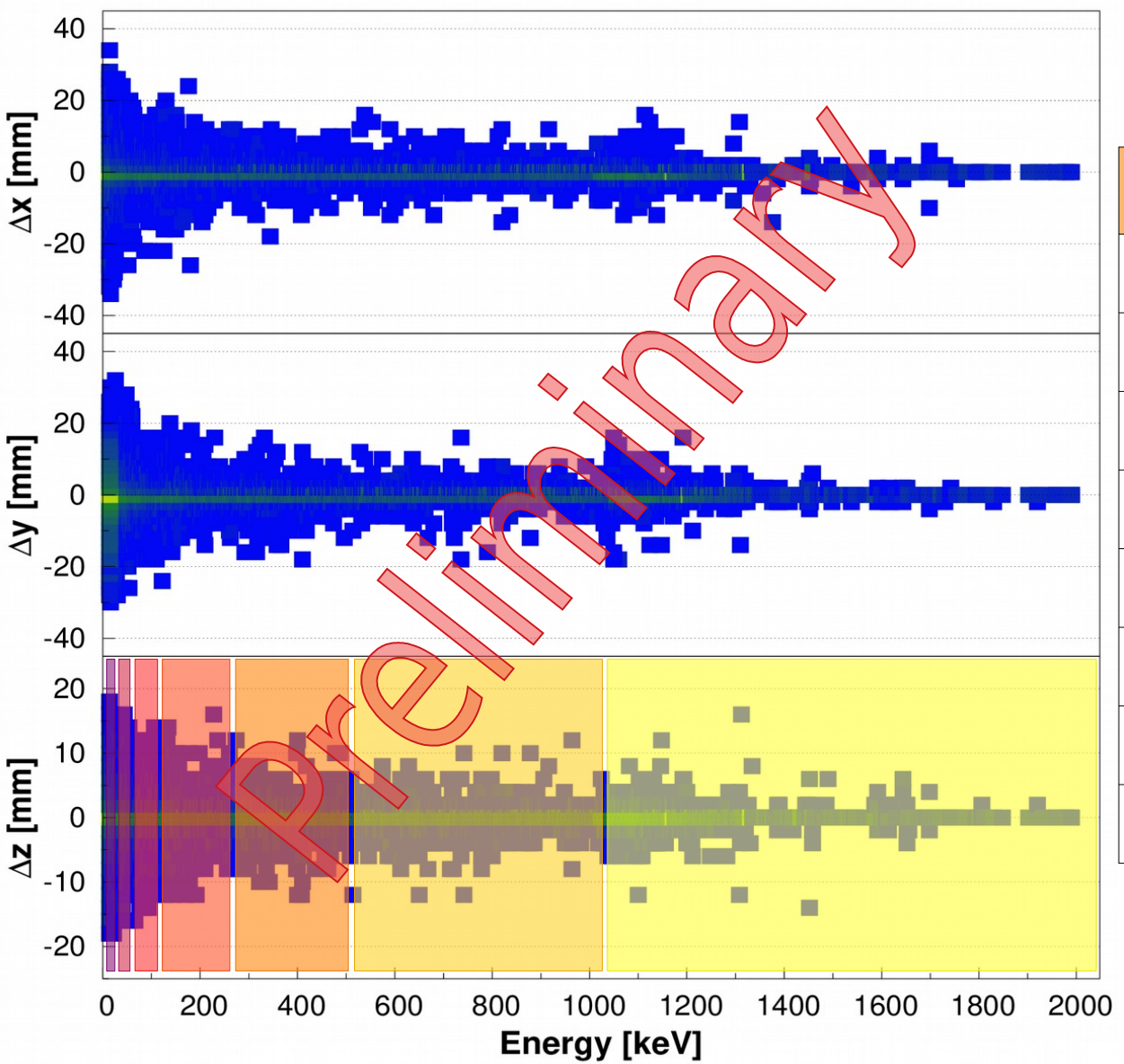
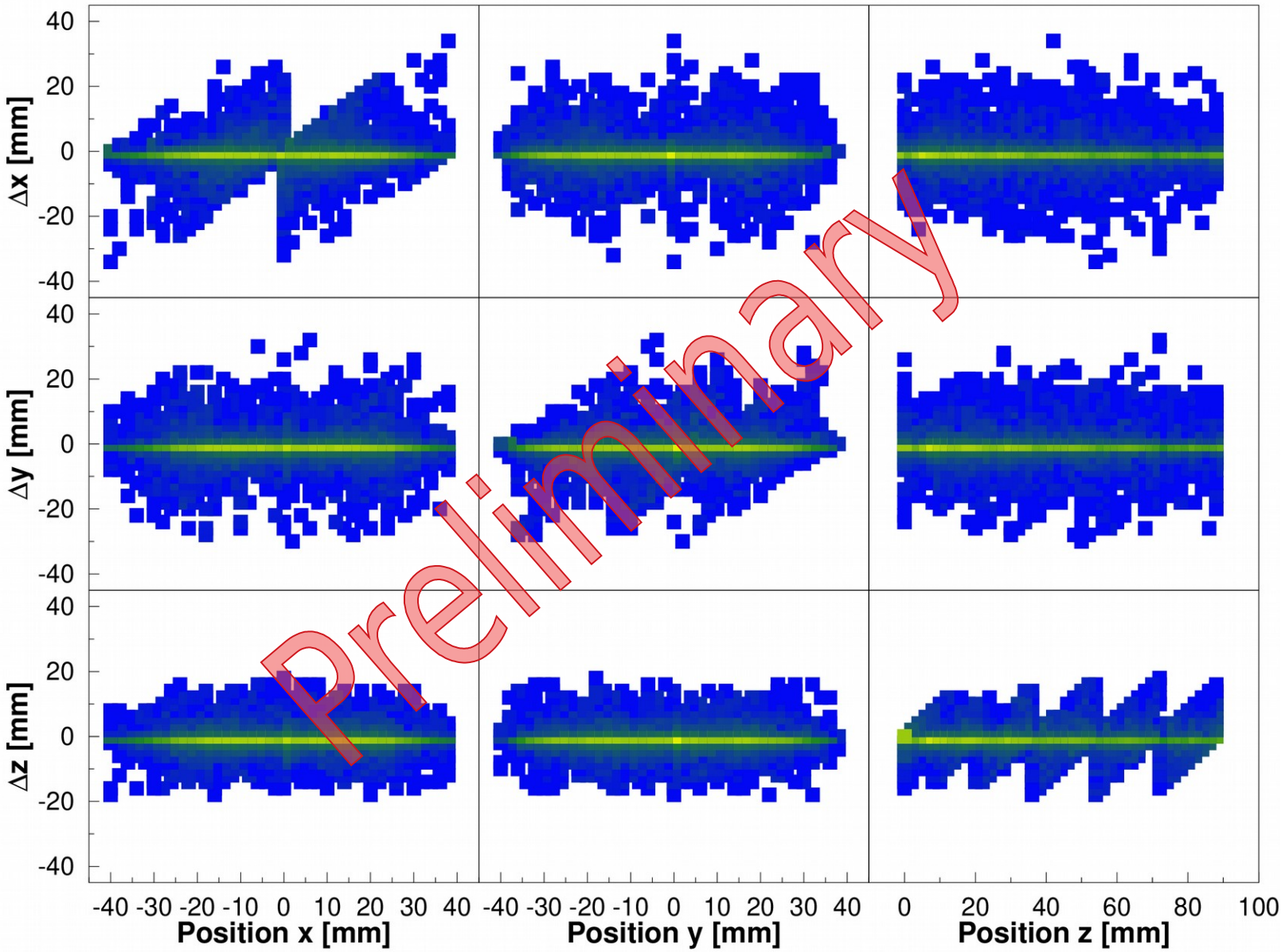
PSA error vs Energy



PSA position error for *z* coordinate as a function of the energy:

Energy range [keV]	-Δ [mm]	+Δ [mm]
8-16	6	6
16-32	6	4
32-64	4	4
64-128	4	4
128-256	4	4
256-512	2	2
512-1024	2	2
1024-2048	2	2

RESULTS
PSA error vs Position



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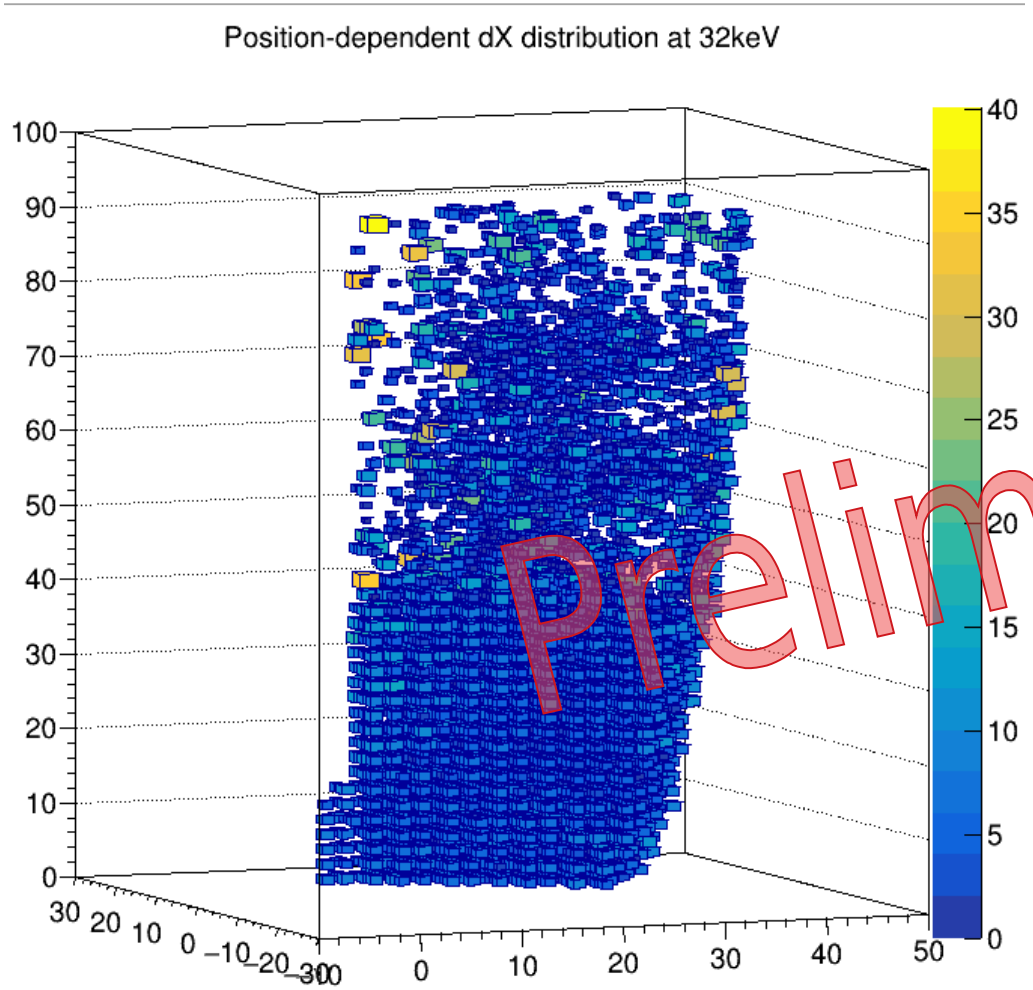

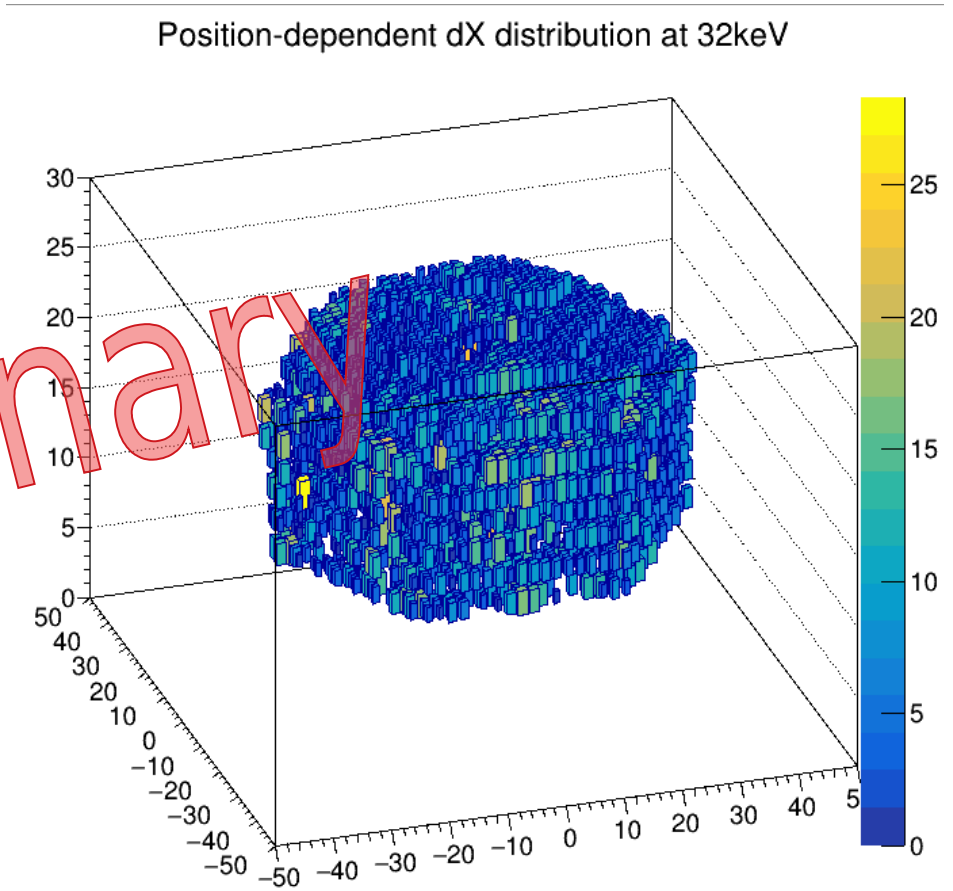

Thanks to
Alain Goasduff and *CloudVeneto*

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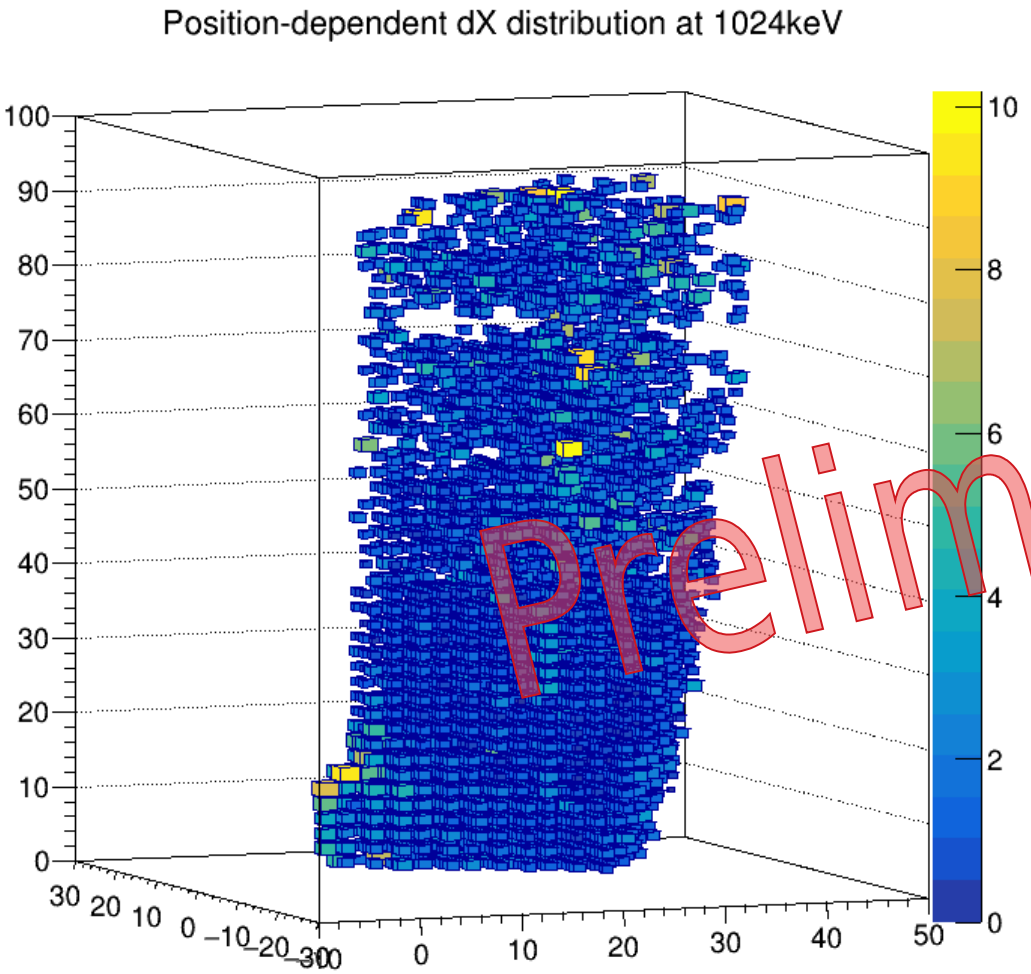

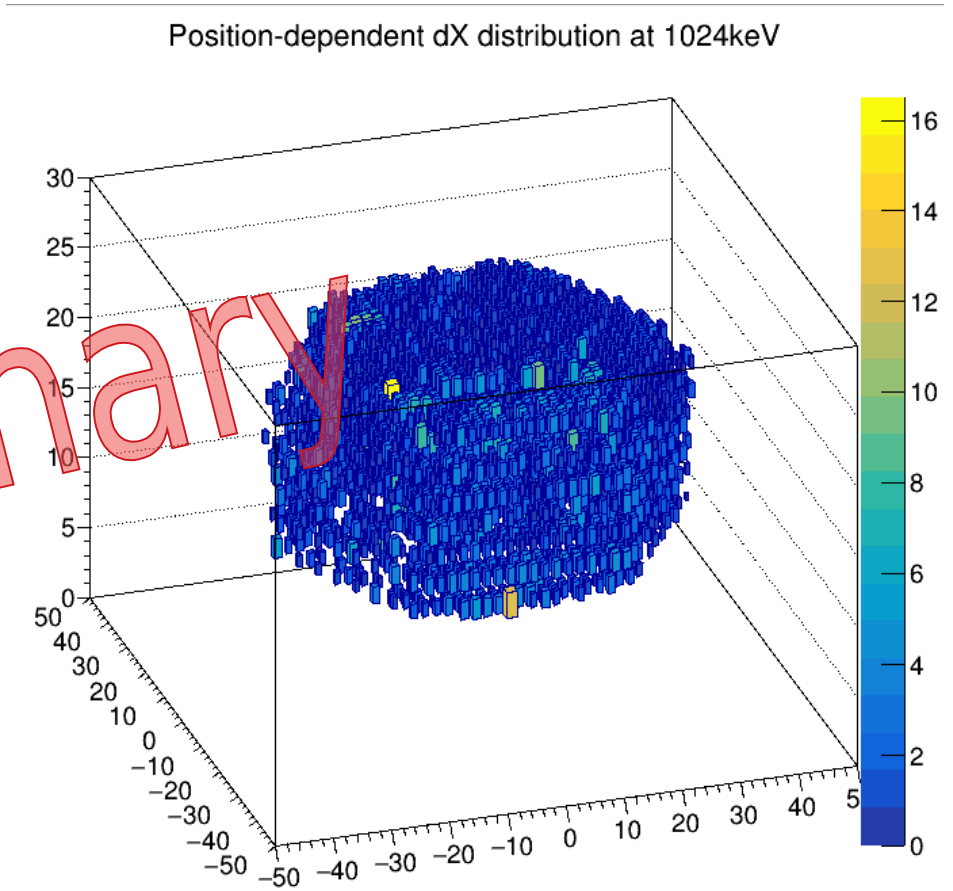

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CONCLUSIONS

- Bootstrapping is an established procedure that can be used to test hypothesis: statistical features of PSA can be inferred (grid-search dependent)
  - In order to have enough statistics, large amount of data and computational resources are required

- Problems in defining how to estimate the uncertainties (?)

- **Preliminary results** highlight the uncertainties increase with the number of firing segments
  - Comparison between overlapping- and single-signals traces

- **Preliminary results** highlight the expected energy dependence of PSA-position fluctuations

- **Preliminary results** highlight that fluctuations are position dependent
  - Defining a map of uncertainties

- By knowing uncertainties dependencies, the PSA procedure can be simplified and it would make the online/offline data process much faster