On the self-calibration capabilities of γ-ray energy tracking arrays

Stefanos Paschalis

AGATA Week March 2021

Motivation

UNIVERSITY of York

Motivation for this work

Exploit the full potential of the arrays using their tracking capabilities to provide *in situ* a high fidelity signal basis

Caveat:

… so far shown within a Geant4 simulation

Motivation for this talk

Status of implementation and to trigger further discussions with PSA experts on the possible steps towards experimental validation of the method

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Special Article – New Tools and Techniques

On the self-calibration capabilities of γ-ray energy tracking arrays

S. Heil[1], S. Paschalis[2,a], and M. Petri[1,2,b]

[1] Institut für Kernphysik, Technische Universität Darmstadt, Darmstadt, Germany
[2] Department of Physics, University of York, York, UK

Part of the UK Agata project (WP4)

- New PDRA starting in May 21 at York, will also look into the implementation and more realistic simulations that include Pulse Shape simulations

Current challenges

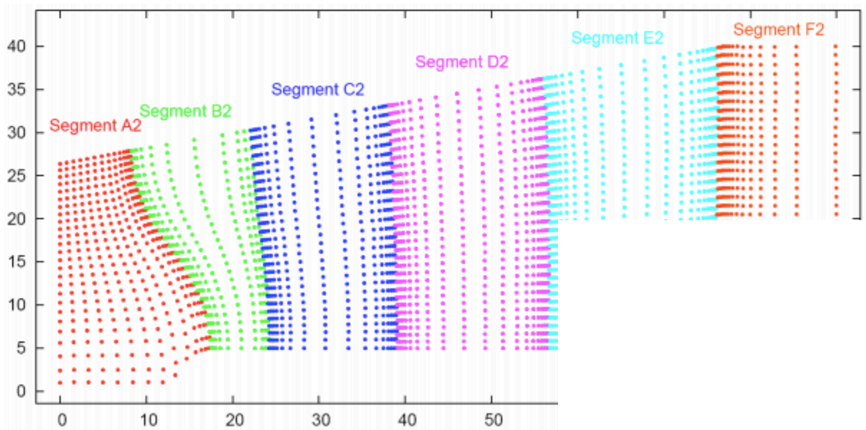
signal basis generation

Experimental (scanning)

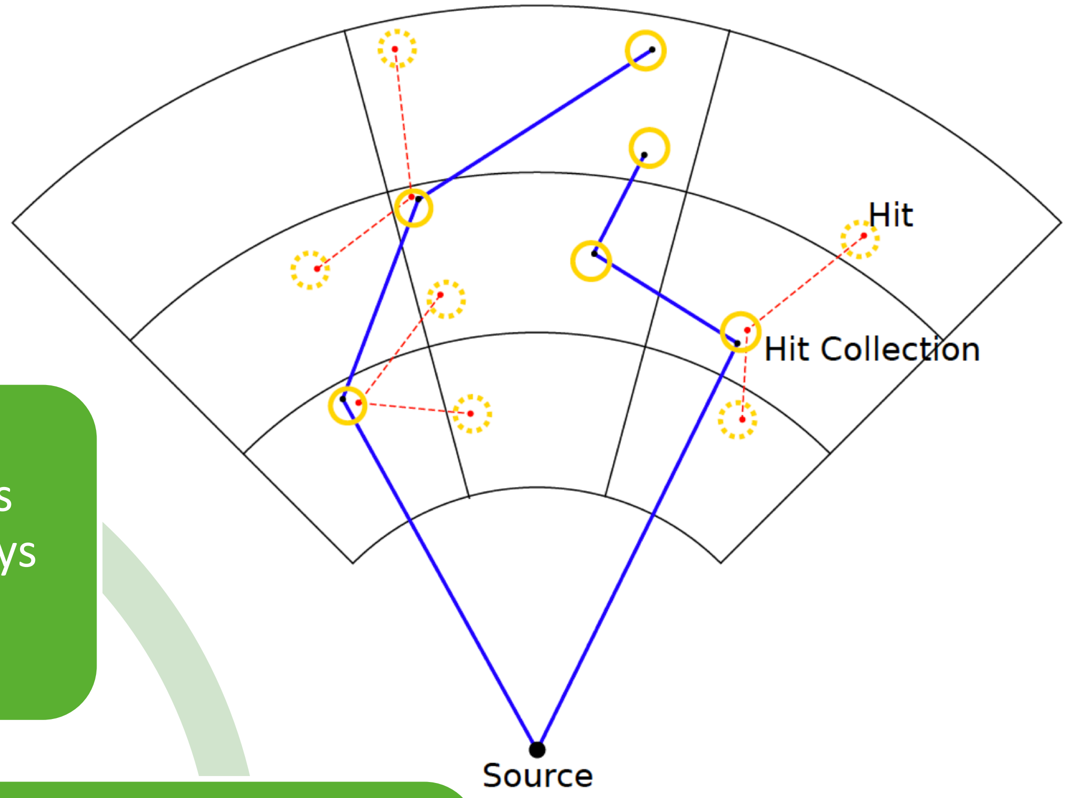
- long acquisition times
- different conditions between scanning and experiment, e.g. noise, radiation damage
- mechanical alignment

Analytical (calculated)

- intrinsic space-charge density
- the electron/hole mobility
- crystal temperature and
- crystal orientation
- passivated and contact thickness
- shape of charge cloud



Method

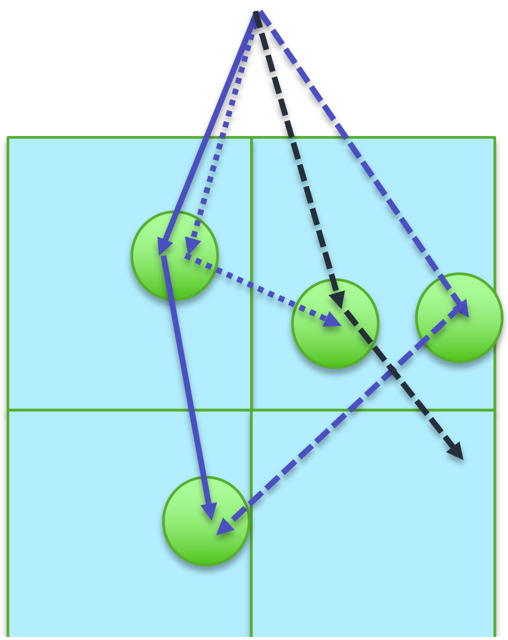


Group interaction points from different gamma-rays into hit collections

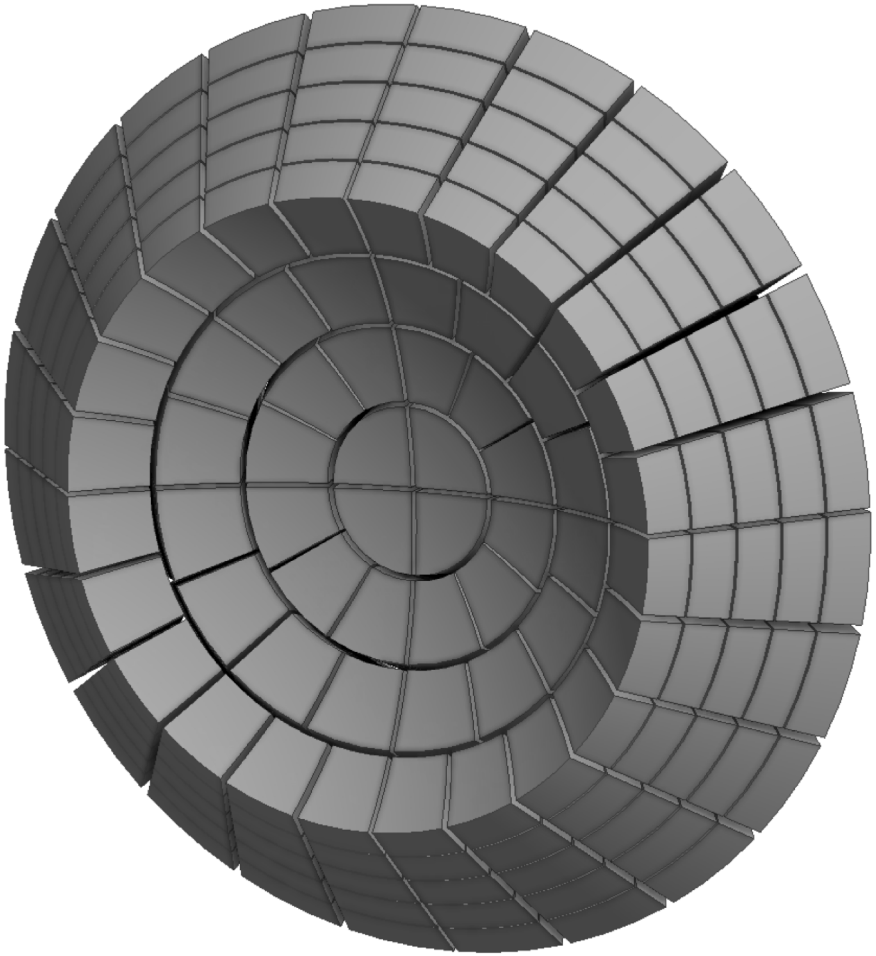
Use Compton formula to order interaction points

Define tracks between interaction points that also link the hit collections with each other

Optimise coordinates of hit collection using the tracks that link their constituent points and Compton formula



Simulation



Monte Carlo simulations (Geant4)

Physics list: G4EmStandardPhysics option4

Solid angle coverage: ~0.6 π sr

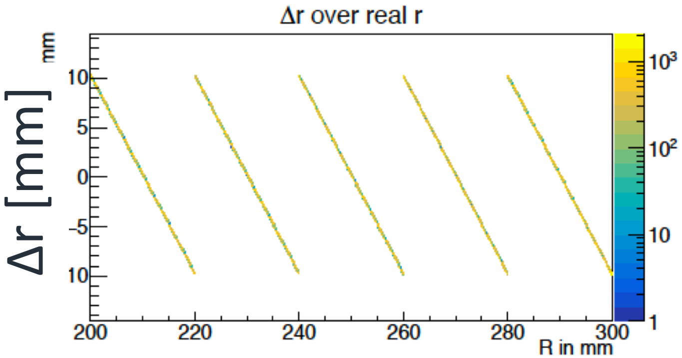
Inner diameter 20 cm
Outer diameter 30 cm

280 segments

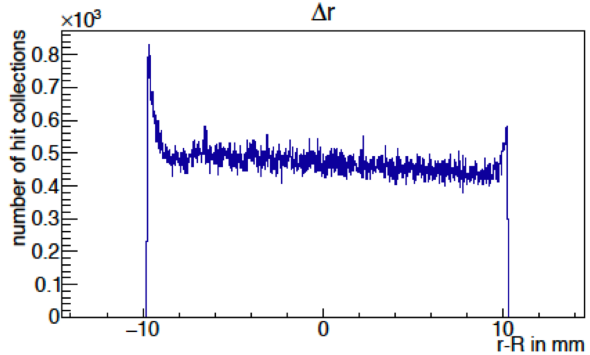
No Pulse Shape simulation included here, only hits and tracks.

Results (simulation)

starting condition



R [mm]

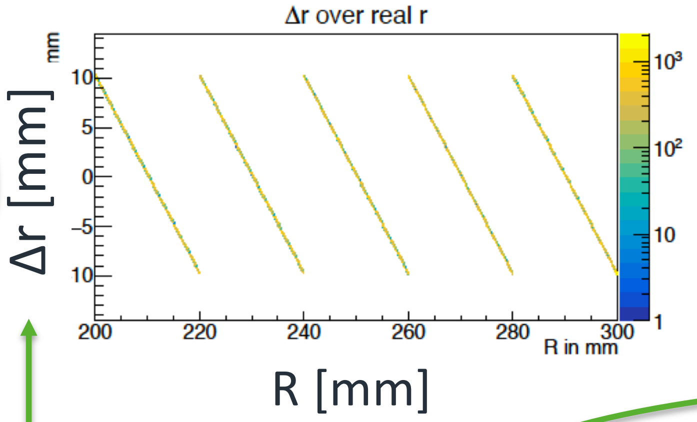


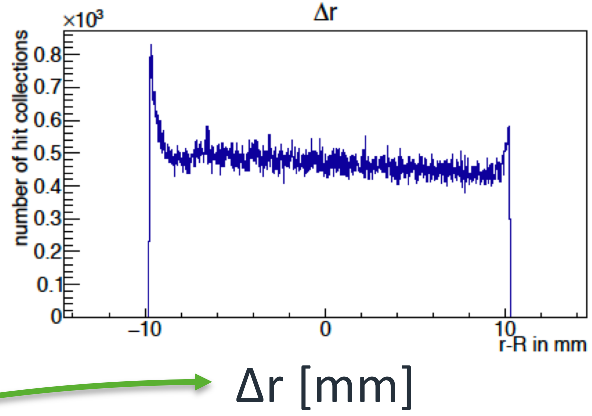
Δr [mm]

- Hit collections are assigned a nominal position inside a segment, e.g. at its centre

Results (simulation)

starting condition





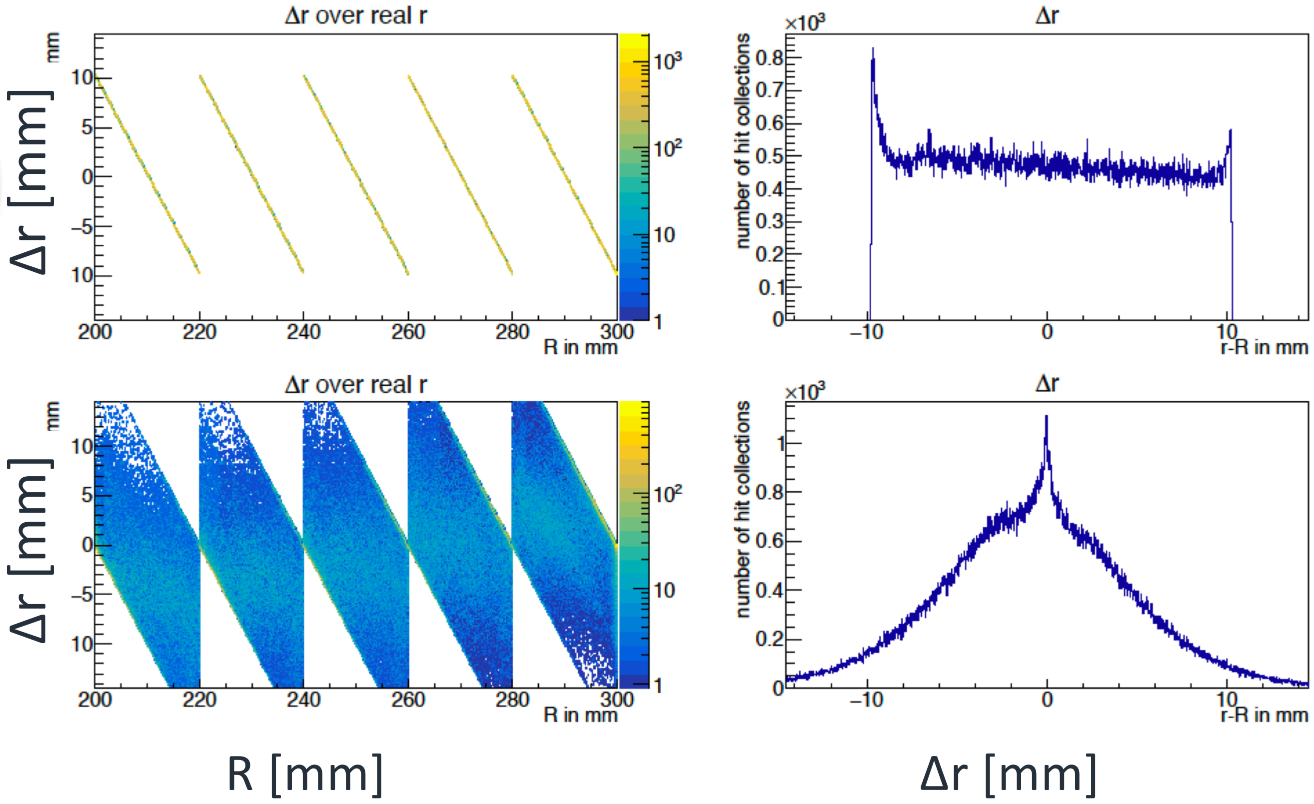
- Hit collections are assigned a nominal position inside a segment, e.g. at its centre

- The **difference** between real and current hit collection position is maximum

Results (simulation)

starting condition

after 1st iteration

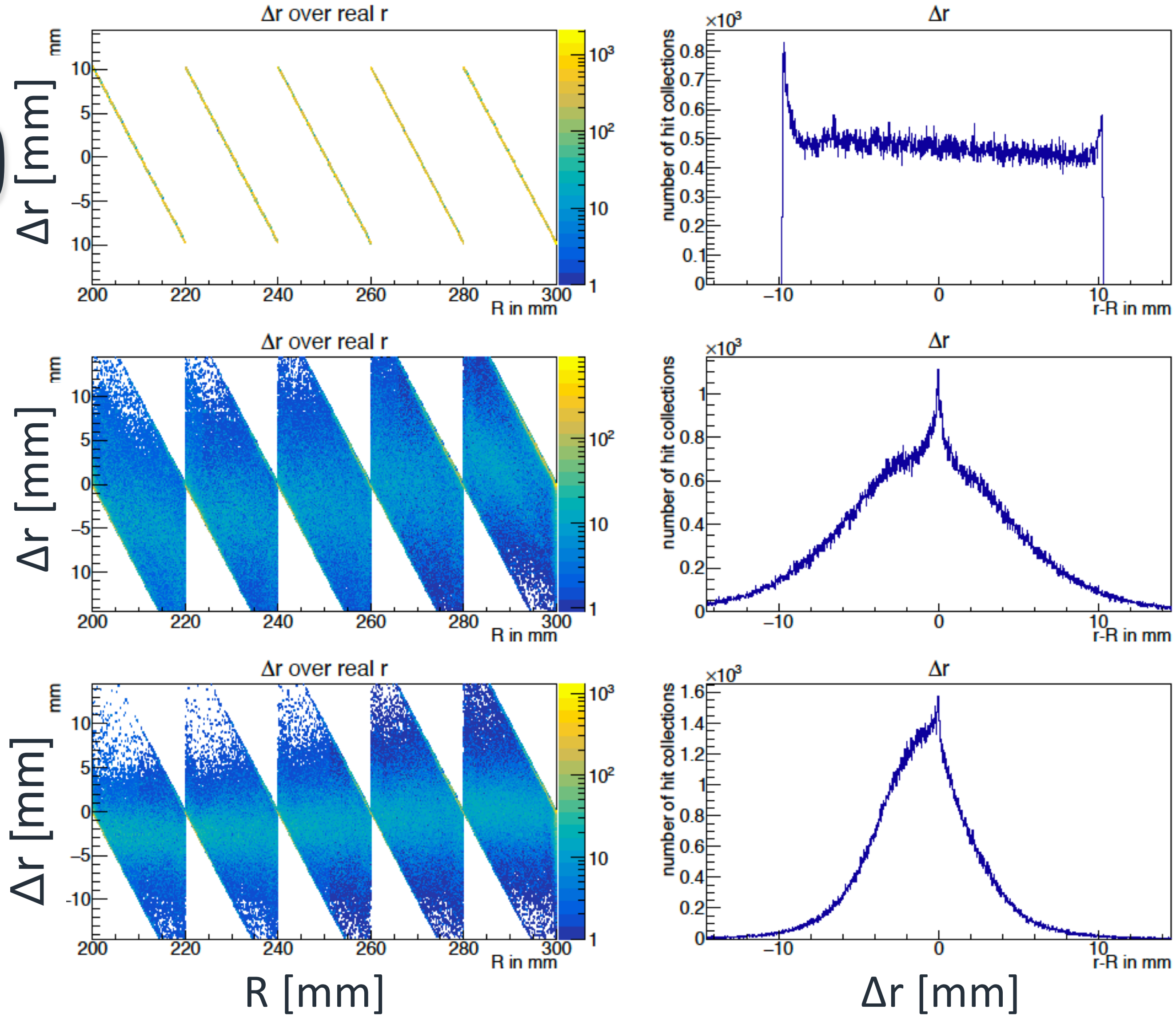


Results (simulation)

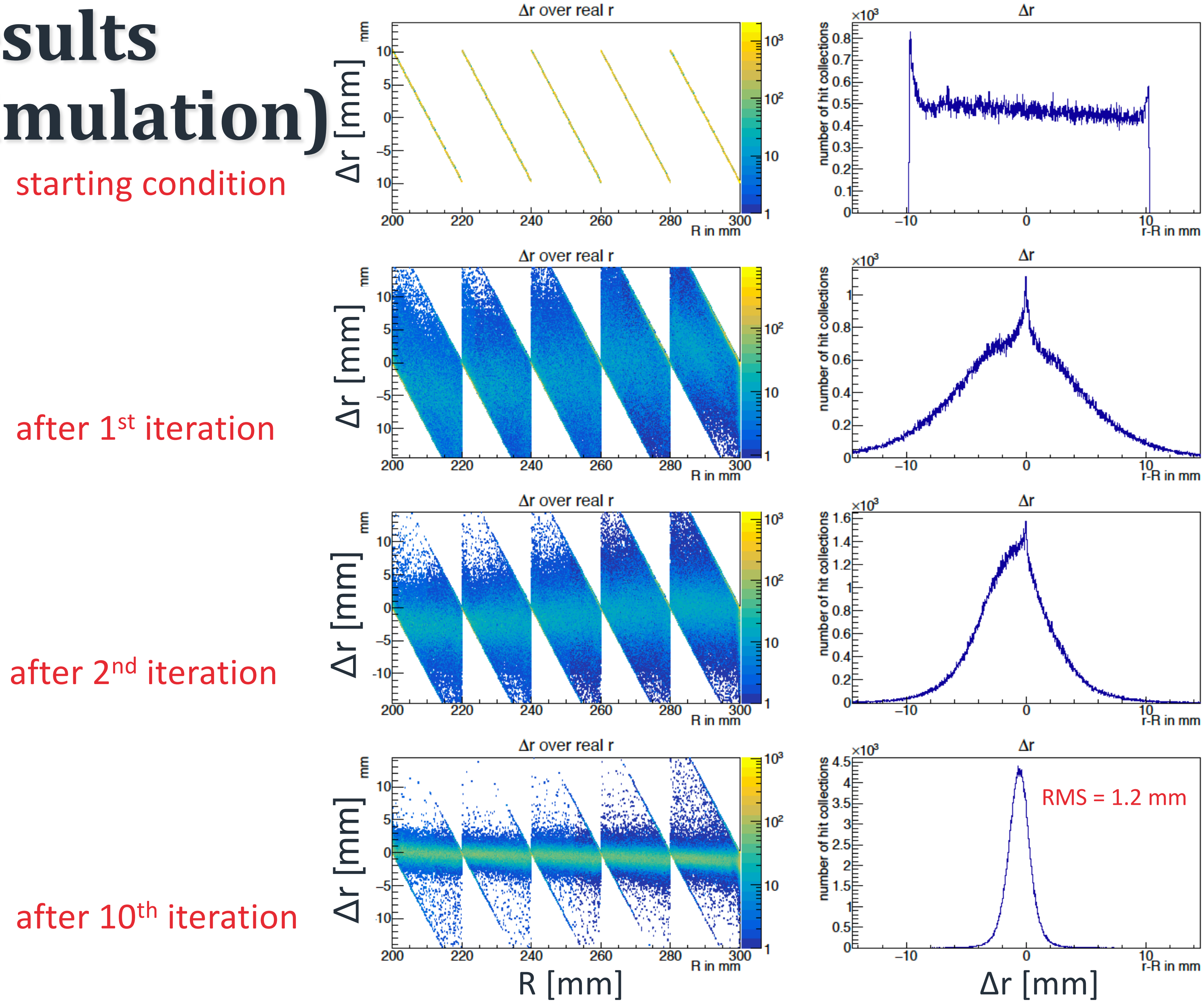
starting condition

after 1st iteration

after 2nd iteration

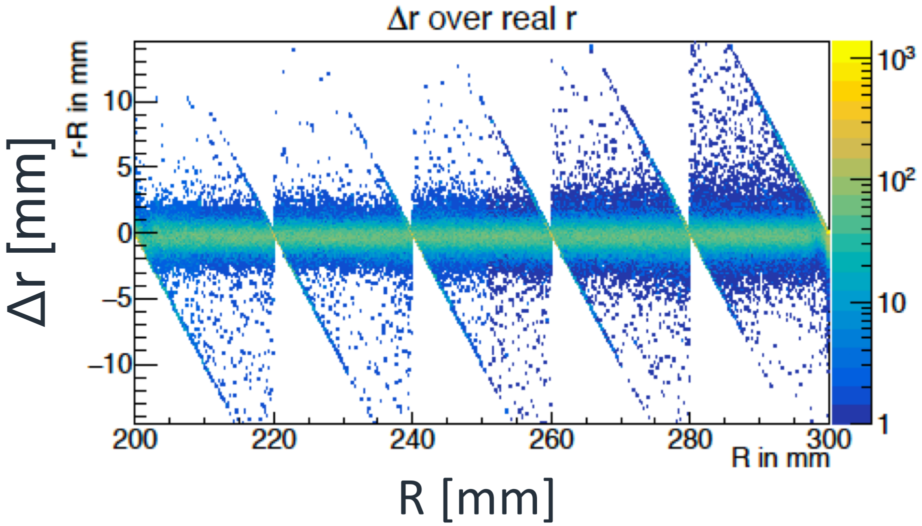


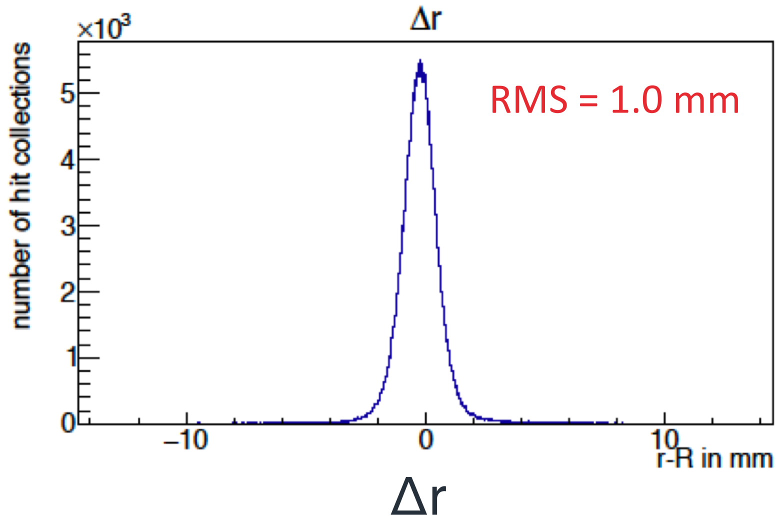
Results (simulation)



Results (simulation)

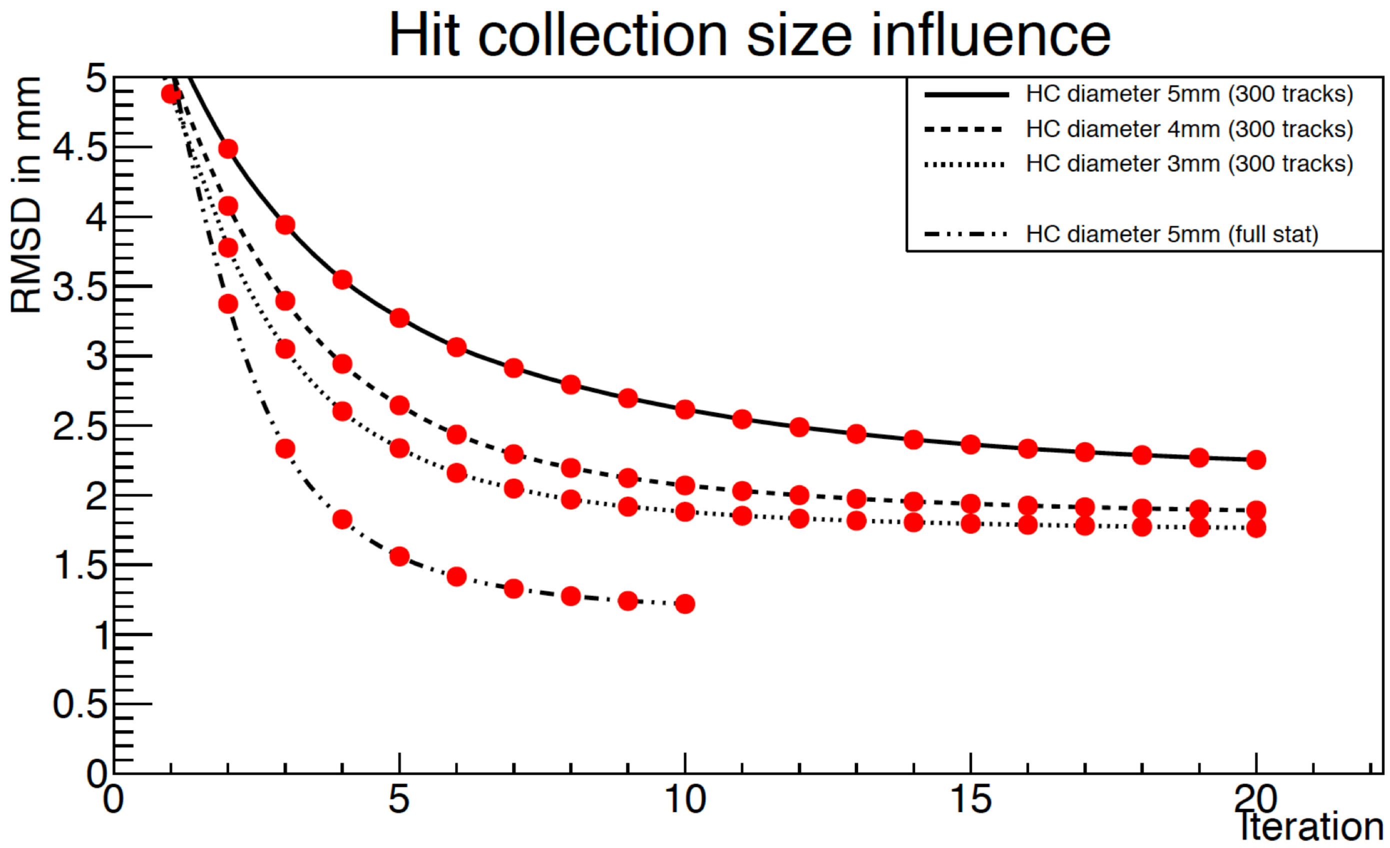
re-tracked with previous self-calibration result





Reconstruction RMS = 1.0 mm
Reconstruction Offset = -0.2 mm

Results (simulation)



Implementation Challenges

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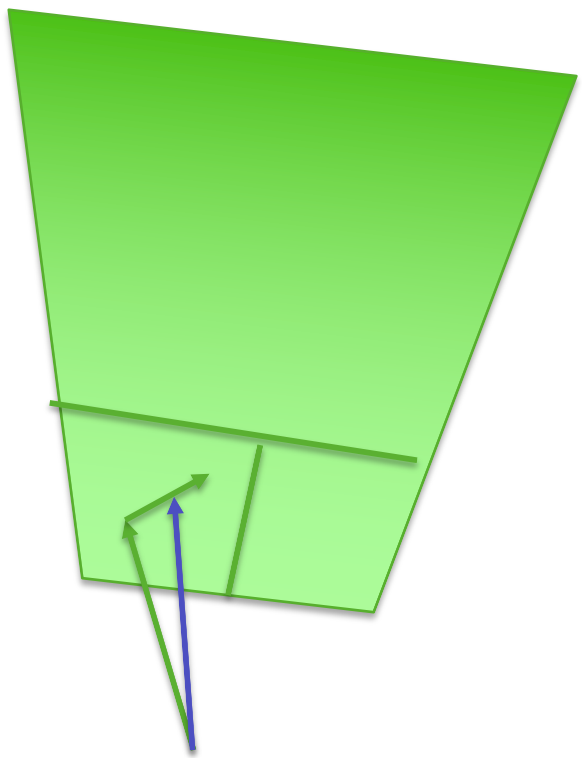
Challenge 1

Ok, simulations show that the principle works but can one group “safely” hits into hit collections using the pulse shapes and avoid multi-hit “contamination”? And how much of this “contamination” Can be taken care by tracking?



Challenge 2

Statistics and calibration timescales are estimated based on simulations and are already long, how much more could be needed under experimental conditions?

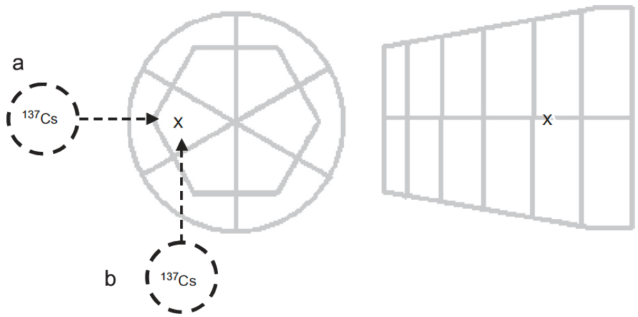
Implementation
What is needed

Measurements:

- The cleanest experimental data set for this method is with one hit segment per crystal (e.g. setting crystal multiplicity trigger >=2 to reduce also the data size)

Analysis:

- Pulse-shape comparison code
- Tracking code to select and order initial data
- Adapt the current self-calibration code to work with experimental data



Nuclear Instruments and Methods in Physics Research A 593 (2008) 440–447

A novel technique for the characterization of a HPGe detector response based on pulse shape comparison

F.C.L. Crespi, F. Camera *, B. Million, M. Sassi, O. Wieland, A. Bracco

Dipartimento di Fisica, Università di Milano and INFN Sezione di Milano, Via Celoria 16, 20133 Milano, Italy

Implementation
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Analysis:

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Simulation:

- Simulated pulse shapes to explore the effectiveness of pulse-shape comparison method and the of multi-hit events

Status

Thanks to Emmanuel Clement!

Source measurements

- New source measurements with crystal multiplicity 2 have been collected in Dec-21. The useful part of the run is only few hours long due to technical issues but older long calibration runs from 2017/18 have been identified and can be used (~48h).

Part of the UK Agata project (WP4)

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Conclusions

- A novel self-calibration method for γ-ray energy tracking arrays is proposed and evaluated with Geant4 simulations
- A basis generation with 1 mm RMS fidelity is possible with realistic statistics (based on this simulation)
- The method promises *in situ* calibration of the arrays in realistic timescales to complement signal basis generation
- First calibration runs with AGATA have been collected/identified
- Development and adjustment of algorithms and method is required to process experimental signals. This will be one of the tasks in the UK AGATA WP4.

Thank you!