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

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

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Motivation



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

Discuss with PSA experts the possible steps towards experimental validation of the method

Current challenges



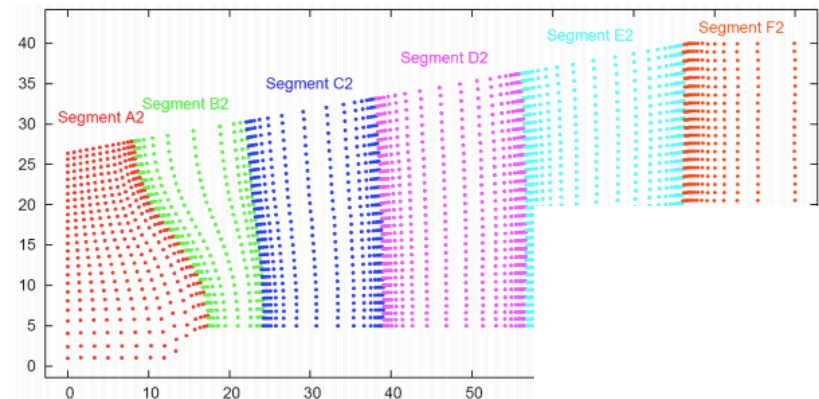
signal basis generation

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



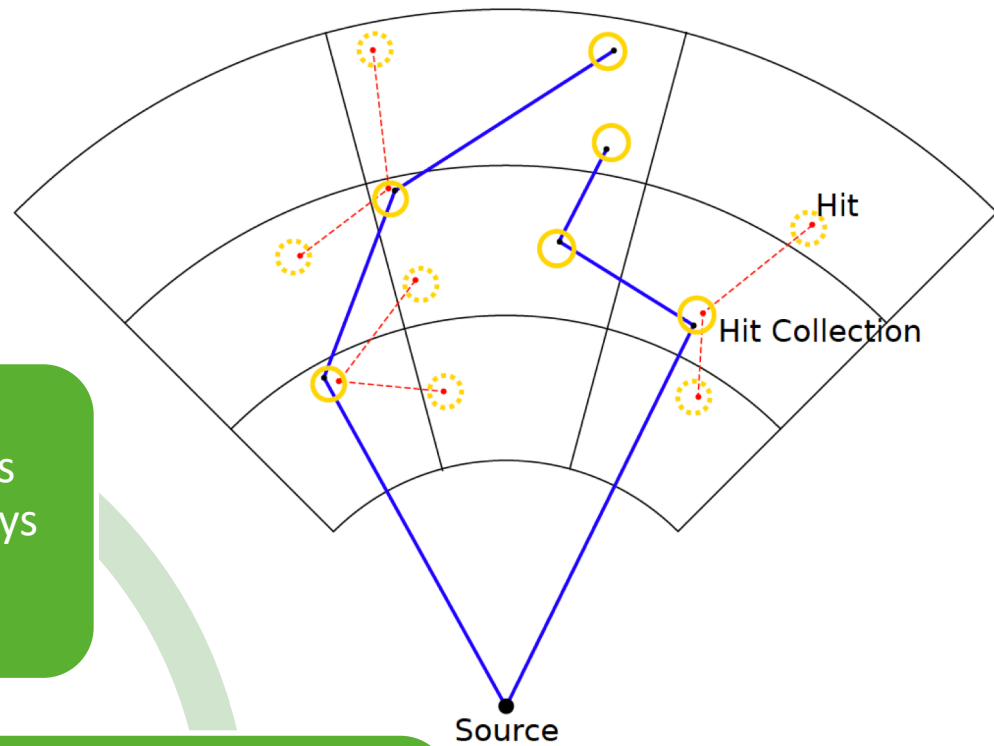
Method

Group interaction points from different gamma-rays into hit collections

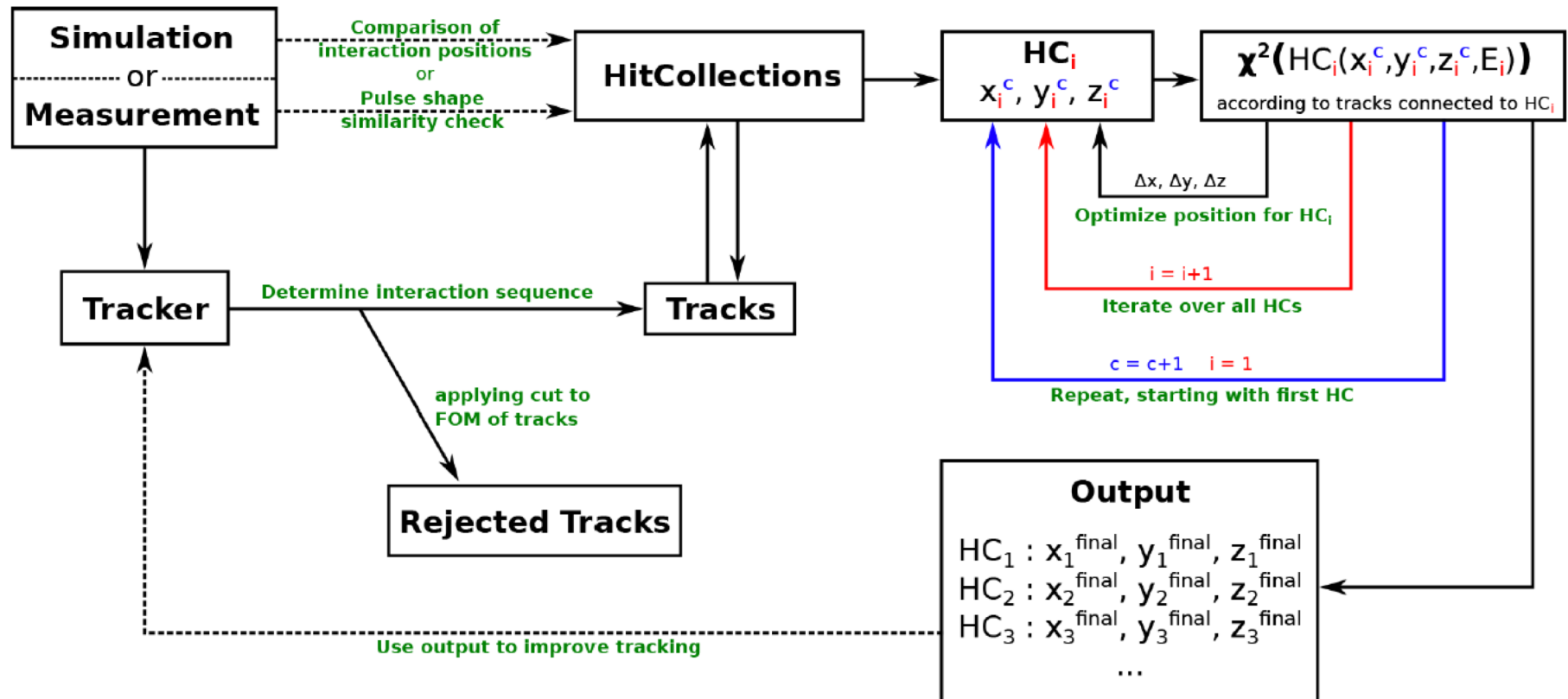
Optimise coordinates of hit collection using the tracks that link their constituent points and Compton formula

Use Compton formula to order interaction points

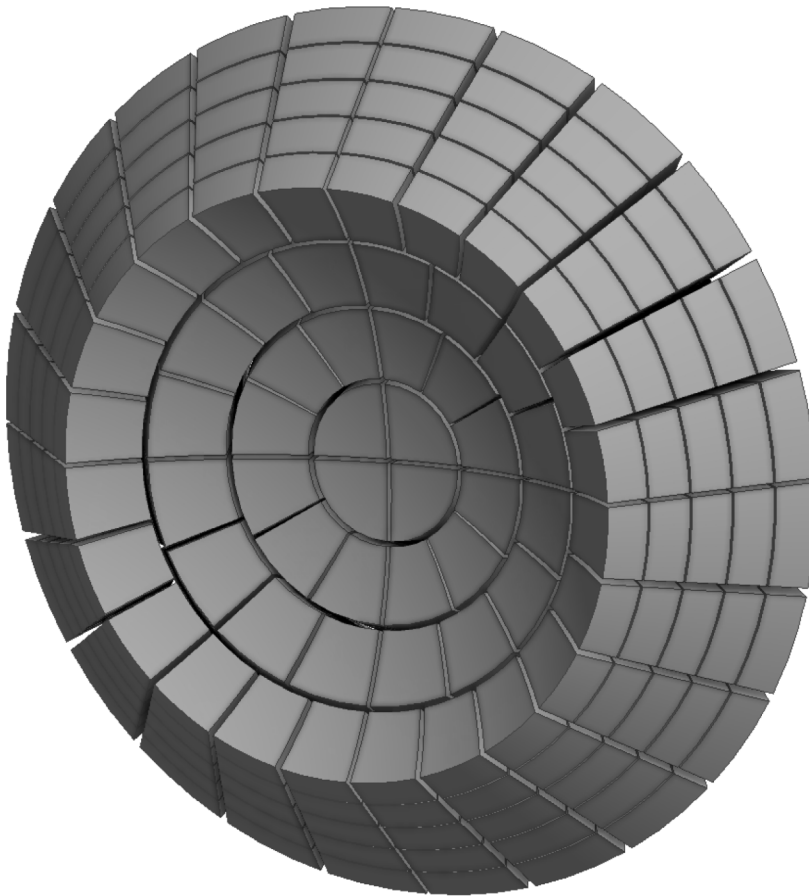
Define tracks between interaction points that also link the hit collections with each other



Method



Simulation



Monte Carlo simulations (Geant4)

Physics list: G4EmStandardPhysics option4

Solid angle coverage: $\sim 0.6 \pi$ sr

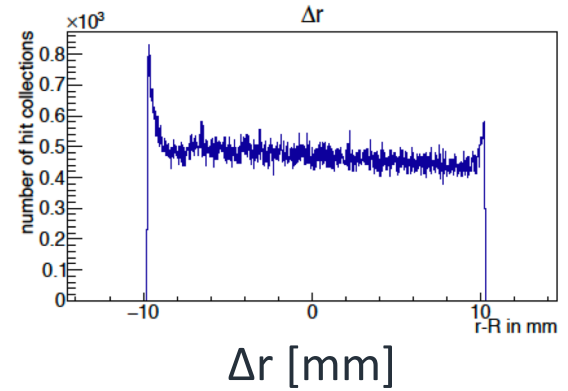
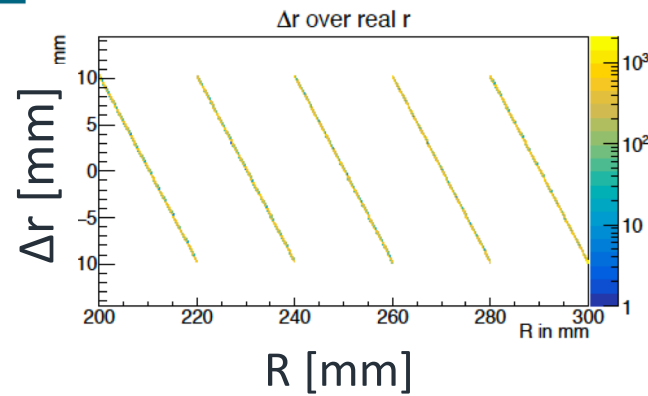
Inner diameter 20 cm

Outer diameter 30 cm

280 segments

Results

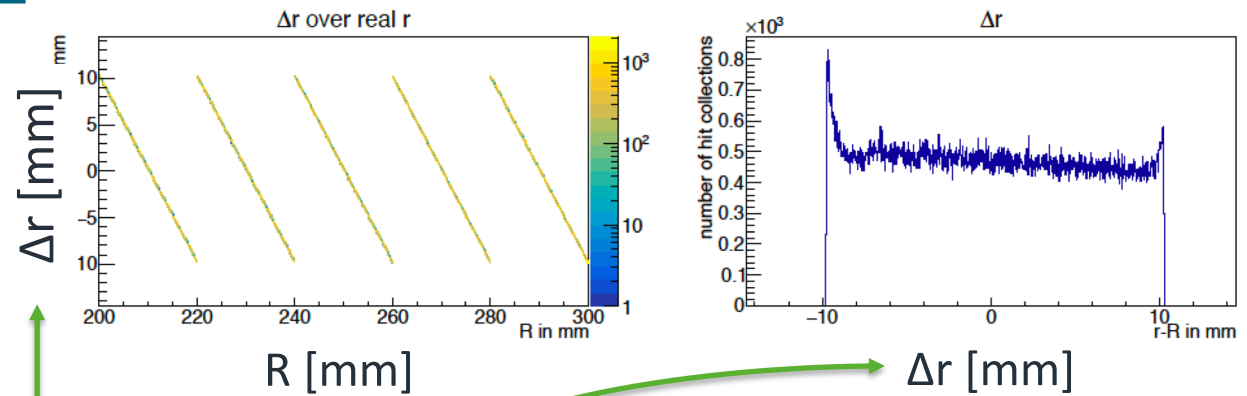
starting condition



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

Results

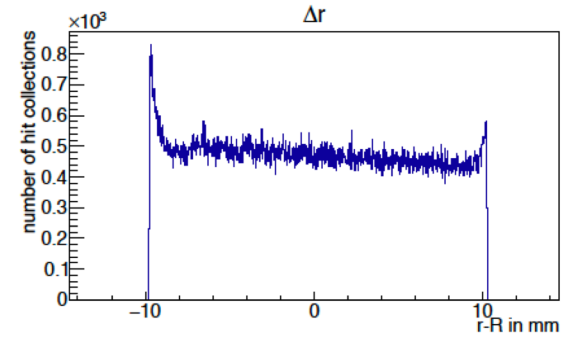
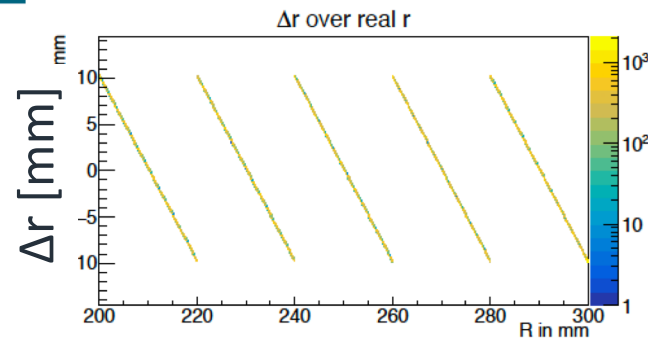
starting condition



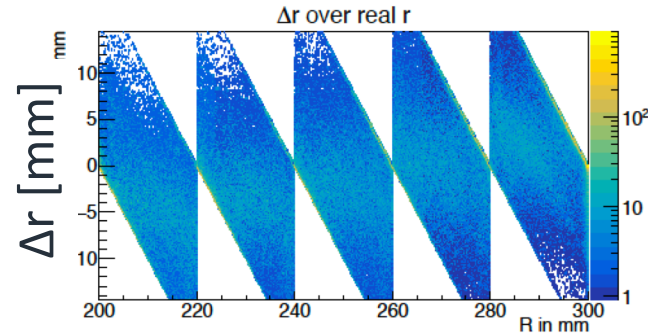
- Hit collections are assigned a nominal position inside a segment, e.g. at its centre
- The **difference** between real and current hit collection position is maximum

Results

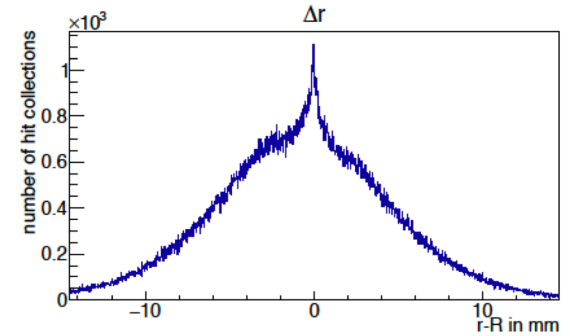
starting condition



after 1st iteration



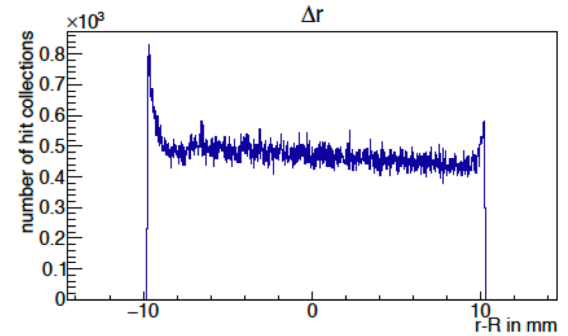
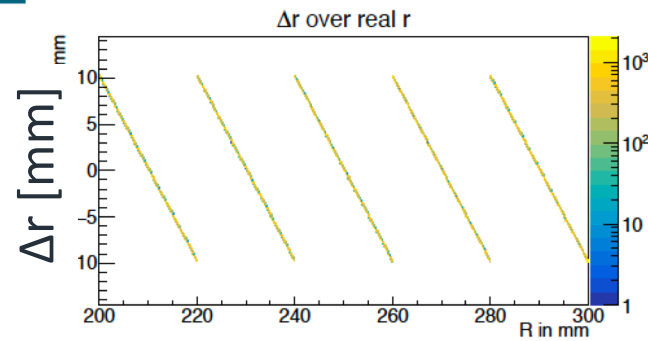
R [mm]



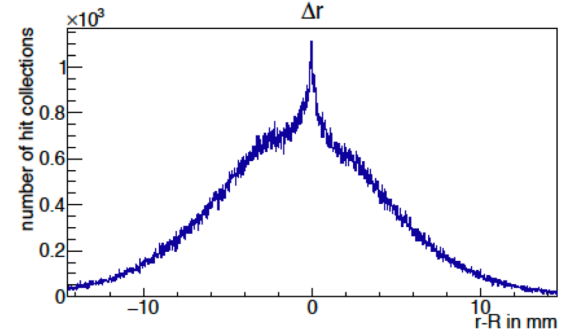
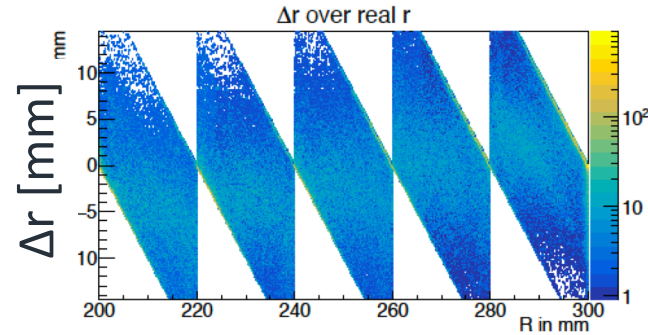
Δr [mm]

Results

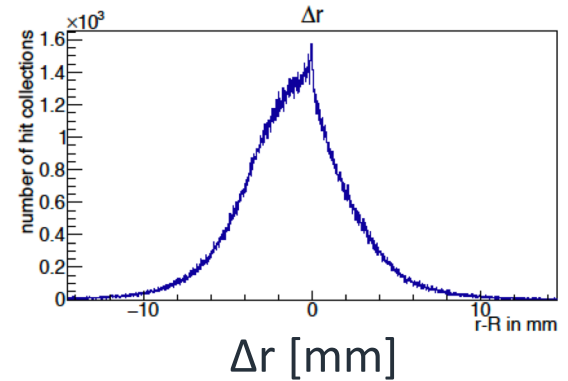
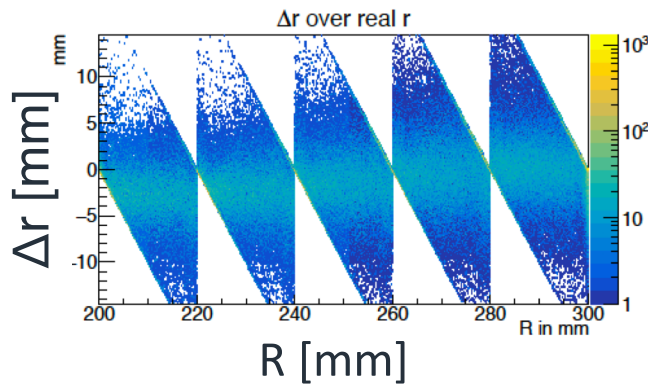
starting condition



after 1st iteration

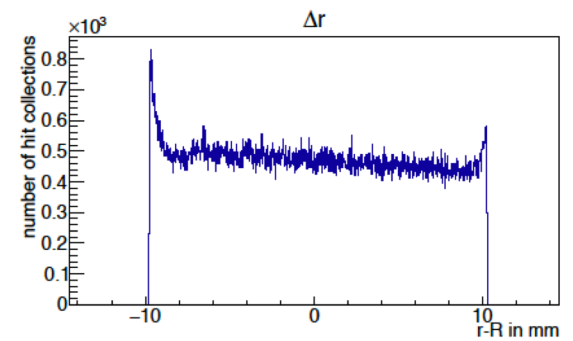
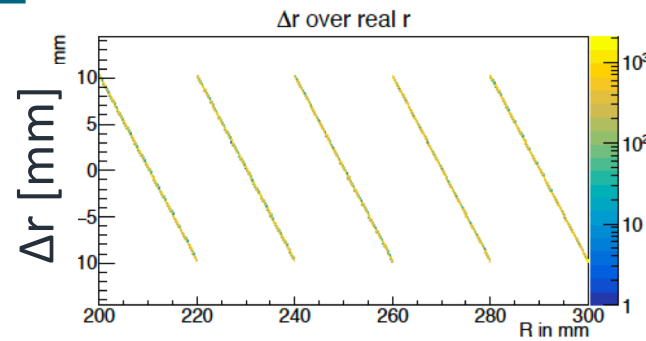


after 2nd iteration

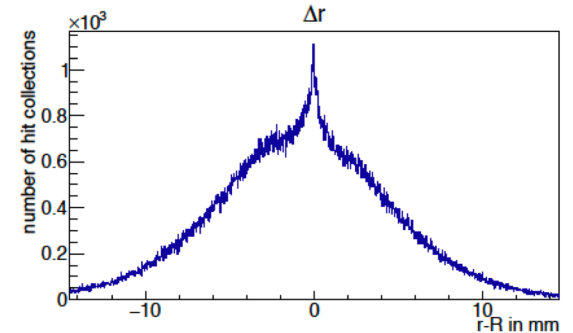
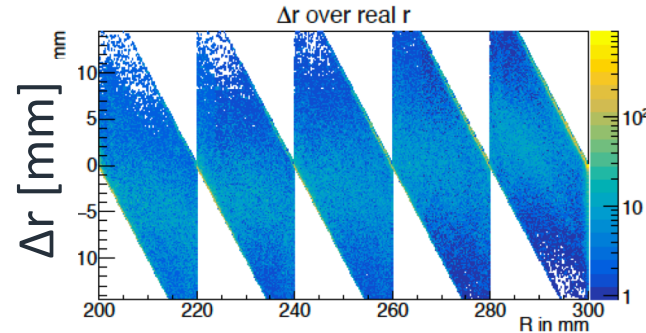


Results

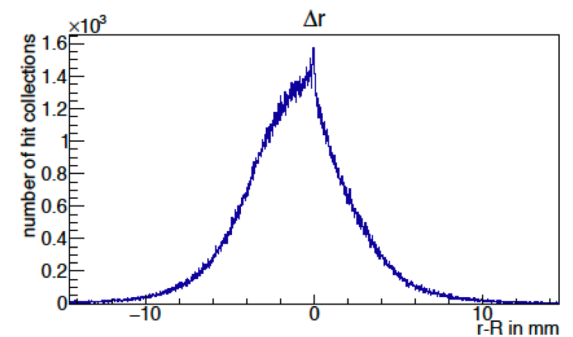
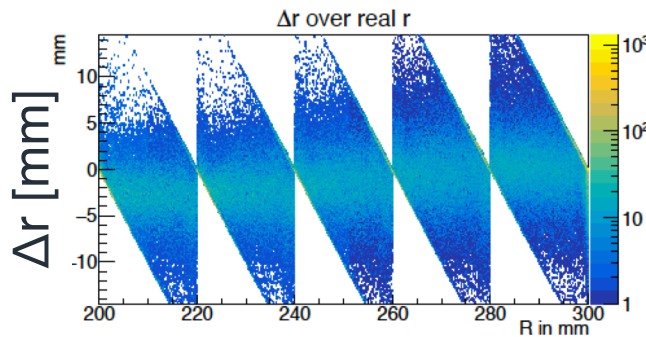
starting condition



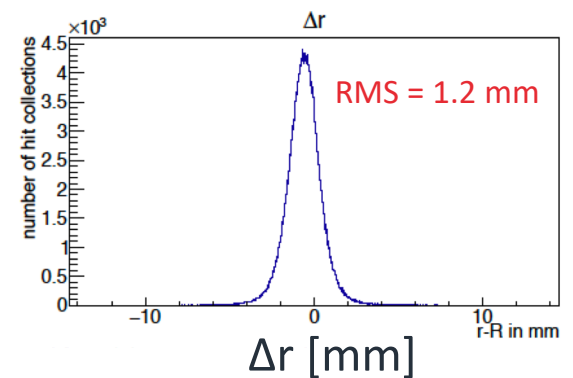
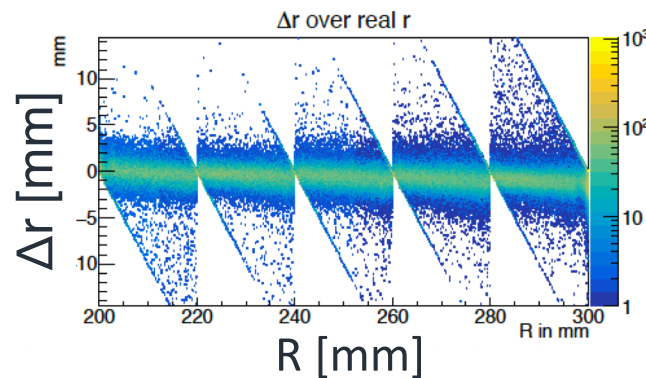
after 1st iteration



after 2nd iteration

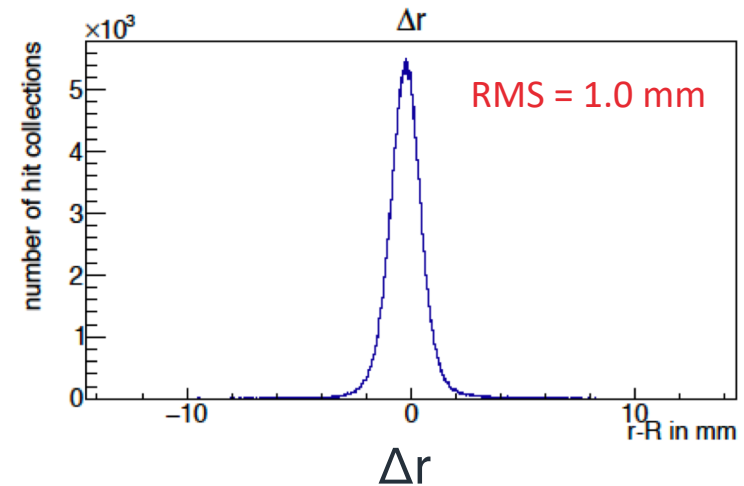
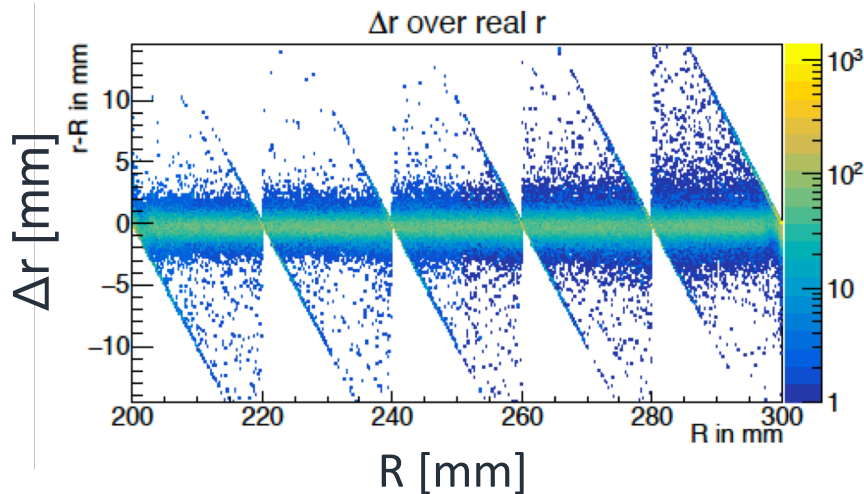


after 10th iteration



Results

re-tracked with previous self-calibration result



Reconstruction RMS = 1.0 mm

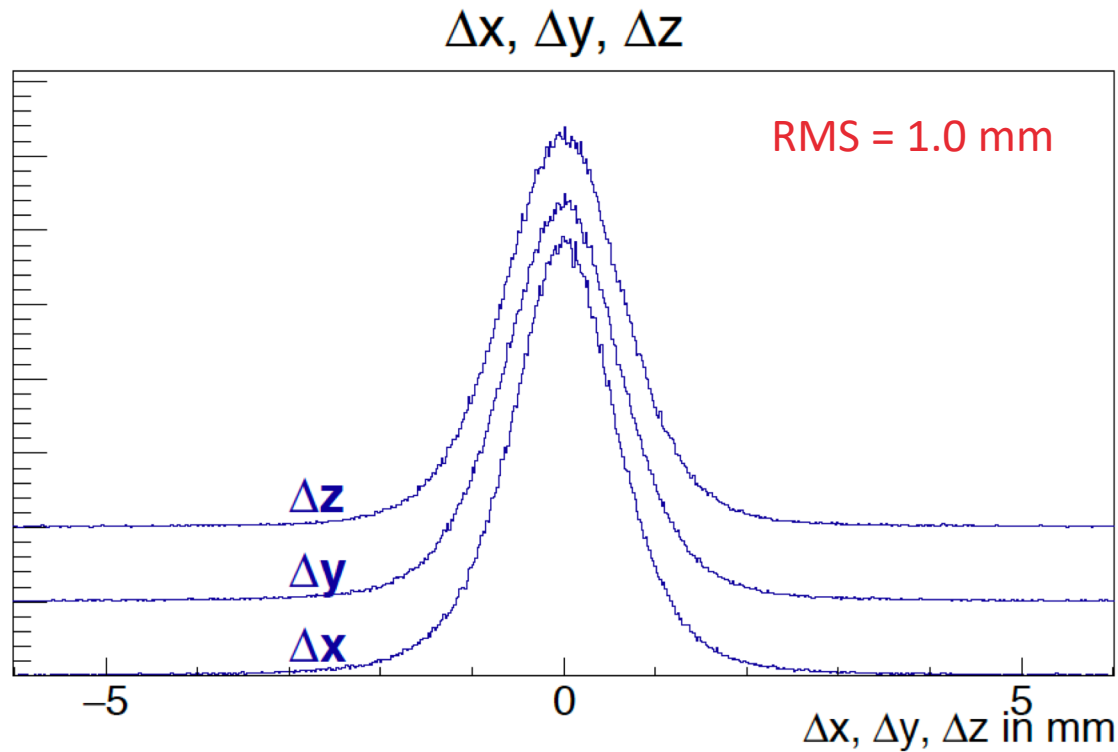
Reconstruction Offset = -0.2 mm

Results



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re-tracked with previous self-calibration result

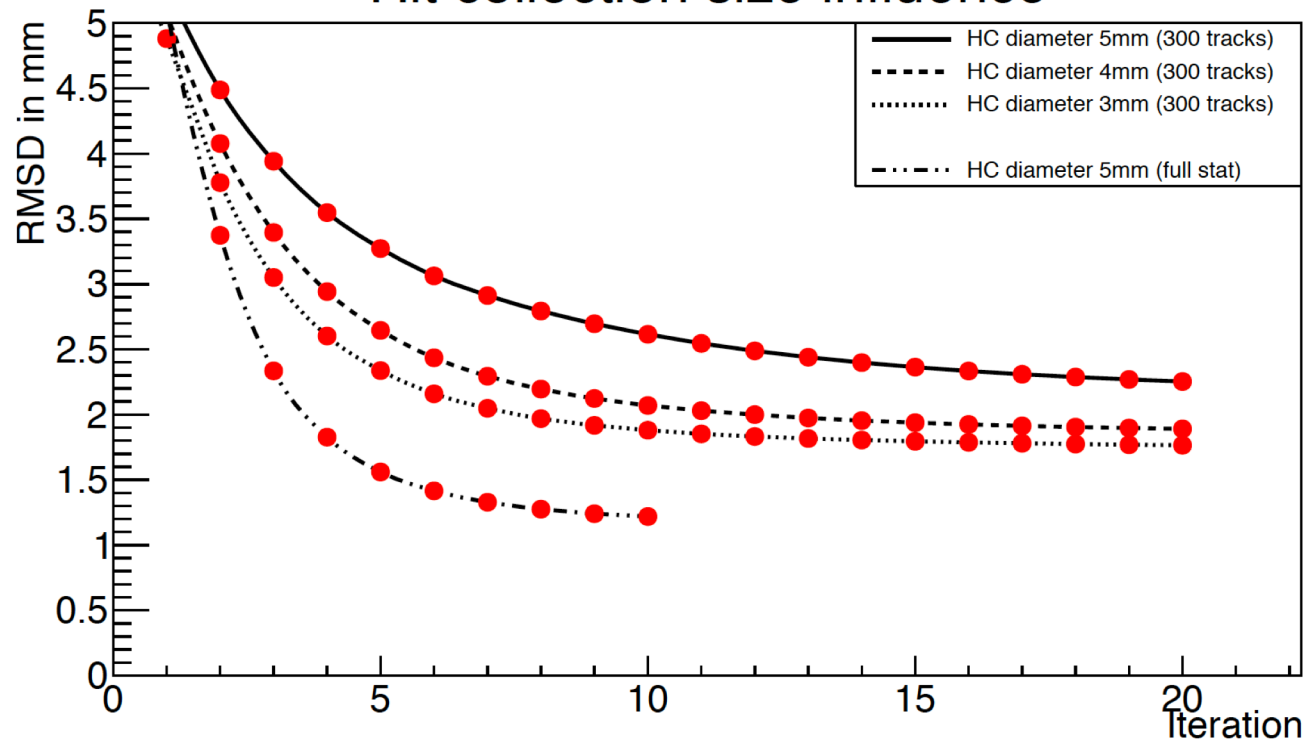


Results



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Hit collection size influence



Outlook: implementation



Measurements:

- The cleanest experimental data set would be with one hit segment per crystal (e.g. can set crystal multiplicity trigger ≥ 2 to reduce also the data size)
- Statistics and calibration timescales (currently estimated to be about a week but a more careful estimate is needed)
- Appropriate high-energy source (^{88}Y) or stick with monoenergetic for simplicity (^{137}Cs), or in-beam data if clean enough

Analysis:

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

Conclusions



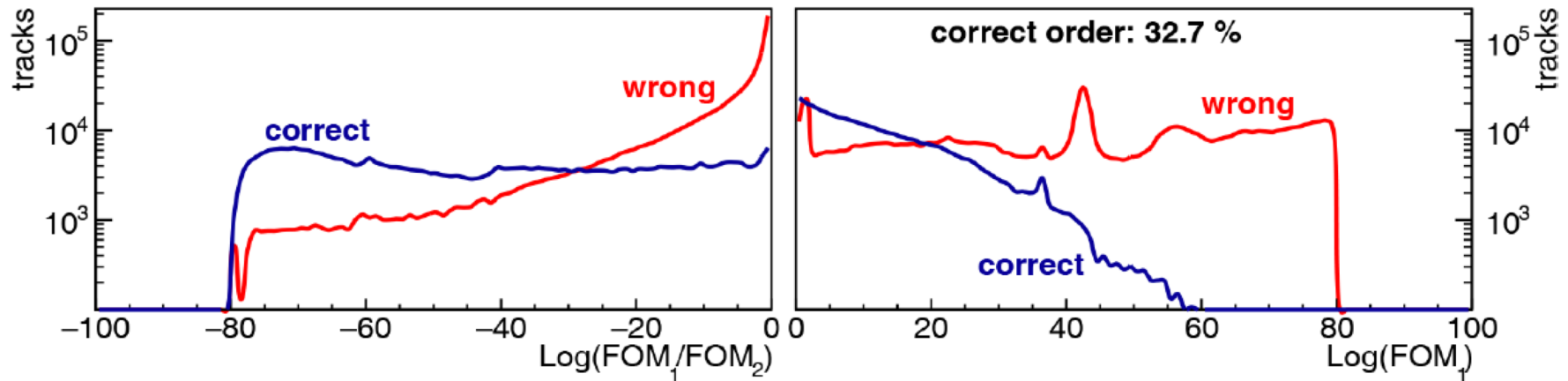
- A novel self-calibration method for γ -ray energy tracking arrays is proposed and evaluated with Geant4 simulations
- A basis generation with 1 mm RMS fidelity is possible with realistic statistics (based on this simulation)
- The method promises *in situ* calibration of the arrays in realistic timescales
- Next steps and challenges towards implementation and experimental validation

Thank you!

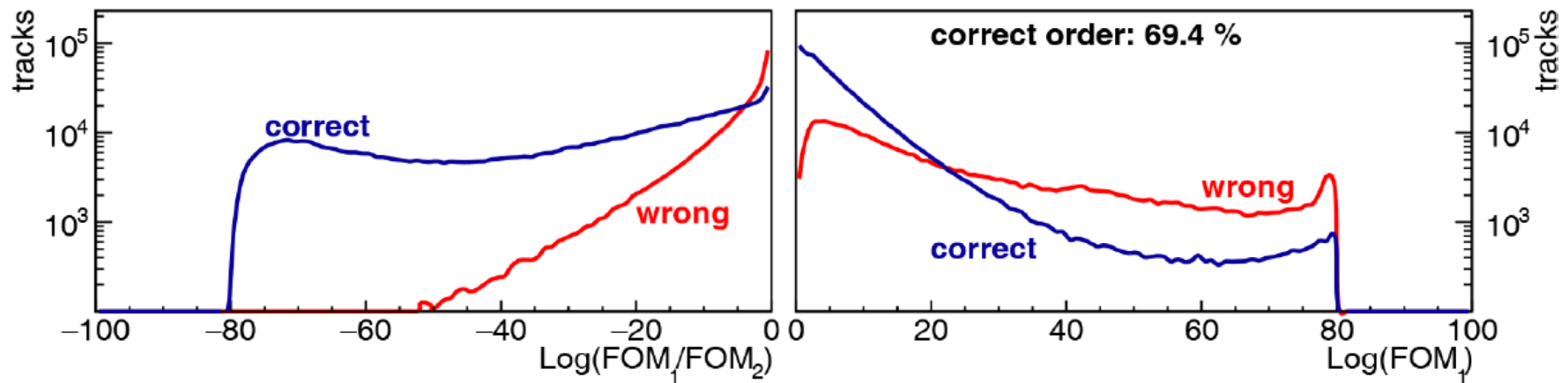
Results



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↓ re-tracked with previous self-calibration result ↓



Results



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