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

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Special Article – New Tools and Techniques

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

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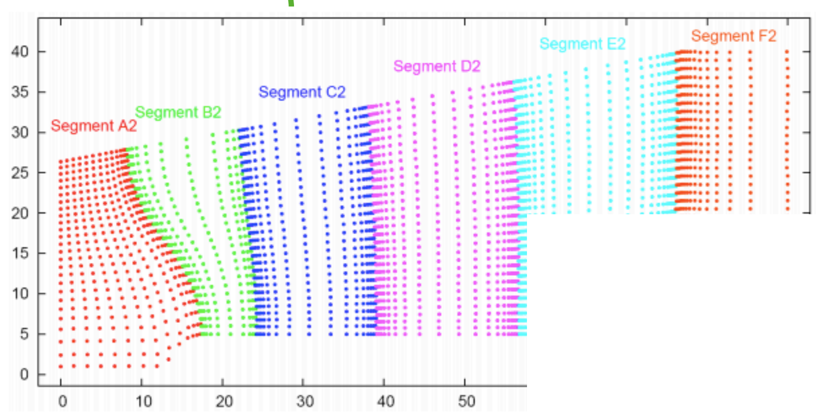
signal basis generation

Experimental (scanning)

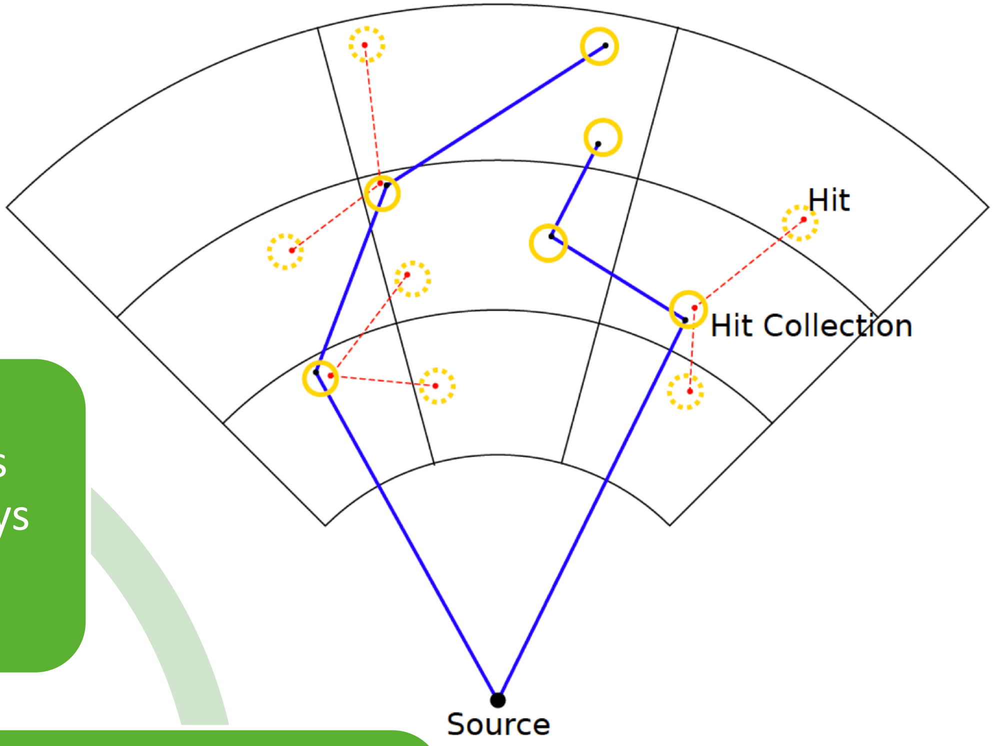
- long acquisition times
- different conditions between scanning and experiment, e.g. noise, radiation damage
- mechanical alignment

Analytical (calculated)

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



Method



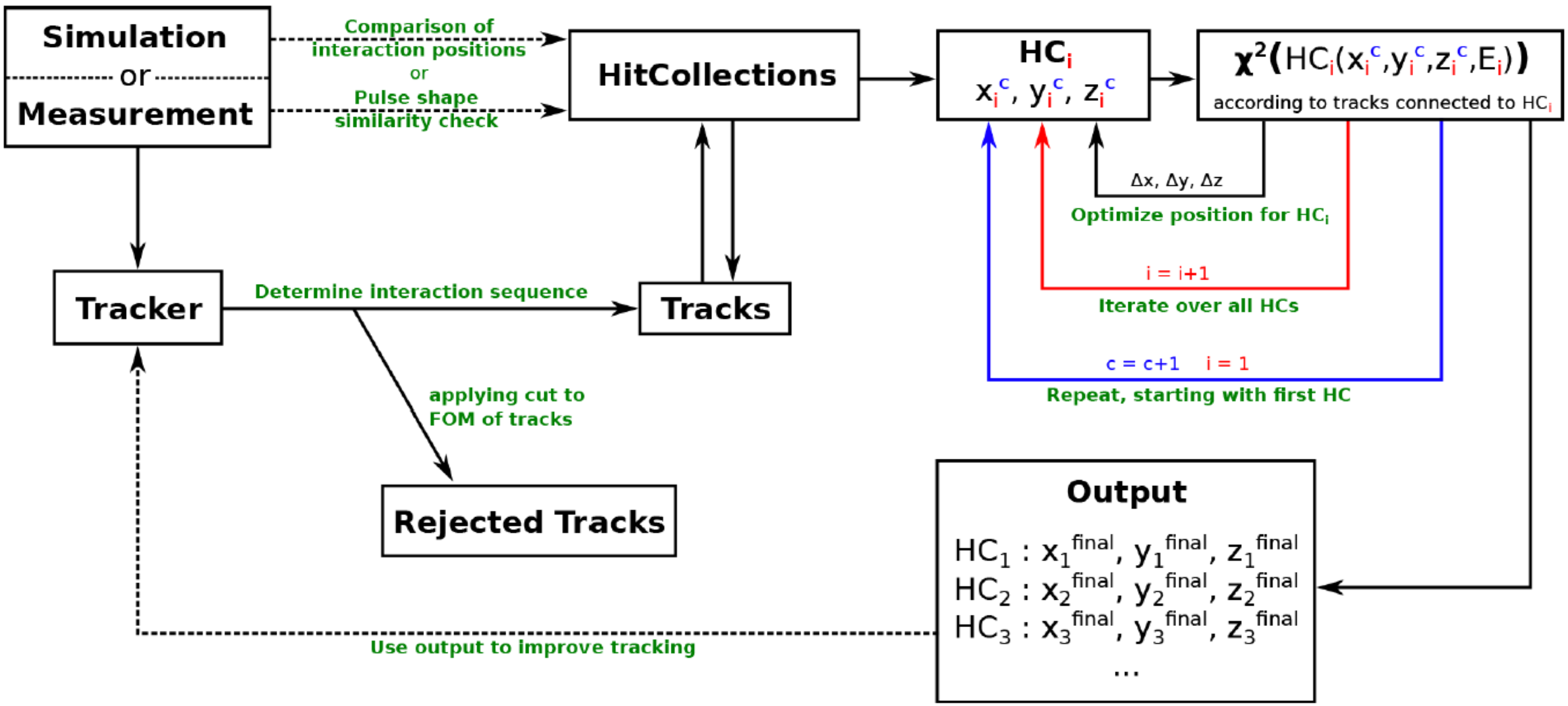
Group interaction points from different gamma-rays into hit collections

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

Method



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Simulation

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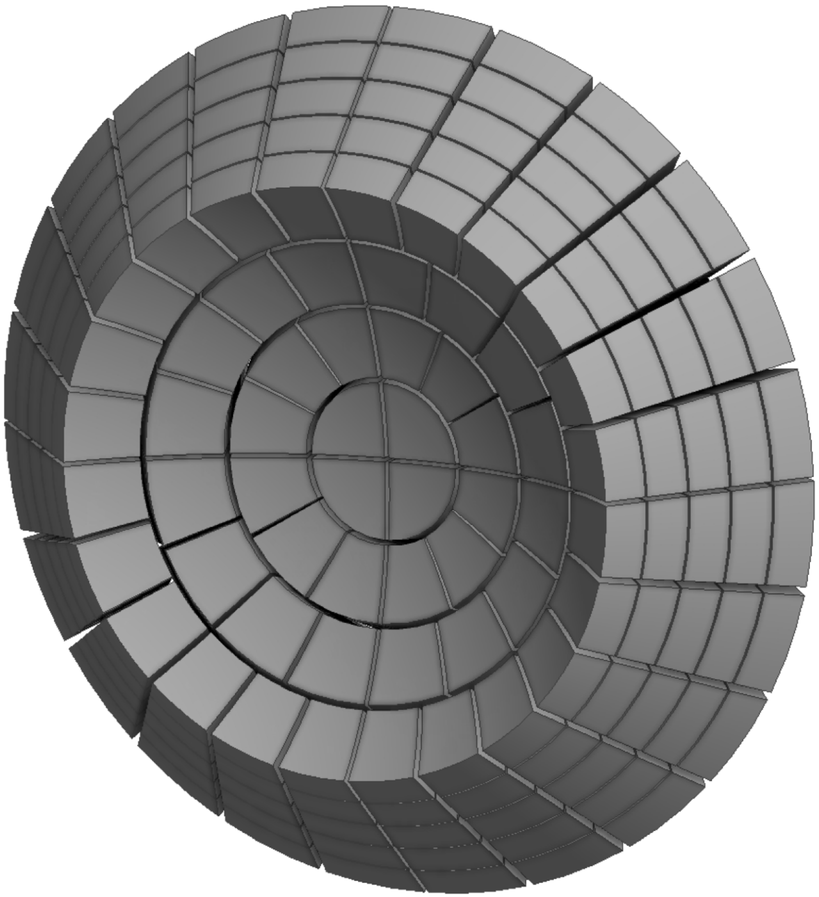


Monte Carlo simulations (Geant4)

Physics list: G4EmStandardPhysics option4

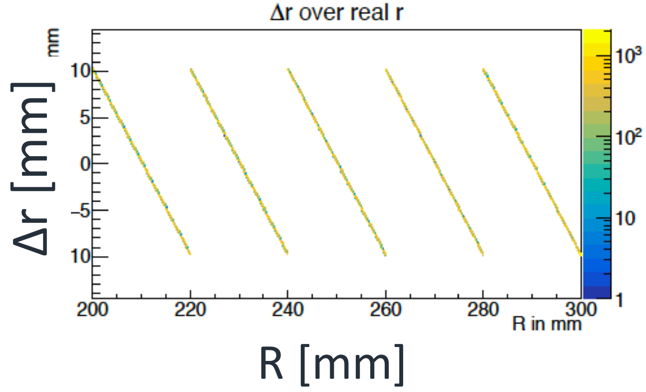
Solid angle coverage: ~0.6 π sr

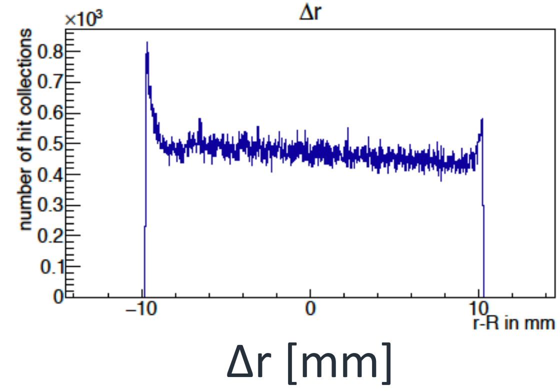
Inner diameter 20 cm
Outer diameter 30 cm

280 segments

Results

starting condition

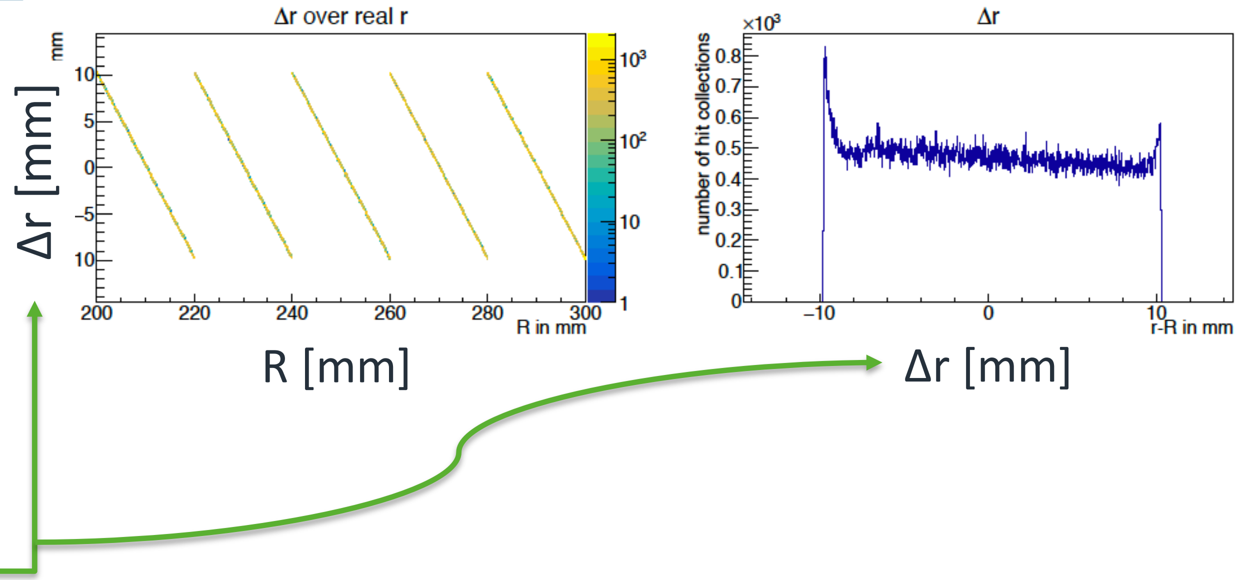




- ➢ Hit collections are assigned a nominal position inside a segment, e.g. at its centre

Results

starting condition

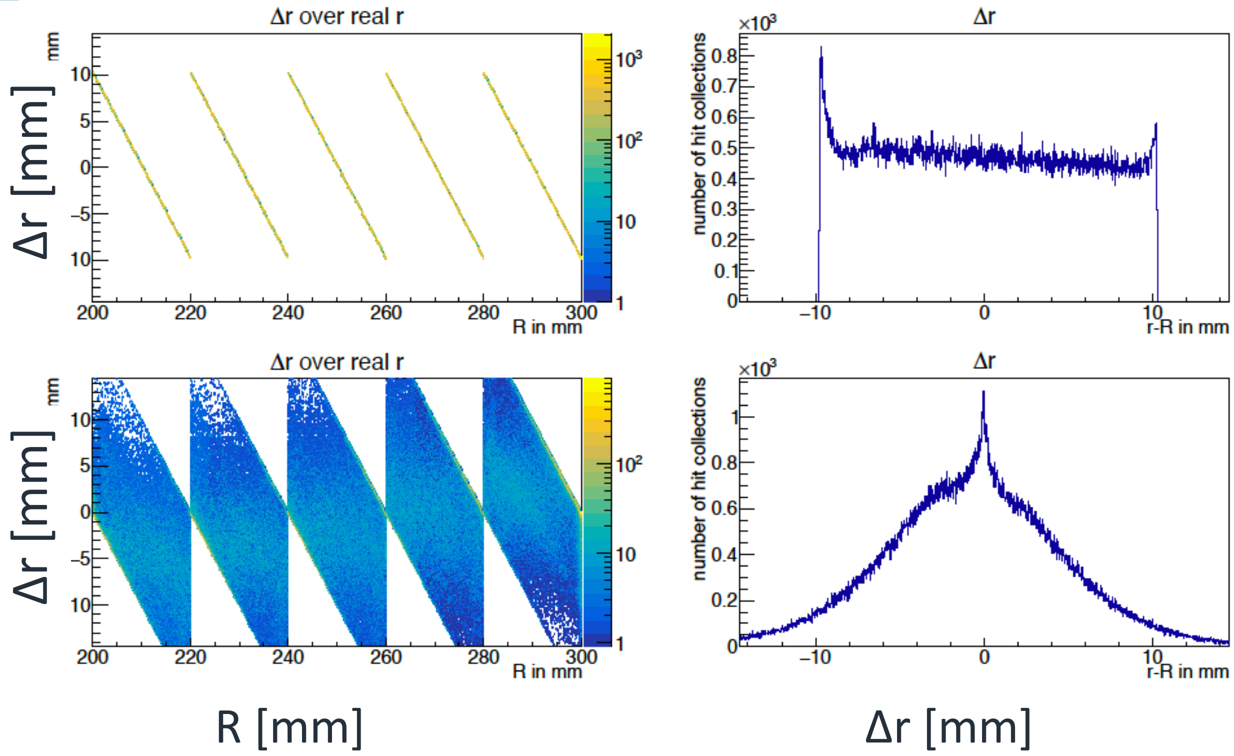


- Hit collections are assigned a nominal position inside a segment, e.g. at its centre
- The **difference** between real and current hit collection position is maximum

Results

starting condition

after 1st iteration

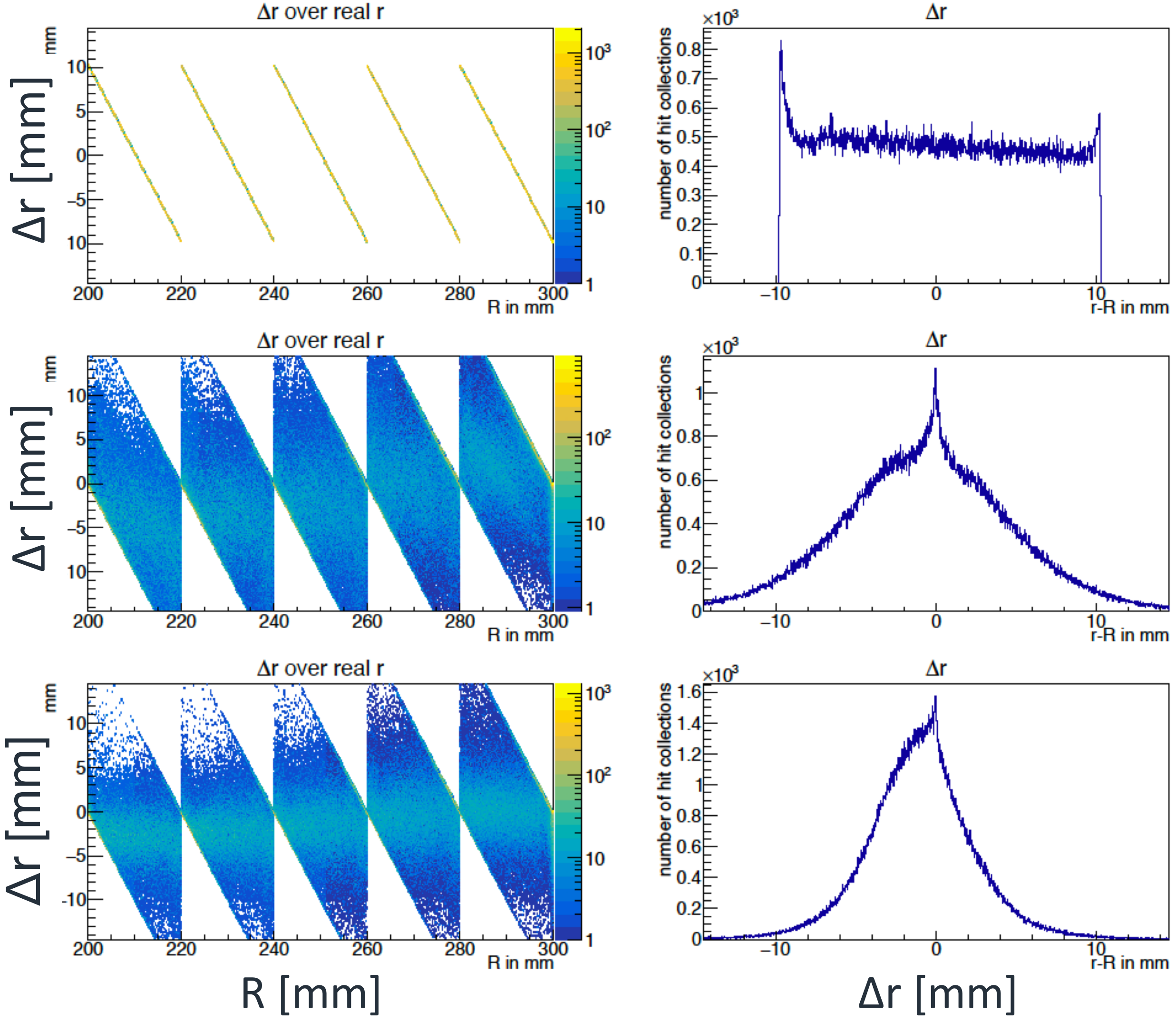


Results

starting condition

after 1st iteration

after 2nd iteration



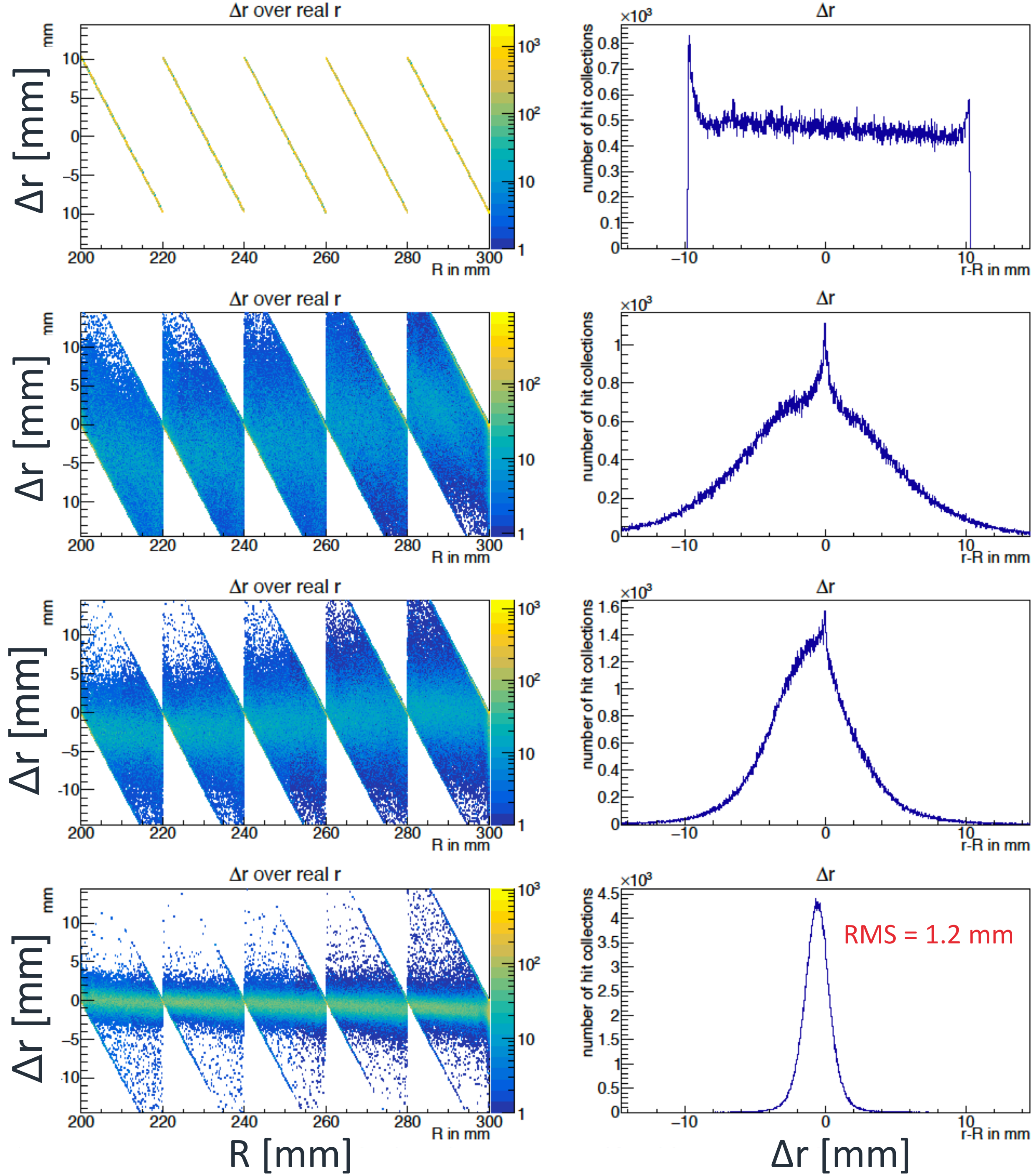
Results

starting condition

after 1st iteration

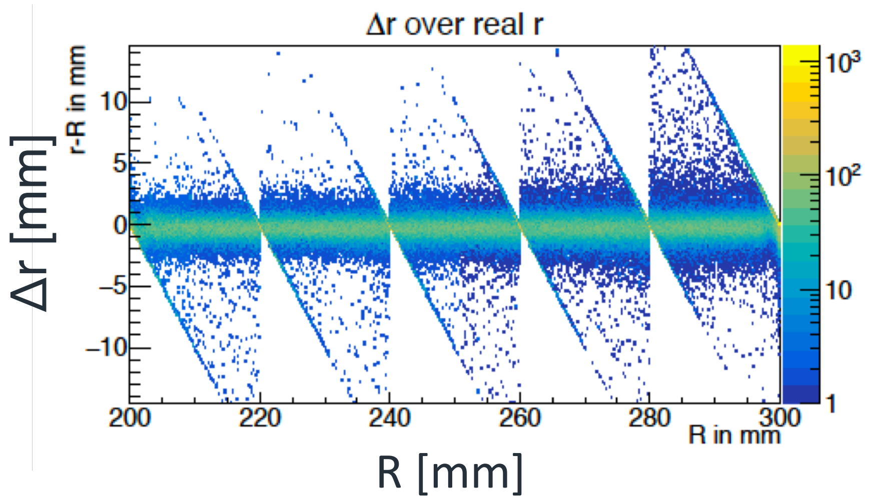
after 2nd iteration

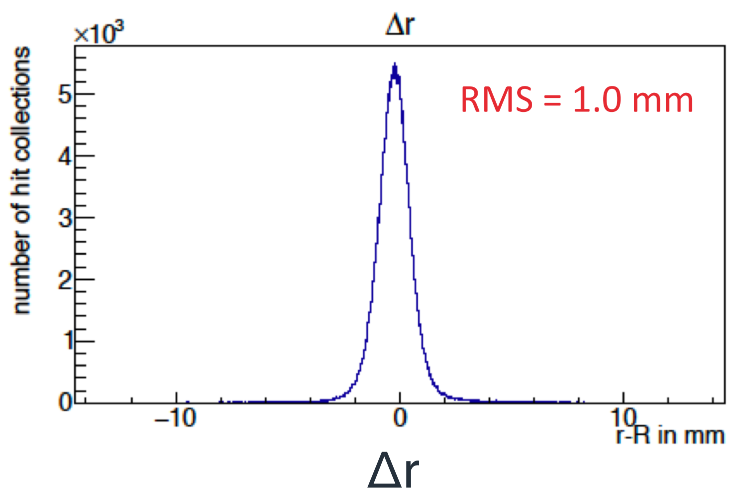
after 10th iteration



Results

re-tracked with previous self-calibration result

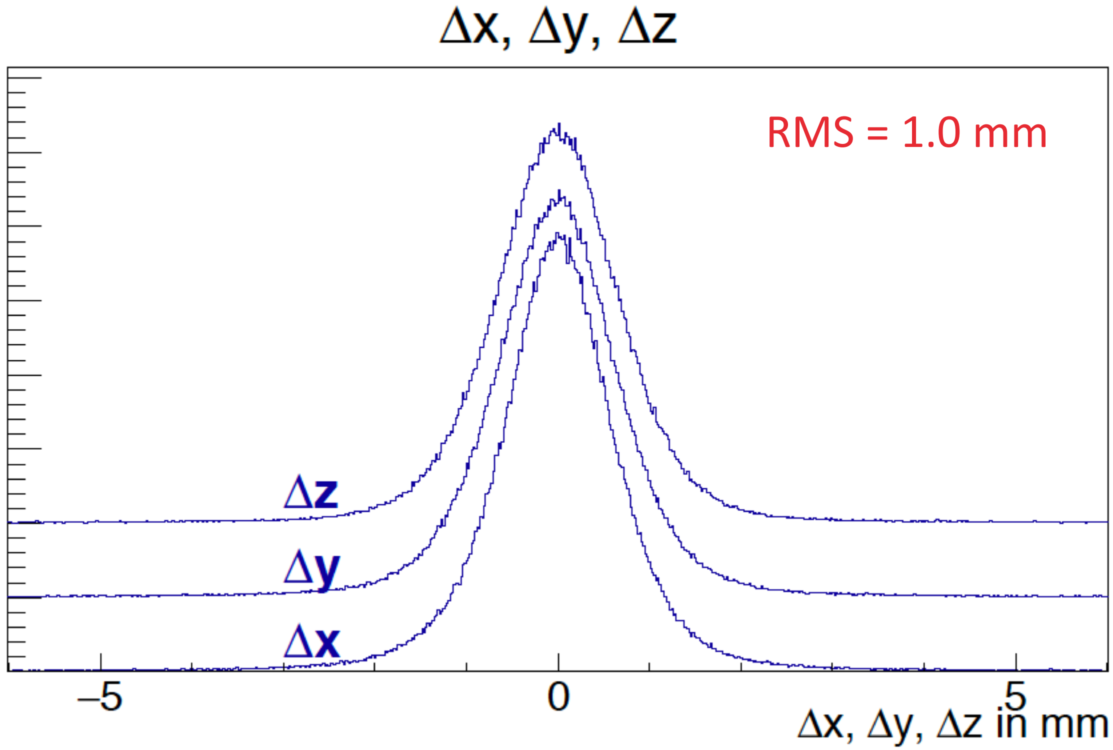




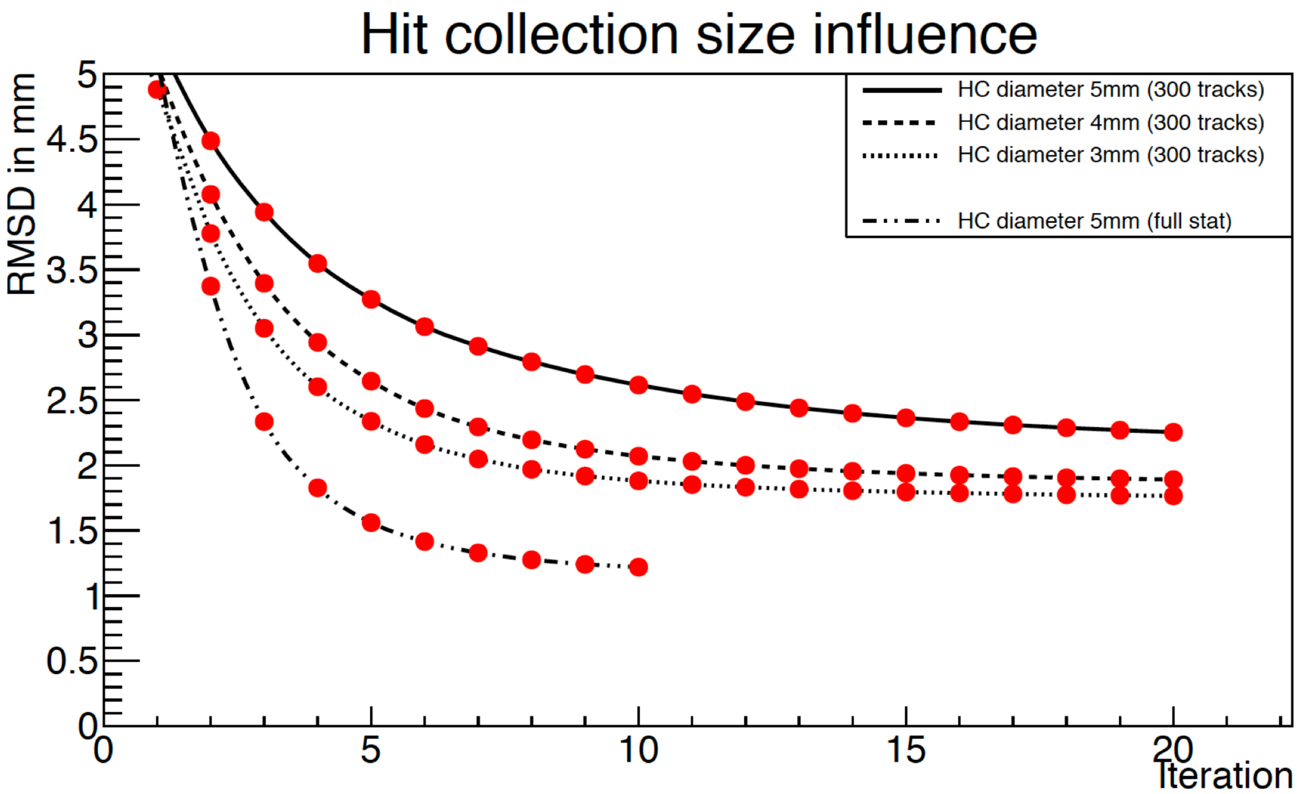
Reconstruction RMS = 1.0 mm
Reconstruction Offset = -0.2 mm

Results

re-tracked with previous self-calibration result



Results


Hit collection size influence
RMSD in mm
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
Iteration
HC diameter 5mm (300 tracks)
HC diameter 4mm (300 tracks)
HC diameter 3mm (300 tracks)
HC diameter 5mm (full stat)

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!