Timepix3 in the AEgIS experiment

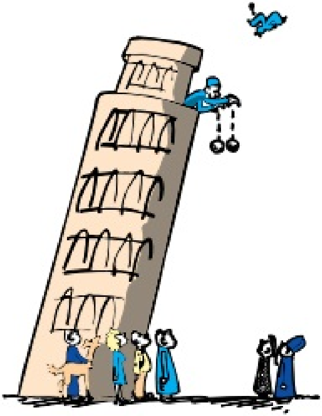
Helga Holmestad

University of Oslo

19/9-2018

AEgIS experiment

Measure the gravitational acceleration of antimatter



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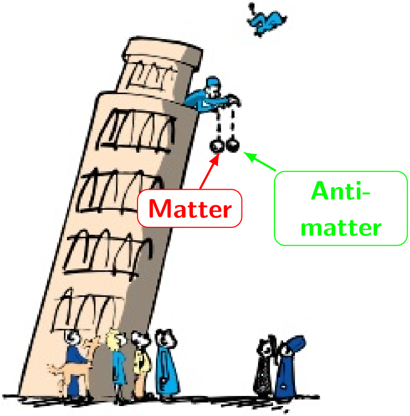
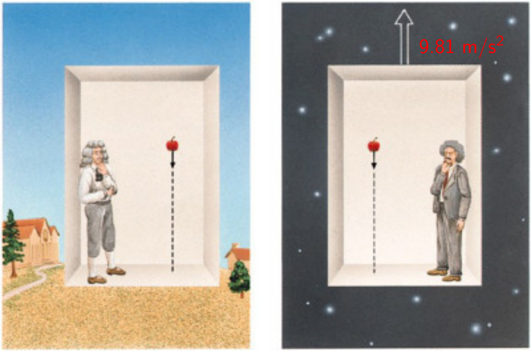


The equivalence principle

- Gravitational field = accelerated frame of reference
- Predicts: $\bar{g} = g$
  - Never been tested before
- Building block of general relativity
  - Bending of light
  - Red shift
- Matter-antimatter assymetry



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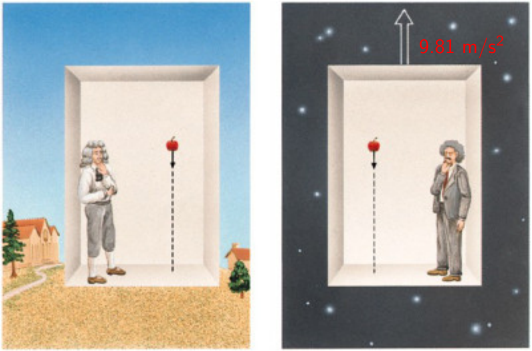

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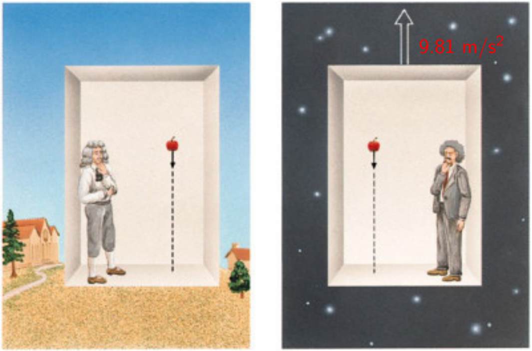
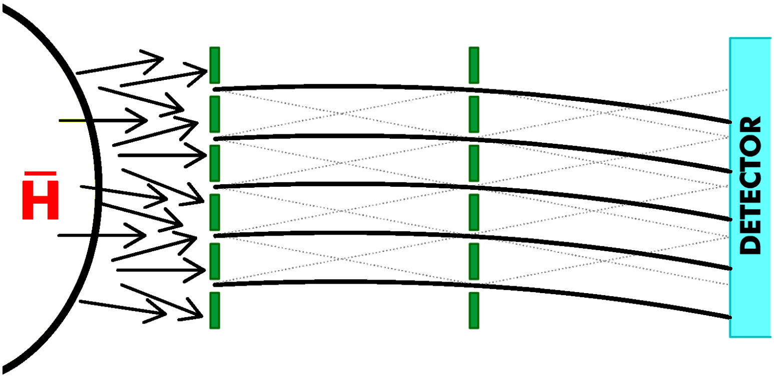


A classical moiré deflectometer



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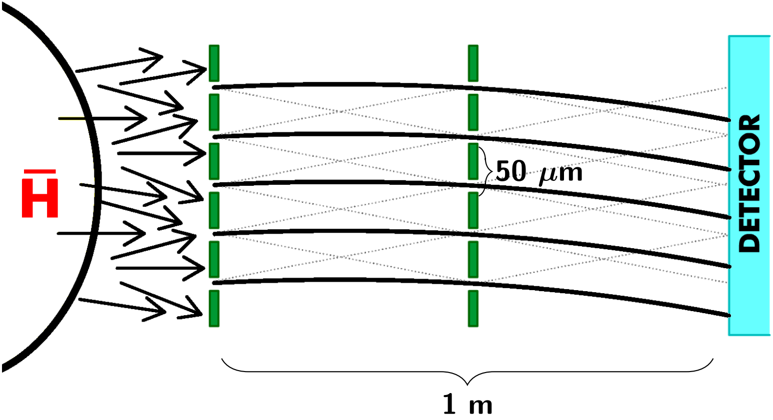

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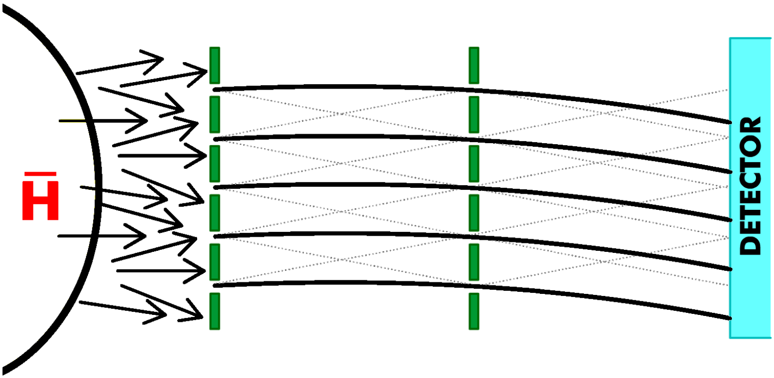

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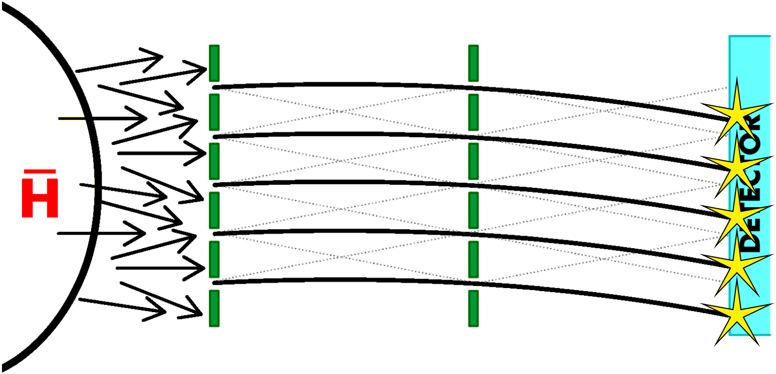

Requirements for the detector

- Tag antihydrogen
  - Fragments from annihilations outside the detector
- Measure time of flight
  - Energy of antihydrogen beam will not be completely uniform
  - Transit time through the moirè deflectometer is around 2ms
- Reconstruct the annihilation point
  - The periodicity of the moire deflectometer is around 50 μm
  - Vertical fall around 10 μm
  - Around 10 μm resolution needed to achieve 1% precision on $\bar{g}$
- Does a detector fullfilling these requirements already exist?

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Silicon pixel detector using the Timepix3 readout system

- 55 μm$\times$55 μm pixels
- Measure both time of arrival and deposited energy
- Time resolution 1–2 ns
- 670 μm thick
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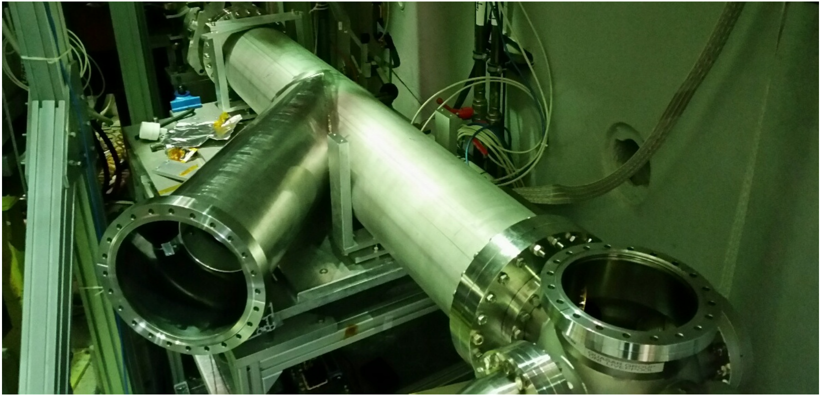
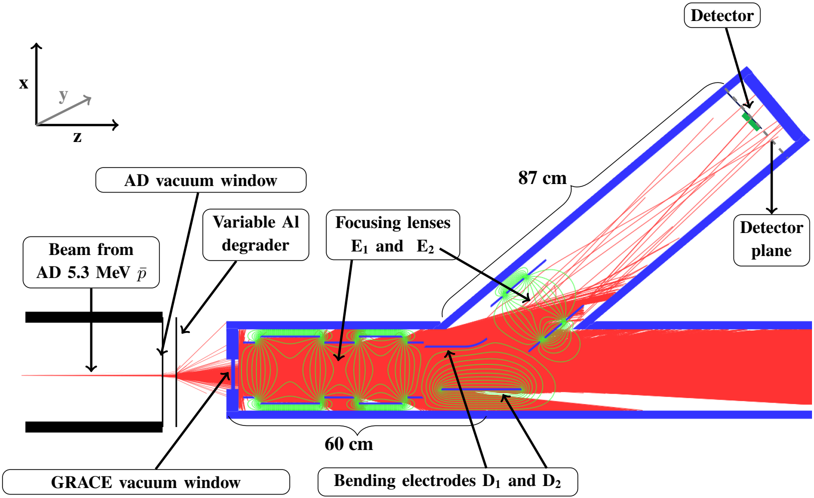
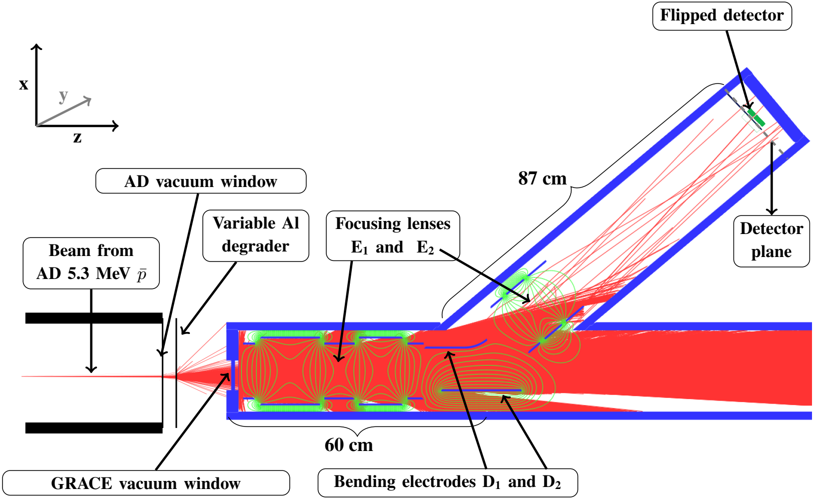
GRACE beamline



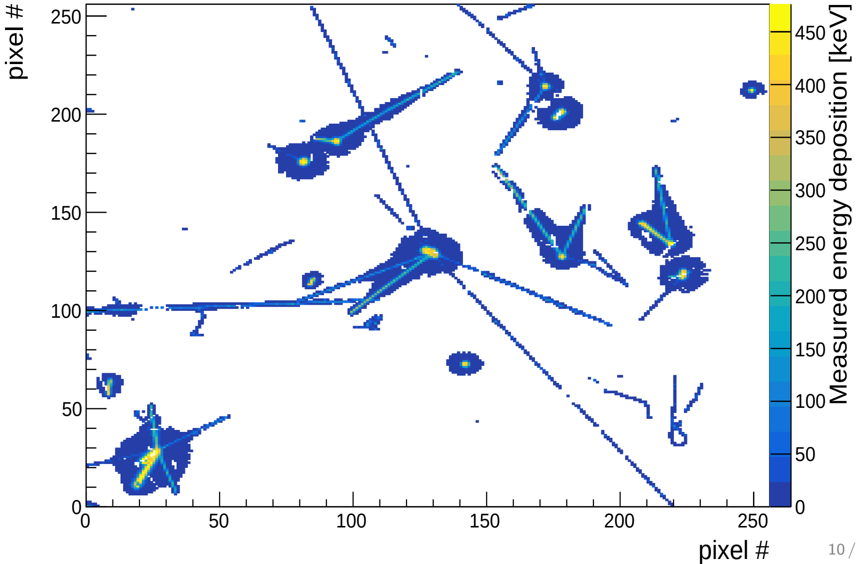
GRACE in standard setting



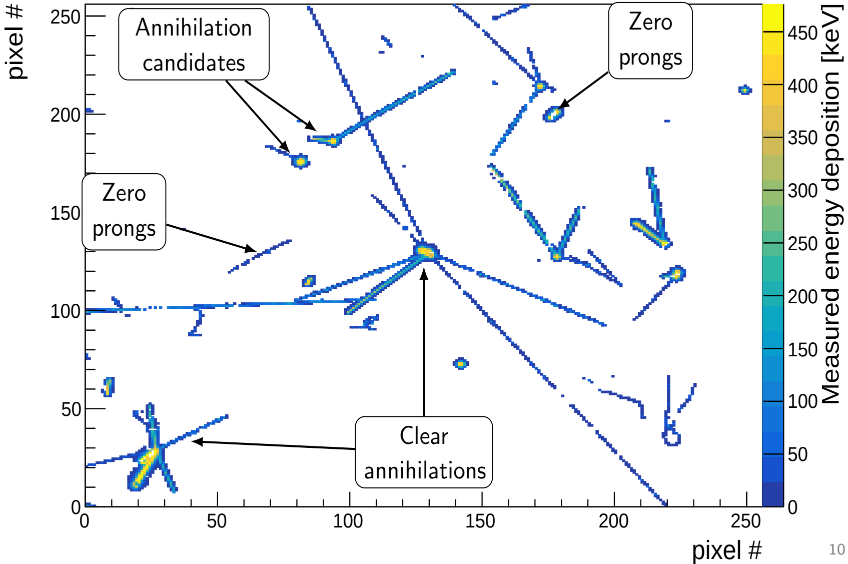
GRACE for reference sample

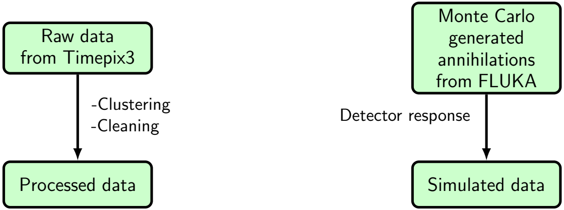


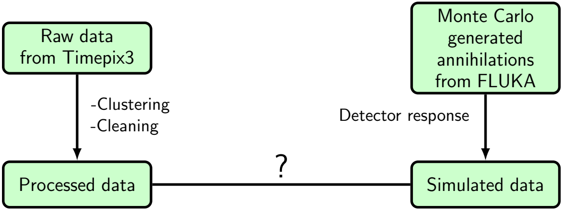
Antiproton data



Antiproton data




Raw data
from Timepix3
-Clustering
-Cleaning
Processed data
Monte Carlo
generated
annihilations
from FLUKA
Detector response
Simulated data


Raw data
from Timepix3
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?
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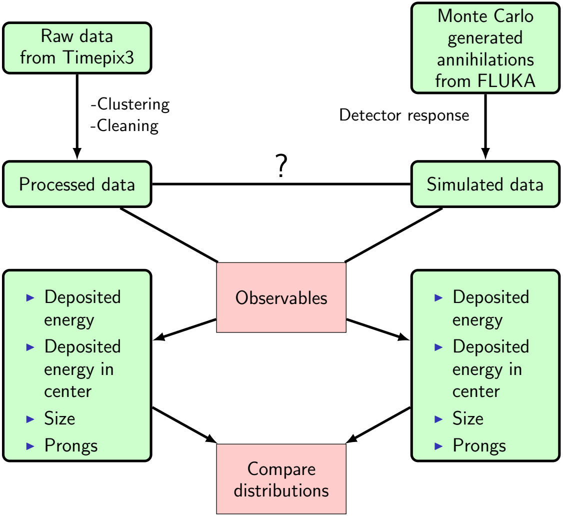
Raw data from Timepix3
-Clustering
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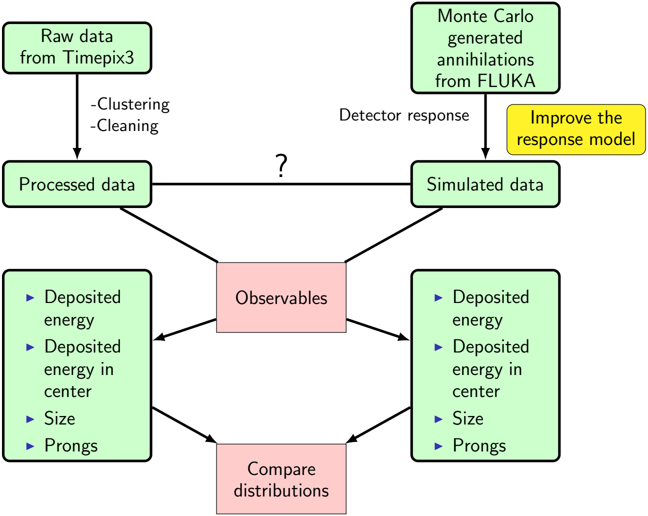
Monte Carlo generated annihilations from FLUKA
Detector response
Processed data
?
Simulated data
Observables
Deposited energy
Deposited energy in center
Size
Prongs
Deposited energy
Deposited energy in center
Size
Prongs
Compare distributions


Raw data from Timepix3
-Clustering
-Cleaning
Monte Carlo generated annihilations from FLUKA
Detector response
Improve the response model
Processed data
?
Simulated data
Observables
Deposited energy
Deposited energy in center
Size
Prongs
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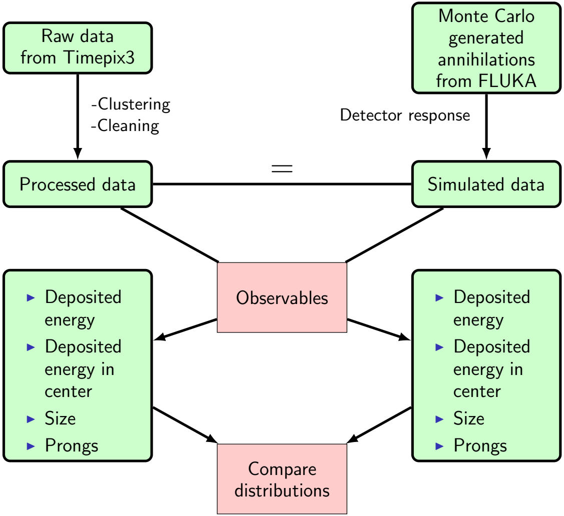
Raw data from Timepix3
-Clustering
-Cleaning
Monte Carlo generated annihilations from FLUKA
Detector response
Processed data
=
Simulated data
Observables
Deposited energy
Deposited energy in center
Size
Prongs
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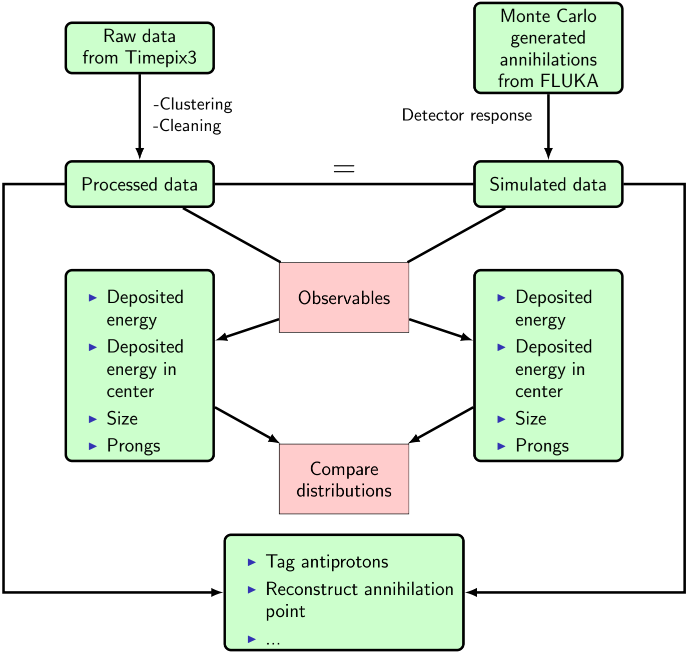
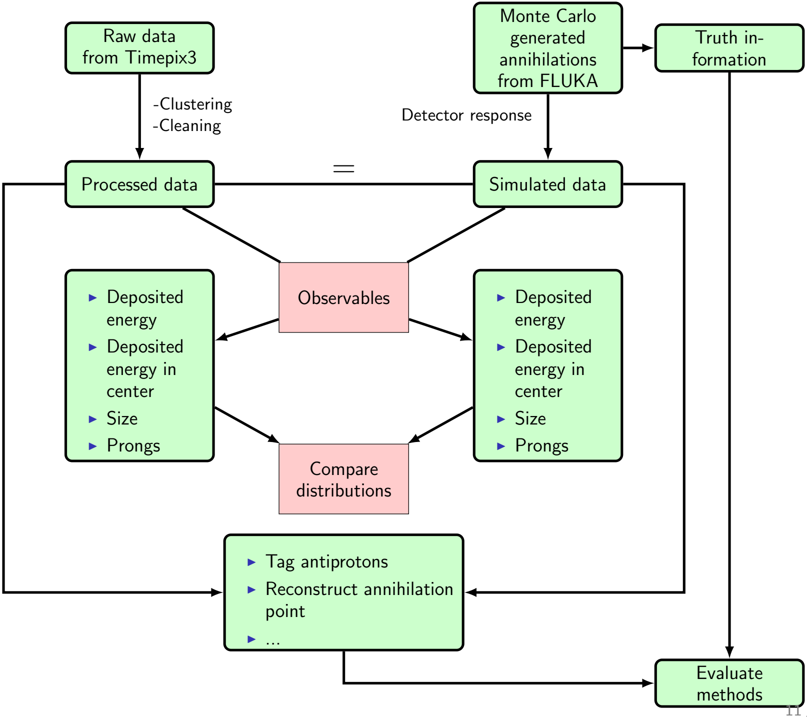
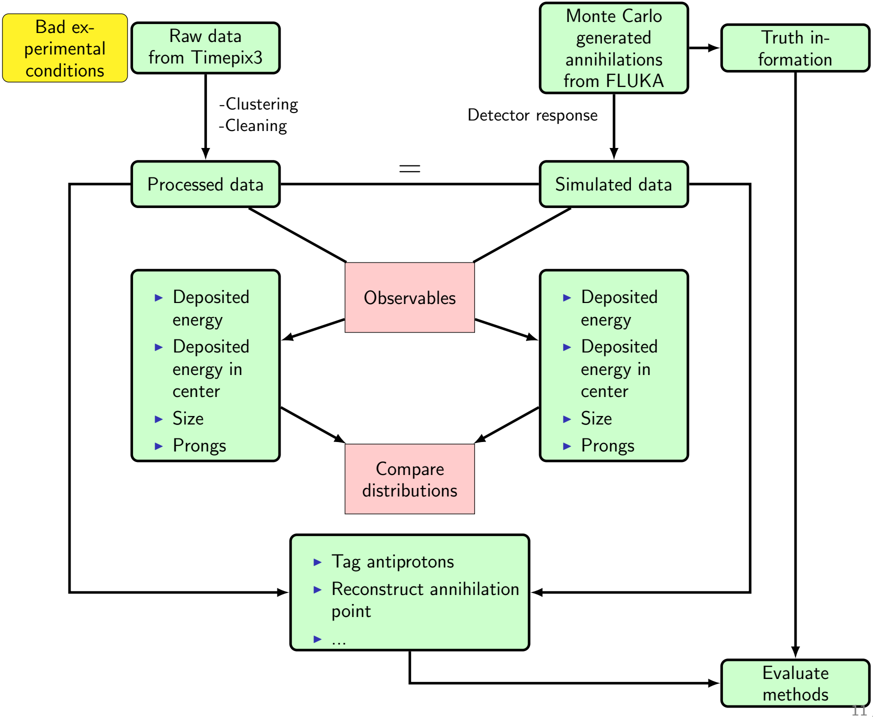
Size
Prongs
Compare distributions



Raw data from Timepix3
-Clustering
-Cleaning
Monte Carlo generated annihilations from FLUKA
Detector response
Processed data
=
Simulated data
Observables
Deposited energy
Deposited energy in center
Size
Prongs
Deposited energy
Deposited energy in center
Size
Prongs
Compare distributions
Tag antiprotons
Reconstruct annihilation point
...


Raw data from Timepix3
-Clustering
-Cleaning
Monte Carlo generated annihilations from FLUKA
Truth information
Detector response
Processed data
=
Simulated data
Observables
Deposited energy
Deposited energy in center
Size
Prongs
Deposited energy
Deposited energy in center
Size
Prongs
Compare distributions
Tag antiprotons
Reconstruct annihilation point
...
Evaluate methods


Bad experimental conditions
Raw data from Timepix3
-Clustering
-Cleaning
Monte Carlo generated annihilations from FLUKA
Truth information
Detector response
Processed data
=
Simulated data
Observables
Deposited energy
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Compare distributions
Tag antiprotons
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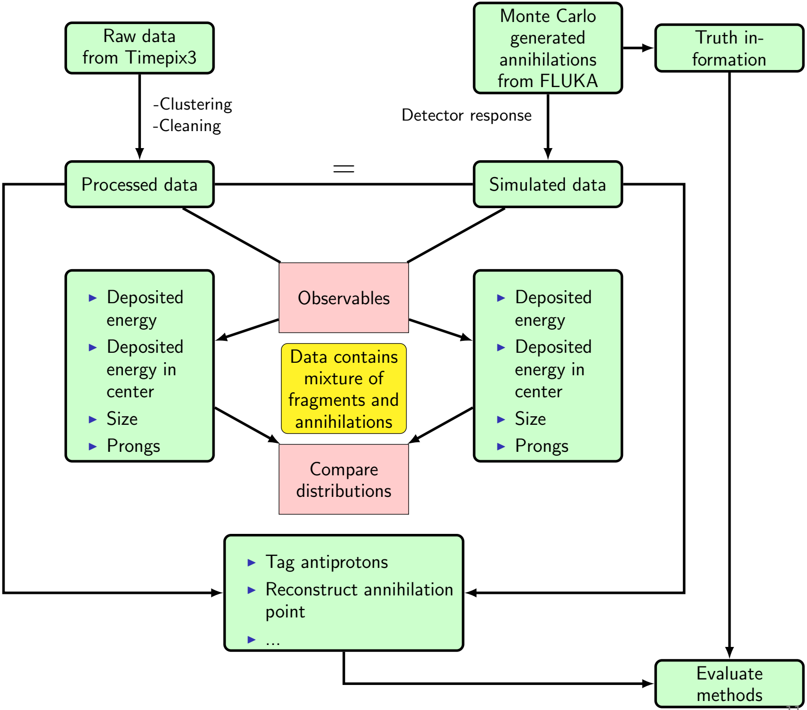
Raw data from Timepix3
-Clustering
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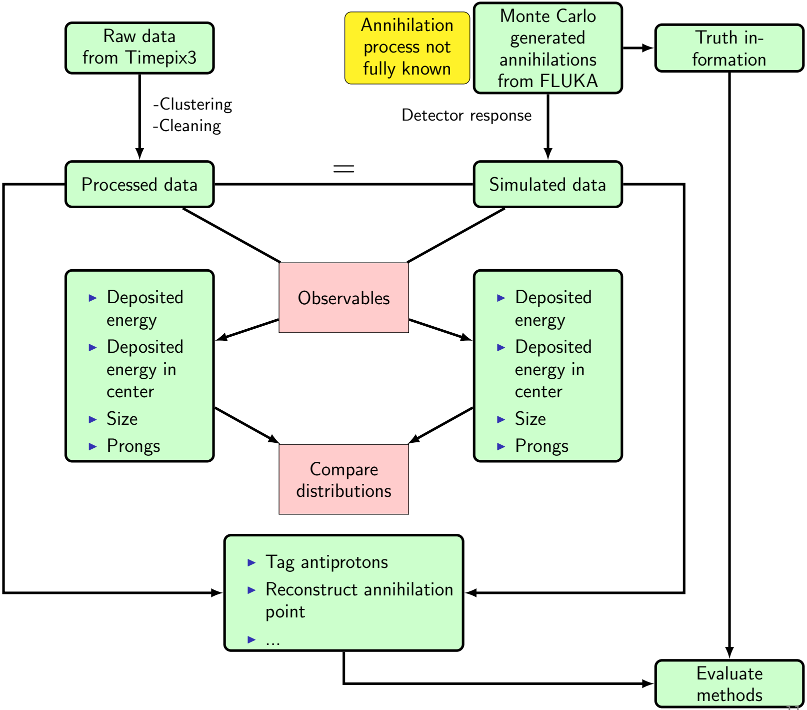
Monte Carlo generated annihilations from FLUKA
Truth information
Detector response
Processed data
=
Simulated data
Observables
Deposited energy
Deposited energy in center
Size
Prongs
Data contains mixture of fragments and annihilations
Deposited energy
Deposited energy in center
Size
Prongs
Compare distributions
Tag antiprotons
Reconstruct annihilation point
...
Evaluate methods


Raw data from Timepix3
-Clustering
-Cleaning
Annihilation process not fully known
Monte Carlo generated annihilations from FLUKA
Truth information
Detector response
Processed data
=
Simulated data
Observables
Deposited energy
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Compare distributions
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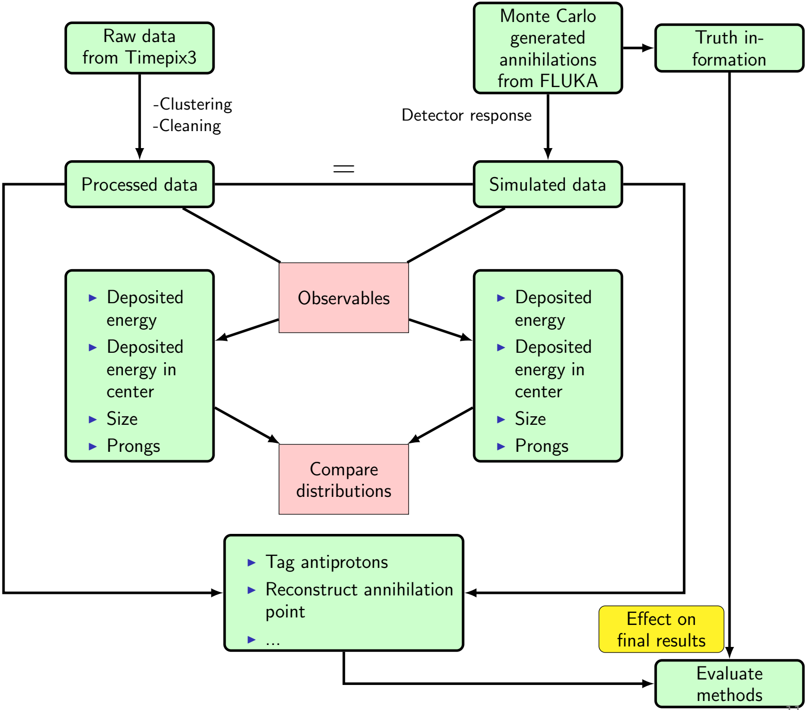
Evaluate methods



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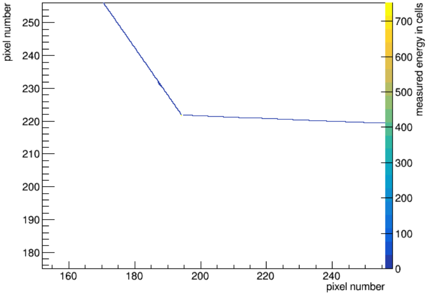
...
Effect on final results
Evaluate methods

Detector response model

- Raw energy depositions in small voxels (FLUKA)
- Parametrized model for charge sharing including the plasma effect
- Volcano effect
- Suppressed pixels in the experimental set-up
- Re-clustering



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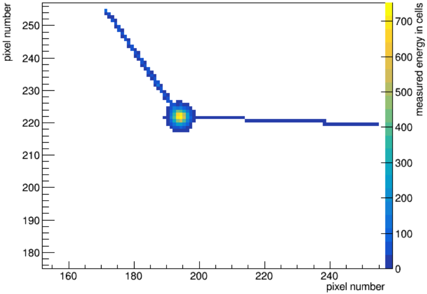

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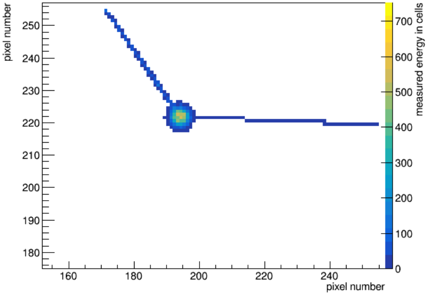

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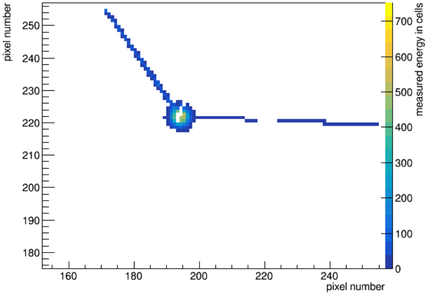

Analyse the data

- Clustering in time and space
- Find center
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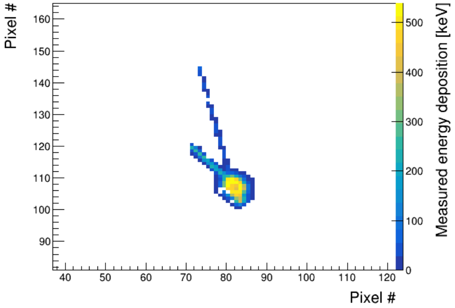
- Reomve center
- Hough transform to identify prongs
- Remove prong (star arms)
- Find more prongs
- Check for single tracks
- Fit lines to the prongs and find intersection (vertex fitting method)



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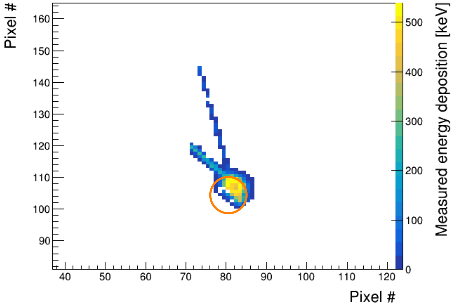

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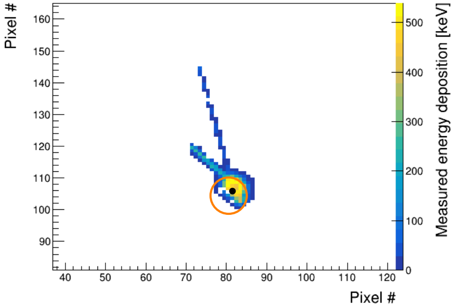

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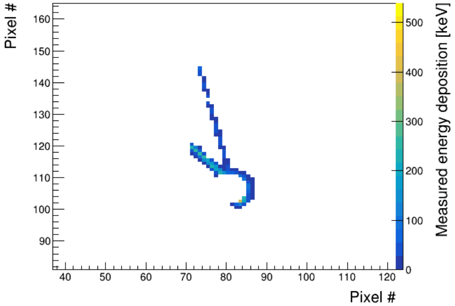

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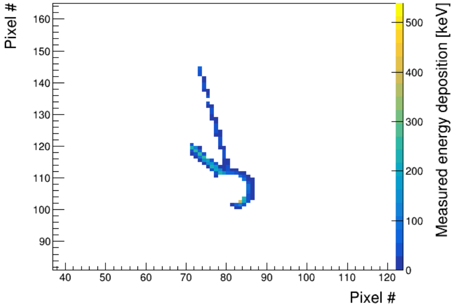

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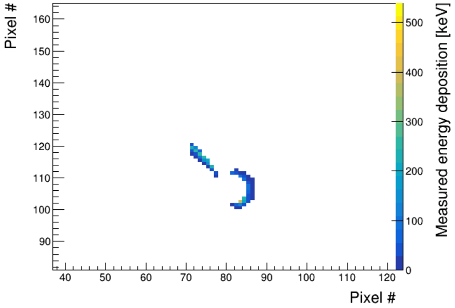

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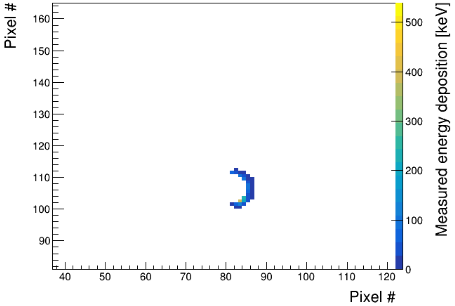

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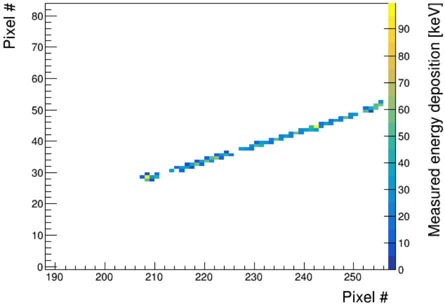

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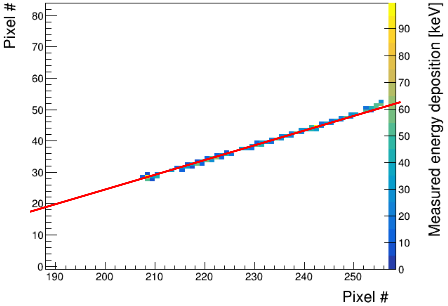

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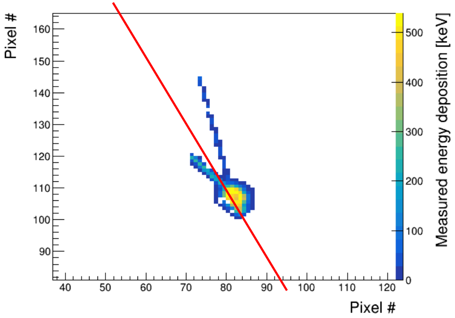

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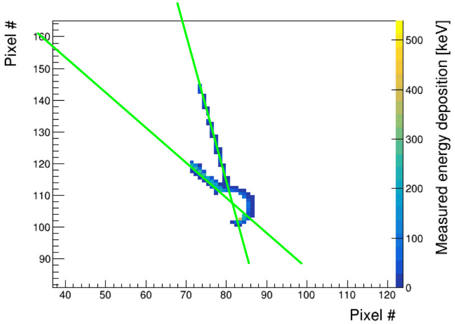
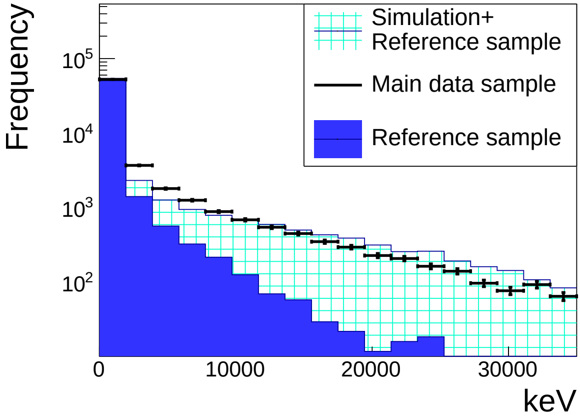


Verification of the simulation

Cluster energy



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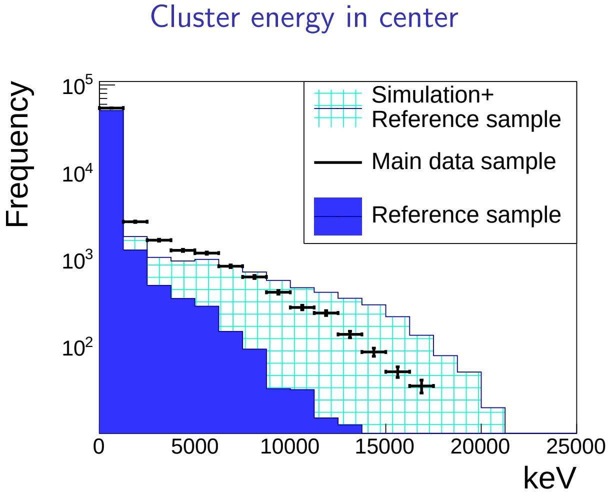

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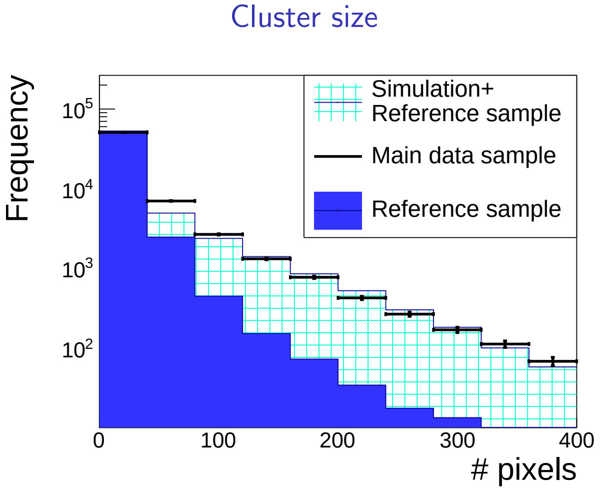
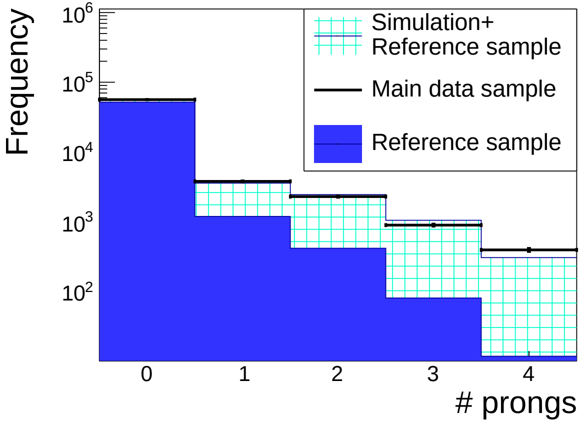


Verification of the simulation

Number of prongs



Tagging efficiency

- Anninhilation clusters are larger and have prongs
- Trade off between tagging efficency and false positive rate
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  - Tagging efficency $50 \pm 10\%$
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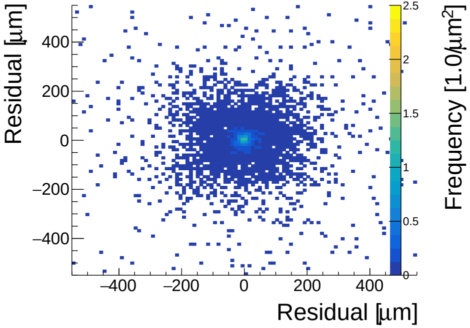
Position resolution

- Mass center method
  - All clusters
  - 93 μm resolution
- Vertex fitting method
  - 45% of all clusters
  - 48 μm resolution
- Vertex fitting method exluding bad fits
  - 22% of all clusters
  - 22 μm resolution
- Change of annihilation fragments shown to have small effect on position resolution $\approx \pm 1 \mu m$



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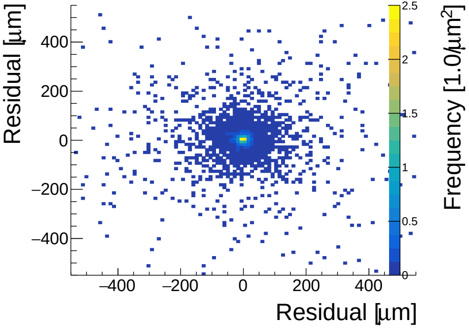

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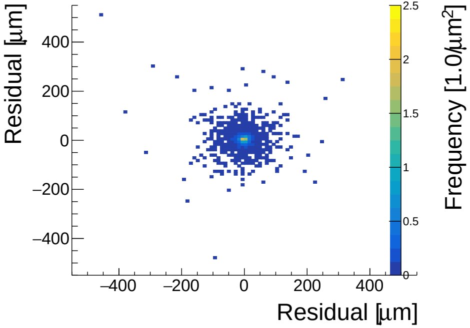

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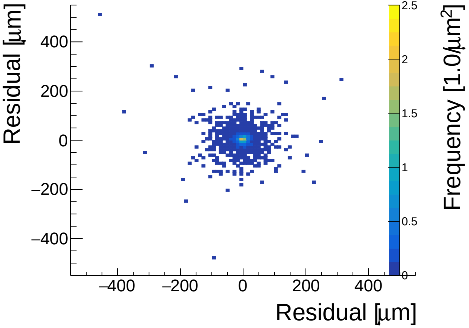

Conclusion

- We can clearly see the annihilation clusters in the Timepix3
- Better understanding of annihilaitons in material
- Better understanding of for large energy depositions in the Timepix3 detector
- Detector response model taking into account th Developed a detector response model, and a full simulation of the GRACE beamline
- Tagging efficiency of $50 \pm 10\%$
- False positive rate $< 1.0\%$
- Position resolution of 22 μm

For more information

Find all the details here

Antiproton tagging and vertex fitting in a Timepix3 detector" S. Aghion et al 2018 JINST 13 P06004 link.

https://github.com/helgaholmestad/finalTimepix.

Thank you and goodbye!!

- Jerome Alozy
- Michael Campbell
- Xavi Cudie
- Lukas Tlustos