Detecting Anti-Hydrogen in the ALPHA-g Antimatter-Gravity Experiment

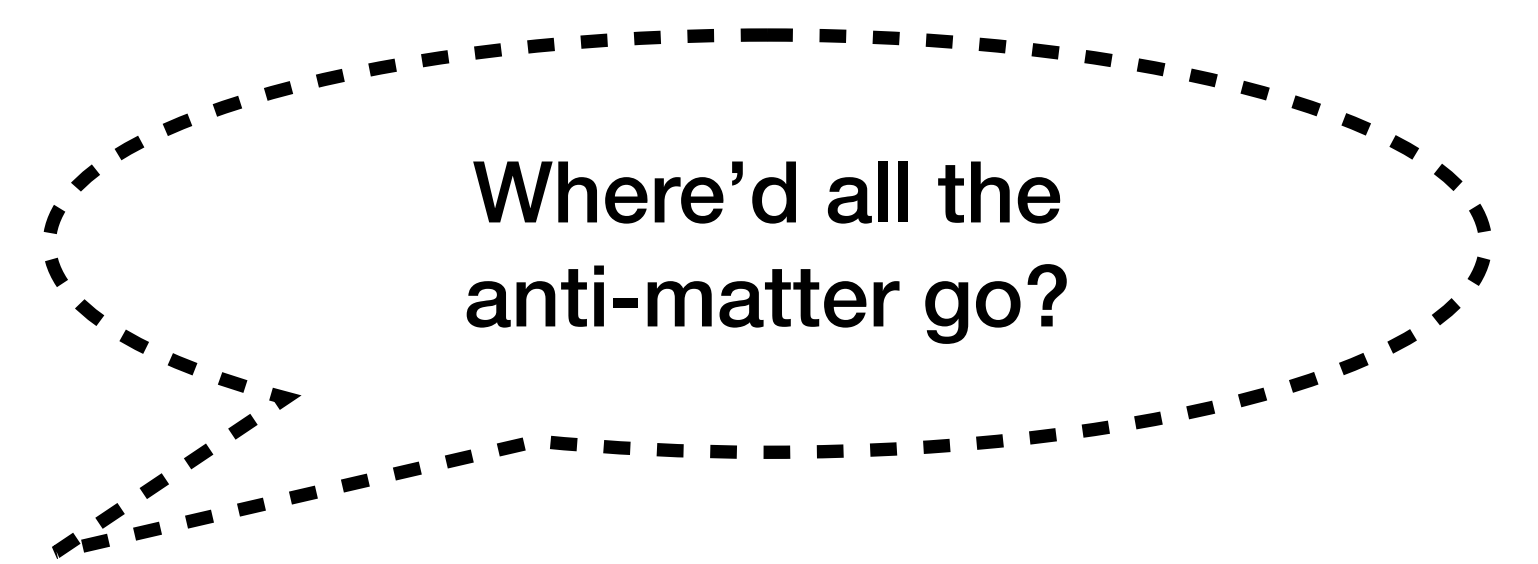**Gareth Smith** – **UBC/TRIUMF PhD Student**

CAP Congress – June 19th, 2023
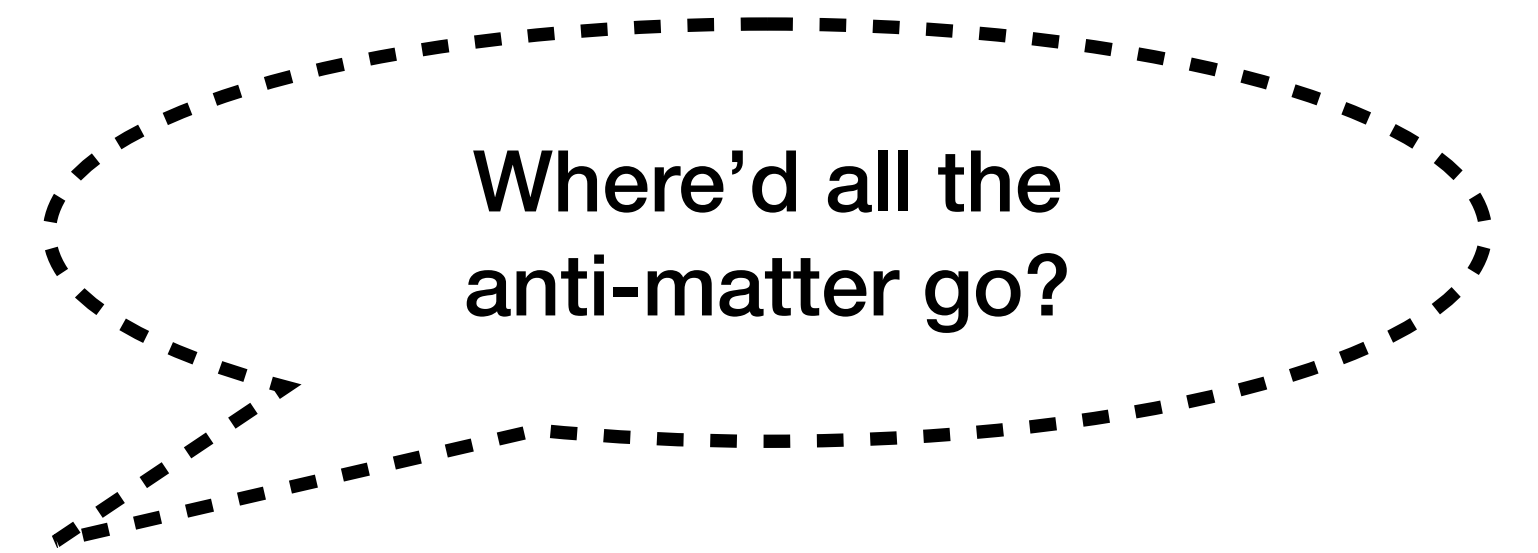
ALPHA Scientific Objectives

- To test fundamental symmetries between matter and antimatter by studying anti-hydrogen atoms.
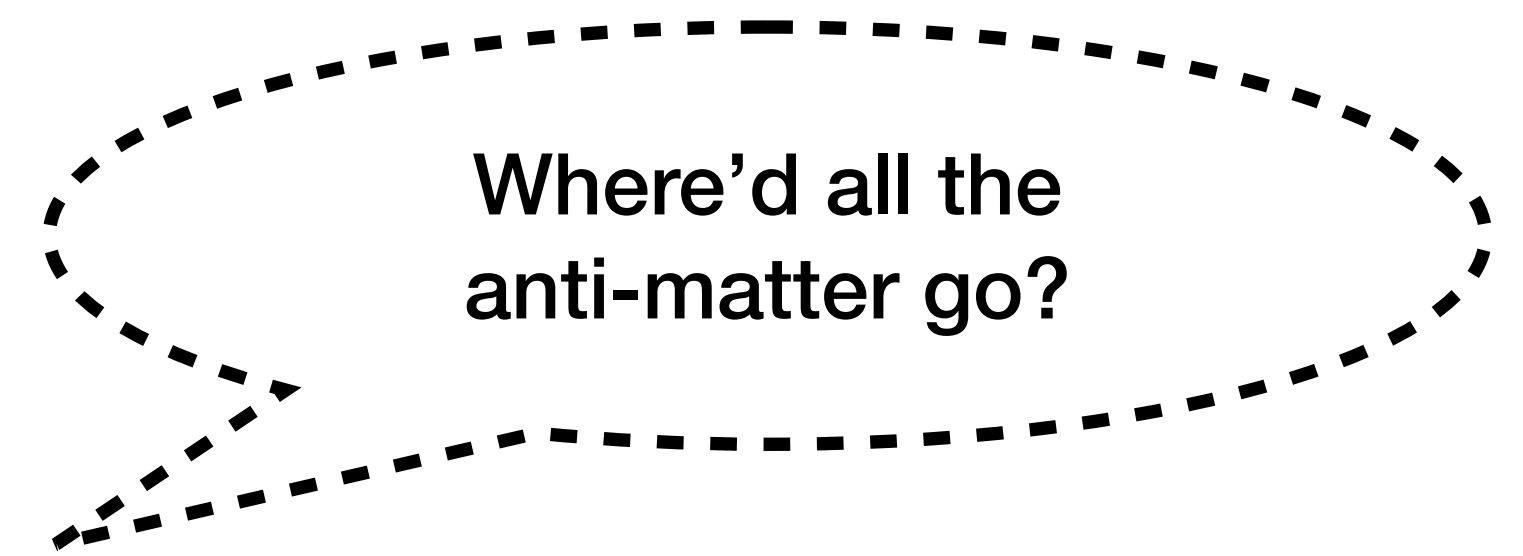
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Where'd all the anti-matter go?

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➡ Charge

Nature **529**, 373–376 (2016).

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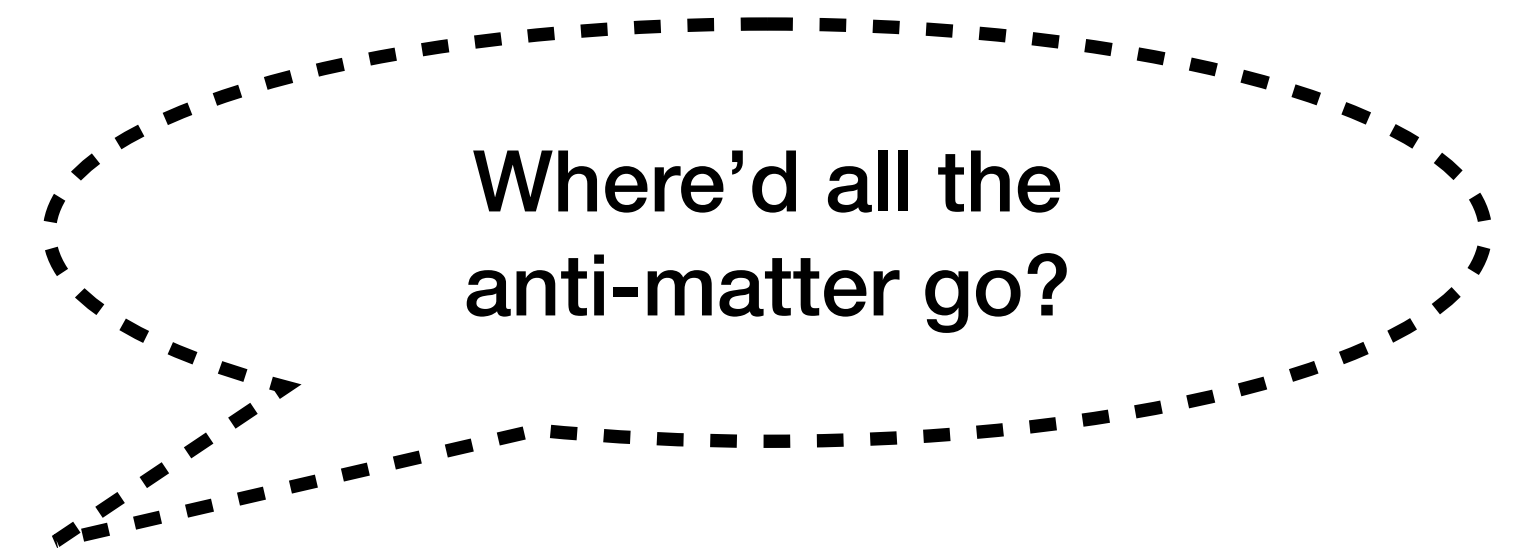
    ➡ 1S – 2S transition   *Nature* **541**, 506–510 (2017).

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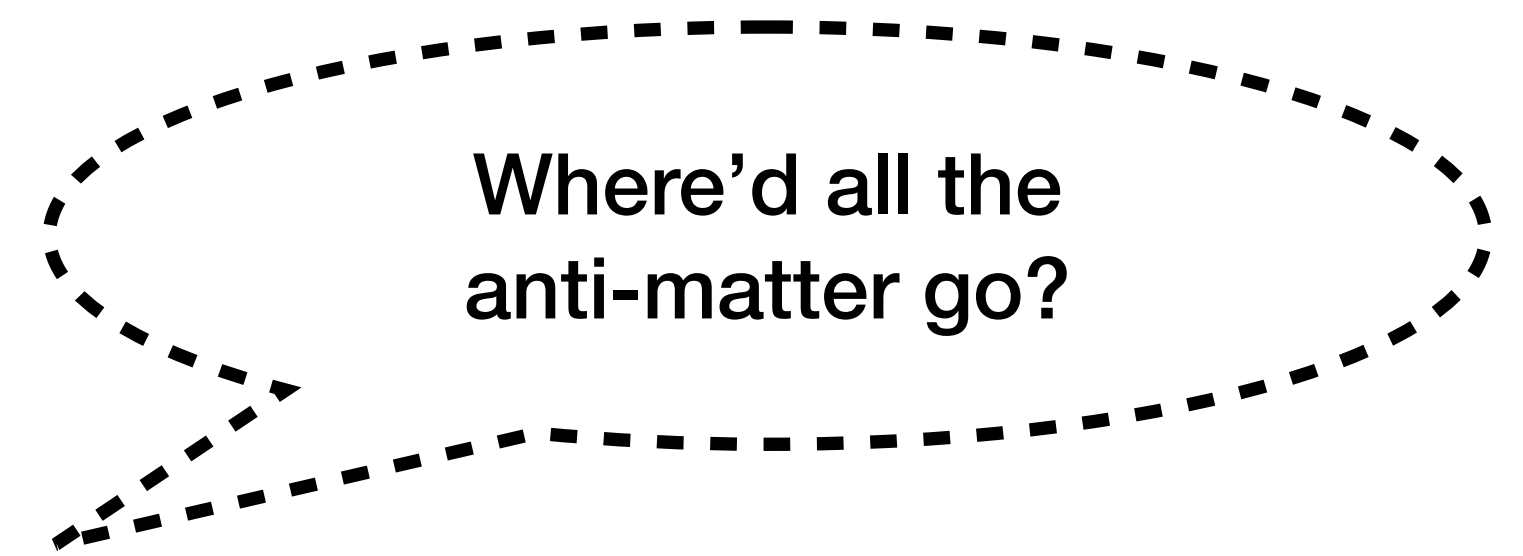   ➡ 1S – 2S transition Nature **541**, 506–510 (2017).

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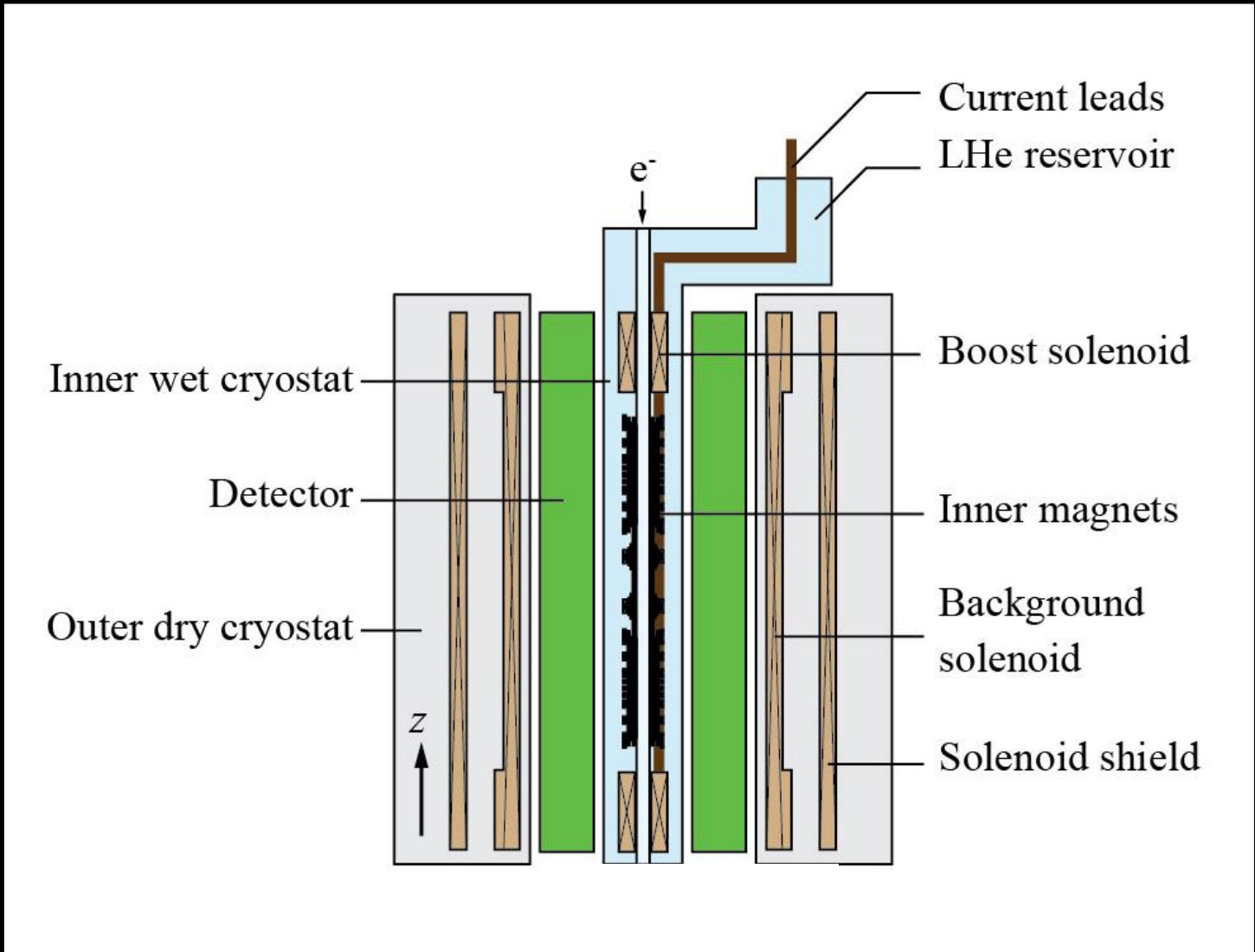
- Need a new experiment:

ALPHA α – g

First data run 2022!
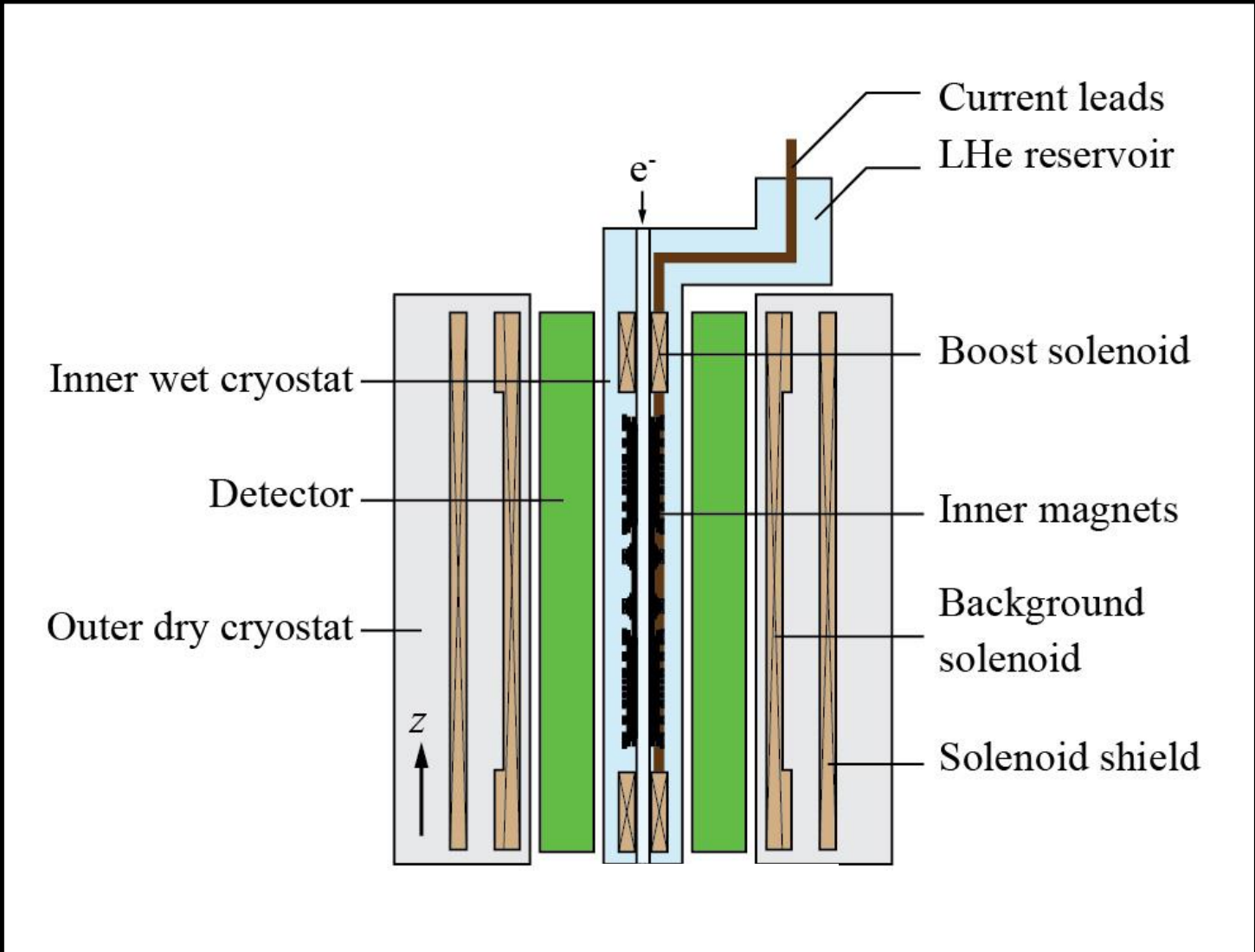
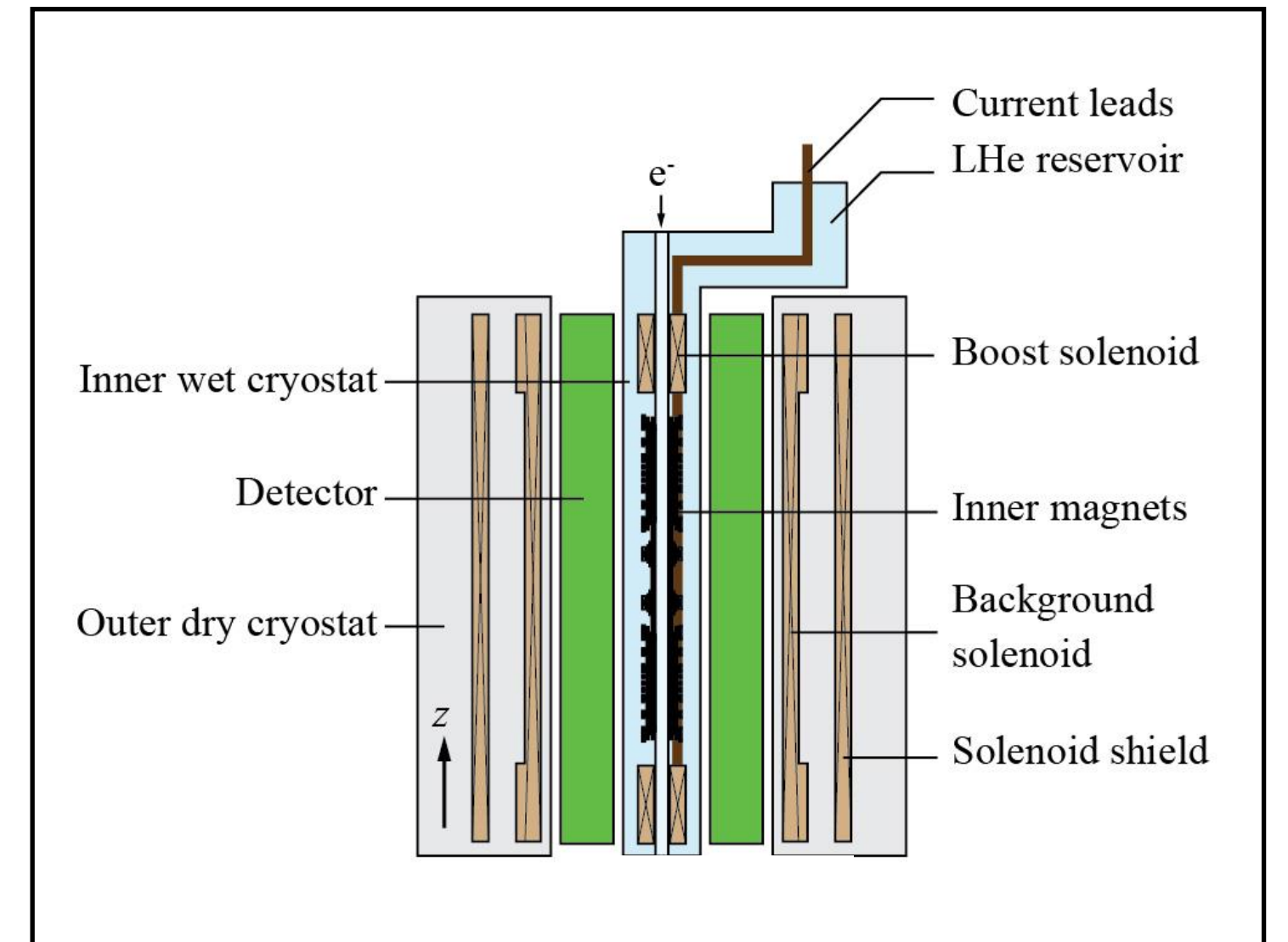# ALPHA-g Experiment

1. Produce and trap anti-hydrogen atoms.

ALPHA-g Experiment

Chukman So

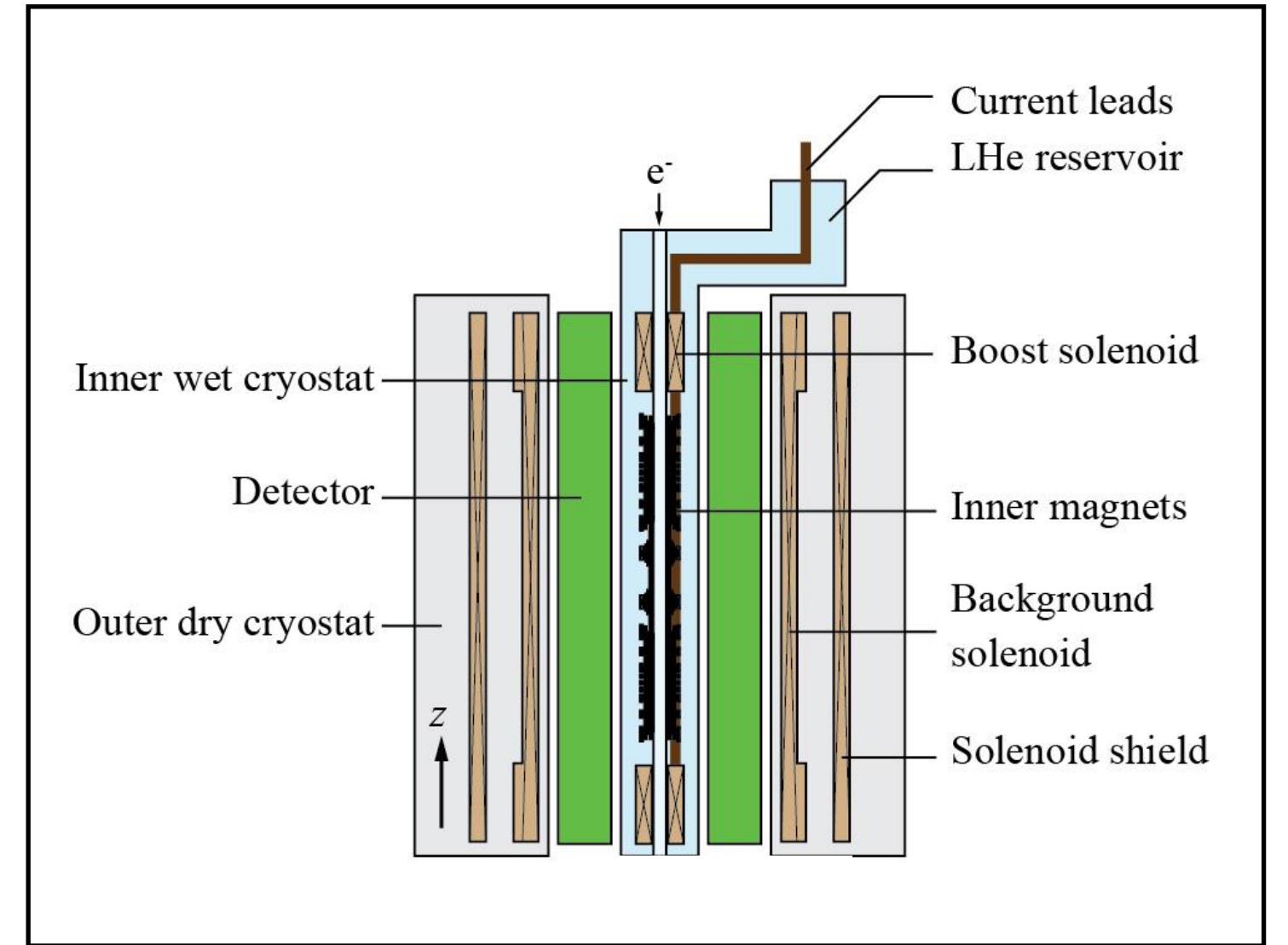1. Produce and trap anti-hydrogen atoms.
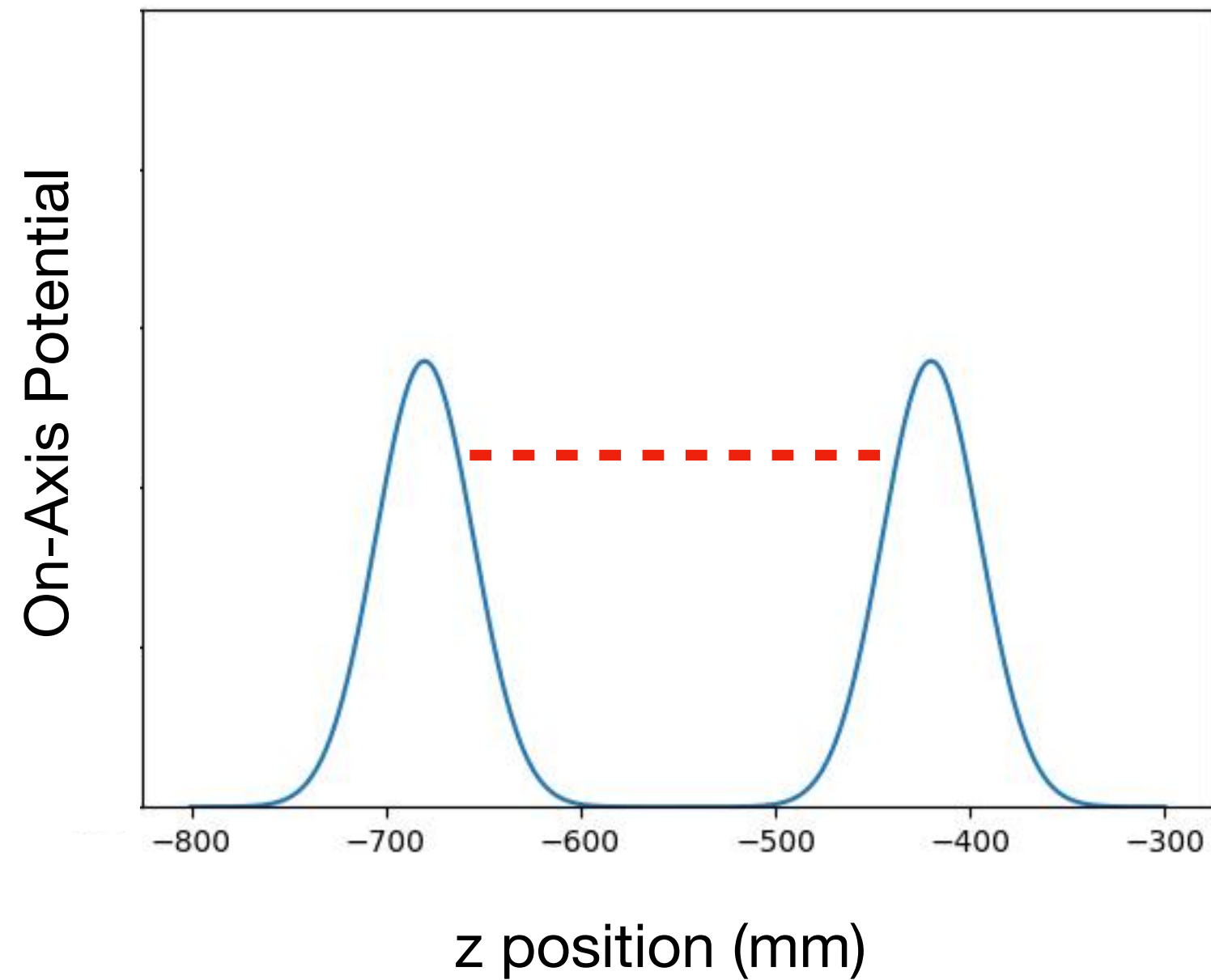
2. Release anti-atoms vertically.

ALPHA-g Experiment

Chukman So

1. Produce and trap anti-hydrogen atoms.

2. Release anti-atoms vertically.

3. Detect fraction of anti-atoms escaping up or down.
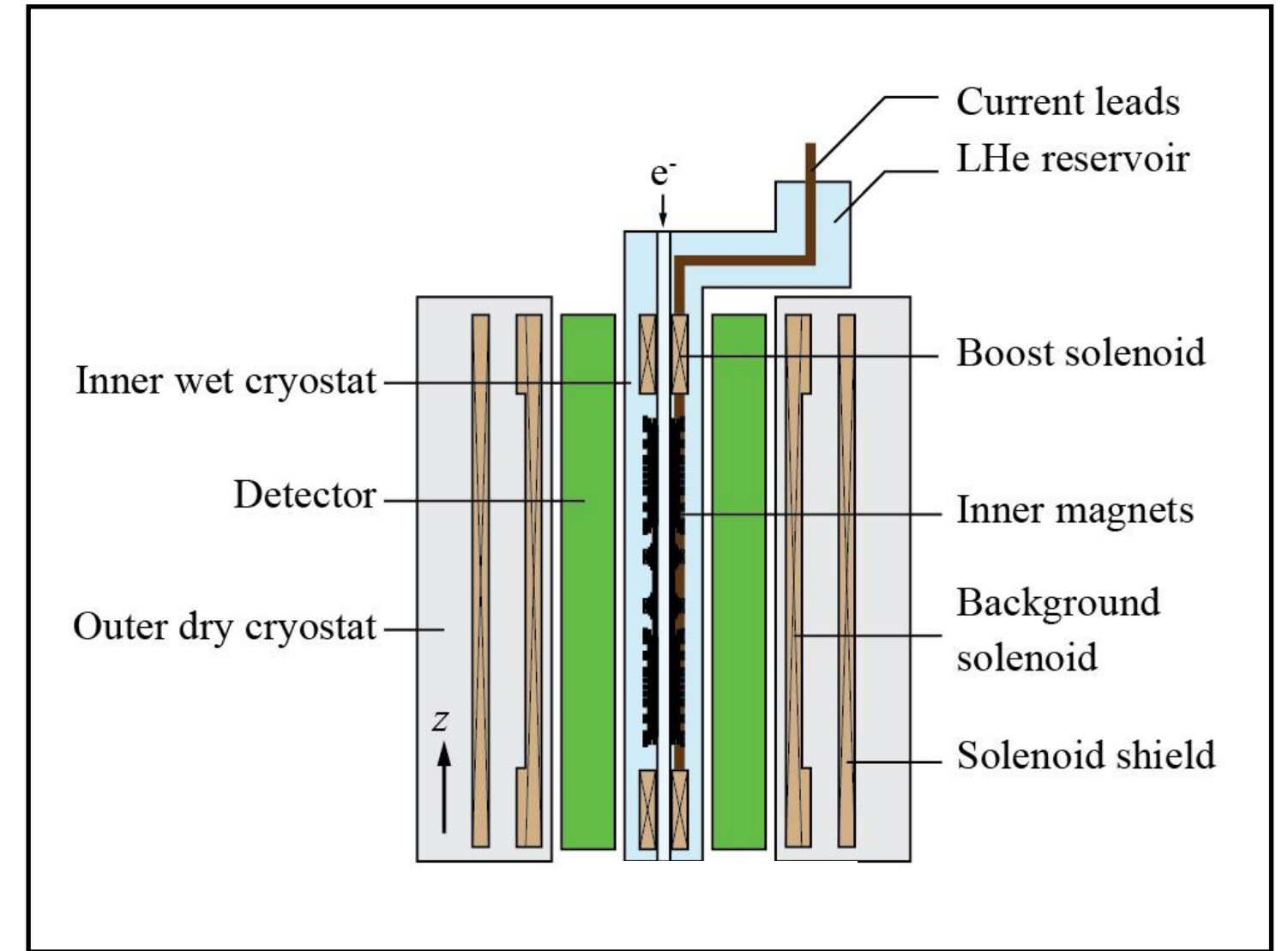
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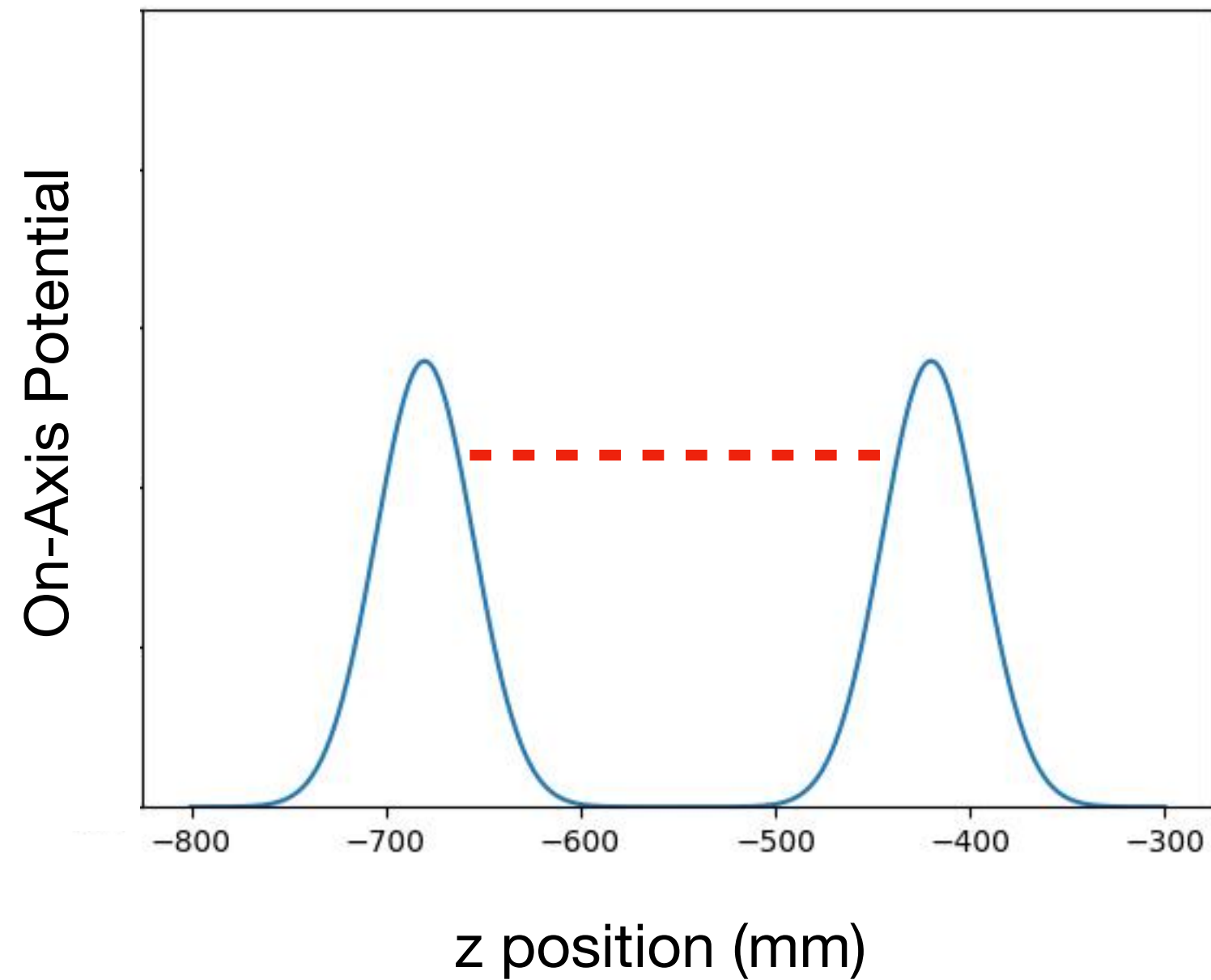3. Detect fraction of anti-atoms escaping up or down.

No Gravity

On-Axis Potential

z position (mm)

Current leads
LHe reservoir
e⁻
Inner wet cryostat
Boost solenoid
Detector
Inner magnets
Outer dry cryostat
Background solenoid
z
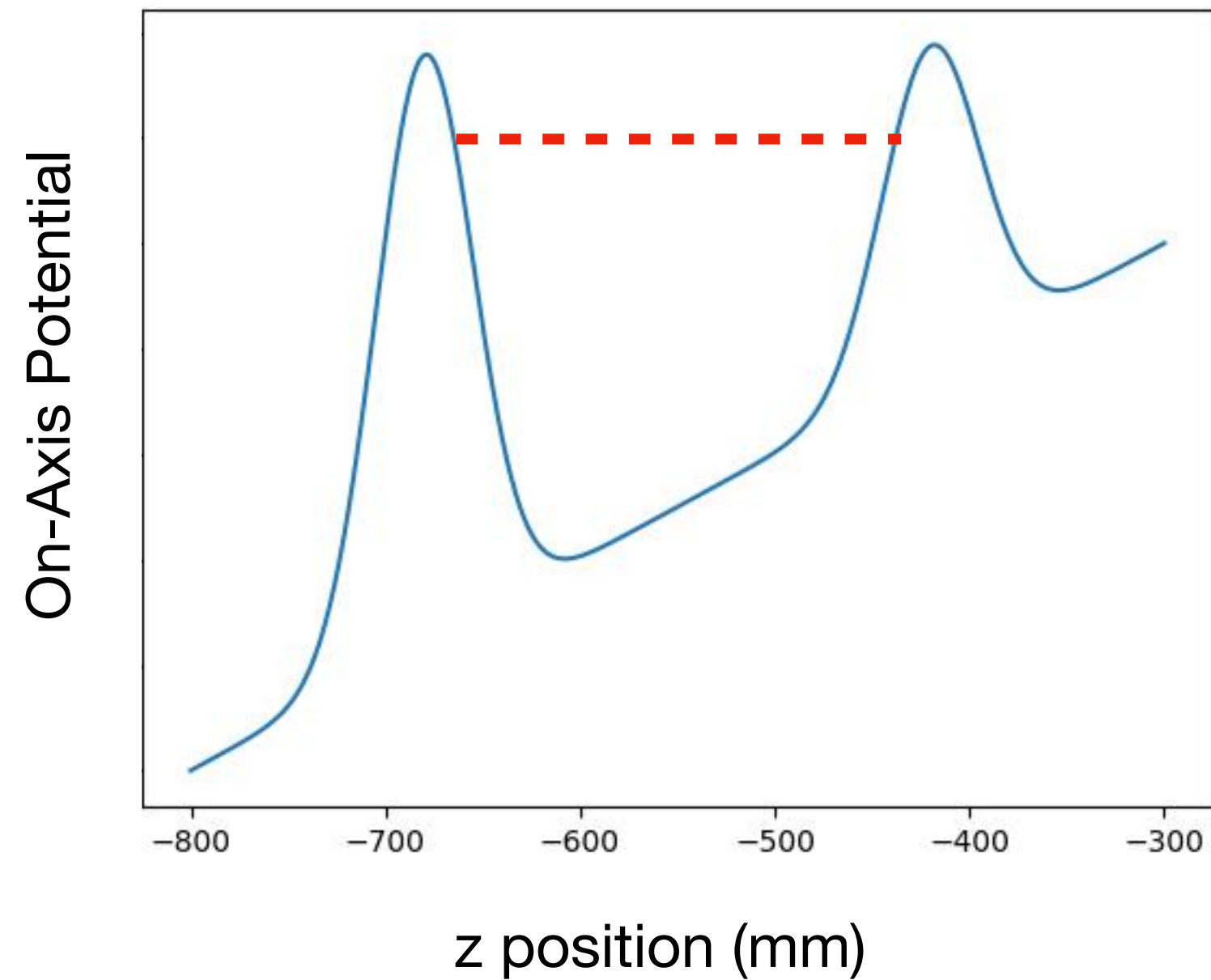Solenoid shield

ALPHA-g Experiment

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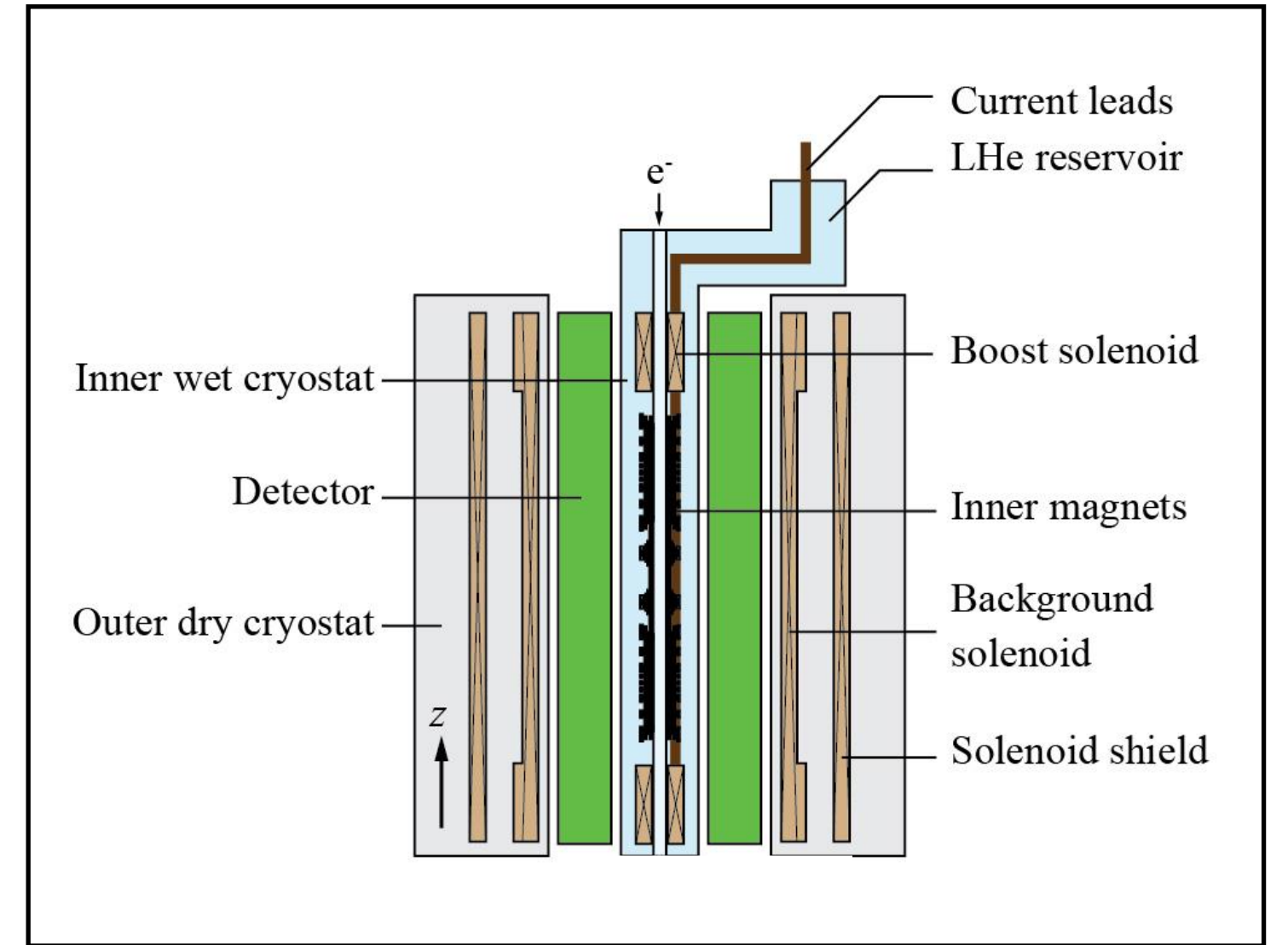3. Detect fraction of anti-atoms escaping up or down.

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Gravity Fully Counterbalanced

z position (mm)

z position (mm)

On-Axis Potential

On-Axis Potential

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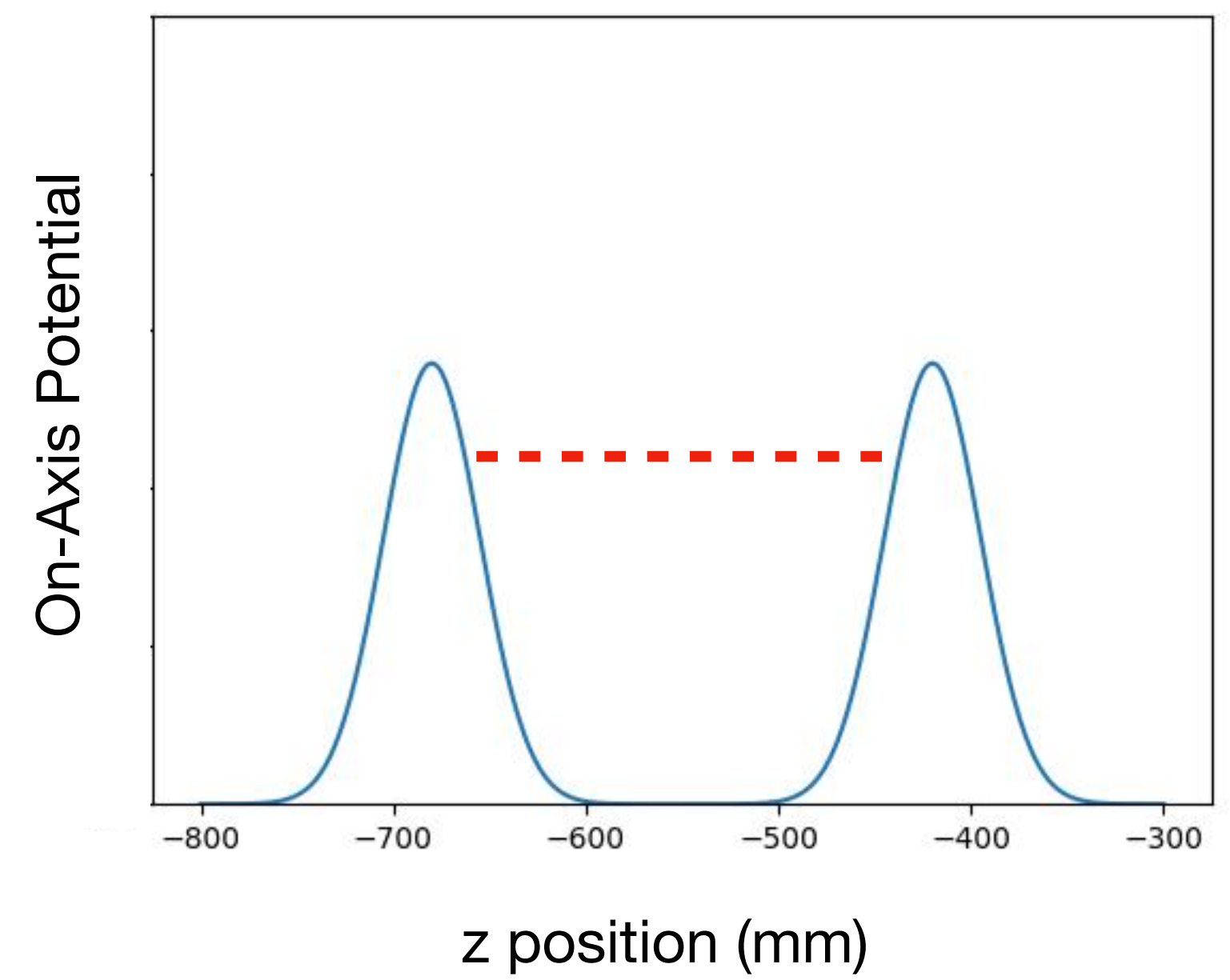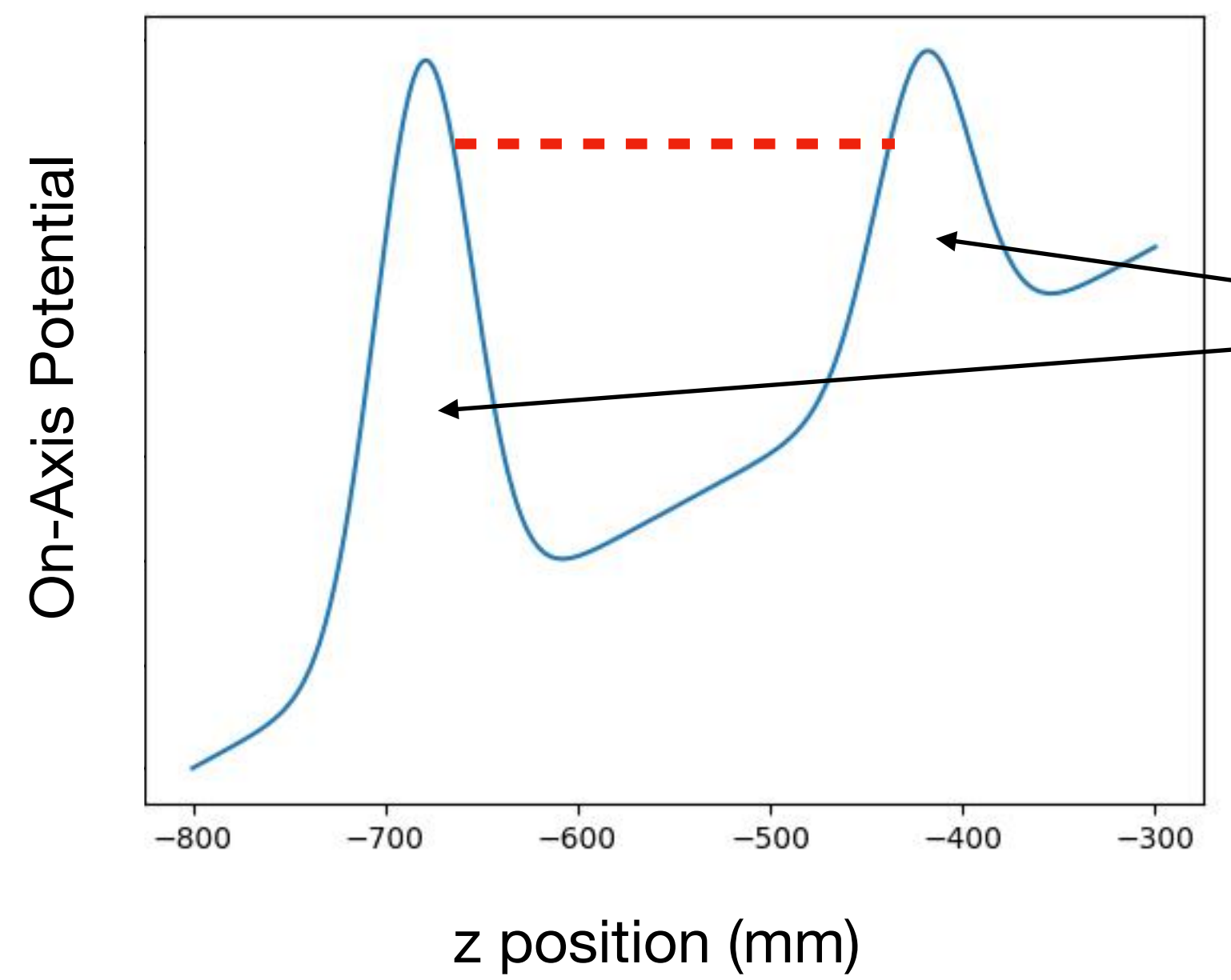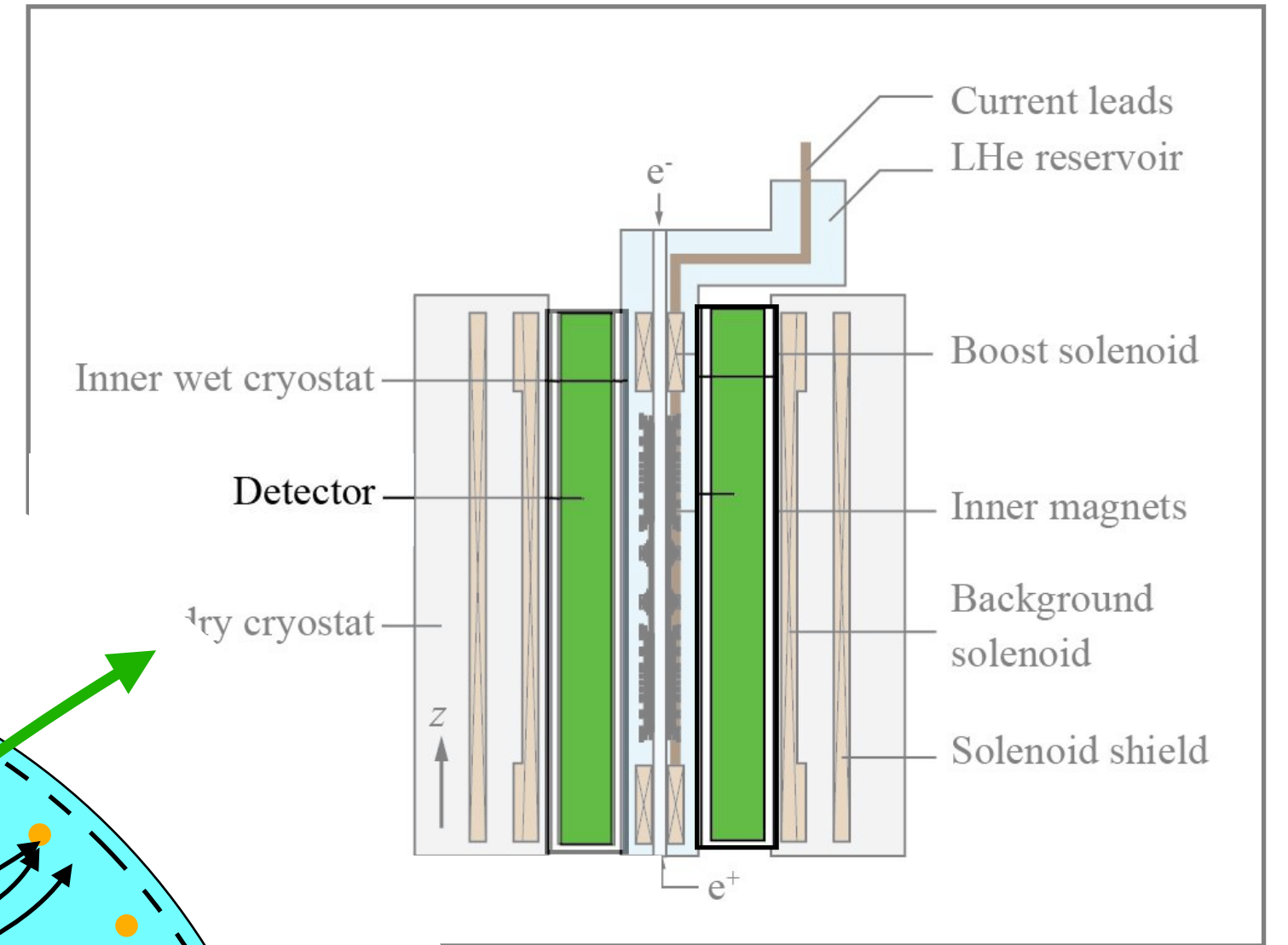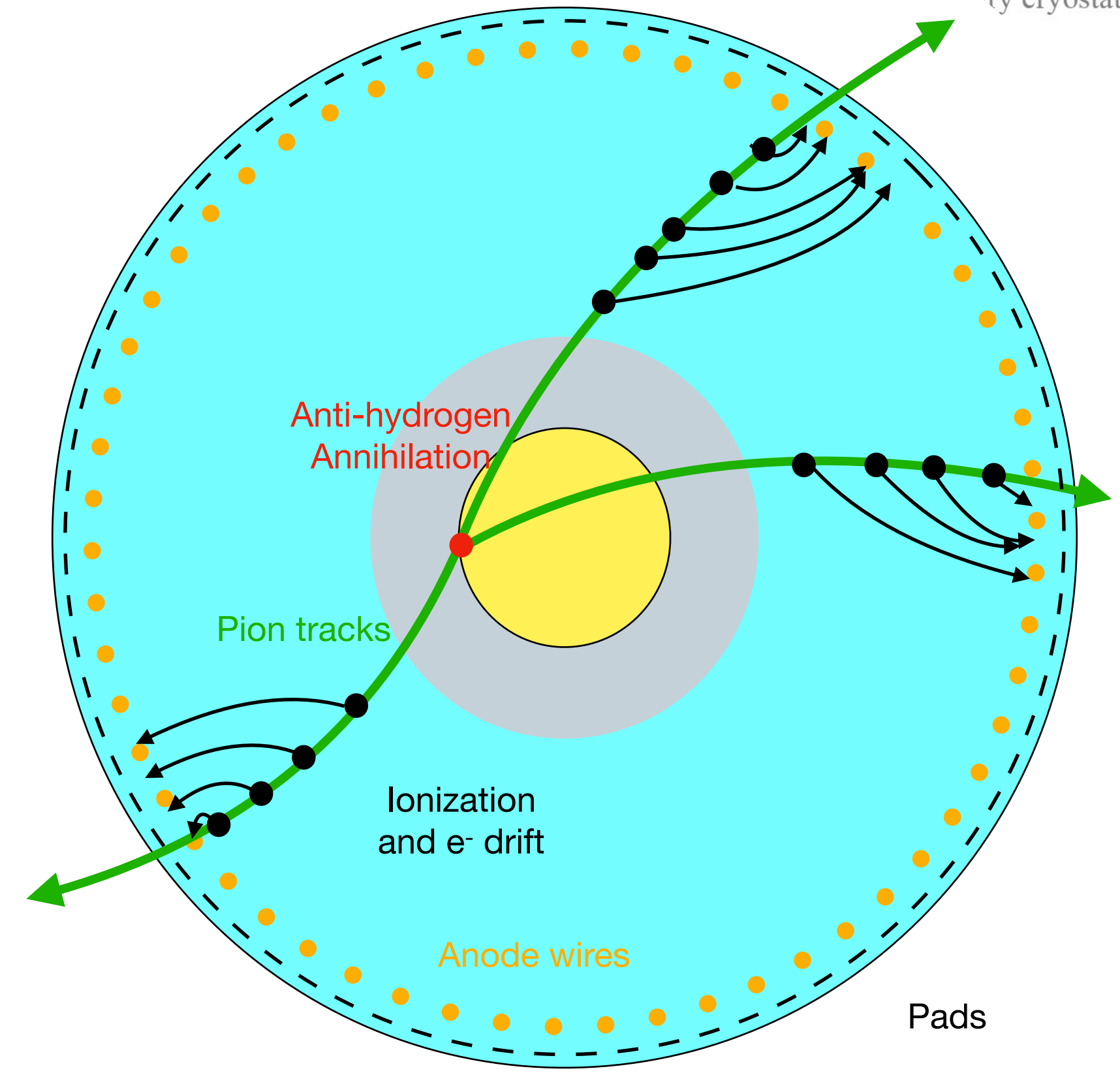

No Gravity

Gravity Fully Counterbalanced

Top and bottom magnetic trapping potentials are offset.

ALPHA-g Tracking Detector

- Use a *Time Projection Chamber* (TPC) to track pions created by anti-hydrogen annihilating on the trap walls.

Chukman So

Current leads
LHe reservoir
Boost solenoid
Inner magnets
Background solenoid
Solenoid shield

Inner wet cryostat
Detector
¹ry cryostat
z
e⁻
e⁺

Anti-hydrogen Annihilation
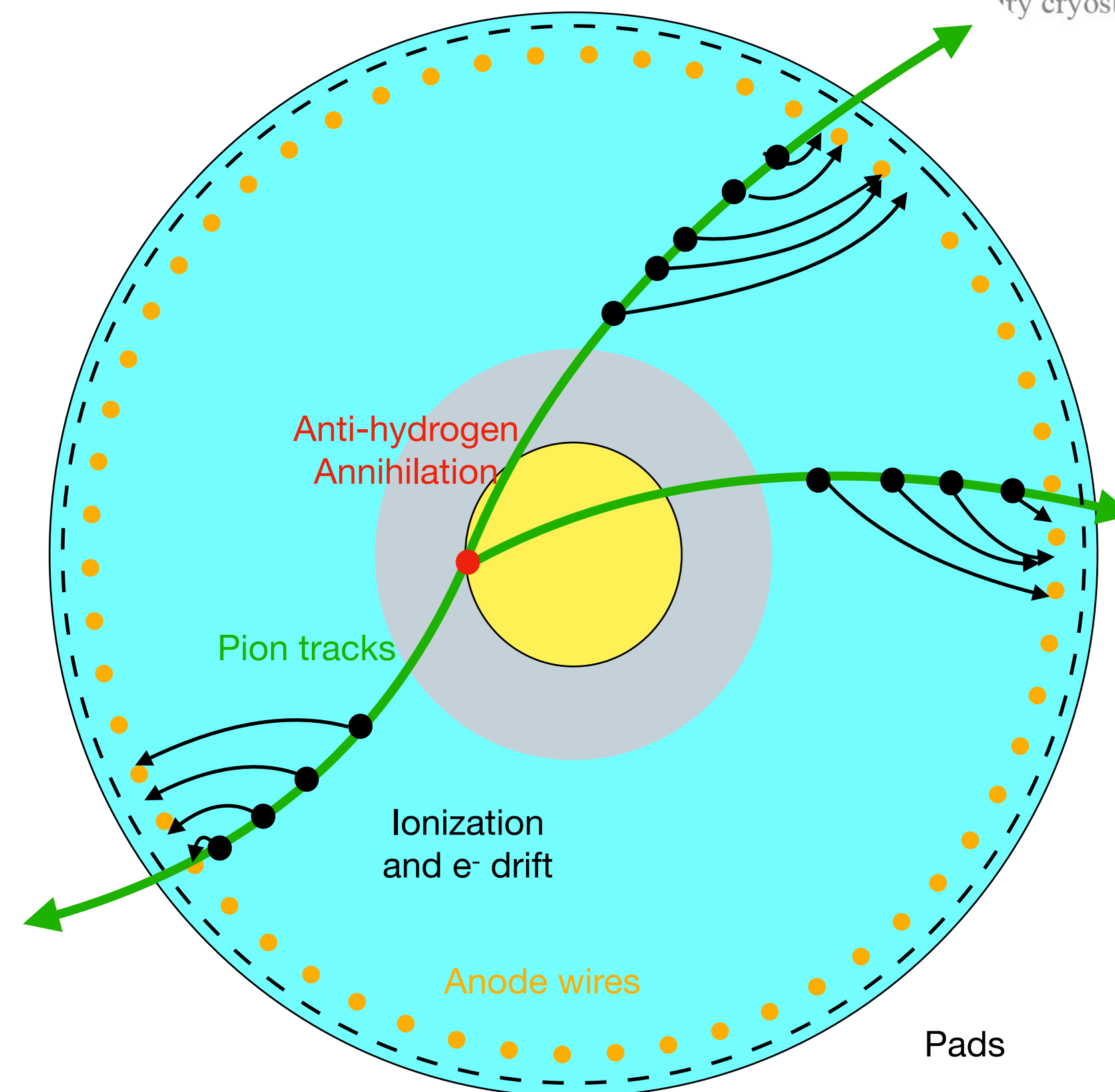
Pion tracks

Ionization and e⁻ drift

Anode wires

Pads

ALPHA-g Tracking Detector

- Use a *Time Projection Chamber* (TPC) to track pions created by anti-hydrogen annihilating on the trap walls.

- 3D position of ionizations from:
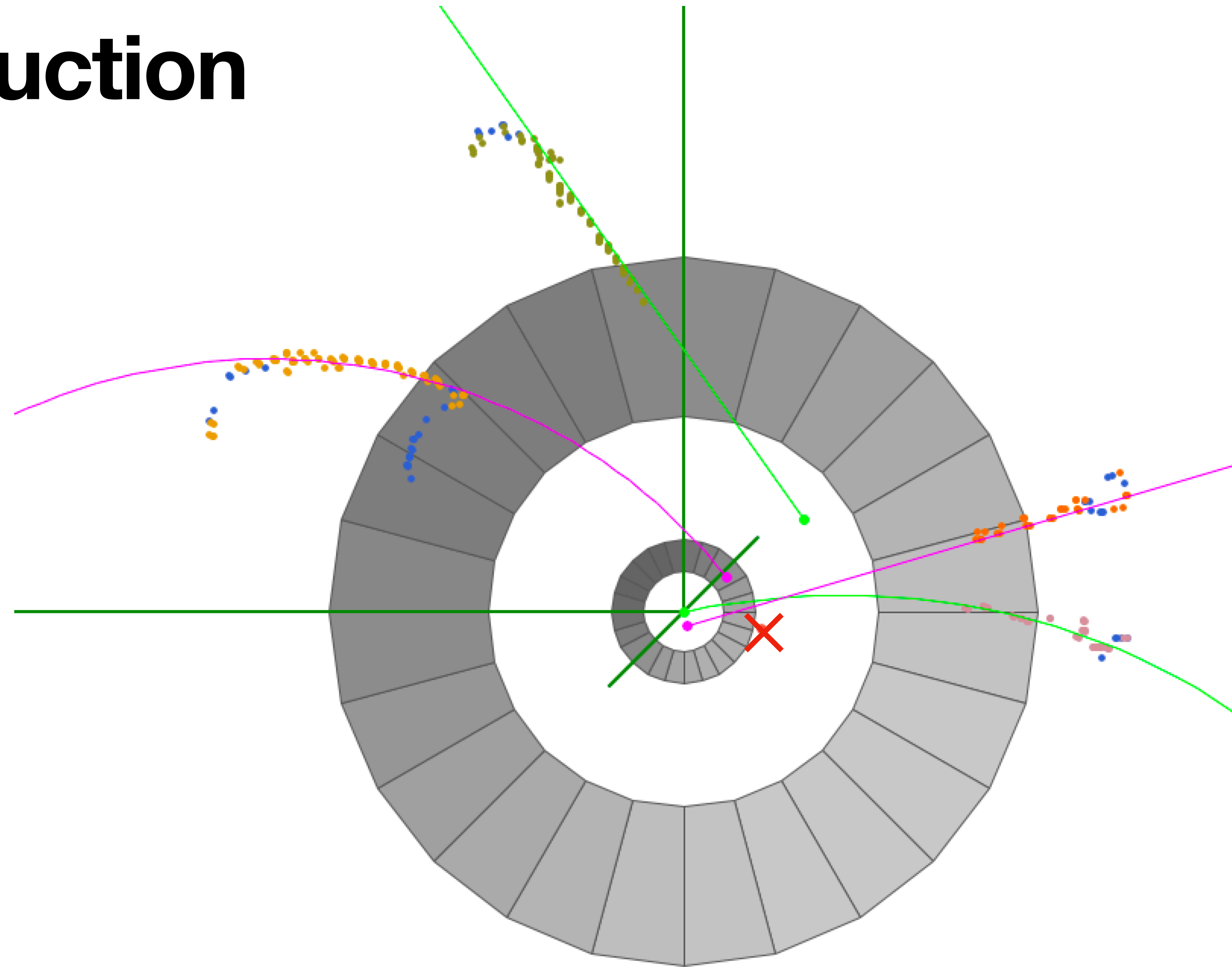   - → Wire position
    - → Pad position
    - → Drift time
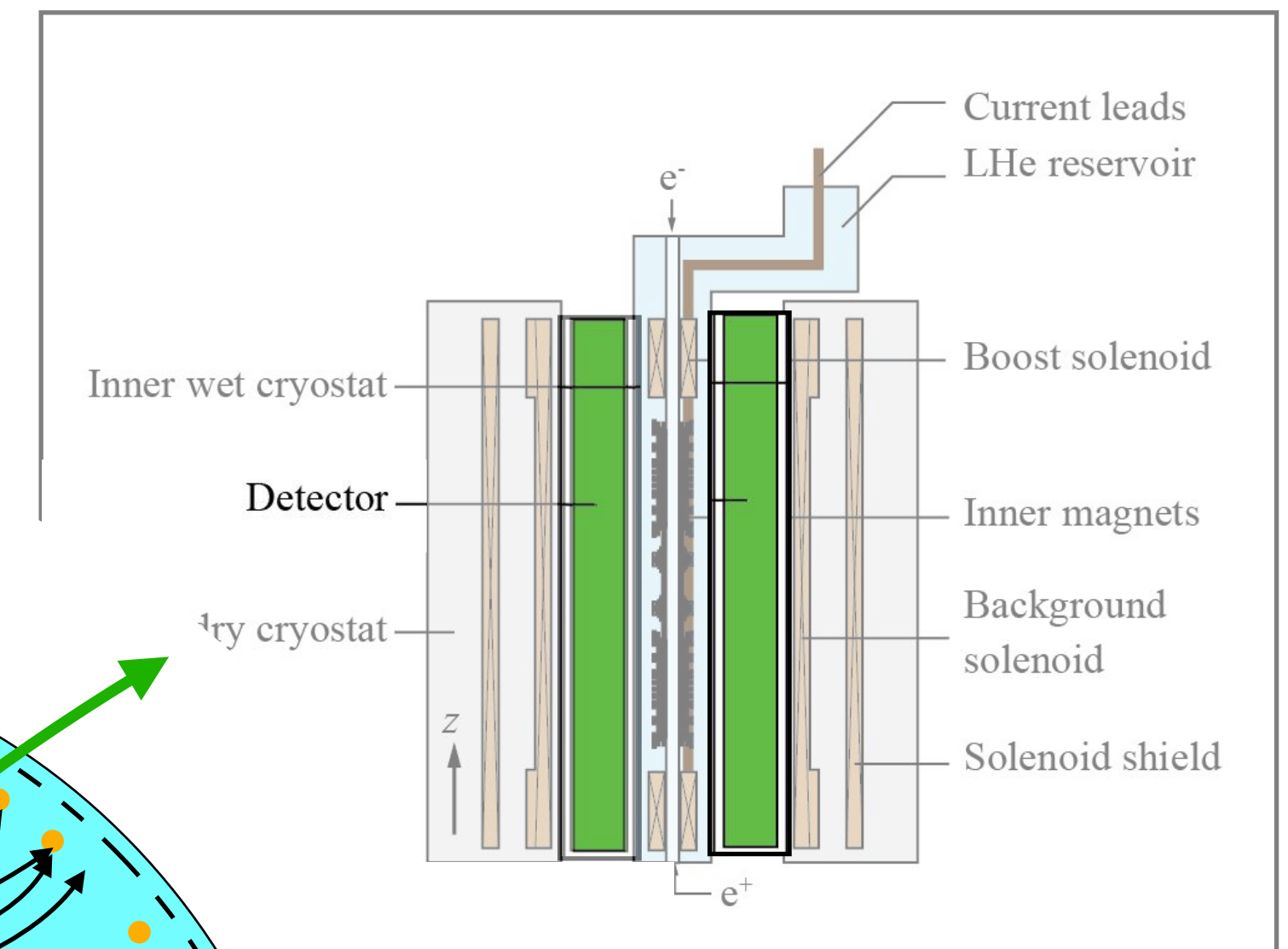
Vertex Reconstruction
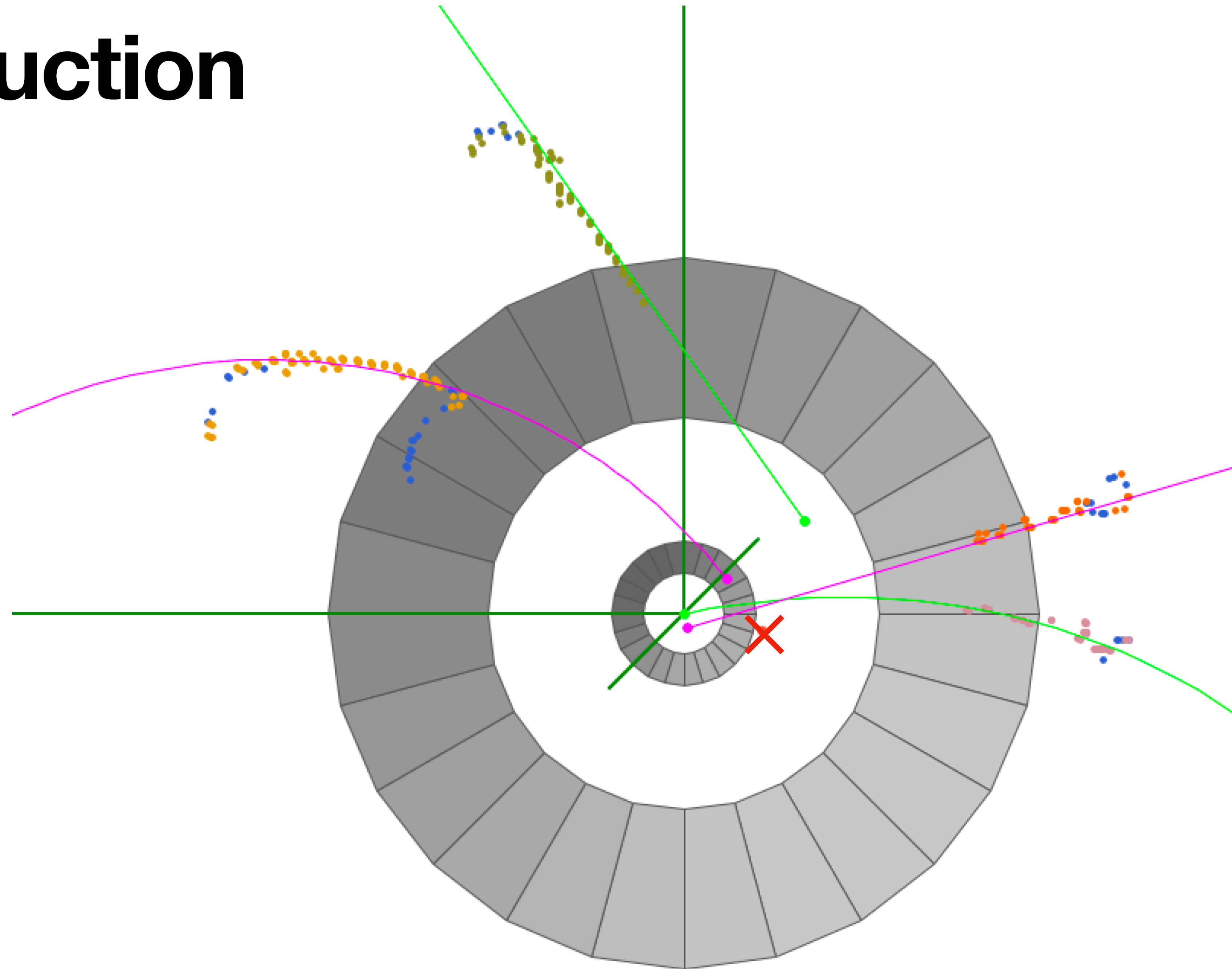
For each event:

1. De-convolute wire signals

*detector drawing not to scale

Vertex Reconstruction

For each event:

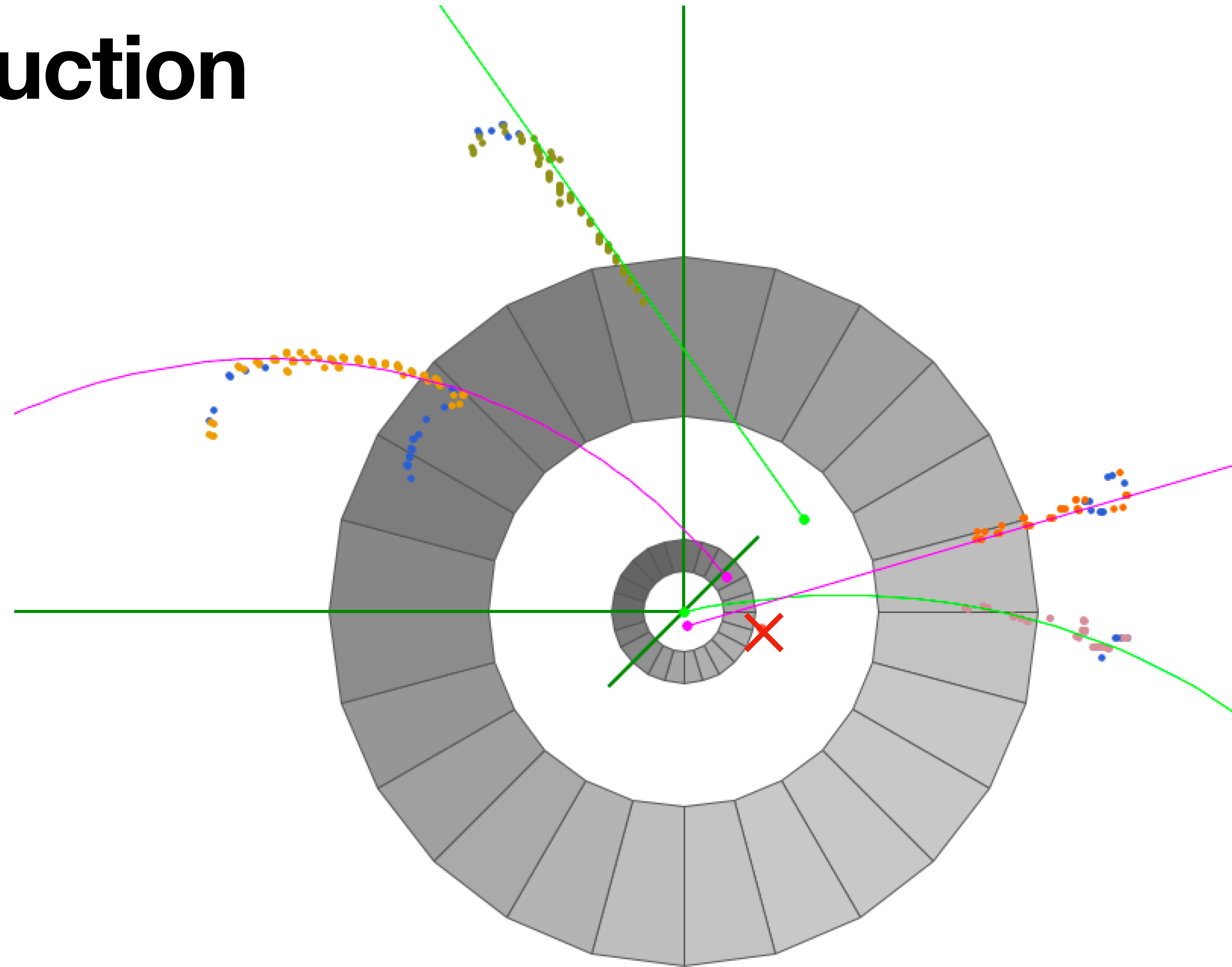1. De-convolute wire signals

2. Wire + pad = *spacepoint*

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Vertex Reconstruction

For each event:

1. De-convolute wire signals

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3. Group spacepoints

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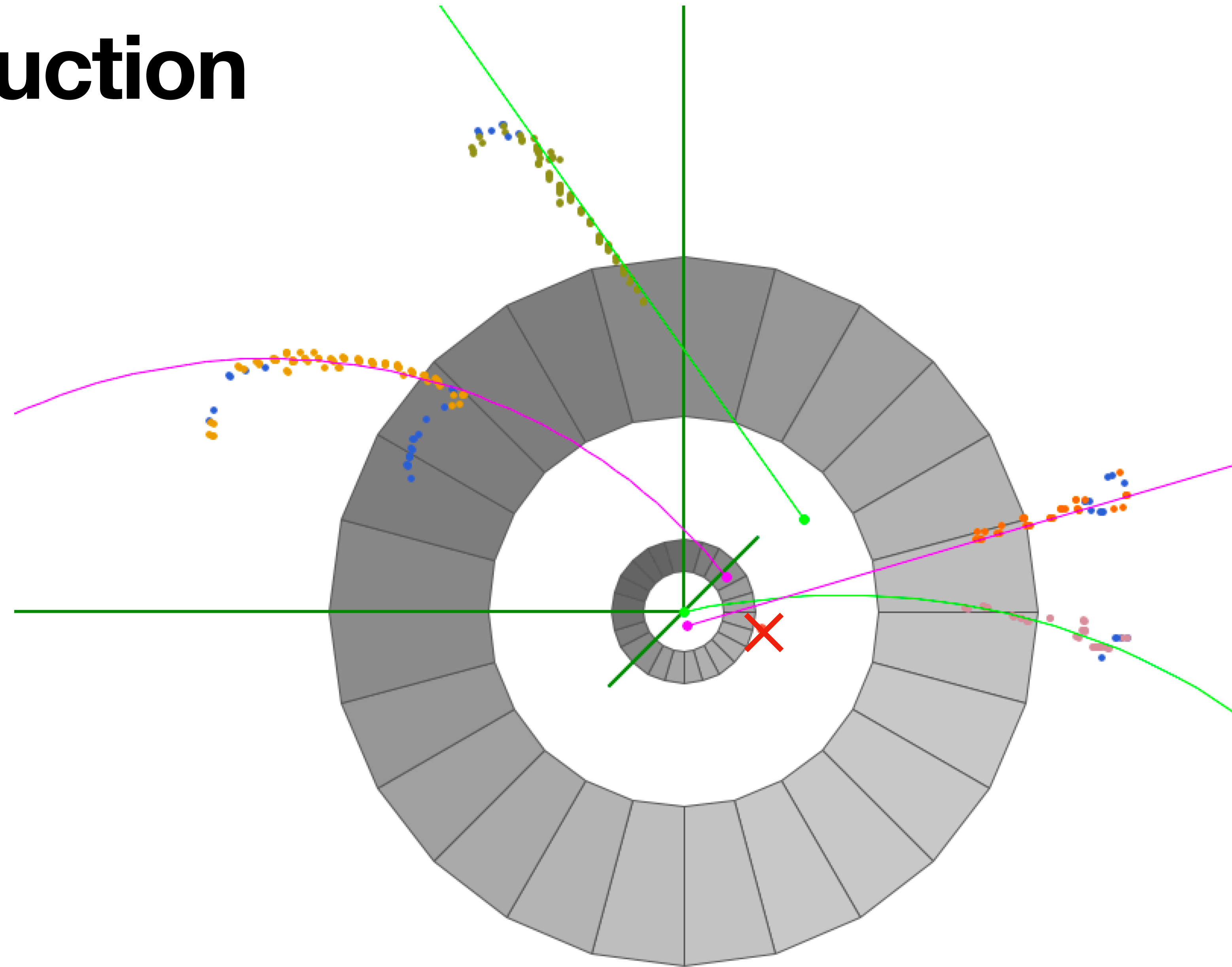
3. Group spacepoints

4. Spacepoints → helix fits

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Vertex Reconstruction

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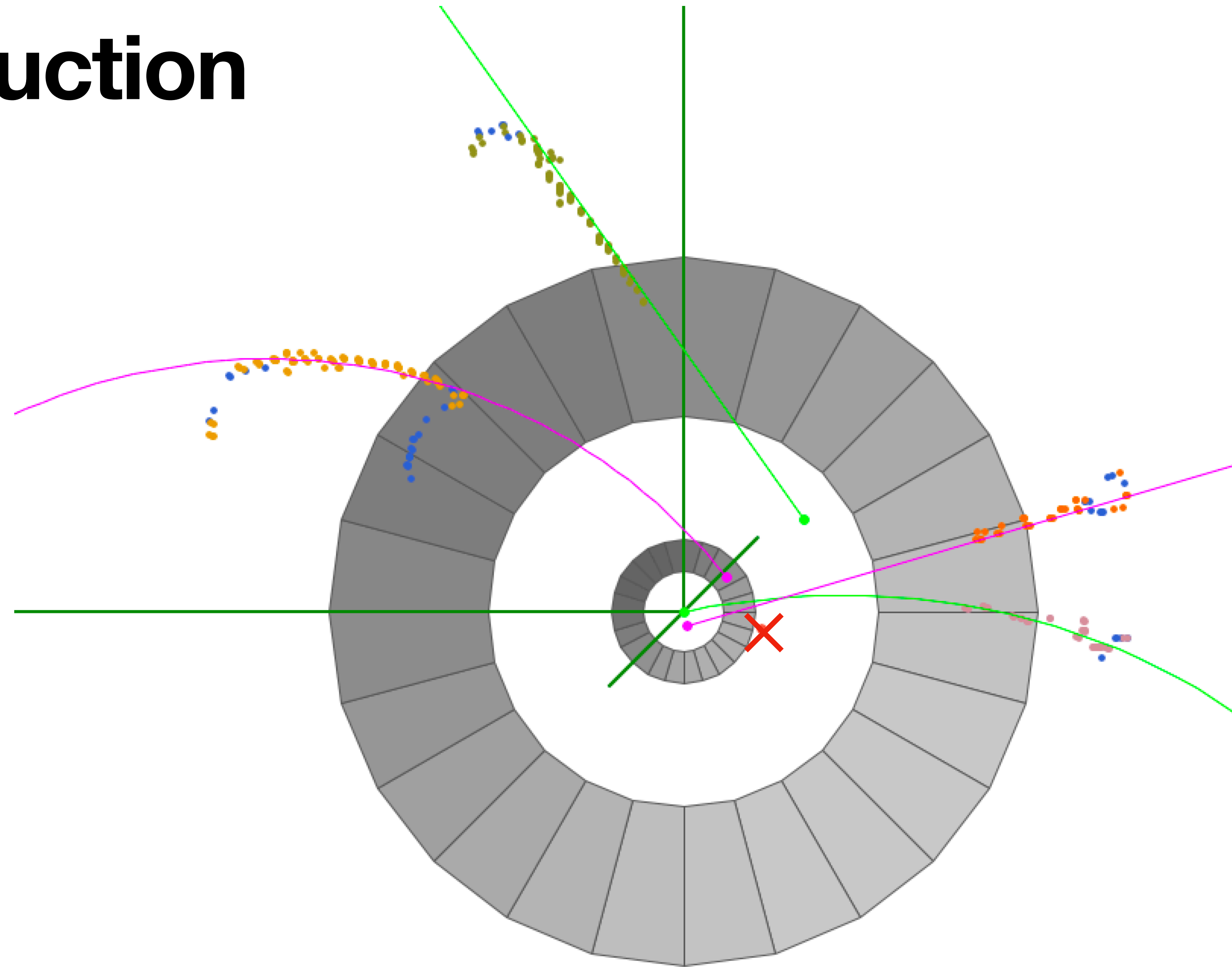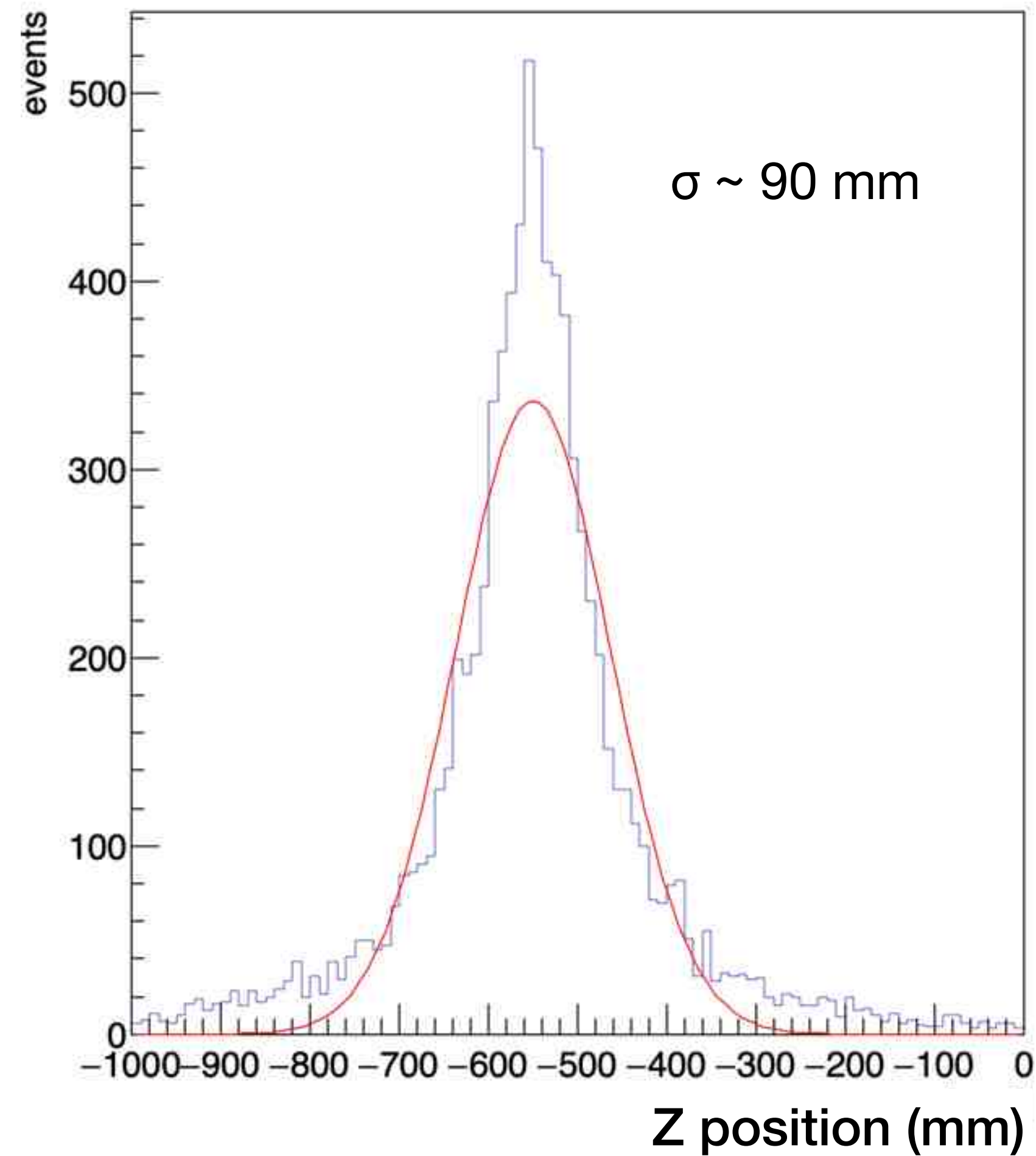
5. Helix fits → vertex position

*detector drawing not to scale

Improving Z Position Resolution

2022 analysis

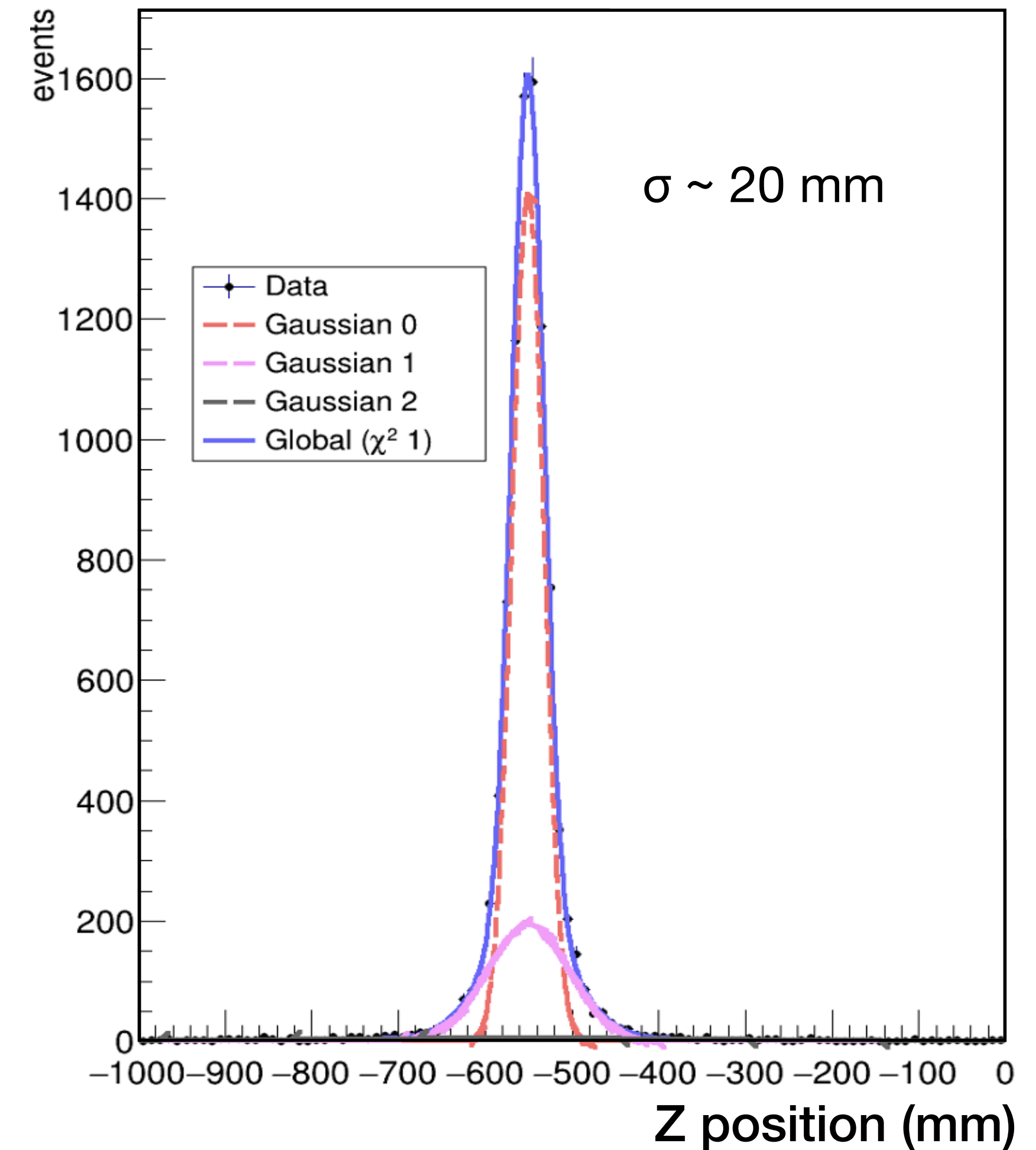σ ~ 90 mm

Algorithm improvements →

2023 analysis

σ ~ 20 mm

ALPHA-g Barrel Scintillator

- 64 plastic scintillator bars enclosing TPC.

~ 3 meters

~ 2cm x 2cm

SiPM array   Plastic scintillator   SiPM array

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ALPHA-g Barrel Scintillator

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- ~ 10 cm Z position resolution

- ~ 200 ps time-of-flight resolution (*)
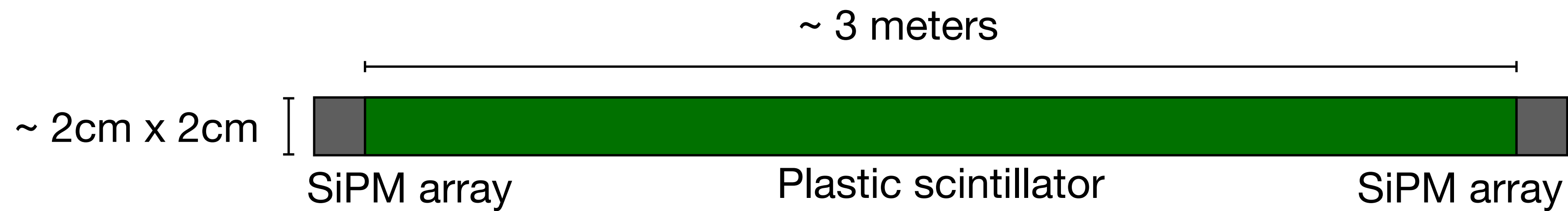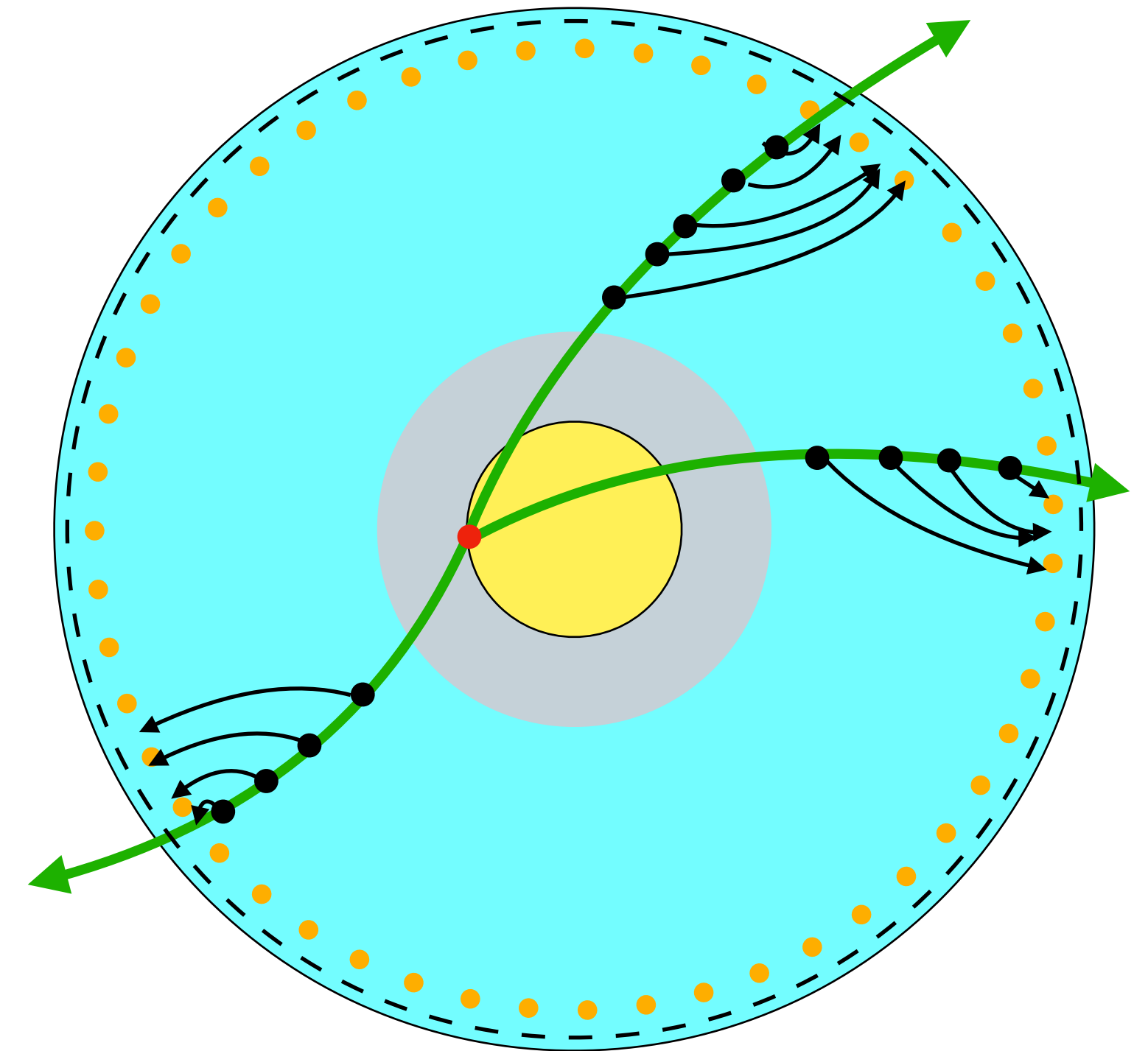
  * after completion of calibrations

~ 3 meters

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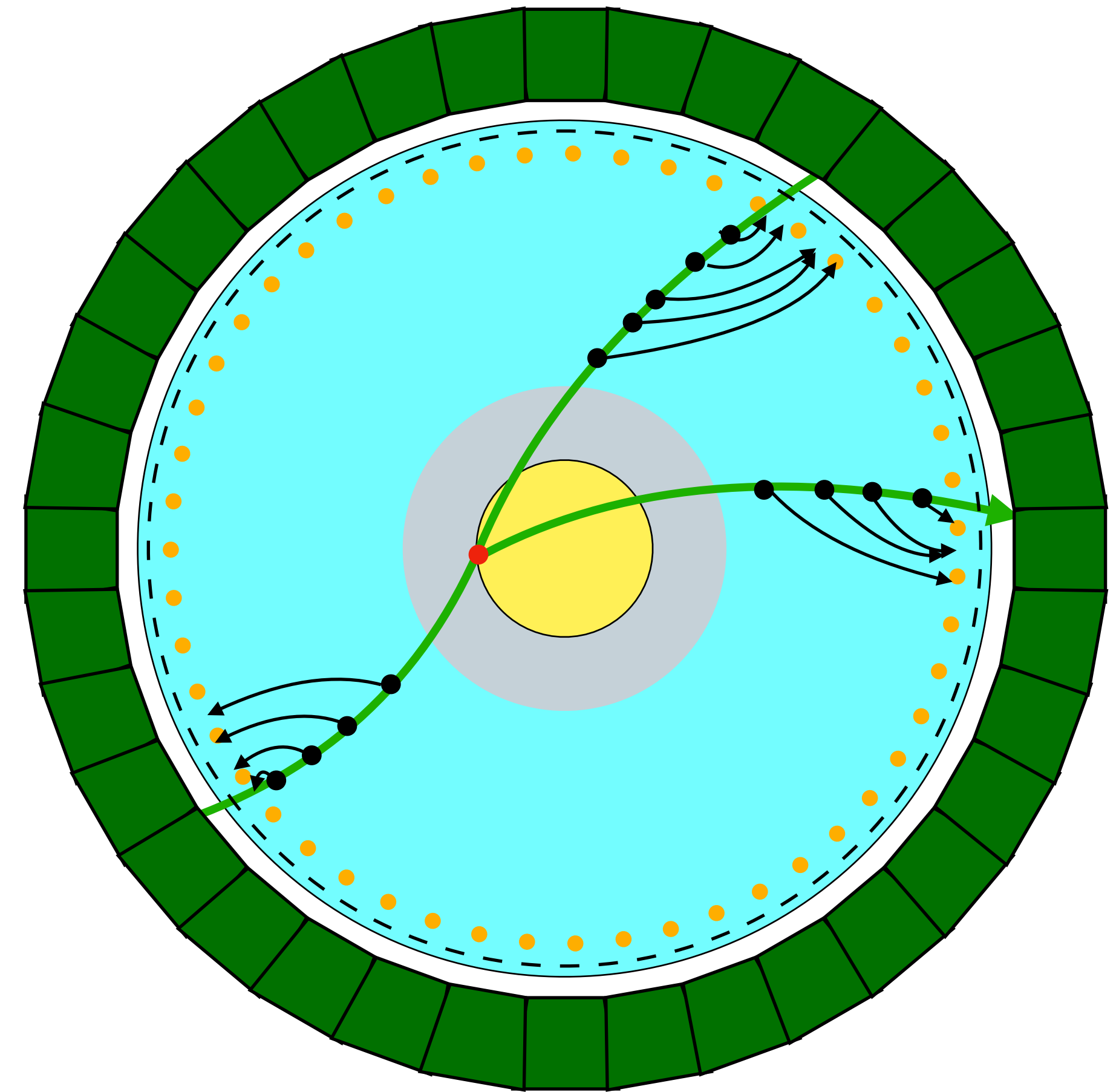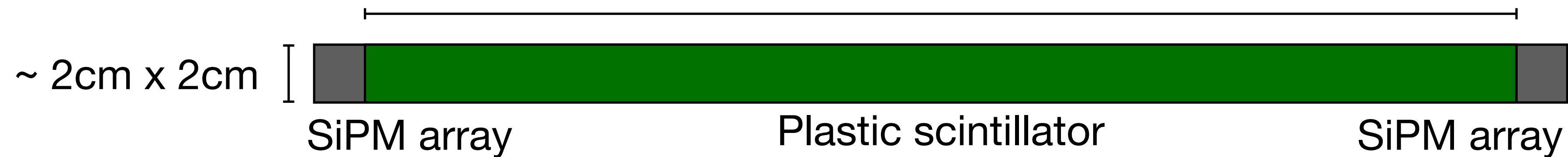SiPM array   Plastic scintillator   SiPM array

ALPHA-g Barrel Scintillator

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- Used for rejecting cosmic ray background.

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SiPM array   Plastic scintillator   SiPM array
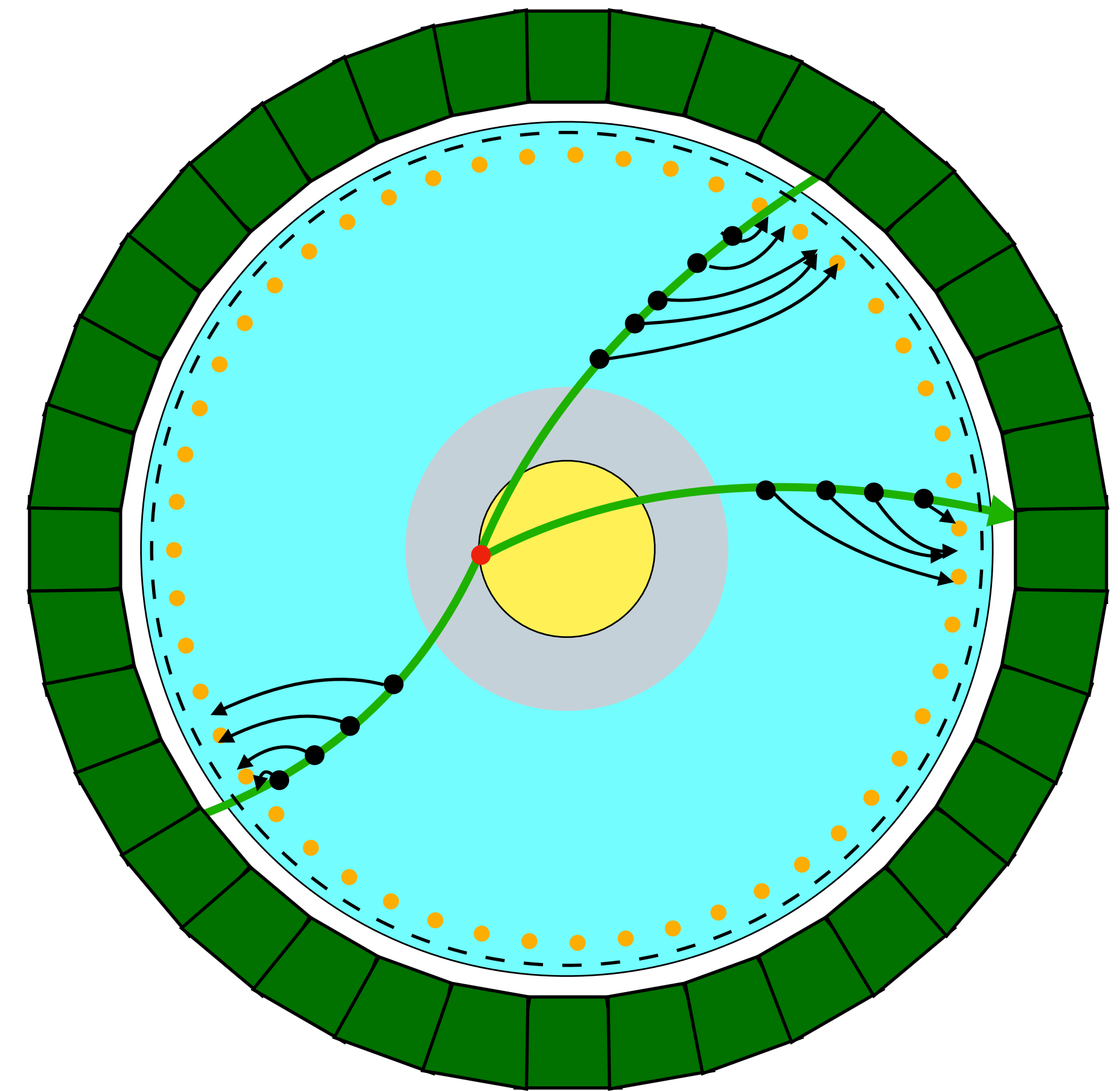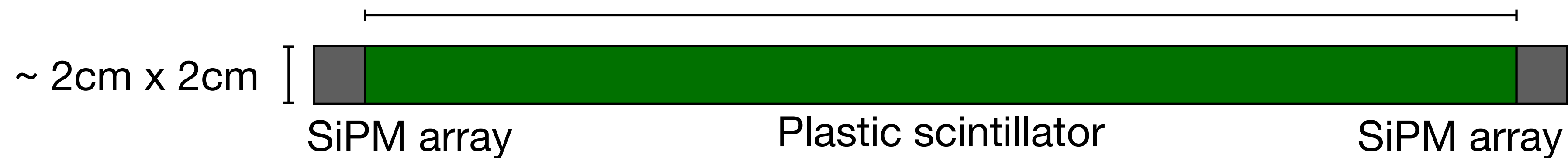
Cosmic Ray Discrimination Using Time-Of-Flight

Case 1: Cosmic ray
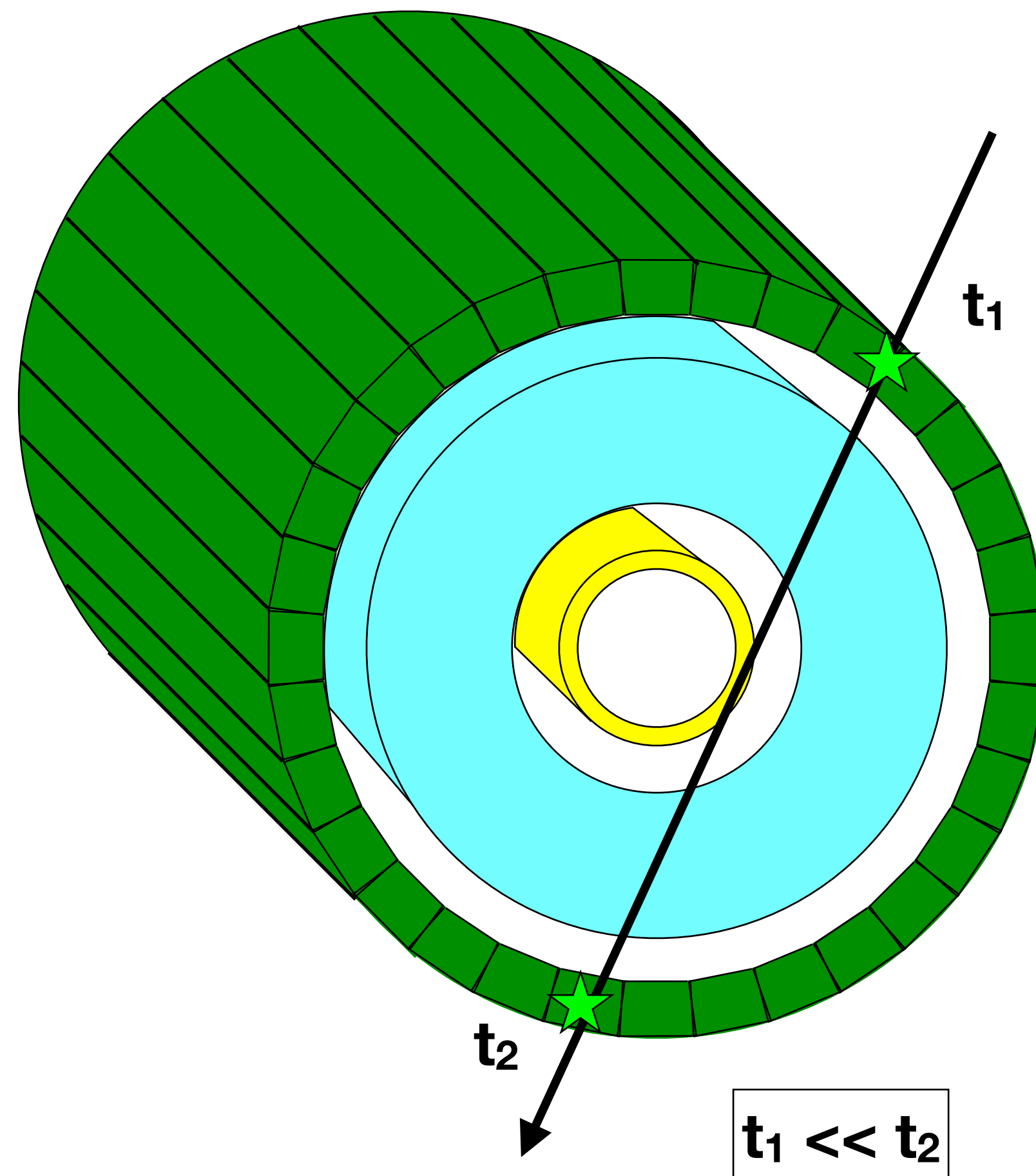
t_1

t_2

$t_1 \ll t_2$

Case 2: $\bar{H}$ annihilation
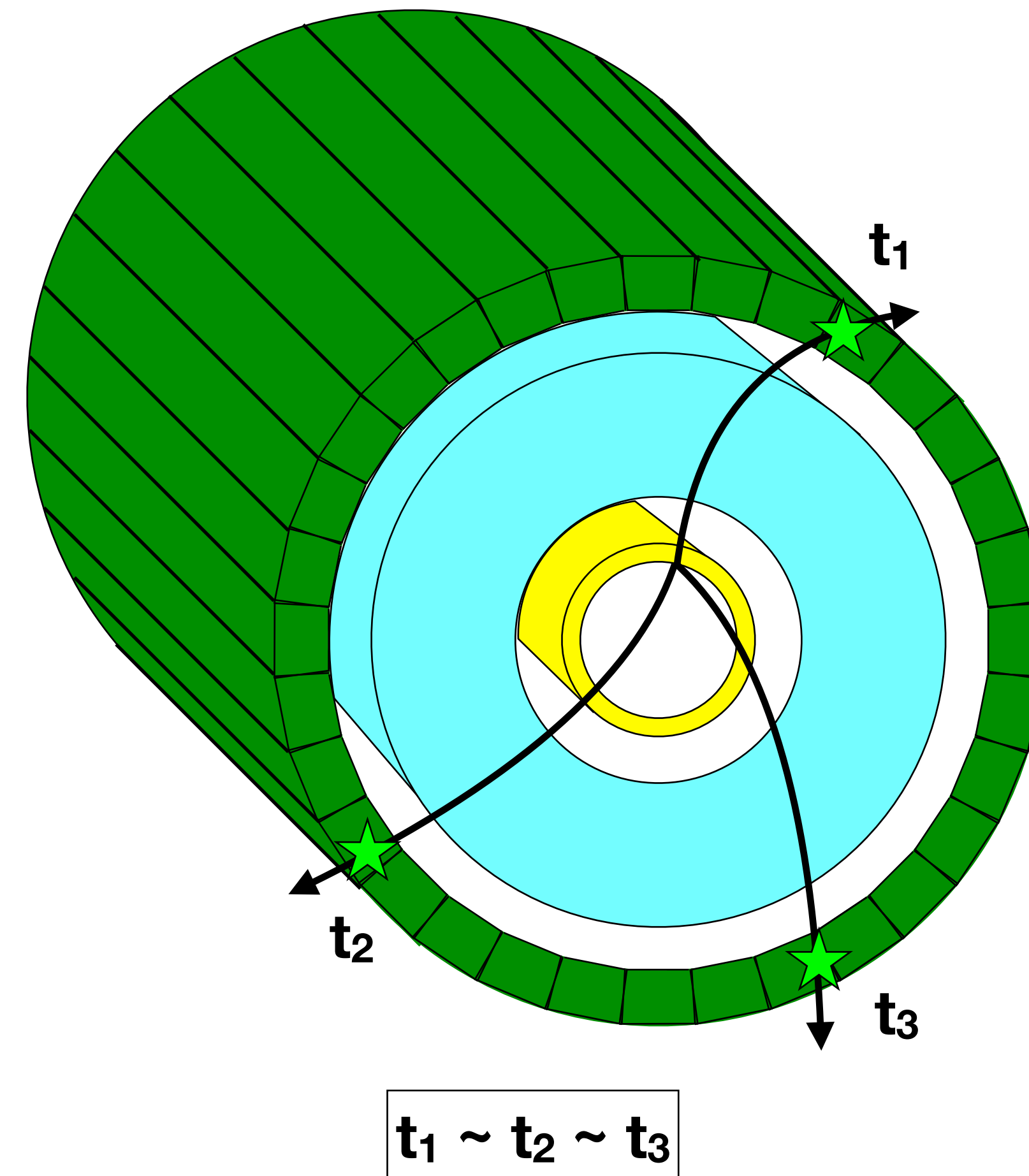
t_1

t_2

t_3

$t_1 \sim t_2 \sim t_3$

Time Calibration (work in progress)

- Can already see direction of particles.

Cosmic ray skimming barrel scintillator

Time →

0 ns   +2 ns

Time Calibration (work in progress)

- Can already see direction of particles.

- Time-of-flight resolution ~ 200 ps is a work in progress.

  ‣ Channel offset correction ~ 5 ns.

  ‣ Time walk correction ~ 5 ns.

Cosmic ray skimming barrel scintillator

Time →

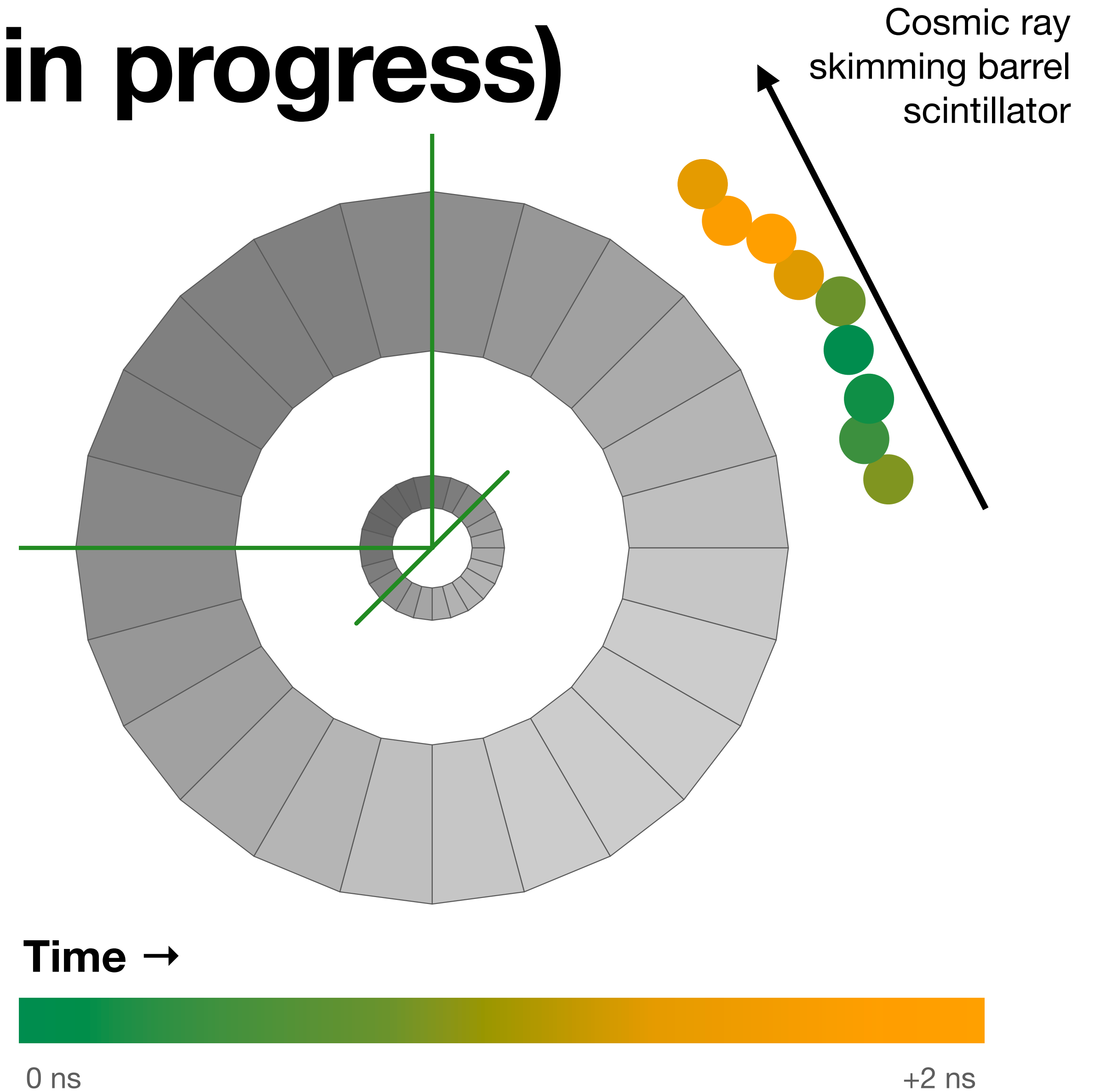0 ns   +2 ns
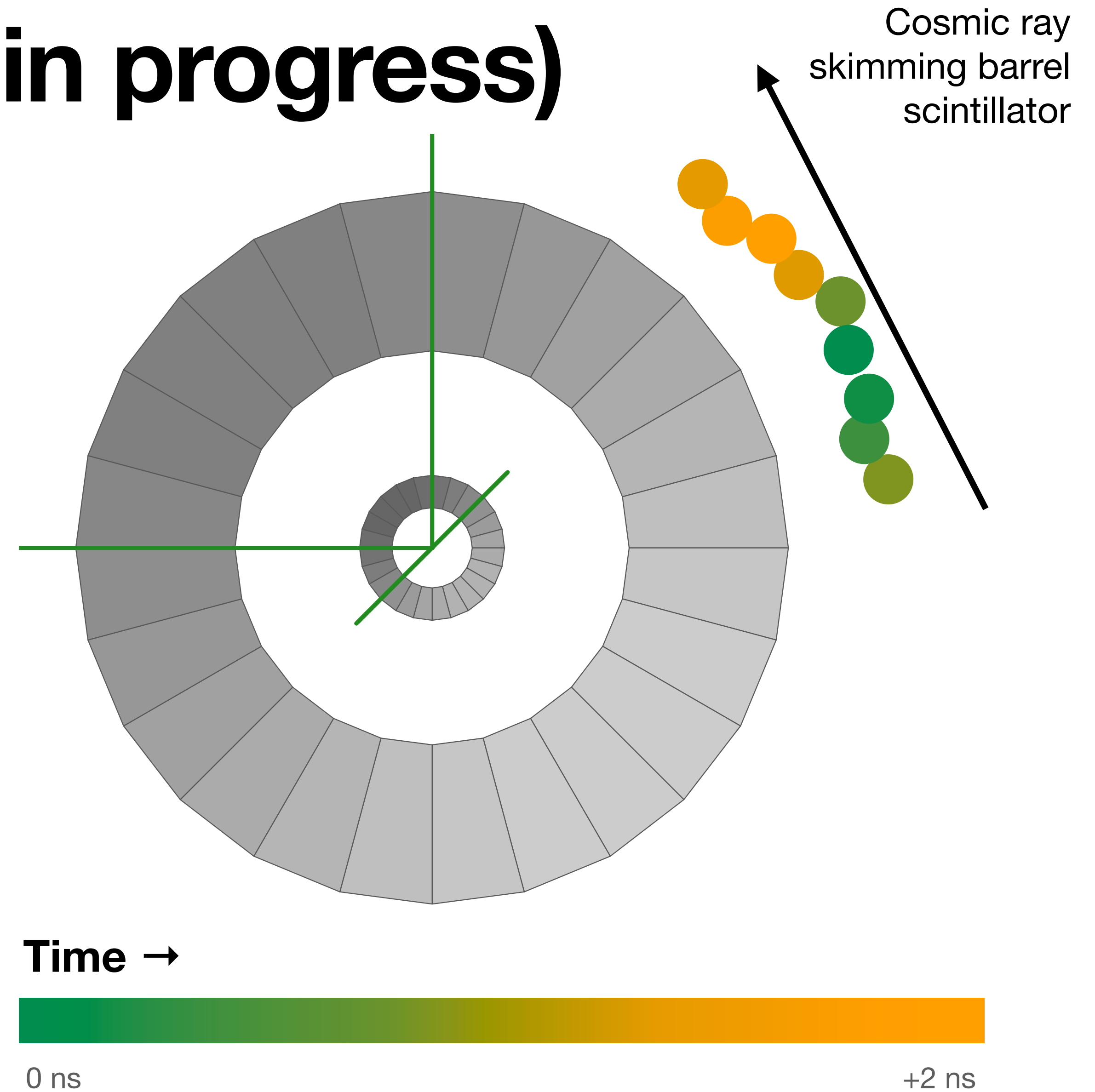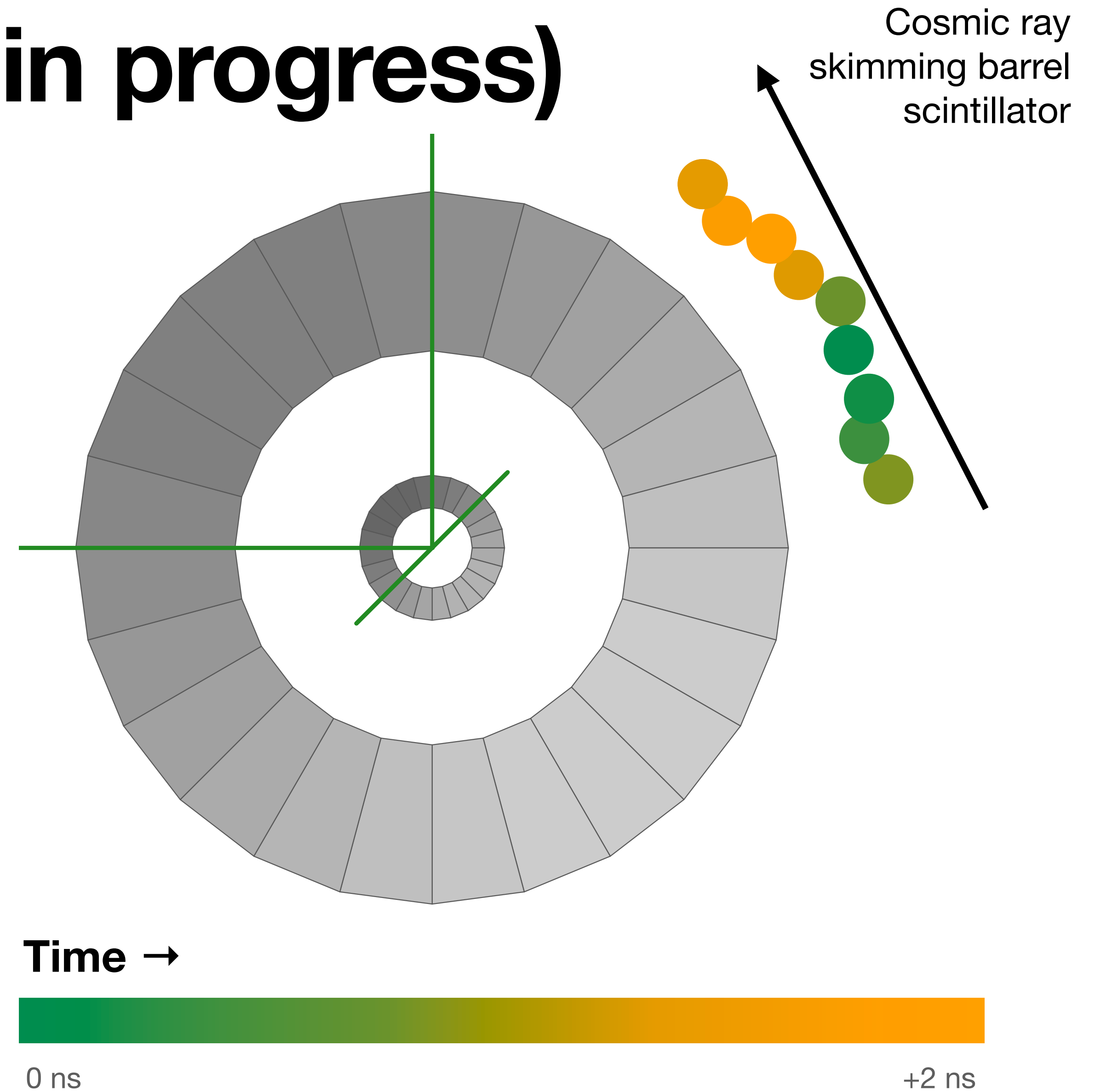
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- Background rejection using Barrel Scintillator hit topology info only.

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Detecting Anti-Hydrogen!

Anti-hydrogen Annihilation Z Position

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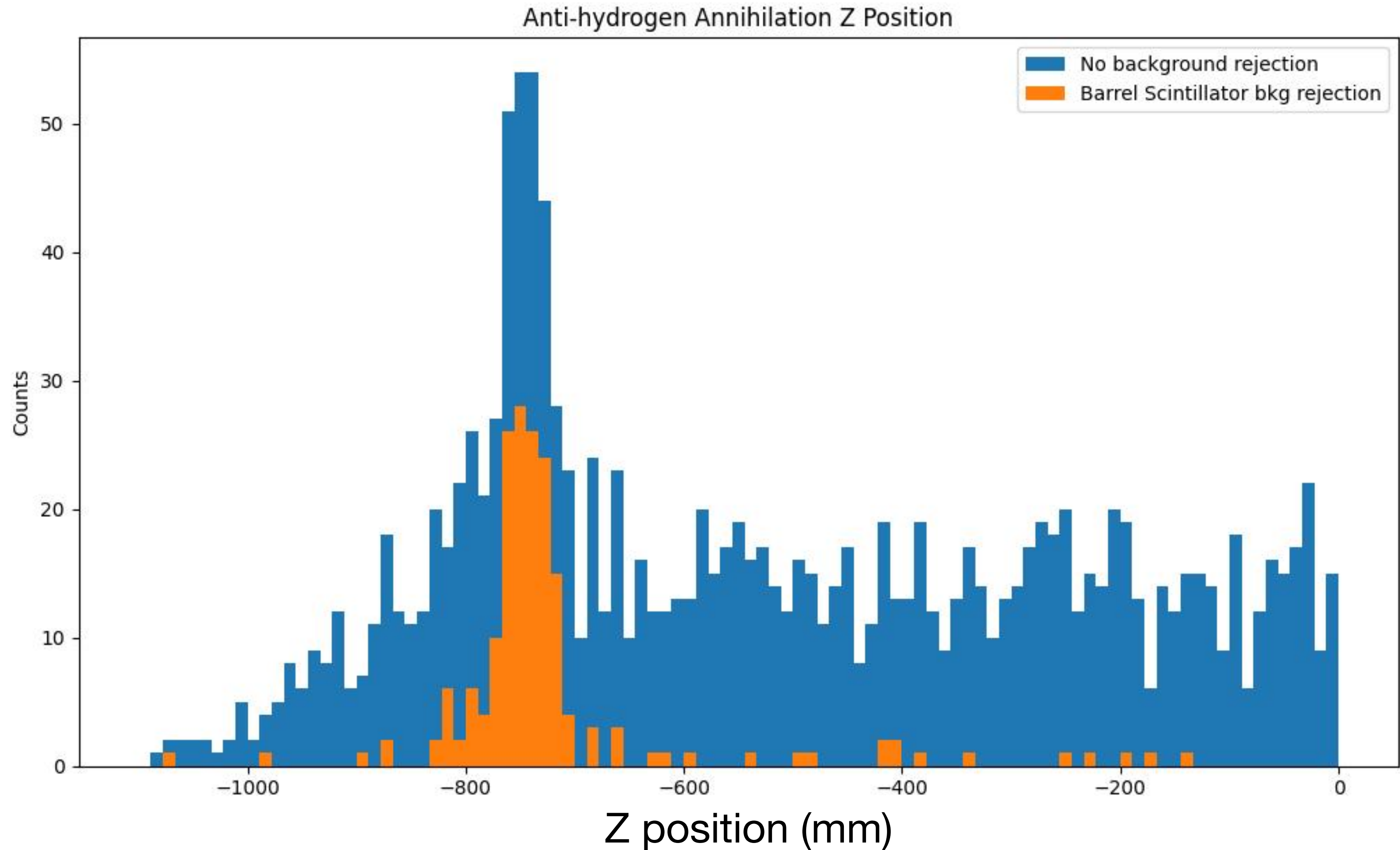
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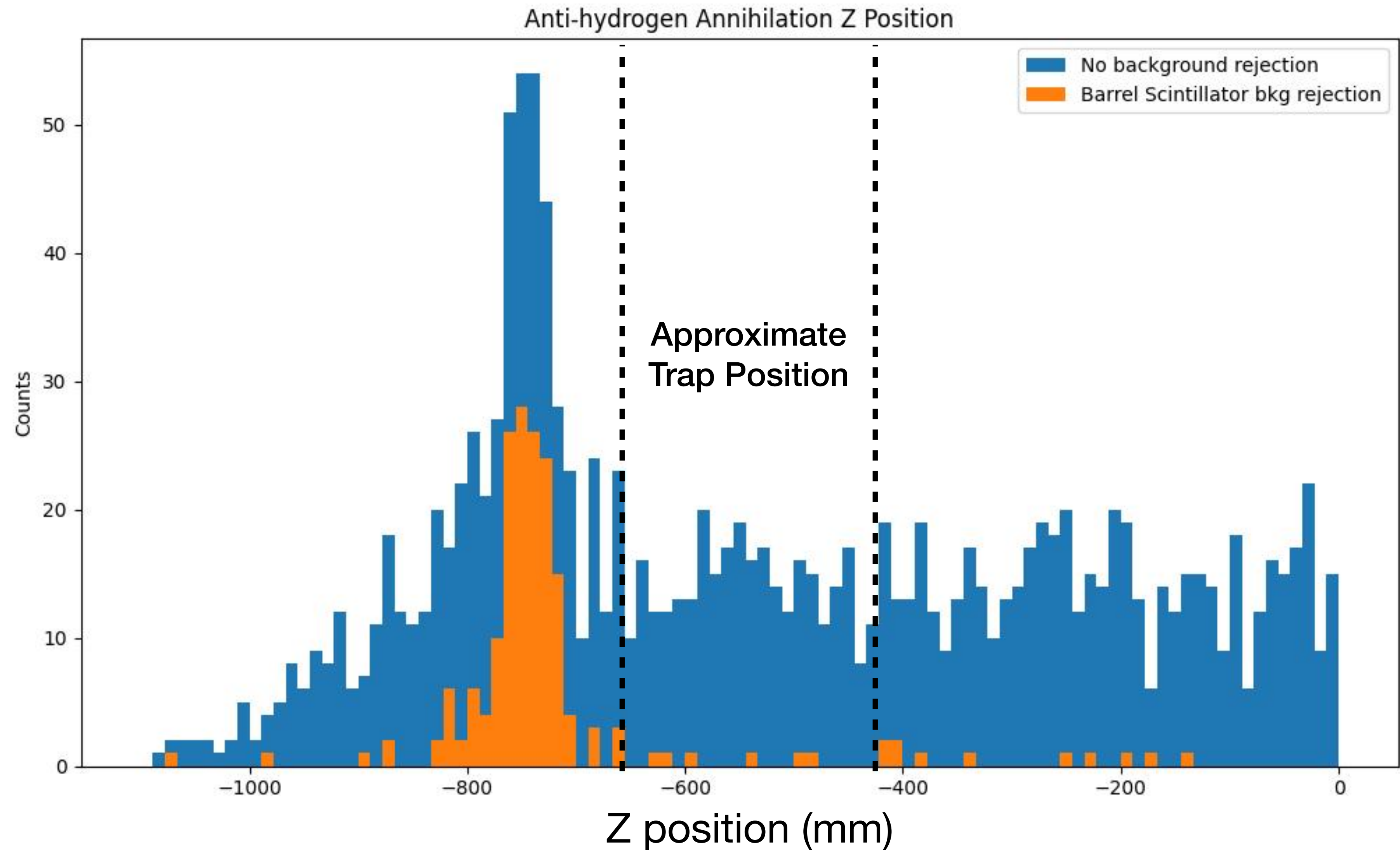
Summary

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Detectors:	Operational

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Detectors:	Operational
Z resolution:	Greatly Improved
Cosmic rays:	Mostly Rejected
Anti-Hydrogen:	Detected

Summary

Detectors:	Operational
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Cosmic rays:	Mostly Rejected
Anti-Hydrogen:	Detected
Time-Of-Flight:	In Progress

Acknowledgements

- Special thanks to CINP for their current Graduate Fellowship support.