Determination of annihilation vertex of antihydrogen using modular J-PET detector

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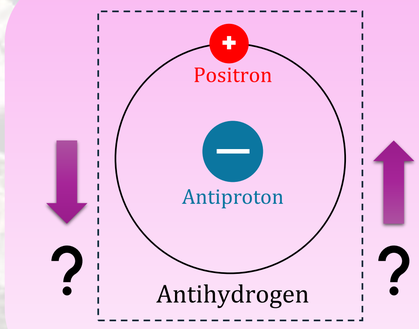
Motivation

First empirical indication of Universality of free fall

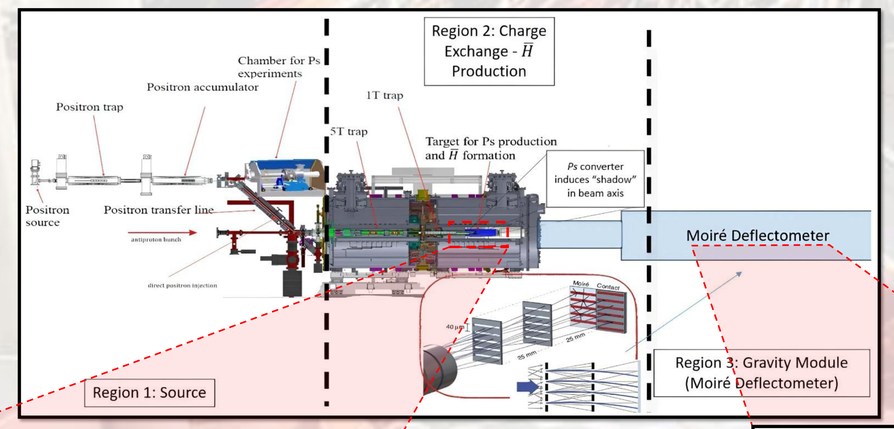
$m_g = m_a$
(for all bodies and regardless of material)

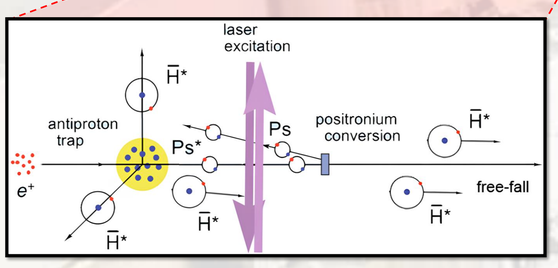
WEP as cornerstone of GTR

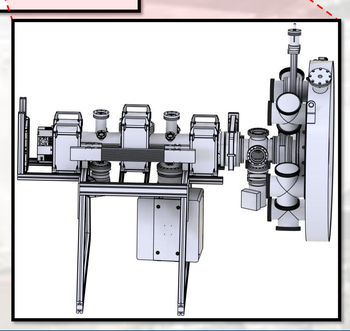


Imbalance?

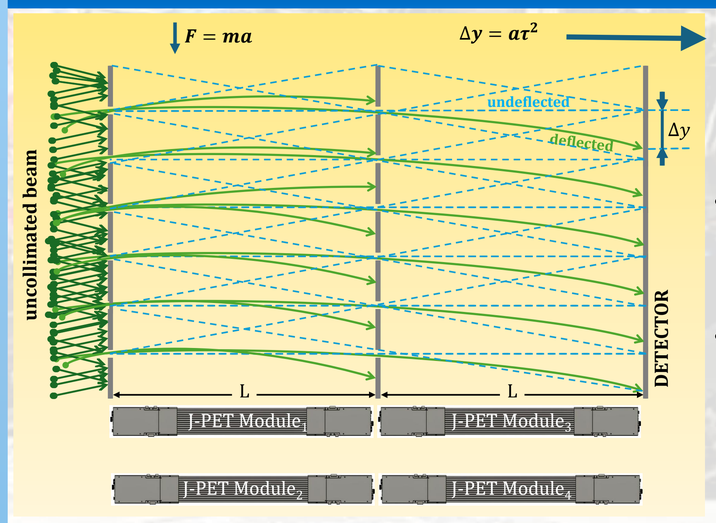
AE$\bar{g}$IS Beamline







Mathematics behind the Experiment

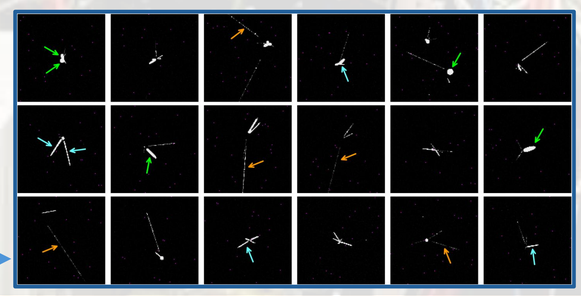


Fringe shift:

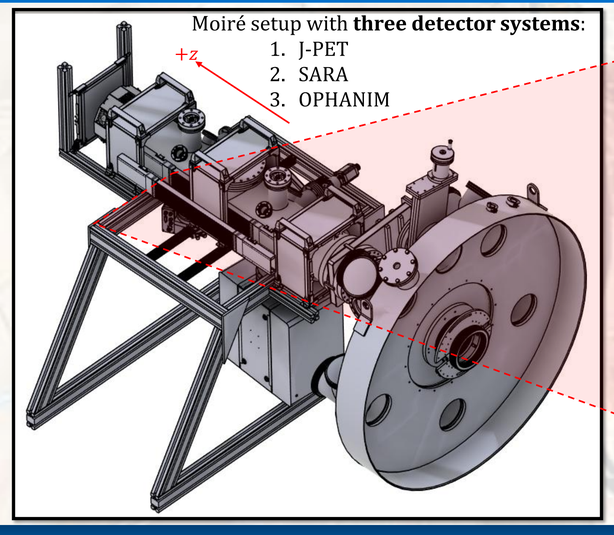
$$\Delta y = F_{\parallel}\frac{\tau^2}{m} = a\tau^2$$

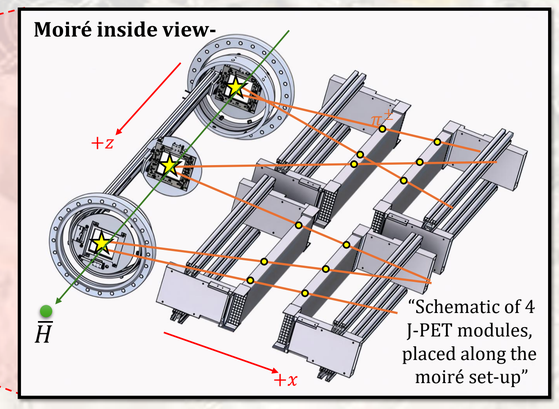
- Δy gives the vertical displacement where a is acceleration and τ is the transit time between the gratings.
- Recently, AE$\bar{g}$IS collaboration demonstrated the potentialities for **real-time annihilation** vertexing with submicrometric resolution [ref]

- **$\bar{H}$ beam profile:** $\bar{H}$ passes through moiré deflectometer. The annihilation vertices will be reconstructed using **J-PET detection** modules.
- **Calibration:** CMOS alternates $\bar{H}$ shots and light to align grids, compensate drifts.
- **Tracks:** Star-shaped prongs (pions, protons, nuclear fragments) give sub-μm vertexing.

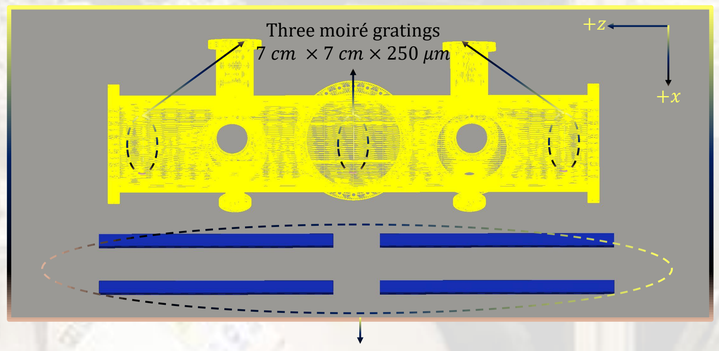


Moiré Deflectometer and the Idea of Vertex Reconstruction

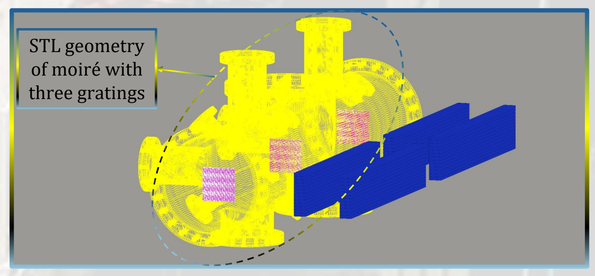




Geant4 Simulations for developing the algorithm of vertex reconstruction



Four J-PET modules
50 cm × 2.5 cm × 0.6 cm

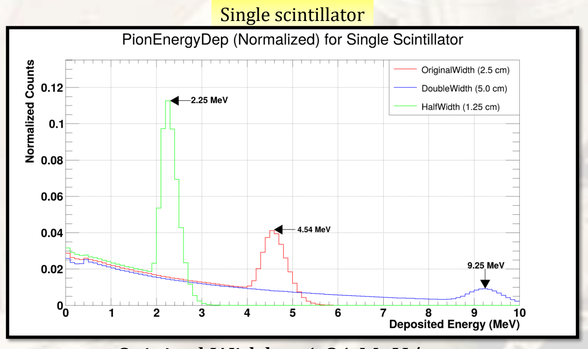


Orthographic view

Results from the Simulated Studies

Energy deposition

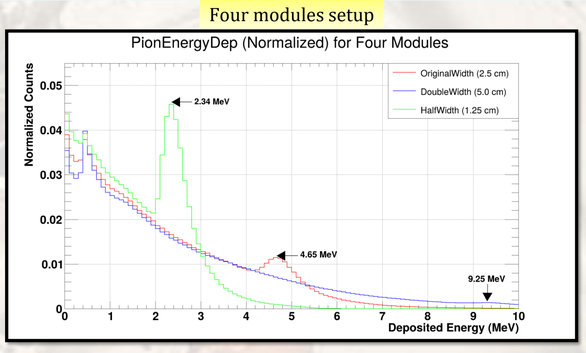
Single scintillator



- Original Width = 1.81 MeV/cm
- Double Width = 1.85 MeV/cm
- Half Width = 1.8 MeV/cm

Pions are MIPs

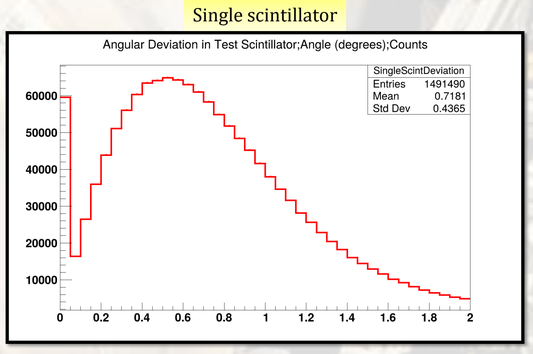
Four modules setup



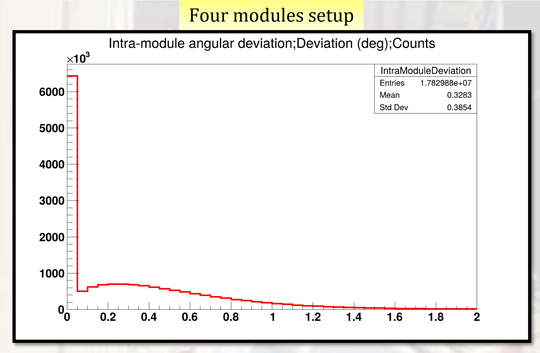
For **muons (also MIPs)**, Energy Deposition in organic scintillators is **2 MeV/cm.**

Angular deviation

Single scintillator



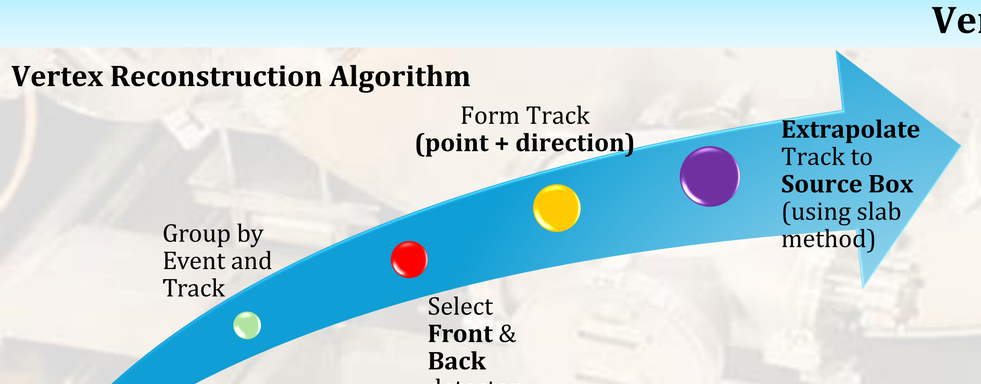
Four modules setup

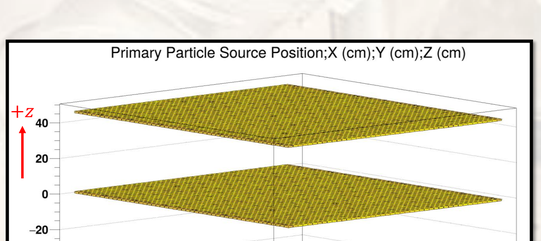


Less angular deviation means the **particle's path is straighter**, which is most important for vertex reconstruction

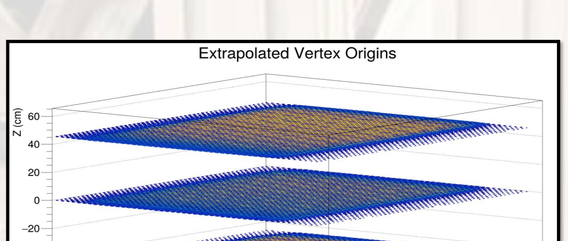
Vertex Reconstruction and Future Plans

Vertex Reconstruction Algorithm

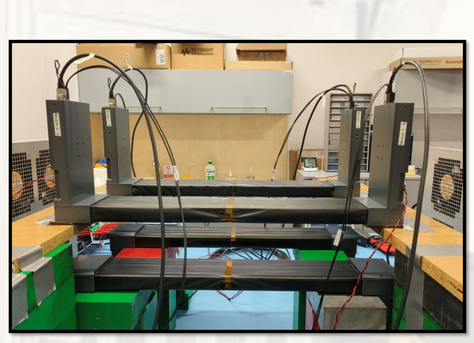




Generated Vertices



Reconstructed Vertices



Testing the J-PET modules, to be installed at AEgIS facility at CERN

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