A Table-Top Experimental setup Testing Silicon Sensors

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Motivation

- **Advantages of Test Beams**:
- High-energy particles with low multiple scattering provide the necessary precision for detailed spatial mapping.
- **Challenges with Test Beams**:
- Require time slots and resources at dedicated facilities (e.g., CERN SPS, DESY).
- Complex setup with specialized tracking telescopes like the EUDET telescope with MIMOSA planes.
- **Our Purpose**
- A discussion on beta particle calibrating the silicon sensors

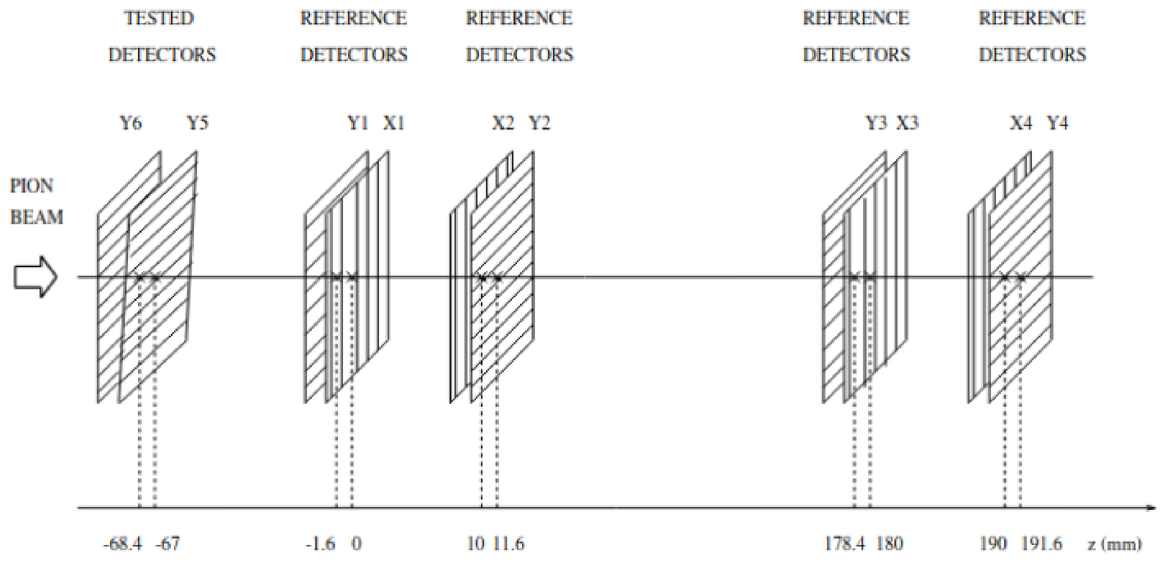
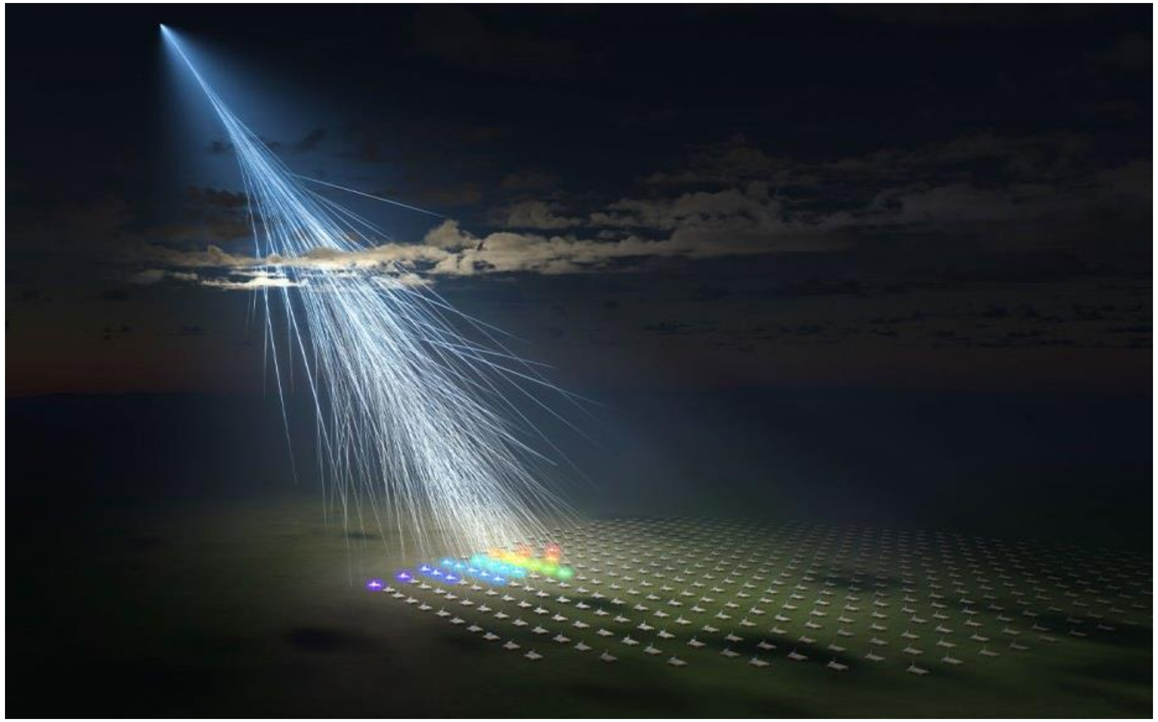


Figure 3: Detector telescope used with a pion beam. The relative positions of the different detectors are reported (in mm) with respect to the X_1 detector, used as the origin.

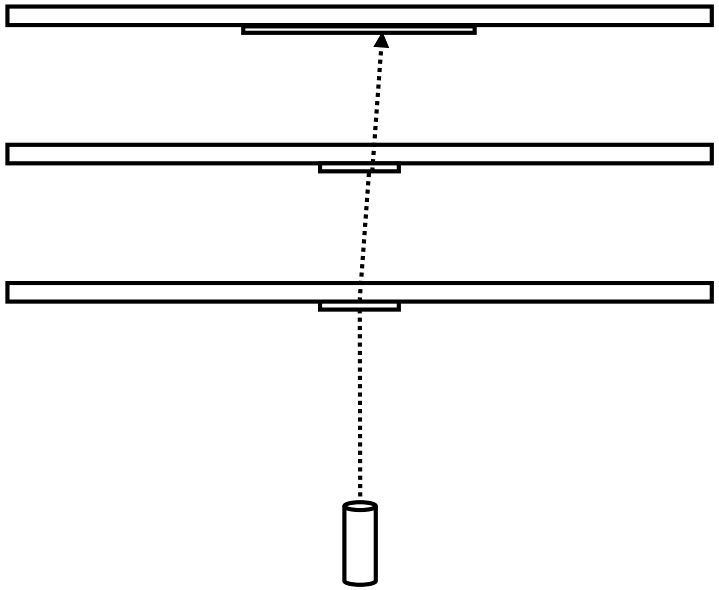
Cosmic Ray Muons?

- **Advantage:**
  - Low multiple scattering
- **Rate of Cosmic Rays**:
  - Muons arrive at ~1 muon/min/cm².
- **Time Requirement**:
  - For a 1mm x 1mm DUT with 5μm x 5μm bins and ~100 events per bin
  - Need **~100 years** by assuming 100% muon detections efficiency for calibration



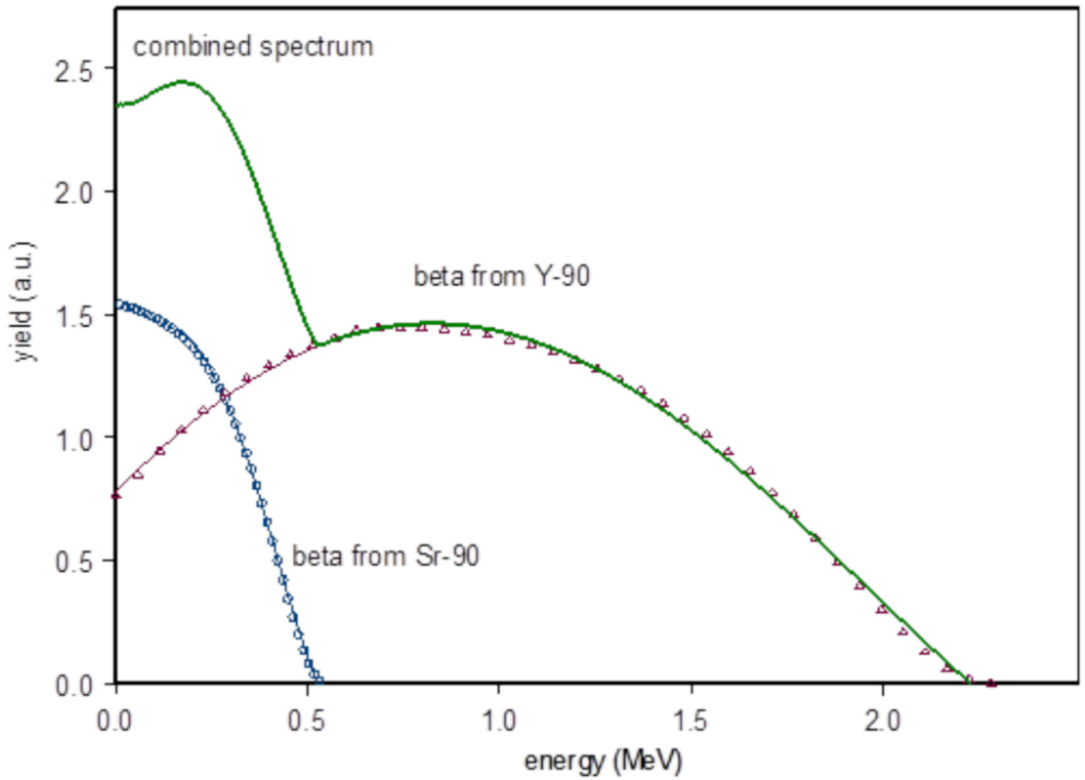
A Table-Top Experiment

- **High-Energy Beta Particles**: Ensures effective penetration and minimal scattering.
- **Detector Configuration**: DUT sandwiched between detectors, with a pixel detector as the final layer.
- **Calibration Goals**: Achieve both time and spatial calibration.
- **Key Considerations**:
    - Source Selection
    - Geometry Placement
    - Multiple-Scattering Analysis

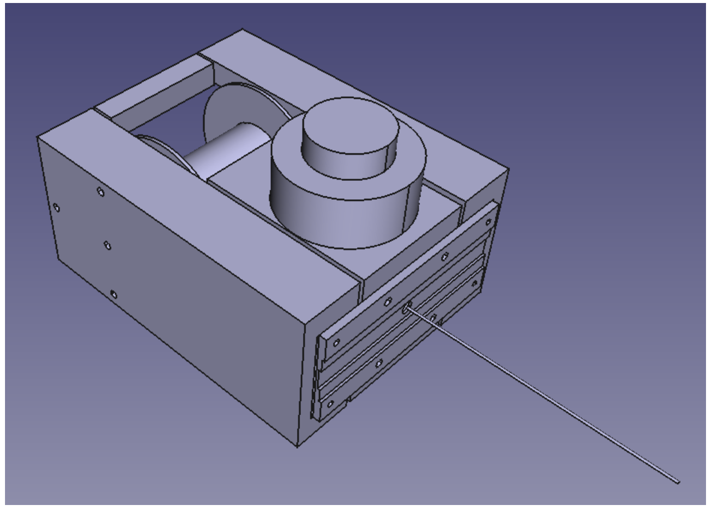


Source Consideration

- **Source Requirements**
- **High-Energy Particles:** Ensures effective penetration and minimal scattering.
- **Stability During Testing:** Long enough half-life to maintain consistent emission over the testing period.
- **Phosphorus-32P**
  - **Maximum Energy**: 1.71 MeV
  - **Half-Life**: ~14.3 days
- **106Ru and 106Rh**
  - **Maximum Energy**: 3.54 MeV (from 106^{106}106Rh decay)
  - **Half-Life**: 106Ru ~373.6 days; 106Rh,~30 seconds.
- **Chosen Source:** 90Sr with a beta spectrum up to 2.28 MeV



Particle Selection - Electron Monochromator



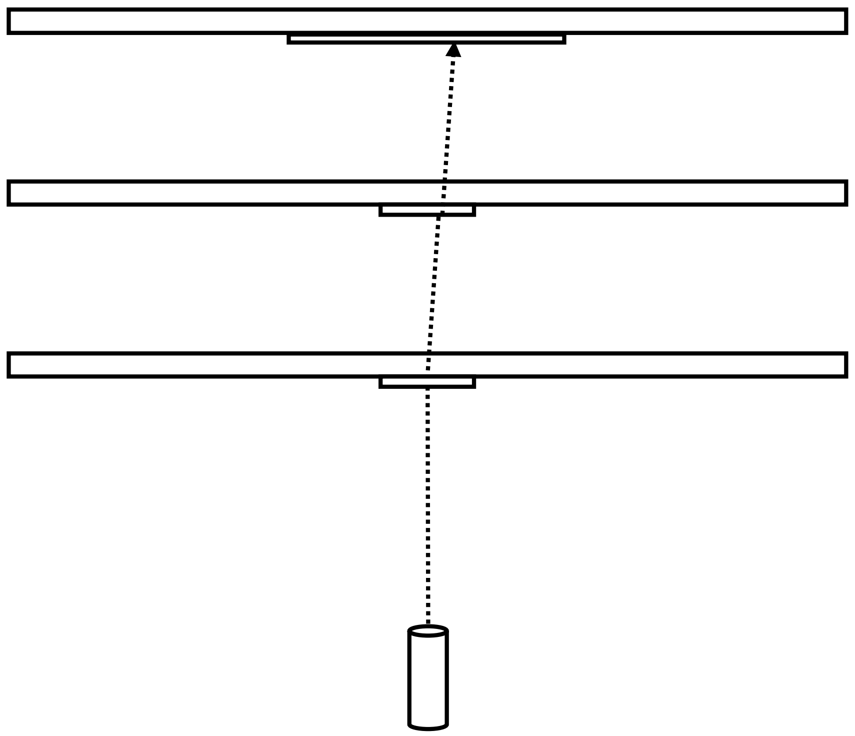
Momentum Selection performance

- **High-Energy Selection**: Reduce multiple-scattering, increase the selection precision.
- **Momentum Precision**: Generally better than 10%, reaching approximately 5% for momenta above 1.5 MeV/c. *(Source: S. Arfaoui, C. Joram, C. Casella, 2015)*

High-Activity Source Requirement

- **Trigger Rate**: Typical trigger rate of around 10 Hz, achieved with thick, square scintillating fibers positioned approximately 1 cm from the exit slit. *(Source: S. Arfaoui, C. Joram, C. Casella, 2015)*

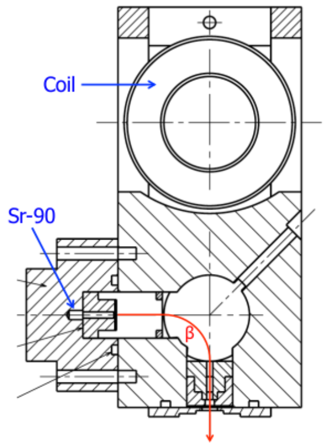
Geometry Placement

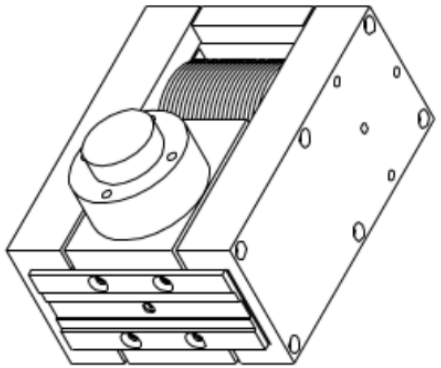


Geometry placement

- **details**:

Scanning Tracking Technique





General Idea:

- Create a **detailed spatial map** of the sensor's response

High-Activity Source Requirement

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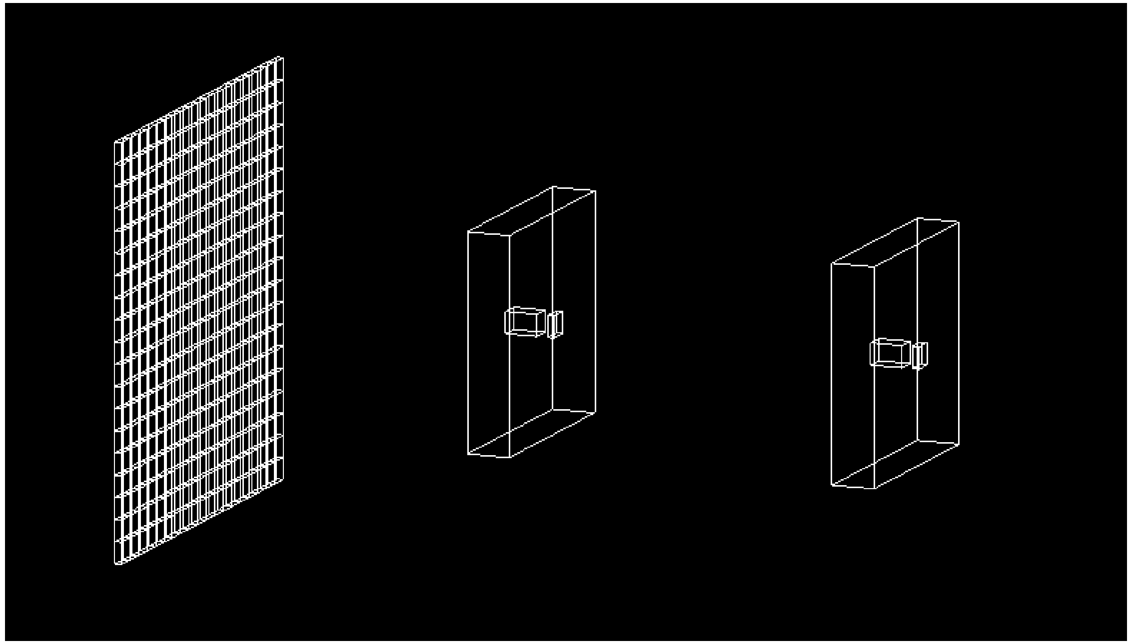
Initial Investigation

- Evaluate the feasibility of the proposed setup using a simplified particle source model.
- By utilizing Geant4 simulations to optimize the geometry for a configuration that minimizes scattering effects, ensuring accurate trajectory measurements.
- **Key Parameter - $\Delta\theta$**: Define $\Delta\theta$ as the angular deviation of a particle moving through each detection sensor.

Geant4 Simulation - Geometry



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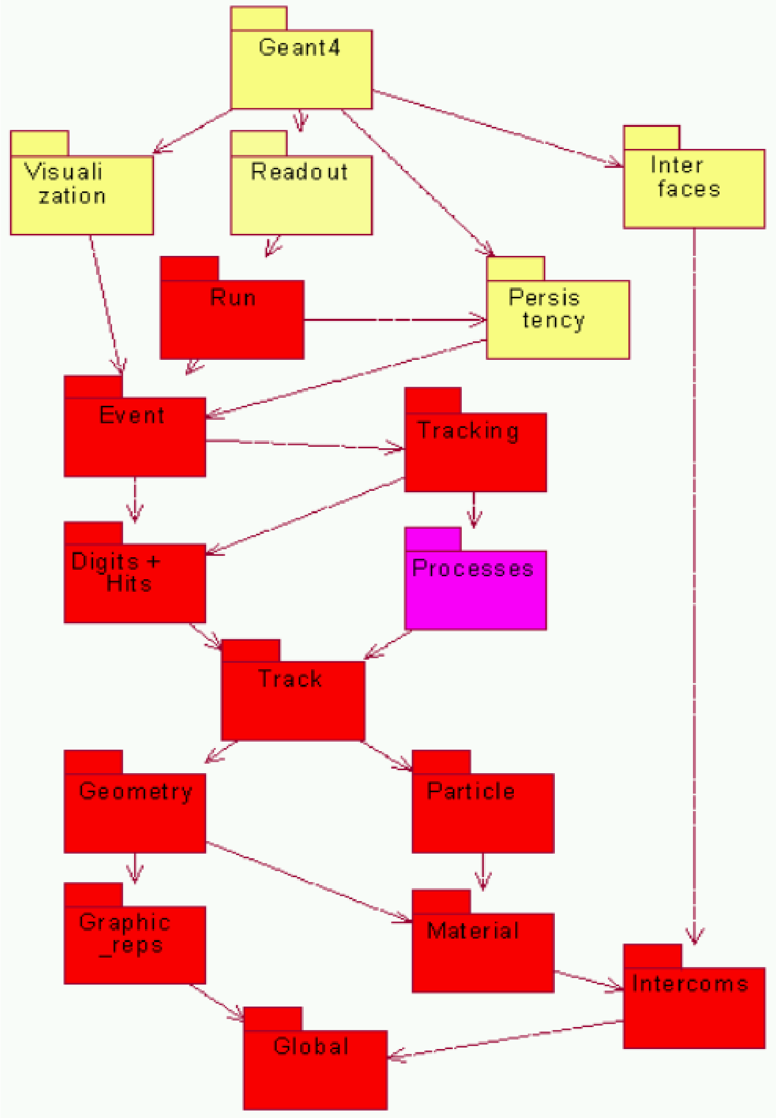
Geant4 Simulation - Physics List

- RegisterPhysics(new **G4DecayPhysics()**);
- RegisterPhysics(new **G4RadioactiveDecayPhysics()**);
  - To generate decay process

- RegisterPhysics(new **G4EmStandardPhysics_option4()**);
  - Compared to **G4EmStandardPhysics,** option4 provides higher accuracy in Multiple Scattering simulation below ~100MeV (V. Ivanchenko, 2018)

Geant4 Simulation – Simulation Structure

- Some thing like this?



Geant4 Simulation – Material definition

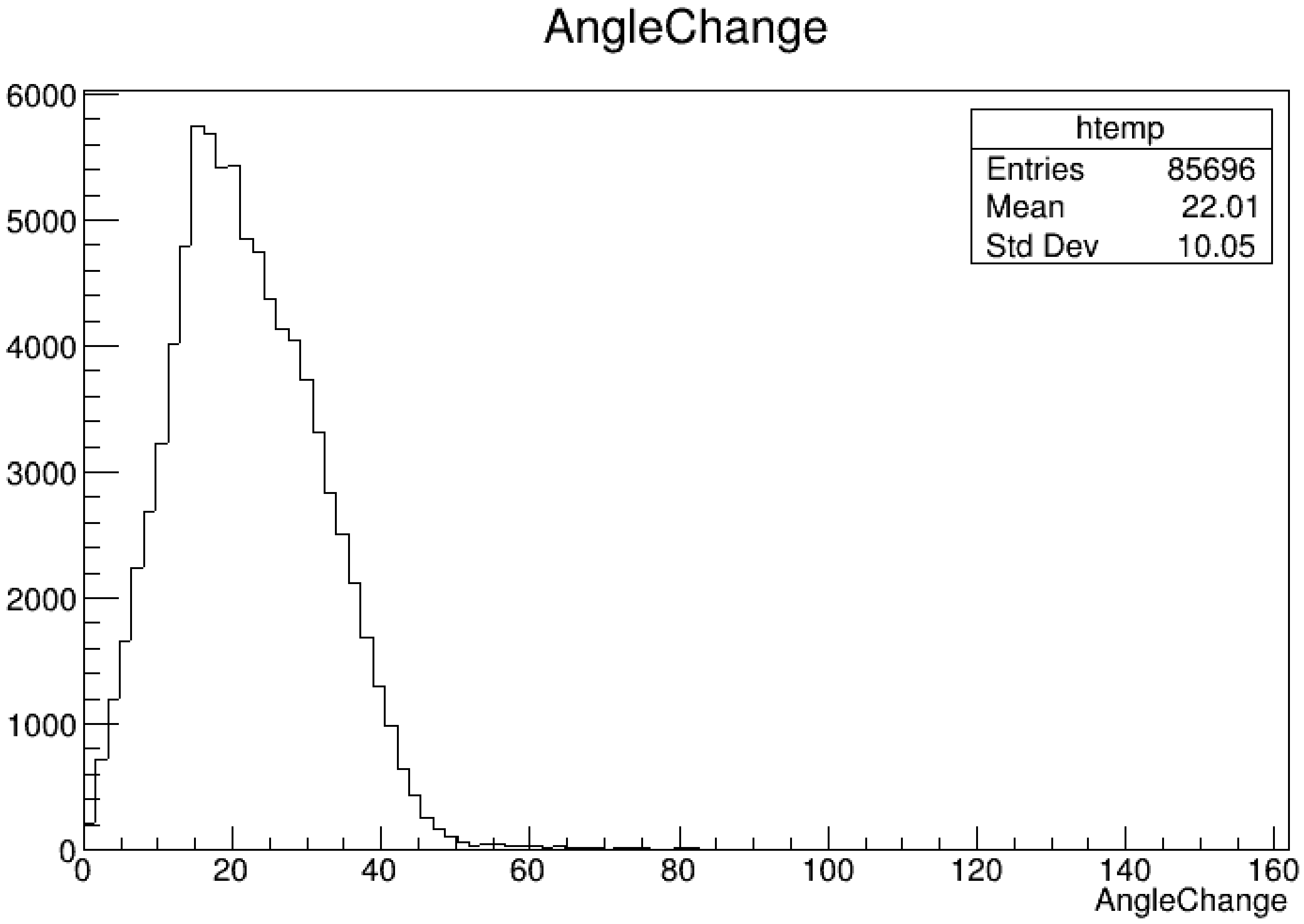
- Silicon Sensors:
  - Assuming pure silicon crystal – G4_Si
- Detector Holder Plate:
  - Woven Glass Fabric composition (15%):
    - Silicon (Si): ~33-35%; Oxygen (O): ~48-50%; Aluminum (Al): ~10-15%;Calcium (Ca): ~3-5%;Magnesium (Mg): ~1-2%
  - Ceramic filler (55%):
    - Oxygen (O): ~50-60%; Silicon (Si): ~20-30%; Aluminum (Al): ~5-15%; Calcium (Ca): ~1-5%; Magnesium (Mg): ~1-3%
  - Hydrocarbon Resin (30%):
    - Carbon (C): ~85-90%; Hydrogen (H): ~8-10%; Oxygen (O): Trace to 5%

Geant4 Simulation – Particle Gun and Tracking Actions

- Option 1 - decay generator:
  - Create random number 0-1, randomly pick 90Sr and 90Y decay process, to get a mixture spectrum
  - Kill the electron tracks if the direction is out side the emiting angle, and kill all the non-electron tracks
  - 1 decay in each G4Event
- Option 2 – Electron particle gun:
  - 2.2MeV electron particle gun, momentum alines on z direction
  - 1 electron generated in each G4Event
- Stop generating until 10^6 tracks are recorded

Primary Results – Total Angular deviation

- by ge



Primary Results – Distribution

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