Straw Tracker simulation in Sampo: current status

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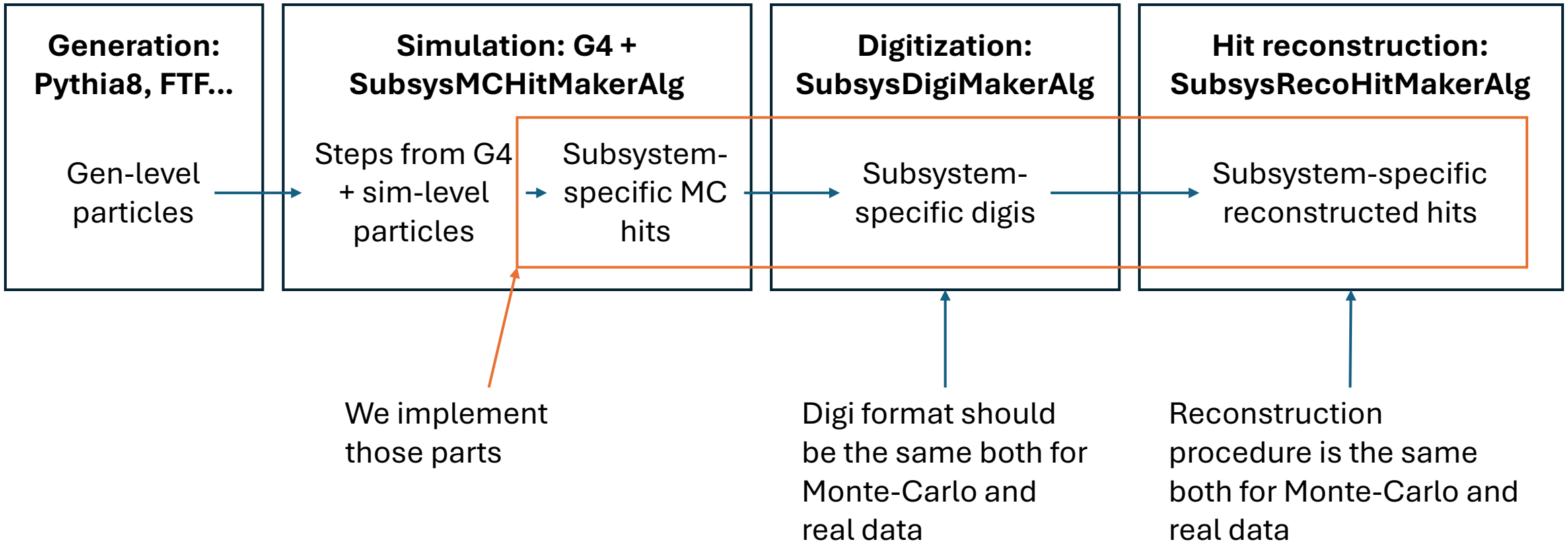
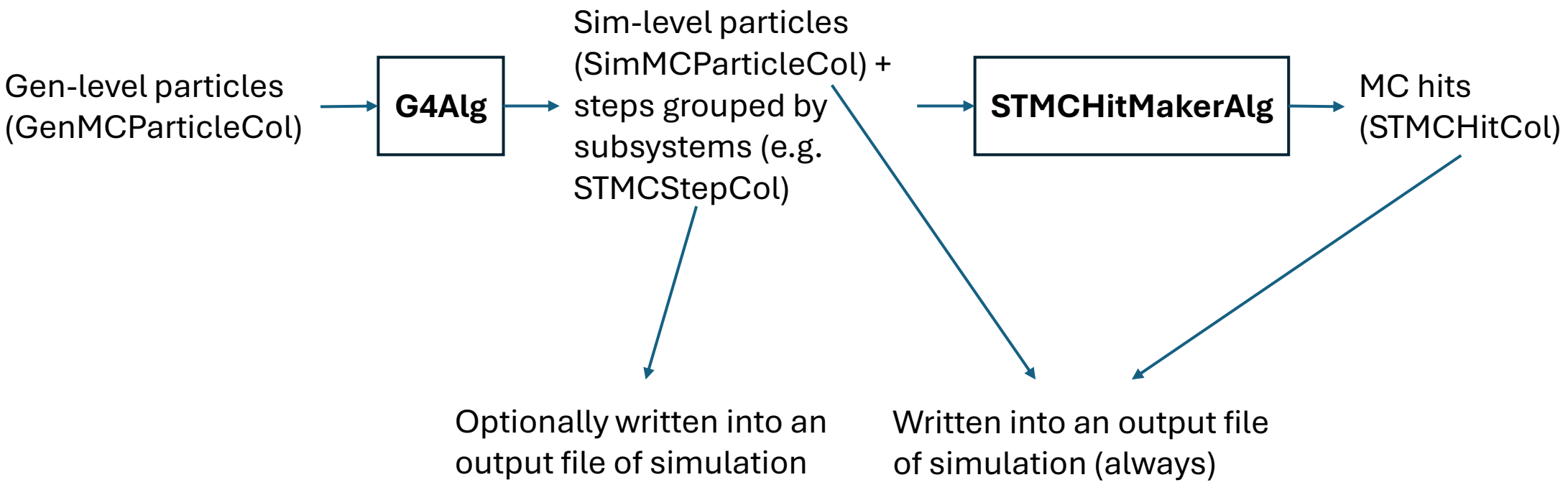
On behalf of SPD Straw Tracker group

XII SPD Collaboration Meeting. November 20, 2026. Dubna

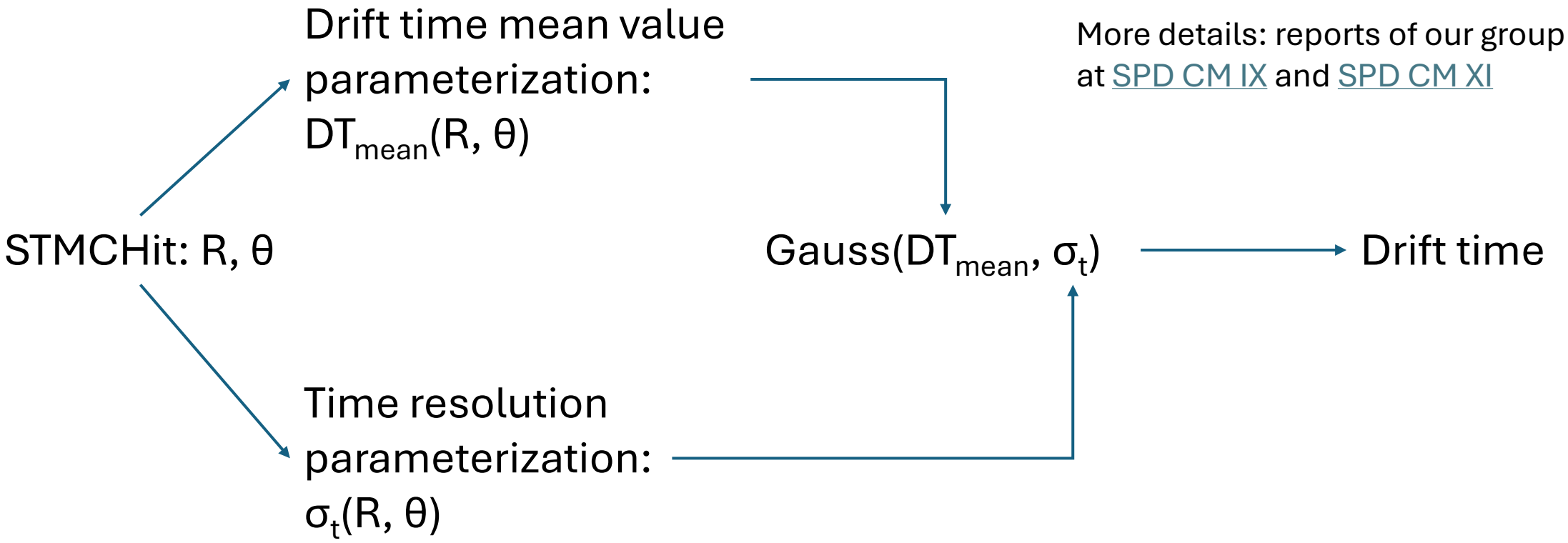
Sampo MC hit production and hit reconstruction



Simulation pipeline – STMCHitMakerAlg

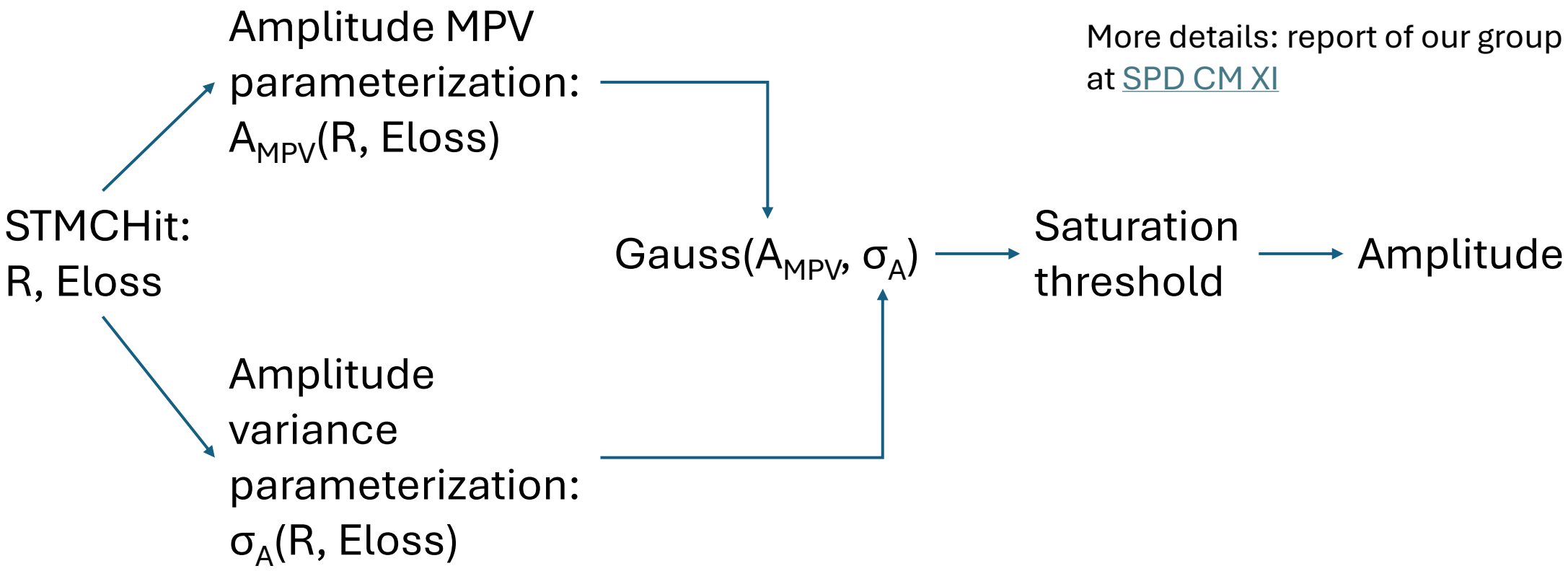


Baseline digitization procedure: drift time



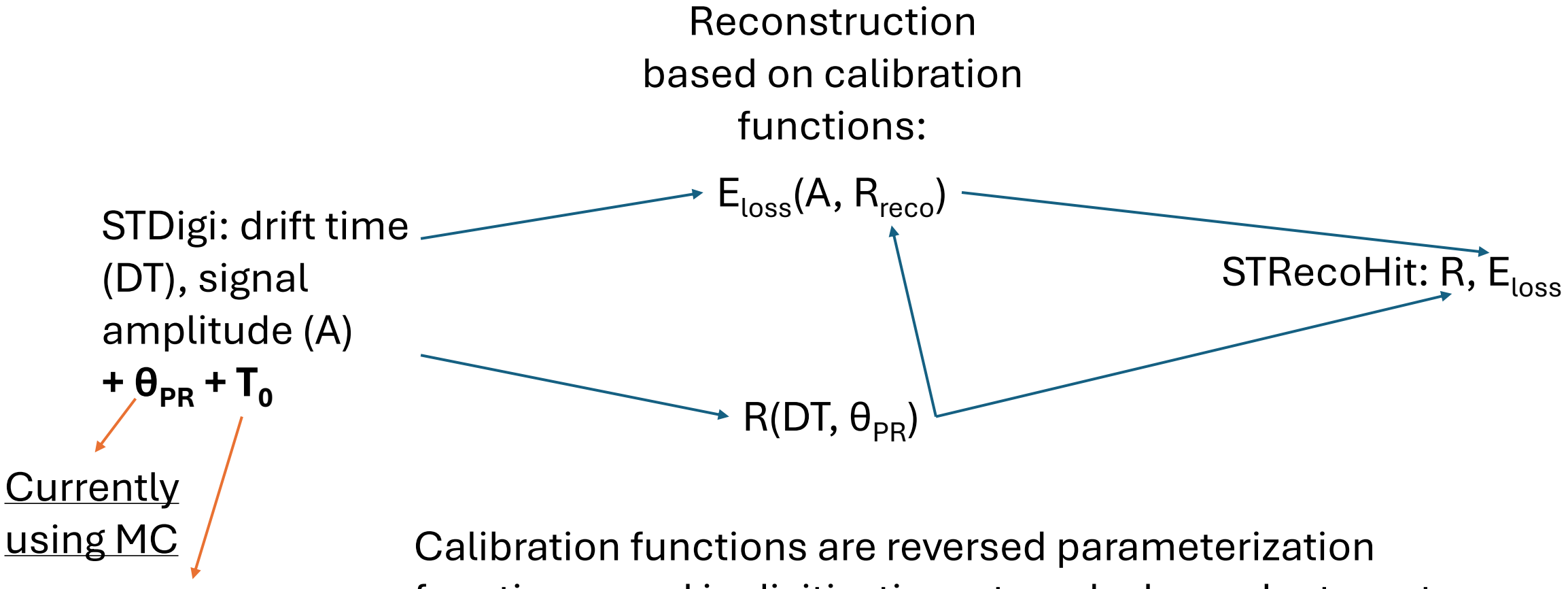
Another option for digitization: using primary ionization clusters (collection of clusters is just a placeholder for now).

Digitization procedure: signal amplitude



More details: report of our group at SPD CM XI

Hit reconstruction



Calibration functions are reversed parameterization functions used in digitization; strongly dependent on straw gas and readout electronics parameters

Models for STMCHit and STDigi

STMCHit:

- Straw id
- Particle id
- Entry and exit points
- Local radial coordinate
- Track polar angle (global)
- Ionization energy loss
- Flag for primary
- Collection of simulated primary ionization clusters (optional)

Recently added for correct treatment of delta-electrons

Cluster structure:

- Radial coordinate
- Number of electrons

STDigi (preliminary):

- Straw id
- Amplitude
- Timeslice number (uint32_t)
- Readout board id
- Flag for validity
- **Coarse time**
- **Fine time**

Drift time

Ongoing developments

Now we are working on STMCHitMakerAlg: MCStep collection → STMCHit collection

- Searching for entry and exit points for each straw
  - If two primary particles cross the same straw – two different hits (hit is unique for pair of particle id and straw id)
  - If primary particle creates a secondary inside a straw (e.g. delta electrons) – single hit
  - If track crosses a wire – merging into a single hit (work in progress)
- Summing ionization energy loss from all the steps including secondaries as the hit ionization energy loss
  - Alternative way is to calculate difference between energies of the particle before and after the straw (to be checked and compared)
- Local radial coordinate calculation (work in progress, includes development of STGeoManager)

Studies with Sampo step collection

In order to develop trustworthy algorithm it was necessary to make preliminary simulation studies and check whether the information that we can obtain from steps is consistent.

Using particle gun: muons, E = 10 GeV, 100k events with 1 particle in each, direction perpendicular to sector, starting point displaced on 2.5 mm in order to avoid interaction with wire.

Studied momentum/energy distributions of particles in simulation and displayed obtained entry and exit points using steps.

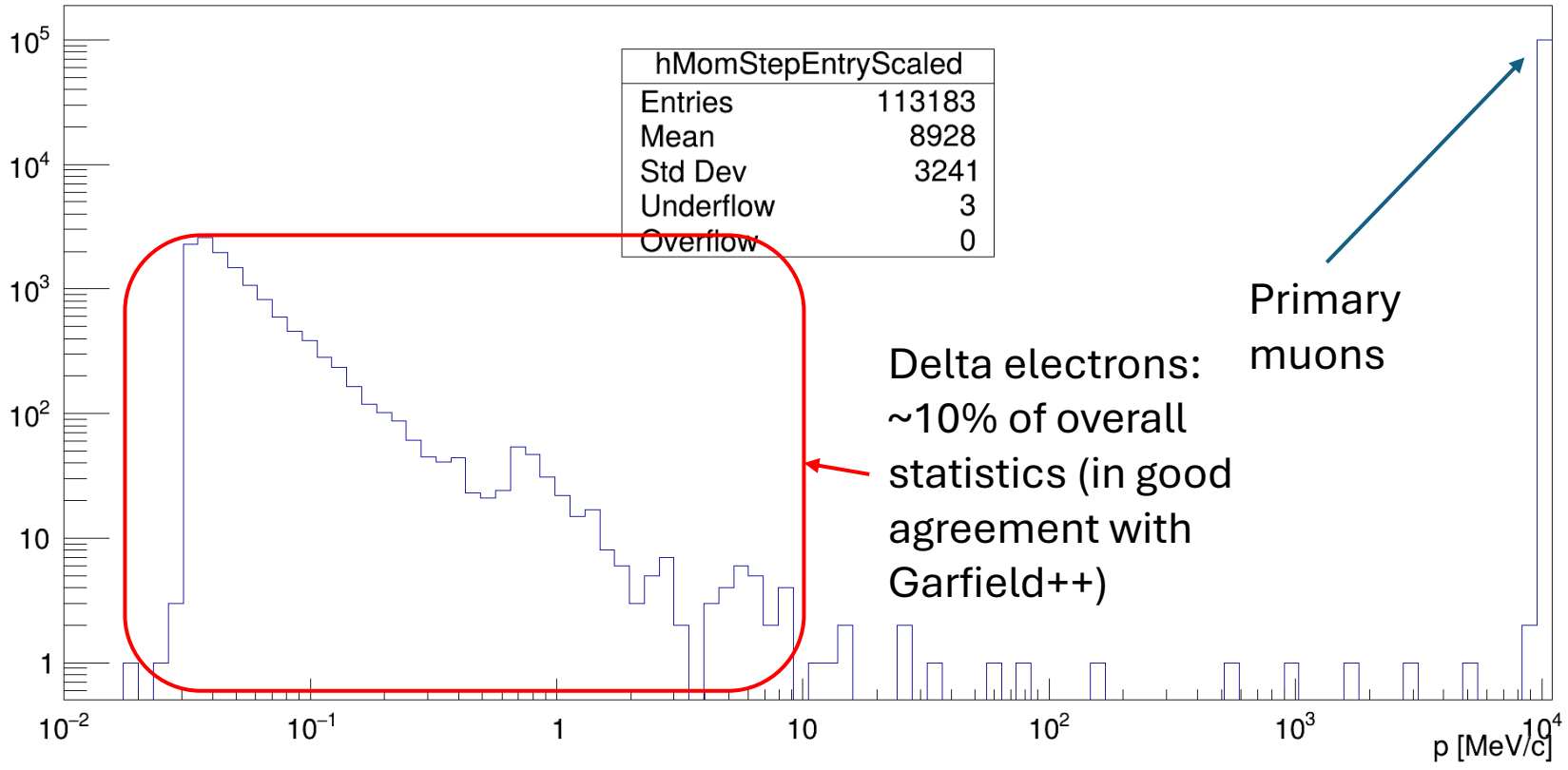
Delta electrons

First straw on muon track: first step in the straw (entry point):

- From muon
- From an electron created in the straw

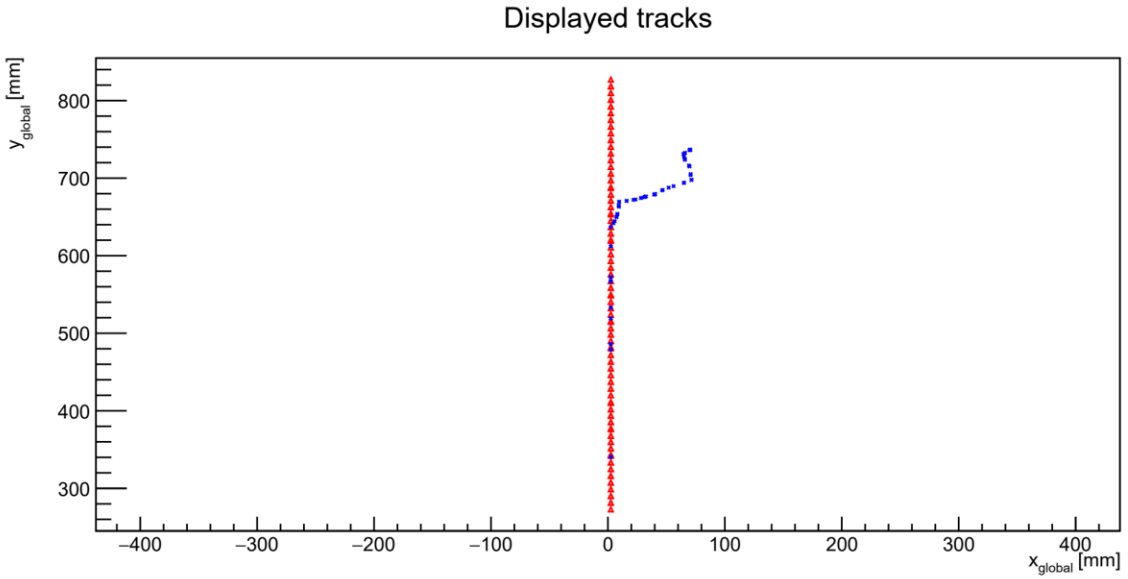
Highlighted peak: delta electrons (low energy cut about 30 keV/c (Geant4) – corresponds to electron energy of ~900 eV).

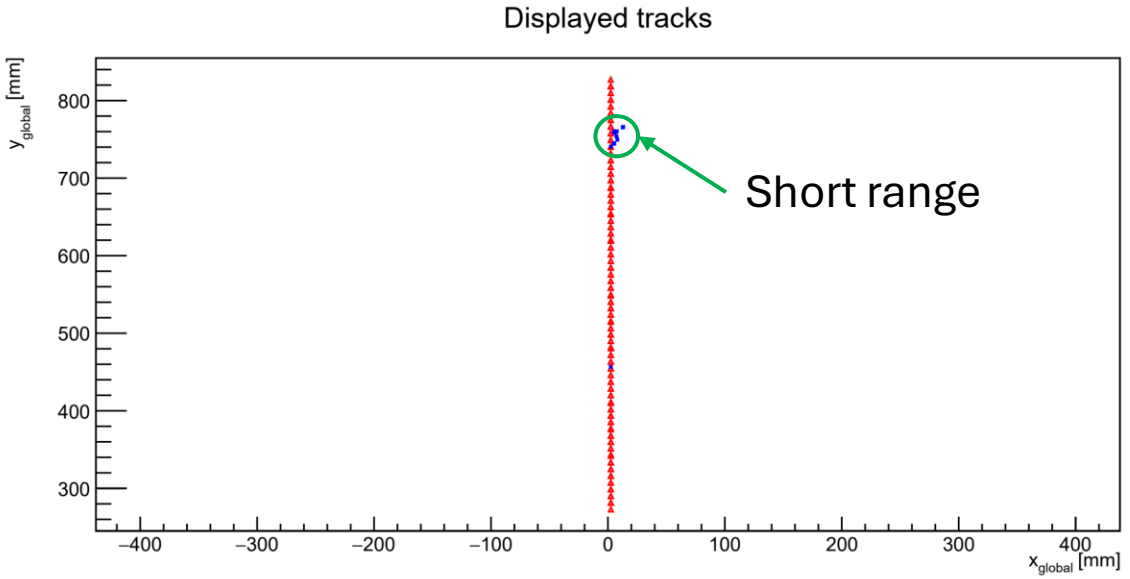
We want to implement parameterizations for drift time and time resolutions – delta electrons are already taken into account in them.



Momentum distribution obtained from first steps in certain straw in the first layer

Display of entry/exit points on XY-plane in Sampo: 1 event



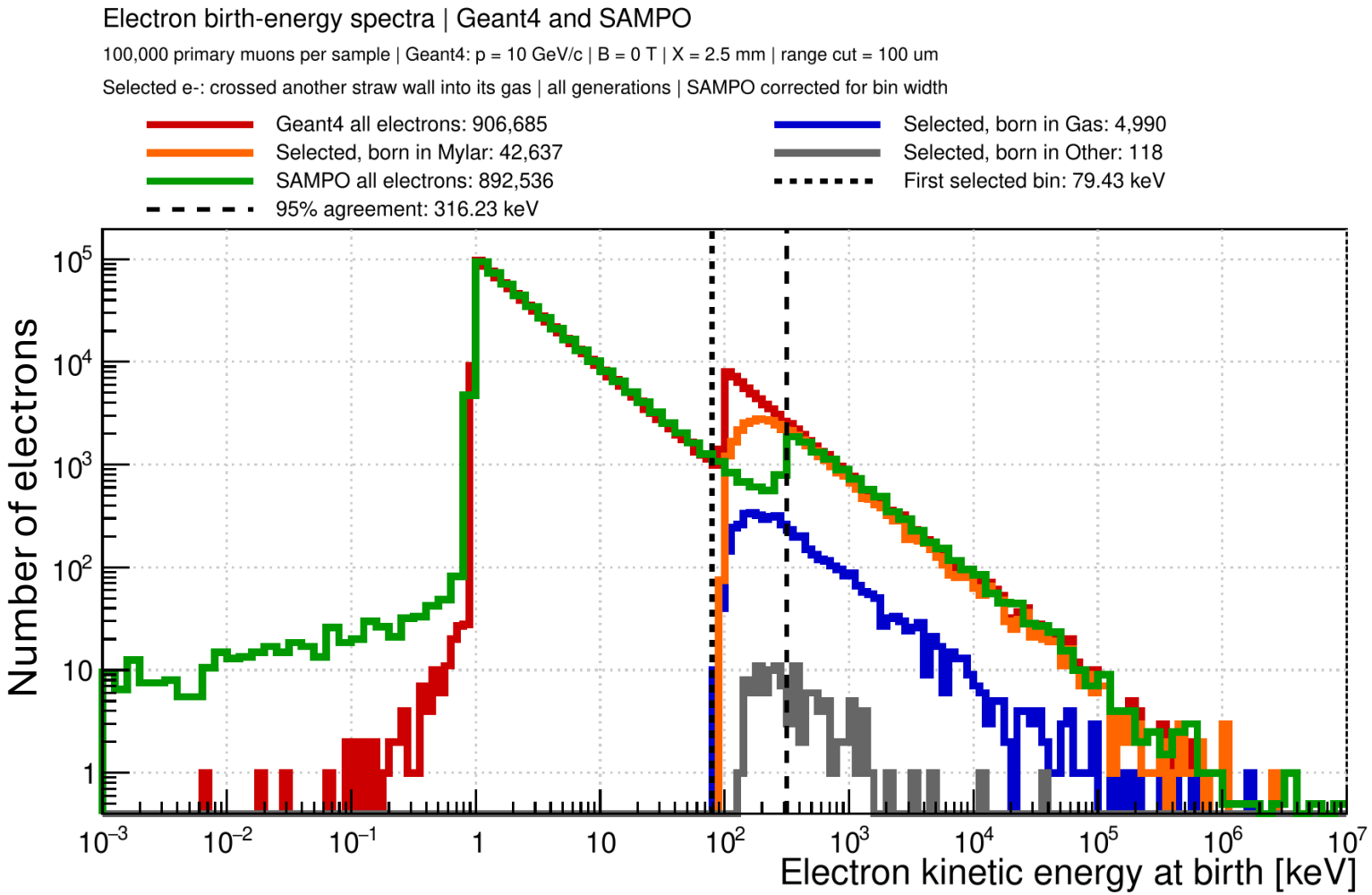


Red points: entry and exit points of **primary muons**. **Blue points**: entry and exit points of **secondaries**. Most of secondary electrons which affect neighbor straws has short ranges (affects only one neighbor straw). Range can be significant (several straws affected) in rare cases (high energy electrons). Sampo simulation, **no magnetic field.**

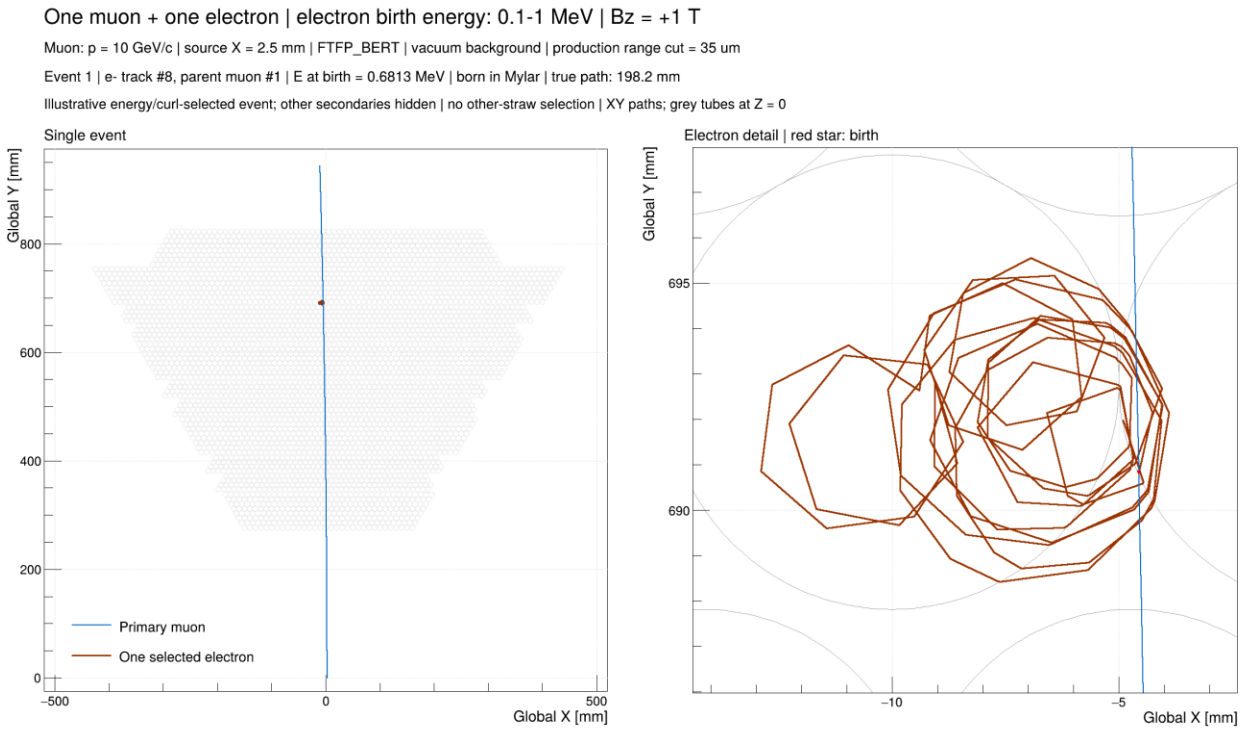
Secondary electrons energy distributions: Geant4 and Sampo results

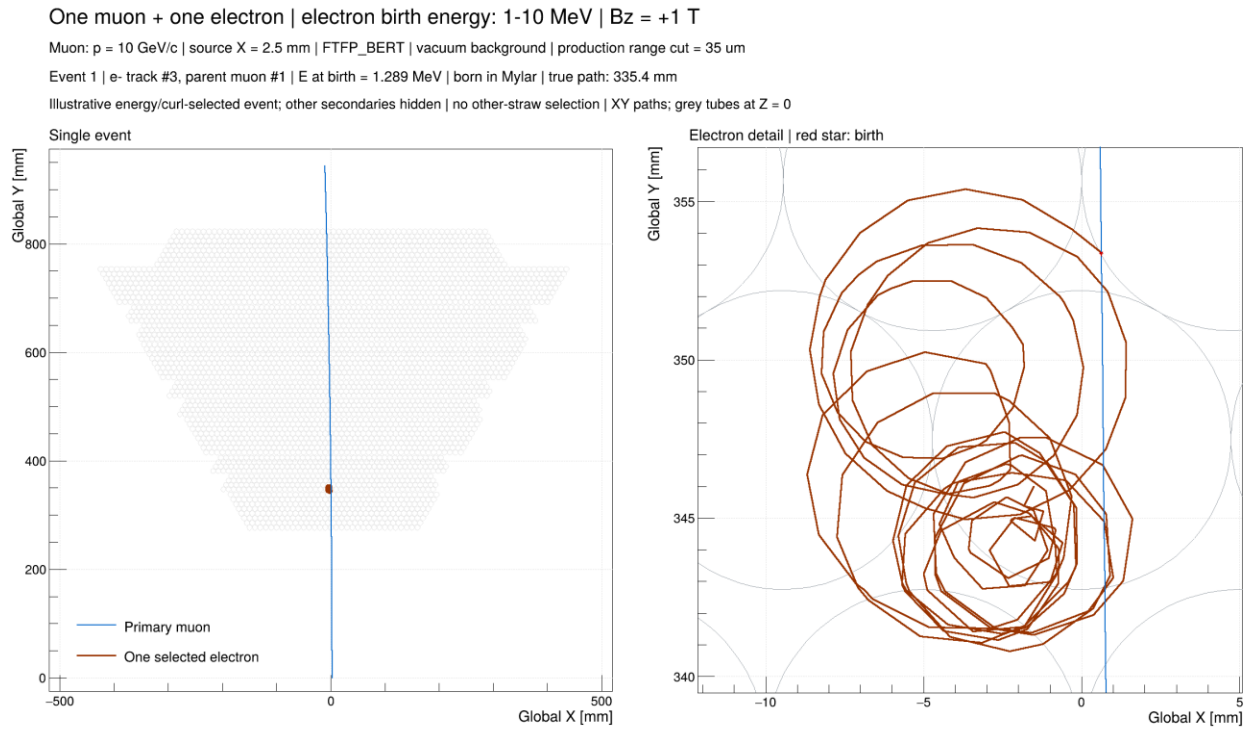
Geant4 simulation provided by Sergey Romakhov.

Selection applied in G4: electron born in one straw should get into the gas of another straw. If delta electron has energy more than ~80 keV, it will get into neighbor straw.



Observation of electrons in neighbor straws in Geant4





One muon event display with a delta electron born. Geant4 simulation by Sergey Romakhov. Magnetic field 1 T has been included.
Left: selected event with one delta electron of energy 0.1-1 MeV; right – delta electron energy of 1-10 MeV.

Conclusions

- **Algorithm for ST MC hits production:**
  - Delta electrons originating in the current straws: for drift time are accounted for in the parameterization; for signal amplitude are accounted in ionization energy loss summed over all steps.
  - Delta electrons originating from a neighbor straw are converted into hit.
  - Total number of delta electrons created in gas is in good agreement with Garfield++ prediction.
  - Delta electrons affecting neighbor straws are mostly created in mylar.
- Next step: finalize and test MC hits production; after that implement digitization procedure

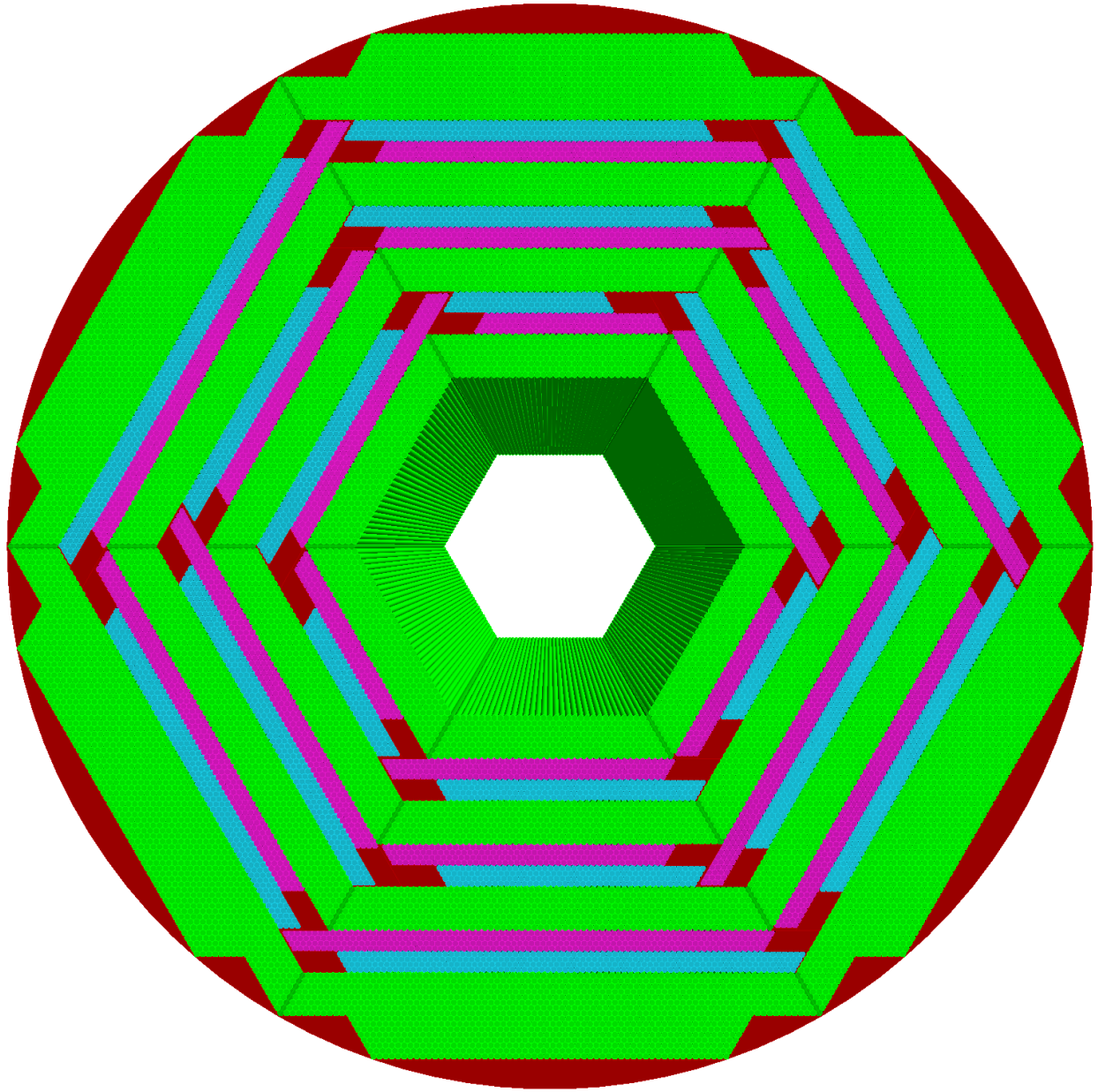
Thank you for your attention!

Straw Tracker Barrel in SPDGeoModel

Sampo makes use of SPDGeoModel to build detector geometry.

ST Barrel geometry implemented in Sampo by Evgeniy Chernyaev – on the right. Stereo angle – 2 degrees.

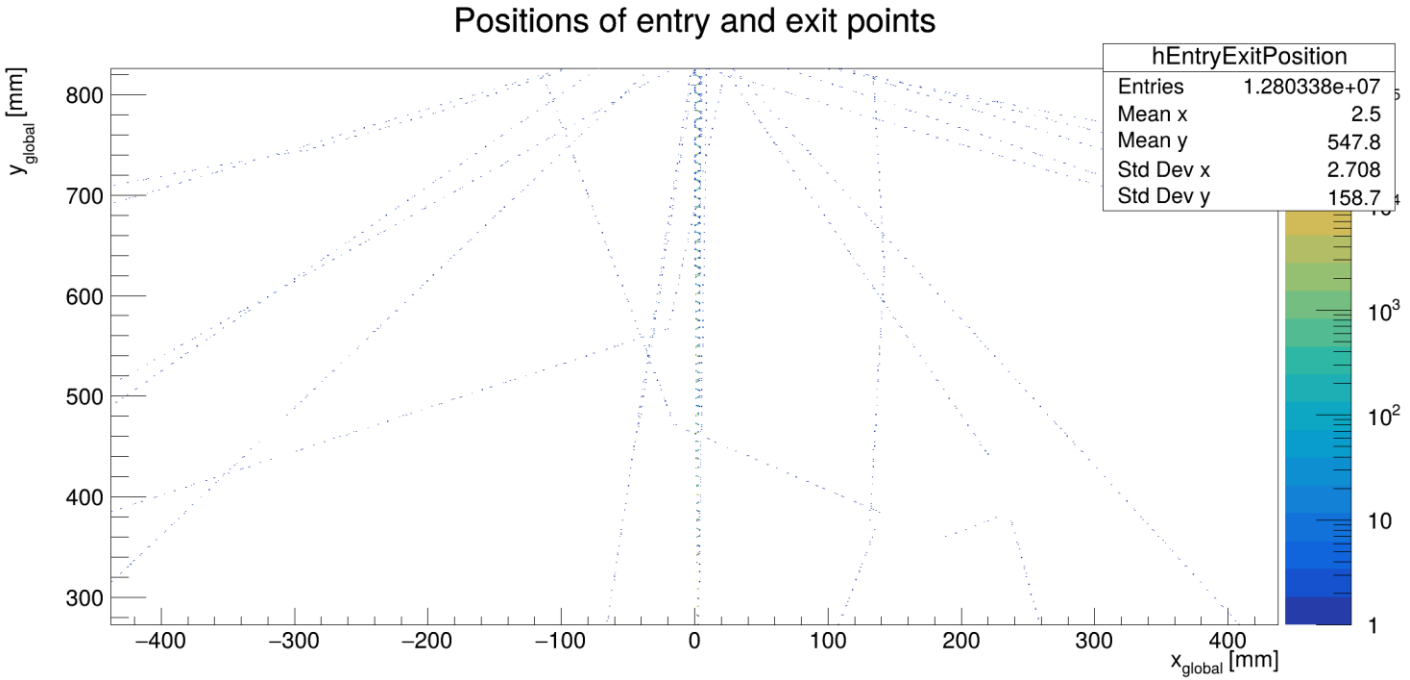
Updated version by Sergey Romakhov with stereo angle ~1.8 degrees (next talk).



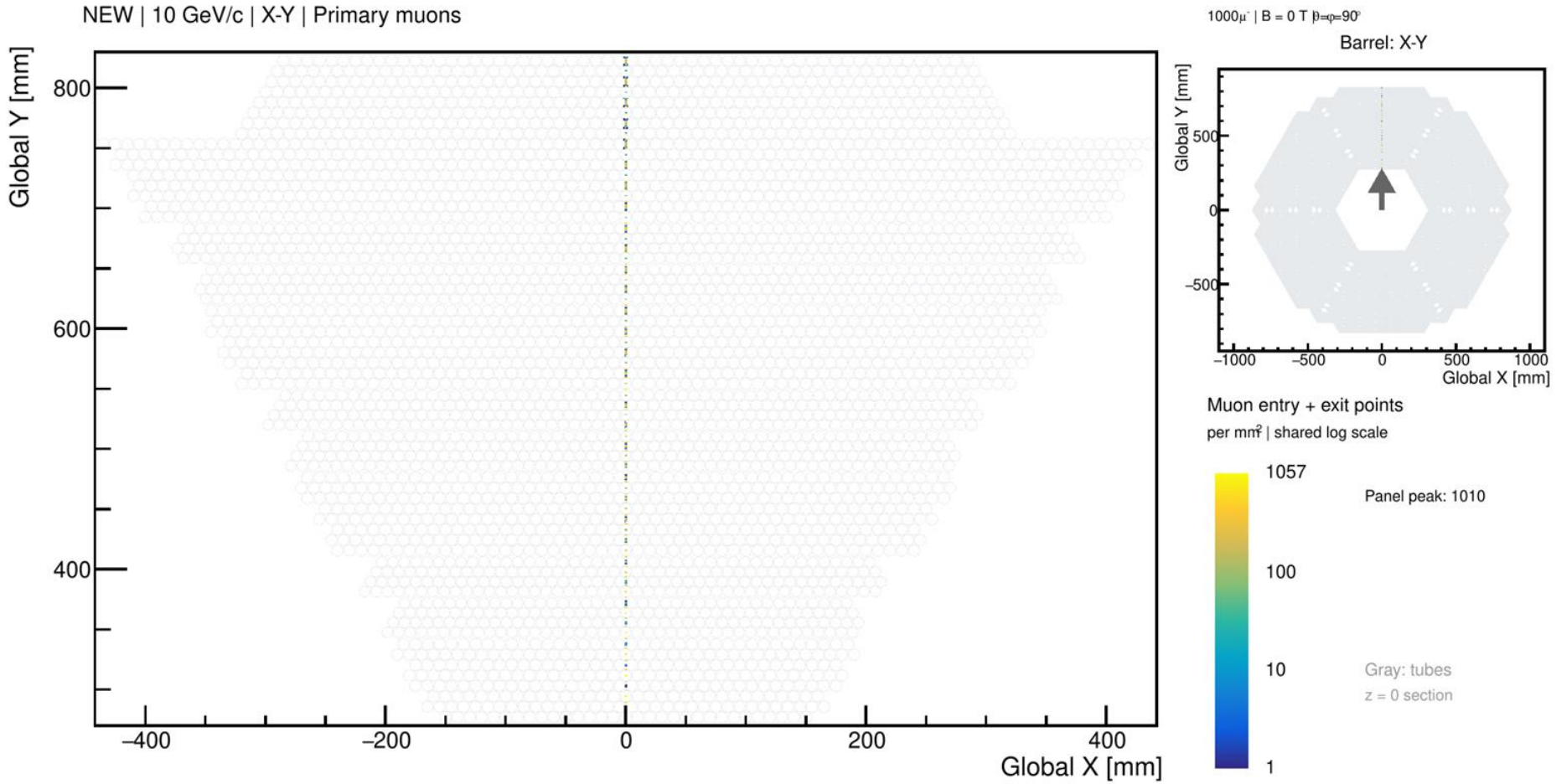
Primary tracks entry and exit points: Sampo

XY coordinates of first and last steps in volumes. Secondaries production turned off with G4 command “/run/setCut 10 km”.

Set offset of particle start position 2.5 mm by X axis in order to avoid interaction with wire. E = 10 GeV, 100k events

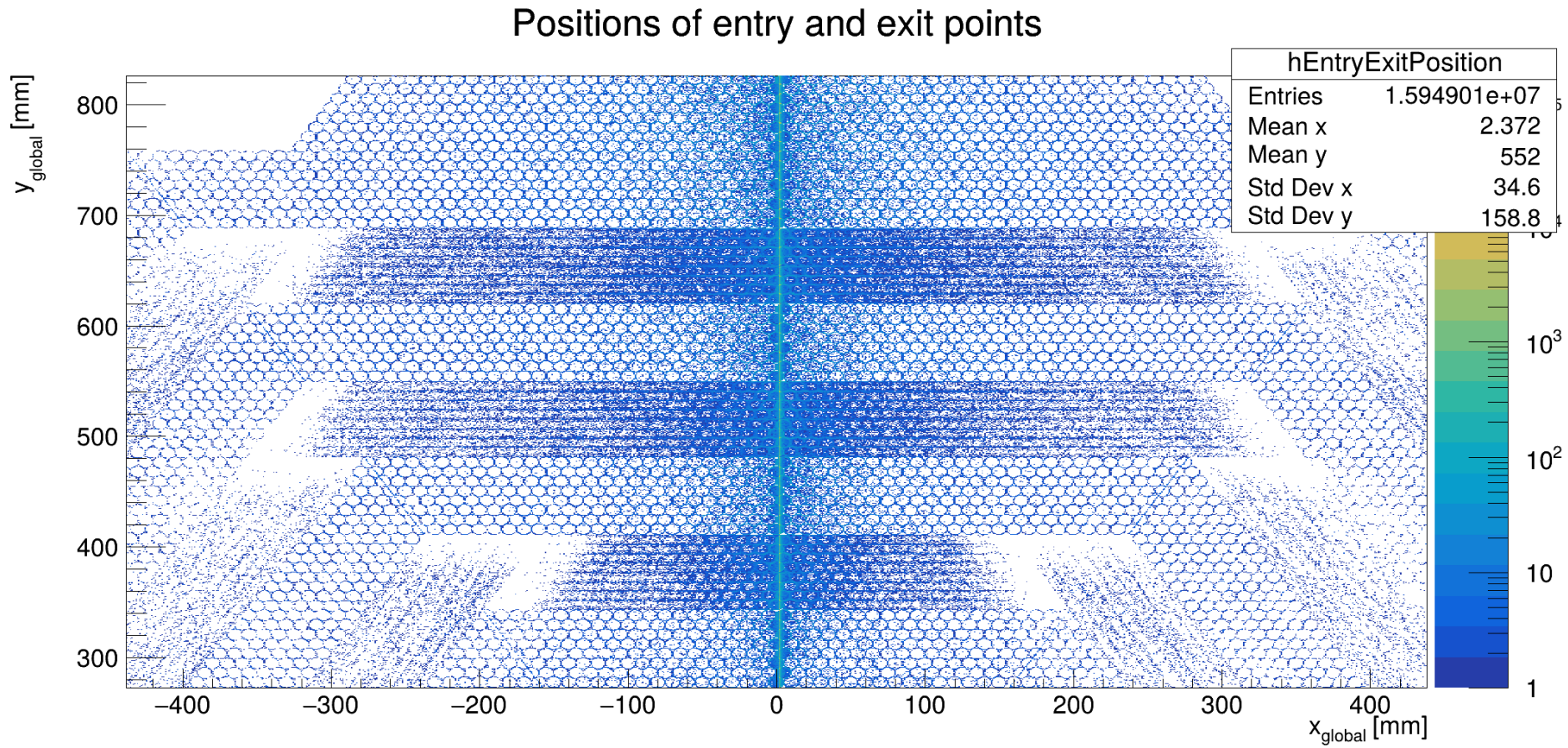


Primary tracks entry and exit points: standalone GEANT4, p = 10 GeV/c



Made by Sergey Romakhov

Display of entry/exit points on XY-plane in Sampo: 100k events

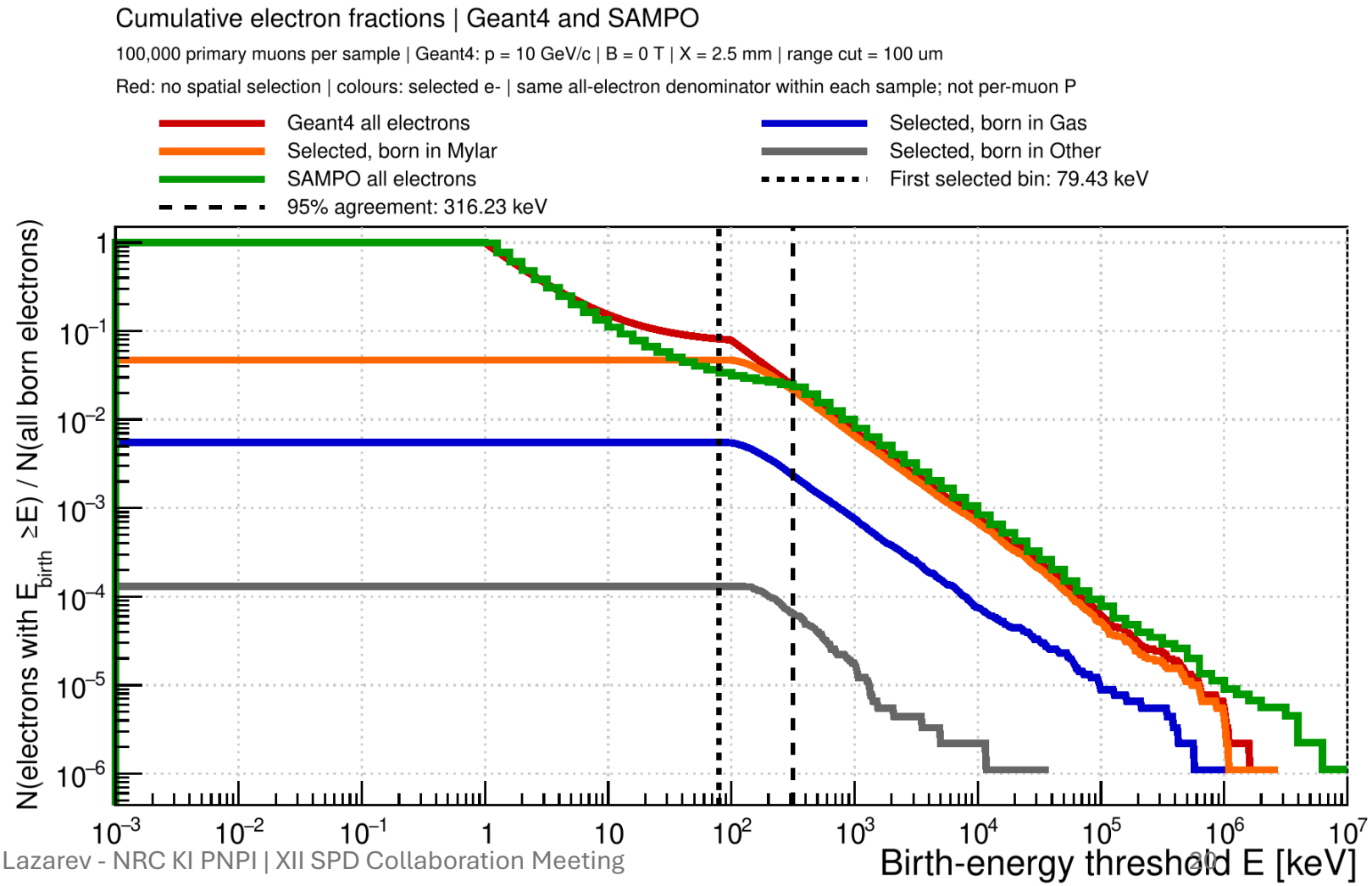


We observe delta electrons in neighbor straws (and rare electrons has significant energies).

No magnetic field.

Secondary electrons energy distributions: Geant4 and Sampo results

Reversed cumulative energy distribution showing the probability for delta electron of having energy at birth **more than E**.



STGeoManager

It stores information about geometry. We propose to store map of STBarrelStrawInfo objects. Map key – detector (straw) id.

We were recommended to return certain values (not these objects) by strawId from STGeoManager.

Also we propose to store diameter of axial and stereo tubes as static const.

```
class STBarrelStrawInfo {
public:
    STBarrelStrawInfo(
        uint32_t strawId,
        uint8_t sector,
        uint8_t layer,
        uint8_t cell,
        int8_t type,
        bool valid,
        const Eigen::Vector3d& tubeAxisEndpointNeg,
        const Eigen::Vector3d& tubeAxisEndpointPos
    );

    uint32_t getStrawId() const;

    uint8_t getSector() const;
    uint8_t getLayer() const;
    uint8_t getCell() const;

    int8_t getType() const;
    bool getValid() const;

    const Eigen::Vector3d& getTubeAxisEndpointNeg() const;
    const Eigen::Vector3d& getTubeAxisEndpointPos() const;

private:
    uint32_t m_strawId{0};                                  // detector id of straw

    uint8_t m_sector{0};                                    // number of sector
    uint8_t m_layer{0};                                     // number of layer
    uint8_t m_cell{0};                                      // number of straw in the layer

    int8_t m_type{0};                                       // -1 is U, 0 is Z, +1 is V
    bool m_valid{true};                                     // setting false causes straw to "turn off"

    Eigen::Vector3d m_tubeAxisEndpointNeg{0.0, 0.0, 0.0};   // coordinates of straw end center, negative Z
    Eigen::Vector3d m_tubeAxisEndpointPos{0.0, 0.0, 0.0};   // coordinates of straw end center, positive Z
};
```

STGeoManagerInitTool

We propose two options for this:

- Default – from GeoGraph
- Optional – from external straw lookup table, which can be saved by STGeoManager – option for standalone digitization and reconstruction (debugging purposes).