Acts Material Interaction

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Material Mapping

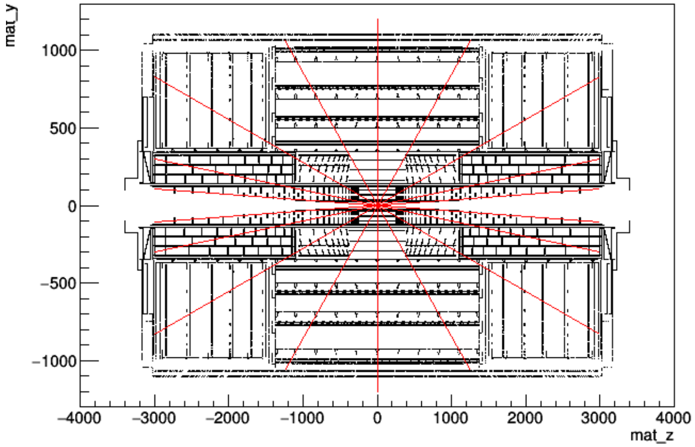
- Particle detector simulated using a **Geant 4**
  🡆 Extremely **precise** but **slow** to use

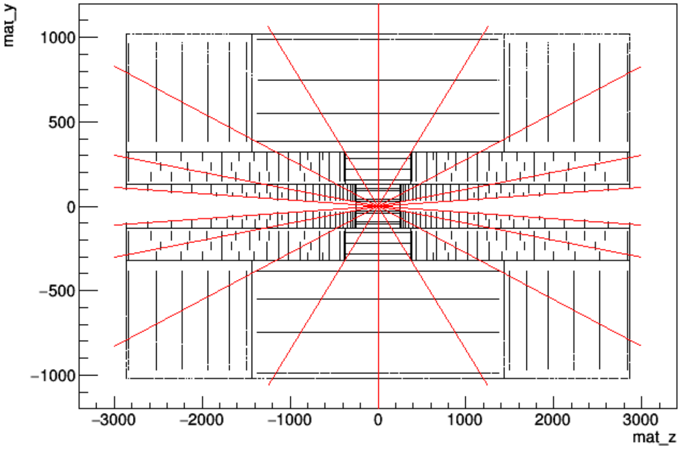
- Track reconstruction: use a simplified geometry 🡆 **Tracking Geometry**

- Only contain geometric information
  🡆 Used to **navigate** through the detector

- Need to account for the effect of **particle/ material interaction** 🡆 where is the material?

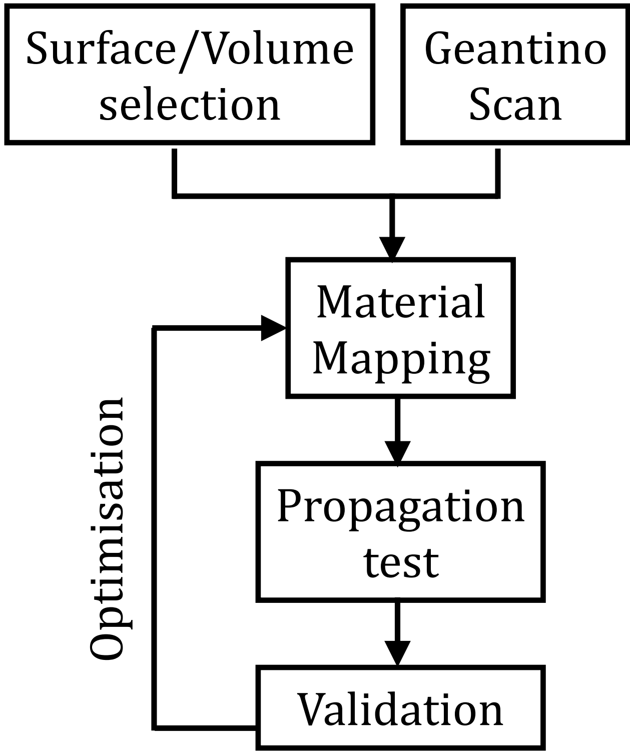
- A simplified model of the material in the detector needs to be built 🡆 **Material map**





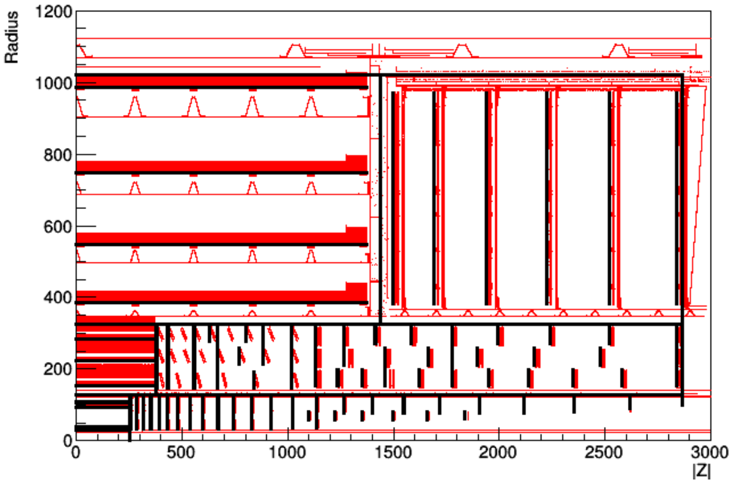
Material Mapping

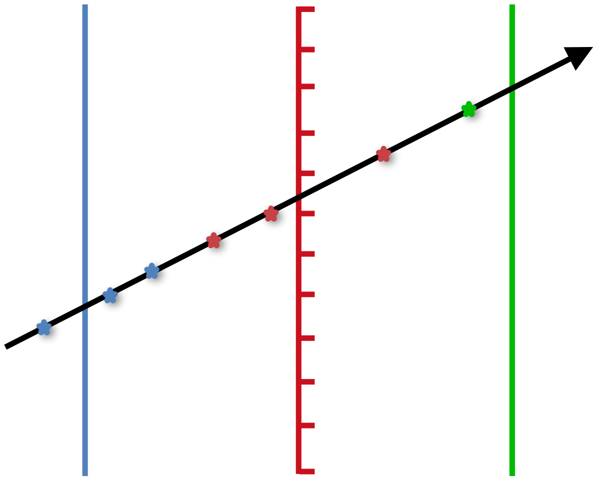
- Two types of mapping :
  - **Surface mapping:** describes tracking volumes and gap material. The material is averaged onto surfaces
  - **Volume mapping:** describes dense material volume (for example, calorimeters). The material interaction is taken into account at each propagation step.
  - Navigation and interaction with volume material not fully implemented yet



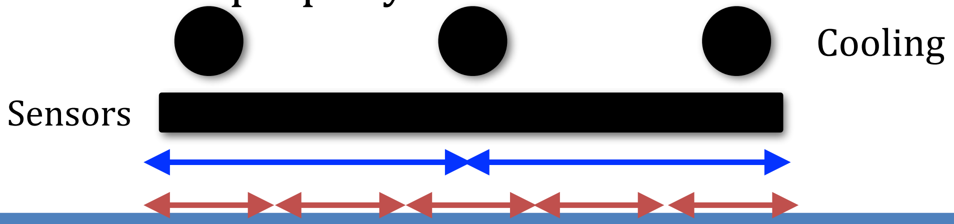
Surface Material Mapping

- To create the map, we select a set of surfaces in our tracking geometry
- We then collect all the materials in our detector with a **G4 simulation** (using geantino)
- We can then associate each material with the closest surface



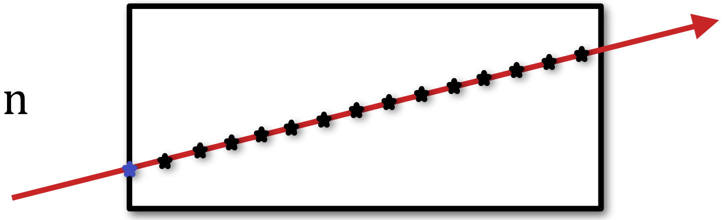


- Each of our mapping surfaces is bin along 2 directions (R, Phi), (Z, phi), …
- The material is thus accumulated in each bin and then averaged for our geantinos to form our map
- The correct binning needs to be found to represent the material properly



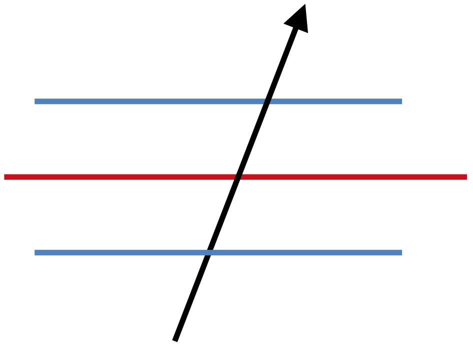
Volume Material Mapping

- Implemented, but the volume material interaction is not fully implemented yet
- A 3D Grid is associated with the volume
- Geant4: 1 geantino interaction created per detector material ➡ Extrapolated points with a **specific** step along the trajectory
- Volume mapping: use all points within the volume
- Each Grid points: average nearby material interaction

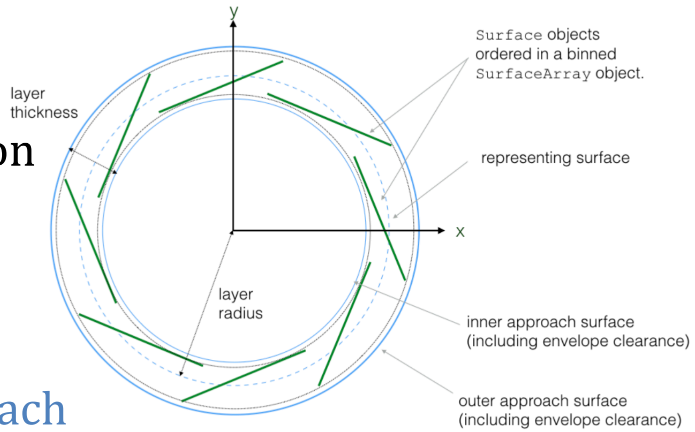


Where should material be mapped ?

- In the current implementation, 3 surfaces per layer:
  - 2 Approach surface
  - 1 Representing surface



- Representing: centre of the layer ➡ can lead to issues if the sensors are not parallel to the approaches (for **passive material,** Representing surfaces are fine)
- First Approach: Create a big asymmetry in the encountered material in forward/backward propagation
- Both Approaches: slower but neatly separate material before and after the active sensor


y
x
layer thickness
Surface objects ordered in a binned SurfaceArray object.
representing surface
layer radius
inner approach surface (including envelope clearance)
outer approach surface (including envelope clearance)

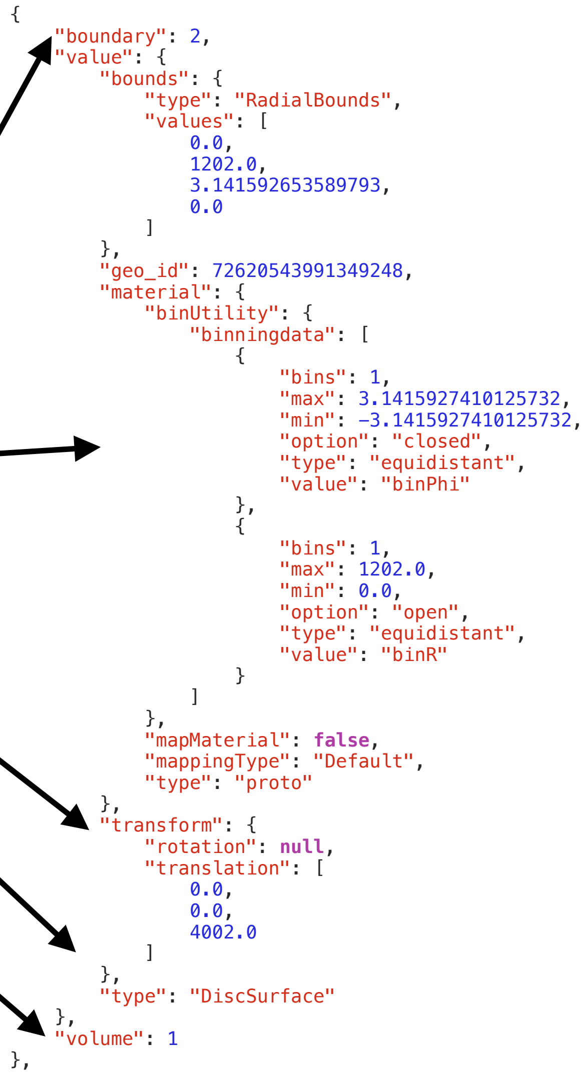
x-y view of a `CylinderLayer` (with planar detection elements)

- **Simplest** solution: Representing surface or first Approach
- The **cleanest** solution: to map on both Approaches

How to perform the material mapping

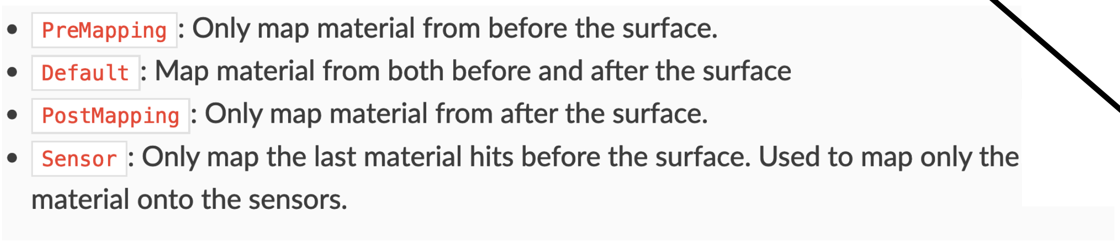
- Tutorial available on readthedocs: https://acts.readthedocs.io/en/latest/howto/run_material_mapping.html

- Mapping process is controlled through JSON files
- One entry per surface with all of its information:
    - Place in the hierarchy
    - Material
    - Transformation
    - Type of surface
    - Volume



```
{
    "boundary": 2,
    "value": {
        "bounds": {
            "type": "RadialBounds",
            "values": [
                0.0,
                1202.0,
                3.141592653589793,
                0.0
            ]
        },
        "geo_id": 72620543991349248,
        "material": {
            "binUtility": {
                "binningdata": [
                    {
                        "bins": 1,
                        "max": 3.1415927410125732,
                        "min": -3.1415927410125732,
                        "option": "closed",
                        "type": "equidistant",
                        "value": "binPhi"
                    },
                    {
                        "bins": 1,
                        "max": 1202.0,
                        "min": 0.0,
                        "option": "open",
                        "type": "equidistant",
                        "value": "binR"
                    }
                ]
            },
            "mapMaterial": false,
            "mappingType": "Default",
            "type": "proto"
        },
        "transform": {
            "rotation": null,
            "translation": [
                0.0,
                0.0,
                4002.0
            ]
        },
        "type": "DiscSurface"
    },
    "volume": 1
},
```

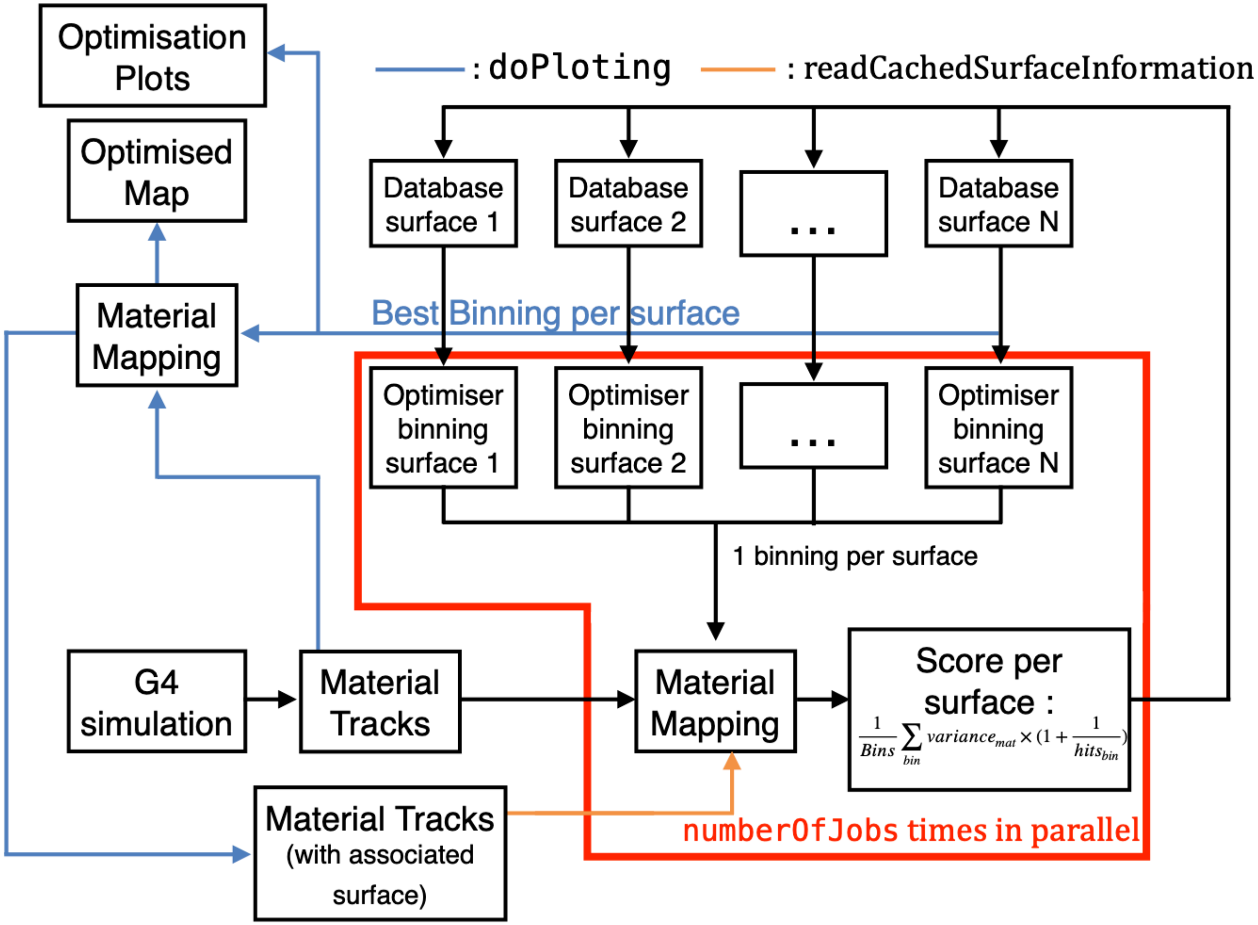
- Changing mapMaterial to true to map on the surface
- The type of mapping can also be changed :



- `PreMapping` : Only map material from before the surface.
- `Default` : Map material from both before and after the surface
- `PostMapping` : Only map material from after the surface.
- `Sensor` : Only map the last material hits before the surface. Used to map only the material onto the sensors.

Auto-tuning of the material mapping

- Automatic optimisation of the mapping is available with Orion
- N mapping running in parallel
- After the N finishes, update the optimiser: score for each binning (variance in each bin)
- After enough iteration, get the best binning per surface ➡ run one last mapping



Optimisation Plots

Optimised Map

:doPloting

: readCachedSurfaceInformation

Database surface 1

Database surface 2

...

Database surface N

Best Binning per surface

Material Mapping

Optimiser binning surface 1

Optimiser binning surface 2

...

Optimiser binning surface N

1 binning per surface

G4 simulation

Material Tracks

Material Mapping

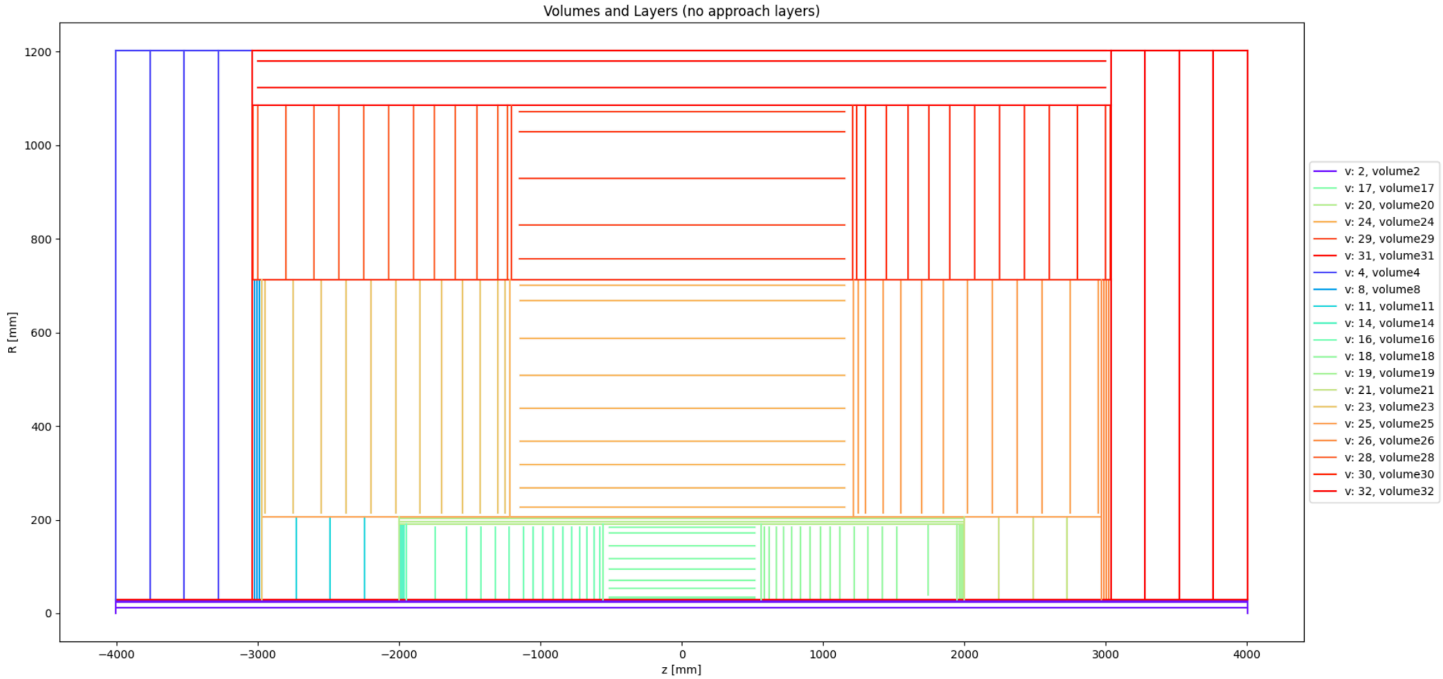
Score per surface : $\frac{1}{Bins}\sum_{bin} variance_{mat} \times (1+\frac{1}{hits_{bin}})$

Material Tracks (with associated surface)

numberOfJobs times in parallel

Material Validation

- **`GeometryVisualisationAndMaterialHandling.py`**:
  Show the position and corresponding volume of all the surfaces ➡ useful to decide where to map



Material Validation

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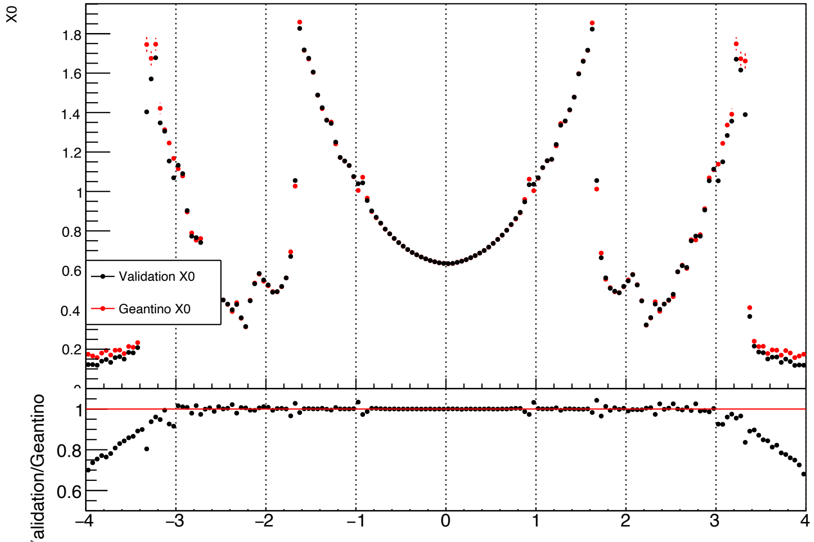
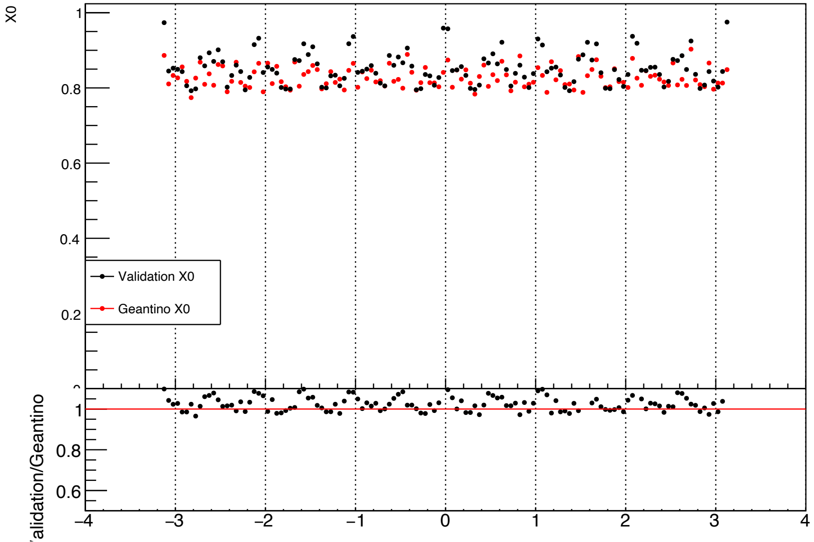
- A few root scripts are available to help visualise the quality of the map :





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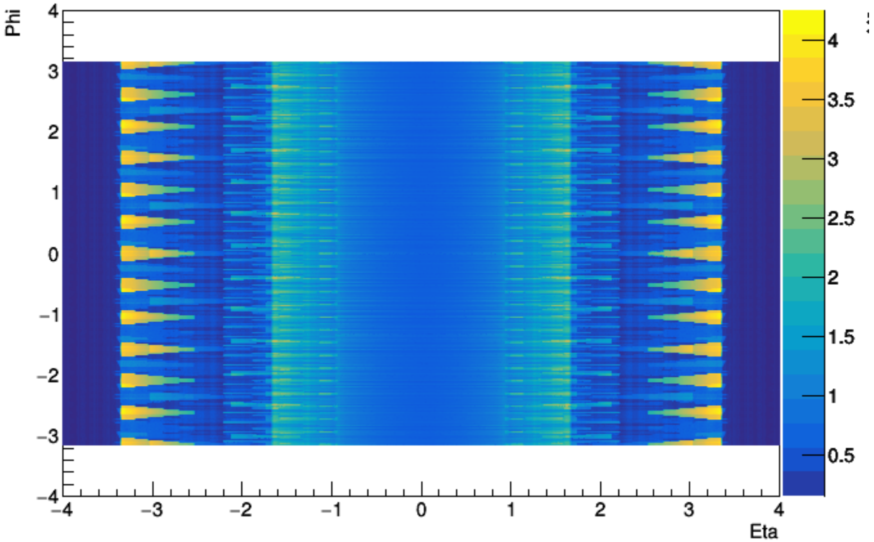
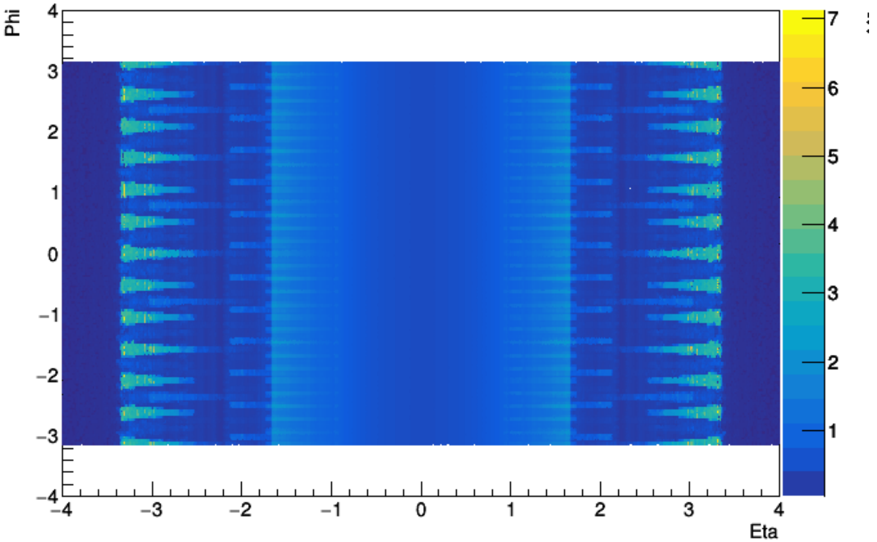


Geant4



Map

Summary

- Material mapping implemented in Acts
- Needed for proper trajectory reconstruction
- Mapping is implemented for both surfaces and volumes, but interaction in volume material is not fully implemented (if you are interested in working on this, don't hesitate to get in contact with me)
- A tutorial is available on readthedocs for the mapping, but if you encounter any issues, don't hesitate to contact me
- An automatic optimisation of the material map is also available using Orion

Questions ?