Simulations for the ViDeO project

Bastian Löher

Group Meeting October 2015

About me

- 2008: Bachelor-Thesis about particle discrimination (n,γ) using pattern classification
- 2010: Master-Thesis about super-fast readout of LaBr scintillators (NEPTUN tagger, IKP)
- 2014: Dissertation on setting up γ^3 experiment at Duke University, measuring decay of Pygmy Dipole Resonance on ^{140}Ce
- Always: Involved in data acquisition and slow control systems at IKP and GSI (LAND/R^{3}B)

ViDeO Project

- Validation project for direction-sensitive radiation detectors taken over from Robert
- I started in June
- Main goal for 2015:
  - Construction and test of car-based prototype detector
- Side goals:
  - Software Improvement (Mapping)
  - Analysis Improvement (Multiple Sources)

ViDeO Project – ToDo

- What do we want to do?
  - Simulate detector behaviour in realistic conditions
  - Build test stand for automatic characterisation
  - Scintillator wrapping & test with PMTs
  - SiPM test with CeBr sample
  - Detector test with SiPM arrays (4x4)

ViDeO Project – ToDo

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ViDeO Project – Simulations

- So far: Only analytical calculations
  - Quick results
  - Simplified geometry, but difficult to change
  - No spectroscopy, only counting
- Now: Monte-Carlo Simulations using GEANT4
  - Realistic detector geometry
  - Realistic radioactive sources + background
  - Takes longer to simulate
  - Energy spectra

ViDeO Project – Simulations

- Toolchain
  - Simulate events: `scintillator_01`
  - Convert output to root file: `bin2root`
  - Digitise events: `digi`
  - Reorder events: `timesort`
  - Analyse events: `analyse`

ViDeO Project – Simulations

- Toolchain / User configurable
  - Simulate events: `scintillator_01`
  - Convert output to root file: `bin2root`
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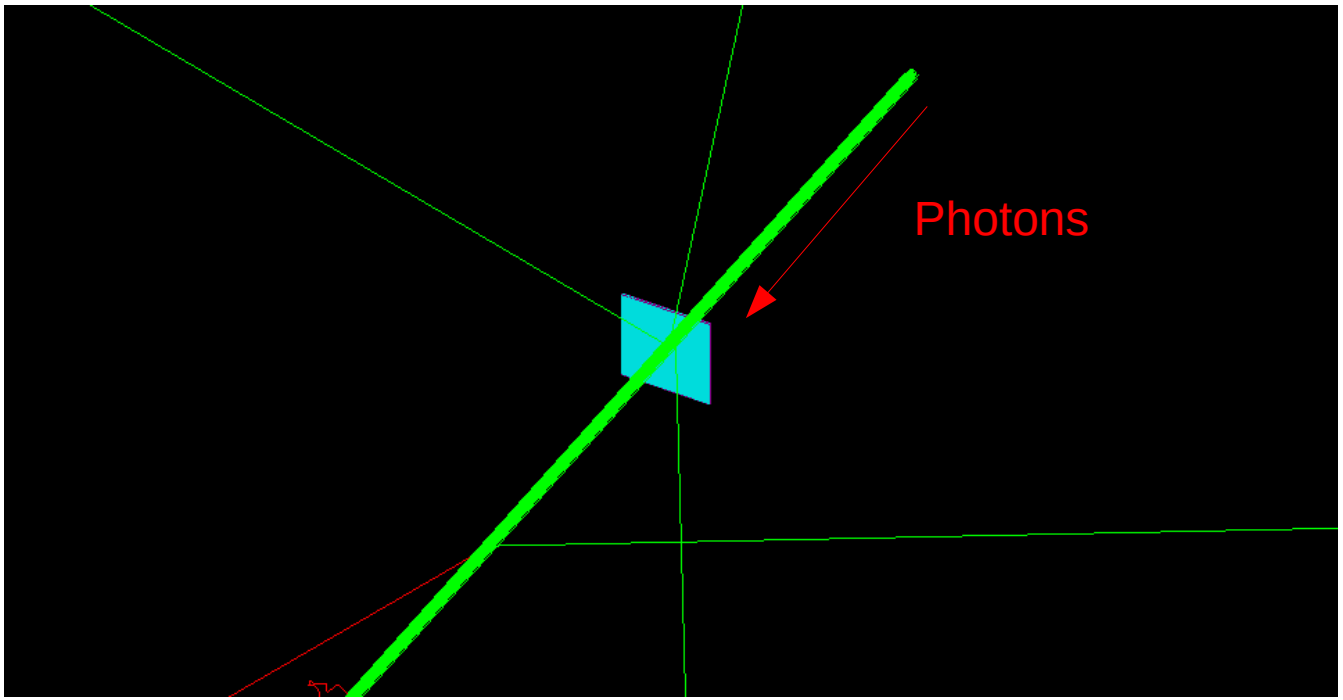
  - Analyse events: `analyse`

ViDeO Project – Simulations

- `Scintillator_01`
  - A parameterised GEANT4 application
  - Fully parameterised particle source (photons)
    - Position, angle, energy, beam size, number of particles
  - Selectable detector geometry
  - Selectable physics list
  - Output format: JSON-like / line / binary
  - Tracking: full step information / event based

ViDeO Project – Simulations

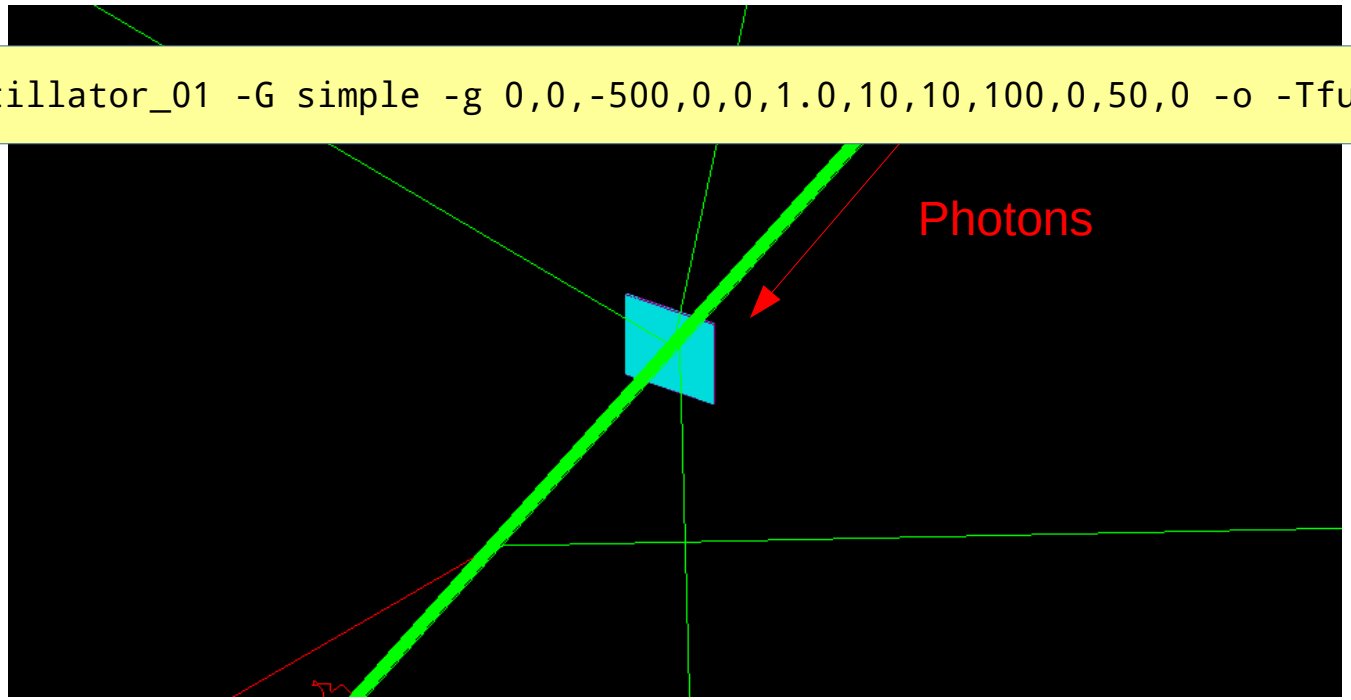
- `Scintillator_01`example
  - 1 MeV photons hitting a thin scintillator plate with a beam cross-section of 10x10 mm²



ViDeO Project – Simulations

- `Scintillator_01`example
  - 1 MeV photons hitting a thin scintillator plate with a beam cross-section of 10x10 mm²

```
./scintillator_01 -G simple -g 0,0,-500,0,0,1.0,10,10,100,0,50,0 -o -Tfull -fblock
```



ViDeO Project – Simulations

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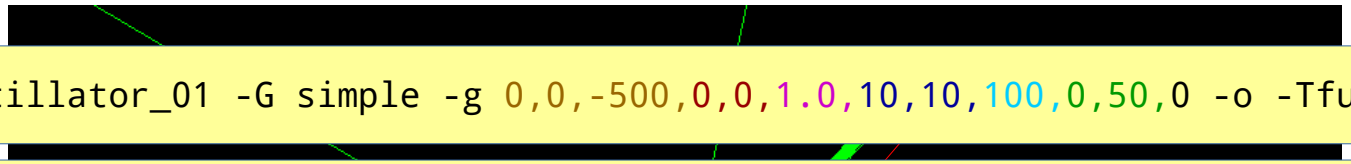

```
./scintillator_01 -G simple -g 0,0,-500,0,0,1.0,10,10,100,0,50,0 -o -Tfull -fblock
```

Generator description:
- 0,0,-500 : x,y,z position (here -500 mm in z)
- 0,0 : source angle (phi, theta in degrees)
- 1.0 : beam energy in MeV
- 10,10 : beam size in x and y
- 100 : number of particles (photons) to simulate
- 0,50 : time, start at time 0, run for 50 seconds
- 0 : detector orientation in degrees

ViDeO Project – Simulations

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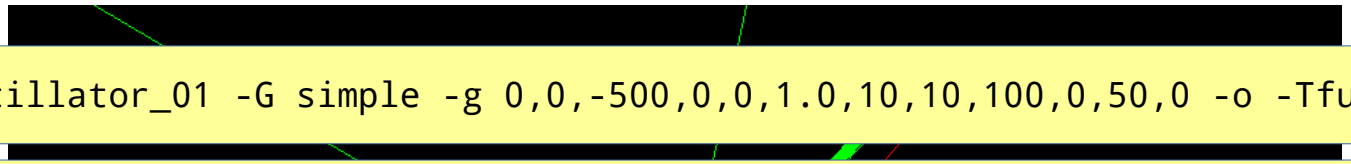


```
./scintillator_01 -G simple -g 0,0,-500,0,0,1.0,10,10,100,0,50,0 -o -Tfull -fblock
```

```
event(0) {
        Step {
                from = "world";
                from_no = -1;
                to = "s1";
                to_no = 1;
                track = 1;
                particle = "gamma";
                particleID = 22;
                process_pre = "";
                process_post = "Transportation";
                position_mm = (-1.548835, -4.198573, -1.000000);
                angle = (0.000000, 0.000000);
                e_kin_mev = 1.000000;
                e_dep_mev = 0.000000;
                time = 1.675217;
        }
        ...
}
```

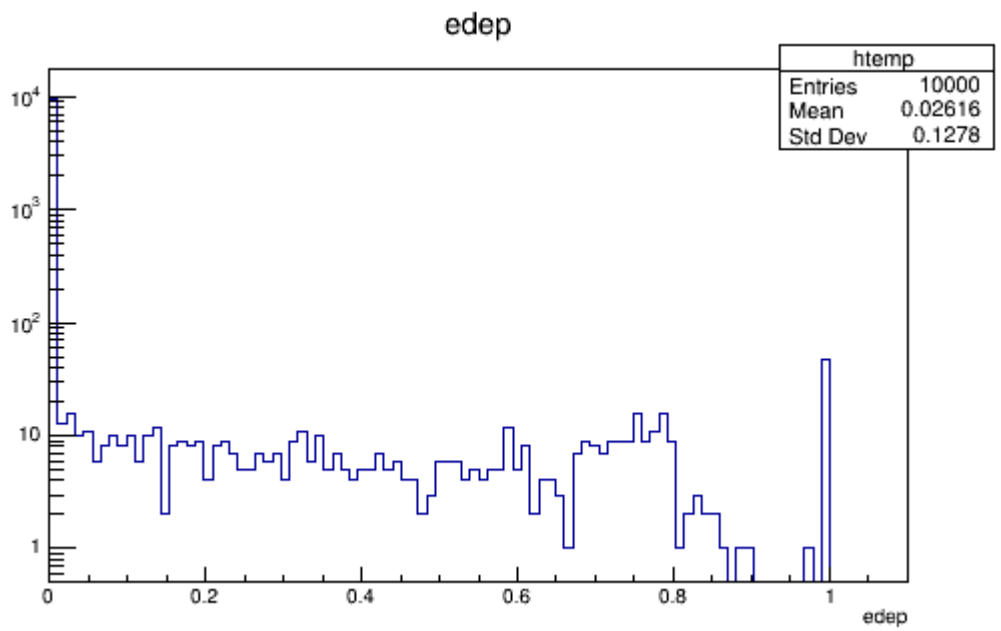
Full tracking
'Block' format
Standard physics list

Block format for debugging
Line format for quick 'awk' analysis
Binary format for storage and 'serious' analysis

ViDeO Project – Simulations

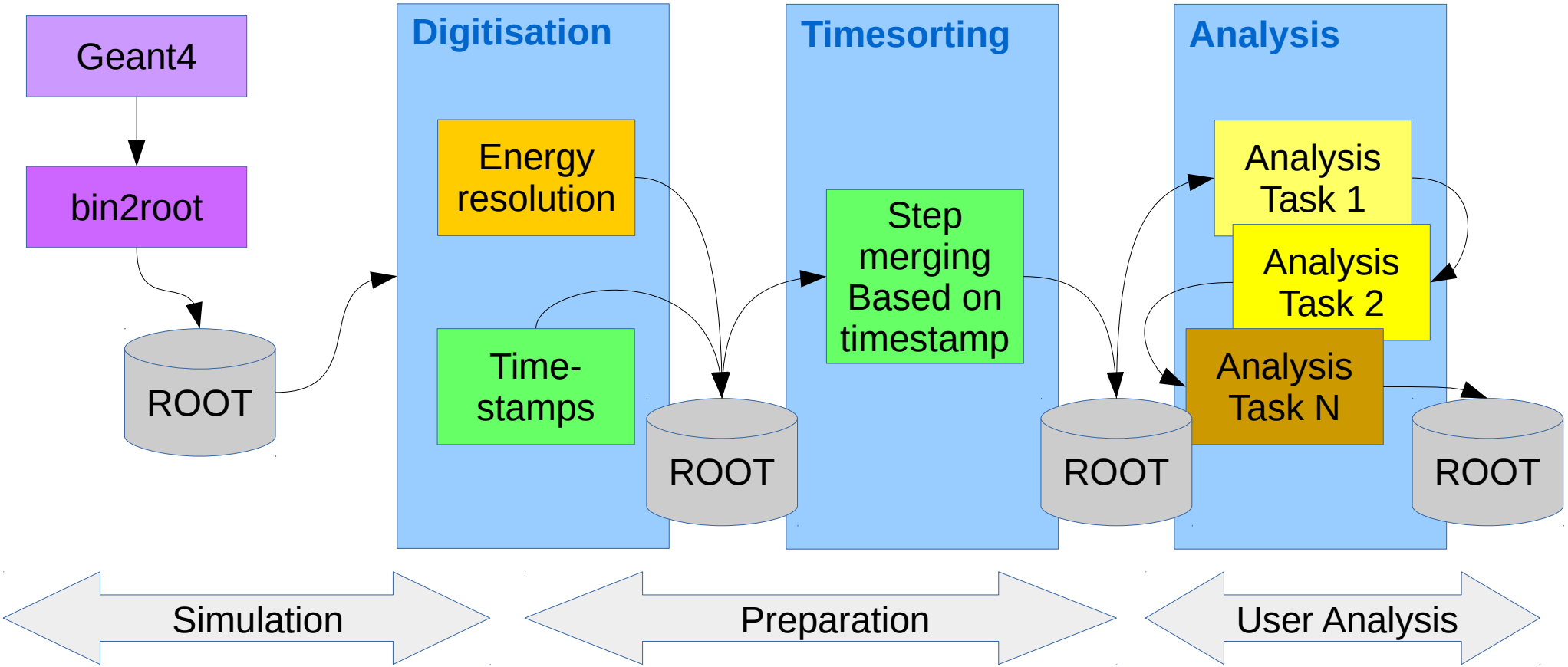
- `Scintillator_01`example + bin2root
  - 1 MeV photons hitting a thin scintillator plate with a beam cross-section of 10x10 mm²

```
./scintillator_01 -G simple -g 0,0,-500,0,0,1.0,10,10,10000,0,50,0 -o -Tevent -fbinary \
| bin2root - /tmp/simple.root
```



ViDeO Project – Simulations

- Toolchain / Data Flow



ViDeO Project – Simulations

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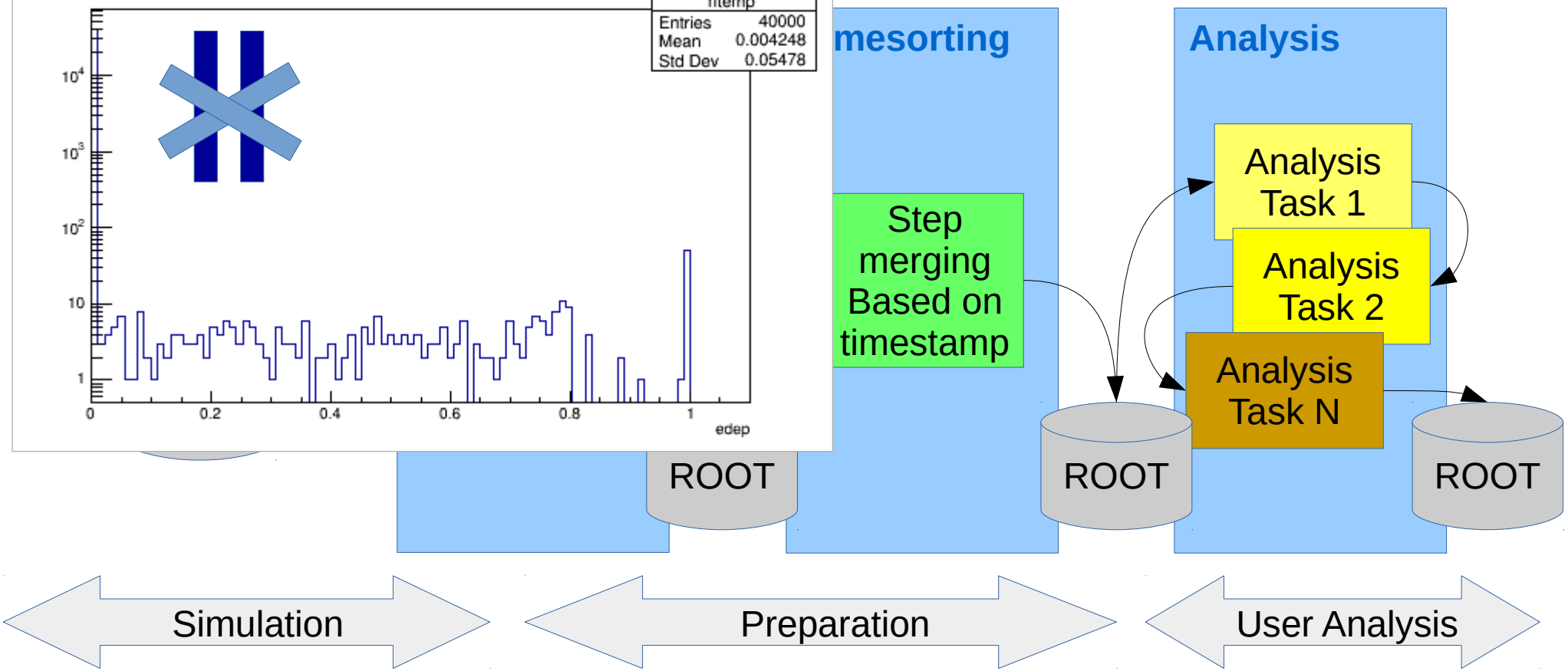

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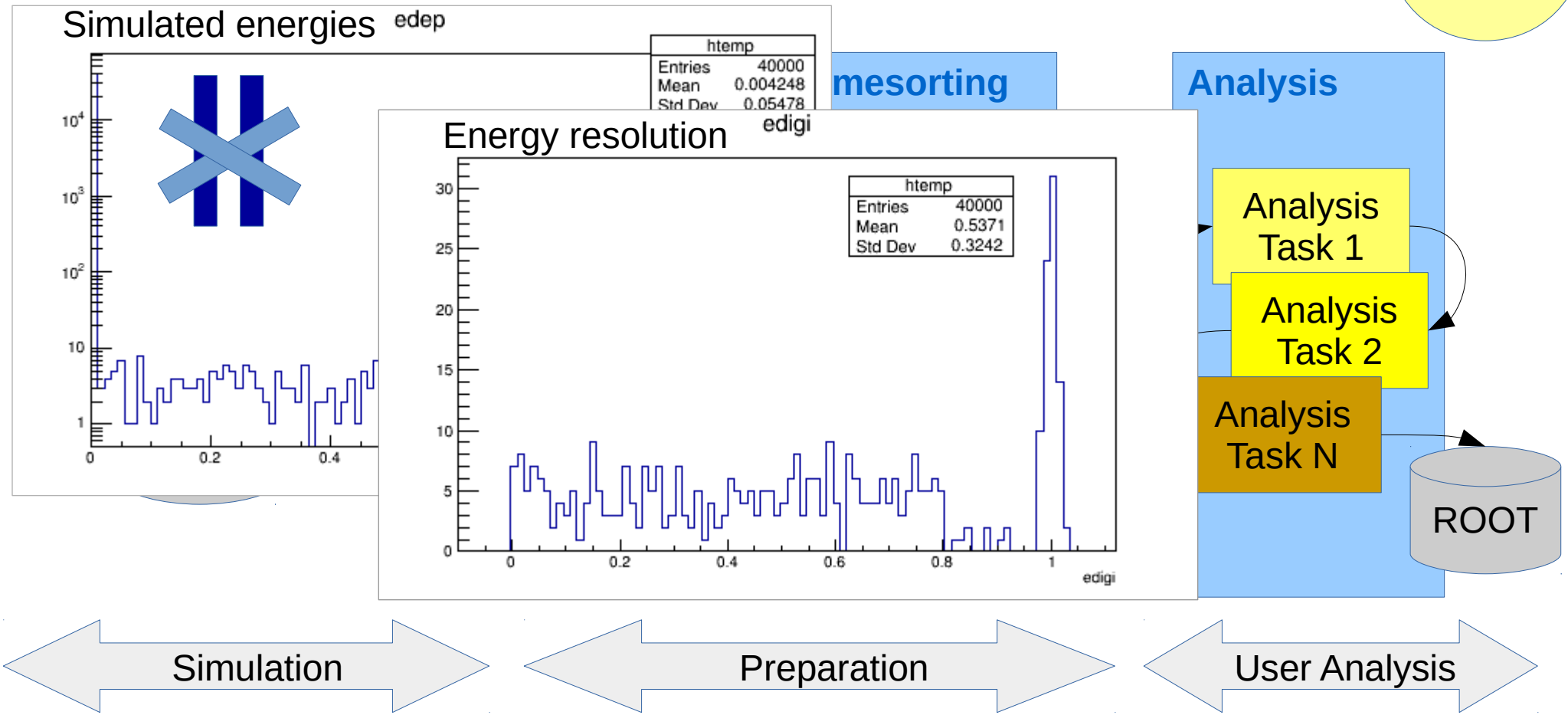

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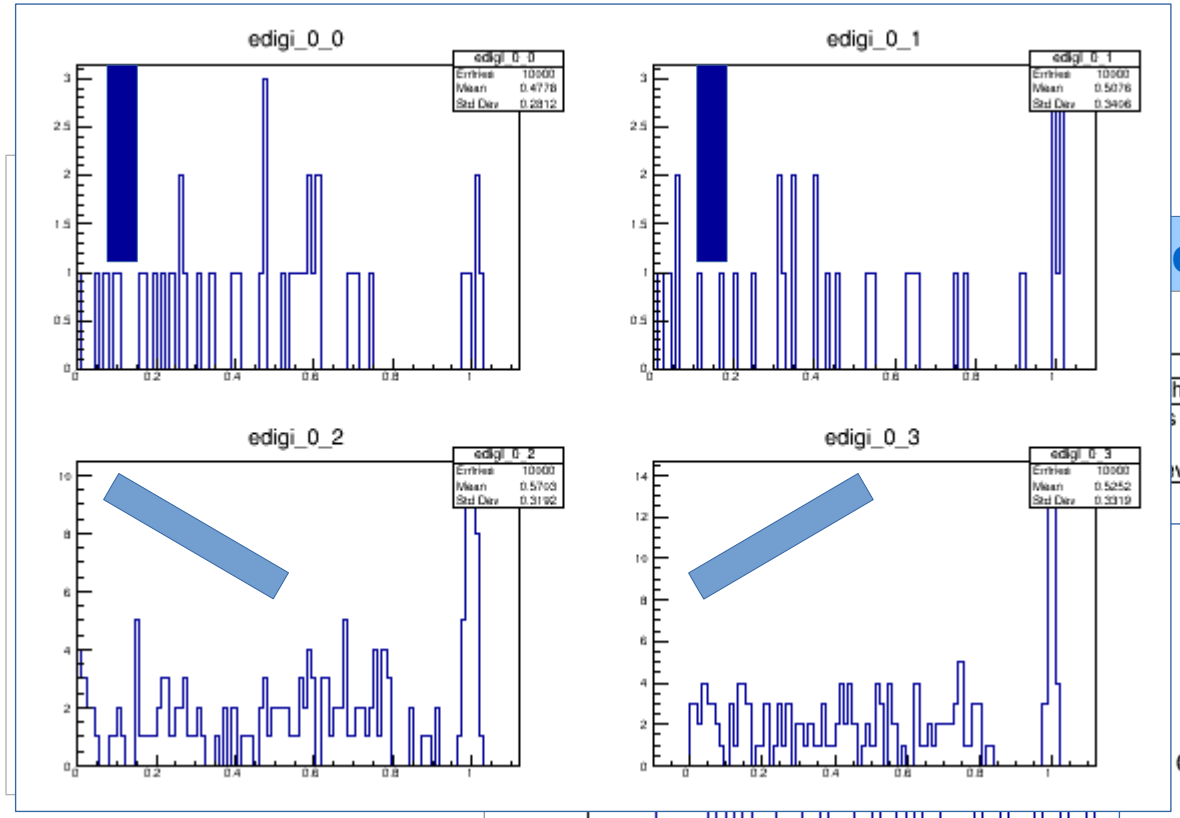

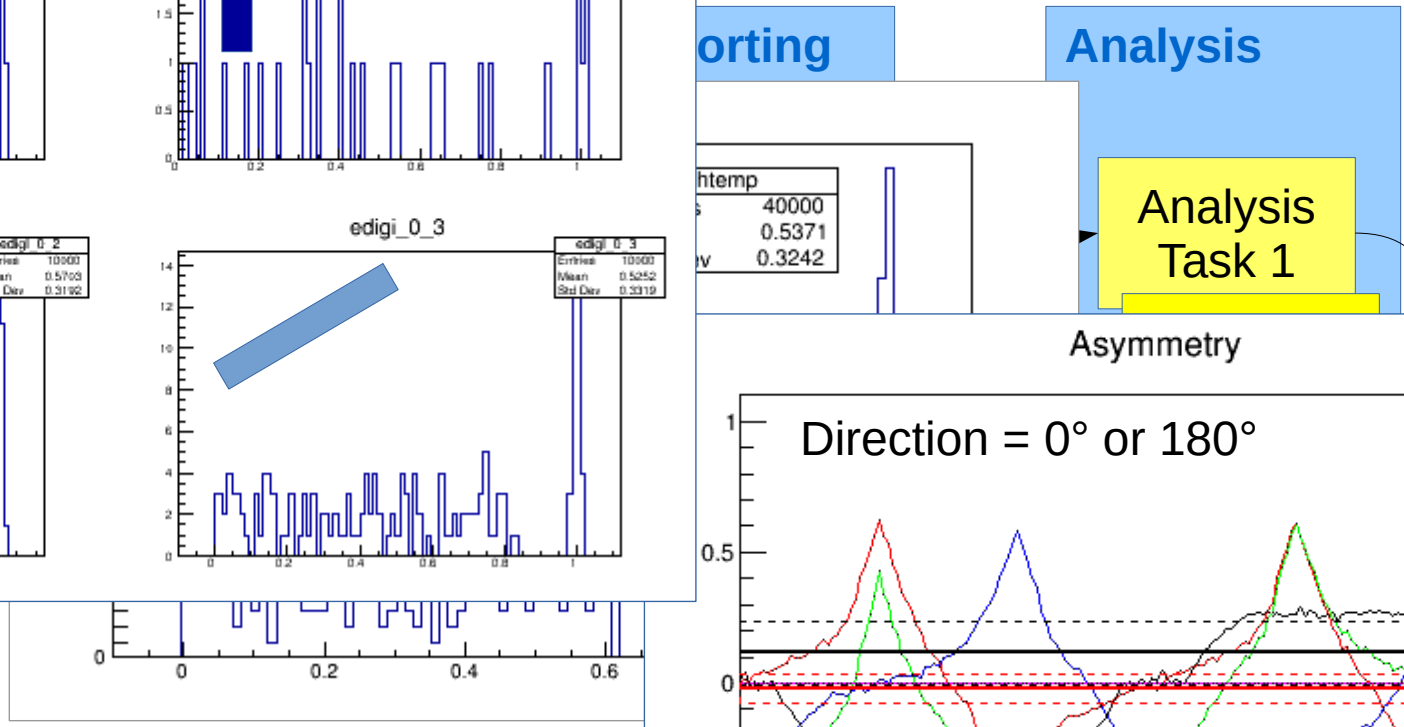

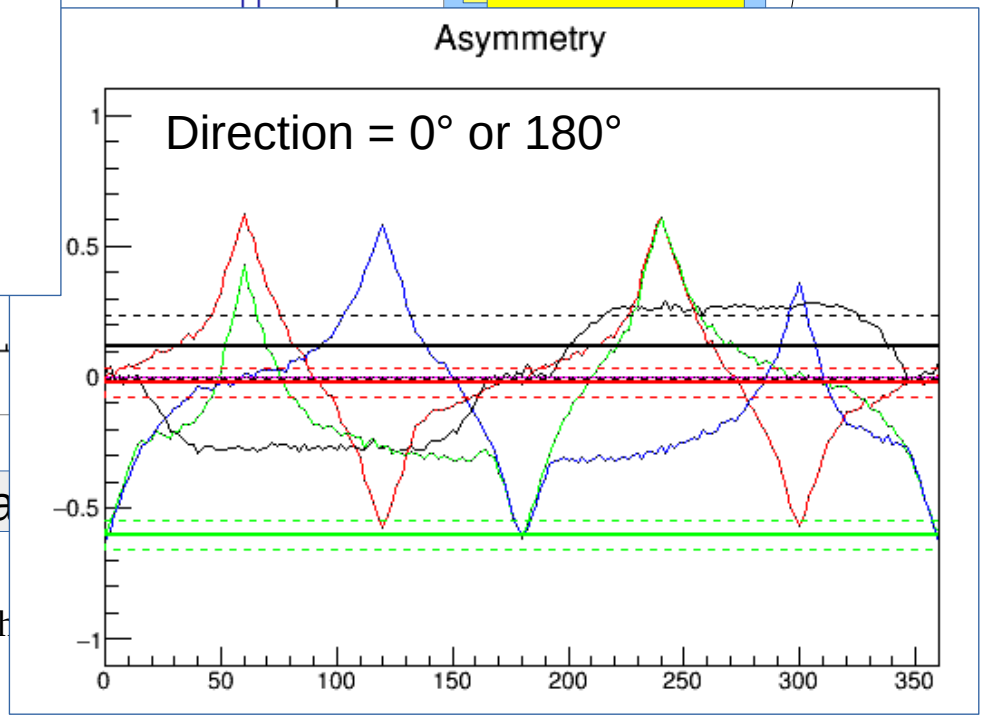

Simulation

Prepara

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ViDeO Project – Simulations

- More useful example – Circle simulation
  - Detector is moved around the source
  - For simplicity, use a generator input file (circle.in)

```
./scintillator_01 -G 8c -g file=circle.in -o -Tevent -fbinary \
| bin2root - /tmp/circle.root
```

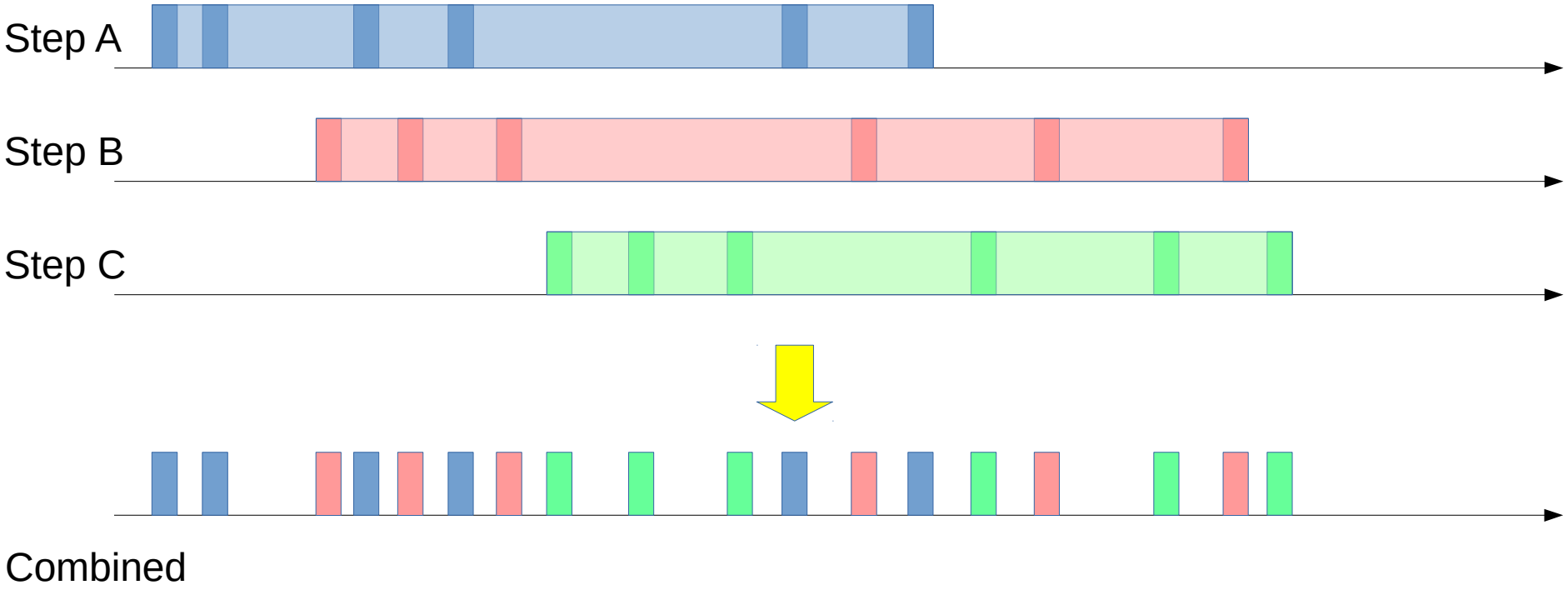
```
beam { { 0,0,-1000}, {0,0}, 0.662, {300,300}, 10000, {0,60}, 0}
beam { { 0,0,-1000}, {0,0}, 0.662, {300,300}, 10000, {60,60}, 10}
beam { { 0,0,-1000}, {0,0}, 0.662, {300,300}, 10000, {120,60}, 20}
beam { { 0,0,-1000}, {0,0}, 0.662, {300,300}, 10000, {180,60}, 30}
beam { { 0,0,-1000}, {0,0}, 0.662, {300,300}, 10000, {240,60}, 40}
beam { { 0,0,-1000}, {0,0}, 0.662, {300,300}, 10000, {300,60}, 50}
...
```

ViDeO Project – Simulations

- Each step in the generator input file produces a step in the root output file:
  - Sim/
    - Steps/
      - Step0 (TTree)
      - Step1 (TTree)
      - ...
    - Info (TTree)
- Info tree contains information about each step (source position, energy, time, etc...)

ViDeO Project – Simulations

- Timesorting sorts and merges steps which were simulated to occur during the same interval:



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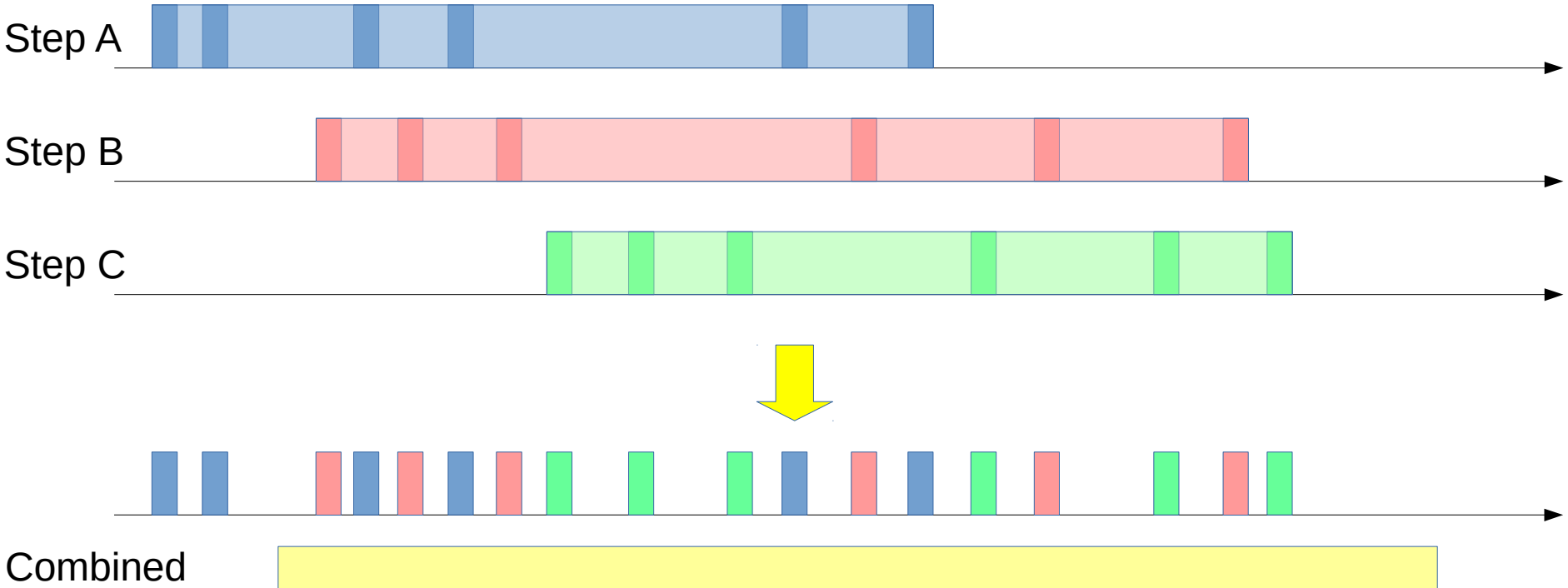
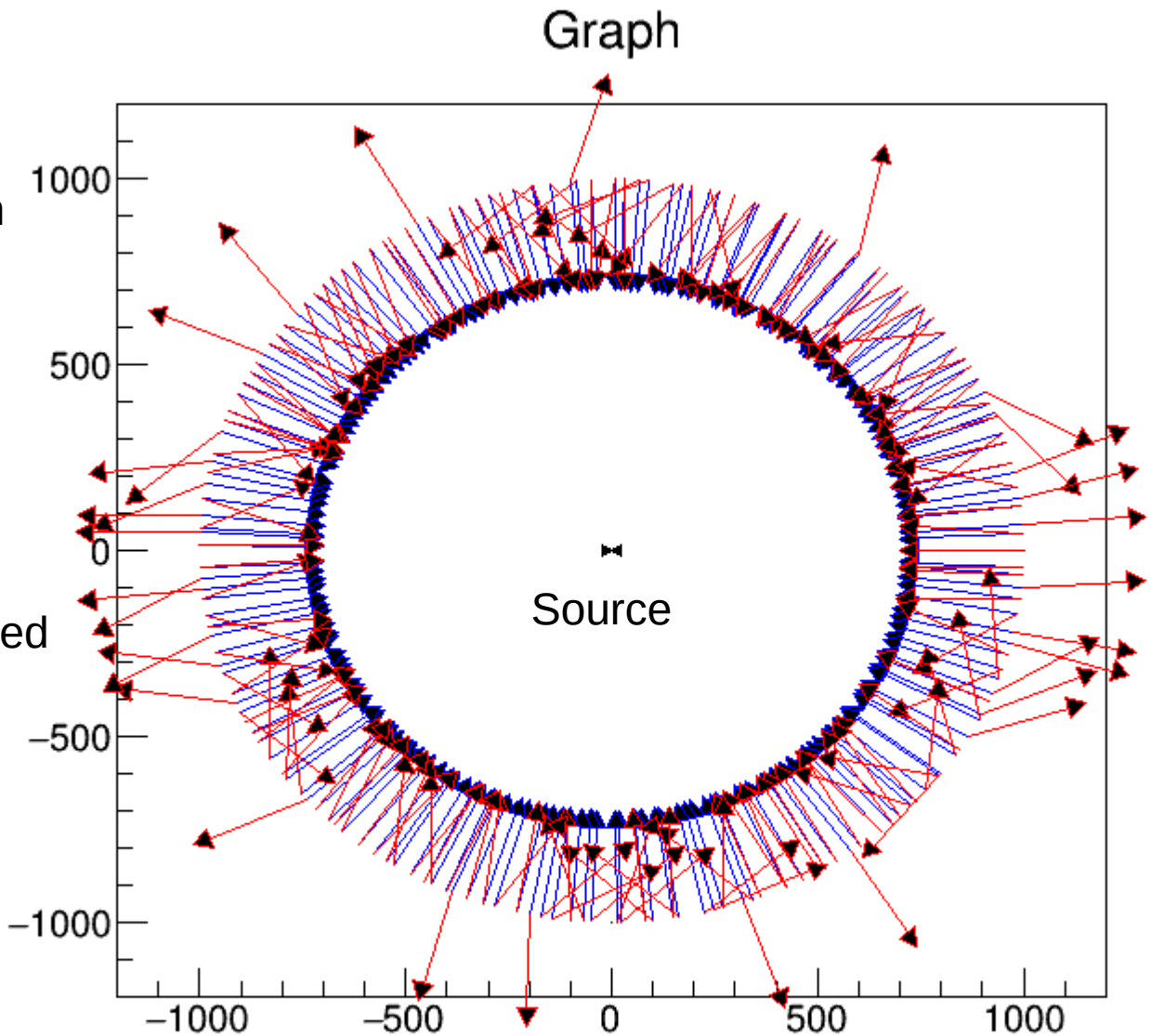


Example: Allows to simulate the beam energy separately from background sources

ViDeO Project – Simulations

Blue:
Actual direction
Red:
Reconstructed direction

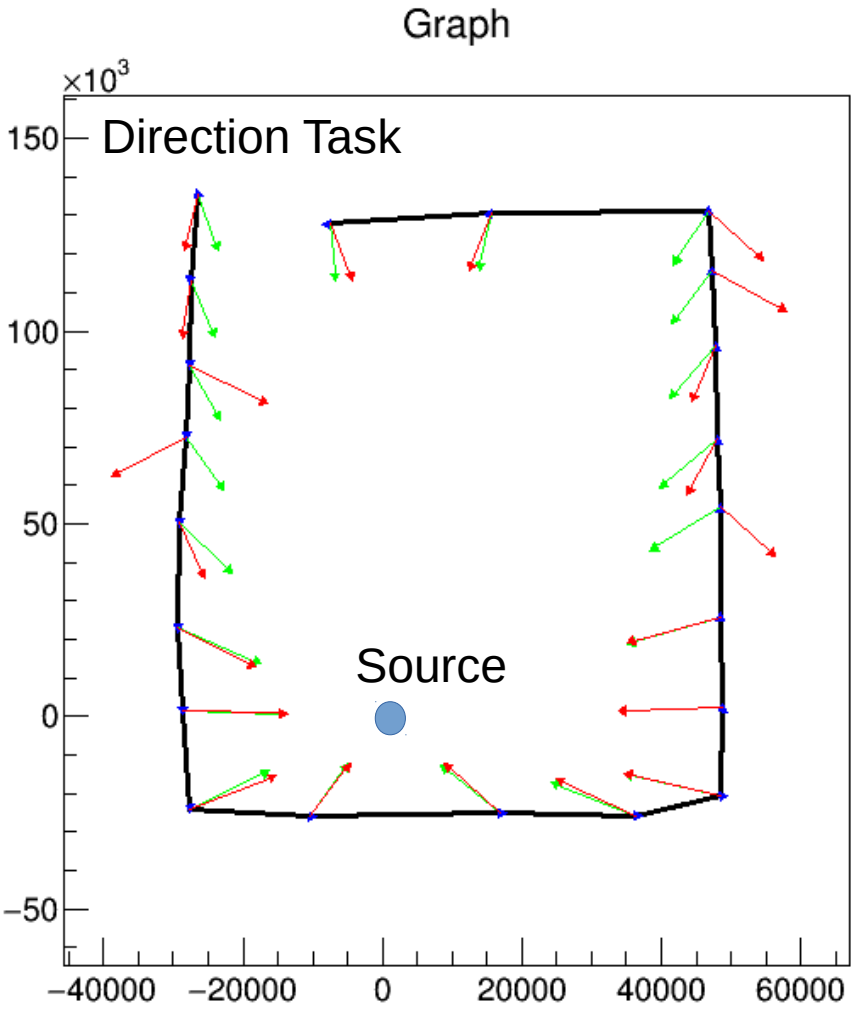
This design:
Strong at 45°
Weak at 90°
Can get confused
At 0°



ViDeO Project – Simulations

- Using generator input files, we can do more!
  - Use a path as input, i.e. the path a detector might be moved during a measurement

Green: Actual direction
Red: Reconstructed

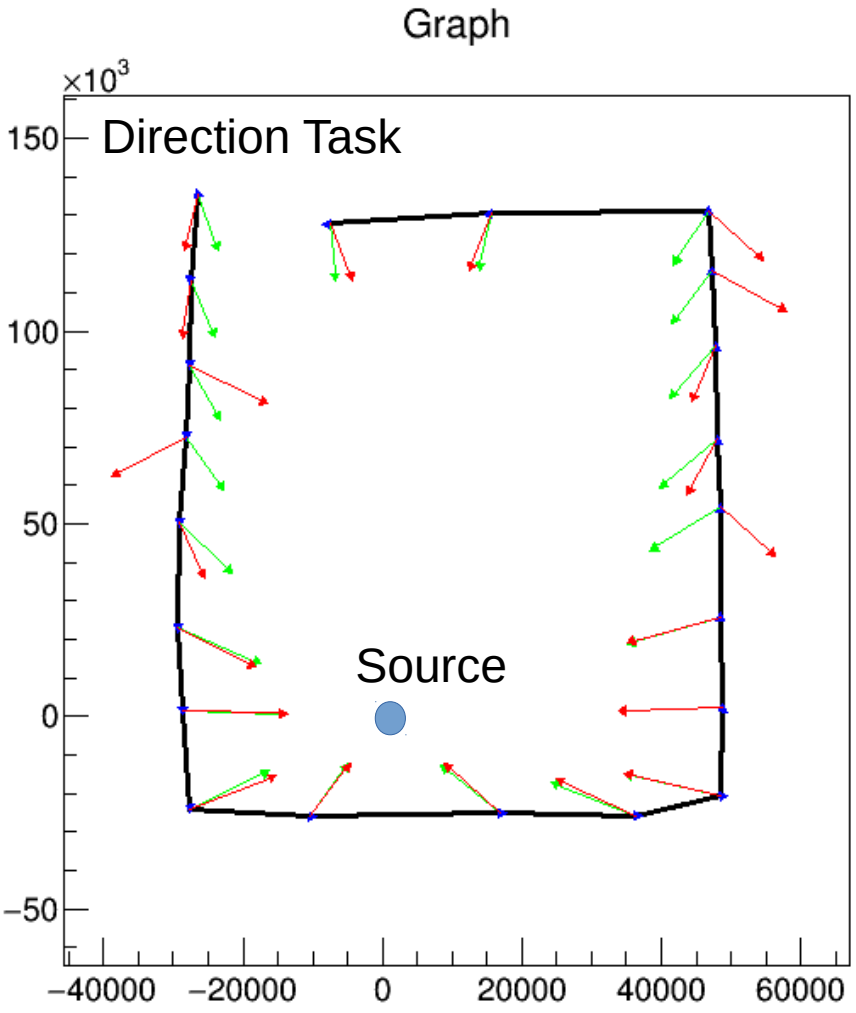


ViDeO Project – Simulations

- Using generator input files, we can do more!
  - Use a path as input, i.e. the path a detector might be moved during a measurement

    Green: Actual direction
    Red: Reconstructed

  - Add some coordinate mapping...



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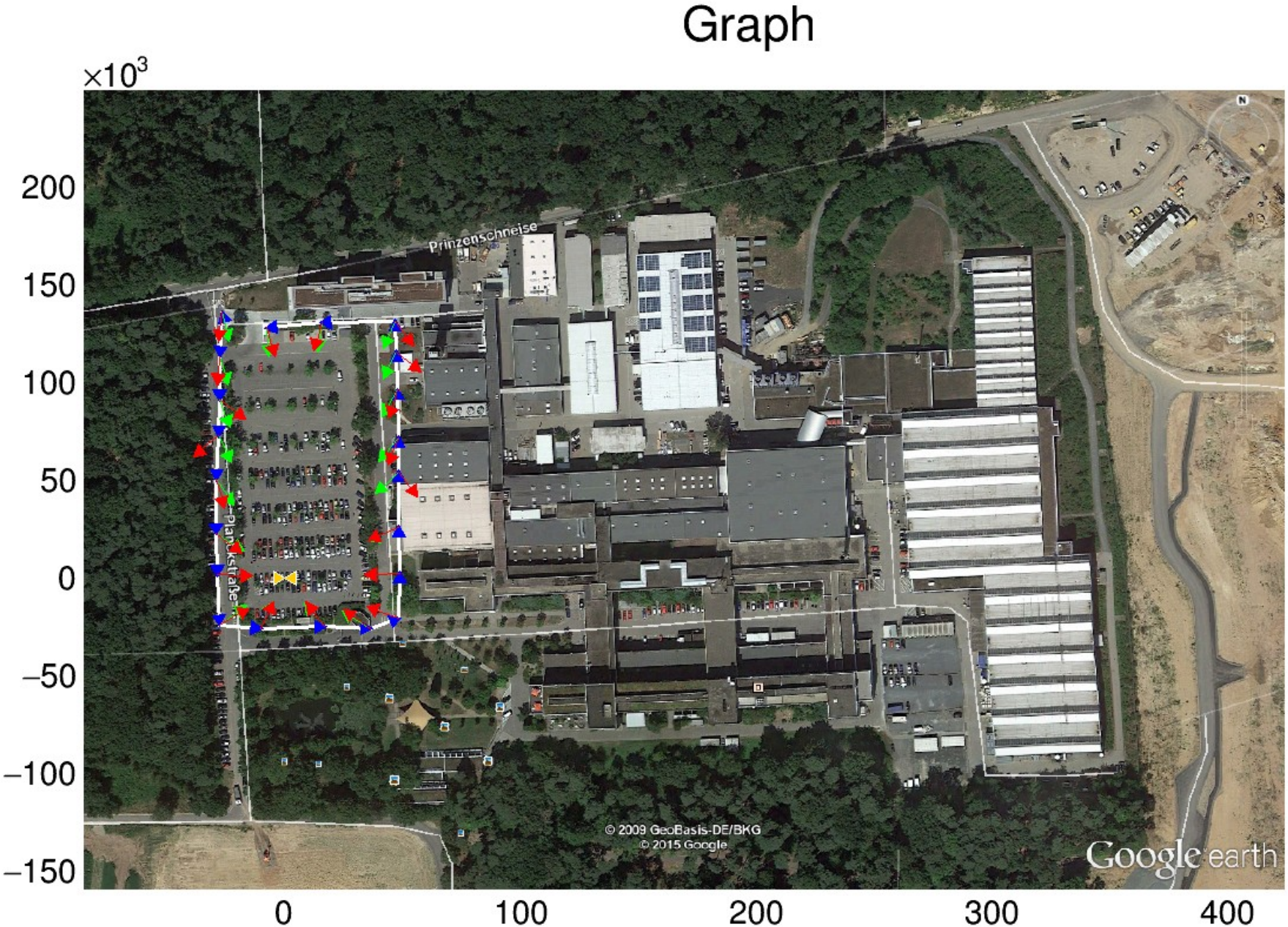

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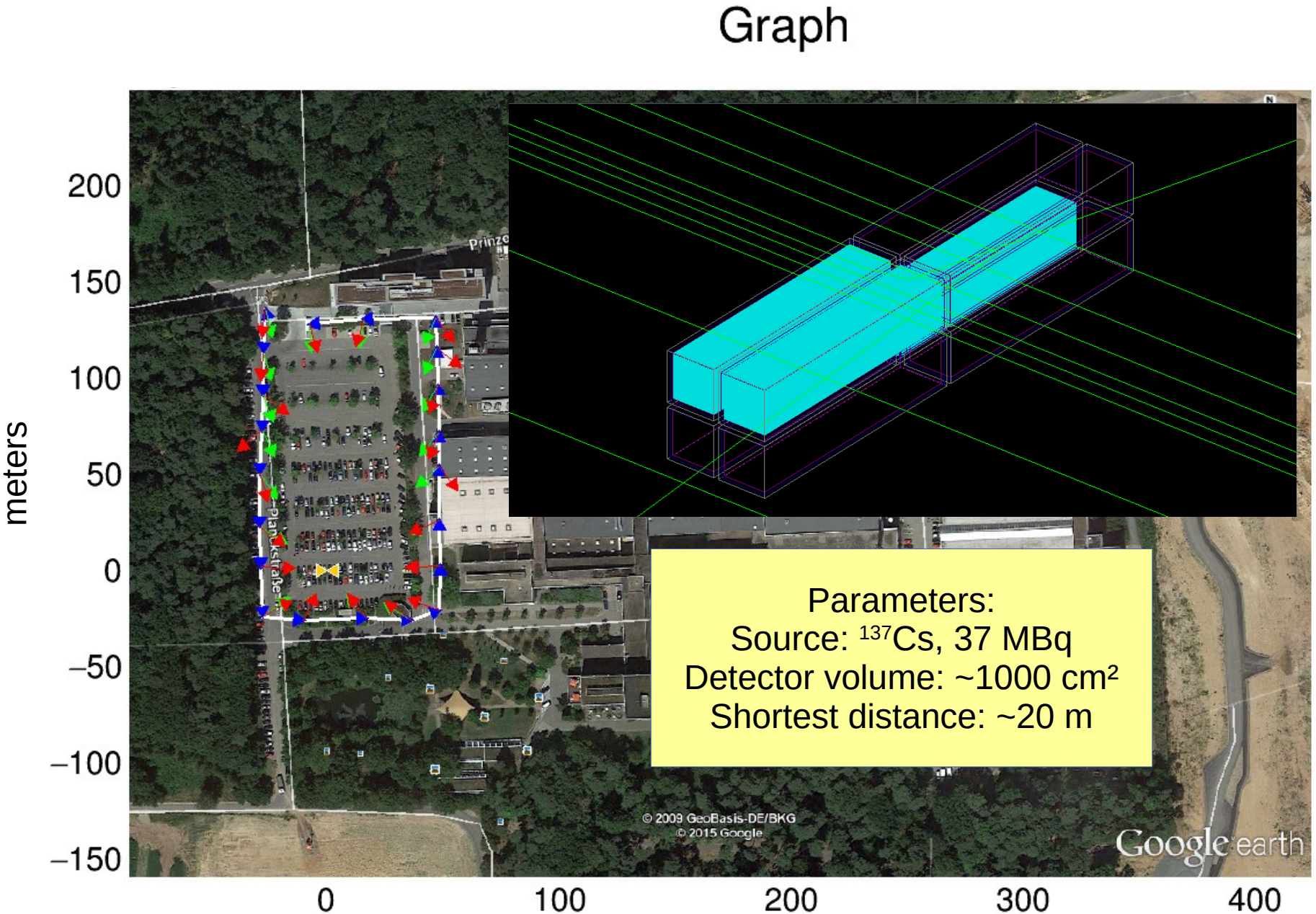
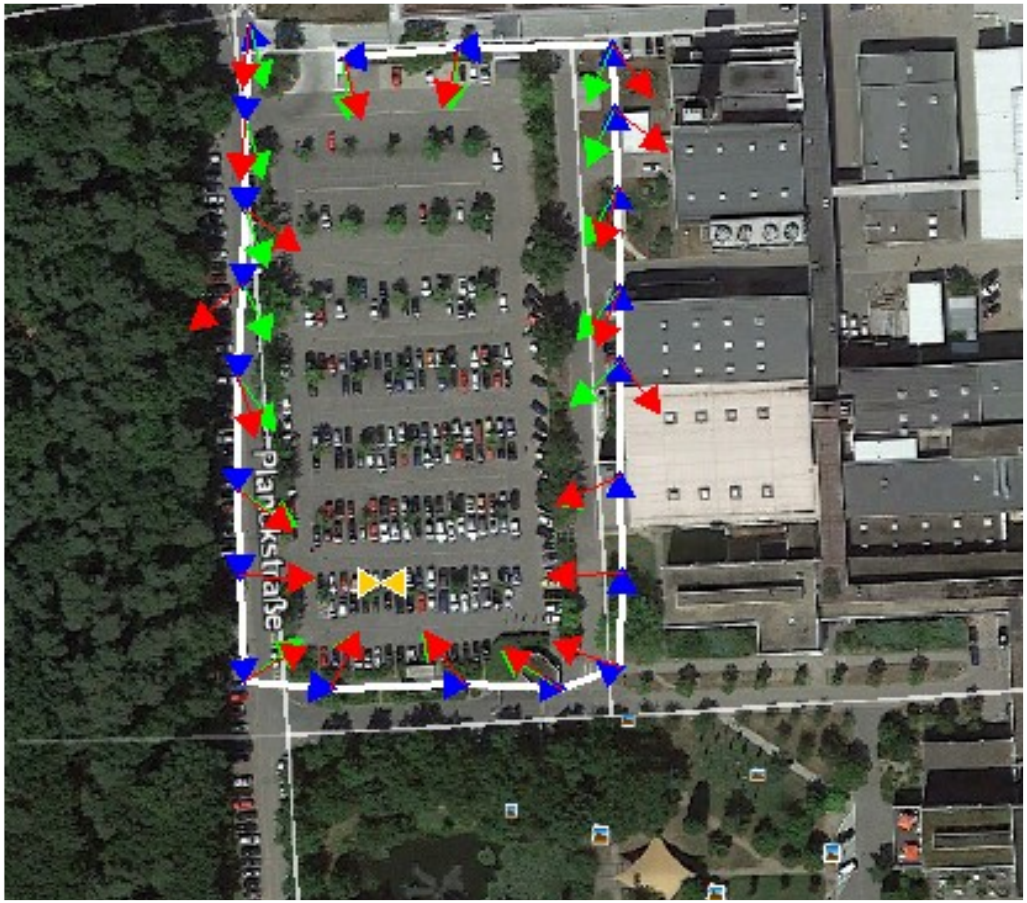


Parameters:
Source: ^{137}Cs, 37 MBq
Detector volume: ~1000 cm²
Shortest distance: ~20 m

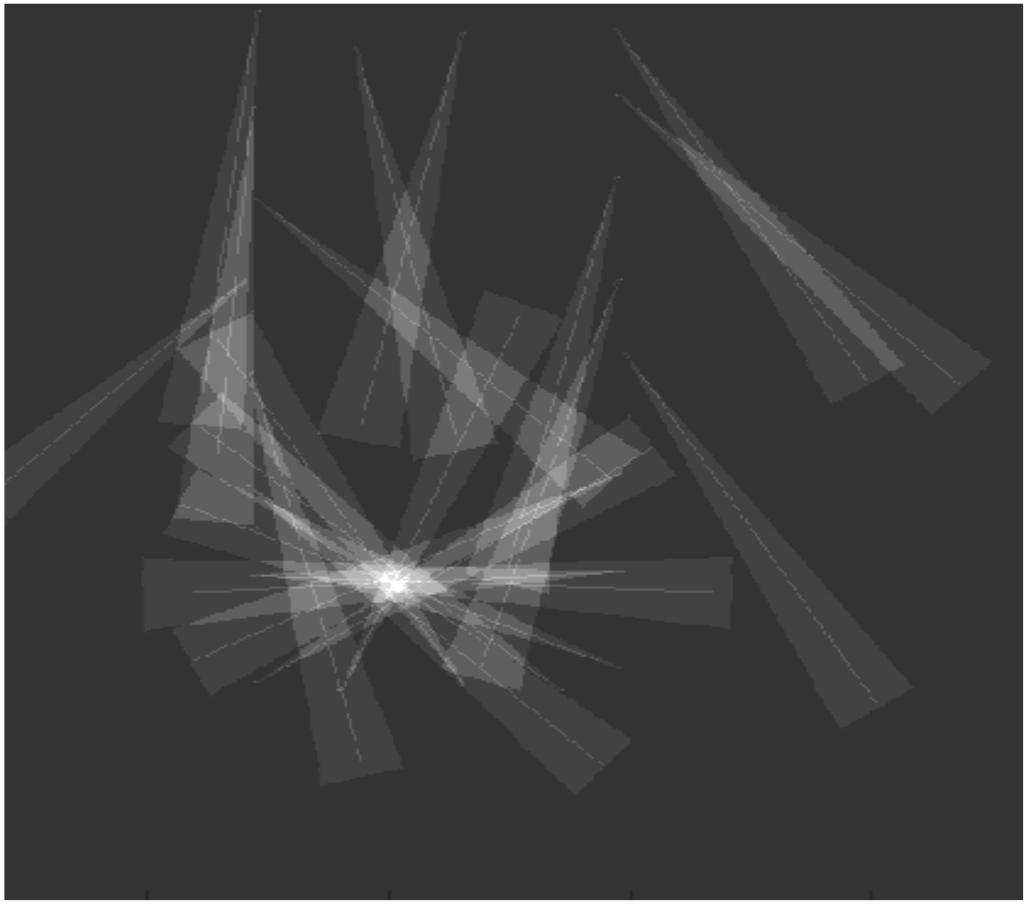
ViDeO Project – Simulations



Direction Task

ViDeO Project – Simulations

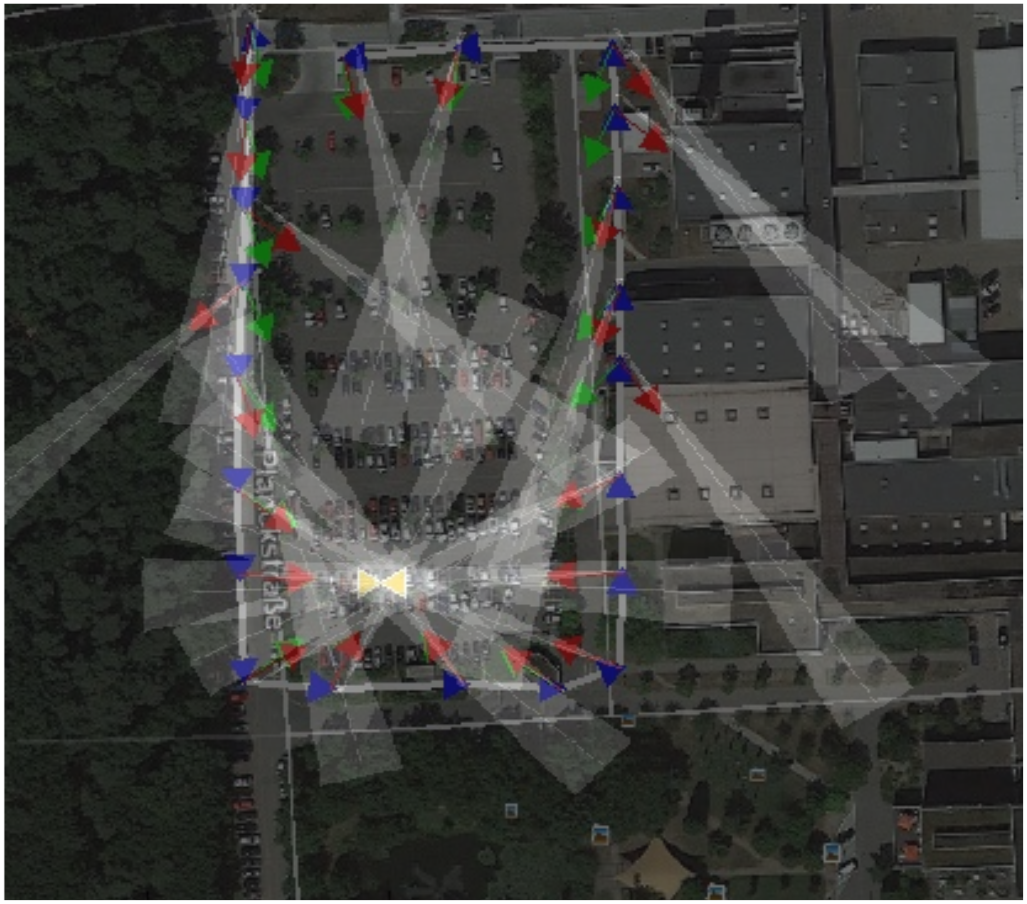
Heatmap



Heatmap Task

ViDeO Project – Simulations

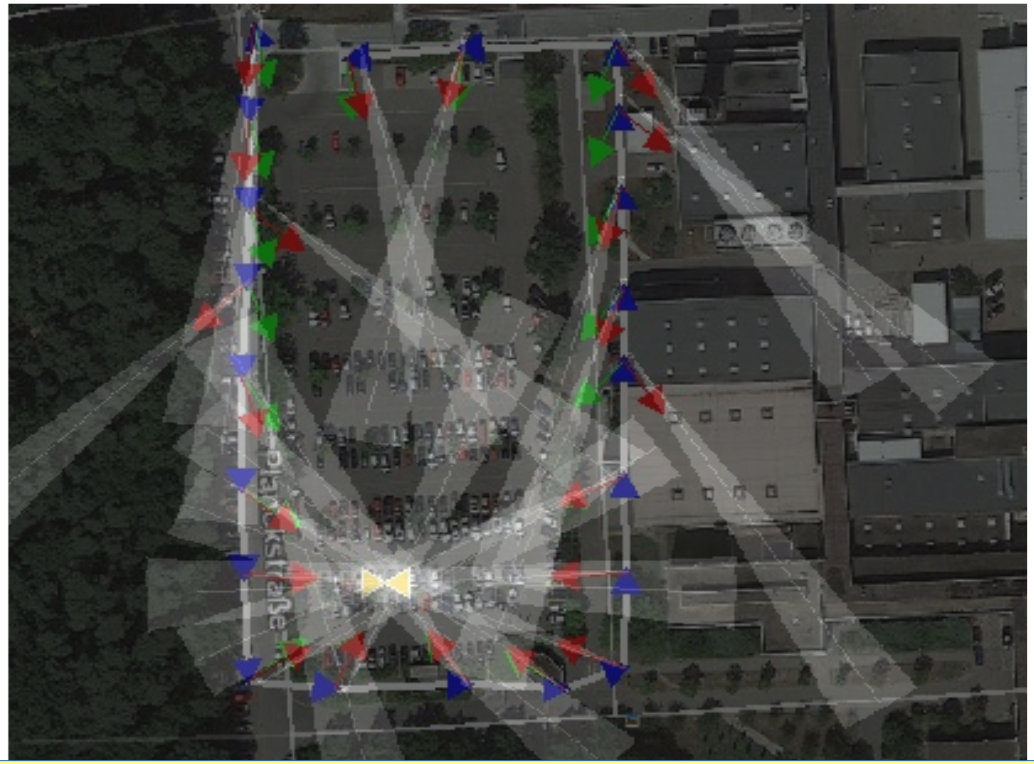
Heatmap - Overlay



Direction Task
Heatmap Task

ViDeO Project – Simulations

Heatmap - Overlay



Direction Task
Heatmap Task

Work in Progress!
All pieces are ready, but have to be
Put together for live demonstration

ViDeO Project – Simulations

- Your own task:
  - Derive from `class Task` and implement the functions:
    - `preinit()` – executed before first step is processed
    - `init()` – executed before each step is processed
    - `run()` – executed during each step
    - `finish()` – executed after each step

ViDeO Project – Simulations

- Your own task:
  - Add your task to main_analyse.cc

```
main(int argc, char *argv[])
{
        char *filename;
        const char *outname;
        EventLoop loop;

        outname = "/tmp/analyse.root";

        loop.setInputFile(filename);
        loop.setOutputFile(outname);
        loop.registerTask(new DirectionTask(&loop));
        loop.registerTask(new HeatmapTask(&loop));
        loop.run();

        return 0;
}
```

ViDeO Project – Simulations

- Users / Use cases
  - ViDeO I, as you have seen
  - Plasma physics, simulating thin Imaging Plates
  - ViDeO II, new detector concepts

Check out the code:
Git clone bloeher@lx-pool.gsi.de:/u/bloeher/git-bare/geant.git
Git clone bloeher@lx-pool.gsi.de:/u/bloeher/git-bare/video.git

Next up:

- Further simulations including natural background radiation
- Quantitative test of detector geometries and estimation of angular resolution
- Evaluation of concepts for ViDeO II

- Questions?