Validating EM physics processes implemented on the GPU prototype

Guilherme, Soon, Philippe

Fermilab

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Outline

- Validation of physics processes in the GPU prototype
  - Infrastructure development
  - Partial results
  - Current status and next steps
- Contributions to the Geant4 Reengineering project

Development of GPU validation infrastructure

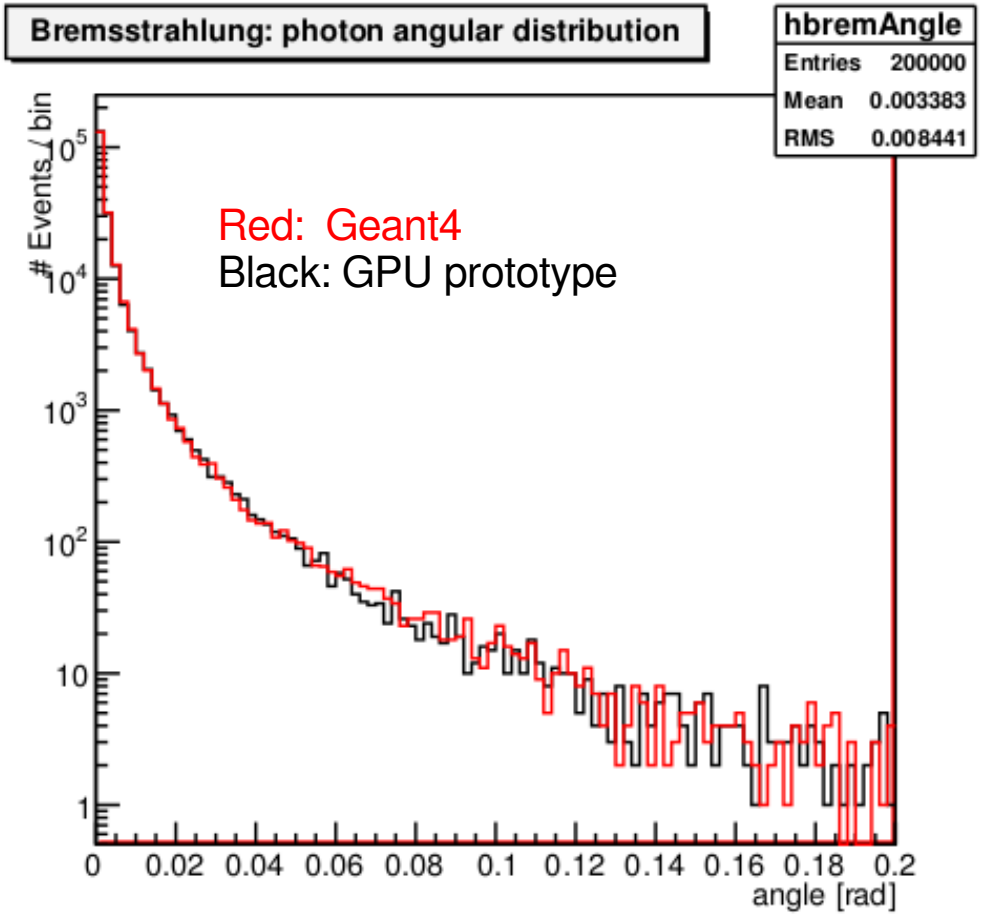
- Histogram management class: GPHistoManager
  - A singleton class, which can be called from anywhere
  - Sets of histograms booked for each physics process to be tested
    - Single place to change histogram parameters
    - Default booking in case a histogram is not booked explicitely
- Next steps:
  - Validation library and build automation (CMake)
  - Upload to git repository
  - Documentation

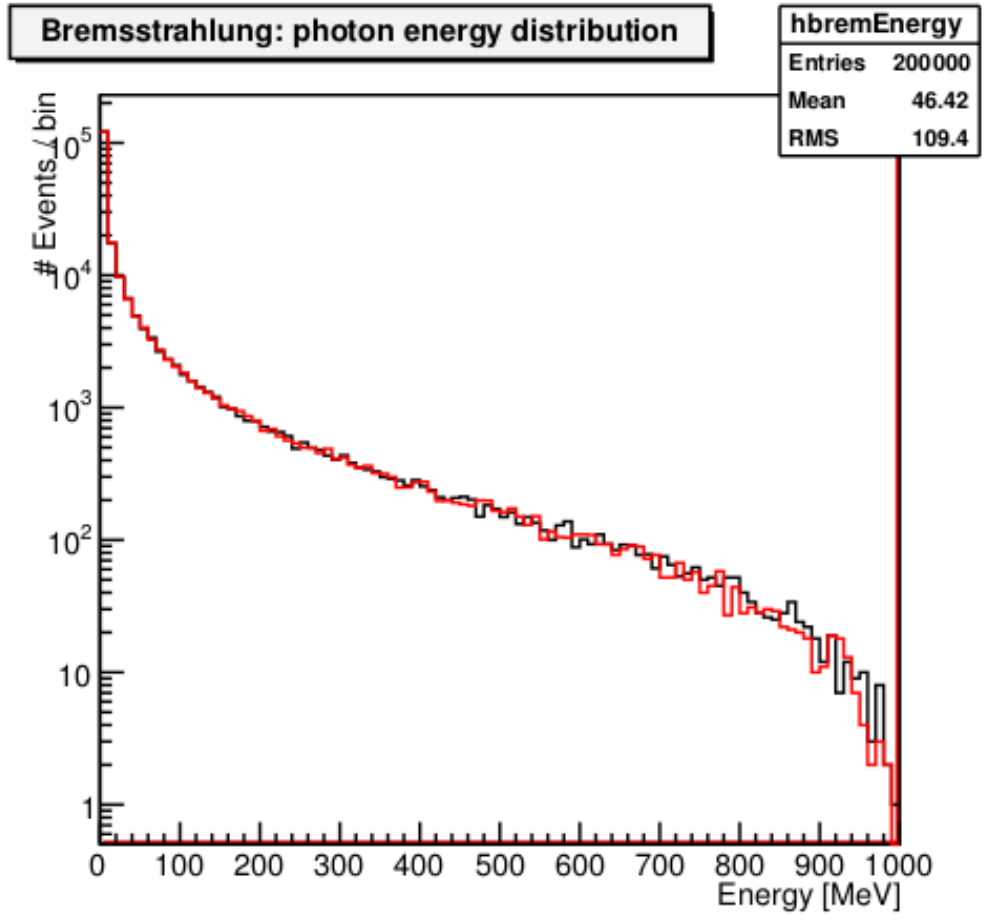
Comparing GPU prototype's physics with vanilla Geant4

- Simple EM physics processes implemented
  - *Bremsstrahlung*
  - *Ionization*
  - *Multiple scattering*
  - *Compton scattering*
  - *Photo-electric effect*
  - *Pair production*
- Started with *Bremsstrahlung* (simplest process): compare a few relevant distributions between GPU prototype and standard Geant4
  - Angular distributions
  - Energy spectrum
  - Step lengths
  - Energy loss in a step

If any distribution looks bad, other variables may be histogrammed to identify what is causing the discrepancies.

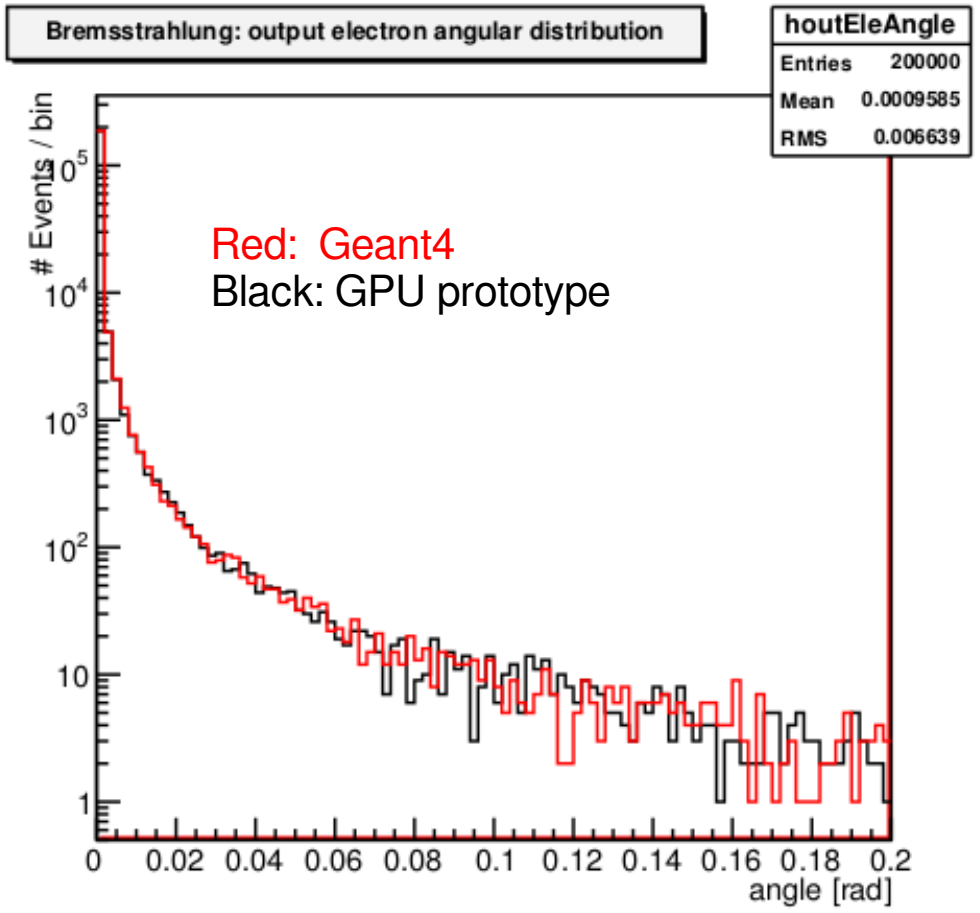
Comparing bremsstrahlung secondaries (photons)

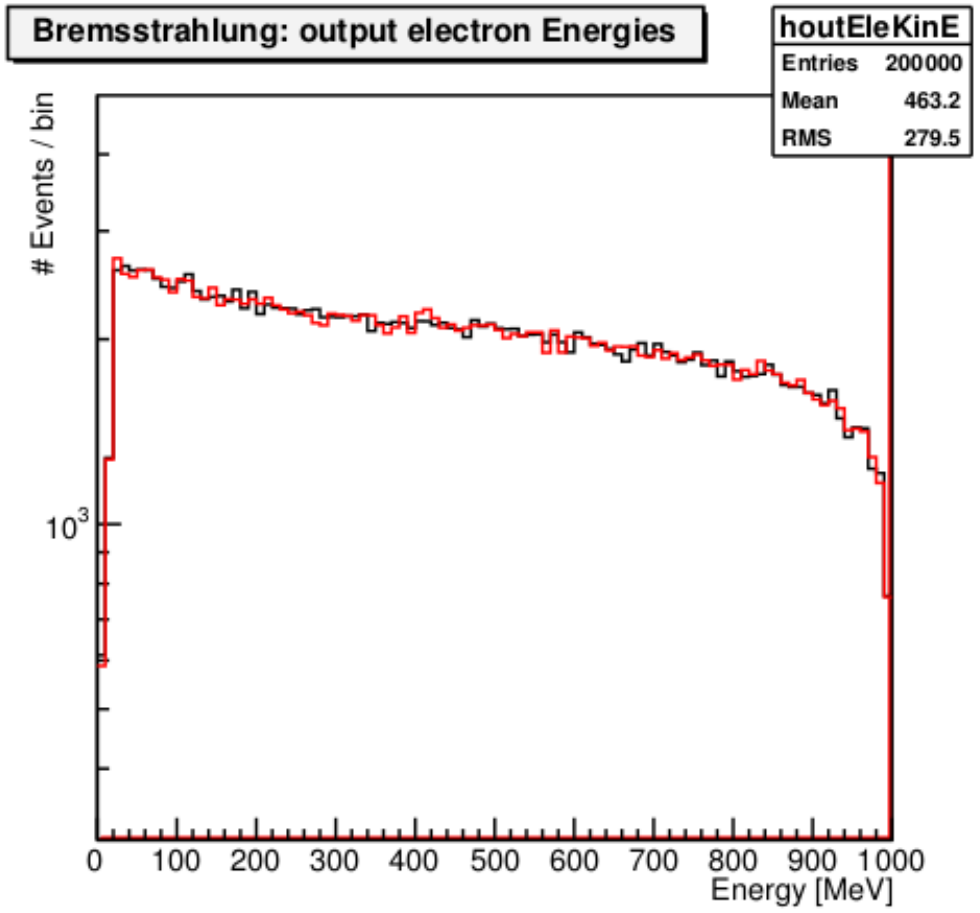




Very good agreement within statistics!

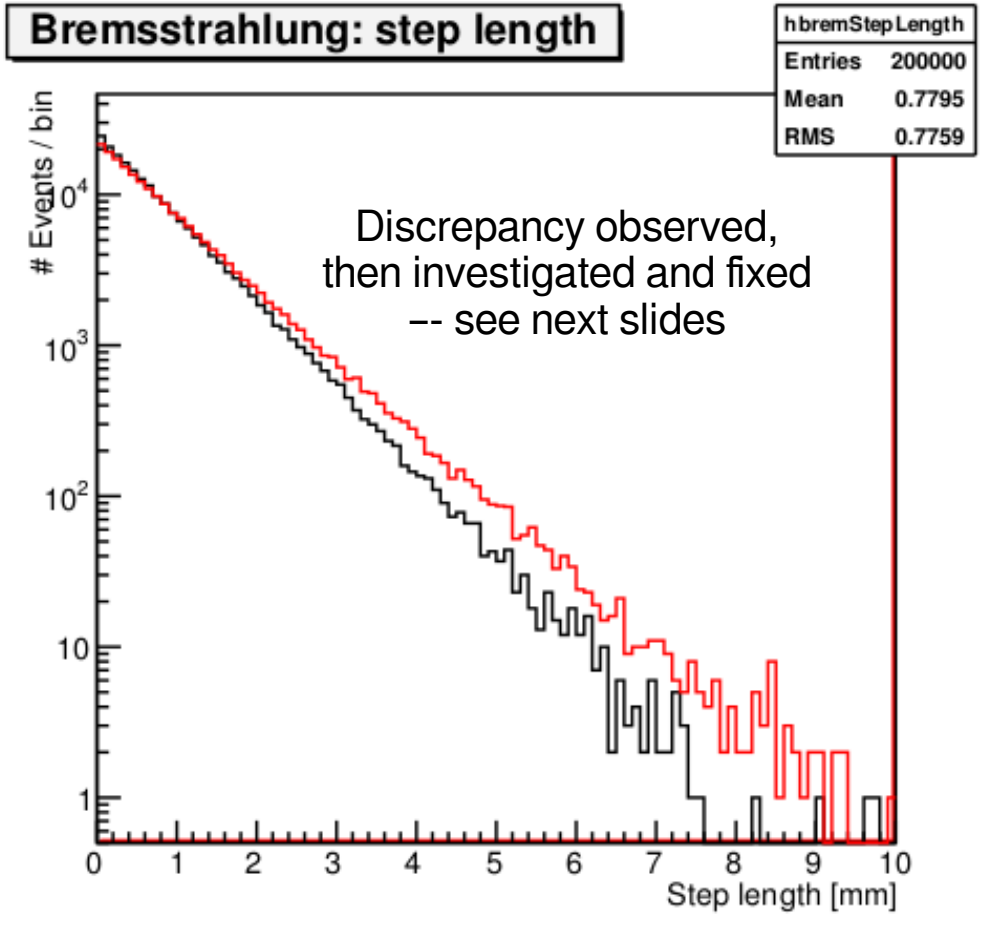
Bremsstrahlung: surviving electrons

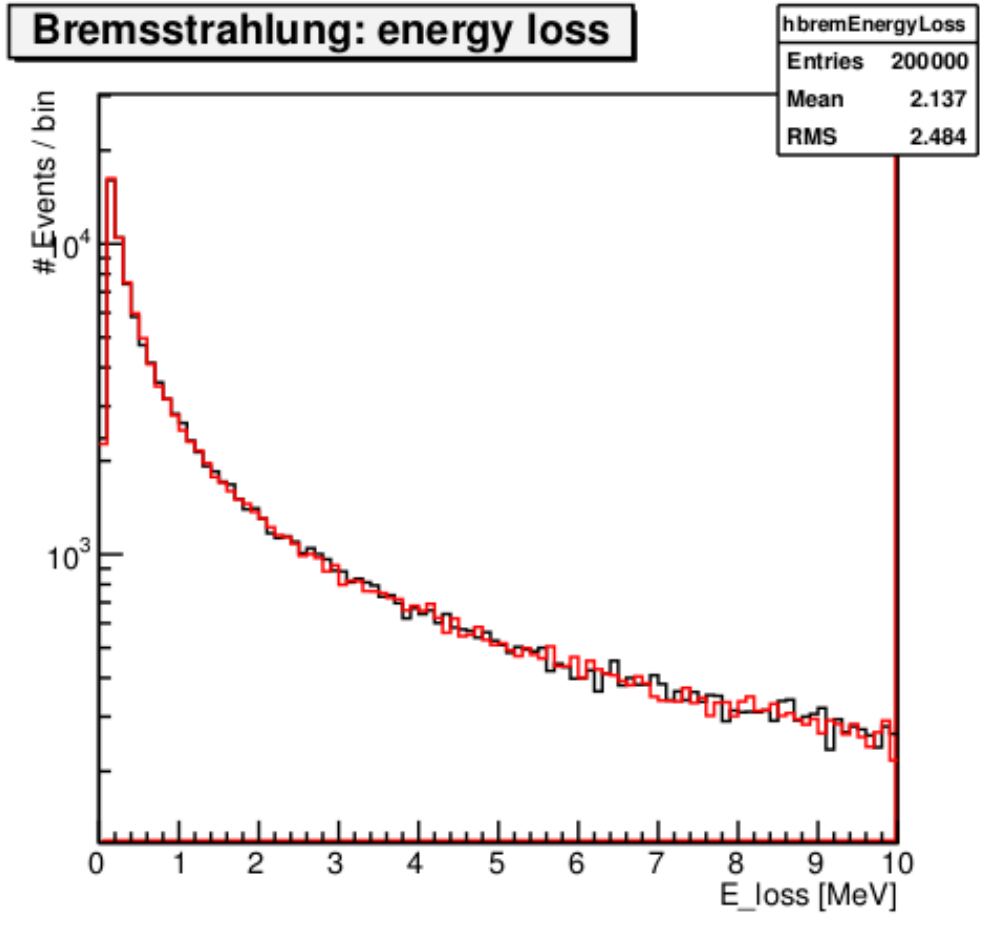




Very good agreement within statistics!

Bremsstrahlung: general properties

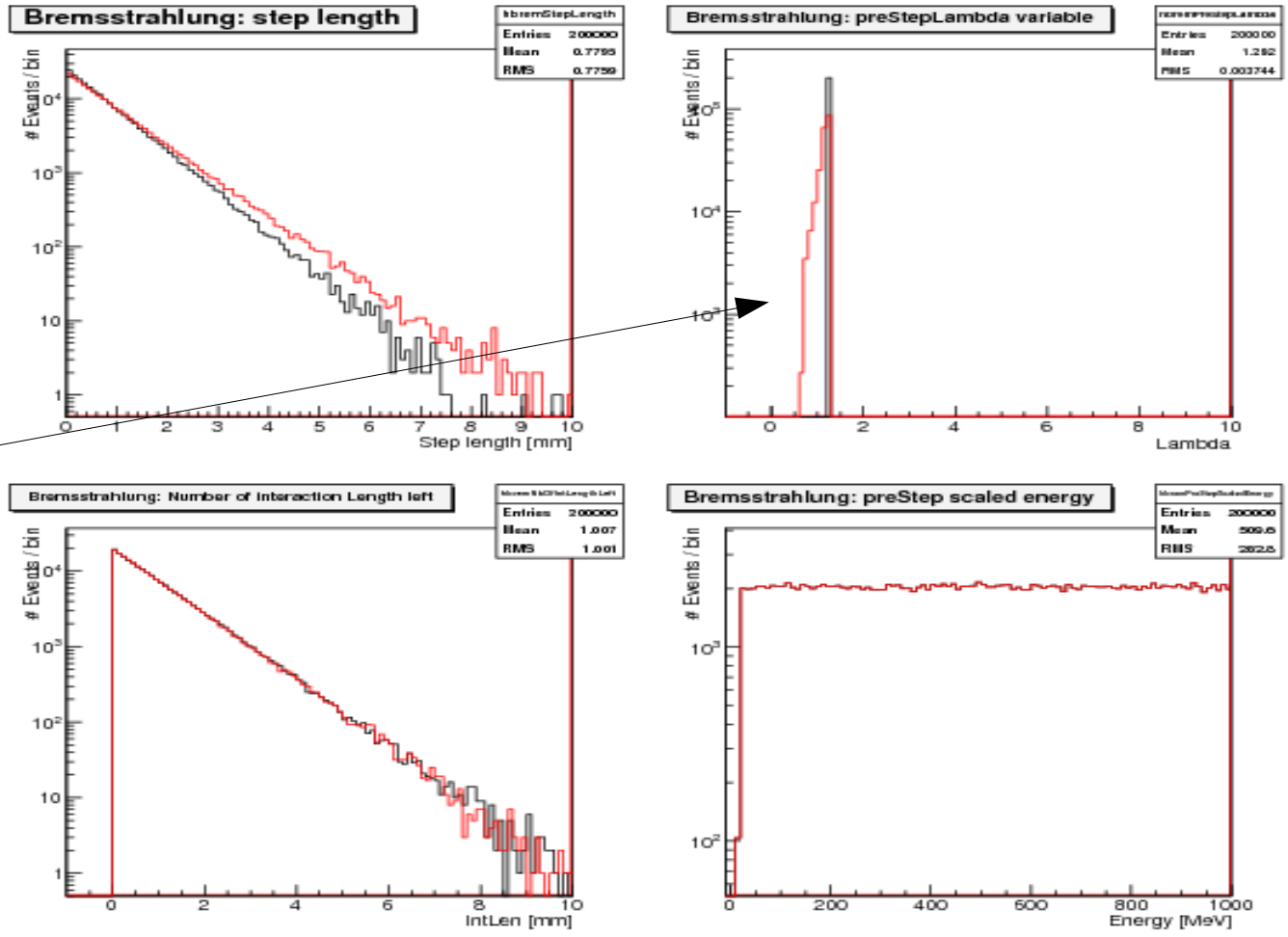




Bremsstrahlung: comparing step length calculations

Looked at these distributions for the main variables in the calculation of step length.

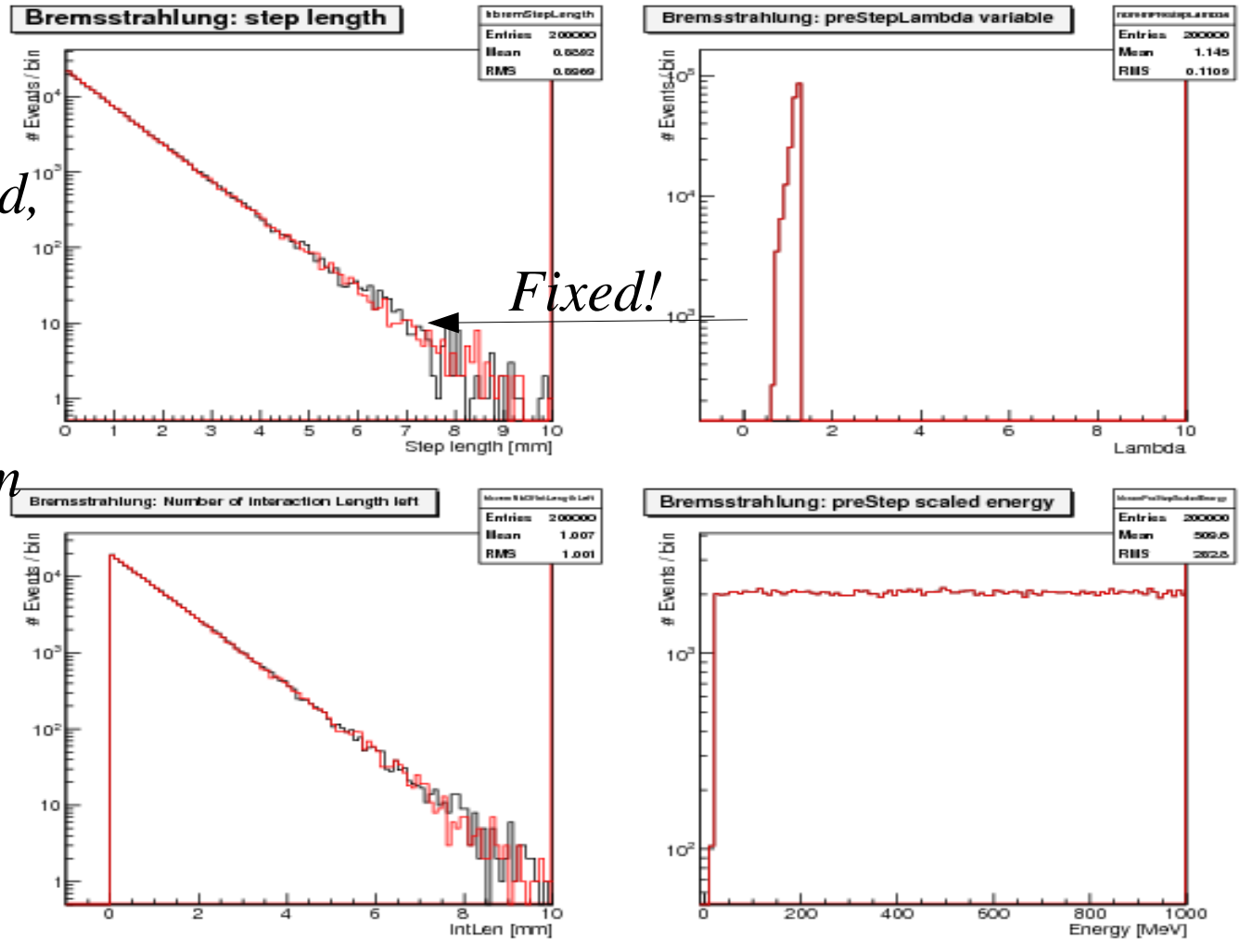
The difference was due to an update of the cross-section tables for release 9.6-p01.



Bremsstrahlung: fixing the step length calculations

A few other minor changes were also needed, including adjustments to material properties and one hardcoded cut value, changed from 1mm to ~0.083mm, as given by the Geant4 job.

As a result, the process ***Bremsstrahlung*** *is now considered to be* ***validated on the GPU*****.**



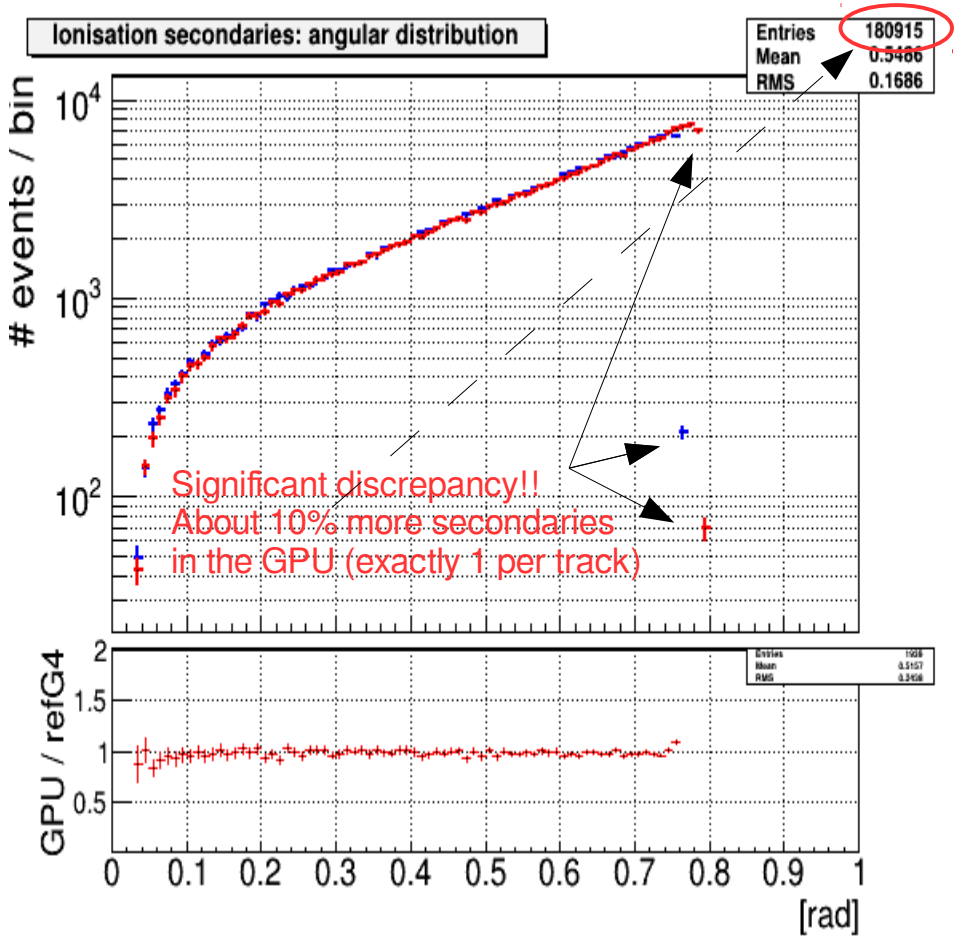
Summary of changes for Bremsstrahlung

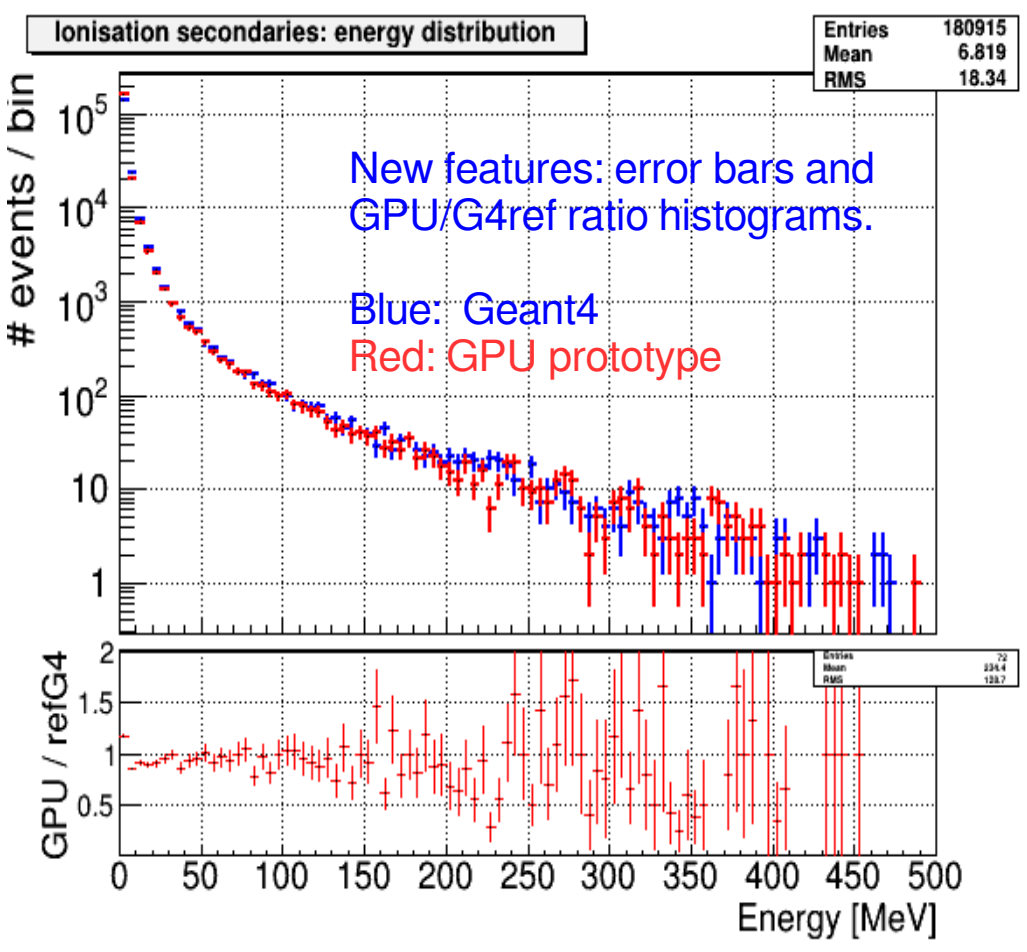
- Adjustment of GPU *$PbWO_4$* material properties to match Geant4

```
- GPElement_Constructor(&ele_O4,8*4,15.9994*4*g/mole);
+ GPElement_Constructor(&ele_O, 8,  15.9994*g/mole);

- GPMaterial_AddElement(aMat,ele_Pb,0.45532661);
- GPMaterial_AddElement(aMat,ele_W, 0.40403397);
- GPMaterial_AddElement(aMat,ele_O4,0.14063942);

+ GPMaterial_AddElement(aMat,ele_Pb,0.4553445);
+ GPMaterial_AddElement(aMat,ele_W, 0.4040084);
+ GPMaterial_AddElement(aMat,ele_O, 0.1406470);
```

- Updated GPU cross-section tables to *Geant4.9.6.p01*
- In GPeBremstrahlung.cc: use hardcoded value `tcut=0.0893347*mm` instead of reading from the `coupleIndex` table, since we have a single material in the GPU.
- *Note: I also experimented with fixed random numbers for explicit comparisons between GPU and Geant4. A lot of work, but it worked!! Comparing histograms is more efficient though.*

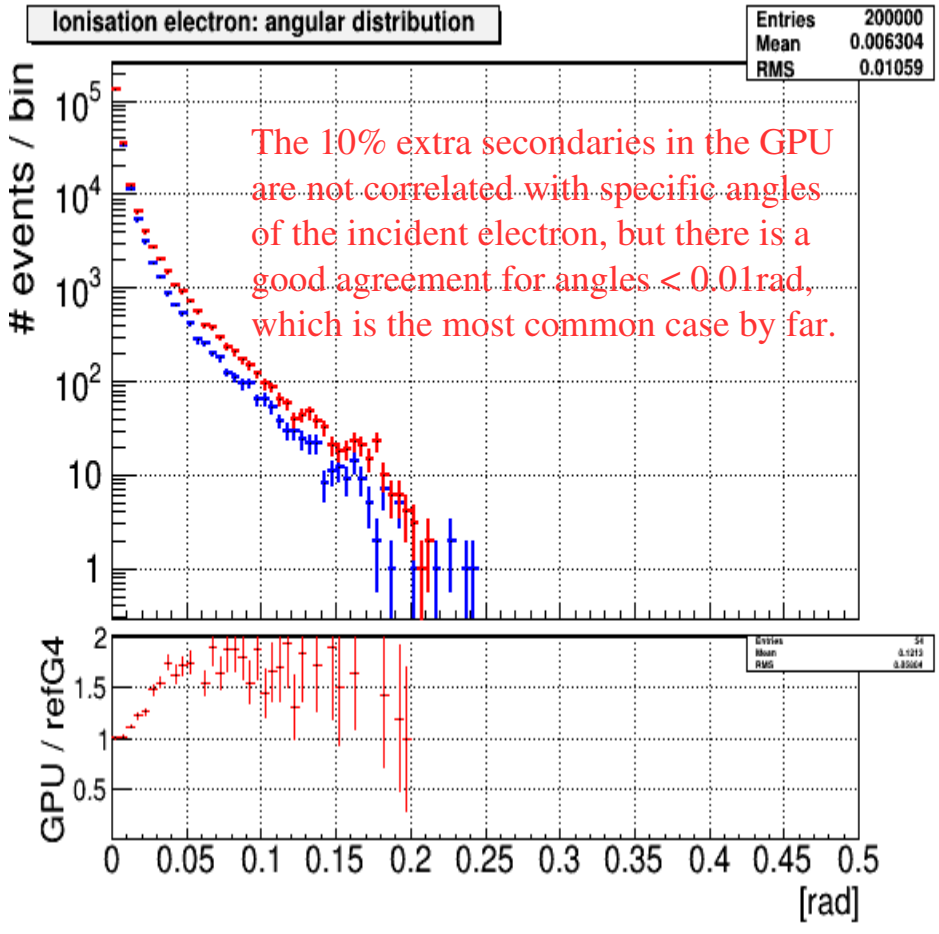
Ionisation process: kinematics of secondary electrons

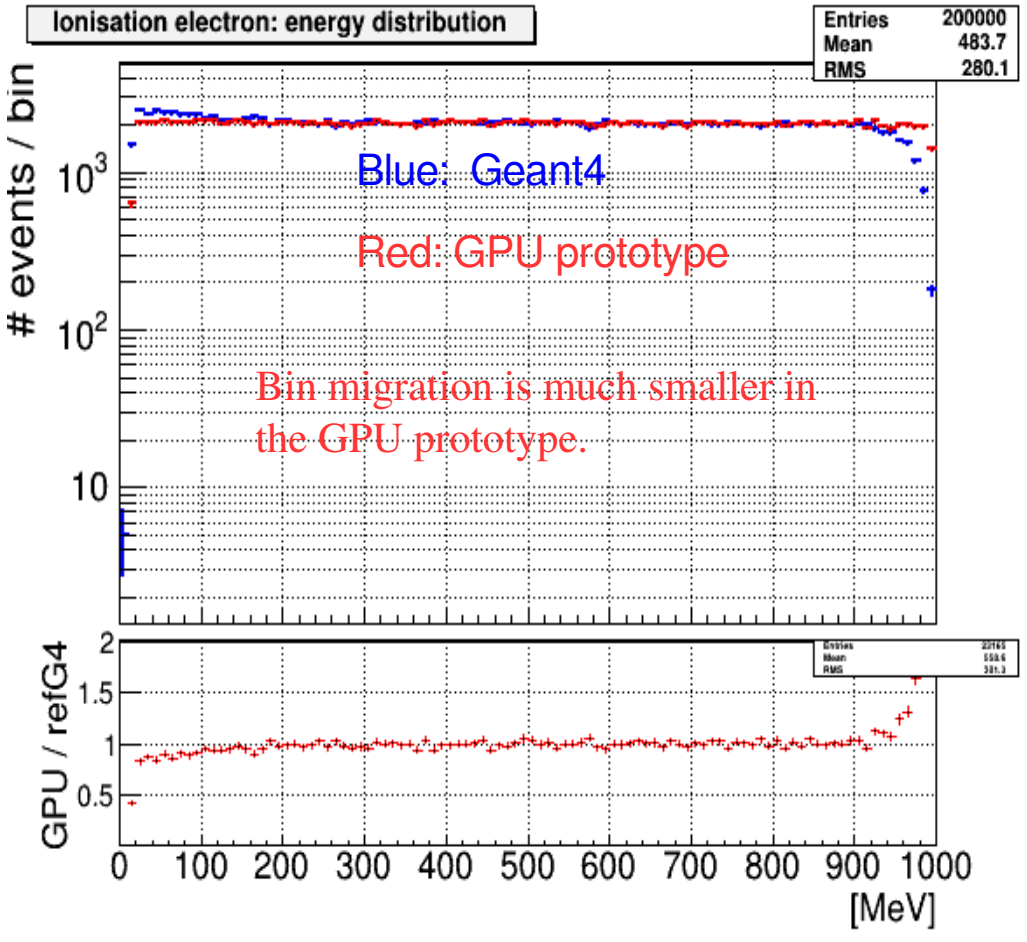




Good overall agreement, except for localized spots, e.g. at high angles of the secondaries.

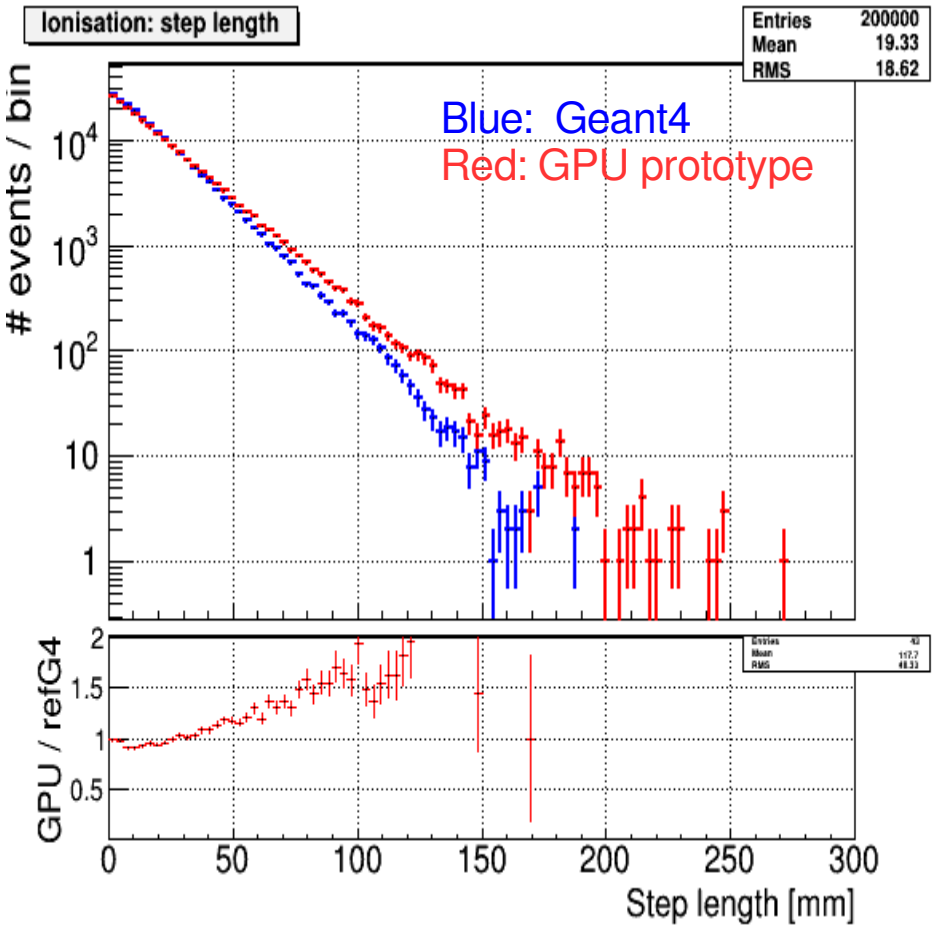
Ionisation process: kinematics of the surviving electron

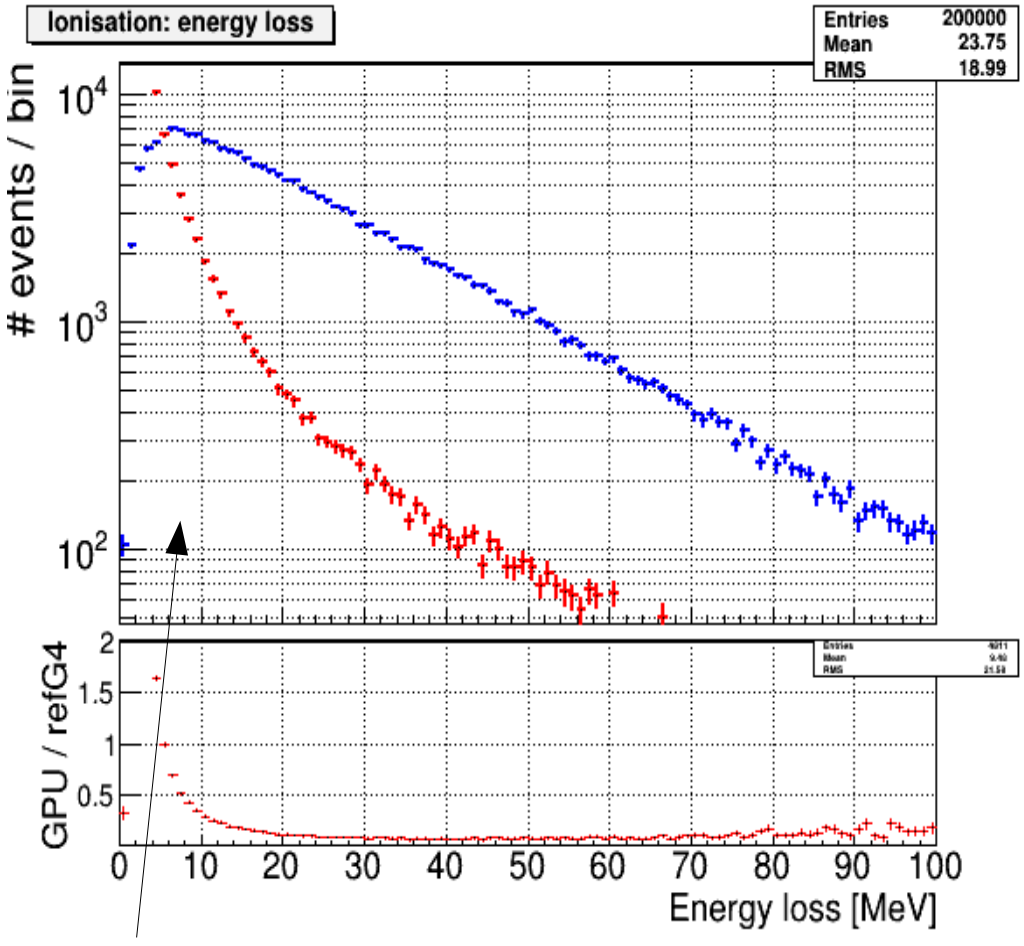




Ionisation process – kinematics of the surviving electron

Ionisation process: general properties





There is a large discrepancy here. Under investigation!

Validation of physics processes in GPU prototype

- Next steps
  - Finish investigation on electron ionisation
  - Validate remaining processes:
    - Bremsstrahlung (done)
    - Ionisation (under way)
    - Multiple scattering
    - Compton scattering
    - Photo-electric effect
    - e^+e^- pair production
  - Produce similar plots for monoenergetic particles, as suggested by Geant4 experts (John Apostolakis and Federico Carminati).
    The claim is that the comparisons are more reliable if done for monoenergetic particles.

- **Important:** prioritize what is to be done, since the reengineering activities have much higher priority!

Geant4 Reengineering Project

- It's not currently possible to port vectorized code to GPU (since it is based on TGeo), while current GPU code is based on Geant4 geometry system
- The plan is to participate in the vectorization of geometry and navigation code with Sandro Wenzel (CERN)...
- ...while in parallel, work in the optimization of existing CUDA code to speed it up
- The expected goal is to become familiar enough with both systems in order to understand and influence the final solution.
- Plan of action:
  - Use NVIDIA profiler to search for optimization opportunities on four of the existing GPU tests: stepper, geometry, tracking and trackingTest2.
  - Learn from the previous porting to CUDA, in order to reuse those tricks.
  - Establish contact with Sandro Wenzel to see how to participate on their work
- Status: just getting started... :-)

Backup slides

Class diagram for GPHistoManager