Reverse Monte Carlo in Geant4 and GRAS

L. Desorgher
SpaceIT GmbH, Bern

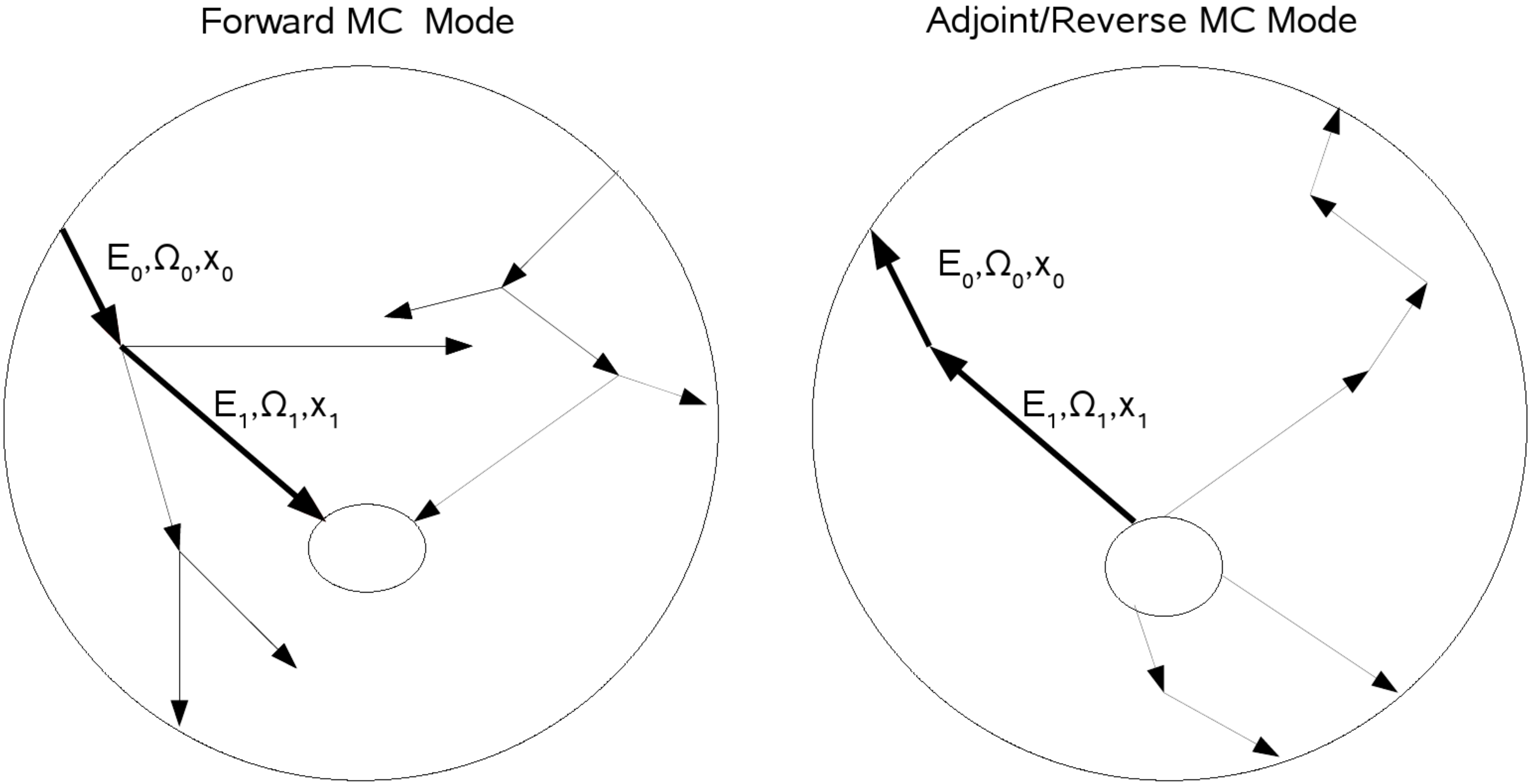
Overview

- Motivations
- Definition of Reverse Monte Carlo (RMC)
- RMC in Geant4
- RMC in GRAS
- Results Reverse vs Forward
- Conclusions

Motivations

- Monte Carlo codes as Geant4 are used to compute radiation effects on components in Space
- Accurate but very computing time consuming
- Need of biasing methods or approximations to speed up these codes
- Reverse Monte Carlo is one of these biasing methods
- The Reverse Minte Carlo method has been implemented in Geant4 and GRAS

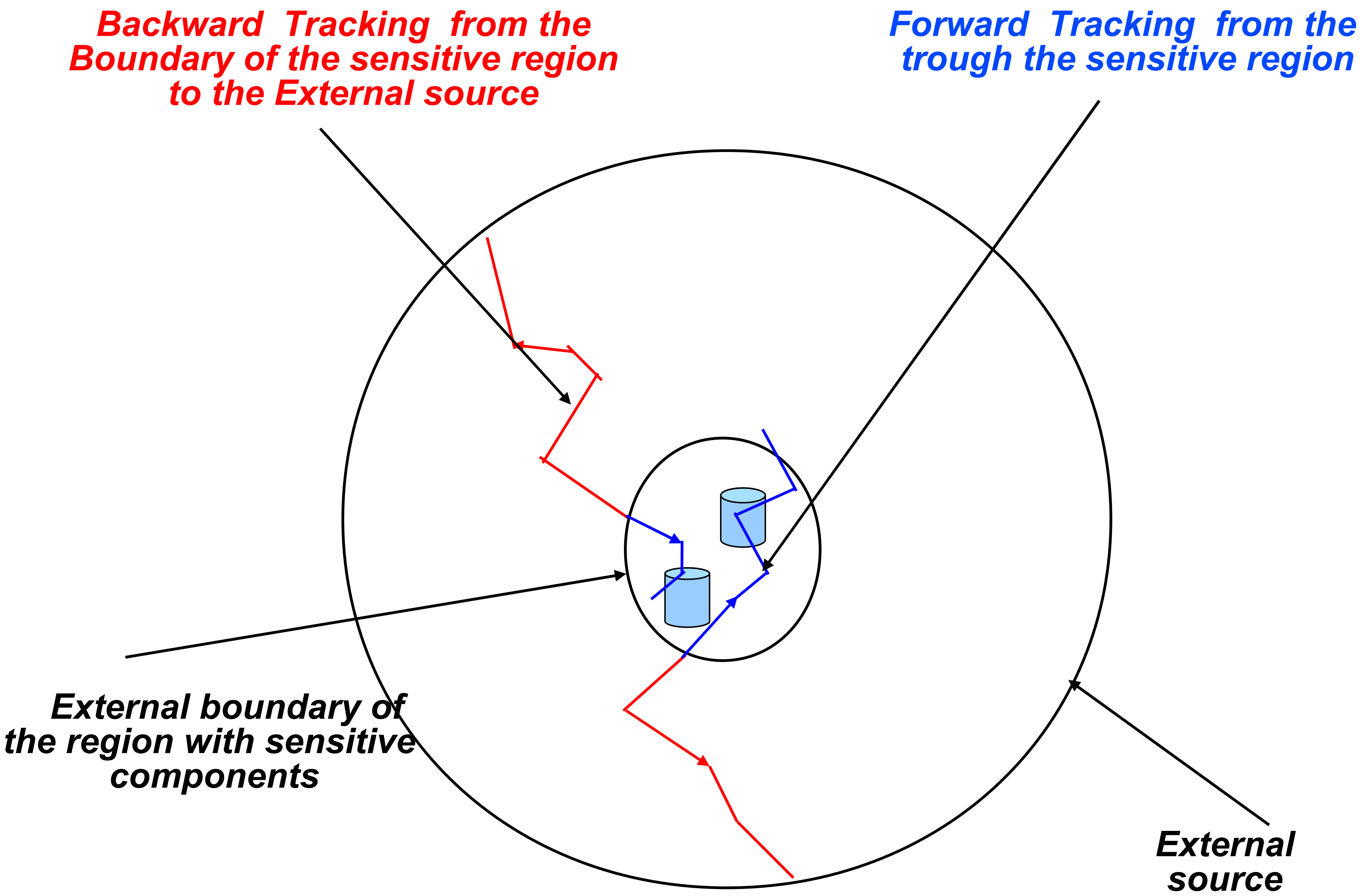
Reverse Monte Carlo method



- ***Start from the external source***
- ***Wasted Computing time for tracks that do not reach the sensitive region***

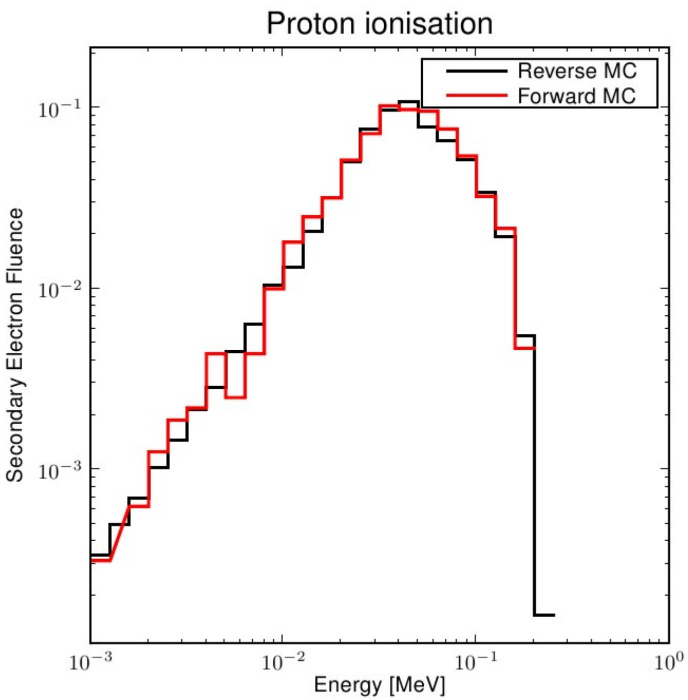
- ***Start from the sensitive region and compute reverse tracks till the external source***
- ***Computing time focuse mainly on tracks that reach the sensitive region***
- ***Much more rapid than forward MC for example to compute e-dose in tiny electronic components***
- ***But tricky while all the physics (cross section, kinematic,..) need to be reversed!!!***

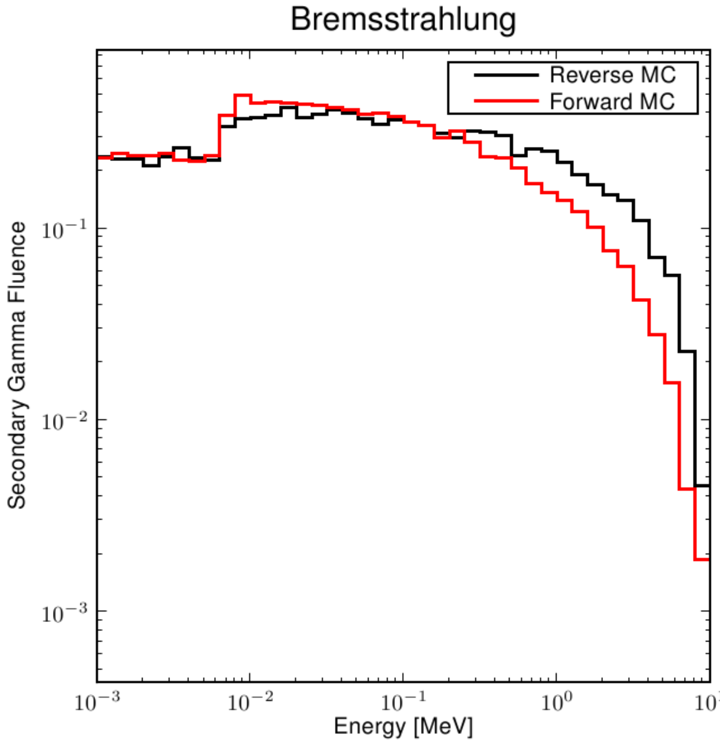
A reverse/adjoint run in Geant4 is a succession of reverse and forward trackings

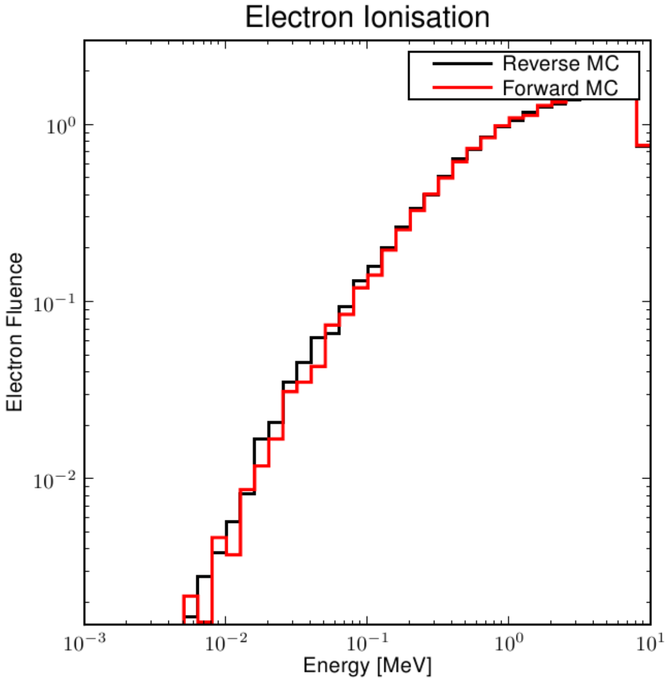


Implemented Reverse processes in Geant4

- ionisation (discrete and continuous) for e-, proton and ion
- multiple scattering
- bremsstrahlung
- Compton scattering
- photo-electric effect



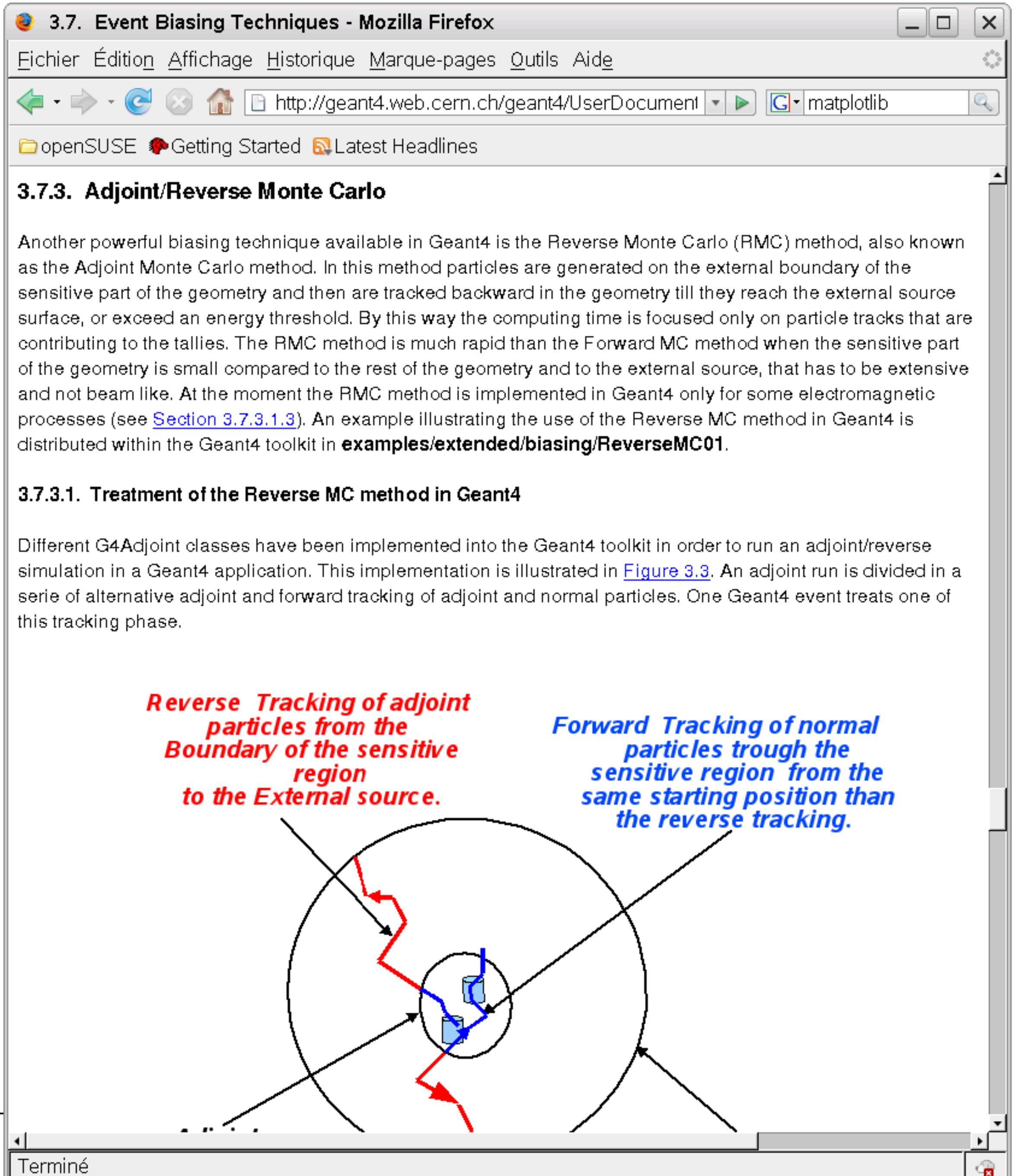




RMC method is available in Geant4 since the version G4.9.3

- Base adjoint classes and reverse processes distributed in the G4 toolkit
- Extended/biasing G4 example to illustrate the use of the RMC method in Geant4
- Documentation in the G4 user guide for application developer

•Publication accepted in NIMA
Desorgher et al., 2010


3.7. Event Biasing Techniques - Mozilla Firefox

Fichier Édition Affichage Historique Marque-pages Outils Aide

http://geant4.web.cern.ch/geant4/UserDocument

matplotlib

openSUSE Getting Started Latest Headlines

3.7.3. Adjoint/Reverse Monte Carlo

Another powerful biasing technique available in Geant4 is the Reverse Monte Carlo (RMC) method, also known as the Adjoint Monte Carlo method. In this method particles are generated on the external boundary of the sensitive part of the geometry and then are tracked backward in the geometry till they reach the external source surface, or exceed an energy threshold. By this way the computing time is focused only on particle tracks that are contributing to the tallies. The RMC method is much rapid than the Forward MC method when the sensitive part of the geometry is small compared to the rest of the geometry and to the external source, that has to be extensive and not beam like. At the moment the RMC method is implemented in Geant4 only for some electromagnetic processes (see Section 3.7.3.1.3). An example illustrating the use of the Reverse MC method in Geant4 is distributed within the Geant4 toolkit in **examples/extended/biasing/ReverseMC01**.

3.7.3.1. Treatment of the Reverse MC method in Geant4

Different G4Adjoint classes have been implemented into the Geant4 toolkit in order to run an adjoint/reverse simulation in a Geant4 application. This implementation is illustrated in Figure 3.3. An adjoint run is divided in a serie of alternative adjoint and forward tracking of adjoint and normal particles. One Geant4 event treats one of this tracking phase.

Terminé

Modification of a Geant4 code to use RMC

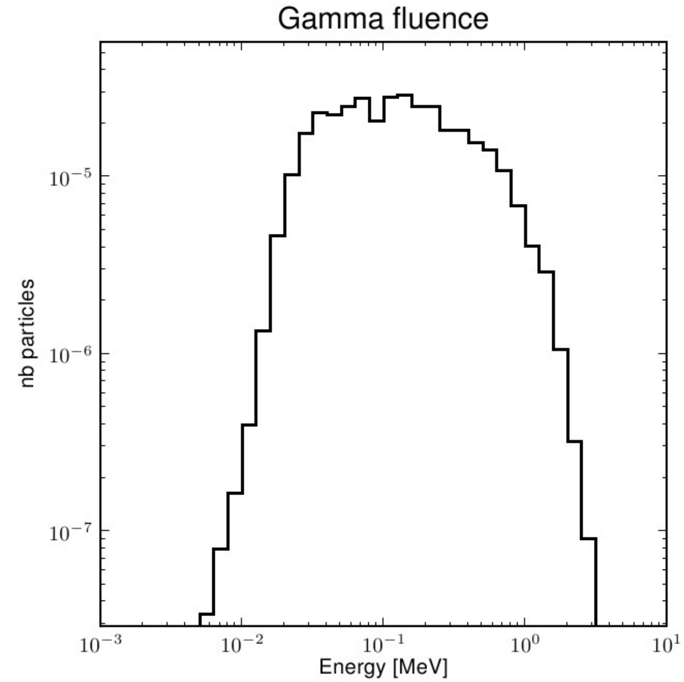
- Create the RMC manager in the main code
- Add adjoint/reverse processes in the physics list
- Update the analysis part of your Geant4 code for normalisation of weights.
- See G4 extended example biasing/ReverseMC01

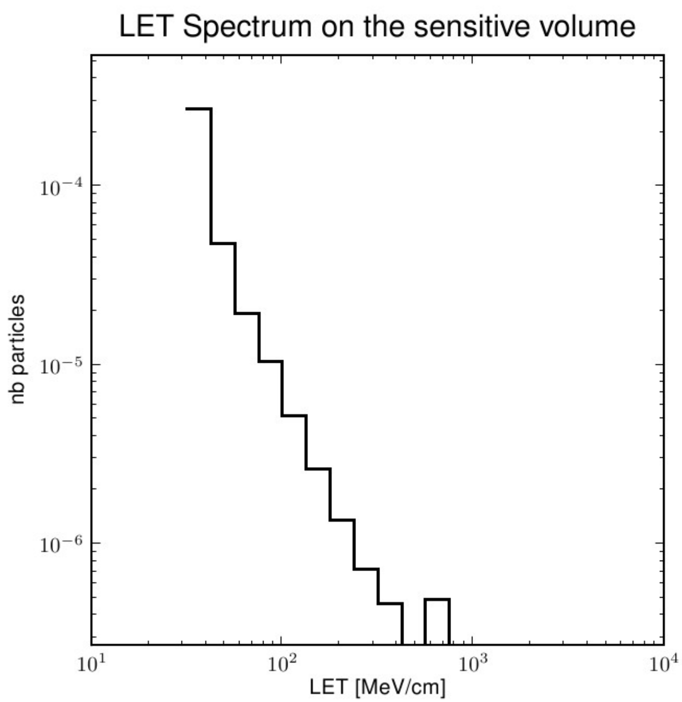
GRAS and RMC

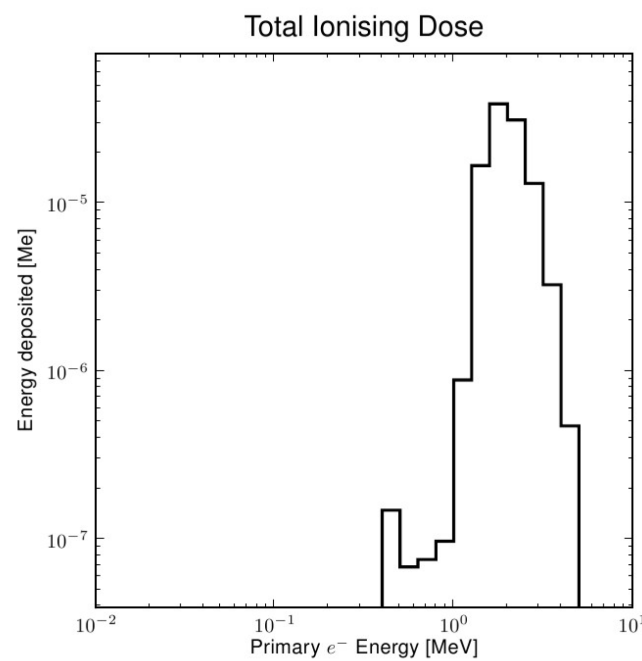
- Geant4 Radiation Analysis for Space
- Simplify the access of Geant4 for radiation analysis
- Availability of analyse modules for common radiation analysis
- It has been adapted during use the RMC method available in Geant4

Reverse MC in GRAS

- Same geometry definition
- Same definition of analysis modules
    - TID in sensitive volumes
    - Particle spectra
    - LET spectra
    - NIEL

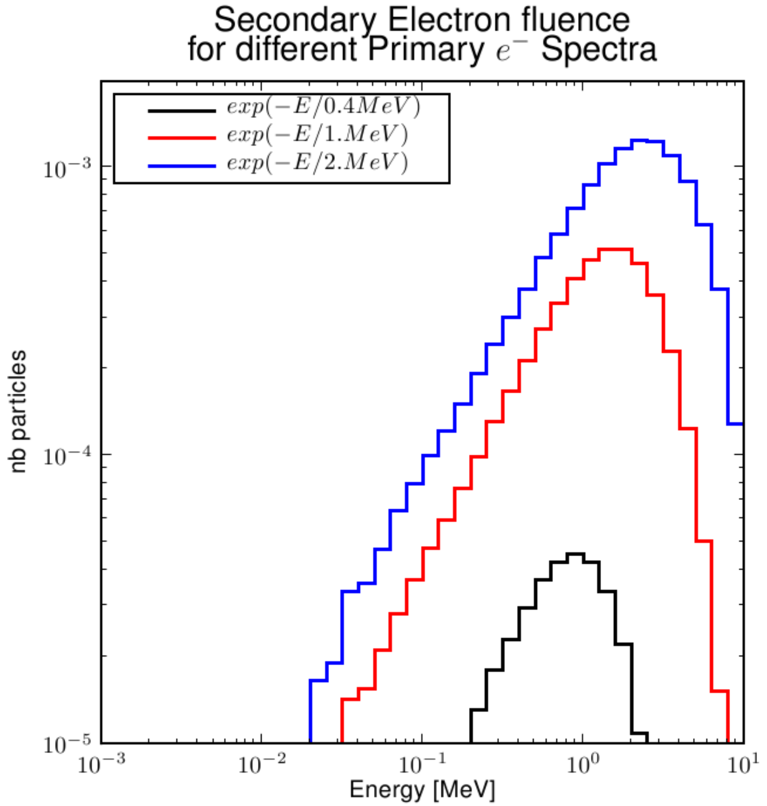






New fonctionalities of GRAS RMC compare to GRAS forward

- Direct normalisation
- Different primary particles and spectra can be specified
- File registering the convergence of the simulation results
- Automatic stop after a user defined Precision of the calculation is reached

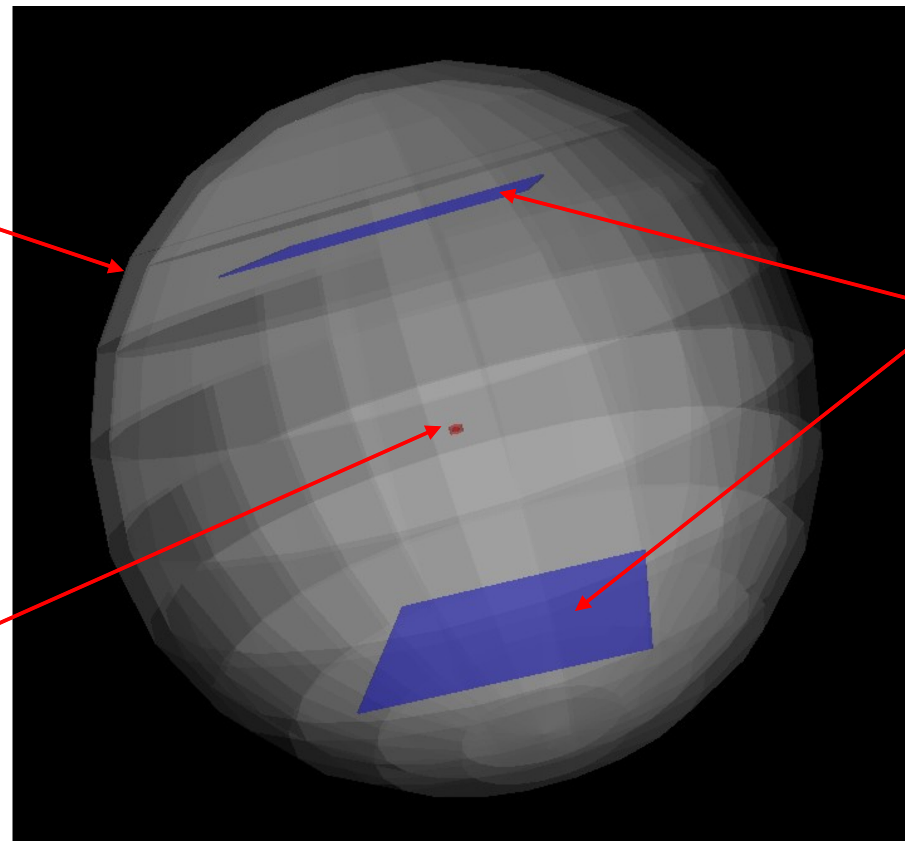


Edep[MeV]	error[MeV]	precision[%]	computing_time[s]
1.269958e-04	3.040472e-05	2.394151e+01	7.100000e-01
1.273392e-04	2.015732e-05	1.582962e+01	1.410000e+00
1.095371e-04	1.475086e-05	1.346654e+01	2.120000e+00
1.076673e-04	1.240530e-05	1.152188e+01	2.830000e+00
1.110131e-04	1.109077e-05	9.990506e+00	3.530000e+00
1.083752e-04	9.612224e-06	8.869392e+00	4.230000e+00
1.088696e-04	8.933815e-06	8.205979e+00	4.950000e+00
1.073973e-04	8.099489e-06	7.541612e+00	5.650000e+00
1.049121e-04	7.402633e-06	7.056033e+00	6.360000e+00
1.063614e-04	7.039227e-06	6.618214e+00	7.050000e+00
1.060443e-04	6.864397e-06	6.473142e+00	7.760000e+00
1.051760e-04	6.529784e-06	6.208434e+00	8.460000e+00
1.046732e-04	6.225381e-06	5.947446e+00	9.160000e+00
1.058603e-04	5.944663e-06	5.615575e+00	9.870000e+00
1.067215e-04	5.797705e-06	5.432557e+00	1.056000e+01
1.056946e-04	5.562687e-06	5.262980e+00	1.127000e+01
1.062925e-04	5.409596e-06	5.089349e+00	1.197000e+01
1.062974e-04	5.236012e-06	4.925813e+00	1.268000e+01
1.072061e-04	5.076824e-06	4.735574e+00	1.339000e+01
1.061439e-04	4.886851e-06	4.603985e+00	1.409000e+01

Simple Example : Energy deposited by e- and protons in a small sensitive Cylinder surrounded by a large aluminum shielding

Spherical Al shielding
Radius 10 cm
Thickness 2 mm

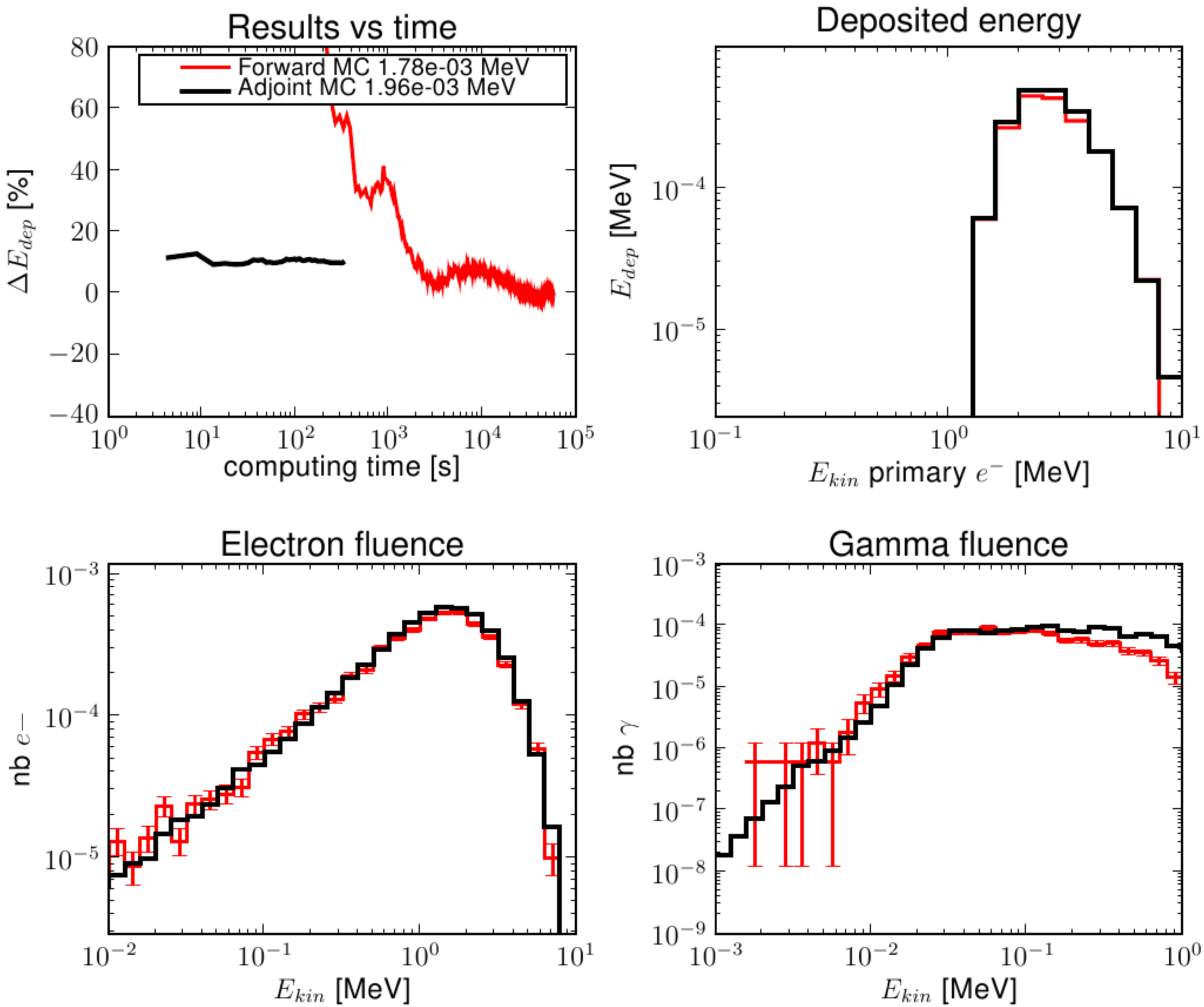
Small Si Sensitive Cylinder
Radius 1mm
Height 1 mm



Tantalum plates
0.5mm Thick

External Spherical source
Radius 10 cm
Primary Particles e- , and protons
Isotropic

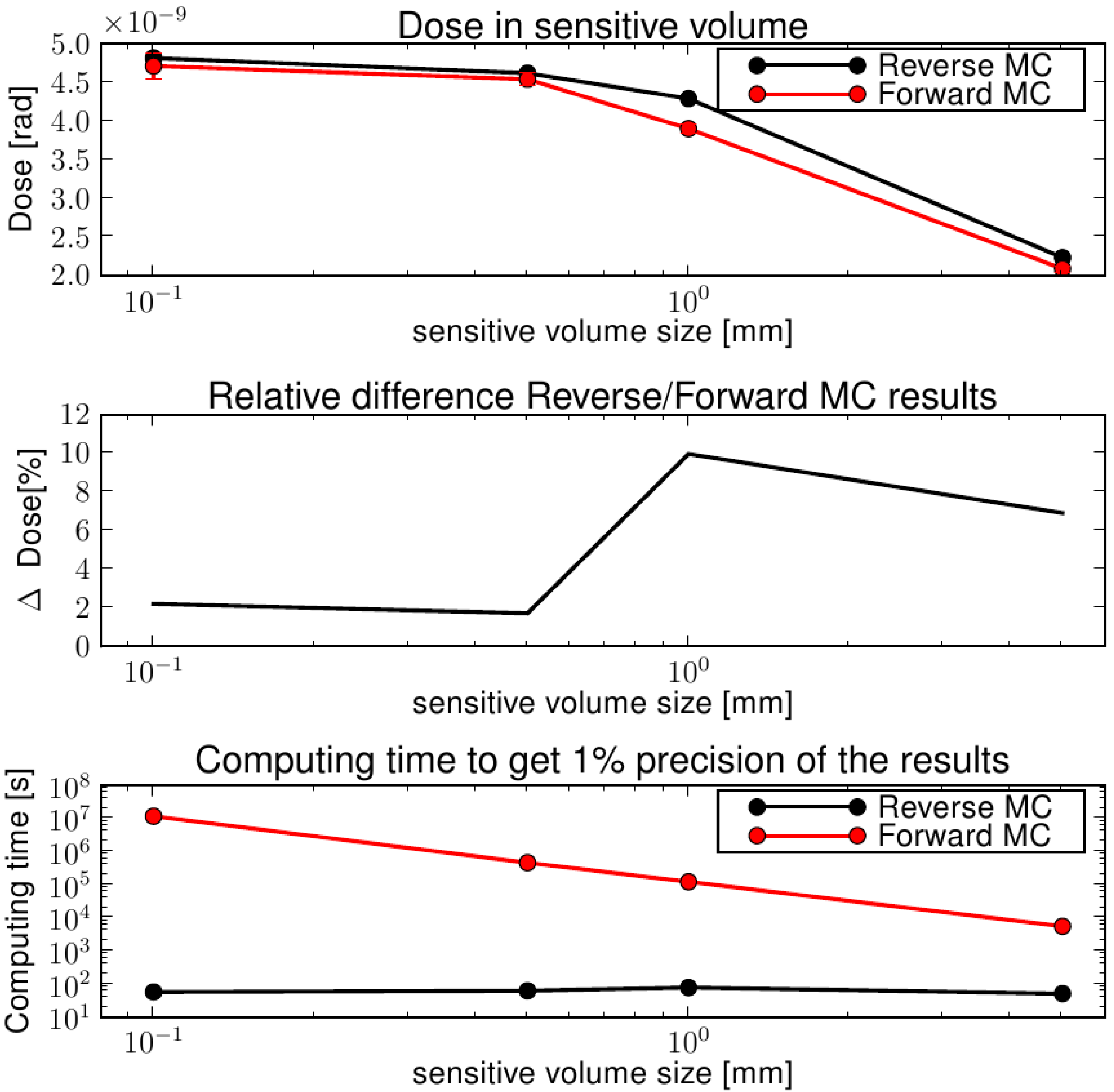
Comparison Reverse and Forward MC simulation



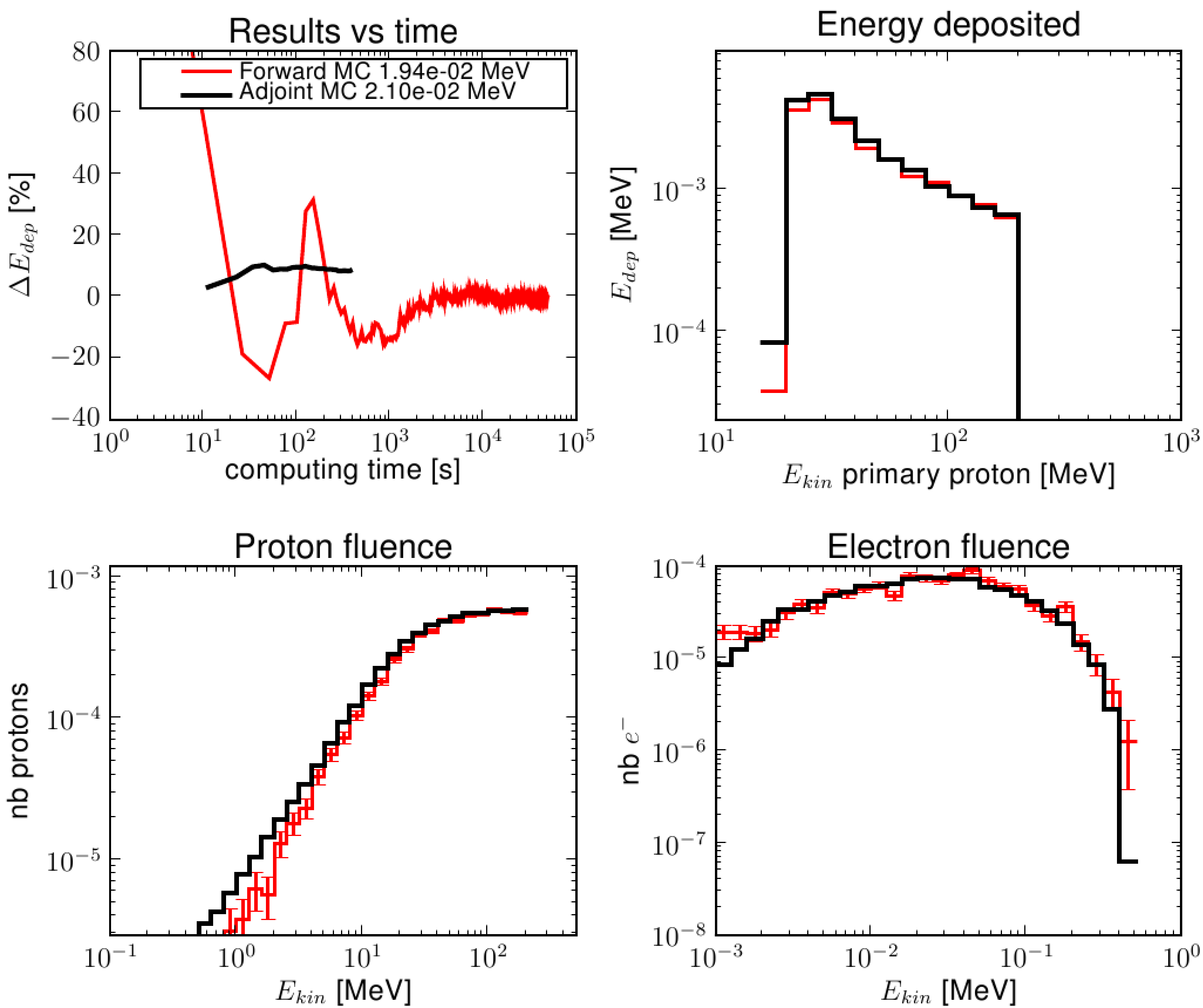
Primary source

- Electrons
- [1 keV, 10 MeV]
- spectrum *exp(-E/MeV)*

Scaling of the results with the size of the sensitive volume



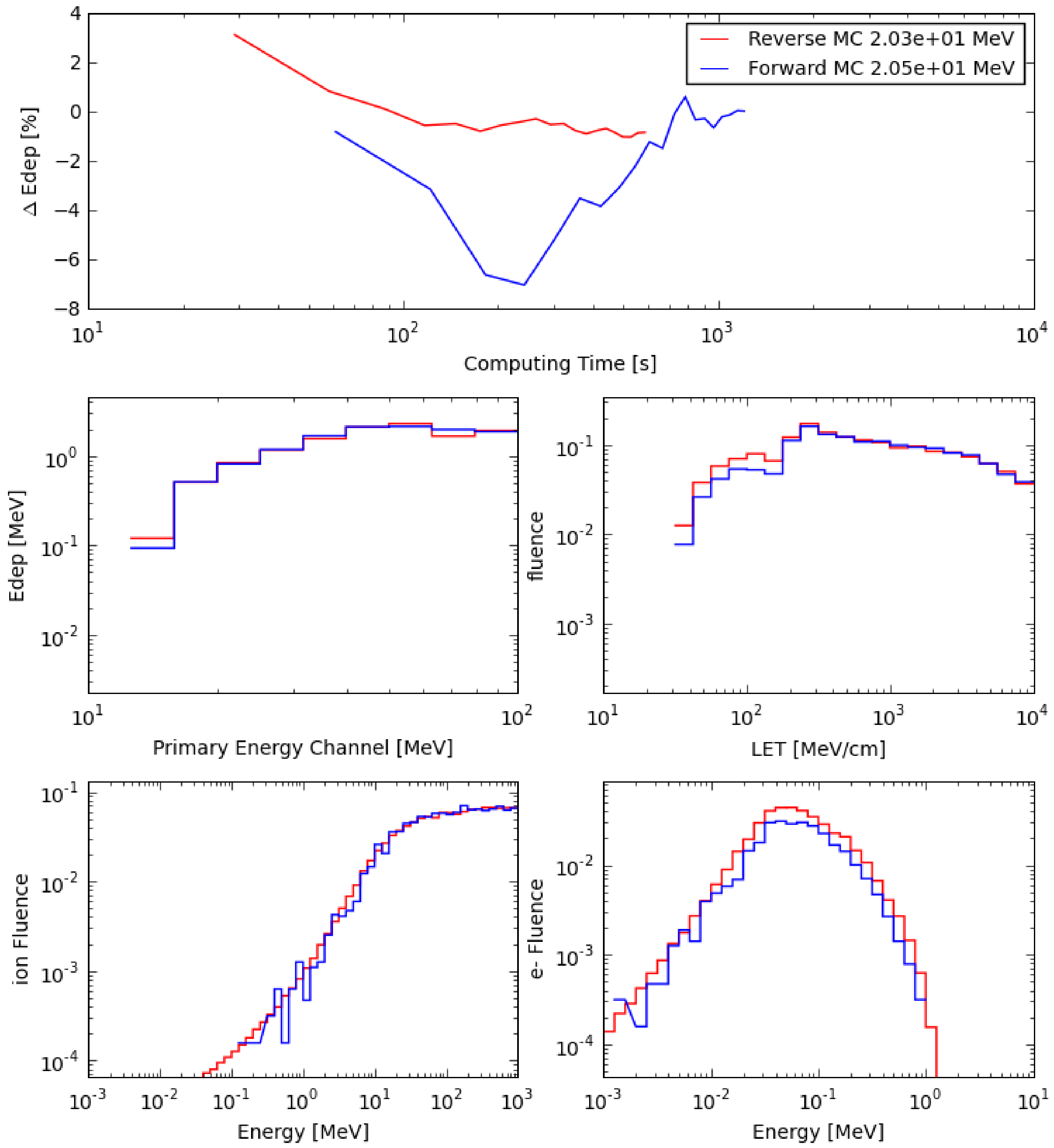
Comparison Reverse and Forward MC simulation



<u>Primary source</u>

- Protons
- [0.1keV, 200MeV]
- spectrum E^{-1}

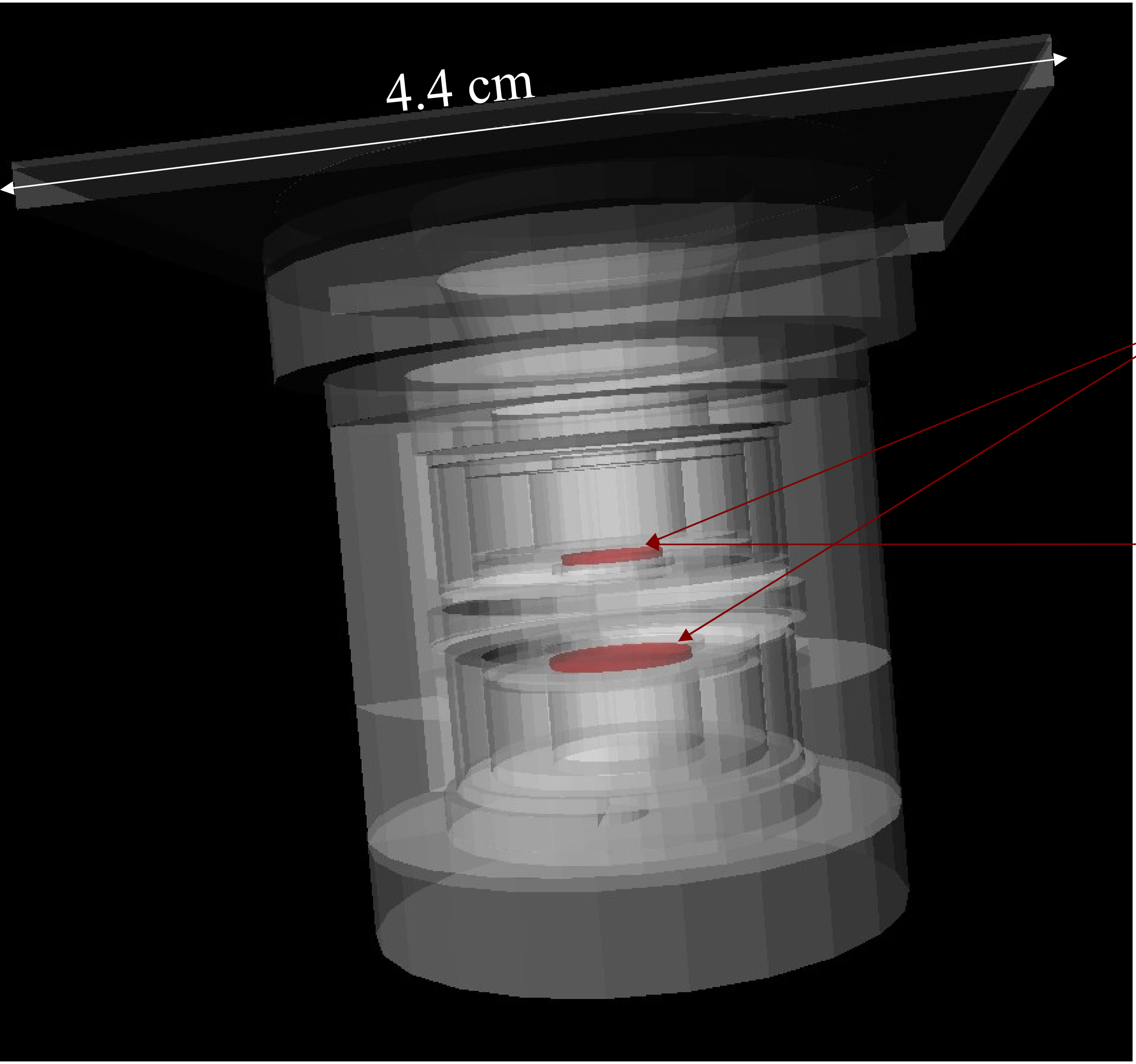
Bigger sensitive volume



<u>Primary source</u>

- Alpha particles
- [0.1, 200 MeV/nuc]
- spectrum *exp(-E/MeV)*

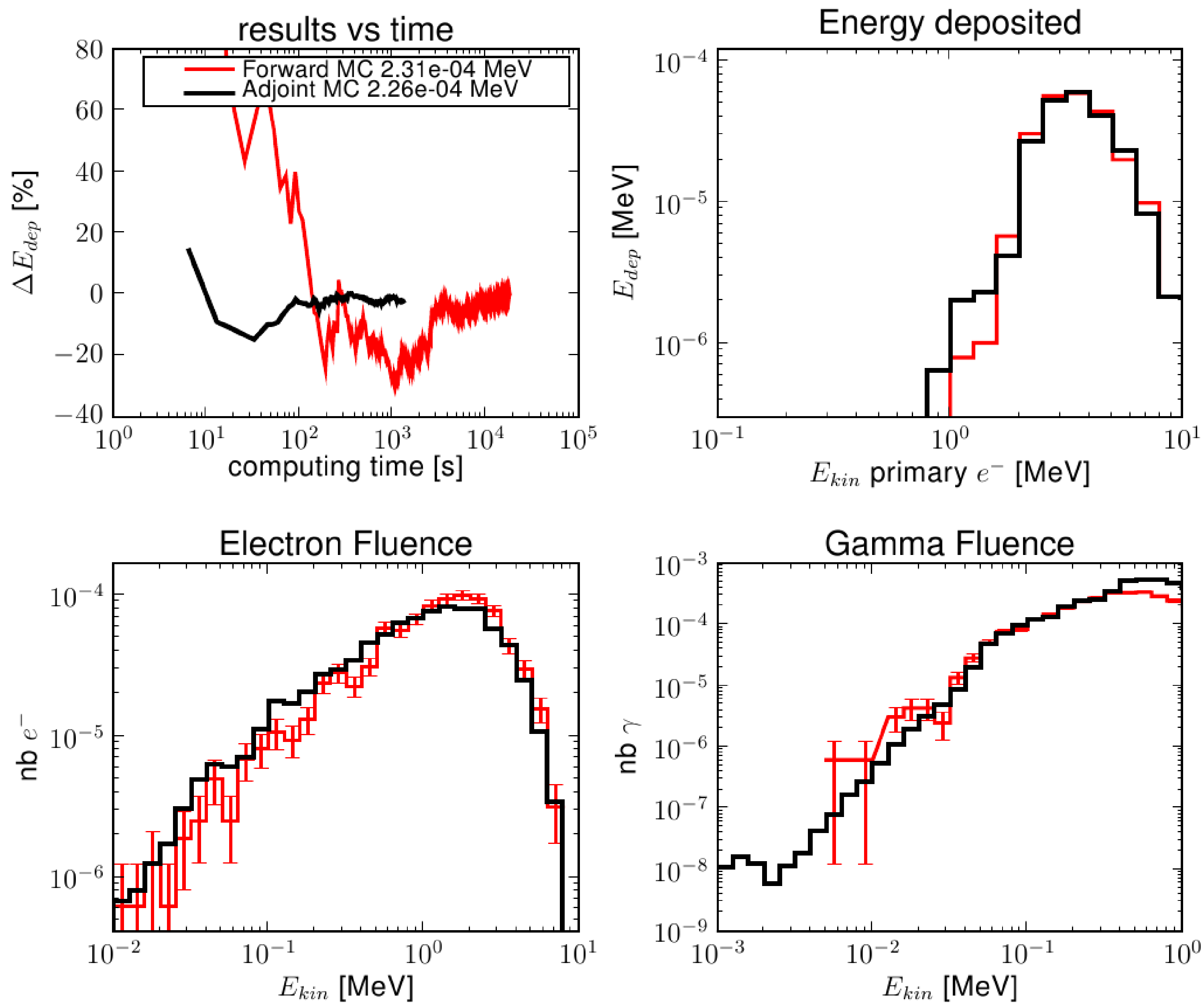
Test with part of the ESA SREM Detector



Silicium diodes surrounded by Al and Ta shielding

In this example we compute :
the dose in the top diode
the flux of secondaries on the top diode

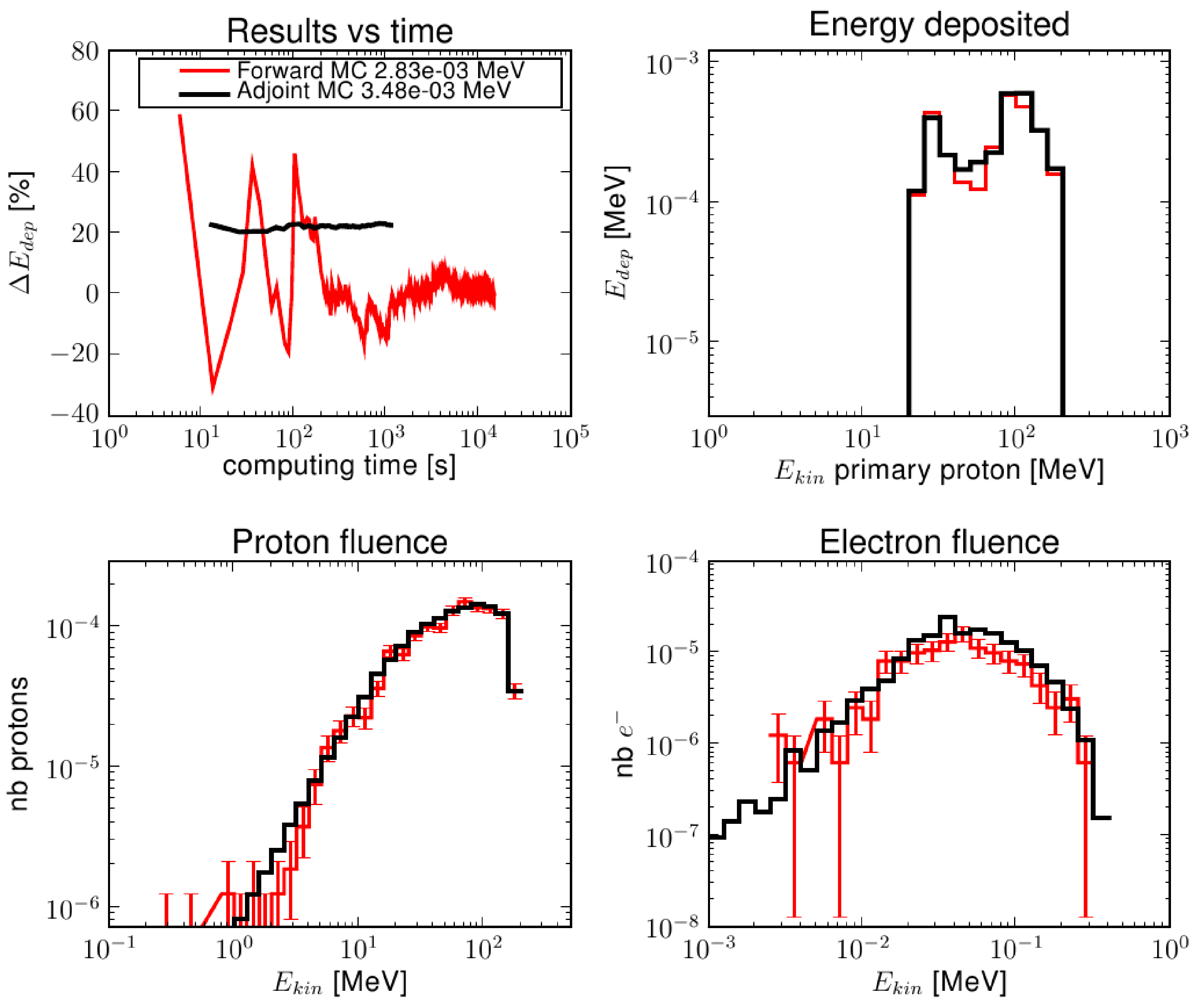
Comparison Reverse and Forward MC simulation



Primary source

- Electrons
- [1 keV, 10 MeV]
- spectrum *exp(-E/MeV)*

Comparison Reverse and Forward MC simulation



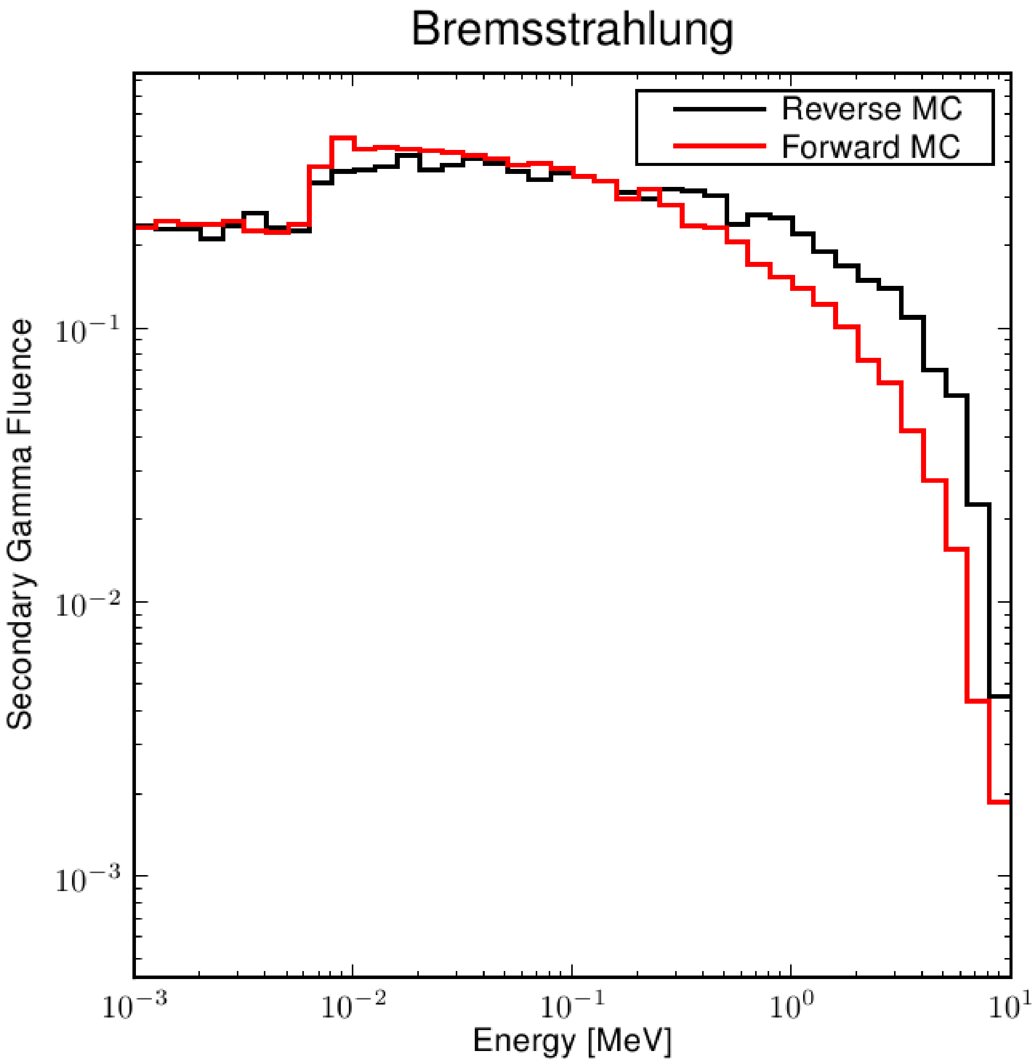
<u>Primary source</u>

- Protons
- [0.1keV, 200MeV]
- spectrum E^{-2}

Some Source of Discrepancies

- The flux of bremstrahlung gamma is bigger than in the forward case at high energy.

- The multiple scattering induce a ~5-10 % increase of the discrepancy



Conclusions and Future work

- We have succesfully implemented the Reverse MC method into Geant4 and in GRAS for rapid radiation dose computation

- The following reverse processes have been considered
  - Ionisation and multiple scattering for e- , protons an ions
  - Bremsstrahlung, Compton and photo-electric effects for e-

- The reverse MC method reaches precise results much more rapidly than the forward MC method

- The maximal discrepancy between the RMC and forward computed total dose is ~ 10-20 %

- Implementation in Spenvis?

- Improvement of the bremstrahlung and multiple scattering is under investigation to decrease the discrepancies

Acknowledgements

<u>G4 Collaboration</u>

M. Asai, M. Verderi, J. Apostolakis,
V. Ivantchenko, G. Cosmo, Fan Lei,
P.Truscott, G Santin, P.Nieminen