

The importance of delta rays when simulating silicon telescopes of submillimeter thickness: a cross test with several Monte Carlo codes

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ALTEA geometry

Simulation of
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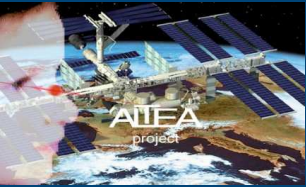
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ALTEA-Space experiment

Experiment description



ALTEA-space is a space-based experiment performed on the ISS (USLab module) between August 2006 and July 2007

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STRUCTURE

- Six silicon telescopes mounted on a helmet (3-d structure)
- Six striped silicon planes (x-y positions) for each telescope

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MEASUREMENTS

- ✓ Characterization of the radiation field inside the ISS (DOSI) -> Identification of ions with charge $5 \leq Z \leq 26$
- ✓ Study of the light flashes -> measurements in collaboration with astronauts (CNSM)

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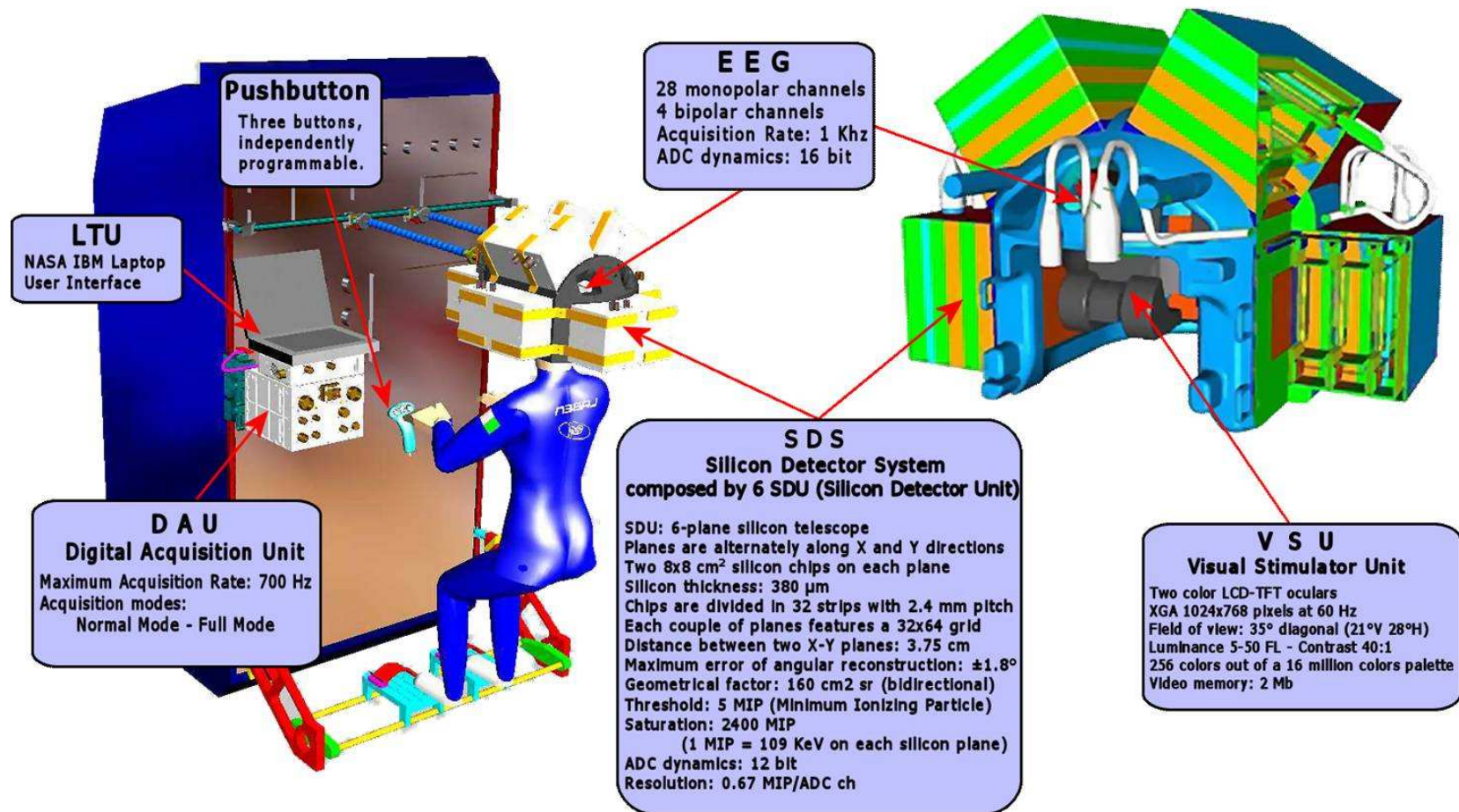
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1. Calibration data - one box tested with monochromatic beams
2. ALTEA-Space DOSI - energy spectrum of ions with charge $5 \leq Z \leq 26$ and energy above ≈ 200 MeV/nucleon)
3. ALTEA-Space CNSM - energy spectrum of particles passing through the eyes



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PHITS code

PHITS (Particle and Heavy Ion Transport System) is a three-dimensional Monte Carlo code developed by RIST, JAEA and KEK (Japan) and Chalmers (Sweden)

PROS

- + transport of all ions ($1 \leq Z \leq 26$)
- + contains a very accurate heavy-ion reaction model (JQMD)
- + reproduces complex 3-D geometries
- + conservation of energy and momentum event by event
- + flexible tallies

PHITS has been successfully tested on several ground- and space-based experiments



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Calibration with PHITS

Comparison with experiments performed at the GSI (Germany)

Simulation details:

Geometry - 1.3 mm of aluminum + 1 plane of silicon (0.38 mm)

Beam - C 100, 600 and 1000 and Ti 200 MeV/nucleon



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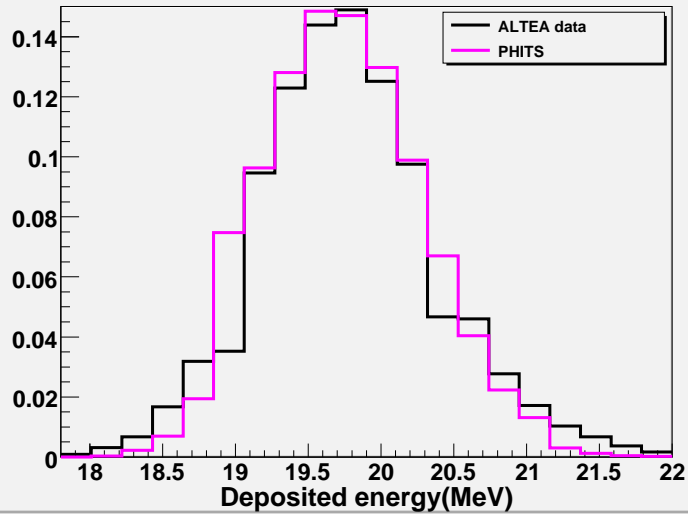
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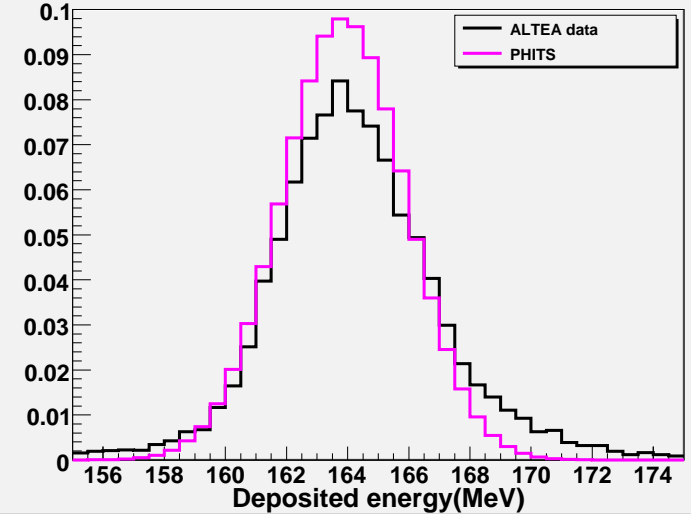
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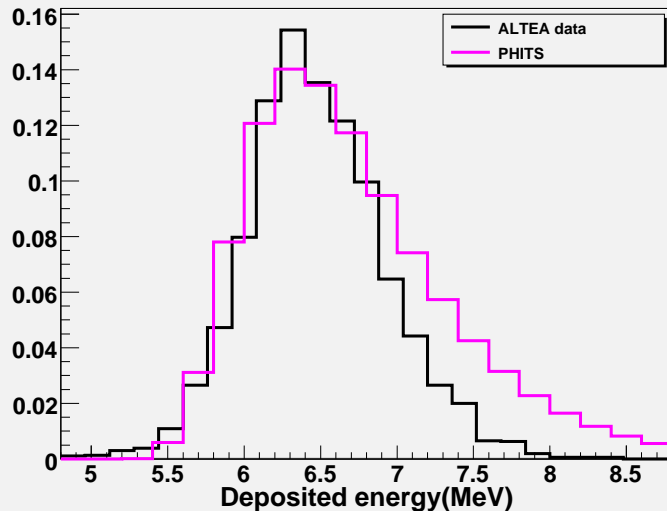
C 100 MeV/nucleon



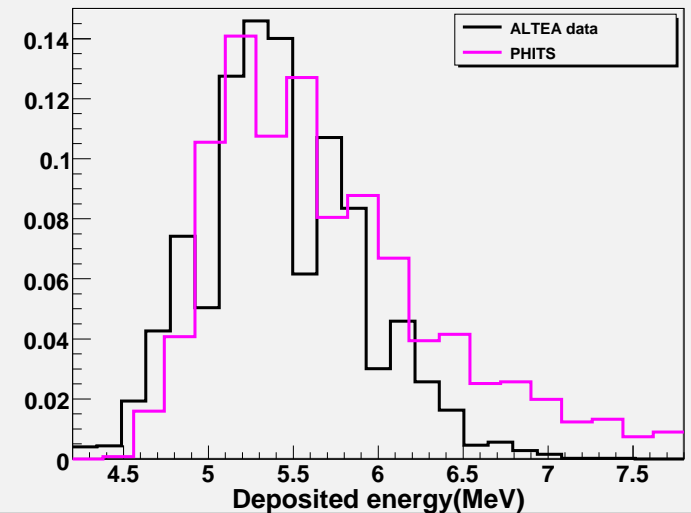
Ti 200 MeV/nucleon



C 600 MeV/nucleon



C 1000 MeV/nucleon



Analysis of the results

- ✓ PHITS reproduces correctly the energy spectra of particles with low energy
- ✓ The simulated energy spectrum is broader and more landau-shaped than the experimental spectrum for high-energy particles

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Our hypothesis: **Delta rays**

- Neglected in PHITS where the energy lost by the particles is equal to the energy absorbed by the detector
- Their production and energy increases with increasing projectile energy -> increasing probability to escape the detector -> decreasing width of the energy spectrum (right side)



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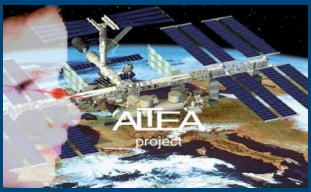
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Fluka results

Geant4 results

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Simulation with other Monte Carlo codes

To validate our hypothesis on the delta rays we run some simulation with Geant4 and Fluka

Simulation details

- ✓ Same geometry as used for PHITS simulations
- ✓ Run each beam with and without transporting the delta rays



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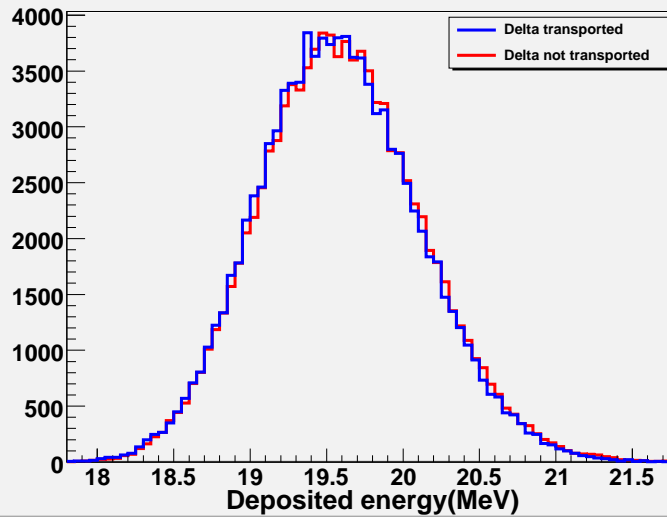
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Fluka results

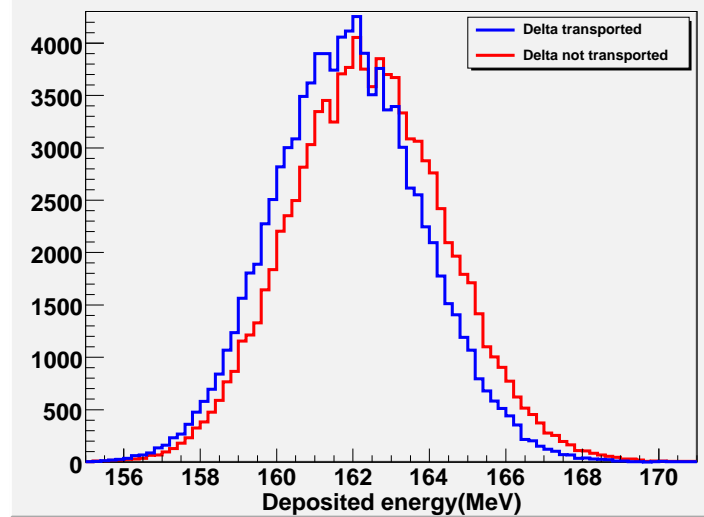
Geant4 results

Results and conclusions

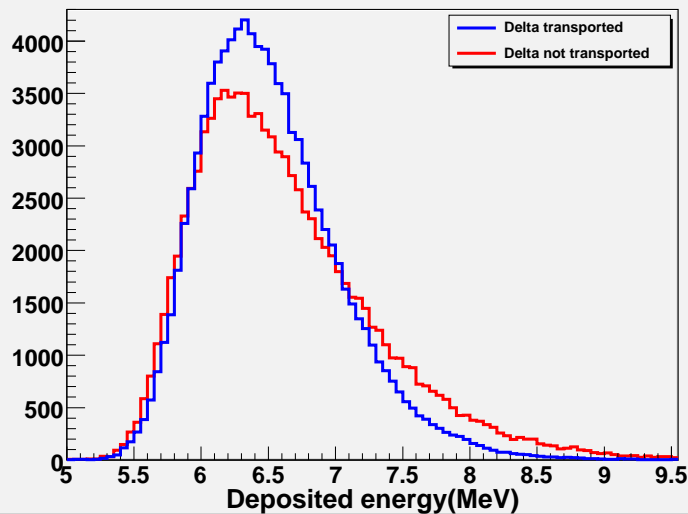
C 100 MeV/nucleon



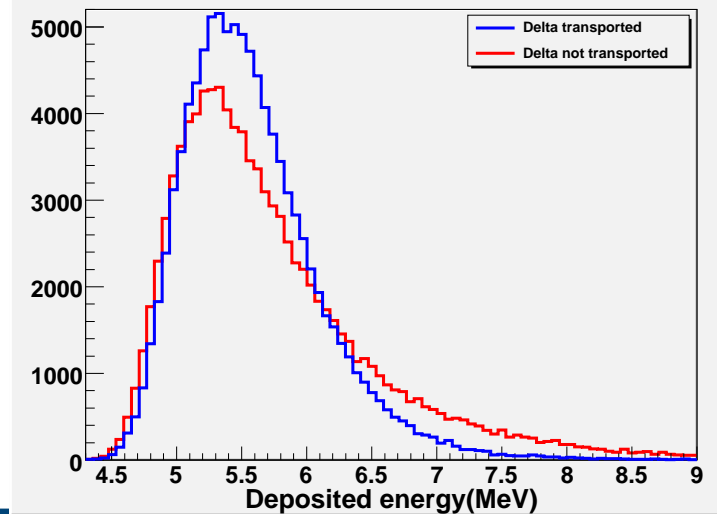
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Geant4 results

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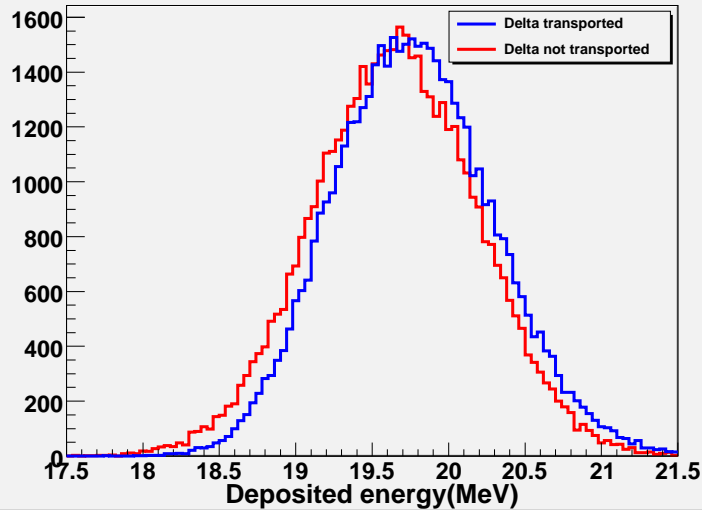
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Fluka results

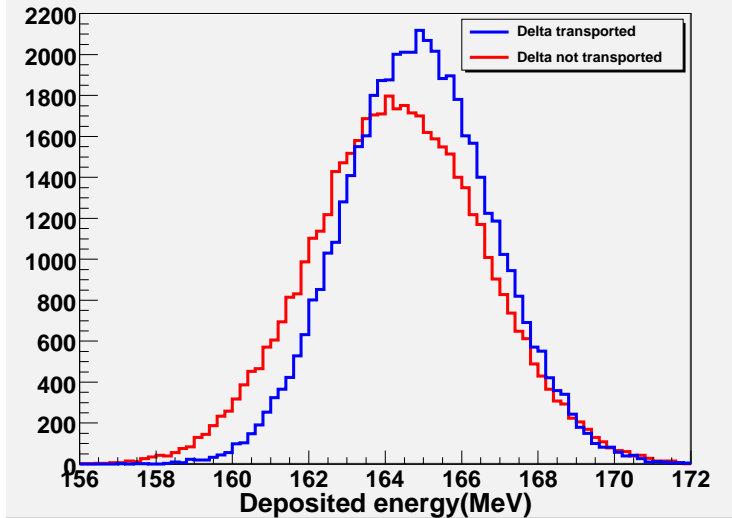
Geant4 results

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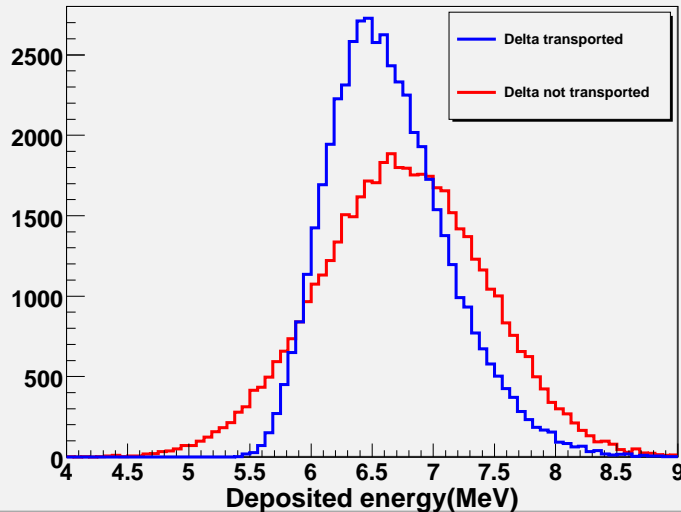
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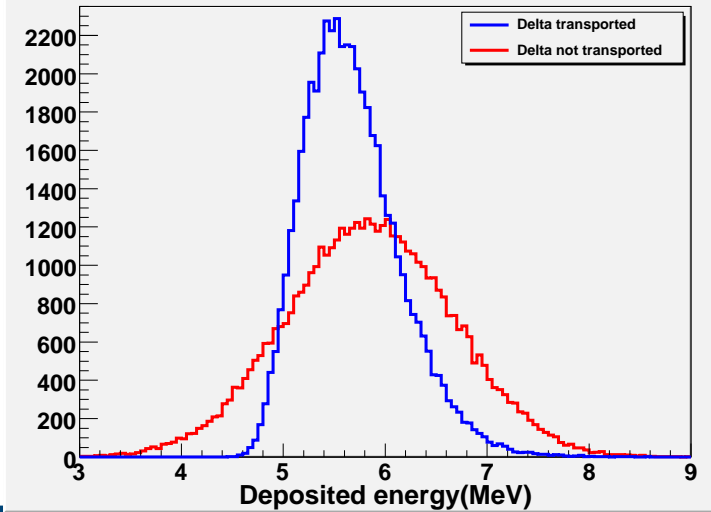
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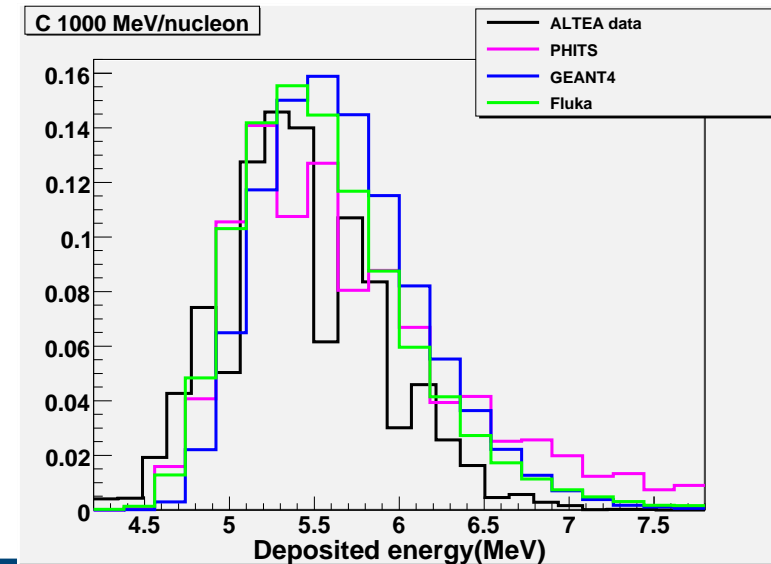
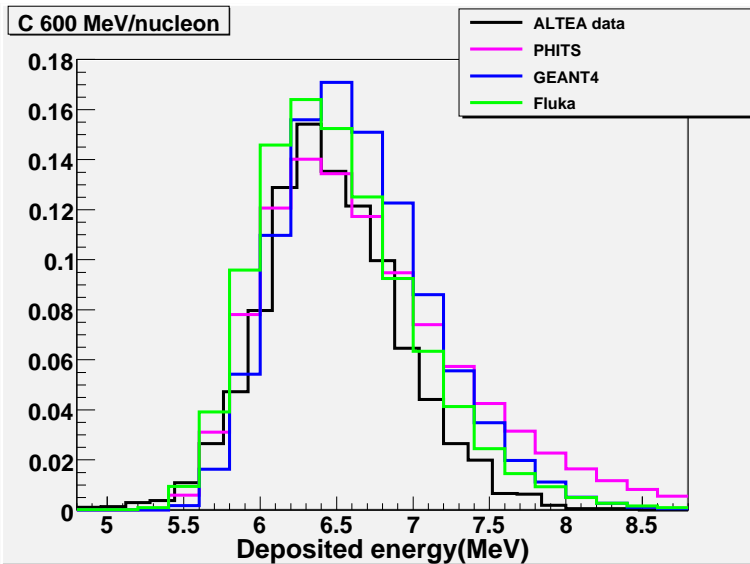
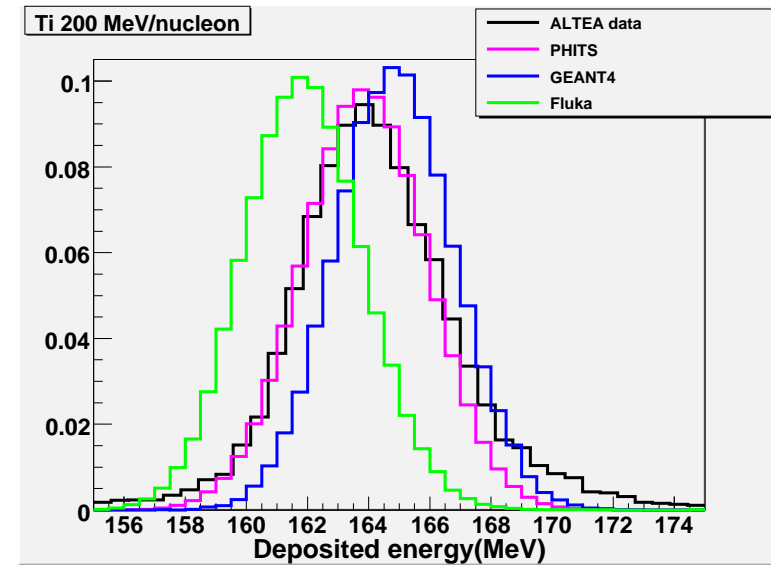
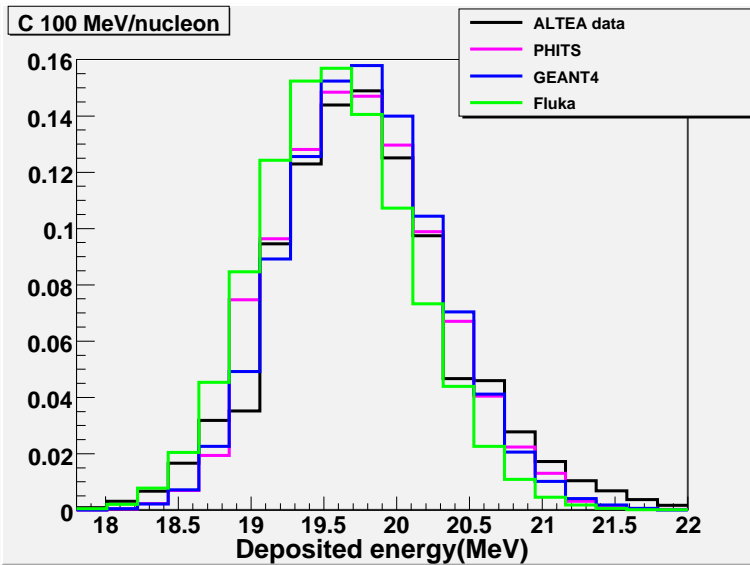
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Conclusions and future work

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- Both Geant4 and Fluka simulations confirmed the importance of the delta rays in the energy spectrum shape and width
- PHITS proved to be a competitive code even without including a model for the production and the transport of delta rays
- ✓ Further investigation on the discrepancy between PHITS and the experimental data
- ✓ Study of the available models for the production and transport of delta rays
- ✓ Benchmark of PHITS