

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

Chiara La Tessa¹, L. Di Fino¹, M. Larosa¹, L. Narici¹, P. Picozza¹,
V. Zaconte¹, D. Mancusi², K. Gustafsson³, L. Sihver³, K. Lee⁴



1. University of Rome “Tor Vergata”, Rome, Italy
2. University of Liège, Liège, Belgium
3. Chalmers University of Technology, Gothenburg, Sweden
4. Space Radiation Analysis Group, Johnson Space Center, NASA, Huston, Tx, USA

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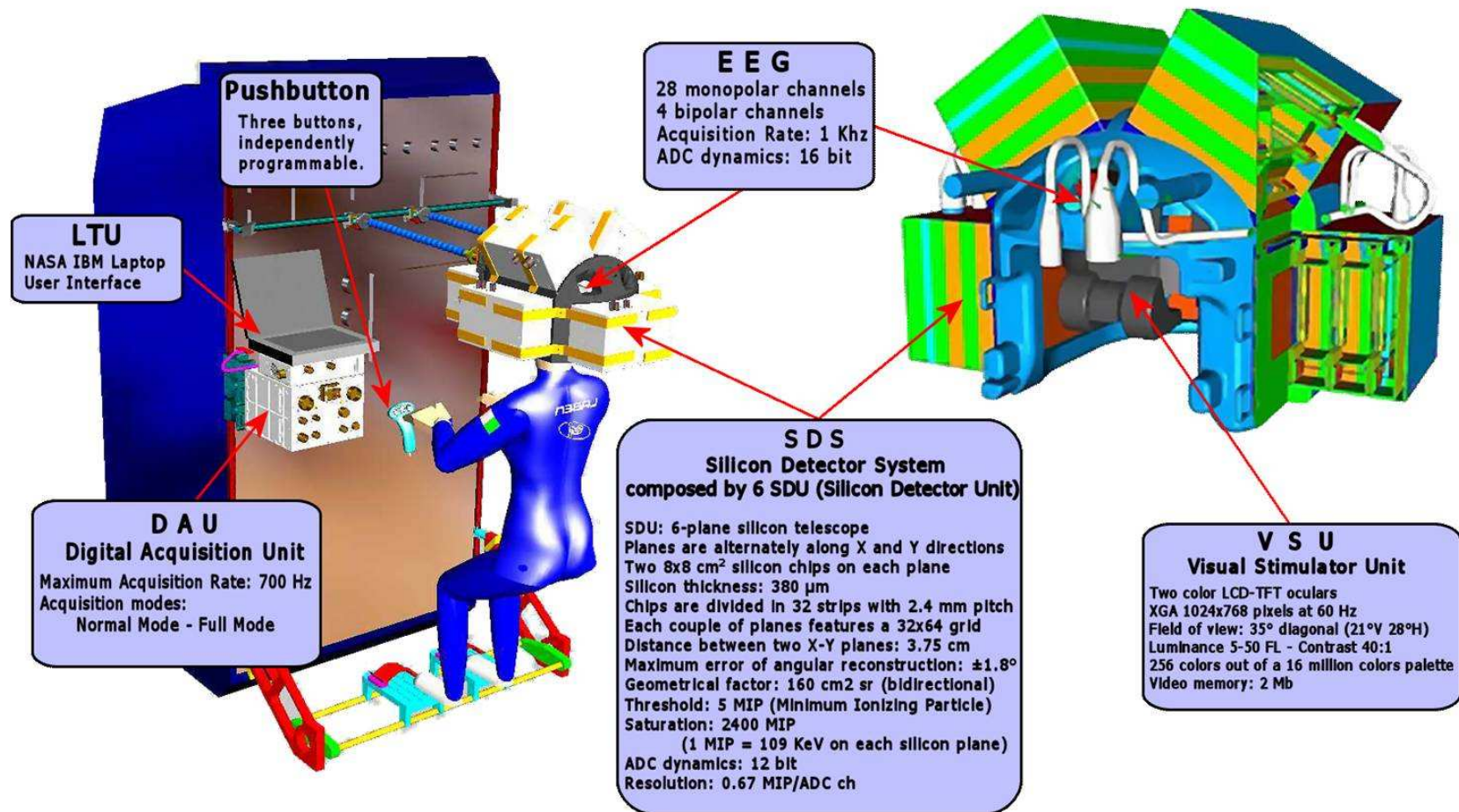
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1. Calibration data - one box tested with monochromatic beams
2. ALTEA-Space DOSI - energy spectrum of ions with charge $5 \leq Z \leq 26$ and energy above ≈ 200 MeV/nucleon)
3. ALTEA-Space CNSM - energy spectrum of particles passing through the eyes



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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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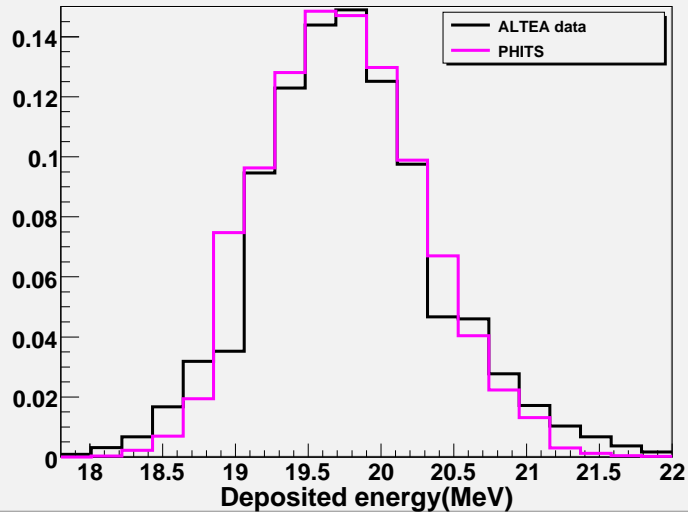
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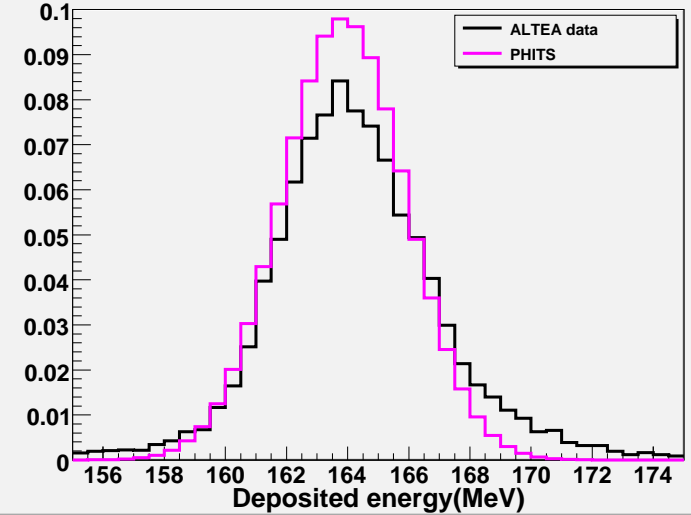
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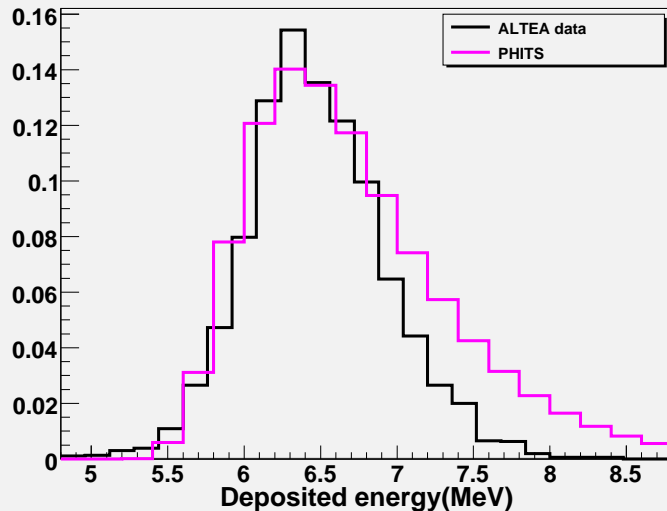
C 100 MeV/nucleon



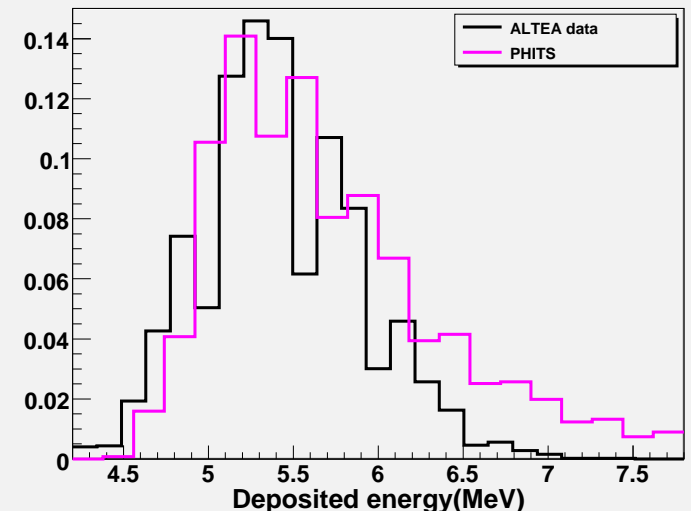
Ti 200 MeV/nucleon



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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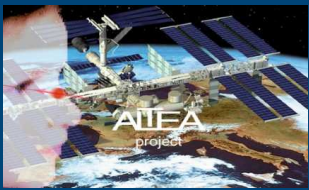
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Fluka results

Geant4 results

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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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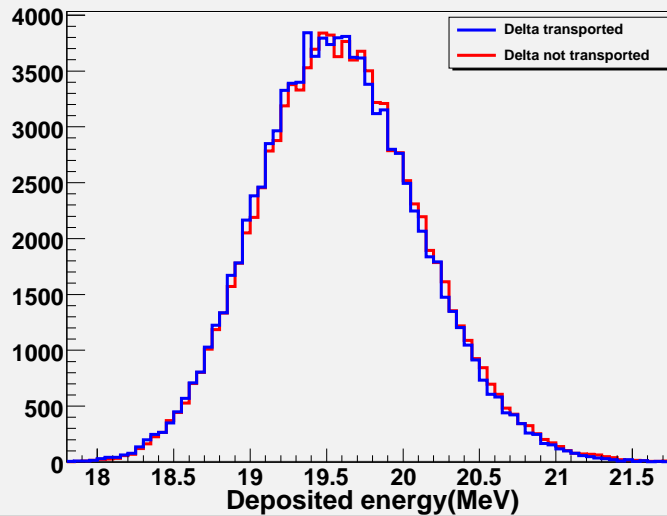
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Fluka results

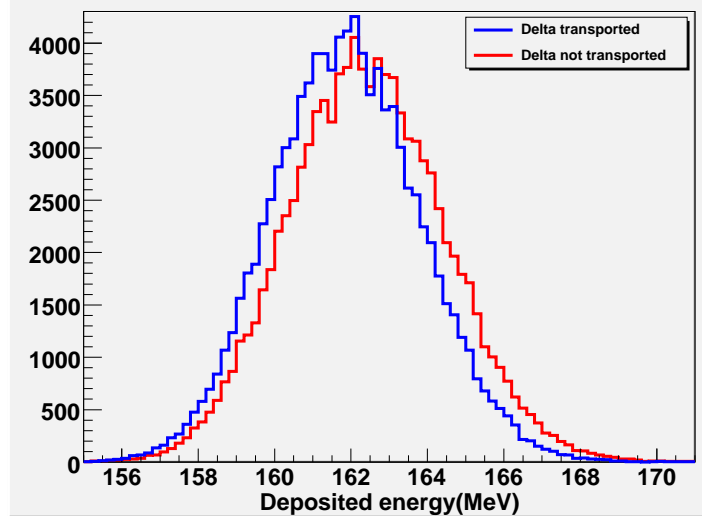
Geant4 results

Results and conclusions

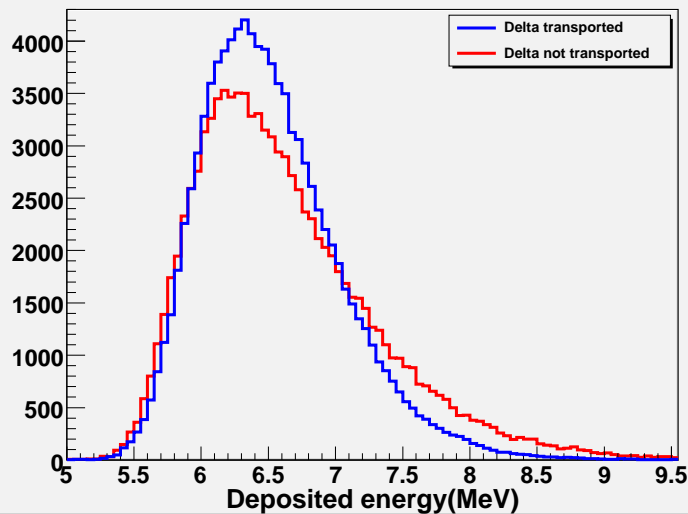
C 100 MeV/nucleon



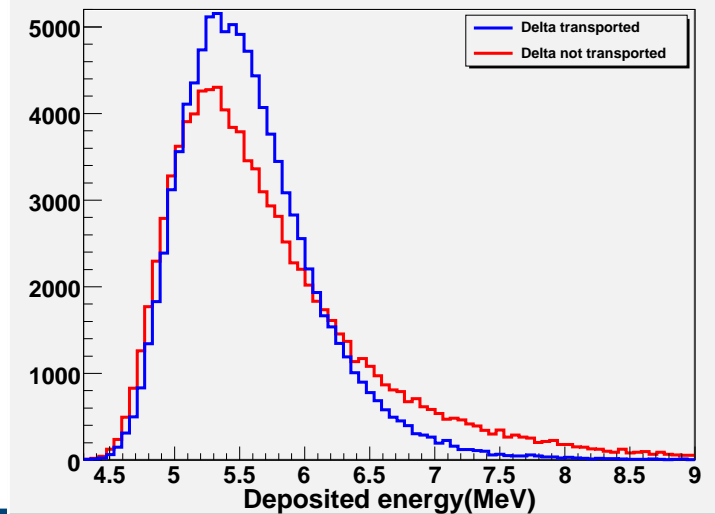
Ti 200 MeV/nucleon



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Geant4 results

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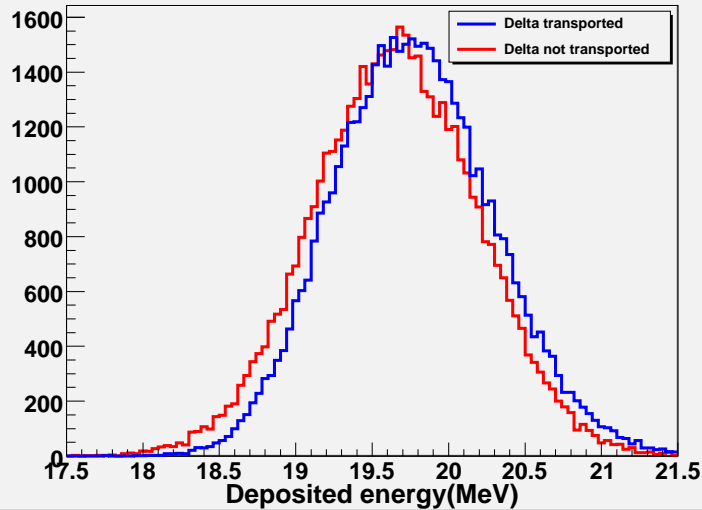
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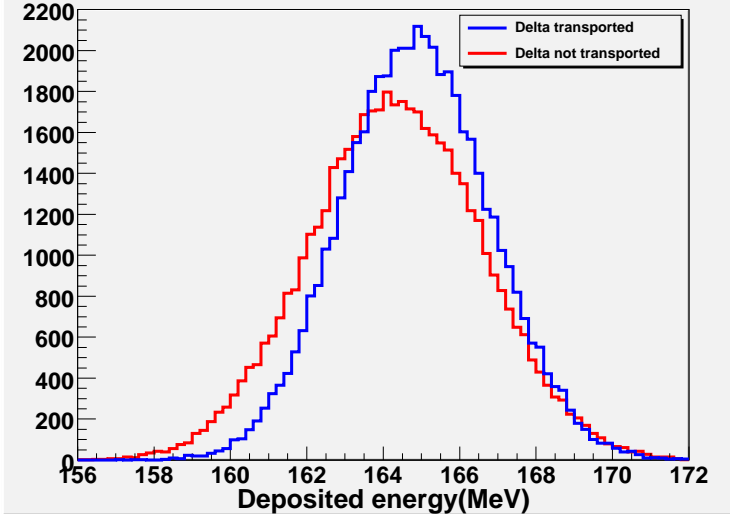
Geant4 results

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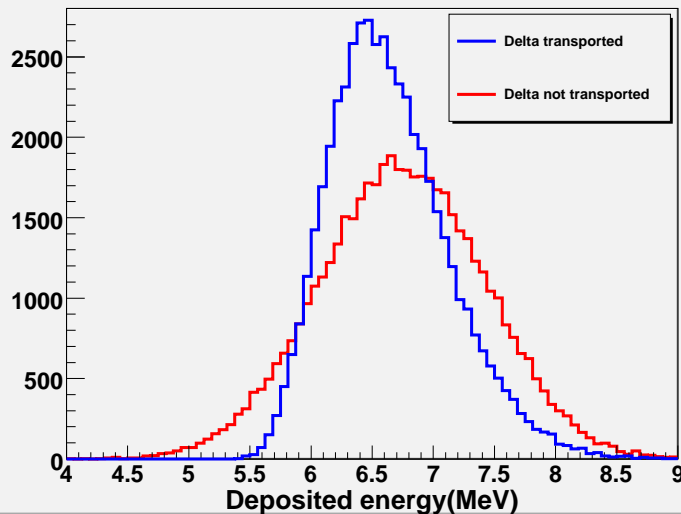
C 100 MeV/nucleon



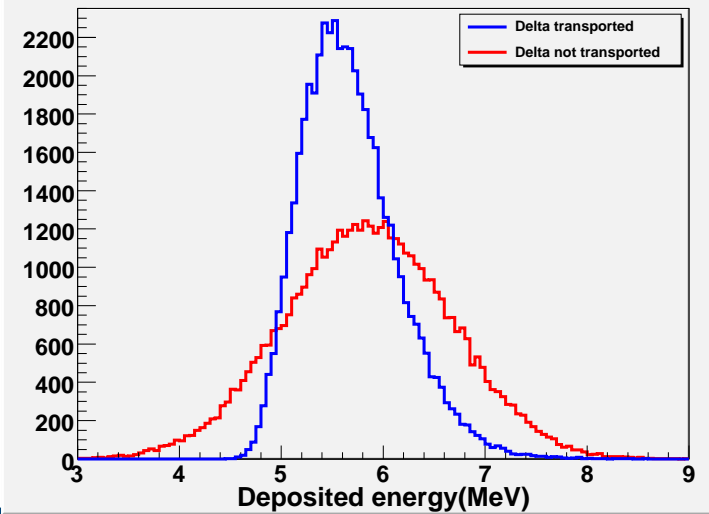
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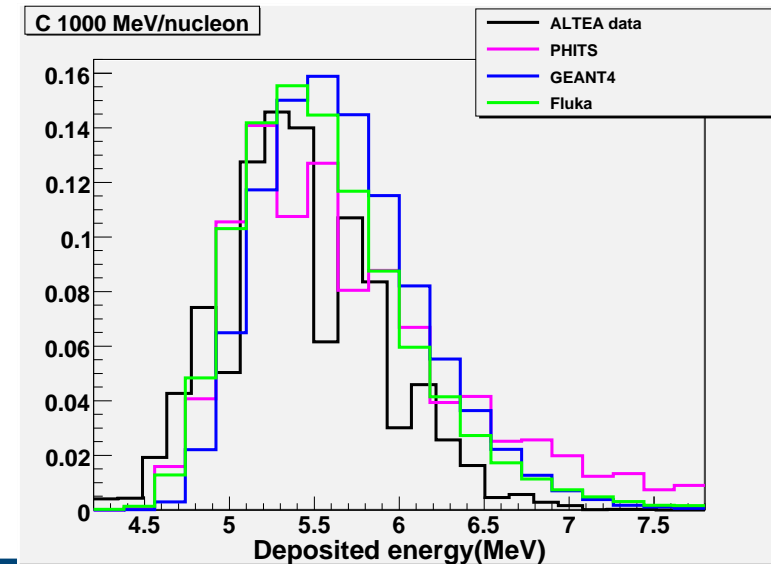
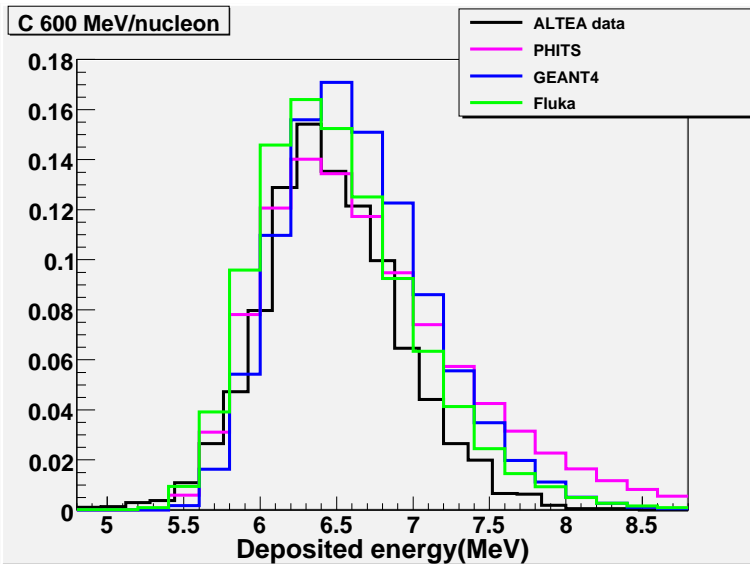
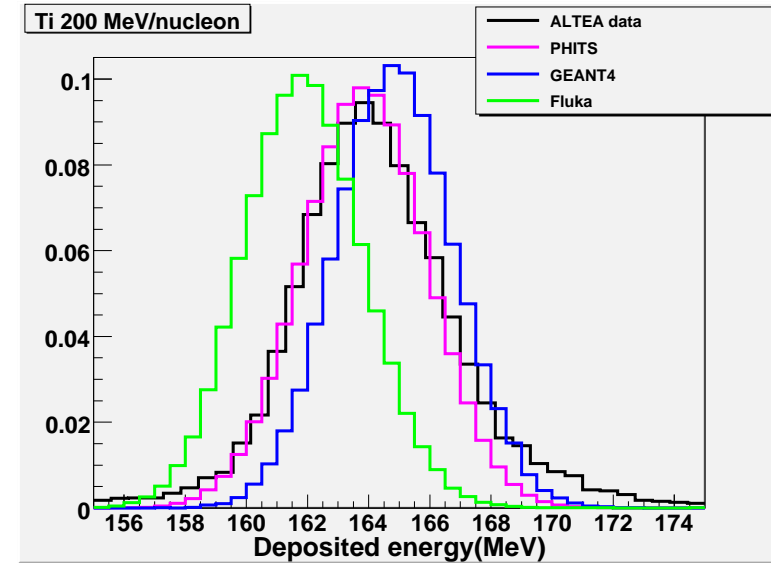
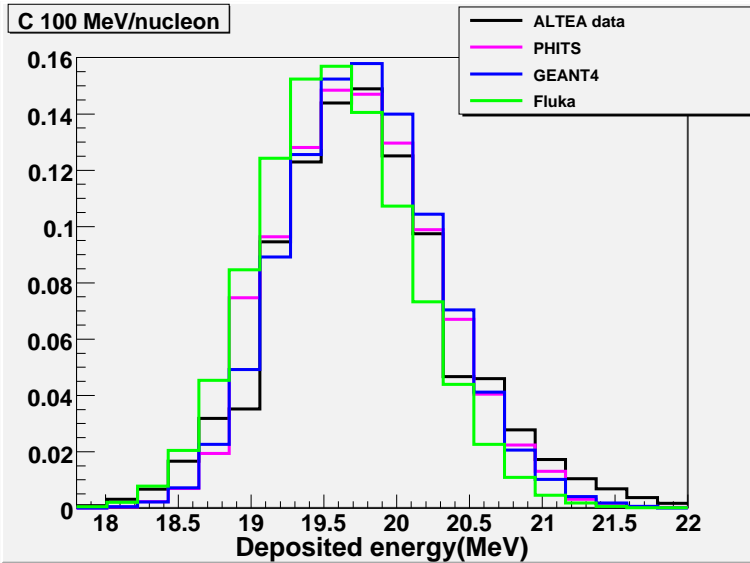
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Conclusions and future work

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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