A GPU Monte Carlo protons transport code for dose calculations : methods and challenges

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Context

- Main advantage of a proton therapy:
  - Reduce total energy deposited in patients
    - Finite range of protons in matter
    - Maximum energy deposit in their distal paths
- Uncertainty range reduction for protons with Monte Carlo simulations **(Paganetti 2012)**
  - 0.3 % in homogenous medium
  - 2.3 % for complex geometries
    - Several mm in terms of protons range

Goals

Monte Carlo simulations with Graphics Processors Units

- **This presentation aims to explain the implementation strategy and ways to address potential challenges**

- Allow a clinical use of Monte Carlo simulations
  - Reduce margins
  - Improve control and quality of treatment

- Use GPUs
  - Accelerate Monte Carlo dose calculation algorithms

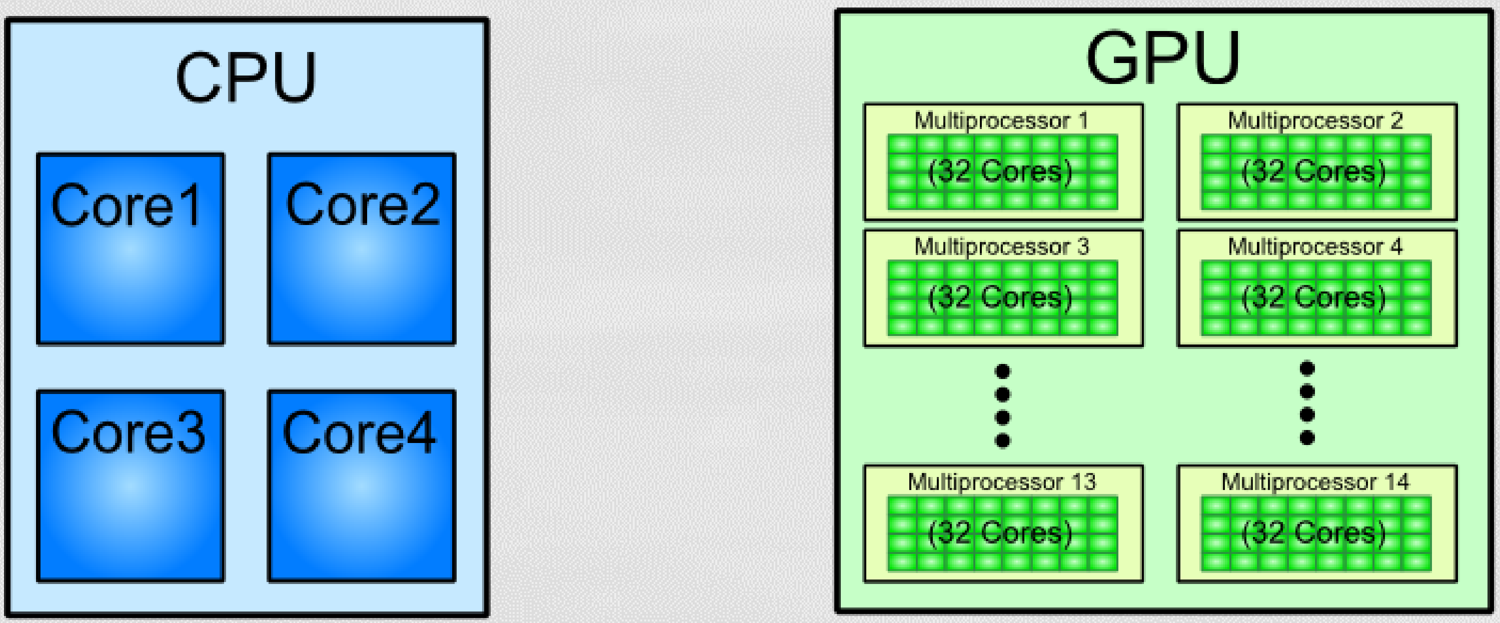
- Implement a Monte Carlo proton transport code in GPUMCD
  - GPUMCD, a validated Monte Carlo dose calculations algorithm for photons and electrons **(Hissoiny 2011)**

Materials

NVIDIA GEFORCE GTX TITAN

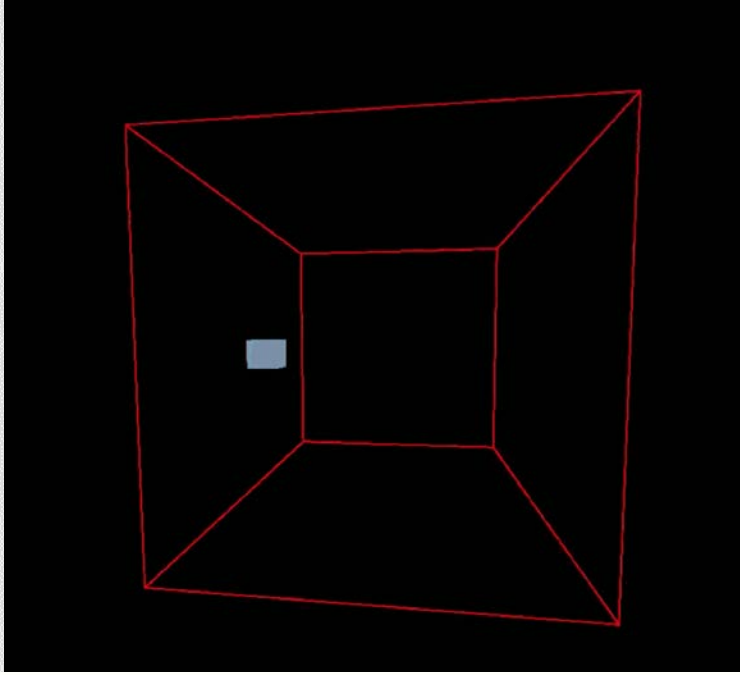
- 2688 cores
- 86016 particles simultaneously
- CUDA

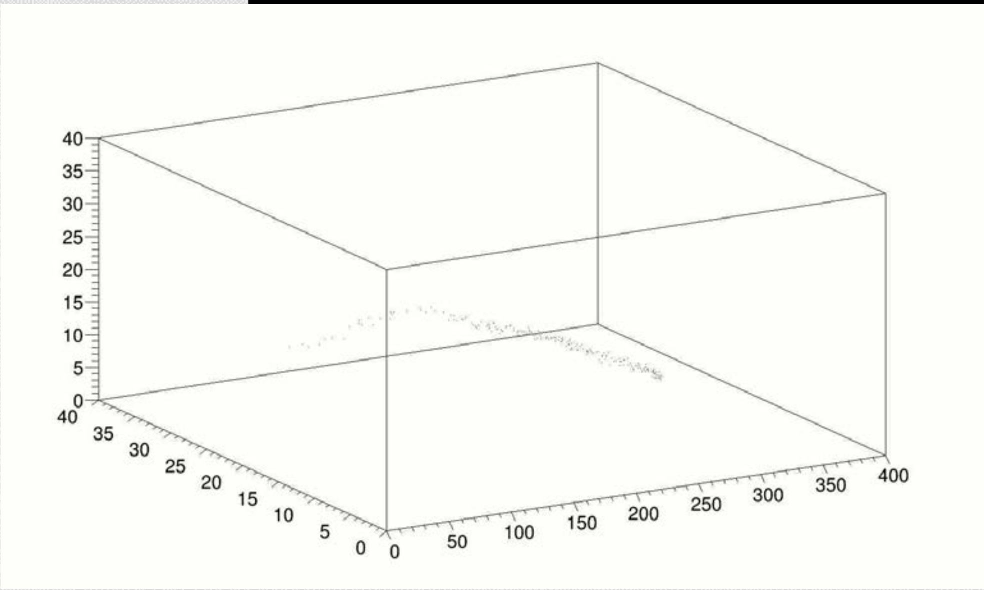
CPU/GPU Architecture Comparison



Methods

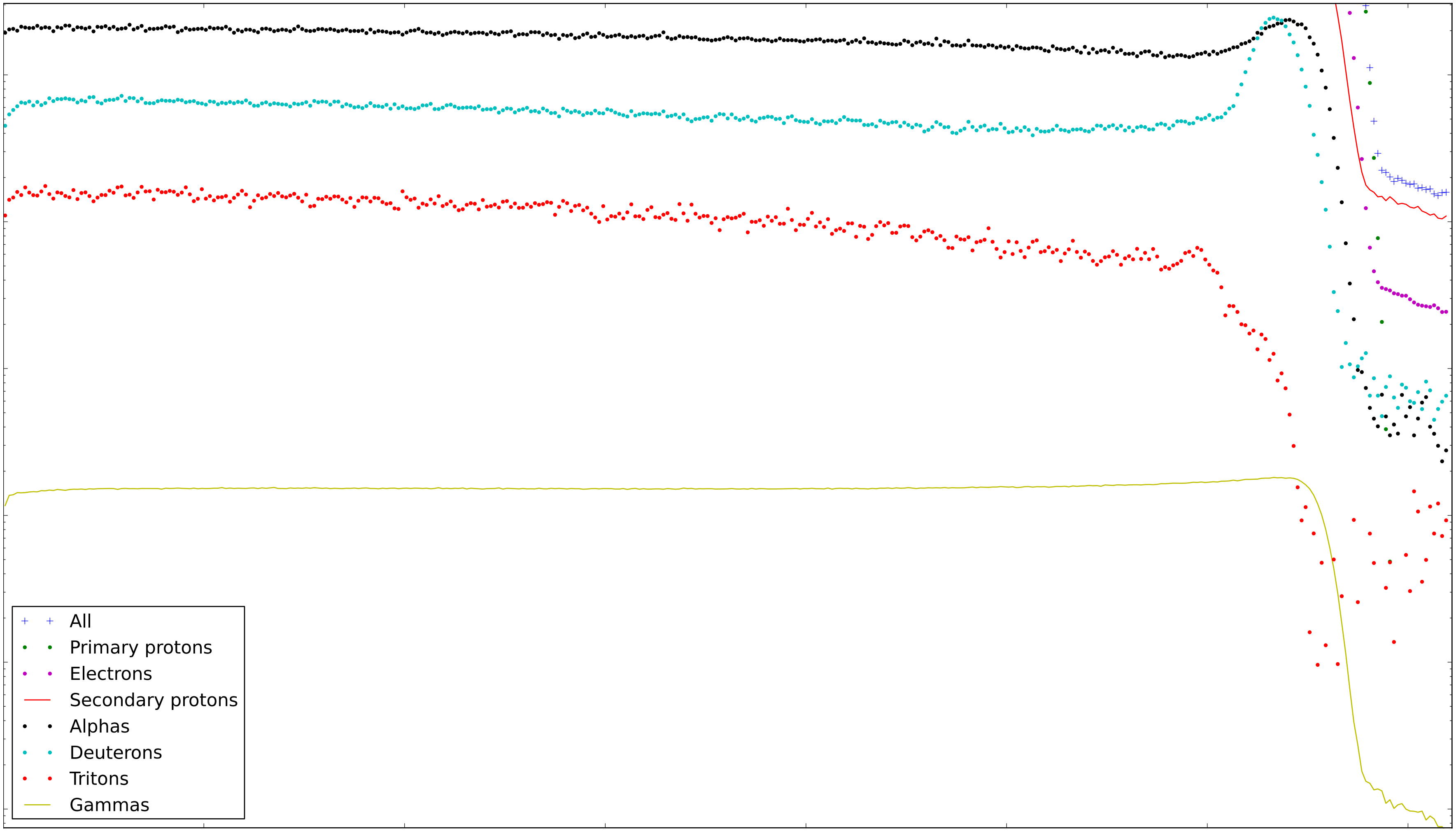
- Geant4 **9.6.patch2**
  - Implementation strategy
  - Validation
  - 11 million protons
  - Statistical uncertainty < 2%
  - Computer cluster



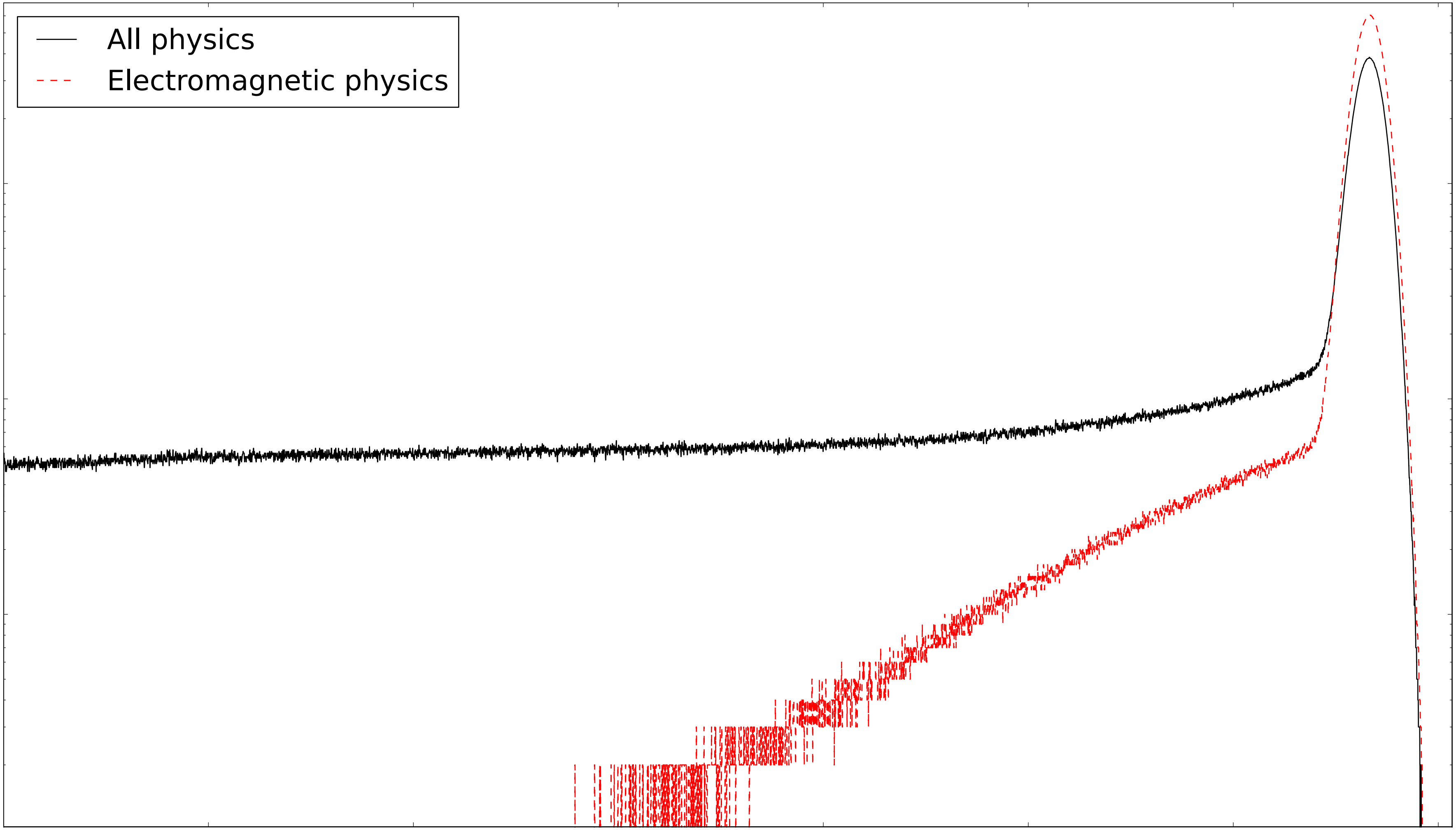


- Physics
  - Electromagnetic
    - EMStandard_opt3
  - Nuclear reactions
    - Binary cascade model

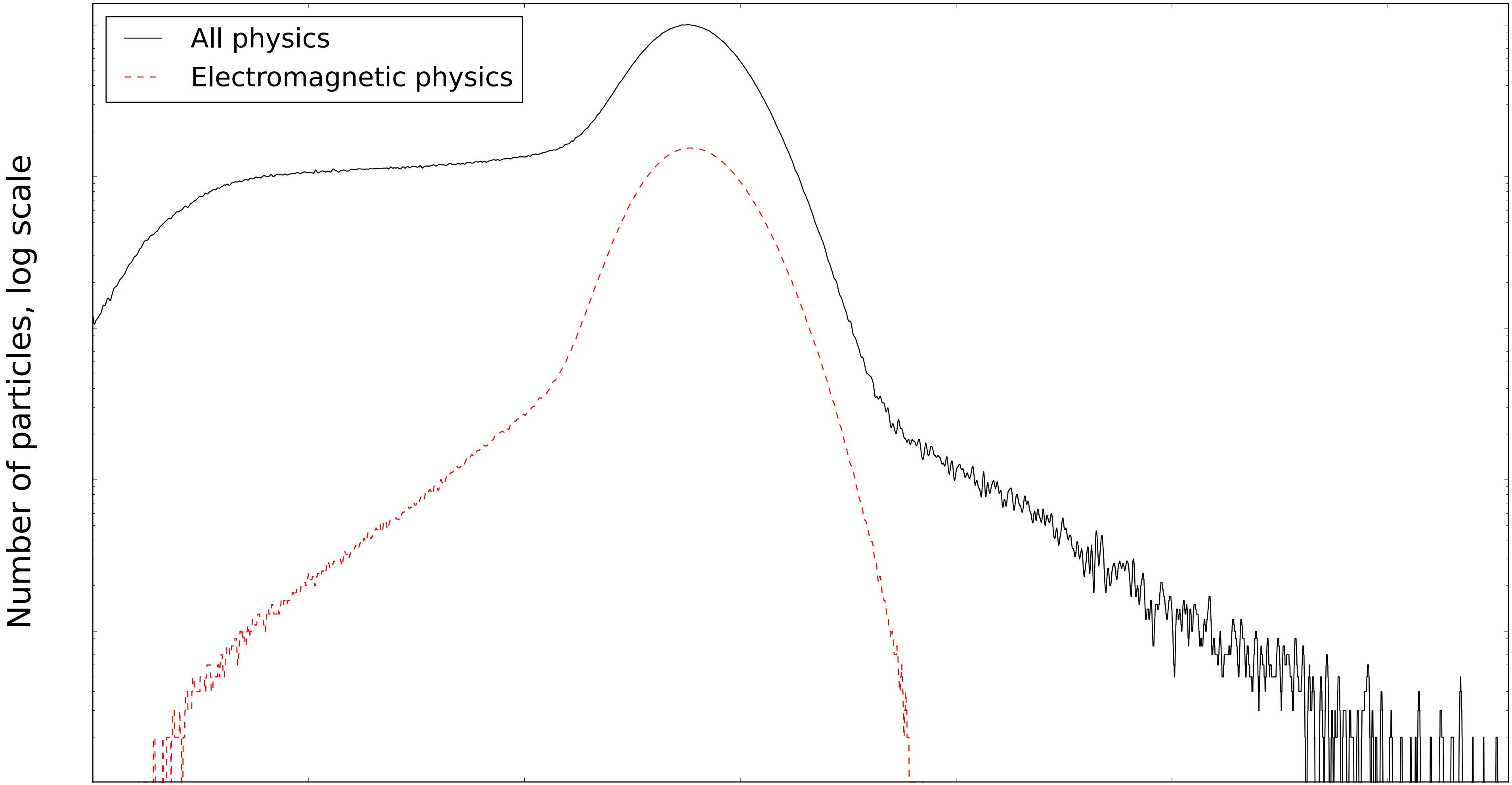
Results


All
Primary protons
Electrons
Secondary protons
Alphas
Deuterons
Tritons
Gammas

Primary proton interactions



Secondary electron interactions



Strategy

- Each core manages protons with the same energy level
  - Stock up on protons when thread divergence increase
  - Gather protons by energy
  - Load protons with the same energy level
- Consider particles which involve significant dose contribution
- Each Core manages same kind of particles **(Hissoiny 2011)**

What we need !

- Physics
  - Electromagnetic physics
    - Ionization and multiple scattering **(geant4 physics reference guide)**
  - Nuclear reactions **(Fippel 2004)**
    - Elastic and inelastic proton-proton, proton-oxygen collisions
  - Manage secondary protons and electrons
- Counteract thread divergence for higher energy proton beams

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