EUROPEAN SPALLATION SOURCE

Geant4/PHITS Benchmarking

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Overview

- Geant4: Monte-Carlo code used at ESS for shielding, backgrounds and detector simulation
- PHITS: Monte-Carlo code used for neutron beamline and shield design of neutron scattering instruments at J-PARC
- PHITS contains many useful features relevant for neutron scattering instrument design
- These features are not by default included in the Geant4 simulation package

Benchmark Tests

- Three benchmark tests shown here:
  - Benchmark 1: Duct-source option
  - Benchmark 2: Duct-source option + supermirror physics
  - Benchmark 3: Duct-source option + supermirror physics + T0 chopper
- Geant4 simulations carried out by Douglas Di Julio
- PHITS simulations carried out by K. Takeda and K. Niita
- PHITS content in these slides is taken from, “Report on Beam Line Design for Neutron Scattering Facility of ESS”, K. Takeda and K. Niita

Duct-source option - Long beamline simulation

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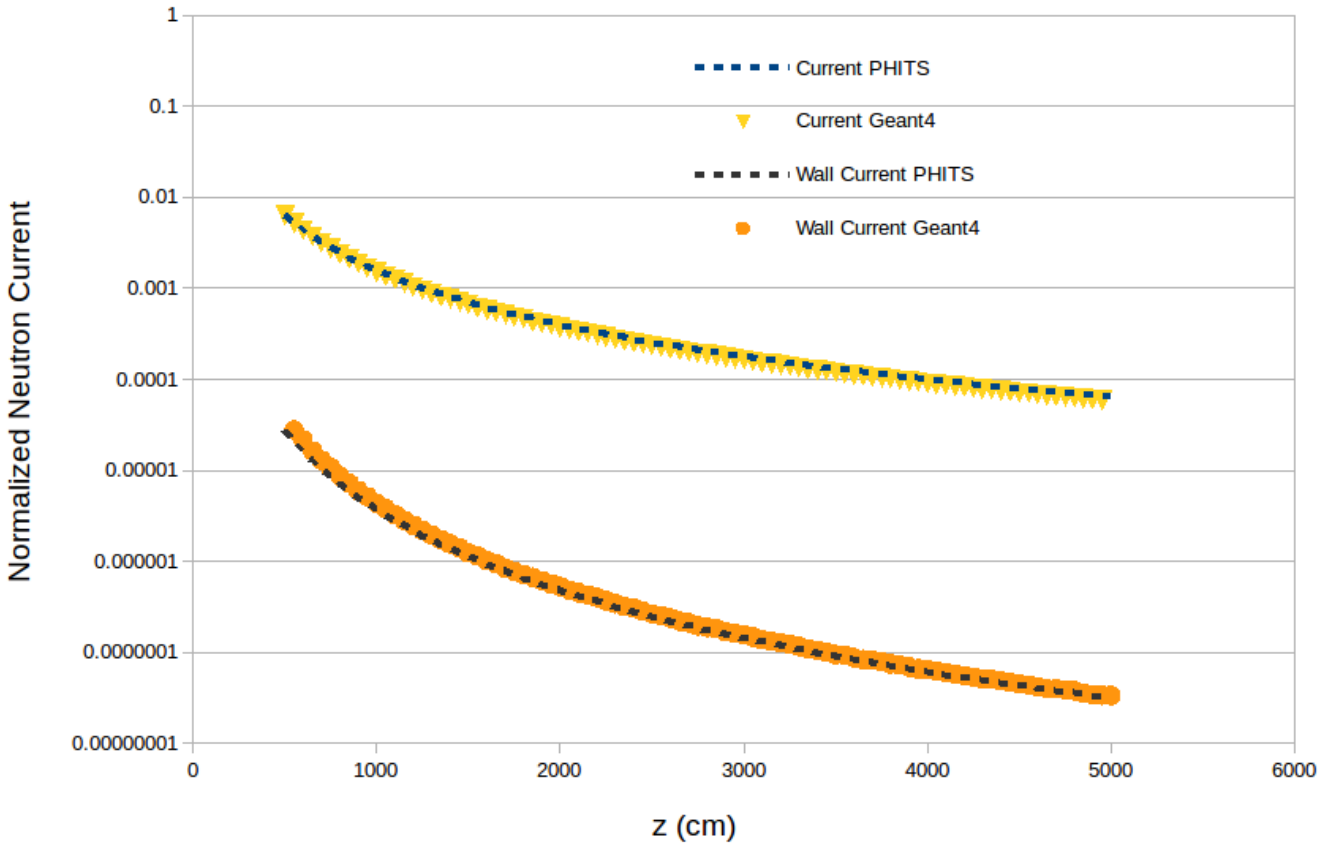
- Current through a beamline decreases as $1/r^2$ as distance from source

- The current crossing the wall of the beamline at 150 m is roughly six orders of magnitude smaller than at 1 m

- To reduce the variance, we introduced a duct source option in Geant4

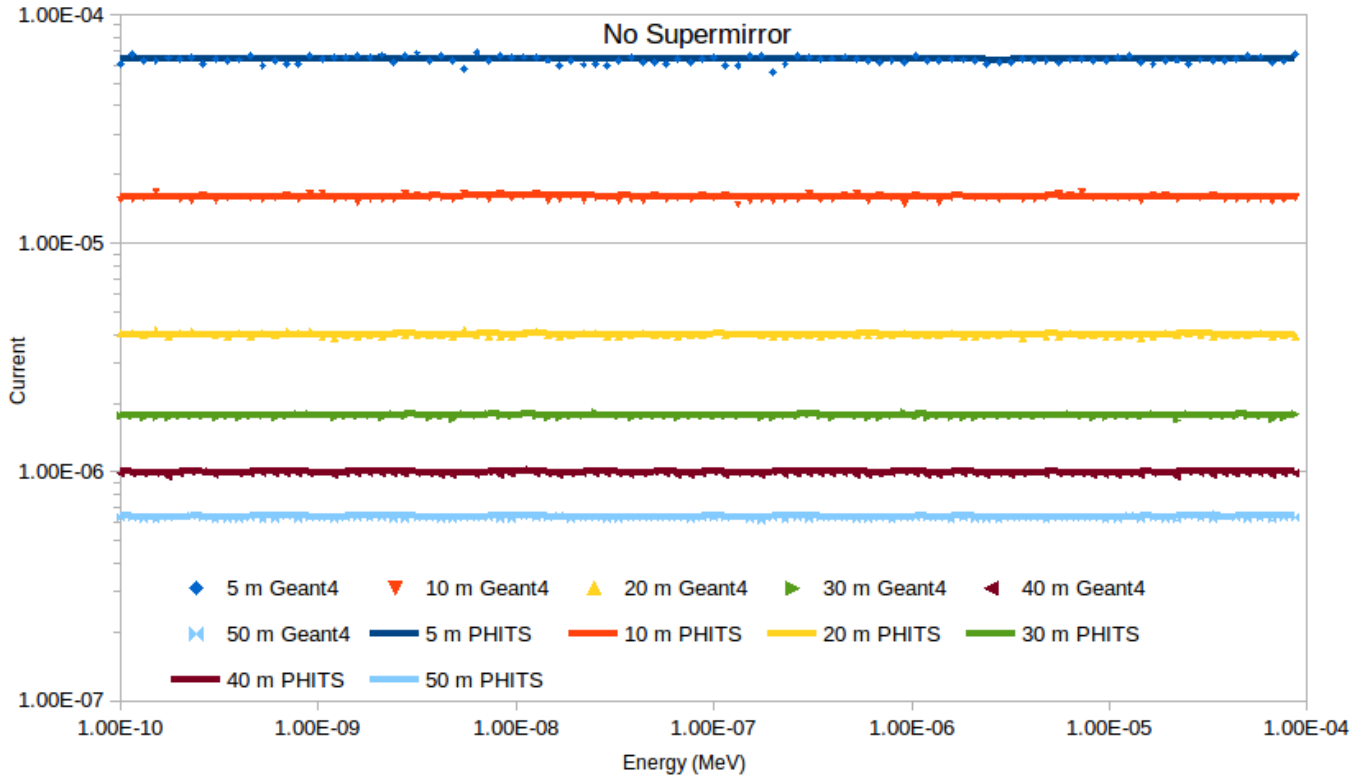
- The idea is to equalize the wall current at any point in a beamline by changing the weights of the neutrons

Duct source variance reduction



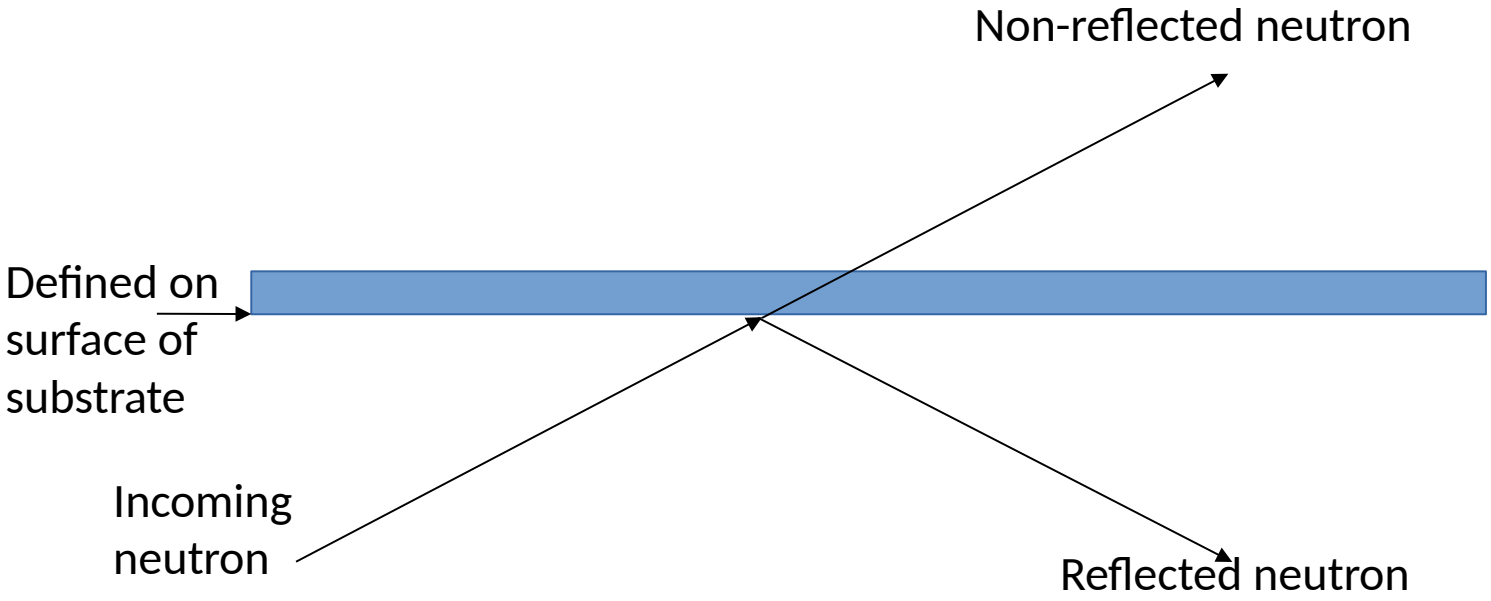
Benchmarked against PHITS

Duct source with no supermirror



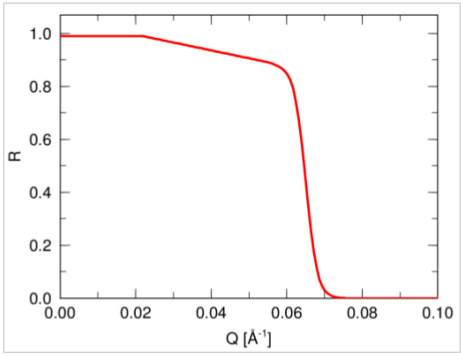
No guide

Supermirror physics



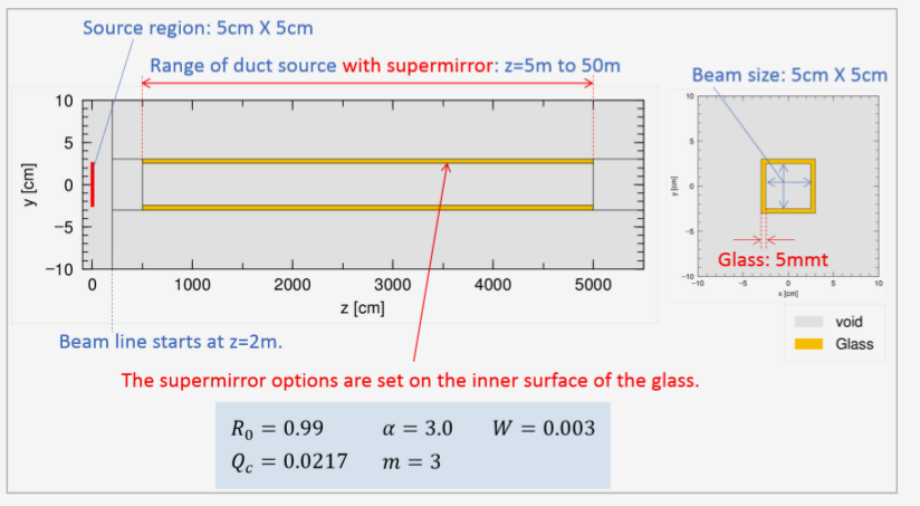
Reflectivity described by empirical formula

$$R = \begin{cases} R_0 & \text{if } Q \leq Q_c \\ \frac{1}{2}R_0\left(1 - \tanh\left[\frac{Q - mQ_c}{W}\right]\right)(1 - \alpha(Q - Q_c)) & \text{if } Q > Q_c \end{cases}$$

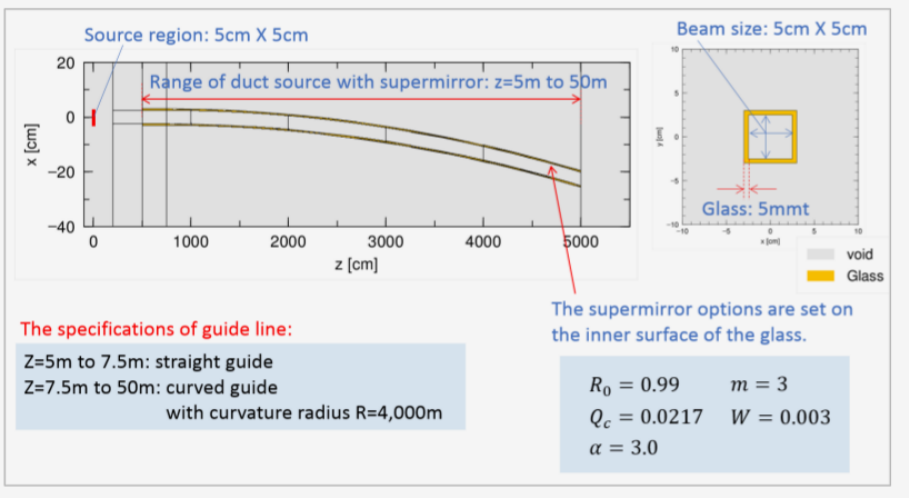


Implemented in Geant4 with support of Xiao Xiao Cai from ESS detector group

Duct-source + supermirror physics

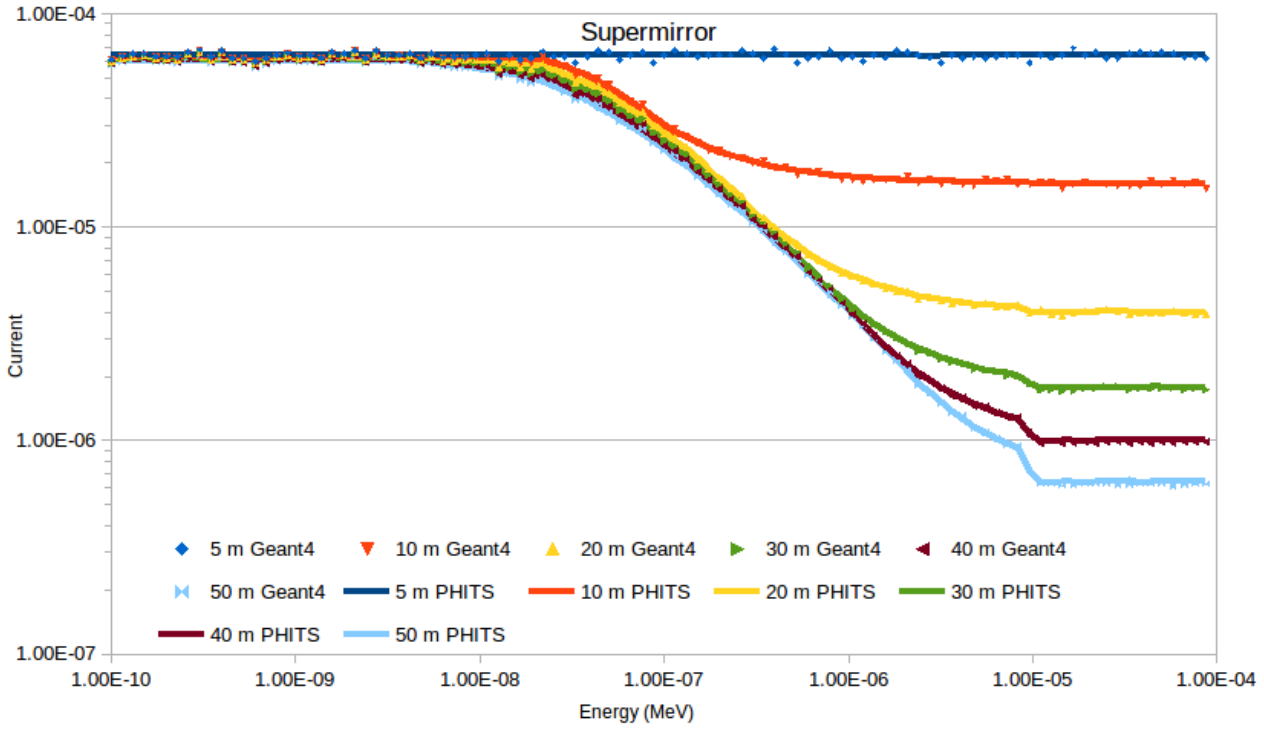


Straight guide



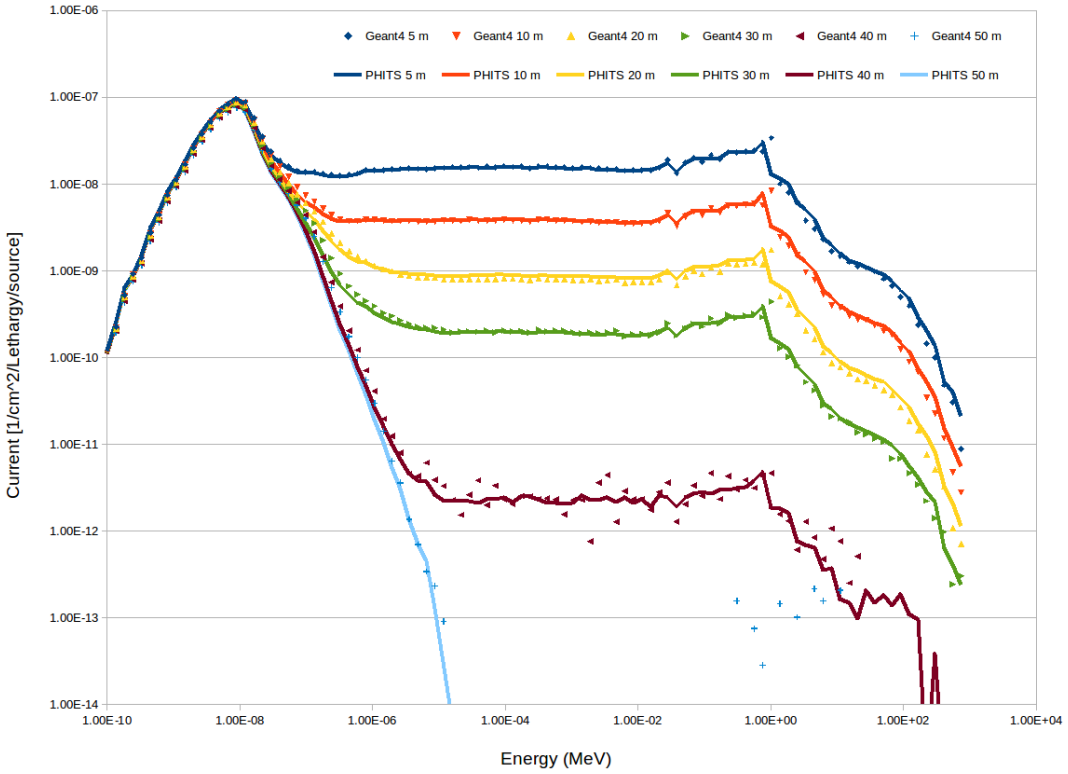
Curved guide

Supermirror physics – with supermirror + duct source



Straight guide

Supermirror physics – with supermirror + duct source



Curved guide

Supermirror physics – neutrons inside and outside the guide

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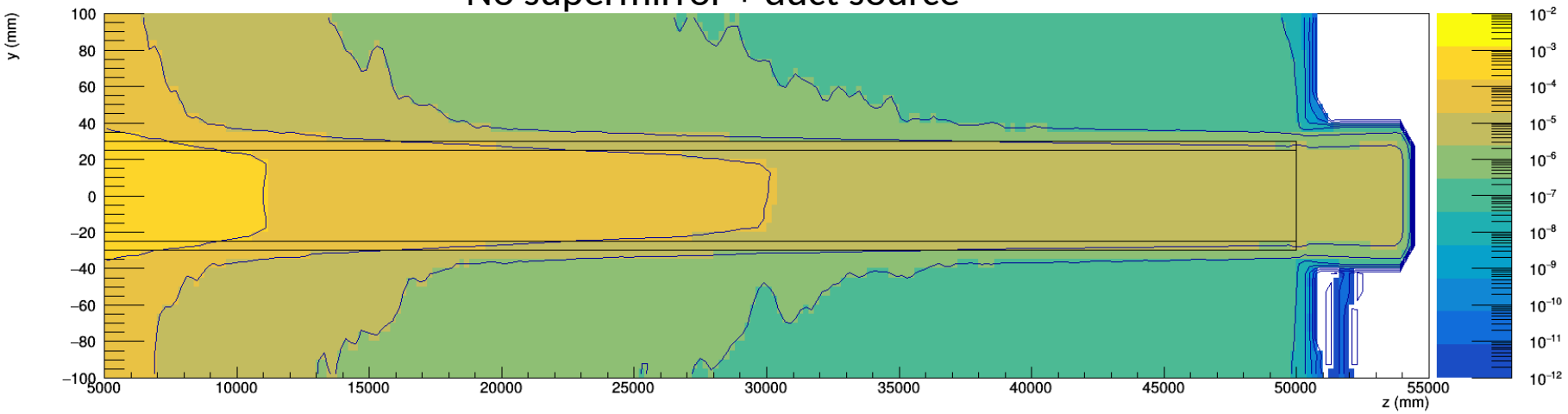
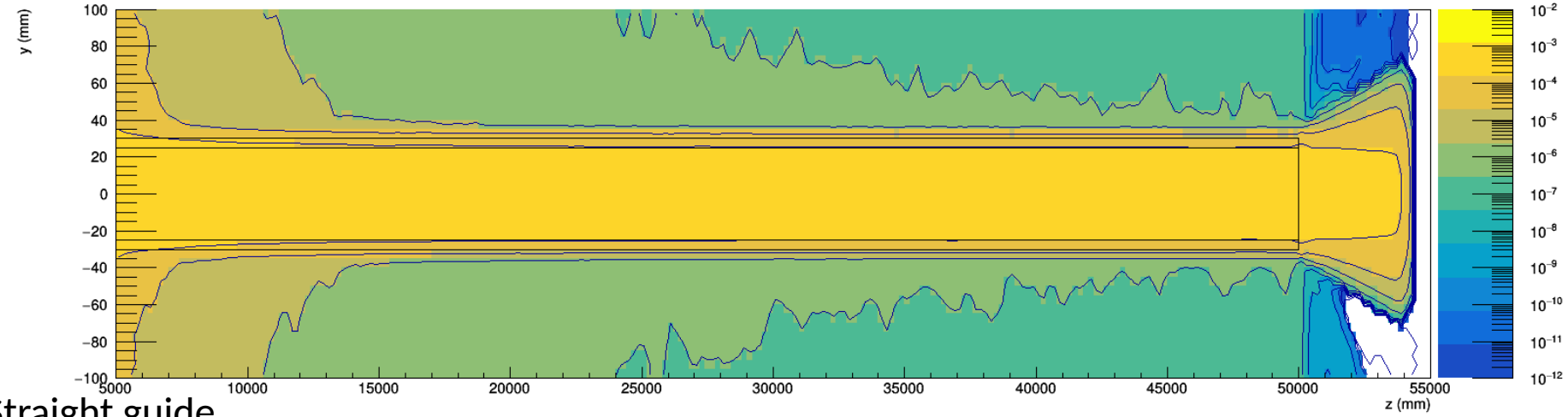
No supermirror + duct source

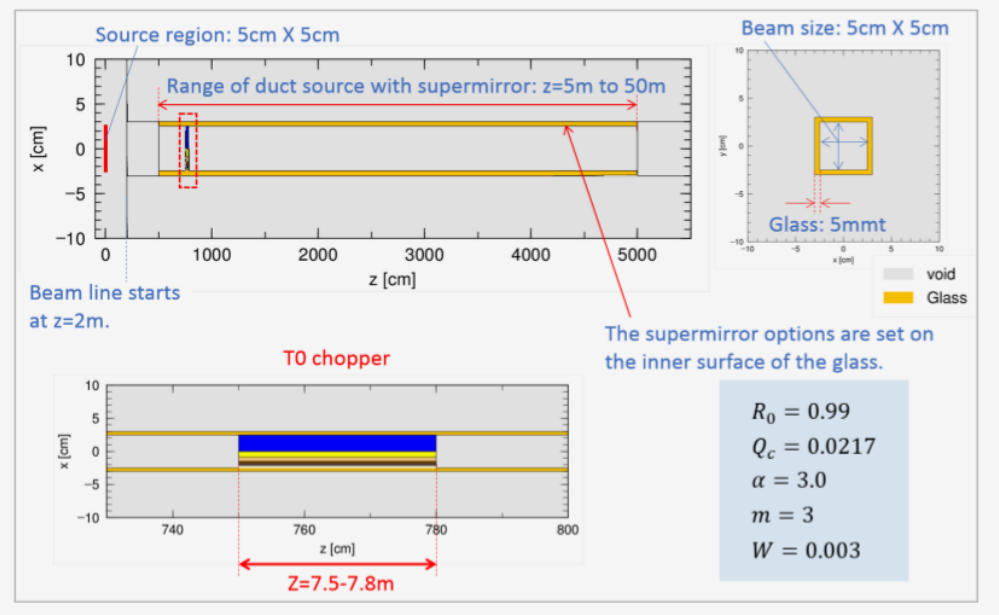


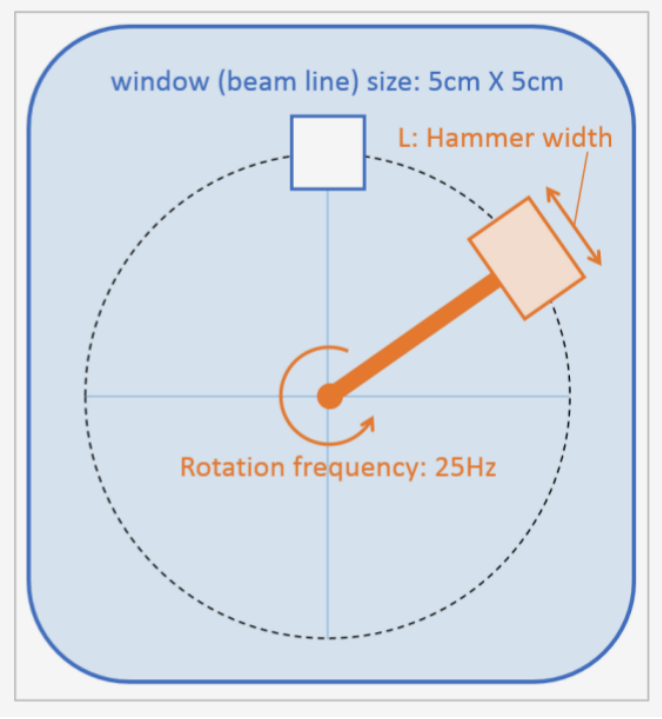
Supermirror + duct source



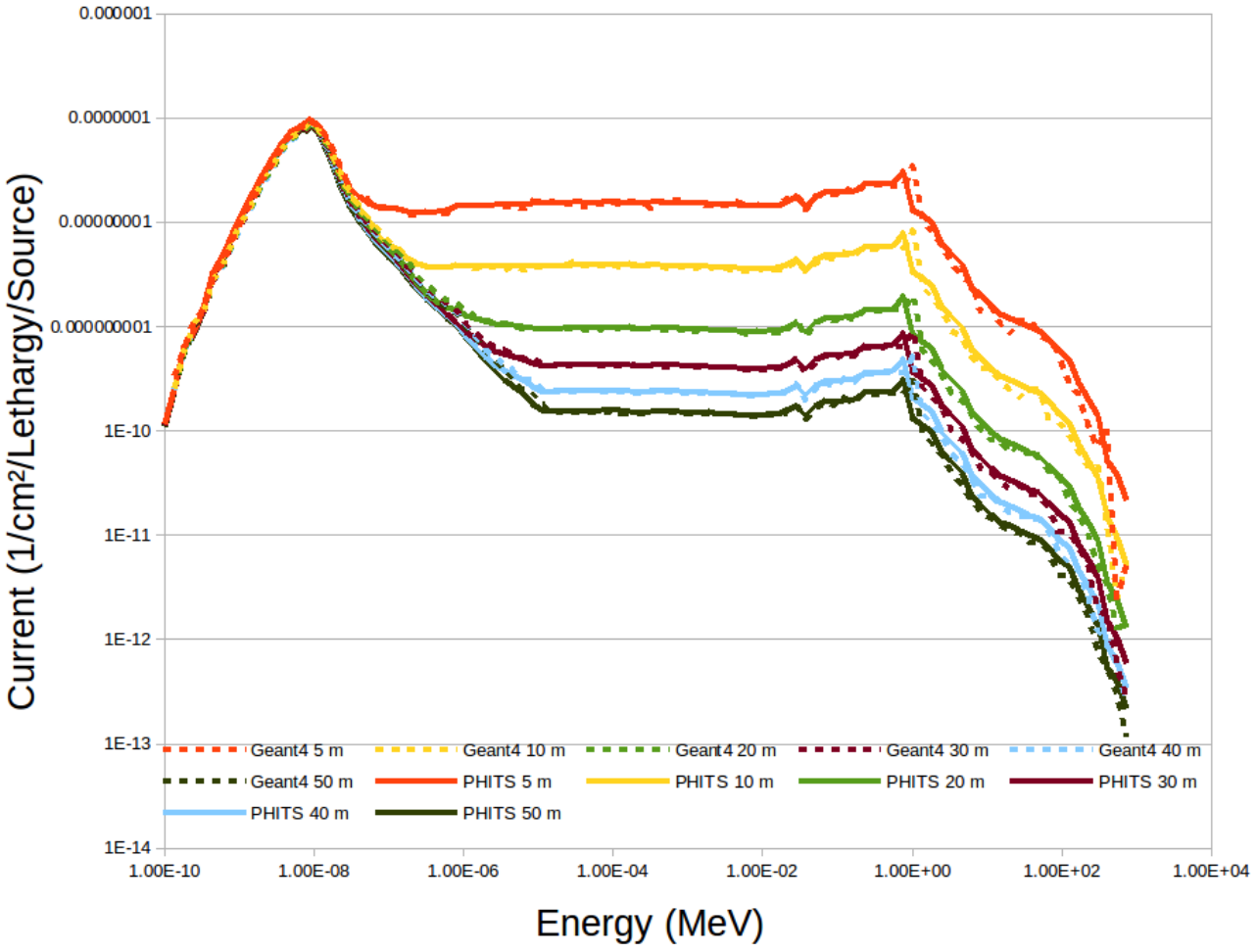
Straight guide

Duct-source + Supermirror with T0 chopper

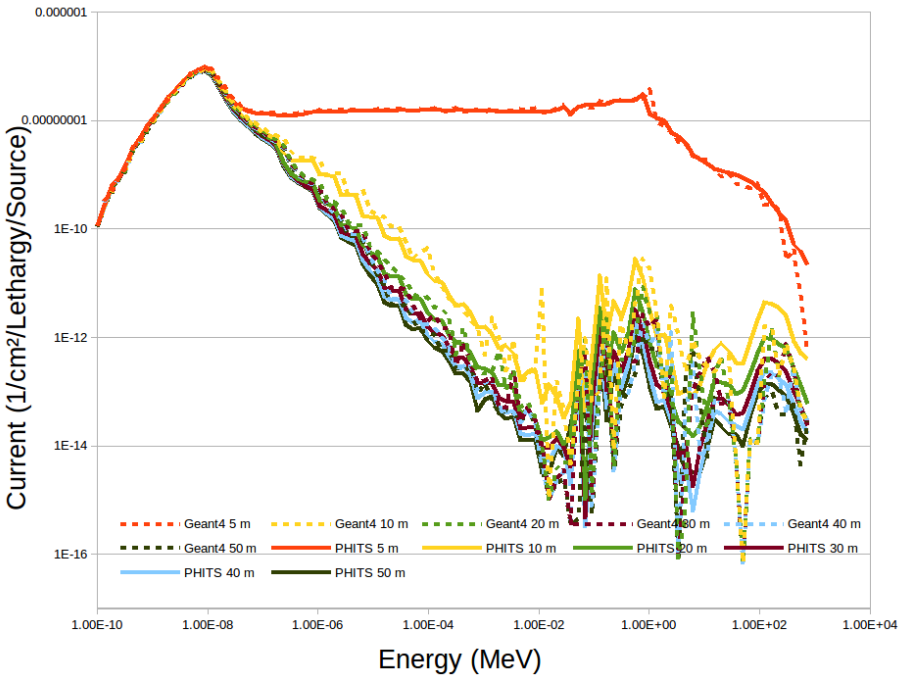




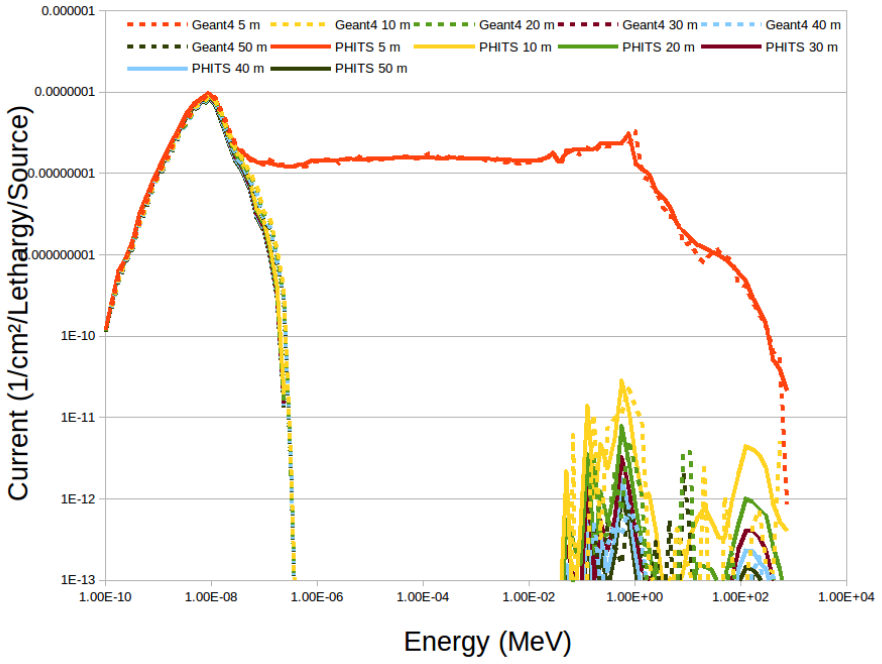
Duct-source + Supermirror with no T0 chopper



Duct-source + Supermirror with T0 chopper



5 cm width



10 cm width

Outlook

- PHITS is being used for neutron beamline and radioactivity calculations at ESS (see Phil's talk)
- One step closer to full signal/noise calculation of a neutron scattering instrument using Geant4 (together with tools from the ESS detector group)