

Geant4 Space Users Forum, 20-22 January 2003
ESTEC, Noordwijk, The Netherlands

Interaction of Protons of about 1 GeV with Thin and
Thick Targets:
Simulation by Geant4 and Comparison with
Experimental Data.

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Abstract

Double differential cross sections of production of secondary particles in interactions of intermediate energy protons with light and medium-weight nuclei are calculated using the Geant4 code. In particular, spectra of secondary neutrons produced in interactions of 585 MeV protons with C, Al, Fe, and Pb-nuclei are considered. Comparison with experimental data and with calculations using the SHIELD transport code is presented and discussed.

Distribution of energy deposition in extended aluminum, iron, and lead targets irradiated by 1 GeV proton beam is simulated by means of Geant4. Comparison with measurements and the SHIELD code calculations is performed.

These applications of Geant4 are of interest for the space radiation shielding problem.

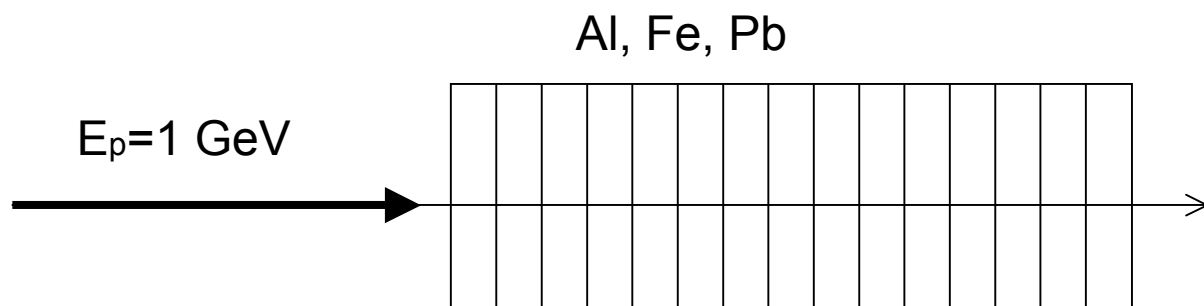
Distribution of energy deposition [MeV/cm] along Z-axis of cylindrical target (R=10 cm, L=60 cm) under proton pencil beam irradiation ($E_p=1$ GeV)

Target Materials: Al, Fe, Pb.

Experimental data: direct calorimetric measurement V.Belyakov-Bodin et al.:

NIM **A295**(1990)140, **A314**(1992)508, **A335**(1993)30 .

Calculation: Geant4, v.4.0 and the SHIELD code

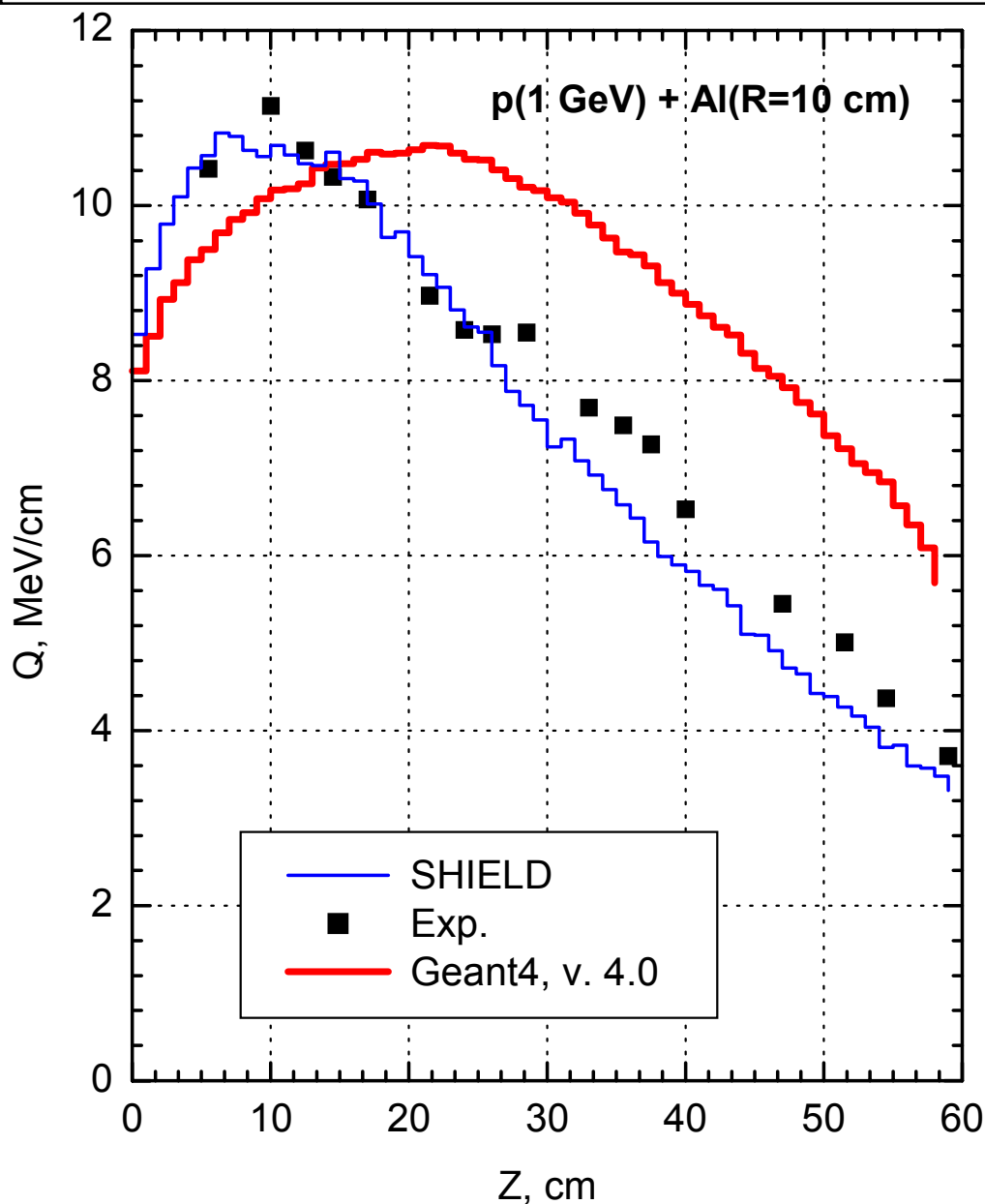


EXPERIMENTAL DATA on Interaction of Hadron Beam with Extended Target (Bel 92).

Type of DATA: Distribution of Energy Deposition over Target Volume.

Short write-up: Interaction of narrow proton beams of 0.8, 1.0 and 1.2 GeV with cylindrical beryllium, carbon and aluminium targets of $L=60$ cm in height and $R=5$ and 10 cm in radius. The beam impinges a target along its z -axis. Calorimetric measurement of distribution of energy deposition along target axis was performed. See original article Bel 92 for more details.

Geant4 and the SHIELD code calculations
Comparison with experiment



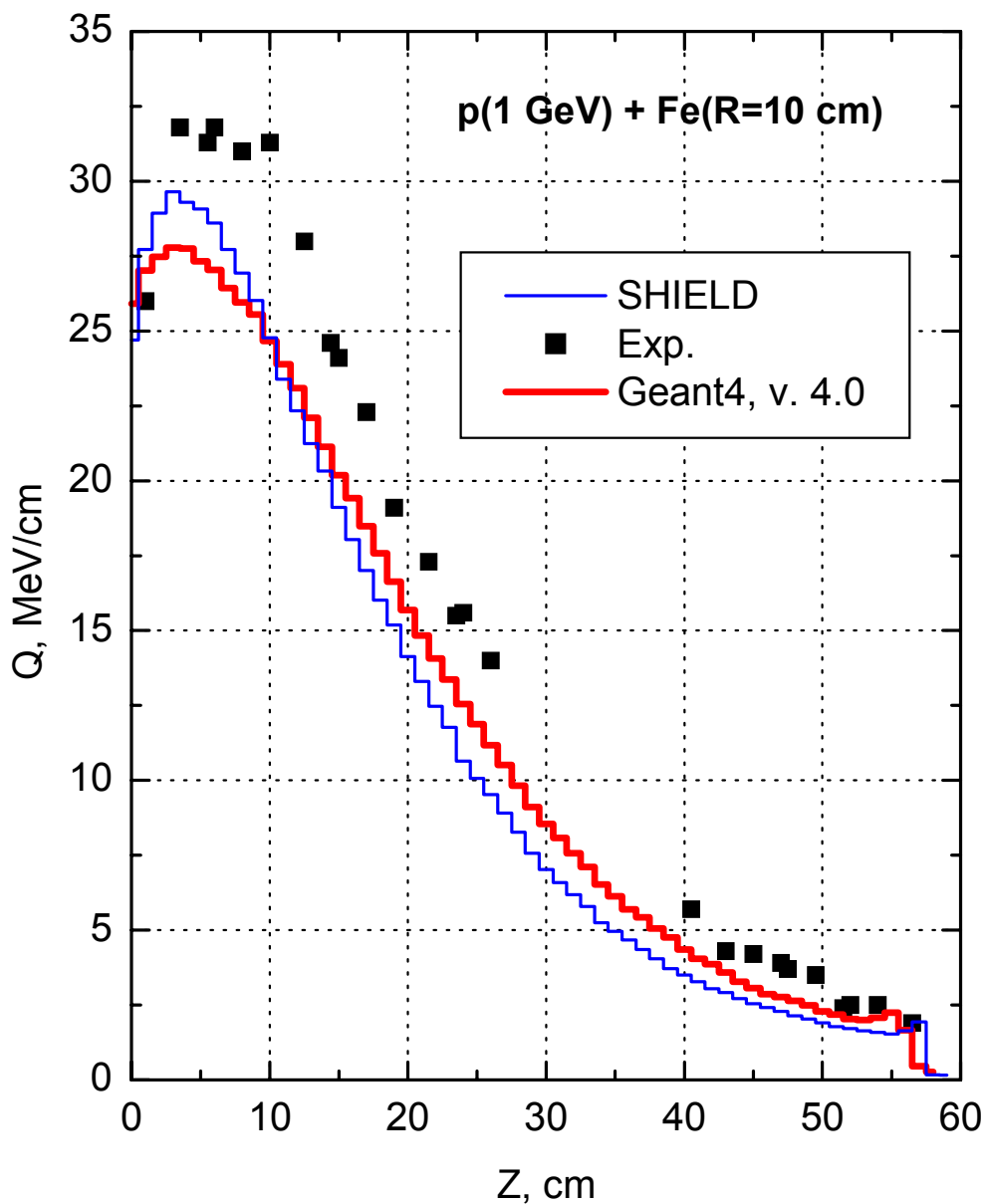
Distribution of energy deposition along z -axis of cylindrical aluminium target ($L=60$ cm, $R=10$ cm). Proton beam energy is 1.0 GeV.

EXPERIMENTAL DATA on Interaction of Hadron Beam with Extended Target
(Bel 93).

Type of DATA: Distribution of Energy Deposition over Target Volume.

Short write-up: Interaction of narrow proton beams of 0.8, 1.0 and 1.2 GeV with cylindrical iron and copper targets of $L=60$ cm in height and $R=5$ and 10 cm in radius. The beam impinges a target along its z-axis. Calorimetric measurement of distribution of energy deposition along target axis was performed. See original article **Bel 93** for more details.

Geant4 and the SHIELD code calculations
Comparison with experiment



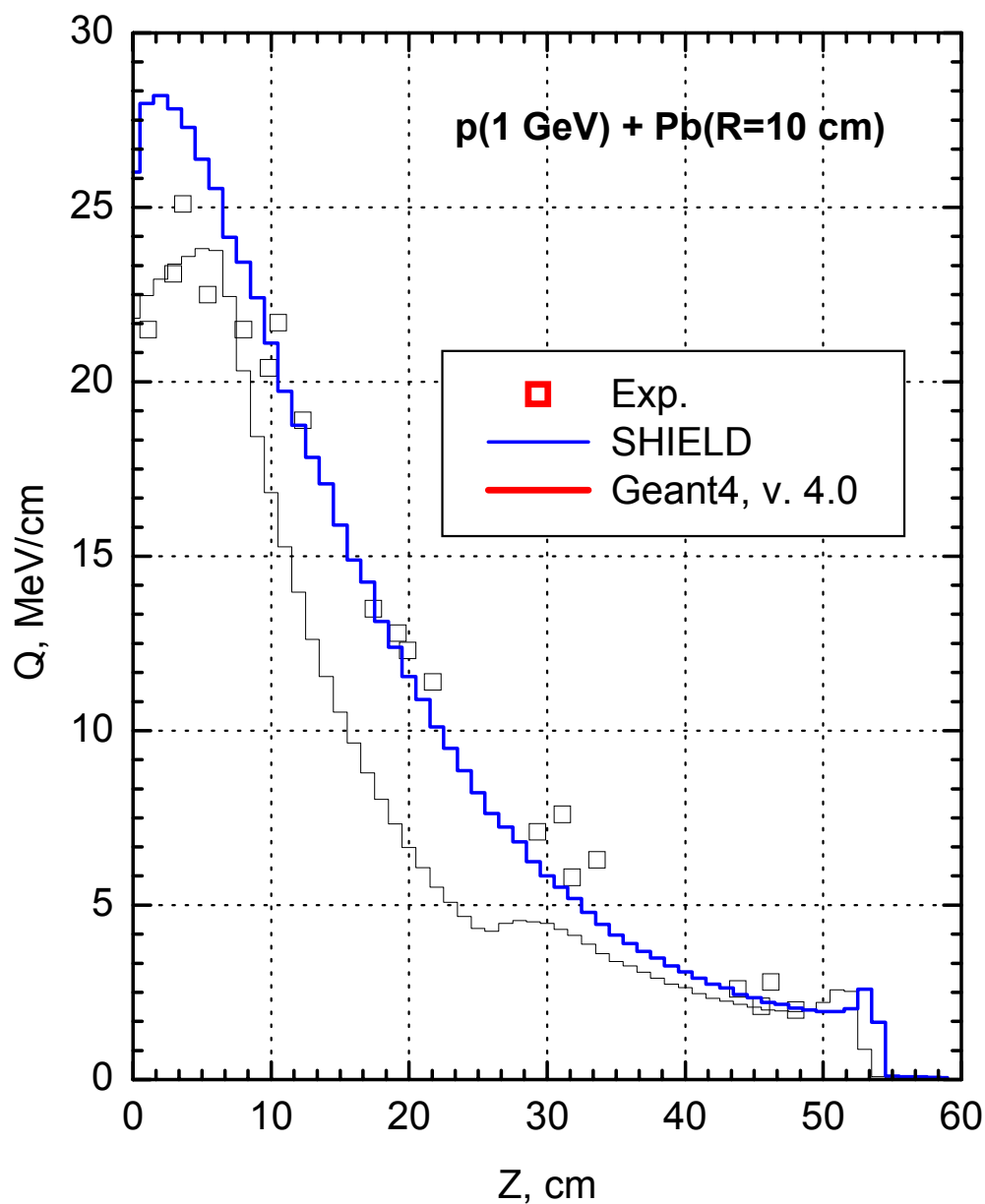
Distribution of energy deposition along z-axis of cylindrical iron target ($L=60$ cm, $R=10$ cm). Proton beam energy is 1.0 GeV.

EXPERIMENTAL DATA on Interaction of Hadron Beam with Extended Target (**Bel 90**).

Type of DATA: Distribution of Energy Deposition over Target Volume.

Short write-up: Interaction of narrow proton beams of 0.8, 1.0 and 1.2 GeV with cylindrical lead targets of $L=60$ cm in height and $R=5$ and 10 cm in radius. The beam impinges a target along its z -axis. Calorimetric measurement of distribution of energy deposition along target axis was performed. See original article **Bel 90** for more details.

Geant4 and the SHIELD code calculations
Comparison with experiment



Distribution of energy deposition along z -axis of cylindrical lead target ($L=60$ cm, $R=10$ cm). Proton beam energy is 1.0 GeV.

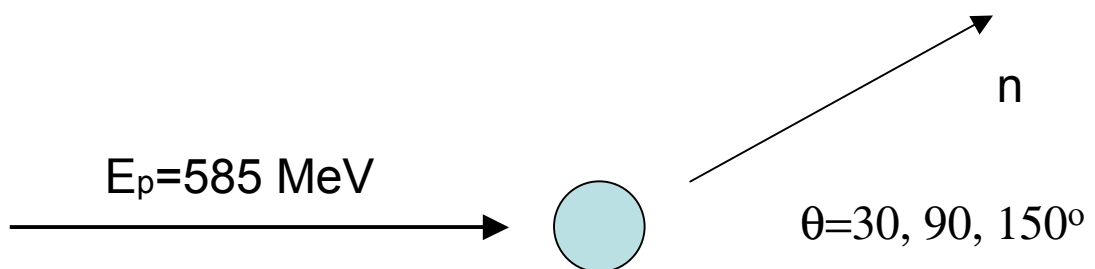
Double differential cross sections [mb/(sr·MeV)] of secondary neutrons in nuclear reactions induced by 585 MeV protons.

Nuclei-targets: C, Al, Fe, Pb.

Experimental data:

S.Cierjacks et al.: Phys. Rev. **C36** (1987)1976.

Calculation: Geant4, v.4.0 and the SHIELD code



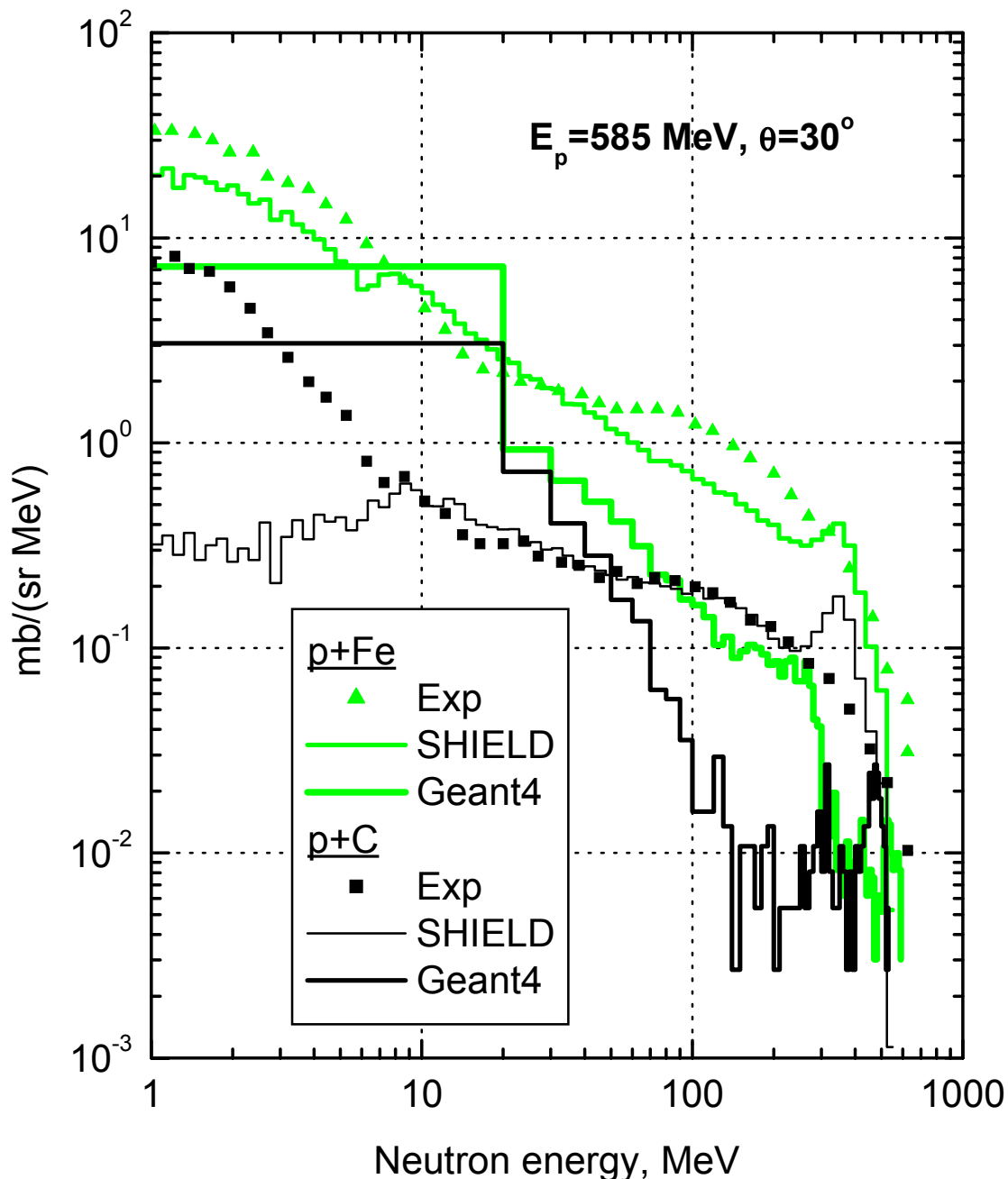
EXPERIMENTAL DATA on Hadron-Nucleus Interaction (**Cie 87**).

Type Type of DATA: Differential Cross Sections of Secondary Particles:

Short write-up: Reaction $p + C, Al, Fe, Pb$ at projectile energy $E_p = 585$ MeV. Double differential cross sections of secondary neutrons are measured. See original article **Cie 87** for more details.

Geant4 and the SHIELD code calculations

Comparison with Experiment



Energy spectra of secondary neutrons observed at 30° in interaction of 585 MeV protons with nuclei C, and Fe.

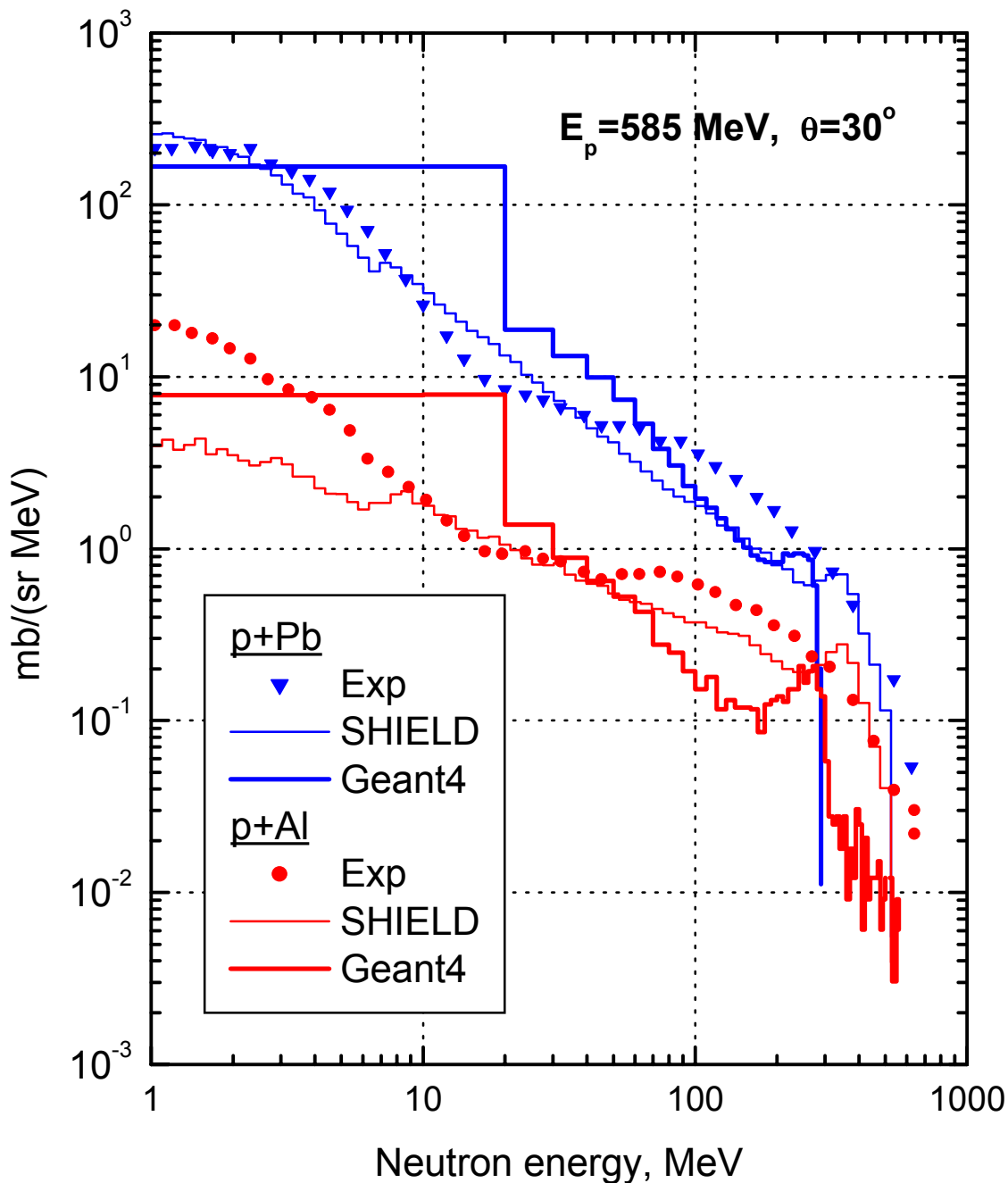
EXPERIMENTAL DATA on Hadron-Nucleus Interaction (**Cie 87**).

Type Type of DATA: Differential Cross Sections of Secondary Particles:

Short write-up: Reaction $p + C, Al, Fe, Pb$ at projectile energy $E_p = 585 \text{ MeV}$. Double differential cross sections of secondary neutrons are measured. See original article **Cie 87** for more details.

Geant4 and the SHIELD code calculations

Comparison with Experiment



Energy spectra of secondary neutrons observed at 30° in interaction of 585 MeV protons with nuclei Al and Pb.

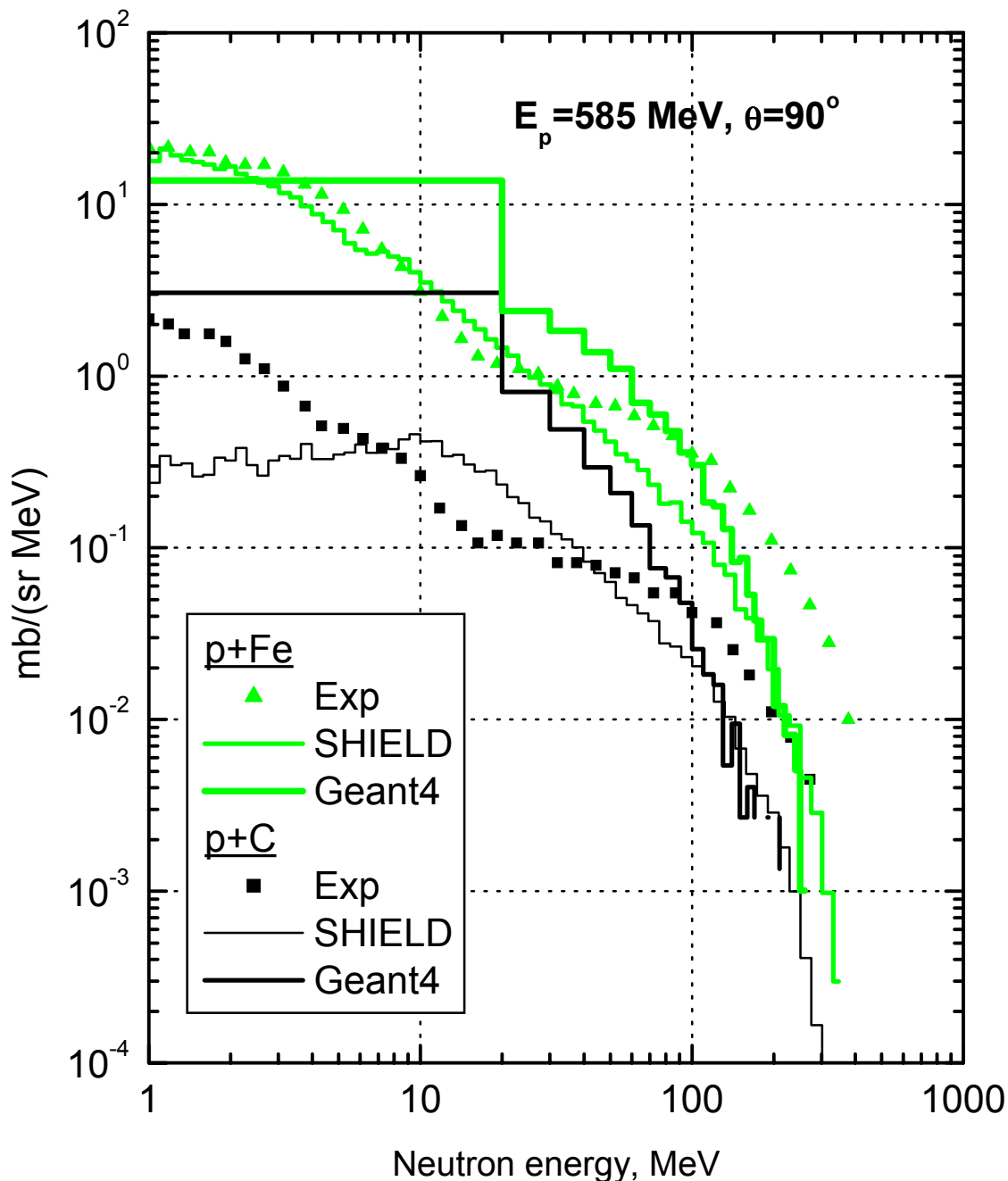
EXPERIMENTAL DATA on Hadron-Nucleus Interaction (**Cie 87**).

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Short write-up: Reaction $p + C, Al, Fe, Pb$ at projectile energy $E_p = 585 \text{ MeV}$. Double differential cross sections of secondary neutrons are measured. See original article **Cie 87** for more details.

Geant4 and the SHIELD code calculations

Comparison with Experiment



Energy spectra of secondary neutrons observed at 90° in interaction of 585 MeV protons with nuclei C and Fe.

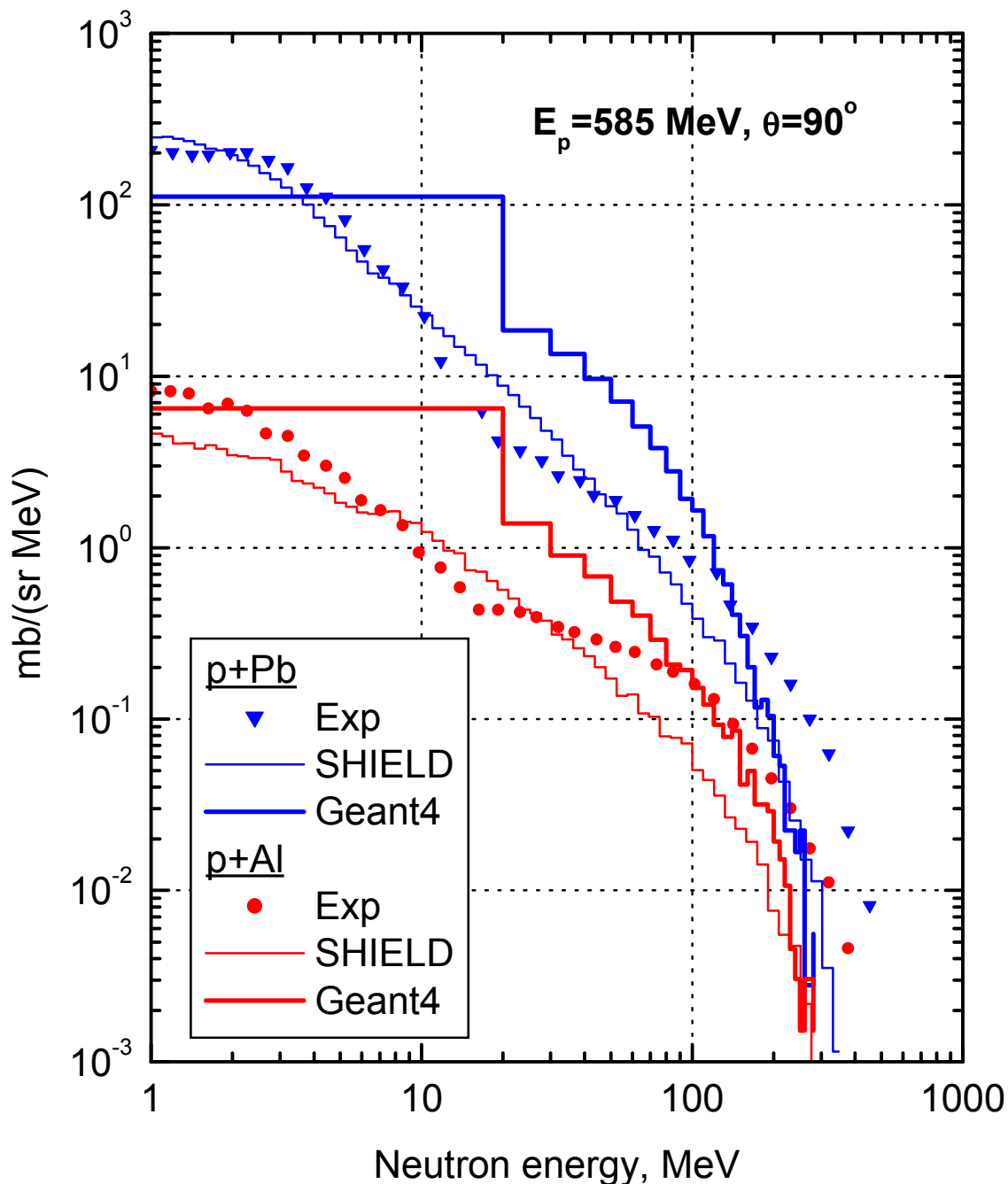
EXPERIMENTAL DATA on Hadron-Nucleus Interaction (**Cie 87**).

Type Type of DATA: Differential Cross Sections of Secondary Particles:

Short write-up: Reaction $p + C, Al, Fe, Pb$ at projectile energy $E_p = 585$ MeV. Double differential cross sections of secondary neutrons are measured. See original article **Cie 87** for more details.

Geant4 and the SHIELD code calculations

Comparison with Experiment



Energy spectra of secondary neutrons observed at 90° in interaction of 585 MeV protons with nuclei Al and Pb.

EXPERIMENTAL DATA on Hadron-Nucleus Interaction (**Cie 87**).

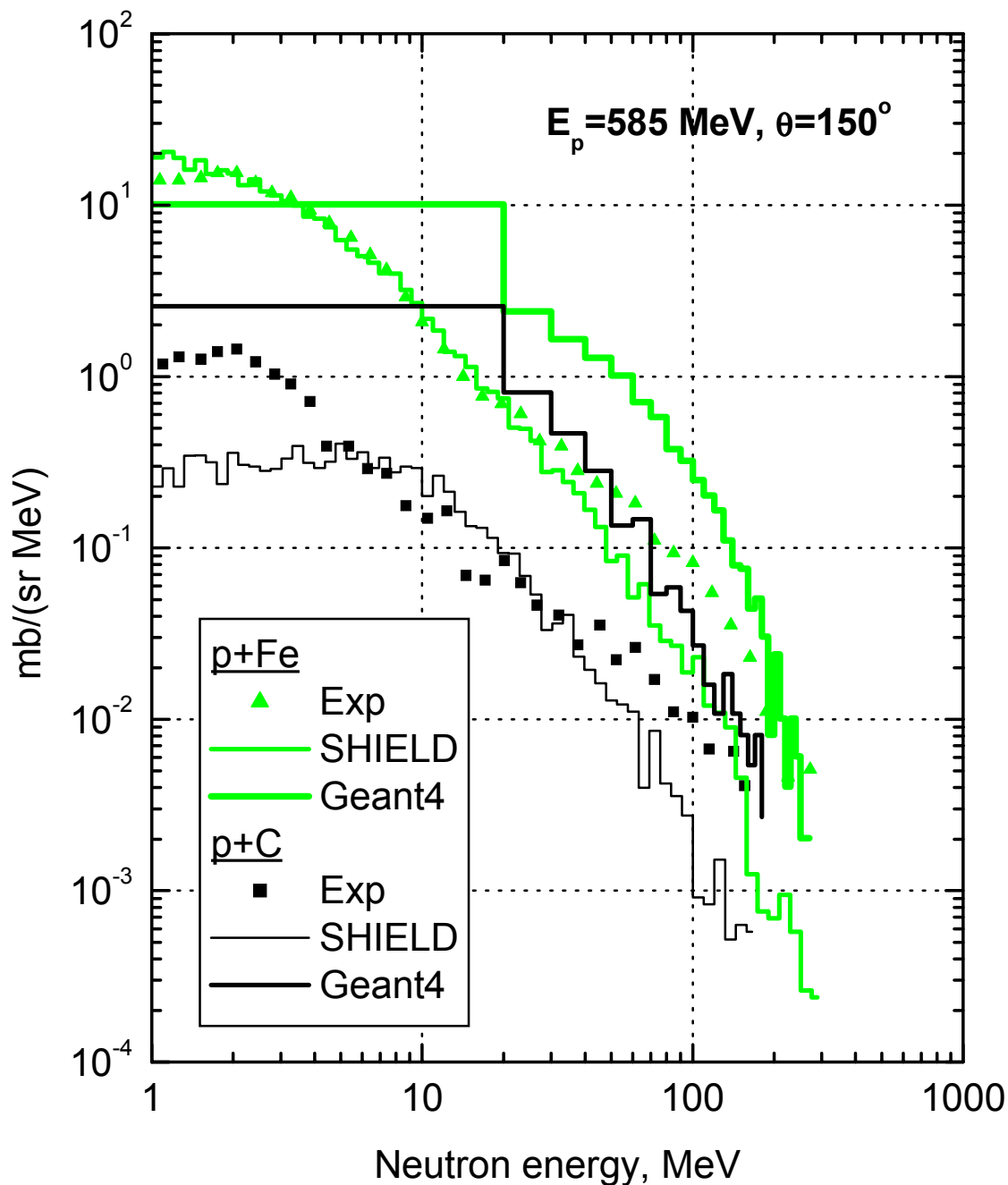
Type Type of DATA: Differential Cross Sections of Secondary Particles:

Short write-up: Reaction $p + C, Al, Fe, Pb$ at projectile energy $E_p = 585$ MeV.

Double differential cross sections of secondary neutrons are measured. See original article **Cie 87** for more details.

Geant4 and the SHIELD code calculations

Comparison with Experiment



Energy spectra of secondary neutrons observed at 150° in interaction of 585 MeV protons with nuclei C and Fe.

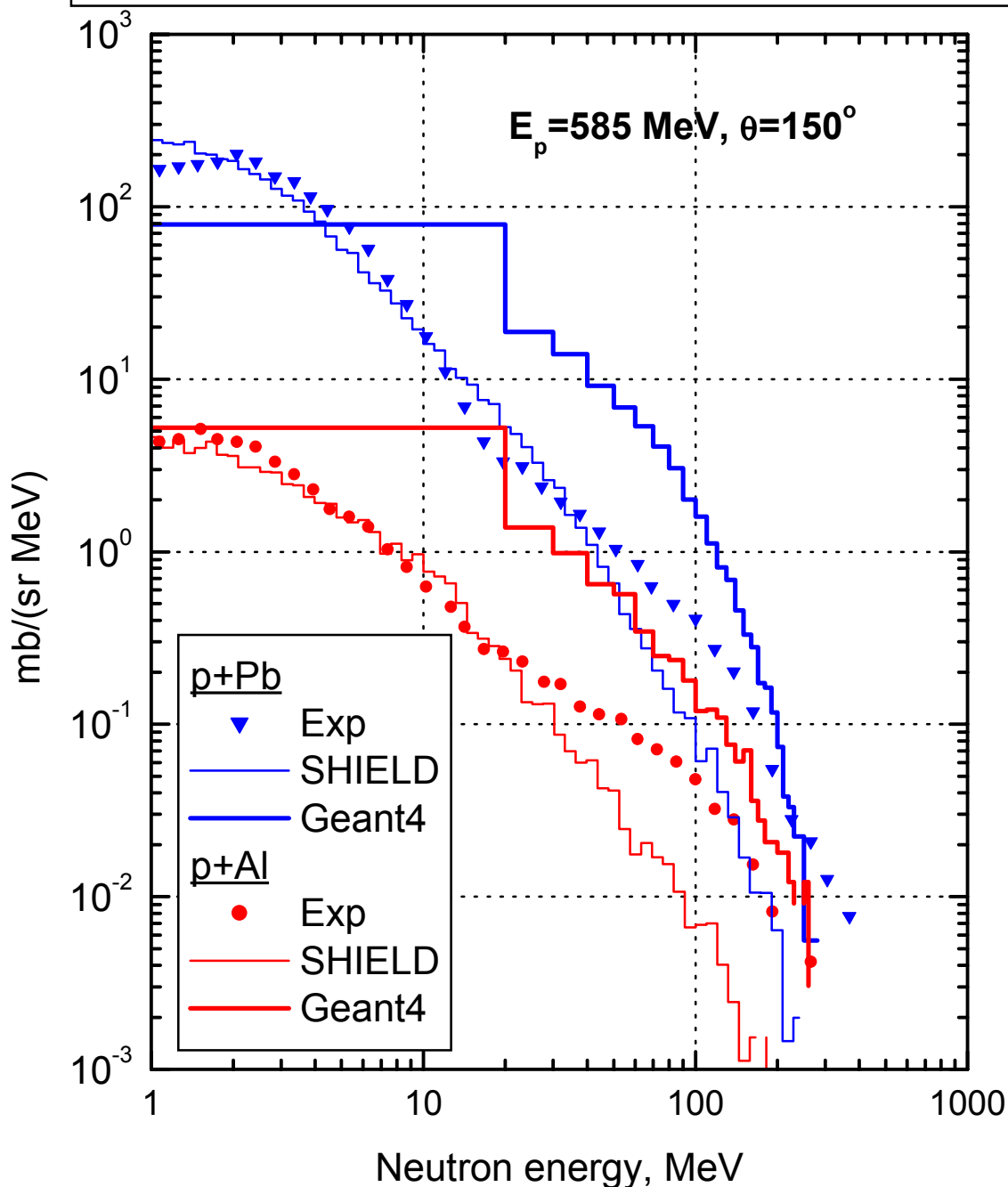
EXPERIMENTAL DATA on Hadron-Nucleus Interaction (Cie 87).

Type Type of DATA: Differential Cross Sections of Secondary Particles:

Short write-up: Reaction $p + C, Al, Fe, Pb$ at projectile energy $E_p = 585$ MeV. Double differential cross sections of secondary neutrons are measured. See original article Cie 87 for more details.

Geant4 and the SHIELD code calculations

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Energy spectra of secondary neutrons observed at 150° in interaction of 585 MeV protons with nuclei Al and Pb.