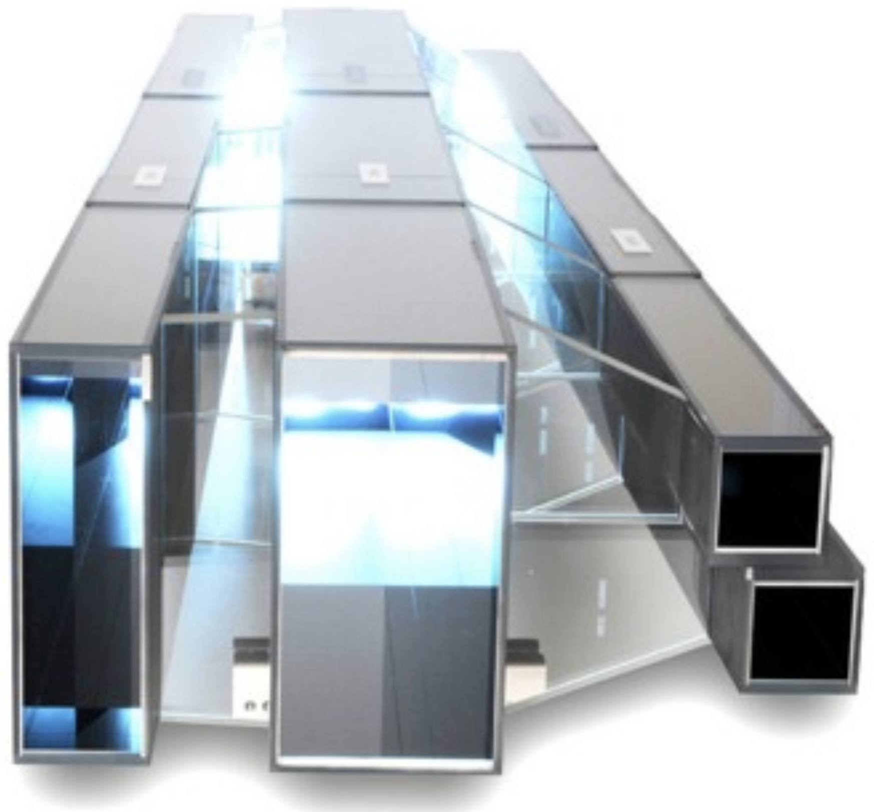

Convert-and-Upgrade Strategies for Research Reactors

Alexander Glaser
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and Woodrow Wilson School of Public and International Affairs
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IAEA Consultancy Meeting on International Cooperation
on Minimizing the Use of HEU in Research, Vienna, September 2013

Revision 3

Background

What Constitutes a Marginal Loss in Reactor Performance?

"In assessing the practical feasibility of utilizing lower enriched fuel in existing research reactors, the agreed criteria are that the safety margins and fuel reliability should not be lower than those for the current design based on highly enriched uranium, and that neither any loss in the overall reactor performance (e.g. flux per unit power) nor any increase in operation costs should be more than marginal."

International Nuclear Fuel Cycle Evaluation (INFCE), 1978–1980

Needs more careful definition of "overall reactor performance"

Research Reactor Utilization

Few applications critically depend on very high neutron flux

Category	Reactors
Teaching and Training	175
Material irradiation and testing	156
Neutron activation analysis	127
Isotope production	96
Neutron radiography	71
Neutron scattering	50
Transmutation	30
Geochronology	26
Gem coloration	21
Boron neutron capture therapy	18
Other	133

IAEA Research Reactor Database (RRDB), September 2013

http://nucleus.iaea.org/RRDB/Reports/Container.aspx?Id=A4

HEU Reactors Worldwide

	Russia	China	Europe	USA	Others	TOTAL
Critical Assemblies	21	1	4	6	5	37
Pulsed Reactors	15	–	3	2	2	22
Steady Power, < 250 kW	2	2	3	1	9	17
Steady Power, > 250 kW	13	–	5	6	4	28
TOTAL	51	3	14	15	20	104
Naval reactors	84	-	13	103	2	202
TOTAL	135	3	27	118	22	306

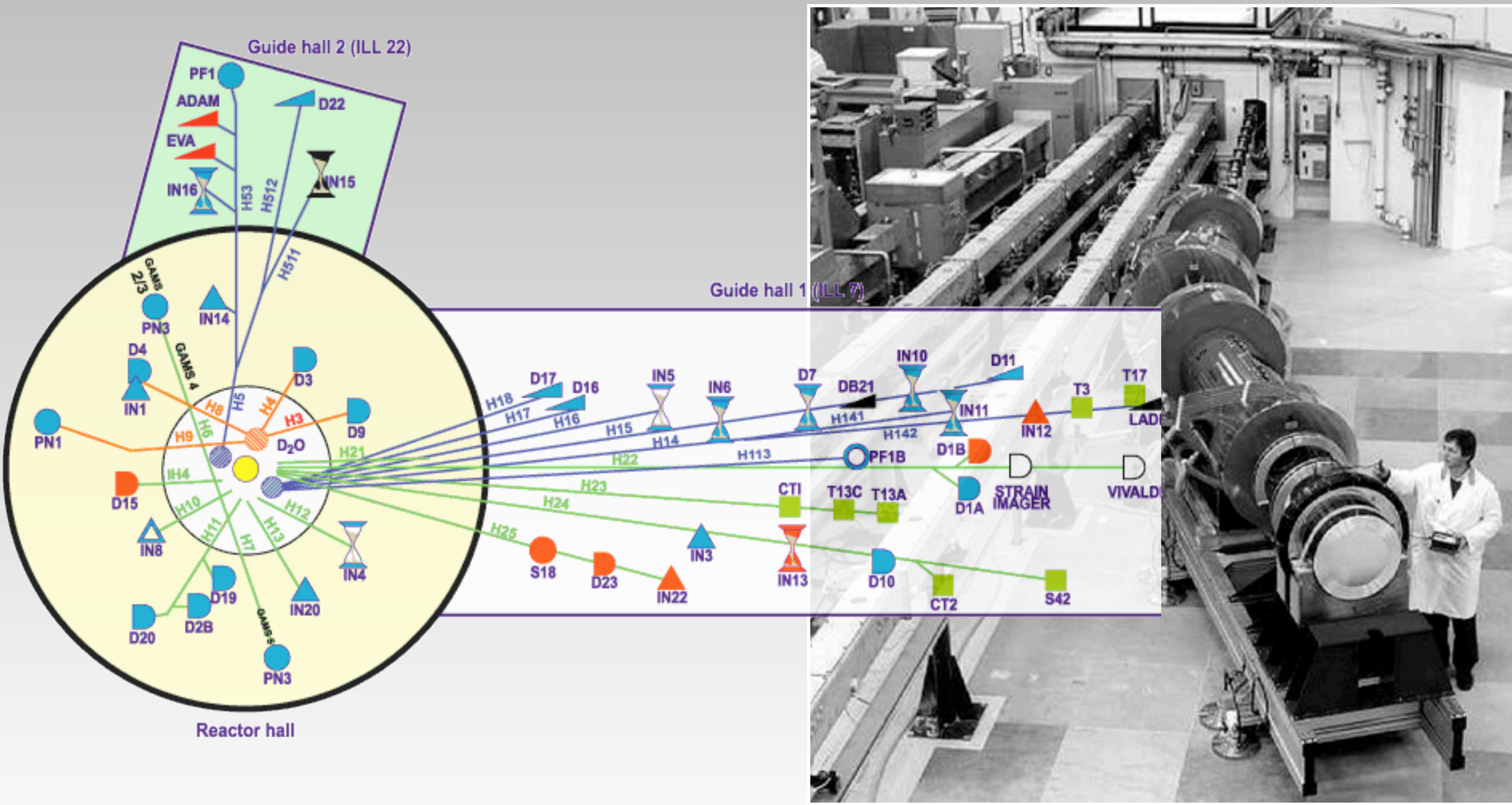
Source: International Panel on Fissile Materials, www.fissilematerials.org

The Potential of Neutron Guide Renewals

at High-Flux Reactors Used for Neutron Research

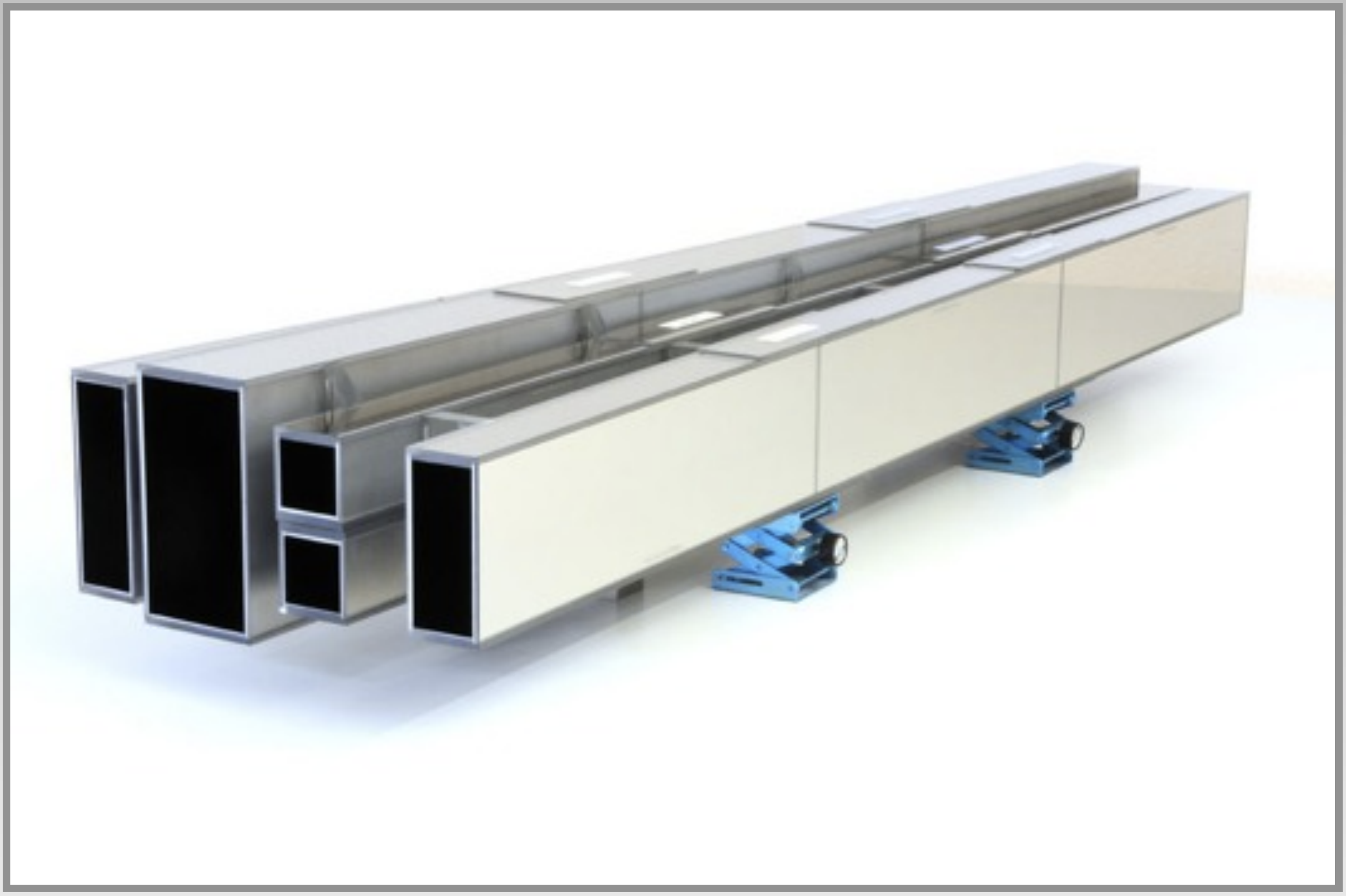
Neutron Guide Hall and Instruments

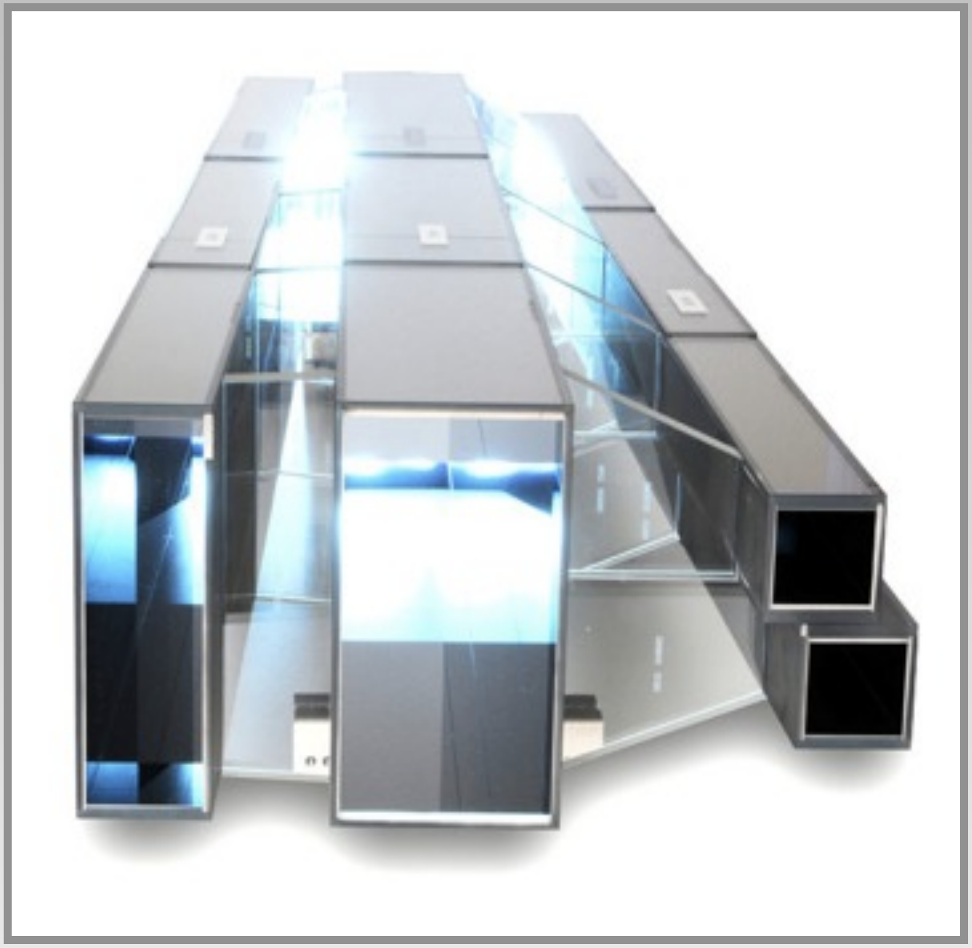
at the High Flux Reactor, Institute Laue Langevin, Grenoble



Source: D. Dubbers, *The Institute Laue-Langevin and its Role in Neutron Science,* Millennium Symposium, April 2006

Supermirrors for Neutron Guides



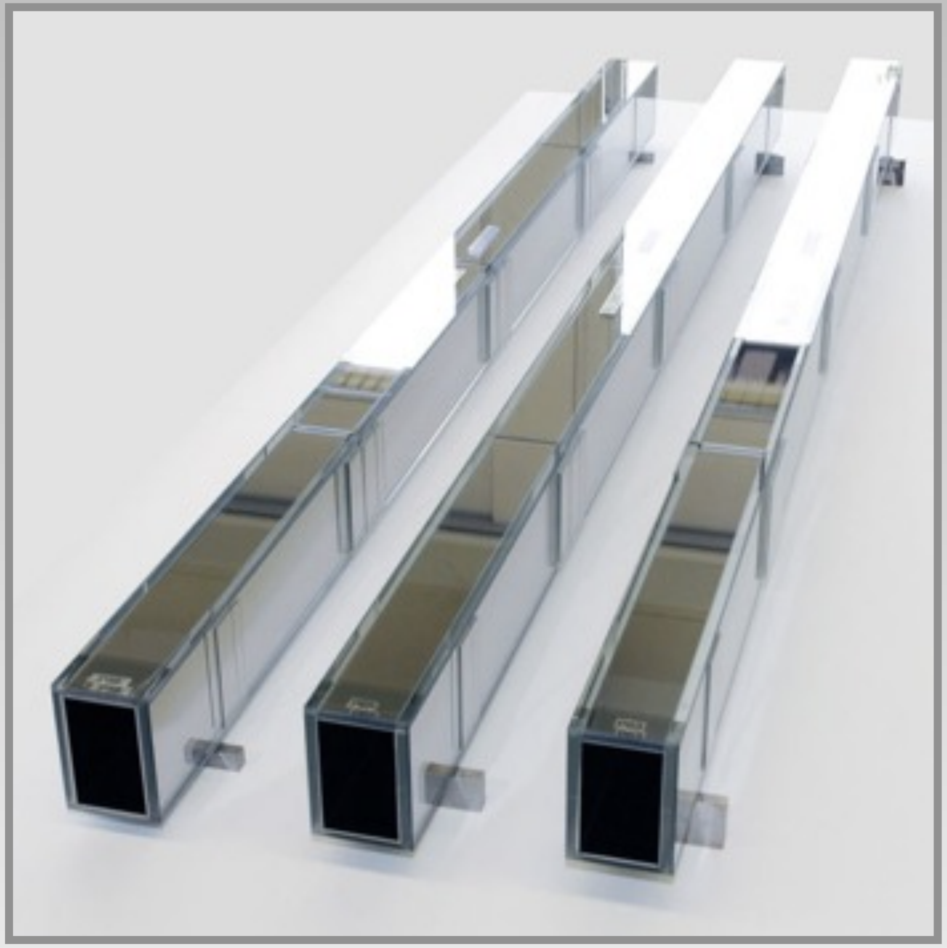


Source: www.swissneutronics.com

“Super Unit” Guides for the NIST Center for Neutron Research (since 2009)

Two main strategies for improvements
Advanced coatings (supermirrors) and advanced geometries (elliptical guides)

Supermirrors for Neutron Guides



Source: www.swissneutronics.com

Elliptic Neutron Guides for the HR Powder Diffractometer, ISIS (since 2007)

Two main strategies for improvements
Advanced coatings (supermirrors) and advanced geometries (elliptical guides)

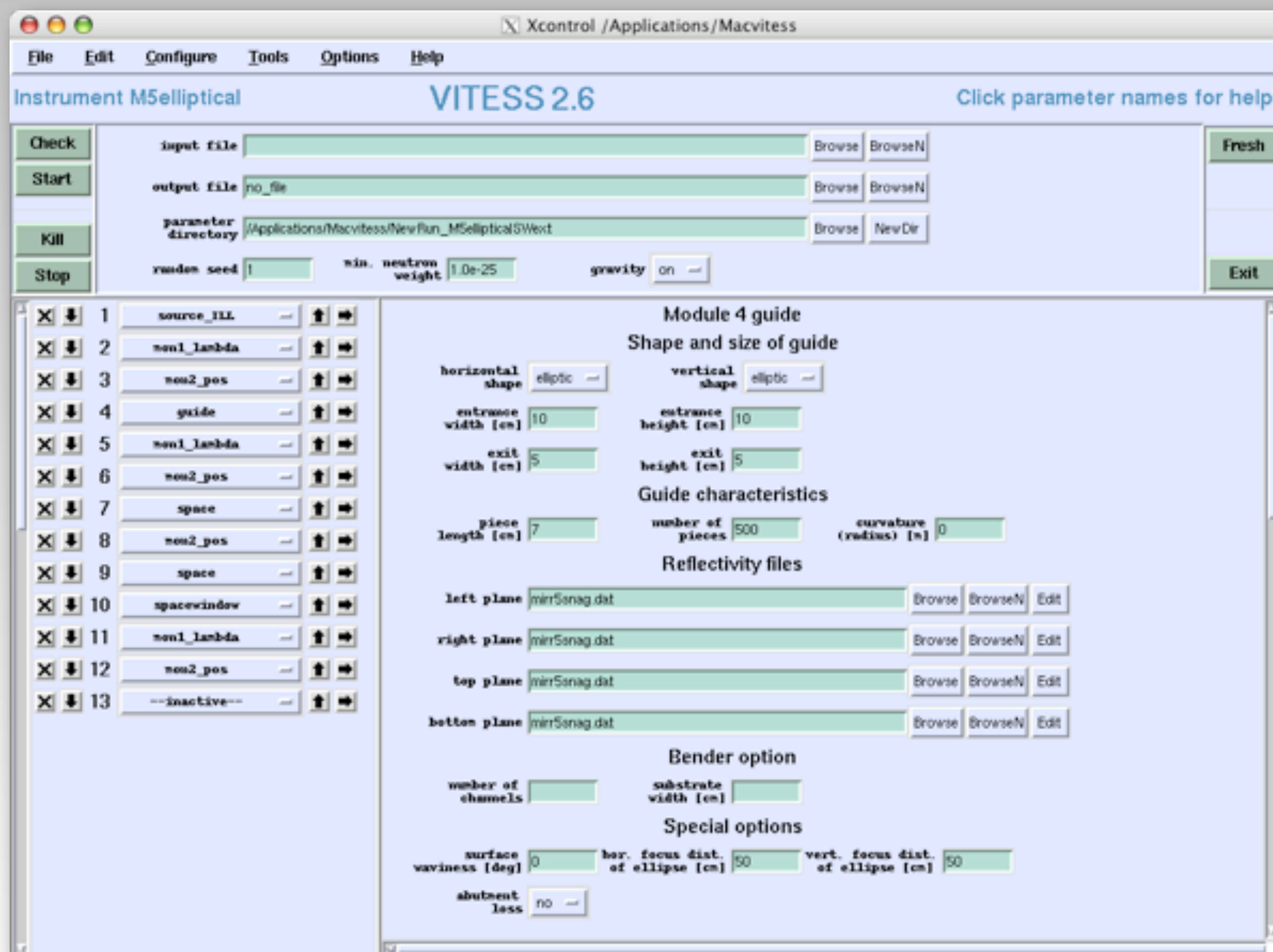
Virtual Experiments with Monte Carlo Raytracing Codes

(VITESS and McStas)

Work with U. Filges, Paul Scherrer Institute, Villigen, Switzerland
Published in Science & Global Security, 20, 2012

Virtual Experiments with VITESS

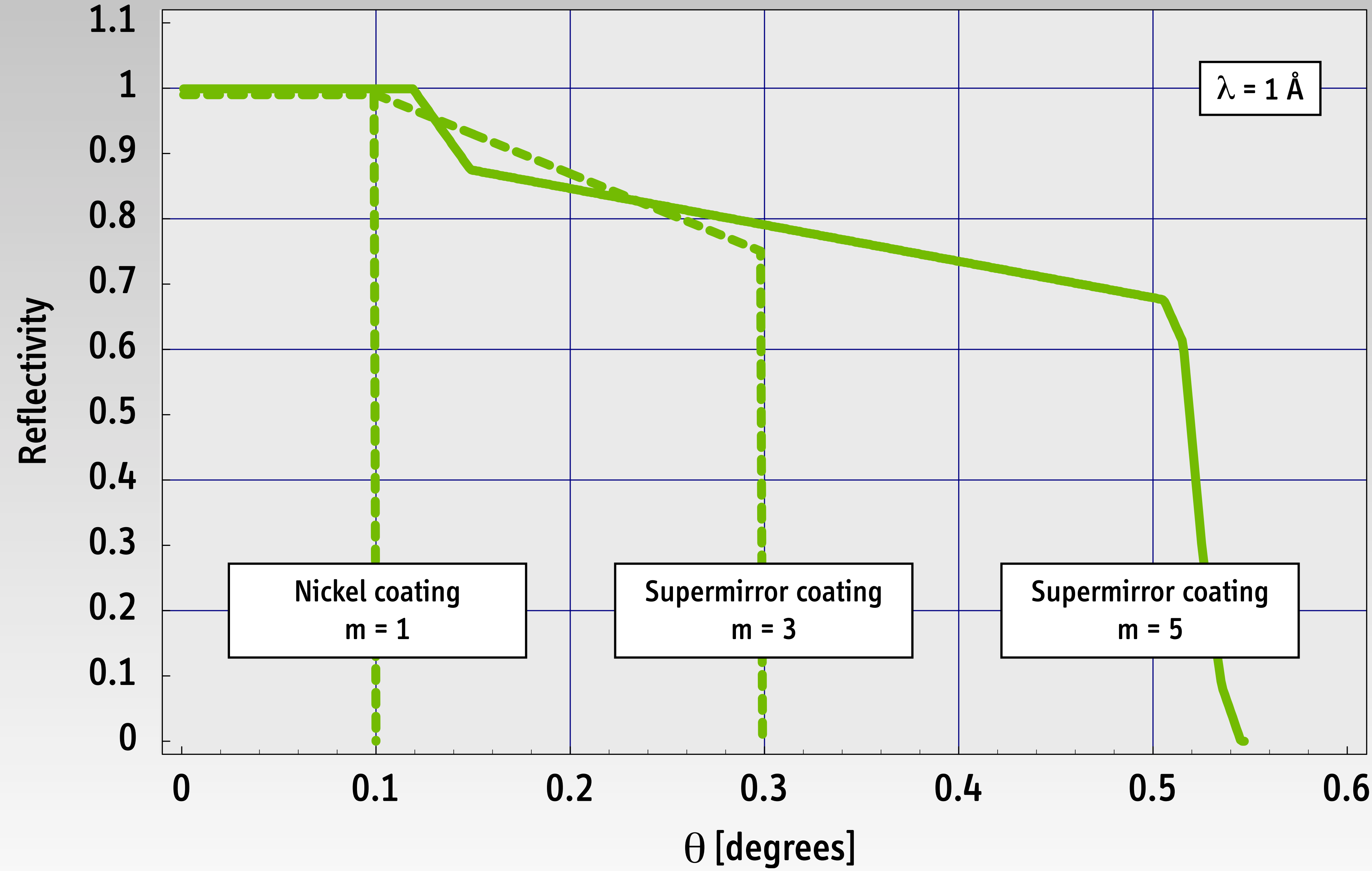
(Virtual Instrumentation Tool for the ESS)



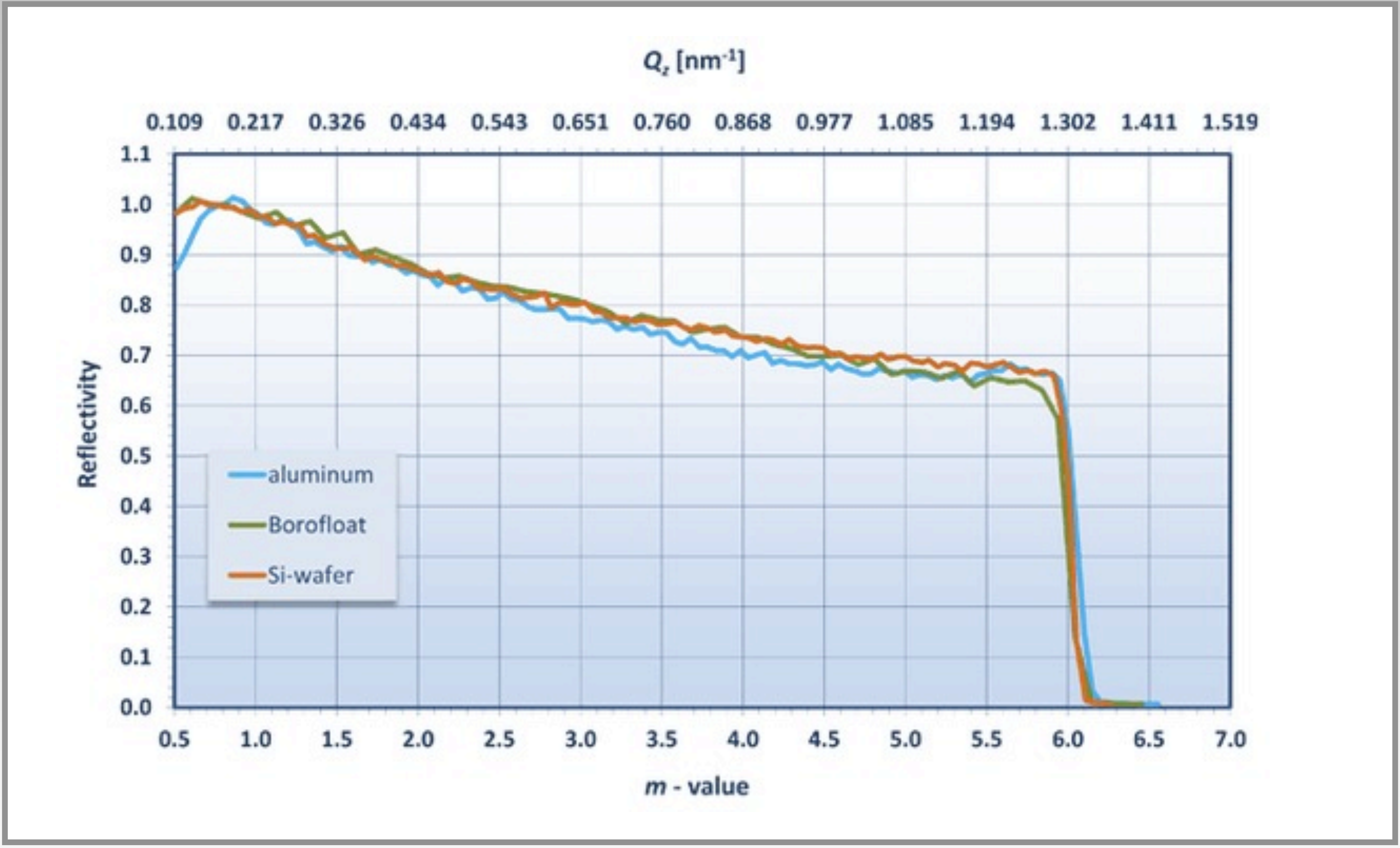
Monte Carlo neutron transport code for neutron scattering at pulsed and continuous neutron sources
Extensively used to design and optimize neutron instruments worldwide

Characterizing Neutron Guides

(Reflectivity curves for various supermirror coatings used for VITESS/McStas simulations)



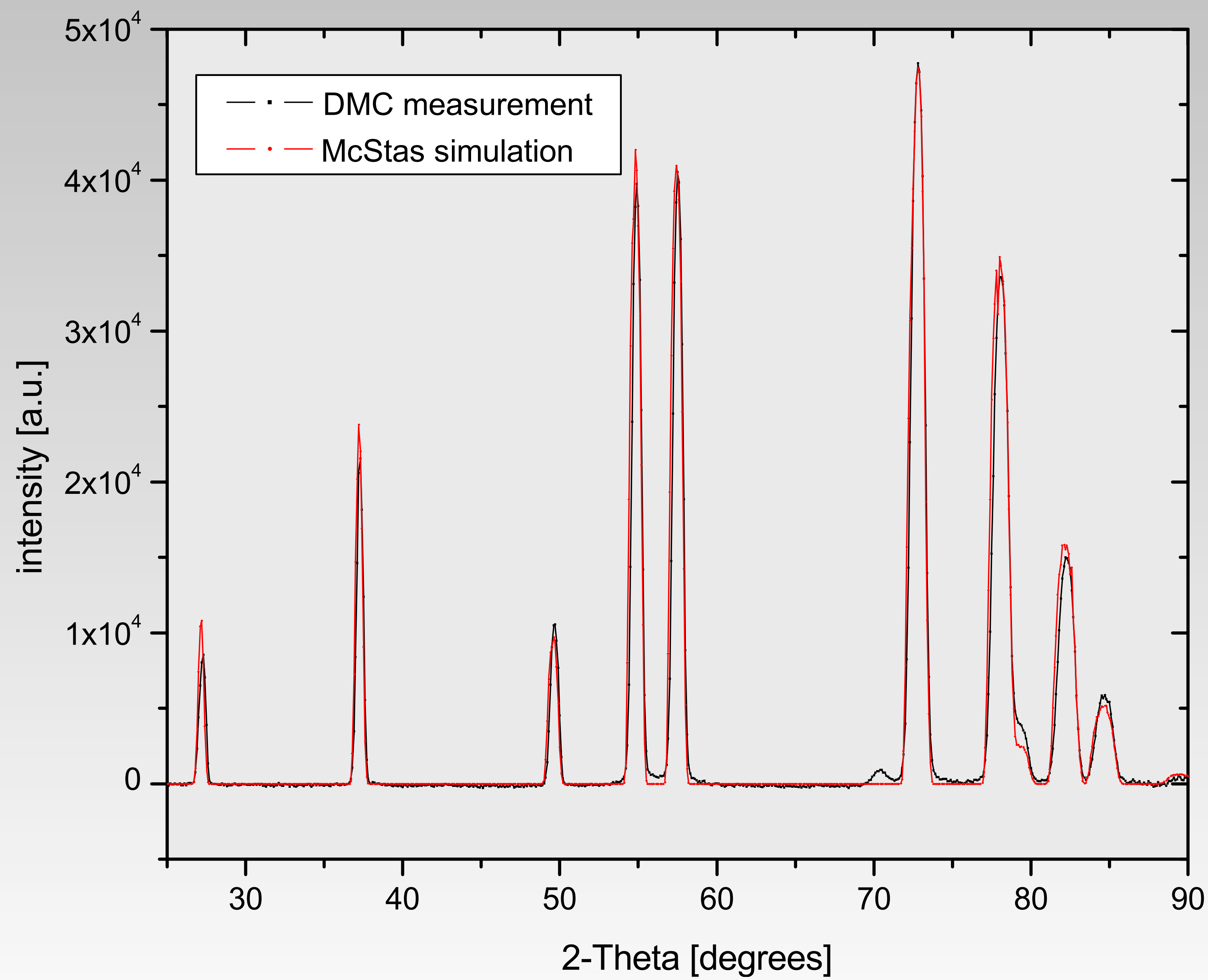
Coatings Are Currently Under Development That Perform Even Better



Source: www.swissneutronics.com

Validating Codes and Simulations

Comparing experimental and simulated data
for the powder diffractometer DMC at SINQ/PSI using a complex sample

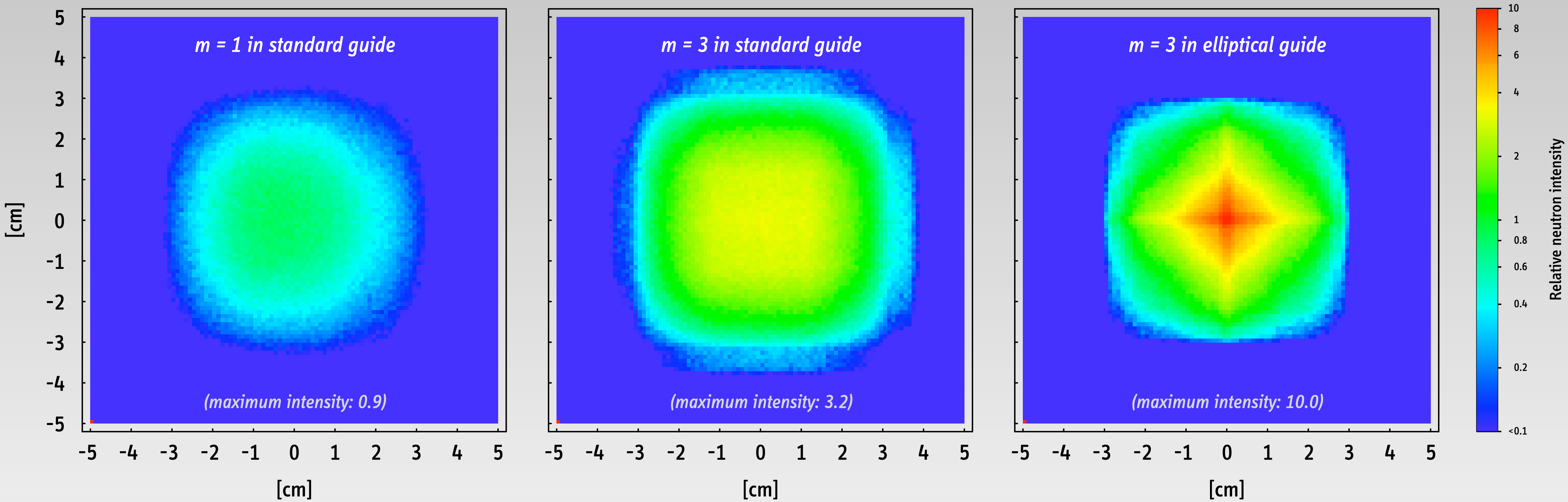


A. Glaser and U. Filges, "Neutron-Use Optimization with Virtual Experiments," *Science & Global Security*, Vol. 20, 2012

Neutron Guide Investigations

Spatial Intensity Distribution

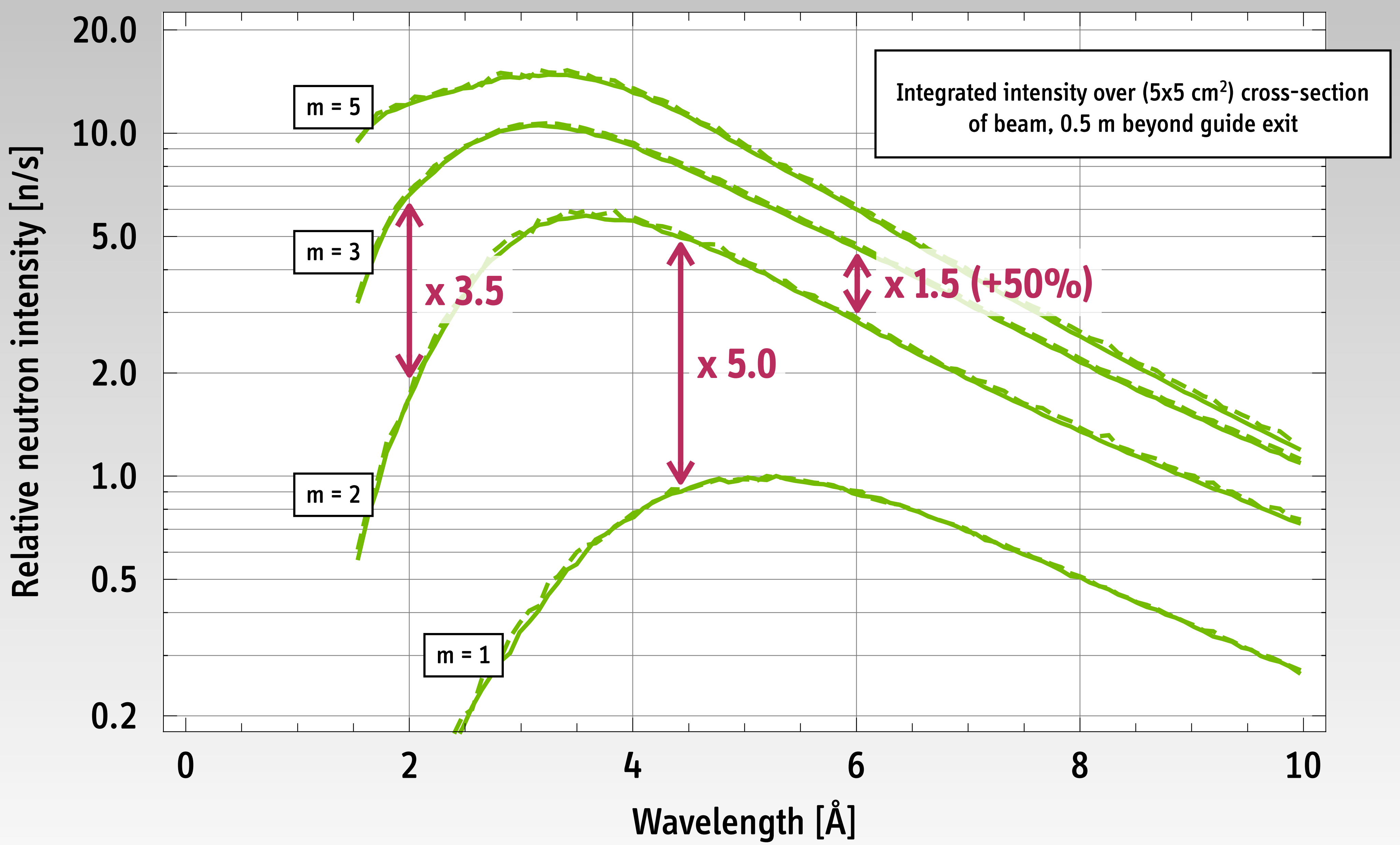
for various supermirror coatings and two guide geometries



Shown are the planes of best focus behind the exit of a guide with a total length of 35 m
Each simulation is based on 10 million neutron tracks

Relative Neutron Intensity

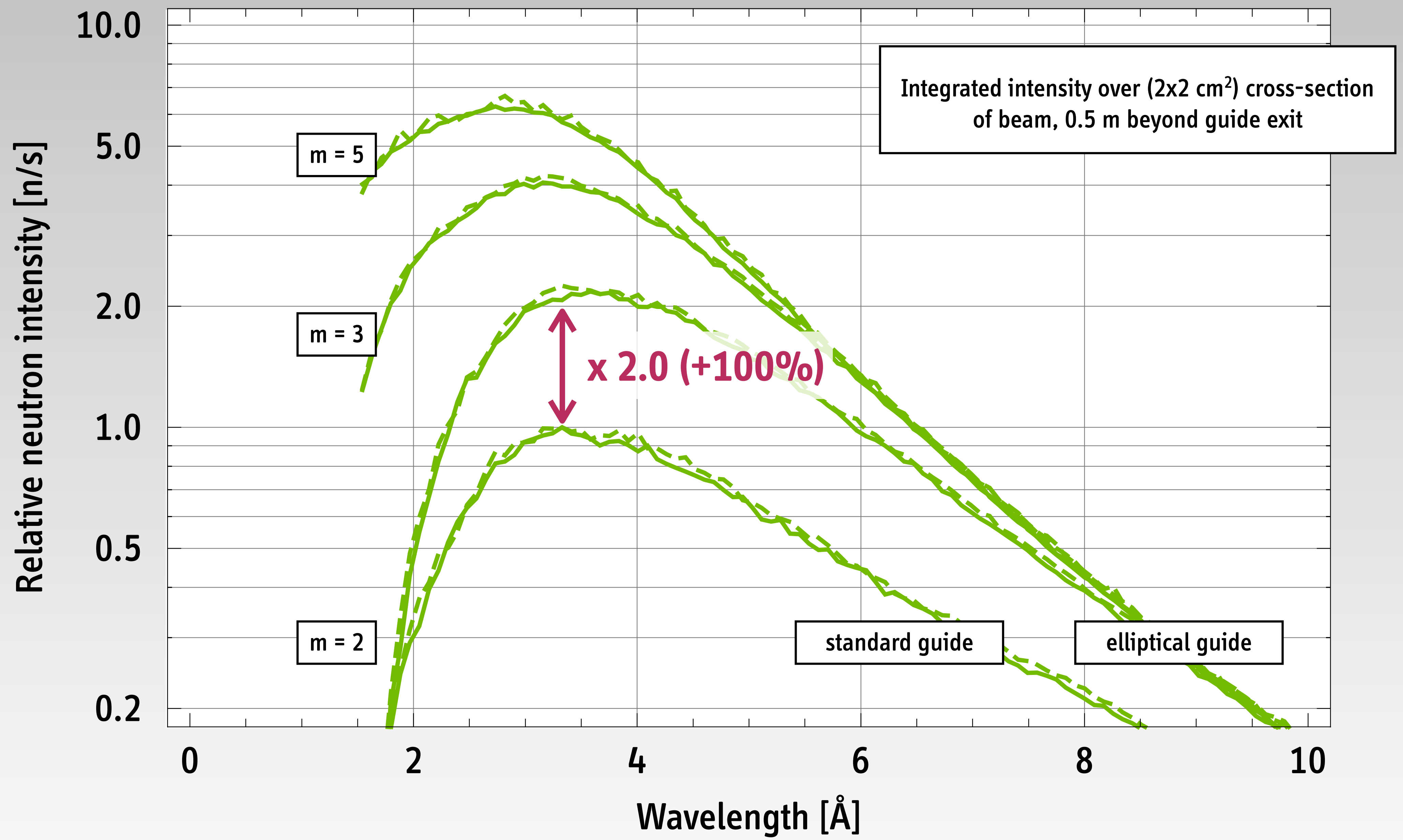
for standard (35-meter) guide with various supermirror coatings



A. Glaser and U. Filges, "Neutron-Use Optimization with Virtual Experiments," *Science & Global Security*, Vol. 20, 2012

Relative Neutron Intensity

Elliptical versus Standard (35-meter) Guides

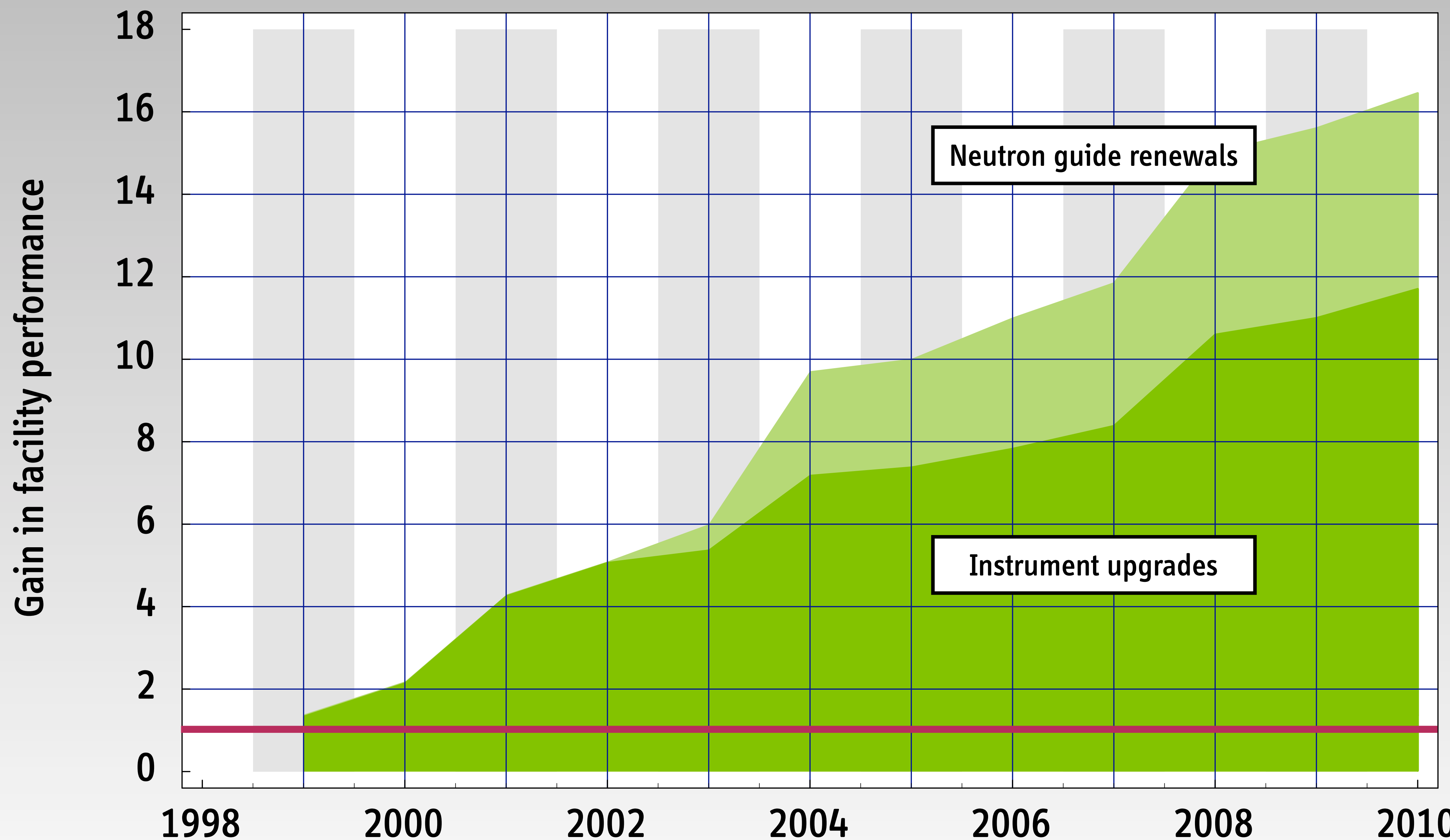


A. Glaser and U. Filges, "Neutron-Use Optimization with Virtual Experiments," *Science & Global Security*, Vol. 20, 2012

Experience with Previous Facility Upgrades

ILL Millennium Program

(Upgrade of the HFR at the Institute Laue-Langevin, Grenoble)



The first phase of the project achieved a 19-fold performance gain; it included 14 upgraded or new instruments; total cost: €42 million

Renaissance: The ILL Millennium Programme 2001–2009, Institut Laue-Langevin, July 2010

Looking Ahead

Convert-and-Upgrade as a Strategy to Support HEU Minimization Efforts?

Viability of Convert-and-Upgrade Strategies

$25–50 million annual operating costs for a modern high-flux research reactor

(IAEA Research Reactor Database)

$55 million have made possible 19-fold performance gain at ILL

in other words

Even an investment equivalent to a fraction of an annual operating budget can lead to a significant performance gain of a facility

(Investments in instrument performance are recovered *very* quickly)

Needs case-by-case analysis taking into account facility-specific aspects

Most sensible for regional or international efforts to create centers-of-excellence for neutron research (and other applications)

Conclusion and Outlook

Neutron guide renewals (and instrument upgrades) can dramatically increase the overall performance of a neutron research facility

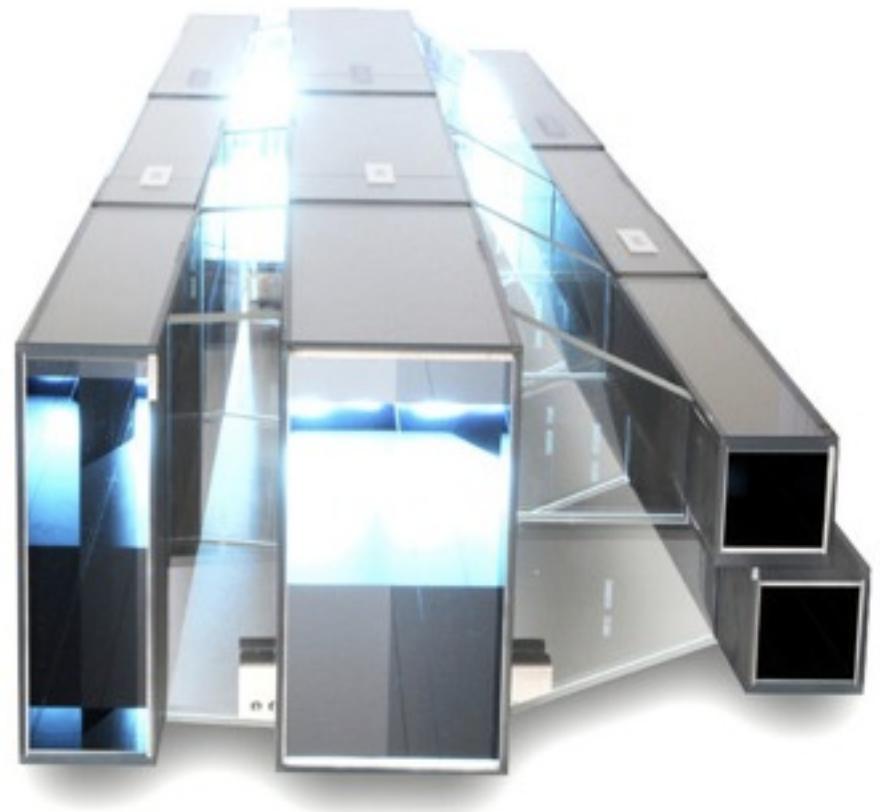
Modern supermirror coatings and advanced guide-geometries generally yield a several-fold increase in neutron intensity across all relevant wavelengths

Flux penalties due to conversion to LEU become effectively irrelevant

Unique Opportunities for operators and users to develop coordinated "convert-and-upgrade" strategies

Ideally, expand scope of feasibility studies on research reactor conversion to include potential of simultaneous facility upgrades

(and permit optimum allocation of available resources)



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