X-Ray Reflection for Geant4-based Accelerator Synchrotron Radiation Simulation Tools

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(presented by G Ganis, CERN)

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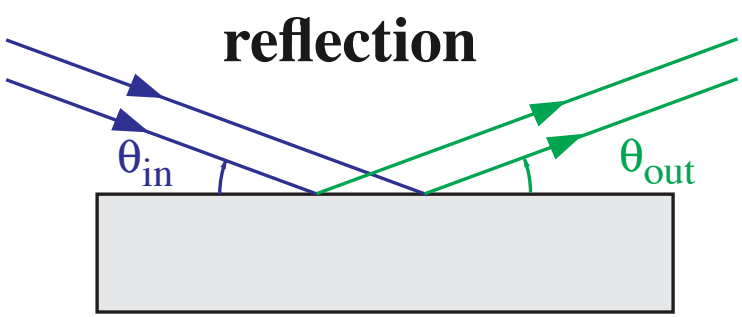
X-ray reflection

It came as a (bad) surprise in LEP : hard (5-10 keV) X-ray photons from synchrotron radiation generated in magnets as far as 200 m from the interaction region can undergo specular (mirror) reflection on the vacuum chamber and reach the interaction region and strongly enhance detector backgrounds. G.v. Holtey, et al., NIM A403, 1998

Depends critically on small orbit/angles of order

1 cm / 100 meter = 0.1 mrad = 100 μrad

Mitigated in LEP using a collimator 120 m from IP



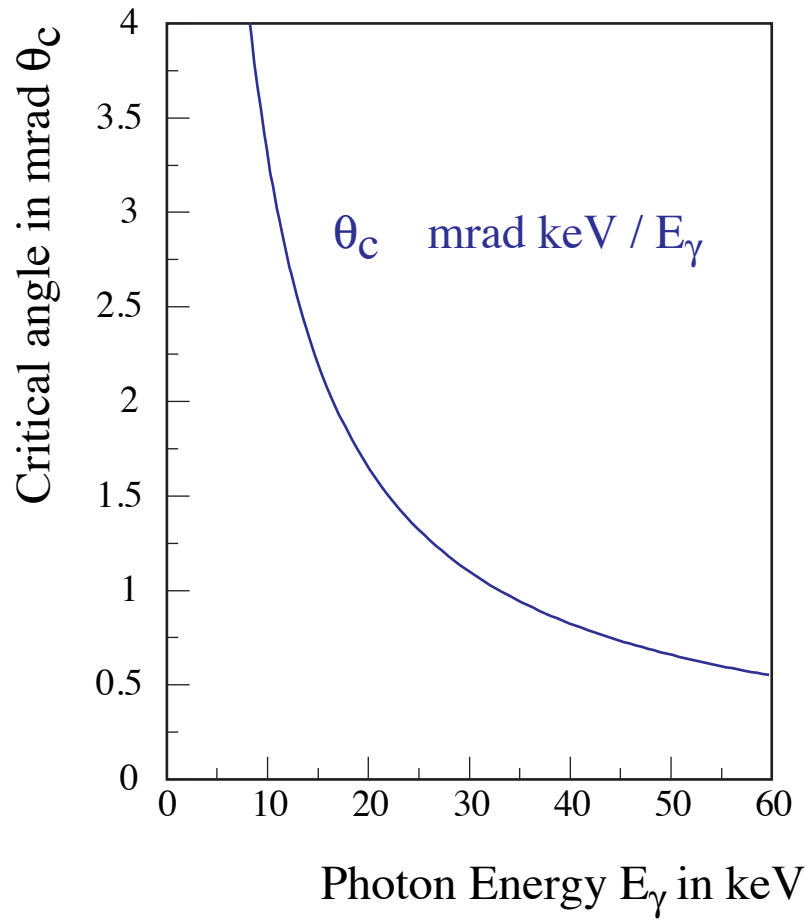
Observations ~ matched with simple model

high reflectivity close to 100 %

below a critical angle

Θc [mrad] = 33 / Eγ [keV]

G.S. Brown and D.E. Moncton,
Handbook on Synchrotron Radiation, Volume 3,
Amsterdam: North-Holland, 1991, pp 120-124.



Motivation for implementation in standard G4

Geant4 is much used in detector and machine studies.

Examples, with further references :

CLIC, D. Arominski et al. NIMA, 983:164522, 2020

FCC, MDISim, BDSim M.Boscolo et al. Eur. Phys. J. Plus (2022) 137:38

The main relevant processes including
X-ray photon generation by synchrotron radiation, absorption and scattering processes are available in standard G4

X-ray specular reflection at grazing angles not (yet)

Of more general interest, example :

Geant4 Simulations Of A Wide-Angle X-Ray Focusing Telescope,

Donghua Zhao et al. Exp Astron (2017) 43:267–283

Implementation in G4 and other codes

Earlier efforts of implementation in G4 :

G4XrayGrazingAngleScattering.cc from Buis, Vacanti obtained via Alexander Howard,

not straightforward to use, surface defined only for Silicon (and Vacuum)

More recently mentioned by Gianfranco Paterno, G4 EM meeting on the 23/2/2023

X-ray reflection is implemented in SynRad+

by Roberto Kersevan, Marton Ady / CERN TE-VSC

and in SYNC_BKG by M Sullivan, SLAC

Data, material dependence

X-Ray data booklet:
https://xdb.lbl.gov/

Reflectivity data web site
https://refractiveindex.info/

Data typically available down to

~0.5 degree (9 mrad)

and up to ~10 keV

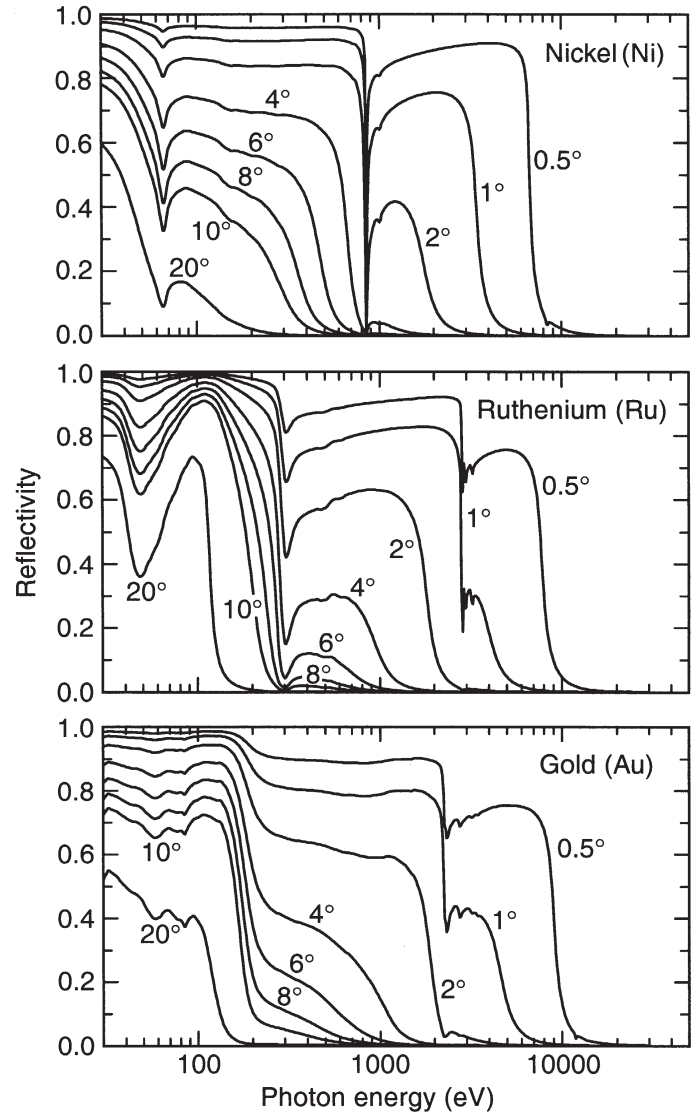


Fig. 4-5. Specular reflectivities of nickel (ρ = 8.90 g/cm^3), ruthenium (ρ = 12.41 g/cm^3), and gold (ρ = 19.3 g/cm^3). The reflectivity is calculated for s-polarization at grazing angles of 0.5, 1, 2, 4, 6, 8, 10, and 20 degrees.

Discussion

An implementation of grazing X-ray reflection as part of the standard G4 distribution appears to be of general interest for a broad range of applications

One challenge :

The lack of data for very small angles < 1 mrad and energies > 10 keV

and the dependence of surface details (rough, smooth) for small grazing angles

Idea : start in this range from a simple model that can be parametrized and extended as more data becomes available

in 0-order could be a default reflection probability like ~ 80 % below a critical angle