Simulating Scintillator Light Collection Using Measured Optical Reflectance

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LAWRENCE BERKELEY NATIONAL LABORATORY

Improve Optical Monte Carlo Methods

Modify GATE and Geant4 to use real BGO reflectance measurements

- **Improve accuracy of existing Monte Carlo codes**

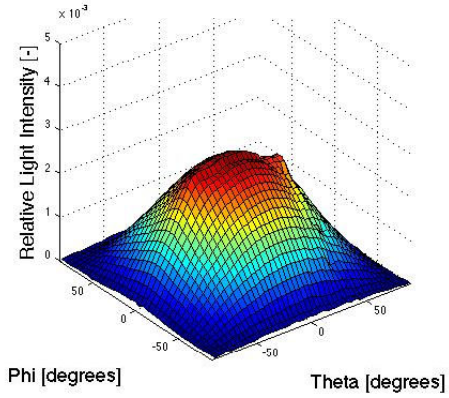
Not all light distributions are linear combinations of specular and Lambertian (diffuse) reflections

- **Improve usability of existing Monte Carlo codes**

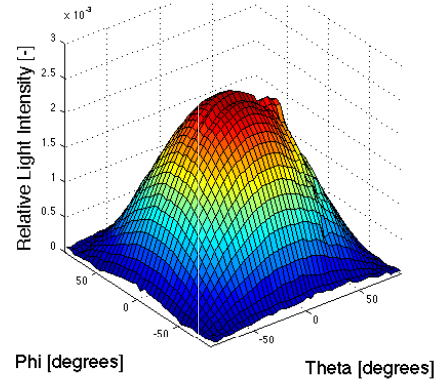
Most users do not have detailed knowledge of the parameter values that need to be set (surface roughness, σ of light spread, etc.)

Commonly Used Reflectors

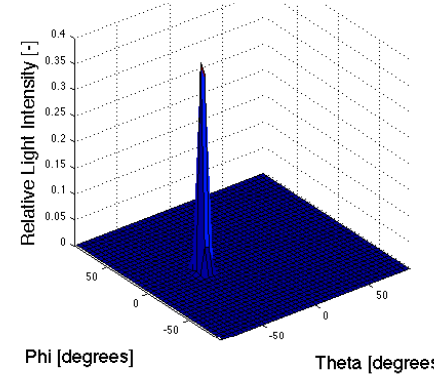
Teflon®



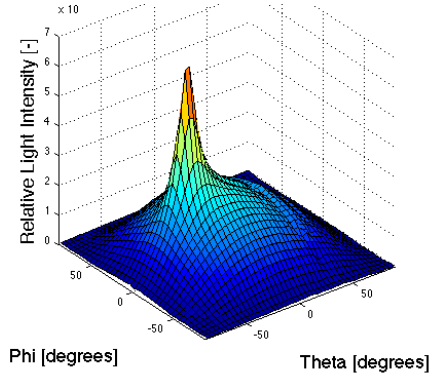
TiO_2



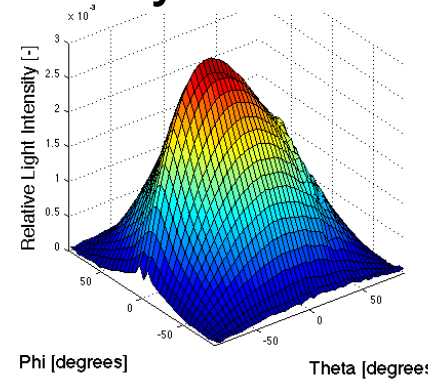
VM2000



Lumirror®

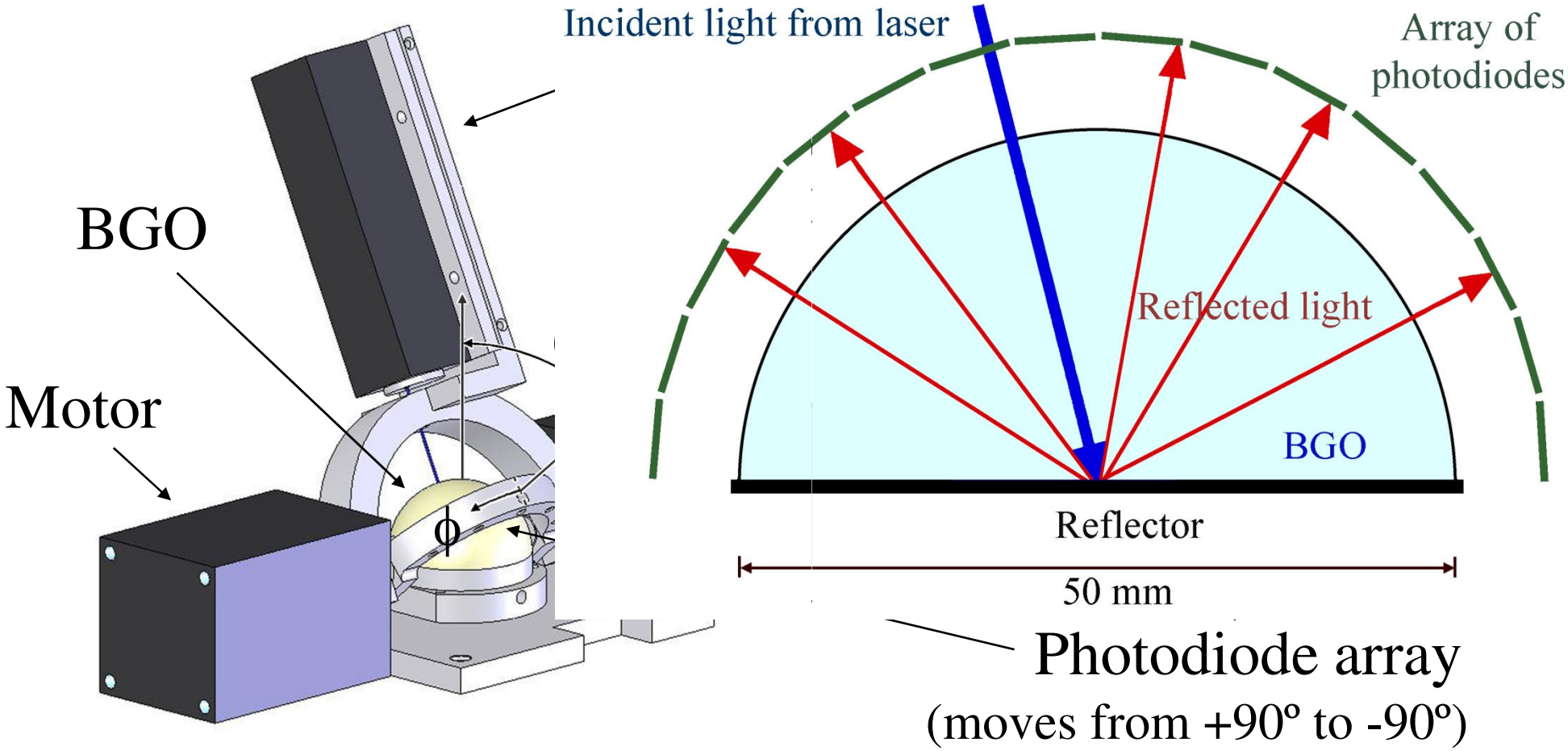


Tyvek®



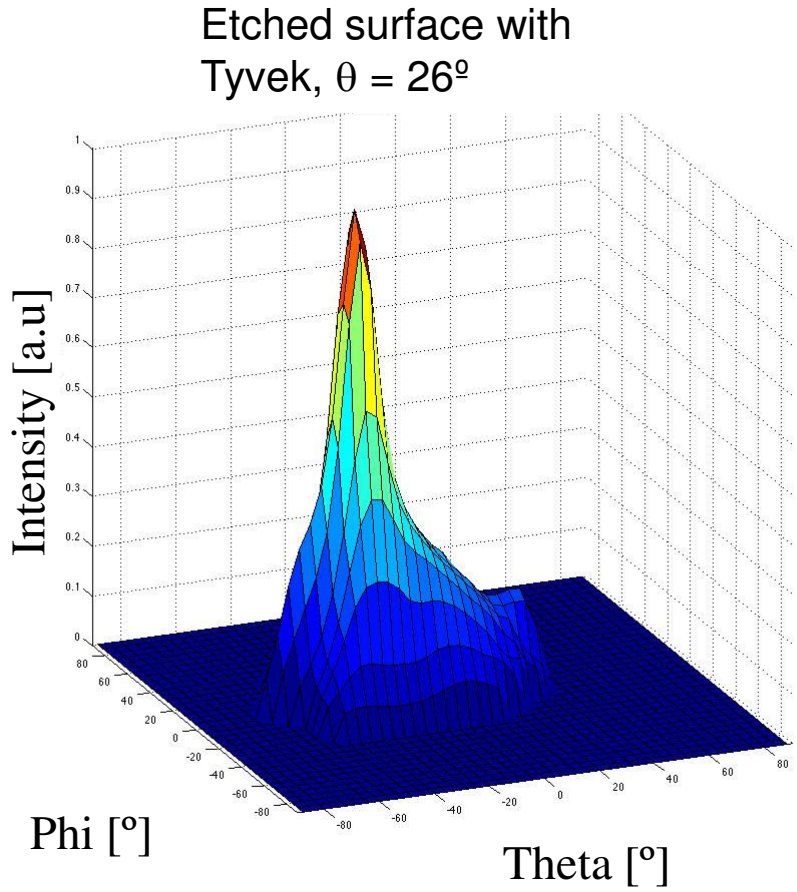
Janecek and Moses, "Optical Reflectance Measurements for Commonly Used Reflectors", IEEE Trans. of Nucl. Sci., Vol. 55, No. 4 (2), pp. 2432-2437, August 2008

Instrument for Measuring Reflectance for Incident and Reflected Angles



Janecek and Moses, "Design of an Instrument to Measure Optical Reflectance of Scintillating Crystal Surfaces", IEEE Trans. of Nucl. Sci., Vol. 55, No. 3 (2), pp. 1381-1386, June 2008

Instrument for Measuring Reflectance for Incident and Reflected Angles

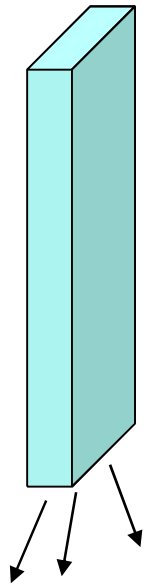


Janecek and Moses, "Measuring Light Reflectance of BGO Crystal Surfaces", IEEE Trans. of Nucl. Sci., Vol. 55, No. 5 (1), p. 2443-2449, October 2008

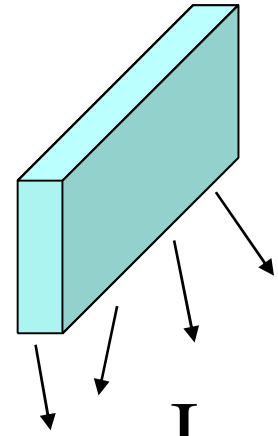
Methods

Validation Method

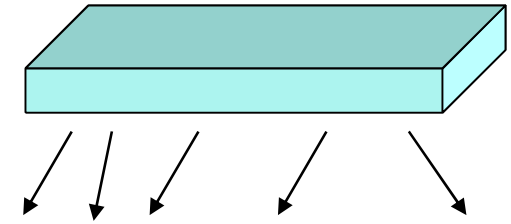
Measure same crystal in three different orientations



I_{Small}

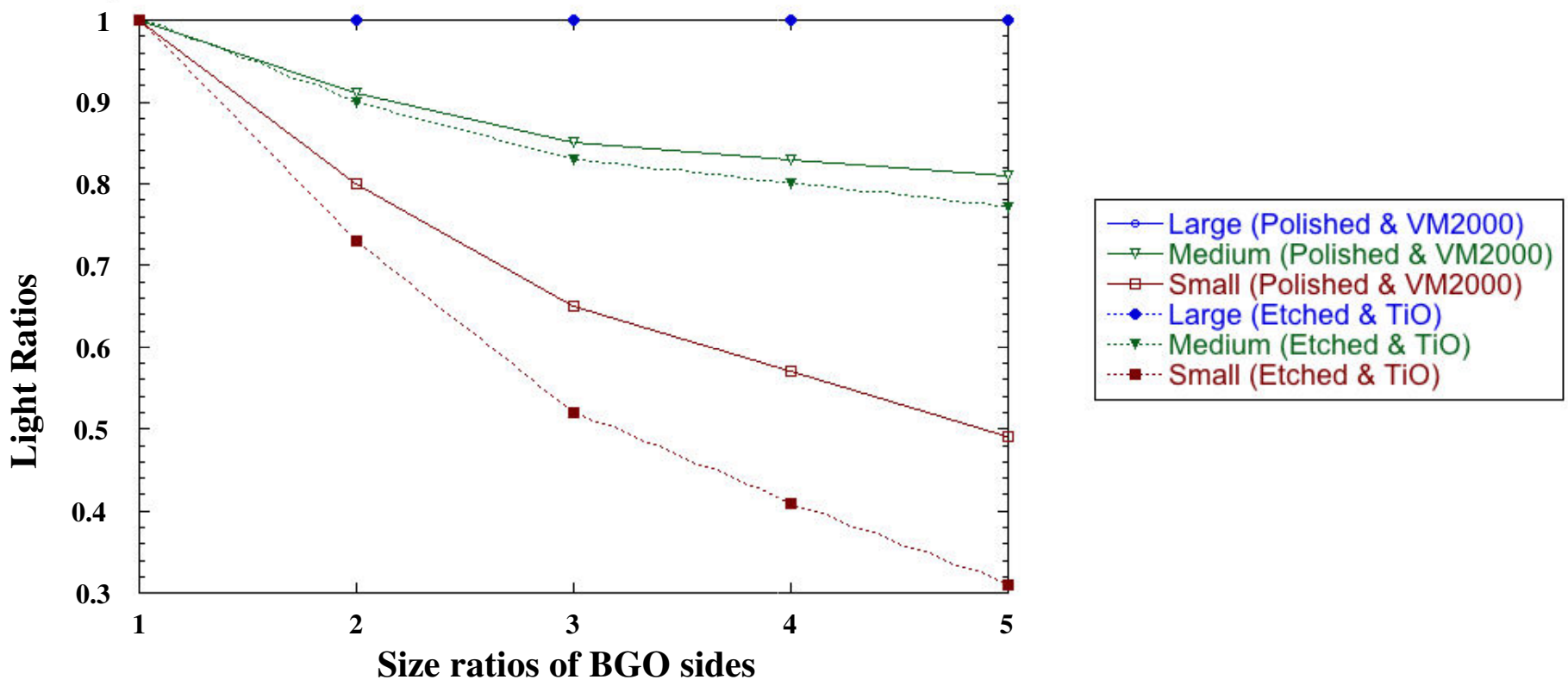


I_{Medium}



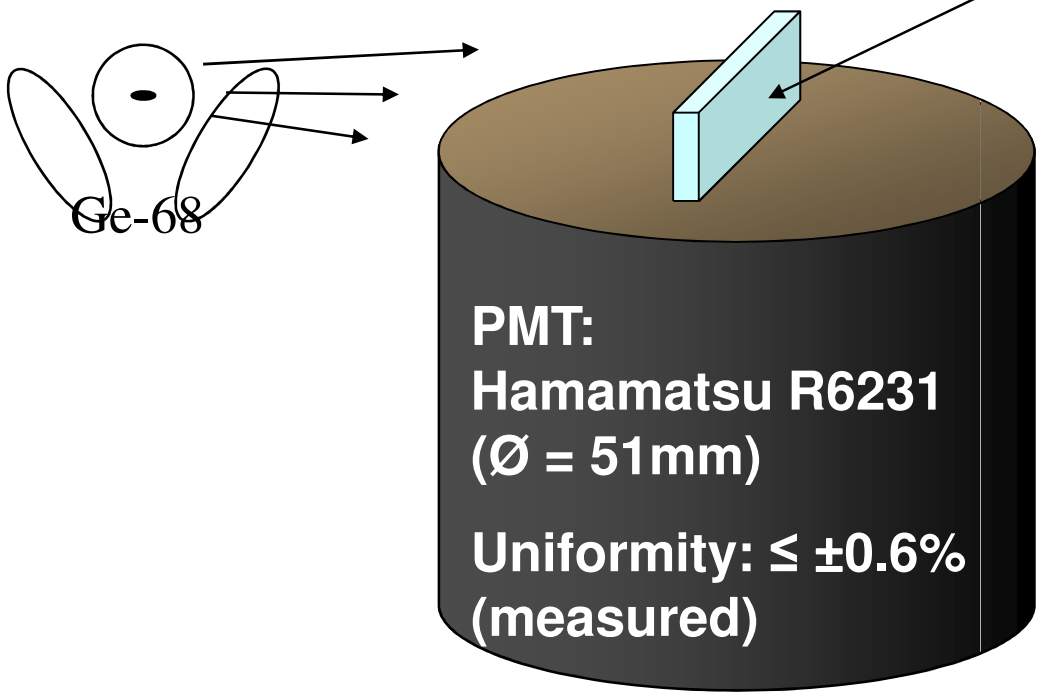
I_{Large}

What Crystal Dimensions To Use?



0.3 cm x 1.0 cm x 3.0 cm

Measured Data



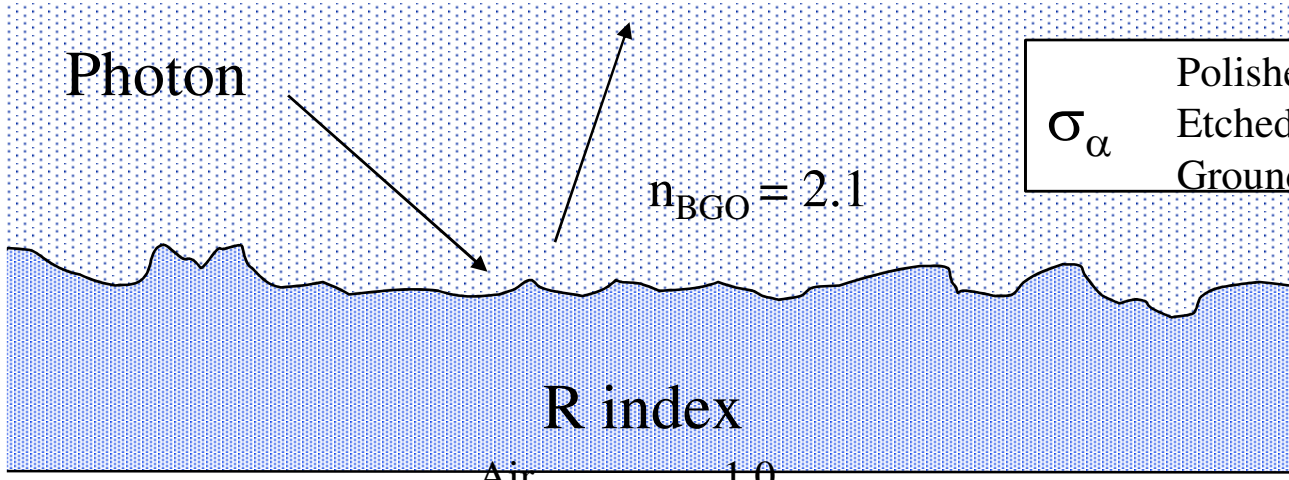
Crystal: 5 polished, 5 etched and 5 ground crystals from Hilger Crystals (U.K.) and Proteus (OH)

Standard Geant4 Simulations

Model: UNIFIED

Reflection Type
Specular Spike, Specular Lobe, Backscatter, Lambertian

Surface
groundbackpainted (ground)
dielectric-dielectric (dielectric-metal)

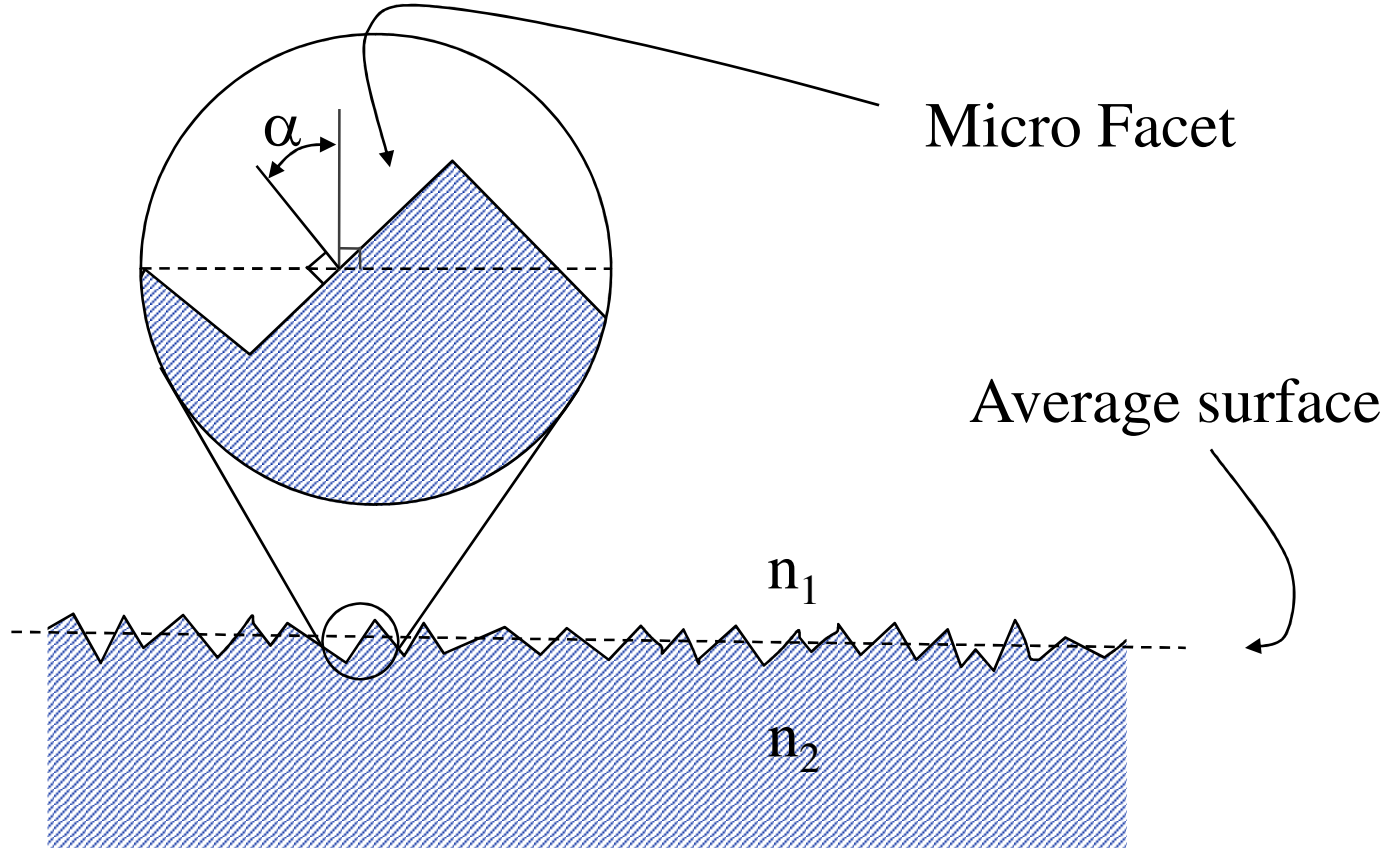


σ_α	
Polished:	1.3º
Etched:	3.8º
Ground:	12º

R index

Air	1.0
Grease	1.404
MeltMount™	1.582
TiO_2	1.61

Surface Roughness



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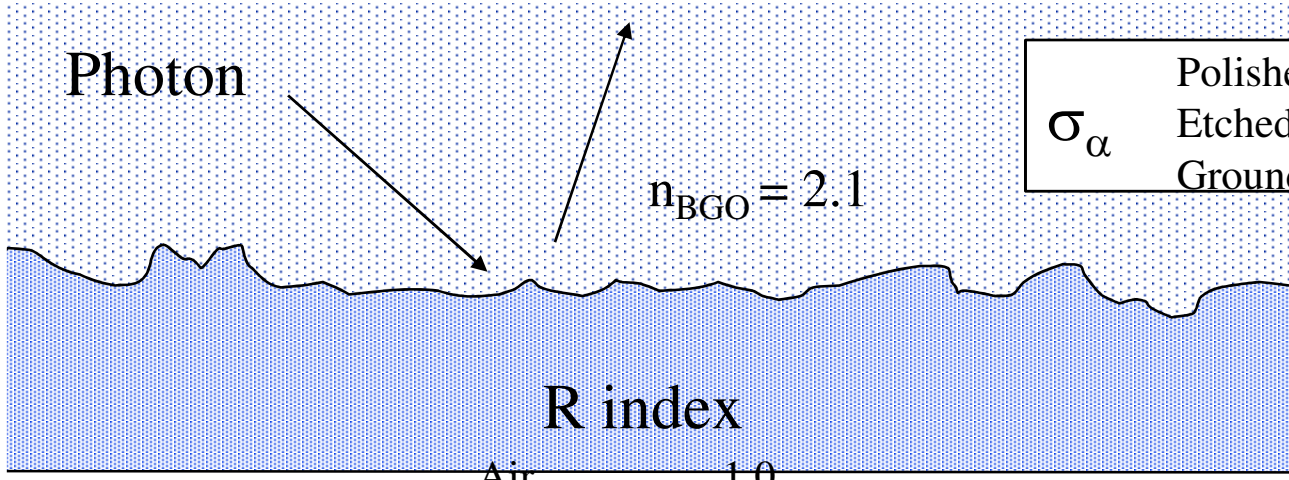

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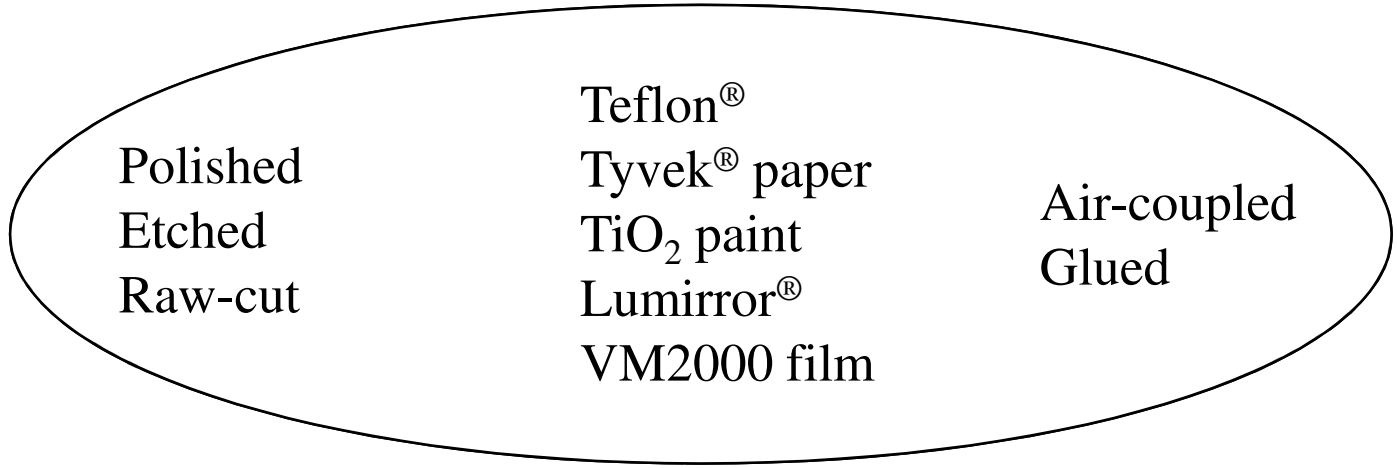
Reflectivity

Teflon®	0.99
VM2000 film	0.985
TiO_2 paint	0.955
Lumirror®	0.98*
Tyvek® paper	0.97*

*measured

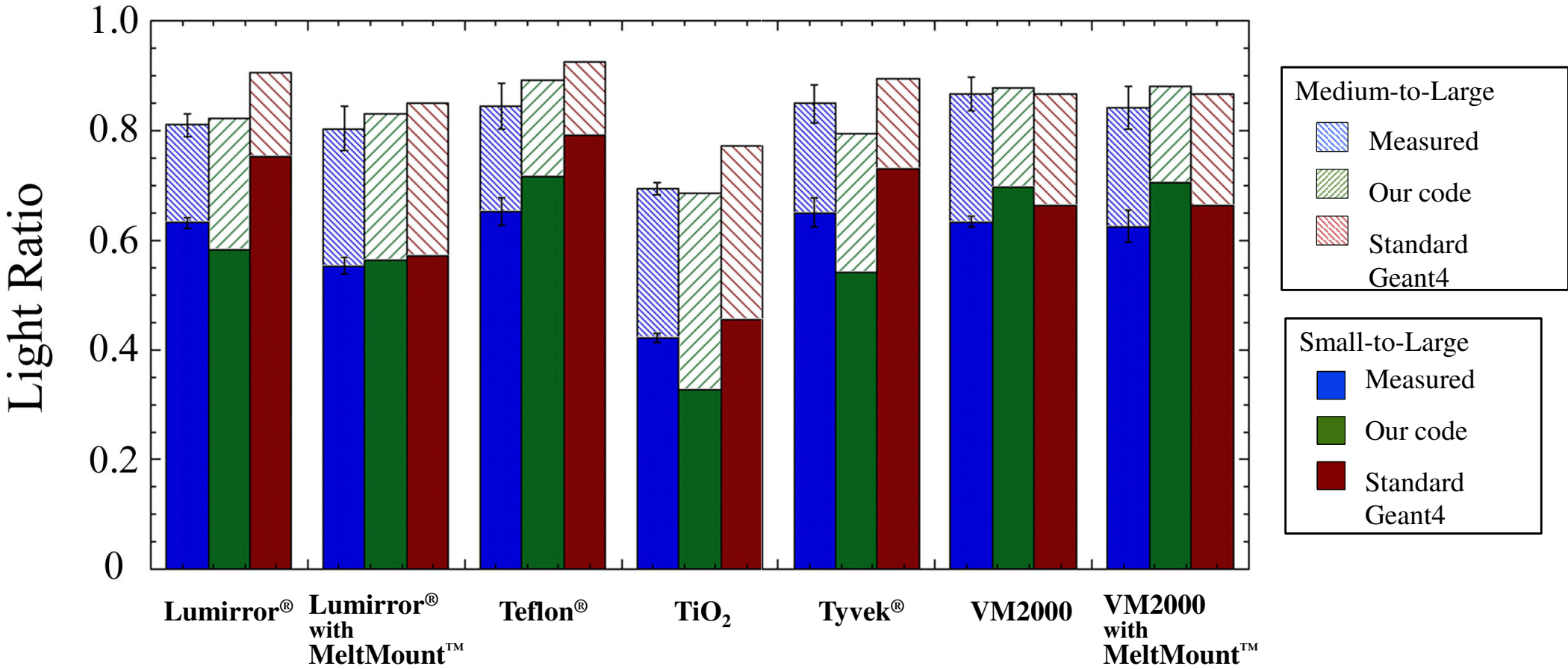
Our Simulations

- **Angular distribution of reflection based on measured data**
- **Implemented via Look-Up-Tables in Geant4 / GATE**
- **Total reflectivity based on literature values (Teflon®, TiO_2, VM2000) and on our measured values (Lumirror®, Tyvek®).**
- **Only user parameters needed are surface / reflector combo**

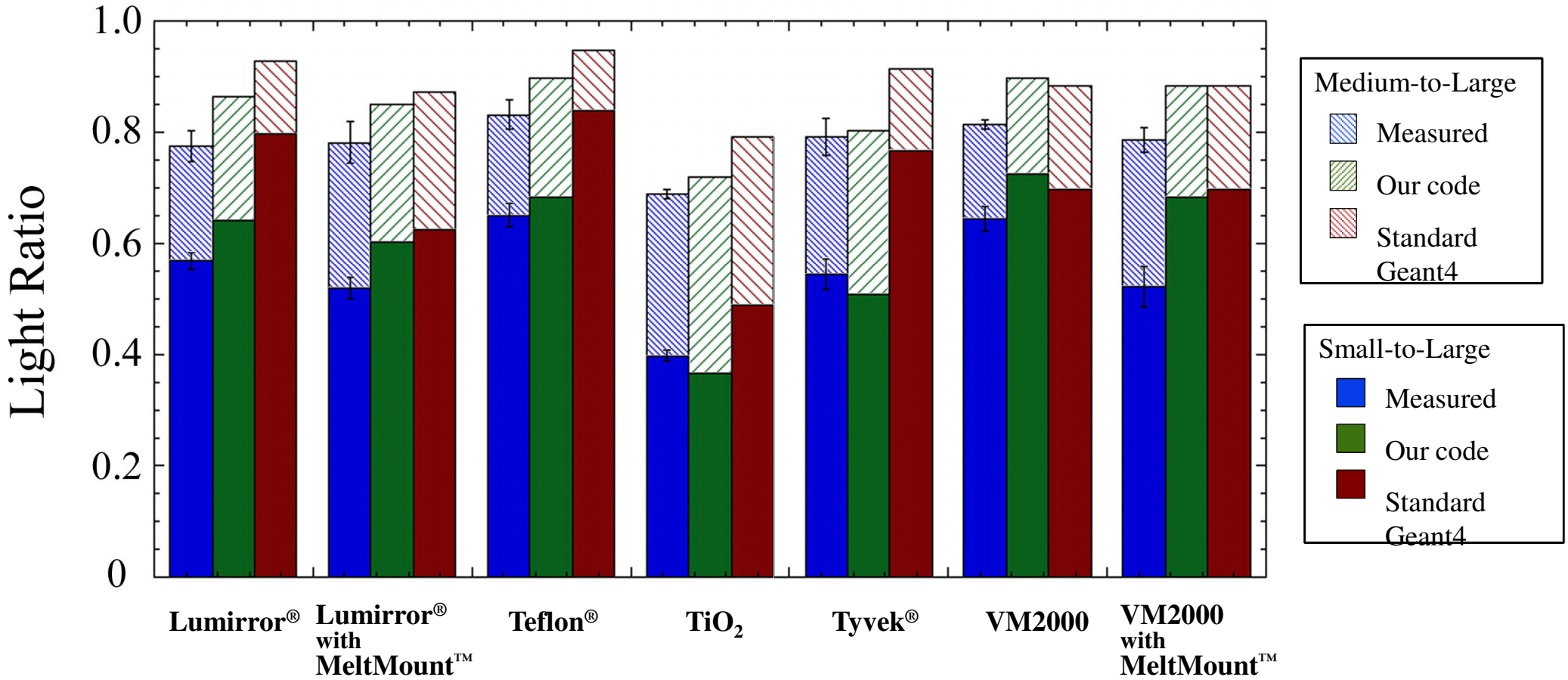


Results

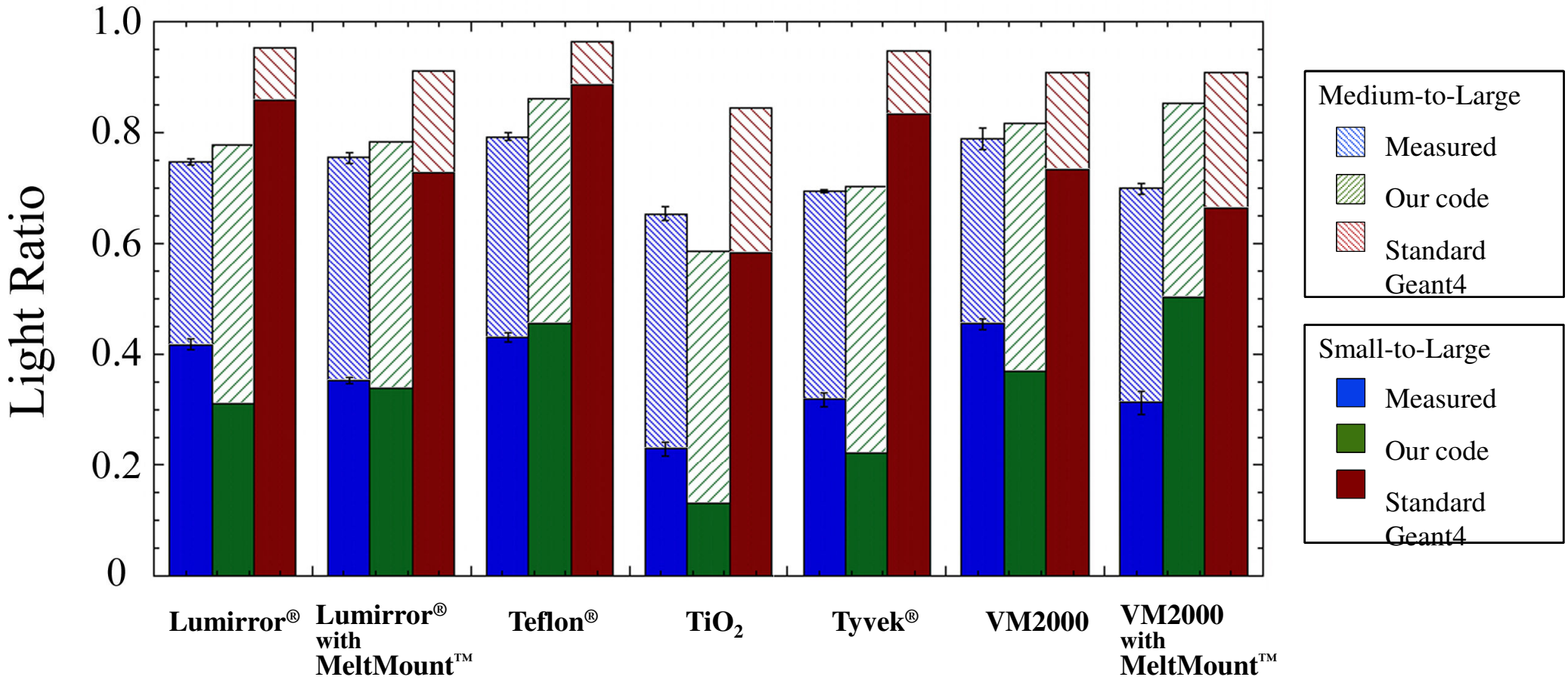
Polished Surfaces



Etched Surfaces

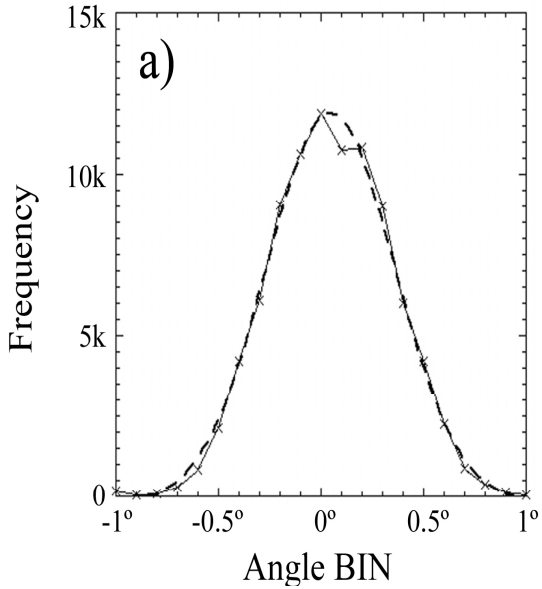


Ground Surfaces

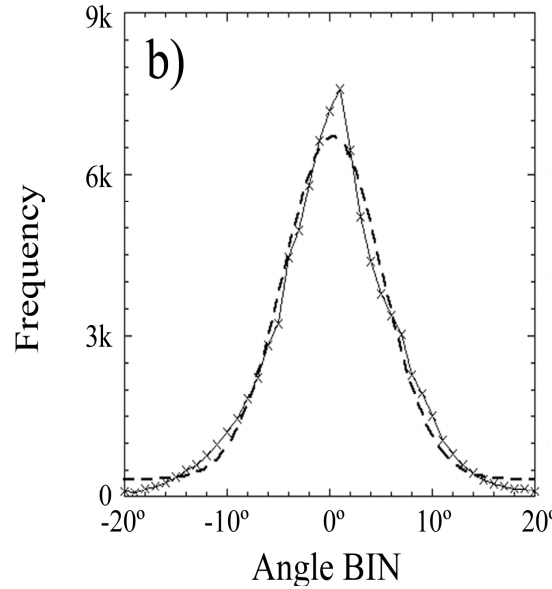


Surface Slopes

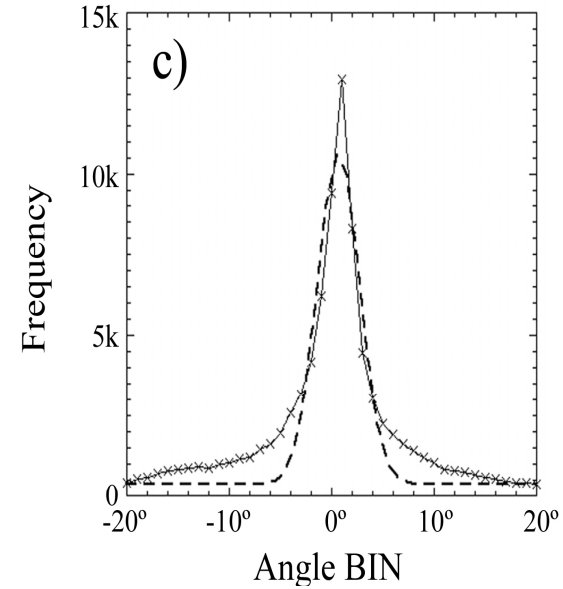
Polished



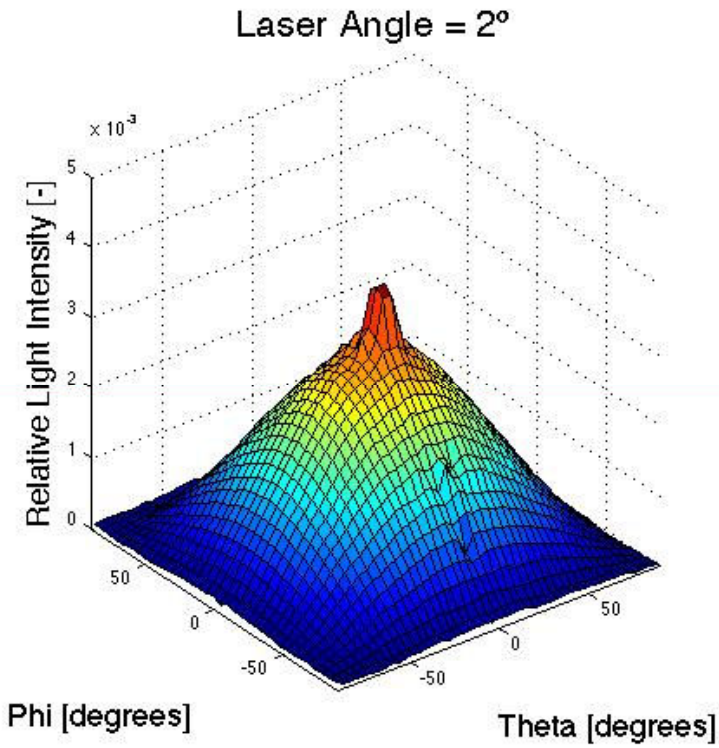
Etched

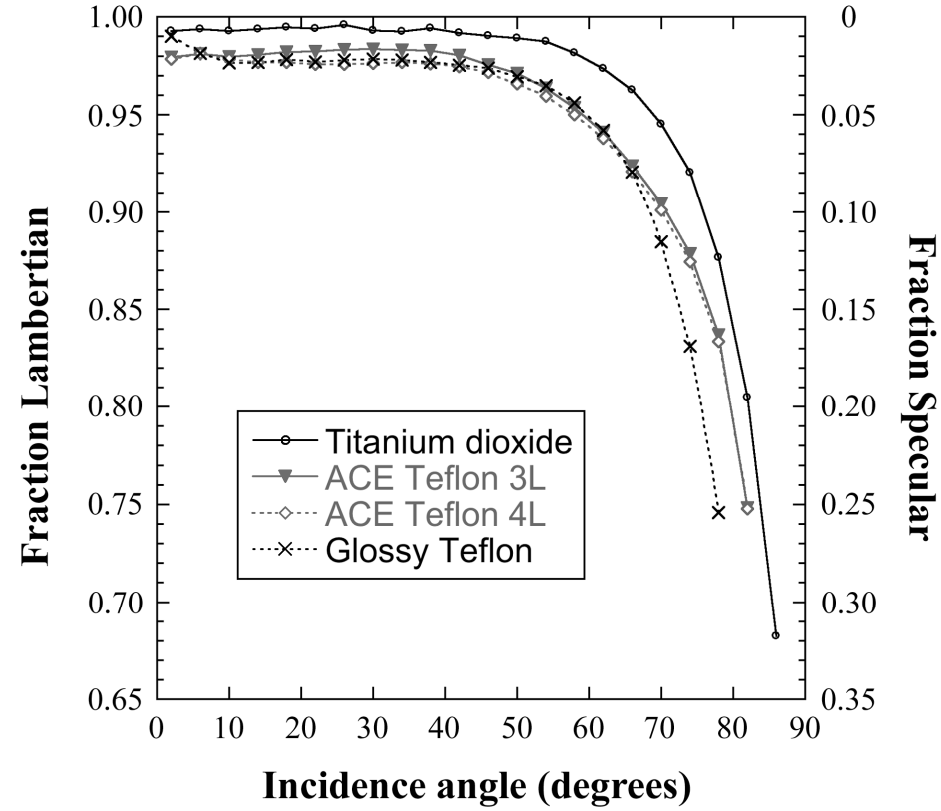


Ground



Constant Probabilities?





Teflon® tape, 3 layers, or 230μm thick

Conclusions

Our simulations are…

More Accurate

- More reflector materials can be simulated
- For non-polished surfaces: Better agreement to measured data with our code than standard Geant4
- Known inaccuracies in existing code are avoided (constant probabilities, Gaussian surface model)

More User-Friendly

- No detailed knowledge required from the user
- The user is only required to know surface type and reflector attached