On the way to an ISO/CIE standard for BSDF data generation for complex fenestration systems

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Lars O. Grobe, Taoning Wang, Greg Ward

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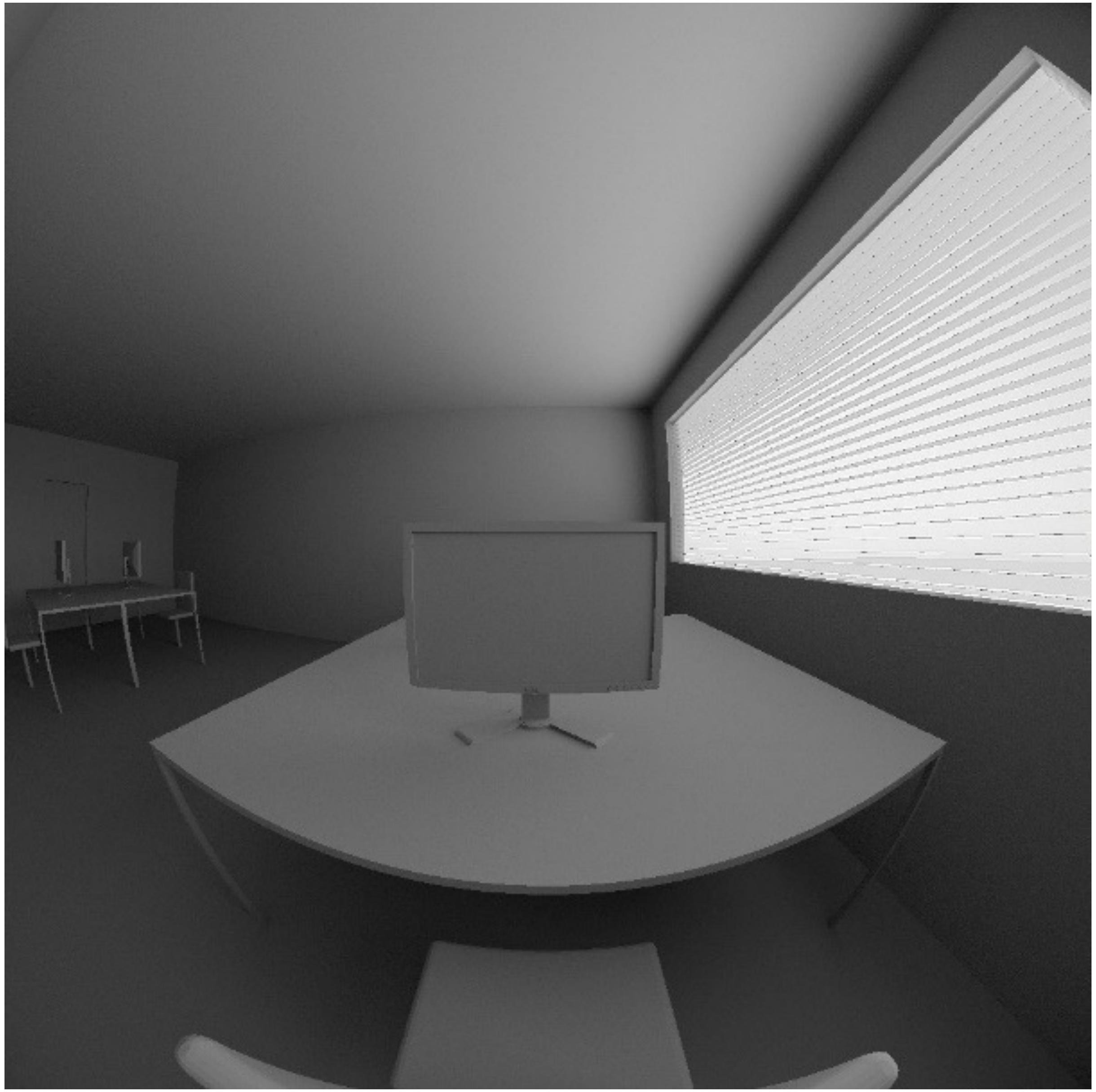
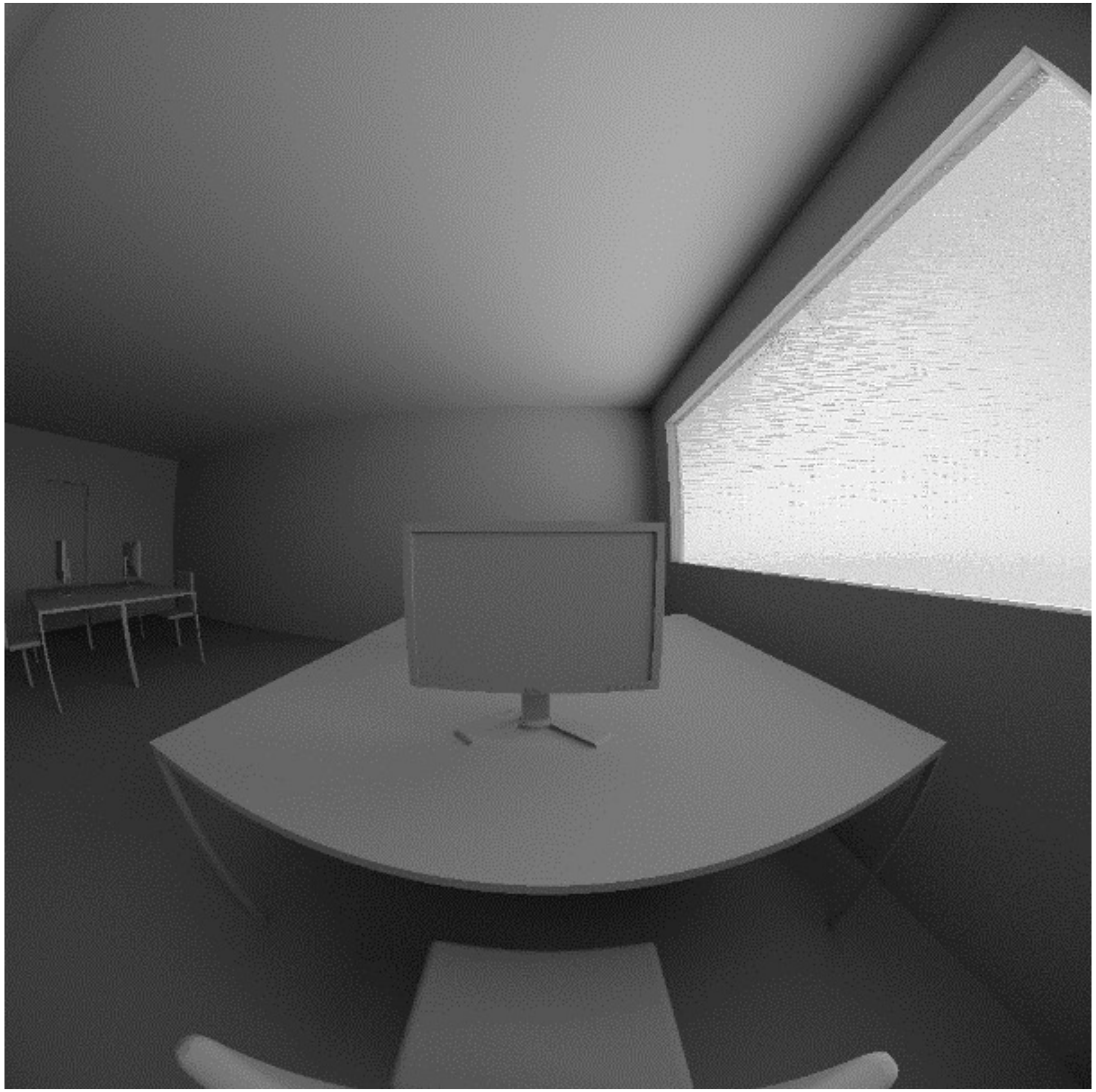
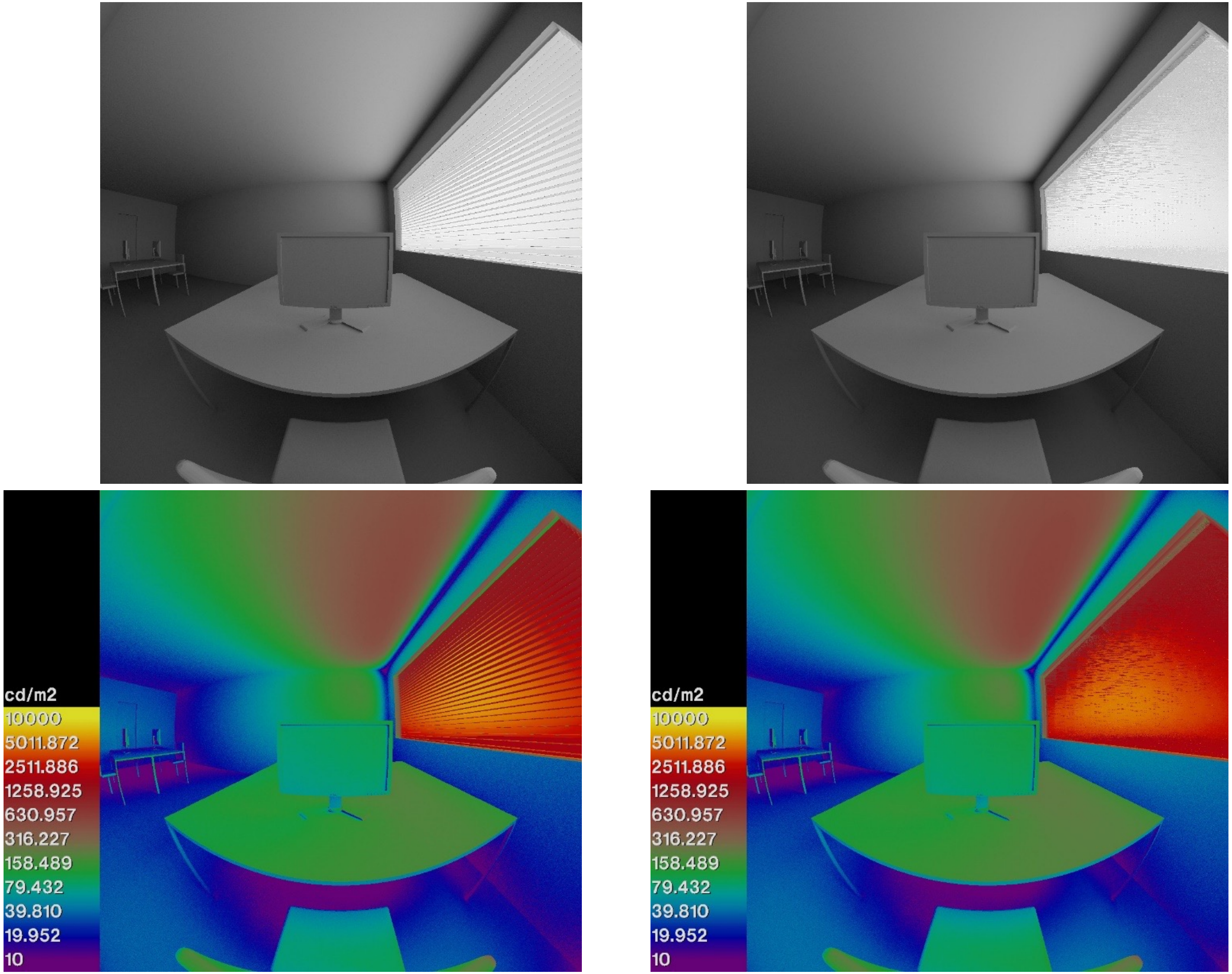
Lausanne, Switzerland

universität innsbruck

ISO cie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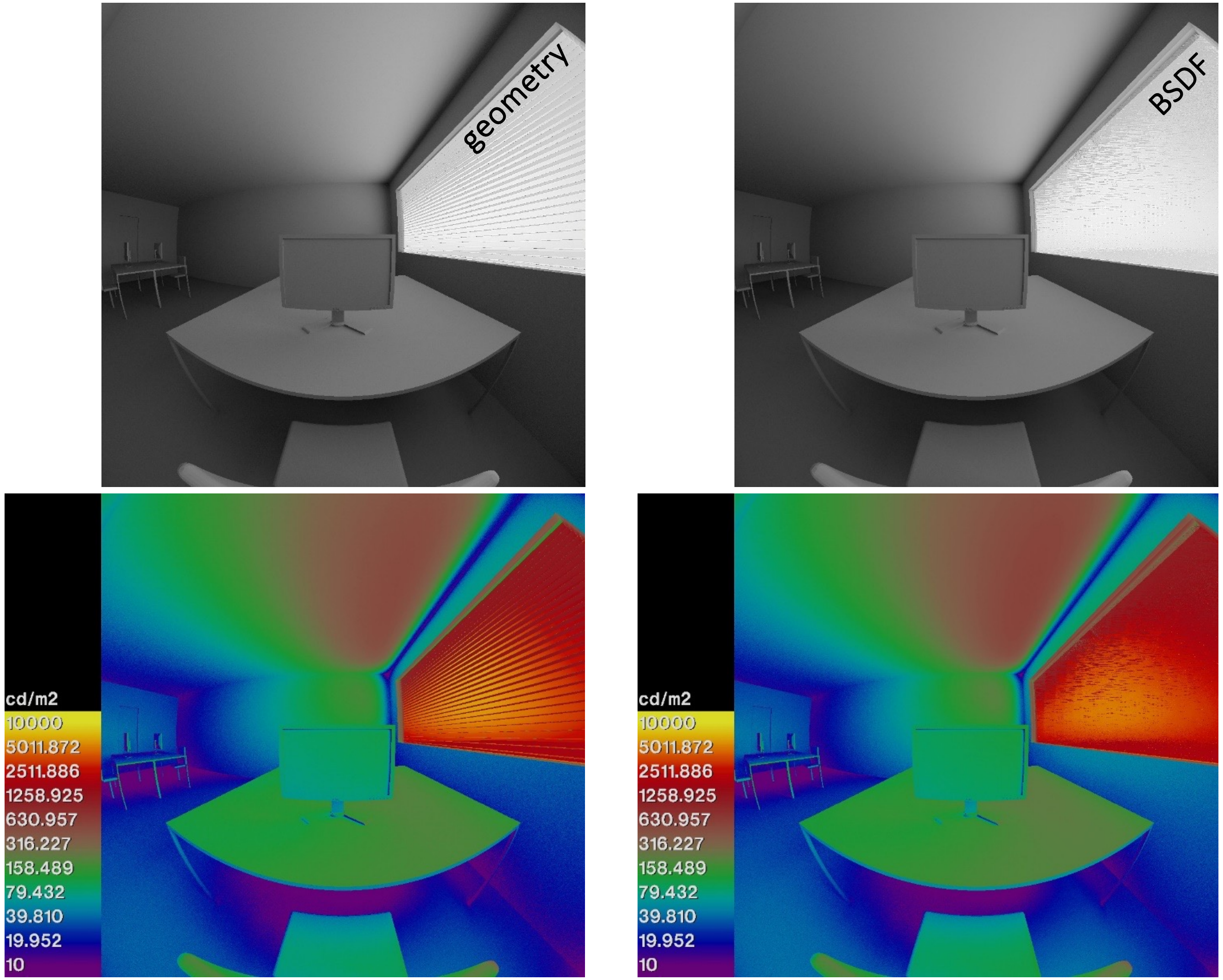
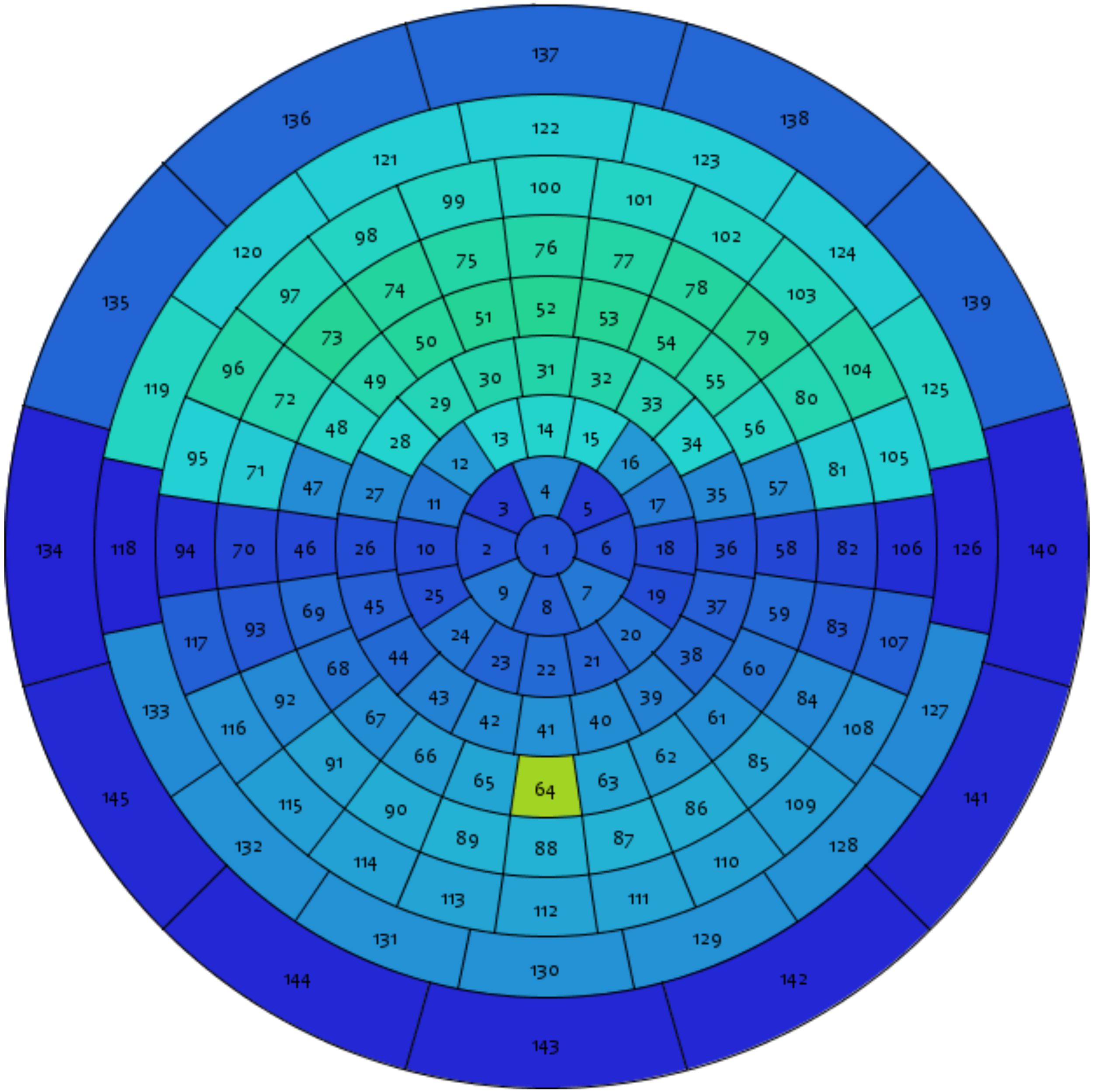
BSDF Background

- One way for including daylighting and shading systems (CFS) in simulations
  - Lighting simulations (sun & skylight)
  - Energy simulations (angular dependent solar gains)
- Already implemented in various tools





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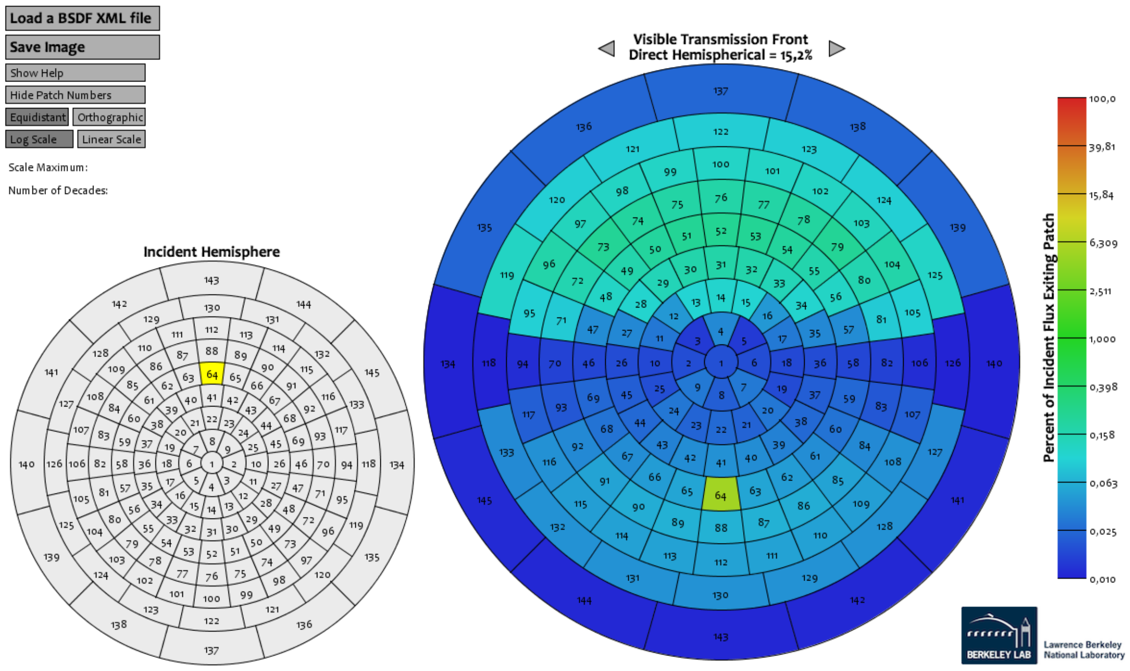
BSDF Data



04_Aussenraffstore_00deg.xml

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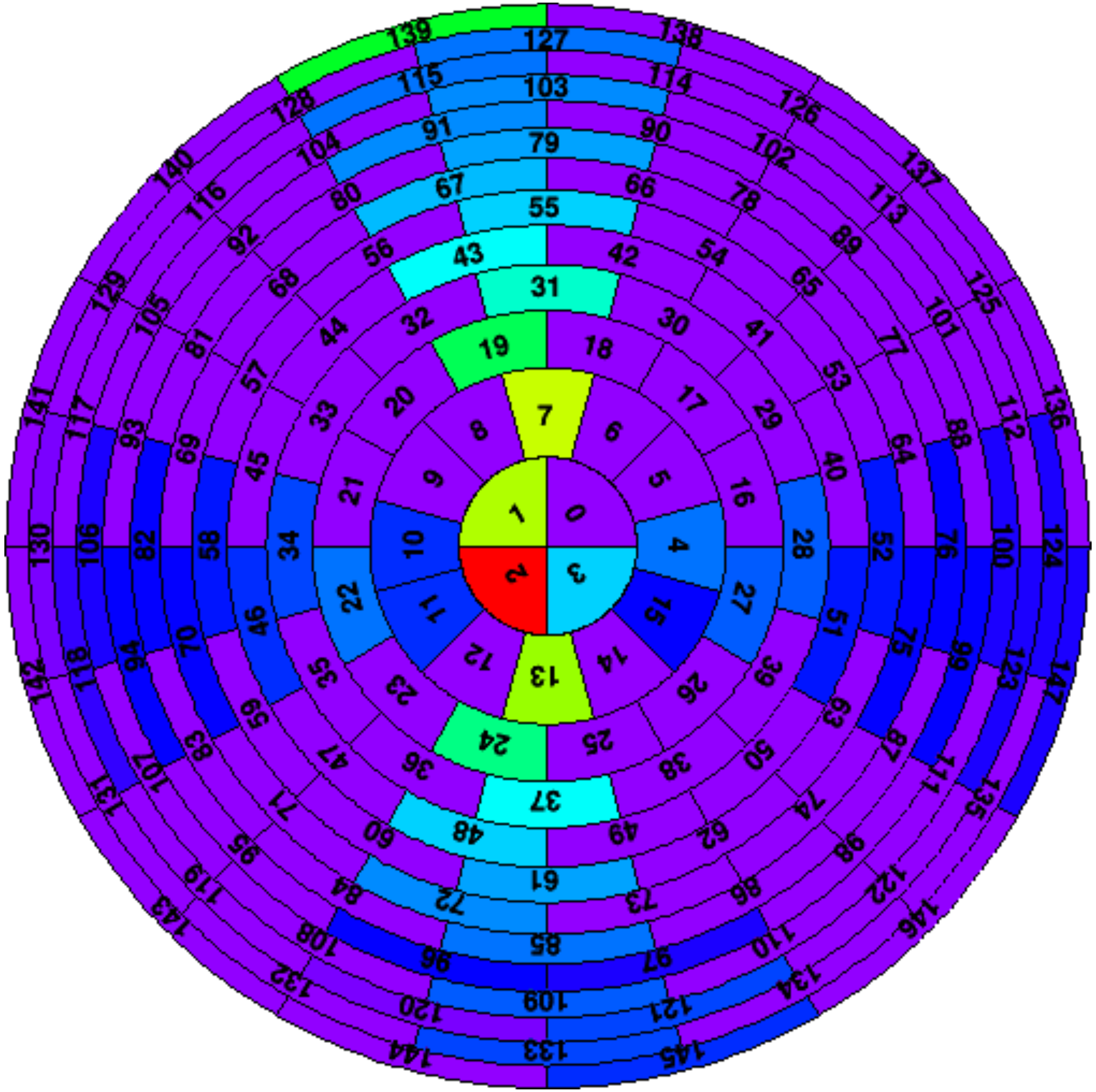
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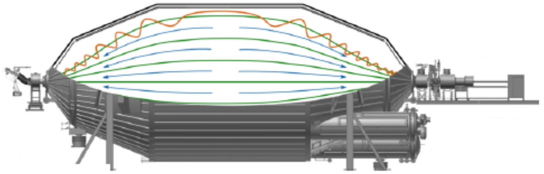
KATRIN – Karlsruhe Tritium Neutrino Experiment

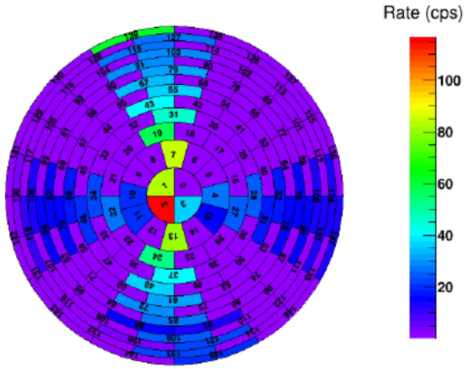
Spectrometer and Detector commissioning

Electron Optics

Alignment:

- Whole wafer can be covered





https://www.taup-conference.to.infn.it/2015/day3/parallel/nua/1_ranitzsch.pdf

KATRIN

6 languages

Article Talk Read Edit View history Tools

From Wikipedia, the free encyclopedia

Coordinates: 49°05′45″N 8°26′10″E

KATRIN is a German acronym (**Ka**rlsruhe **Tri**tium **N**eutrino Experiment) for an undertaking to measure the mass of the electron antineutrino with sub-eV precision by examining the spectrum of electrons emitted from the beta decay of tritium. The experiment is a recognized CERN experiment (RE14).[1][2] The core of the apparatus is a 200-ton spectrometer.

Transport of the main spectrometer to the Karlsruhe Institute of Technology.

In 2015, the commissioning measurements on this spectrometer were completed, successfully verifying its basic vacuum, transmission and background properties.[3] The experiment began running tests in October 2016. The inauguration took place 11 June 2018, with the first tritium measurements by the experiment (the so-called First Tritium or FT 2-week engineering run in mid-2018). The projected experiment duration at the time was 5 years. The first science measurements (so-called first campaign) took place 10 April 2019.[4]

In February 2022, the experiment announced an upper limit of $m_\nu < 0.8\ \mathrm{eV}\, c^{-2}$ at 90% confidence level.[5][6] In April 2025 this result was improved to $m_\nu < 0.45\ \mathrm{eV}\, c^{-2}$ at the same confidence level.[7]

Construction and assembly [edit]

The spectrometer was built by MAN DWE GmbH in Deggendorf. Although only 350 km from Karlsruhe, the tank's size made land transport impossible.[8] Instead, it was shipped in autumn 2006 by water, down the Danube to the Black Sea, through the Mediterranean Sea and Atlantic Ocean to Rotterdam, then up the Rhine to Karlsruhe. This 8600 km long detour limited land travel to only the final 7 km from the Leopoldshafen docks to the laboratory.

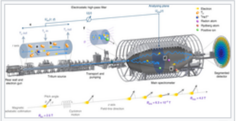
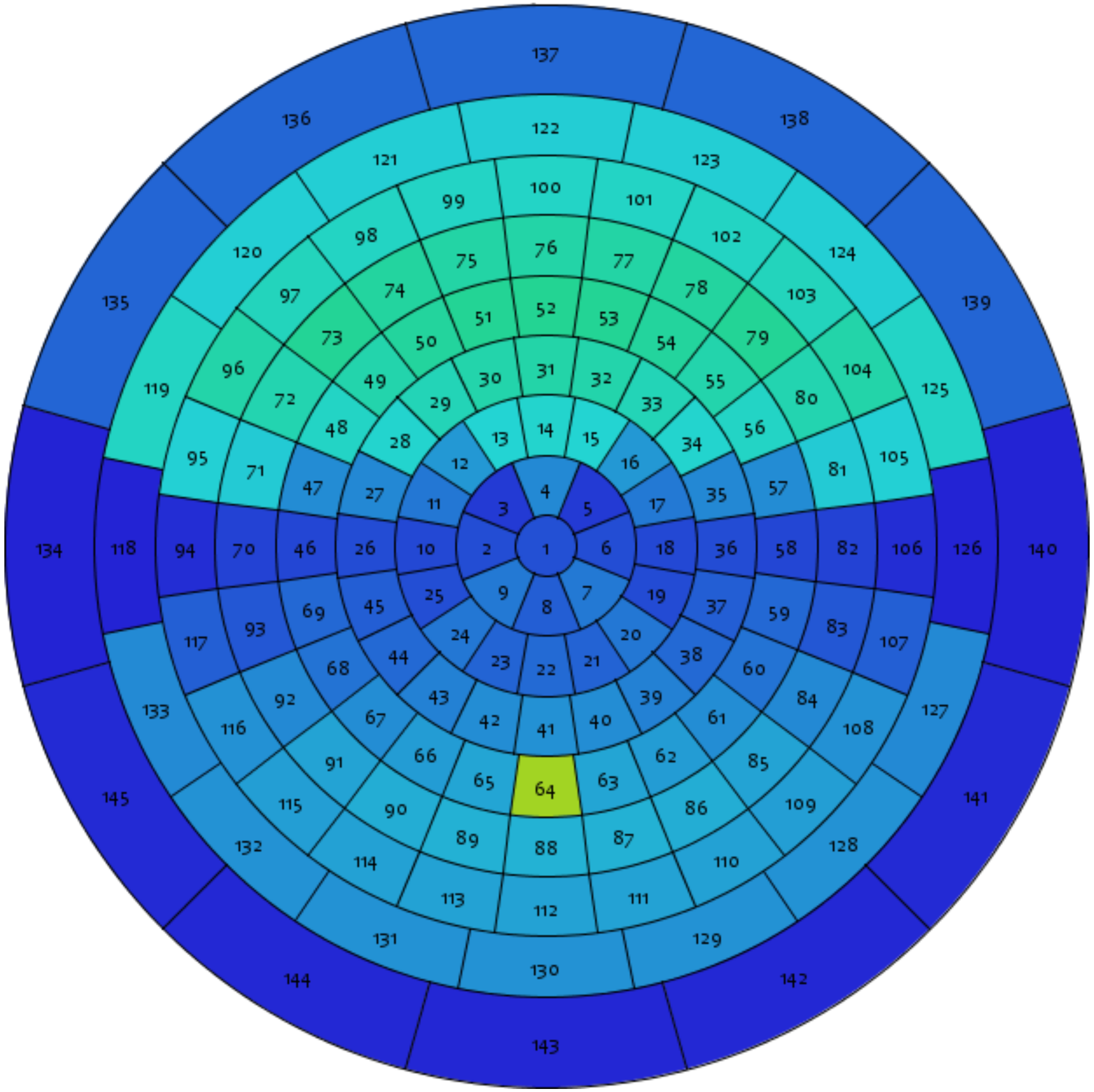


Illustration of KATRIN beamline and its main components.[5]

The construction proceeded well with several of the major components on-site by 2010. The main spectrometer test program was scheduled for 2013 and the complete system integration for 2014.[9] The experiment is located at the former Forschungszentrum Karlsruhe, now Campus Nord of the Karlsruhe Institute of Technology.

https://en.wikipedia.org/wiki/KATRIN



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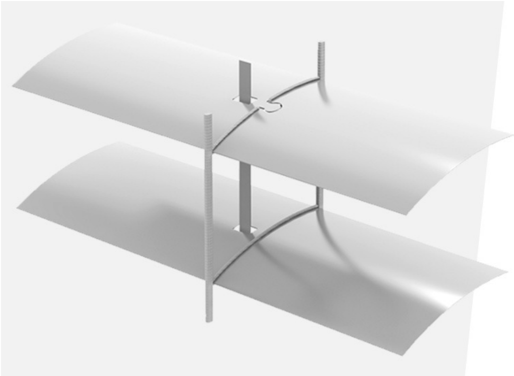
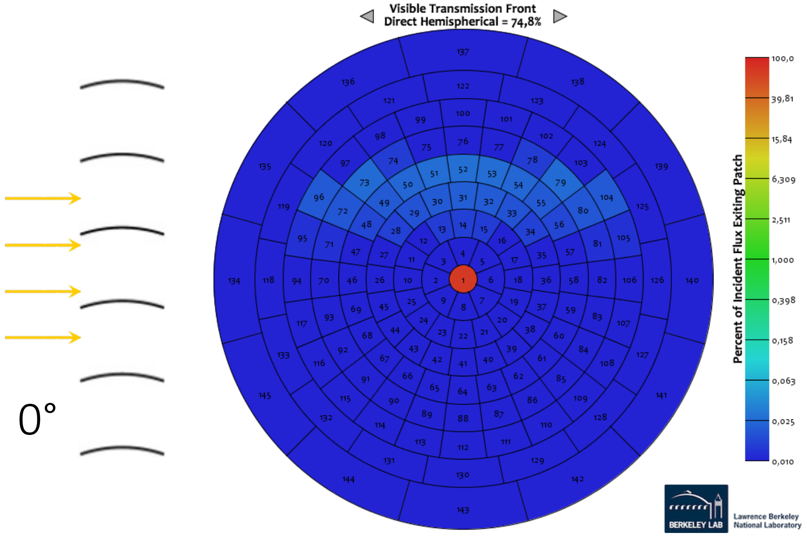
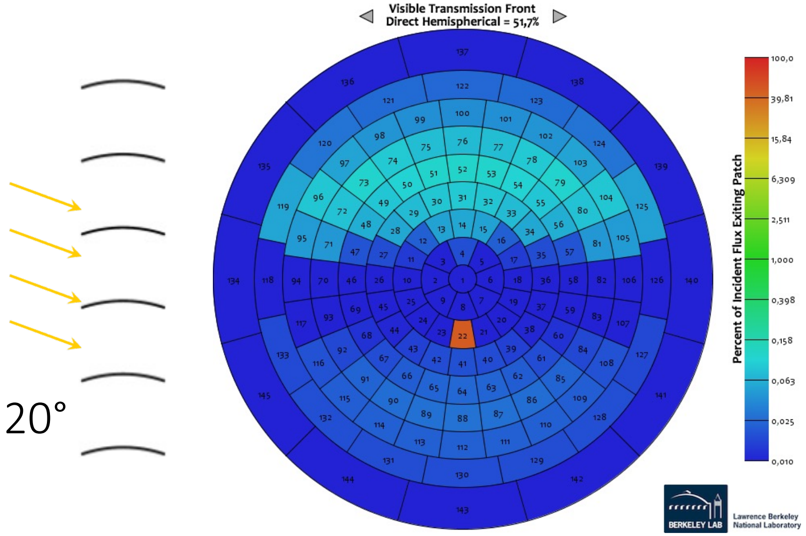
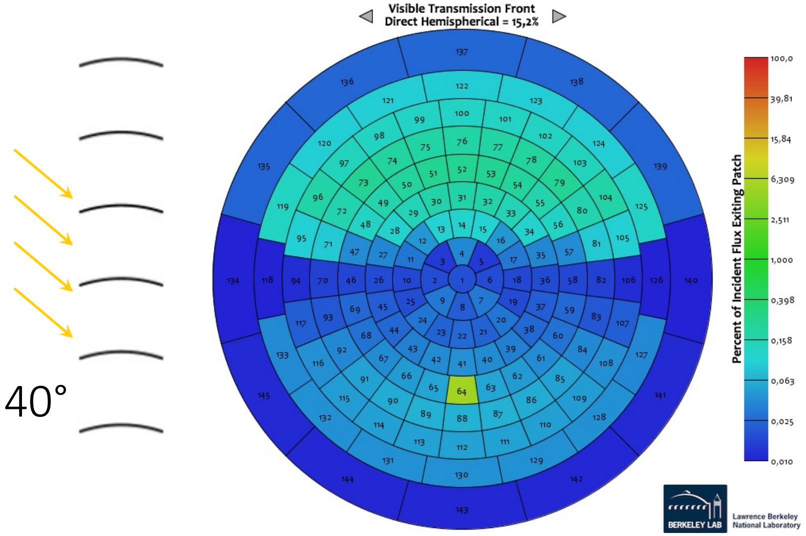
Example BSDF: Exterior venetian blinds @ 0° tilt

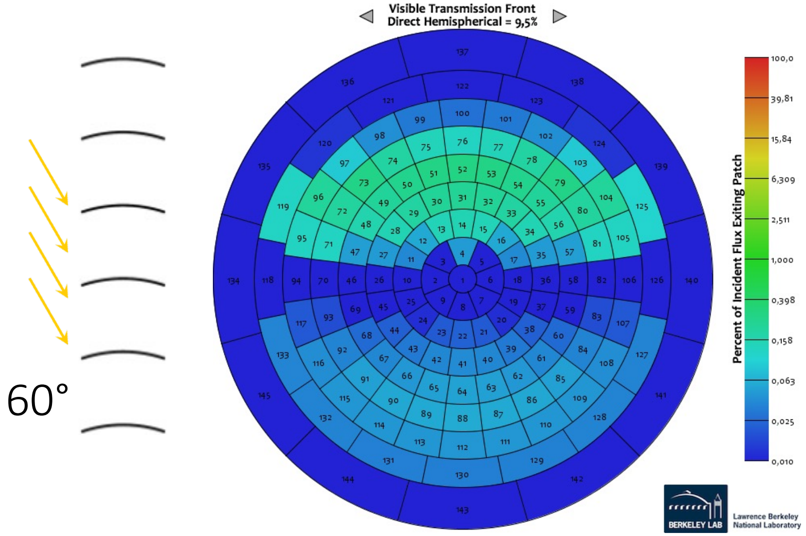


Example: HELLA AF 60
www.hella.info









BSDF Data

04_Aussenraffstore_00deg.xml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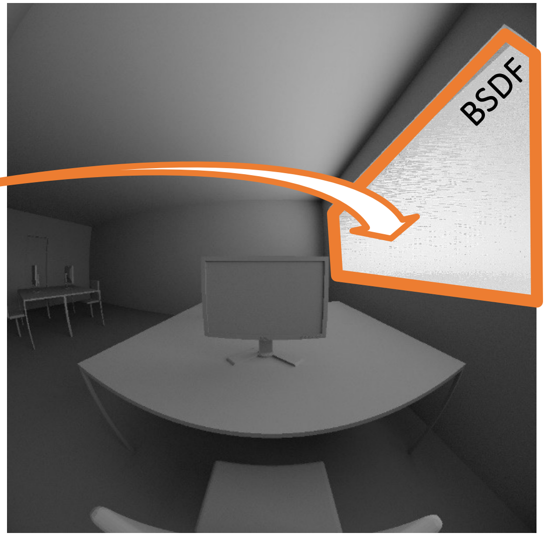
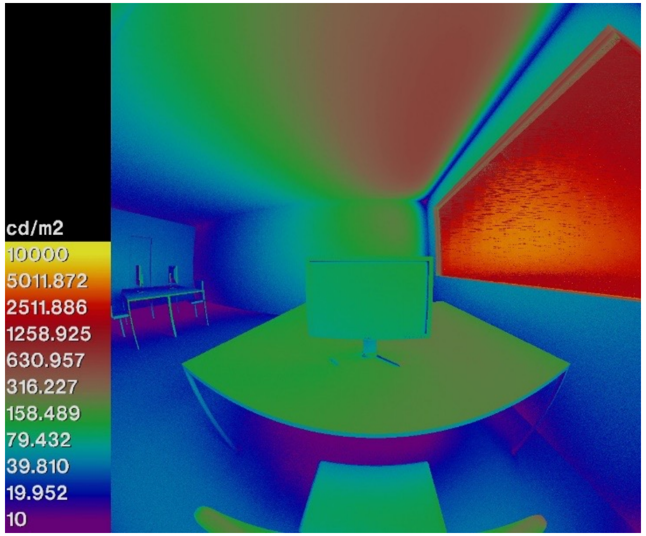
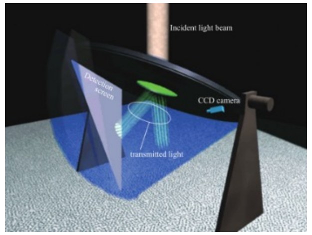
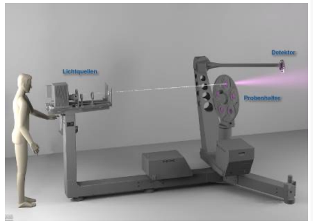
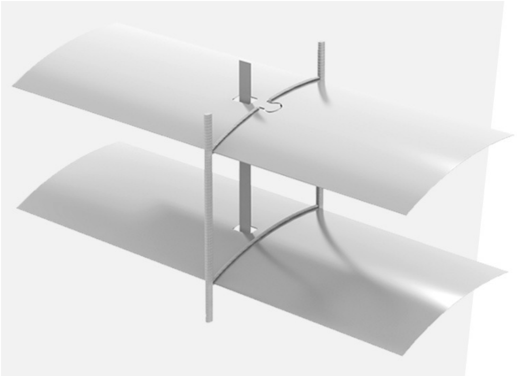




BSDF Data Generation







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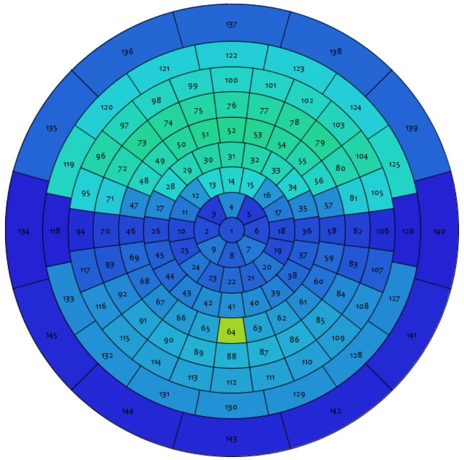


Example: HELLA AF 60
www.hella.info

genBSDF

RADSITE | radiance-online.org

WINDOW 7.6

Lucid Shape
Computer Aided Ligthing

ASAP® 2015

Virtual gonio-photometer
based on
Zemax

IEA SHC Task 61 / Annex 77: Analysis and evaluation of BSDF characterization of daylighting systems.
https://doi.org/10.18777/ieashc-task61-2021-0012

History of BSDFs for CFS

(an excerpt)

1977: Definition of nomenclature for BRDFs
F. Nicodemus et al.

1999: IEA SHC Task 21: Measurement of BTDFs
IEA SHC Task 21 experts

2006: Bidirectional photometric data for CFS
M. Andersen, J. de Boer

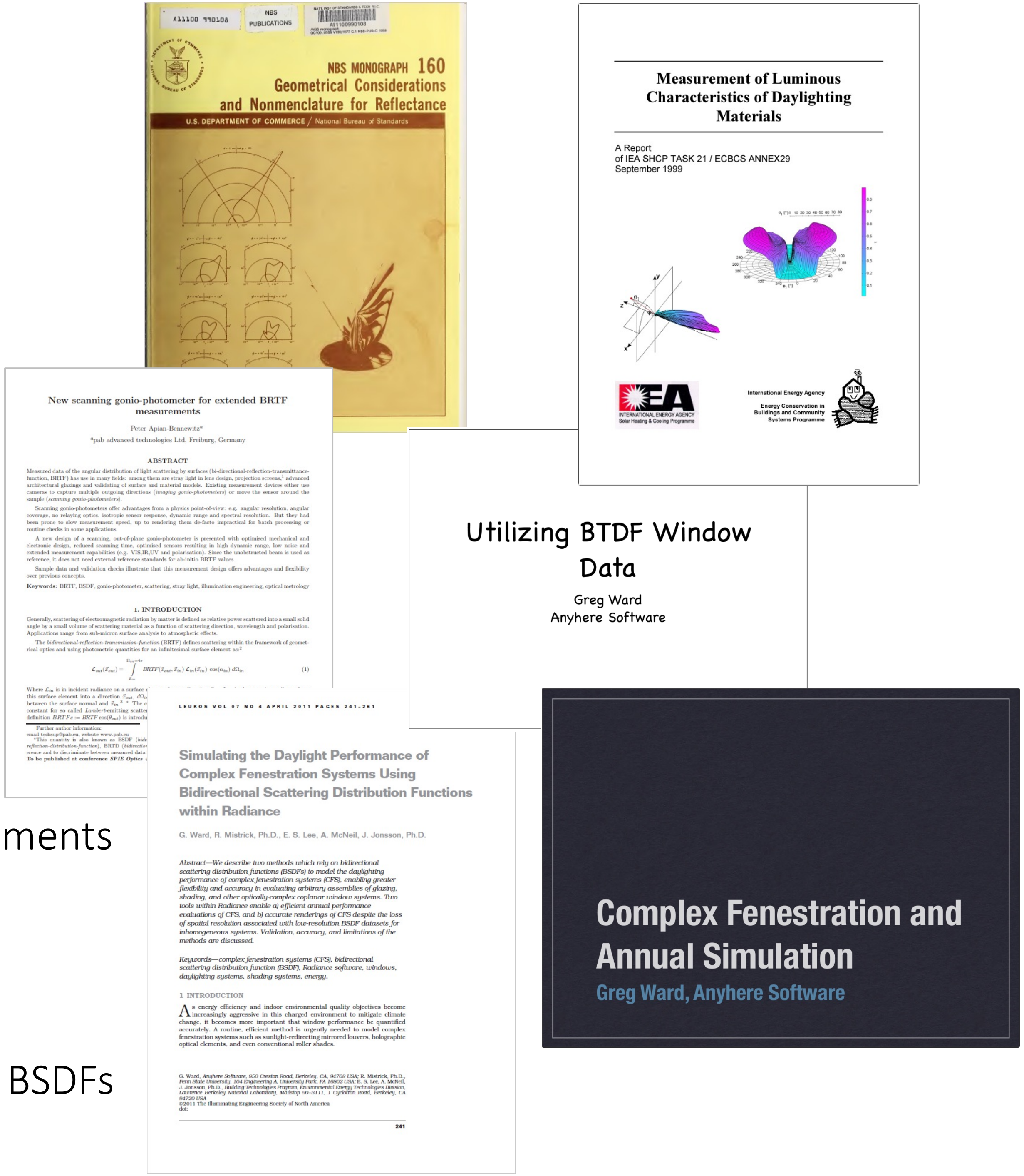
2007: BTDFs in mkillum
G. Ward

2009: Three-phase method
G. Ward

2010: Scanning goniophotometer for BTDF measurements
P. Apian-Bennewitz

2011: Simulating the Daylight performance of CFS
G. Ward, R. Mistrick, E. Lee, A. McNeil, J. Jonsson

2011: BSDF Material Primitive & Variable-resolution BSDFs
G. Ward, A. McNeil



History of BSDFs for CFS (cont‘d)

(an excerpt)

2014: Tensor tree BSDFs
G. Ward, M. Kurt, N. Bonneel

2014: Five-phase method
A. McNeil

2021: Peak extraction
D. Geisler-Moroder, G. Ward, T. Wang, E. Lee

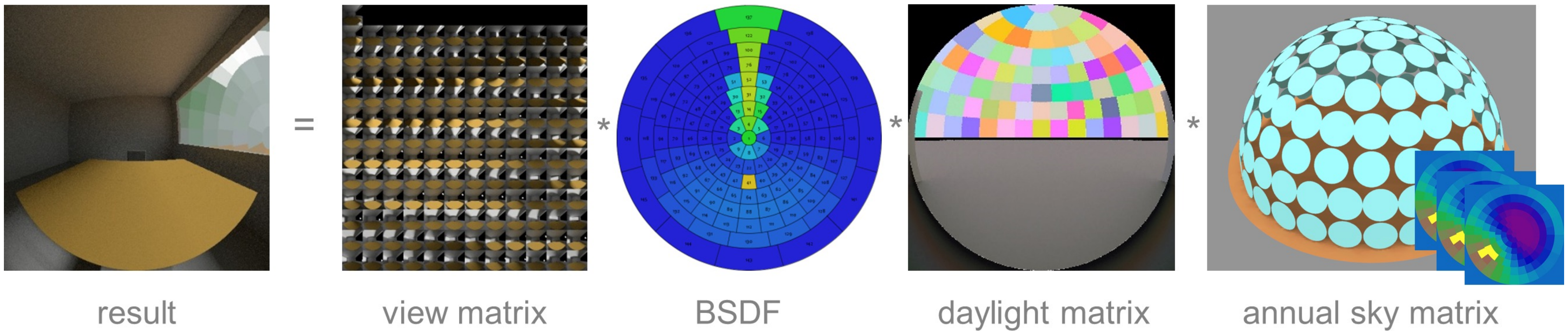
2021: IEA SHC Task 61: white paper & round robin
IEA SHC Task 61 experts

2022: Field Validation
T. Wang, E. Lee, G. Ward, T. Yu

2024: LRT Paper
IEA SHC Task 61 experts

2024: Launch of ISO/CIE 25176
D. Geisler-Moroder / IEA SHC Task 70

3-Phase-Method



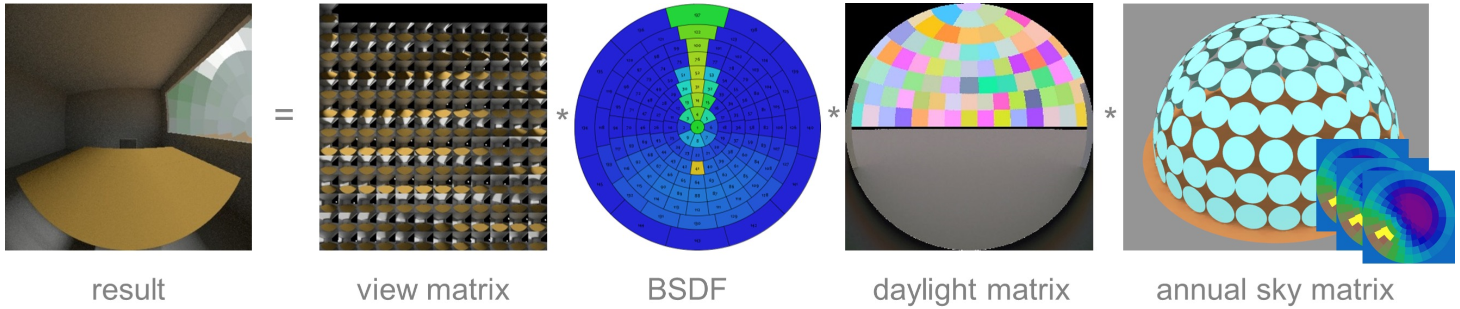
I = VTDS

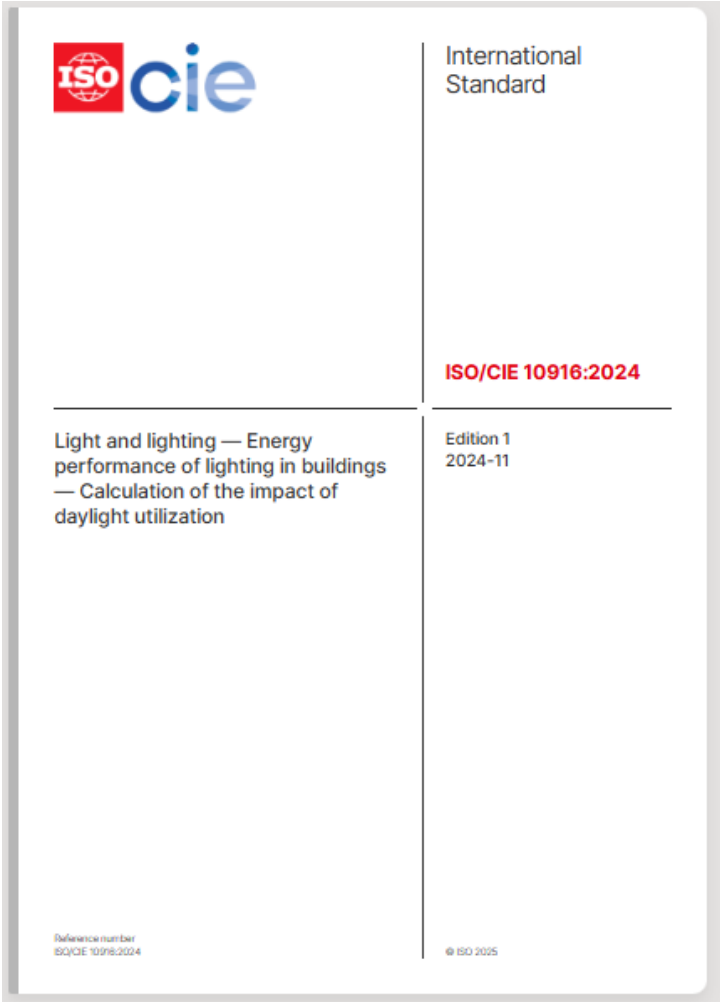
I … result, e.g. annual illuminance values
V … view matrix, combining measurement points with patches at interior of façade
T … transmission matrix, i.e. BTDF (transmission component of BSDF)
D … daylight matrix, combining patches at exterior of façade with sky patches
S … annual sky matrix

Trigger: ISO/CIE 10916:2024

New Annex B: Comprehensive hourly calculation

- Matrix based daylight calculation method relying on BSDF data
- 3-Phase-Method



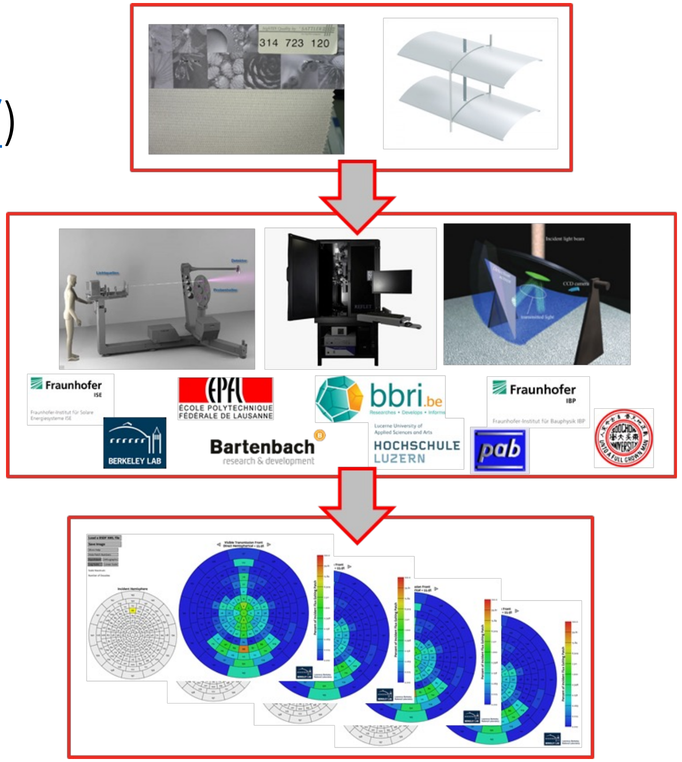


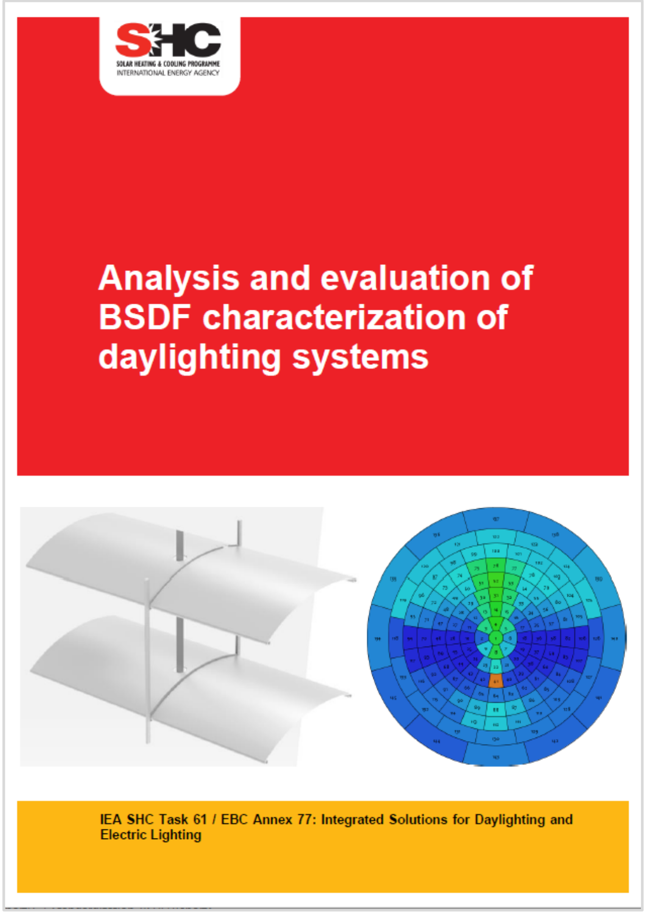
I = VTDS

I … result, e.g. annual illuminance values
V … view matrix, combining measurement points with patches at interior of façade
T … transmission matrix, i.e. BTDF (transmission component of BSDF)
D … daylight matrix, combining patches at exterior of façade with sky patches
S … annual sky matrix

International Collaboration & Harmonization

Completed IEA SHC Task 61 / EBC Annex 77: Integrated Solutions for Daylighting and Electric Lighting (https://task61.iea-shc.org/)





Analysis and Evaluation Report

- » Review of currently used methods
- » Round Robin test

Online:
https://doi.org/10.18777/ieashc-task61-2021-0012

International Collaboration & Harmonization

Completed IEA SHC Task 61 / EBC Annex 77:
Integrated Solutions for Daylighting and
Electric Lighting (https://task61.iea-shc.org/)

White Paper

» BSDF definitions

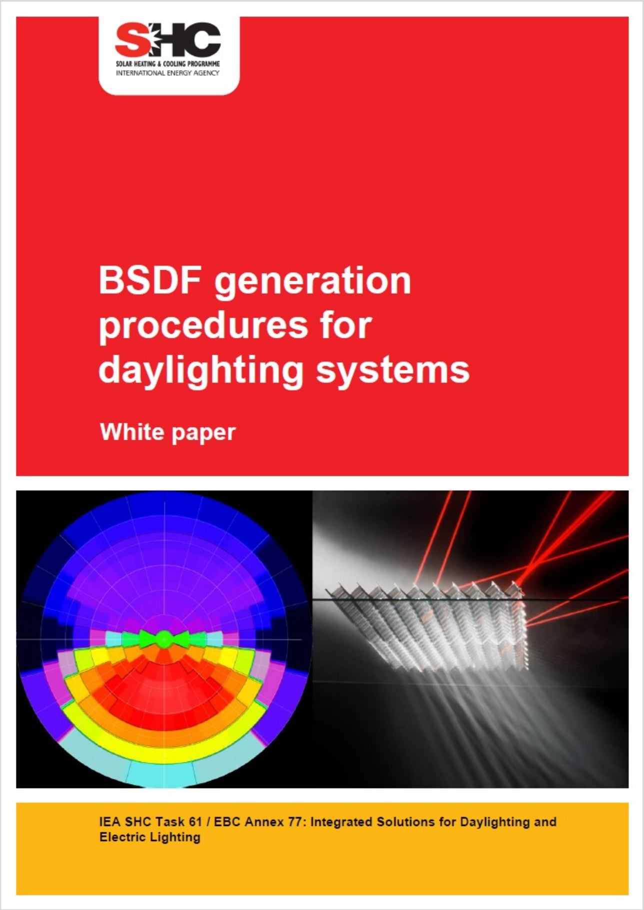
» Scope

» BSDF resolution

» Proposed BSDF generation procedures

» Proposed characterization types for various kinds of daylight systems

Online:
https://doi.org/10.18777/ieashc-task61-2021-0001



International Collaboration & Harmonization

Lighting Research & Technology
OnlineFirst, November 26, 2024

https://doi.org/10.1177/14771535241291838

Sage Journals

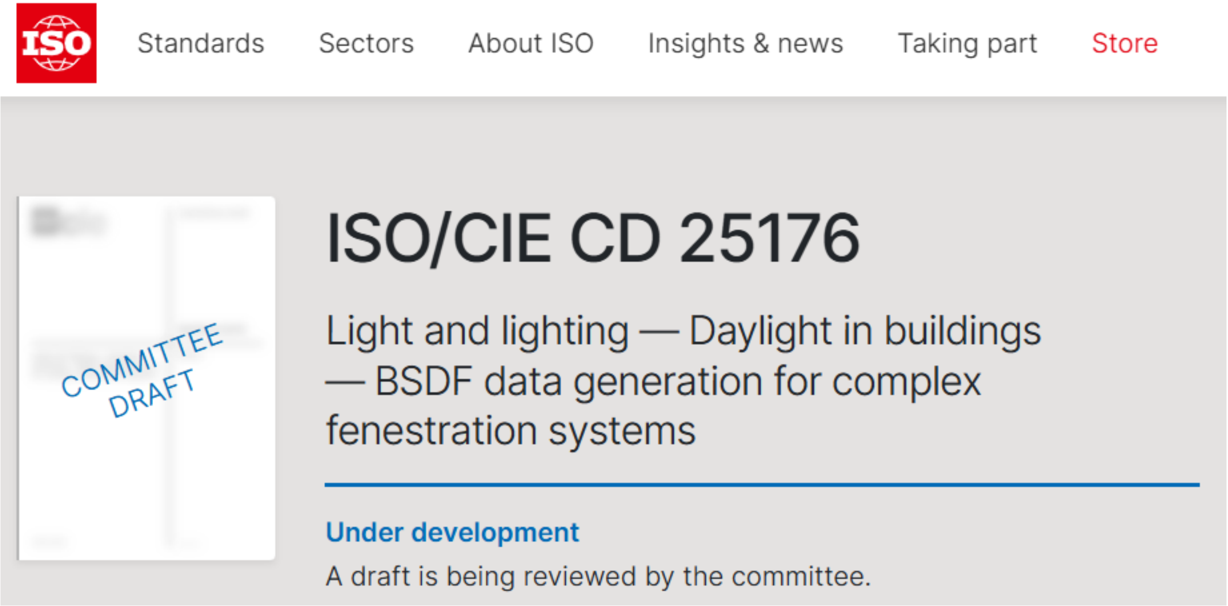
BSDF Data generation for daylight applications: A call for international standardization

D Geisler-Moroder [a], ES Lee [b], P Apian-Bennewitz [c], J de Boer [d], B Bueno [e], B Deroisy [f], Y Fang [d], LO Grobe [g,h], M Hauer [a,i], S Hoffmann [j], JC Jonsson [b], C Maurer [e], D Plörer [a,g], S Subramaniam [j], Z Tian [k], T Wang [b], G Ward [l], R Weitlaner [m], and HR Wilson [e]

Abstract
Standardized methods for generating angle-dependent, bidirectional, solar-optical properties for complex fenestration systems do not exist, which means that energy and daylight evaluations in building performance simulations often suffer from major inaccuracies. This position paper provides an overview of state-of-the-art data-driven methods for characterizing light scattering properties of fenestration materials and blind systems (e.g. fabrics, metal slats, patterned glazing), validation via laboratory, simulation and field tests, and salient issues in support of standardization of such methods via the International Standardization Organization (ISO). The ISO standard is intended to provide the fundamental underpinnings for recently mandated daylight standards that rely on bidirectional scattering distribution function data for climate-based daylight modelling and building performance simulations.

https://doi.org/10.1177/14771535241291838

ISO/CIE 25176



SCOPE

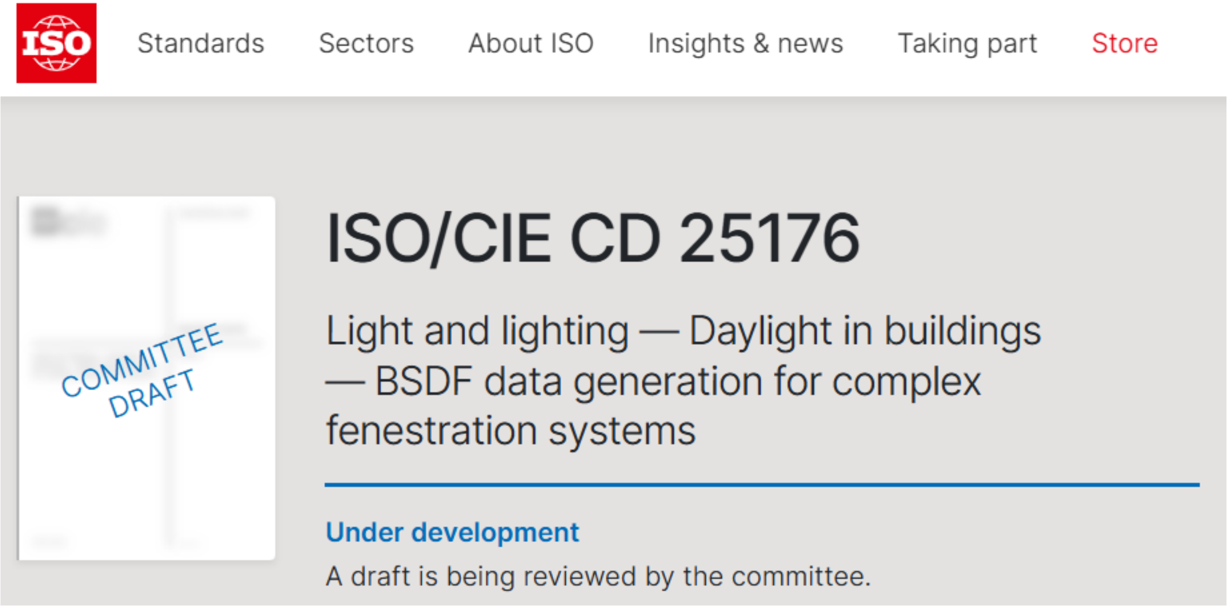
This document applies to the broad range of materials and systems, e.g. fabric shades, venetian blinds, prismatic glass, etc., that are used on windows and skylights to control daylight, sunlight, glare, privacy, and view to the outdoors. It specifies procedures for producing comprehensive angle-dependent, solar-optical scattering data that can then be used to compute a wide range of performance metrics.

This document specifies procedures for:

» characterizing angle-dependent, optical properties (transmittance, reflectance, absorptance) of glazing and shading materials and systems, i.e. "complex fenestration systems" (CFS) and then

» generating tabulated bidirectional scattering distribution function (BSDF) data sets for use as input to simulation tools or standardized calculation methods such as the comprehensive hourly calculation method defined in ISO/CIE 10916:2024.

Proposed structure

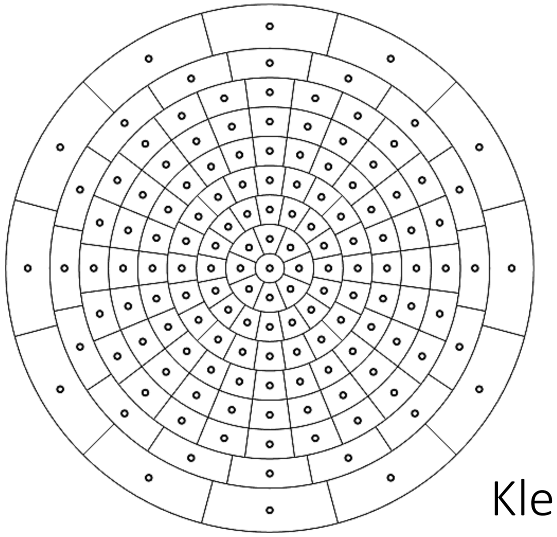


- » Introduction
- » Scope
- » Normative references
- » Terms, definitions
- » BSDF data resolution
- » BSDF generation procedures
  - – BSDF generation procedure for microscopic systems
  - – BSDF generation procedure for macroscopic systems
- » Reporting of additional information
- » Annexes

BSDF data resolution

» **Low-resolution BSDF**
average patch sizes between 0.0239 sr and 0.1373 sr
(i.e. cones with full opening angles of 10° to 24°)

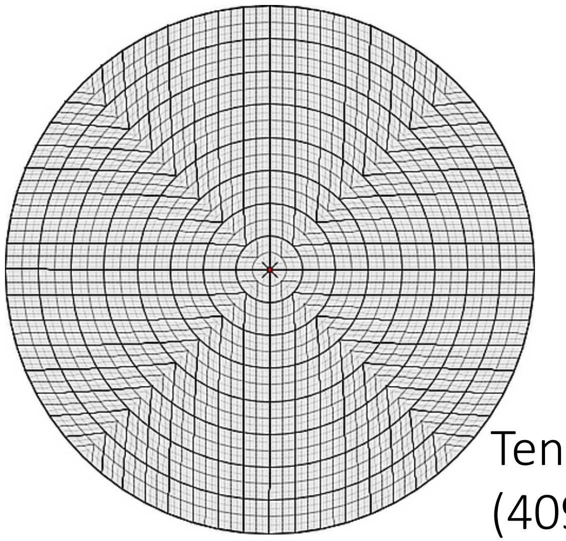
Examples:
Klems, IEA21, Tensor tree up to $2^4 * 2^4$ (256)



Klems (145)

» **High-resolution BSDF**
average patch sizes less than 0.0239 sr
(i.e. cones with full opening angles less than 10°)

Examples:
Tensor tree $2^5 * 2^5$ (1024) or higher

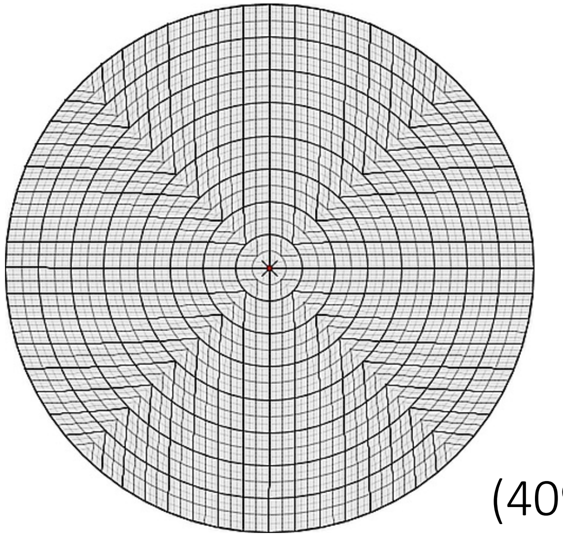


Tensor tree 2^6 x 2^6 (4096)

BSDF data resolution

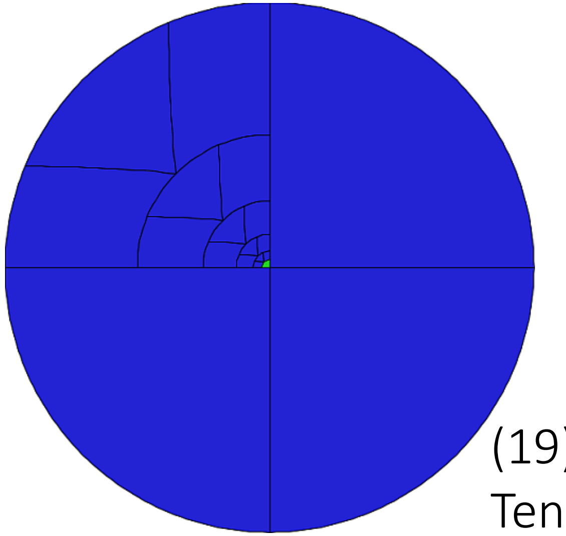
» **Fixed-resolution BSDF**
2D (**n×m**) matrix for **n** incident and **m** exiting directions

Examples:
Klems (145×145), IEA21 (145×1297),
Tensor tree (n × n) with n = $2^i * 2^i$



(4096)
Tensor tree 2^6 x 2^6

» **Variable resolution BSDF**
Tensor tree resolution reduced for areas with almost diffuse scattering (i.e. nearly constant BSDF), and high for non-diffuse areas to preserve peaks



(19) reduced from
Tensor tree 2^6 x 2^6

Proposed structure

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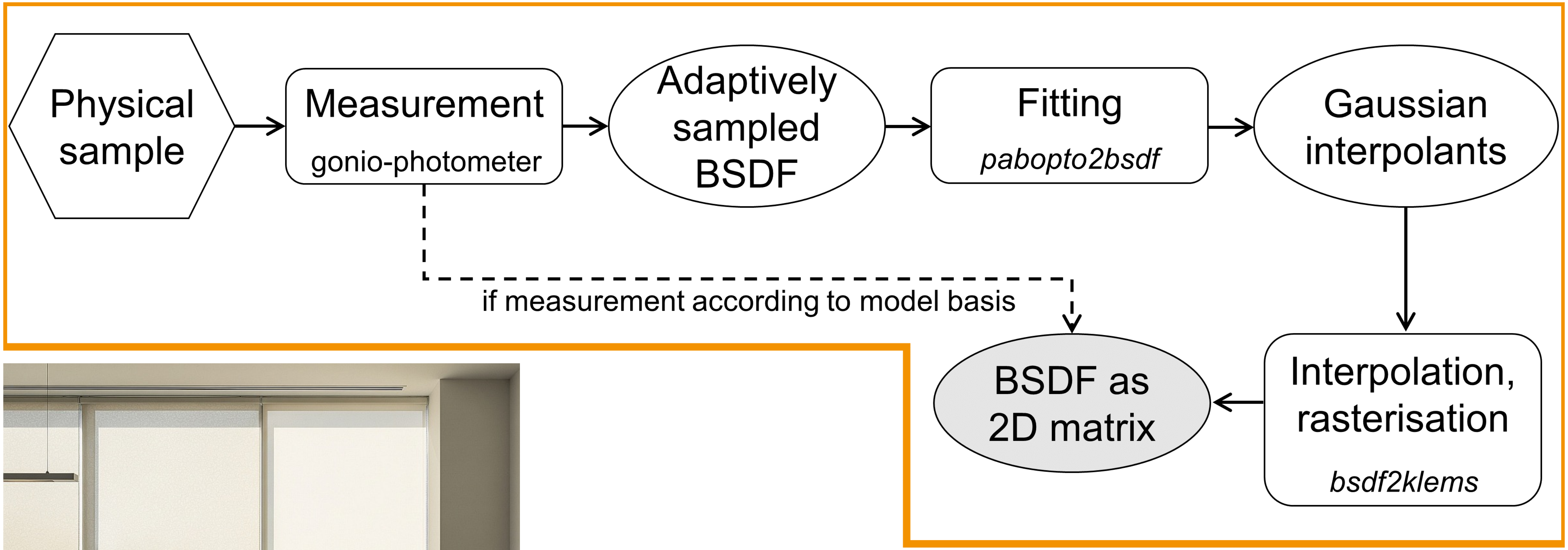
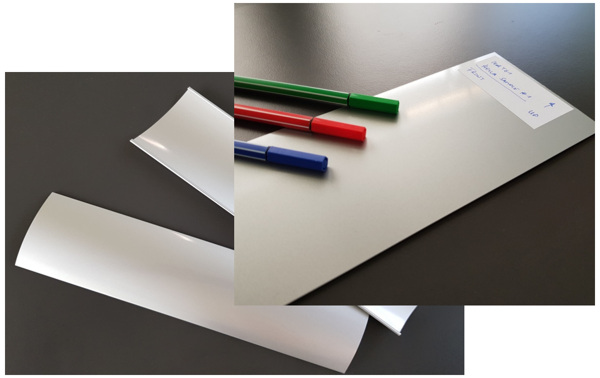


Measurement-based | Microscopic systems



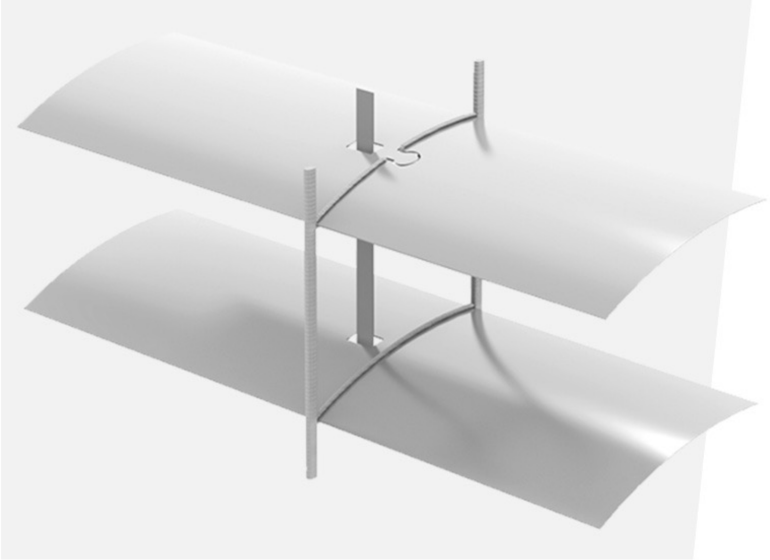
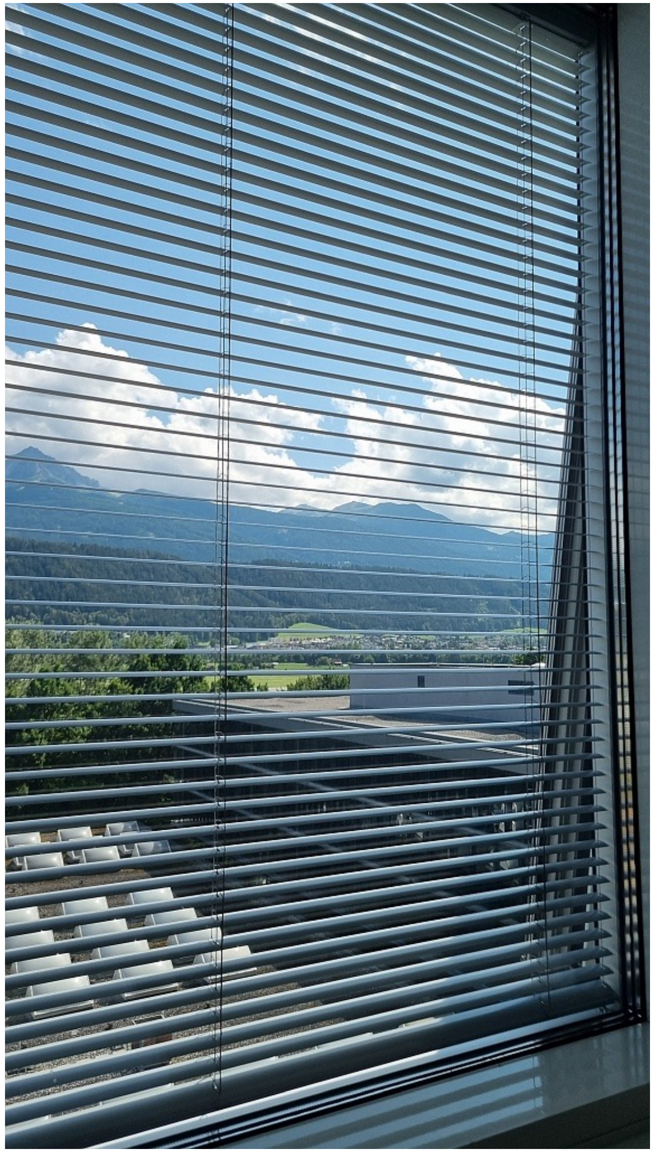
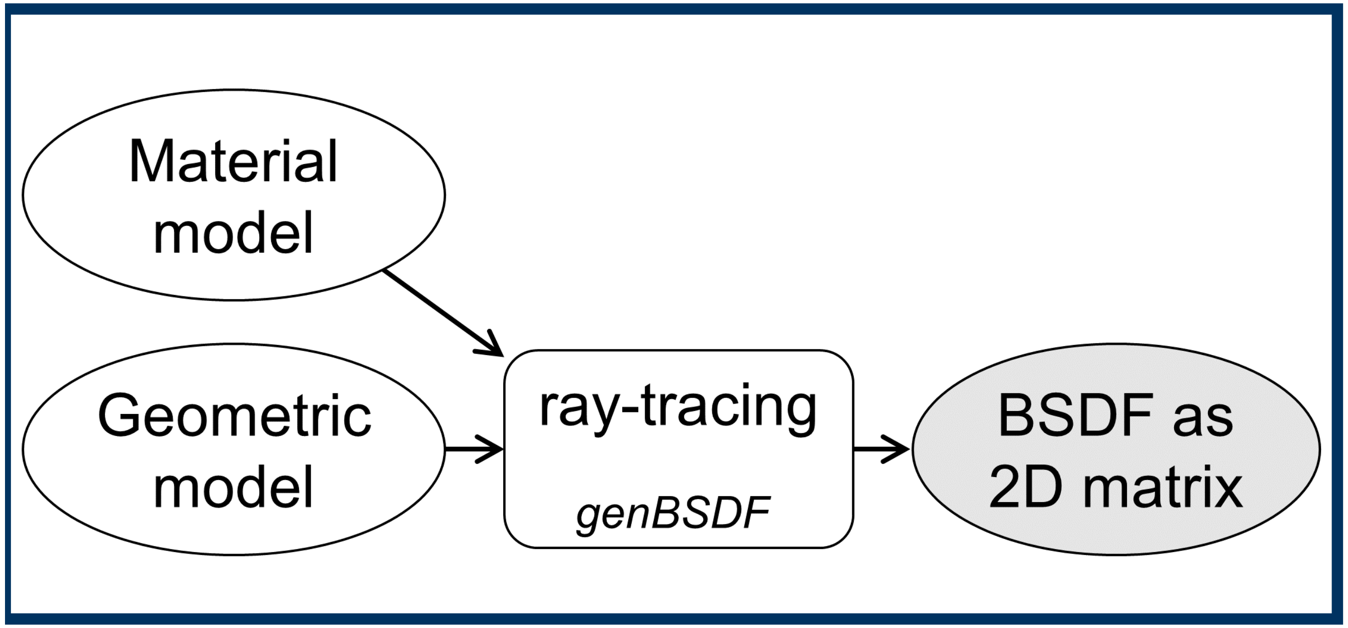
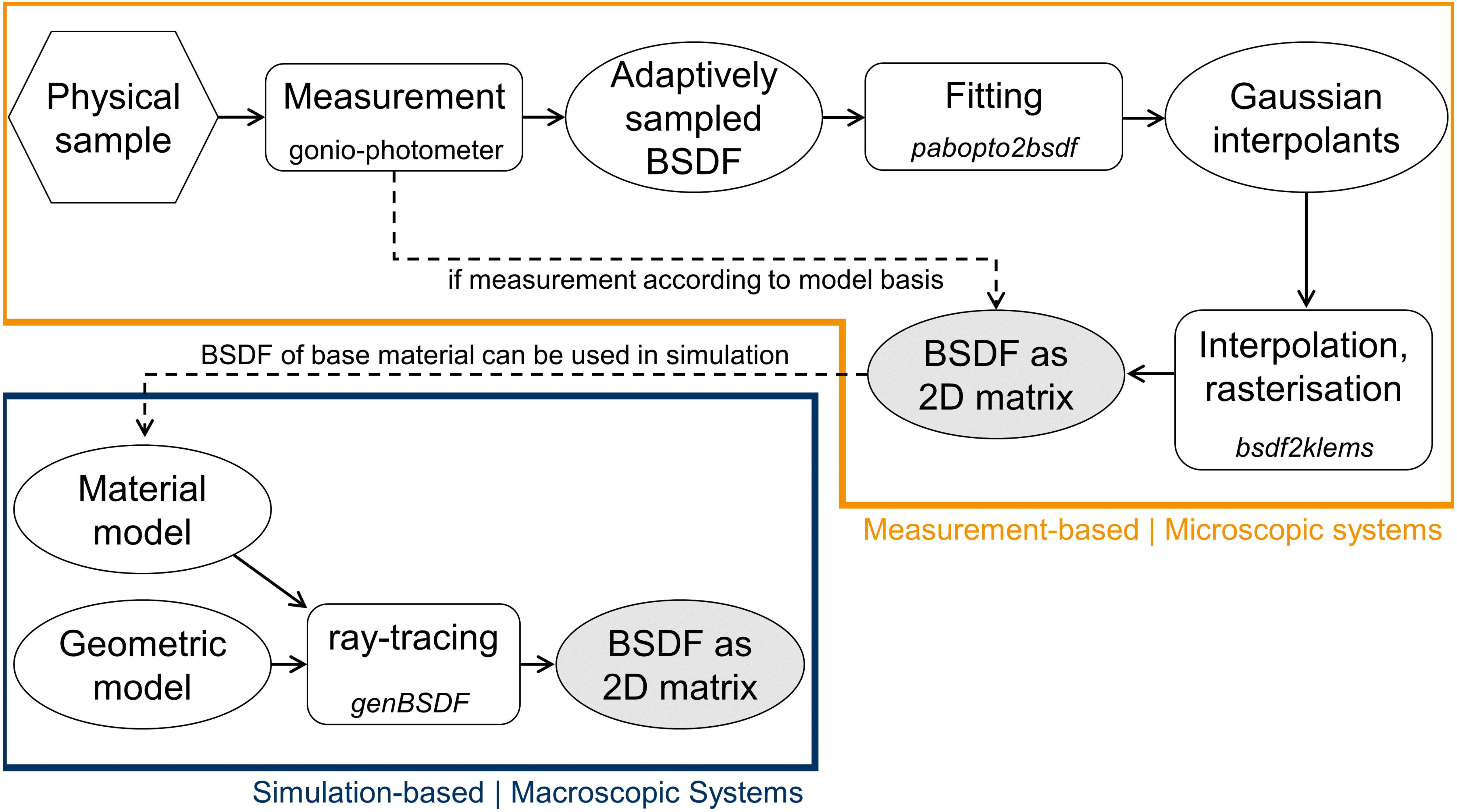


Image: www.hella.info





Simulation-based | Macroscopic Systems



Physical sample
Measurement
gonio-photometer
Adaptively sampled BSDF
Fitting
pabopto2bsdf
Gaussian interpolants
if measurement according to model basis
Interpolation, rasterisation
bsdf2klems
BSDF as 2D matrix
BSDF of base material can be used in simulation
Measurement-based | Microscopic systems
Material model
Geometric model
ray-tracing
genBSDF
BSDF as 2D matrix
Simulation-based | Macroscopic Systems

Annexes

- Angular bases for BSDF discretization
- Incident directions for goniophotometric measurements
- Interpolation of goniophotometer measurements
- Validation of the direct-hemispherical transmittance values
- Data format for tabulated BSDF data sets
- Preparation of proxy geometry for inclusion in BSDF data file
- Example procedure for fabric shades
- Example procedure for venetian blinds
- Generation of tabulated BSDF data with high spatial resolution
- Applicability of parametric models in the BSDF generation for macroscopic systems

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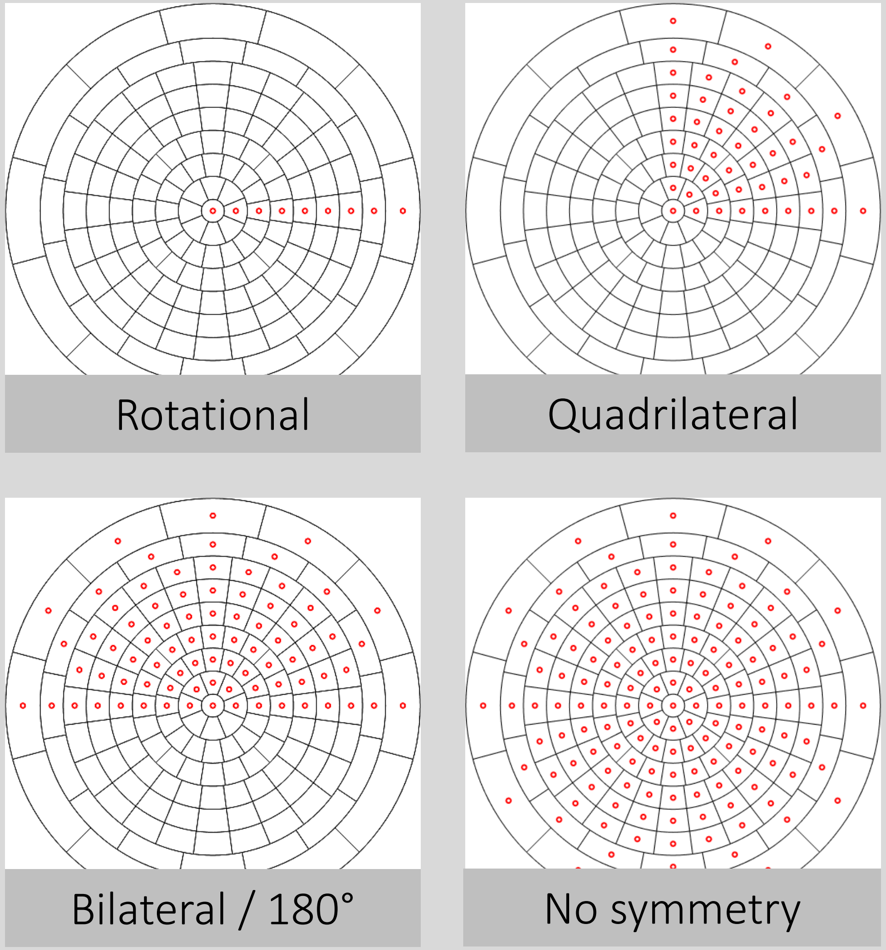

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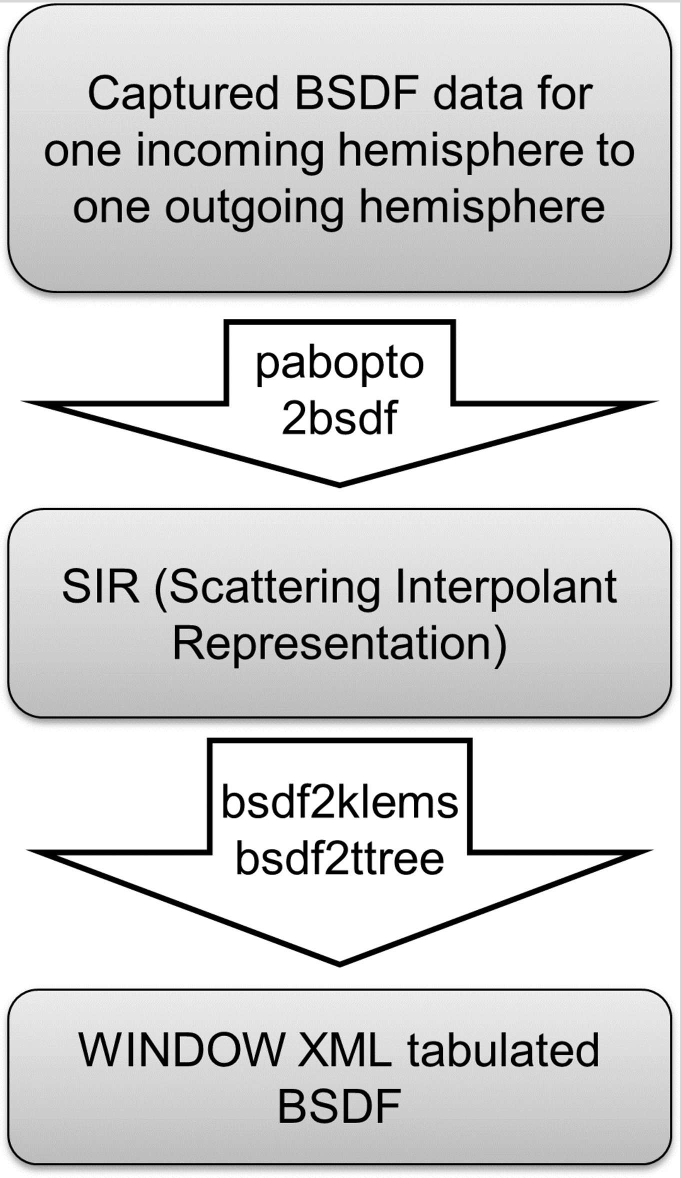

Annexes

- » BSDF Data File Format
- » XML Schema Definition
- » MetaData

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- Created by: genBSDF -n 12 +geom meter +mgf +f +b -c 7250
ISO25176_AnnexH_VenetianBlinds.mgf -->
<WindowElement xmlns:bsdf="urn:iso:cie:25176:bsdf:1.0"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="urn:iso:cie:25176:bsdf:1.0
https://www.iso.org/schemas/example/25176/bsdf/1.0/bsdf.xsd">
<WindowElementType>System</WindowElementType>
<FileType>BSDF</FileType>
<Optical>
<Layer>
   <Material>
      <Name>Name</Name>
      <Manufacturer>Manufacturer</Manufacturer>
      <DeviceType>Other</DeviceType>
      <Thickness unit="meter">0.034641</Thickness>
      <Width unit="meter">4</Width>
      <Height unit="meter">2</Height>
   </Material>
   <Geometry format="MGF">
<MGFblock unit="meter">xf -t 0.000000 -0.980000 0
# Y-axis points "up", Z-axis into room, right-handed coordinates
m LightGreyLambert =
rd .7
rs .0 .0
sides 2
o VenetianBlinds
xf -rx -30 -a 67 -t 0 .03 0
o Slat
v v1 =
p -2 0 -.04
v v2 =
```

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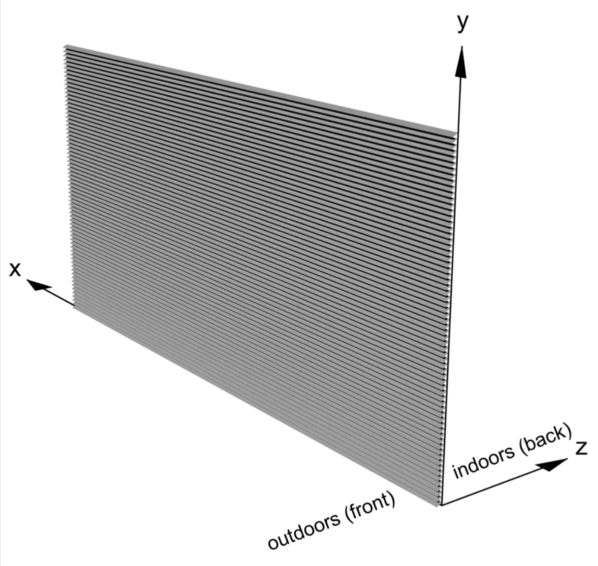

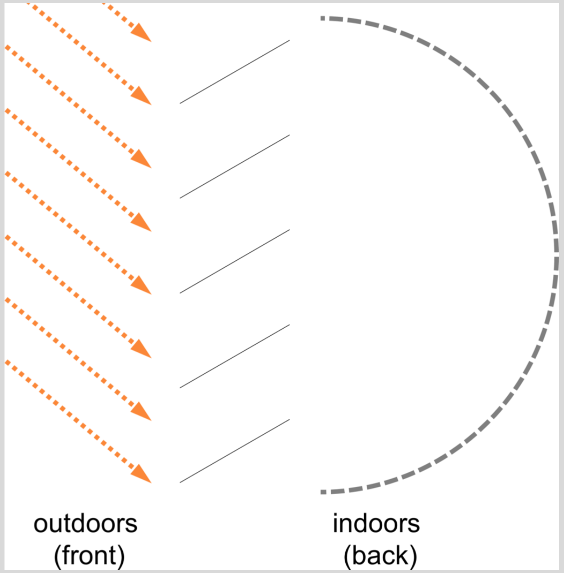

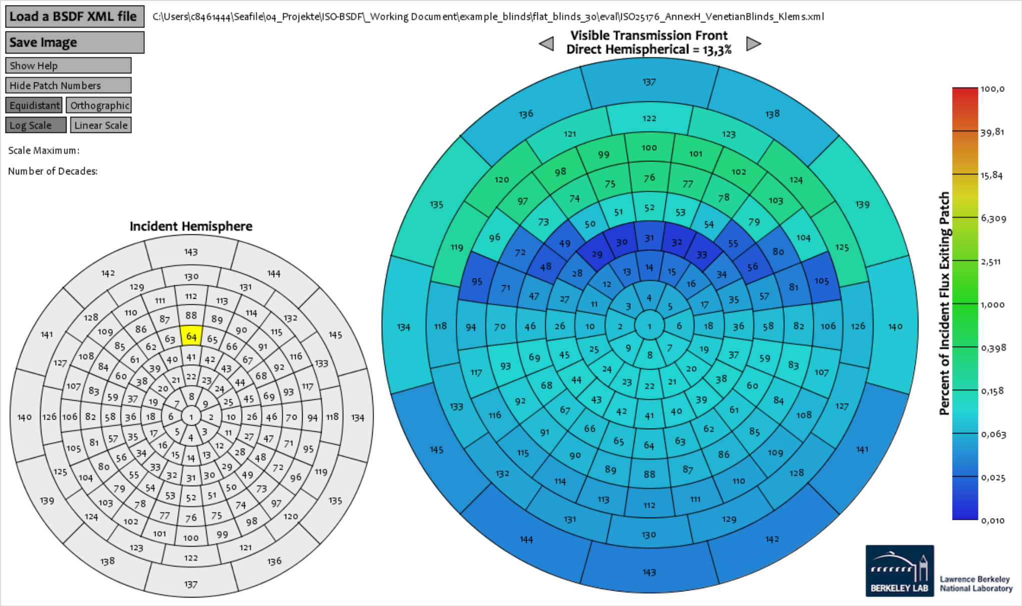

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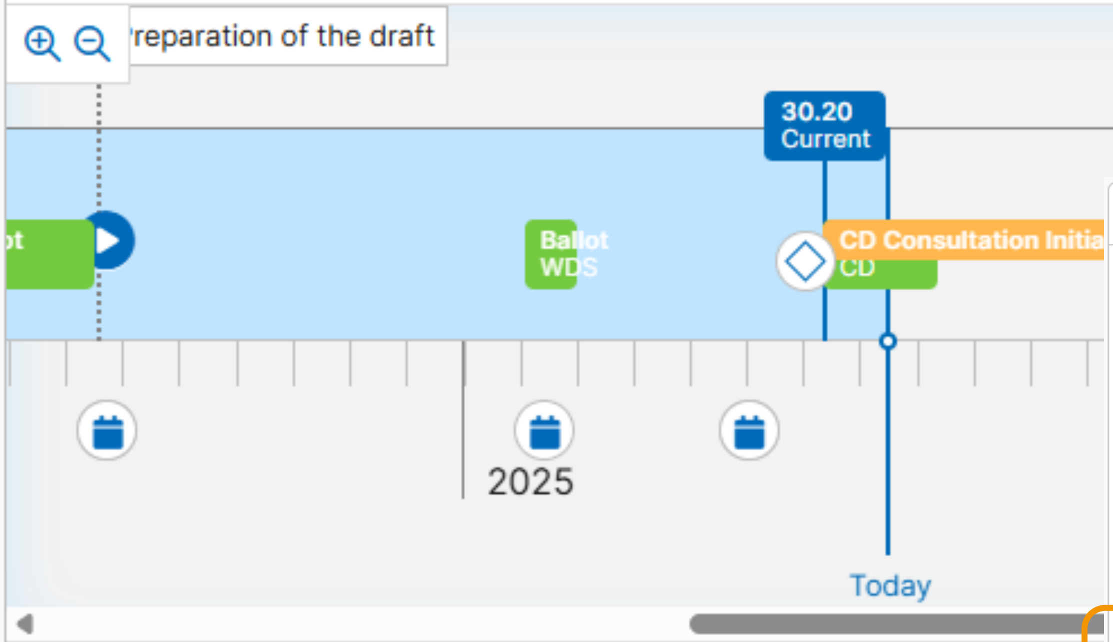
- **Applicability of parametric models in the BSDF generation for macroscopic systems**

For the following materials, the use of the referenced parametric models is considered valid without further justification if the selection of parameters is justified and reported.

Material	Parametric model(s)
Clear float glass w/o coating	Fresnel model or Schlick's approximation
Clear float glass w coating	Hybrid equivalent model, Single-thin-film model
Conductive and non-conductive flat surfaces with no visible structure, i.e., mirror-like reflection	Ward/Geisler-Moroder/Dür BRDF model

Timeline

Registration date	Timeframe	Time since registration	In stage	STATUS
2024-06-20	36 months	13 months	30.20 for 1 month 3 days	en CD consultation initiated



Project approved (clock starts)

Meeting

Past period

Critical period

Stage

Stage	Version	Description	Go to draft	Target date	Limit date	Started	Status
10.00	1	Proposal for new project registered				2024-03-27	Closed
10.20	1	New project ballot initiated		2024-03-27		2024-03-27	Closed
10.60	1	Close of voting		2024-06-19		2024-06-20	Closed
10.99	1	New project approved				2024-06-20	Closed
20.00	1	New project registered in TC/SC work programme				2024-06-20	Closed
20.20	1	Working draft (WD) study initiated		2025-02-05		2025-02-05	Closed
20.60	1	Close of comment period		2025-03-05		2025-03-06	Closed
30.00	1	Committee draft (CD) registered		2025-06-30		2025-07-03	Closed
30.20	**1**	**CD consultation initiated**				**2025-07-16**	**Current**
30.60	1	Close of comment period					Awaiting
30.92	1	CD referred back to Working Group					Awaiting
30.99	1	CD approved for registration as DIS					Awaiting
40.00	1	DIS registered		2026-02-15	2026-06-20		Awaiting
40.99	1	Full report circulated: DIS approved for registration as FDIS					Awaiting
50.00	1	Final text received or FDIS registered for formal approval					Awaiting
60.00	1	International Standard under publication					Awaiting
60.60	1	International Standard published		2027-06-20	2027-06-20		Awaiting

Show less

Radiance Workshop

We want your feedback and opinion!

» Do you use BSDFs for CFS?
In Radiance? Or in other tools as well? If so, which ones?

» If you obtain BSDFs externally, where do you get them from?
And do you receive information about how they were created?

» Is the origin and validity of BSDF data important to you? How do you verify this?

» If you create BSDFs yourself, what methodology do you use?

» What are the biggest hurdles/challenges when creating BSDFs?

» ...?

Acknowledgements

"CFS4LowCarb: Integrated Light-Thermal Solutions for Complex Fenestration Systems Towards Low Carbon Buildings"

in the "TECXPORT Bilateral Cooperation Austria – PRC/MOST 2022" programme, contract 903877, and

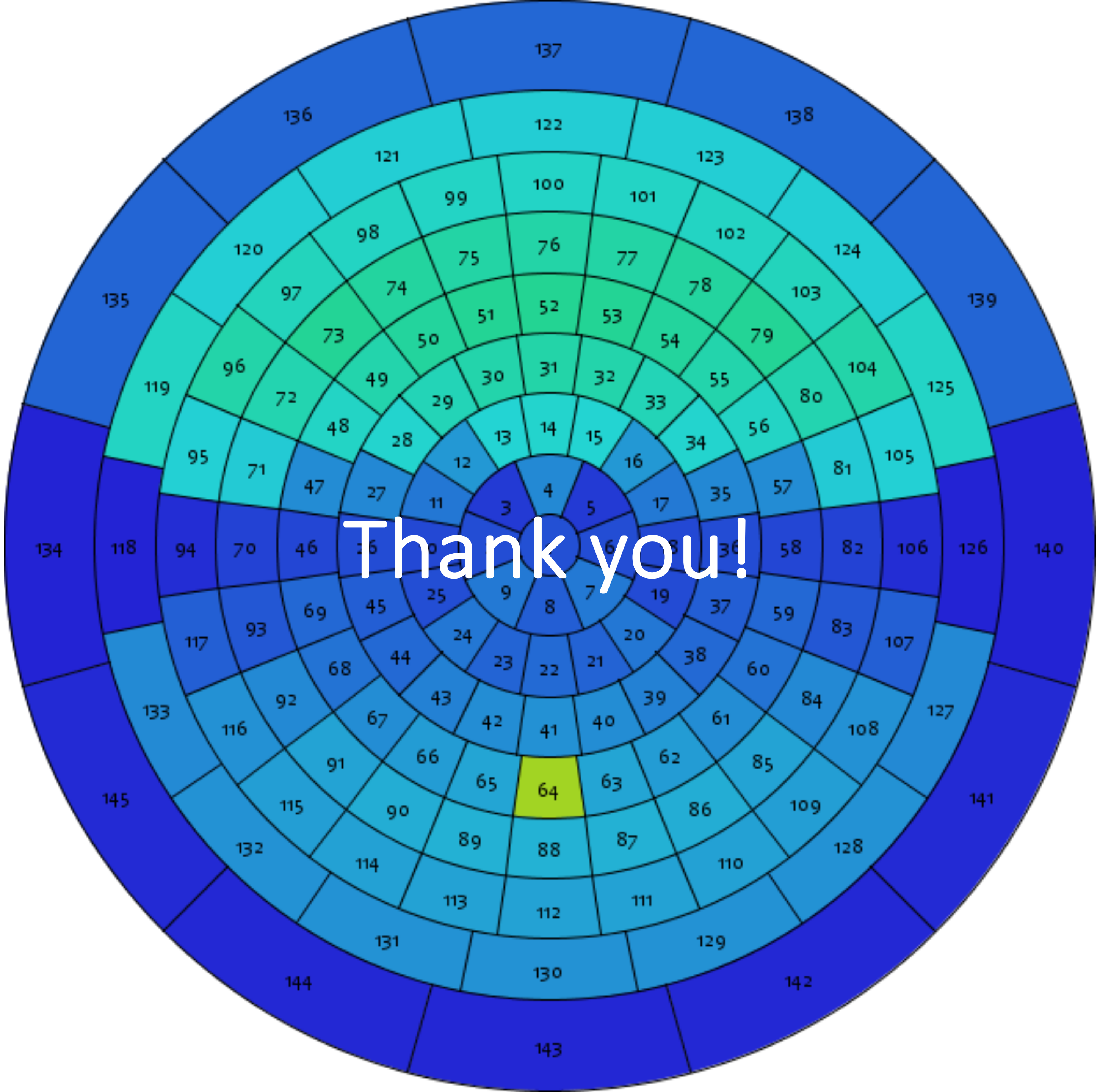
"IEA SHC Task 70 / EBC Annex 90 Low Carbon, High Comfort Integrated Lighting"

in the "IEA Research Cooperation" programme, contract 900356, both financed by the Federal Ministry of Austria for Innovation, Mobility and Infrastructure BMIMI and managed by the Austrian Research Promotion Agency FFG

Funded by

Federal Ministry
Innovation, Mobility
and Infrastructure
Republic of Austria

FFG
Promoting Innovation.



Thank you!

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David.Geisler-Moroder@uibk.ac.at

www.uibk.ac.at