VALIDATION OF A GEOMETRICAL MODEL IN RADIANCE FOR THE DESIGN OF TEXTILE SHADING DEVICES

Researcher:

Abel Sepúlveda Luque

Fraunhofer-Institut

für Solare Energiesysteme ISE

Freiburg, 04.09.2018

www.ise.fraunhofer.de

Fraunhofer ISE

Introduction

Thermal

Glare

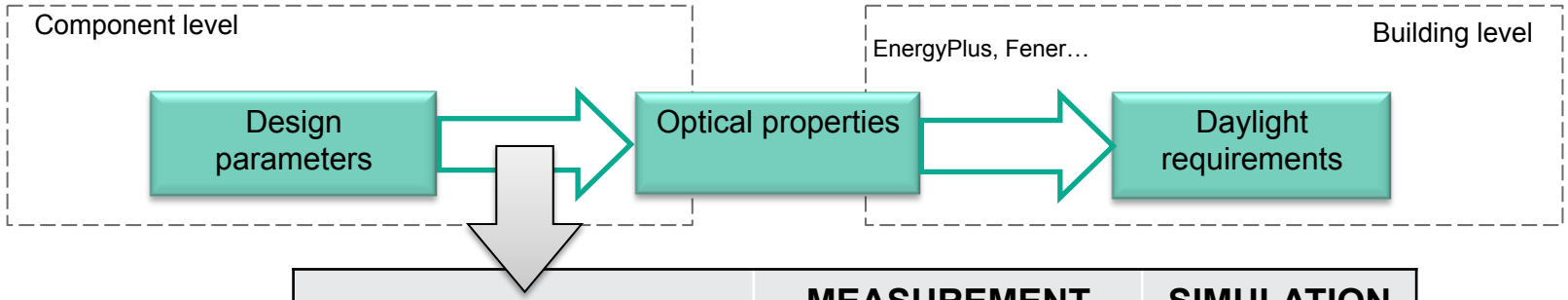
Daylight

…but too simple optical behaviour to reach:

Minimum glare and
maximum daylight autonomy
in **modern buildings**

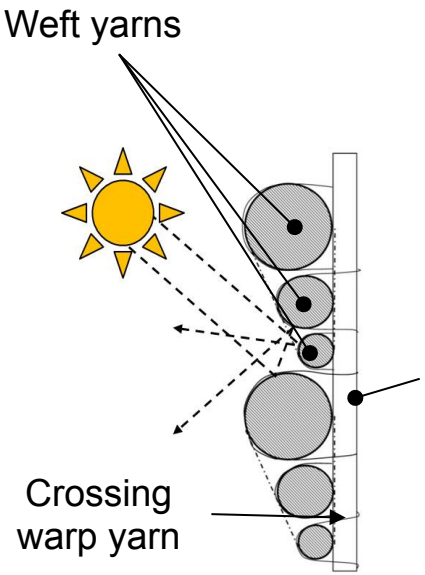
Fraunhofer ISE

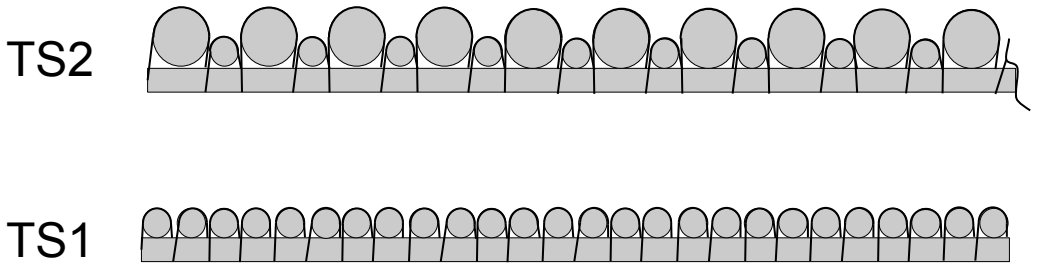
Context: Optimization of yarn structures to achieve a specific optical performance



	MEASUREMENT	SIMULATION
Manufactured samples?	YES	NO
How much is it?	EXPENSIVE	"CHEAP"
Flexible design?	NO	YES
Reliable results?	YES	???

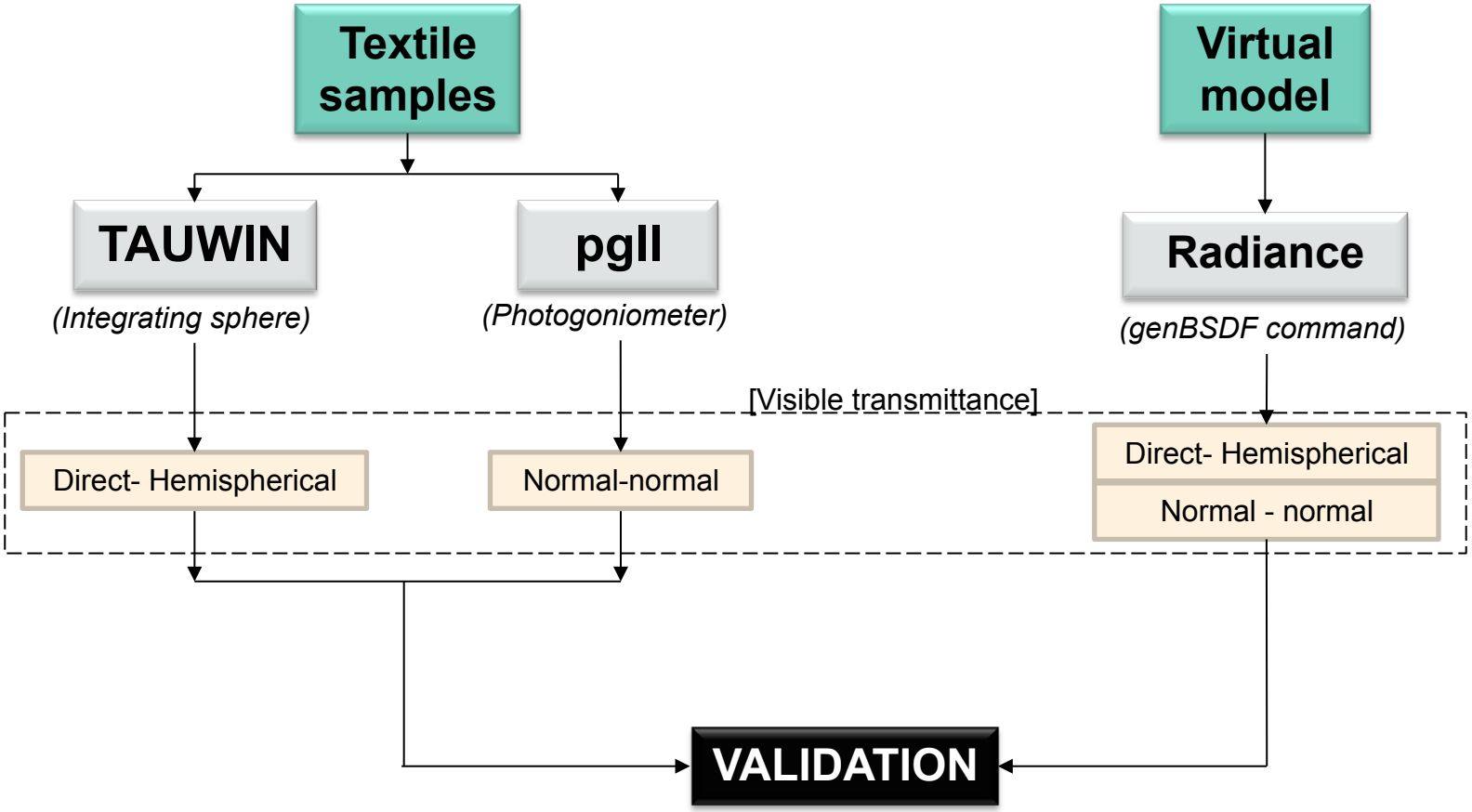
*Leno-weave fabric concept:





***Source:** *Ettlin Spinnerei and Weber Produktions GmbH*

Methodology

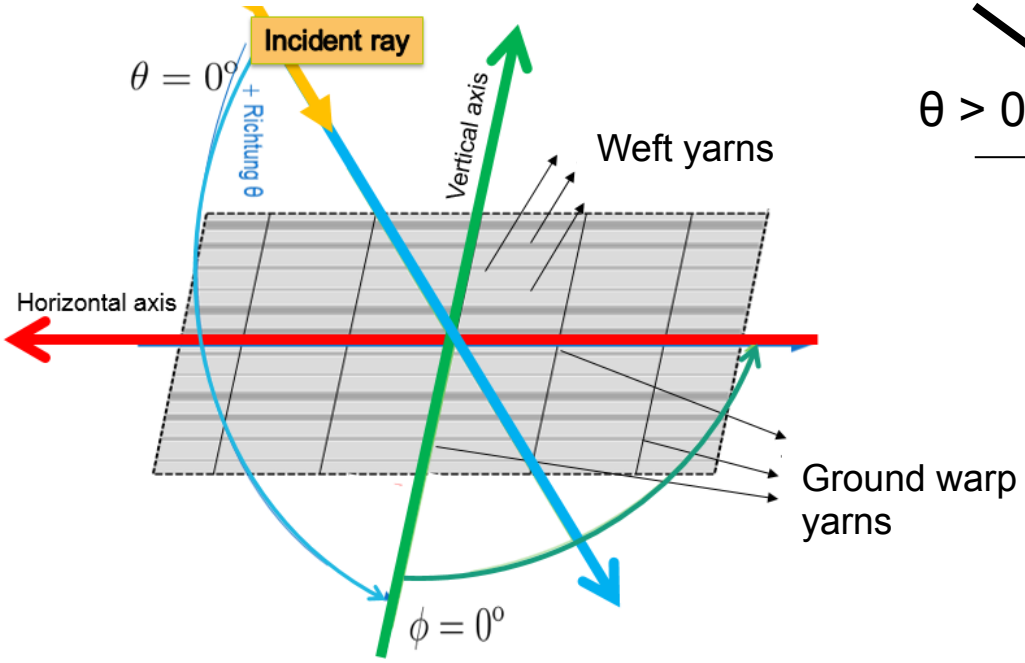


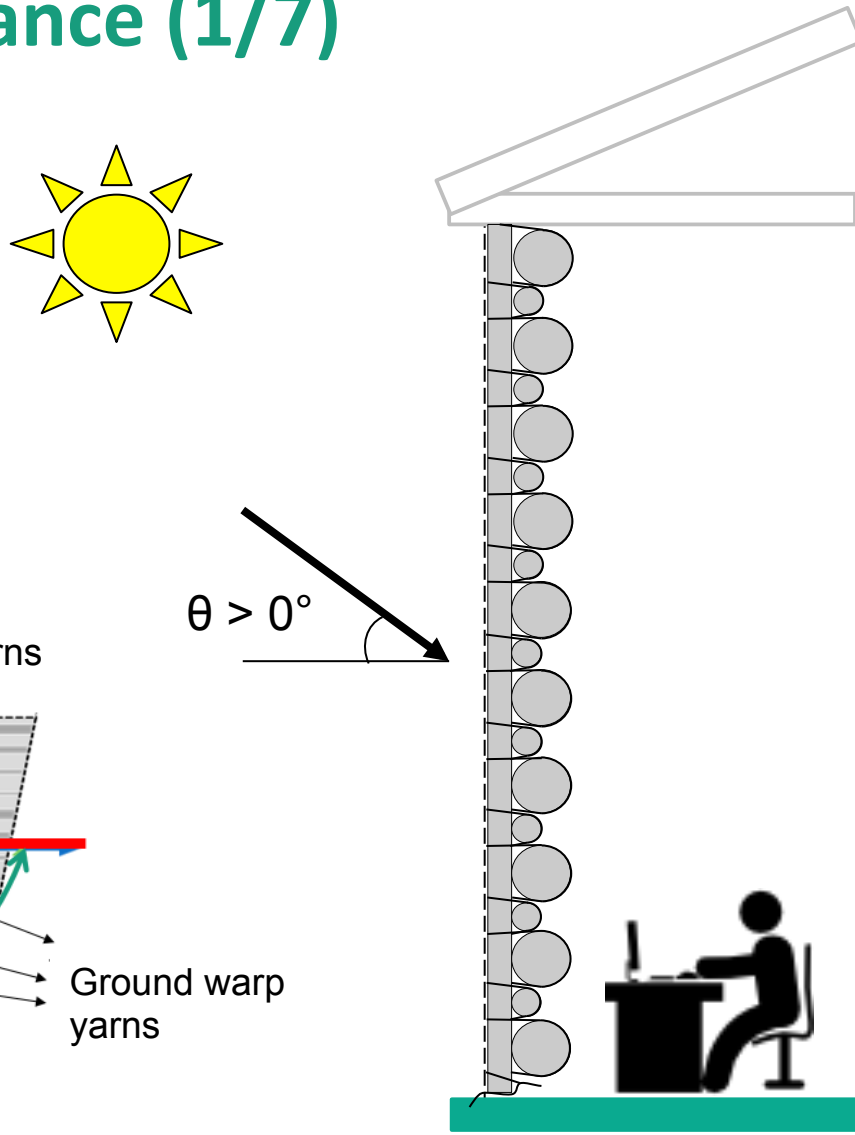
Geometrical model in Radiance (0/7)

- Orientation
- Sample size
- Sample box location
- Sample box dimensions
- genBSDF parameters
- Crossing warp yarn modelling

Geometrical model in Radiance (1/7)

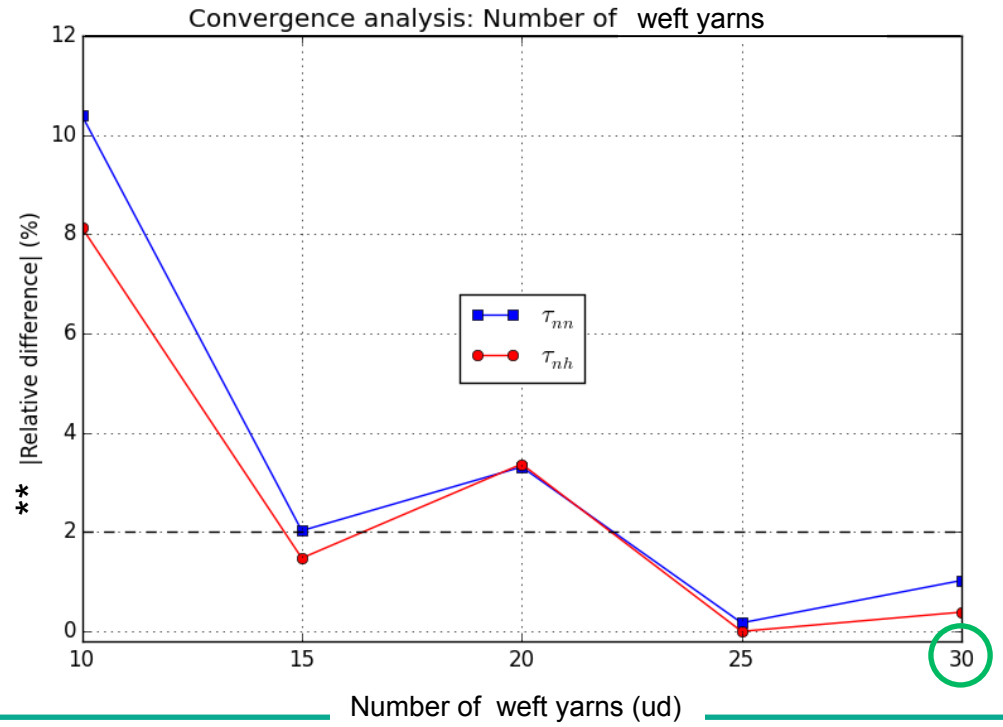
- **Orientation**
- Sample size
- Sample box location
- Sample box dimensions
- genBSDF parameters
- Crossing warp yarn modelling





Geometrical model in Radiance (2/7)

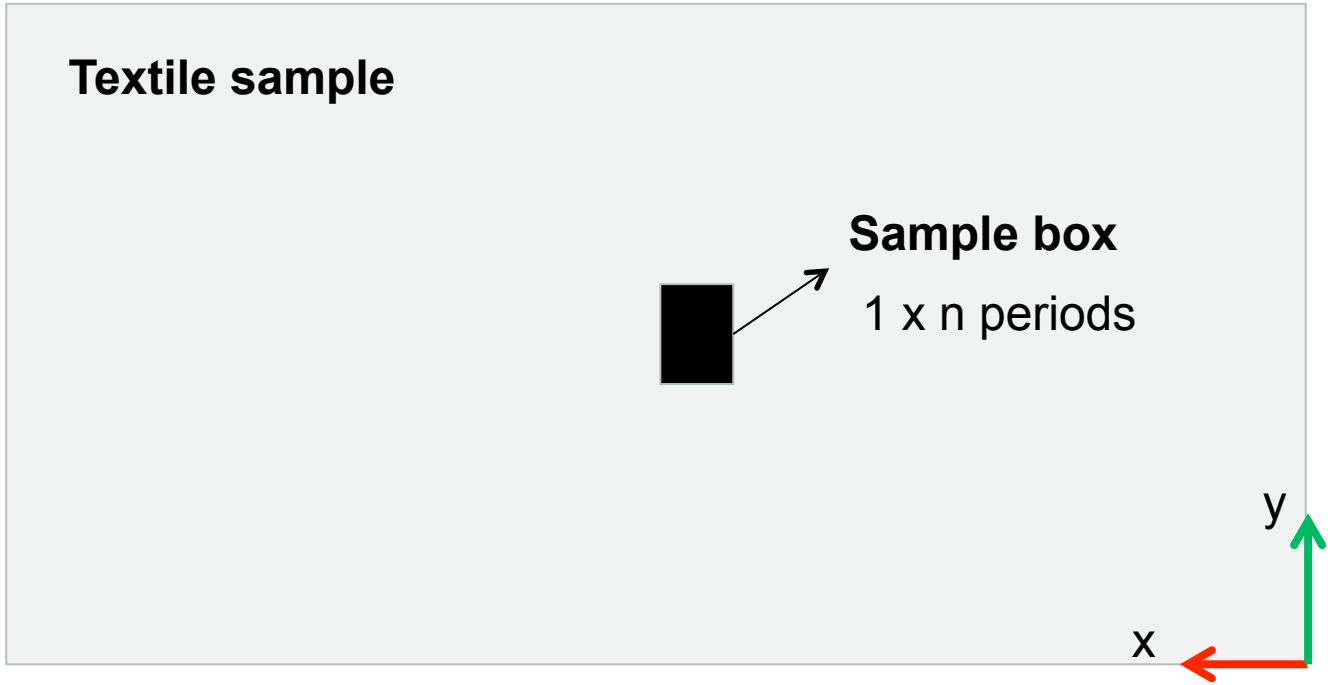
- Orientation
- **Sample size:** 30 ud/ different diameter per vertical period
- Sample box location:
- Sample box dimensions
- genBSDF parameters
- Crossing warp yarn modelling



$$**Relative\ difference = 100 \cdot (\tau\downarrow i+1 - \tau\downarrow i / \tau\downarrow i\ )$$

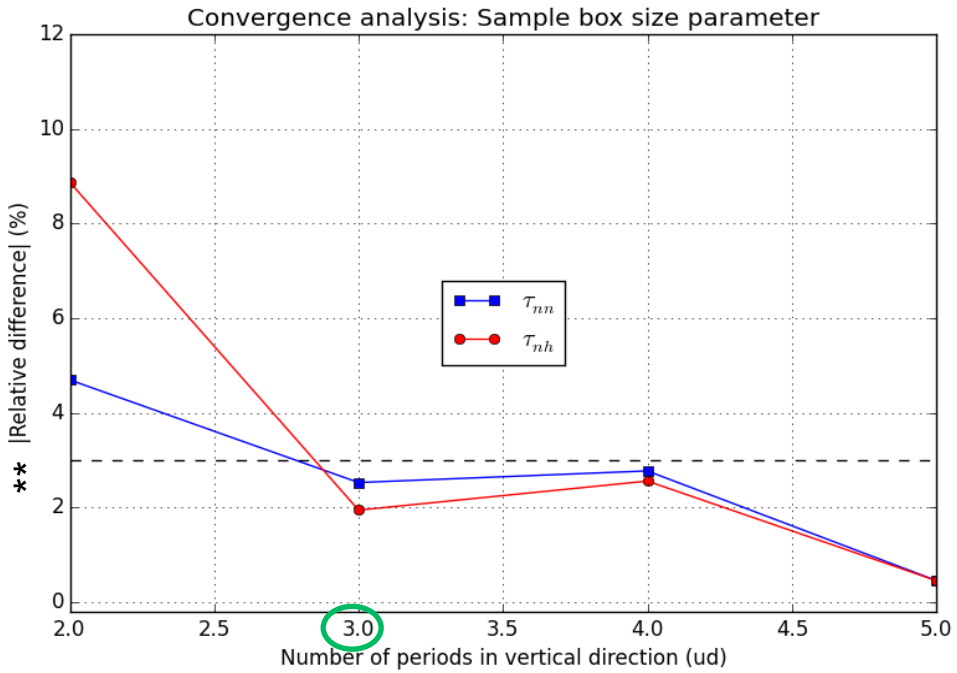
Geometrical model in Radiance (3/7)

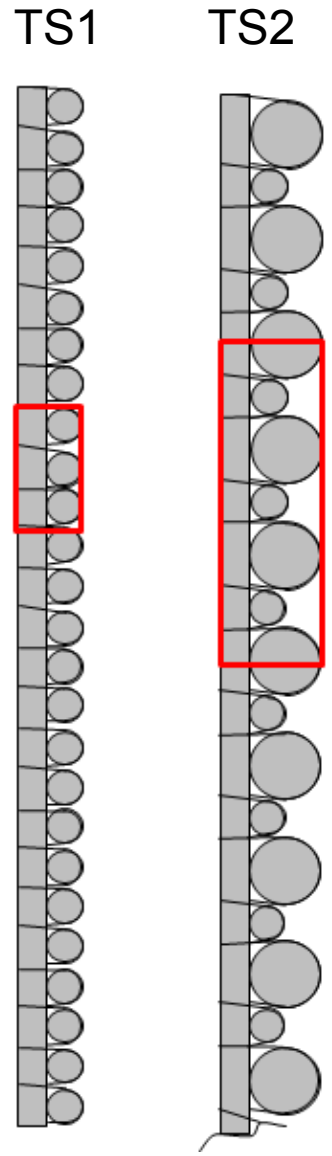
- Orientation
- Sample size: 30 ud/ different diameter per vertical period
- **Sample box location:** In the middle of the sample
- Sample box dimensions
- genBSDF parameters
- Crossing warp yarn modelling



Geometrical model in Radiance (4/7)

- Orientation
- Sample size: 30 ud/ different diameter per vertical period
- Sample box location: In the middle of the sample
- **Sample box dimensions**
- genBSDF parameters
- Crossing warp yarn modelling

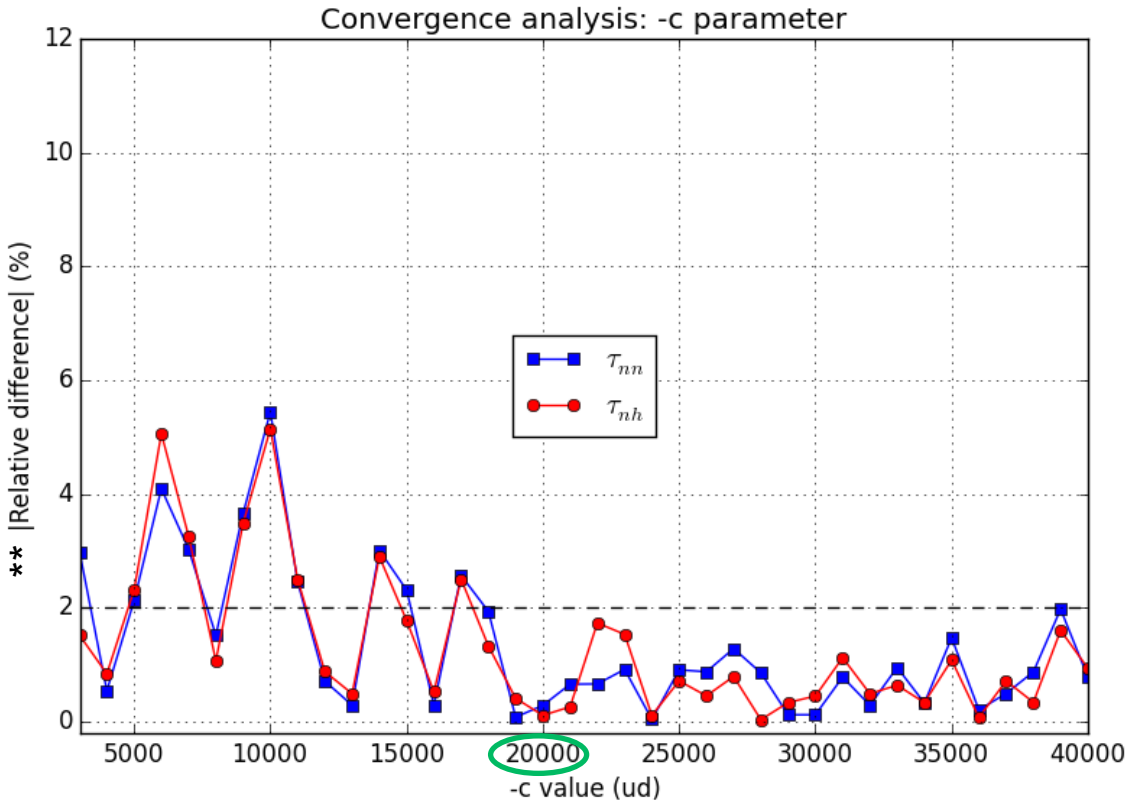




$$**Relative\ difference = 100 \cdot (\tau\downarrow i+1 - \tau\downarrow i / \tau\downarrow i\ )$$

Geometrical model in Radiance (5/7)

- Orientation
- Sample size: 30 ud/ different diameter per vertical period
- Sample box location: In the middle of the sample
- Sample box dimensions
- **genBSDF parameters**
- Crossing warp yarn modelling



$$**Relative\ difference = 100 \cdot (\tau\downarrow i+1 - \tau\downarrow i / \tau\downarrow i\ )$$

Geometrical model in Radiance (6/7)

- Orientation
- Sample size: 30 ud/ different diameter per vertical period
- Sample box location: In the middle of the sample
- Sample box dimensions
- **genBSDF parameters**
- Crossing warp yarn modelling

Summary table		
-ab	5	Number of bounced traced
-ad	200	Number of rays spawned
-lw	5.85e-4	Minimum weight of a traced ray (1)
-st	4.90e-3	Threshold for specular sampling (2)
-c	20000	Samples per incident direction

Surface parameters	
R	0.05
G	0.05
B	0.05
Specularity	0.07
Roughness	0

Reflectance = 0.117*

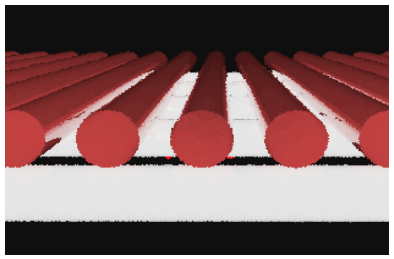
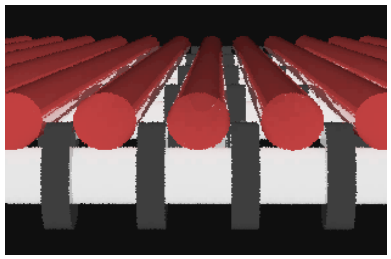
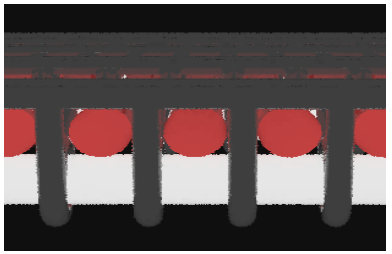
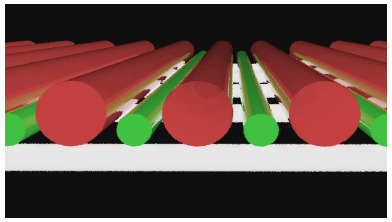
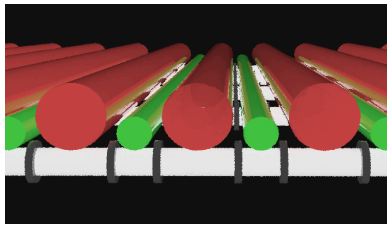
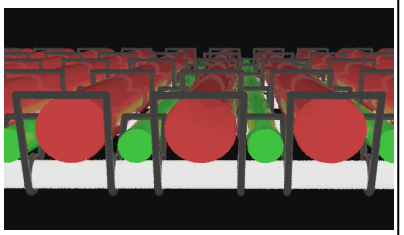
$$lw = Reflectance \times 1/ad \quad (1)$$

$$st = Specularity \wedge 2 \quad (2)$$

* http://www.jaloxa.eu/resources/radiance/colour_picker/index.shtml

Geometrical model in Radiance (7/7)

- Orientation
- Sample size: 30 ud/ different diameter per vertical period
- Sample box location: In the middle of the sample
- Sample box dimensions
- genBSDF parameters: -c 20000 -ab 5 -ad 200 -lw 5.85e-4 -st 4.90e-3
- **Crossing warp yarn modelling**

	Without	Rings	Realistic	Compactness
TS 1				55 u/cm
TS2				39 u/cm

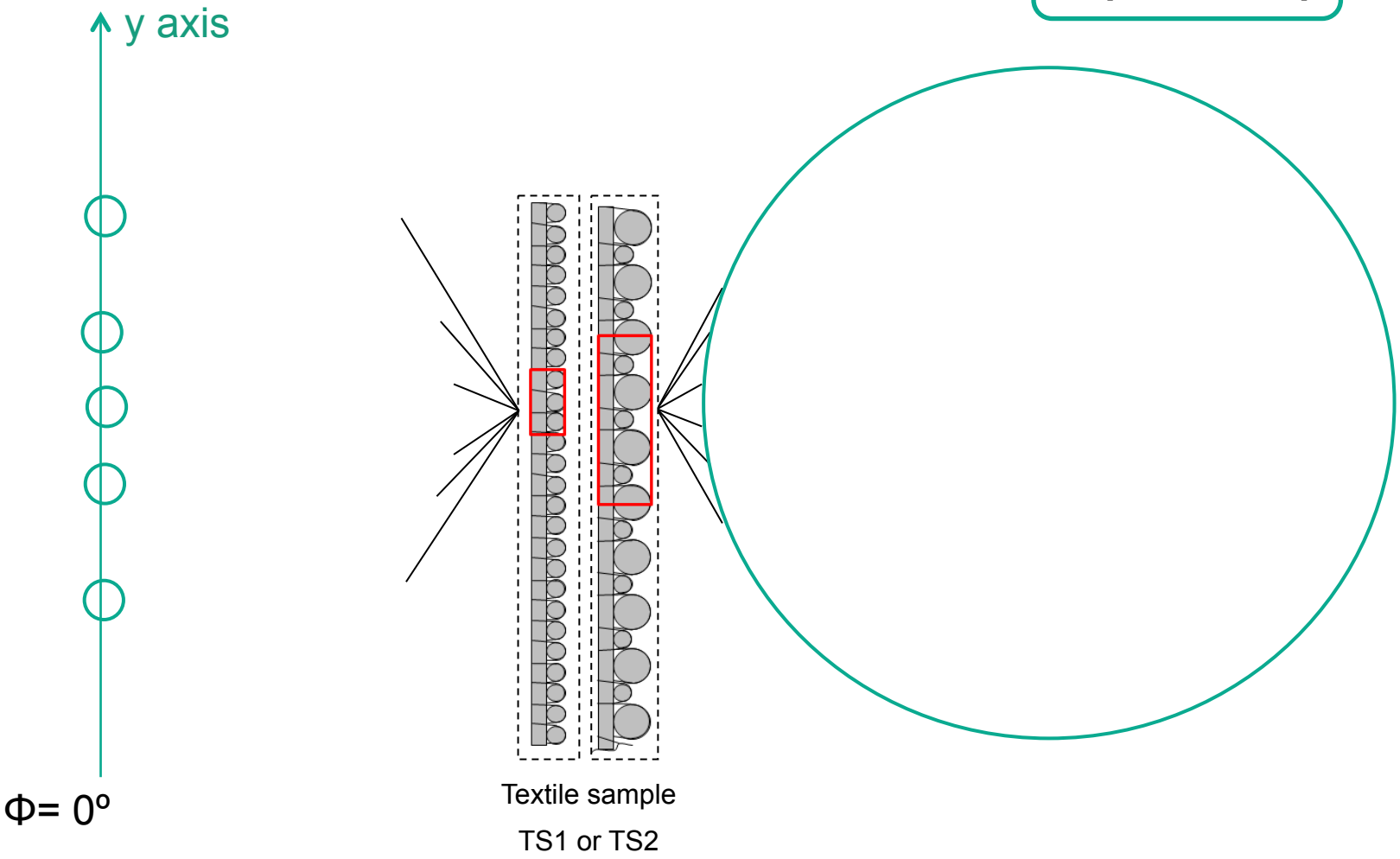
Validation process (1/2) – Reference values

- The reference transmittance (front) values used are:

Nomal-normal + Direct- Hemispherical for these angles:

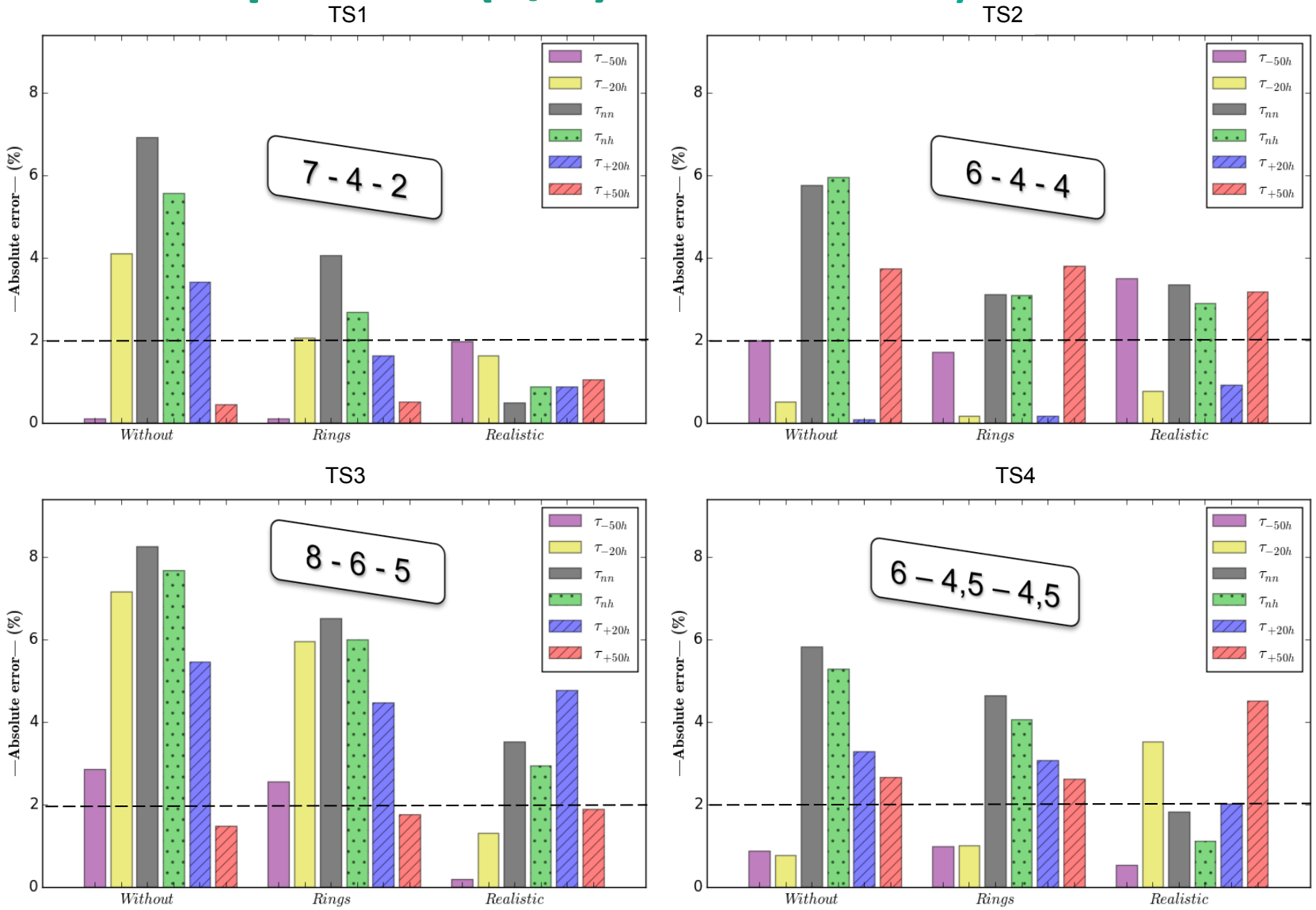
Φ= [0]

θ= [-50,-20,0,20,50]



Fraunhofer ISE

Validation process (1/2) – Error analysis



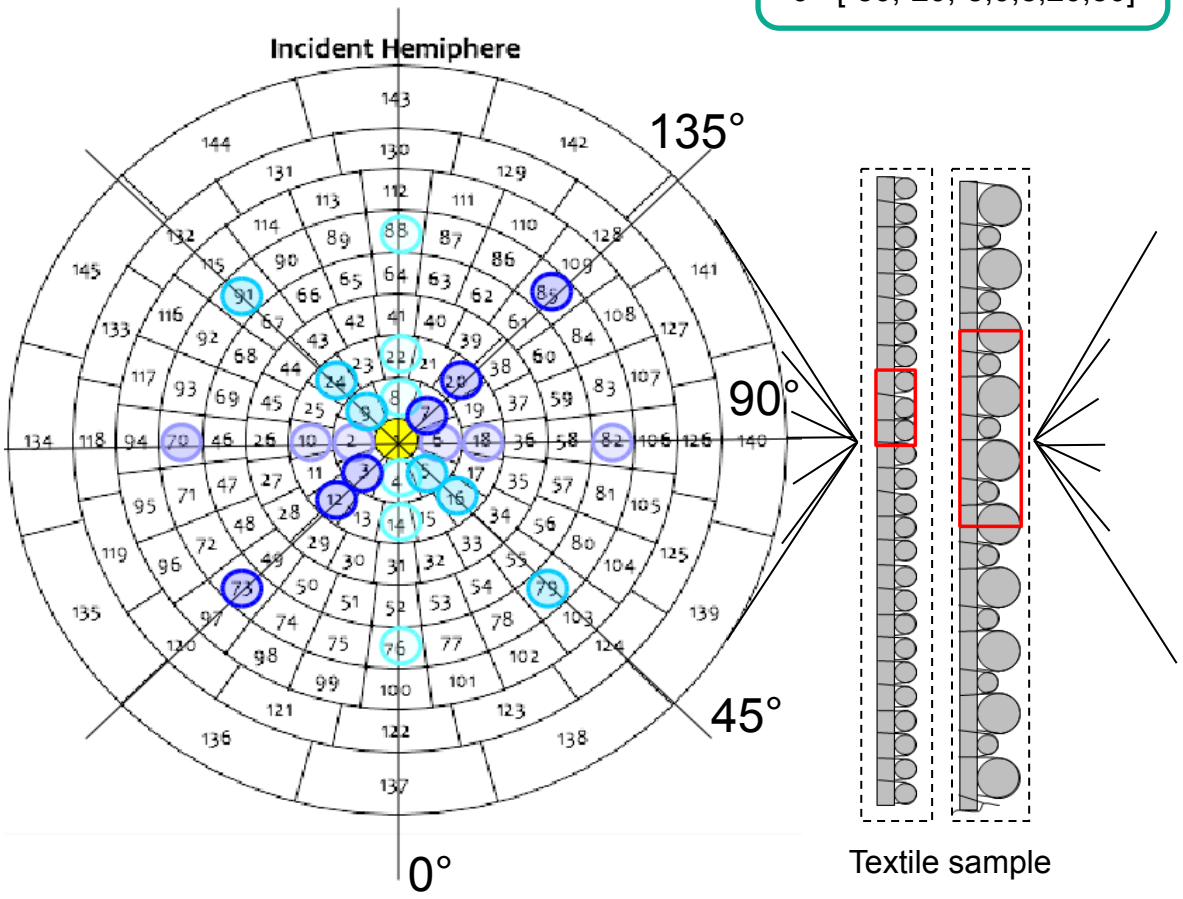
Fraunhofer ISE

Validation process (2/2) – Reference values

- The reference transmittance (front) values used are direct- hemispherical for the following angles:

Φ= [0,45,90,135]

θ= [-50,-20,-8,0,8,20,50]

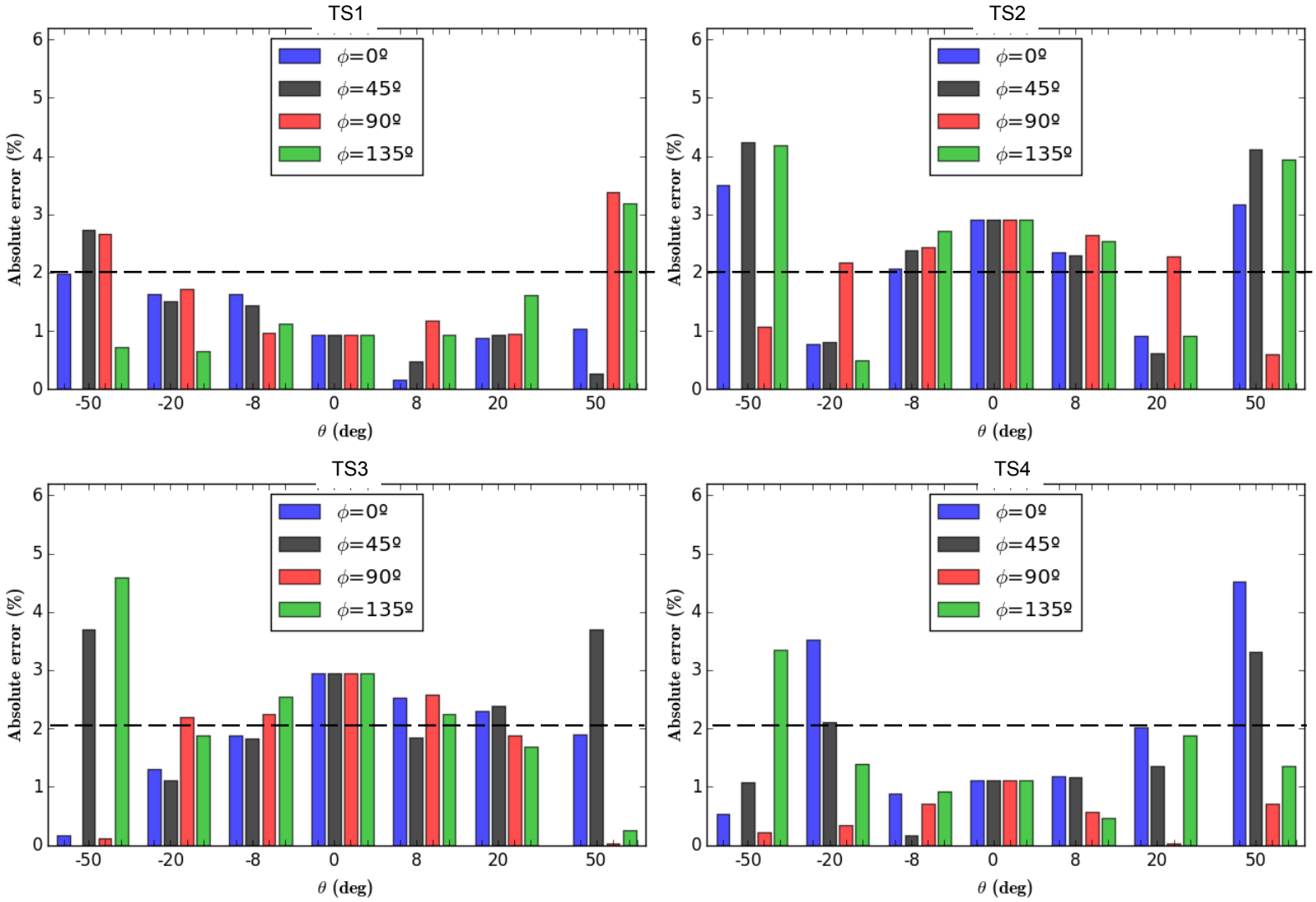


Textile sample

TS1 or TS2

Fraunhofer ISE

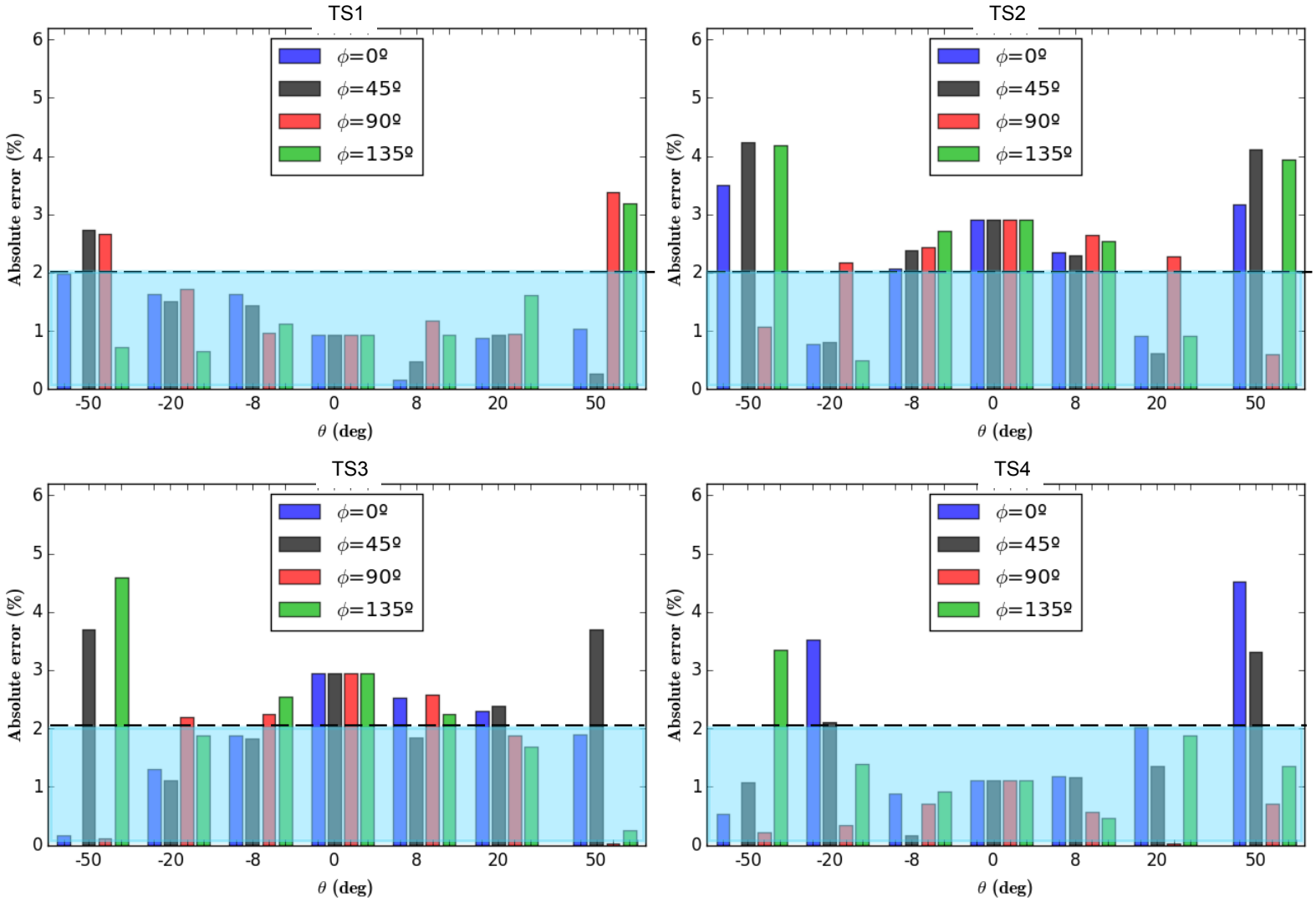
Validation process (2/2) – Analysis of uncertainties



Fraunhofer ISE

Validation process (2/2) – Analysis of uncertainties

Uncertainty due to the Virtual model

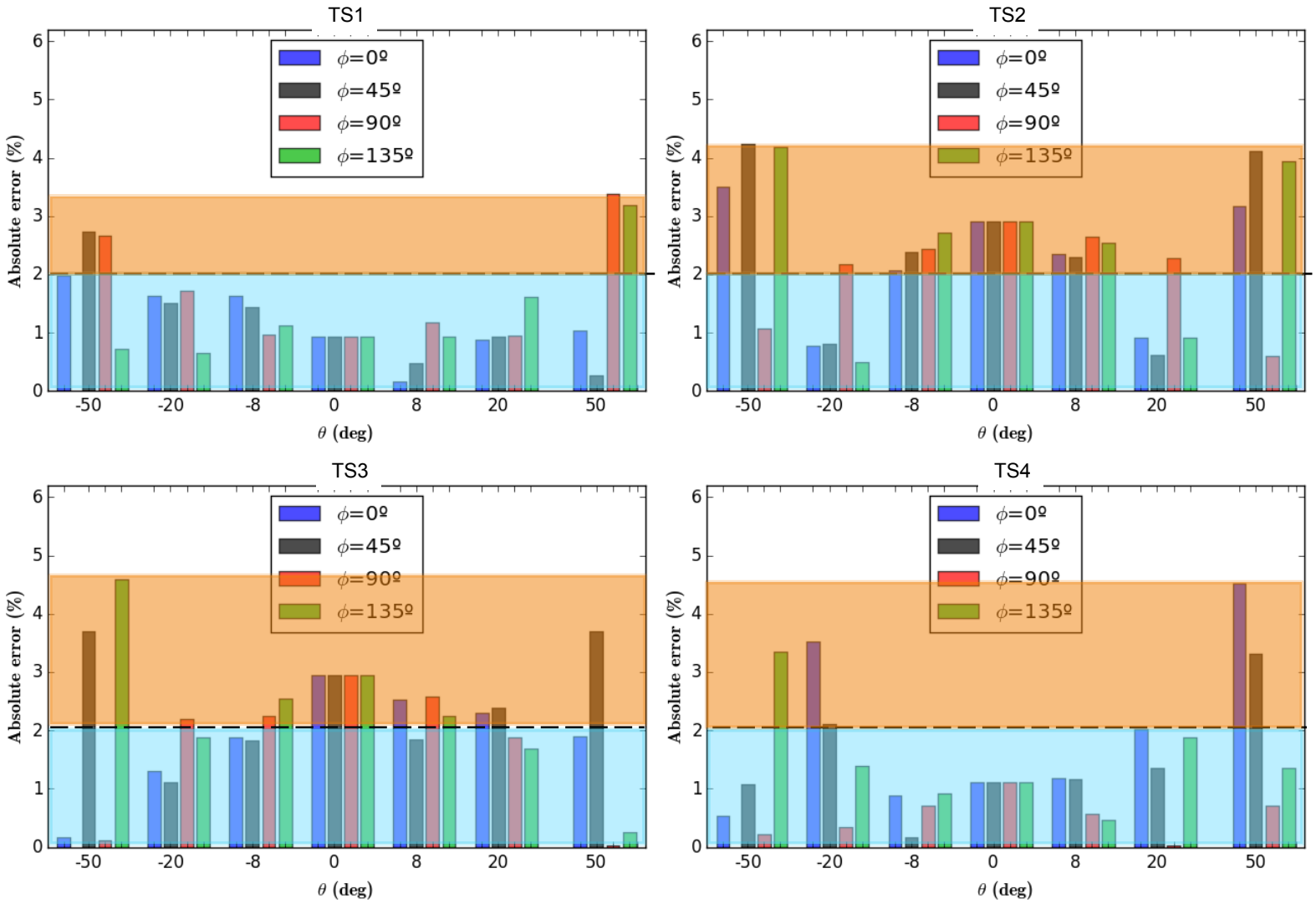


Fraunhofer ISE

Validation process (2/2) – Analysis of uncertainties

Uncertainty due to the Virtual model

Uncertainty due to Experiments + Fabrication



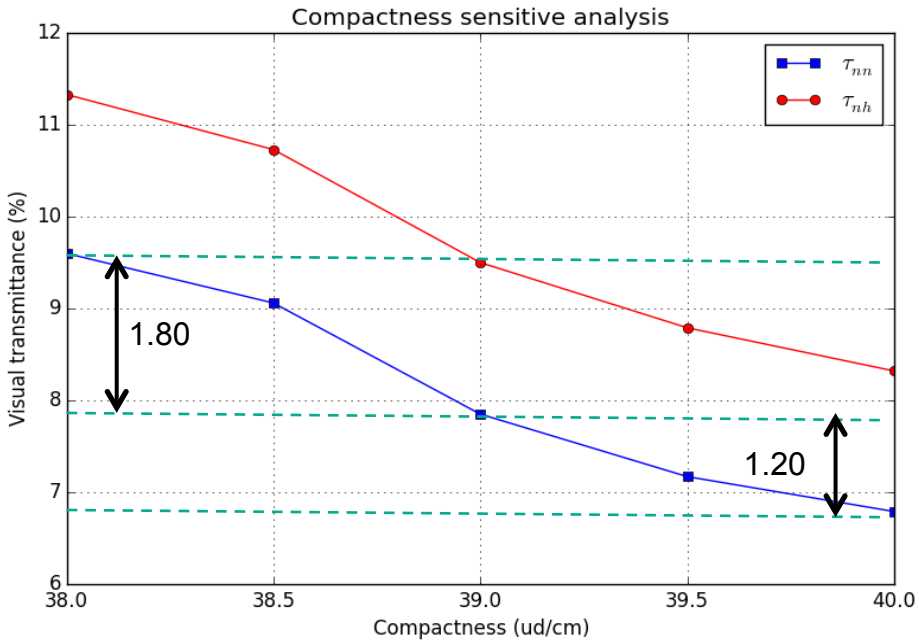
Fraunhofer ISE

Validation process (2/2) – Analysis of uncertainties

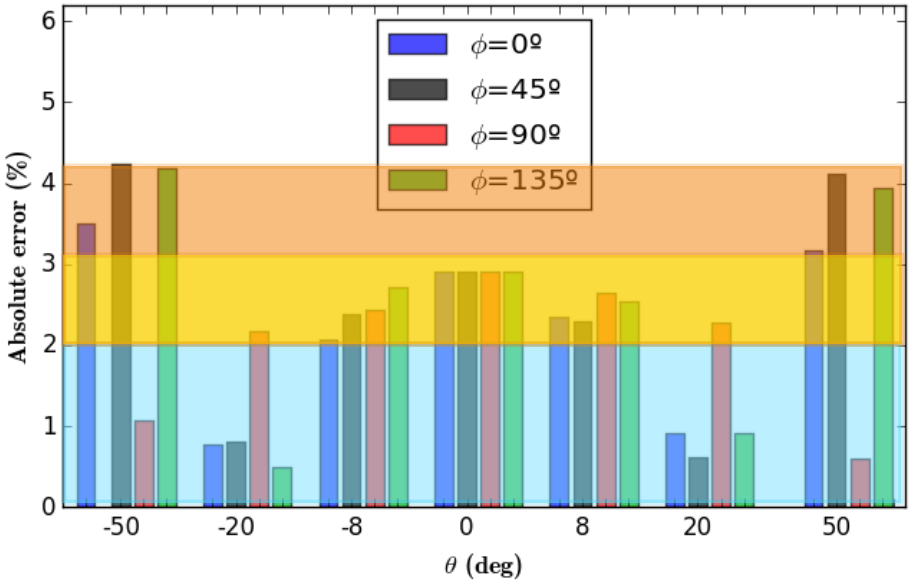
Uncertainty due to the Virtual model

Uncertainty due to Experiments + Fabrication

- Let‘s make a sensitive analysis for slight deviations of the compactness in textil sample 2:
- Compactness values: 39 ± 1 (du/cm)



TS2



- Absolute changes in terms of visual front transmittance around 1.5 % for a deviation of 1 ud/cm in compactness of weft garns!

Fraunhofer ISE

CONCLUSIONS

I. **Detailed geometrical** of textiles are **required** in order to get **reliable simulation results**.

II. Some **differences** between **measurements** and **simulations** are still **observed**. Possible **sources** of **error**:

- **Virtual model uncertainties**

Number of threads, sample box design, -c, crossing warp yarn modelling and Klems angular description, idealized geometrical model of yarns that in reality are deformed.

- Real model tolerances:

Irregular textile surfaces, compactness deviations due to the sewing process.

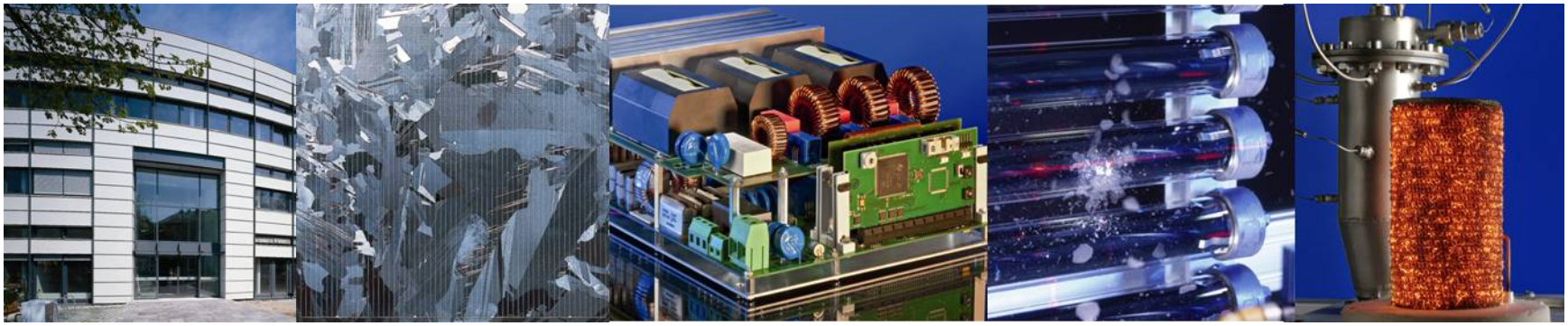
- Experimental process:

Orientation, sample tension, textile samples dirt, measurement accuracy

III. **Radiance** is able to get **reliable BSDF data** sets from **complex textiles** much **faster** and **cheaper** than **experimental** processes.

IV. The use of **Radiance-based virtual models** of **textiles** makes it **possible** to **optimize yarn geometries** for **solar shading applications** with **enhanced functionality**.

Thank you for your attention!



Fraunhofer Institute for Solar Energy Systems ISE

Abel Sepúlveda Luque

abel.sepulveda@ise.fraunhofer.de

www.ise.fraunhofer.de

Gefördert durch:

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

The present study has been funded by the Federal Ministry of Economic Affairs and Energy by a resolution of the German parliament (Project ID: 03ET1432A).