



**D
AN
IELS**

University of Toronto
John H. Daniels Faculty of
Architecture, Landscape, and Design

Two Applications of Lighting Measurement + Radiance Simulations

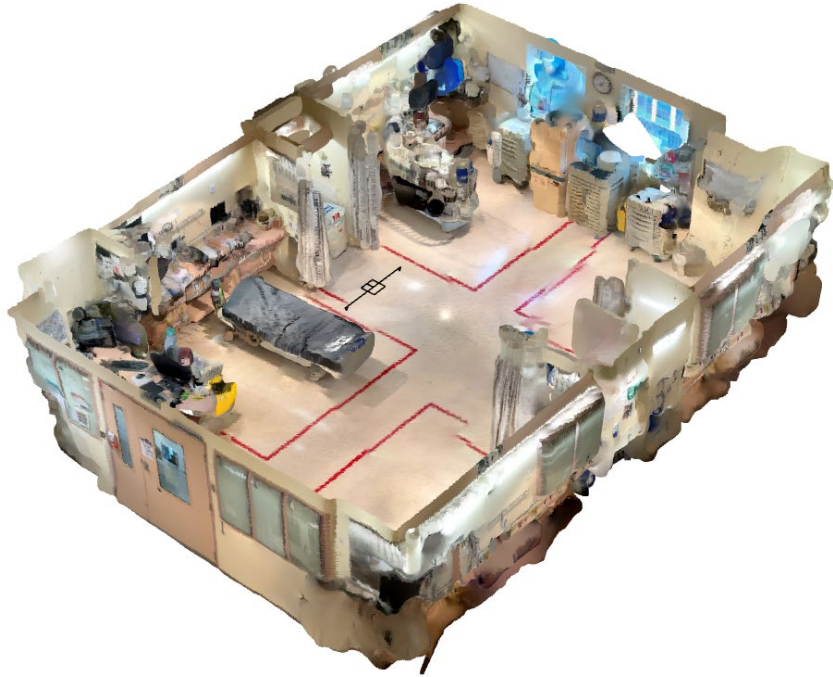
Alstan Jakubiec

Fion Yang Ouyang, Nazanin Ganjehzadeh

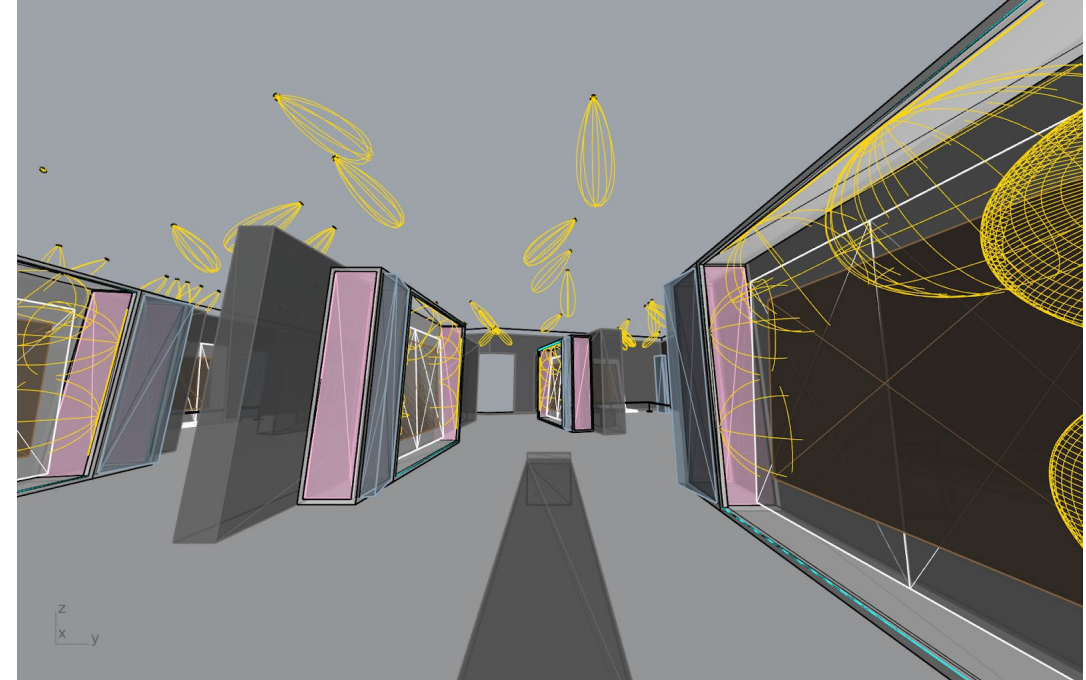
Cora Xintian Liu

24th International Radiance Workshop

Two projects...



01 ICU
Intensive Care Units



02 AGO
Museum Exhibition Design



SickKids[®]

01 ICU

Lighting Characterization,
Human-Centric Analysis, and
Simulation of Urban Intensive
Care Units

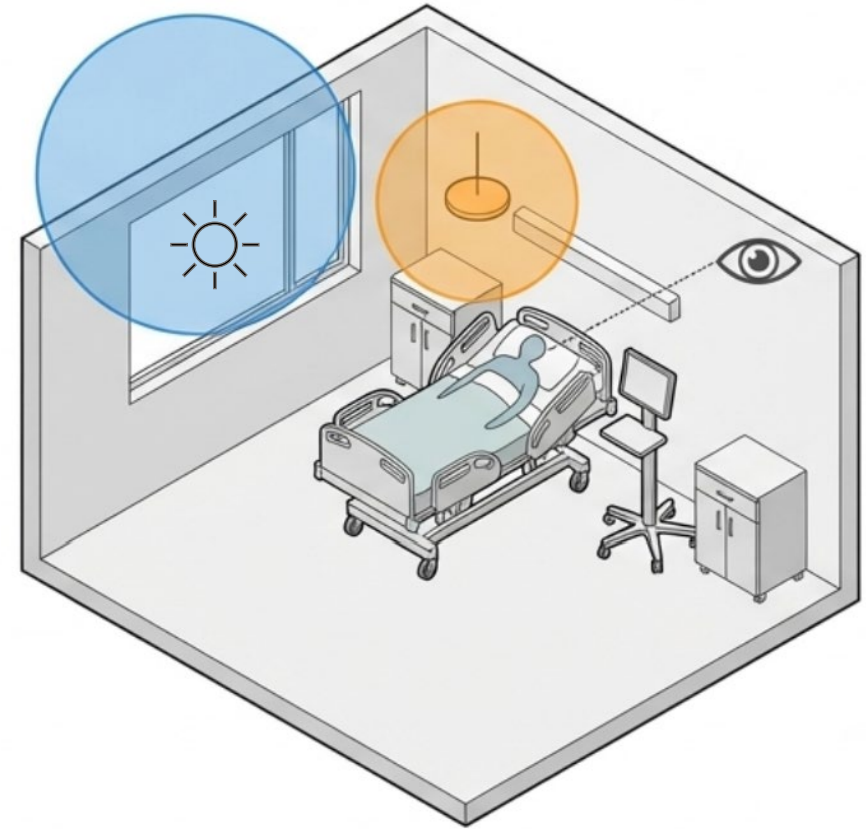
Contributors:

Fion Yang Ouyang, Nazanin Ganjehzadeh, Stephen Verderber, Chris Parshuram, Jacob Wilson, Alexandra Li, Alstan Jakubiec

ICU Lighting Experience

In an ICU room, light is experienced through multiple overlapping dimensions:

1. **Visual task performance:** observation, documentation, procedures.
2. **Patient visual comfort:** brightness, glare, contrast, rest conditions.
3. **Circadian exposure:** eye-level melanopic exposure over time.
4. **Spatial position:** patient zone, bedside zone, documentation zone, door-room transition.



Disconnects Between Metrics and Experienced Light

Standard metrics can miss important ICU lighting conflicts:

Typical design focus	What may be missed
Minimum illuminance	Patient eye-level exposure at rest
Uniformity across a task plane	Bright sources or glare within field of view
Task lighting	Patient comfort
Point-in-time readings	Temporal variability from weather, shades, and switch use
Daylight access as a room attribute	Room to room orientation effects and façade dependence



Measuring ICU Lighting is Methodologically Difficult

The workflow must capture spatial, visual, temporal complexity:

1

Point-in-time measurements

A measurement is highly dependent on weather, time, shade position, and switch state.

2

Multiple lighting layers

Daylight, ambient lighting, examination lighting, wall lighting, and task lighting.

3

Multiple observer positions

Patient, staff, documentation, and transition zones.

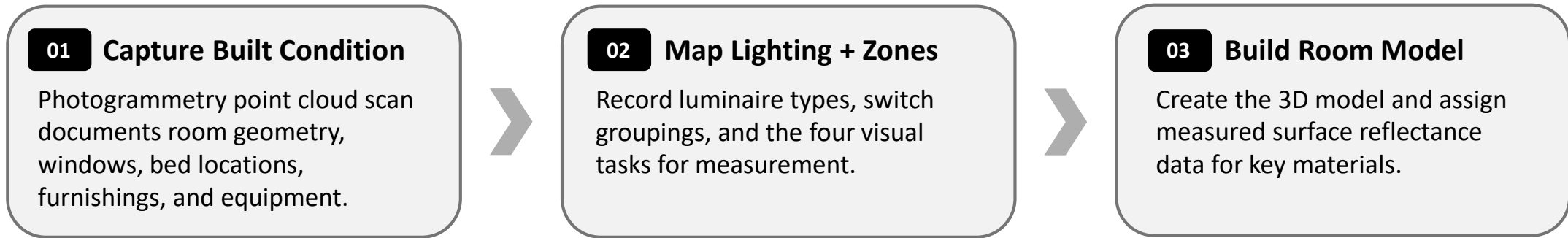
4

High workflow cost

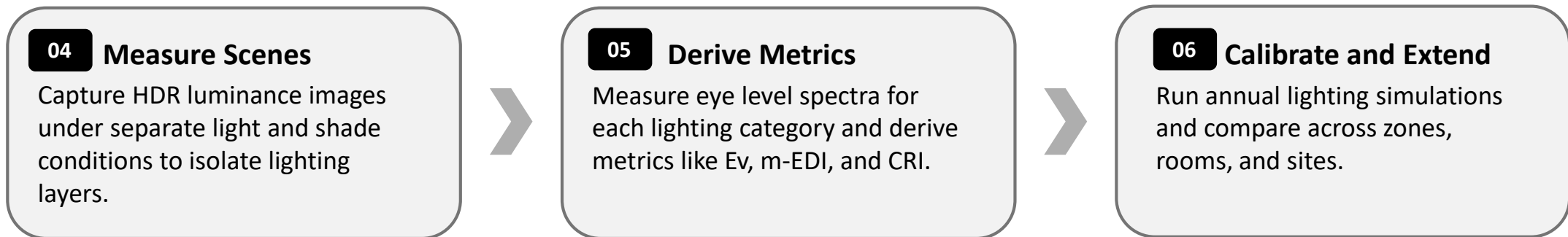
HDR imaging, spectral measurement, reflectance scanning, 3D capture, and model calibration.

Overall Workflow for Characterizing ICU Lighting

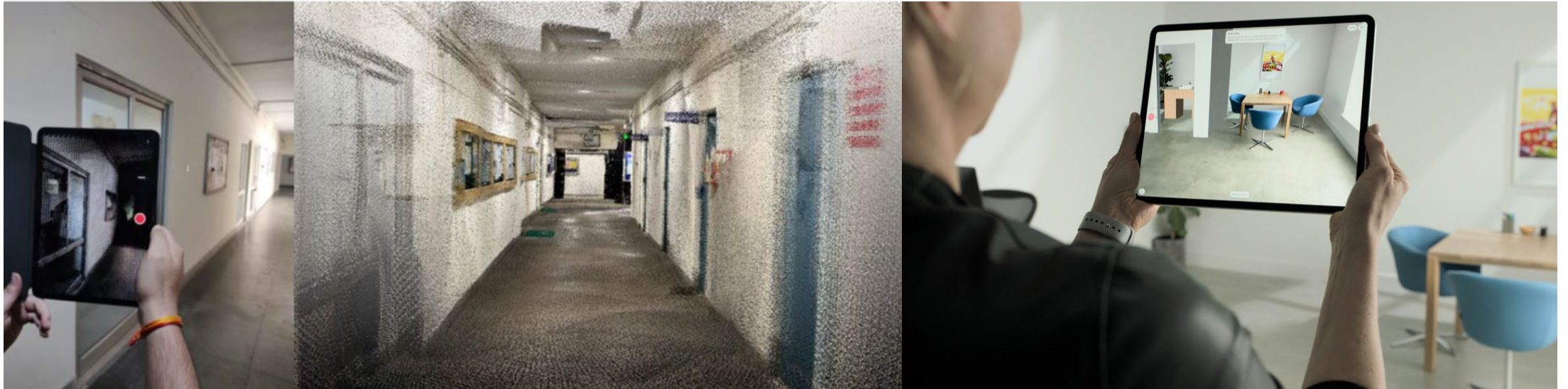
FIELD DOCUMENTATION + MEASUREMENT



METRICS, CALIBRATION, AND SIMULATION



3D Scanning - Equipment



Reference image for Harshit et.al (2024) and Apple (2020)

3D Point Cloud Captures

1. Capture Built Conditions



SickKids



Lakeridge - Ajax



Lakeridge Oshawa



Sunnybrook



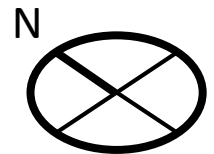
Toronto General



St. Michael's



Mount Sinai



ICU Design Comparisons

SickKids



Lakeridge - Ajax



ICU Design Comparisons

SickKids



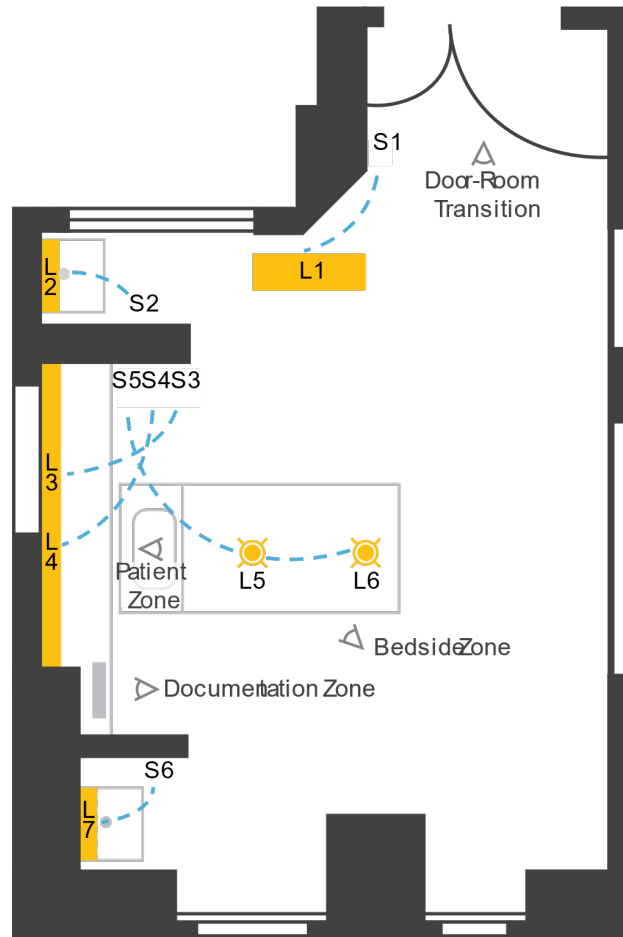
Mount Sinai



Lights, Switches, and Assessment Zones

2. Map Lighting + Zones

SICKKIDS ROOM 111 EXAMPLE



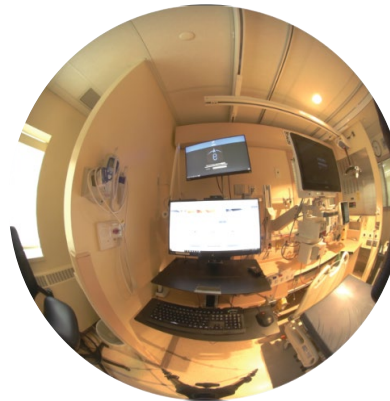
4 ASSESSMENT ZONES



1. Door-Room Transition



2. Patient Zone



3. Documentation Zone

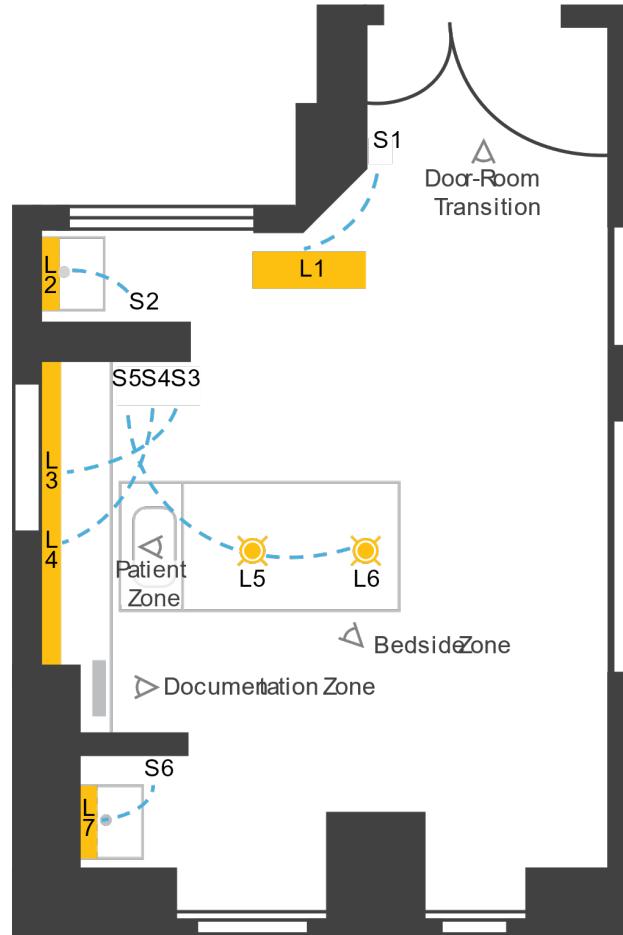


4. Bedside Zone

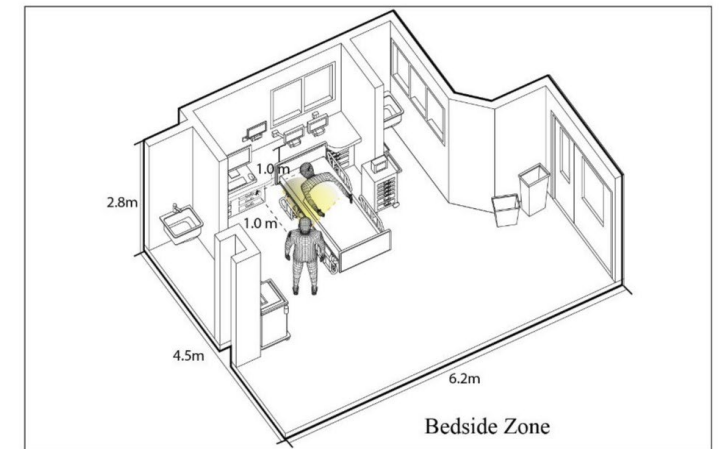
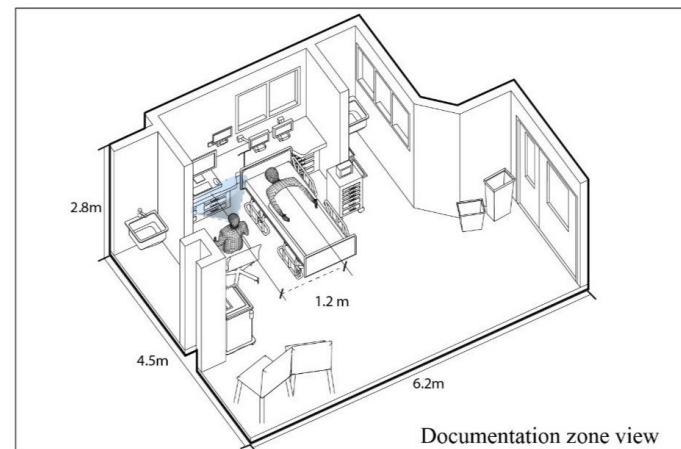
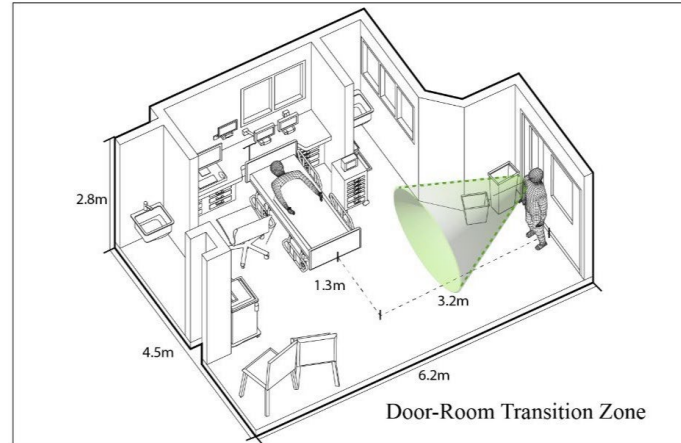
Lights, Switches, and Assessment Zones

2. Map Lighting + Zones

SICKKIDS ROOM 111 EXAMPLE



4 ASSESSMENT ZONES



Spectral Measurement - Equipment

1. Sekonic Spectrometer C-7000



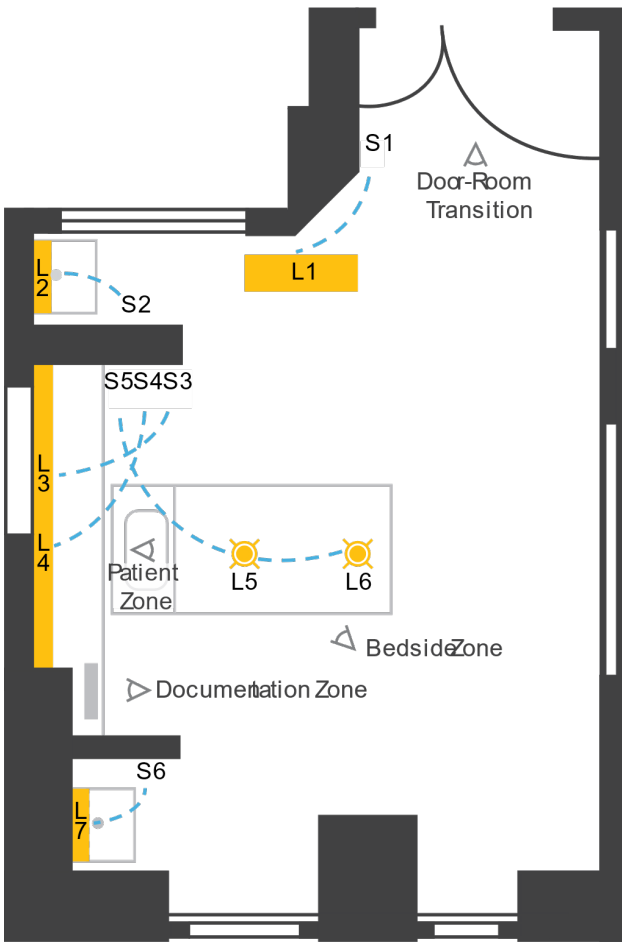
2. Konica Minolta Spectrophotometer CL-500A



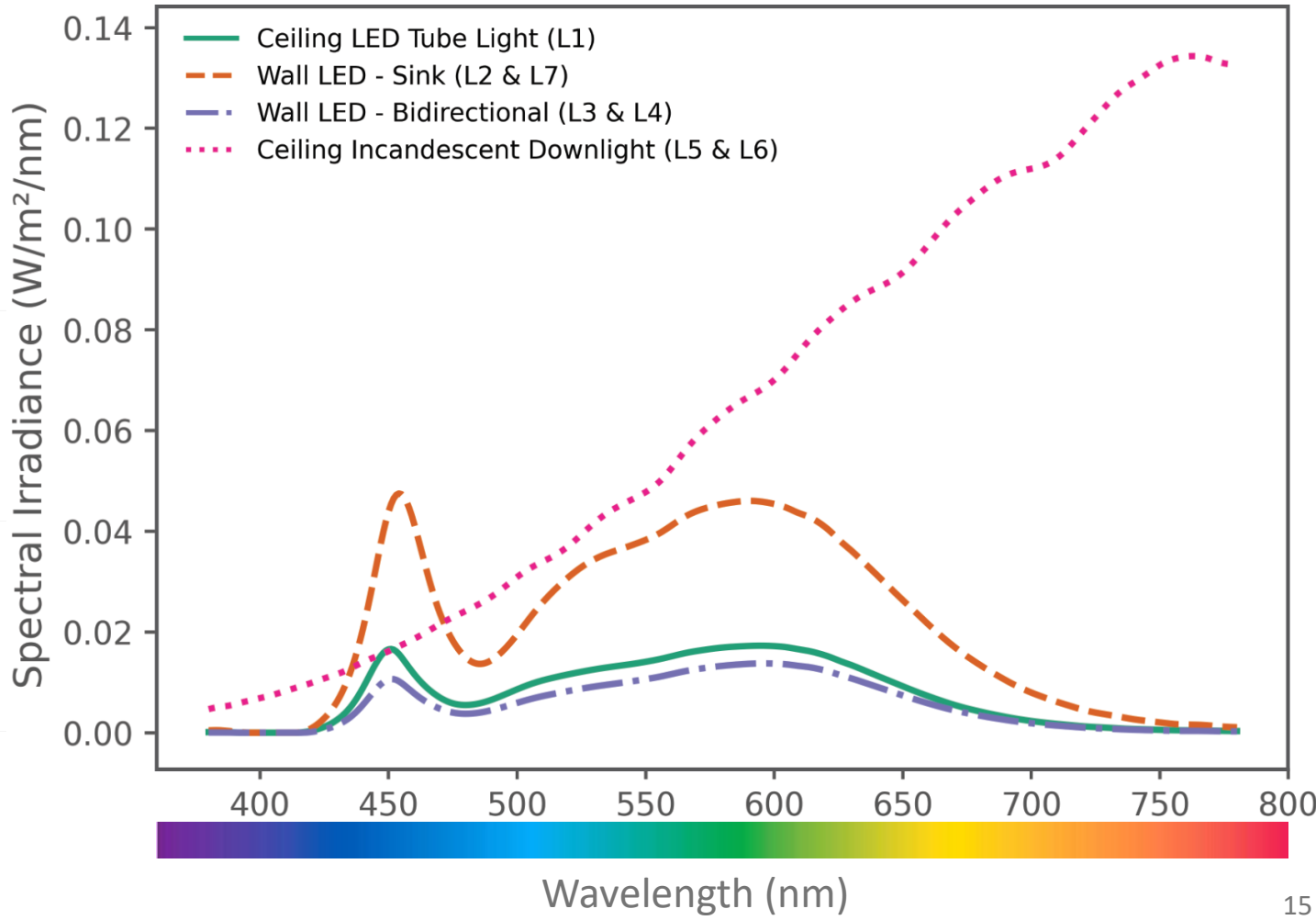
Spectral Measurement of Electric Lights

2. Map Lighting + Zones

SK - RM 111



SPECTRAL POWER DISTRIBUTION



Material Reflectance Measurement - Equipment

1. Spectro 1 by Variable

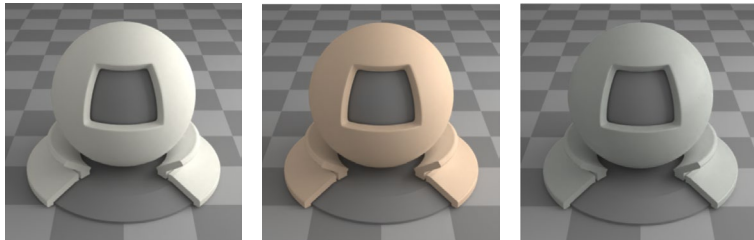


2. Konica Minolta Spectrophotometer CM-2500d



Material Reflectance and Model Calibration

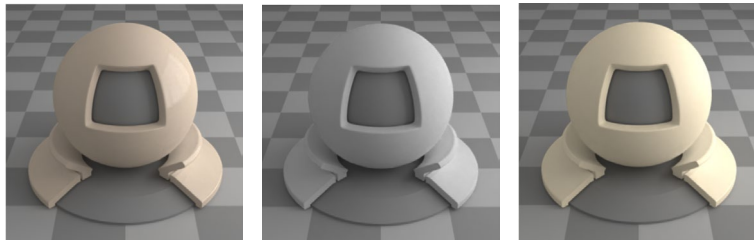
SK MATERIALS



Ceiling

Doors

Equipment

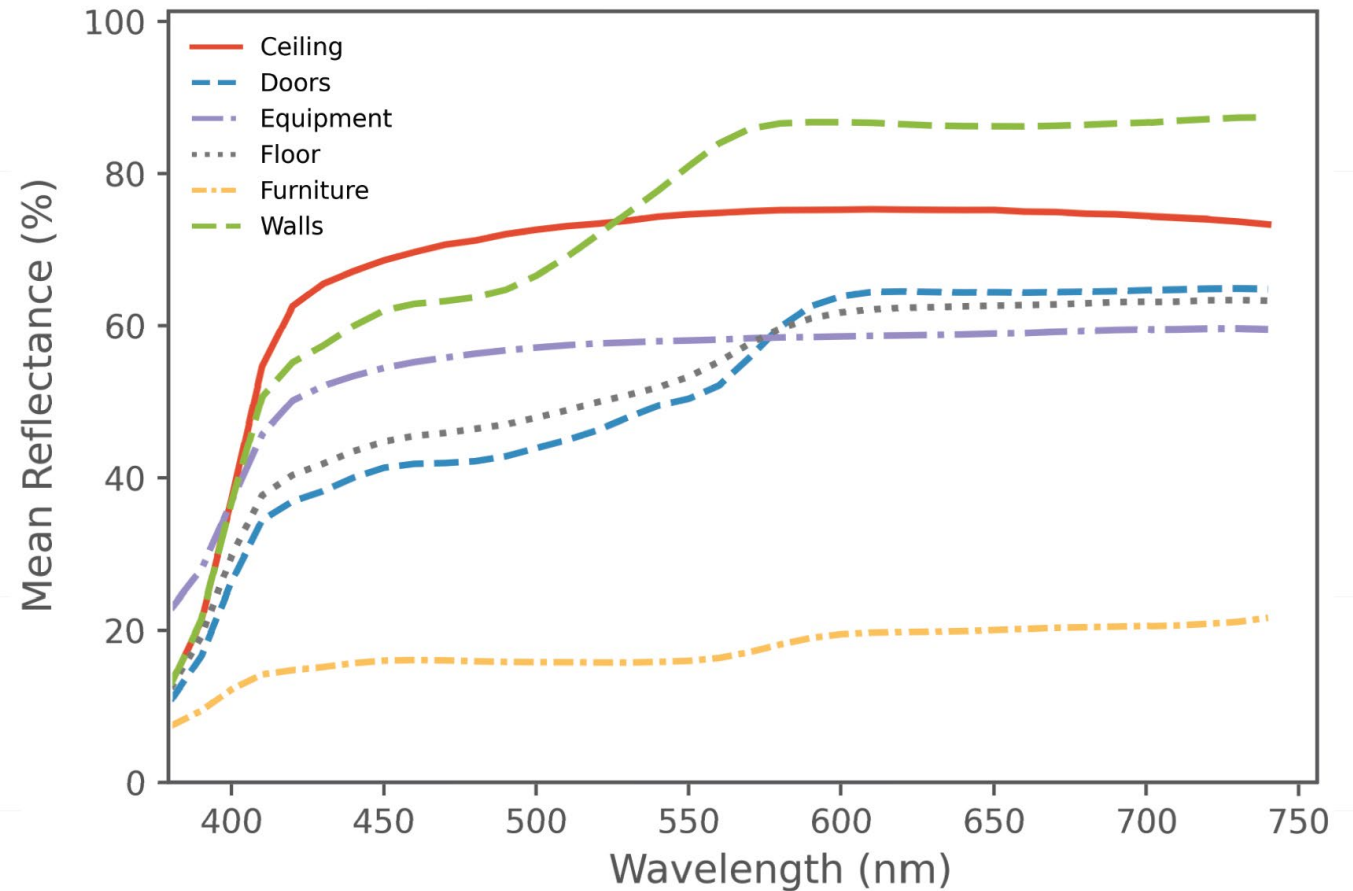


Floor

Furniture

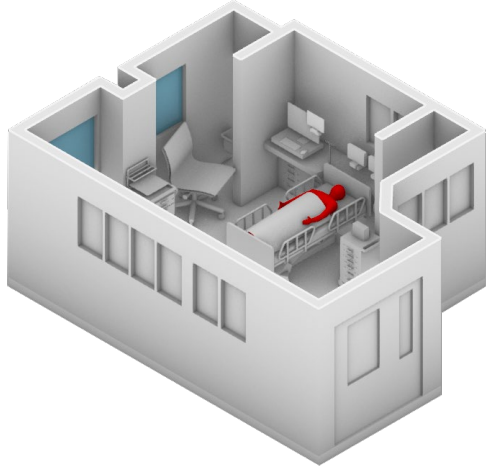
Walls

MATERIAL REFLECTANCE

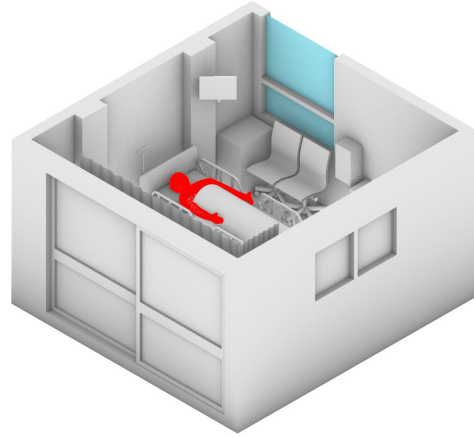


3D Models of ICU Rooms

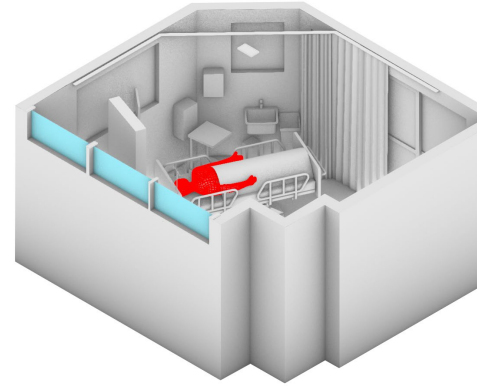
3. Build Room Models



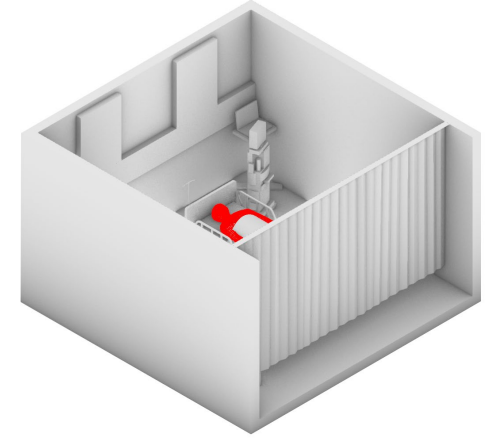
SickKids



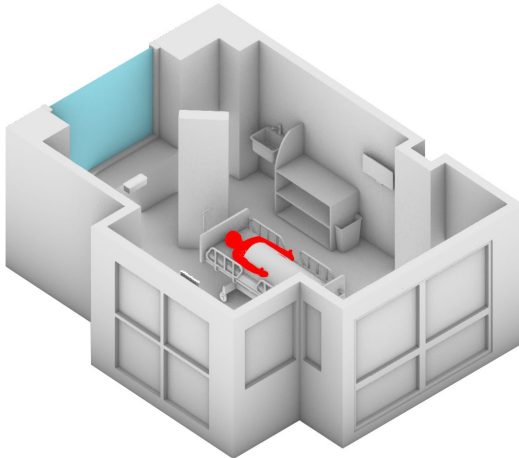
Lakeridge - Ajax



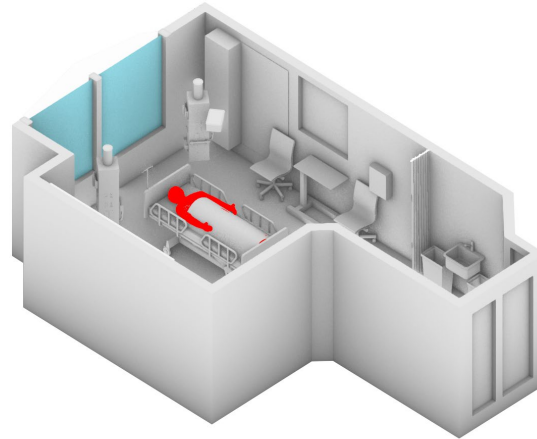
Lakeridge Oshawa



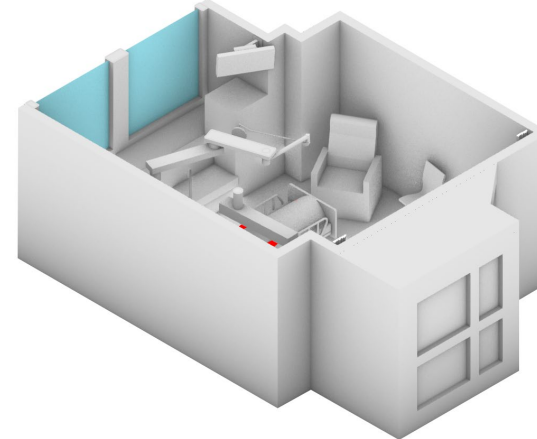
Sunnybrook



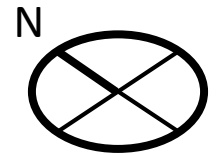
Toronto General



St. Michael's



Mount Sinai



High Dynamic Range Photography - Equipment

1. Canon Camera



2. Fisheye Lens



Total HDR Captured at SickKids

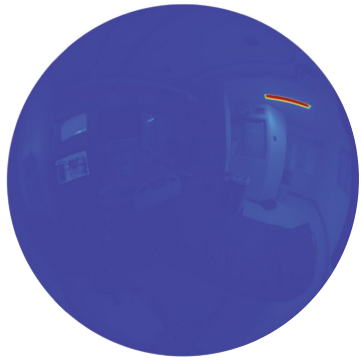
4. Measure Controlled Scenes

$$\begin{array}{ccccccccc} \mathbf{19} & = & \mathbf{42} & \times & \mathbf{4} & \times & \mathbf{6} & \approx & \mathbf{1,008} \\ \text{Total ICU rooms} & & \text{Total bedspaces} & & \text{View zones per bedspace} & & \text{Average lighting conditions per room} & & \text{Total HDR states} \end{array}$$

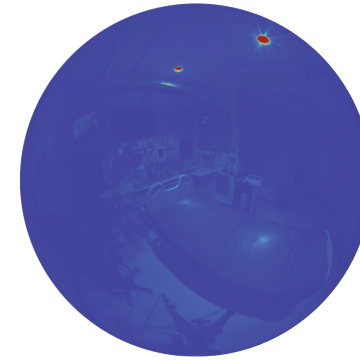
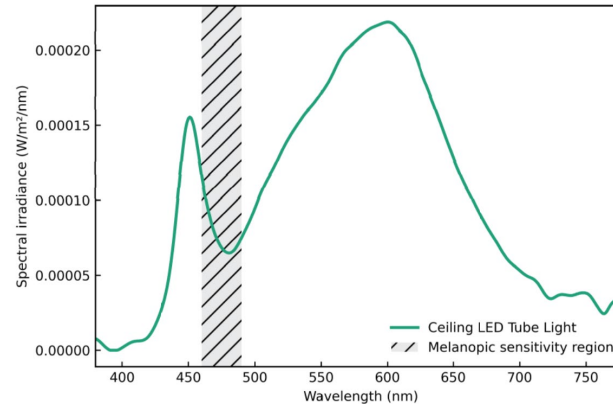
HDR Captures of Different Lighting Layers

4. Measure Controlled Scenes

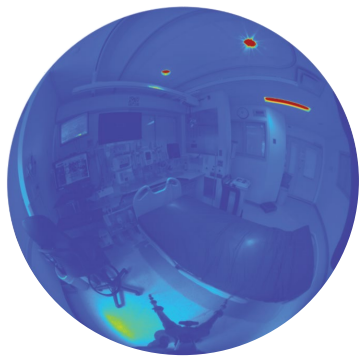
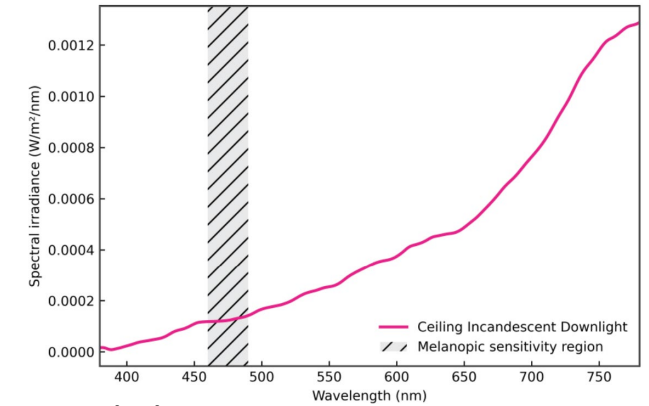
SICKKIDS ROOM 111BEDSIDE ZONE EXAMPLE



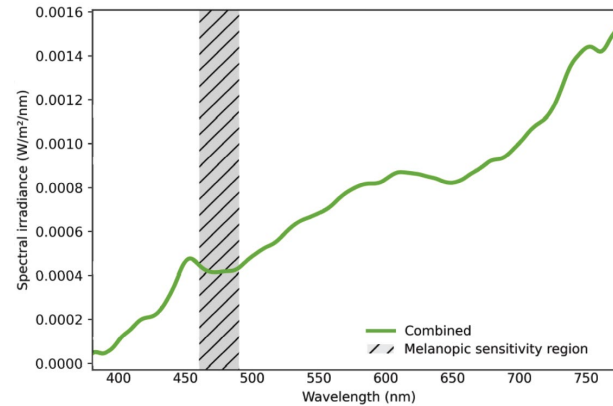
Ceiling - LED Tube Light



Ceiling Incandescent Downlight

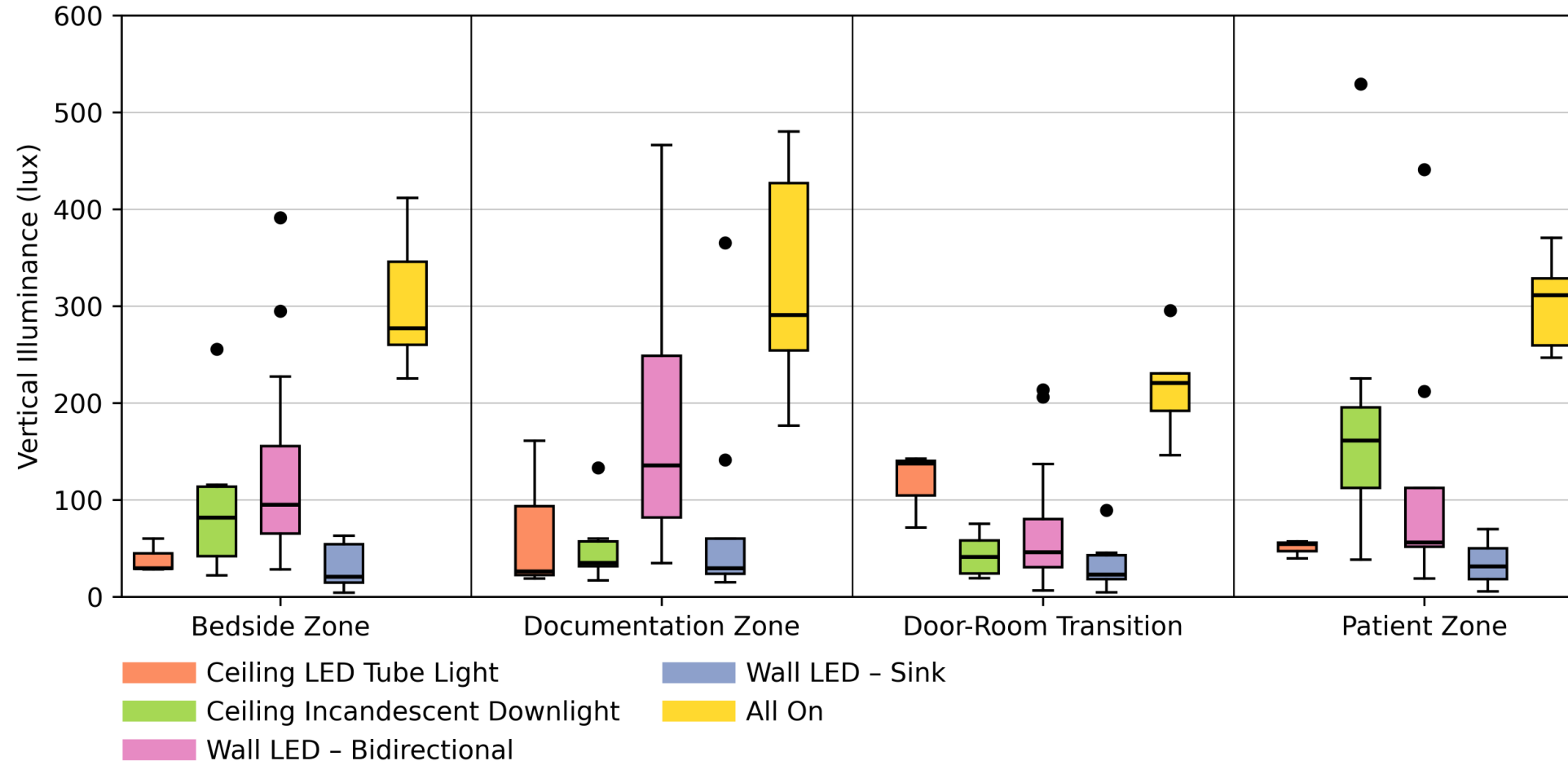


Ceiling LED + Incandescent + Daylight

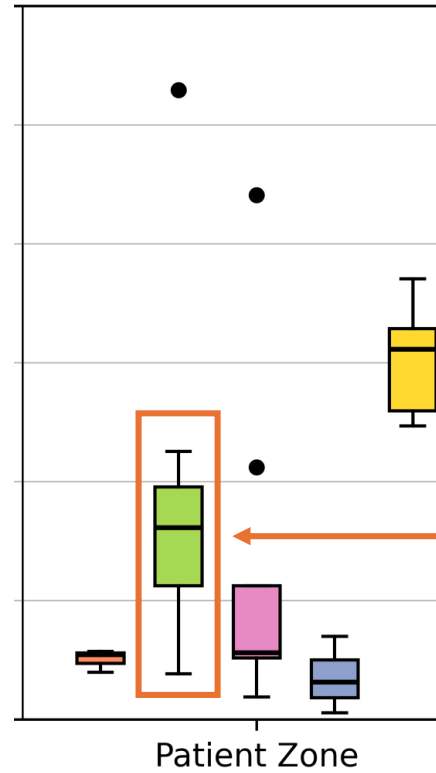
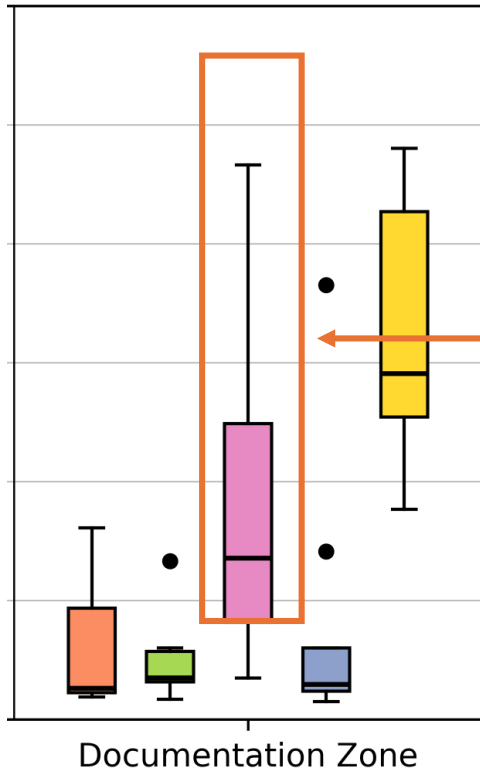


Vertical Illuminance

SICKKIDS ICU EXAMPLE – Vertical illuminance by zone and light category



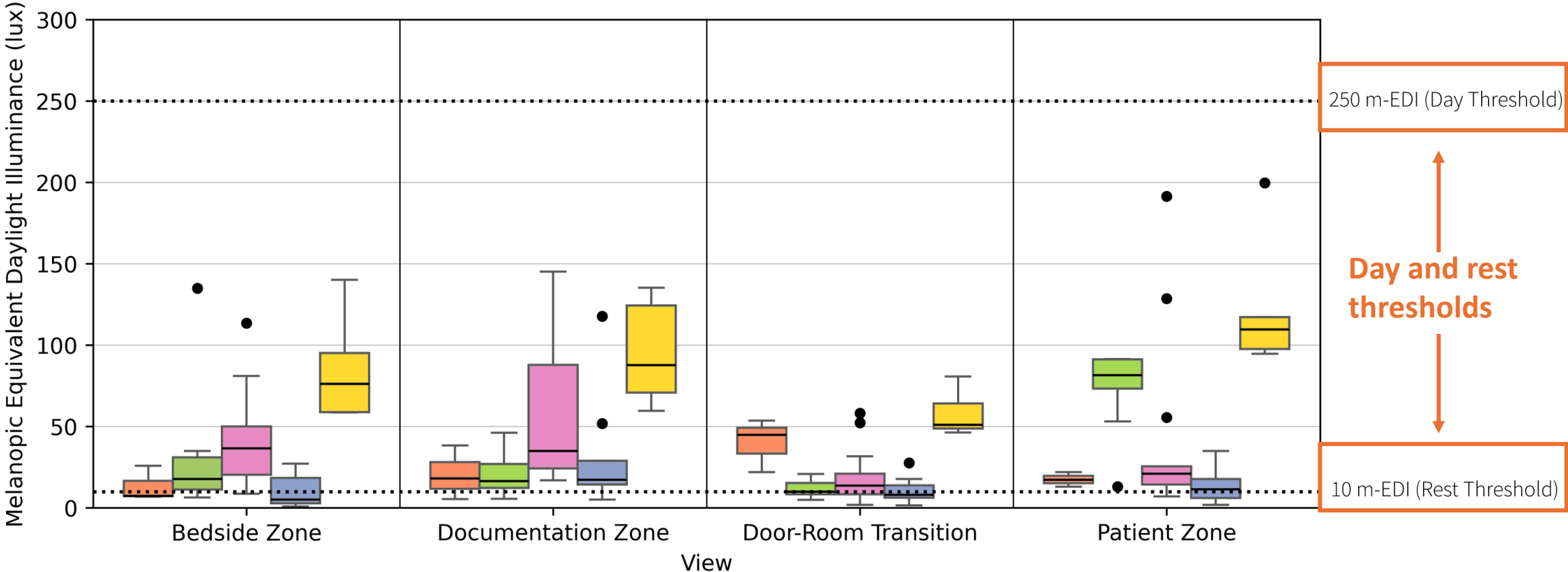
Vertical Illuminance



- Ceiling LED Tube Light
- Ceiling Incandescent Downlight
- Wall LED - Bidirectional
- Wall LED - Sink
- All On

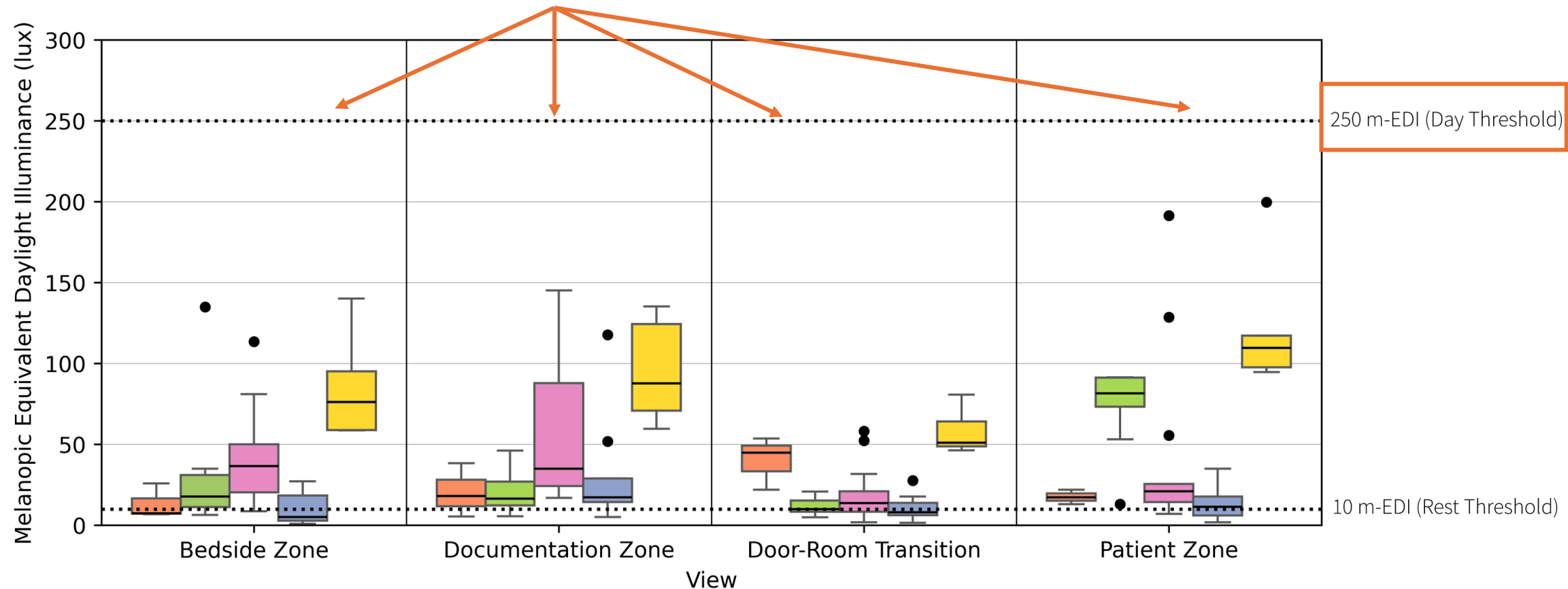
Visibility and Melanopic Exposure

SICKKIDS ICU EXAMPLE – Melanopic Equivalent Daylight Illuminance by zone and light category



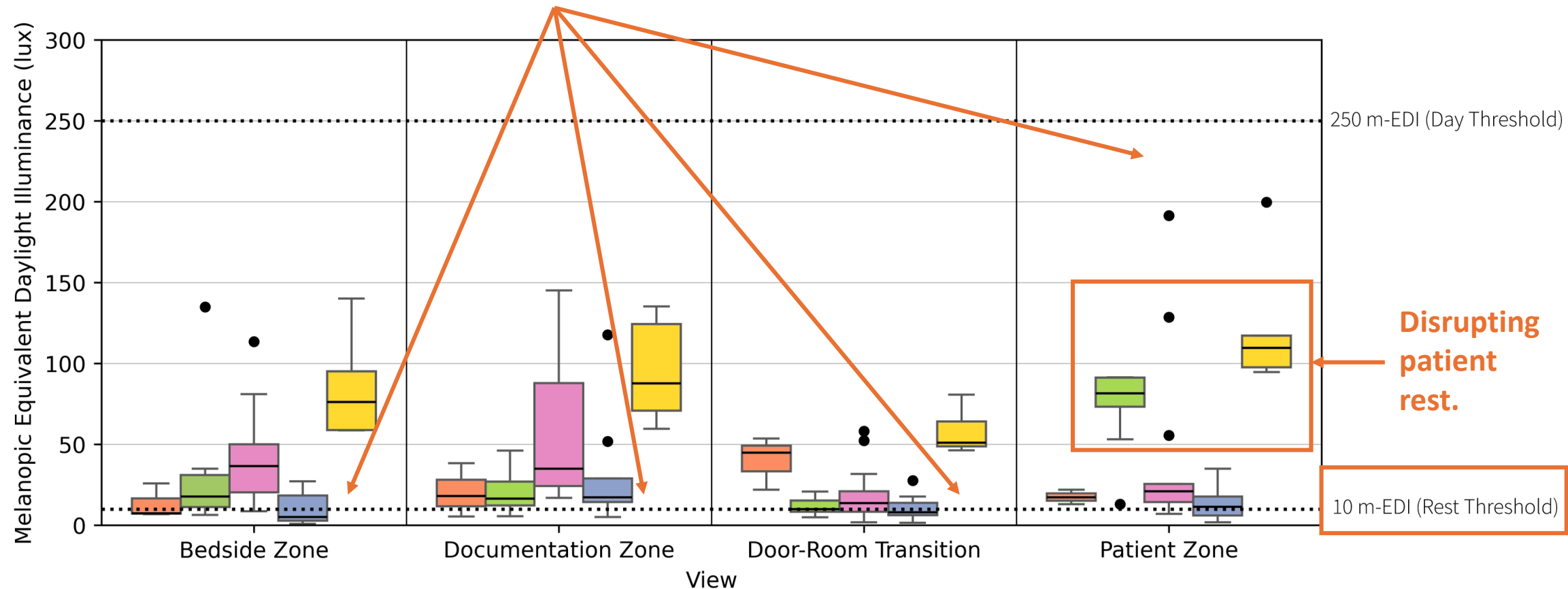
Visibility and Melanopic Exposure

All lighting conditions remain below the daytime m-EDI target.



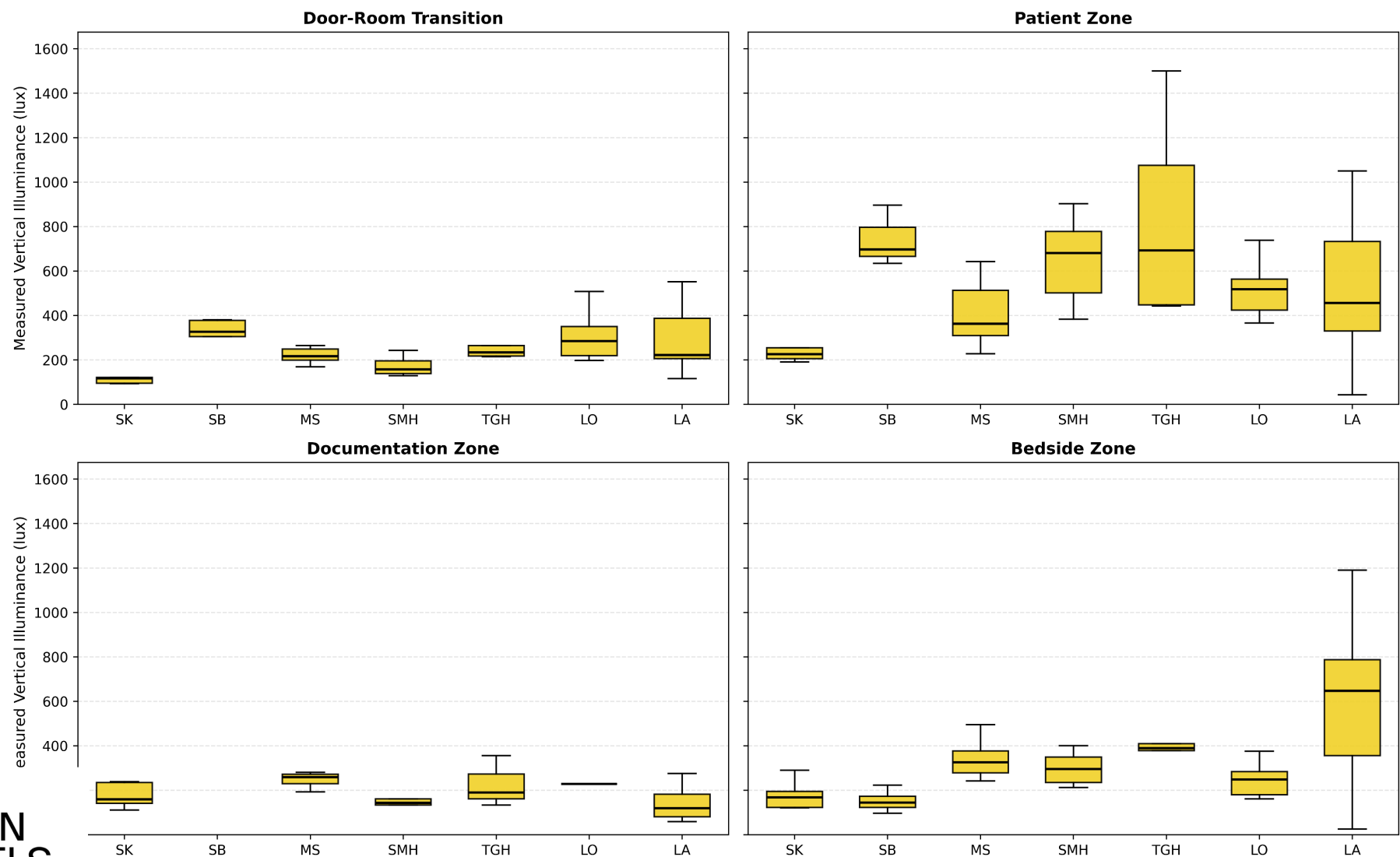
Visibility and Melanopic Exposure

Most lighting conditions exceed the nighttime m-EDI target.

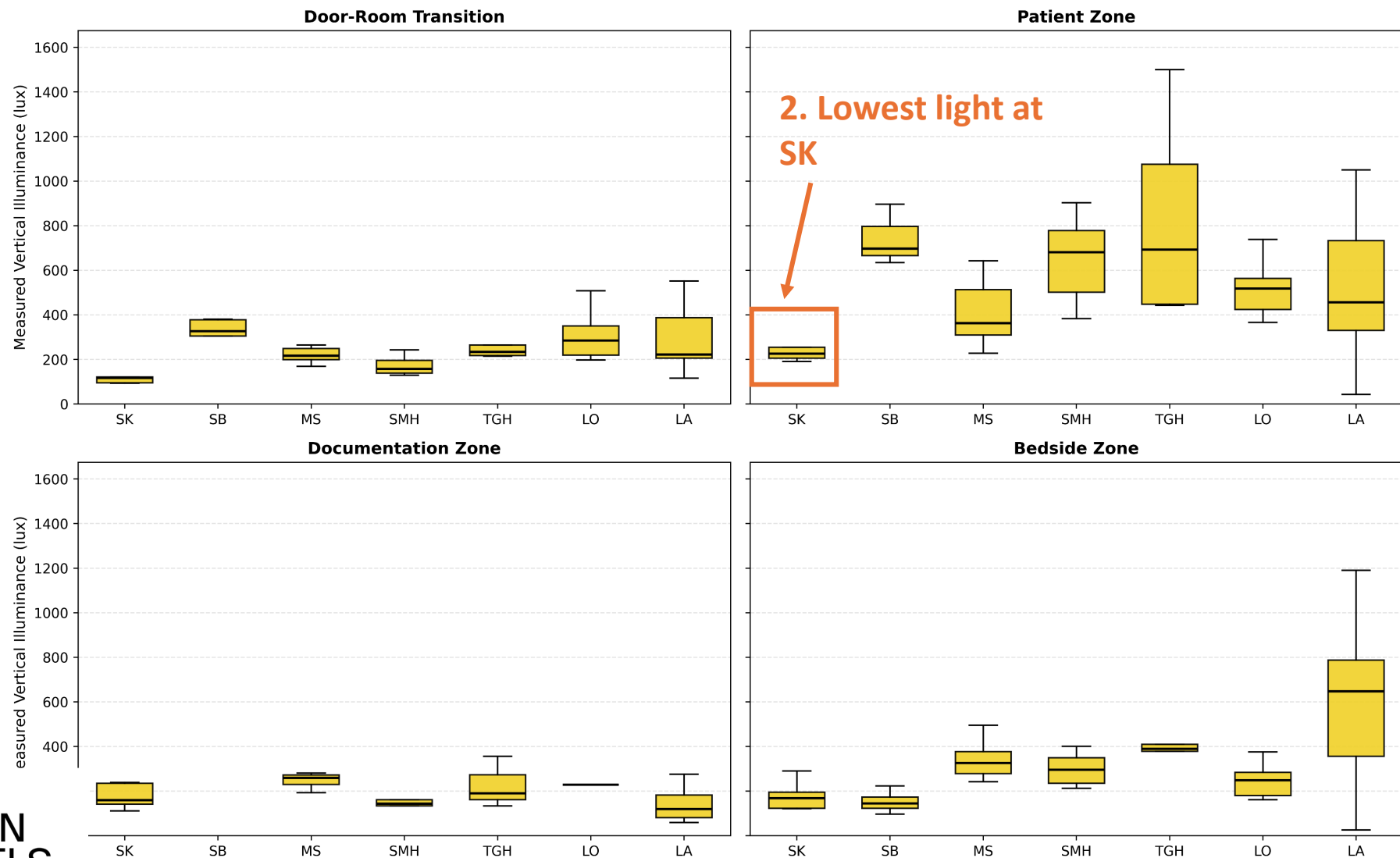


Vertical Illuminance Comparison Across Sites

All lights on



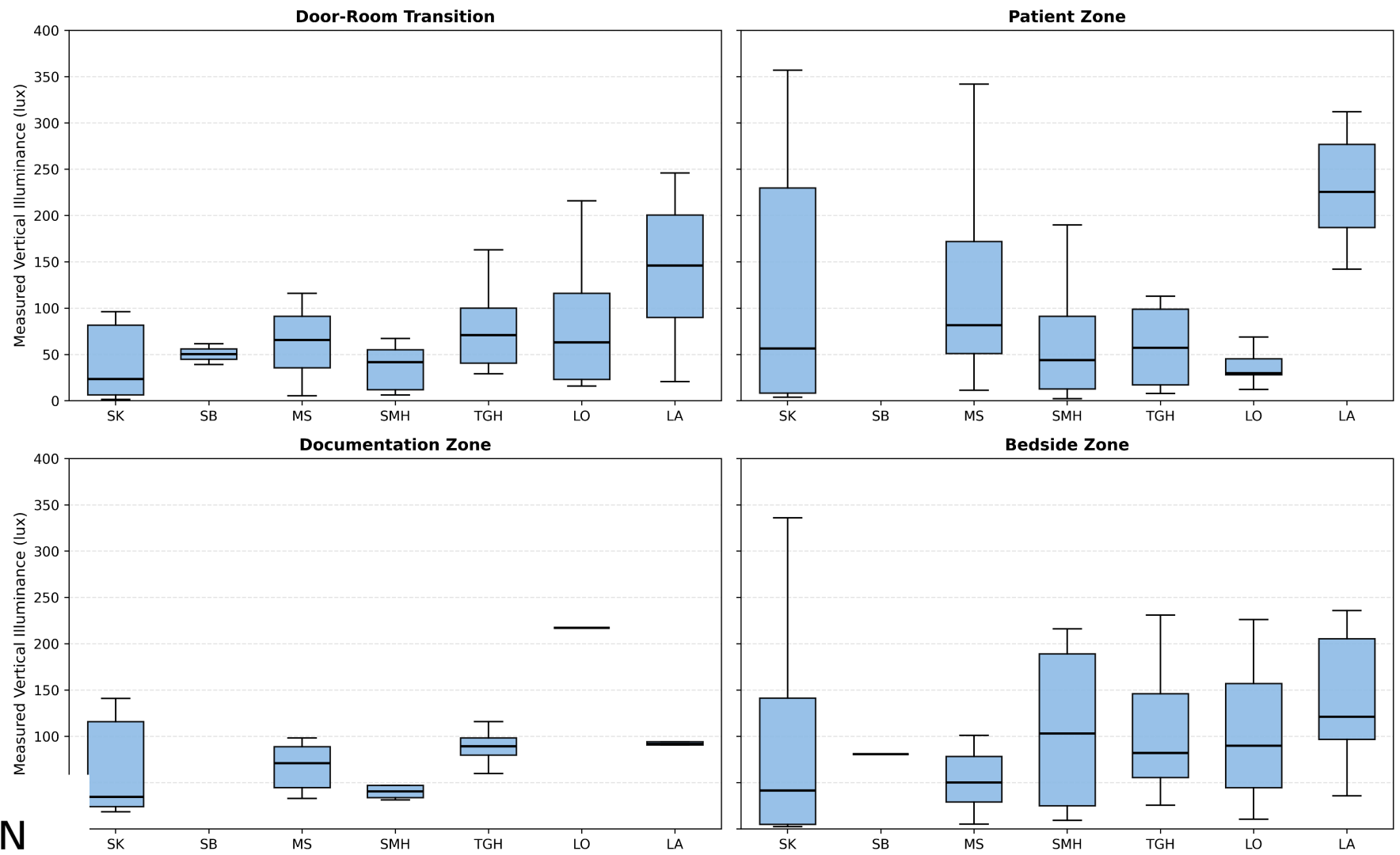
Vertical Illuminance Comparison Across Sites



1. EV varies substantially across sites and zones.

Vertical Illuminance Comparison Across Sites

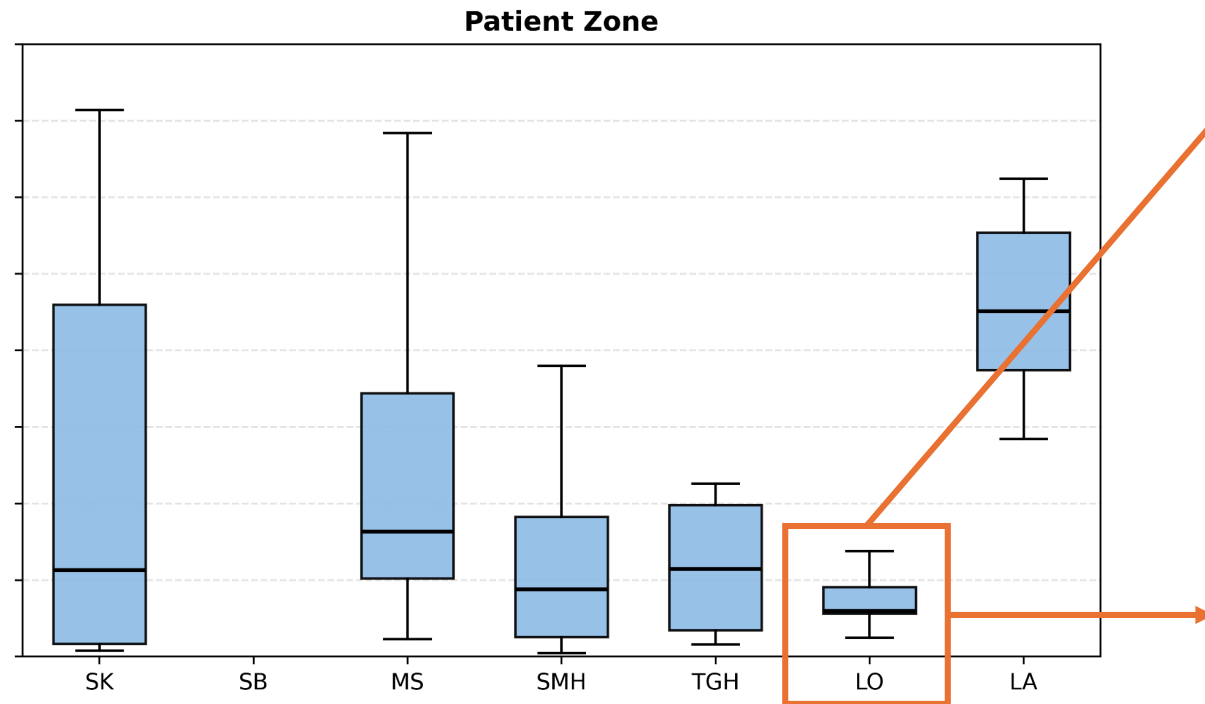
Daylight



Daylight EV varied substantially across sites and zones.

Vertical Illuminance Comparison Across Sites

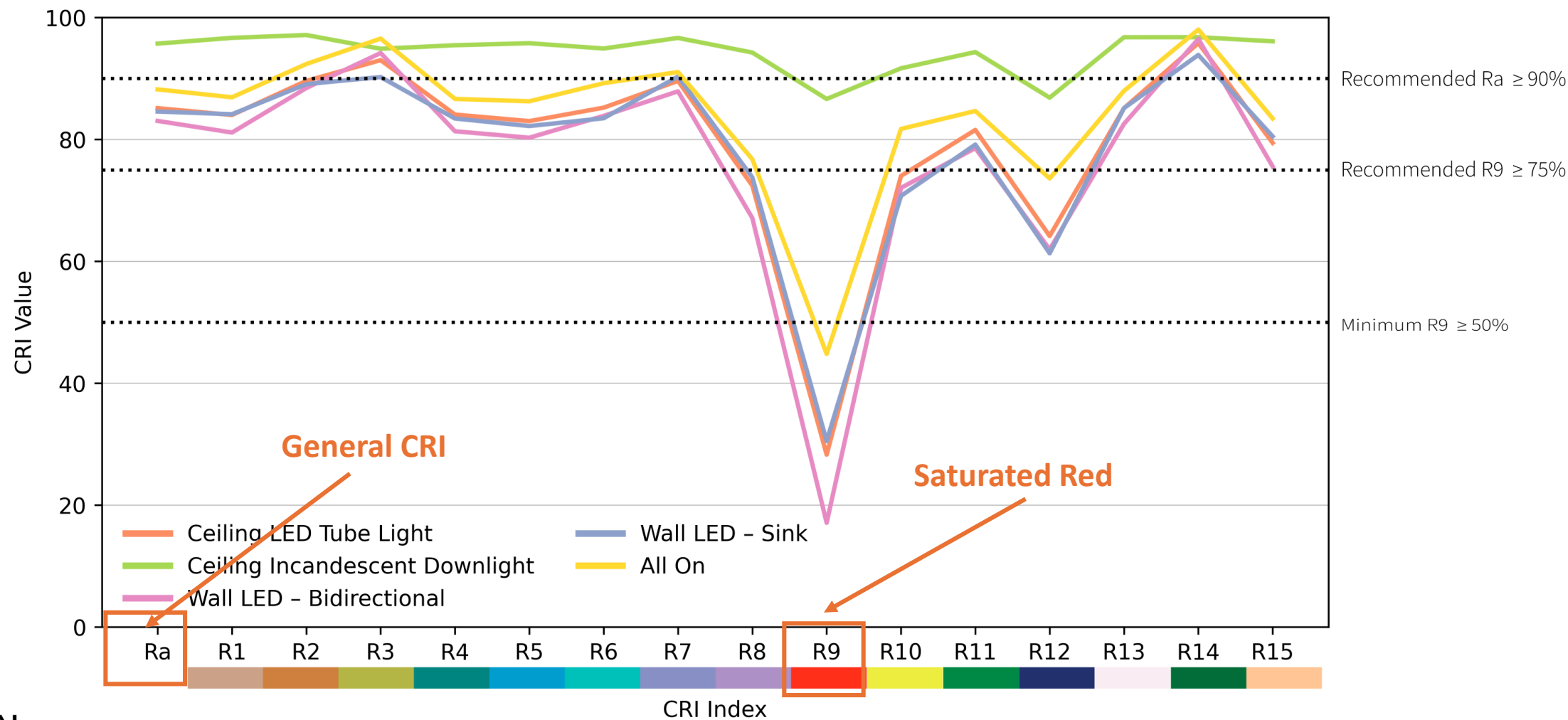
Daylight



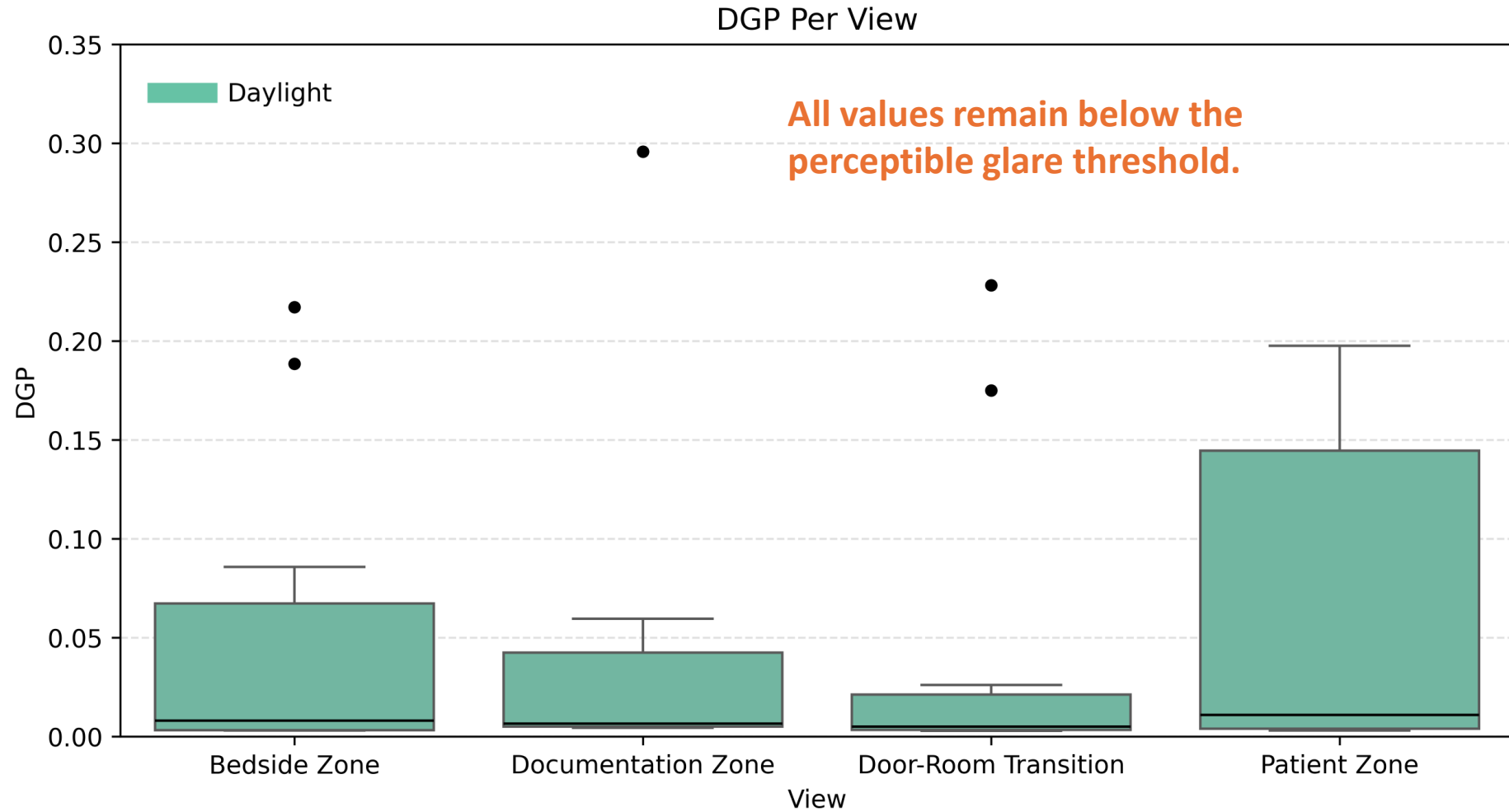
Patient faces away from the windows, and the windows are small and high



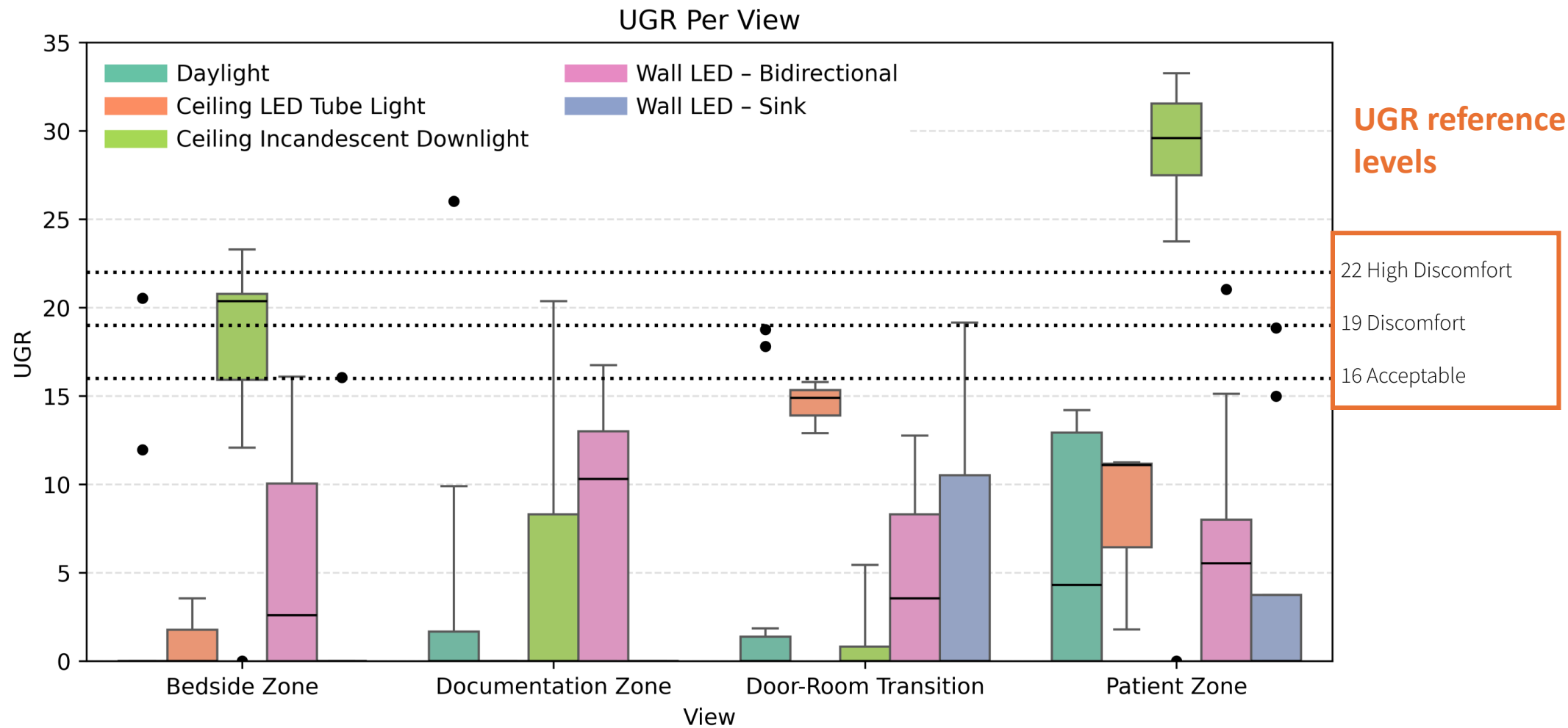
Color Rendering Index at SickKids



Visual Comfort at SickKids



Visual Comfort at SickKids



Monitor Visibility at SickKids

48.5 ratio

shades
down



41.7 ratio

shades
up



27.8 ratio

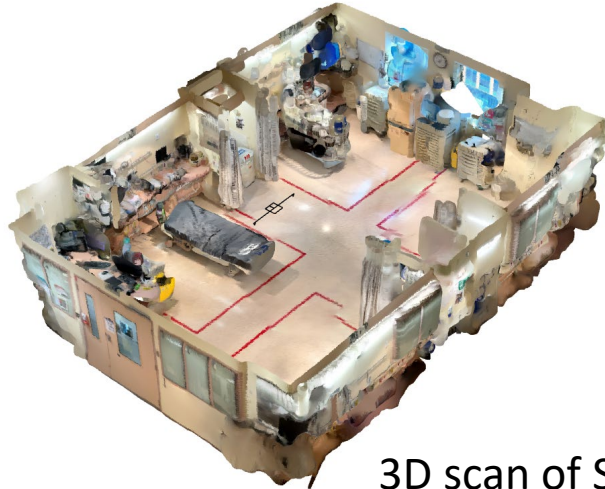
all lights
on



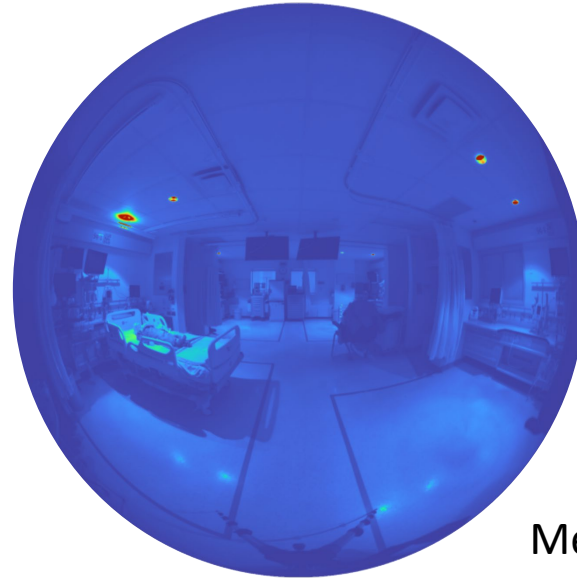
Ideal ratio
> 4.5



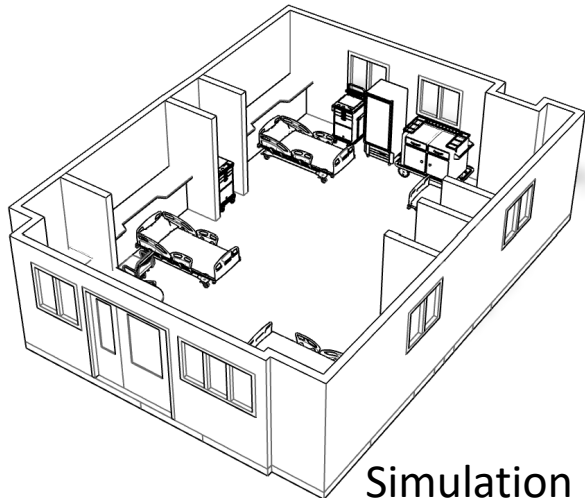
Lighting Models



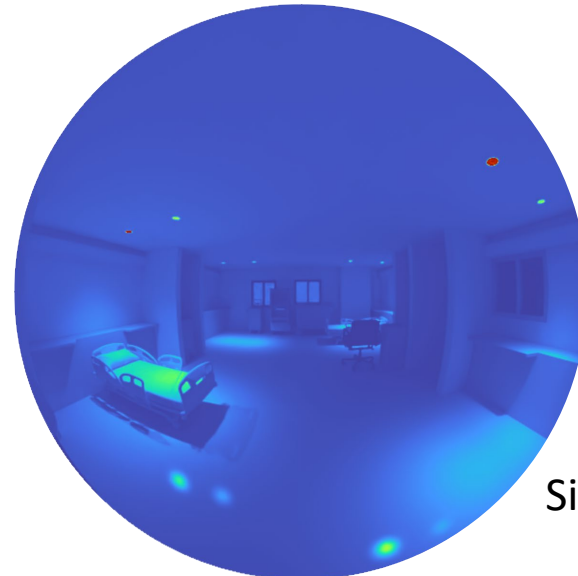
3D scan of SK94



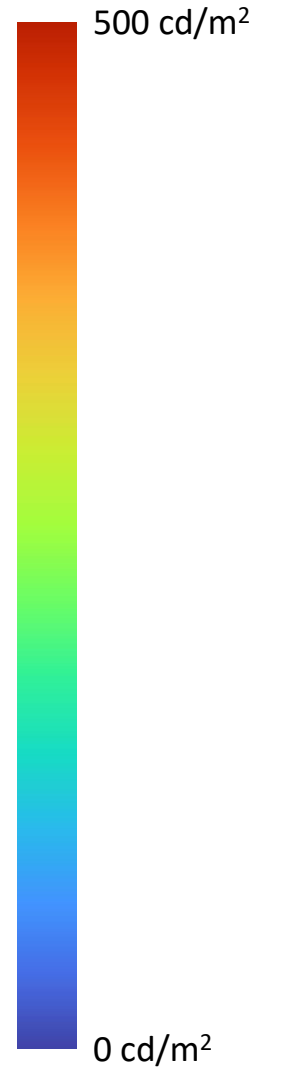
Measurement



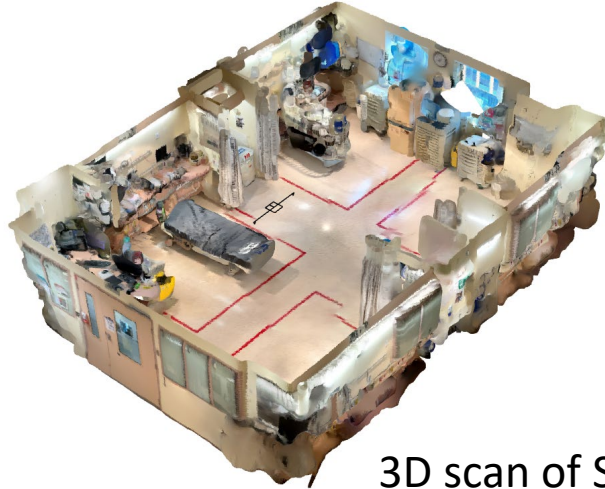
Simulation model of SK94



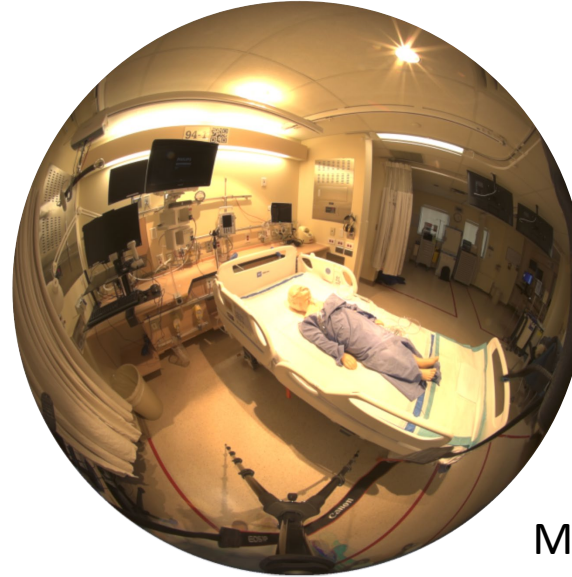
Simulation



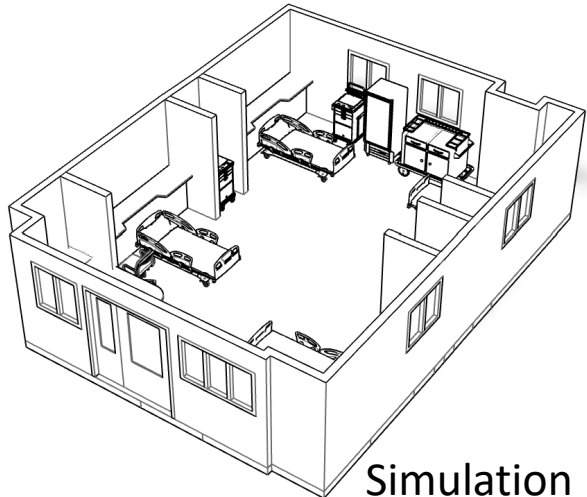
Lighting Models



3D scan of SK94



Measurement



Simulation model of SK94



Simulation

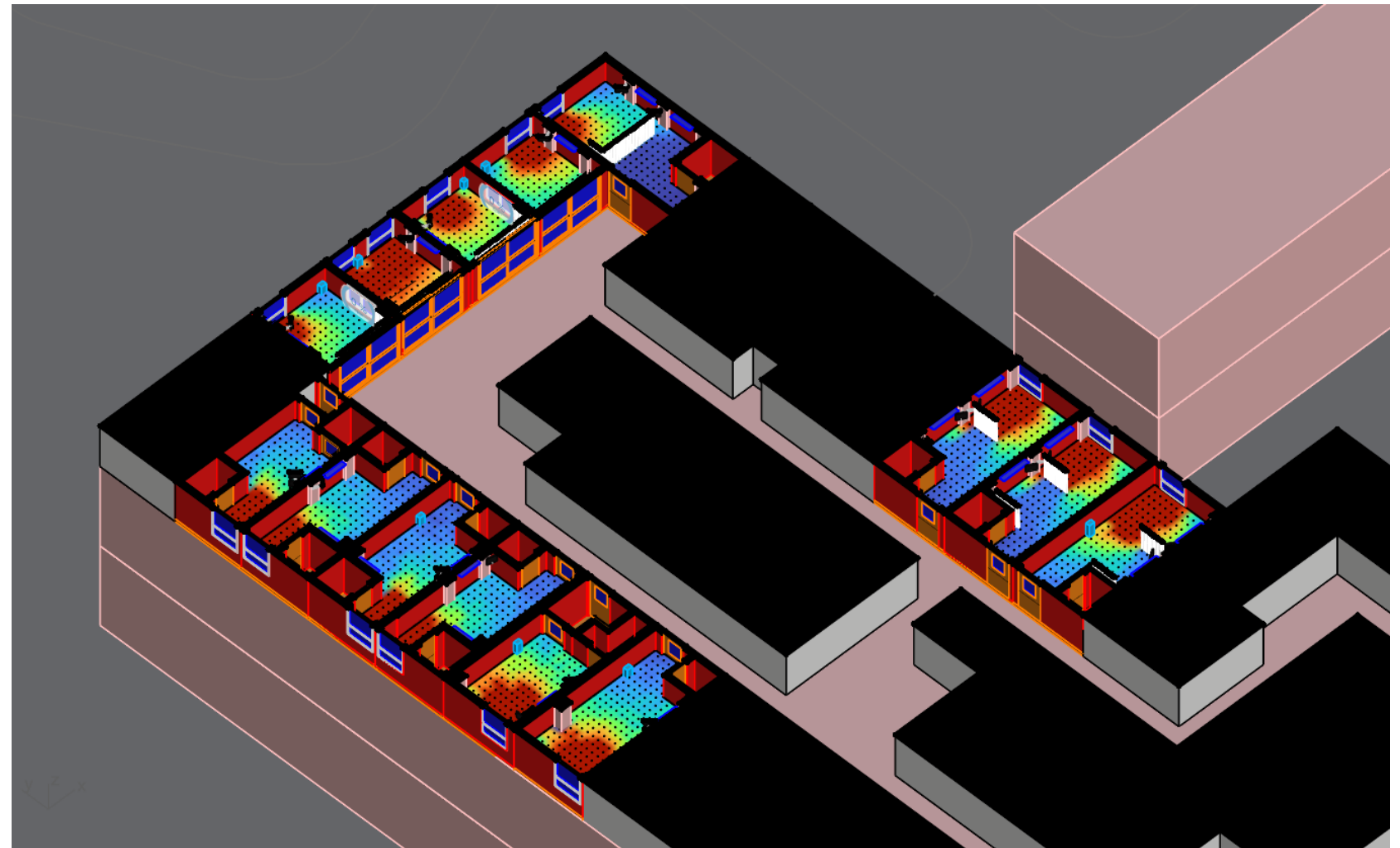
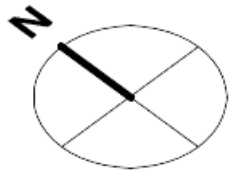
[In progress] Simulation results - Sunnybrook

Daylit area sDA300lx/50

22.9%

Mean illuminance

382 lx



0  500

mean annual illuminance (lx)

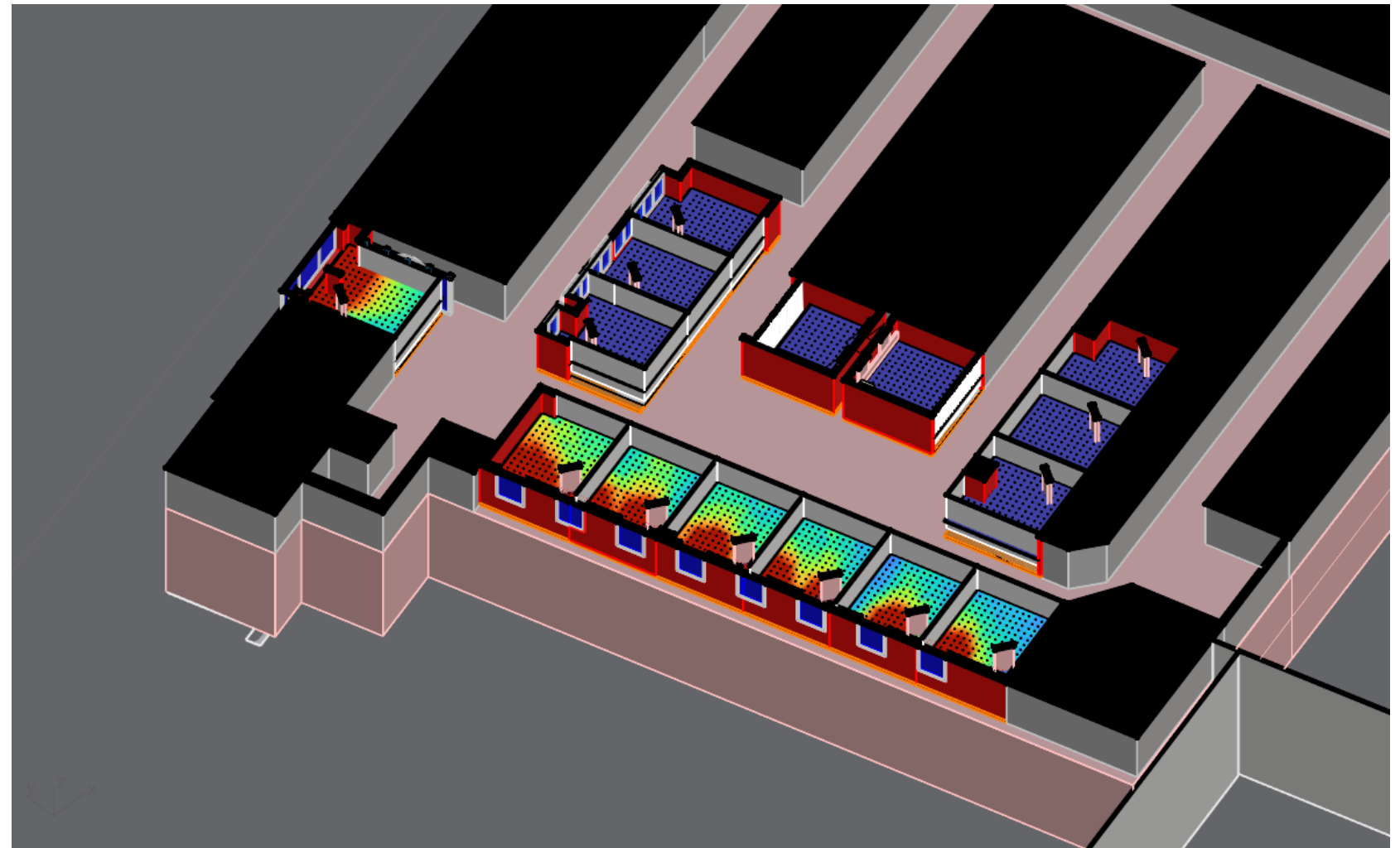
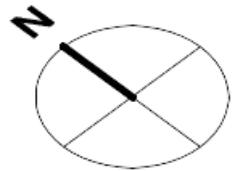


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[In progress] Simulation results - Lakeridge

Daylit area sDA300lx/50
12.6%

Mean illuminance
294 lx



0  500
mean annual illuminance (lx)

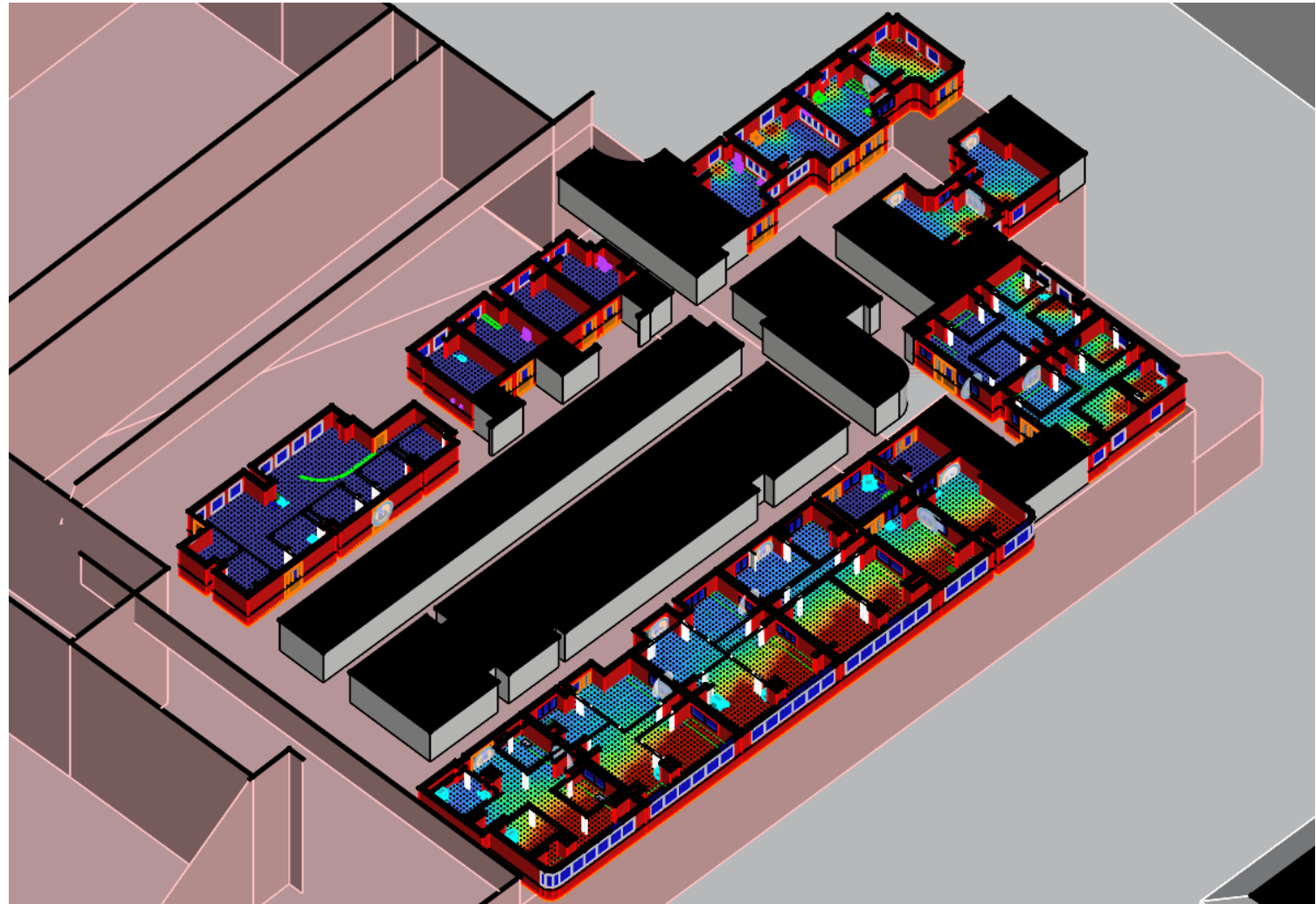
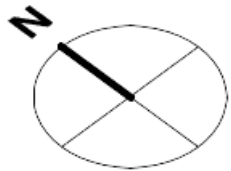
[In progress] Simulation results - SickKids

Daylit area sDA300lx/50

19.1%

Mean illuminance

493 lx





Royal Ontario
Museum

02 ROM

Integrating Advanced Lighting Design in Preventive Conservation Strategies for Museums

Contributors:

Cora Xintian Liu, Cara Krmpotich

Quilts: Made in Canada Exhibition



Open Display Cases

Photo by Cora Xintian Liu



Plexiglass-enclosed Display Cases

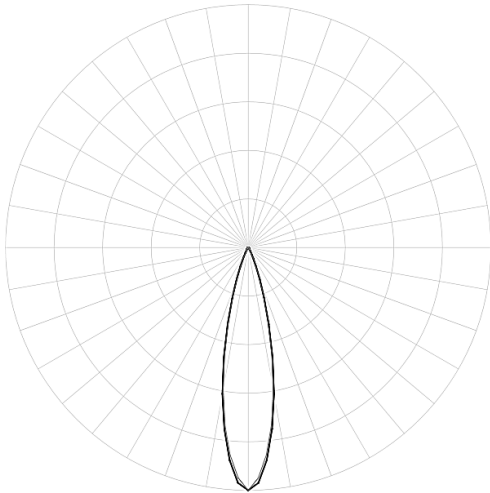
Photo by Cora Xintian Liu

HDR photography, UGR glare & reflections

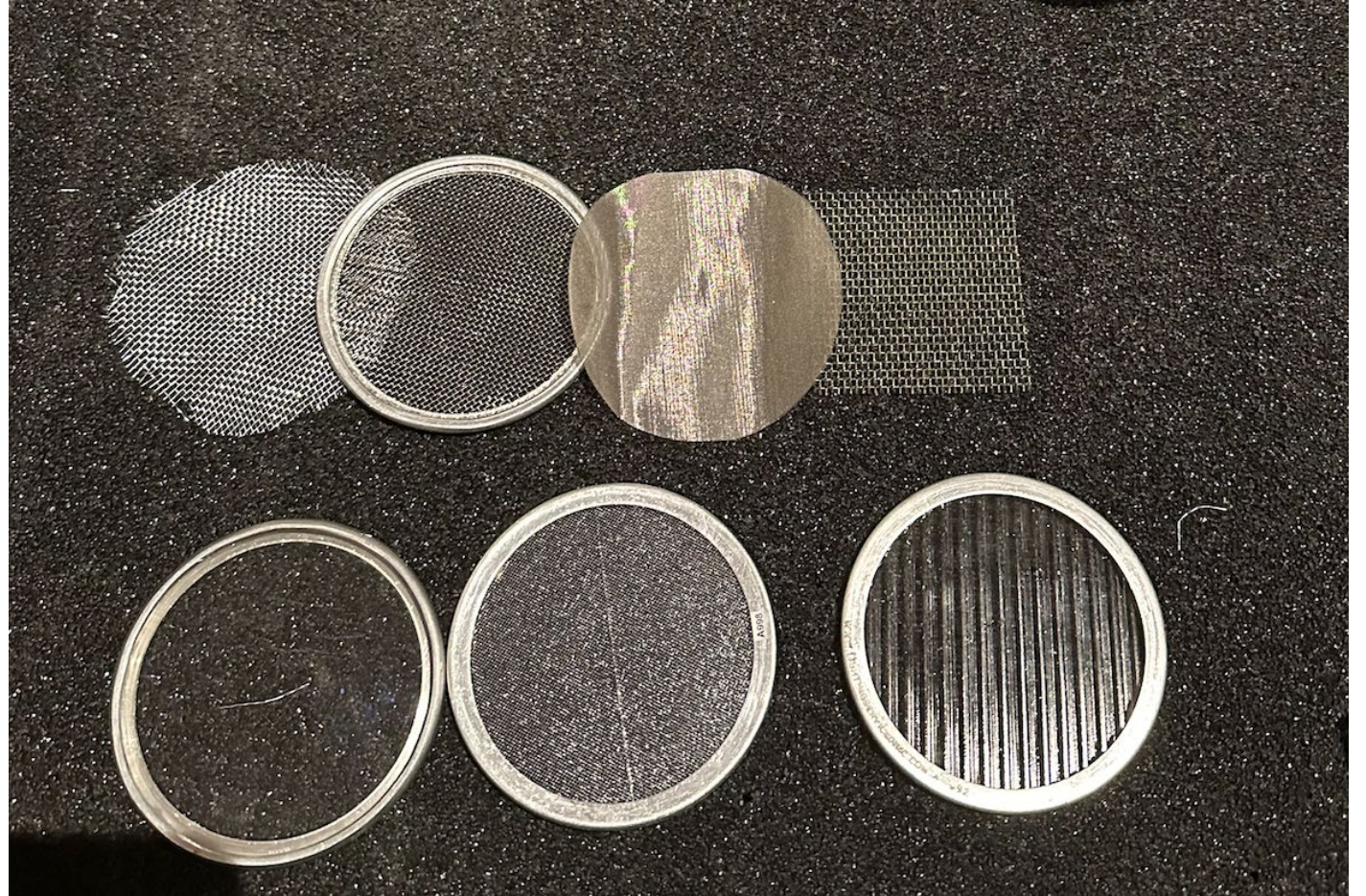
Location	Height	UGR
Light Table, Eight-Pointed Star Pieced quilt, 1838 - 40. Childs dress, 1816 - 29.	Adult Seated on Bench	20.67
Light Table, Eight-Pointed Star Pieced quilt, 1838 - 40. Childs dress, 1816 - 29.	Adult Stand - 5 feet 6 inches (Look Down)	0
"Crazy" pieced and appliqué quilt, 1884	Adult Seated/Child - 50 inches	15.44
"Crazy" pieced and appliqué quilt, 1884	Adult Stand - 5 feet 6 inches	4.64
Life of Joseph appliqué quilt, around 1860	Adult Seated on Bench	20.53
Pieced Quilt, around 1840 or later. Young girl's bodice, part of a dress, around 1838.	Adult Stand - 5 feet 6 inches	1.37
Star of Bethlehem pieced quilt, around 1840 - 1860, at Entrance facing Byzantium Gallery.	Adult Seated/Child - 50 inches	13.49
Star of Bethlehem pieced quilt, around 1840 - 1860, at Entrance facing Byzantium Gallery.	Adult Stand - 5 feet 6 inches	13.64
Haudenosaunee Passport, 2010	Adult Seated/Child - 50 inches	3.6
Haudenosaunee Passport, 2010	Adult Stand - 5 feet 6 inches	5.37
Push and Pull , 2020 at Entrance (Projector test #1)	Adult Seated/Child - 50 inches	0
Push and Pull , 2020 at Entrance (Projector test #2)	Adult Seated/Child - 50 inches	0
Push and Pull , 2020 at Entrance (Projector test #3)	Adult Stand - 5 feet 6 inches	0



Luminaires, a modelling challenge



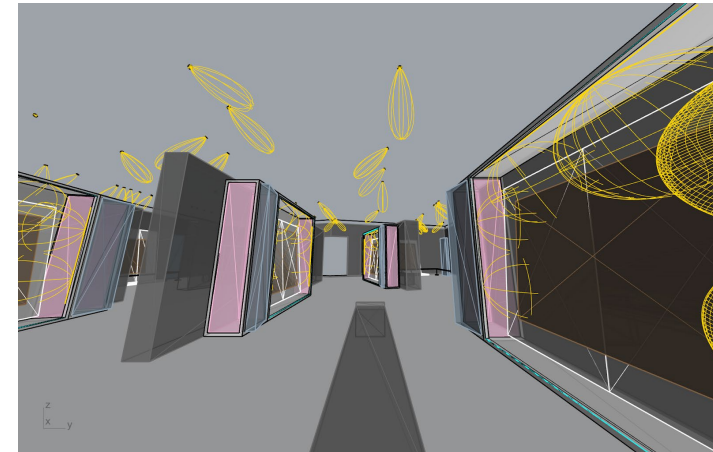
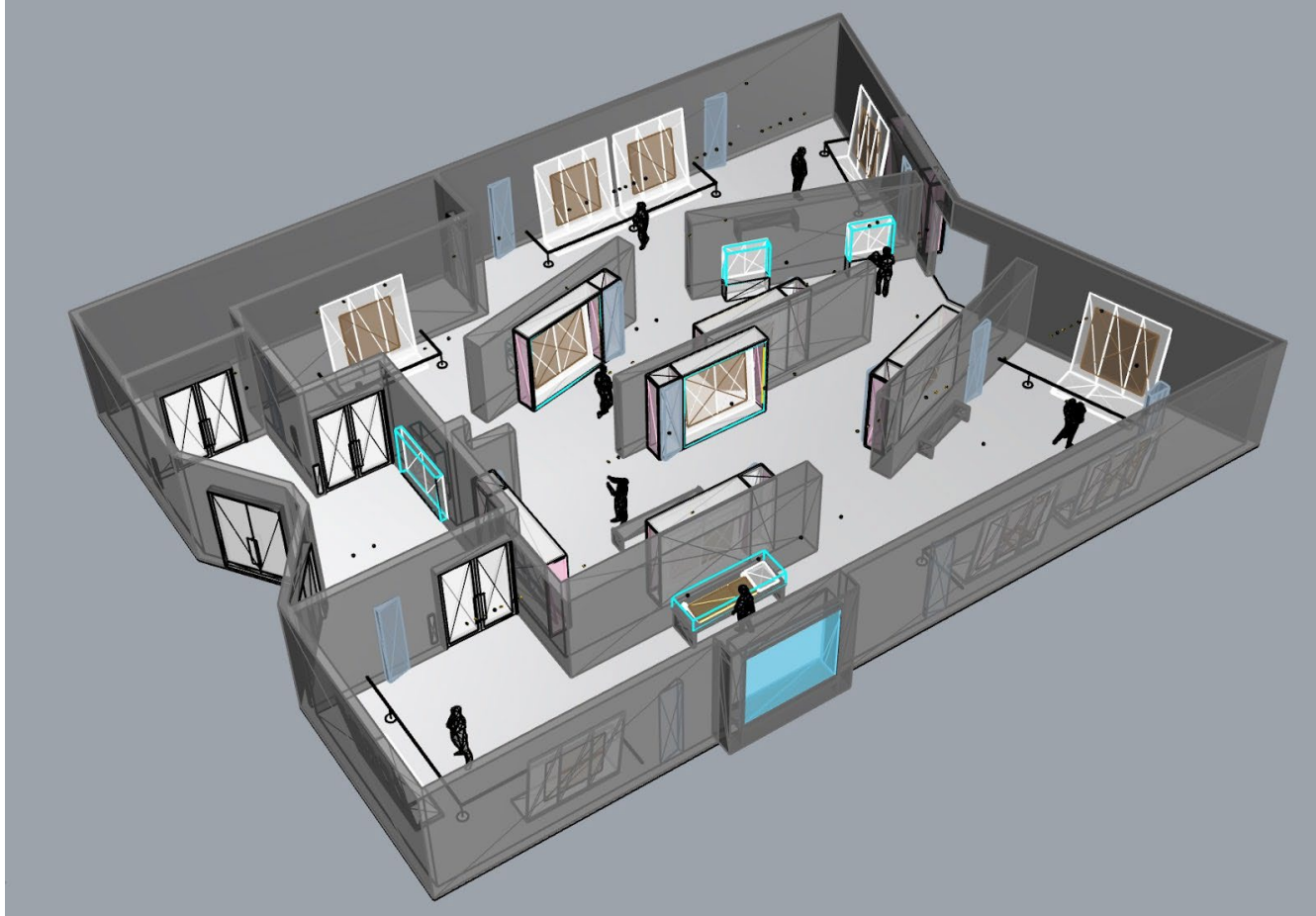
**SORAA BRILLIANT HL
MR16 – GU10 Lamp**



Lighting Filters Used by the ROM (Uncharacterized)

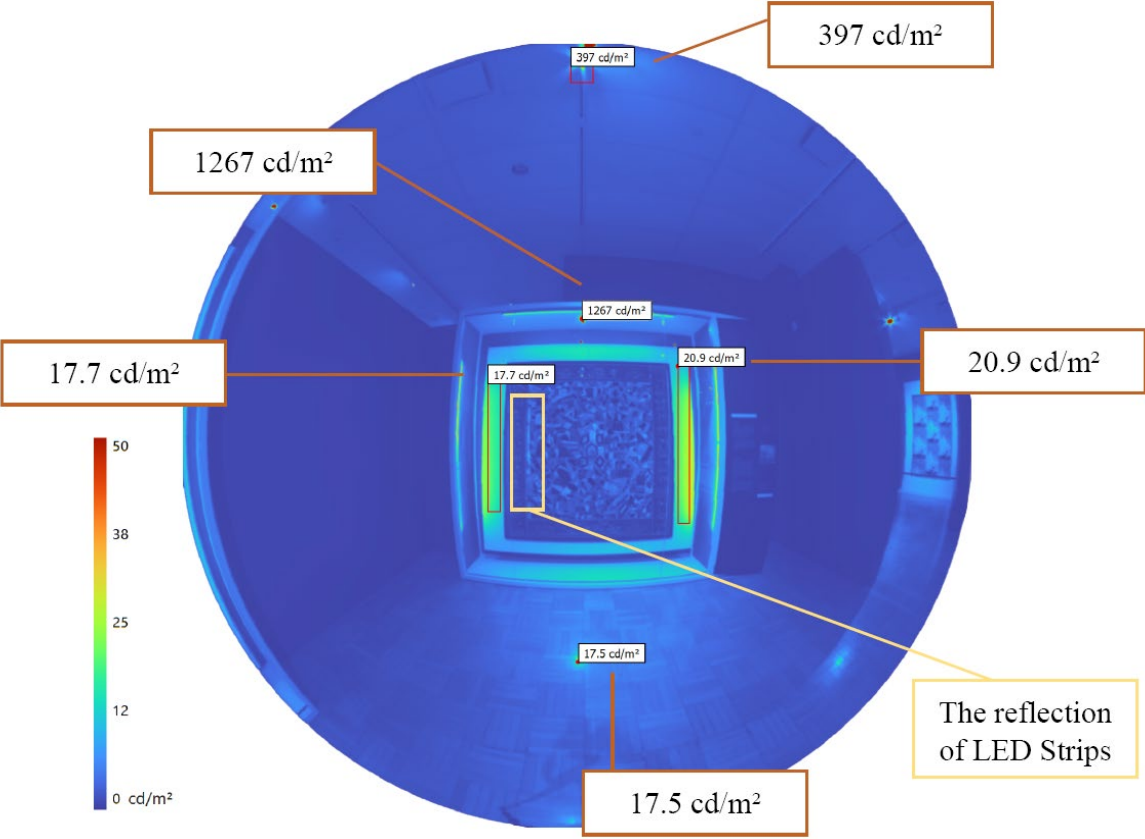
Photo by Cora Xintian Liu

As-built 3D model

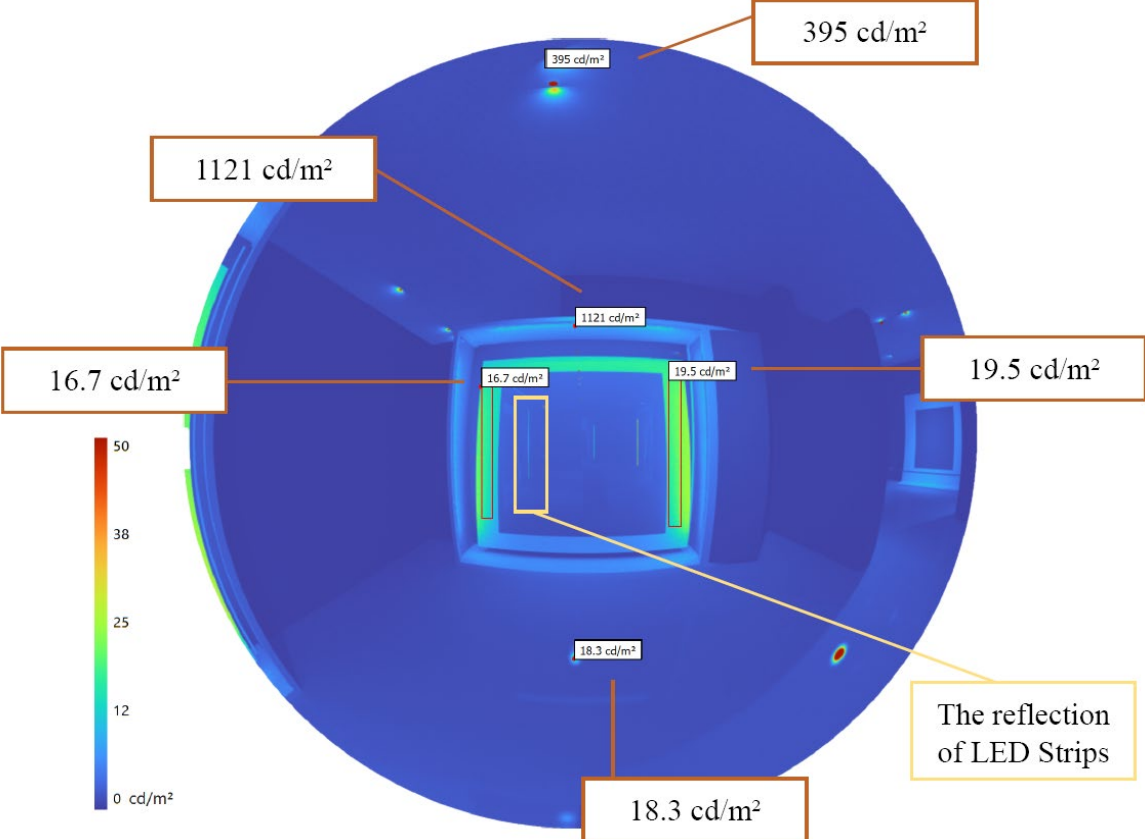


Model and Luminaire Placements
by Cora Xintian Liu

Calibration



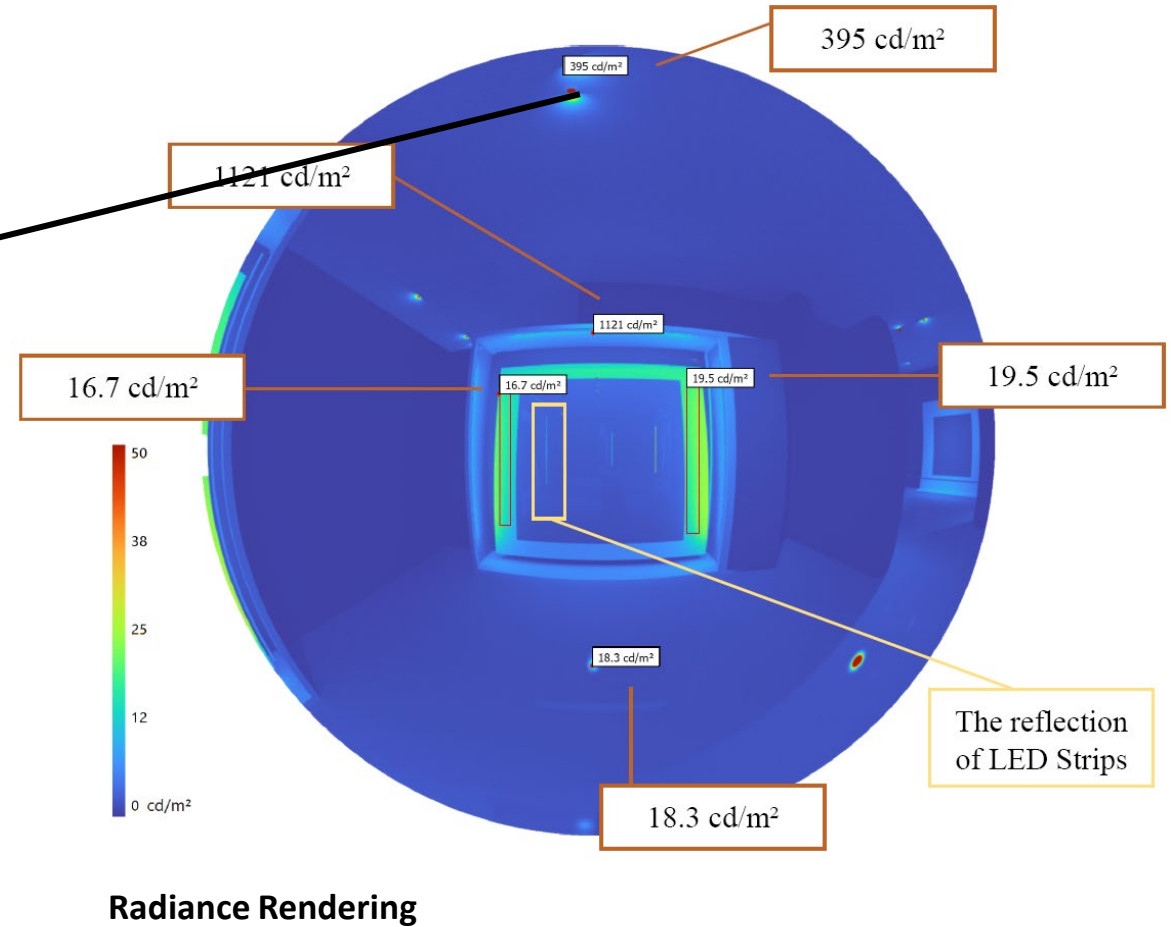
HDR Photograph



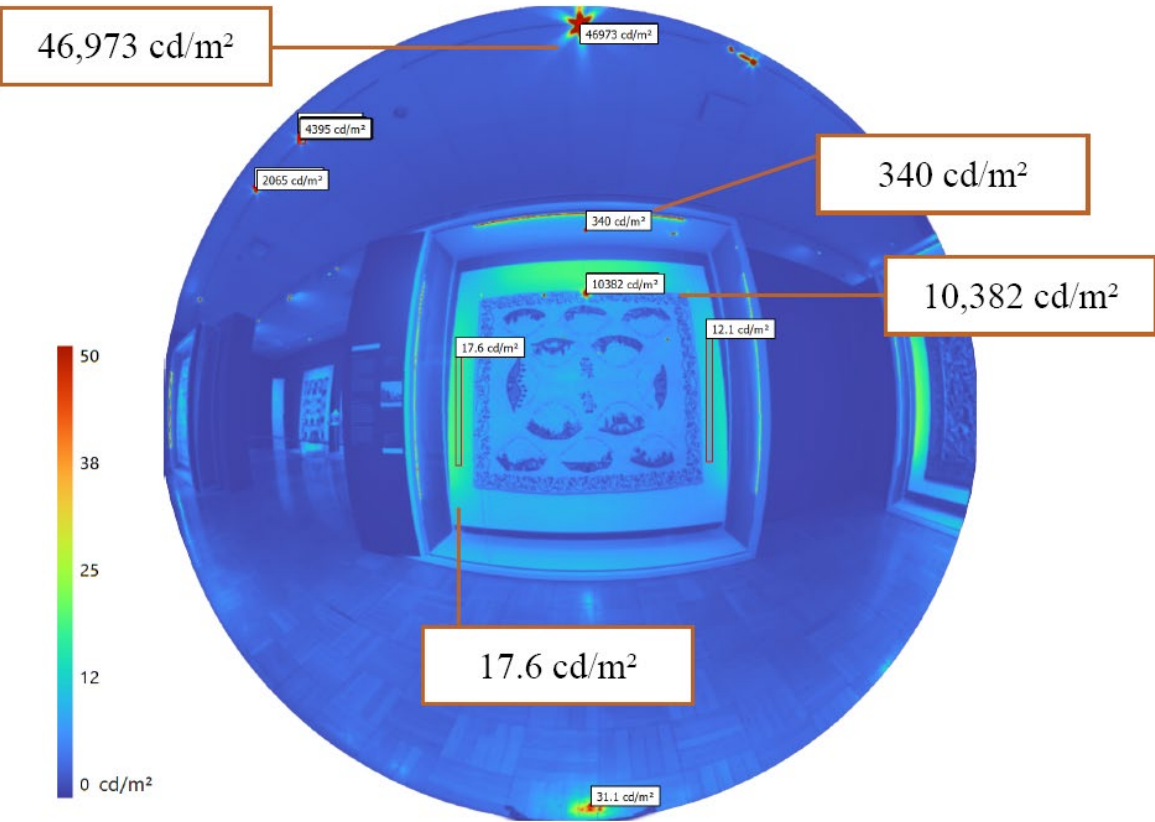
Radiance Rendering

Calibration

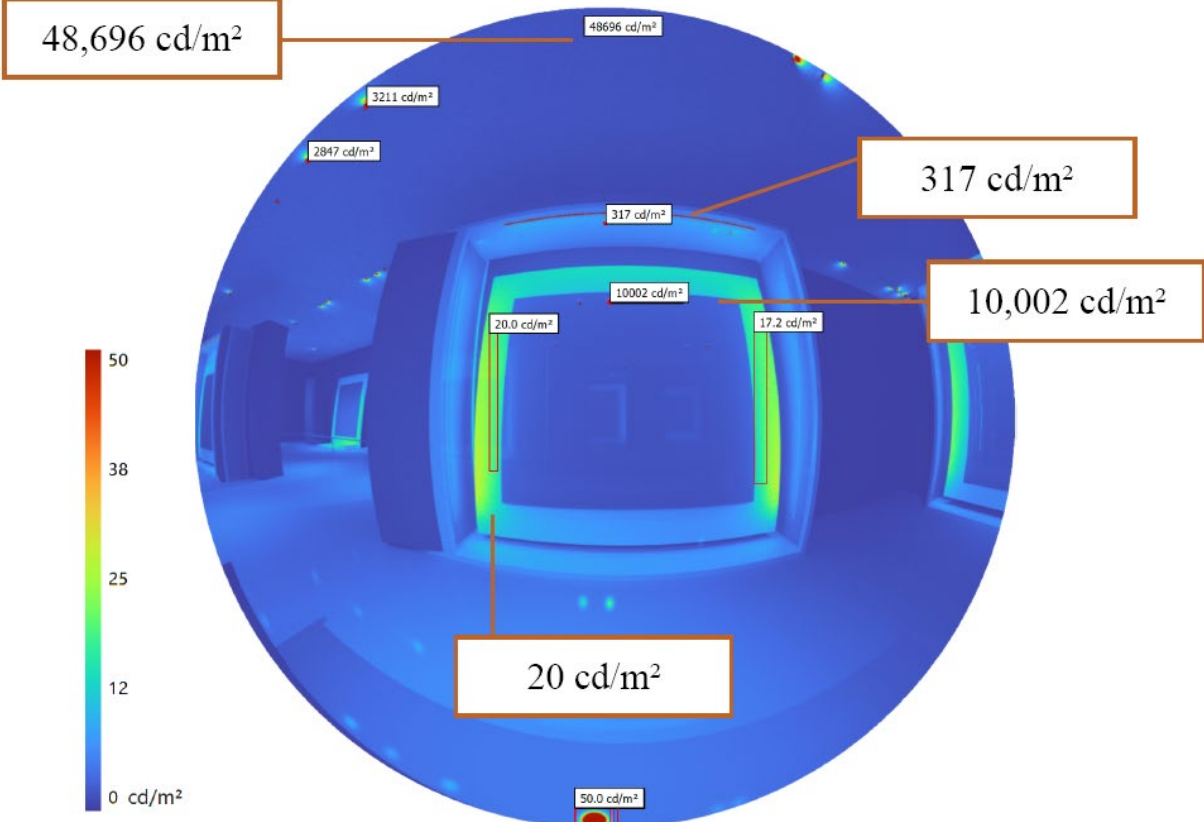
```
void BRTDfunc 2layer_fabric
10
    rR_clear rG_clear rB_clear
    0.45*tspec 0.45*tspec
0.45*tspec
    0 0 0
    fabric_2layer.cal
0
15
    0 0 0 0 0 0
    0.0 0.0 0.0
    0.12 0.12 0.12
    0.12 0.12 0.12
```



Calibration



HDR Photograph



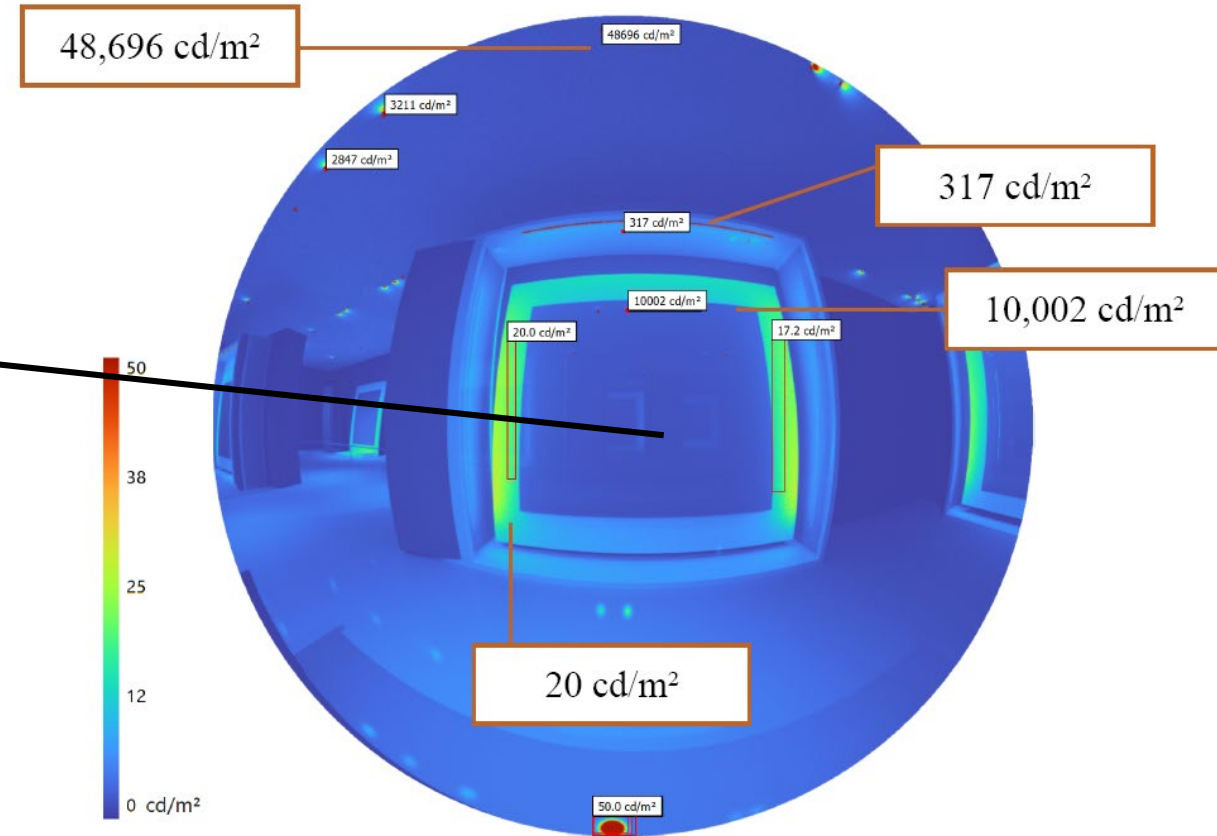
Radiance Rendering

Calibration

```
void brightfunc grefl  
2 refl glassrefl.cal  
0  
1 0.88
```

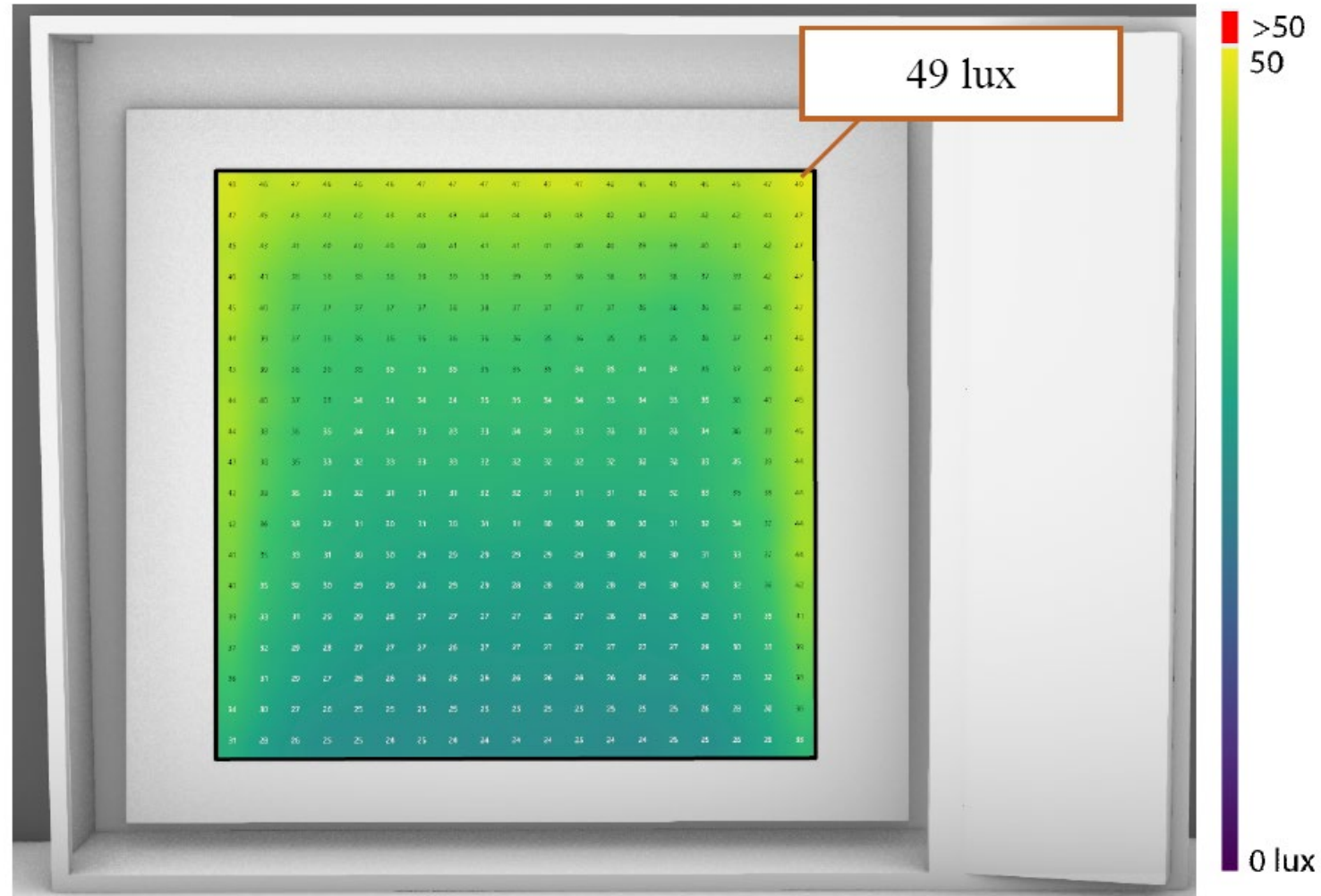
```
void glass glass88  
0  
0  
3 0.952 0.952 0.952
```

```
grefl mirror m000007  
1 glass88  
0  
3 1 1 1
```



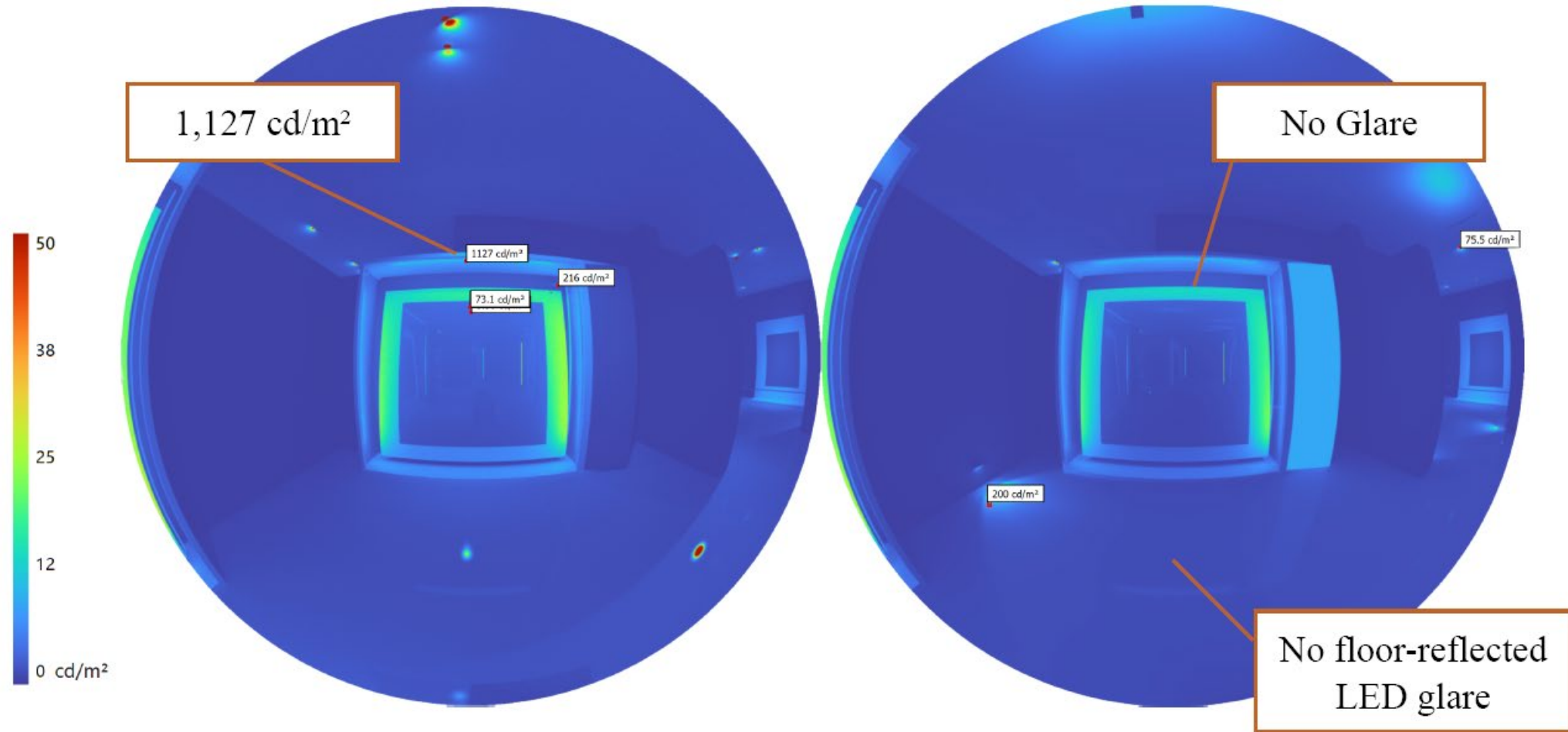
Radiance Rendering

50 lx illuminance calculation

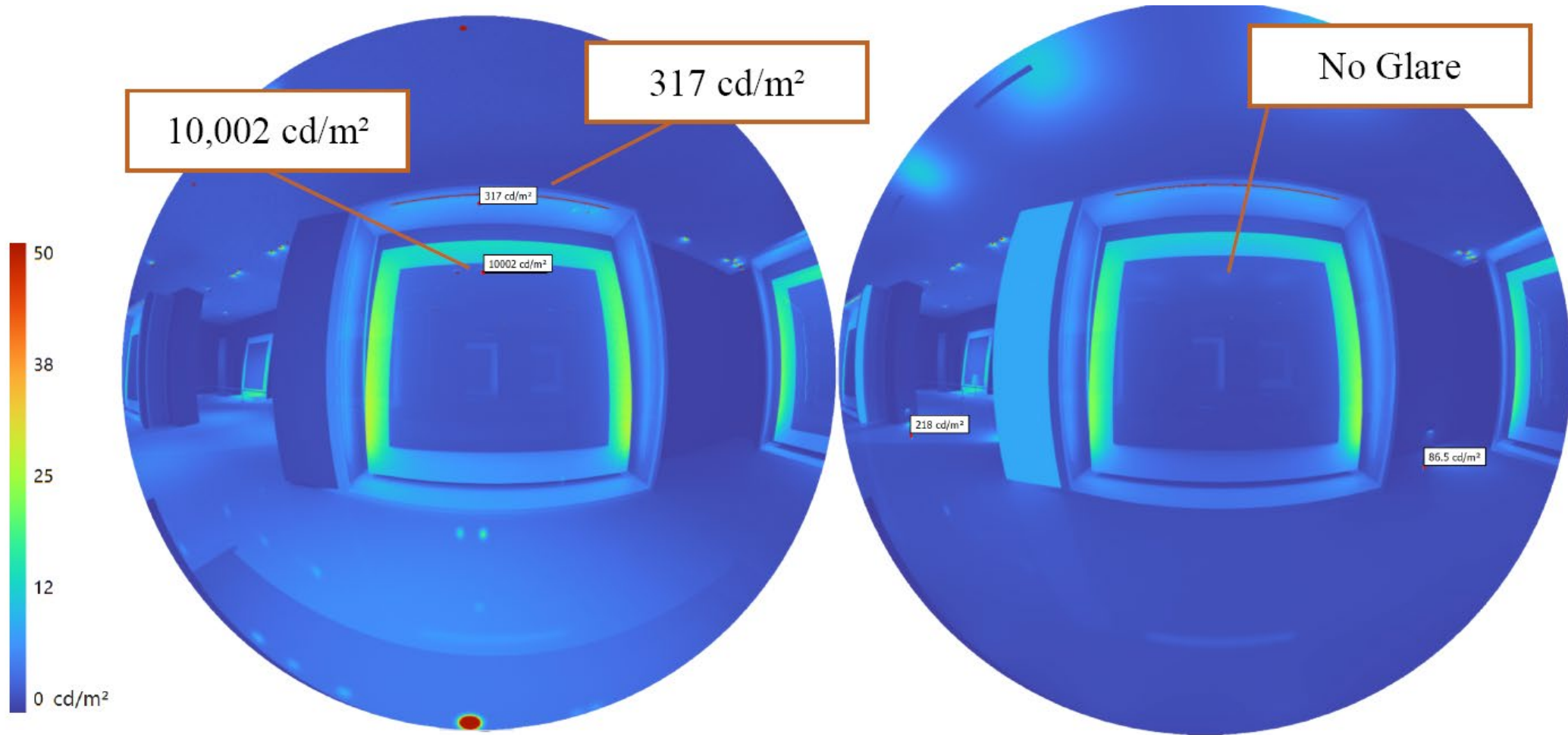


Illuminance calculation integrating diffused spots and LED strips
by Cora Xintian Liu

Some design ideas... diffuse lighting



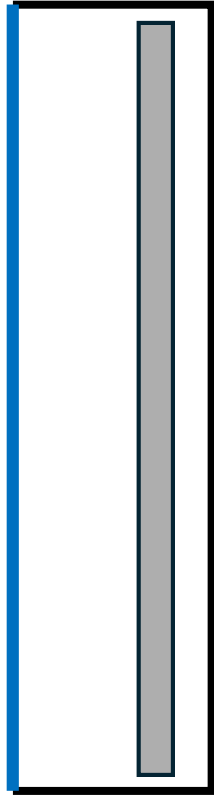
Some design ideas... diffuse lighting



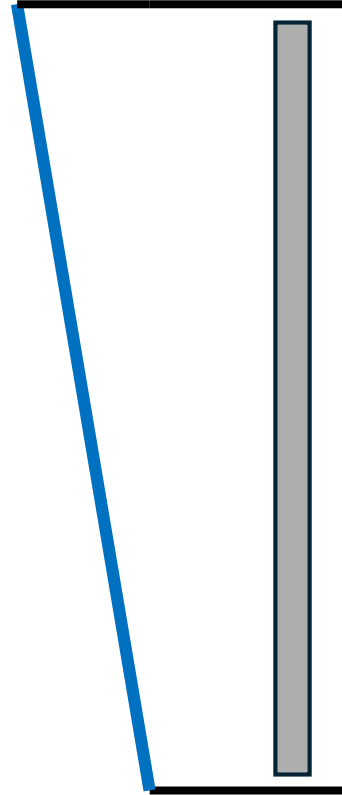
Original Design Rendering

With Diffuse Luminaires and Supplemental Floor Lighting

Some design ideas... changing the angle of incidence

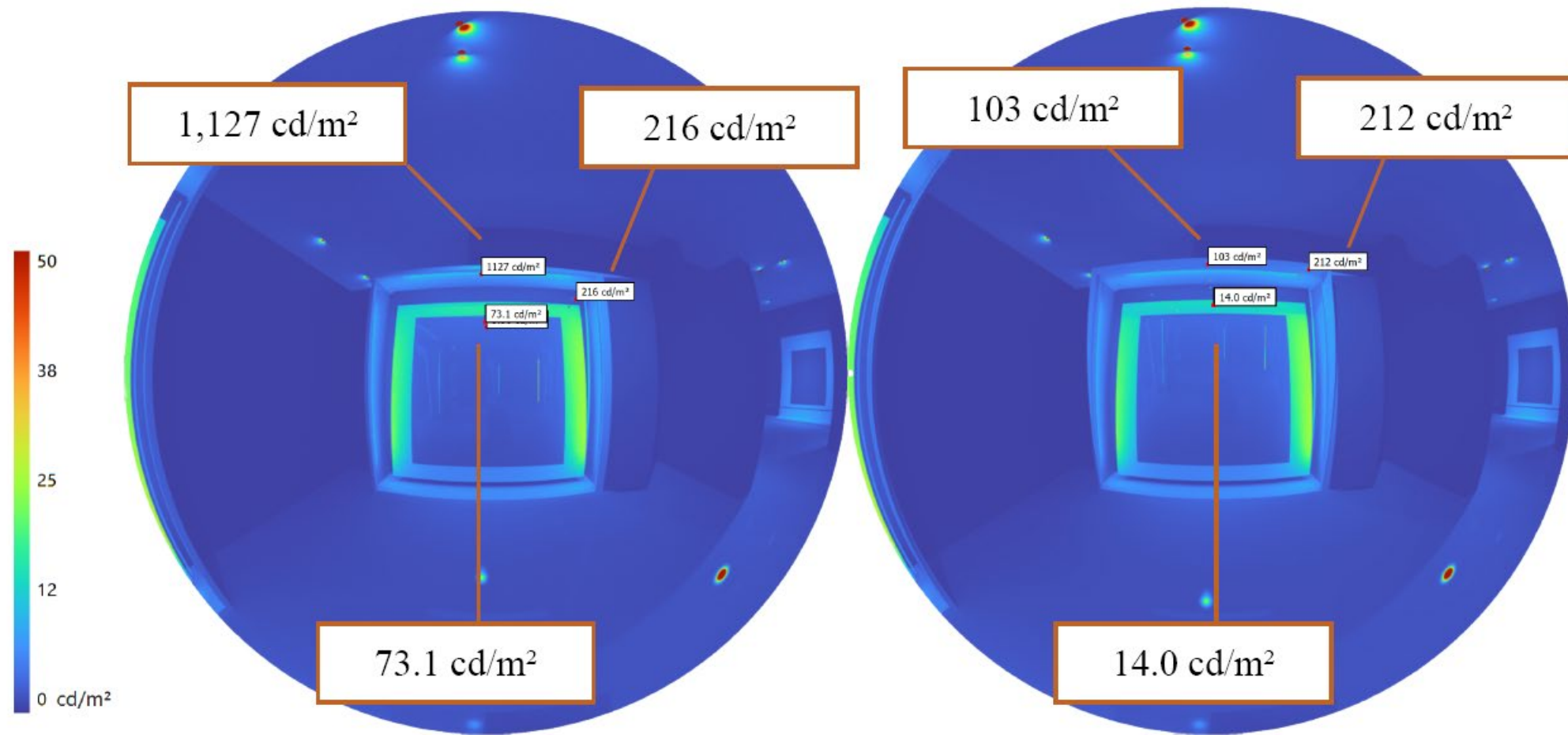


Original Design



With Plexiglass Tilted Forwards

Some design ideas... changing the angle of incidence



Original Design Rendering

With Plexiglass Tilted Forwards

Thank you.