Validation of the new VELUX Daylight Visualizer

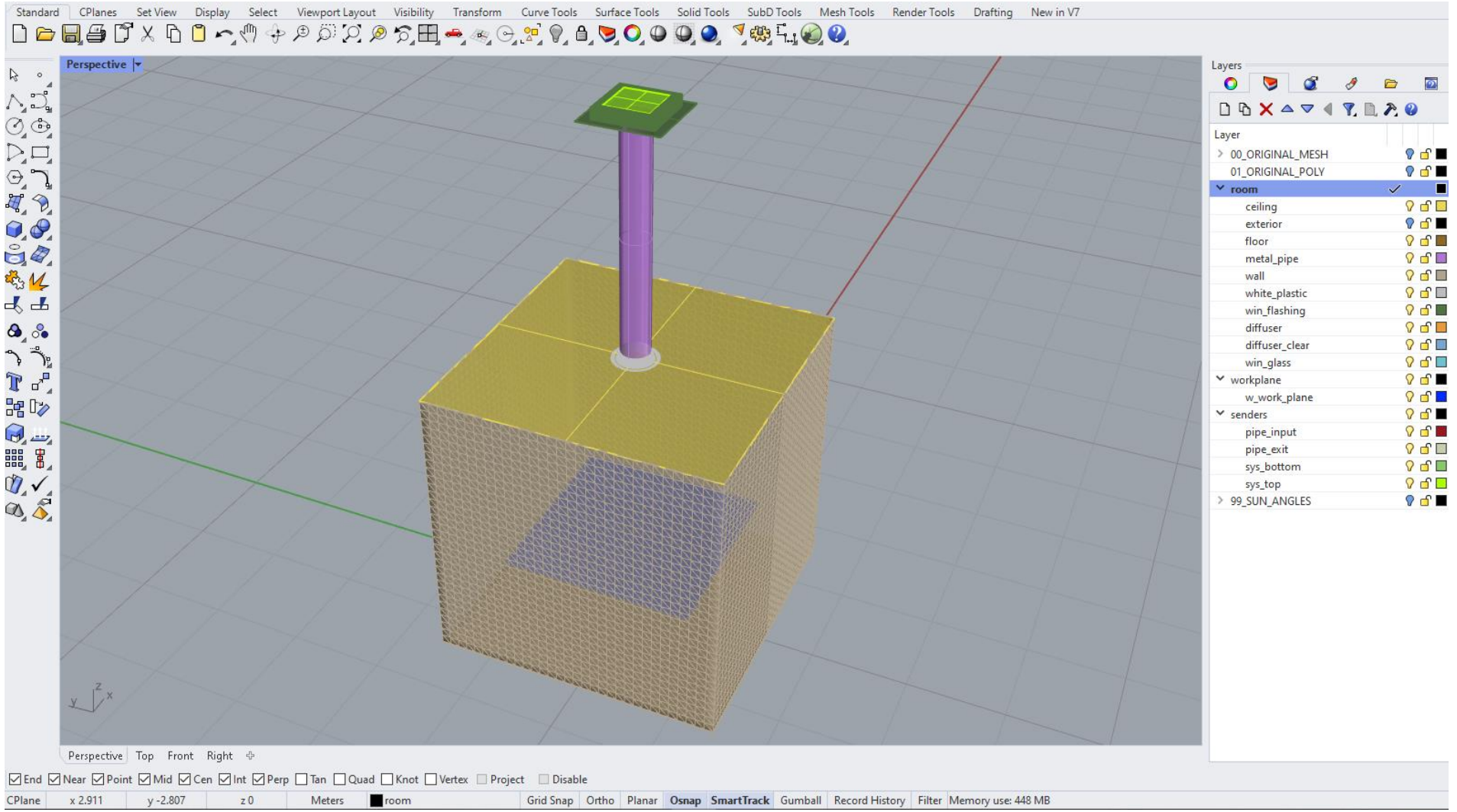
Part 2: Techie stuff and a 2008 flashback

David Geisler-Moroder, Bartenbach GmbH
Nicolas Roy, VELUX A/S
Lukas Prost, Luxion Inc.

RADIANCE Workshop 2022
3-5 August 2022, Toronto, Canada

Validation of light pipe simulations

- Simple box with single light pipe
- Clear glass top window
- Clear glass outlet cover

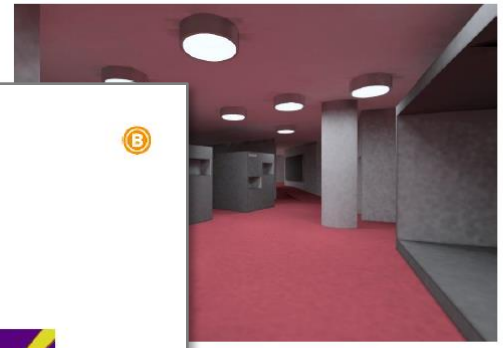


Validation of light pipe simulations

- Light pipes in Radiance

Lichtwelt „inspire“ @ Bartenbach

Application of Photon Mapping for Simulation of Light Tubes



Light tube without Fresnel structure

sky condition:
CIE overcast sky
Aldrans/Austria
March 21, 12:00 CET

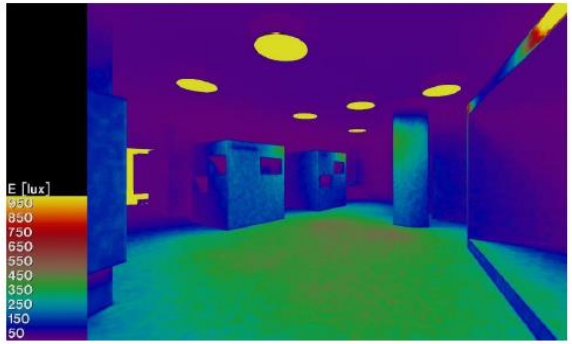
David Geisler-Moroder, Bartenbach GmbH / 17.08.2015

Lichtwelt „inspire“ @ Bartenbach

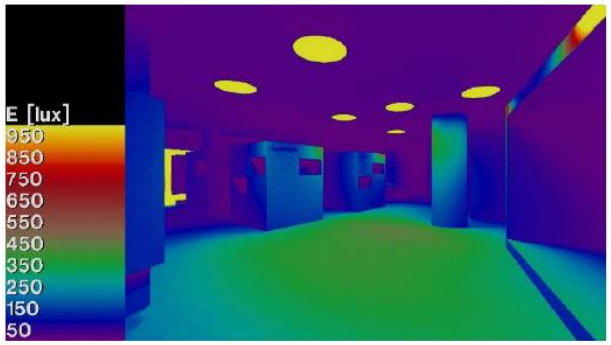
Application of Photon Mapping for Simulation of Light Tubes

Validation with classic RADIANCE

Photon Mapping



classic RADIANCE



Photon Mapping Applications

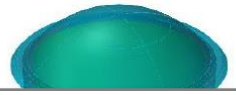
David Geisler-Moroder, Bartenbach GmbH / 17.08.2015

Validation of light pipe simulations

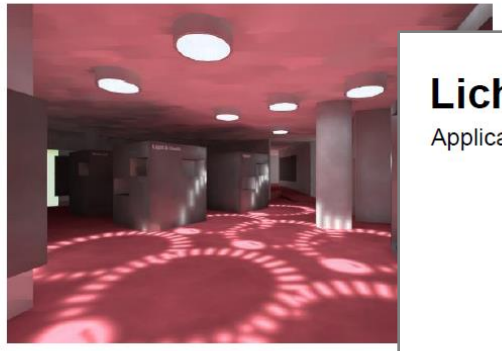
- Light pipes in Radiance

Lichtwelt „inspire“ @ Bartenbach

Application of Photon Mapping for Simulation of Light Tubes



obj2rad -f



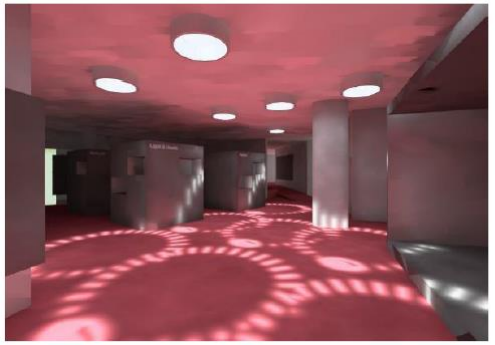
obj2rad

using the surface normal information and the *texfunc* functionality helps, but is still not satisfying…

Photon Mapping Applications

Lichtwelt „inspire“ @ Bartenbach

Application of Photon Mapping for Simulation of Light Tubes



Light tube without Fresnel structure

sky condition:
CIE clear sky
Aldrans/Austria
June 21, 13:00 CEST

modeling the light tubes as native geometry

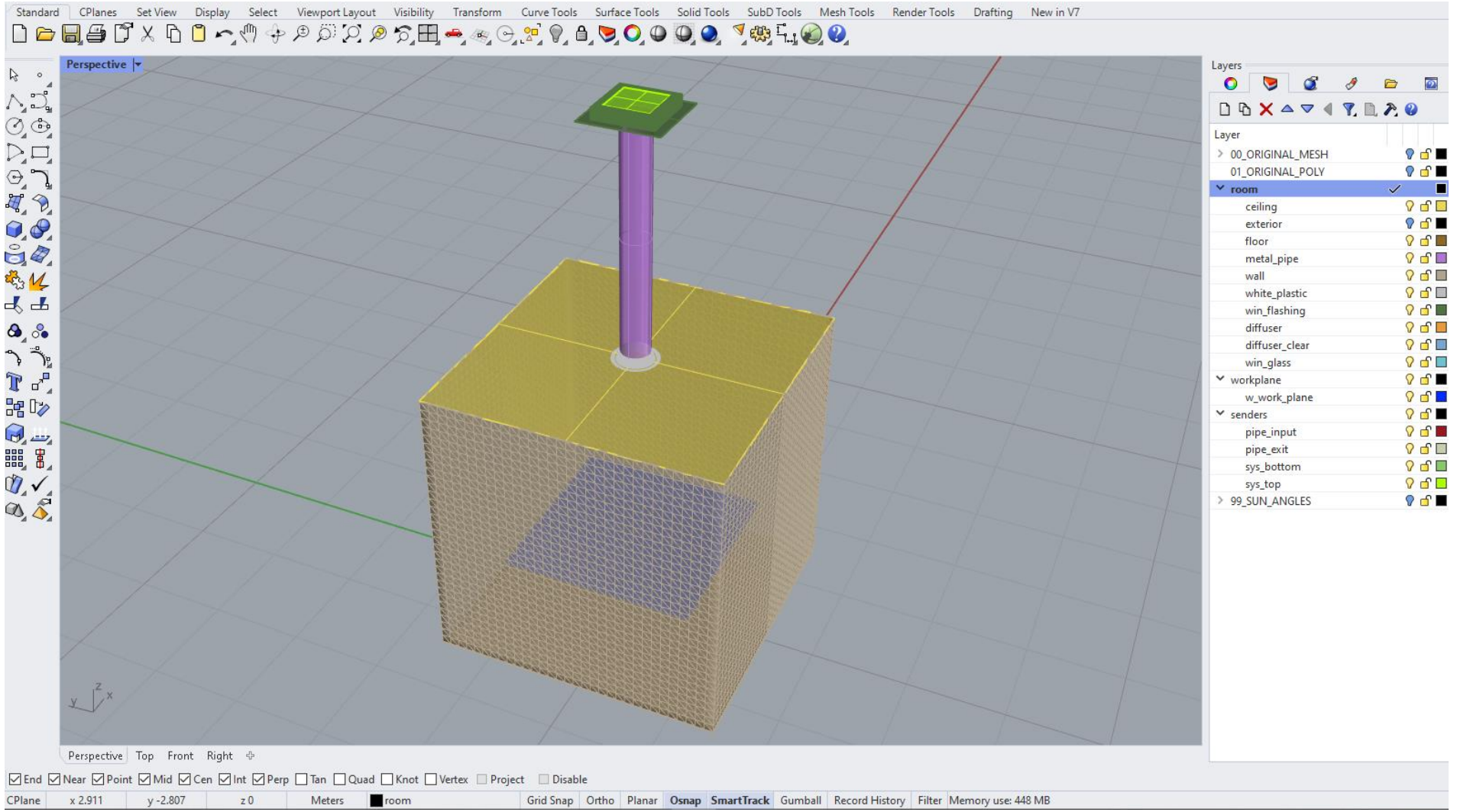
```
tube_plain__miro tube mirotube
0
0
7 0 0 0 0 0 0.65 0.4
```

Photon Mapping Applications

David Geisler-Moroder, Bartenbach GmbH / 17.08.2015

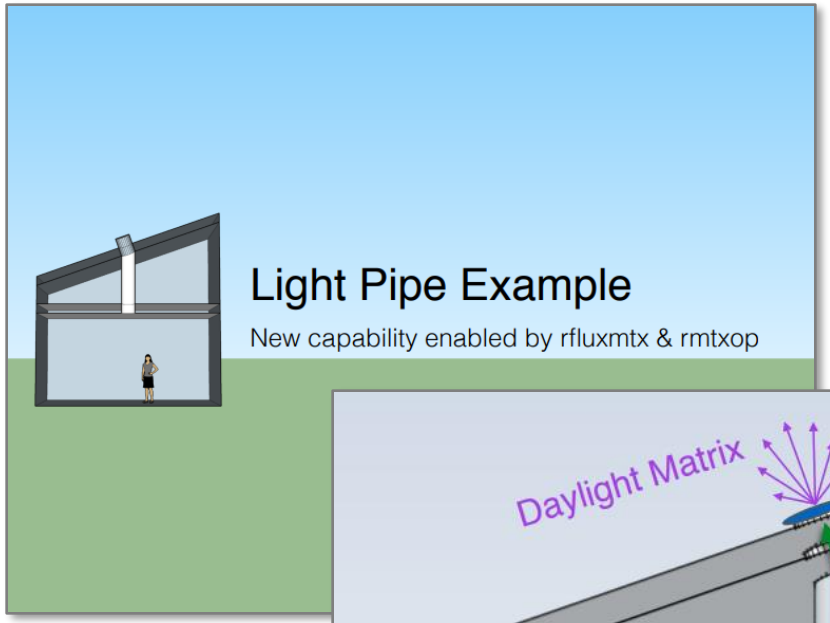
Validation of light pipe simulations

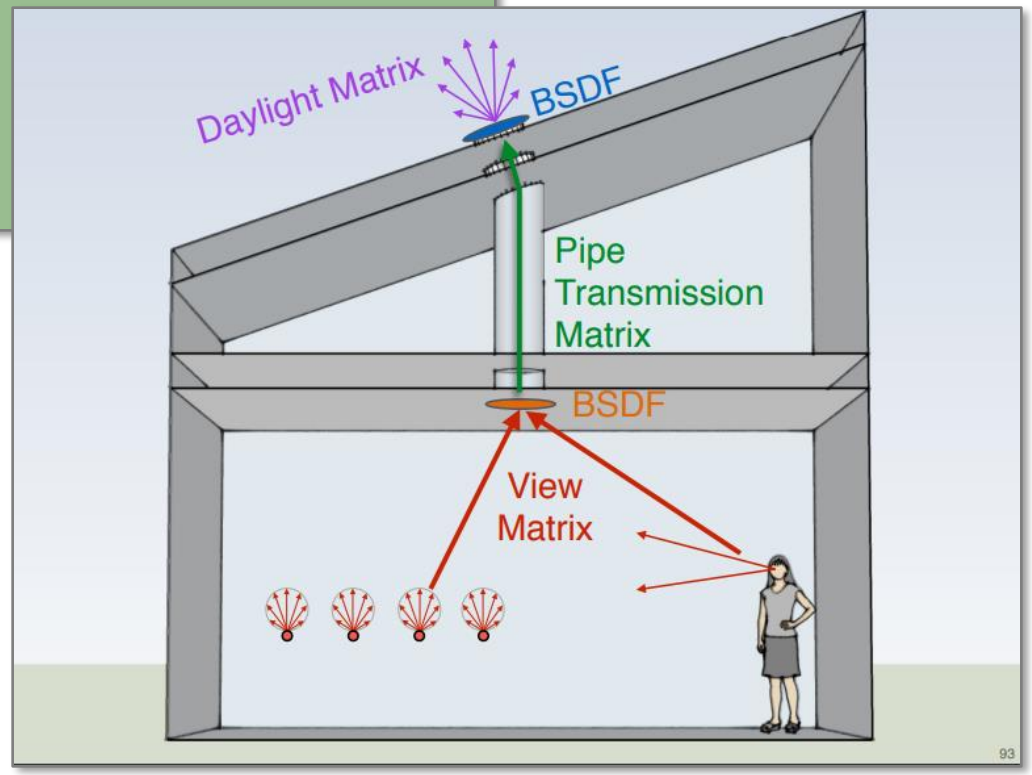
- Simple box with single light pipe
- Clear glass top window
- Clear glass outlet cover
- Finely resolved geometry of the light pipe
- Matrix approach is less sensitive (averaging over patch area)

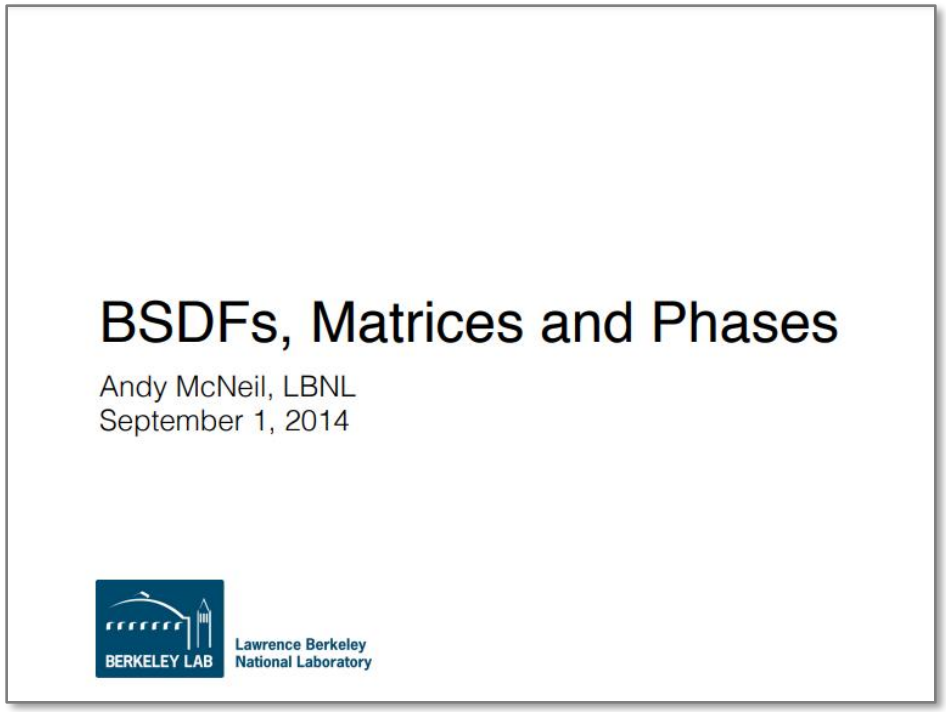


Validation of light pipe simulations

- Workflow: Andy McNeil showed the capability introduced with rfluxmtx and rmtxop







Slides: A. McNeil: https://www.radiance-online.org/community/workshops/2014-london/presentations/day1/McNeil_BSDFsandPhases.pdf

Validation of light pipe simulations

View Matrix (sensor points)

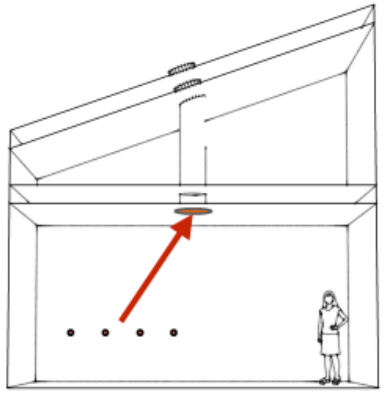
of Points

```
rfluxmtx -n 8 -faa -I+ -ab 12 -ad 50000 -lw 2e-5 -y 6 \
    <points.txt - objects/LP_bottom.rad \
    materials_light.rad model.rad > results/points.vmx
```

Sender

Model

Receiver

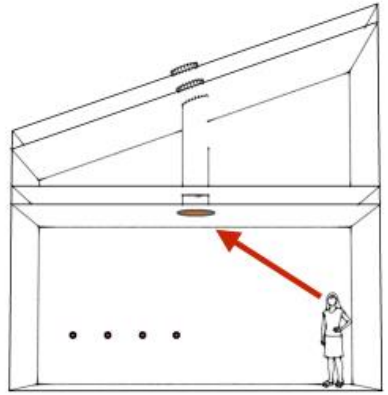


```
#@rfluxmtx h=kf u=+Y

LP_bottom polygon f_119_0
0
0
72
   3.107166  2.827189  3.048000
   3.048000  2.819400  3.048000
   2.988834  2.827189  3.048000 ...
```

94

Why do we use the light material?

```
vwrays -fa -vf views/v2.vf -x 600 -y 600 | \
    rfluxmtx -n 8 `vwrays -vf views/v2.vf -x 600 -y 600 -d` \
    -fac -ab 6 -ad 1000 -lw 1e-3  - objects/LP_bottom.rad \
    materials_light.rad model.rad
```



light materials are sampled deterministicly, which is desirable for the light pipe because:

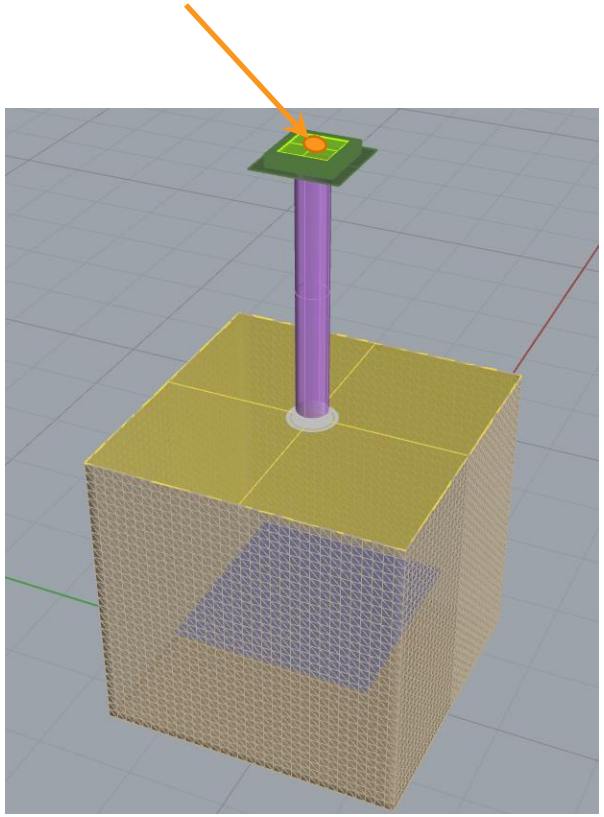
- small aperture
- no nearby points

96

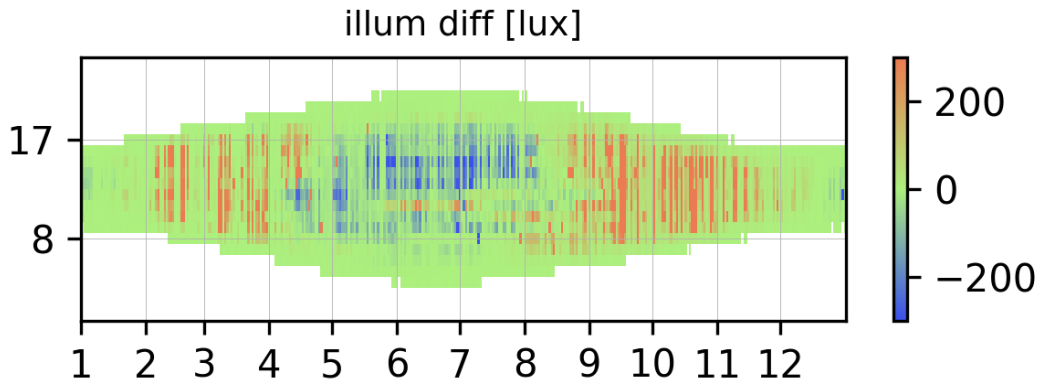
Slides: A. McNeil: https://www.radiance-online.org/community/workshops/2014-london/presentations/day1/McNeil_BSDFsandPhases.pdf

Validation of light pipe simulations: first results

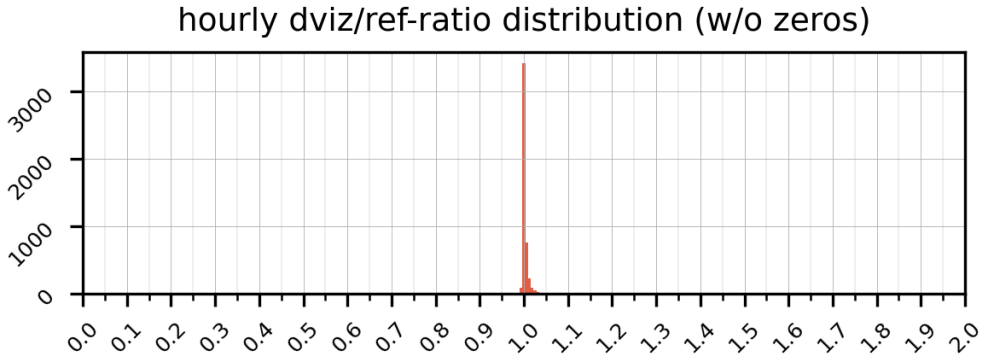
- Exterior sensor point checking incident light is good…



spnt0 - room_b1_v01_clear_glass_cop_Total - 0°



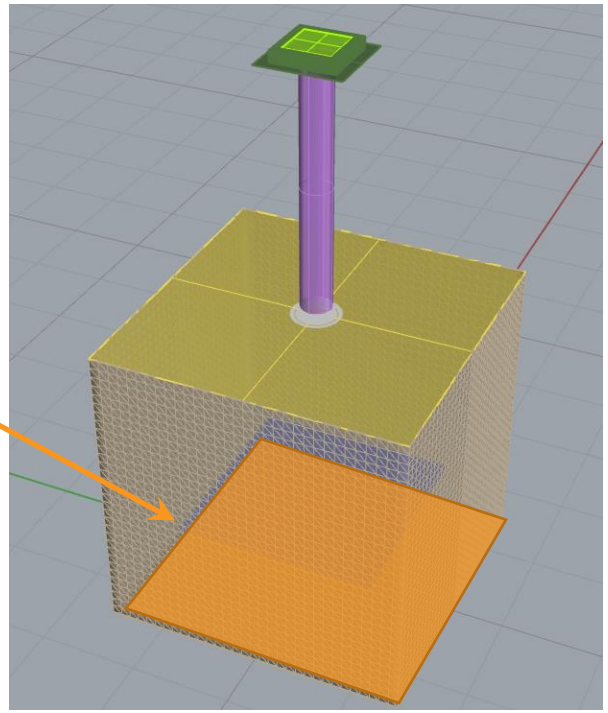
spnt0 - room_b1_v01_clear_glass_cop_Total - 0°

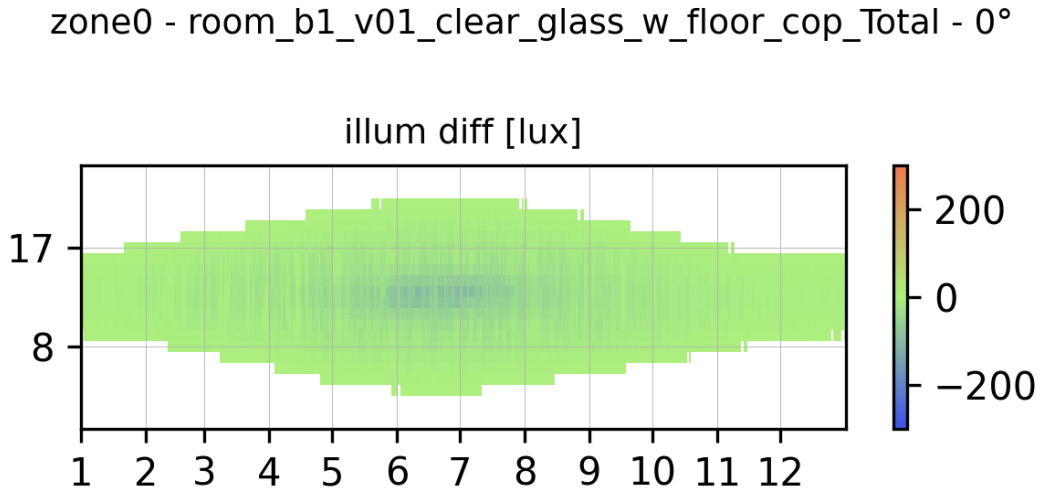


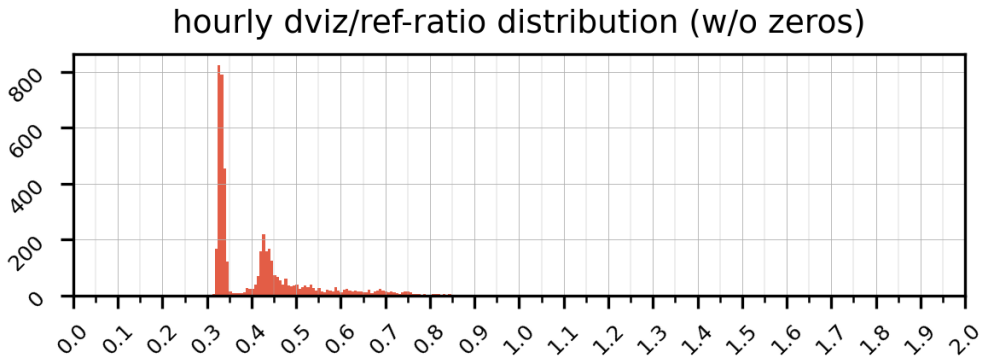
TAI_{dviz} - TAI_{ref}	TAI_{dviz}/TAI_{ref}	avg diff	mean diff	std diff
200 748.868	1.002	43.107	43.107	206.029

Validation of light pipe simulations: first results

- Interior results were quite off…



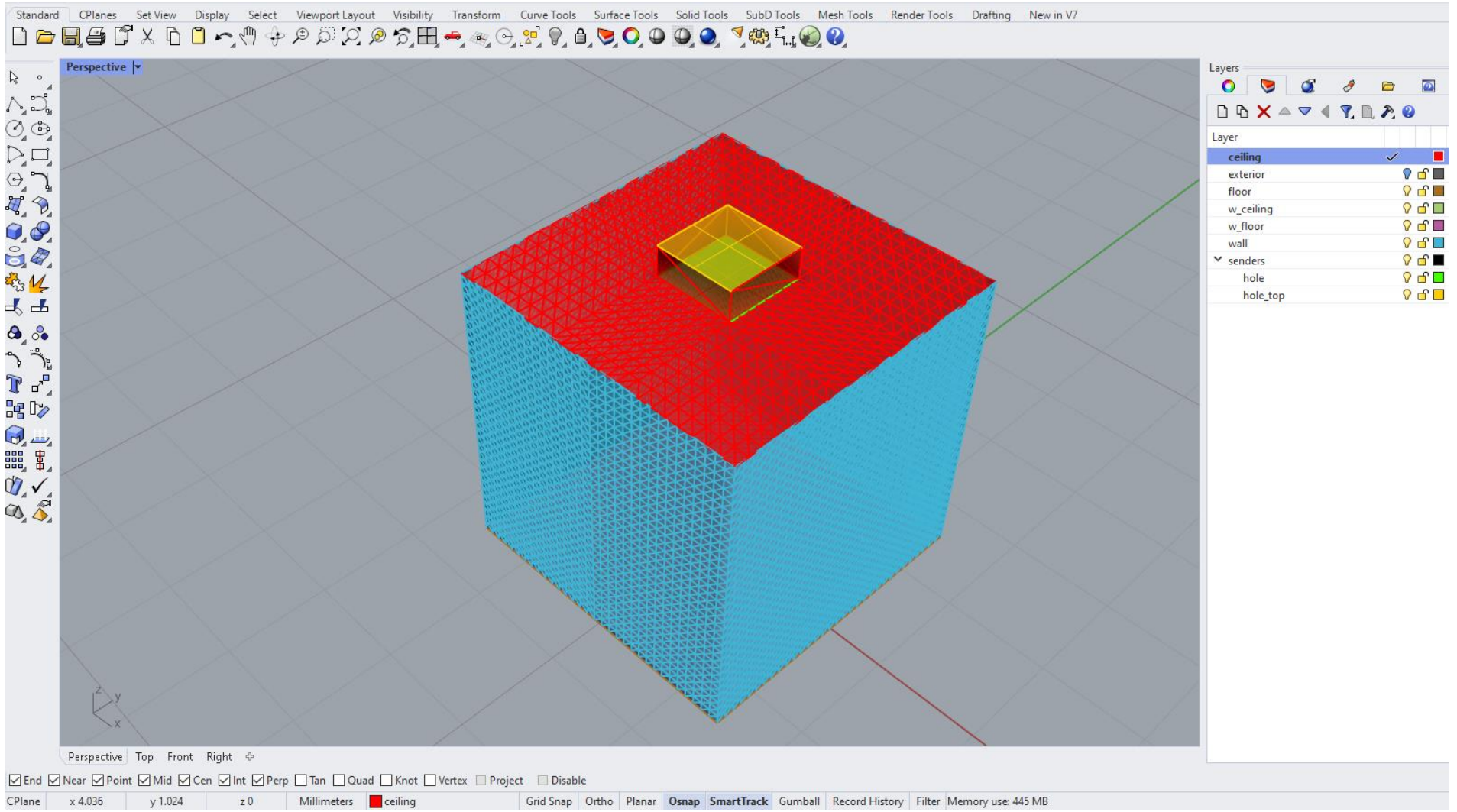




TAI_{dviz} - TAI_{ref}	TAI_{dviz}/TAI_{ref}	avg diff	mean diff	std diff
−70 326.555	0.464	−15.101	−15.101	16.234

Simple test box

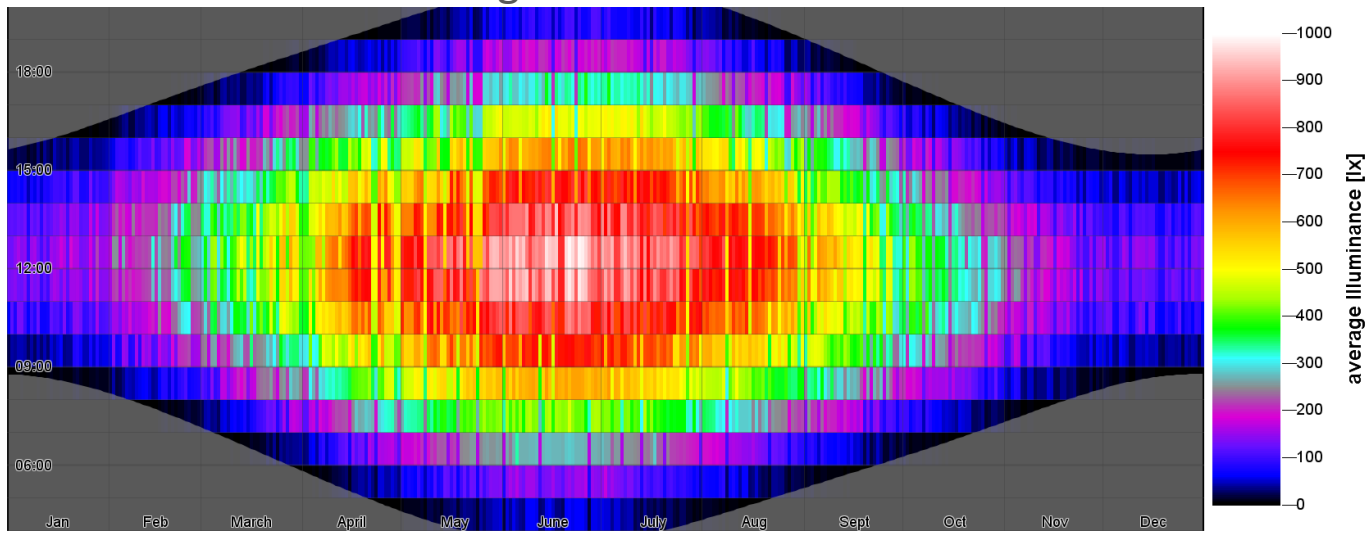
- Simple box with rectangular opening in the ceiling
- Without glazing
- Two- and three-phase methods applied
- Comparing view matrix calculation for 3-PM with light and glow



Simple test box

- RADIANCE results:
  3-PM calculation with view matrix generated using a

"light" modifier

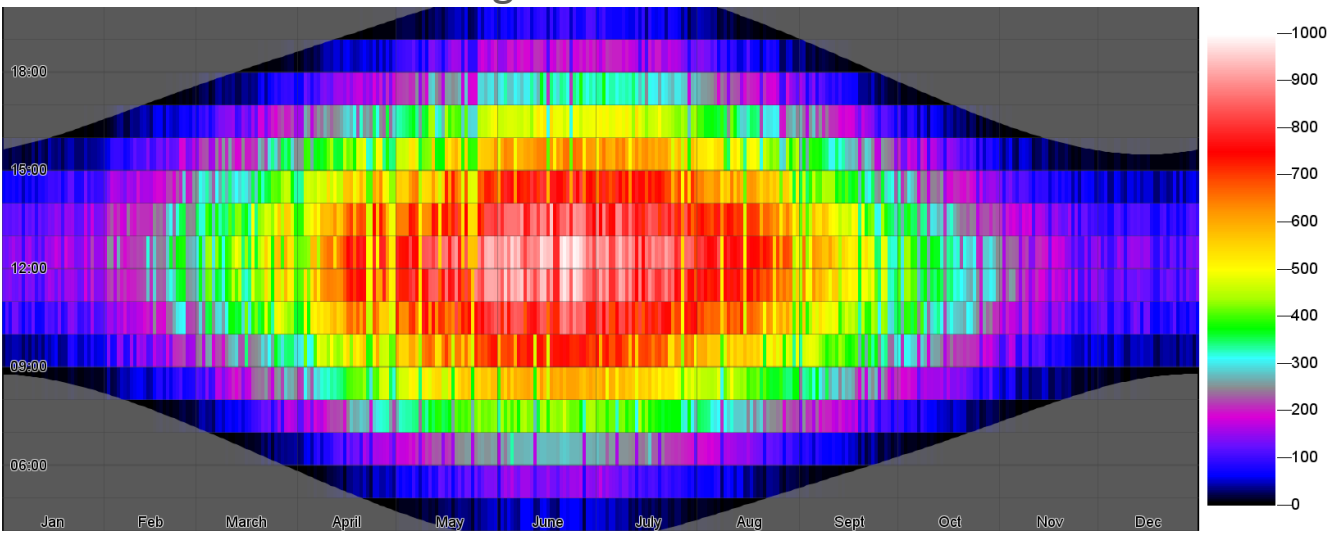


rcontrib options:
-V- -w- -I+ -ab 5 -ad 20000
-lw 1e-8 -lr -8 -dt 0.0 -ds 0.0001

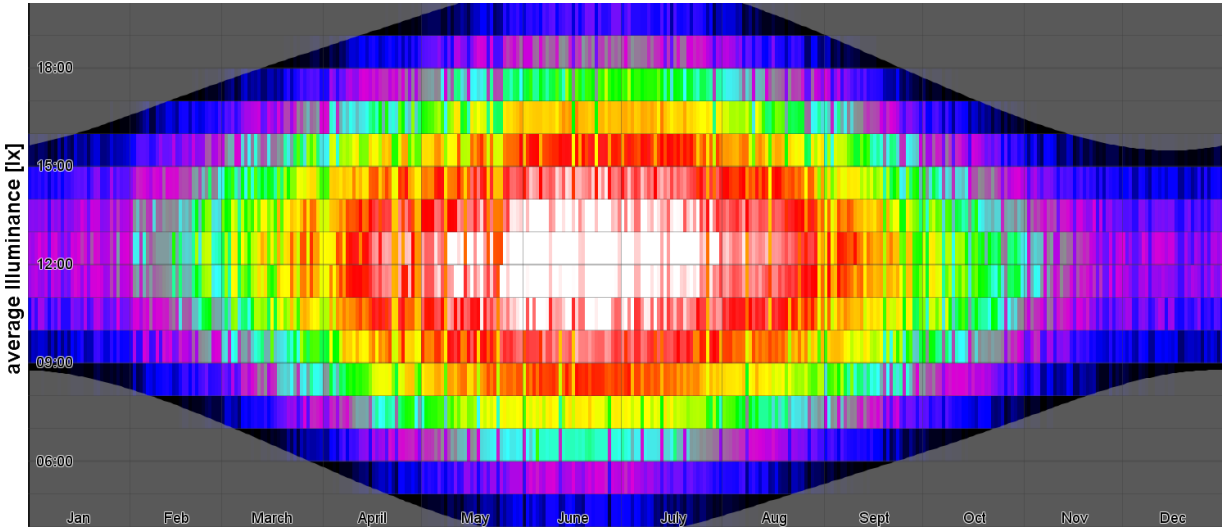
Simple test box

- RADIANCE results:
  3-PM calculation with view matrix generated using a

“light” modifier



“glow” modifier



rcontrib options:
-V- -w- -I+ -ab 5 -ad 20000
-lw 1e-8 -lr -8 -dt 0.0 -ds 0.0001

Avg. Error: 24%!

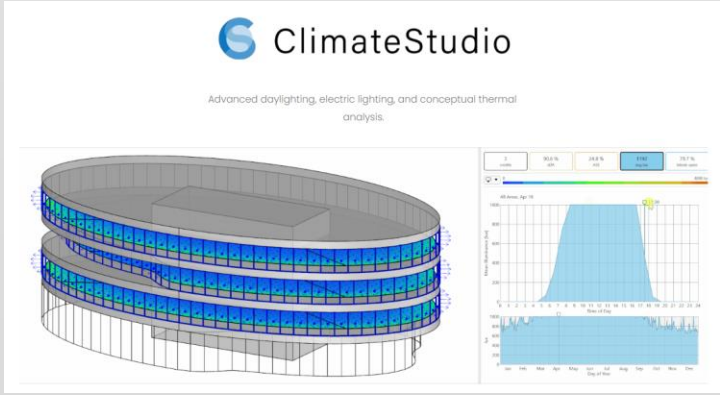
rcontrib options:
-V- -w- -I+ -ab 5 -ad 50000
-lw 1e-8 -lr -8

Radiance vs. Radiance

RADSITE | radiance-online.org

```
1
2  void glow senders__sys_bottom
3  0
4  0
5  4  43.484 43.484 43.484 0
6
7  # E = phi / pi*(r^2+h^2)
8  # E = 100, h = 3.0, r = 0.192247; --> phi = 2839 lm
9  # A = r^2*pi = 0.1161 m2
10 # L = phi / (pi*A) = 7783.65 cd/m2
11 # R = 43.484 W/m2
12
13 ###################################
14
15 senders__sys_bottom ring senders__sys_bottom
16 0
17 0
18 8  0 0.005 3.086499929
19    0 0 -1
20    0 0.192247
21
```

vs.



LightStanza

RELUX® light simulation tools

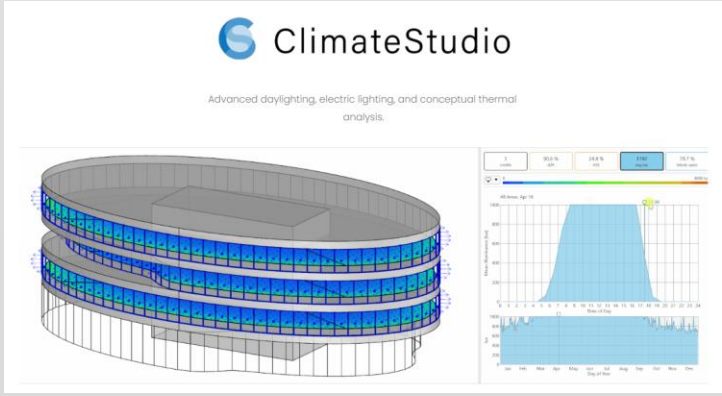
Pollination

Radiance vs. Radiance

rcontrib options:
-V- **-w+** -I+ -ab 5 -ad 20000
-lw 1e-8 -lr -8 -dt 0.0 -ds 0.0001

rtrace: warning - aiming failure for light source

vs.



LightStanza

RELUX® light simulation tools

Pollination

Radiance Workshop 2008

Radiance Workshop 2008

Radiance Workshop 2008

Validation of Radiance against CIE171:2006 and Improved Adaptive Subdivision of Circular Light Sources

David Geisler-Moroder Arne Dür

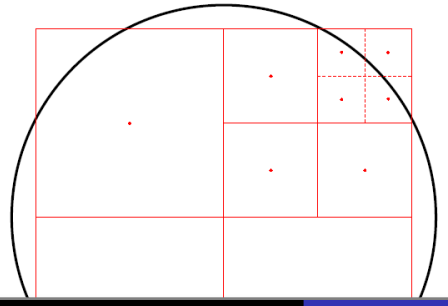
Department of Mathematics
University of Innsbruck, Austria

7th International RADIANCE workshop
Fribourg Switzerland
30-31 October 2008

Current Implementation

Radiance:
(Ward and Shakespeare, 1998)

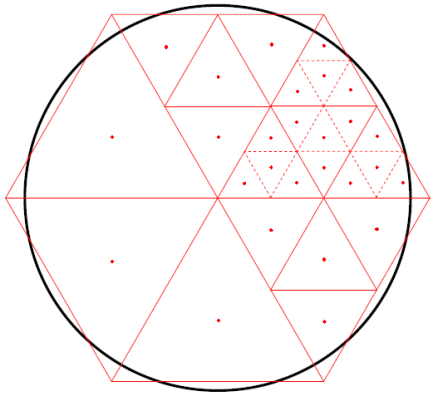
- all flat light sources approximated as rectangles
- circular light source approximated as square
- jittering over full source volume: probability for *aiming failure*: 9
- full subdivision, 4 out of 64 rays source

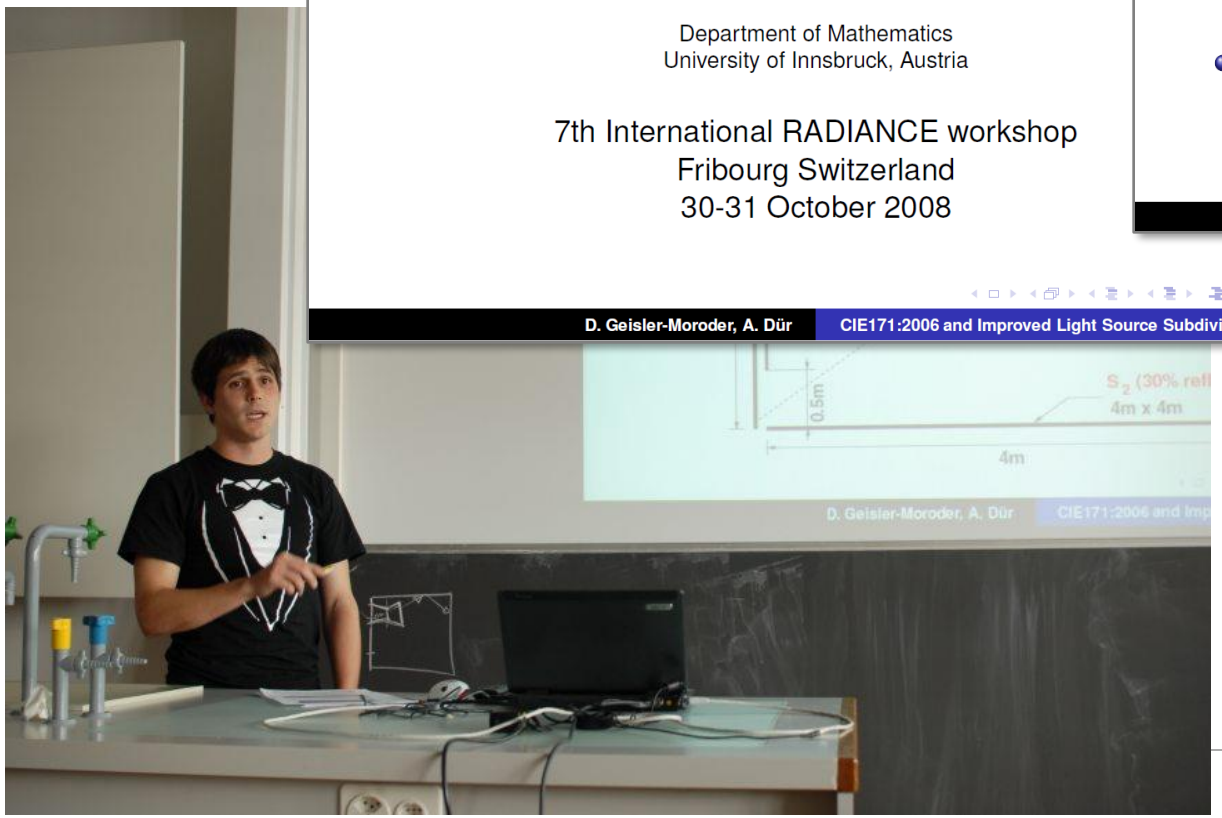


Triangulation approach

Improved subdivision:

- approximate circular light source as hexagon
- subdivide hexagon into equilateral triangles
- jittering over full source volume: probability for *aiming failure decreases from 9.1% to 3.7%*
- full subdivision, no jittering: all 96 rays hit light source

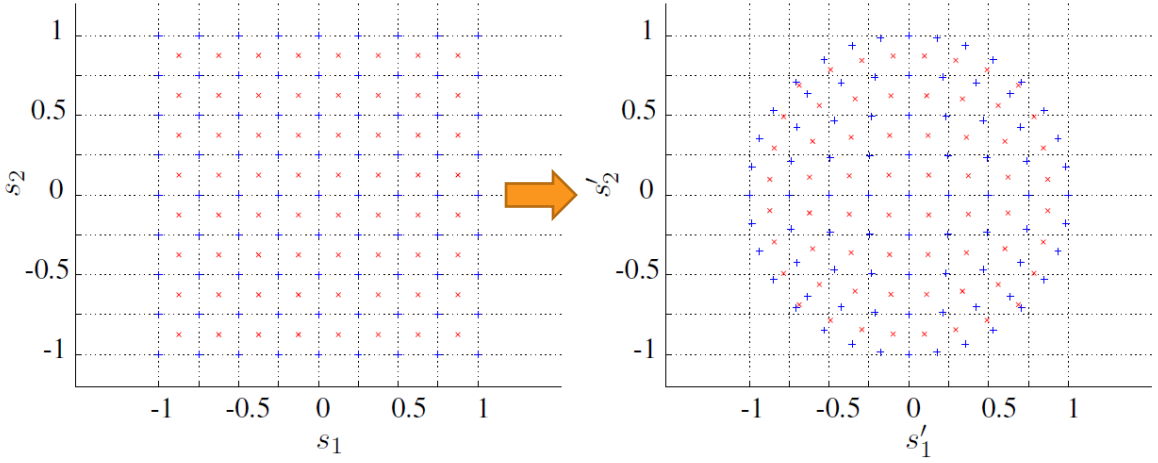




Circular light sources in Radiance

- Greg implemented an improved version in 2008:

$$(s_1', s_2') = \left(s_1\sqrt{1 - \frac{s_2^2}{2}},\ s_2\sqrt{1 - \frac{s_1^2}{2}} \right)$$



root/radiance/ray/src/rt/srcsamp.c

Colored Diff | Show | (Generate patch)

Comparing ray/src/rt/srcsamp.c (file contents):
Revision 2.11 by *greg*, Sat Sep 13 17:31:35 2003 UTC vs.
Revision 2.12 by *greg*, Sat Dec 6 01:08:53 2008 UTC

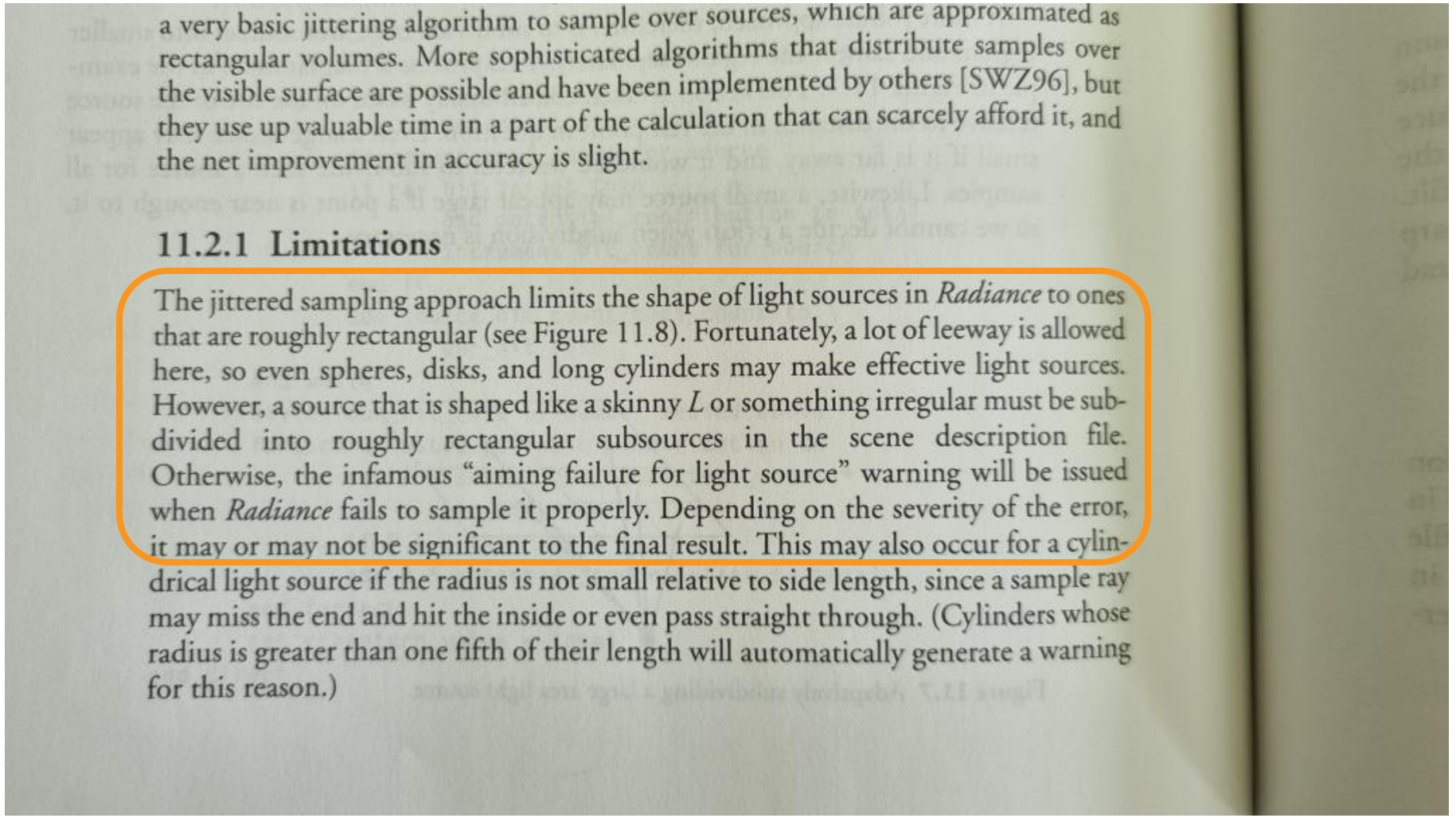
```
#                Line 57 | Line 57 | nextsample:
57                              d = urand(ilhash(dimlist,ndims+2)+samplendx);
58                              if (source[si->sn].sflags & SFLAT) {
59                                      multisamp(vpos, 2, d);
60              <                       vpos[2] = 0.5;
60              >                       vpos[SW] = 0.5;
61                              } else
62                                      multisamp(vpos, 3, d);
63                              for (i = 0; i < 3; i++)
#                Line 68 | Line 68 | nextsample:
68
69                      for (i = 0; i < 3; i++)
70                              vpos[i] += (double)cent[i]/MAXSPART;
71              +                                       /* avoid circular aiming failures */
72              +       if (source[si->sn].sflags & SCIR) {
73              +               FVECT   trim;
74              +               double  d;
75              +               if (source[si->sn].sflags & (SFLAT|SDISTANT)) {
76              +                       d = 1.12837917;         /* correct setflatss() */
77              +                       trim[SU] = d*sqrt(1.0 - 0.5*vpos[SV]*vpos[SV]);
78              +                       trim[SV] = d*sqrt(1.0 - 0.5*vpos[SU]*vpos[SU]);
79              +                       trim[SW] = 0.0;
80              +               } else {
81              +                       trim[SW] = trim[SU] = vpos[SU]*vpos[SU];
82              +                       d = vpos[SV]*vpos[SV];
83              +                       if (d > trim[SW]) trim[SW] = d;
84              +                       trim[SU] += d;
85              +                       d = vpos[SW]*vpos[SW];
86              +                       if (d > trim[SW]) trim[SW] = d;
87              +                       trim[SU] += d;
88              +                       d = 1.0/0.7236;         /* correct sphsetsrc() */
89              +                       trim[SW] = trim[SV] = trim[SU] =
90              +                                       d*sqrt(trim[SW]/trim[SU]);
91              +               }
92              +               for (i = 0; i < 3; i++)
93              +                       vpos[i] *= trim[i];
94              +       }
95                                      /* compute direction */
96                      for (i = 0; i < 3; i++)
97                              r->rdir[i] = source[si->sn].sloc[i] +
```

Diff Legend

– Removed lines
+ Added lines

Direct calculation in Radiance

- Rendering with Radiance, page 510:

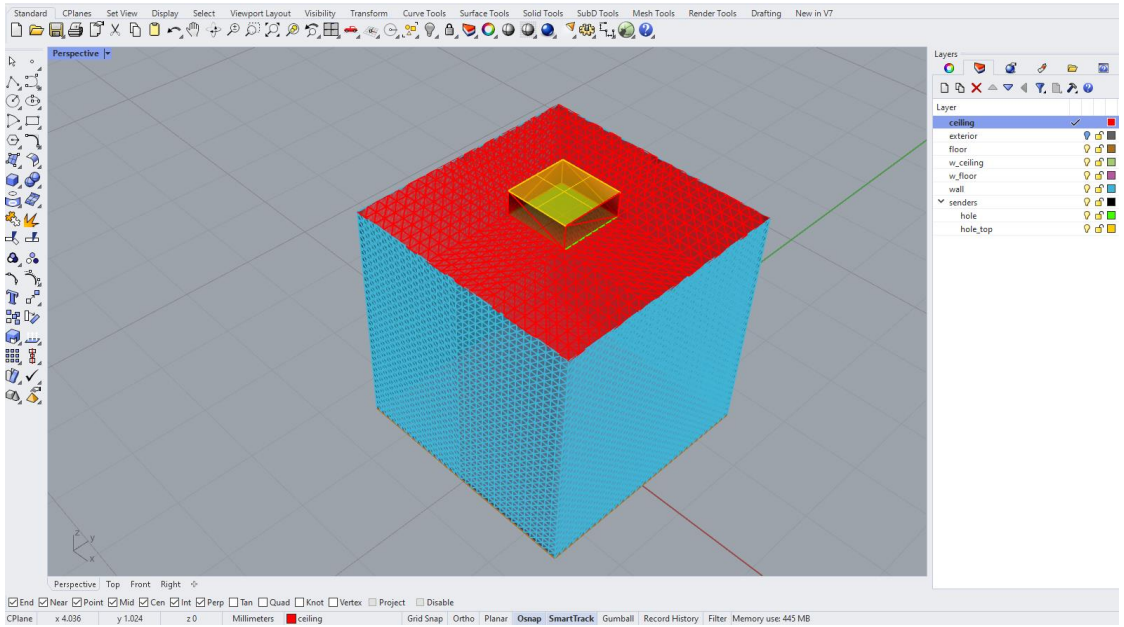


a very basic jittering algorithm to sample over sources, which are approximated as rectangular volumes. More sophisticated algorithms that distribute samples over the visible surface are possible and have been implemented by others [SWZ96], but they use up valuable time in a part of the calculation that can scarcely afford it, and the net improvement in accuracy is slight.

11.2.1 Limitations

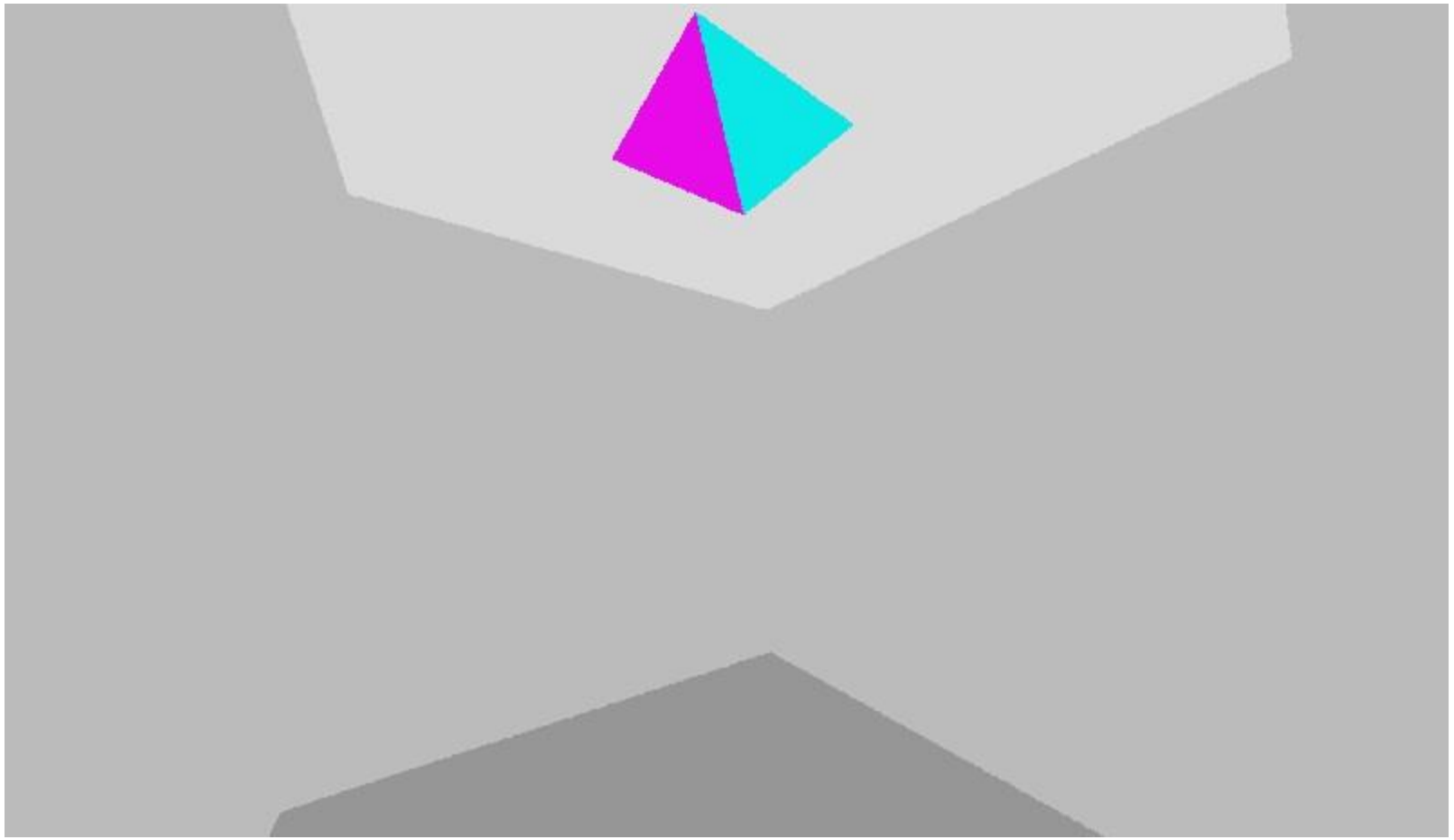
The jittered sampling approach limits the shape of light sources in *Radiance* to ones that are roughly rectangular (see Figure 11.8). Fortunately, a lot of leeway is allowed here, so even spheres, disks, and long cylinders may make effective light sources. However, a source that is shaped like a skinny *L* or something irregular must be subdivided into roughly rectangular subsources in the scene description file. Otherwise, the infamous "aiming failure for light source" warning will be issued when *Radiance* fails to sample it properly. Depending on the severity of the error, it may or may not be significant to the final result. This may also occur for a cylindrical light source if the radius is not small relative to side length, since a sample ray may miss the end and hit the inside or even pass straight through. (Cylinders whose radius is greater than one fifth of their length will automatically generate a warning for this reason.)

Simple test box



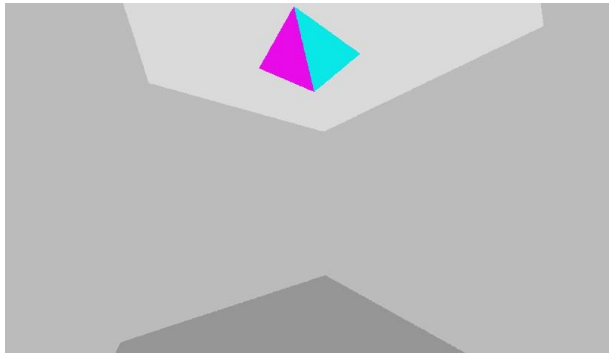

```
#@rfluxmtx h=kf u=+Y

void glow senders__hole
0
0
4 1 1 1 0


###################################

# obj2rad -m RoomB3_SimMod_senders_hole.map RoomB3_SimMod_senders_hole.obj
# Rhino

senders__hole polygon senders__hole.1
0
0
9
        0.400000006         0.400000006         3.099999905
        0.400000006        -0.400000006         3.099999905
       -0.400000006        -0.400000006         3.099999905

senders__hole polygon senders__hole.1
0
0
9
       -0.400000006        -0.400000006         3.099999905
       -0.400000006         0.400000006         3.099999905
        0.400000006         0.400000006         3.099999905

# Done processing file: RoomB3_SimMod_senders_hole.obj
# 12 lines, 11 statements, 0 unrecognized
senders/RoomB3_SimMod_senders_hole_GLOW.rad lines 1-31/31 (END)
```

Light source sampling



Light source sampling

light



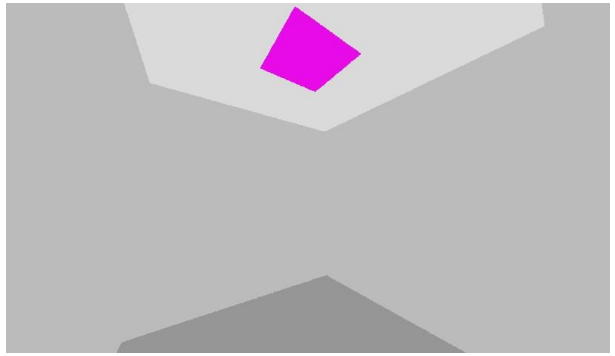
Source geometry: 2 triangles

Options #1
E = 75.2lx
Warning: aiming failure

Options #2:
E = 99.3lx
Warning: -

Default options
E = 99.3lx
Warning: -

light



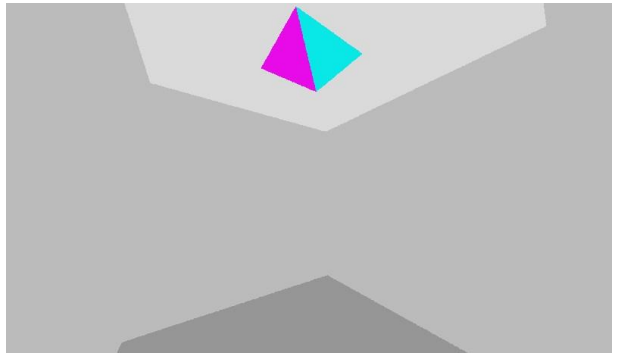
Source geometry: 1 quad

Options #1:
E = 97.8lx
Warning: -

Options #2:
E = 100.0lx
Warning: -

Default options
E = 98.3lx
Warning: -

glow



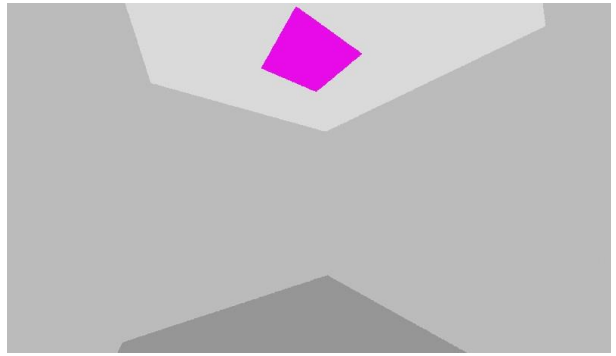
Source geometry: 2 triangles

Options #1:
E = 97.8lx
Warning: aiming failure

Options #2:
E = 97.8lx
Warning: -

Default options
E = 0lx
Warning: no light sources found

glow



Source geometry: 1 quad

Options #1:
E = 97.8lx
Warning: aiming failure

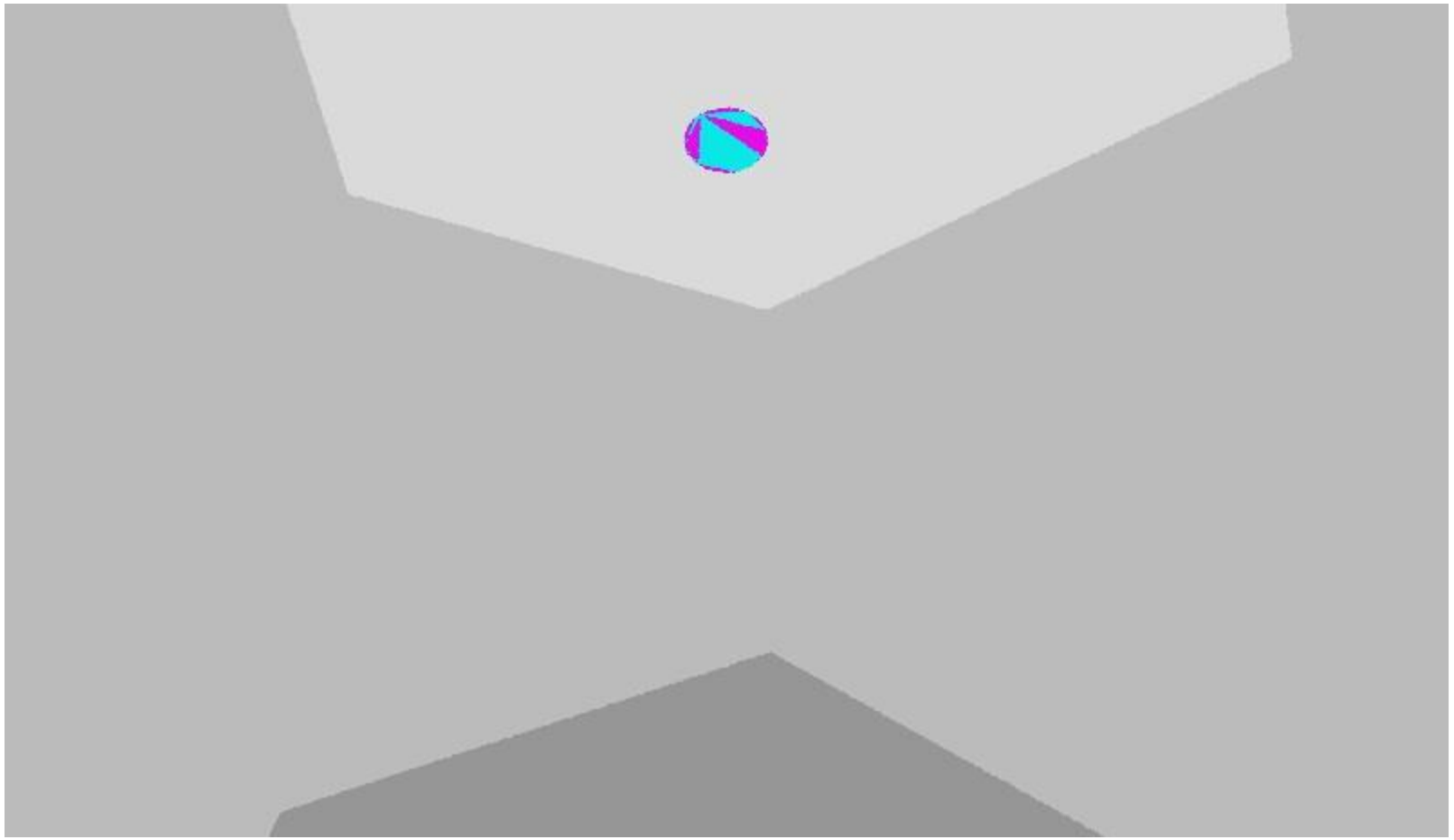
Options #2:
E = 97.8lx
Warning: -

Default options
E = 0lx
Warning: no light sources found

Options #1: defaults & -ab 1 -ad 105000 -dt 0 -ds 1e-4
Options #2: defaults & -ab 1 -ad 105000 -dt 0 -ds 0
Default options (rtace defaults): -dt 0.03 -ds 0.2 -ab 0 -ad 1024

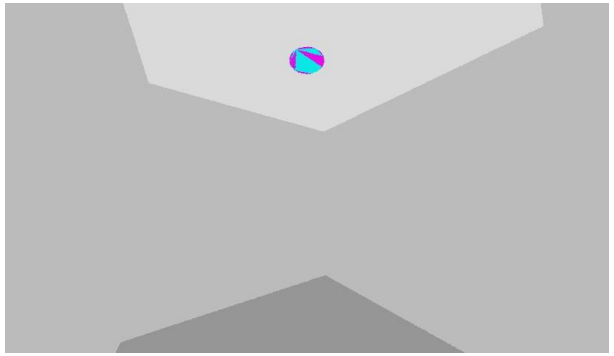
(Simulations without room)

Light source sampling



Light source sampling

light



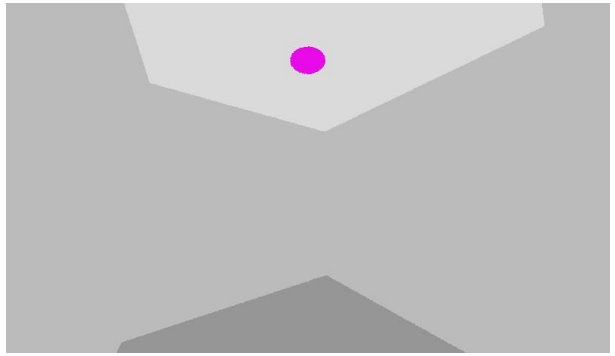
Source geometry: 38 triangles

Options #1:
E = 59.8lx
Warning: aiming failure

Options #2:
E = 99.6lx
Warning: -

Default options
E = 98.9lx
Warning: -

light



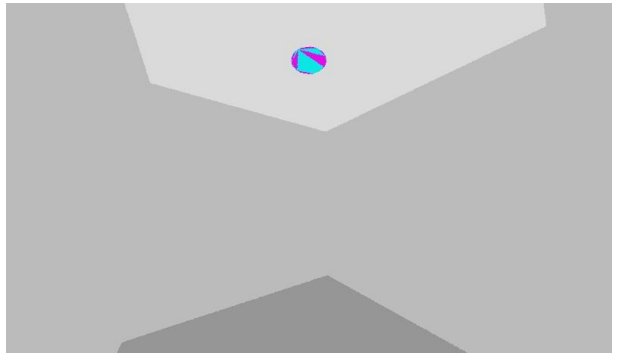
Source geometry: 1 ring

Options #1:
E = 100.0lx
Warning: -

Options #2:
E = 100.4lx
Warning: -

Default options
E = 100.4lx
Warning: -

glow



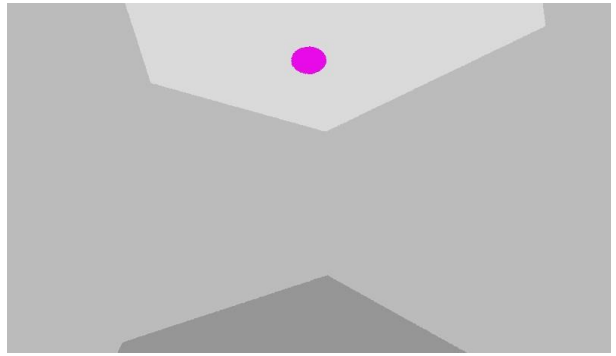
Source geometry: 38 triangles

Options #1:
E = 98.3lx
Warning: aiming failure

Options #2:
E = 98.3lx
Warning: -

Default options
E = 0lx
Warning: no light sources found

glow



Source geometry: 1 ring

Options #1:
E = 99.5lx
Warning: aiming failure

Options #2:
E = 99.5lx
Warning: -

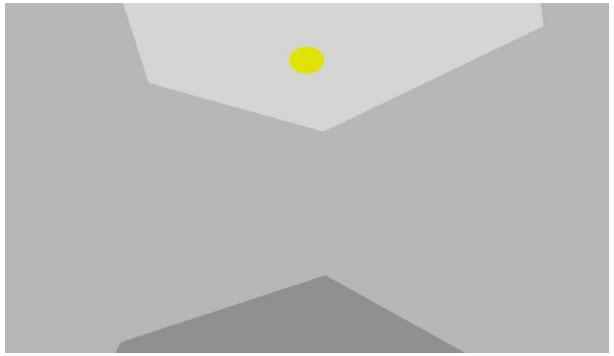
Default options
E = 0lx
Warning: no light sources found

Options #1: defaults & -ab 1 -ad 105000 -dt 0 -ds 1e-4
Options #2: defaults & -ab 1 -ad 105000 -dt 0 -ds 0
Default options (rtace defaults): -dt 0.03 -ds 0.2 -ab 0 -ad 1024

(Simulations without room)

Light source sampling

light



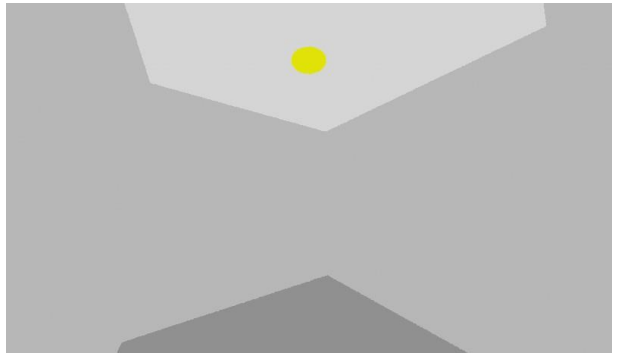
Source geom.: 24-sided polygon

Options #1:
E = 92.7lx
Warning: aiming failure

Options #2:
E = 99.3lx
Warning: -

Default options
E = 99.3lx
Warning: -

glow



Source geom.: 24-sided polygon

Options #1:
E = 98.6lx
Warning: aiming failure

Options #2:
E = 98.6lx
Warning: -

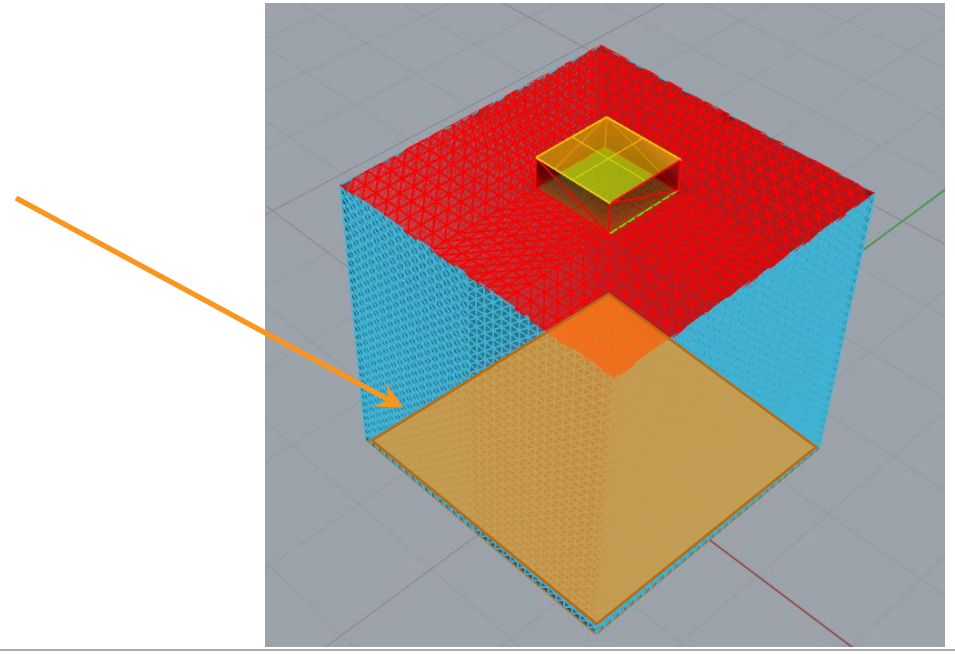
Default options
E = 0lx
Warning: no light sources found

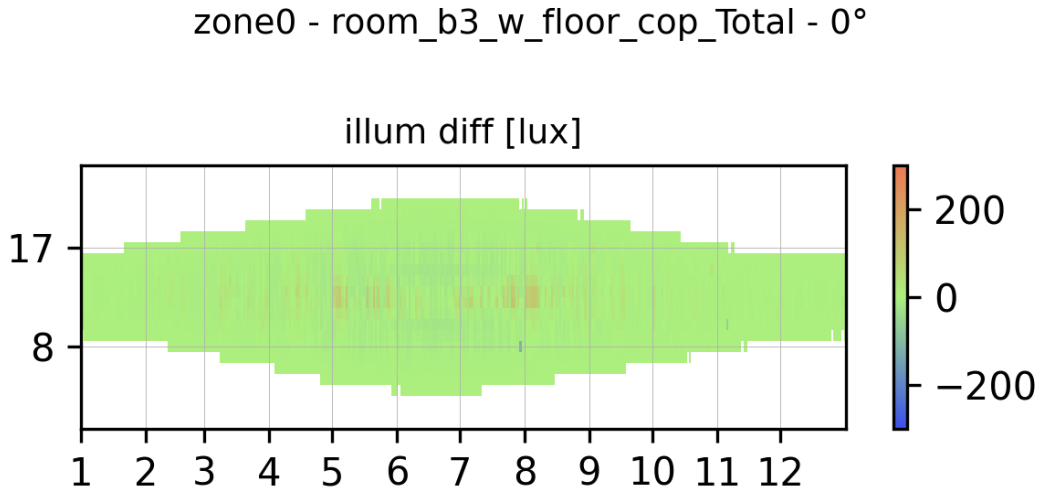
Options #1: defaults & -ab 1 -ad 105000 -dt 0 -ds 1e-4
Options #2: defaults & -ab 1 -ad 105000 -dt 0 -ds 0
Default options (rtace defaults): -dt 0.03 -ds 0.2 -ab 0 -ad 1024

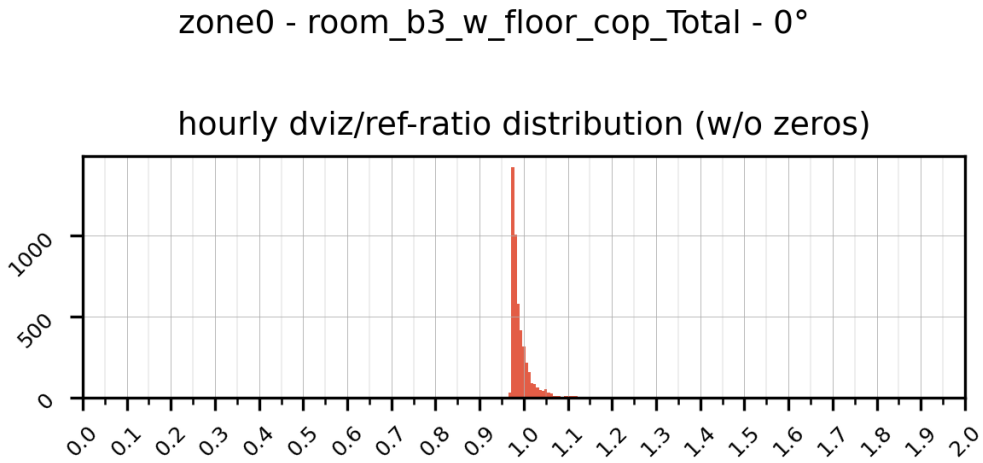
(Simulations without room)

Comparison for simple test box

- Interior results are good



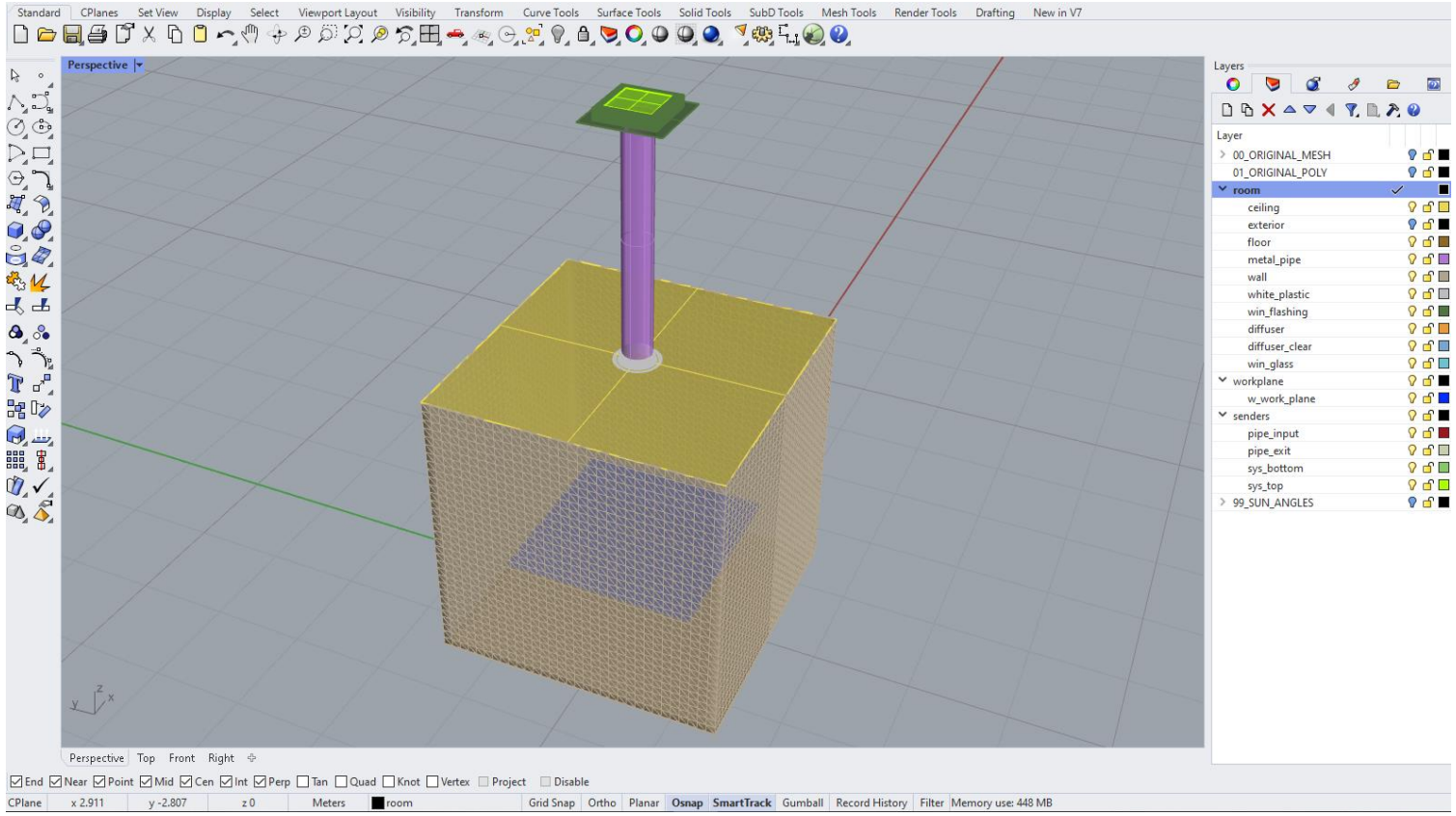




TAI_{dviz} - TAI_{ref}	TAI_{dviz}/TAI_{ref}	avg diff	mean diff	std diff
5869.285	1.004	1.260	1.260	13.398

VELUX Daylight Visualizer Validation – Next steps

- Simple test scene comparison successful
- Light pipe results are still off
  - Gathering of caustic photons is currently an issue
- Resume validation work
  - Light pipe shapes
  - Various diffuser materials (BSDFs)
  - Analyze for different climates



Discussion

Ideas for implementation of improved source sampling:

Triangles / polygons:

- Triangulation for polygons
- Rejection sampling
- Force –ds 0 for triangles
- Force –ds 0 for all polygons with ≠ 4 vertices

Circular sources:

- Shirley-Chiu mapping for circular sources

rtrace: warning - aiming failure for light source