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INSTITUTE OF ENGINEERING; UNIVERSITY OF ALGARVE; CAMPUS DA PENHA; FARO-PORTUGAL

RAYTRACING OPTICAL ANALYSIS OF A SOLAR FUNNEL COOKER

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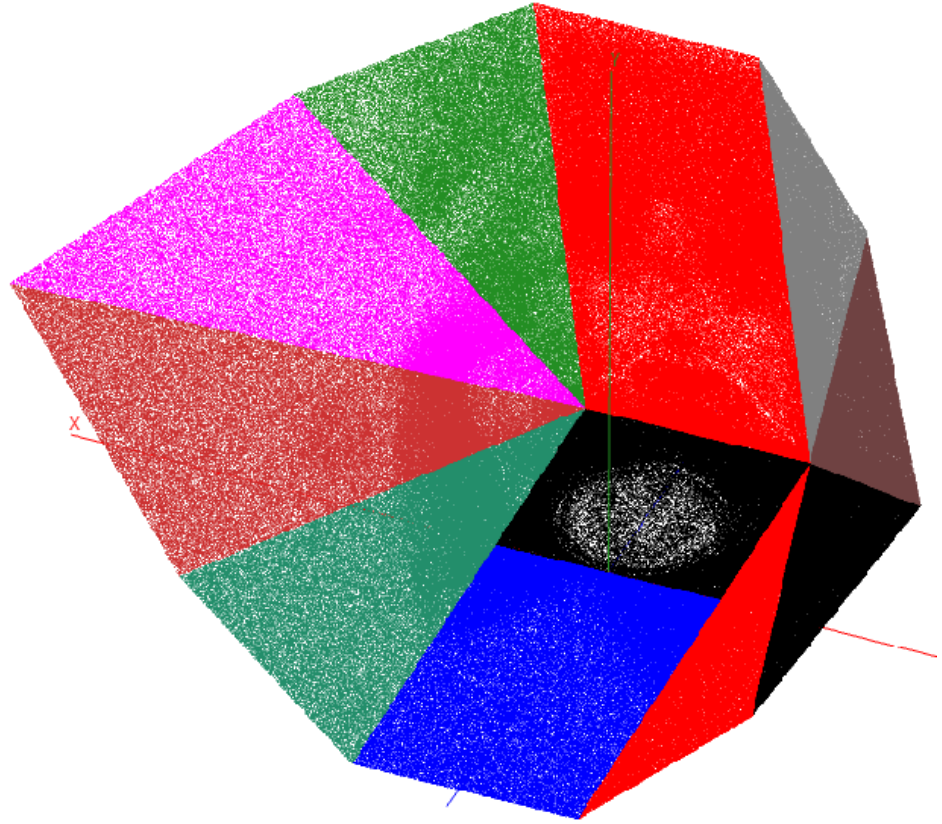
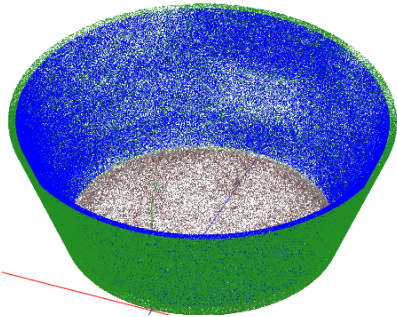
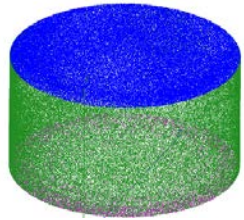
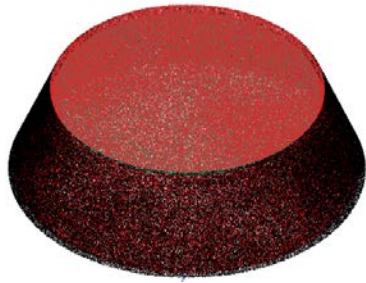
Optical Analysis of a Funnel Solar Cooker using Raytracing



**SolTrace: A Ray-Tracing Code
for Complex Solar Optical
Systems**



NREL Soltrace model of the funnel solar cooker



NREL Soltrace model input data

SolTrace 2012.7.9 : C:/Users/ACA/Dropbox/INV/COCCINA SOLAR/_SOLTRACE/_RAYTRAX02/CASOS/0420/raytracing_cocina.stinput

File Run Optics Stage Help

Sun Shape

Optical Properties

- Reflector
- Olla
- Vidrio front
- Vidrio back

System Stages

- Etapa Unica**
- Etapa X
- Etapa de conteo

Trace Options

Results

- Intersections
- Flux Maps
- Ray Data
- Scripting
- Help

Stage Properties

Name: Etapa Unica

Virtual stage

Multiple hits per ray

Trace through

Global Coordinates

Origin X: 0.000000 Y: 0.000000 Z: 0.000000

Aim point X: 0.017452 Y: 0.000000 Z: 0.999848

Z rotation: 0.000000 deg

Clipboard actions: Copy Paste

Element Editing

Insert... Z Rotation...

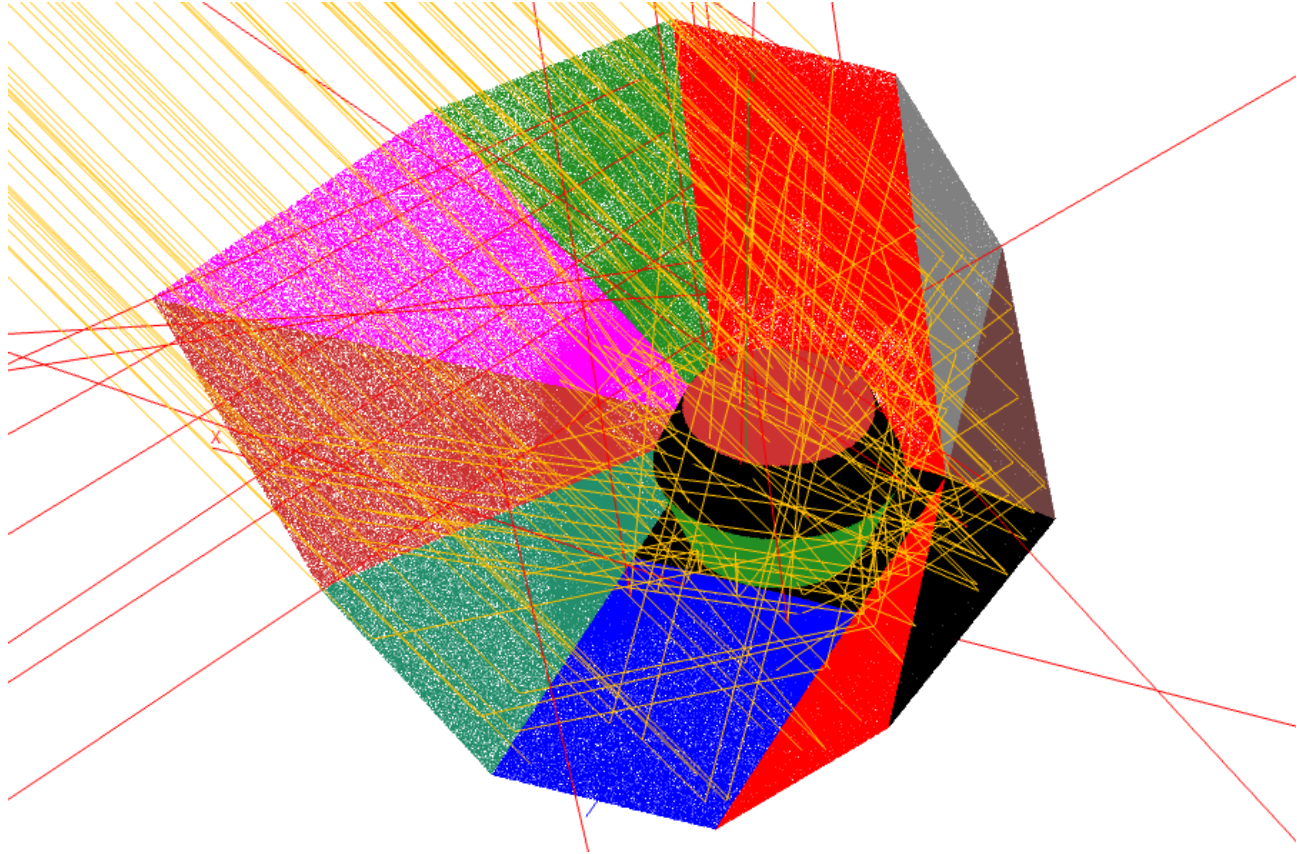
Append... Aperture...

Delete... Surface...

Delete all Optics...

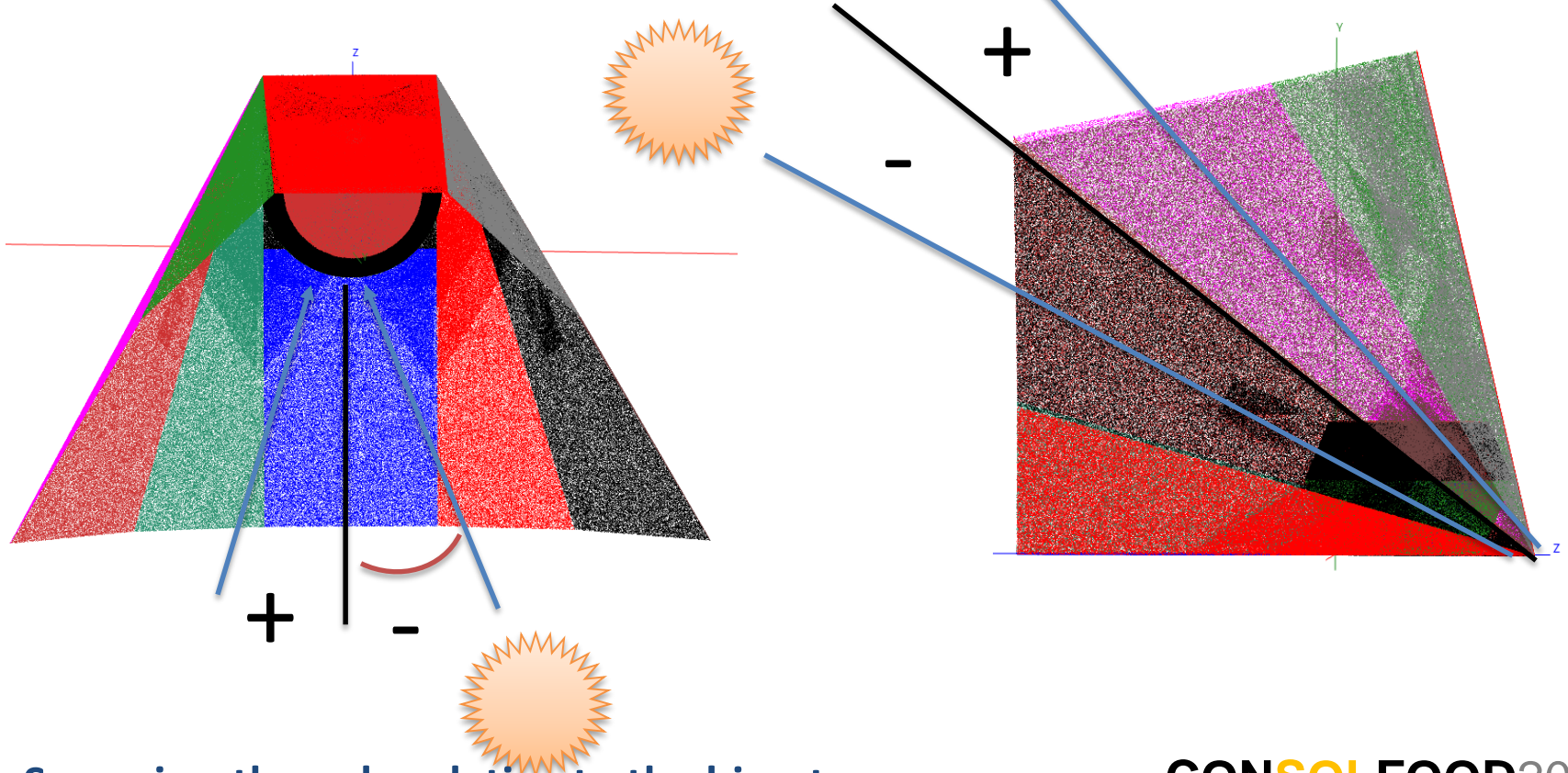
	En.	X-Coord.	Y-Coord.	Z-Coord.	X-AimPt.	Y-AimPt.	Z-AimPt.	Z-Rot.	Aperture	Surface	Interaction	Oj
1	<input checked="" type="checkbox"/>	0	0	0.125	0	1	0.125	0	r-0.25,0.25,0,0,0,0,0,0	f-0,0,0,0,0,0,0,0	Reflection	Reflecto
2	<input checked="" type="checkbox"/>	0	0.3163	0.1755	0	0.08698	-0.7979	0	r-0.25,0.65,0,0,0,0,0,0	f-0,0,0,0,0,0,0,0	Reflection	Reflecto
3	<input checked="" type="checkbox"/>	0	0	-0.2	0	1	-0.2	0	r-0.25,0.4,0,0,0,0,0,0	f-0,0,0,0,0,0,0,0	Reflection	Reflecto
4	<input checked="" type="checkbox"/>	0.125	0	0.25	0.002646	-0.0287	0.1282	-9.4	i-0,0,0,0.65,-0.2692,0.65,0,0	f-0,0,0,0,0,0,0,0	Reflection	Reflecto
5	<input checked="" type="checkbox"/>	0.125	0	0.25	-0.0892	5.105e-05	0.126	-10.6	i-0,0,-0.2692,0.65,-0.65,0.65,...	f-0,0,0,0,0,0,0,0	Reflection	Reflecto
6	<input checked="" type="checkbox"/>	0.125	0	0.25	-0.0892	0.1207	0.2215	-4.6	i-0,0,-0.65,0.65,-0.65,0.2692,...	f-0,0,0,0,0,0,0,0	Reflection	Reflecto
7	<input checked="" type="checkbox"/>	0.125	0	0.25	0.002646	0.1251	0.25	0	i-0,0,-0.65,0.2692,-0.65,0,0,0	f-0,0,0,0,0,0,0,0	Reflection	Reflecto
8	<input checked="" type="checkbox"/>	-0.125	0	0.25	-0.002646	-0.0287	0.1282	9.4	i-0,0,0.2692,0.65,0,0.65,0,0	f-0,0,0,0,0,0,0,0	Reflection	Reflecto
9	<input checked="" type="checkbox"/>	-0.125	0	0.25	0.0892	5.105e-05	0.126	10.6	i-0,0,0.65,0.65,0.2692,0.65,0,0	f-0,0,0,0,0,0,0,0	Reflection	Reflecto
10	<input checked="" type="checkbox"/>	-0.125	0	0.25	0.0892	0.1207	0.2215	4.6	i-0,0,0.65,0.2692,0.65,0.65,0,0	f-0,0,0,0,0,0,0,0	Reflection	Reflecto
11	<input checked="" type="checkbox"/>	-0.125	0	0.25	-0.002646	0.1251	0.25	0	i-0,0,0.65,0,0.65,0.2692,0,0	f-0,0,0,0,0,0,0,0	Reflection	Reflecto
12	<input checked="" type="checkbox"/>	0	0.126	0.09178	0	1.126	0.09178	0	c-0.19,0,0,0,0,0,0,0	f-0,0,0,0,0,0,0,0	Reflection	Olla
13	<input checked="" type="checkbox"/>	0	0.076	-0.003219	0	0.076	0.9968	0	l-0,0,0.1,0,0,0,0,0	t-10.5263,0,0,0,0,0,0,0	Reflection	Olla
14	<input checked="" type="checkbox"/>	0	0.026	0.09178	0	0.974	0.09178	0	c-0.19,0,0,0,0,0,0,0	f-0,0,0,0,0,0,0,0	Reflection	Olla
15	<input checked="" type="checkbox"/>	0	0.167	0.09178	0	1.167	0.09178	0	c-0.2,0,0,0,0,0,0,0	f-0,0,0,0,0,0,0,0	Refraction	Vidrio bi
16	<input checked="" type="checkbox"/>	0	0.162	0.09178	0	0.838	0.09178	0	c-0.1941,0,0,0,0,0,0,0	f-0,0,0,0,0,0,0,0	Refraction	Vidrio bi
17	<input checked="" type="checkbox"/>	0	0.006	0.09178	0	1.006	0.09178	0	c-0.1777,0,0,0,0,0,0,0	f-0,0,0,0,0,0,0,0	Refraction	Vidrio bi

NREL Soltrace Ray-tracing of the funnel solar cooker



Sun elevation and sun azimuth angles relative to the cooker

Sun elevation angle relative to the bisector



Sun azimuth angle relative to the bisector

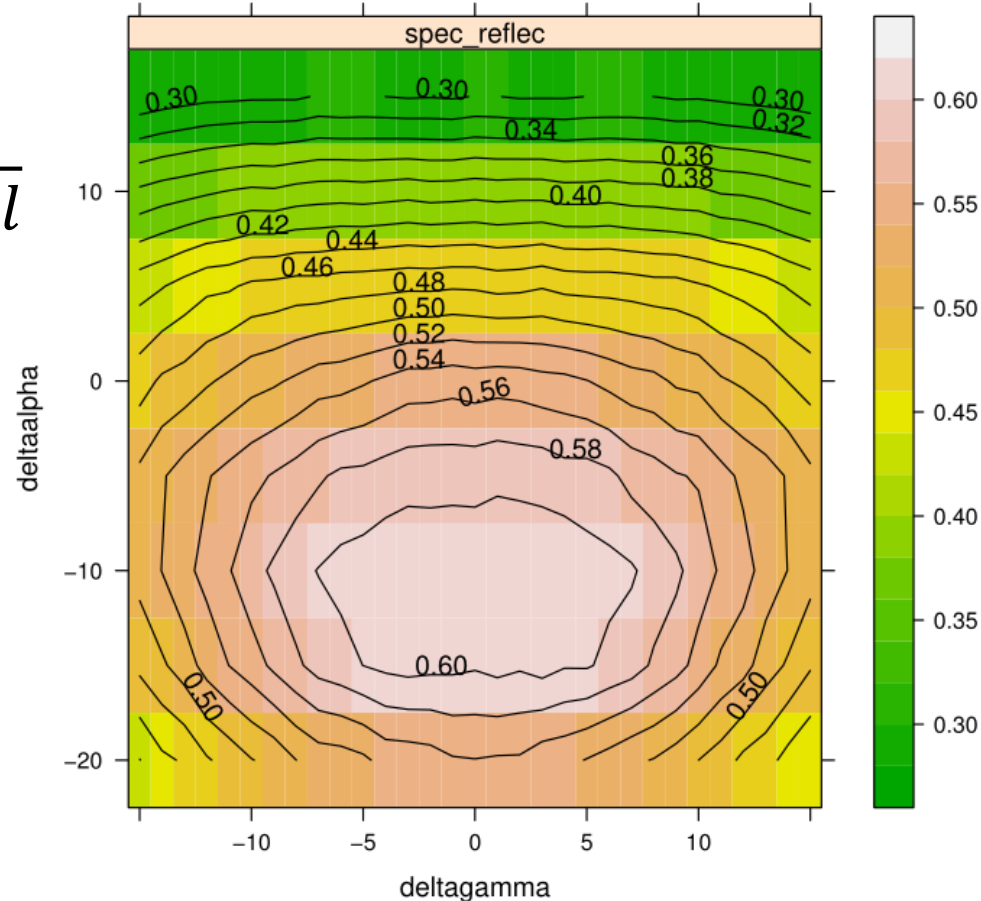
Optical efficiency with perfect optics, perfect geometry

$$\eta_{opt} = \frac{\text{Pow absorbed in pot}}{\text{Pow on aperture normal}}$$

Panels ref ρ : 1

Glass trans τ : 1

Pot abs α : 1



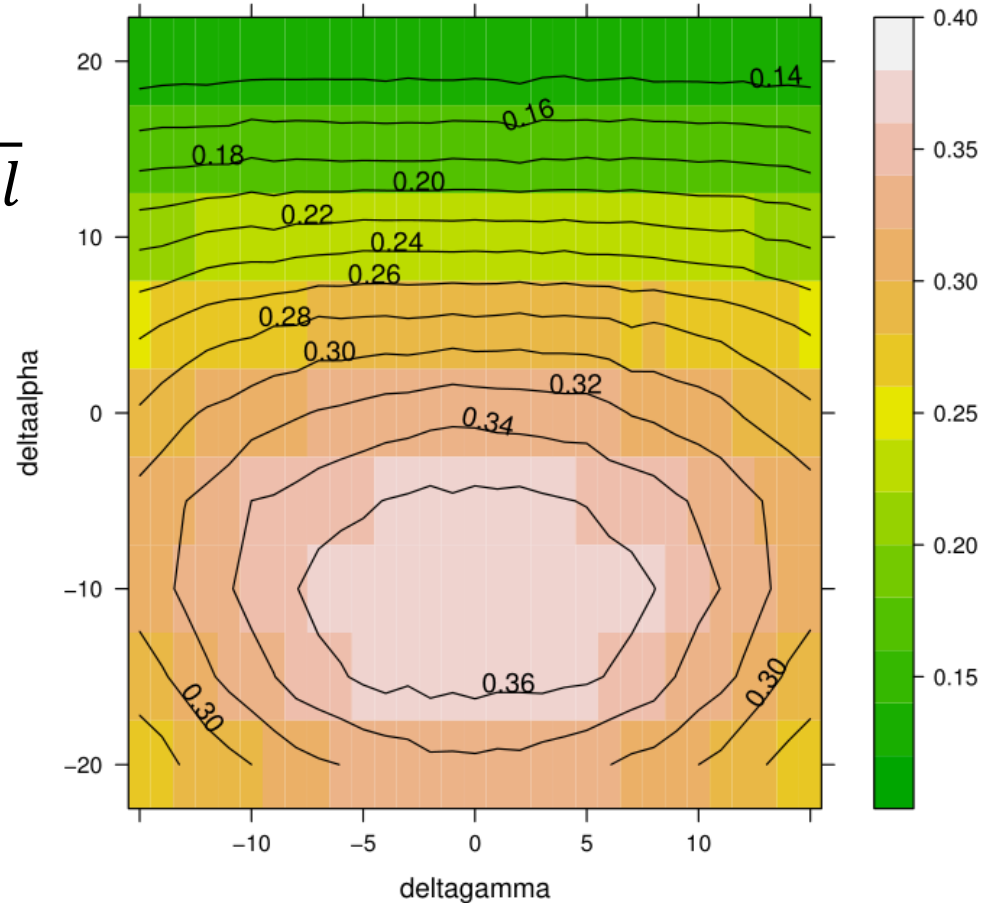
Optical efficiency with non perfect optics, perfect geometry

$$\eta_{opt} = \frac{\text{Pow absorbed in pot}}{\text{Pow on aperture normal}}$$

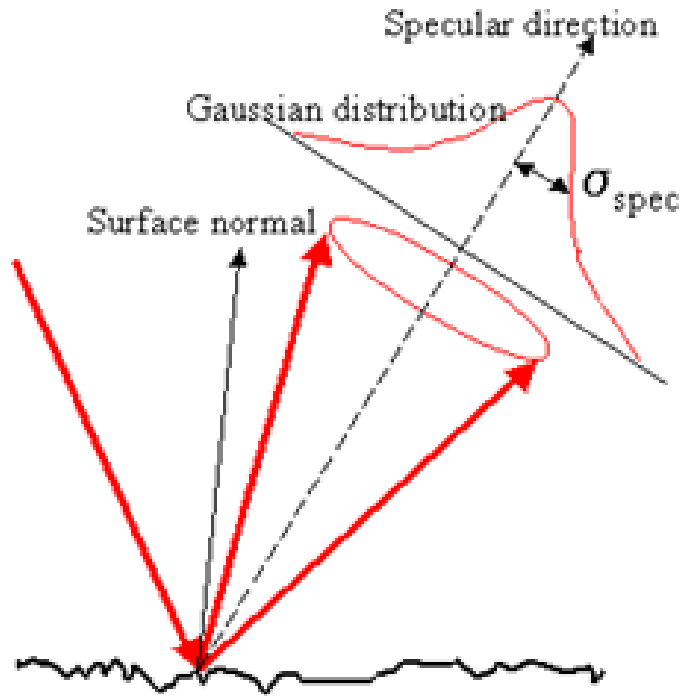
Panels ref ρ : **0.85**

Glass trans τ : **0.85**

Pot abs α : **0.9**



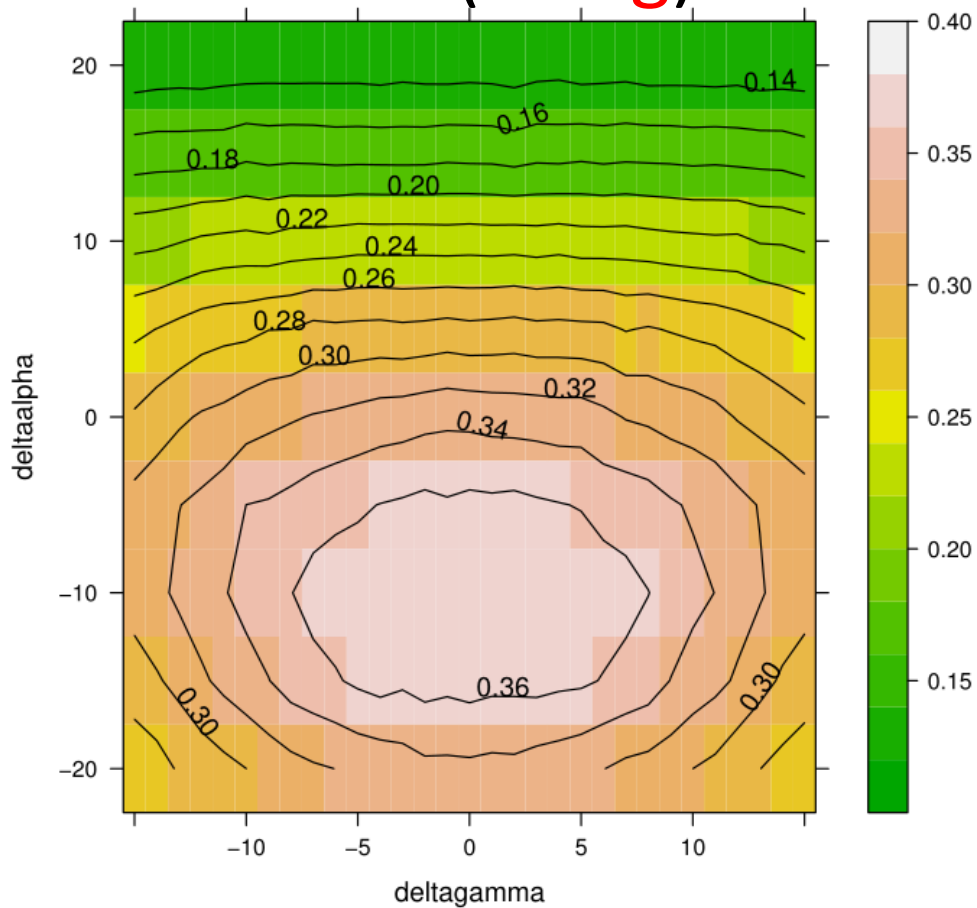
Optical efficiency with non perfect optics and specular errors



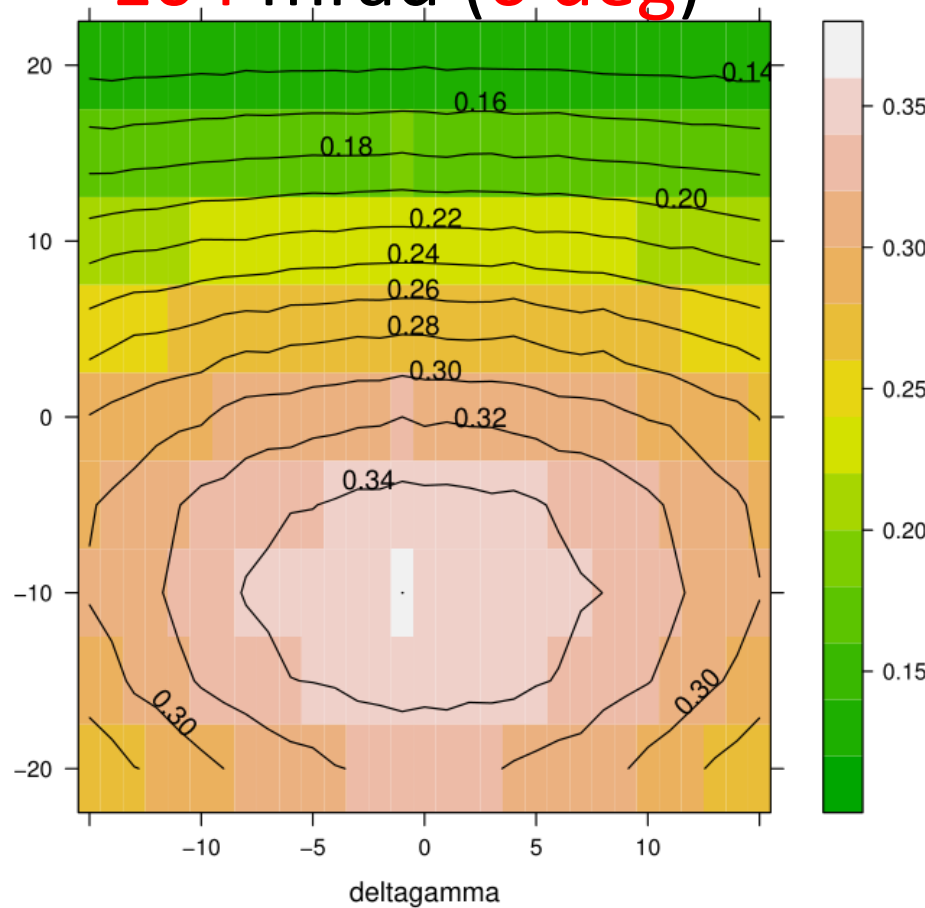
104 mrad (6 deg)

Effect of the specular errors on the optical efficiency

0 mrad (0 deg)



104 mrad (6 deg)



Simple check on the cooking power at delta temp = 0 C

Normal aperture area : 0,55 m²

TEST RESULTS

G = 700W DT = 0 $P_s = 100$ W

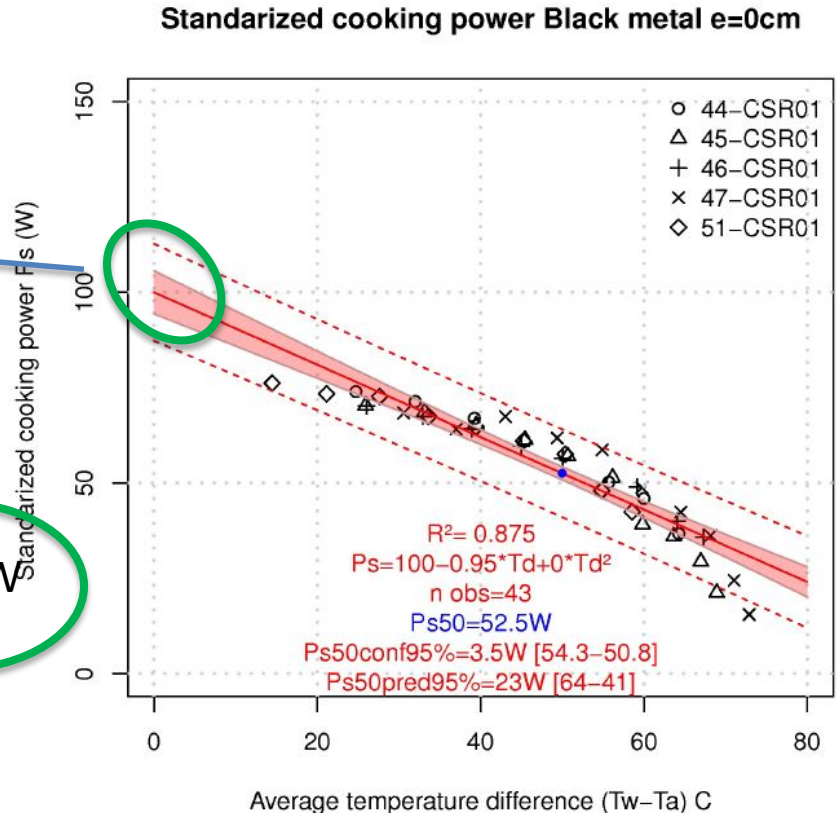
RAYTRACING

Beam fraction 85% GB = 595 W

Neglect diffuse fraction GD = 0 W

Optical efficiency $\eta_{op} \approx 35\%$

Power absorbed = $0,35 * 0,55 * 595 = 114,5$ W



Conclusions and perspectives

Optical efficiency is around **35%** at peak

The **'sweet spot'** is **quite wide** and located about 10 deg below the bisector angle of the funnel

Specular errors do not reduce much the efficiency

The **raytracing results** are compatible with the results from experimental testing

Raytracing models support the understanding of experimental results

Future work: transparent lid, elevation of the receiver, summer configuration of the cooker, other cookers, optimization of the reflector

...