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Advances in Solar Thermal Food Processing

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

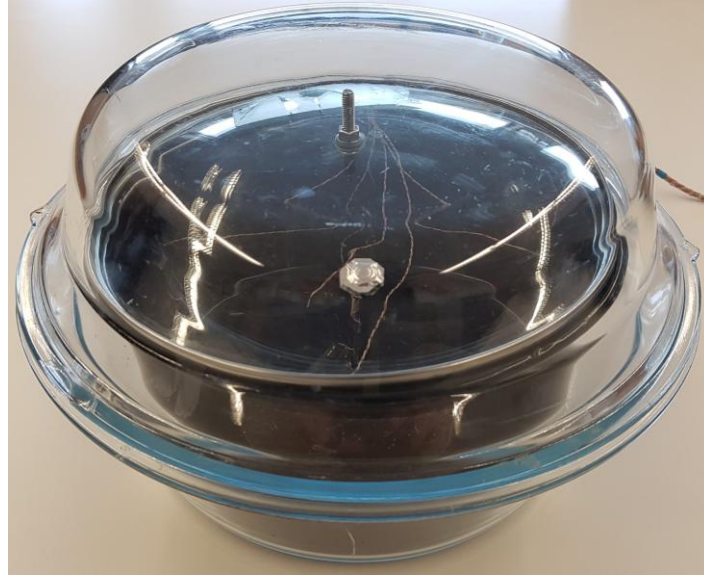
RAYTRACING OPTICAL ANALYSIS OF A SOLAR FUNNEL COOKER

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¹ University of Málaga

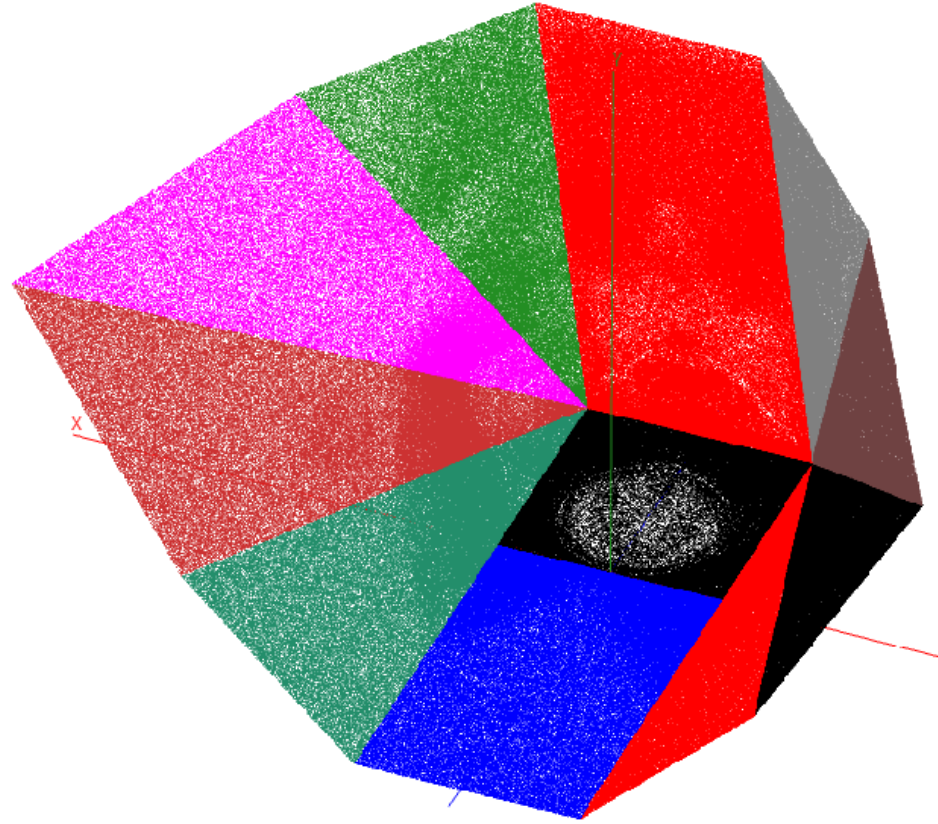
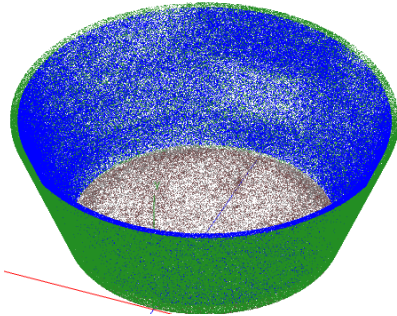
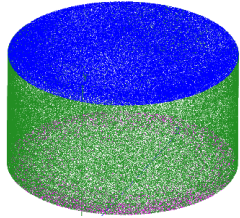
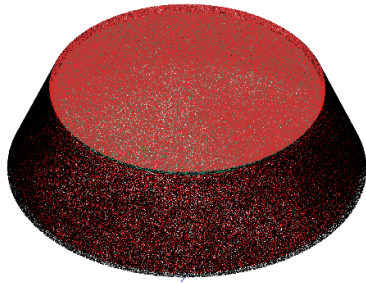
² University of Algarve

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/_COCINA SOLAR/_SOLTRACE/_RAYTRAX02/CASOS/0420/raytracing_cocina.stinput

File Run Optics Stage 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...

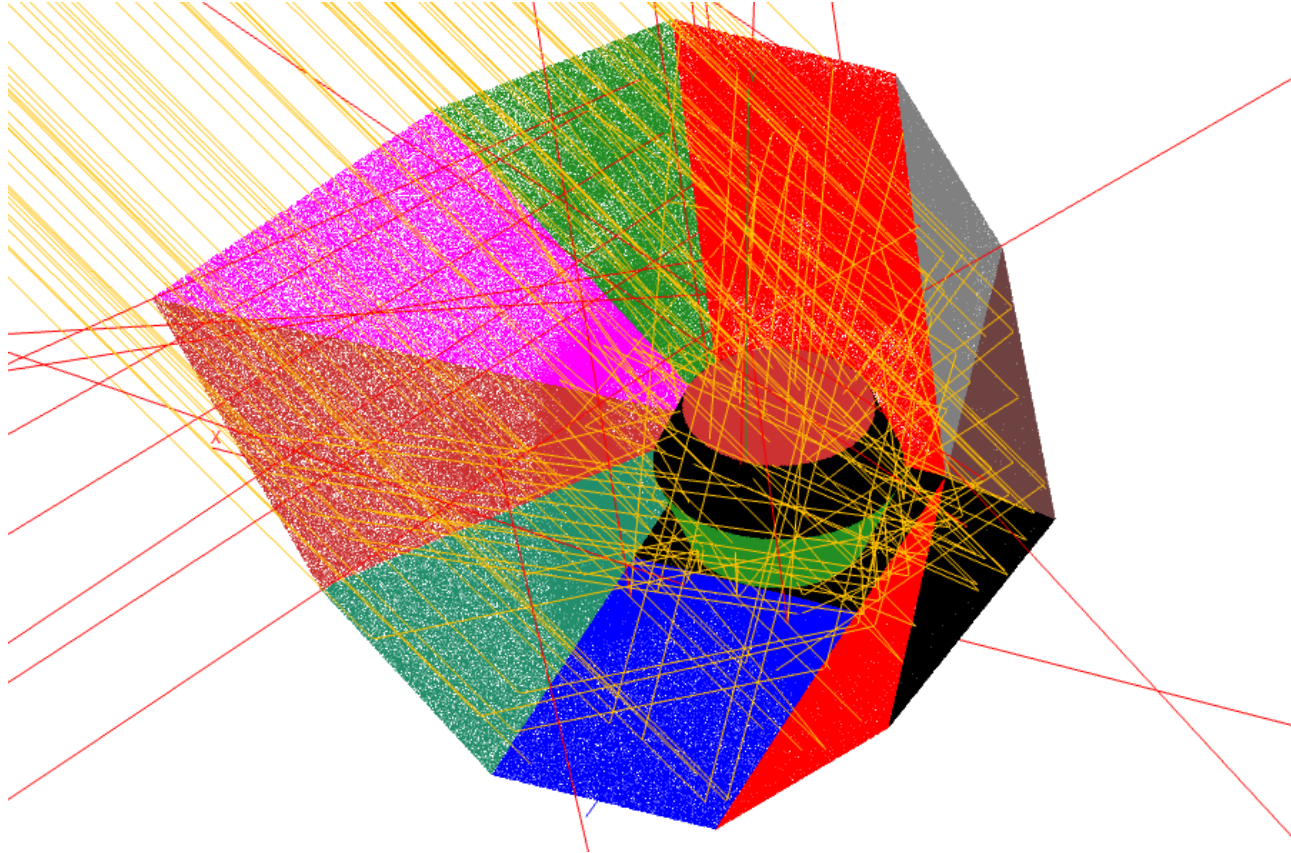
Append... Aperture...

Delete... Surface...

Delete all Optics...

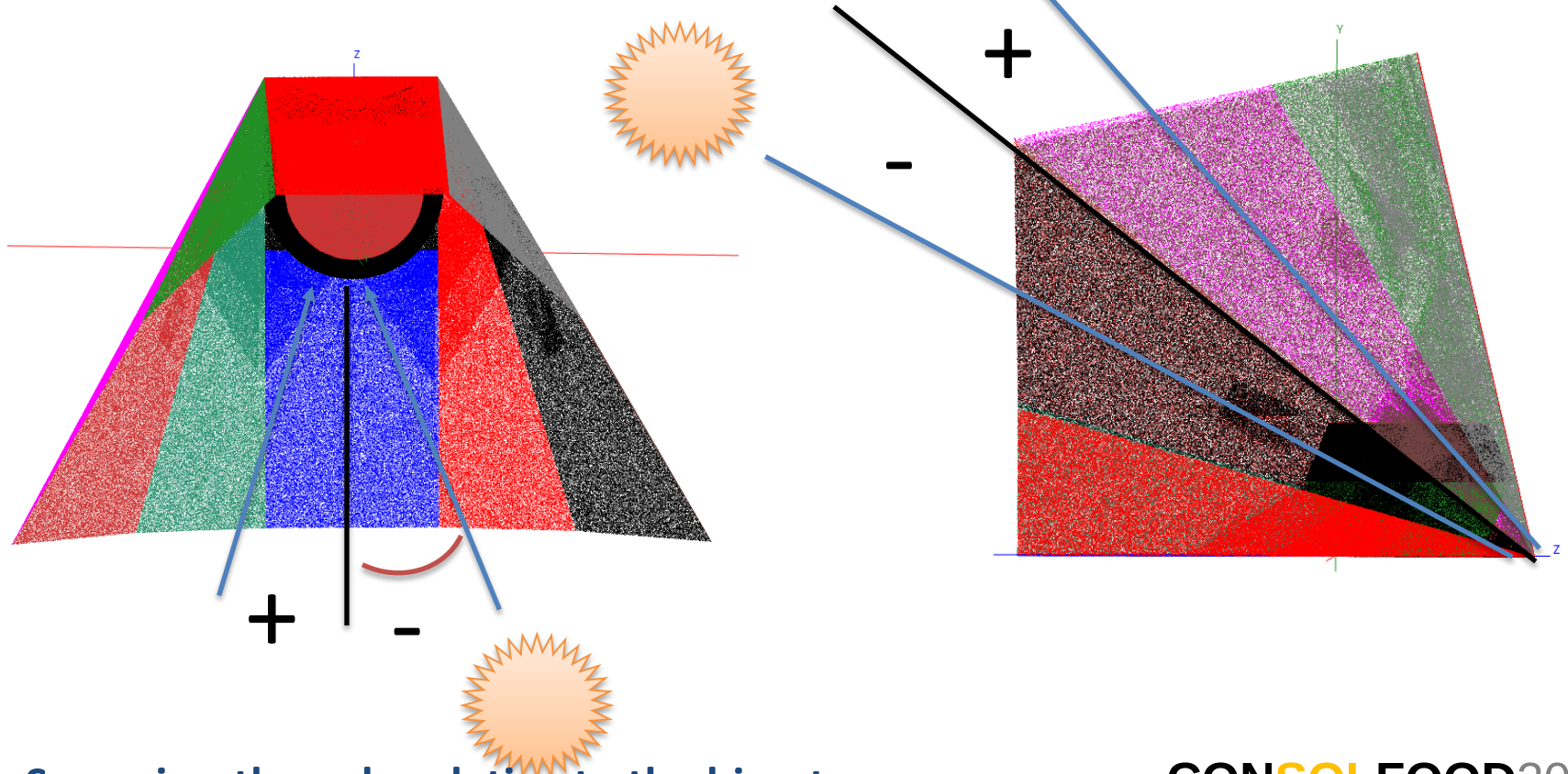
	En.	X-Coord.	Y-Coord.	Z-Coord.	X-AimPt.	Y-AimPt.	Z-AimPt.	Z-Rot.	Aperture	Surface	Interaction	Obj
1	☒	0	0	0.125	0	1	0.125	0	r-0.25,0.25,0,0,0,0,0	f-0,0,0,0,0,0,0	Reflection	Reflect
2	☒	0	0.3163	0.1755	0	0.08698	-0.7979	0	r-0.25,0.65,0,0,0,0,0	f-0,0,0,0,0,0,0	Reflection	Reflect
3	☒	0	0	-0.2	0	1	-0.2	0	r-0.25,0.4,0,0,0,0,0	f-0,0,0,0,0,0,0	Reflection	Reflect
4	☒	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	Reflection	Reflect
5	☒	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	Reflection	Reflect
6	☒	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	Reflection	Reflect
7	☒	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	Reflection	Reflect
8	☒	-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	Reflection	Reflect
9	☒	-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	Reflection	Reflect
10	☒	-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	Reflection	Reflect
11	☒	-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	Reflection	Reflect
12	☒	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	Reflection	Olla
13	☒	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	☒	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	Reflection	Olla
15	☒	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	Refraction	Vidrio ba
16	☒	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	Refraction	Vidrio ba
17	☒	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	Refraction	Vidrio ba

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

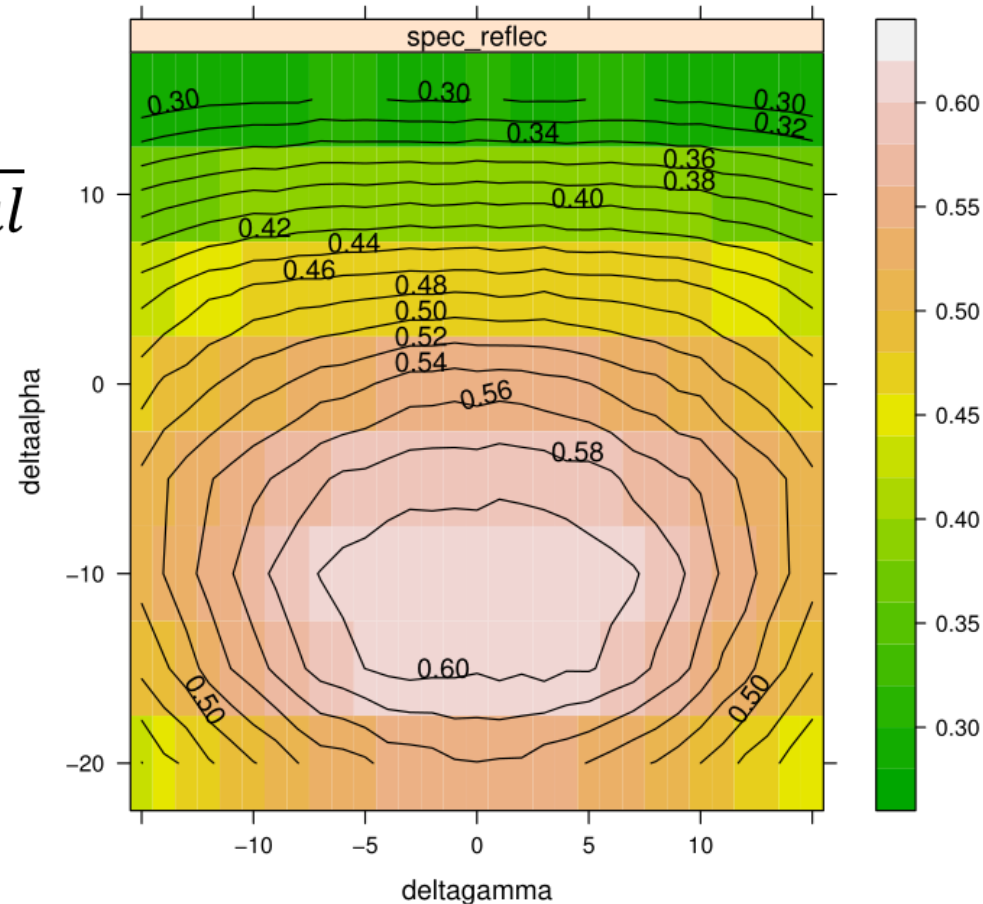
Optical efficiency with perfect optics, perfect geometry

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

Panels ref ρ : 1

Glass trans τ : 1

Pot abs α : 1



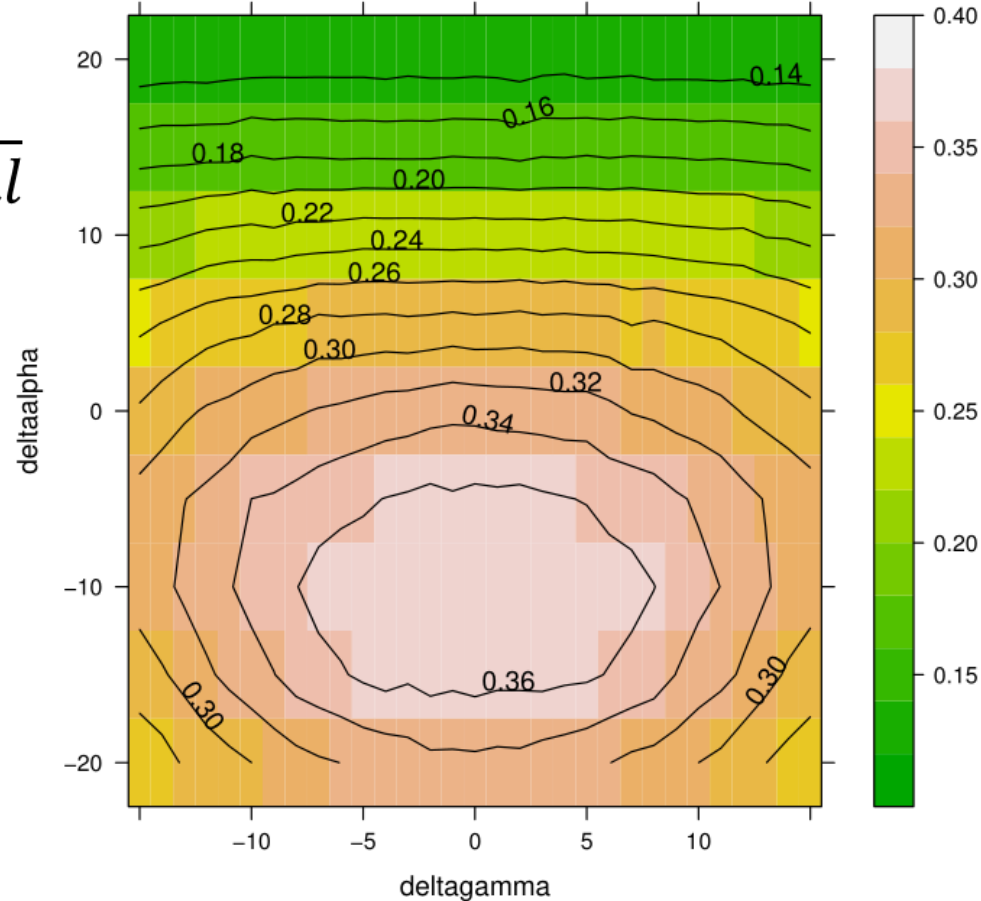
Optical efficiency with non perfect optics, perfect geometry

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

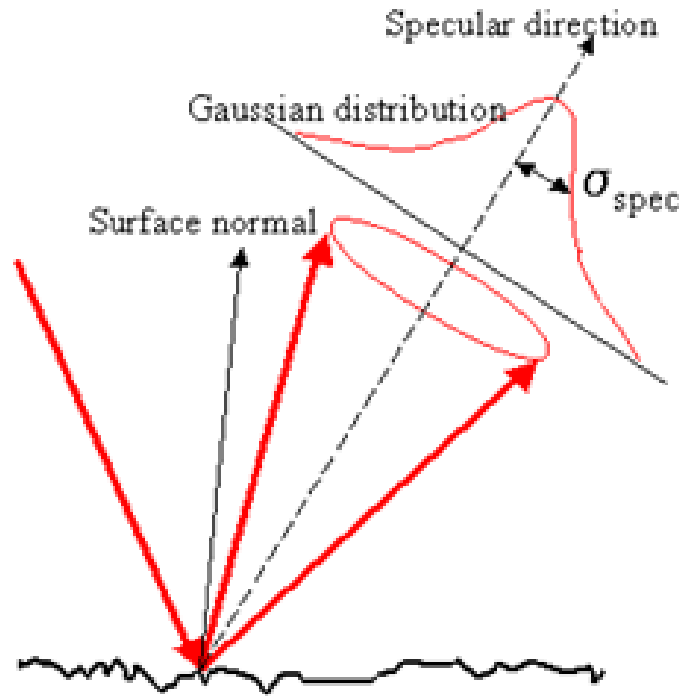
Panels ref ρ : 0.85

Glass trans τ : 0.85

Pot abs α : 0.9



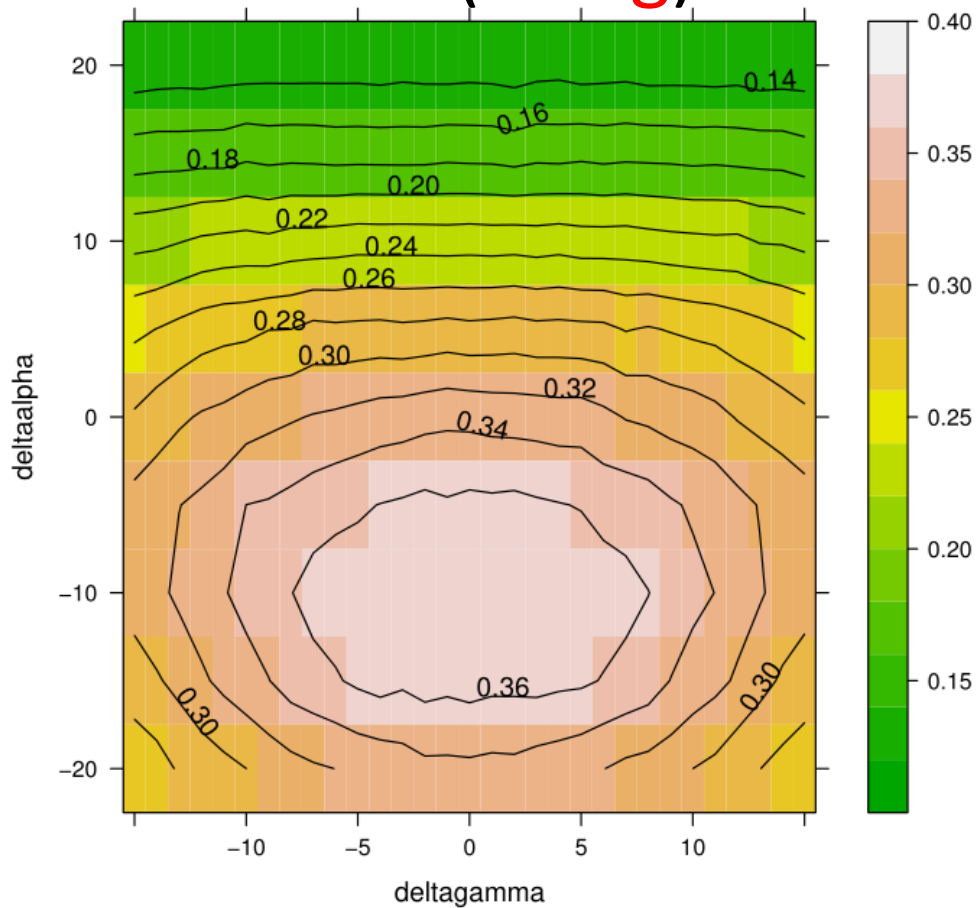
Optical efficiency with non perfect optics and specular errors



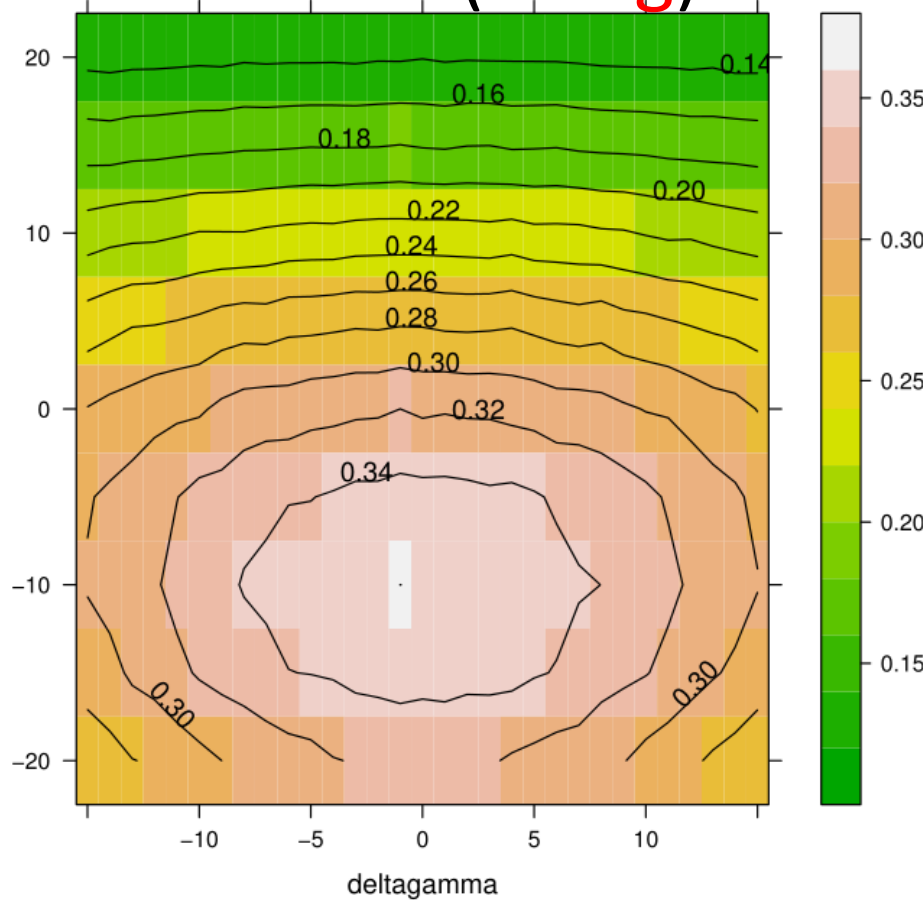
104 mrad (6 deg)

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

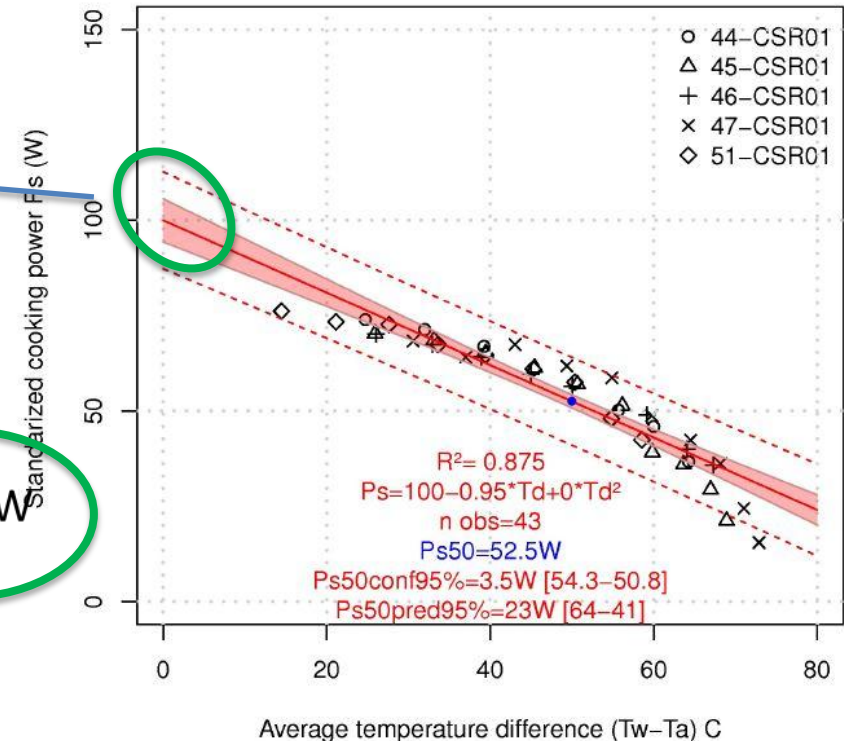
Beam fraction 85% GB = 595 W

Neglect diffuse fraction GD = 0 W

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

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

Standardized cooking power Black metal e=0cm



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

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