"CHARACTERIZATION OF CPC SOLAR CONCENTRATORS BY A LASER METHOD"

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OUTLINE

Introduction

The “direct” method of optical characterization

The “laser” method of optical characterization

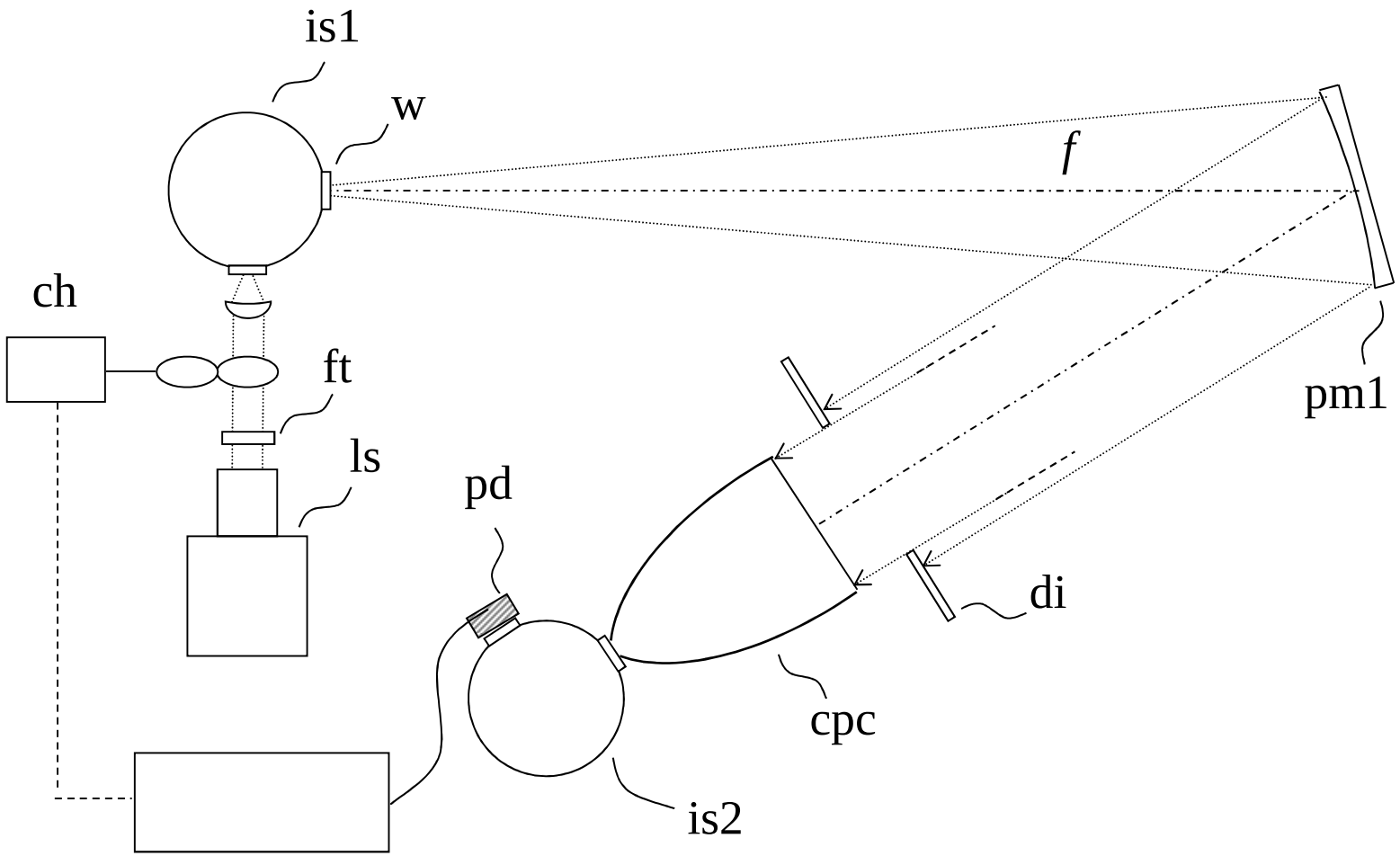
Application to a Truncated and Squared CPC

Conclusions

INTRODUCTION

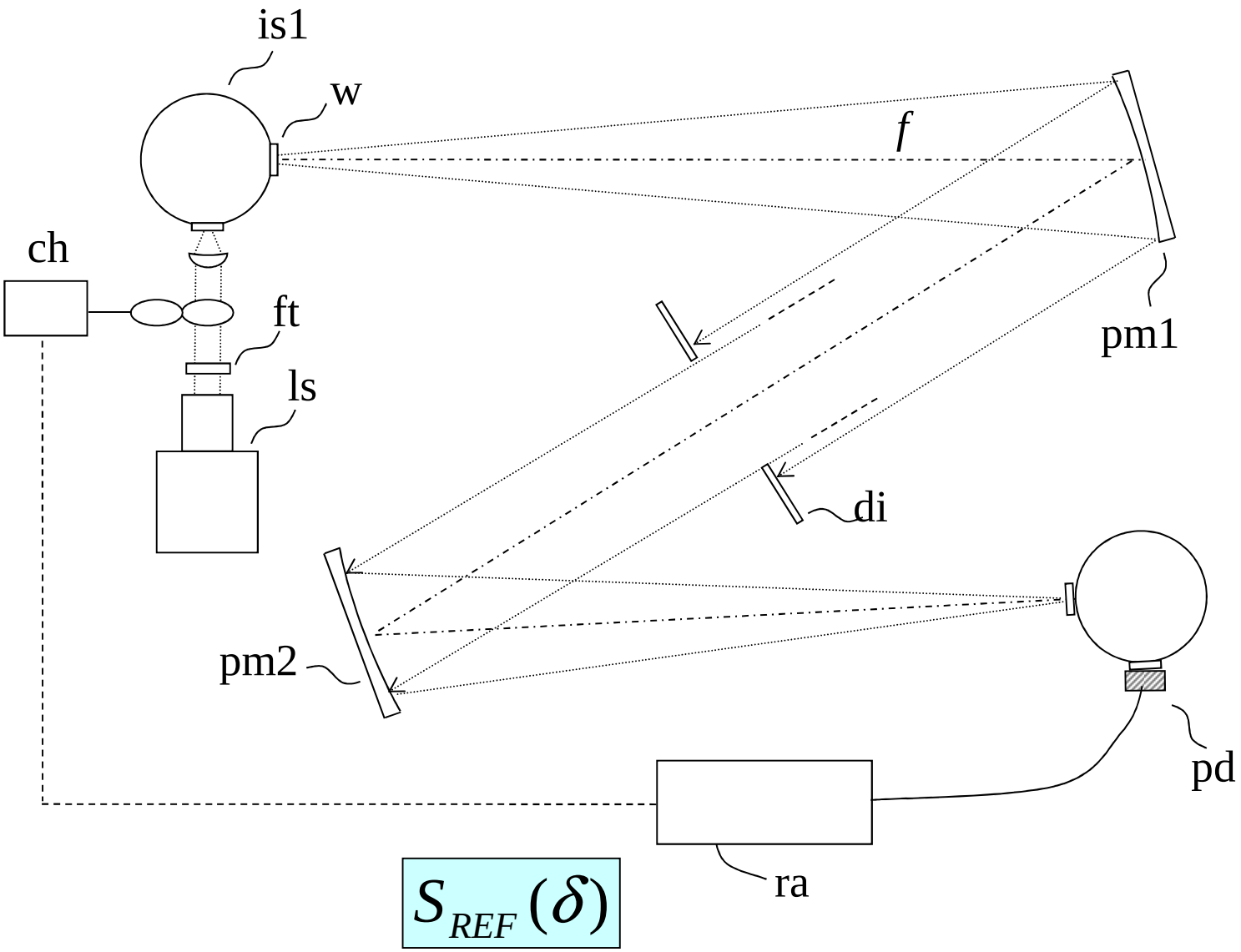
DIRECT METHOD FOR OPTICAL CHARACTERIZATION OF SOLAR CONCENTRATORS

Measurement of output flux



$S_{CPC}(\delta)$

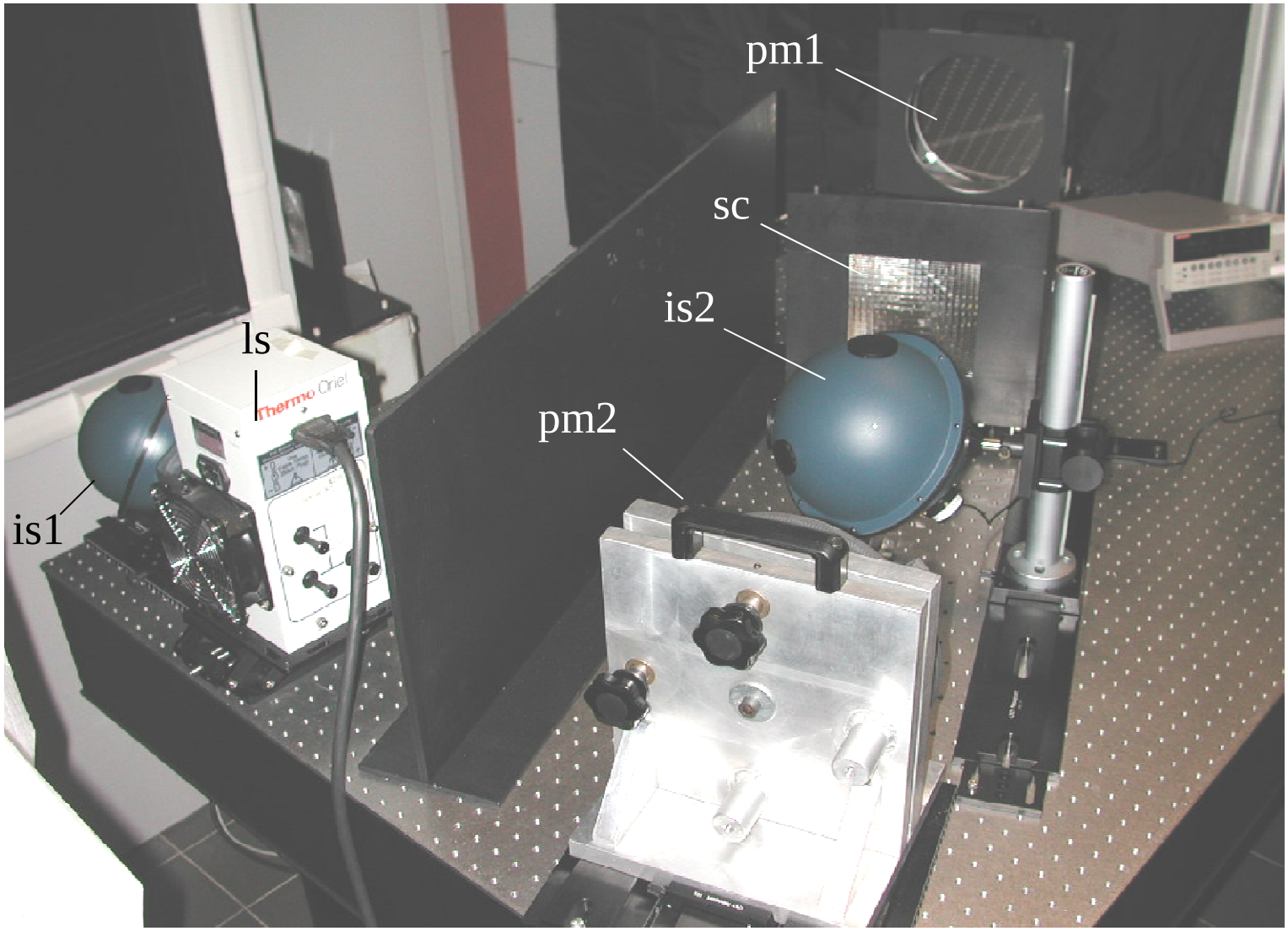
Measurement of input flux



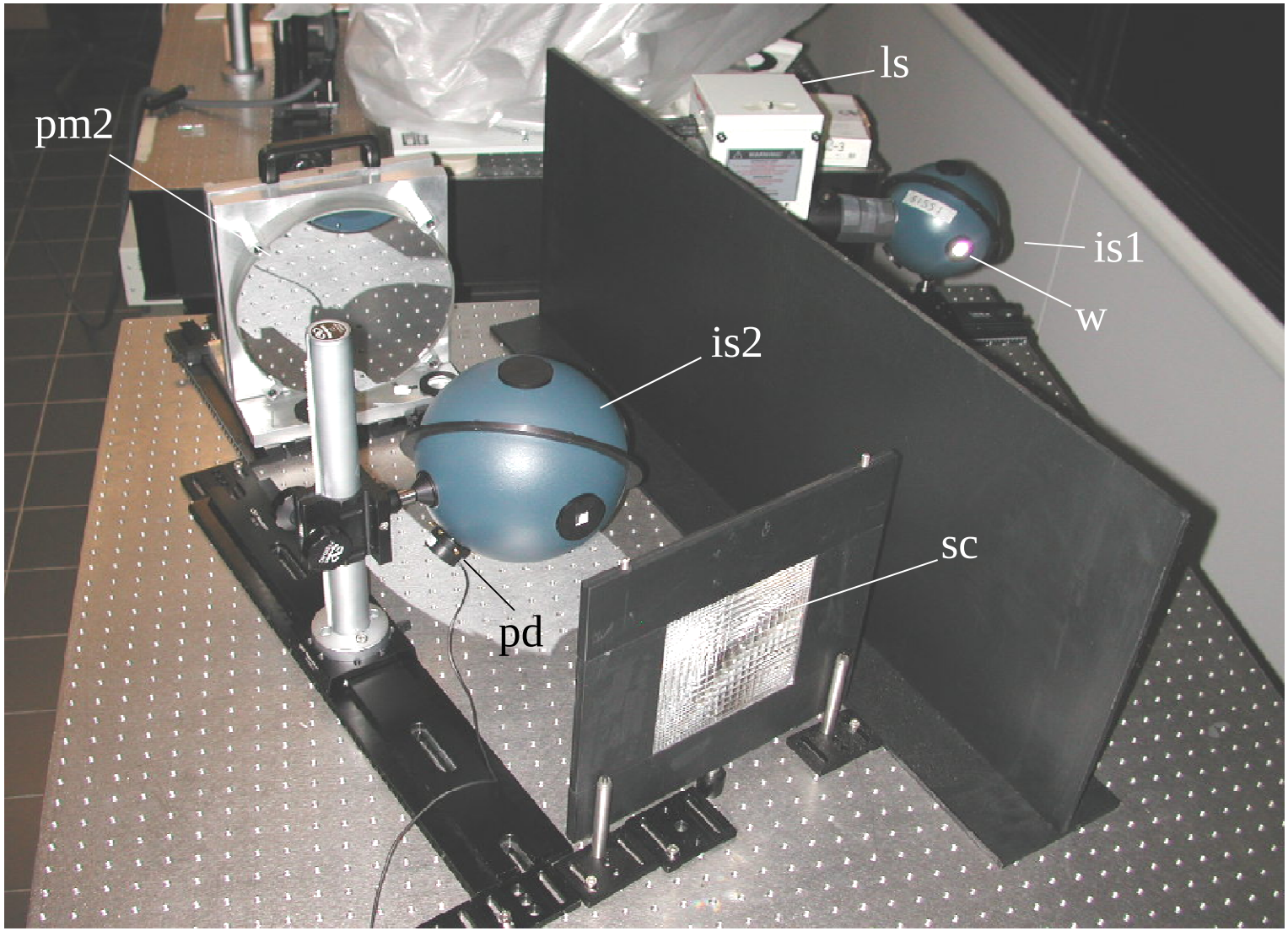
Optical efficiency as function of incidence angle δ

$$\eta(\delta) = S_{CPC}(\delta) \cdot \frac{R_{pm}}{S_{REF} \cdot \cos\delta}$$

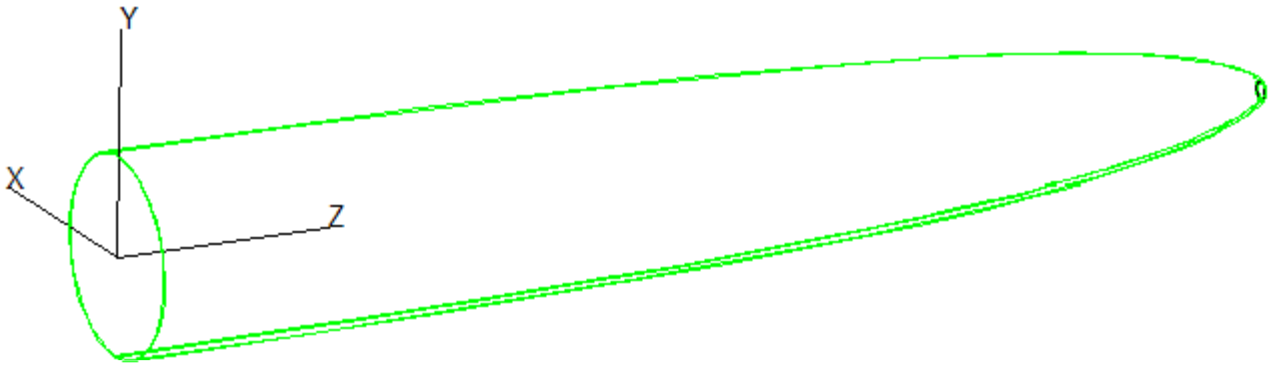
The optical apparatus



The optical apparatus

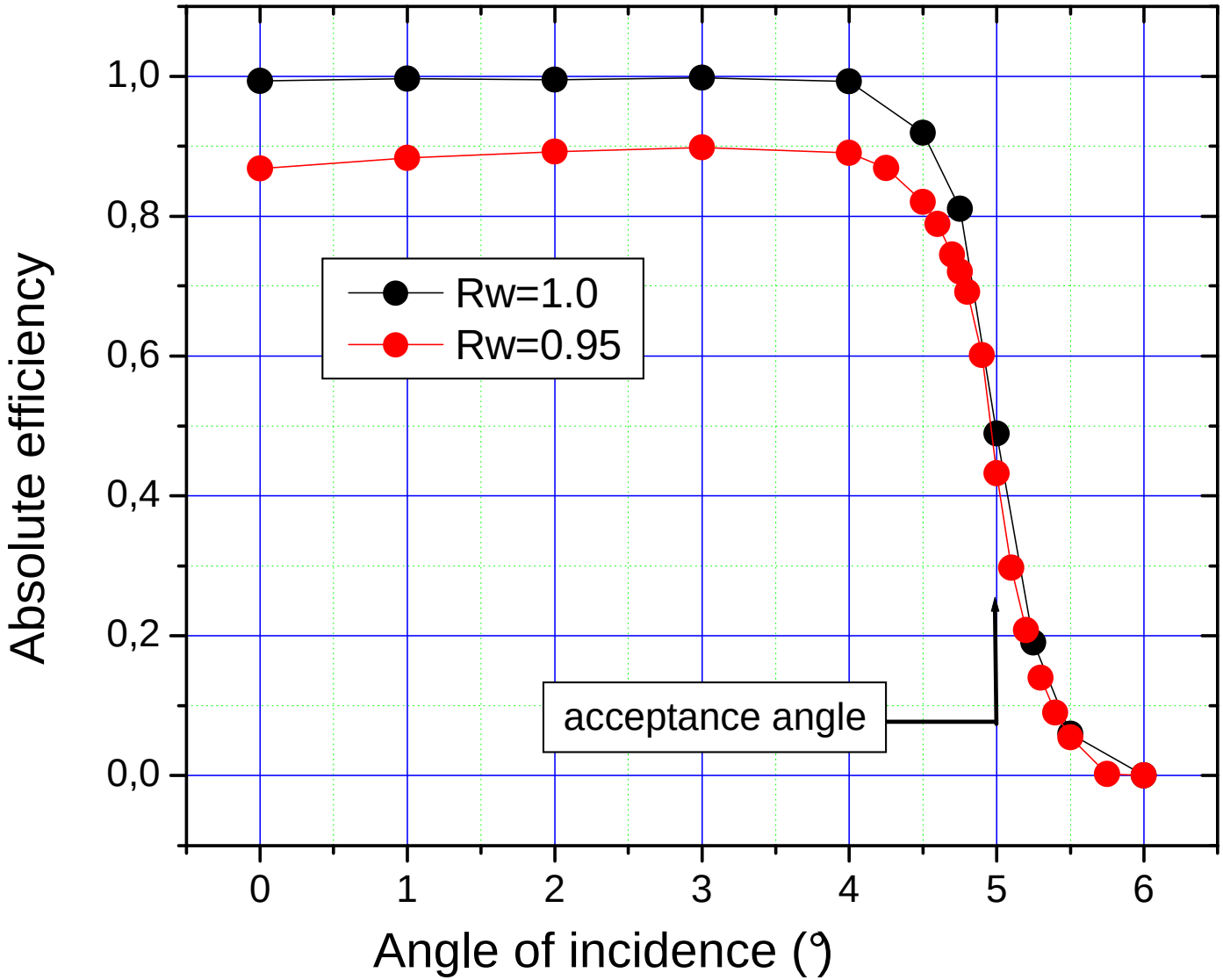


The ideal 3D-CPC



ideal cpc
r(out) = 5 mm
Axis tilt = 5°
r(in) = 57.4 mm
L = 712.9 mm

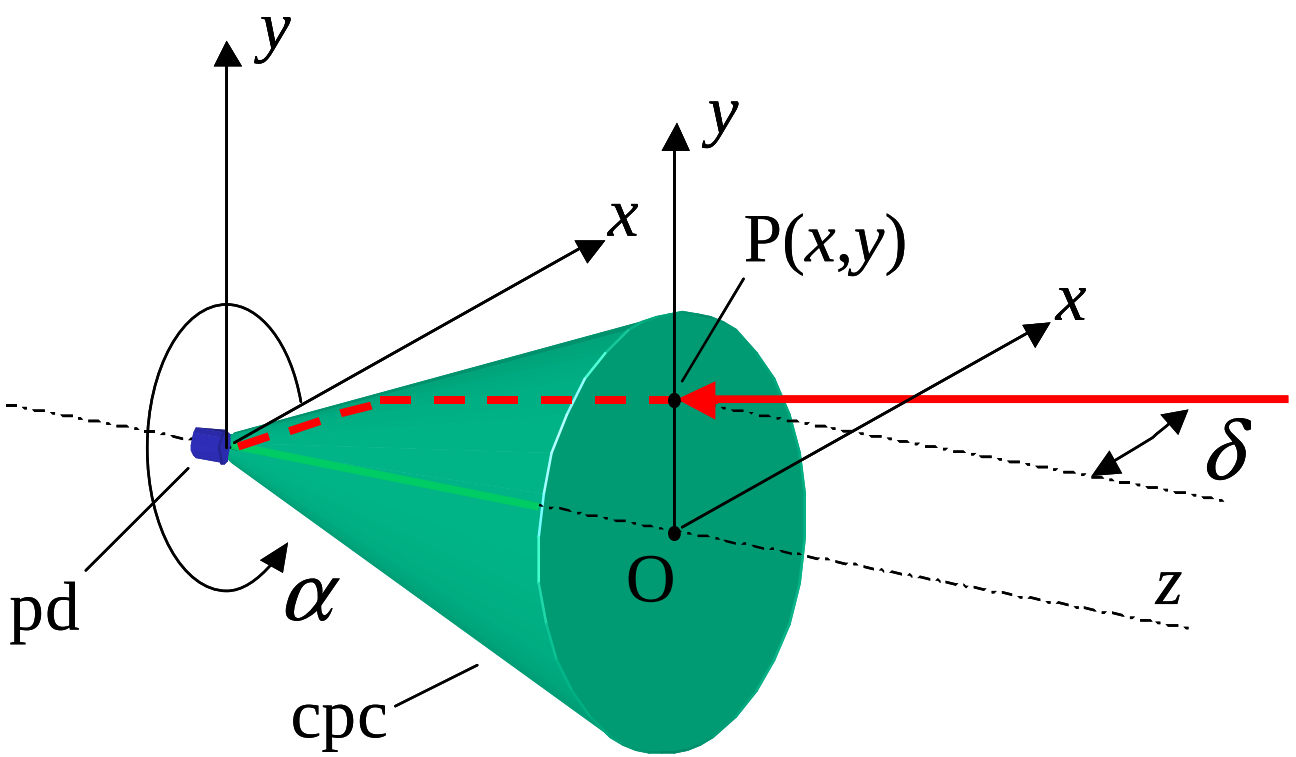
The optical efficiency



LASER METHOD FOR OPTICAL CHARACTERIZATION OF SOLAR CONCENTRATORS

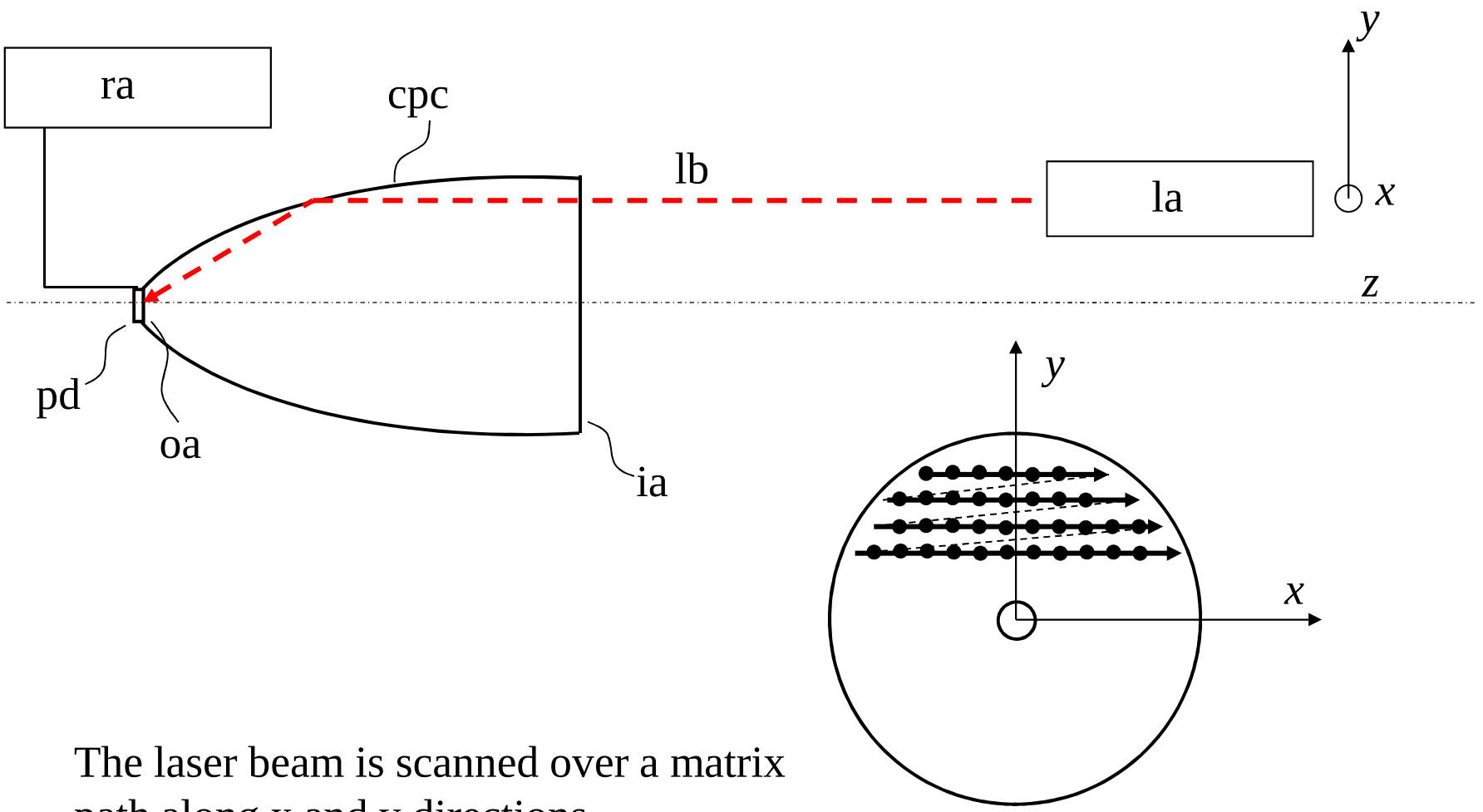
MEASUREMENT OF OPTICAL EFFICIENCY

The basic principle



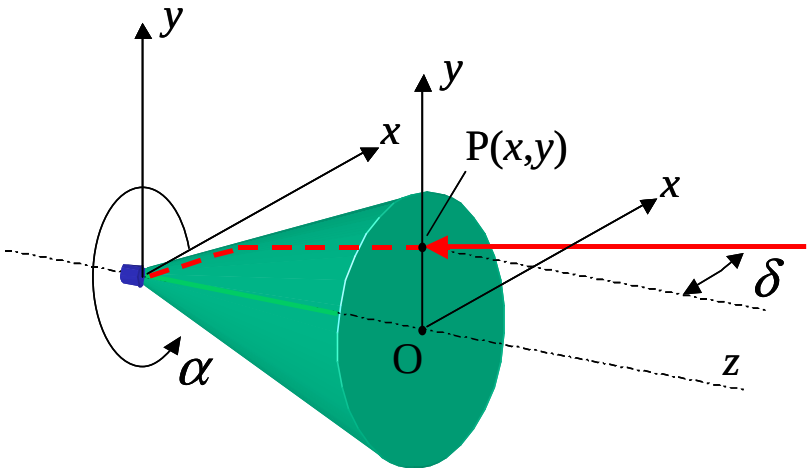
The laser beam is oriented at α (azimuth) and δ (zenith) angles respect to CPC

The basic principle

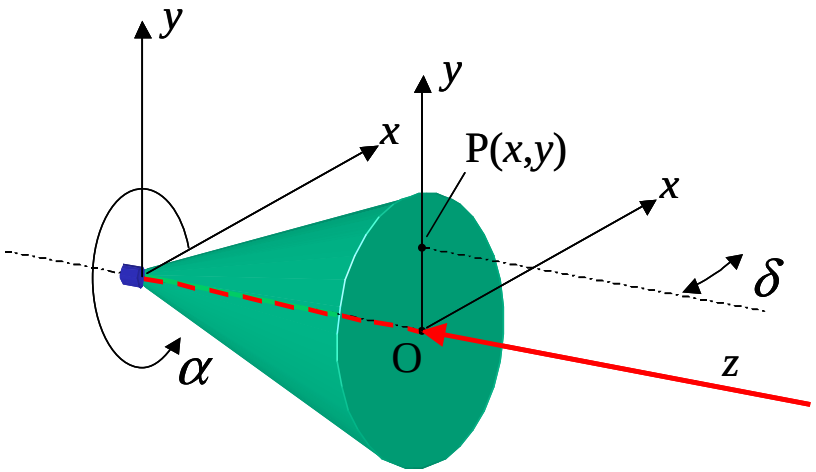


The laser beam is scanned over a matrix path along x and y directions

The basic principle



Measurement of <u>output</u> flux, $F_{CPC}(x,y,\alpha,\delta)$



Measurement of <u>input</u> flux, F_{REF}

The basic principle

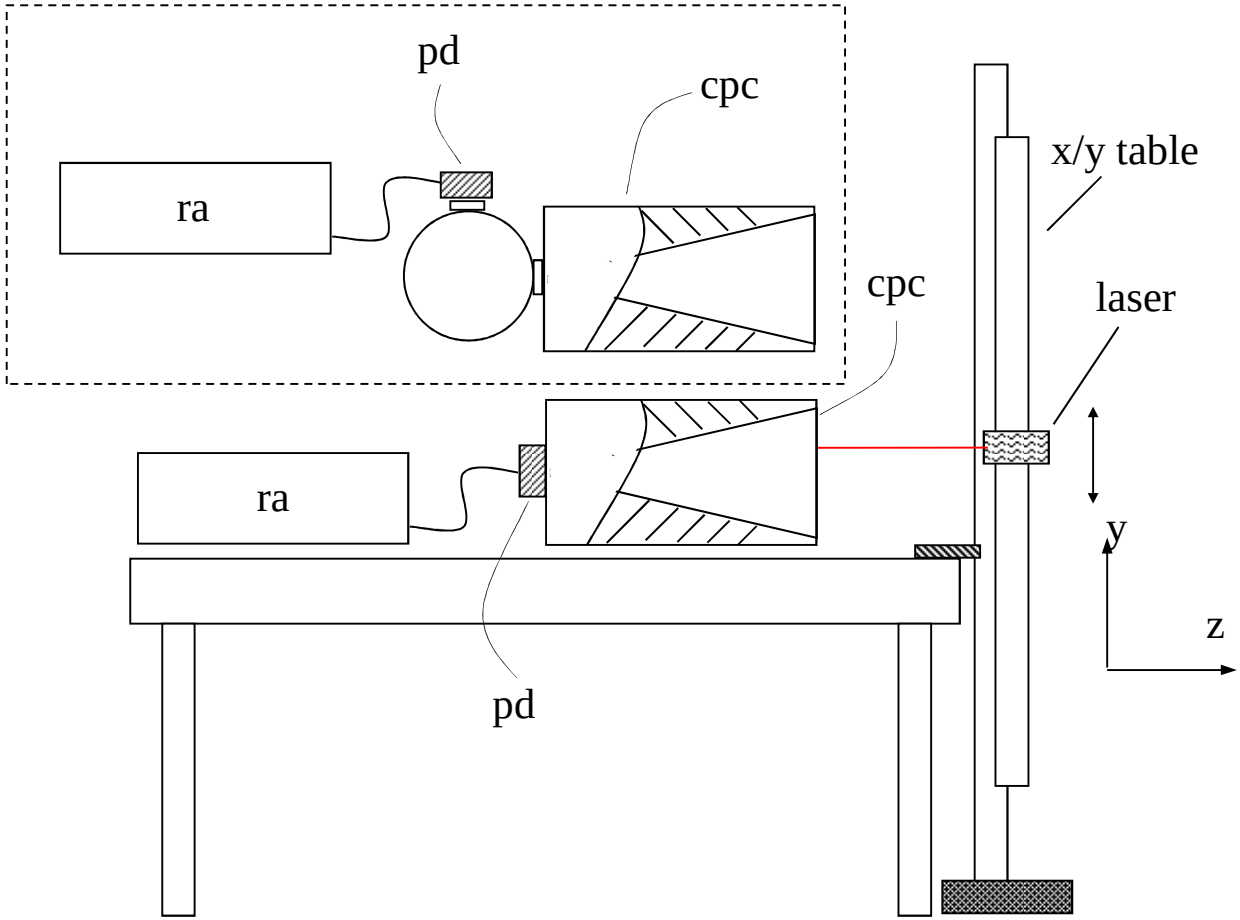
Local efficiency of light collection:

$$\eta(x, y, \alpha, \delta) = \frac{F_{CPC}(x, y, \alpha, \delta)}{F_{REF}}$$

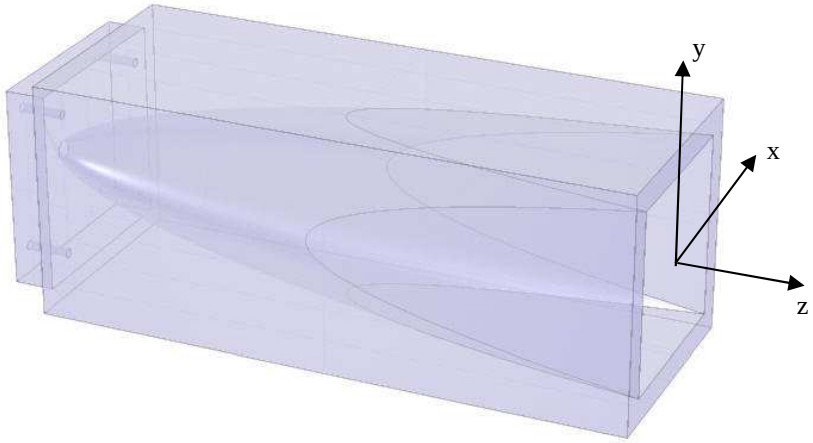
Optical efficiency of CPC:

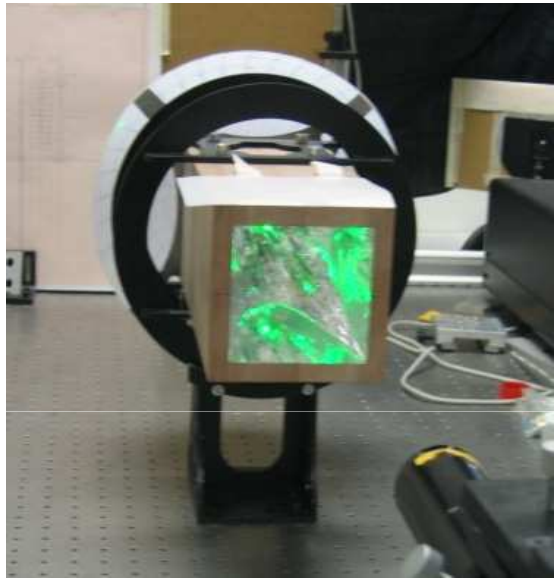
$$\eta(\alpha, \delta) = \frac{\overline{F}_{CPC}(\alpha, \delta)}{F_{REF}}$$

The experimental set-up



Truncated and Squared CPC (TS-CPC)





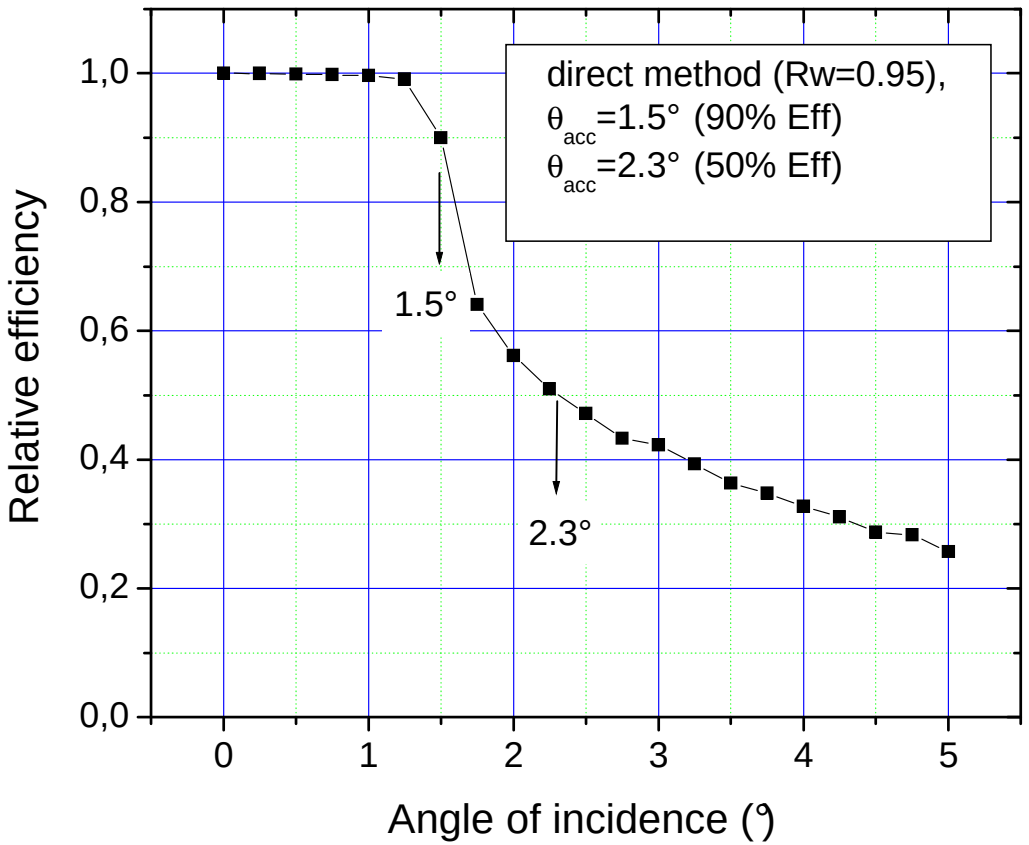
TS-CPC
r(out) = 5 mm
l(in) = 100 mm
L = 350 mm

Truncated and Squared CPC (TS-CPC)

Classic "direct" method

Simulations with TracePro

Truncated and Squared CPC (TS-CPC)



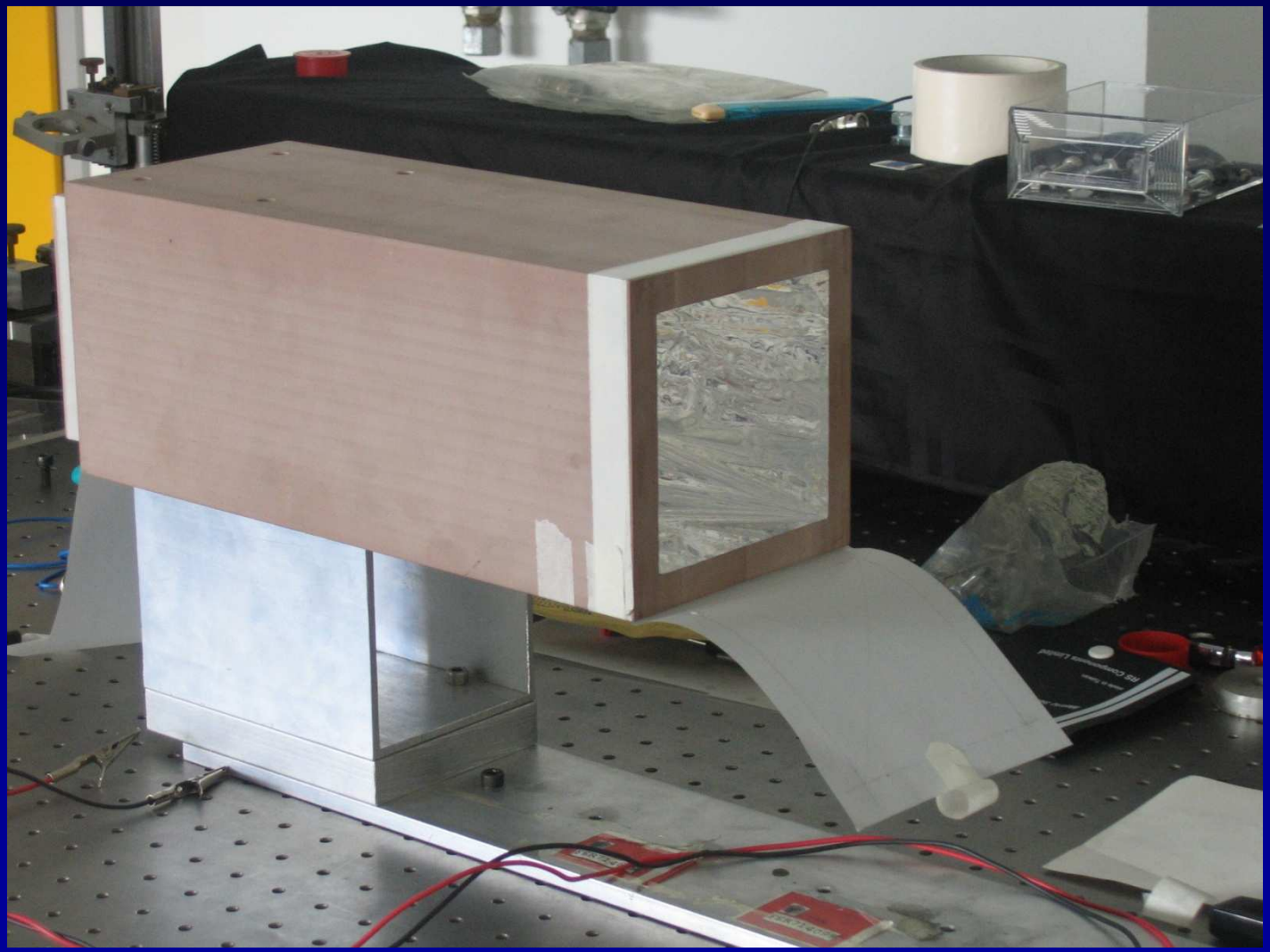
Acceptance angle:

1.5° (90% Efficiency)
2.3° (50% Efficiency)

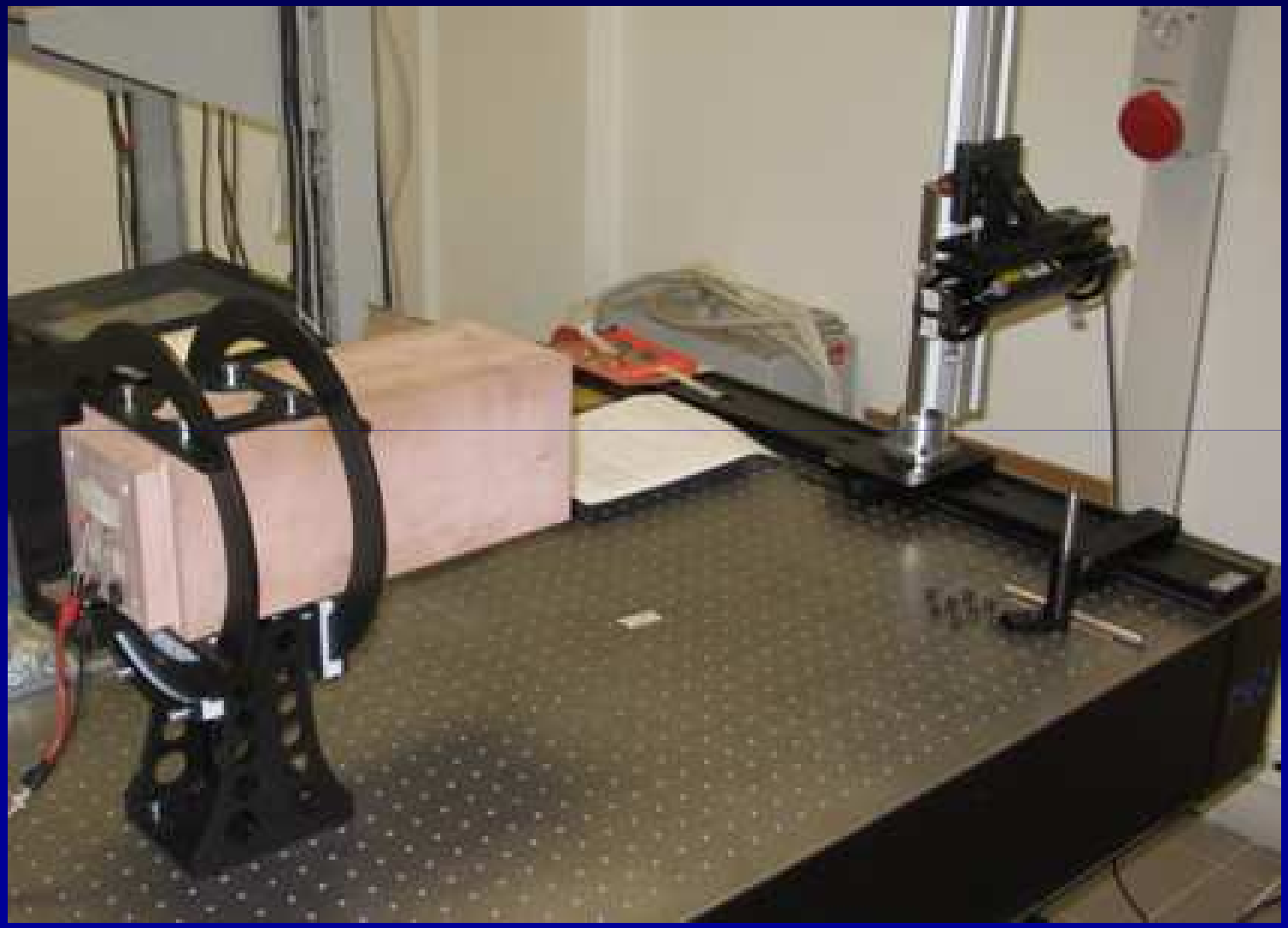
Truncated and Squared CPC (TS-CPC)

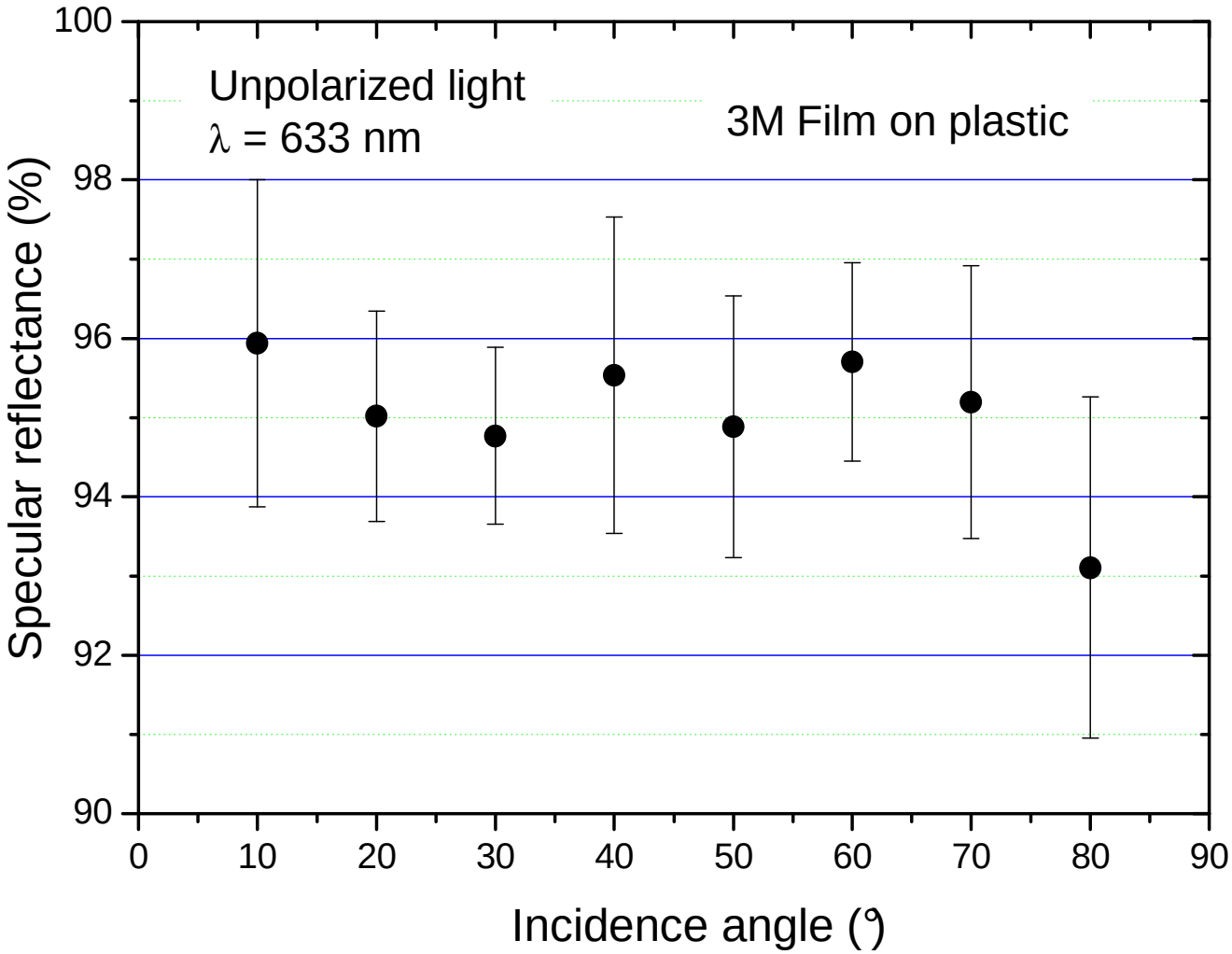
Laser method

Truncated and Squared CPC (TS-CPC)



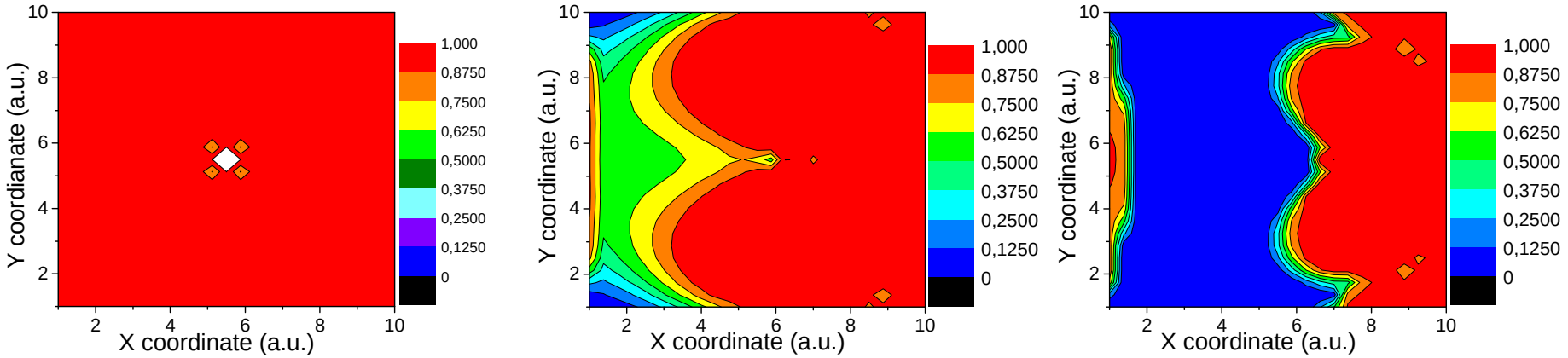
The experimental set-up





Average Reflectance of 3M film: 95±1%

Simulated maps of optical efficiency (α = 0°)

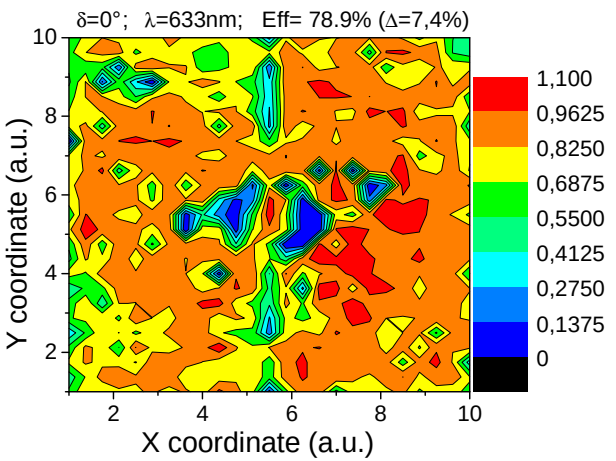


δ = 0°

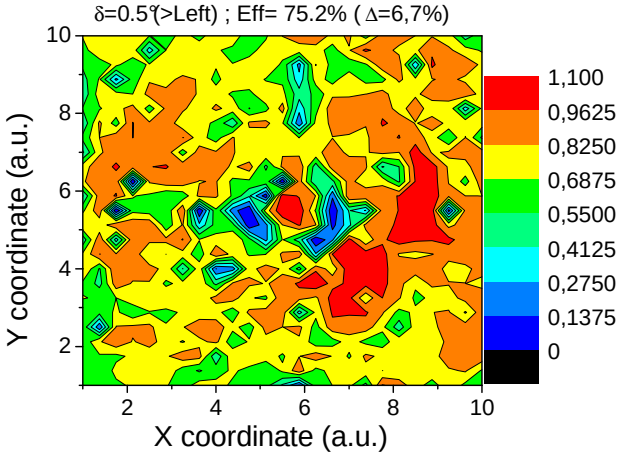
δ = 1.5°

δ = 2.5°

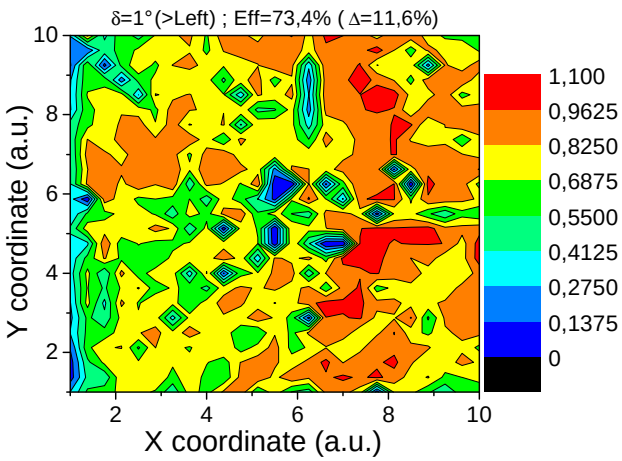
Experimental maps of optical efficiency (α = 0°)



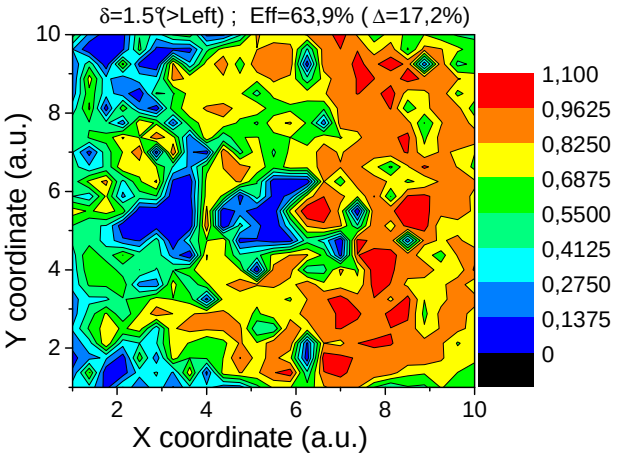
$\delta = 0°$



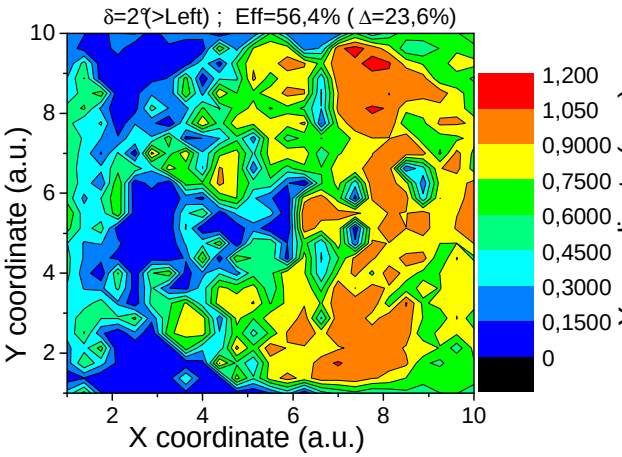
$\delta = 0.5°$



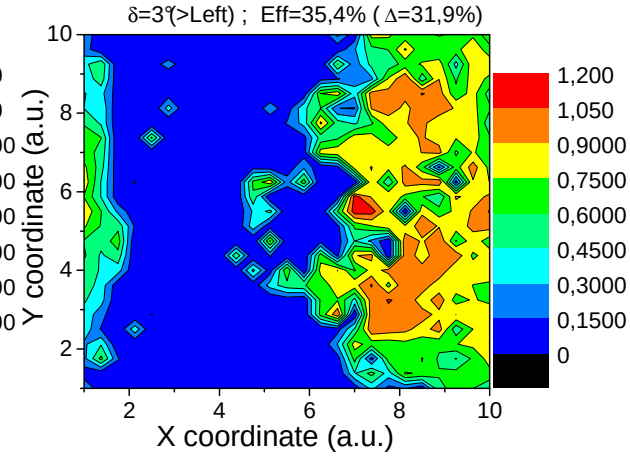
$\delta = 1.0°$



$\delta = 1.5°$

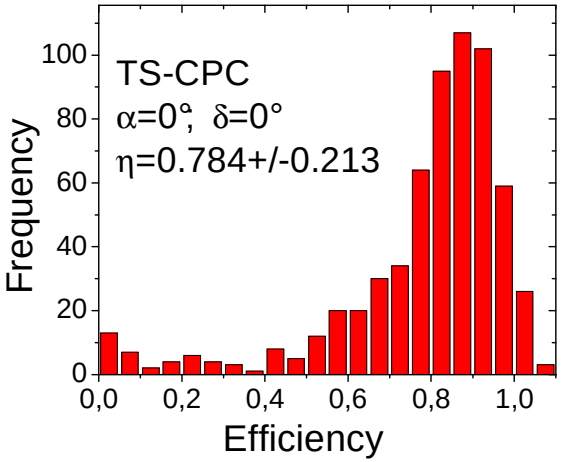


$\delta = 2.0°$

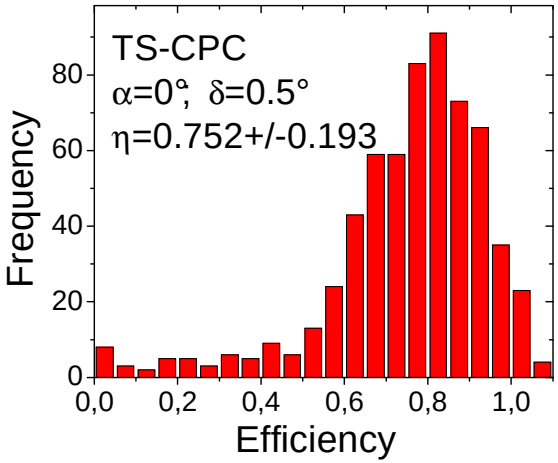


$\delta = 3.0°$

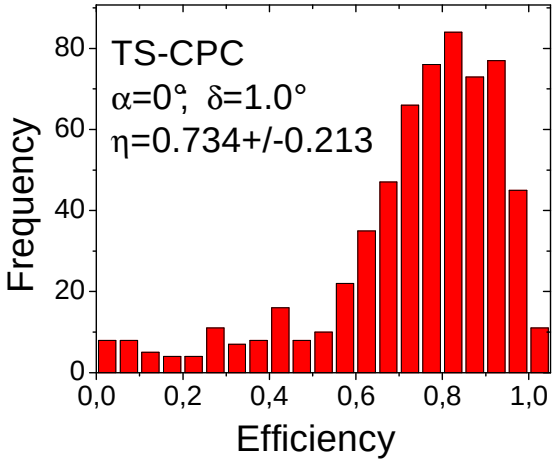
Experimental maps of optical efficiency (α = 0°)



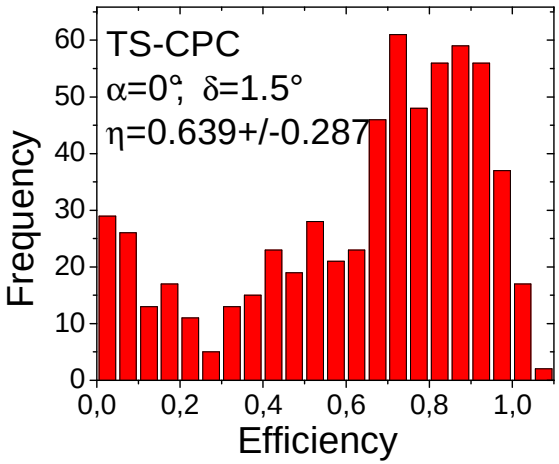
$\delta = 0°$



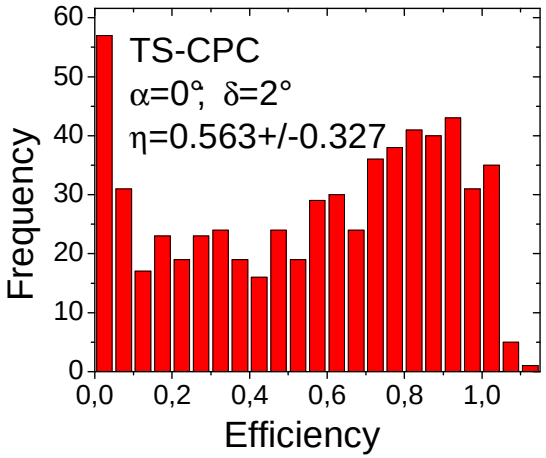
$\delta = 0.5°$



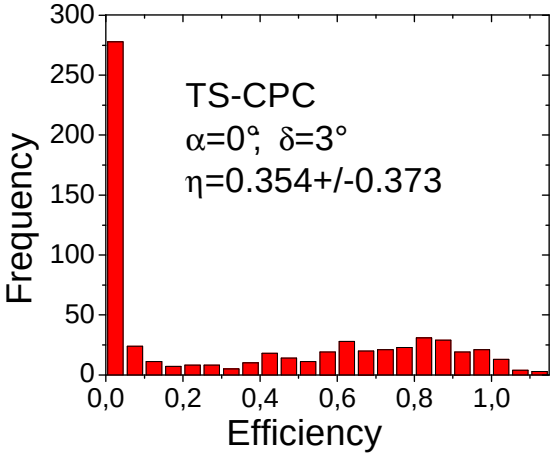
$\delta = 1.0°$



$\delta = 1.5°$

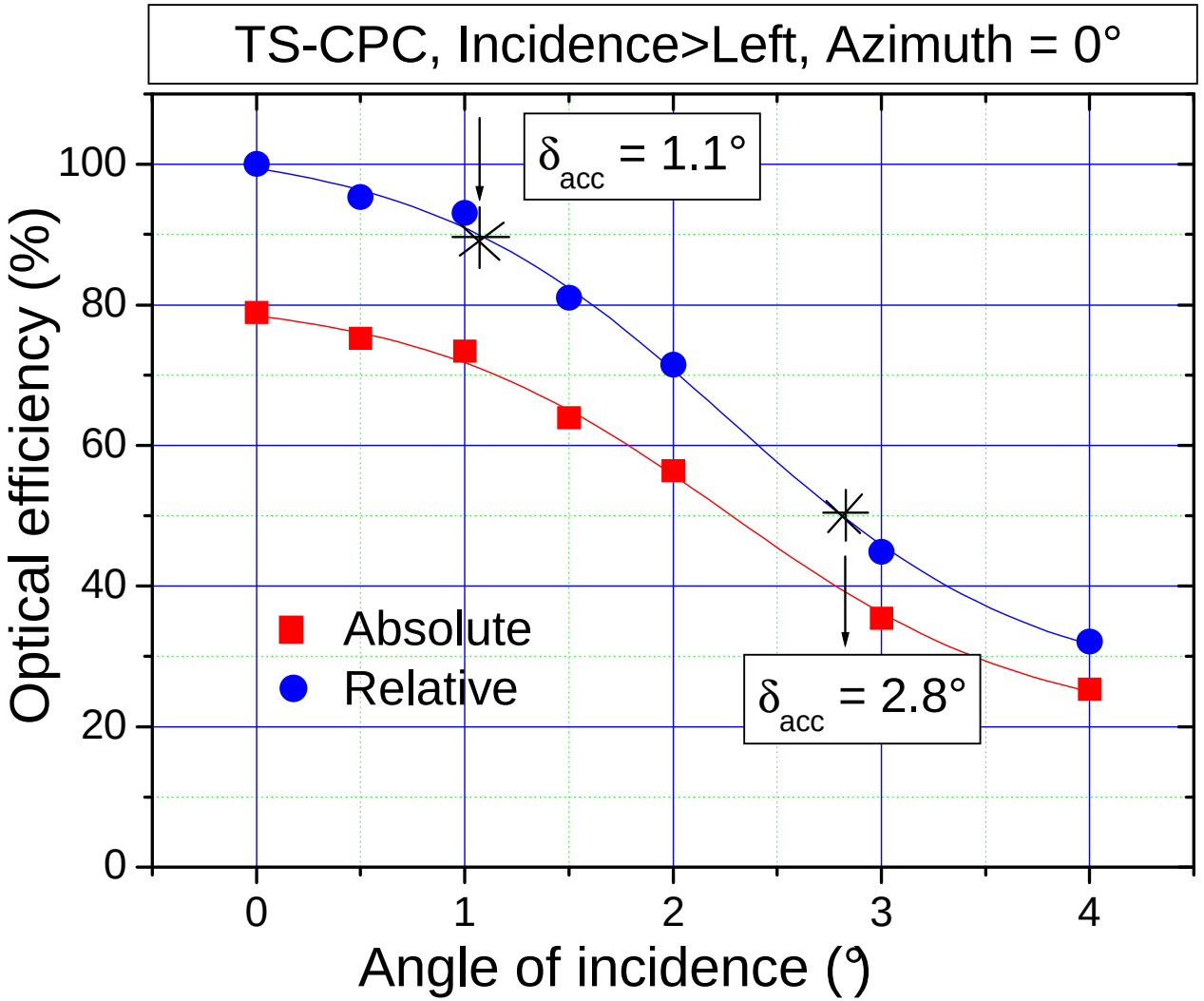


$\delta = 2.0°$

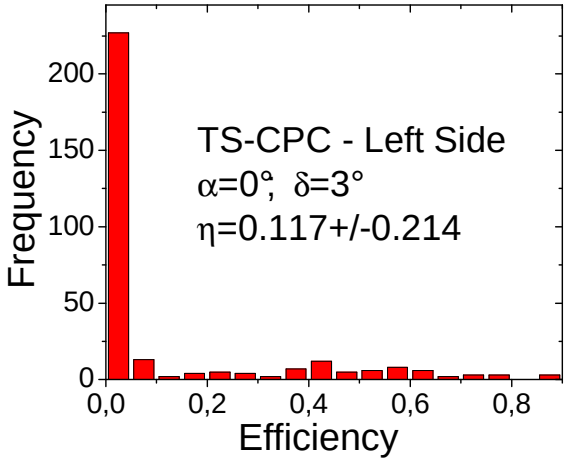


$\delta = 3.0°$

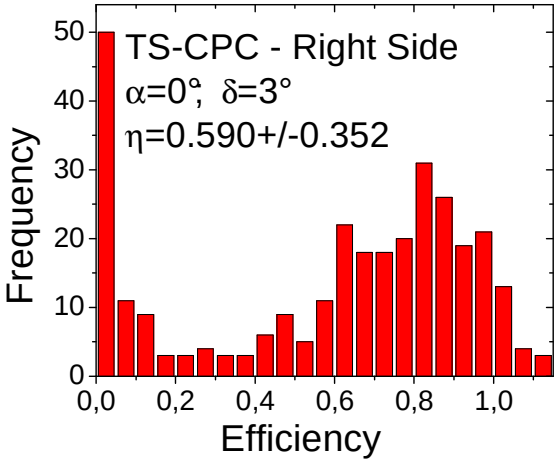
Experimental optical efficiency (α = 0°)



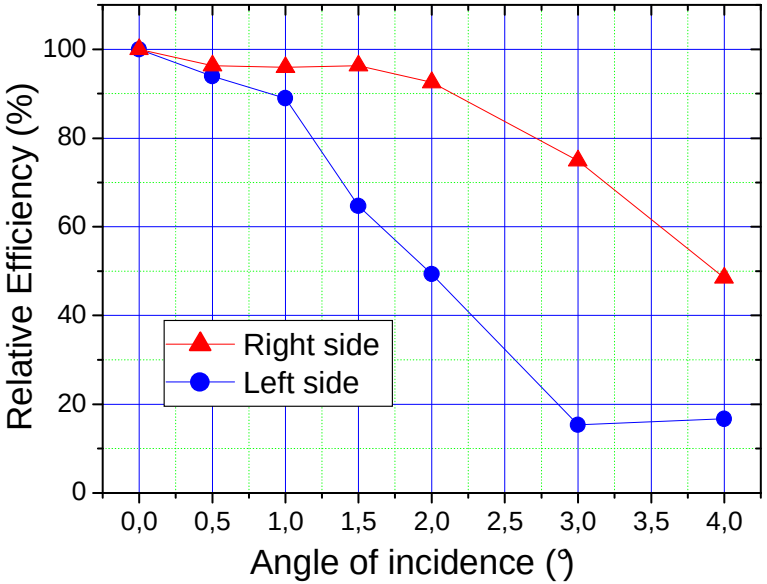
Experimental optical efficiency (α = 0°)

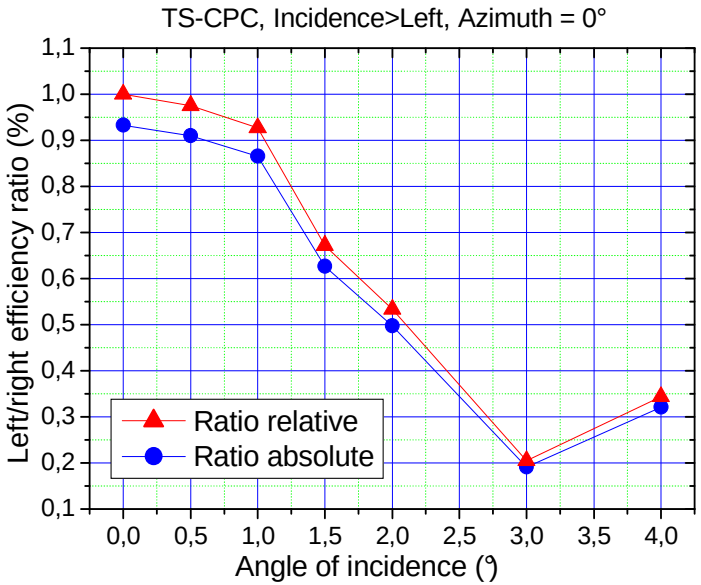


Left side

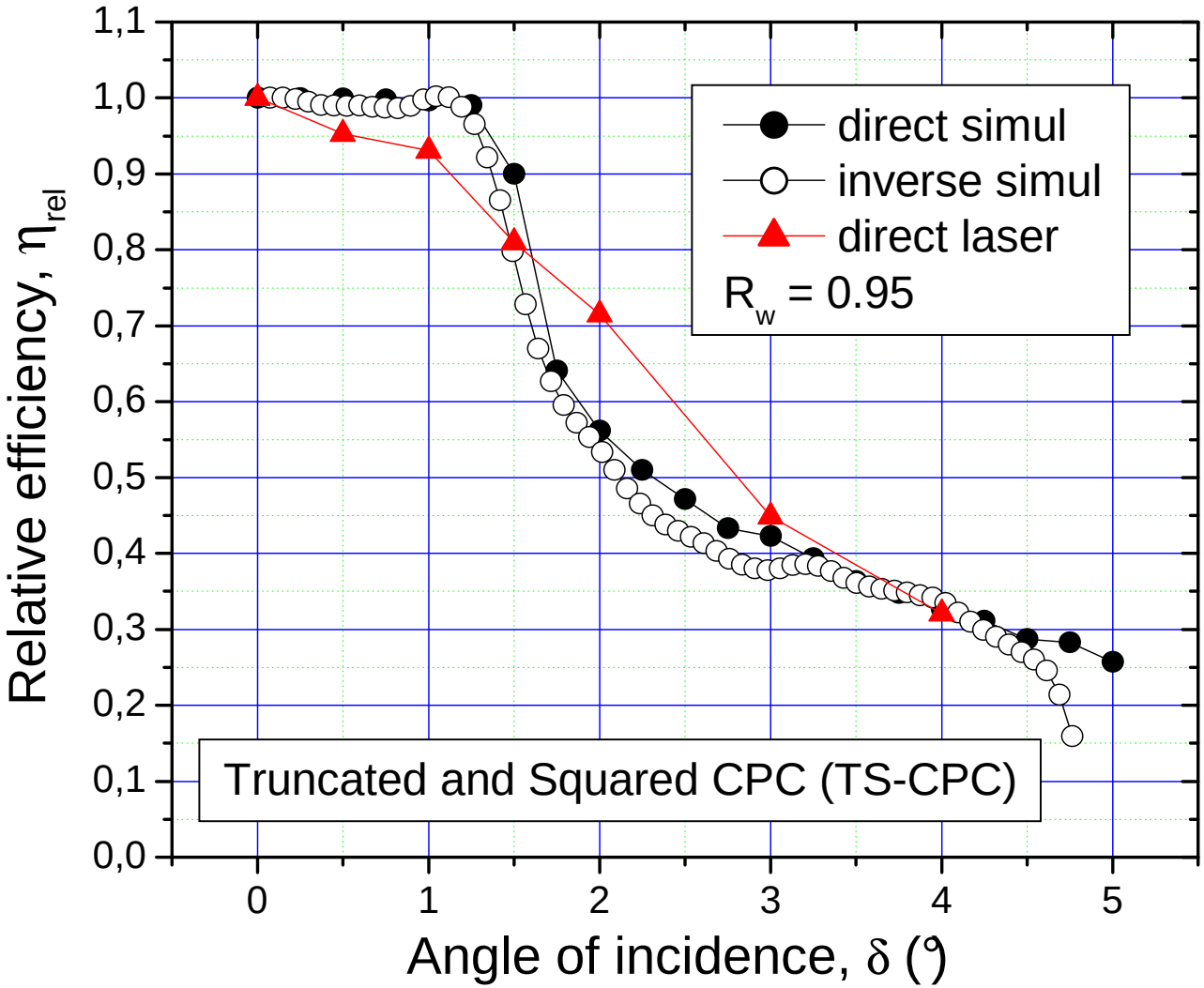


Right side

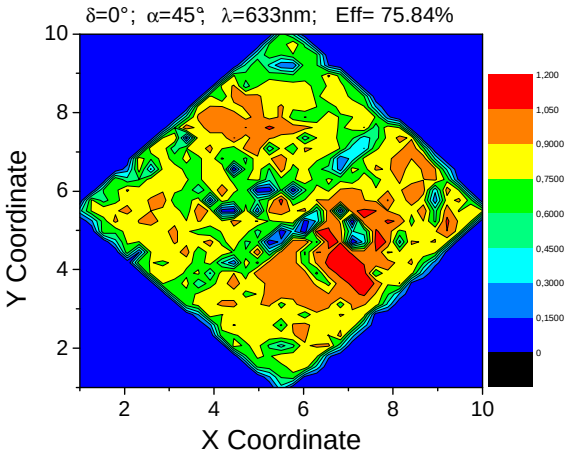




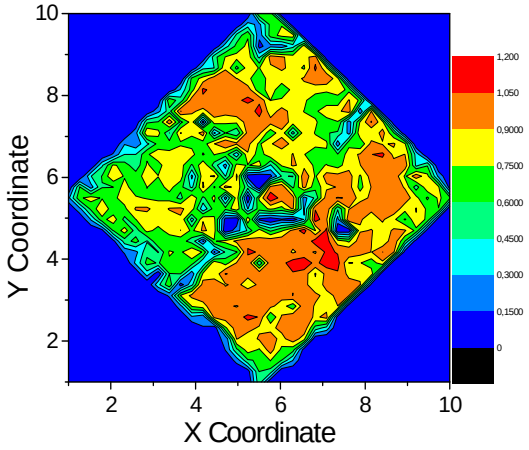
TS-CPC - Comparison between direct and inverse methods



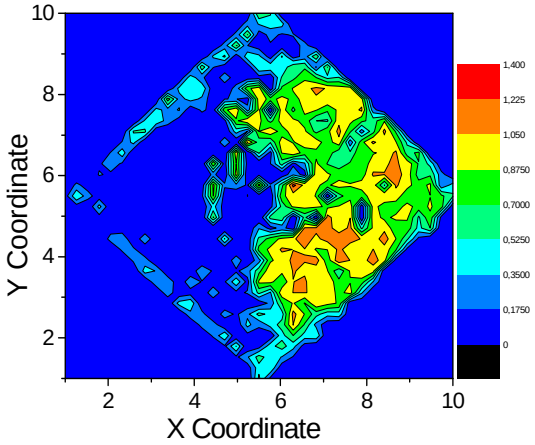
Experimental maps of optical efficiency (α = 45°)



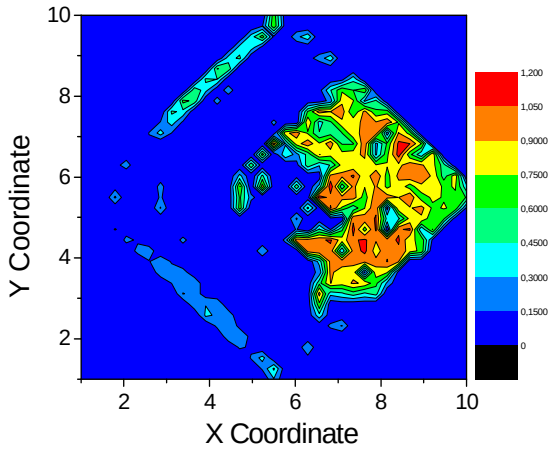
$\delta = 0°$



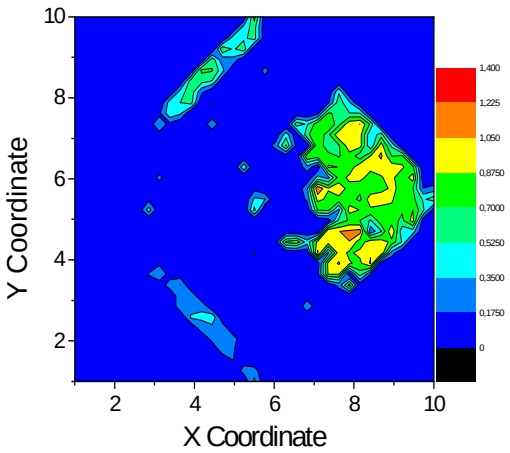
$\delta = 1.0°$



$\delta = 2.0°$



$\delta = 3.0°$



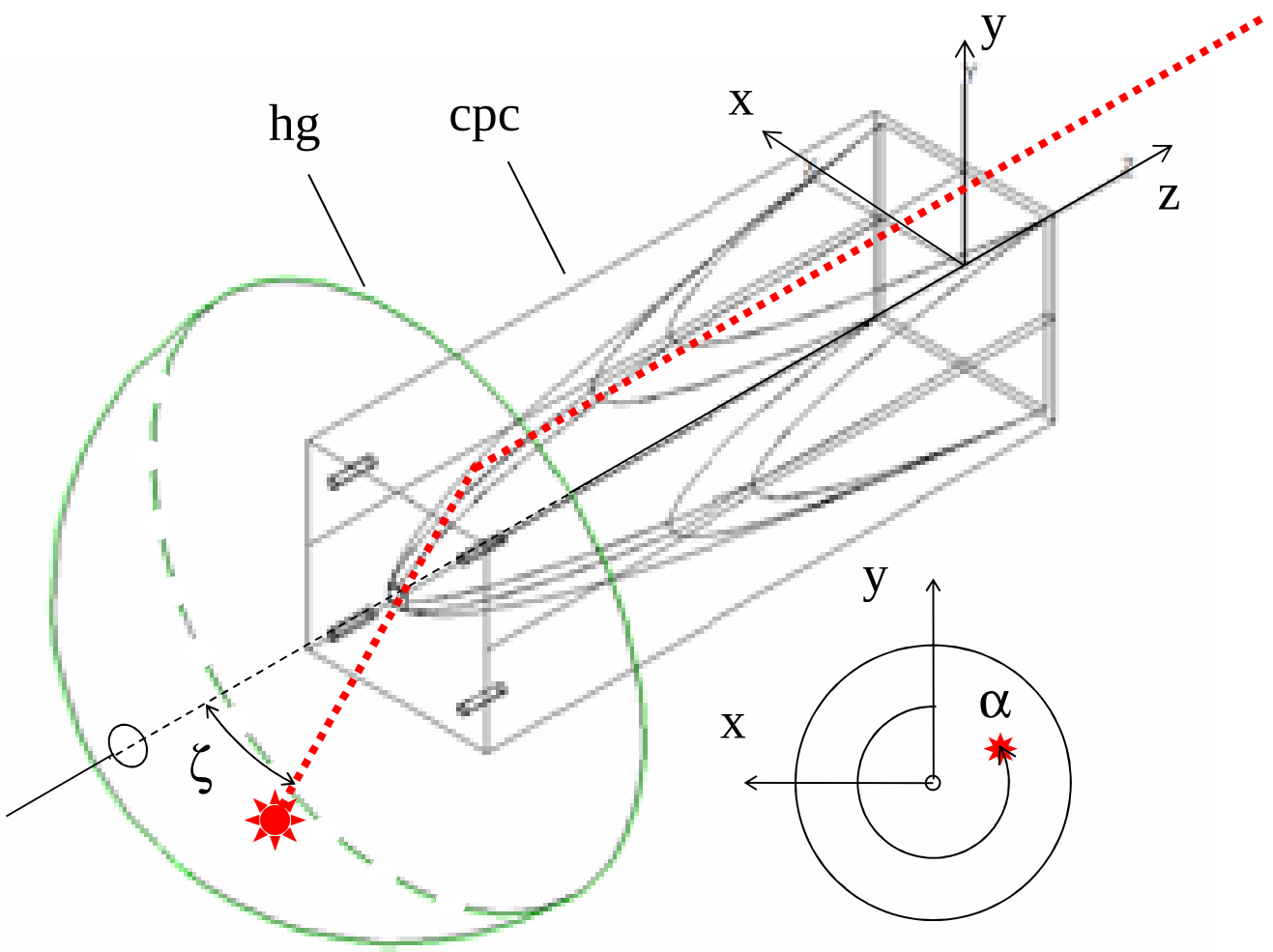
$\delta = 4.0°$

Summary of results

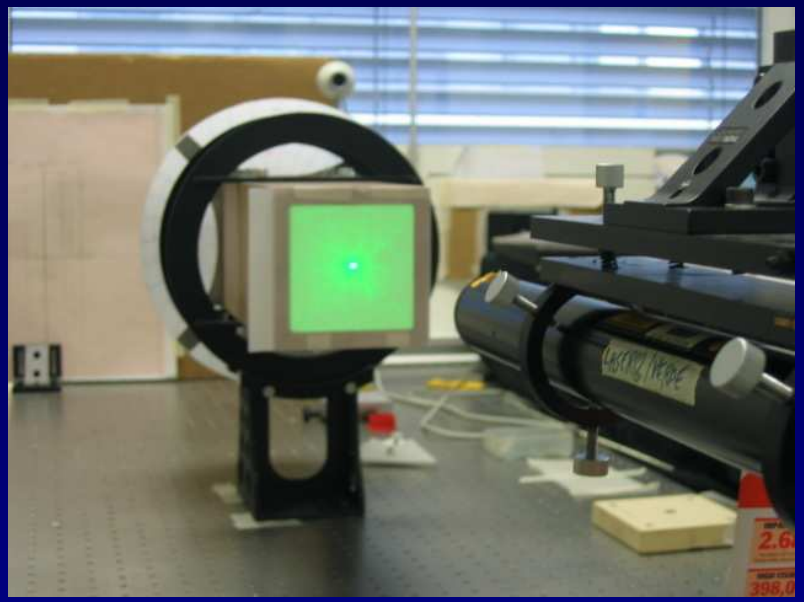
Method		Ideal 3D-CPC		TS-CPC		HT-CPC	
		90% Eff	50% Eff	90% Eff	50% Eff	90% Eff	50% Eff
Direct	Simul	4.5°	5.0°	1.5°	2.3°	4.5°	5.1°
	Exp			1.1° (laser)	2.8° (laser)		
Inverse	Simul	4.5°	5.0°	1.4°	2.1°	4.5°	5.1°
	Exp			0.8°	1.9°		

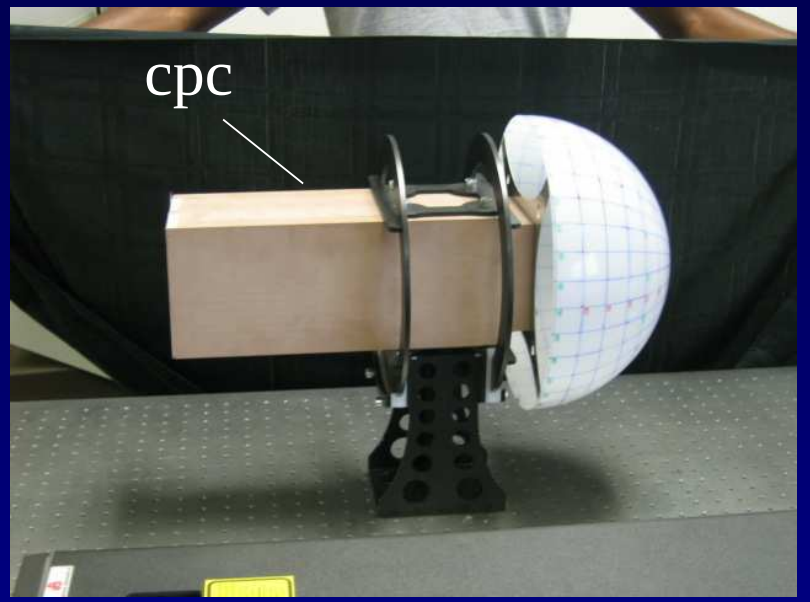
MEASUREMENT OF BEAM EXIT ANGLE

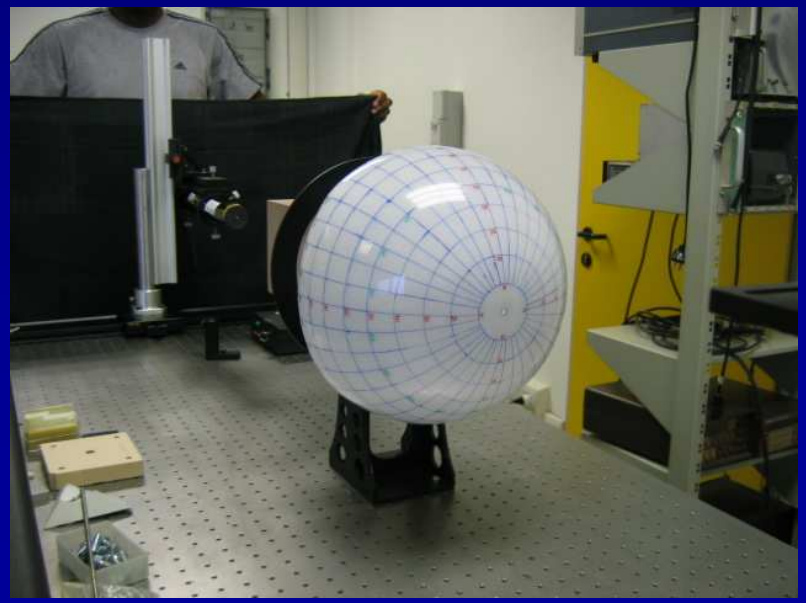
The basic principle

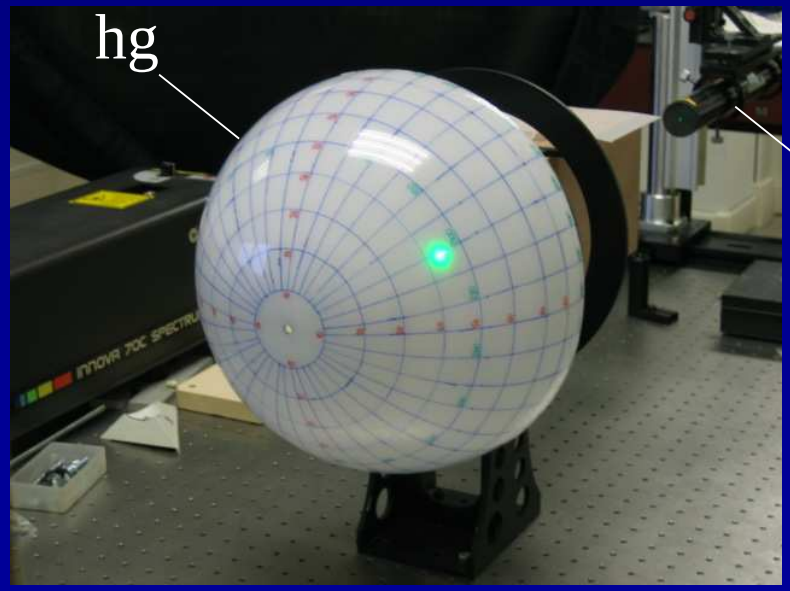


The experimental set-up

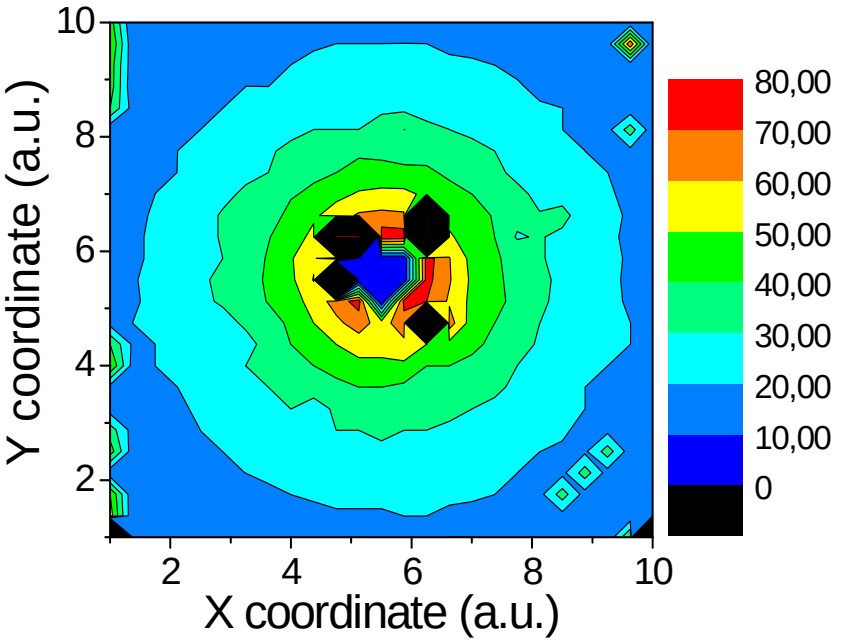




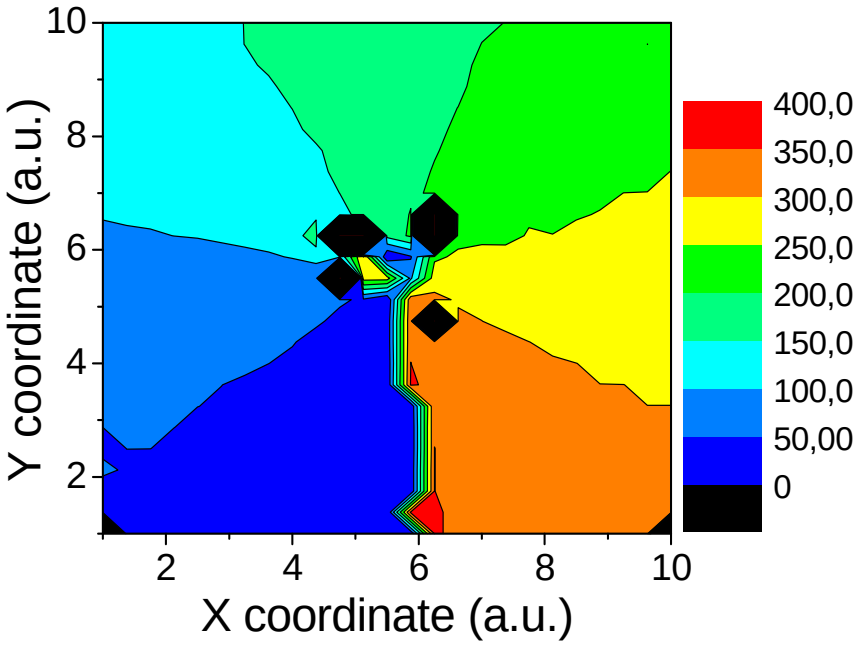




Beam exit angles maps

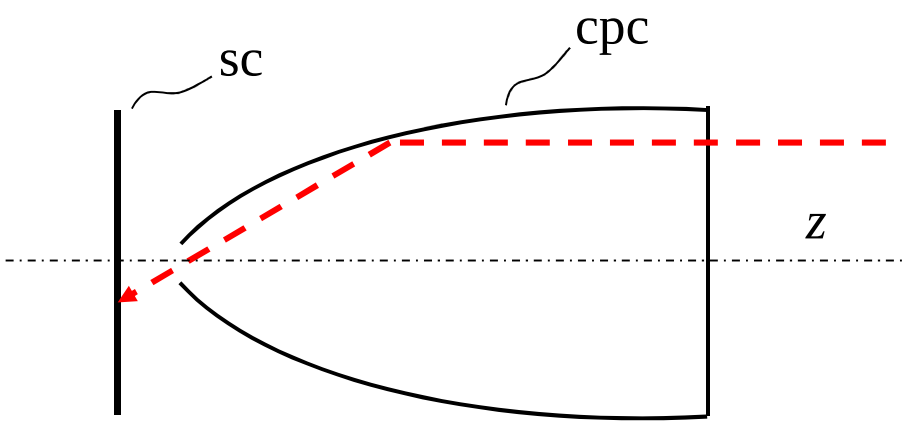


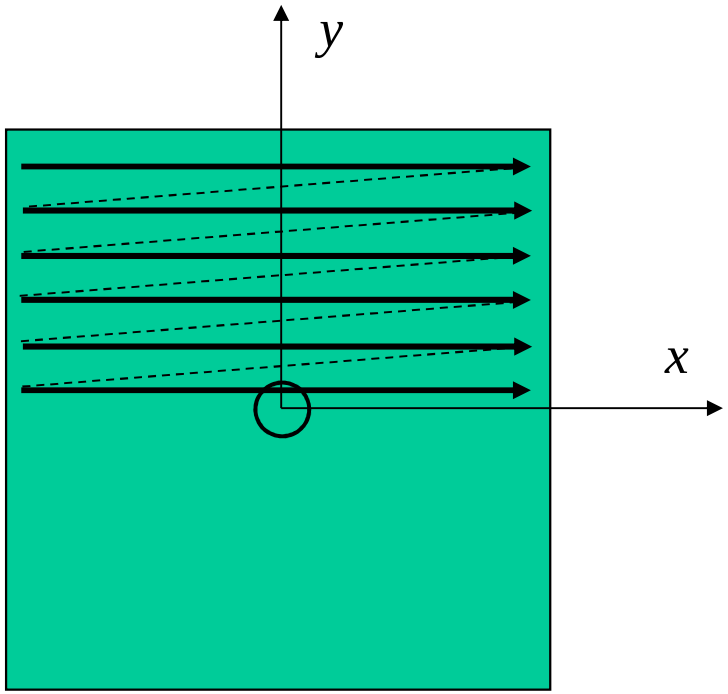
Zenith angle, ζ



Azimuth angle, α

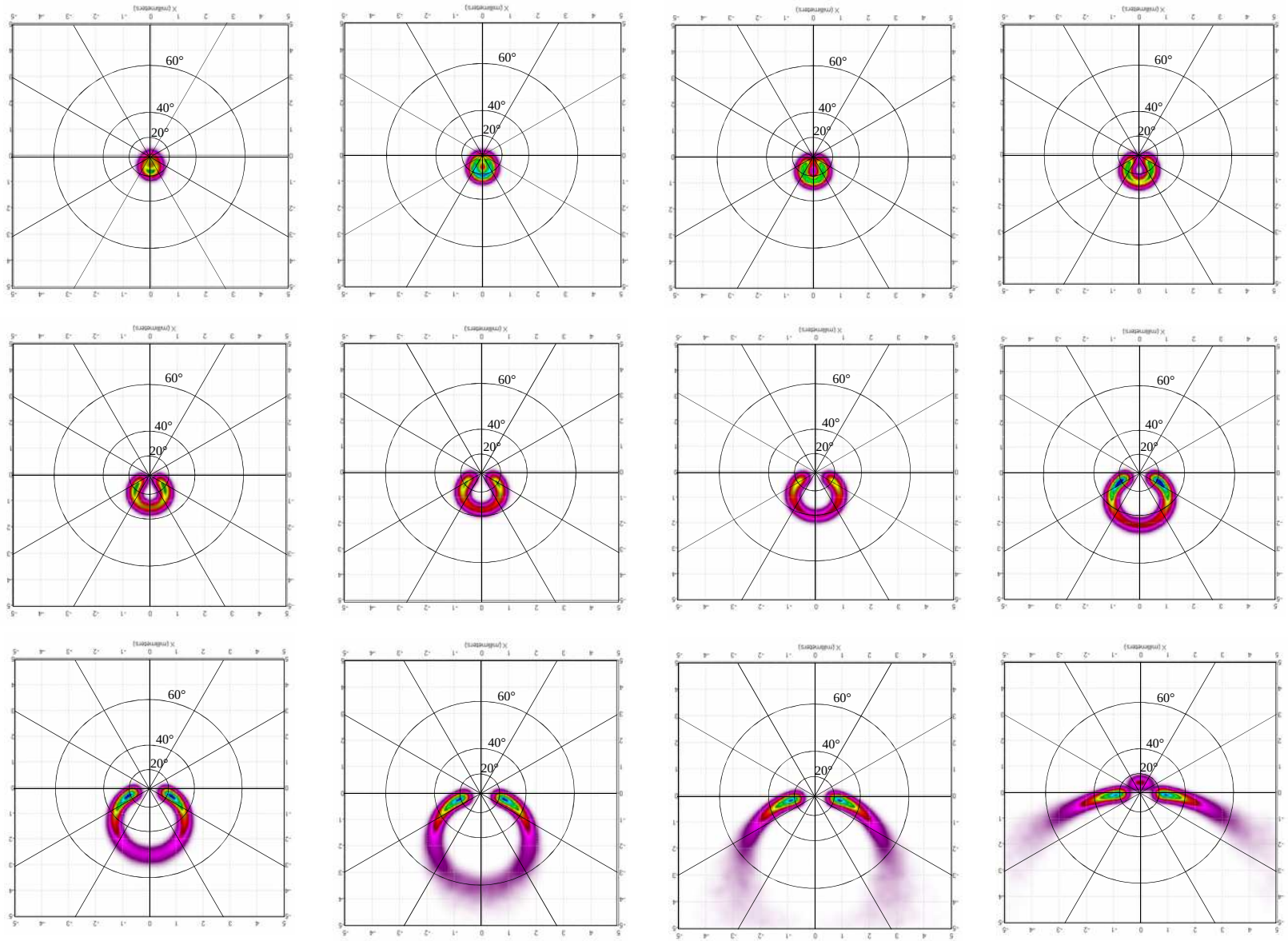
Beam exit angles paths (simulations)





Screen 10 cm size
at 2 cm distance
from the CPC

Beam exit angles paths (simulations)



CONCLUSIONS

We have performed the scanning of CPC concentrators by a laser beam.

By this method it is possible to reveal local defects of the internal wall and manufacturing inaccuracies of the surface.

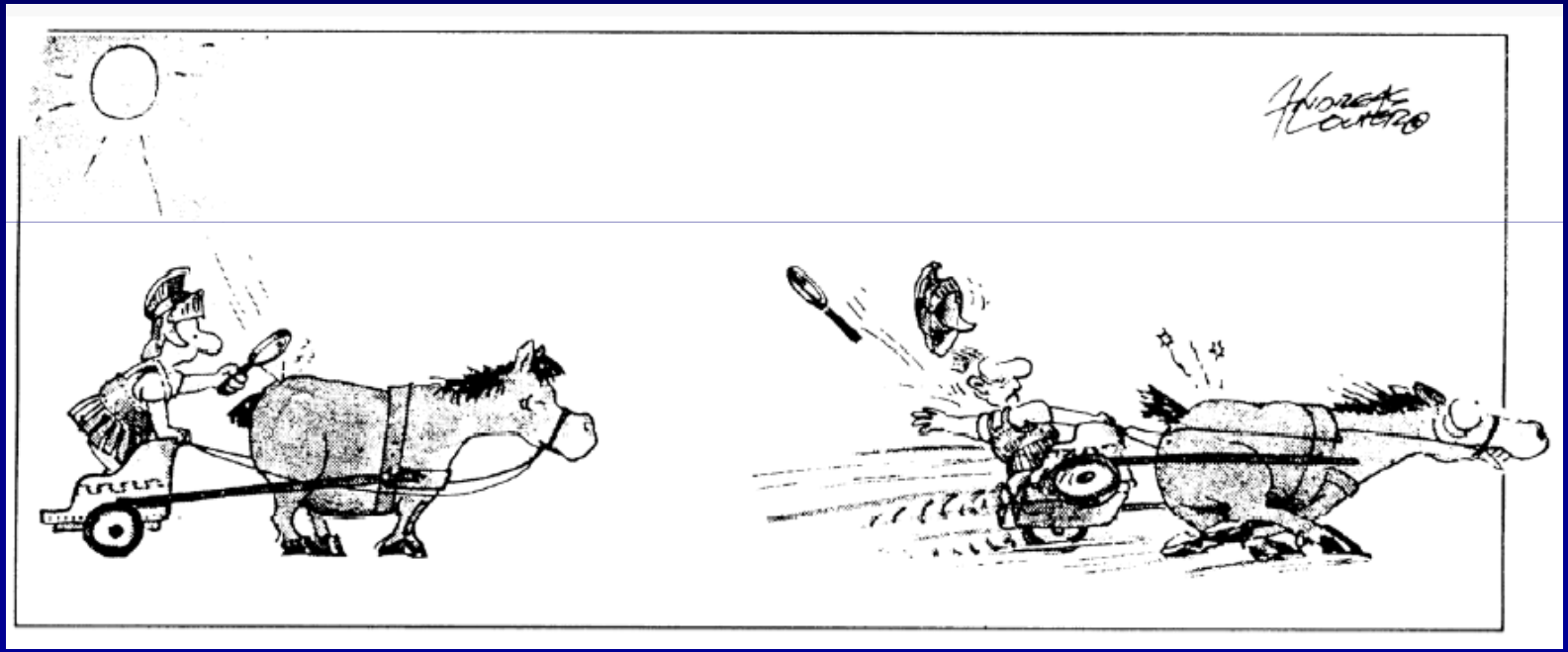
We have compared the optical measurements with simulations made on the CAD model of the prototype.

We have analyzed maps of local efficiency as function of orientation of the incident beam and studied the exit beam angular dependence as function of beam position on input aperture.

We have characterized truncated and squared 3D-CPCs (TS-CPC) and derived the angle-resolved optical efficiency curves and the associated acceptance angle.

The end

Thanks



Solar concentration in ancient Rome