ISSI Workshop
DIARAD TSI Absolute Value

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Outline

- Motivation for a thermal efficiency related to electrical effects $\alpha_{th,elect} < 1$
- Determination of $\alpha_{th,elect}$
- Determination of the TSI
- Impact on TSI values
- Conclusions

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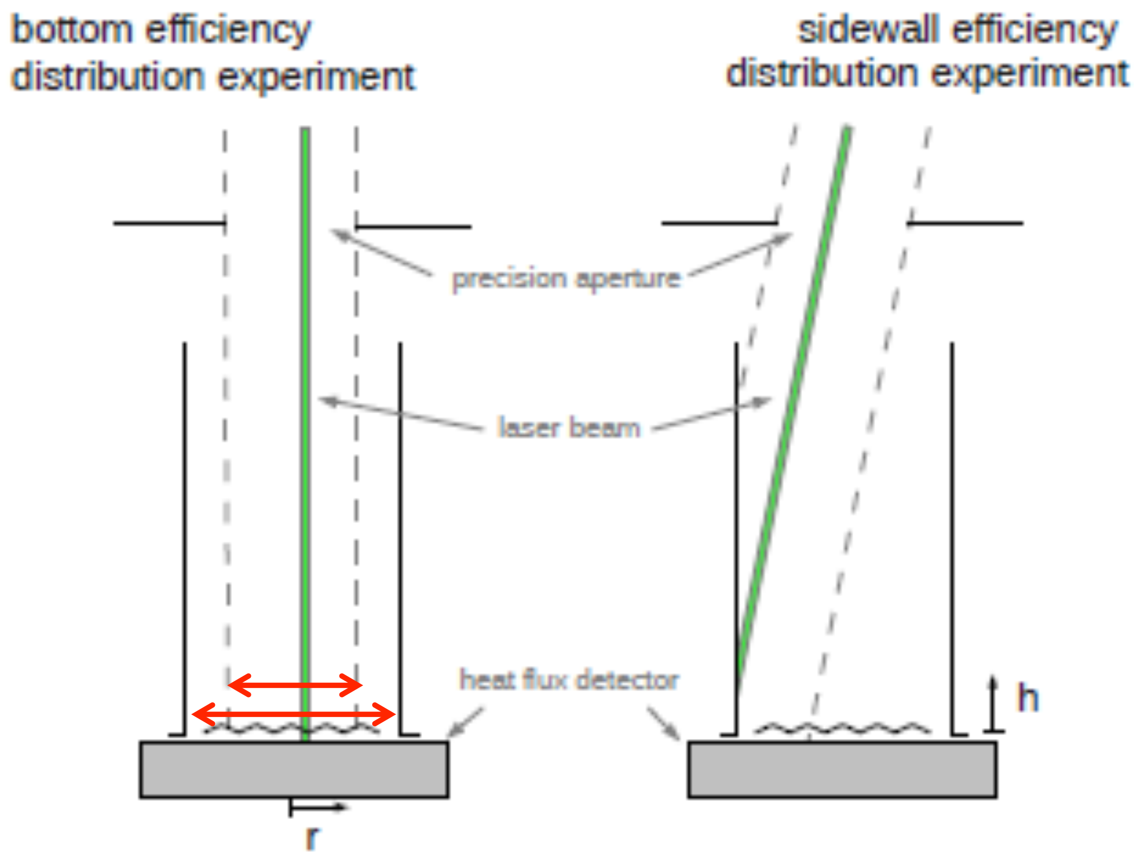
Motivation for $\alpha_{th,elect}$ (1/3)

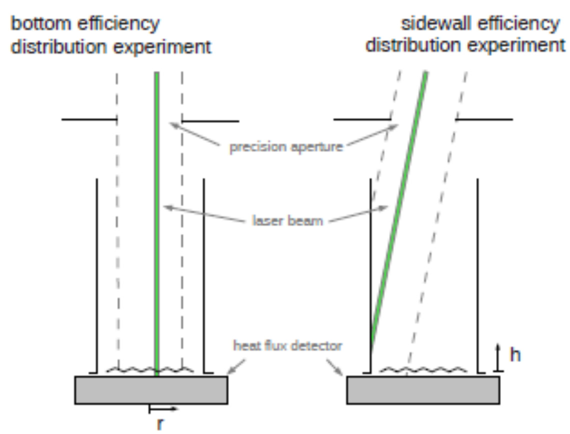


Motivation for $\alpha_{th,elect}$ (2/3)

There exist two power contributions to the cavity:

1) The optical power originating from the sun.

2) The electrical power delivered to the heating resistor.



Both powers are transferred into heat,
the absorbed heat is detected with a certain efficiency.

Motivation for $\alpha_{th,elect}$ (3/3)

In previous research:

$\alpha_{th,elect} = 1$ No heat losses were considered for the detection of the heat dissipated by the heating resistor.

However, once the electrical power is transferred into heat, this heat is detected by the Pelletier element in a similar way as the heat originating from the sun.

→ Assumptions:

1) $\alpha_{th,elect} < 1$

2) The detected heat dissipated by the heating resistor and the heat originating from the sun are both detected with the same LOCAL efficiency.

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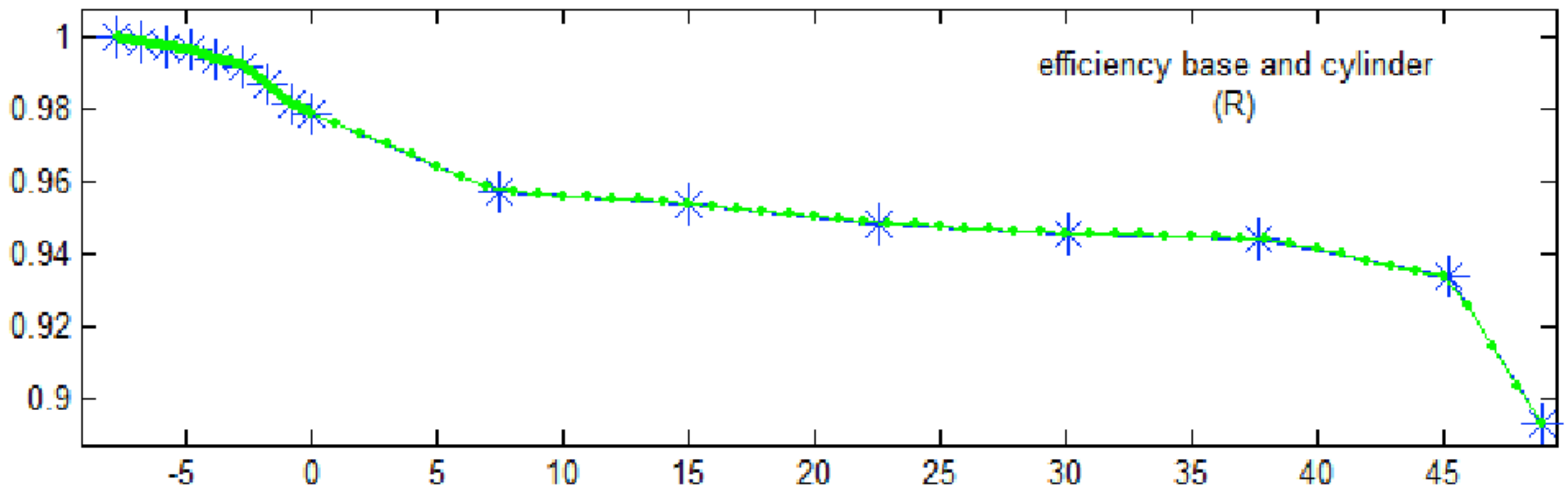
Determination of $\alpha_{th,elect}$ (1/2)

$$\alpha_{th,opt} = \frac{\text{measured solar power}}{\text{absorbed solar power}} \quad < 1$$

$$\alpha_{th,elect} = \frac{\text{measured electrical power}}{\text{absorbed electrical power}} \quad < 1$$

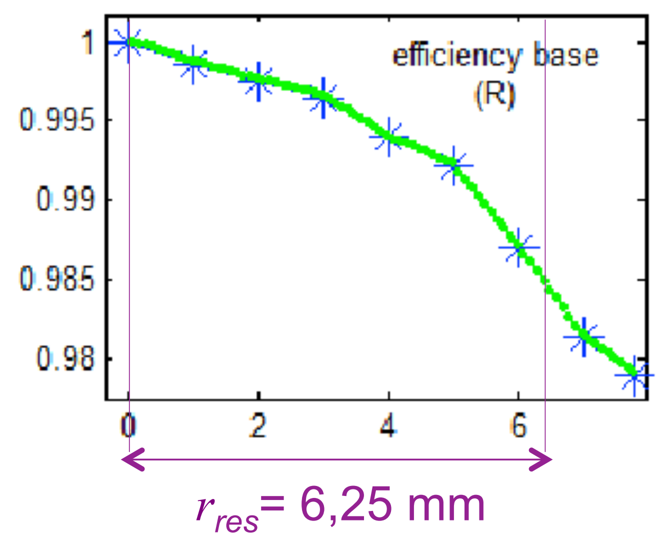
Both parameters are calculated from
the experimentally measured local efficiency:



Determination of $\alpha_{th,elect}$ (2/2)

$\alpha_{th,elect} =$ mean efficiency over the area of the heating resistor (radius r_{res}) at the base

$$\alpha_{th,elect} = \frac{1}{r_{res}^2} \sum_{n=1}^{N_{res}} \left[r(n)^2 - r(n-1)^2) \right] \; eff_r(n)$$



Comparison with the determination of $\alpha_{th,opt}$ (1/2)

Main term

Correction 1st order reflections

Correction 2st order reflections

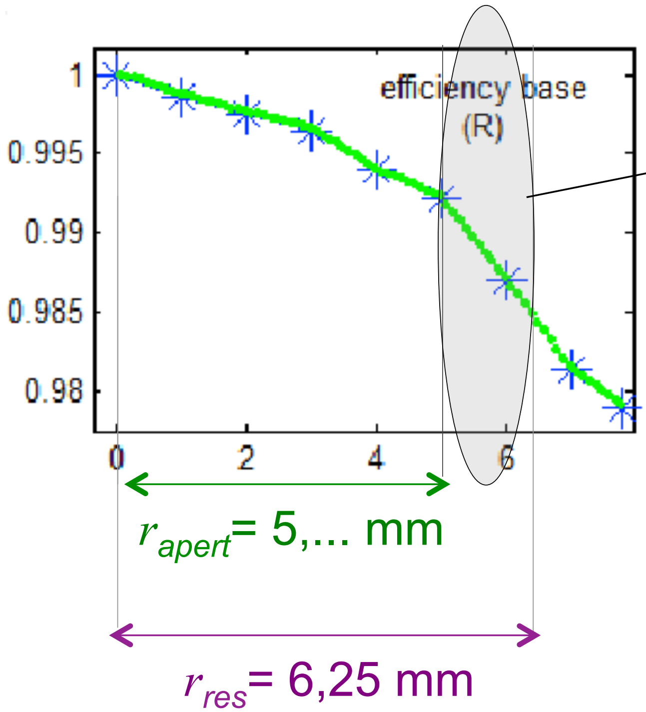
Correction reflection at the mirror

$$\begin{aligned}
\alpha_{th,opt}\, a_R = {} & a_{paint}\, \overline{eff_r} \\
& + (1 - a_{paint})\ a_{paint} \sum_{m=1}^{M} F_{disk-\Delta z_m}\, eff_z(m) \\
& + (1 - a_{paint})^2\, a_{paint} \sum_{n=1}^{N} \sum_{m=1}^{M} F_{disk-\Delta z_m}\ [F_{\Delta z_m - \Delta r_n}\, eff_r(n) + F_{\Delta z_m - \Delta z_m}\, eff_z(m)] \\
& + (1 - a_{paint})\ a_{paint}\, F_{disk-mirror}\, \overline{eff_r}
\end{aligned}$$

Comparison with the determination of $\alpha_{th,opt}$ (2/2)

$\alpha_{th,elect}$ = mean over area heating resistor

main term of $\alpha_{th,opt}\, a_R$ = mean over (projected) area precision aperture



REMARK:

→ The difference between both mean values will rel
on only one or two measurement points

→ Possible contribution to the accuracy
of the final ratio $\alpha_{th,elect}$ / $\alpha_{th,opt}$

INACCURACY OF $\alpha_{th,elect}$:
mainly determined by the uncertainty
on the diameter of the heating resistor

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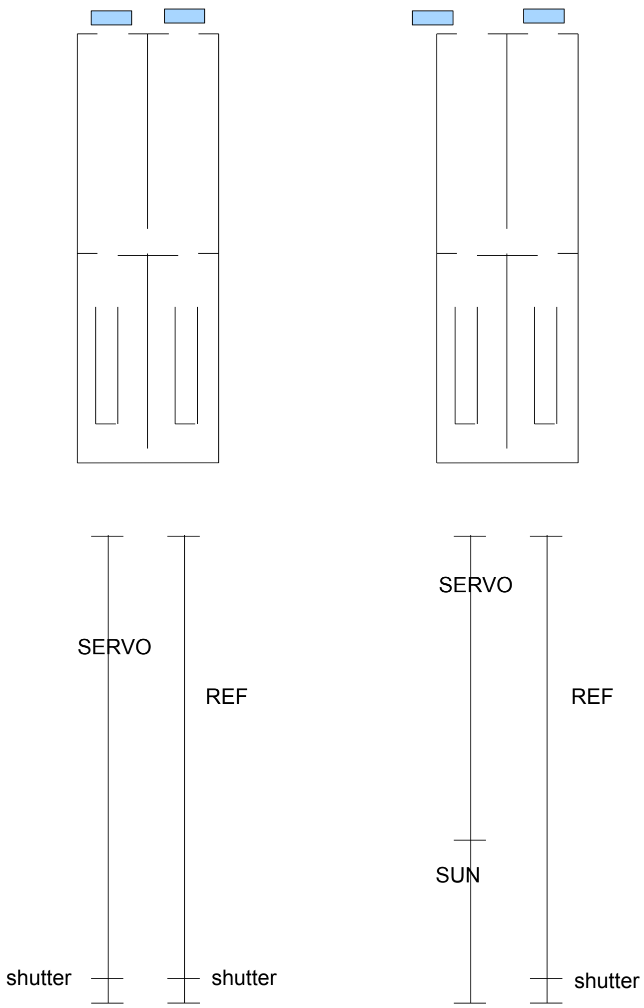
Equilibrium equations (A02)



$$P_{SUN} + P_{open} = P_{ref} + P_{shutter}$$

$$P_{close} + P_{shutter} = P_{ref} + P_{shutter}$$

$$P_{SUN} = P_{close} - P_{open} + P_{shutter}$$

WITHOUT additional effects: diffraction and scattering at the front aperture, backscattering at the optical baffle, emissivity of the shutter, reflection at the shutter, absorptivity of the cavity, thermal expansion of the precision aperture, ...

Equilibrium equation Corrected for thermal efficiency

Approach in NT100:

$$\alpha_{th,opt} P_{SUN} = P_{close} - P_{open} + \alpha_{th,opt} P_{shutter}$$

$$\Rightarrow P_{SUN} = \frac{P_{close} - P_{open}}{\alpha_{th,opt}} + P_{shutter}$$

New approach:

$$\alpha_{th,opt} P_{SUN} = \alpha_{th,elect} P_{close} - \alpha_{th,elect} P_{open} + \alpha_{th,opt} P_{shutter}$$

$$\Rightarrow P_{SUN} = \frac{\alpha_{th,elect}}{\alpha_{th,opt}} (P_{close} - P_{open}) + P_{shutter}$$

ratio close to 1

WITHOUT additional effects: diffraction and scattering at the front aperture, backscattering at the optical baffle, emissivity of the shutter, reflection at the shutter, absorptivity of the cavity, thermal expansion of the precision aperture, ...

TSI equation

$$I = \frac{1}{S(T)} \frac{\Delta P \, \frac{\alpha_{th,elect}}{\alpha_{th,opt} \, A_r} + C_{shutter}}{1 + \Sigma + \Sigma' + \delta}$$

$$C_{shutter} = (P_{shutter} + P_{shutter,refl}) \, (1 + \Sigma_{shutter})$$

$$TSI = \frac{I}{\cos(\text{depointing angle})} \left(\frac{\text{distance to sun}}{1 \text{ AU}} \right)^2 \left(1 + 2 \, \frac{v}{c}\right)$$

(adaption of equation in NT100)

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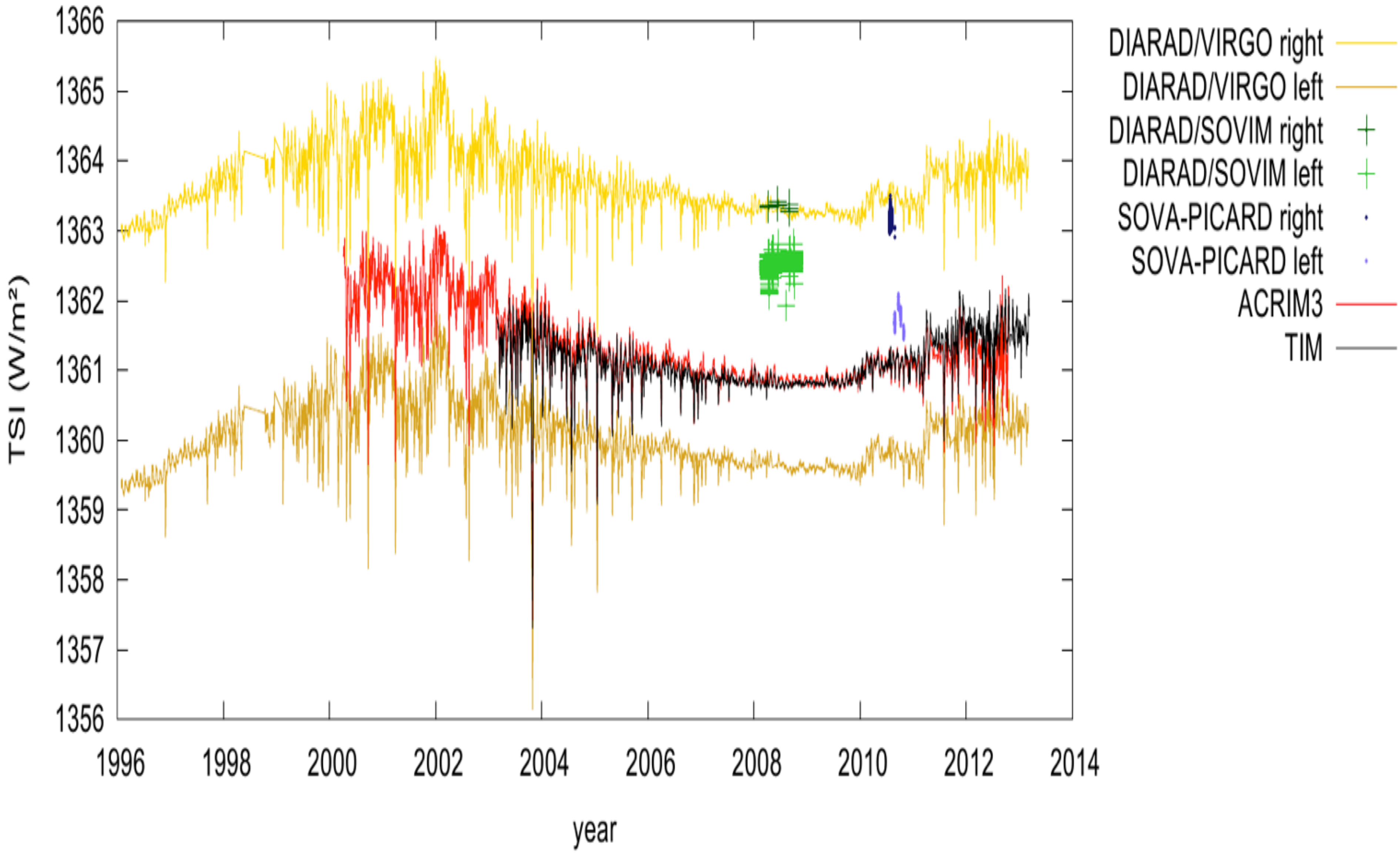
Total Solar Irradiance measurement series



Conclusions

- Introduction of the new parameter $\alpha_{th,elect}$ results in lower TSI values, closer to the TIM and ACRIM values.

- The thermal efficiency parameters $\alpha_{th,opt}$ and $\alpha_{th,elect}$ calculated from this experimental data could result in an uncertainty of ± 2.5 W/m² on the TSI values.

Paper finalized, will be submitted soon