



First Summer School
Part A: Line-focus Solar Thermal Technologies
September 20-24, 2021

Lecture 9:
Design criteria for new Parabolic Trough Collectors

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Design Criteria for new Parabolic Trough Collectors

Content

- **Basic guidelines for new designs of parabolic trough collectors**
- **Software tools for the design of parabolic trough collectors**



Design Criteria for new Parabolic Trough Collectors

Content

➤ **Basic guidelines for new designs of parabolic trough collectors**

Software tools for new designs of parabolic trough collectors



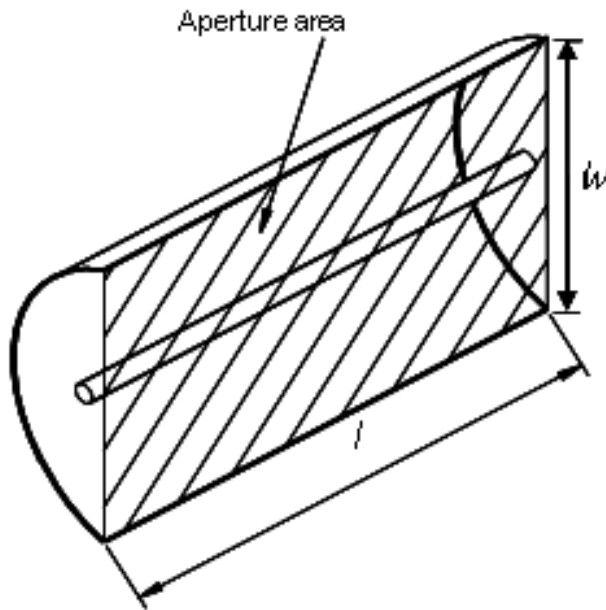
Design of New Parabolic Trough Collectors

The design of new parabolic trough collectors:

- *is commercially interesting nowadays*
- *is a multidisciplinary task and previous experience is very valuable*
- *needs the experimental evaluation of prototypes*
- *must take into consideration the intended commercial applications*

Design of New Parabolic Trough Collectors

Geometrical Concentration Ratio



$$C_{geo} = \frac{A_c}{A_a} = \frac{w \cdot l}{\pi \cdot d_a \cdot l} = \frac{w}{\pi \cdot d_a}$$

A_c = net collector aperture area (m²)

A_a = absorber area (m²)

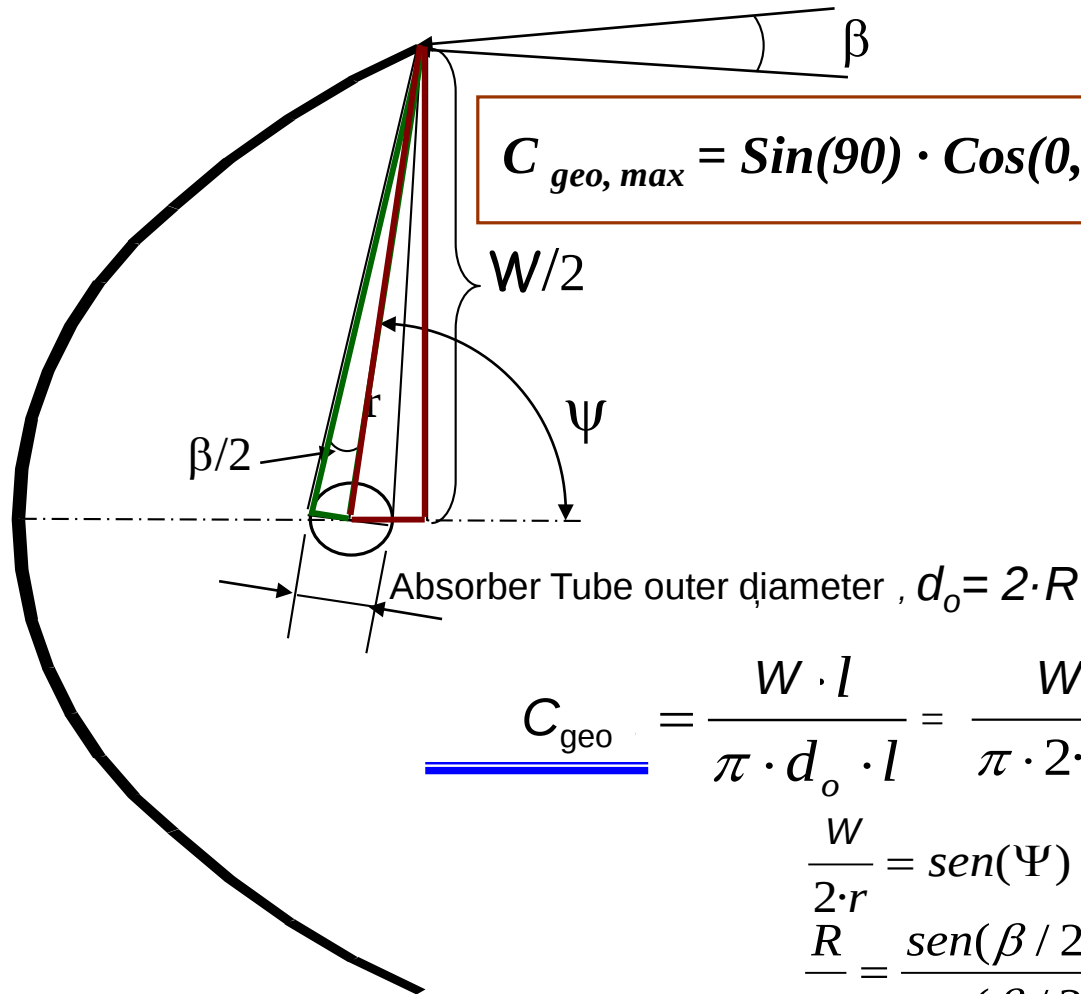
w = aperture width (m)

l = total length (m)

d_o = absorber diameter (m)

Design of New Parabolic Trough Collectors

Theoretical Maximum Geometrical Concentration Ratio



$$C_{geo, max} = \sin(90) \cdot \cos(0,266) / \pi \sin(0,266) \cong 70$$

$$\underline{C_{geo}} = \frac{W \cdot l}{\pi \cdot d_o \cdot l} = \frac{W}{\pi \cdot 2 \cdot R_o} = \frac{r \cdot \sin(\Psi)}{\pi \cdot R} = \frac{\sin(\Psi) \cdot \cos(\beta / 2)}{\pi \cdot \sin(\beta / 2)}$$

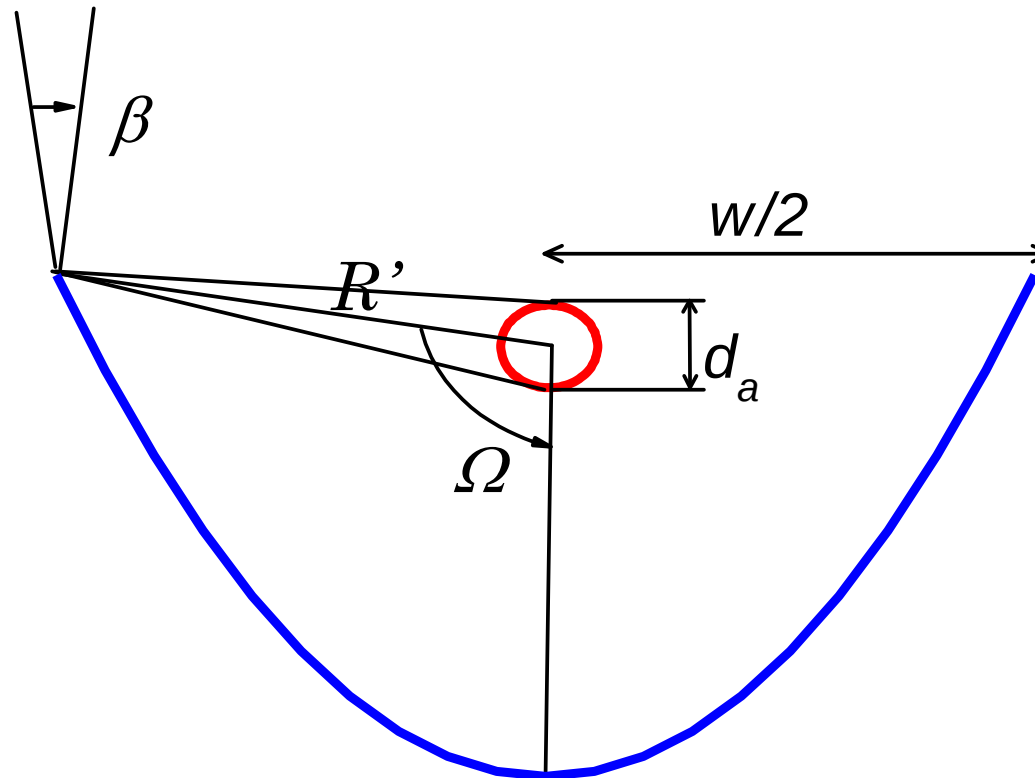
$$\frac{W}{2 \cdot r} = \sin(\Psi)$$

$$\frac{R}{r} = \frac{\sin(\beta / 2)}{\cos(\beta / 2)}$$



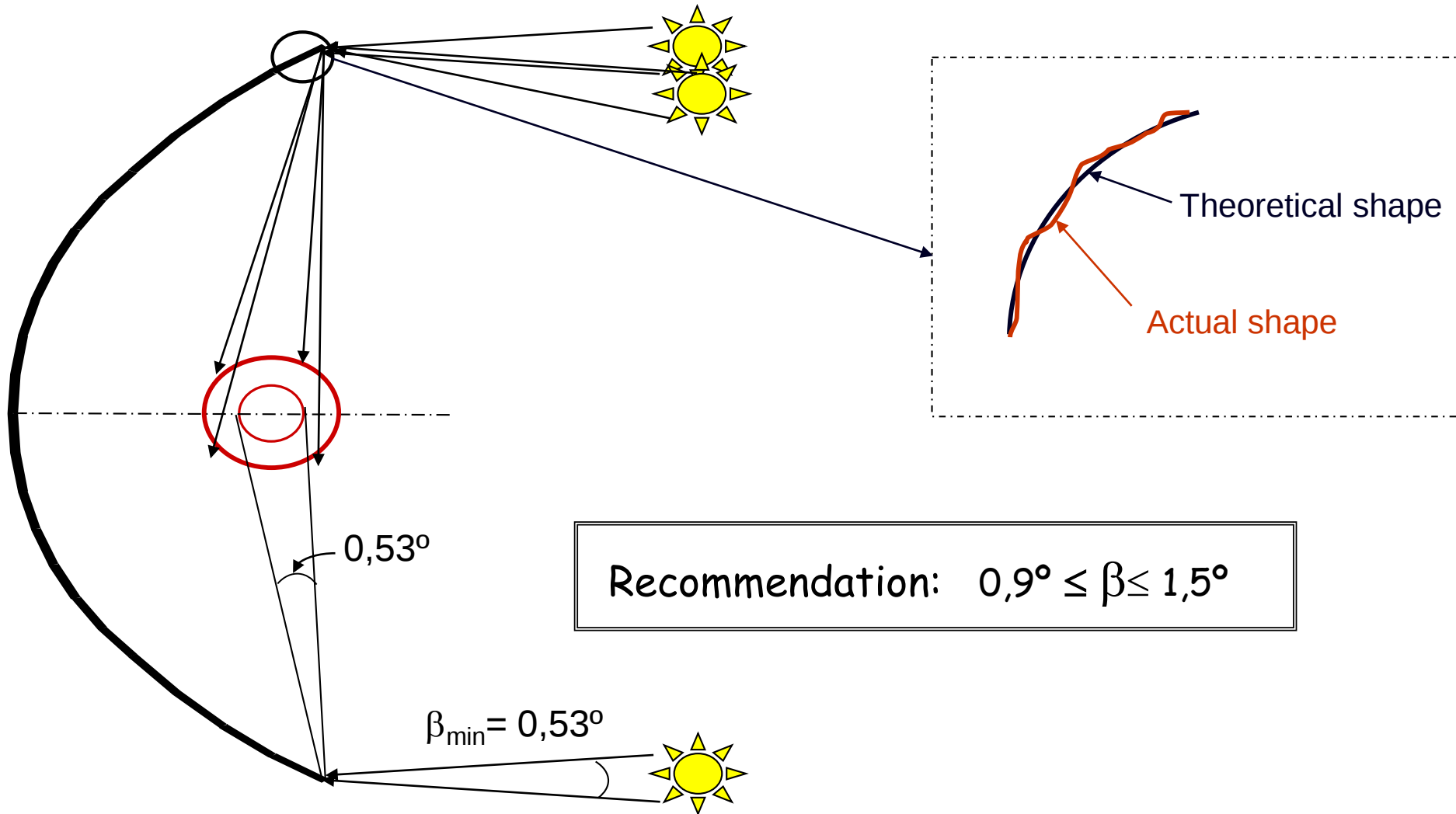
Design of New Parabolic Trough Collectors

Acceptance angle, β , and Aperture angle, ψ



Design of New Parabolic Trough Collectors

Acceptance Angle, β ,

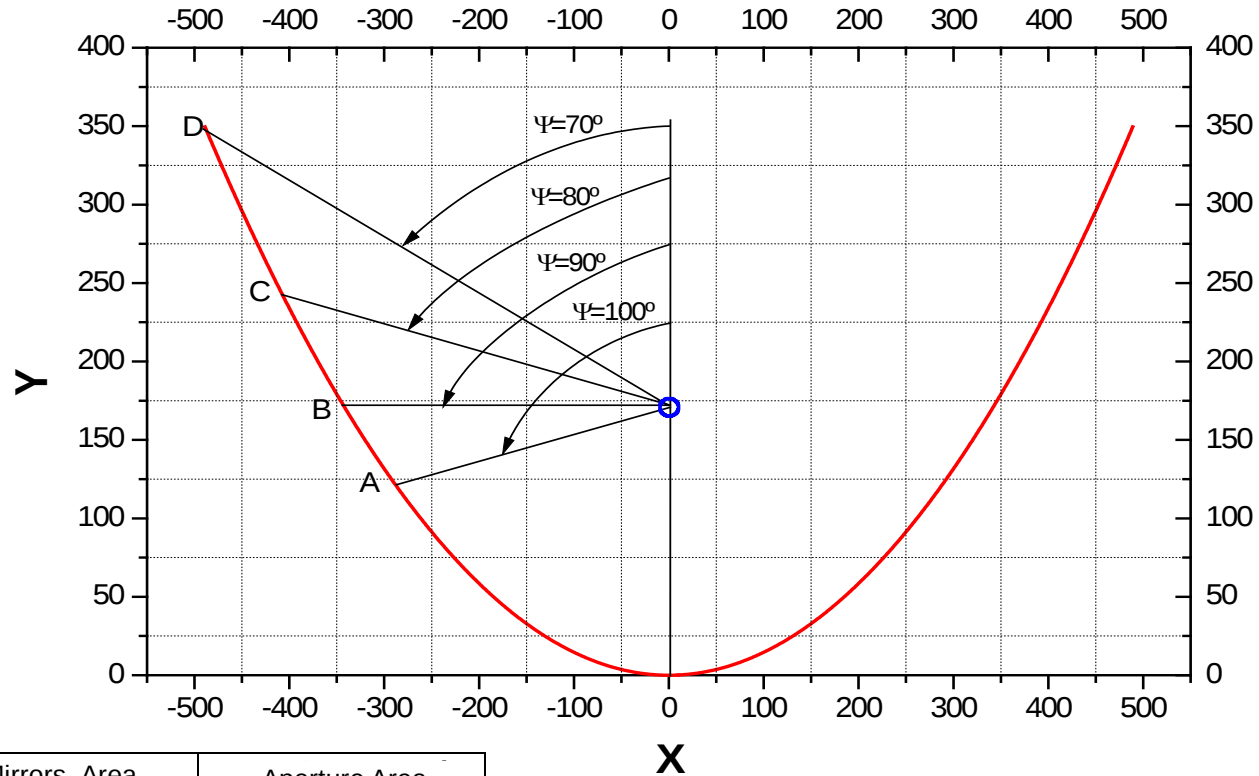
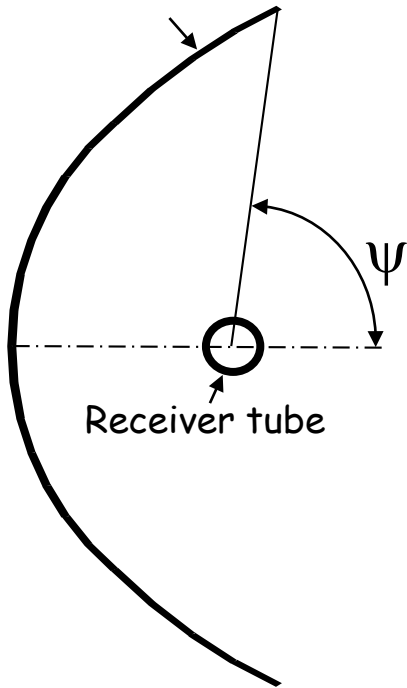




Design of New Parabolic Trough Collectors

Aperture Angle, ψ

Parabolic reflector



Aperture Angle, ψ	Aperture Area m^2	Mirrors Area m^2	Aperture Area / Mirrors Area
100	68,5	75,97	0,90
90	81,4	93,46	0,87
80	97,0	116,62	0,83
70	116,2	148,34	0,78



Design of New Parabolic Trough Collectors

Other recommendations for the collector design (I)

➤ *the size of the collector:*

- Big: for solar thermal electric plants
- Medium: for industrial process heat applications
- Small: for air conditioning systems or similar ones (small solar fields)

➤ *Structural design:*

- Maximum mechanical torsion at collector end $\leq 0,3^\circ$

➤ *Receiver tube type:*

- For $T > 300^\circ\text{C}$: evacuated tube with good selective coating
- For $T < 250^\circ\text{C}$: non-evacuated tube, with carbon steel and black chrome, nickel or thermal paint with high absorptivity
- For $250^\circ\text{C} \leq T \leq 300^\circ$: the type of receiver tube depends on the expected efficiency



Design of New Parabolic Trough Collectors

Other recommendations for the collector design (II)

- *Accuracy of the solar tracking system: $\approx 0,1^\circ$*
- *Type of solar tracking control:*
 - Either option (open-loop or close-loop control) have good performance
- *Type of Drive Unit:*
 - For small-size collectors: electric motor with reduction gear box
 - For big-size collectors: hydraulic units



Design Criteria for new Parabolic Trough Collectors

Content

Basic guidelines for new designs of parabolic trough collectors

➤ **Software tools for new designs of parabolic trough collectors**



Design of New Parabolic Trough Collectors

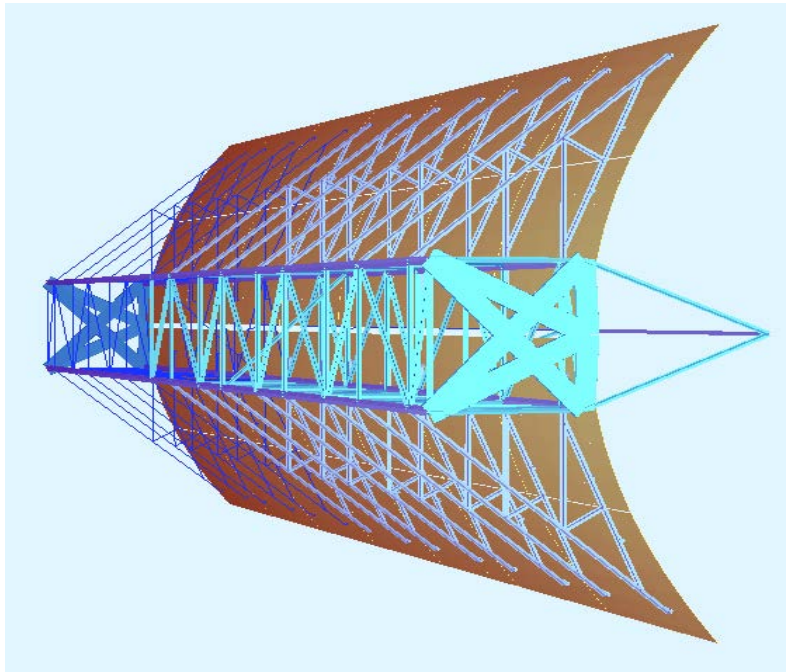
Software tools for the design of parabolic trough collectors

- *Design tools for supporting structures, based on FEM (ANSYS)*

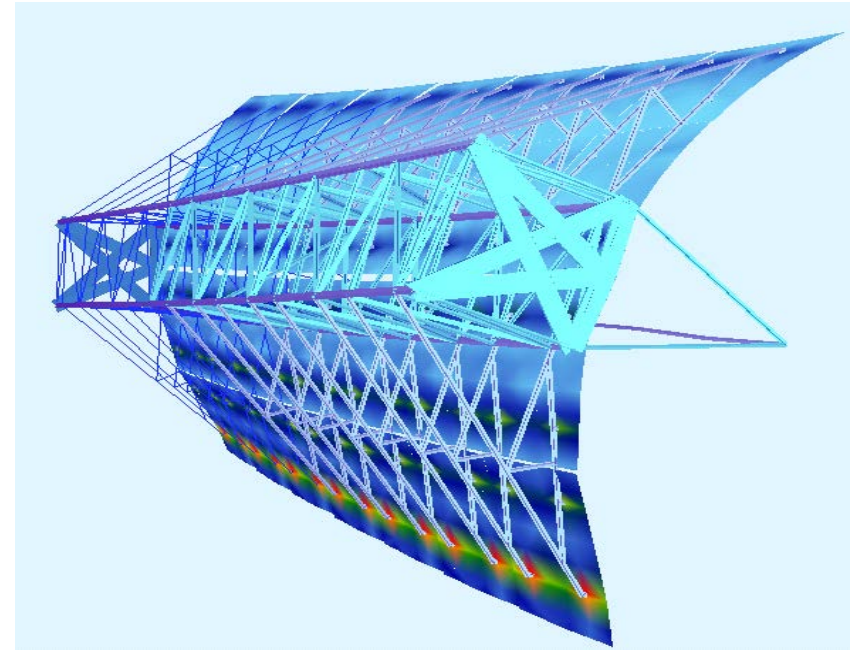


Design of New Parabolic Trough Collectors

Space frame performance analysis with ANSYS



Structure without deformation



Structure deformation by torque



Design of New Parabolic Trough Collectors

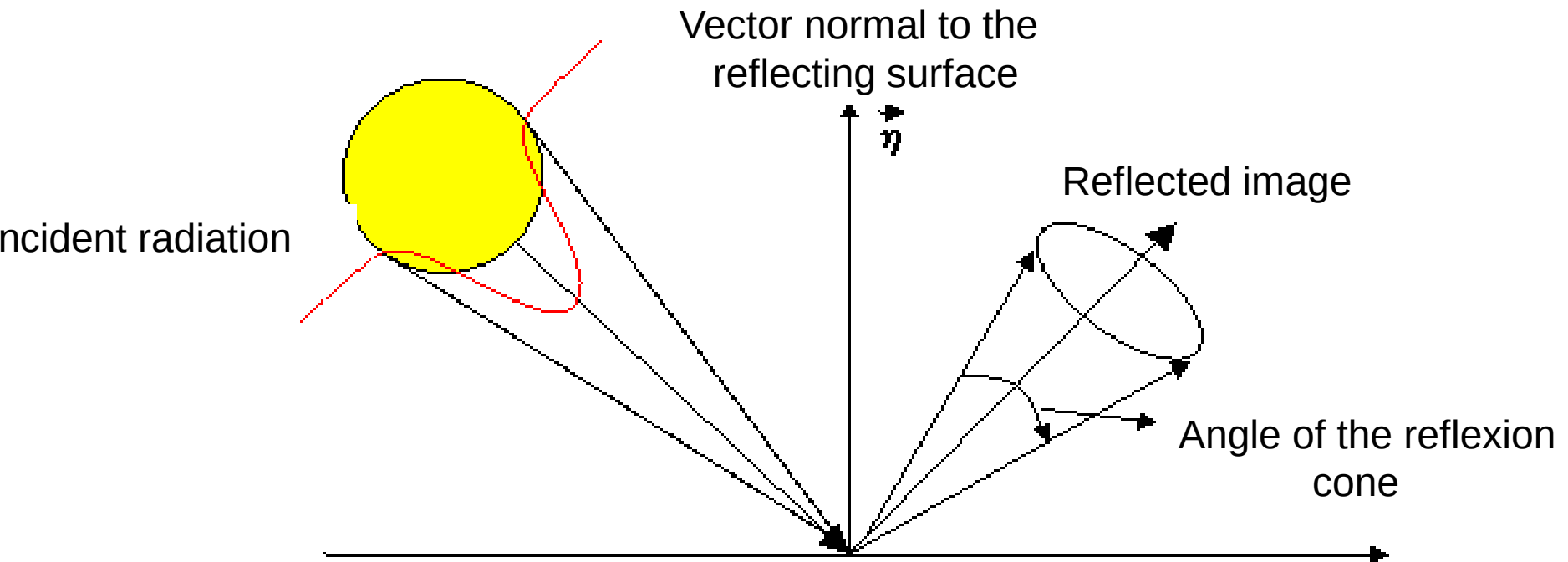
Software tools for the design of parabolic trough collectors

- *Design tools for supporting structures, based on FEM (ANSYS)*
- *"Ray tracing" computer programs*



Design of New Parabolic Trough Collectors

“Ray Tracing”: angular distribution of both the incident and the reflected radiation





Design of New Parabolic Trough Collectors

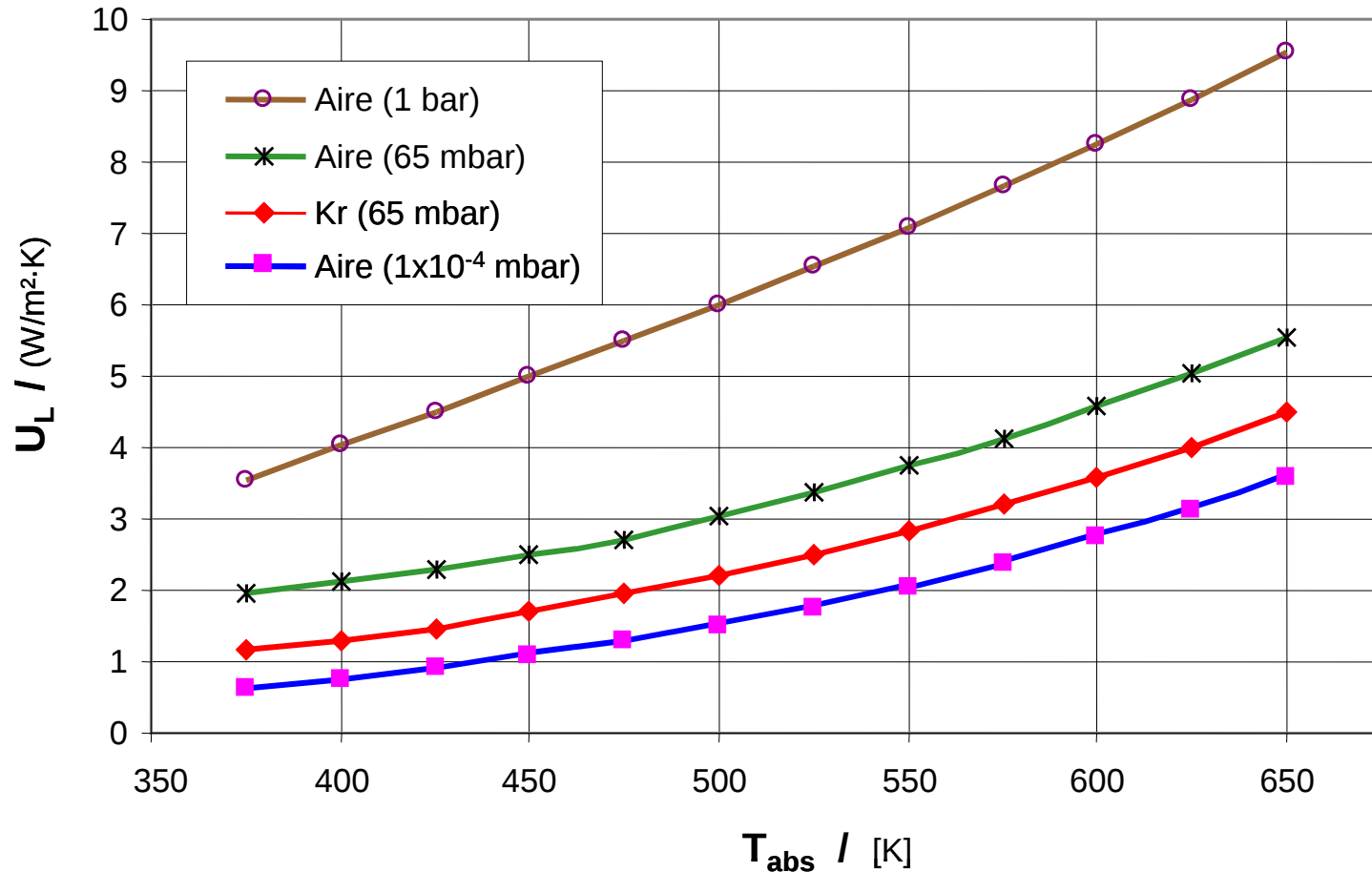
Software tools for the design of parabolic trough collectors

- *Design tools for supporting structures, based on FEM (ANSYS)*
- *"Ray tracing" computer programs*
- *Tools for thermal simulation of receiver tubes*



Design of New Parabolic Trough Collectors

Simulation of the thermal loss global coefficient in a receiver tube with different gases in the annulus between the steel absorber and the glass cover (Rojas, 1993).





Design of New Parabolic Trough Collectors

Software tools for the design of parabolic trough collectors

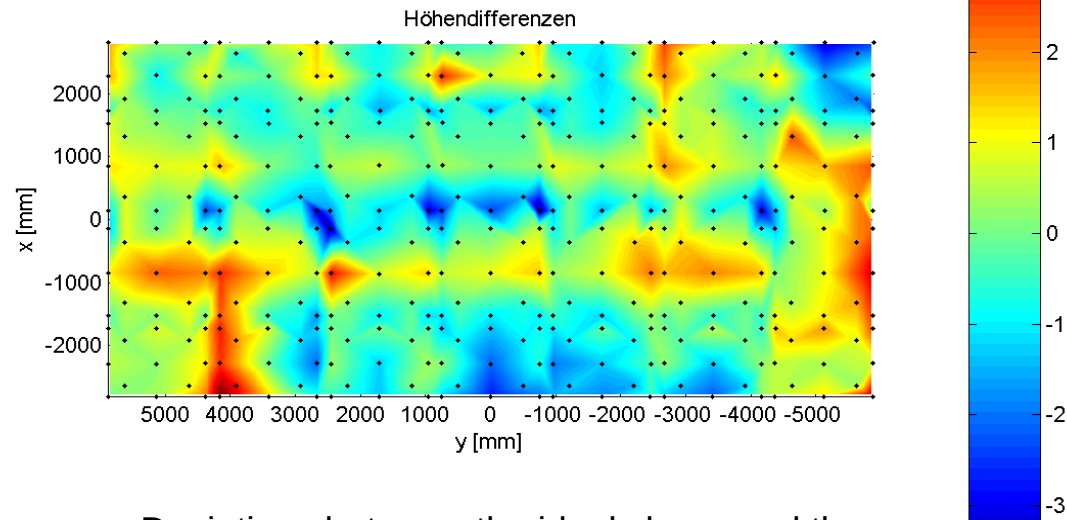
- *Design tools for supporting structures, based on FEM (ANSYS)*
- *"Ray tracing" computer programs*
- *Tools for thermal simulation of receiver tubes*
- *Tools for geometric analysis of concentrators*

Design of New Parabolic Trough Collectors

Evaluation of the geometric shape accuracy using “Photogrammetry”



Parabolic trough concentrator with
“Targets” attached for Photogrammetry



Deviations between the ideal shape and the
actual shape of a parabolic trough surface



Design of New Parabolic Trough Collectors

Final Recommendation

!! Use standard commercial components whenever possible (e.g., steel profiles, mirrors and steel tubes of standard sizes).
The manufacture cost of the collectors will be much higher otherwise;;

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- Thank you very much for your attention**
- Questions?**

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