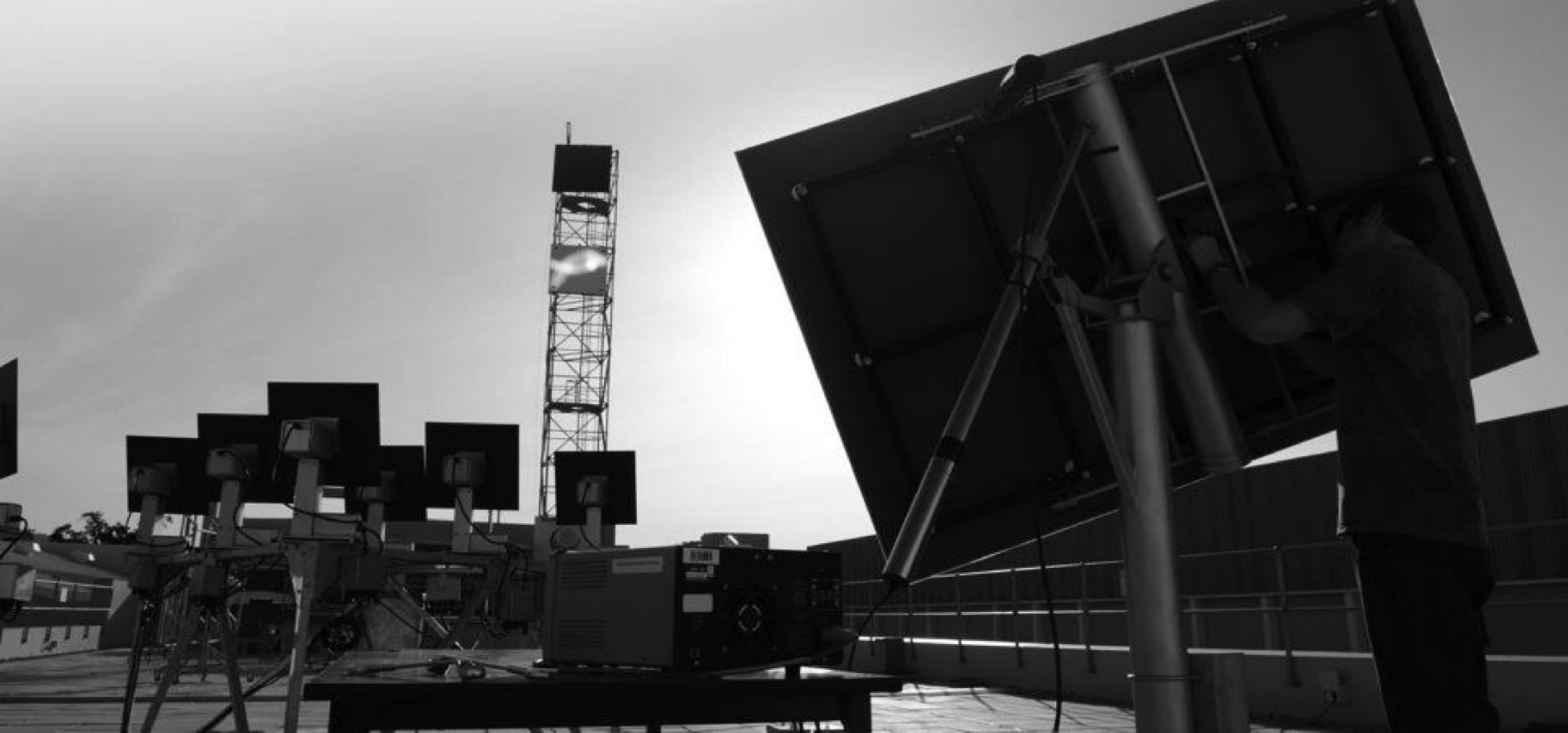
STERG

SOLAR THERMAL ENERGY RESEARCH GROUP



Stationary Booster Reflectors for Solar Thermal Process Heat Generation

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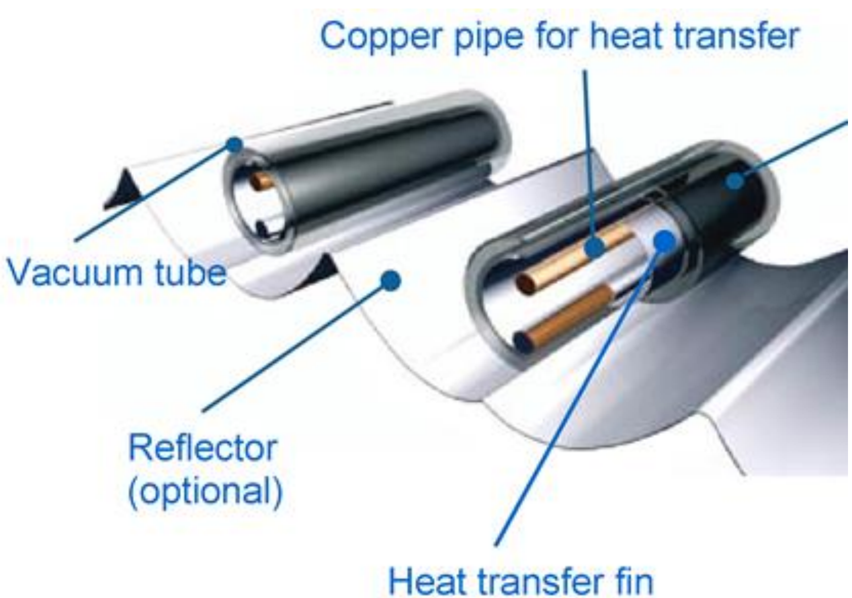
AGENDA

- Stationary Concentrators
- Efficiency Tests and Output Simulation
- Monitoring of a Pilot Plant
- Marginal Costs
- Summary and Outlook

Stationary Concentrators

External Compound Parabolic Concentrators (CPC´s)



Very common: CPC´s for evacuated tube collectors (Weiss and Rommel 2008)

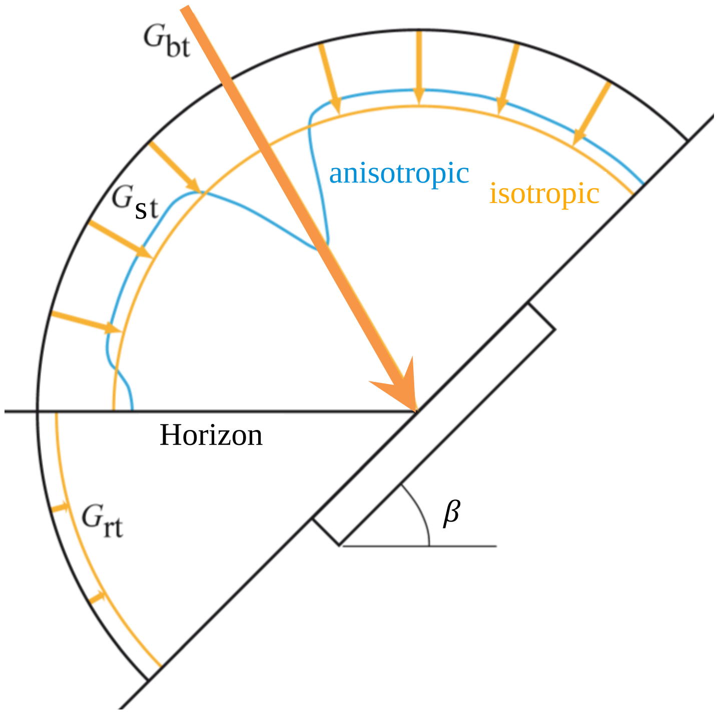
External CPC for flat evacuated SRB collector (Picture: Intersolar Munich 2011)

Stationary Concentrators

Flat booster reflectors

Flat-plate collector field with corrugated aluminium sheet booster reflectors in Östhammer, Sweden.
Picture: Karlsson, cp. (Rönnelid and Karlsson **1999**)

Stationary Concentrators: Diffuse Matters!



G_{bt} = Beam irradiance (Aperture 5.72°)

G_{st} = Diffuse from sky

G_{rt} = Diffuse from ground

RefleC-Collector at pilot plant Laguna (positive transversal incidence angle indicated)

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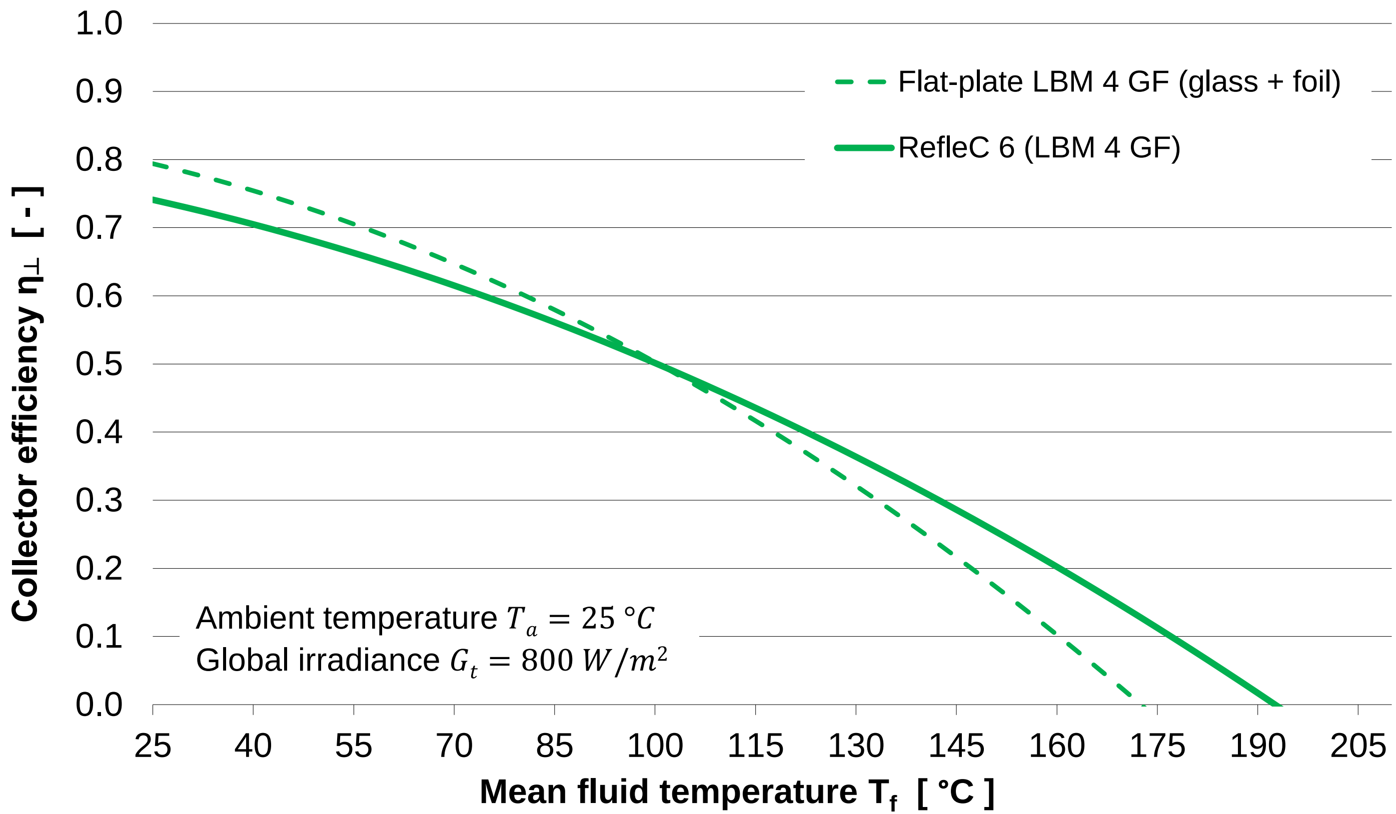
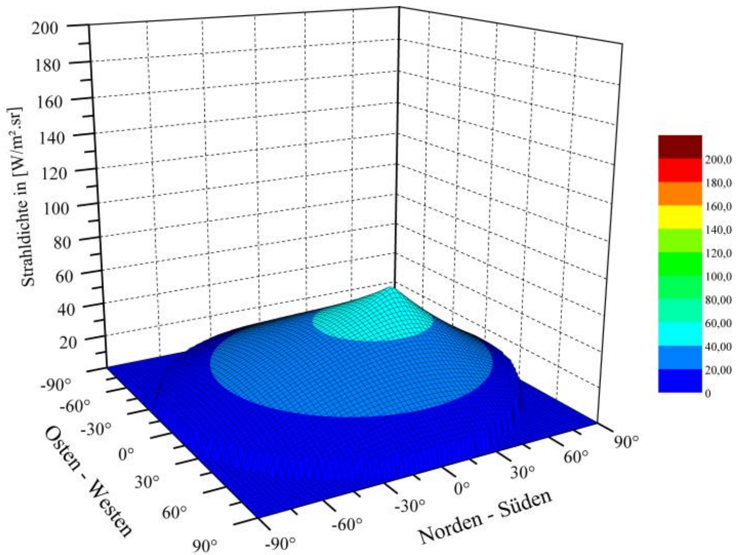
Efficiency Tests and Output Simulation

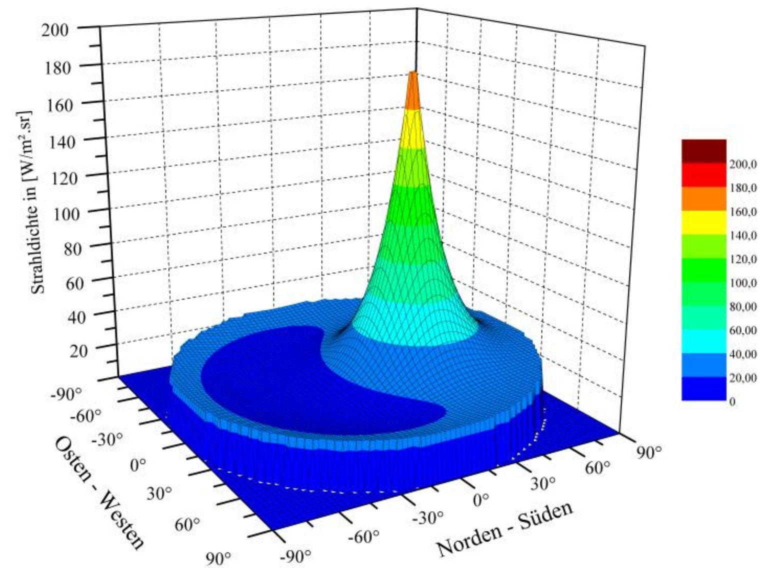
Measured efficiency curves of RefleC and its flat-plate



Efficiency Tests and Output Simulation

Diffuse distribution from Brunger model (48 classes)





Distribution of diffuse irradiance for a **slightly covered** sky

k = 0.95, kt= 0.35

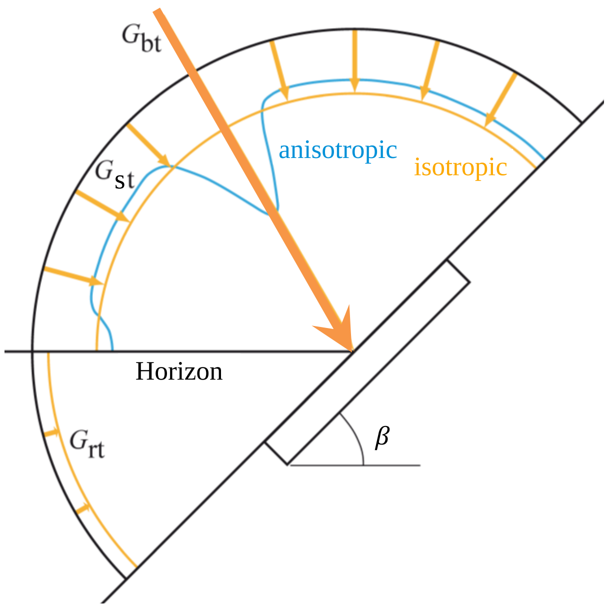
Distribution of diffuse irradiance for a **clear sky**

k = 0.25, kt= 0.75

k = fraction of diffuse

k_t= clearness index

Collector Simulation Model Type 154

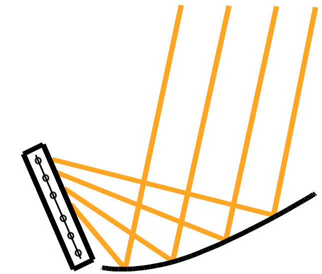


G_{bt} = Beam irradiance

G_{st} = Diffuse from sky

G_{rt} = Diffuse from ground

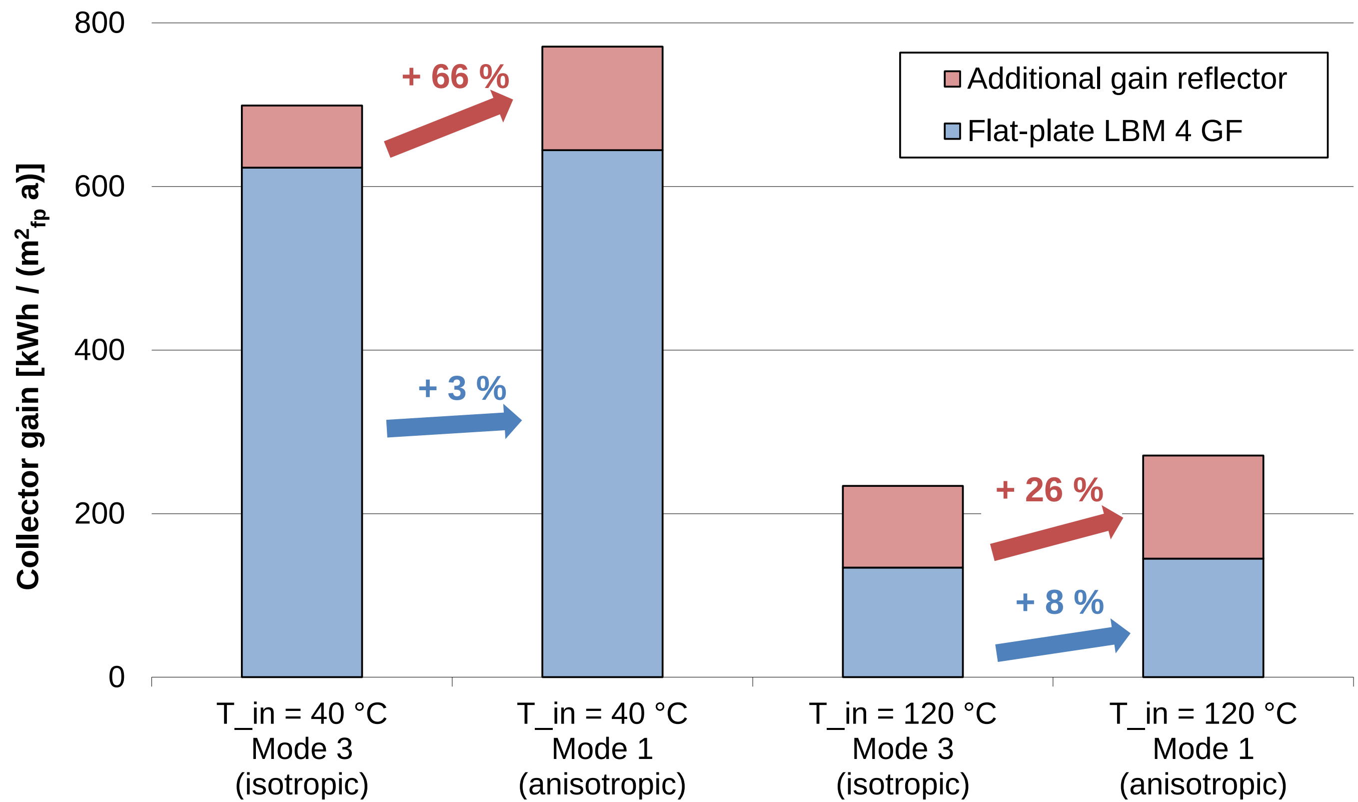
Hess, S. and Hanby, V. I. (2014). Collector Simulation Model with Dynamic Incidence Angle Modifier for Anisotropic Diffuse Irradiance. Energy Procedia 48(0): 87-96



Three modes for diffuse-IAM:

- Mode **1**: Anisotropic for sky (dynamic), isotropic for ground (once per sim)
- Mode 2: Isotropic for sky (once per sim), isotropic for ground (one per sim)
- Mode **3**: Manual input of one hemispheric IAM for isotropic diffuse

Effect of Booster Reflectors



Annual output of RefleC 6 GF (blue plus red) and its receiver LBM 4 GF (blue) in **Würzburg**. Output increase by booster is **20 %** at constant T_{in} = 40 °C and **87 %** at T_{in} = 120 °C

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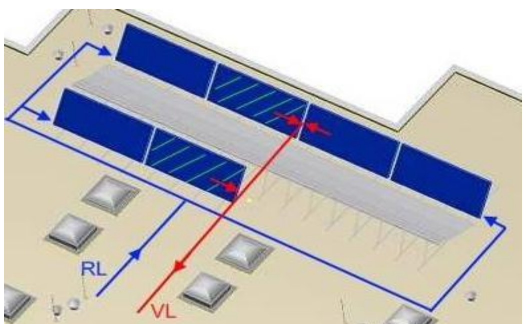
Monitoring: Laundry Laguna, GER

Wagner Solar

Reference flat-plates (glass-foil, front) and new RefleC-collectors (back)



Flow
collector field

System

Pilot Plant: System Concept

- Increased temperatures for solar loop and storage
- Three thermal loads on process- and supply level

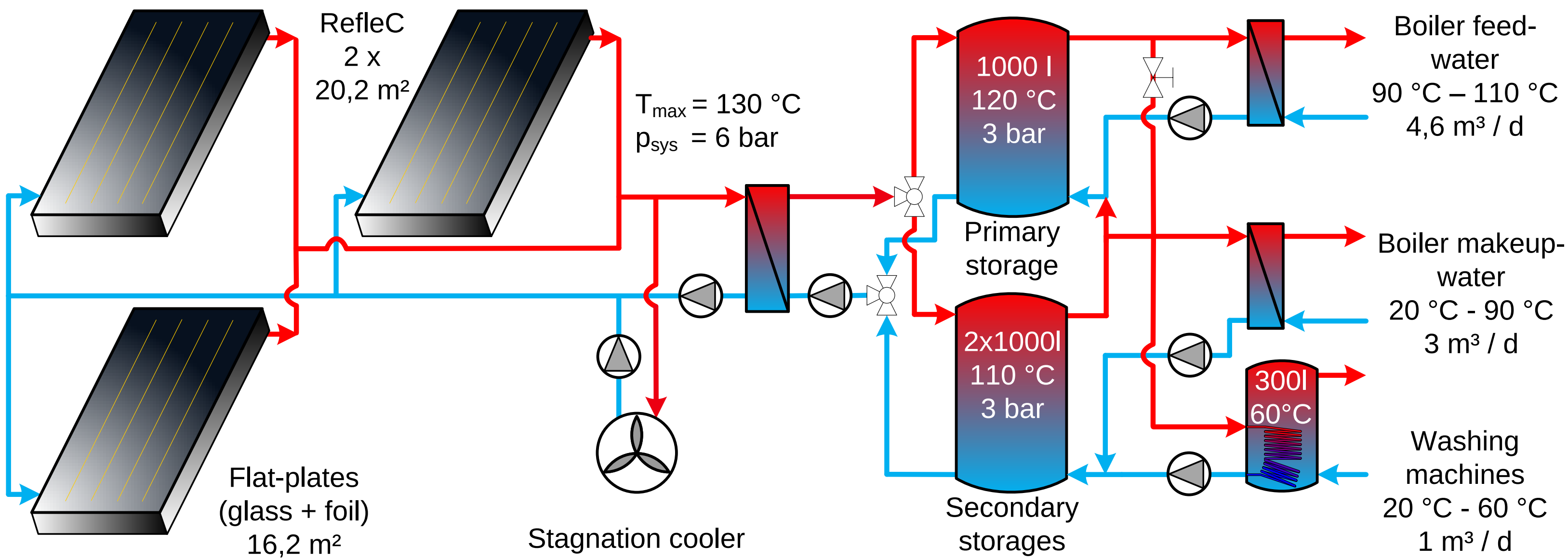
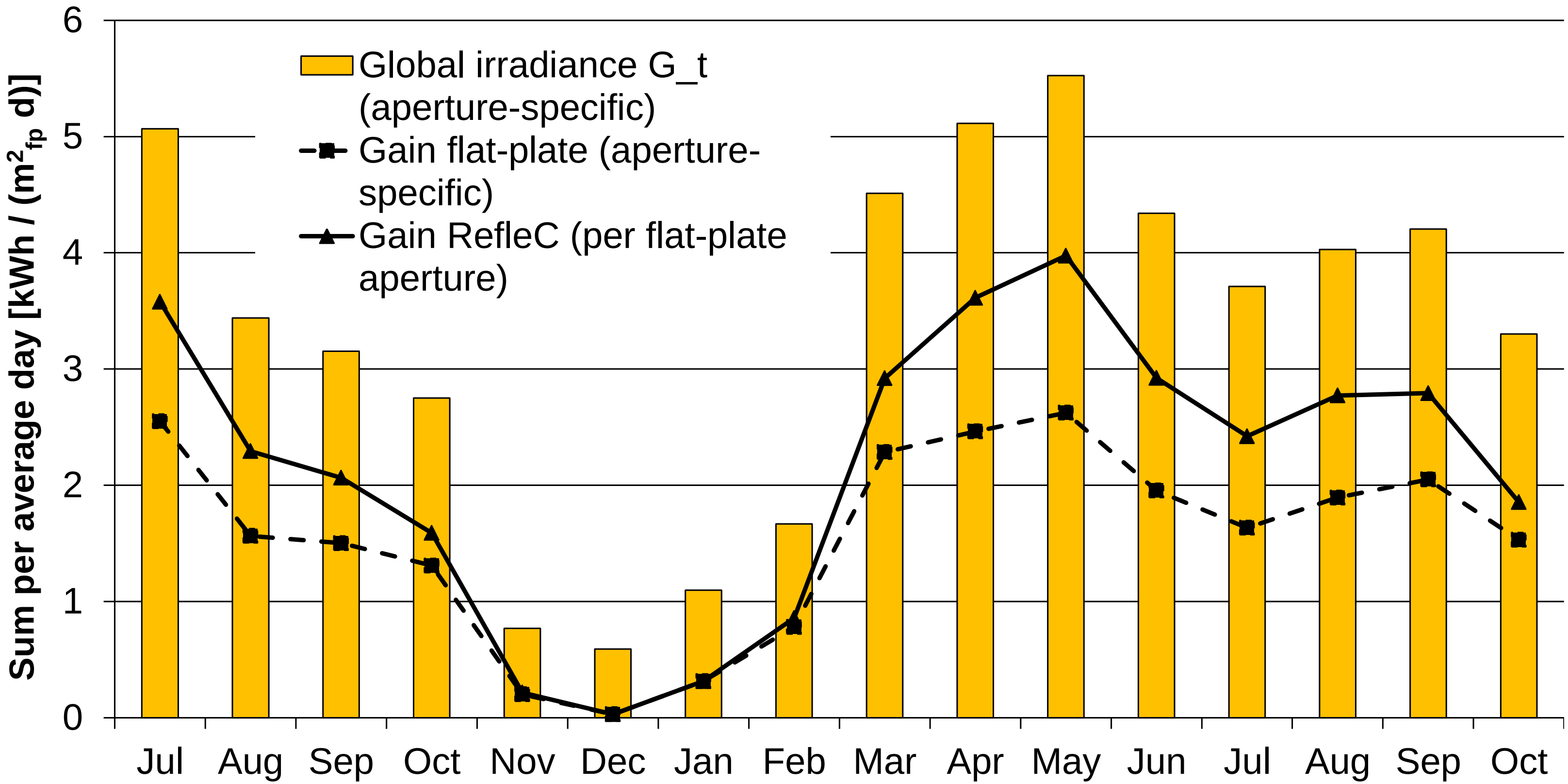


Fig: Simplified system concept of the RefleC pilot plant

Monitoring

Additional gains over 16 months

+ 39.1 % all temperatures
+ 78.1 % T > 80 °C



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What can RefleC Boosters cost?

$$K_{inv} = \frac{K_{sol} \cdot Q_{sol}}{f_a}$$

Parameters:

- Field simulations: additional gain boosters Würzburg = 126.0 kWh/m^2 Seville 212.5 kWh/m^2 flat plate
- Monitoring: system efficiency 0.86 (i.e. 108 kWh/m$^2_{fp}$ supplied in Wb)
- Conventional heat 0.06 EUR/kWh, aim for solar heat 0.04 EUR/kWh
- Lifetime 20 years, interest rate 4 %, no costs for maintenance & operation

Results:

- Investment in Würzburg max. 40 EUR/m^2 of booster (= 480 EUR/LBM fp), amortization static: 9 years
- Seville: 67 EUR/m2 booster (= 804 EUR/LBM); amortization 5.4 years

Calculated according to VDI 6002, 2004

Summary and Outlook

Dissertation available: **www.reiner-lemoine-stiftung.de**

- Previous research undervalued increase by boosters
- Increase in annual gain <u>largely independent of</u> collector <u>working temperature</u> → process heat!
- <u>Cost/performance</u> ratio <u>increases with higher overall irradiation</u>.

- Marginal reflector costs in regions with higher irradiance to be determined (e.g. South Africa → Solar PACES)
- RefleC-boosters for other stationary collectors
- Comparison to other collector types for various applications

Thank you!

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Pilot Plant: Charge, Storage, Discharge

Primary storage tank (left), two parallel secondary storages (center), expansion vessel and the hot water storage for the washing machines

RefleC 6 in OptiCAD

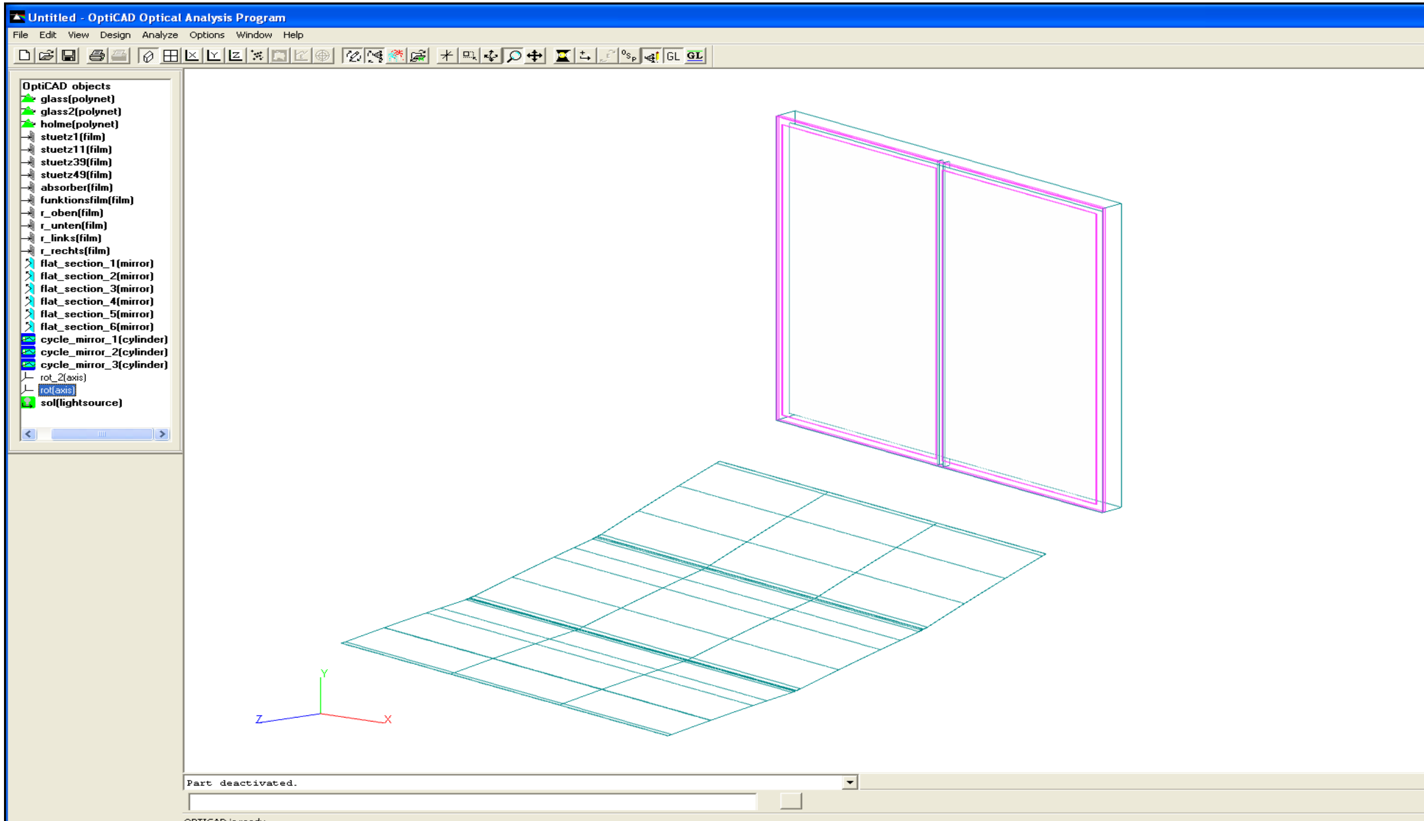
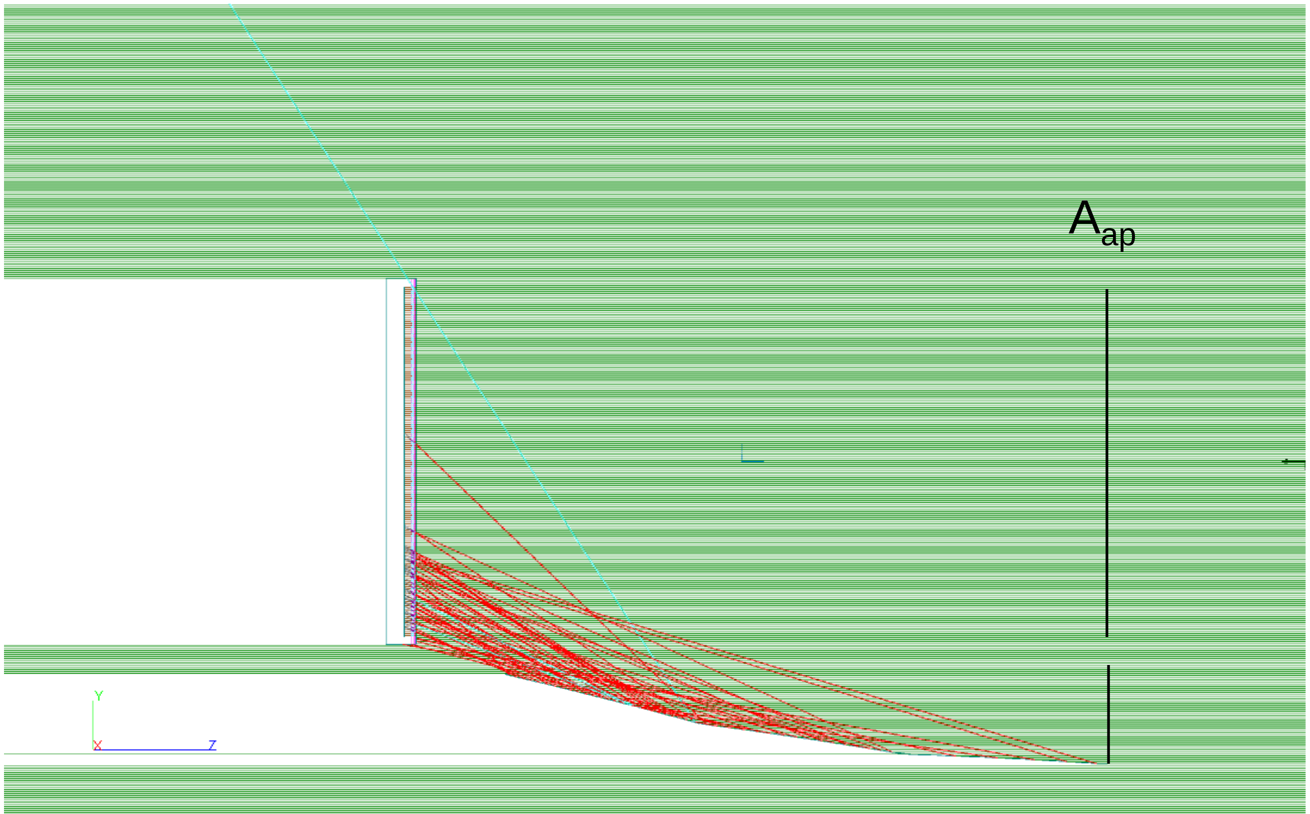


Fig.: Screenshot from OptiCad

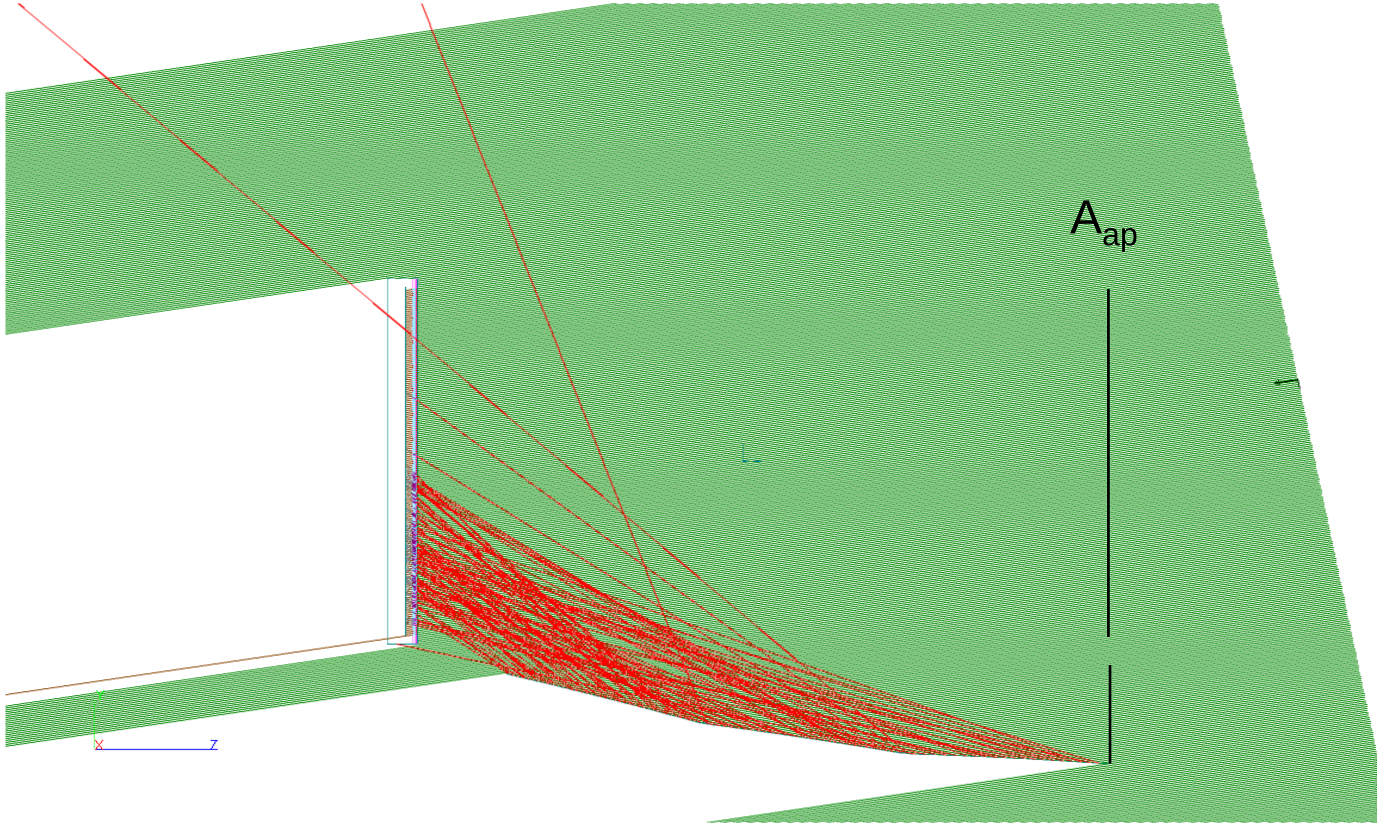
RefleC 6: IAM_{dir}-transversal

theta_t = 0°



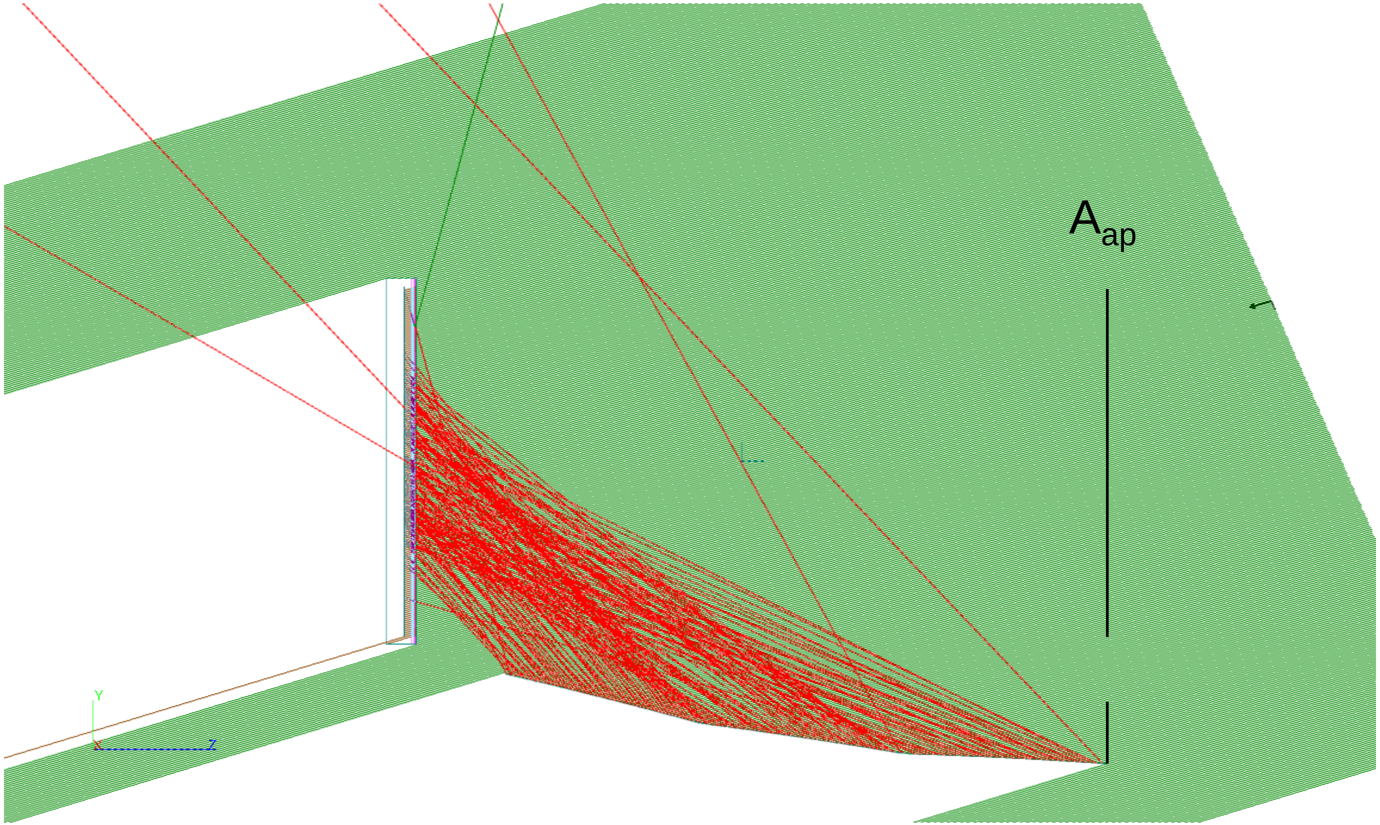
RefleC 6 : IAM_{dir}-transversal

theta t = 10°



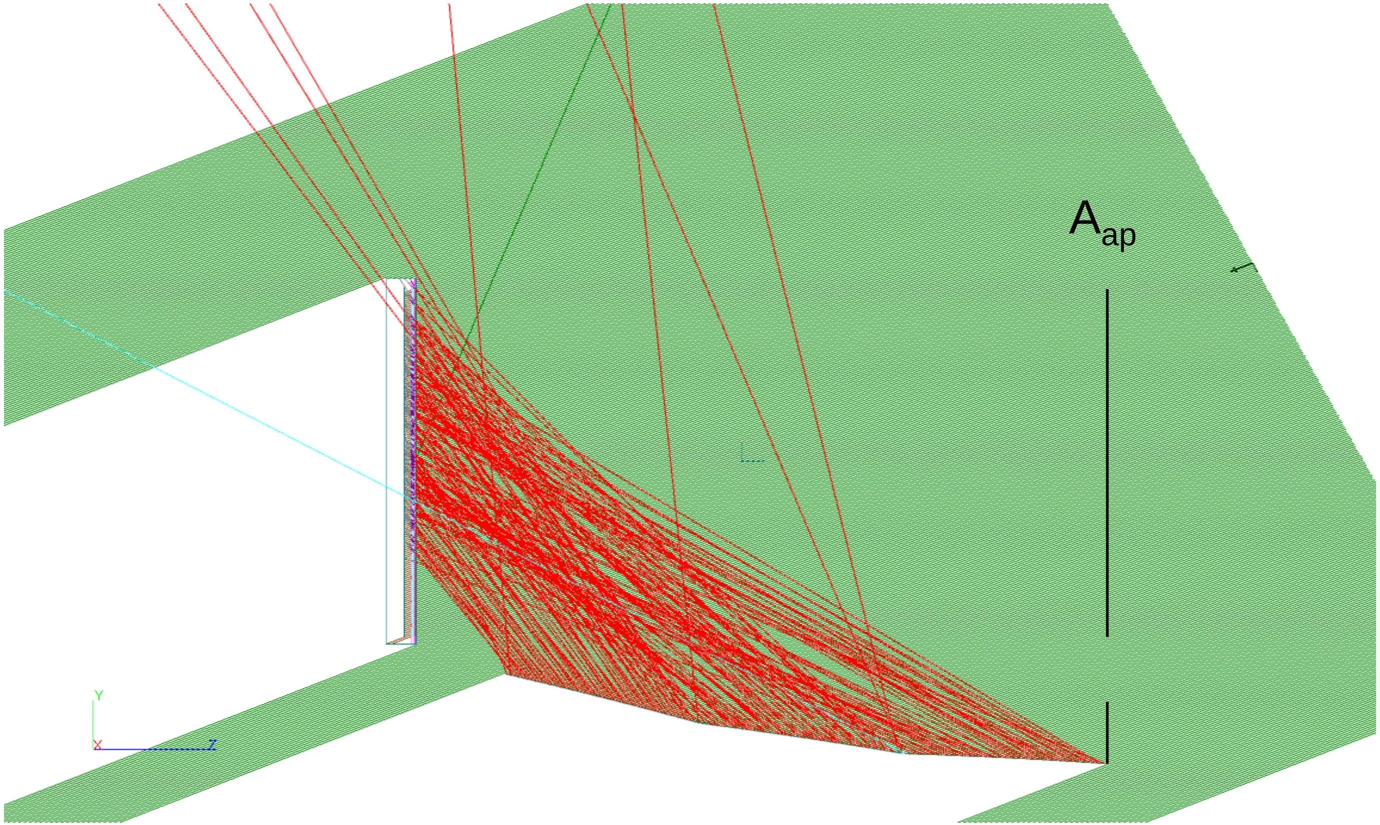
RefleC 6 : IAM_{dir}-transversal

theta t = 20°



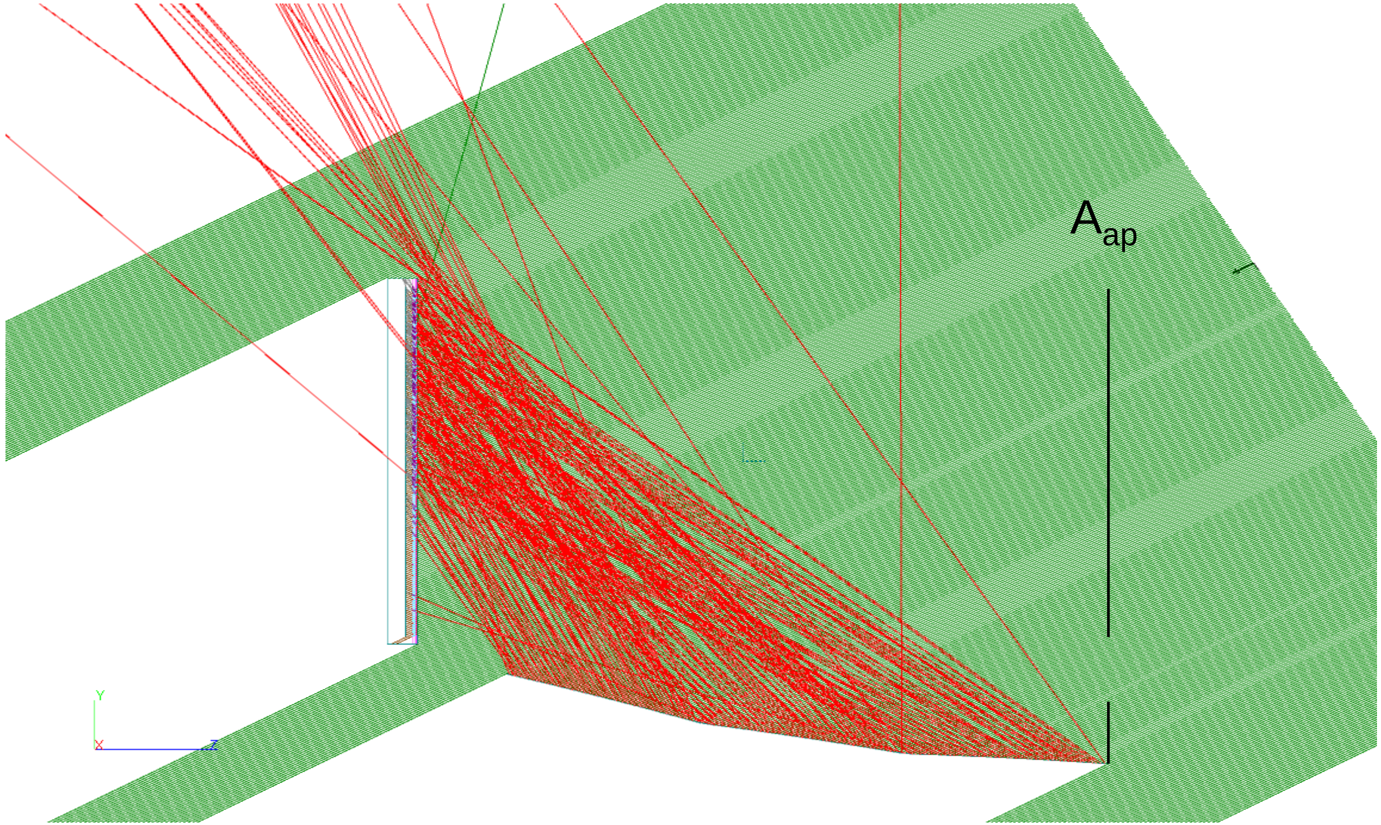
RefleC 6 : IAM_{dir}-transversal

theta t = 25°



RefleC 6 : IAM_{dir}-transversal

theta t = 30°



RefleC 6 : IAM_{dir}-transversal

theta t = 40°