Dependency of Bifaciality on Irradiance Level

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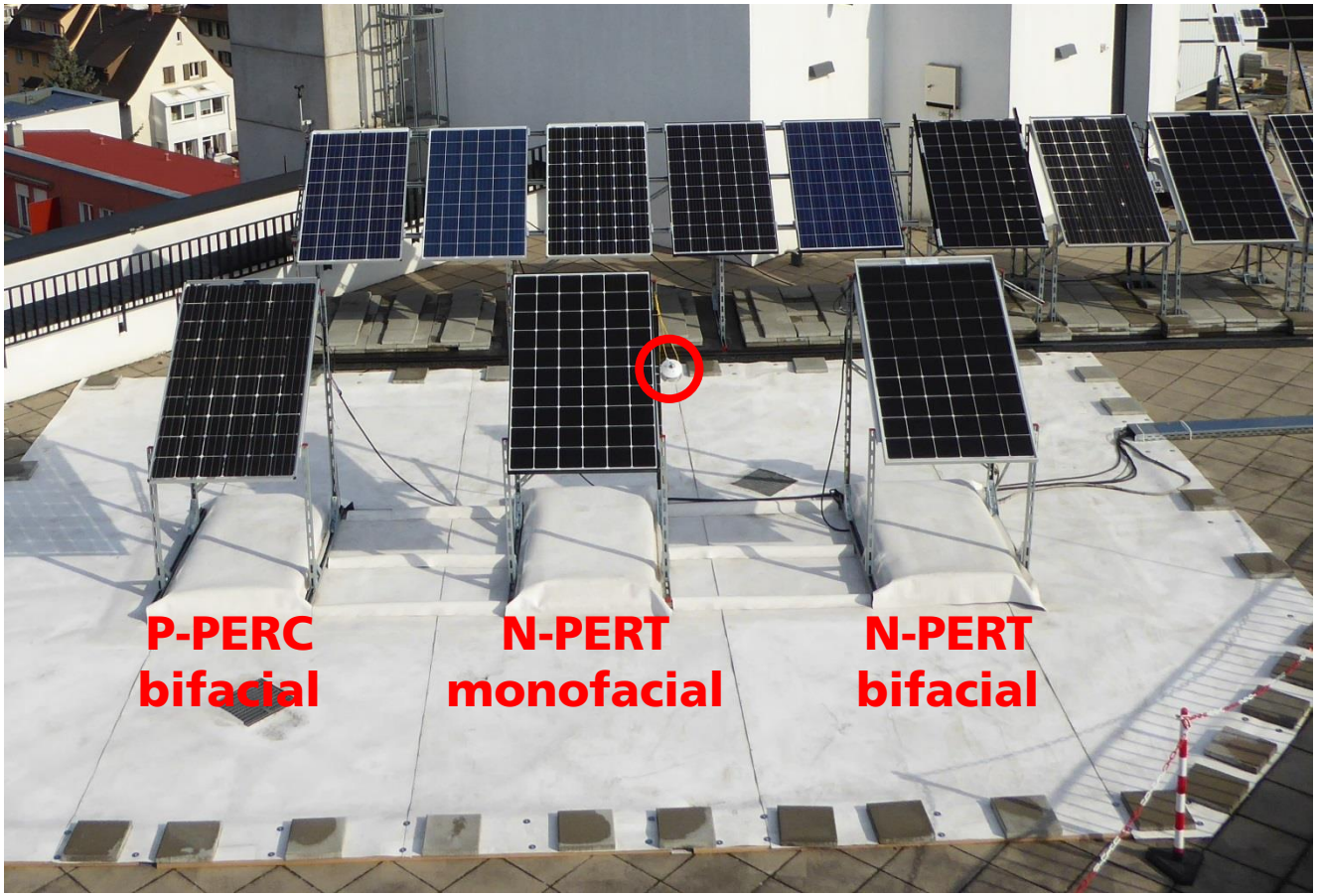
AGENDA

- Experimental setup
- Experimental results
- How to explain these results?
- Conclusions

Experimental setup

- Symmetrical setup operated for 1 year
- Albedo = 75%...80%
- Average irradiation gain = 35%
- See also Poster by Hyun Jung Park et al. (Ballroom)



Experimental setup
Perfomance parameters

- $BG_{OPT} = \frac{G_{BACK}}{G_{FRONT}}$ (Optical gain, instantaneous or cumulated)
- $BG_{MOD} = \frac{P_{BACK}}{P_{FRONT}}$ (Module power or energy gain)

$$= \frac{G_{BACK} * \eta_{BACK}}{G_{FRONT} * \eta_{FRONT}}$$ (η : module efficiency)

$$= BG_{OPT} * \varphi$$ (φ : bifaciality factor)

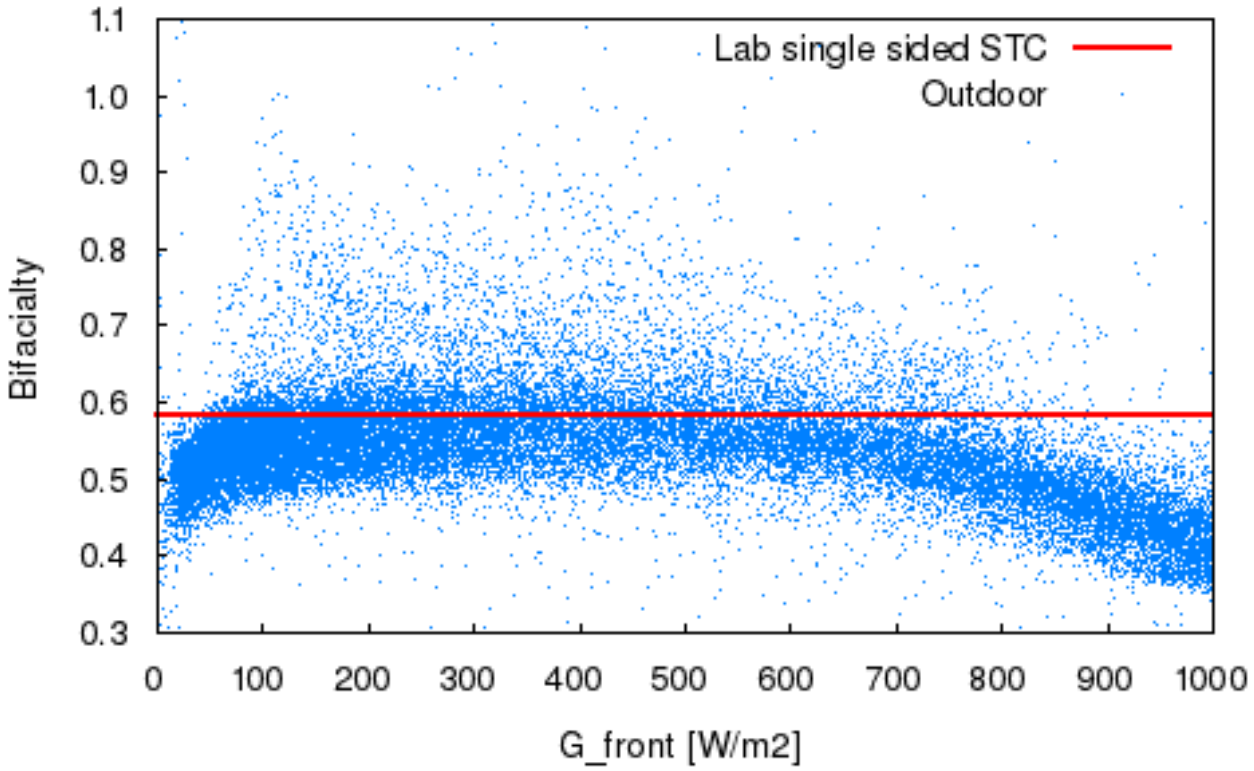
- $\varphi = \frac{BG_{MOD}}{BG_{OPT}}$

Experimental results
Annual average values

Module	BG_{OPT}	φ	BG_{MOD} calc.	BG_{MOD} obs.	obs. / calc.
P-PERC	34.7%	58.2%	20.2%	16.5%	81.7%
N-PERT	34.7%	87.4%	30.3%	26.5%	87.2%

Experimental results
One year of measured data

P-PERC module: Bifaciality factors “data sheet” vs. outdoor operation



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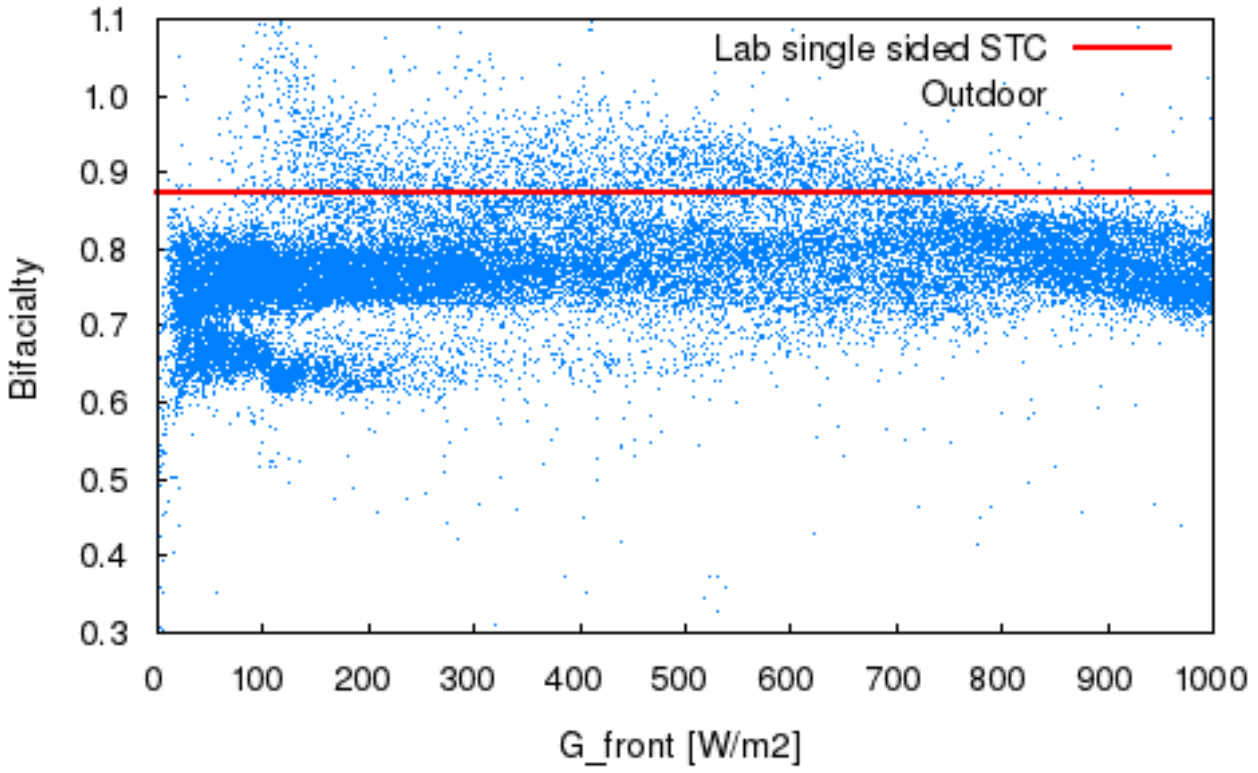
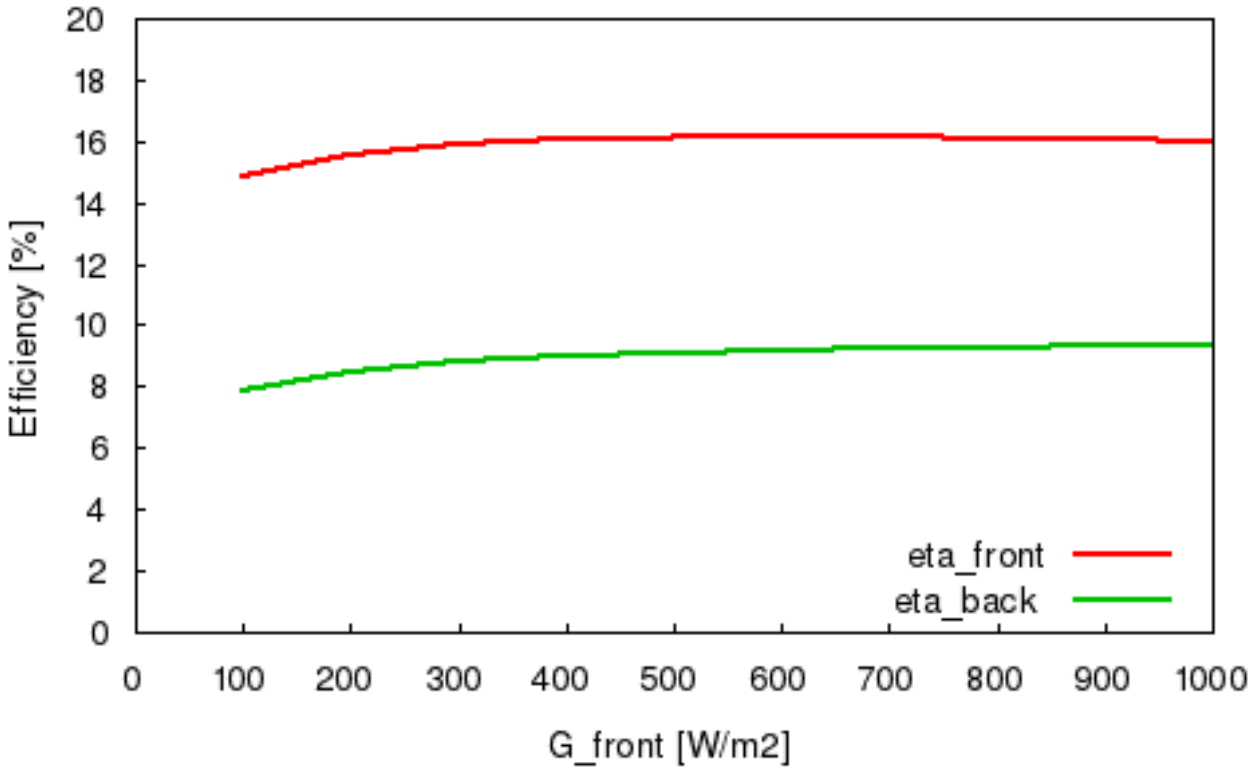


How to explain these results?
Laboratory Measurements I

P-PERC module: single sided absolute efficiencies



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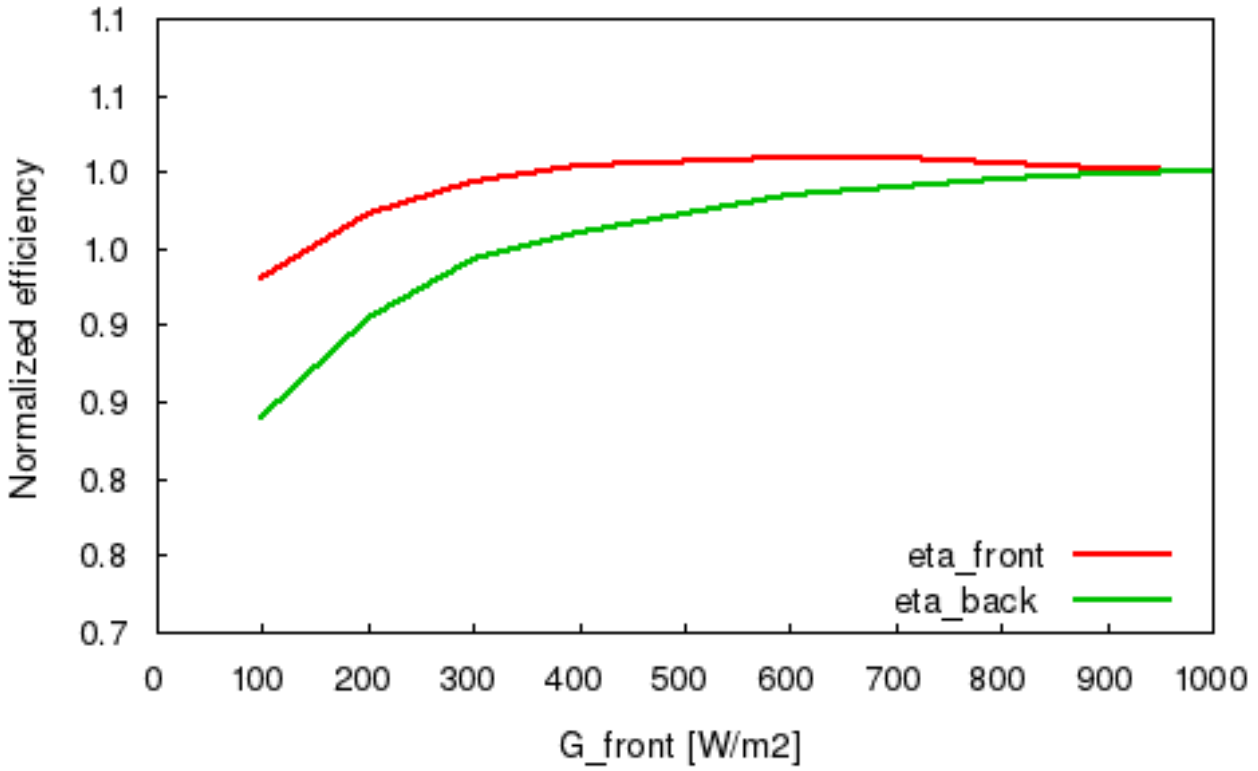
P-PERC module: single sided normalized efficiencies



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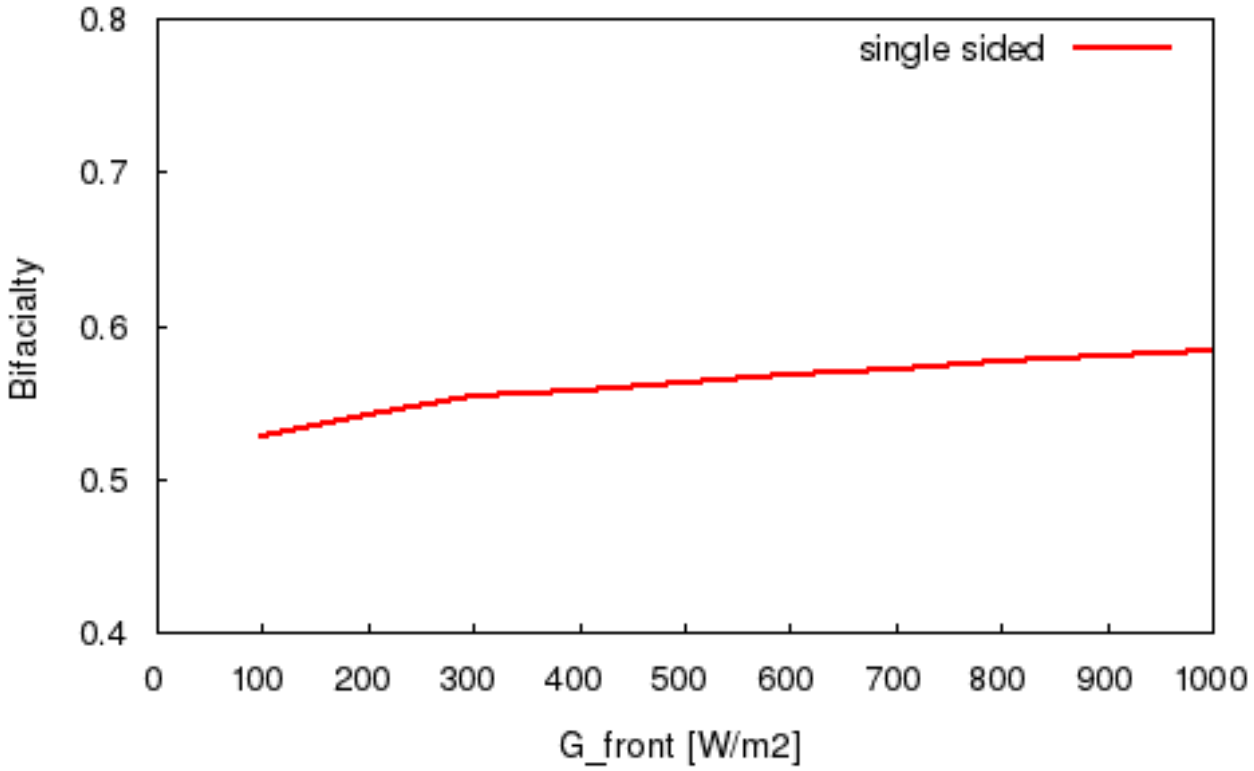
Laboratory Measurements I

P-PERC module: ratio of single sided absolute efficiencies (STC bifacialty)



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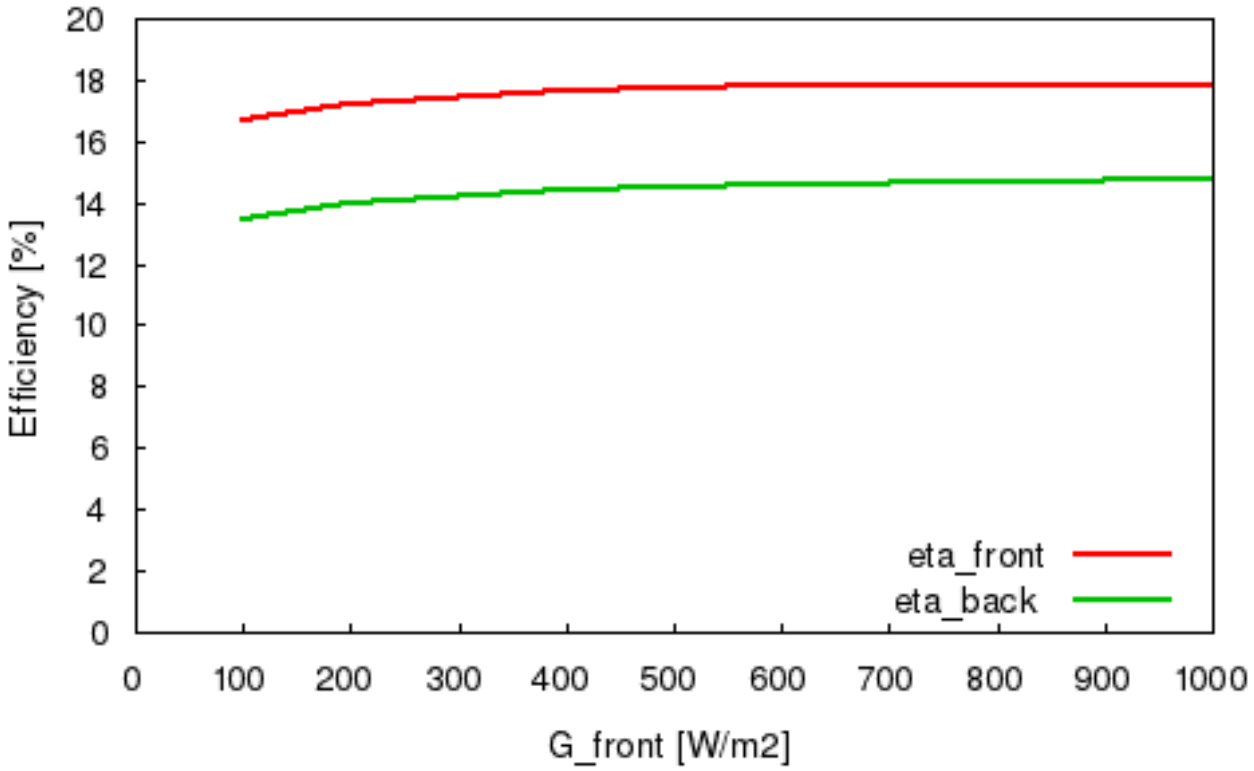

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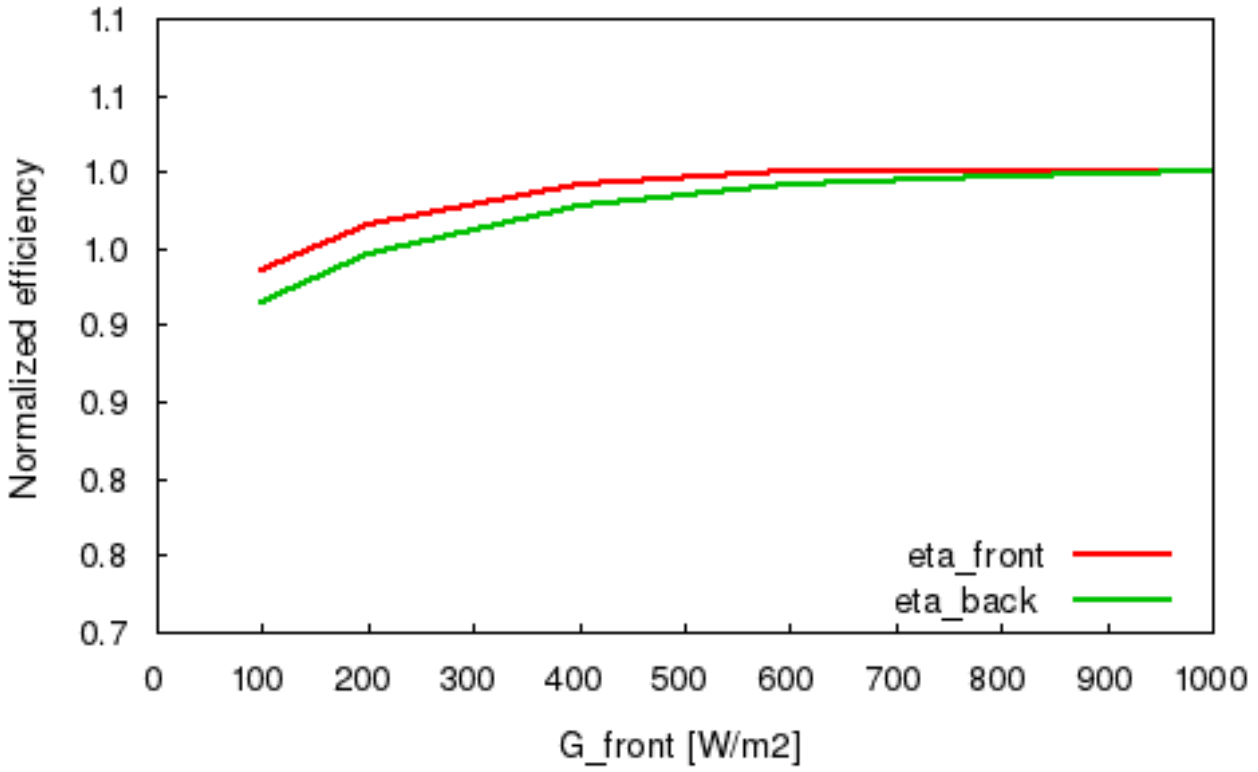

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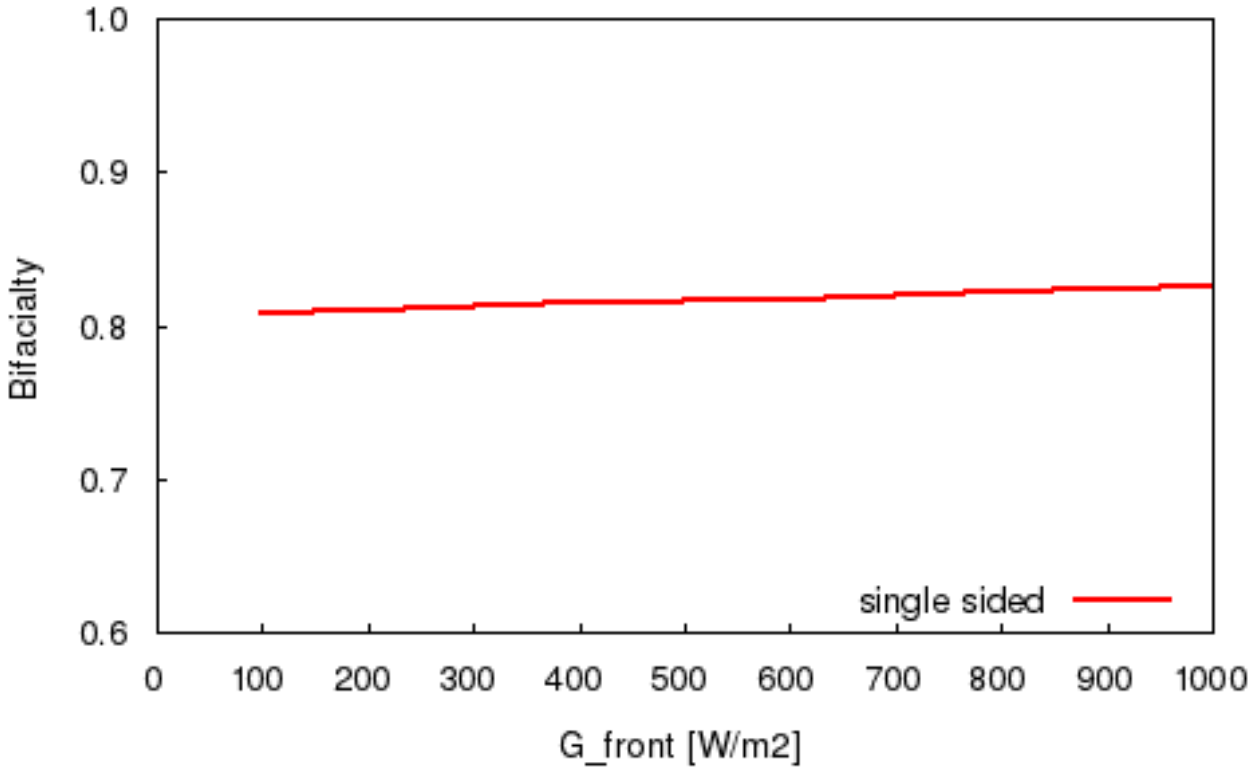

How to explain these results?
Laboratory Measurements II

Calibration of full size bifacial modules under bifacial irradiance

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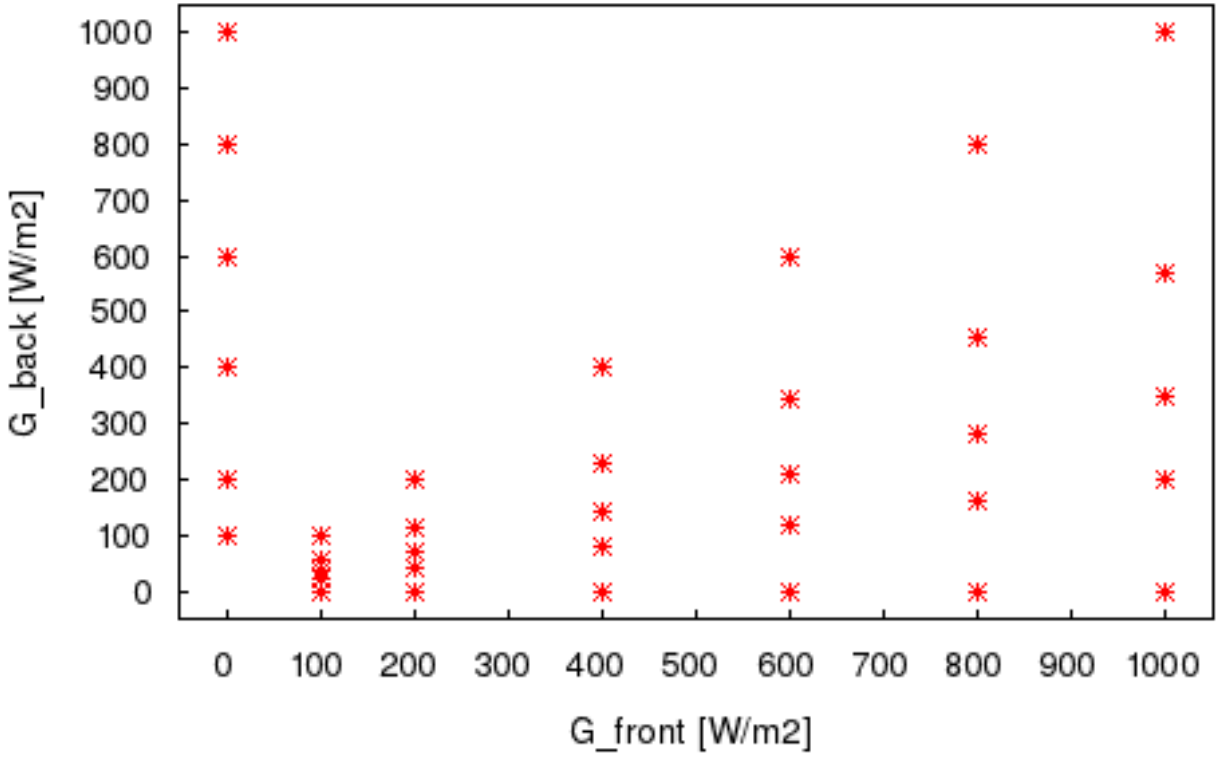

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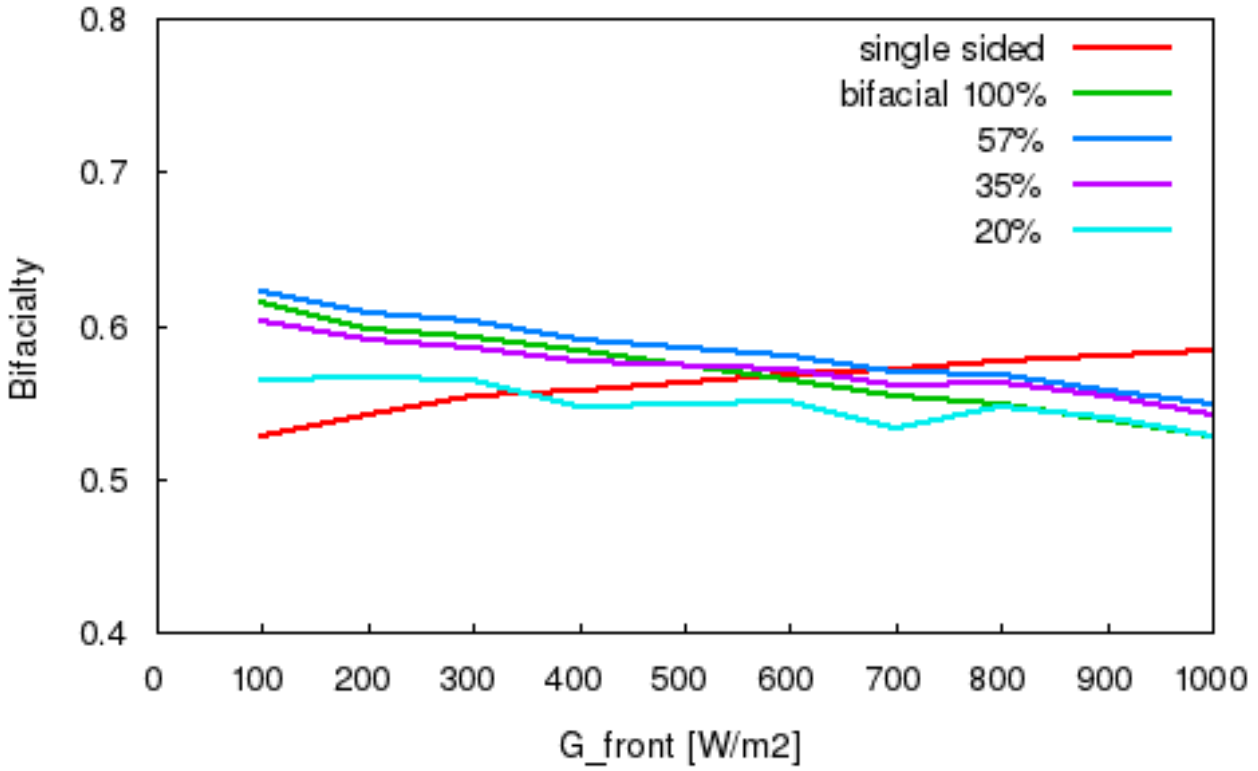
Laboratory Measurements II

P-PERC module: bifacialty values from bifacial measurements



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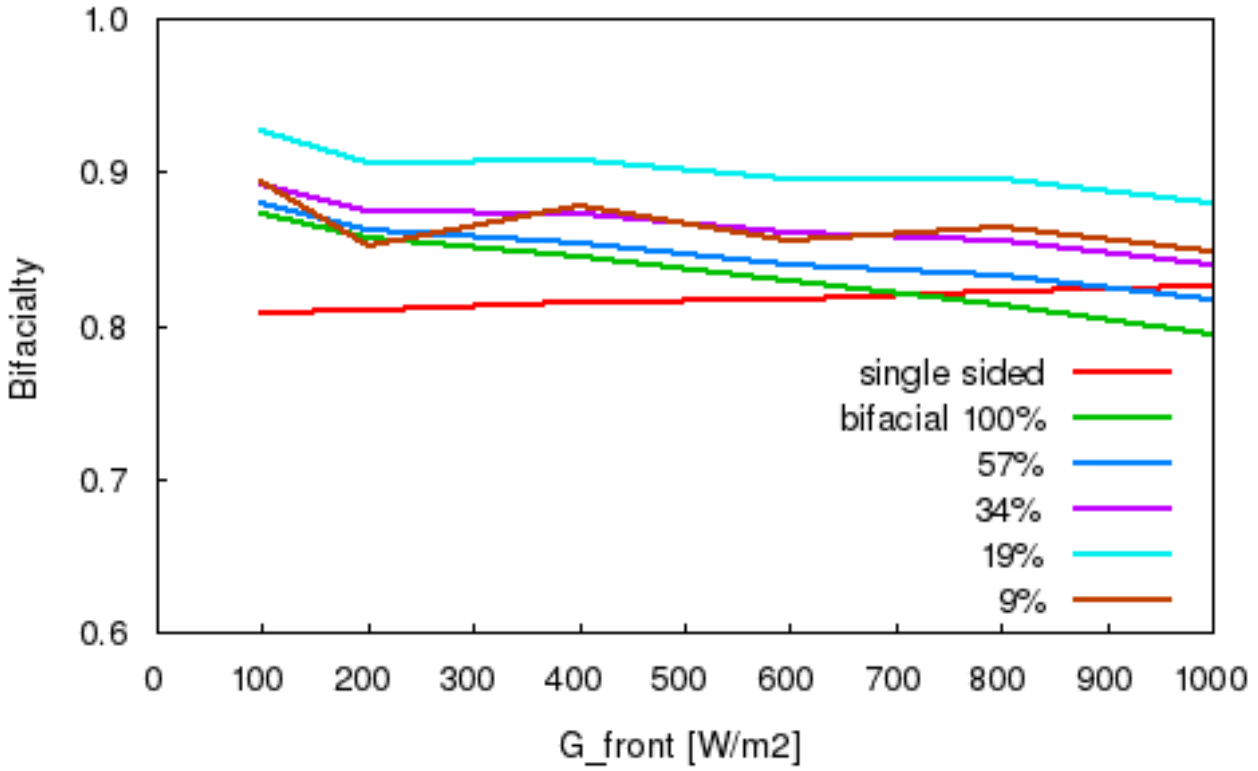
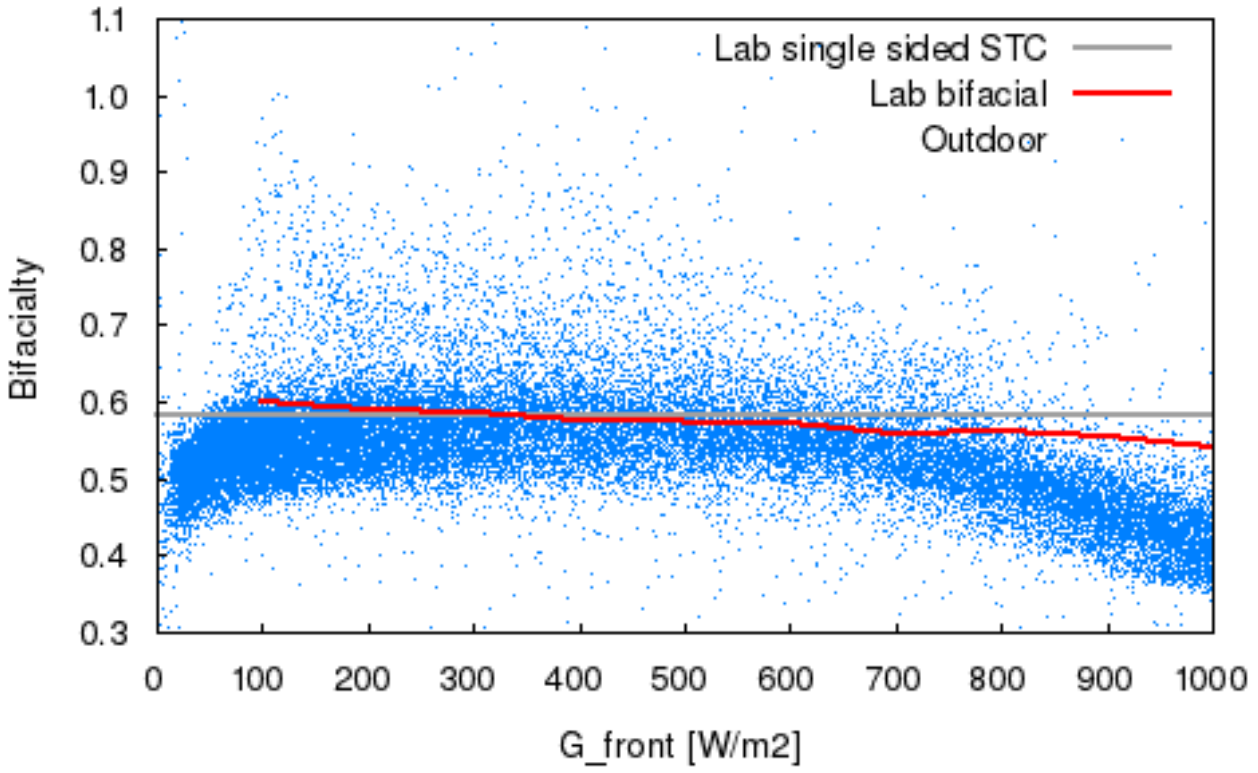


How to explain these results?
Outdoor Measurements

P-PERC module: bifaciality values from laboratory and outdoor measurements



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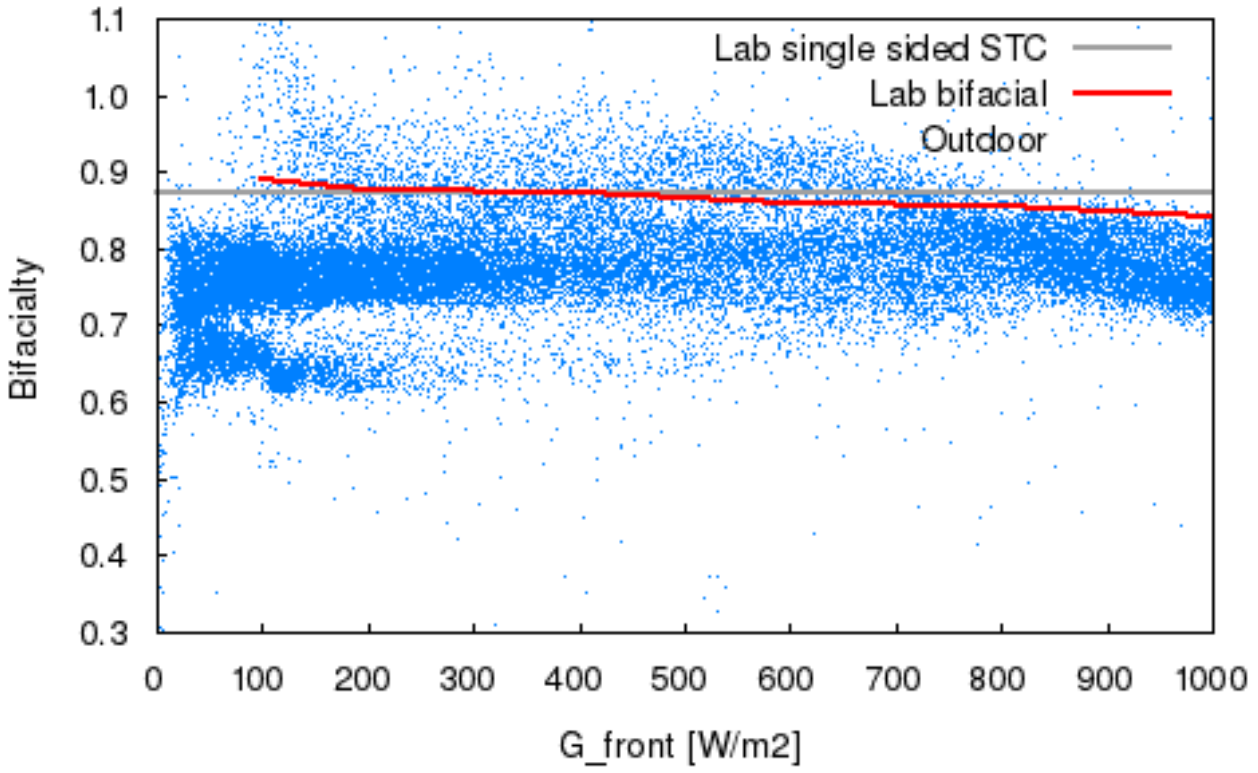


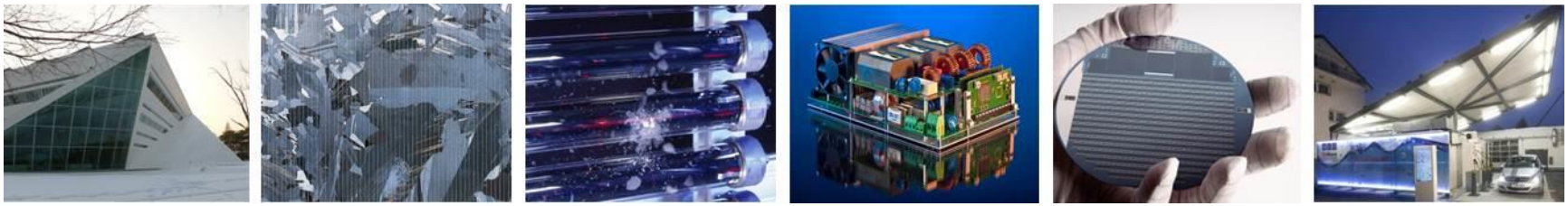
Conclusions
Open questions

- Comparison of BG_{OPT} (single spot measurements) to BG_{MOD} (full size module power measurements) does not account for inhomogeneities in rear side irradiance
- One monofacial reference module only (P-PERC bifacial referred to N-PERT monofacial, however, normalized front side efficiencies are quite similar)
- Different angles of incidence for laboratory and outdoor measurements
- Temperature correction for bifacial modules is preliminary only

Conclusions
Things we learned

- Bifacialty φ is not a constant value
- Bifacialty φ from single sided STC measurements is not the best estimator
- Annual deviation from a single value of φ depends on irradiance statistics
  - Individual calculations seem to be necessary
  - More comprehensive laboratory characterization seems to be necessary
  - Energy rating for bifacial modules sees one more challenge

Thank you for your attention!



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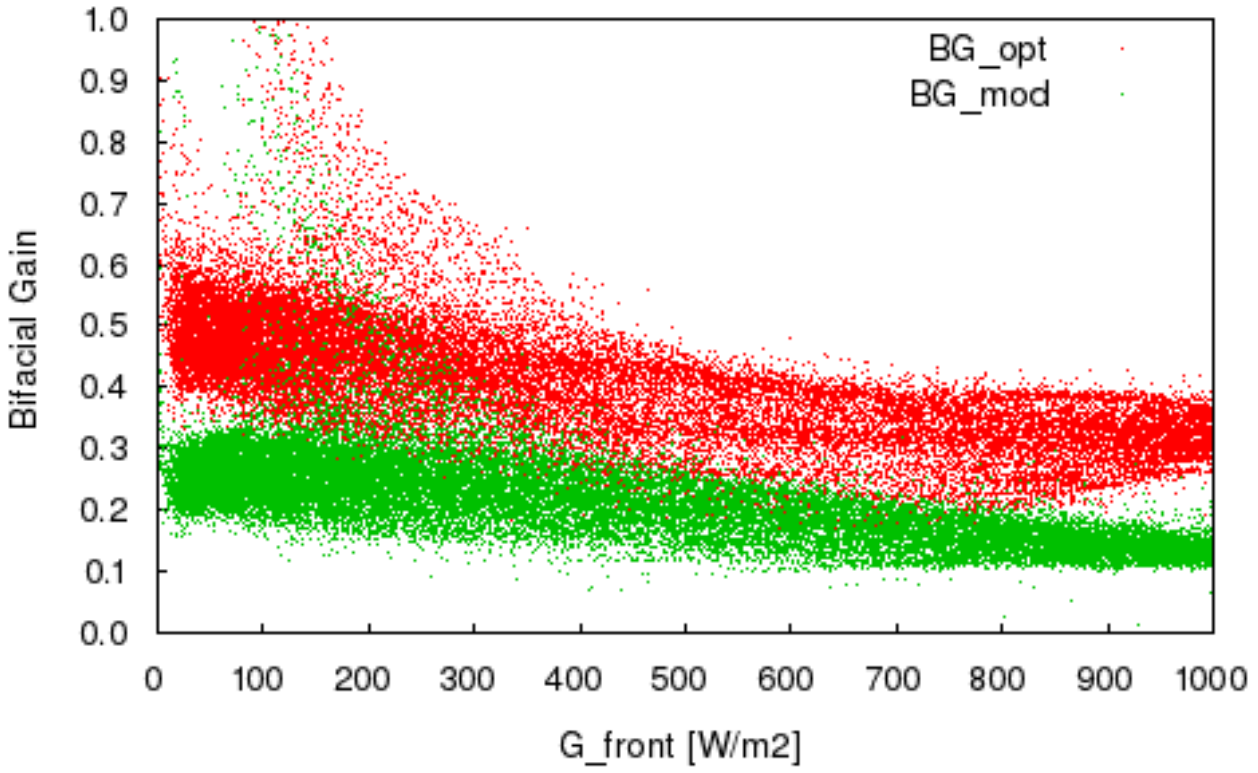
Outdoor Measurements

P-PERC module: optical and module power bifacial gain



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