STRENGTH OF SOLAR CELLS AND DAMAGE OF CUTTING PROCESSES

Felix Kaule[1] and Stephan Schoenfelder[1,2]

[1] Fraunhofer CSP
[2] HTWK-Leipzig

Fraunhofer CSP

PV DAYS 2017
October 24-25 | Halle (Saale)
Visit us on www.pv-days.com

offen
© Fraunhofer Center for Silicon-Photovoltaics CSP

AGENDA

- Methods
- Results
  - Full Cells
  - Half Cells
- Conclusions

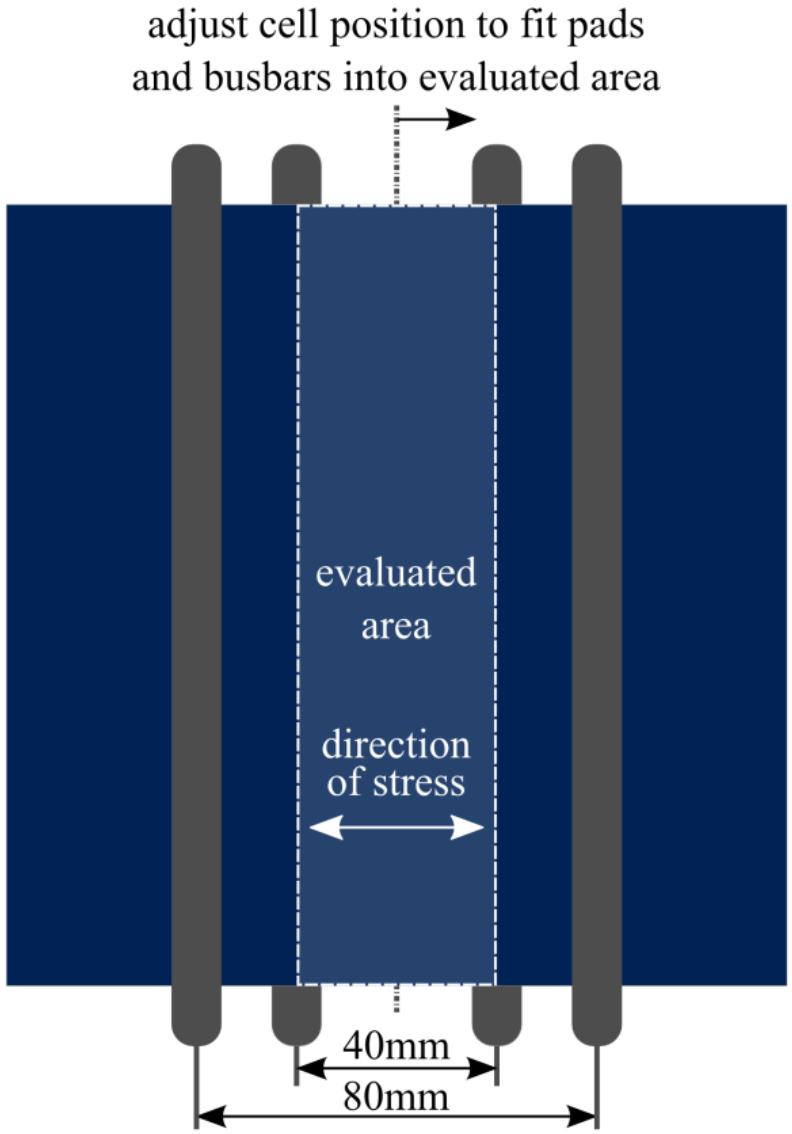
offen
© Fraunhofer Center for Silicon-Photovoltaics CSP

Methods

4-Point bending
test setup

Weibull evaluation

DIN SPEC 91351
first international standard for
mechanical strength for solar Si-wafer



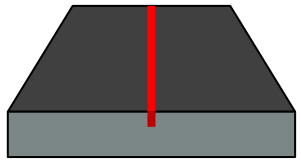
offen
© Fraunhofer Center for Silicon-Photovoltaics CSP
Fraunhofer CSP

Methods

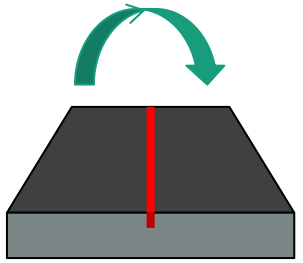
Cell Cutting Technologies

Laser
(Laser Scribe and Cleavage)

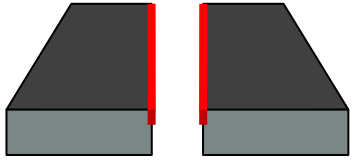
laser scribe



bending
till cleavage

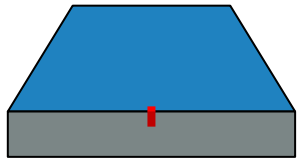


damage on
side of laser entrance
(back side)

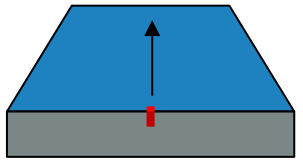


TLS
(Thermal Laser Scribing)

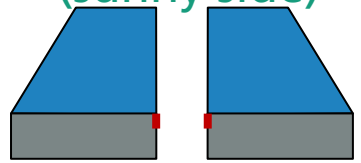
initial
laser scribe



crack propagation
with laser + cooling

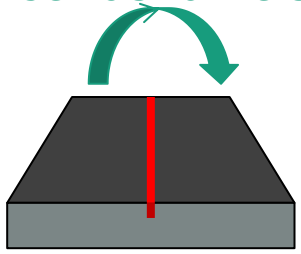


damage on
initial laser scribe
(sunny side)

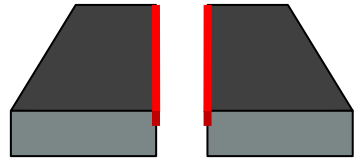


Stress Cut

bending and
laser scribe till cleavage

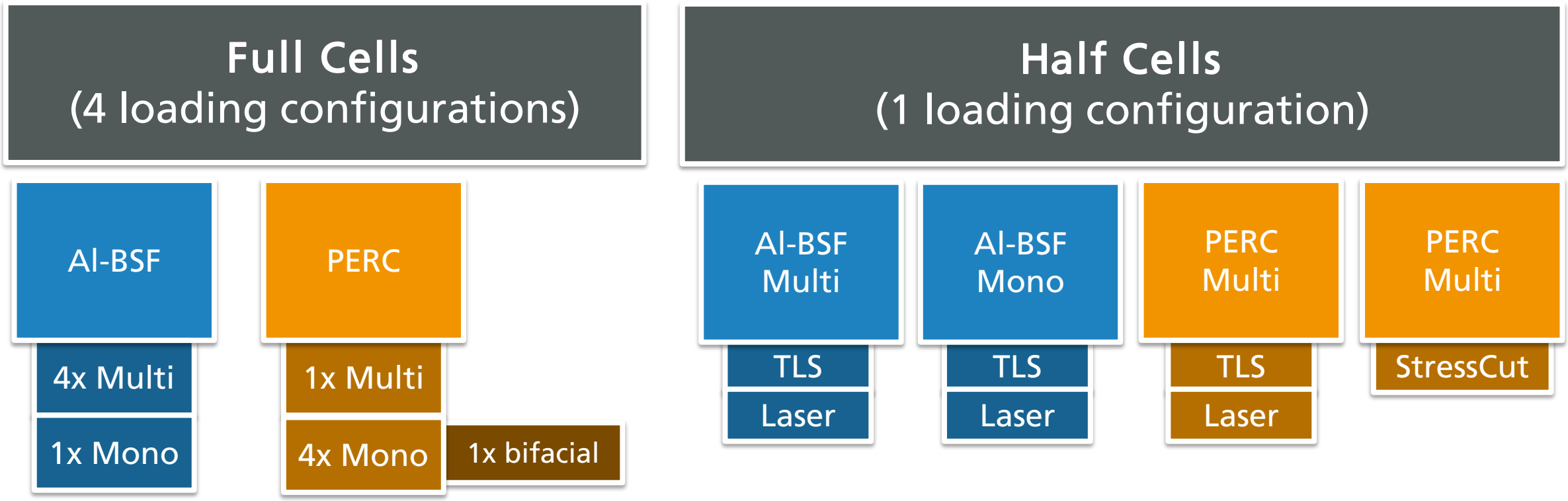


damage on
side of laser entrance
(back side)



© Fraunhofer Center for Silicon-Photovoltaics CSP

Methods



13 different solar cells
6 different manufacturers
2189 broken cells

offen
© Fraunhofer Center for Silicon-Photovoltaics CSP
Fraunhofer CSP

Methods
Explanation

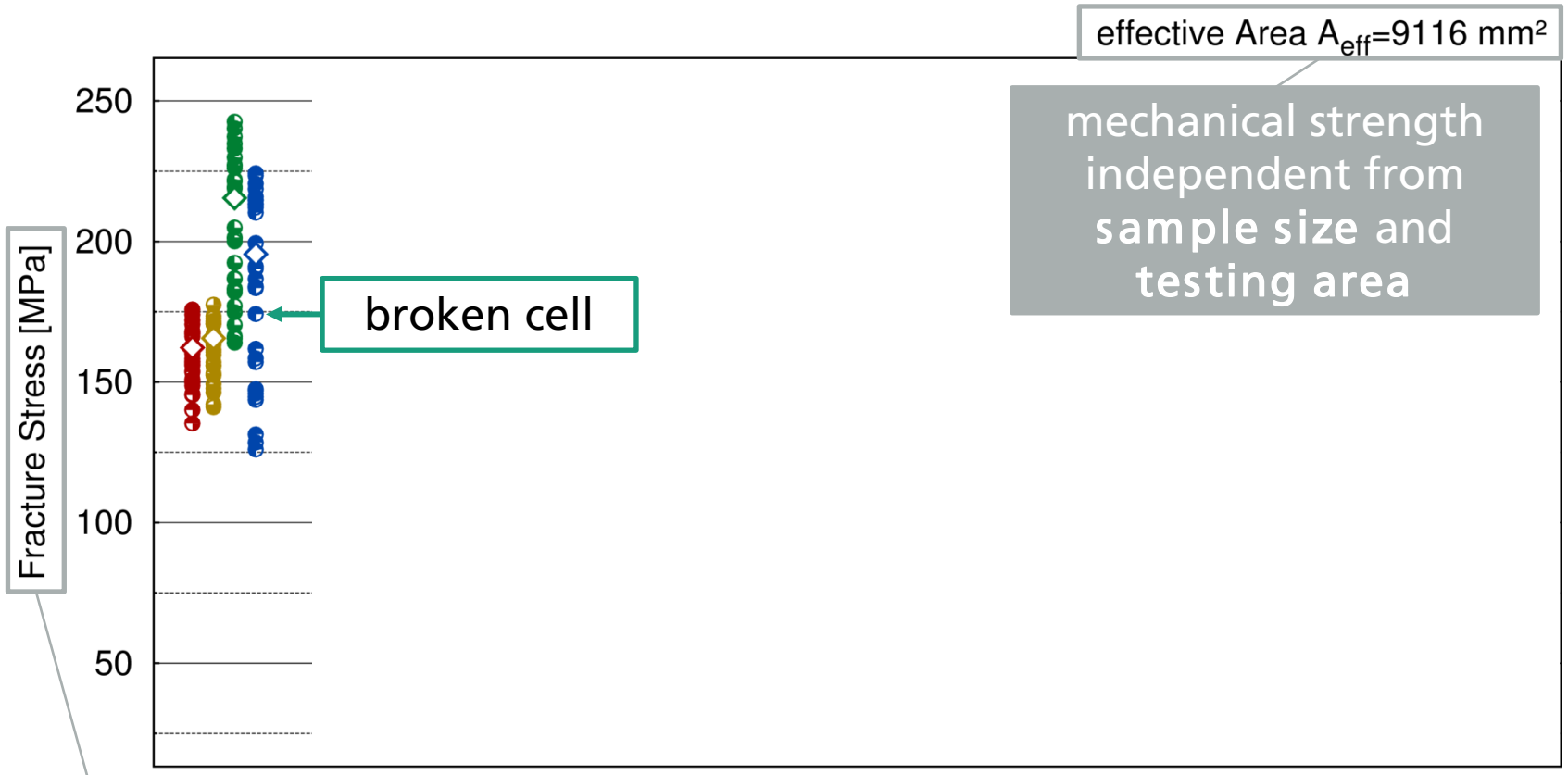
mechanical strength independent from **thickness**

offen
© Fraunhofer Center for Silicon-Photovoltaics CSP
Fraunhofer CSP

Methods
Explanation

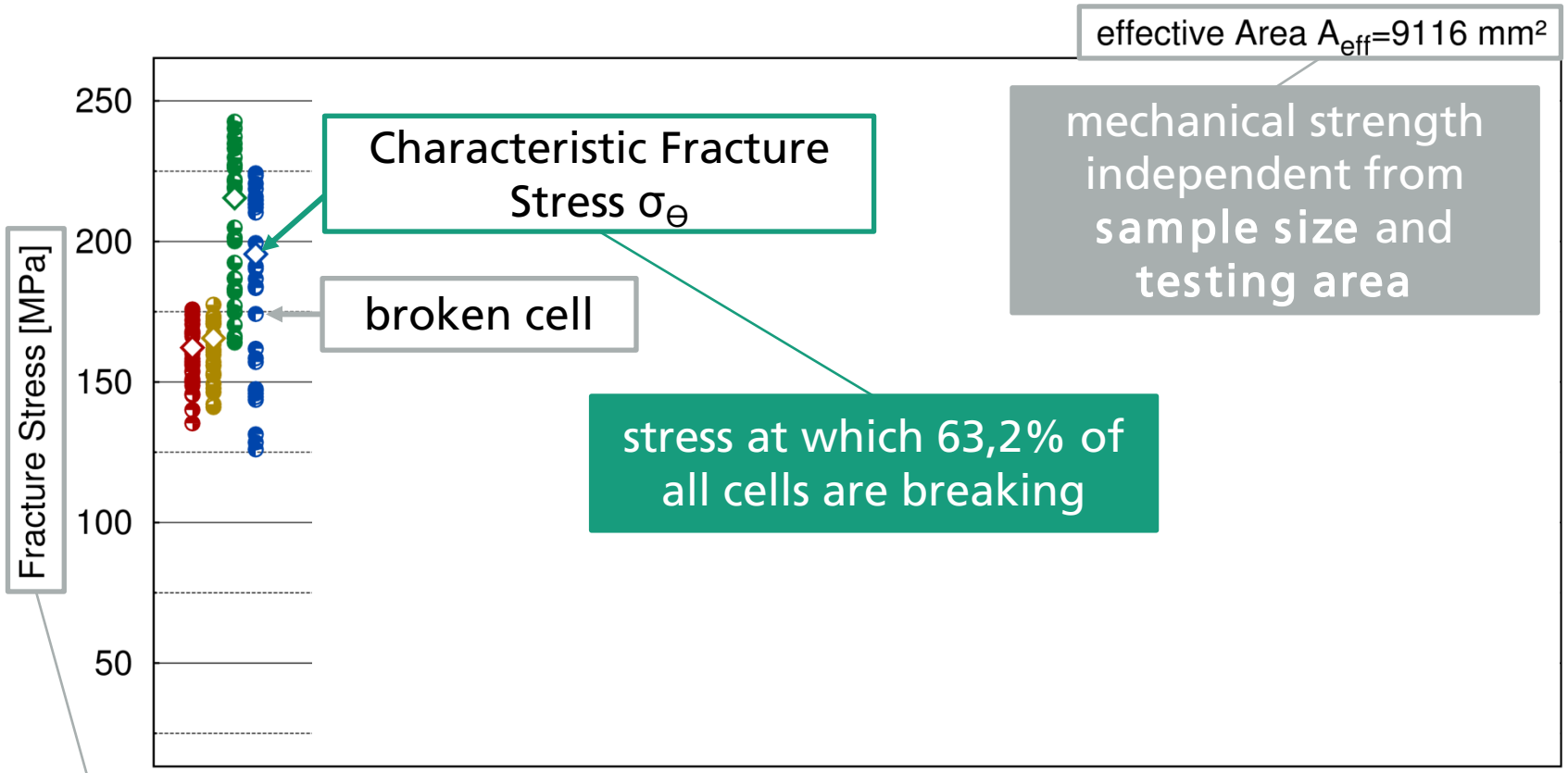
offen
© Fraunhofer Center for Silicon-Photovoltaics CSP
Fraunhofer CSP

Methods
Explanation



© Fraunhofer Center for Silicon-Photovoltaics CSP

Methods
Explanation



offen
© Fraunhofer Center for Silicon-Photovoltaics CSP
Fraunhofer CSP

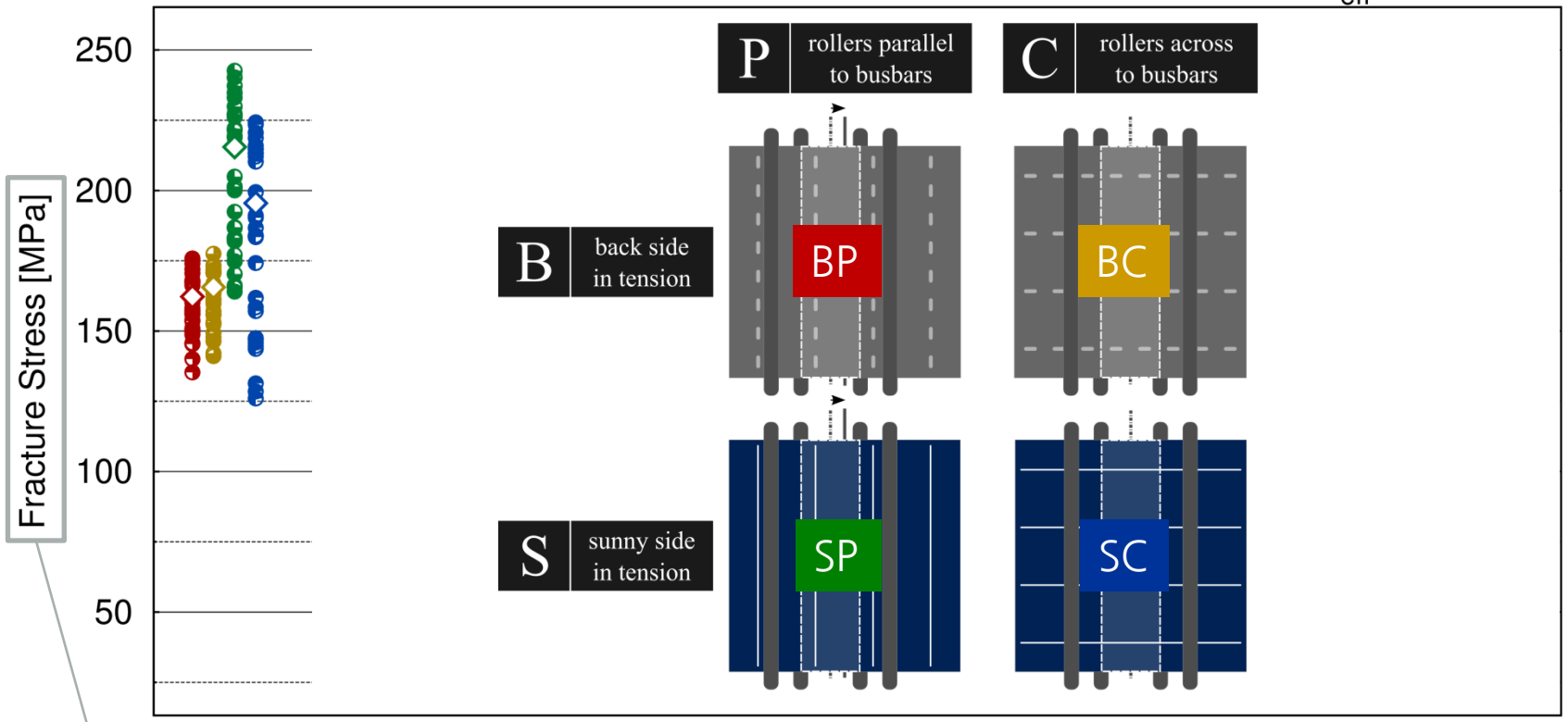
Methods
Explanation

four different types of loadings

◆ Characteristic Fracture Stress

Tension Side | Rollers to Busbars	
Back Side | Parallel	Sunny Side | Parallel
Back Side | Cross	Sunny Side | Cross

effective Area A_{eff}=9116 mm²

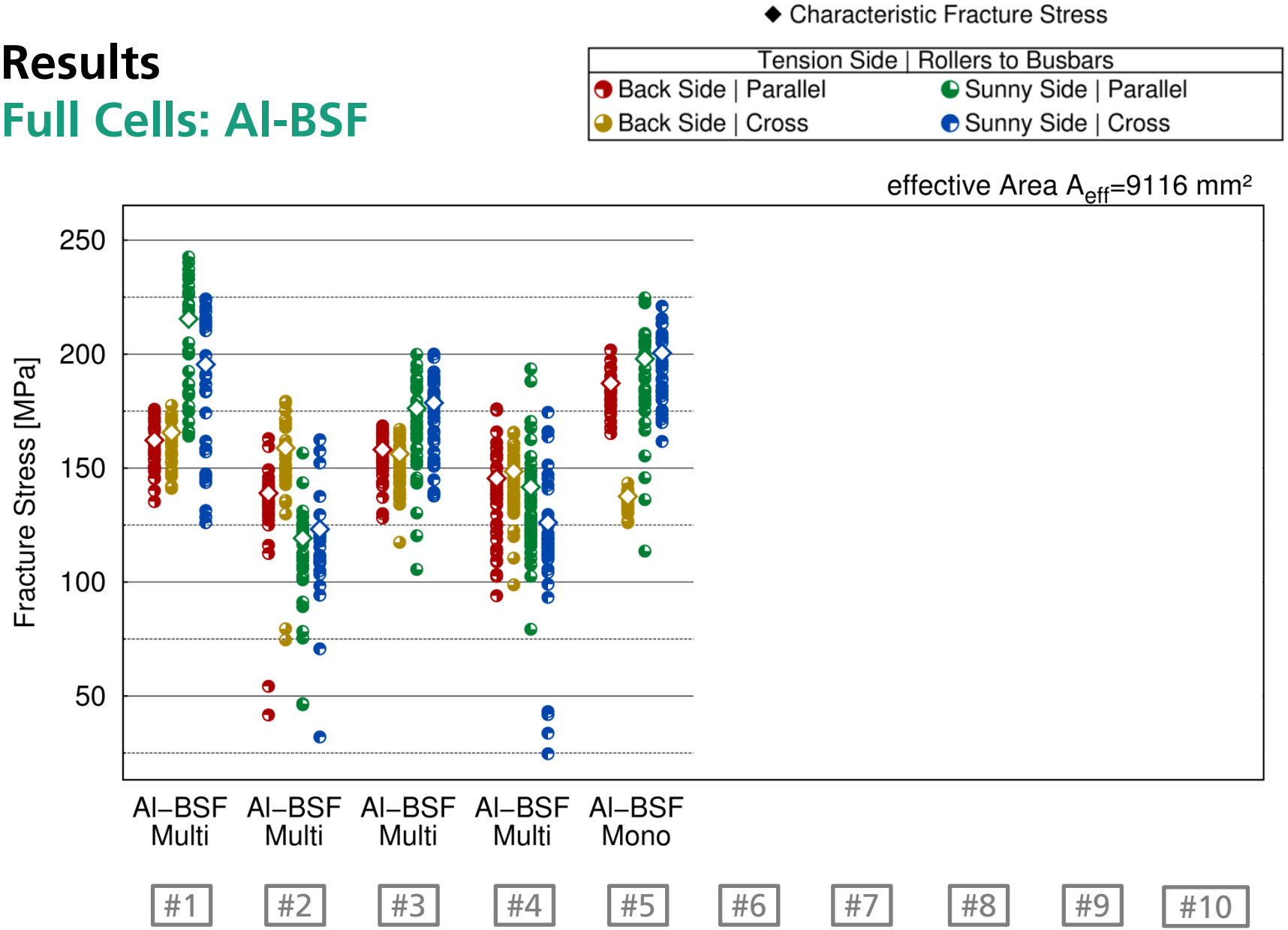


mechanical strength independent from thickness

offen
© Fraunhofer Center for Silicon-Photovoltaics CSP
Fraunhofer CSP

Results

Full Cells: Al-BSF



Back side lower scattering compared to sunny side

Weakest loading side:

back: #1, #3, #5
sunny: #2, #4

Cross and parallel loading mostly in same range for each side

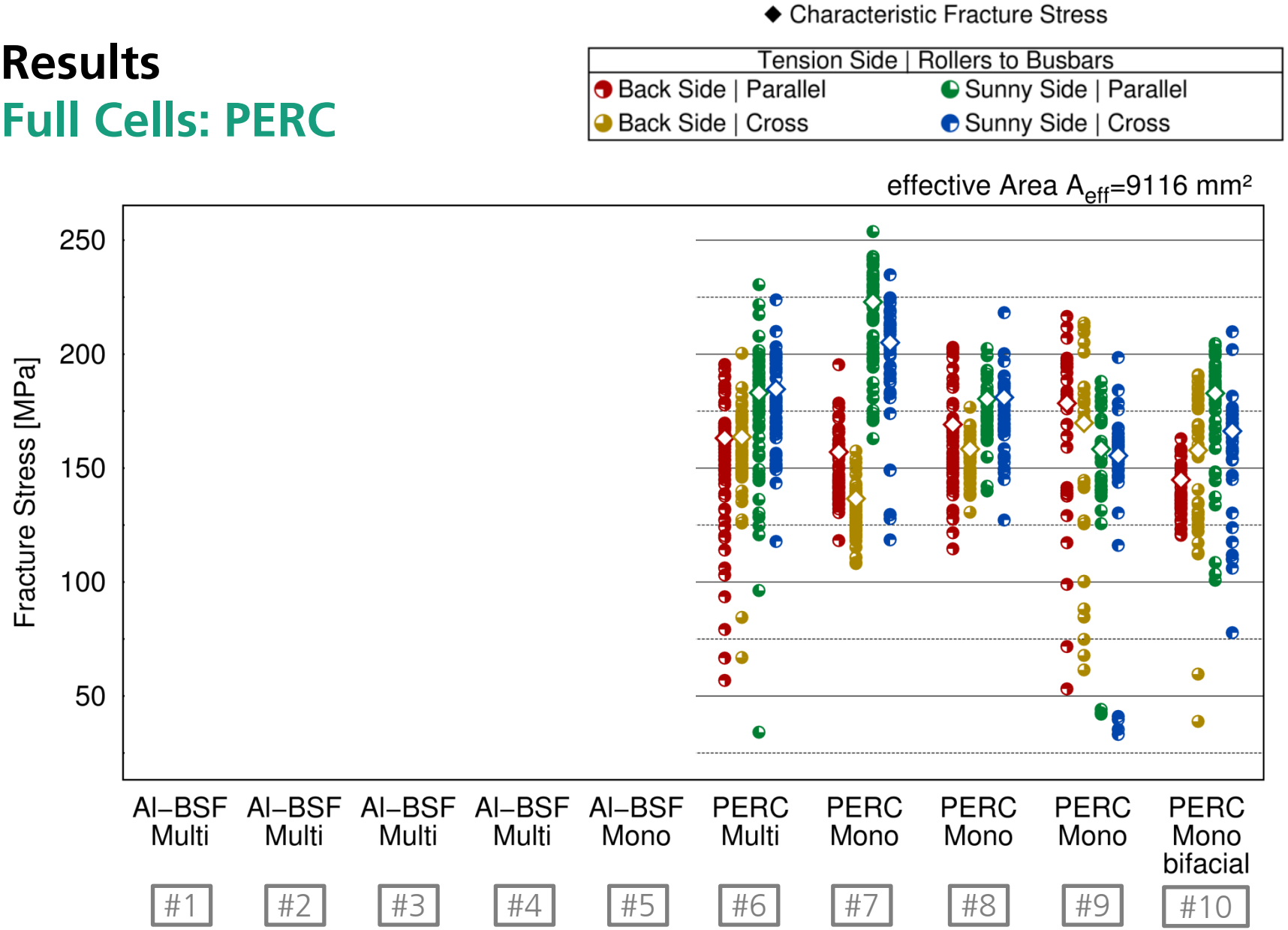
offen

© Fraunhofer Center for Silicon-Photovoltaics CSP

Fraunhofer CSP

Results

Full Cells: PERC



Back side lower characteristic fracture stress for #6, #7, #8 and #10

Cross and parallel loading mostly in same range for each side

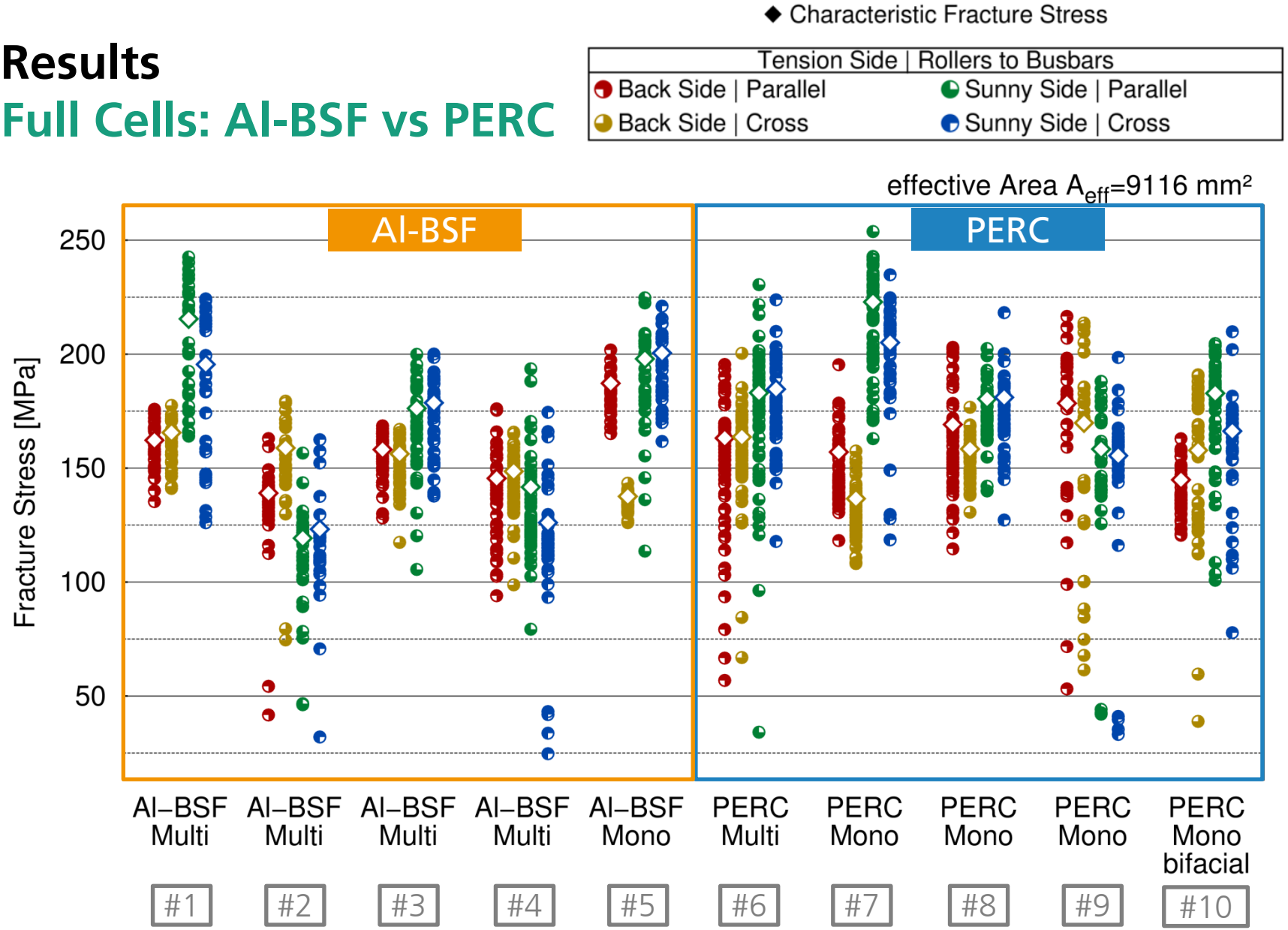
offen

© Fraunhofer Center for Silicon-Photovoltaics CSP

Fraunhofer CSP

Results

Full Cells: Al-BSF vs PERC



No major difference between Al-BSF and PERC

Al-BSF cells showed mostly lower scattering on the back sides compared to PERC cells

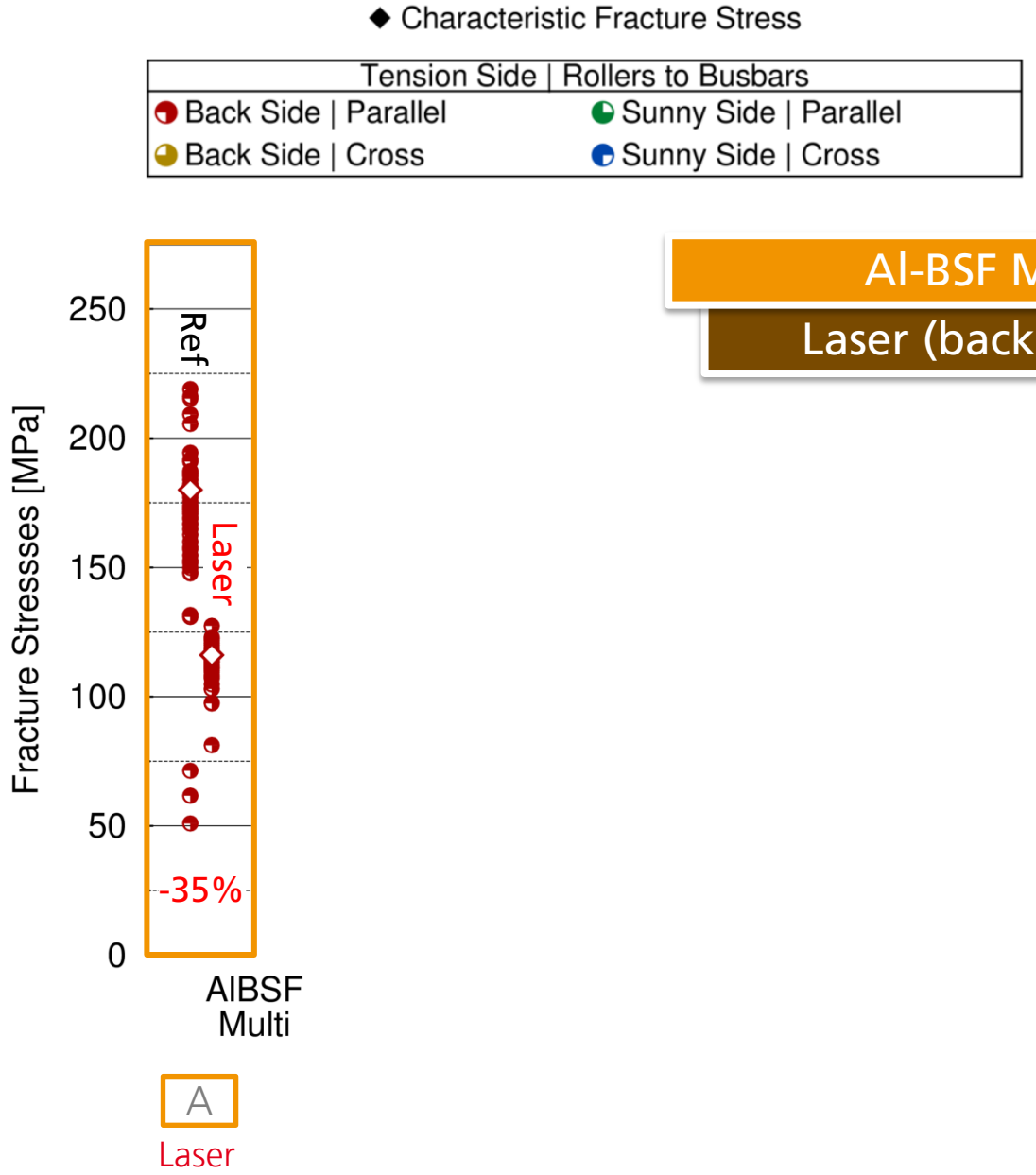
offen

© Fraunhofer Center for Silicon-Photovoltaics CSP

Fraunhofer CSP

Results

Half-Cells: Al-BSF



Al-BSF Multi

Laser (back): -35%

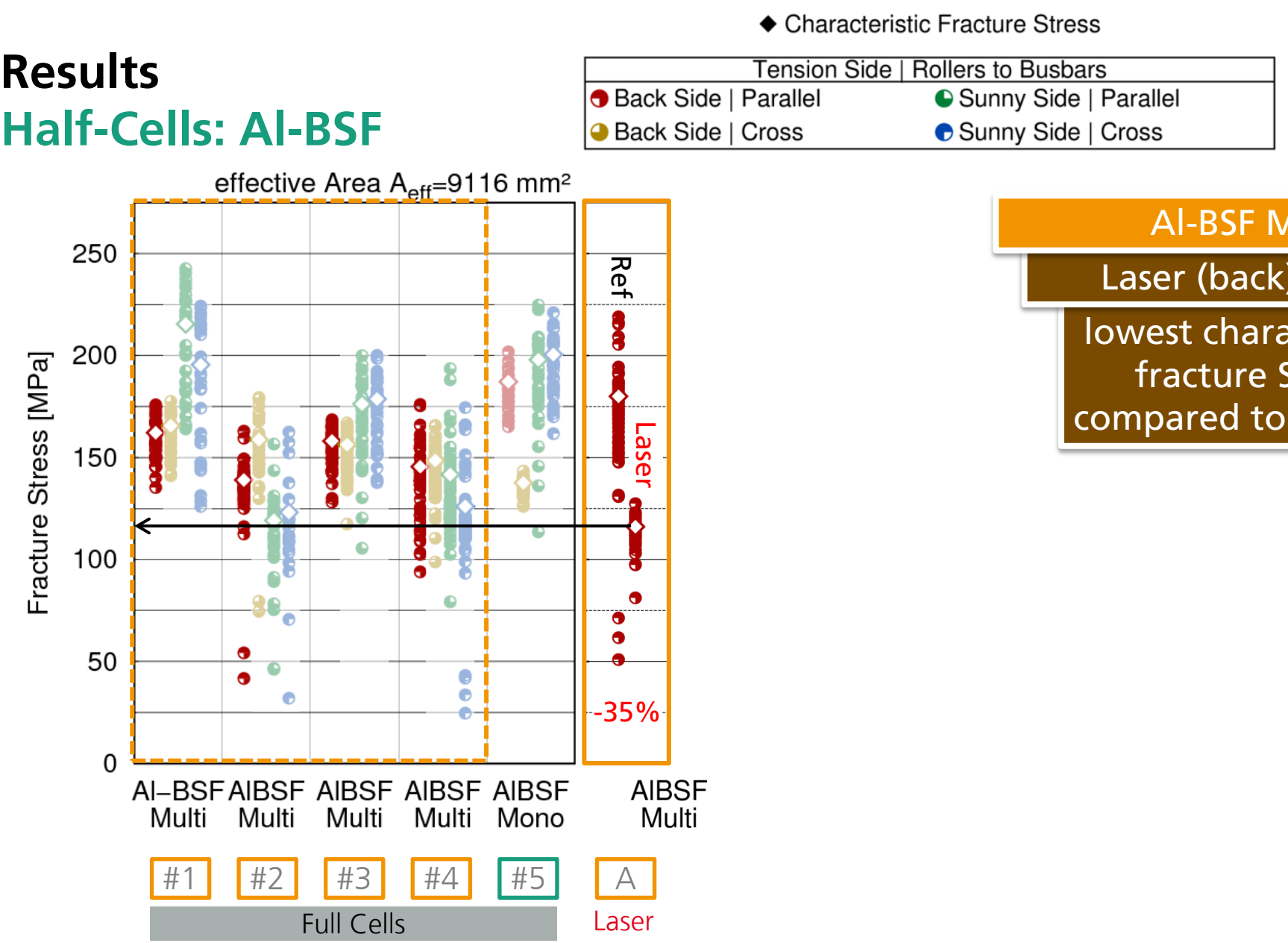
offen

© Fraunhofer Center for Silicon-Photovoltaics CSP

Fraunhofer CSP

Results

Half-Cells: Al-BSF



Al-BSF Multi

Laser (back): -35%

lowest characteristic fracture Stress compared to full cells

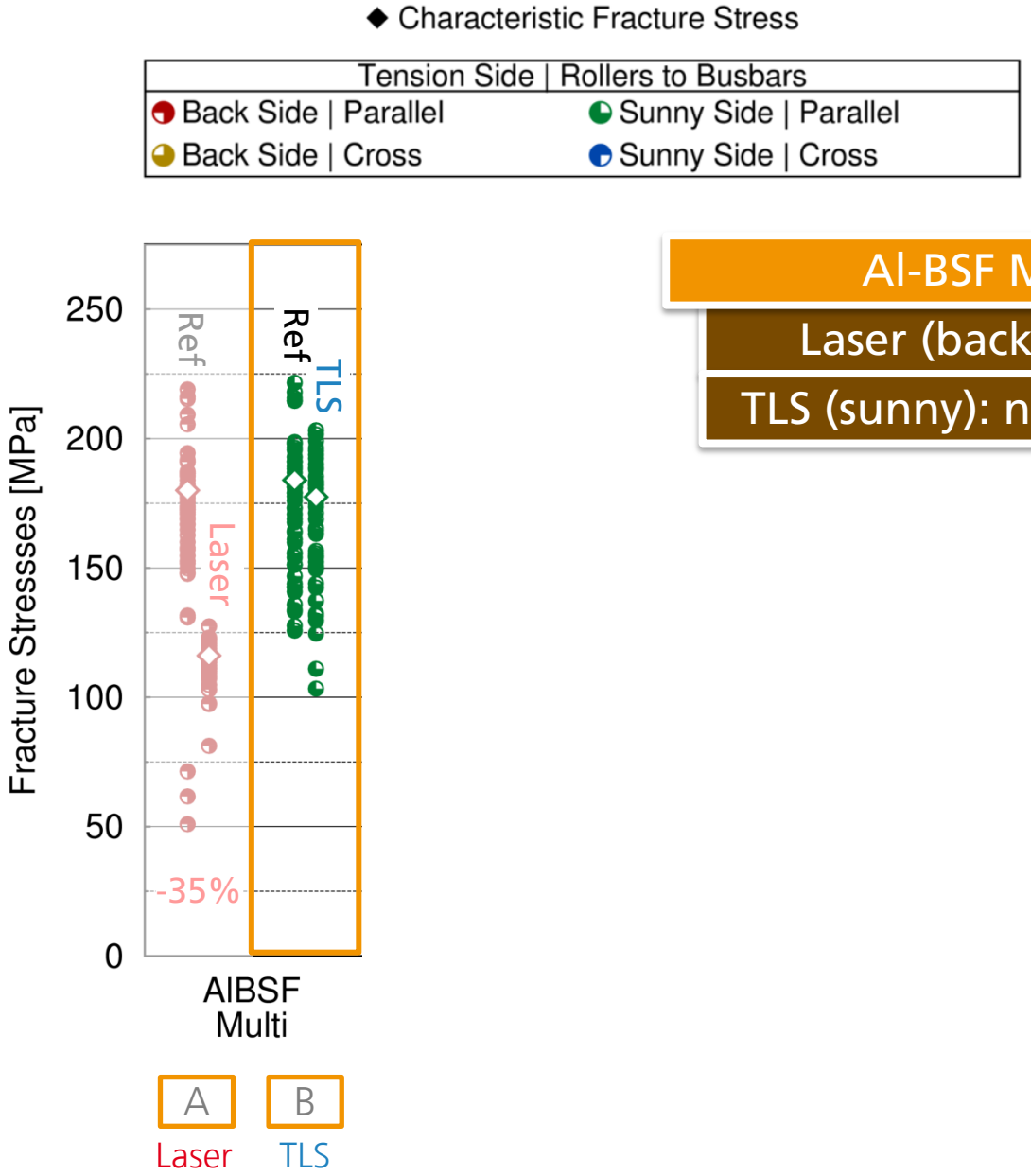
offen

© Fraunhofer Center for Silicon-Photovoltaics CSP

Fraunhofer CSP

Results

Half-Cells: Al-BSF



Al-BSF Multi

Laser (back): -35%

TLS (sunny): no damage

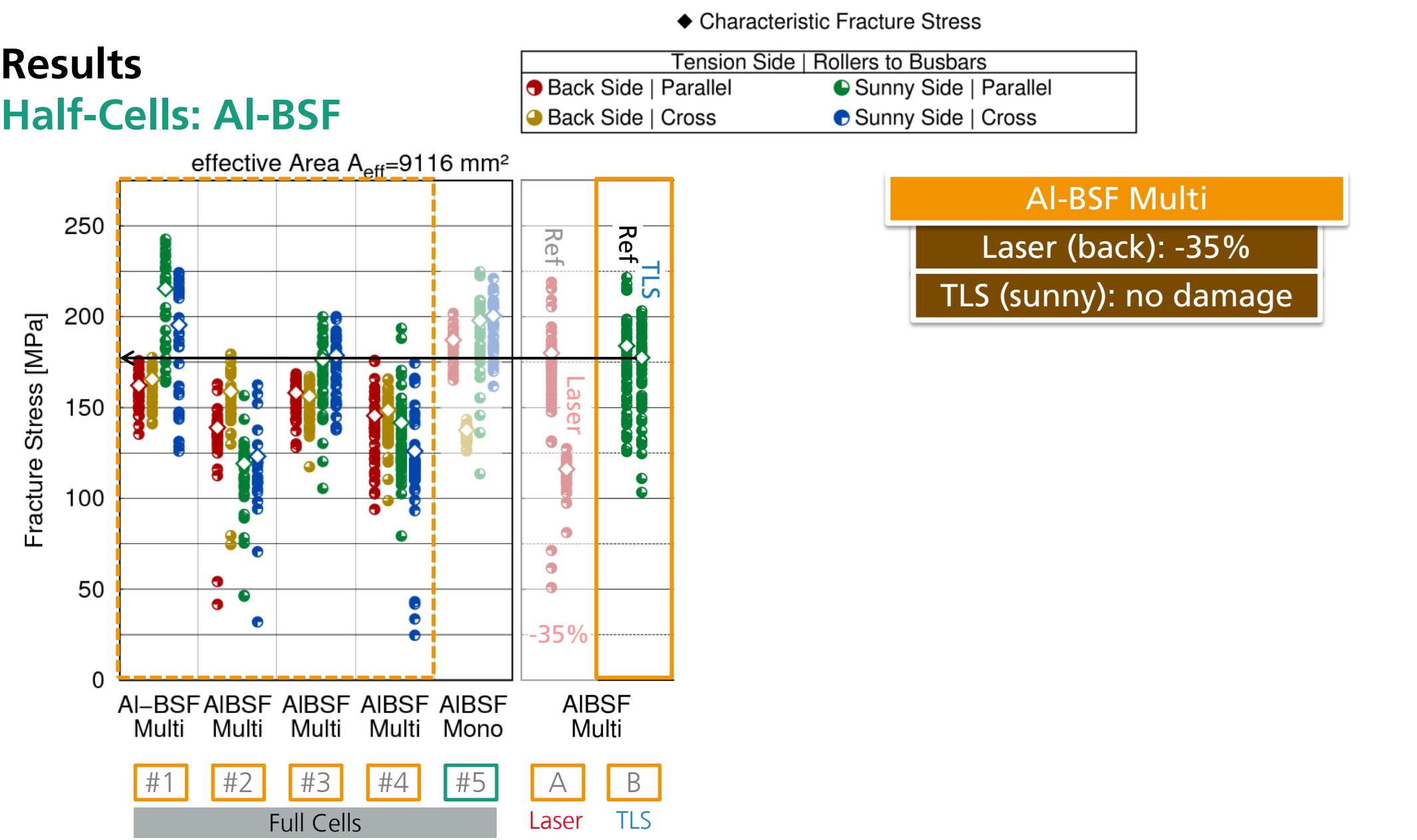
offen

© Fraunhofer Center for Silicon-Photovoltaics CSP

Fraunhofer CSP

Results

Half-Cells: Al-BSF



Al-BSF Multi

Laser (back): -35%

TLS (sunny): no damage

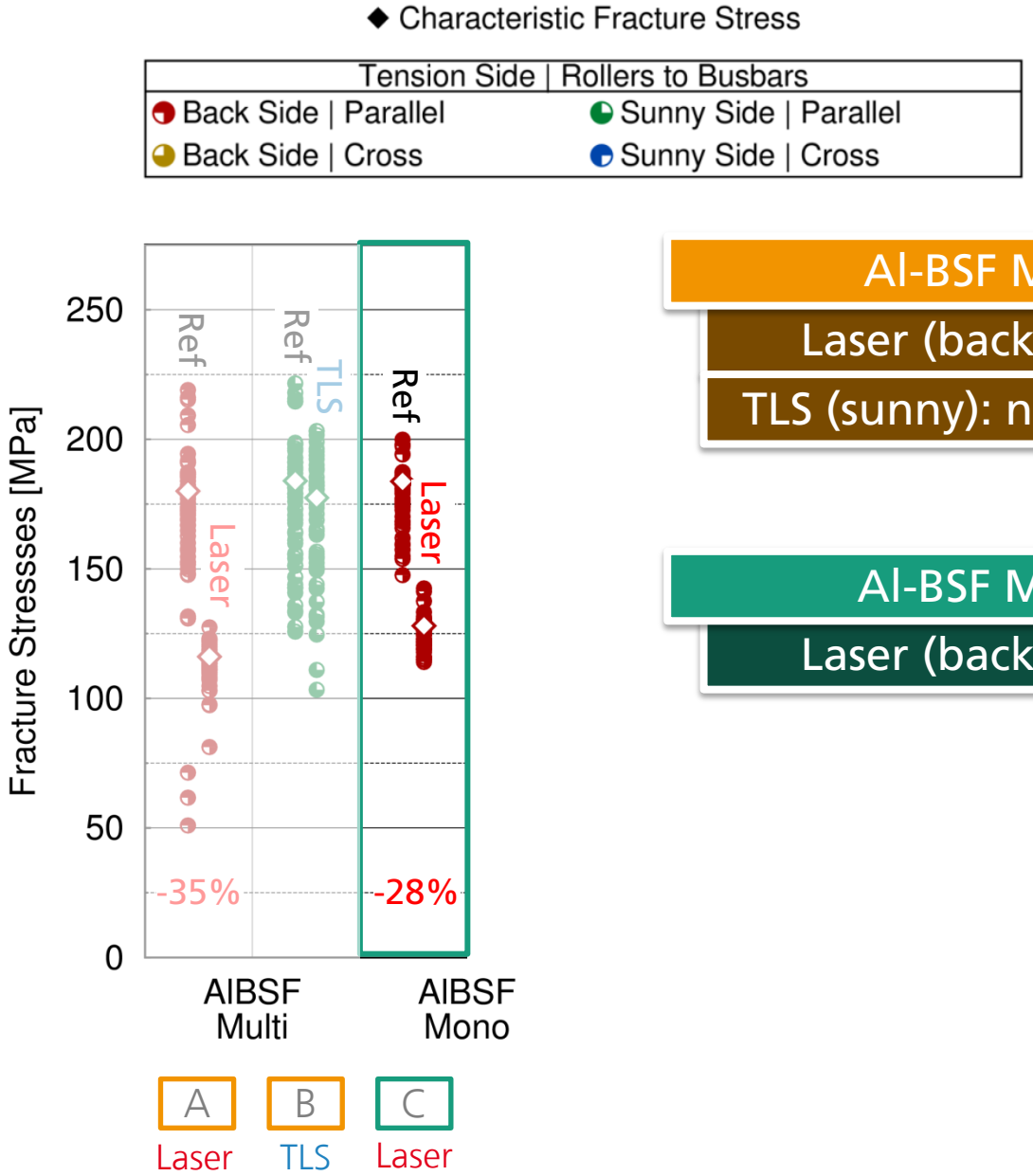
offen

© Fraunhofer Center for Silicon-Photovoltaics CSP

Fraunhofer CSP

Results

Half-Cells: Al-BSF



Al-BSF Multi

Laser (back): -35%

TLS (sunny): no damage

Al-BSF Mono

Laser (back): -28%

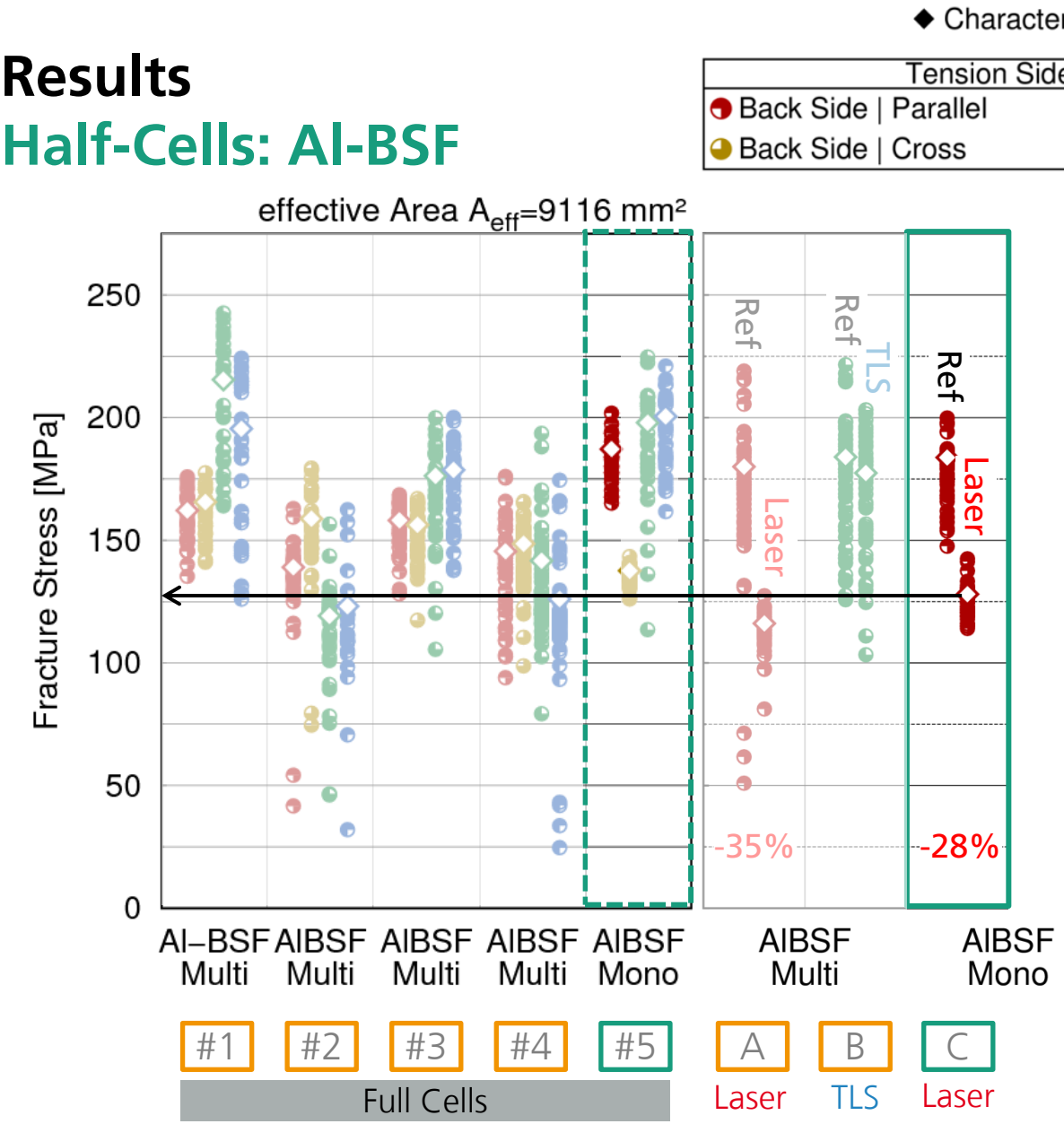
offen

© Fraunhofer Center for Silicon-Photovoltaics CSP

Fraunhofer CSP

Results

Half-Cells: Al-BSF



Al-BSF Multi

Laser (back): -35%

TLS (sunny): no damage

Al-BSF Mono

Laser (back): -28%

lowest characteristic fracture Stress compared to full cells

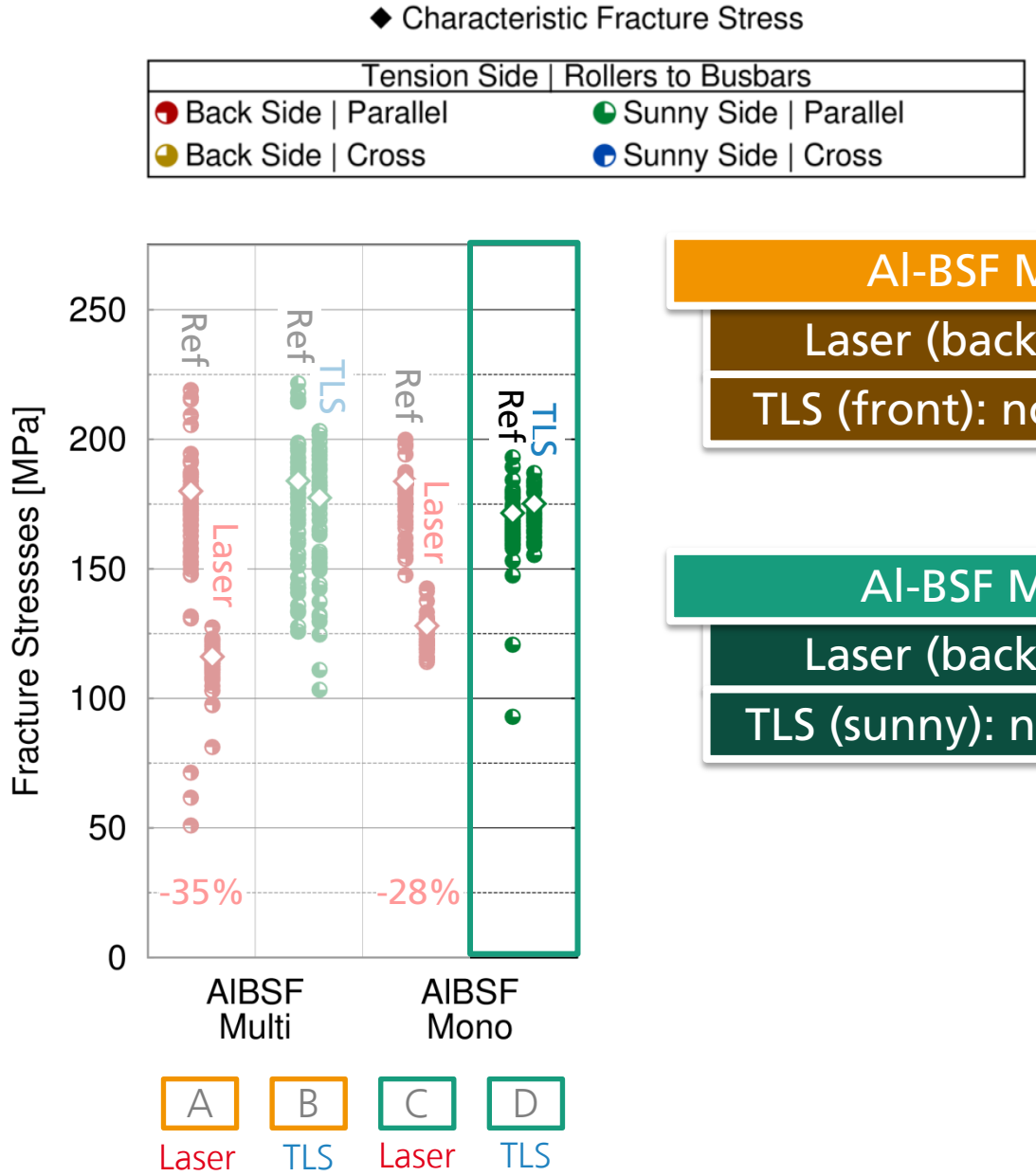
offen

© Fraunhofer Center for Silicon-Photovoltaics CSP

Fraunhofer CSP

Results

Half-Cells: Al-BSF



Al-BSF Multi

- Laser (back): -35%
- TLS (front): no damage

Al-BSF Mono

- Laser (back): -28%
- TLS (sunny): no damage

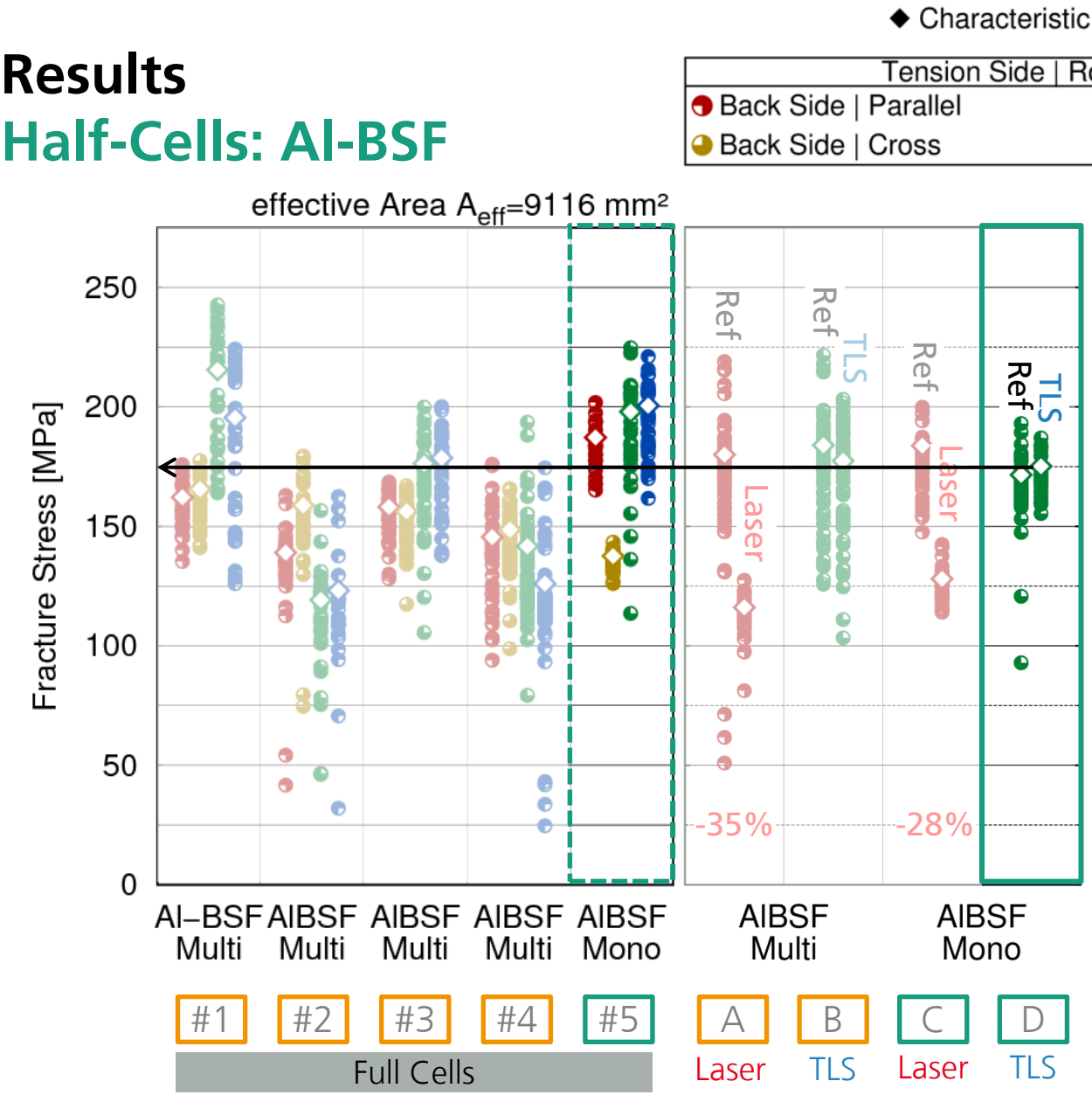
offen

© Fraunhofer Center for Silicon-Photovoltaics CSP

Fraunhofer CSP

Results

Half-Cells: Al-BSF



Al-BSF Multi

- Laser (back): -35%
- TLS (front): no damage

Al-BSF Mono

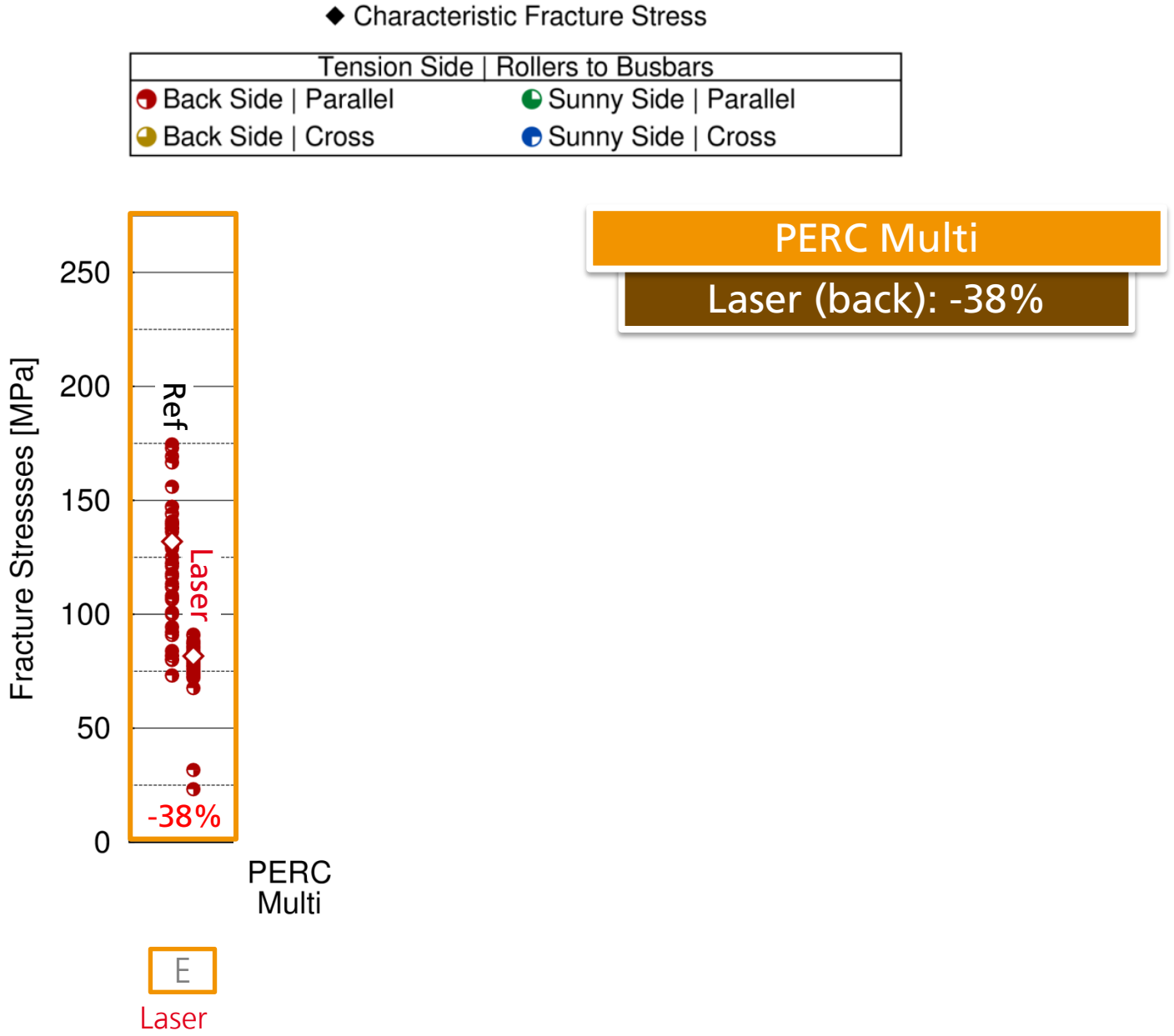
- Laser (back): -28%
- TLS (sunny): no damage

offen

© Fraunhofer Center for Silicon-Photovoltaics CSP

Fraunhofer CSP

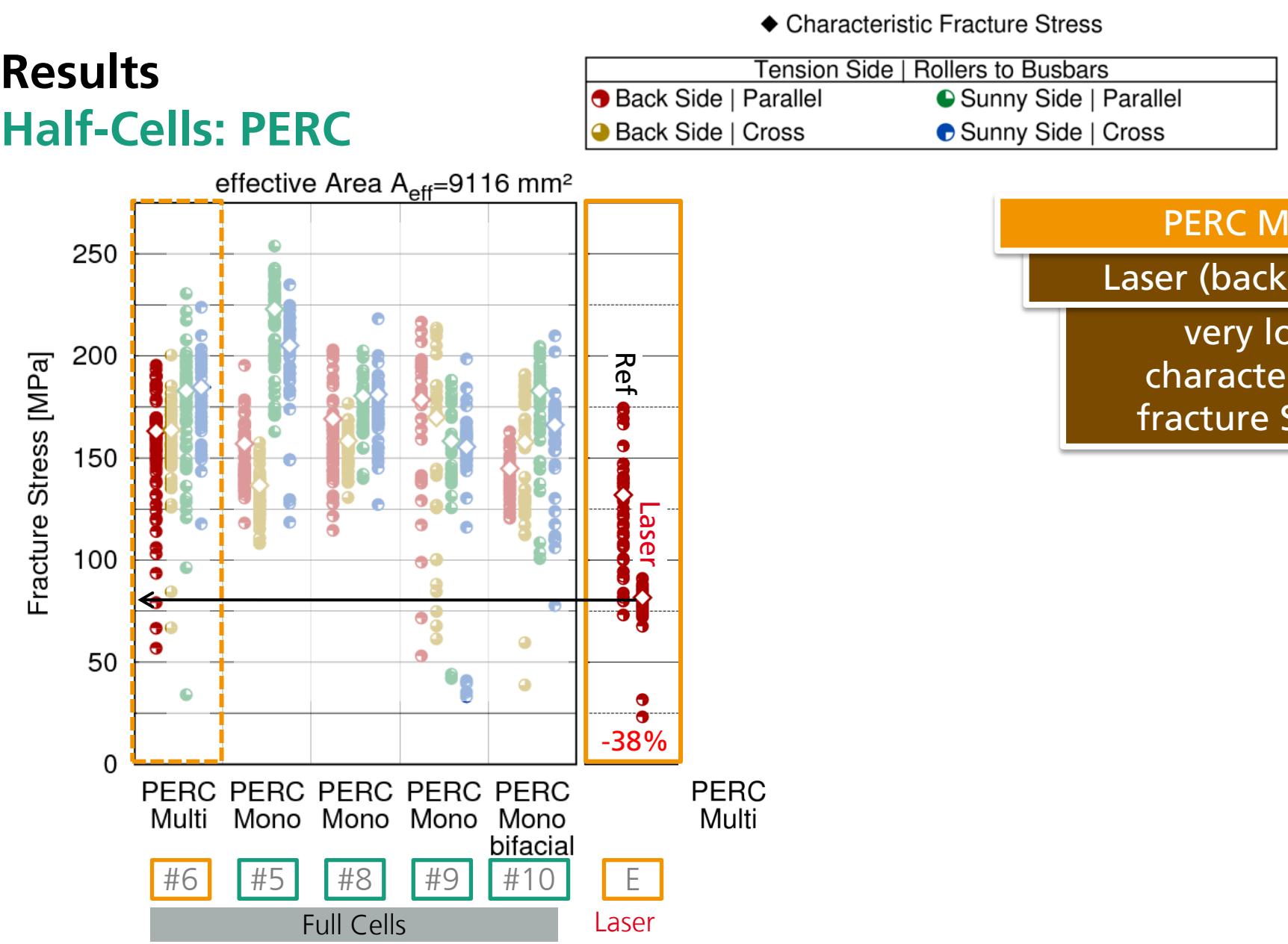
Results
Half-Cells: PERC



offen
© Fraunhofer Center for Silicon-Photovoltaics CSP
Fraunhofer CSP

Results

Half-Cells: PERC



PERC Multi

Laser (back): -38%

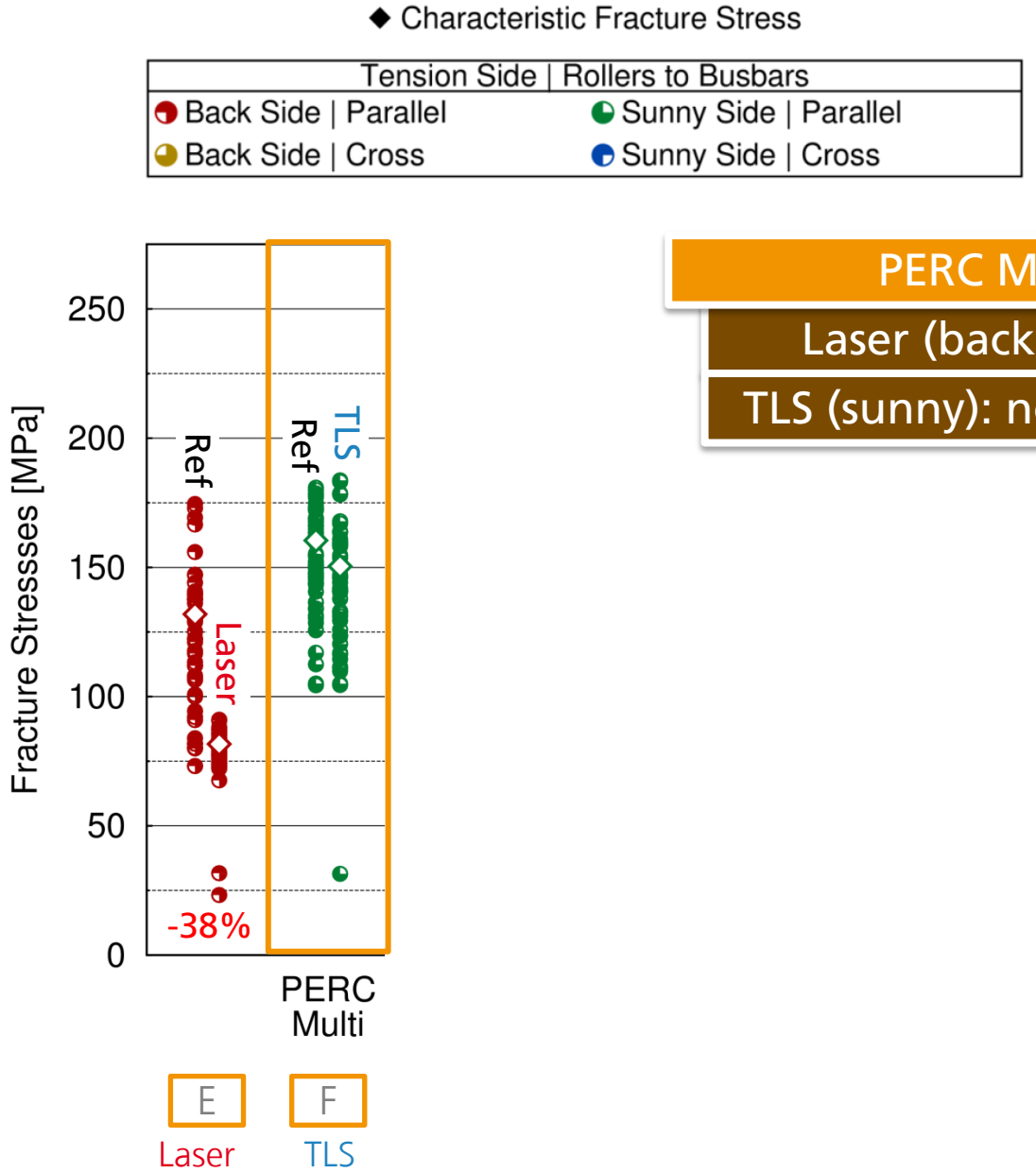
very low characteristic fracture Stress

offen

© Fraunhofer Center for Silicon-Photovoltaics CSP

Fraunhofer CSP

Results
Half-Cells: PERC



PERC Multi

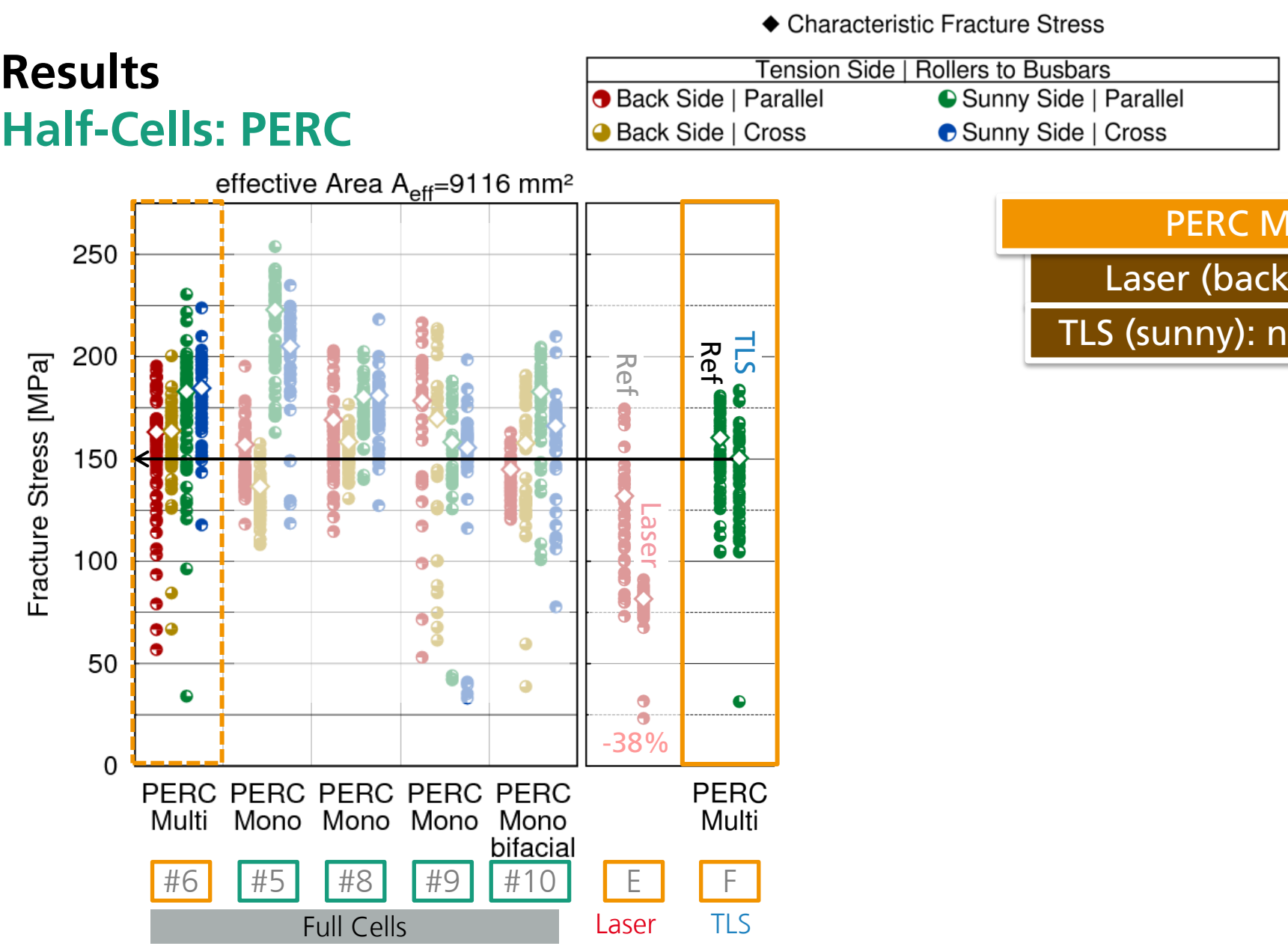
Laser (back): -38%

TLS (sunny): no damage

offen
© Fraunhofer Center for Silicon-Photovoltaics CSP
Fraunhofer CSP

Results

Half-Cells: PERC



PERC Multi

Laser (back): -38%

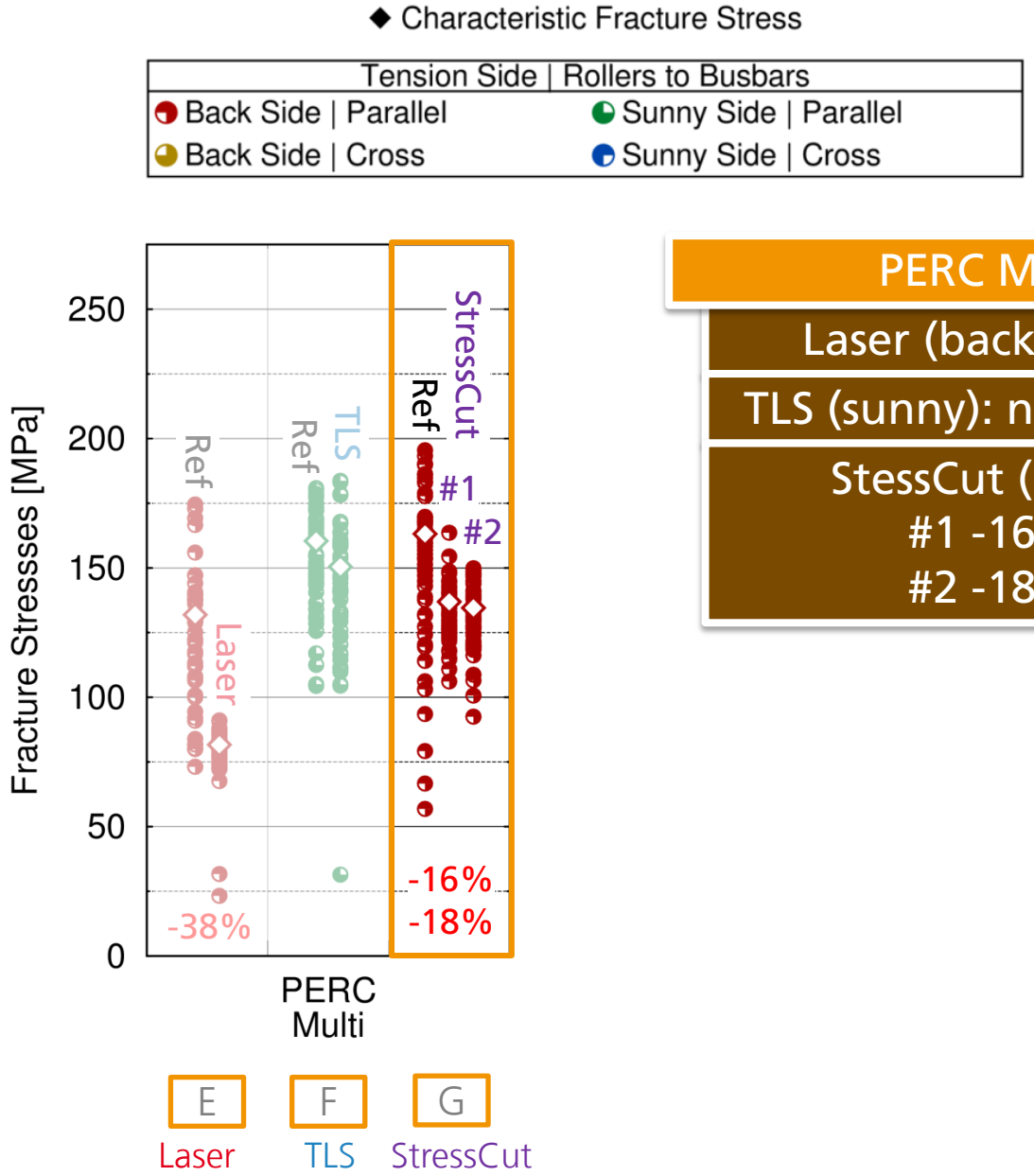
TLS (sunny): no damage

offen

© Fraunhofer Center for Silicon-Photovoltaics CSP

Fraunhofer CSP

Results
Half-Cells: PERC



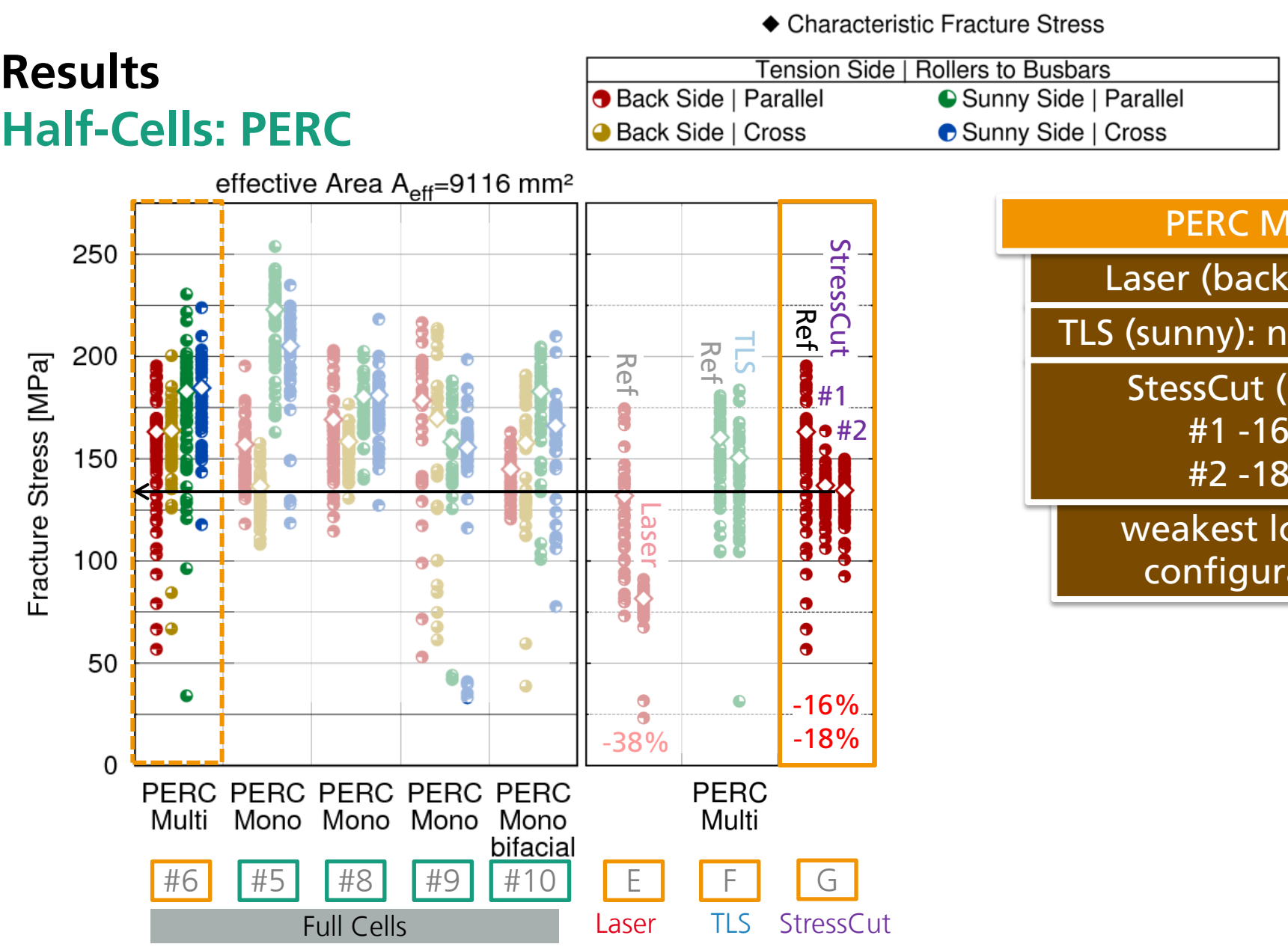
PERC Multi

- Laser (back): -38%
- TLS (sunny): no damage
- StessCut (back):
  #1 -16%
  #2 -18%

offen
© Fraunhofer Center for Silicon-Photovoltaics CSP
Fraunhofer CSP

Results

Half-Cells: PERC



PERC Multi

- Laser (back): -38%
- TLS (sunny): no damage
- StessCut (back):
  #1 -16%
  #2 -18%
- weakest loading configuration

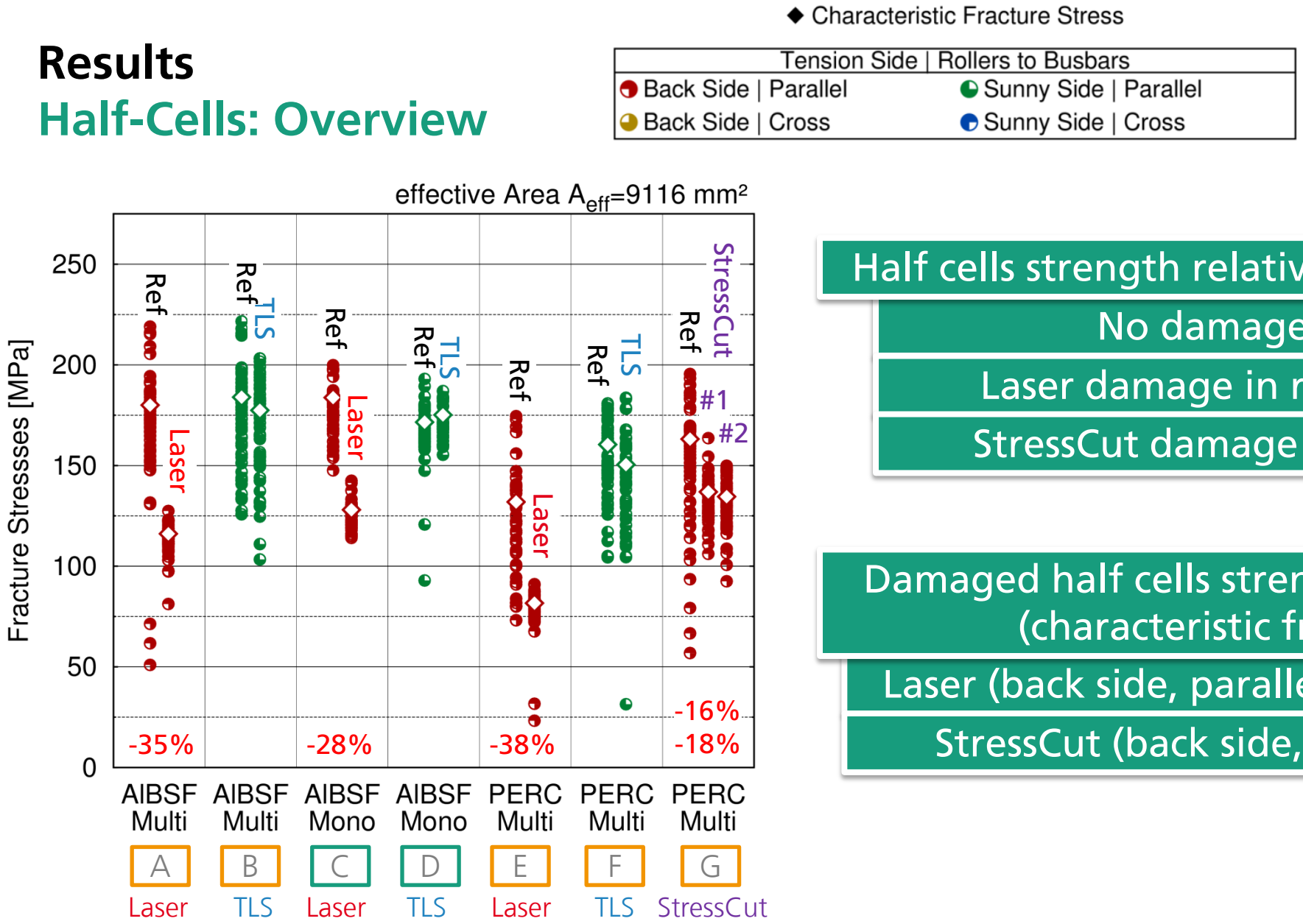
offen

© Fraunhofer Center for Silicon-Photovoltaics CSP

Fraunhofer CSP

Results

Half-Cells: Overview



Half cells strength relative to reference batches:

- No damage from TLS
- Laser damage in range of 30-40%
- StressCut damage in range of 18%

Damaged half cells strength in absolute values (characteristic fracture stress):

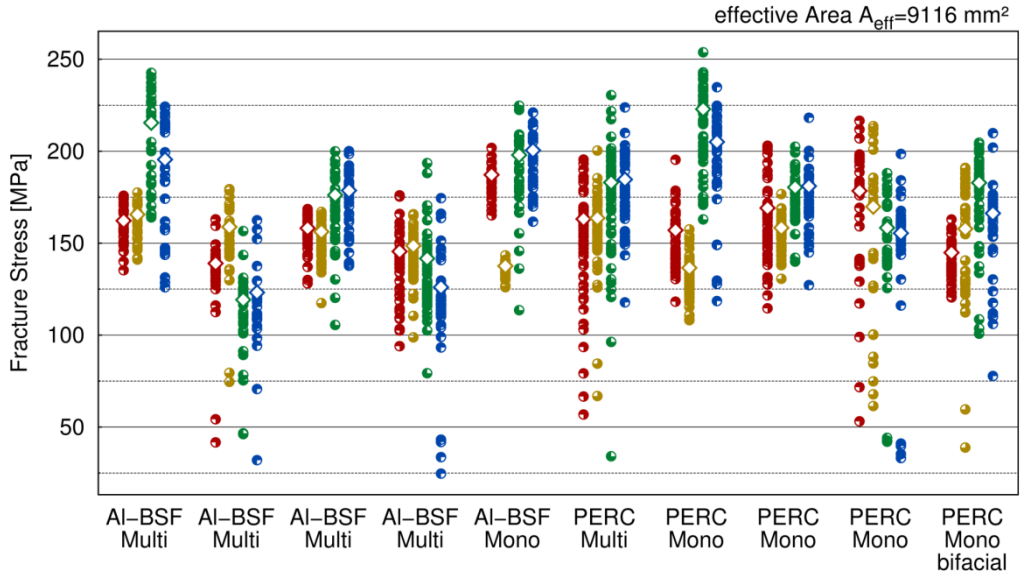
- Laser (back side, parallel): 80 MPa – 130 MPa
- StressCut (back side, parallel): 135 MPa

offen

© Fraunhofer Center for Silicon-Photovoltaics CSP

Fraunhofer CSP

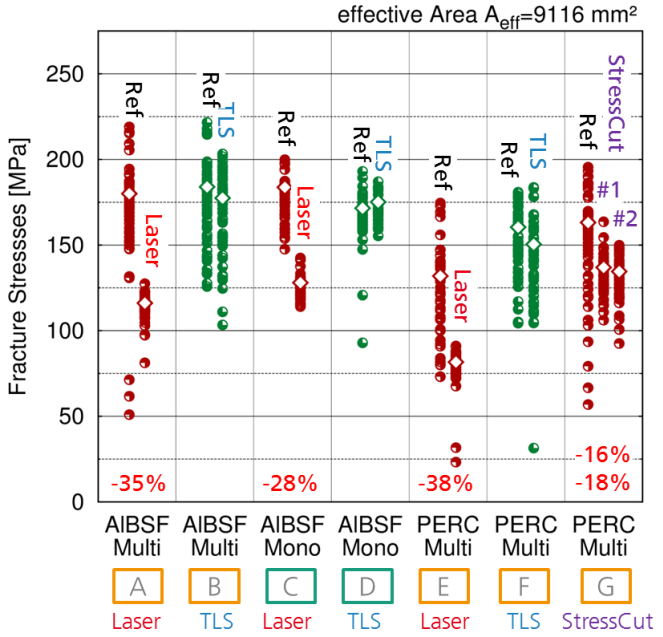
Conclusion



Strength of Full Cells

No general strength behavior for Al-BSF or PERC cells could be observed
→ Strength dependent on individual cell process

To evaluate a certain solar cell type:
→ Benchmark test needs to be performed



Damage from cutting technologies

TLS no damage

Laser damage: 20% - 40%

→ Laser cutting leads to a strong decrease in mechanical strength and will be the dominant defect for cell breakage

© Fraunhofer Center for Silicon-Photovoltaics CSP

Acknowledgement

Special thanks to:

Thomas Ackermann | Kjell Bühler | Julia Hesselbarth

This work was funded by the Federal Ministry of Education and Research in the Innoprofile initiative „MechSi“ (contract no. 03IPT607X) and by German Federal Ministry for Economic Affairs and Energy initiative „SolarTLS“ (contract no. 0325893C)

© Fraunhofer Center for Silicon-Photovoltaics CSP