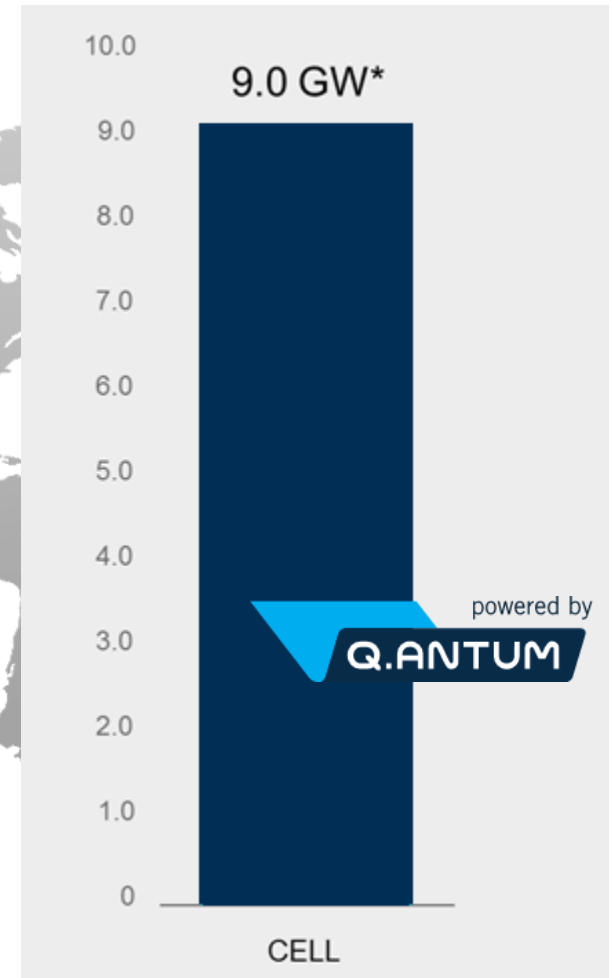
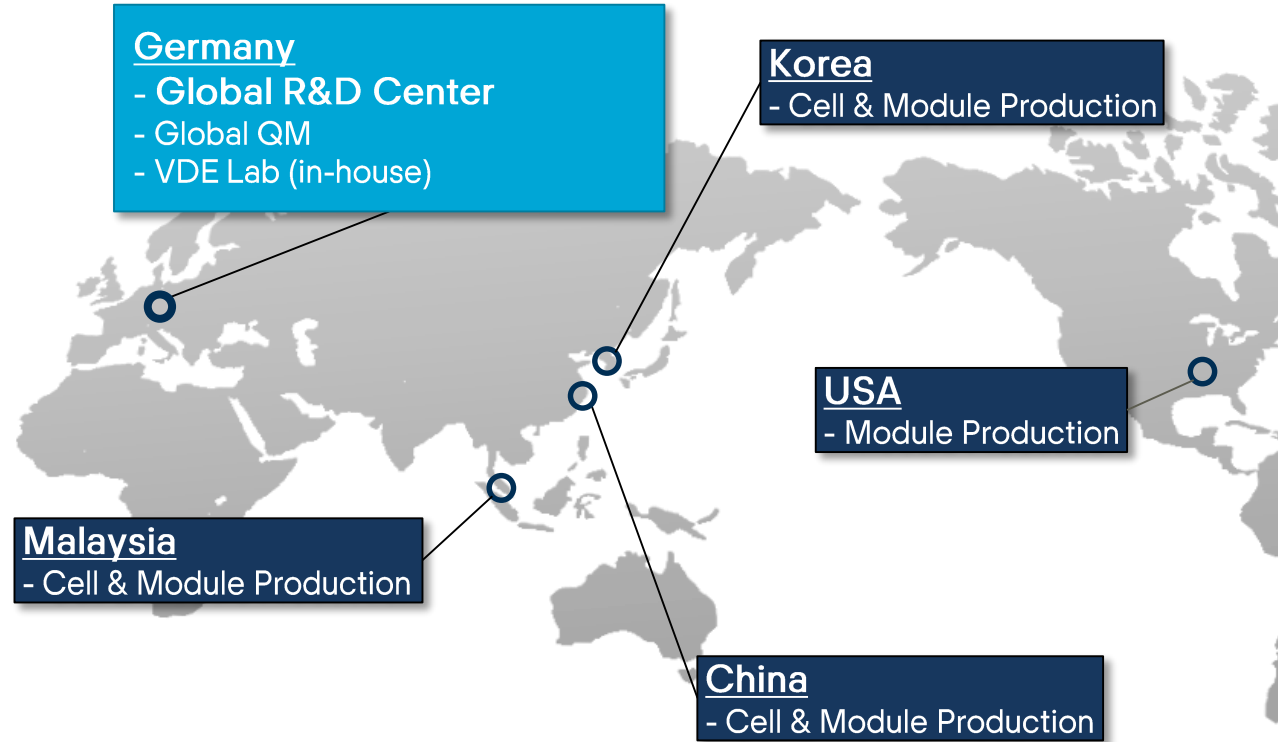


BIFACIAL TECHNOLOGY AT HANWHA Q CELLS


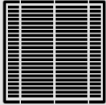
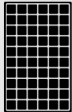


Dominik Buß, Richard Won, Ronny Bakowskie, Florian Stenzel,
Benjamin Lee, Marco Malagnino, René Zimmermann, Evelyn
Herzog, Thomas Dinkel, Martina Queck

BifiPV Workshop 2019
Amsterdam | 2019-09-16



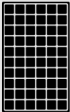


GLOBAL OPERATION FOR R&D AND PRODUCTION



* Production capacity as of end of Q1, 2019

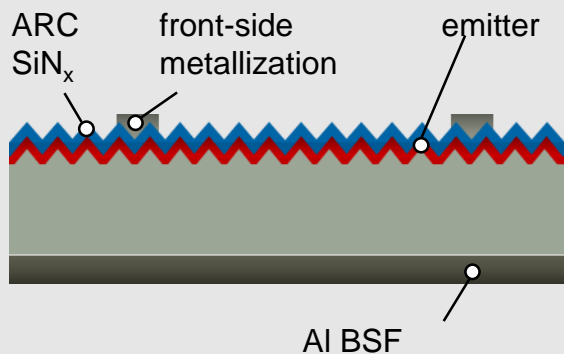
-  Hurdles towards Bifacial PV
-  Cell evolution
-  Module evolution
-  System optimization
-  Current achievements

Hurdle	Past	Today
Cost effectiveness	Not cost effective	?
Front side efficiency	Suffering from Bifaciality	?
Number of BB	Low, bad FF for Bifacial	?
Field experience	Hardly reliable data	?
Simulation models	Hardly validated	?

-  Hurdles towards Bifacial PV
-  Cell evolution
-  Module evolution
-  System optimization
-  Current achievements

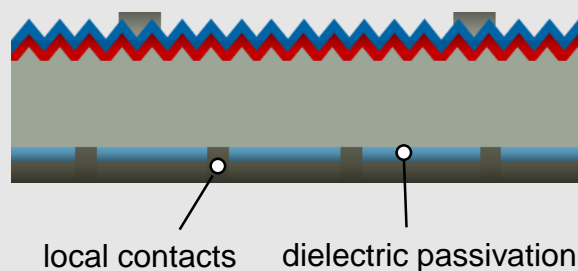
Challenge: Achieve Bifacial gain without losing front side efficiency

Standard Monofacial



Well known technology

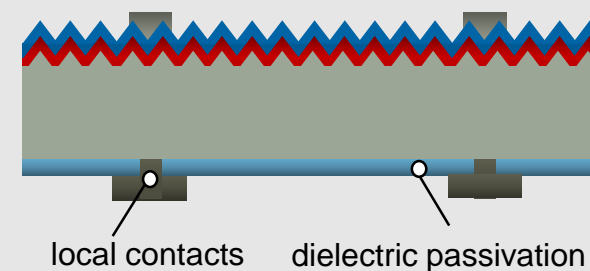
Q.ANTUM Technology Monofacial



Minimized recombination losses, improvements on

- Power
- Low light performance
- Temperature coefficient

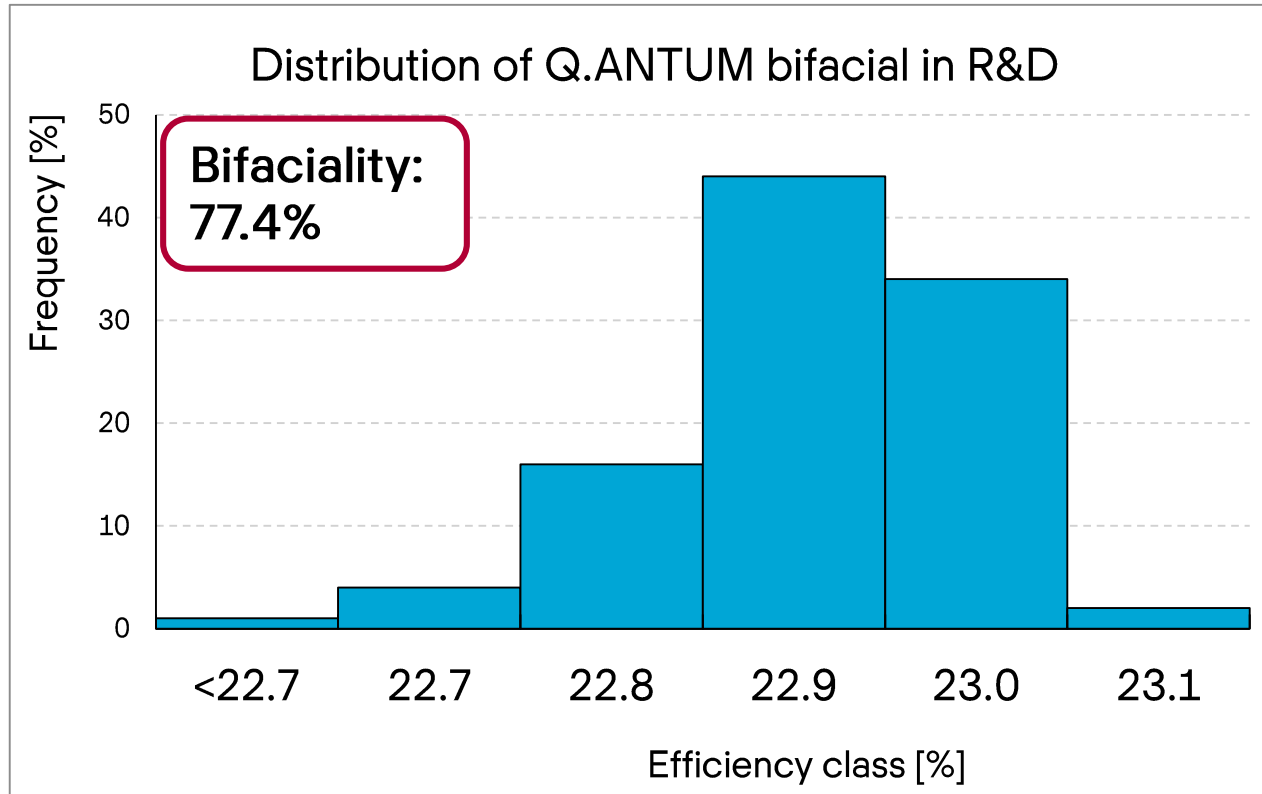
Q.ANTUM Bifacial



All Q.ANTUM features + Bifaciality

Delta front efficiency ~ 0.1%_{abs}

The cost effective Q.ANTUM process enables highly efficient BIFACIAL cells



Latest R&D bifacial cell run:


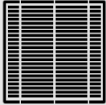
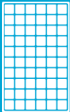


- 12 bus bars technology
- Ultra fine line single screen printed front contacts
- Homogeneous emitter
- Batch size ~100 wafers

	Eff. [%]	Voc [mV]	Jsc [mA/cm ²]	FF [%]
Median	22.9 ± 0.1	683.1 ± 1	41.0 ± 0.1	81.8 ± 0.2
Best cell*	23.1	684.8	41.1	81.9

Best produced bifacial cell with 23.1% front side efficiency

* Certified 12BB measurement at ISFH-CalTec

[1] F.Stenzel et. al: Approaching 23 % and Mass Production of Bifacial p-Cz Q.ANTUM PERC Solar Cells, PVSEC 2019, Marseille

-  Hurdles towards Bifacial PV
-  Cell evolution
-  **Module evolution**
-  System optimization
-  Current achievements

MODULE EVOLUTION

Q.POWER L-G5



+15 Wp

Q.PLUS L-G4



powered by
Q.ANTUM

Standard Al-BSF
Multicrystalline
2015 | 335 Wp

+20 Wp

Q.PEAK L-G4



powered by
Q.ANTUM

Q.ANTUM
Multicrystalline
2016 | 350 Wp

+20 Wp

Q.PEAK DUO L-G5



powered by
Q.ANTUM / DUO

Q.ANTUM DUO
Monocrystalline
2018 | 390 Wp

+10 Wp
+ Bifaciality



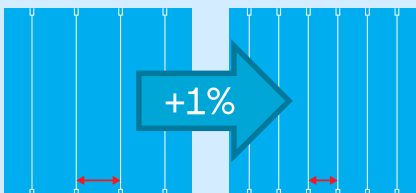
powered by
Q.ANTUM / DUO

Q.ANTUM DUO BIFACIAL
Monocrystalline
2020 | 400 Wp + rear side

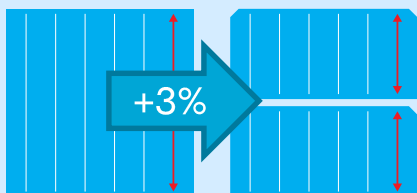
powered by

Q.ANTUM / DUO

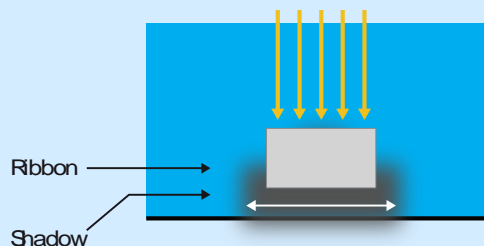
6BB



Half cut cells

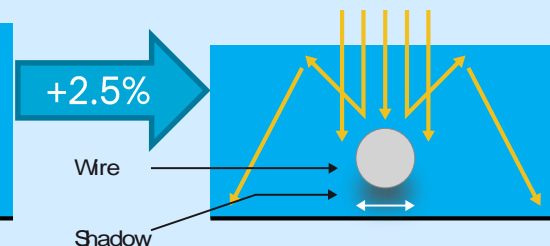



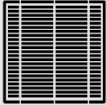
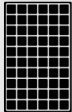


Ribbons



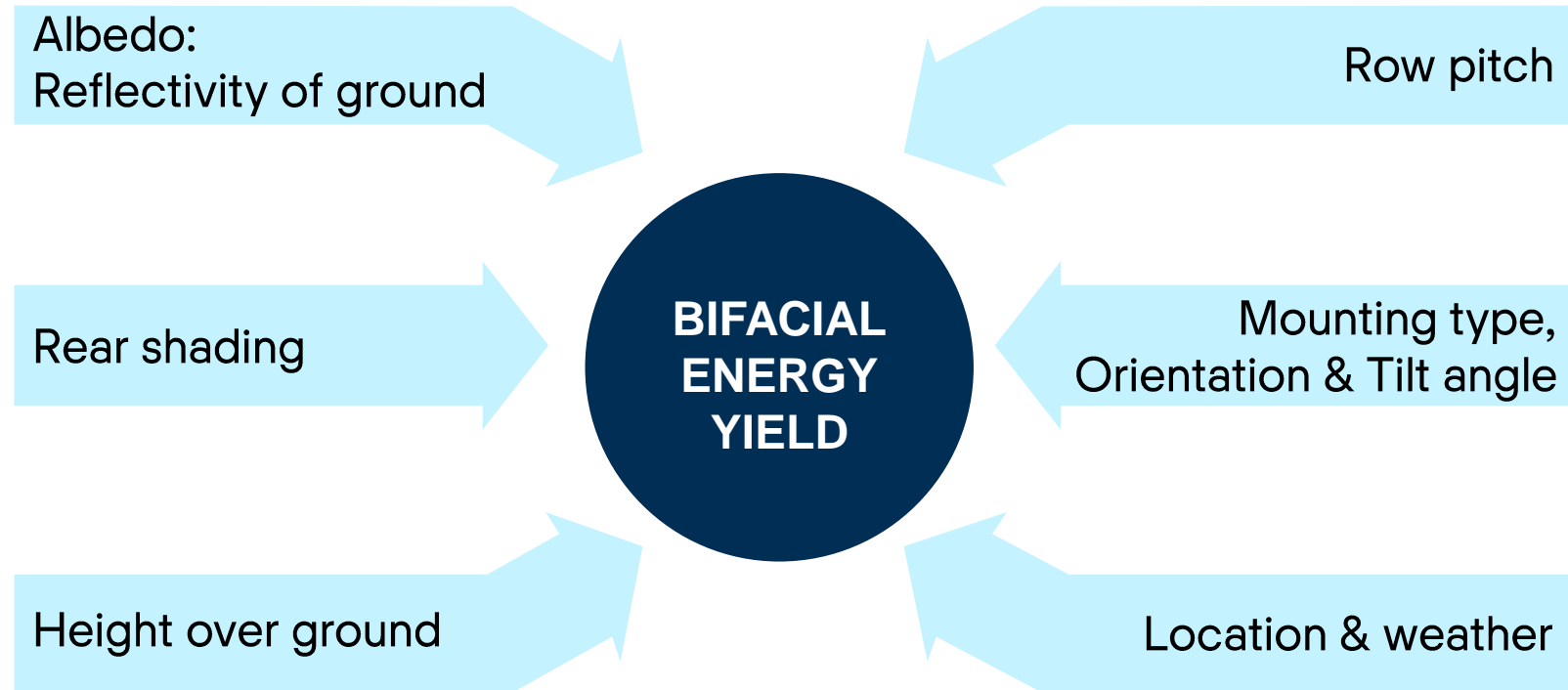
to

Wires



-  Hurdles towards Bifacial PV
-  Cell evolution
-  Module evolution
-  System optimization
-  Current achievements

External influences which effect the energy output of bifacial systems



Various opportunities for yield improvement!

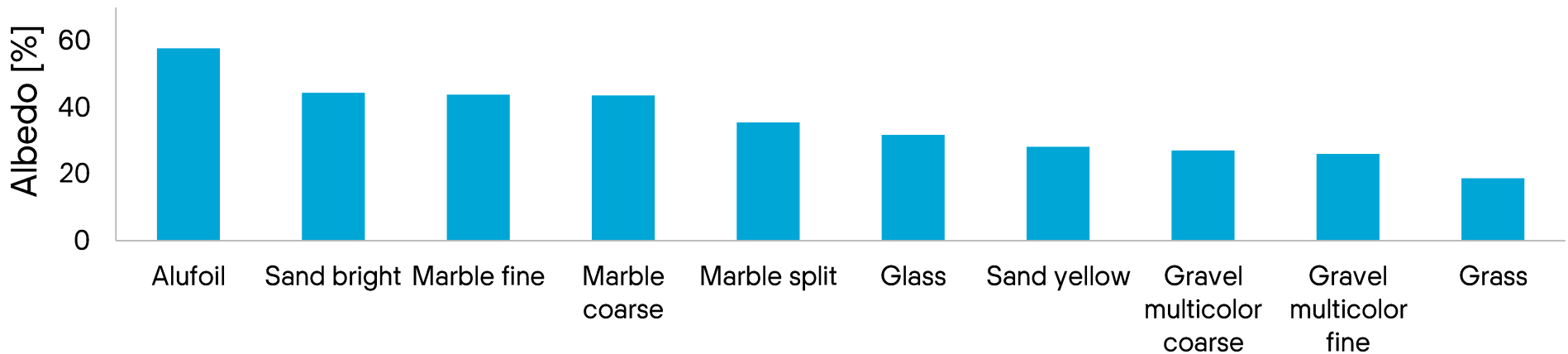
Example: Prepared patches of various ground material



Spectrally sensitive c-Si Sensors



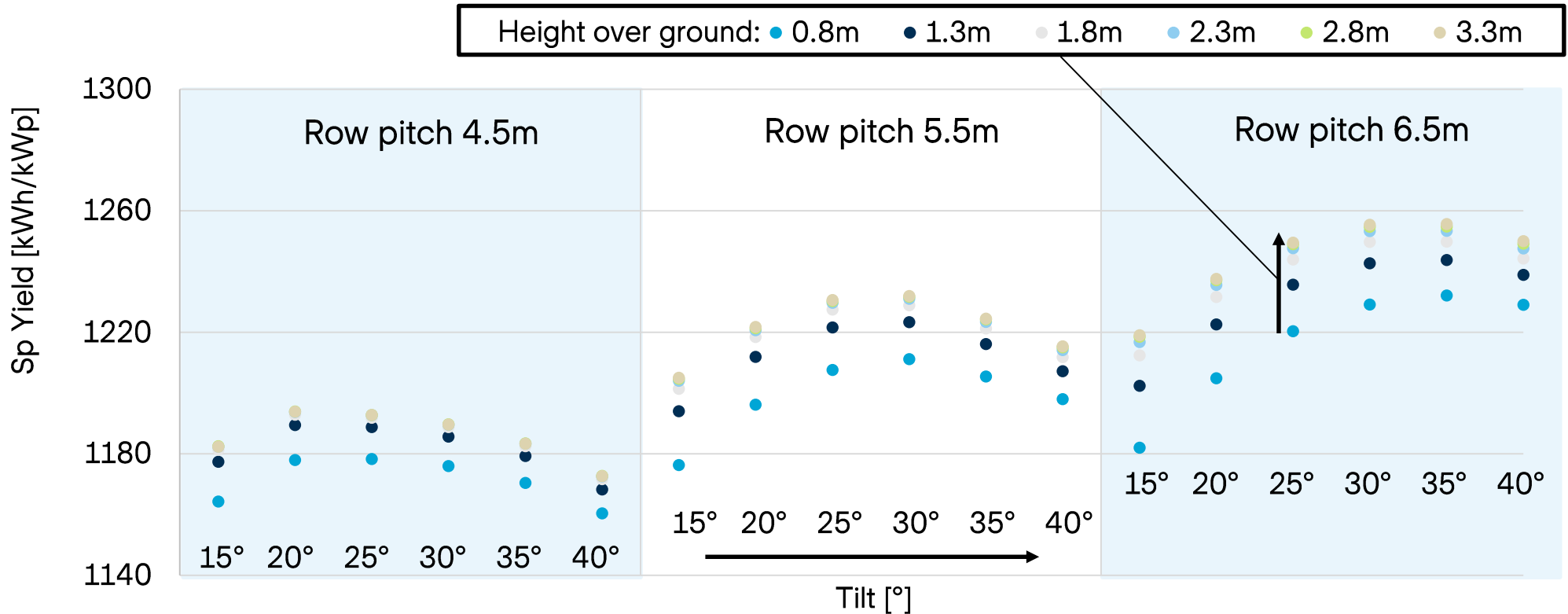
Albedo



In-field characterization of different influences at our test field in Germany

- Height over ground
- Row pitch
- Tilt angle

Specific Yield vs. tilt – row pitch - rack height



Optimization of system design parameters by simulation

SYSTEM OPTIMIZATION

Step 1:
Put Bifacial module in
existing field racking



Step 2:
Optimize racking,
increase height



Step 3:
Boost Albedo



Step 4:
Optimize tilt angle,
increase row pitch



SIM MEAS. PRO / CON

- ✗ Rear shading
- ✗ Height
- ✗ Grass Ground
- ✗ Tilt angle
- ✗ Row pitch

- ✓ Rear shading
- ✓ Height
- ✗ Grass Ground
- ✗ Tilt angle
- ✗ Row pitch

- ✓ Rear shading
- ✓ Height
- ✓ White gravel
- ✗ Tilt angle
- ✗ Row pitch

- ✓ Rear shading
- ✓ Height
- ✓ White gravel
- ✓ Tilt angle
- ✓ Row pitch

+6...8%

Optimized
mounting

+9%

Boosted
Albedo

+16...19%

Optimized
tilt & pitch

Under
investigation

+7%

+9%

+17%

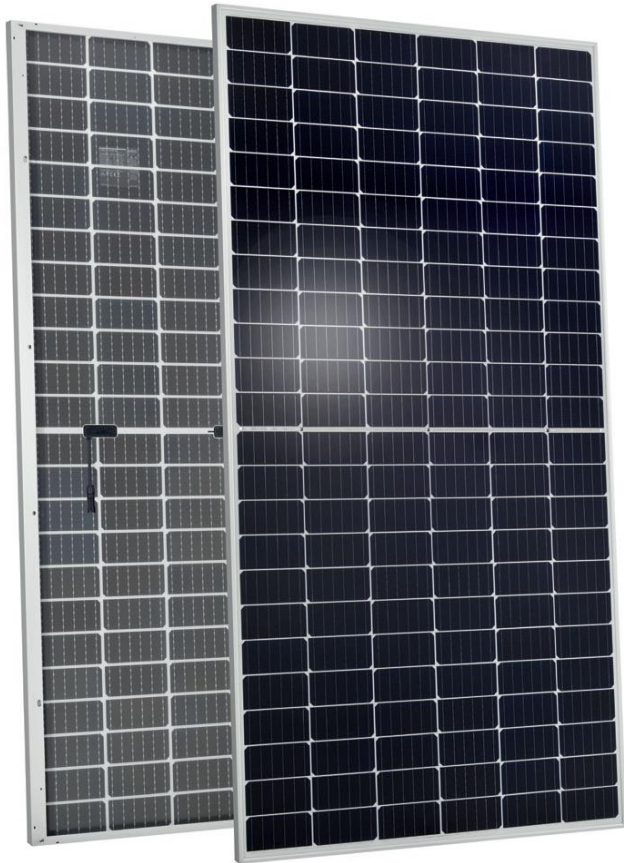
+20%

Up to 20% Bifacial Energy Yield Gain with optimized design

	Hurdles towards Bifacial PV
	Cell evolution
	Module evolution
	System optimization
	Current achievements

Hurdle	Past	Today
Cost effectiveness	Not cost effective	Cost effective Q.ANTUM process
Front side efficiency	Suffering from Bifaciality	Delta ~ 0.1% _{abs}
Number of BB	Low, bad FF for Bifacial	Increased to 6 for high FF
Field experience	Hardly reliable data	Increasing database
Simulation models	Hardly validated	More and more validated models

**The Q.ANTUM DUO technology
enables cost effective high performance bifacial modules!**



powered by

Q.ANTUM **DUO**

Q.PEAK DUO L-G5.3/BF features:

- Enabling lowest LCOE
- Glass/glass module
- White grid in between cell spacing to maintain $P_{MPP,front}$
- Extended power warranty of 30years
- Low module weight of 26kg
- High power classes 380-400Wp and an efficiency rate of up to 19.9%
- Bifaciality 70%

No compromises in front side power