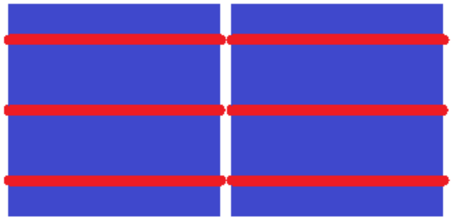
Cell interconnection without glueing or soldering for crystalline PV-modules

Johann Summhammer and Zahra Halavani
Solar Cells Group, TU-Vienna, Vienna, Austria. http://www.ati.ac.at/~summweb

Motivation:

Standard **156 x 156 mm²** silicon solar cells are HIGH CURRENT devices (9 A)

➔ Thick wiring needed for small ohmic loss **(I^2)**

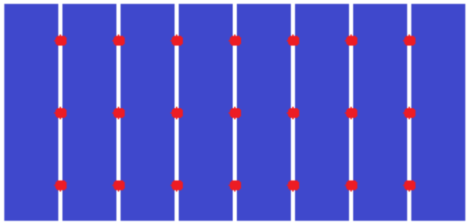


➔ Problem:

- High shading
- Soldering difficult with thickness below 150 µm (cracks)
- Glueing possible but expensive

Consequence:

Rectangular cells, e.g. **39 x 156 mm²,** connected at long side



➔ **Ohmic loss per cell reduced by factor 16**

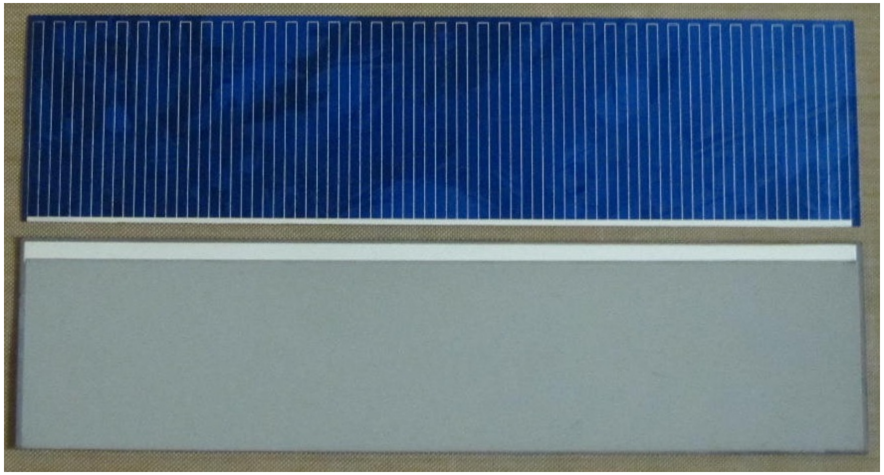
➔ **LESS STRINGENT REQUIREMENT ON CELL INTERCONNECTION**

The ideal concept of QuarterCells

(introduced by J. Summhammer and H. Rothen, 24th EUPVSEC, Hamburg, 2009, p.2221)

Mono- or poly-crystalline silicon solar cells of 156 x 156 mm² with special layout of metallization

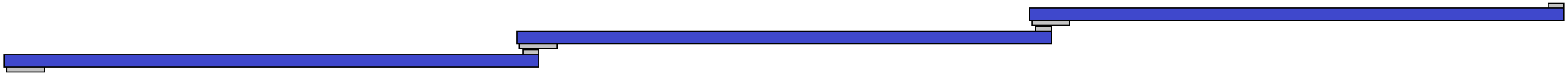
Cut by laser ➔ **4 QuarterCells of 156 x 39 mm²**



front

back

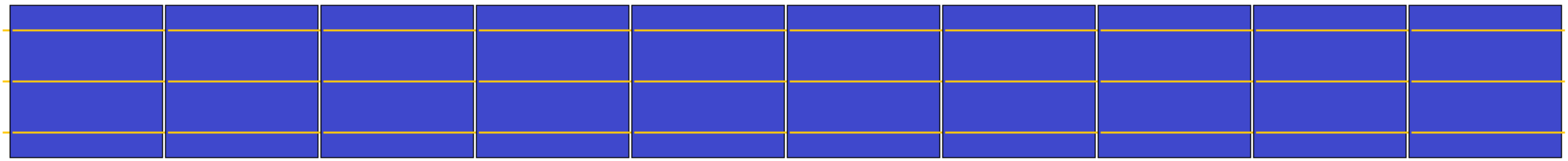
Interconnection by overlap: front bus bar is covered
back bus bar of next cell on top of front bus bar
➔ **very short electrical paths**

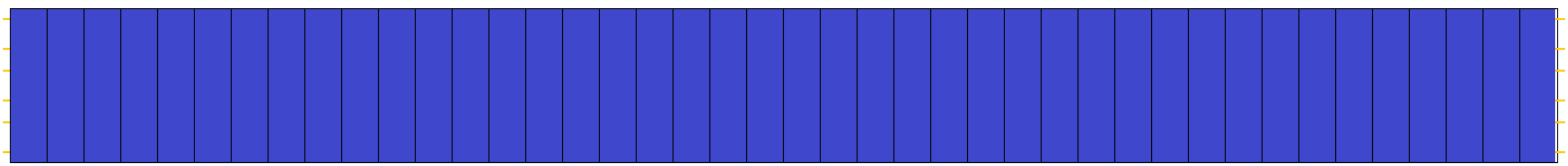


Comparison of strings

Quadratic cells 156 x 156:

Area loss by bus bars:	2.9 %
Area loss by cell spacing:	1.3 %
Ohmic loss in bus ribbons at peak power:	2.3 %
TOTAL:	**6.5 %**





QuarterCells 156 x 39:

Area loss by bus bars:	0.0 %
Area loss by cell spacing:	0.0 %
Ohmic and area loss because of more fingers:	~ 0.2 %
TOTAL:	**0.2 %**

→ For same module area: **QuarterCells give about 6% more peak power**

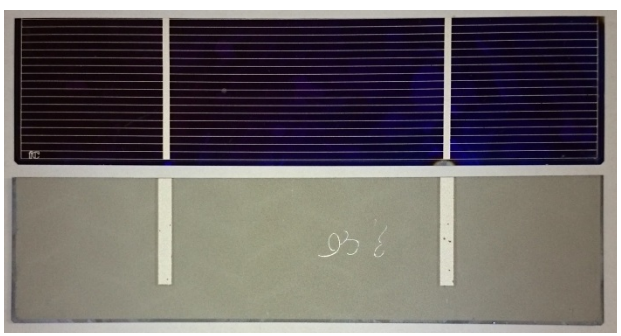
Here we test: <u>Interconnection by pressure,</u> NO soldering, NO glueing

Concept: Cells become bent around contact strips in laminated glass – backsheet module.

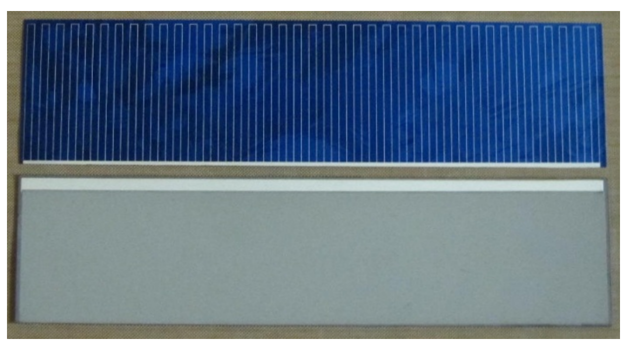
- ➔ permanent bend creates force between cell bus bars and contact strips
- ➔ good electrical contact
- ➔ cells can slide against each other

Tests with

Cut from standard cells

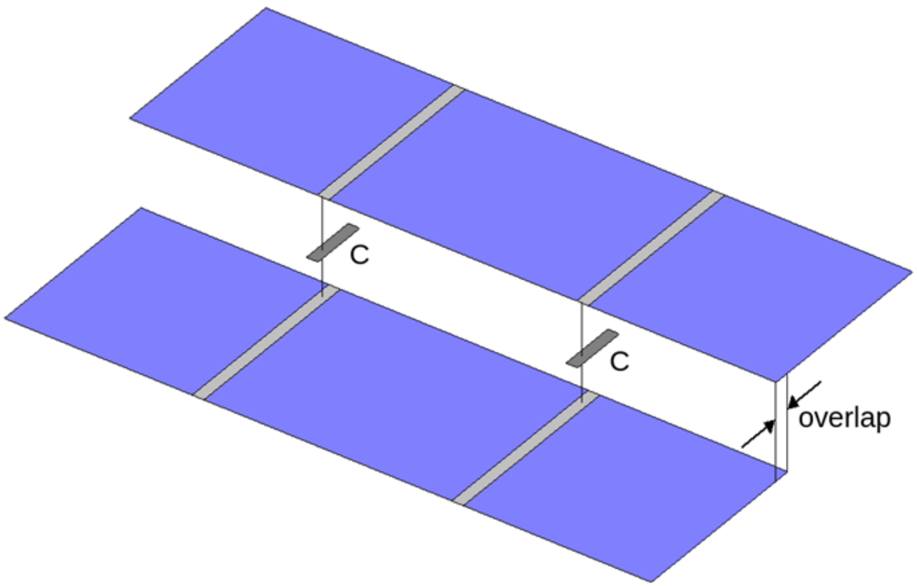


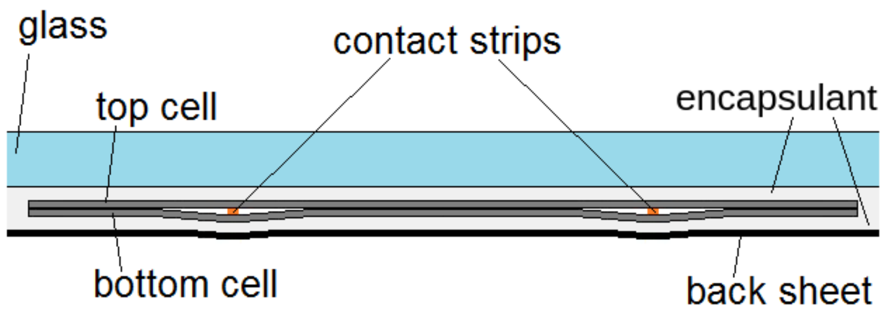
QuarterCells of type P

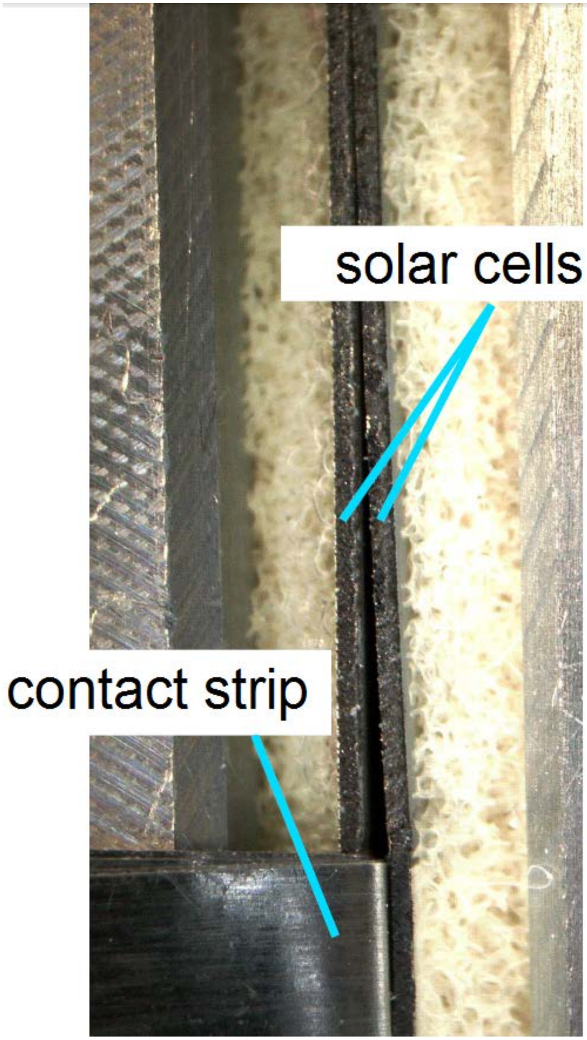


QuarterCells of type K

Standard cells scheme (standard 156 x 156 quadratic cells cut in 4 pieces):



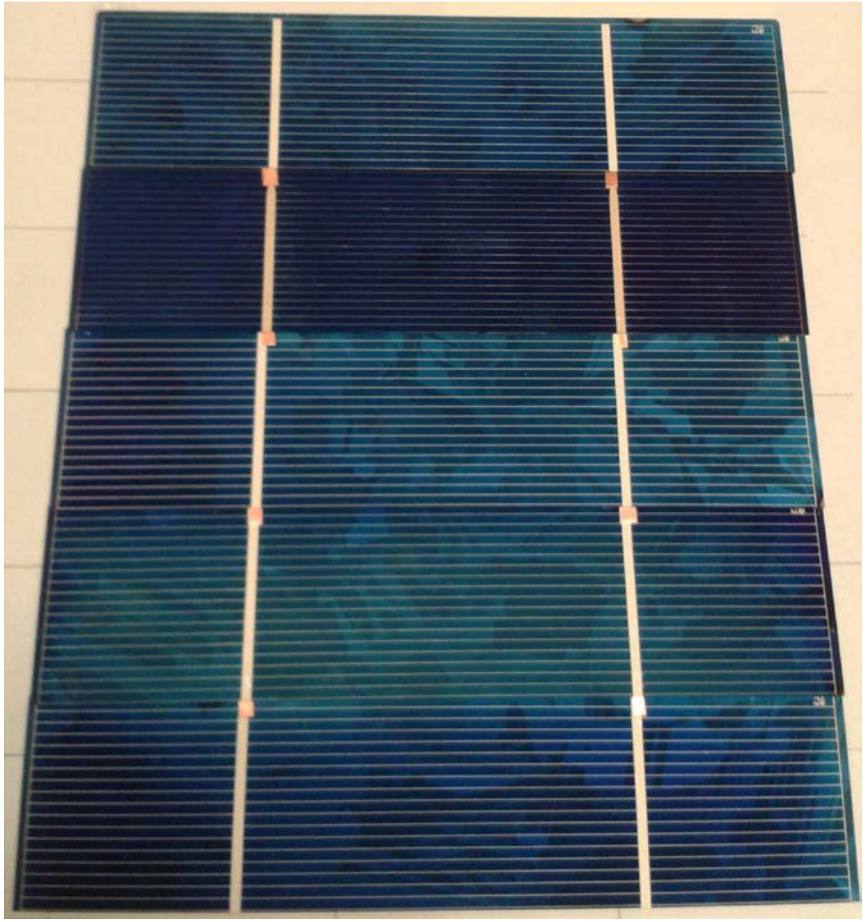


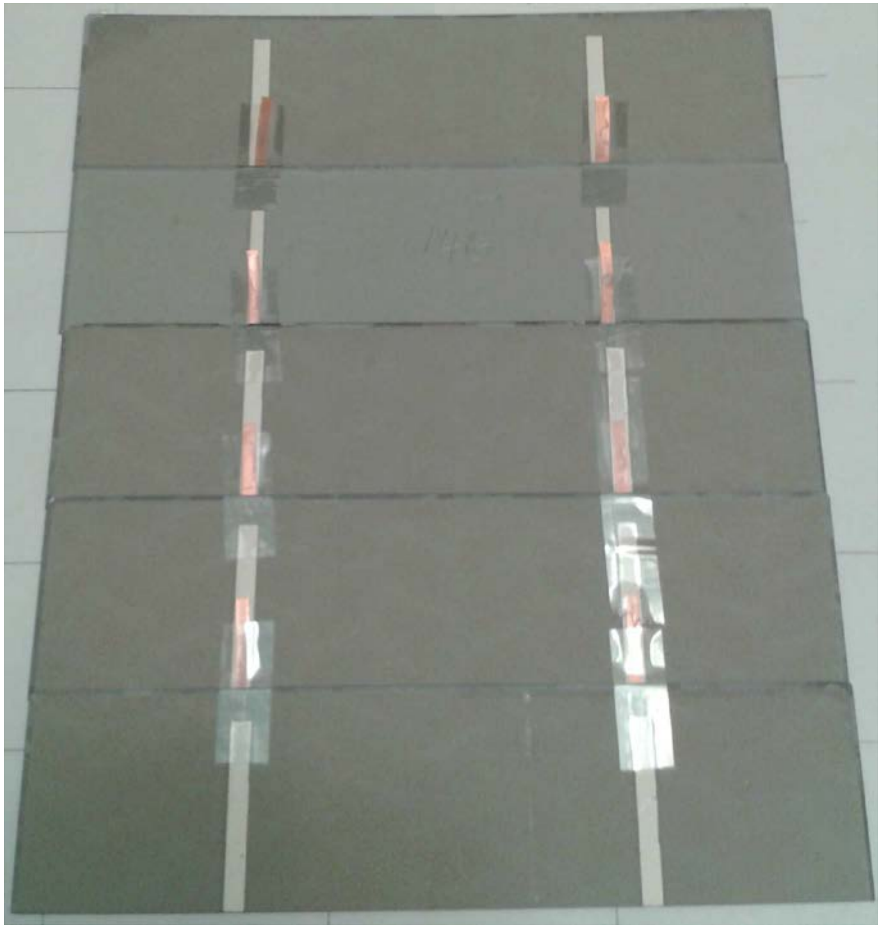


J.J. Lang, M.Sc.-Thesis, 2014

Front and back side of small module with 5 standard cells

Contact strips: Cu
Connection to outside: soldering



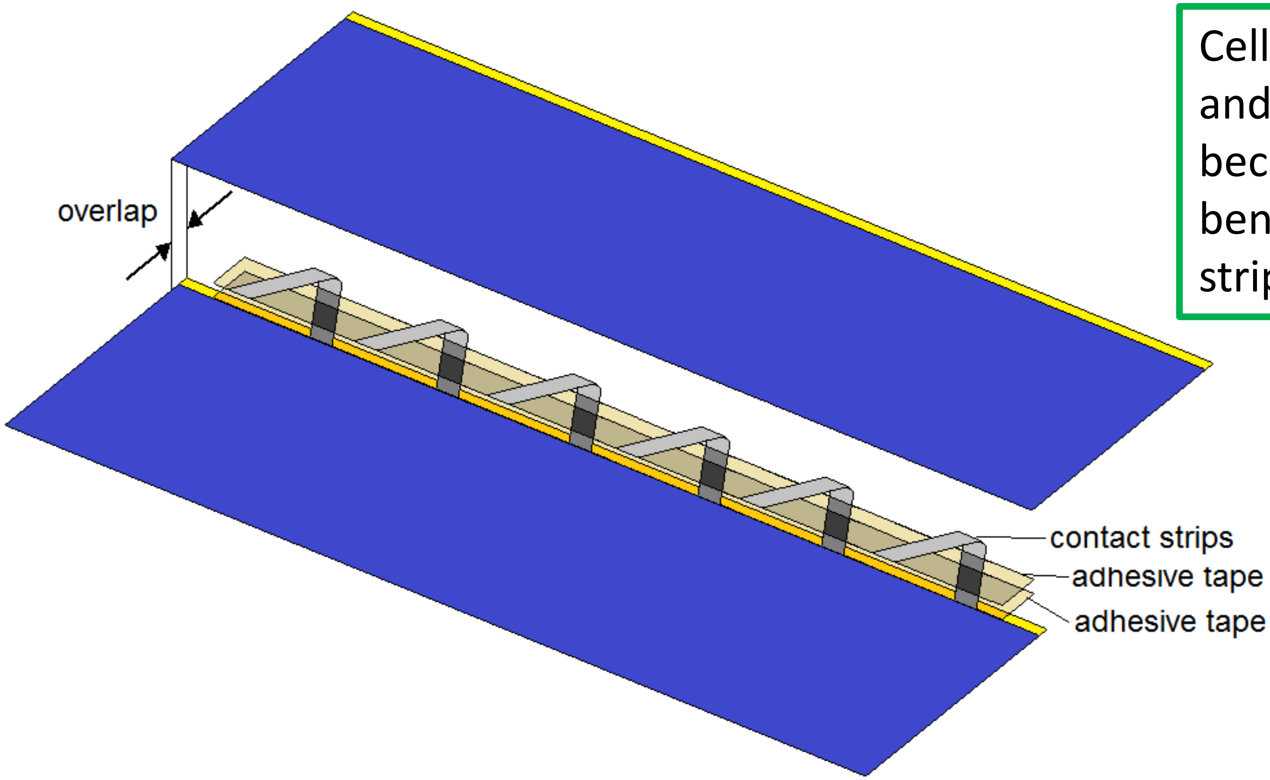


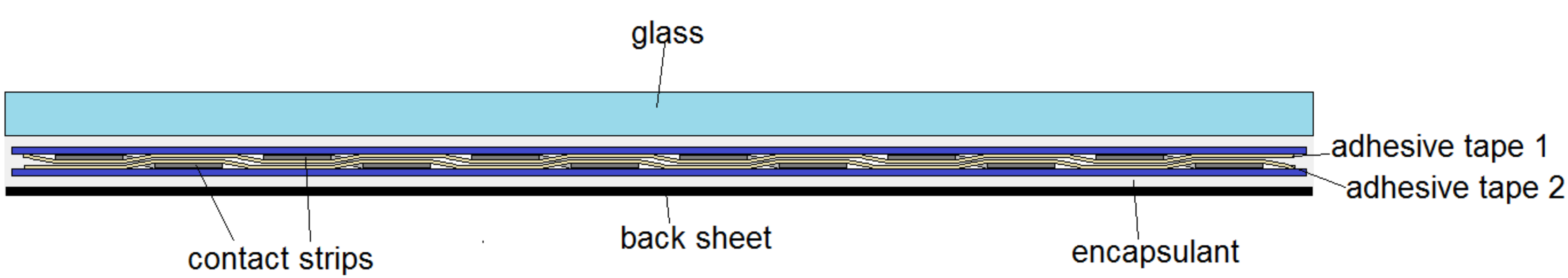
Cells are held together by high temperature adhesive tape

QuarterCells „P“

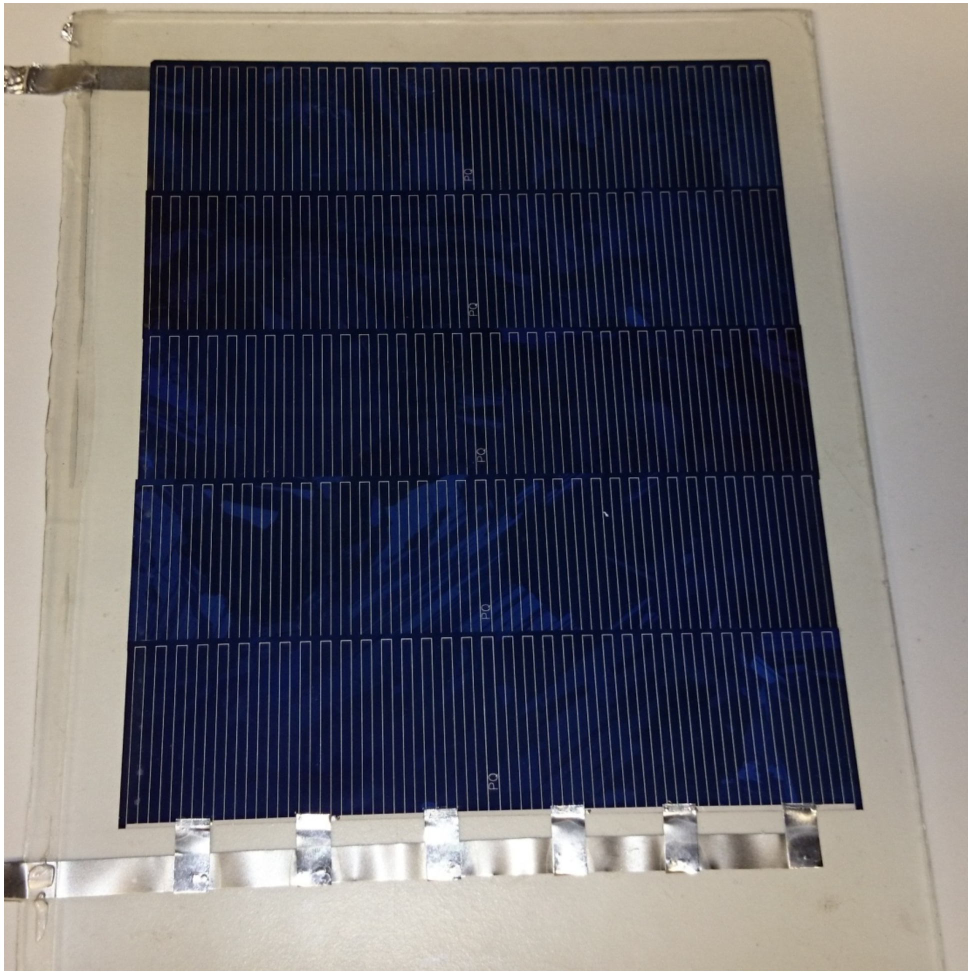
Special connection with two adhesive tapes and coated Cu-tape wrapped around

Cells can slide back and forth a little because of round bend in contact strips



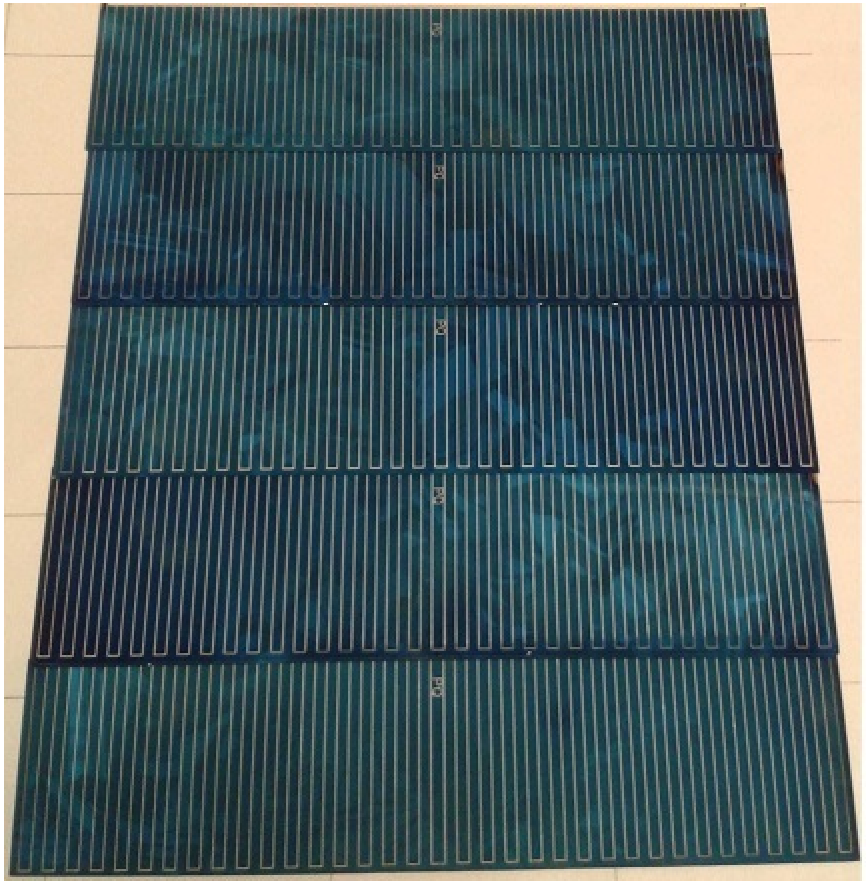


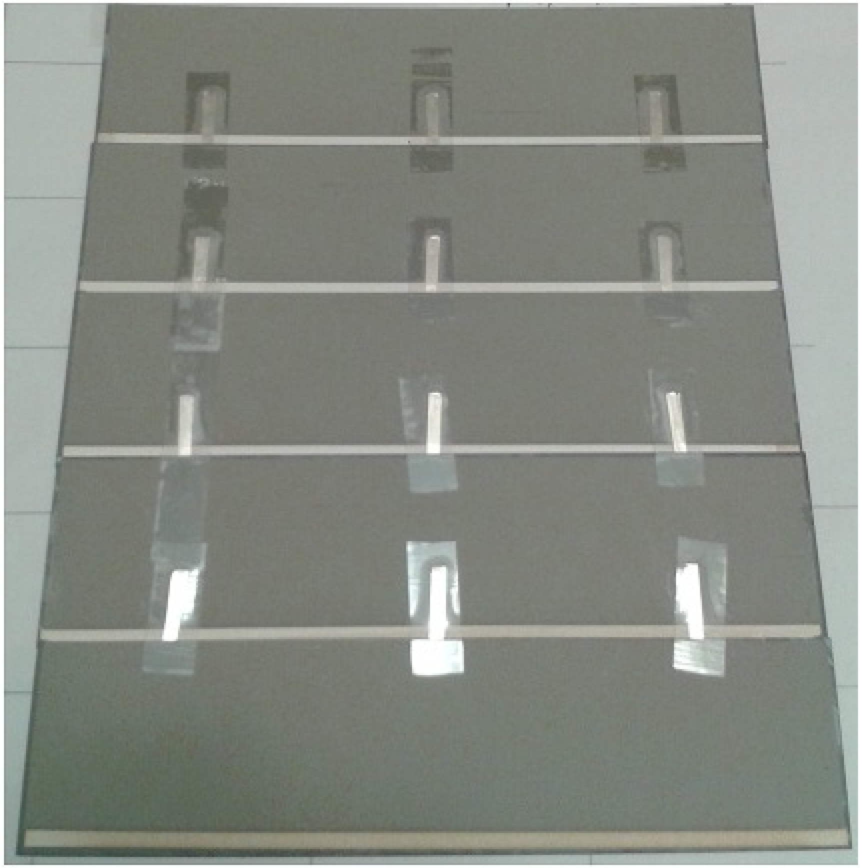
Front and Back side of small module with 5 QuarterCells „P“



Another method of intereconnecting QuarterCells „P“

Straight contact strips placed between cells, analogous to method for standard cells



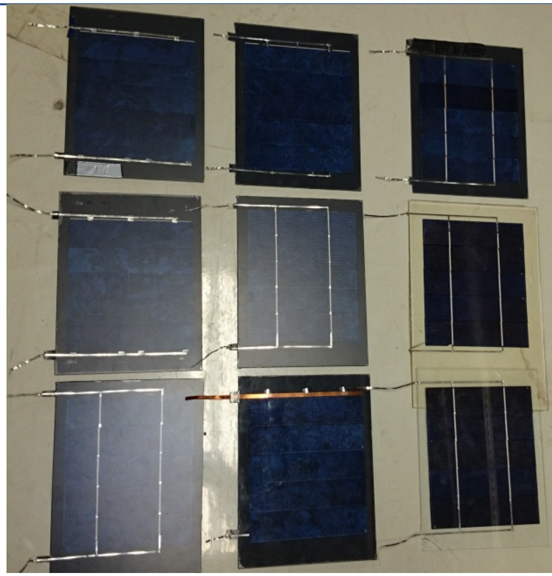


This study:

Rapid ageing of small modules each with 5 cells

Outdoor tests of large modules (240 W class)

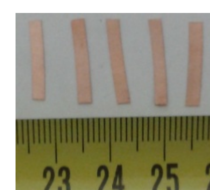
Temperature cycling:
-24°C to +87°C 3 cycles per day.



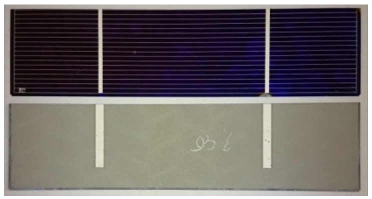
Tested: different cells
different types and thicknesses of contact strips (50 – 300 µm)

Types of contact strips:

- SnPbAg-coated (solar ribbon, but not soldered)
- Ag-coated
- Pure Cu
- Sn-covered Fe



Rapid ageing of small modules

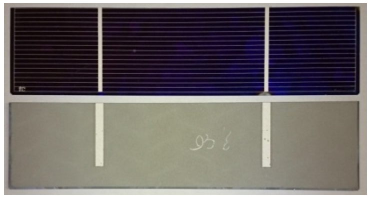


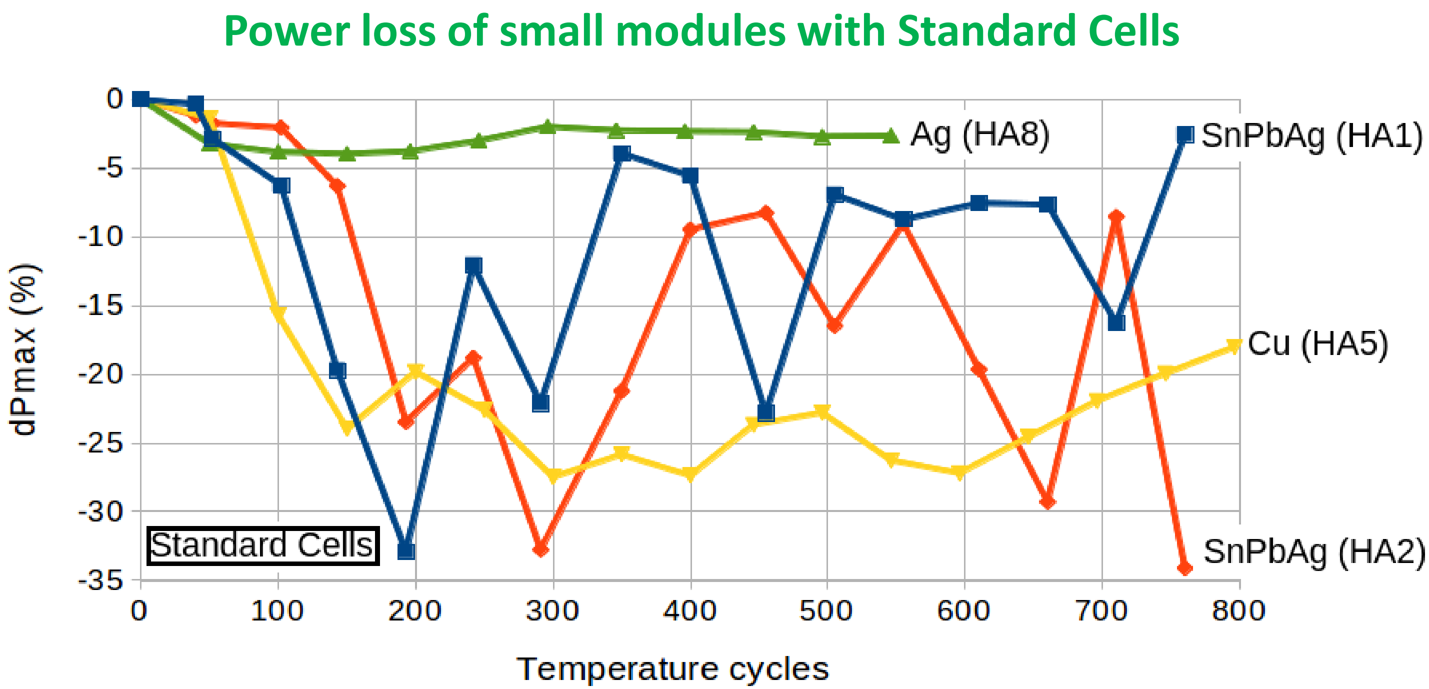
Cell type	Module name	Contact strips		
		Coating, µm	TxW[mm]	#
Standard	HA1	SnPbAg, 15	0.15 x 2.5	2
	HA2	SnPbAg, 15	0.20 x 2.0	2
	HA5	Cu	0.20 x 2.5	2
	HA8	Ag, ~1	0.30 x 2.2	2
QuarterCell “K”	HA3	Ag, 6.5	0.19 x 5.0	4
	HA4	Ag, 6.5	0.19 x 5.0	4
	HA9	Ag, ~1	0.30 x 2.2	3
	HA11	Ag, 6.5	0.25 x 5.0	3
	SU2	Cu	0.20 x 5.0	3
QuarterCell “P”	MeSn1	SnPb, 6.5	0.05 x 3.5	7
	MeSn2	SnPb, 6.5	0.05 x 3.5	7
	MeAg1	Ag, 6.5	0.05 x 5.0	7
	MeAg2	Ag, 6.5	0.05 x 5.0	7
	HA6	Ag, 6.5	0.19 x 2.5	3
	Fe2	Sn on Fe*	0.20 x 2.0	3

* „tinned iron“

Rapid ageing of small modules

IV-curve measurements under 1000 W/m², typically after every 50 temperature cycles



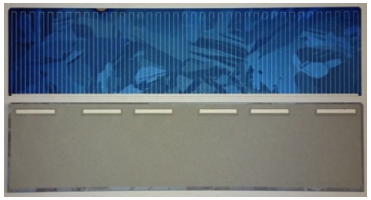


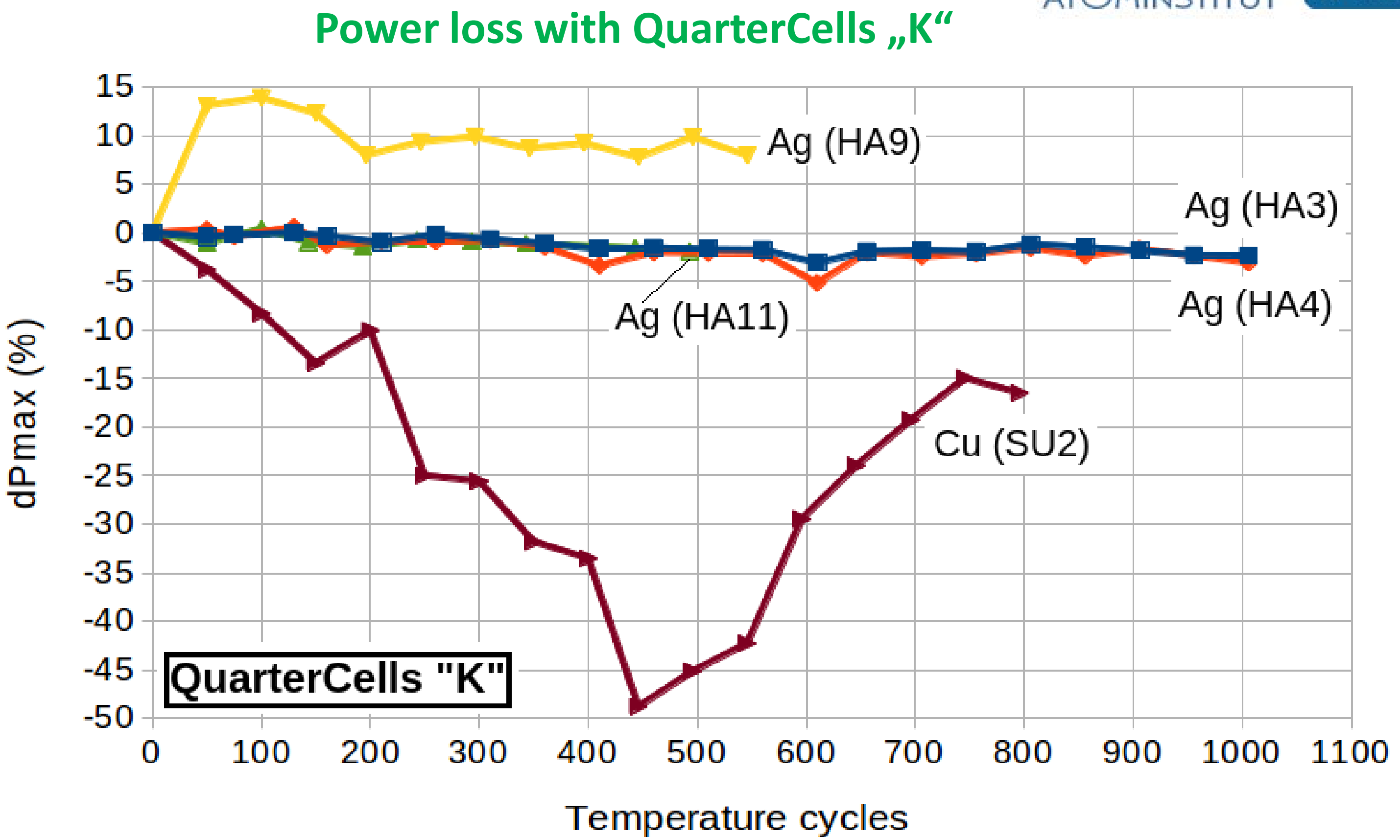
SnPbAg-coating (normal solar ribbon but NOT soldered): abrasions ➔ strong fluctuations of series resistance, fast decline of Pmax with occasional recovery

Pure Cu: initial fast increase of series resistance and then slow decrease; **oxidations?**

Ag-coating: only very slow decrease in Pmax

Rapid ageing of small modules





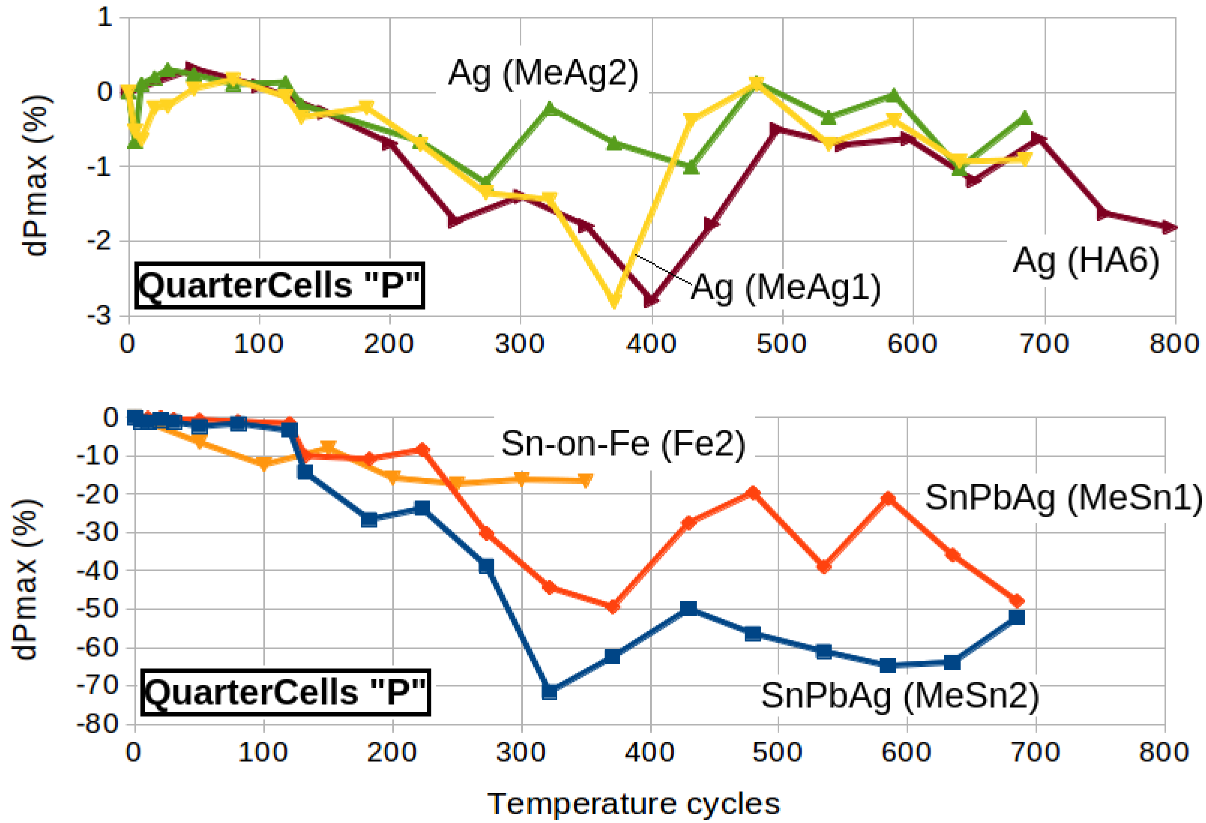
Pure Cu: again fast decrease in power and then recovery

Ag-coating: often an initial increase in power, probably due to formation of larger contact area by rubbing during temperature cycles, then only slow decrease in Pmax

(SnPbAg not tested)

Rapid ageing of small modules

Power loss with QuarterCells „P“



Ag-coating: again initial increase of Pmax of all three modules, then only slow decrease
High lamination pressure is better! (MeAg1: 600 mbar, MeAg2: 800 mbar)

SnPbAg-coating: contact strips were of wrap-type. Good performance for 120 cycles, then abrasions, fluctuations of series resistance, fast decline of Pmax

Sn on Fe („tinned Fe“): better than SnPbAg, but much worse than Ag

Outdoor tests with large modules

~ 163 x 98 cm

Each module: 6 strings in series, 42 cells per string (except 5 and 8)
cell overlap 2 mm (except 5)

4: Standard cells
SOLDERED
(reference)

3: Standard cells
Ag 2x
T = 0.24 mm

2: Standard cells
Ag 2x
T = 0.19 mm

1: Standard cells
SnPbAg 2x
T = 0.22 mm

8: QuarterCells „K“
Ag 3x
T = 0.25 mm
(41 cells / string)

7: Standard cells
Cu
T = 0.20 mm

6: Standard cells, 3BB
Ag 3x
T = 0.24 mm

5: QuarterCells „K“
Ag 4x
T = 0.19 mm
Overlap 5mm
(46 cells / string)

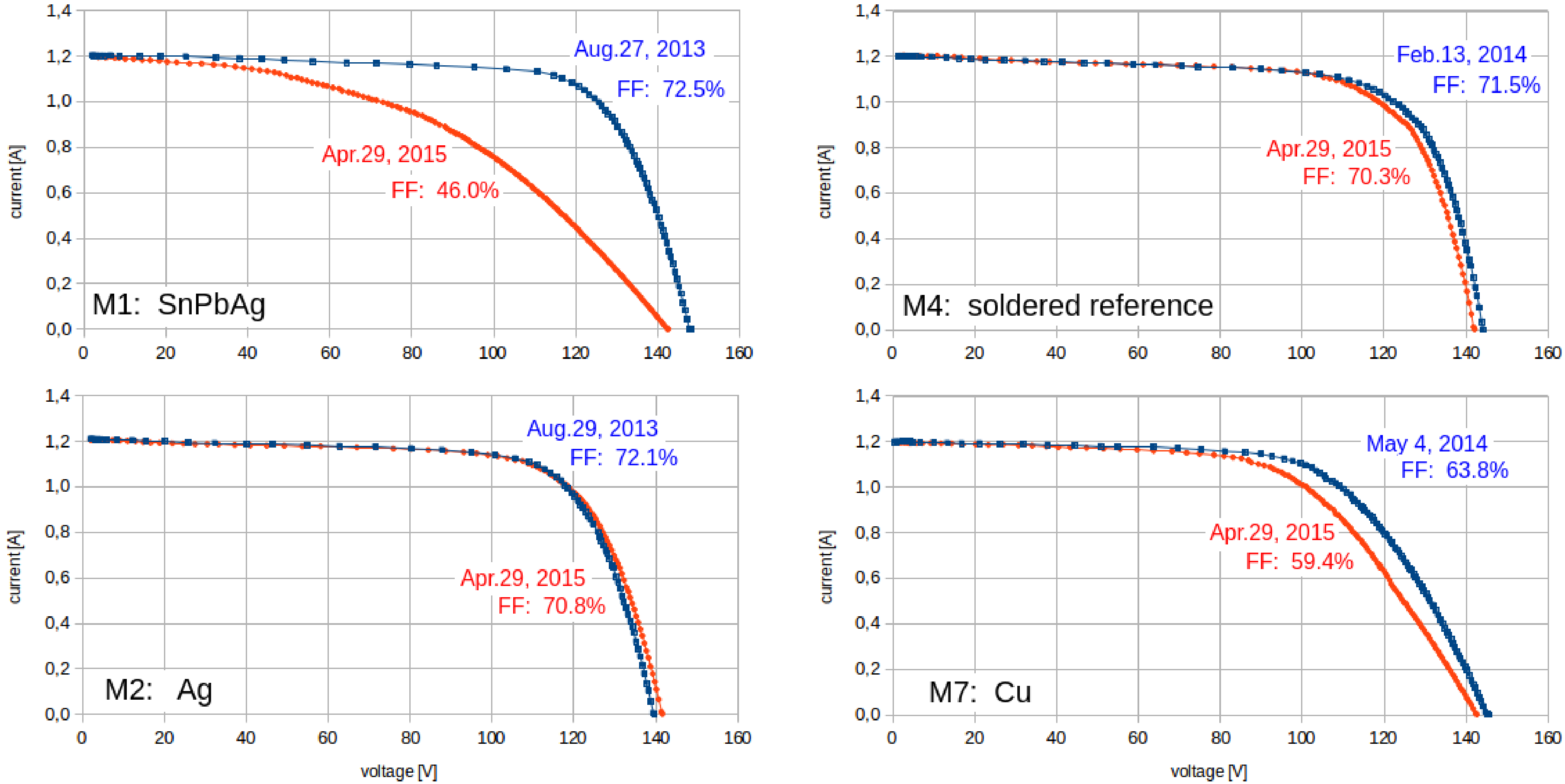
T= thickness of contact strips

Outdoor tests with large modules

- measure IV-curves every 2 minutes for several days
- short circuit modules for several days to weeks

Ageing: Increase of Rser ➔ decrease of fill factor

Selected IV-curves: Isc = 1.2 A



SnPbAg:
strong deterioration

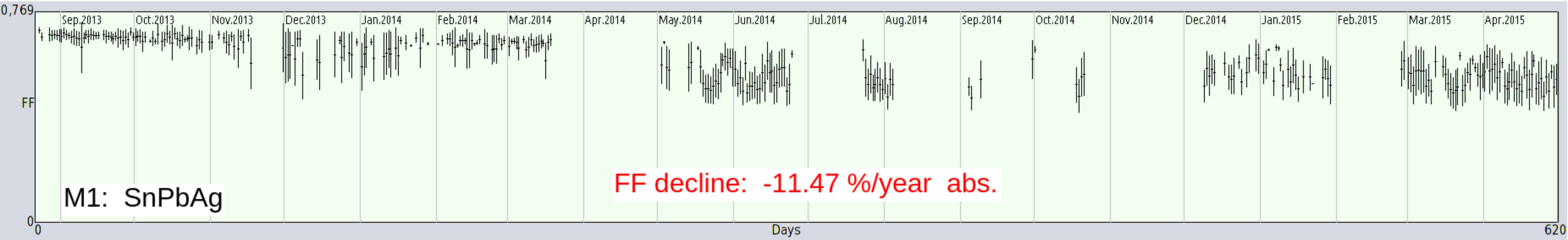
Ag:
little deterioration

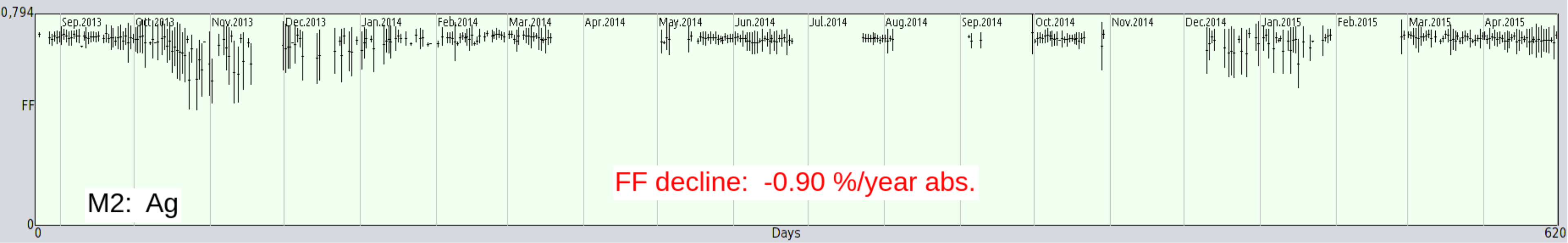
Cu: initial low FF
deteriorates further

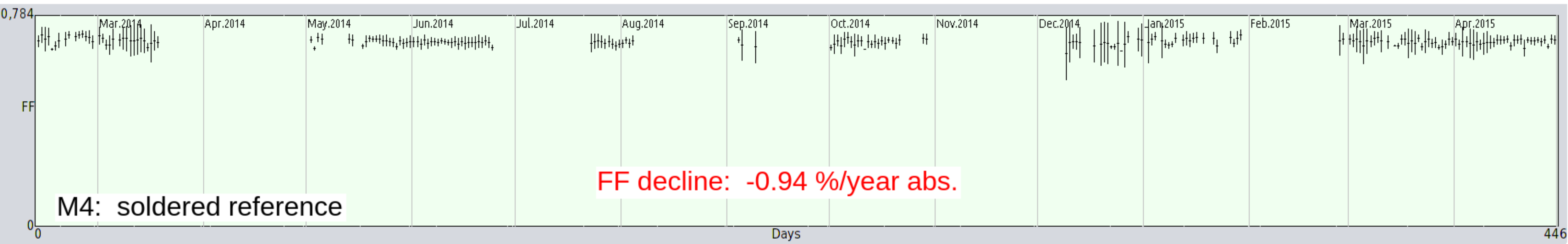
Agrees with rapid aging tests of small modules

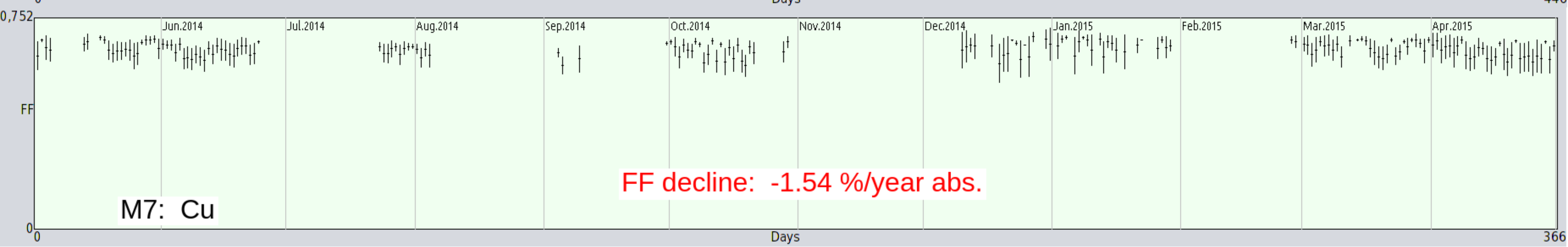
Outdoor tests with large modules

Decline of fill factor over time (IV-curves with Pmax > 20 W and FF > 40% to exclude data from partial shading)









Outdoor tests with large modules

Expected Power Loss per Year

Method: An IV-curve with Isc around 1.2 A from the first few days is extrapolated to an IV-curve of same Isc, but with observed FF-decline of one year. Then both curves are extrapolated to illumination of 1000 W/m², and Pmax of these curves are compared. Data included until Apr. 29, 2015.

Module	First day	Contact strip coating	Max. Power measured outdoor [W]	ΔP / year [%]
1	Aug.23, 2013	SnPbAg	183.7	-29.6
2	Aug.29, 2013	Ag	226.5	-2.4
3	Feb.13, 2014	Ag	217.4	-2.4
4	Feb.13, 2014	**SOLDERED, ref.**	215.7	**-2.5**
5	Feb.13, 2014	Ag	209,4	-2.5
6	May 2, 2014	Ag	222.4	+0.2*
7	May 2, 2014	Cu	168.0	-4.5
8	Sep. 4, 2014	Ag	204.4	Not enough data

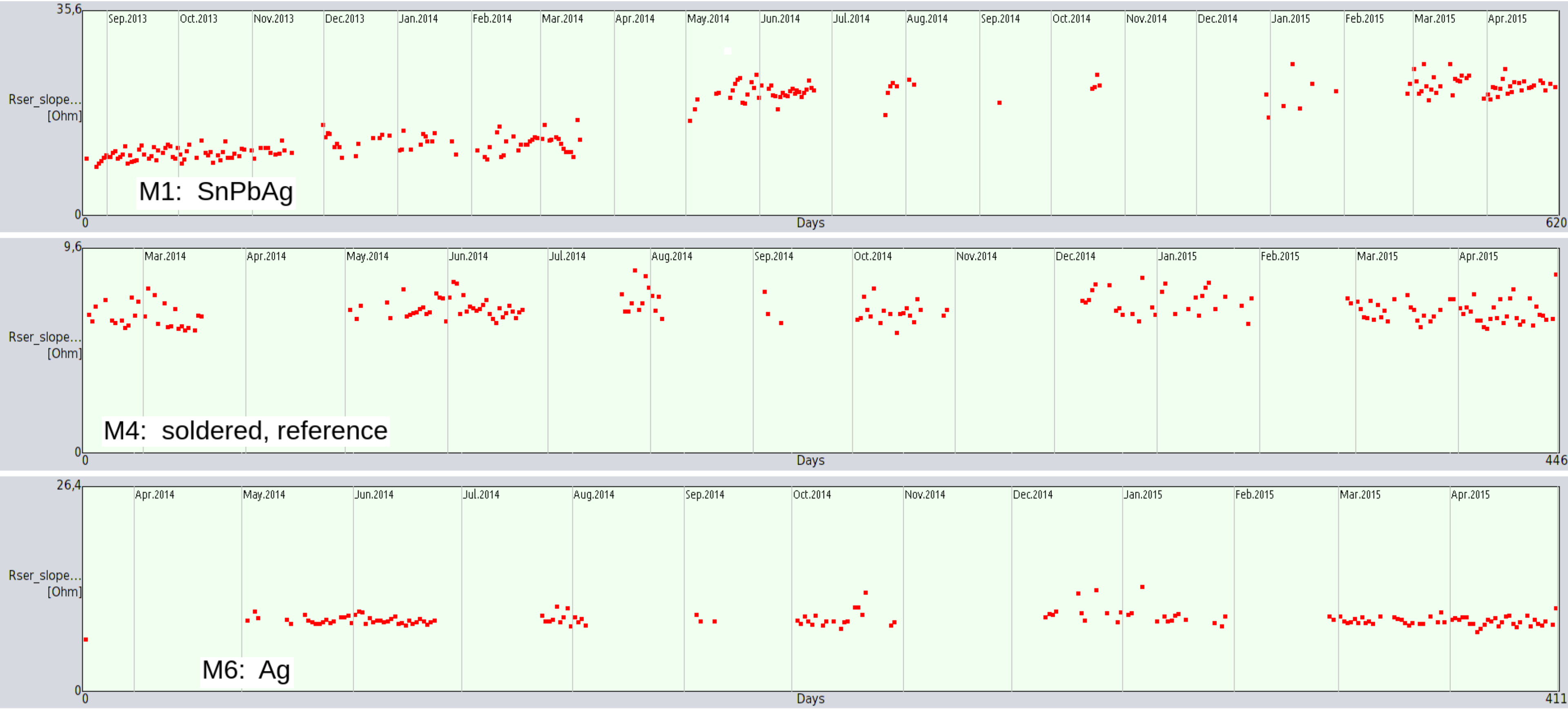
SnPbAg is very bad, Cu is bad, Ag is as good as soldered interconnections

* Cells from different company

Outdoor tests with large modules

Inverse slope of IV-curve near Uoc is very sensitive to change of series resistance

Averaged for IV-curves with Pmax between 80 W and 160 W. Slope taken from Uoc to 40% of Ipmax.



M1: SnPbAg:	strong increase of series resistance
M2: soldered reference:	slow increase of series resistance
M6: Ag:	apparent slow decrease of series resistance

Conclusions

- „Pressure-Only“ cell interconnections, produced by a slight bending of overlapped cells with contact strips in between are a possible method of stringing of glass – back sheet type crystalline Si modules

- Ag proved to be the best contact material to screen printed bus bars. It performed as good as soldered interconnections

- Low current is preferable
  - ➔ Change of cell format is necessary
  - ➔ Short rectangular cells, which should be overlapped at the long edges
  - ➔ High voltage modules are possible

- „Pressure-Only“ interconnections save 70 – 90% of copper in a typical 240 W module

- „Pressure-Only“ interconnections could be optimal for stringing of very thin Si solar cells. They avoid the mechanical and thermal stress of soldering bulky metal onto the cells.