NREL National Renewable Energy Laboratory

Innovation for Our Energy Future

Results from the Second International Module Inter-comparison

S. Rummel,[1] A. Anderberg,[1] K. Emery,[1] D. King,[2] G. TamizhMani,[3]
T. Arends,[3] G. Atmaram,[4] L. Demetrius,[4] W. Zaaiman,[5] N. Cereghetti
W. Herrmann,[7] W. Warta,[8] F. Neuberger,[8] K. Morita,[9] and Y. Hishikaw

[1]National Renewable Energy Laboratory (NREL), USA
[2]Sandia National Laboratories (SNL), USA
[3]PV Testing Laboratory-Arizona State University (PTL-ASU), USA
[4]Florida Solar Energy Center (FSEC), USA
[5] European Commission, Directorate General - Joint Research Centre, (IES-RE-ESTI), European Union
[6]Laboratorio Energia Ecologia Economia (LEEE), Switzerland
[7]Immisssionsschutz und Energiesysteme GmbH Test Centre for Energy Technologies (TÜV), Germany
[8]Institute of Solar for Energy Systems (Fraunhofer ISE),Germany
[9]Japan Electrical Safety & Environment Technology Laboratories (JET), Japan
[10]National Institute of Advanced Industrial Science and Technology (AIST), Japan

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History

1987 to 1989 - PEP ’87

Cells, cell in module package and module of identical type

2 day meeting of participants, PTB issued formal report, 1990 presented at 21 IEEE PVSC

Range Si Modules; I_{sc} = 2-5%, FF = 1-2%, V_{oc} = 2-5%

Range a-Si tandem Modules I_{sc}= 8%, FF= 2.5%, V_{oc} = 1%

Final Report analyzed data using 2 standard deviations,

I_{sc} 2-6% for Si, 3-10% for a-Si, FF 1-2%, V_{oc} 0-5%

1992 to 1994 - ASTM E1036 Interlaboratory Test Program

encapsulated cells provided, (Range in P_{max} ~5%)

P_{max} 95 % repeatability limit (within laboratory) = 0.7%

P_{max} 95 % reproducibility limit (between laboratory) = 6.7%

Manufacture sponsored intercomparisons -

often only 2 labs & results usually not published.

Goals

Evaluate differences in module IV parameters With Respect to Standard Reference Conditions between

- National Calibration facilities
- ISO-17025 Accredited PV
- Qualification or Calibration Labs

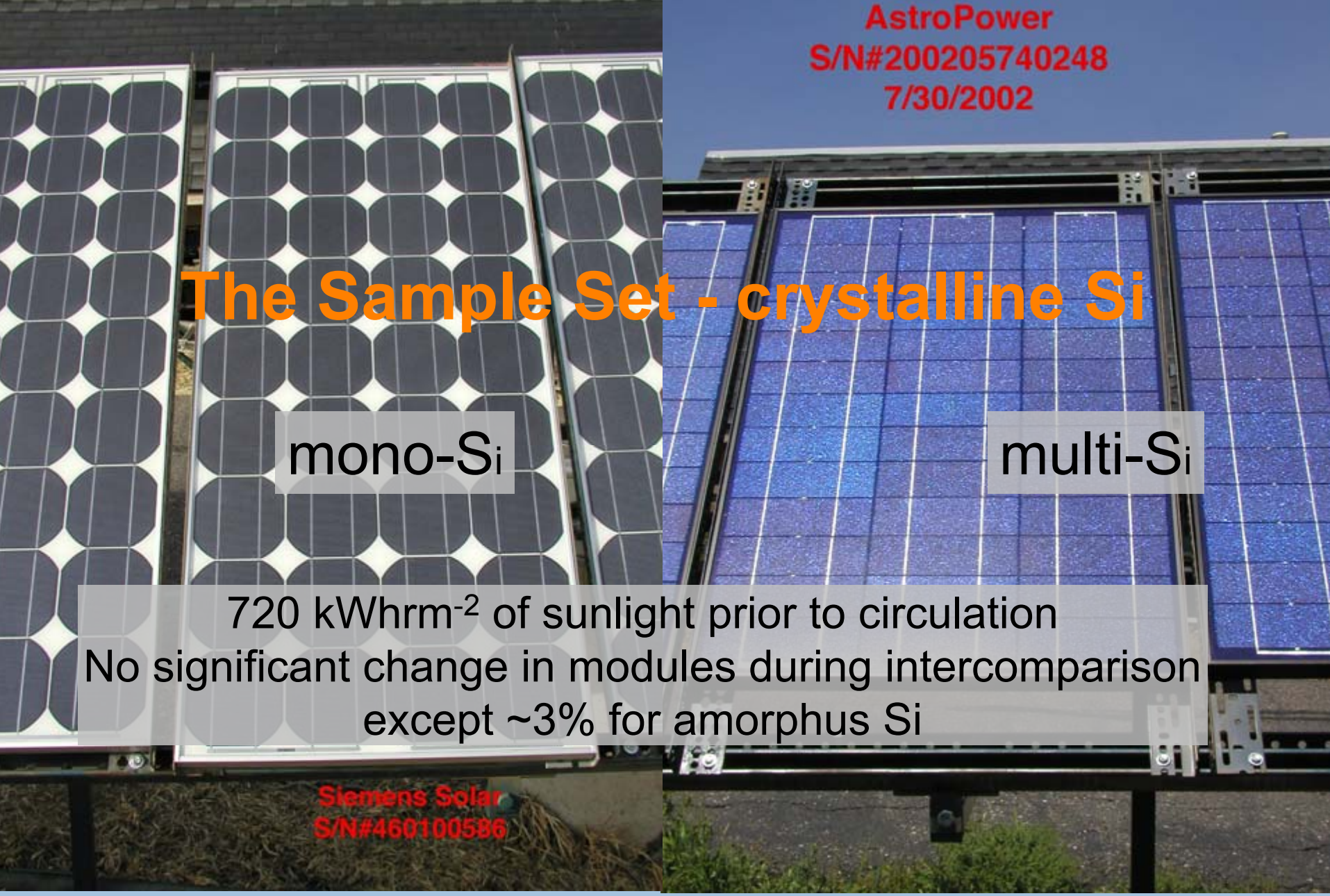
Modules Chosen to –

Identify differences in participants scope

- Flat-plate, Concentrator
- Single-junction, Multi-junction
- Crystalline Si, Thin-film
- "Typical" Quantum Efficiency supplied by the manufacturer
- No reference cell is provided

Include Samples that have had measurement related problems

- Bias Rate, Current Matching for Multi-junction,
- Sensitivity to Spatial Nonuniformity, Tracking for concentrator



The Sample Set - crystalline Si

mono-Si

multi-Si

720 kWhrm^{-2} of sunlight prior to circulation

No significant change in modules during intercomparison except ~3% for amorphus Si

The Sample Set - CdTe & CIGS

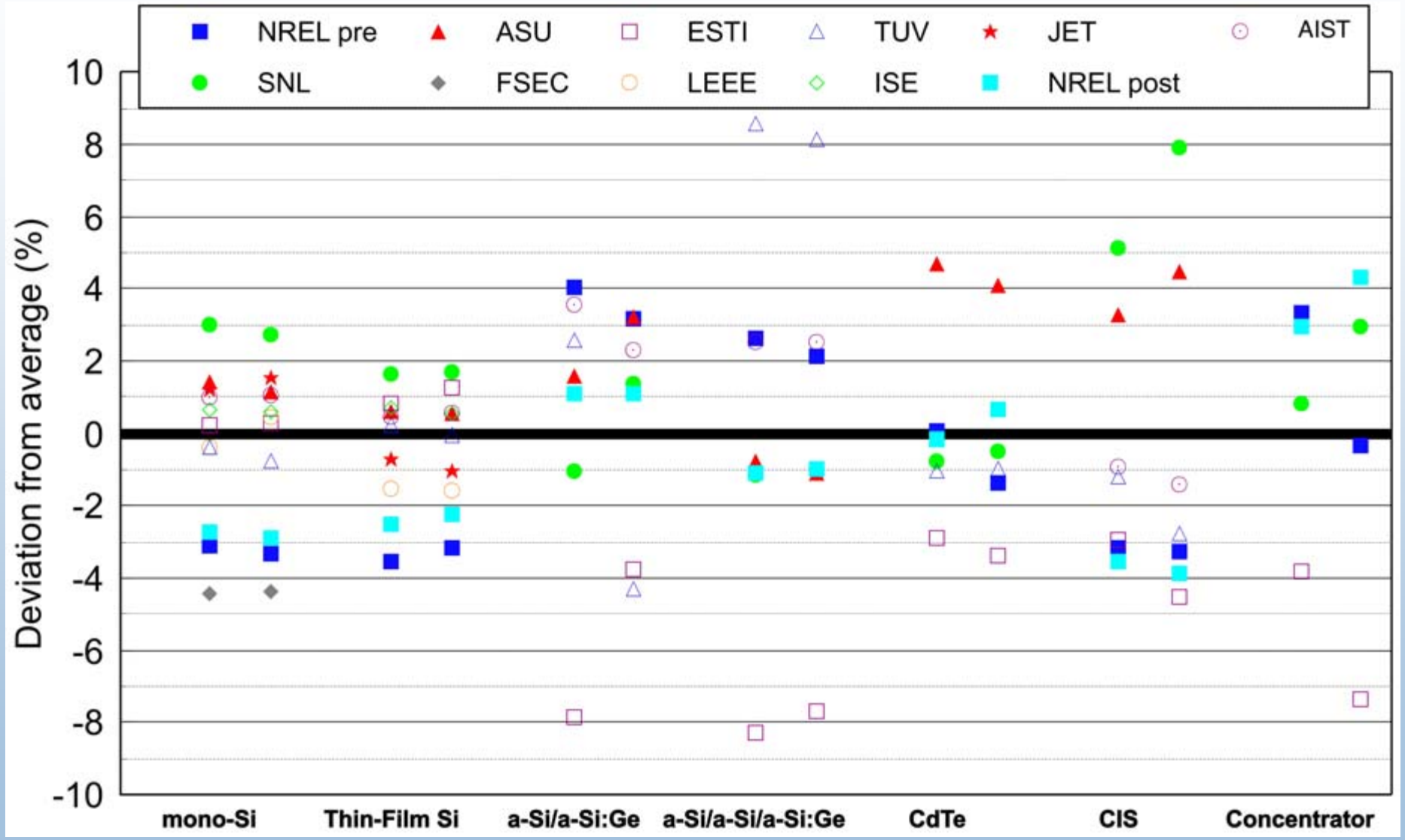
The Sample Set - amorphous Si

a-Si/a-Si

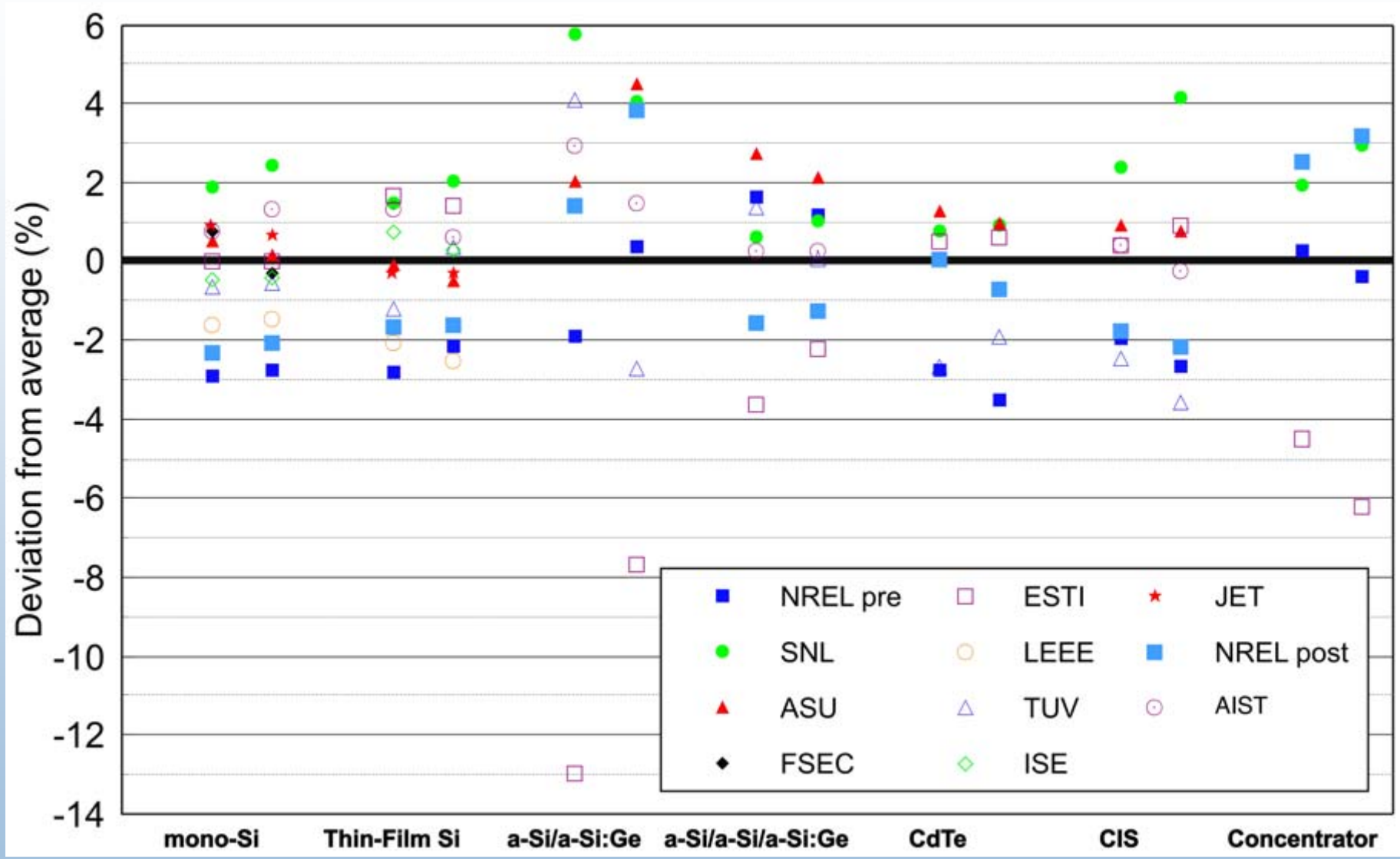
a-Si/a-Si/a-Si:Ge

The Sample Set - PEP ’87 Concentrator

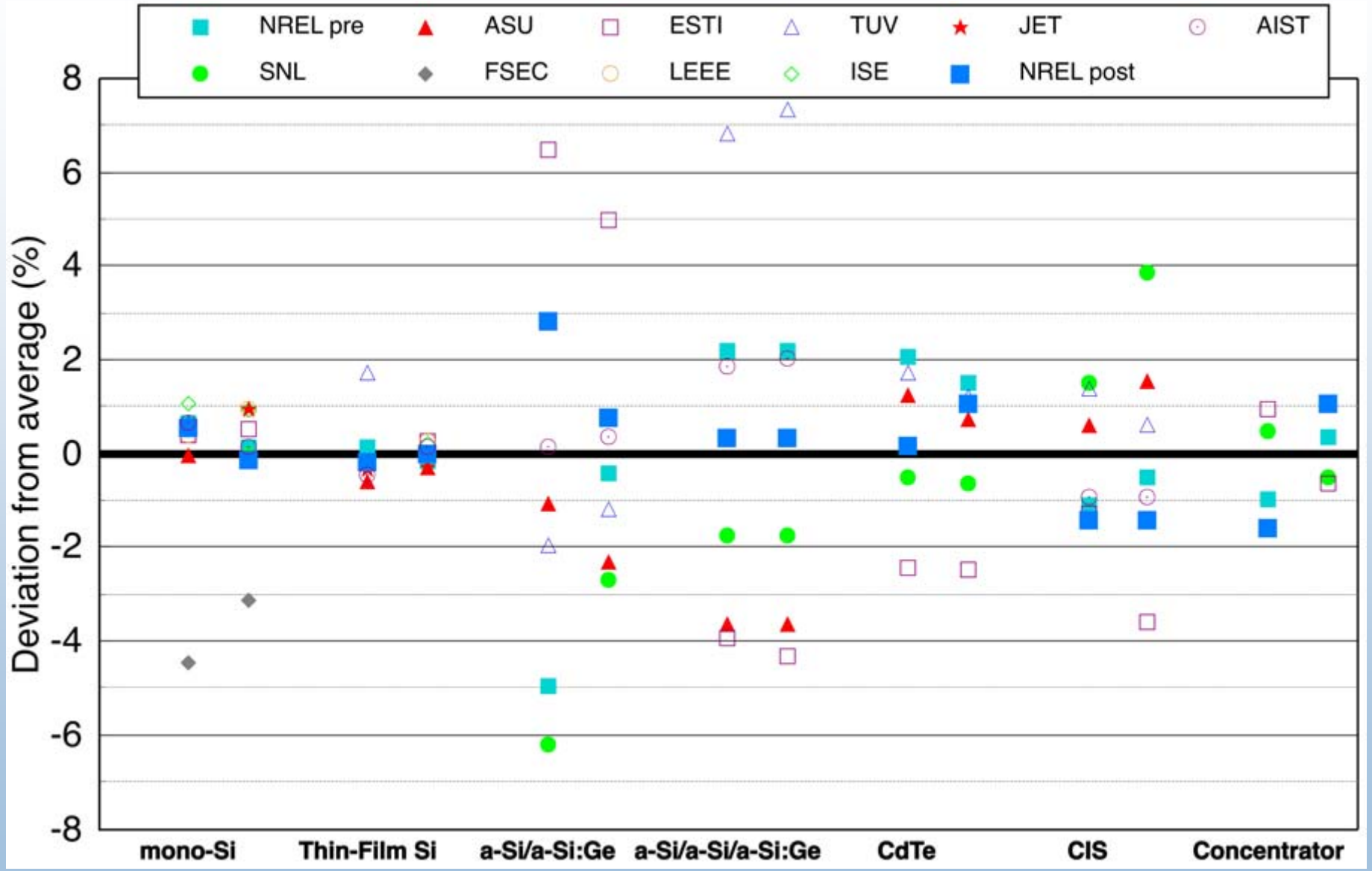
Results - P_{max} @ 25 C, 1000 Wm^{-2}, IEC Global Reference spectrum



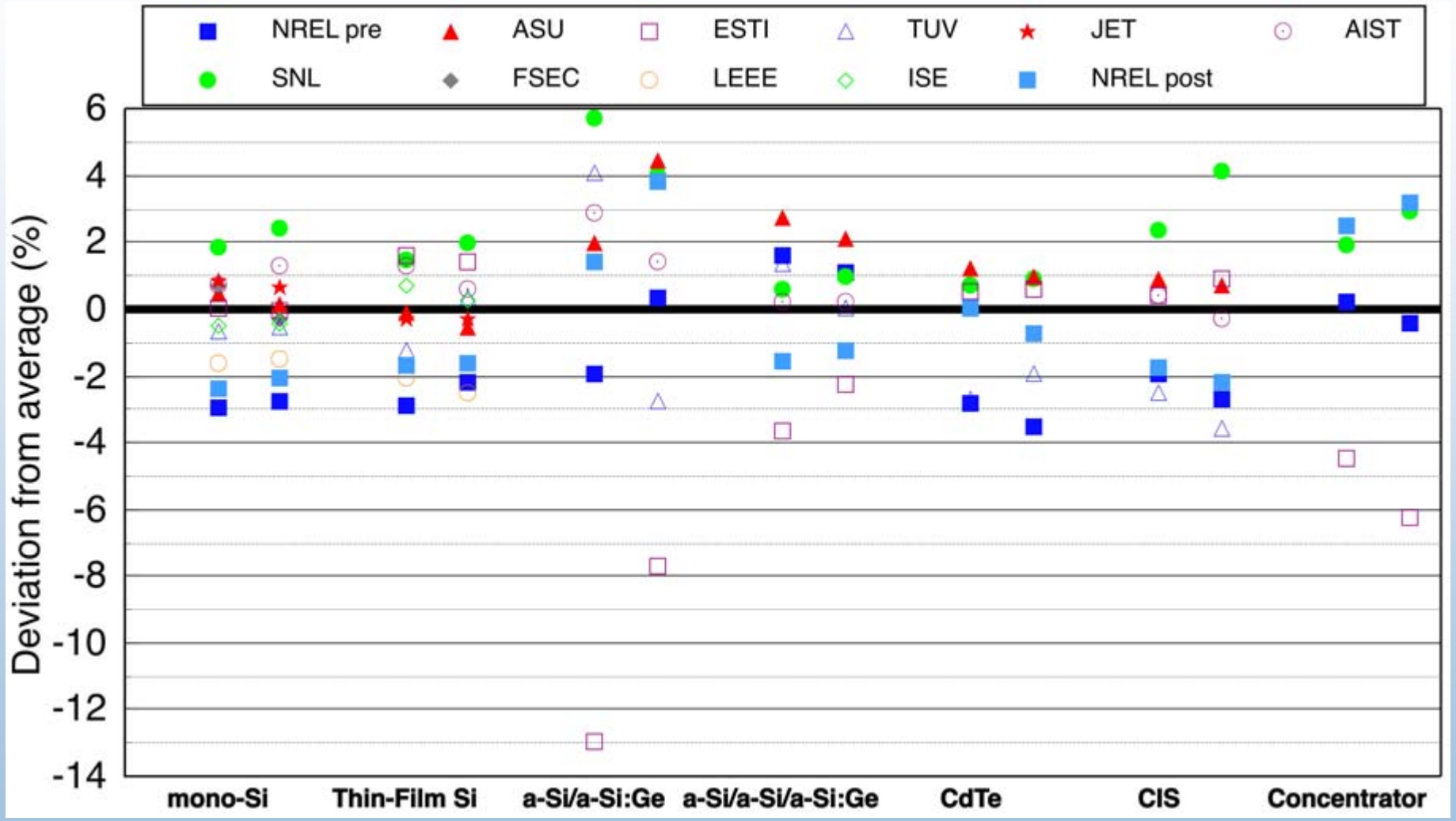
Results - I_{sc}


Deviation from average (%)
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
mono-Si
Thin-Film Si
a-Si/a-Si:Ge
a-Si/a-Si/a-Si:Ge
CdTe
CIS
Concentrator
NREL pre
ESTI
JET
SNL
LEEE
NREL post
ASU
TUV
AIST
FSEC
ISE

Results - Fill Factor



Results - Voc


NREL pre
ASU
ESTI
TUV
JET
AIST
SNL
FSEC
LEEE
ISE
NREL post
Deviation from average (%)
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
mono-Si
Thin-Film Si
a-Si/a-Si:Ge
a-Si/a-Si/a-Si:Ge
CdTe
CIS
Concentrator

Summary

- Range in I_{sc} for Si 5%, CIS 5 & 8%, CdTe 4%, Multijunction range 4 to 19% depending on module. Not having the luxury of a matched reference cell, Representative cell, or the Measured Module spectral responsivity may be the cause of larger differences than previous module intercomparisons.
- Range in P_{max} for Si 6 & 7%, CIS or CdTe 8%, Multijunction range 7 to 17% depending on module.
- Range in V_{oc} for Si 4 to 5%. About an 8 C temperature range would be required to account for a 5% V_{oc} difference.
- Several participants didn't measure concentrator or thin-film modules because they were outside their scope.