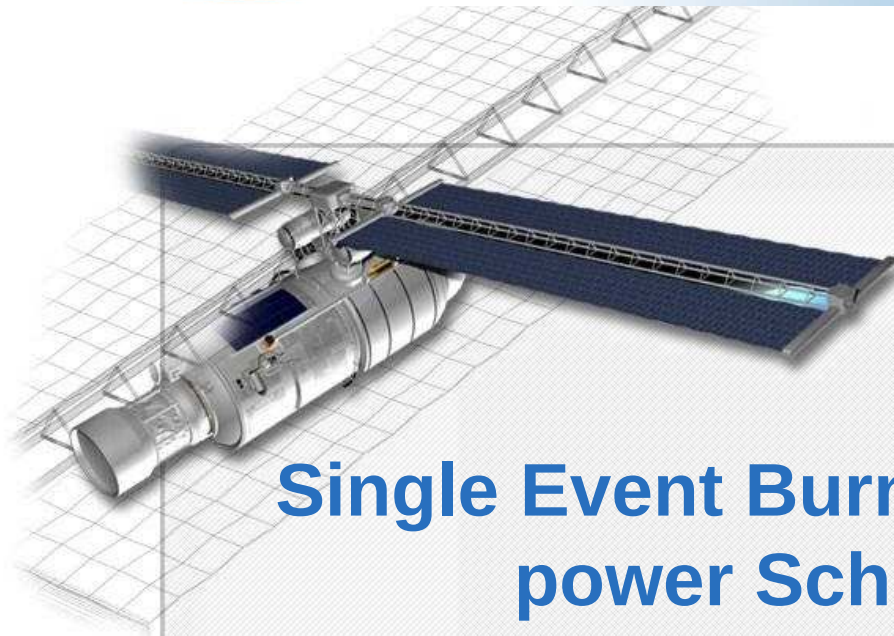




Single Event Burnout testing of high power Schottky diodes

Presented by Pierre GARCIA

Enoal LE GOULVEN, Fabien WIDMER, Athina VAROTSOU
with the support of Cesar BOATELLA-POLO

Contract No 4000118250

This project at a glance :

- **40h of beam**
- **Around 270 Runs**
- **20 references tested**
- **Around 100 parts irradiated**

Introduction

- Silicon Schottky diodes have been traditionally considered immune to destructive SEE
- Recent works published on literature have shown that silicon power Schottky diodes may be sensitive to destructive events while reverse biased under heavy ion irradiation
- This activity consists of performing SEB test under heavy ions on 20 different references of 7 different manufacturers
- For this study parts were provided by STMicroelectronics, Thales Alenia Space and Airbus Defence and Space

Previous campaign 2015

Power Schottky diodes from STMicroelectronics							
Reference	Identification		Package	VRRM(V)	IF (Per diode)	IR (@VRRM) (A)	Number of sample
STPS20100FY1	Marking	FE1652	TO-254	100	10A	150.0E-6	15
STPS1045S1	Marking	FE1650	SMD 0.5	45	10A	100.0E-6	13
STPS6045C2FSY1	Marking	FE1651	TO-254	45	30A	500.0E-6	15
STPS40H100C2FY	Date code	1144A	TO-254	100	20A	10.0E-6	10
	ST O/C #	LOTID 33125B10ZY LOTID 33125B1001					
	Trace Code	33125B10ZY					
	Bulk ID	T2R02J0SE023					
	Marking	5106-013-01 FR Beo					
STPS3045C	Marking	FE1652	TO-254	45	15A	200.0E-6	10
STPS20200C	Marking	FE1653	TO-254	200	10A	15.0E-6	10
STPS61170C	Marking	FE1654	TO-254	170	30A	60.0E-6	10
STPS40100HR	Marking	FE1655	TO-254	100	20A	30.0E-6	10
New generation prototype							

QPL product

Results

Irradiation performed at Ganil

		Xe (LET=61.02MeV.cm ² /mg)			Kr (LET=27.18MeV.cm ² /mg)		
		Ok	Failed PIST	Fail	Ok	Failed PIST	Fail
STMicroelectronics	STPS20100 (QPL)	75%	80%	100%			
	STPS1045 (QPL)	100%					
	STPS6045 (QPL)	100%		75%			
	STPS40100 (QPL)	70%*	75%	100%			
	STPS3045 (NEW)	< 50%**	50%	78%	78%		100%
	STPS20200 (NEW)	50%		75%	75%		100%
	STPS61170C (NEW)	40%	50%	76%	44%		59%
	STPS40H100 (NEW)	50%	65%	80%	75%		100%

*2 parts pass 75%

**Not tested

- All QPL parts considered PASS at 75%
- These parts are used on space mission at 75% maximum Vr
- New prototypes are considerably more sensitive to SEB



Fail : IR > IR @ VRRM

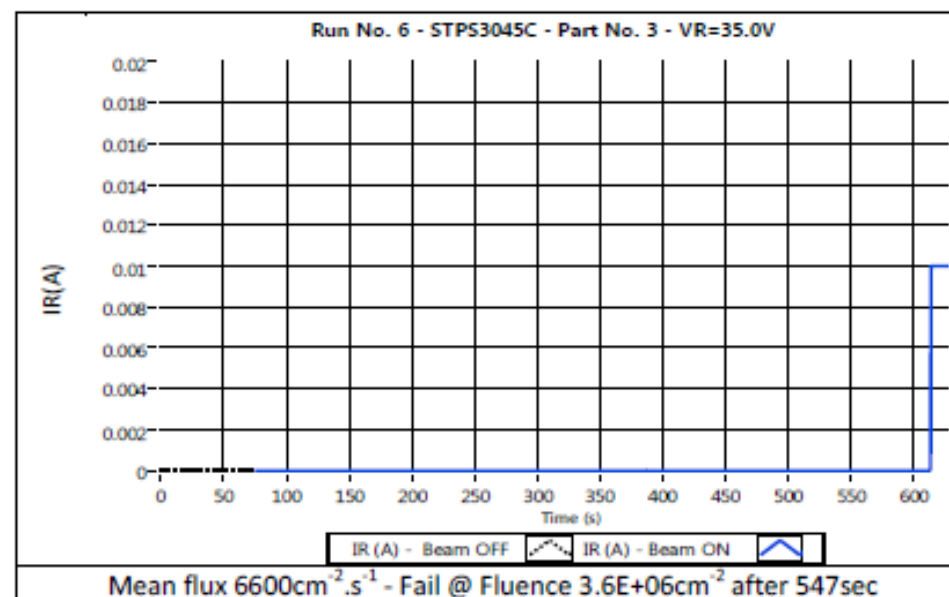
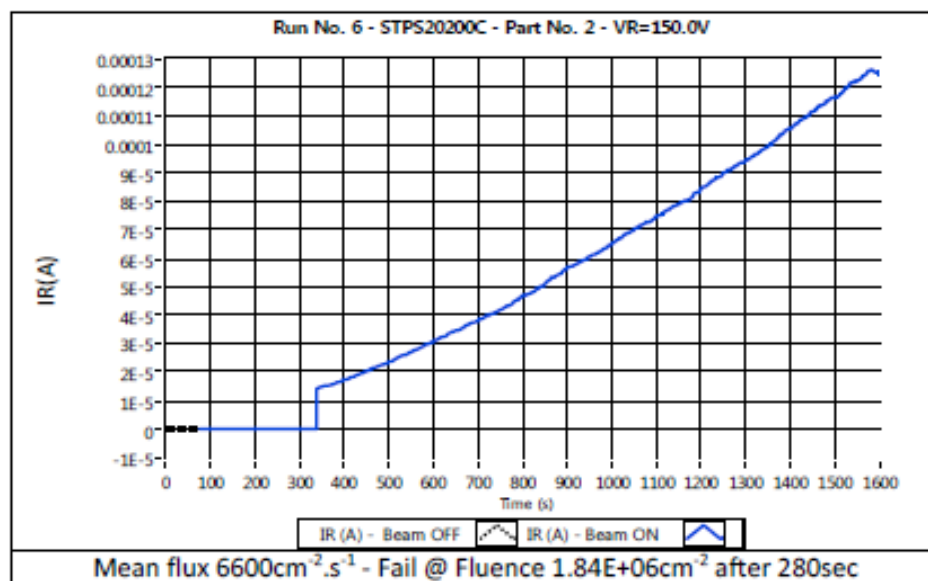


PASS: IR < IR @ VRRM

Number XX% : Value of the % of VRMAX

Previous campaign Results

Focus on STM Schottky diode result



Two different failure signature were observed during the first GANIL campaign. Current step was the most common. Ir degradation with fluence was only observed in some of the new prototypes.

Parts information 1/2

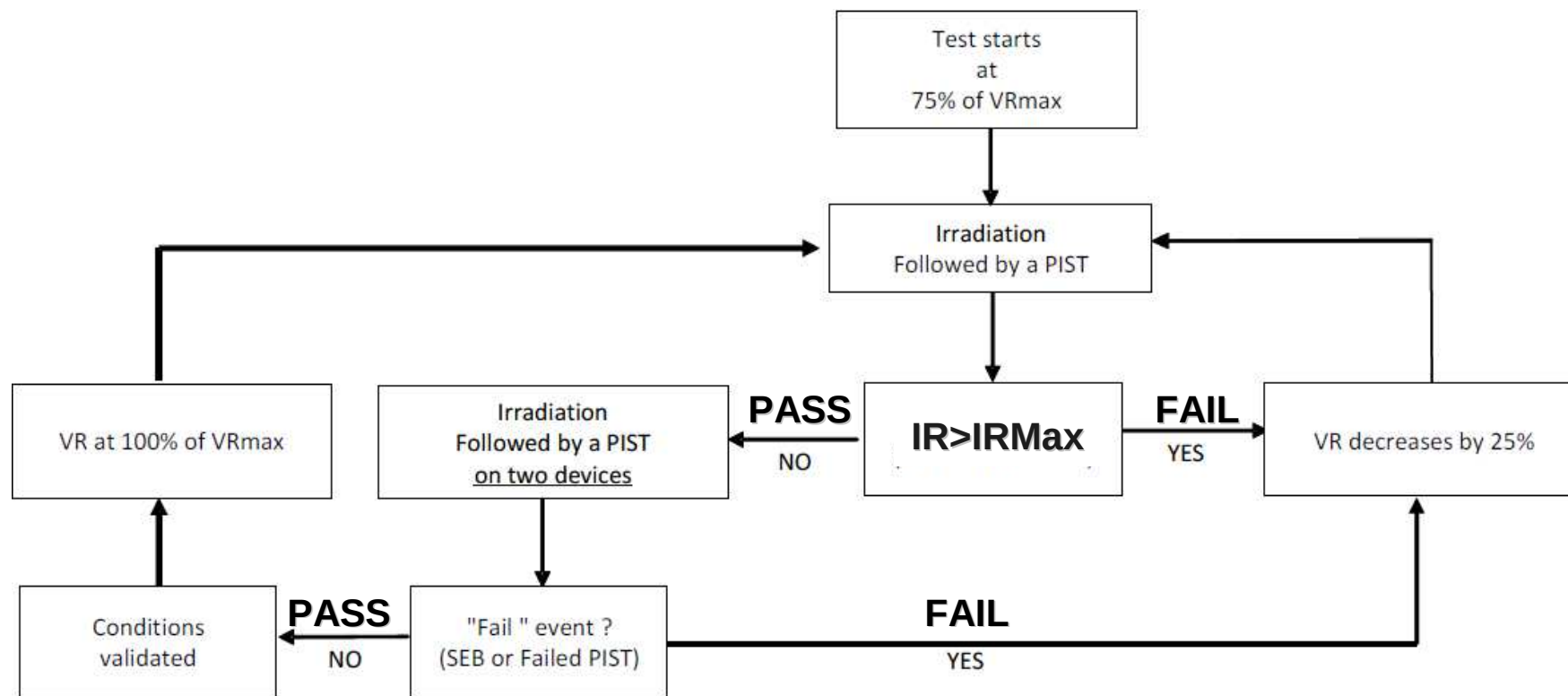
Reference	Diode Type	SiC	Manufacturer	Package	VRRM (V)	Number of sample
STPS3045-XF54S02Y	Schottky	no	STMicroelectronics	SMD 05	45V	10
STPS80H100	Schottky	no		SMD 1	100V	10
STPS30170-XZ04P029	Schottky	no		SMD 05	170V	10
STTH60400	Ultrafast	no		SMD 1	400V	8
STTH61W04CSA1 (equivalent STTH60400)	Ultrafast	no				2
STPSC1006	Schottky	yes		TO-220-2	600V	13
STPS40M60CR	Schottky	no		TO-220-3	60V	15
STPSC10H065	Schottky	yes		TO-220-2	650V	11
STPS4045CW	Schottky	no		TO-247-3	45V	11
STPS5H100BY	Schottky	no		DPACK	100V	5

Parts information 2/2

Reference	Diode Type	SiC	Manufacturer	Package	VRRM (V)*	Number of sample
35CGQ100	Schottky	no	International Rectifier	TO-254	100V*	15
45CKQ100	Schottky	no		TO-258	100V	5
120LQ100	Schottky	no		SMD-1	100V*	12
HFB25HJ20	Ultrafast	no		SMD.5	200V	5
80CLQ150	Schottky	no		SMD-1	150V*	11
SML10SIC06SMD5	Schottky	yes	SemeLAB Limited	SMD.5	600V	6
MBRB8H100T4G	Schottky	no	On Semiconductor	D ² PACK	100V	6
BAS21LTG1	Fast Switching	no		SOT23	250V	5
1N6817	Schottky	no	Microsemi	ThinKey™ 2	100V*	9
SHDC124545P	Schottky	no	Sensitron Semiconductor	TO-258	150V*	12

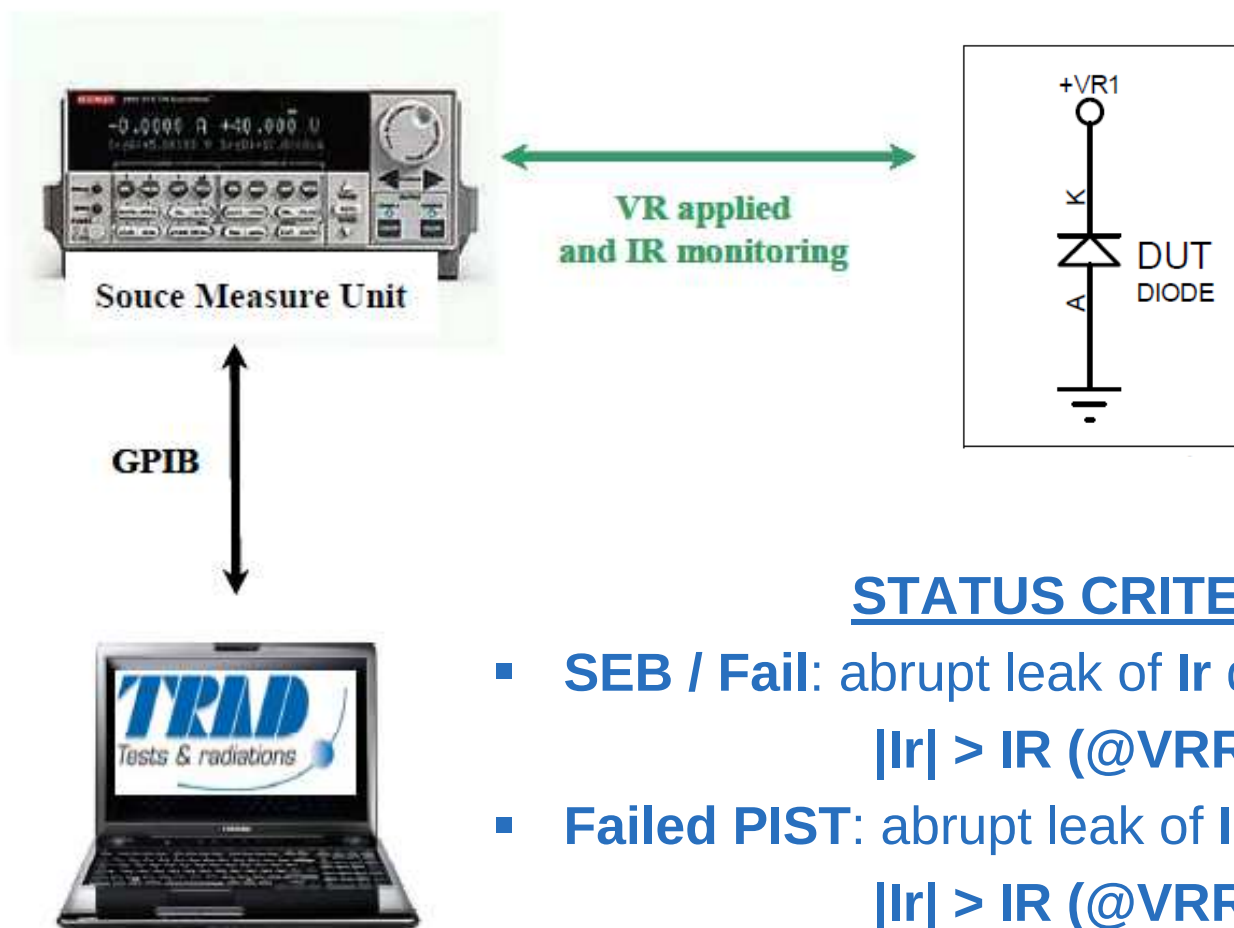
Test procedure and setup

Irradiation performed at UCL



- PIST (Post-Irradiation STress) Test : After the irradiation, a stress is applied to the diode in order to reveal any latent damage on the irradiated devices.

Test procedure and setup



STATUS CRITERIA

- **SEB / Fail:** abrupt leak of I_r during irradiation
 $|I_r| > I_R (@VRRM)$
- **Failed PIST:** abrupt leak of I_r during stress test
 $|I_r| > I_R (@VRRM)$

SEE tests: Beam description

Irradiation facility: U.C.L.

IRRADIATION BEAM CHARACTERISTICS	
Heavy Ions used :	Ions used: $^{124}\text{Xe}^{35+}$ (62.5 MeV.cm²/mg), $^{83}\text{Kr}^{25+}$ (LET=32.4MeV.cm²/mg), $^{53}\text{Cr}^{16+}$ (LET=16MeV.cm²/mg), $^{27}\text{Al}^{8+}$ (LET=5.7MeV.cm²/mg) Fluence: 1.10⁷ cm⁻² (in two steps 1.10⁶ and 9.10⁶ cm⁻²) for Si Fluence: 3.10⁵ cm⁻² for silicon carbide diode

Results

The derated accepted is 75% of @VRMax

		Xe (LET=62.5MeV.cm ² /mg)			Kr (LET=32.4MeV.cm ² /mg)			Cr (LET=16MeV.cm ² /mg)			Al (LET=5.7MeV.cm ² /mg)		
		Ok	Failed PIST	Fail	Ok	Failed PIST	Fail	Ok	Failed PIST	Fail	Ok	Failed PIST	Fail
STMicroelectronics	STTH60400	100%											
	STPS3045	75%											
	STPS4045CW	56%		75%									
	STPS30170	50%	75%	100%	75%								
	STPS40M60CR	50%		75%	75%								
	STPS80H100				75%								
	STPS5H100BY		75%	75%	75%								
	STPSC10H065*				57%		93%	66%		100%	100%		
	STPSC1006*				50%		86%	69%		93%	93%		100%
International Rectifier	45CKQ100	100%											
	35CGQ100	100%											
	HFB25HJ20	75%		100%									
	120LQ100	75%		100%									
	80CLQ150	75%		100%									
On semi	BAS21LTG1	100%											
	MBRB8H100T4G	75%		100%									
Semelab	SML10SIC06SMD5*		29%	58%	33%		50%		42%				
diodes inc.	1N4148WQ	100%											
Microsemi	1N6817	75%											
Sensitron	SHDC124545P	100%											

* Silicone carbide diode

 Fail : IR > IR @ VRRM

 PASS: IR < IR @ VRRM

Number XX% : Value
of the % of VRMAX

Results

		Xe (LET=62.5MeV.cm ² /mg)			Kr (LET=32.4MeV.cm ² /mg)			Cr (LET=16MeV.cm ² /mg)			Al (LET=5.7MeV.cm ² /mg)		
		Ok	Failed PIST	Fail	Ok	Failed PIST	Fail	Ok	Failed PIST	Fail	Ok	Failed PIST	Fail
STMicroelectronics	STTH60400	100%											
	STPS3045	75%											
	STPS4045CW	50%		75%									
	STPS30170	50%	75%	100%	75%								
	STPS40M60CR	50%		75%	75%								
	STPS80H100				75%								
	STPS5H10 BY		75%	75%	75%								
	STPSC10H 065												
	STPSC100												100%
International Rectifier	45CKQ100	100%											
	35CGQ100	100%											
	HFB25HJ2												
	120LQ100												
	80CLQ150	75%		75%									
On semi	BAS21LTG1	100%											
	MBRB8H100T4G	75%		100%									
Semelab	SML10SIC06SMD5*		20%	50%	33%		50%		50%				
diodes inc.	1N4148WQ	100%											
Microsemi	1N6817	75%											
Sensitron	SHDC124545P	100%											

PART could be FAIL but not necessary not functional

* Silicone carbide diode

 Fail : IR > IR @ VRRM

 PASS: IR < IR @ VRRM

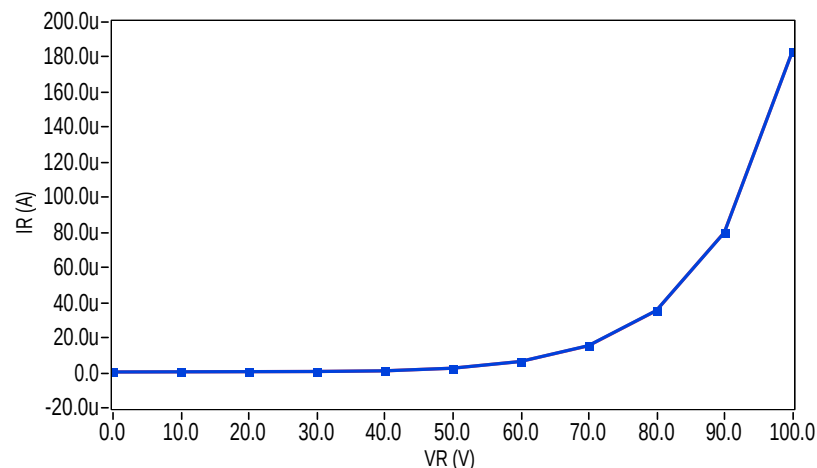
STMicroelectronics Results

		Xe (LET=62.5MeV.cm ² /mg)			Kr (LET=32.4MeV.cm ² /mg)			Cr (LET=16MeV.cm ² /mg)			Al (LET=5.7MeV.cm ² /mg)		
		Ok	Failed PIST	Fail	Ok	Failed PIST	Fail	Ok	Failed PIST	Fail	Ok	Failed PIST	Fail
STMicroelectronics	STTH60400	100%											
	STPS3045	75%											
	STPS4045CW	56%		75%									
	STPS30170	50%	75%	100%	75%								
	STPS40M60CR	50%		75%	75%								
	STPS80H100				75%								
	STPS5H100BY		75%	75%	75%								
	STPSC10H065*				57%		93%	66%		100%	100%		
	STPSC1006*				50%		86%	69%		93%	93%		100%

* Silicon carbide diode

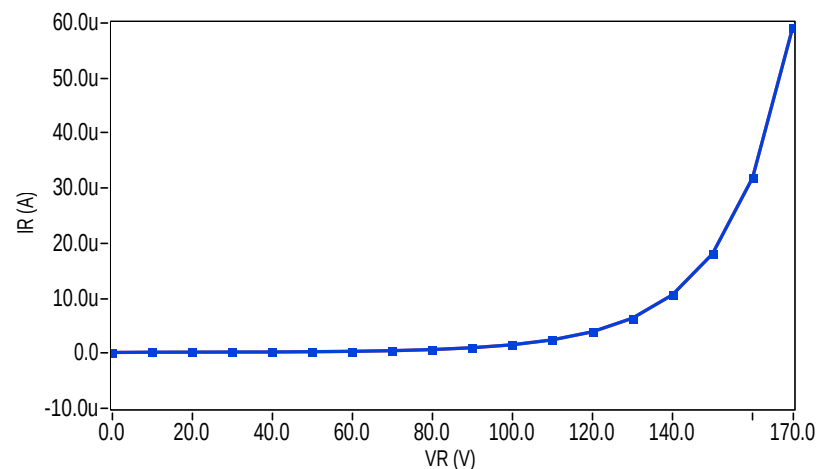
- 2 references Fail after a PIST due to a degradation of the leakage current
(for the example IR_{max} respectively equal to 3.5μA and 20μA)

POST-PIST Test - Run No. 131 - STPS5H100BY-TR No. 2 - up to +100V



VR=0V to 100V VR=100V to 0V

POST-PIST Test - Run No. 16 - STPS30170 No. 23 - up to +170V



VR=0V to 170V VR=170V to 0V

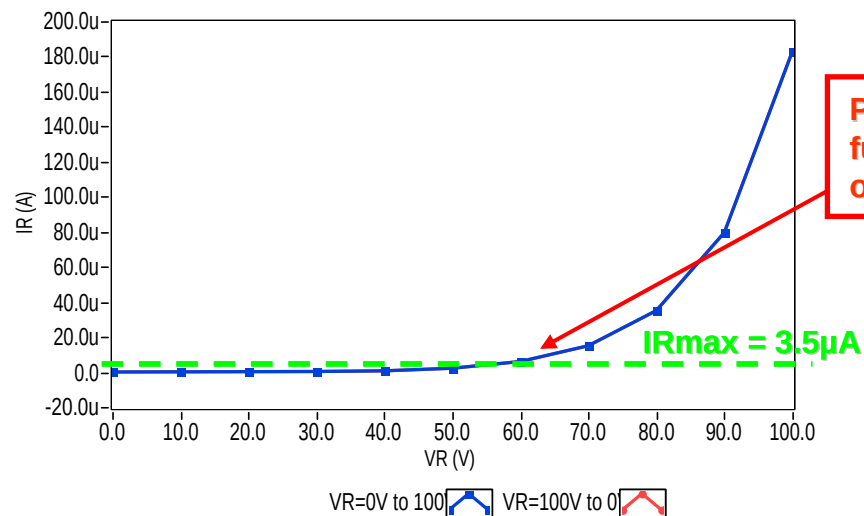
STMicronics Results

		Xe (LET=62.5MeV.cm ² /mg)			Kr (LET=32.4MeV.cm ² /mg)			Cr (LET=16MeV.cm ² /mg)			Al (LET=5.7MeV.cm ² /mg)		
		Ok	Failed PIST	Fail	Ok	Failed PIST	Fail	Ok	Failed PIST	Fail	Ok	Failed PIST	Fail
STMicronics	STTH60400	100%											
	STPS3045	75%											
	STPS4045CW	56%		75%									
	STPS30170	50%	75%	100%	75%								
	STPS40M60CR	50%		75%	75%								
	STPS80H100				75%								
	STPS5H100BY		75%	75%	75%								
	STPSC10H065*				57%		93%	66%		100%	100%		
	STPSC1006*				50%		86%	69%		93%	93%		100%

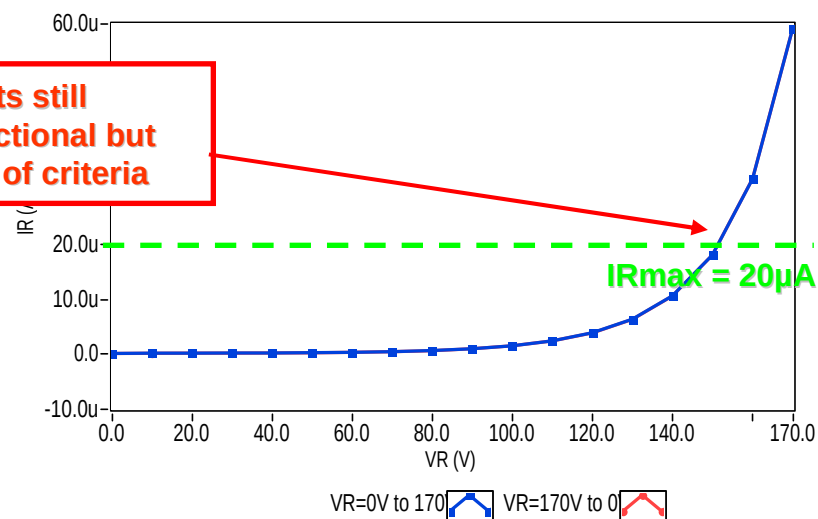
* Silicone carbide diode

- 2 references Fail after a PIST due to a degradation of the leakage current
(for the example IRmax respectively equal to 3.5μA and 20μA)

POST-PIST Test - Run No. 131 - STPS5H100BY-TR No. 2 - up to +100V



POST-PIST Test - Run No. 16 - STPS30170 No. 23 - up to +170V



Parts still functional but out of criteria

Results

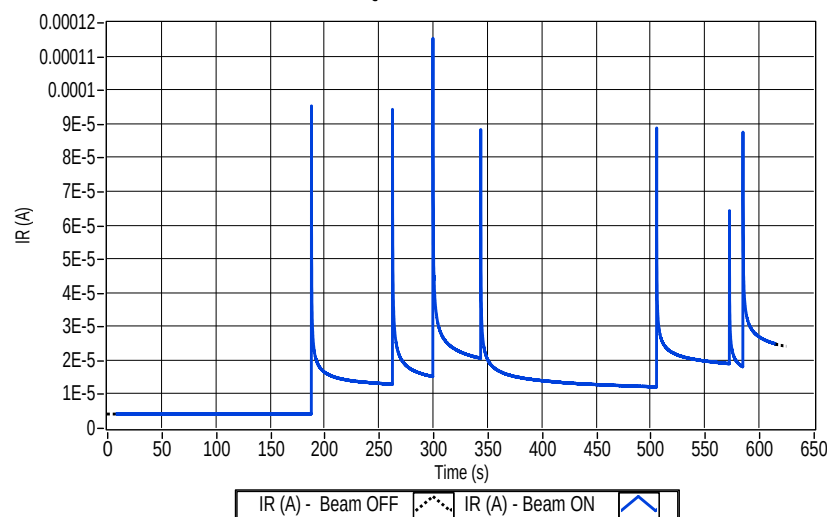
		Xe (LET=62.5MeV.cm ² /mg)			Kr (LET=32.4MeV.cm ² /mg)			Cr (LET=16MeV.cm ² /mg)			Al (LET=5.7MeV.cm ² /mg)		
		Ok	Failed PIST	Fail	Ok	Failed PIST	Fail	Ok	Failed PIST	Fail	Ok	Failed PIST	Fail
STMicroelectronics	STTH60400	100%											
	STPS3045	75%											
	STPS4045CW	50%		75%									
	STPS30170	50%	75%	100%	75%								
	STPS40M60CR	50%		75%	75%								
	STPS80H100				75%								
	STPS5H100BY		75%	75%	75%								
	STPSC10H065*				50%		50%	50%		100%	100%		
	STPSC1006*				50%		50%	50%		93%	93%		100%
International Rectifier	45CKQ100	100%											
	35CGQ100	100%											
	HFB25HJ20	75%		100%									
	120LQ100	75%		100%									
	80CLQ150	75%		100%									
On semi	BAS21LTG1	100%											
	MBR88H100T4G	75%		100%									
Semtech	SML10SIC06SMD5*		100%	100%	100%		100%	100%					
diodes inc.	1N4148WQ	100%											
Microsemi	1N5817	75%											
Sensitron	SHDC124545P	100%											

*** Silicone carbide diode**

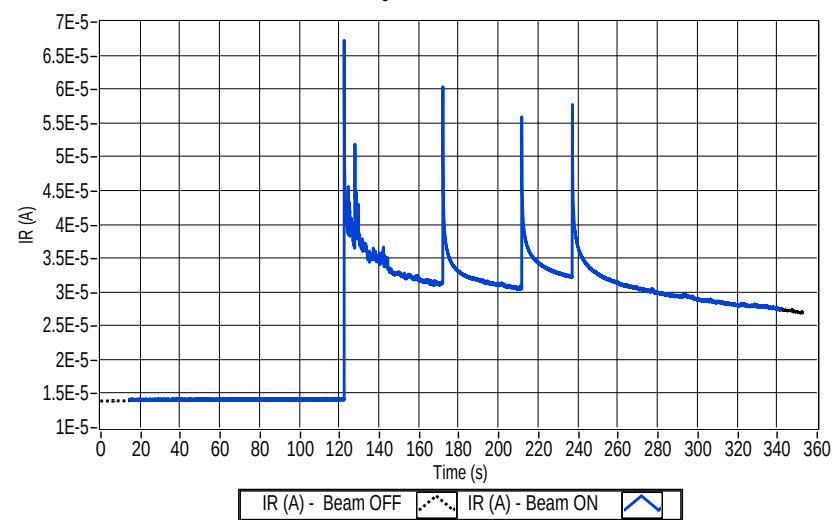
Internal Rectifier Results

Focus on IR Schottky diode result

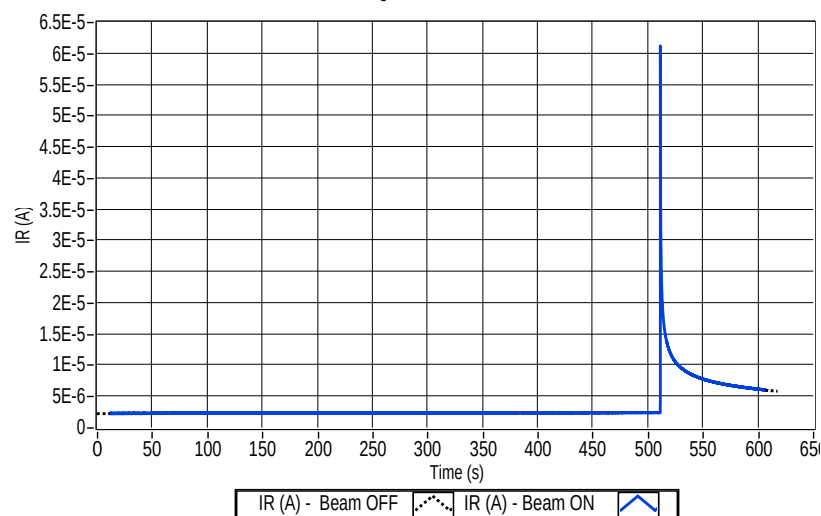
Run No. 39 - 35CGQ100 - Part No. 107 - VR=100.0V



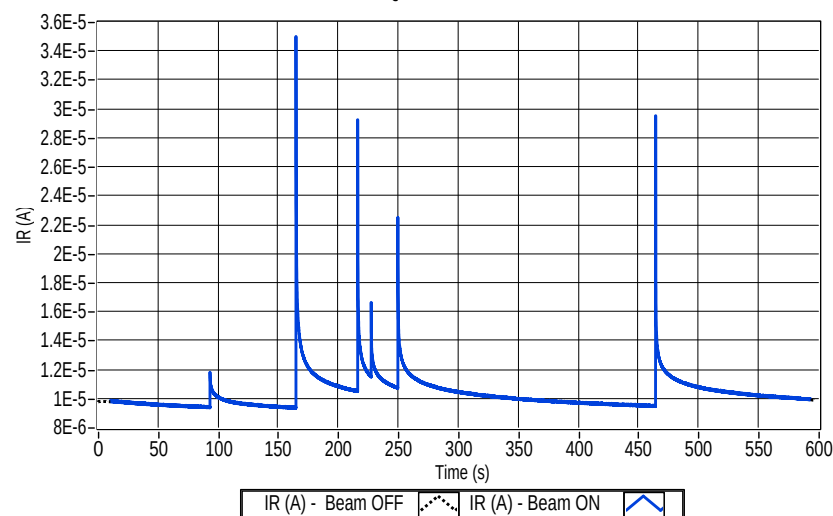
Run No. 52 - 120LQ100 - Part No. 1 - VR=100.0V



Run No. 64 - 80CLQ150 - Part No. 4 - VR=112.5V

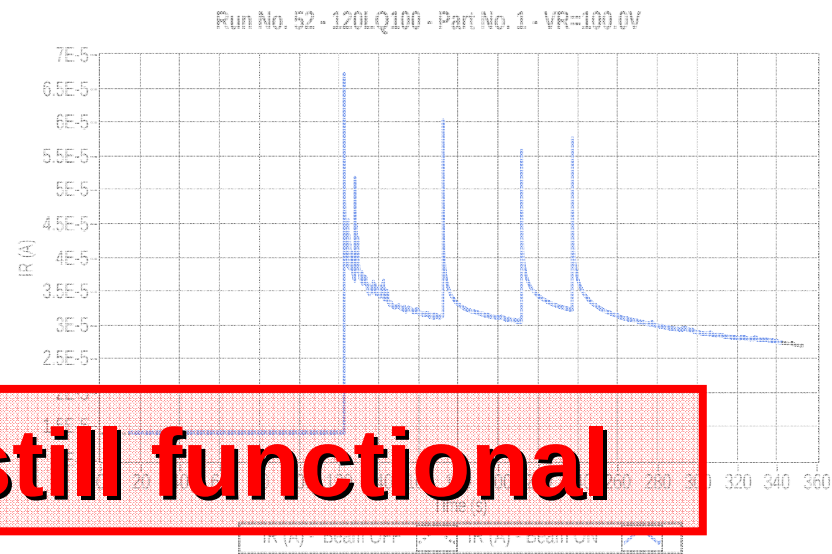
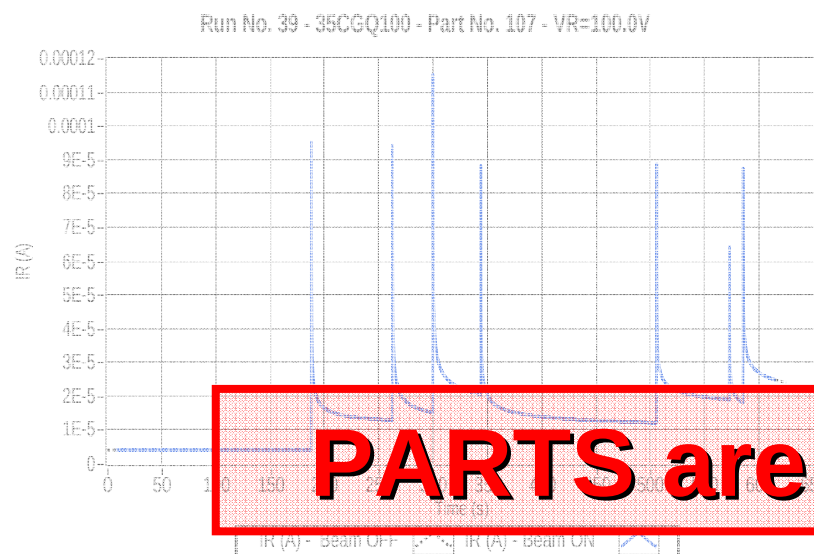


Run No. 106 - 45CKQ100 - Part No. 5 - VR=100.0V

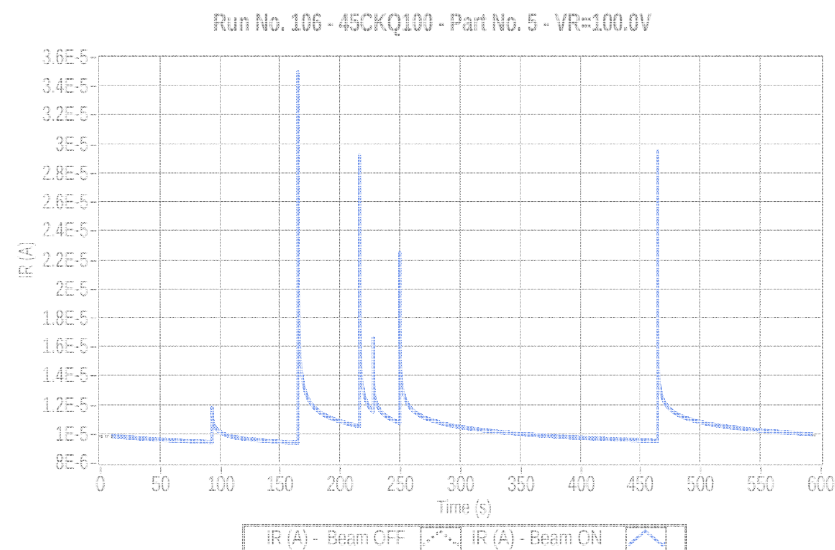
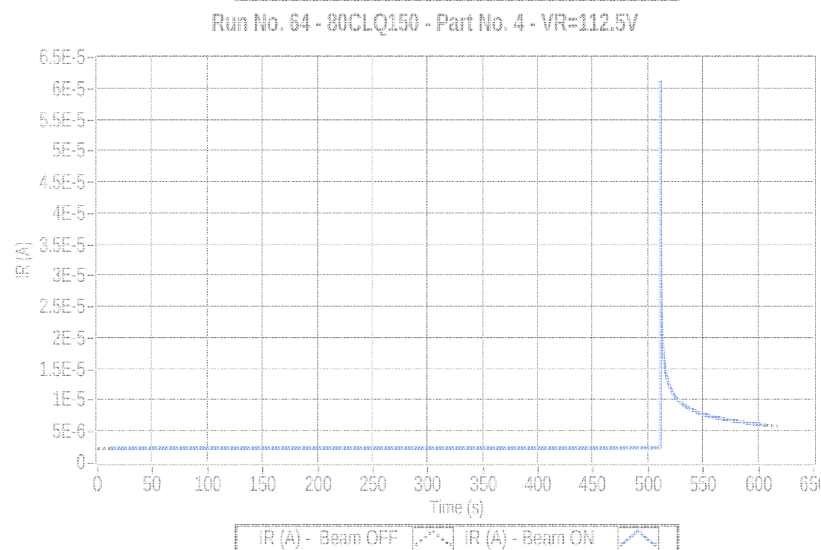


Results

Focus on IR Schottky diode result



PARTS are still functional



Results

		Xe (LET=62.5MeV.cm ² /mg)			Kr (LET=32.4MeV.cm ² /mg)			Cr (LET=16MeV.cm ² /mg)			Al (LET=5.7MeV.cm ² /mg)		
		Ok	Failed PIST	Fail	Ok	Failed PIST	Fail	Ok	Failed PIST	Fail	Ok	Failed PIST	Fail
STMicroelectronics	STTH60400	100%											
	STPS3045	75%											
	STPS4045CW	50%		75%									
	STPS30170	50%	75%	100%	75%								
	STPS40M60CR	50%		75%	75%								
	STPS80H100				75%								
	STPS5H100BY		75%	75%	75%								
	STPSC10H065*				57%		93%	66%		100%	100%		
	STPSC1006*				50%		86%	69%		93%	93%		100%
International Rectifier	45CKQ100	100%											
	35CGQ100	100%											
	HFB25HJ20	75%		100%									
	120LQ100	75%		100%									
	80CLQ150	75%		100%									
On semi	BAS21LTG1	100%											
	MBRE8H100T4G	75%		100%									
Semelab	SML10SIC06SMD5*		29%	58%	33%		50%		42%				
diodes Inc.	1N4148WQ	100%											
Microsemi	1N5817	75%											
Sensitron	SHDC124545P	100%											

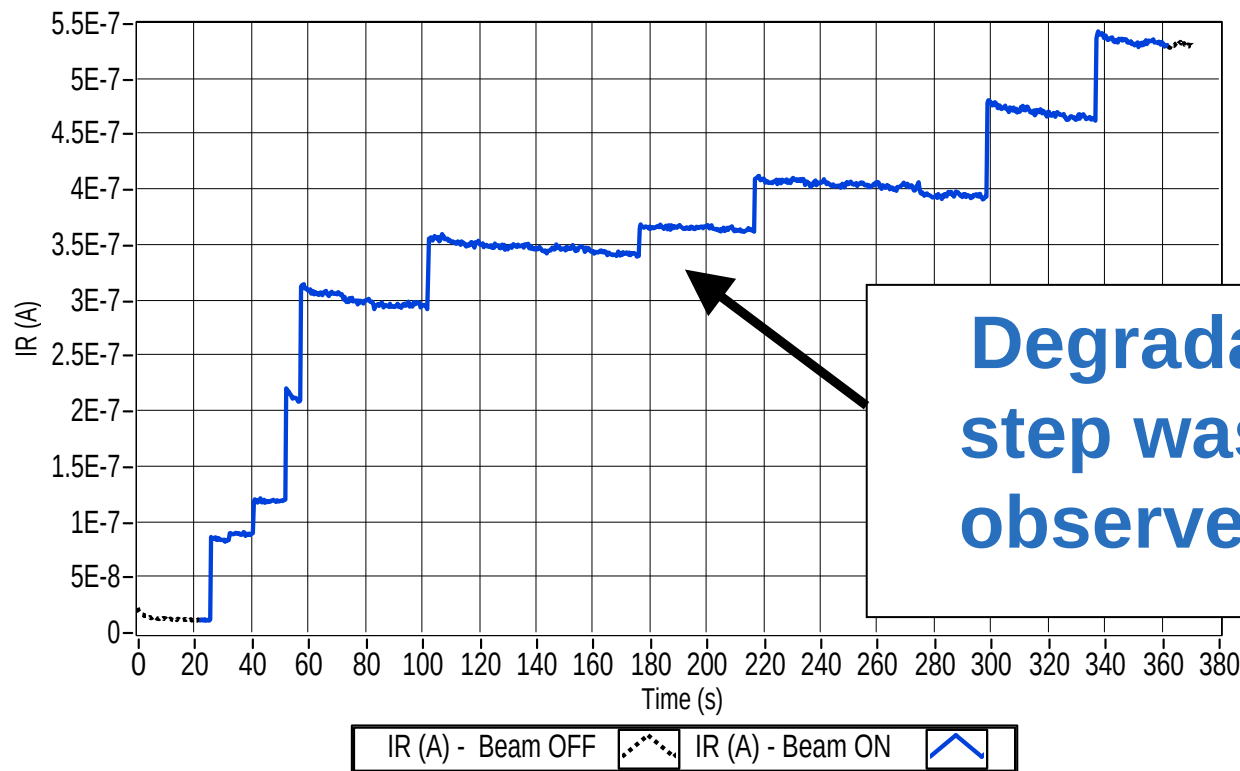
*** Silicon carbide diode : No information on literature about the sensitivity of SiC diode**

SiC diodes are most sensitive to destructive event

Results

Focus on SiC Schottky diode result

Run No. 218 - STPSC1006 - Part No. 7 - VR=275.0V

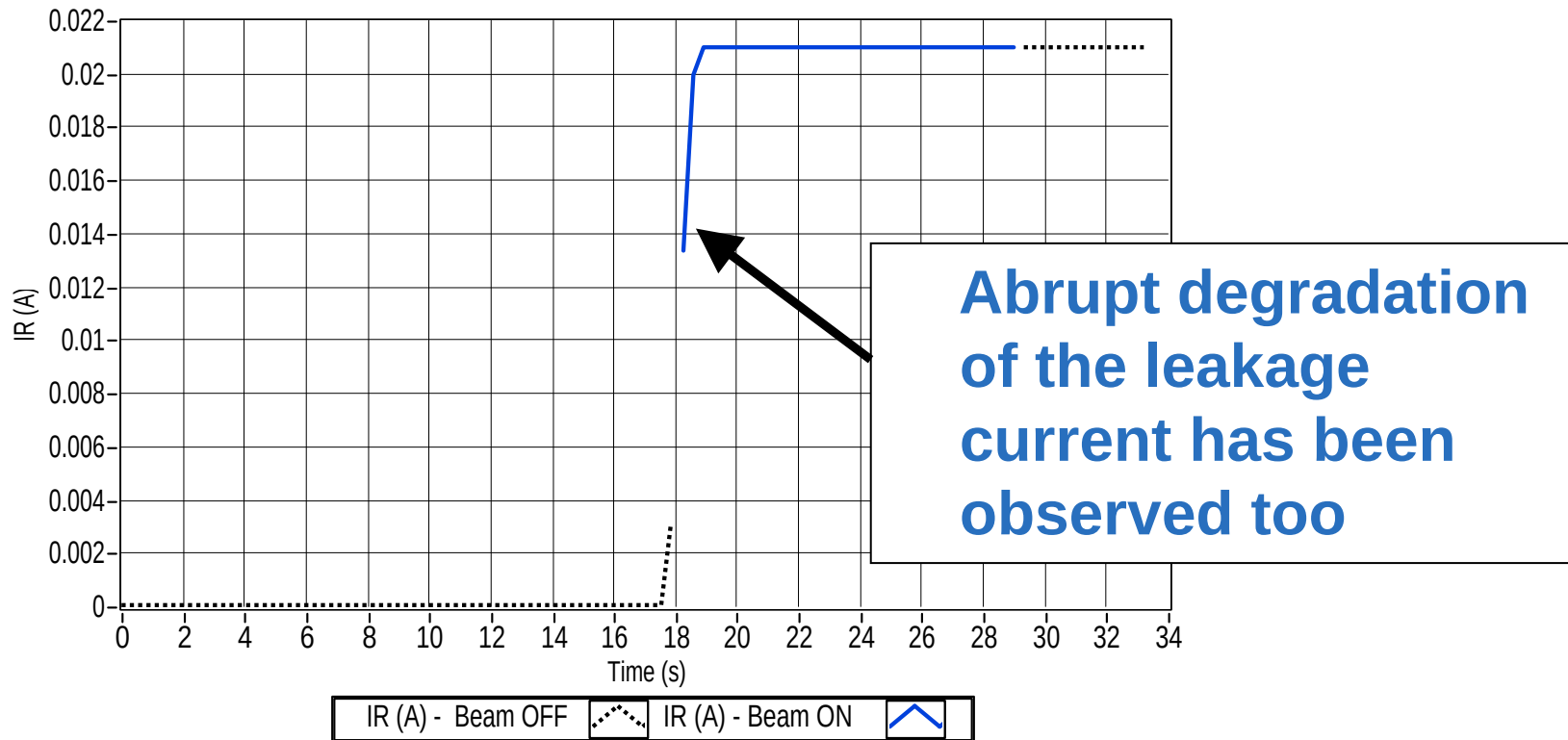


Degradation by step was also observed

Results

Focus on SiC Schottky diode result

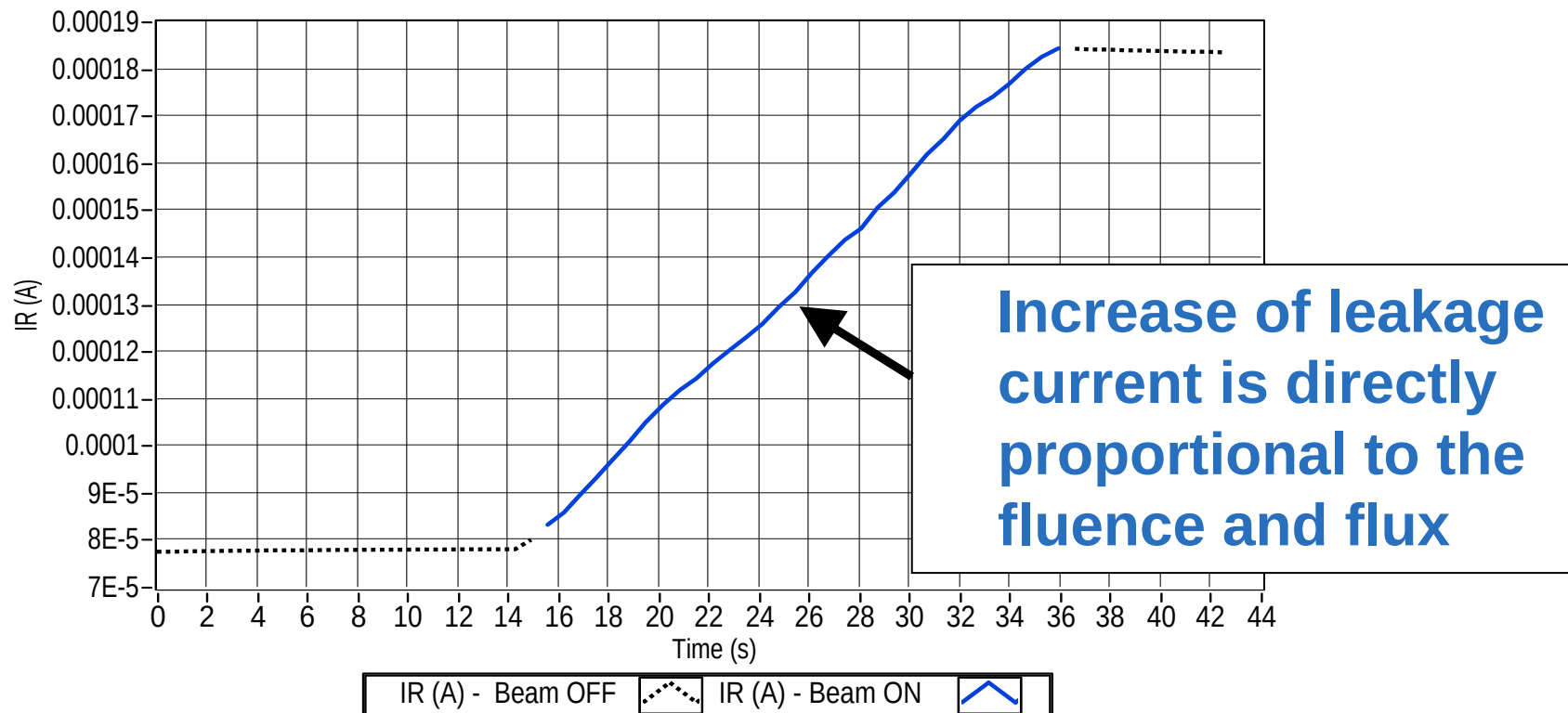
Run No. 216 - SML10SIC06SMD5 - Part No. 5 - VR=450.0V



Results

Focus on SiC Schottky diode result

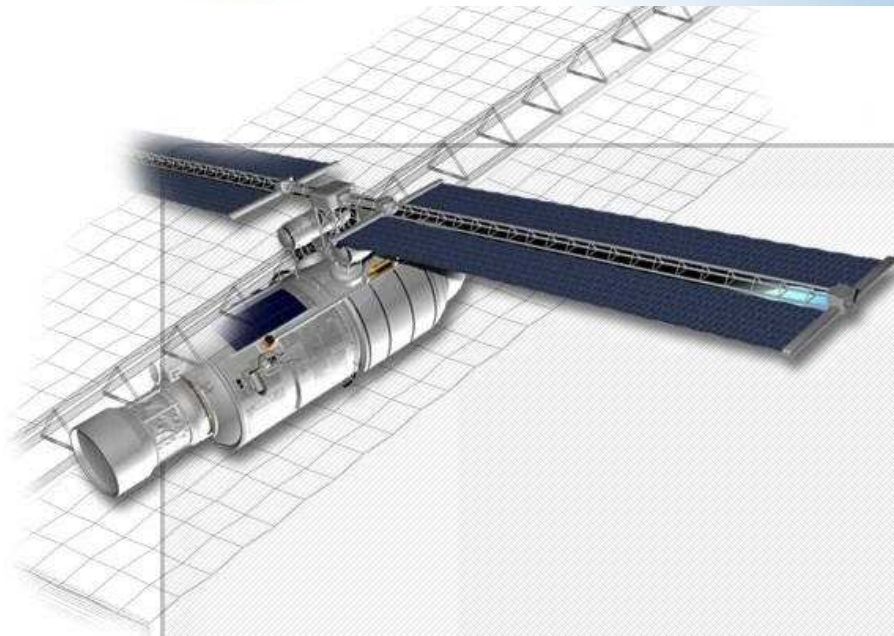
Run No. 168 - SML10SIC06SMD5 - Part No. 1 - VR=300.0V



These signatures were observed for the 3 references of SiC diode.

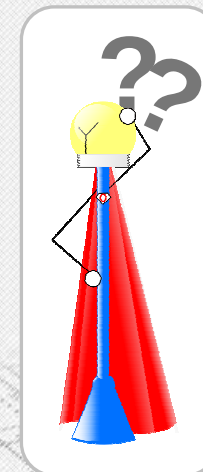
CONCLUSION

- 11 of the 20 references tested are degraded due to heavy ions irradiation
- SiC diode technology is more sensitive than Si diode technology
- More investigation on SiC diode have to be performed in order to understand the different phenomenon observed



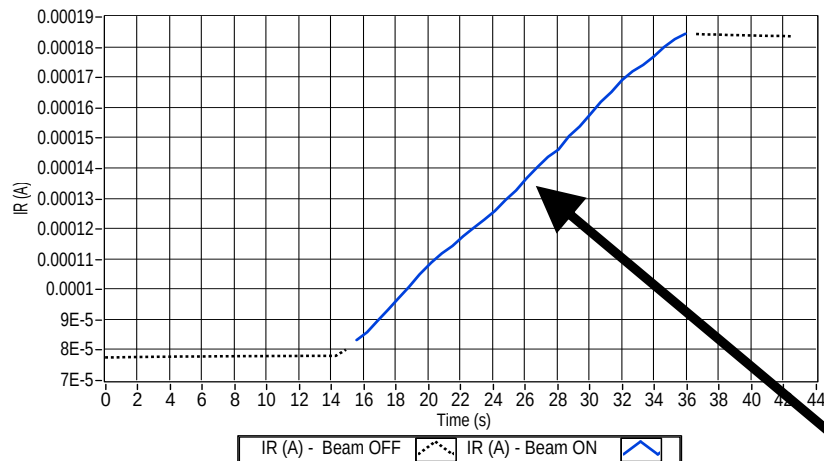
TRAD

**Thank you for your attention,
any question ?**

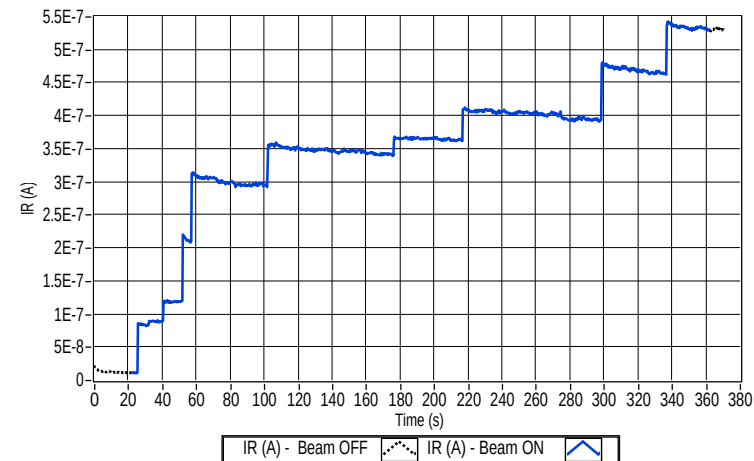


Focus on SiC Schottky diode result

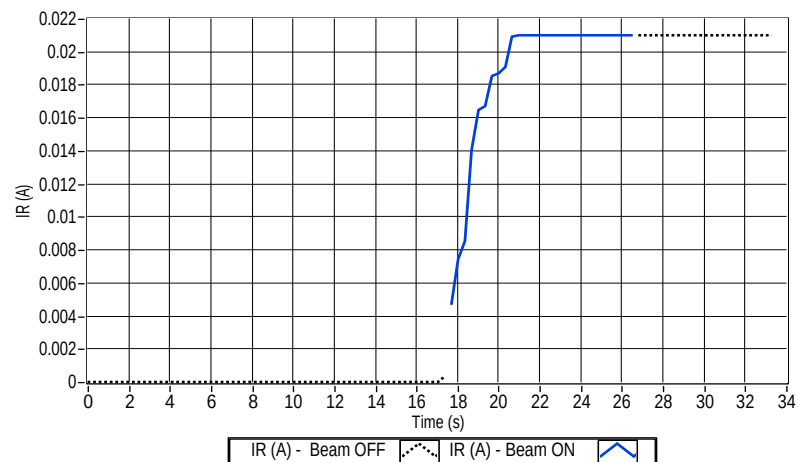
Run No. 168 - SML10SIC06SMD5 - Part No. 1 - VR=300.0V



Run No. 218 - STPSC1006 - Part No. 7 - VR=275.0V



Run No. 238 - STPSC10H065 - Part No. 2 - VR=350.0V



- This increase of leakage current is directly proportional to the fluence and flux
- Signatures observed on the 3 SiC reference