SEGR/SEB Radiation test Method Study

Presentation of Results & Analysis following Heavy ions Irradiations

ESA contract n° 22328/08/NL/PA

A. CARVALHO*, Ch. BINOIS*, R. MANGERET*, M. MARINONI* & V. FERLET-CAVROIS**

*** EADS-ASTRIUM SAS**

**** ESA/ESTEC**

Presentation to CNES/ESA Days

(March, 29th 2011)

All the space you need

esa

ASTRIUM
AN EADS COMPANY

Description of the study

- To study Post-Irradiation Gate Stress Test (PIGST) method for SEGR characterization through electrical and heavy ion testing
  1. Characterization of studied devices for SEGR under heavy ion beam and during PIGST
  2. Investigation of 3 different approaches for Gate Stress
     - *PIGS*
     - *Time To Breakdown (TTBD)*
     - *and Charge To Breakdown (QTBD)*
  3. Study of the breakdown behaviour of devices through accurate measurements
  4. Correlation of observed failures during PIGST and during heavy ion irradiation
- Two different N-channel MOSFET types selected

Part Type	**2SK4219 (FUJI)**
Characteristics	100V N-Channel
Package	SMD0.5
Die area	~12 mm²
Gate oxide thickness	not provided

Part Type	**HG0K (STM)**
Characteristics	100V N-Channel
Package	TO-3
Die area	29 mm²
Gate oxide thickness	47nm

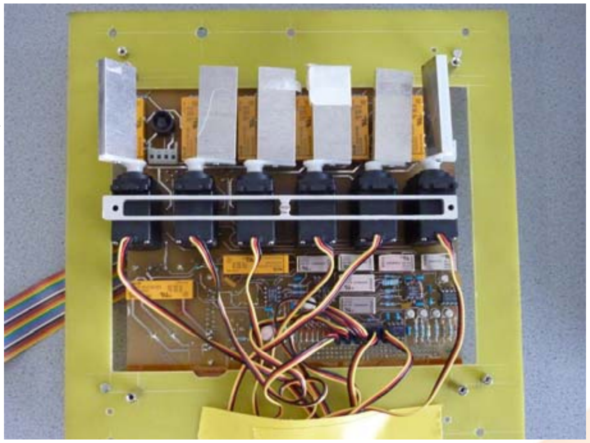
Chronological events

- May 2009: Kick-off
- June 2009 : 1st HI testing at UCL facility
- May 2010: Follow-on meeting on ESA premises
- June 2010: Key personnel replacement
- July 2010: 2nd HI testing at UCL facility
- April 2011: Laser testing at ASTRIUM-IW facility
- ~May-June 2011: 3rd HI testing at UCL facility

All the space you need

Experimental setup presentation (1/5)

- The original setup
  - was designed in 2004
  - was used for the 1st test campaign in June 2009
  - needs to be improved for
    - ✓ a better accuracy on Igss measurement
    - ✓ drain charge collection detection
    - ✓ Vgsth measurement
    - ✓ IDss on line
    - ✓ PIGS range increase



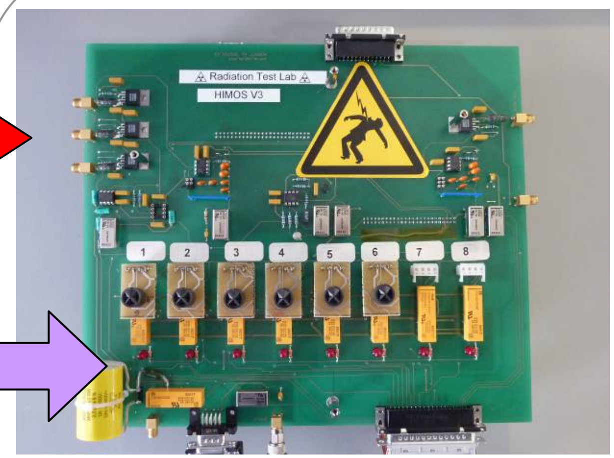
- A new Test setup has been developped and used during the 2nd irradiation campaign in July 2010

Experimental setup presentation (2/5)

▪ New Test setup description

TESTER BAY

- Power Supplies
- SMU's
- Digitizer
- Main Monitoring program



TEST BOARD

- Sample Holder + selection of devices
- Front end analog stages (SEB, CSA for QD VGSth…)
- Local control program (FPGA & µP)

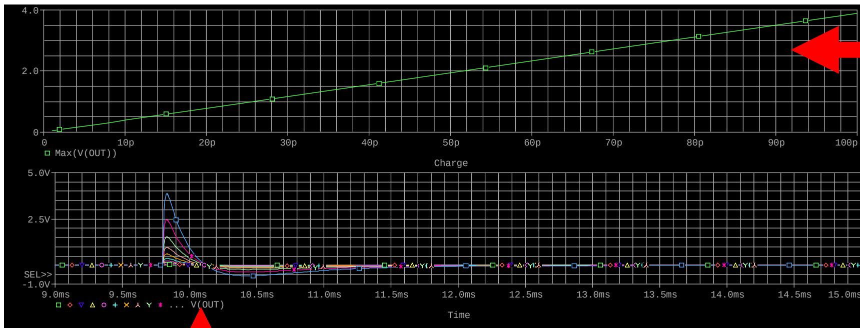
Remote control computer

Experimental setup presentation (3/5)

- Test system characteristics
  - 8 test slots
  - Can hold P and N channel up to 600V Vds and +/-100V Vgs
  - On line measurement of Igss (10pA to 100mA) and Idss
  - SEB detection and Drain charge collection integrated acquisitions
  - Integrated Vgsth measurement for N channel (P to be added)
  - Embedded Processor and FPGA (RTOS for short time response and local tasks management)
  - Remote controlled operation
  - Integrated autotest to check device and tester integrity before irradiation (a not connected device is seen unsensitive)

Experimental setup presentation (4/5)

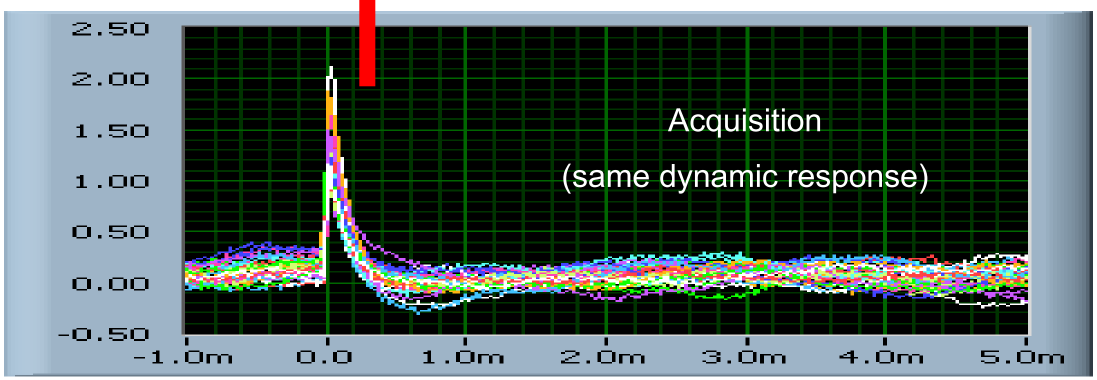
- Focus on Integrated charge collection system



Pspice Simulation

Theoritical conversion ratio
40mV/pC

To be calibrated by comparison with ESA test setup by using EADS IW Laser test bench



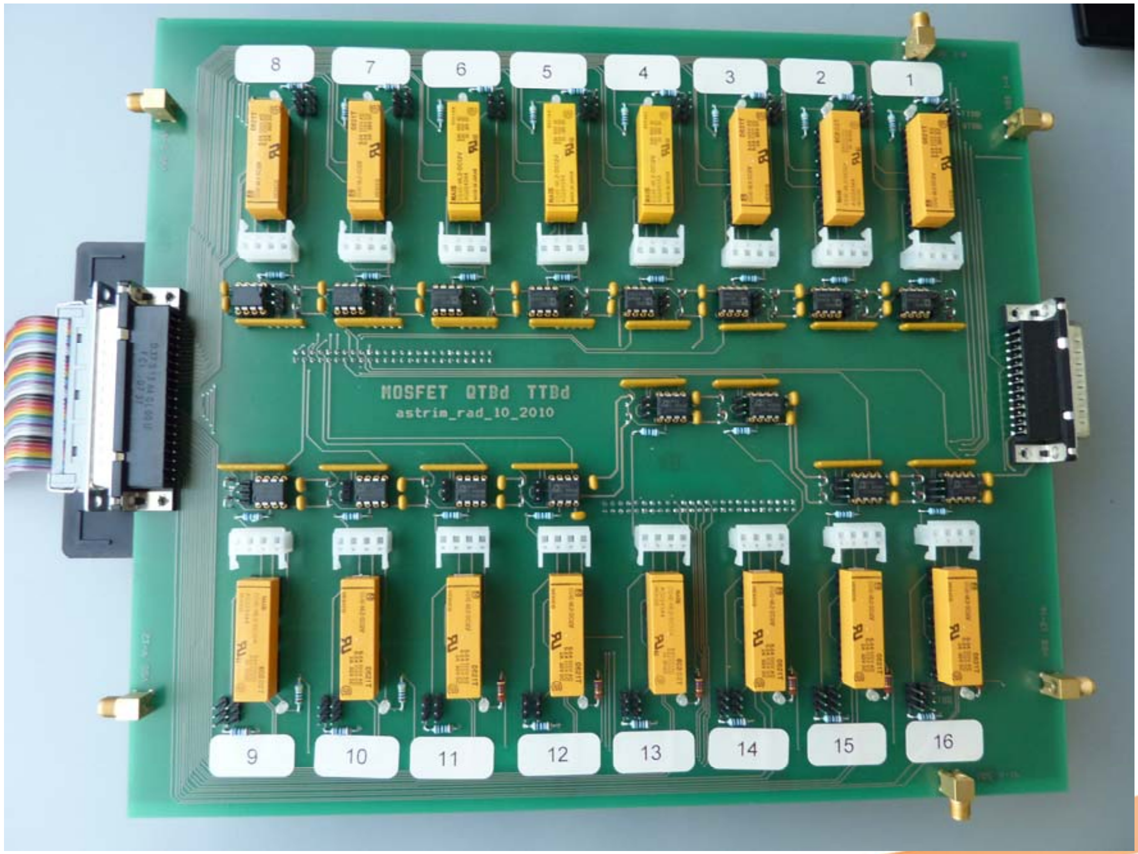
Low Frequency noise is coming from the Drain supply

*** Good indicator to check if device is really irradiated*

Works also for P channel

Experimental setup presentation (5/5)

- QTBD & TTBD board



16 test slots

Visual information for device health state

QTBD or TTBD selectable per slot

Experimental Results from WP2100

✓Characterization of SOA for SEGR

All the space you need

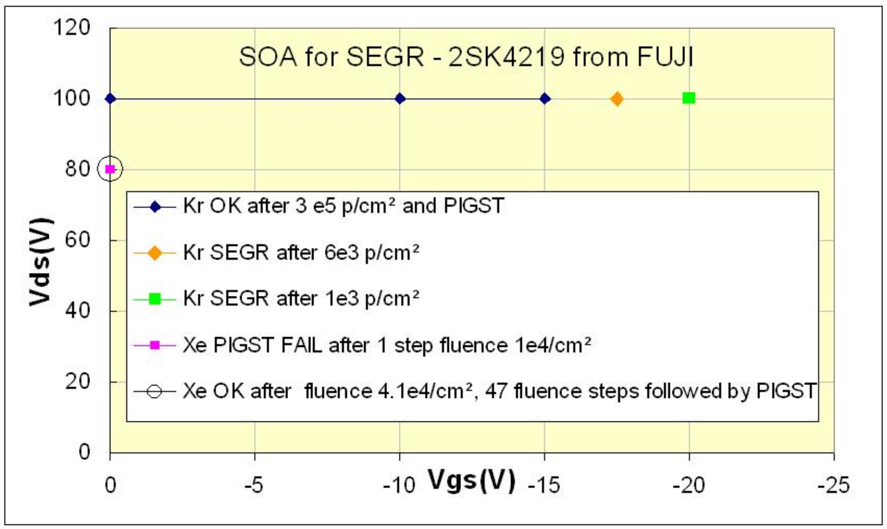
ASTRIUM
AN EADS COMPANY

Experimental Results from WP2100

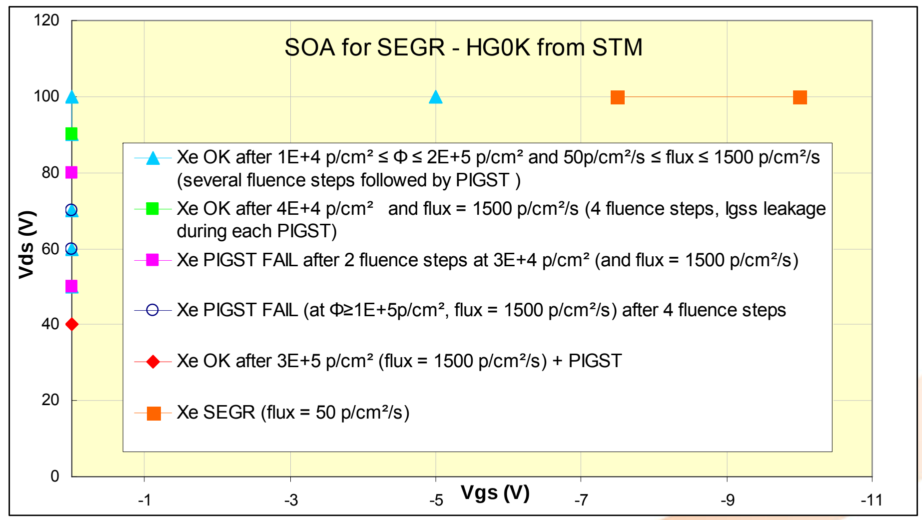
- 1st irradiation test campaign performed at UCL facility

Heavy Ion specie	*HI energy [MeV]*	*Range [µm Si]*	*LET [MeV.mg.cm^{-2}]*
$^{83}Kr^{25+}$	756	92.0	31.0
$^{132}Xe^{26+}$	459	43.0	67.7

- Characterization of SOA for SEGR



2SK4219 (FUJI)



HG0K (STM)

SEGR or PIGS failure observed only for fluences higher than 1E+4 p/cm² : Multiple impacts suspected
→ **"SEGR Study on Power MOSFETs: Multiple Impacts Assumption"** D. Peyre *et al., IEEE TNS Vol 55, Iss 4, pp. 2181-2187 , 2008*

All the space you need

ASTRIUM
AN EADS COMPANY

Experimental Results from WP2200

✓Intrinsic breakdown voltage assessment

✓Charge collection at drain level measurement

Experimental Results from WP2200 (1/7)

- 2nd irradiation test campaign performed at UCL facility

Heavy Ion specie	*HI energy [MeV]*	*Range [µm Si]*	*LET [MeV.mg.cm^{-2}]*
$^{132}Xe^{26+}$	459	43.0	67.7

- Intrinsic breakdown voltage of the gate oxide assessment (1/3)

PIGST evolution at higher voltage levels explored until gate rupture occurred. PIGS test repeated by increasing the maximum voltage (in + and - polarity) in small steps

➡ Voltage threshold for leakage current onset is much higher than spec limit of device (20V)

Experimental Results from WP2200 (2/7)

- Intrinsic breakdown voltage of the gate oxide assessment (2/3)

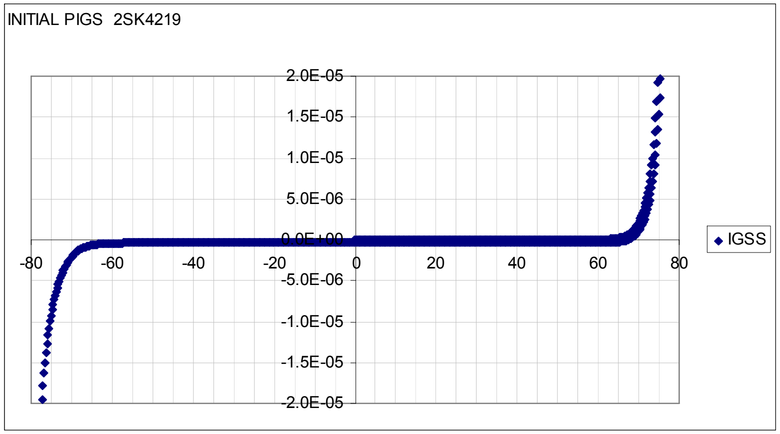
➡ Extended PIGS levels defined after this evaluation:

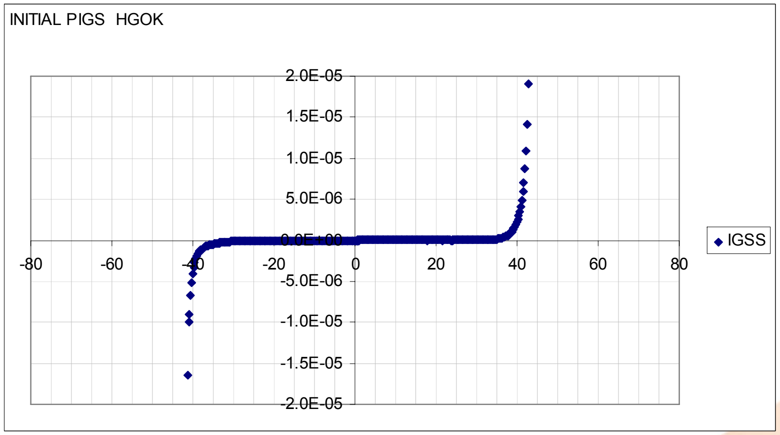
	2SK4219	**HG0K**
Standard specification	Vgs = +20V/-20V	Vgs = +20V/-20V
Experimental Target Leakage onset (+100nA/-100nA)	Vgs = +60V/-45V	Vgs = +30V/-24V
Experimental Target limit leakage	Vgs = +65V/-60V Typical current 200nA/-300nA	Vgs = +36V/-30V Typical current 100nA/-120nA

Experimental Results from WP2200 (3/7)

- Intrinsic breakdown voltage of the gate oxide assessment (3/3)

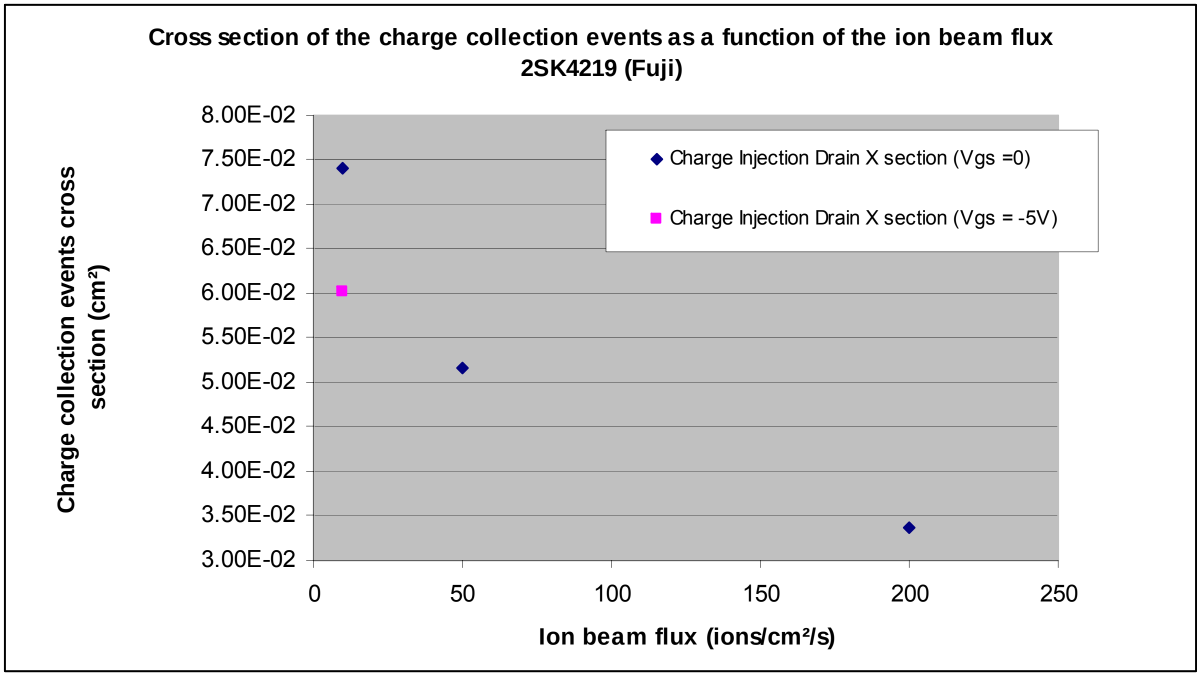
➡ Fuji parts have far higher intrinsic breakdown voltage (Vbd) than STM parts





Experimental Results from WP2200 (4/7)

Charge Collection at Drain Level: Flux Effect (1/3)



Limiting the flux below 50 ions.cm^{-2}.s^{-1} gives a reasonnable detection ratio of the charge collection events

Experimental Results from WP2200 (5/7)

Charge Collection at Drain Level: Flux Effect (2/3)

➡ The lower the flux, the higher the charge collection events cross section

➡ Even in over-blocking condition on Vgs, charge collection measurement is still possible

EADS-ASTRIUM

test	SEE sensitivity					default Xsection									5.00E-07		5.00E-07		5.00E-07
comp	MOS_STM	VDS Max Rating		100 V															
Type	N																		
														Charge Injection Drain		SEB		SEGR	
Run	devices	Ion	LET (MeV cm²/mg)	Range (µm)	flux (p/cm²/s)	Fluence (/cm²)	Vgsth_p rérad (V)	Vgsth_p ostrad (V)	Vds (V)	Vgsoff	PIGS_ post rad	Vgs(V) @ PIGS failure	Trigg (V)	Nb events GRD	X section	Nb events	X section	Nb events	X section
36	205	132 Xe 26+	67.7	43	8	9.4E+03	3.553	3.524	80	0 V	OK	-		1000	1.06E-01		5.00E-07		5.00E-07
37	206	132 Xe 26+	67.7	43	15	5.0E+03	3.476	3.455	80	0 V	OK	-		552	1.10E-01		5.00E-07		5.00E-07
38	207	132 Xe 26+	67.7	43	15	5.0E+03	3.407	3.526	80	0 V	OK	-		595	1.19E-01		5.00E-07		5.00E-07

➡ Confirmation with STM parts that fluxes below 50 ions.cm^{-2}.s^{-1} give reasonnable detection ratio of the charge collection events

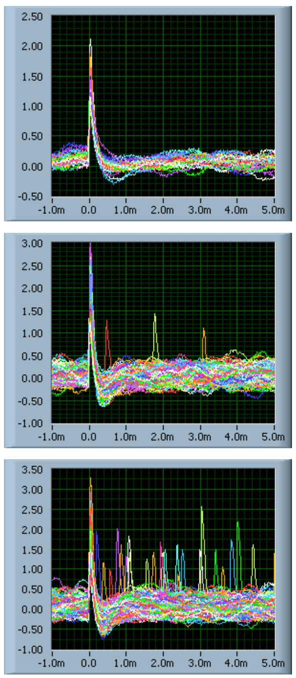
All the space you need

ASTRIUM AN EADS COMPANY

Experimental Results from WP2200 (6/7)

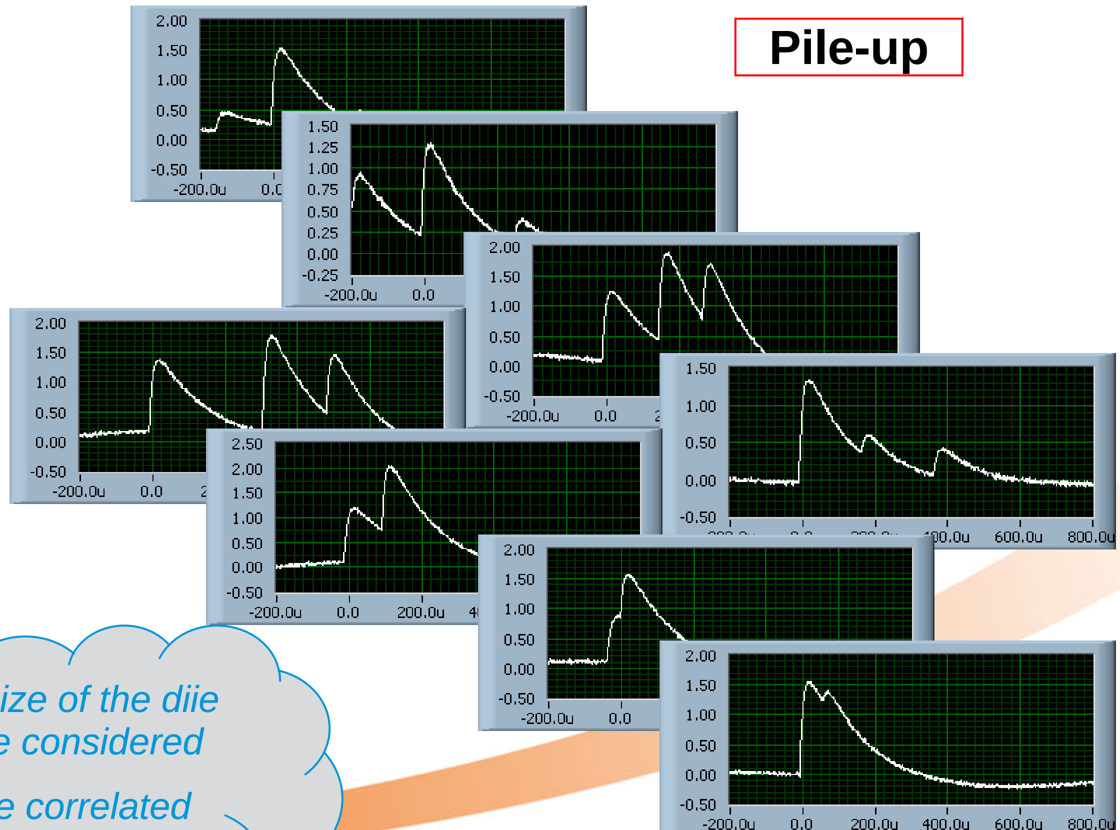
- Charge Collection at Drain Level: Flux Effect (3/3)
  - 2 Probable causes of issue

Count loss



Flux increase

Pile-up

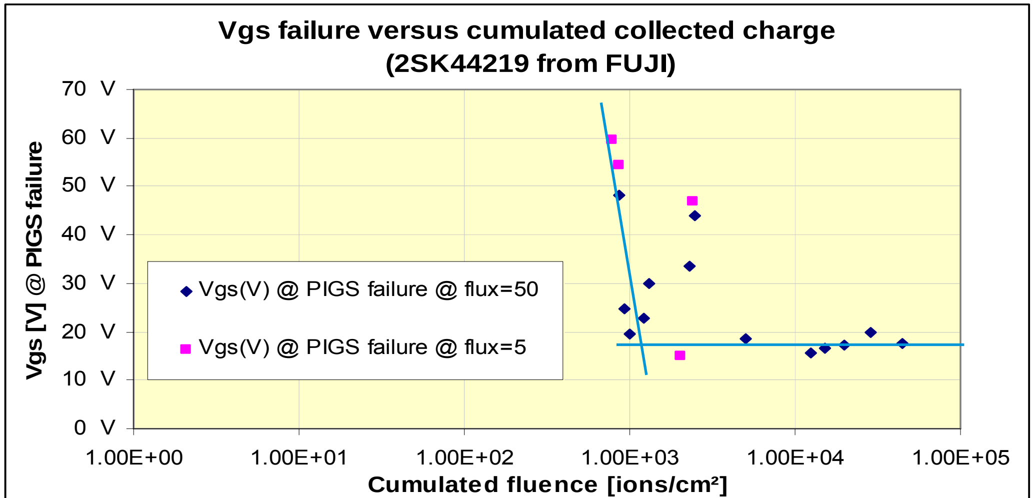


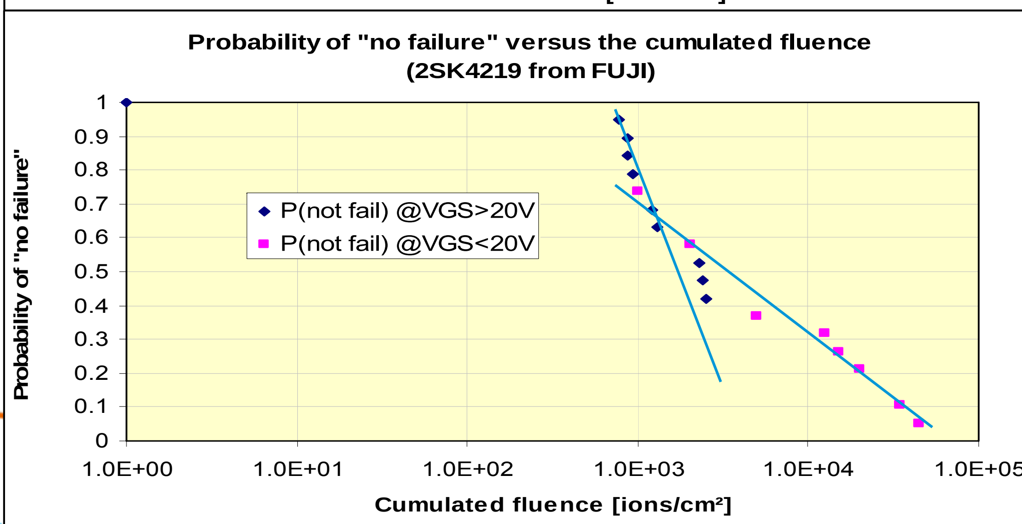
*** The size of the diie shall be considered*

Can be correlated with the accelerator dosimetry

Experimental Results from WP2200 (7/7)

- Breakdown Vgs during PIGST: Fluence Effect





lower fluences ⟷ higher Vgs failure during PIGST

Φ<5E+3 ions.cm^{-2} ⟷ Vgs failure during PIGST ≥ 20V

➡ The higher the fluence, the higher the probability of failure during PIGST

➡ Needs a deeper statistical analysis

Conclusion

- Extended PIGS levels have been defined and leakage current onset determined
- Charge collection at drain level can be used as a smart checking tool during irradiation (Beam presence, characteristics and dosimetry check)
- Charge collection at drain level can be used also under over-blocking conditions
- Breakdown Vgs during PIGST depends on cumulated fluence *(Multiple impact suspected)*

Work to be performed

- Completion of SOA for SEGR
- QBD and TBD tests on irradiated parts and pristine parts (as reference)
- Intrinsic breakdown voltage versus breakdown voltage during PIGST: is there a link?
- Laser testing (Charge collection circuit calibration)
- Confirm the results by a statistical study
- …