Status of Active Monitors

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CERN PH and TS Departments

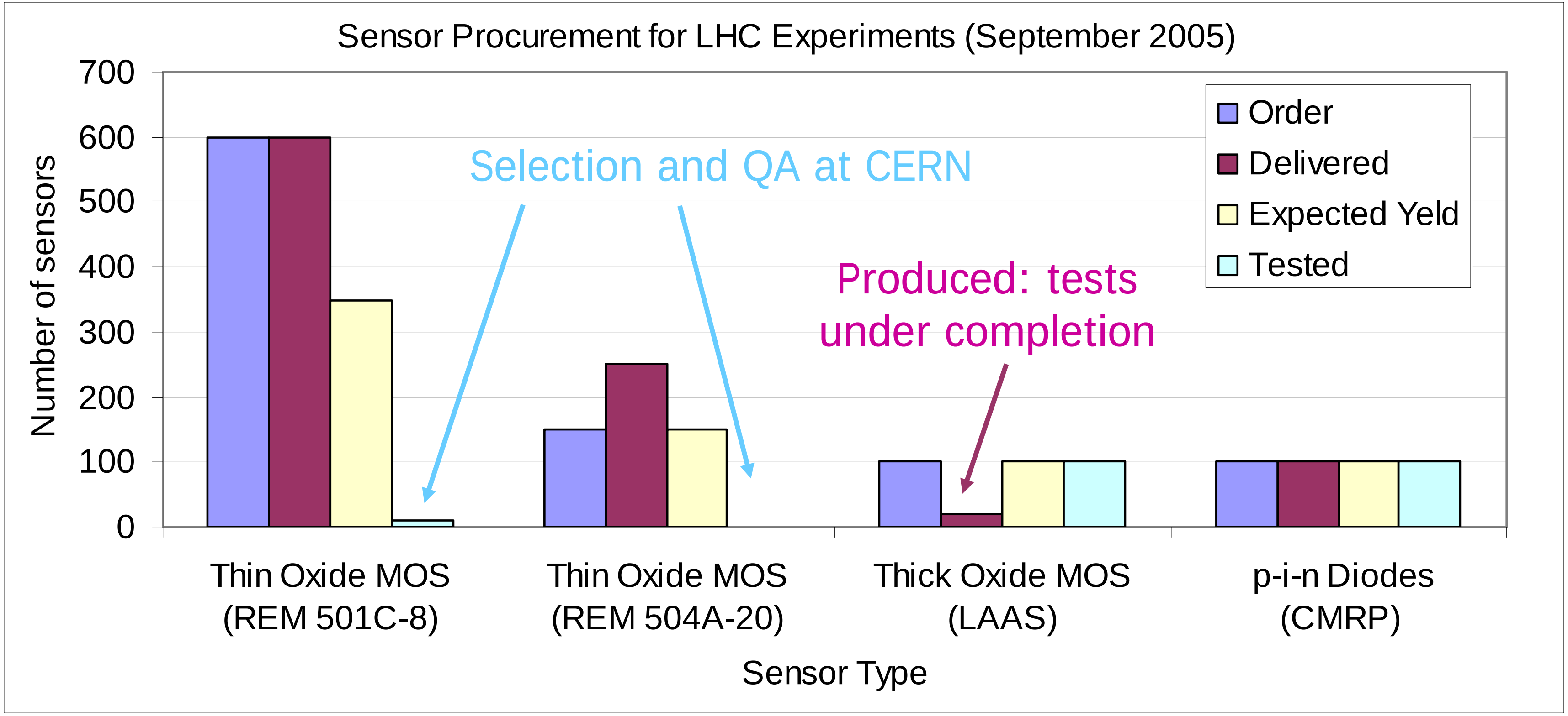
Riccardo Capra (GEANT4 Simulations)

INFN Genova

Outline ...

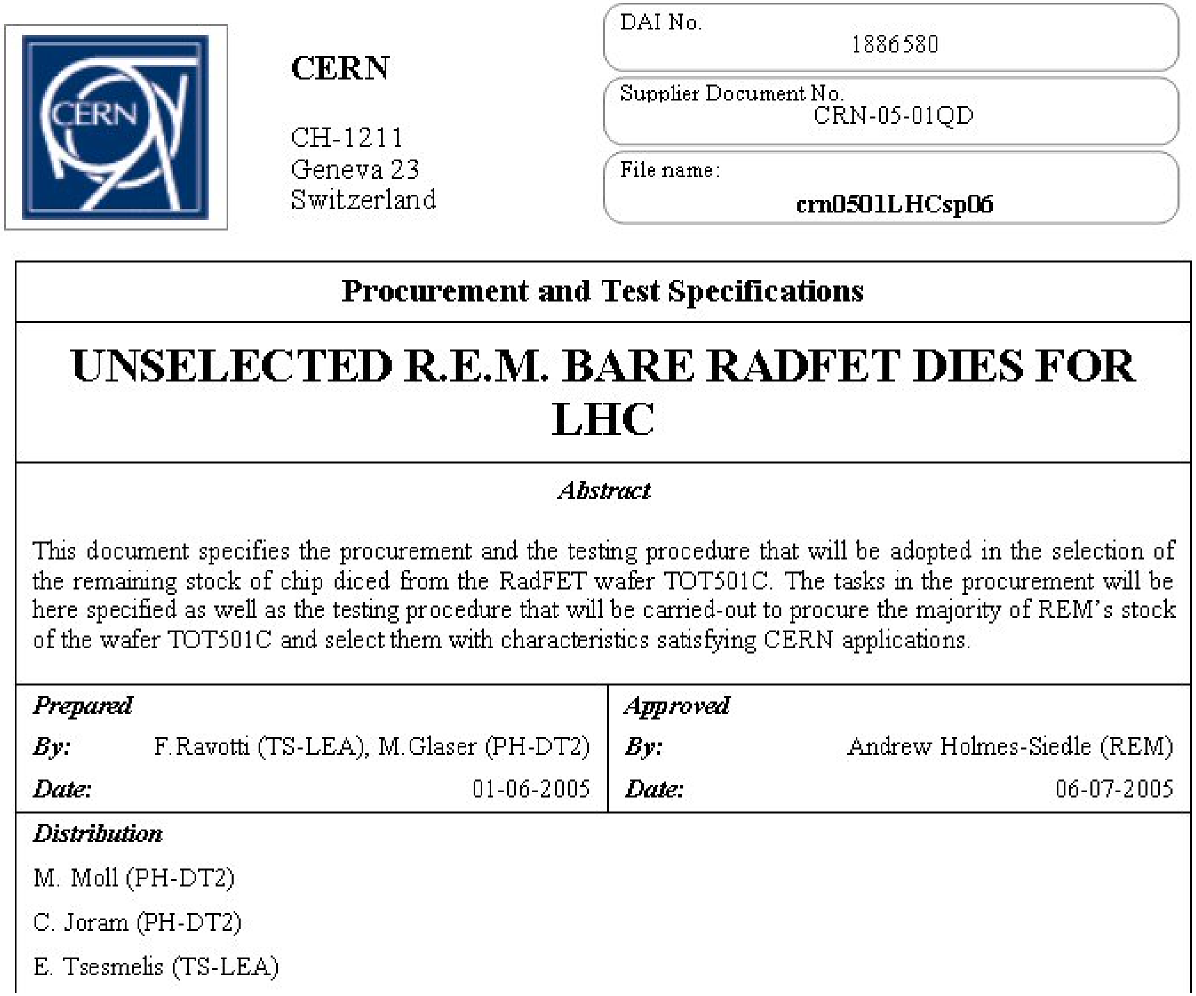
- Status of sensor procurement;
- Selection criteria for RadFETs;
- Quality Assurance (QA) procedure for the active monitors;
- Experiment sensor packaging: design and simulations;
- Conclusions on RadFET Isochronal Annealing studies;
- BPW34 readout protocol optimization;
- News on new devices, OSL R&D, etc..

Sensor Procurement



Following the Experiment request of March 22nd, 2005 all the sensors have been procured and the QA procedure for the "Thin Oxide" RadFETs is ongoing.

MOS Selection Criteria



CERN

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Supplier Document No. CRN-05-01QD

File name: **crn0501LHCsp06**

Procurement and Test Specifications

UNSELECTED R.E.M. BARE RADFET DIES FOR LHC

Abstract

This document specifies the procurement and the testing procedure that will be adopted in the selection of the remaining stock of chip diced from the RadFET wafer TOT501C. The tasks in the procurement will be here specified as well as the testing procedure that will be carried-out to procure the majority of REM's stock of the wafer TOT501C and select them with characteristics satisfying CERN applications.

Prepared		***Approved***	
By:	F.Ravotti (TS-LEA), M.Glaser (PH-DT2)	***By:***	Andrew Holmes-Siedle (REM)
Date:	01-06-2005	***Date:***	06-07-2005

Distribution

M. Moll (PH-DT2)

C. Joram (PH-DT2)

E. Tsesmelis (TS-LEA)

8 pages document defining in detail the procurement and QA parameters for the CERN Thin Oxide RadFETs.

MOS Selection Criteria

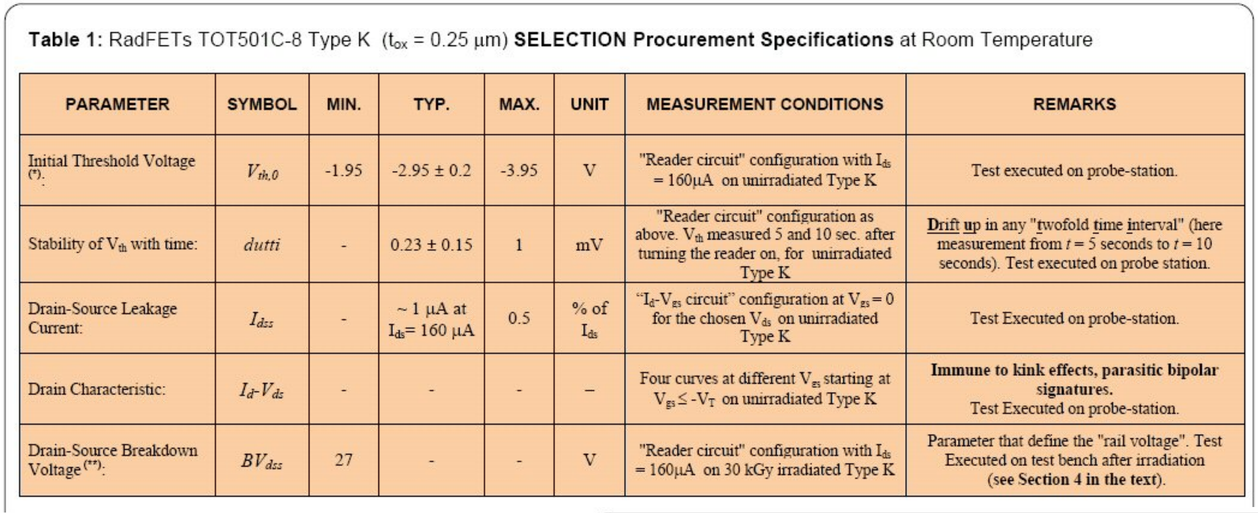


Table 1: RadFETs TOT501C-8 Type K (t_{ox} = 0.25 µm) **SELECTION Procurement Specifications** at Room Temperature

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT	MEASUREMENT CONDITIONS	REMARKS
Initial Threshold Voltage (*):	$V_{th,0}$	-1.95	-2.95 ± 0.2	-3.95	V	"Reader circuit" configuration with I_{ds} = 160µA on unirradiated Type K	Test executed on probe-station.
Stability of V_{th} with time:	*dutti*	-	0.23 ± 0.15	1	mV	"Reader circuit" configuration as above. V_{th} measured 5 and 10 sec. after turning the reader on, for unirradiated Type K	**Drift up** in any "twofold time interval" (here measurement from $t = 5$ seconds to $t = 10$ seconds). Test executed on probe station.
Drain-Source Leakage Current:	I_{dss}	-	~ 1 µA at I_{ds}= 160 µA	0.5	% of I_{ds}	"I_d-V_{gs} circuit" configuration at V_{gs} = 0 for the chosen V_{ds} on unirradiated Type K	Test Executed on probe-station.
Drain Characteristic:	I_d-V_{ds}	-	-	-	–	Four curves at different V_{gs} starting at $V_{gs} \leq -V_T$ on unirradiated Type K	**Immune to kink effects, parasitic bipolar signatures.** Test Executed on probe-station.
Drain-Source Breakdown Voltage (**):	BV_{dss}	27	-	-	V	"Reader circuit" configuration with I_{ds} = 160µA on 30 kGy irradiated Type K	Parameter that define the "rail voltage". Test Executed on test bench after irradiation (see **Section 4 in the text**).

"red table" contains parameters considered as accept-reject values

"green table" contains parameters used for batch assignment

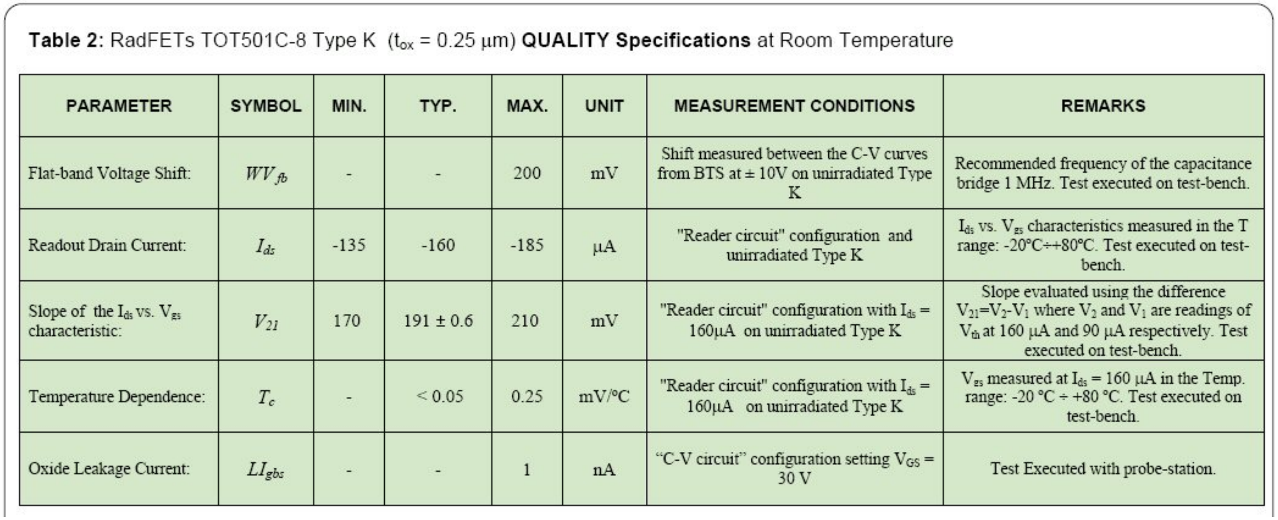
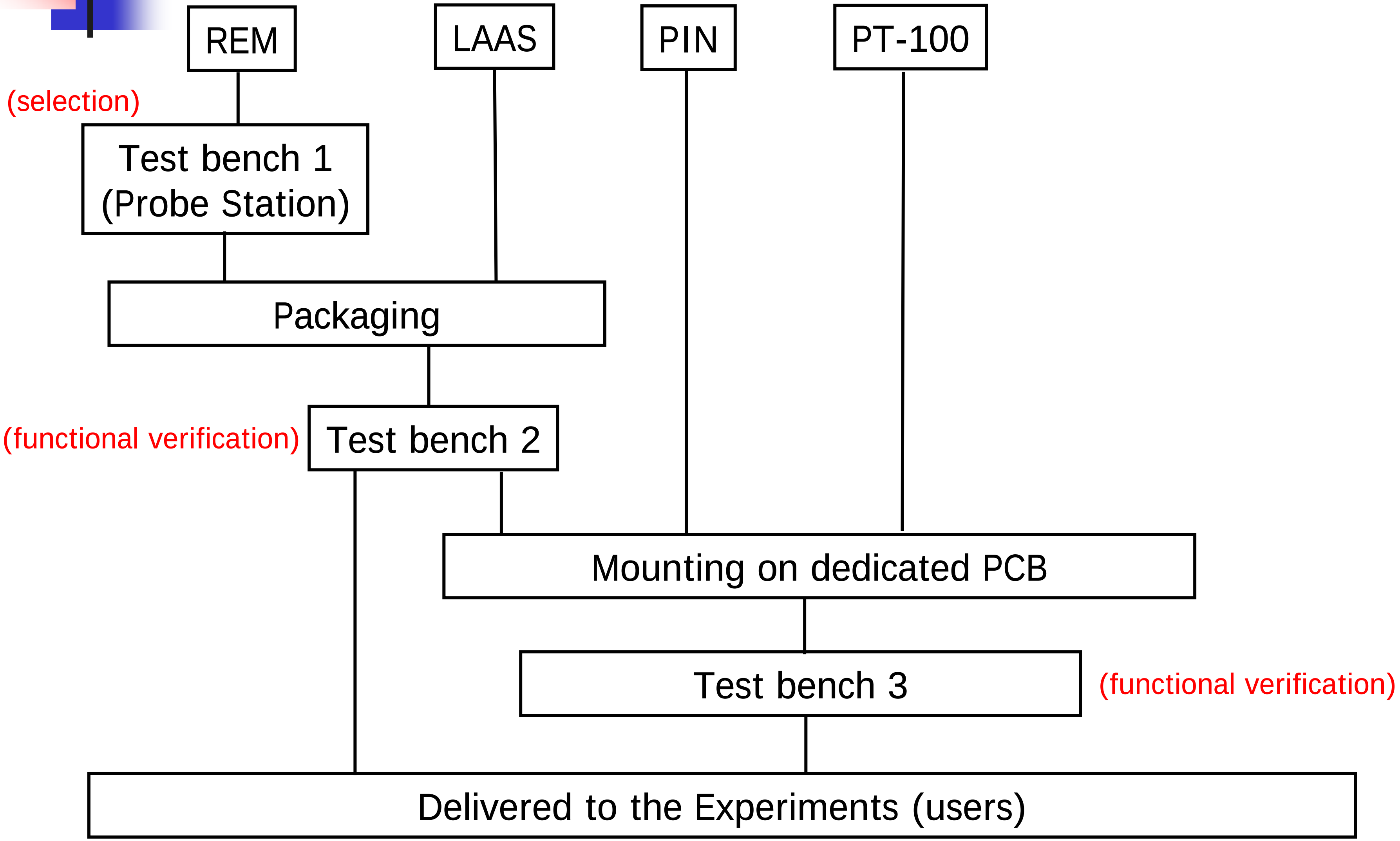


Table 2: RadFETs TOT501C-8 Type K (t_{ox} = 0.25 µm) **QUALITY Specifications** at Room Temperature

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT	MEASUREMENT CONDITIONS	REMARKS
Flat-band Voltage Shift:	WV_{fb}	-	-	200	mV	Shift measured between the C-V curves from BTS at ± 10V on unirradiated Type K	Recommended frequency of the capacitance bridge 1 MHz. Test executed on test-bench.
Readout Drain Current:	I_{ds}	-135	-160	-185	µA	"Reader circuit" configuration and unirradiated Type K	I_{ds} vs. V_{gs} characteristics measured in the T range: -20°C÷+80°C. Test executed on test-bench.
Slope of the I_{ds} vs. V_{gs} characteristic:	V_{21}	170	191 ± 0.6	210	mV	"Reader circuit" configuration with I_{ds} = 160µA on unirradiated Type K	Slope evaluated using the difference $V_{21}=V_2-V_1$ where V_2 and V_1 are readings of V_{th} at 160 µA and 90 µA respectively. Test executed on test-bench.
Temperature Dependence:	T_c	-	< 0.05	0.25	mV/°C	"Reader circuit" configuration with I_{ds} = 160µA on unirradiated Type K	V_{gs} measured at I_{ds} = 160 µA in the Temp. range: -20 °C ÷ +80 °C. Test executed on test-bench.
Oxide Leakage Current:	LI_{gbs}	-	-	1	nA	"C-V circuit" configuration setting V_{GS} = 30 V	Test Executed with probe-station.

QA Procedure



REM

LAAS

PIN

PT-100

(selection)

Test bench 1 (Probe Station)

Packaging

(functional verification)

Test bench 2

Mounting on dedicated PCB

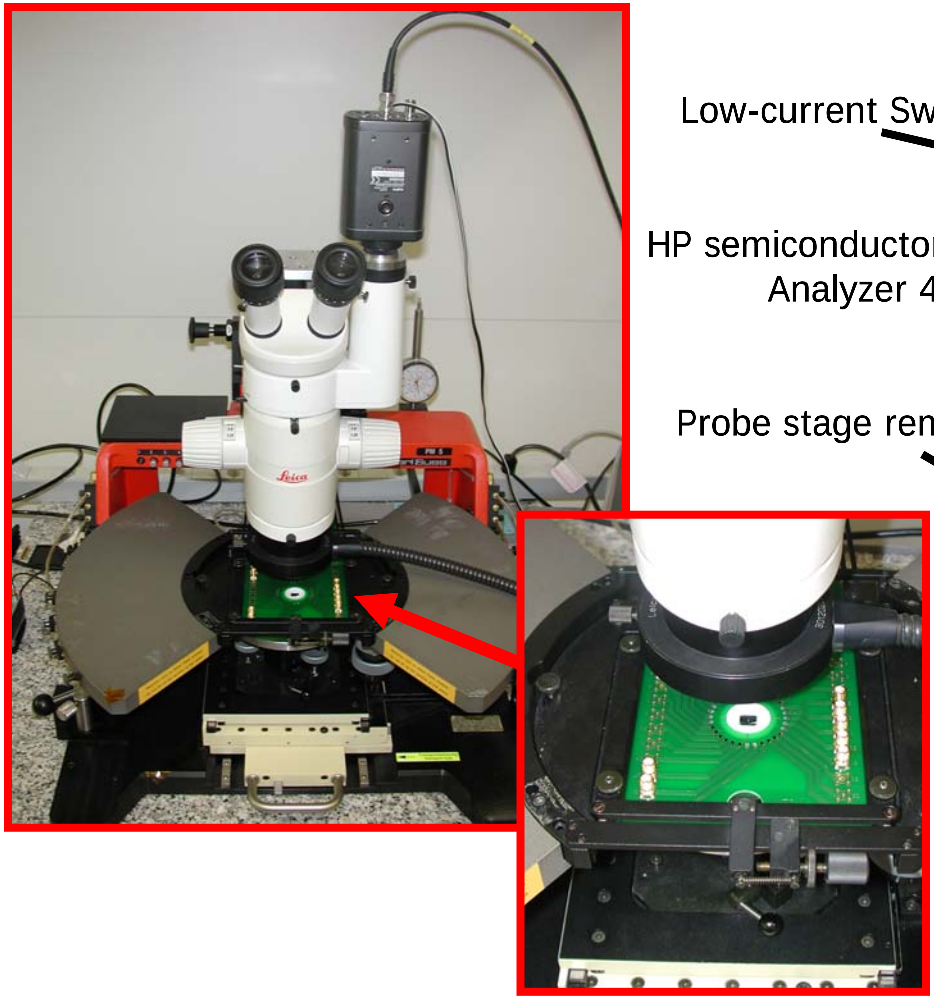
Test bench 3

(functional verification)

Delivered to the Experiments (users)

Test bench 1

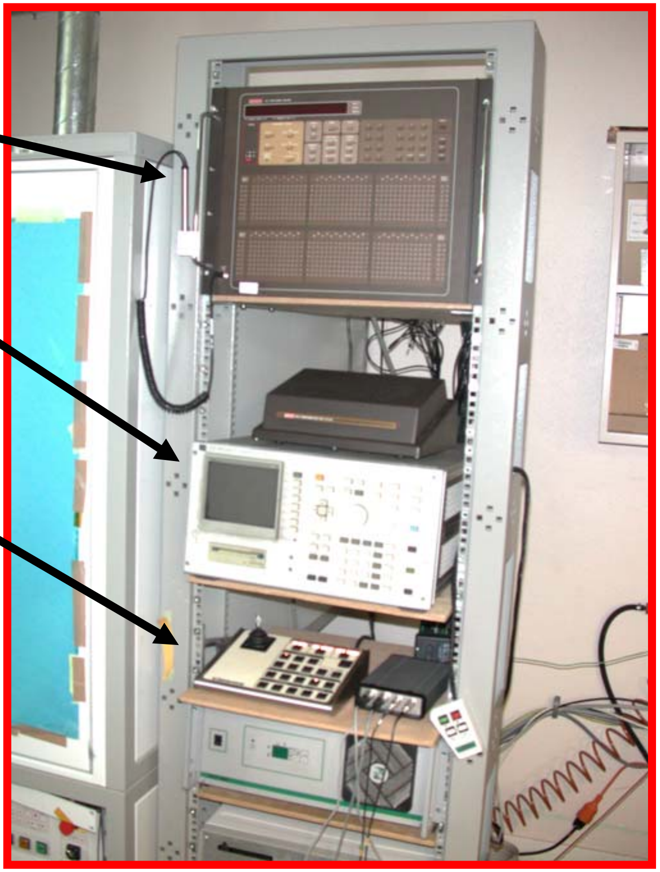
Probe-station for REM RadFETs Selection



Low-current Switch Matrix

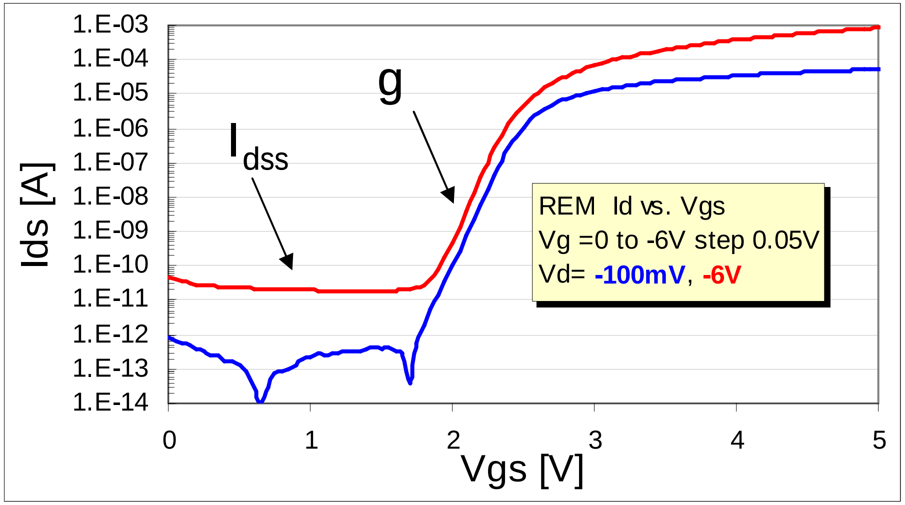
HP semiconductor-parameters
Analyzer 4155B

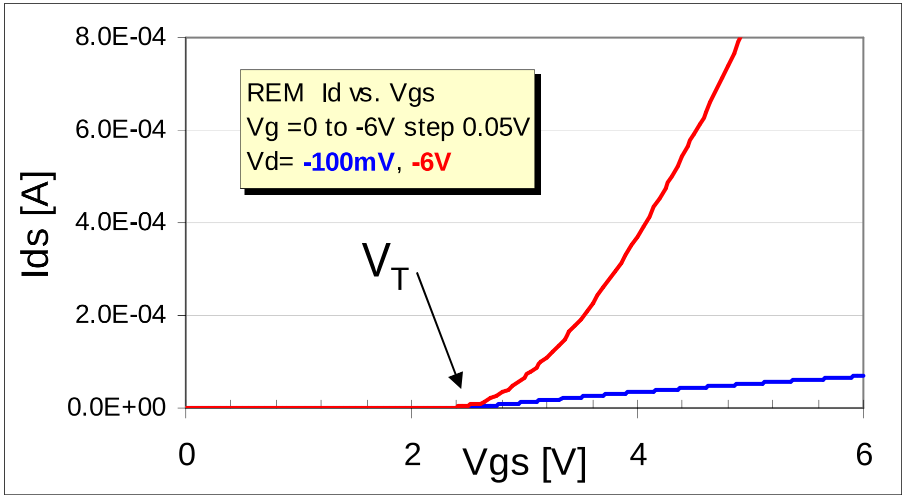
Probe stage remote control

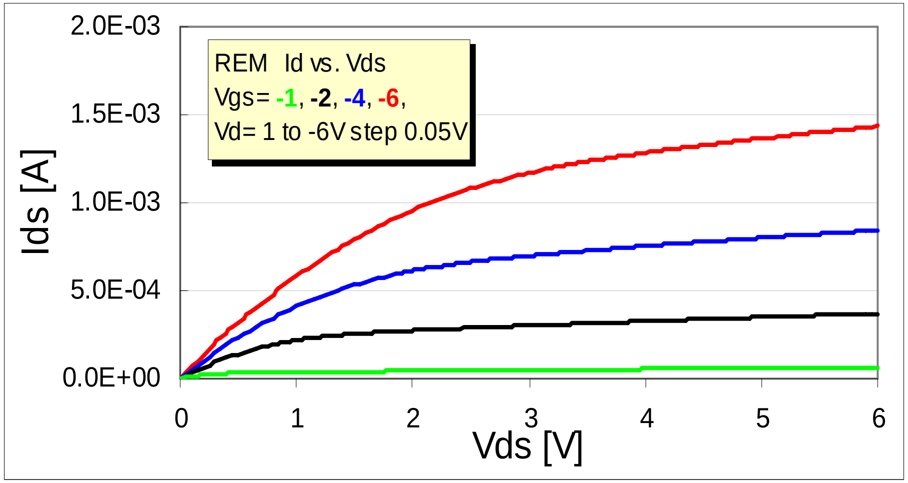


Test bench 1

First Results on REM TOT-501C (Type-K) dies







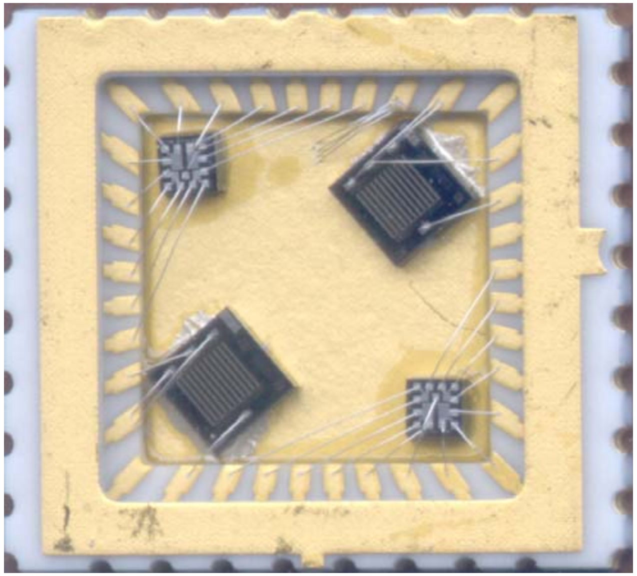
First 20 components show good behavior with respect to CERN specifications!

RadFETs Packaging

~~Development by External Company~~

Commercial Packaging (i.e. TO-5, DIP) cannot satisfy all Experiment Requirements (dimensions/materials)

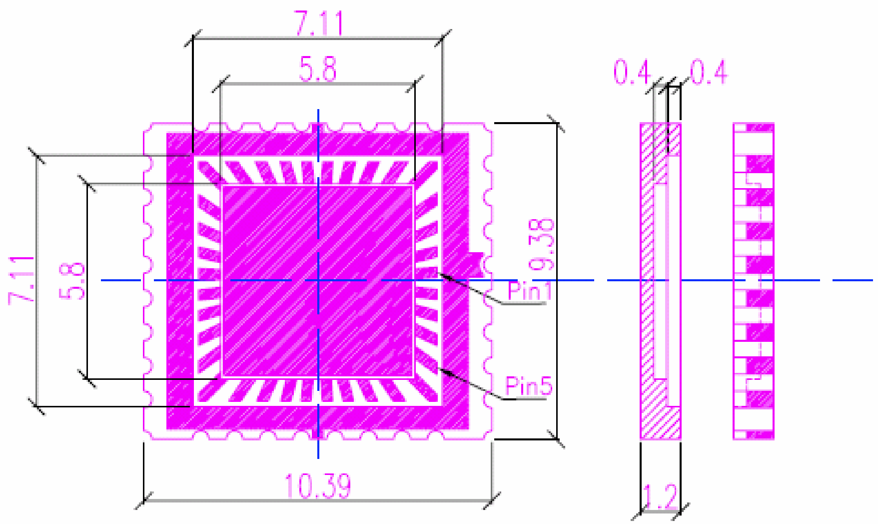
Development / study in-house at CERN

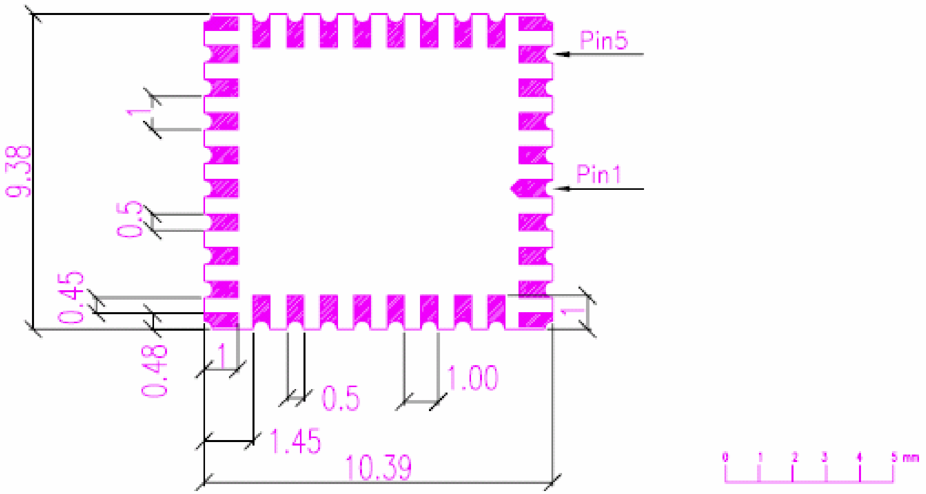


< 10 mm^2 36-pin Al_2O_3 carrier
+ 0.2 ÷ 0.4 mm cover

- High Integration level: up to 10 FETs;
- Customizable Internal layout;
- Standard External Connectivity;
- Possibility to integrate diode and Temp. probe;
- 2k parts available at CERN!

Part Dimensions
36 pin square Ceramic Chip Carrier
MIL-STD-105 D





Part bounding (Model 1 ATLAS RM)

01-C1-D3-K
02-C1-S2-K
03-C1-G2-K
04-C1-D2-K
05-FREE
06-FREE
07-FREE
08-C1-BULK
09-FREE
10-FREE
11-FREE
12-C1-S3-K
13-C1-G3-K
14-C2-S
15-C2-BULK
16-C2-G
17-C2-D
18-C3-G3-K
19-C3-D3-K
20-C3-S2-K
21-C3-G2-K
22-C3-D2-K
23-FREE
24-FREE
25-FREE
26-C3-BULK
27-FREE
28-FREE
29-FREE
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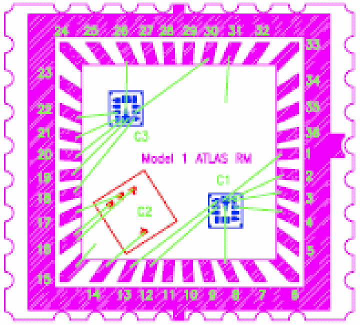
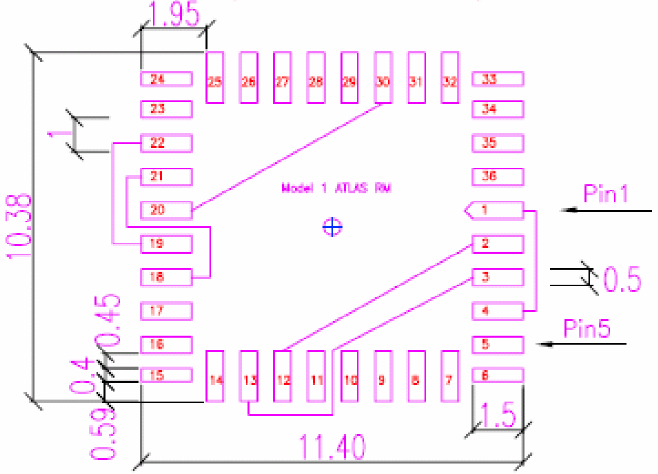
31-C2-BULK
32-FREE
33-FREE
34-FREE
35-FREE
36-FREE



C1-REM-TOT501C K-0.25um
C2-LAAS 1.6 um
C3-REM-TOT504A K-0.13um

Land pattern LDCC36 (Model 1 ATLAS RM)



1	Kyocera 36LDCC 9.38 x 10.38 x 1.2 mm3 Specification: AS-1003-A	1	Ceramic Kyocera A-473	Metallization W or equivalent Lead frame 42 Alloy. Gold plating 99.8% 1.5 um	
QUANT.	DESCRIPTION	POS	MAT.	OBSERVATIONS	REF.CERN

ENS/ASS | S.ENS/S.ASS

Chip carrier for REM-LAAS MOSFET dosimeters

RADMON
ATLAS RM
36LD Chip Carrier

ECHELLE SCALE		NOM/NAME	DATE
10:1	DES/DRA.	M.Glaser	21/06/2005
	CONTROL.		
	APPRO.		

PH-DT2-SD
REMPLACE/REPLACES 17/06/2005

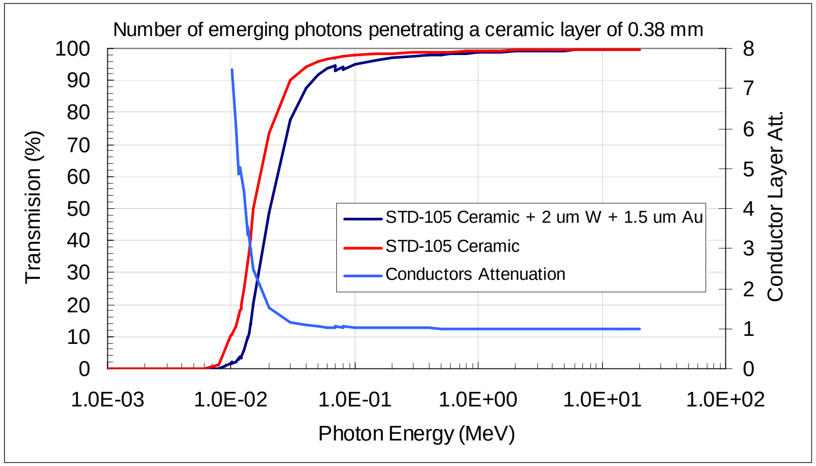
07TS-PH-001 2
IND. 1

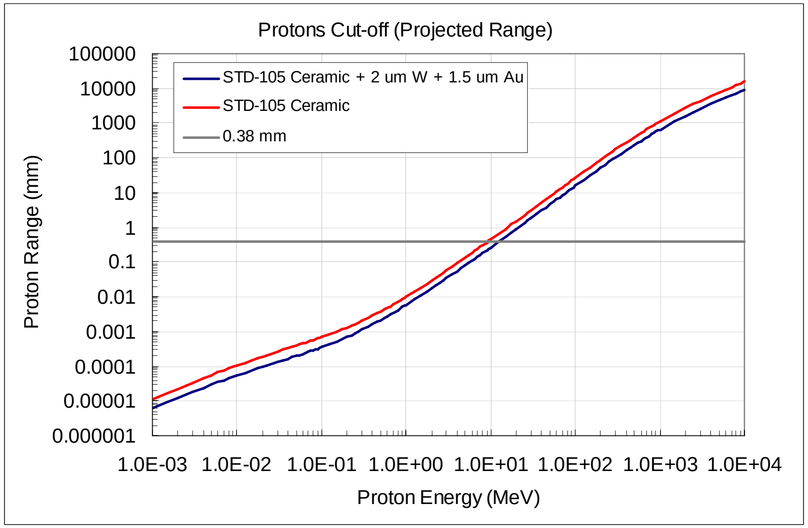
RadFETs Packaging

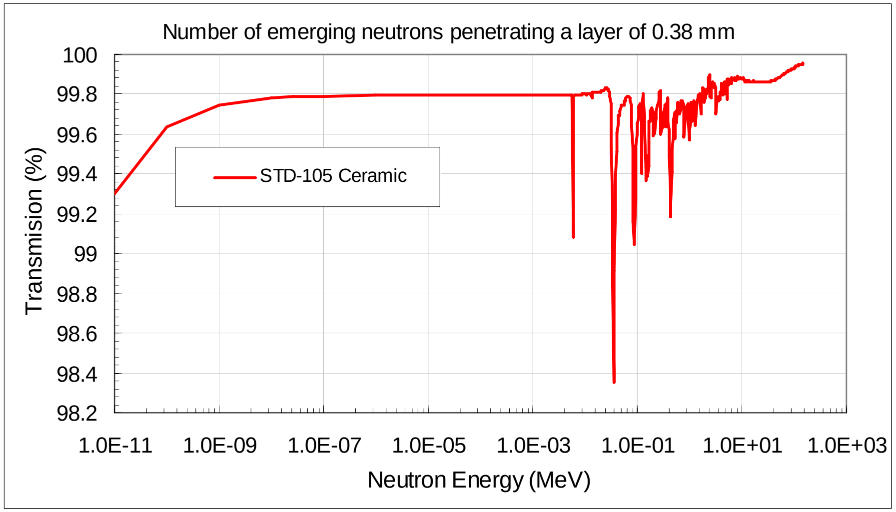
First order Calculations

(Al_2O_3 layer 0.38 mm)

- X = 3-4 % X_0 (10.3 mm);
- *e* cut-off ≅ 550 KeV;
- *p* cut-off ≅ 10 MeV;
- photons transmission ≥ 20 KeV;
- <u>*n*</u> attenuation ≅ 2-3 %;
- metallization layers affect transport for a few %

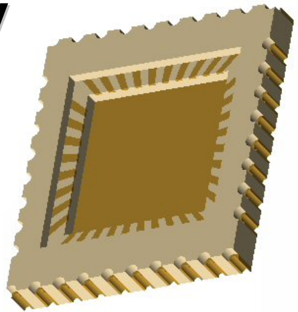






RadFETs Packaging

GEANT4 Simulations on Full Carrier Geometry

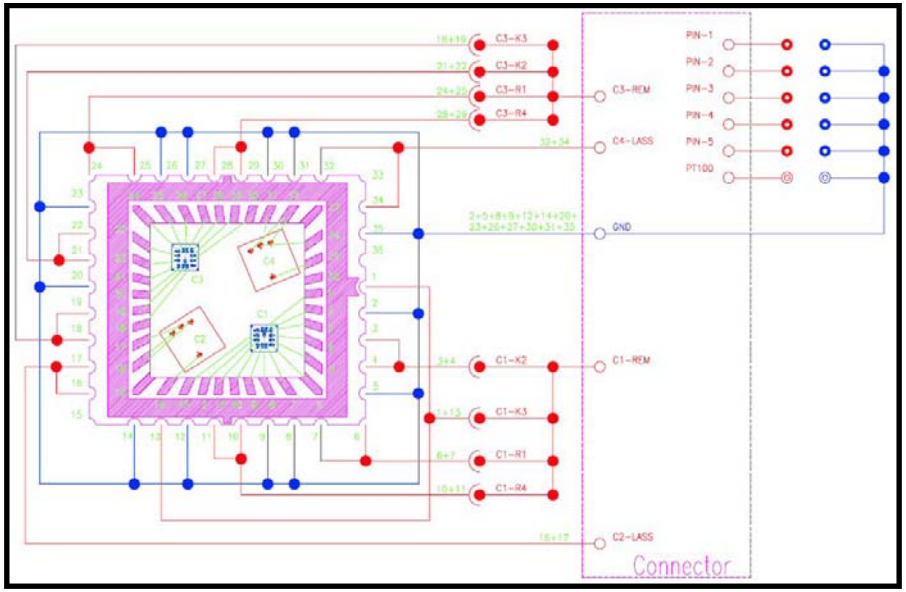


Full-Package Geometry designed in GEANT4

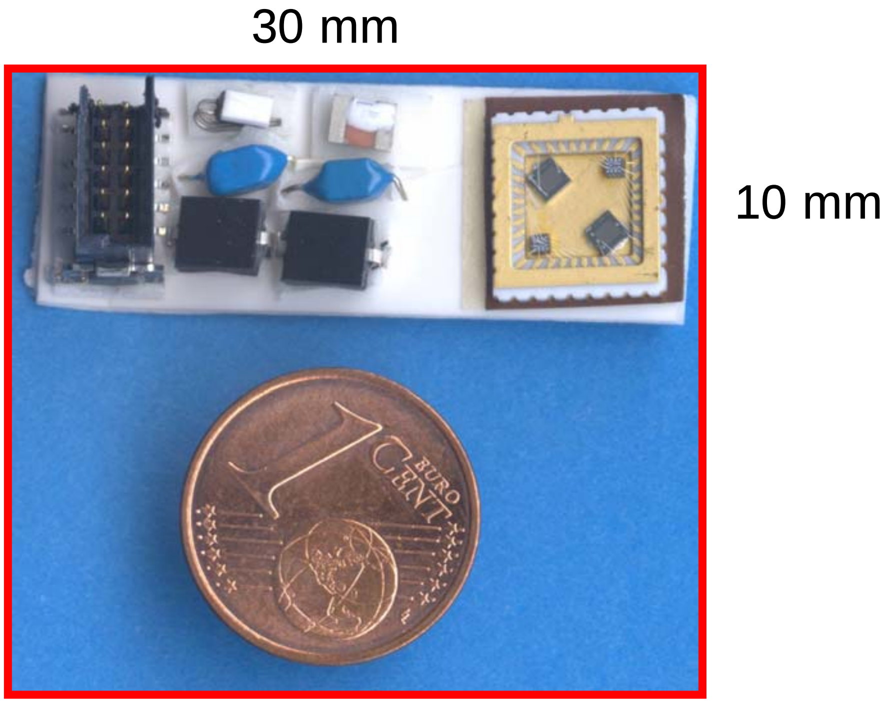
- Collaboration with “INFN Sezione di Genova” [R. Capra];
- Work started in August 2005;
- Main Goals:
  a) **Validate Packaging** for the Experiments
    1. Analysis of the energy cut-off introduced by the packaging;
    2. Optimization of the packaging materials and thicknesses (cut-off thresholds);
    3. Analysis of the particle spectra interacting with the dosimeters volume;
  b) Contribute in the development of a **Geant4 Advanced Example**:
    1. Comparison measurement/simulation in single and mixed hadron field (IRRAD2);

Packaging multi-Layer layout

Dedicated Sensor PCB



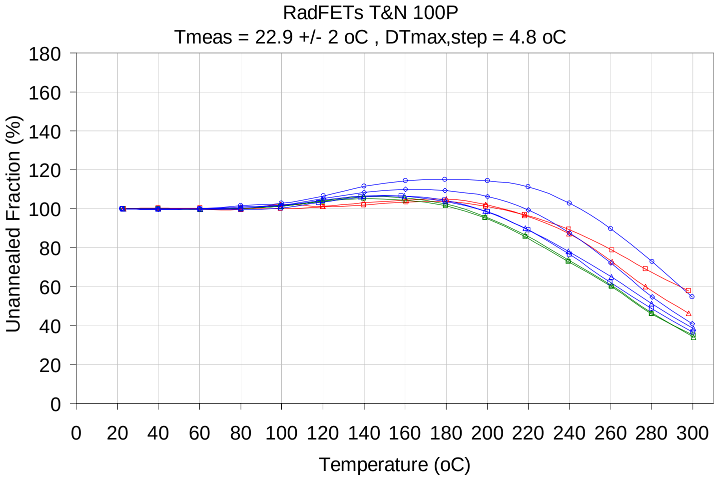
- ➢ Set of PCBs designed to host Sensor Packaging + *p-i-n* sensors + PT-100 probe;
- ➢ Some prototypes are currently under construction on standard PCB material (FR4);

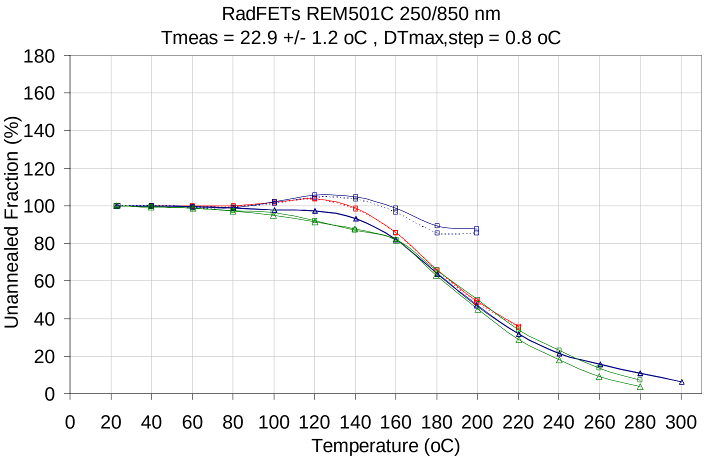


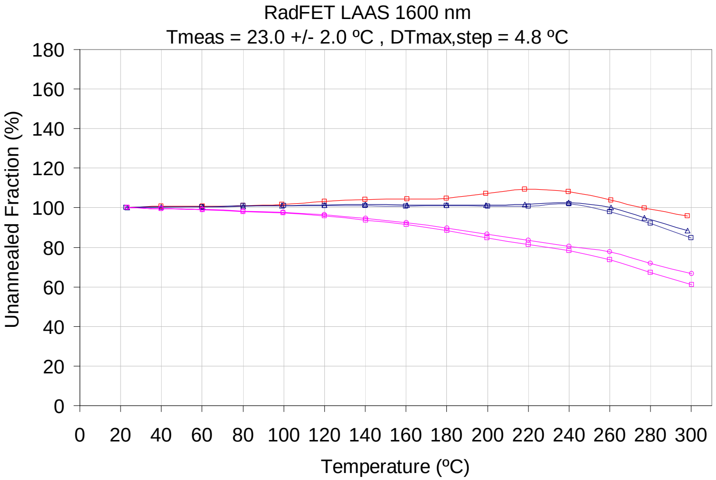
- ➢ The feedback of GEANT4 simulation studies will help to optimize the PCB material;
- ➢ The signals will be available on a CERN standard connector plug (12 pins).

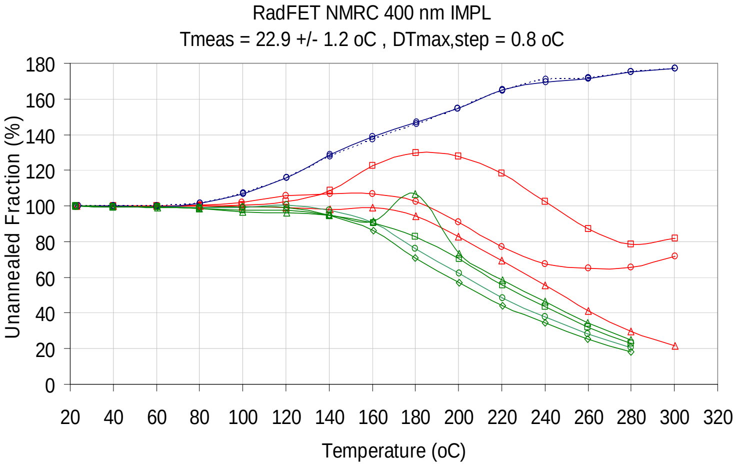
RadFETs Isochronal Annealing

Broad measurement campaign on all devices investigated for the “Sensor Catalogue”


RadFETs T&N 100P
Tmeas = 22.9 +/- 2 oC , DTmax,step = 4.8 oC


RadFETs REM501C 250/850 nm
Tmeas = 22.9 +/- 1.2 oC , DTmax,step = 0.8 oC


RadFET LAAS 1600 nm
Tmeas = 23.0 +/- 2.0 ºC , DTmax,step = 4.8 ºC


RadFET NMRC 400 nm IMPL
Tmeas = 22.9 +/- 1.2 oC , DTmax,step = 0.8 oC

More than 50 devices were investigated

Irradiation performed in 5 different radiation fields (n,p,γ)

Plots represent the un-annealed charge fraction vs. Temperature

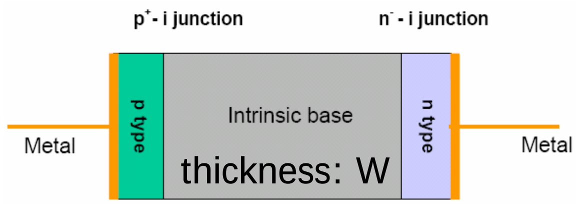
RadFETs Isochronal Annealing

- The different behaviour measured reveal differences in the fabrication processes;
- The correlation curve behaviours ⇔ microscopic phenomena in SiO_2 is under study;
- Some curve behaviours are very unusual and at the moment unexplained;
- First quantitative analysis based on the Un-annealed fraction (U_F):

Device Type	Package	Unusual behaviours	Temp. at which the $\lvert\Delta U_F\rvert < 20$ %	Equivalence in years of utilization at 30 ºC
LAAS 400 nm	die / DIL	present	240 ºC	~ 100 years
LAAS 1600 nm	**die / DIL**	**absent**	**300 ºC**	**> 10^4 years**
REM 250 nm	**die / DIL**	**absent**	**160 ºC**	**~ 1-10 years**
NMRC 400 nm IMPL	die / DIL	present	120 ºC	~ months
T&N 500 nm	DIL	absent	160 ºC	~ 1-10 years
T&N 250 nm	DIL	absent	220 ºC	> 10 years
T&N 100 nm	DIL	absent	220 ºC	> 10 years

The results confirm the choice done for the "Sensor Catalogue"

BPW34 Readout Optimization



In a *p-i-n* structure: $\Delta V_F = \Delta V_{F,junctions} + \Delta V_{F,base}$

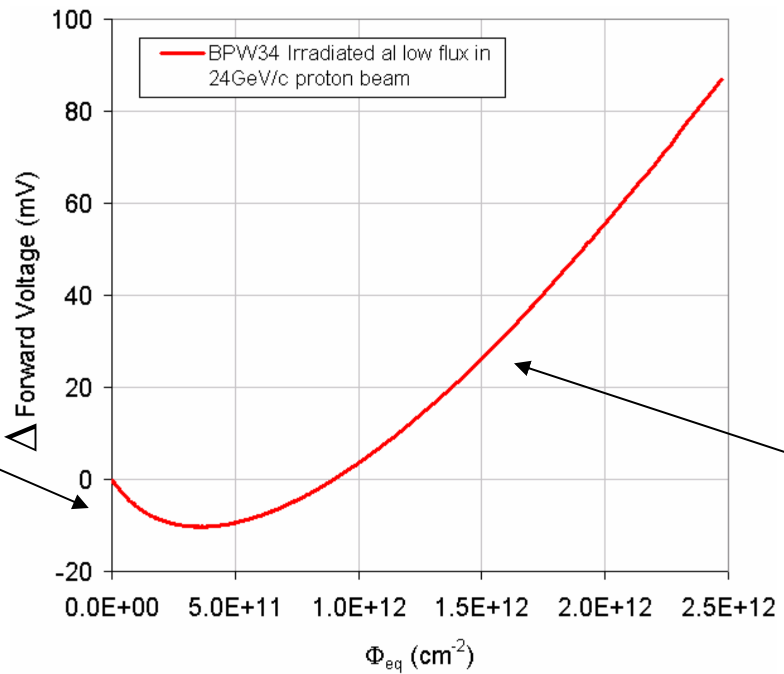
BPW34 behaviour of V_F under hadron irradiation follows the Swartz-Thurston theoretical study (1966) for a diode with low W/L ratio in conditions of intermediate injection (1 mA).

$\Delta V_F \approx \Delta V_{F,junct.}$

$\tau \downarrow$

$L \downarrow$

$V_{F,\ junct.} \propto L \downarrow$



W of a BPW34:

210 μm (ref.) - 320 μm (our meas.)

-vs.-

1 mm to 2.5 mm "dosimetric" diodes

$\Delta V_F \approx \Delta V_{F,base}$

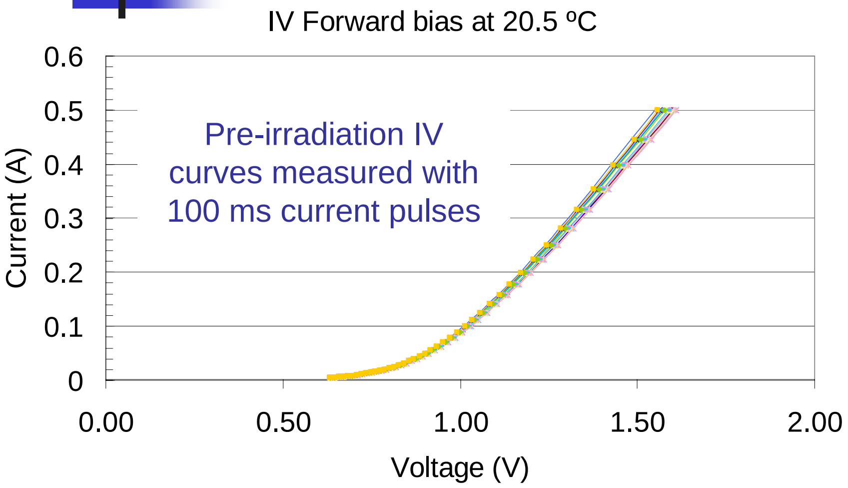
L continue to ↓

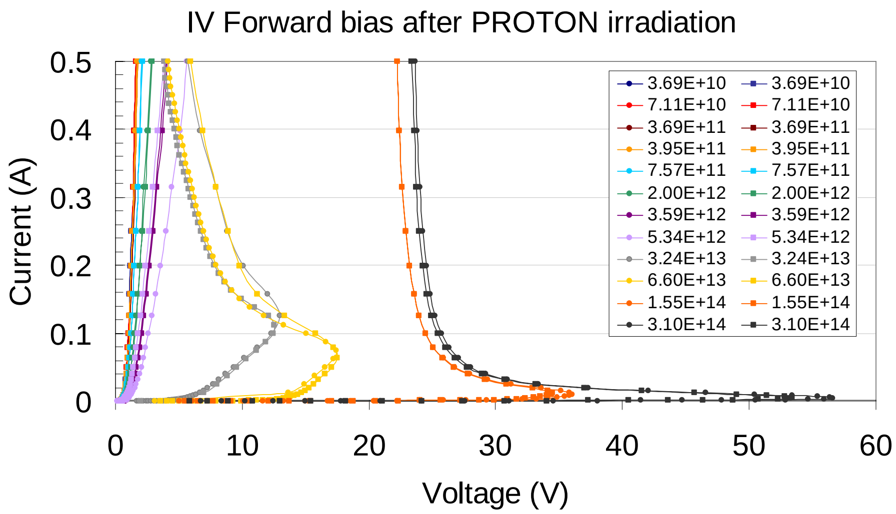
$V_{F,\ base} \propto W/L \uparrow$

and $\propto \rho_{base} \uparrow$

V_F = ƒ (~~material~~, ~~geometry~~, readout current density, pulse length)

BPW34 Readout Optimization

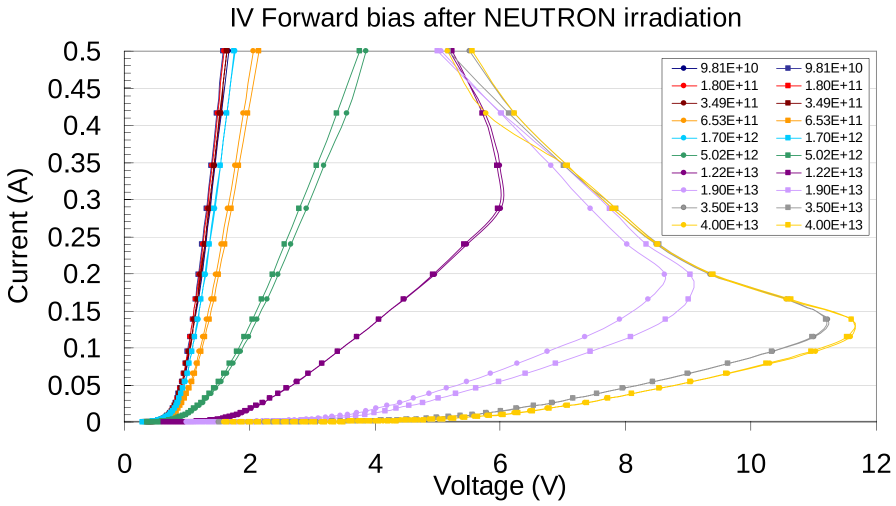

IV Forward bias at 20.5 ºC


IV Forward bias after PROTON irradiation

For $\Phi_{eq} > 2\text{-}3\times10^{13}\ \mathrm{cm}^{-2}$ → “thyristor - like” behaviour has been measured.

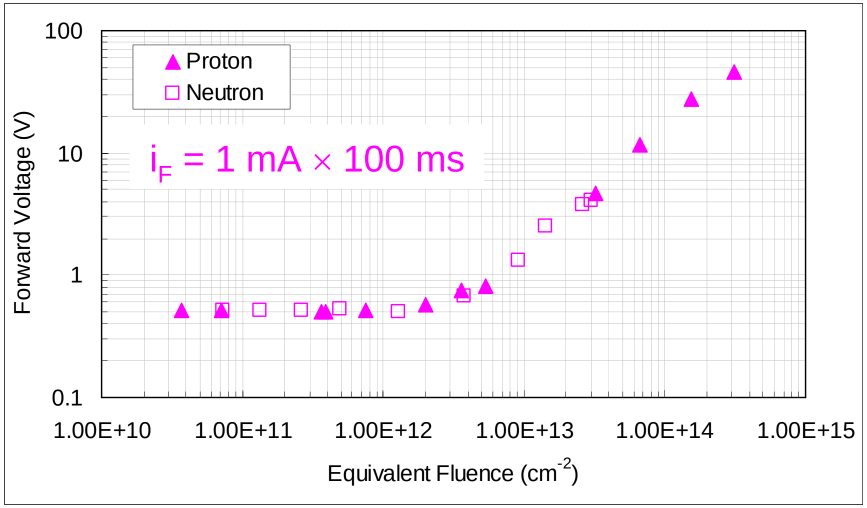
1. Real *p-n-p-n* induced by radiation ?
2. Strong thermal heating effect ?

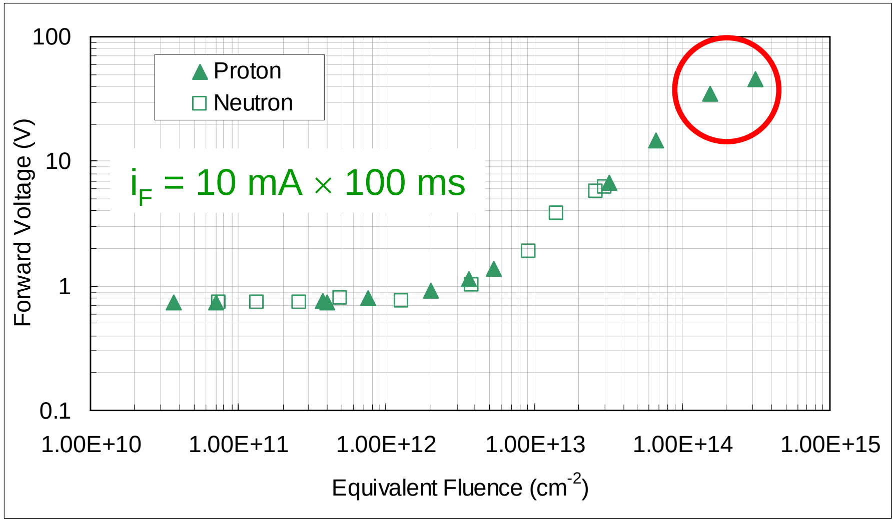
→ Keep I_F < 50 mA is a good precaution!

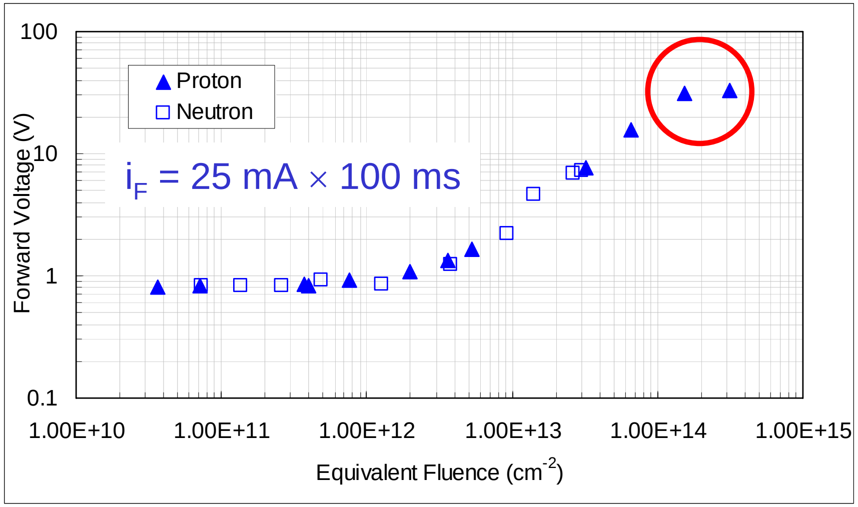

IV Forward bias after NEUTRON irradiation

BPW34 Readout Optimization

Injection Level


i_F = 1 mA × 100 ms


i_F = 10 mA × 100 ms


i_F = 25 mA × 100 ms

For $\Phi_{eq} < 2\times10^{12}$ cm^{-2}

→ Sensitivity increase negligible!

For $\Phi_{eq} > 2\times10^{12}$ cm^{-2}

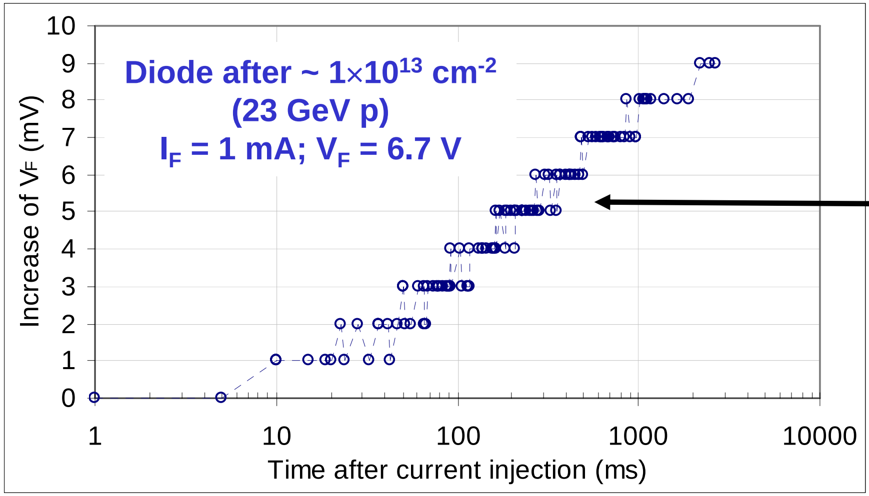
→ S (10 mA) > 14 % compared S (1 mA);

→ S (25 mA) > 36 % compared S (1 mA);

→ Saturation Φ_{eq} appear early.

BPW34 Readout Optimization

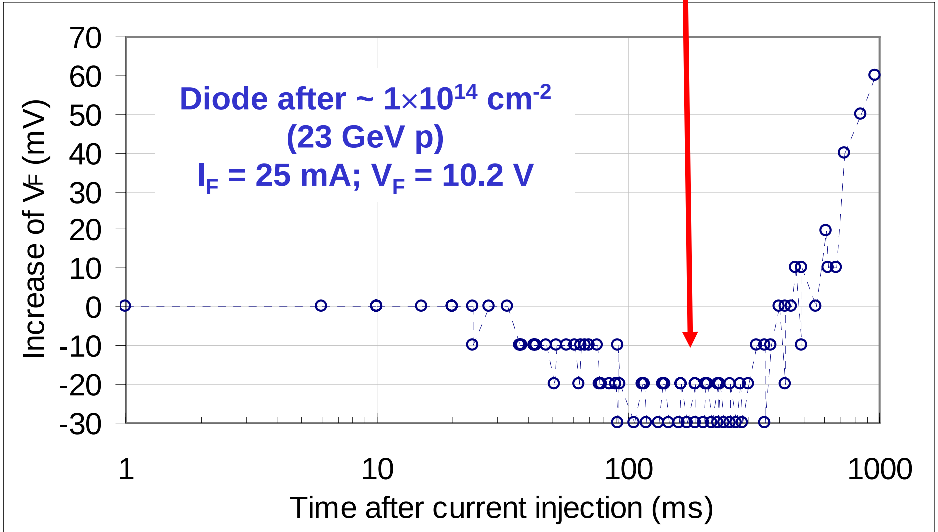
Forward current pulse length



Log behavior with *t* after current injection …

→ Probably border effects due to charge trapping in Si - SiO_2 and/or Si – metal.

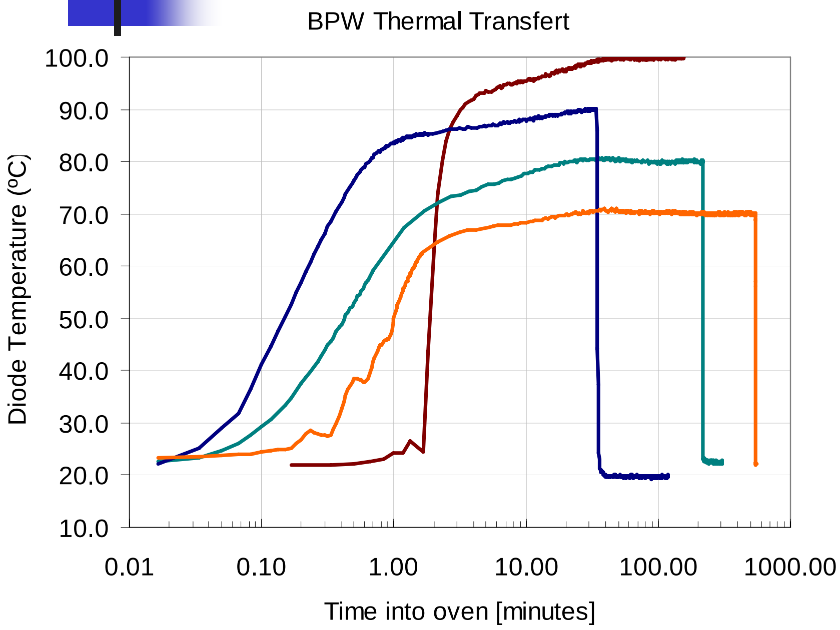
At high currents after high irradiation, heating effects are visible



Keep the readout-time ≤ 200 ms is advisable ($\varepsilon < 0.5$ %). An "optimized" pulse-length of 50 ms has been chosen for the following annealing tests.

BPW34 Readout Optimization

Annealing Studies 01



ANNEALING PROTOCOL

A. Diode dip in water at the annealing temperature;

B. Diode dip in water with melting ice for 10 s;

C. Diode in contact with a copper plate at RT for 1 min;

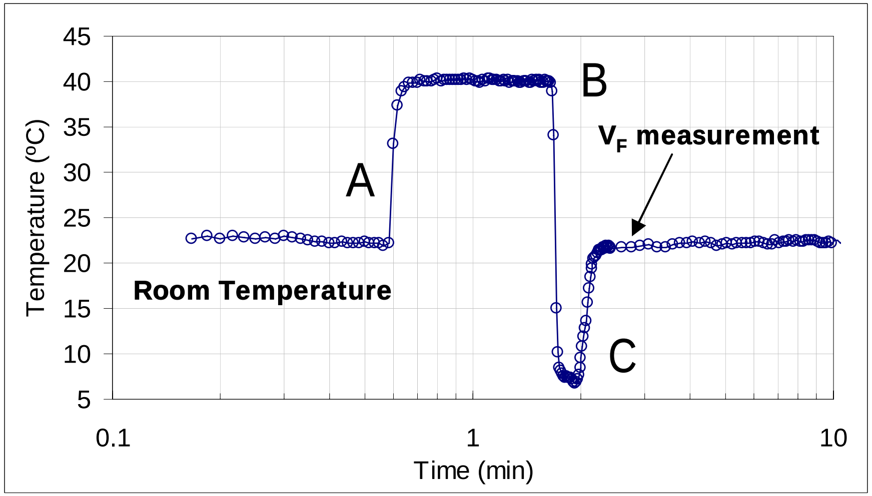
→ **Annealing Temperature reached in a few seconds**

Study of the thermal transfer thought the diode plastic package

→ Diode package in contact with metal plate at the wanted annealing temperature;

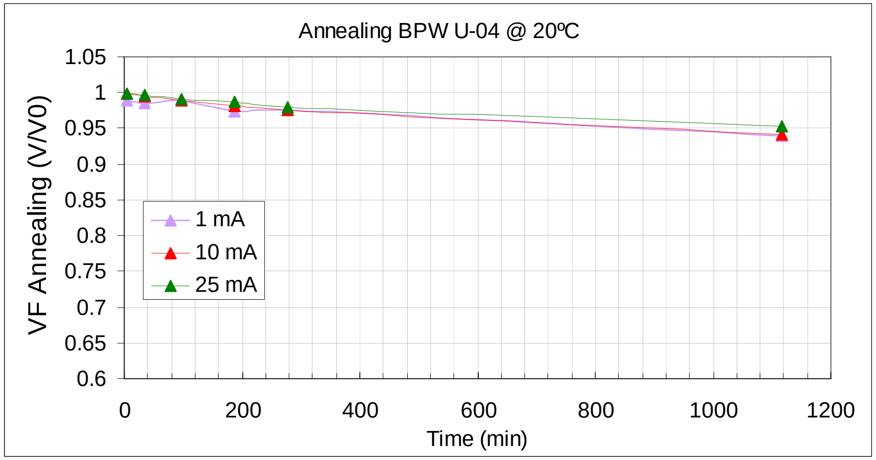
→ Readout on-line of V_F at 10 μA x 100 ms;

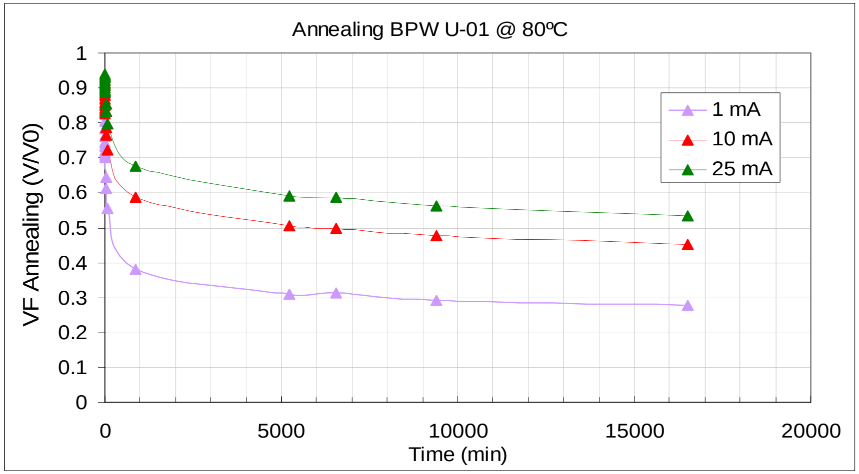
→ **The Si die needs 20-30 min to reach the wanted Temp.!**

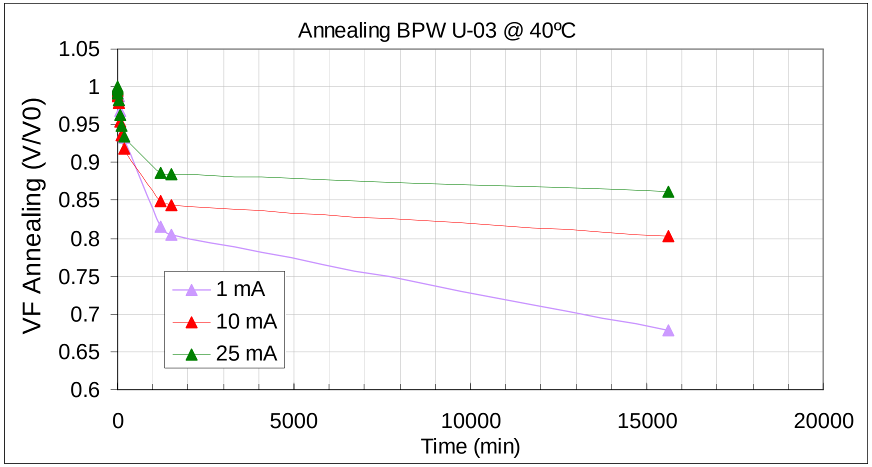


BPW34 Readout Optimization

Annealing Studies 02



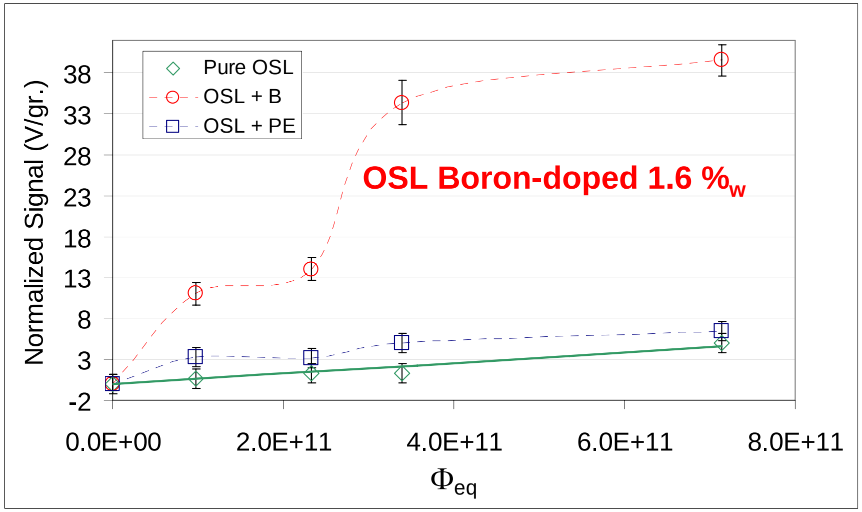




Diodes Irradiated to 1x10^{14} p/cm^{2} (24 GeV/c)

RELATIVE CHANGE OF THE VOLTAGE LESS SIGNIFICANT AT HIGH INJECTION LEVELS!

Neutron-sensitive OSLs



Repeated experiment on the "old" 2004 material shows a saturation-like behaviour for the samples doped with Boron

Sample sets sent to Ljubljana for neutron irradiation in JSI TRIGA reactor

New materials prepared by CEM^2 in 2005:

1. Raw OSL (< 50 μm)
2. OSL Boron-doped 0.2 %$_w$
3. OSL Boron-doped 0.4 %$_w$
4. OSL Boron-doped 0.8 %$_w$
5. OSL Boron-doped 1.18 %$_w$
6. OSL coated with ~ 60 μm Paraffin

More sophisticate Dosimetry made with ALANINE, TLDs, Si-detectors, films, etc.

New *p-i-n* diodes (LBSD) and detectors have been also irradiated in parallel.
→ Sensor Catalogue

Czech *p-i-n* diodes (LBSD)

Visit at the Long Base Silicon Diodes supplier factory (CMI, Prague) in July 2005


wafer


dies


wired diodes


encased diodes

Sensor annealing well investigated.

Two readout modes:

1. “on-line” → correcting for the fading in the data treatment;
2. “off-line” → performing thermal treatment (2 min in boiling water).

“recommended” I_F pulse for readout: 25 mA × 40 ms

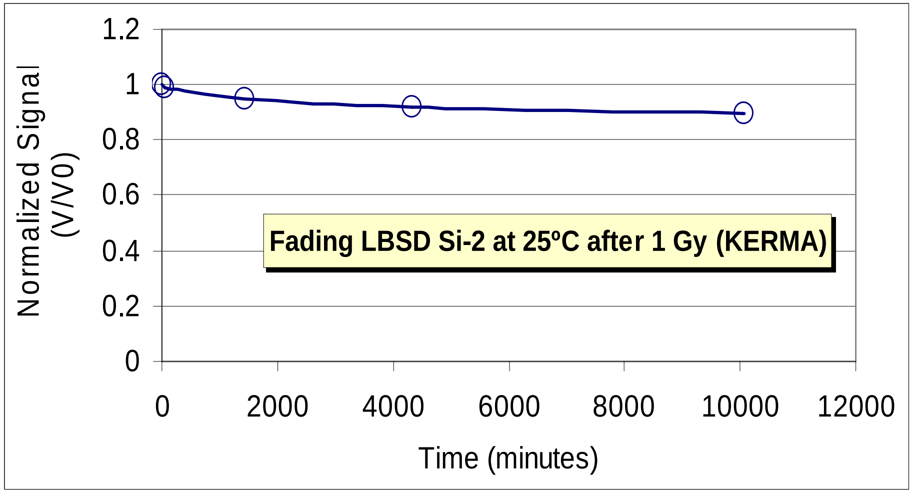
Type “Si-1”:

- KERMA: 0.1-30 Gy ($\Phi_{eq} \sim 1.2\text{x}10^{12}\ \text{cm}^{-2}$)
- n_F sensitivity: ~ 130 mV/Gy

Type “Si-2”:

- KERMA: 0.01-5 Gy ($\Phi_{eq} \sim 2\text{x}10^{11}\ \text{cm}^{-2}$)
- n_F sensitivity: ~ 1 V/Gy

γ sensitivity ~ 0.05 % n sensitivity


Fading LBSD Si-2 at 25ºC after 1 Gy (KERMA)

Conclusion

- All requested sensors are procured.
- Testing and Packaging/PCB under way;
- Started GEANT4 simulation for Packaging optimization;
- Isochronal Annealing studies for RadFETs finalized;
- BPW34 readout protocol fixed, Annealing studies at 3 injection levels well under way (first results presented);
- New series of n-sensitive OSL and LBSD under investigation;

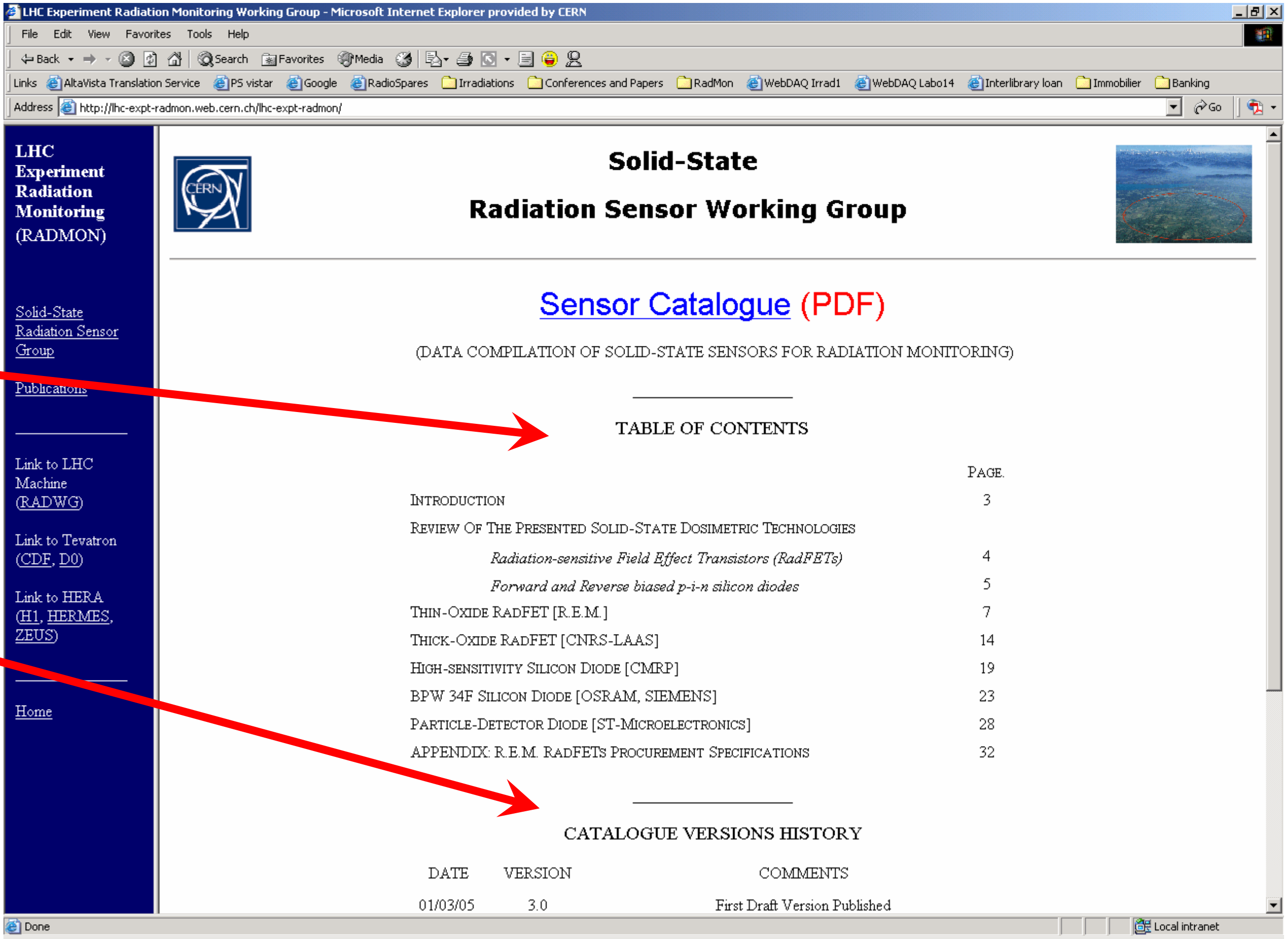
Sensor Catalogue

http://lhc-expt-radmon.web.cern.ch/lhc-expt-radmon/

Index of available sensors

Catalogue Updates

(last 27/06/05)



LHC Experiment Radiation Monitoring (RADMON)

Solid-State Radiation Sensor Group

Publications

Link to LHC Machine (RADWG)

Link to Tevatron (CDF, D0)

Link to HERA (H1, HERMES, ZEUS)

Home

Solid-State

Radiation Sensor Working Group

Sensor Catalogue (PDF)

(DATA COMPILATION OF SOLID-STATE SENSORS FOR RADIATION MONITORING)

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CATALOGUE VERSIONS HISTORY

DATE	VERSION	COMMENTS
01/03/05	3.0	First Draft Version Published

Experiments Sensor-Requirements

	Status	Thin Oxide FETs	Thick Oxide FETs	High Sensitivity p-i-n	BPW 34 p-i-n	Si-Detector p-i-n
ALICE	March 2005	10	20	30	0	0
ATLAS	February 2005	36 [ID] (18+18)	100 [RoA]	36 [ID] 100 [RoA]	20 [ID]	0
CMS	March 2005	a few ?	a few ?	a few ?	/	/
LHCb	March 2005	30	30	50	30	0
TOTEM	March 2005	A contact-person has been appointed				

[ID] = Inner Detector; [RoA] = Rest of Atlas