28th RD50 Workshop on radiation

Doping Profile Evaluation of neutron Irradiated structures

Evangelos – Leonidas Gkougkousis[1]

Abdenour Lounis[1,2], Clara Nellist[1]

- [1]Laboratoire de l'Accélérateur Linéaire
- [2]Universite Paris SUD

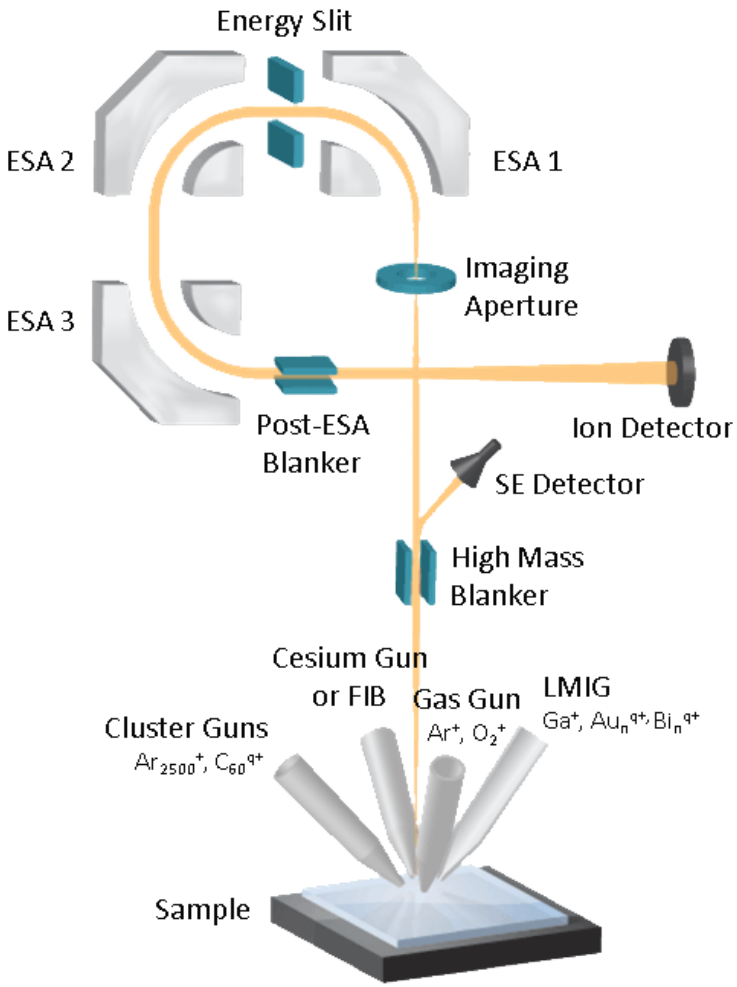
Torino – June 8, 2016

•Overview

- Introduction
  - SiMS Methodology and proton irradiated results
- Phosphorus test structures
  - CiS implanted structure
- Boron test Structures
  - The B→Li neutron capture
  - ADVACAM implanted structures
- Irradiated LGAD doping profile
  - Test structure definition
  - C-Stop evaluation under neutron irradiation
- Conclusion

• Introduction

Secondary Ion Mass Spectroscopy (SiMS)



- ✓ Analytical technique to characterize near surface layers (10μm)
- ✓ Primary ion beam sputter material off target
- ✓ Concentration resolution up to 10^{13} atoms/cm^3
- ✓ Depth resolution down to 5nm
- ✓ Total dopant profile
- ✓ Destructive method

Principles

GEMAC Versailles

•Introduction

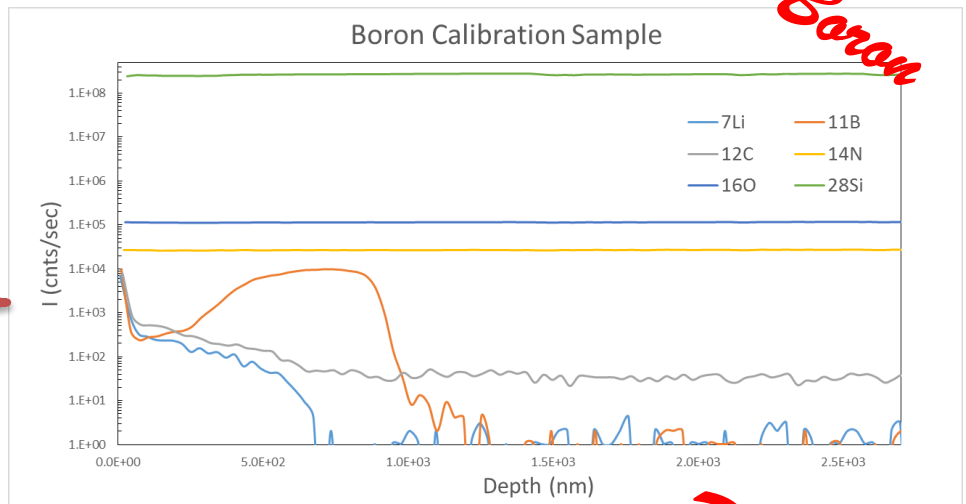
Secondary Ion mass Spectrometry Calibration

Relative Sensitivity Factor

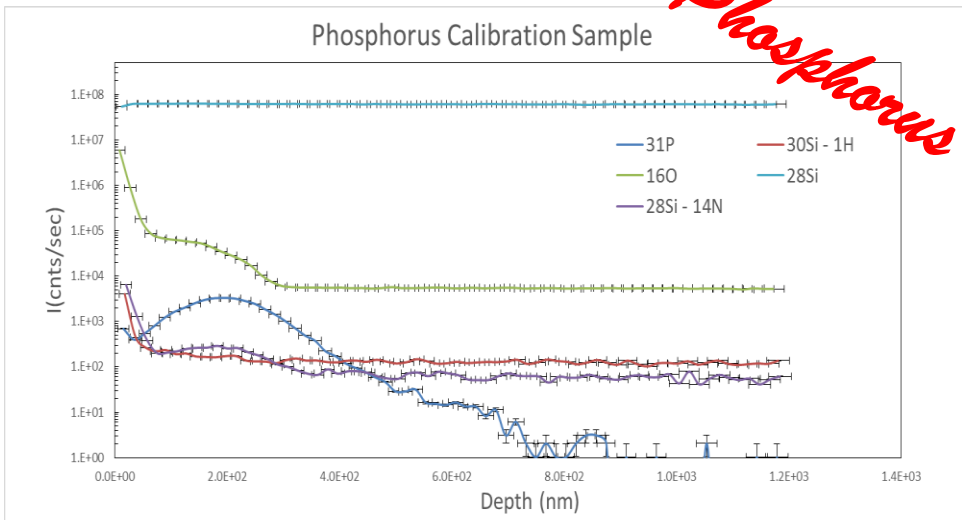
- ✓ Calculated in each measurement campaign
- ✓ Converts measured current to absolute concentration
- ✓ Estimated using specific calibration targets
- ✓ Crucial to calculate total implanted dose

RSF Estimation		RSF (atoms/cm³) Individual	RSF (atoms/cm³) Mean	δRSF
Phosphorus	1st	9.91E+22	9.88E+22	5.08E+21
	2nd	9.84E+22		
Boron	1st	6.02E+22	6.17E+22	3.70E+21
	2nd	6.31E+22		

Boron



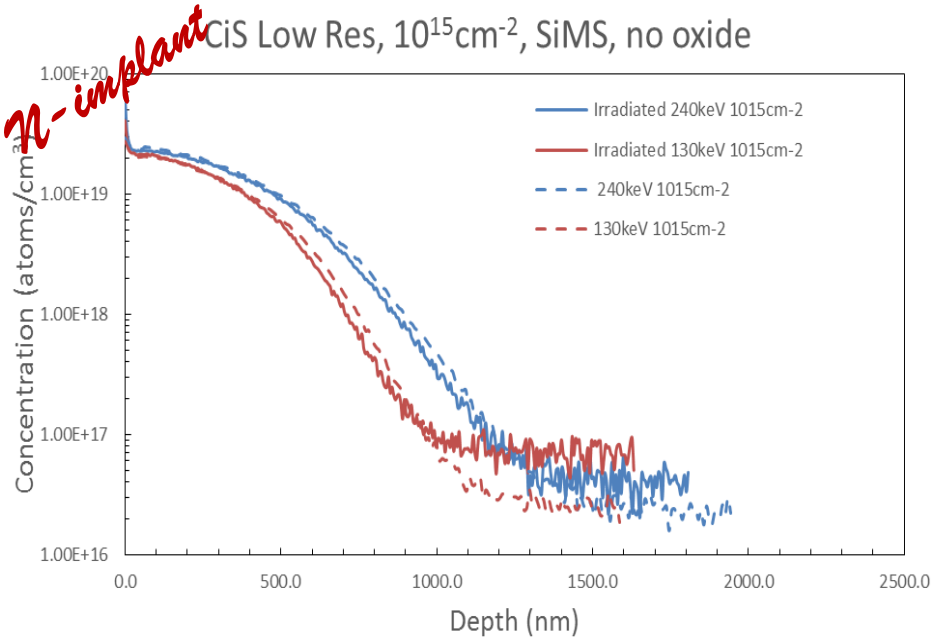
Phosphorus

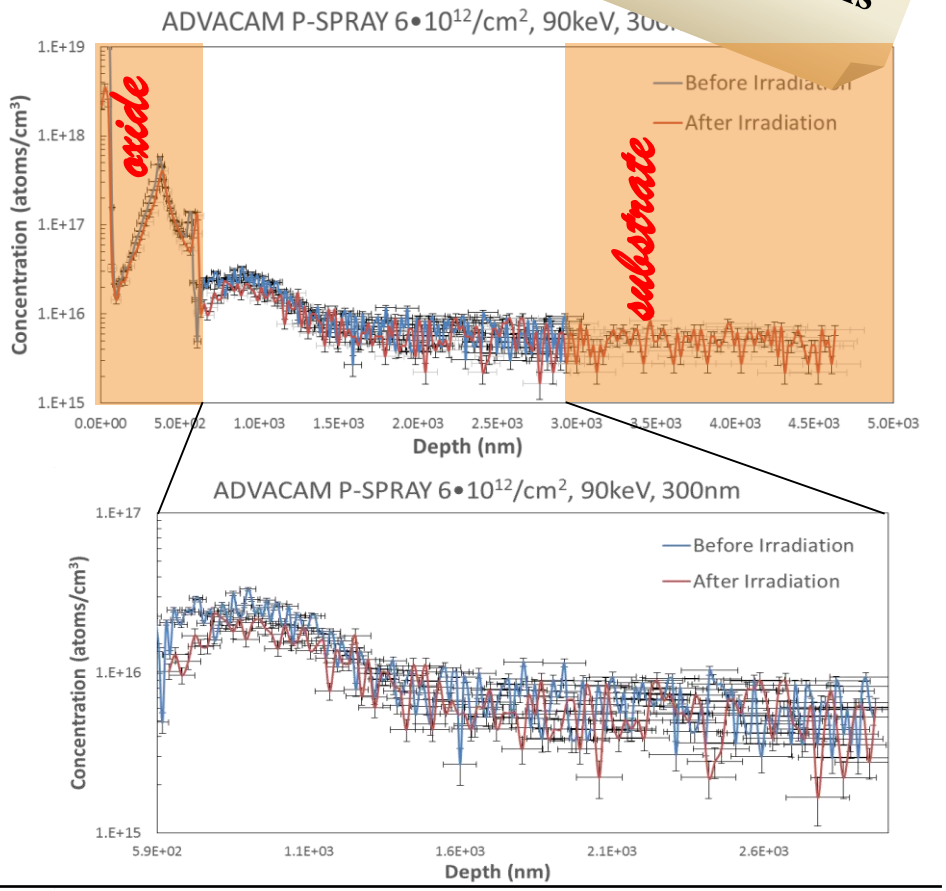


• Introduction

Proton irradiated profiles

10^{16} N_{eq}/cm^2 @ 23MeV protons





- No alteration for phosphorus implanted samples
- Indications for reduction of total implant in boron implanted samples

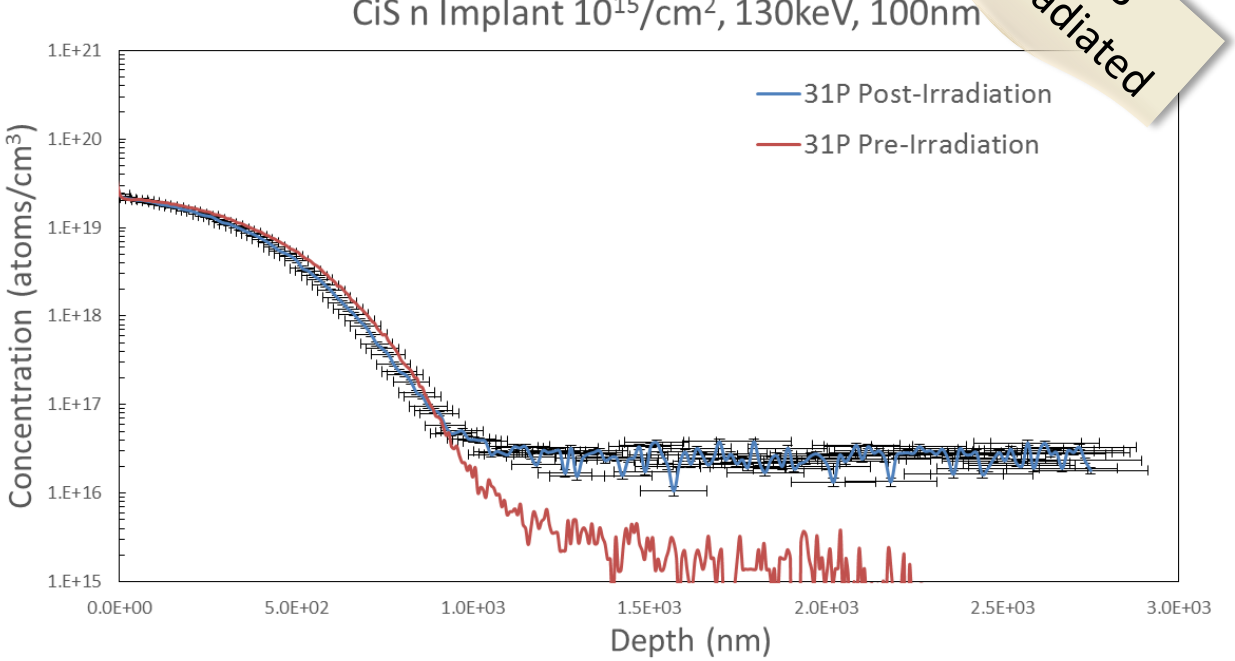
Implanted Dose	6×10^{12} atoms/cm_2, 90keV, 300nm	
	Before Irradiation	After Irradiation
atoms/cm^3	1.39 ± 0.62	0.987 ± 0.471

•Phosphorus Test structures

Cis n-in-n $10^{15}/cm^2$ @130keV

- ✓ Fluence of 10^{16} n_{eq}/cm^2
- ✓ Thermal neutrons
- ✓ Cooled during storage and transport

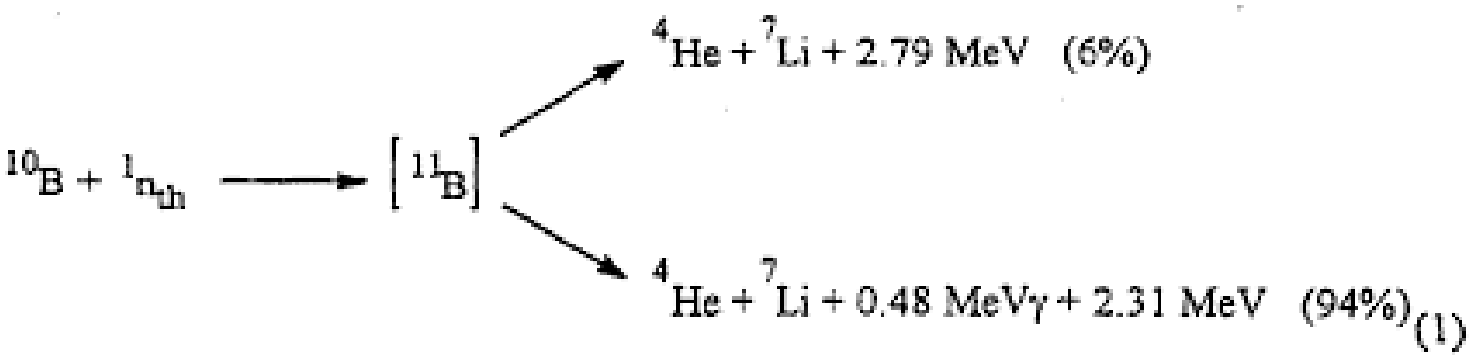
JIS Irradiated



- The bopping profile o the neutron irradiated samples seems unaffected
- Agreement within uncertainties
- Higher detection limit due to timing constraints induces deviations at lower part of the profiles

•Boron test structures

The B→Li Neutron capture

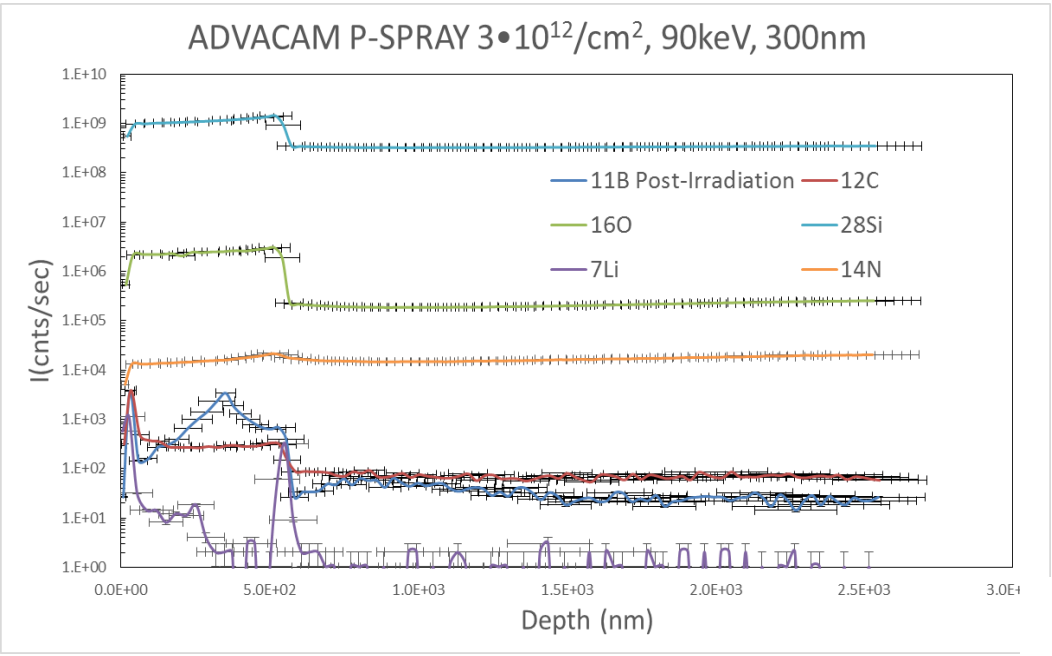


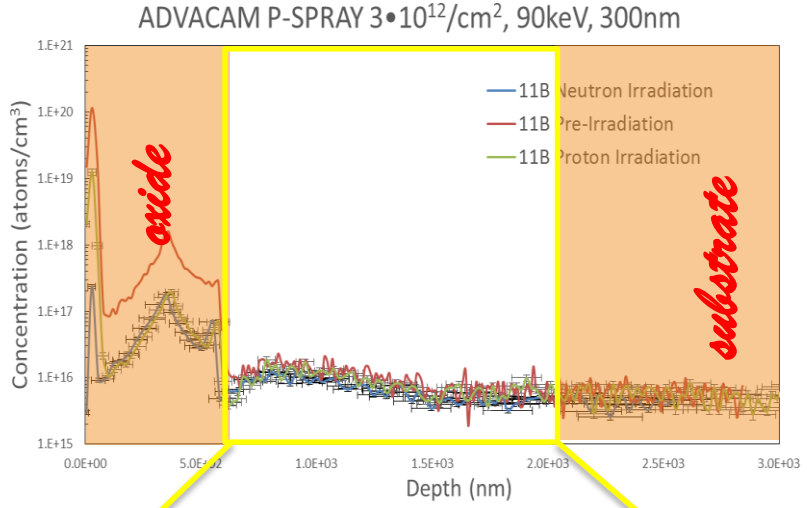
- Boron neutron capture with thermal neutrons
- Well known reaction in medical physics
- Used for cancer detection in brain tumor cases
- Very low expected cross-section

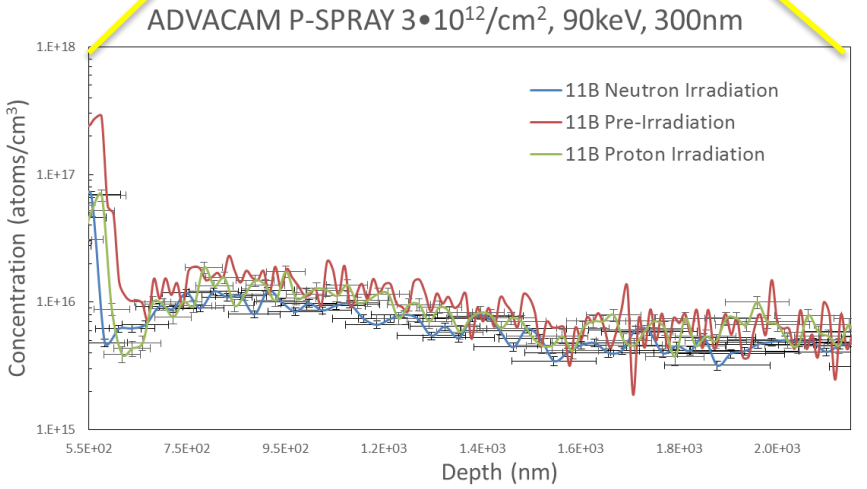
•Boron test structures

10^{16} N_{eq}/cm^2 @ thermal neutrons

ADVACAM implanted structures





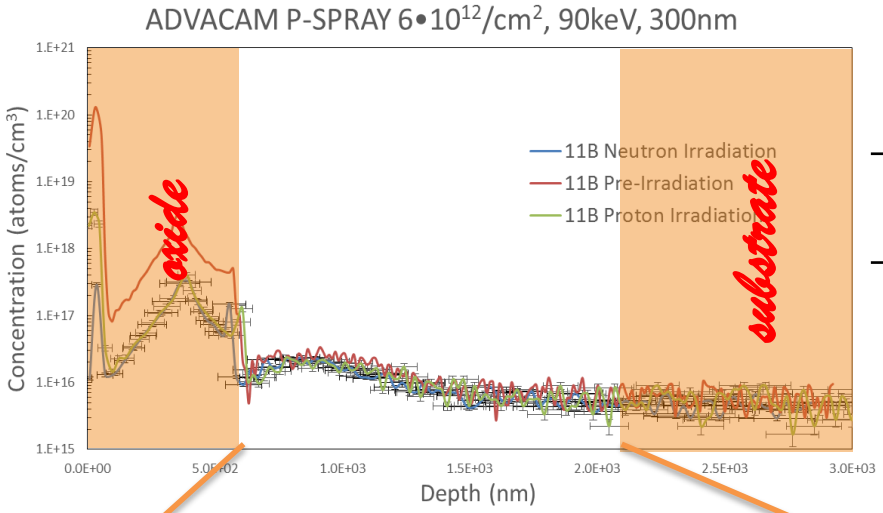


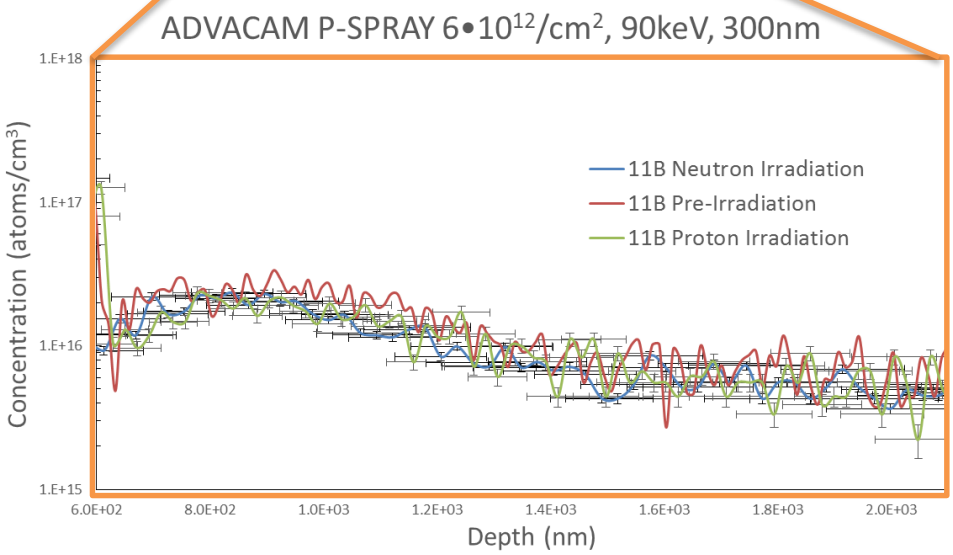
Integrated Dose	3×10^{12} atoms/cm^2, 90keV, 300nm		
	Before Irradiation	After proton Irradiation	After neutron Irradiation
10^{12} atoms/cm^2	1.78 ± 0.97	1.19 ± 0.75	1.19± 0.60

•Boron test structures

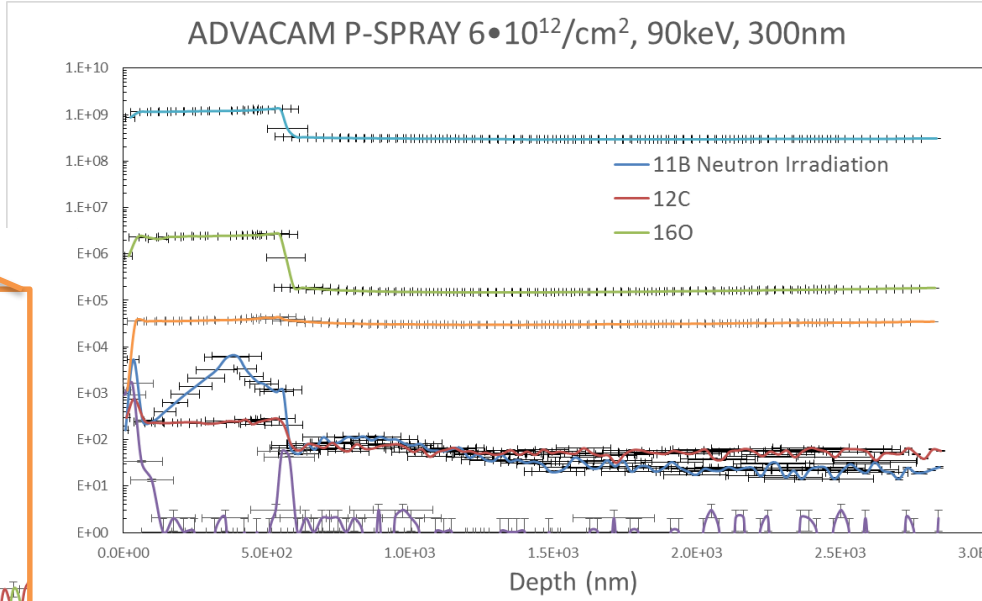
ADVACAM implanted structures

10^{16} N_{eq}/cm^2 @ thermal neutrons





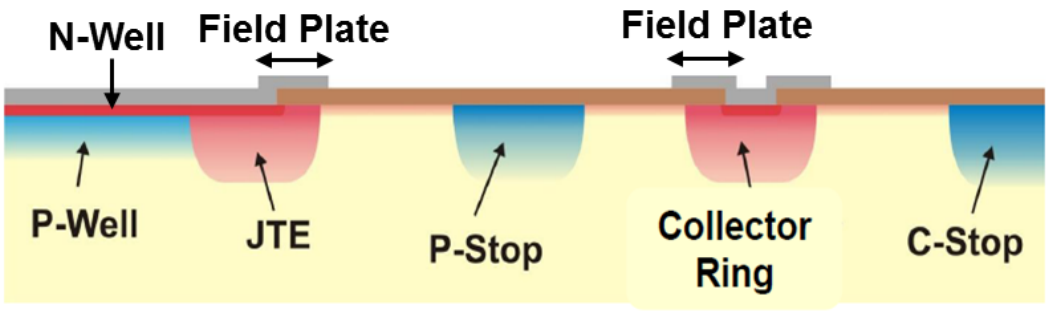
Integrated Dose	6×10^{12} atoms/cm^2, 90keV, 300nm		
	Before Irradiation	After proton Irradiation	After neutron Irradiation
10^{12} atoms/cm^2	2.47 ± 0.52	1.91 ± 0.75	1.91 ± 0.96



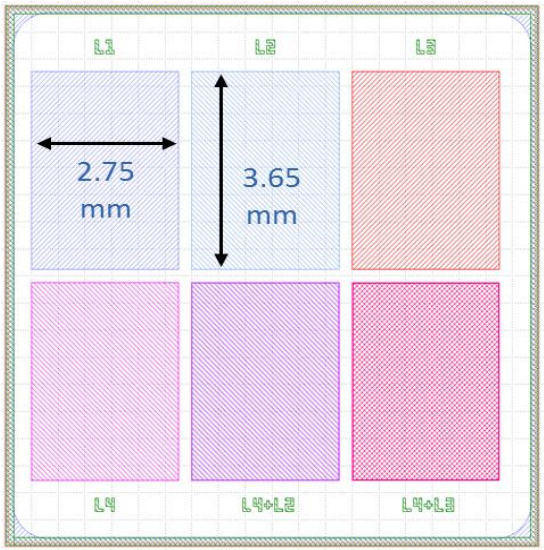
• LGAD Irradiated doping profile

Test structure and regions

- Goal: production process evaluation
- Test structure with six distinct regions
- Different doping parameters per regions
- Comparison with simulations



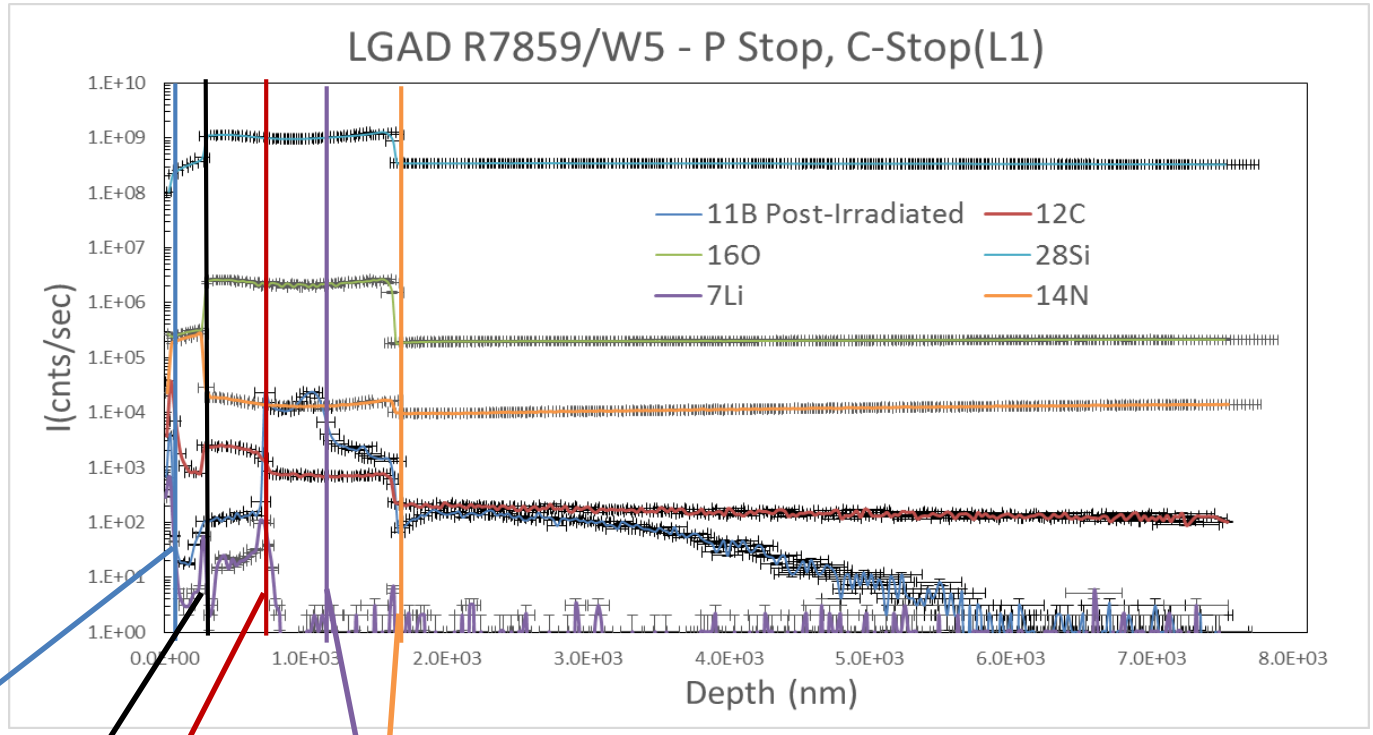
- L1 P-Stop, C-Stop Well
- L2 P-Well (P Multiplication)
- L3 JTE
- L4 N-Well
- L4 + L2 N-Well over P-Well
- L4 + L3 N-Well over JTE



• Irradiated LGAD doping Profile

LGAD Measurements, C-Stop (L1) - Boron

$2 \cdot 10^{15}\ N_{eq}/cm^2$ @ thermal neutrons



SiMS Metal Layer

Screen Oxide

Nitride Passivation

Latter thermal Oxide

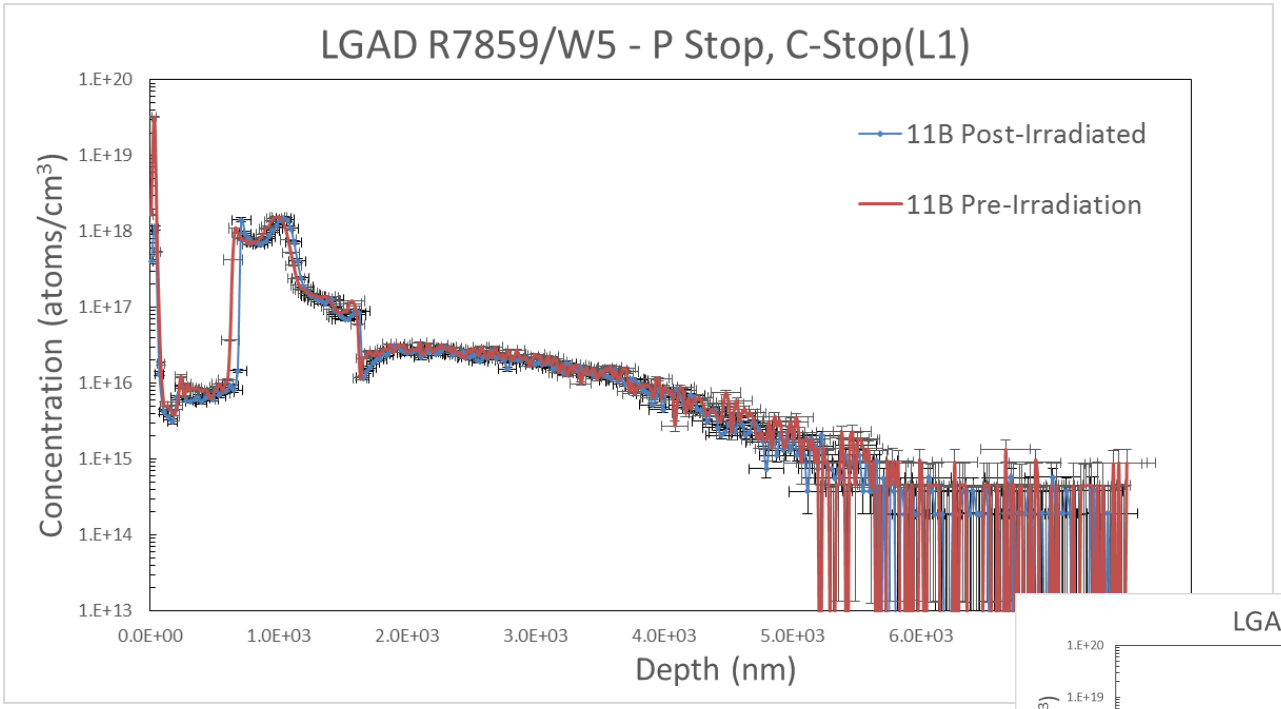
Layer	Thickness (nm)	Ion Velocity (nm/sec)
Au	55 ± 6	2.8 ± 1.0
Si3N4 Passivation	223 ± 7	3.1 ± 0.6
Primary Si02	382 ± 9	2.4 ± 0.4
Post implantation SiO2	929 ± 7	2.6 ± 0.3
Silicon	6014 ±13	2.5 ± 0.1

- ✓ Presence of Li on the interface
- ✓ Only in traces and not within bulk

• Irradiated LGAD doping Profile

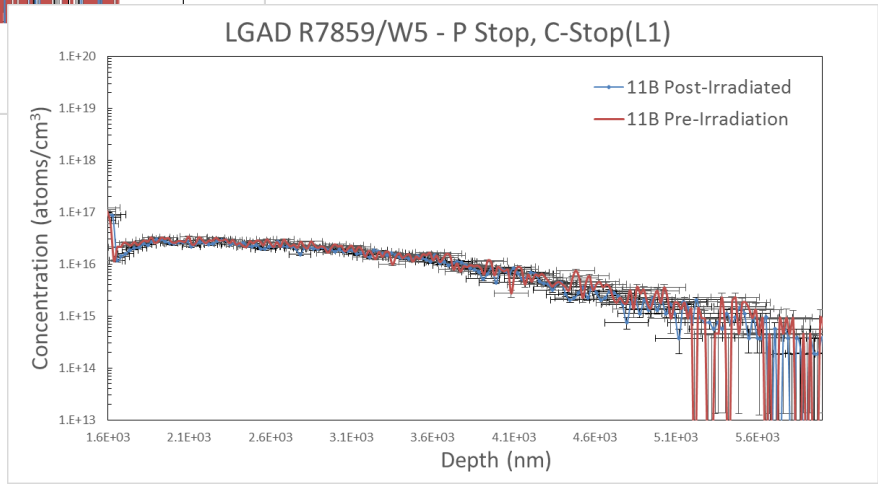
LGAD Measurements, C-Stop (L1) - Boron

$2 \cdot 10^{15}\ N_{eq}/cm^2$ @ thermal neutrons



- Same RSF definition
- Slightly different experimental conditions
- Faster abrasion and higher detection limit on irradiated profile

- No significant variation observed
- A systematic displacement is present in all profiles towards deeper regions but of no relation with irradiation



•Conclusions

Outcome and plans

- The evolution of the total doping profile with radiation has been studied
- Results with neutrons do not indicate any significant deviation from non-irradiated profiles
- Presence of Lithium has been detected but in significantly small quantities
- Any deviations from non-irradiated profiles can be attributed to experimenta effects and are of systematic nature.