Carrier lifetime variations in pion irradiated and annealed Si

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CERN

Outline

- Motivation
- Samples and anneals
- Measurement instrument and regimes
- Carrier lifetime profiling
- Carrier lifetime variation with fluence
- Comparison of characteristics of the pion, neutron and proton irradiated Si

Motivation

- To study carrier lifetime changes under pion irradiation and anneals in comparison with neutrons and protons
- To profile irradiation homogeneity by "pion beam"
- To test VUTEG-5-AIDA instrument installed at CERN

Samples and anneals

PION IRRADIATION RUN 2014 at PSI

12/05/2014 - 02/06/2014

The experimental hardness factor for 300 MeV/c pions is = 1.11

Due to the uncertainty on the hardness factor, the equivalent fluences shall be quoted with an error of +- 20 %

The Temperature during irradiation ranged from 25 ºC to 26.5 ºC

Many thanks to PSI for providing us this pion beam line.

Dear user please don't forget to add this acknowladgement note into your publications:

"This work was performed at the proton accelerator, Paul Scherrer Institut, Villigen, Switzerland."

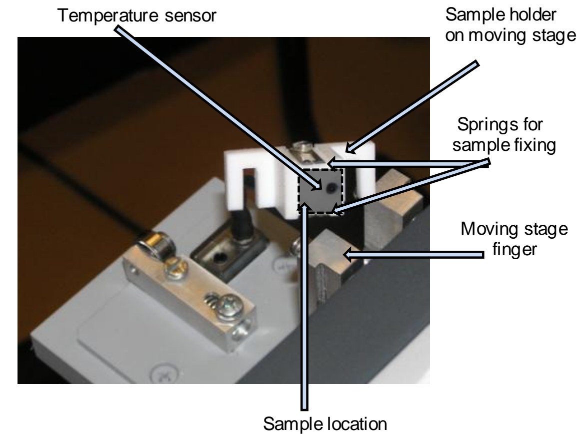
SET #	Sample ID	Comment	User	Req. Fluence [π/cm²]	Detector Size [mm x mm]	Time IN	Time OUT	Al #	Achieved Flu. [π/cm²]	Error [+/- %]
1907	AIDA 2012 - Cz-n and Fz-n		Vaiktus	1.00E+11	10x10	20/05/2014 16:12	20/05/2014 16:16	from SEC	1.34E+11	7
1908	AIDA 2012 - Cz-n and Fz-n		Vaiktus	3.00E+11	10x10	20/05/2014 16:12	20/05/2014 16:39	from SEC	2.74E+11	7
1909	AIDA 2012 - Cz-n and Fz-n		Vaiktus	1.00E+12	10x10	20/05/2014 16:12	20/05/2014 18:01	from SEC	7.68E+11	7
1910	AIDA 2012 - Cz-n and Fz-n		Vaiktus	3.00E+12	10x10	20/05/2014 16:12	20/05/2014 18:54	from SEC	2.41E+12	7
1911	AIDA 2012 - Cz-n and Fz-n		Vaiktus	1.00E+13	10x10	20/05/2014 16:12	21/05/2014 01:07	2951	1.07E+13	7
1912	AIDA 2012 - Cz-n and Fz-n		Vaiktus	3.00E+13	10x10	20/05/2014 16:12	21/05/2014 10:27	2952	3.70E+13	7
1913	AIDA 2012 - Cz-n and Fz-n		Vaiktus	1.00E+14	10x10	20/05/2014 16:12	23/05/2014 16:01	3003-3012-3013	1.00E+14	7
1914	AIDA 2012 - Cz-n and Fz-n		Vaiktus	3.00E+14	10x10	20/05/2014 10:22	26/05/2014 22:46	2982	1.71E+14	7
1915	AIDA 2012 - Cz-n and Fz-n		Vaiktus	1.00E+15	10x10	20/05/2014 10:22	02/06/2014 06:00	2980	4.26E+14	7
1916	AIDA 2012 - Cz-n and Fz-n	MAX	Vaiktus	3.00E+15	10x10	20/05/2014 10:22	02/06/2014 06:00	2953	5.12E+14	7

Samples: Cz and FZ Si wafer fragments of ~10×10 mm^2 with bare surfaces (native oxide)

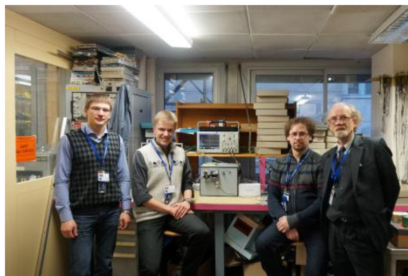
Isothermal anneals at T=80 C with $t_{T,\,exposure}=\Sigma_{n=1}^{7}\,[t_n+2t_{n-1}]$, t_1=4 min., $t_0=0$

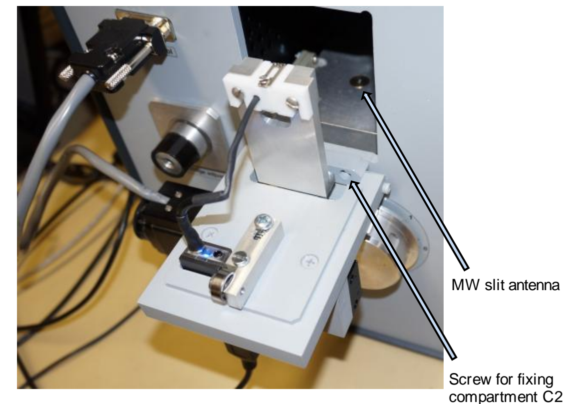
Measurement instrument and regimes

AIDA

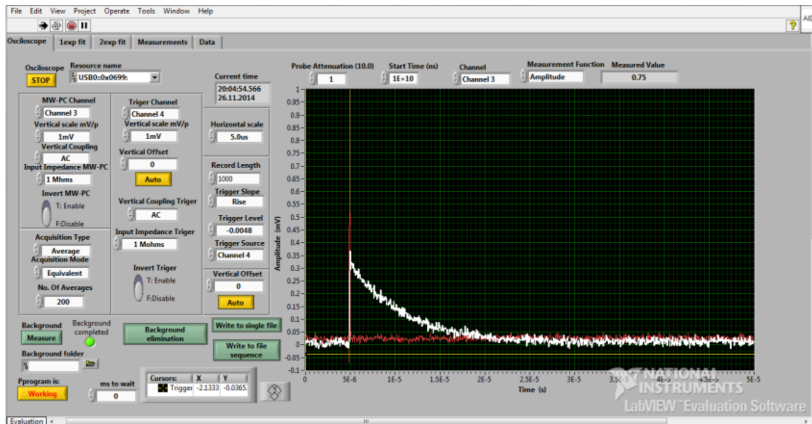


VUTEG-5-AIDA

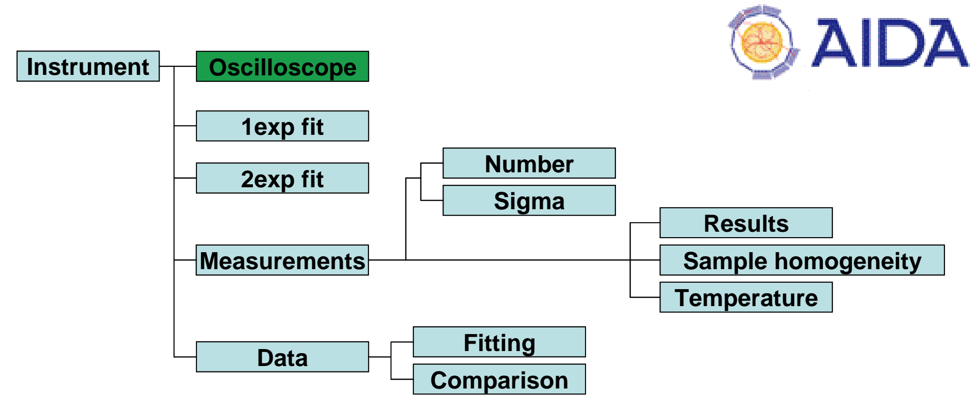


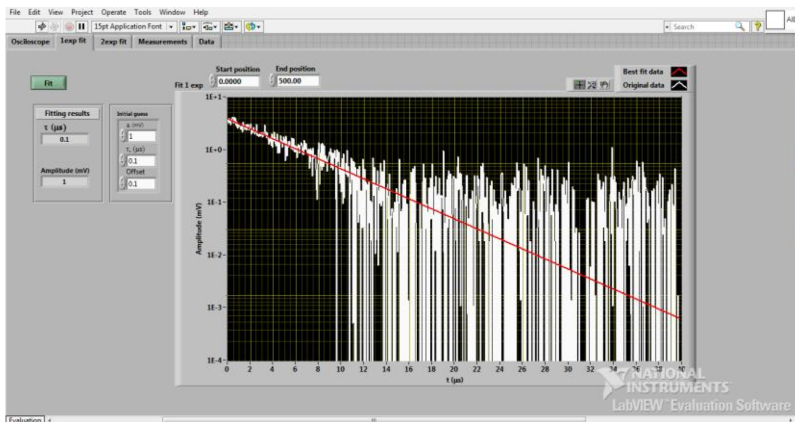


Measurement instrument and regimes

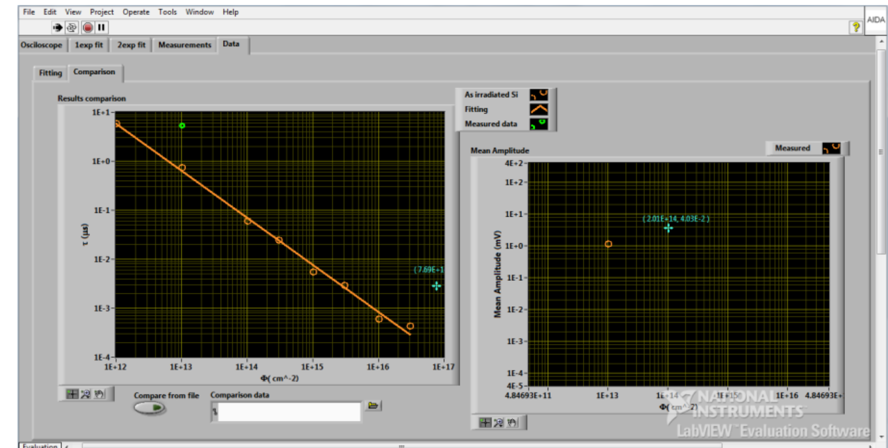


The main view of the window for oscilloscope control





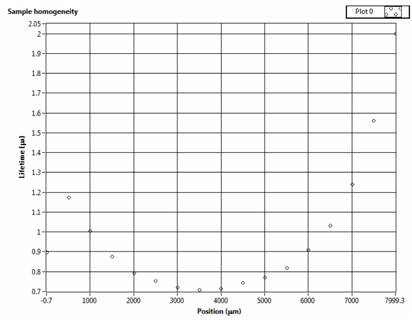
A general view of the window for the single exponential fitting

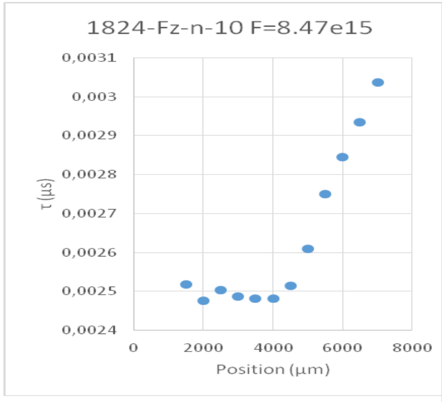


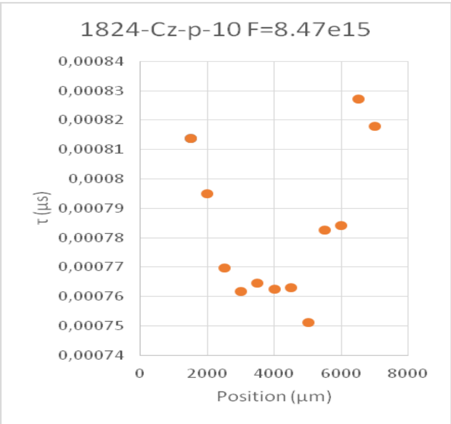
A general view of the "Data" window with displayed "Comparison" sub-window

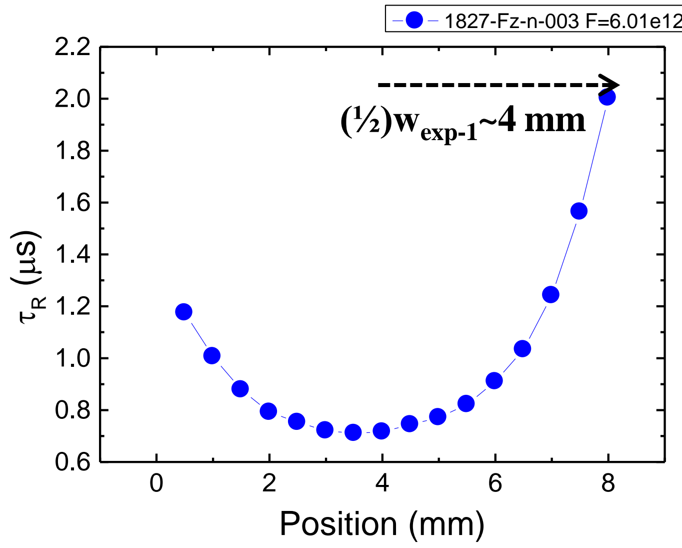
Carrier lifetime profiling

26 GeV/c protons

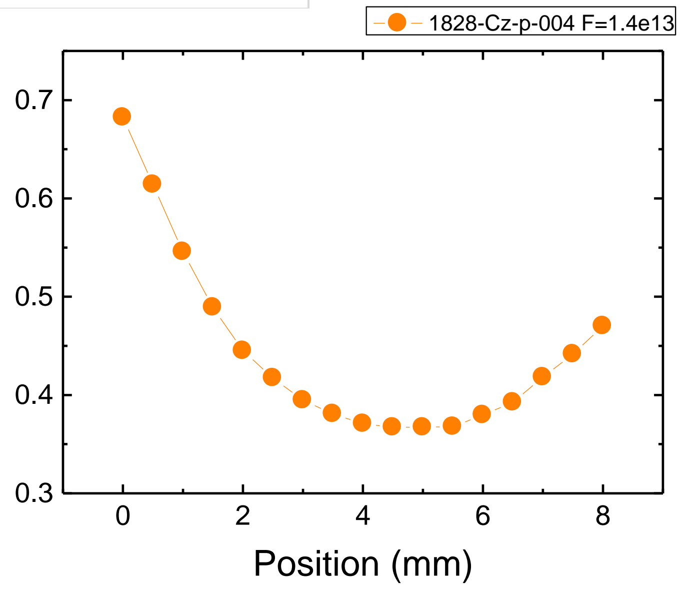






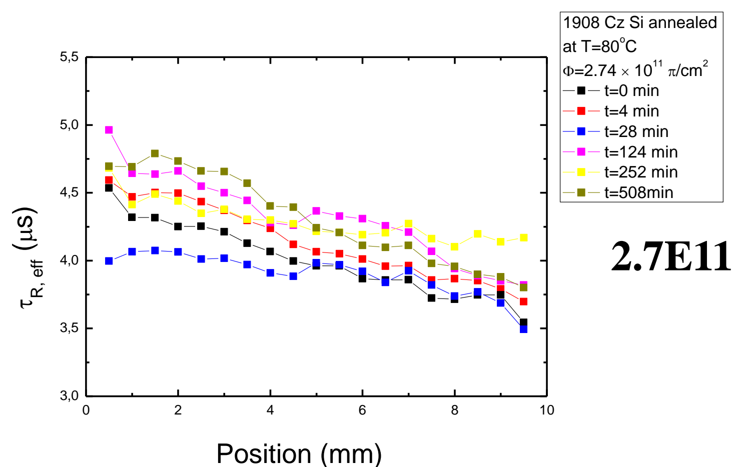


Rather significant lateral inhomogeneity within proton beam: lifetime value variation 2-3 times

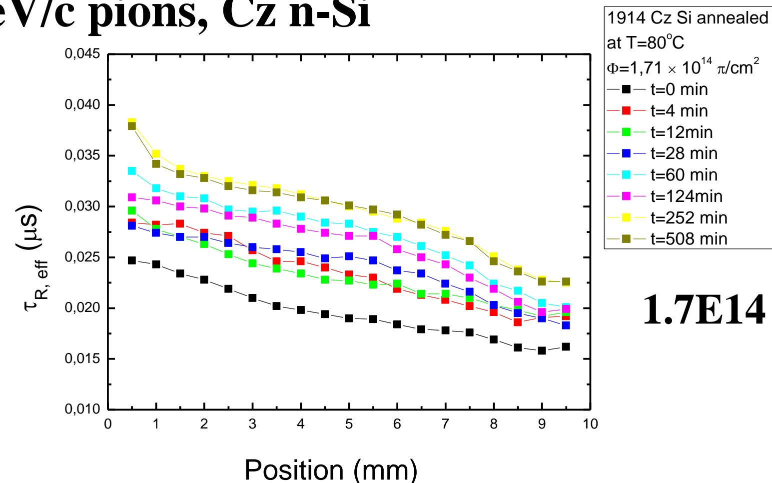


Carrier lifetime profiling

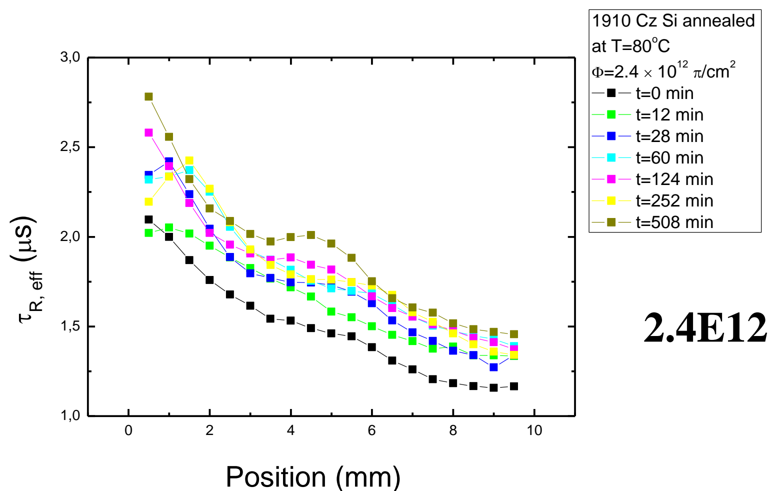
300 MeV/c pions, Cz n-Si



2.7E11

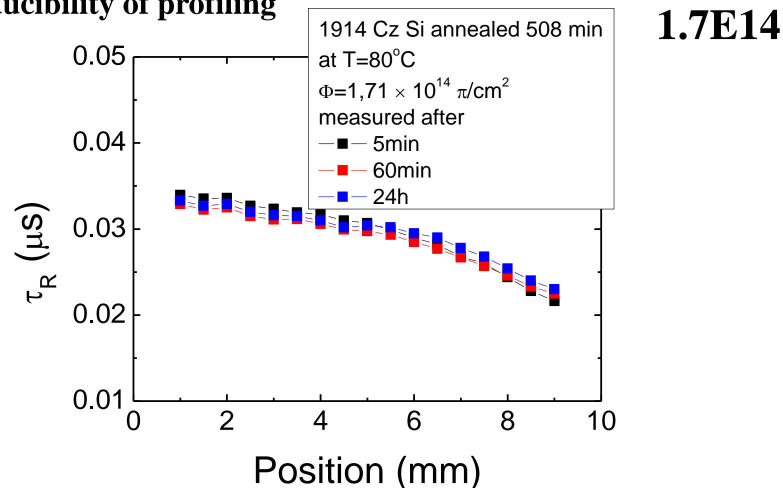


1.7E14



2.4E12

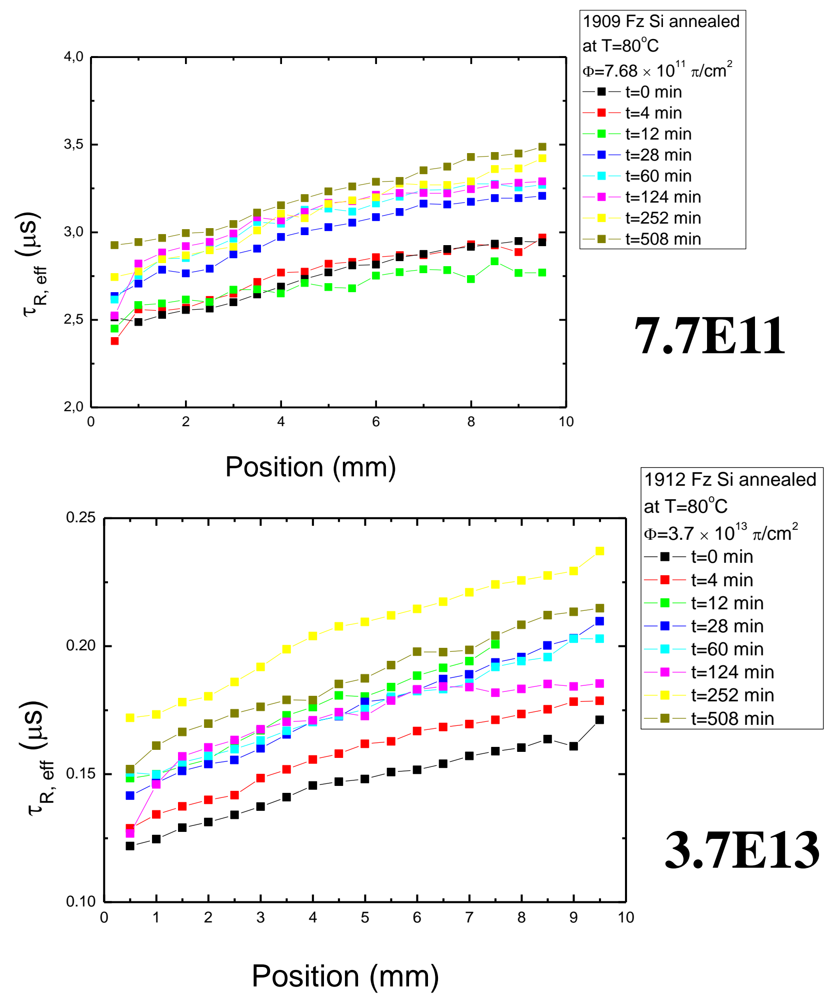
Reproducibility of profiling



1.7E14

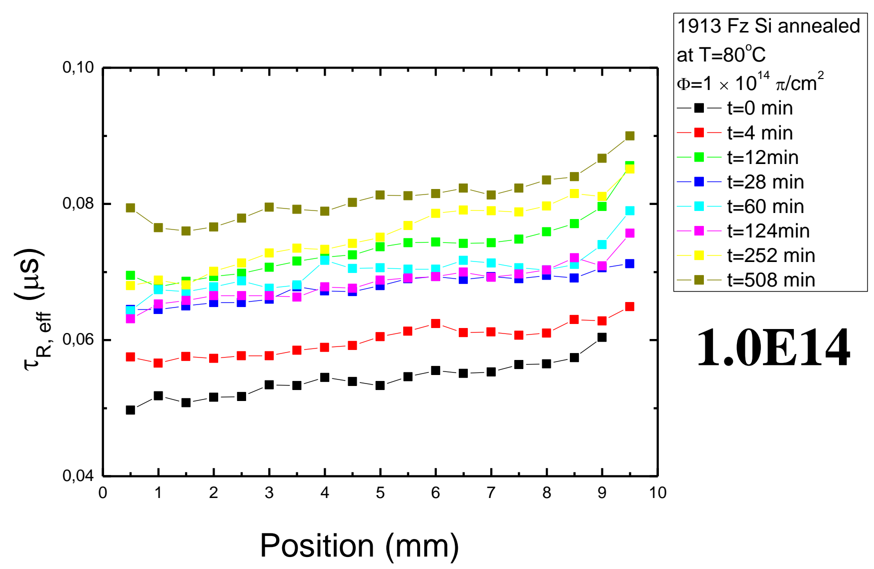
Carrier lifetime profiling

300 MeV/c pions, FZ n-Si



7.7E11

3.7E13

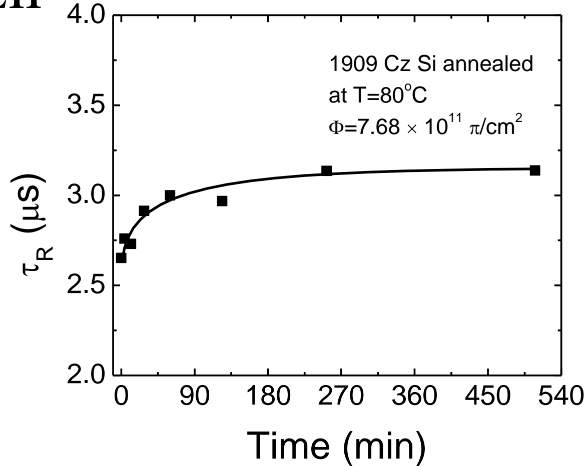


1.0E14

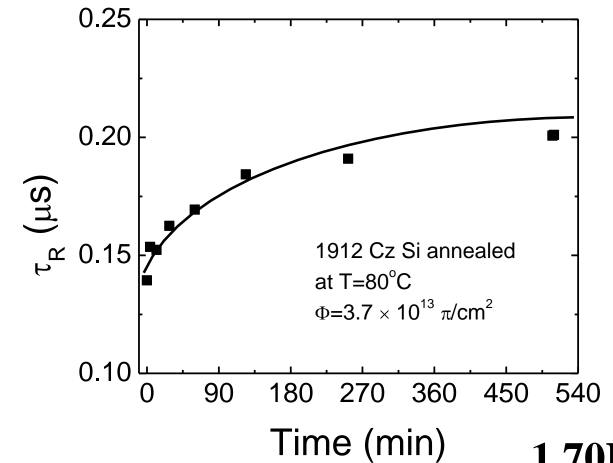
Carrier lifetime dependence on anneal exposure time

300 MeV pions, Cz n-Si

7.7E11



3.70E13

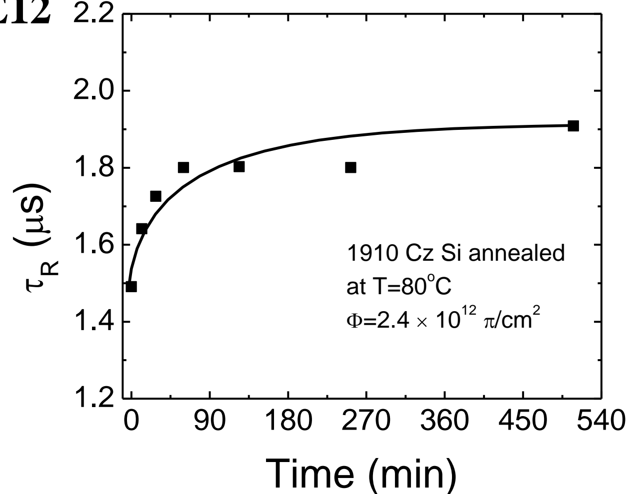


Averaged over profile

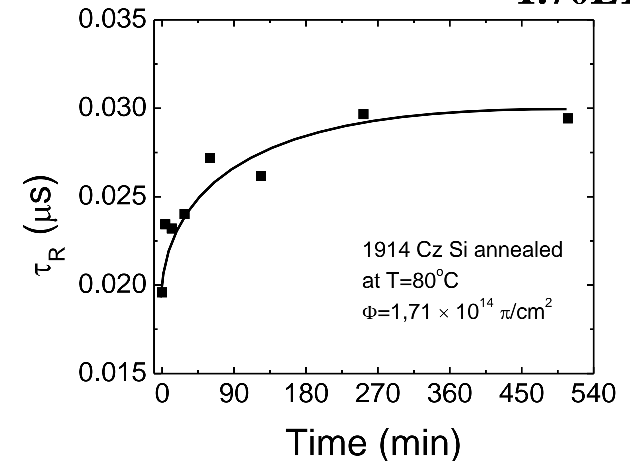
Lifetime increase ≤50 %

Saturation after ~ 90 min.

2.4E12



1.70E14

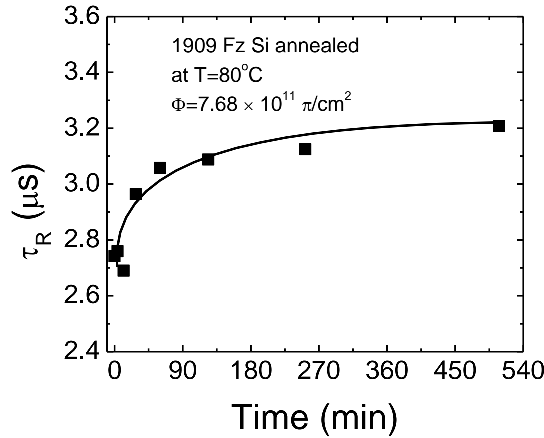


Carrier lifetime dependence on anneal exposure time

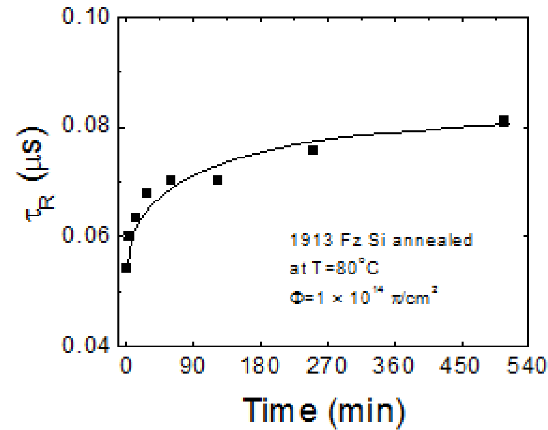
300 MeV/c pions, FZ n-Si

Averaged over profile

7.7E11



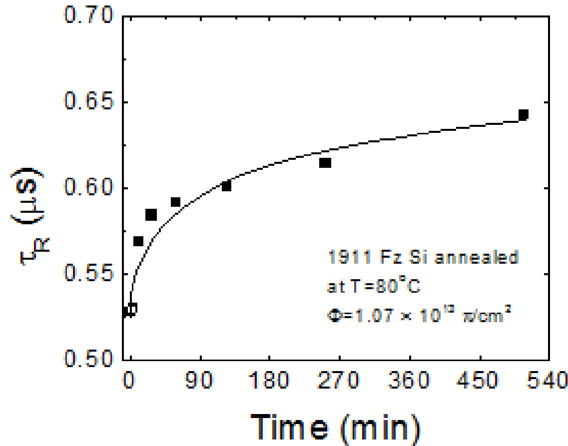
1.0E14



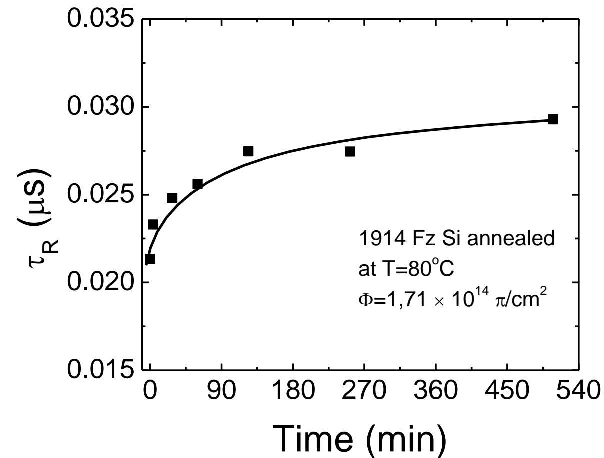
Lifetime increase ≤30 %

Saturation after ~ 90 min.

1.07E13

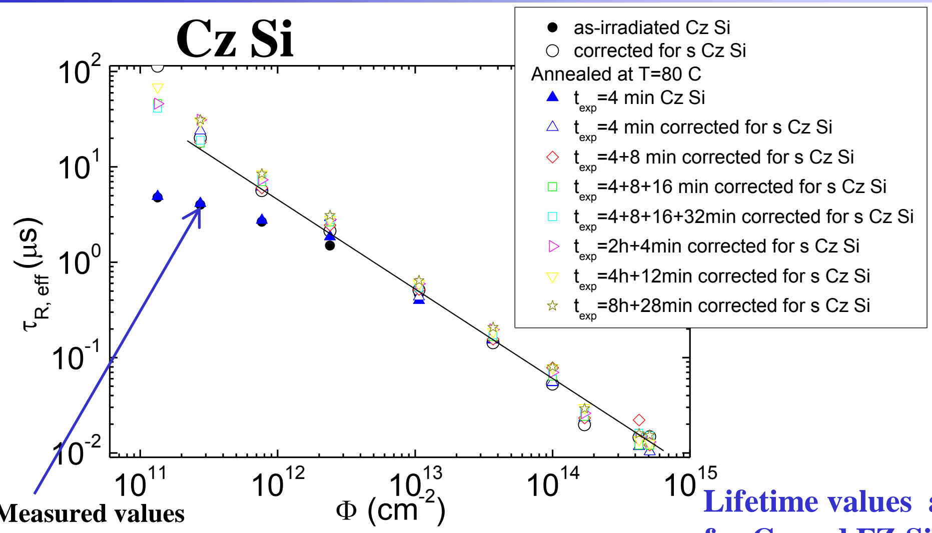


1.7E14

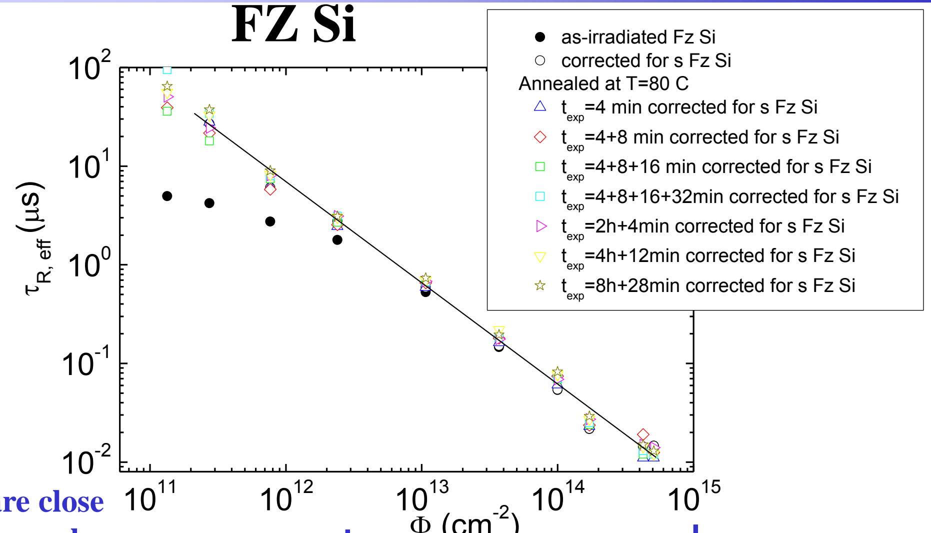


Carrier lifetime variation with fluence

Cz Si



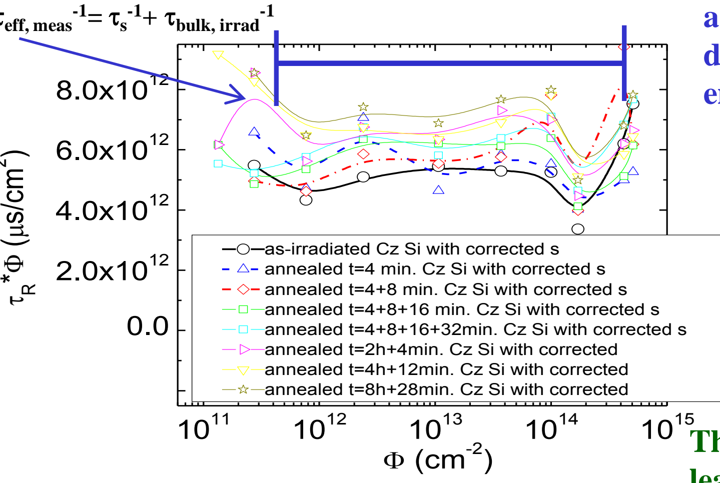
FZ Si



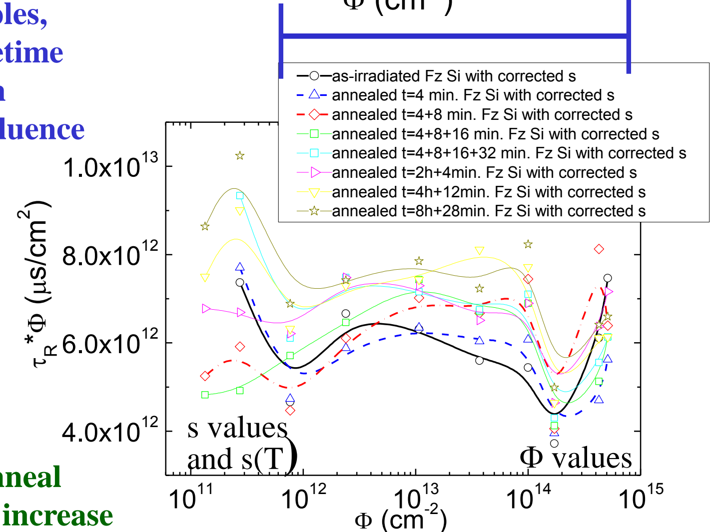
Measured values at low Φ:

$\tau_{eff,\,meas}^{-1} = \tau_s^{-1} + \tau_{bulk,\,irrad}^{-1}$

Lifetime values are close for Cz and FZ Si samples, and recombination lifetime decreases linearly with enhancement of pion fluence

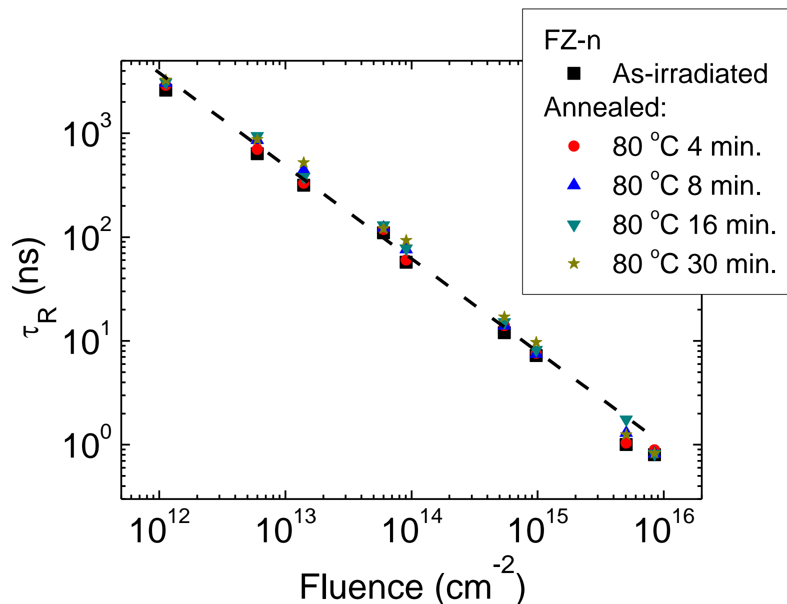


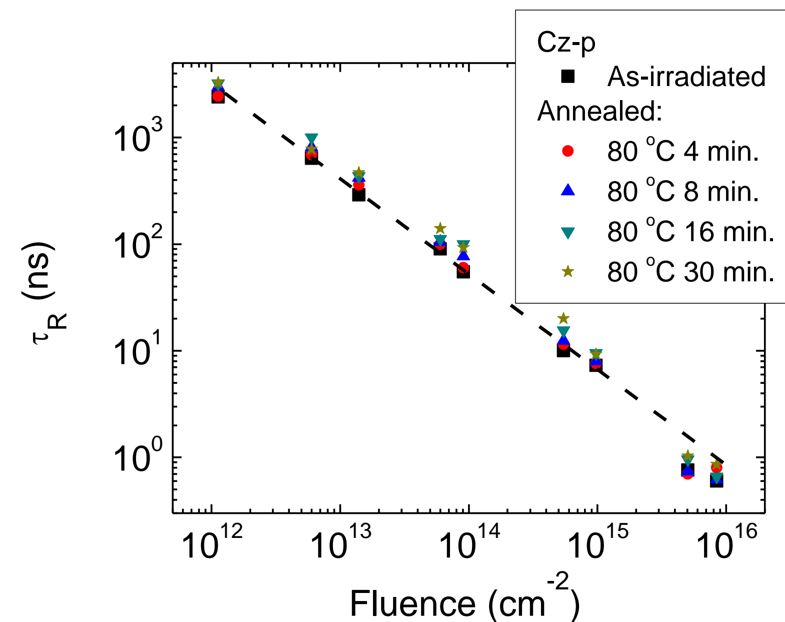
The longest 508 min. anneal leads to < 50% lifetime increase



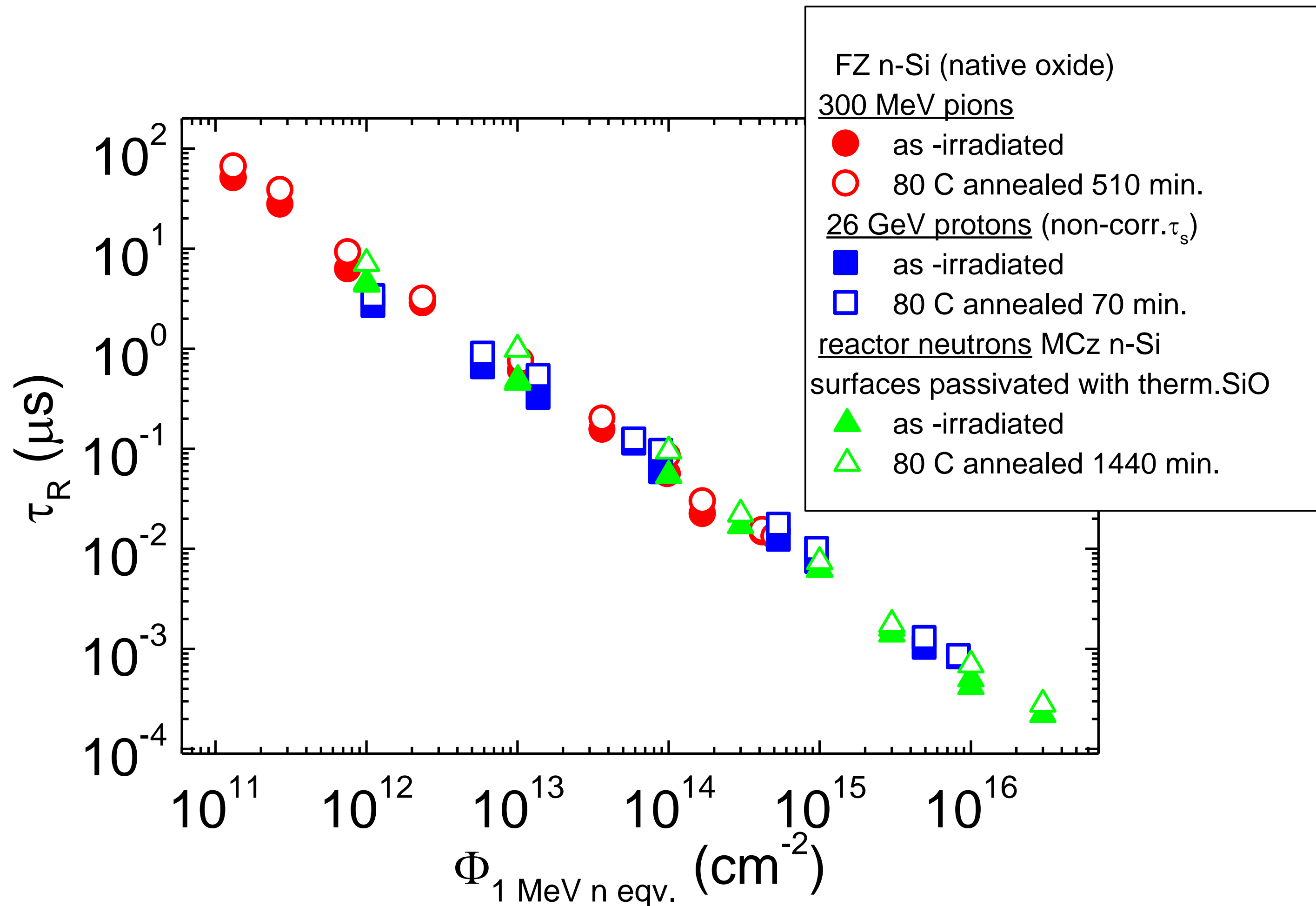
Comparison of characteristics of the pion, neutron and proton irradiated Si

26 GeV protons



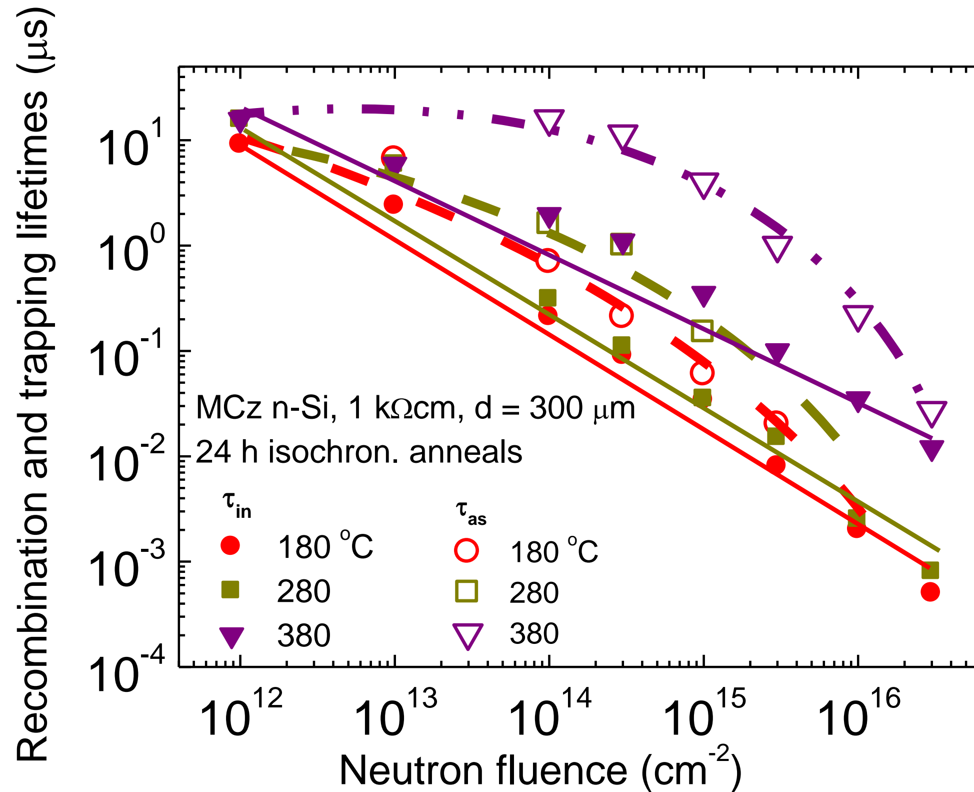


Comparison of characteristics of the pion, neutron and proton irradiated Si



Characteristics of the neutron irradiated Si after 24 h isochronal anneal

MCz n-Si, reactor neutrons



Conclusions

- **Rather significant lateral inhomogeneity within 26 GeV proton beam: lifetime value variation 2-3 times**
- **Smoother profiles ($\Delta\tau \leq 50$ %) obtained for 300 MeV pion irradiated samples**
- **The longest 508 min. anneal leads to < 50% lifetime increase, while saturation appears after 90 min. anneal**
- **Lifetime values are close for Cz and FZ Si samples, and recombination lifetime decreases linearly with enhancement of pion fluence**
- **Carrier lifetime dependence on fluence fits the same curve for pions, protons and reactor neutrons**

Acknowledgements

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Thank you for your attention