Evolution of carrier lifetime characteristics in Si structures during and post-irradiated by neutrons and protons

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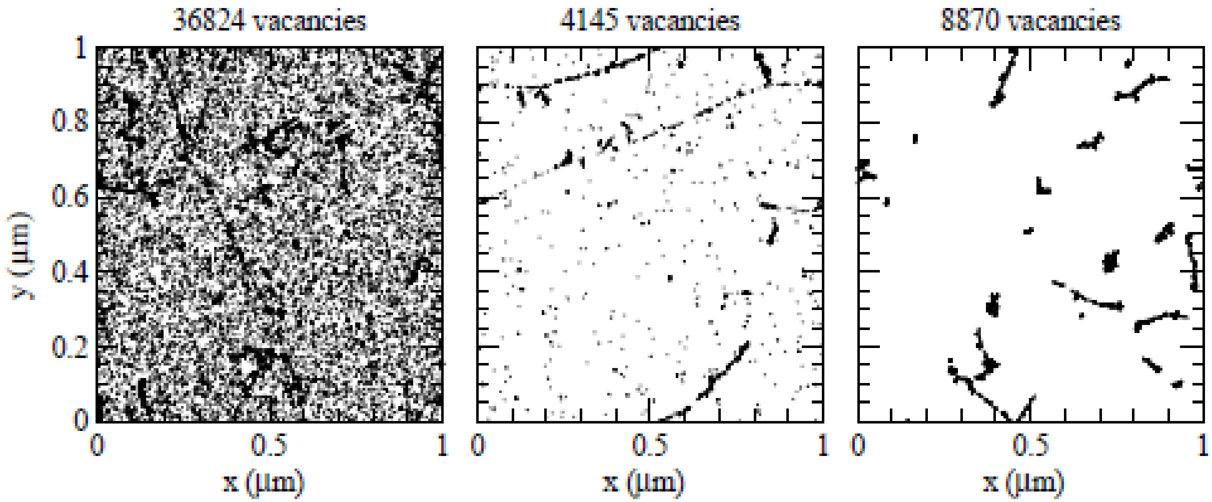
Outline

- Motivation
- Comparative analysis of evolution of the carrier recombination characteristics
- Summary

Motivation

- It is well known the generation of defects by irradiation of hadrons.
- Vacancies generated by 10 MeV protonais, 24 GeV/c protonais (middle) ir 1 MeV neutronais. Fluence: 10^{14} cm^{-2} . [M.Huhtinen. NIMA 491 (2002) 194–215]



But:

1) it is not well understood what happens during the irradiation.

Neutron irradiation creates clusters, neutrons – clusters and point defect that can work as the traps between the clusters, but also protons generates the nonequilibrium free carrier pairs.

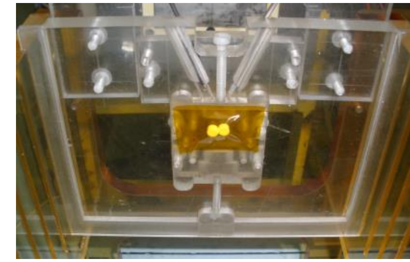
2)

Why is it important?:

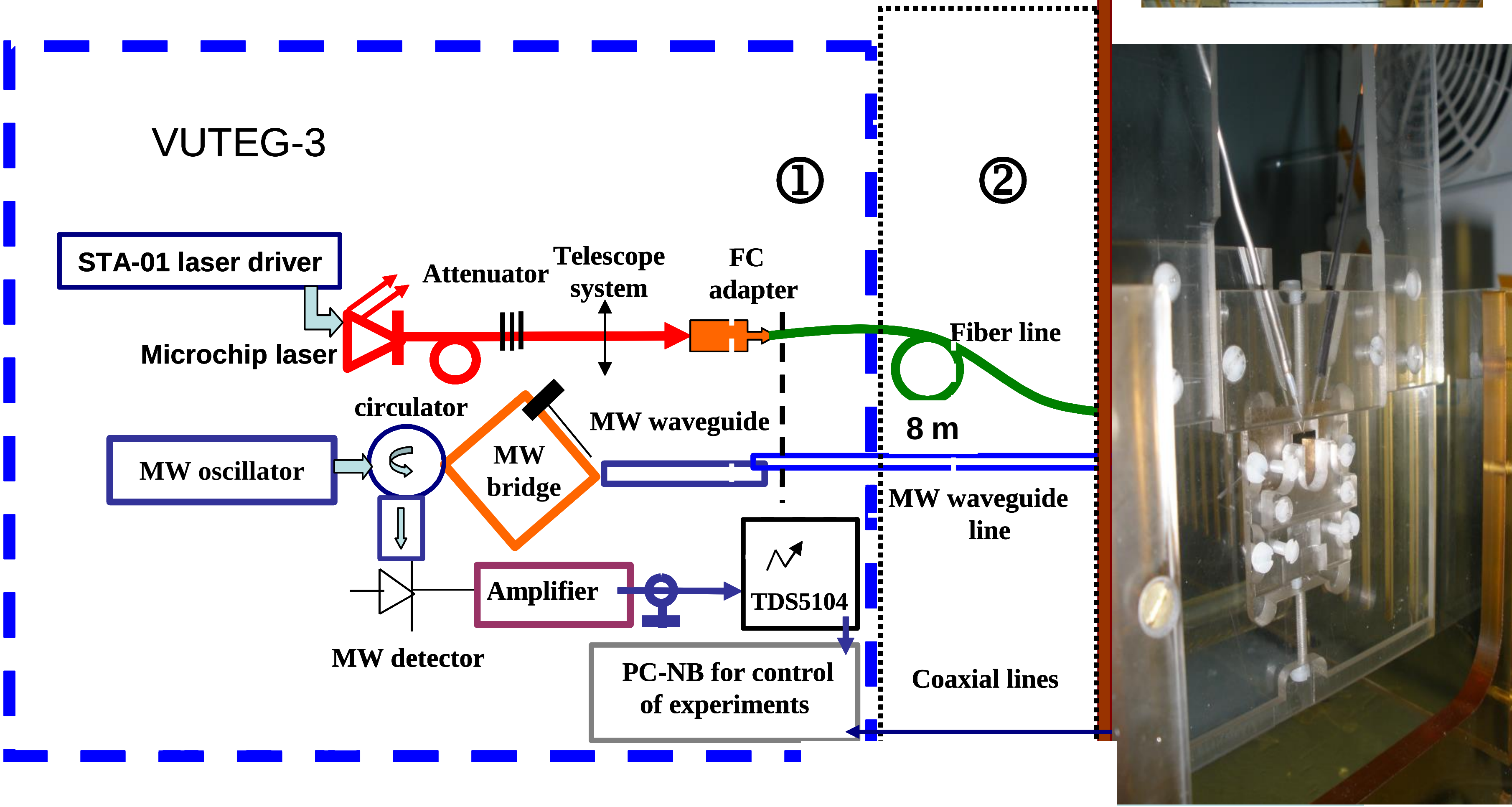
- If the non-equilibrium carriers change the recombination processes, this knowledge can predict the signal changes and to foresee possible modifications of the detector performance
- What is a role of these free carriers can be analyzed only by investigation of the behaviour of the photoresponse during the irradiation of semiconductor by the hadrons and comparison with the results of investigation of the irradiated samples.
- It is interesting to compare a change of carrier drift and recombination characteristics during neutron and proton irradiations

For this purpose we designed the instrument that allows the remote measurement of recombination process and photoresponse by microwave and pulse technique.

Sketch of experiments



MW-PC measurement setup



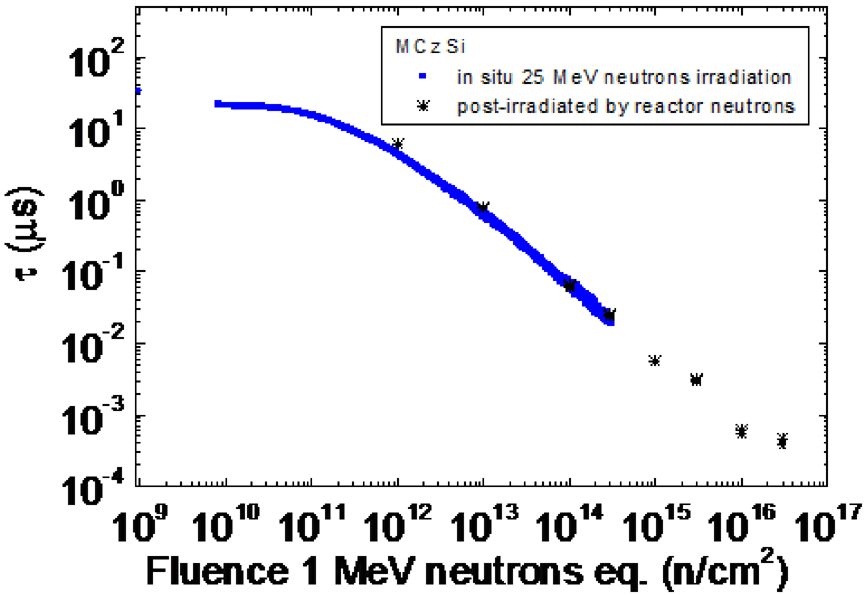
The experimental results with this device were presented at previous RD50 workshops, now we give some comparison of different experiments (that explains a big number of co-authors) using the irradiation by protons and neutron beam.

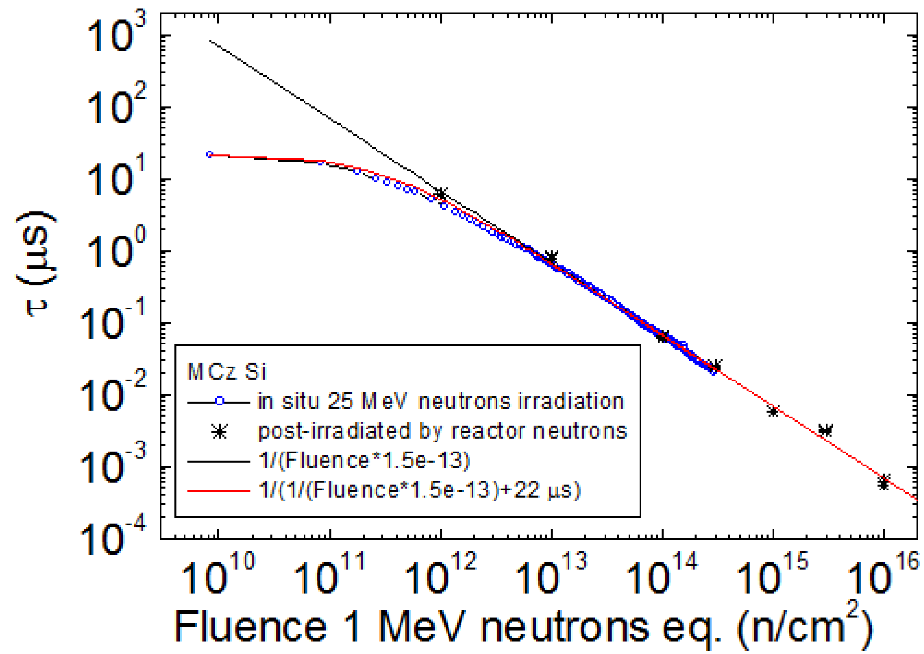
Comparison of results of the in situ changes of recombination lifetime in MCZ Si wafers during spallator 25 MeV neutrons irradiation and post-irradiated by reactor neutrons

$$\tau_{R,cluster} = \frac{1}{v_T \sigma_{cl} N_{cl}}$$

$$1/\tau = 1/\tau_{cluster} + 1/\tau_{surface}$$

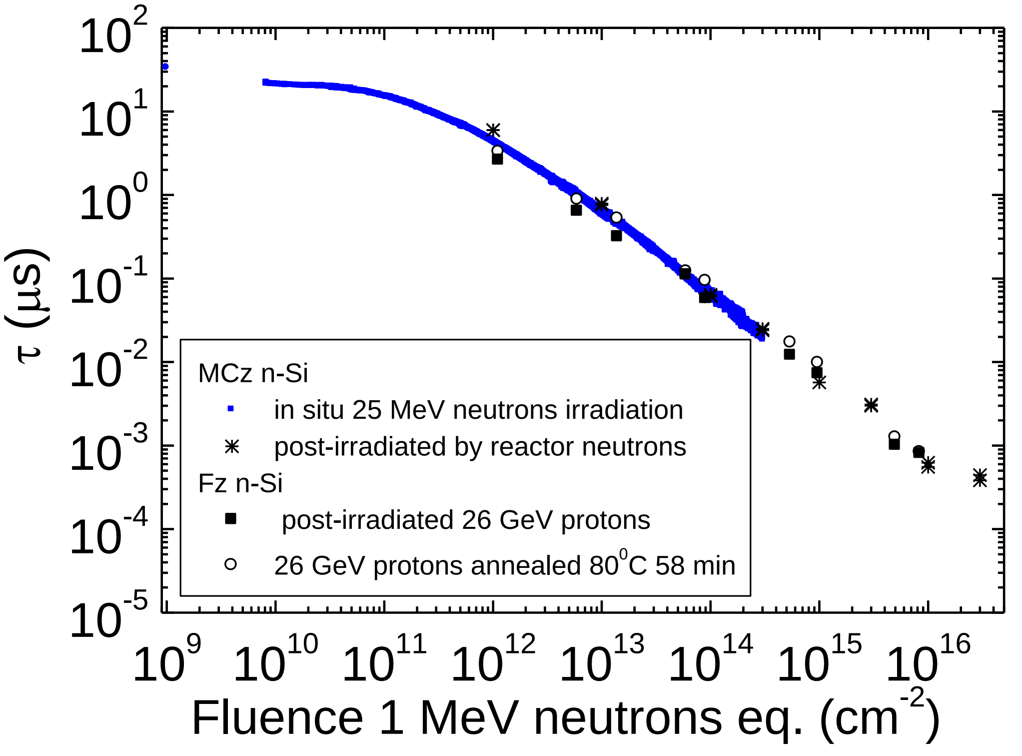
$\tau_{surface}$**=22** μs





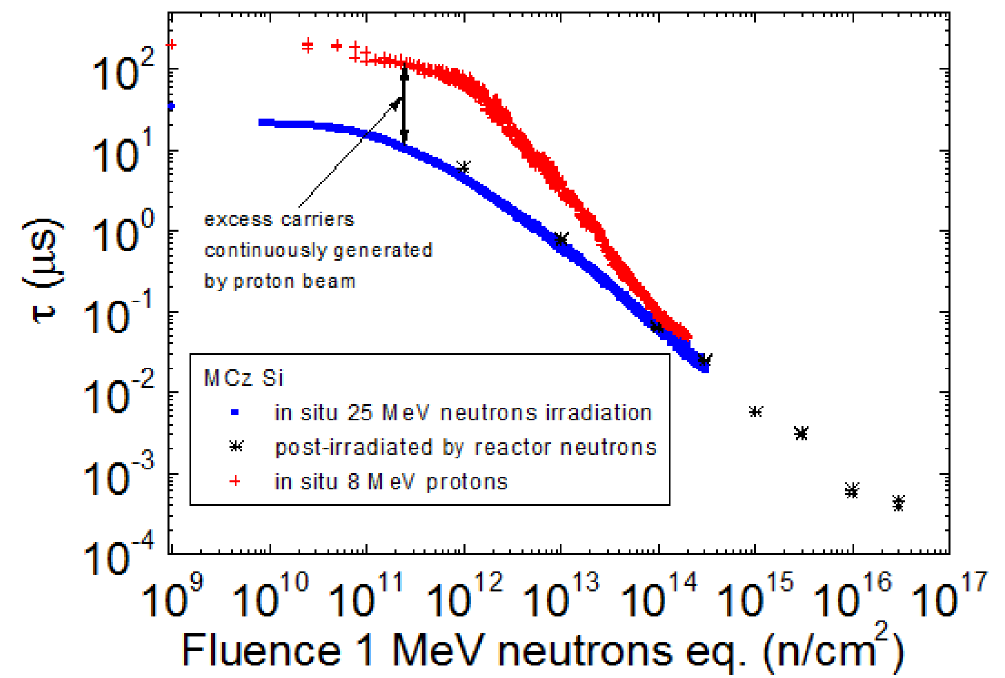
The results show: the neutron beam creates defects (clusters) in the same way as reactor neutrons.

The in situ changes of recombination lifetime (in MCZ Si) during spallator 25 MeV neutrons irradiation compared with lifetime variations in MCZ n-Si wafers post- irradiated by reactor neutrons and post-irradiated by 26 GeV protons as well as annealed FZ n-Si wafers

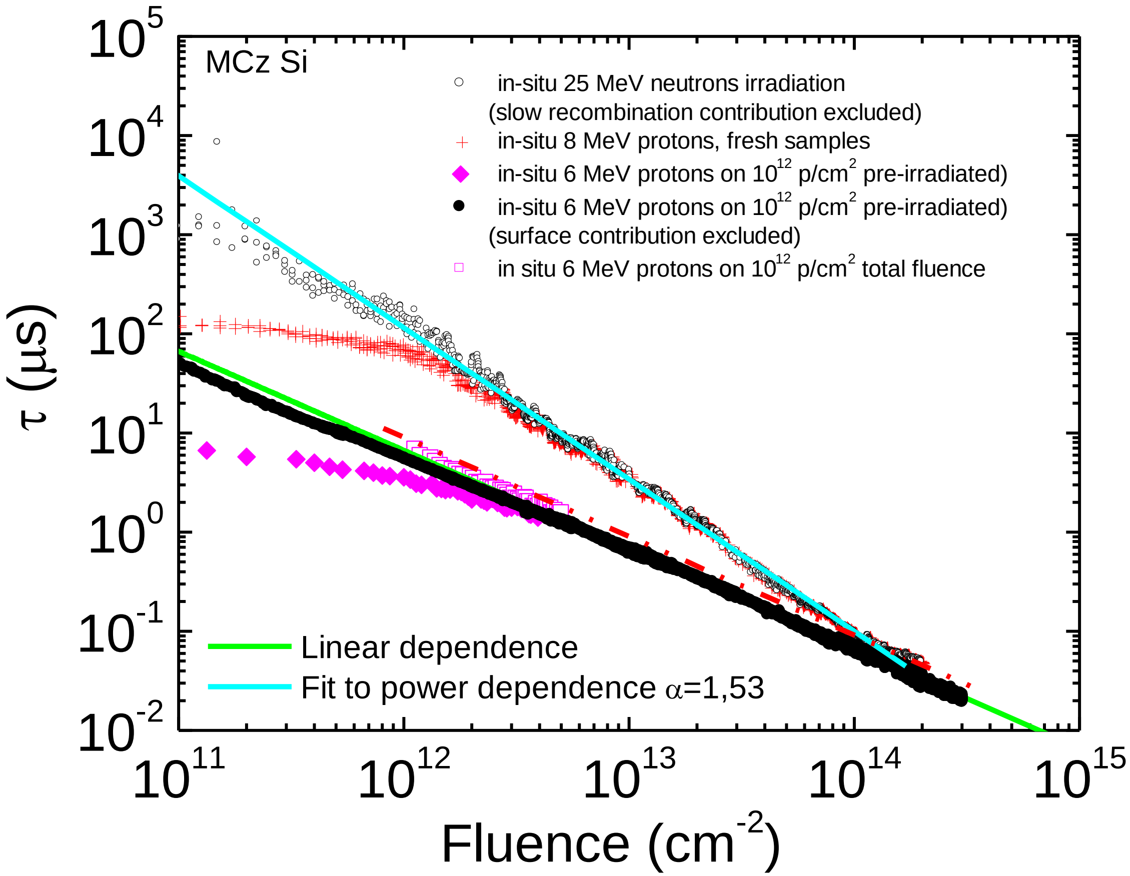


Comparison of the recombination lifetime measured in-situ during the irradiation by protons (8 MeV) and by neutrons (25 MeV spallator neutrons) and with the post-irradiated by reactor neutrons GIVES a SIGNIFICANT DIFFERENCE . All samples MCZ n-Si wafers

Evident increase of the lifetime in the "non-exposed by protons" sample can be understood as a role of free carriers that reduce, via screening of surface potential, the role of the recombination at the sample surface



More complicated situation appears at the fluence when the recombination in the clusters prevails.



Proton irradiation a bit increase lifetime at high fluence, and it appears a new component which depends on fluence as a power law with index ~1,5.

The further analyze is necessary.

Summary

- **Neutrons and protons creates the similar cluster dependent recombinantion (trapping** in biased samples**) centers.**

- **Carrier lifetime in situ changes during neutron irradiation correlate well with that dependence obtained for post irradiated material hadrons in the range of high irradiation fluences**

- **Free carriers generated by protons screen the potential barriers at the surfase and around the clusters, but the additional component of the lifetime increase remains problematic.**

Acknowledgements.

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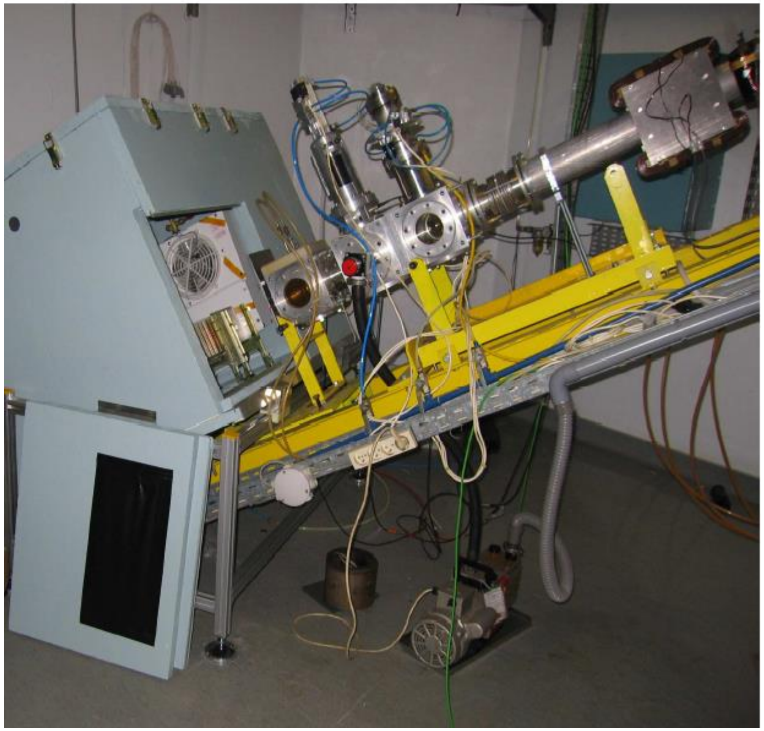
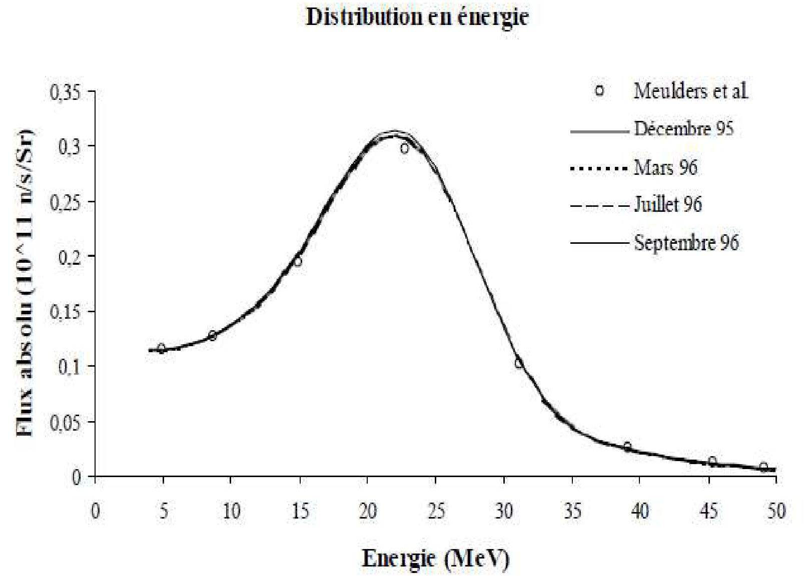
Thank You for attention!

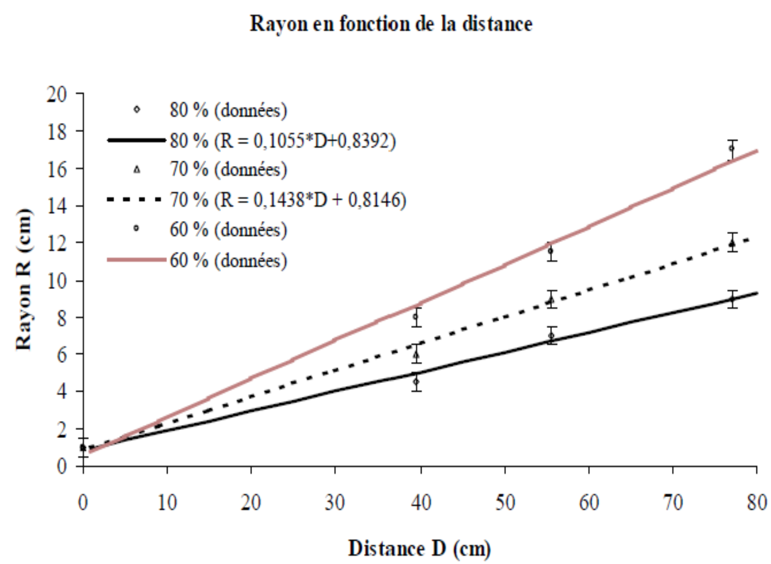
Neutron source at Louvain la Neuve University

The energy spectrum of the out-coming neutron beam is dominated by a peak in the region of 25 MeV.





Neutron spatial distribution variation with distance from the target



The high flux neutron line is located at the Louvain la Neuve -Cyclotron. It uses a primary 50 MeV deuteron beam that is sent on a thin beryllium target. The high cross section reaction $^{9}Be(d,n)^{10}B$ produces the high flux neutron beam.

To keep the gamma and charged particle contamination as low as possible filters are placed outside the target box and fixed to the box window, made of three layers: 1 cm thick polyethylene, 1 mm Cadmium and 1 mm Lead. The filter also removes from the beam the low energy neutrons.