U N I V E R S I T Y O F B E R G E N

Department of physics and technology

Measurements and simulations of in-phantom neutron dose from a proton pencil beam

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Introduction

- In proton therapy, neutrons produced in collimators or in the patient body will contribute to dose to the patient
- This neutron dose is mainly associated with a potential increased risk of radiation induced second cancer after treatment
- Assessments of in-phantom neutron dose has predominantly been done using passive detectors

We present the first application of a novel compact and active detector for measurements of in-phantom neutron dose from proton therapy

Methods The SRAM detector

- The detector was developed at the University of Bergen and is based on registration of Single Event Upsets (SEUs) in Static Random Access Memories (SRAMs)
- The SRAM detector counts SEUs (bit flips) caused by inelastic collisions between neutrons and nuclei in the SRAM chip
- The neutron fluence is proportional to the number of bit flips detected

BIT FLIP

Changes the value of a memory cell:

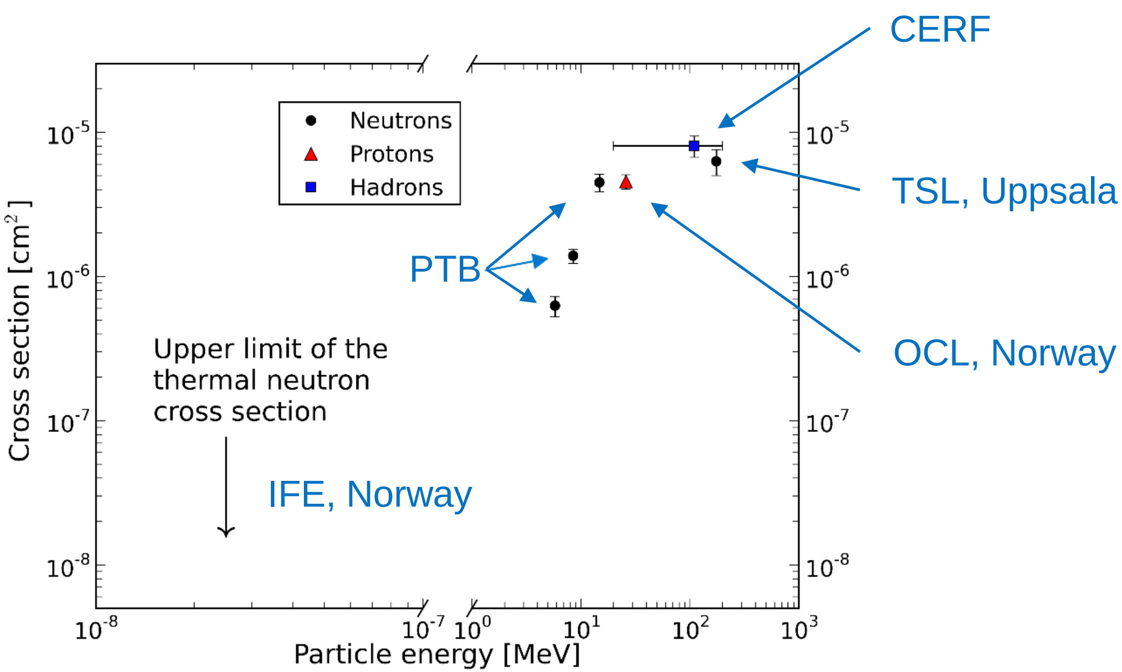
1 ⟶ 0

or

0 ⟶ 1

Methods The SRAM detector

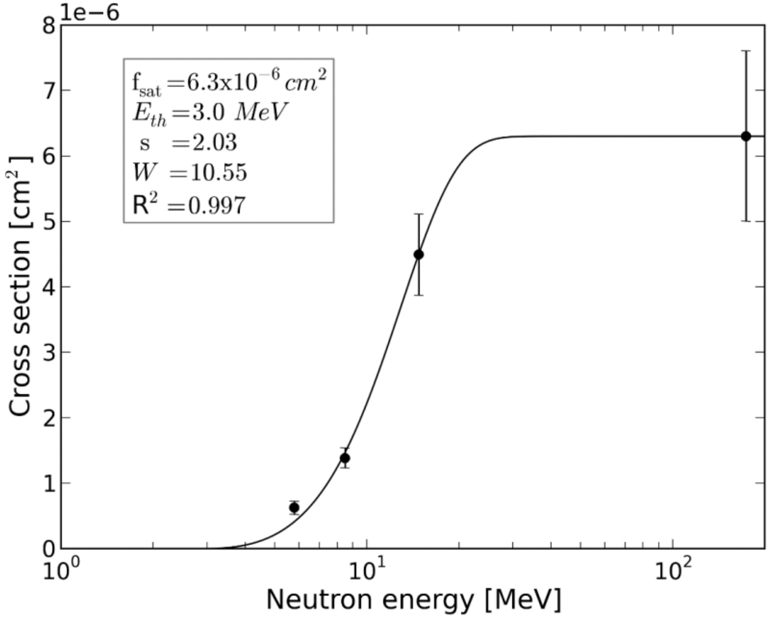
- The SRAM detector was characterized through irradiation experiments at several European research facilities



Data from: KS. Ytre-Hauge et al., Nucl.Instrum.Methods A 804 (2015) 64.

Methods The SRAM detector

- The SRAM detector was characterized through irradiation experiments at several European research facilities
- Steep increase in neutron sensitivity above the (assumed) detection threshold of 3 MeV



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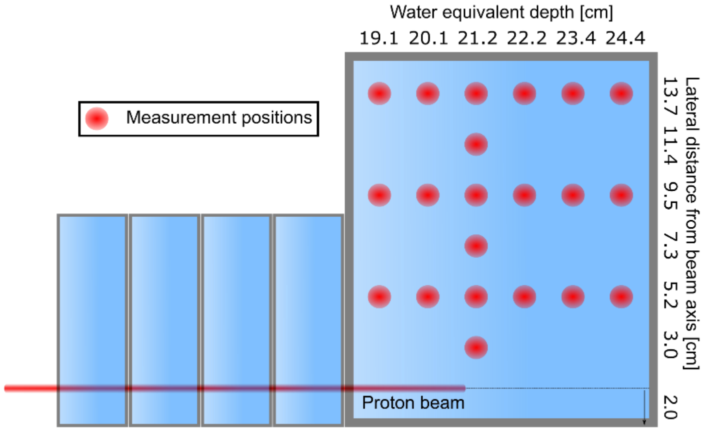
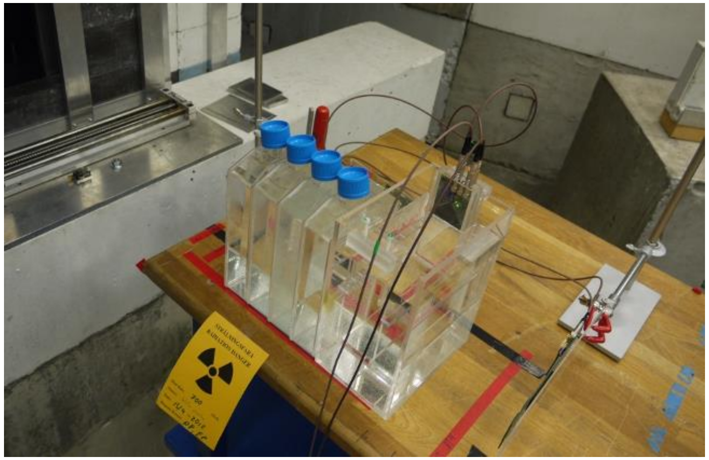
Methods Experimental setup

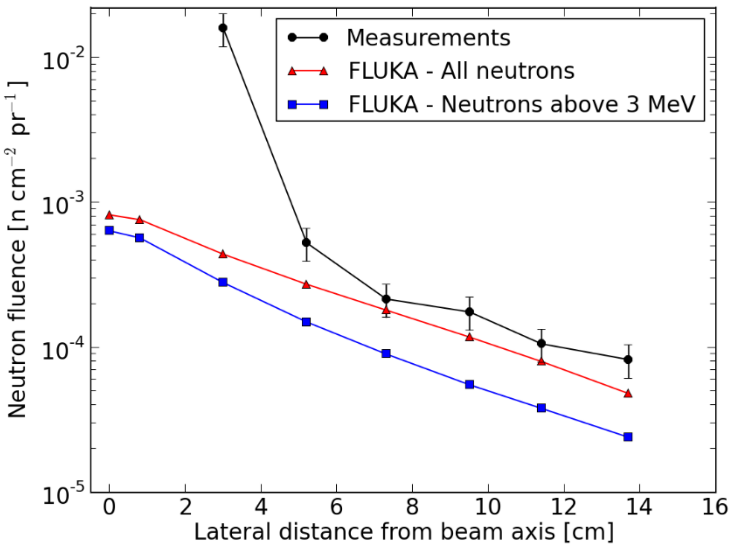
- Measurements were performed at The Svedberg Laboratory (TSL, Uppsala)
- 178 MeV proton pencil beam (uncollimated) with FWHM 1.33 cm
- Monte Carlo simulations were performed with the FLUKA code for comparison





Results Neutron fluence

- Neutron fluence at Bragg peak depth decreases steeply with lateral distance from beam axis
- Measurements indicate same trend as simulations, but consistently higher values



1 treatment Gray = 5.65 x 10^9 protons

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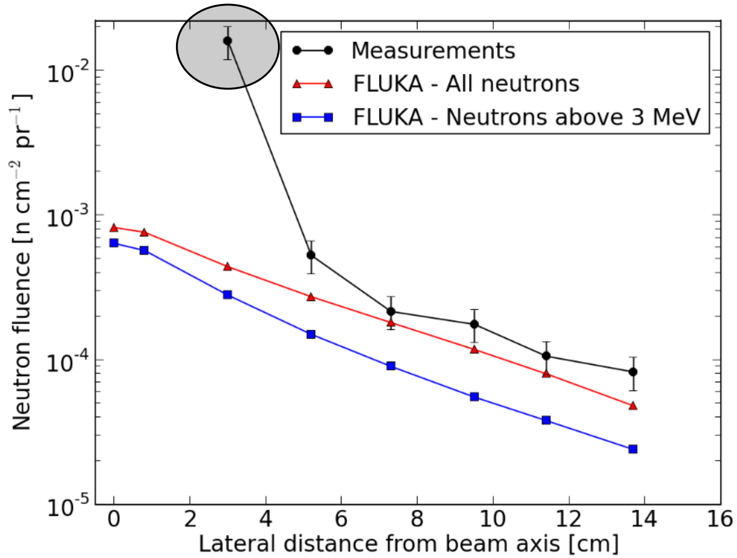
- Measurements at 3.0 cm indicate response to charged particles



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Results Neutron dose estimates

- Neutron dose, H*(10), at Bragg peak depth decreases steeply with lateral distance from beam axis
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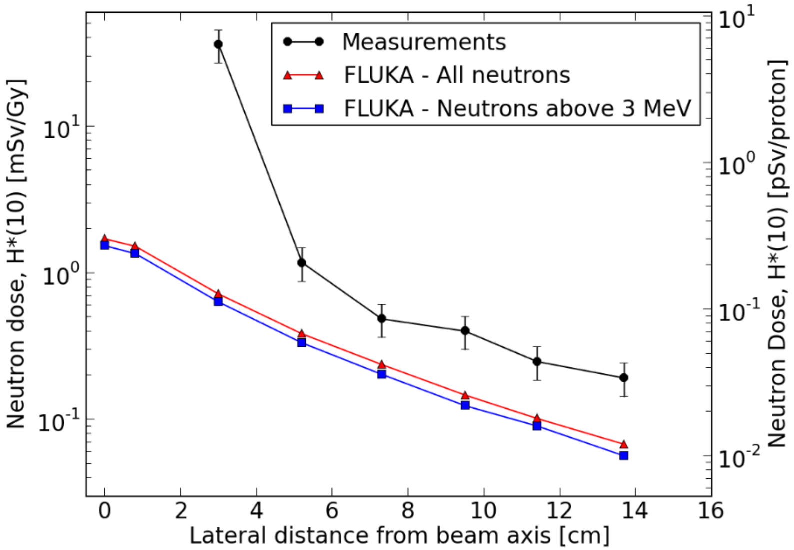

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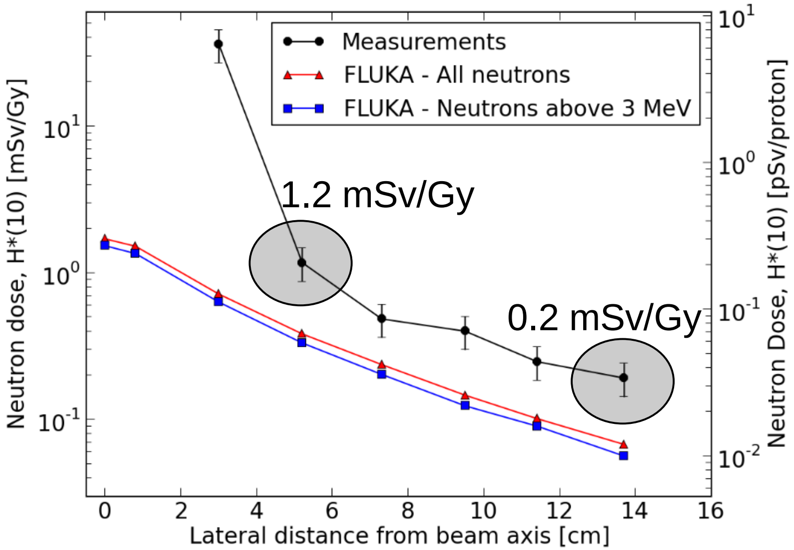

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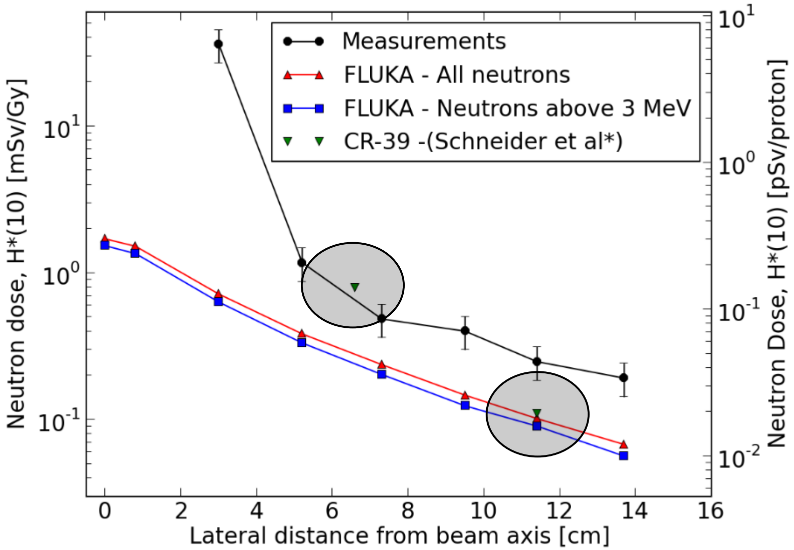
- Results are comparable to findings with passive detectors (CR-39)



*U. Schneider, et al., Int. J. Radiat. Oncol. Biol. Phys. 53 (2002) 244.

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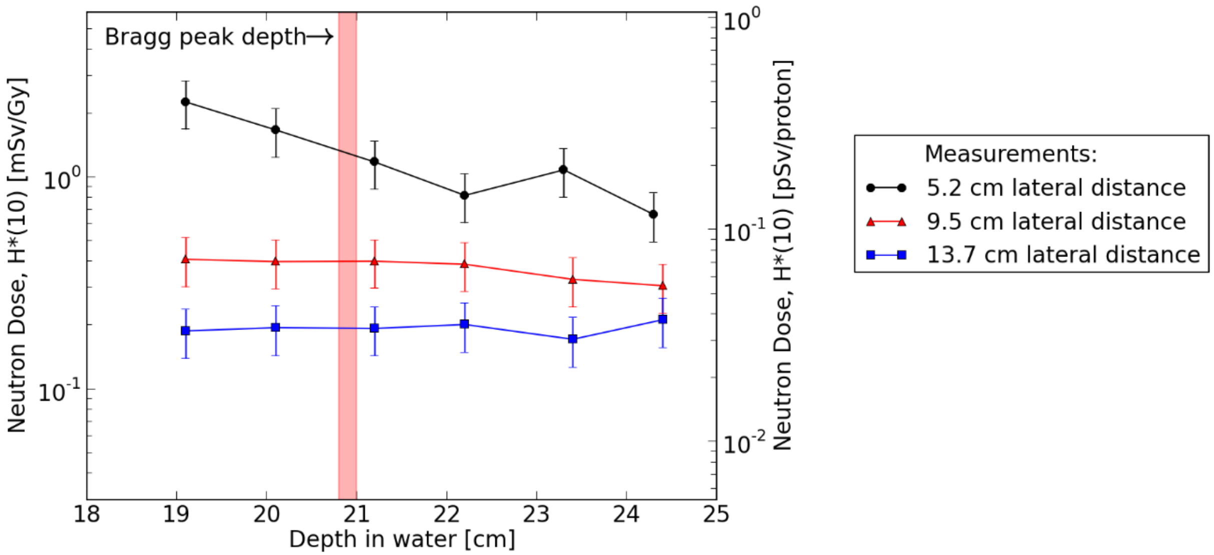
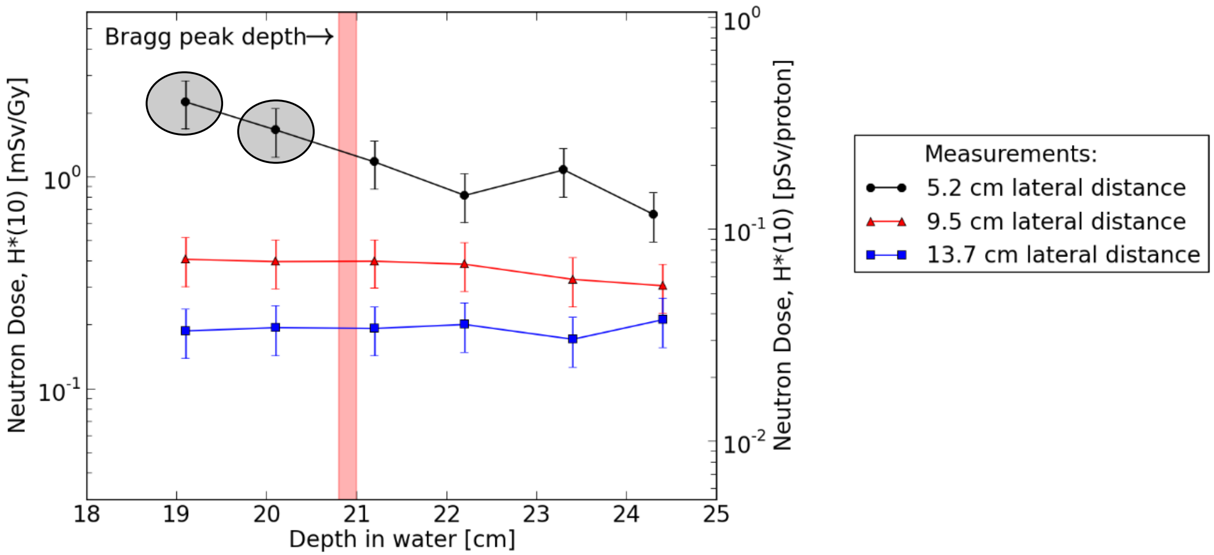


Results Neutron dose estimates

- Relatively stable neutron dose as a function of depth
- Possible response to charged particles prior to Bragg peak close to the beam axis



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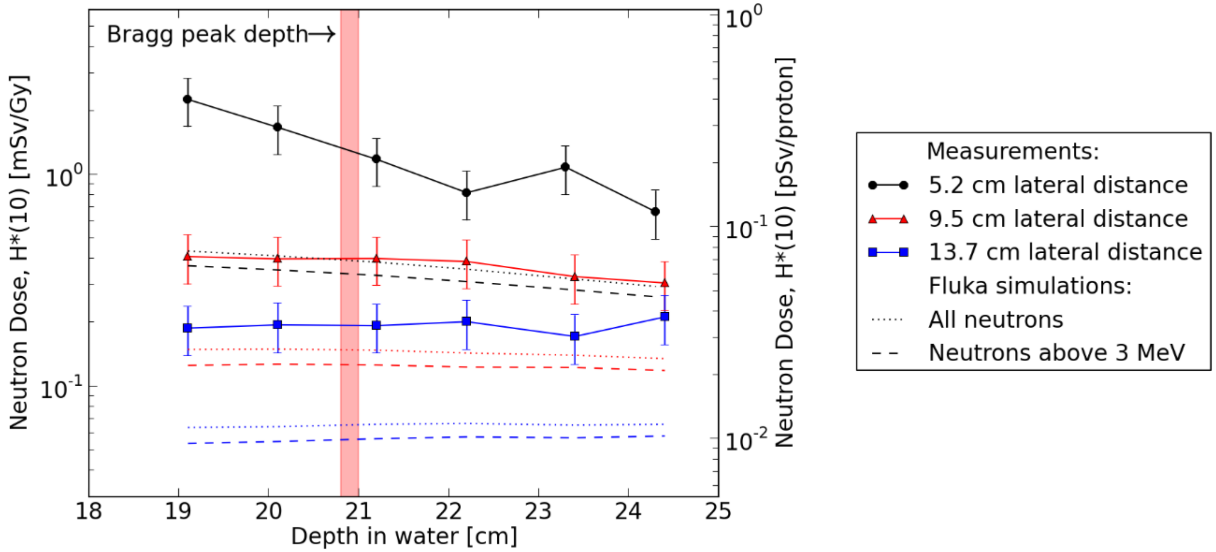
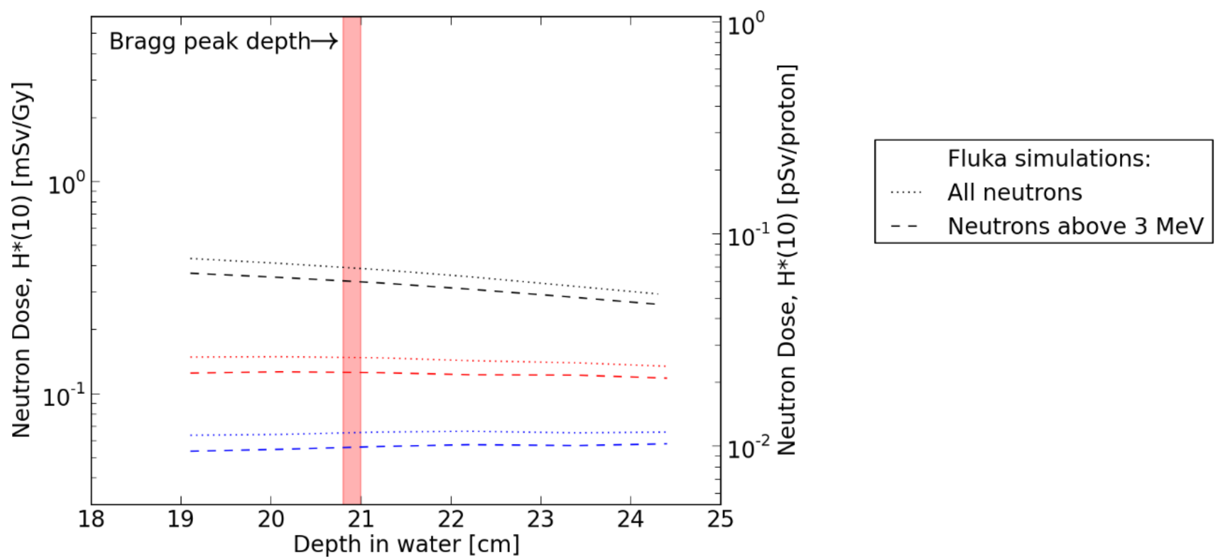


Results Neutron dose estimates

- Monte Carlo simulations indicated that between 84% and 90% (depending on position) of the neutron dose was due to neutrons with energy above 3 MeV

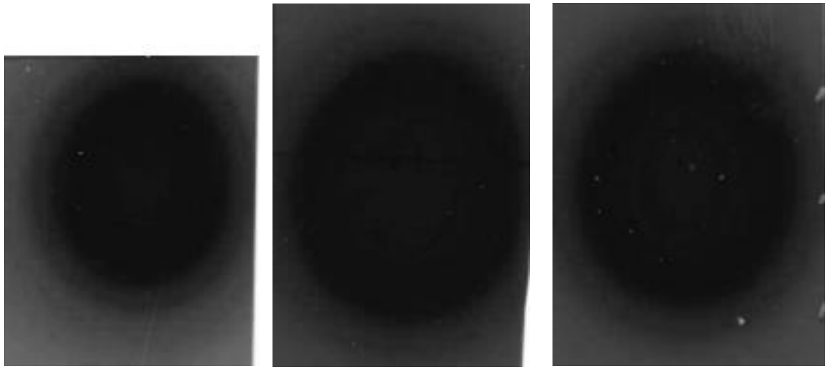
→ the detector covers the most important energy region



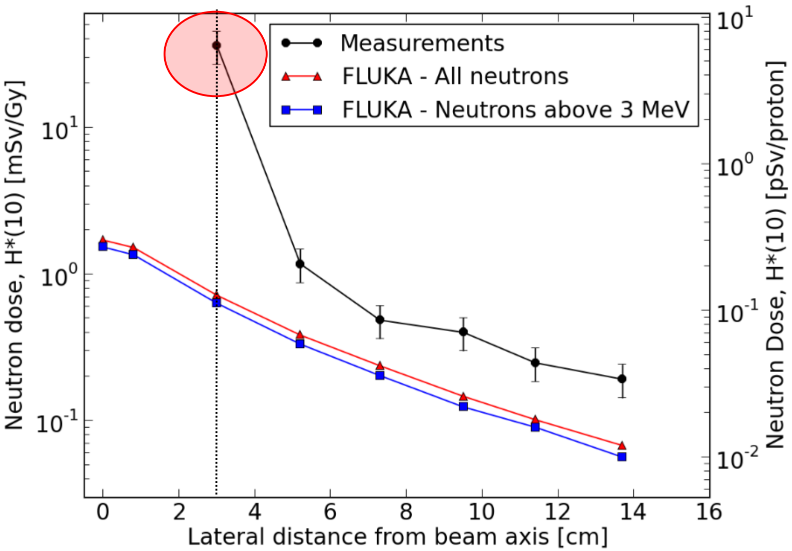
Results Experimental uncertainties

- High measured neutron doses may be due to possible defocus of beam during experiment
- GafChromic film irradiation and high detector response at 3 cm off-axis supports this hypothesis

GafChromic film irradiation



Start intermediate Final



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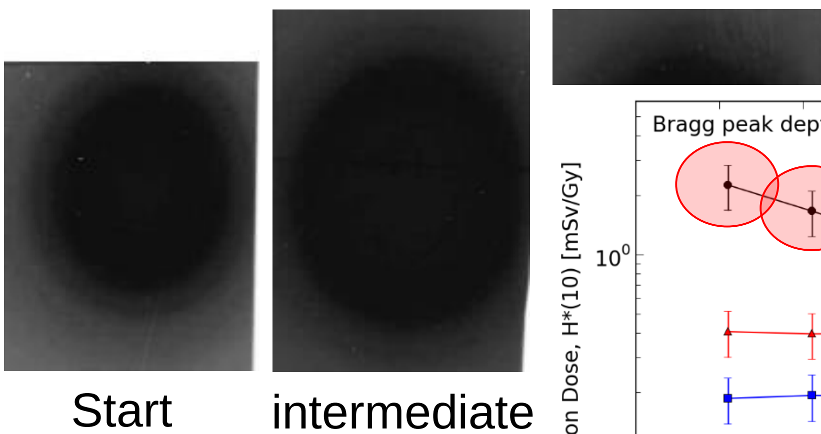

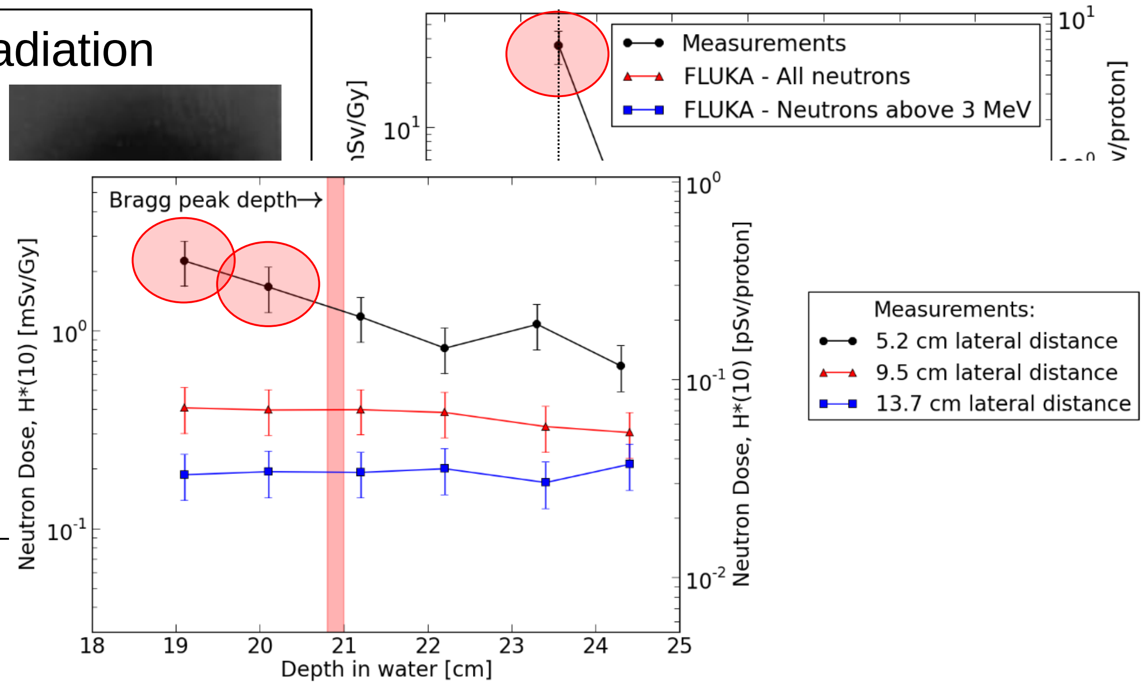

Conclusions

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- Measurements indicate a steep decrease in neutron dose with lateral distance: 1.2 mSv/Gy at 5.2 cm decreasing to 0.2 mSv/Gy at 13.7 cm distance from beam axis
- This work shows the potential for using the SRAM detector in particle therapy as an alternative to passive detectors


Thank you
Bergen particle therapy center