Deutsche Neutronenstreutagung 2024 @ RWTH Aachen

Neutron sensitive Microchannel Plate with a Timepix3 readout

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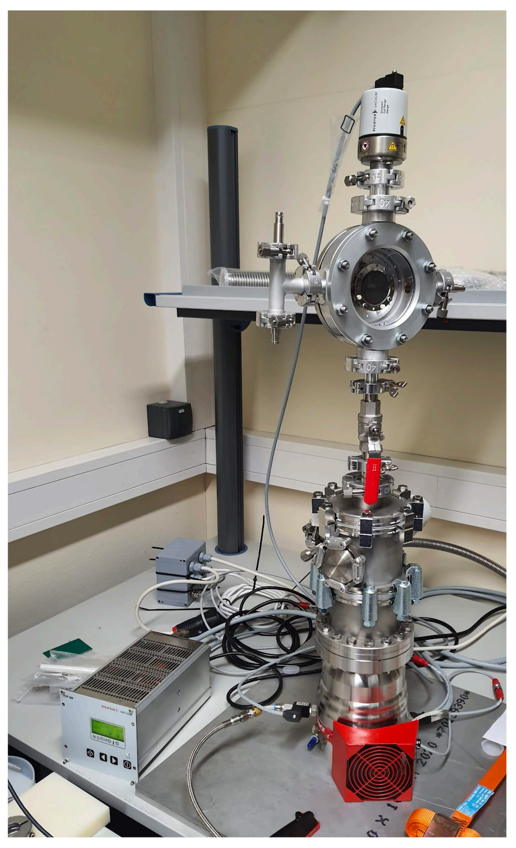
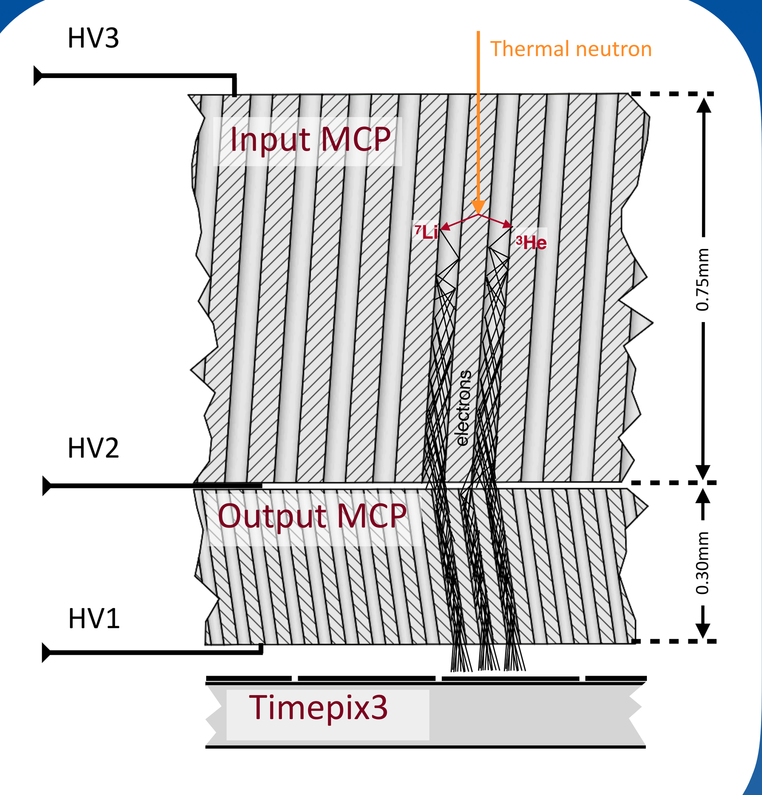


Neutron sensitive MicroChannel Plate (MCP)

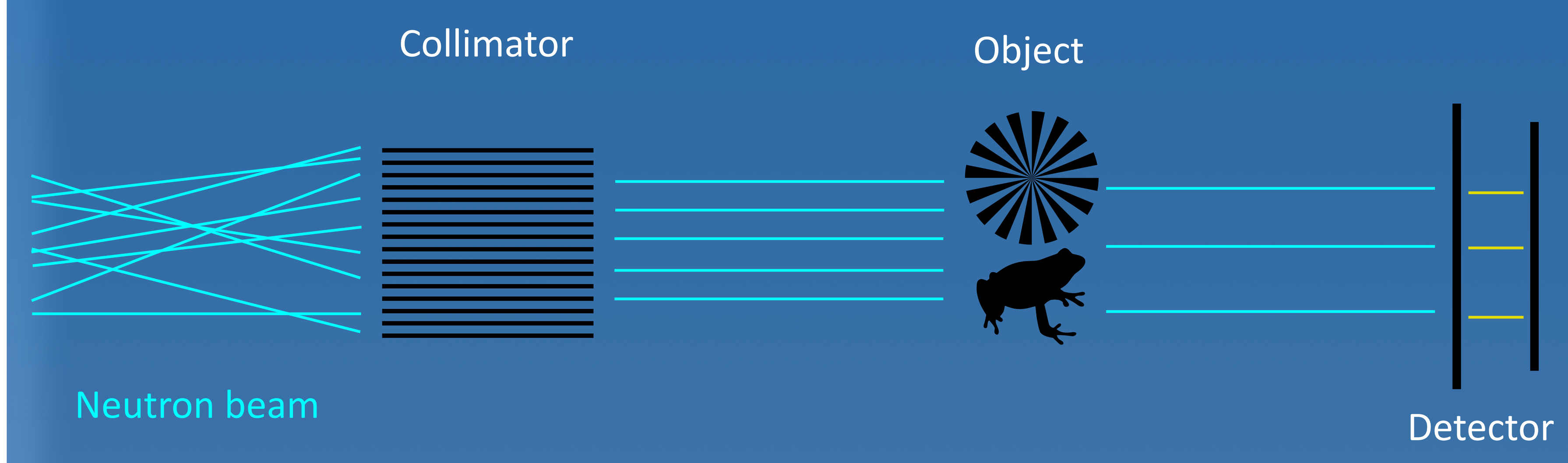
We present a neutron-sensitive MicroChannel Plate (MCP) detector integrated with a Timepix3 readout system. This study aims to combine the high gain and low background noise of the MCP with the excellent time and position resolution of the Timepix3. The MCP is doped with boron-10, which captures neutrons and decays into lithium ions and alpha particles. Within the microchannels, these charged particles are converted to electrons and amplified. The Timepix3 readout, offering a clock frequency of 640 MHz and a pixel pitch of 55 µm, is positioned very close to the MCP to collect the signal and record the neutron positions. Utilizing four Timepix3 chips results in an active area of 28 mm x 28 mm. The detector is sensitive to thermal neutrons, and previous studies indicate that the detector can achieve up to 10 µm spatial resolution [1] with more than 50% thermal neutron detection efficiency [2]. These features make our detector a promising candidate for neutron imaging and radiography applications.



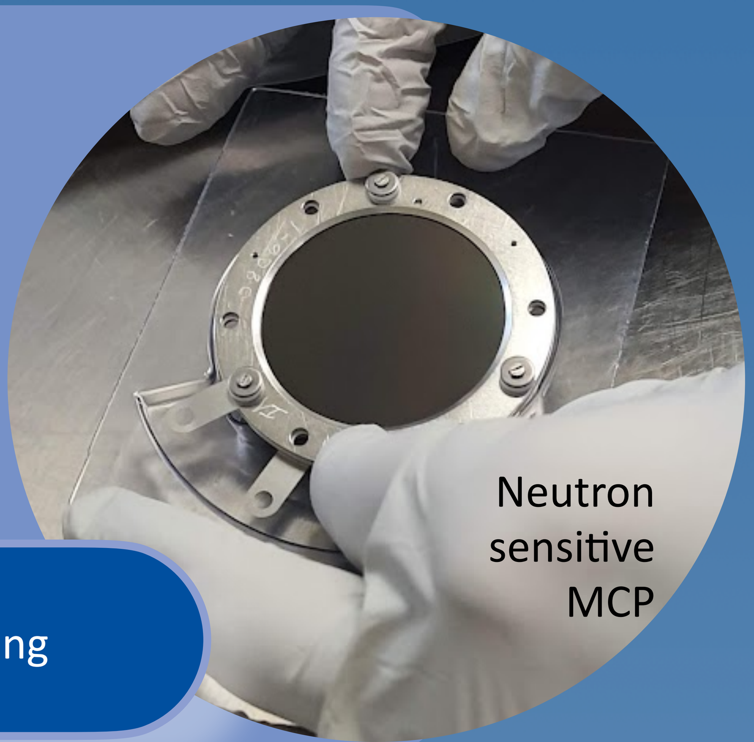
Working principle of MCP

Experimental Setup

A collimated beam is required to achieve a high resolution of the MCP detector. The MCP must be positioned in close proximity to the Timepix ASICs and enclosed in a vacuum.

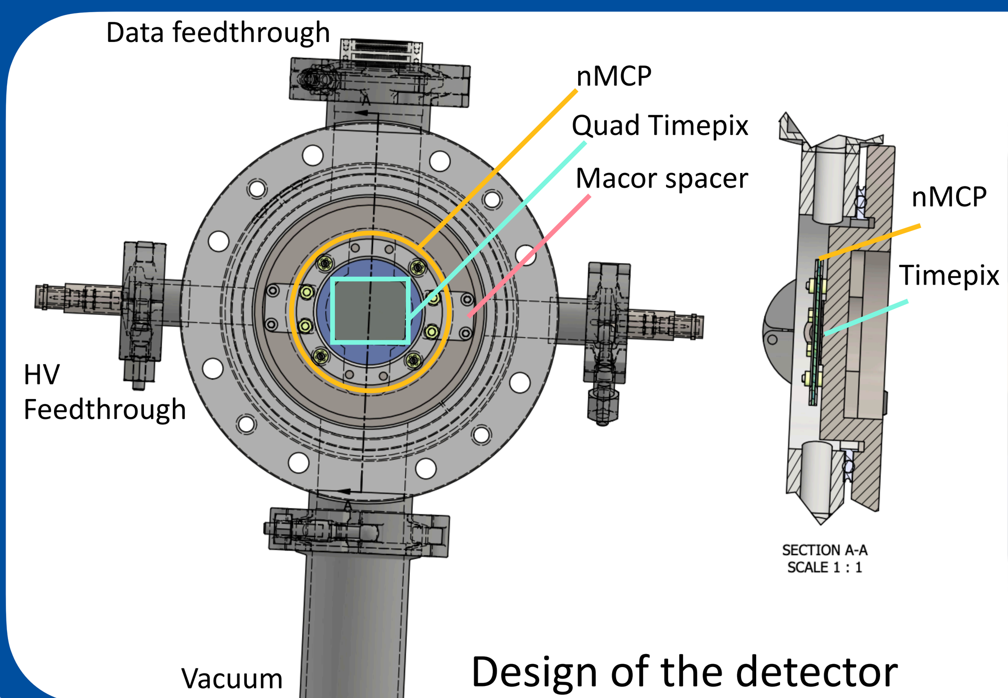


The neutron-sensitive MCP [1] has an active diameter of 40 mm and consists of two stages: the MCP doped with boron and gadolinium to absorb neutrons, coupled with a standard MCP for signal amplification. The MCP is mounted on the detector flange using alumina screws and Macor holders and has three high voltage levels.

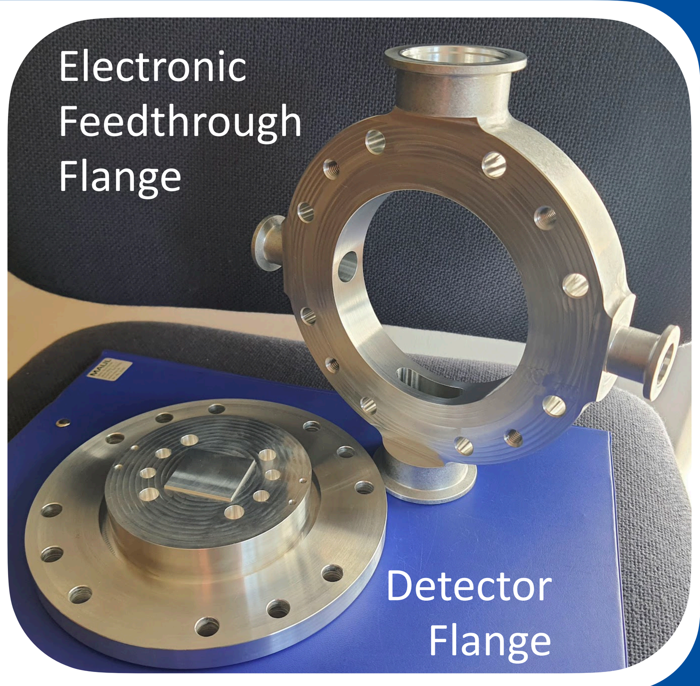


- Currently high voltage and stability tests ongoing

Aluminum vacuum flanges were designed and fabricated from aluminum in the workshop and underwent vacuum testing, achieving a pressure level below 10^{-6} mbar. A 40-pin electronic feedthrough has been installed above the detector to transmit Timepix signals to the readout system, with the remaining electronics positioned outside the detector chamber.

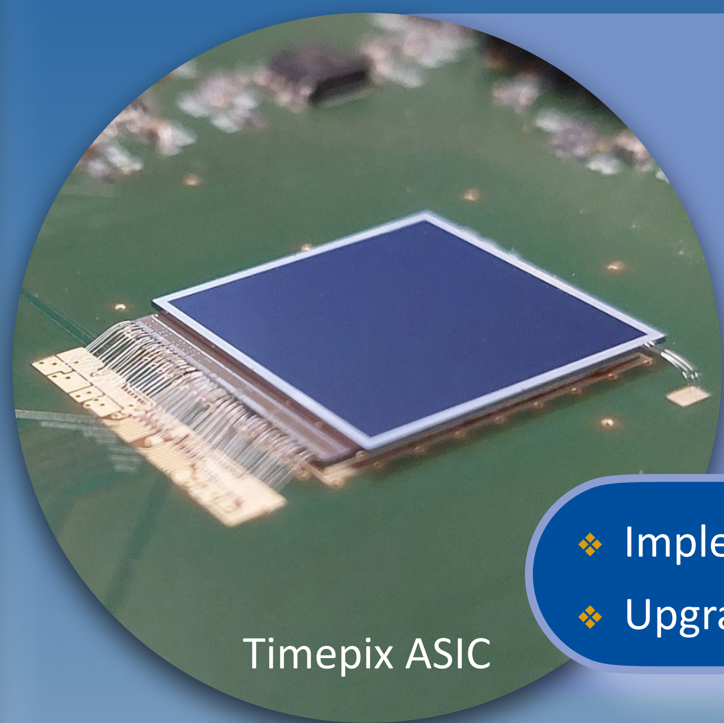


Design of the detector



- We plan to test the detector on a thermal neutron beam at the beginning of 2025

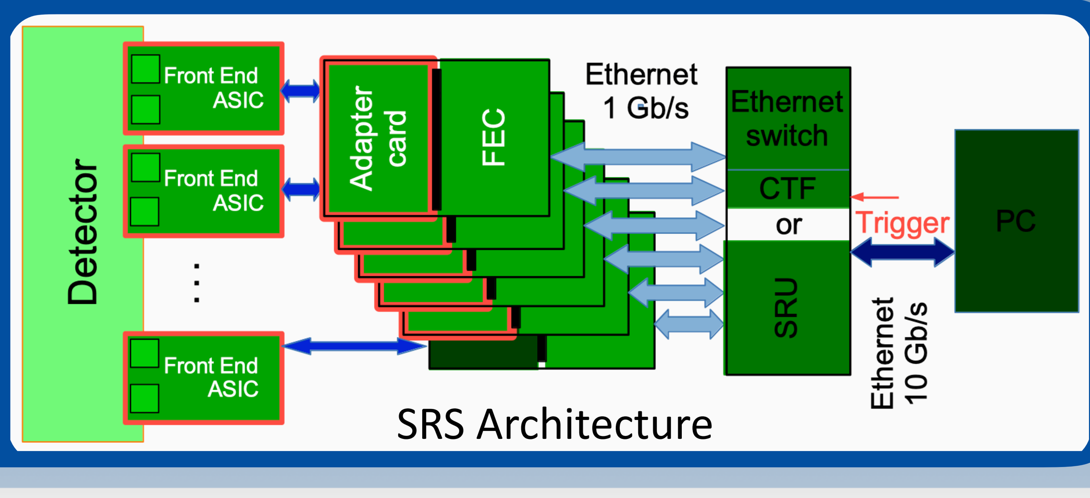
Readout System



	Timepix	Timepix3
	256 x 256 ASICs, 55 µm pixel pitch	256 x 256 ASICs, 55 µm pixel pitch
	Time **or** Charge	Time **and** Charge
	Frame readout	Data-driven readout
	25 ms dead time [4]	Dead-time free [5]

- Implementation of Timepix ASIC is ongoing
- Upgrade to quad-Timepix3 ASIC in the future

Scalable Readout Systems (SRS) developed by RD51 collaboration at CERN will be used to digitize the data [6].

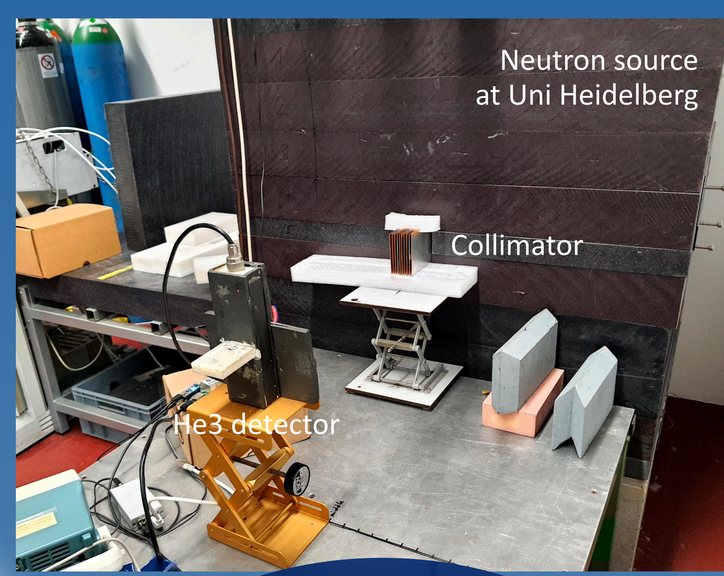


SRS Architecture

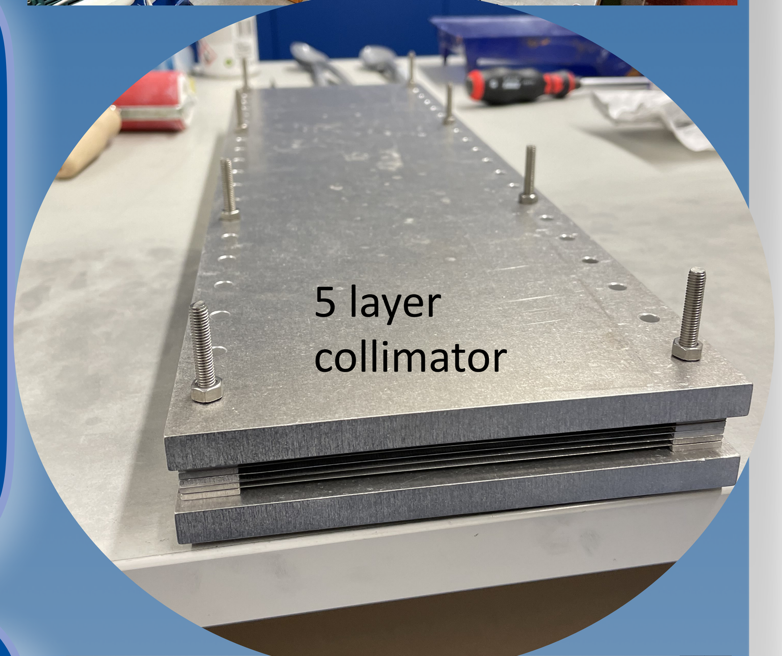
Collimator

Element	Reaction	CS at 25.2 meV
^{3}He	$^{3}\mathrm{He}+n \longrightarrow {}^{3}\mathrm{H}+764\,\mathrm{keV}+p$	5327 b
^{6}Li	$^{6}\mathrm{Li}+n \longrightarrow {}^{3}\mathrm{H}+\alpha+4.78\,\mathrm{MeV}$	940 b
^{10}B	$^{10}\mathrm{B}+n \longrightarrow {}^{7}\mathrm{Li}+\alpha+2.79\,\mathrm{MeV}\ (6\,\%)$	3837 b
	$^{10}\mathrm{B}+n \longrightarrow {}^{7}\mathrm{Li}^{*}+\alpha+2.31\,\mathrm{MeV}\ (94\,\%)$	
^{155}Gd	$^{155}\mathrm{Gd}+n \longrightarrow {}^{156}\mathrm{Gd}+\gamma+e^{-}+(30-180)\,\mathrm{keV}$	61000 b
^{157}Gd	$^{157}\mathrm{Gd}+n \longrightarrow {}^{158}\mathrm{Gd}+\gamma+e^{-}+(30-180)\,\mathrm{keV}$	254000 b
^{235}U	$^{235}\mathrm{U}+n \longrightarrow$ fission fragments $+\,160\,\mathrm{MeV}$	584 b

Neutron absorption reaction of elements [3]



A collimator was constructed using aluminum plates measuring 50 cm x 15 cm, coated with a paint mixed with gadolinium oxide powder. The plates are spaced 2 mm apart. Different paints and application methods are under evaluation, and neutron absorption is being simulated. Two such collimators are required to achieve collimation in both directions, with the design aiming for a high L/D ratio.



- Absorption has been measured at the Cf252 neutron source at Uni-Heidelberg
- 5 layers of collimator has been constructed
- Construction of 50 layers is ongoing
- Tests are planned to be done soon

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4. Llopart, X., et al. "Timepix: A 65k Programmable Pixel Readout Chip." Nucl. Instrum. Methods Phys. Res. A, 2007. DOI: 10.1016/j.nima.2007.08.079
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