Development of GEM detector as a compact neutron spectrometer for fusion plasmas

Monitoring of 2022 activities

M. Scholz, U. Wiącek, K. Drozdowicz, A. Jardin, U. Woźnicka,
A. Kulińska, A. Kurowski
Institute of Nuclear Physics Polish Academy of Science, Kraków, Poland
W. Dąbrowski, B. Łach
AGH University of Science and Technology Faculty of Physics and Applied Computer Science, Kraków, Poland
Didier Mazon,
IRFM CEA, France

Preliminary NS-GEM demonstrator design and first tests with NG-14 MeV neutron source.

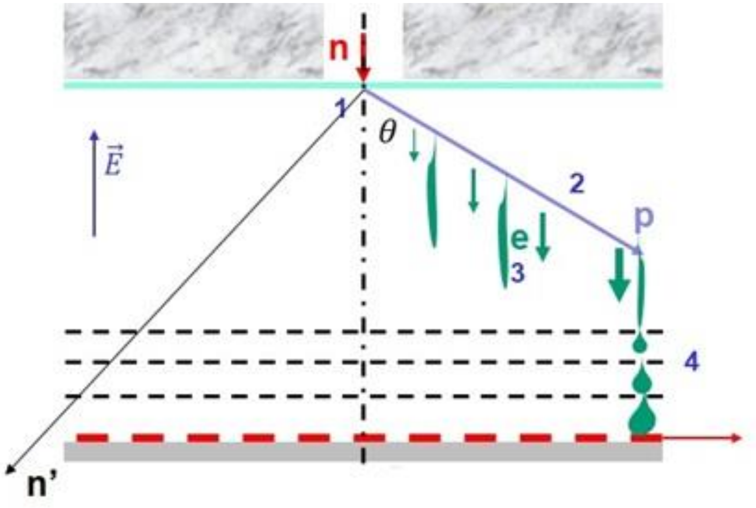
1. Theory and modelling: NS-GEM synthetic diagnostic. The first evaluation of performance analysis of NS-GEM design.

2. NS-GEM Demonstrator: Construction and testing of the laboratory demonstrator NS-GEM.

3. Neutron generator NG-14 MeV: Performance test of the 14 MeV neutron source experimental set-up. NS-GEM Tests. Series 1.

Introduction

$$E_n = \frac{E_p}{cos^2\theta}$$

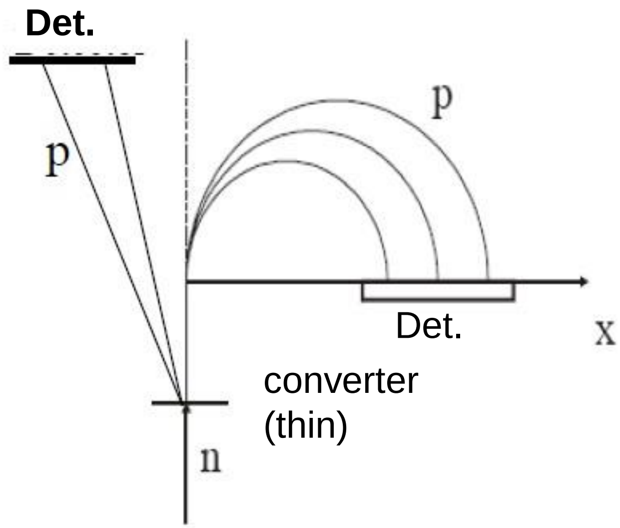


TPR

vacuum

MPR

vacuum, magnet, size, weight



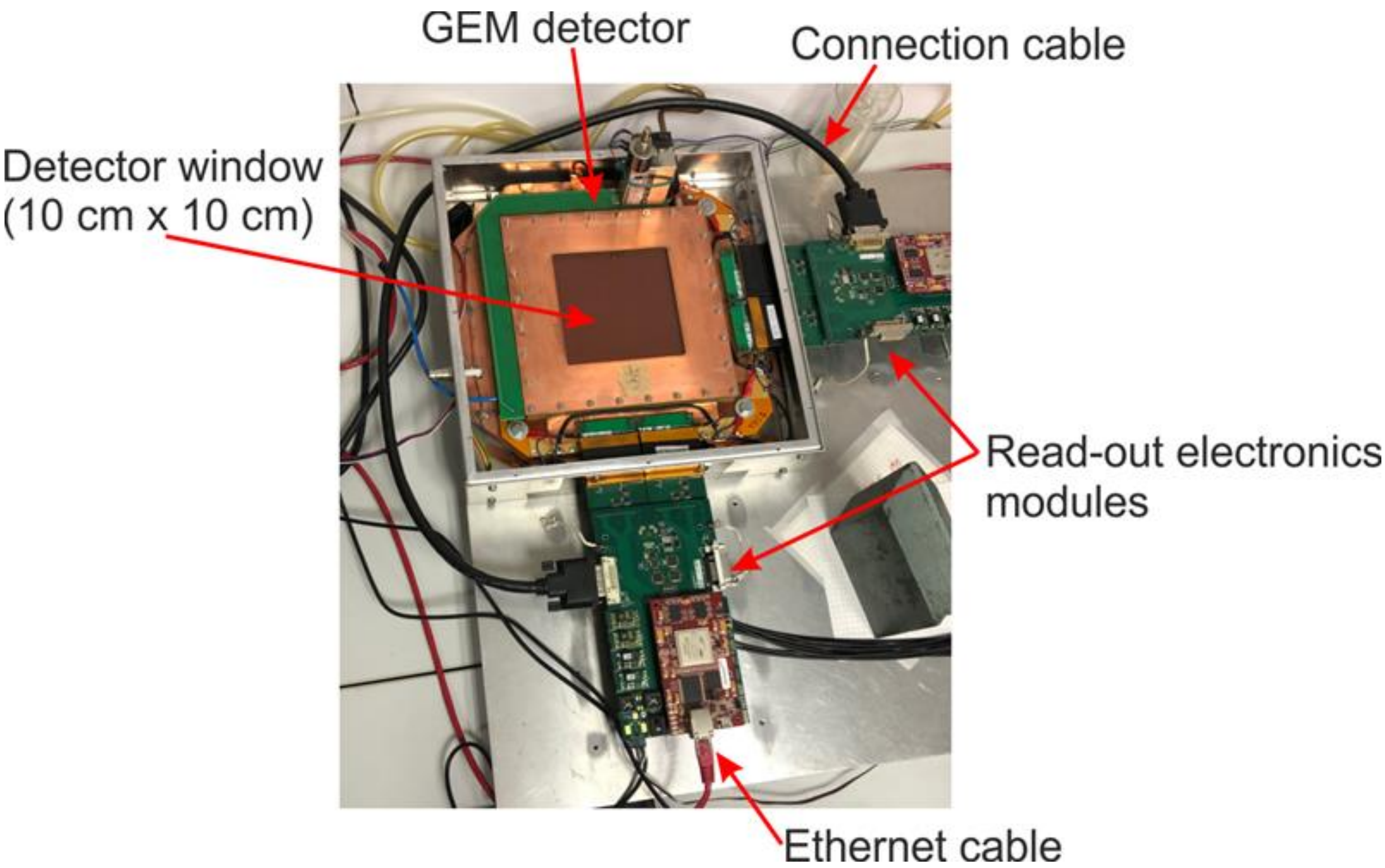
about 8%.

3.4 to 4.2 %

(+) pro: sensitivity (background rejection)

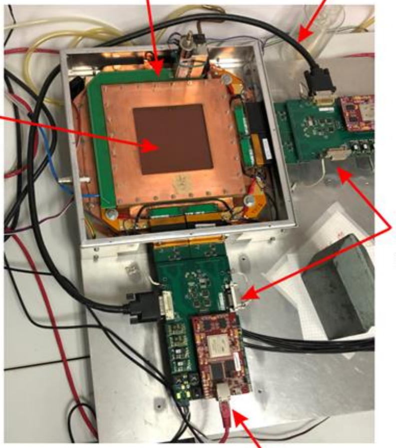
(-) con: low efficiency, complexity

GEM detector



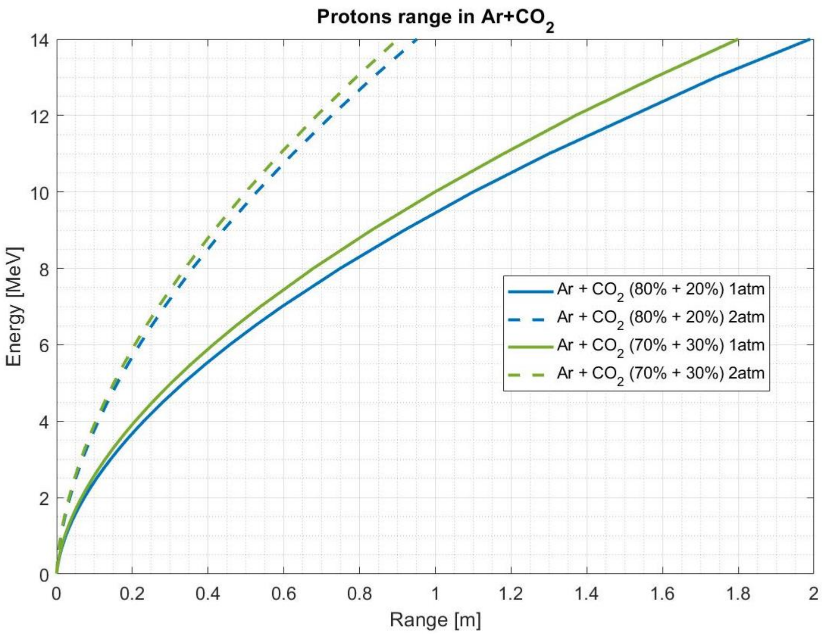
The GEM detector developed at the laboratory of Nuclear Electronics and Radiation Detection Group

GEM detector



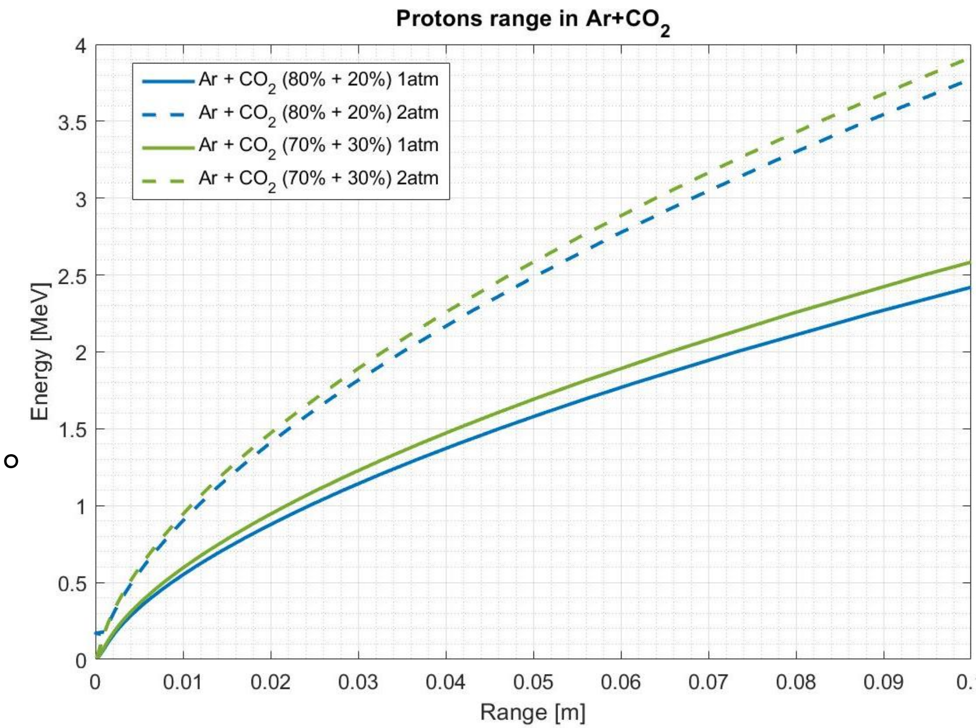
- The presented detector is a 10×10 cm^2 GEM detector with 2-D strip read-out at a pitch of 0.8 mm.
- Both sides of the chamber are read out by electronics modules (ASICs).
- The read-out system allows for recording full 2-D maps of the detailed spatial distribution of gas gain and energy resolution across the detector area (not only average parameters for the entire detector).
- This detector can give information about the position and energy of protons coming to the detector area.
- The working gas of this detector is Ar/CO2 gas mixture with various compositions.

NS-GEM detector feasibility study



SRIMM calculations

Proton Energy vs Range



$$En = \frac{Ep}{cos^2\theta} \rightarrow \begin{matrix} En = 14\ MeV \\ Ep = 2.5\ MeV \end{matrix} \rightarrow \theta = 65°$$

For distance 10 cm – max. 2.5 MeV protons

Summary 2021

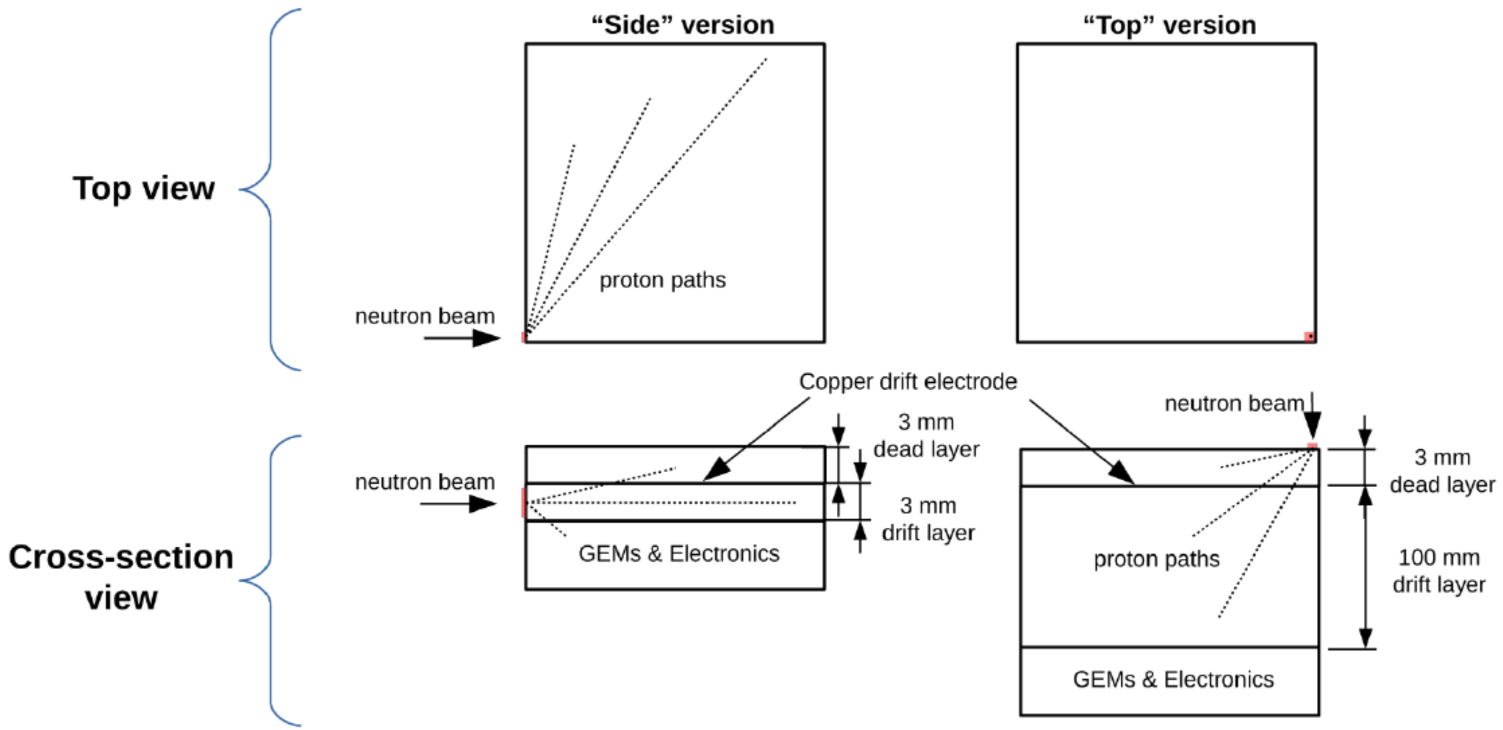
Expected inputs from simulations

- Optimum converter thickness
- Expected range of track lengths
- Charge distribution along the track
- Rate of events (protons)

<u>Next steps:</u>

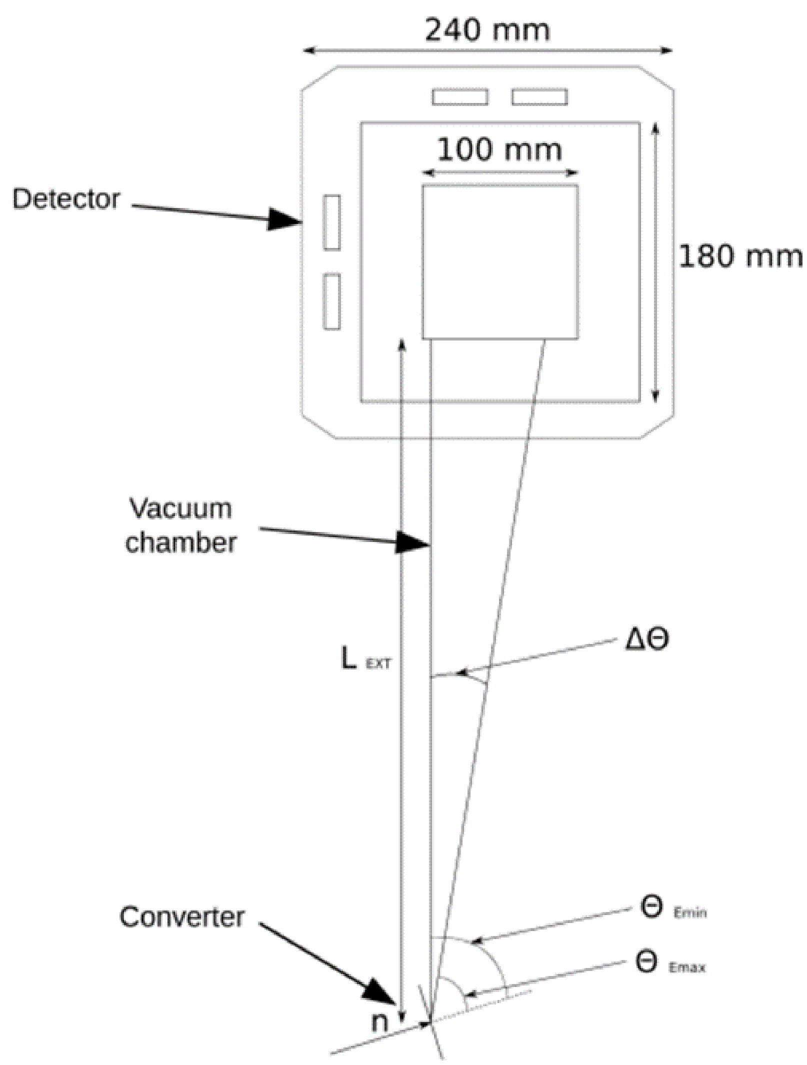
- To chose the type of converter
- To chose the thickness of the converter
- To check another geometry neutron „beam” vs GEM
- to prepare a optimal neutron collimator for 14 MeV neutrons and final experimental set-up

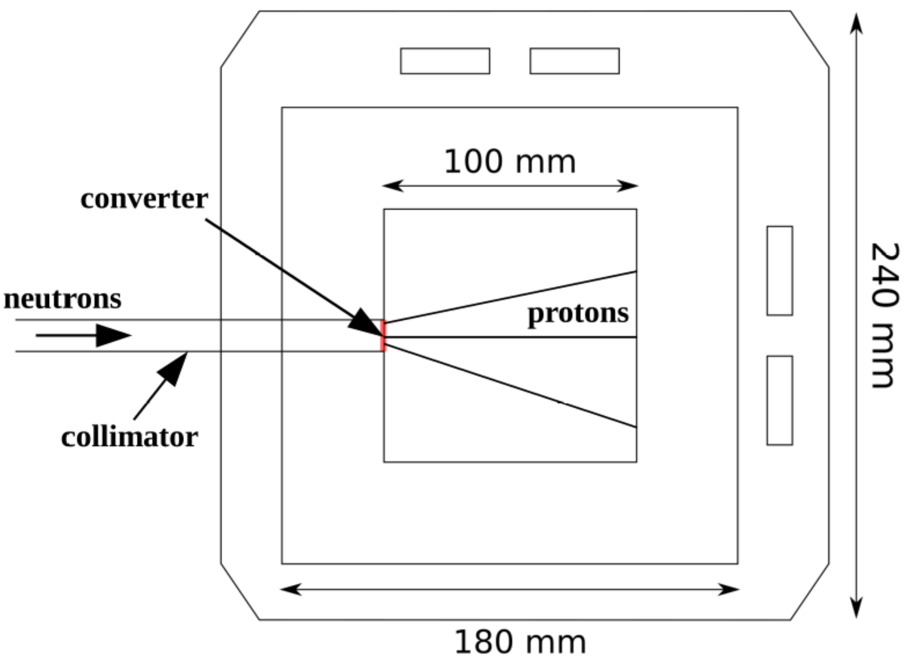
Geometry neutron „beam” vs GEM



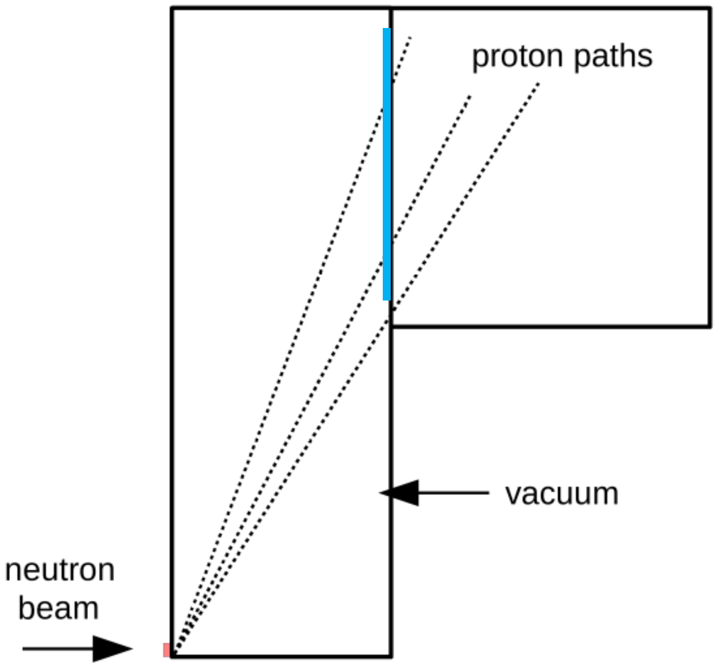
- Side version of detector window has more advantages and is much easier to construct
- Energy resolution of 5% for 14 MeV neutrons is possible but vacuum chamber is necessary, material for detector window should be chosen carefully and additional cutting for proton track shape is necessary.

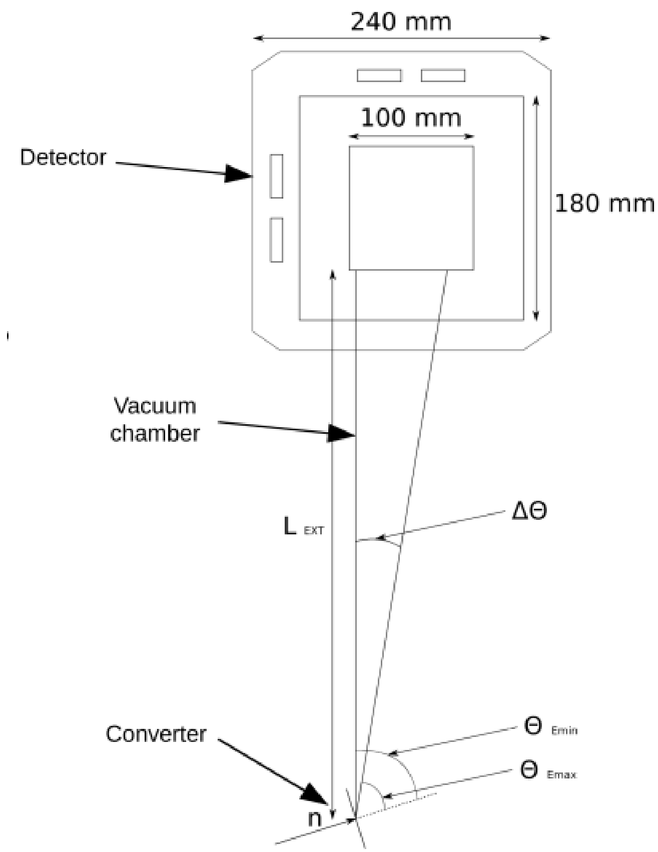
Geometry neutron „beam" vs GEM





Geometry neutron „beam” vs GEM





Proposal of the detector set-up design.

The distance between the neutron-proton converter and the detector window is assumed as L_{max}.

The arrangement of the system is such that only protons that exit the converter at angles greater than 65° ($\Delta\Theta$) will reach the detector.

Influence of detector's window material on resulting energy resolution

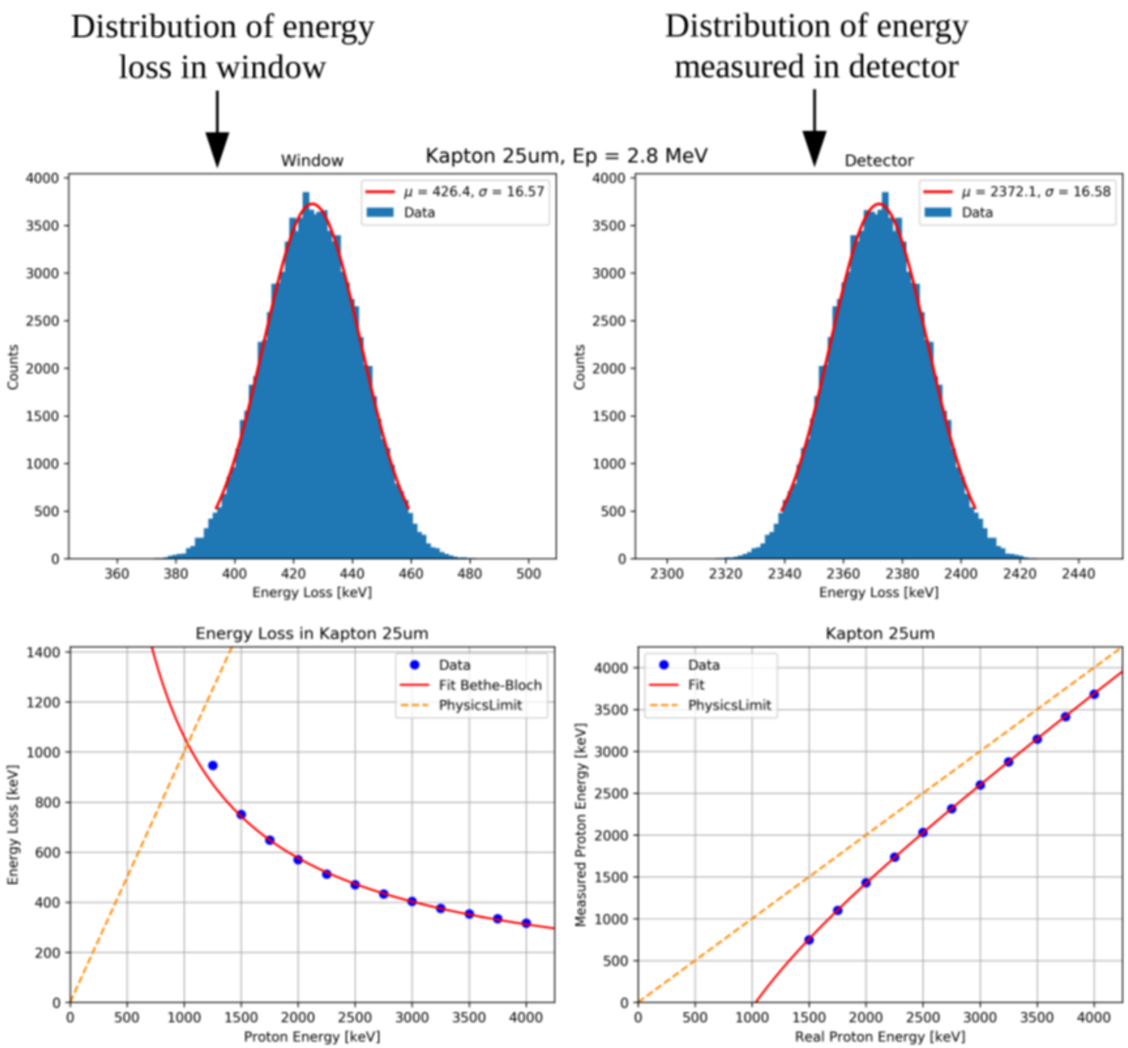
The following variables were taken into account:

- Different window materials and thicknesses:
- Kapton: 5, 12.5, 25, 50 µm
- Aluminum: 10, 30, 50 µm
- Different vacuum arm extensions: L_{EXT} = 0, 100, 200, 300, 400 mm
- Different converter width: d_{conv} = 1, 2 cm

For estimation of the energy loss in the detector window two possible ways of correction were applied and tested used:

1. By adding the same mean energy loss for each proton.
2. By determining individual proton energy based on the window energy loss model (Fit).

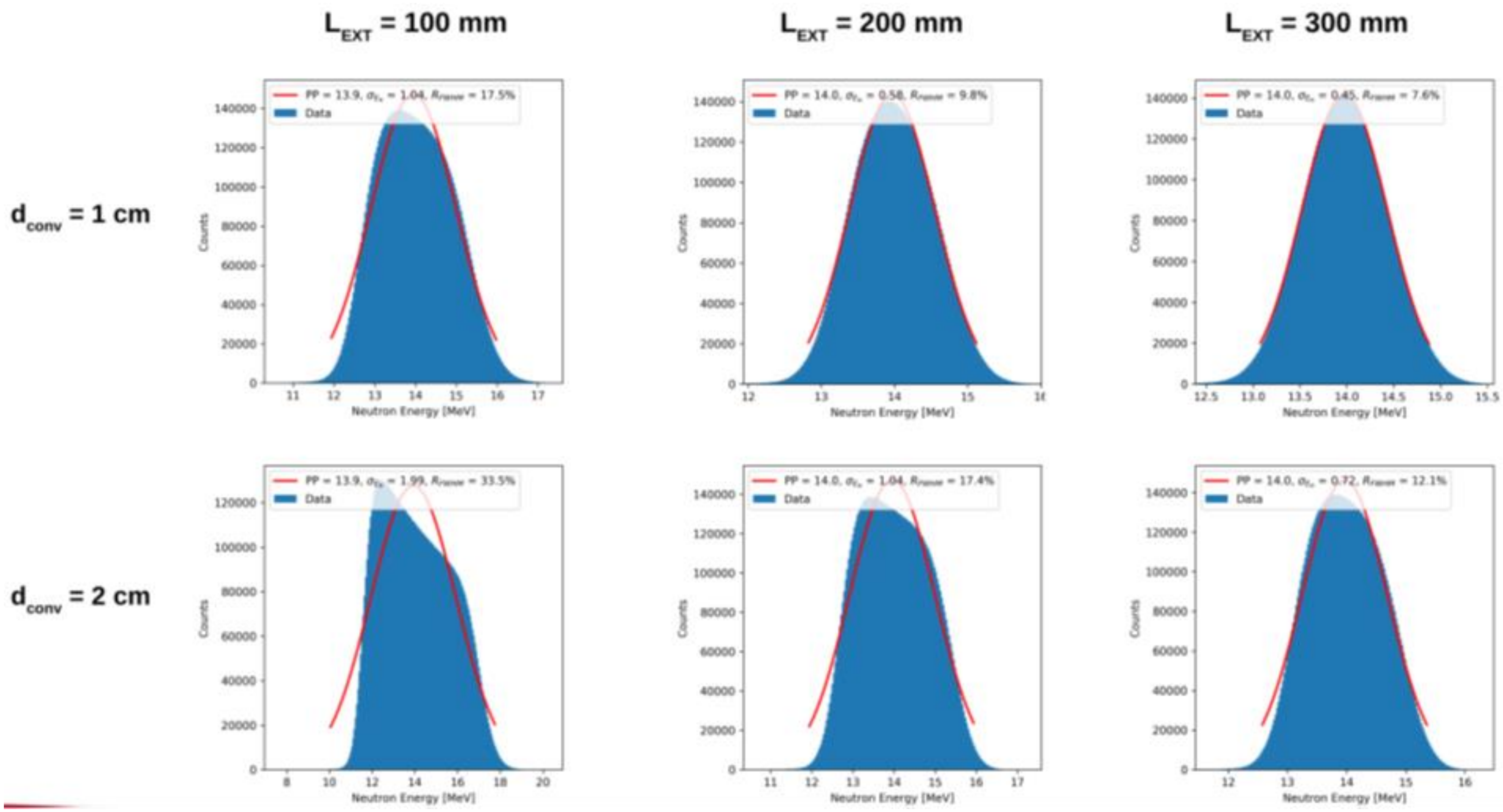
Influence of detector's window material on resulting energy resolution



The conclusion from these analyses:
Results obtained for both types of correction are the same.

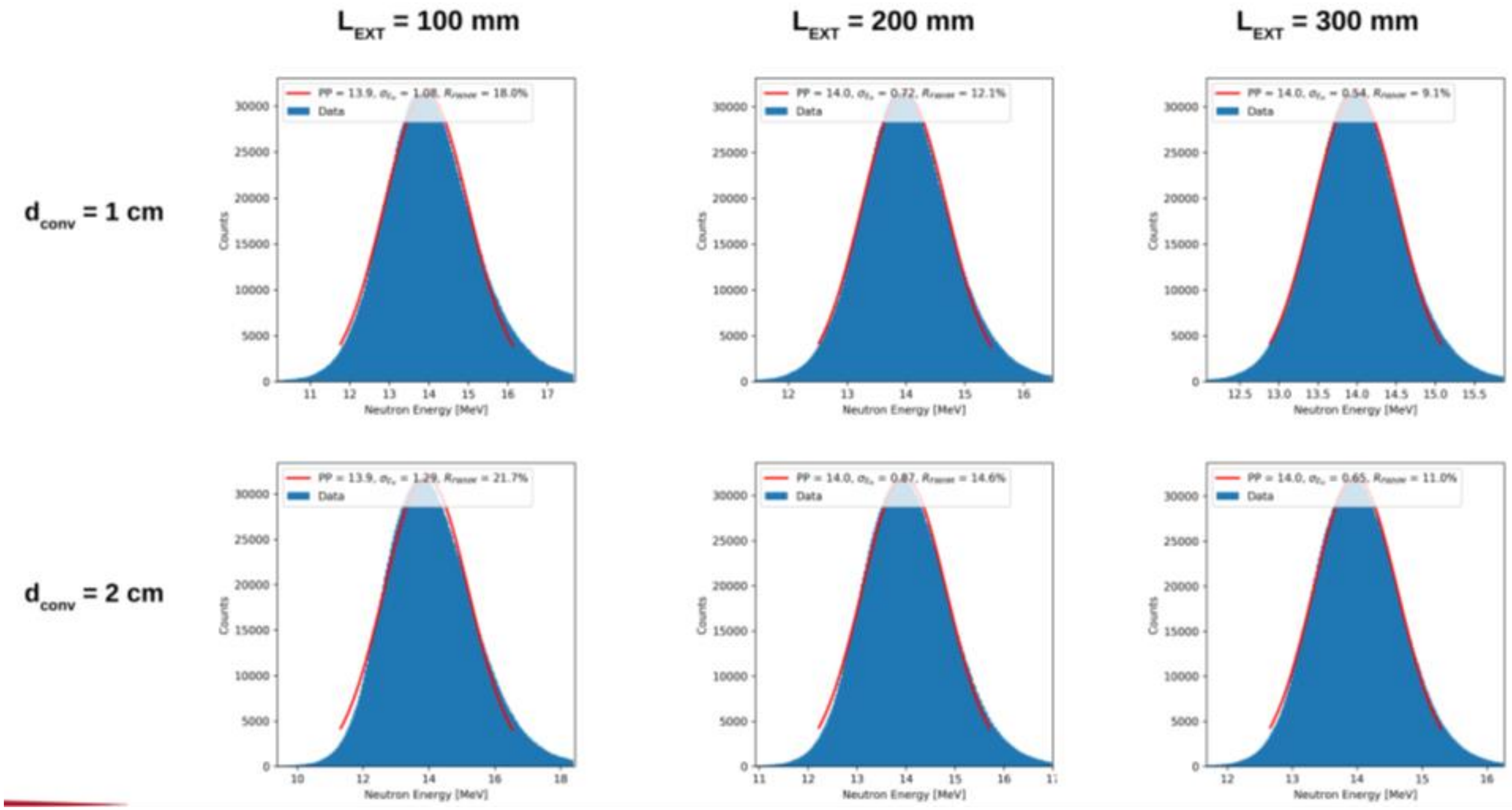
Influence of detector's window material on resulting energy resolution

The impact of measured proton energy on the reconstructed spectrum of neutrons proton energy: 0.8 MeV; a detector window - Kapton of thickness 12.5 μm and two diameters of converter (d_{conv} = 1 cm and 2 cm).



Influence of detector's window material on resulting energy resolution

The impact of measured proton energy on the reconstructed spectrum of neutrons proton energy: 2.6 MeV; a detector window - kapton of thickness 12.5 μm and two diameters of converter (d_{conv} = 1 cm and 2 cm).



Influence of detector's window material on resulting energy resolution

For d_{conv} = 1 cm

Material	Energy Range [Mev]	Energy Resolution [%]				
		L_{EXT} = 0 [mm]	L_{EXT} = 100 [mm]	L_{EXT} = 200 [mm]	L_{EXT} = 300 [mm]	L_{EXT} = 400 [mm]
Kapton 5um	0.4 – 2.5	? – 34.8	17.6 – 18.1	9.2 – 12.2	6.7 – 9.2	5.6 – 7.4
Kapton 12.5um	0.8 – 2.6	23.2 – 34.9	17.5 – 18.0	9.8 – 12.1	7.6 – 9.1	6.8 – 7.3
Kapton 25um	1.2 – 2.8	29.4 – 34.9	17.4 – 18.0	10.2 – 12.1	8.3 – 9.1	7.7 – 7.4
Kapton 50um	1.9 – 3.2	57.8 – 33.4	16.3 – 17.3	9.3 – 11.7	7.2 – 8.8	6.4 – 7.2
Aluminum 10um	0.9 – 2.65	43.0 – 36.2	17.8 – 18.8	10.0 – 12.7	7.7 – 9.6	6.8 – 7.7
Aluminum 30um	1.7 – 3.1	50.6 – 37.9	17.2 – 19.8	10.3 – 13.4	8.5 – 10.2	7.8 – 8.2
Aluminum 50um	2.3 – 3.5	67.3 – 38.1	16.9 – 19.7	10.4 – 13.3	8.8 – 10.1	8.1 – 8.2

Results for E_n=14MeV and $ArCO_2$ 70/30 @ 1.0 atm. pressure
(discrimination on proton's track shape not applied)

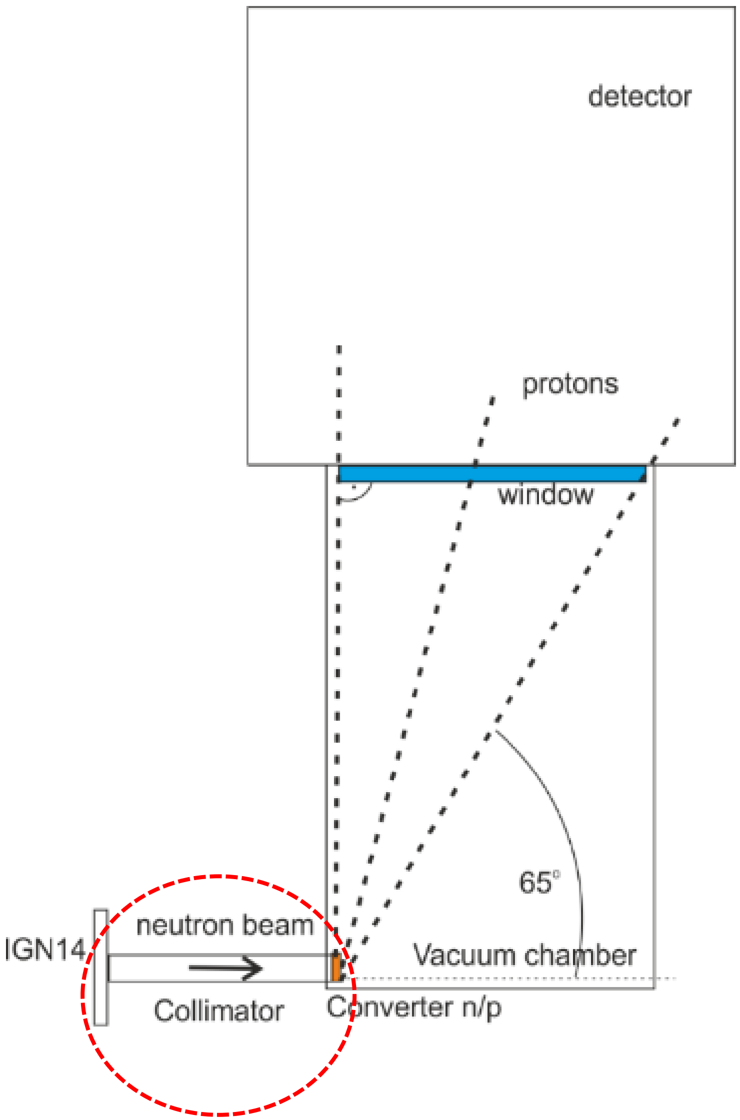
Influence of detector's window material on resulting energy resolution

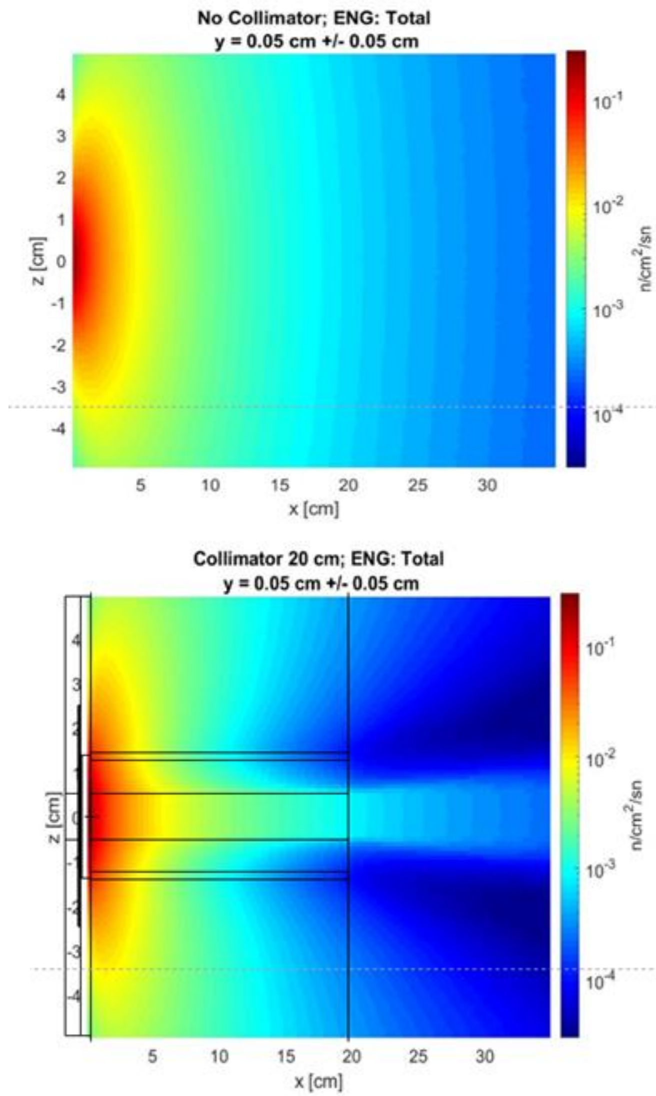
For d_{conv} = 2 cm

Material	Energy Range [Mev]	Energy Resolution [%]				
		L_{EXT} = 0 [mm]	L_{EXT} = 100 [mm]	L_{EXT} = 200 [mm]	L_{EXT} = 300 [mm]	L_{EXT} = 400 [mm]
Kapton 5um	0.4 – 2.5	? – 41.1	37.6 – 21.7	17.7 – 14.7	11.9 – 11.1	9.2 – 8.9
Kapton 12.5um	0.8 – 2.6	? – 41.2	33.5 – 21.7	17.4 – 14.6	12.1 – 11.0	9.6 – 8.8
Kapton 25um	1.2 – 2.8	? – 41.1	32.9 – 21.5	17.3 – 14.5	12.3 – 10.9	10.0 – 8.8
Kapton 50um	1.9 – 3.2	? – 39.7	30.8 – 20.8	16.4 – 14.1	11.4 – 10.6	9.1 – 8.6
Aluminum 10um	0.9 – 2.65	? – 42.1	32.9 – 22.2	17.3 – 15.0	12.1 – 11.3	9.5 – 9.1
Aluminum 30um	1.7 – 3.1	? – 43.1	31.8 – 22.9	17.0 – 15.5	12.2 – 11.7	10.0 – 9.5
Aluminum 50um	2.3 – 3.5	? – 43.2	30.8 – 22.8	16.7 – 15.4	12.1 – 11.7	10.1 – 9.4

Results for E_n=14MeV and $ArCO_2$ 70/30 @ 1.0 atm. pressure
(discrimination on proton's track shape not applied)

The neutron collimator

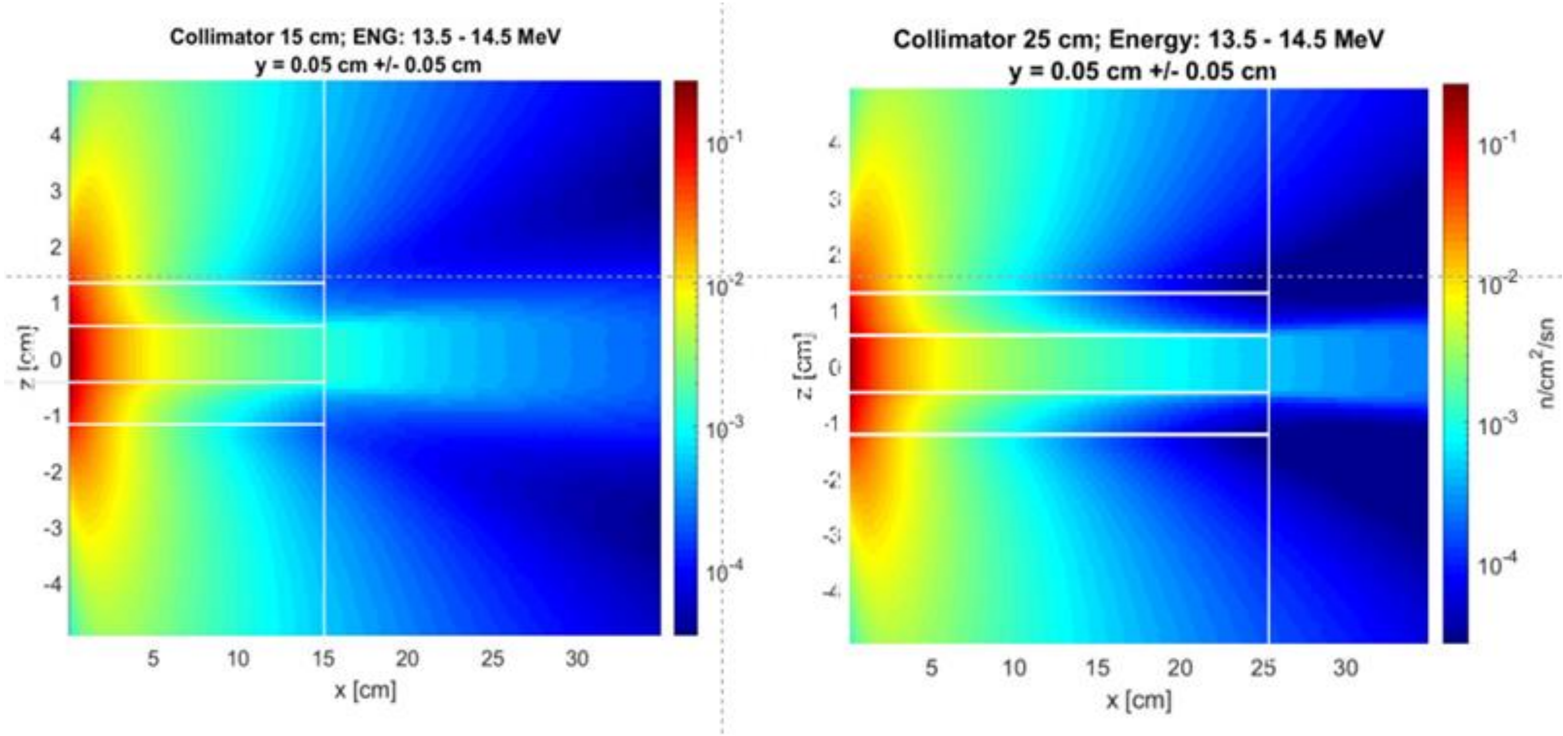




The validity of the use of a collimator is presented in the two figures.

The neutron collimator

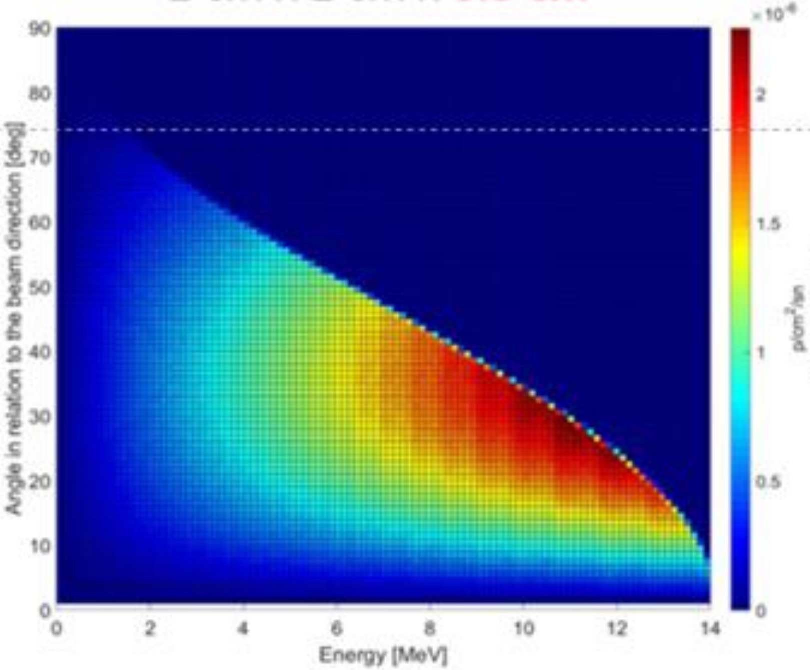
Dependence of the neutron beam collimation on the collimator length (is presented for two length of collimator: 15 cm and 25 cm



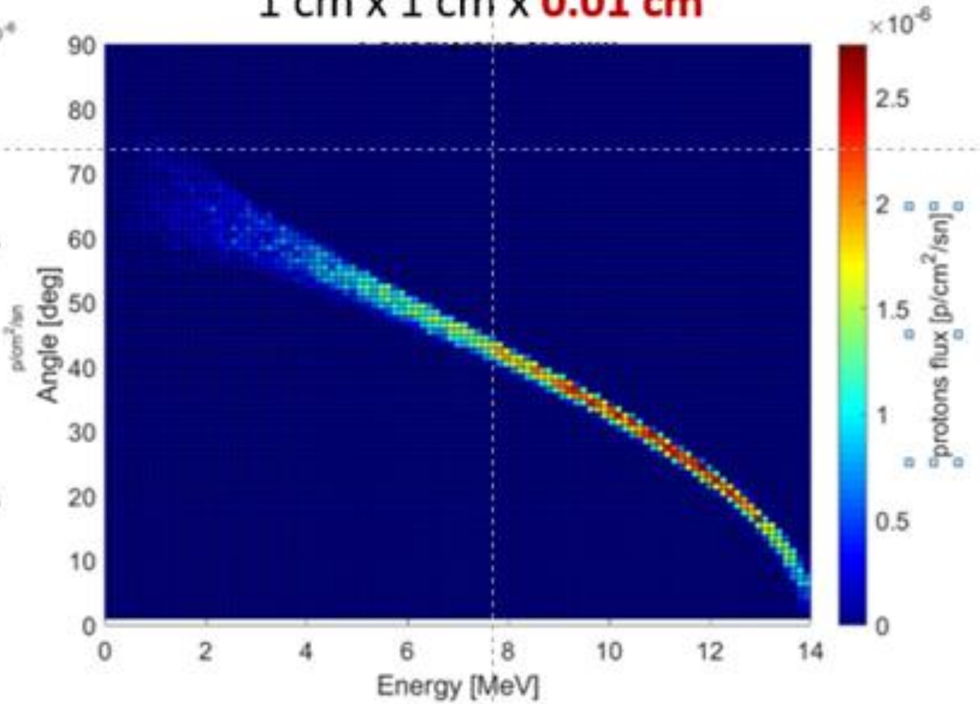
The neutron converter

Influence of the converter thickness on the energy-angle distribution of protons

Polyethylene:
1 cm x 1 cm x **0.3 cm**



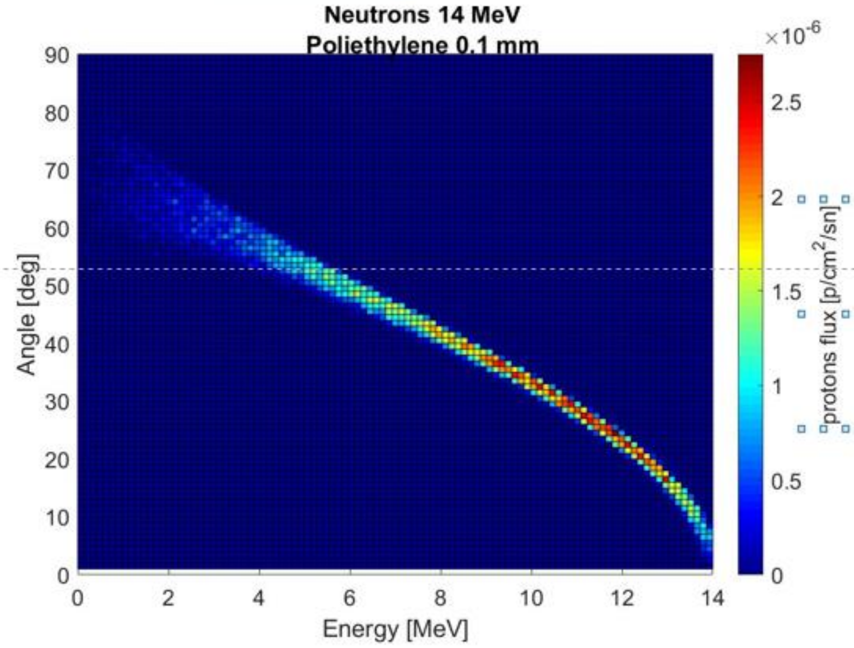
Polyethylene:
1 cm x 1 cm x **0.01 cm**



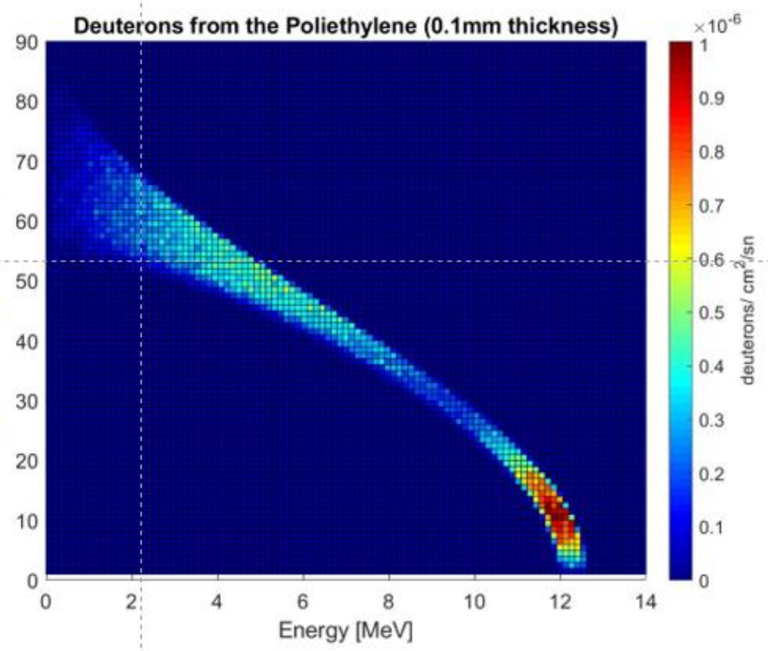
The neutron converter

Influence of the material of converter on the energy-angle distribution of protons

Polyethylene – Proton distribution



Deuterized Polyethylene – Deuteron distribution



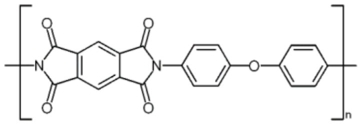
Material for detector window

Materials for detector window under investigation:

Kapton - poli(4,4'-oksydifenylen-piromellitimidyna) $(C_{22}H_{10}N_2O_5)_n$

ρ =1.42 g/cm^3

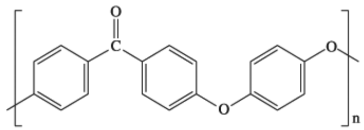
5, 12.5, 25 μm



Mylar - poli tereftalan etylenu PET $(C_{10}H_8O_4)_n$

ρ = 1.39 g/cm^3

12.5, 23 μm



PEEK $(C_{19}H_{12}O_3)_n$

ρ = 1.32 g/cm^3

25 μm

MIKA – Muscovit $KAl_2[AlSi_3O_{10}(OH,F)_2]$)

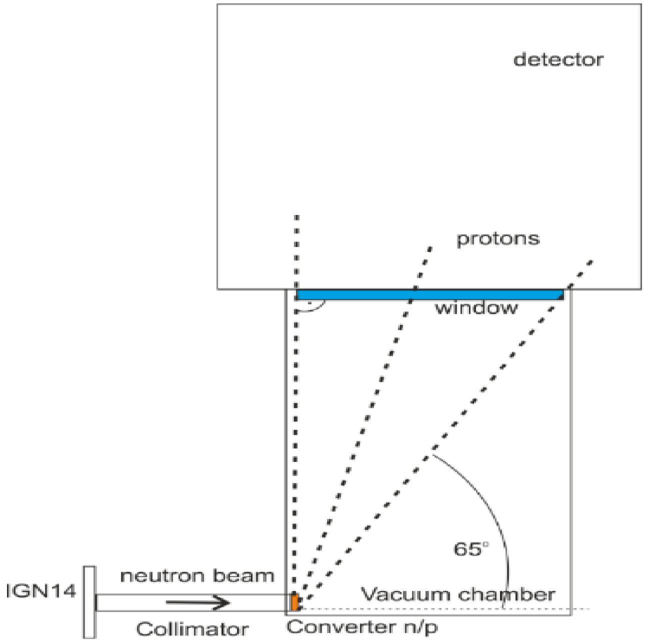
ρ = 2.75 – 3.4 g/cm^3 (3 g/cm^3)

10 μm

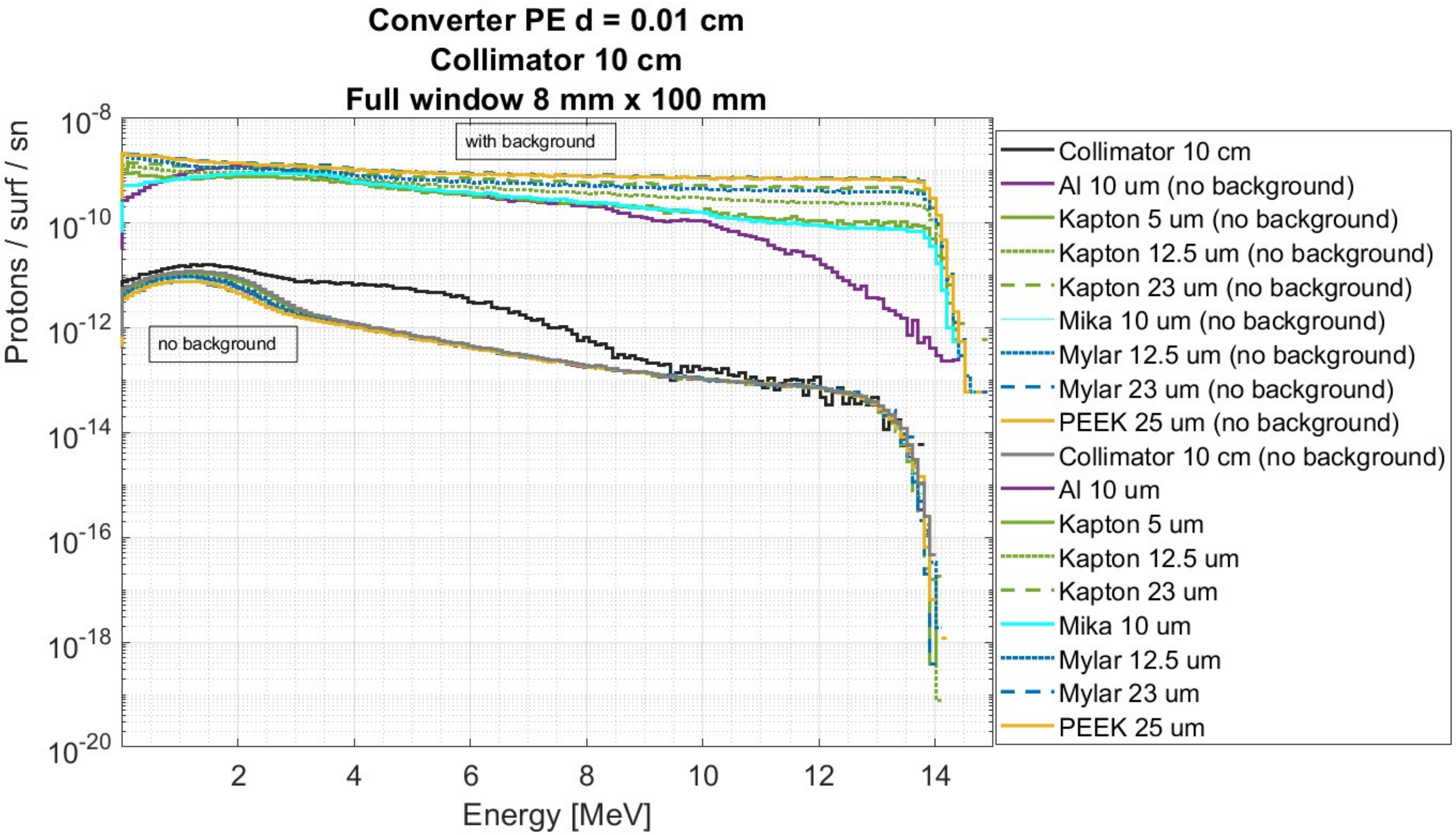
Al

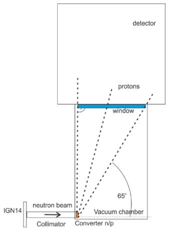
ρ = 2.6989 g/cm^3

10 μm

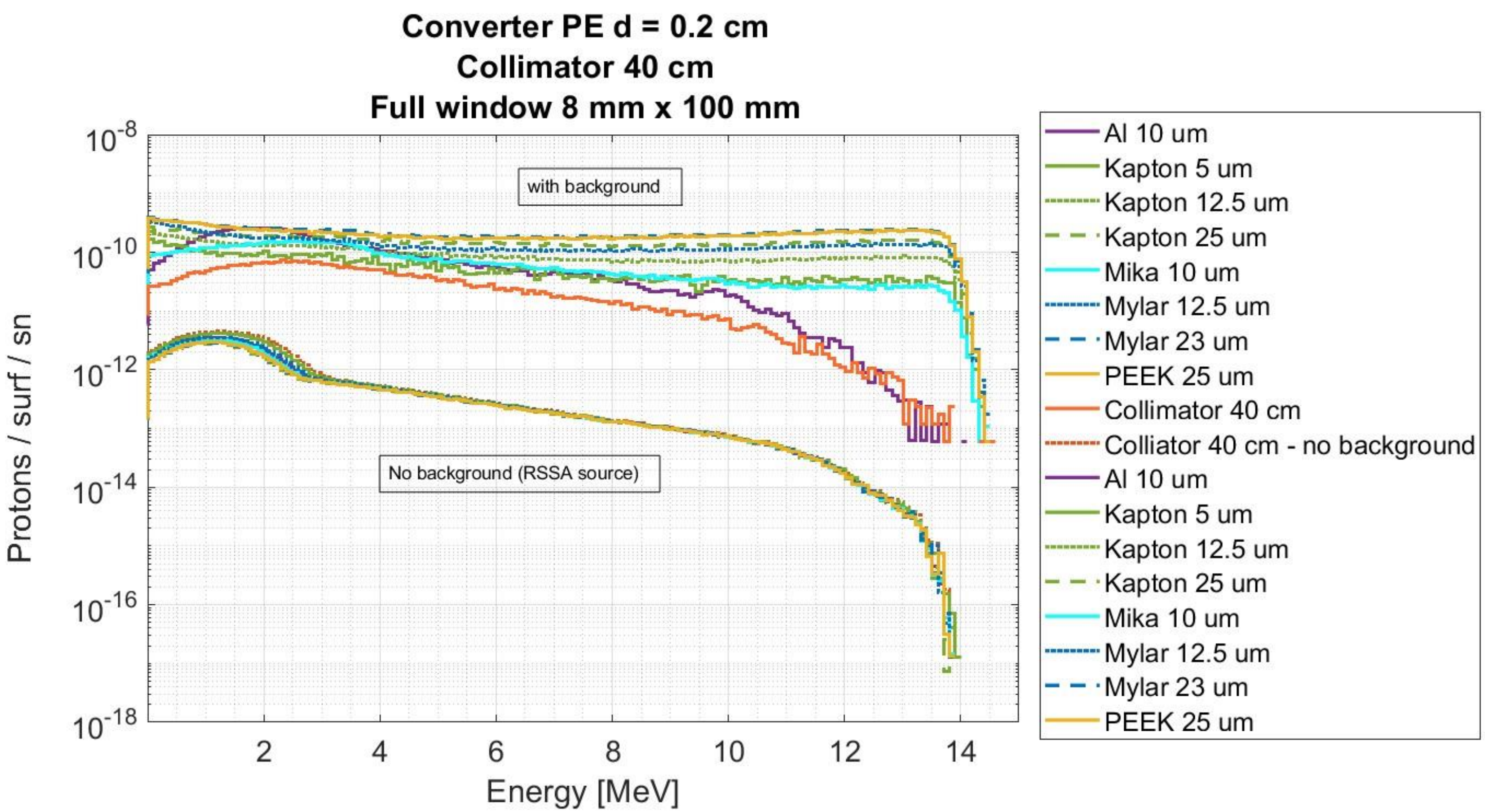


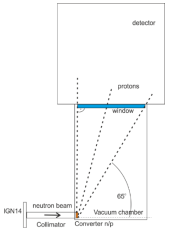
Material for detector window v.s. protons in detector window (in & out)



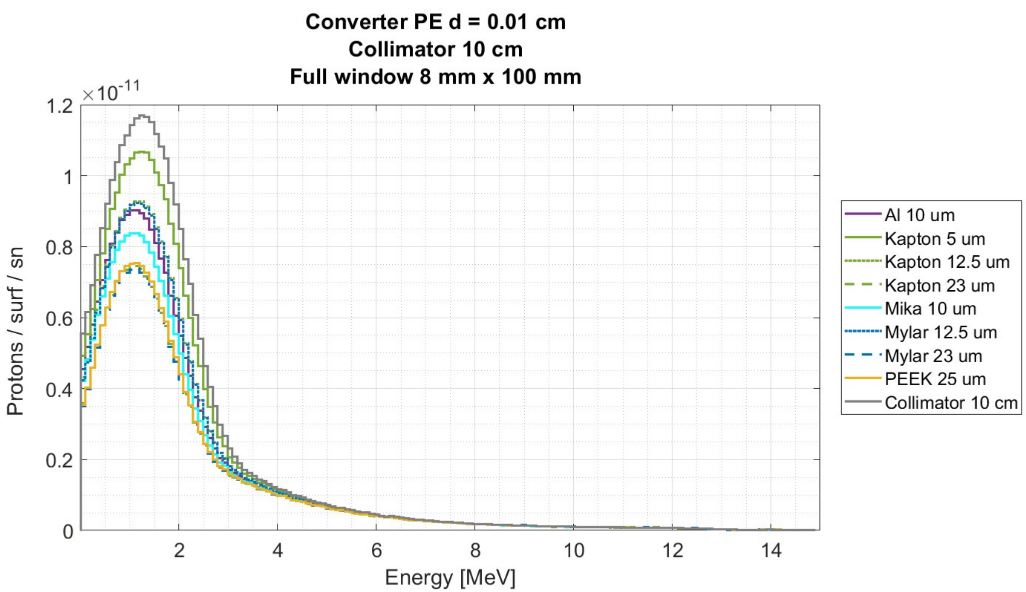


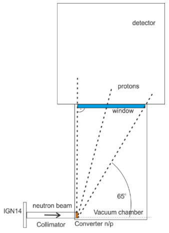
Material for detector window v.s. protons in detector window (in & out)

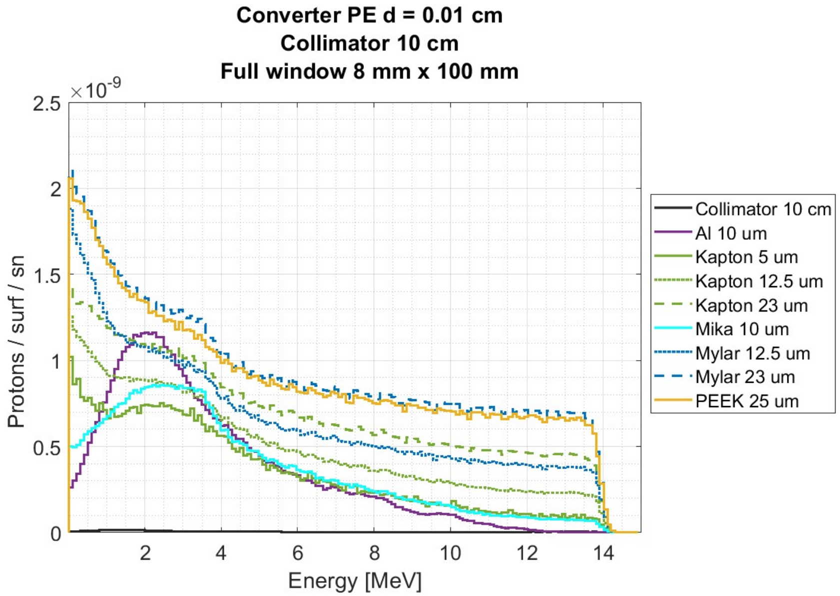




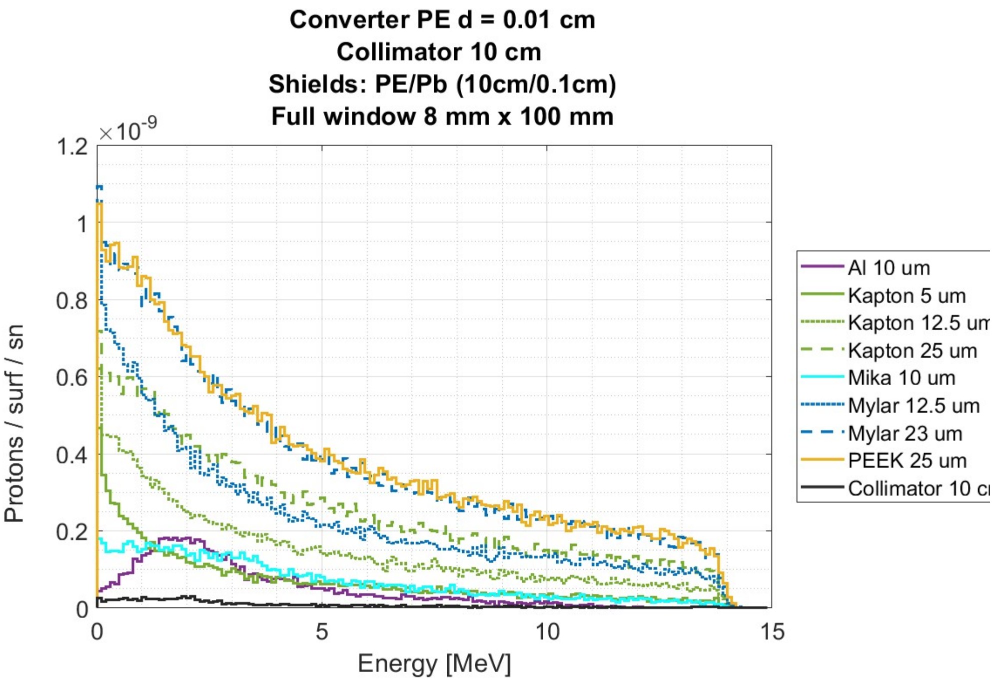
Material for detector window v.s. protons in detector window (in & out)

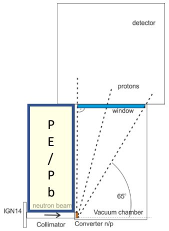


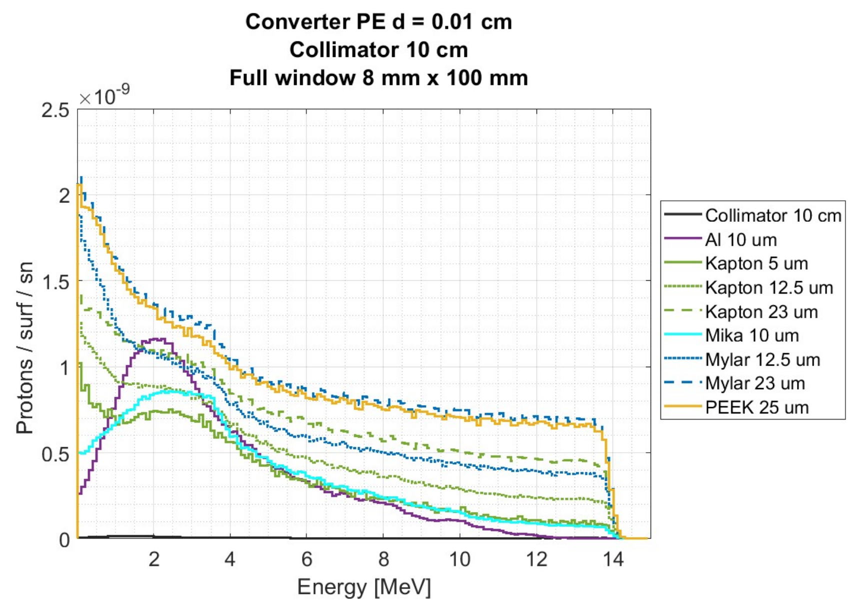




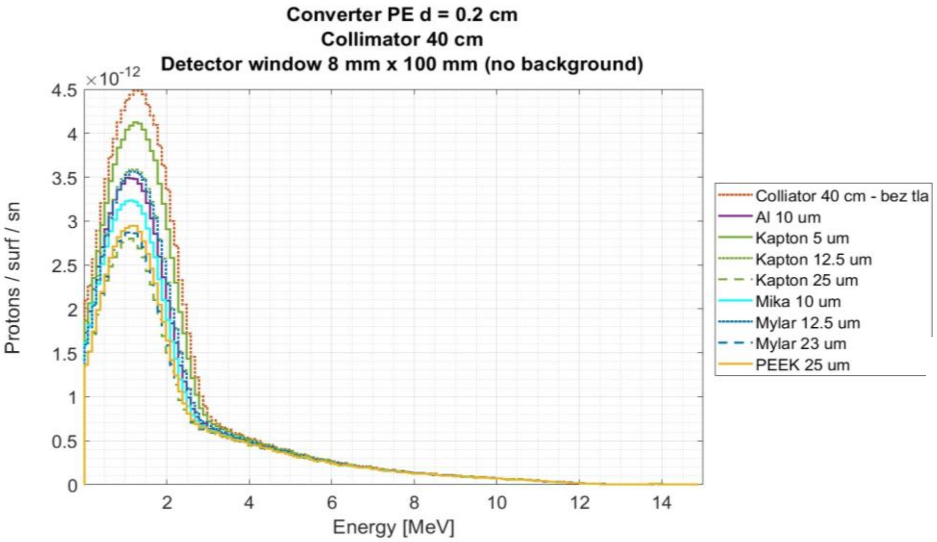
Material for detector window v.s. protons in detector window (in & out)

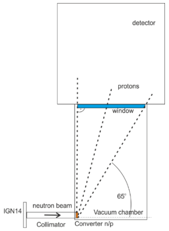


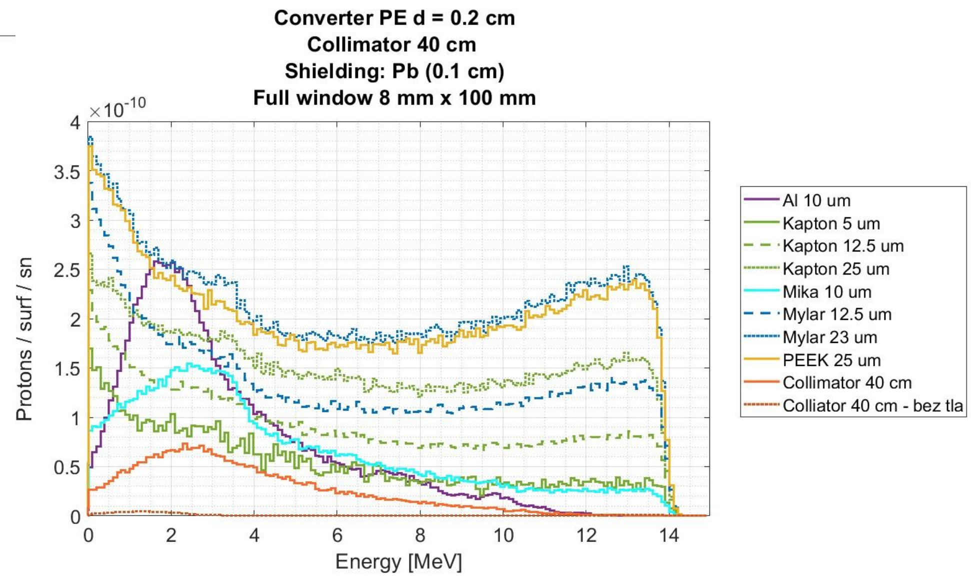




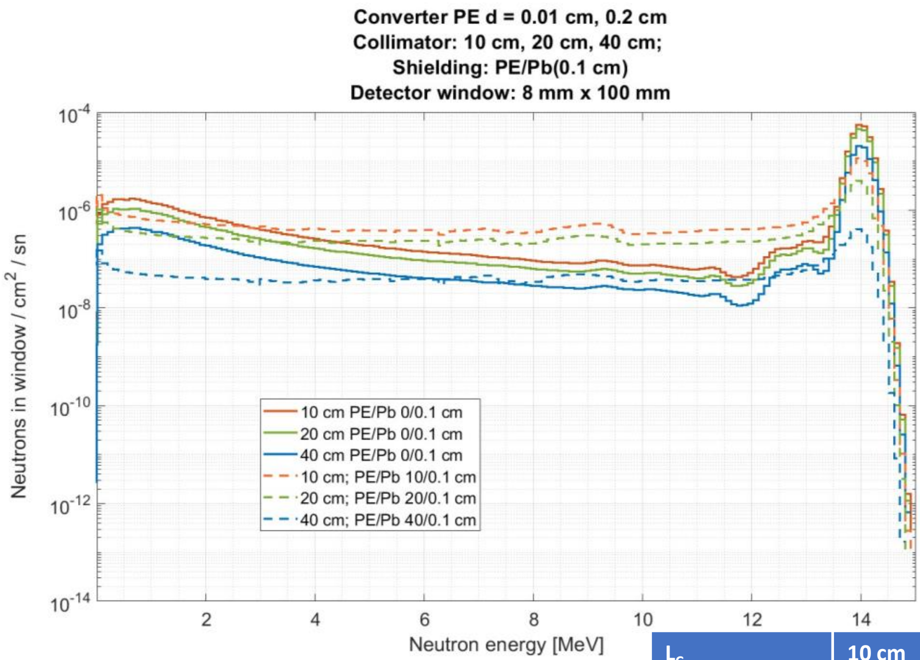
Material for detector window v.s. protons in detector window (in & out)

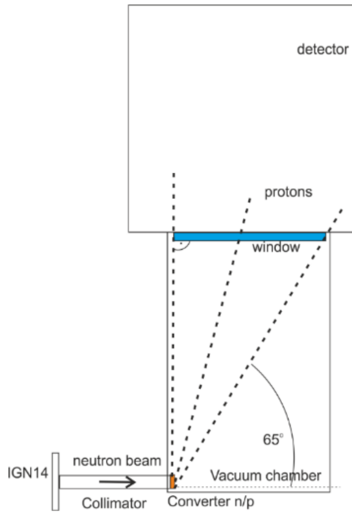


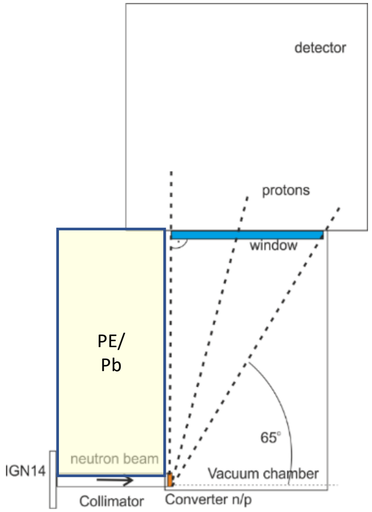




Neutrons flux in detetector window (d = 10 um)

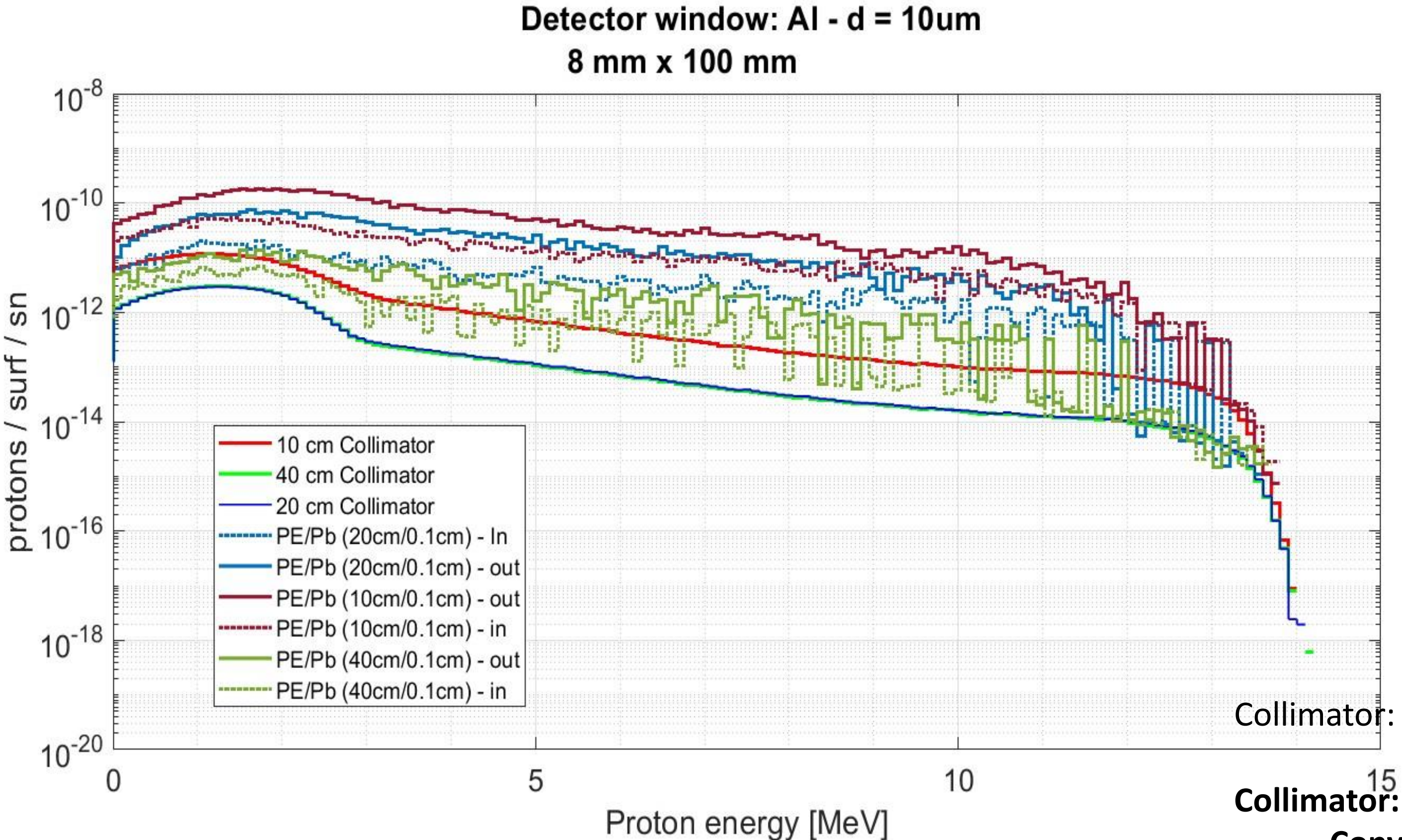


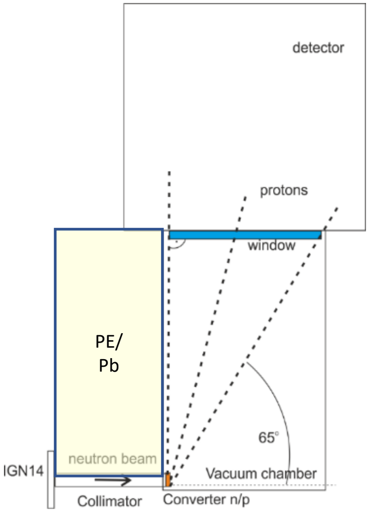




L_C	10 cm		20 cm		40 cm	
PE	0 cm	10 cm	0 cm	20 cm	0 cm	40 cm
SUM (n/ m^2/sn)	2.58e-4	1.27e-4	1.99e-4	6.28e-5	8.93e-5	9.03e-6
<8MeV >8MeV	4.03e-5 2.17e-4	5.20e-5 7.49e-5	2.45e-5 1.75e-4	2.95e-5 3.34e-5	1.06e-5 7.87e-5	4.54e-6 4.49e-6
$\frac{n_{E>8MeV}}{n_{E<8\,MeV}}$	5.38	1.44	7.14	1.13	7.40	0.99

Protons in detector window (in & out)



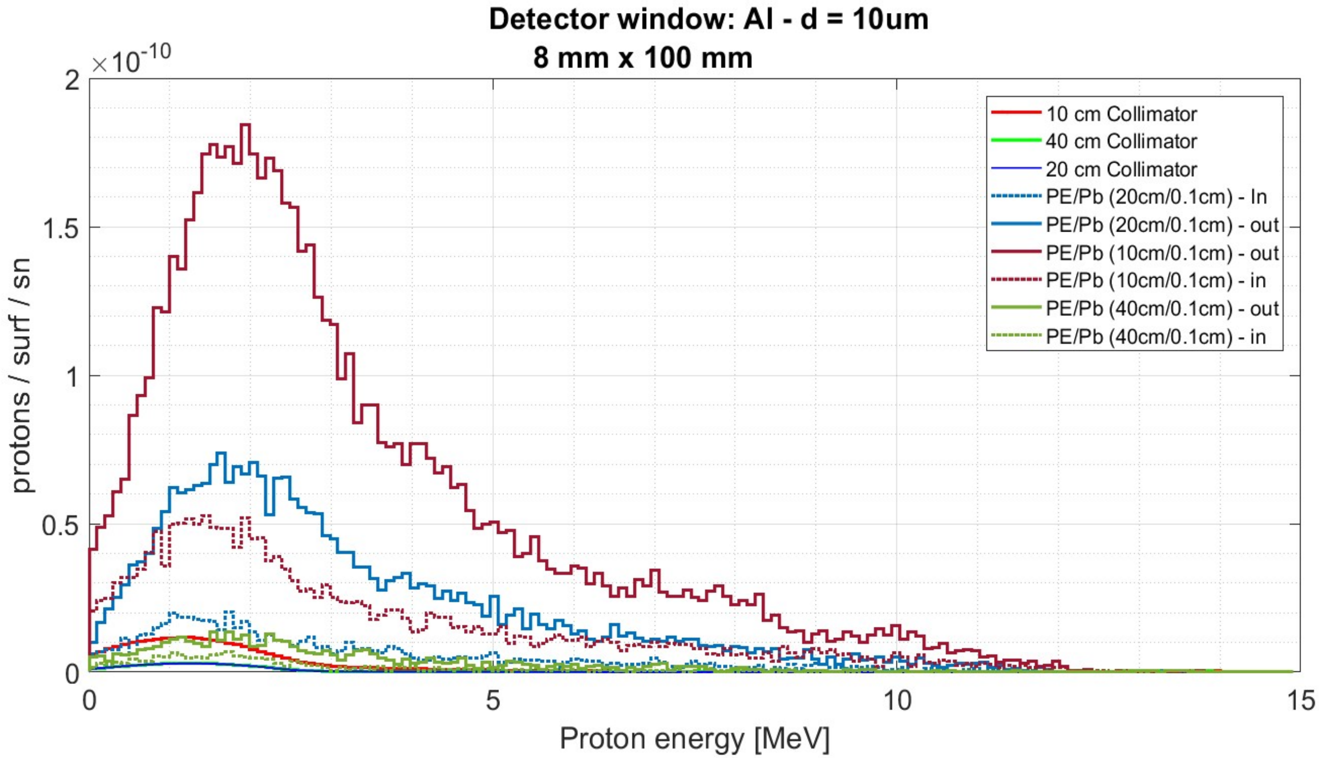


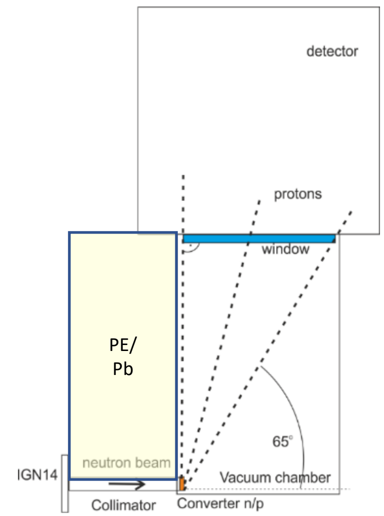
Collimator: L_C = 10, 20 cm; ϕ_C = 1 cm

Collimator: L_C = 40 cm; ϕ_C = 2 cm

Converter thickness = 0.2 cm

Protons in detector window (in & out)

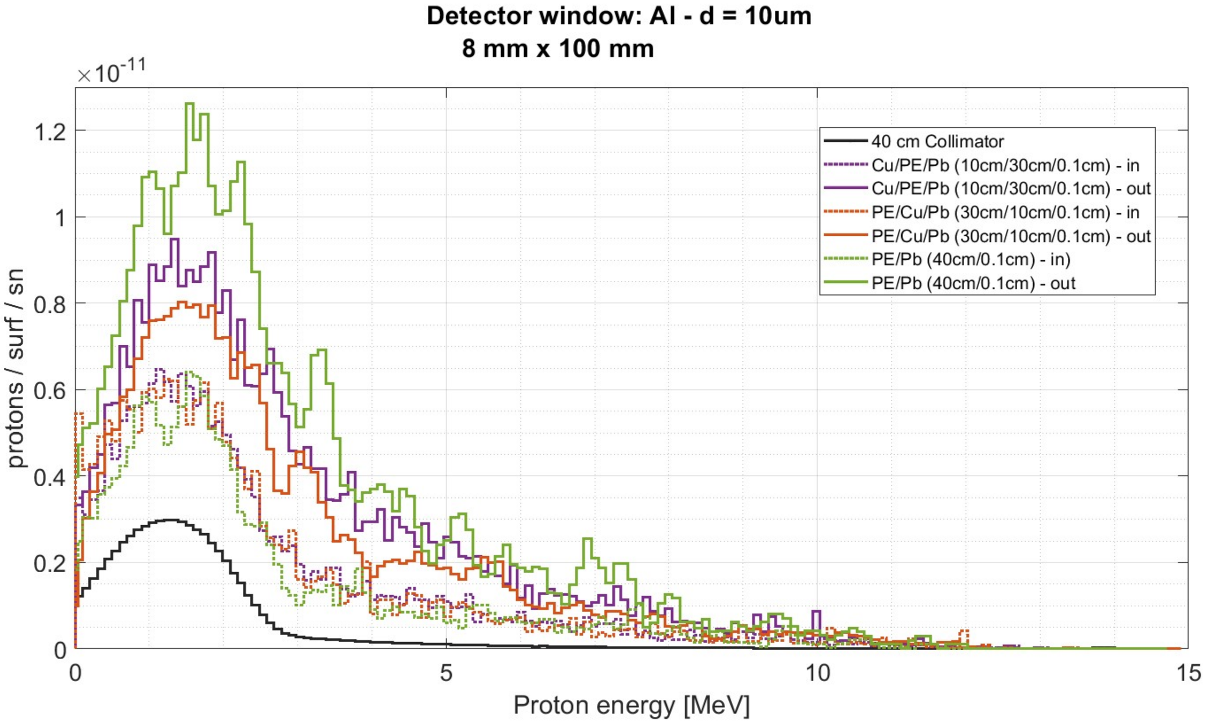


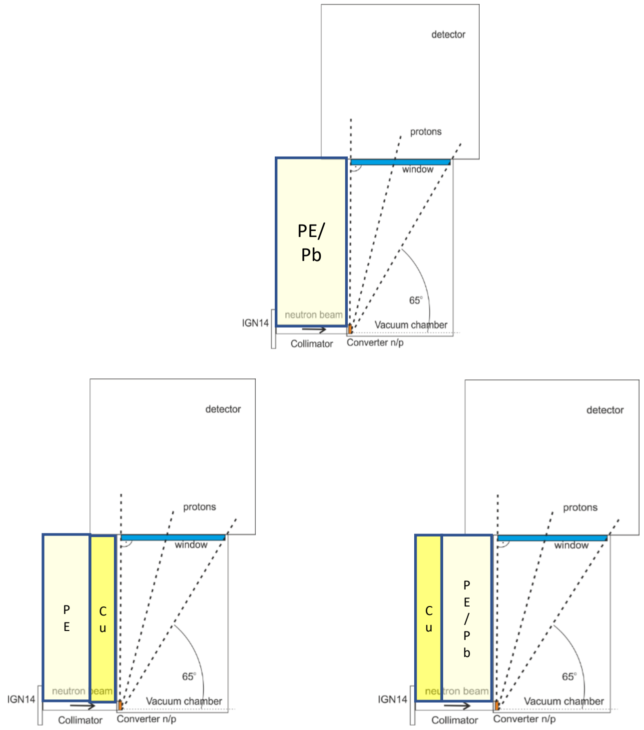


Collimator: L_C = 10, 20 cm; ϕ_C = 1 cm

Collimator: L_C = 40 cm; ϕ_C = 2 cm
Converter thickness = 0.2 cm

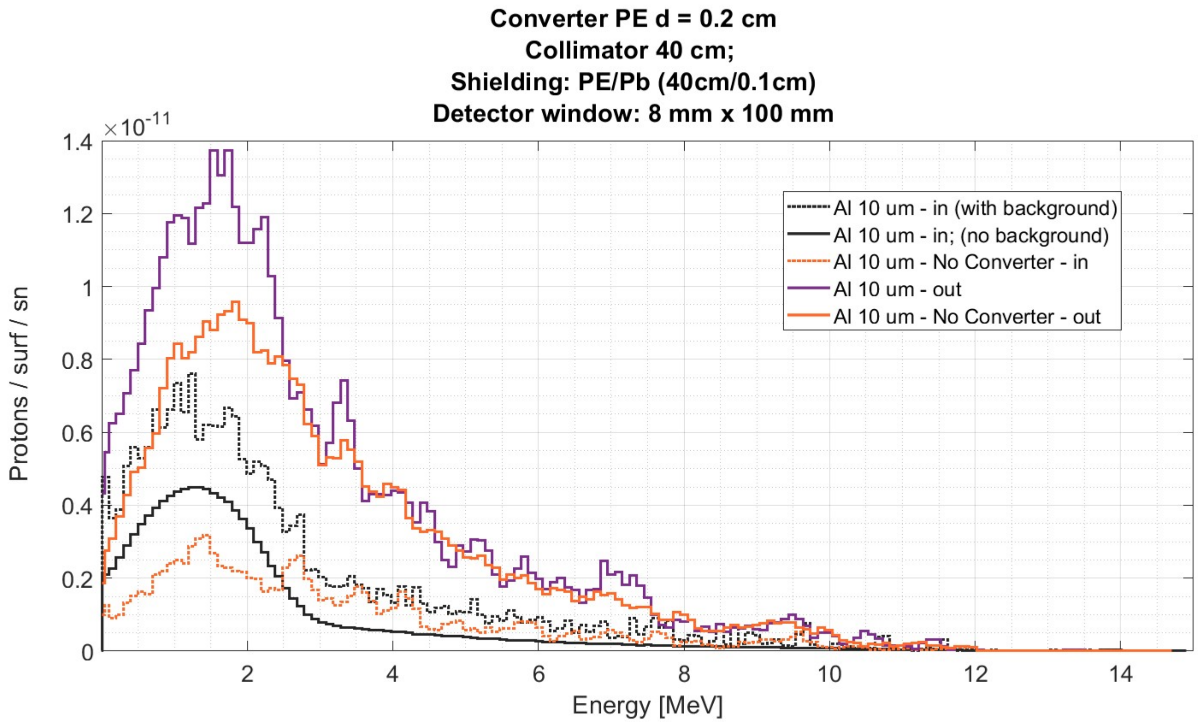
Protons in detector window (in & out)

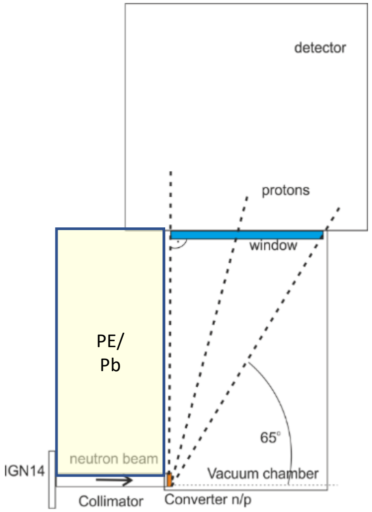




Collimator: L_C = 40 cm; ϕ_C = 2 cm
Converter thickness = 0.2 cm

Protons in detector window (in & out)

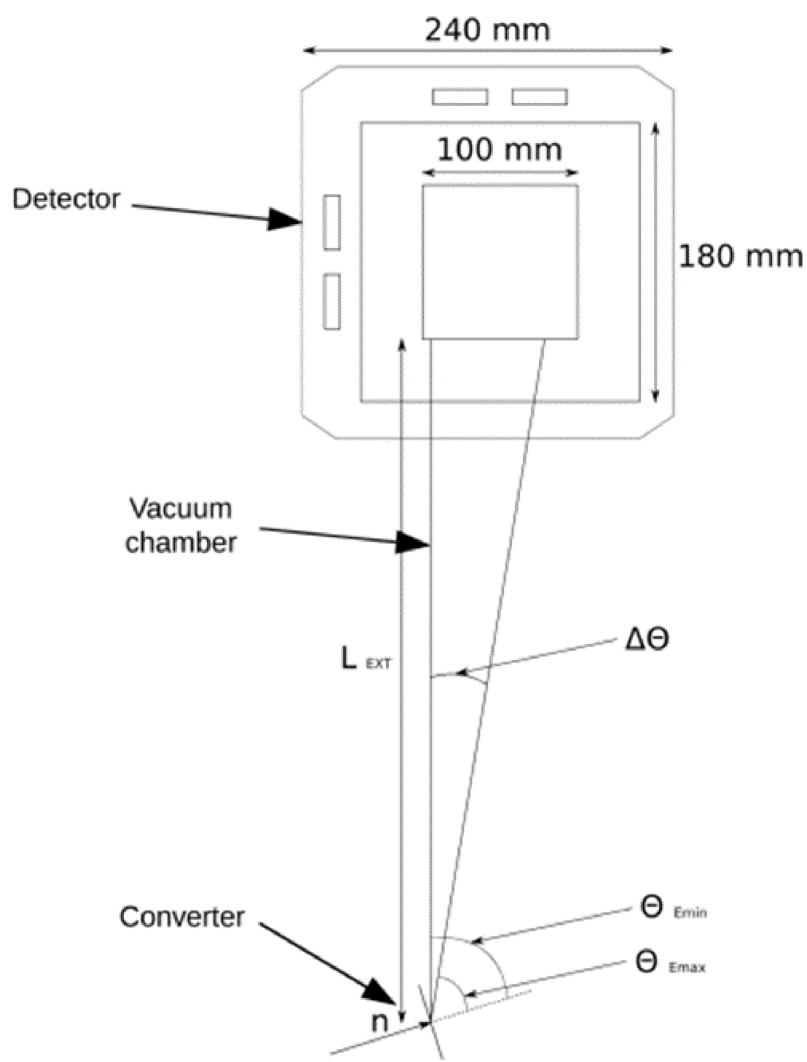


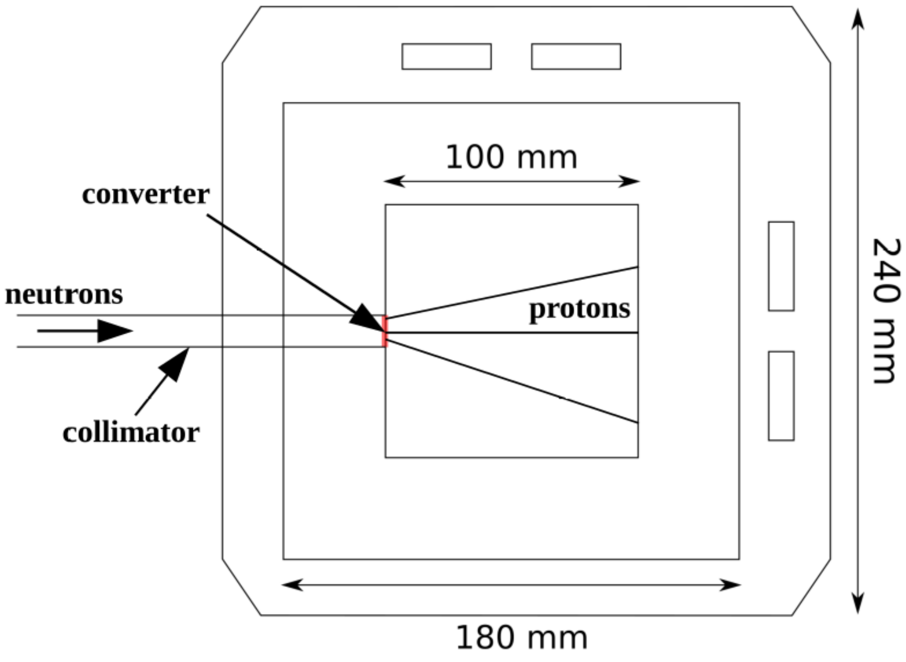


Next steps…

- Detector window works as converter
- 40 cm – not enough to eliminate a neutron background
- To find a way how eliminate background from neutrons – material?

To check another geometry neutron „beam" vs GEM





Summary

Meetings Dates:

- 15.03.2022
- 26.04.2022
- 19.05.2022
- 28.06.2022
- 21.07.2022
- 26.09.2022

Collecting meetings data:

https://wiki.euro-fusion.org/wiki/Project_No12