CHARACTERIZATION OF NEUTRON LEAKAGE FIELD COMING FROM $^{18}O(P,N)^{18}F$ REACTION IN PET PRODUCTION CYCLOTRON

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Research Centre Rez

- Member of the UJV Group
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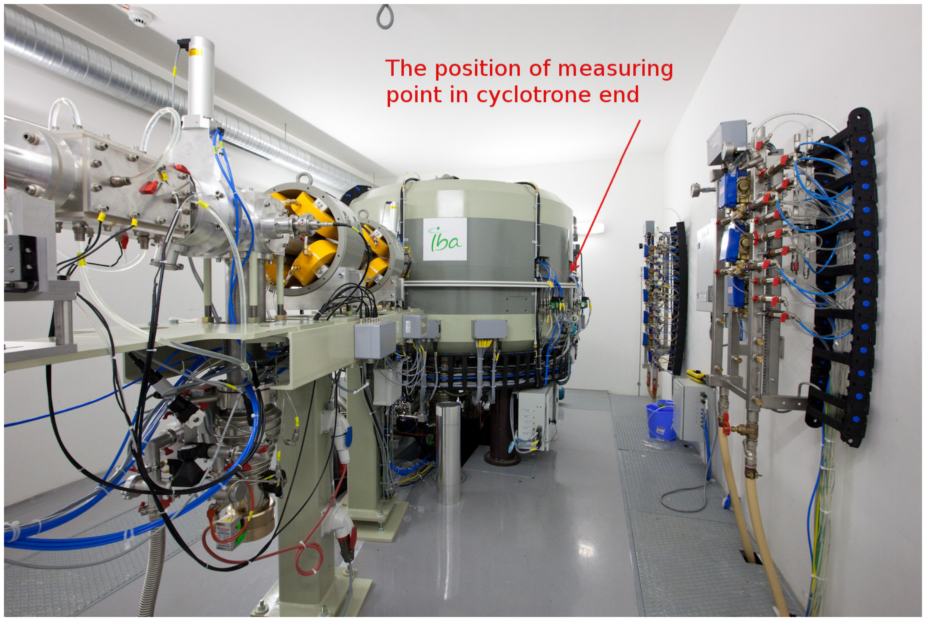
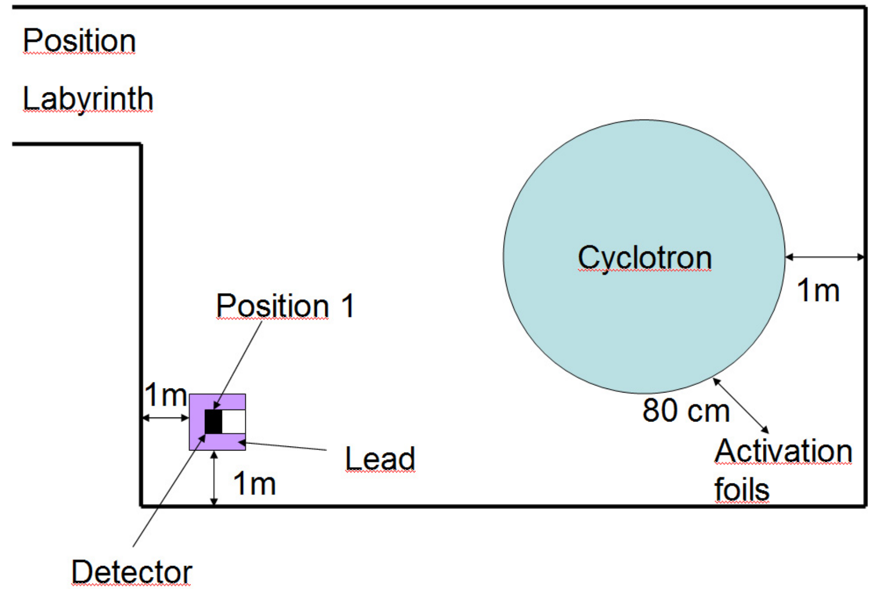
- Partner of governmental bodies in power generation safety, security and strategy
- Partner of universities in educating new generation of experts
- Member of international research consorcia in European research programmes
- Member of Technology Platforms (SNETP, TPUE)
- Member of ExCom of the European Energy Research Alliance (EERA)

IBA Cyclone 18/9 cyclotron





The product is 2-fluoro-2-deoxy-D-glucose (FDG) labeled by 18F which origins from 18O(p,n)18F reaction.

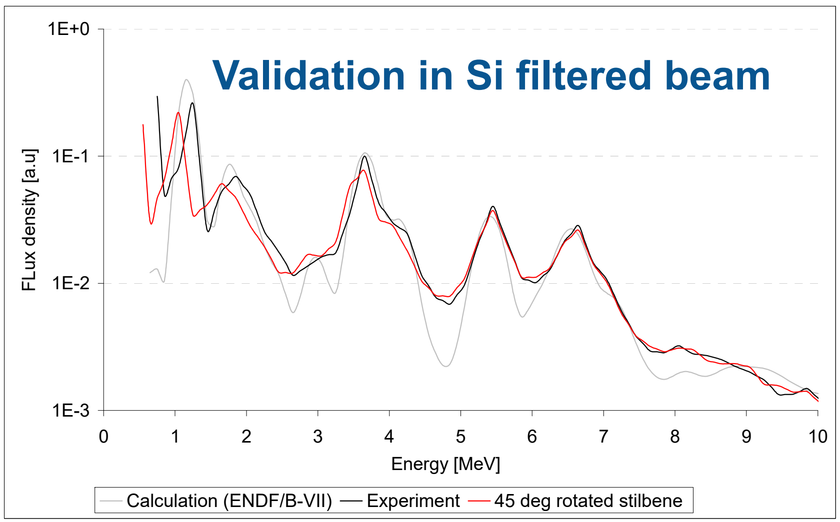
Cyclotron is located inside a 4 m wide and 5.75 m long concrete shielding bunker.

Measurements were performed during irradiation (by 18 MeV protons) of 2.7 ml 18O enriched water (min. 98 %).

The current generated by the proton beam on the target was ~75 μA or 0.92 μA.

Measurements with stilbene scintilation detector

- The calibration was tested in Si filtered neutron beam
- the effect of anisotropy was tested in Si beam as well
- Energy calibration



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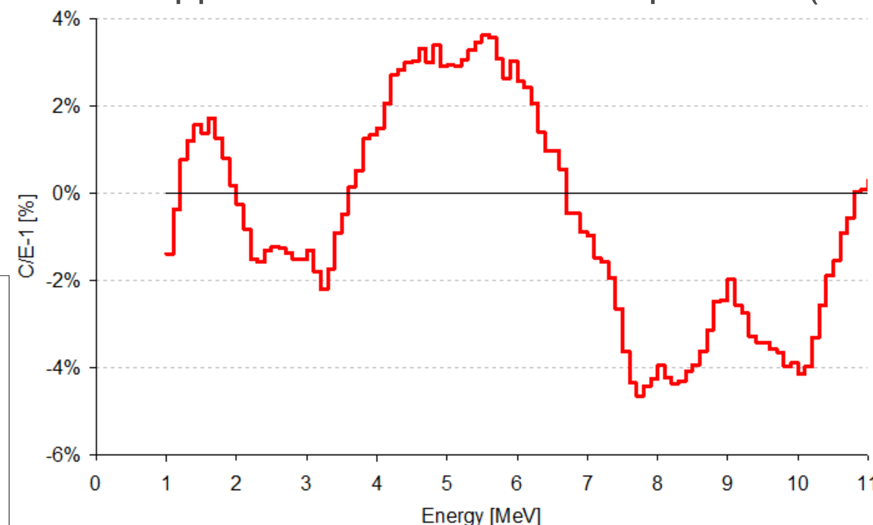
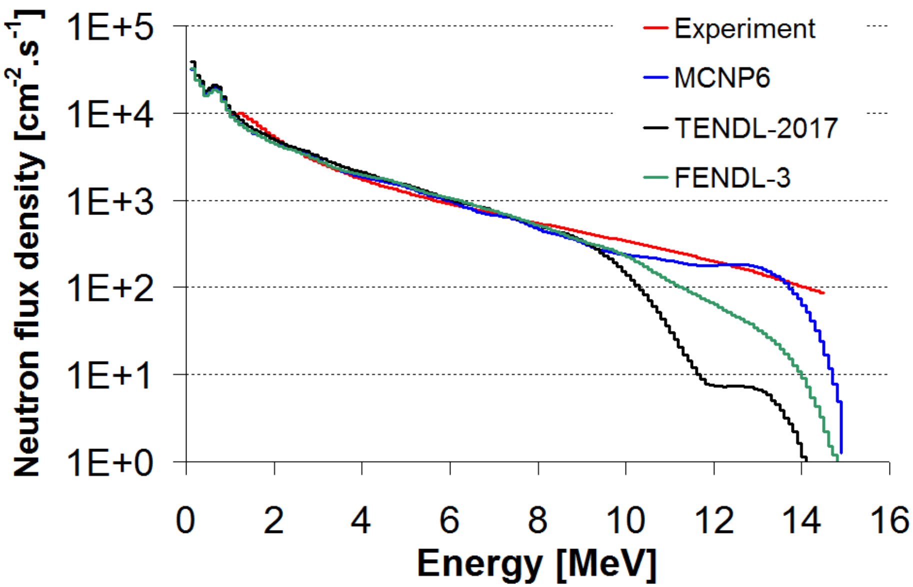
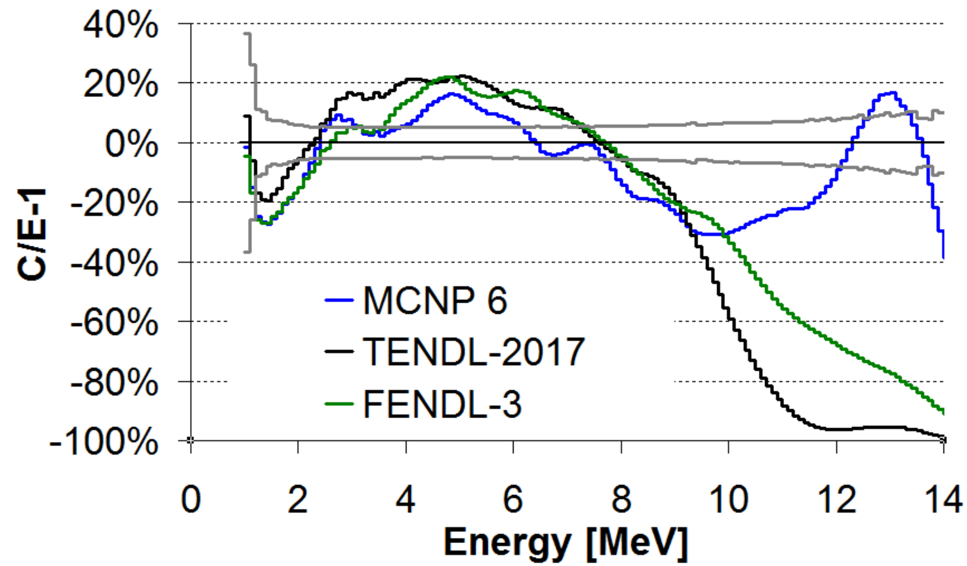


- Measurement with pure 252Cf source
- Efficiency calibration

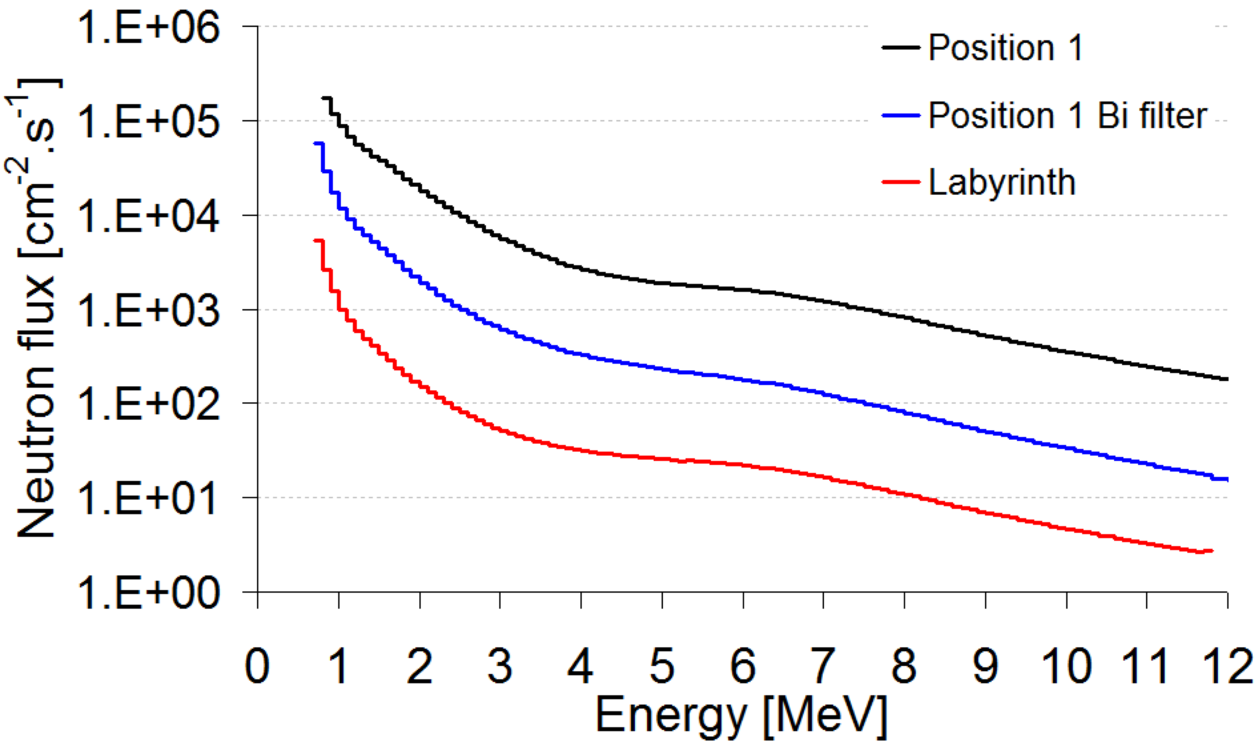
Neutron spectra measurement





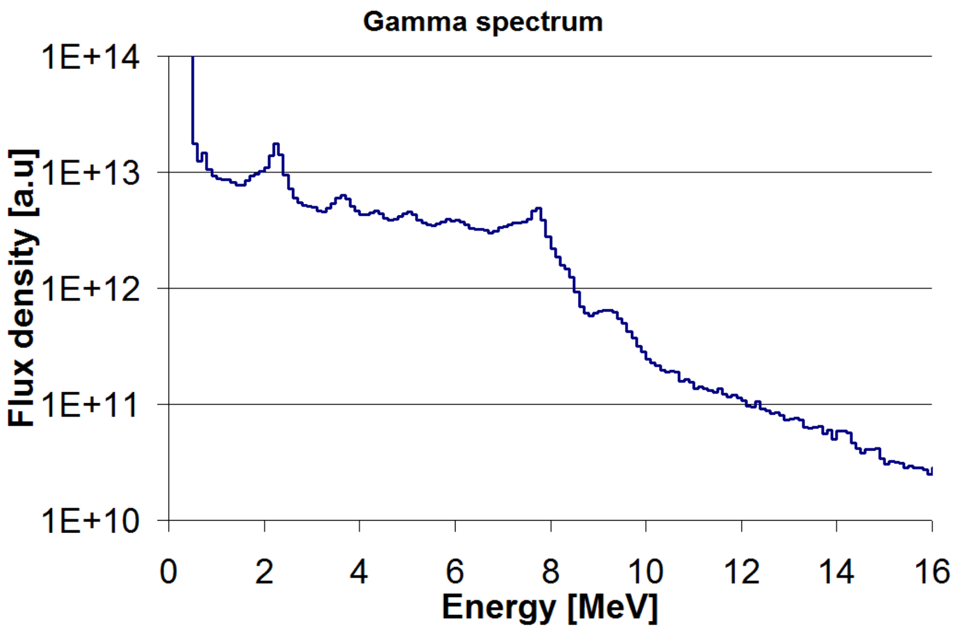
All calculations are reasonable up to 9 MeV.
The most reasonable agreement with experiment is in the case of MCNP6 calculation.
For energies higher than 10 MeV, the difference is up to five times higher the respective uncertainty.

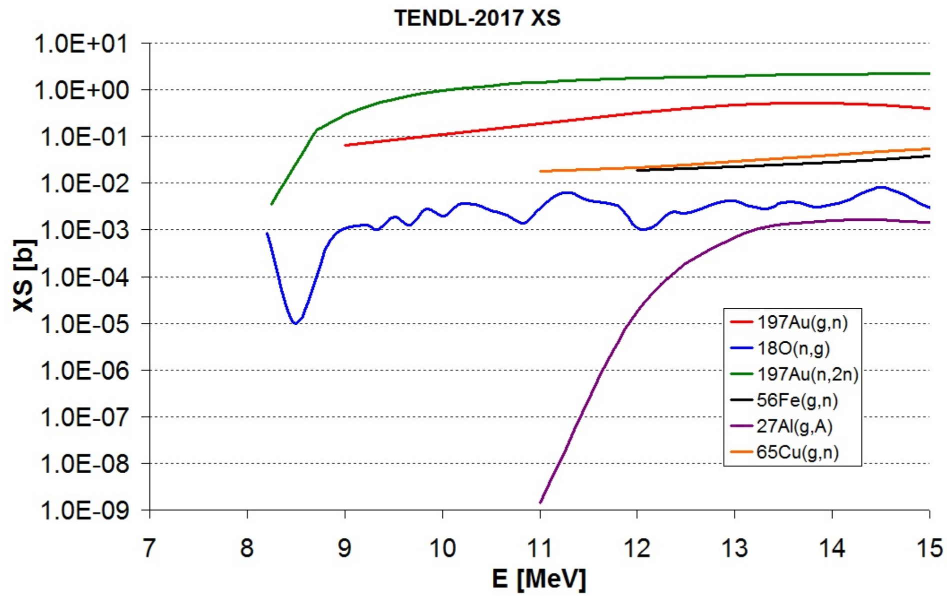
Neutron spectra measurement



The shape of spectra is very similar for energies higher than 3 MeV.

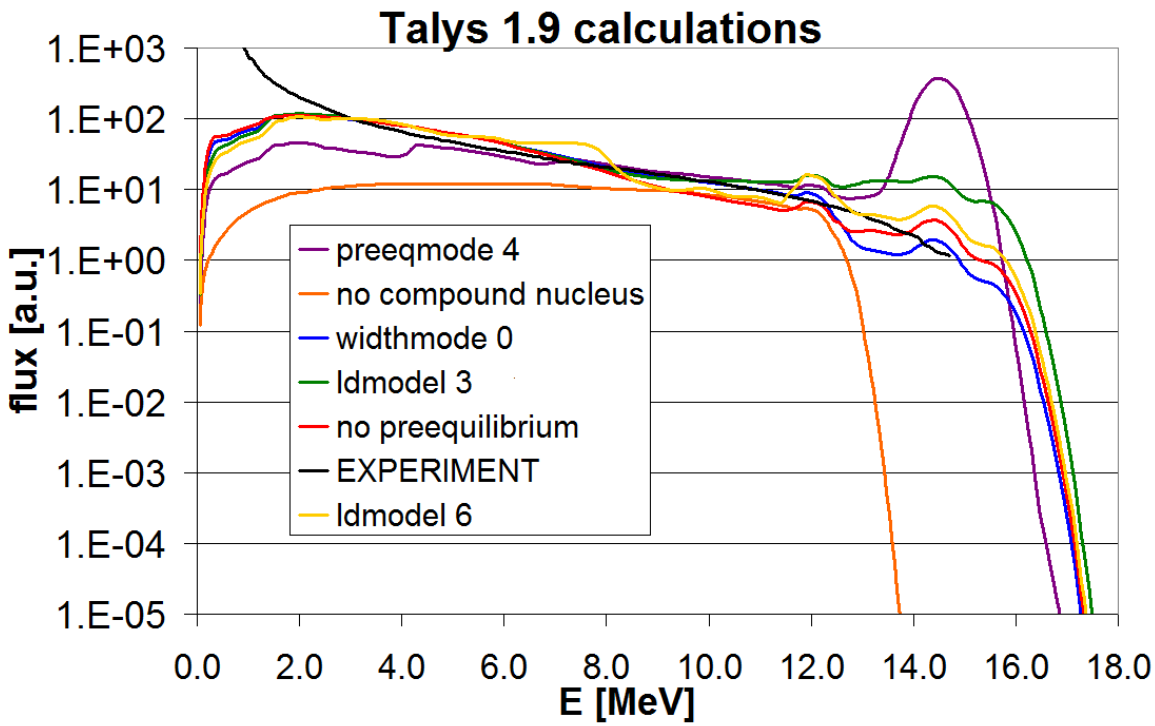
Gamma spectra measurement





- In the case of activation fetectors measurements, beware of parasitic gamma induced reactions.
- In the case of ^{196}Au gamma spectroscopy the parasitic (g,n) reaction contributes is 30%.

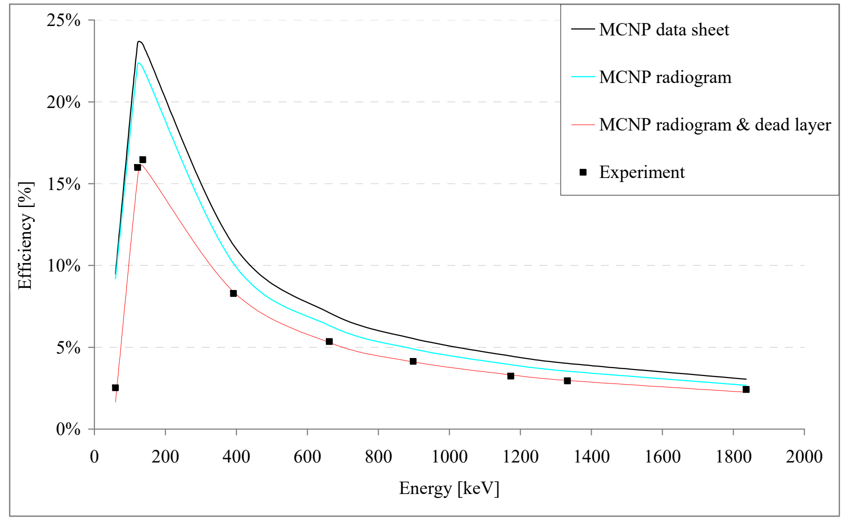
Calculations with Talys-1.9

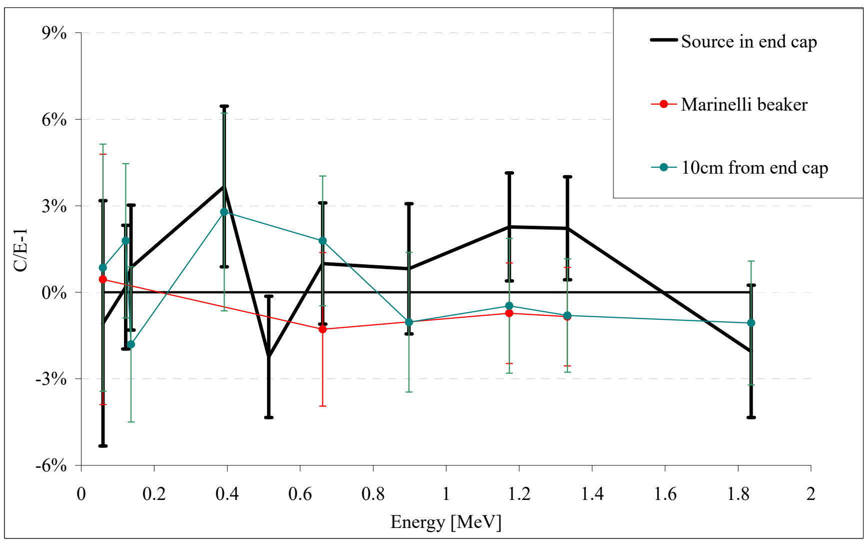


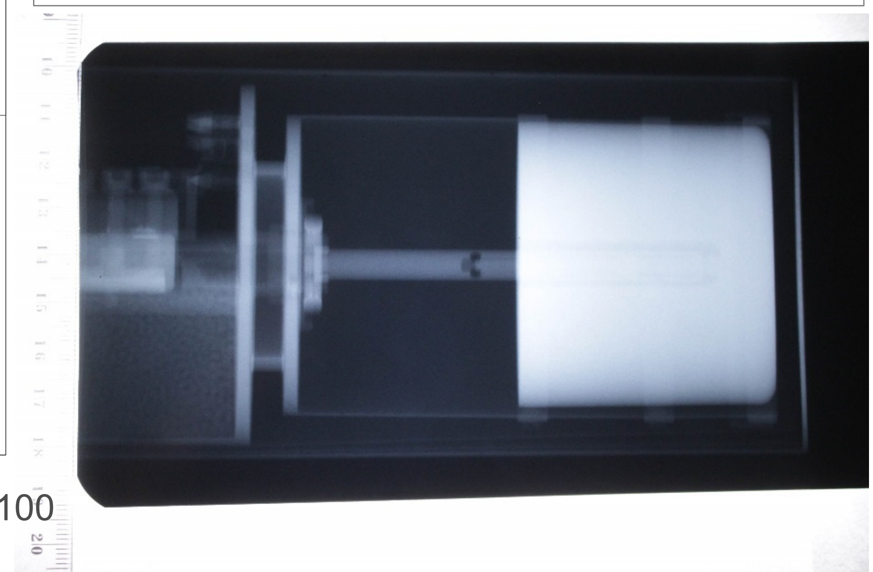
Agreement is satisfactory for neutron energies higher than 2 MeV.
The lower energies are influenced by the backscattered neutrons.
The best agreement is achieved with no width fluctuation corrections in compound nucleus, pure Hauser-Feshbach model.

Gamma spectroscopy for samples

- **Most important is detector sensitivity !!!**
- **Sample needs proper detector characterization (calculated efficiency)**
  - Experimentally measured insensitive layer and detector dimensions







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Reactor dosimetry XS comparison in different libraries

	MCNP6	FENDL-3	TENDL-2017
$^{54}Fe(n,p)$	21.7 %	25.7 %	-1.9 %
$^{54}Fe(n,\alpha)$	14.9 %	-10.4 %	-43.8 %
$^{27}Al(n, \alpha)$	-6.5 %	-34.3 %	-63.2 %
$^{63}Cu(n, \alpha)$	35.5 %	6.2 %	-33.6 %

C/E-1 of measured reaction rates in end of the cyclotron.

	MCNP6	FENDL-3	TENDL-2017
$^{58}Ni(n,p)$	13.4 %	23.1 %	-2.8 %
$^{54}Fe(n,p)$	19.8 %	29.4 %	1.4 %
$^{54}Fe(n,\alpha)$	-5.0 %	-20.6 %	-49.3 %
$^{27}Al(n,\alpha)$	-13.2 %	-34.1 %	-62.2 %
$^{60}Ni(n,p)$	-7.3 %	-18.9 %	-47.0 %
$^{58}Ni(n,x)^{57}Co$	-2.5 %	-73.2 %	-96.3 %

C/E-1 of measured reaction rates 80 cm from cyclotron end.

	MCNP6	FENDL-3	TENDL-2017
$^{54}Fe(n,p)$	4.5%	29.1 %	-2.7 %
$^{54}Fe(n,\alpha)$	-67.8%	-29.0 %	-59.6 %
$^{63}Cu(n,\alpha)$	-68.2%	-31.6 %	-61.0 %

C/E-1 of measured reaction rates 8.5 cm below the target axis.

No satisfying results in any library!

Conclusions

- The methodology of characterization of leakage neutron field of the ^{18}F production cyclotron was presented and applied for IBA Cyclone 18/9 cyclotron.
- The tested libraries show significant discrepancies, they are not suitable for a precise description of the secondary neutron field.
- The TENDL-2017 and FENDL-3 libraries differ significantly in the shape of the spectrum in the high-energy tail, whereas MCNP6 default model is incorrect in angular distribution.
- The calculations of the ^{18}F production yields using MCNP6 and TENDL-2017 show agreement with experiment within uncertainties.
- The flux with can be characterized with neutron activation analysis. Beware of gamma induced reactions.
- A leakage neutron field is an interesting option for irradiation experiments due to quite high flux.

THANK YOU FOR ATTENTION