Definition of a standard neutron field with the $^{7}Li(p,n)^{7}Be$ reaction

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[2] GSI and University of Giessen, Darmstadt/Giessen

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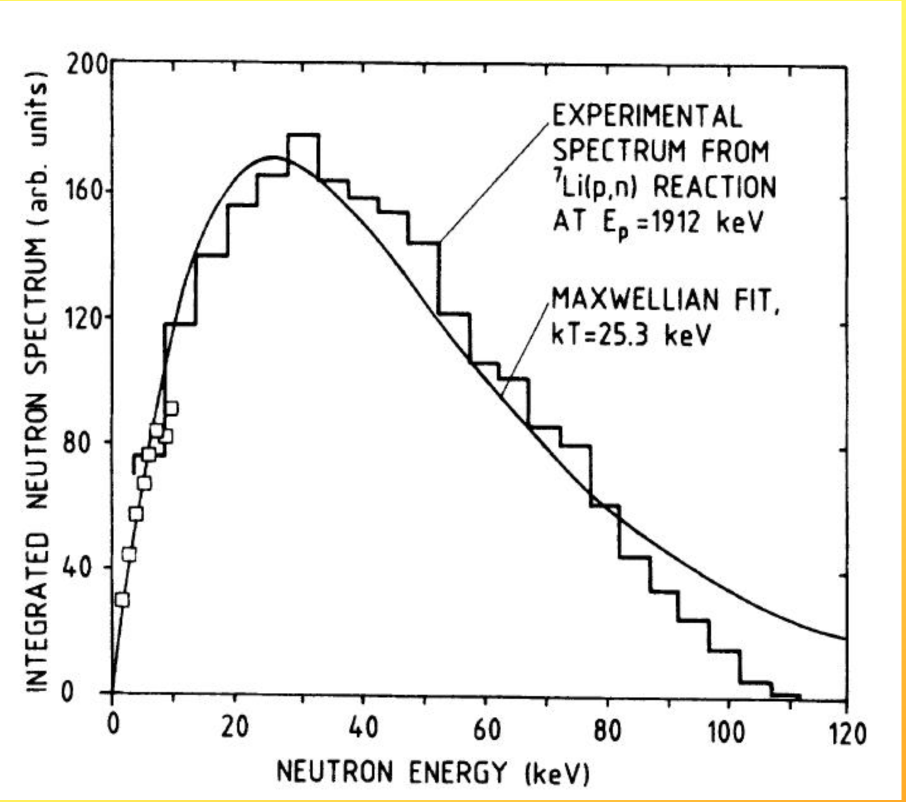
[4] Karlsruhe Institute of Technology (KIT), Karlsruhe

[5] IAEA, Nuclear Data Section, Vienna, Vienna

$^{7}Li(p,n)^{7}Be$ as neutron source

- for E_p=1912 keV → quasi-maxwellian energy distribution with kT=25 keV
- neutron emission: forward peaked with 120° opening angle



Ratynski and Käppeler, Phys. Rev. C **37** (1988)

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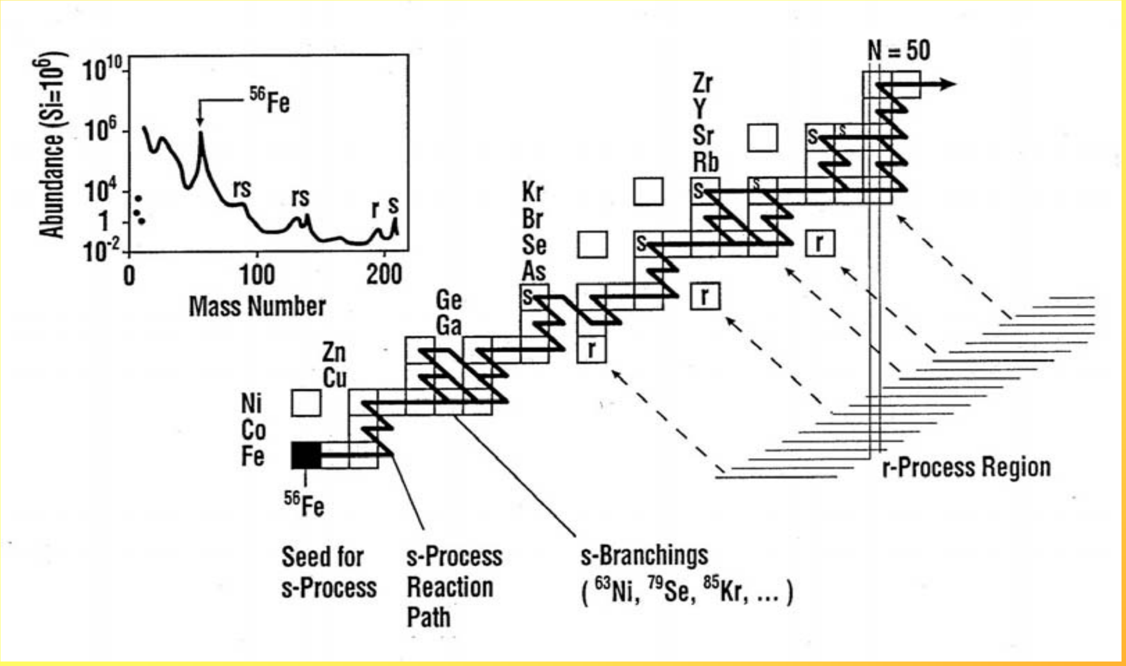
Motivation

Nucleosynthesis in stars beyond Fe:

- s-process (slow neutron capture) responsible for 50% of abundances between Fe and Bi



F. Käppeler, A. Mengoni, Nucl. Phys. A **777** (2006)

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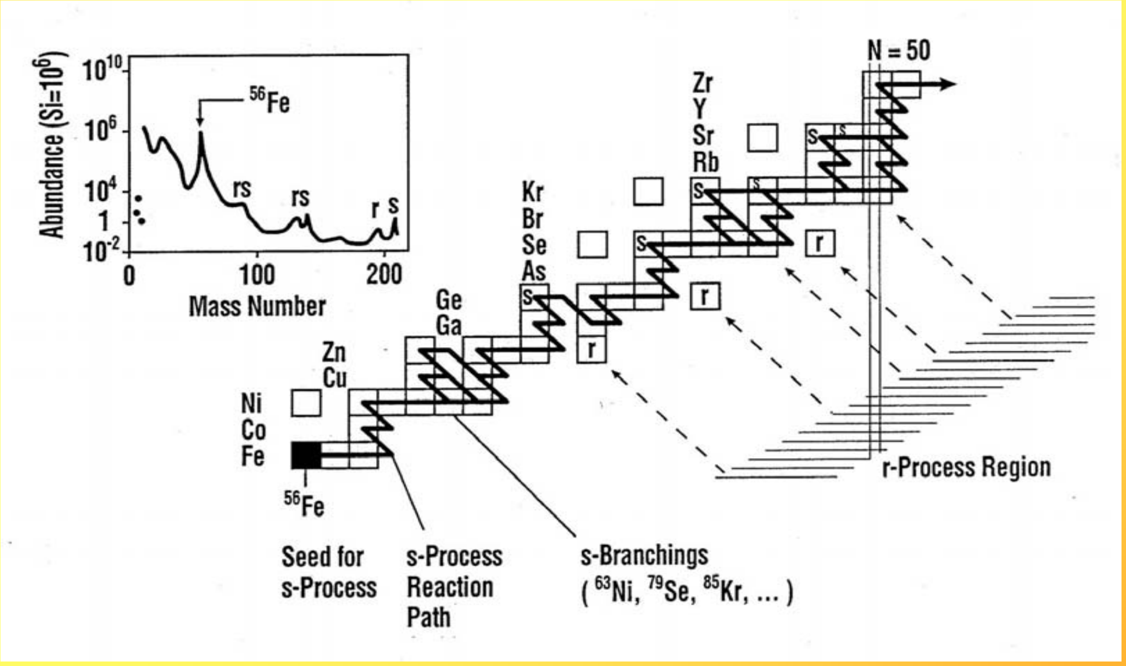

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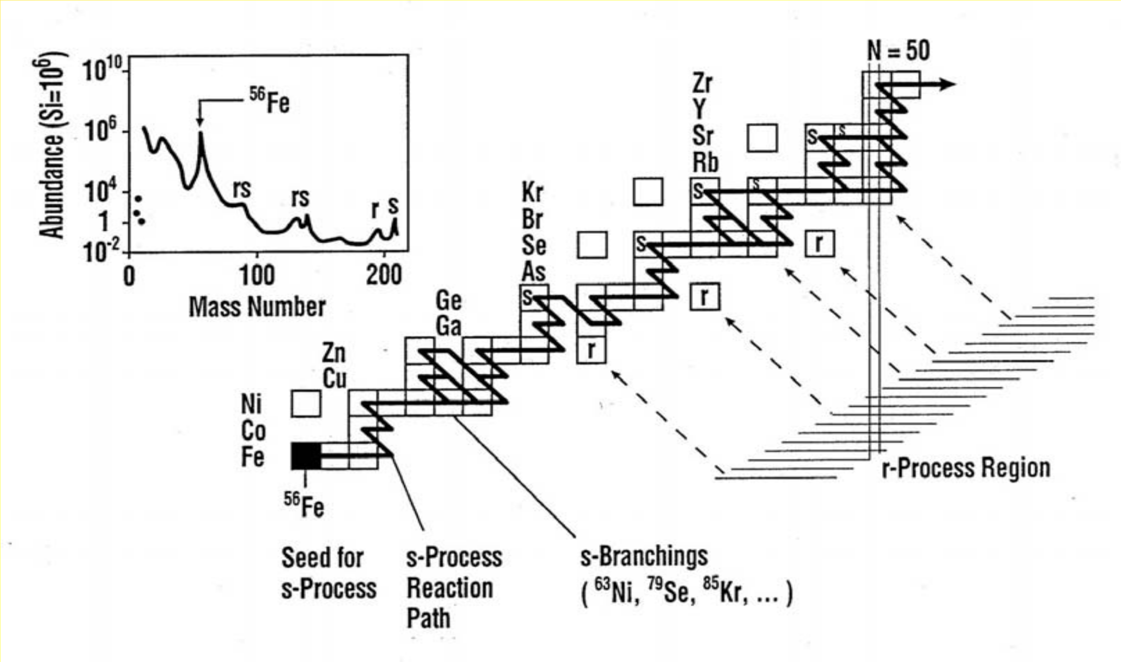

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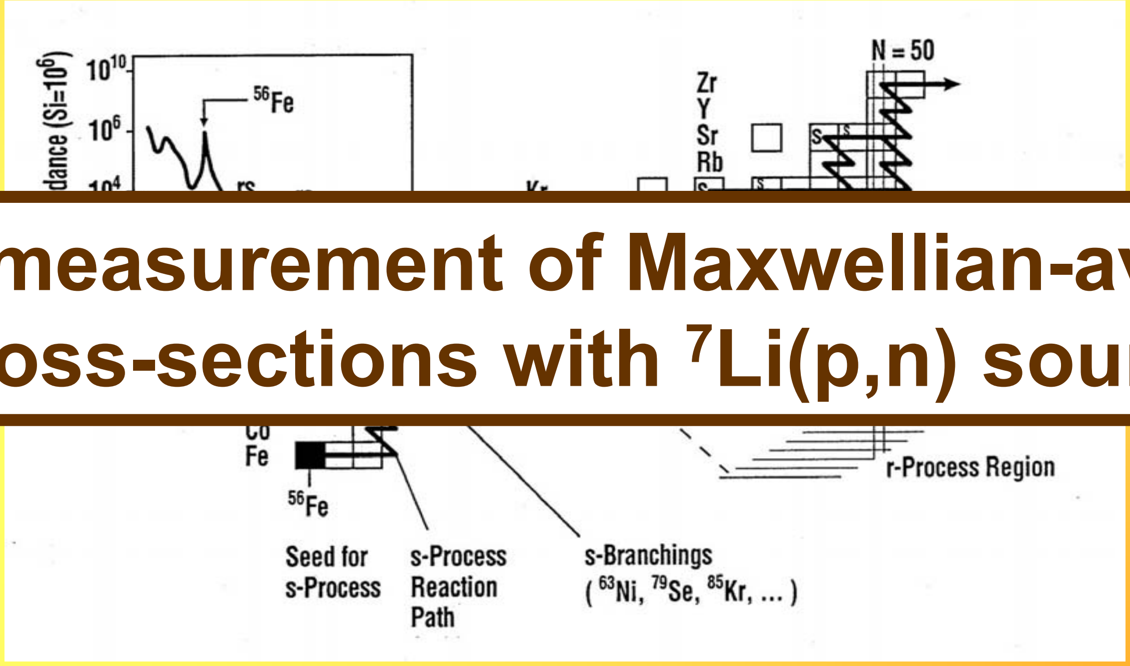

Direct measurement of Maxwellian-averaged cross-sections with ^{7}Li(p,n) source

F. Käppeler, A. Mengoni, Nucl. Phys. A **777** (2006)

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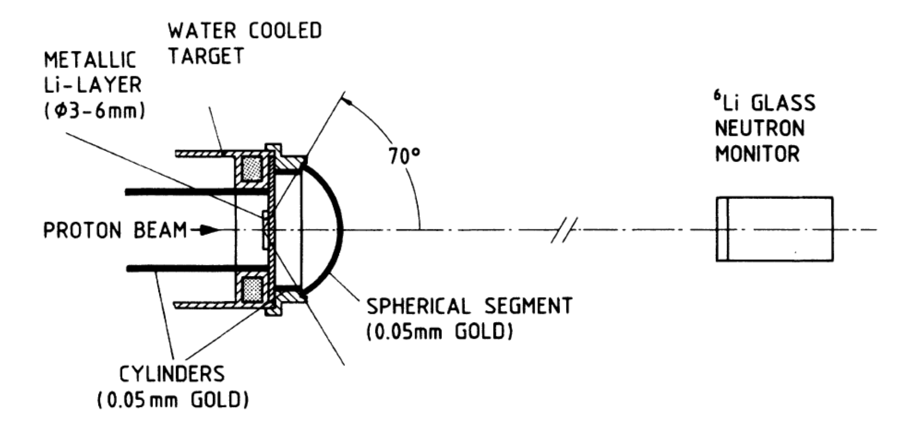
Measurement of $^{197}Au(n,\gamma)$ at KIT*

Ratynski and Käppeler (Phys. Rev. C **37**, 1988)

- spherical Au sample covering whole beam
- absolute flux determination by ^{7}Be activity of Li target



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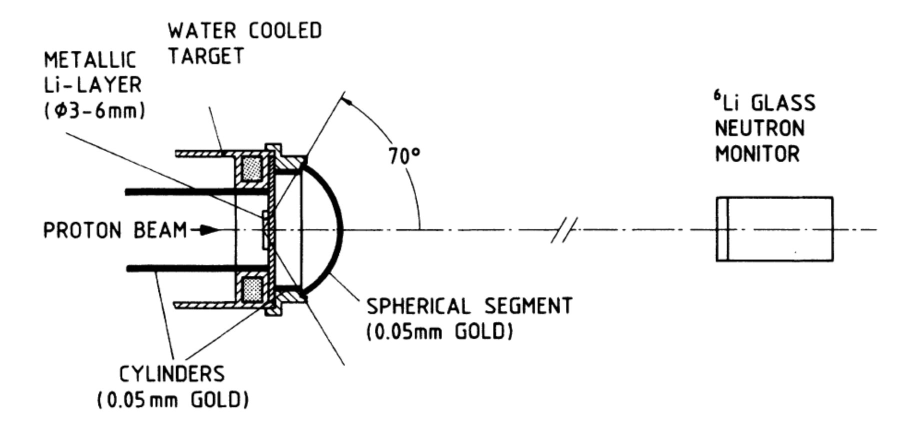

$$\sigma(25\text{keV})_{EXP} = 586 \text{ mb} \pm 1.4\%$$

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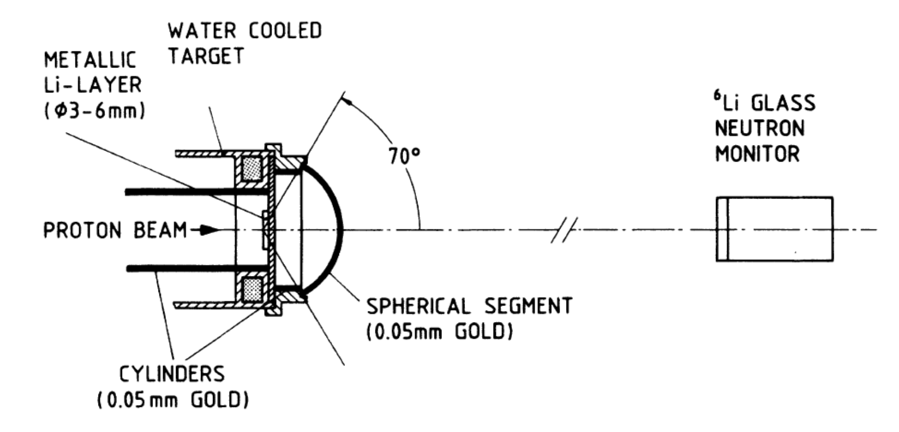

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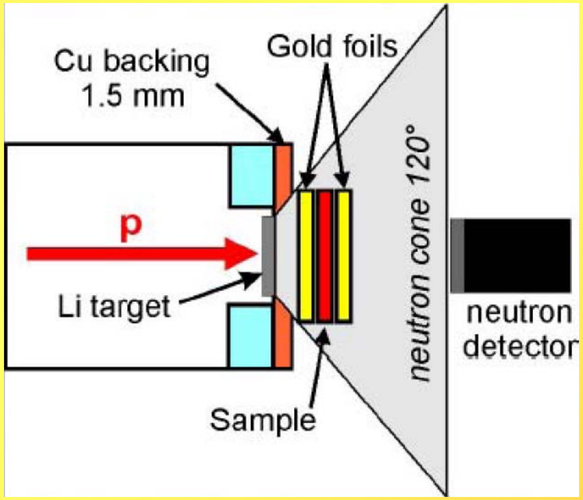
for transformation to Maxwellian-averaged cross-section (MACS):

- energy dependence of cross-section
- neutron spectrum

* former FZK

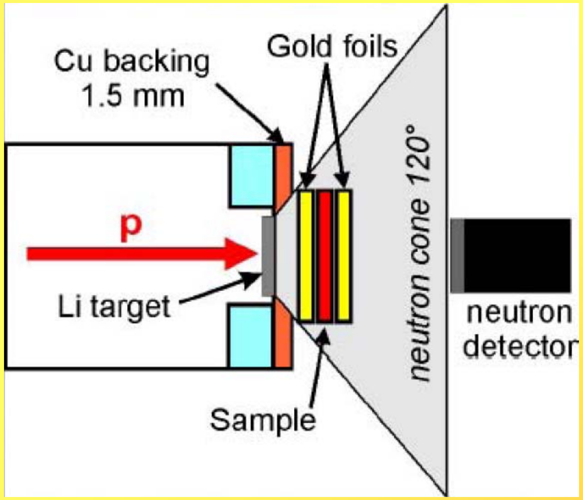
Other measurements of MACS at KIT



Other measurements of MACS at KIT

Short-lived radioisotopes:

- Activation + decay counting
- ^{58}Fe, ^{59}Co, ^{87}Rb, ^{88}Sr, ^{89}Y, ^{139}La, etc. (Heil et al., Dillmann et al., Käppeler et al., O'Brien et al.....)



Long-lived radioisotopes:

- Activation + Accelerator Mass Spectrometry (AMS)
- AMS labs: ATLAS (Argonne), GAMS (Munich), VERA (Vienna)
- ^{9}Be, ^{13}C, ^{40}Ca, ^{54}Fe, ^{58,62}Ni, ^{78}Se, ^{209}Bi, etc. (Coquard et al., Dillmann et al., Nassar et al., Rugel et al., Wallner et al. ....)

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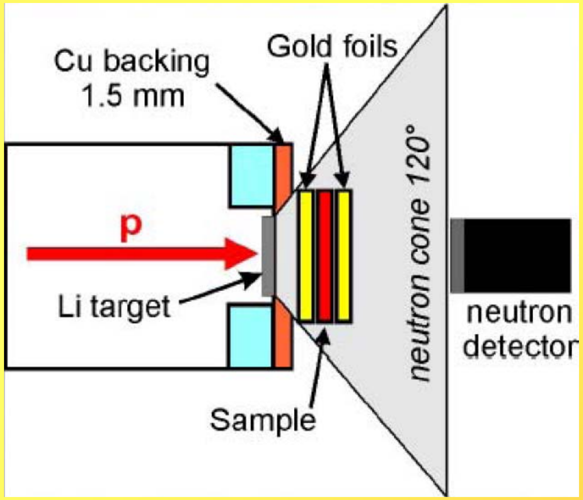

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All relative to ^{197}Au(n,γ) cross-section!

$^{197}Au(n,\gamma)$ as standard cross-section

- recommended standard for thermal and from 0.2-2.8 MeV
- 3-200 keV: 6-8 % discrepancy between Ratynski-Käppeler evaluation and standard evaluation

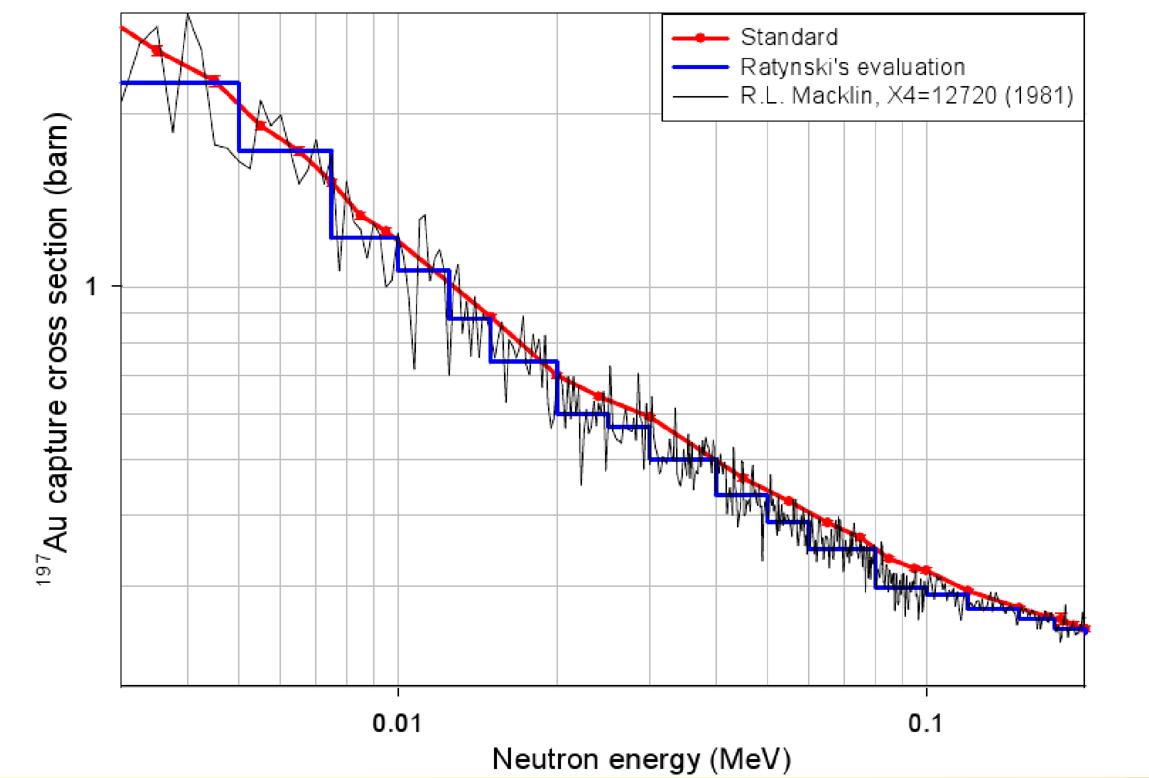

Figure by V.G. Pronyaev

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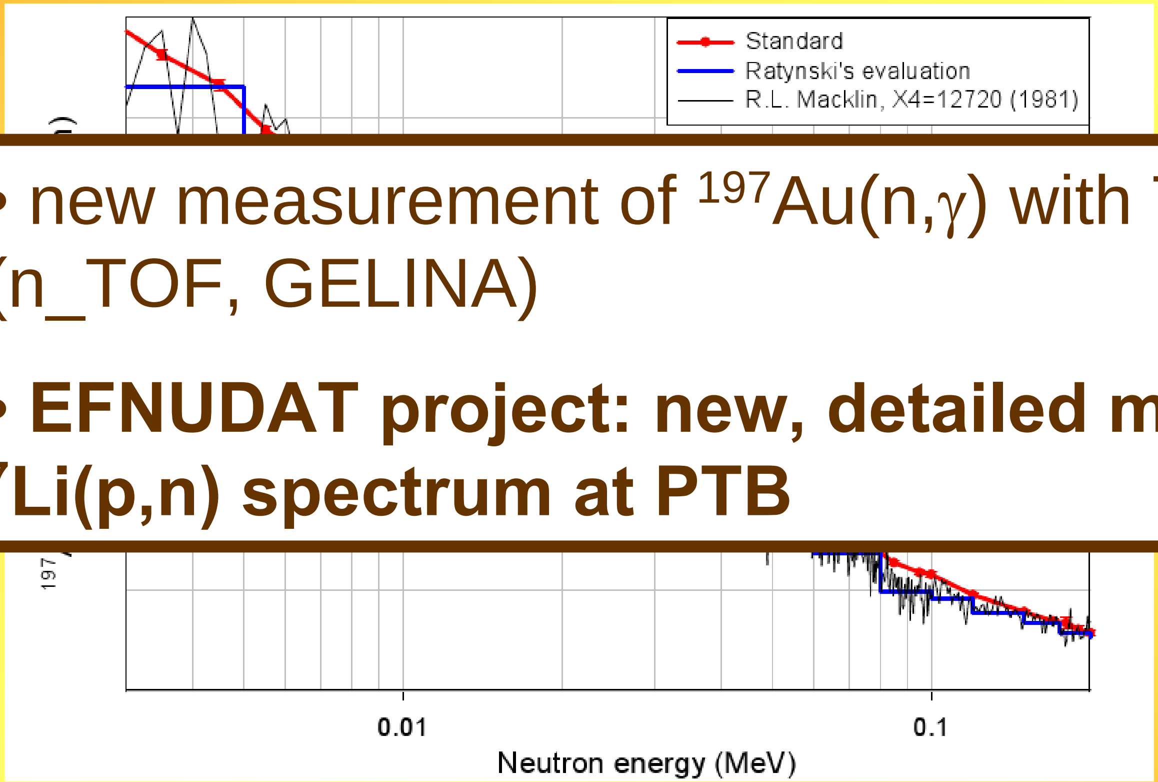
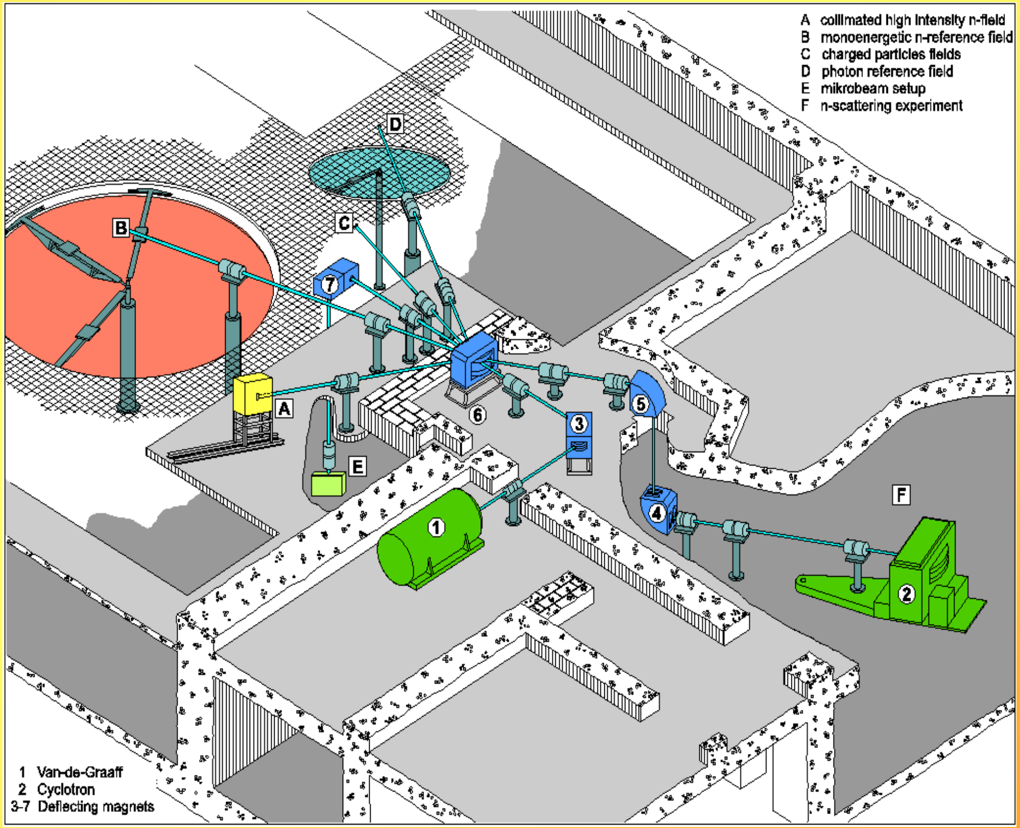


- new measurement of $^{197}Au(n,\gamma)$ with TOF technique (n_TOF, GELINA)
- **EFNUDAT project: new, detailed measurement of $^{7}Li(p,n)$ spectrum at PTB**

Figure by V.G. Pronyaev

Experimental setup at PTB

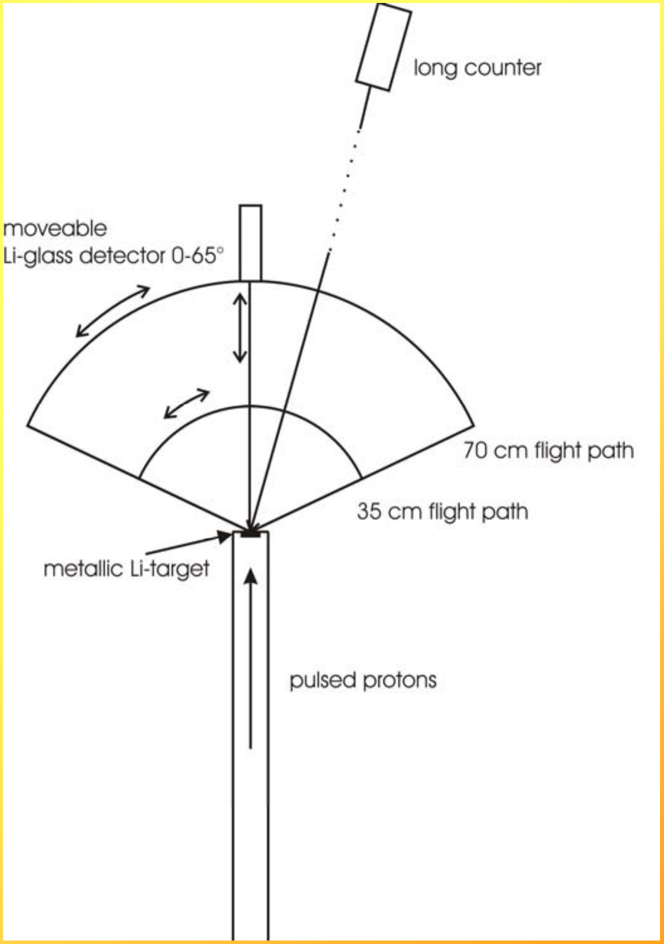
- calibrated setup for angular distribution measurements
- Proton source: 3.75 MV Van de Graaff
- E_p=1912±1 keV
- Repetition Rate: 0.625 MHz
- Pulse width (FWHM): 3ns
- Average proton current: 0.5-0.8 μA



Experimental setup at PTB

Target:

- Metallic Li evaporated on Ta
- 10 μm thickness (565 μg/cm²) → protons slowed down below reaction threshold (E_{thres}=1881 keV)



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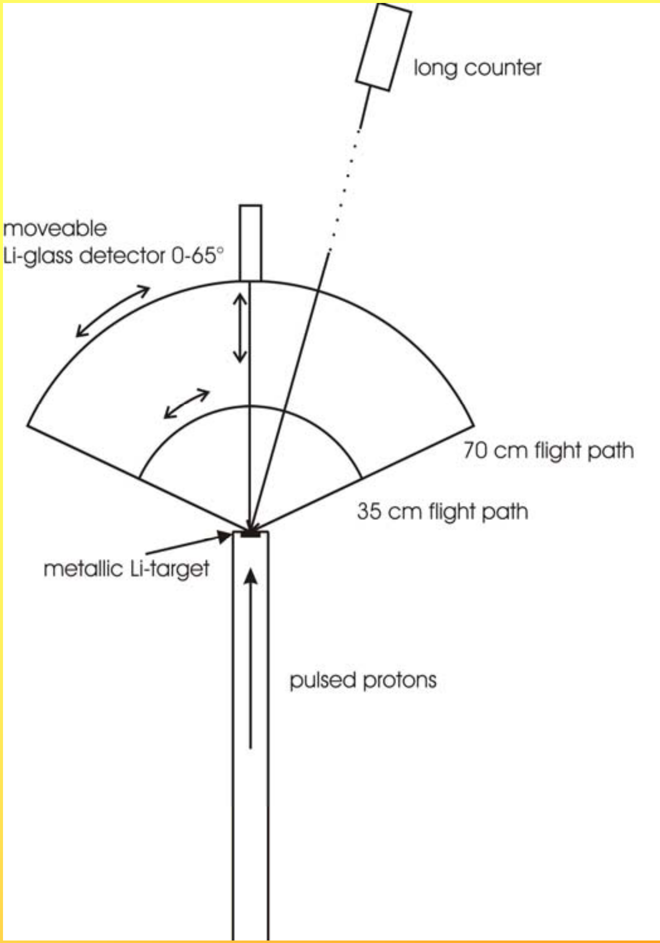
Positions:
- two flight paths: 35 cm and 70 cm
- angles: 0-65 deg, steps of 5 deg



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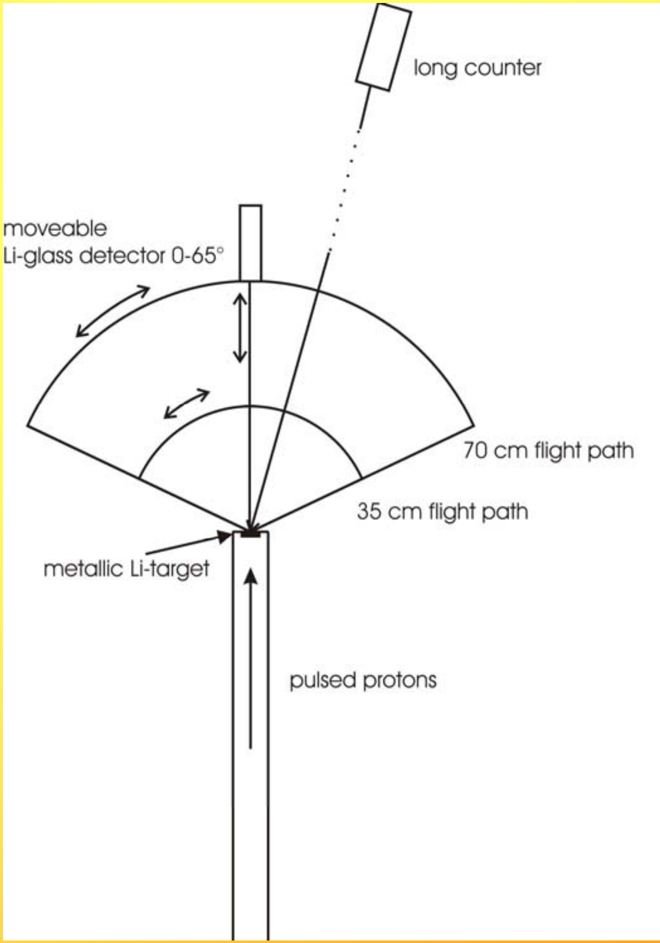
Detectors:

- moveable Li-glass
- Long counter (fluence determination)



Experimental setup at PTB

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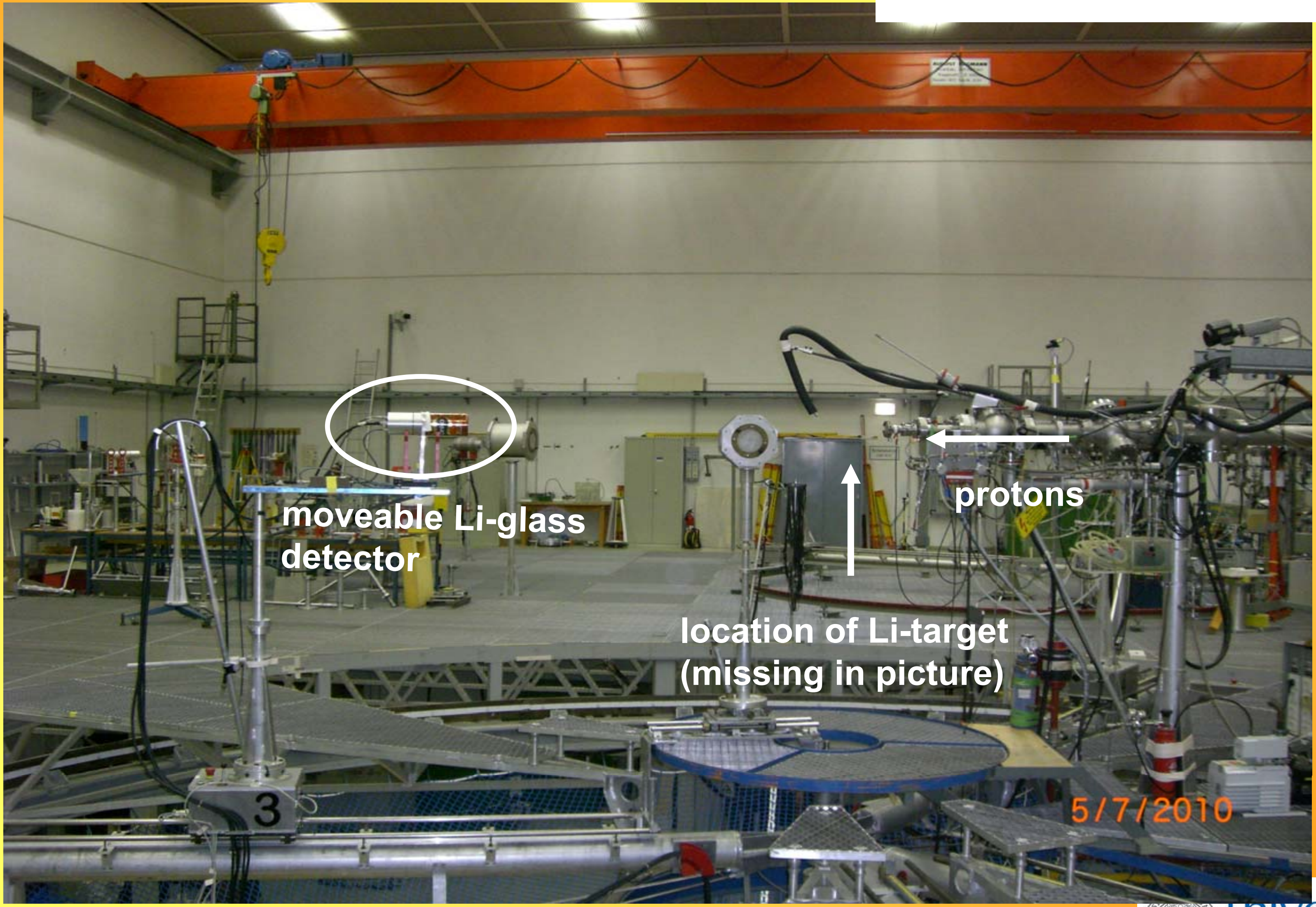

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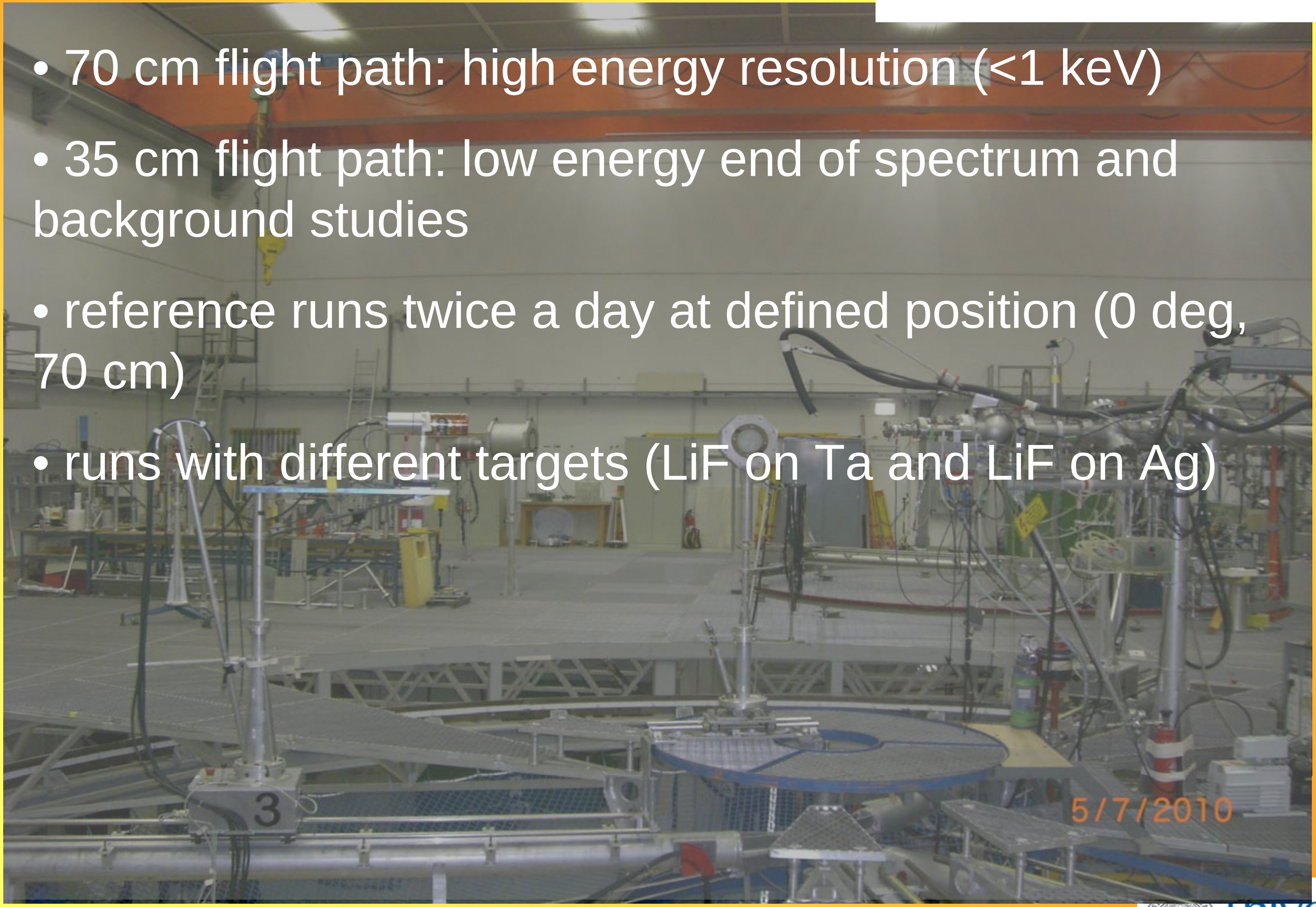
Experimental setup at PTB

- 70 cm flight path: high energy resolution (<1 keV)
- 35 cm flight path: low energy end of spectrum and background studies
- reference runs twice a day at defined position (0 deg, 70 cm)
- runs with different targets (LiF on Ta and LiF on Ag)



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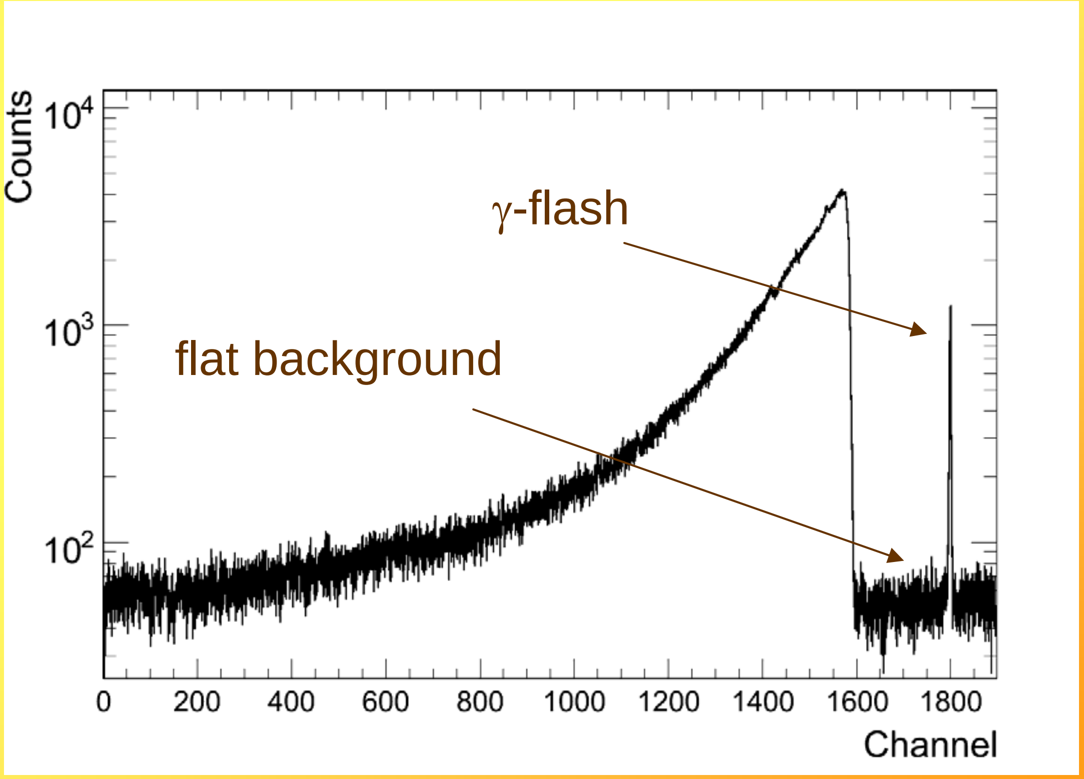
Data reduction

- dead-time correction and background subtraction
- time-of-flight to neutron energy conversion
- detection efficiency: $^{6}Li(n,t)^{4}He$ cross-section (standard!)
- neutron fluence: long-counter
- solid angle correction



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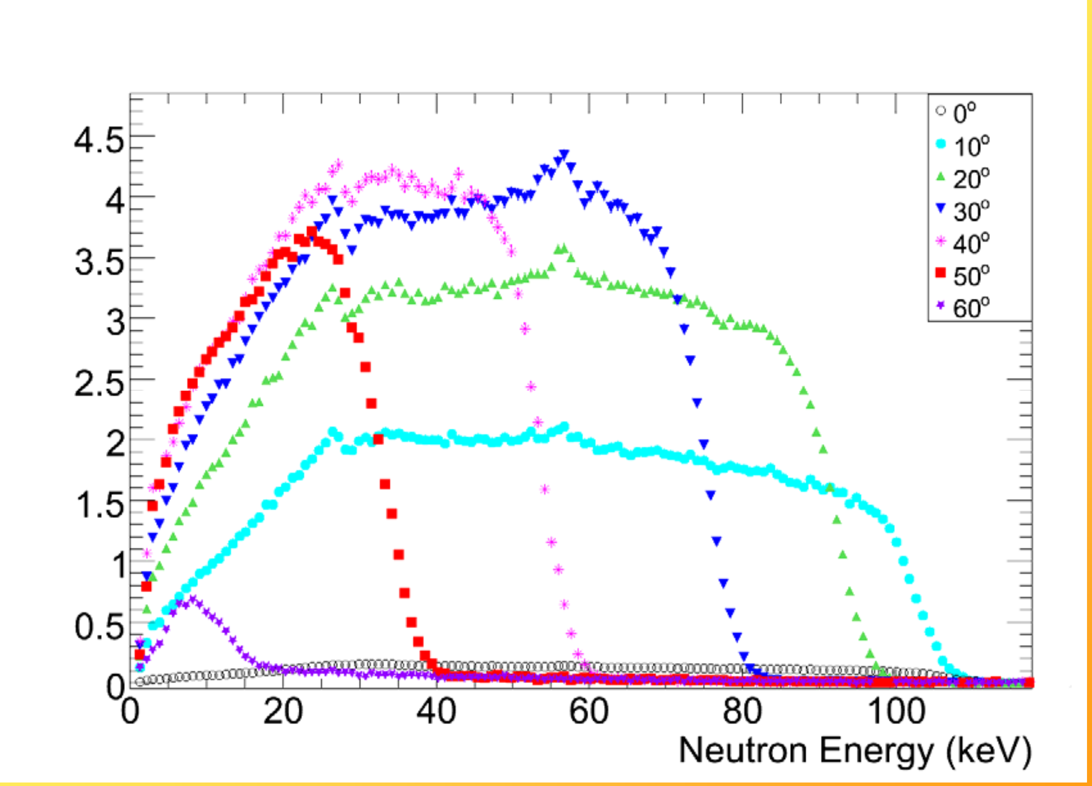

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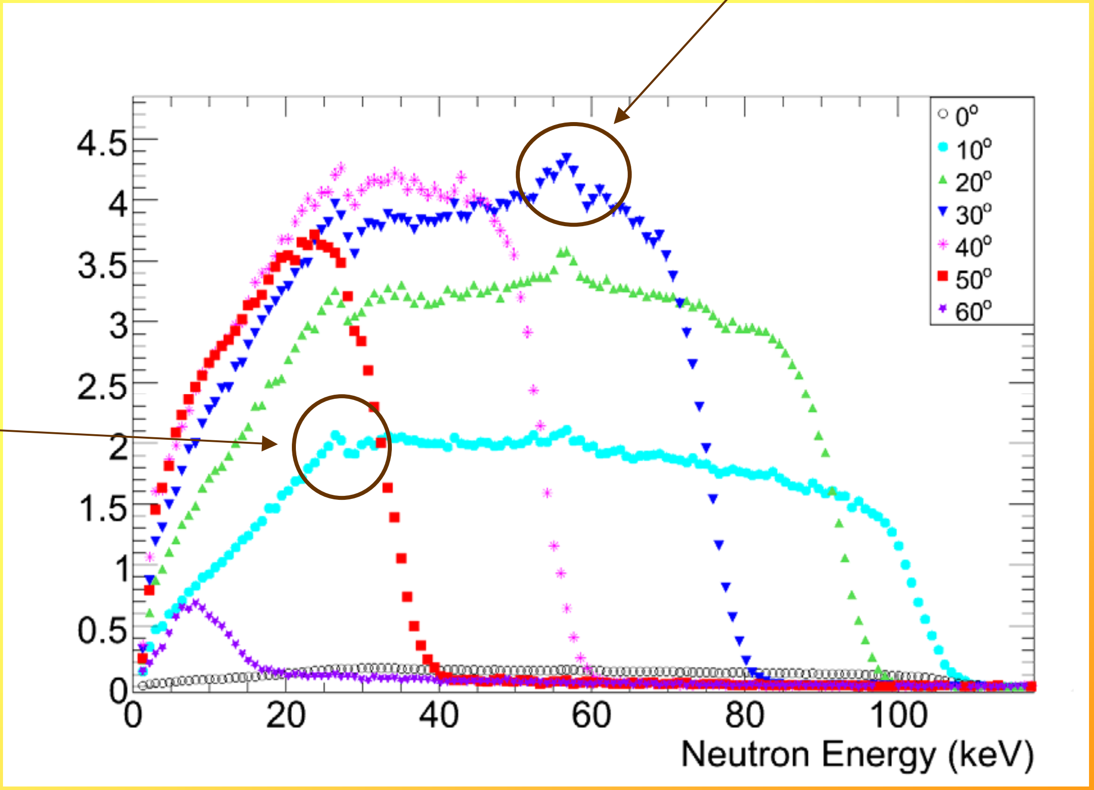
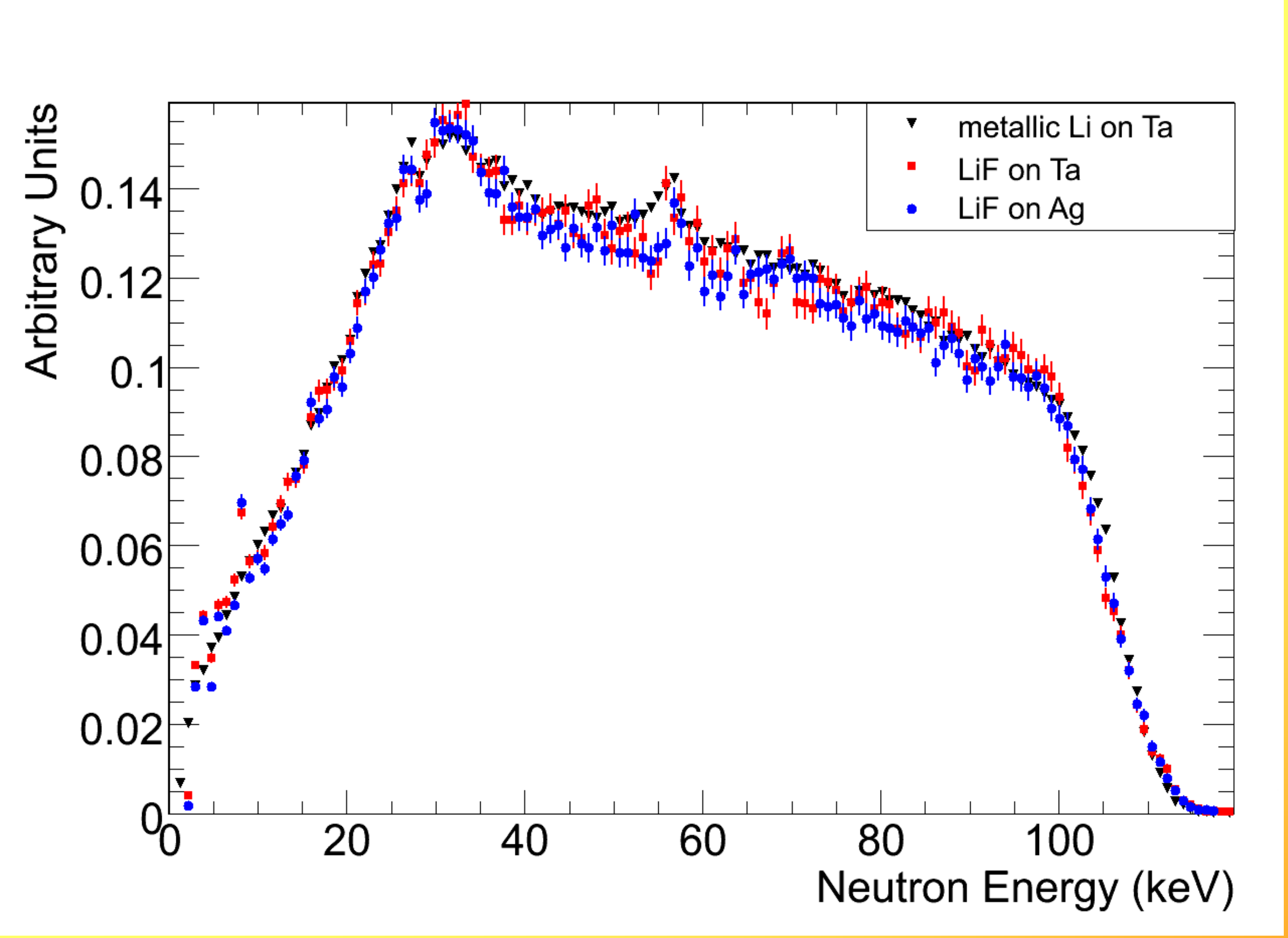
^{28}Si-resonance
(Li-glass)

^{56}Fe-resonance
("coffee-resonance")

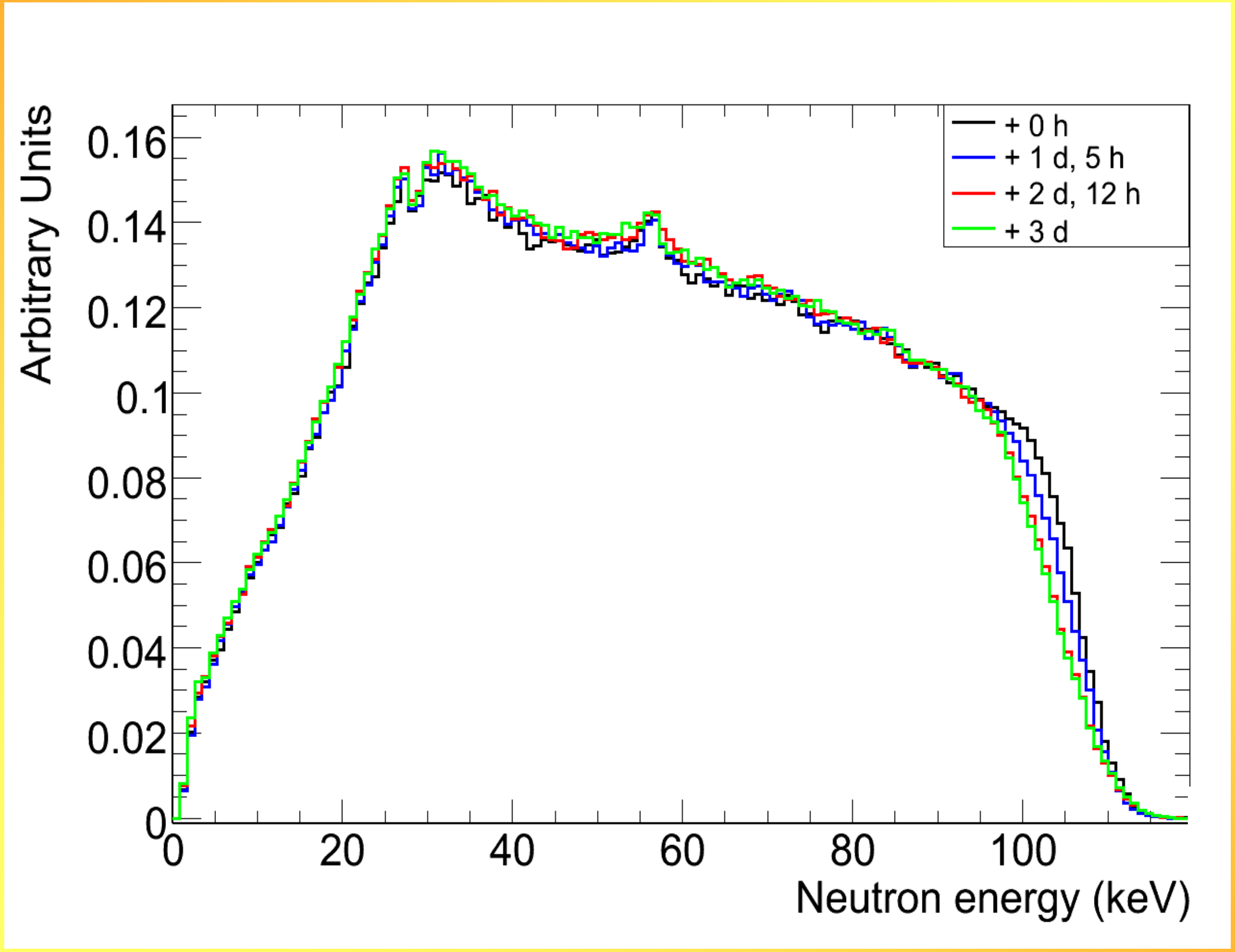


70 cm flight path

Reference Runs: different targets



Reference Runs: target stability



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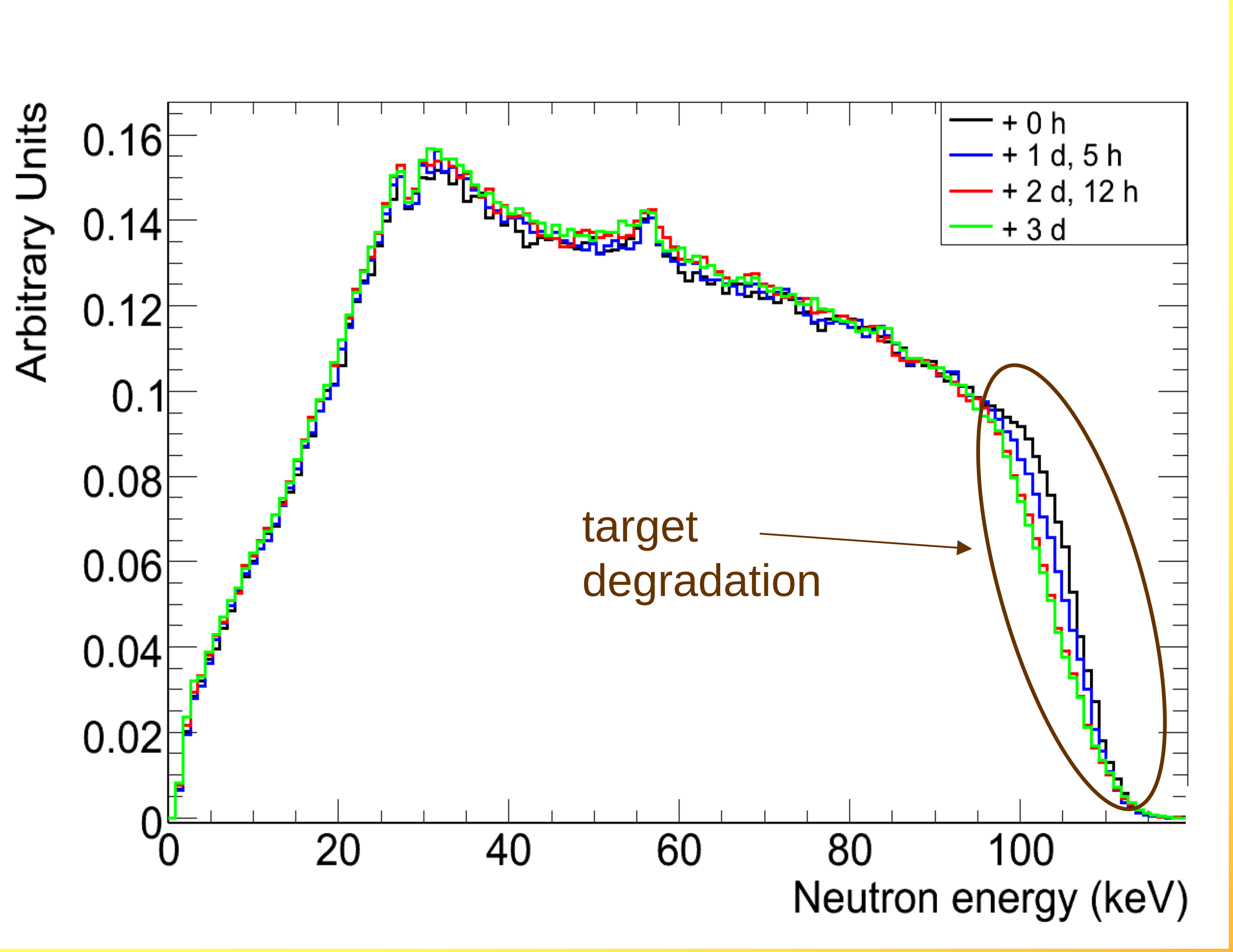
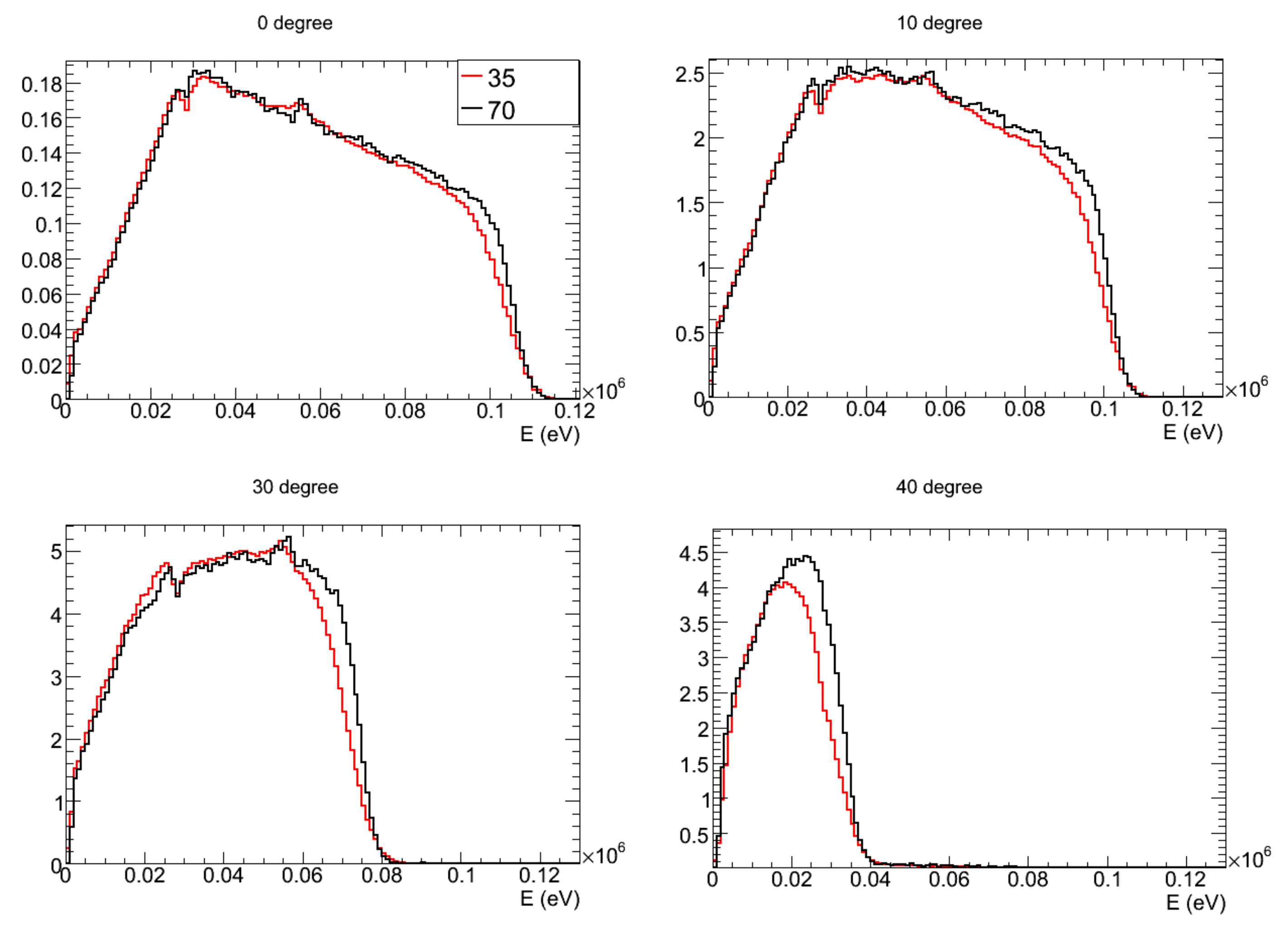


Different angles: 35 cm vs. 70 cm



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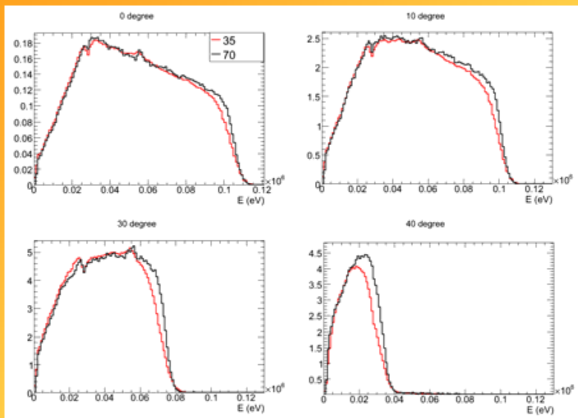
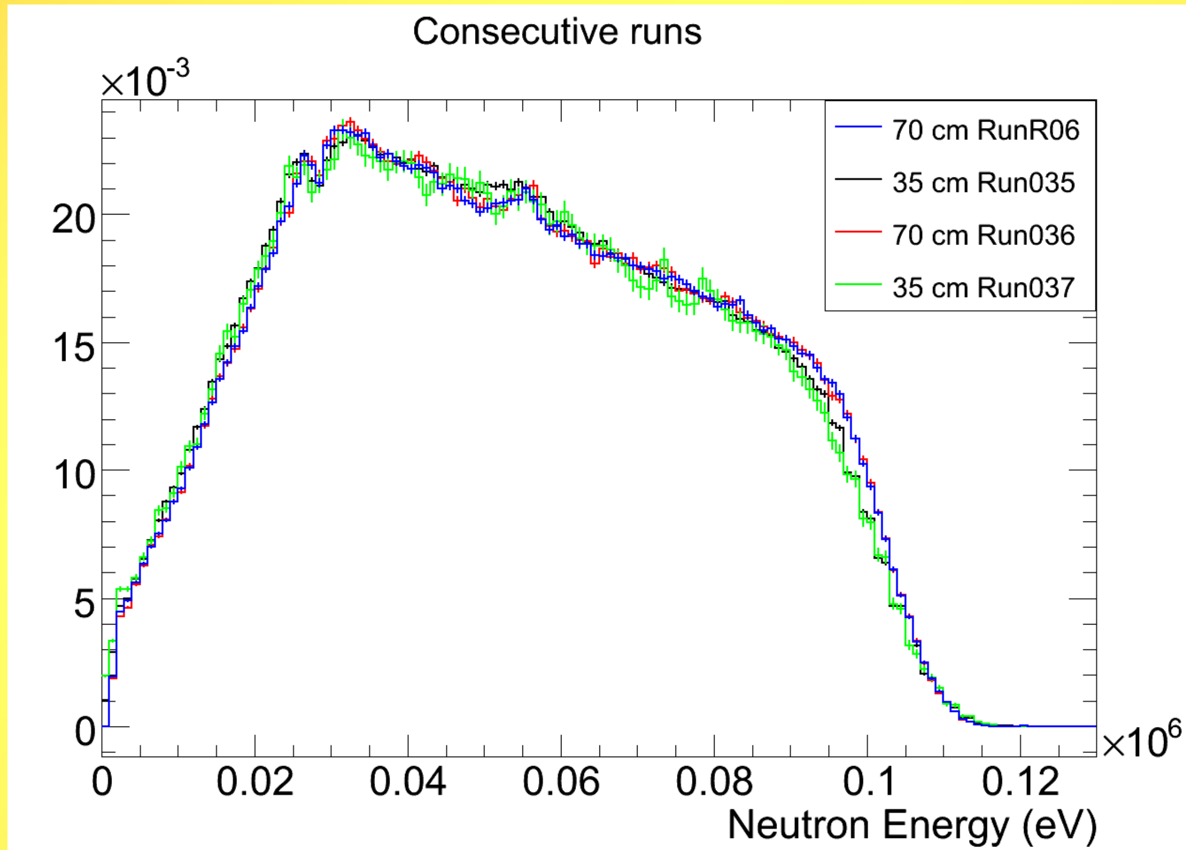


no target aging effect because:



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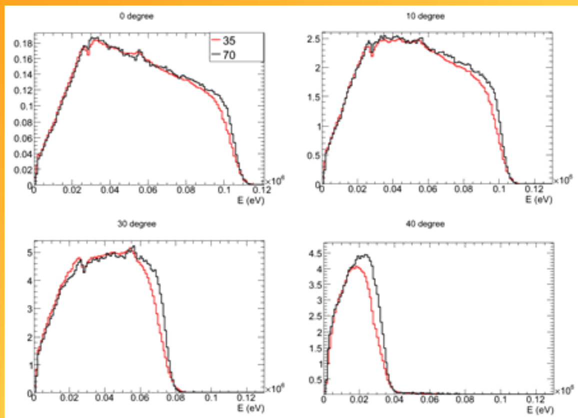

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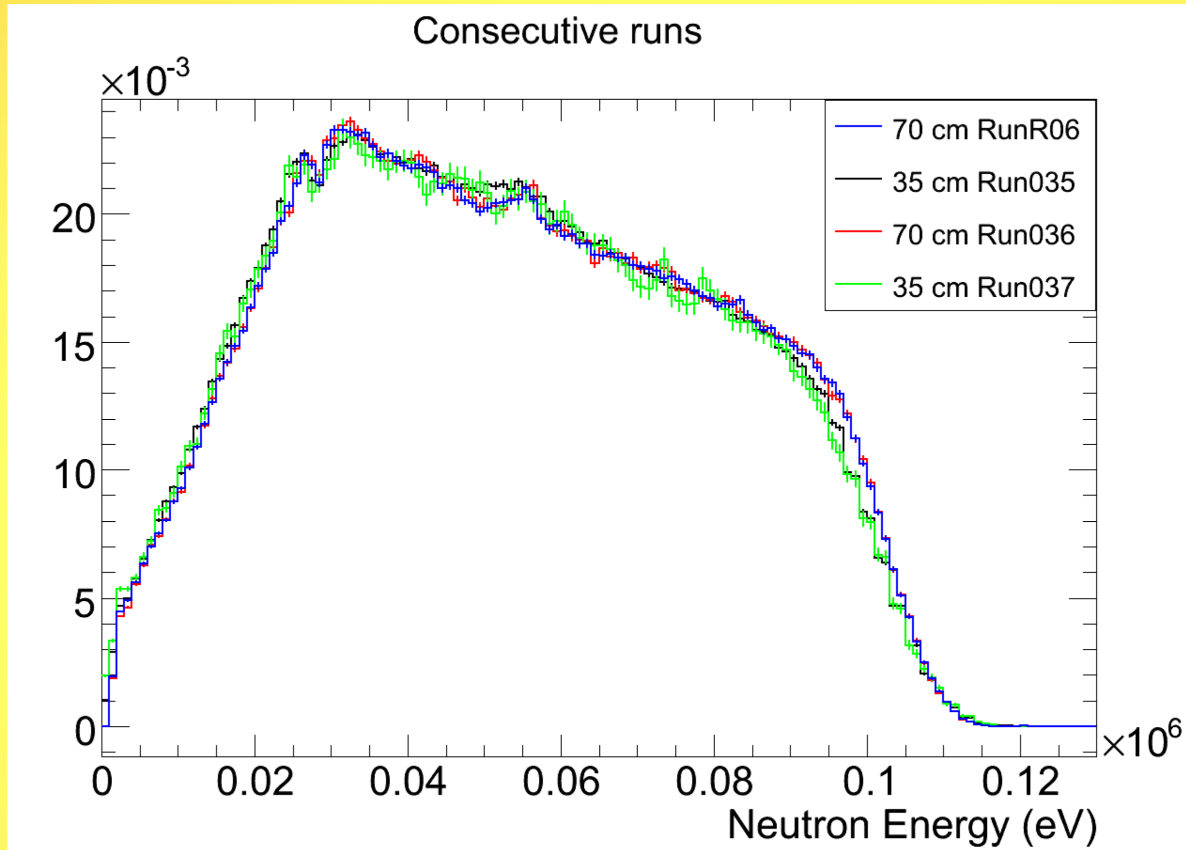
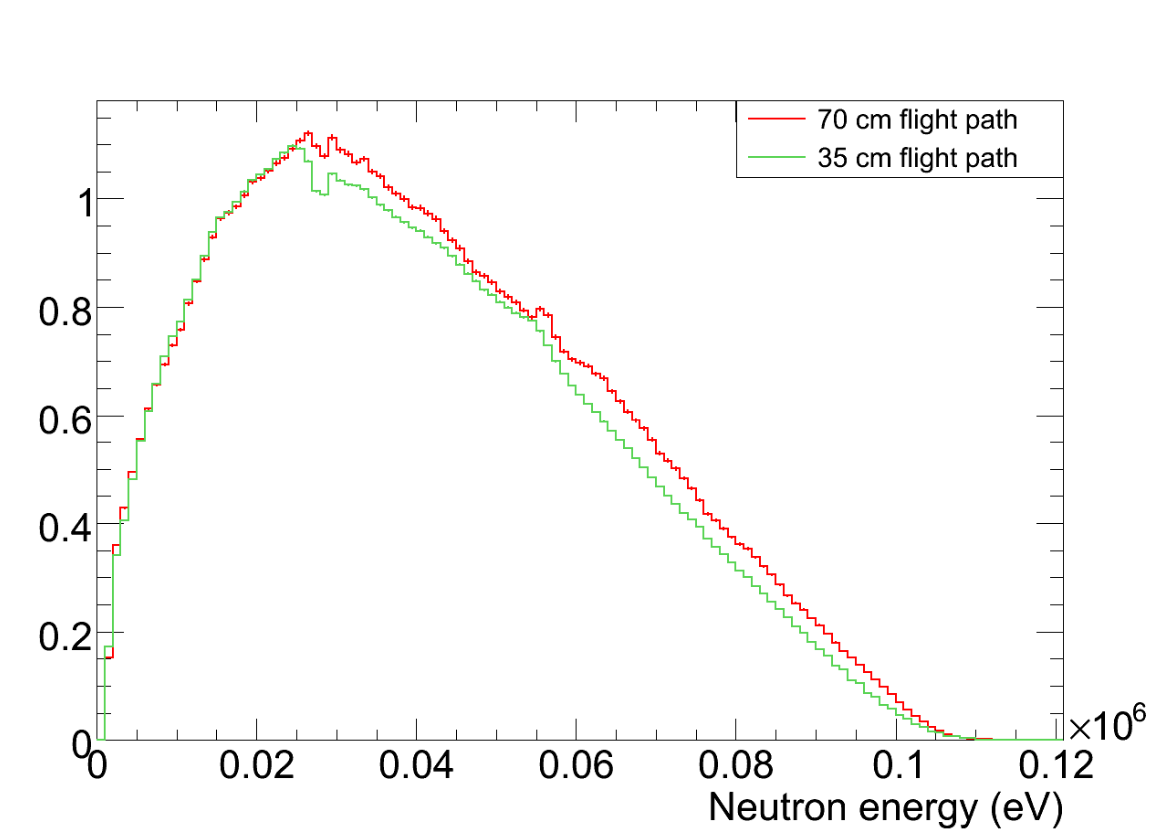


- closer look to kinematics → different angle covered at different flight paths

Summed spectra



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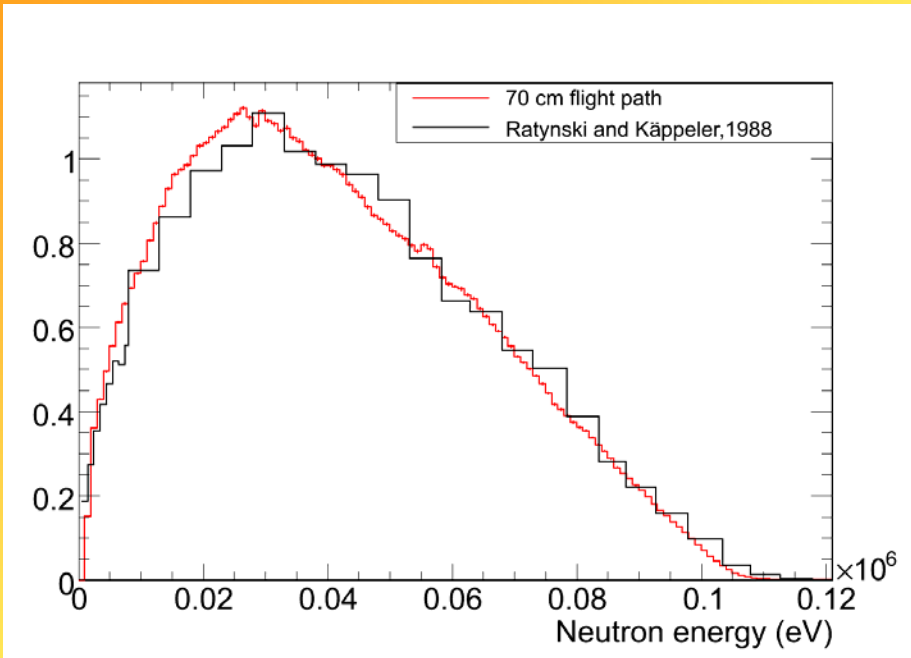

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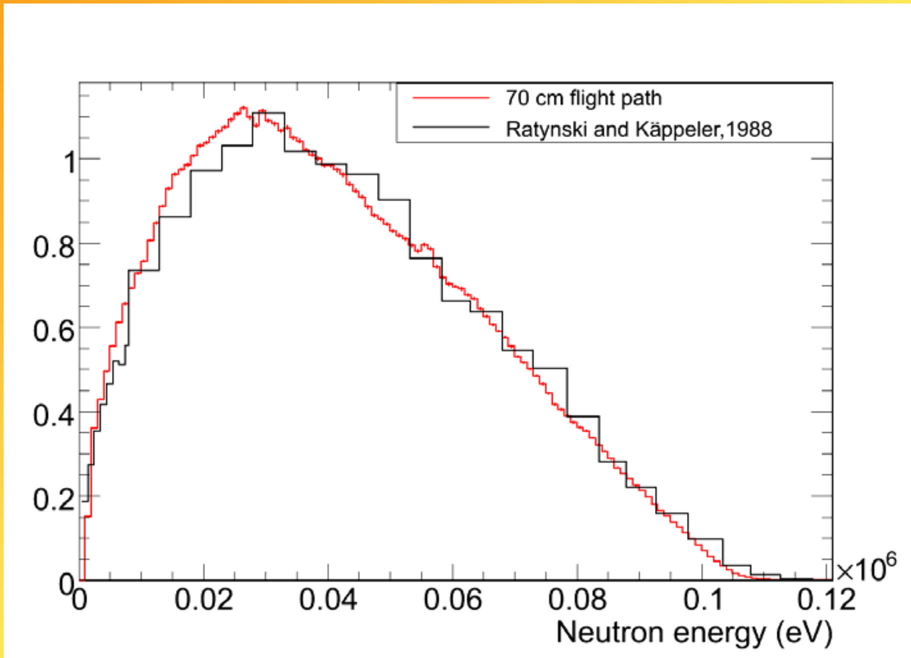
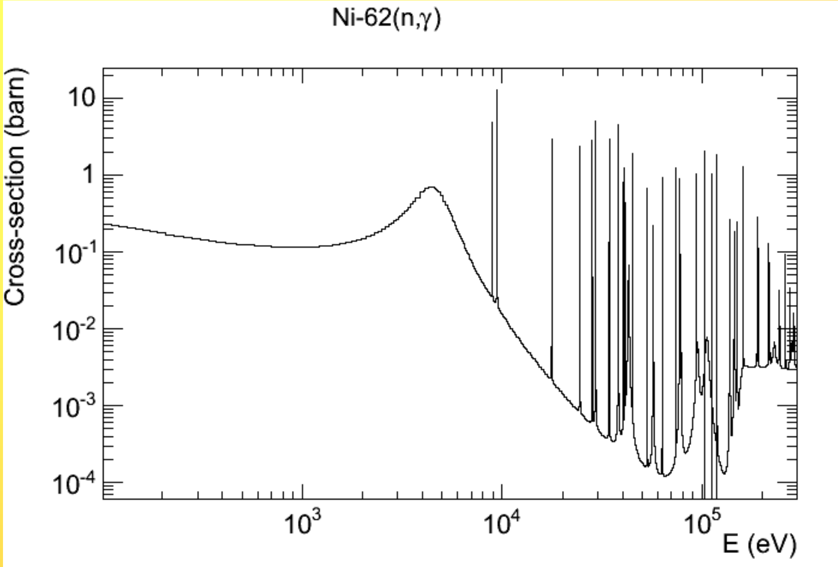


effect on averaged cross-section:

example: **^{62}Ni(n,γ)** (JENDL library)



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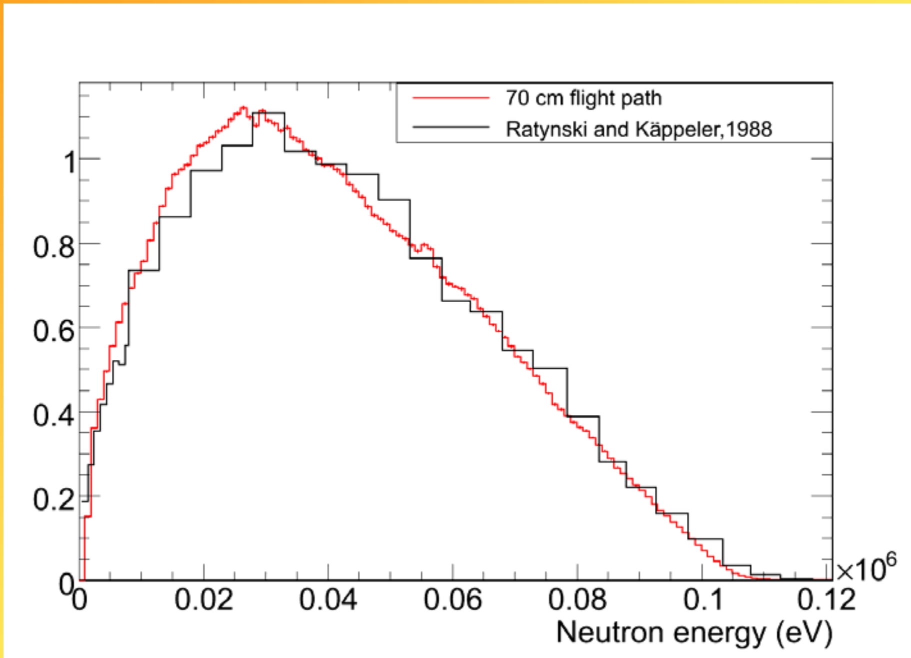
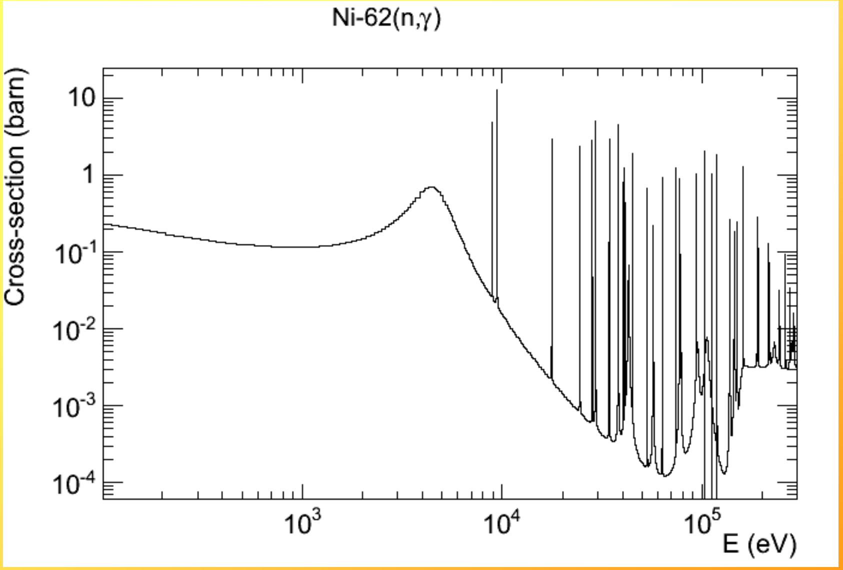


effect on averaged cross-section:

example: ^{62}**Ni(n,γ)** (JENDL library)

- 22.7 mb for Ratynski and Käppeler spectrum
- 23.7 mb for PTB spectrum

→ 4% effect



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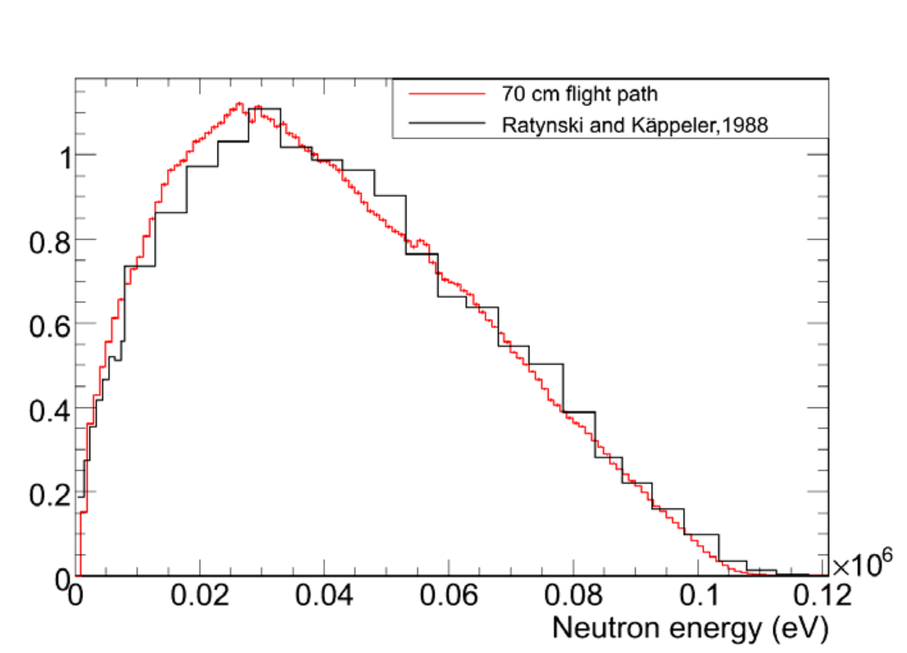

^{197}**Au(n,γ)** (ENDF-B7 library)

- 633 mb for Ratynski and Käppeler spectrum
- 630 mb for PTB spectrum

only 0.5 % difference !

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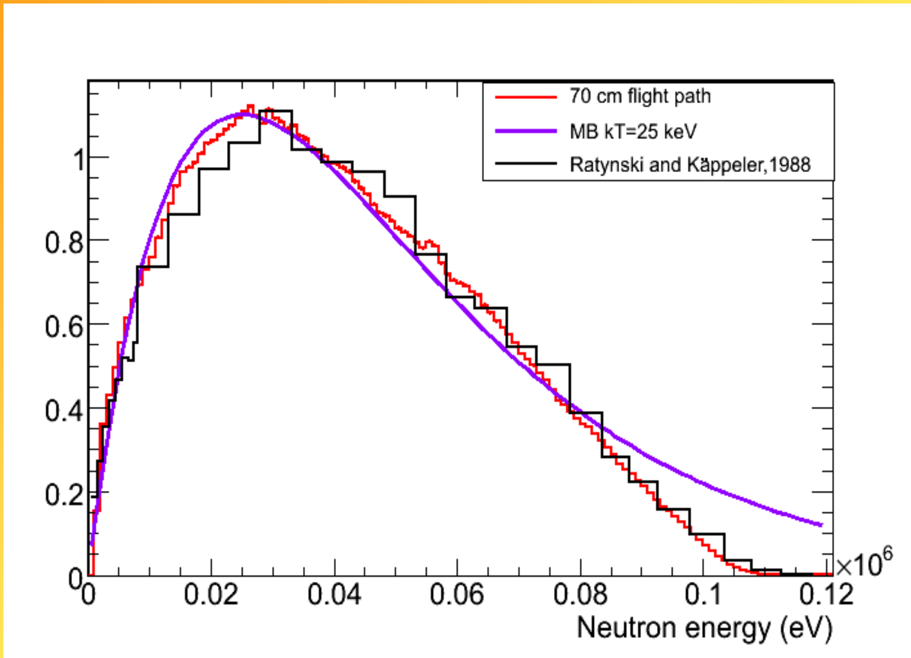
Summed spectra



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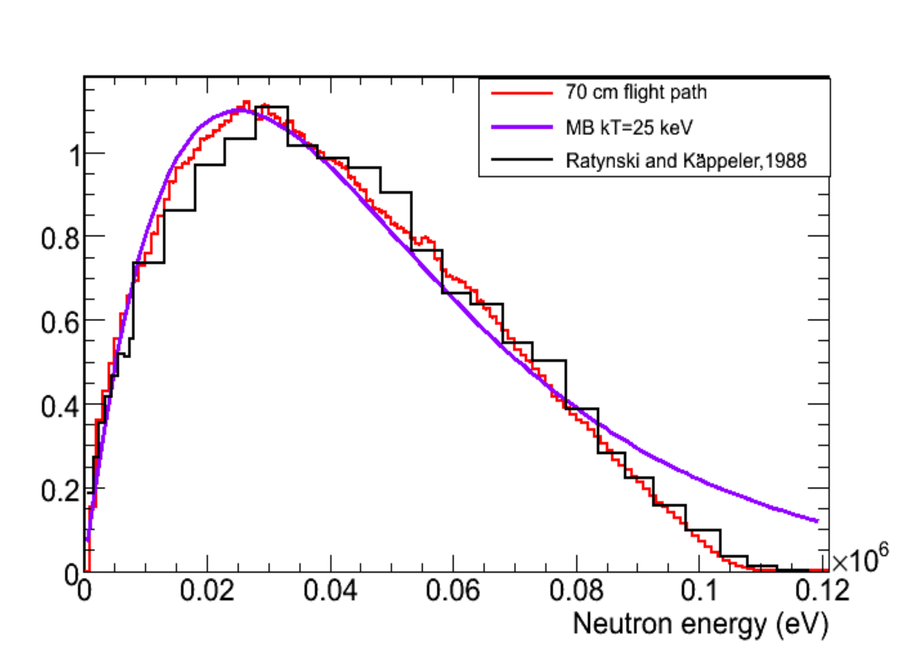

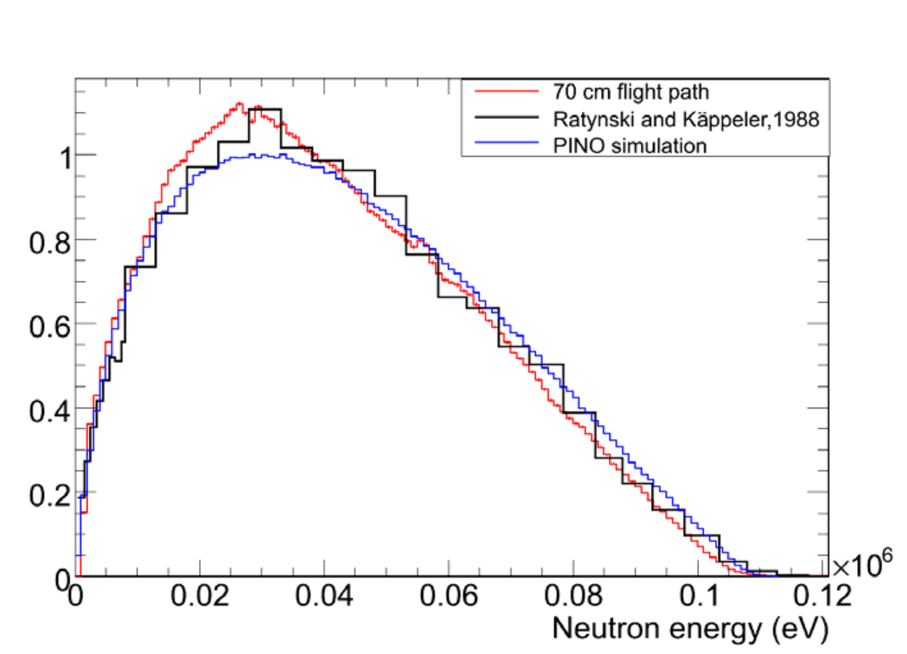

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- PINO- a tool for simulating neutron spectra resulting from the ^{7}Li(p,n) reaction, R. Reifarth et al. , Nucl. Instr. Meth. A **608**, 139 (2009)

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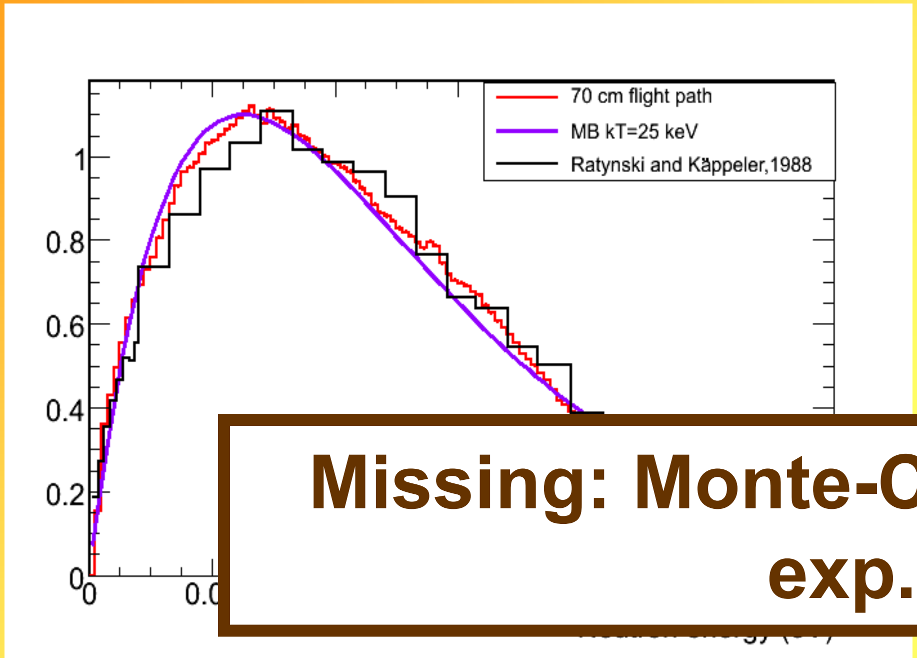

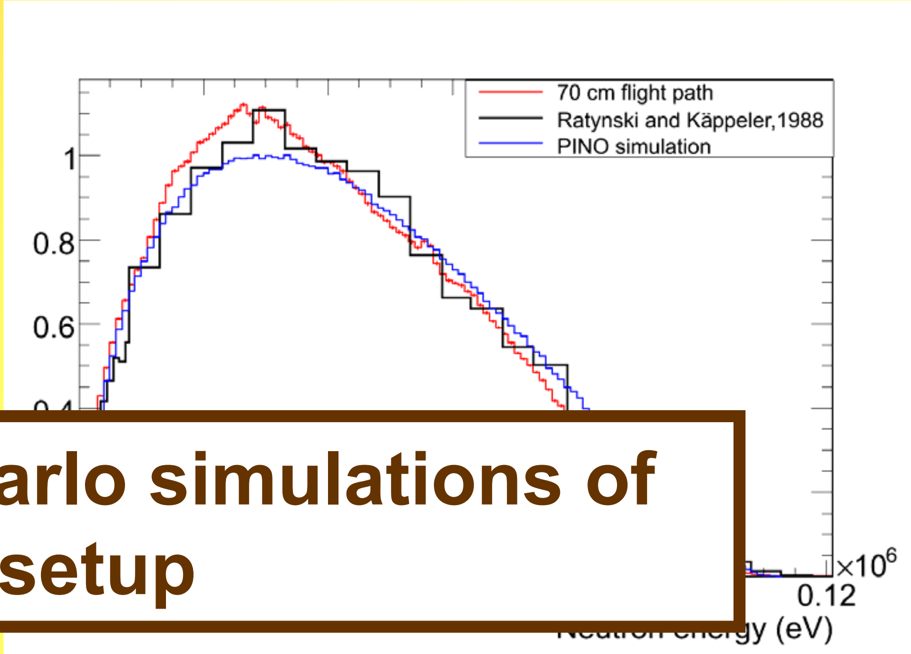

Missing: Monte-Carlo simulations of exp. setup

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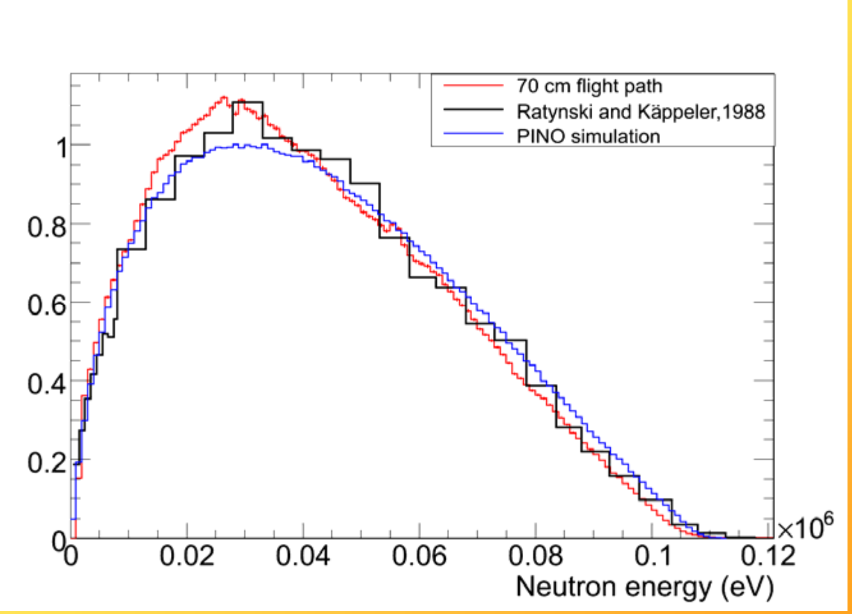
Conclusions

- "aging-effect" of target causing shift to lower energies but cannot explain differences in different flight paths
- neutron spectrum not sensitive to different targets
- low and high energy-end of spectrum comparable to Ratynski and Käppeler measurement
- differences to Ratynski and Käppeler between 10-60 keV
- good agreement to PINO simulation up to 15 keV
- MC-simulations of various experimental effects underway



Thank you for your attention!

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