A neutron source for FY studies at IGISOL-JYFLTRAP

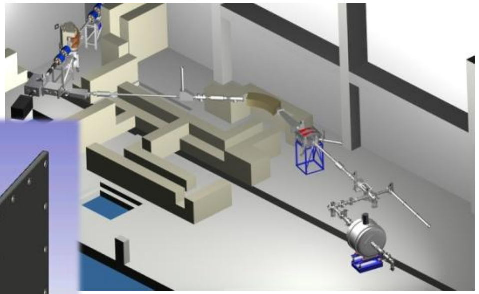
A. Al-Adili[1], M. Lantz[1], **A. Mattera[1]**, S. Pomp[1], A.V. Prokofiev[1],
V. Rakopoulos[1], A. Solders[1], D. Gorelov[2], H. Penttilä[2], S. Rinta-Antila[2]

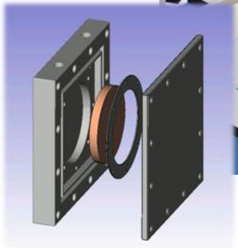
1 UPPSALA UNIVERSITET

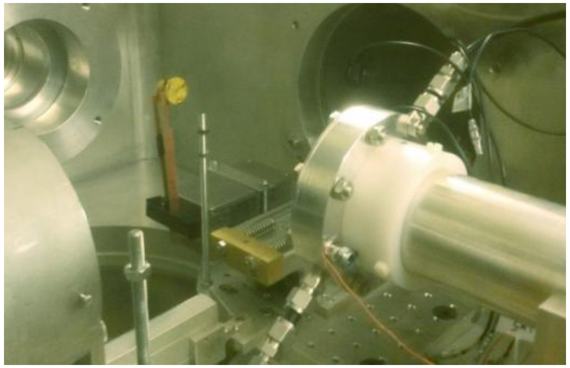
2 JYVÄSKYLÄN YLIOPISTO UNIVERSITY OF JYVÄSKYLÄ

Outline

- Fission Yields at IGISOL-JYFLTRAP
- N-source design
- Validation measurements
  - at The Svedberg Laboratory (BSS+LSci)
  - at n-IGISOL (TFBCs)
- Future Plans
- Conclusion







The IGISOL facility at JYFL

IGISOL-JYFLTRAP
@ University of Jyväskylä,
Finland

Measurement of p-induced fission yields with On-Line Isotope separator and Penning trap

IGISOL-JYFLTRAP was upgraded and re-located in 2010 to a new, bigger experimental hall ...

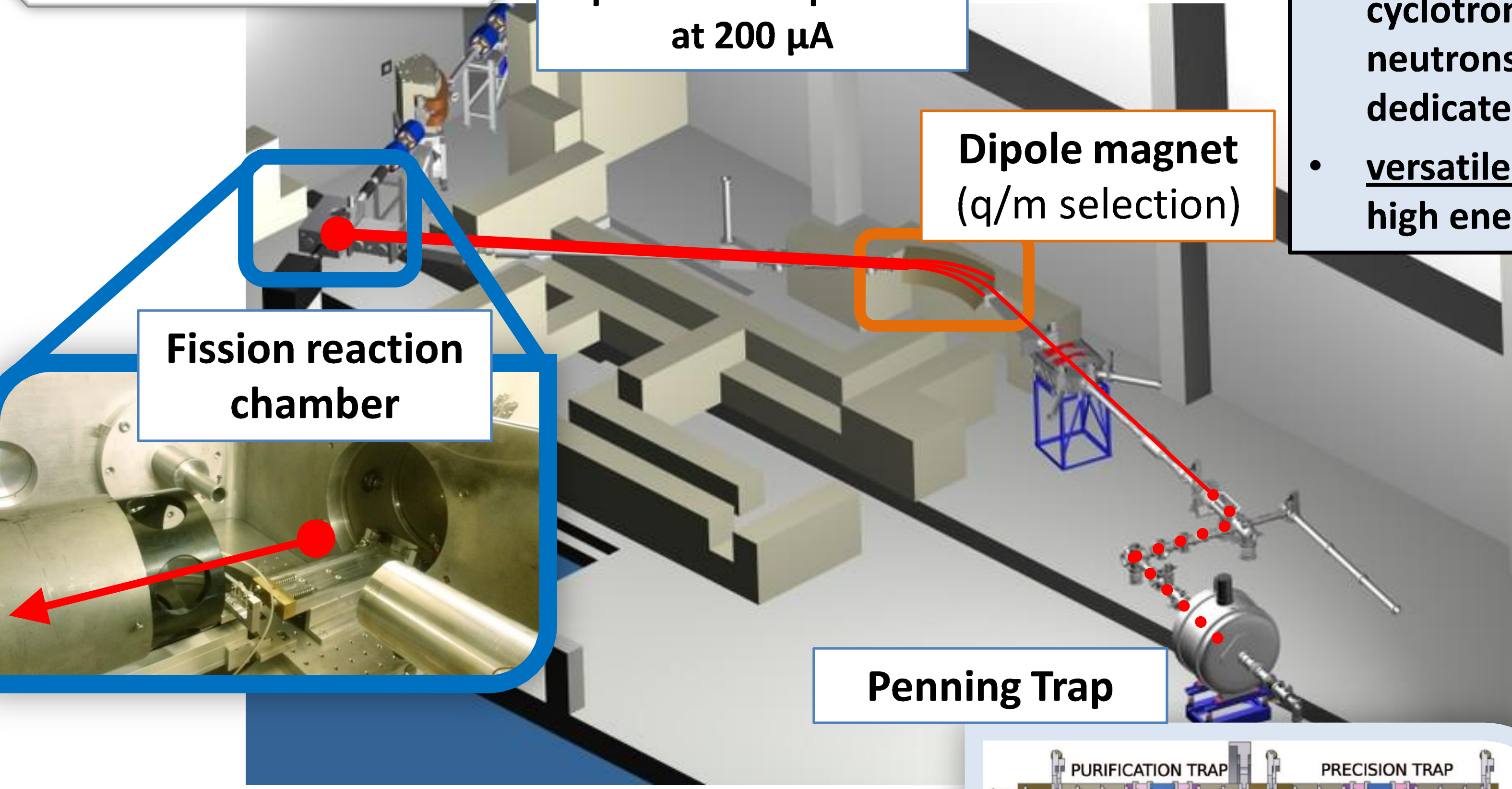
UPPSALA UNIVERSITET

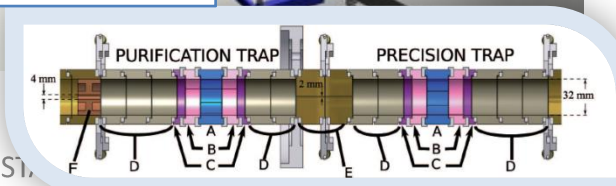
The IGISOL facility at JYFL

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

New MCC30 cyclotron is now commissioned and operating:
Up to 30 MeV protons at 200 μA

- Convert the high-intensity 30 MeV proton (/deuteron) beam cyclotron at IGISOL to neutrons with a dedicated source
- versatile source (low and high energy)



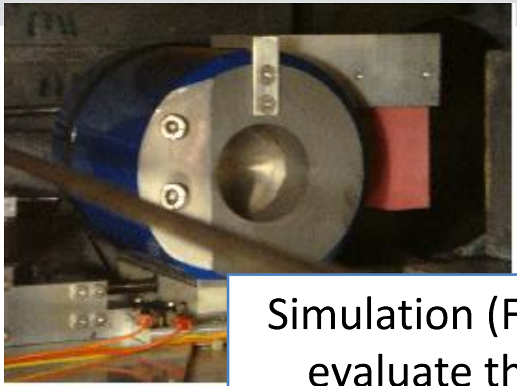


Designing the neutron source…

UPPSALA UNIVERSITET

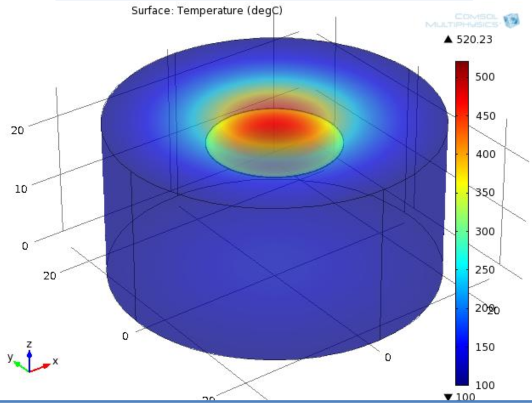
- The first idea:

A full-stop target (Tungsten or Beryllium) similar to the ANITA n-source at The Svedberg Laboratory (Uppsala)

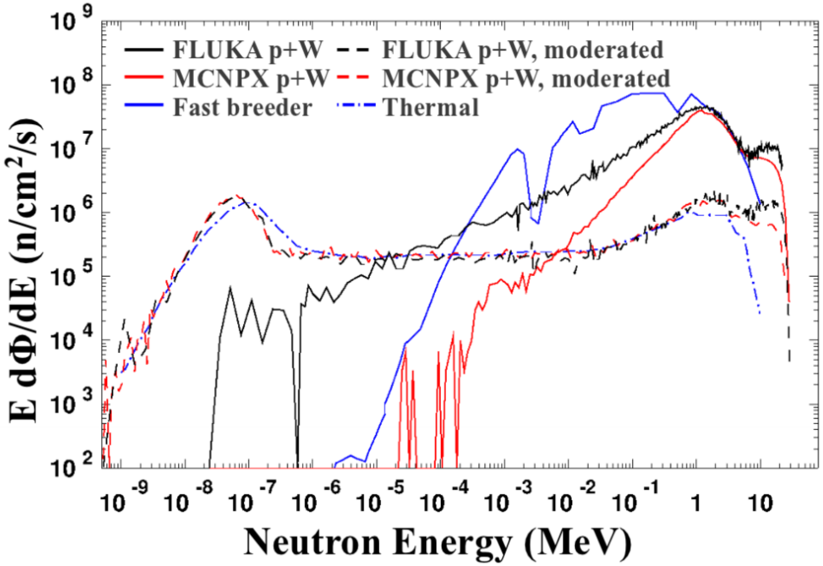


Simulation (FLUKA, MCNPX) to evaluate the neutron yield

cooling problems?

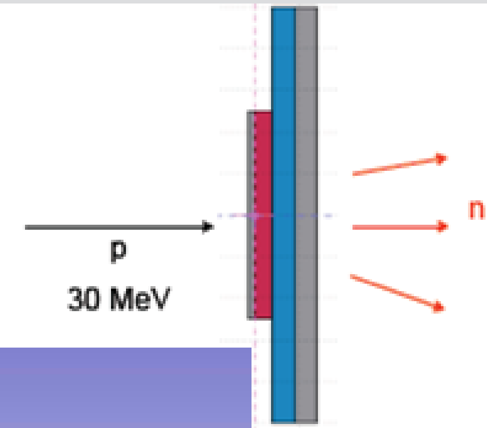


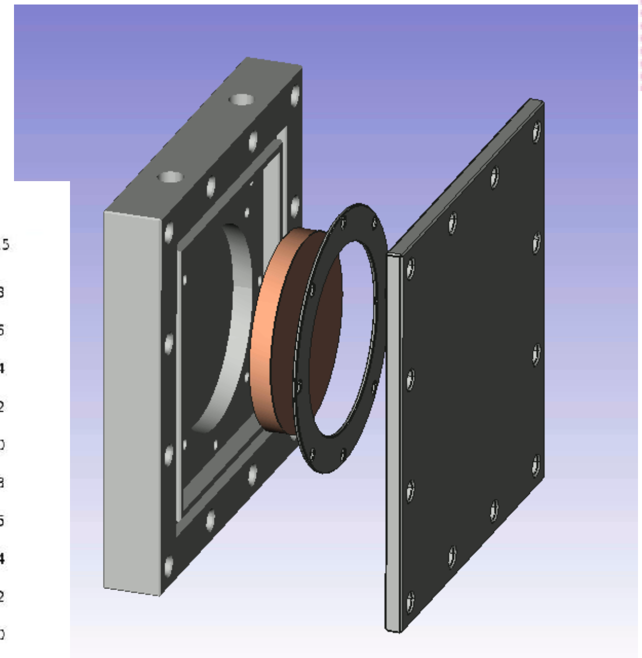
How to ensure an **effective cooling** and a reasonable temperature inside the target?
Hydrogen build-up in the target?

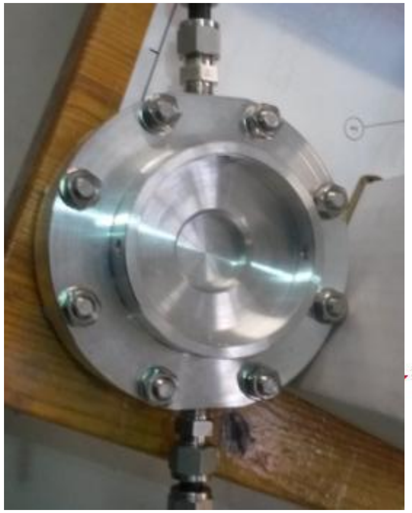


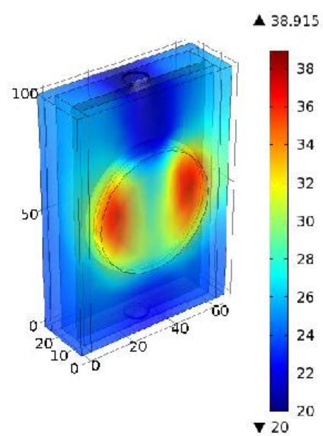
Designing the neutron source…

- water-cooled Be-target:
  - 50 mm diameter
  - 5 mm thickness
- 30 MeV protons will **stop in the cooling water**:
  - ✓ <u>**less** effort to remove **heat** (up to 6 kW)</u>
  - ✓ <u>**reduced hydrogen build-up**</u>
  - × Only -5% reduction in neutron yield
  - × activation in water



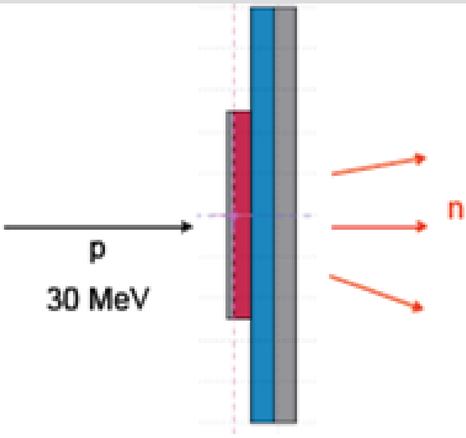


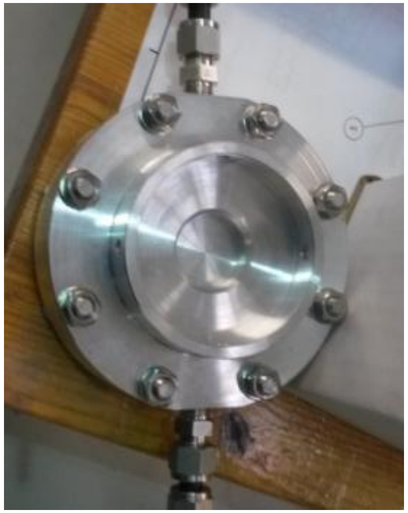




Designing the neutron source…

- water-cooled Be-target:
  - 50 mm diameter
  - 5 mm thickness
- 30 MeV protons will **stop in the cooling water**:
  - ✓ <u>**less** effort to remove **heat** (up to 6 kW)</u>
  - ✓ <u>**reduced hydrogen build-up**</u>
  - × Only -5% reduction in neutron yield
  - × activation in water





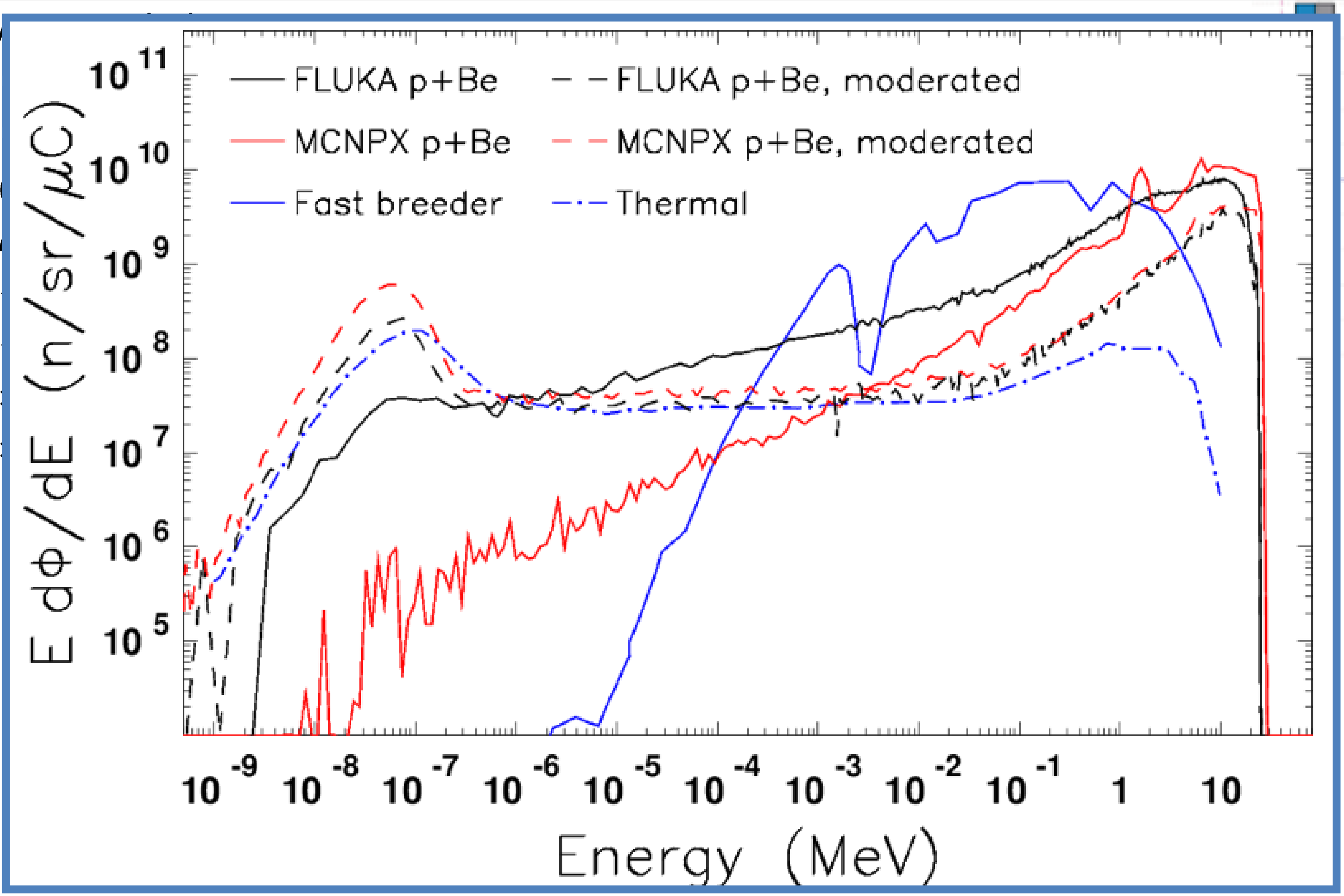
A flexible design was investigated:

Possibility to add a moderator for studies with thermal neutrons and to change the target thickness for semi-monoenergetic neutrons.

Designing the neutron source…

UPPSALA UNIVERSITET

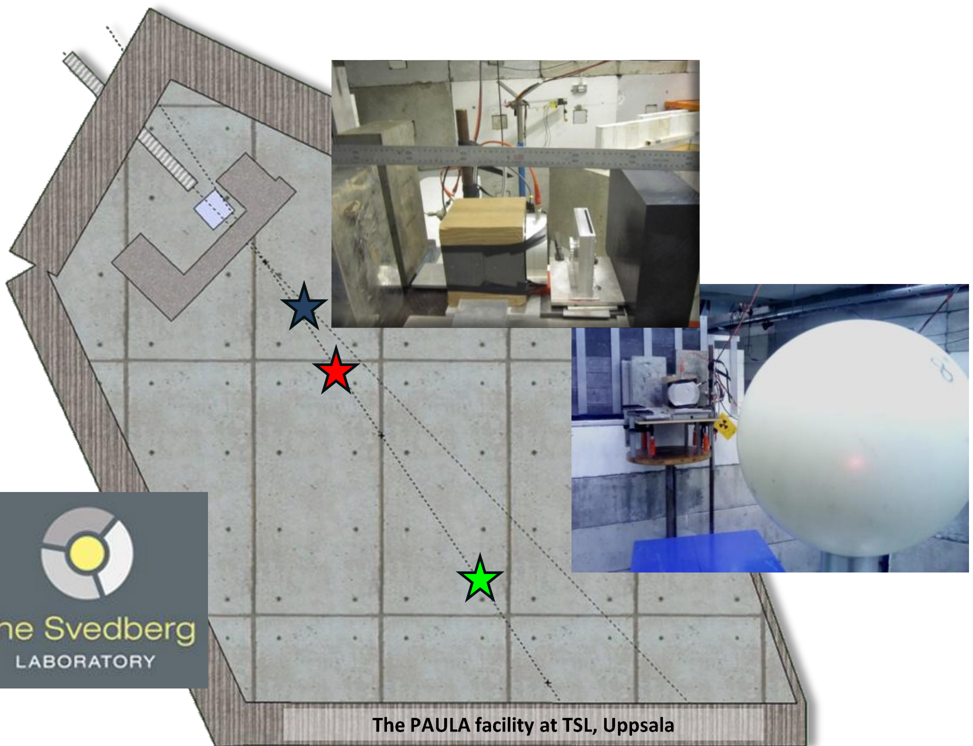
- w
- 3(
  w



UPPSALA UNIVERSITET

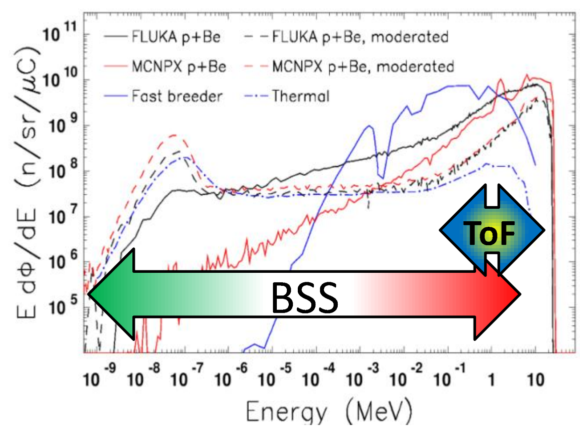
Benchmark of the simulations with a prototype of the p-n converter

- Measured **energy of accelerated protons**: 37.25 ± 0.5 MeV
- Average **proton energy at target**: 29.62 MeV
- Proton energy spread (FWHM) at target: 0.57 MeV
- Repetition **period of beam micropulses**: 44.2 ns



The Svedberg LABORATORY

- Two different techniques:
  - **Bonner Spheres** for the low-energy part (LNF-INFN)
  - Time of Flight (liquid scintillator) for the high-energy part (UU)



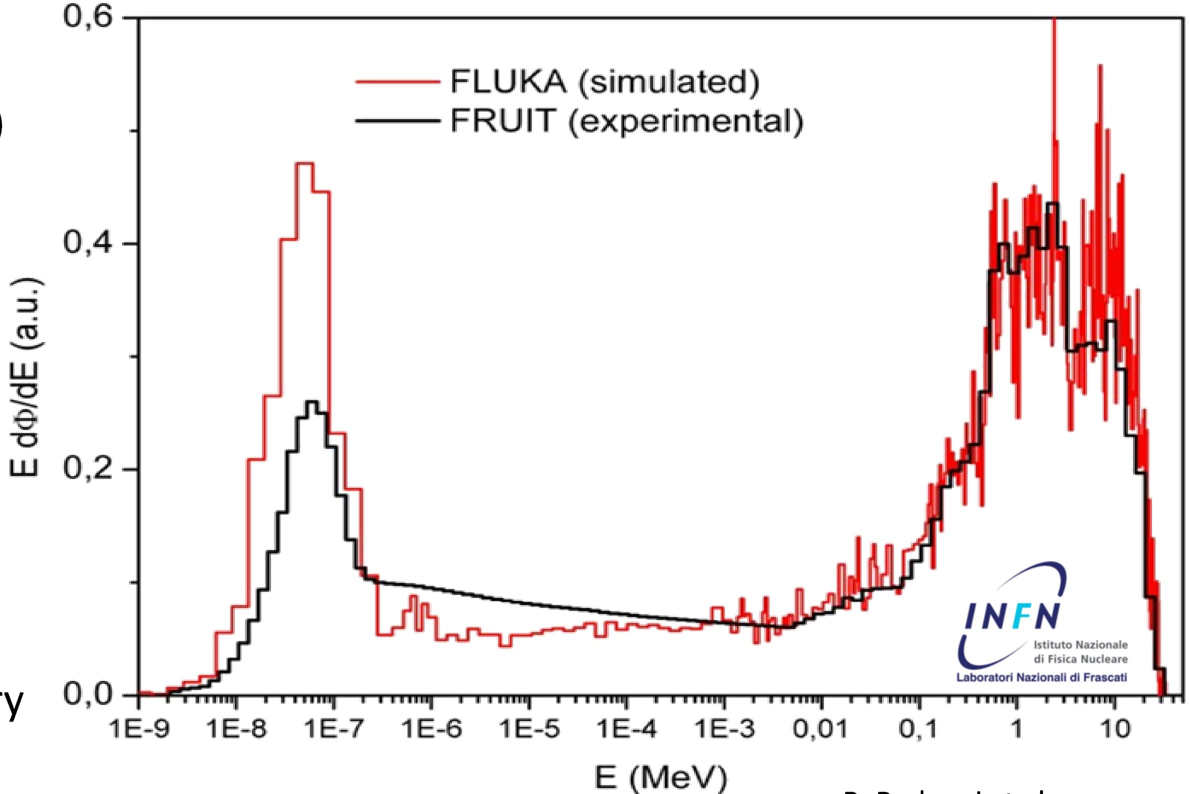
Analysis & Results

BSS - unmoderated source

Uncertainties considered:

- 3 % beam+monitoring stability (repeated exp. with same sphere)
- 3 % overall unc on BSS response matrix
- < 1 % BSS counting statistics
- 2 % unc on BSS calibration (periodically repeated at LNF)

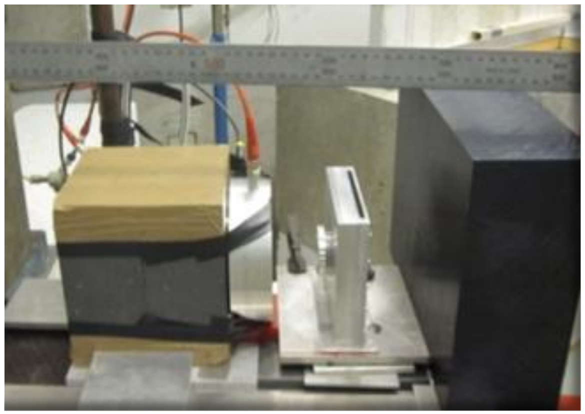
The **discrepancy** between FLUKA and the BSS measurement at thermal energies **could be attributed to the low-energy** (very room-dependent) **background** in the experimental hall.



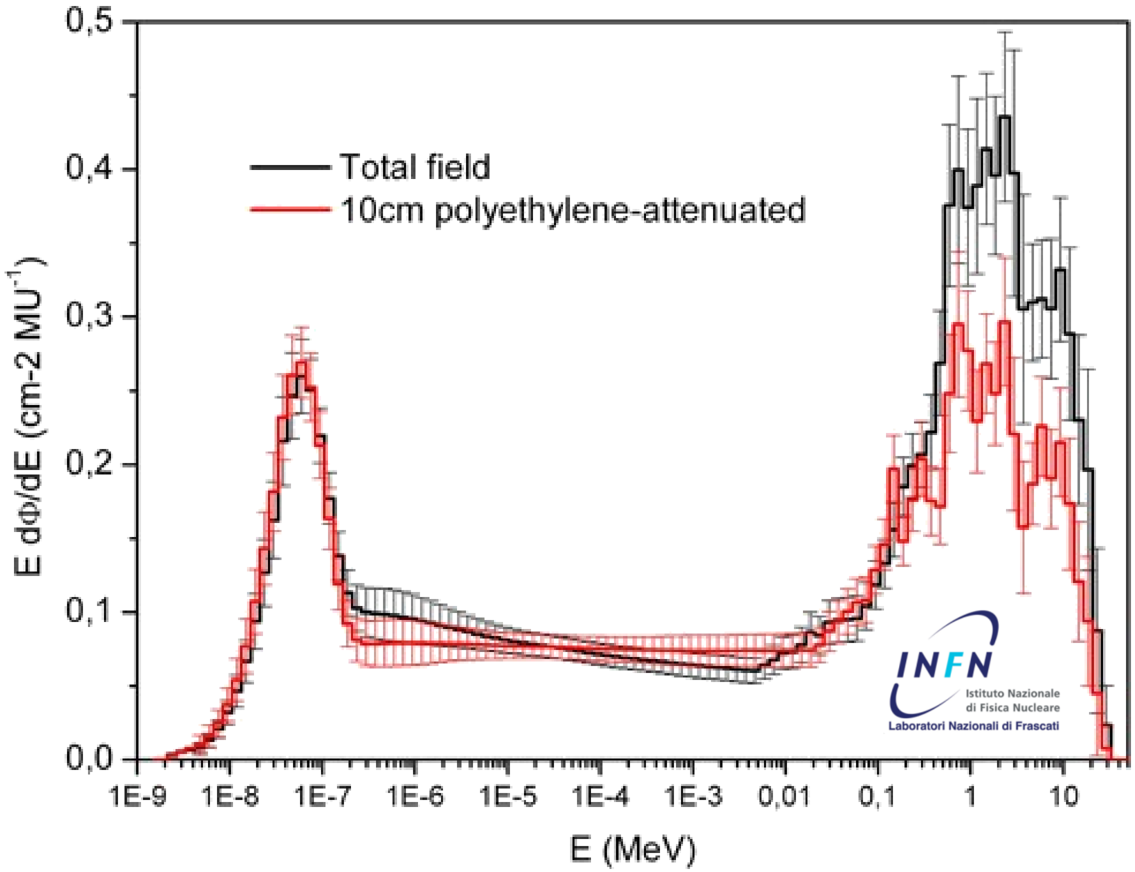
R. Bedogni et al.

Analysis & Results

BSS - moderated source



The energy spectrum from a source moderated with 10 cm polyethylene was also measured during the TSL campaign.



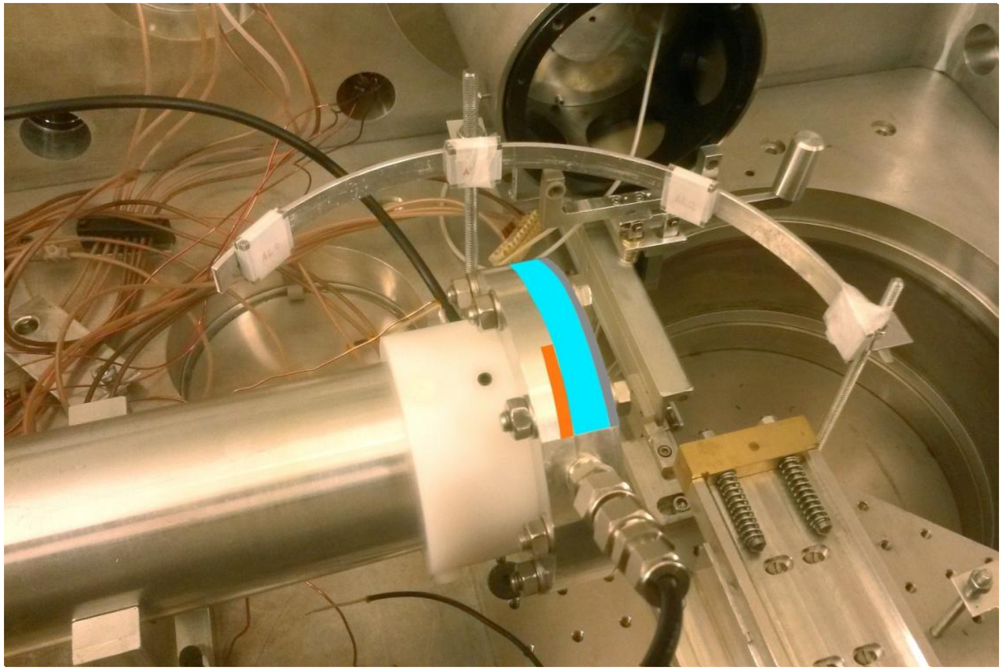
UPPSALA UNIVERSITET

Tests of the source at JYFL

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

TFBCs & NAA

The source was first put in place on March, 23rd 2014.

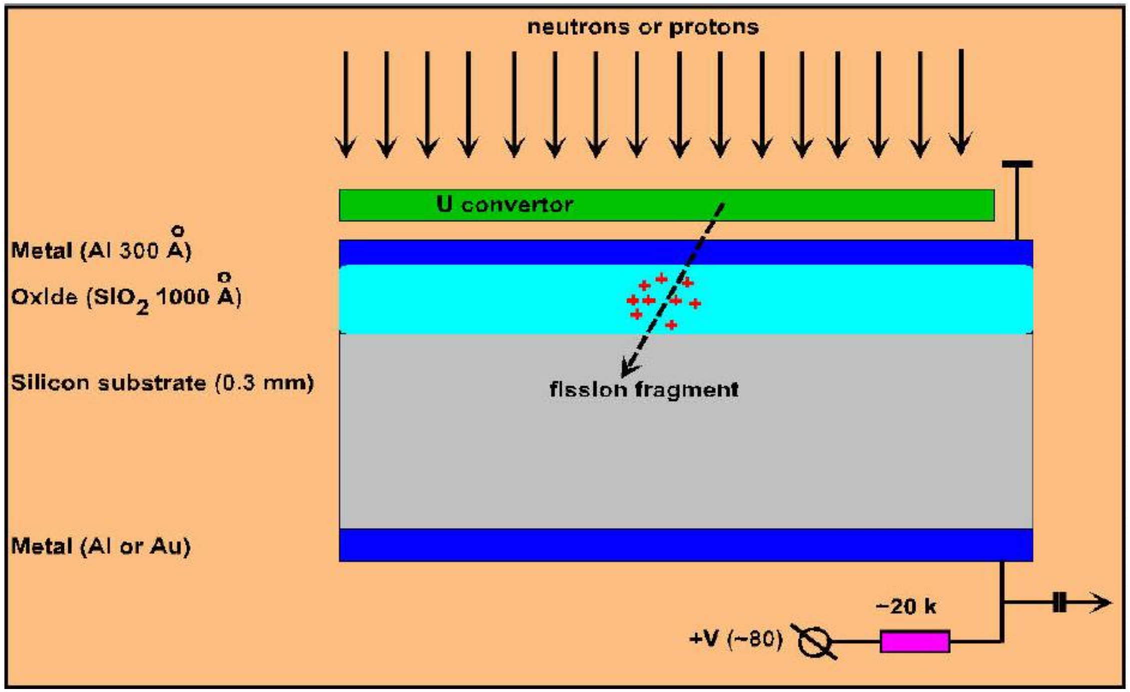


A measurement with **Thin Film Breakdown Counters** and Neutron Activation Analysis (NAA) was performed to estimate the neutron flux and the energy spectrum of the neutron source at the position of the fission target

Tests of the source at JYFL

TFBC functioning principle

Thin Film Breakdown Counters (TFBC)



Tests of the source at JYFL

TFBC functioning principle

Non sensitive to light ions, beta and gamma.

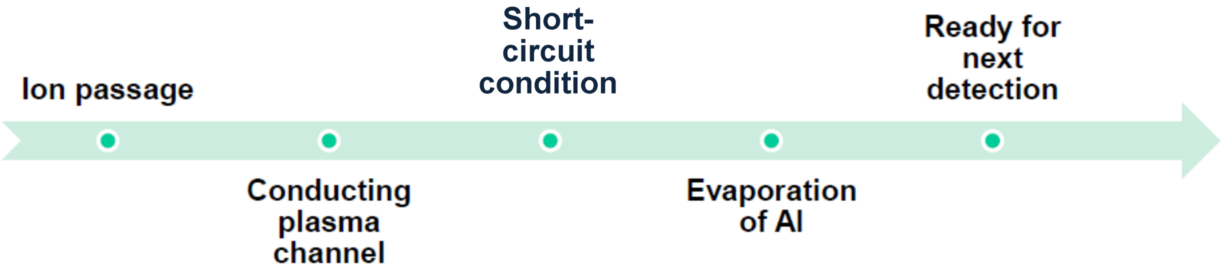
Pulse Height ~ 0.1-5 V

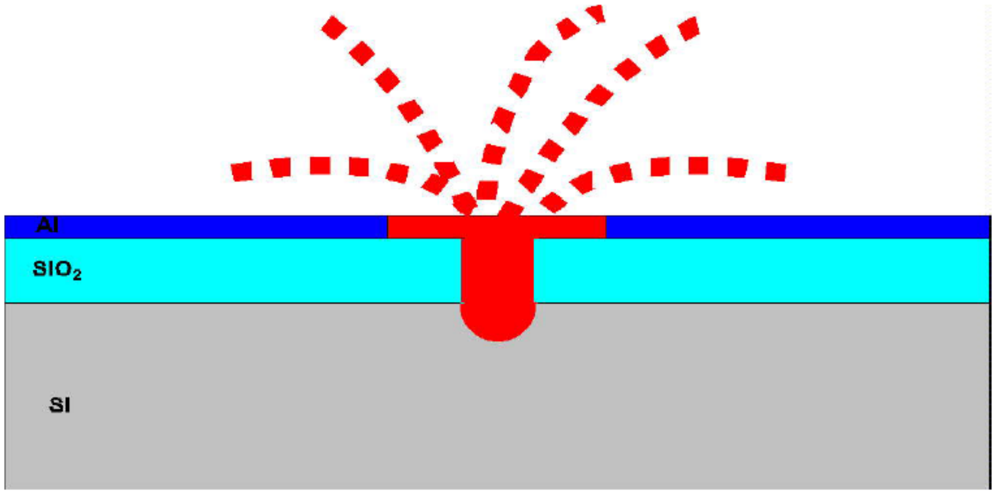
Fluctuation of response time: 0.1 ns

Operational resources: 10^5 - 10^7 detections/cm^2

Max detection rate: ~ 10 Hz

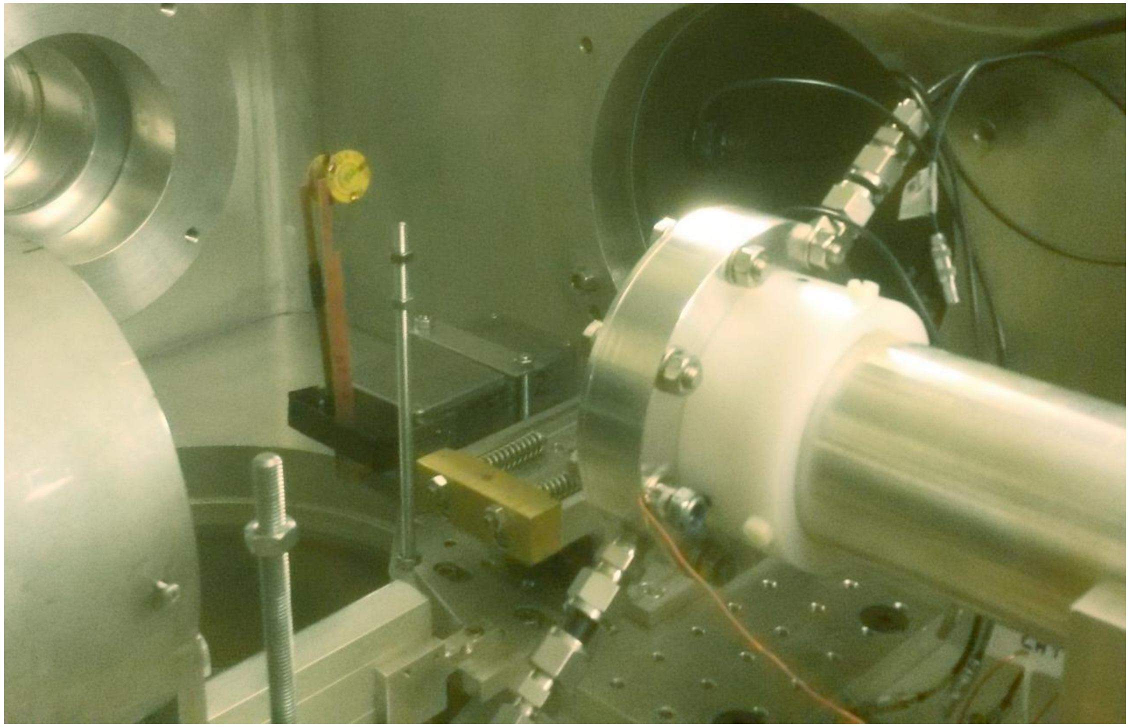
Timeline of a detection act in a TFBC





Tests of the source at JYFL

TFBCs & NAA



TFBC were used to validate the simulated energy spectra using a Time-of-Flight measurement.

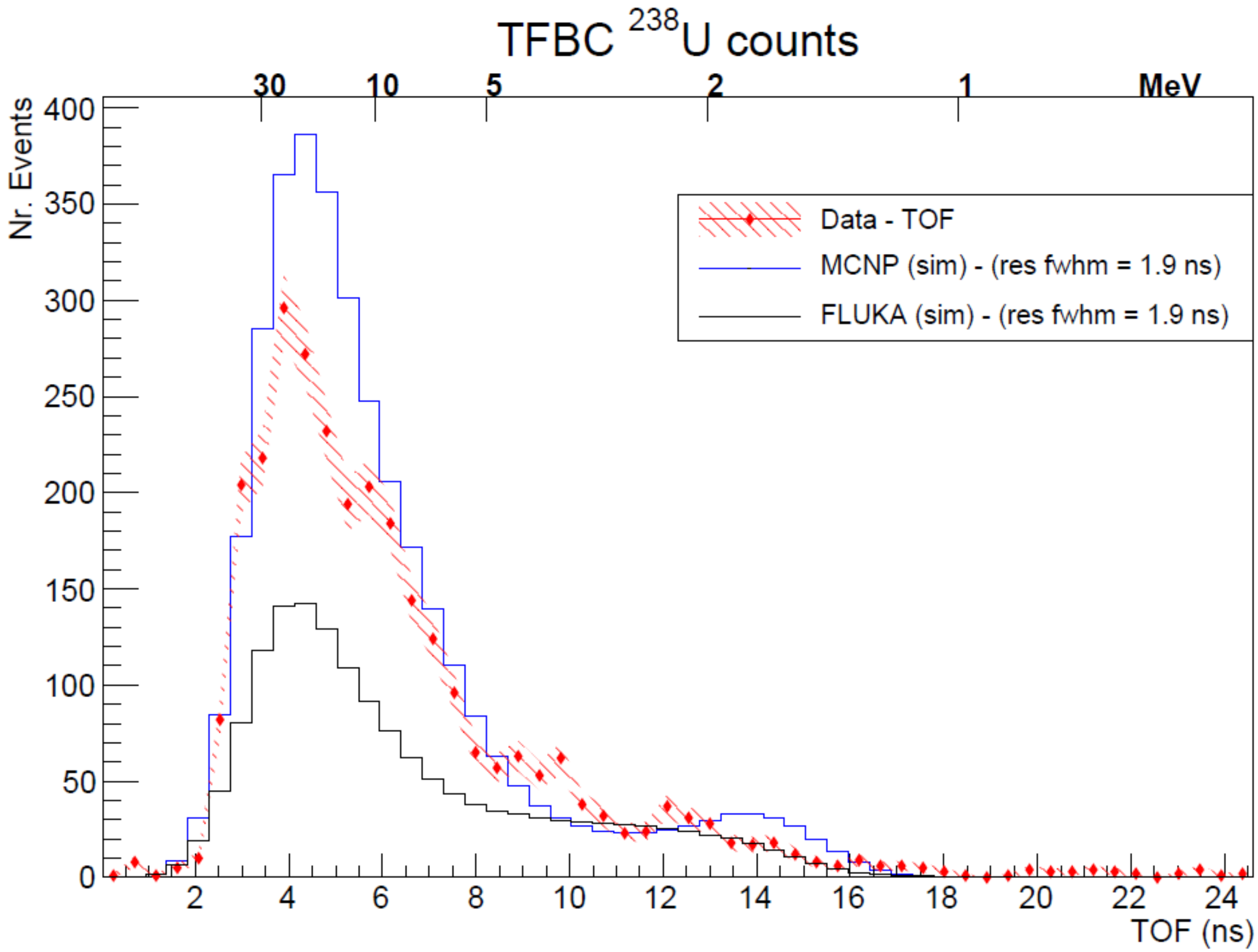
Feasibility test for a possible use as beam monitors for n-induced FY measurements

Tests of the source at JYFL

TFBCs & MC Simulations

The results of the feasibility test are not conclusive, but still quite promising…

A longer measurement of the neutron flux and TOF is planned (and financed under CHANDA).



Tests of the source at JYFL

UPPSALA UNIVERSITET

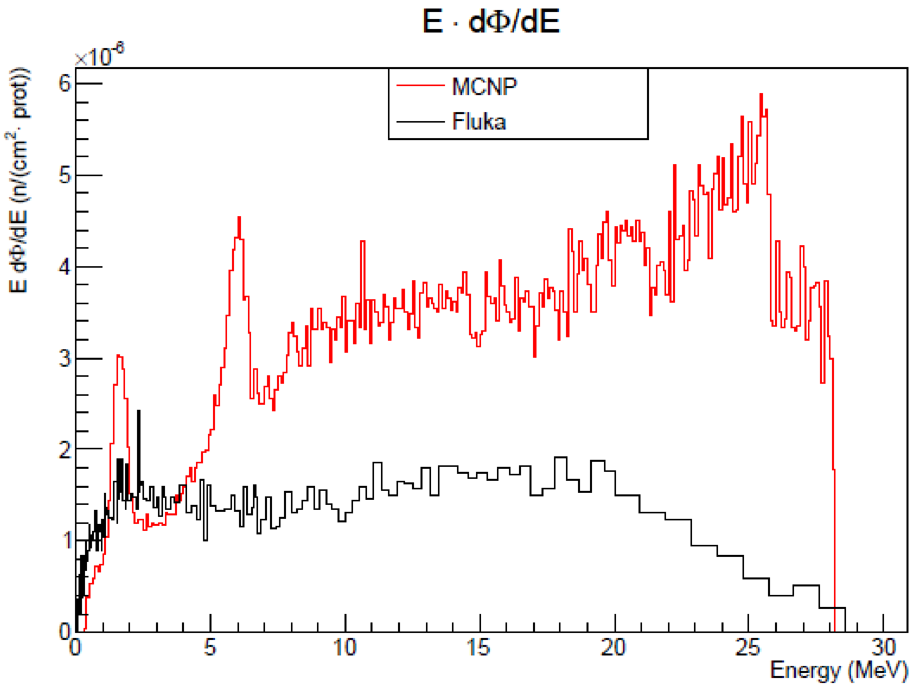
JYVÄSKYLÄN YLIOPISTO UNIVERSITY OF JYVÄSKYLÄ

TFBCs & MC simulations

MCNPX	TOTAL	>1 MeV	>10 MeV
FLUX	$(2.6 \pm 0.6) \cdot 10^{10}$ n/(sr · s)	$(2.5 \pm 0.6) \cdot 10^{10}$ n/(sr · s)	$(1.1 \pm 0.3) \cdot 10^{10}$ n/(sr · s)
FLUKA	**TOTAL**	**>1 MeV**	**>10 MeV**
FLUX	$(4.0 \pm 0.9) \cdot 10^{10}$ n/(sr · s)	$(3.0 \pm 0.7) \cdot 10^{10}$ n/(sr · s)	$(0.9 \pm 0.2) \cdot 10^{10}$ n/(sr · s)

FOR 1 μA OF PROTONS ON TARGET

THE GOAL OF 10^{12} FAST NEUTRONS ON THE FISSION TARGET IS WITHIN REACH



… more conclusive results will come once the NAA analysis is completed

UPPSALA UNIVERSITET

Future plans …

JYVÄSKYLÄN YLIOPISTO UNIVERSITY OF JYVÄSKYLÄ

FY campaigns at n-IGISOL

Coming measurements:

- **n-induced measurements of FY** from targets well studied and relatively easy to get hold of (ex. ^{235}U, ^{238}U, ^{232}Th) for comparison and validation of the technique.

- new (more complete) **measurement of the n-energy spectrum** with TFBCs (new batch of TFBCs will be ordered from Khoplin Radium Institute, St. Petersburg)

- once the setup has been tested and results compared successfully with previous experimental data, several parameters can be changed such as:
  - Neutron energy spectrum (going to moderated / semi-monoenergetic spectra)
  - Fissionable targets (depending on availability)

UPPSALA UNIVERSITET

Conclusions & Outlook

JYVÄSKYLÄN YLIOPISTO UNIVERSITY OF JYVÄSKYLÄ

Achieved:

- ✓ design (simulation) and construction of a mock-up of the neutron source (p-n converter)
- ✓ Run to measure the energy spectra in two configurations (unmoderated and moderated target) at TSL
- ✓ Run with the n-source in place at JYFL (only partial results)

Still to do:

- ❑ Complete analysis for absolute flux and energy spectra for the TSL measurement
- ❑ Comparison of BSS-TOF results for the TSL measurement
- ❑ Analysis of the NAA data from JYFL run and comparison with TFBC data
- ❑ Characterization of the source in moderated configuration

A neutron source for FY studies at IGISOL-JYFLTRAP

Thank you!

A. Al-Adili[1], M. Lantz[1], **A. Mattera[1]**, S. Pomp[1], A.V. Prokofiev[1],
V. Rakopoulos[1], A. Solders[1], D. Gorelov[2], H. Penttilä[2], S. Rinta-Antila[2]

1 UPPSALA UNIVERSITET

2 JYVÄSKYLÄN YLIOPISTO UNIVERSITY OF JYVÄSKYLÄ