Measurement of the inelastic neutron scattering cross section of ^{56}Fe

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Data needs for fast reactors and ADS

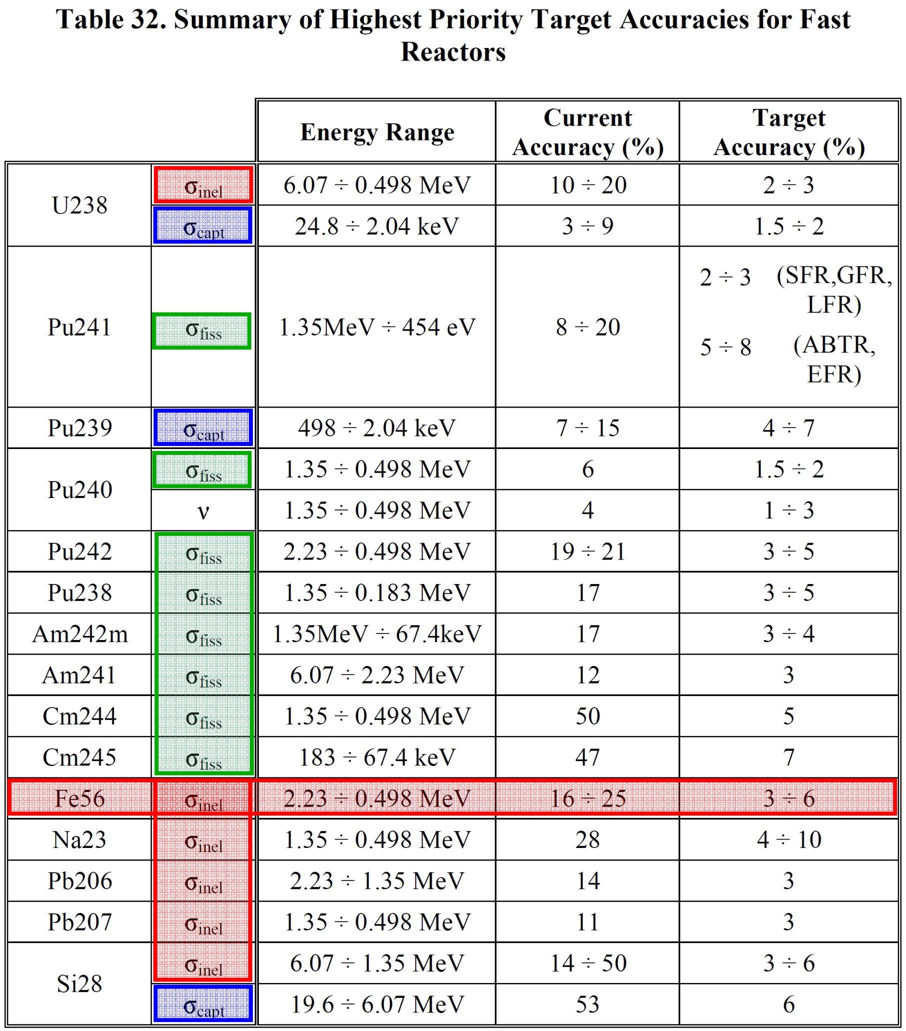


Table 32. Summary of Highest Priority Target Accuracies for Fast Reactors

		Energy Range	Current Accuracy (%)	Target Accuracy (%)
U238	σ_{inel}	6.07 ÷ 0.498 MeV	10 ÷ 20	2 ÷ 3
	σ_{capt}	24.8 ÷ 2.04 keV	3 ÷ 9	1.5 ÷ 2
Pu241	σ_{fiss}	1.35MeV ÷ 454 eV	8 ÷ 20	2 ÷ 3 (SFR,GFR, LFR) 5 ÷ 8 (ABTR, EFR)
Pu239	σ_{capt}	498 ÷ 2.04 keV	7 ÷ 15	4 ÷ 7
Pu240	σ_{fiss}	1.35 ÷ 0.498 MeV	6	1.5 ÷ 2
	ν	1.35 ÷ 0.498 MeV	4	1 ÷ 3
Pu242	σ_{fiss}	2.23 ÷ 0.498 MeV	19 ÷ 21	3 ÷ 5
Pu238	σ_{fiss}	1.35 ÷ 0.183 MeV	17	3 ÷ 5
Am242m	σ_{fiss}	1.35MeV ÷ 67.4keV	17	3 ÷ 4
Am241	σ_{fiss}	6.07 ÷ 2.23 MeV	12	3
Cm244	σ_{fiss}	1.35 ÷ 0.498 MeV	50	5
Cm245	σ_{fiss}	183 ÷ 67.4 keV	47	7
Fe56	σ_{inel}	2.23 ÷ 0.498 MeV	16 ÷ 25	3 ÷ 6
Na23	σ_{inel}	1.35 ÷ 0.498 MeV	28	4 ÷ 10
Pb206	σ_{inel}	2.23 ÷ 1.35 MeV	14	3
Pb207	σ_{inel}	1.35 ÷ 0.498 MeV	11	3
Si28	σ_{inel}	6.07 ÷ 1.35 MeV	14 ÷ 50	3 ÷ 6
	σ_{capt}	19.6 ÷ 6.07 MeV	53	6

➔ fast neutron spectrum

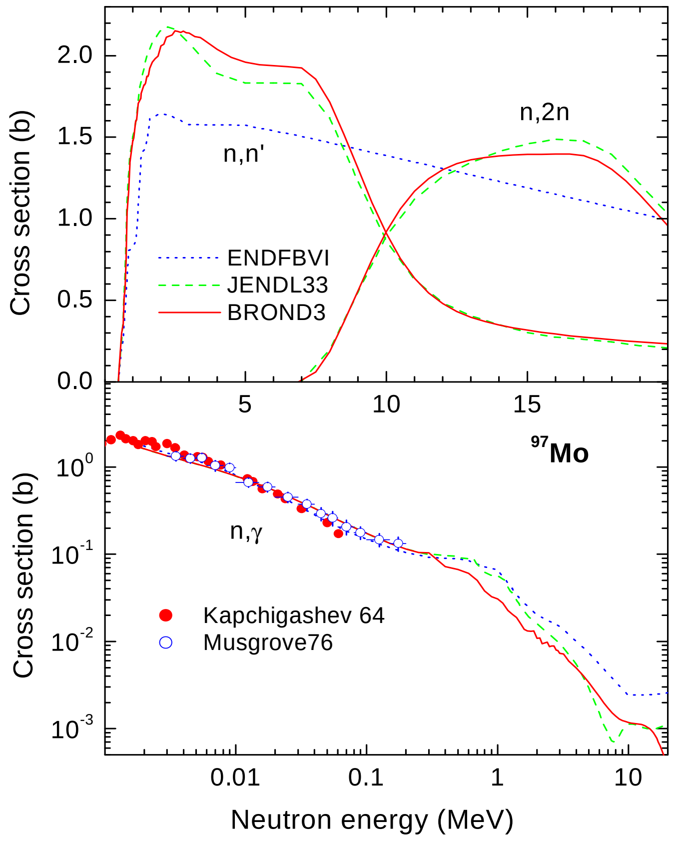
➔ U,Pu + minor actinides
structural & coolant materials

- neutron induced fission
- neutron capture
- neutron inelastic scattering

➔ ^{56}Fe (n,n'γ) ^{56}Fe

http://www.nea.fr/html/science/wpec/volume26/volume26.pdf

nELBE research program:



A. V. Ignatyuk, priv.com. 2008

- Investigation of fast neutron induced reactions of relevance for nuclear transmutation and the development of Gen IV reactor systems

1. **Inelastic neutron scattering (n,n‘γ)**
   ^{56}Fe, Mo, Pb, ^{23}Na and total neutron cross sections σ_{tot} (Ta, Au, Al, C, H)
2. **Neutron induced fission cross sections of minor actinides (radioactive targets)**

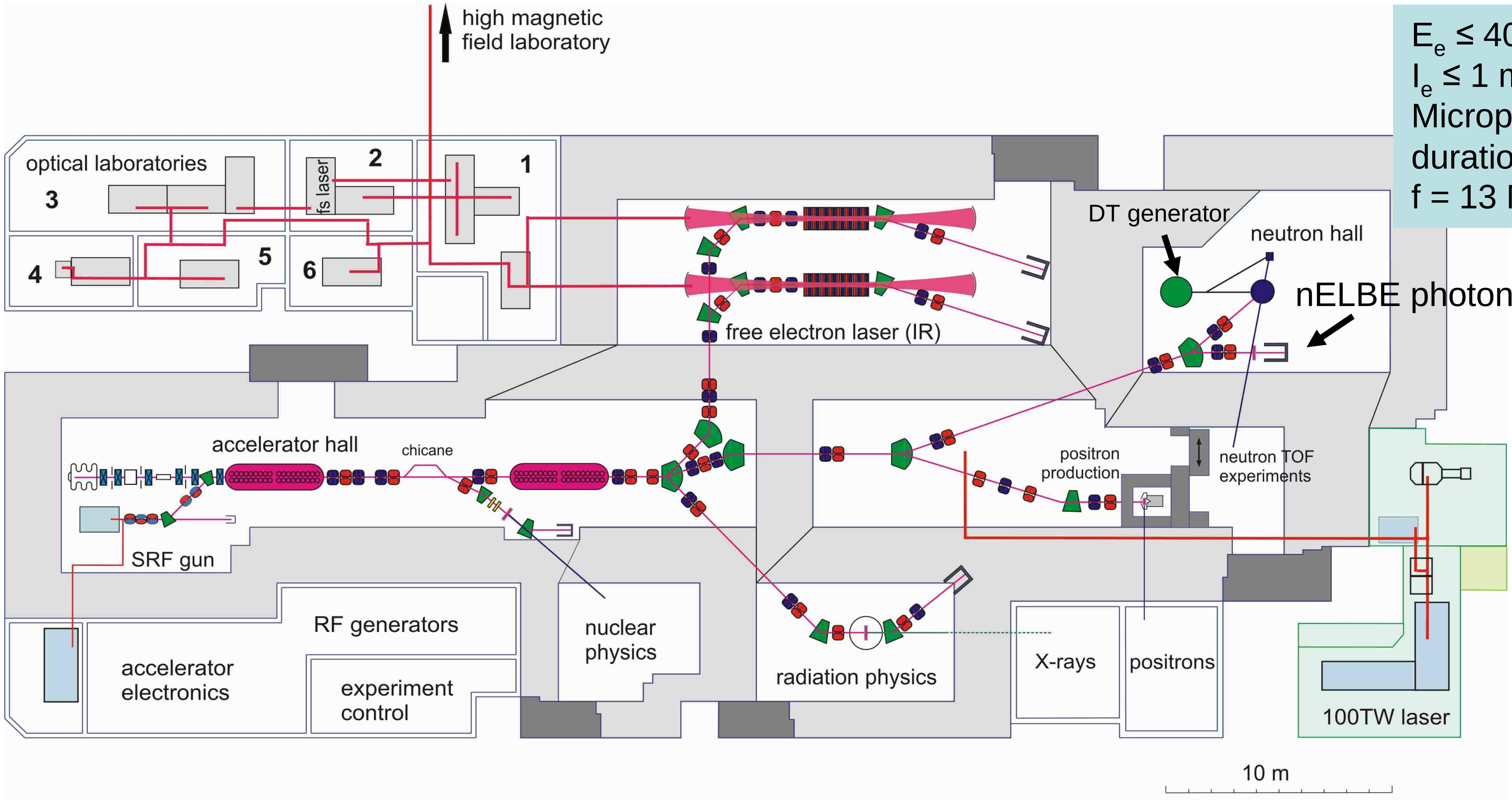
Collaboration with n_TOF at CERN

Joint research project „Nuclear physics studies of relevance for transmutation…“ (German Federal Ministry for Science and Technology funded , 02NUK13)

GEFÖRDERT VOM

Bundesministerium
für Bildung
und Forschung

ELBE: Electron Linear accelerator with high Brilliance and low Emittance



$E_e \leq 40$ MeV
$I_e \leq 1$ mA
Micropulse
duration $\Delta t < 10$ ps
f = 13 MHz / 2^n

1: Diagnostic station, IR-imaging and biological IR experiment
2: Femtosecond laser, THz-spectroscopy, IR pump-probe experiment
3: Time-resolved semiconductor spectroscopy, THz-spectroscopy
4: FTIR, biological IR experiment
5: Near-field and pump-probe IR experiment
6: Radiochemistry and sum frequency generation experiment, photothermal deflection spectroscopy

FZ Dresden-Rossendorf invites external groups for experiments at ELBE

ELBE: Electron Linear accelerator with high Brilliance and low Emittance

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Micropulse
duration $\Delta t < 10$ ps
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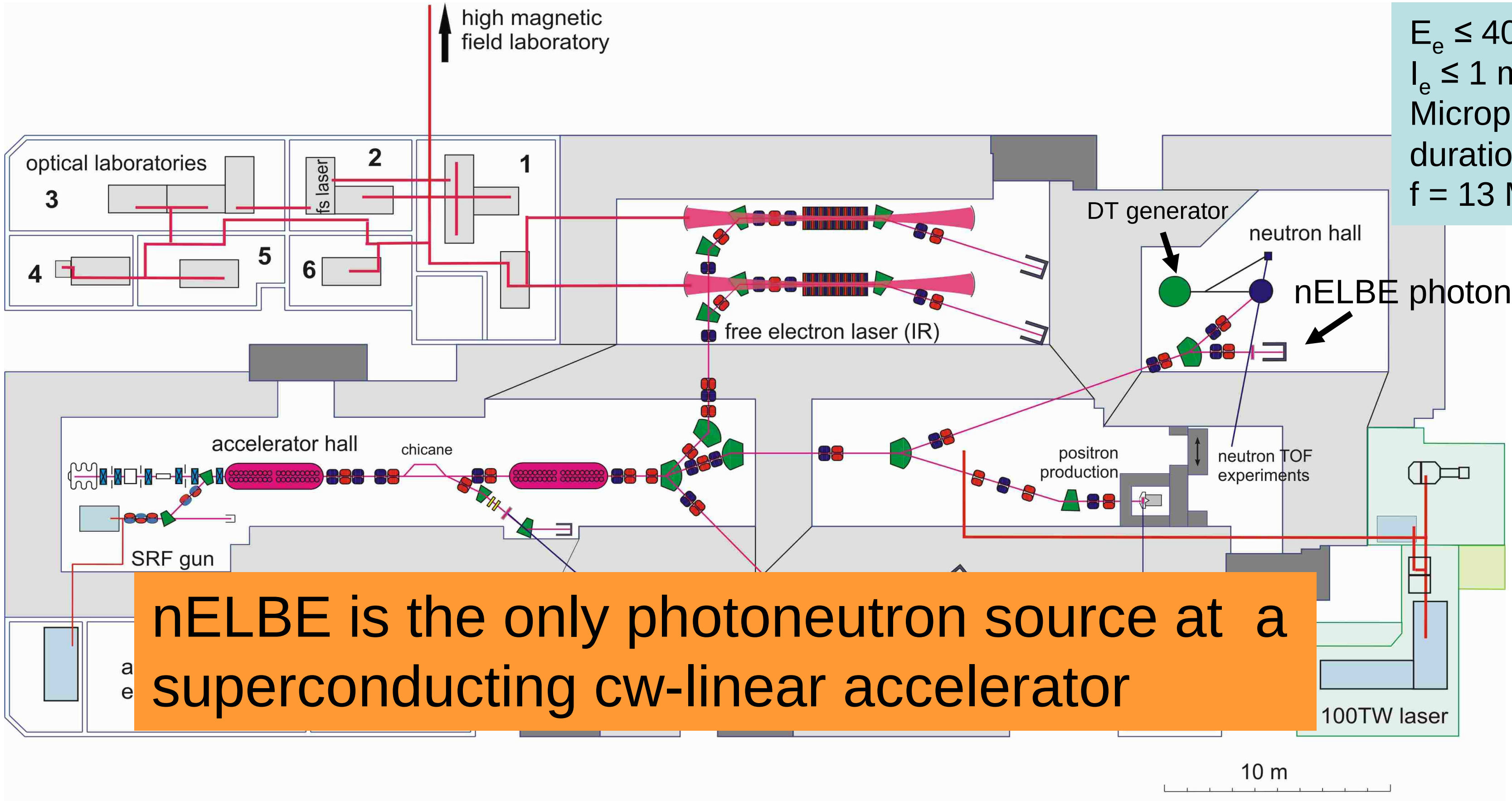
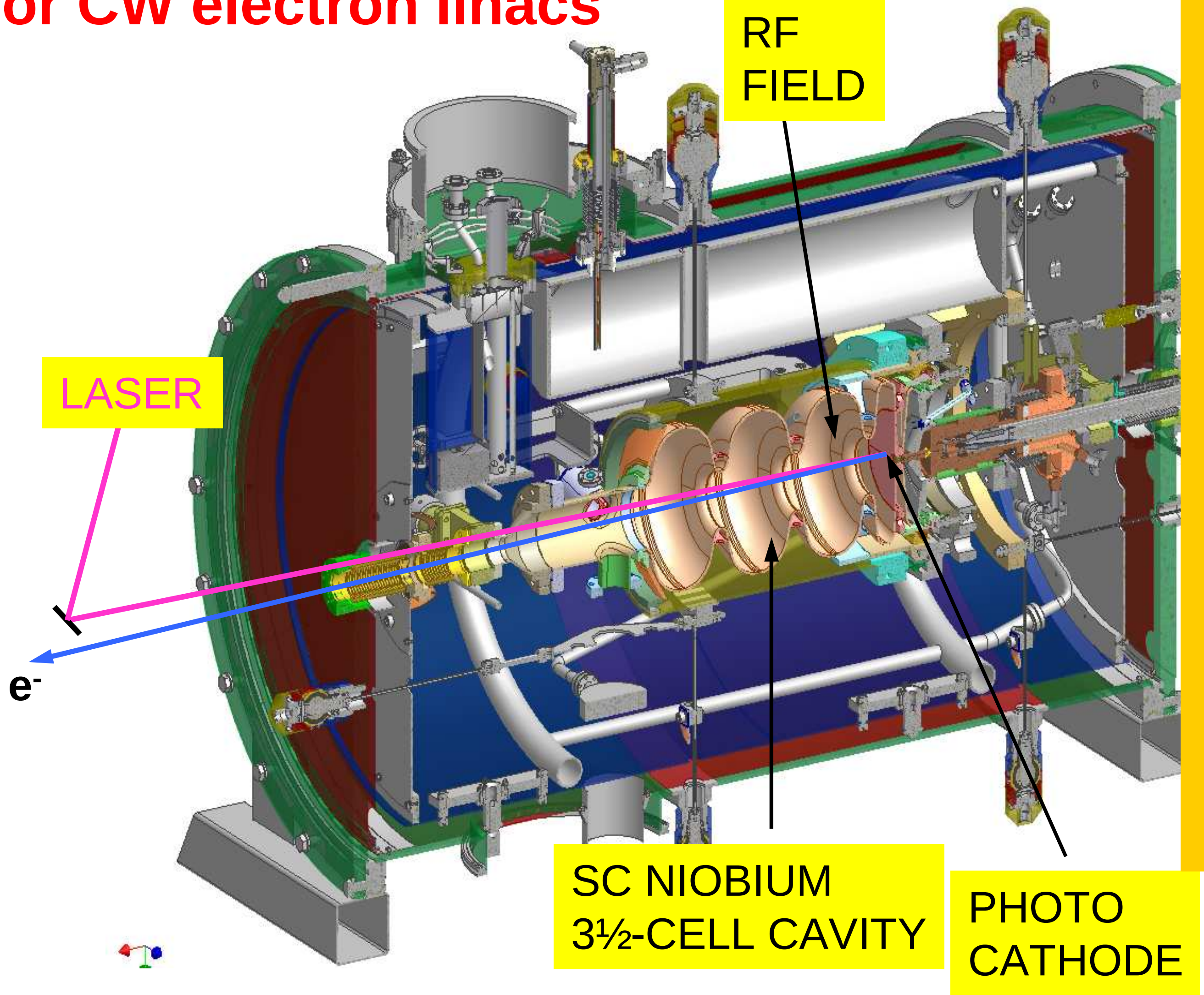


nELBE is the only photoneutron source at a superconducting cw-linear accelerator

1: Diagnostic station, IR-imaging and biological IR experiment
2: Femtosecond laser, THz-spectroscopy, IR pump-probe experiment
3: Time-resolved semiconductor spectroscopy, THz-spectroscopy
4: FTIR, biological IR experiment
5: Near-field and pump-probe IR experiment
6: Radiochemistry and sum frequency generation experiment, photothermal deflection spectroscopy

FZ Dresden-Rossendorf invites external groups for experiments at ELBE

Generation of high-brightness beams for CW electron linacs



1. **direct production of short pulses:** laser & photo cathode
2. **high acceleration field at cathode:** radio frequency field
3. **CW operation for high average current:** superconducting cavity

⇩

ELBE SRF PHOTO INJECTOR

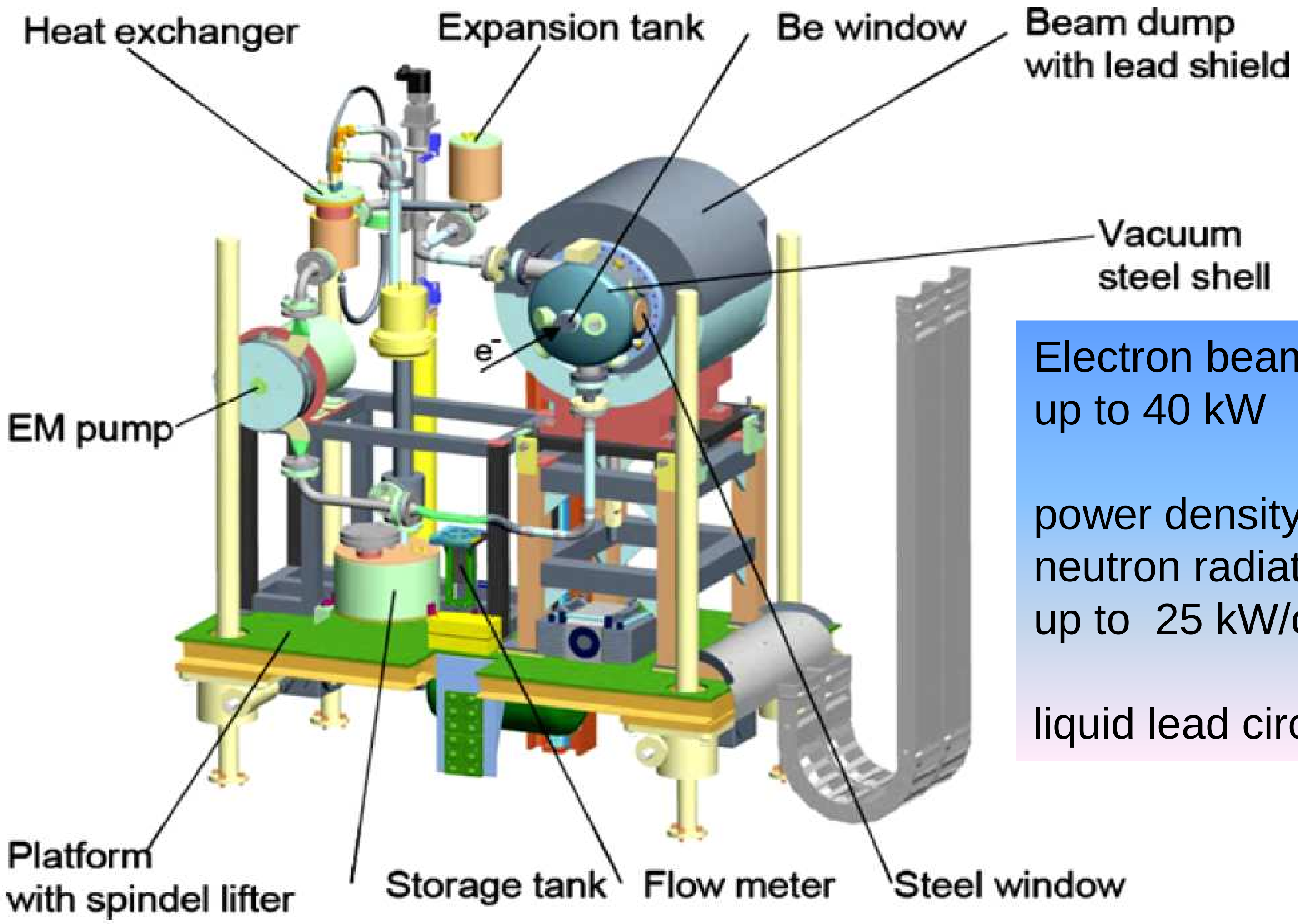
nELBE at ELBE : something special

- superconducting electron accelerator cw operation with variable micropulse repetition rate
  - micropulse charge 80 pC (thermionic Injector)
  - micropulse length $\Delta t < 10$ ps ➔ precise definition of time of flight
- For time of flight measurements the repetition rate is adjustable 13 MHz / 2^n , n = 0,…,10
- Very high repetition rate (200 kHz), low instantaneous neutron-flux
  ➔ background of photon flash from bremsstrahlung is reduced

- SRF Laser-Injector (micropulse charge 0.4 - 1 nC)
  ➔ 500 kHz / 0.5 mA
  ➔ average beam power up to 20 kW for time of flight measurements!

fligh path	4.0 - 8.0 m
neutron flux on target sample	$1.5\cdot10^7$ cm^{-2} s^{-1}
neutron energy range (Liquid lead target, without moderator)	100 keV < E_n < 10 MeV
energy resolution with 6.0 m flight path	$\Delta E/E < 1$ %

nELBE Photoneutrontarget

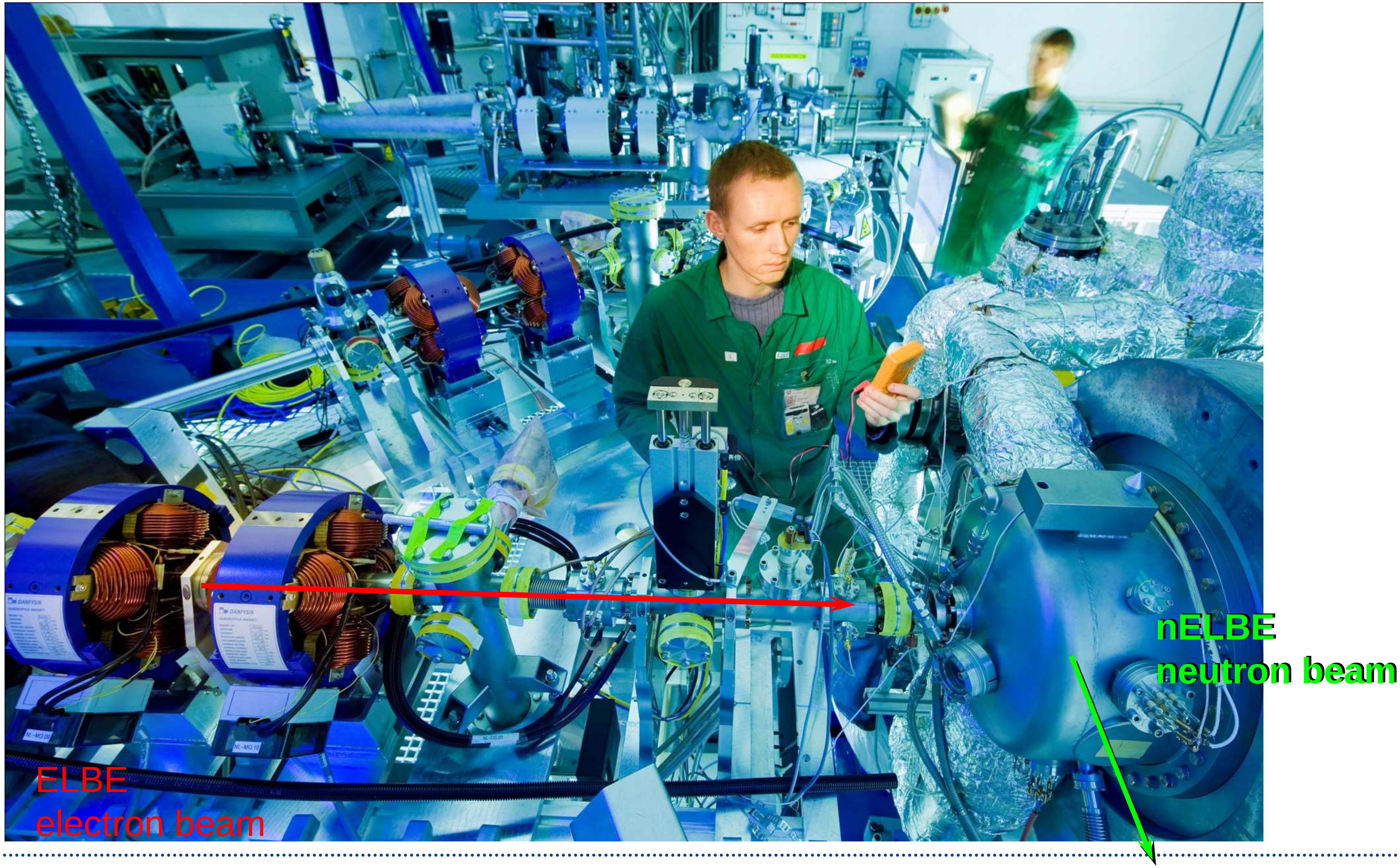


Electron beam power
up to 40 kW

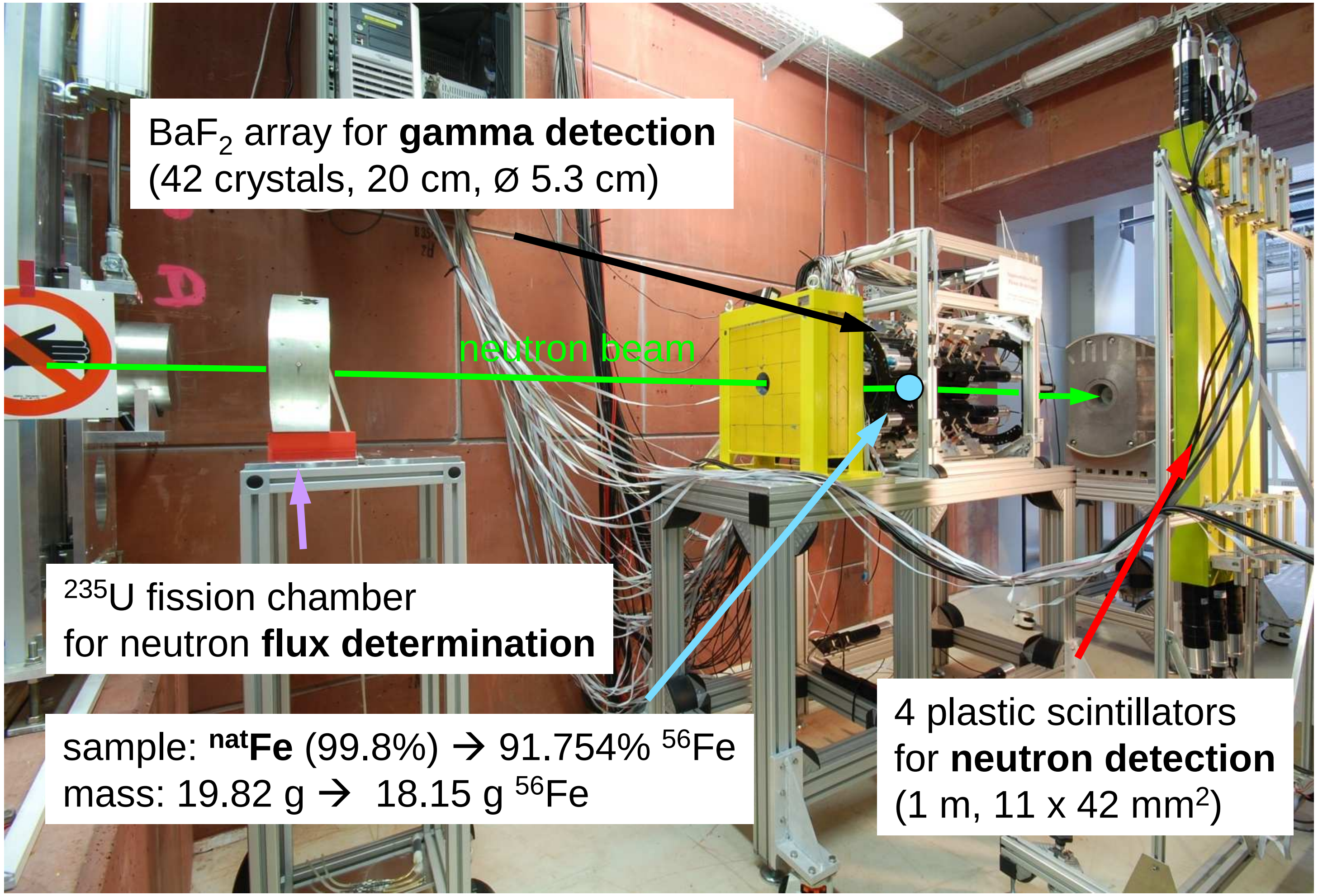
power density in the
neutron radiator
up to 25 kW/cm^3

liquid lead circuit for heat transport

nELBE – photoneutron source



nELBE – inelastic neutron scattering setup



BaF$_2$ array for **gamma detection**
(42 crystals, 20 cm, ø 5.3 cm)

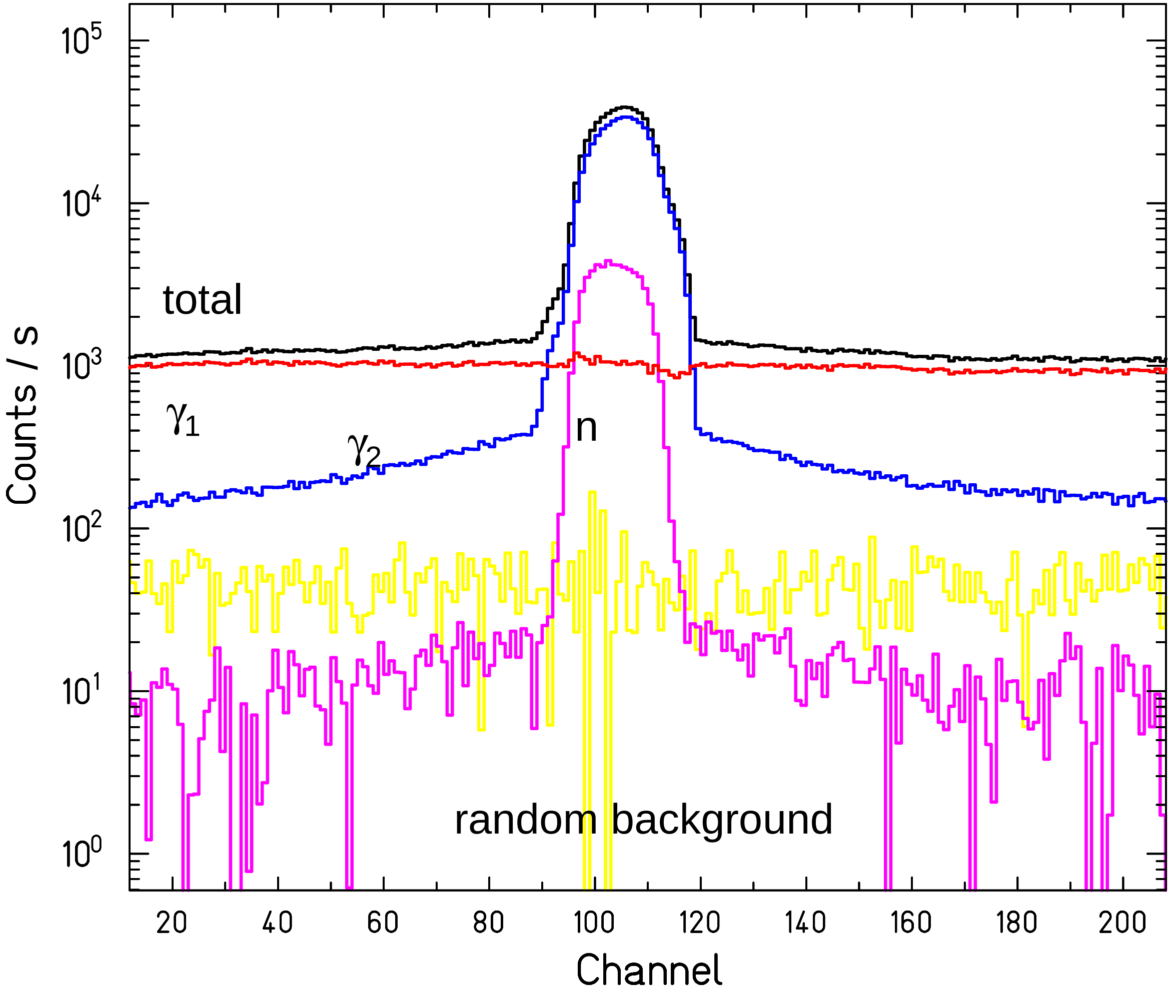
^{235}U fission chamber
for neutron **flux determination**

sample: **^{nat}Fe** (99.8%) → 91.754% ^{56}Fe
mass: 19.82 g → 18.15 g ^{56}Fe

4 plastic scintillators
for **neutron detection**
(1 m, 11 x 42 mm^2)

flight paths:
source – sample:
600 cm
sample – BaF$_2$ scint.:
30 cm
sample – plastic scint.:
100 cm

Beam profile



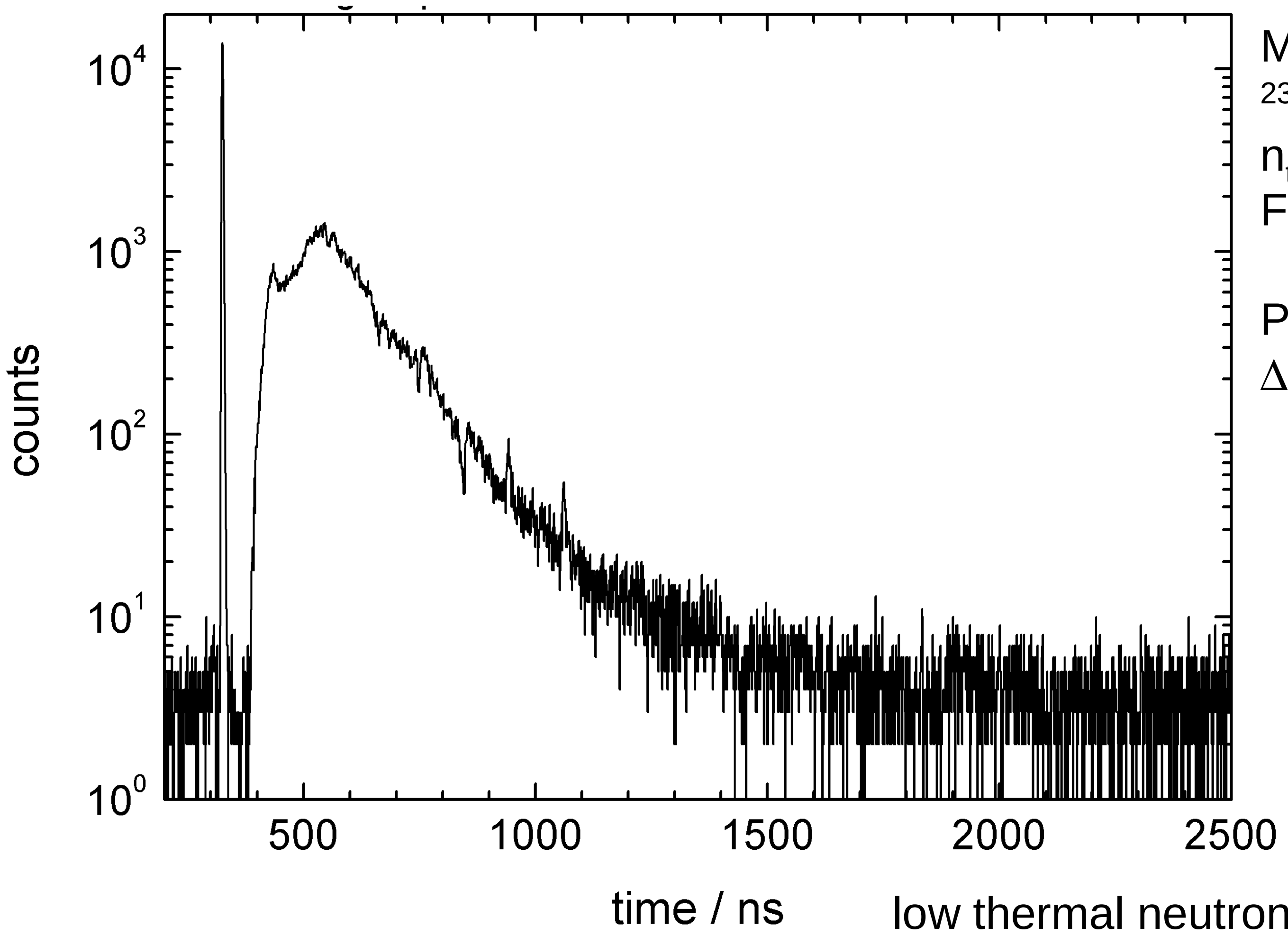
Plastic scintillator stepped through the beam both vertical and horizontal.

ToF measurement ➔ separation of different components in the spectrum

Detector- diameter 11 mm

N-beam diameter ca. 6 cm

Neutron time of flight spectrum with fission chamber

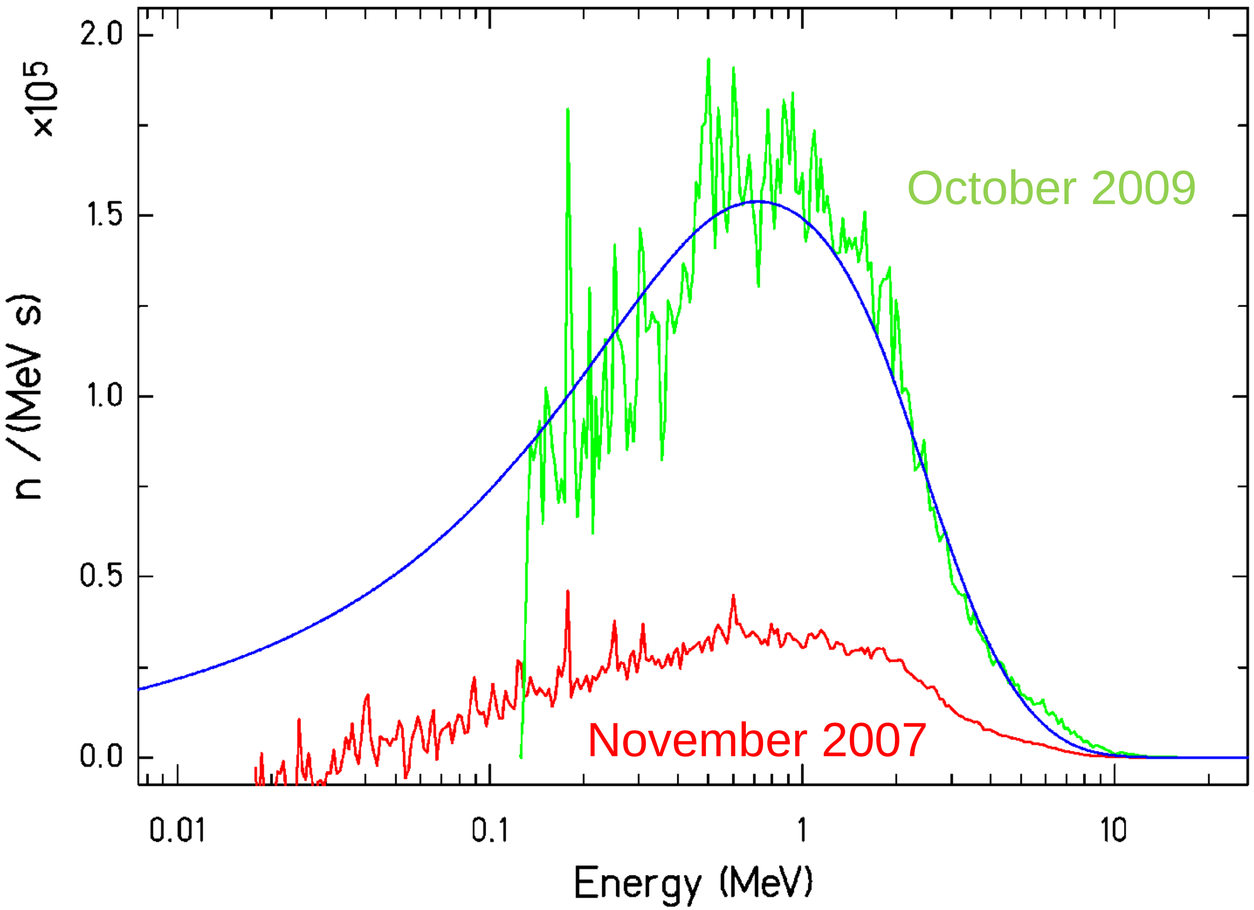


Measured with PTB
^{235}U fission chamber
n_t = 5 mg/cm^2
Fission rate: 6 s^{-1}

Photofission:
Δt(FWHM) = 4 ns

low thermal neutron background
$J_{Cd}/J < 8*10^{-5}$
from comparison with/without Cd absorber

nELBE neutron spectrum

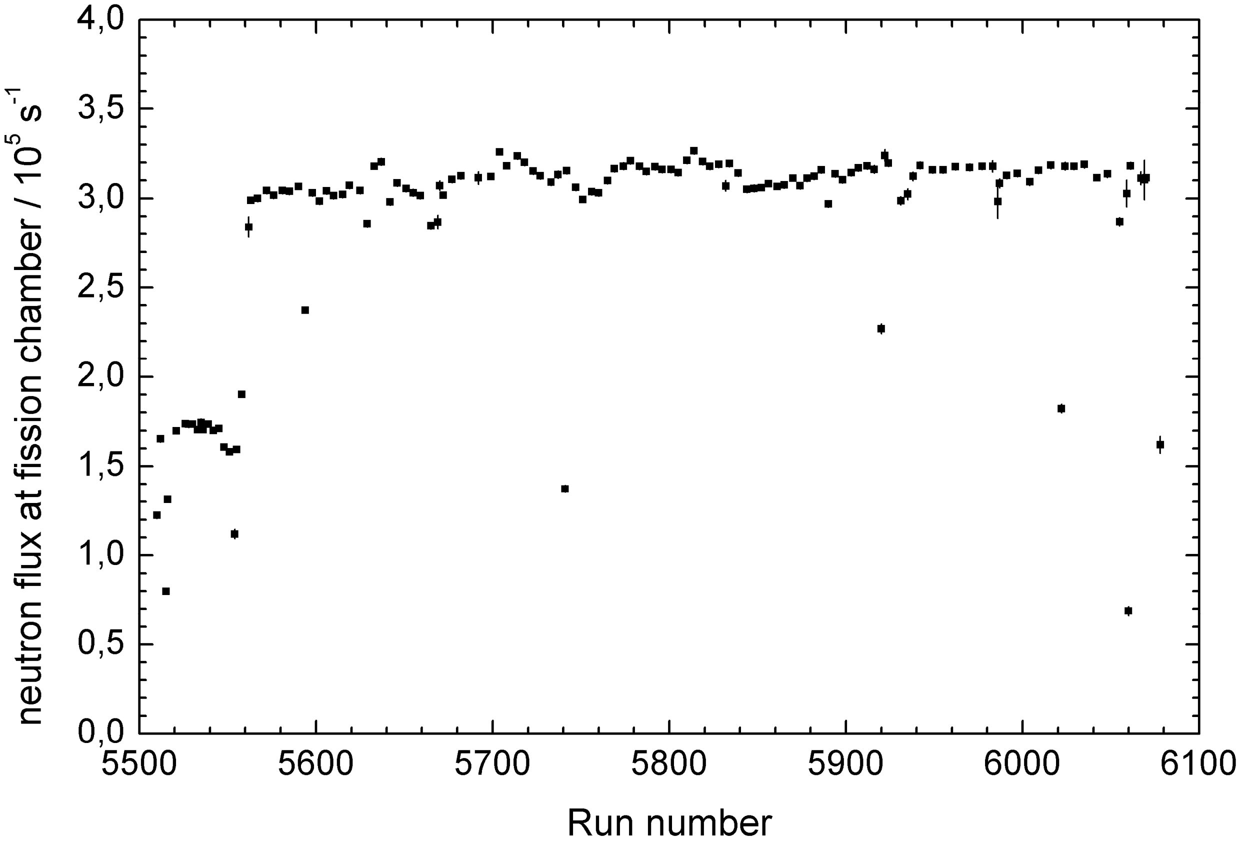


28.10.2009:
neutron source strength:
$1.4*10^{11}$ n/s
neutrons on target:
$4.5*10^{4}$ n/(cm^{2} s)

$<I_{e-}>$ = 19 µA
Max. thermionic injector
at 200 kHz rate

Fission chamber as primary beam monitor (from PTB, Braunschweig)
Spectrum is very similar to fast neutron spectrum e.g. ^{235}U(n,f) (ENDF-VII)

Neutron flux with fission chamber

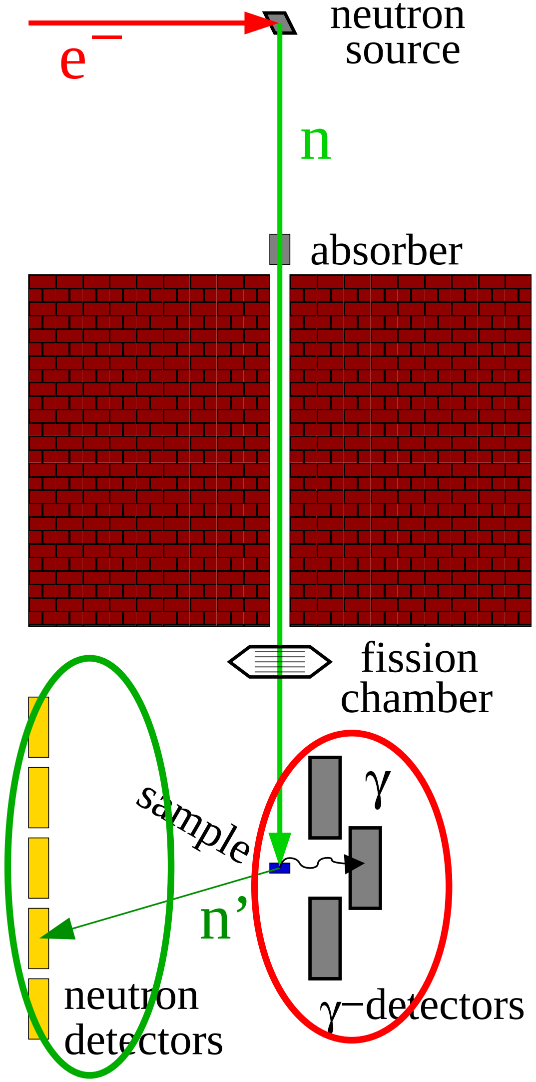


$\langle I_{e-} \rangle$ = 13 µA

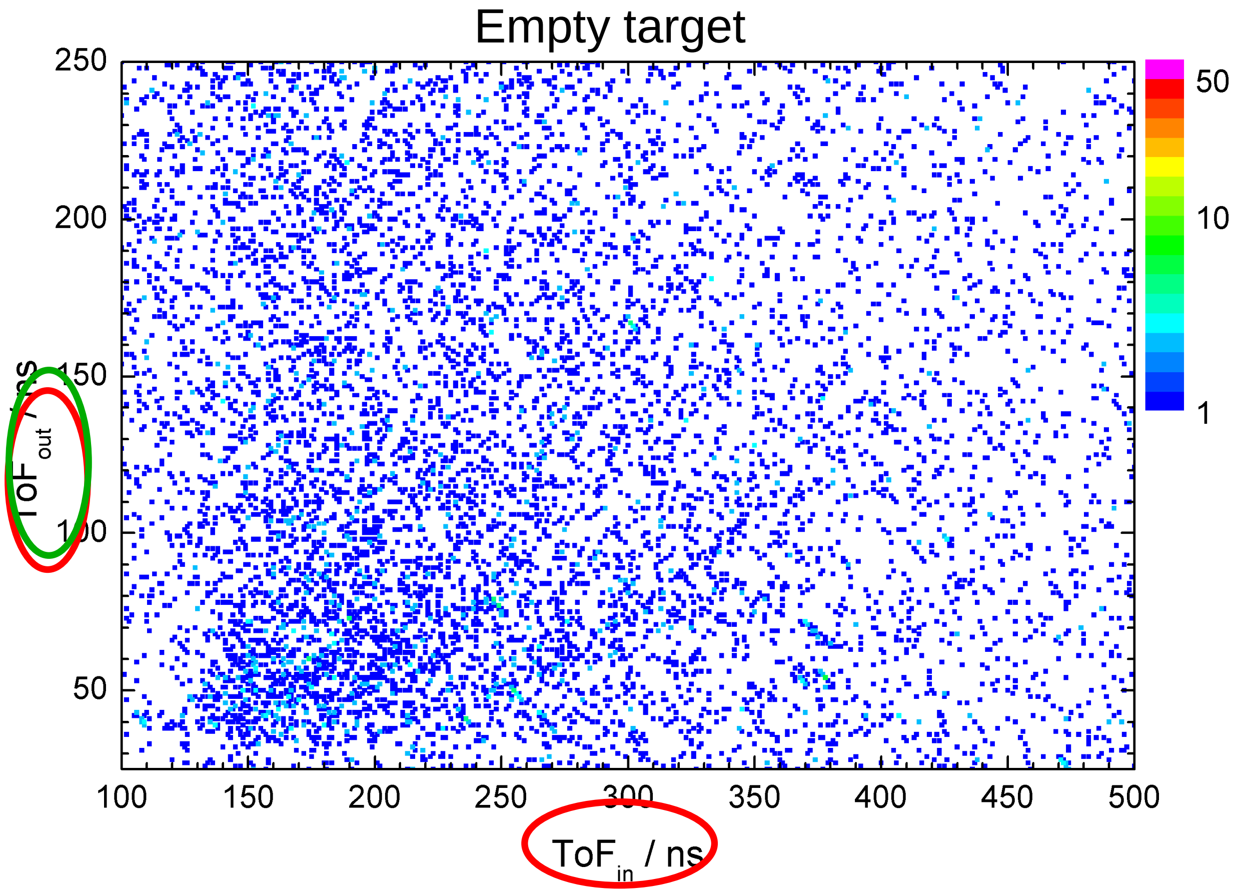
Beam line
Transmission
Optimized
at 200 kHz rate

Beam time:
≈250 hours
May 6-16

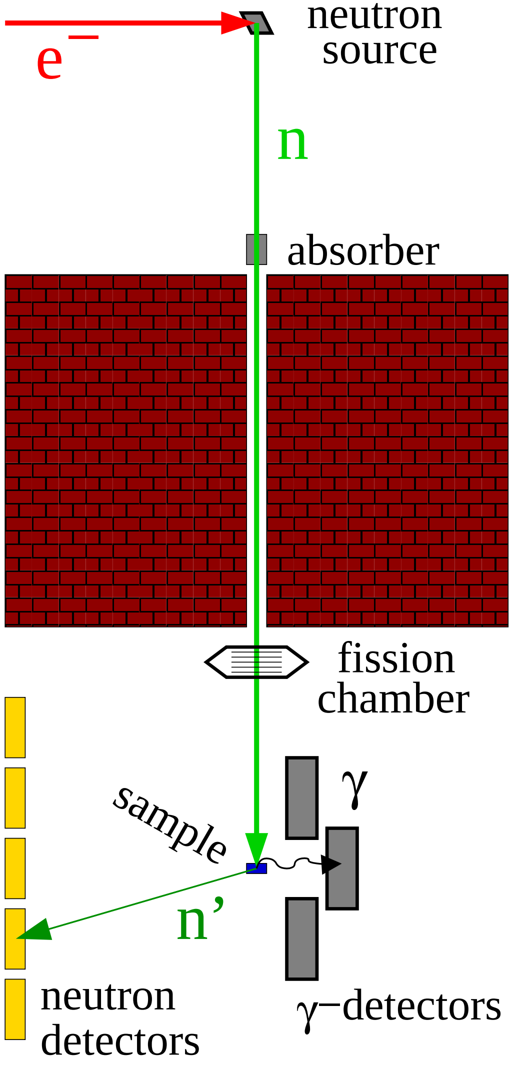
Double time of flight measurement – Inelastic scattering



$$^{56}\mathrm{Fe}(n,n'\gamma)^{56}\mathrm{Fe} \left\{ \begin{array}{l} ^{56}\mathrm{Fe} + n \rightarrow {}^{56}\mathrm{Fe}^* + n' \\ ^{56}\mathrm{Fe}^* \rightarrow {}^{56}\mathrm{Fe} + \gamma \end{array} \right.$$

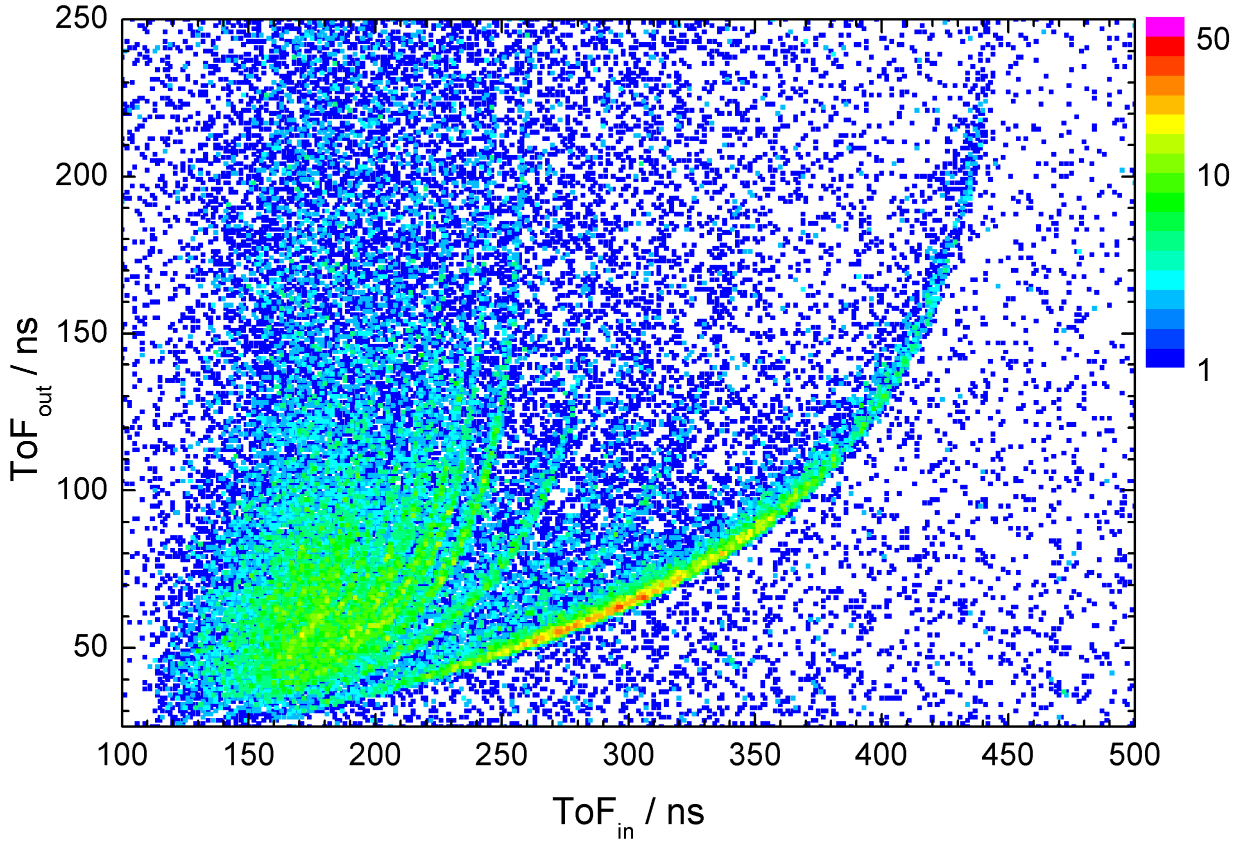


Double time of flight measurement – Inelastic scattering



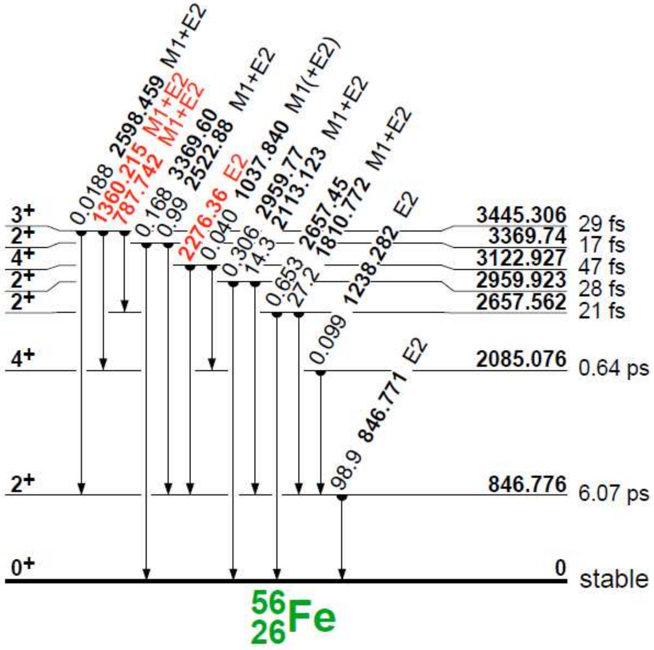
$$^{56}\mathrm{Fe}(\mathrm{n},\mathrm{n}'\gamma)^{56}\mathrm{Fe}\ \begin{cases} ^{56}\mathrm{Fe}+\mathrm{n}\rightarrow{}^{56}\mathrm{Fe}^{*}+\mathrm{n}' \\ \qquad\qquad ^{56}\mathrm{Fe}^{*}\rightarrow{}^{56}\mathrm{Fe}+\gamma \end{cases}$$

with ^{nat}Fe target

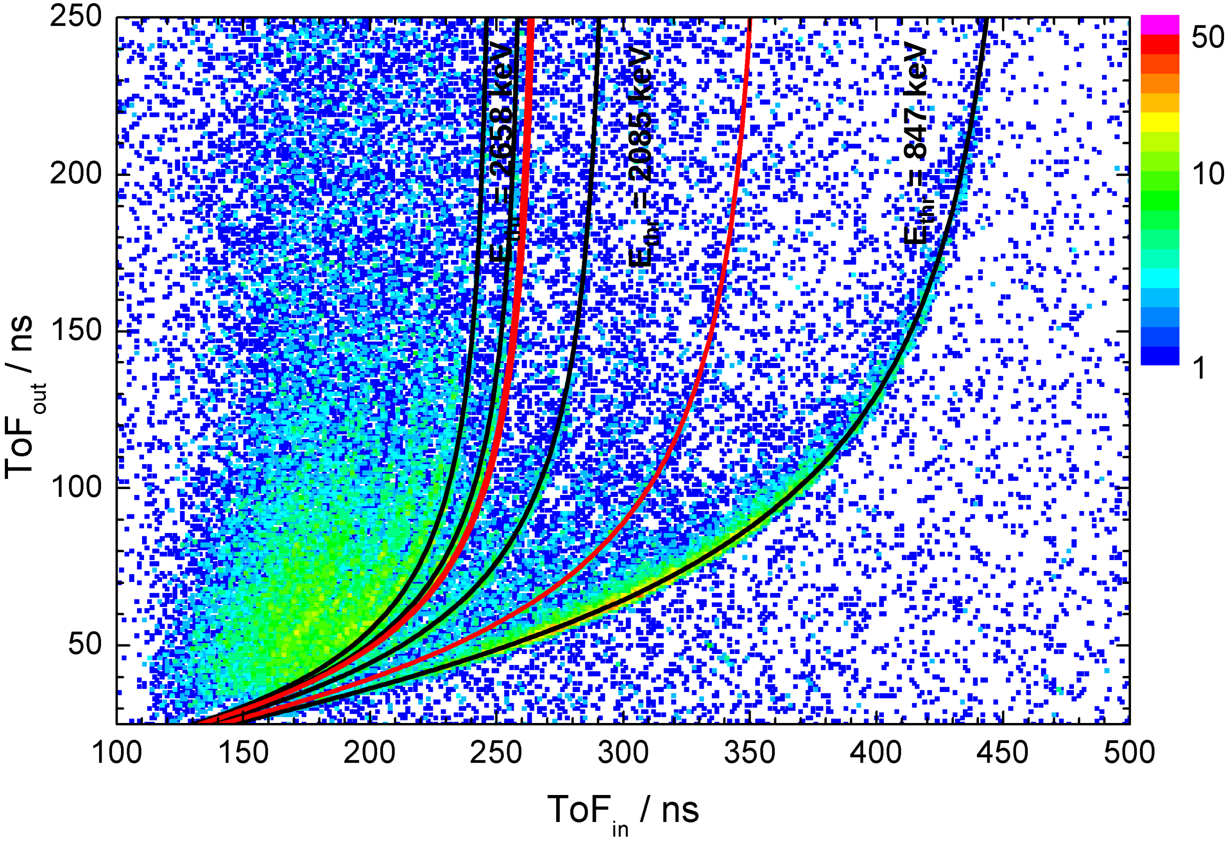


Double time of flight measurement – Inelastic scattering

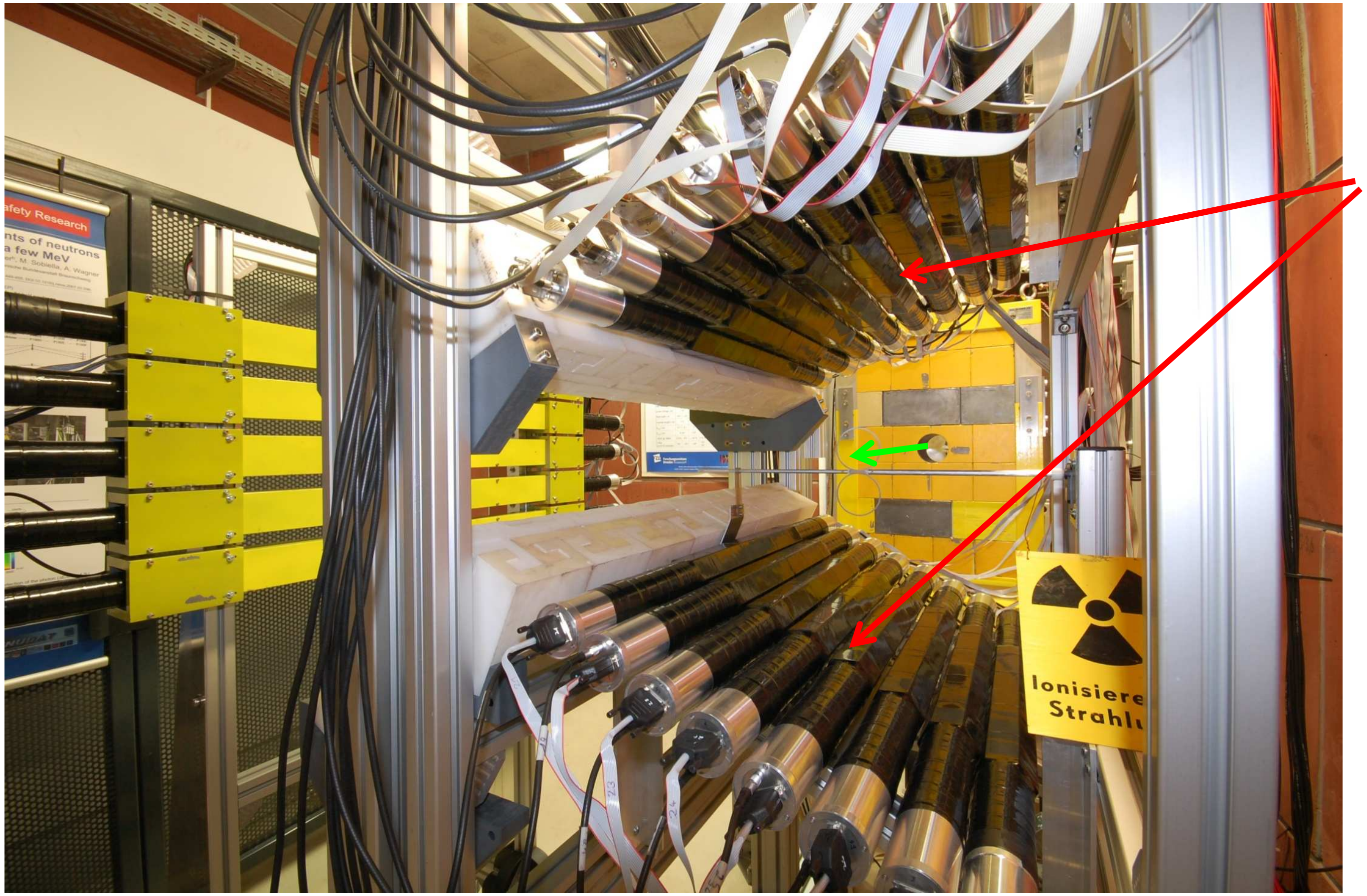
$$^{56}\mathrm{Fe}(\mathrm{n},\mathrm{n}'\gamma)^{56}\mathrm{Fe}\quad\left\{\begin{aligned}&^{56}\mathrm{Fe}+\mathrm{n}\rightarrow{}^{56}\mathrm{Fe}^{*}+\mathrm{n}'\\&^{56}\mathrm{Fe}^{*}\rightarrow{}^{56}\mathrm{Fe}+\gamma\end{aligned}\right.$$



^{nat}Fe & kinematics calculation ^{54}Fe* visible



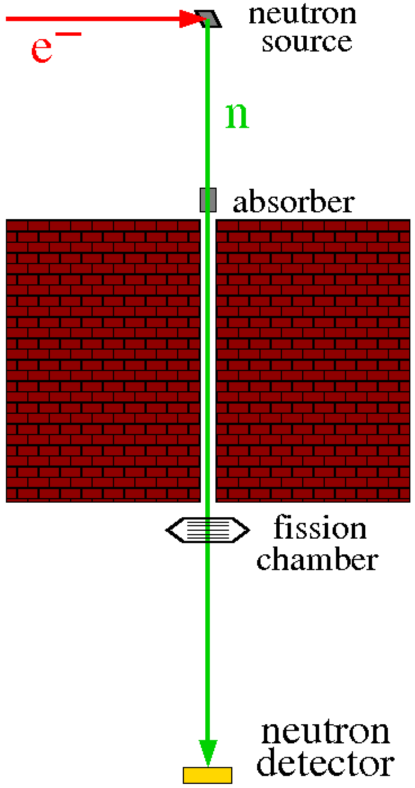
New BaF_2 array setup

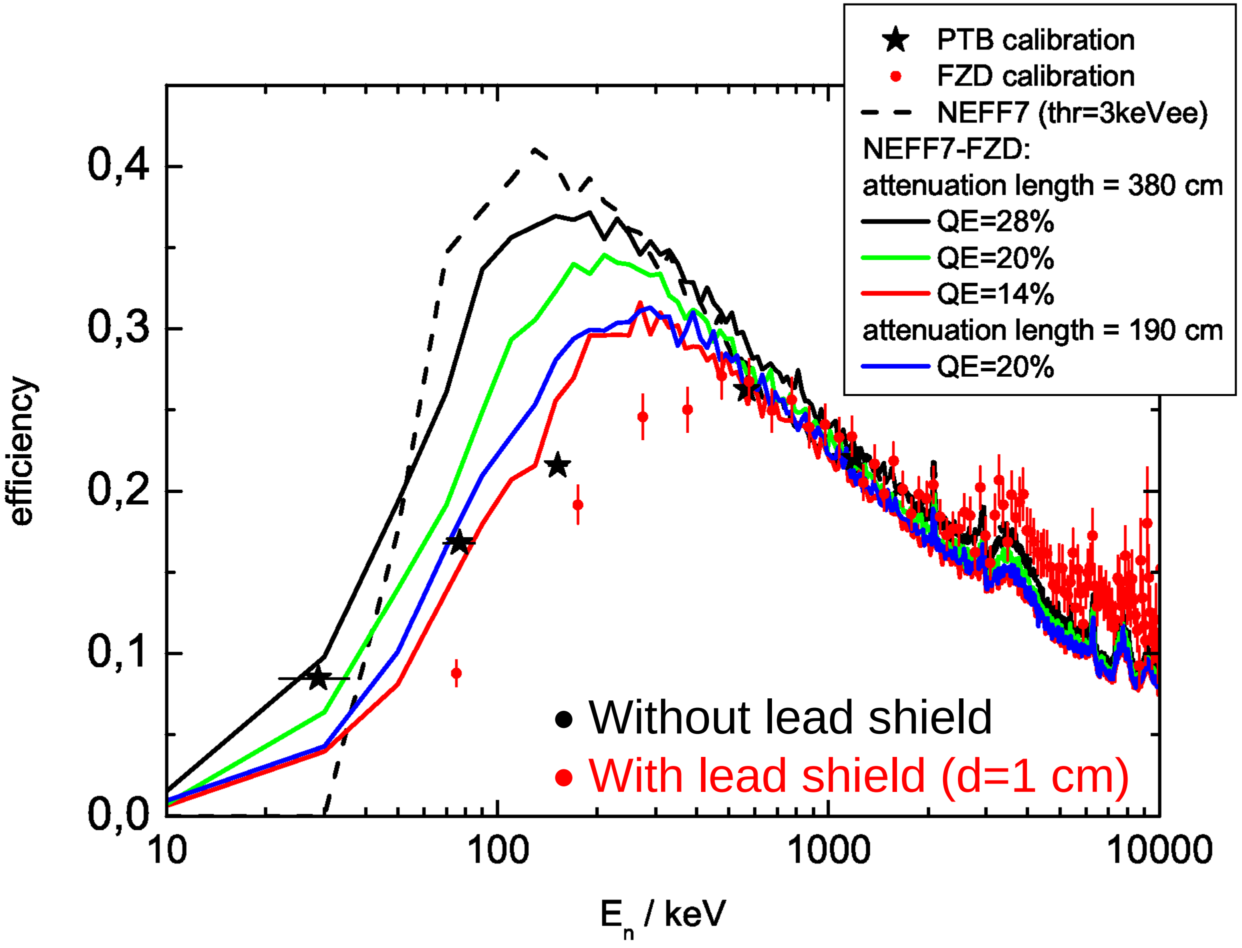


BaF_2 V-shaped array
Double sided read-out

borated PE shield
towards
plastic scintillators

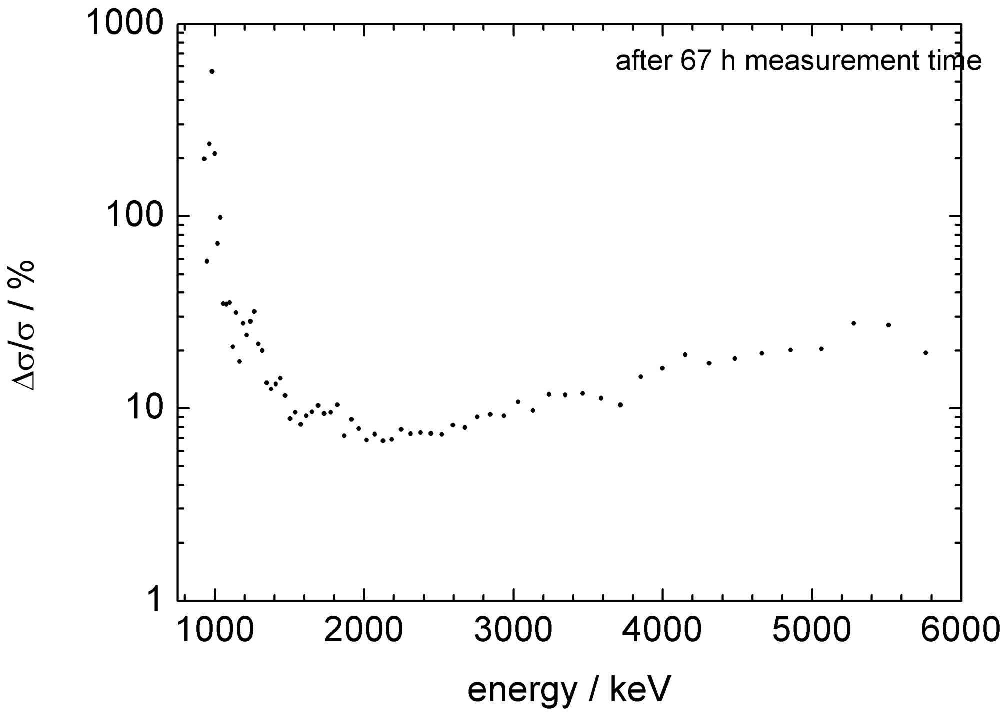
Plastic scintillators: neutron detection efficiency





R. Beyer et al. , NIM A575 (2007) 449

Experimental Uncertainties



Experimental uncertainties:

Counting statistics (E_n= 2 MeV): ≈5%
incl. empty target subtraction

Neutron primary intensity (FC):

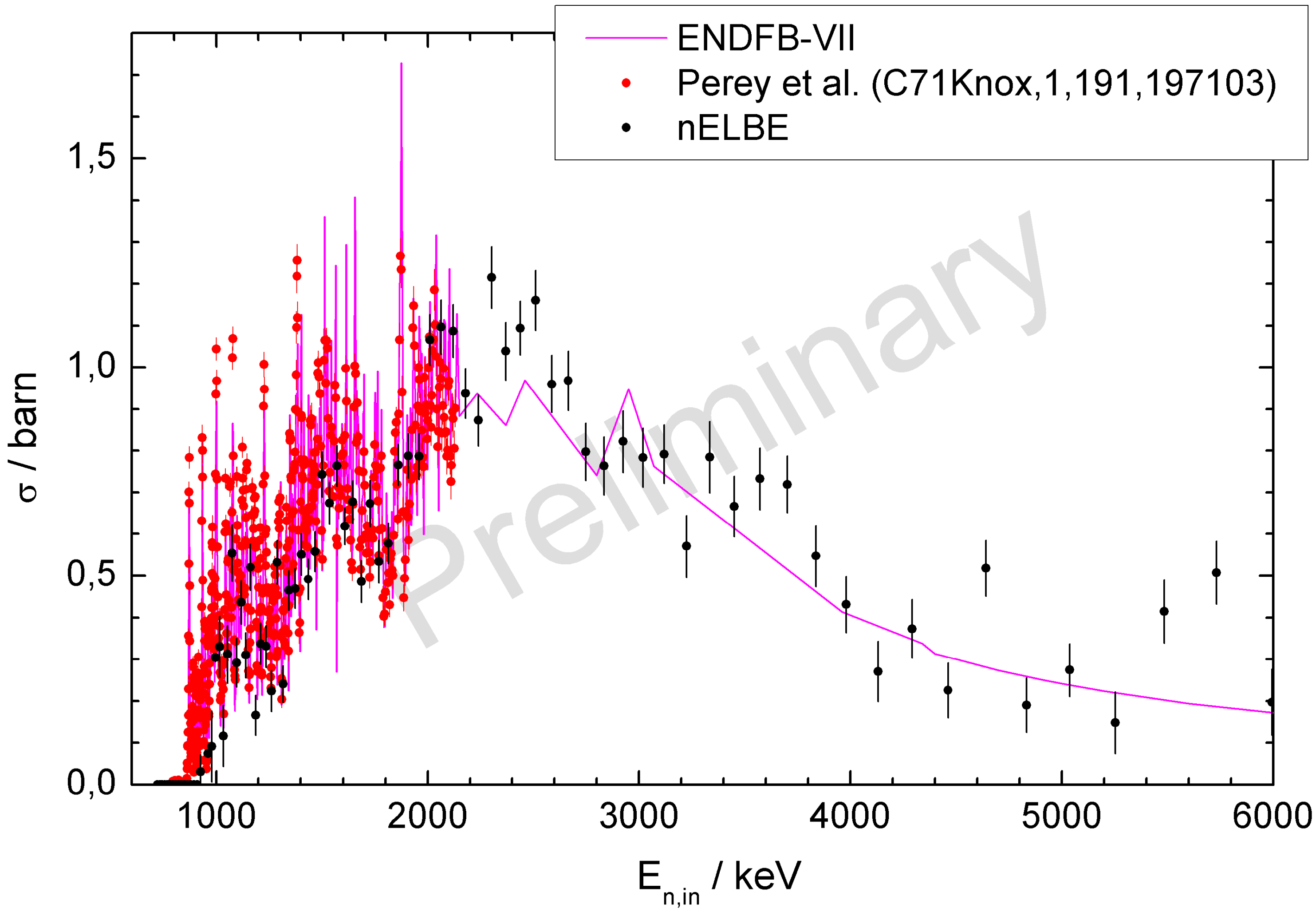
statistics	≈3%
efficiency	≈3.8%
neutron flux geometry scaling	≈1 %

Detection efficiency

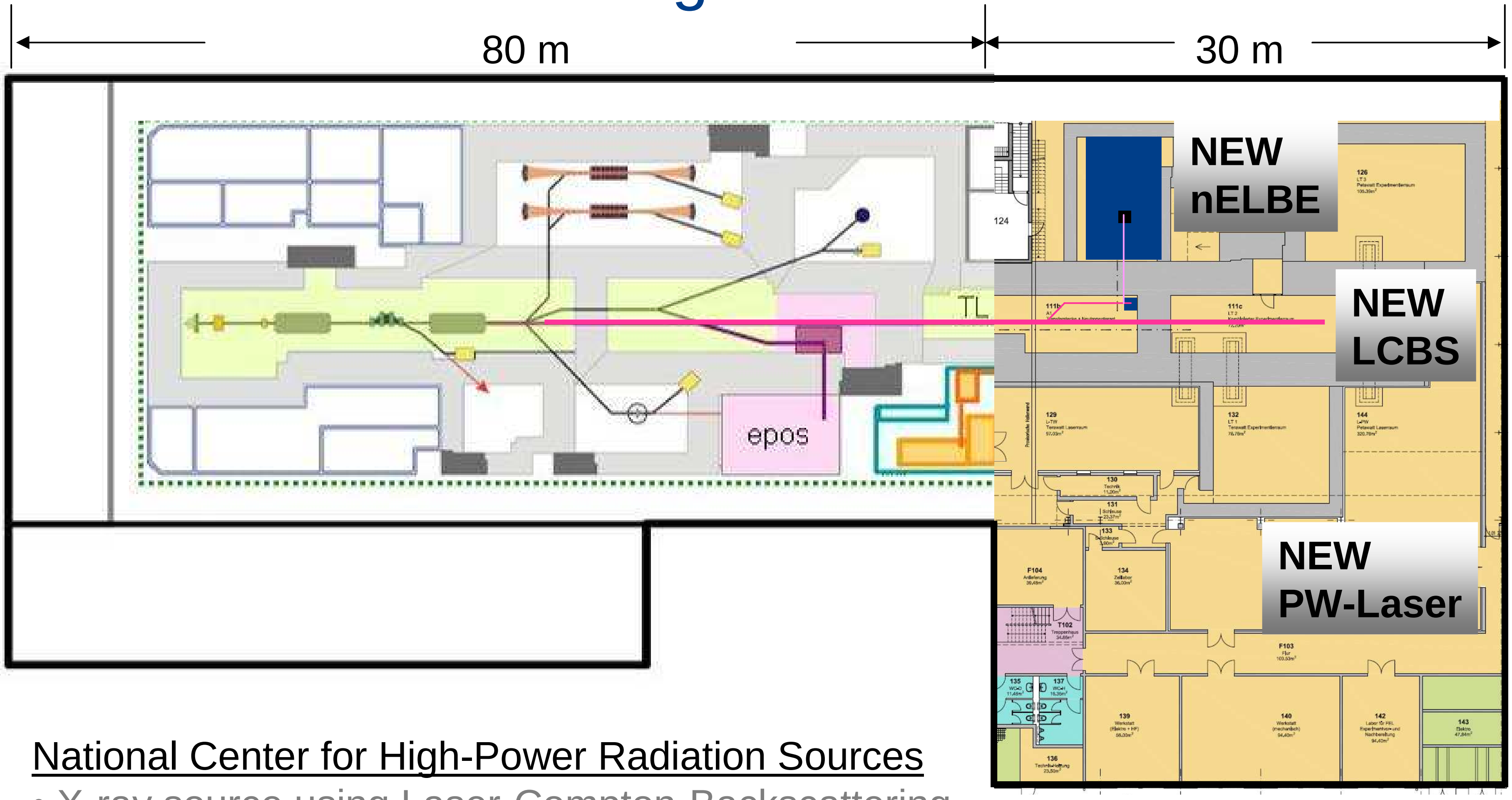
BaF_2 array	≈1.5%
Plastic scintillators	≈3.2%

Total: **≈8%**

The ^{56}Fe(n,n'γ) cross section for the 1st excited state



National Center for High-Power Radiation sources



ground breaking started April 2010

National Center for High-Power Radiation Sources

- X-ray source using Laser-Compton-Backscattering
- High-Power Laser (PW) for Ion Acceleration
- New Neutron Time-of-Flight Facility for Transmutation Studies

Summary and outlook

- The nELBE time of flight facility is intended to deliver data on fast neutron induced reactions relevant to transmutation of nuclear waste (fast reactors , ADS systems)

- First experiments were performed on inelastic neutron scattering of ^{56}Fe(n,n'γ) using a double time of flight setup.

- The new superconducting RF Injector will increase the bunch charge to 1nC and the neutron intensity by more than a factor of 10.

- A new time of flight hall is being built as part of the center of high power radiation sources.

Spare slides
(End of talk was one slide before)

Thanks to all collaborators

FZD, Institute of Radiation Physics:

A.R. Junghans, D. Bemmerer, E. Birgersson, E. Grosse, R. Hannaske, A. Hartmann, K. Heidel, M. Kempe, K. Kossev, M. Marta, R. Massarczyk, A. Matic, K.-D. Schilling, R. Schwengner, M. Sobiella, A. Wagner, The ELBE Crew

FZD, Institute of Safety Research:

E. Altstadt, C. Beckert, A. Ferrari, V. Galindo, K. Noack, F.-P. Weiss

FZD, Department Radiation Protection and Safety:

B. Naumann

FZD, Department Research Technology:

R. Schlenk, S. Schneider

TU Dresden:

H. Freiesleben, D. Gehre, M. Greschner, A. Klix, K. Seidel

Physikalisch Technische Bundesanstalt Braunschweig:

M. Mosconi, R. Nolte, S. Röttger

Others:

T. Beyer, M. Erhard, J. Klug , C. Nair, C. Rouki, G. Rusev

Transmutationsrelevante kernphysikalische Untersuchungen langlebiger Aktinide

Transmutationsrelevante kernphysikal
Einsatz moderner technologischer
und numerischer Methoden

TRAKULA

Verbundprojekt zum Kompetenzerhalt in der nuklearen Sicherheits- und Strahlenforschung:

- Produktion und Nutzung schneller Neutronen zur Untersuchung inelastischer Neutronenstreuung und Spaltung minorer Aktinide
- MeV Gamma-Spektroskopie und Entwicklung hochauflösender Detektoren (Compton-Kamera)
- Herstellung und Nutzung dünner Aktiniden Targets
- Veranstaltung von Graduierten-Seminaren:

  PTB Braunschweig September 2010 –
  “Experimentelle Systeme und Methoden der Transmutationsforschung”

TUM
TECHNISCHE UNIVERSITÄT MÜNCHEN

TECHNISCHE UNIVERSITÄT DRESDEN

PTB

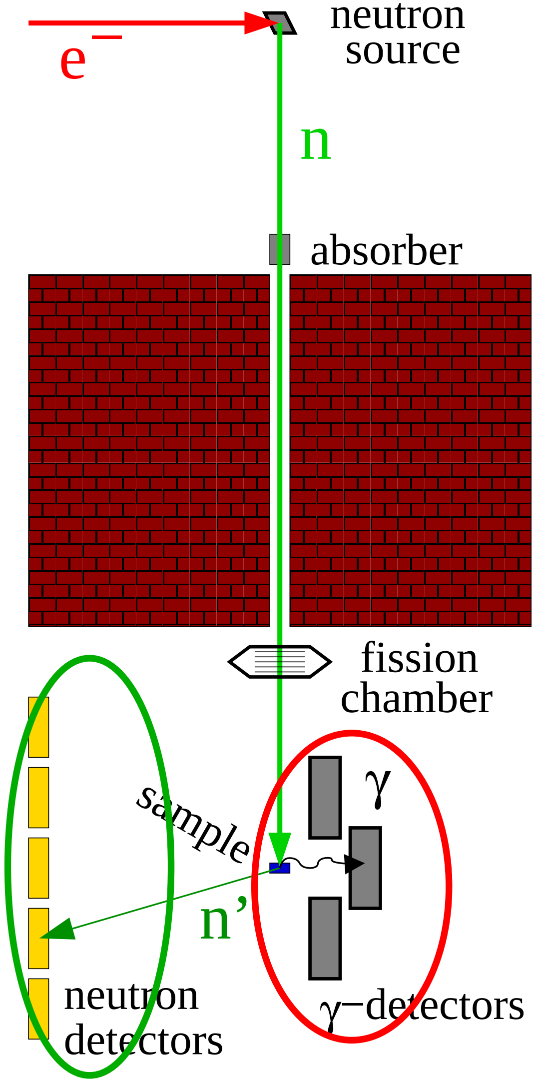
JG|U
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

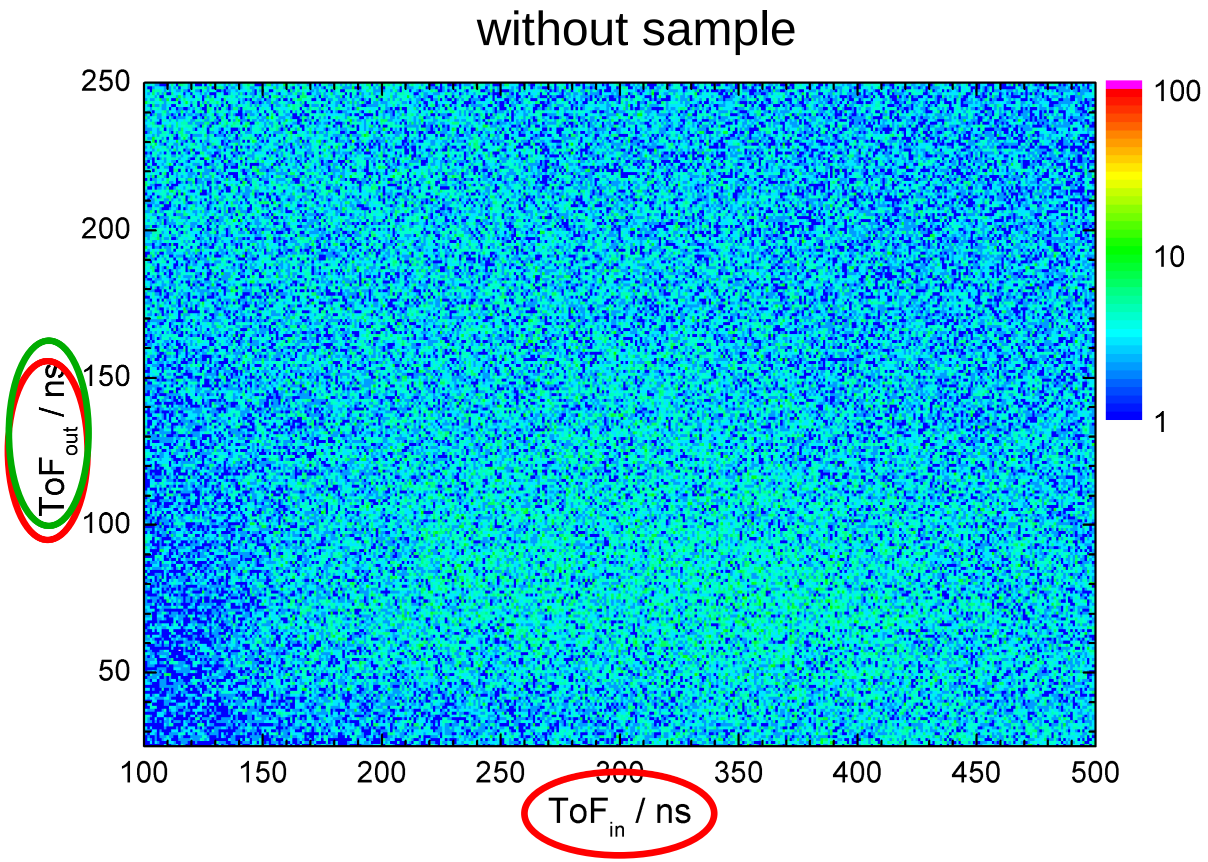
FZD
Forschungszentrum Dresden Rossendorf

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

Double time of flight measurement – Inelastic scattering

$$^{56}\mathrm{Fe}(n,n'\gamma)^{56}\mathrm{Fe}\;\left\{\begin{array}{l} ^{56}\mathrm{Fe}+n\rightarrow{}^{56}\mathrm{Fe}^{*}+n' \\ \qquad\qquad ^{56}\mathrm{Fe}^{*}\rightarrow{}^{56}\mathrm{Fe}+\gamma \end{array}\right.$$





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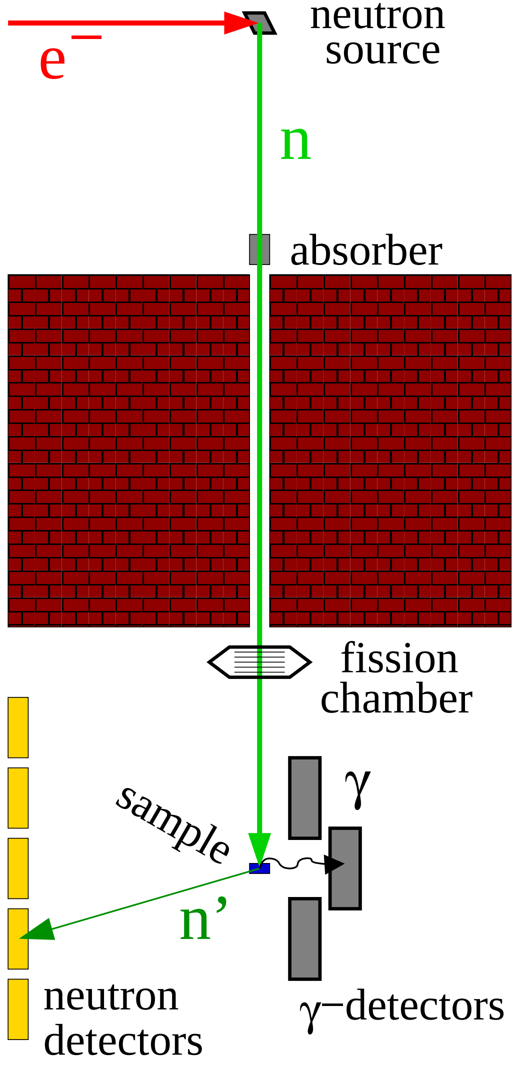

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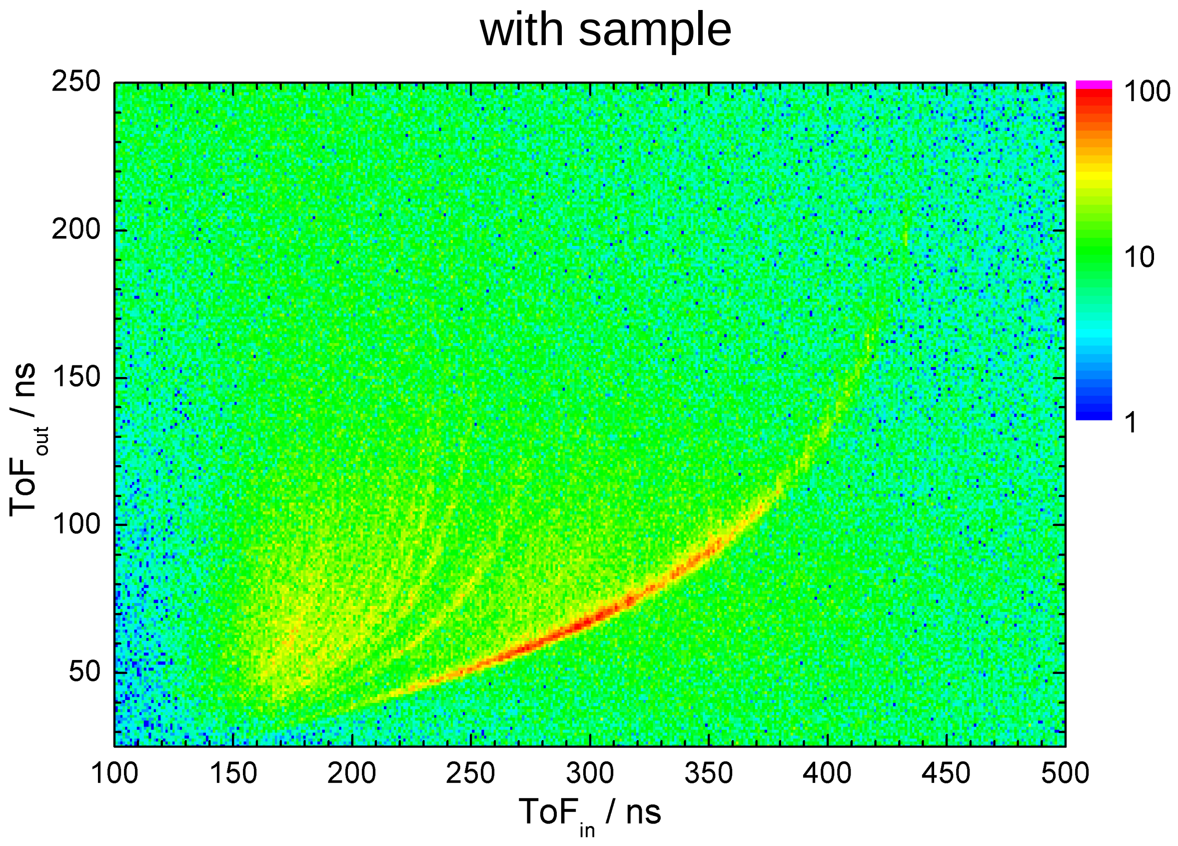

Double time of flight measurement – Inelastic scattering

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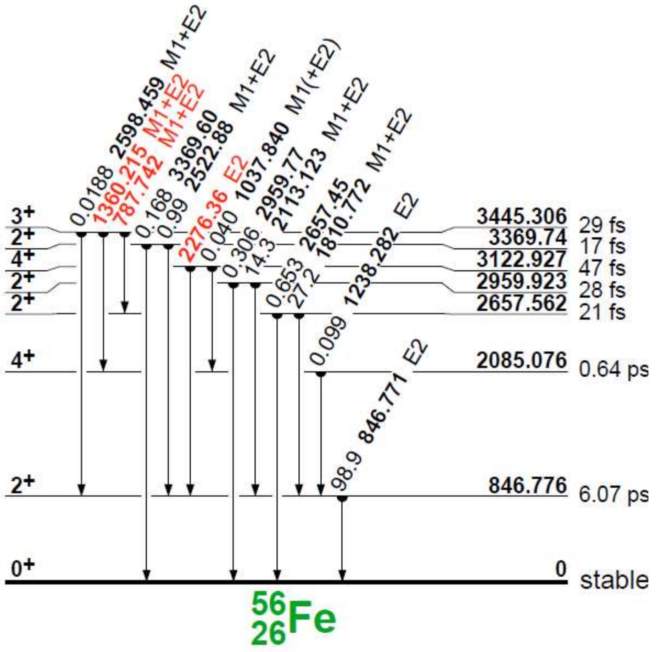
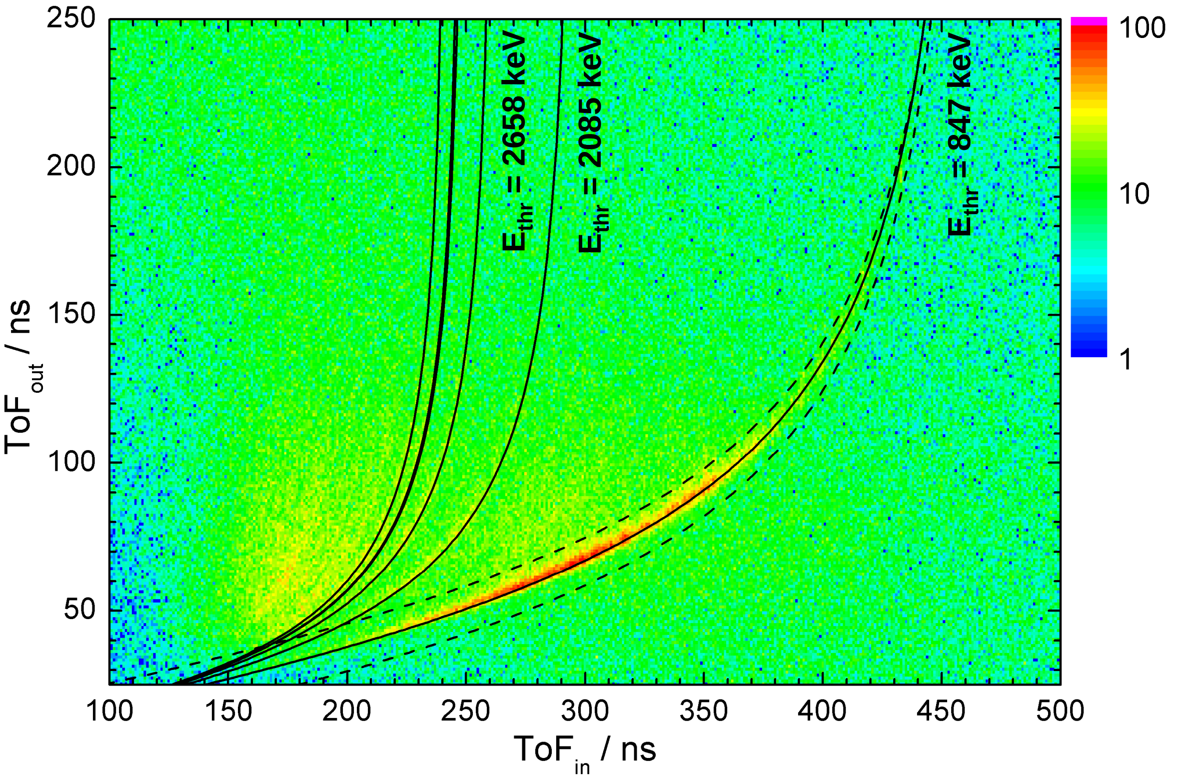
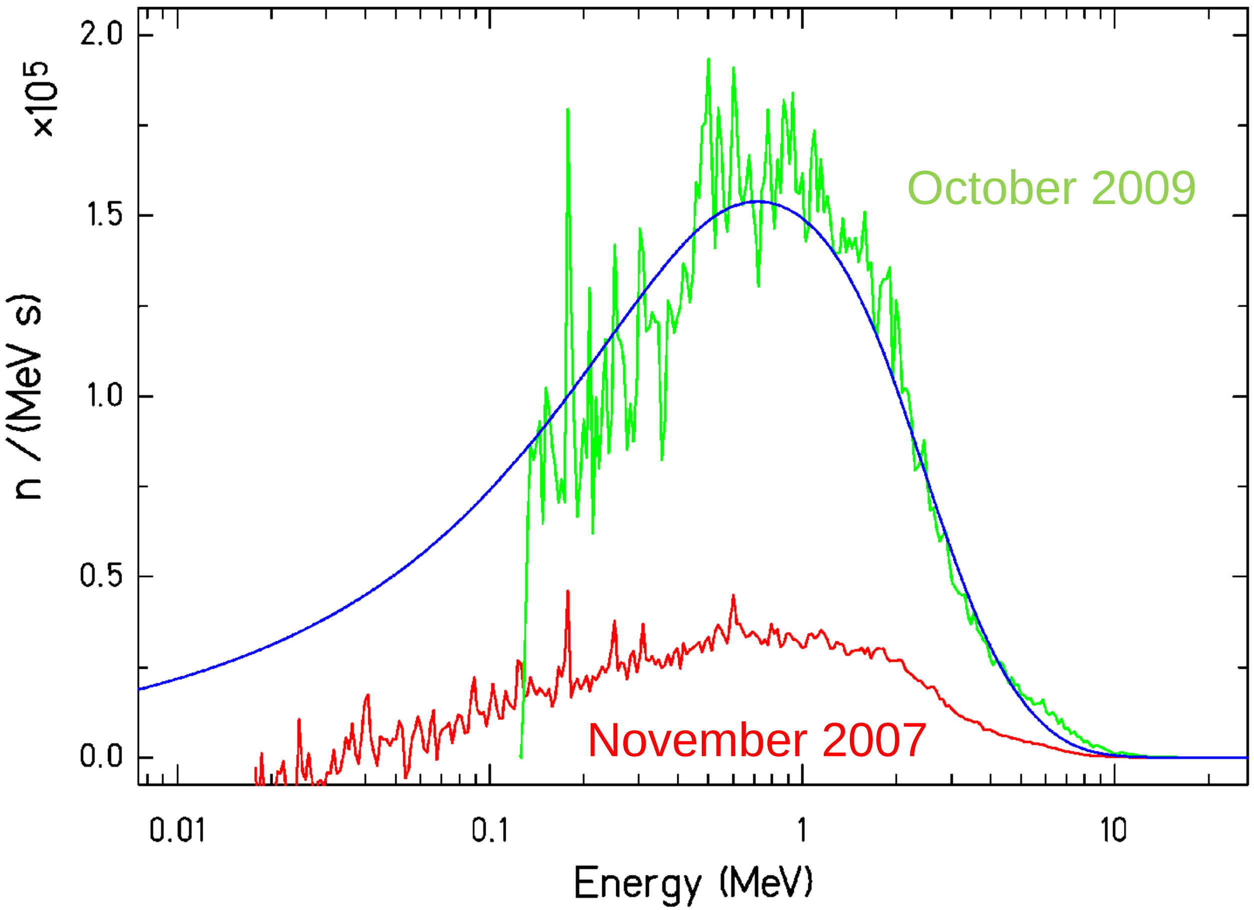


with sample + kinematics calculation



nELBE neutron spectrum



Measured with
^{235}U fission chamber
Δt(FWHM) = 4 ns
n_t = 5 mg/cm^2
28.10.2009:
neutron source strength:
1.4*10^{11} n/s
neutrons on target:
4.5*10^{4} n/(cm^2 s)

$\langle I_{e-} \rangle$ = 19 µA
Max. thermionic injector
at 200 kHz rate

Fission chamber as primary beam monitor (from PTB, Braunschweig)
Spectrum is very similar to fast neutron spectrum e.g. ^{235}U(n,f) (ENDF-VII)

ToF – facilities producing fast neutrons

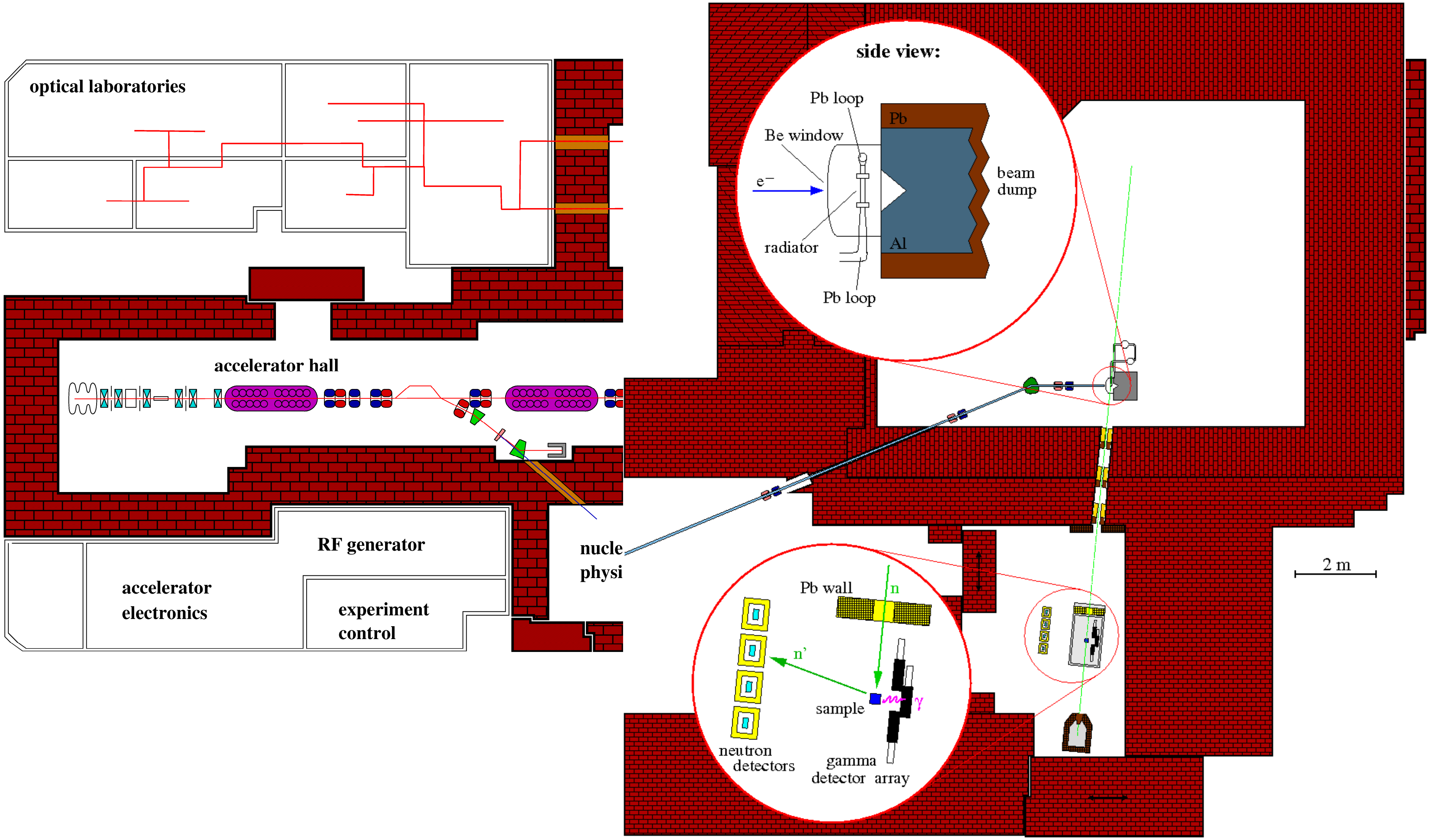
	p, linac + ring						e, linac				ELBE	
n-ToF-device	CERN n-ToF		JPARC MLF		ORNL SNS	LANL LANSCE	IREN + ^{239}Pu*		ORNL ORELA	IRMM GELINA	FZD n-ELBE	ELBE + photo-gun
beam power / kW	10		100	1000$^+$	1000	80	10		8	10	5	40
rep. rate / s^{-1}	0.4		25		60	20	150		500	800	$2\cdot10^5$	$5\cdot10^5$
flight path L / m	183	20$^+$	≈ 25		84	20	60	500	40	200	5	5
n-pulse length / ns	> 7		100		500	125	400		> 4	<1	< 1	< 1
E_{min} / eV	0.1	0.1	≈ 0.1		0.1	1	10		10	$2\cdot10^5$	$1\cdot10^5$	$5\cdot10^4$
E_{max} / eV	$3\cdot10^8$		$\approx 10^6$		$\approx10^8$	$\approx10^6$	$5\cdot10^6$		$5\cdot10^6$	$20\cdot10^6$	$7\cdot10^6$	$7\cdot10^6$
ΔE/E @ 1MeV	0.5%	5%	< 2 %		> 10 %	≈ 17 %	9%	1%	< 4 %	< 2 %	< 2 %	< 2 %
n-flux Φ_L at 1MeV (s·cm^2·MeV)$^{-1}$ exp. site	$2\cdot10^4$	$2\cdot10^6$	10^6	$5\cdot10^7$	10^7	$\approx 3\cdot10^5$	10^5	10^3	10^4	$4\cdot10^4$	$2\cdot10^4$	$4\cdot10^6$
$Q = \Phi_L / \Delta E/E$	$4\cdot10^6$	$4\cdot10^7$	$5\cdot10^8$	$2\cdot10^{10}$	$< 10^8$	$4\cdot10^7$	10^6	10^5	$2\cdot10^5$	$2\cdot10^6$	$5\cdot10^6$	$2\cdot10^8$

$^+$ Project

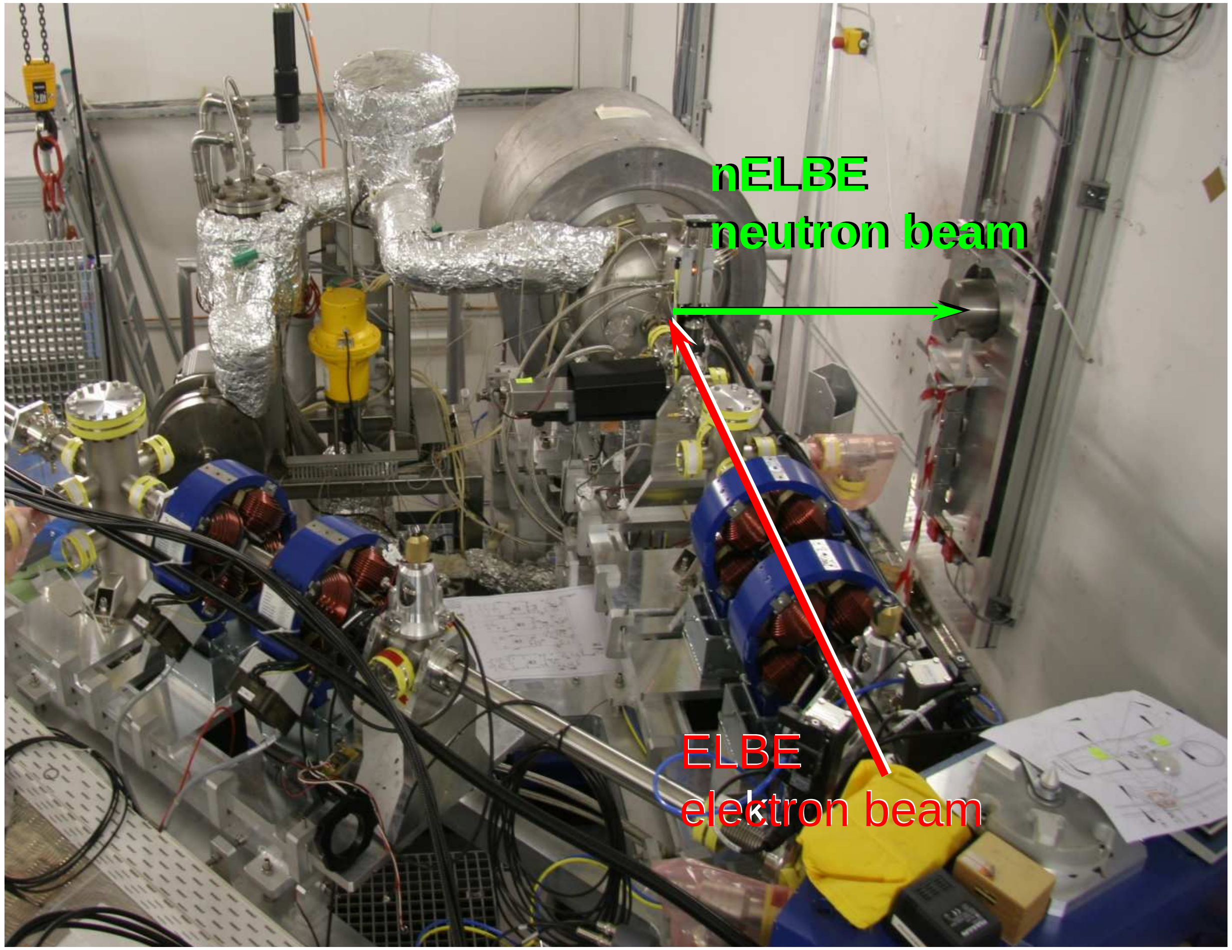
Facilities for materials research,
nuclear research also possible

* delayed neutrons
from fission !

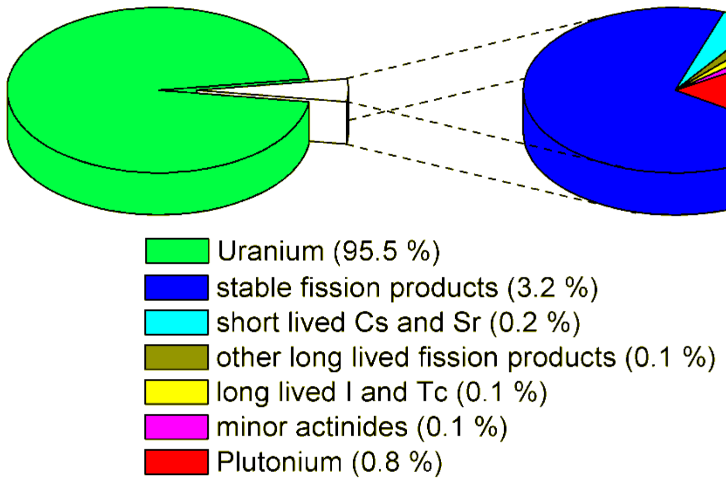
nELBE – neutron facility at ELBE



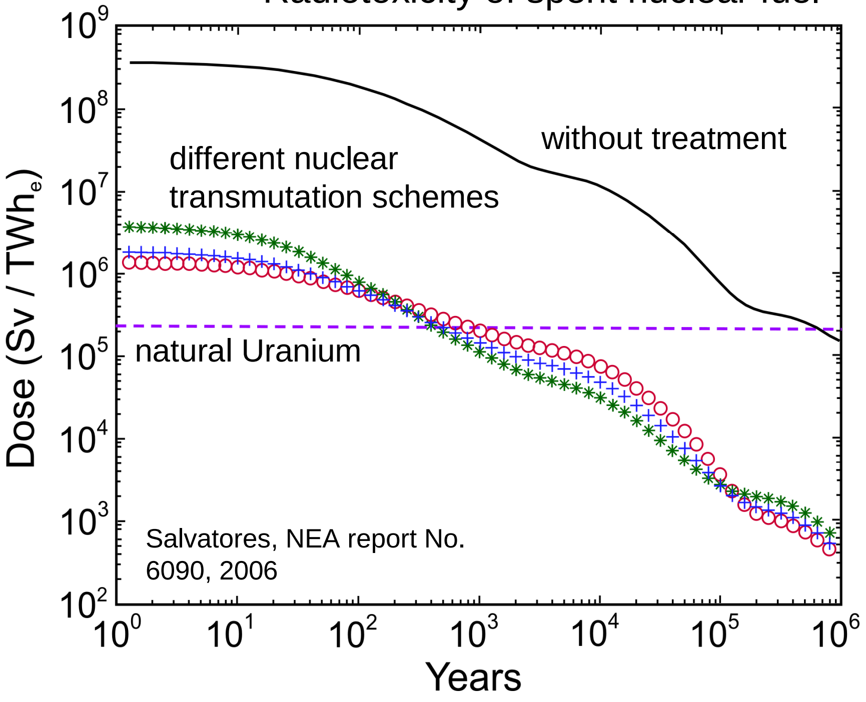
nELBE – neutron production



The nuclear waste problem



Radiotoxicity of spent nuclear fuel



Salvatores, NEA report No. 6090, 2006

long lived isotopes cause main part of long term radiotoxicity

➔ **safe disposal is necessary for more 500,000 years**

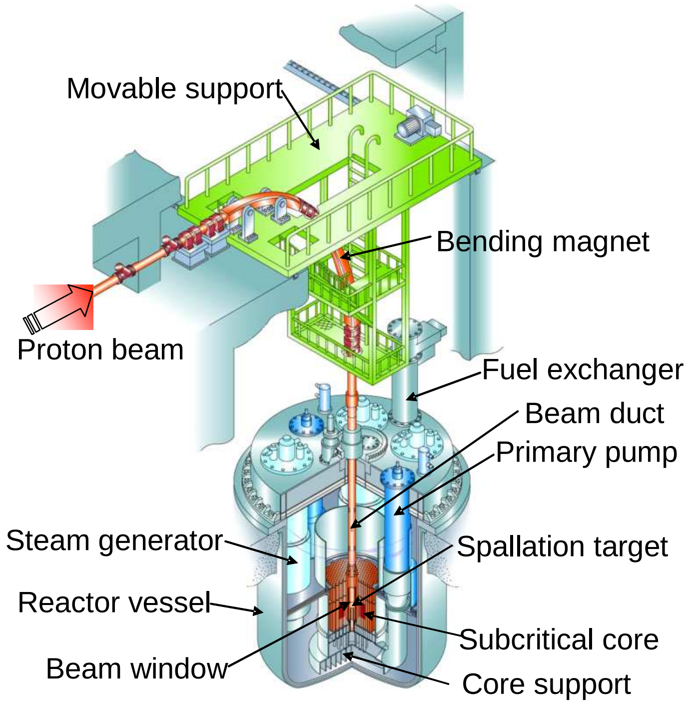
➔ treatment of nuclear waste can **reduce disposal time by several orders of magnitude**

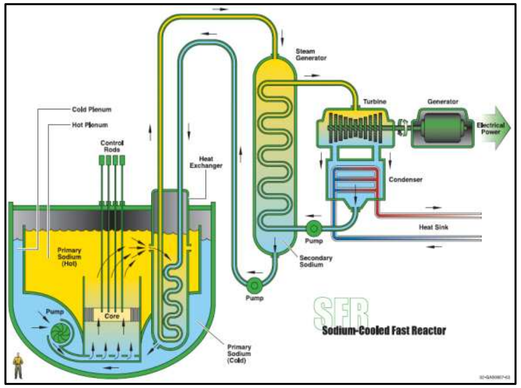
➔ **Partitioning:** separate actinides from the rest

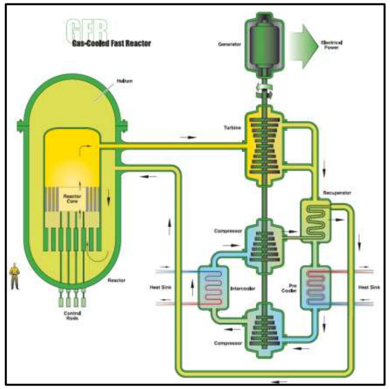
➔ **Transmutation:** convert long lived isotopes into short lived ones

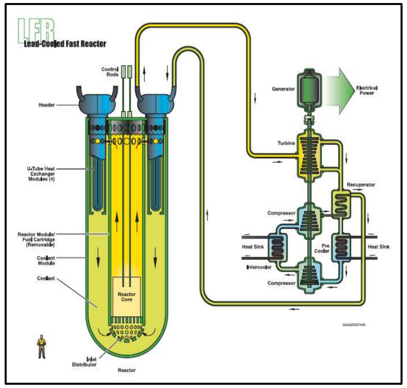
→ A.R. Junghans, HK 1.3, Mo 10:00

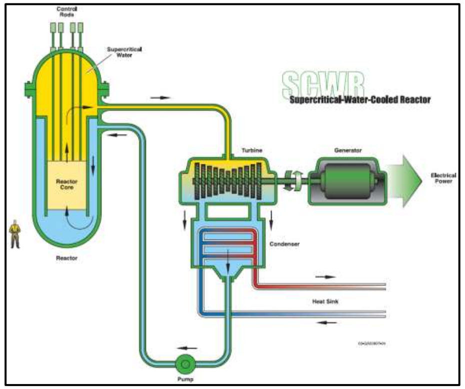
Accelerator driven systems / Generation IV nuclear reactors









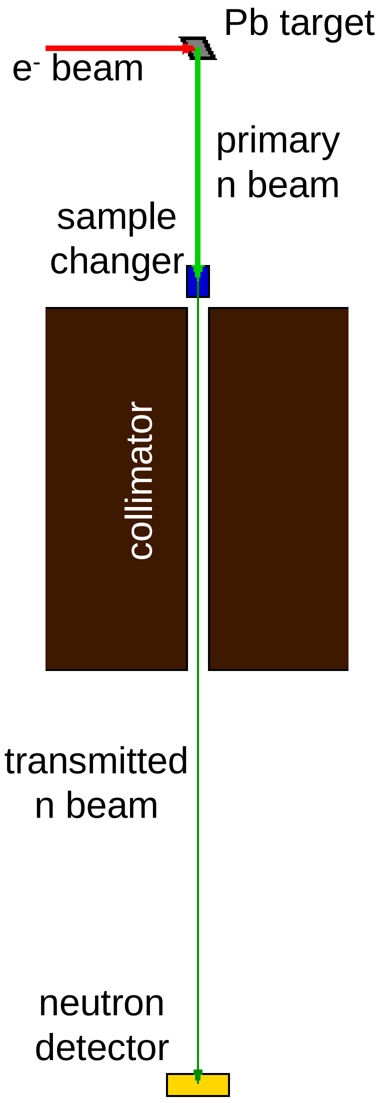


➔ **fast neutron** induced fission is used to produce electrical power and to **burn up long lived actinides**

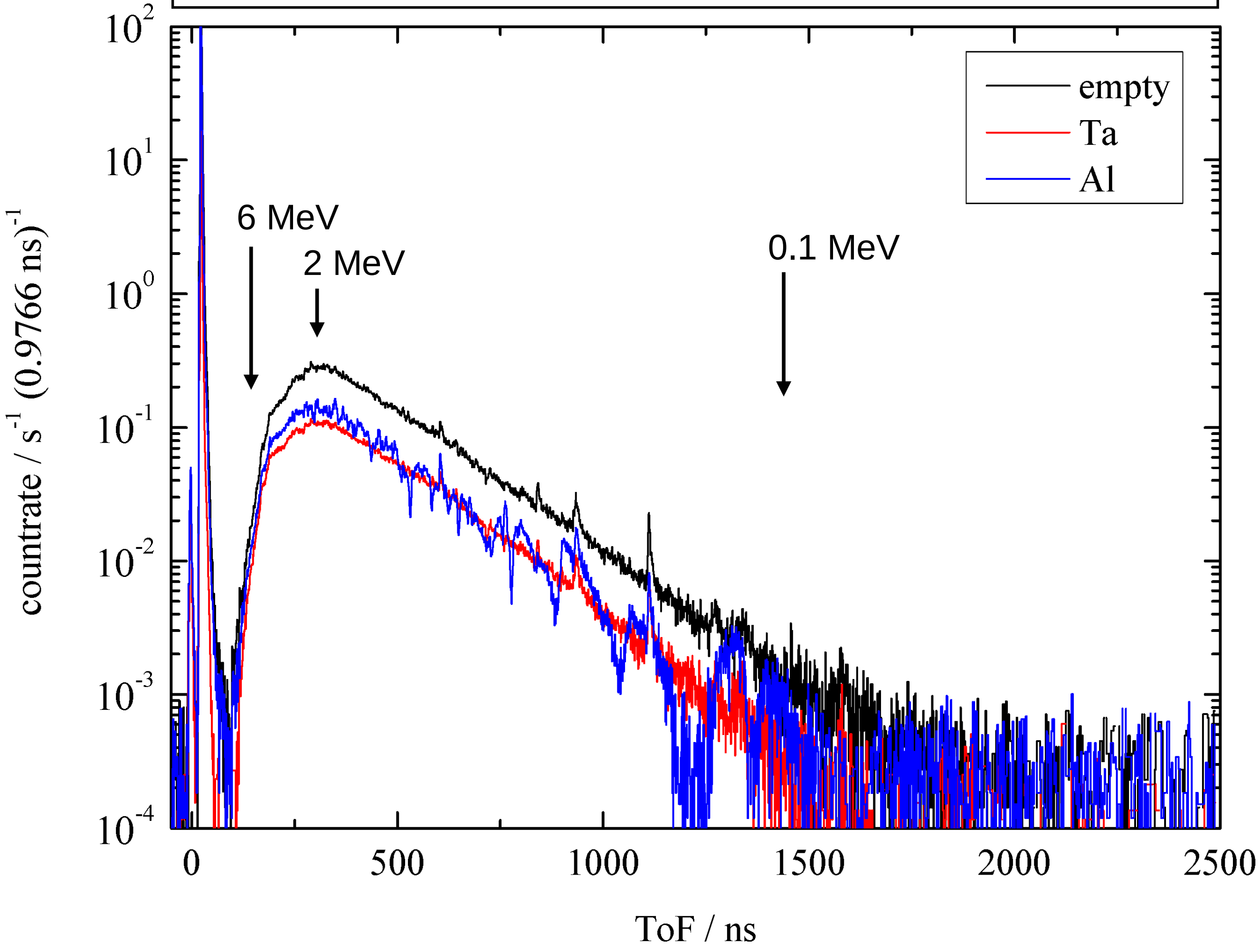
Hiroyuki OIGAWA
Presentation at Euratom PARTRA Cluster Meeting at FZK, Feb. 2008

http://www.gen-4.org/Technology/roadmap.htm

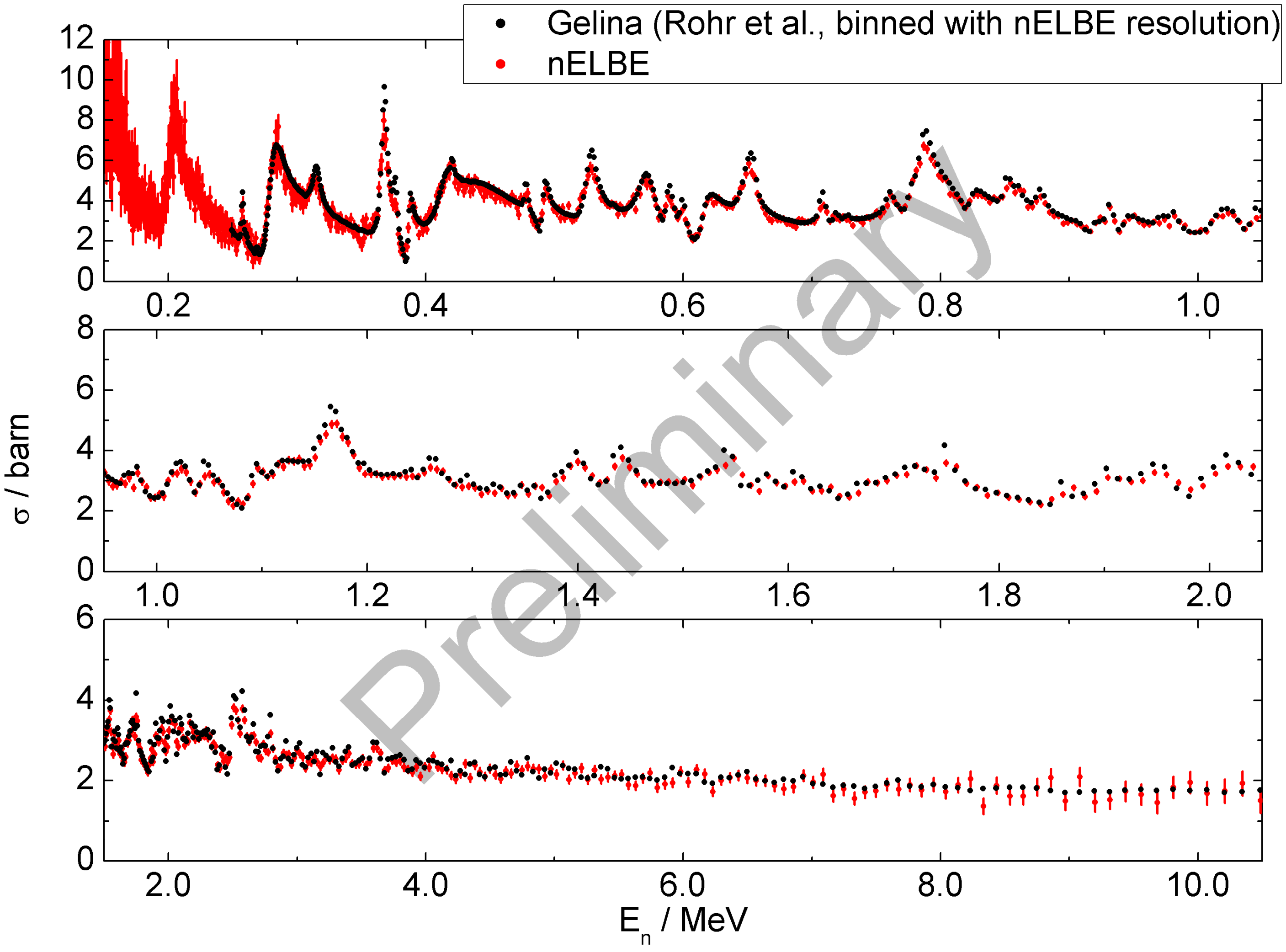
Experimental methods and results - Transmission



$$\sigma_{total} = \sigma_{(n,n)} + \sigma_{(n,n'\gamma)} + \sigma_{(n,\gamma)} + \sigma_{(n,p)} + \sigma_{(n,\alpha)} + \ldots$$



Total neutron cross section of ^{27}Al

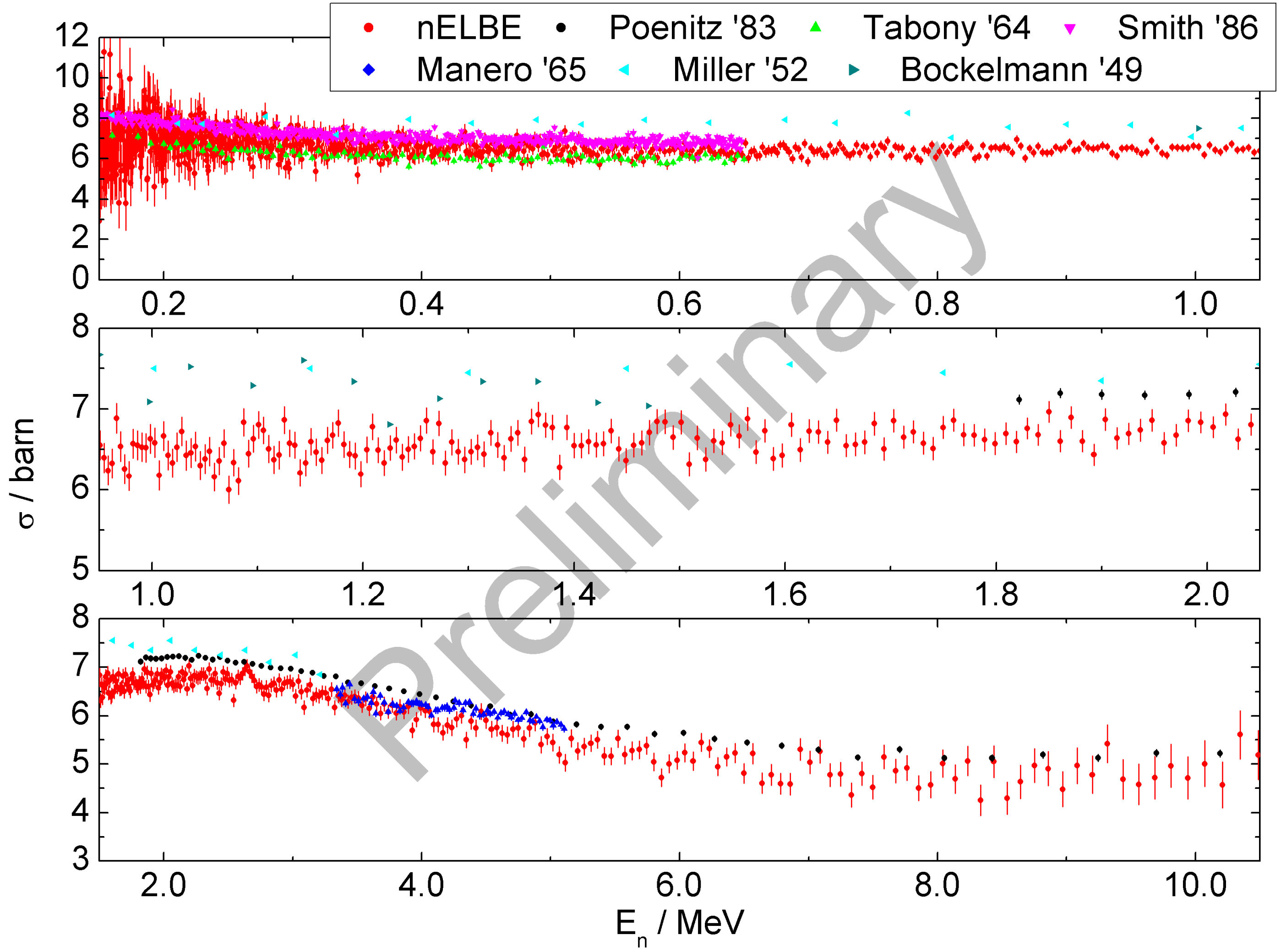


good agreement with high resolution data

→

nELBE works fine for transmission measurements

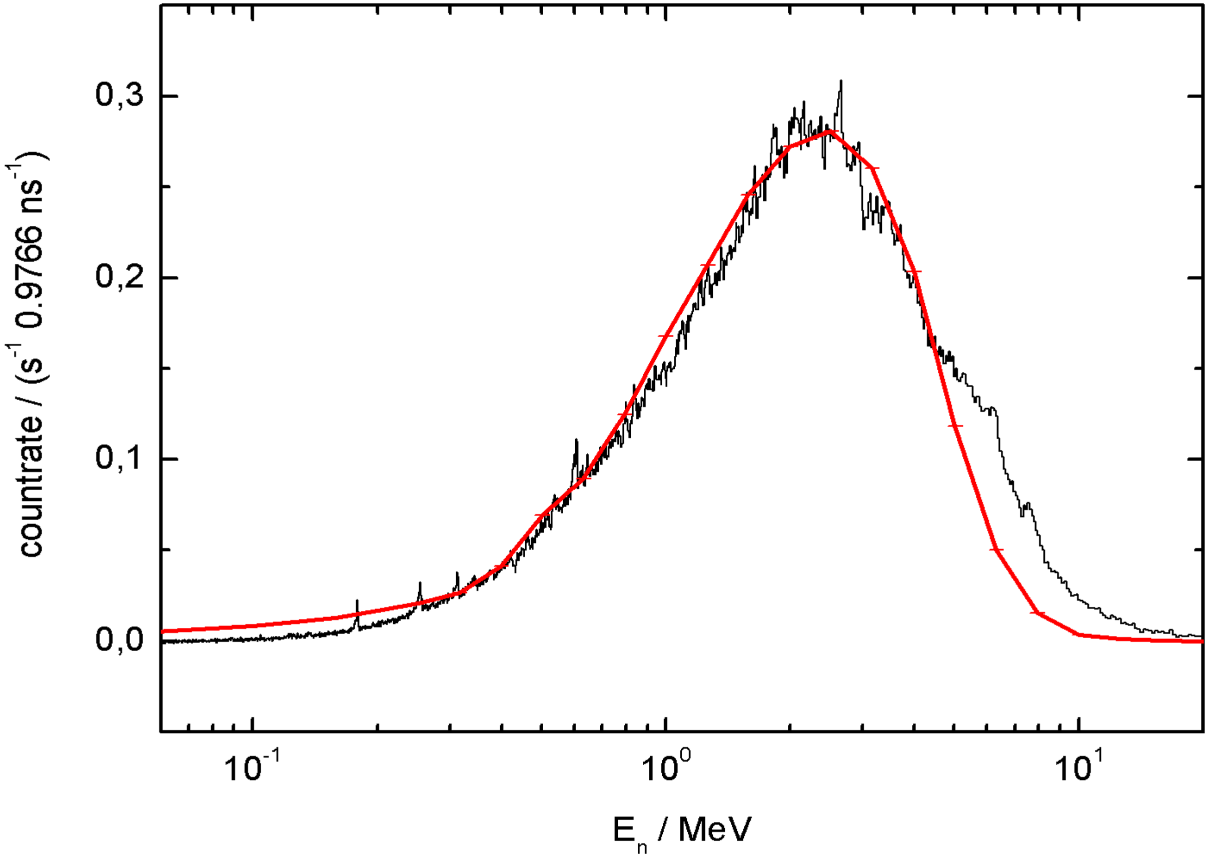
Total neutron cross section of ^{181}Ta



nELBE could close gap between 0.6 and 2.0 MeV

further investigations with different sample thicknesses are ongoing

nELBE Neutronenspektrum



- Elektronenstrahlenergie 33 MeV
- Simulationsrechnung stimmt gut mit der Messung überein
- Neutronenspektrum wie in einem schnellen Reaktor

Neutron beam intensity comparison

Facility	CERN n-ToF	CERN n-ToF Phase-2	LANL NSC	ORNL SNS	FZK VdG	ORNL ORELA	IRMM GELINA	nELBE	nELBE with SRF-gun
Pulse charge / nC	ca. 10^3	ca. 10^3	$4\cdot10^3$	$3\cdot10^4$	0.01	ca. 100	ca. 100	0.08	1.8
Power / kW	10	10	60	1000	0.4	8	7	5	40
Pulse rate / s^{-1}	0.4	0.4	20	60	$2.5\cdot10^5$	500	800	$5\cdot10^5$	$5\cdot10^5$
Flight Path / m	183	Ca. 20	60	84	0.8	40	20	4	4
n-pulse length / ns	>7	>7	125	100-700	ca. 1	>4	>1	< 0.4	< 0.4
E_{min} / eV	0.1	0.1	1	0.1	10^3	10	10	$2\cdot10^5$	$2\cdot10^5$
E_{max} / eV	$3\cdot10^8$	$3\cdot10^8$	ca. 10^8	ca. 10^8	$2\cdot10^5$	$5\cdot10^6$	$4\cdot10^6$	$7\cdot10^6$	$7\cdot10^6$
resolution at 1 MeV / %	0.5%	5%	> 10 %	> 20 %	ca. 5 %	< 1 %	< 2 %	ca. 1 %	ca. 1 %
n flux density / $s^{-1}cm^{-2}$ (E decade)$^{-1}$	10^5	ca.10^7	ca. 10^6	10^6 -10^7	ca. 10^4	10^4	$4\cdot10^4$	$1\cdot10^5$	$3\cdot10^6$

Deutsche Akademie der Naturforscher Leopoldina/
Nationale Akademie der Wissenschaften

acatech – Deutsche Akademie der Technikwissenschaften

Berlin-Brandenburgische Akademie der Wissenschaften
(für die Union der deutschen Akademien der Wissenschaften)

**Konzept
für ein integriertes
Energieforschungsprogramm
für Deutschland**

http://www.acatech.de/

Research potential

Module 1: Renewable

Module 2: Fossile

Module 3: Nuclear

Modul 3: Kernenergie

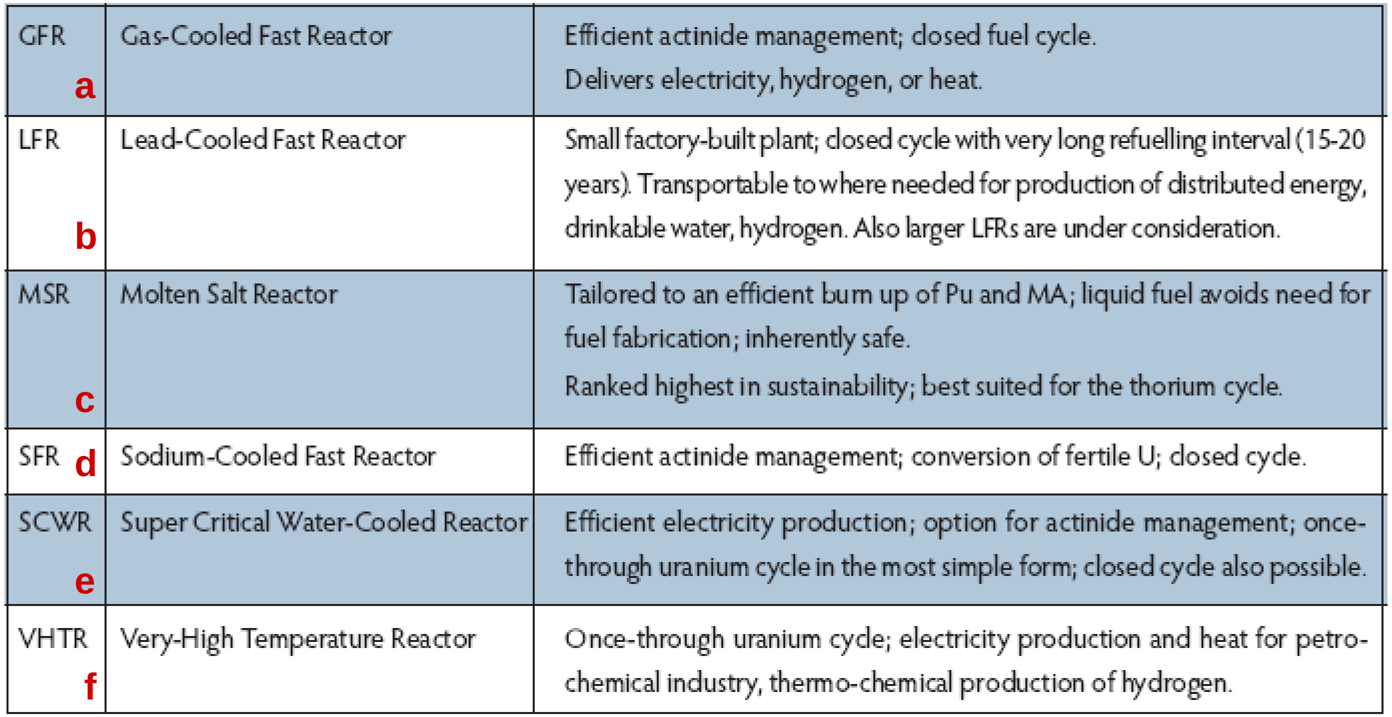
Quelle: acatech
Konzept
für ein integriertes
Energieforschungsprogramm
für Deutschland

Module 3: Nuclear power

Germany has – in contrast to most other european countries – decided to abandon nuclear power. In the course of this legislation the remaining federal research funds for nuclear safety and final storage were reduced to a minimum. Even if Germany will stick to this decision and will shut down all nuclear power stations in the next ca. 15 years, a further need for research is indispensable in the fields of nuclear safety, final storage and radiation research.It is both in the common interest as well as in the national self-interest to further develop the very high german safety standards to contribute to the design, the operation and the building of future nuclear power plants elsewhere in the world.

Generation IV nuclear reactor types

as selected by an international panel to be designed and evaluated numerically on the basis of <u>accurate data</u>, eventually to be tested later in integral experiments.



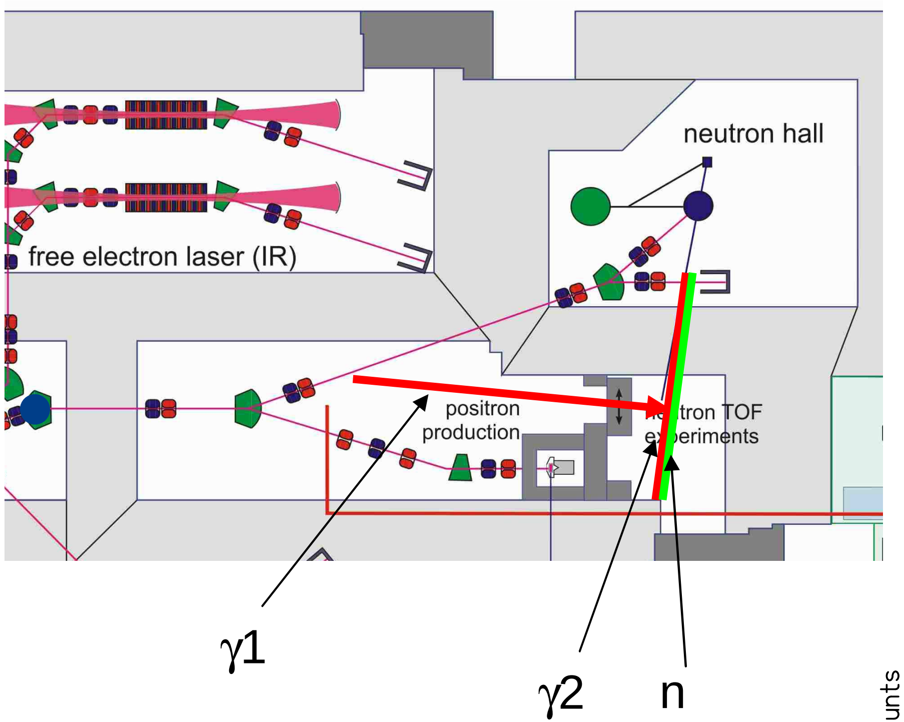
	type	dedication
GFR a	Gas-Cooled Fast Reactor	Efficient actinide management; closed fuel cycle. Delivers electricity, hydrogen, or heat.
LFR b	Lead-Cooled Fast Reactor	Small factory-built plant; closed cycle with very long refuelling interval (15-20 years). Transportable to where needed for production of distributed energy, drinkable water, hydrogen. Also larger LFRs are under consideration.
MSR c	Molten Salt Reactor	Tailored to an efficient burn up of Pu and MA; liquid fuel avoids need for fuel fabrication; inherently safe. Ranked highest in sustainability; best suited for the thorium cycle.
SFR d	Sodium-Cooled Fast Reactor	Efficient actinide management; conversion of fertile U; closed cycle.
SCWR e	Super Critical Water-Cooled Reactor	Efficient electricity production; option for actinide management; once-through uranium cycle in the most simple form; closed cycle also possible.
VHTR f	Very-High Temperature Reactor	Once-through uranium cycle; electricity production and heat for petro-chemical industry, thermo-chemical production of hydrogen.

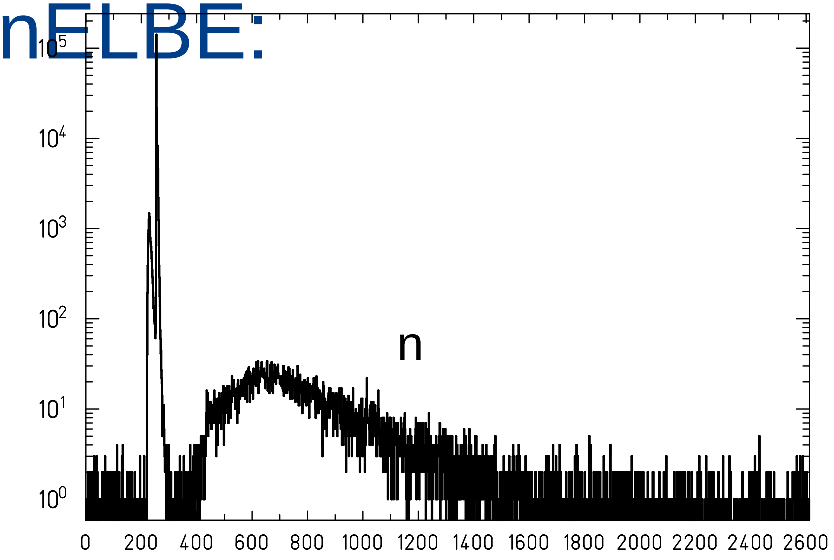
Only for type e water is selected as coolant, thus accurate <u>fast</u> neutron data are required.

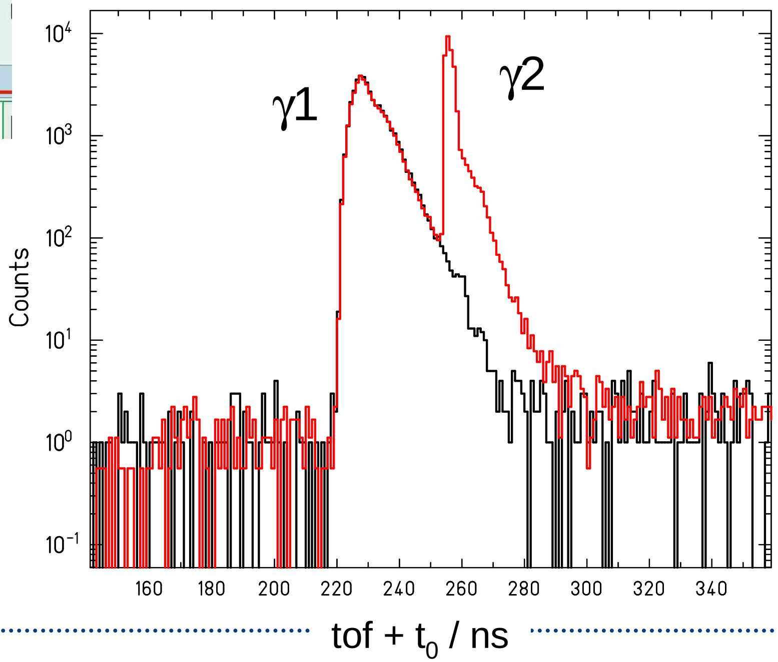
GENERATION IV NUCLEAR ENERGY SYSTEMS

	Neutron Spectrum	*Fuel Cycle*	*Size*	*Applications*	*R&D*
Gas-Cooled Fast Reactor (GFR)	Fast	Closed	Med	Electricity, Actinide Mgmt., Hydrogen	Fuels, Materials, Safety
Lead-alloy Fast Reactor (LFR)	Fast	Closed	Small to Large	Electricity, Actinide Mgmt., Hydrogen	Fuels, Materials compatibility
Sodium Fast Reactor (SFR)	Fast	Closed	Med to Large	Electricity, Actinide Mgmt.	Advanced Recycle
Very High Temp. Gas Reactor (VHTR)	Thermal	Open	Med	Electricity, Hydrogen, Process Heat	Fuels, Materials, H_2 production
Supercritical Water Reactor (SCWR)	Thermal, Fast	Open, Closed	Large	Electricity	Materials, Safety
Molten Salt Reactor (MSR)	Thermal	Closed	Large	Electricity, Actinide Mgmt., Hydrogen	Fuel, Fuel treatment, Materials, Safety and Reliability

time of flight spectrum at nELBE:





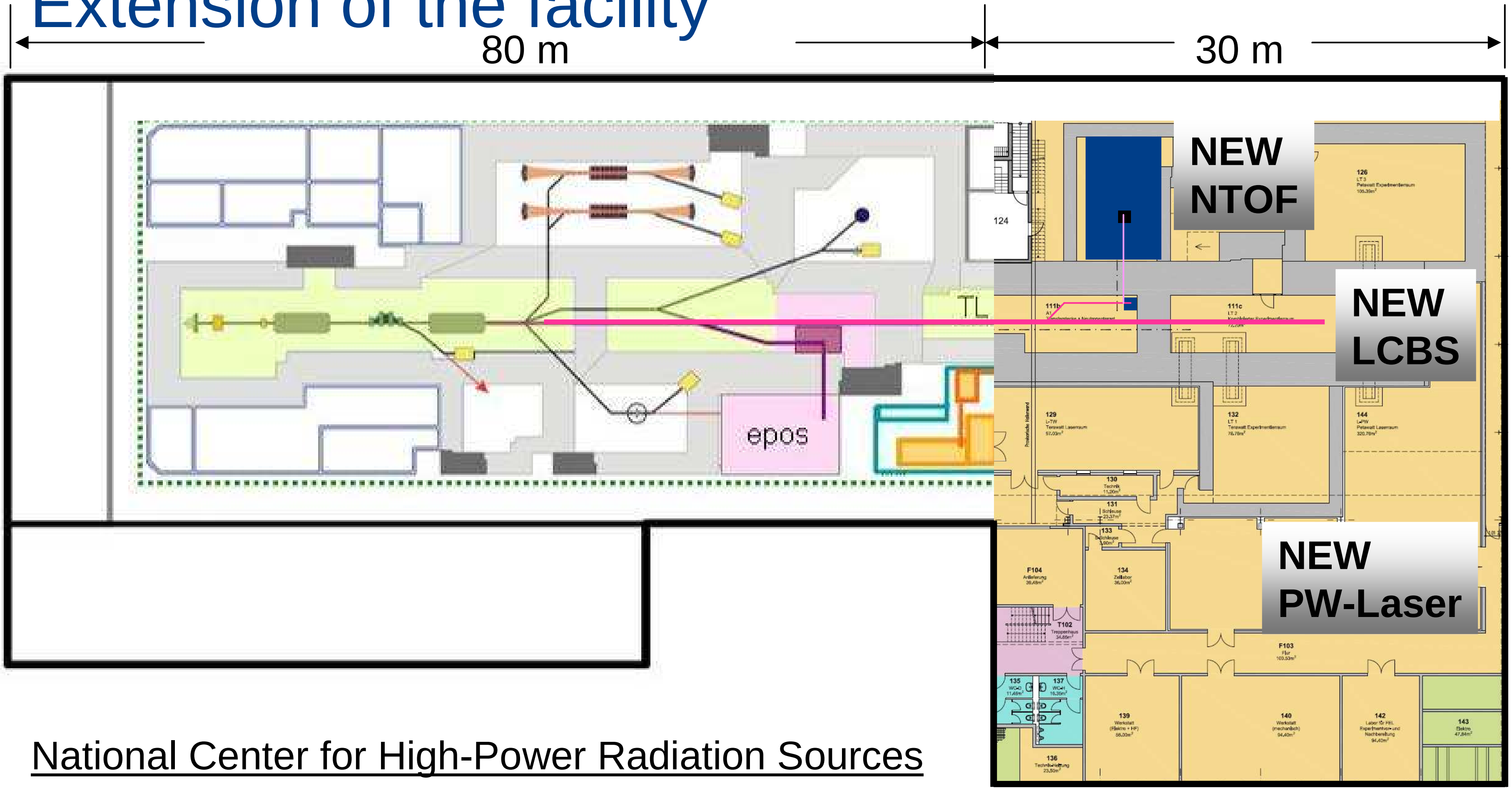


photon time of flight from radiator 22 ns

-from beamline losses < 22 ns

neutron time of flight 150 – 1600 ns

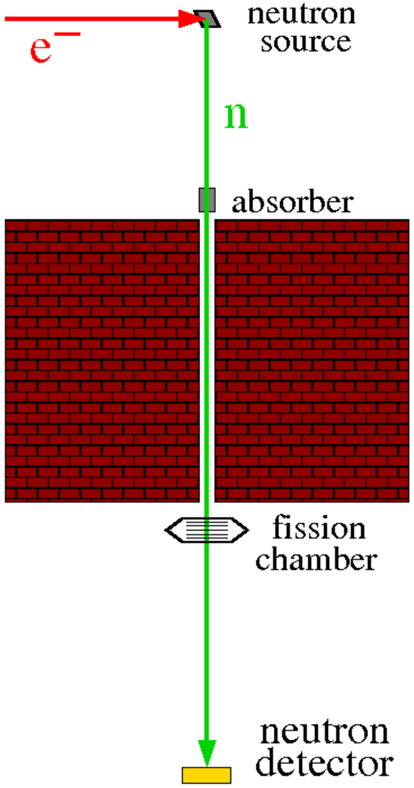
Extension of the facility

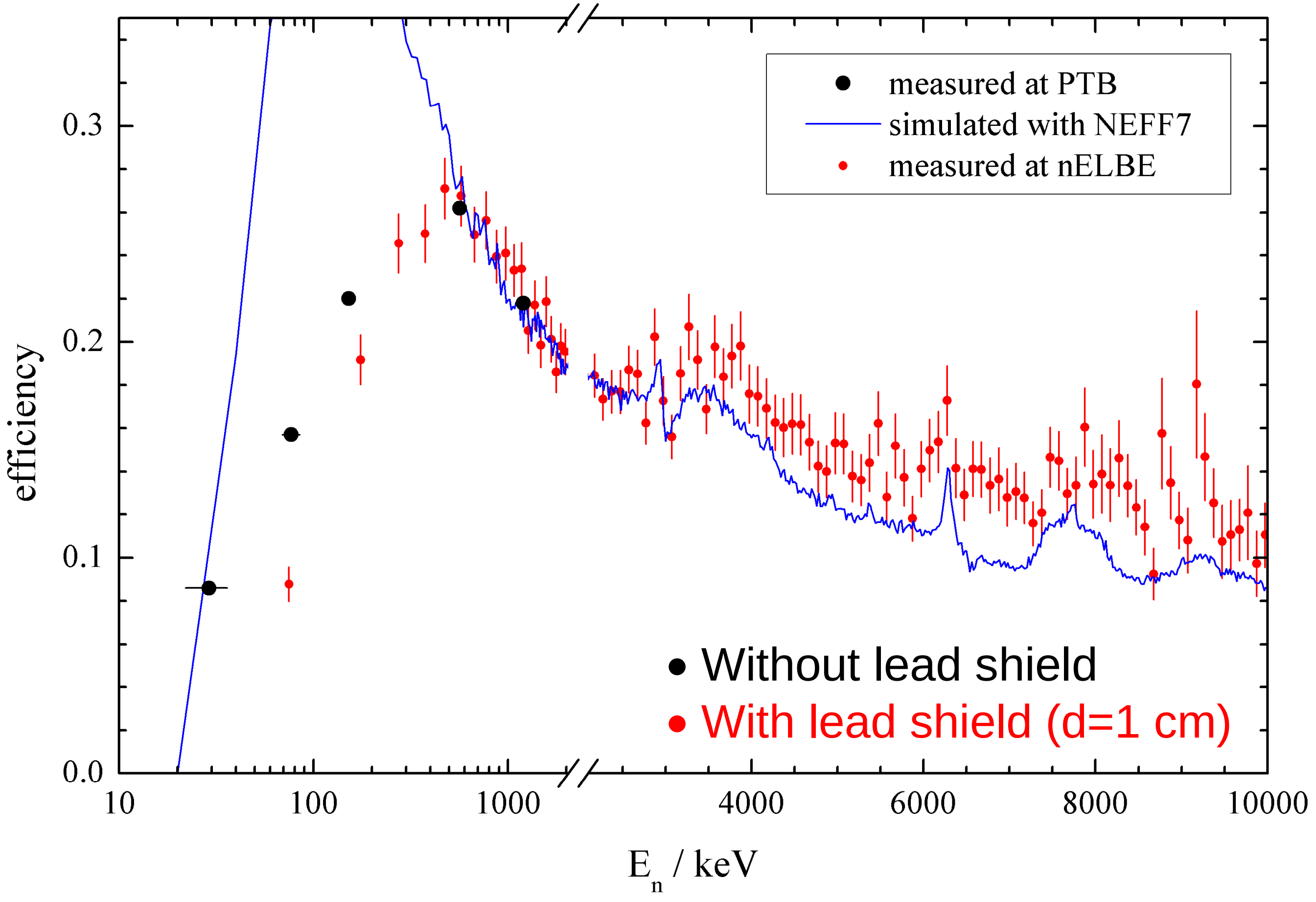


<u>National Center for High-Power Radiation Sources</u>

- X-ray source using Laser-Compton-Backscattering
- High-Power Laser (PW) for Ion Acceleration
- New Neutron Time-of-Flight Facility for Transmutation Studies

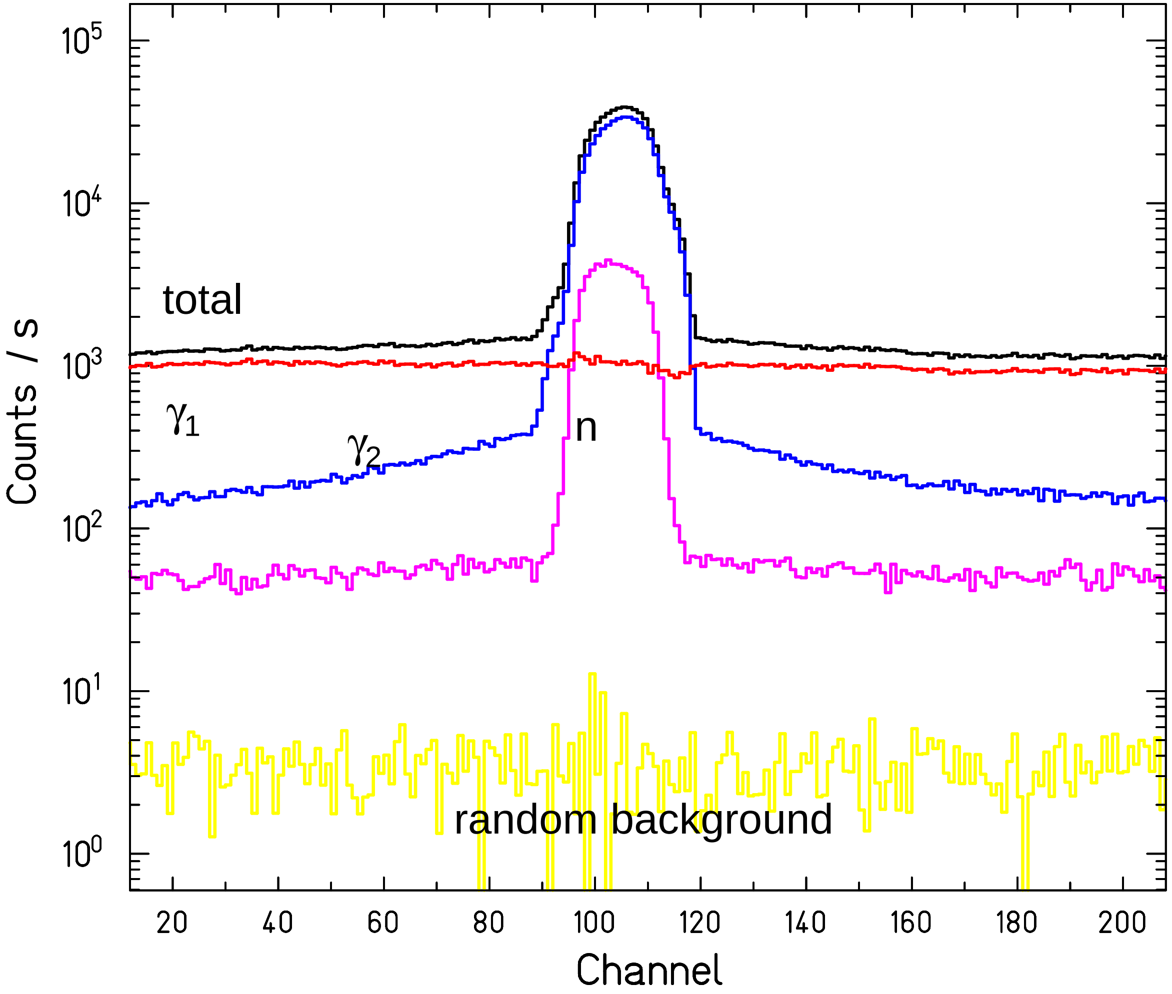
Plastic scintillators: neutron detection efficiency



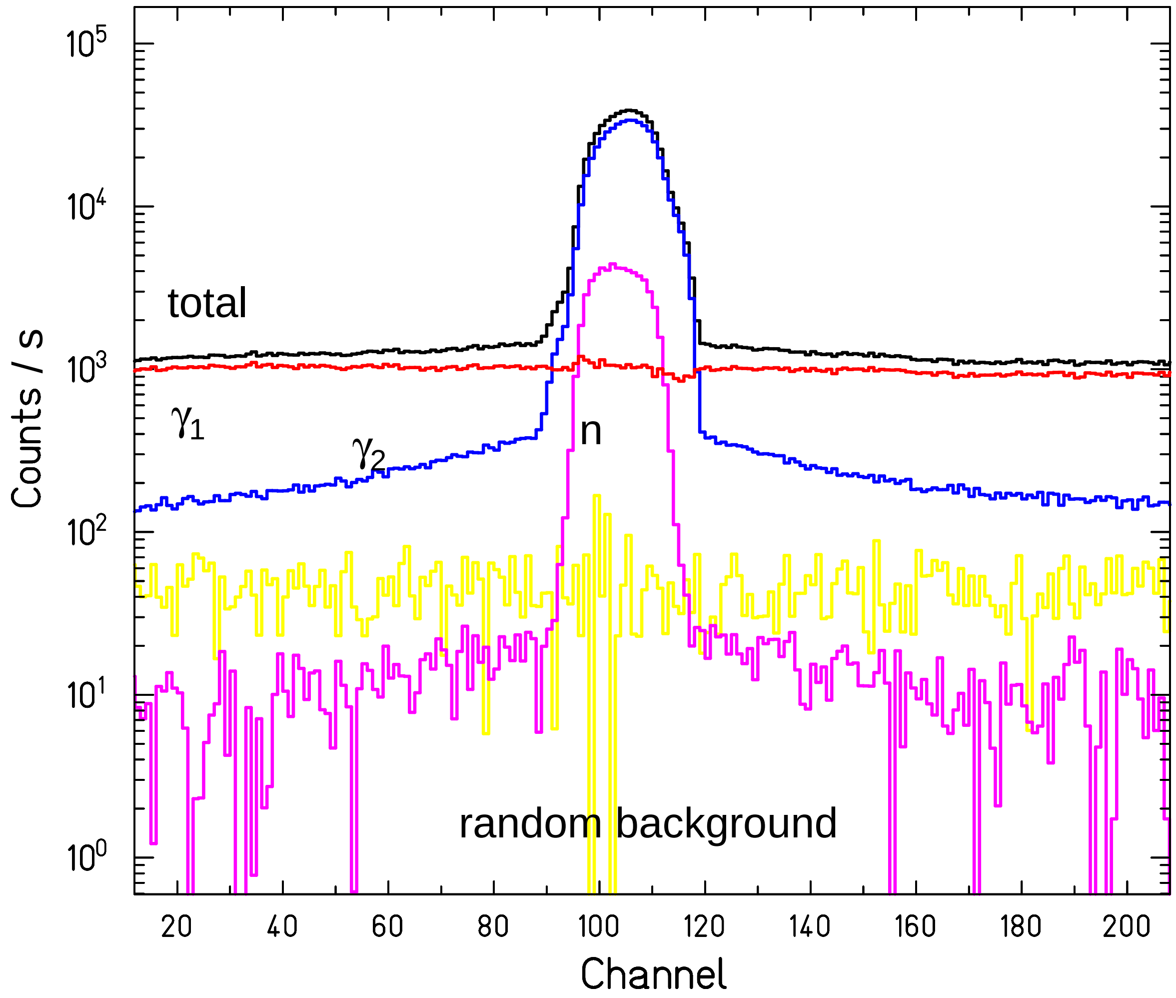


R. Beyer et al. , NIM A575 (2007) 449

Vertical Beam Scan (Run 2859)



Vertical Beam Scan



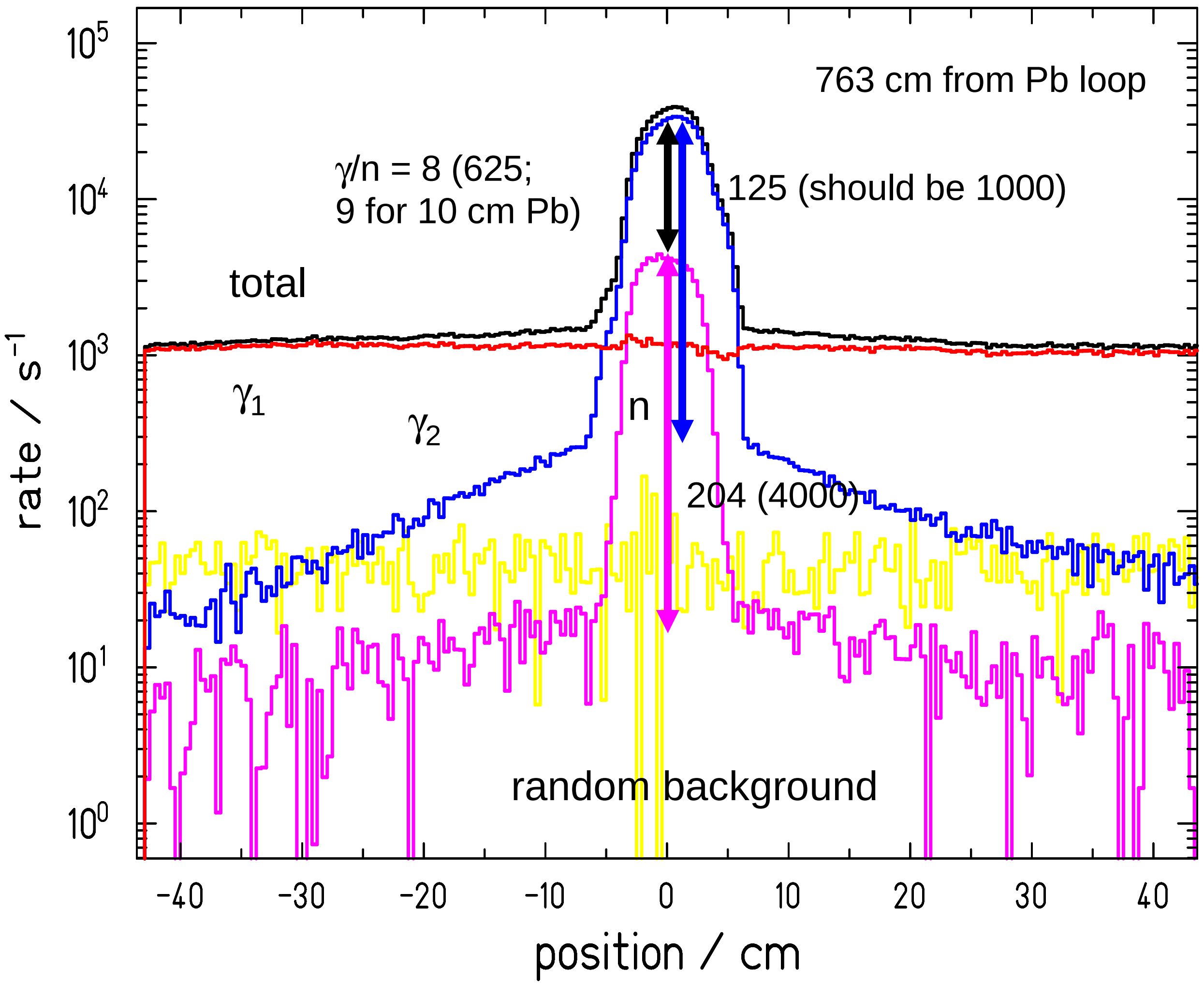
Plastic scintillator stepped through the beam both vertical and horizontal.

ToF measurement ➔ separation of different components in the spectrum

Detector- diameter 11 mm

N-beam diameter ca. 6 cm

Vertical Beam Scan (Run 2859)



Klug et al., NIMA 577(2007)641

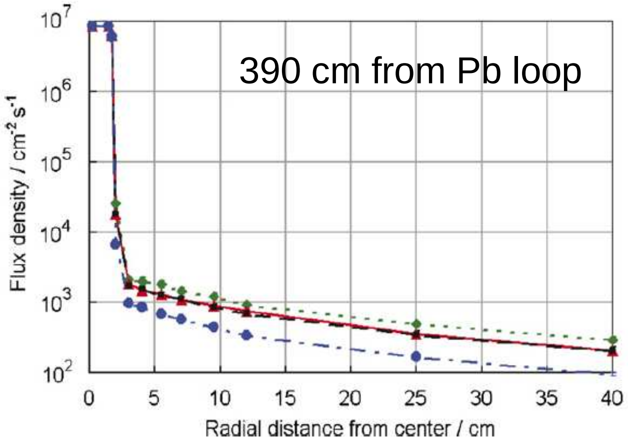


Fig. 8. Radial profile of the neutron flux after four different collimator types 3.9 m from the radiator ($E_e = 30$ MeV, $I_e = 1$ mA). The line styles indicate the neutron beam profile behind the respective collimator shown in Fig. 7.

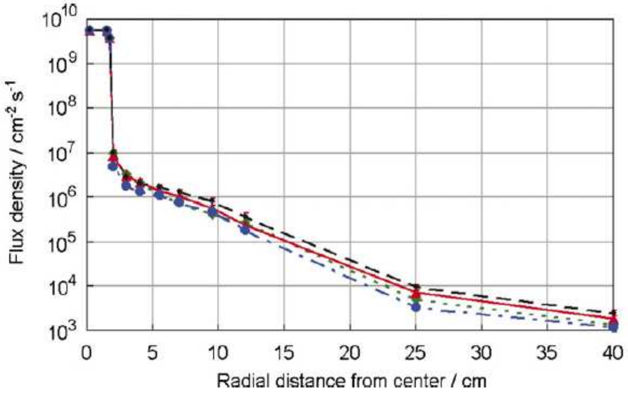
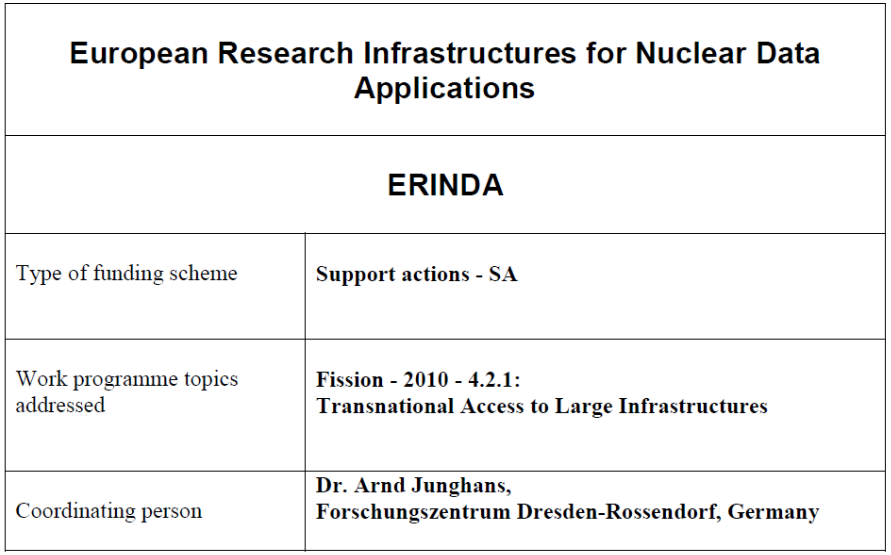
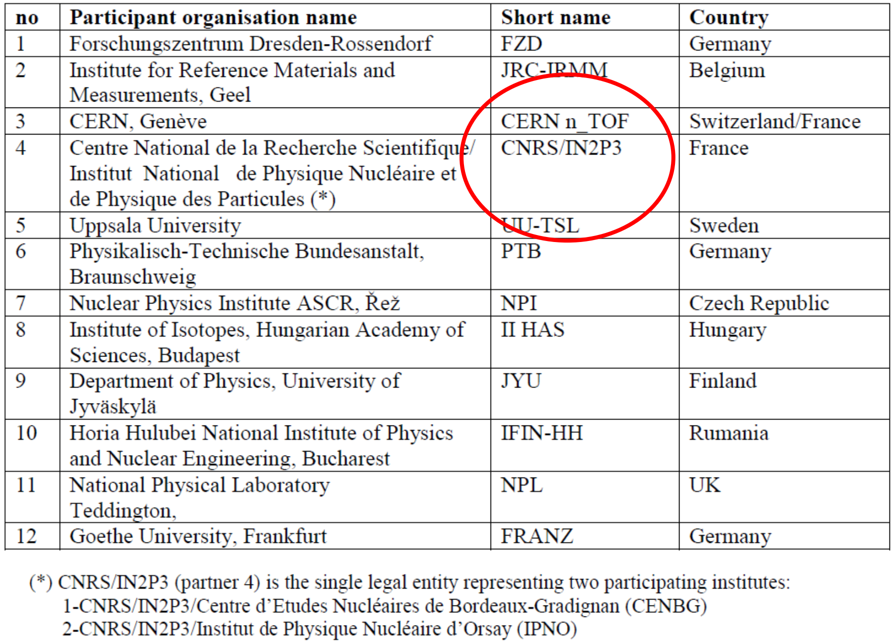


Fig. 9. Photon flux densities after four different collimator types, analog to the neutron beam profiles in Fig. 8.

Successor: FP7-Fission-2010 - ERINDA



European Research Infrastructures for Nuclear Data Applications	
ERINDA	
Type of funding scheme	**Support actions - SA**
Work programme topics addressed	**Fission - 2010 - 4.2.1:** **Transnational Access to Large Infrastructures**
Coordinating person	**Dr. Arnd Junghans,** **Forschungszentrum Dresden-Rossendorf, Germany**



no	**Participant organisation name**	**Short name**	**Country**
1	Forschungszentrum Dresden-Rossendorf	FZD	Germany
2	Institute for Reference Materials and Measurements, Geel	JRC-IRMM	Belgium
3	CERN, Genève	CERN n_TOF	Switzerland/France
4	Centre National de la Recherche Scientifique/ Institut National de Physique Nucléaire et de Physique des Particules (*)	CNRS/IN2P3	France
5	Uppsala University	UU-TSL	Sweden
6	Physikalisch-Technische Bundesanstalt, Braunschweig	PTB	Germany
7	Nuclear Physics Institute ASCR, Řež	NPI	Czech Republic
8	Institute of Isotopes, Hungarian Academy of Sciences, Budapest	II HAS	Hungary
9	Department of Physics, University of Jyväskylä	JYU	Finland
10	Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest	IFIN-HH	Rumania
11	National Physical Laboratory Teddington,	NPL	UK
12	Goethe University, Frankfurt	FRANZ	Germany

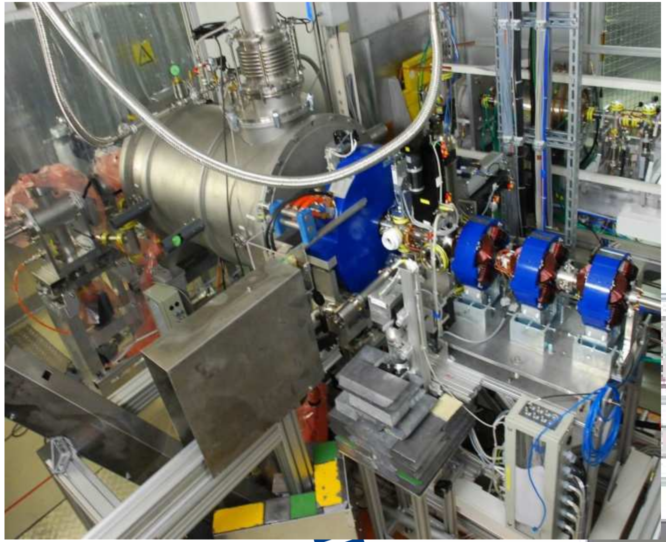
(*) CNRS/IN2P3 (partner 4) is the single legal entity representing two participating institutes:
1-CNRS/IN2P3/Centre d'Etudes Nucléaires de Bordeaux-Gradignan (CENBG)
2-CNRS/IN2P3/Institut de Physique Nucléaire d'Orsay (IPNO)

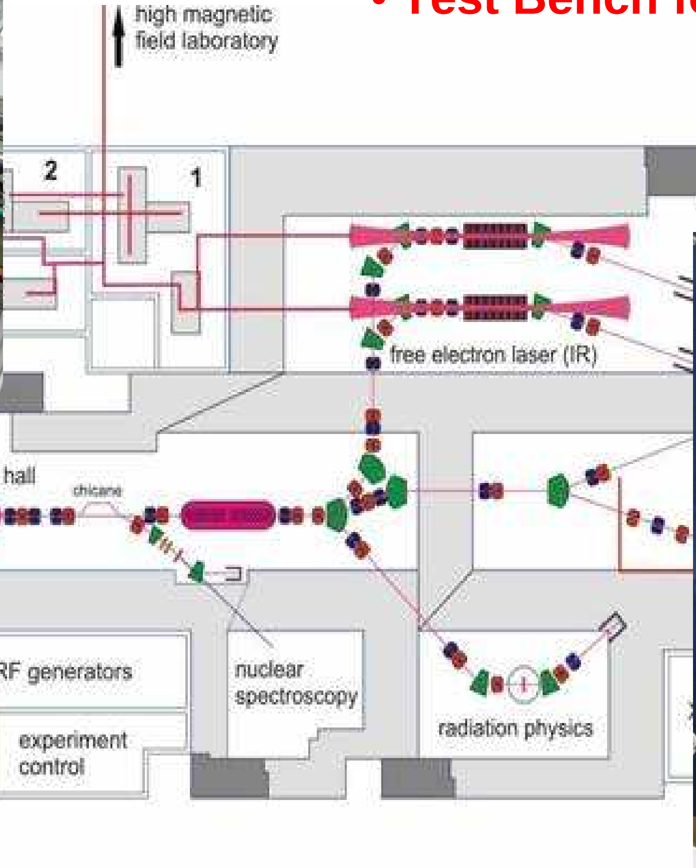
Transnational Access Activity providing mutual exchange and outside user access to partner infrastructure.

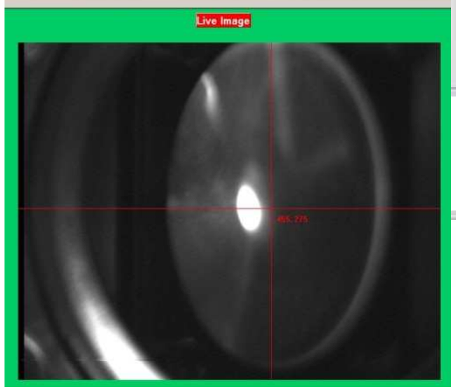
FZD heads and coordinates the activities.

Superconducting RF Photo Injector

- **New Injector for the ELBE SC Linac**
- **Test Bench for SRF Gun R&D**







First accelerated SRF gun beam at ELBE on Febr. 5, 2010

New improved Nb cavities Produced with JLab

Results and Outlook

- Fast neutrons are the decisive for the transmutation of long-lived minor actinides in shorter-lived fission products.
- The time frame for final storage can be reduced to historical times (< 1000 years) through a closed nuclear fuel cycle including partitioning and transmutation.

- Precise experimental data for fast-neutron induced reactions like (n,n‘γ) (n,tot) and (n,f) using radioactive targets are required for the development of transmution facilities (fast reactors, ADS)

- BMBF Verbundprojekt
  „Transmutationsrelevante kernphysikalische Untersuchungen …“
  together with TU Dresden, Uni Mainz, TU München, Uni Köln und PTB Braunschweig seit 01.10.2009

GEFÖRDERT VOM

Bundesministerium
für Bildung
und Forschung

Sustainable Nuclear Energy Technology Platform

More and better quality data

Availability of accurate nuclear data (cross sections, decay constants, branching ratios, etc.) is the basis for precise reactor calculations both for current (applications to higher burn-up, plant life extension) and new generation reactors. *Additional experimental measurements and their detailed analysis and interpretation are required in a broad range of neutron energies and materials. This is particularly true for fuels containing minor actinides for their transmutation in fast spectra*

SNETP
SUSTAINABLE NUCLEAR ENERGY
TECHNOLOGY PLATFORM

Strategic Research
Agenda

May 2009