From EXILL to FIPPS

ILL : *A. Blanc, A. Chebboubi, H, Faust, M. Jentschel, U. Kőster, P.Mutti, T. Soldner*
CEA-Saclay : *T. Materna, S. Panebianco*
GANIL : *G. De France*
LNL: *C.A. Ur*
LPSC-Grenoble : *C. Sage, G. Kessedjian*
University of Milano : *S. Leoni*
University of Warsaw : *W. Urban*
University of West Scotland : *G. Simpson*

Summary

- Nuclear physics at ILL
- EXILL
  - Motivation
  - Setup
  - Performances
- FIPPS
  - FIPPS layout
  - Phase I
  - Phase II&III
- Conclusion

Institut Laue-Langevin

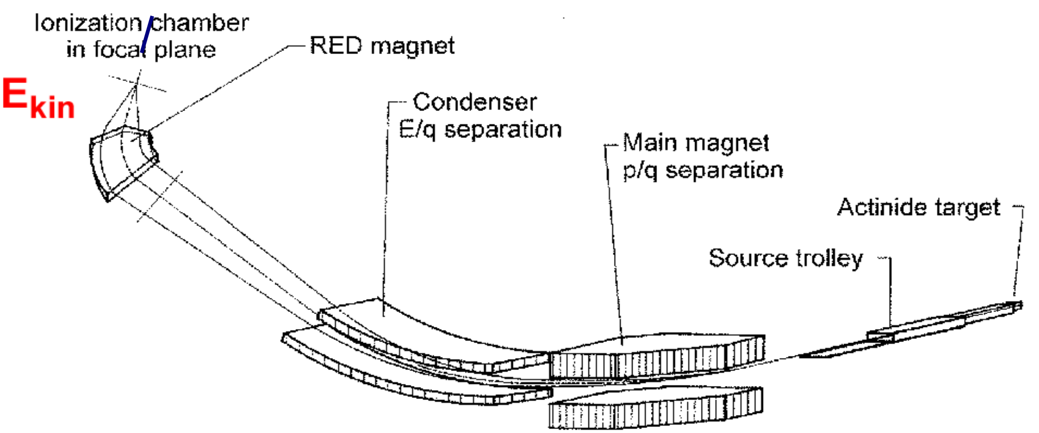
- operates 58 MW high flux reactor with intense extracted neutron beams
- operating since 1971
- today 14 member states: F, D, UK, E, CH, A, I, CZ, S, HU, B, SK, DK, IN
- over **40 instruments**, mainly for neutron scattering
- **user facility:** 2000 scientific visitors from 45 countries per year

Nuclear Physics at ILL (1)

- The LOHENGRIN fission fragment separator:

$\Delta A/A$ = 3E-4 – 3E-3
$\Delta E/E$ = 1E-3 – 1E-2

up to 10^5/s mass-separated fission fragments ($T_{1/2} \geq \mu s$)



$m v^2 / r_{el} = q E$ $\qquad$ $m v^2 / r_{magn} = q v B$

$E_{kin} / q = E / 2 r_{el}$ $\qquad$ $m v / q = B r_{magn}$

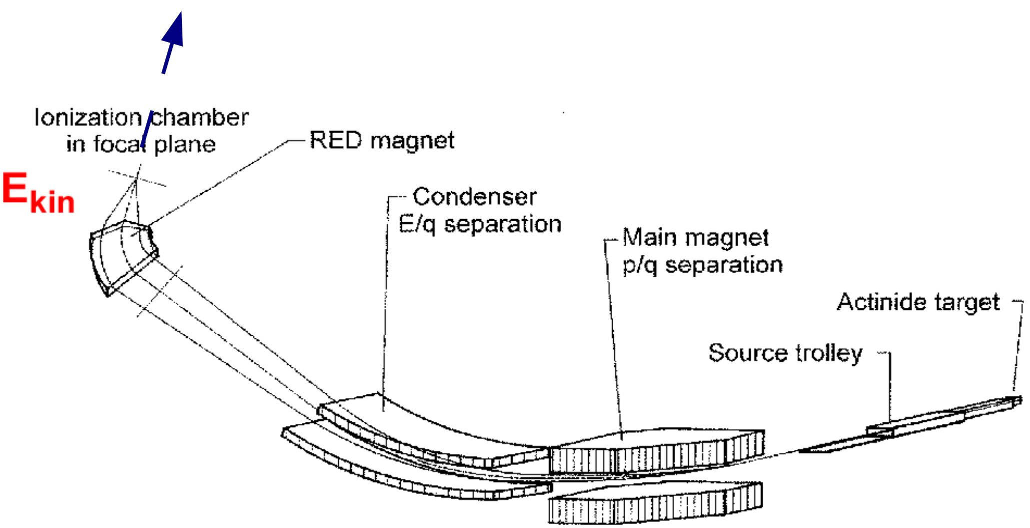
P. Armbruster et al., Nucl. Instr. Meth. 139 (1976) 213.

Nuclear Physics at ILL (1)

- The LOHENGRIN fission fragment separator:

$\Delta A/A$ = 3E-4 – 3E-3
$\Delta E/E$ = 1E-3 – 1E-2

up to 10^5/s mass-separated fission fragments ($T_{1/2} \geq \mu s$)

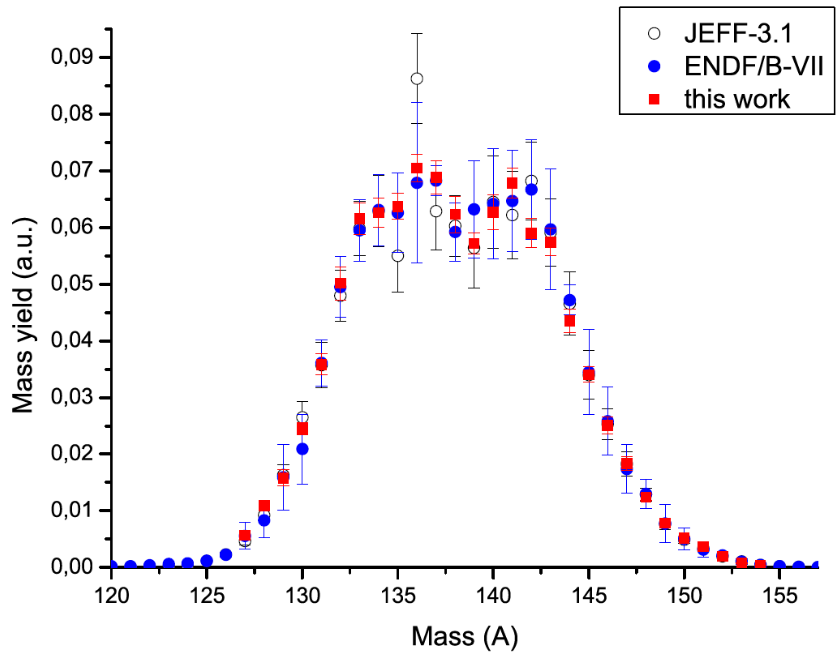


$$m v^2 / r_{el} = q E \qquad m v^2 / r_{magn} = q v B$$

$$E_{kin} / q = E / 2 r_{el} \qquad m v / q = B r_{magn}$$

P. Armbruster et al., Nucl. Instr. Meth. 139 (1976) 213.

233U(n,f) mass yields



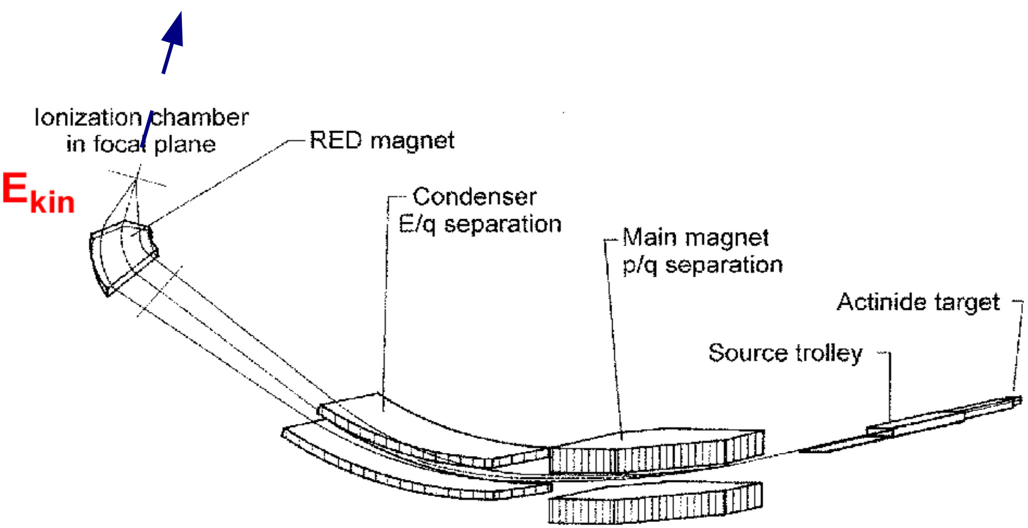
F.Martin PhD thesis(2014) :233U(n,f)

Nuclear Physics at ILL (1)

- The LOHENGRIN fission fragment separator:

ΔA/A = 3E-4 – 3E-3
ΔE/E = 1E-3 – 1E-2

up to 10^5/s mass-separated fission fragments ($T_{1/2} \geq \mu s$)

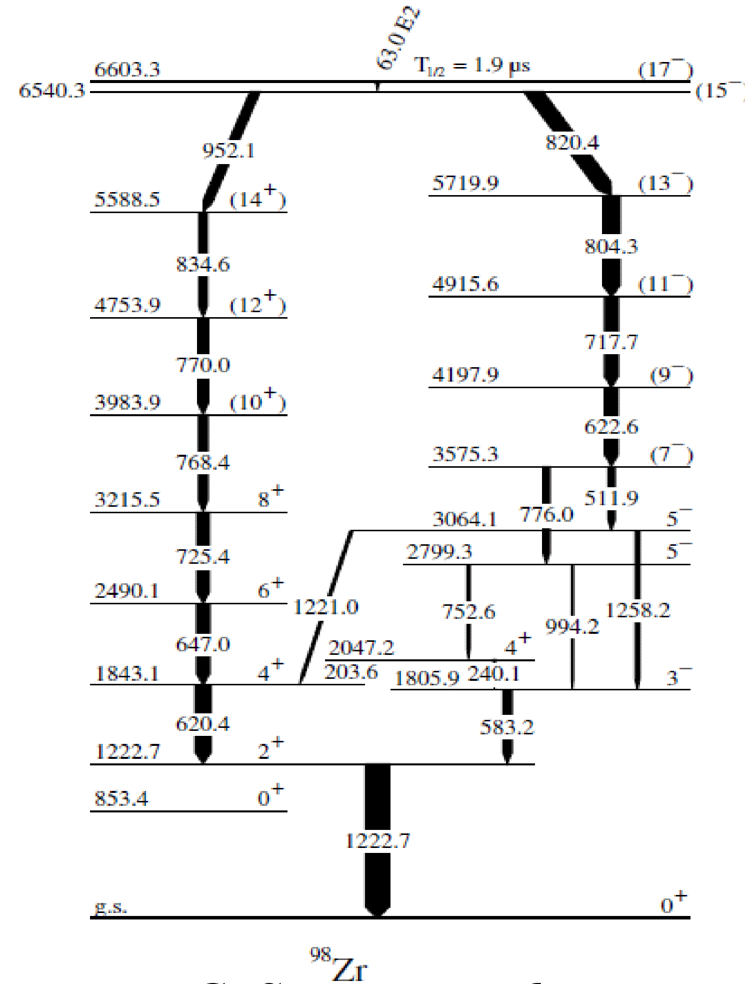


$$m v^2 / r_{el} = q E \qquad m v^2 / r_{magn} = q v B$$

$$E_{kin} / q = E / 2 r_{el} \qquad m v / q = B r_{magn}$$

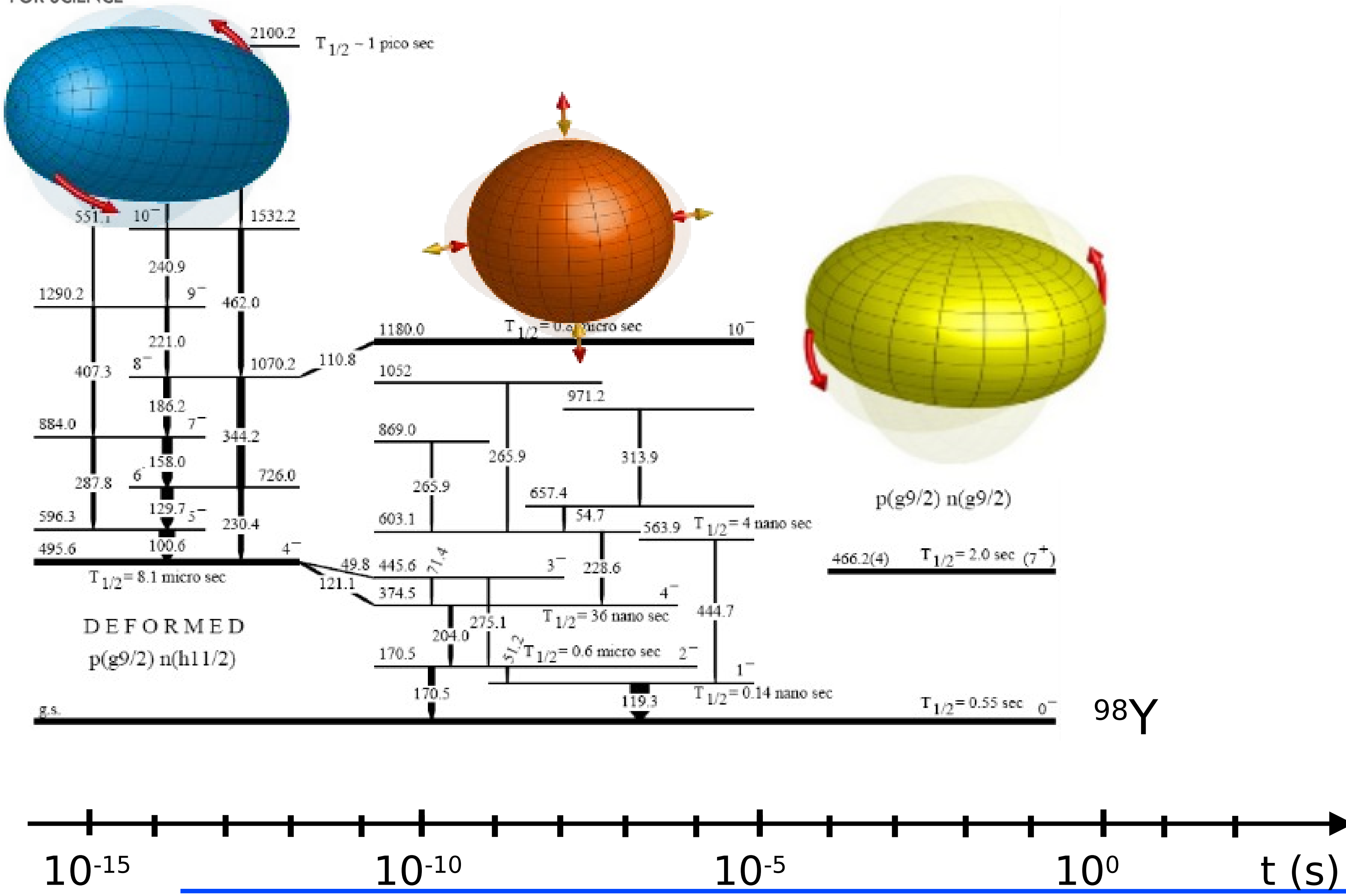
P. Armbruster et al., Nucl. Instr. Meth. 139 (1976) 213.

17^- isomer at 6.6 MeV in ^{98}Zr

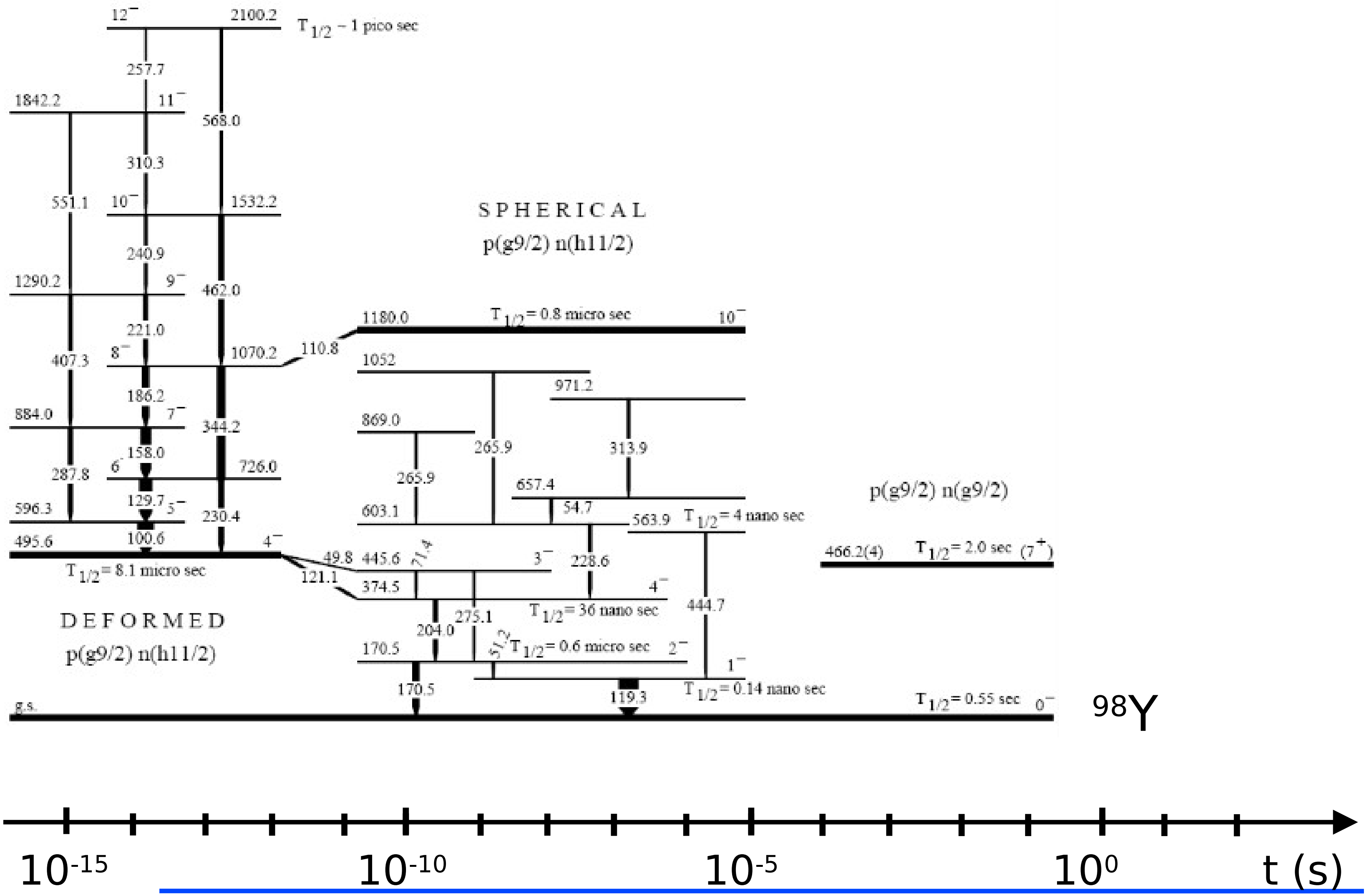


G. Simpson et al., Phys. Rev. C 74 (2006) 064308.

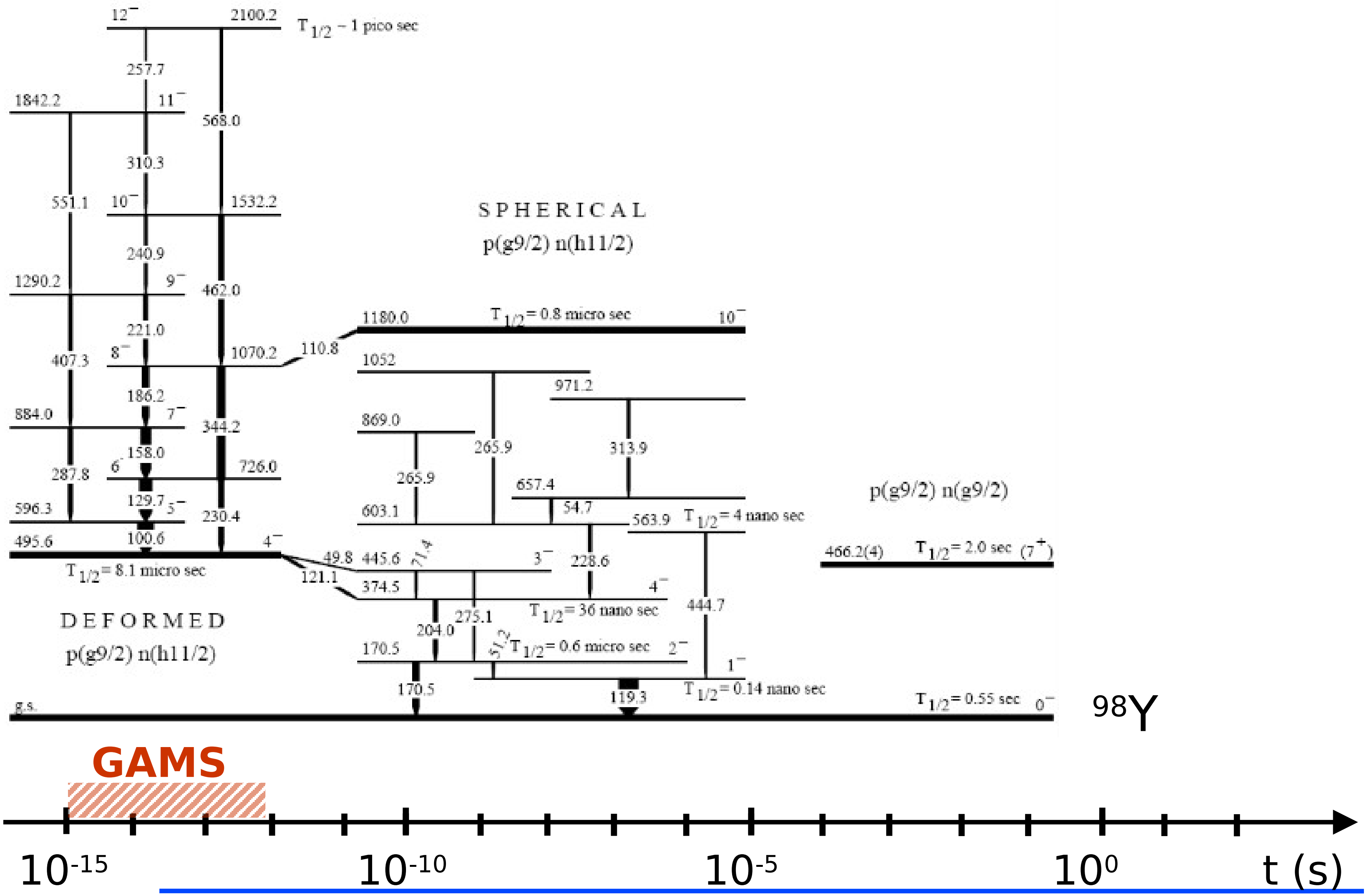
Nuclear Physics at ILL (2)



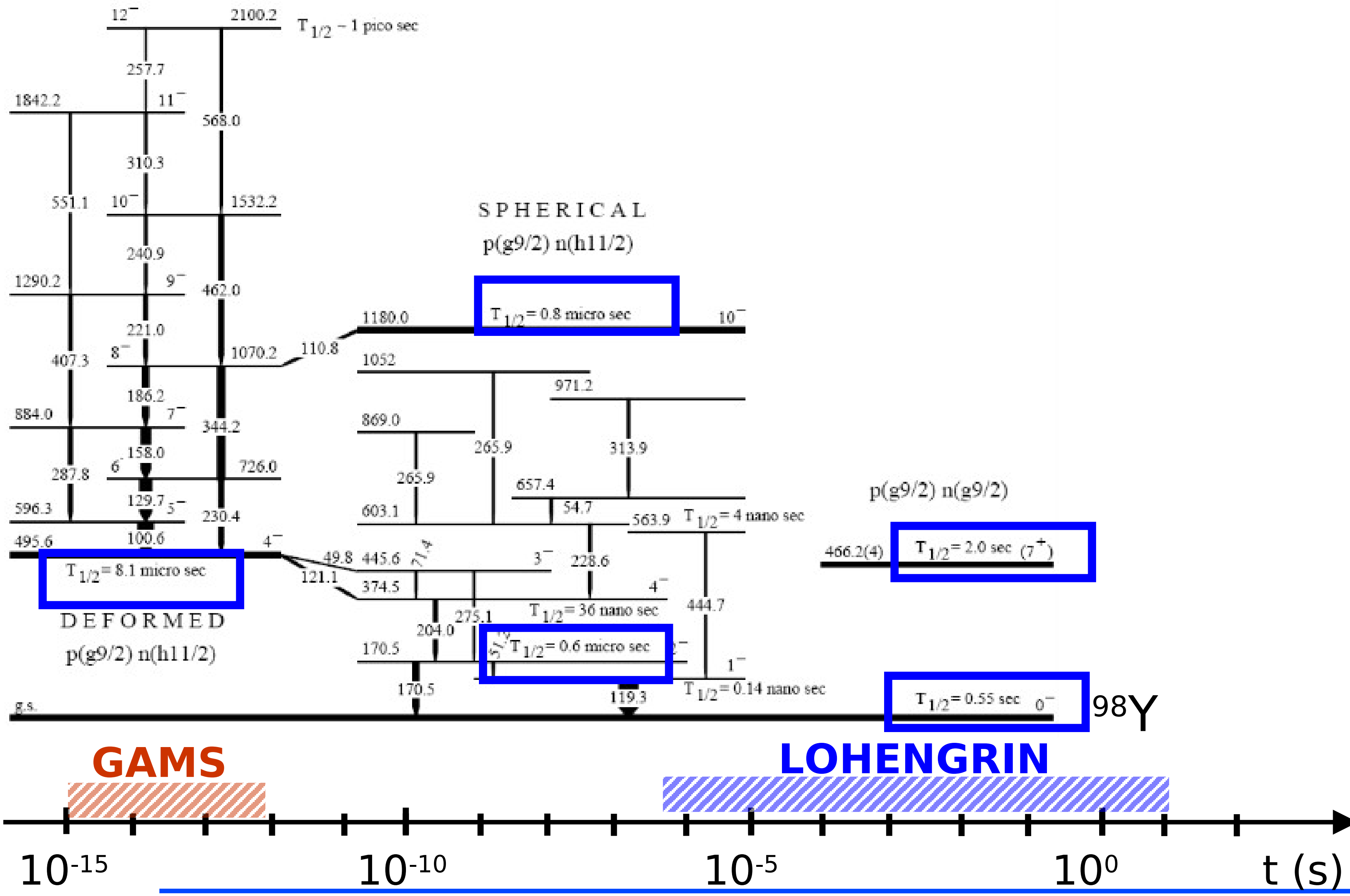
Nuclear Physics at ILL (2)



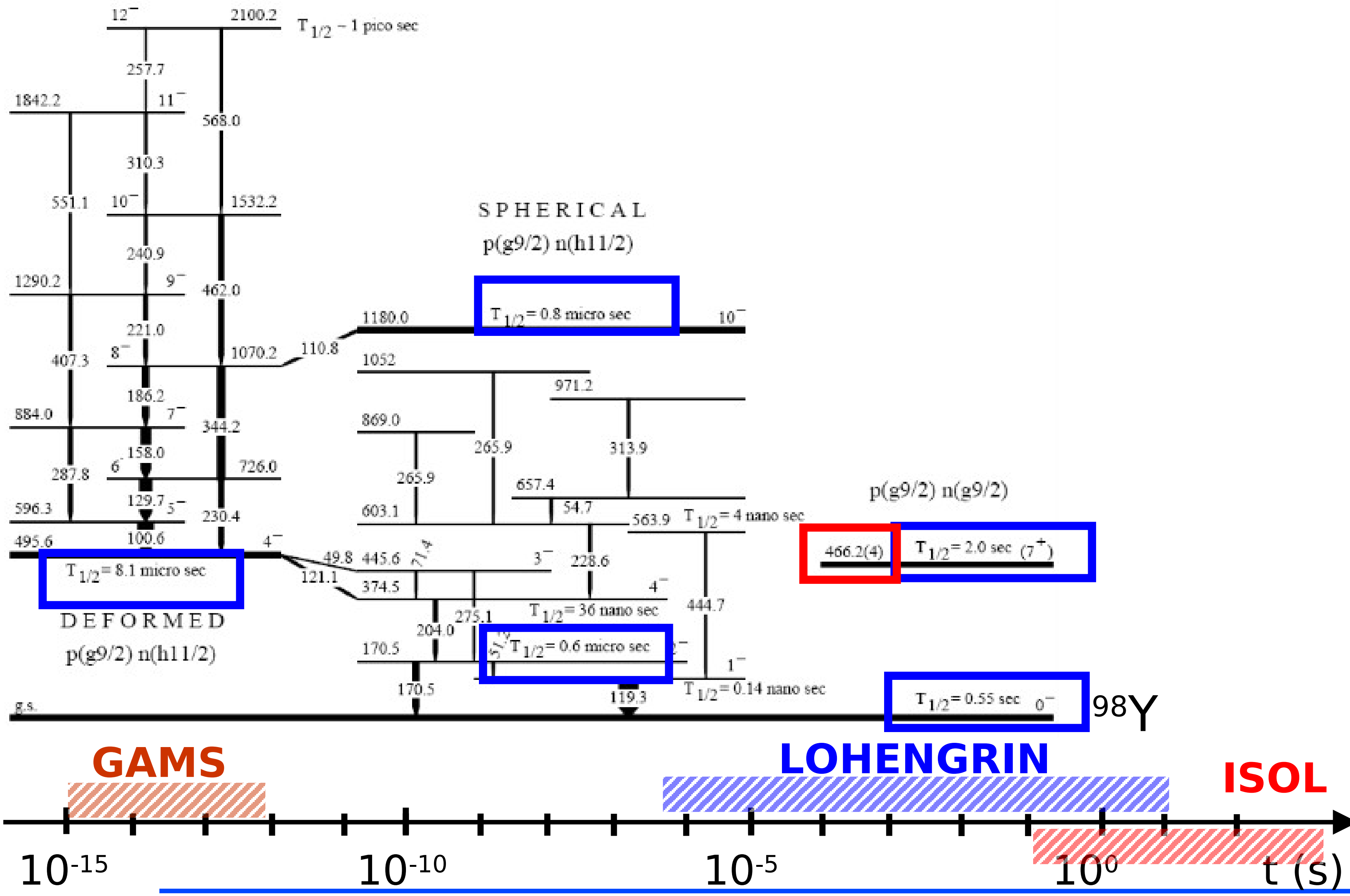
Nuclear Physics at ILL (2)



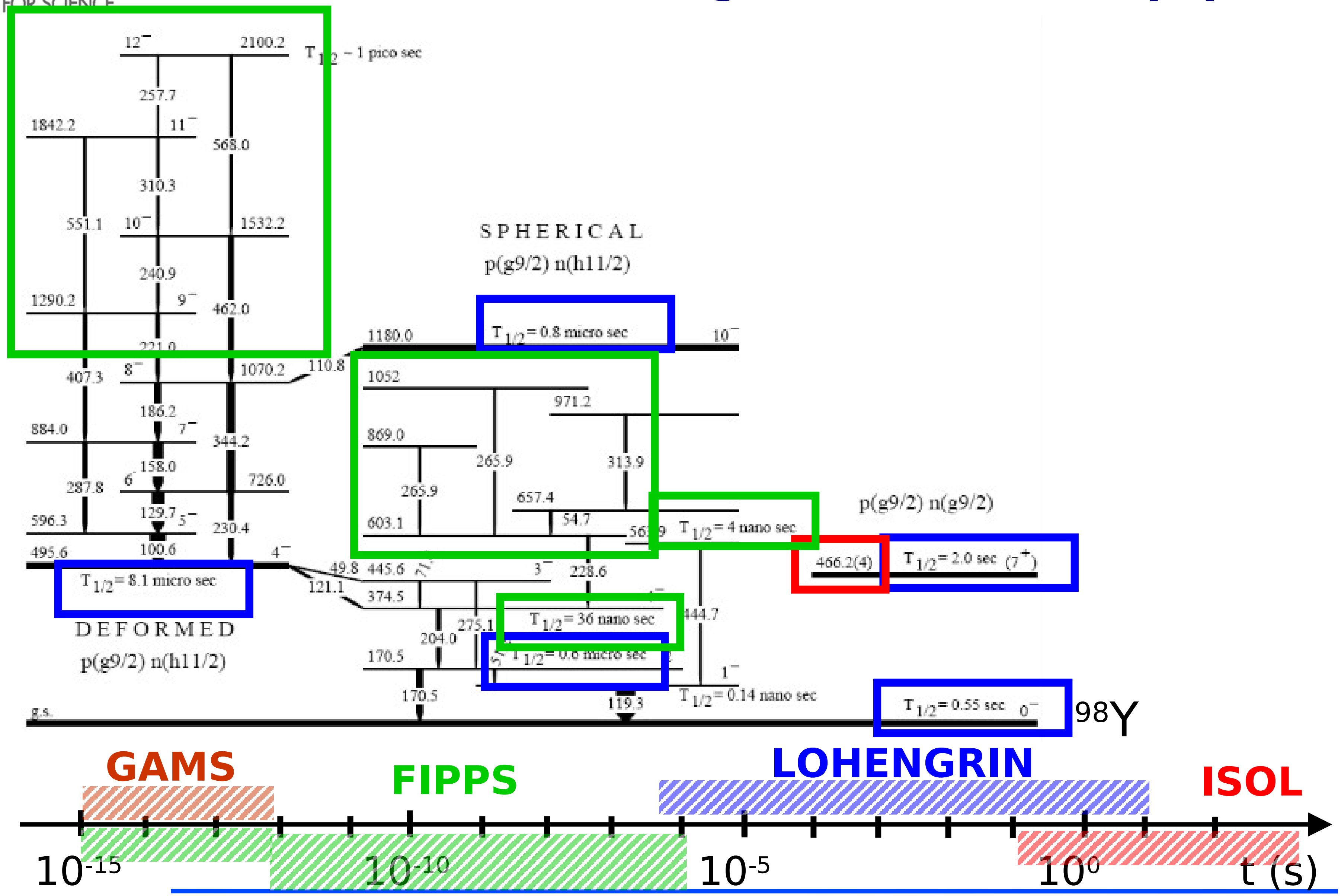
Nuclear Physics at ILL (2)



Nuclear Physics at ILL (2)



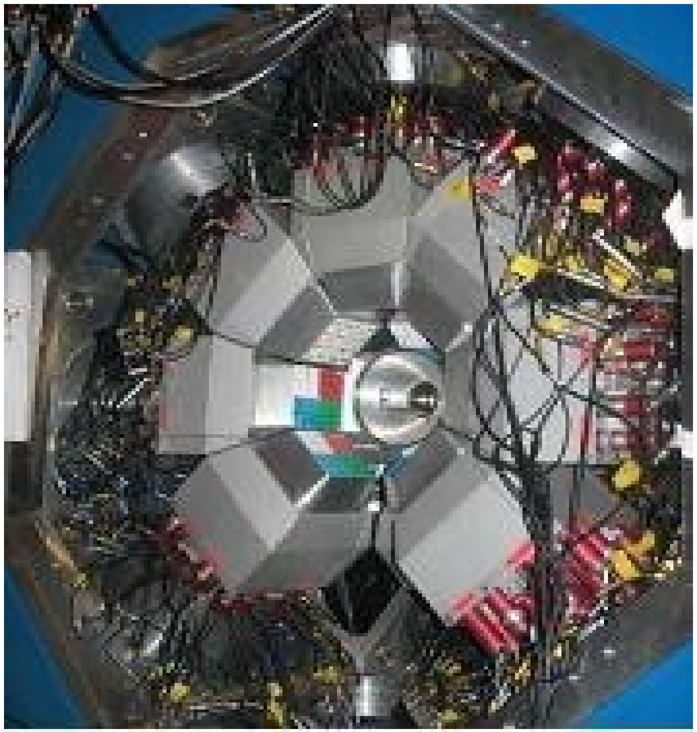
Nuclear Physics at ILL (2)



EXILL

- **Motivation**
- Setup
- Peformances

EXogam @ ILL



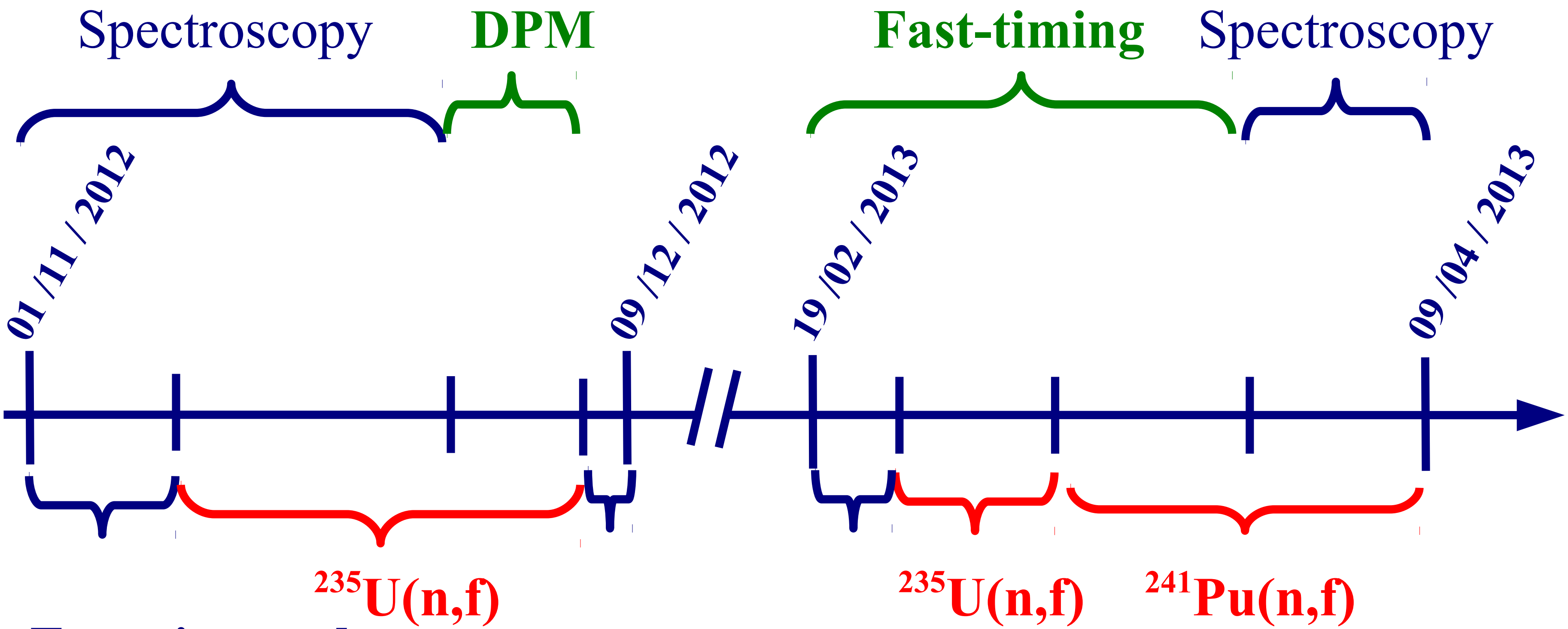
High efficiency germanium array

58 MW high flux reactor with intense extracted neutron beams

=> γ-ray spectroscopy of cold neutron induced reactions

The EXILL campaign

- The EXILL campaign spread other 2 reactor cycles (~100 days)

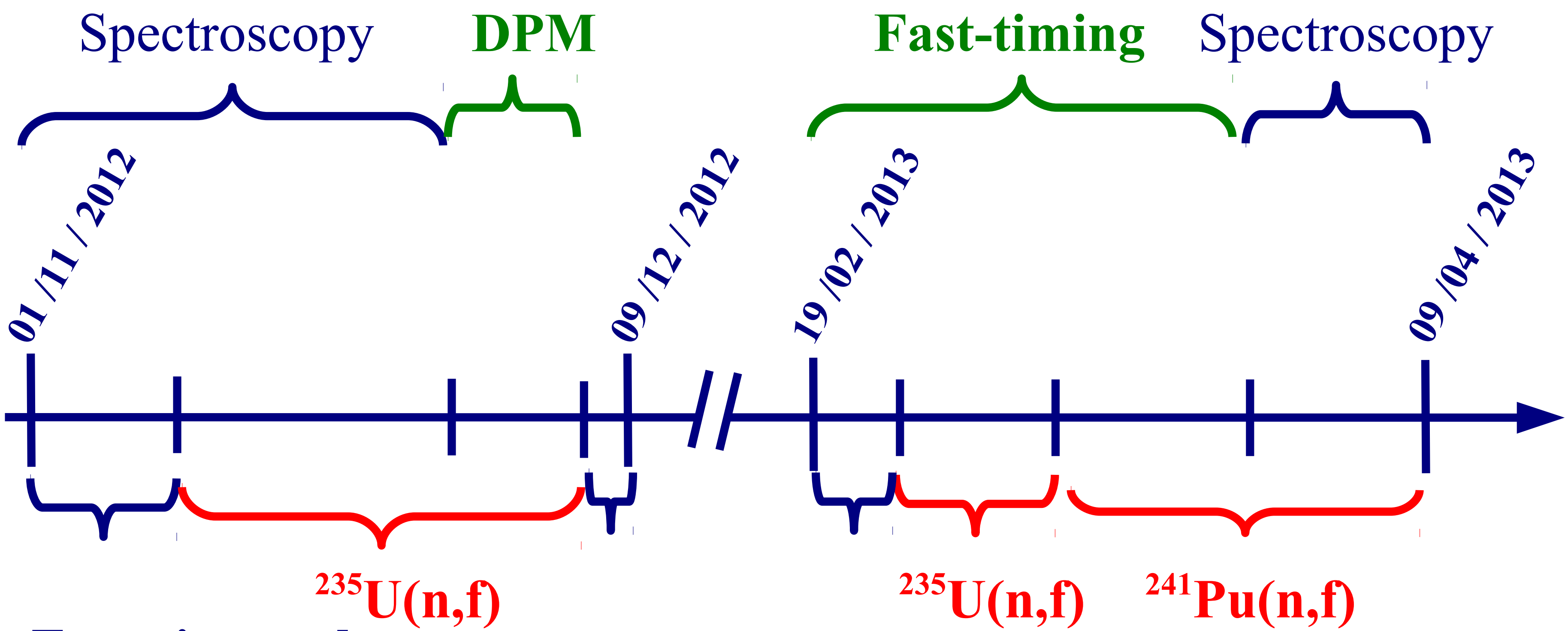


Experimental program:

- Prompt spectroscopy of fission products
- Lifetime measurements via Doppler broadening (τ < 100fs)
- (n,γ)
- Lifetime measurements using fast timing (τ < 5ps)

The EXILL campaign

- The EXILL campaign spread other 2 reactor cycles (~100 days)

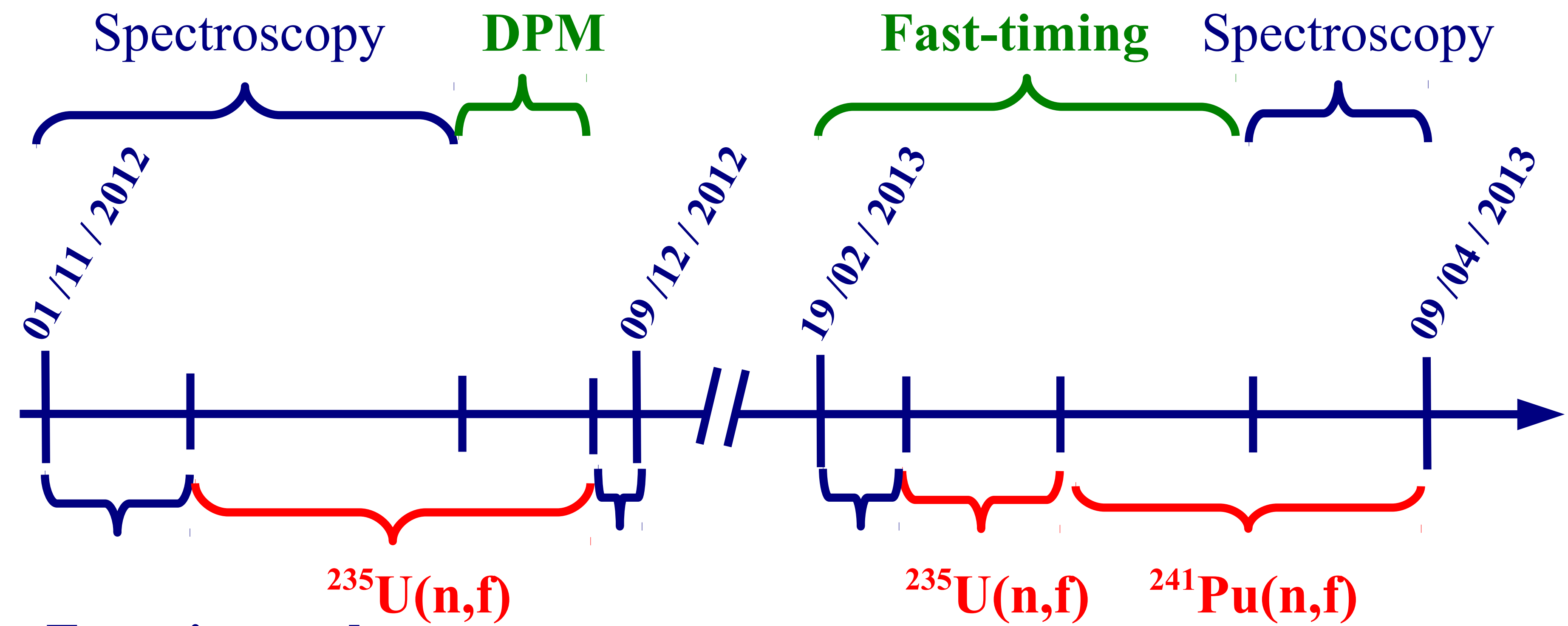


<u>Experimental program:</u>

- Prompt spectroscopy of fission products
- Lifetime measurements via Doppler broadening ($\tau < 100$fs)
- (n,γ) → **J. Jolie talk**
- Lifetime measurements using fast timing ($\tau < 5$ps)

The EXILL campaign

- The EXILL campaign spread other 2 reactor cycles (~100 days)

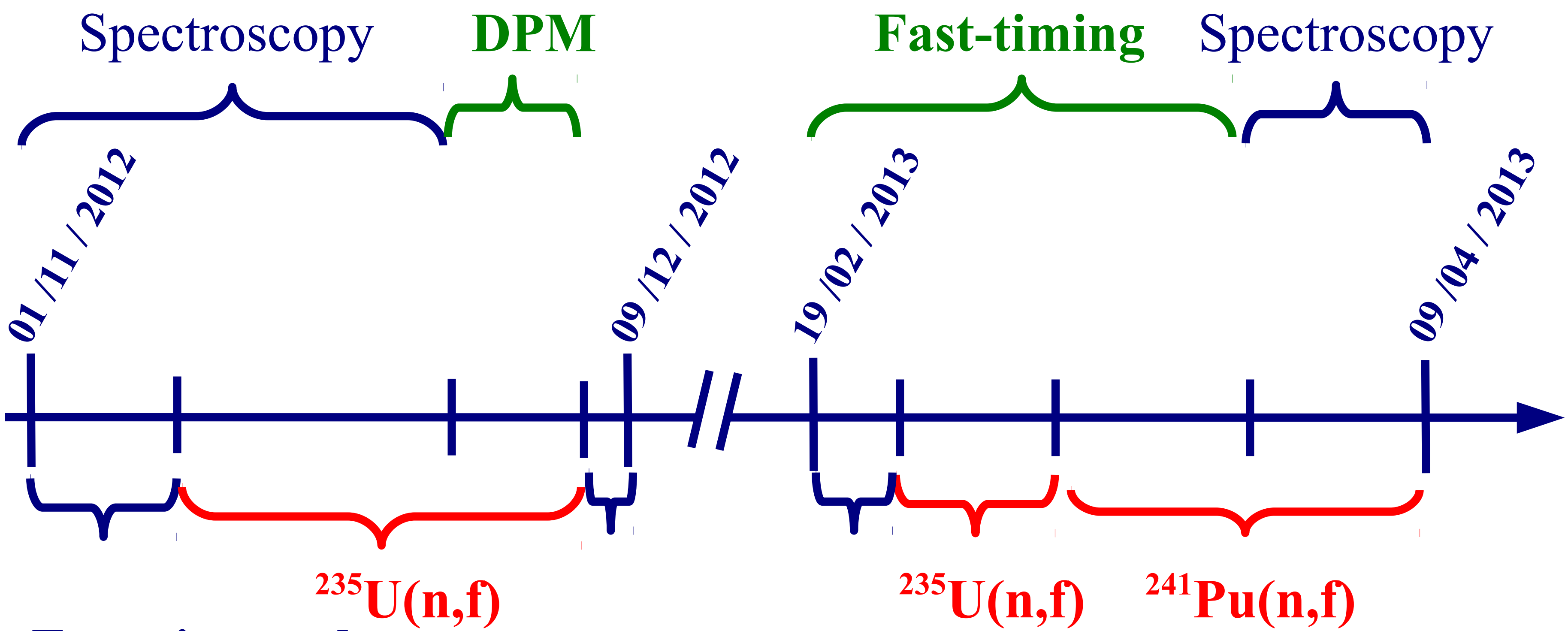


Experimental program:

- Prompt spectroscopy of fission products
- Lifetime measurements via Doppler broadening ($\tau < 100$fs)
- (n,γ) → **J. Jolie talk**
- Lifetime measurements using fast timing ($\tau < 5$ps) → **J-M. Regis talk**

The EXILL campaign

- The EXILL campaign spread other 2 reactor cycles (~100 days)

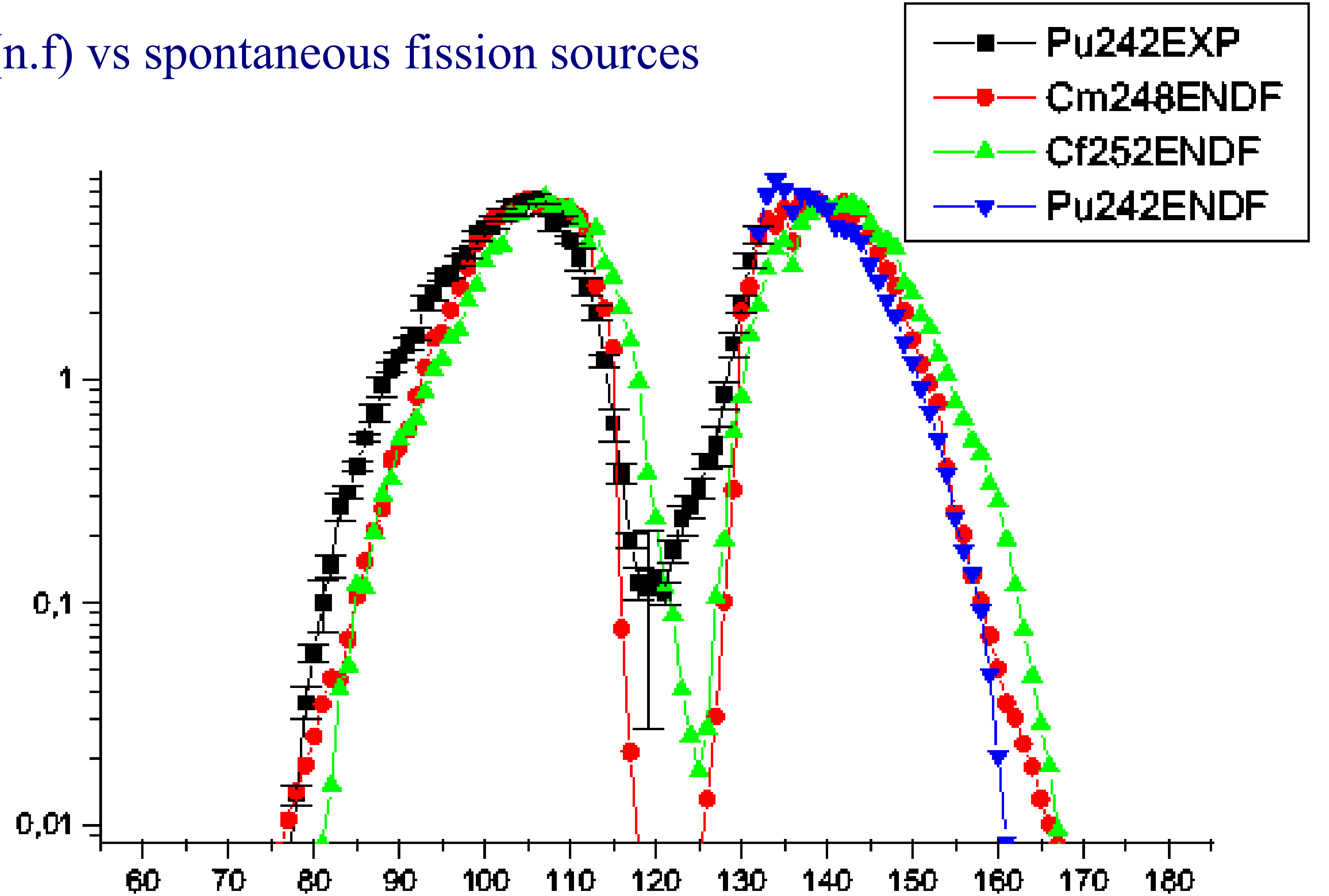


Experimental program:

- Prompt spectroscopy of fission products
- Lifetime measurements via Doppler broadening (τ < 100fs)
- (n,γ) → **J. Jolie talk**
- Lifetime measurements using fast timing (τ < 5ps) → **J-M. Regis talk**

^{241}Pu(n,fission)

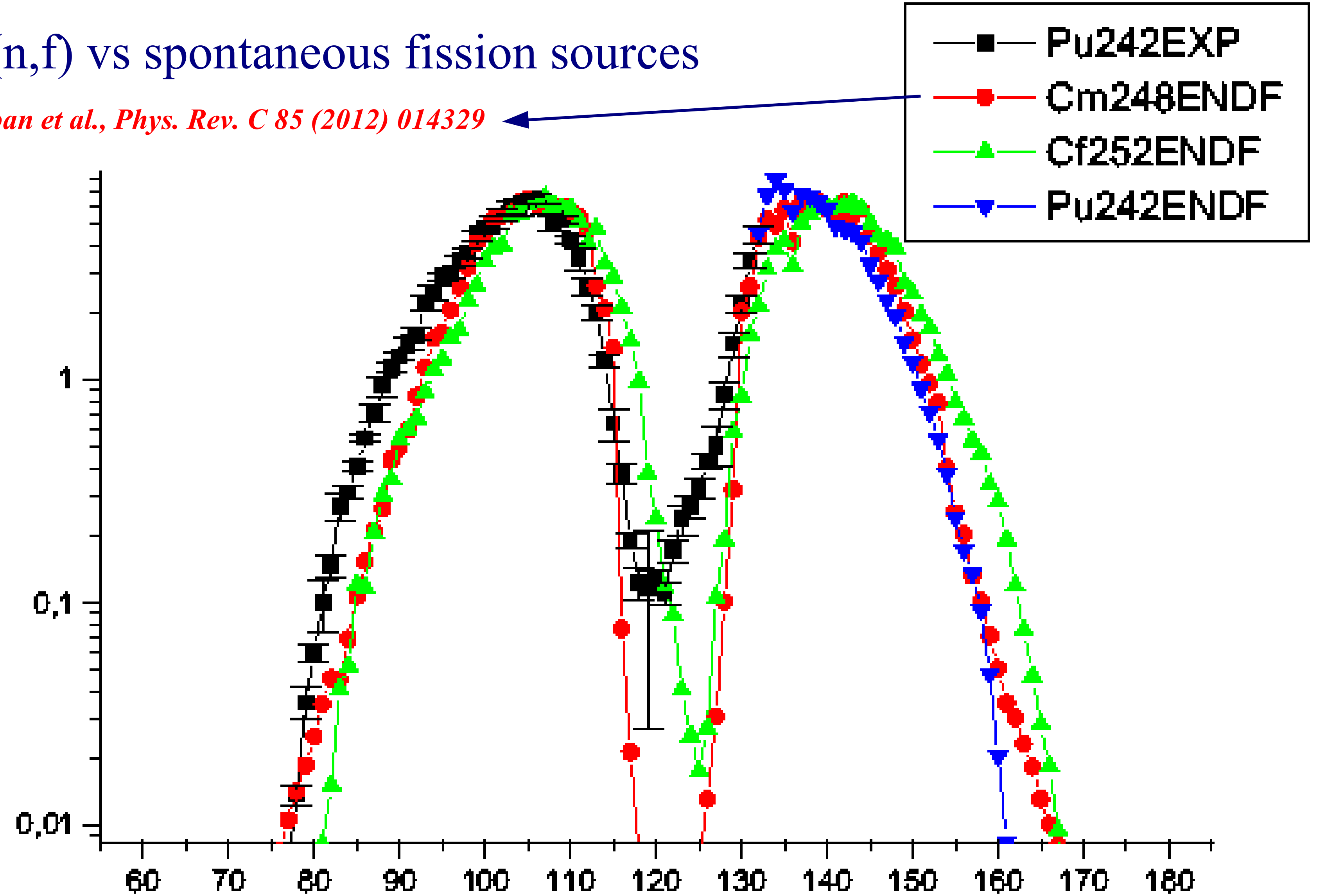
- ^{241}Pu(n.f) vs spontaneous fission sources



^{241}Pu(n,fission)

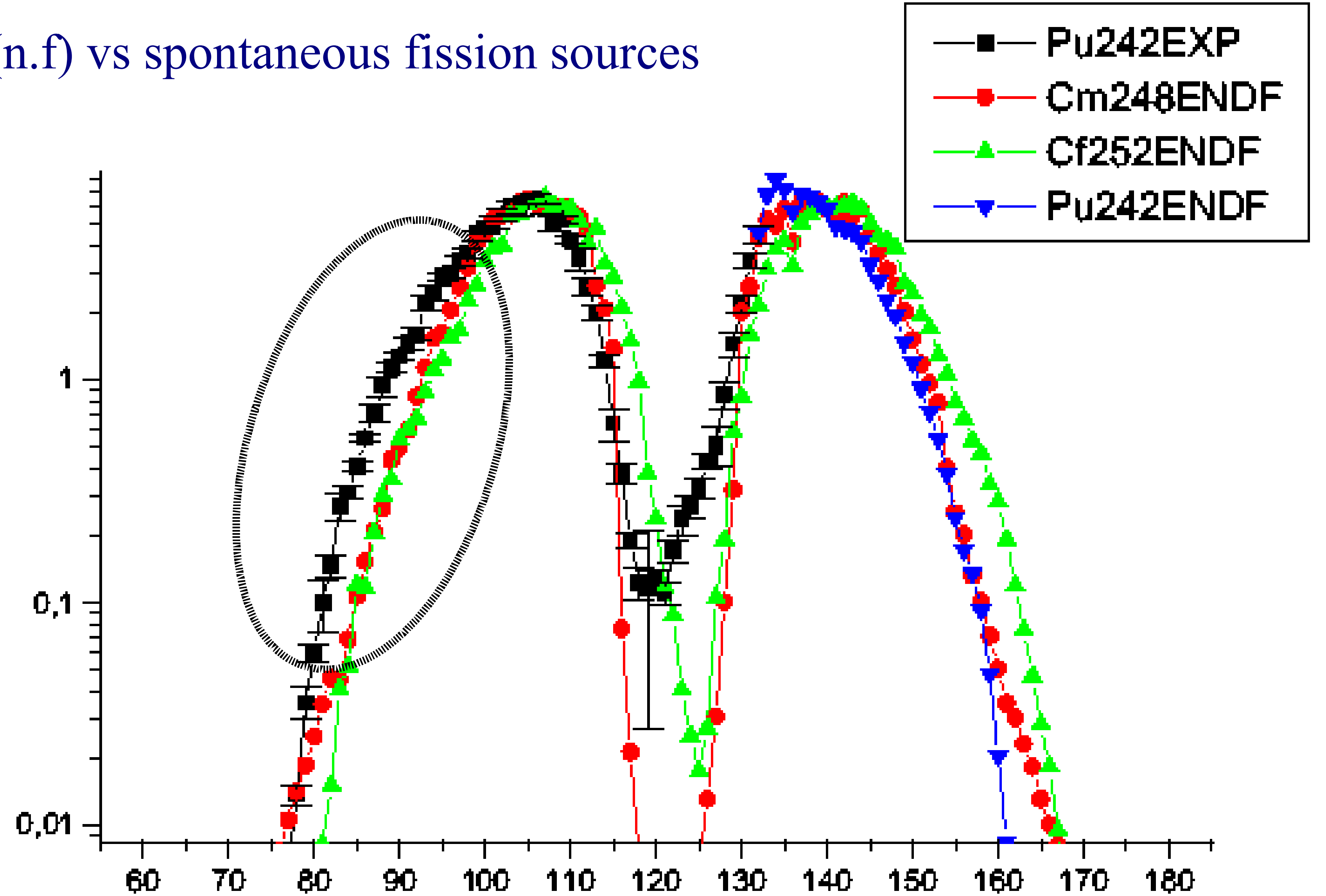
- ^{241}Pu(n,f) vs spontaneous fission sources

W. Urban et al., Phys. Rev. C 85 (2012) 014329



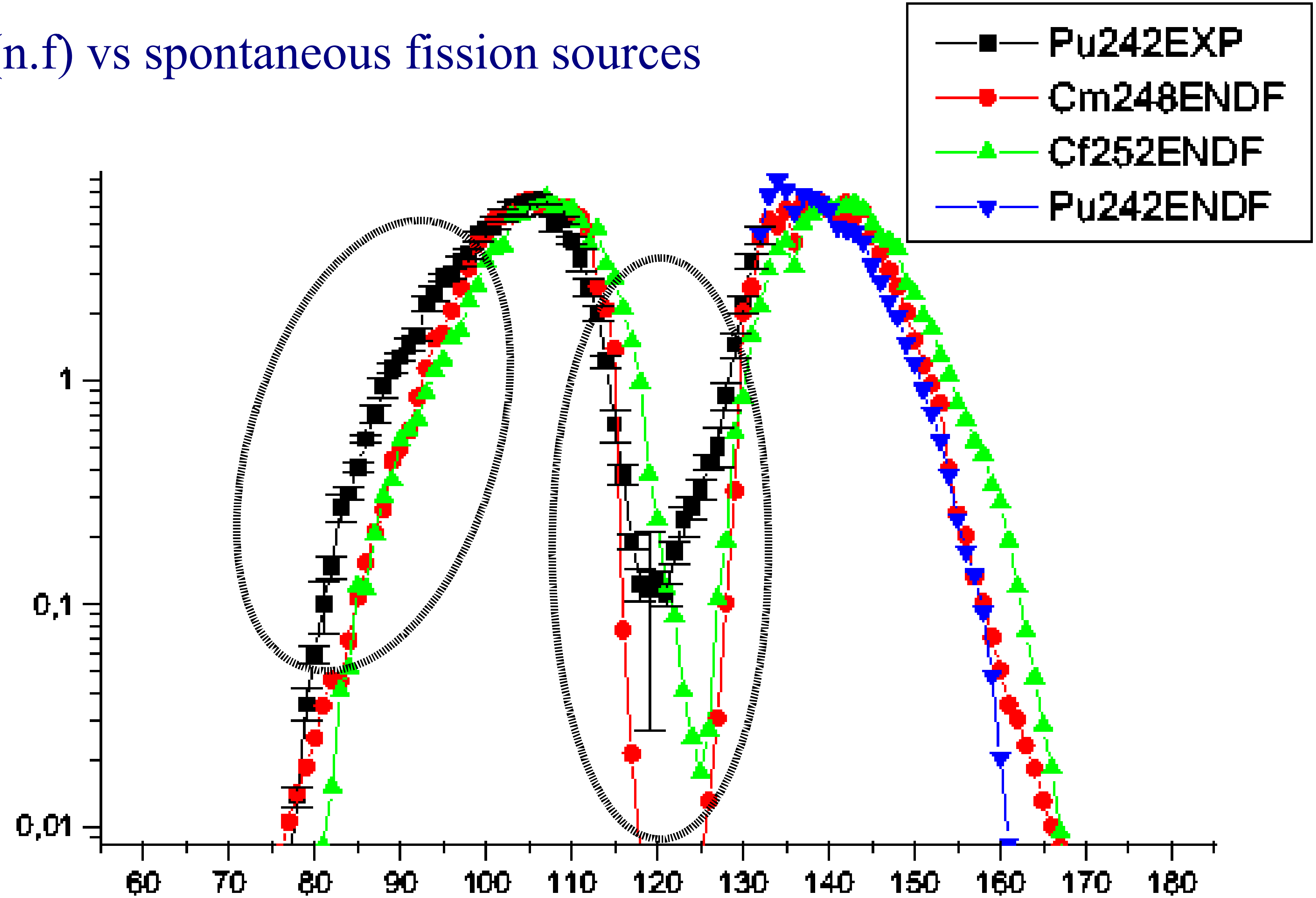
^{241}Pu(n,fission)

- ^{241}Pu(n.f) vs spontaneous fission sources



^{241}Pu(n,fission)

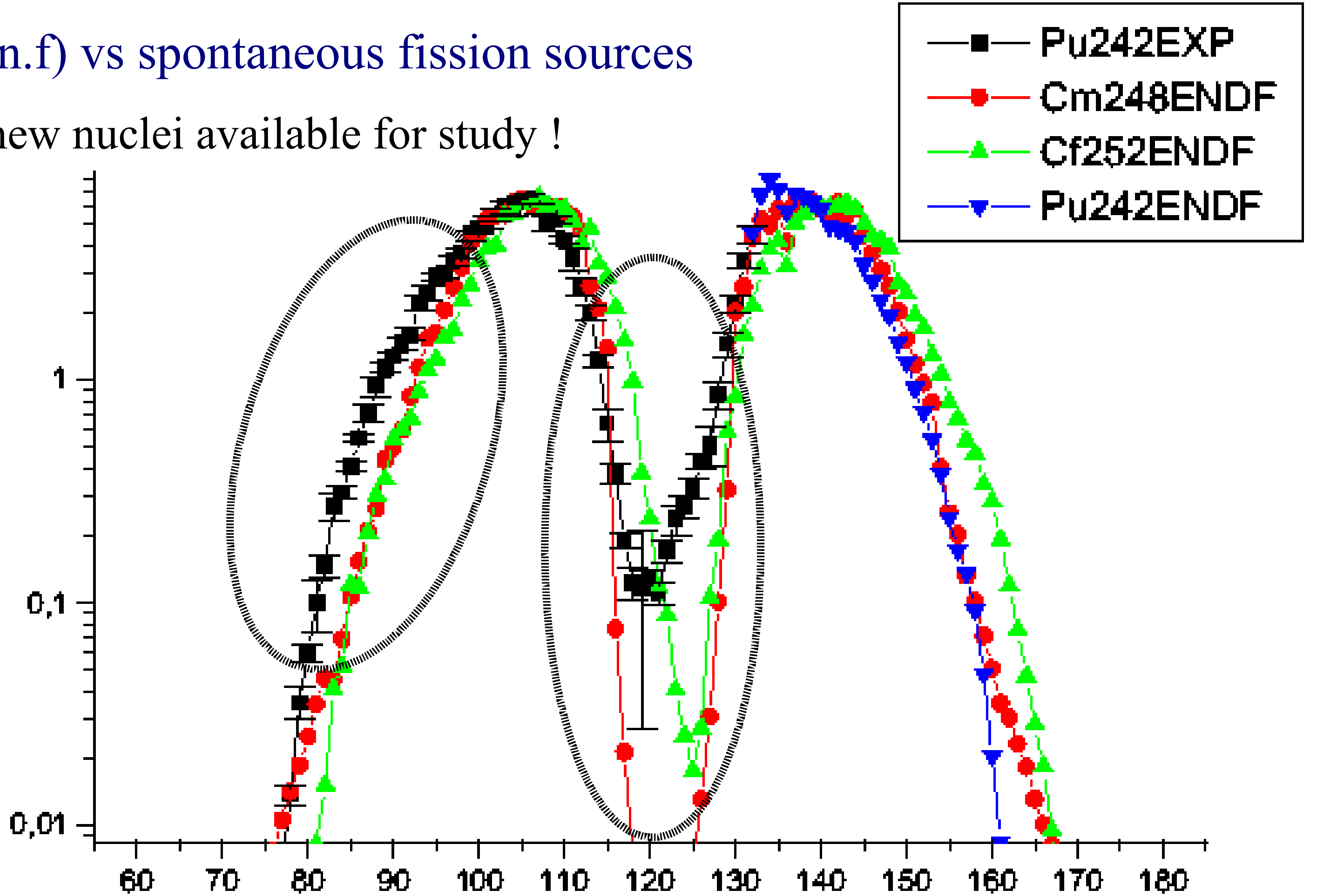
- ^{241}Pu(n.f) vs spontaneous fission sources



^{241}Pu(n,fission)

- ^{241}Pu(n.f) vs spontaneous fission sources

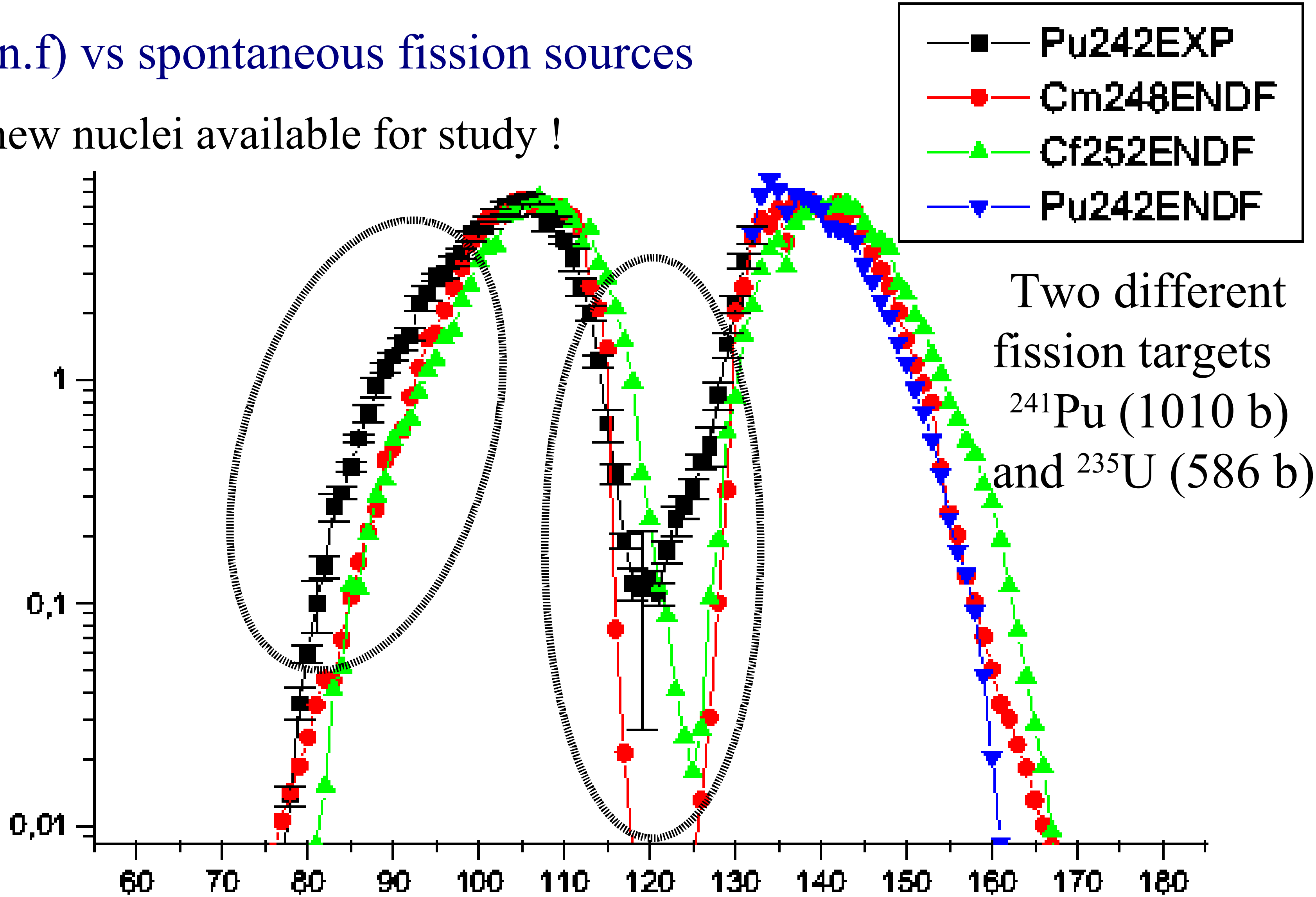
~30 new nuclei available for study !



^{241}Pu(n,fission)

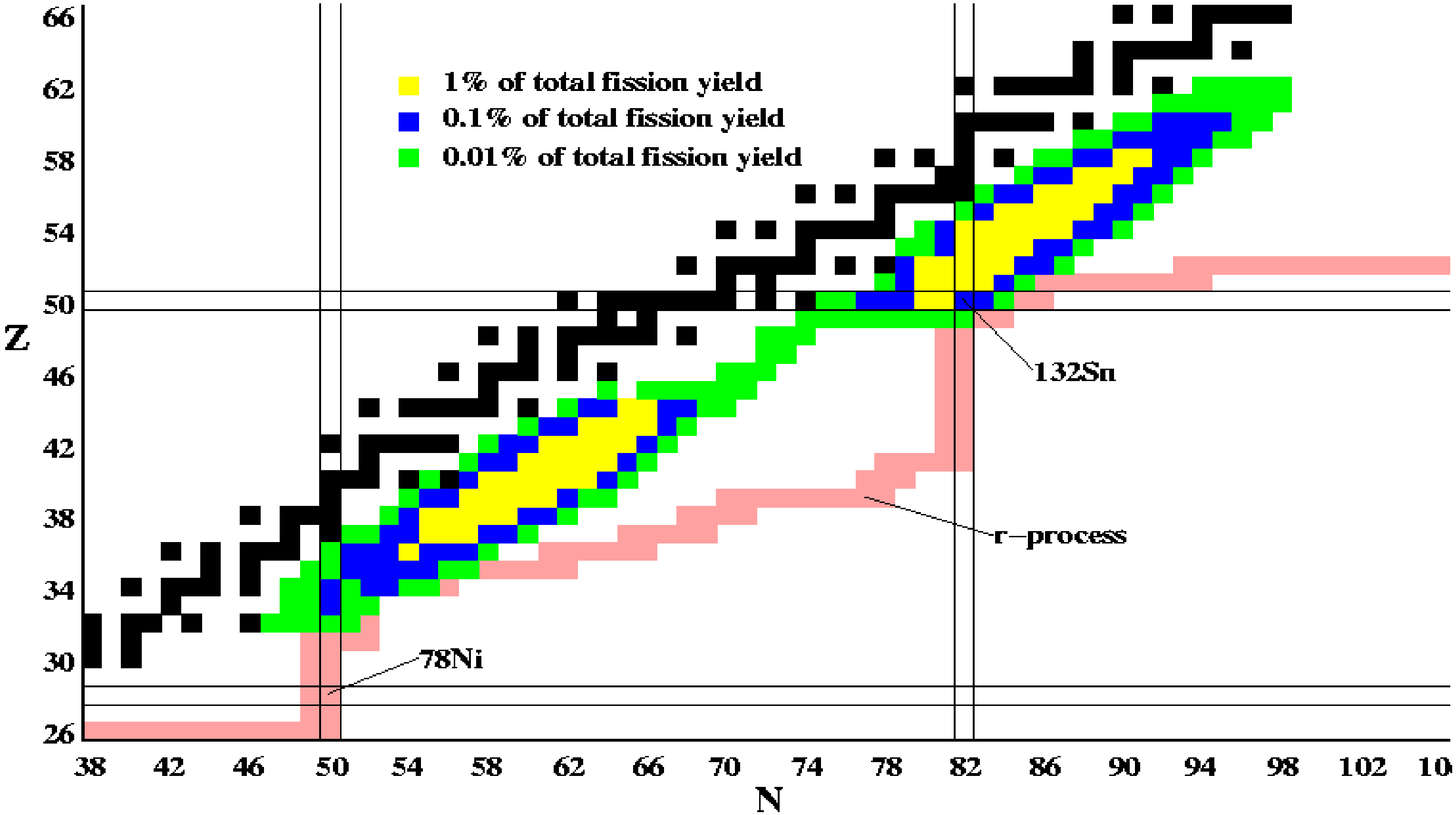
- ^{241}Pu(n.f) vs spontaneous fission sources

~30 new nuclei available for study !

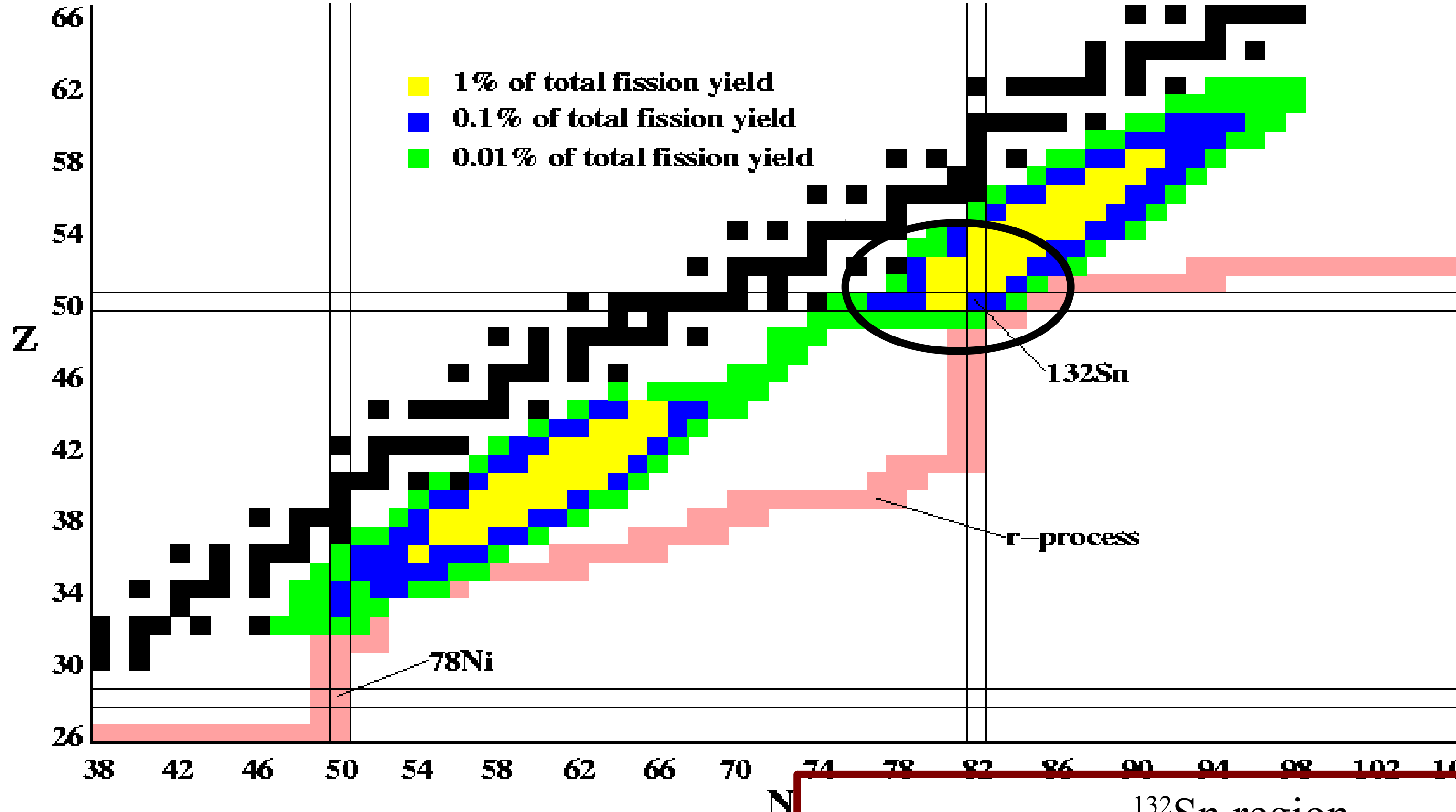


Two different fission targets ^{241}Pu (1010 b) and ^{235}U (586 b)

^{241}Pu(n,fission)



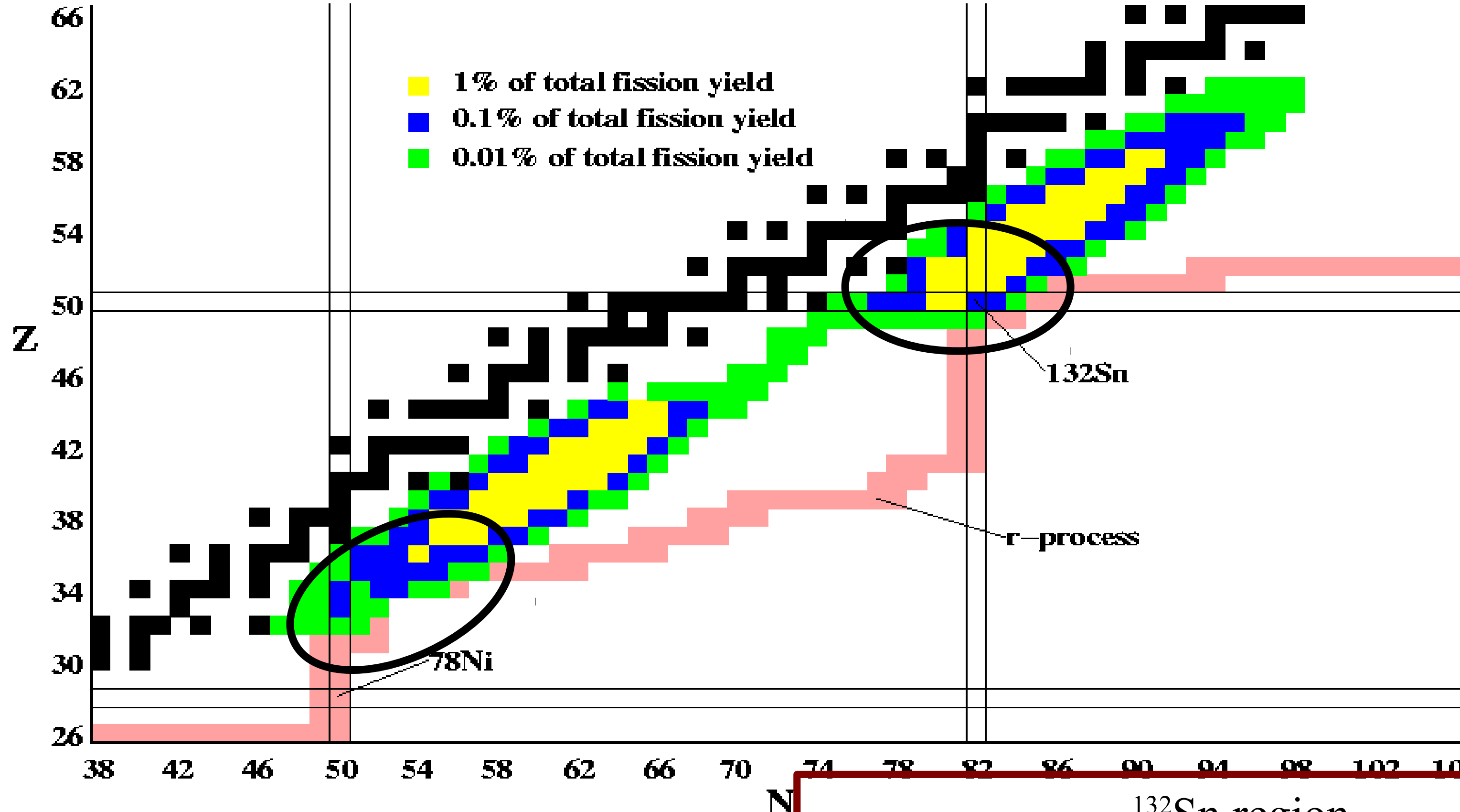
^{241}Pu(n,fission)



<u>^{132}Sn region</u>

Nuclei have a simple structure -good for testing the shell model far from stability. Shell model calculations work quite well for In nuclei close to ^{132}Sn -but less well away from it.

^{241}Pu(n,fission)



<u>Mass 85 region</u>

See properties of nuclei close to ^{78}Ni (r-process nuclei).
Few orbits play important roles in deformation

<u>^{132}Sn region</u>

Nuclei have a simple structure -good for testing the shell model far from stability.
Shell model calculations work quite well for In nuclei close to ^{132}Sn -but less well away from it.

NEUTRONS FOR SCIENCE

EXILL

- Motivation
- **Setup**
- Performances

EXILL

- EXILL requirements:
  - EXOGAM clovers + HPGe detectors
  - Well collimated neutron beam
  - Target environment allowing (n,f) of ^{235}U and ^{241}Pu
  - Trigger less acquisition system
  - Combination with scintillators for fast timing

EXILL

- EXILL requirements:
  - EXOGAM clovers + HPGe detectors
  - Well collimated neutron beam
  - Target environment allowing (n,f) of ^{235}U and ^{241}Pu
  - Trigger less acquisition system
  - Combination with scintillators for fast timing

EXILL

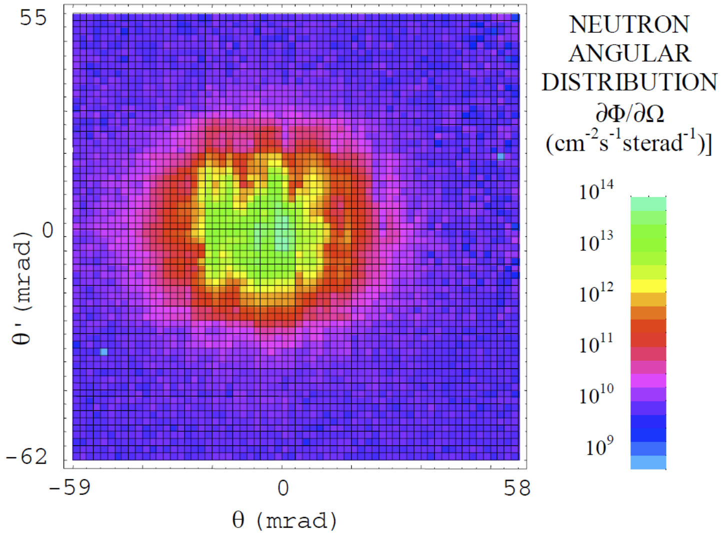
- EXILL requirements:
  - EXOGAM clovers + HPGe detectors
  - Well collimated neutron beam
  - Target environment allowing (n,f) of ^{235}U and ^{241}Pu
  - Trigger less acquisition system
  - Combination with scintillators for fast timing

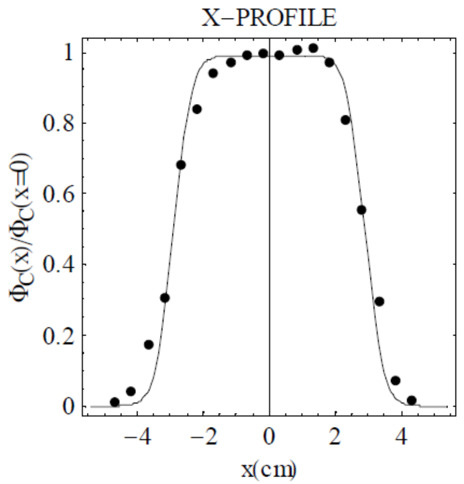
6 GASP detectors lent by LNL

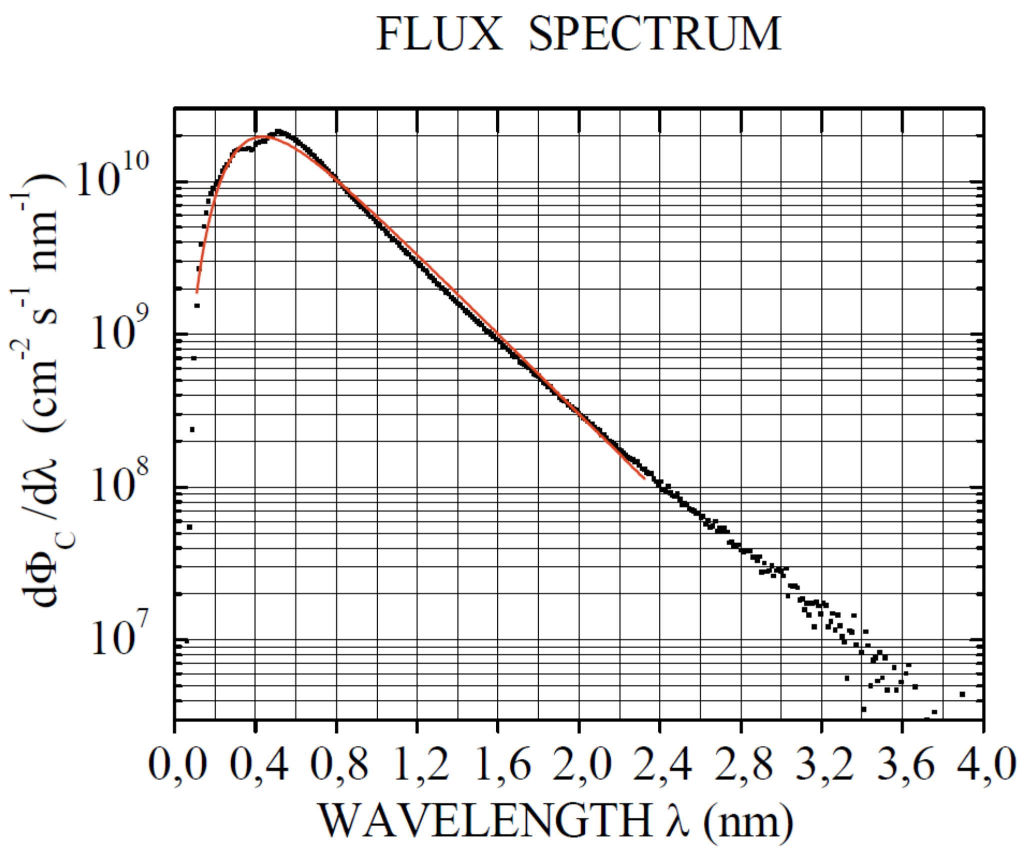
EXILL

- EXILL requirements:
  - EXOGAM clovers + HPGe detectors
  - Well collimated neutron beam
  - Target environment allowing (n,f) of ^{235}U and ^{241}Pu
  - Trigger less acquisition system
  - Combination with scintillators for fast timing

Ballistic neutron guide H113 @ PF1b

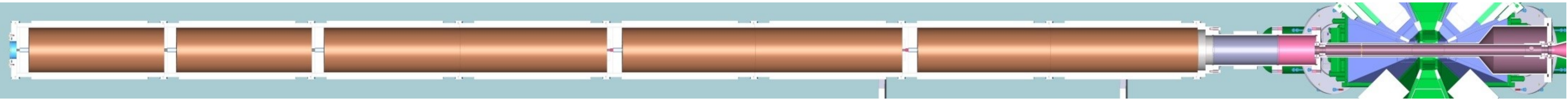




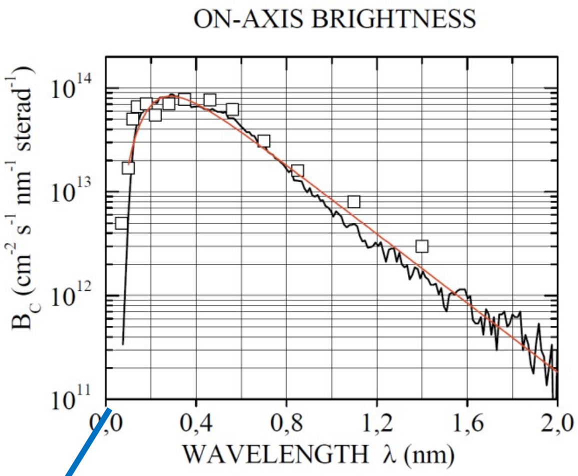


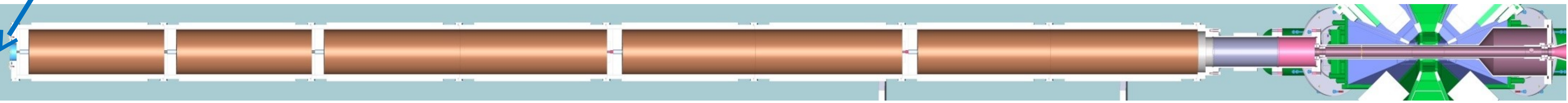
H. Abele et al., "Characterization of a ballistic supermirror neutron guide
arXiv: nucl-ex/0510072

Neutron collimation system

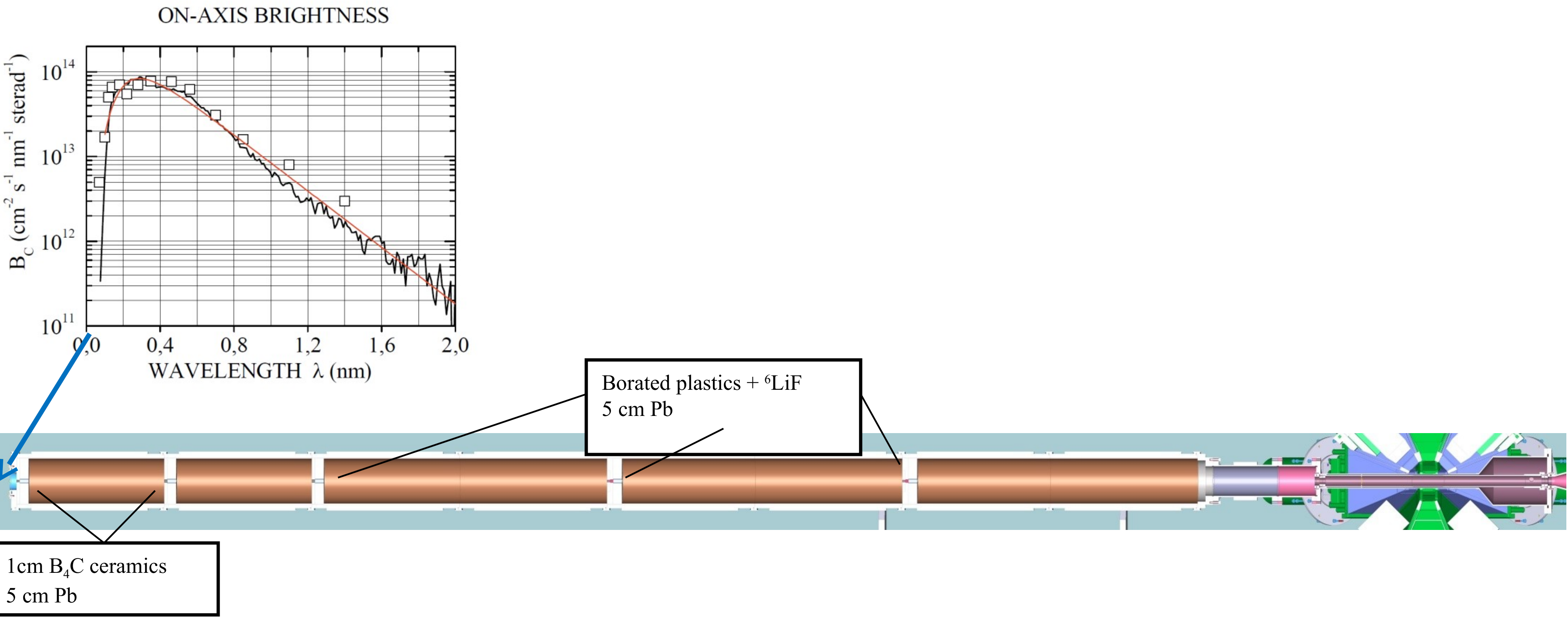


Neutron collimation system

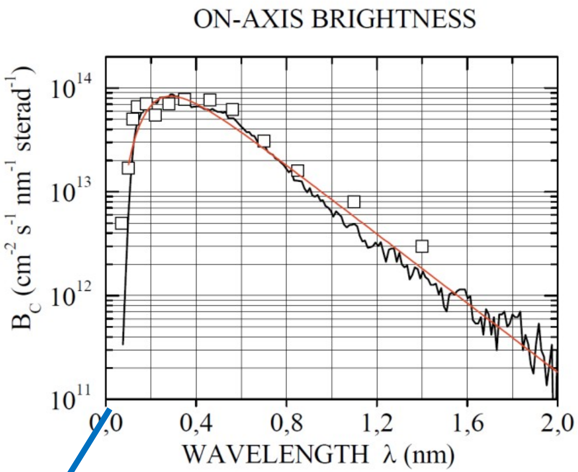


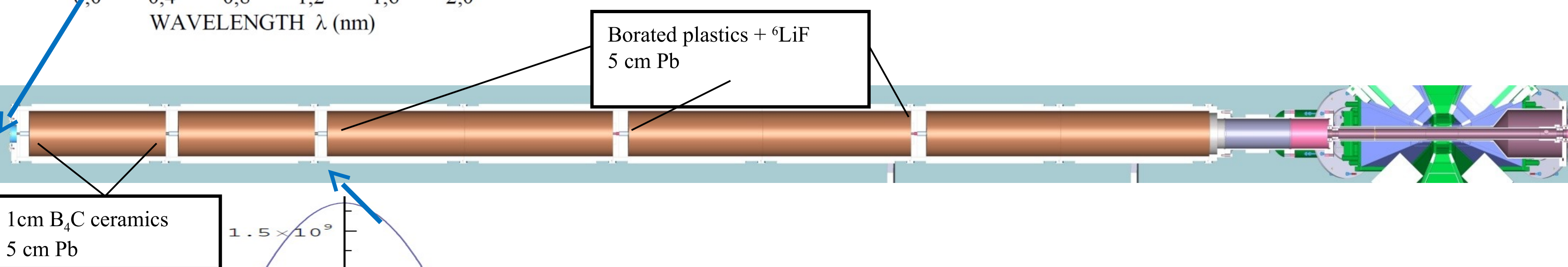


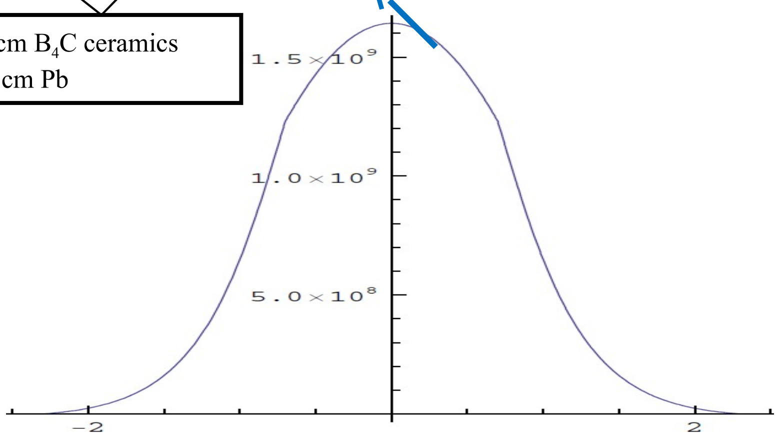
Neutron collimation system



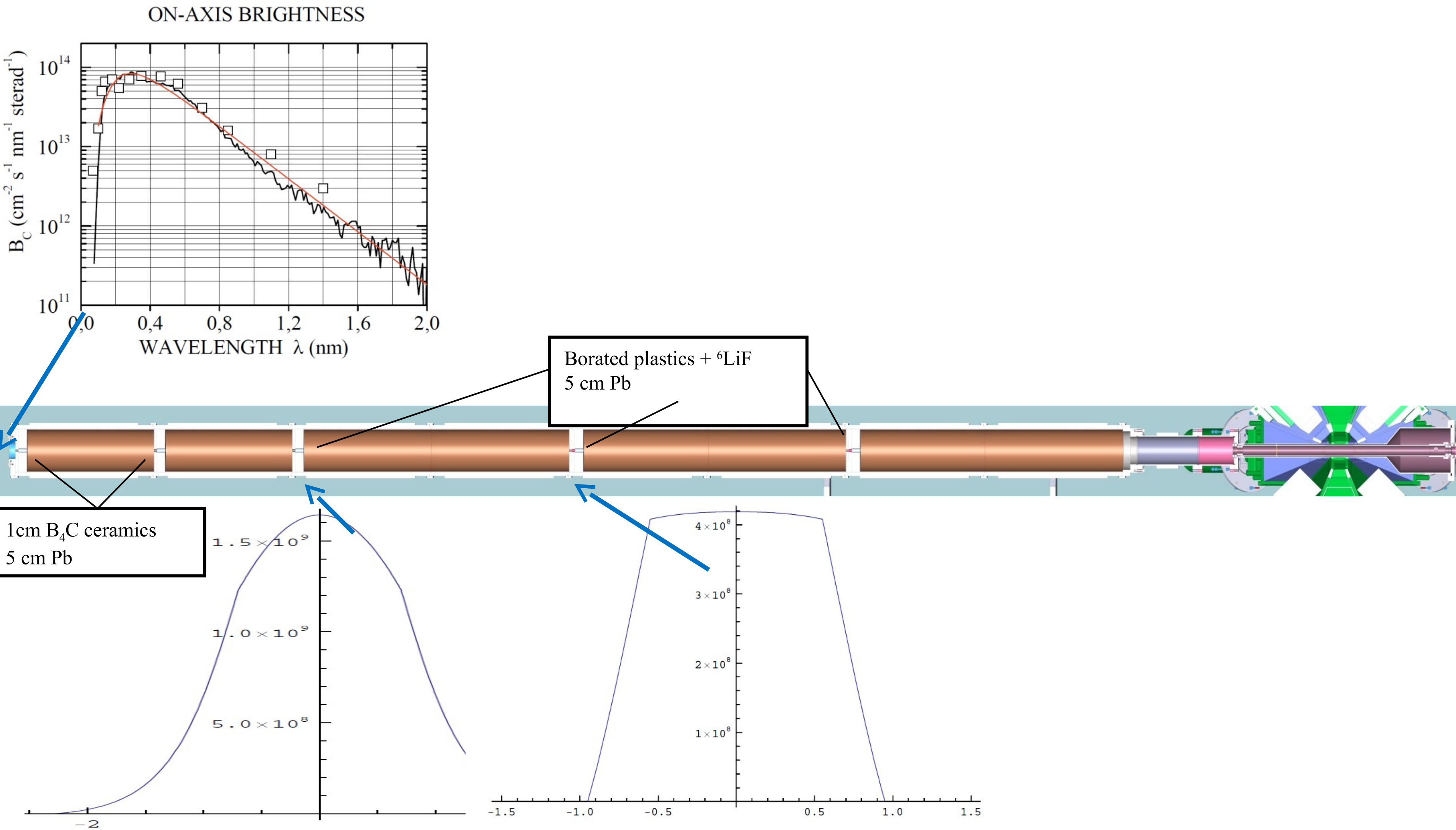
Neutron collimation system



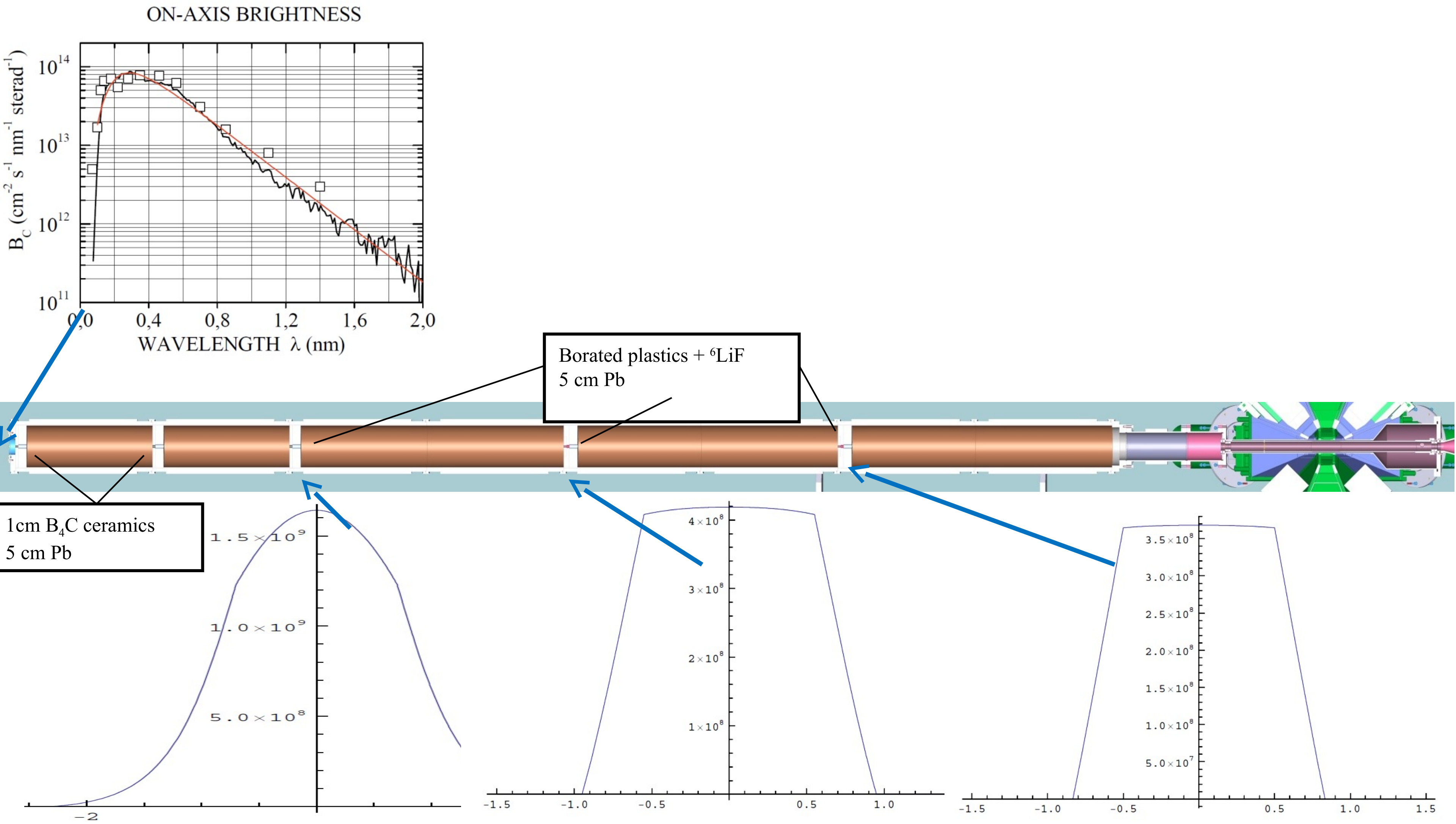




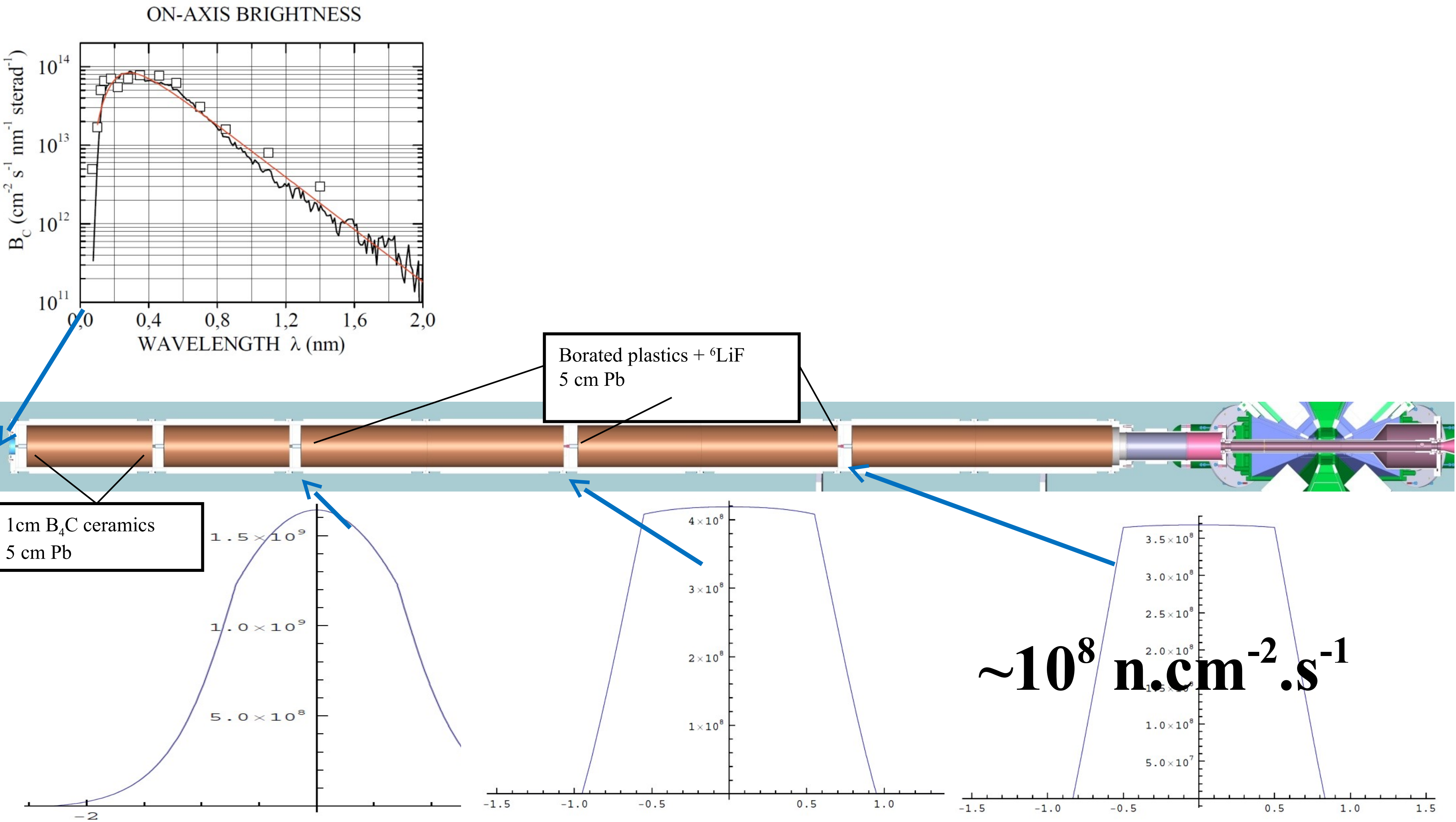
Neutron collimation system



Neutron collimation system

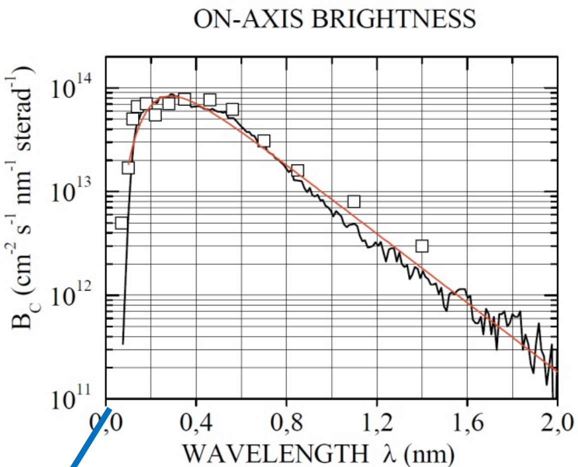


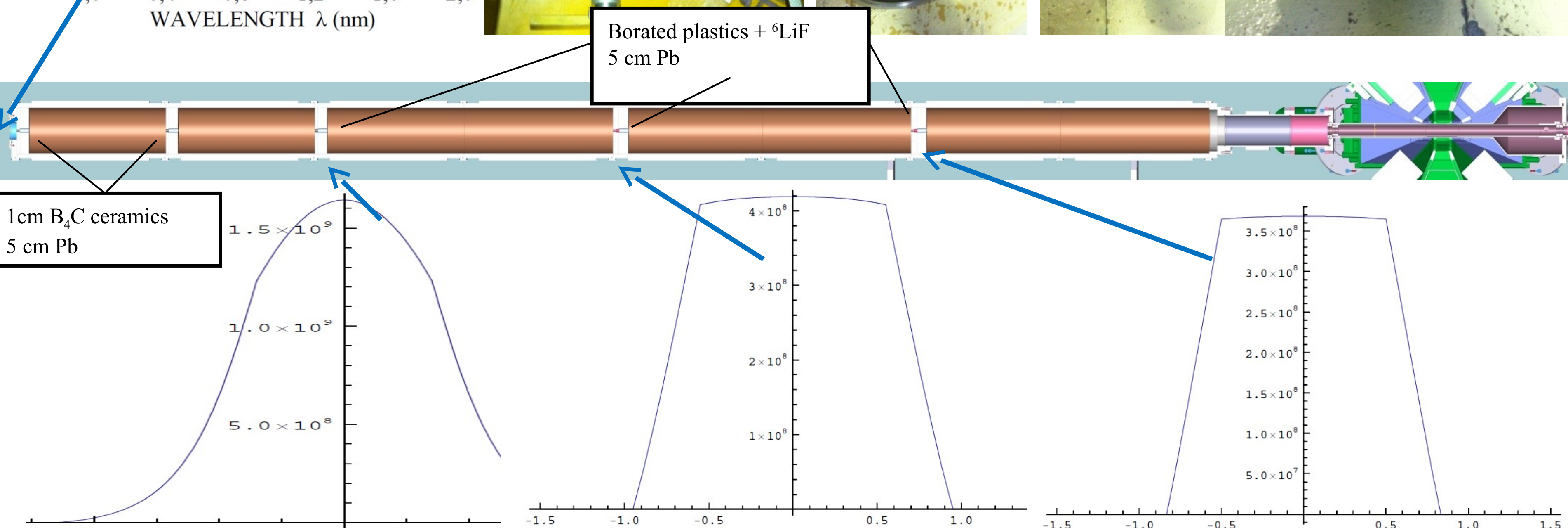
Neutron collimation system



~10^8 n.cm^{-2}.s^{-1}

Neutron collimation system

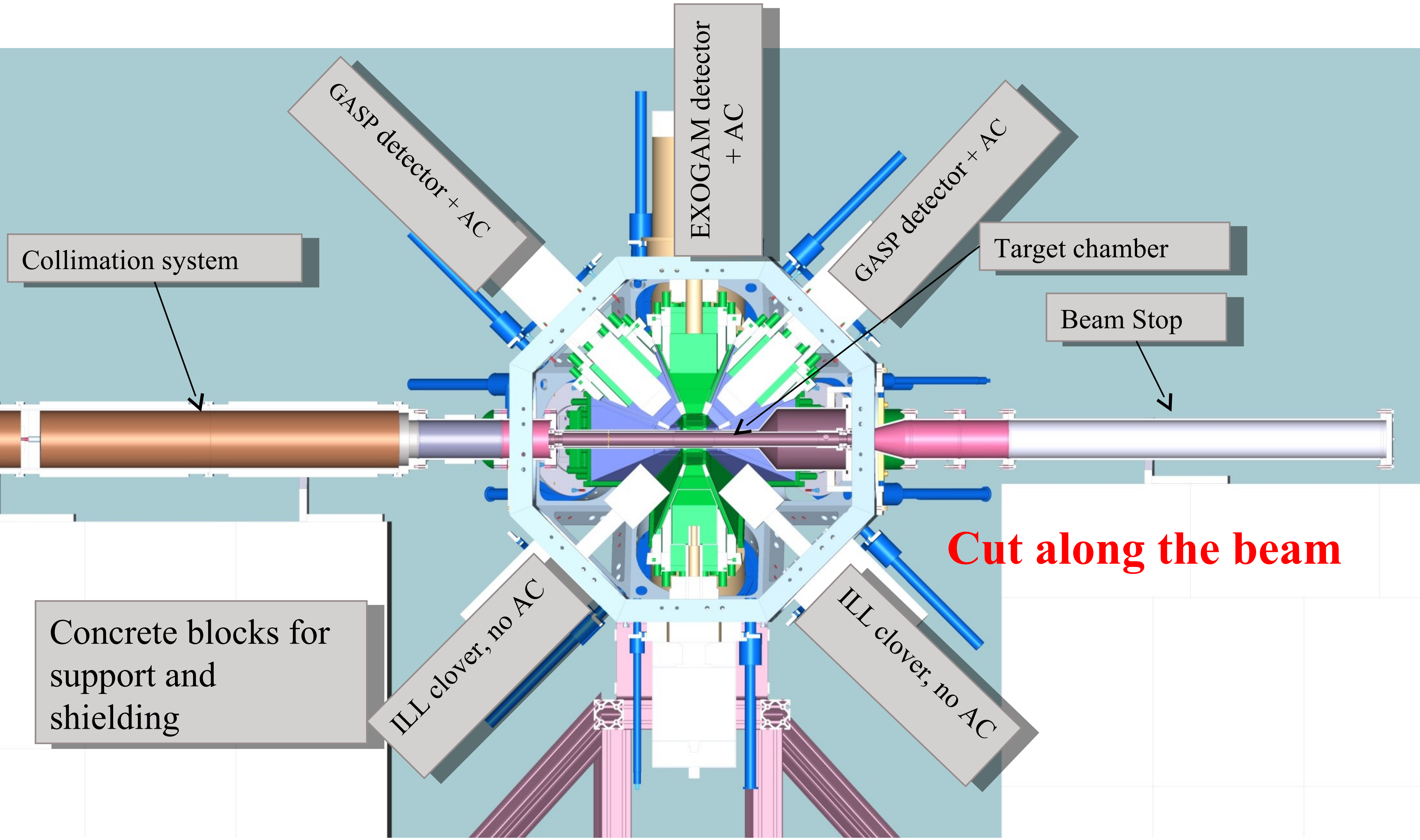




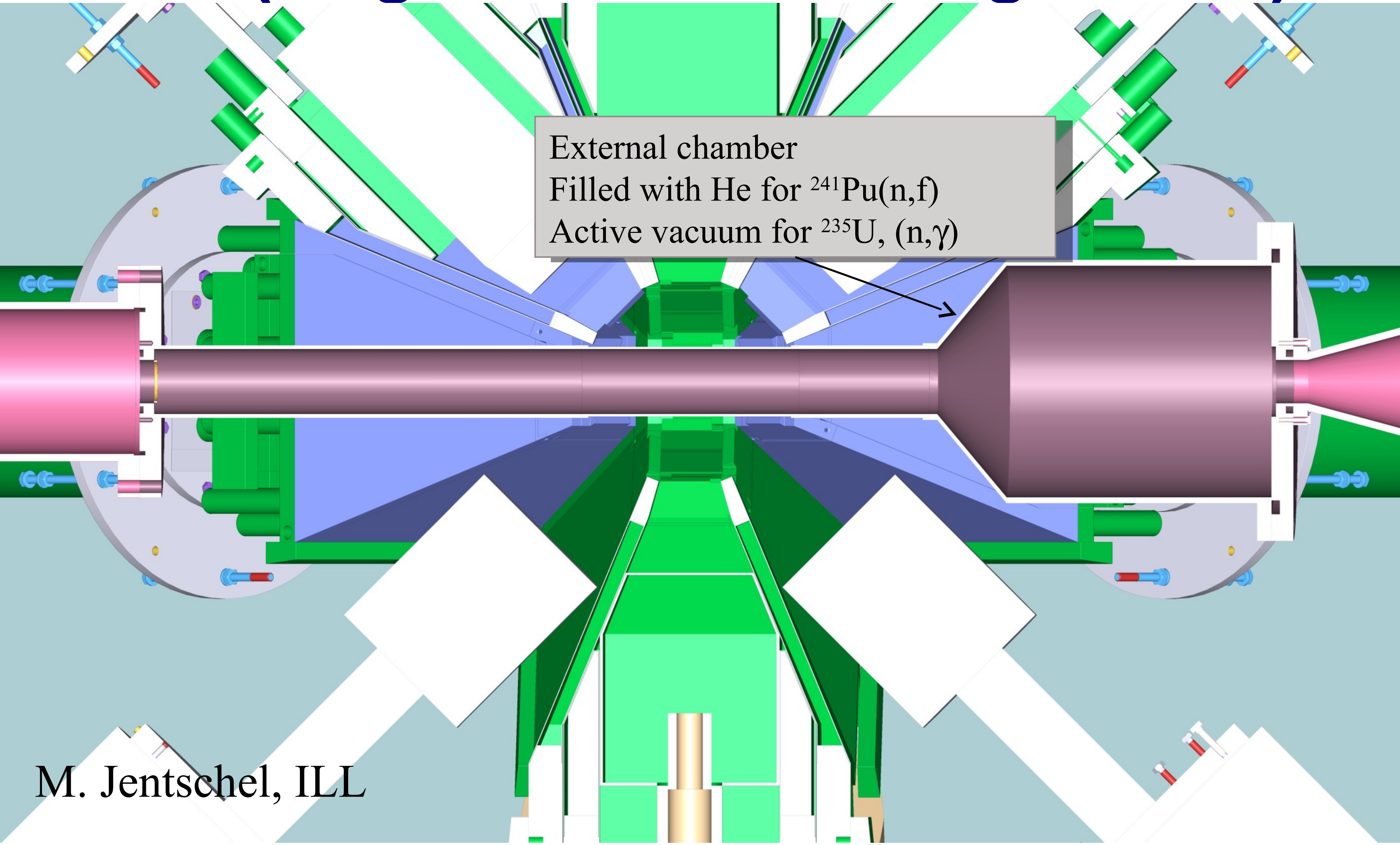
EXILL

- EXILL requirements:
  - EXOGAM clovers + HPGe detectors
  - Well collimated neutron beam
  - Target environment allowing (n,f) of ^{235}U and ^{241}Pu
  - Trigger less acquisition system
  - Combination with scintillators for fast timing

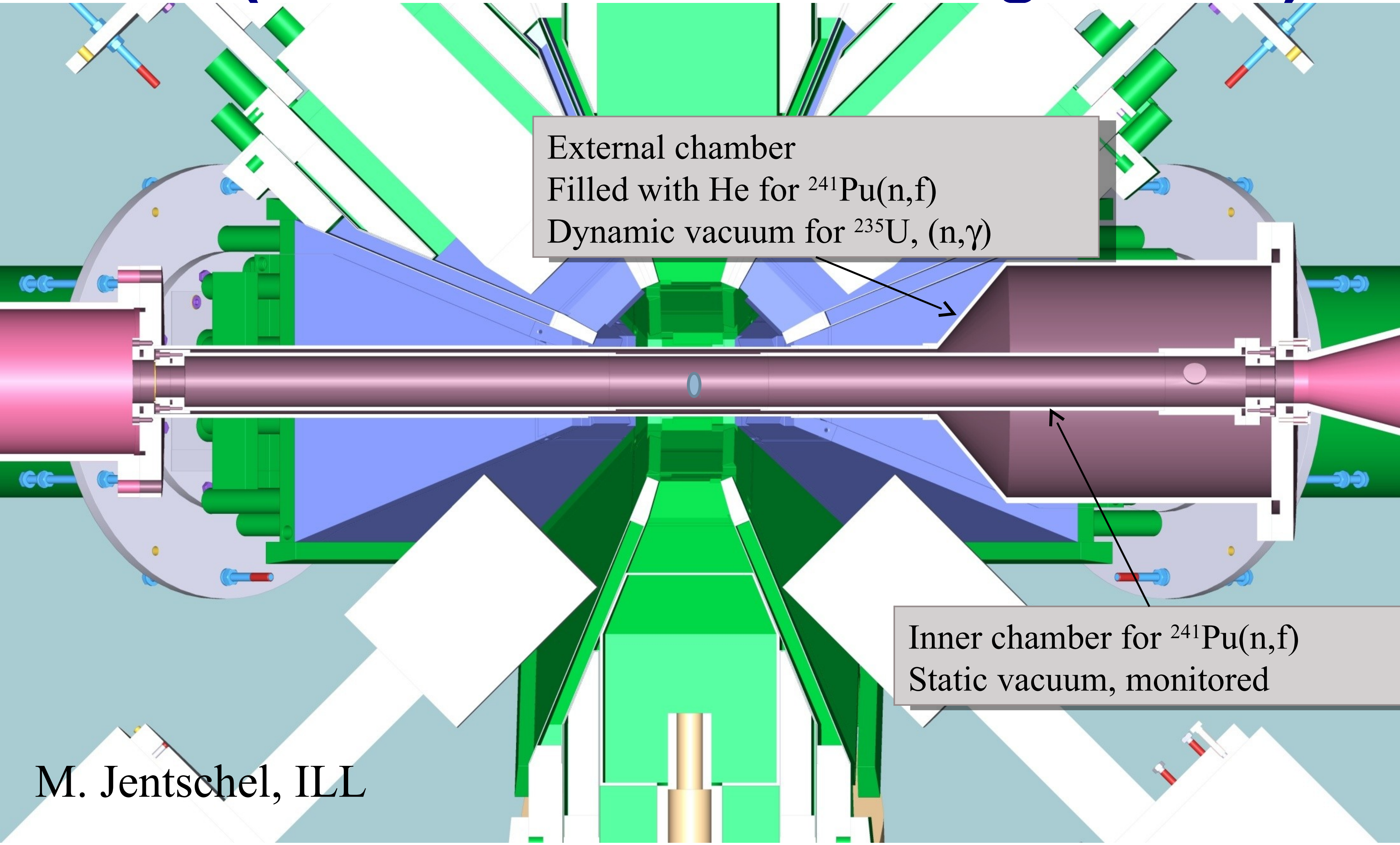
EXILL in PF1b experimental zone



EXILL target chamber (single chamber configuration)



EXILL target chamber (double chamber configuration)



M. Jentschel, ILL

Fission targets

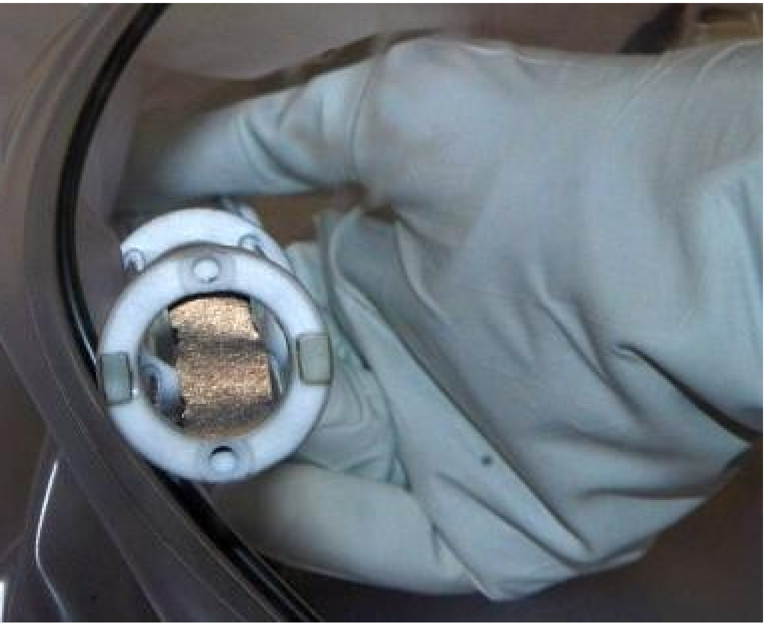
Targets **sandwiched between dense backings** for rapid stopping of fission fragments.

1. **^{235}U-Zr/Sn, nominal fission rate 70 kHz**
   3 layers UO_2 (total 575 μg/cm^2 of 99.7% enriched ^{235}U)
   laminated with Sn between 15 μm thick Zr foils (nuclear grade, <50 ppm Hf)

2. **^{235}U-Be, nominal fission rate 90 kHz**
   1 layer UO_2 (675 μg/cm^2 of 99.7% enriched ^{235}U)
   glued with thin layer of cyanoacrylate between 25 μm thick Be foils

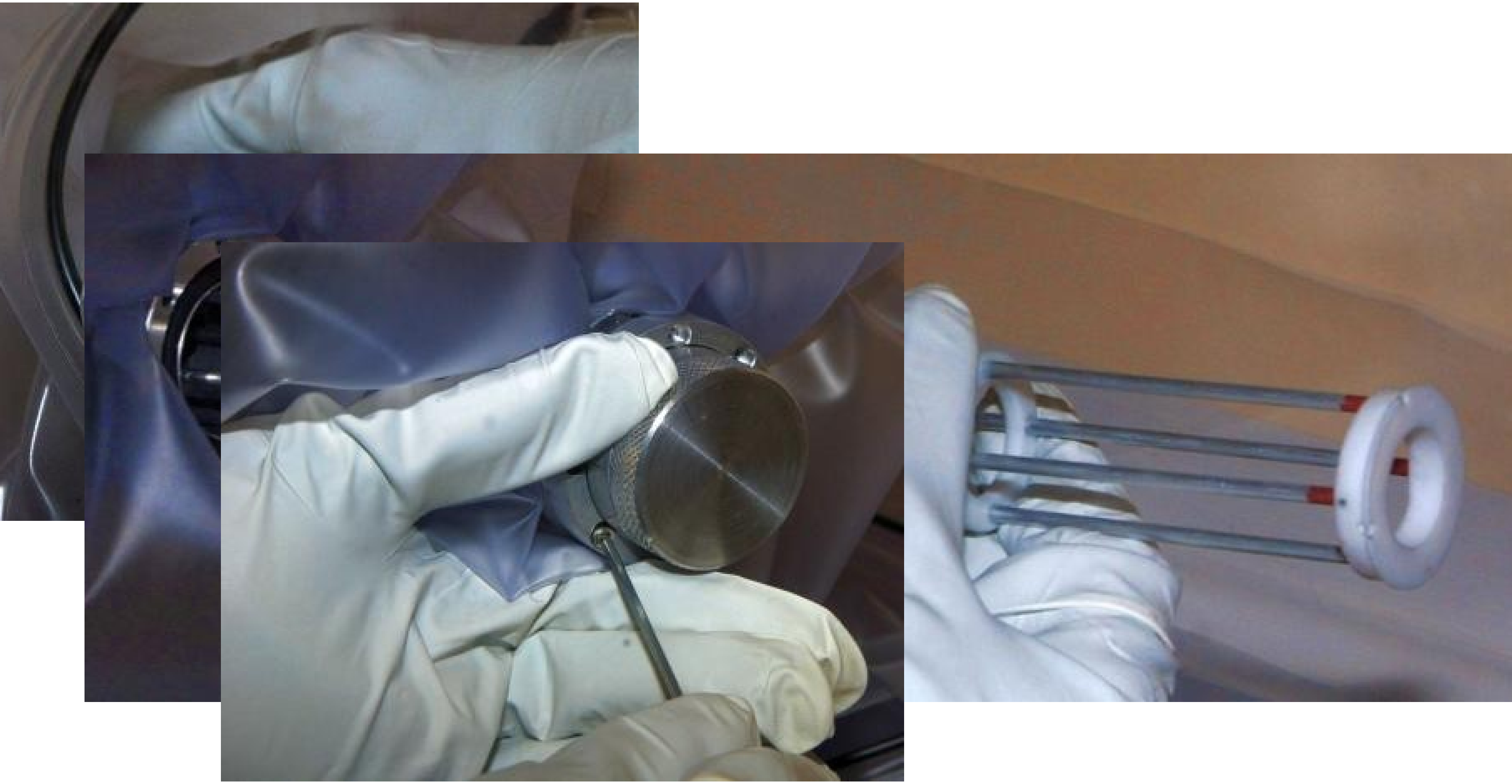
3. **^{241}Pu-Be, nominal fission rate 70 kHz**
   1 layer PuO_2 (300 μg/cm^2 of 78.6% ^{241}Pu, plus non-fissile ^{240}Pu and ^{242}Pu)
   glued with thin layer of cyanoacrylate between 25 μm thick Be foils
   - ^{241}Am daughter freshly separated and target prepared at Kernchemie Mainz

^{241}Pu target and its inner vacuum chamber



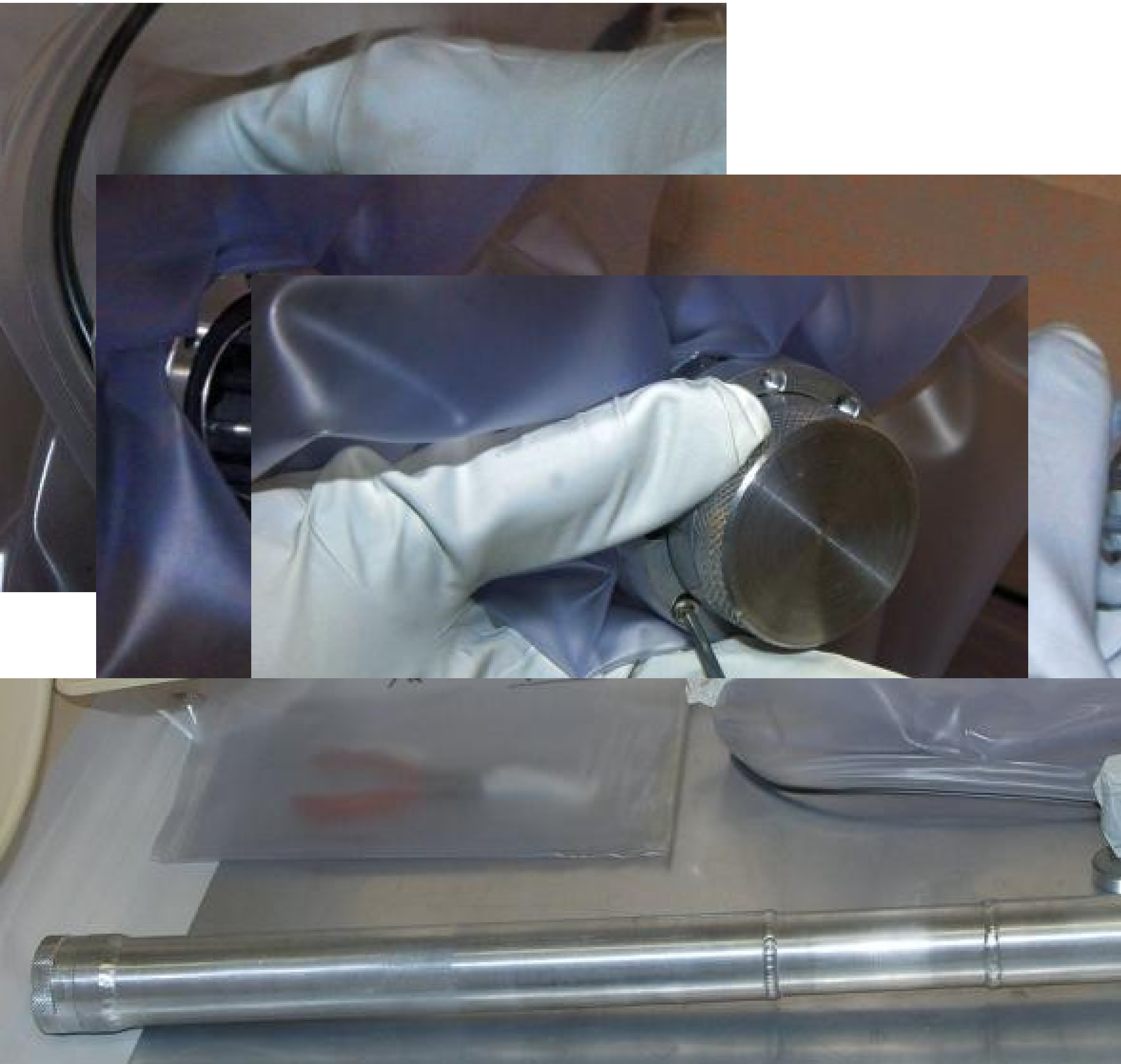
^{241}Pu target and its inner vacuum chamber

^{241}Pu target and its inner vacuum chamber



^{241}Pu target and its inner vacuum chamber

^{241}Pu target and its inner vacuum chamber

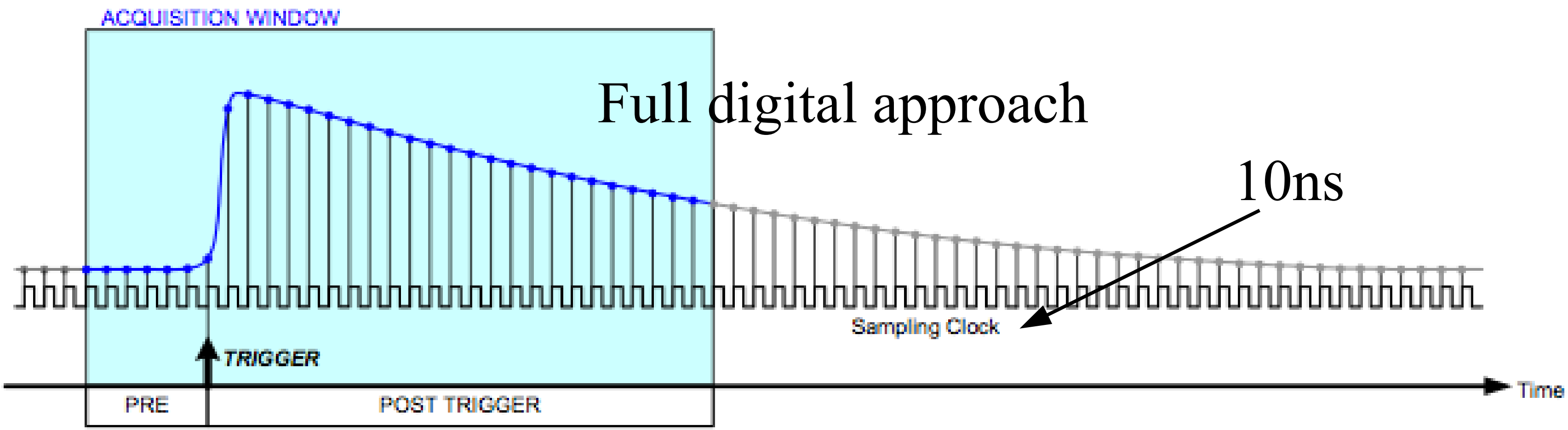


EXILL

- EXILL requirements:
  - EXOGAM clovers + HPGe detectors
  - Well collimated neutron beam
  - Target environment allowing (n,f) of ^{235}U and ^{241}Pu
  - Trigger less acquisition system
  - Combination with scintillators for fast timing

New triggerless DAQ

- Requirements:
  - Handle high event rate (>600 kHz)
  - Minimize dead time
  - Accurate timing
  - High data throughput



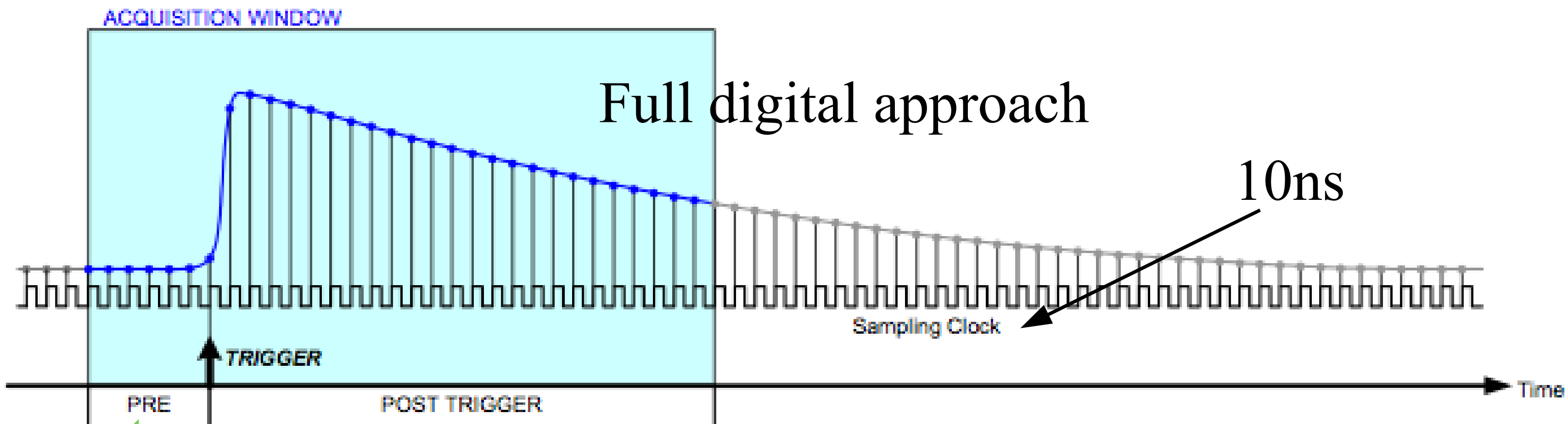
Full digital approach

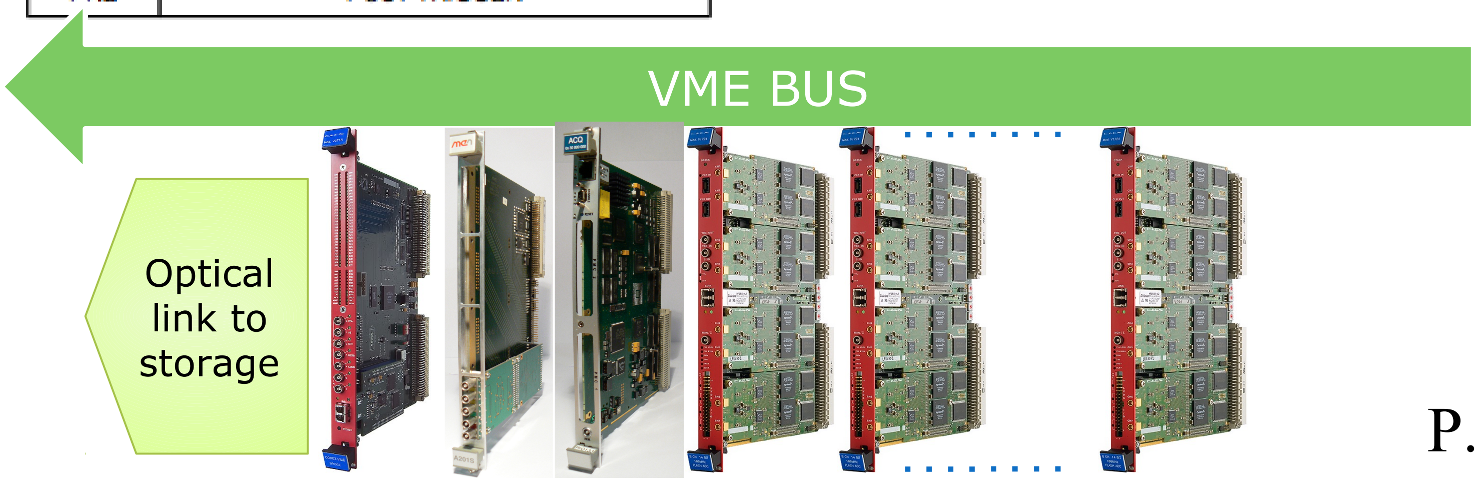
10ns

P. Mutti, ILL

New triggerless DAQ

- Requirements:
  - Handle high event rate (>600 kHz)
  - Minimize dead time
  - Accurate timing
  - High data throughput

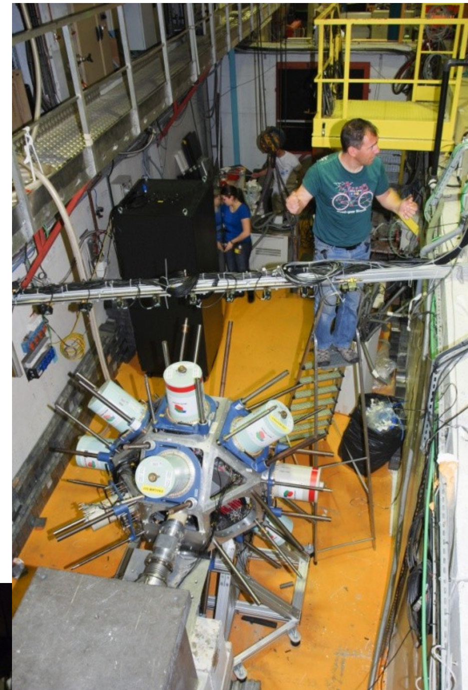


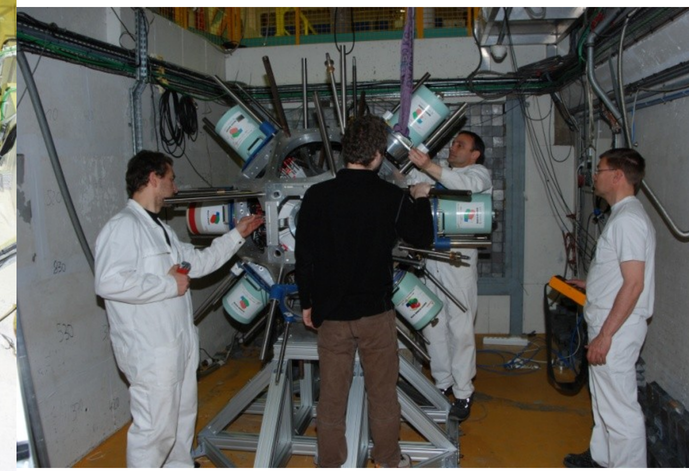


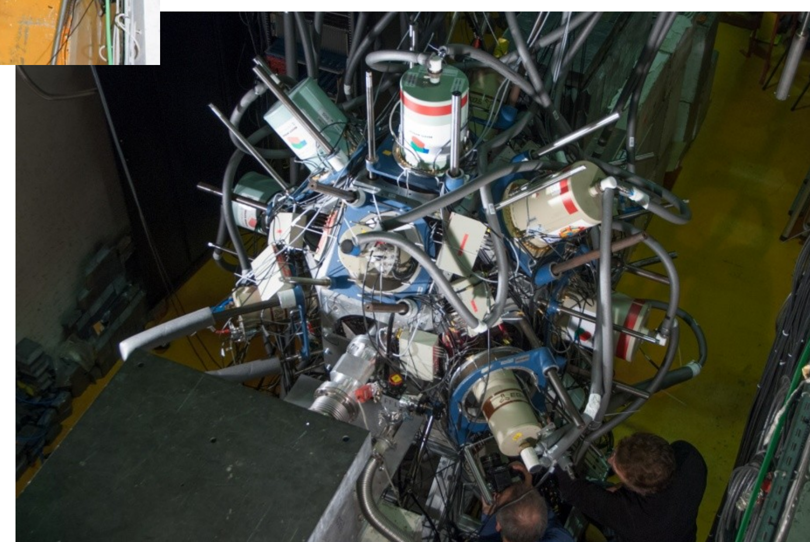
P. Mutti, ILL

NEUTRONS FOR SCIENCE

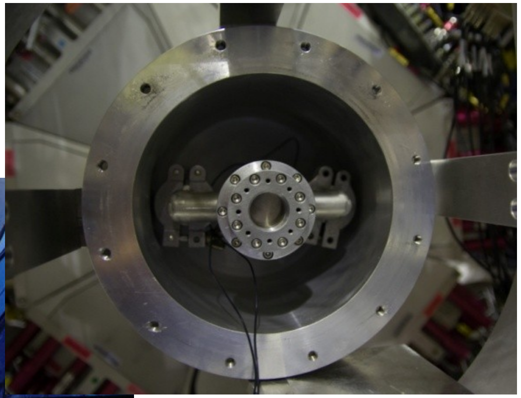
EXILL installation within 10 days

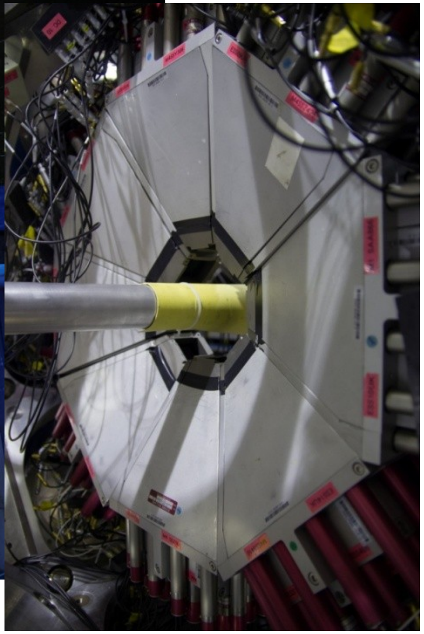






EXILL installation within 10 days





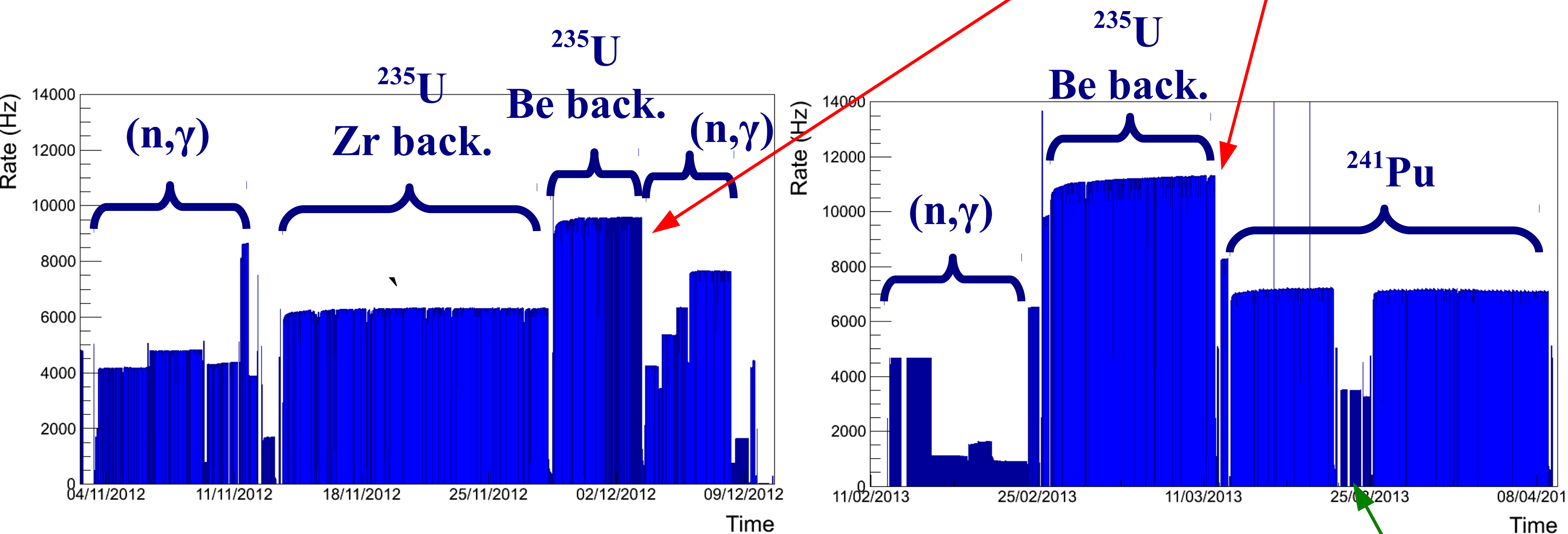
EXILL

- Motivation
- Setup
- **Performances**

Data taking

10 kHz per crystal trigerless data taking achieved, 60 crystals

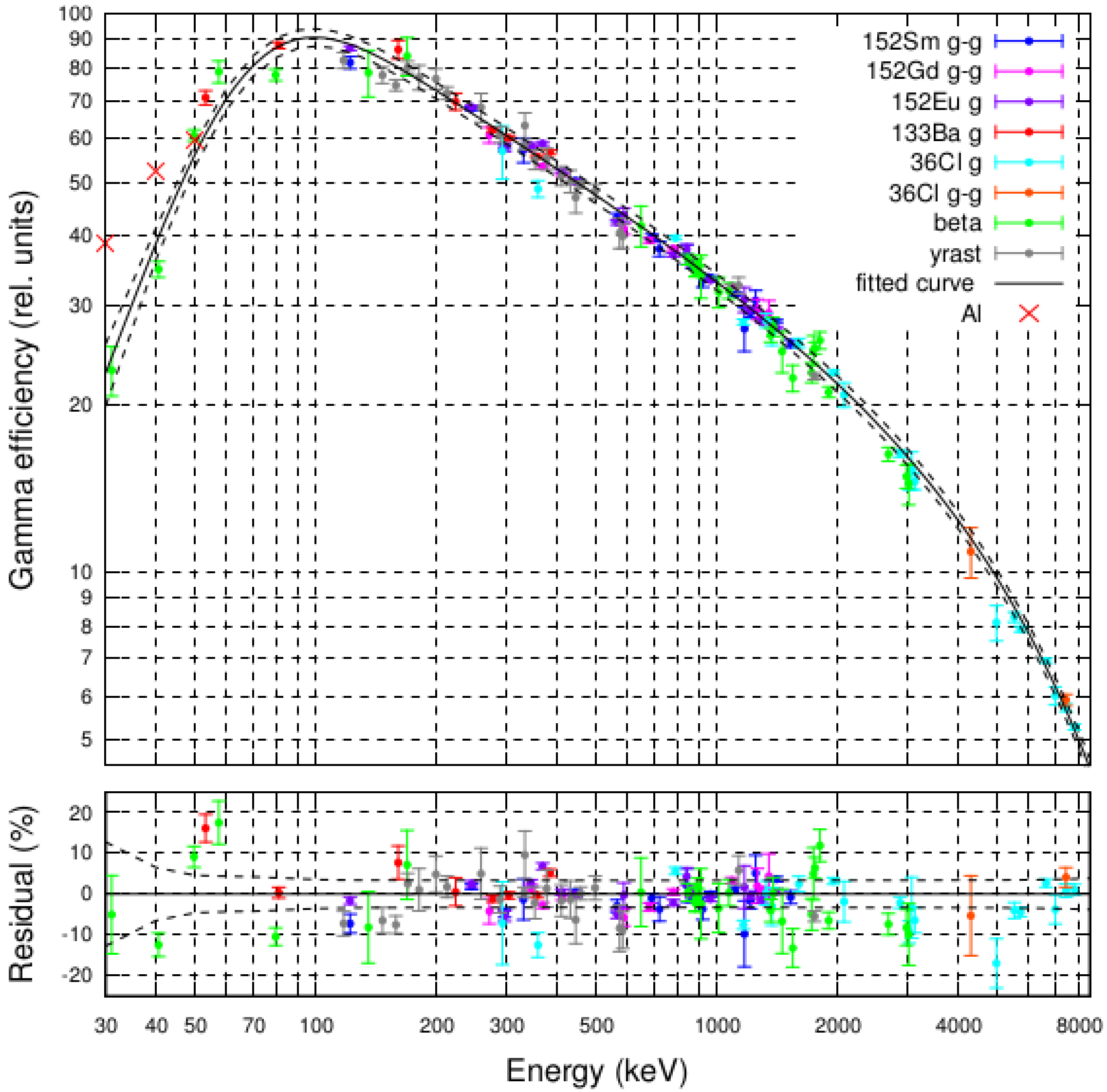
- Clover 0, Crystal 0 rate as a function of time



Setup changing, (n,γ) during nights

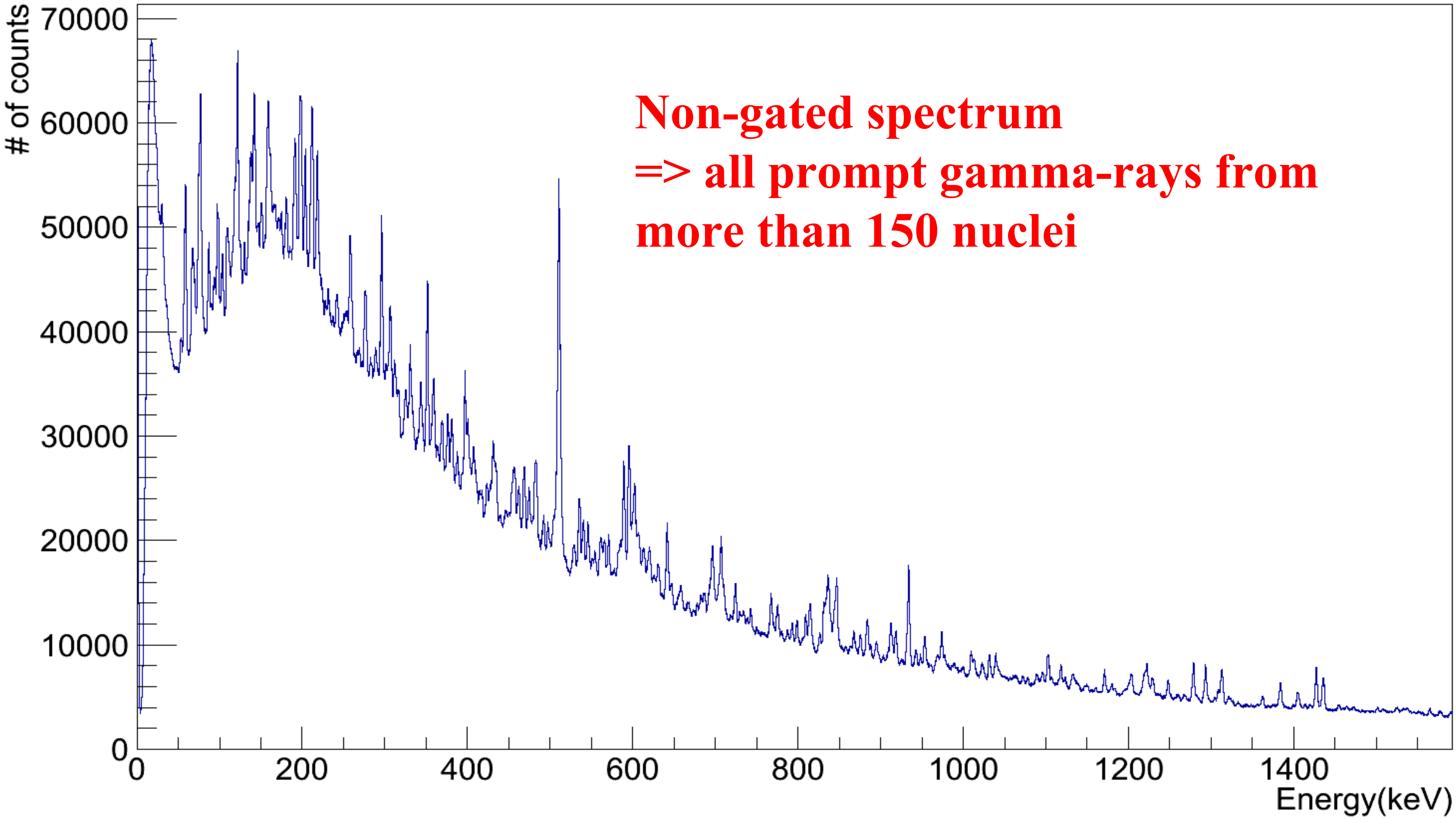
=> >95% of beam time dedicated to measurement

Efficiency



Paweł Bączyk poster

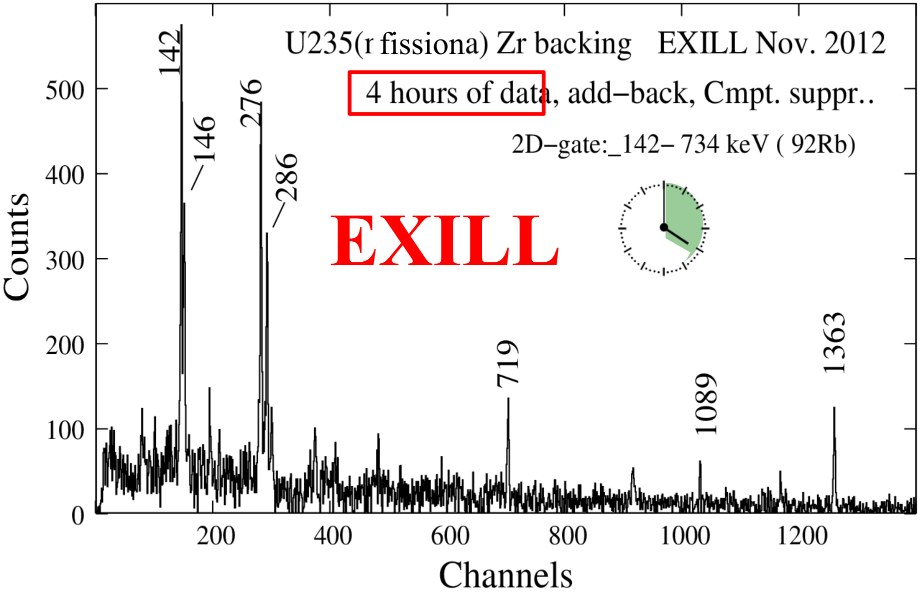
“Online” spectroscopy: ^{92}Rb



Non-gated spectrum
=> all prompt gamma-rays from more than 150 nuclei

“Online” spectroscopy: ^{92}Rb

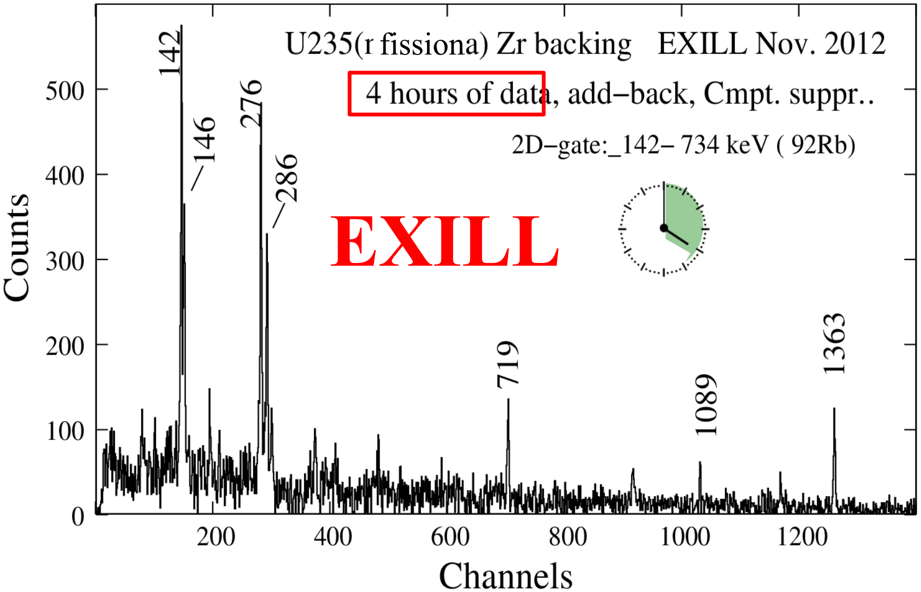
- ^{92}Rb: gamma-gamma spectrum **gated on 142-734 keV** γ-rays



W. Urban, ILL

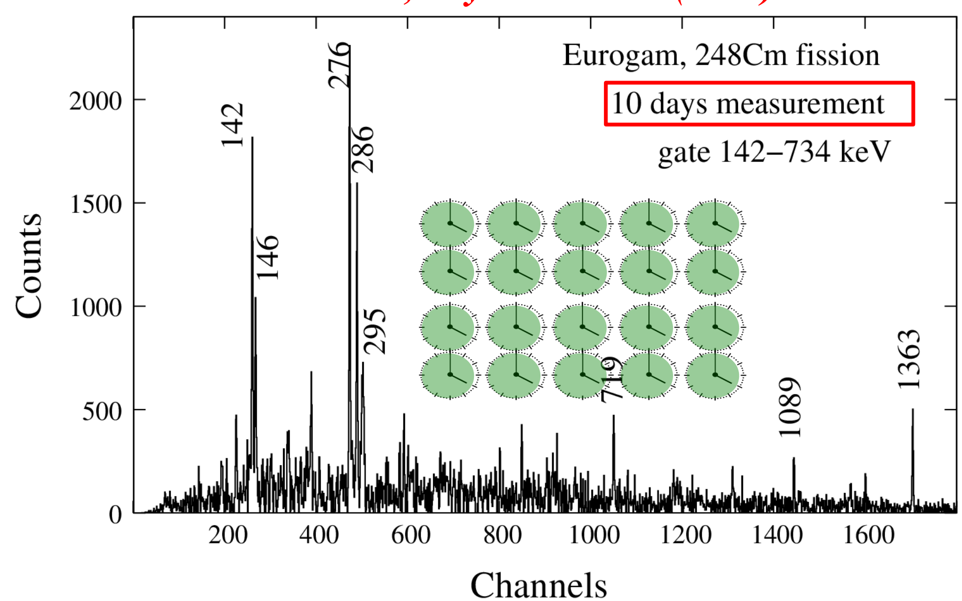
"Online" spectroscopy: ^{92}Rb

- ^{92}**Rb**: gamma-gamma spectrum **gated on 142-734 keV** γ-rays



EUROGAM

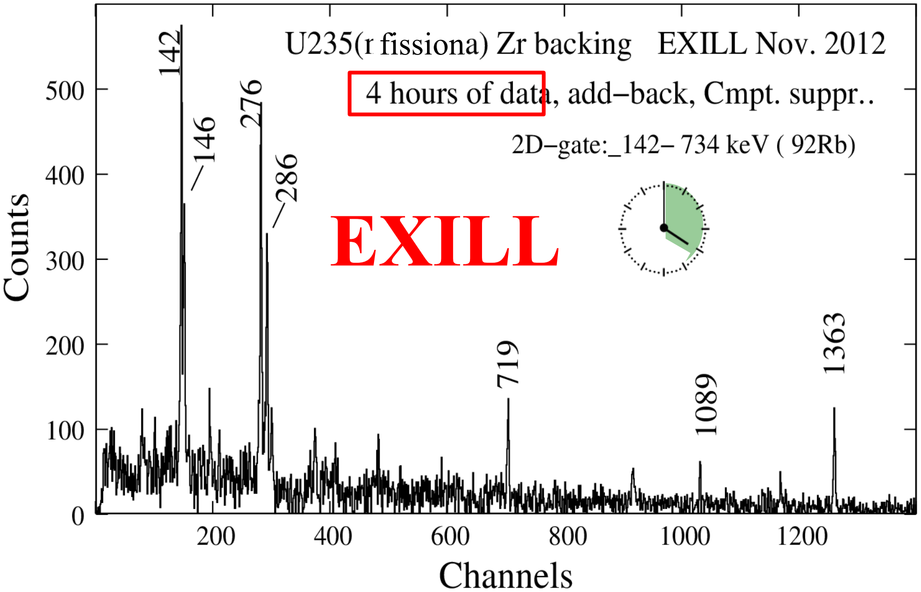
W. Urban et al., Phys. Rev. C 85 (2012) 014329



W. Urban, ILL

"Online" spectroscopy: ^{92}Rb

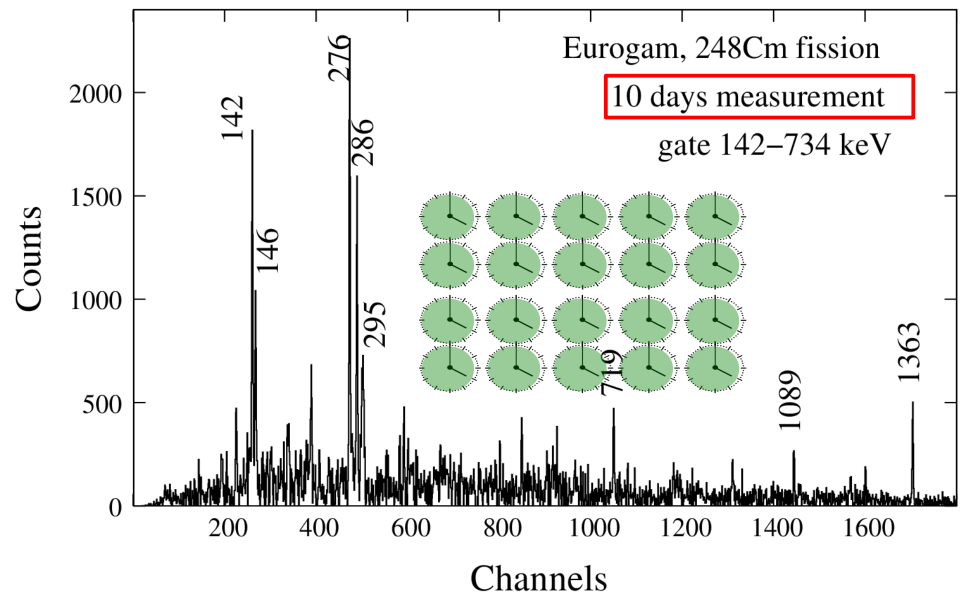
- **^{92}Rb**: gamma-gamma spectrum **gated on 142-734 keV** γ-rays



Much higher statistics
=> allow studying much weaker populated nuclei

EUROGAM

W. Urban et al., Phys. Rev. C 85 (2012) 014329



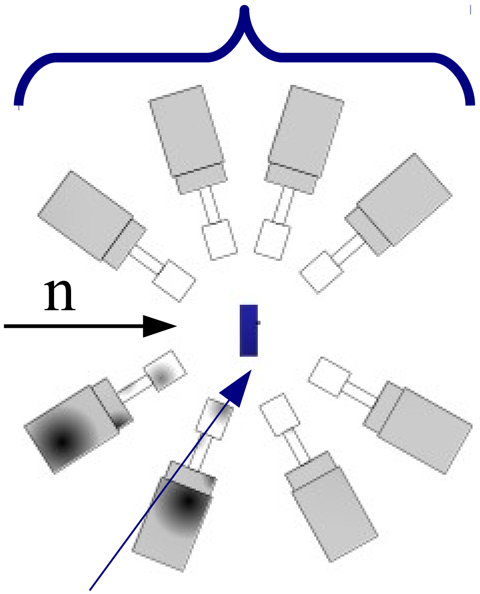
W. Urban, ILL

FIssion Product Prompt γ-ray Spectrometer

- **FIPPS layout**
- Phase I
- Phase II&III

FIPPS layout

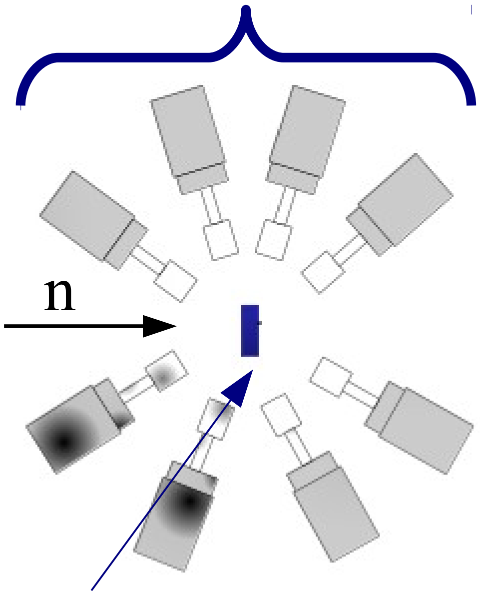
~4π γ-ray detection with Ge array
(EXOGAM-like)



Fission target with a thick backing

FIPPS layout

~4π γ-ray detection with Ge array (EXOGAM-like)

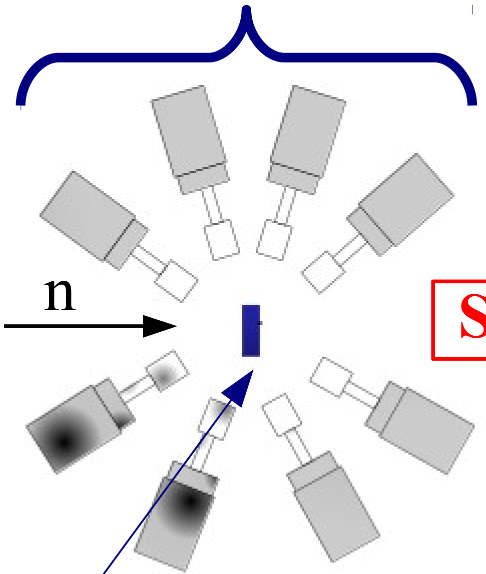


Fission target with a thick backing

- "Left" fragment: stopped in backing
  → Doppler free γ detection
  → determination of A, Z, E*, $\bar{J}$, yield

FIPPS layout

~4π γ-ray detection with Ge array
(EXOGAM-like)



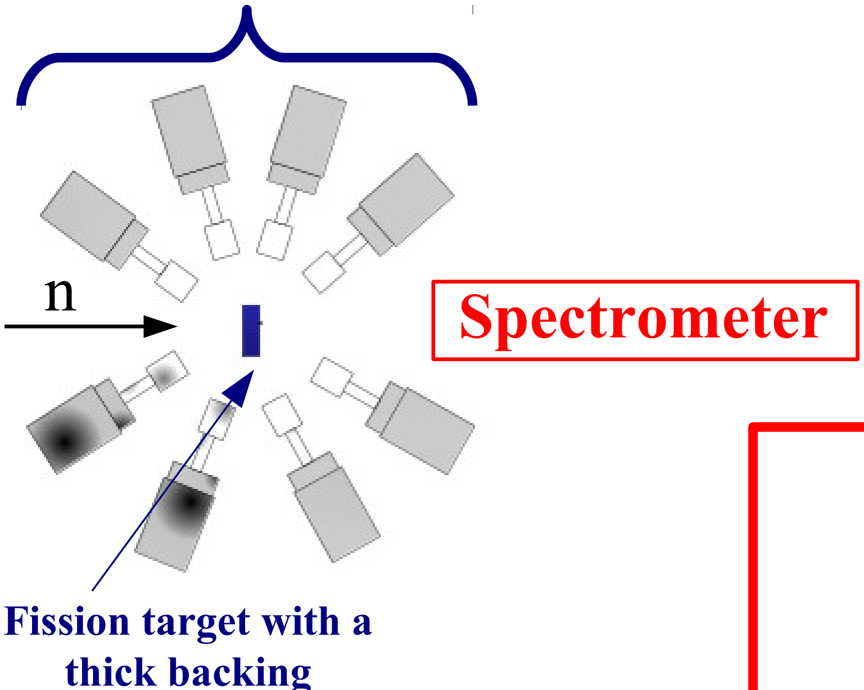
Spectrometer

Fission target with a thick backing

- "Left" fragment: stopped in backing
  → Doppler free γ detection
  → determination of A, Z, E*, $\bar{J}$, yield
- "Right" fragment: fragment identification

FIPPS layout

~4π γ-ray detection with Ge array (EXOGAM-like)



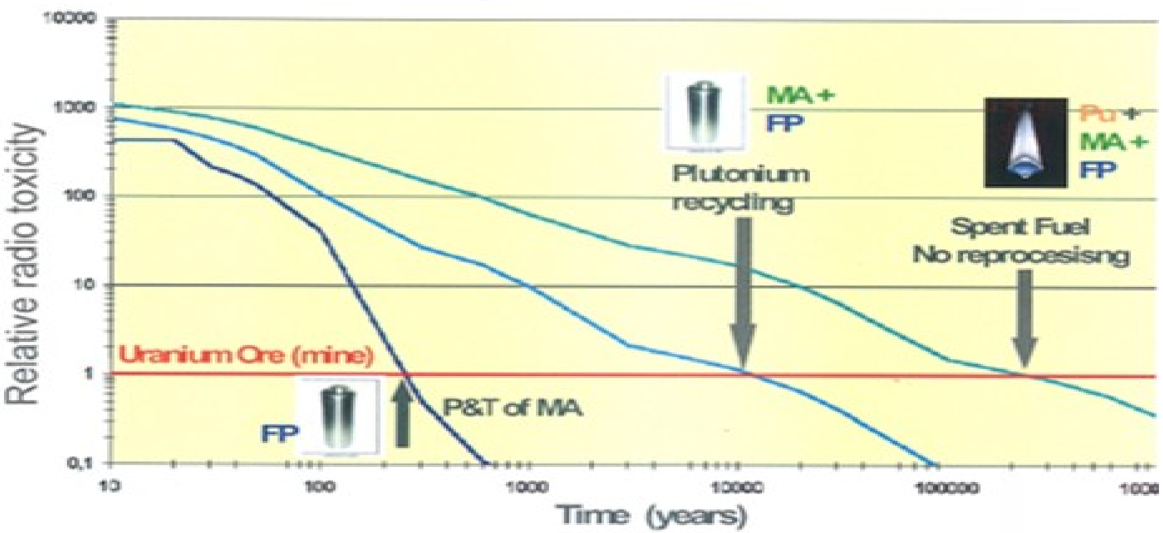
- “Left” fragment: stopped in backing
  → Doppler free γ detection
  → determination of A, Z, E*, $\bar{J}$, yield
- “Right” fragment: fragment identification

LARGE ACCEPTANCE MANDATORY

FIPPS scientific case

- Fundamental physics :
  - Detailed spectroscopy of neutron rich nuclei, astrophysical r-process
  - Nuclear fission studied via prompt spectroscopy
    - γ spectroscopy of the first fragment
    - identification of the second fragment

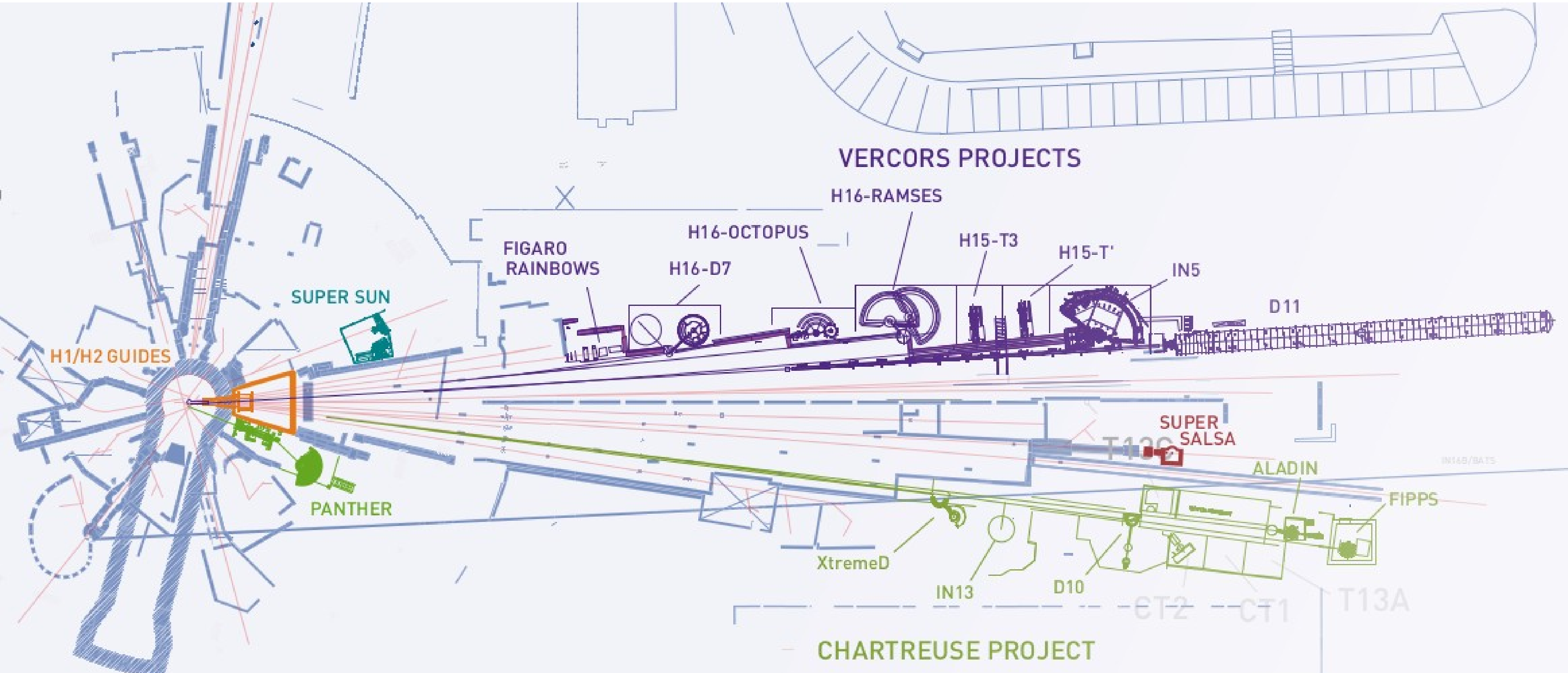
- Applied physics :
  - Nuclear waste burning
  - Generation IV reactors
  - Elemental imaging



The ILL Endurance program

Endurance (to year 2020 and beyond): 7 upgrades, 7 new instruments

=> 30 M€



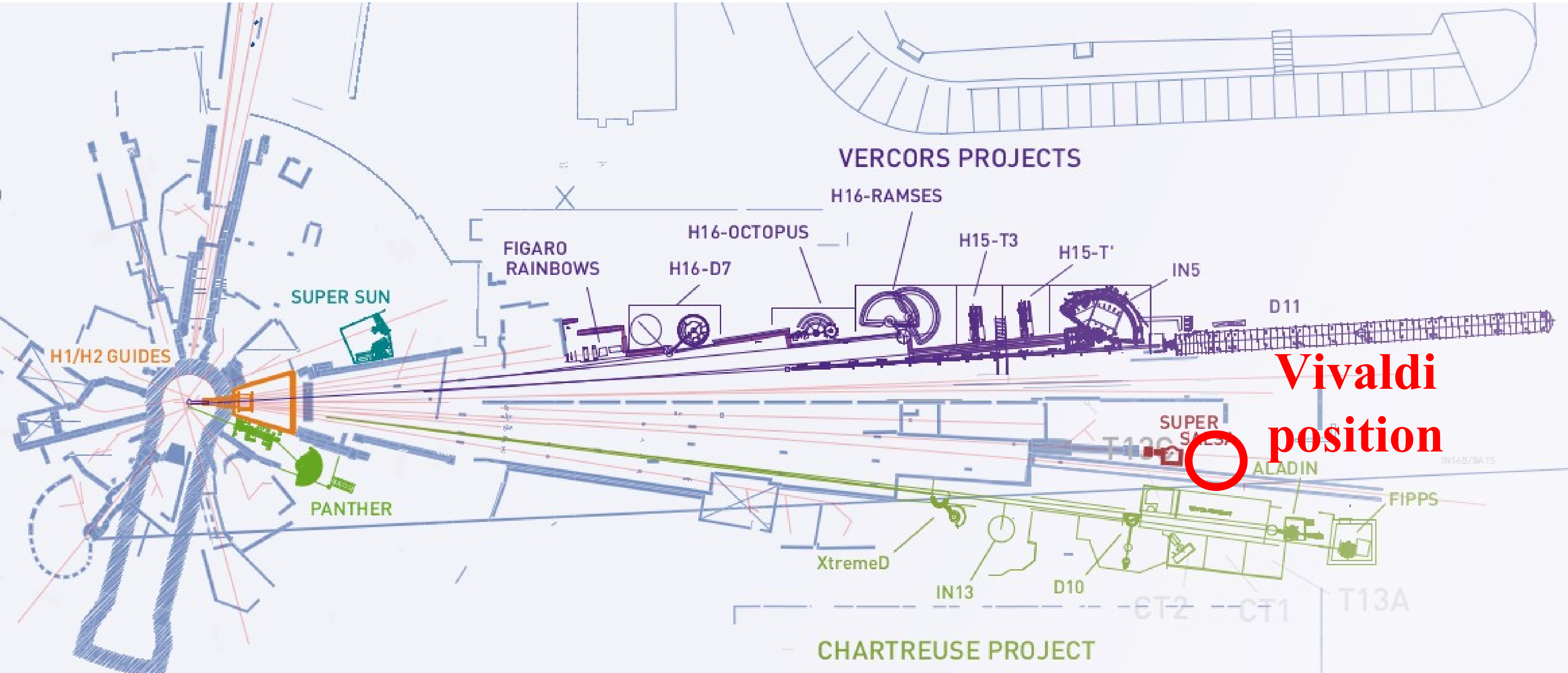
The ILL Endurance program

Endurance (to year 2020 and beyond): 7 upgrades, 7 new instruments

=> 30 M€

FIPPS:

- phase I: **H22** end position **Ge array only** (233U, 235U)
-
-



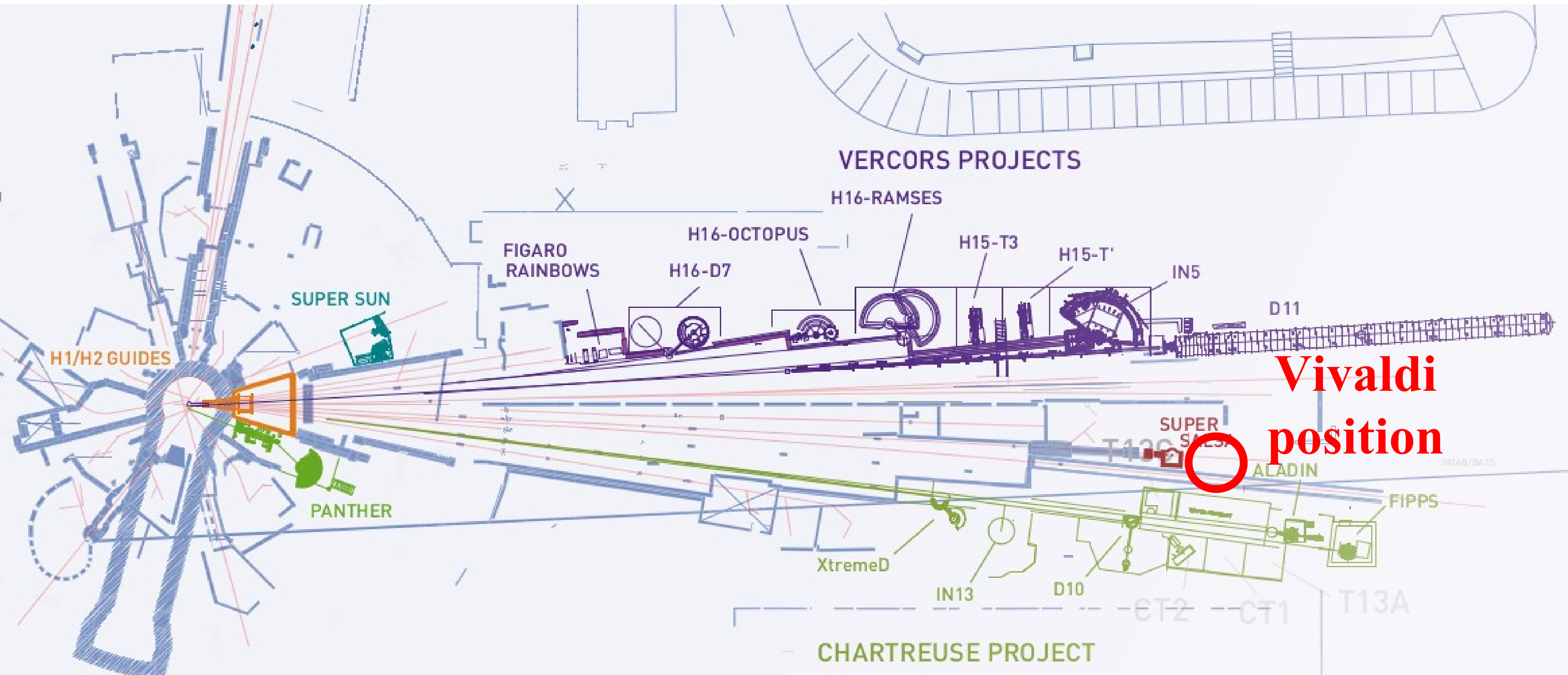
The ILL Endurance program

<u>Endurance</u> (to year 2020 and beyond): 7 upgrades, 7 new instruments

=> 30 M€

FIPPS:

- phase I: **H22** end position **Ge array only** (233U, 235U)
- phase II: **H22** end position **with spectro.**
-



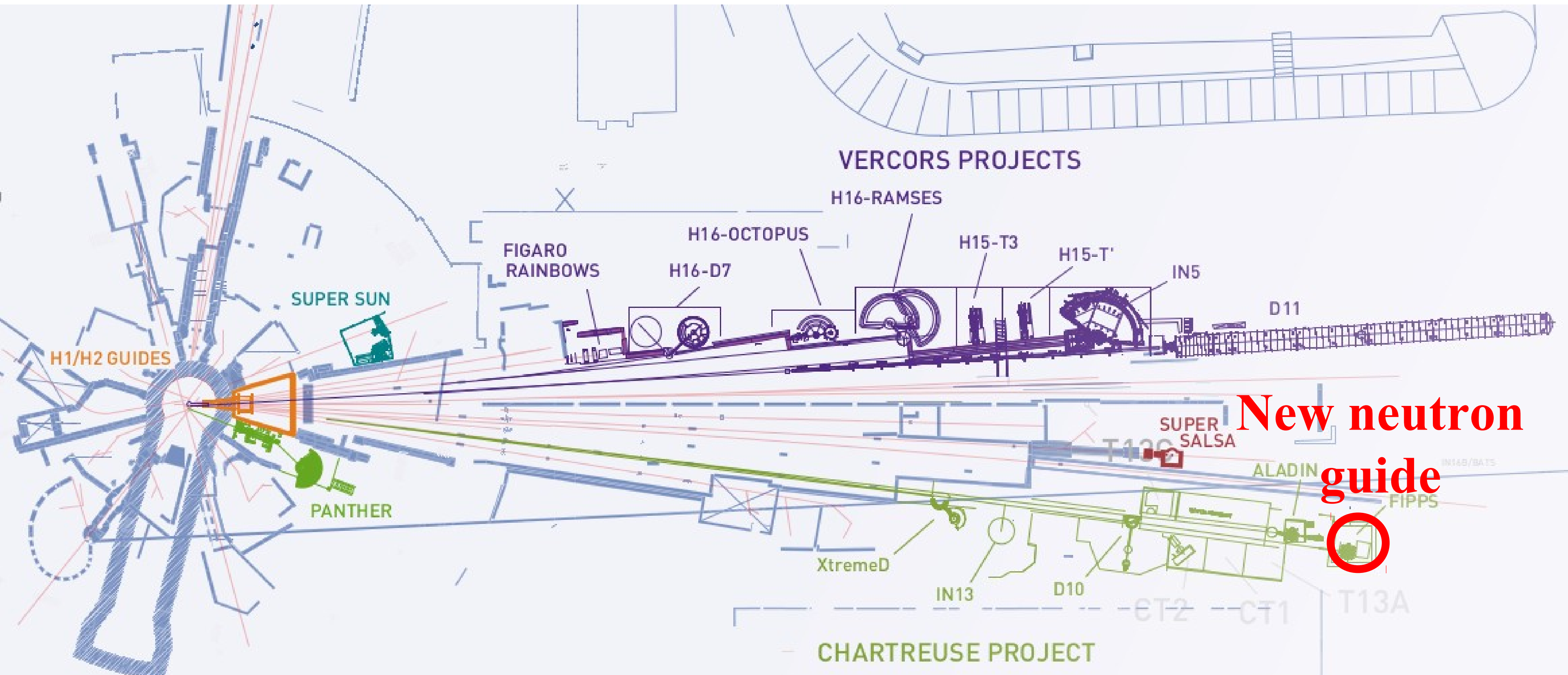
The ILL Endurance program

Endurance (to year 2020 and beyond): 7 upgrades, 7 new instruments

=> 30 M€

FIPPS:

- phase I: **H22** end position **Ge array only** (233U, 235U)
- phase II: **H22** end position **with spectro.**
- phase III: **H24** end position with a **dedicated casemate** => (239Pu, 242Am, 249Cf, ...)

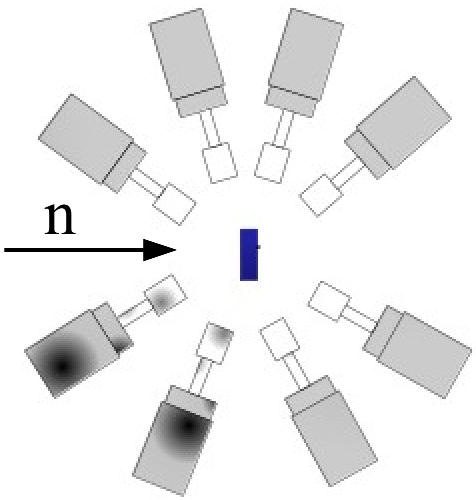


The ILL Endurance program

	Cost (k€)	Available at ILL
Phase I: Ge detector array		
mechanics	50	√ (depending on the array design)
Ge detectors	1500	X
electronics	70	√ (from EXOGAM campaign)
LN2 filling system	10	√ (from EXOGAM campaign)
$LaBr_3(Ce)$ detectors	100	√ (from FATIMA collaboration)
Collimation system	40	√ (from EXOGAM campaign)
H22 casemate shielding	50	X
Phase II: Spectrometer		
Gas-Filled Magnet	500	X
TOF detector+electronics	20	X
TPC detectors+electronics	100	X
various mechanics	50	X
Phase III: relocation at H24	400	X
Total	2890 - 270 = 2620 k€ +15% => 3013 k€	

FIssion Product Prompt γ-ray Spectrometer

- FIPPS layout
- **Phase I**
- Phase II&III



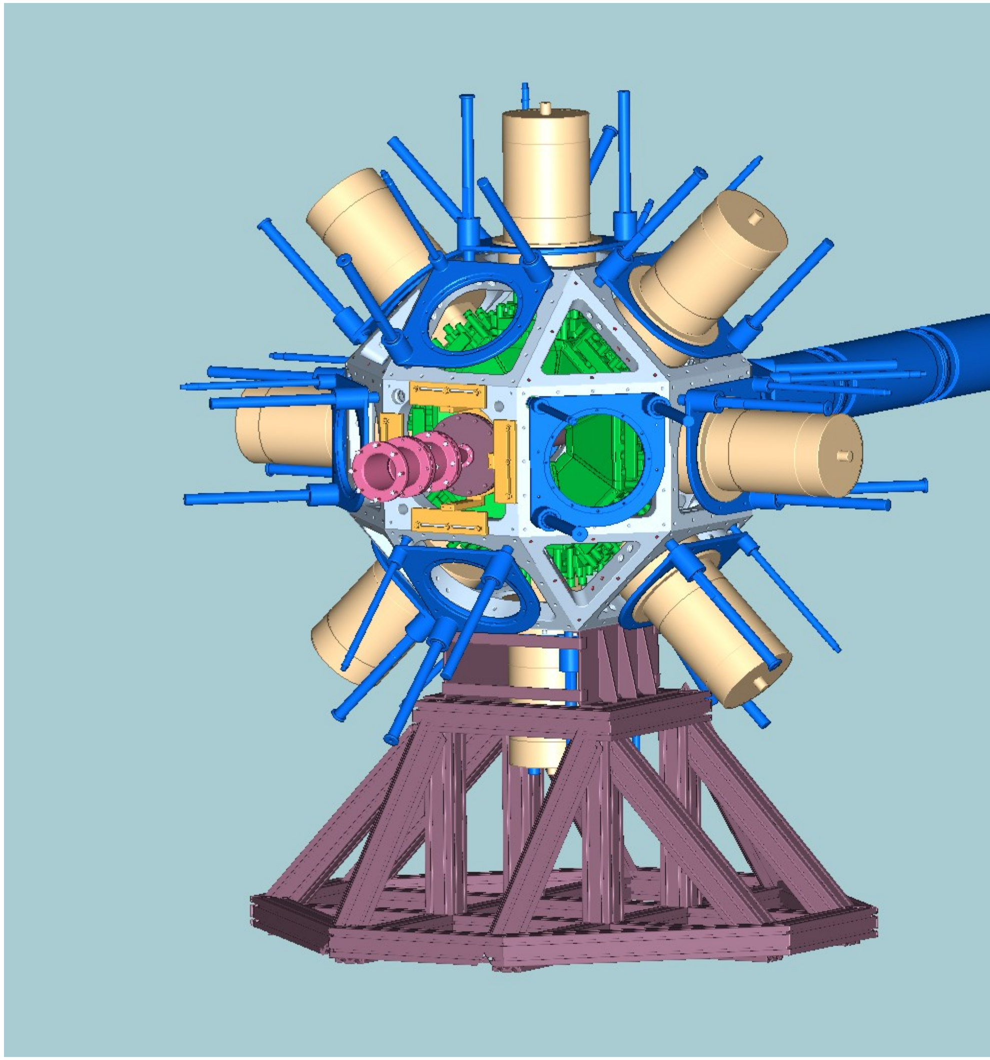
FIPPS phase I: Ge array

EUROGAM clovers in a central ring

Full ring = 8 Clovers

- 1200 keuros (catalogue price)
- **relative efficiency** higher than for simple co-ax.Ge
- **Not segmented**
- Be window on demand (low gamma energy loss)

  => **additional identification using X-rays** (down to 2-3 keV)
- **Permanently at ILL**
- **Large space** around the ring for additional detectors



FIPPS phase I: Ge array

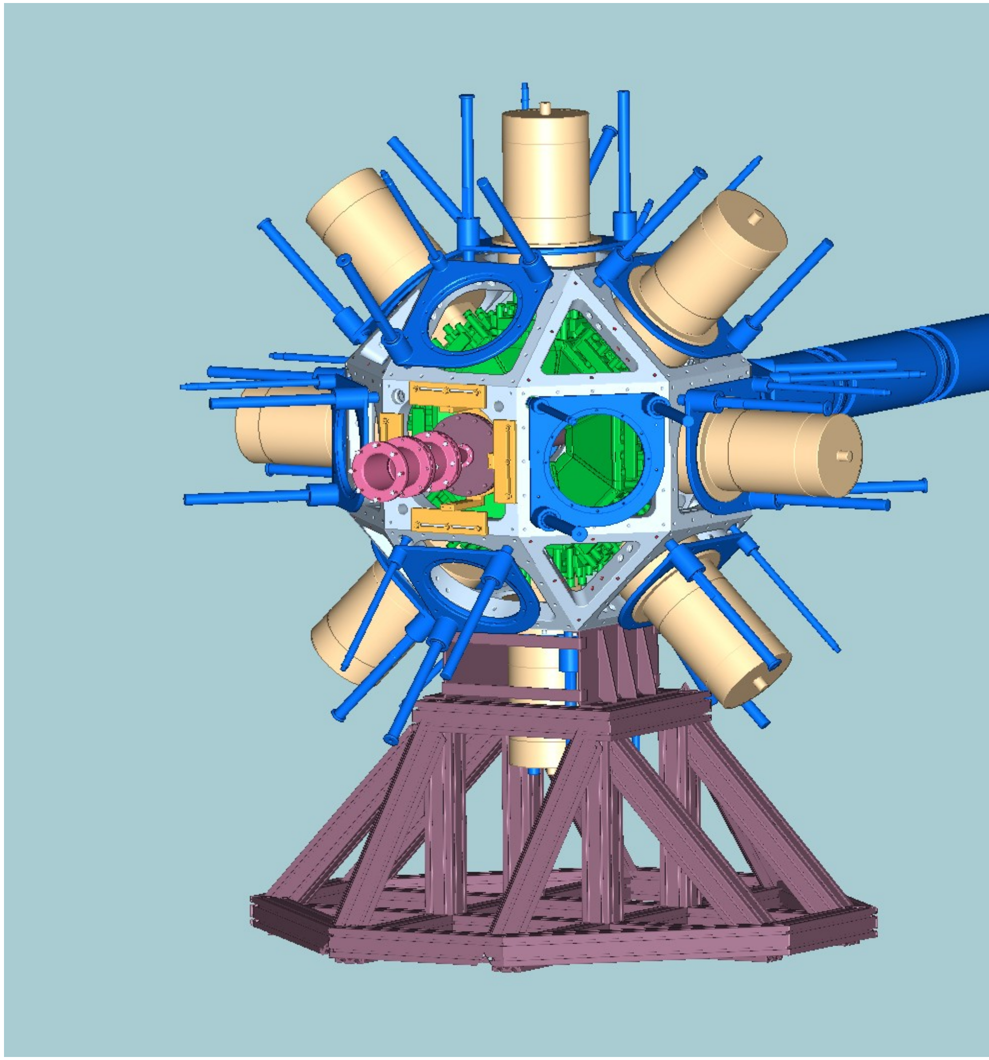
EUROGAM clovers in a central ring

Full ring = 8 Clovers

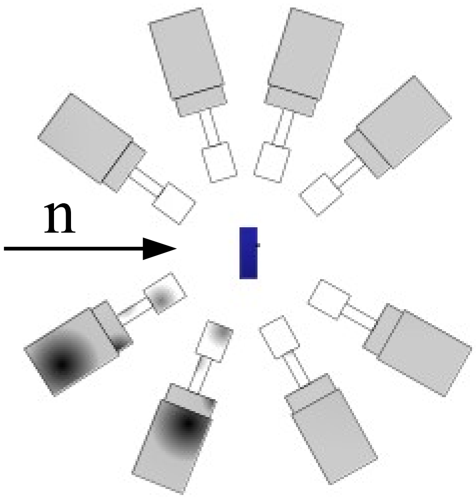
- 1200 keuros (catalogue price)
- **relative efficiency** higher than for simple co-ax.Ge
- **Not segmented**
- Be window on demand (low gamma energy loss)

  => **additional identification using X-rays** (down to 2-3 keV)
- **Permanently at ILL**
- **Large space** around the ring for additional detectors

=> other Ge, LaBr, neutron detectors, ...



FIPPS phase I: some ideas



Ideas from: _last EXILL meeting
_ informal discussion with users (O. Litaize, G. Kessedjian, O. Serot, G. Simpson, ...)

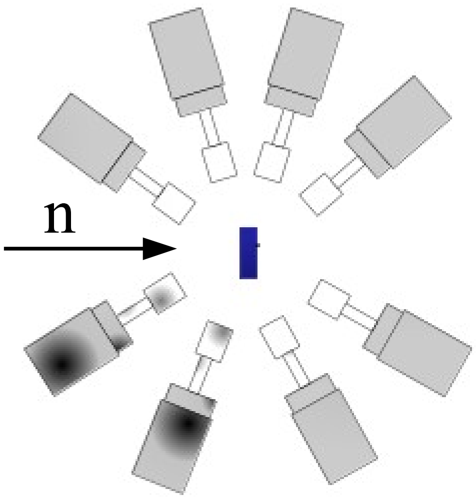
Nuclear structure:

- **DPM** measurements
  → we learnt a lot from the EXILL-DPM measurement
- **plunger** measurements
- **g factor** measurements
- new **spectroscopy** campaign

Fission:

- **prompt γ-ray** *(NEA High Priority Request List for 235U and 239Pu)*
  A. Oberstedt et al., PRC 87, 051602 (2013)
  → possible observables: total γ-ray spectra, Eγ distribution and multiplicity, per fission or per fragment pair
  → **EXILL data** analysis difficult: need complex **γ-γ-γ analysis** with background from long-life isomers
- **neutron** emission
  → neutron-γ correlations ??
- actinides **(n,γ)** measurements

FIPPS phase I: some ideas



Ideas from: _last EXILL meeting
_ informal discussion with users (O. Litaize, G. Kessedjian, O. Serot, G. Simpson, ...)

Nuclear structure:

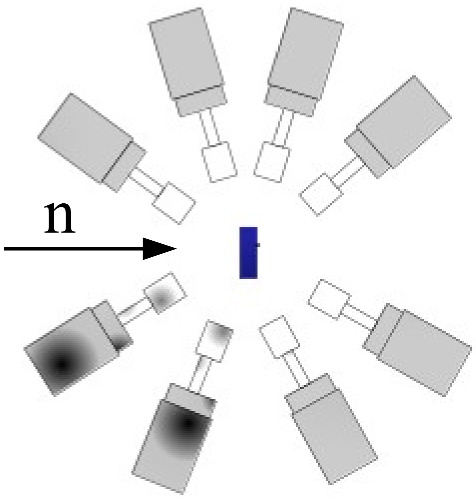
- **DPM** measurements
  → we learnt a lot from the EXILL-DPM measurement
- **plunger** measurements
- **g factor** measurements
- new **spectroscopy** campaign

Fission:

- **prompt γ-ray** *(NEA High Priority Request List for 235U and 239Pu)*
  A. Oberstedt et al., PRC 87, 051602 (2013)
  → possible observables: total γ-ray spectra, Eγ distribution and multiplicity, per fission or per fragment pair
  → **EXILL data** analysis difficult: need complex **γ-γ-γ analysis** with background from long-life isomers
- **neutron** emission
  → neutron-γ correlations ??
- actinides **(n,γ)** measurements

Fission TAGGING/VETO

FIPPS phase I: some ideas



Ideas from: _last EXILL meeting
_ informal discussion with users (O. Litaize, G. Kessedjian, O. Serot, G. Simpson, ...)

Nuclear structure:

- **DPM** measurements
  → we learnt a lot from the EXILL-DPM measurement
- **plunger** measurements
- **g factor** measurements
- new **spectroscopy** campaign

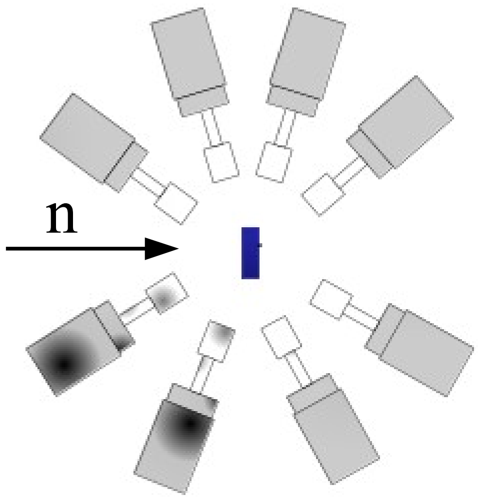
Could help in reducing γ background and identifying fission flash

Fission:

- **prompt γ-ray** *(NEA High Priority Request List for 235U and 239Pu)*
  A. Oberstedt et al., PRC 87, 051602 (2013)
  → possible observables: total γ-ray spectra, Eγ distribution and multiplicity, per fission or per fragment pair
  → **EXILL data** analysis difficult: need complex **γ-γ-γ analysis** with background from long-life isomers
- **neutron** emission
  → neutron-γ correlations ??
- actinides **(n,γ)** measurements

Fission TAGGING/VETO

FIPPS phase I: some ideas



Ideas from: _last EXILL meeting
_ informal discussion with users (O. Litaize, G. Kessedjian, O. Serot, G. Simpson, ...)

Nuclear structure:

- **DPM** measurements
  → we learnt a lot from the EXILL-DPM measurement
- **plunger** measurements
- **g factor** measurements
- new **spectroscopy** campaign

Fission:

- **prompt γ-ray** *(NEA High Priority Request List for 235U and 239Pu)*
  A. Oberstedt et al., PRC 87, 051602 (2013)
  → possible observables: total γ-ray spectra, Eγ distribution and multiplicity, per fission or per fragment pair
  → **EXILL data** analysis difficult: need complex **γ-γ-γ analysis** with background from long-life isomers
- **neutron** emission
  → neutron-γ correlations ??
- actinides **(n,γ)** measurements

Need active target with up to 2 mg/cm3 of actinide

FIPPS phase I: scintillating active target

- Principle of a liquid scintillating active target: dissolve the actinide into a scintillator

G. Bélier et al., *NIM A, Vol. 664(1), 341-346, 2012.*

FIPPS phase I: scintillating active target

- Principle of a liquid scintillating active target: dissolve the actinide into a scintillator

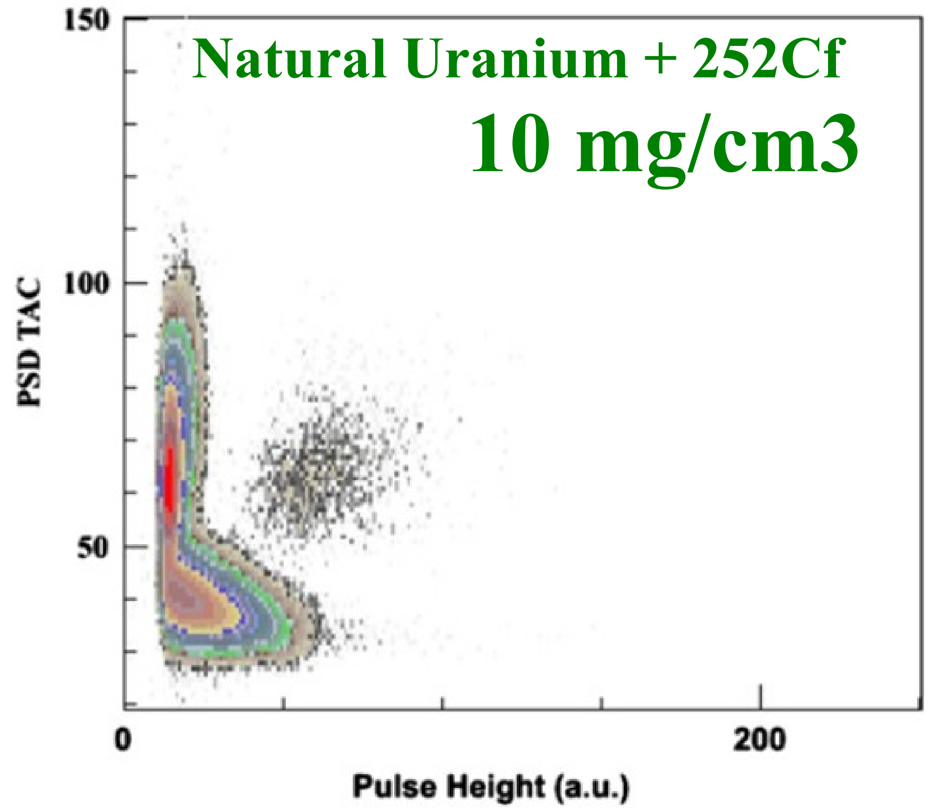
- Actinide inside the detector active volume
- **Very high efficiency**
- **Ease of fabrication**
- Heavy loads possible (**up to 10 mg/cm3**)
- Doppler broadening lower than in gas cells (to be calculated)
- Can stand **up to 10MBq** activities

G. Bélier et al., *NIM A, Vol. 664(1), 341-346, 2012.*

FIPPS phase I: scintillating active target

- Principle of a liquid scintillating active target: dissolve the actinide into a scintillator

- Actinide inside the detector active volume
- **Very high efficiency**
- **Ease of fabrication**
- Heavy loads possible (**up to 10 mg/cm3**)
- Doppler broadening lower than in gas cells (to be calculated)
- Can stand **up to 10MBq** activities

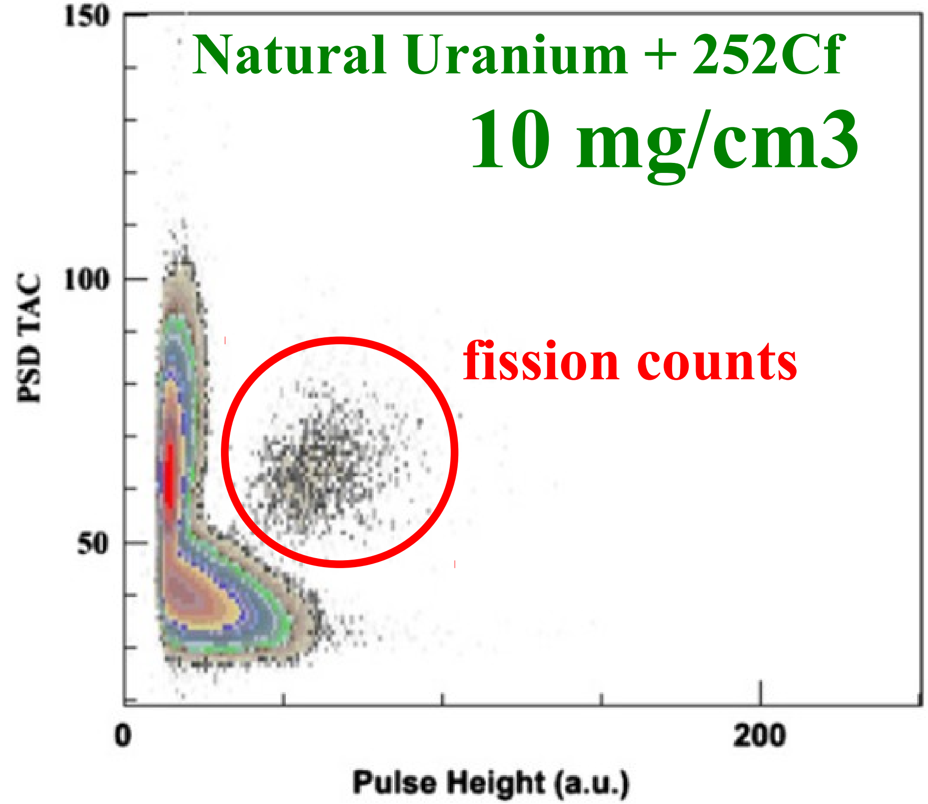


G. Bélier et al., *NIM A, Vol. 664(1), 341-346, 2012.*

FIPPS phase I: scintillating active target

▶ Principle of a liquid scintillating active target: dissolve the actinide into a scintillator

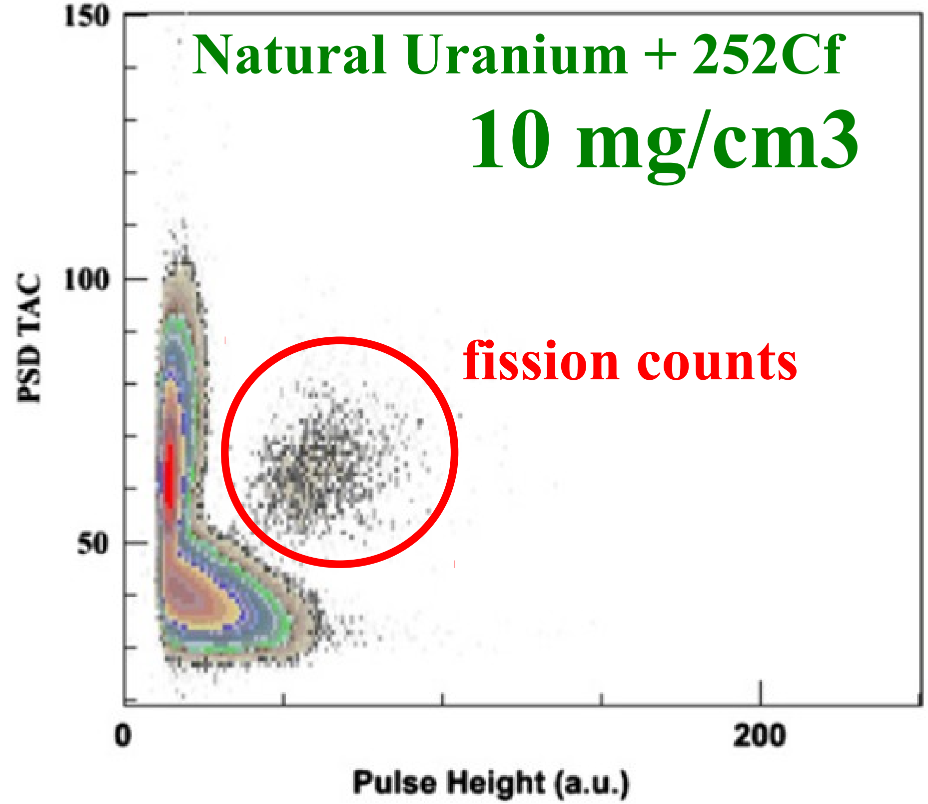
- Actinide inside the detector active volume
- **Very high efficiency**
- **Ease of fabrication**
- Heavy loads possible (**up to 10 mg/cm3**)
- Doppler broadening lower than in gas cells (to be calculated)
- Can stand **up to 10MBq** activities



G. Bélier et al., *NIM A, Vol. 664(1), 341-346, 2012.*

FIPPS phase I: scintillating active target

- Principle of a liquid scintillating active target: dissolve the actinide into a scintillator



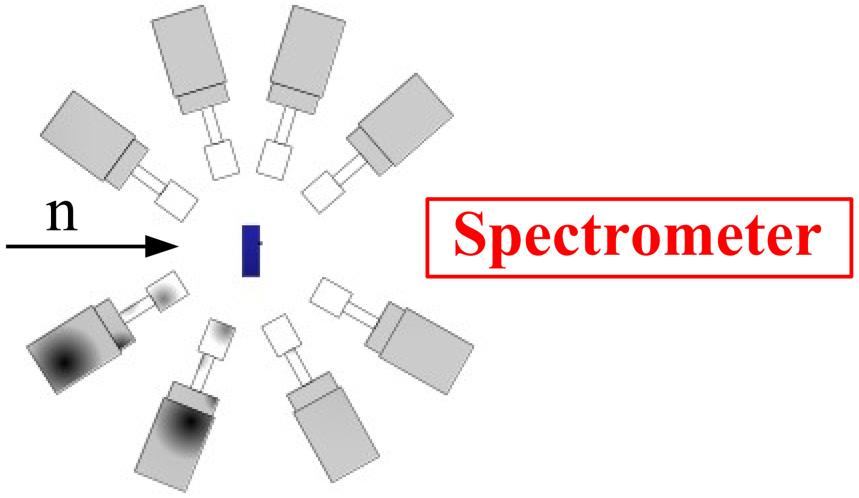
- Actinide inside the detector active volume
- **Very high efficiency**
- **Ease of fabrication**
- Heavy loads possible (**up to 10 mg/cm3**)
- Doppler broadening lower than in gas cells (to be calculated)
- Can stand **up to 10MBq** activities

Ageing test to be performed at the ILL (~500 days of operation at PF1B)

G. Bélier et al., *NIM A, Vol. 664(1), 341-346, 2012.*

FIssion Product Prompt γ-ray Spectrometer

- FIPPS layout
- Phase I
- **Phase II&III**



FIPPS phase II: first design propositions

- **Focusing magnet:**

FIPPS phase II: first design propositions

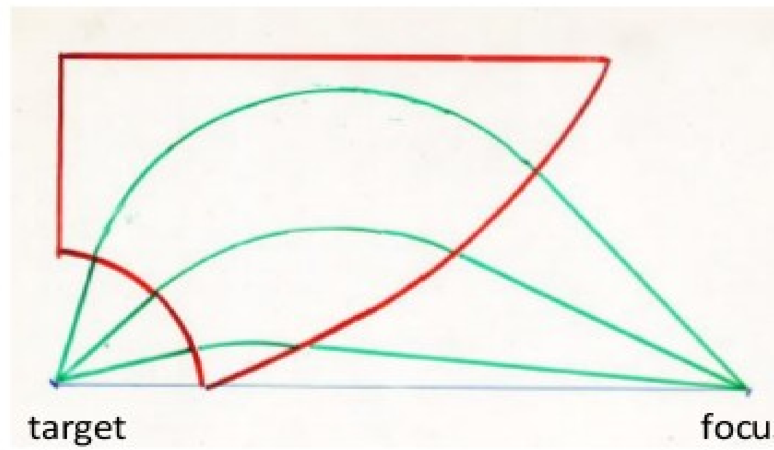
Focusing magnet:

H. Faust, fission 2013

<u>Possible magnet design:</u>

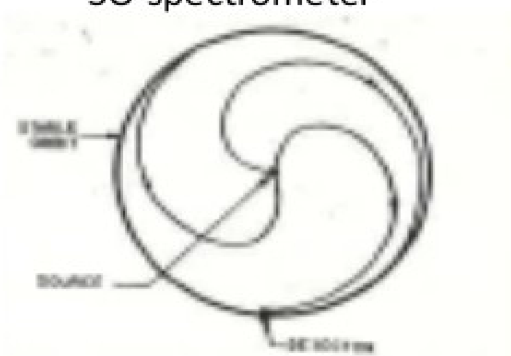
1) Constant B-field

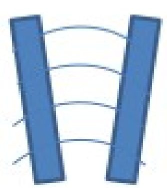
$$\frac{\Delta\Omega}{\Omega} \approx 3.4\%$$



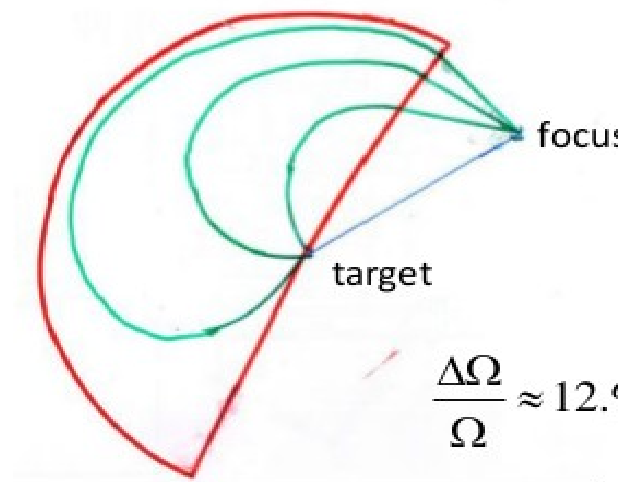
2) B=1/r field

-strong double focusing-
SO-spectrometer





$$B \propto \frac{1}{r}$$



$$\frac{\Delta\Omega}{\Omega} \approx 12.\%$$

FIPPS phase II:
first design propositions

Focusing magnet:

+:

- possible study at the focal plane
- known technique: Gas Filled Magnet
- good mass resolution

-:

- not "all" fission product accessible in the same time → EXILL-like campaign not possible
- limited acceptance (design 1) OR limited space for ancillary detectors (design 2)

FIPPS phase II: first design propositions

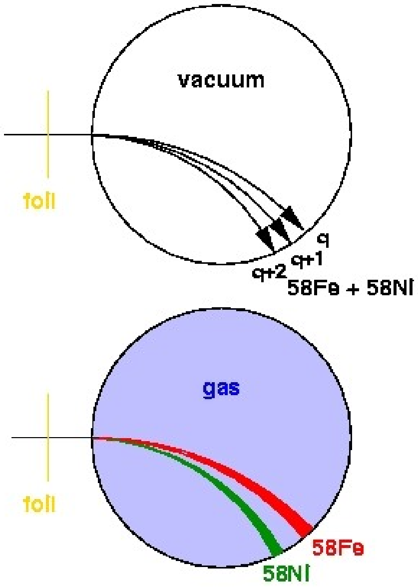
- **“Non-focusing” magnet:**

FIPPS phase II: first design propositions

"Non-focusing" magnet:

Gas-Filled Magnet

Charge "focusing"



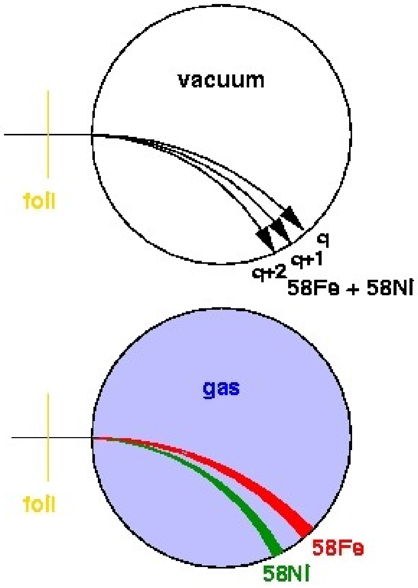
Time Projection Chamber

FIPPS phase II: first design propositions

"Non-focusing" magnet:

Gas-Filled Magnet

Charge "focusing"



Bρ(A,Z)

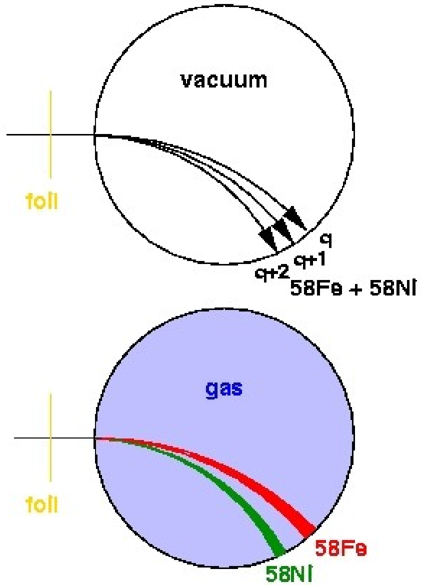
Time Projection Chamber

FIPPS phase II: first design propositions

"Non-focusing" magnet:

Gas-Filled Magnet

Charge "focusing"

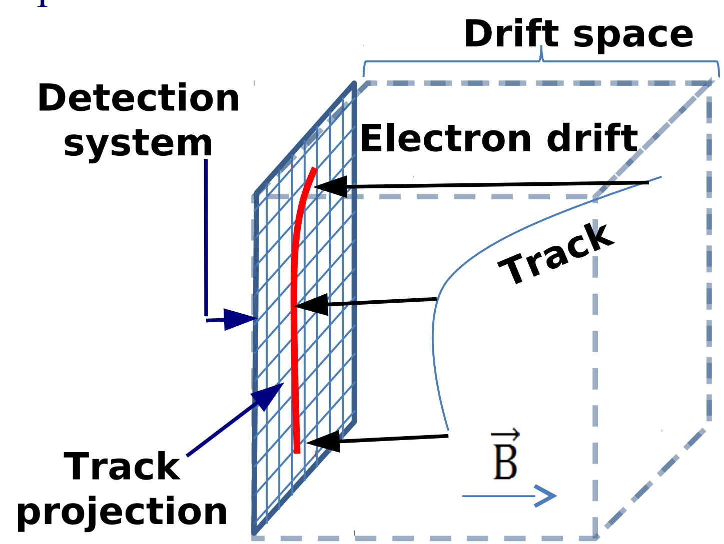


Bρ(A,Z)

Time Projection Chamber

Energy loss (~100 keV/cm) in gas leads to ionization

- charges can be collected to follow the particle tracks

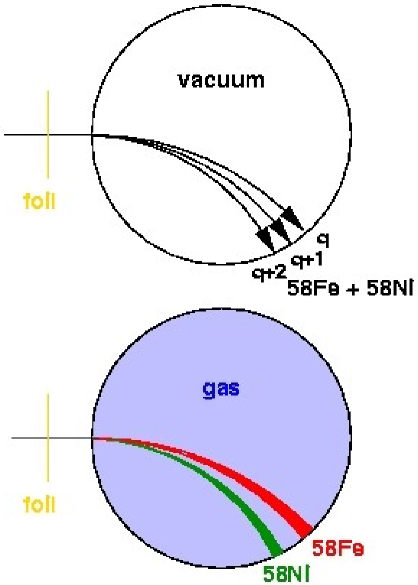


FIPPS phase II: first design propositions

“Non-focusing” magnet:

Gas-Filled Magnet

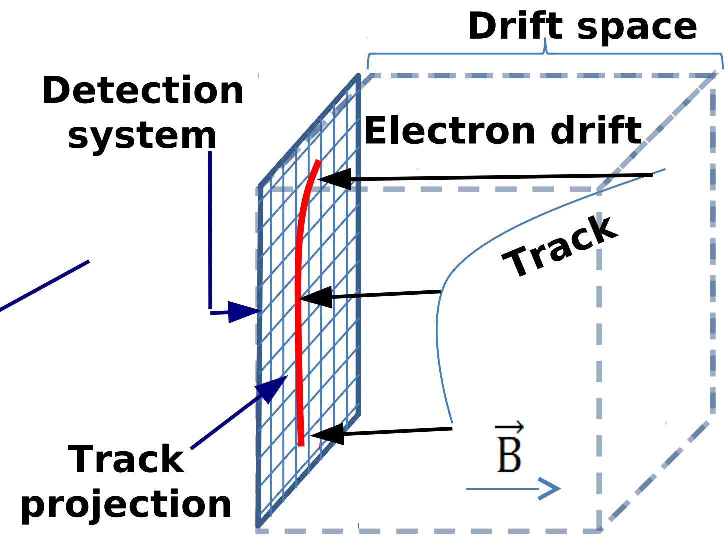
Charge “focusing”



Time Projection Chamber

Energy loss (~100 keV/cm) in gas leads to ionization

- charges can be collected to follow the particle tracks



tracking

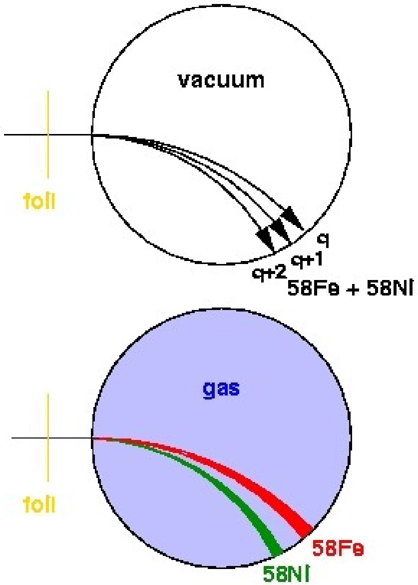
Bρ(A,Z)

FIPPS phase II: first design propositions

“Non-focusing” magnet:

Gas-Filled Magnet

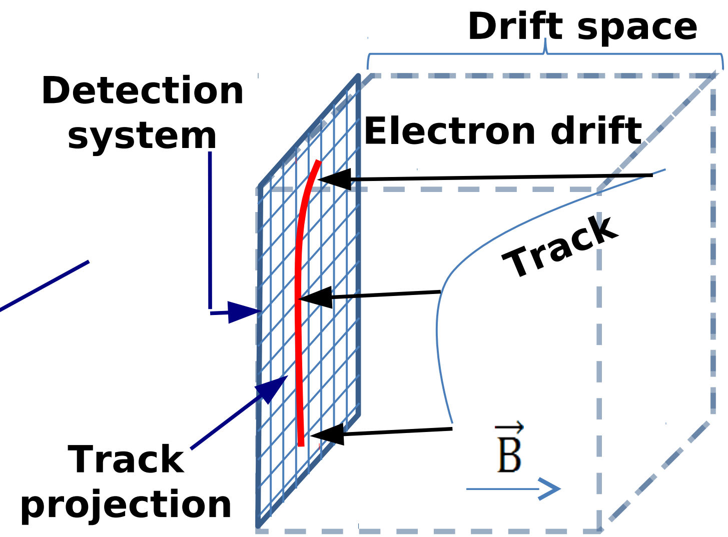
Charge “focusing”



Time Projection Chamber

Energy loss (~100 keV/cm) in gas leads to ionization

- charges can be collected to follow the particle tracks



tracking

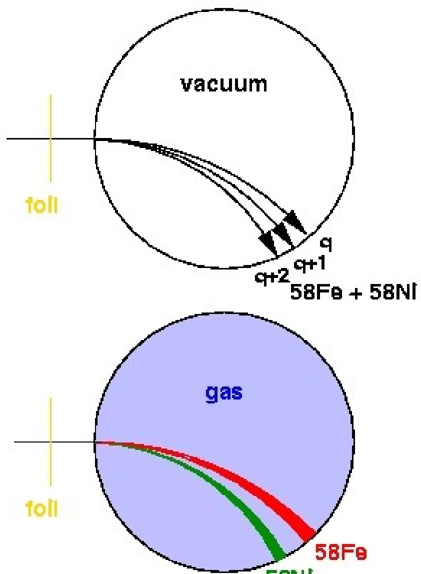
$B\rho(A,Z)$ + $dE/dx(E,Z)$

FIPPS phase II: first design propositions

“Non-focusing” magnet:

Gas-Filled Magnet

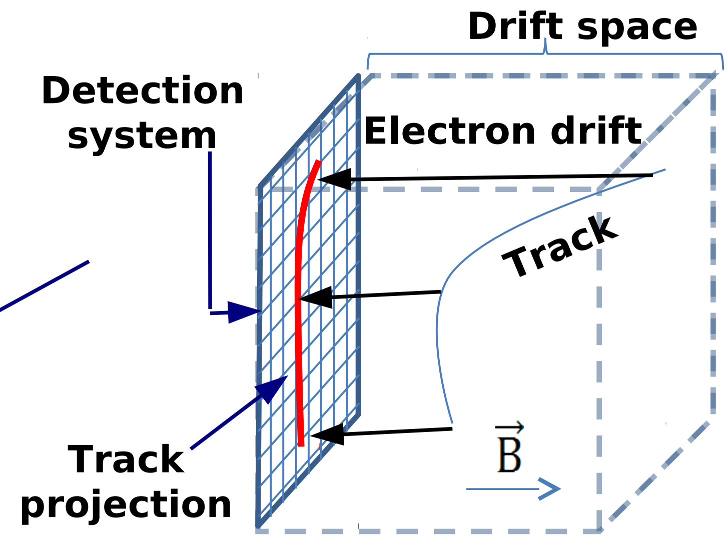
Charge “focusing”



Time Projection Chamber

Energy loss (~100 keV/cm) in gas leads to ionization

- charges can be collected to follow the particle tracks

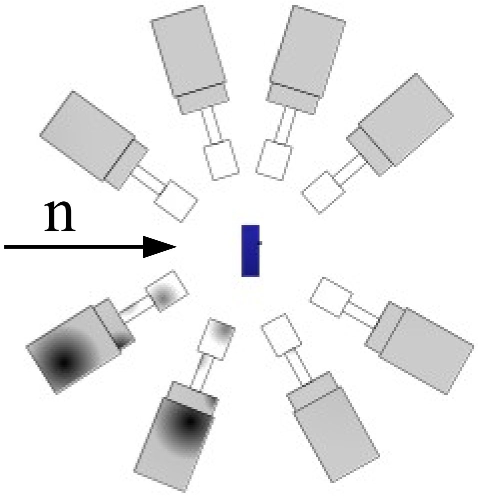


tracking

$B\rho(A,Z)$ + $v(A,E)$ $dE/dx(E,Z)$

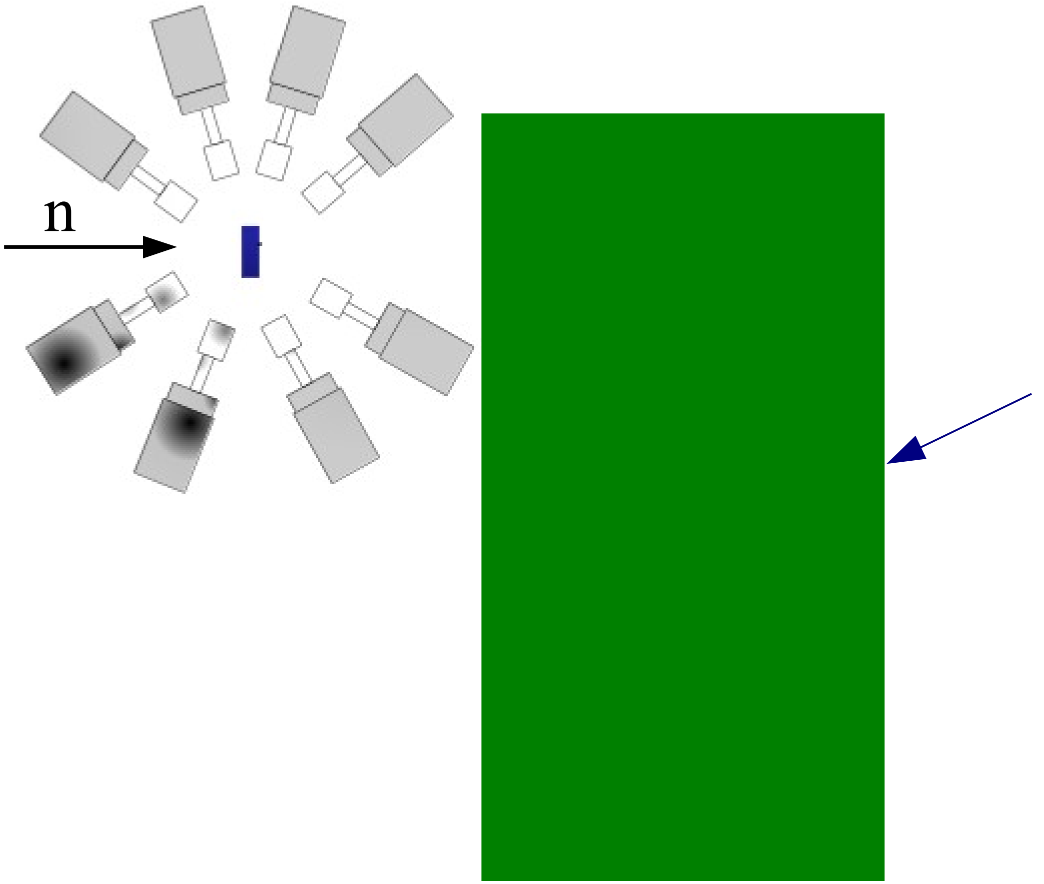
FIPPS phase II: first design propositions

- **“Non-focusing” magnet:**



FIPPS phase II: first design propositions

"Non-focusing" magnet:

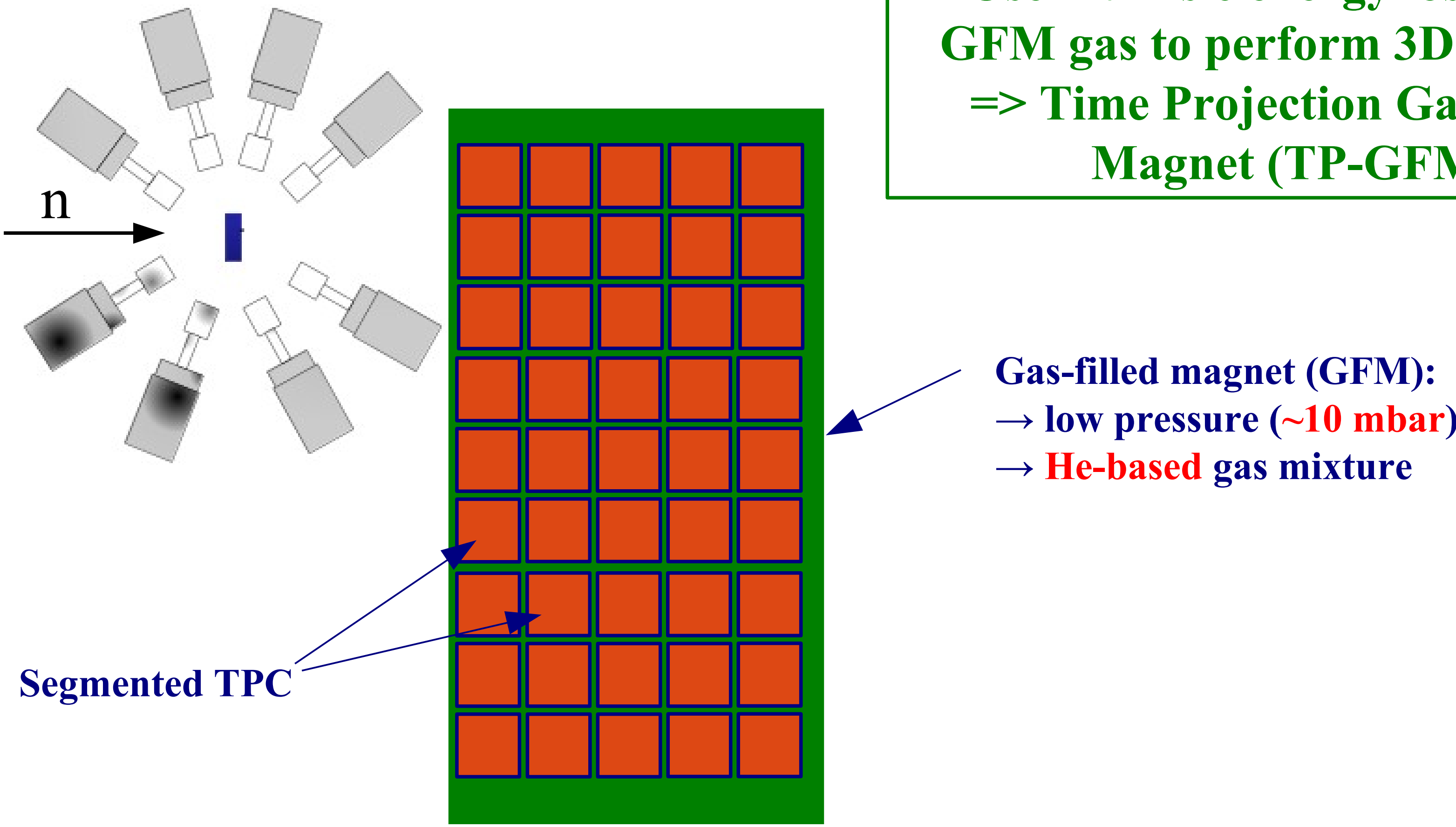


Gas-filled magnet (GFM):
→ low pressure (~10 mbar)
→ He-based gas mixture

FIPPS phase II: first design propositions

- **"Non-focusing" magnet:**

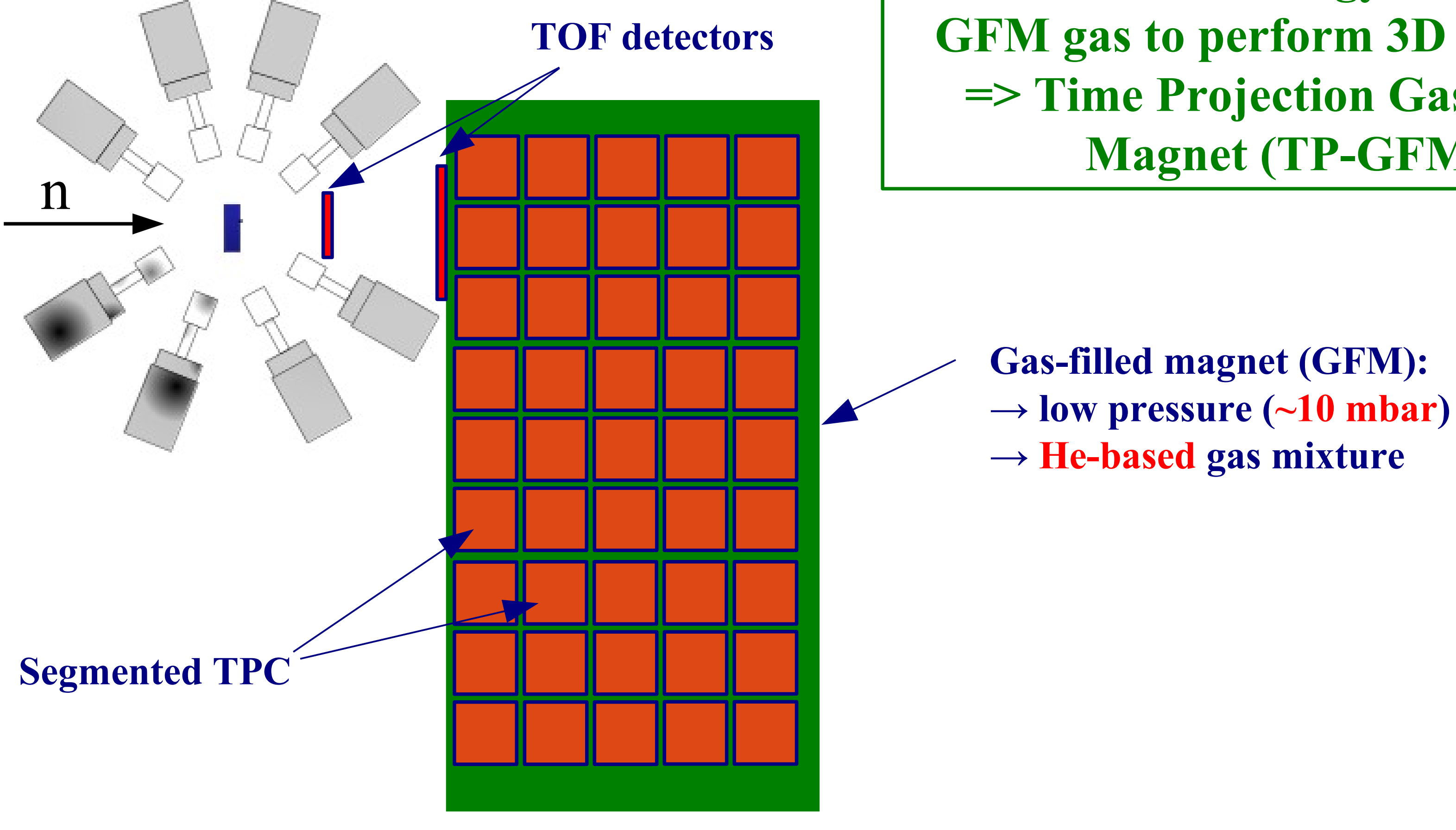
New concept:
Use intrinsic energy loss inside GFM gas to perform 3D tracking => Time Projection Gas-Filled Magnet (TP-GFM)



FIPPS phase II: first design propositions

"Non-focusing" magnet:

New concept:
Use intrinsic energy loss inside GFM gas to perform 3D tracking
=> Time Projection Gas-Filled Magnet (TP-GFM)



FIPPS phase II: first design propositions

"Non-focusing" magnet:

+:

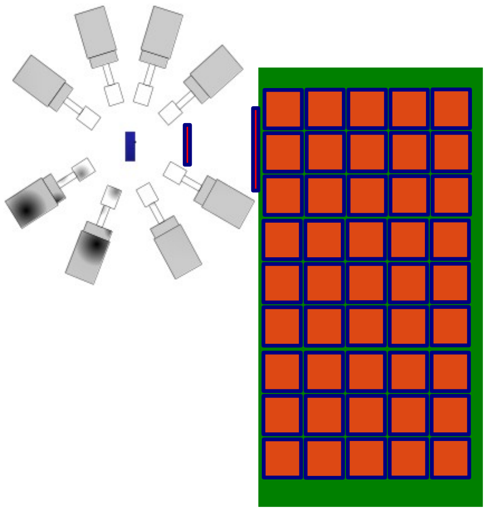
- "All" fission product accessible in the same time
- large acceptance
- large space around the Ge array for ancillary detectors

-:

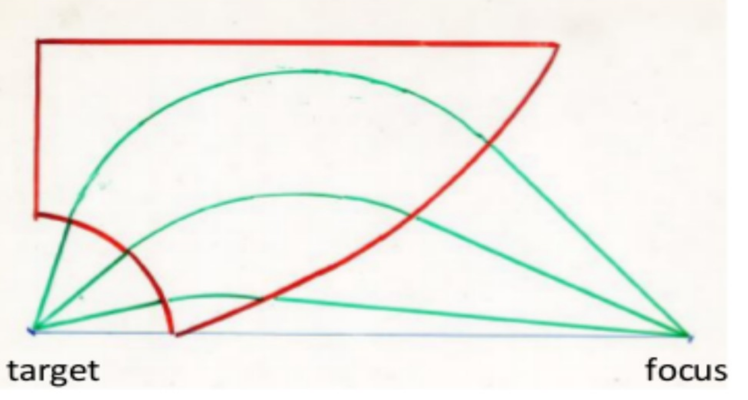
- no focal plane study (and fragments are stopped in the gas anyway)
- limited mass resolution with respect to standard GFM (to be determined)
- new technique

FIPPS phase II: first design propositions

- "Non-focusing" magnet:

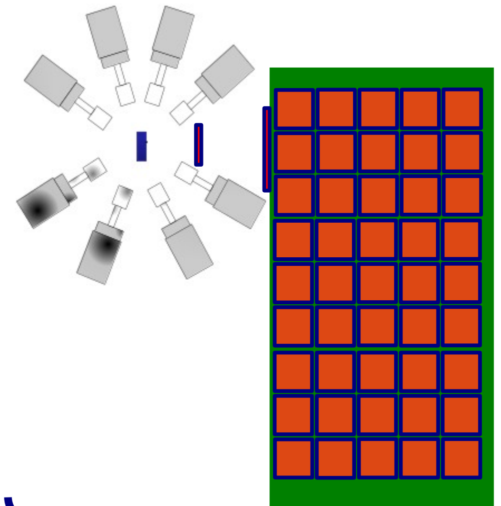


- Focusing magnet:

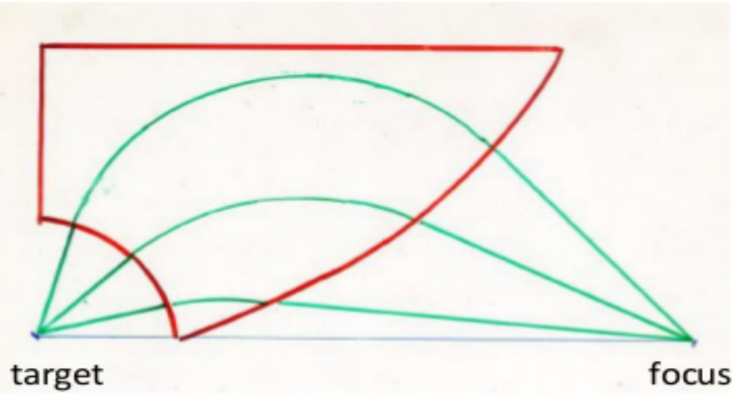


FIPPS phase II: first design propositions

- "Non-focusing" magnet:



- Focusing magnet:



2 instruments in 1

Magnet design allowing focusing or not depending on the needs

Conclusion

Conclusion (1)

- All **EXILL** requirements achieved:
  - Halo-free **pencil neutron beam** (1 cm^2), ~10^8 $n.cm^{-2}.s^{-1}$
  - **Safe target environment** allowing (n,f) of actinides targets (^{235}U, ^{241}Pu)
  - Up to **50 Ge crytals and 16 LaBr scintillators** operating simultaneously
  - **Trigerless DAQ**, >10 kHz/crystal, **>600kHz total**

- ~100 days of data taking
  - **>60 Tb of data stored**, storage shared between:
    - CC IN2P3 Lyon
    - ILL
    - LPSC-Grenoble

  GRID-based user-friendly access using IRODS

Conclusion (2)

FIPPS:

- Phase I: Ge array
  - safe-handling of various actinide targets → **ILL know-how**
  - halo-free pencil beam of neutron → **experimentally validated**
  - safe operation of Germanium array close to neutron beam → **experimentally validated**
  - triggerless DAQ with high-rate capability (~6kHz/crystal) → **experimentally validated**
  - fission veto/tagging using scintillating active target → **being tested**
- Phase II: Ge array + Spectrometer
  - Designing phase:
    - first design proposition: 2 instruments in 1 → is it feasible?
- Phase III: relocation at the end position of a new ILL guide

Conclusion (2)

	Cost (k€)	Available at ILL
Phase I: Ge detector array		
mechanics	50	√ (depending on the array design)
Ge detectors	1500	X
electronics	70	√ (from EXOGAM campaign)
LN2 filling system	10	√ (from EXOGAM campaign)
$LaBr_3(Ce)$ detectors	100	√ (from FATIMA collaboration)
Collimation system	40	√ (from EXOGAM campaign)
H22 casemate shielding	50	X
Phase II: Spectrometer		
Gas-Filled Magnet	500	X
TOF detector+electronics	20	X
TPC detectors+electronics	100	X
various mechanics	50	X
Phase III: relocation at H24	400	X
Total	**2890 - 270 = 2620 k€** **+15% => 3013 k€**	

Conclusion (3)

- **FIPPS:** potential interests
  - detailed spectroscopy of neutron rich nuclei
  - nuclear fission study
  - fast neutron beams
  - reaction study in inverse kinematic?

} **Moveable spectrometer**

FIPPS is part of the new ILL ENDURANCE program => 3M€
Final answer October 2014

The EXILL collaboration

NEUTRONS FOR SCIENCE

CSNSM

DE LA RECHERCHE À L'INDUSTRIE cea

Yale University

LUX ET VERITAS

BARC

ATOMS IN THE SERVICE OF THE NATION

NEUTRONS FOR SCIENCE

IPHC Institut Pluridisciplinaire Hubert CURIEN STRASBOURG

ipnl

TECHNISCHE UNIVERSITÄT DARMSTADT

MTA atomki DEBRECEN

UNIVERSITAS COMPLVTENSIS MATRITENSIS

University of Brighton

UNIVERSITAS VARSOVIENSIS

UNIVERSITE JOSEPH FOURIER SCIENCES, TECHNOLOGIE, SANTÉ

LPSC Grenoble Laboratoire de Physique Subatomique et de Cosmologie

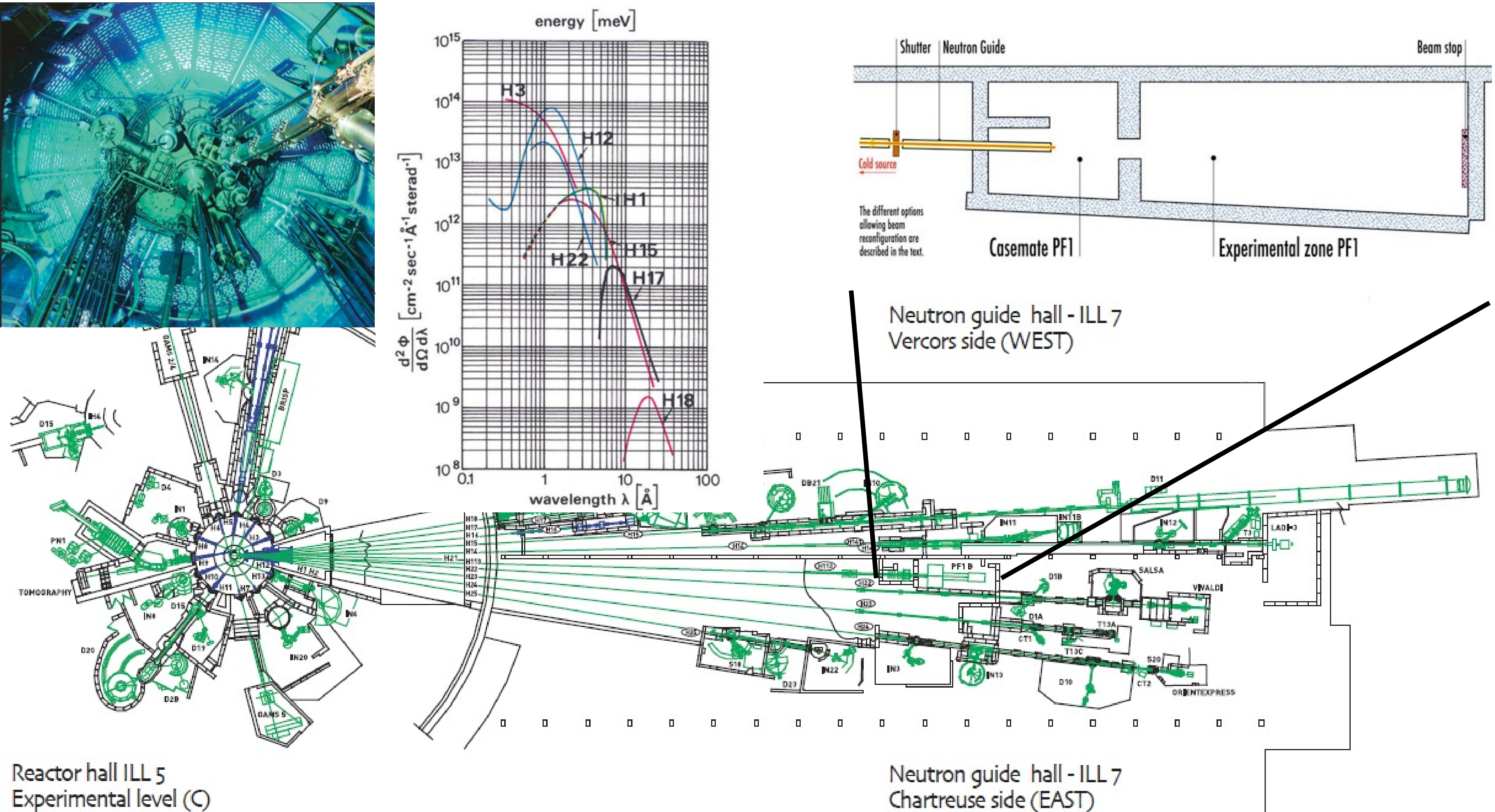
GANIL spiral2 laboratoire commun CEA/DSM CNRS/IN2P3

UNIVERSITY OF SURREY

INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Legnaro

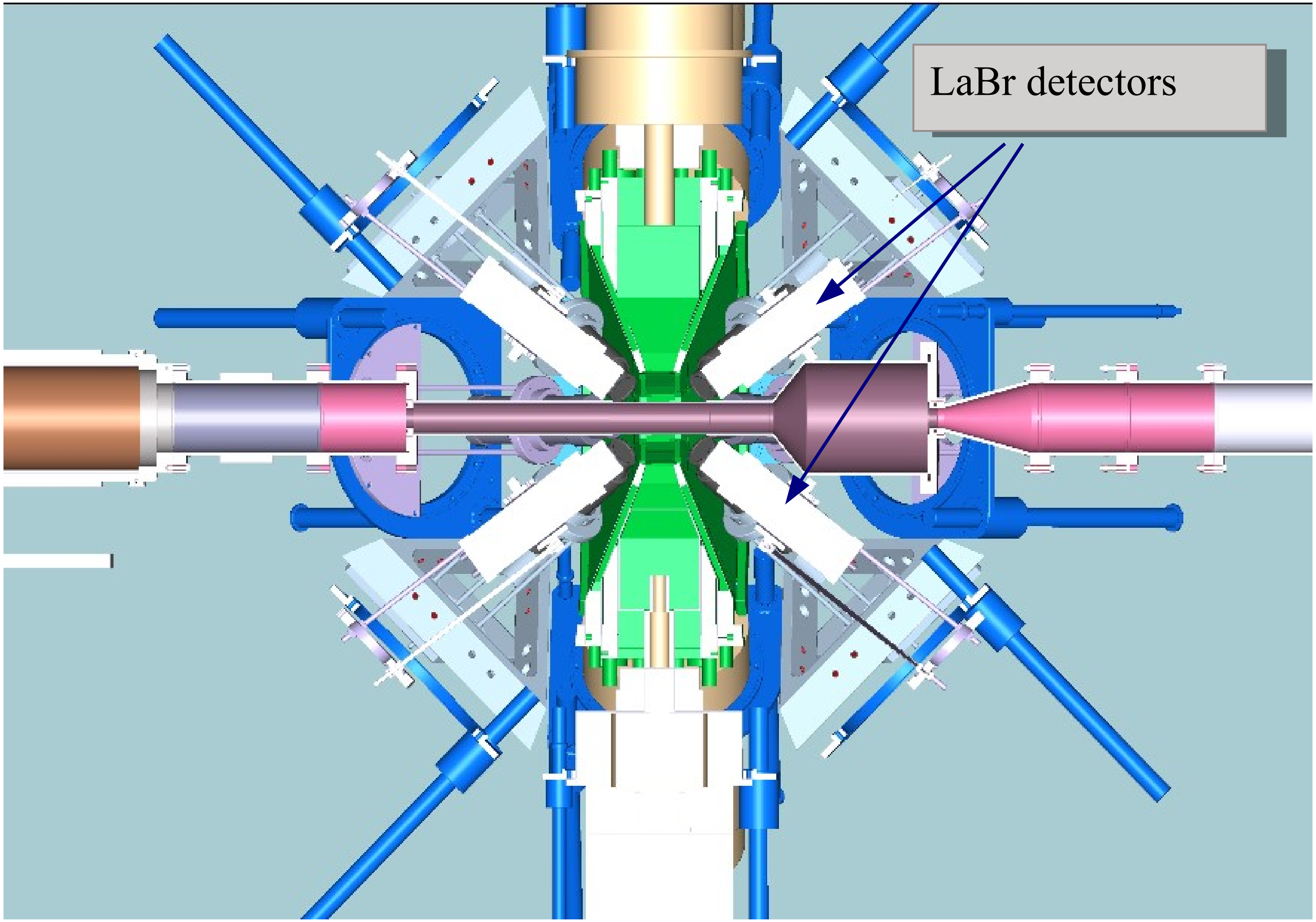
BACKUP

From the reactor to PF1b



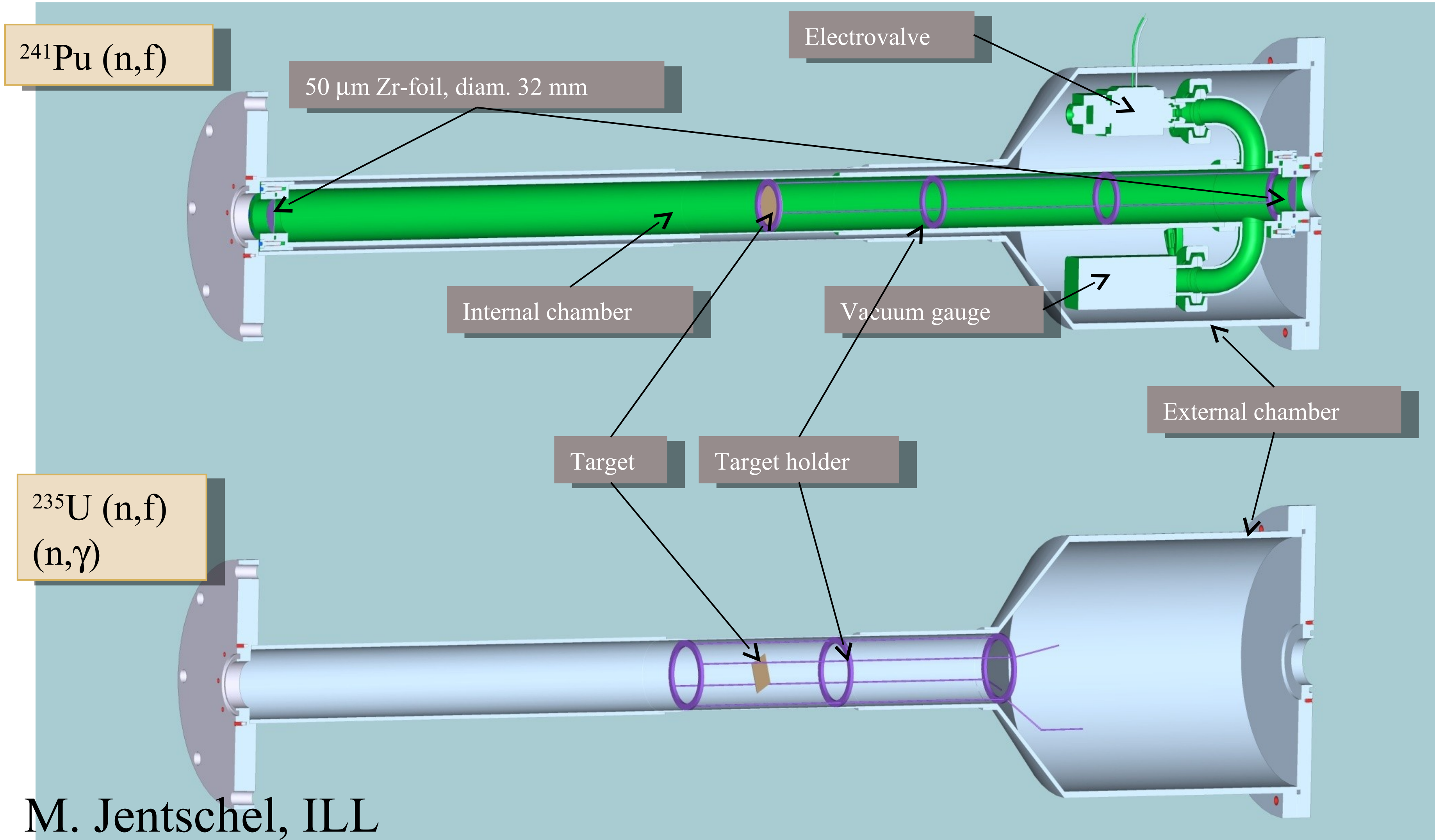
reactor (5×10^{14} n cm^{-2} s^{-1}) → ballistic neutron guide → PF1b zone (2×10^{10} n cm^{-2} s^{-1})

EXILL in PF1b experimental zone



M. Jentschel, ILL

EXILL chamber: two configurations



Design consideration for fission targets

Targets sandwiched between dense backings for rapid stopping of fission fragments.

Boundary conditions for backing material:

- low neutron capture cross-section
- minimize neutron scattering ⇒ no/low hydrogen
- high stopping power to minimize Doppler broadening of picosecond states
- avoid high *Z* to limit attenuation of low energy gamma rays
- chemically compatible with deposition technique of actinide layer
- non-cubic lattice with electric field gradient may perturb angular correlations

⇒ **Two alternative solutions**

1. Medium *Z* backing for fast stopping:

15 μm Zr foils laminated by cold-rolling with Sn as filler material

2. Low *Z* backing for minimum gamma ray attenuation at slightly slower stopping:

25 μm Be foils glued with thin layer of cyanoacrylat

Fission targets

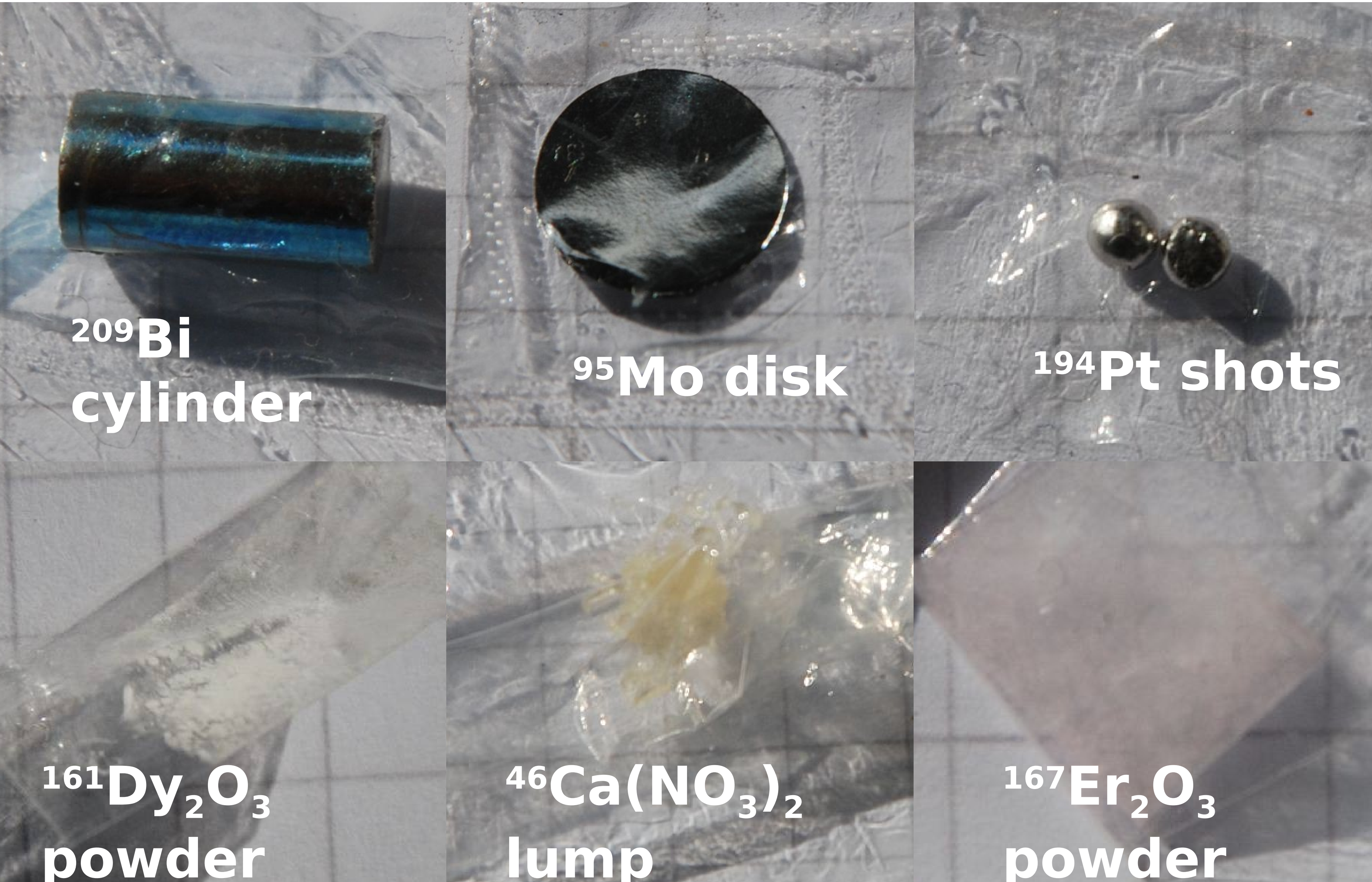
1. **^{235}U-Zr/Sn, nominal fission rate 70 kHz**
   3 layers UO_2 (total 575 μg/cm^2 of 99.7% enriched ^{235}U)
   laminated with Sn between 15 μm thick Zr foils (nuclear grade, <50 ppm Hf)
   15 days for (n,γγγ) spectroscopy with complete Ge array

2. **^{235}U-Be, nominal fission rate 90 kHz**
   1 layer UO_2 (675 μg/cm^2 of 99.7% enriched ^{235}U)
   glued with thin layer of cyanoacrylate between 25 μm thick Be foils
   5 days for (n,γγγ) spectroscopy with complete Ge array
   14 days for ultrafast timing measurements with mixed Ge/$LaBr_3$:Ce array

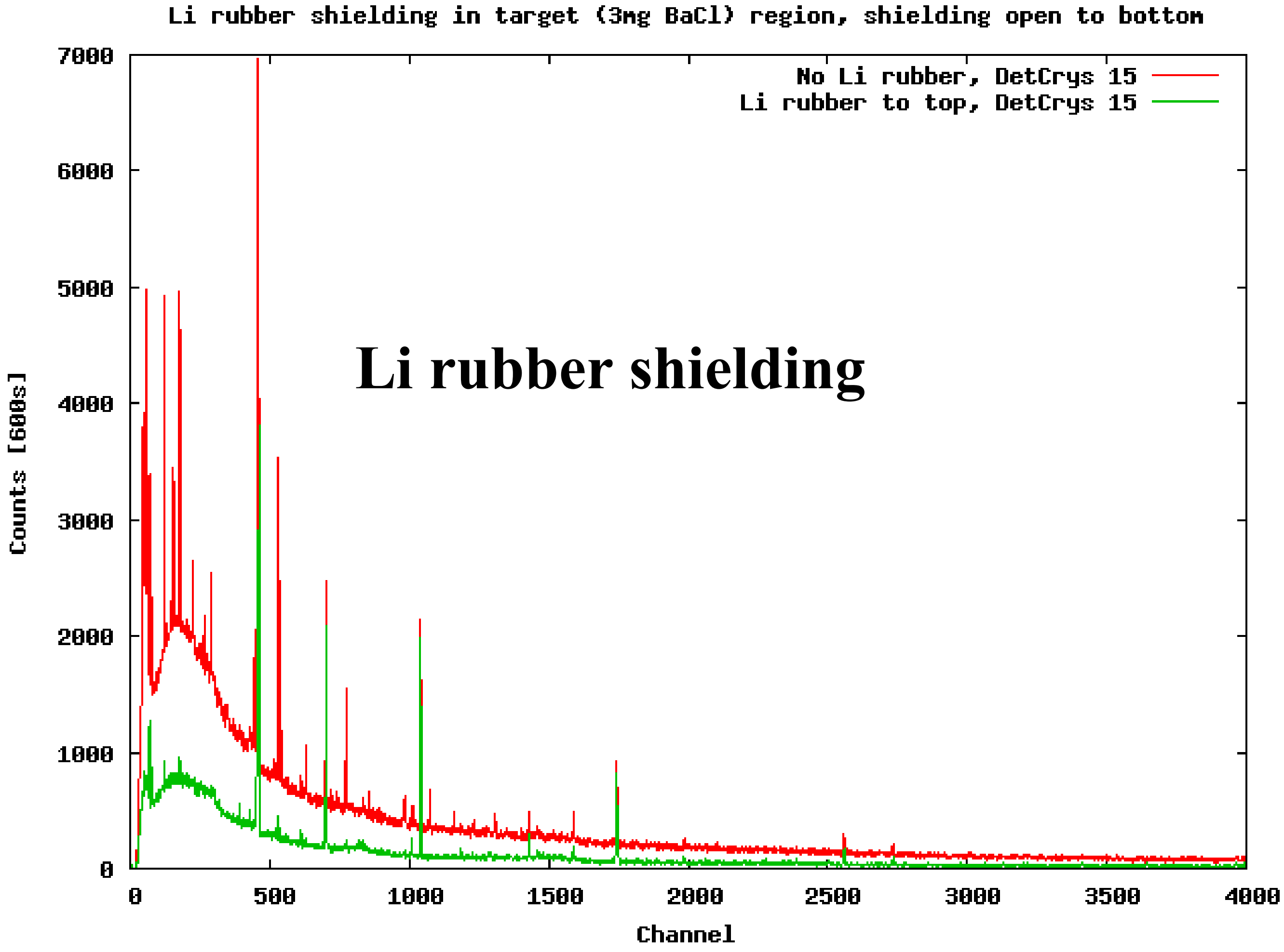
3. **^{241}Pu-Be, nominal fission rate 70 kHz**
   1 layer PuO_2 (300 μg/cm^2 of 78.6% ^{241}Pu, plus non-fissile ^{240}Pu and ^{242}Pu)
   glued with thin layer of cyanoacrylate between 25 μm thick Be foils
   - ^{241}Am daughter freshly separated and target prepared at Kernchemie Mainz

   15 days for (n,γγγ) spectroscopy with complete Ge array
   9 days for ultrafast timing measurements with mixed Ge/$LaBr_3$:Ce array

Stable isotopes EXILL target for (n,γ)



Background measurements



Background measurements