FIPPS
FIssion Product Prompt gamma-ray Spectrometer

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CEA-Saclay : *T. Materna*
LPSC-Grenoble : *G. Kessedjian, C. Sage, G. Simpson*
University of Warsaw : *W. Urban*

Summary

- Nuclear physics at ILL
- EXILL
  - Motivation
  - Setup
  - Performances
- FIPPS
  - FIPPS layout
  - FIPPS with fast neutrons
- 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

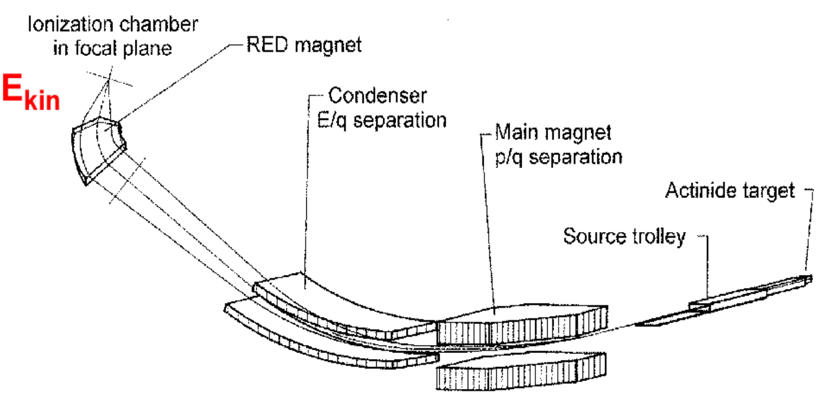
Nuclear Physics at ILL (1)

- The LOHENGRIN fission fragment separator:

ΔA/A = 3E-4 – 3E-3
ΔE/E = 1E-3 – 1E-2

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

The LOHENGRIN recoil separator

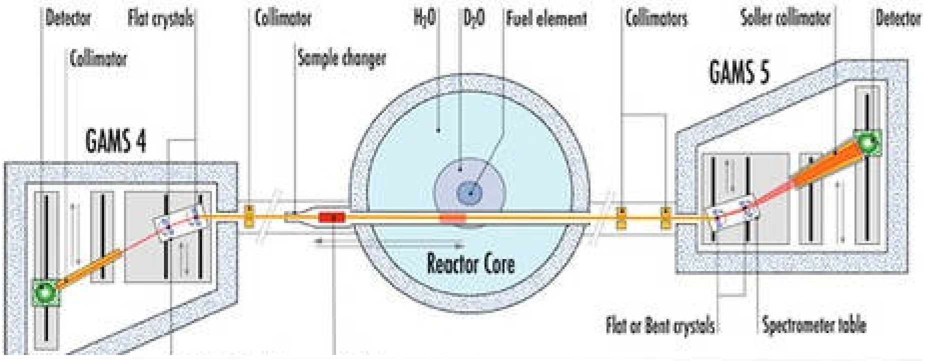


$$m v^2 / r_{el} = q E \qquad m v^2 / r_{magn} = q v B$$

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

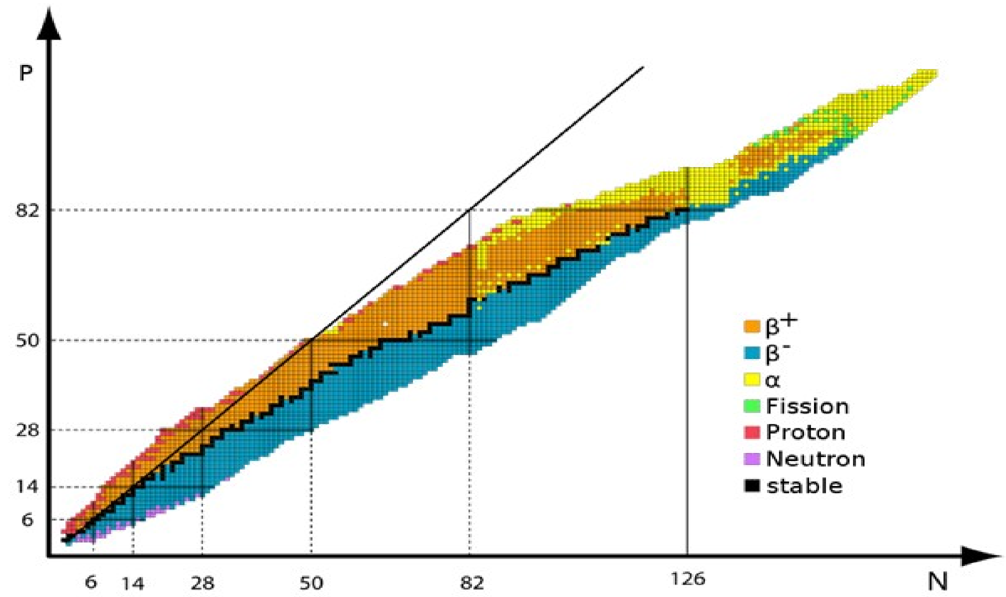
P. Armbruster et al., Nucl. Instr. Meth. 139 (1976) 213.

- Gamma-ray spectrometer (GAMS):

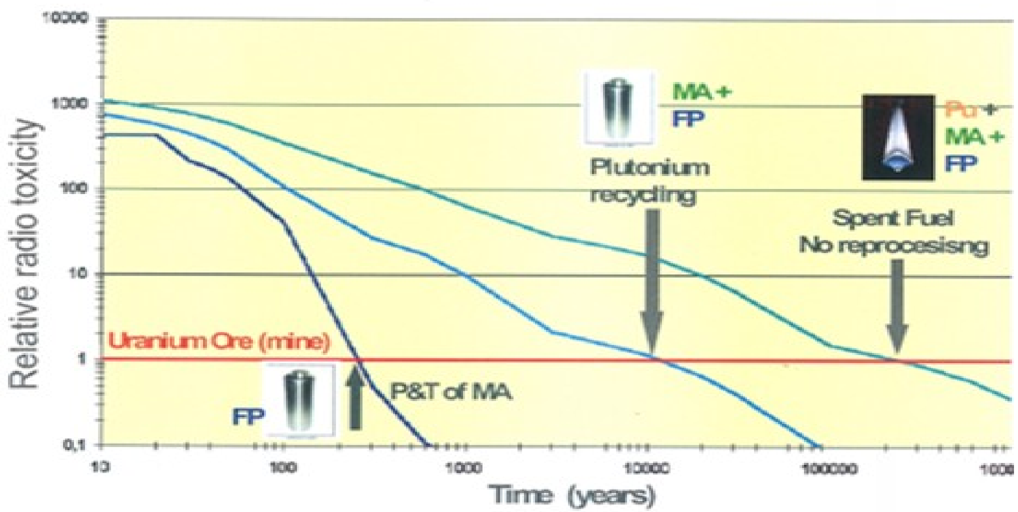


Nuclear Physics at ILL (2)

- Fundamental physics :
  - Detailed spectroscopy of neutron rich nuclei, astrophysical r-process
  - Nuclear fission studied via prompt spectroscopy



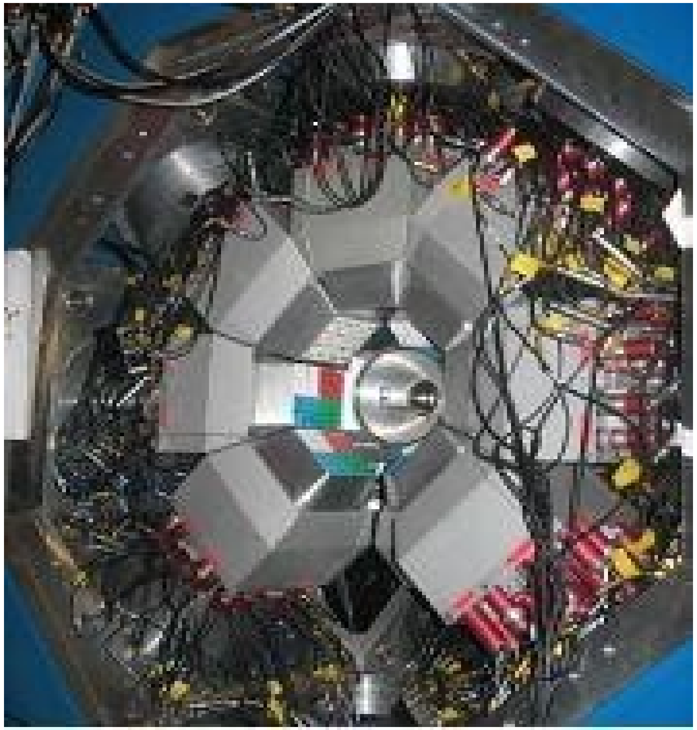
- Applied physics :
  - Nuclear waste burning
  - Generation IV reactors
  - Elemental imaging



EXILL

- **Motivation**
- **Setup**
- **Peformances**

EXogam @ ILL



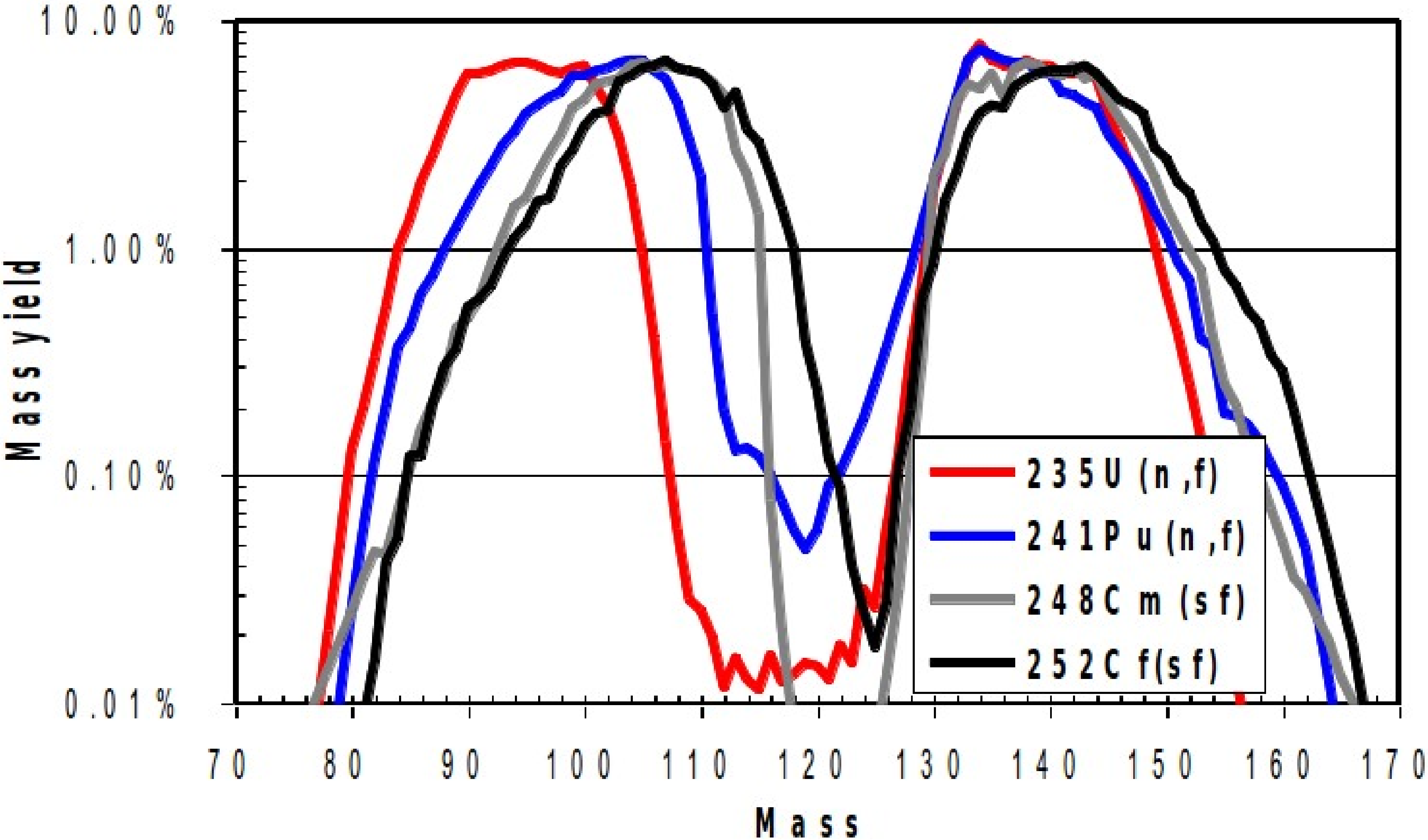
High efficiency germanium array

58 MW high flux reactor with intense extracted neutron beams

=> γ-ray spectroscopy of cold neutron induced reactions on 14 **stable** and 3 **actinide** targets

^{235}U(n,fission)

- ^{241}Pu(n,f) and ^{235}U(n,f) vs spontaneous fission sources



EXILL

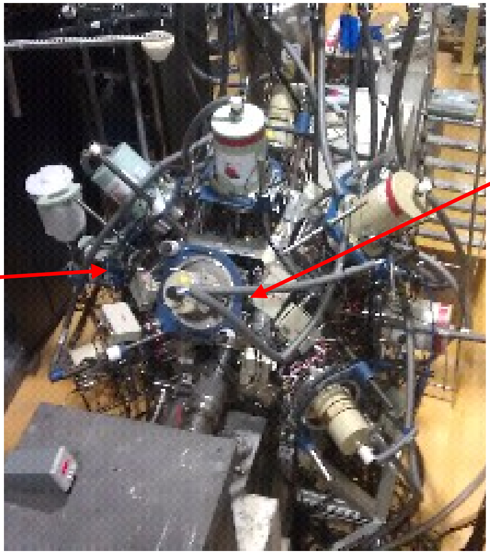
- Motivation
- **Setup**
- Performances

The EXILL setup

- EXILL campaign at PF1B: **EX**OGAM @ **ILL**

(October 2012 → April 2013)

EXOGAM+GASP array:
Provided by GANIL and LNL



235U and 241Pu targets with thick backing

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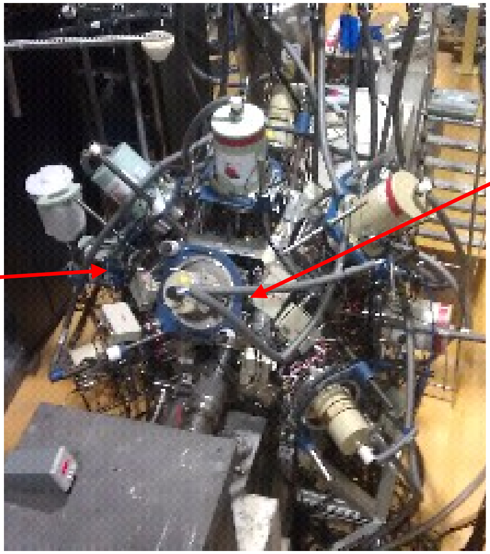

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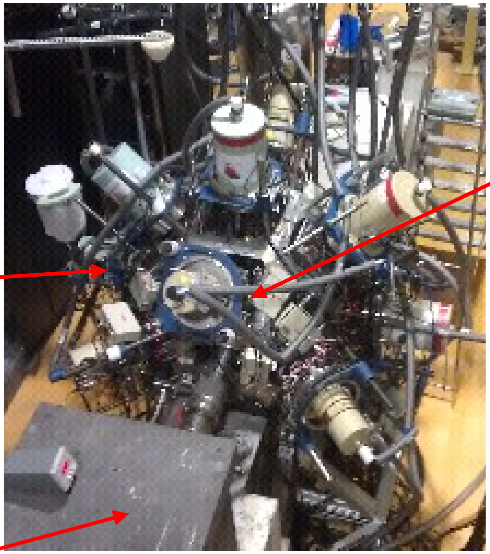
Collimation:
ϕ12 mm "pencil" neutron beam



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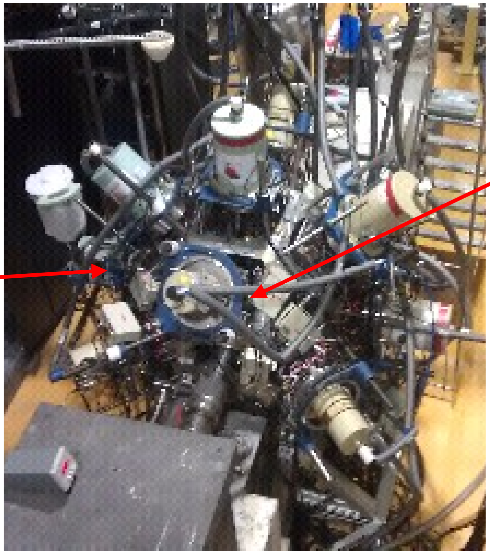
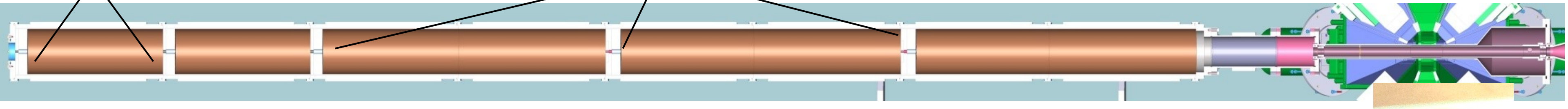


235U and 241Pu targets with thick backing

Borated plastics + ^{6}LiF
5 cm Pb

1cm B_4C ceramics
5 cm Pb



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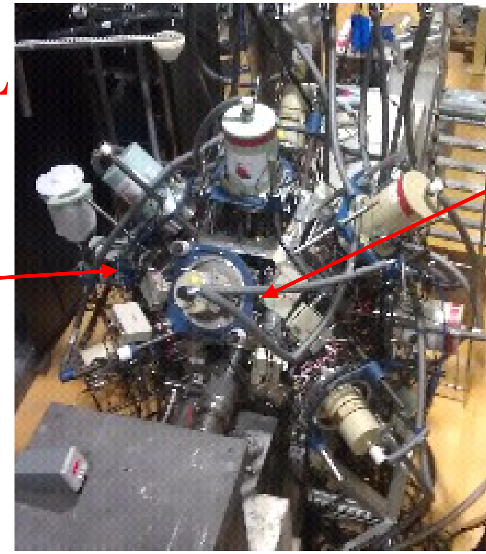

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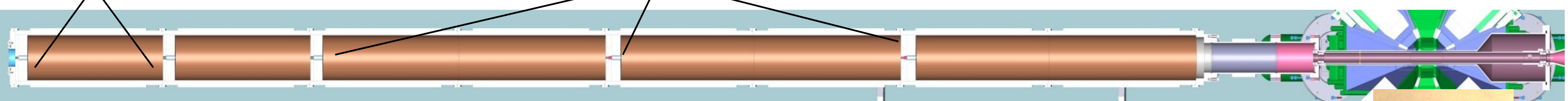

10^{10}

20*6 cm^2

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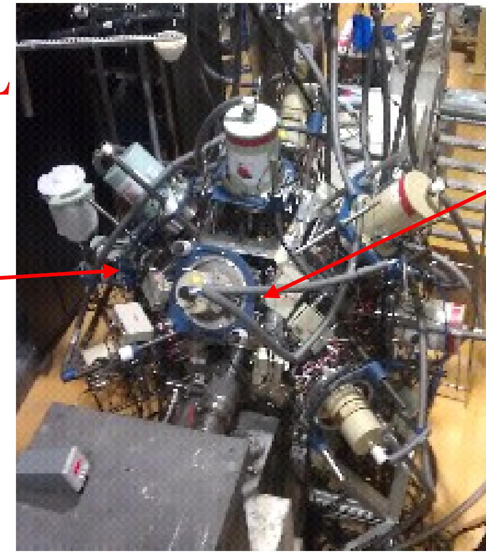

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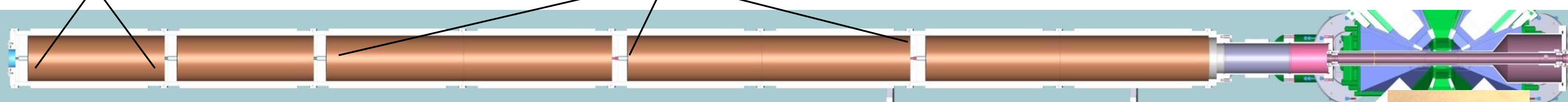


10^{10}
20*6 cm^2

→

10^{8}
1 cm^2

Fission targets

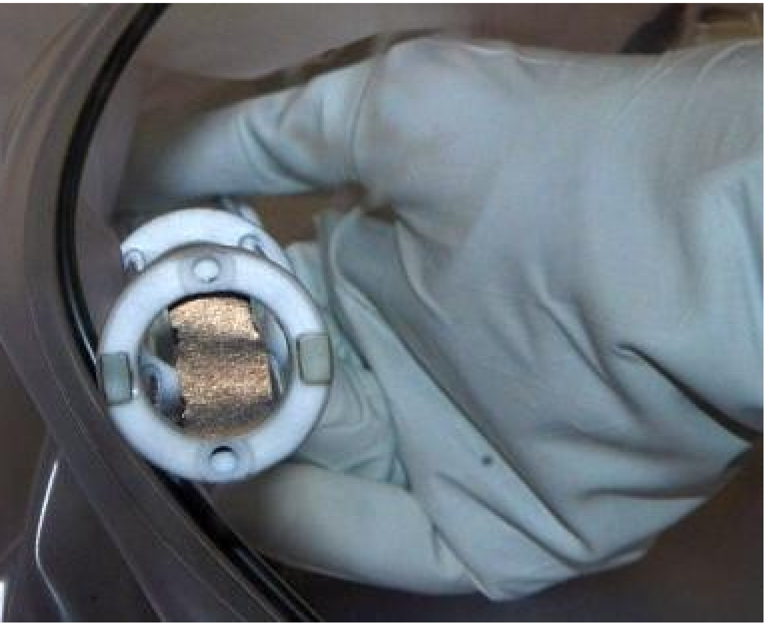
Targets **sandwiched between dense backings** for rapid stopping of fission fragments.

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

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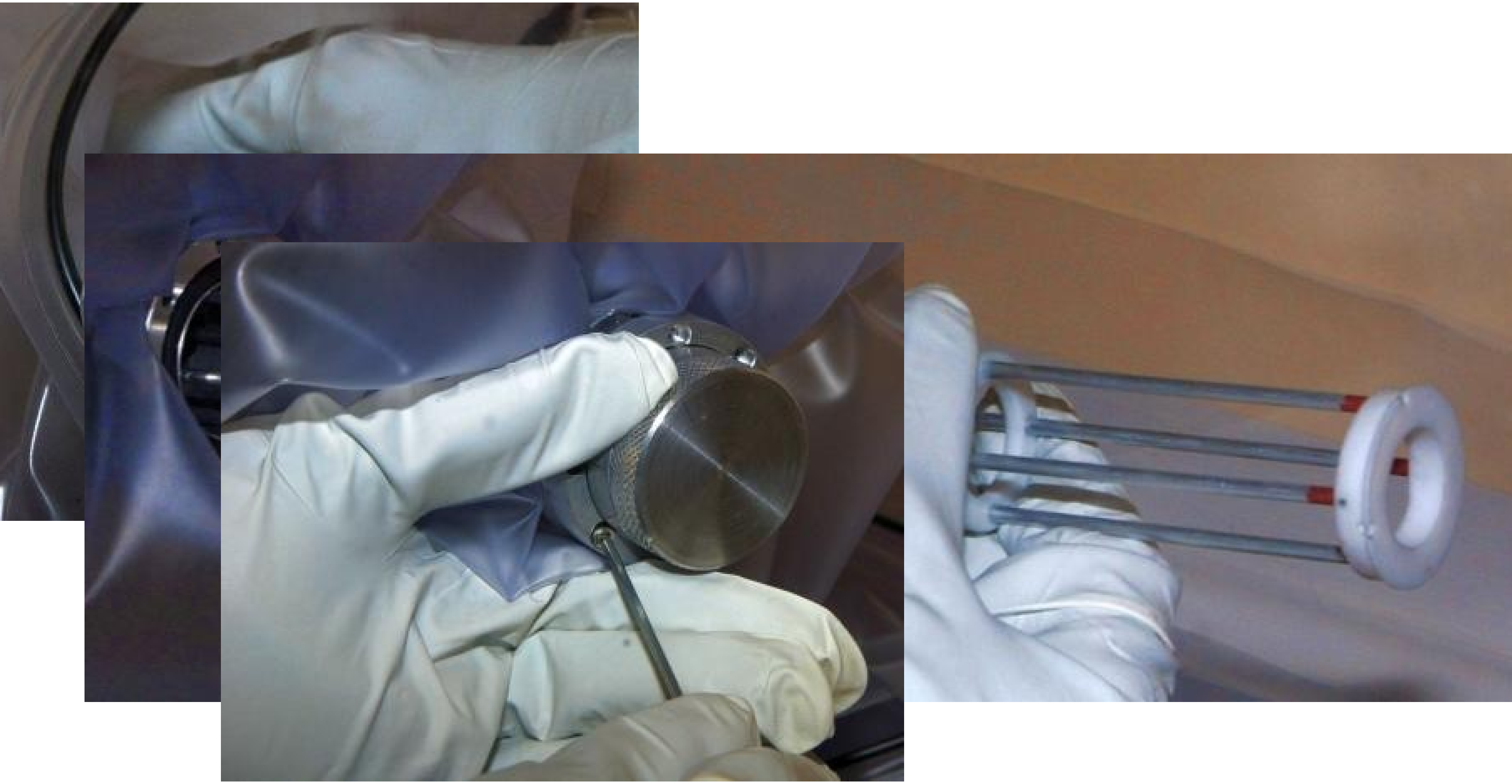

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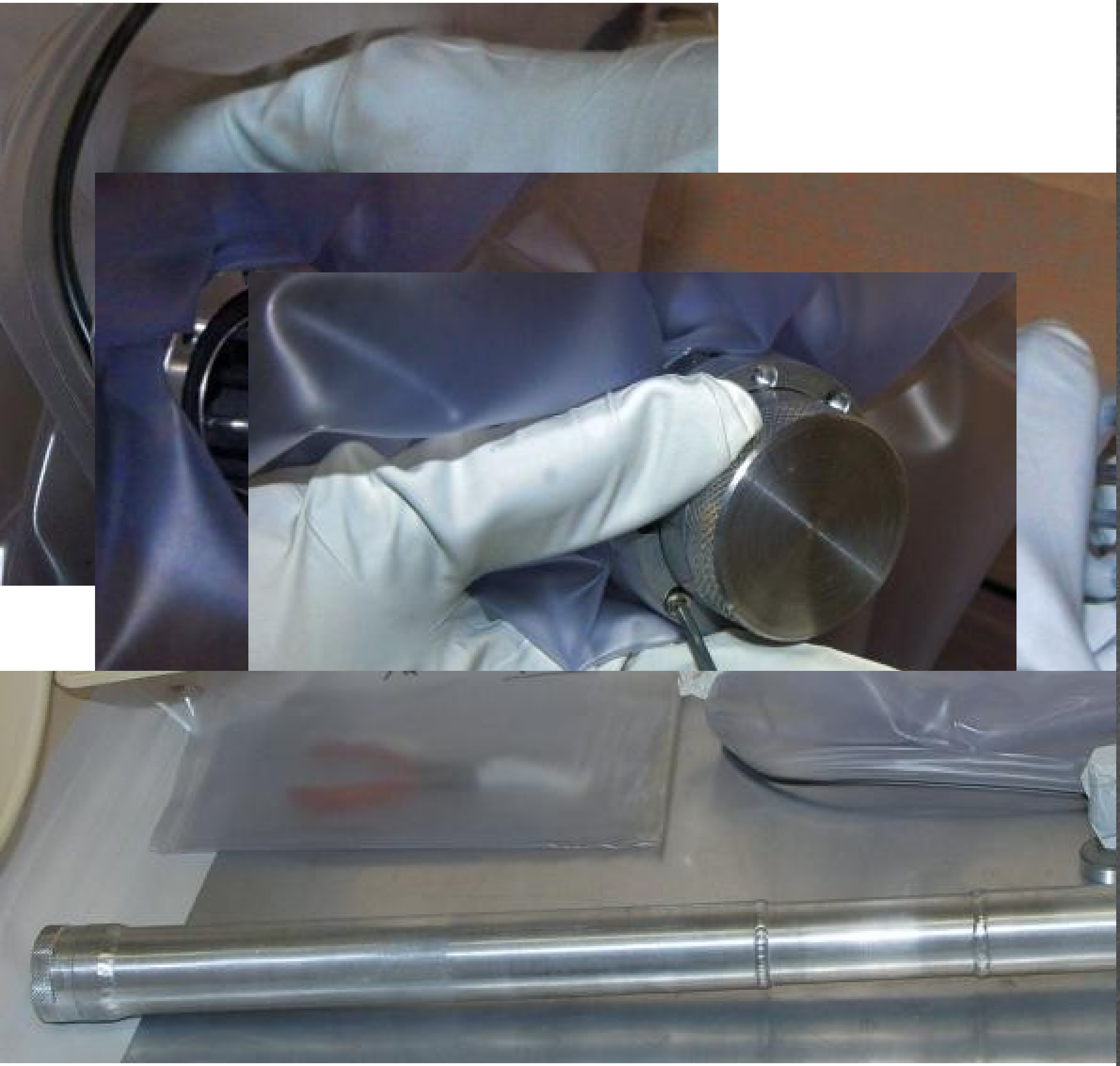
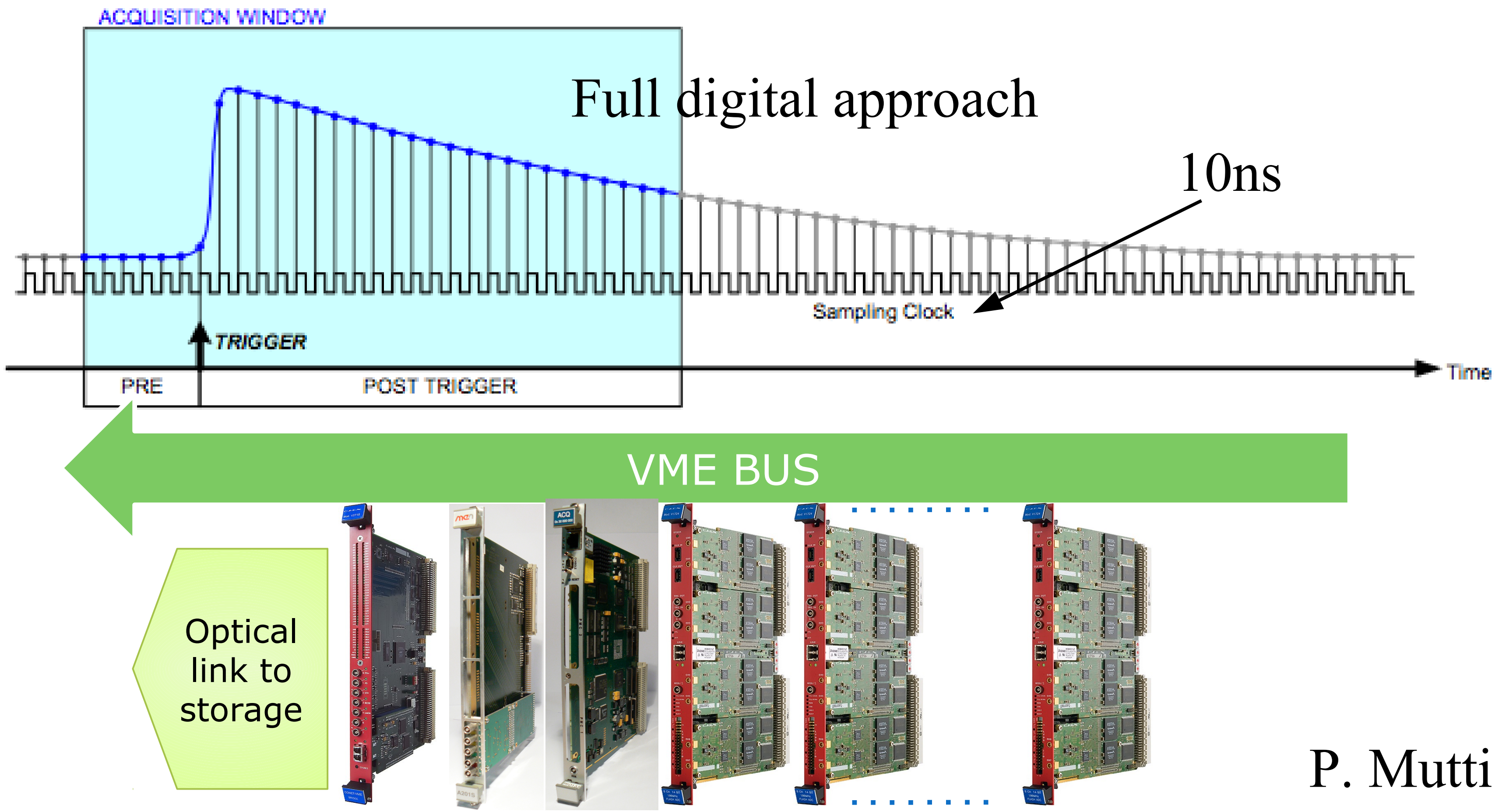


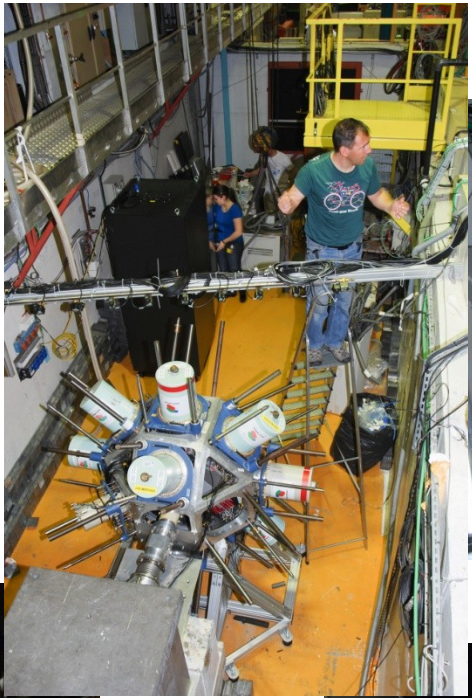
New triggerless DAQ

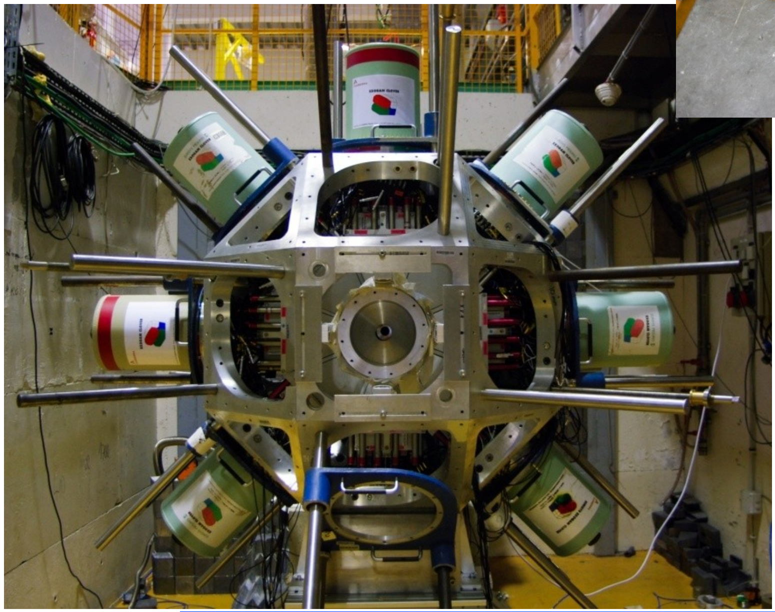
- Requirements:
  - Handle high event rate (>600 kHz)
  - Minimize dead time
  - Accurate timing
  - High data throughput

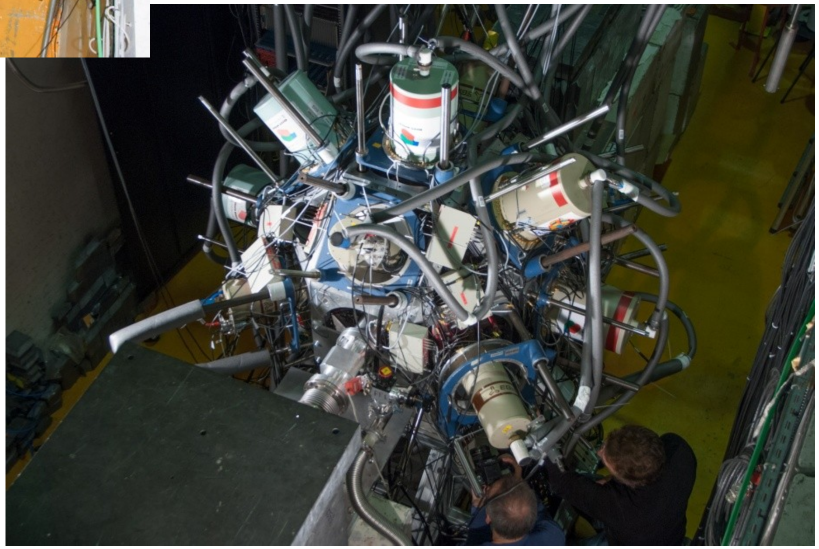


P. Mutti, ILL

EXILL installation within 10 days







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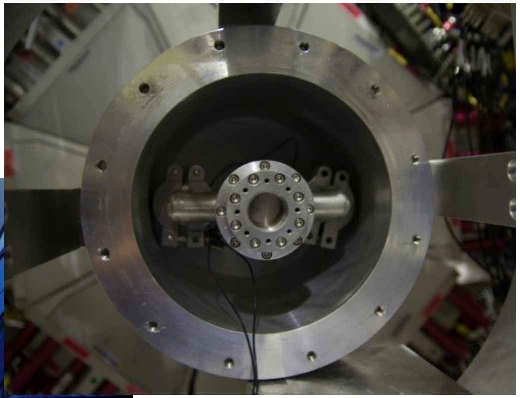
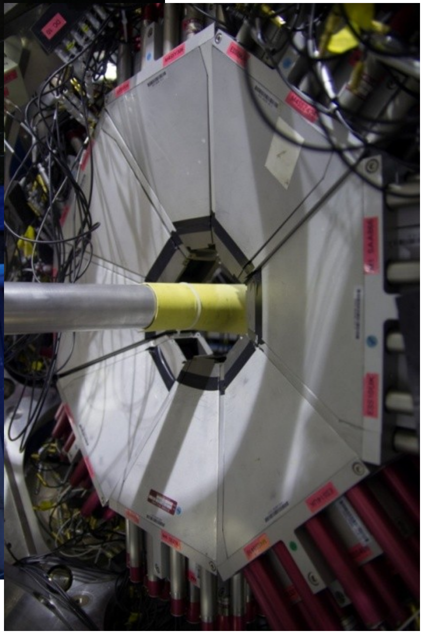




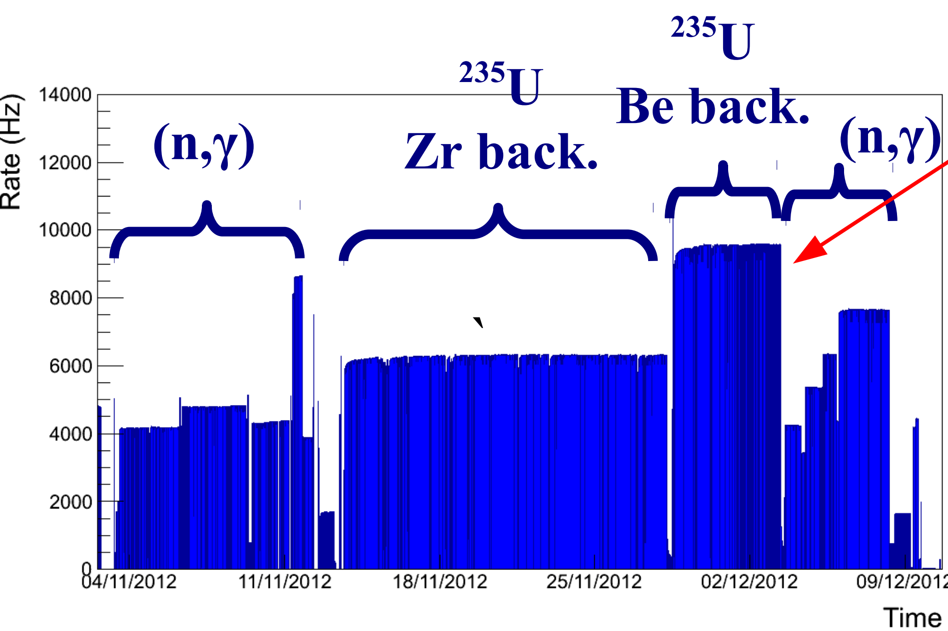
EXILL

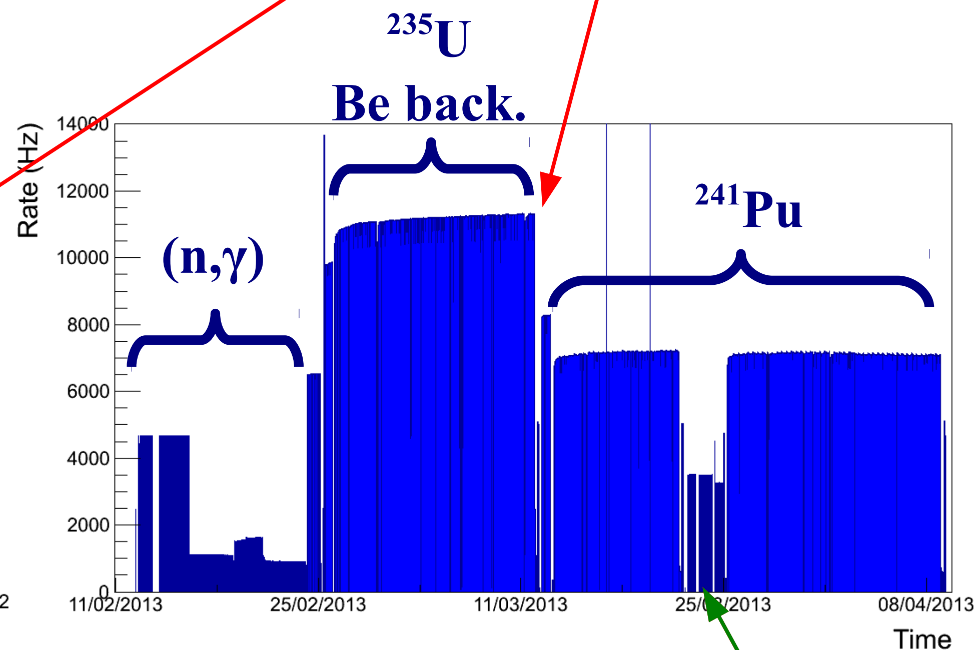
- Motivation
- Setup
- **Performances**

Data taking

10 kHz per crystal trigerless data taking achieved, 60 crystals

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

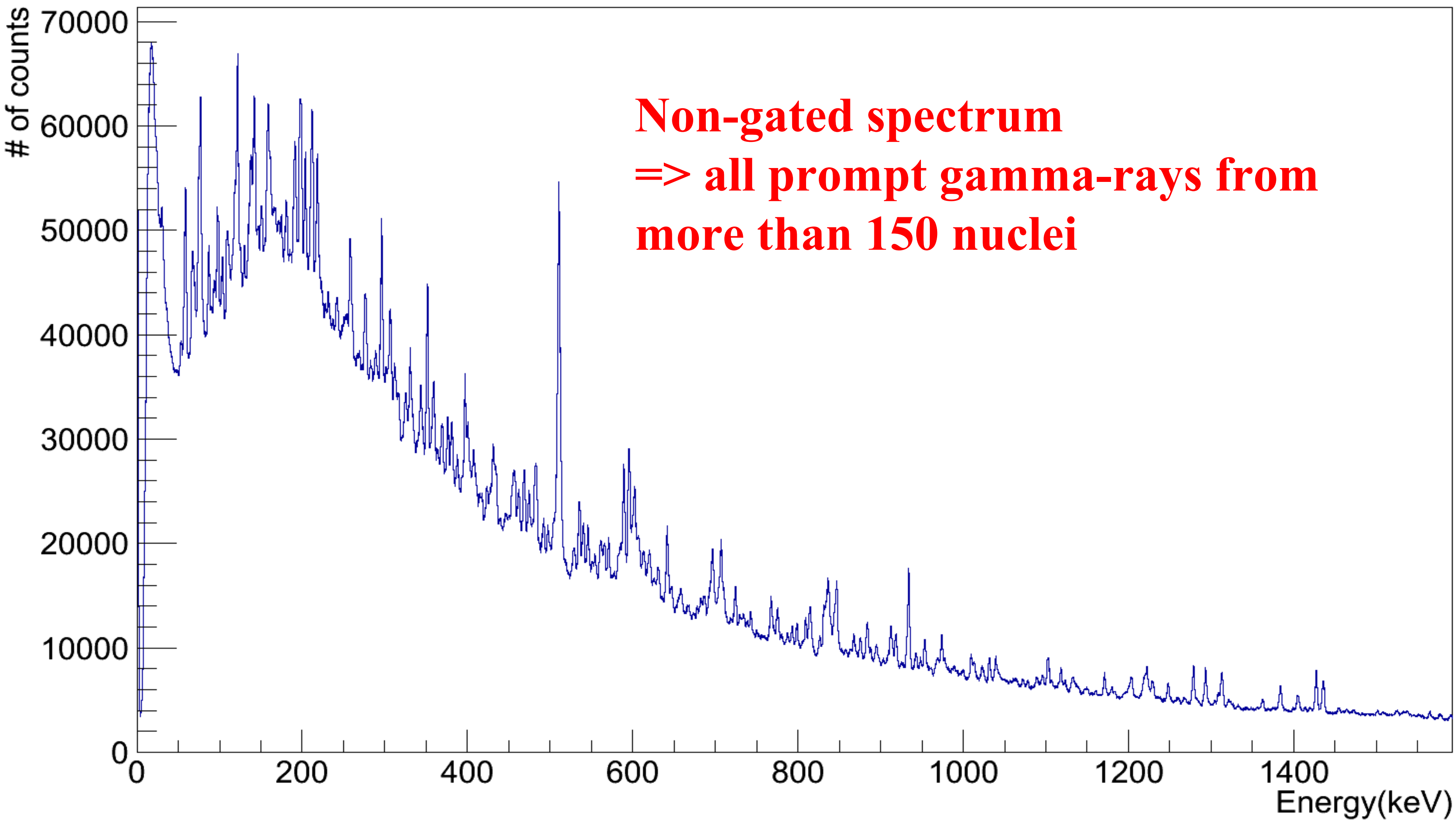




Setup changing, (n,γ) during nights

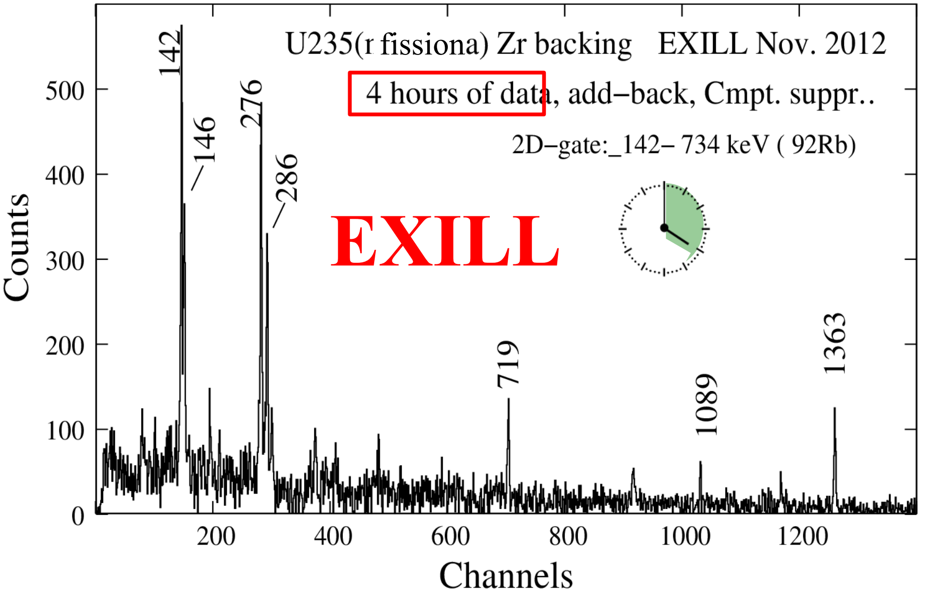
=> >95% of beam time dedicated to measurement

“Online” spectroscopy: ^{92}Rb



“Online” spectroscopy: ^{92}Rb

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



W. Urban, ILL

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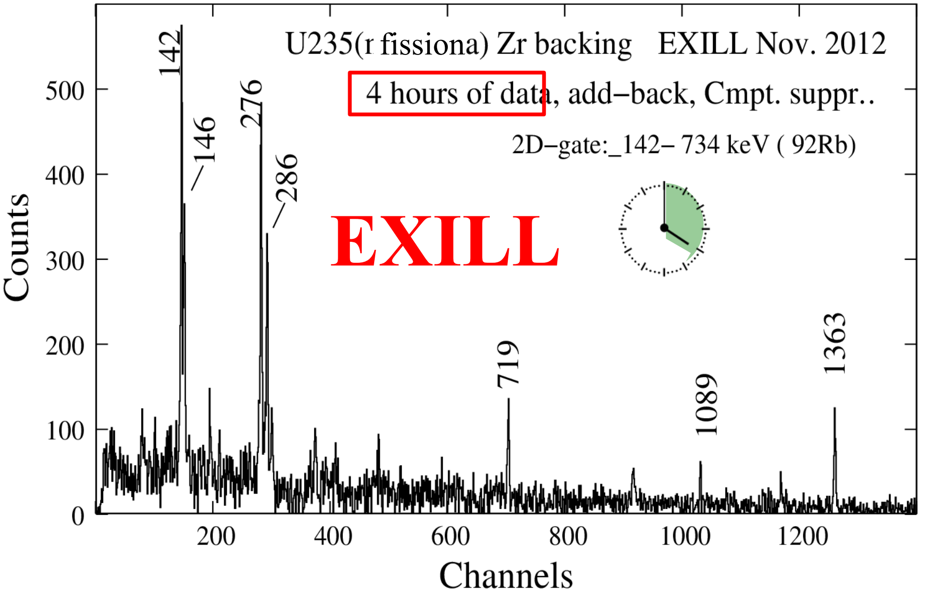
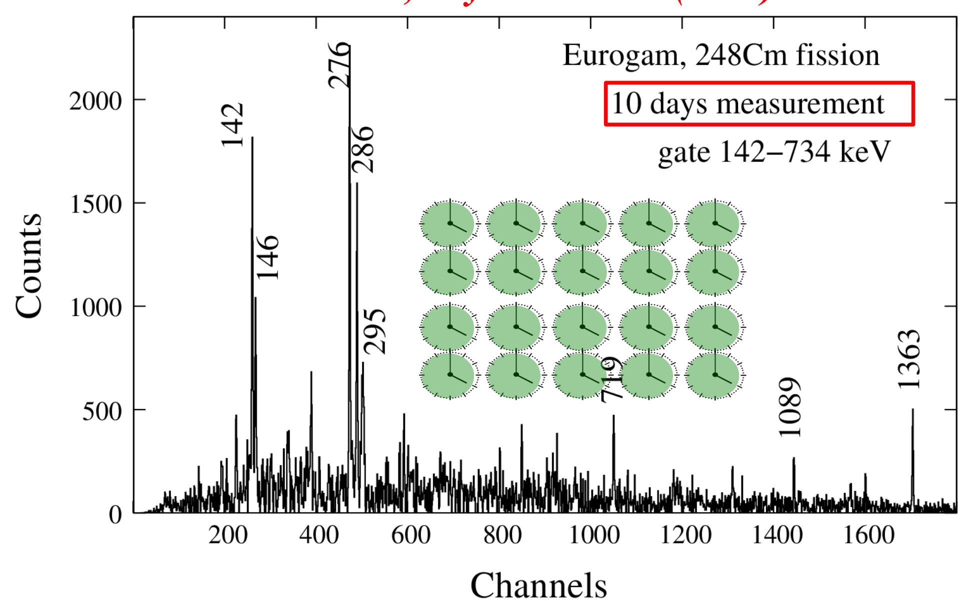


EUROGAM

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



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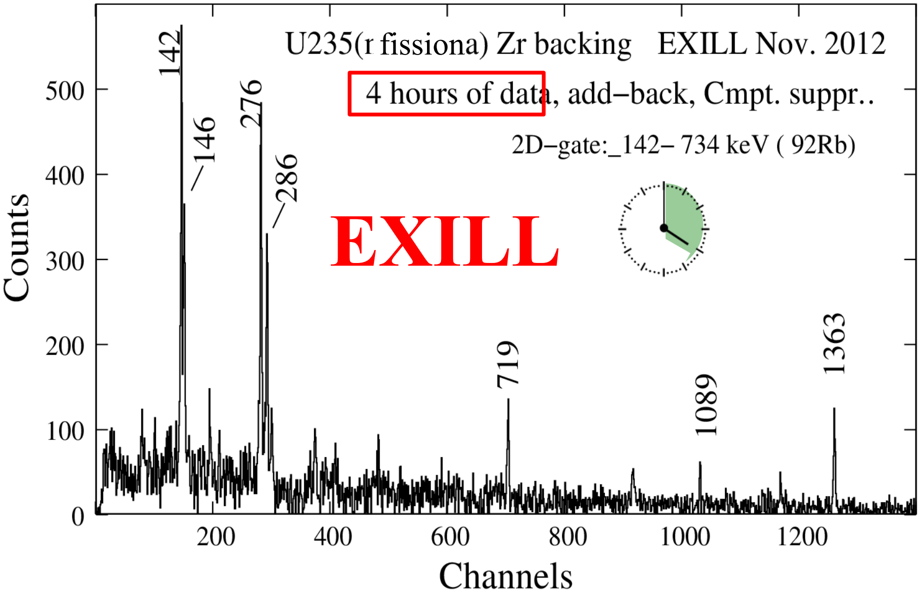

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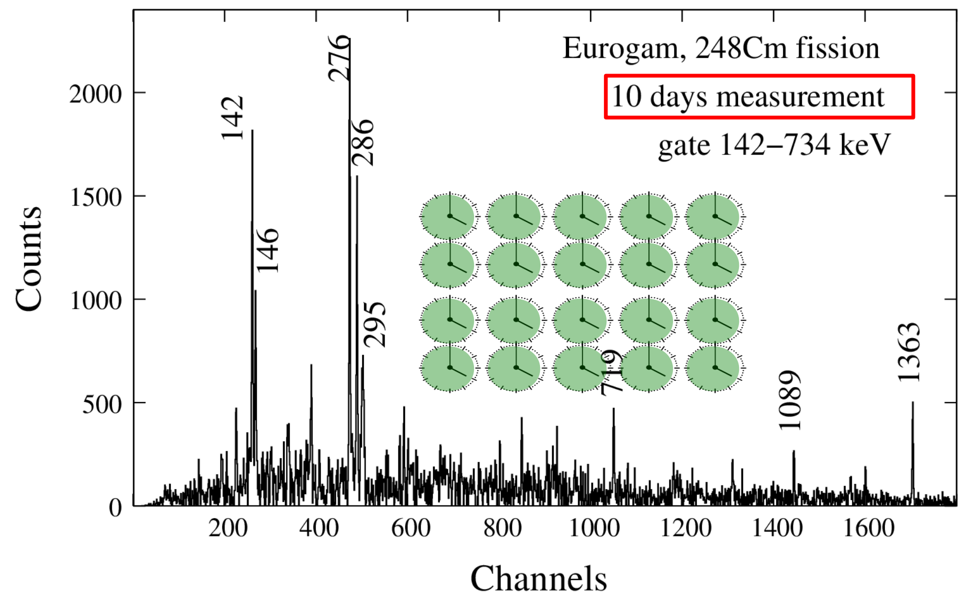

Much higher statistics
=> allow studying much weaker populated nuclei

W. Urban, ILL

First results

- *"Germanium-gated γ–γ fast timing of excited states in fission fragments using the EXILL&FATIMA spectrometer"*, J.M. Regis & al., NIM A, 763, Pages 210–220

- *"Test of the SO(6) selection rule in 196Pt using cold-neutron capture"*, J. Jolie et al., NuclearPhysics A 11/2014

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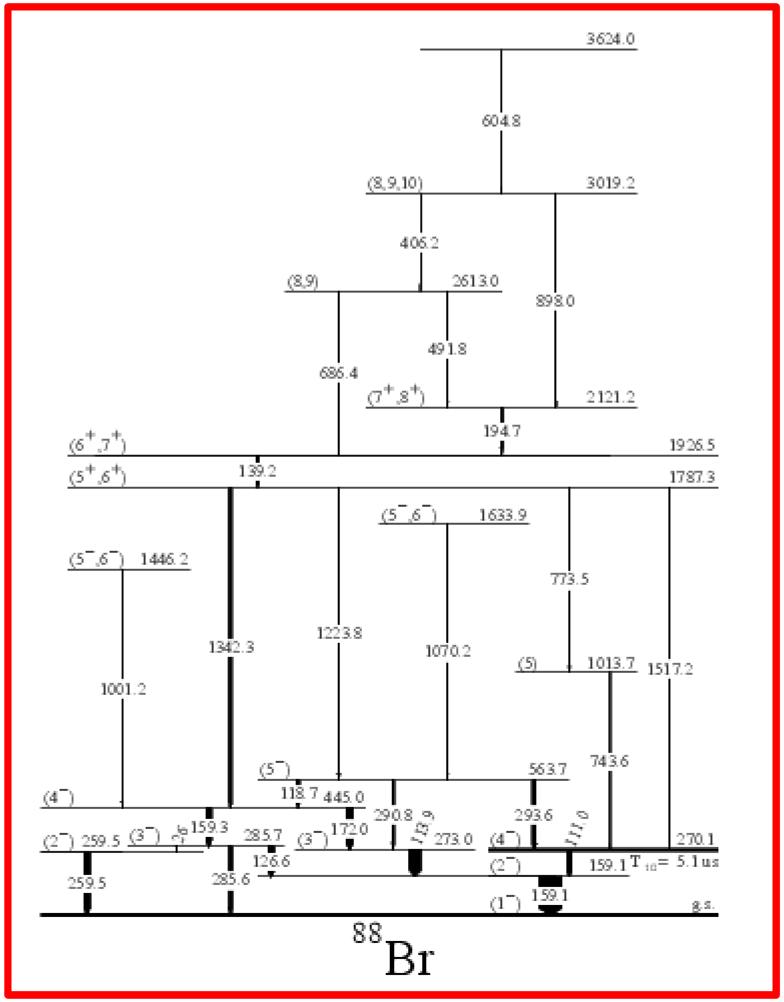
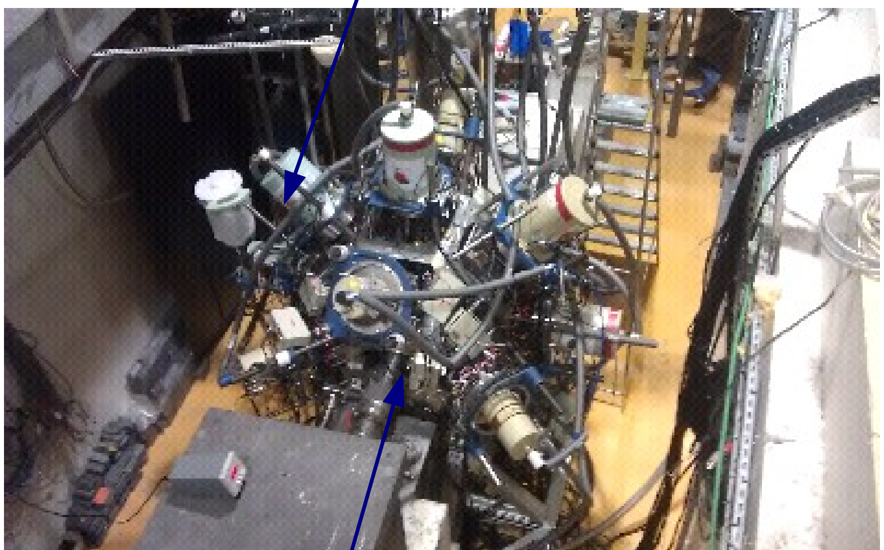


FIssion Product Prompt γ-ray Spectrometer

- **FIPPS layout**
- FIPPS with fast neutrons

FIPPS layout

γ-ray detection with Ge array (EXILL-like)



Fission target with a thick backing

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Spectrometer

+

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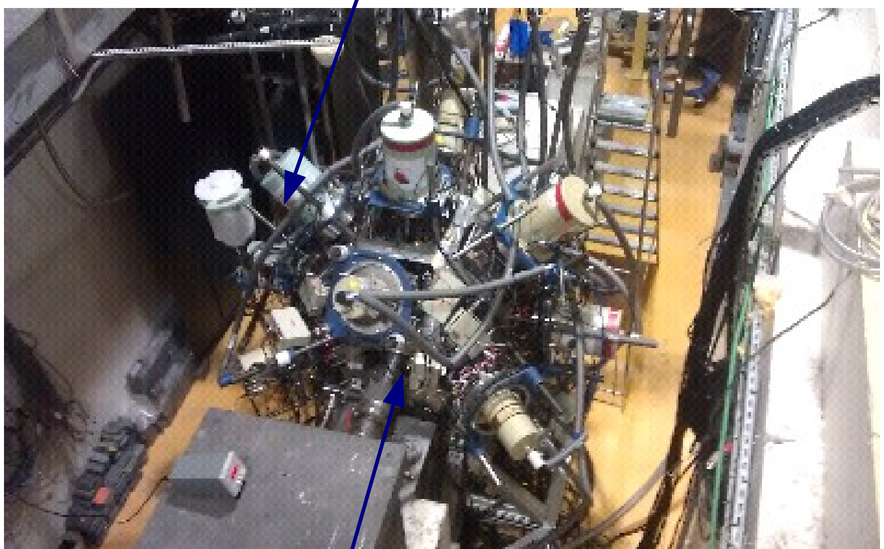

Fission target with a thick backing

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Spectrometer

- Large acceptance ~10% (close to Ge array efficiency)
- Not necessarily good mass resolution (~3-4 is acceptable)
- Focal plan (for fission and 0.1 us isomers studies)

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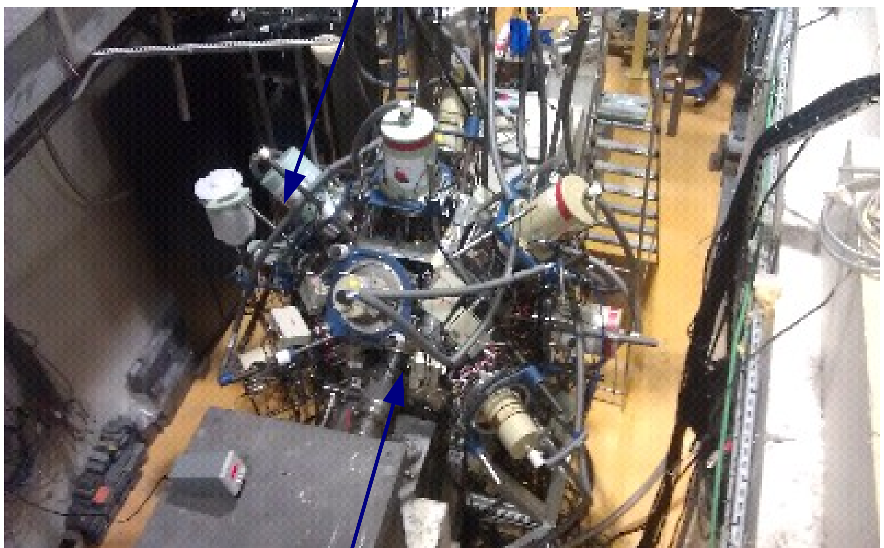

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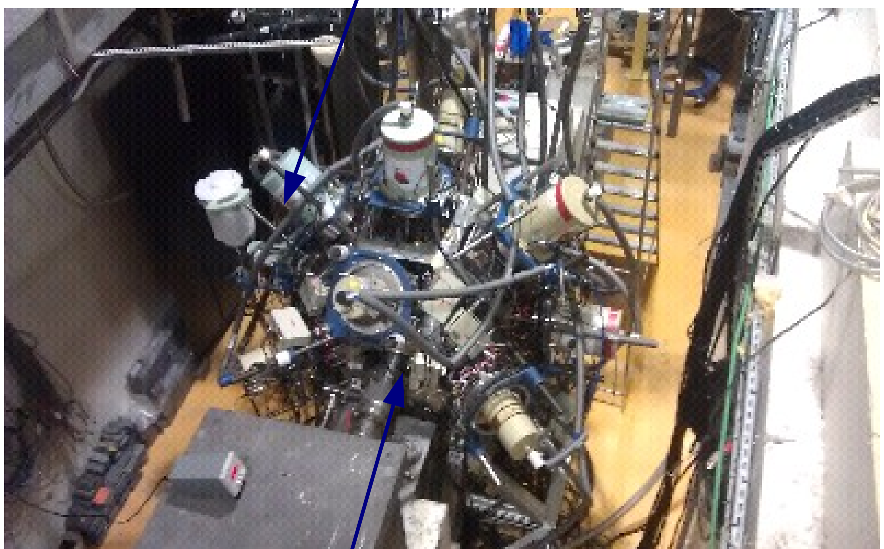

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- Allows Ekin measurement
- Allows dE/dx measurement

- Moveable for fast neutrons studies

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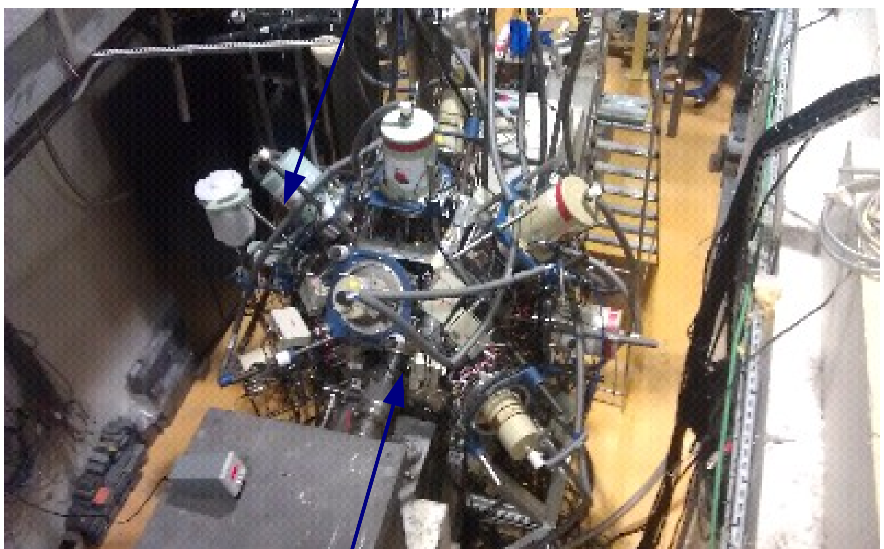

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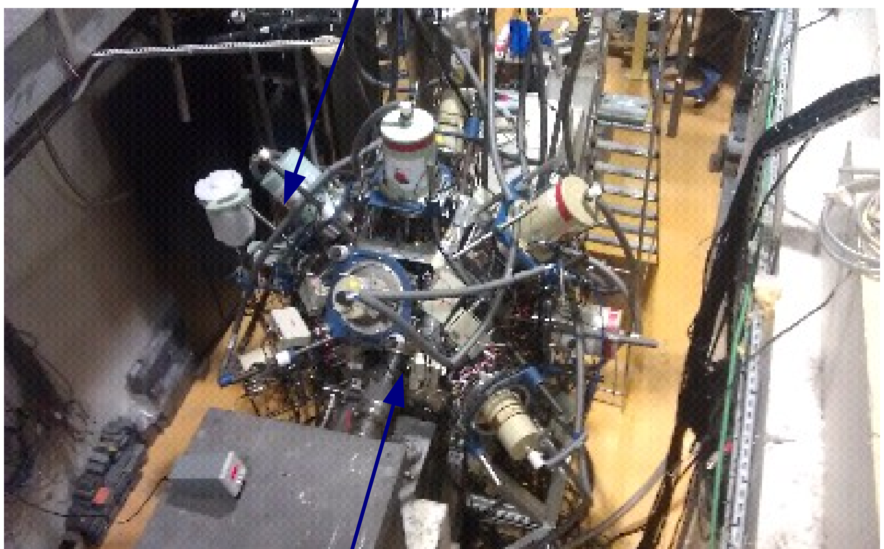

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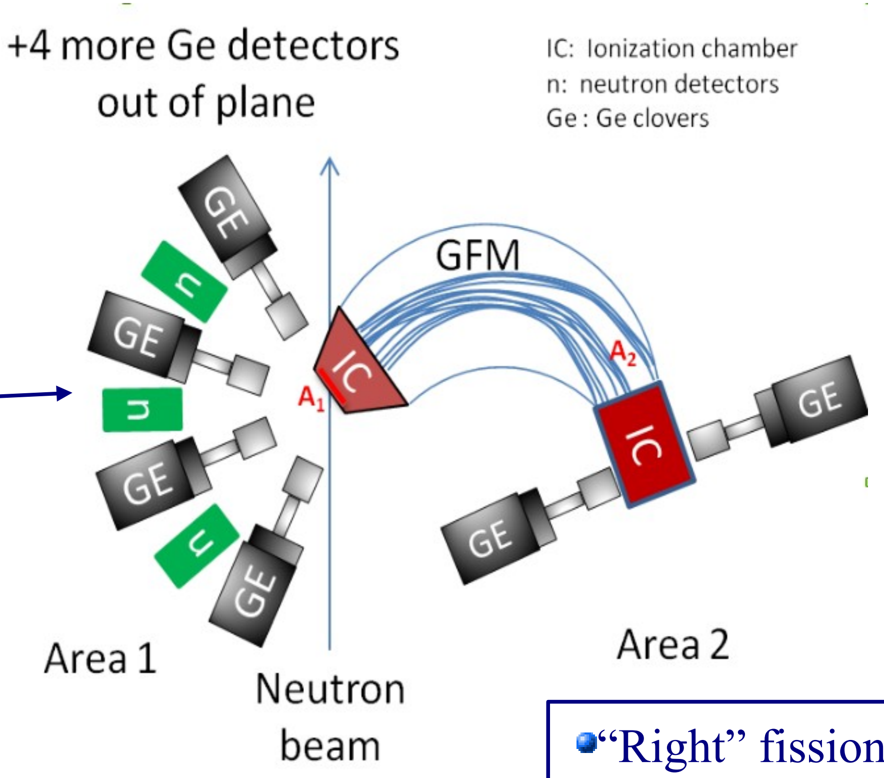
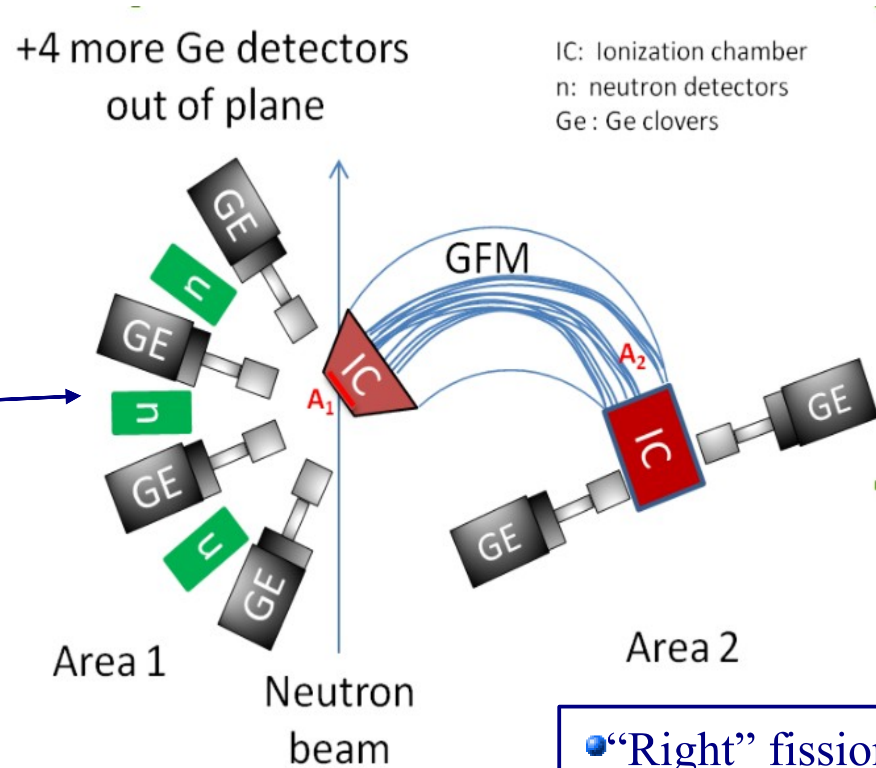


EXILL-like

- "Left" fission fragment: stopped in backing
→ Doppler free **γ detection**

- "Right" fission fragment:
→ mass identification with a Gas-Filled magnet for **filtering**
→ **Ekin & dE/dx** measurement with Ionization chamber **using intrinsic energy loss in the gas**

FIPPS layout



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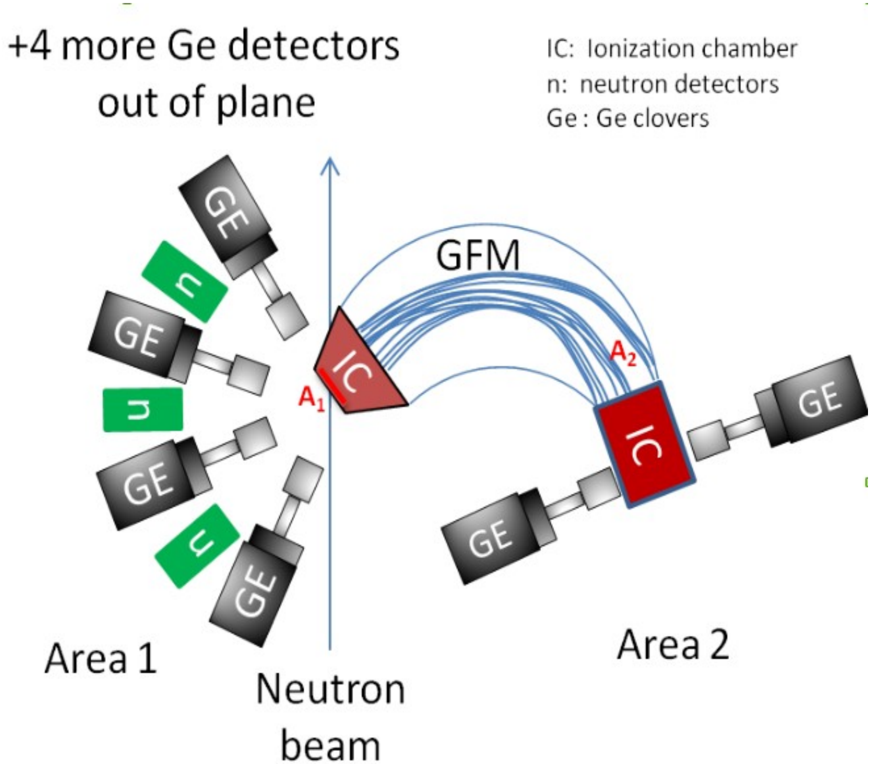
+ Ancillary detectors:
→ neutron detectors
→ LaBr3(Ce) for fast timing
→ low energy Ge detectors
→ ...

FIPPS layout



- Gas-Filled Magnet: **simulations on going**
- Ionization chambers → **LPSC know-how** (in used at Lohengrin since 20 years)

FIssion Product Prompt γ-ray Spectrometer

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FIPPS with fast neutrons

- Nuclear structure:
  - allow to reach **more neutron rich nuclei** by changing the fissioning system

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- Nuclear fission:
  - Fission yields
  - Correlation between spin distribution and kinetic energy

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  - allow to reach **more neutron rich nuclei** by changing the fissioning system
  - but **much lower cross section** (2 orders of magnitude)

    → need **thicker target** which may not be compatible with a mass spectrometer
- Nuclear fission:
  - Fission yields
  - Correlation between spin distribution and kinetic energy
  - Low cross sections are less a problem since the analysis does not necessarily requires a triple coincidence

Conclusion

Conclusion (1)

FIPPS:

- Phase I: Ge array (end of 2016)
  - 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**

    → **possible use of 233U, 235U, 239Pu, 241Pu, 245Cm, 247Cm, 249Cf, 251Cf, ...**
  - triggerless DAQ with high-rate capability (~6kHz/crystal) → **experimentally validated**
  - fission veto/tagging using scintillating active target → **being tested**
- Phase II: Ge array + Spectrometer
  - 2016: end of design and looking for funding

The spectrometer is designed to be moveable.

Interest from fast neutrons facilities is welcome.

Conclusion (2)

First FIPPS clovers during second half of 2016
=> possible (n,γ) measurements during the last cycle of 2016

- Job offers at the ILL in the context of FIPPS:
  - **2 Master internship (4-6 months)**
    → Fission trigger development: A. Blanc, blanc@ill.fr
    → FIPPS collimation system: U. Koester, koester@ill.fr
  - **1 FIPPS intrument responsible (5 years position)**
  - **1 PhD**
    → Lifetime and g-factor measurments with FIPPS : M. Jentschel, jentschel@ill.fr

The EXILL collaboration

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