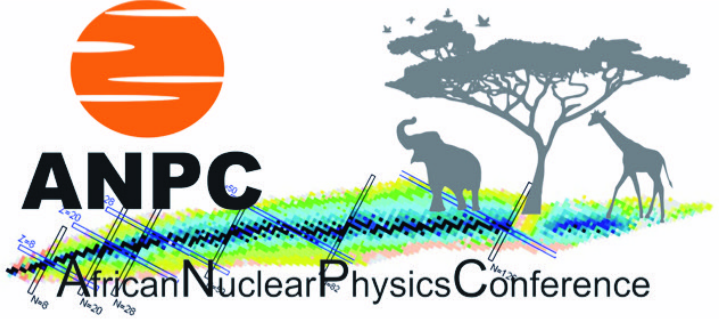


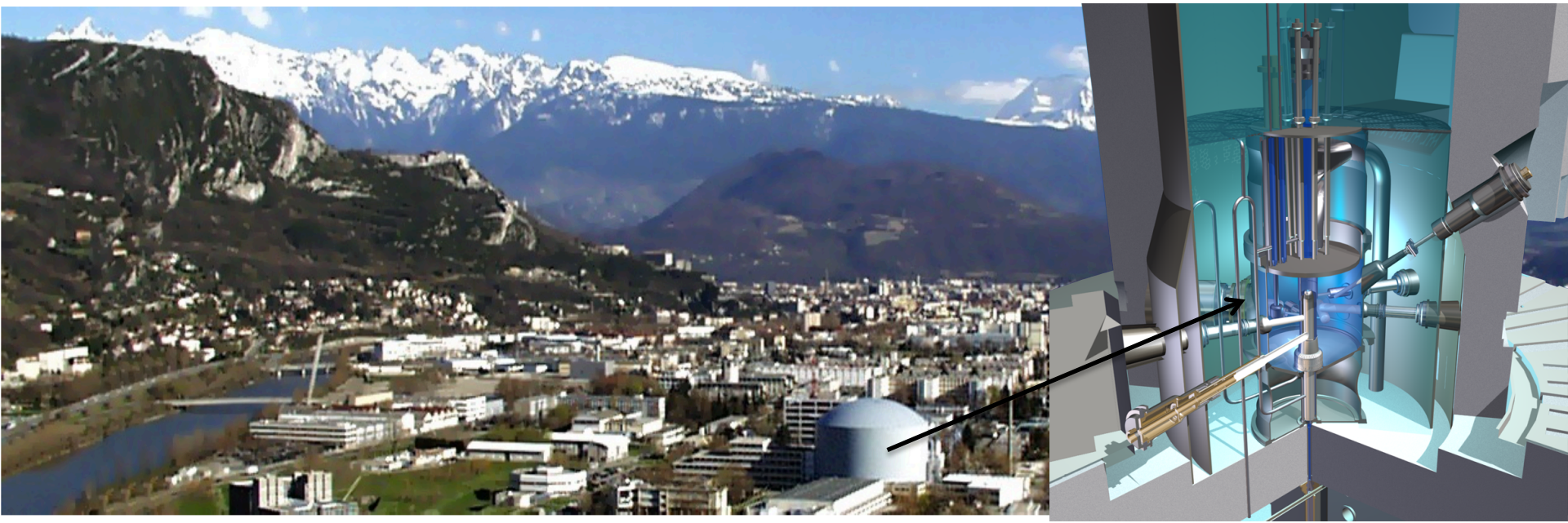
Nuclear spectroscopy with thermal neutrons and actinide targets in ILL

Yung Hee KIM

H. Faust, F. Kandzia, U. Koester, M. Jentschel, C. Michelagnoli,

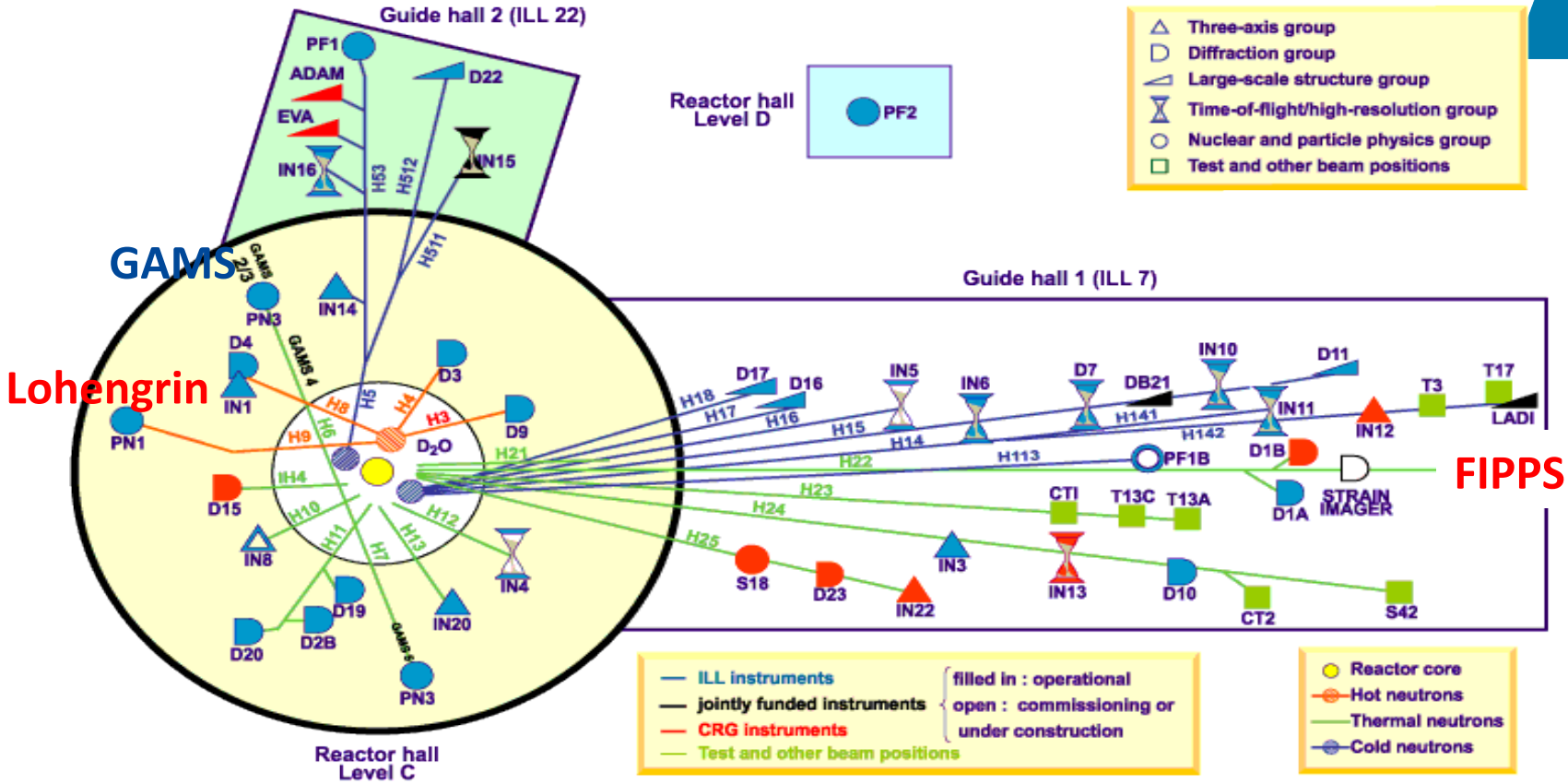
Institute Laue-Langevin

Institut Laue Langevin



- **57 MW research reactor ($5 \cdot 10^{18}$ n/s)**
- **Neutron beams with up to $2 \cdot 10^{10}$ n.cm^{-2}s^{-1} flux**

ILL instruments



GAMS

Lohengrin

FIPPS

40 instruments running simultaneously for 150-200 days per year

LOHENGRIN recoil separator

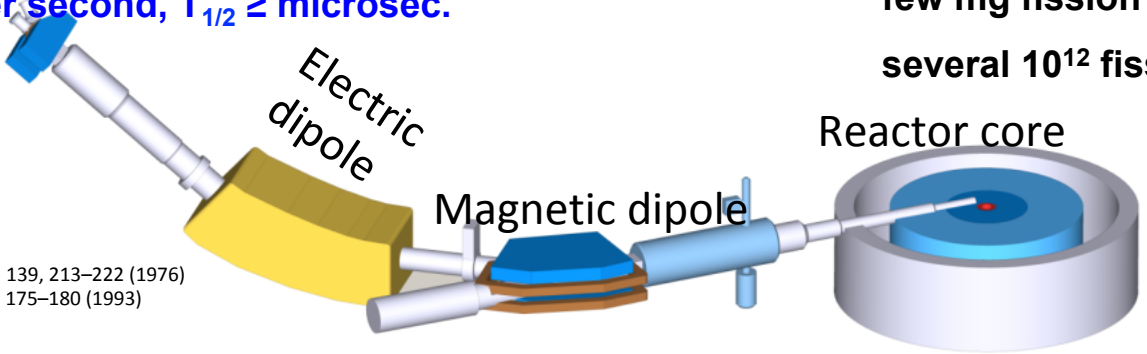
mass-separated fission fragments,

up to 10^5 per second, $T_{1/2} \geq$ microsec.

flux $5 \cdot 10^{14}$ n./cm^2/s

few mg fission target

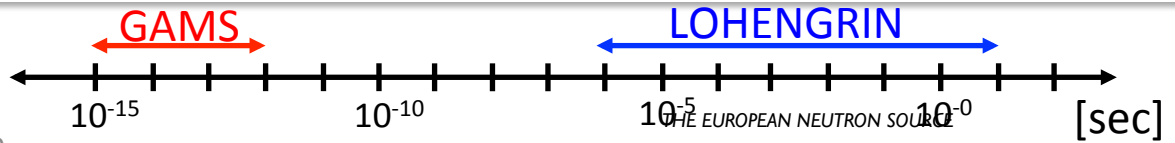
several 10^{12} fissions/s



P. Armbruster et al., NIM 139, 213–222 (1976)
G. Fioni et al., NIMA 332, 175–180 (1993)

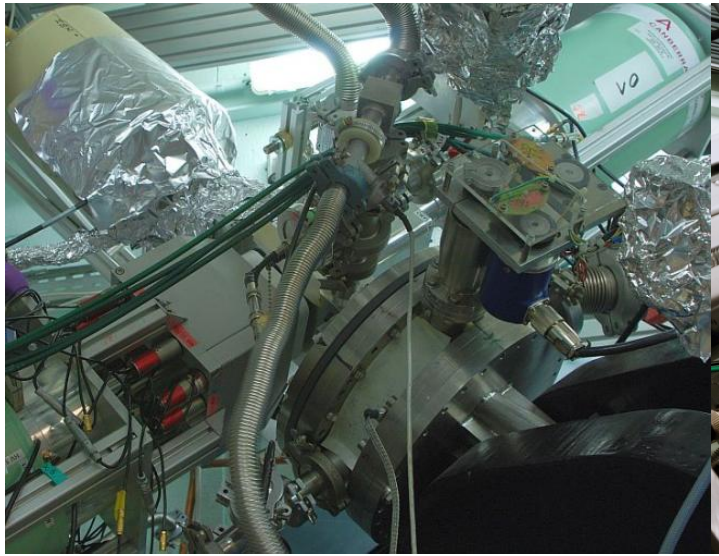
- High resolution A/Q, Ek/Q selection (A/ΔA = 1500, E/ΔE = 100 − 1000)
- Small acceptance (~0.03 msr)
- Fission reaction mechanism study
- Nuclear structure:
  - Isomer decay ($t_{1/2}$> 0.5 us)
  - β-decay

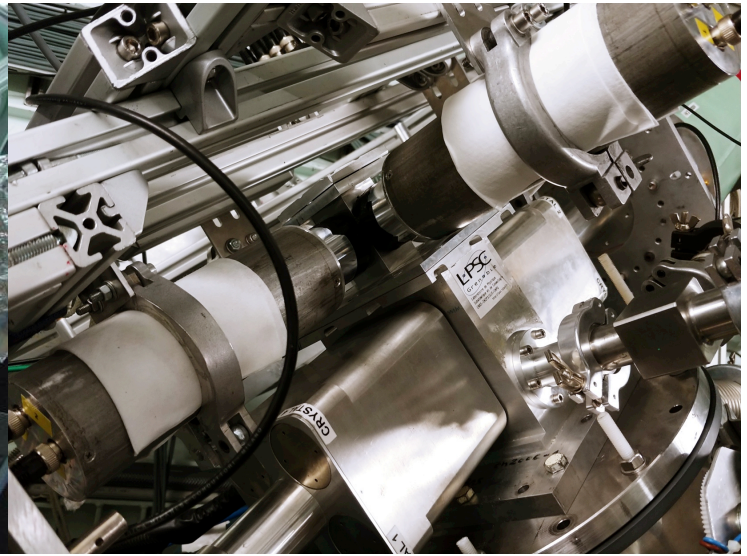
Lifetime measurement accessible range



LOHENGRIN recent physics program

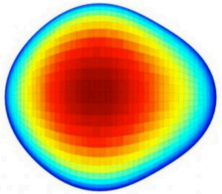
- 1. Nuclear spectroscopy (**isomer**/β-decay)
  - Conversion electron (Si-detector (LN2 cooled)+2 Ge-clover)
  - ps Life-time measurement (4 $LaBr_3$+2 Ge-clover)





LOHENGRIN recent physics program

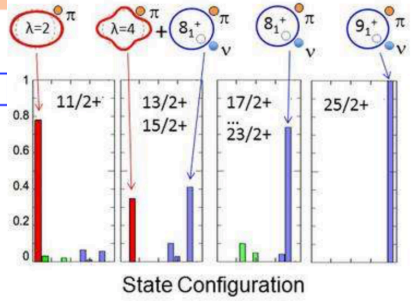
- 1. Nuclear spectroscopy (isomer/β-decay)

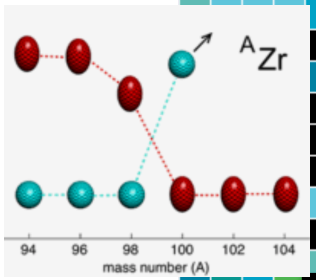


145Cs, 146Cs: U of Warsaw

128Sb :ILL

133Sb: Milan





98Zr: ILL

92Y,94Y,
94Y, 95Y, 101Y
: Krakow

97Sr:IKP-Kolon

95Kr: ILL

Life-time measurement using $LaBr_3$+Ge-clover
Conversion electron+Ge-clover

NEUTRONS FOR SOCIETY

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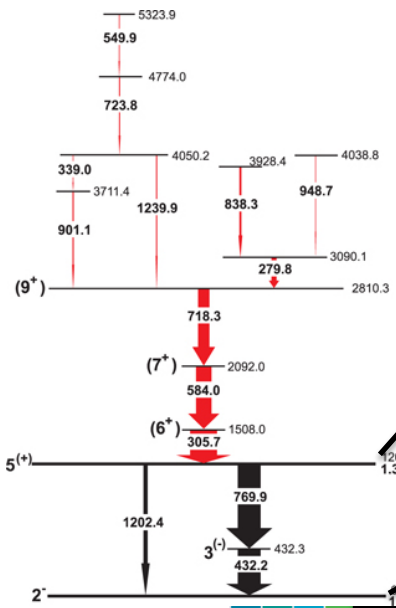

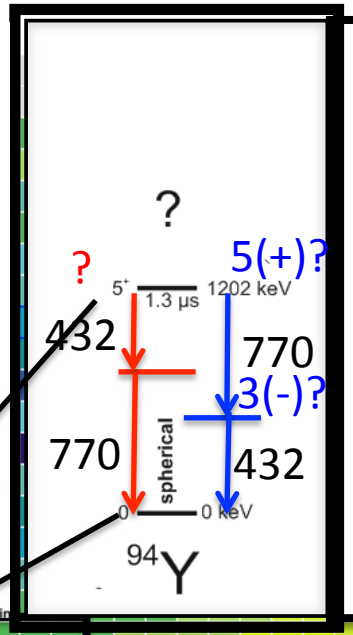

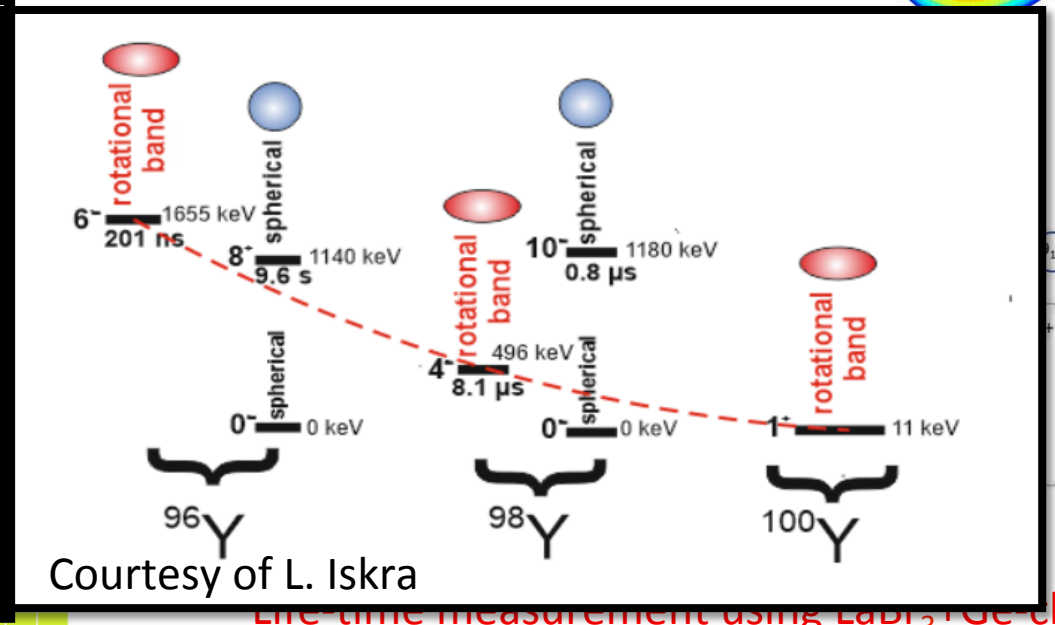

Courtesy of L. Iskra

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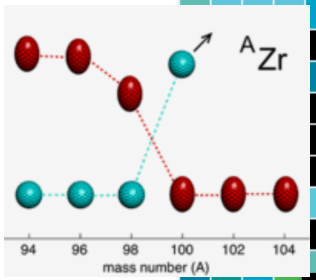

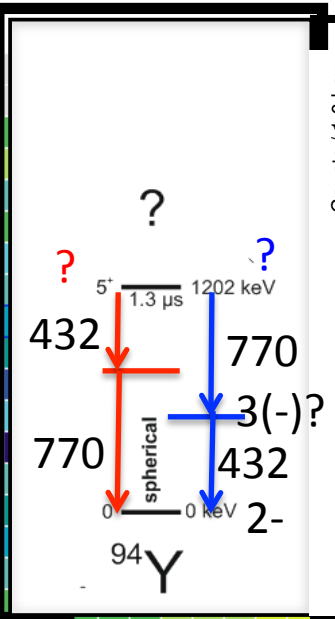

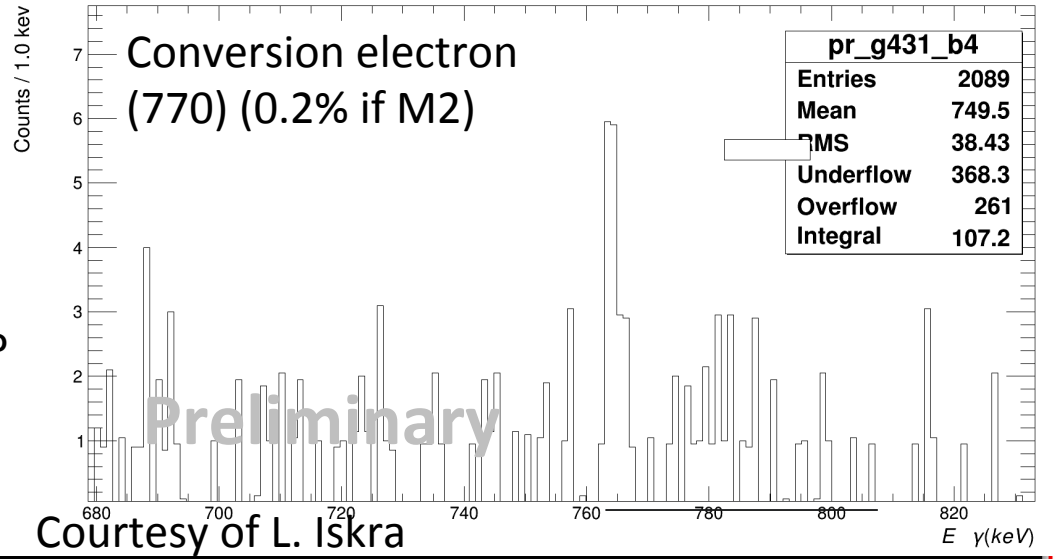

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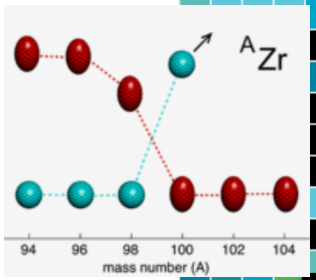

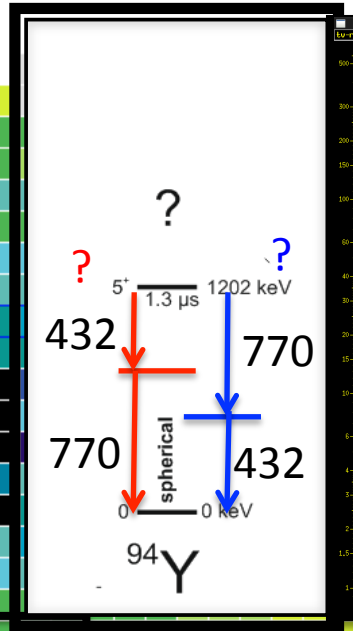

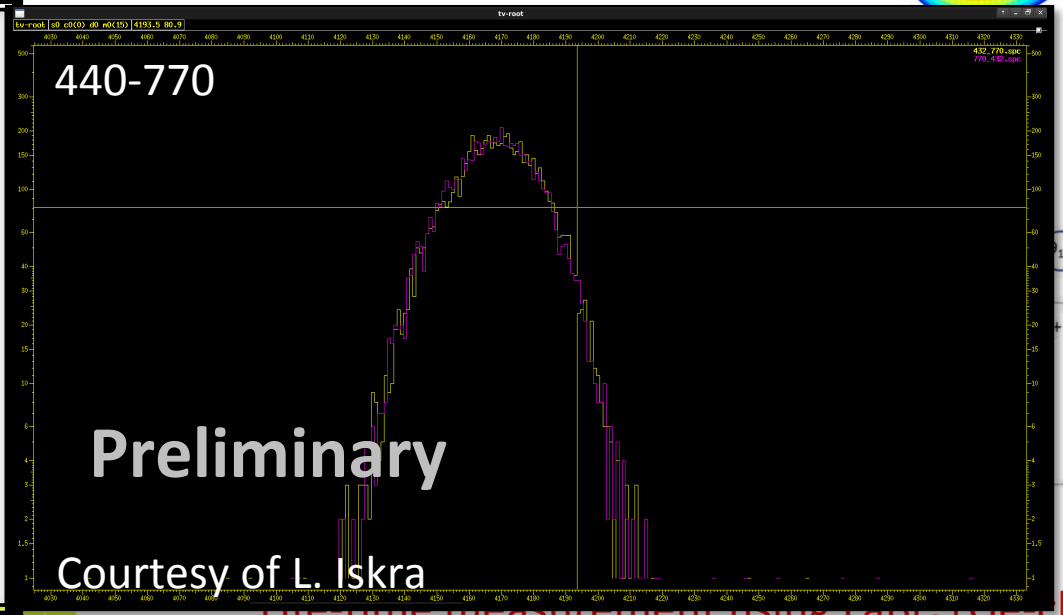

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Life time measurement using $LaBr_3$+Ge clover

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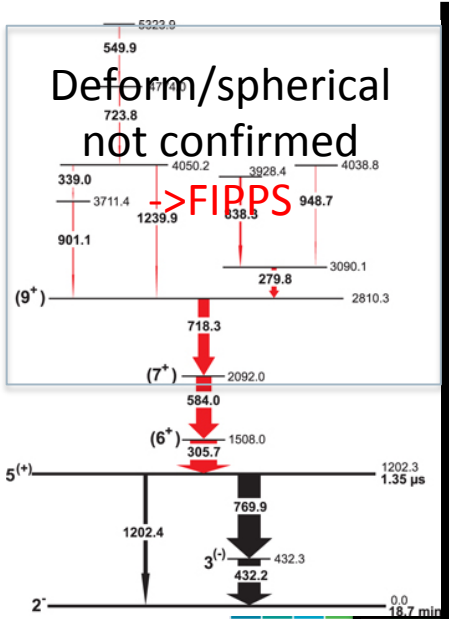

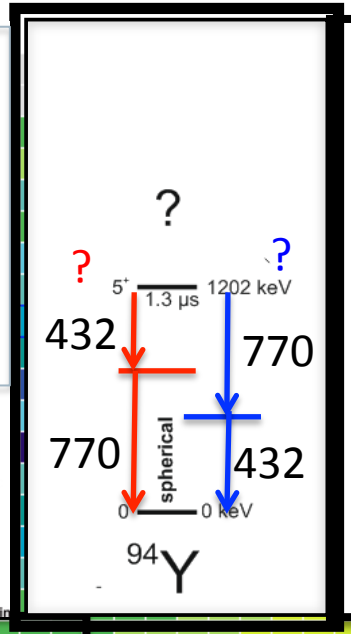

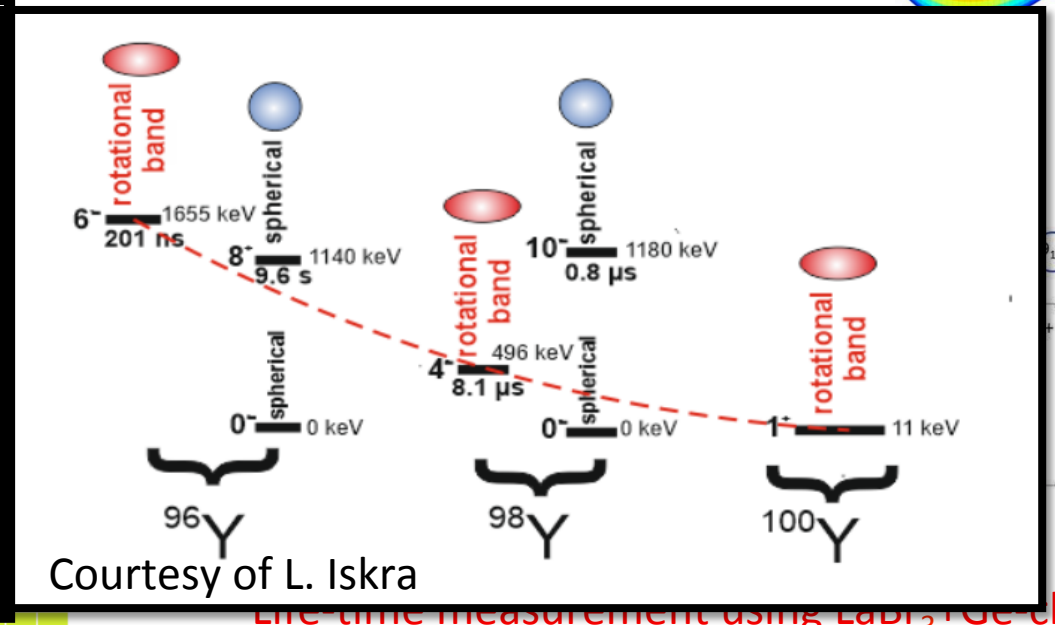

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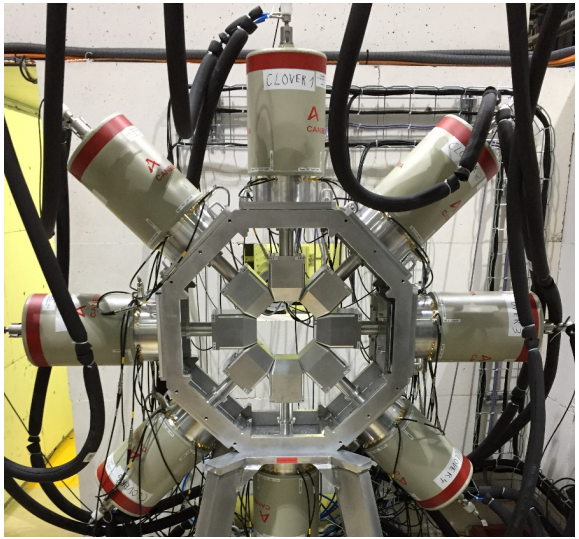
Life-time measurement using $LaBr_3$+Ge clover

Conversion electron+Ge-clover

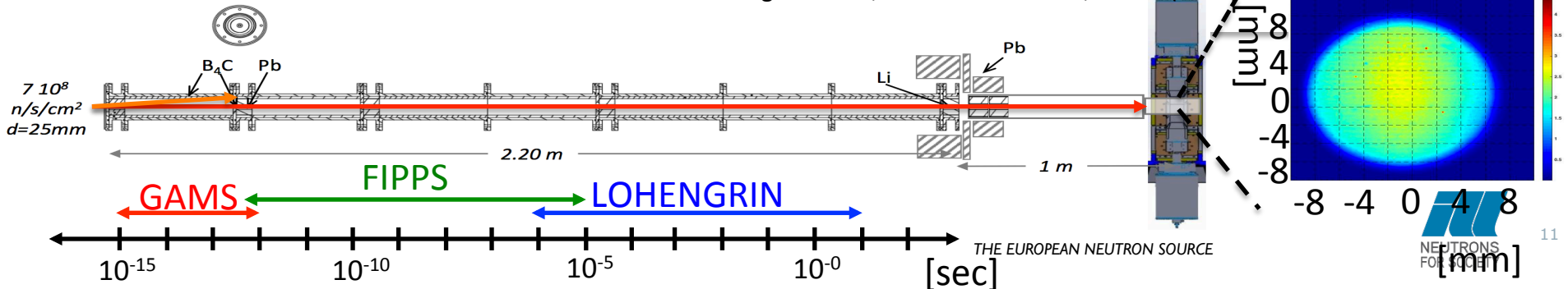
NEUTRONS FOR SOCIETY

FIPPS phase-I



- Intense collimated neutron beam (10^8 n/cm^2/s, d=1.5cm)
- 8 High-resolution gamma detectors (HPGe clovers)
  + fully digital DAQ (<10 kHz/crystal)
- 90° ring configuration for angular correlation

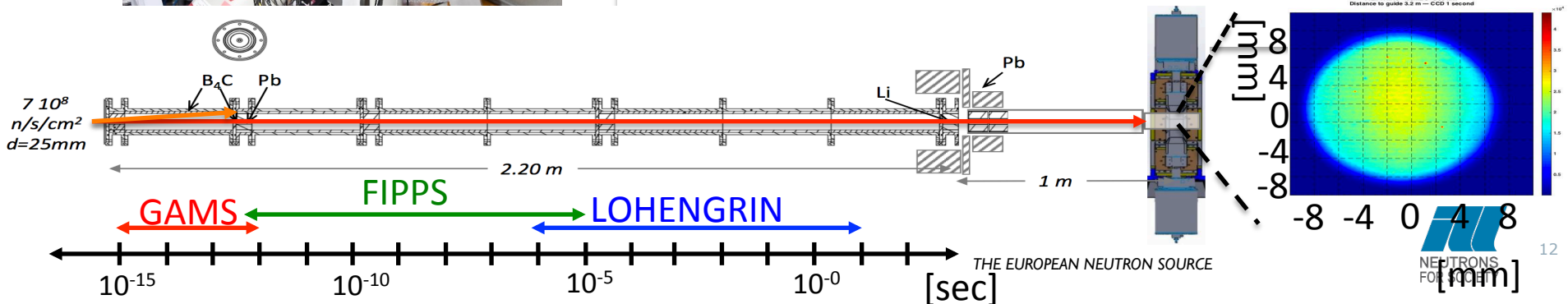
C. Michelagnoli et al., EPJ Web Conf. 193, 04009 (2018)



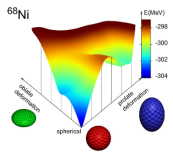
FIPPS phase-I

- Intense collimated neutron beam (10^8 n/cm^2/s, d=1.5cm)
- 8 High-resolution gamma detectors (HPGe clovers)+Anti-Compton Shields + fully digital DAQ (<10 kHz/crystal)

30% improvement in P/T



(n,γ) on stable (rare) and radioactive targets



Milan, IFIN-HH

IKP Cologne

167Er

175Lu

176Lu

IKP Cologne

ILL

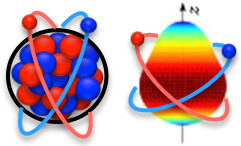
160Gd

CEA B. le Chatel

205Tl

205,206Pb

Milan, Krakow



61,63,64Ni

Manchester

13C

149Sm

146Nd

IFIN-HH

145Nd

TU-Darmstadt

96,97,98Mo

Warsaw

115,117,119Sn

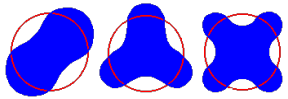
99Ru, 123,125Te

111Cd

CSNSM, Univ. Guelph

41,44Ca

Milan

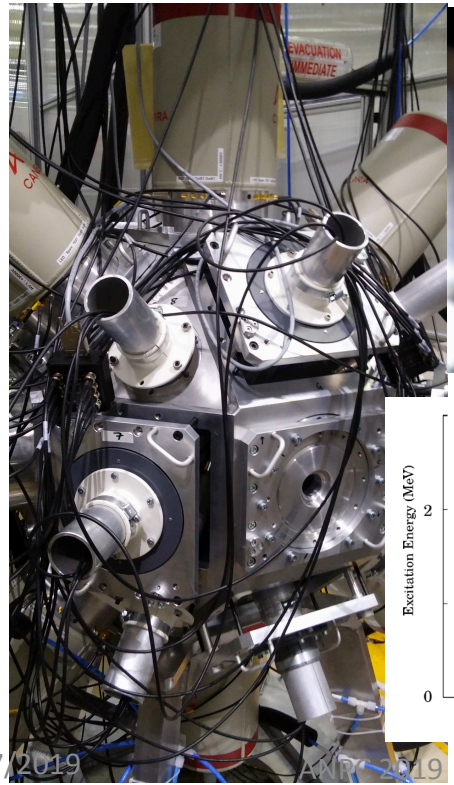


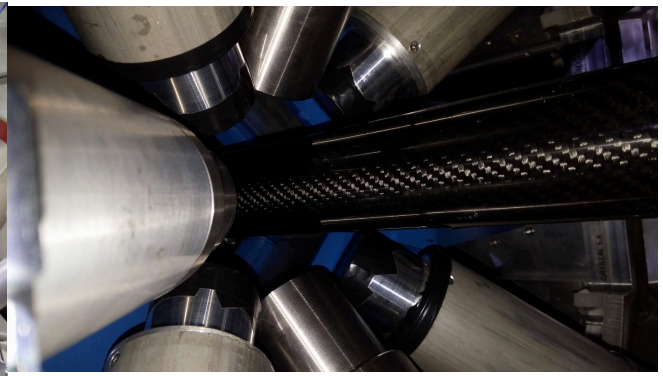
lifetime measurement technique (gas target)

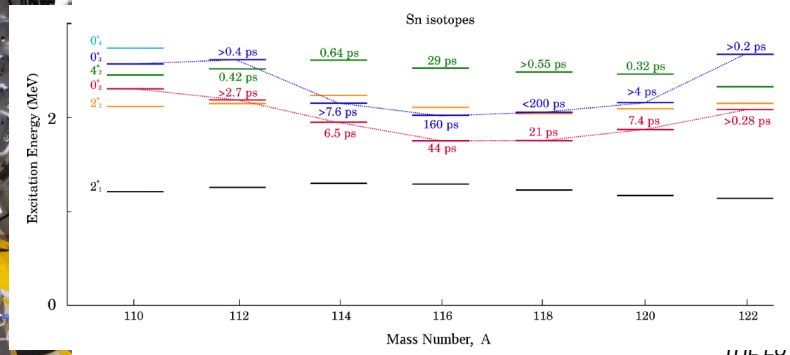
Milan, ILL

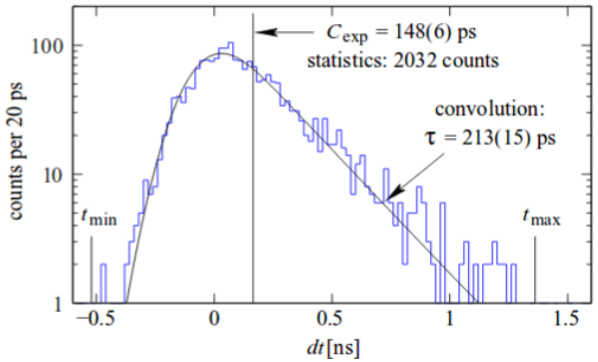
FIPPS recent physics programs

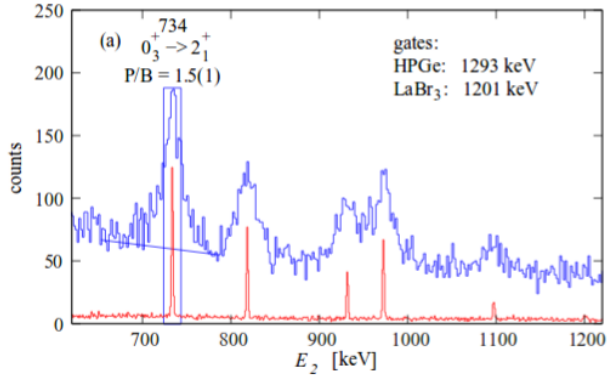
- (n,γ) fast timing campaign 16 LaBr3 (Univ. of Köln)







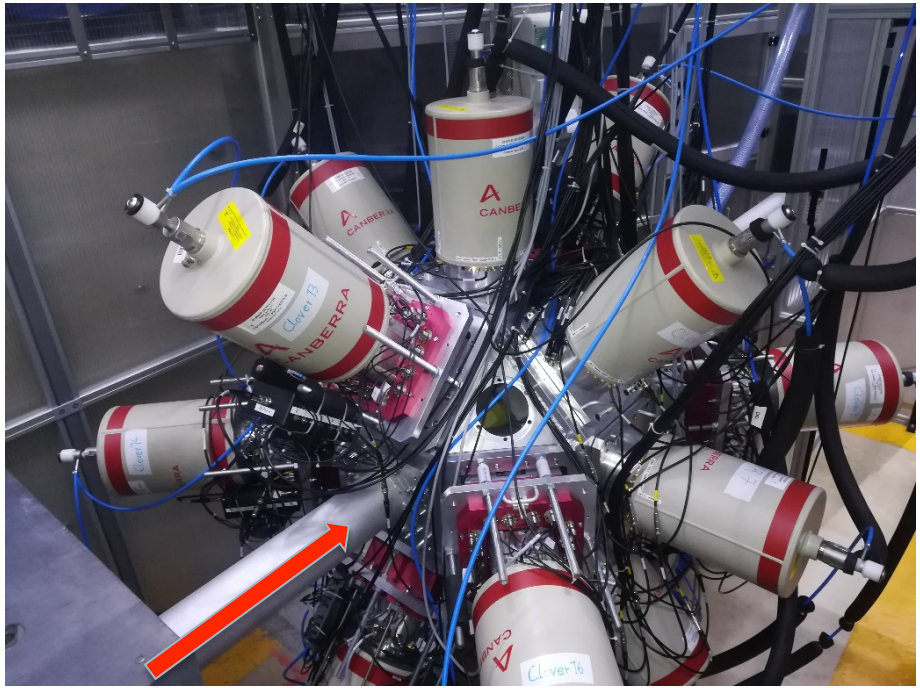




C. M. Petrache et al., Phys. Rev. C. 99 (2019) 024303

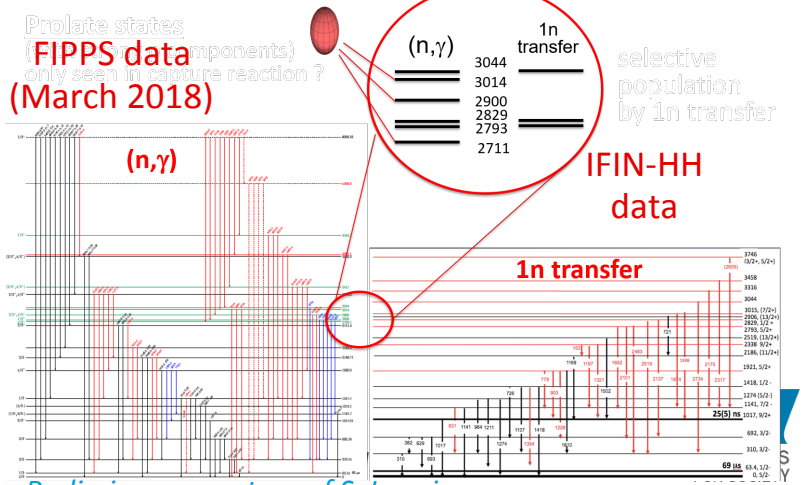
FIPPS recent physics program

- (n,γ) campaign + 8 Ge clover (IFIN-HH)



16 Ge-clover array at thermal neutron beam:
Abs. eff.: ~6% at 1.4 MeV
x3.4 triple γ-efficiency

evolution of shape coexistence and **shape isomerism in the nickel isotopes**

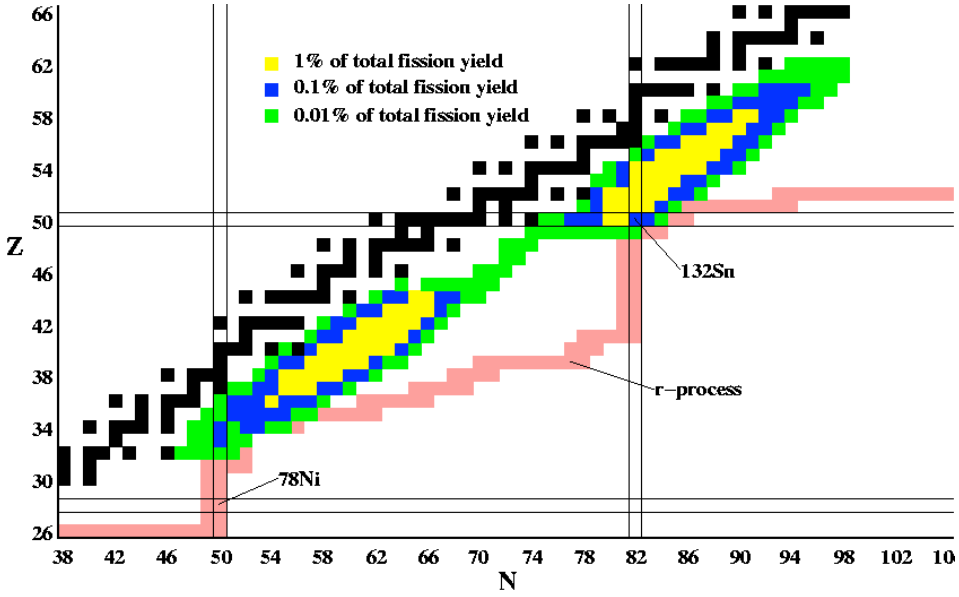


^{66}Ni: S. Leoni et al., PRL118 (2017) 162502

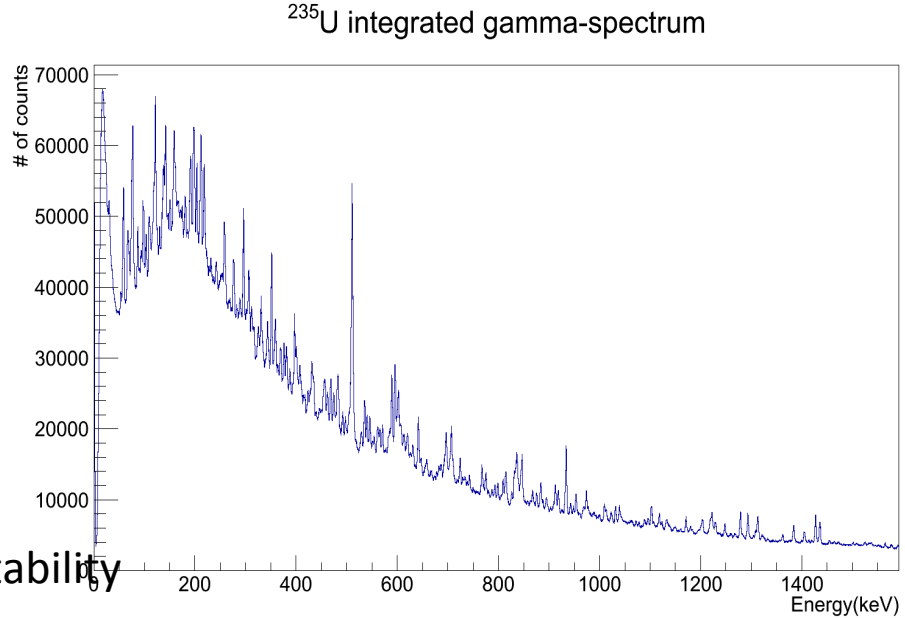
MCSM: T. Otsuka et al., JPG43 (2016) 024009

FIPPS recent physics program

235U fission campaign



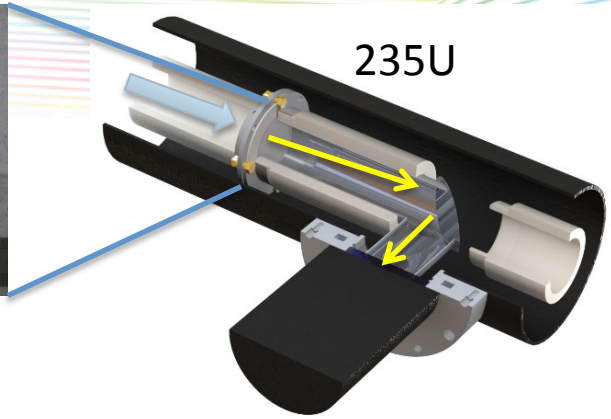
>200 different nuclei from fission



- understanding of nuclear structure far from stability
- modeling of the fission mechanism
- nuclear properties along *r-process* path

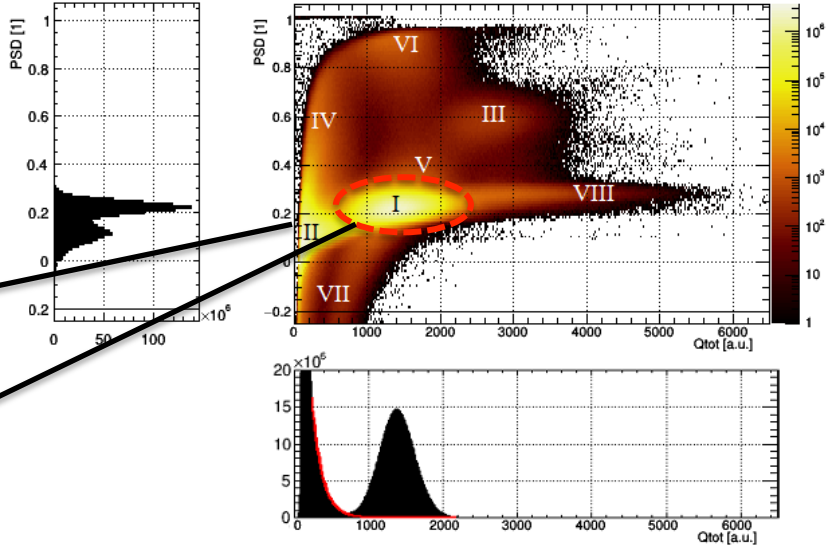
PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **10**, 014701 (2007)

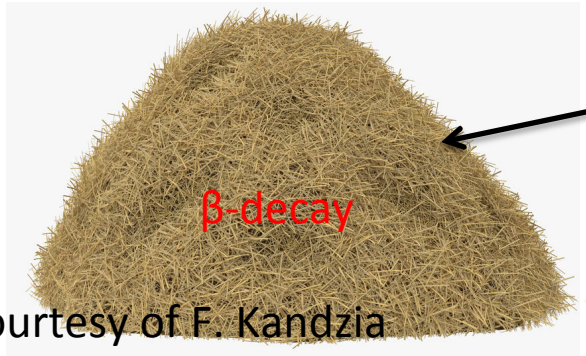
FIPPS fission tag



- fission rate 12 kHz
- coincidences PMT- $\gamma - \gamma$: 10 kHz
- total: 1.5E11 fission tagged $\gamma - \gamma$ coinc.
  (36 days, Sep-Oct 2018)

- Fission detection efficiency: 85% (preliminiary)
- Fission mis-identification: 0.3%
- β-mis-identification: ~0.4%

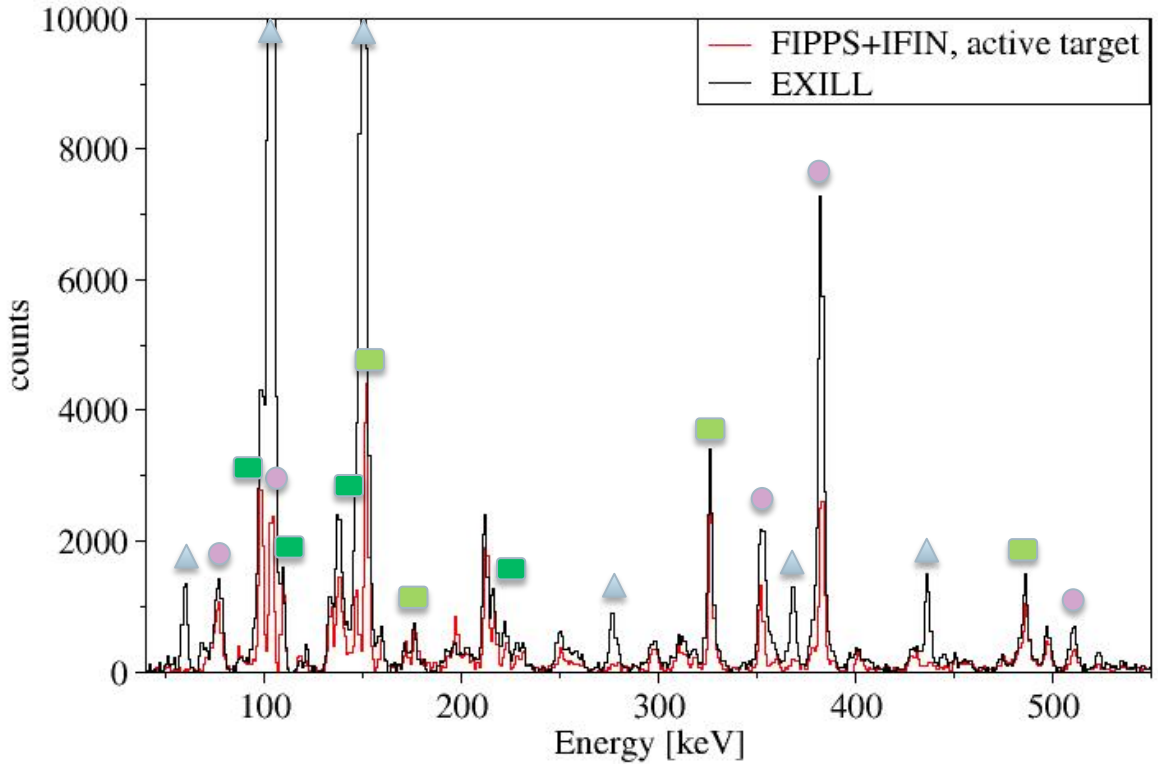


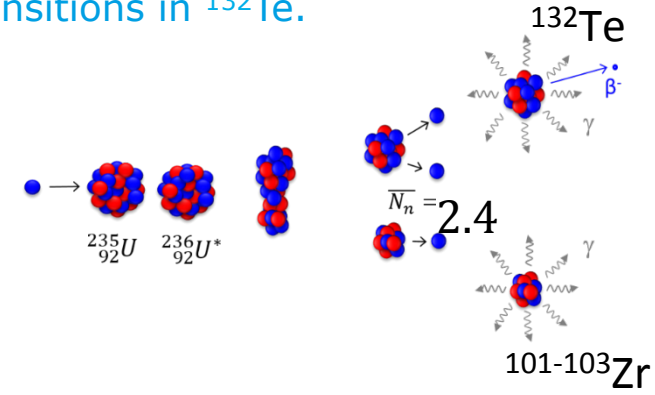


Courtesy of F. Kandzia

Suppression of beta decay using active target

Coincidences with $2^+ \rightarrow 0^+$ (974 keV) and $4^+ \rightarrow 2^+$ (697 keV) transitions in ^{132}Te.





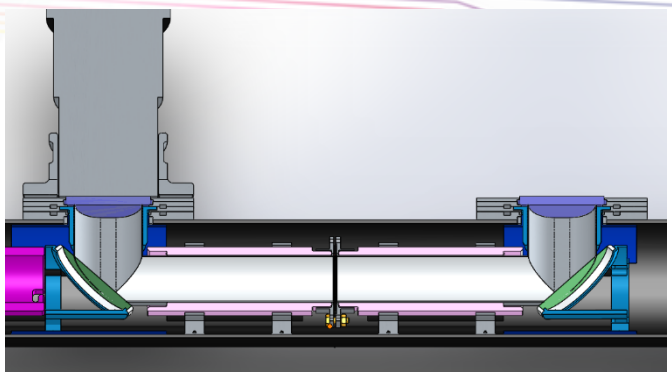
- ^{132}Te
- ^{132}Sb (β-)→^{132}Te
- ^{102}Zr
- ^{101}Zr

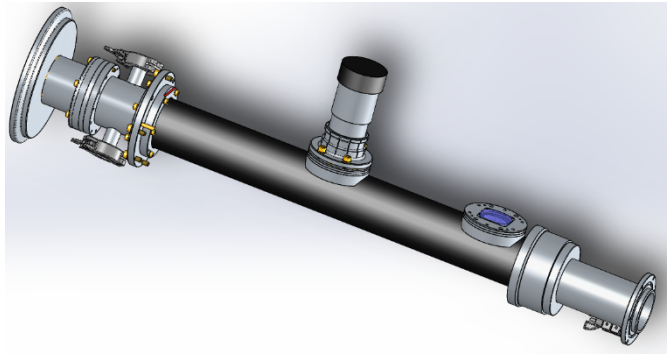
Future opportunities

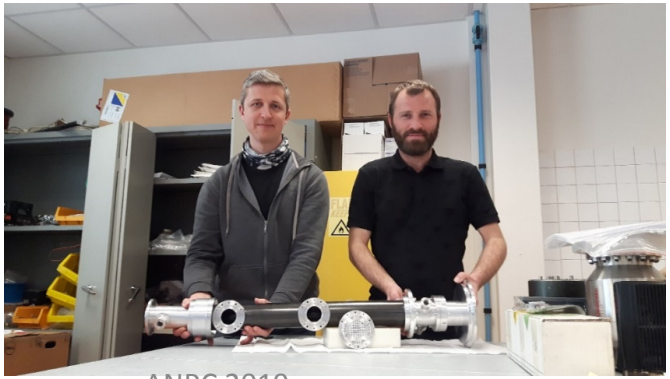
Now running $^{233}U(n,f)$

- Double target cell (downstream + upstream)
- 2 optically separated volumes
  => increasing fission rate w/o increasing pile-up

- U-235 test run (2019 June 17-23)
- U-233 run (2019 June 24-ongoing)

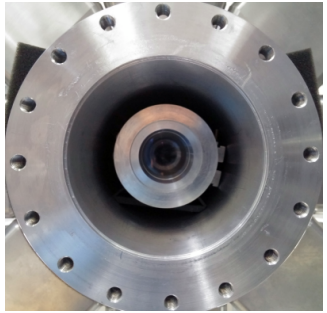






F. Kandzia, R. Pommier

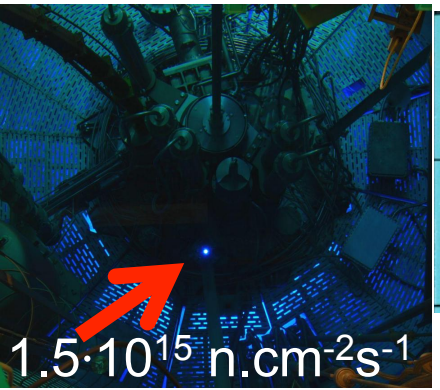
Possible rare targets (n,g) experiments

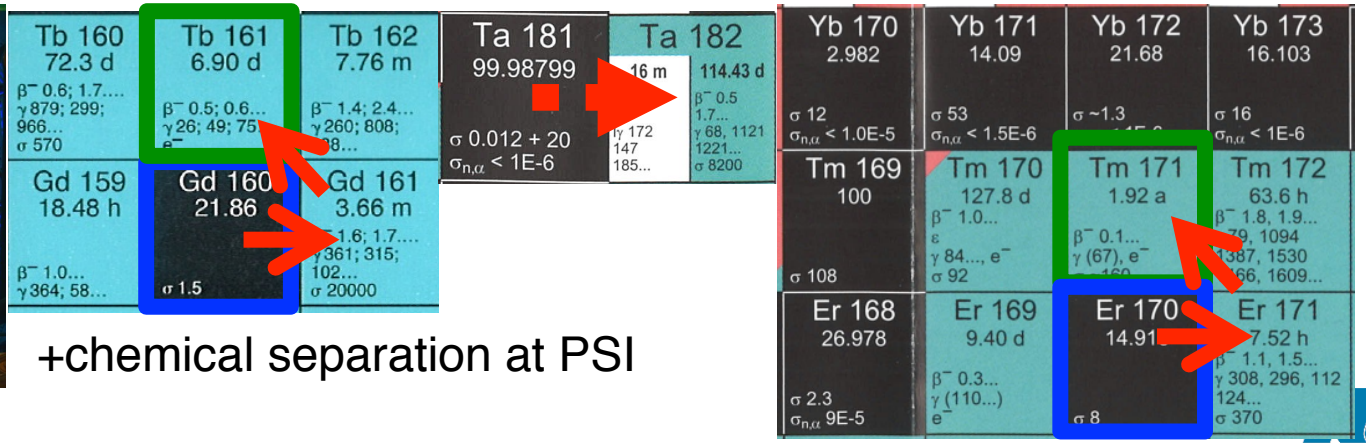


Noble gas target w/ 1 gen. Gas target cell $^{20\text{-}22}$Ne,$^{36\text{-}40}$Ar, $^{78\text{-}83}$Kr, $^{124\text{-}136}$Xe

Courtesy of M. Jentschel

ILL generated radioactive target

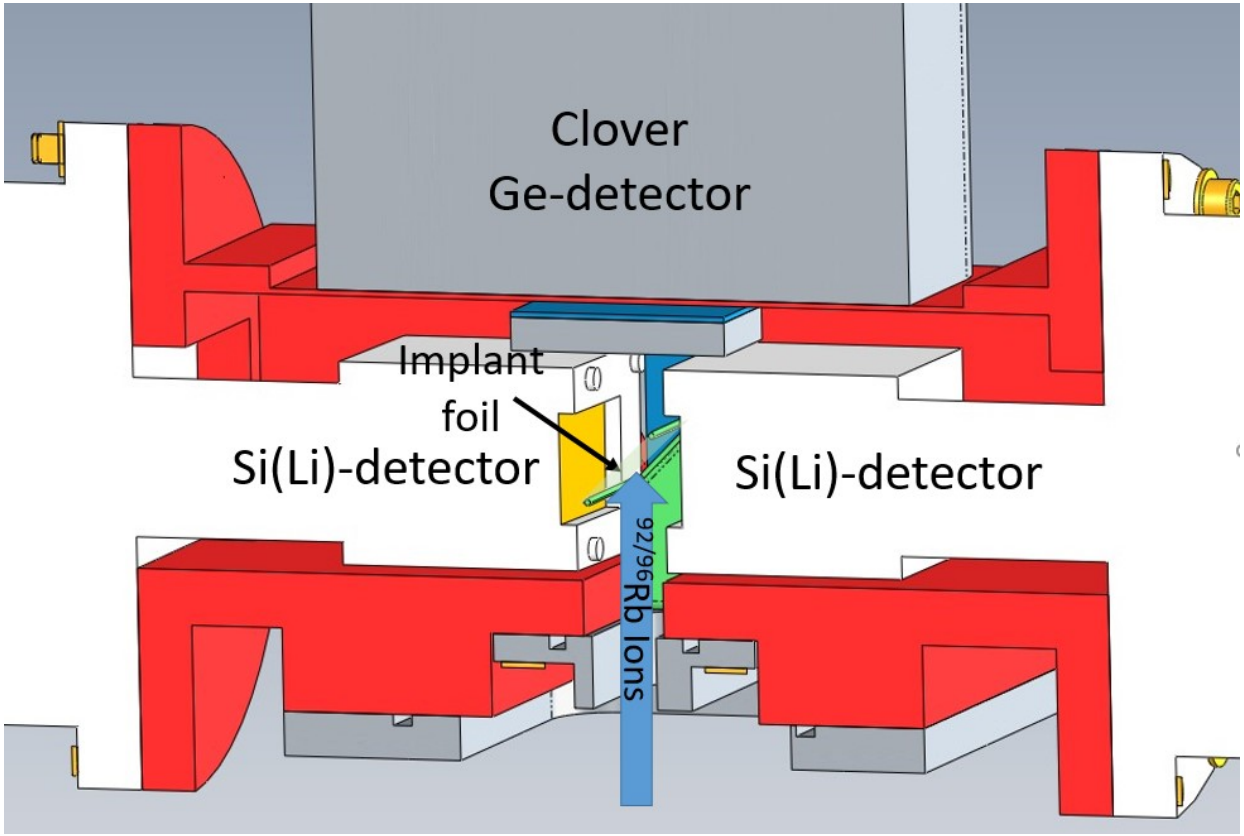




+chemical separation at PSI

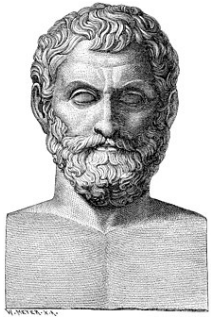
- Courtesy of U. Koester

New Conversion electron setup(Lohengrin)



- x1.5 efficiency from one Si setup
- X-ray & conv. e- coincidence
- One experiment accepted for study E0 transition strength study

New Concept- 1/r +Thales circle



- Fragment Virtical to the manget entrance
- 1/R field ->Same Bp in all region

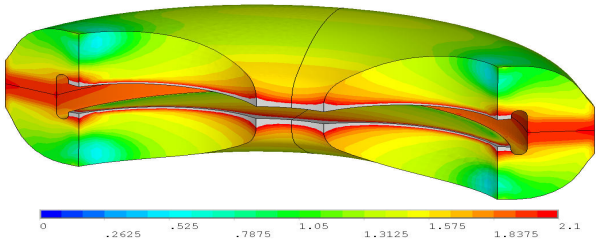
->Automatic Focusing!

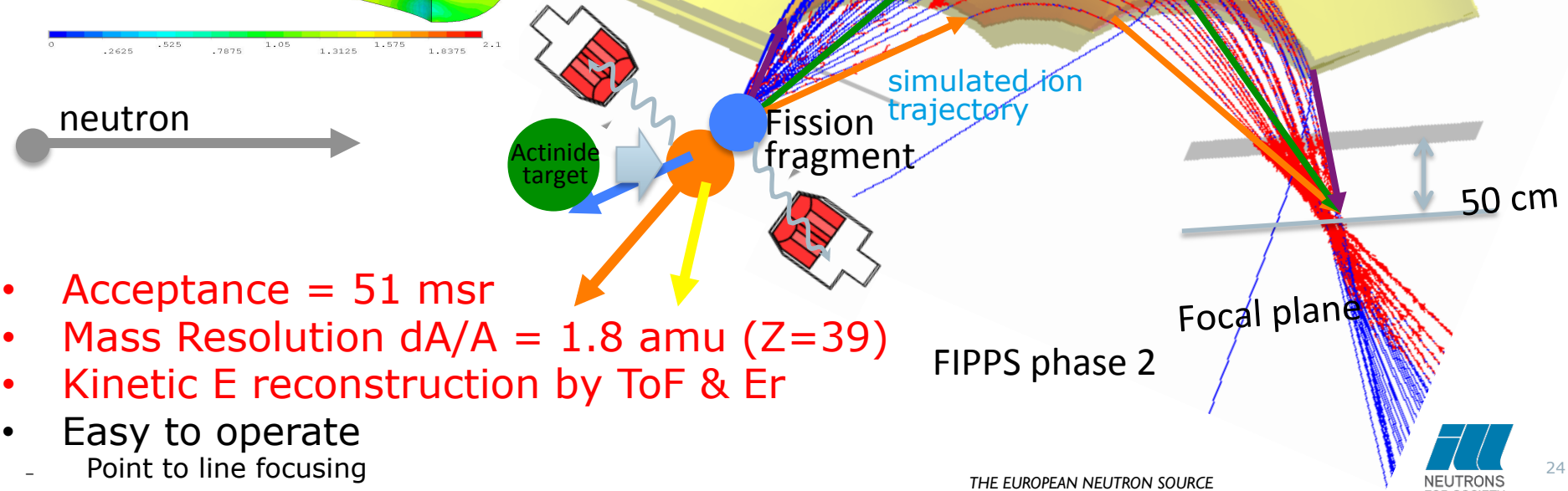
Initial idea from H. Faust

FIPPS phase 1

FIPPS-PHASE2 GEANT4 simulation

- Realistic field calculation from ANSYS

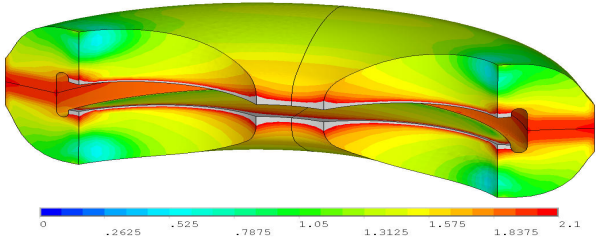


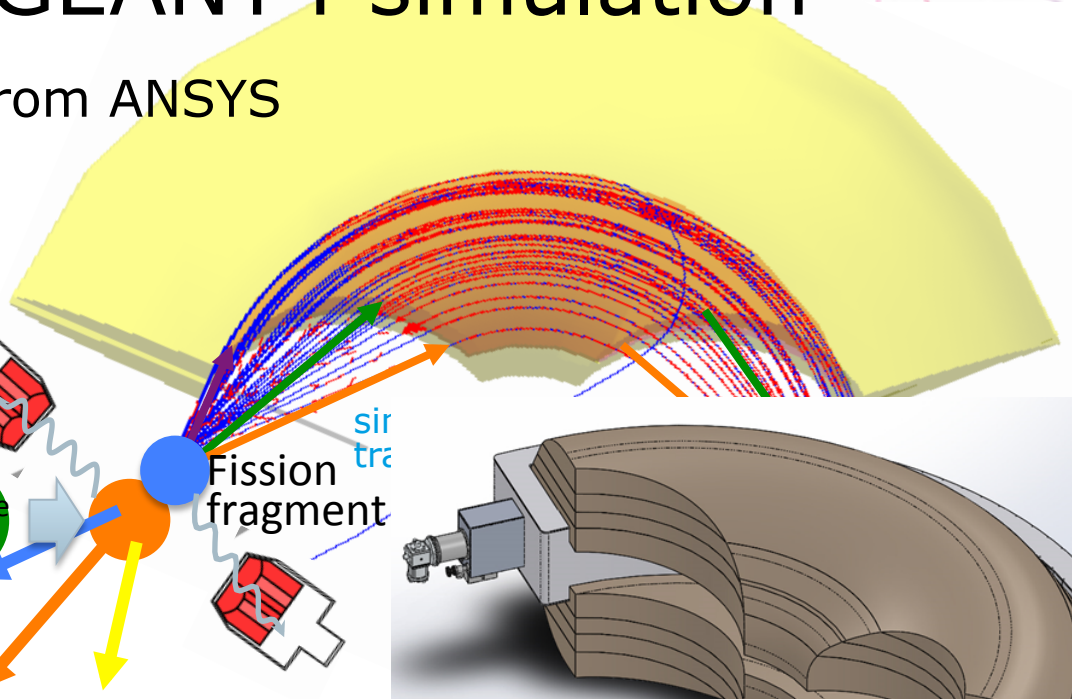


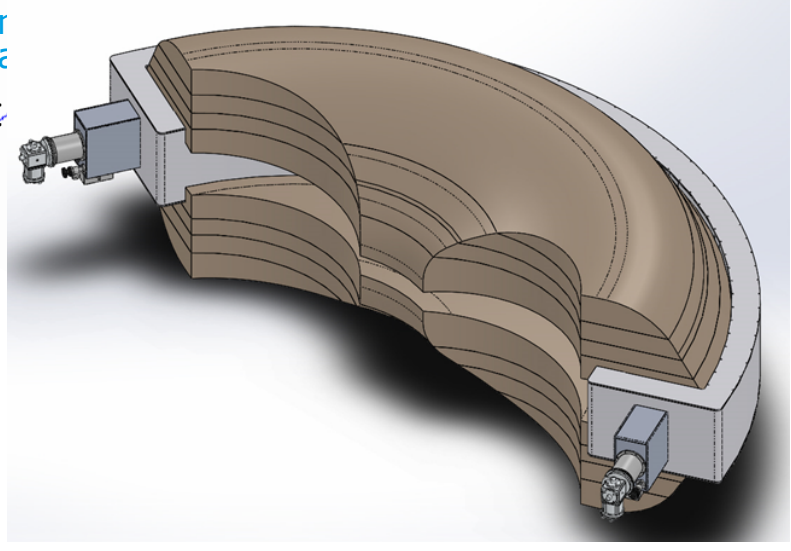
- Acceptance = 51 msr
- Mass Resolution dA/A = 1.8 amu (Z=39)
- Kinetic E reconstruction by ToF & Er
- Easy to operate
  - Point to line focusing

FIPPS-PHASE2 GEANT4 simulation

- Realistic field calculation from ANSYS







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Summary & Outlook

- Rich Nuclear Physics program at ILL using LOHENGRIN/FIPPS neutron induced reactions
- Versatile setup for your needs
- *FIPPS fission tag*: new spectroscopic info on n-rich fission fragments (data are open for LoI)

- Future perspectives
  - Radio active target (n,g) experiments @ FIPPS
  - Fast-timing/conversion electron/ Fission study @ Lohengrin
  - Long future: FIPPS phase2 GFM
- Next ILL proposal submission deadline: September 2019 Please Contact US!

LoI for transuranium target (^{245}Cm)

17th International Symposium on Capture Gamma-Ray Spectroscopy and Related Topics - CGS17

August 31 – September 4, 2020 Grenoble, France

MAIN TOPICS

- Nuclear Structure
- Nuclear Reactions
- Nuclear Astrophysics
- Fundamental interactions and Symmetries
- Nuclear Data
- Experimental Techniques and Facilities
- Interdisciplinary Studies and Applications

DEADLINES

Abstract: 28/02/2020