FIPPS
FIssion Product Prompt gamma-ray Spectrometer

ILL : *A. Blanc, A. Chebboubi, H. Faust, M. Jentschel, U. Kőster, W. Urban*
LPSC-Grenoble : *G. Kessedjian, G. Simpson*
CEA-Saclay : *T. Materna, S. Panebianco*

Institut Laue-Langevin

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

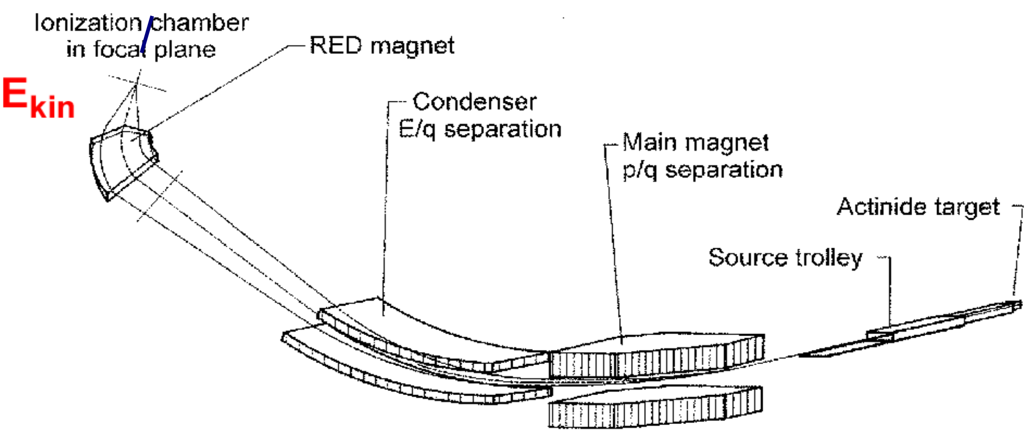
Nuclear Physics at ILL (1)

- The LOHENGRIN fission fragment separator:

$\Delta A/A = 3E\text{-}4 - 3E\text{-}3$

$\Delta E/E = 1E\text{-}3 - 1E\text{-}2$

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

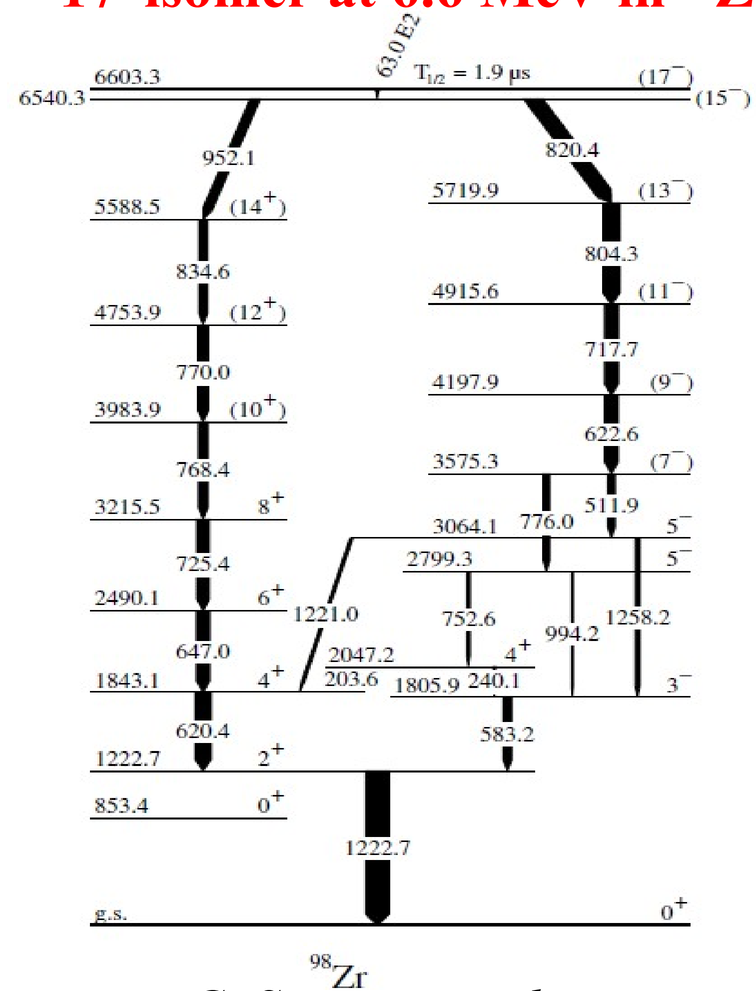


$$m\,v^2 / r_{el} = q\,E \qquad m\,v^2 / r_{magn} = q\,v\,B$$

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

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

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

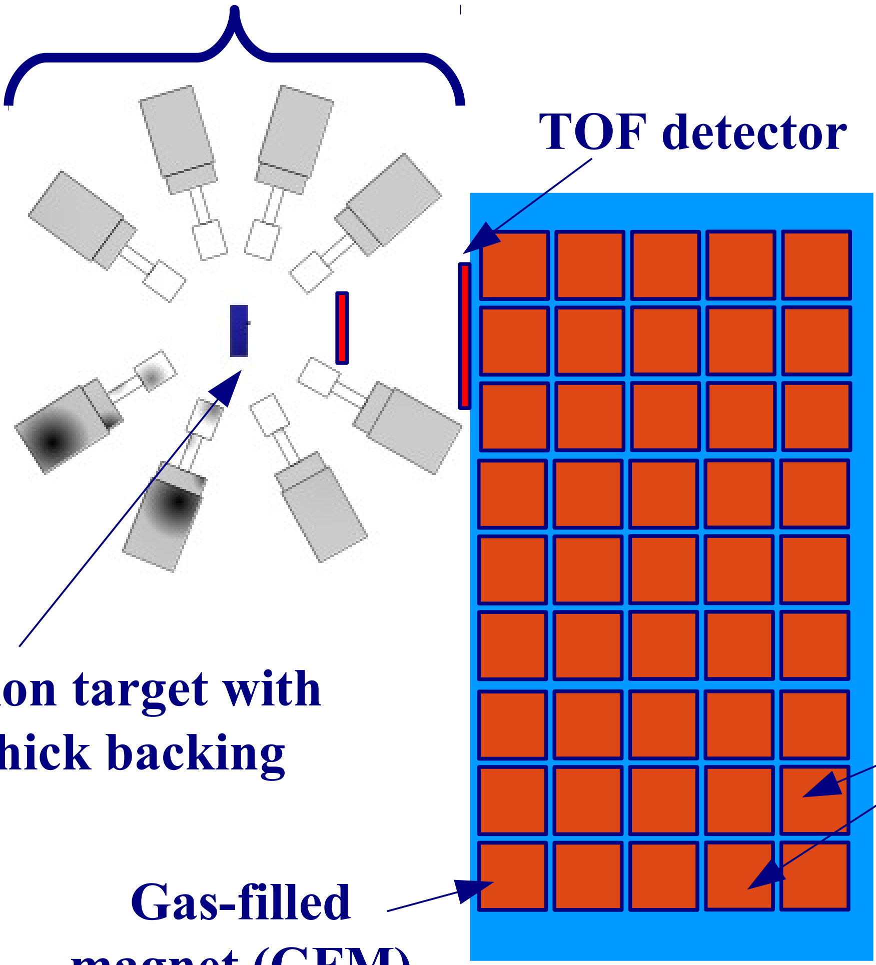


G. Simpson et al., Phys. Rev. C 74 (2006) 064308.

FIPPS layout

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

TOF detector



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

- “Right” fragment:
  → TOF: velocity
  → magnet + TPC
  } A, Z

Segmented Time Projection Chamber (TPC)

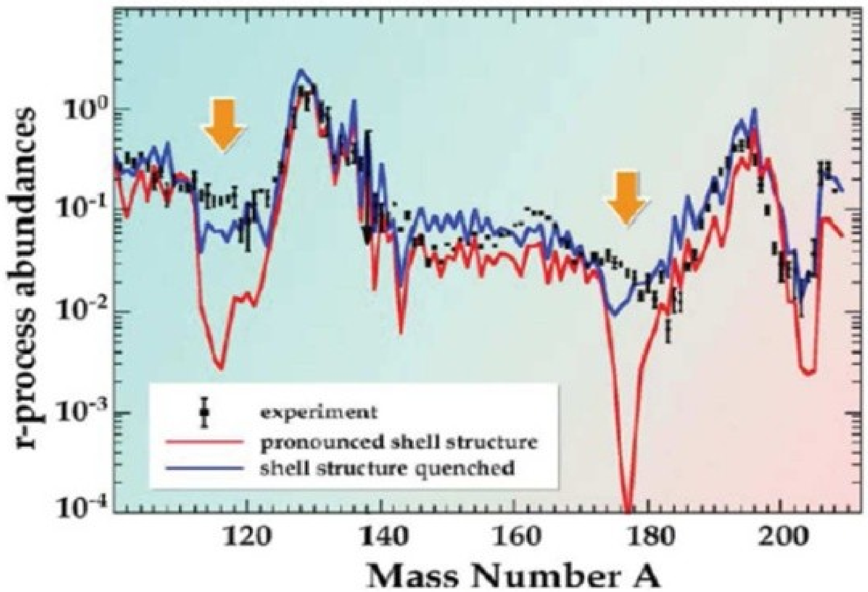
Fission target with a thick backing

Gas-filled magnet (GFM)

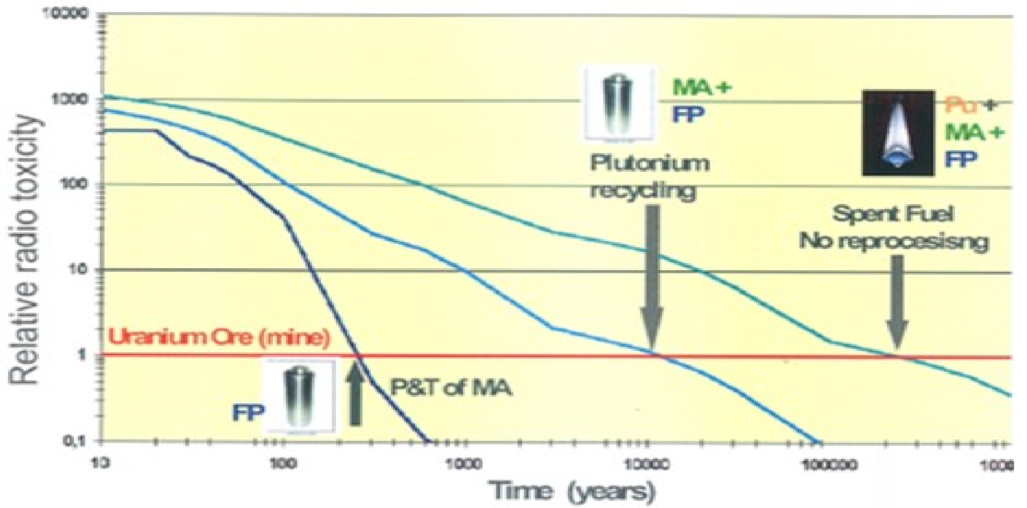
=> Time Projection Gas-Filled Magnet (TP-GFM)

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

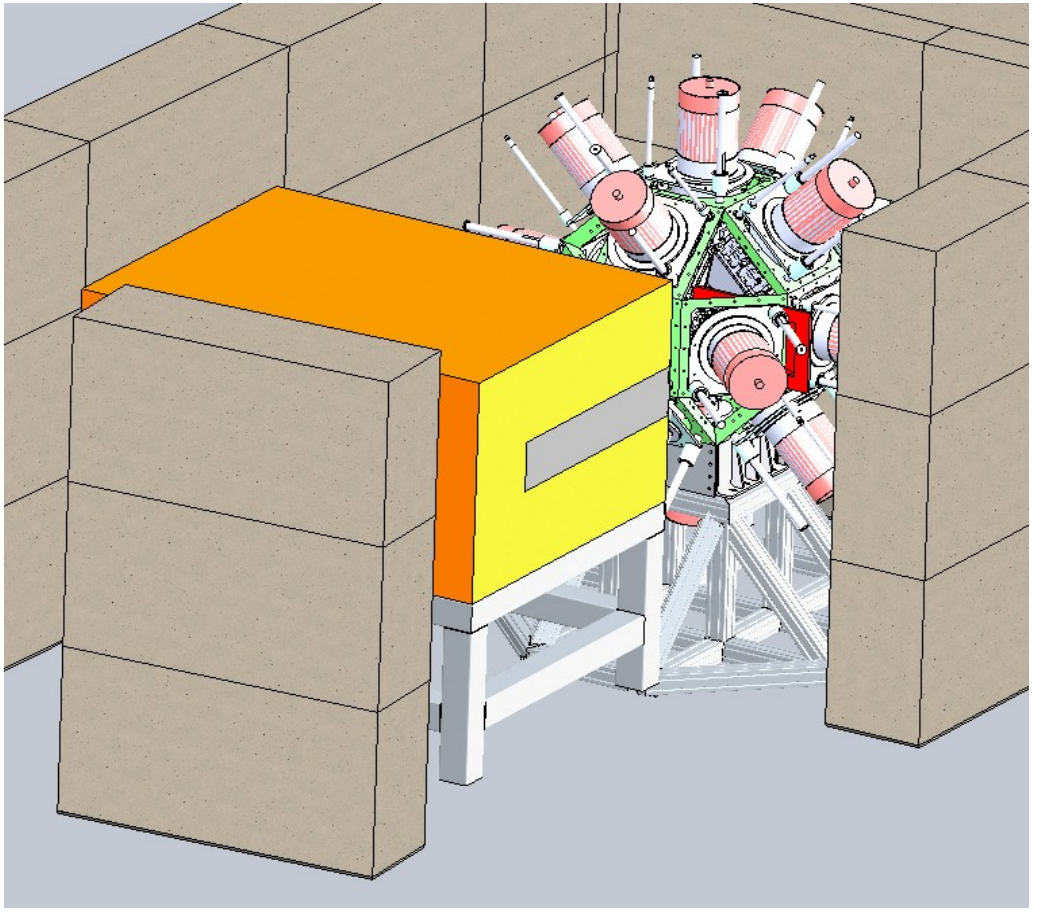


- Applied physics :
  - Nuclear waste burning
  - Generation IV reactors
  - Elemental imaging



FIPPS siting

- End of H22 neutron guide:
  - Thermal neutrons
  - Divergence: horizontal 0.2°, vertical 0.2°
  - ~10*10 mm^2
  - ~9*10^7 $n/cm^2.s^{-1}$
- TP-GFM "moveable":
  - Potential interest with fast neutron beams (NFS @ GANIL, …)
  - Reaction study in inverse kinematic ("active" target with tracking capability)
  - ...

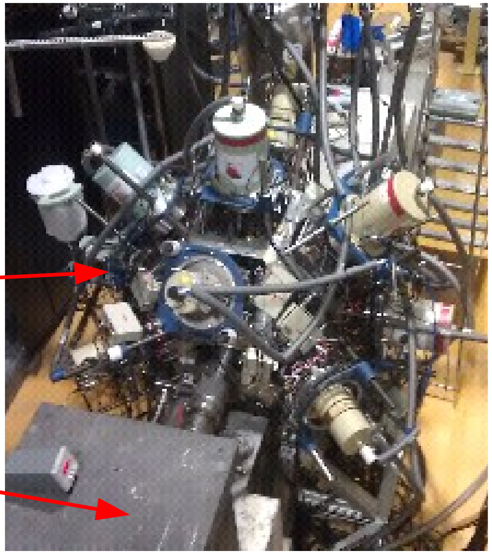


Germanium Array

- EXILL campaign: EXOGAM @ ILL (October 2012 → April 2013)

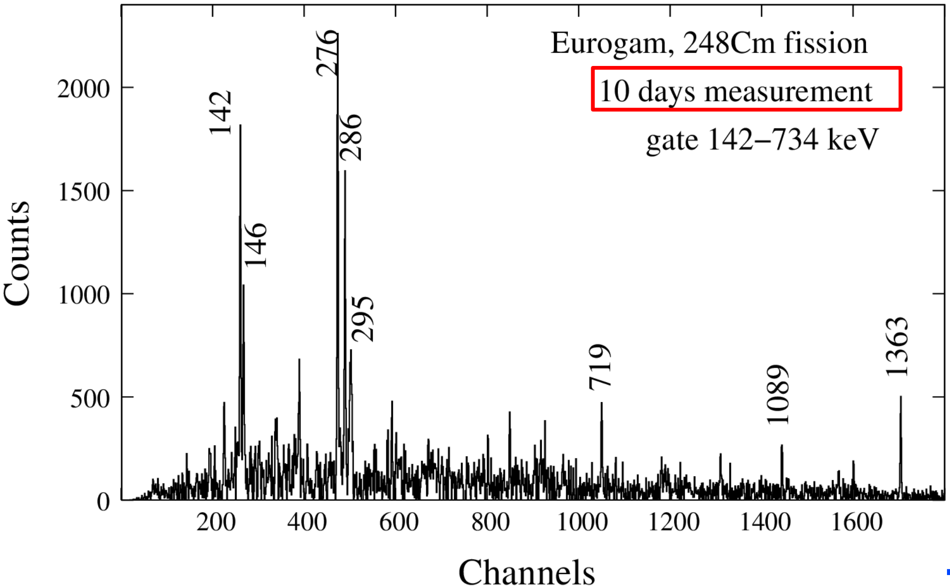
EXOGAM+GASP array: Provided by GANIL and LNL

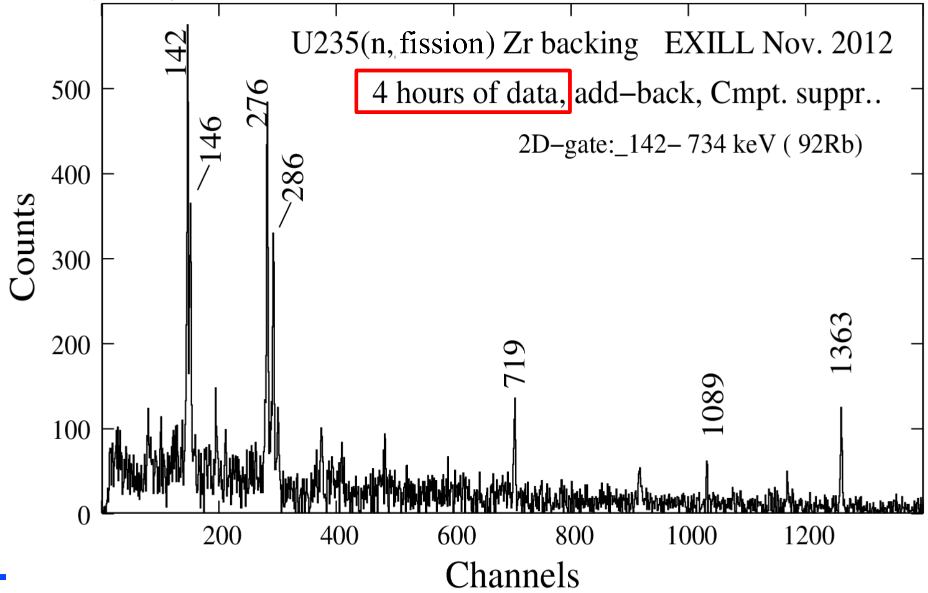
Collimation: ϕ12 mm "pencil" neutron beam



235U and 241Pu targets with thick backing

=> 92Rb: γ-γ spectrum gated on 142-734 keV γ-rays

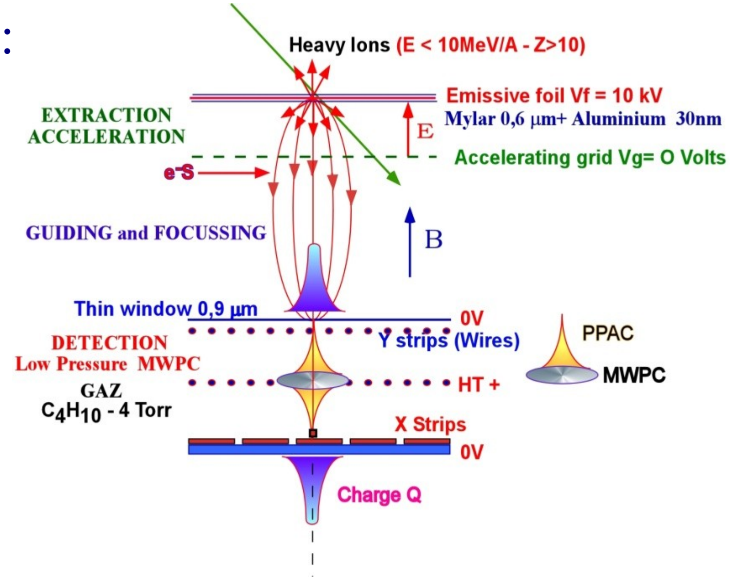




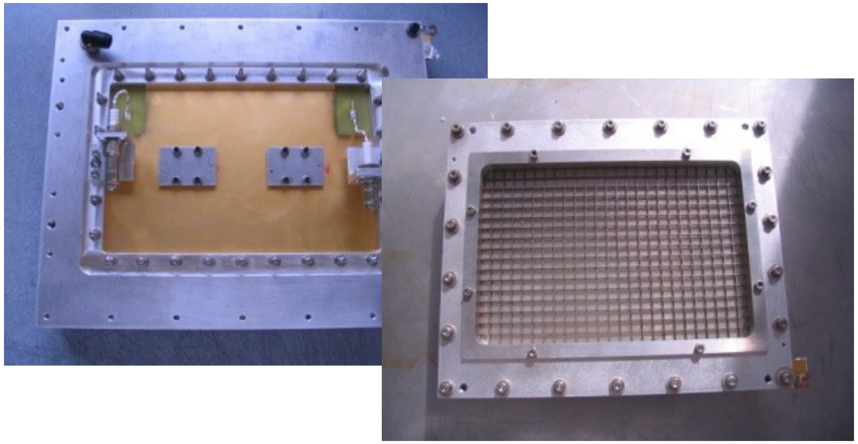
TOF detector

- New large TOF detector for fission spectroscopy:
  - Dimension ≃ 260 x 210 mm2
  - Useful surface ≃ 200 x 140 mm2

  - Emissive foil = 0.5 um mylar foil at 10 kV
  - Electron detector = low pressure gas detector
  - Two anodes made of (ϕ=20 um) wires at mid-distance (1.6 mm) between the detector window and a pixelated cathode



- Current measured performances (Cf source):
  - Time resolution < 150 ps
  - Spatial resolution < 5 mm
  - With a focusing magnetic field, better than 1 mm



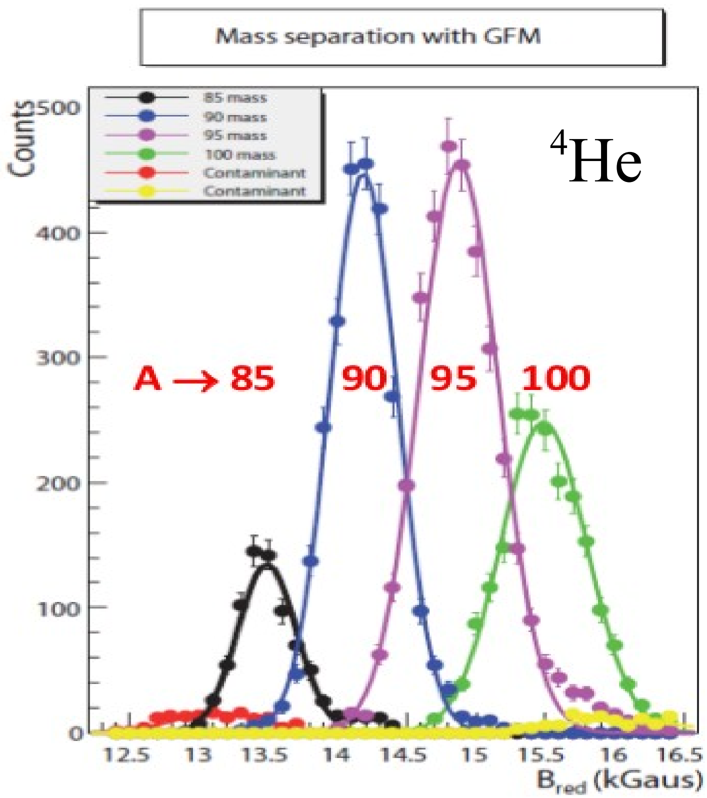
- To be done:
  - Test with ion beams at Lohengrin in May-June 2013

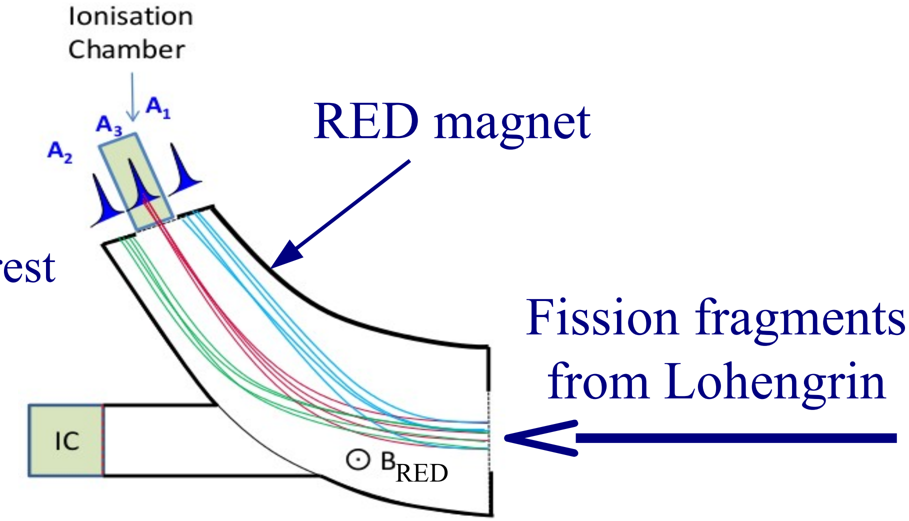
T. Materna, CEA-Saclay

TP-GFM: development of a GFM spectrometer @ Lohengrin

Goal of Instrument:
- Improve the separation power of Lohengrin
- increase the sensitivity in symmetry. region

Scope :
- fission, nuclear structure and astrophysical interest





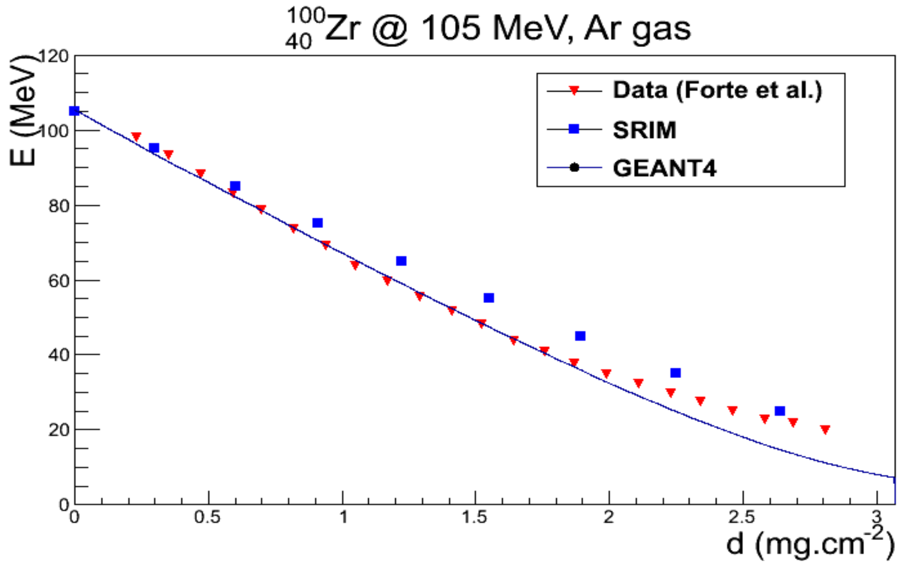
Complementary to the TP-GFM development:

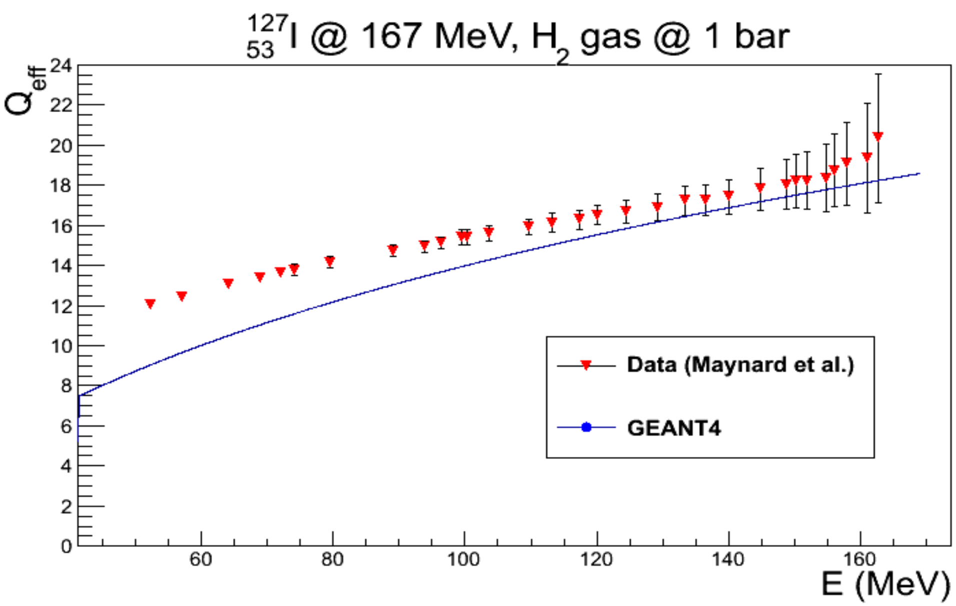
→ the results can be used as inputs (gas pressure, …) for the GEANT4 simulations

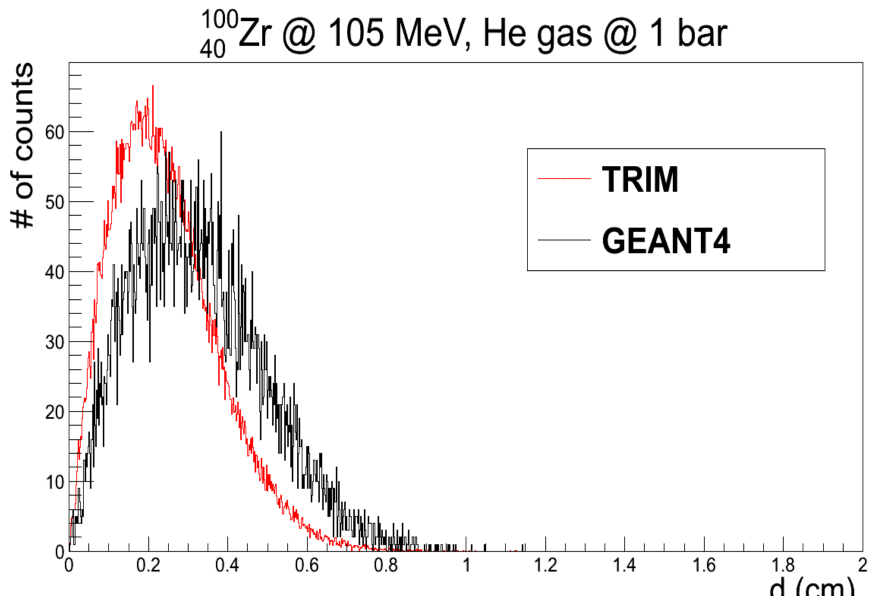
G. Kessedjian, LPSC-Grenoble

TP-GFM: GEANT4

- Geant4 is a **toolkit** for the simulation of the passage of particles through matter. Its areas of application include **high energy, nuclear and accelerator physics**, as well as studies in medical and space science.

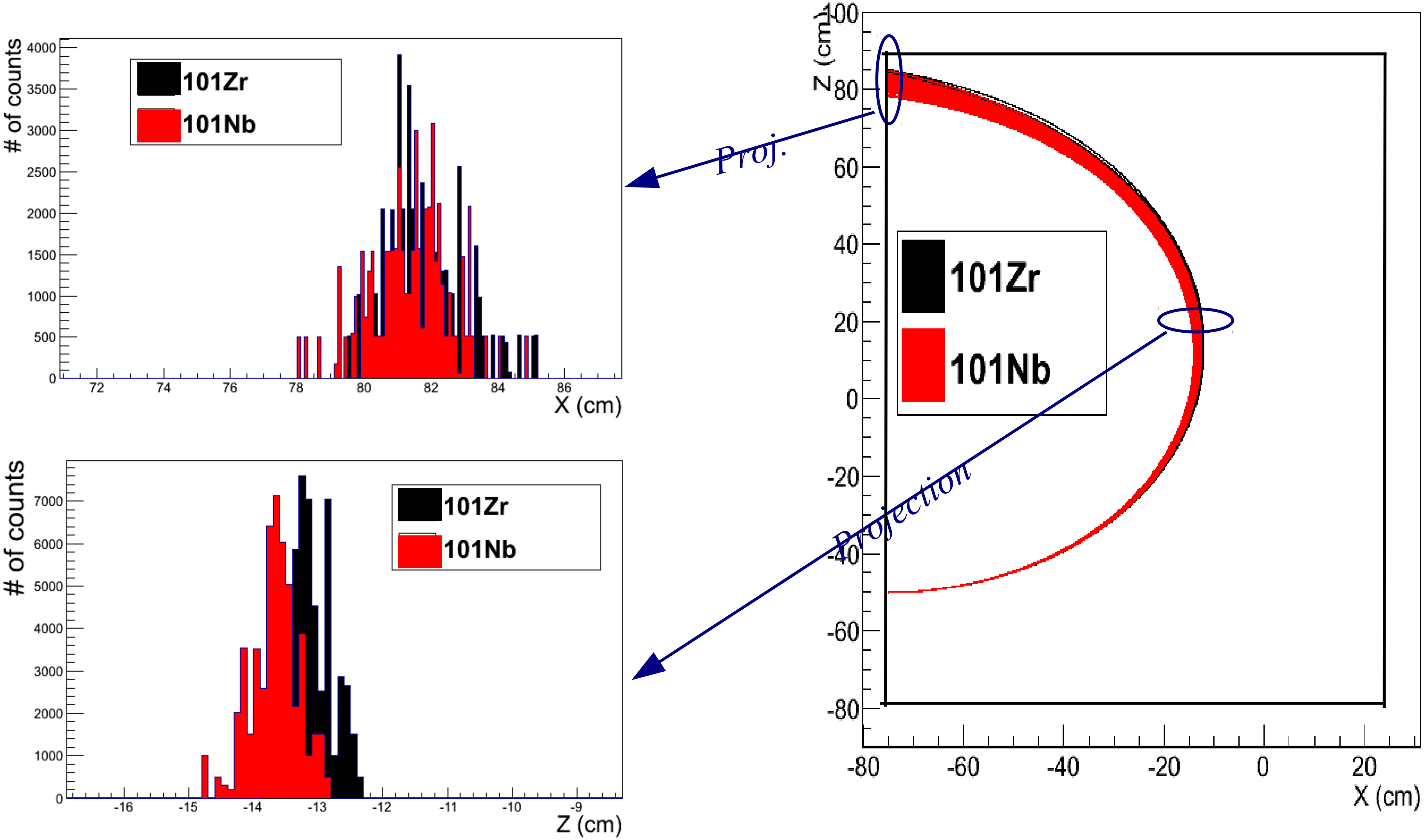






TP-GFM: GEANT4 simulations (1)

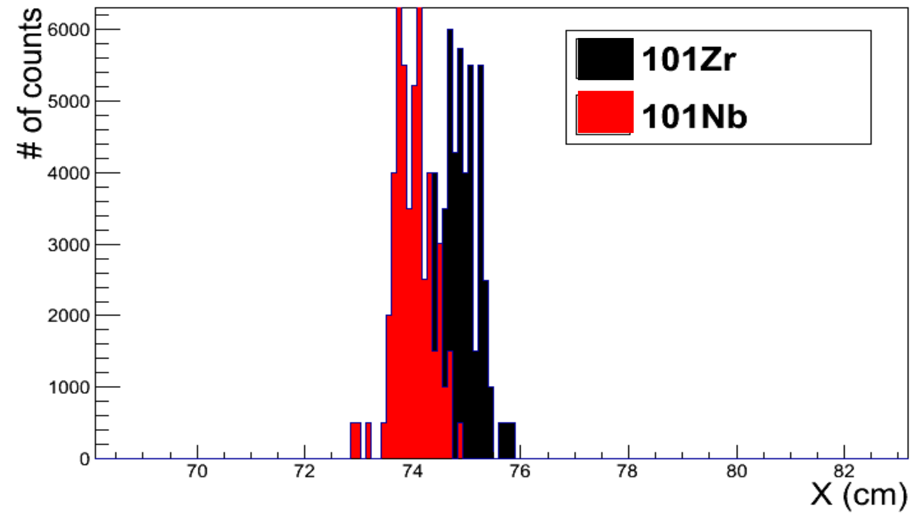
- $^{101}Zr/^{101}Nb$ @ 105MeV, He gas @ **40mbar**, B=16kG



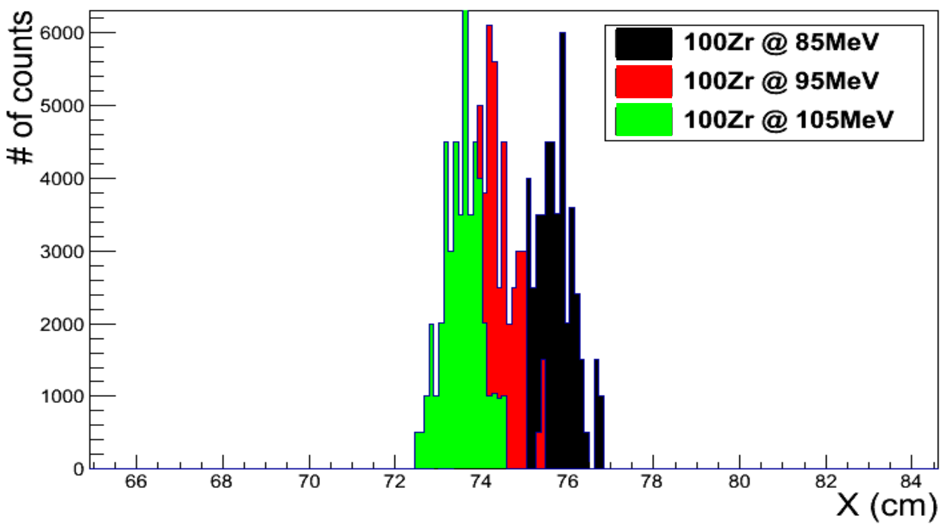
TP-GFM: GEANT4 simulations (2)

- First GEANT4 simulations show that, in the combination of TOF and TP-GFM allows rough identification of isotopes. Even a tagging with dZ and dA~2 significantly cleans the γ spectra.

^{101}Zr/^{101}Nb @ 105MeV, He gas @ 20mbar, B=16kG
Distribution at the end of the GFM (see previous slide)



^{100}Zr @ 85/95/105MeV, He gas @ 20mbar, B=16kG
Distribution at the end of the GFM (see previous slide)

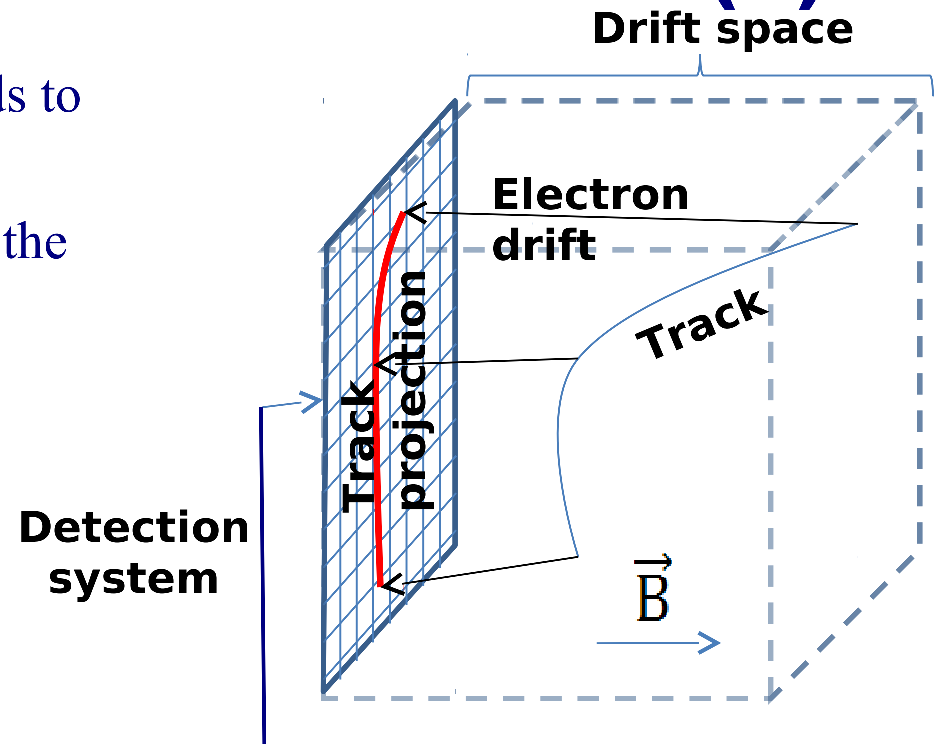


New inputs are needed before starting further simulations for final TP-GFM sizing:

→ results from the GFM @ Lohengrin
→ working mixture/pressure for the TPC (see slide 19)
(→ bigger computer)

Time-Projection Chamber (1)

- Energy loss (~100 keV/cm) in gas leads to ionization
  - charges can be collected to follow the particle tracks
- Time Projection Chamber:
  - good 3D-tracking capability
  - can cover large surfaces
  - compact setup
  - isotopic ID from ΔE or range



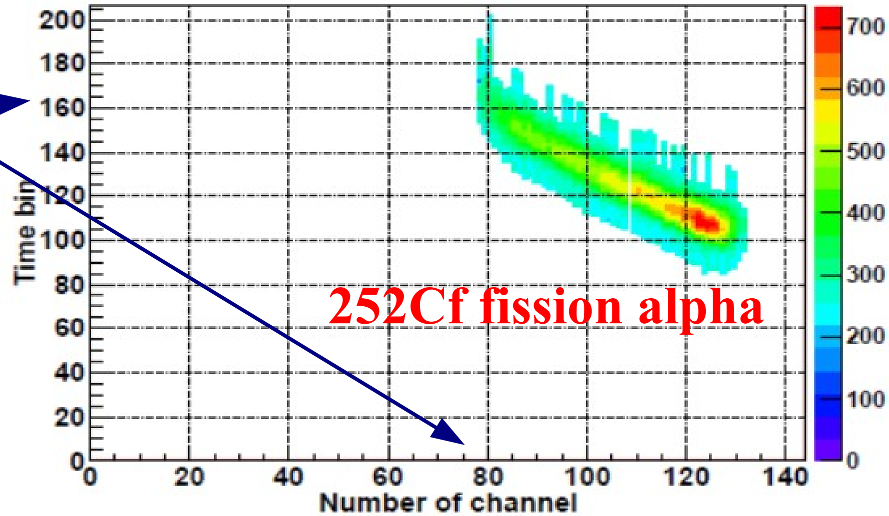
Profit from high energy physics technology:
eg: ALICE, 88m3, 570000 ch., 0.25mm resolution, 2000 particles simultaneously

Various read-out options:

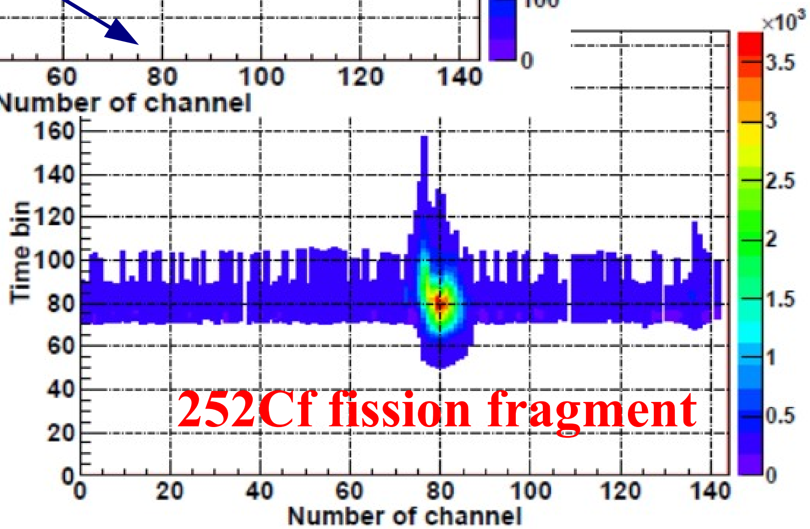
- Multi-Ware Proportional Chambers (MWPC)
- **Micromegas (MM)**
- Gas Electron Multiplier (GEM)
- Optical read-out

Time Projection Chamber (2)

- FIDIAS (FIssion Detector at the Interface with Astrophysics) project at CEA-Saclay: development of a Micromegas detector for “low-energy” fission fragment
  - Prototype successfully tested with He gas at 1 bar (252Cf source)
  - New dedicated DAQ board tested in November: 1kHz achieved



- Test at Lohengrin in May-June 2013:
  - to be tested at low pressure (down to 10 mbar) with different gas mixtures (He, He+isobutane)
  - to be tested with ion beams



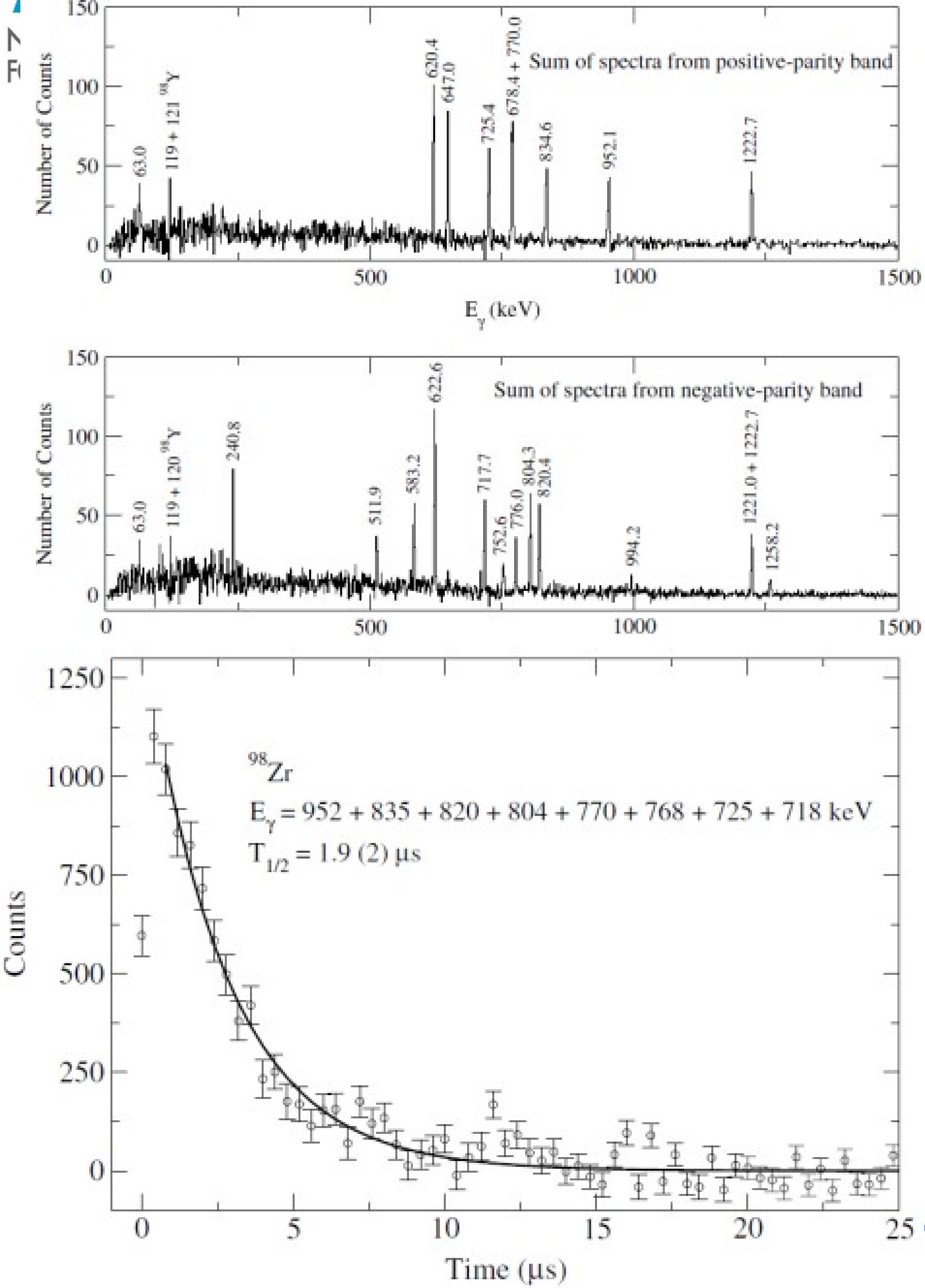
S. Panebianco et al., Nucl. Instr. Meth. A, to be published.

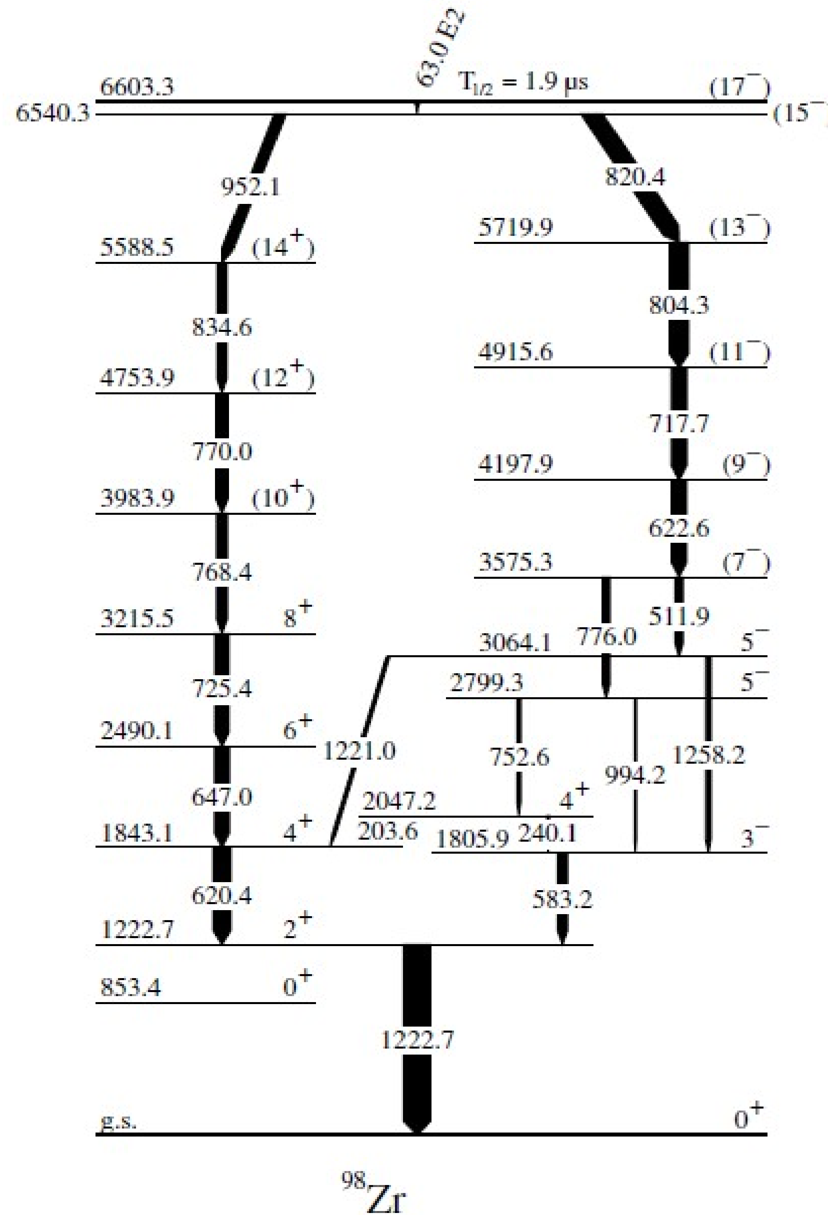
Conclusion

- Development of the FIssion Product Prompt γ-ray Spectrometer:
  - 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**
  - **TOF detector being tested**
  - Gas-Filled Magnet: **simulations on going**
    - **Inputs are welcome**
  - TPC: use of intrinsic energy loss in the GFM for tracking purpose → **being tested**
- Potential interests:
  - detailed spectroscopy of neutron rich nuclei
  - nuclear fission study
  - fast neutron beams
  - reaction study in inverse kinematic
  - ...suggestions?

Back up

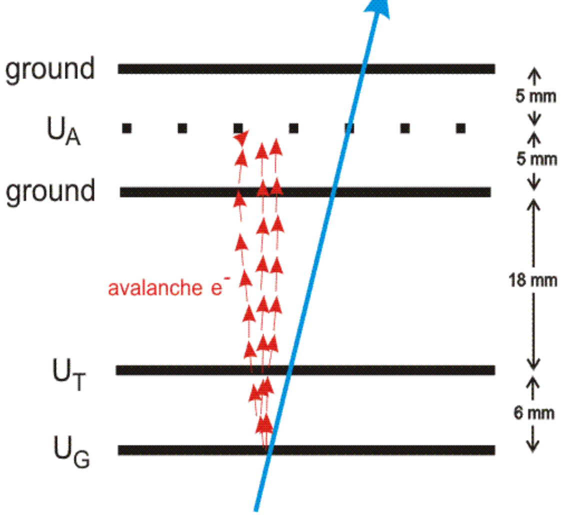
17^- isomer at 6.6 MeV in ^{98}Zr



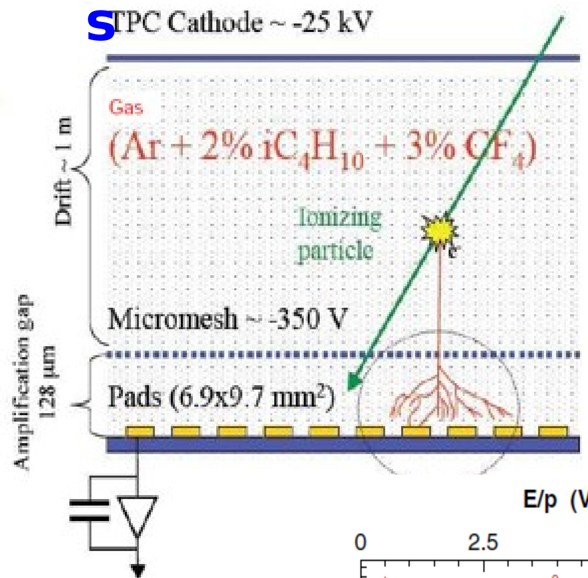


TPC read-out options

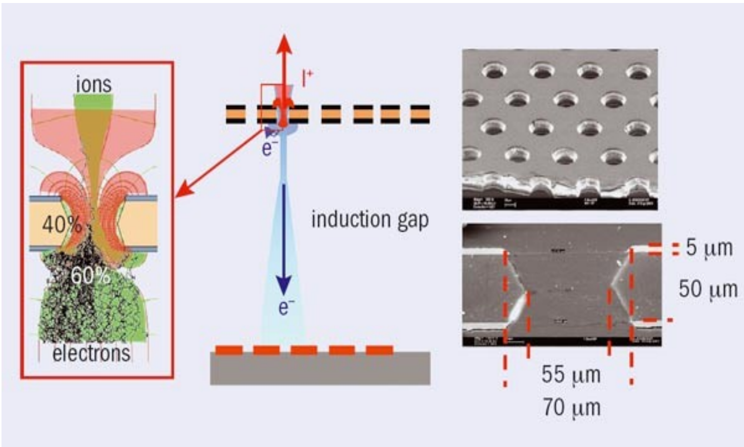
MWPC



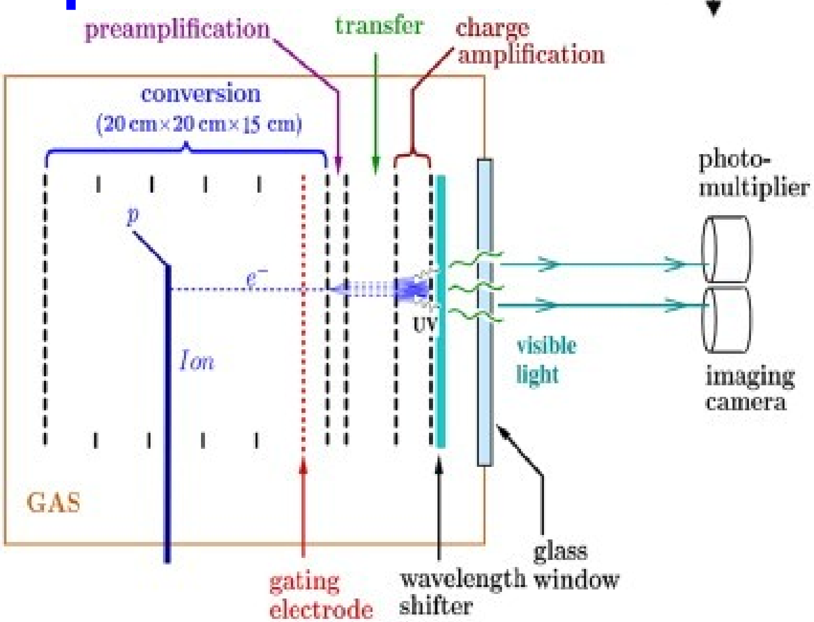
Micromegas

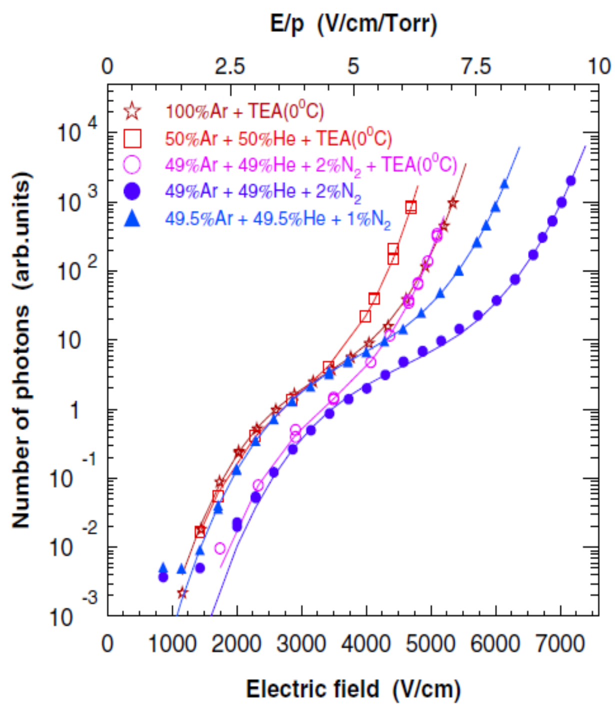


GEM

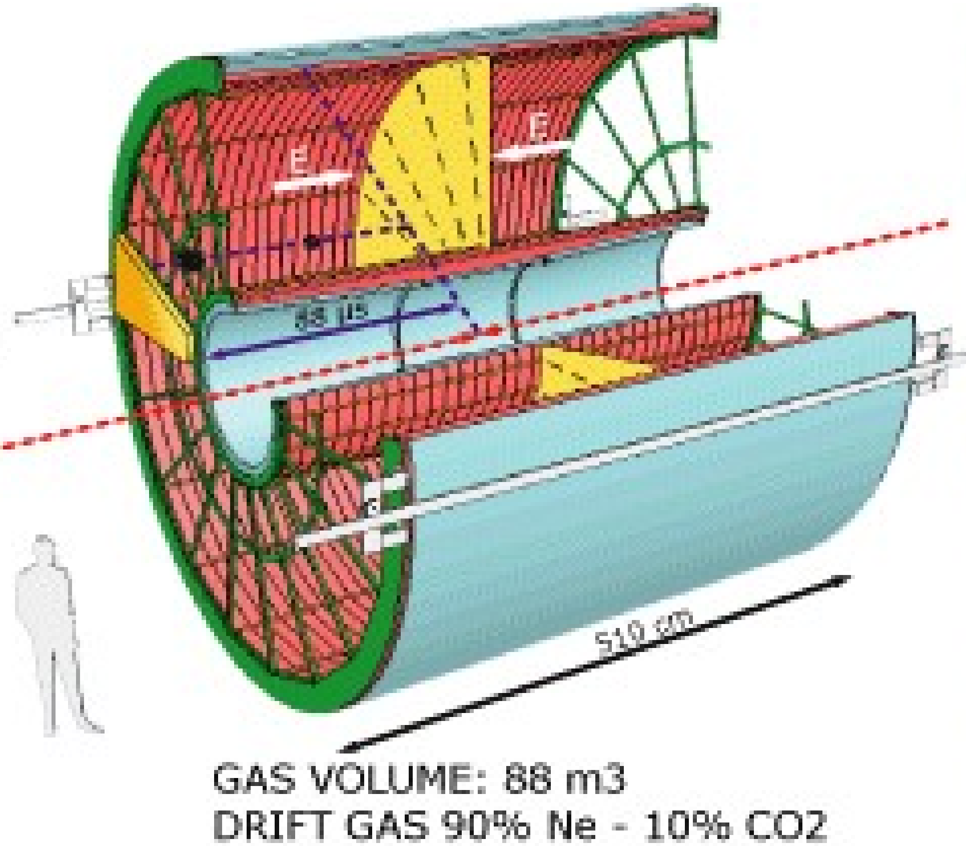


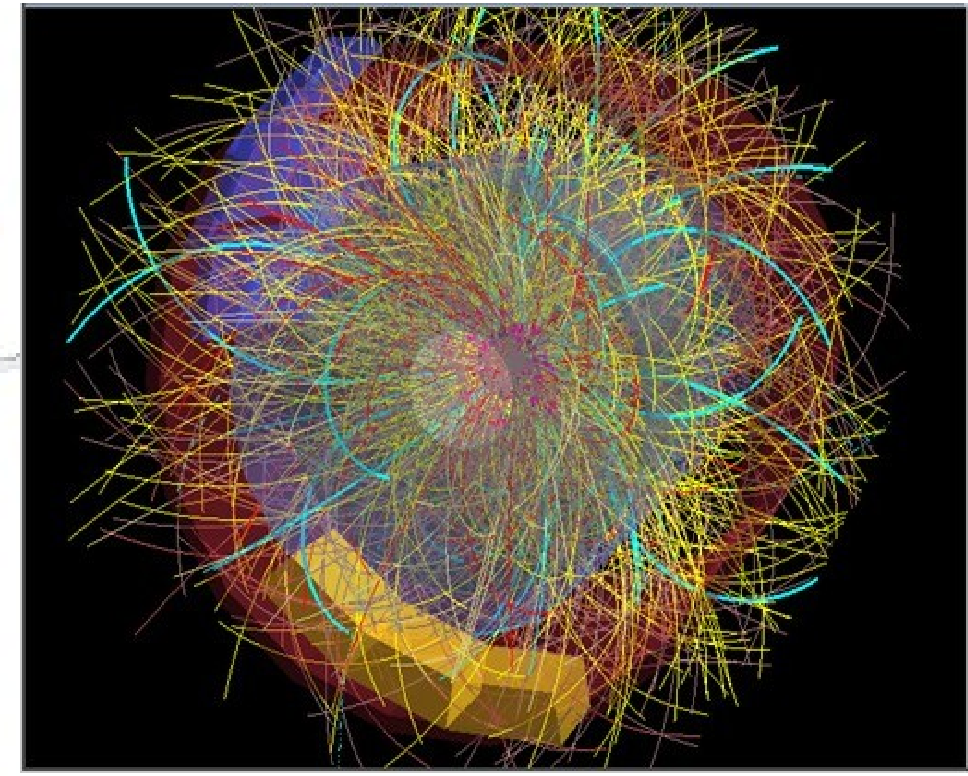
Optical





TPC





e.g. ALICE: 570000 ch., 0.25 mm resolution, 2000 particles simultaneously

⇒ profit from high energy physics technology