Gamma spectroscopy of the fission products with Gas-Filled Magnet

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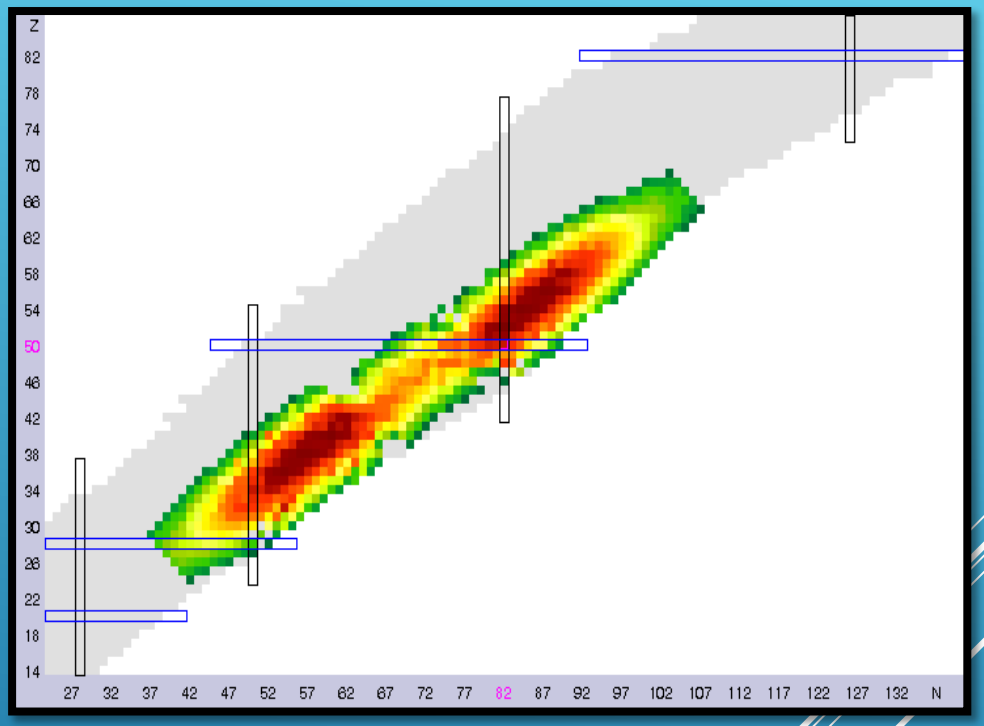
➢ spontanious fission

Many prompt gamma spectroscopy experiments in 1990's and 2000's

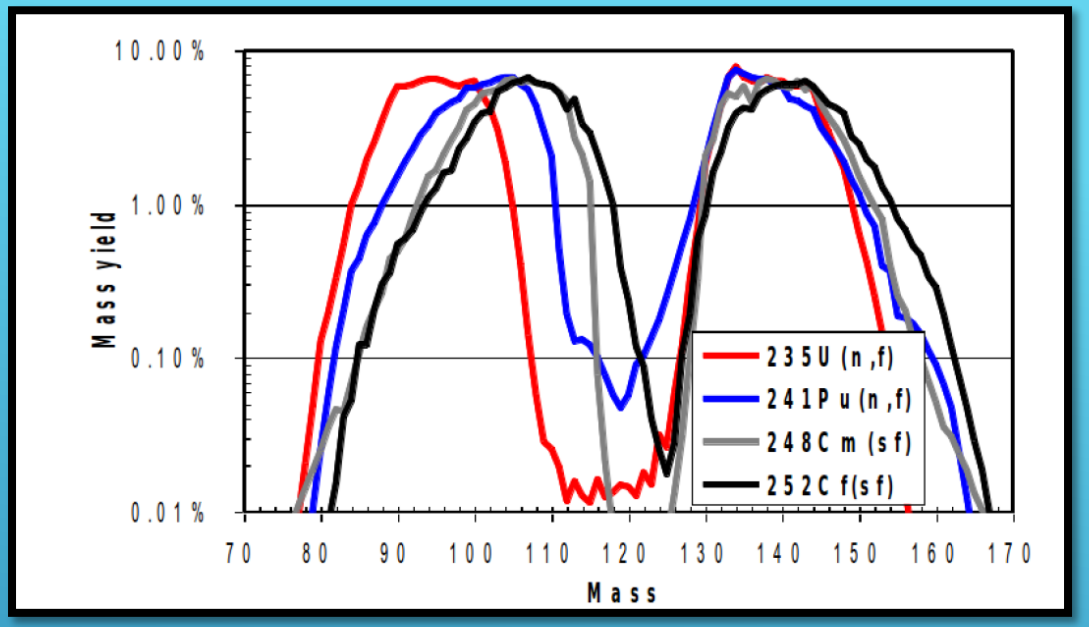
Efficient arrays of Ge detectors: Exogam, Euroball, Gammasphere



- Only the ^{252}Cf and ^{248}Cm fission sources are available

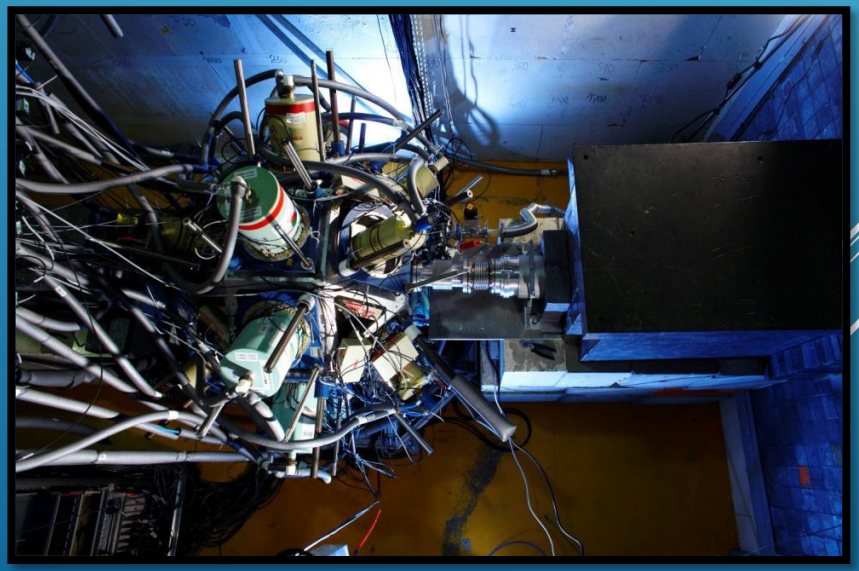
- Tag of the fission event

- spontanious fission
- **neutron-induced fission**



Courtesy of A. Blanc

EXILL



Experimental details

EXILL

Institut Laue-Langevin (Grenoble) (2012)

- Cold nutrons from ILL reactor induced fission of on ^{235}U and ^{241}Pu

Institut de physique nucléaire (Orsay) (2018)

- Fast nutrons from LICORNE induced fission of on ^{238}U and ^{232}Th

Gamma spectroscopy HPGe

- 10 clover detectors
- 6 large coaxial detectors

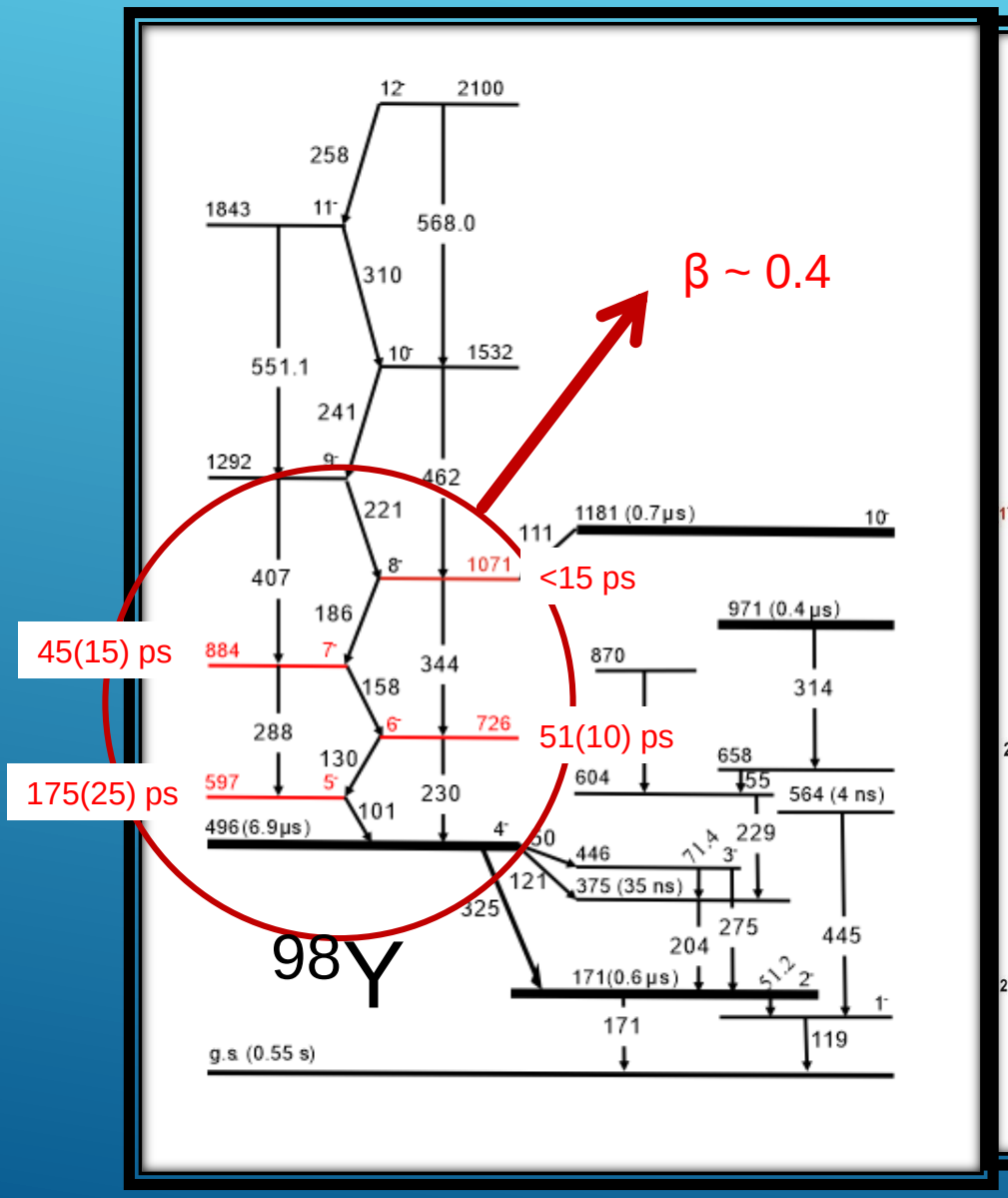
- 24 clover detectors
- 10 large coaxial detectors

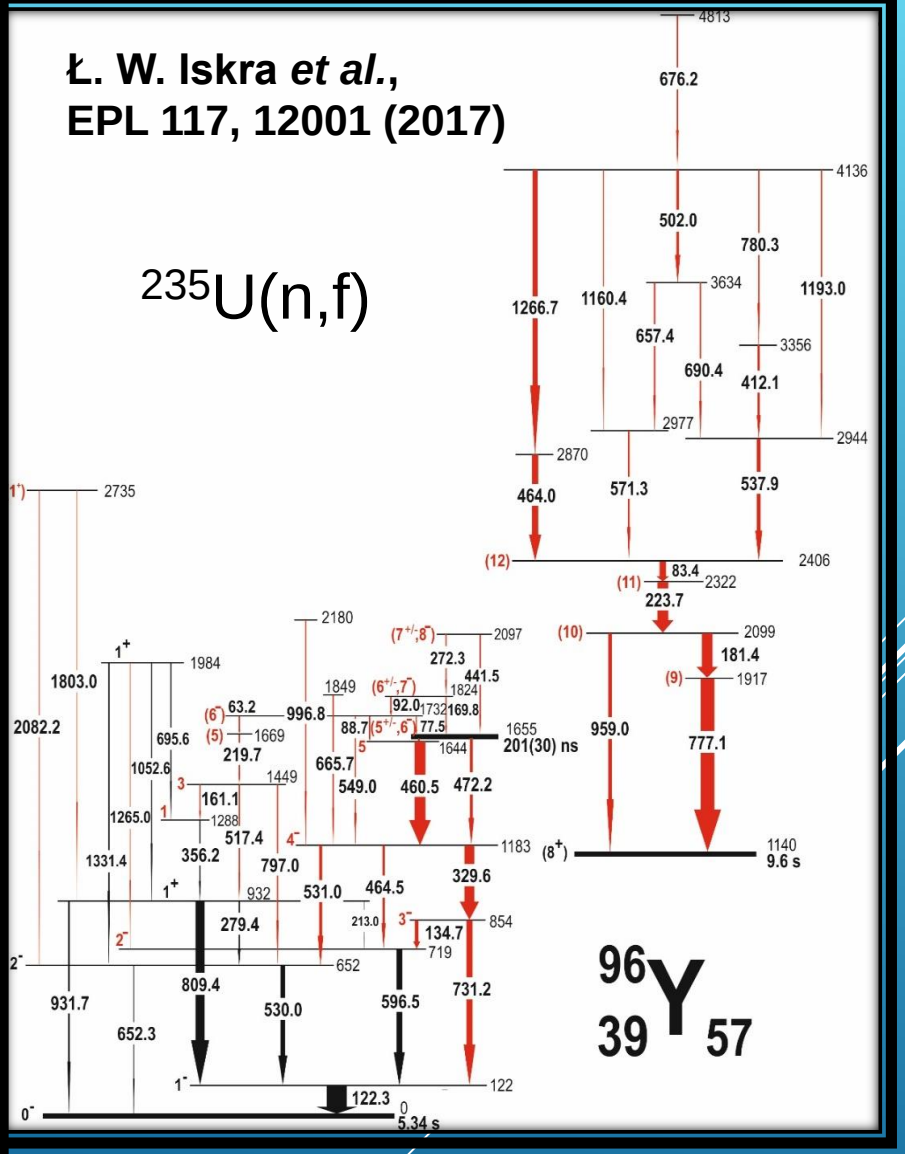
Lifetime measurements

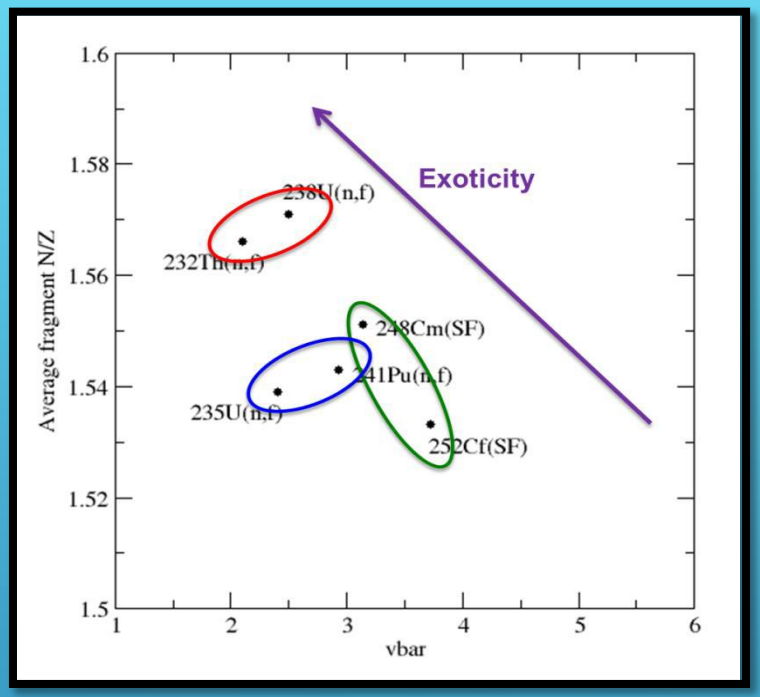
- HPGe + 16 $LaBr_3$
- continuous neutron flux

- HPGe + 20 $LaBr_3$
- pulsed beam with 400 ns repetition time

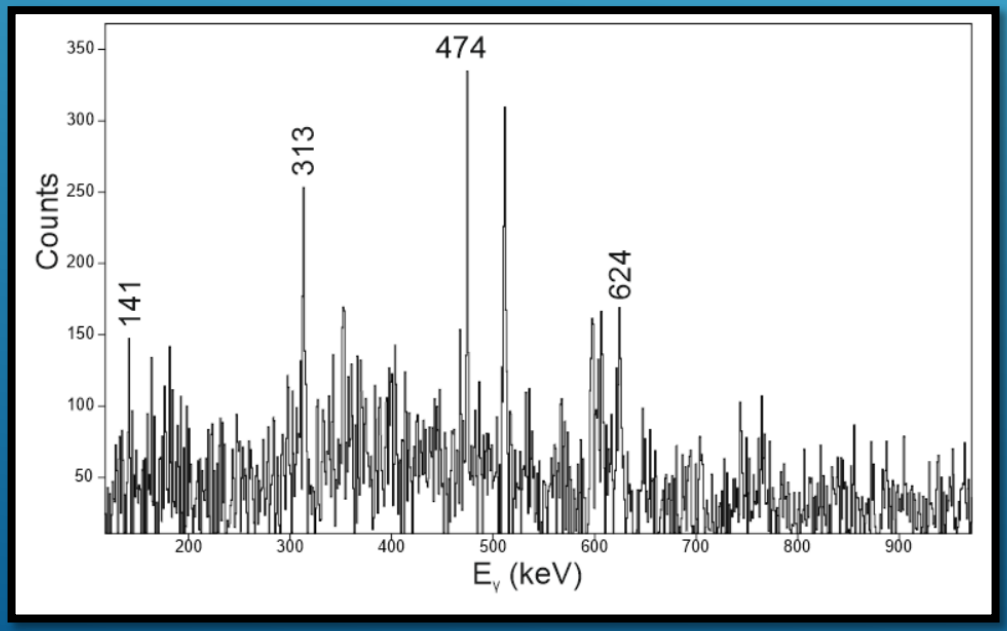
EXILL

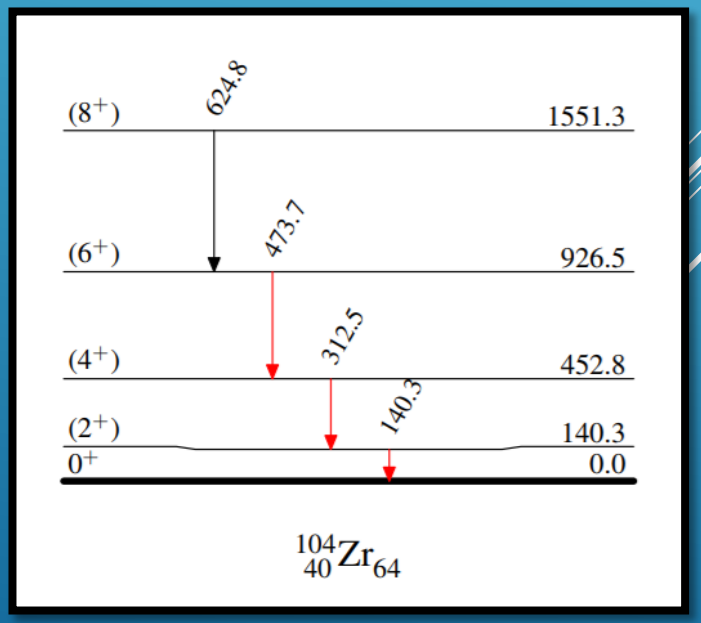

45(15) ps
175(25) ps
β ~ 0.4
<15 ps
51(10) ps
98Y
12⁻ 2100
258
1843 11⁻
568.0
310
10⁻ 1532
551.1
241
1292 9⁻
462
221
111 1181 (0.7 µs) 10⁻
407
8⁻ 1071
186
971 (0.4 µs)
884 7⁻
344
870
314
158
288
6⁻ 726
130
658
604
597 5⁻
230
564 (4 ns)
55
496(6.9µs) 4⁻
101
60
446
71.4
3⁻ 229
121
375 (35 ns)
325
204
275
445
171(0.6 µs) 2⁻
51.2
1⁻
171
119
g.s (0.55 s)


Ł. W. Iskra et al.,
EPL 117, 12001 (2017)
235U(n,f)
96 39 Y 57
4813
676.2
4136
502.0
780.3
3634
1193.0
1266.7
1160.4
657.4
3356
690.4
412.1
2977
2944
2870
464.0
571.3
537.9
(12)
2406
83.4
(11) 2322
223.7
(10) 2099
181.4
(9) 1917
959.0
777.1
1140
9.6 s
(8⁺)
1183
329.6
854
134.7
719
731.2
652
596.5
530.0
809.4
122
122.3
0
5.34 s
1⁻
0⁻
2⁻
1⁺
279.4
931.7
652.3
531.0
464.5
797.0
356.2
517.4
1288
161.1
1449
665.7
549.0
460.5
472.2
1655
201(30) ns
1644
88.7
92.0
77.5
1732
169.8
1824
441.5
272.3
2097
(7⁺/⁻;8⁻)
1849
(6⁺/⁻,7⁻)
996.8
63.2
(6⁻)
(5) 1669
219.7
695.6
1052.6
1265.0
1331.4
932
213.0
2180
2082.2
1803.0
1984
2735
1⁺
1⁻



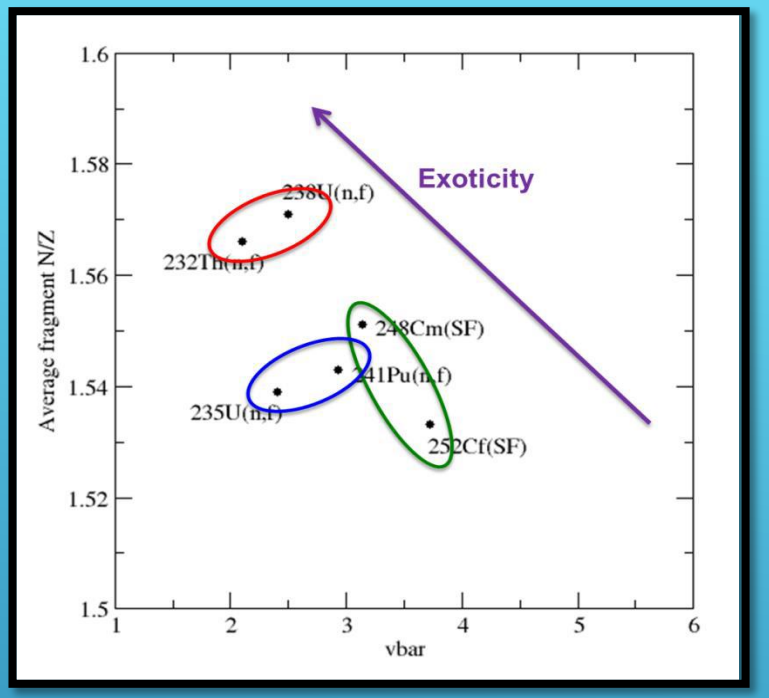
Courtesy of J.N. Wilson





- spontanious fission
- neutron-induced fission
- **proton-induced fission**

Pulsed proton beam up to 230 MeV at CCB



Courtesy of J.N. Wilson

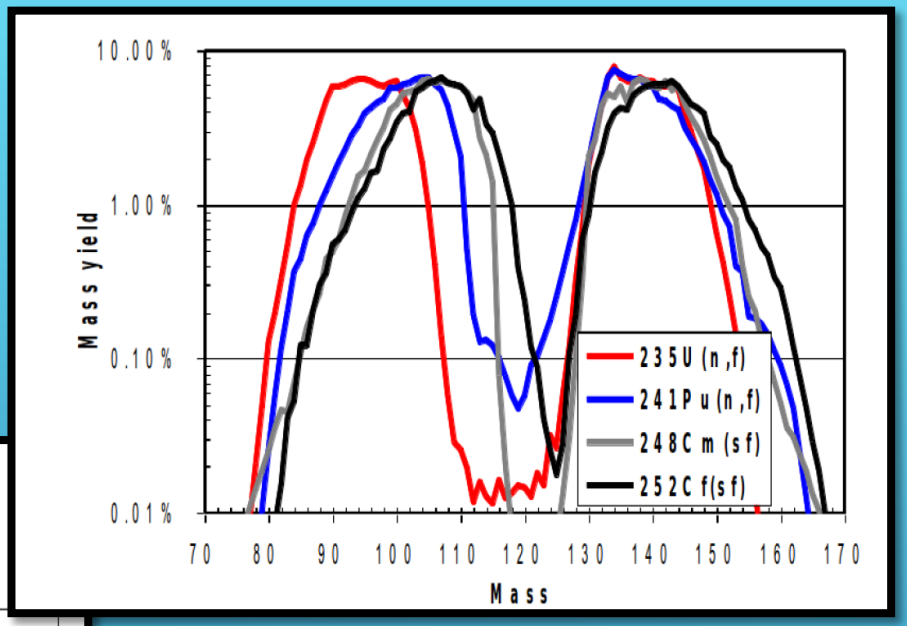
p +

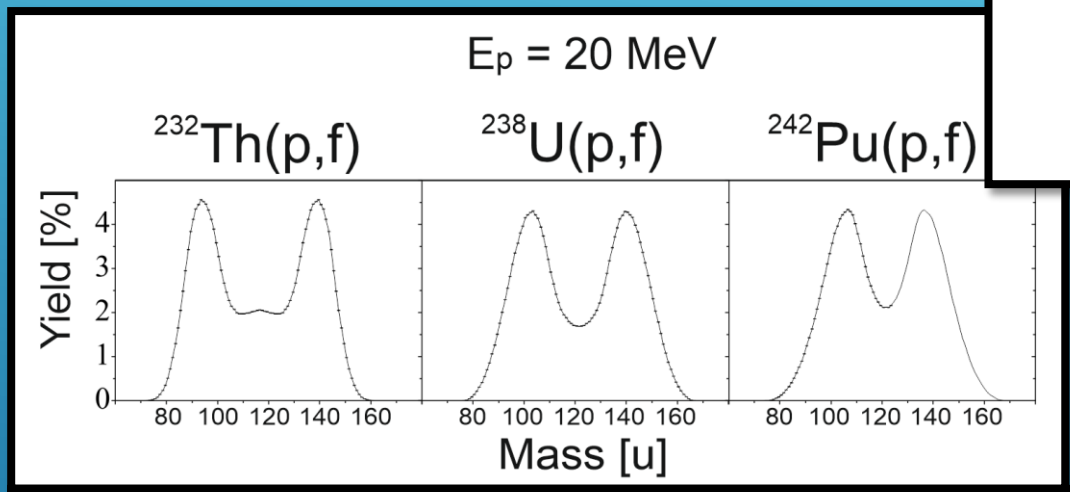
$^{232}Th \rightarrow {}^{233}Pa$ 1.57

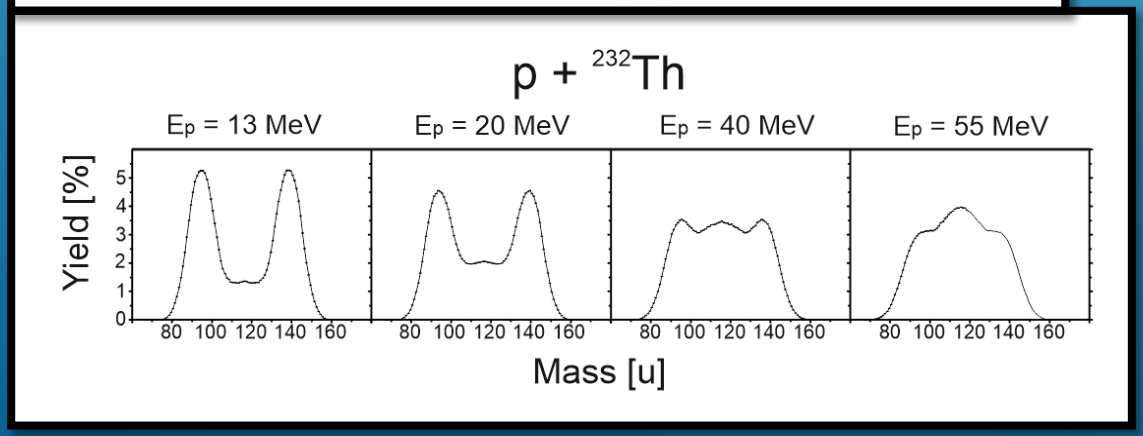
$^{238}U \rightarrow {}^{239}Np$ 1.58

$^{242}Pu \rightarrow {}^{243}Am$ 1.57

- spontanious fission
- neutron-induced fission
- **proton-induced fission**





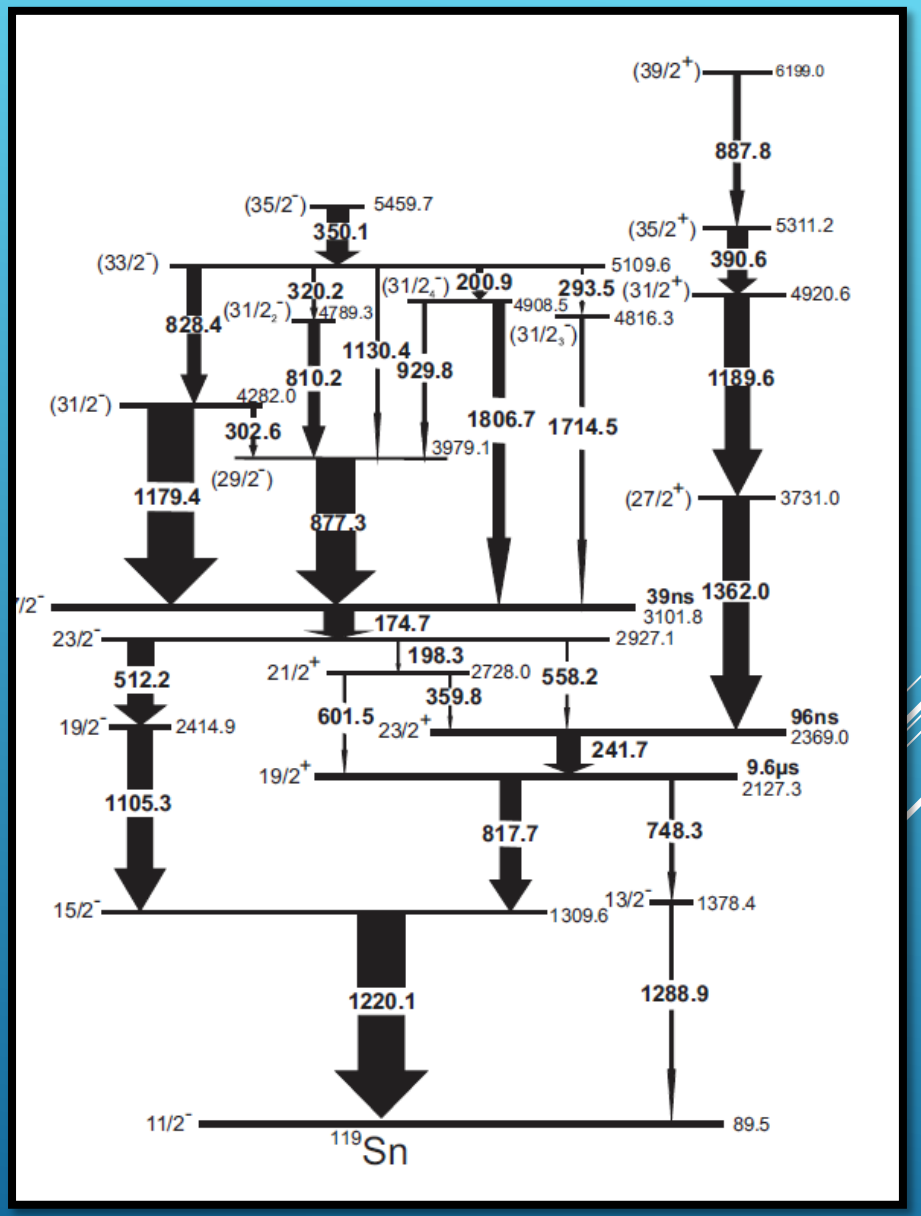


^{78}Ni

Data from JYFL Accelerator Laboratory (Finland) see:
K. B. Gikala et al. ***Physics of Atomic Nuclei, 2016, Vol. 79, No. 9–10, pp. 1367–1374 (2016)***

- spontanious fission
- neutron-induced fission
- proton-induced fission
- **heavy ion-induced fission**

- Large number of evaporated neutrons
- „Contamination” from quasifission and inelastic processes



$^{238}U(^{64}Ni,fission)$

Ł. W. Iskra *et al.*, PRC 93, 014303 (2016)

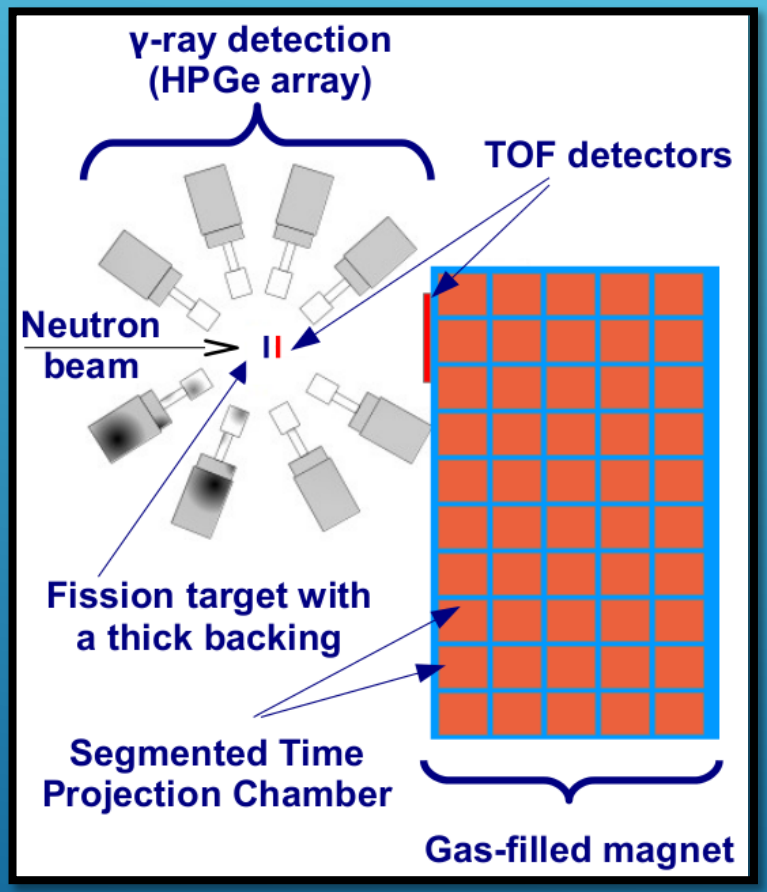
Ł. W. Iskra *et al.*, PLB 788, 396 (2019)

Gas-filled magnet concept

(P. Armbruster et al., Nucl. Instr. Meth 137, 103 (1976).)

„Left" fragment stopped in backing
→ Doppler free prompt γ detection

„Right" fragment will fly to the spectrometer
→ A, Z determination; daleyed γ spectroscopy



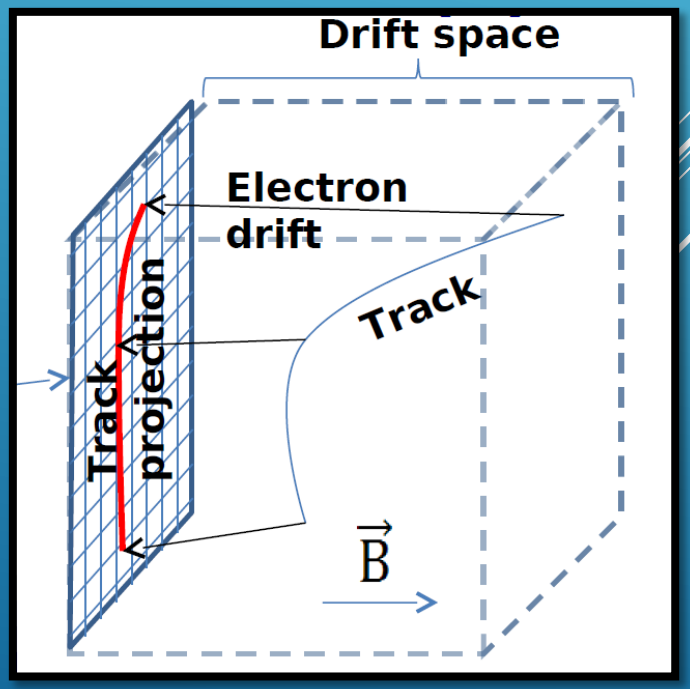
Courtesy of A. Blanc

TOF → *v* (A, E)

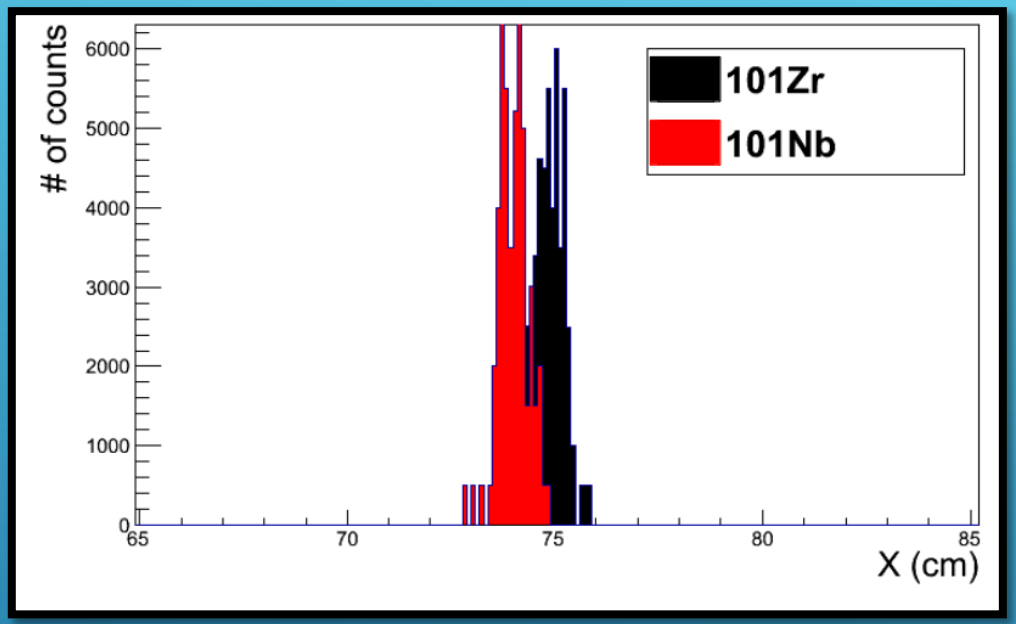
$B\rho \sim \frac{A}{Z^{\alpha}}$ Bρ (A, Z)

$\frac{dE}{dx}(Z,E)$

} **A, E, Z for each track**

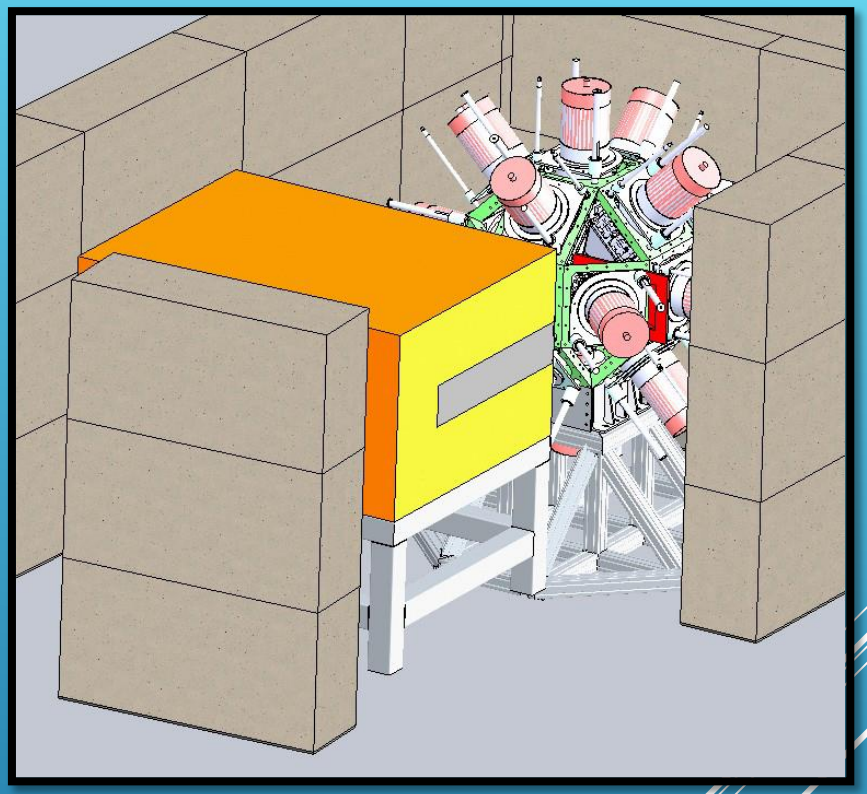


^{101}Zr/^{101}Nb @ 105 MeV, He gas @ 20mbar, B=1.6 T



Geant4 simulation

Courtesy of A. Blanc



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

Collaboration group

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Thank you for your attention