



Measurements of Fission Fragment Masses and Proton Numbers at ILL and n_TOF, CERN

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Athens, Greece

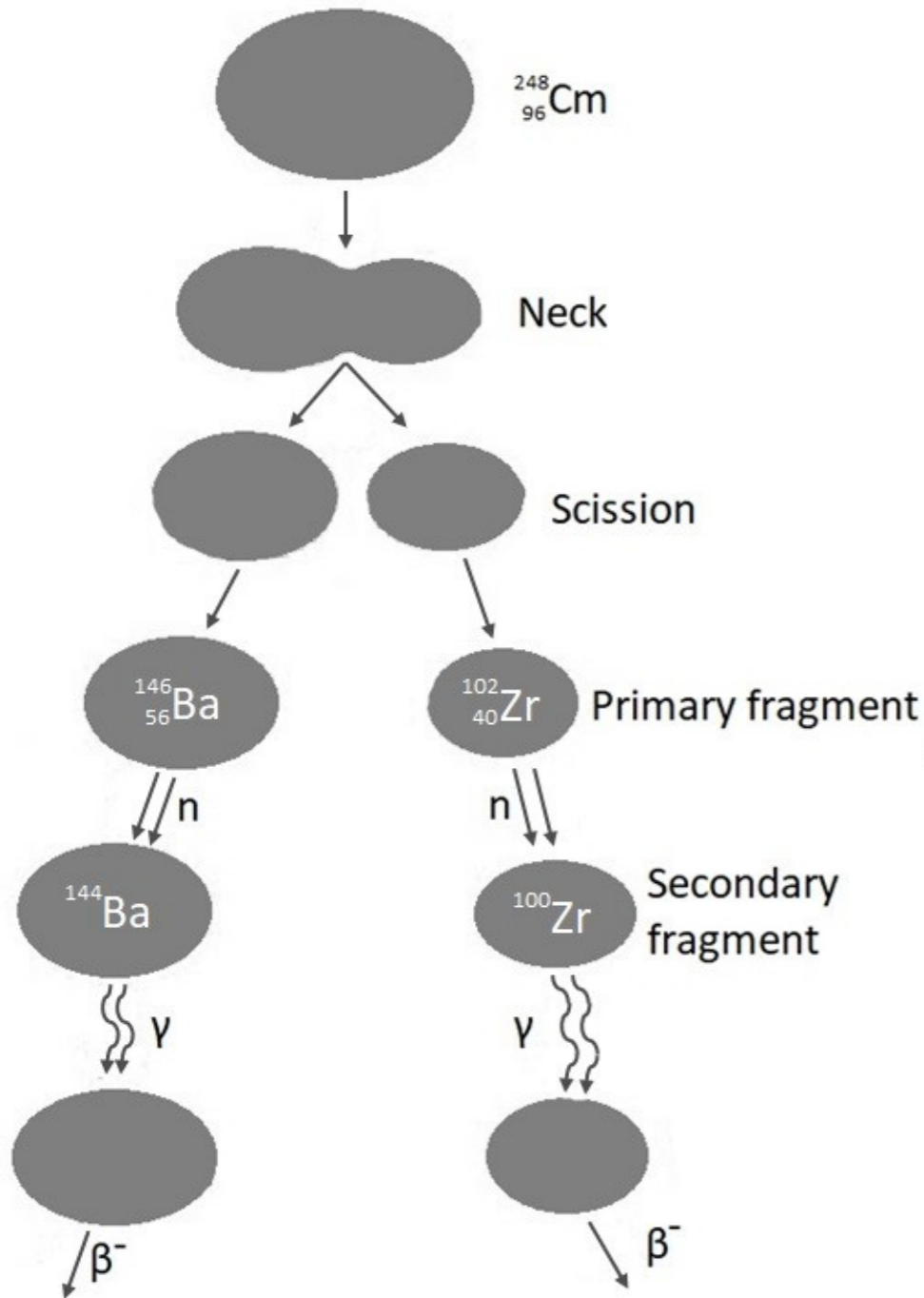
6 - CERN

7 - TU Wien, Austria

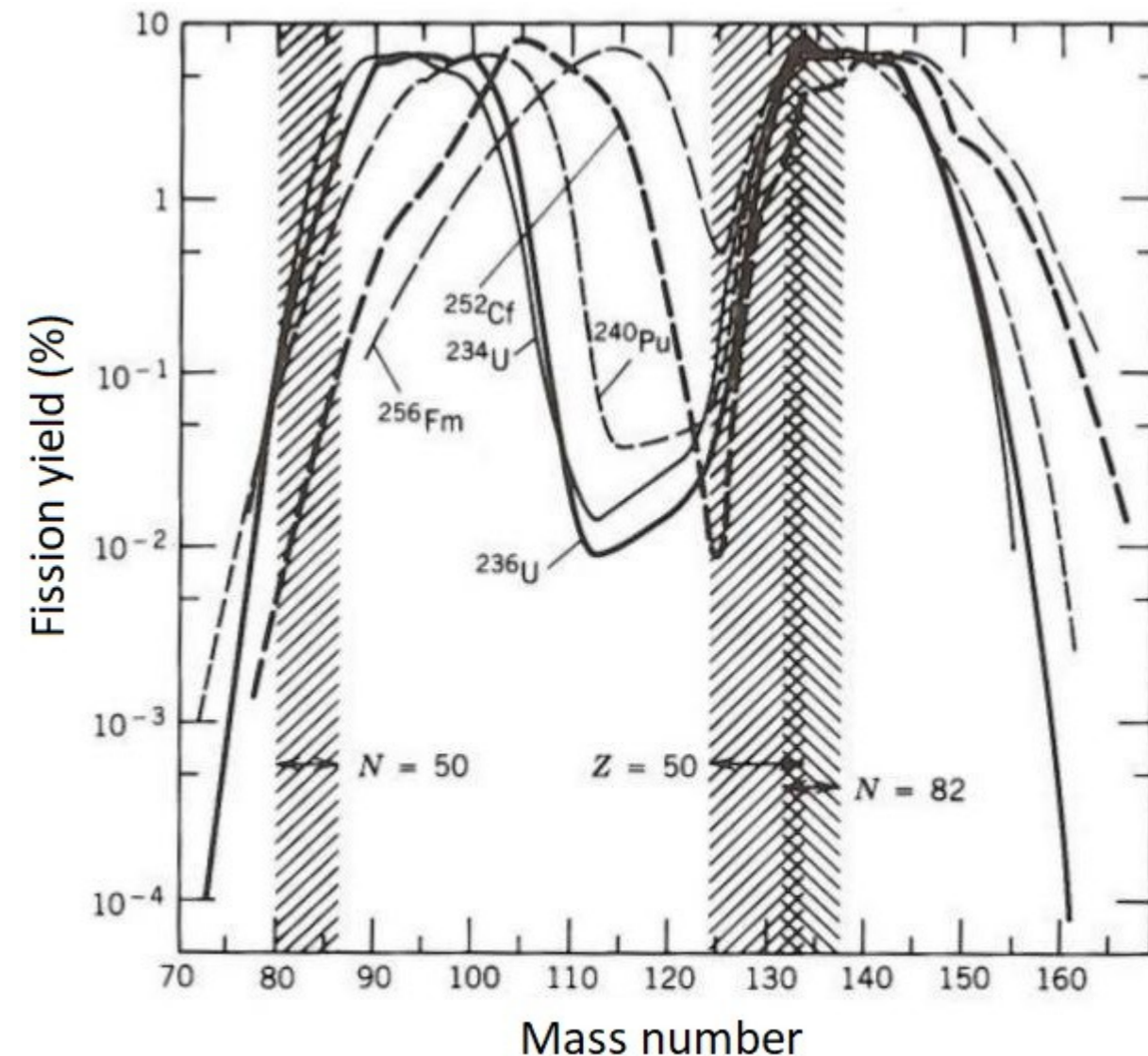
Structure

- Nuclear Fission
- Bragg Detectors and Fragment Measurements
- Institut Laue Langevin
- n_TOF
- Conclusion

Nuclear Fission



- Binary fission mostly produces FF with different mass
- Double-magic $Z=50$ $N=82$ (^{132}Sn) shell closure very strong and defines the heavier fragment
- Left-over matter forms a lighter fragment



K.F. Flynn et al., Phys. Rev. C 5, 1725 (1972).

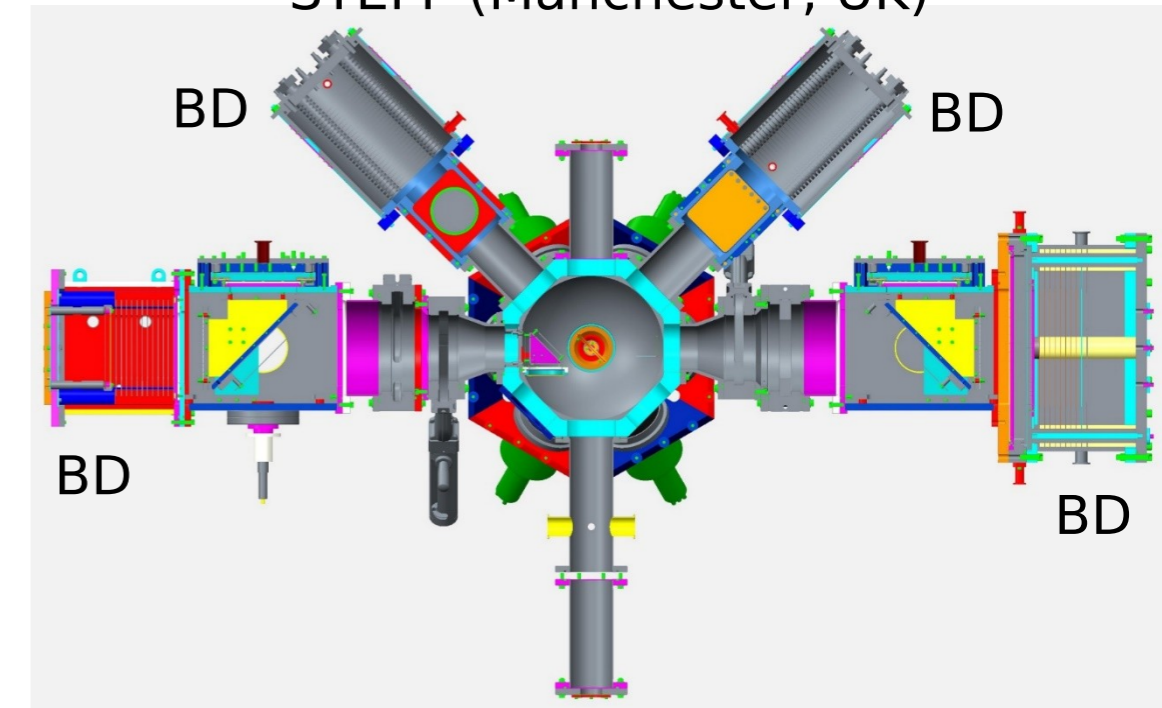
I. Ahmad and W.R. Phillips, Reports on Progress in Physics **58**, 1417 (1995).

Fission Experiments

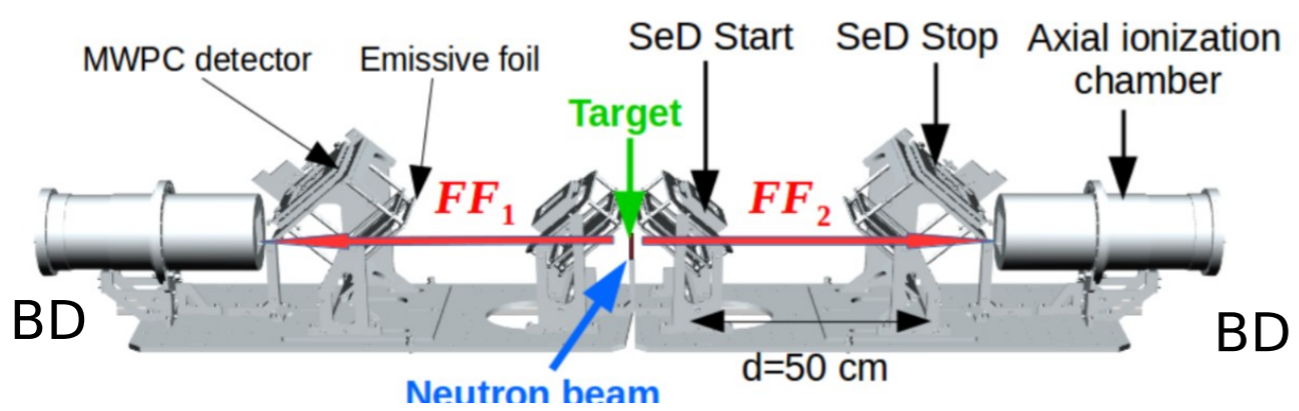
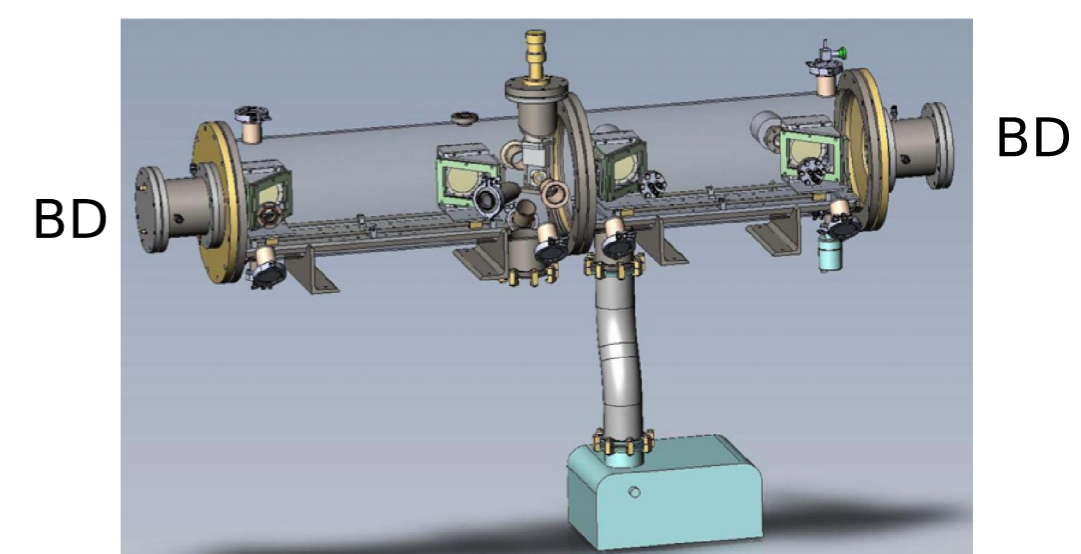
USEFUL OBSERVABLES

- FF A,N,Z, KE → Frequently use Bragg Detectors
- Prompt neutron/gamma energies, multiplicities, angular distributions
- Typically, correlated measurements of fission observables needed, requiring large arrays

STEFF (Manchester, UK)

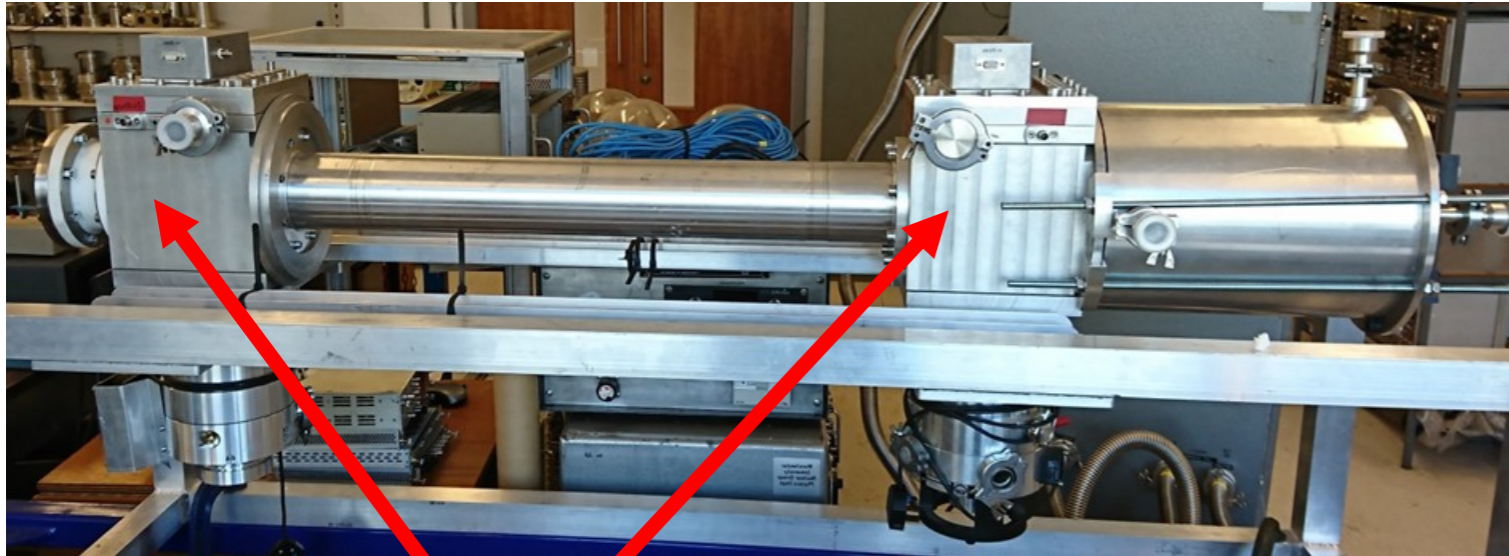


SPIDER (Los Alamos, USA)

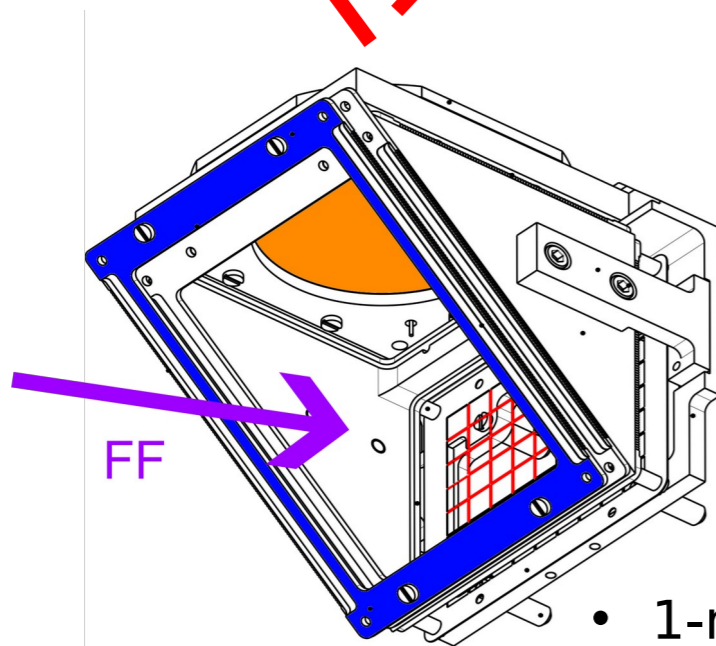
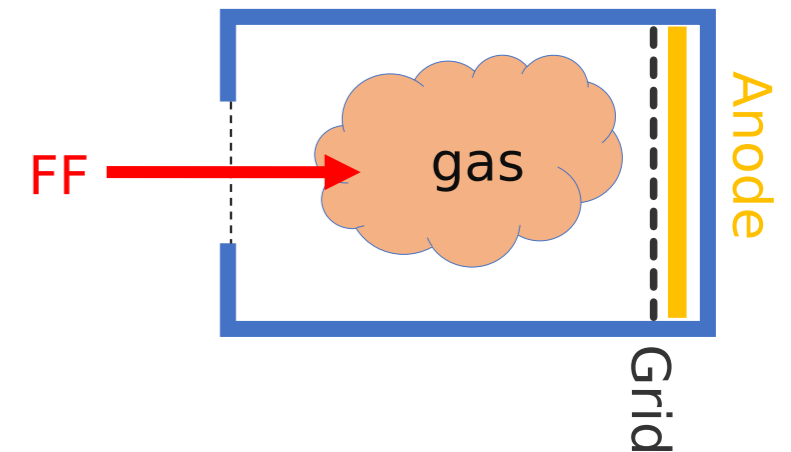


FALSTAFF (CEA, France)

Bragg Detectors and Fragment Measurements



Bragg Detector

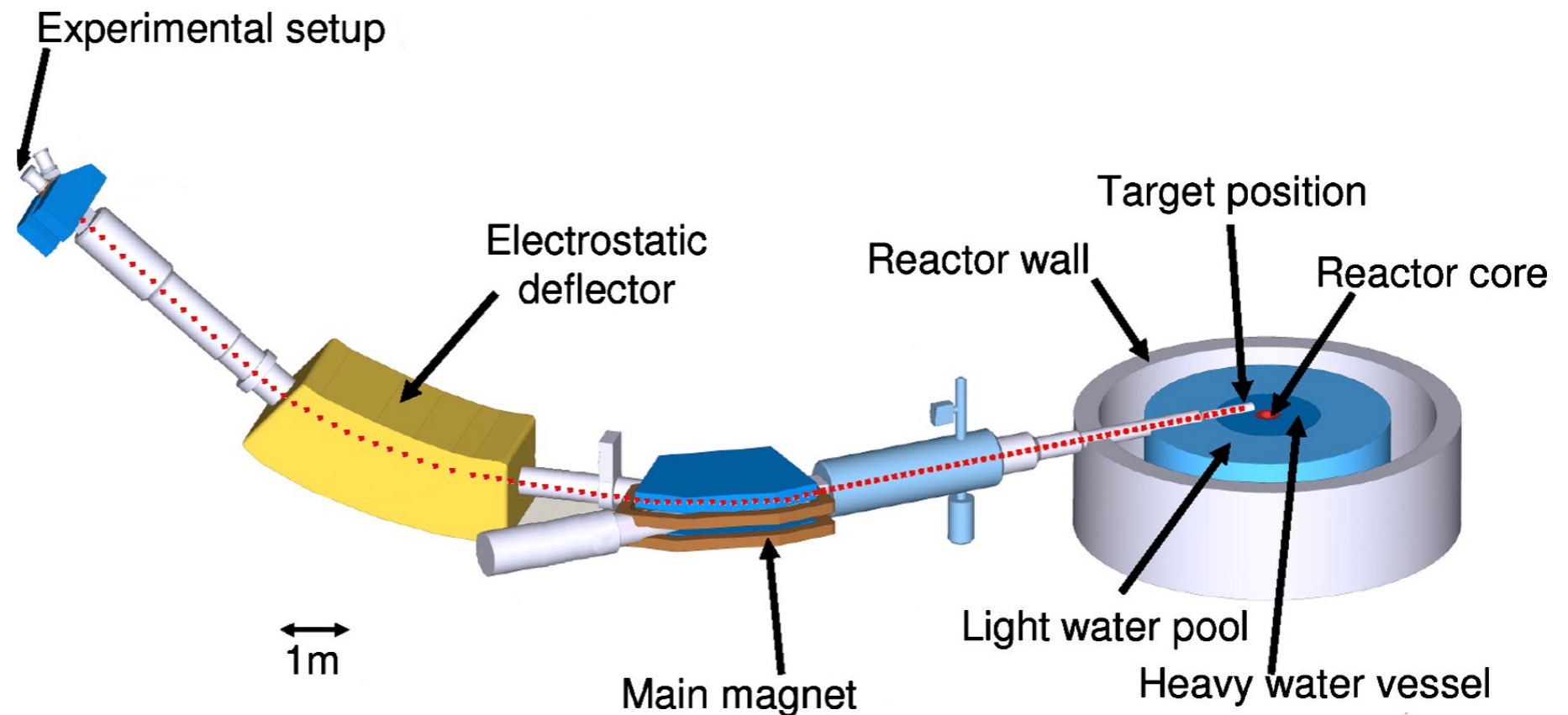


- 1-meter flightpath
- ~100 nm formvar+Al foils
- 700 ps TOF resolution

- Bragg detector is a coaxial ionization chamber
- Typical gasses CF₄, argon, isobutane (iC₄H₁₀)
- Kinetic energy resolution 0.5 MeV
- Grid ensures linear response, blocks +ve ions

FiFI at Lohengrin

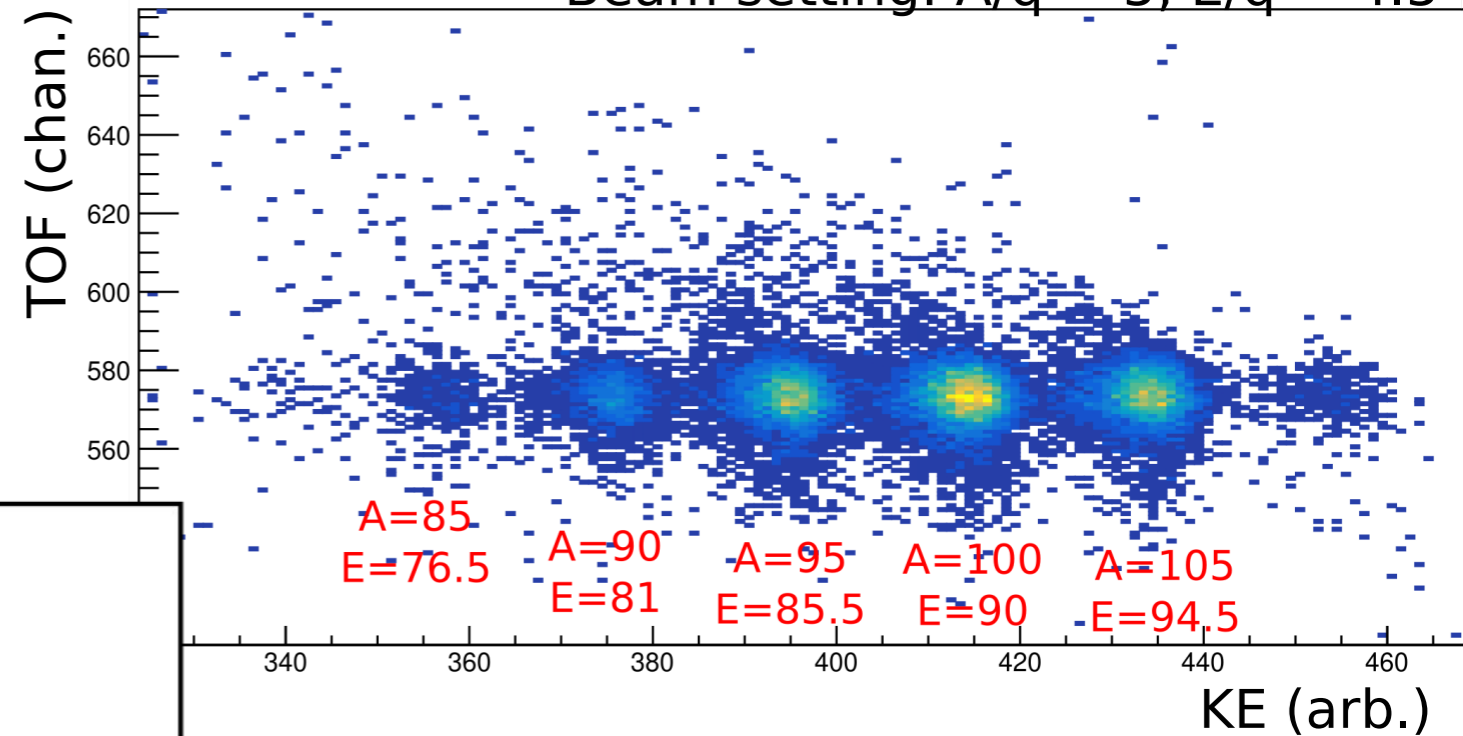
- Fission Fragment Identification (FiFI) arm used at Lohengrin for two weeks measurement in June 2021
- ^{239}Pu target
- Lohengrin separates by A/q and E/q
- Aim is investigating ionization signal traces for any variations correlated to fragment Z



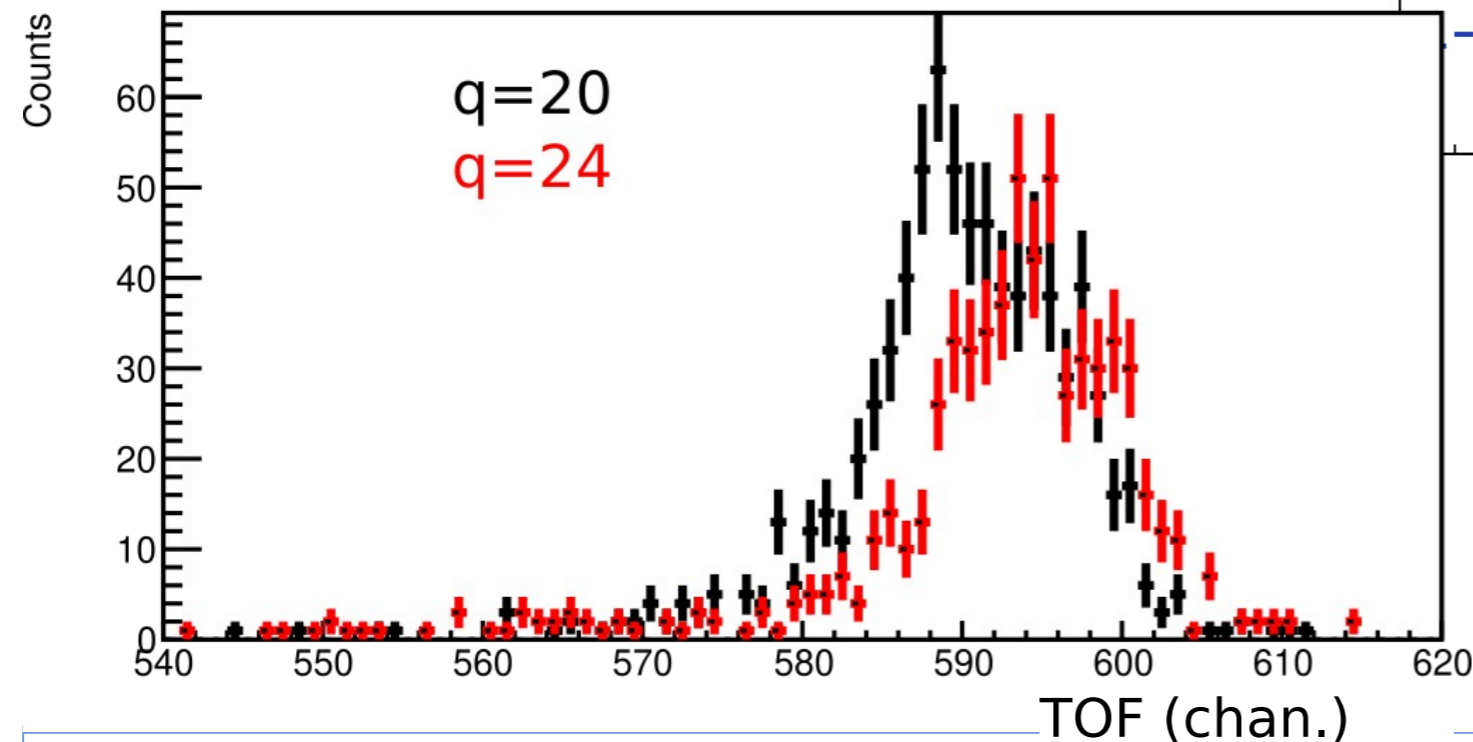
A Little Preview of Results

- Lohengrin separates by A/q and E/q
- For each q state of all FF produced in target, only one mass and energy will satisfy both ratios
- Each peak corresponds to a single ionic charge state
- Each mass contains a mix of Z
- All FF have the same velocity
- Bias Z yield with q gate

Beam setting: $A/q = 5$, $E/q = 4.5$

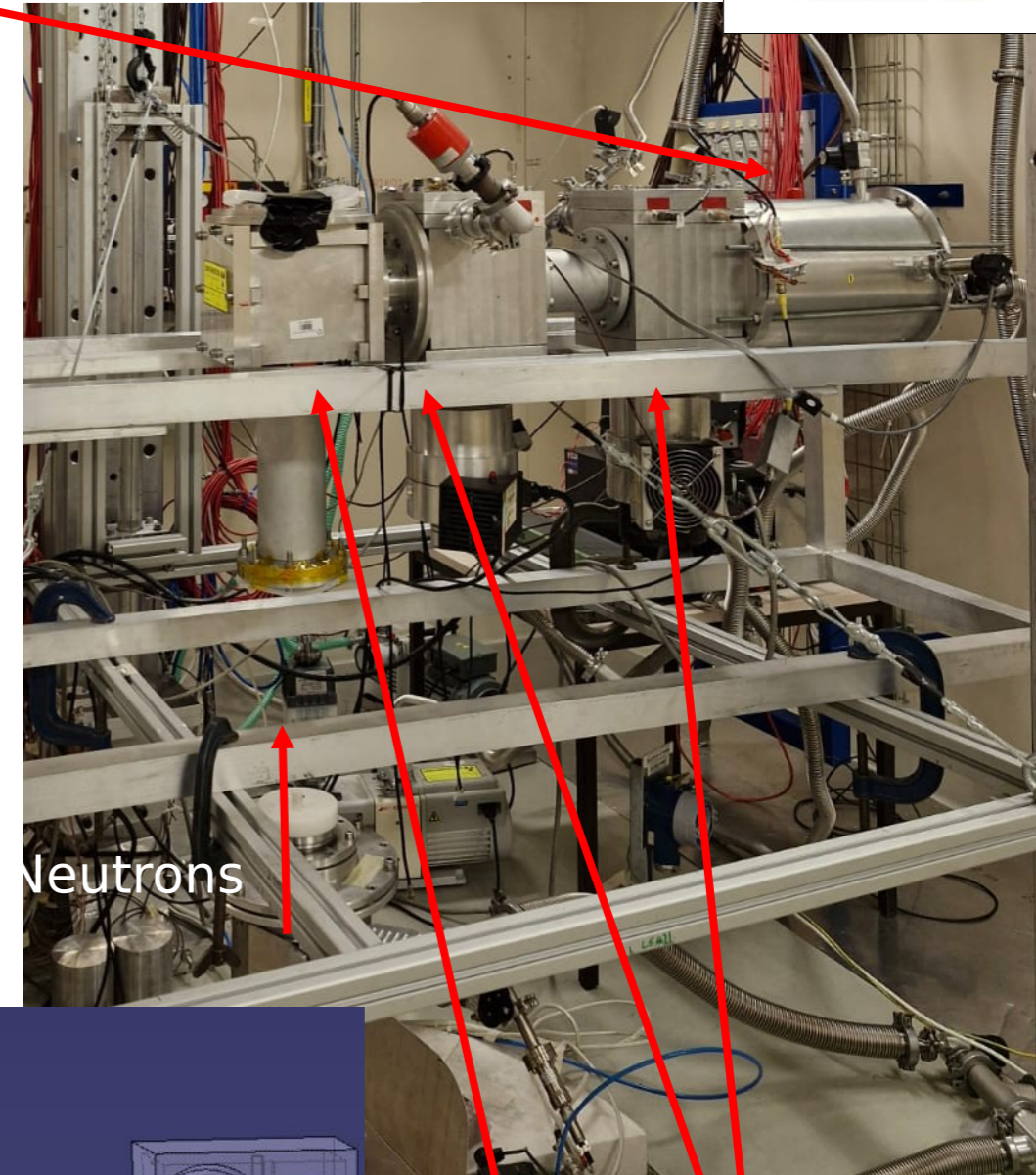


$A=111$, $E=94$



n_TOF, CERN

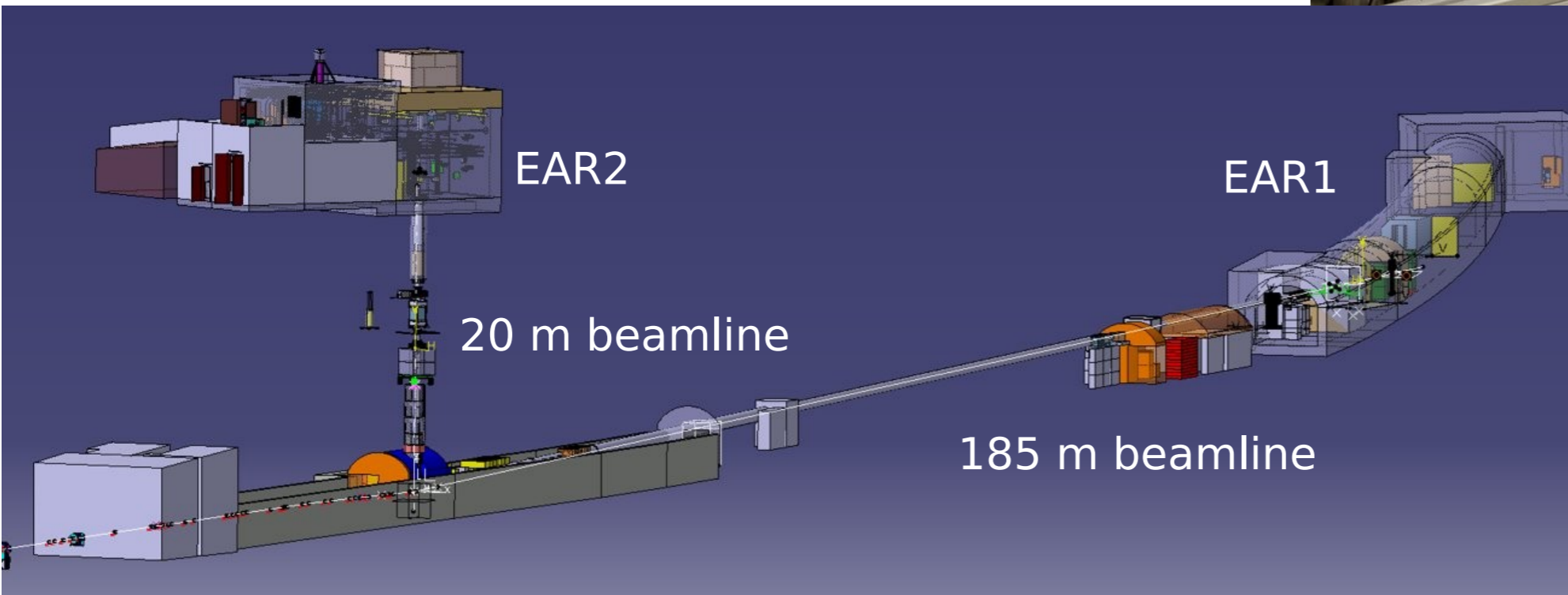
- 0.8% geometric efficiency → Need high flux at EAR2
- Higher gamma flash
- 2 beam collimators: $\varnothing 6\text{cm}$ and $\varnothing 2\text{cm}$
- FiFI TOF section shortened from 1 m to 0.5 m to improve statistics
- Use $\varnothing 6\text{cm}$ ^{235}U target for testing
- Use fast neutrons (0.5-10 MeV) to measure fission mass yields
- Plans for ^{243}Am and ^{230}Th for nuclear waste in fast reactors and thorium fuel cycle



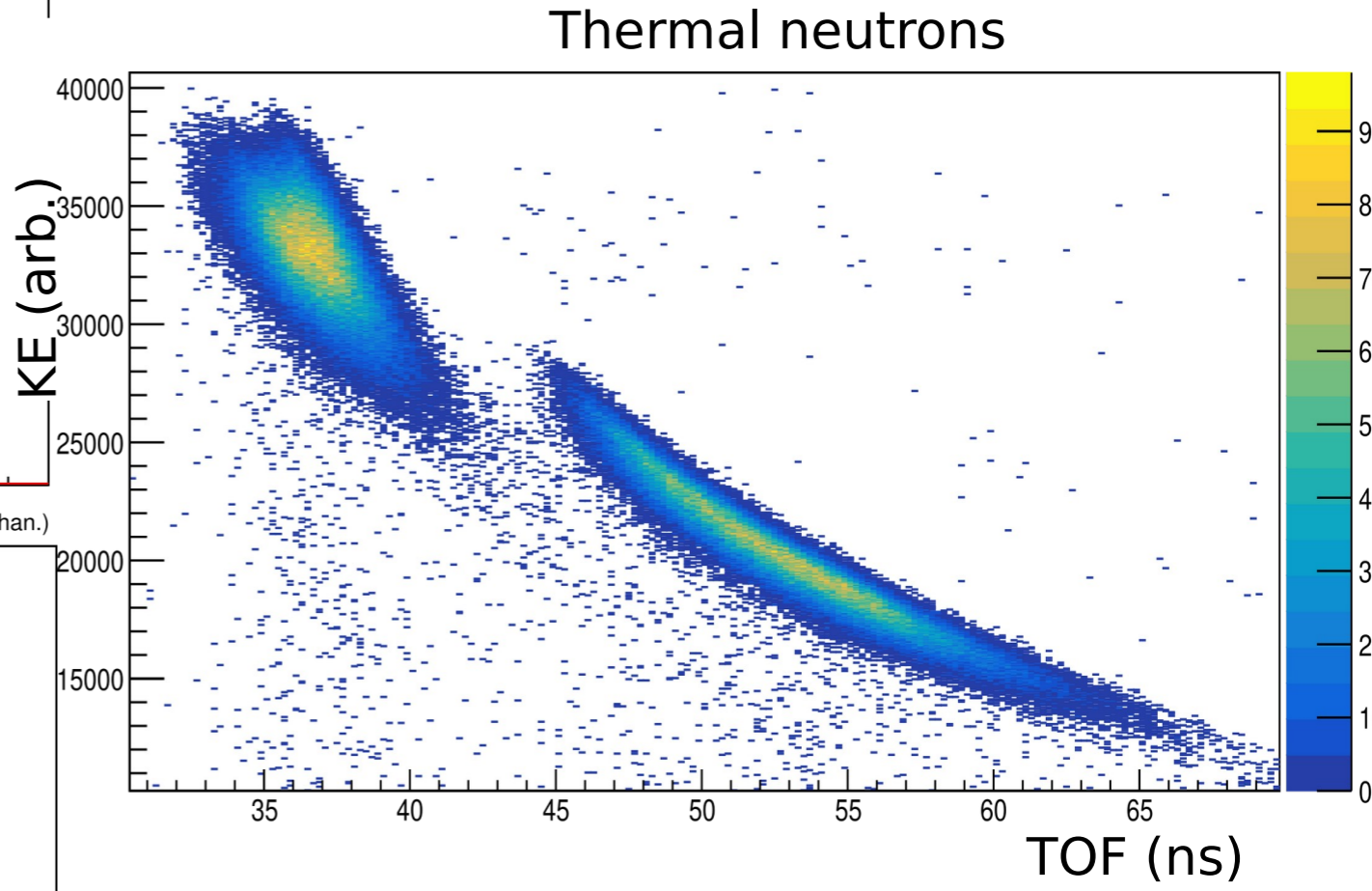
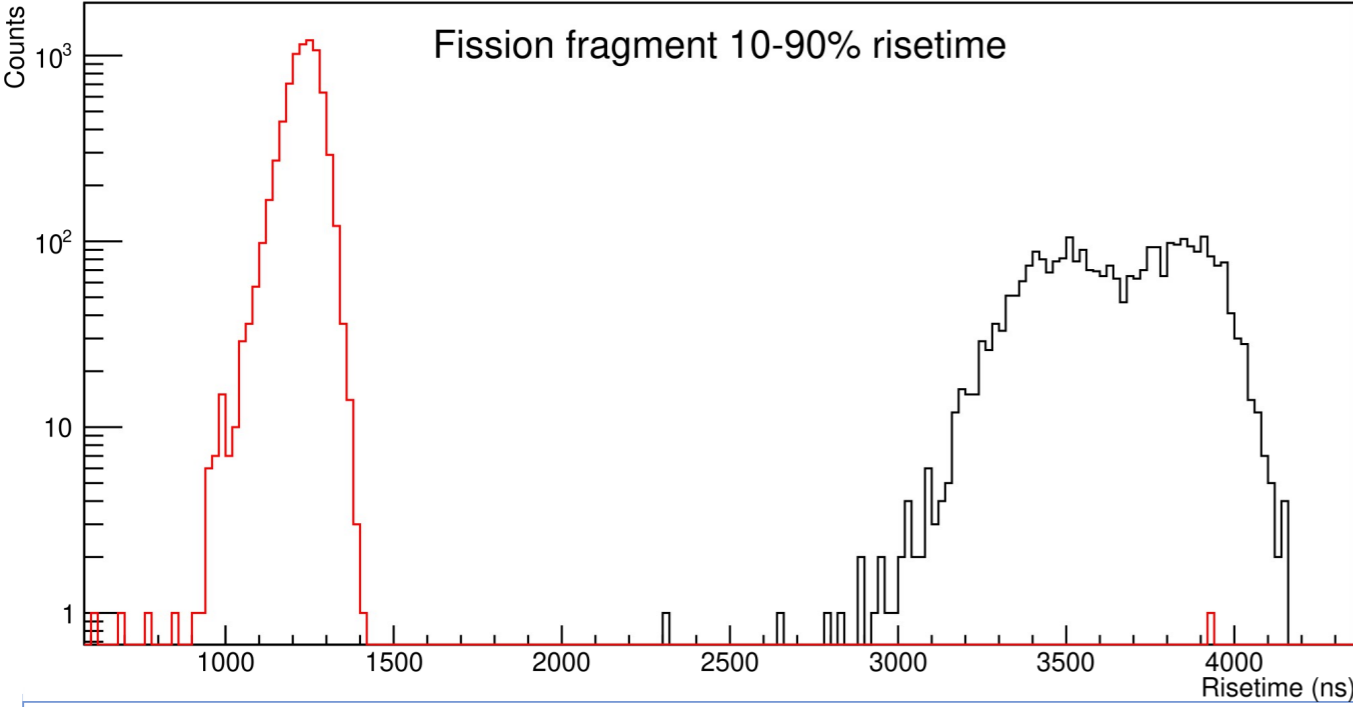
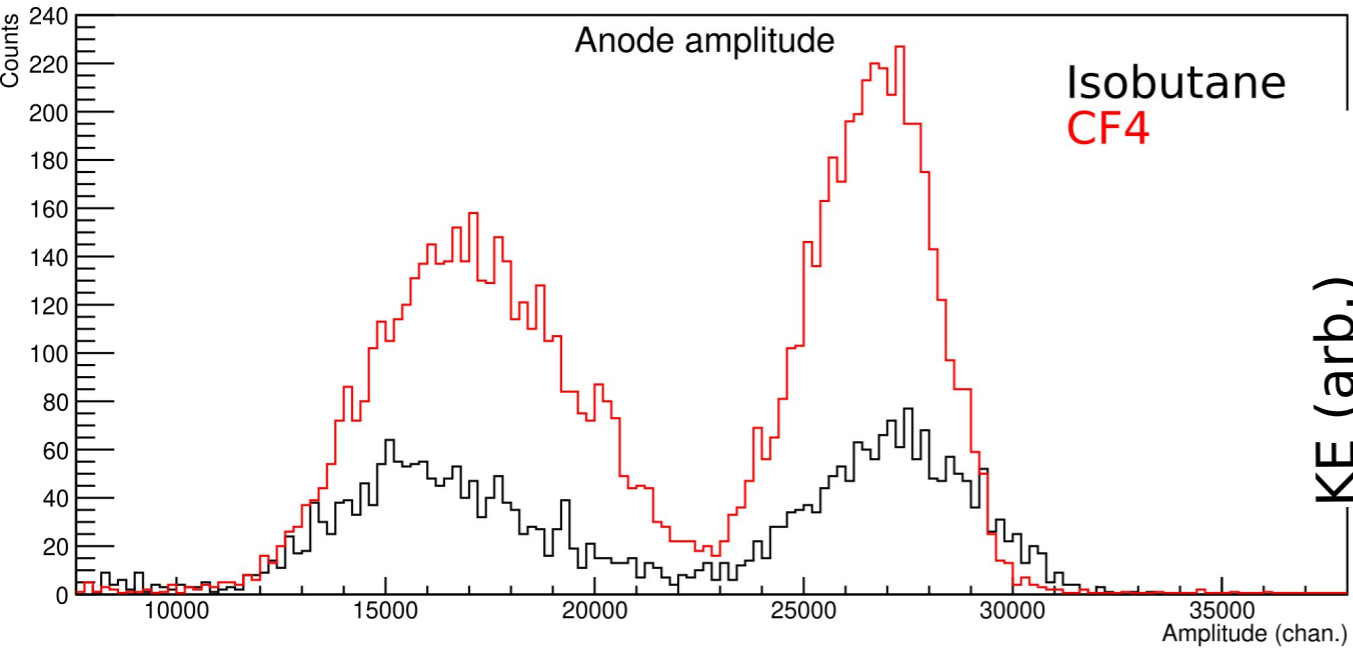
Neutrons

Timing detectors

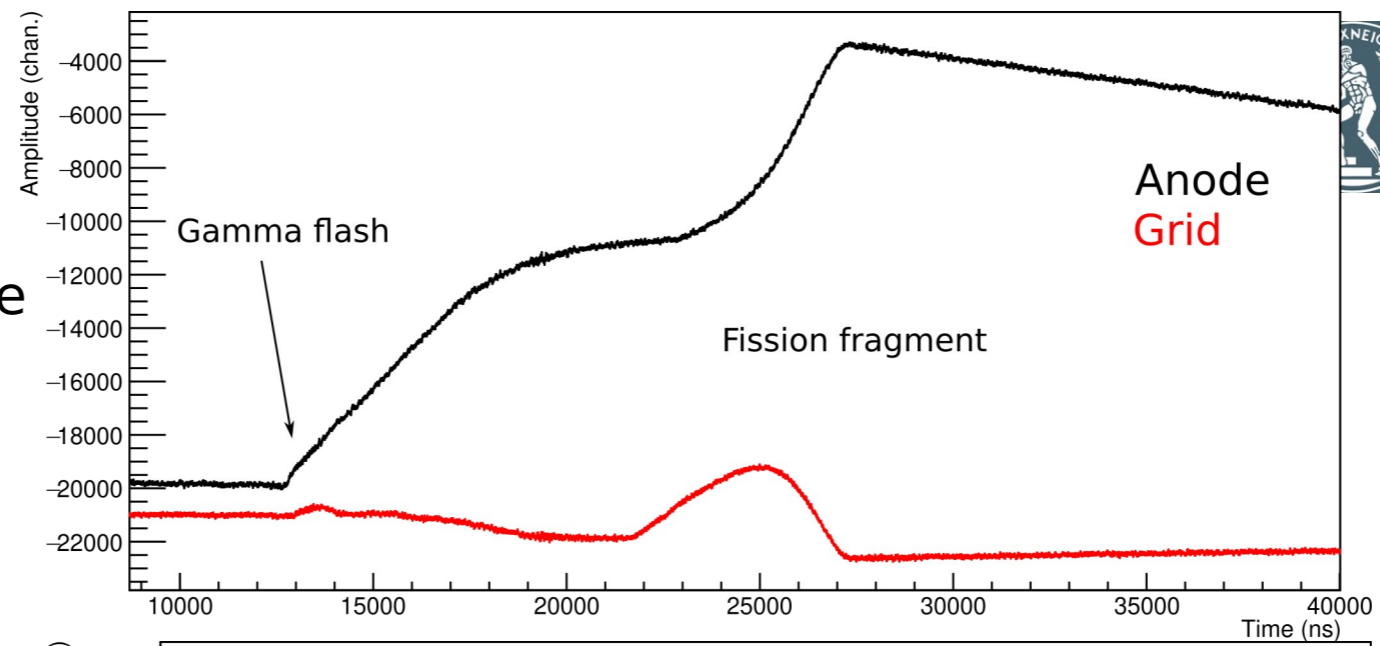
^{235}U



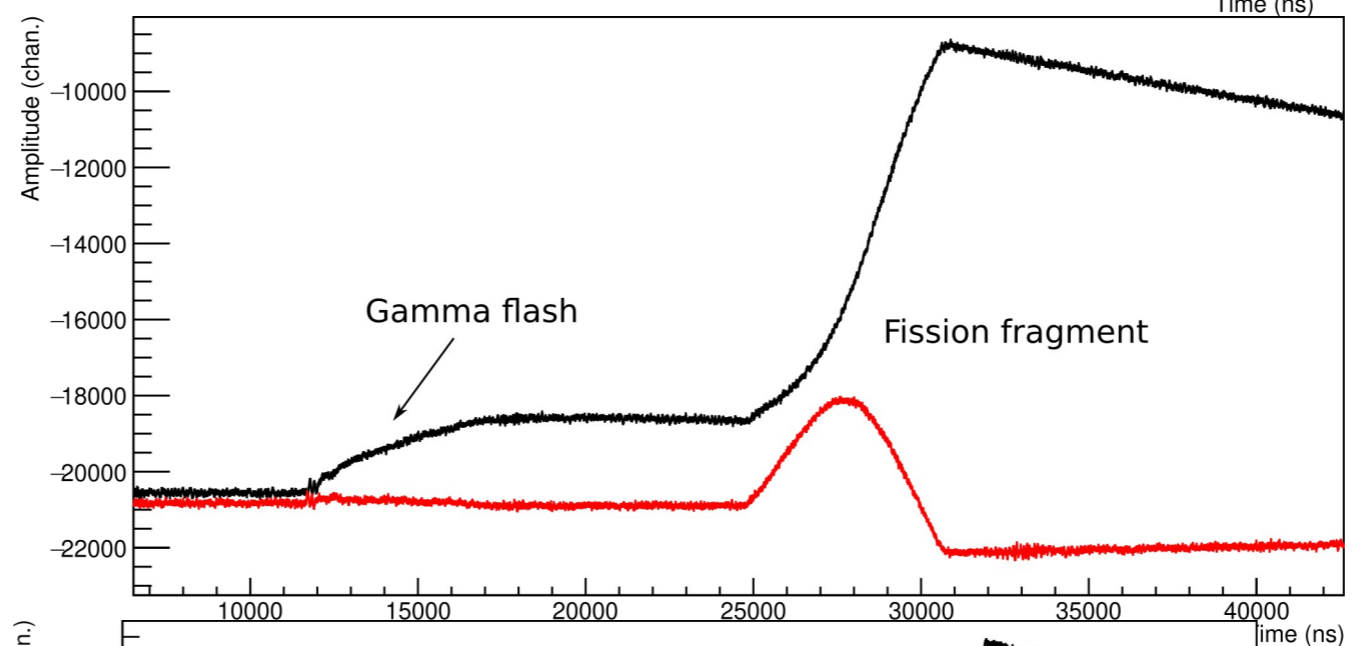
Test results



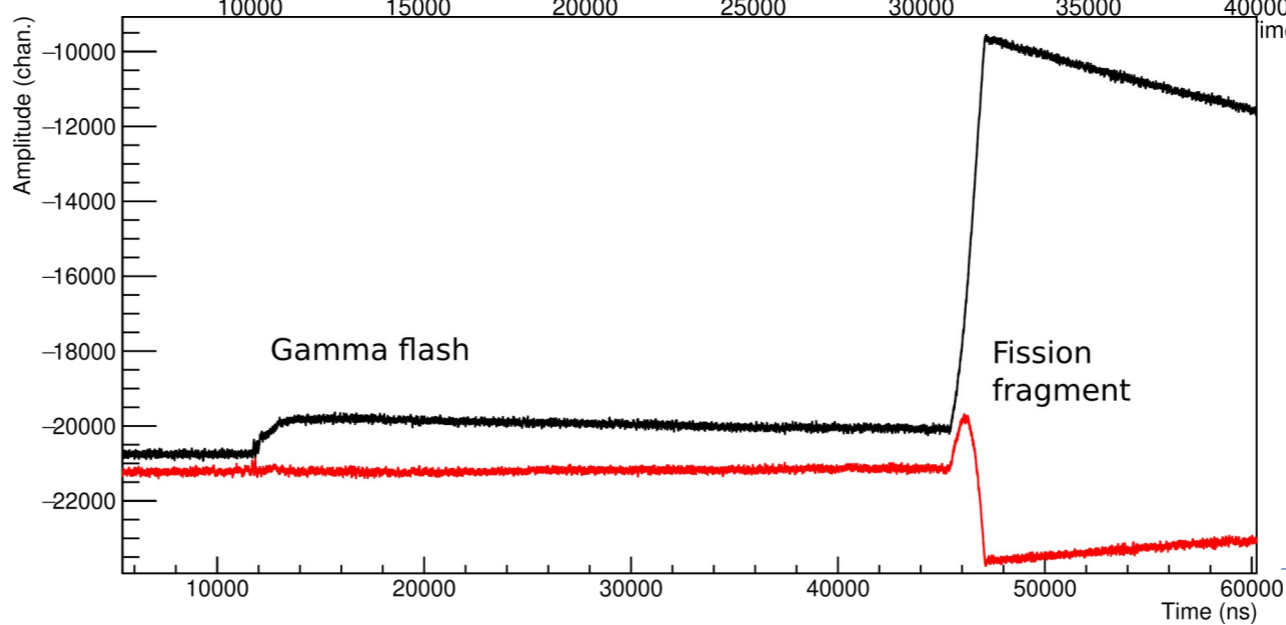
ø6cm collimator isobutane



ø2cm collimator isobutane



ø2cm collimator CF4





Conclusion



- ILL analysis ongoing
- Calibration is completed
- Use such data to identify Z-dependent variations

- n_TOF analysis ongoing
- Investigated fill gases and collimation
- Tests with silicon and scintillators planned
- Campaigns for measuring mass yields of ^{243}Am and ^{230}Th in the future?

THANK YOU