FISSION STUDY USING SAMURAI SPECTROMETER AT RIKEN

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"Nuclear Fission and Structure of Exotic Nuclei"
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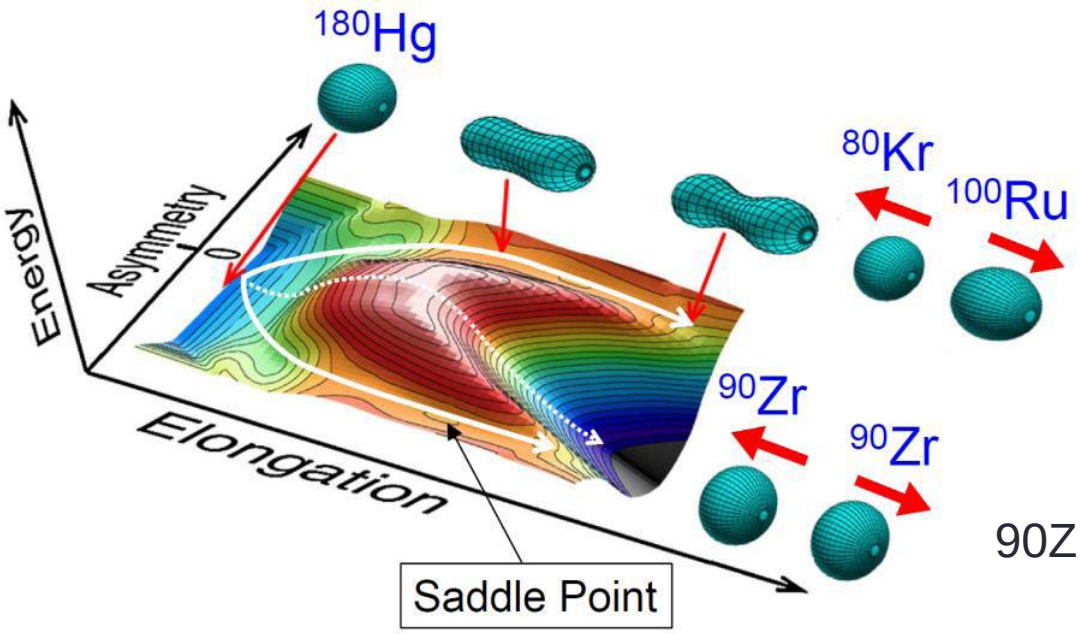
Contents

- Motivation : potential surface study with fission
- New and powerful method: (p,2p) (p,pn) (p,n)reaction with SAMURAI
- Uniqueness of our project
  - Current status of the project
  - test experiment
- Summary

Potential surface : ^{180}Hg

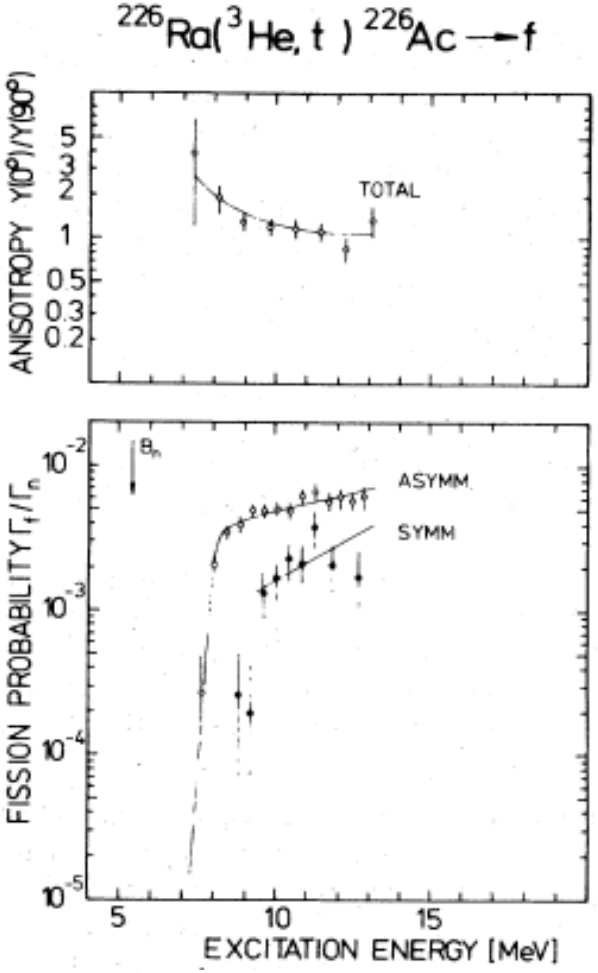
- Beta-delayed fission from ^{180}Tl
- The fission fragment distribution is asymmetric mass pattern
- Ex < Qb~10 MeV -> symmetry fission can not be ocured

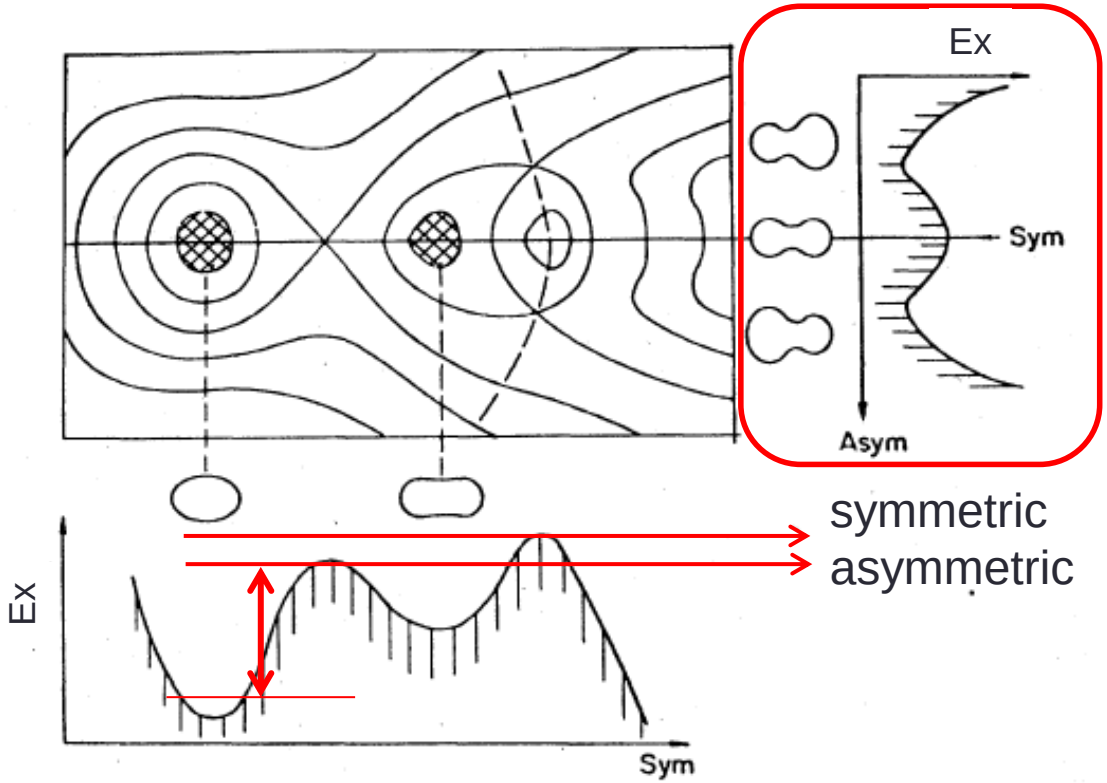


90Zr(Z=40, N=50:magic)

A. Andreyev, .., Nishio, .., Ichikawa, Iwamoto, .. *et al*., Phys. Rev. Lett. **105**, 252502(2010).

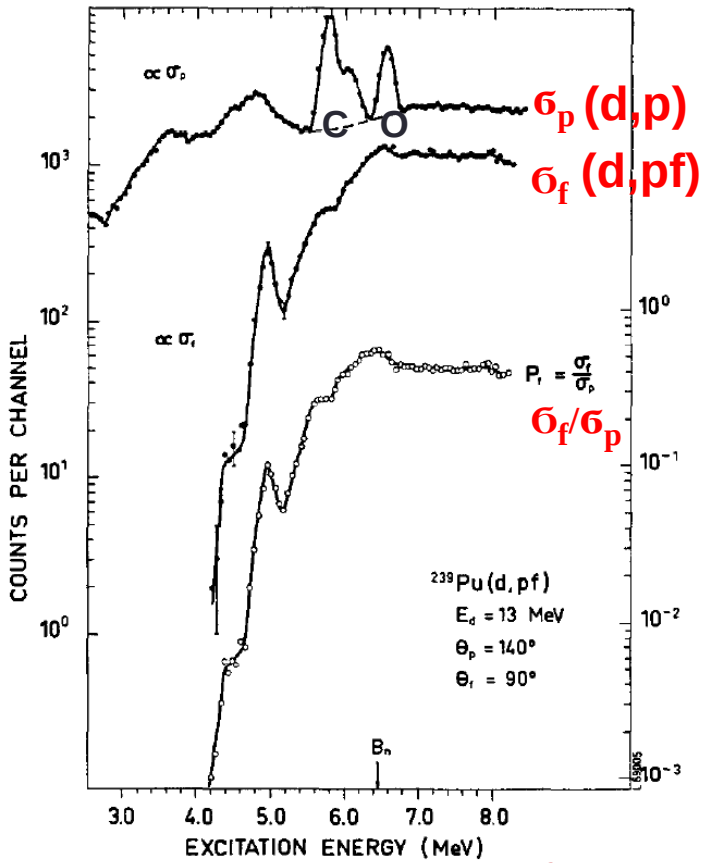
fission fragment distribution as a function of Ex

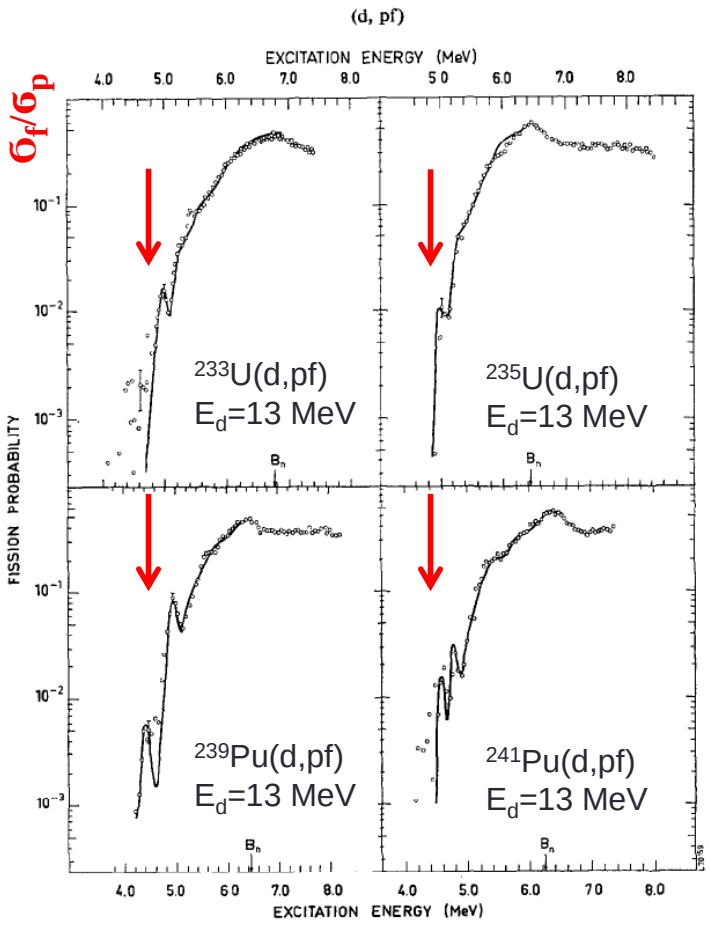




Hans J. Specht, Rev. Mod. Phys. 46, 773-787 (1974).

Fission probability as a function of Ex

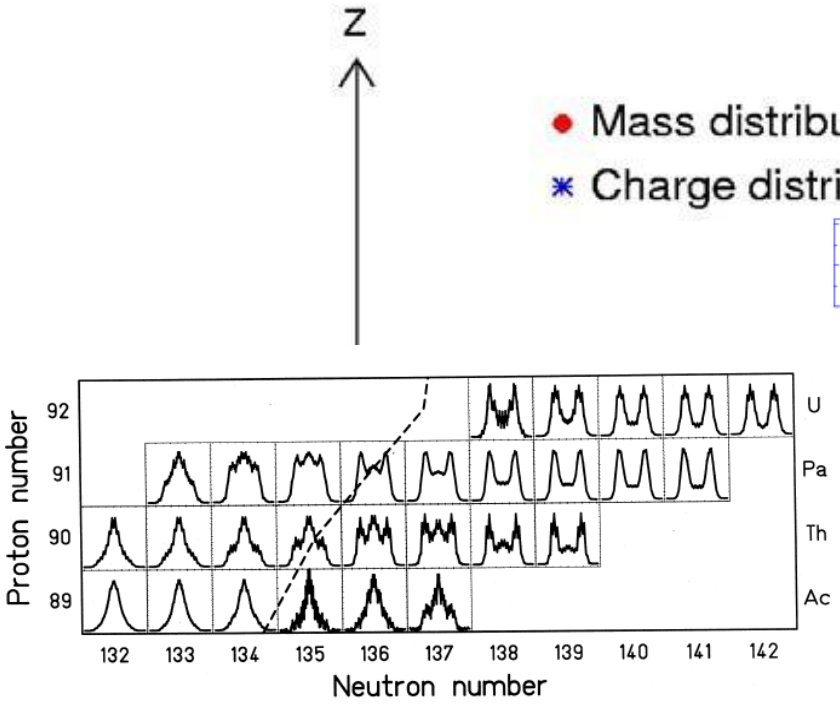


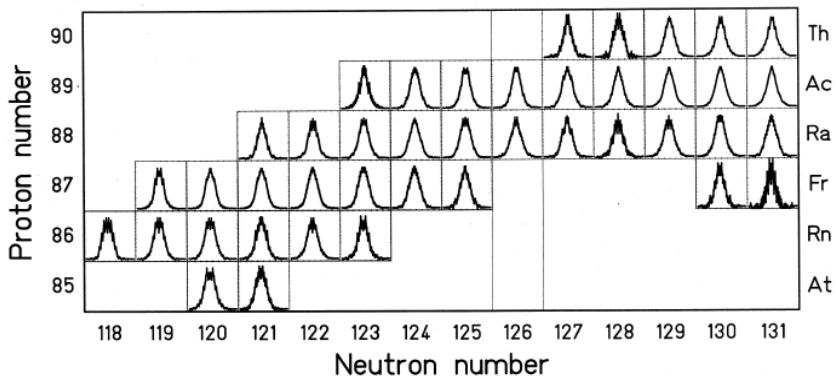


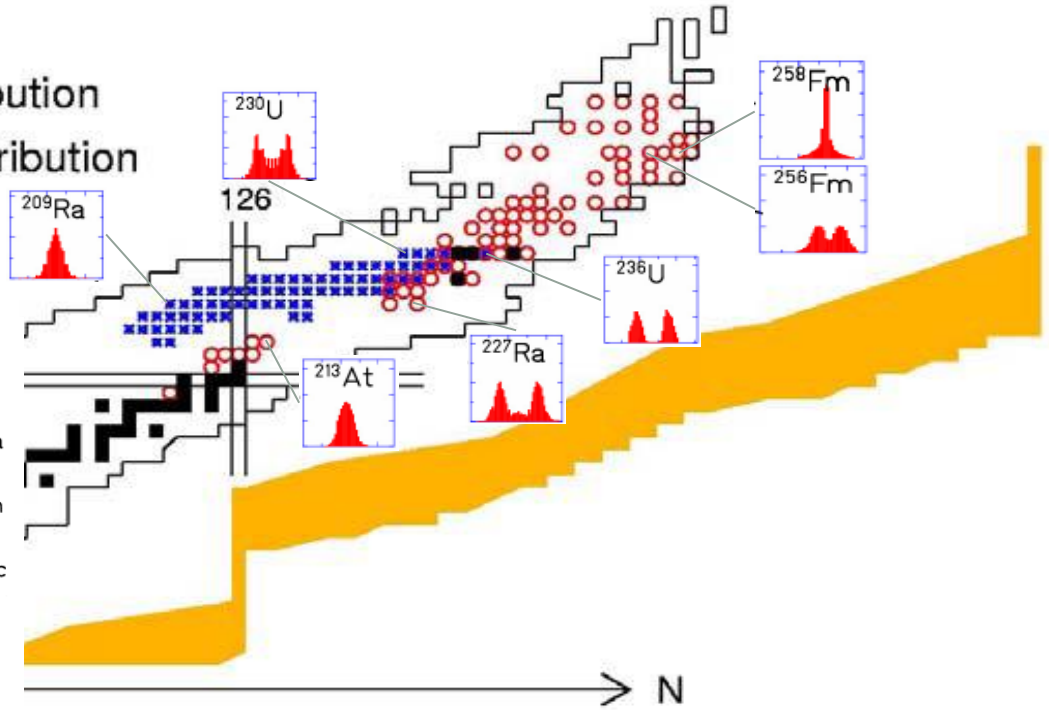
Earlier fission barrier studies at low energies employing direct nucleon-transfer reactions

B.B. Back et al.; Nucl. Phys. **A165** (1971) 449
E. Konecny et al.; Phys. Lett. B **45** (1973) 329

Recent Experimental Data







SAMURAI experiment

- New and powerful method with SAMURAI
  - Inverse kinematics with (p,2p), (p,pn), (p,n) reaction
    -> decide the excitation energy by missing mass spectroscopy
  - large acceptance and good resolution
    -> charge(Z) and mass(A) distribution of fission fragment

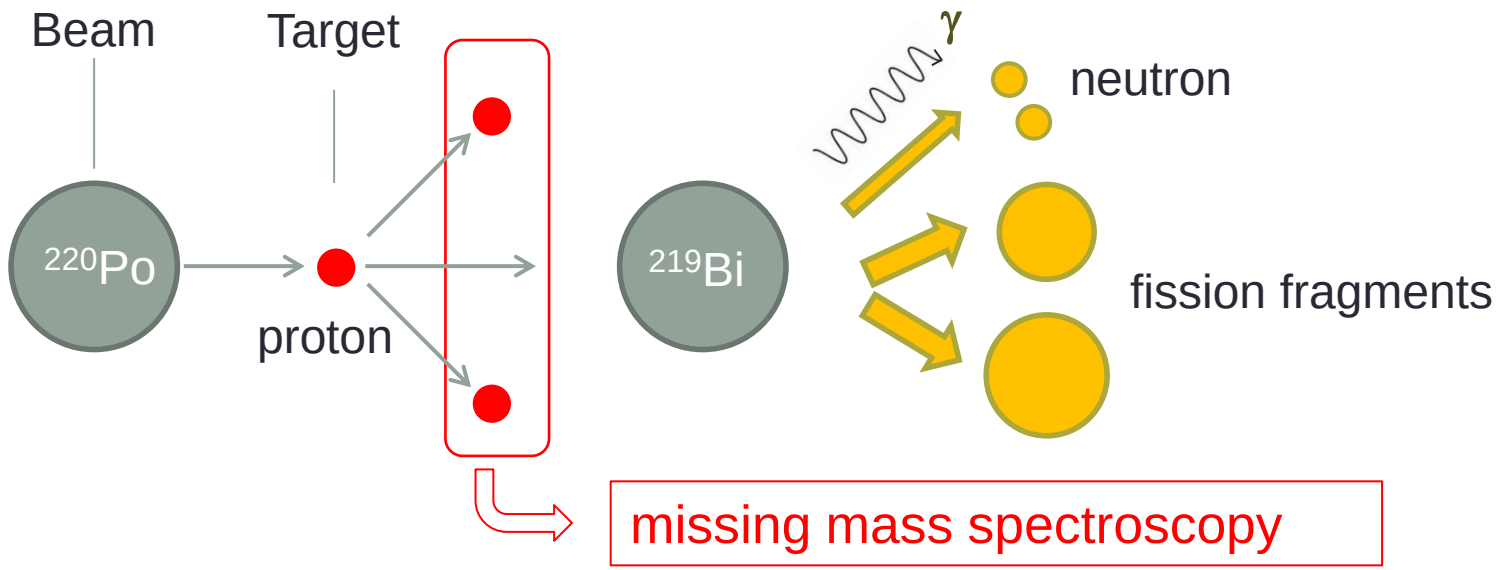
Our Experiment Outline

- experiment @ RIBF + BigRIPS + SAMURAI magnet
  beam : neutron-rich heavy RI beam @ ~300 AMeV

- method : inverse kinematics with (p,2p)

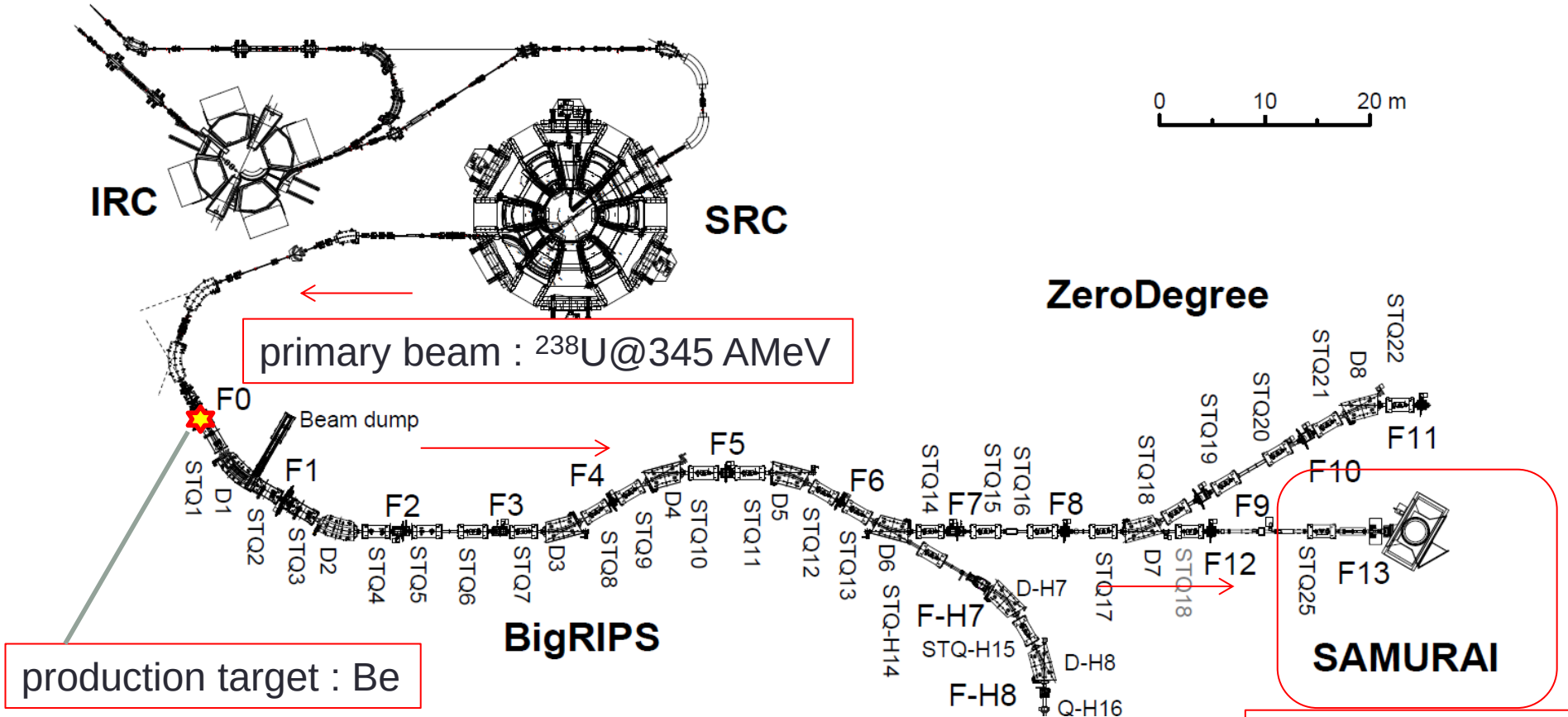
- measurement : Excitation energy <- missing mass spectroscopy
  -> fission barrier
  -> charge(Z) and mass(A) distribution of fission fragments

Inverse kinematics with (p,2p) reaction

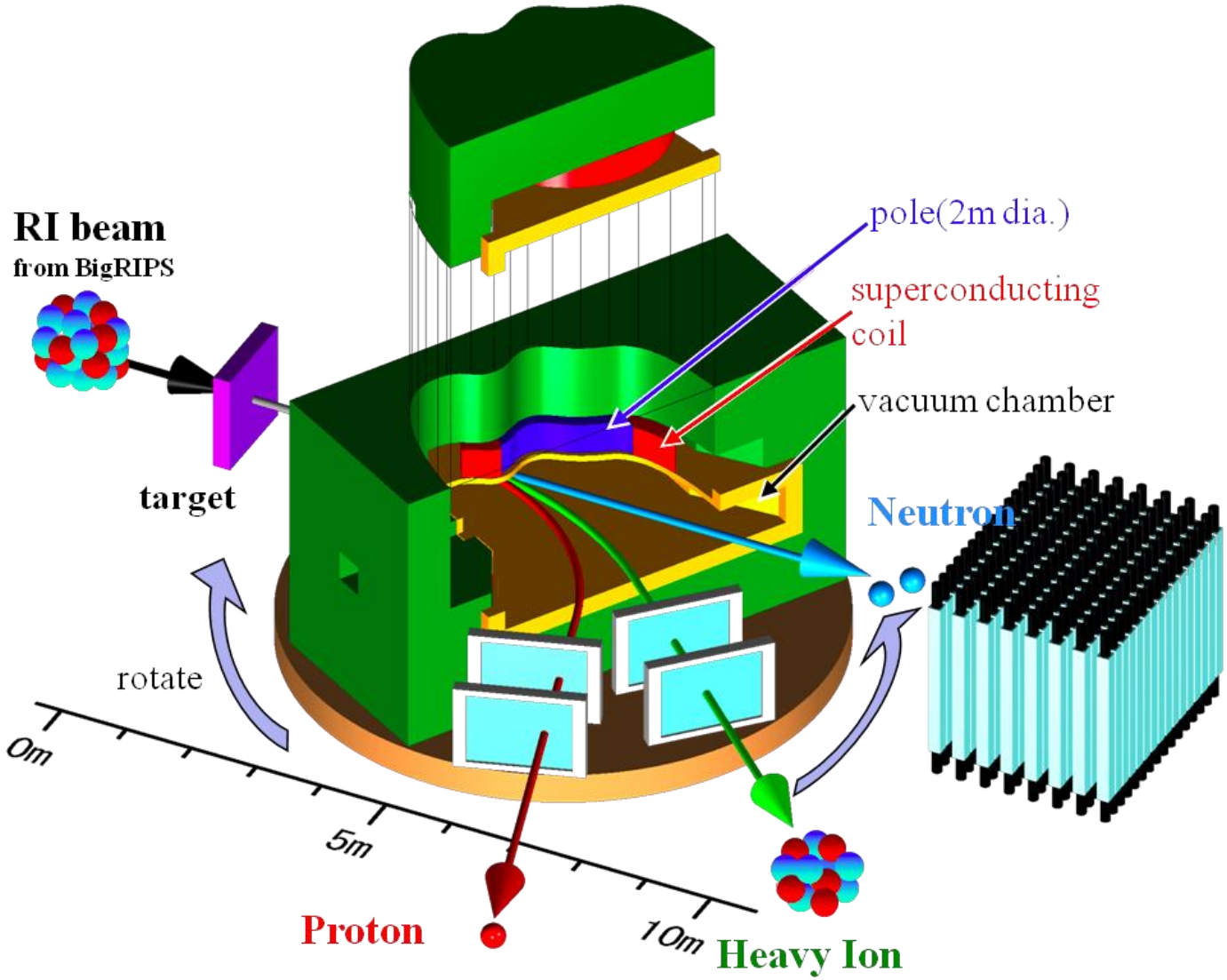


- proton knockout (p,2p) reaction
  - cross section : large
  - high momentum transfer
  - 2 proton measurement -> low background
- We can decide excitation energy directly with missing mass spectroscopy

RIBF and BigRIPS and SAMURAI magnet



SAMURAI（Superconducting Analyser for MUlti-particle from RAdio Isotope beam）magnet



Test Experiment

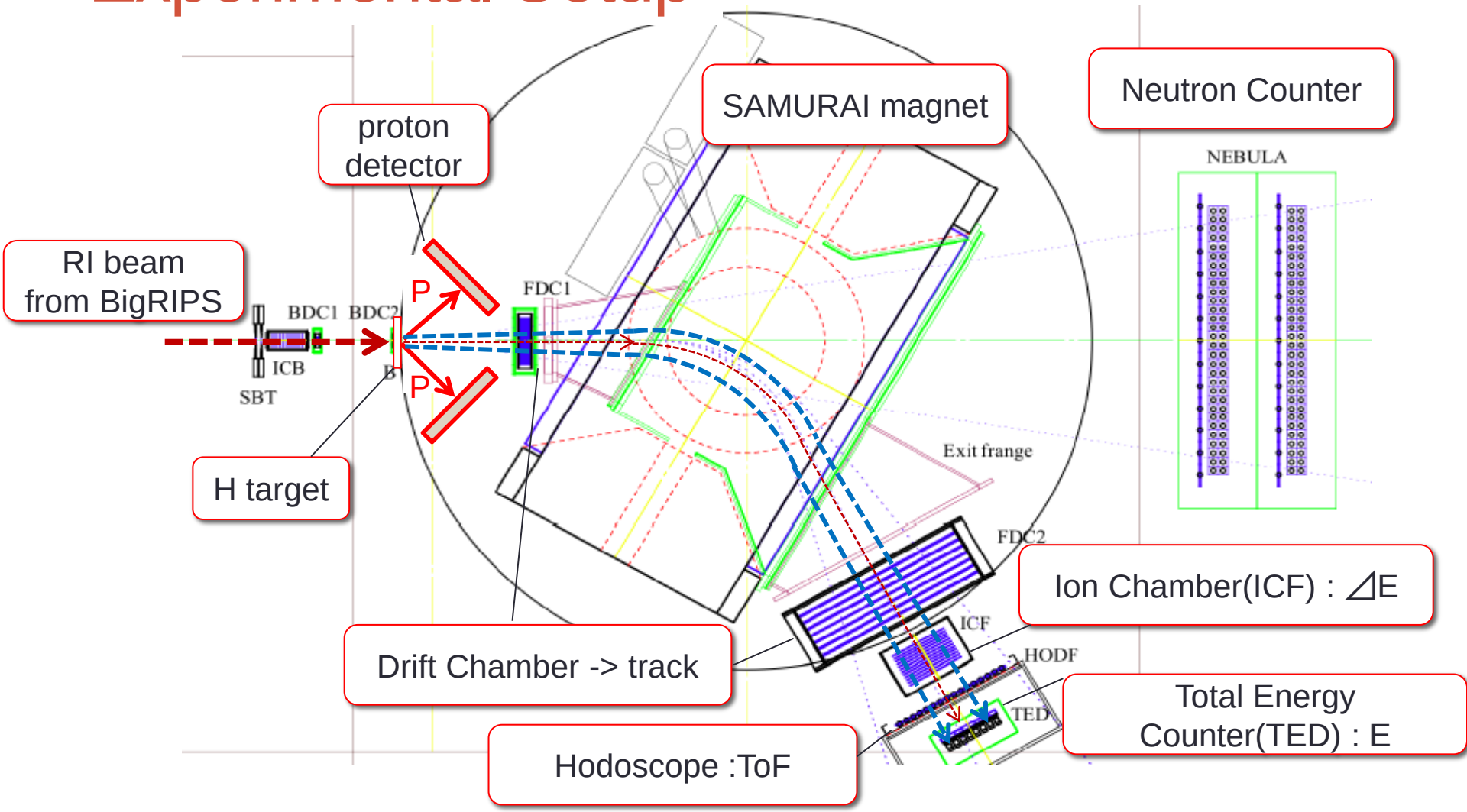
- Beam : ^{238}U @ ~300 AMeV, ~10^4 pps
- Target : liquid H

- Purpose
  - 2 proton trigger
  - Experimental challenge : detector operation
    Z of beam =92, minimum Z of fragment ~ 30
  - 2 fission fragments measurement and
    charge(Z) and mass(A) separation

- Beam Time
  - 1 day @ 3/31 – 4/1

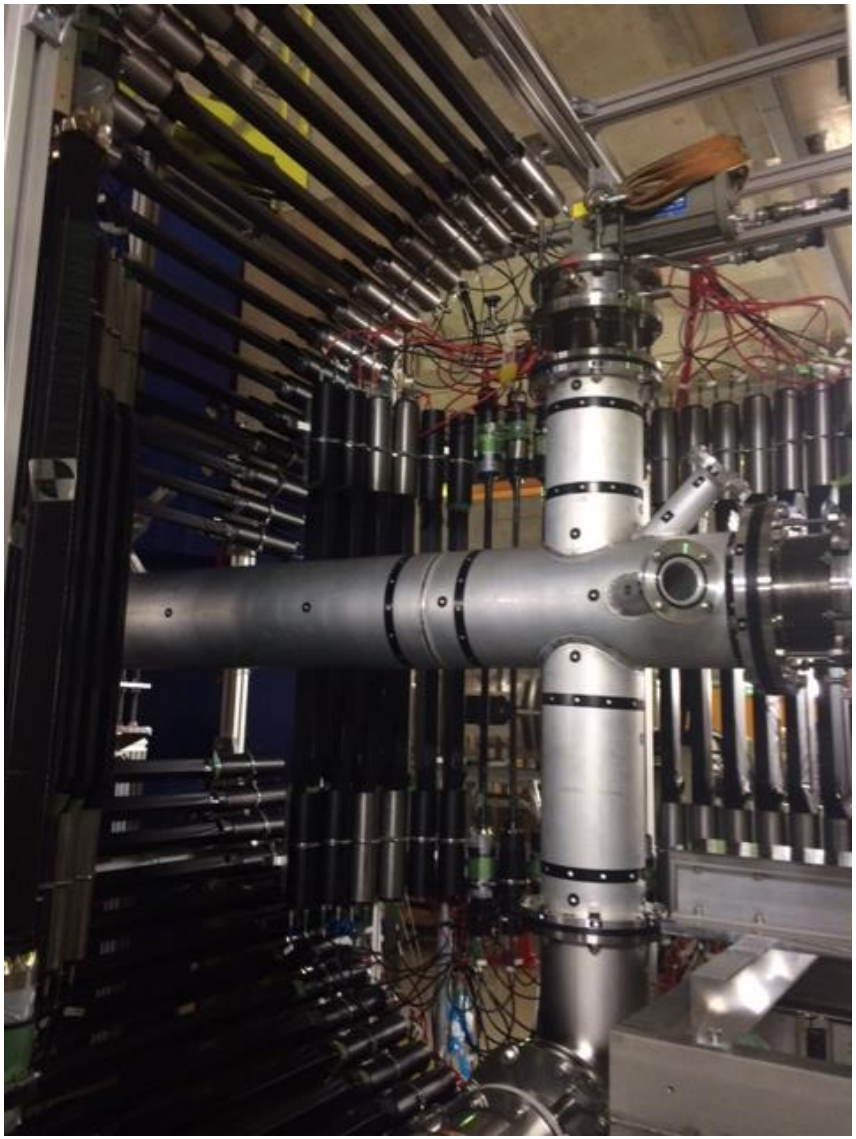
- There is no resolution for excitation energy

Experimental Setup



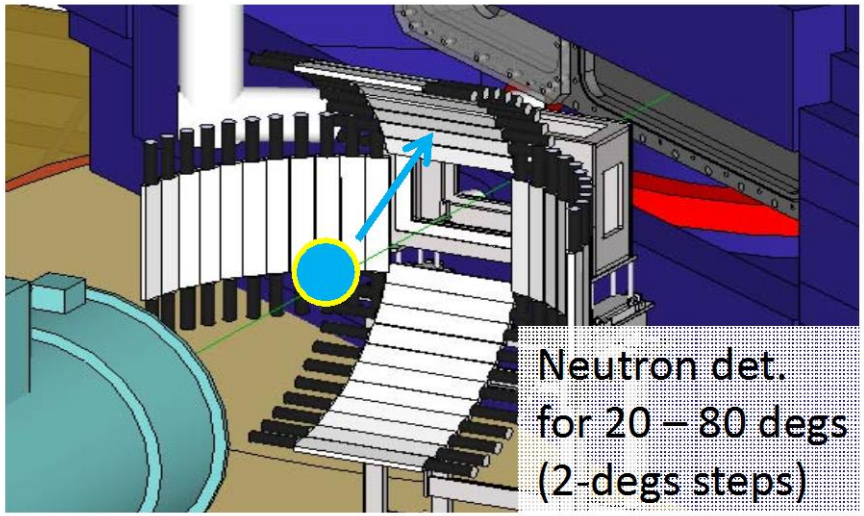
Charge(Z) and Mass(A) can be separated by Bρ⊿E-ToF(E)

Target Chamber and proton counter



- 2p trigger : multiplicity =2

UP and DOWN counters
or
LEFT and RIGHT counters



ICF , hodoscope and TED

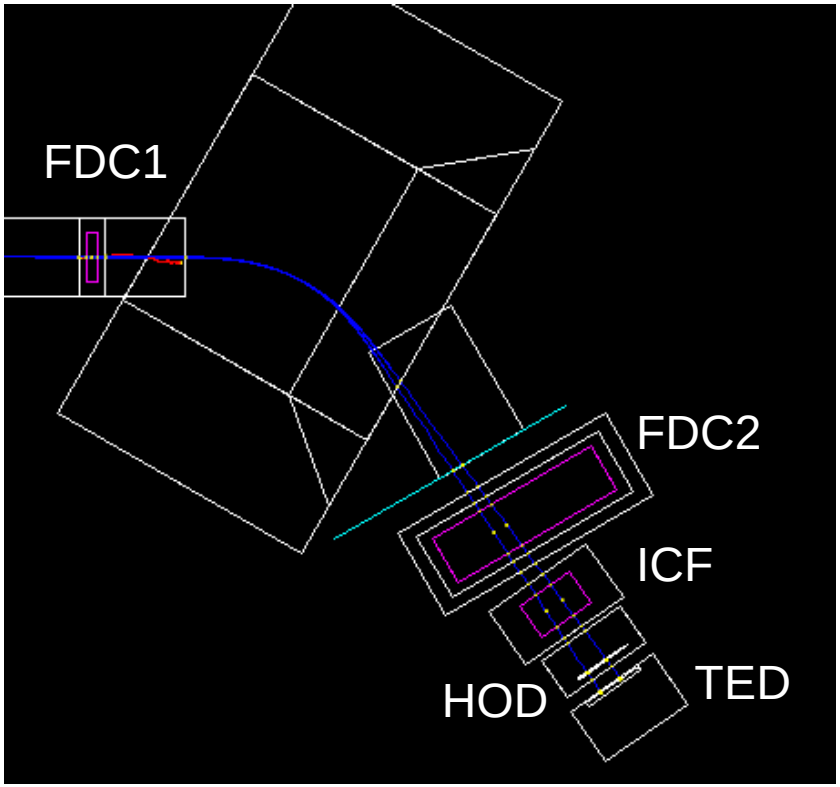
- ICF : multilayer Ion Chamber for PID of flagment -> Z
  - active area (80cm×40cm) is divided to 4parts
  - charge resolution $\sigma_z \fallingdotseq$ 0.17 between Z=8 and 36 @250 AMeV
- hodoscope : ToF counter -> Q/A
  - consist of 7bars(10cm×45cm×5mmt) with double side PMTs
  - time resolution $\sigma_t \fallingdotseq$ 2~300 ps
  - we can use fission trigger : multiplicity=2
- TED : total energy counter -> A
  - consist of 32 pure CsI crystal(10cm×10cm, 8×4) with PMTs
  - mass resolution $\sigma_A \fallingdotseq$ 0.15 up to mass=80 @250 AMeV

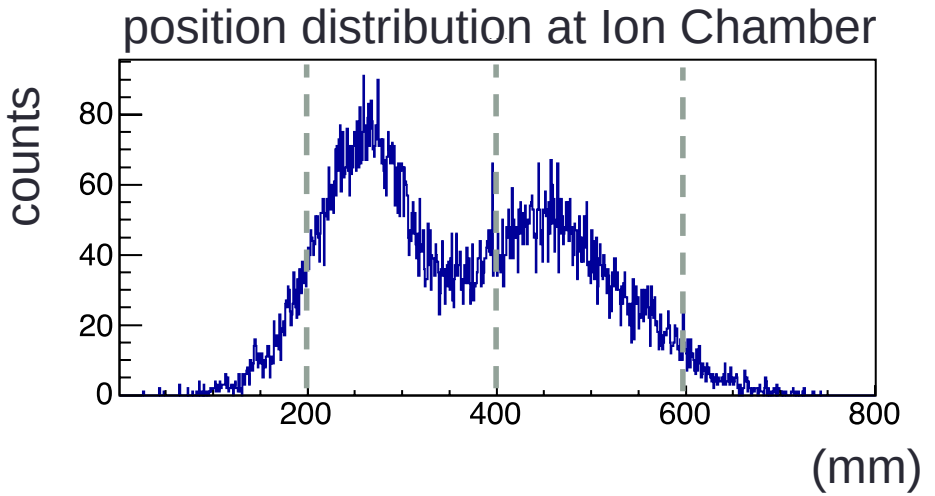
SAMURAI and fragment counters

Histogram of Simulation

- The magnetic setting and counter setting for test Experiment was decided with Geant4

  -> Almost of all fission fragments can enter the counters!

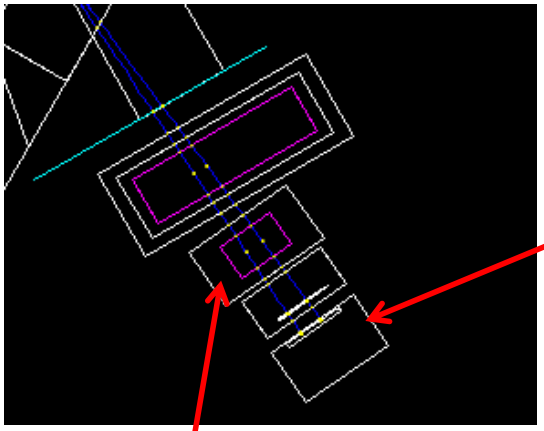


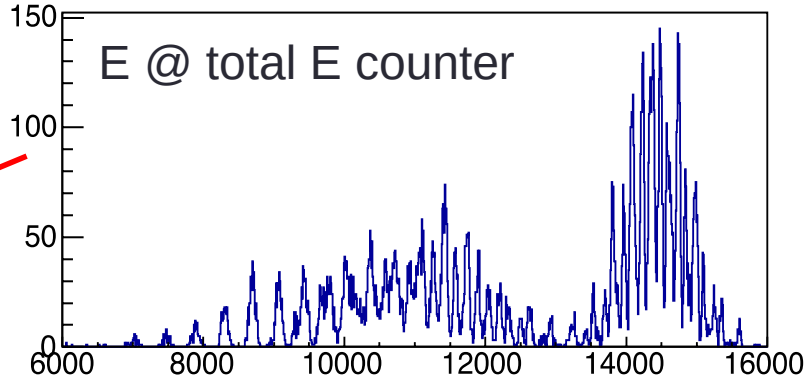


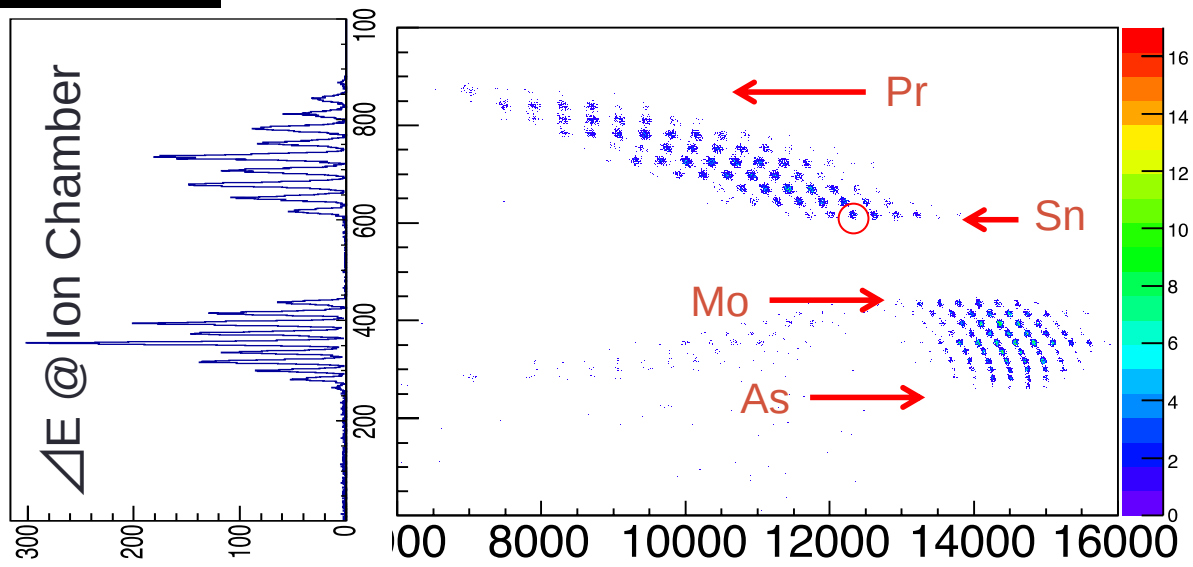
ICF is divided to 4 parts

-> fission fragments can be detected

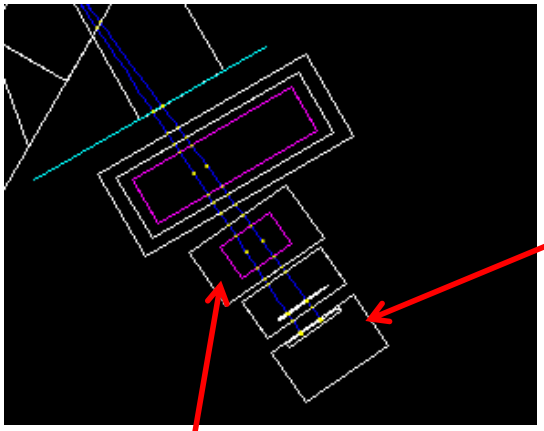
Exp.) Histogram of Simulation

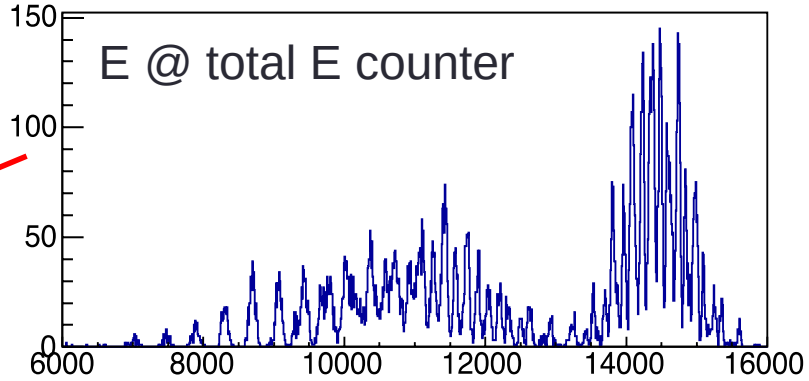


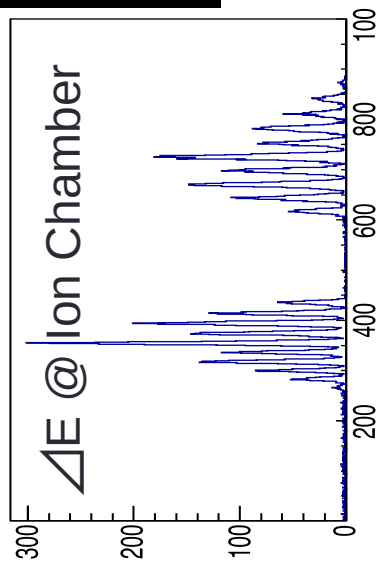


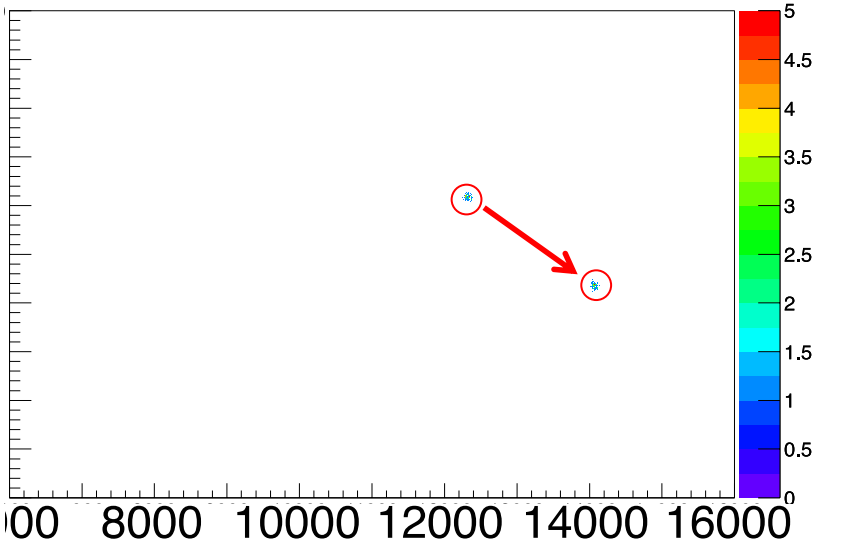


Exp.) Histogram of Simulation









large

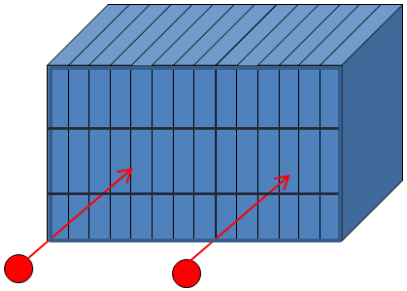
∝Z

small

∝Q/A

Development for Next Experiment

- New Detector 1
  - Segmented Ion Chamber
  - Sasano-san@RIKEN got the RIKEN internal fund for this counter
  - I will develop this counter !



- New Detector 2
  - Hodoscope which has good time resolution and thin plastic (vertical and horizontal bar)

- 2 proton Detector
  - Drift Chamber(position and angle) and NaI(energy)
  - Already Existed

- Ge-counter of in-flyght γ emission for particle tagging.

Next Experiment

- Beam : ^{210}Bi (300 pps)
  ^{213}Po (270 pps)
  ^{219}At (130 pps)
  -> Total Beam rate ~ $4*10^3$ pps by LISE++
- Target : Solid H

- Estimation
  - N=1.1 x 10^7 fragment events per day for ^{218}Po
  - (p,2p) cross section ~ 100 ub/MeV at 1g/cm^2 H_2 target
    ->$5*10^2$ events/day·MeV

Summary

- Our goal of fission experiment
  - charge and mass distribution and fission probability as a function of excitation energy
- New and powerful method at SAMURAI with (p,2p)
- Current status of our project
- Test experiment will be start
- New detector development
- Next experiment

Thank you