Pairing in neutron rich nuclei: An Active Target Tritium TPC

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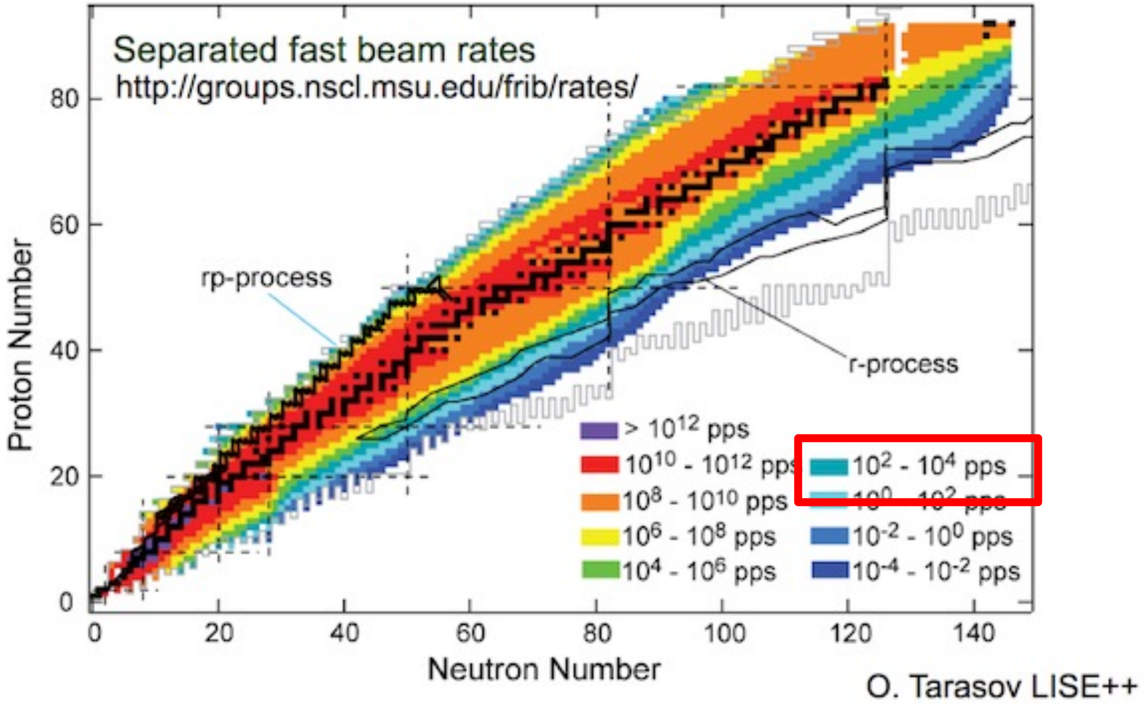
Contribution to the Nuclear Structure and Reaction Experiment Working Group
2022 NSAC Long-Range Plan Town Hall Meeting



Maximize physics reach on N/Z

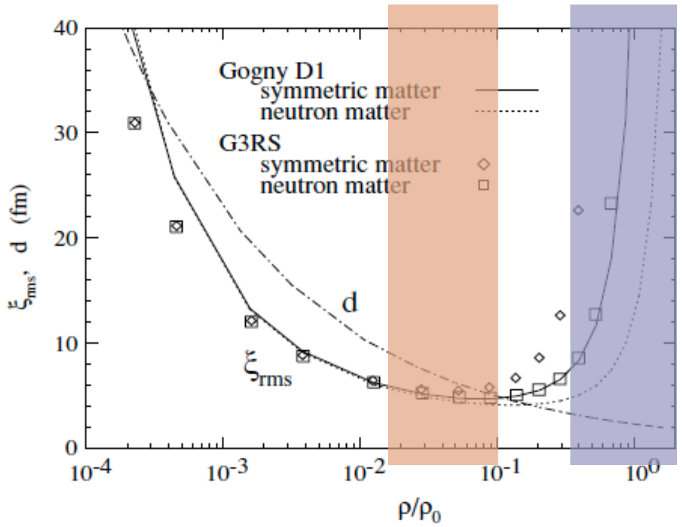
Large efficiency and resolving power

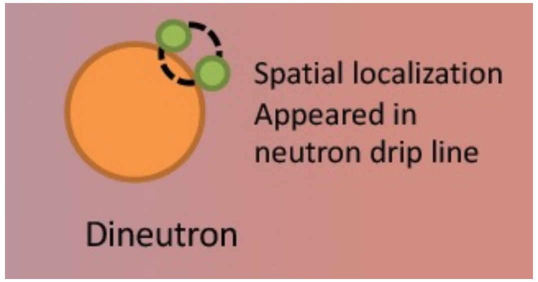
Target and detector in one device

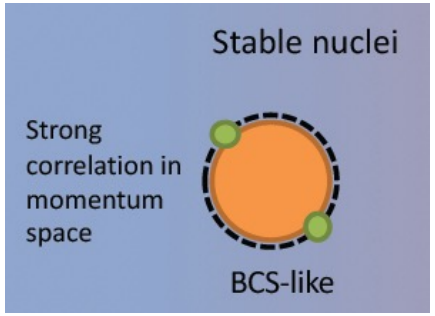
D. Bazin, T. Ahn, Y. Ayyad, S. Beceiro-Novo, A.O.Macchiavelli, W. Mittig, J.S. Randhawa
Low energy nuclear physics with active targets and time projection chambers,
Progress in Particle and Nuclear Physics, Volume 114 (2020)

Pairing in neutron rich nuclei

Correlation Length vs. Separation







Matsuo et al. PRC 73 (2006)044309
Pillet et al. PRC 76 (2007)024310

Key observable 2N transfer reactions

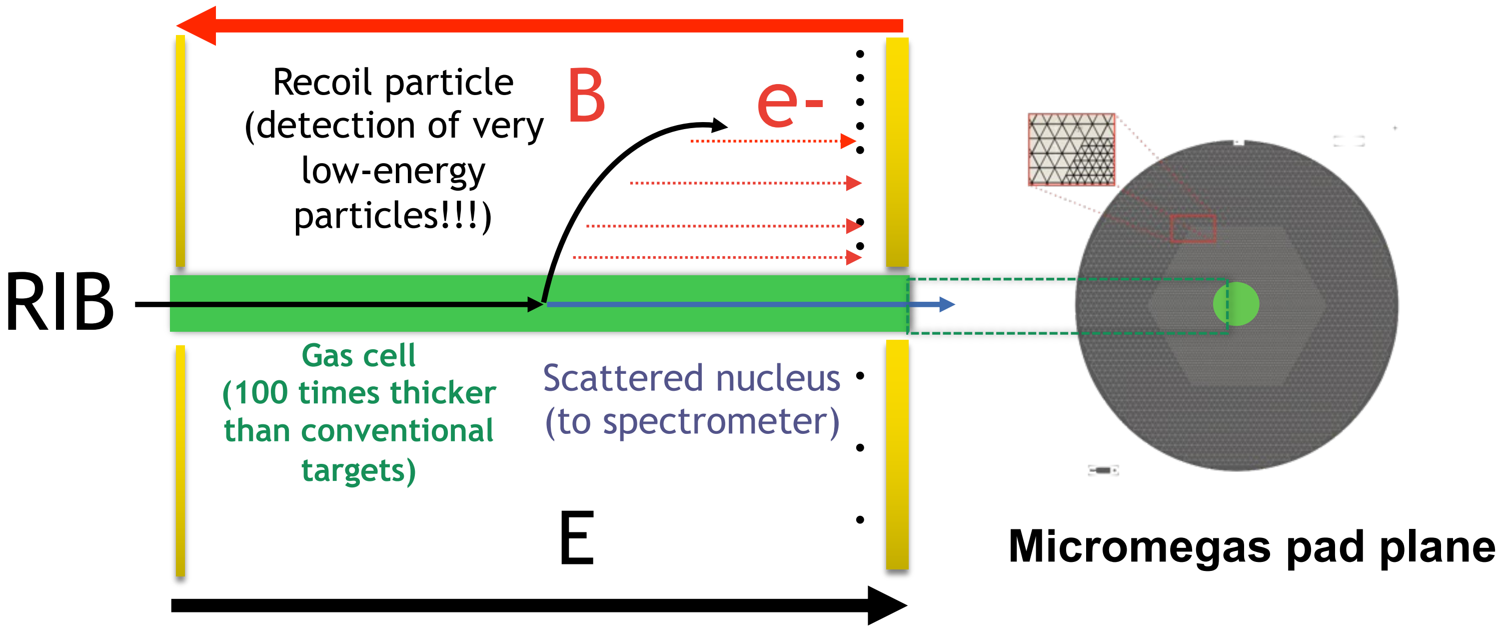
For example: Pairing vibrations beyond ^{78}Ni and ^{132}Sn

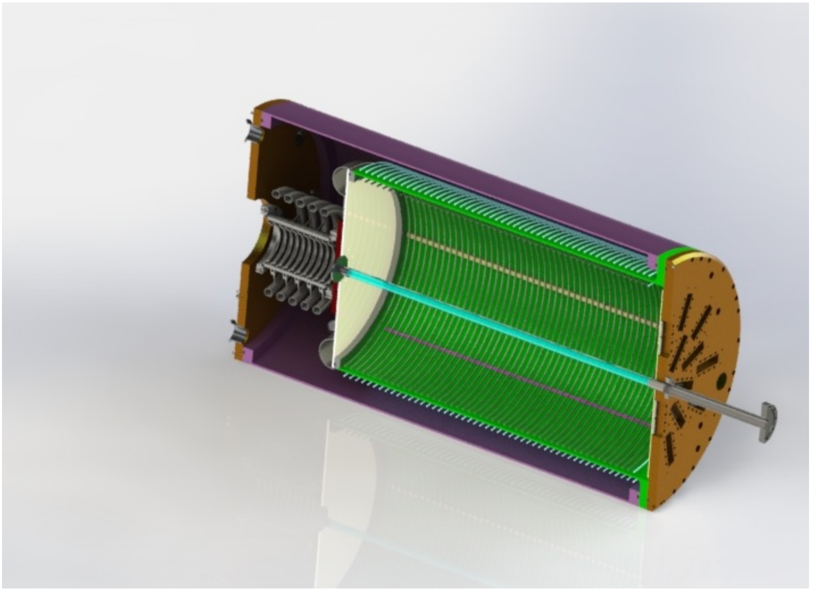
While one could consider reactions such as (^{18}O,^{16}O), **(t,p) reactions clearly stand as the best tool to study pairing correlations in nuclei**

A dedicated
Active Tritium Target TPC (AT^{3}PC)

OAK RIDGE National Laboratory

Conceptual design of the AT^{3}PC





Mylar cell 1 cm diameter

200 torr of **pure** tritium ~ 20Ci

Equivalent to 3.2 mg/cm^2

(~ 100 times thicker than current foils)

Advantages

- Also for rare gases: ^{3}He → **(^{3}He,p) for *np* pairing at N=Z**
- Improved rate capabilities with two isolated regions: gas cell and drift volume.
- Confinement of beta particles inside the cell due to the magnetic field.

Challenges

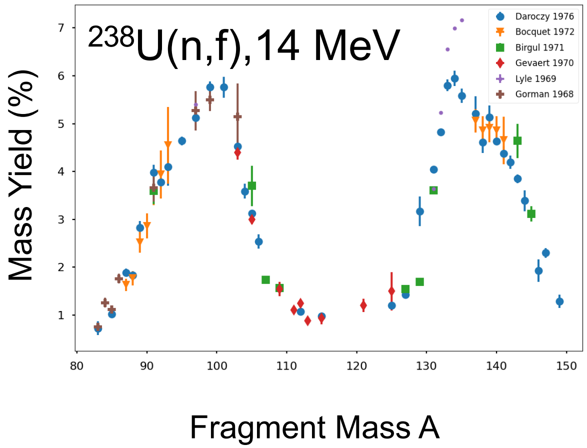
- **Tritium poses a hazard. Several safety layers will be required. Double/Triple enclosing volumes**
- Preserve the homogeneity of the electric field along the beam axis
- Proper material for the cell (mylar, boron nitride, kevlar, graphene…)
- Reconstruction of vertex. Energy and angular resolution
- Design of pad plane: Granularity and geometry

Work is on-going …. Stay tuned

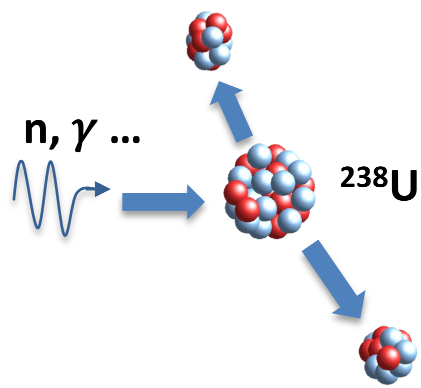
Fission in Direct and Inverse Kinematics

Gaps in fission data: FPY, TKE, n, γ

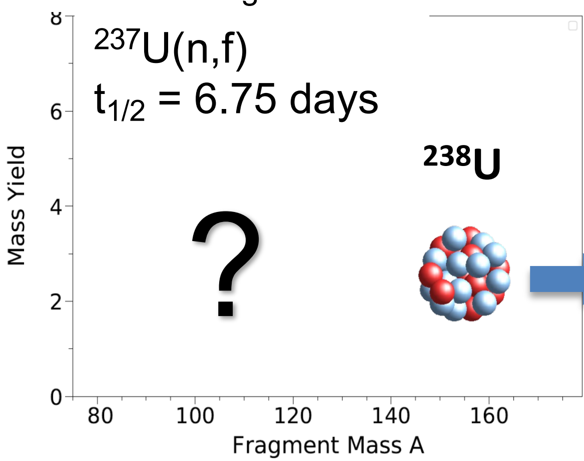
Ron Malone



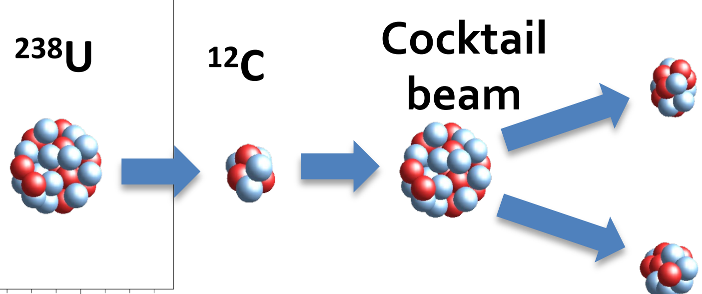
DIRECT KINEMATICS



- **Requires stable targets**
- High-resolution in energy with monoenergetic beams
- Limited charge information from radio-chemical techniques or β-delayed γ spectroscopy



INVERSE KINEMATICS



- Boosted reaction $\Rightarrow$ high-precision charge and mass identification
- High-quality correlated data (FPY, TKE, ν_{tot}) for many nuclei at once
- Poor energy resolution due to the reaction mechanism
- **Fission study of exotic actinide isotopes**

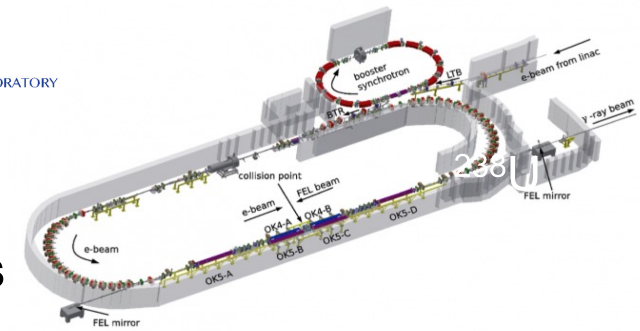
Fission fragment data exist for only a small fraction of nuclei. Inverse kinematics is the only way to access neutron-rich systems.

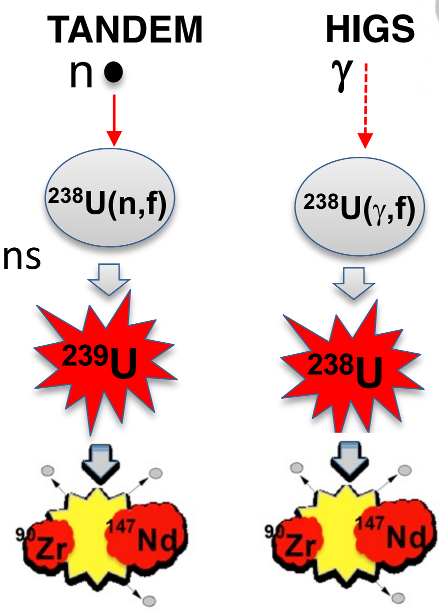
Direct Kinematics Measurements

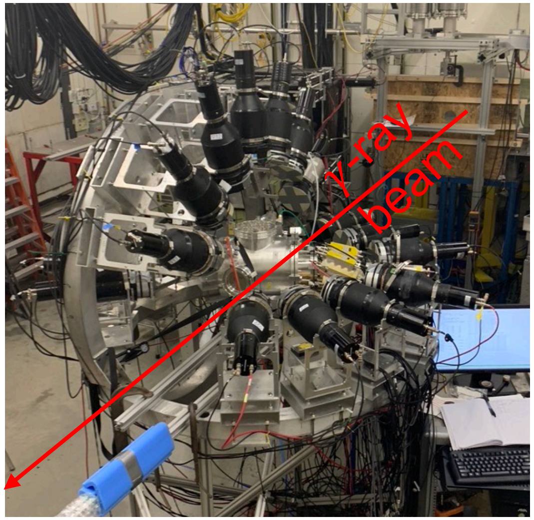
- Needed to benchmark inverse kinematics and explore specific excitation energies
- Frisch-grid ionization chamber:
  - **Fragment mass, kinetic energy, angular distributions, prompt particles, and correlations**
- Photofission at HγGS
  - Monoenergetic, polarized photons
  - 1 – 100 MeV, ΔE/E ~ 1-5%
- Neutron-induced at TUNL tandem lab
  - Monoenergetic beams
  - 0.06 – 20 MeV, ΔE/E ~ 3-5%

TUNL
Triangle Universities Nuclear Laboratory

HγGS





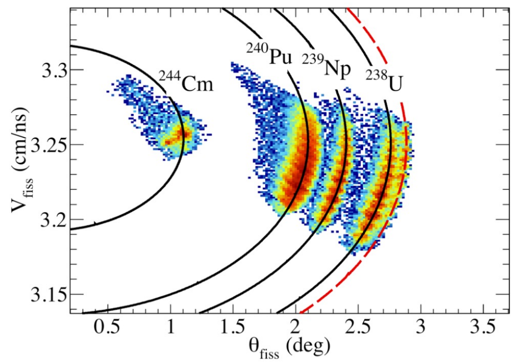


Need for direct kinematics measurements to benchmark inverse kinematics.

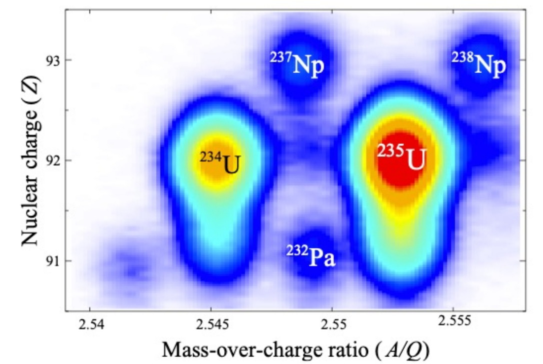
Inverse Kinematics Measurements

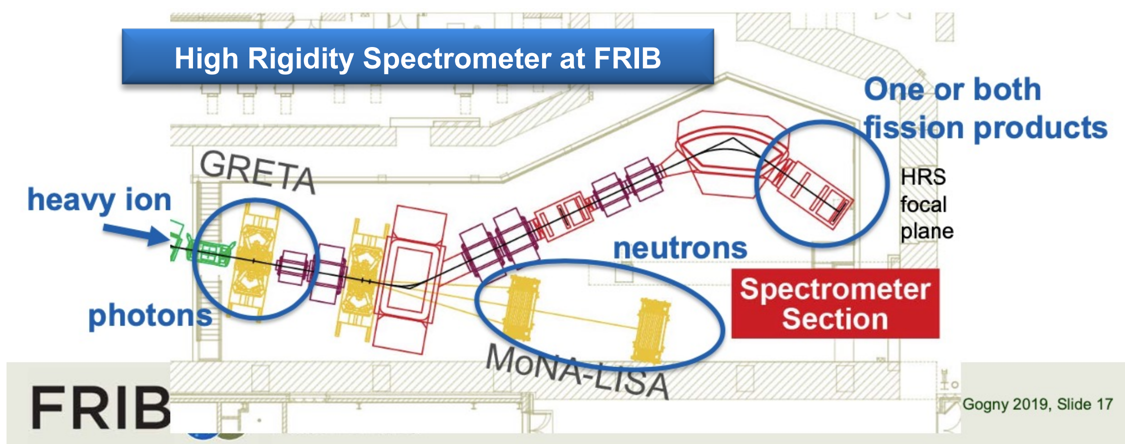
- Access to exotic nuclei
- Precise identification of the mass and the nuclear charge for both fission fragments
- **Direct measurements of fission-fragment yields, TKE, neutron multiplicity, and correlations**

D. Ramos et al., Phys. Rev. C **97**, 054612 (2018).



J.-F. Martin et al., Phys. Rev. C **104**, 044602 (2021).





Top: Measured fission systems from measurements with VAMOS at GANIL (left) and SOFIA at GSI (right).
Bottom: Proposed setup for fission measurements in inverse-kinematic -using HRS @ FRIB. From R. Zegers slides (2019)

The HRS at FRIB is crucial for US-based studies of fission in exotic nuclei.