

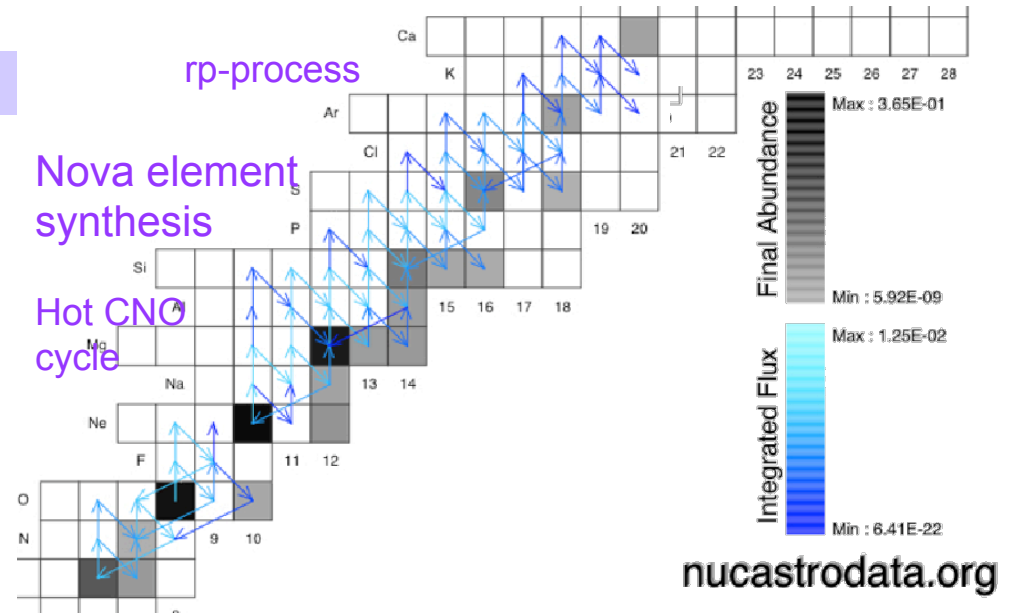
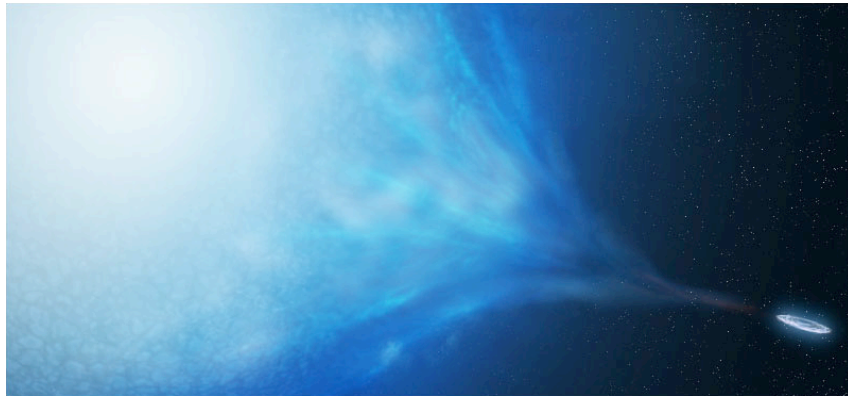
# recoil separators for capture reaction measurements

## overview

- **astrophysics motivation:** capture reactions on proton-rich unstable nuclei needed to understand novae & x-ray bursts
- **recoil separator approach:** detection of recoils, using a separator, is the best *direct* approach to measure these reactions
- **need for a dedicated device:** we need a dedicated device we can optimize for these long, challenging experiments
- **recoil separator proposal:** there is a proposal for a new device – SEparator for CAPture Reactions SECAR [Manoel Couder's talk]
- **much work to do:** suggest we form a working group to organize and get a great system built and astrophysics program planned



## astrophysics motivation



## novae & x-ray bursts

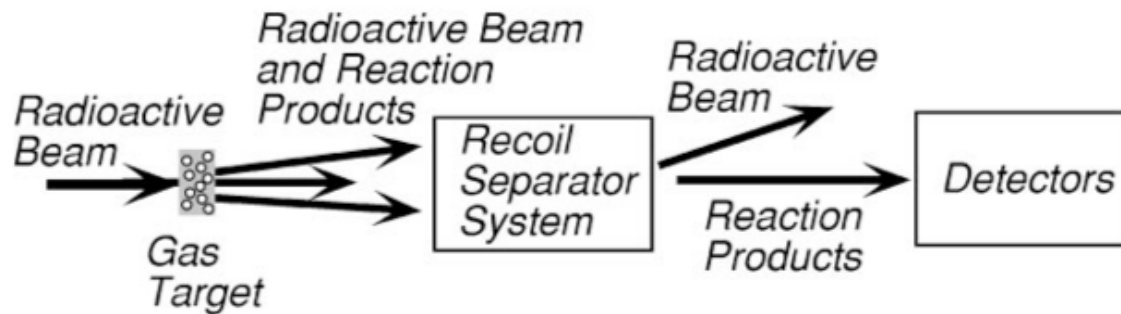
- capture reactions on proton-rich unstable nuclei **power** novae & x-ray bursts
- these rates are **crucial inputs** into simulations of these explosions
- changing certain rates changes simulation predictions of **energy generation** and **element creation** in these outbursts
- these impact novae & X-ray bursts **observables**

## capture reactions

- most rates are **unmeasured**, and **hard to model** due to individual resonances
- nuclei have lifetimes too short for rad targets → **RIB measurements needed**



## recoil separator approach



### approach

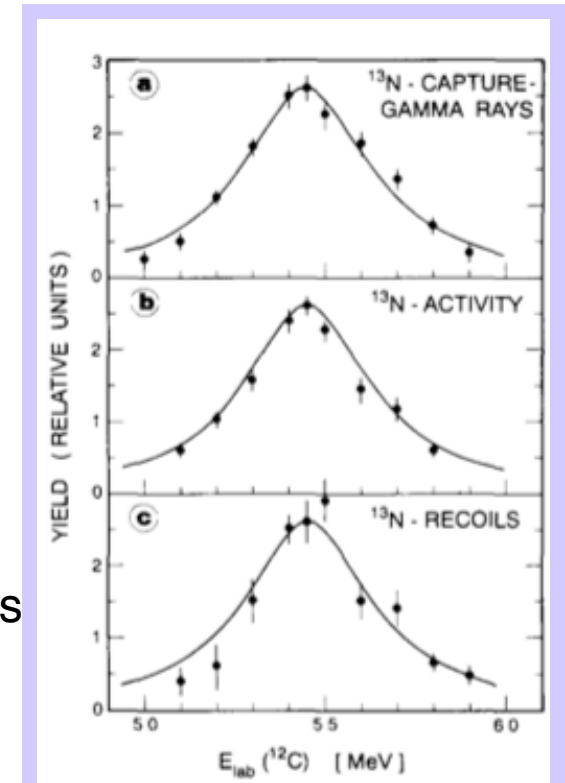
- directly measure capture reactions with low-energy beams of radioactive nuclei incident on a H or He gas target

### advantages

- directly obtain resonance strengths
- experiments are **conceptually simple** – just count recoils
- forward focussing of recoils makes **high efficiency** measurements possible

### challenges

- only 1 in  $\sim 10^{12}$  beam particles fuse with protons ... **low yield, long experiments** !
- **unreacted beam particles** enter separator located along beam axis -- need **beam rejection** of  $10^{-10} - 10^{-12}$  (or more) of separator & good focal plane detector



proof of concept with  $^{12}\text{C}(p,\gamma)^{13}\text{N}$   
Smith, Rolfs, Barnes NIMA306  
(1991) 233



## dedicated device – technical reasons

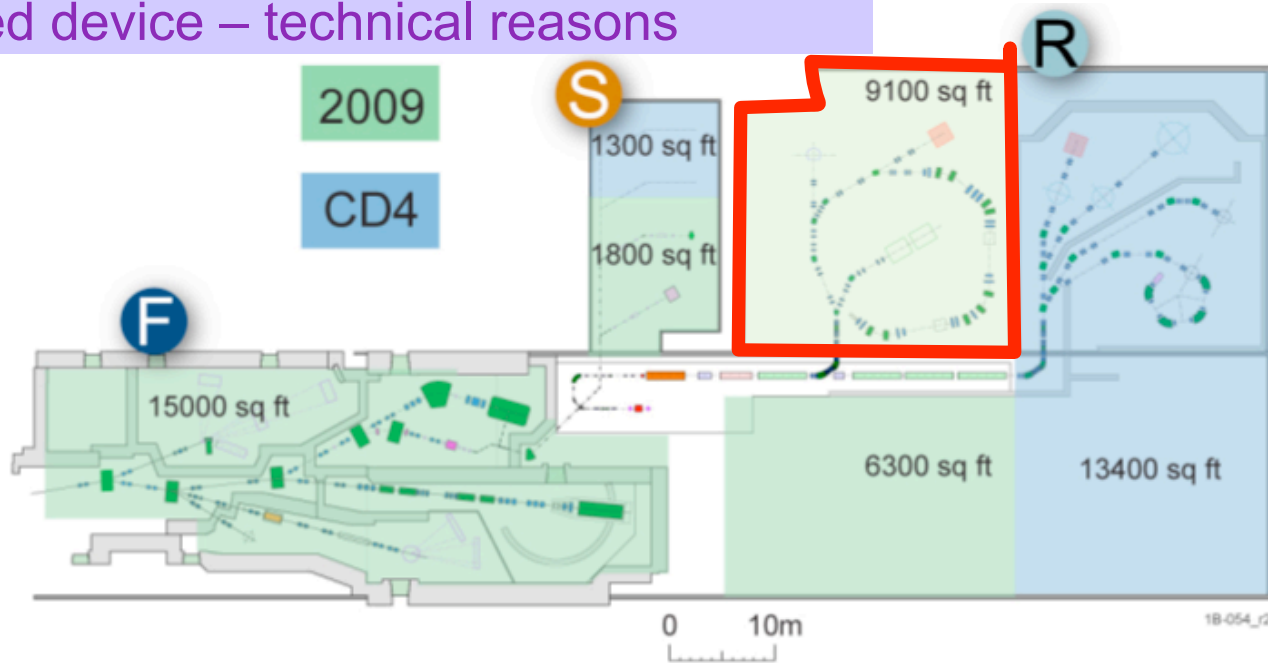


Figure 2: Proposed experimental area configuration of FRIB at MSU. F, S, R refer to Fast, Stopped, and Reaccelerated beam areas. The color code indicates the proposed completion time.

- separator utilizes **low energy beams** – not compatible with high energy hall
- **optimization** of components [magnets, velocity filters, slits] and ion optics **necessary** for high ( $\sim 10^{12}$ ) rejection of unreacted beam particles
- target area needs windowless gas target system that is likely **incompatible** with other systems [e.g., gamma ray ball detectors...]



## dedicated device – logistical reasons

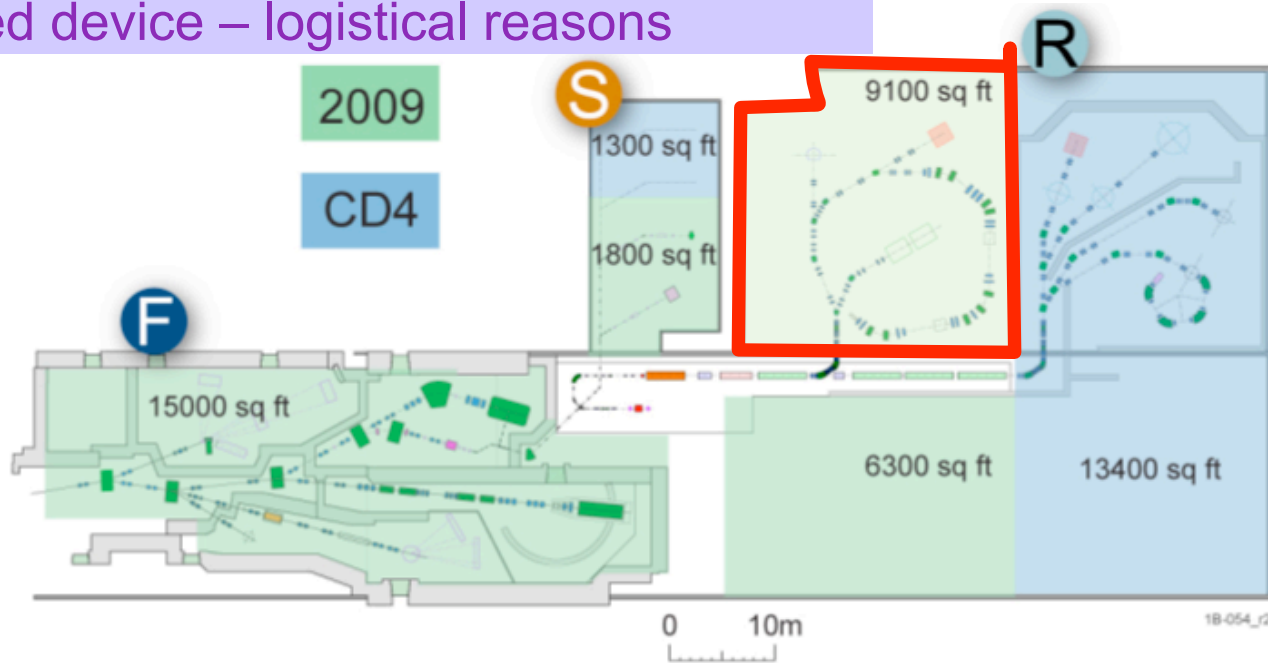
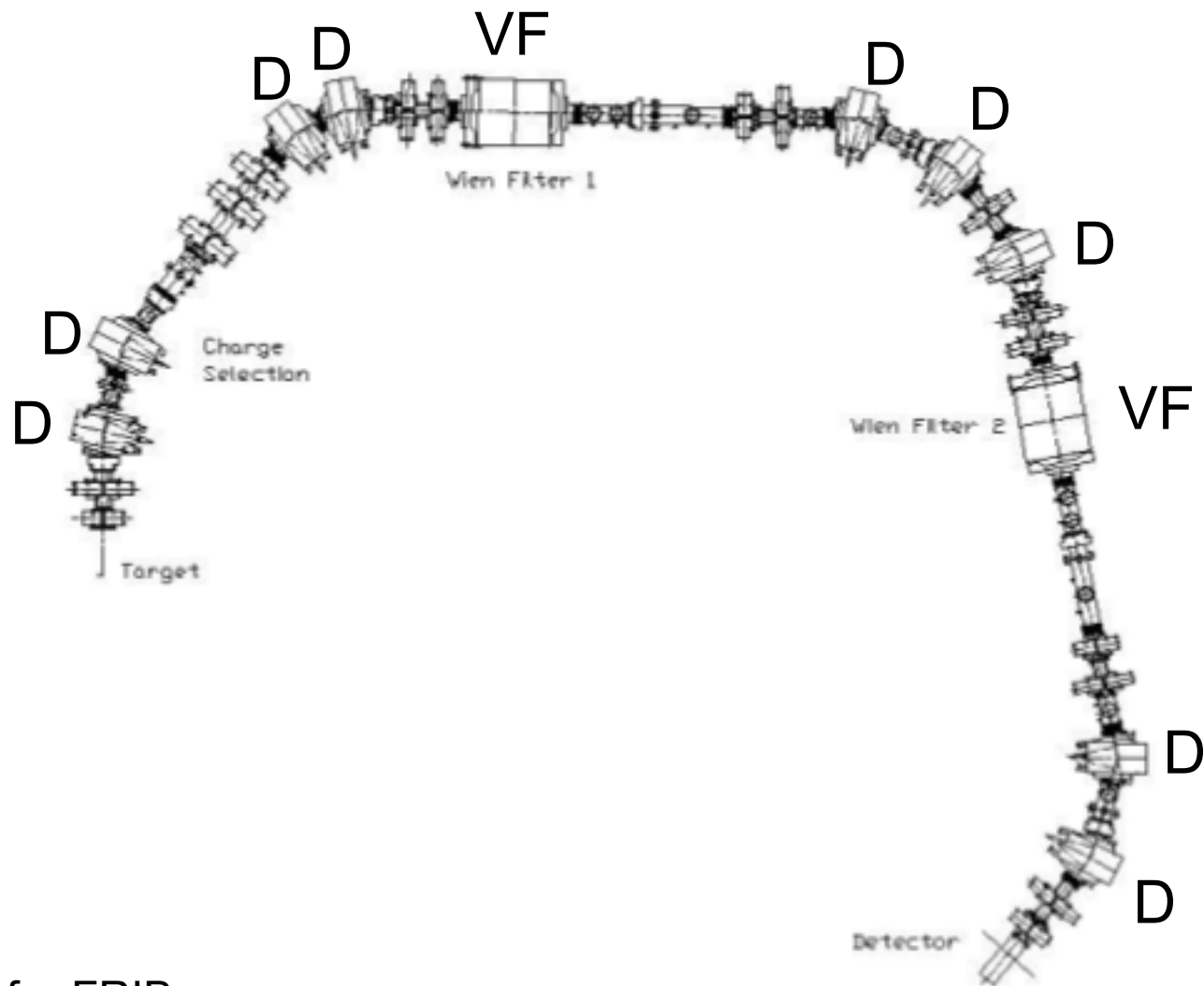


Figure 2: Proposed experimental area configuration of FRIB at MSU. F, S, R refer to Fast, Stopped, and Reaccelerated beam areas. The color code indicates the proposed completion time.

- low yield of capture reactions suggests **long running times** (~ weeks) -- impractical on a multi-purpose device with many associated users
- **lengthy commissioning period** to optimize separator and associated experimental equipment also impractical on a multi-purpose device
  - **similar conclusions** reached at NISOL / RIA workshops in 1998, 2003, 2004
- separator is needed for experiments in the NSCL ReA3 area **soon (!) – before higher energy FRIB halls are available**



## recoil separator proposal



- new device for FRIB
- SEparator for CApture Reactions (SECAR) -- Manoel Couder's presentation



## working group

- much work to do on recoil separator and associated experimental equipment
- crucial to **plan** out a **viable experimental program**
  - direct capture reaction measurements need to be **combined** with **indirect** measurements in the **low-energy hall** [scattering...]  
and **higher energy hall** [transfer]
  - crucial to involve theorists as well
- important to get organized !
- formerly we had the Astrophysics at RIA [ARIA] Working Group

- suggest launching a new Working Group in the FRIB era ...  
tentative name: the **SuNBuRN Collaboration**  
**Studies of Nucleosynthesis with Beams of Radioactive Nuclei**

