N/Z Dependence of Isotopic Yield Ratios as a Function of Fragment Kinetic Energy

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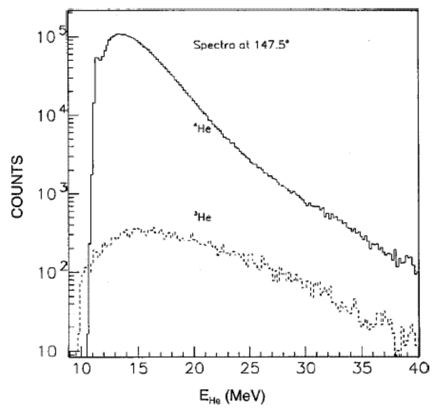
Background

Experimental evidence has shown that the lightest isotope produced in a multifragmentation reaction tends to be the most energetic. This trend is seen with the isotopes of elements with 2<Z<8.



Graph from PRC, Vol. 44, Pg 44 (1991)

•Spectra taken from a ^{3}He + ^{nat}Ag reaction

•$\langle E_{4He}\rangle < \langle E_{3He}\rangle$

•Also seen with Li, Be, B, C, and N isotopes*

* PRC, Vol. 44, Pg 44 (1991)

A Possible Explanation: Pre-equilibrium Fragment Emission

Current bulk multifragmentation models cannot explain these results

- The bulk motion term predicts that the lightest isotope will have the smallest mean energy of the isotope (figure 2)

The Expanding Emitting Source model (EES), a binary decay model, has been shown by researchers at Michigan State University to model well the mean energies of element with 2≤Z≤8 (figure 1)

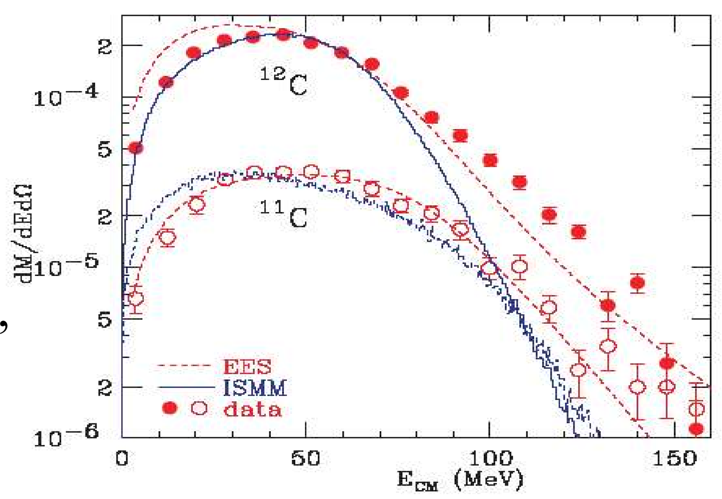


figure 1**

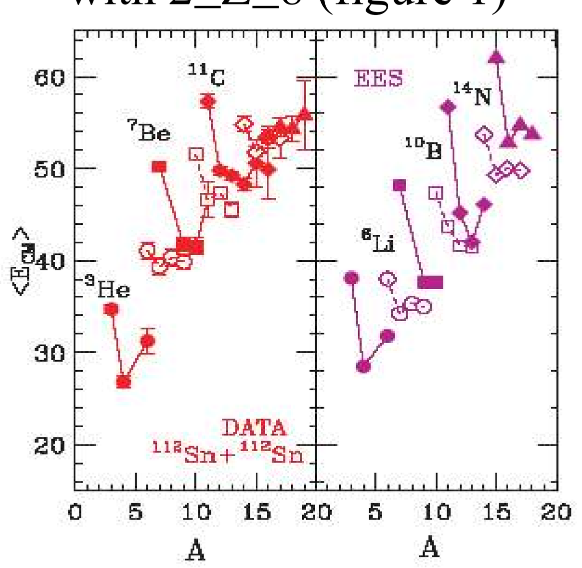


figure 2**

- This success of the EES model points to the conclusion that fragments are released pre-equilibrium by a binary decay mechanism
- In this model, ^{11}C is preferentially emitted prior to ^{12}C (figure 4) and both isotopes tend to have a greater mean energy when emitted earlier (figure 3), leading to ^{11}C having a greater mean energy than ^{12}C.

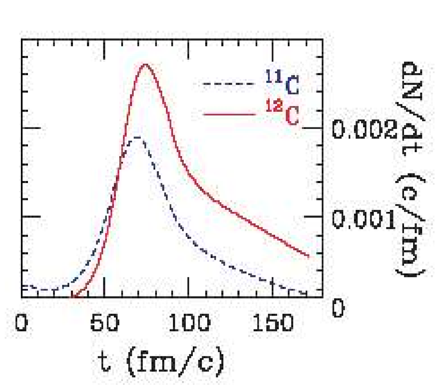


figure 4**

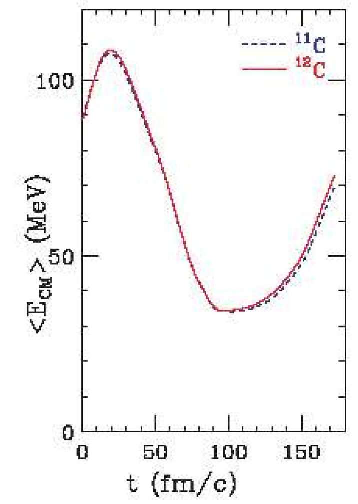


figure 3**

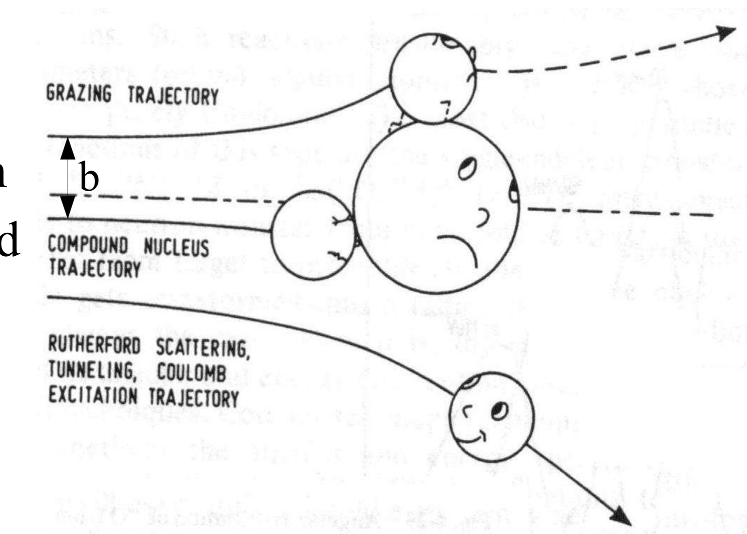
** Lynch, private communication (NSRC preprint, Liu et al)

Questions with explanation

- Does this trend occur in systems too light to for pre-equilibrium C emission?
- Is this trend a relic of the beam's N/Z?

Projectile Fragmentation

- When b is near the grazing trajectory, fragmentation of the projectile can occur via grazing collisions or coulomb excitation
- Little to no nuclei are exchanged in this process and the fragmenting projectile like fragment' (PLF) is very close in nuclear composition to the projectile



- Projectile fragmentation reactions do not require a full 4 pi detector, and are much less expensive to study

The Reactions we are studying

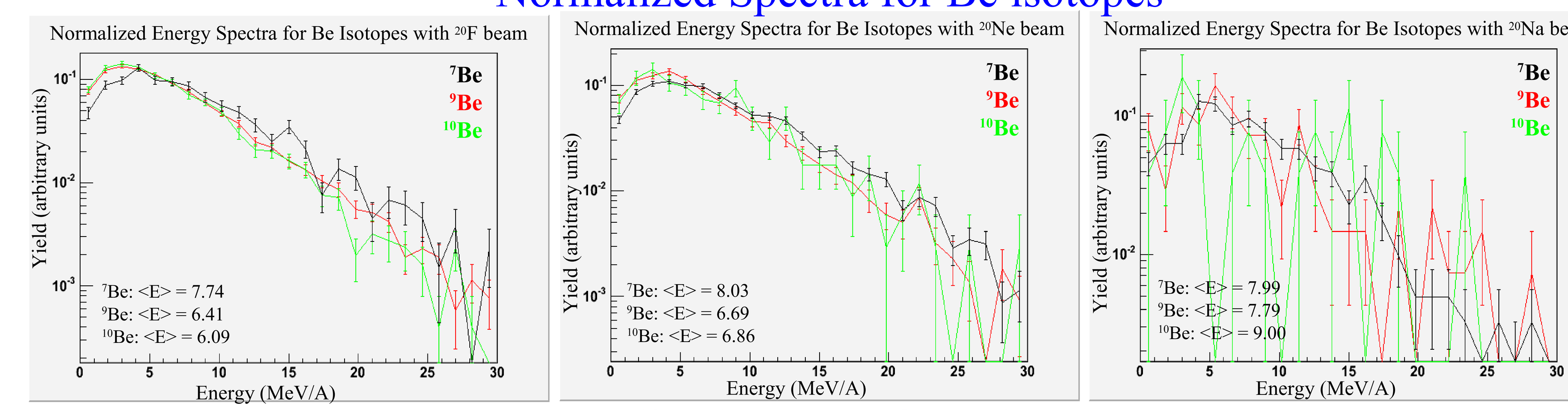
- All data analysed using ROOT
- Isobaric beams (same A), ^{20}F, ^{20}Ne, ^{20}Na, on ^{197}Au
  - Using isobaric projectiles allows us to gauge the impact of the beam's N/Z on peak energies of the fragments
- Fragments from projectile fragmentation with little nuclei exchange
  - The only fragmentation events counted are those in which the detected Z from all fragments is equal to the Z of the beam and the detected A is between 18 and 22
  - Only events in the forward angle (from 1.6 to 44.8 degrees)

Event Reconstruction

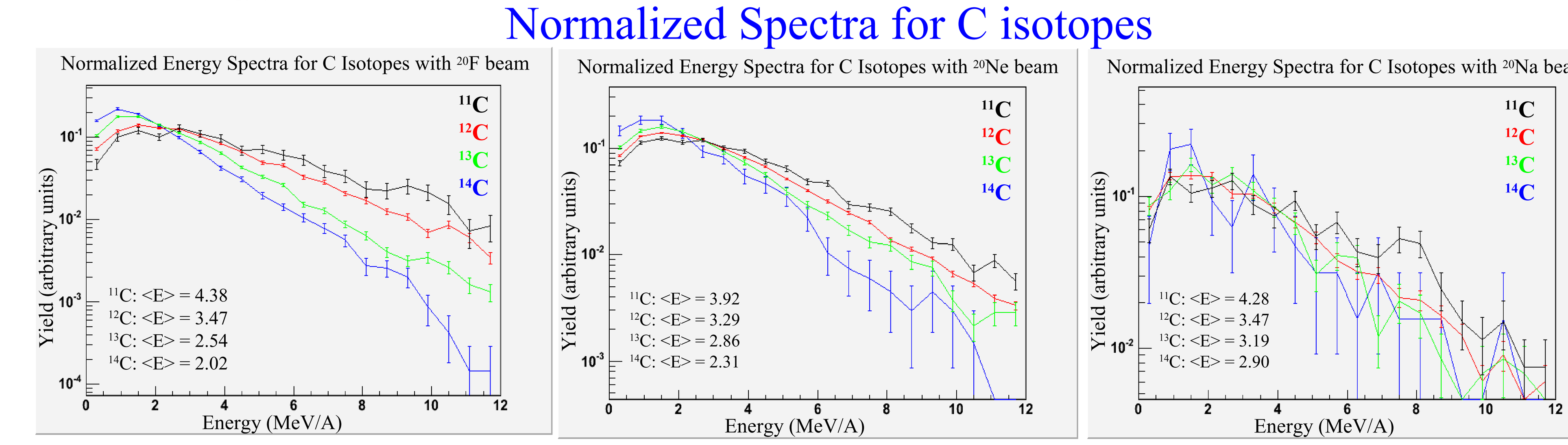
- All data analysed using ROOT
- A 'quasi-projectile' is reconstructed from the fragments' kinetic energy and lab trajectory and then the fragment angles and energy are translated to the quasi-projectile centrer of mass frame
- Focused on energy spectra for isotopes of carbon and nitrogen
- Data grouped for middle angles, $36<\theta_{qp}<126$, and forward/backward ngles, $0<\theta_{qp}<36$ and $126<\theta_{qp}<180$

Results

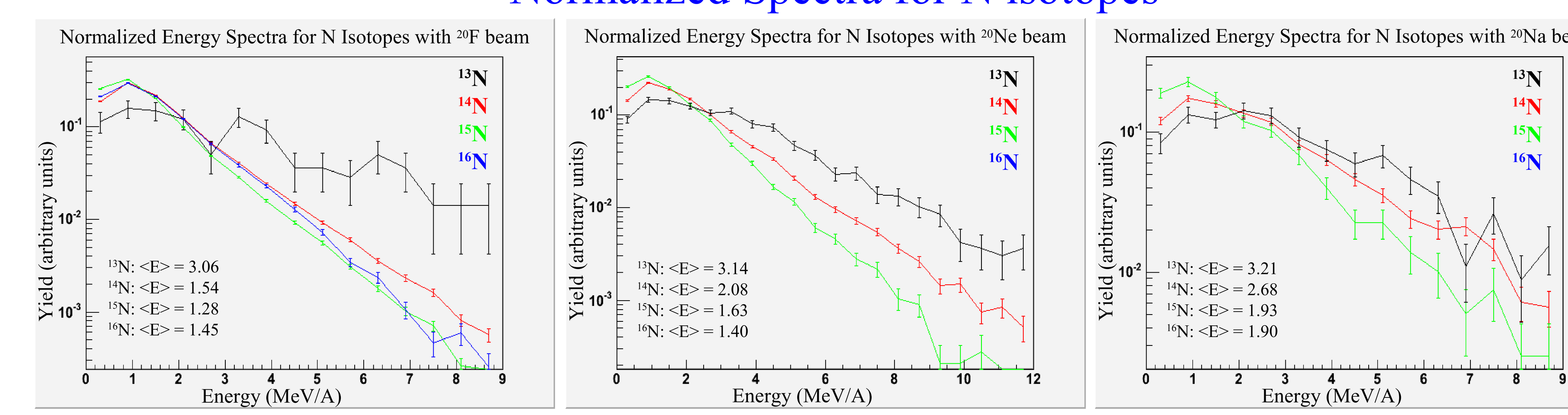
Normalized Spectra for Be isotopes



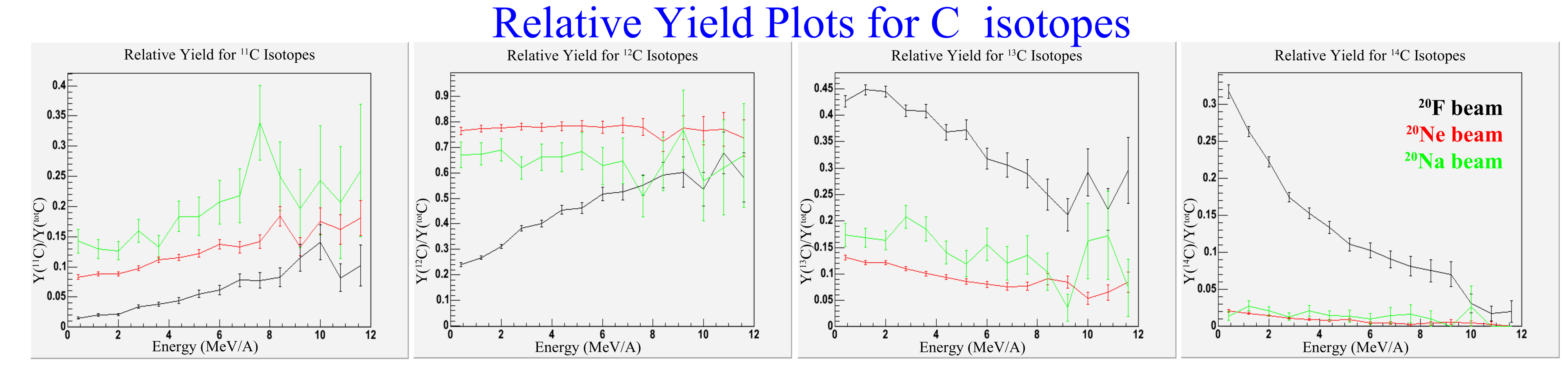
Normalized Spectra for C isotopes



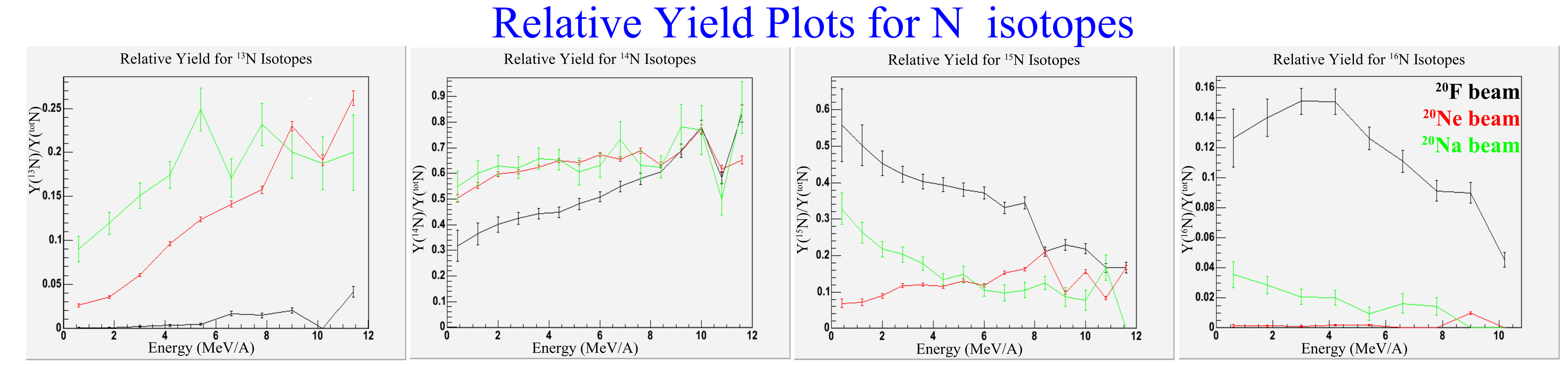
Normalized Spectra for N isotopes



Relative Yield Plots for C isotopes



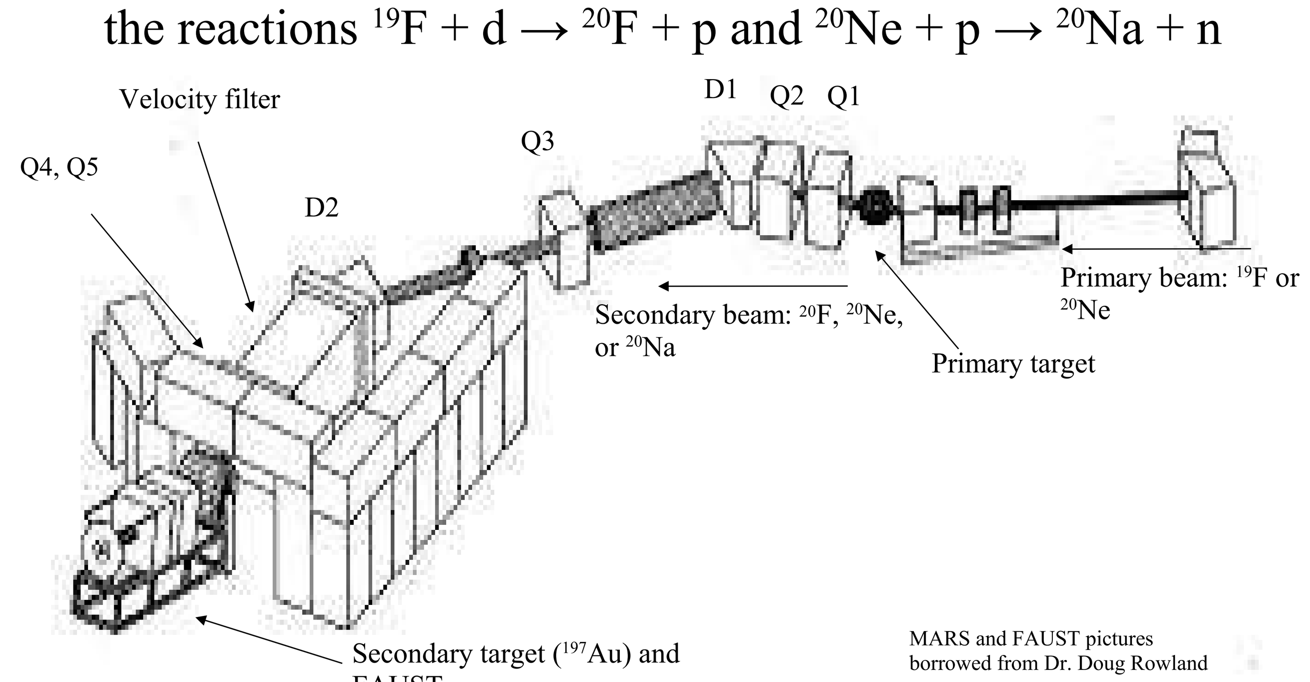
Relative Yield Plots for N isotopes



Experimental: MARS and FAUST

MARS (Momentum Achromat Recoil Spectrometer)

- Radioactive (secondary) beams ^{20}F and ^{20}Na produced in the reactions $^{19}F + d \rightarrow {}^{20}F + p$ and $^{20}Ne + p \rightarrow {}^{20}Na + n$

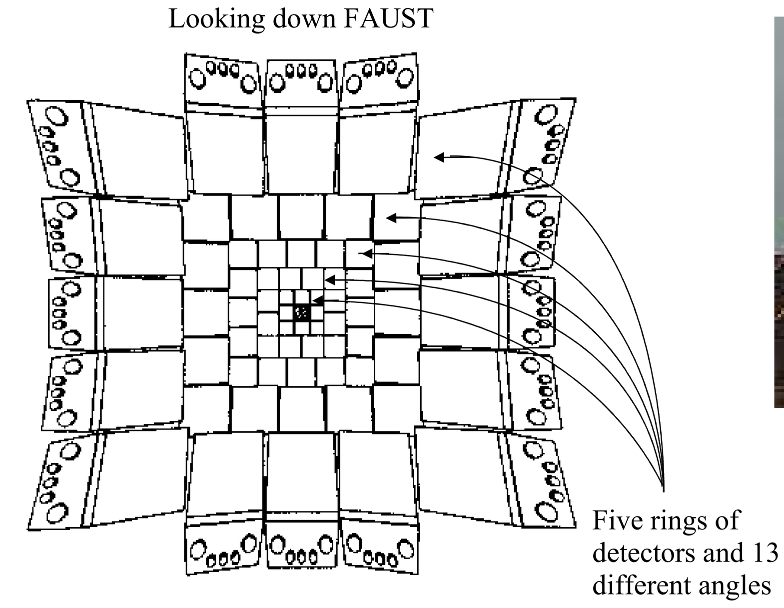


MARS and FAUST pictures borrowed from Dr. Doug Rowland

FAUST (Forward Array Using Silicon Technology)

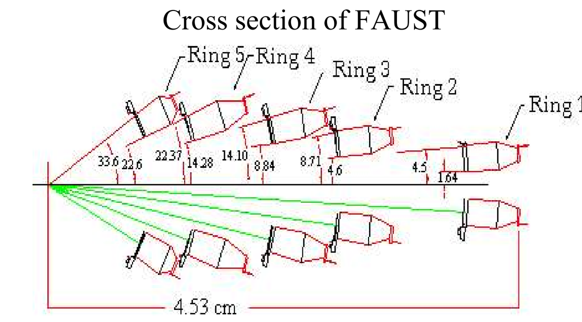
- Forward Array: Covers lab angles from 1.6 to 44.8 degrees
- Isotropic identification up to Z = 7

Looking down FAUST



Real live FAUST

Cross section of FAUST



Conclusions

- As expected, the spectra for Be, C, and N fragments exhibit a greater mean energy for the lightest isotope
- Conclusions are difficult to draw from the Na beam because of the low statistics
- The relative yield plots show a difference of behavior for ^{20}F beam than for the other beams, possibly signifying a dependence of isotope yield ratios on the N/Z of the beam
- To further investigate the adherence of these trends to theory, this data should be compared to bulk fragmentation models, such as SMM, and sequential decay models, such as EES or GEMINI

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