New mass measurements of neutron rich nuclides at the NSCL

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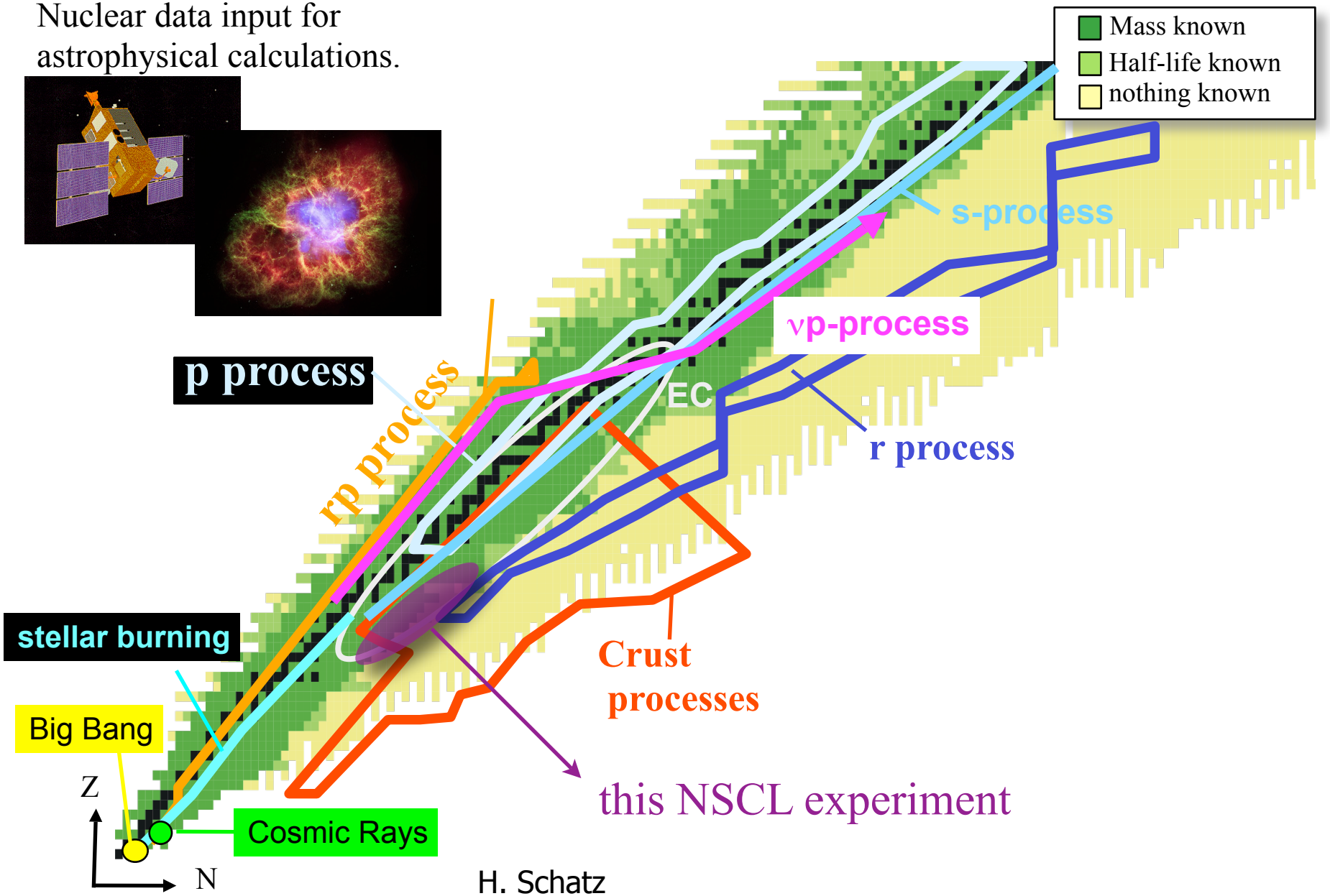
Outline

- Physics motivation: masses as input for astrophysical calculations and as test for current mass models.
- Time-of-flight (TOF) mass measurement experiments at the National Superconducting Cyclotron Laboratory (NSCL).
- experiment 1035: Mass measurements near the N=50 shell gap.

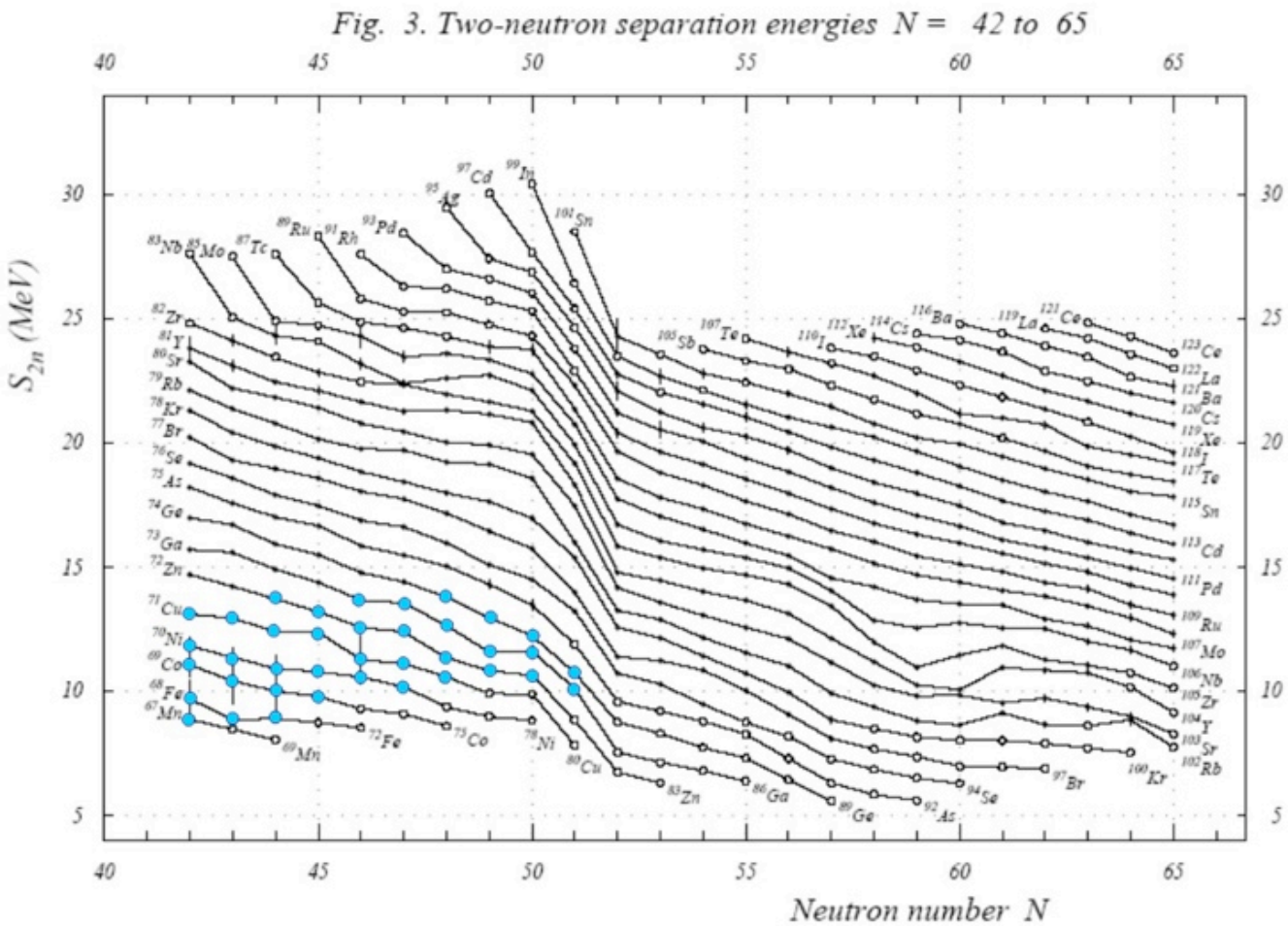
Motivation I: astrophysics

Nuclear data input for astrophysical calculations.



H. Schatz

Motivation II: nuclear structure



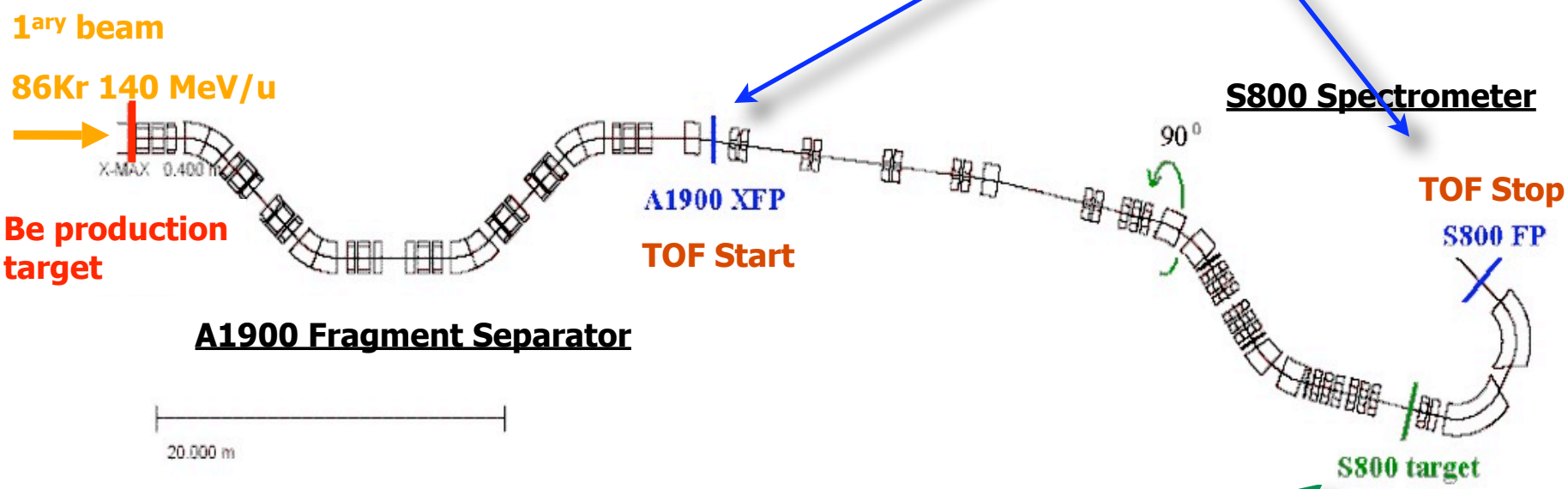
All global mass models give a similar fit to measured masses (RMS ~ 650 keV), but they diverge when extrapolating the results to new masses.

TOF experiments at the NSCL

Measure time-of-flight (TOF) + magnetic rigidity (Bρ):

$$B\rho = \frac{\gamma m}{q}\left(\frac{dx}{dt}\right)$$

timing detectors
(flight path 58m)



momentum measurement

First experiment at the NSCL: "Mass measurements near the N=50 shell gap".

Bρ measurement at
S800 dispersive plane

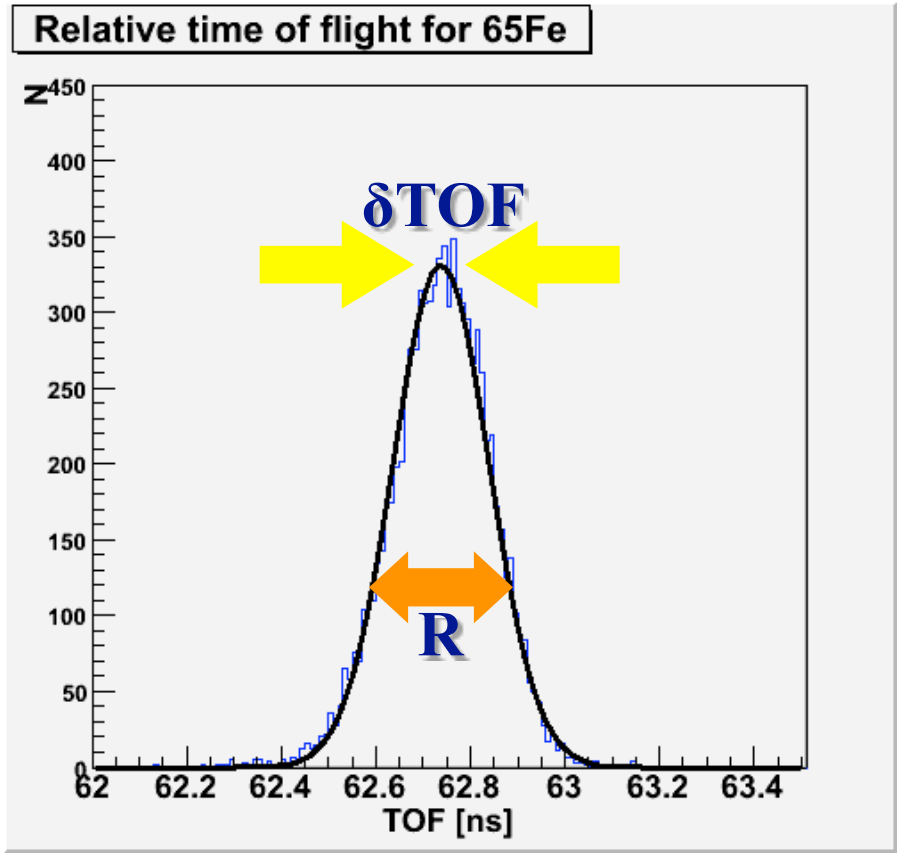
Resolution vs Precision

Measurement goal: 200 keV mass **precision** (δm) (2×10^{-6} relative precision for A~70 nuclei)

$$\delta m \propto \frac{m}{R\sqrt{N}}$$

for N = 10000 events

need **resolution** $R = 1\times10^{-4}$



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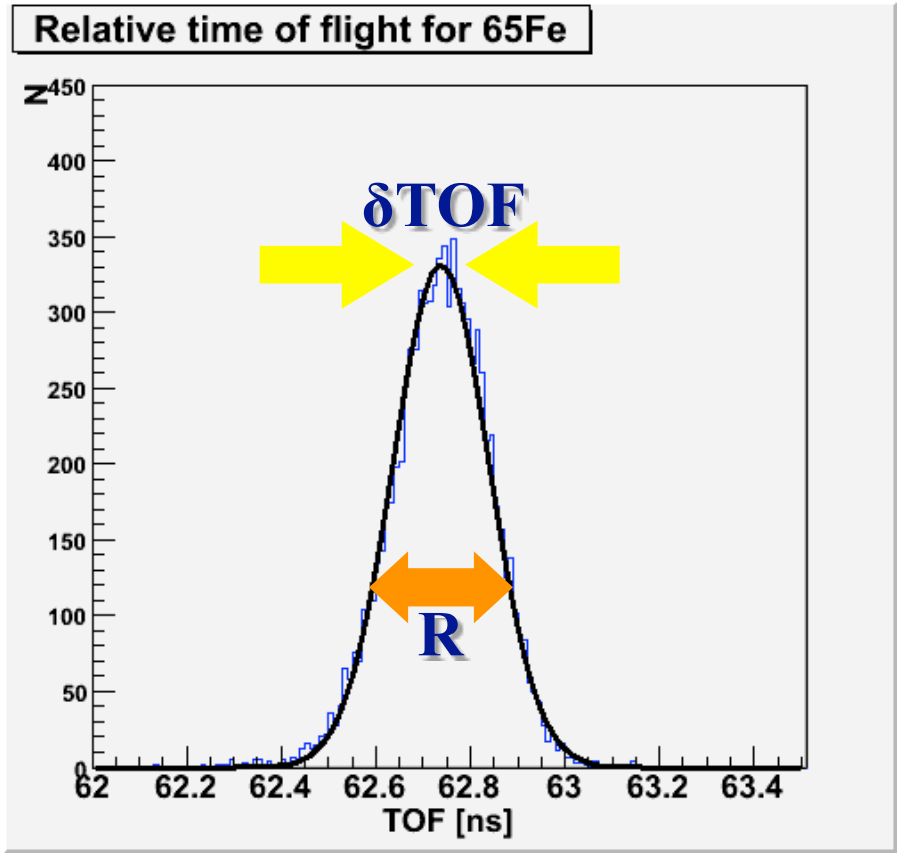
For TOF technique:

R = Δm/m ≈ Δtof/tof

tof ≈ 500ns

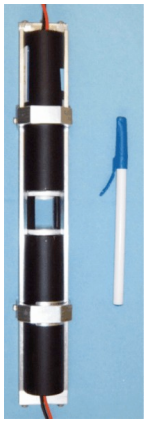
need Δtof= 100ps (detector resolution)

We have to determine TOF centroid with uncertainty of **1 ps**!

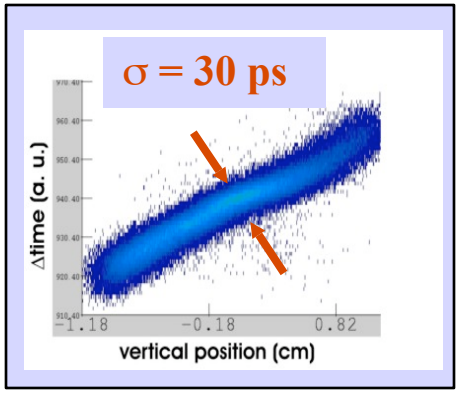


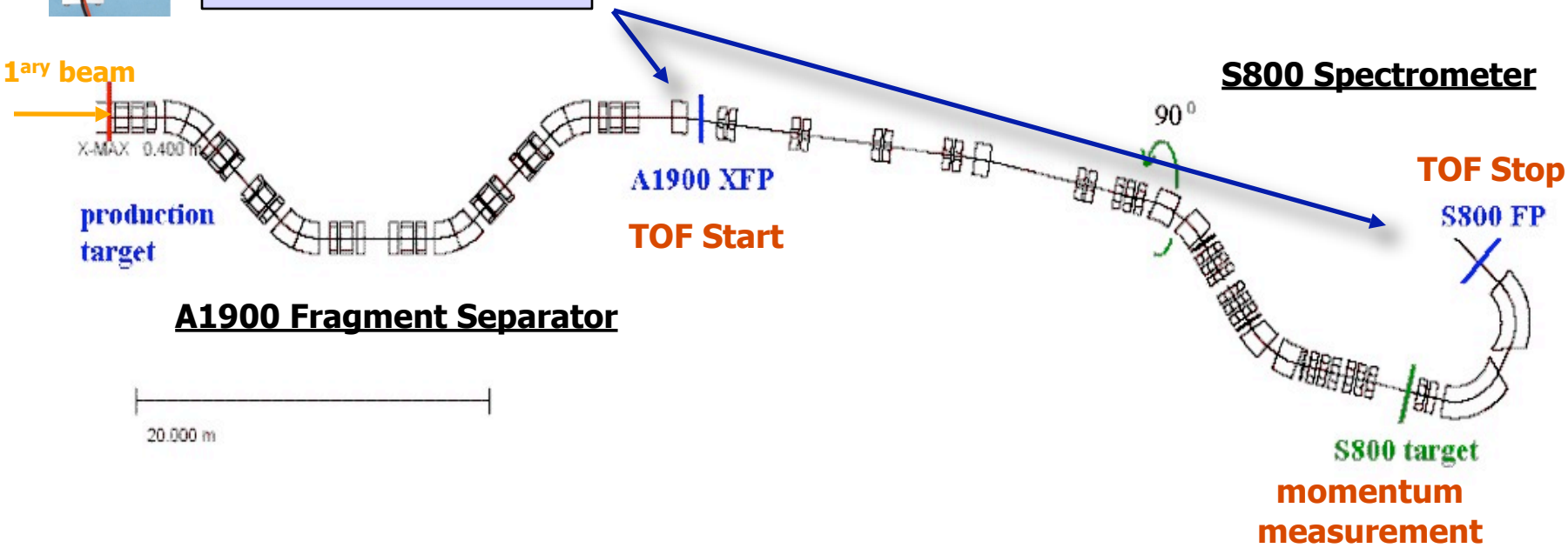
Experimental set up for TOF mass measurements

Timing detectors: fast plastic scintillators



Timing scintillator test run



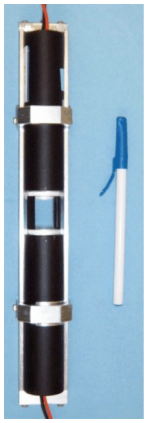


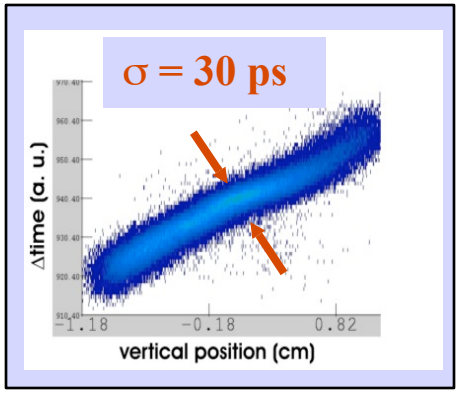
Experimental set up for TOF mass measurements

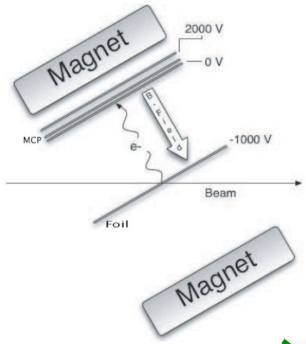
Timing detectors: fast plastic scintillators

Microchannel plate detectors: obtain Bρ by measuring ions position at S800 dispersive plane

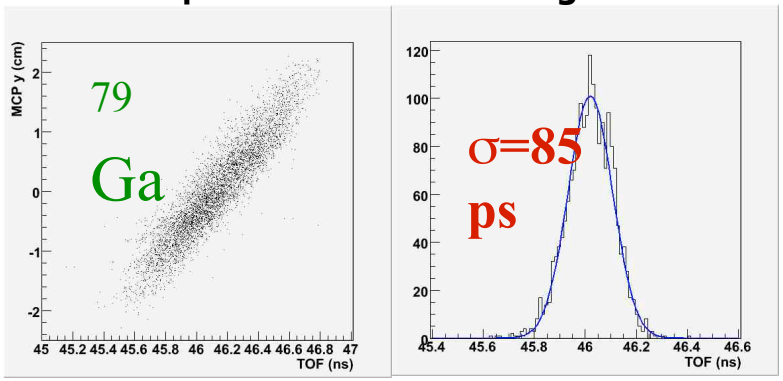
Timing scintillator test run

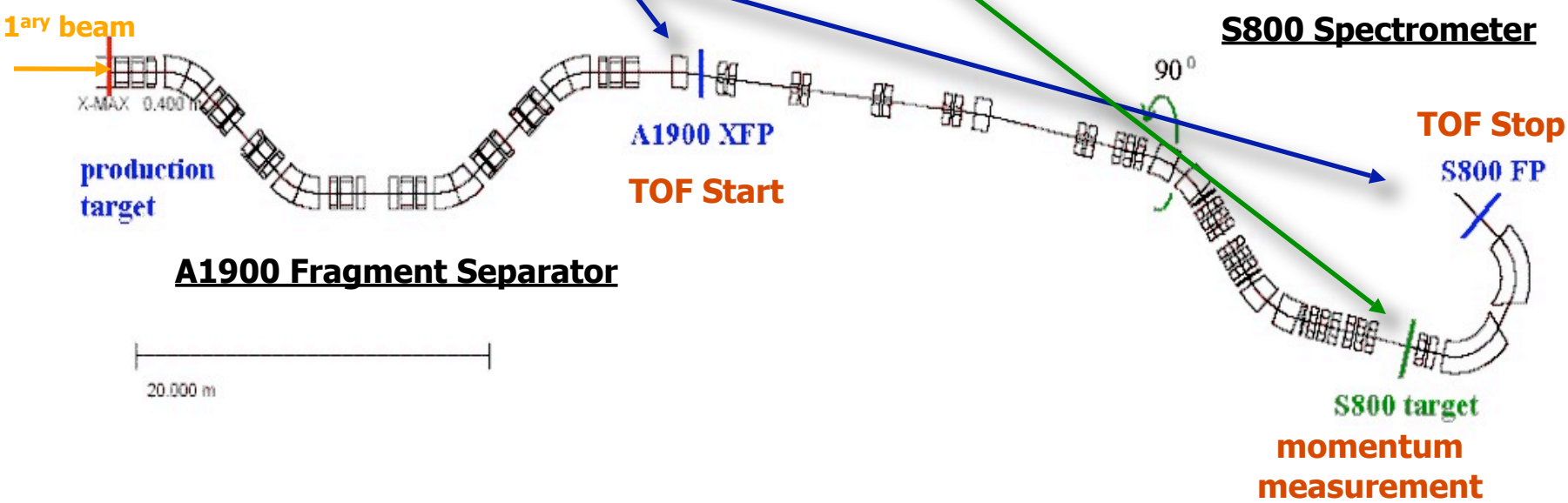






Bρ corrected time of flight

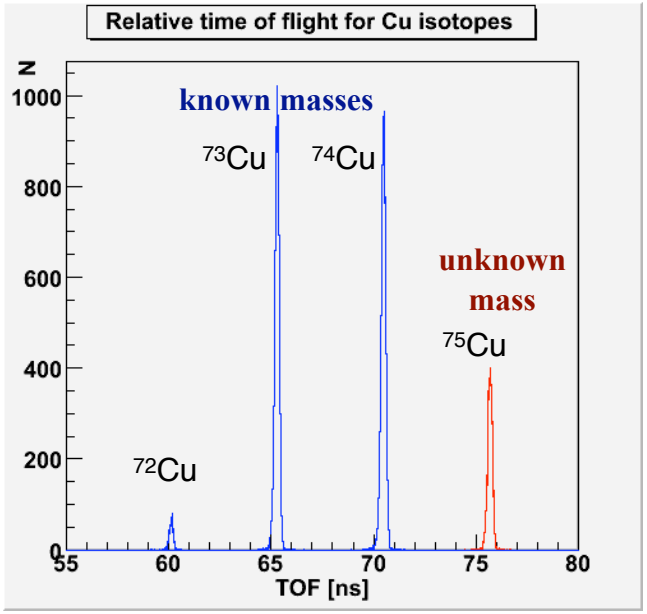




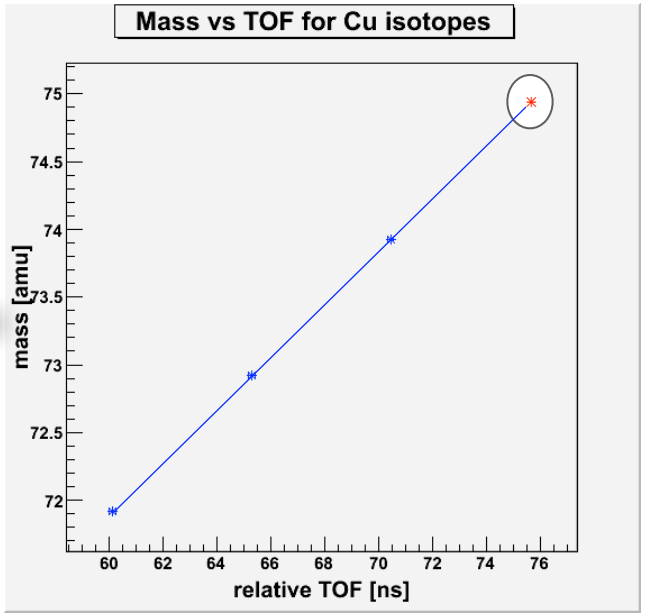
The role of calibration masses

Isotopes with known masses used to construct a calibration function for the mass vs time-of-flight relation. The calibration function should also take into account systematic effects intrinsic to the experimental setup – e.g. energy losses in the detectors, higher order beam optics contribution to the time of flight.

$$B\rho = \frac{\gamma m}{q}\left(\frac{dx}{dt}\right)$$

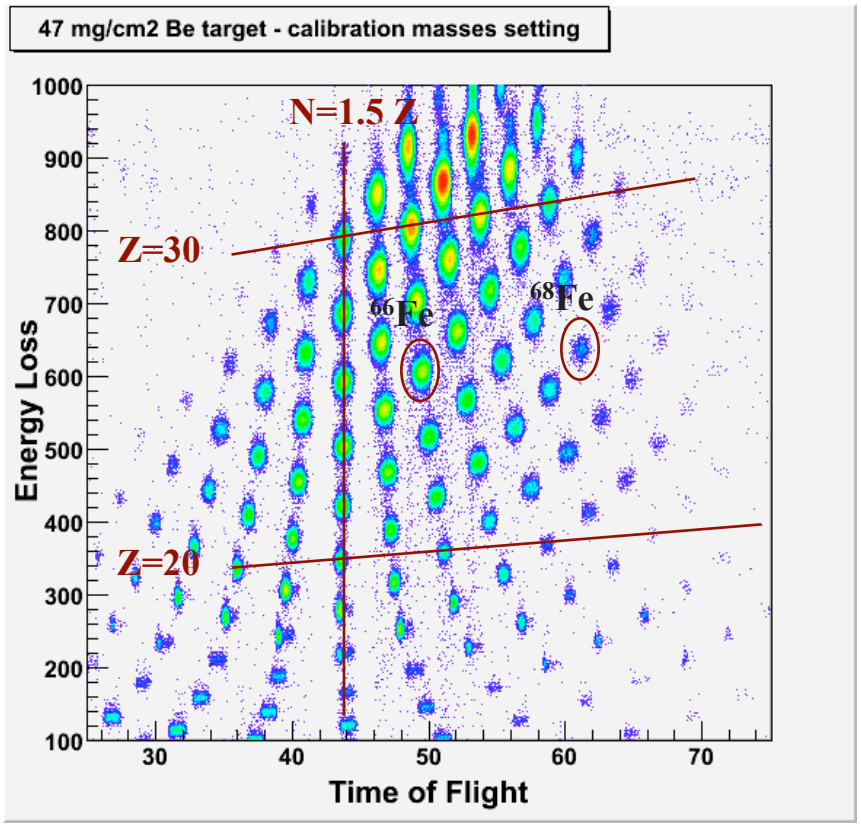


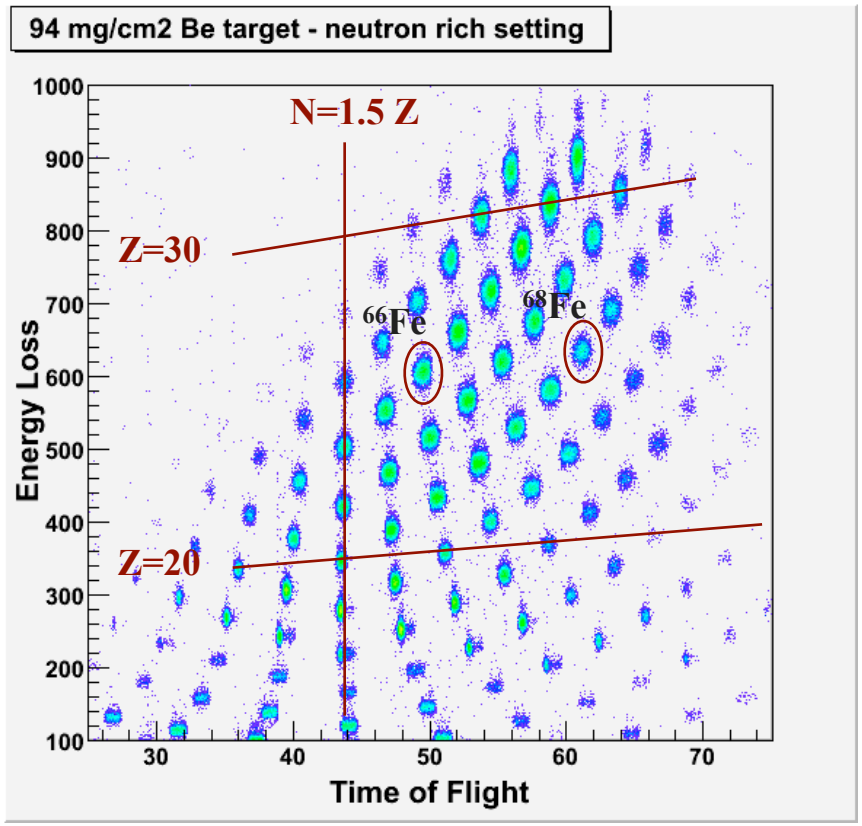
$$\frac{m}{q} = f(TOF, A, Z)$$



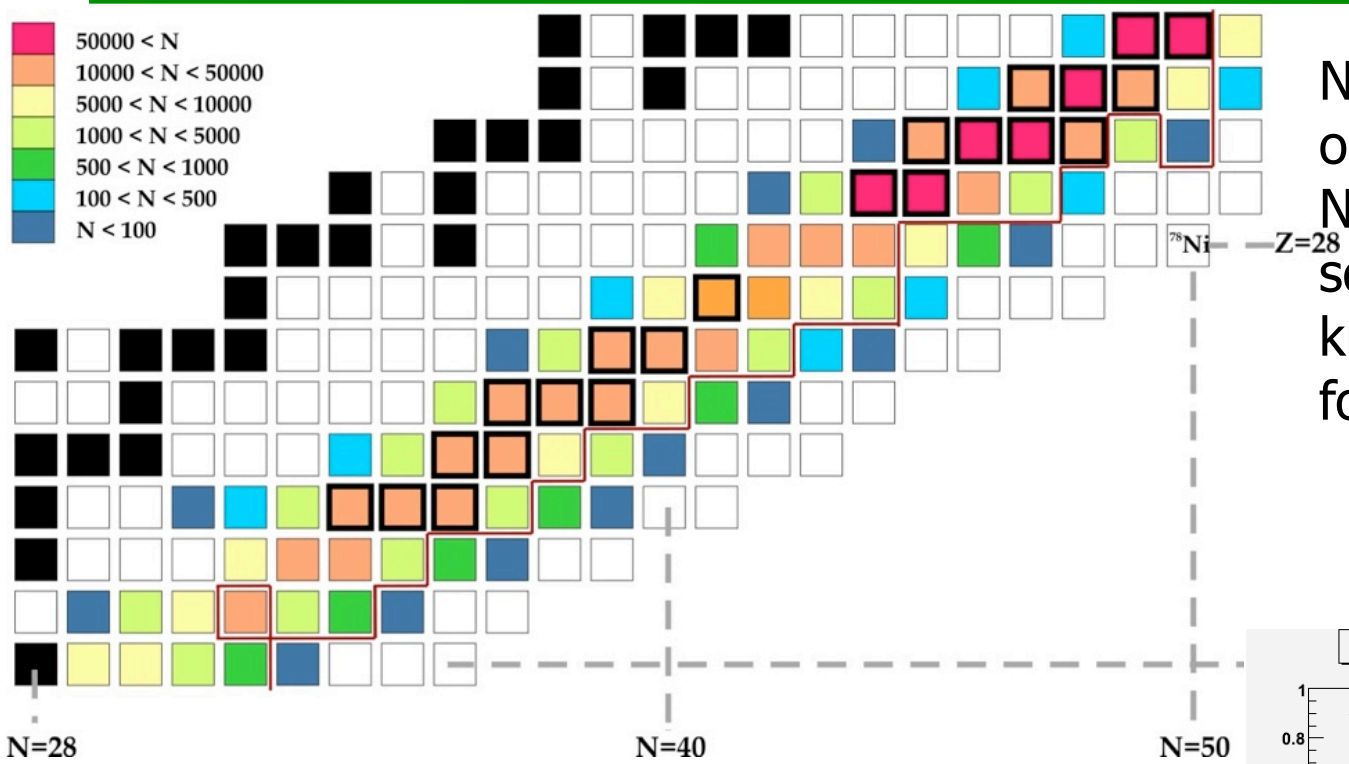
Production of neutron rich fragments

Alternating between Be production targets of different thickness allowed us to produce a large variety of isotopes (**calibration + unknown masses**) without any further change to the experimental set up.





Preliminary results



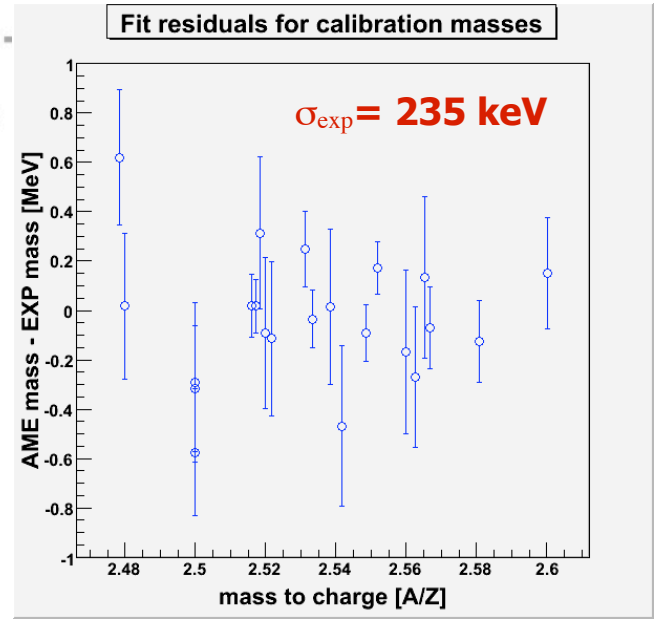
Limit for experimentally known masses in latest Atomic Mass Evaluation (AME2003)

Number of events observed during recent NSCL experiment. Bold squares indicate the 22 known masses used for calibration.

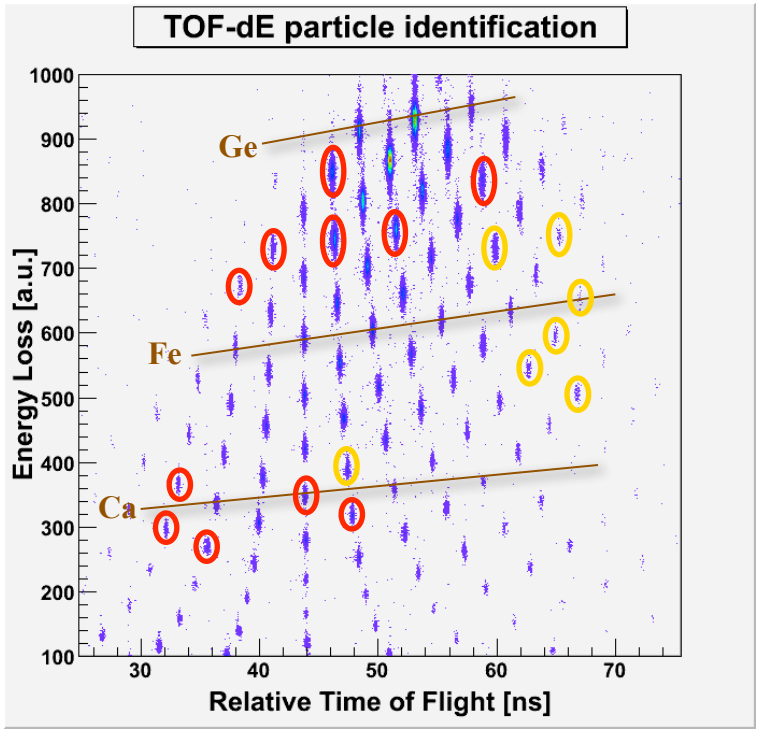
Mass calibration function:

$$\frac{m}{q} = \frac{B\varrho\,(P0\,(P14\,TOF_{offset} + TOF_{\exp}) - \Delta tof)}{\gamma\,L}$$

$$\Delta tof = f\left(\Delta E, Z^3, \left(\frac{A}{Z}\right)^3\right)$$



Conclusion



- known masses (error < 30 keV)
- unknown masses (AME2003): 53Sc, 61V, 63Cr, 66Mn, 69Fe, 72Co, 73Ni, 74Ni

- We've demonstrated the feasibility of TOF mass measurements at the NSCL.
- Further analysis in progress to better understand systematic of experimental setup and test mass calibration function.
- Next generation heavy ion facility (ISF) would allow us to extend mass measurements towards drip line.

Thanks!!

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web: **http://groups.nscl.msu.edu/nero/**