# Compact step-range filters for charged particle spectroscopy on the NIF

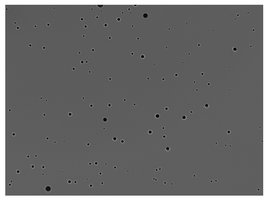
T. M. Johnson[1], B. Lahmann[1], A. Birkel[1], J. A. Pearcy[1], G. D. Sutcliffe[1], N. V. Kabadi[1], J. H. Kumimune[1], B. L. Reichelt[1], T. Evans[1], S. G. Dannhoff[1], C. W. Chung[1], M. Gatu Johnson[1], J. A. Frenje[1], T. Sarginson[2], C. M. Hardy[2], C. T. Casey[2], A. B. Zylstra[2], C. K. Li[1]

*[1]Massachusetts Institute of Technology, Plasma Science and Fusion Center*
*[2]Lawrence Livermove National Laboratory*

National Nuclear Security Administration

MIT PSFC

## SRFs use the properties of CR39 to convert particle track diameters into particle energies

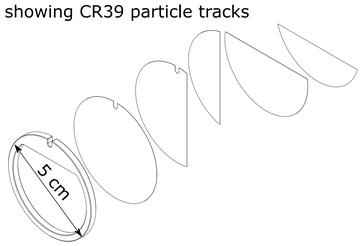


Example microscope frame showing CR39 particle tracks

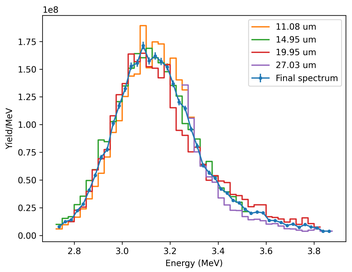
Charged particles passing through CR39 leave trails of broken molecular bonds.

High energy particles leave smaller tracks while low energy particles (~1 MeV) leave large tracks.

The relationship between particle energy and track diameter varies from piece to piece of CR39.




Schematic of an SRF. Filters of different thicknesses overlap to make the windows have different energy coverages.

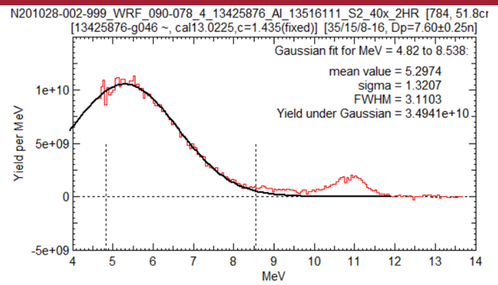



The main deliverable of the SRF is a charged particle spectrum.

From the spectrum, total yield, spectral width, and areal density can be extracted.

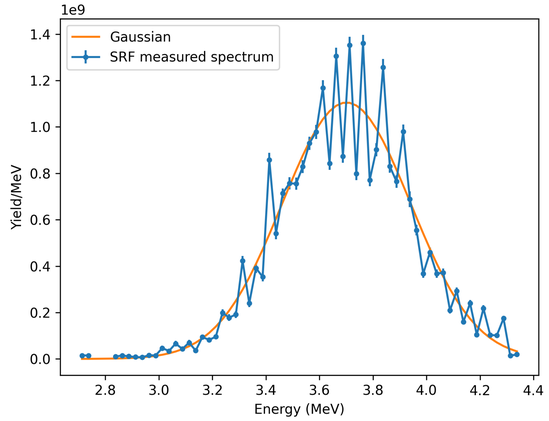
SRFs have the ability to measure arbitrarily shaped charged particle spectra. This is done by finding the relationship between diameter and energy that maximizes window overlap. Redundancy in the window energy coverage is essential for this analysis technique.

## Commonly used charged particle spectrometers fail to capture the compression $D^3He$ compression peak



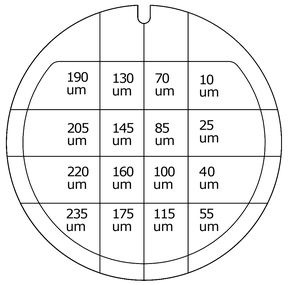

The $D^3He$ proton compression spectrum is important for diagnosing surrogate implosion areal density. The low energy coverage of the SRF make it well suited for this measurement.

## SRFs can measure DD proton spectra to low energies on the NIF




SRF DD-p spectrum measured on proton radiography Discovery Science shot. The energy upshift is consistent with $D^3He$-p spectrum and pTOF particle bang time measurements.

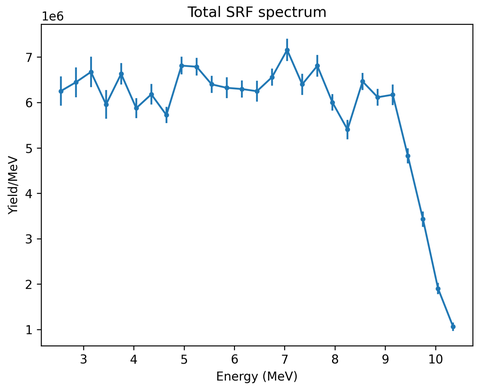
## SRFs can be easily customized to make specific measurements such as the $^3He^3He$ proton spectrum




This SRF was designed to have a wide energy range coverage while still having enough statistics on each window.

It can cover energies between 2 and 12 MeV.

This energy range is important for the $^3He^3He$ proton spectrum.




Preliminary $^3He^3He$ proton spectrum measured on OMEGA. Previous experiments used WRF spectrometers to measure down to about 6 MeV. Theoretical models for this spectrum are particularly sensitive to the low energy portion of the spectrum.

## New mechanical design helps to protect the SRFs on the NIF and could allow for filter calibration

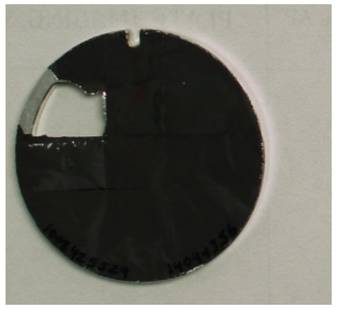
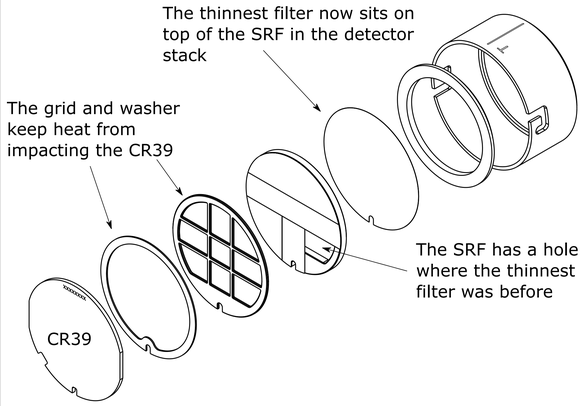


Photo shows post-shot destroyed SRF

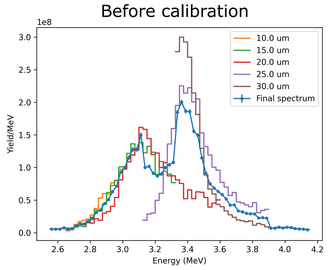
The high energy environment of the NIF is hostile to thin tantalum filters.

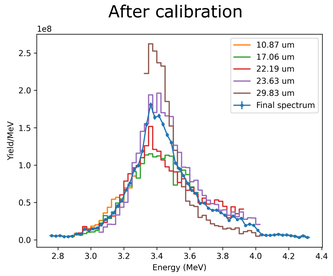
Previous designs with the best low energy coverage suffer from severe damage.

A new idea is to separate the thinnest filter from the rest of the filters making it replaceable.




## With the SRFs surviving the shot, the filters can be calibrated on an accelerator to reduce uncertainty



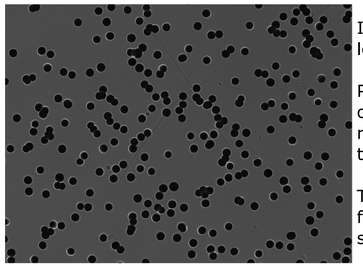

The manufacturer quotes filter thickness uncertainties from 15% to 25%.

The actual filter thickness can be determined by comparing the accelerator SRF spectrum to a known accelerator SBD spectrum.

A montecarlo method is used to vary filter thicknesses until the mean energy and width match the SBD spectrum.

Data on the left shows accelerator DD proton spectra.

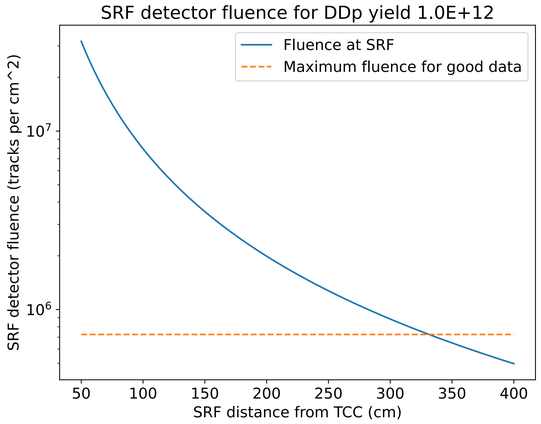
## Modified DIM design could let SRFs operate at higher yields

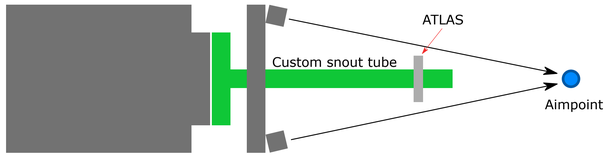


Information on the CR39 is lost at high fluence.

Particle tracks start to overlap and artificially reduce the yield and modify the track diameters.

This limits the data quality from SRFs on high yield shots.




New DIM design with custom snout would allow for the SRFs to be farther away from the implosion and let it operate at higher yields. Increasing standoff distance would also help with survivability of the SRF especially on indirect drive shots.

## References

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A. Zylstra, et al., Nucl. Instrum. Methods Phys. Res., 2012

## Acknowledgements

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