Improved signal-to-background utilizing coincidence counting of charged particle tracks in CR-39

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Abstract

CR-39 has proven invaluable for diagnosing implosions due to its EMP-insensitivity, but it is slightly sensitive to neutrons, some of which masquerade as signal events. While this is not a problem for many conventional nuclear diagnostics at OMEGA, it is desirable to deal with it for the Magnetic Recoil Spectrometer (MRS) and the neutron Wedge Range Filter Spectrometer (nWRF) that are currently being developed at OMEGA.

Orders-of-magnitude increased rejection of neutron CR-39 events can be accomplished by performing coincidence counting on the front and back sides of CR-39: Since only signal protons that penetrate the CR-39 will leave spatially coincident pairs of tracks on both sides, neutron-induced tracks can be discarded. We are currently developing this coincidence counting technique to lower the background level in CR-39 data. This poster presents the current status of this project.

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Outline

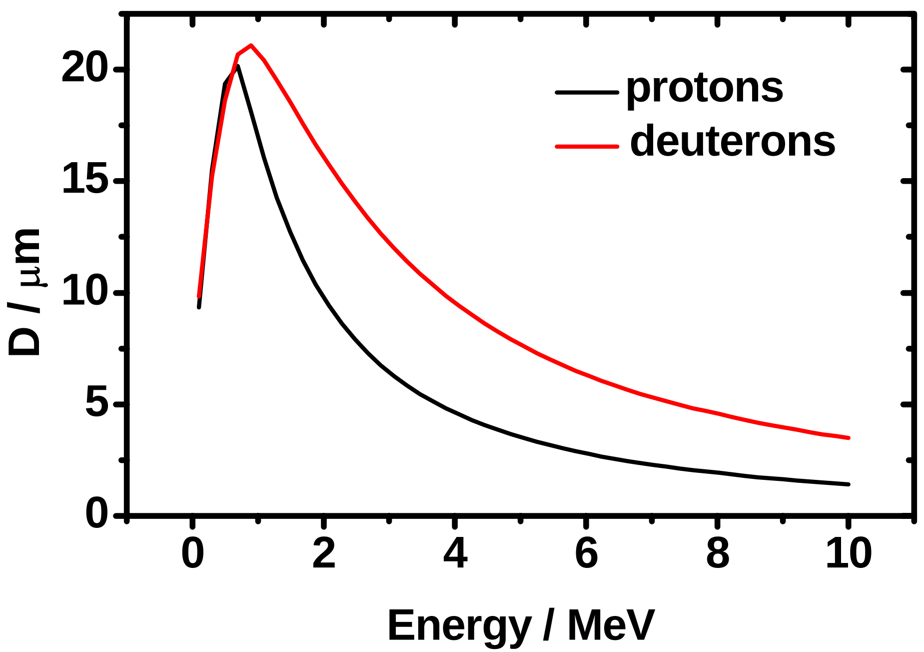
- Introduction to the Coincidence Counting Technique (CCT):
  - Charged particle track detection with CR-39
  - The principle of coincidence counting of signal tracks in thin CR-39
  - The principle of rejecting background tracks using the CCT
  - The CCT is more effective for deuterons than for protons
- Experimental study of the CCT:
  - Microscope images of the CR-39 front and back sides
  - Track diameter distributions on the front and back side
  - Measured and predicted correlation radius distribution
- Motivation for coincidence counting: Application of the CCT to data with high neutron background
  - The Magnetic Recoil Spectrometer (MRS)**
  - The neutron Wedge Range Filter spectrometer (nWRF)
- Summary

**J.A. Frenje et al., QO3.00010, J. A Frenje et al., Rev. Sci. Instrum 72, 854 (2001).

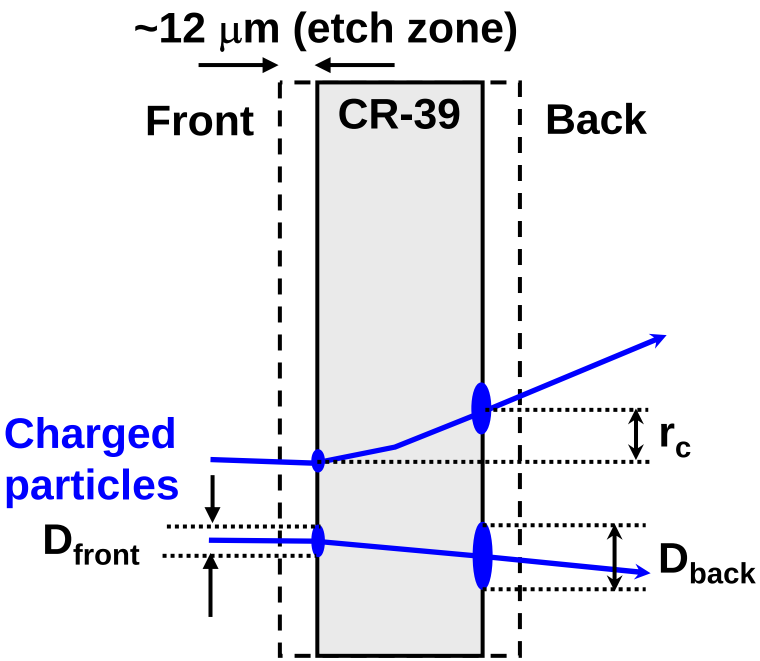
Charged particle track detection with CR-39

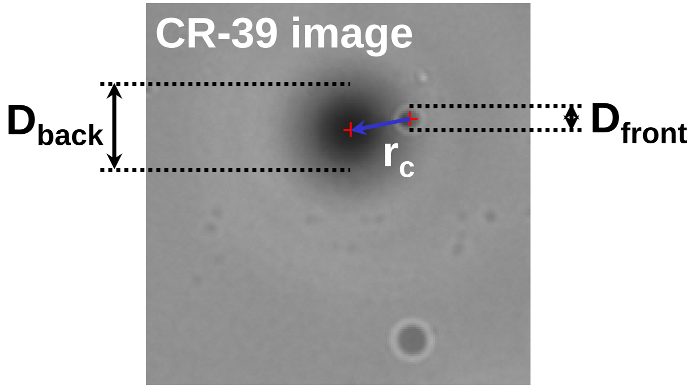
- Charged particles leave tracks of damage while passing through CR-39 ($C_{12}H_{18}O_7$).
- Conical holes (tracks) are formed along the tracks during etching.
- Track diameter (D) depends on particle, particle energy, and etch time.

6 h etch in 6M NaOH



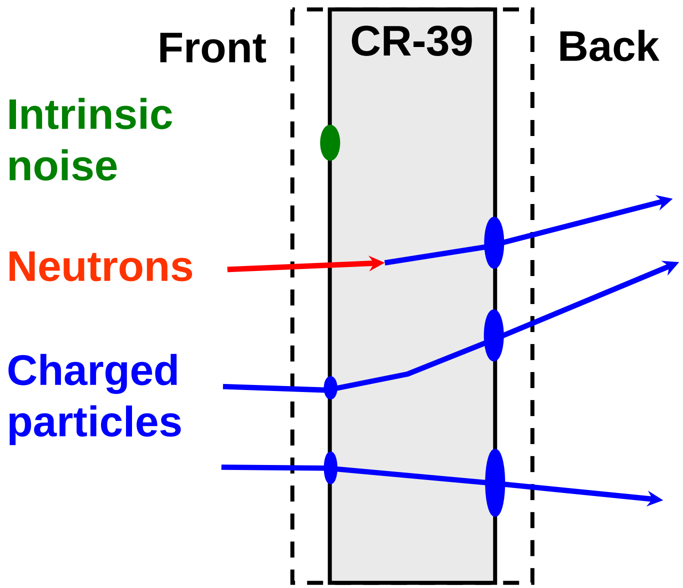
The principle of coincidence counting of signal tracks in thin CR-39 (100-300 μm)

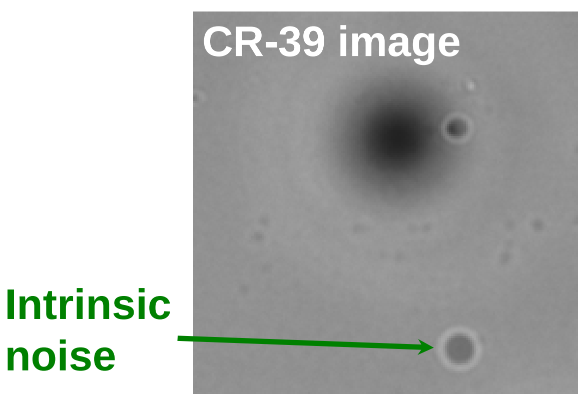




- **Charged particles of sufficiently high energy penetrate the CR-39 and leave tracks on front and back sides with diameters D_{front} and D_{back}, respectively.**
- **Non-perpendicular incidence and straggling in CR-39 cause lateral displacement between front and back side tracks (→ correlation radius r_c).**
- **The parameters r_c, D_{front}, D_{back} (and track contrast) are used as constraints in the search of correlated tracks on the front and back side.**

The principle of rejecting background tracks using the CCT





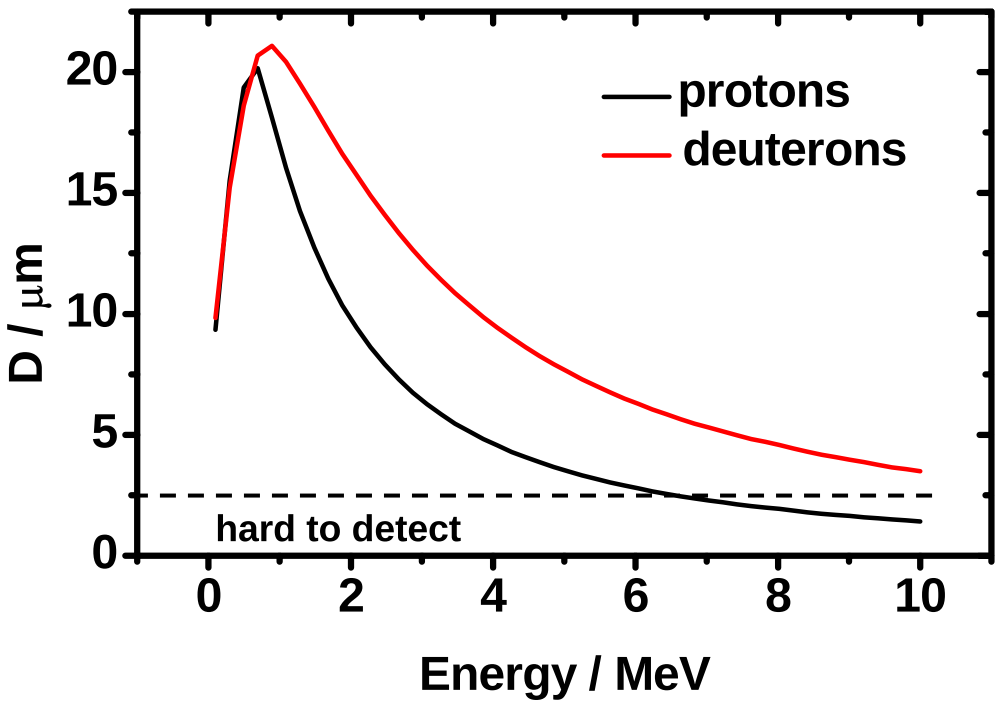
- **Neutron-induced tracks and intrinsic noise can be effectively rejected using the CCT, since they do not leave tracks on both sides of the CR-39.**

- **For increasing background track densities, the probability for random coincidences of front and backside tracks increases.**

- **Most neutrons penetrate the CR-39 without interacting (detection efficiency is of order 10^{-4}**).**

****J. A Frenje et al., Rev. Sci. Instrum 73, 2597 (2002).**

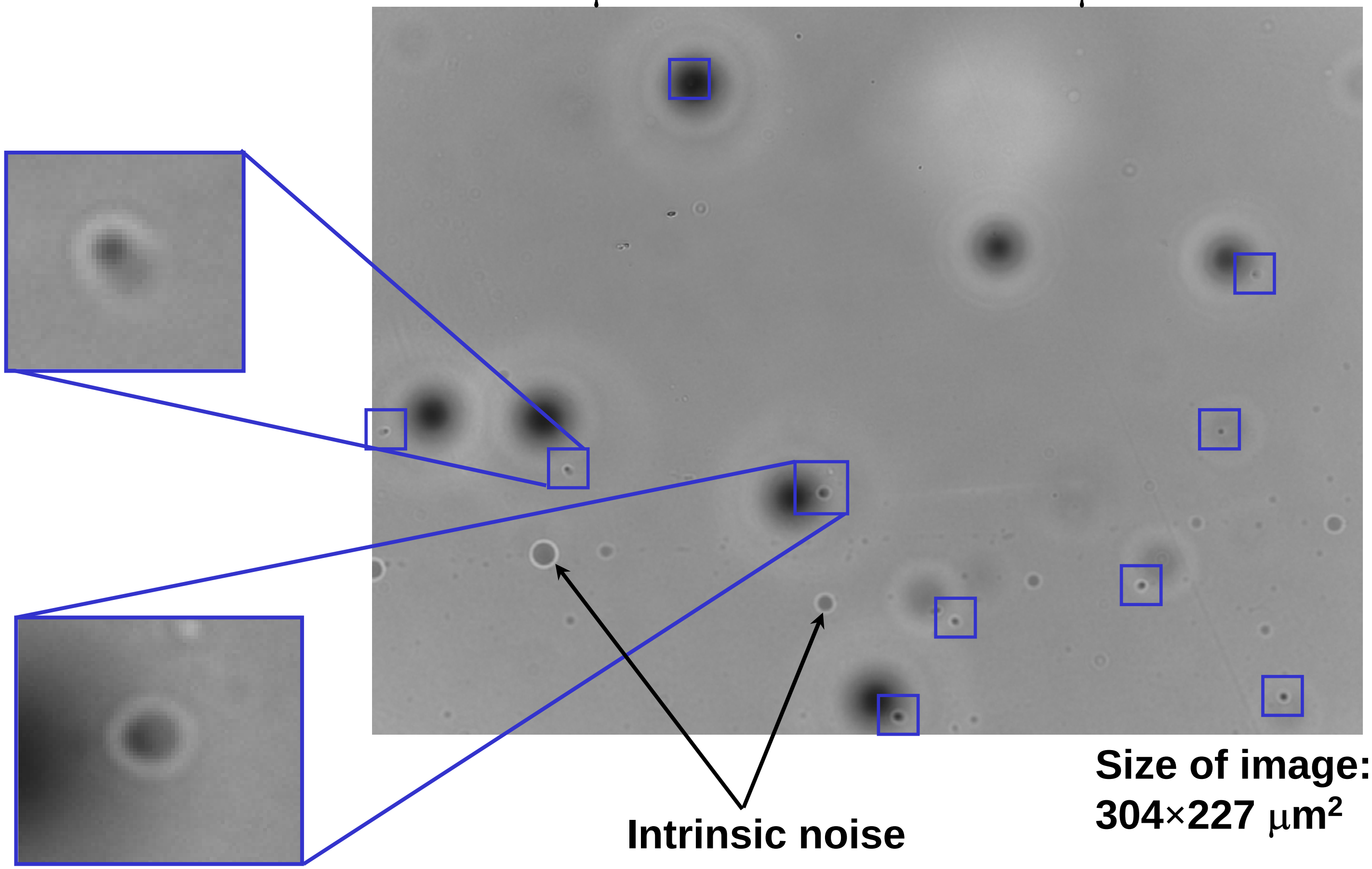
The CCT is more effective when applied to deuterons than to protons



- **Protons of energies above 6 MeV produce very small tracks and are not easily detectable. → Filtering is required to reach optimal energy range.**
- **Deuterons produce larger, more visible tracks. → Considerably less filtering is needed, resulting in less straggling and smaller correlation radii.**

A microscope image of the CR-39 front side

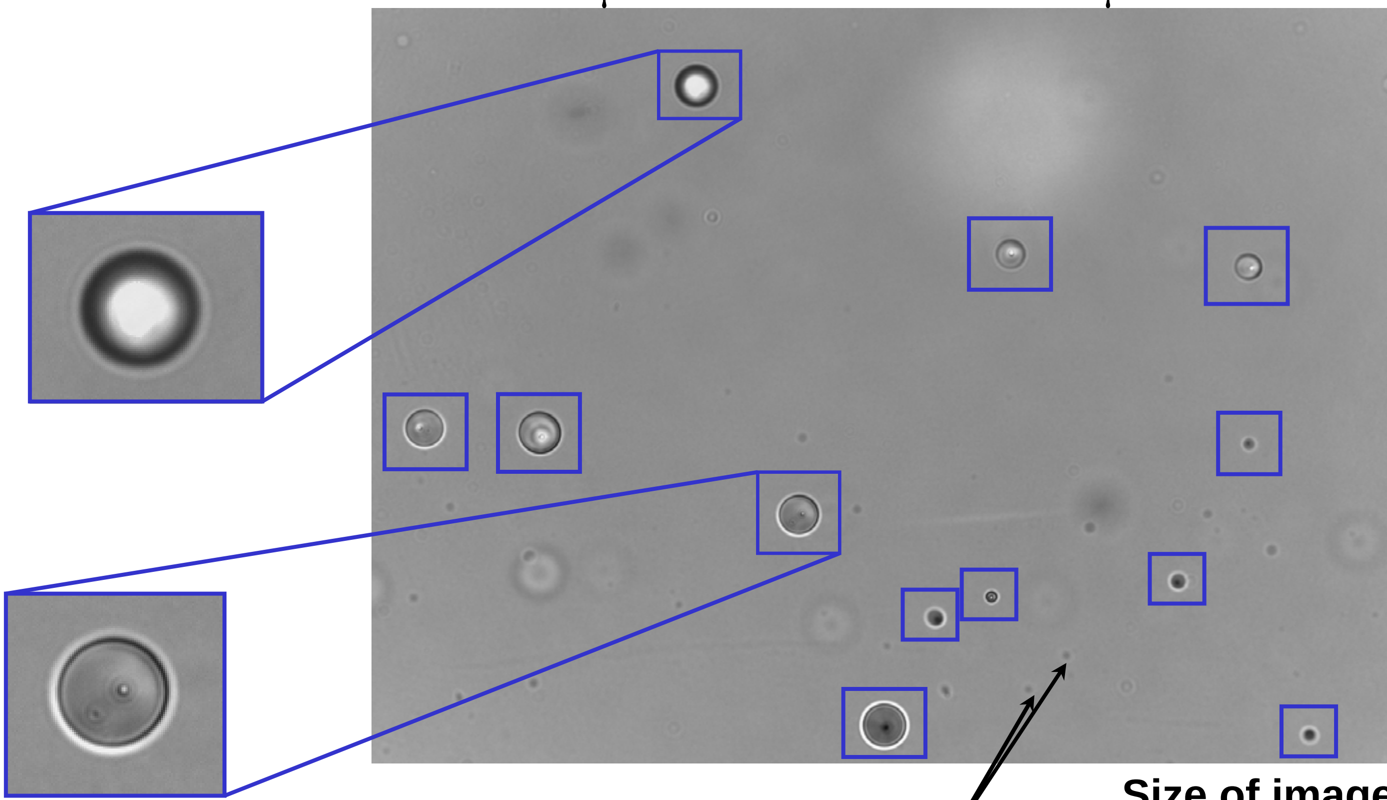
Typical front side D^3He-proton tracks
for 100 μm CR-39 behind a 1100 μm Al filter



Size of image:
304×227 μm^2

A microscope image of the CR-39 back side

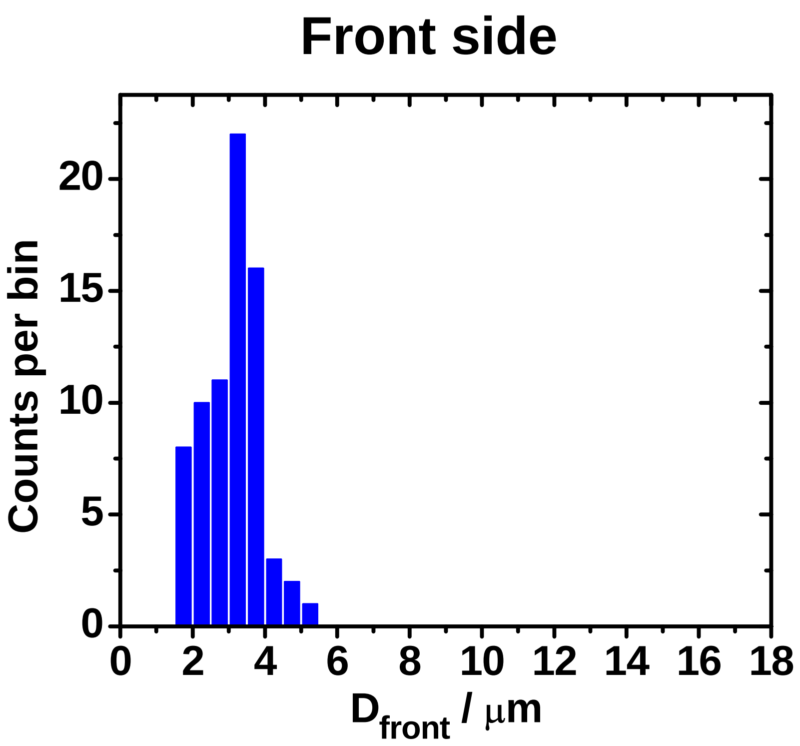
Typical backside D^3He-proton tracks
for 100 μm CR-39 behind a 1100 μm Al filter

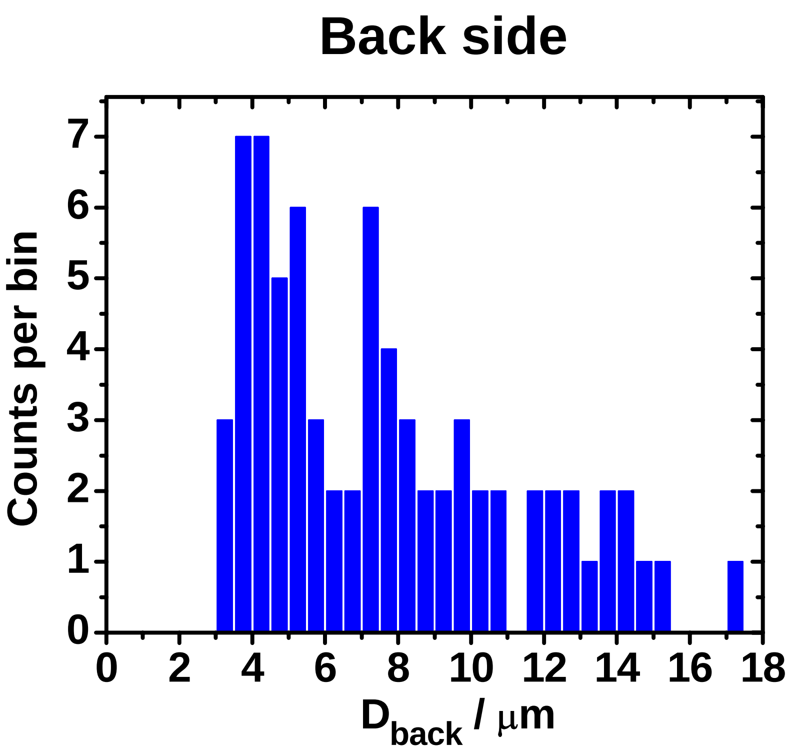


Intrinsic noise

Size of image:
304×227 μm^2

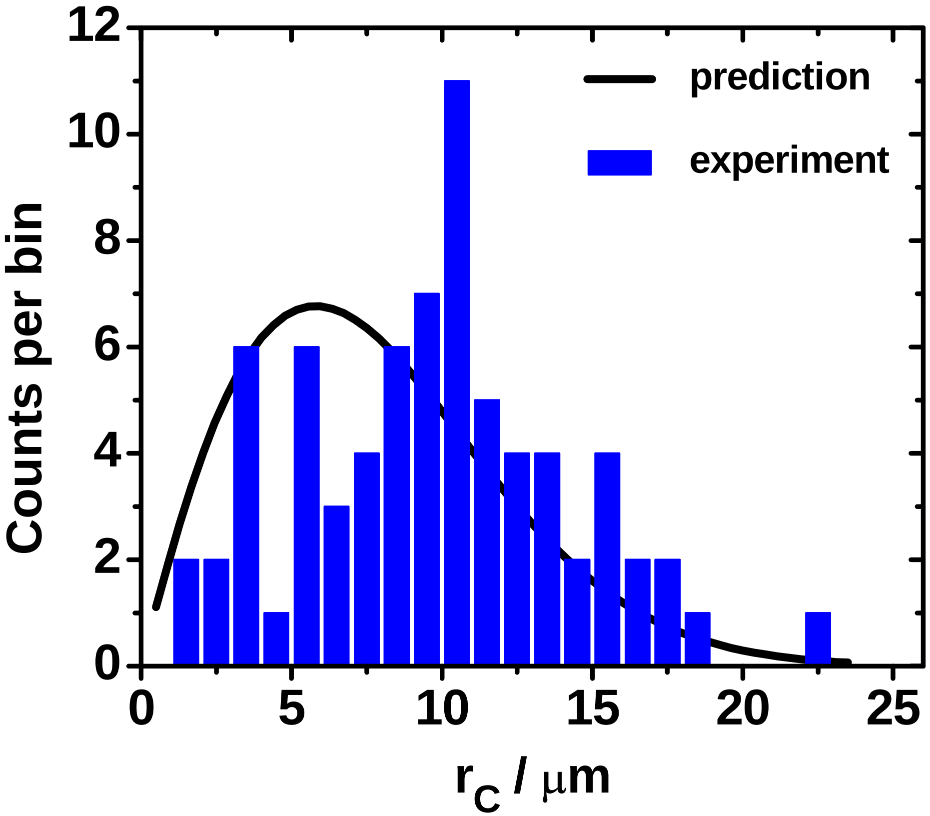
Track diameter distributions on the front and back side





	Experimental	Prediction
$\langle D_{front} \rangle$	3.1 μm	4.7 μm
$\langle D_{back} \rangle$	7.7 μm	7.4 μm

Measured correlation radius distribution [f(r_c)] agrees well with the prediction



Application of the CCT to data with high neutron background

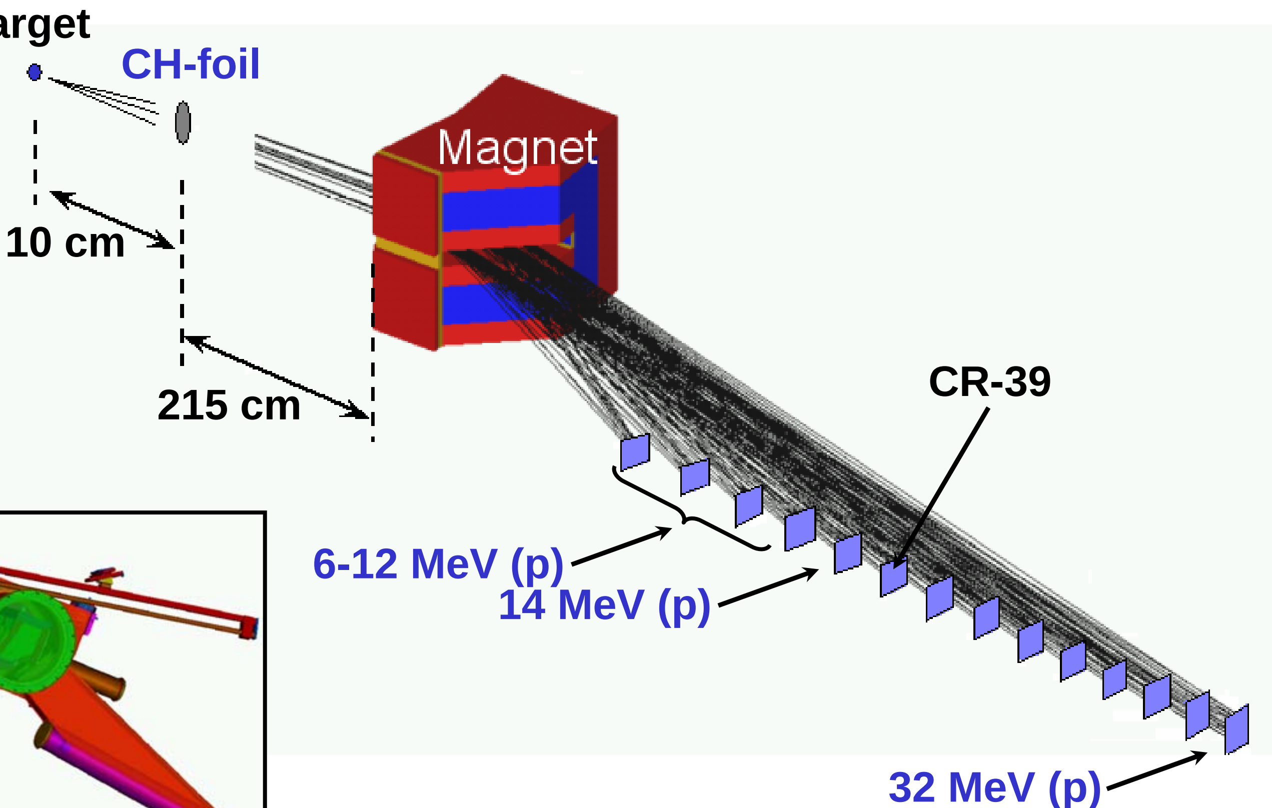
CCT is generally applicable to CR-39 based charged particle diagnostics for the purpose of significantly reducing the neutron induced background.

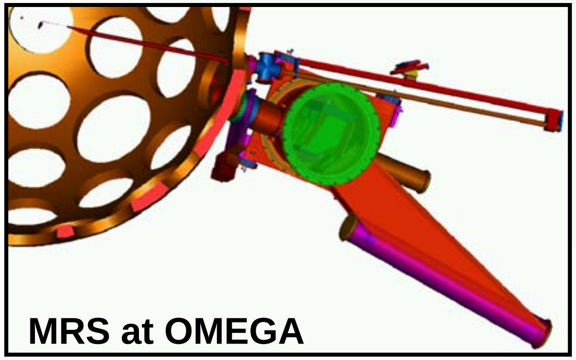
Of particular relevance are:

- **The Magnetic Recoil Spectrometer (MRS).**
- **The neutron Wedge Range Filter (nWRF) spectrometer.**

The magnetic recoil spectrometer (MRS) for measurements of down-scattered neutrons at OMEGA

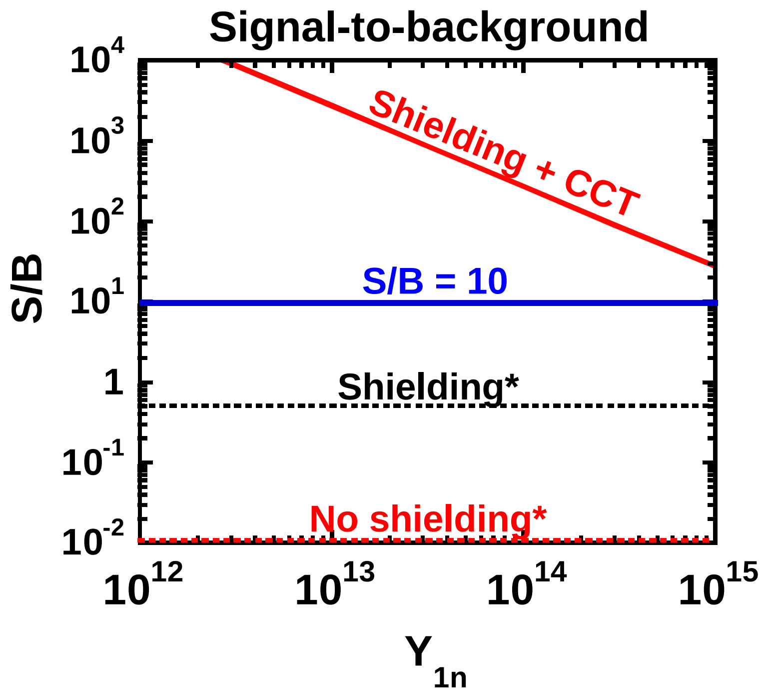
Minimizing neutron background is necessary for the implementation of the MRS





**J.A. Frenje et al., QO3.00010, J. A Frenje et al., Rev. Sci. Instrum 72, 854 (2001).

CCT* + MRS shielding point design** increases S/B >>10 for the down-scattered neutron measurements at OMEGA



The signal-to-background (S/B) ratio depends on correlation radius (r_c) and primary yield (Y_{1n}):

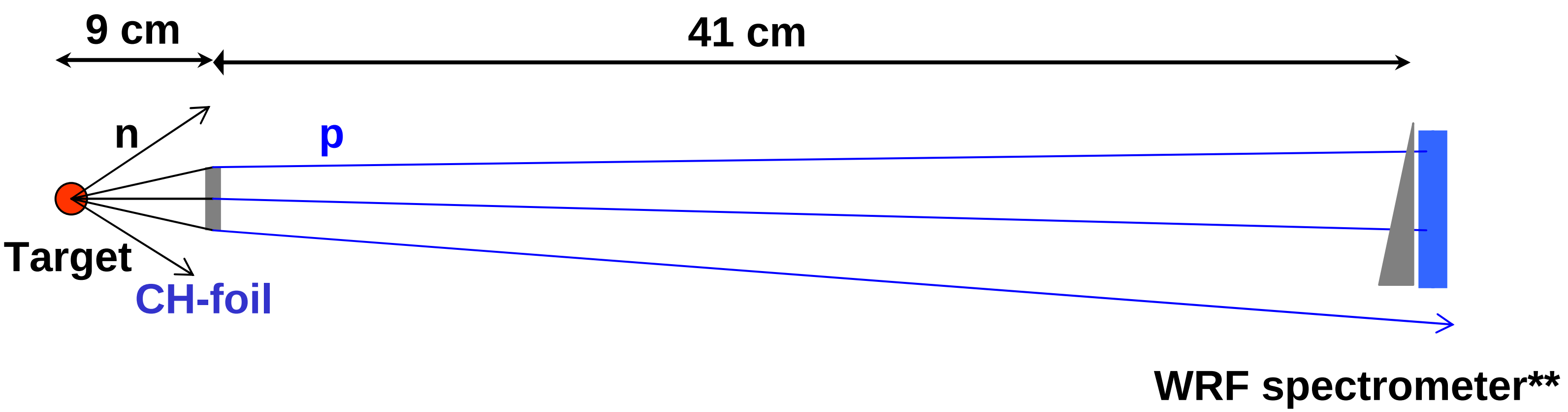
$$\frac{S}{B} \sim \frac{1}{Y_{1n} \cdot r_c^2}$$

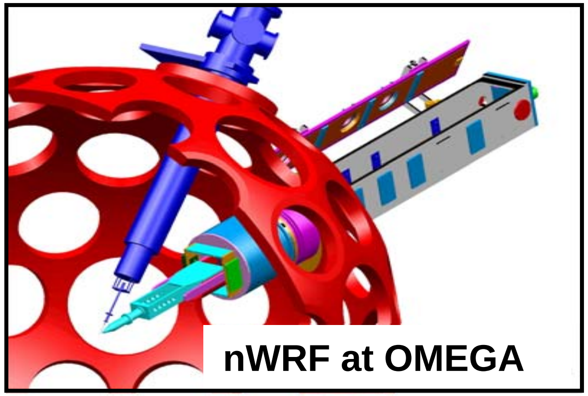
The depicted S/B is based on the simplest implementation of the CCT: counting of correlated tracks and random coincidences without considering the track diameters or other characteristics (e.g. contrast). Including this information can further increase the S/B obtained with the CCT.

* The CCT is not required at the NIF, since extensive shielding will protect the MRS.
** D.T. Casey et al., FP1.00009.

The neutron Wedge Range Filter (nWRF) spectrometer for neutron measurements in high EMP environments

The CCT significantly improves the performance of the nWRF spectrometer



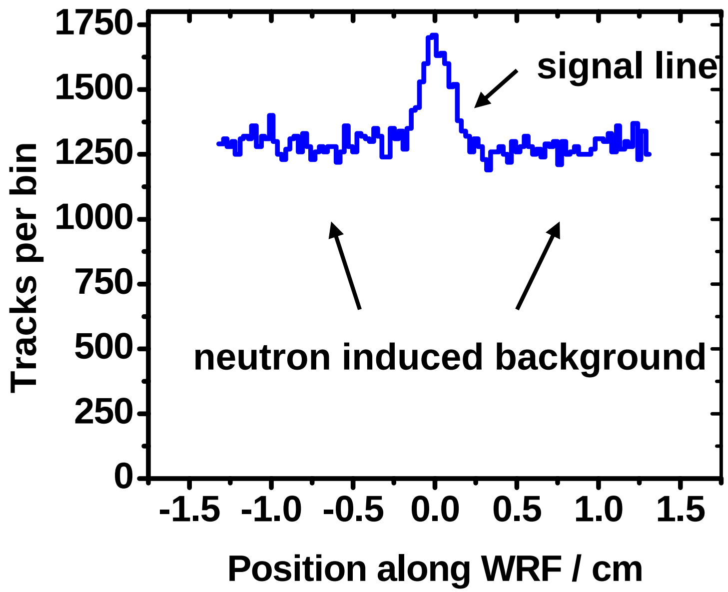


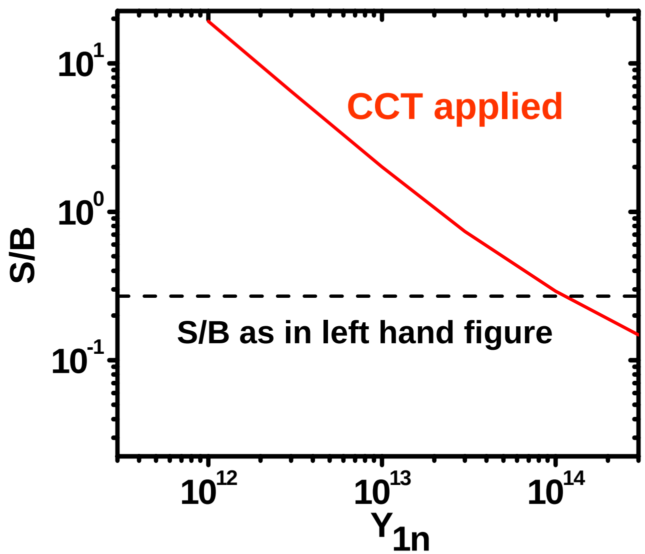
nWRF at OMEGA

** F.H.Seguin et al., Rev. Sci Instrum. 72 (2001) 854.

CCT increases S/B in the nWRF data by a factor 7 for a primary neutron yield of 10^{13}

- First nWRF data from a proof of principle experiment ($Y_{n1}= 5{\cdot}10^{13}$) shows that an increase in S/B is desirable (left figure).
- The CCT in its simplest implementation (right figure) improves S/B only slightly. An S/B increase of an order of magnitude or more can be achieved by including information about track diameters and contrast.





- Optimizing the experimental setup and changing the WRF material (to for instance Tantalum) will further reduce the background level.

Summary

- **The coincidence counting technique (CCT) utilizes thin CR-39 (100 – 300 μm) for detection of charged particle track pairs on its front and back sides, and, as a consequence thereof, for the rejection of uncorrelated neutron background tracks.**

- **The first proof-of-principle experiment demonstrates that CCT is feasible.**

- **Quantitative comparisons of these experimental data with numerical calculations show:**
  - **We have a fairly good understanding of the proton track diameter distributions on the front and back side of the CR-39.**
  - **The measured correlation radius distribution agrees well with the calculated.**

- **Implementation of the CCT can increase the S/B in the MRS data taken at OMEGA by orders of magnitude.**

- **The benefit of the CCT can be increased by including information about the track diameters and contrast, and exploiting the favorable properties of deuterons.**