Cross-section measurements for knockout reactions

Vasily Volkov

S341 Experiment

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TU Darmstadt / GSI Darmstadt / TU München /
U Santiago de Compostela/U Bratislava

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Experimental proposal S341

- Title: **Neutron Knockout Reactions from Proton-rich Carbon Isotopes**

- Spokesperson: Joachim **Enders**, TU Darmstadt

- GSI Contact Person: Helmut **Weick**, GSI Darmstadt

- Year of Approval: 2007 (A)

- Shifts: **7** approved (6 main + 1 parasitic)
  - 7 used (6main + 1parasitic)
  - 0 left (0 main + 0 parasitic)

Motivation: Spectroscopic factors

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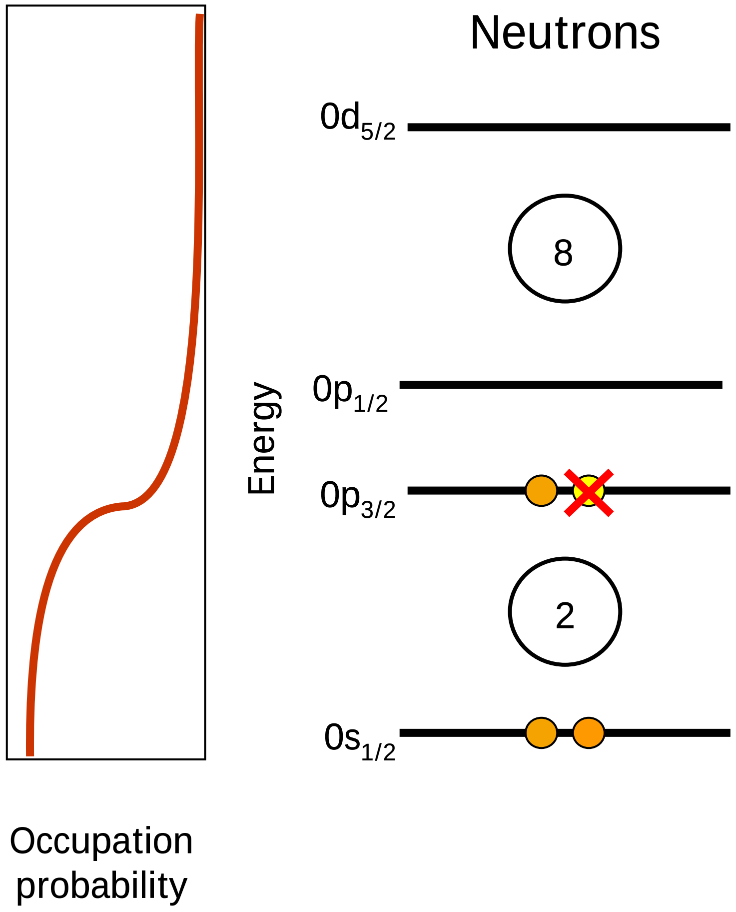
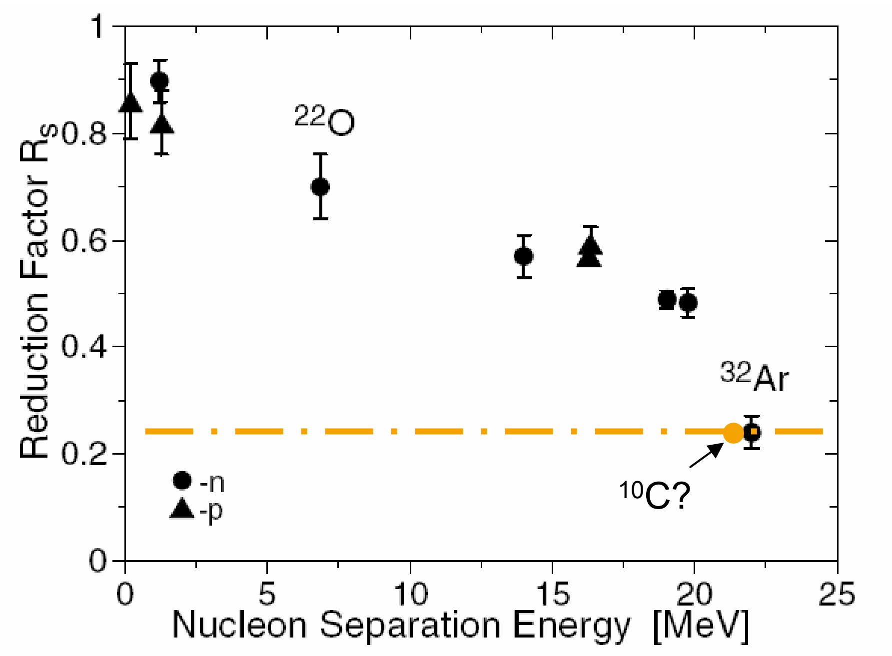


- **Spectroscopic factors**
  - occupation probability depends on binding energy
  - experimental access
    - – transfer reactions
    - – electron-induced knockout
    - – nucleus-induced knockout
    - – nucleon-induced knockout

- **Knockout from ^{10}C/^{11}C**
  - learn about evolution of spectroscopic factors in the deeply-bound $0p_{3/2}$ neutron shell

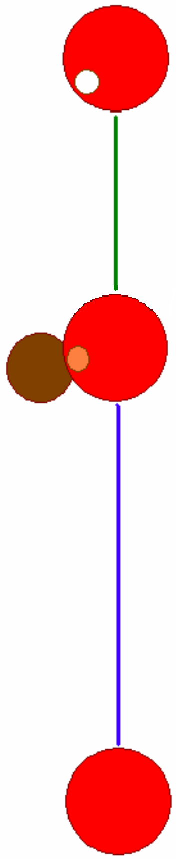
One-nucleon knockout

A. Gade et al., PRL 93 (2004) 024501



- Quenching of spectroscopic factors
  - Experimental spectroscopic factors smaller than predicted within the shell model
- Mass region accessible by ab-initio models
- More data for the large separation energies needed

One-nucleon knockout reactions



- **Reaction of type $^{9}Be(^{10}C,^{9}C)X$**
  - inclusive reaction only if nuclear structure of the residue is „simple“
  - only one bound state in ^{9}C
- **High sensitivity**
  - fast beams, thick targets
    - measure small cross sections
    - low incident beam intensities
- **Eikonal approximation appropriate**
  for describing the reaction mechanism
  - reliable extraction of spectroscopic factorsx

Motivation: two-neutrons knockout

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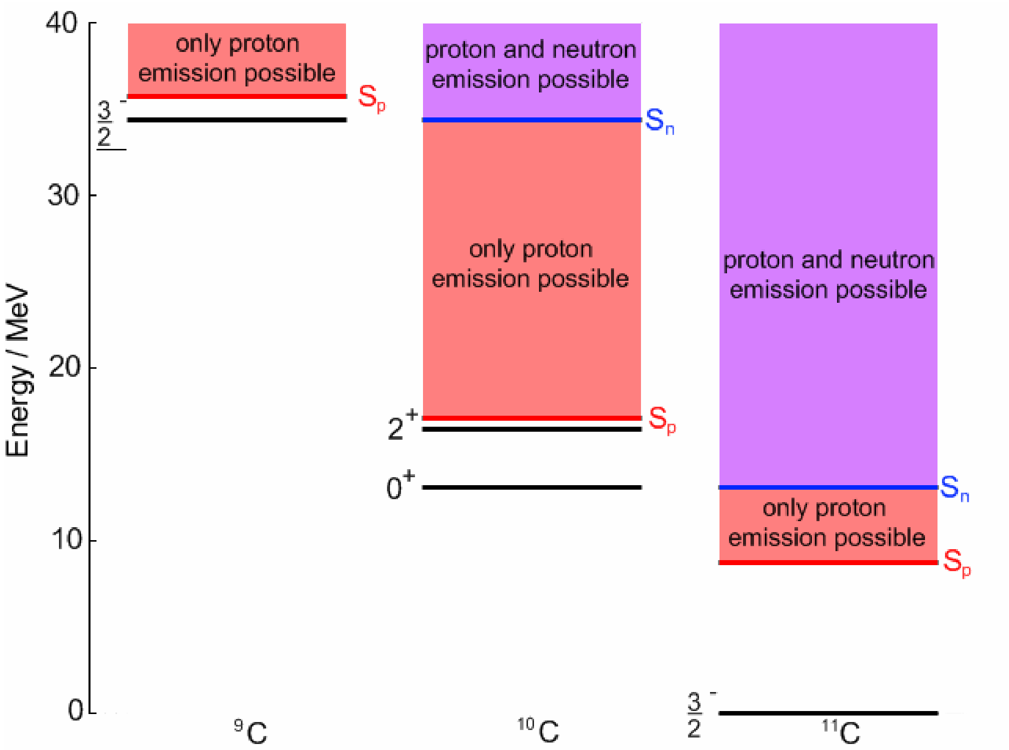

- Direct reaction or not?
- Cross-section
- Spectroscopic factor?

Image** taken from Bachelor diploma paper 'Two-Neutron Knockout Reactions from ^{11}C'* ***by Matthias Holl *(TUD, April 2009)*

Experimental Setup

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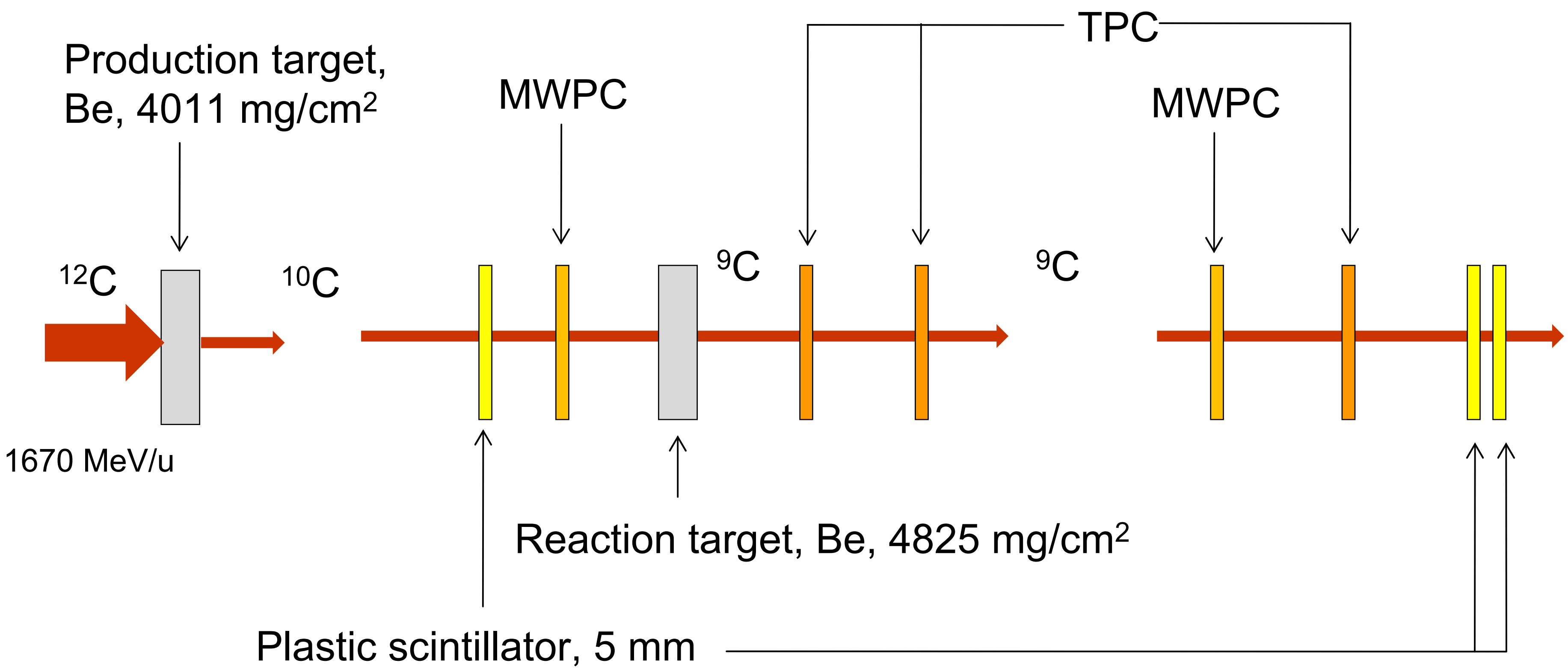
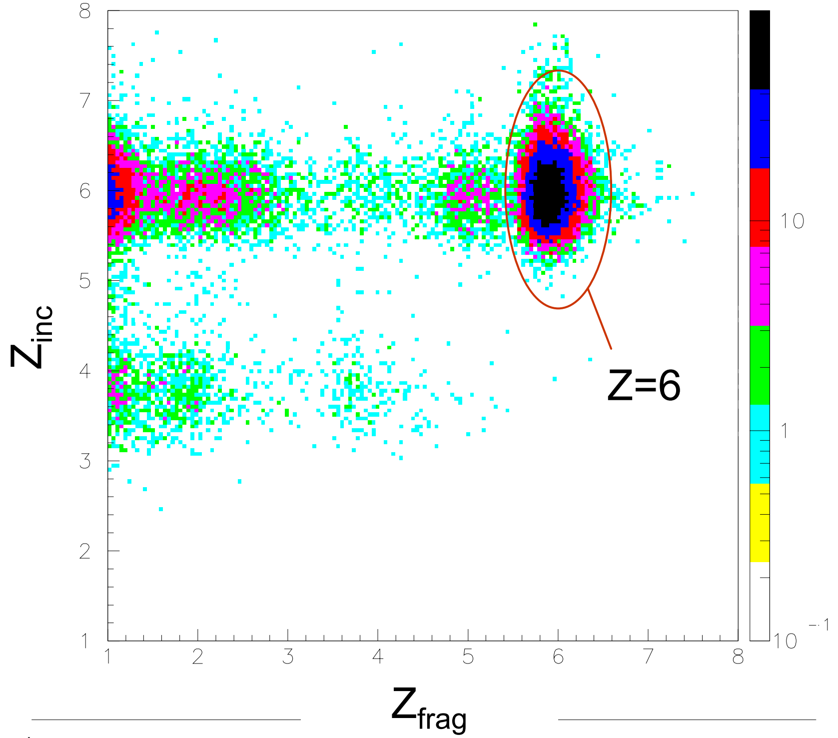
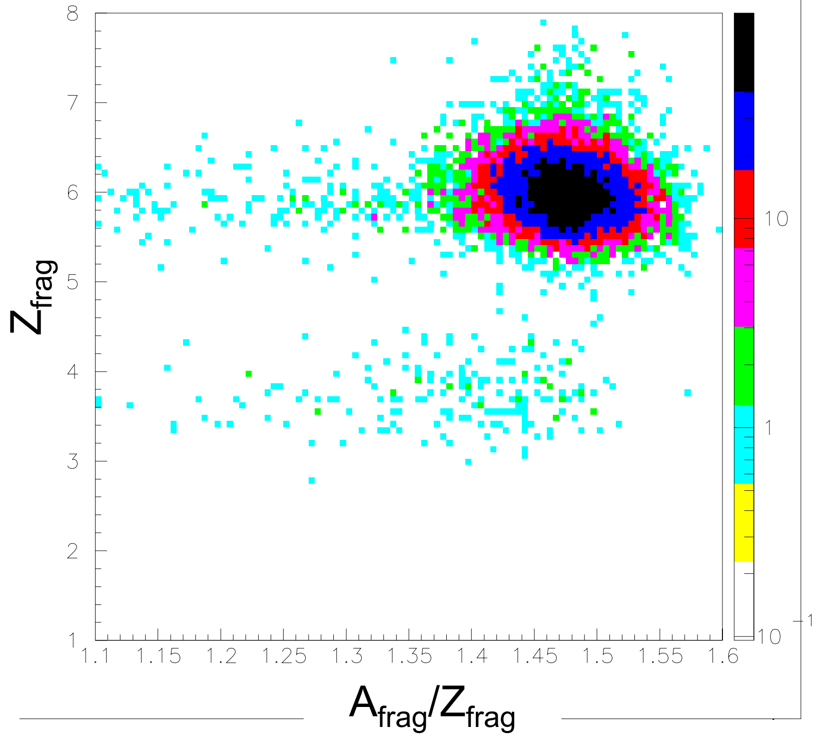


Particle identification

- Charge identification of incoming particles
- A/Z identification of the fragments





Measured cross-sections, one-neutron

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$$\sigma_{\exp} = \frac{\frac{N_s}{N_i} \cdot A}{N_A \cdot L \cdot \rho} =$$

$^{12}C \rightarrow {}^{11}C$	$^{11}C \rightarrow {}^{10}C$	$^{10}C \rightarrow {}^{9}C$
51 mb	*24 mb*	*21.4 mb ± 1.7 mb*

PRELIMINARY

Where:

N_s – number of scattered particles

N_i – number of incident particles

A – molar mass

$L \cdot \rho$ – target thickness in mg/cm^2

- Background from the matter in beamline substracted
- Corrected for the losses
- Corrected for the efficiency
- Corrected for the optical transmission

Theoretical prediction for $^{10}C \rightarrow {}^{9}C$

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(J.Tostevin, Priv.Com.)

23.4 mb

||

$$\sigma_{th} = \left(\frac{A}{A-1} \right)^2 \cdot C^2 S \cdot \sigma_{sp}$$

||

40.5 mb

(A. Brown, Priv.Com., Cohen-Kurath effective p-shell interaction)

Where:

A – atomic mass

C^2S – spectroscopic factor

σ_{sp} – single-particle cross-section

R_s – quenching factor

$$\boxed{C^2S = 1.7}$$

- The quenching factor obtained in the experiment is $R_s = 0{,}53$
- About 60% lower than predicted

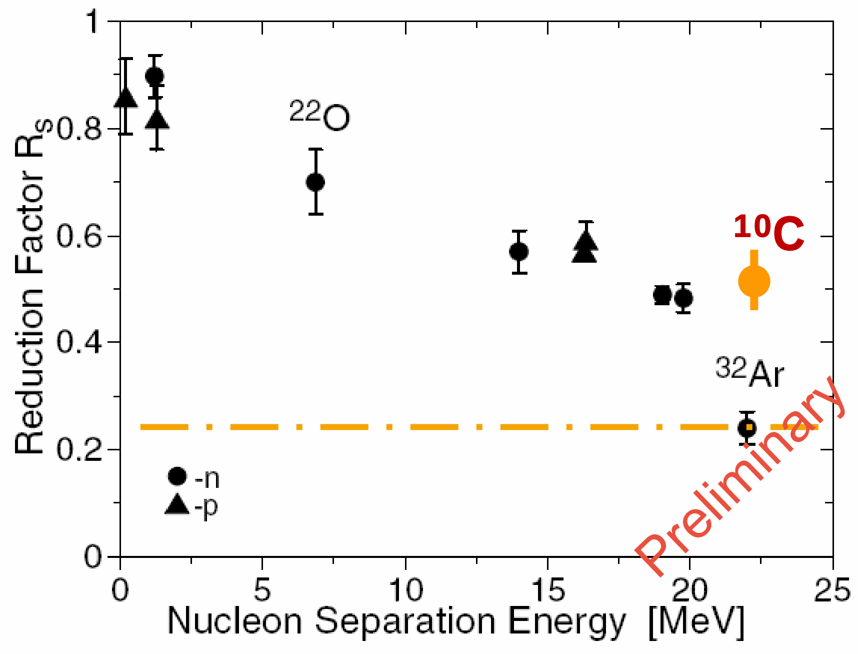
Comparison with theory

	CK	GFMC*
C^2S	1.73	1,04
R_s	0.53	0.88

**Green Function Monte-Carlo (R.B. Wiringa, Priv.Com)*

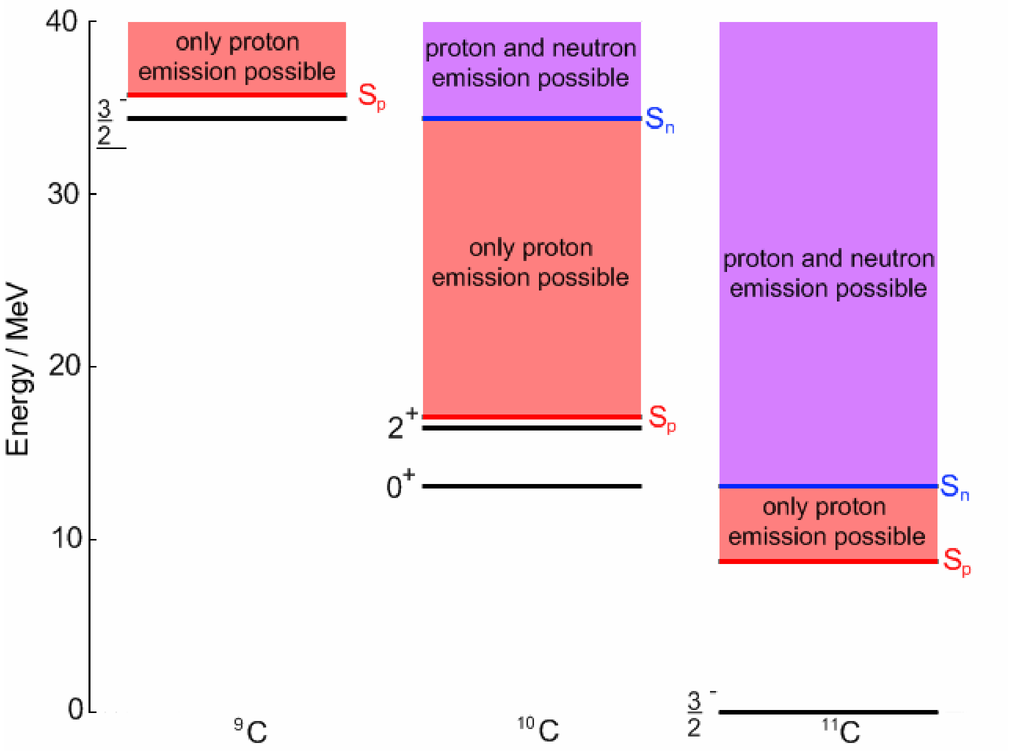
One-nucleon knockout

A. Gade et al., PRL 93 (2004) 024501



- Theoretically predicted quenching factor is larger
- Spectroscopic factor depends not only on binding energy
- Good agreement with Green Function Monte-Carlo ab-initio calculations
- Further datasets to be analysed

Two-nucleon knockout



Analysis, this and further images
*by **Matthias Holl***

Measured cross-section:

$$\sigma = (2.89 \pm 0.12) mb$$

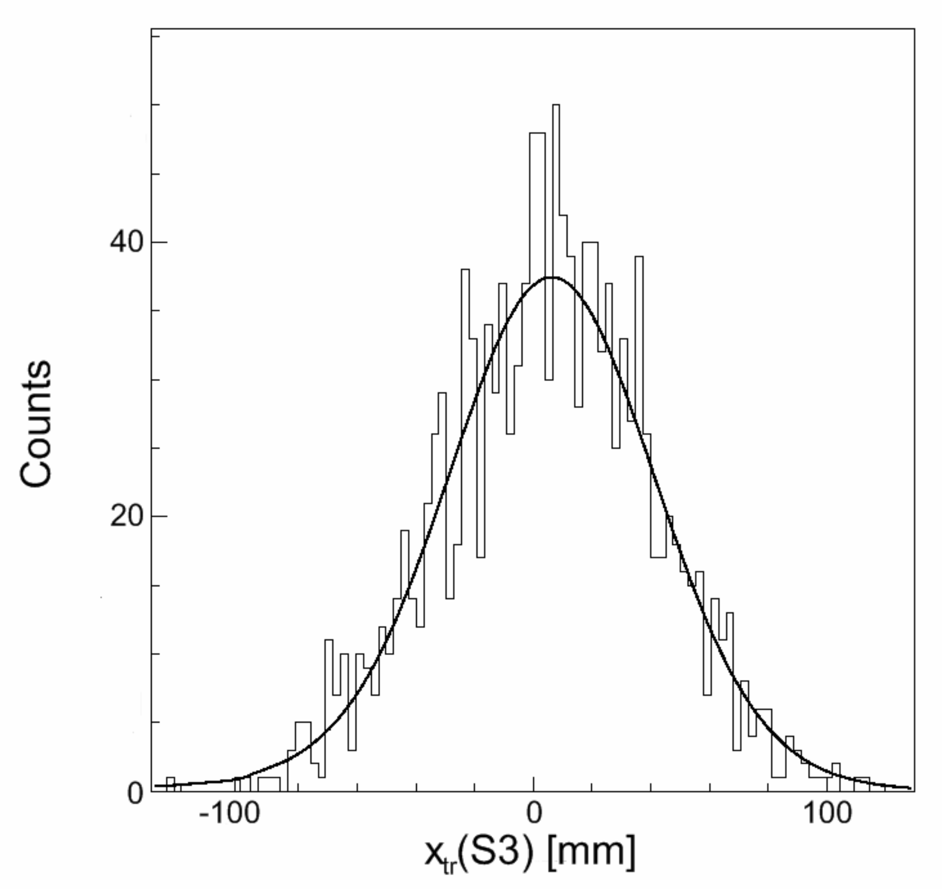
Quenching factor:

$$R_s = \sigma_{exp} / \sigma_{th} = 0.63 \pm 0.03$$

Two-proton cross-section:

$$\sigma = (8.40 \pm 0.31) mb$$

Two-neutron knockout: momentum distribution



Distribution width:

$$\sigma_{p,CM}=(132,98 \pm 6,48) MeV/c$$

Information on the reaction mechanism:

Comparison with sequential one-neutron knockout distributions

Sequential knockout of two neutrons

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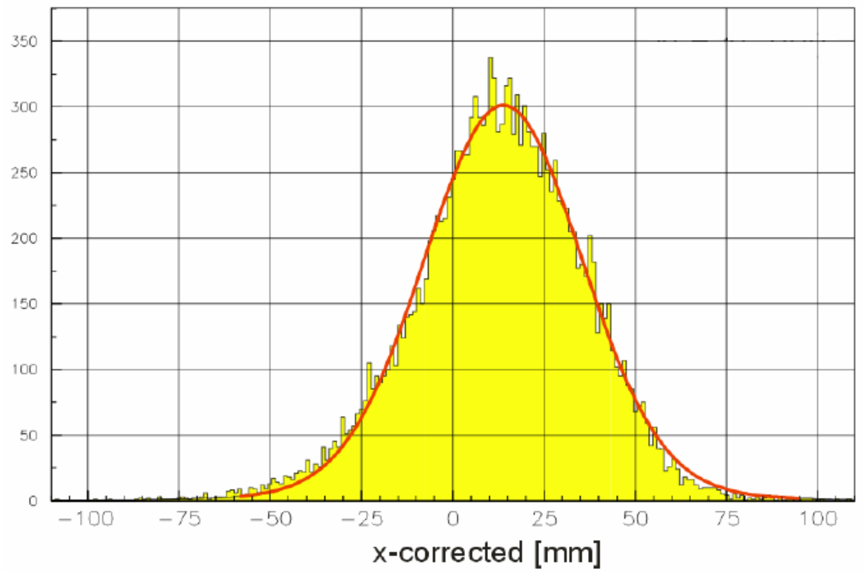
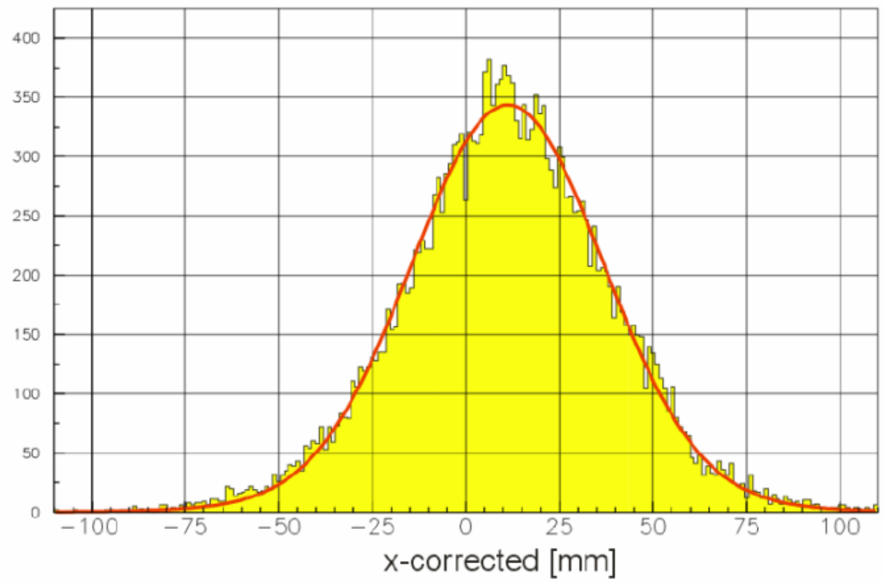
$^{9}Be(^{11}C,^{10}C)X$



$\sigma_p = (90.3 \pm 4.8) MeV/c$

$^{9}Be(^{10}C,^{9}C)X$



$\sigma_p = (97.2 \pm 3.4) MeV/c$

$$\sigma_p = \sqrt{90.3^2 + 97.2^2} \approx 132.5 \ MeV/c$$

Summary & Outlook

- Cross-sections measured for:

→ One-neutron knockout
→ Two-neutron knockout
→ Two-proton knockout

- Momentum distribution for two-neutron knockout studied

→ Two-neutron knockout found to be direct reaction

- To do:

→ Cross-section for $^{9}Be(^{9}C,^{8}B)X$
→ Datasets for other reactions measured are to be analysed