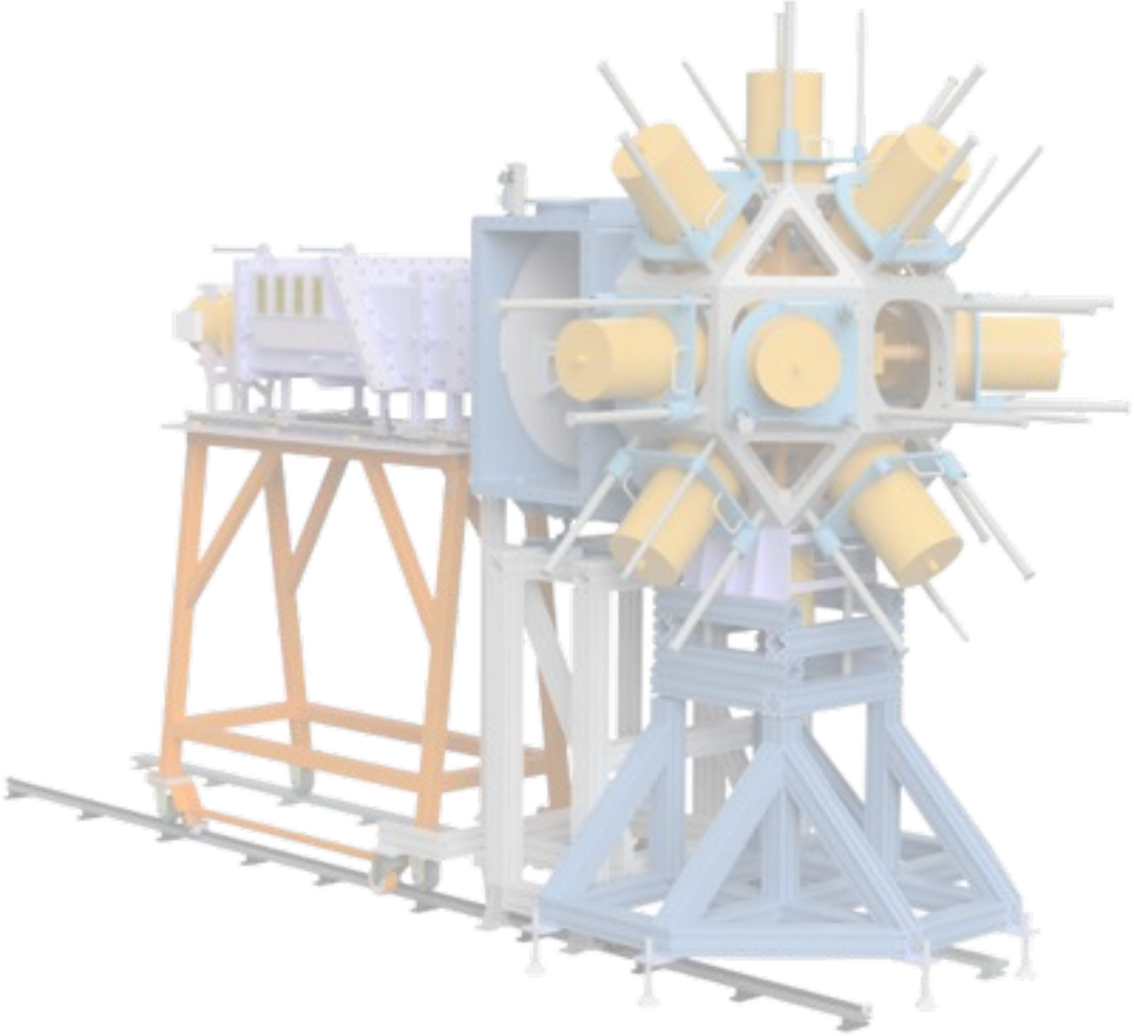
Proton-neutron pairing in the fp-shell via the $^{48}Cr(p,^{3}He)^{46}V$ transfer reaction



HUGO JACOB (IJCLAB, CNRS)
hjacob@ijclab.in2p3.fr

27/05/2025

iJCLab Irène Joliot-Curie
Laboratoire de Physique des 2 Infinis

cnrs

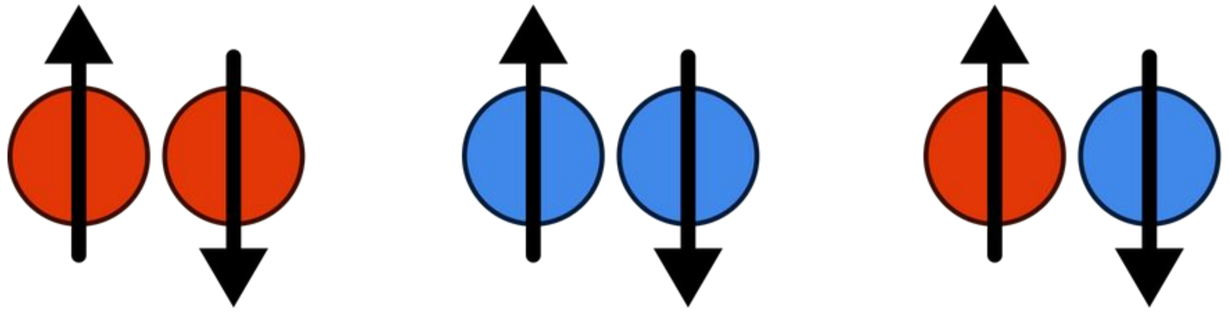
université PARIS-SACLAY

INPC 2025
May 25-30, 2025
DCC, Daejeon, Korea

Scientific motivations

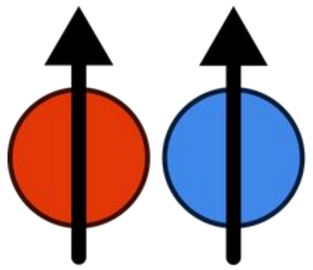
Proton-neutron pairing

Isovector (J=0, T=1)



proton-proton   neutron-neutron   proton-neutron

Isoscalar (J=1, T=0)

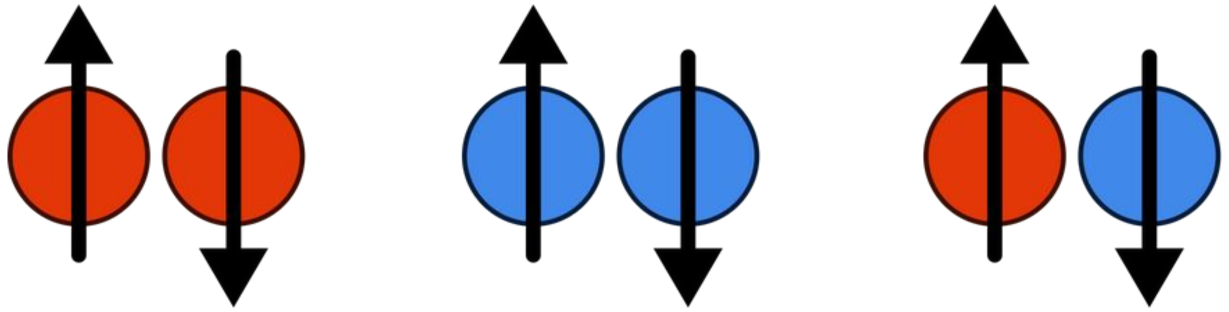


proton-neutron

- Observable mostly, if not only, in N=Z nuclei
- 2 different channels available, with different strengths
- Deuteron only bound in isoscalar channel (J=1, T=0)
- Pairing effects depend on the collectivity of the shell

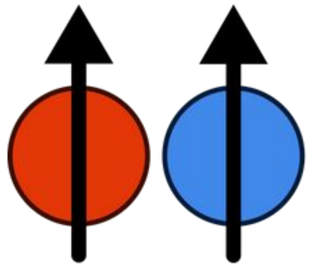
Proton-neutron pairing

Isovector (J=0, T=1)



proton-proton neutron-neutron proton-neutron

Isoscalar (J=1, T=0)



proton-neutron

- Observable mostly, if not only, in N=Z nuclei
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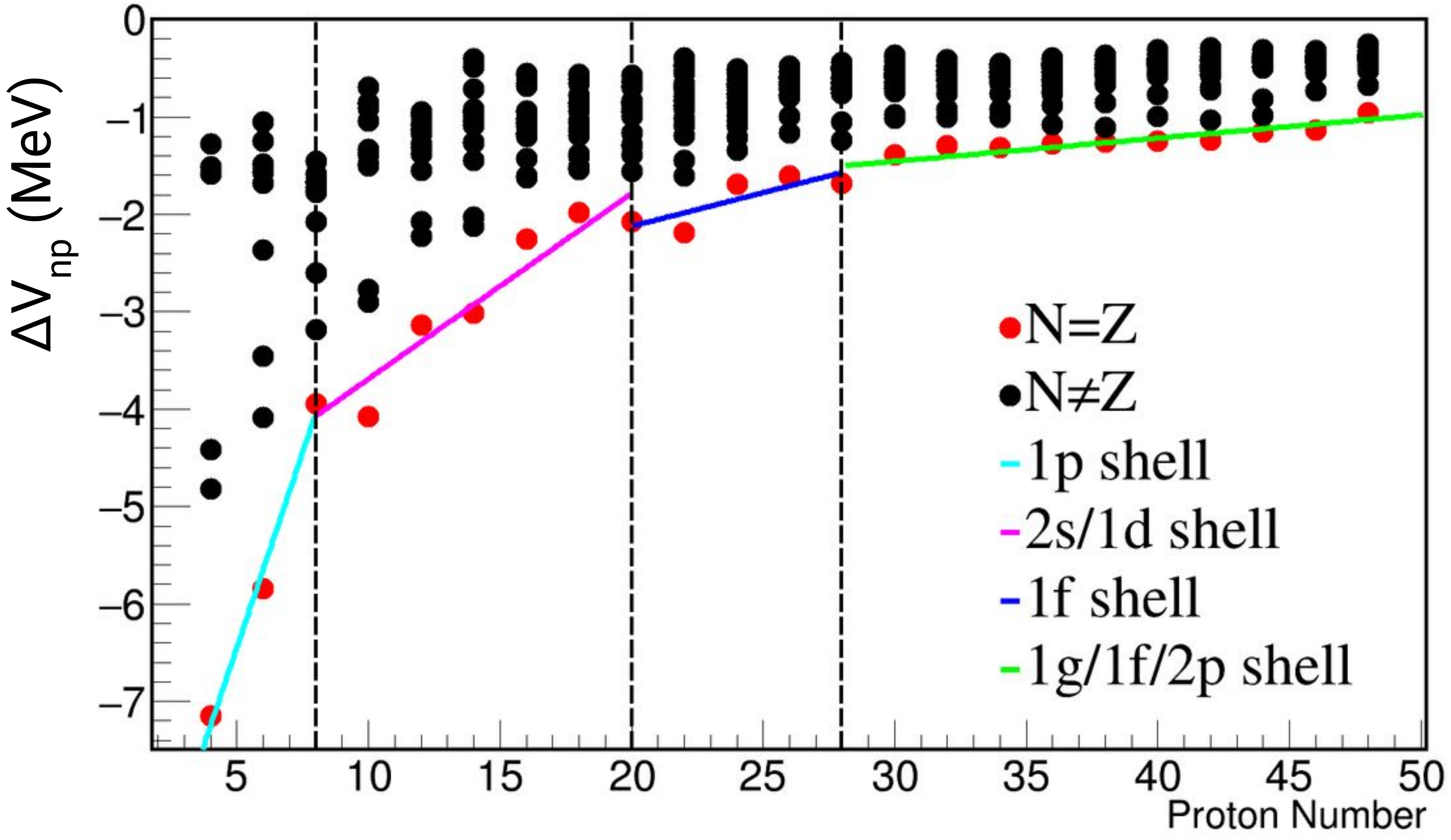
Binding energy anomaly in N=Z nuclei



Double binding energy formula:

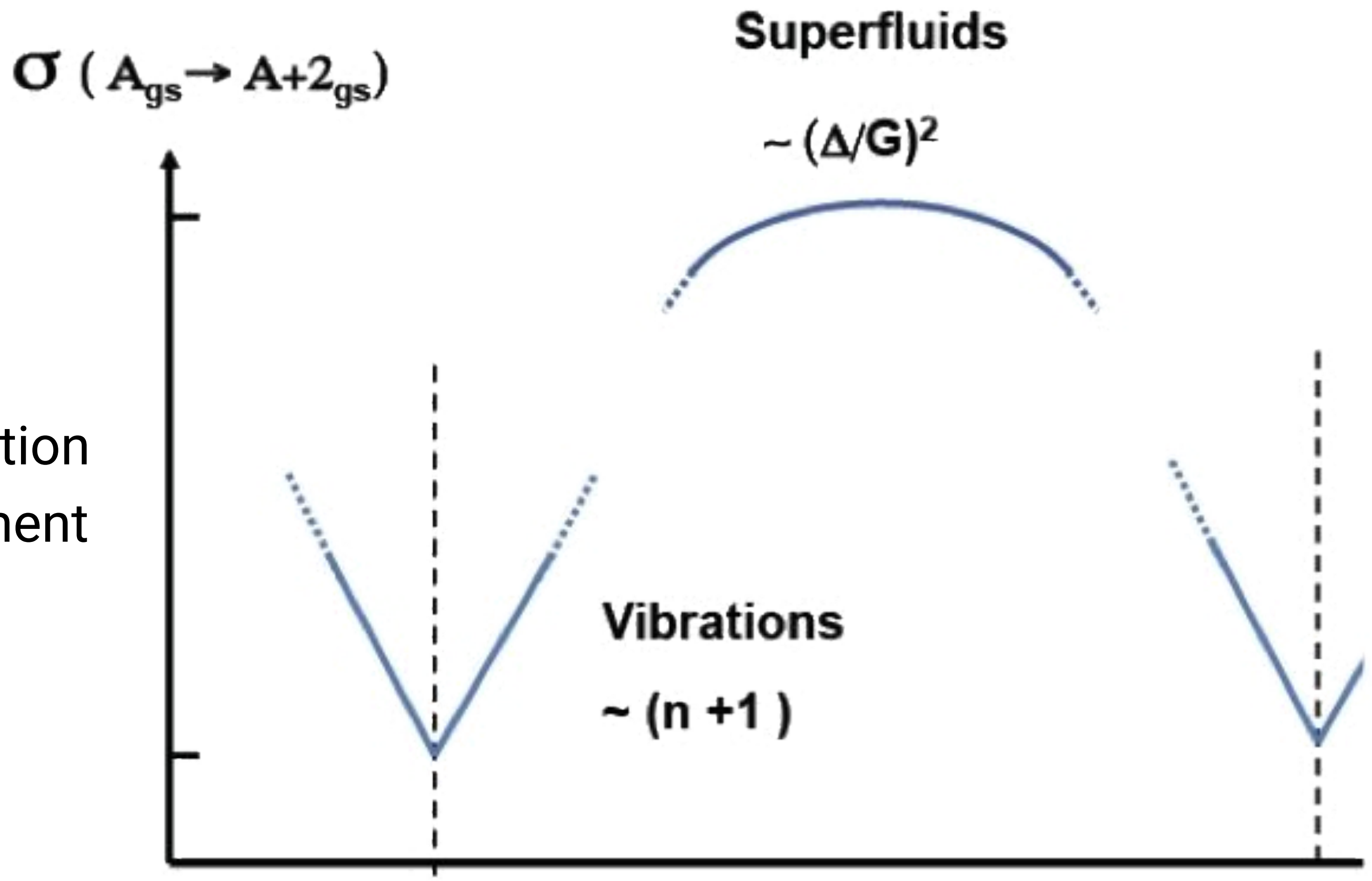
ΔV_{np} = 1/4(B(N,Z) - B(N,Z-2) - B(N-2,Z) + B(N-2,Z-2))

Data from ENSDF using TkN software

Two-nucleon transfer reaction

Schematic diagram of the cross section
of a two-nucleon transfer

Cross-section
enhancement



closed shell

closed shell

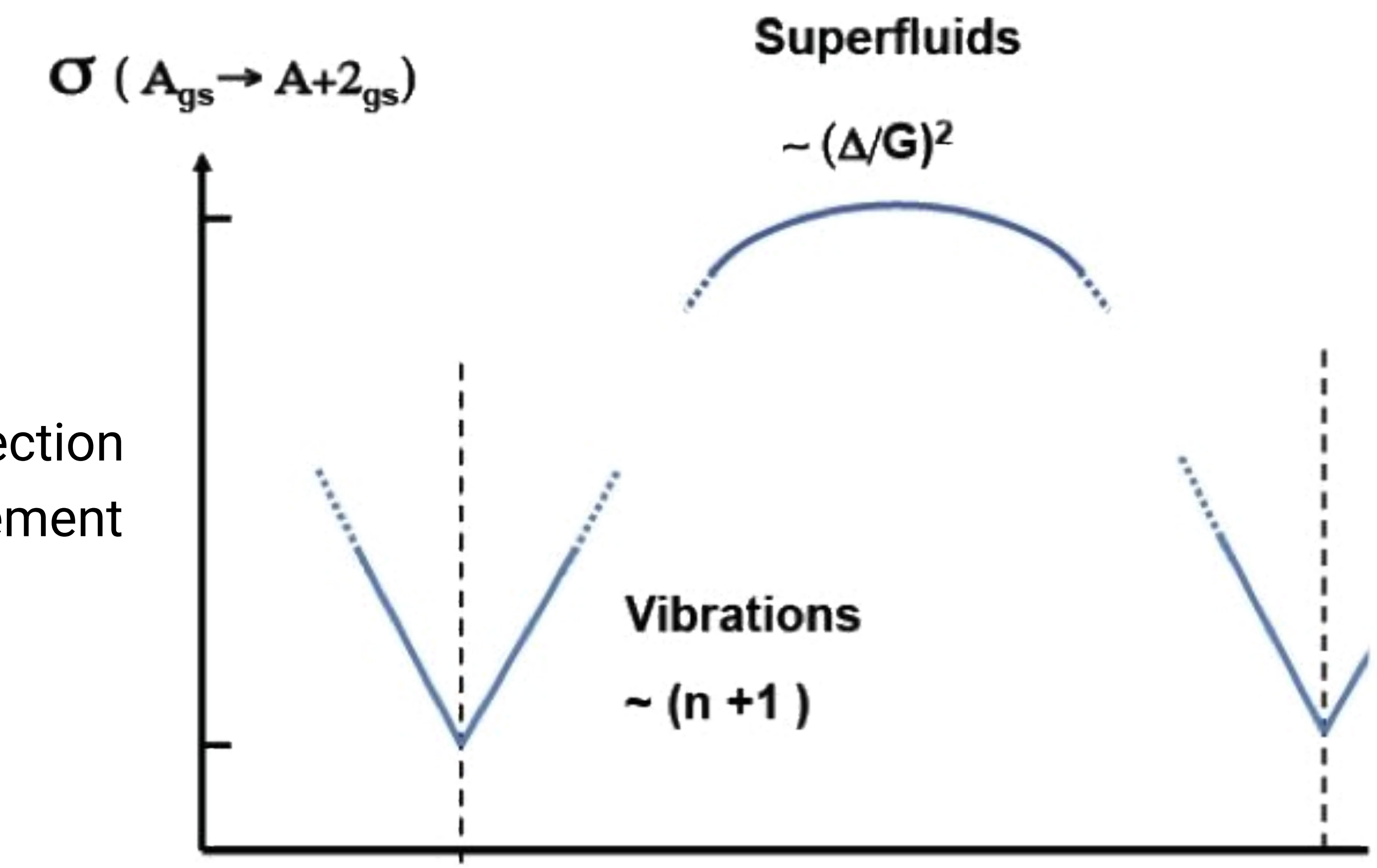
S. Frauendorf and A.O. Macchiavelli, Progress in Particle and Nuclear Physics, 24-90 **78**, 2014

- Near closed shell, cross-section increasing proportionally to the number of pairs (vibrational)
- In the middle of the shell, cross-section depends on the gap and pairing strength (rotational)

Two-nucleon transfer reaction

Schematic diagram of the cross section of a two-nucleon transfer

Cross-section enhancement



closed shell

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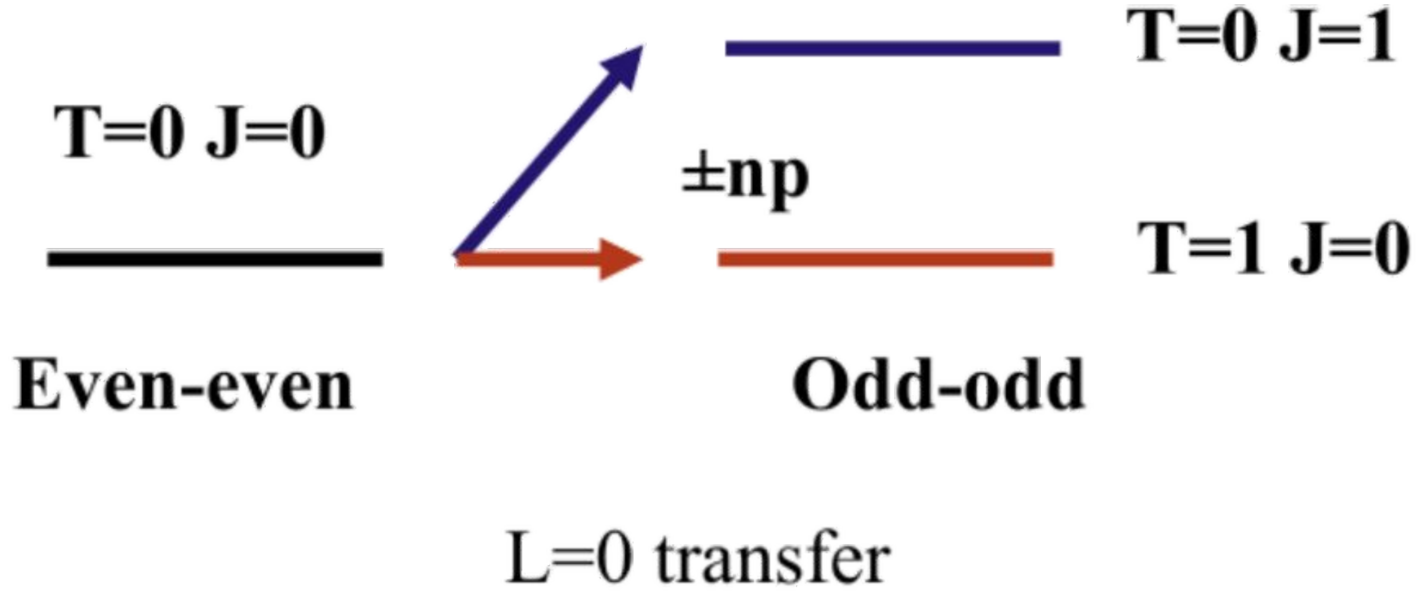
S. Frauendorf and A.O. Macchiavelli, Progress in Particle and Nuclear Physics, 24-90 **78**, 2014

- Near closed shell, cross-section increasing proportionally to the number of pairs (vibrational)
- In the middle of the shell, cross-section depends on the gap and pairing strength (rotational)

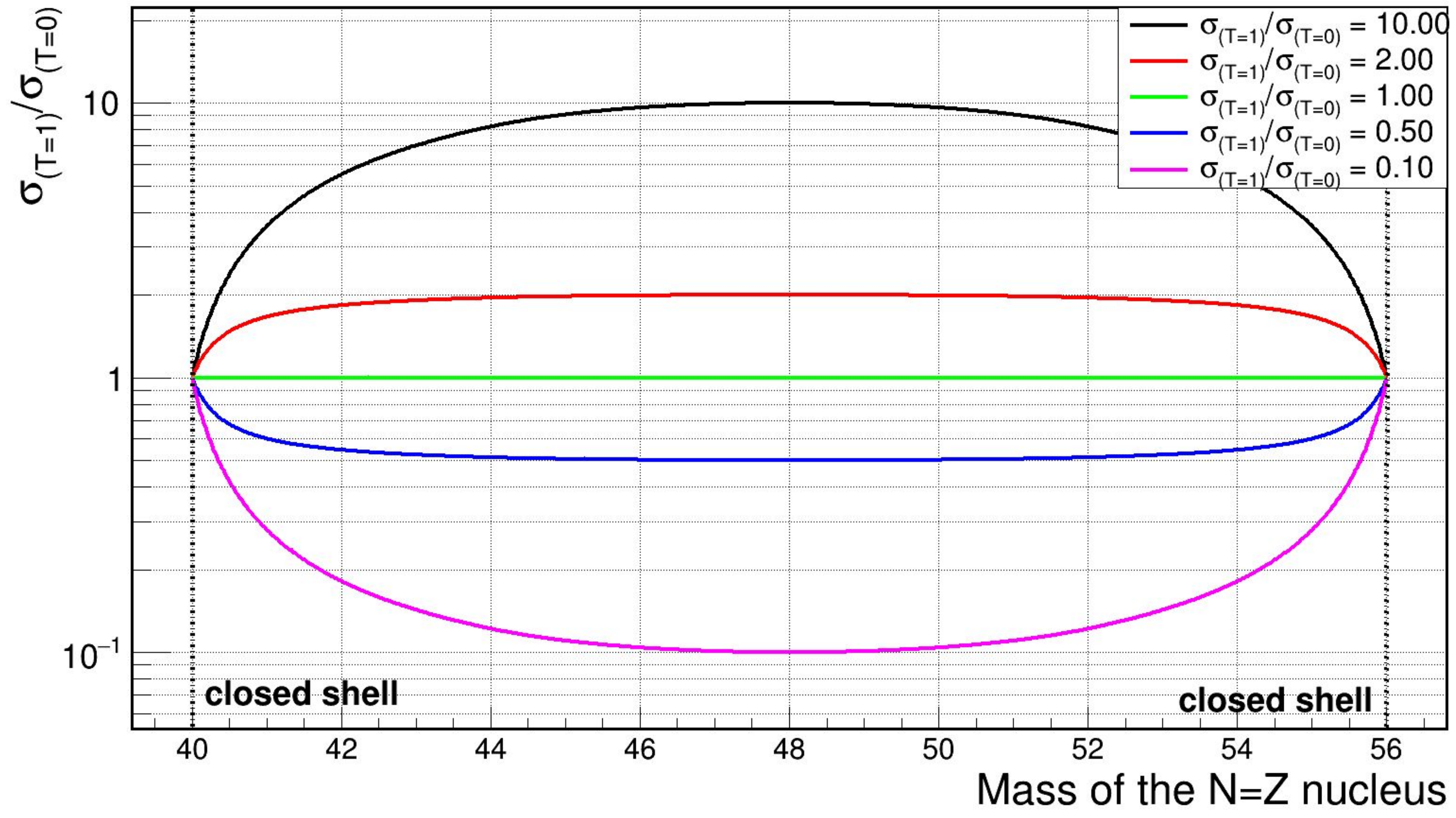
(p,³He) selection rules allow to populate both low-lying states



- Transfer to (T=0, J=1) state gives information on isoscalar pairing strength, and similarly for (T=1, J=0) and isovector pairing strength.
- Same reaction mechanism: L=0 transfer (DWBA) necessary to discriminate L=2

Cross section ratios

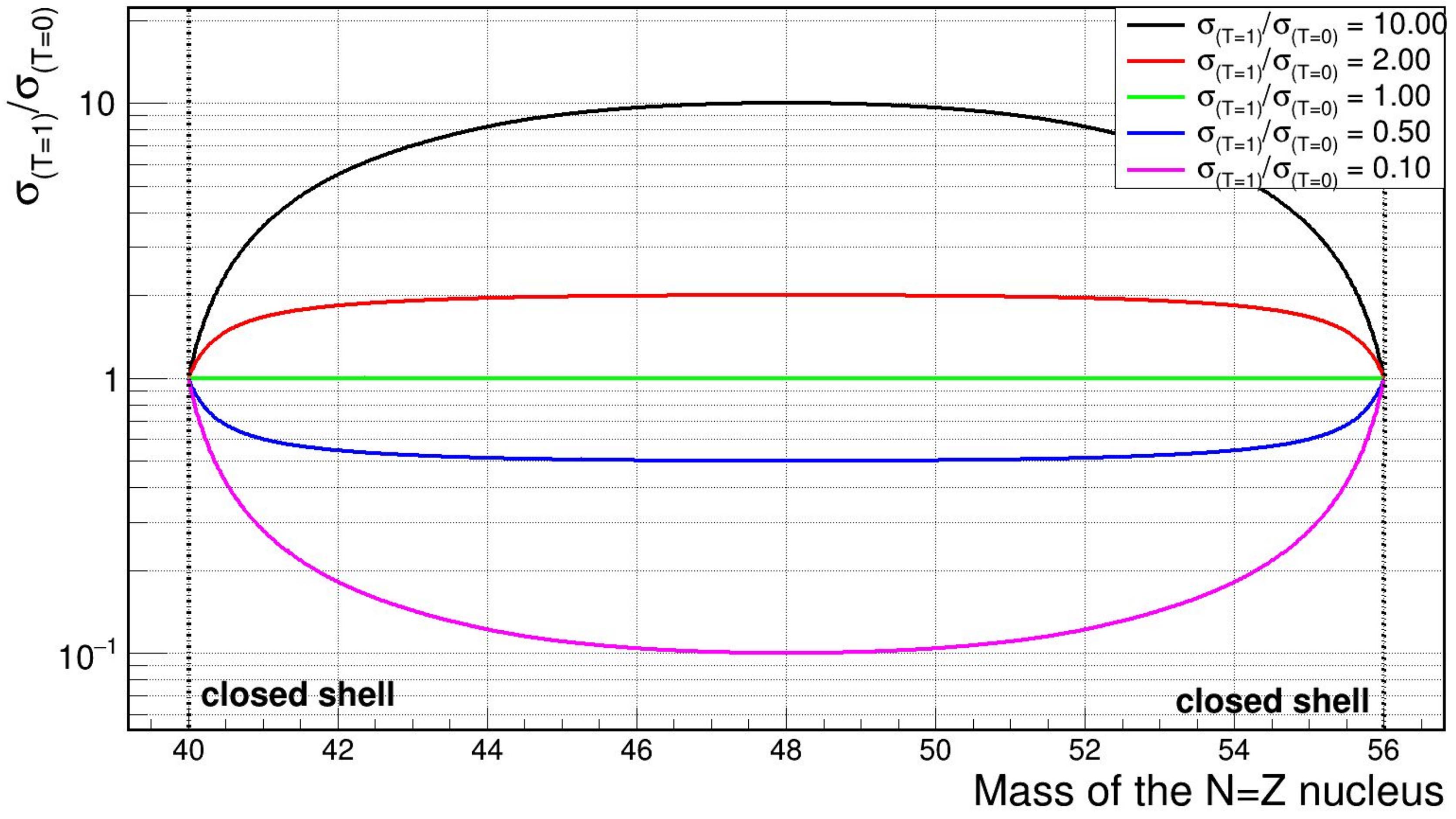
Schematic diagram of the cross section ratio



- Cross section ratio: useful to get rid of experimental biases
- Proton-neutron pairs: cross-section ratio shows the competition between isoscalar and isovector pairing channels

Cross section ratios

Schematic diagram of the cross section ratio



- Cross section ratio: useful to get rid of experimental biases
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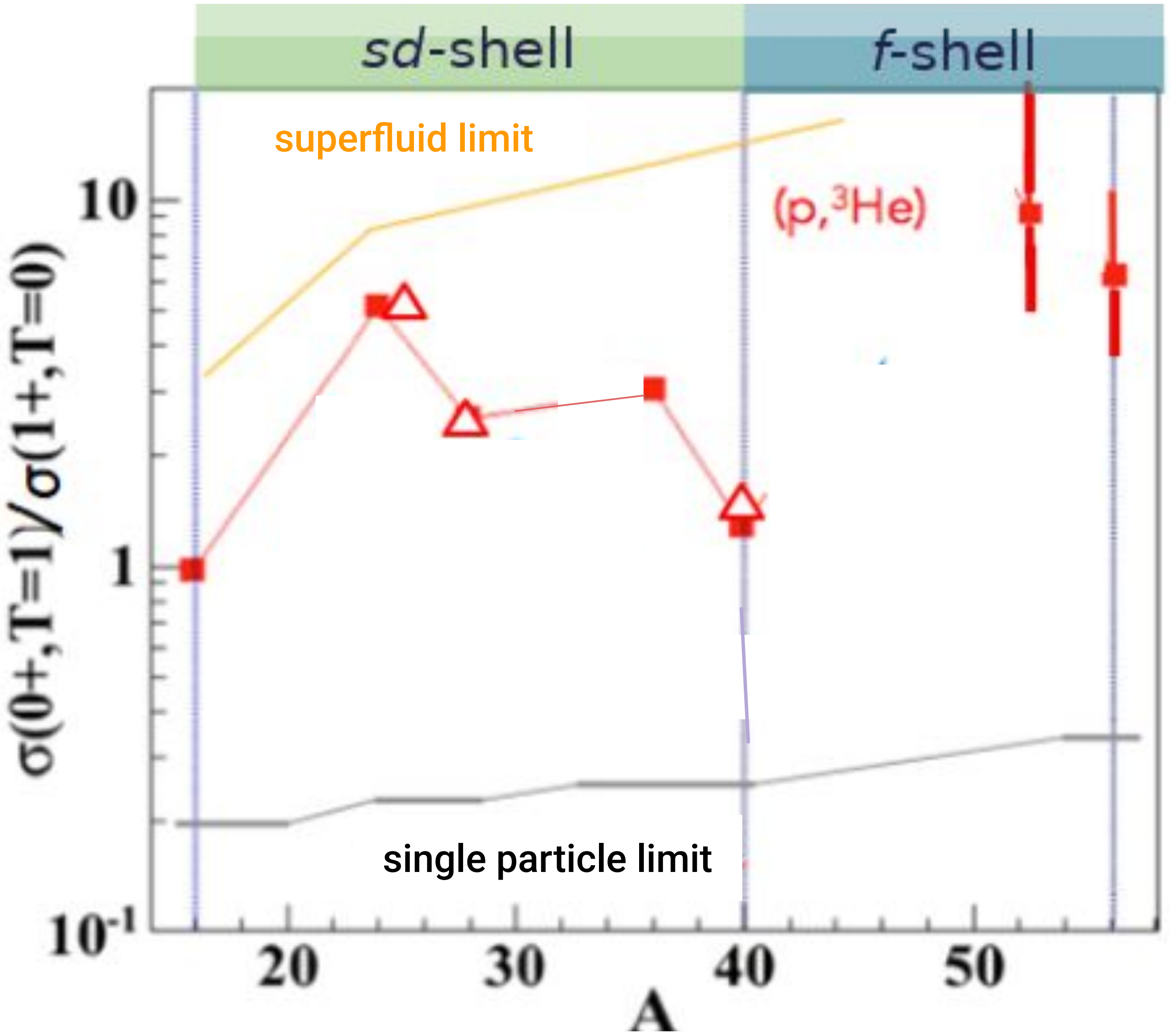
Systematics in the sd and f shells

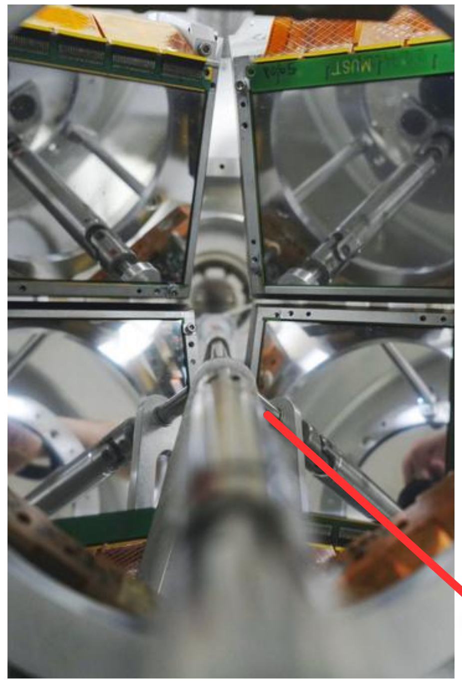


Courtesy of M. Assié and A. Macchiavelli

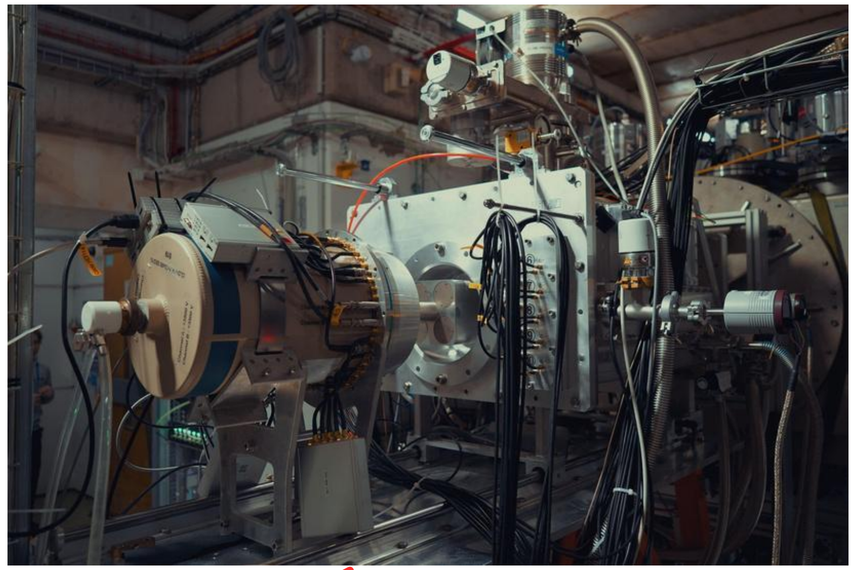
Experimental setup

MUGAST@LISE at GANIL

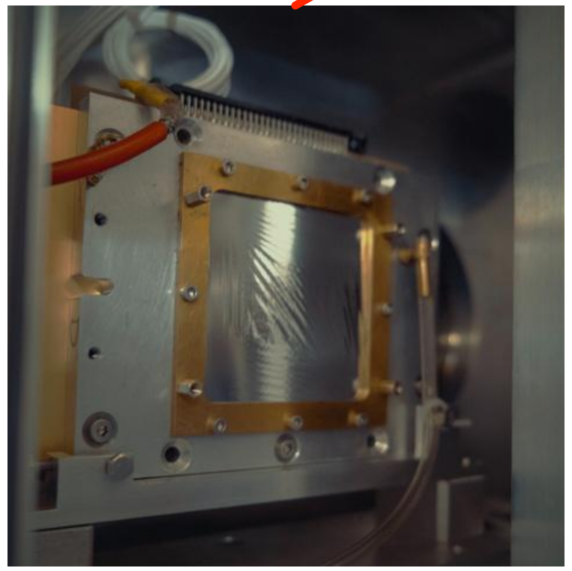
- ^{48}Cr 30MeV/u beam produced by fragmentation of ^{50}Cr and selected by LISE spectrometer at GANIL
- Impinging beam on a 5mg/cm² CH_2 target



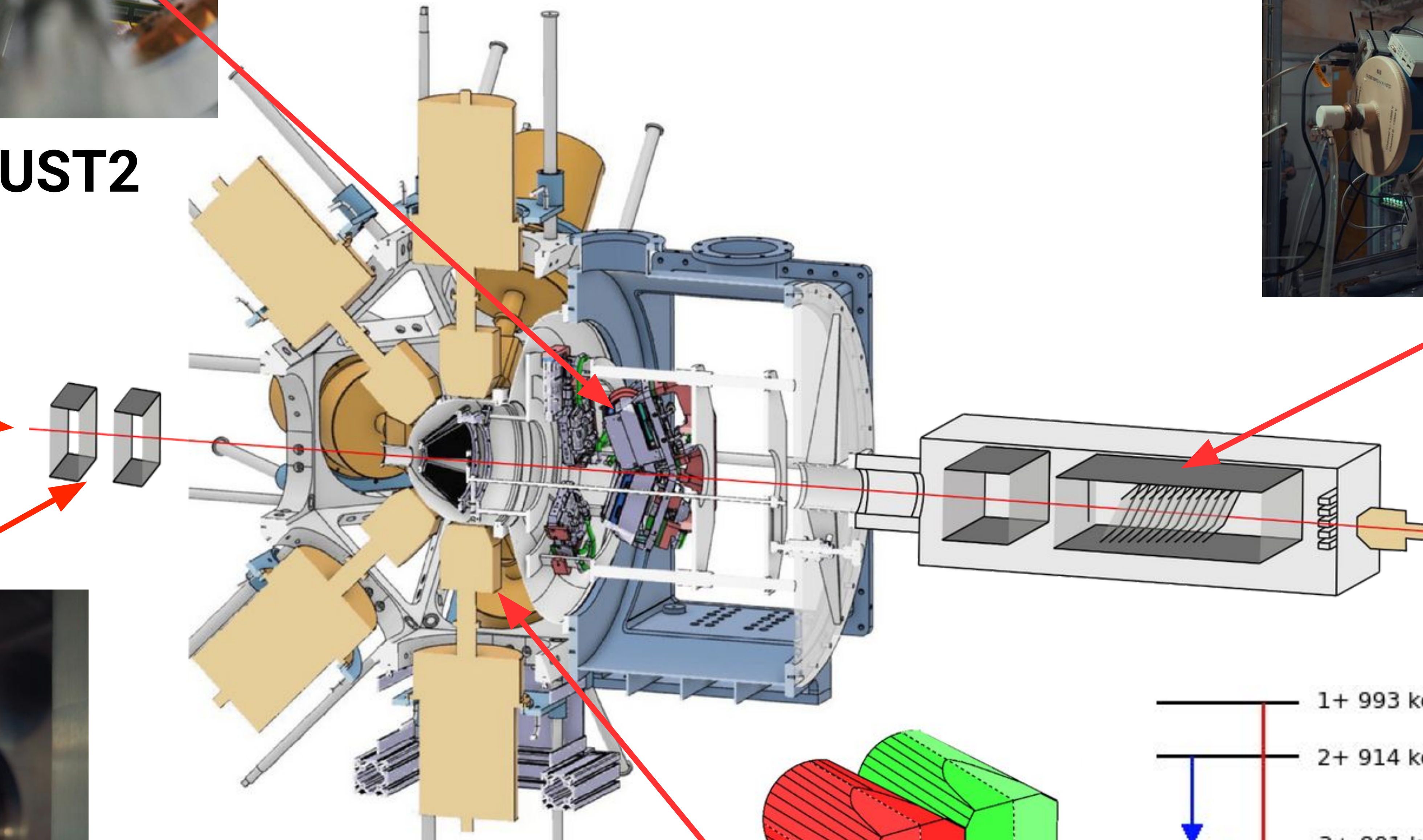
MUST2

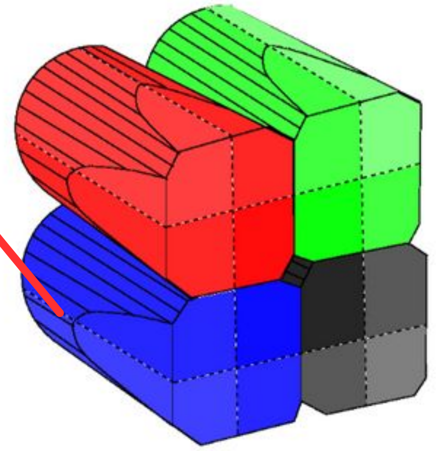


ZDD

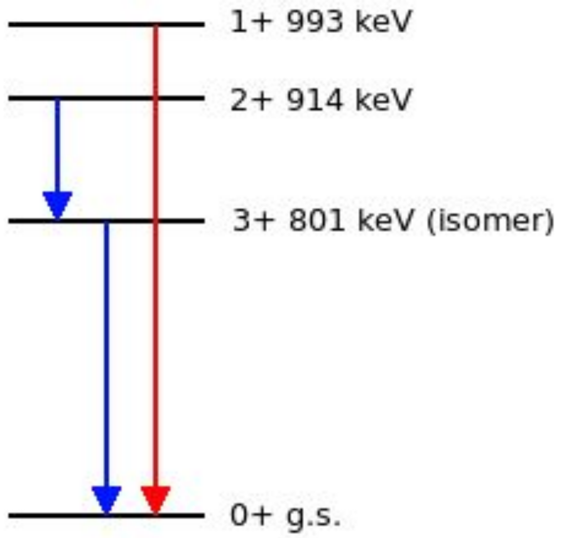


CATS (MWPC)



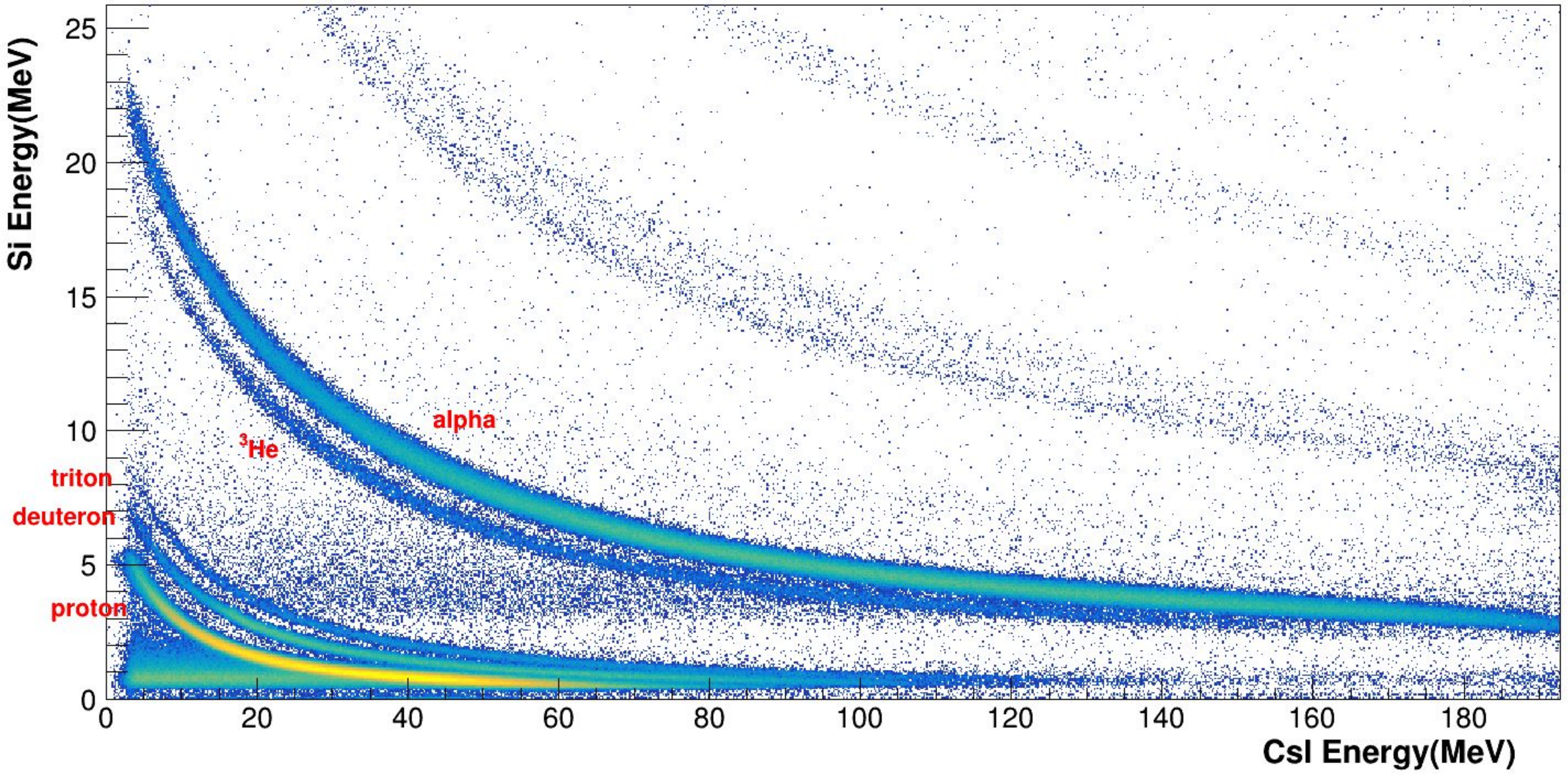


EXOGAM



Reaction channel selection

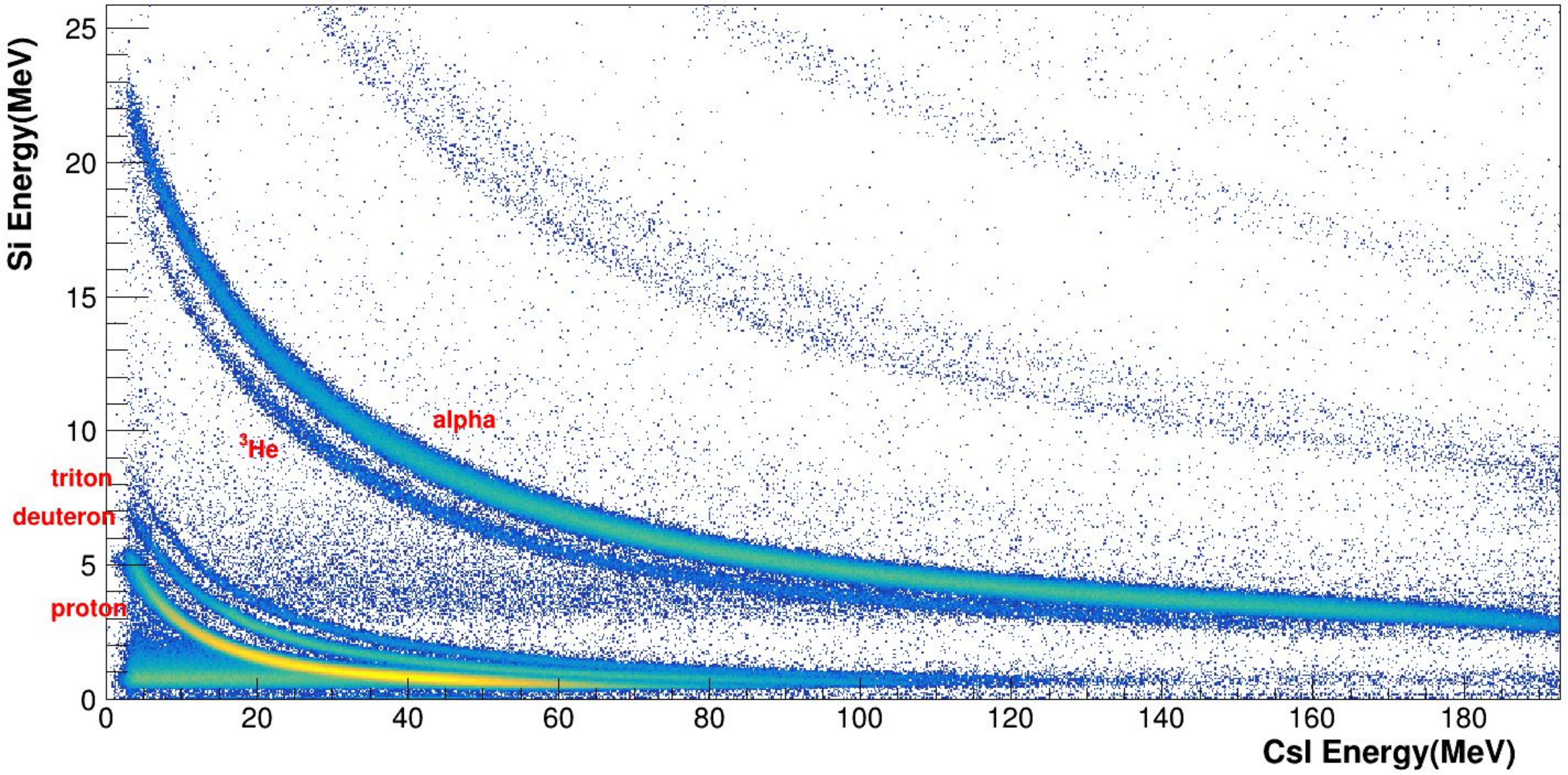
MUST2 identification



- Identification performed with $\Delta E/E$ (DSSD and CsI)
- Selection of ^{3}He particles before selection in ZDD

Reaction channel selection

MUST2 identification



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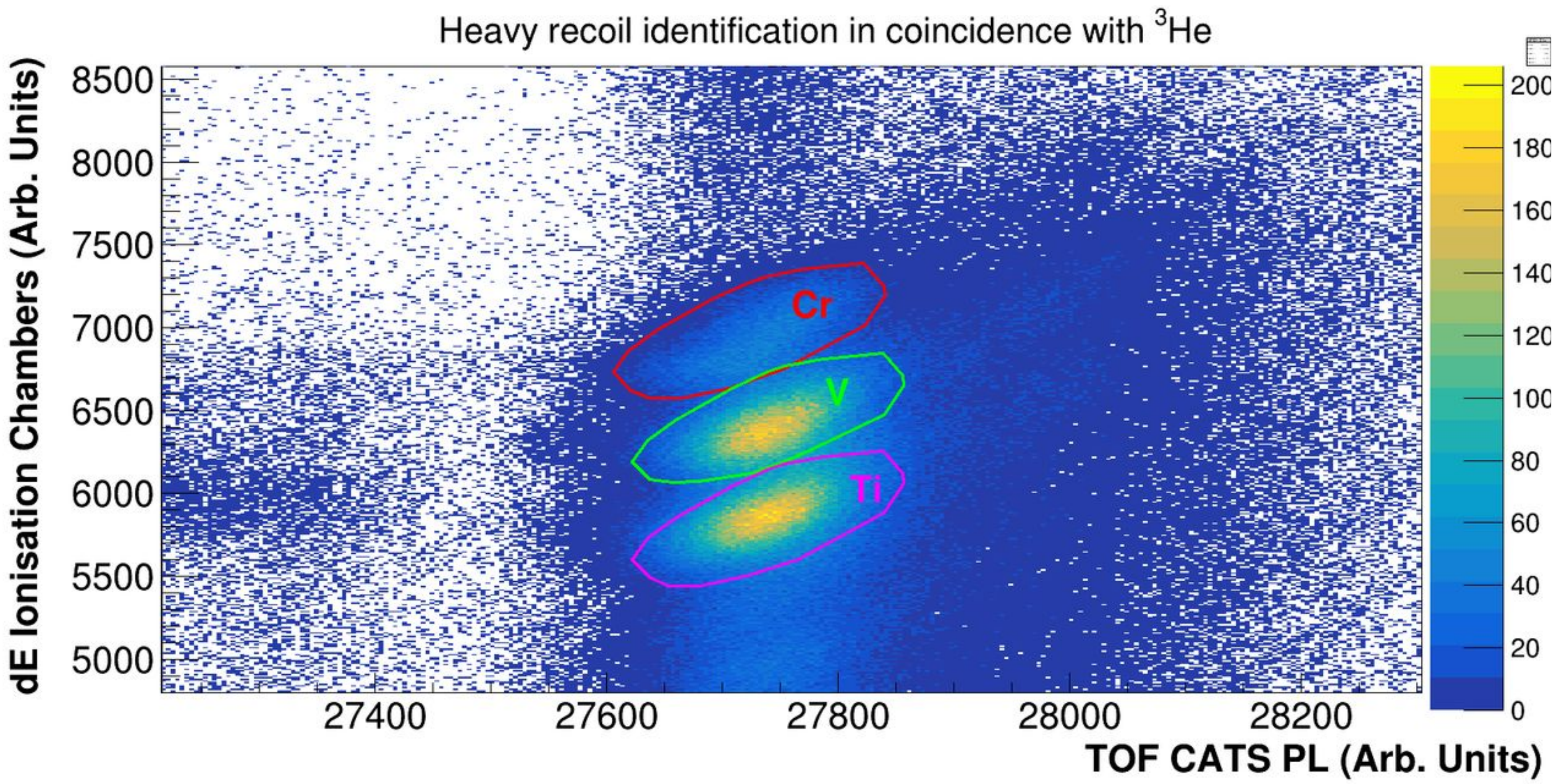
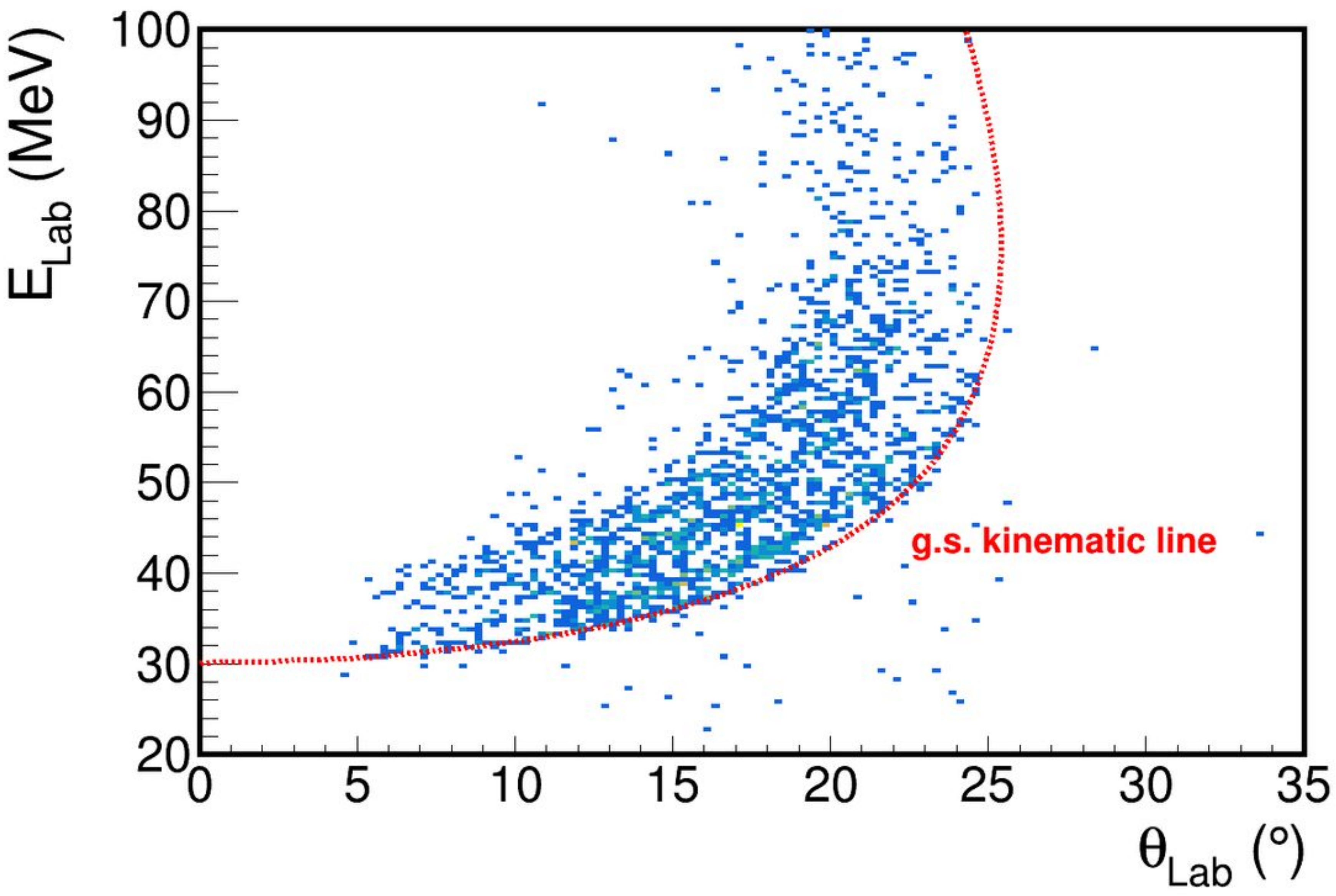
ZDD identification



- Identification performed with ΔE/TOF (TOF CATS PL)
- Typical nuclei used in our analysis are Cr, V and Ti

MUST2 kinematics

(p,^{3}He) kinematic line



MUST2 kinematics

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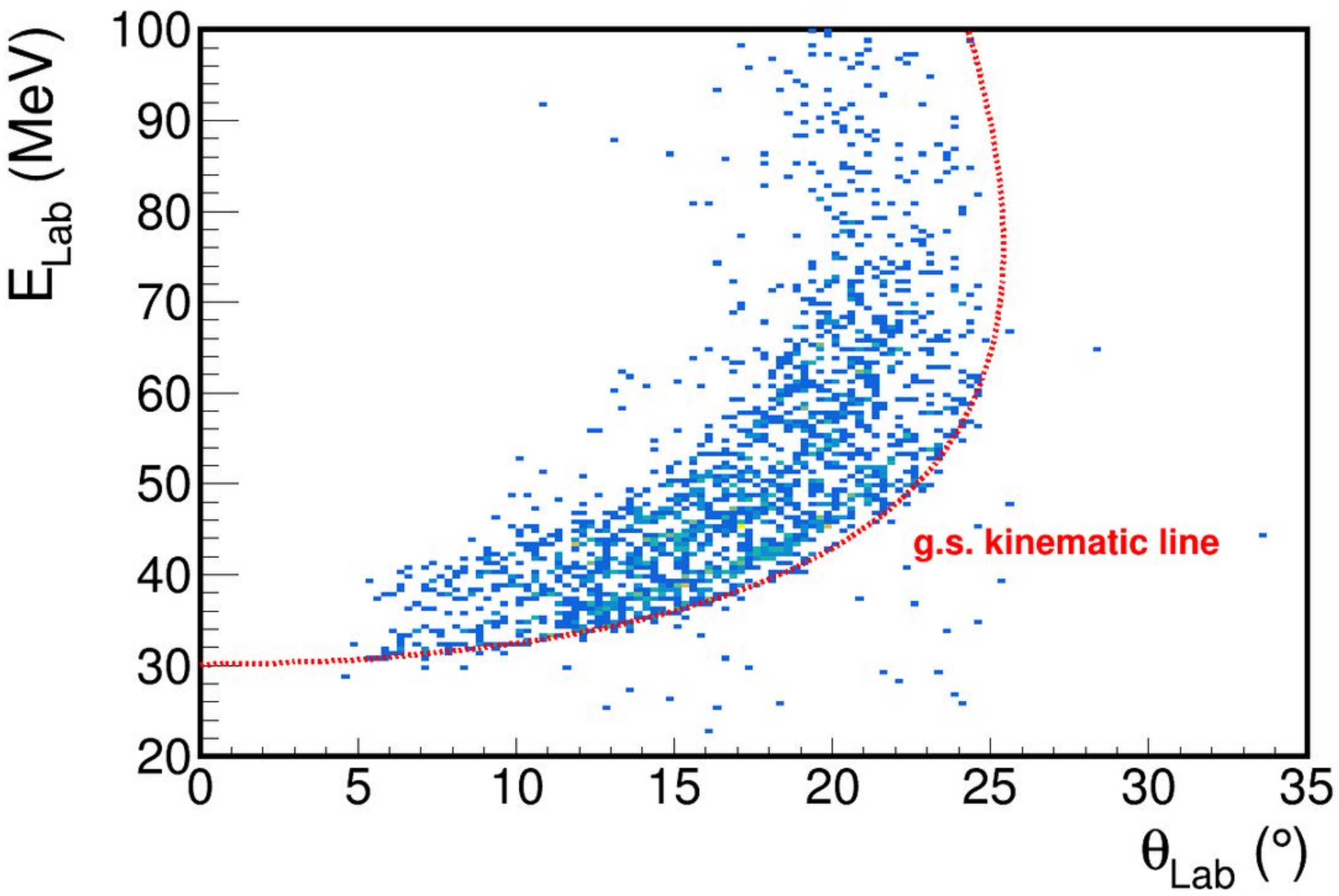
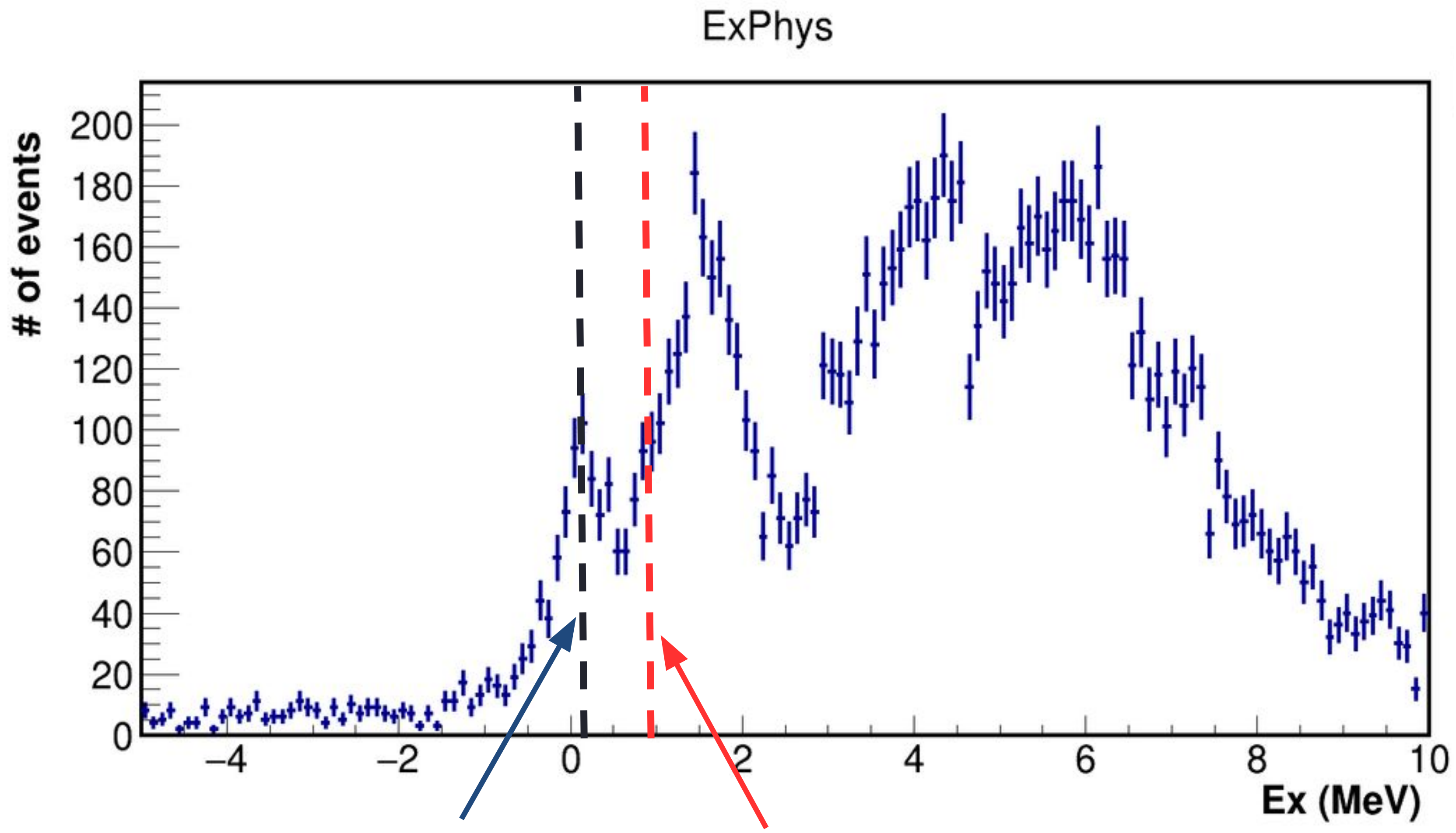


^{46}V excitation energy

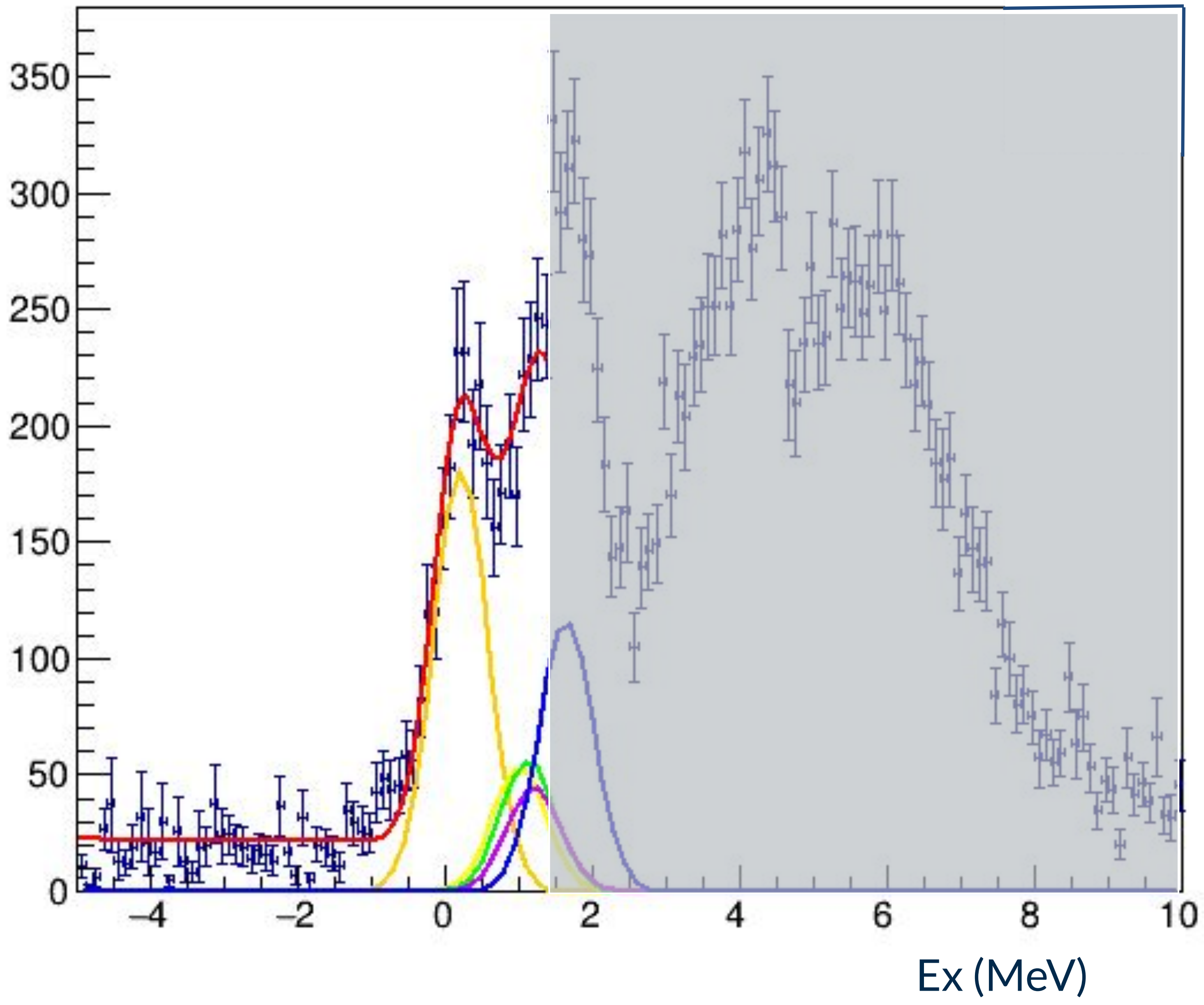


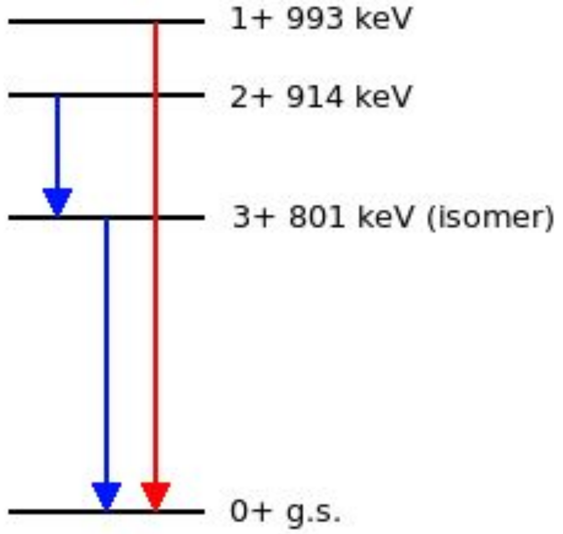
Isovector g.s. (0+,T=1) Isoscalar (1+,T=0)

Preliminary results

Fitting experimental data

Excitation energy fit

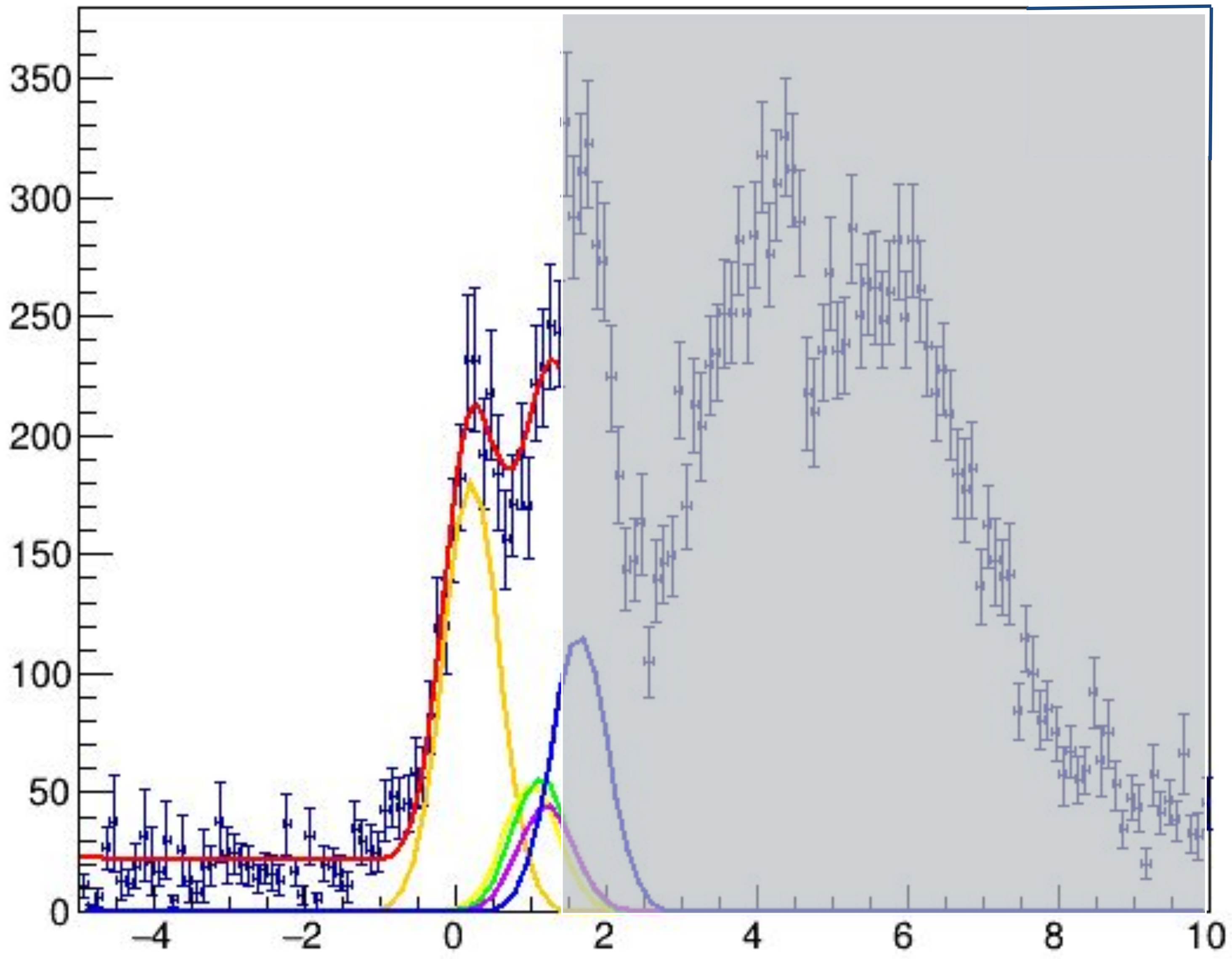




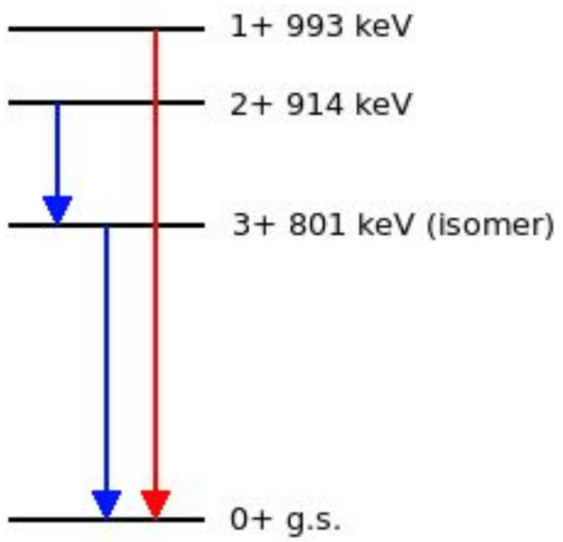
Fitting experimental data

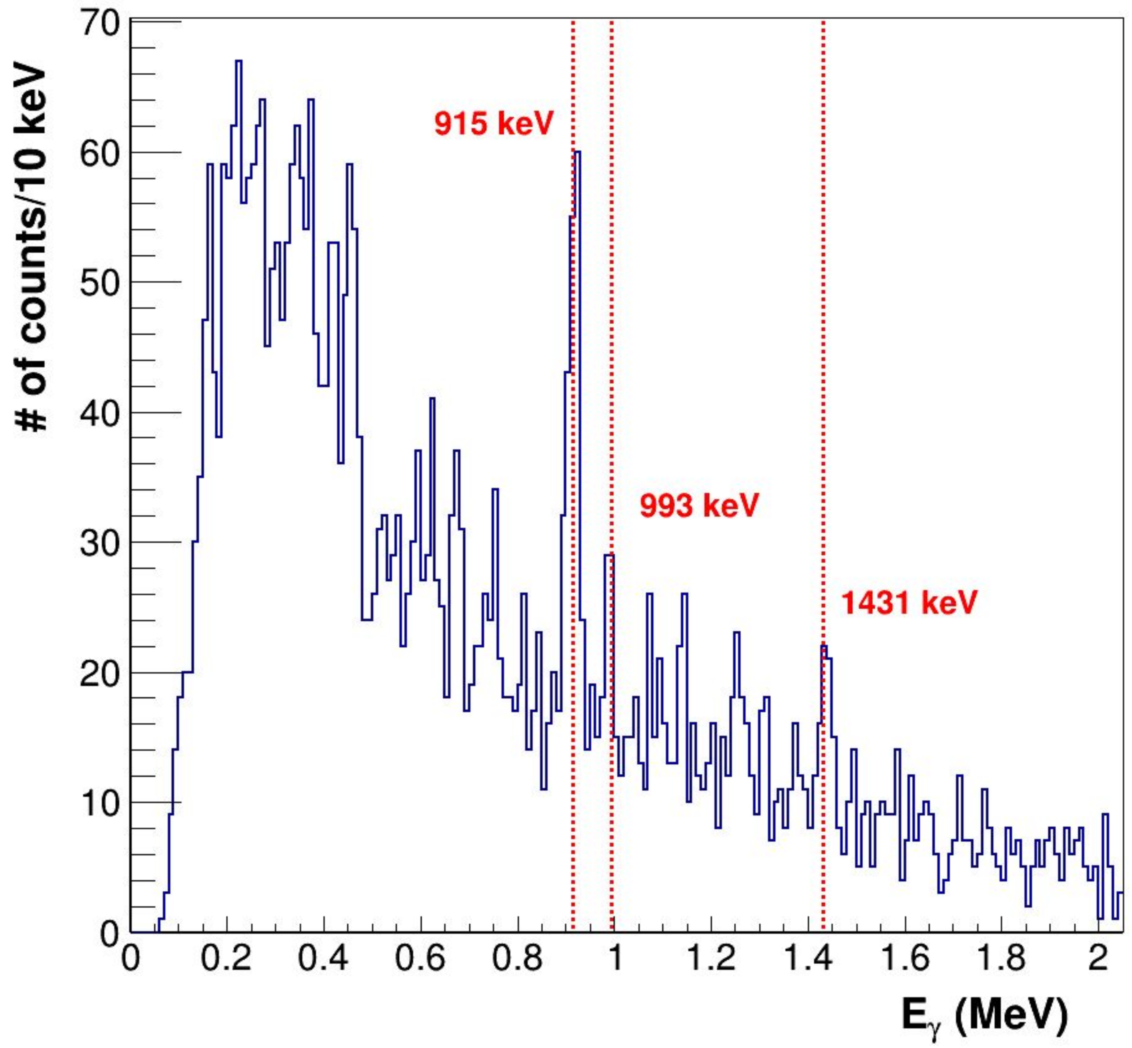
Excitation energy fit

γ-ray energy



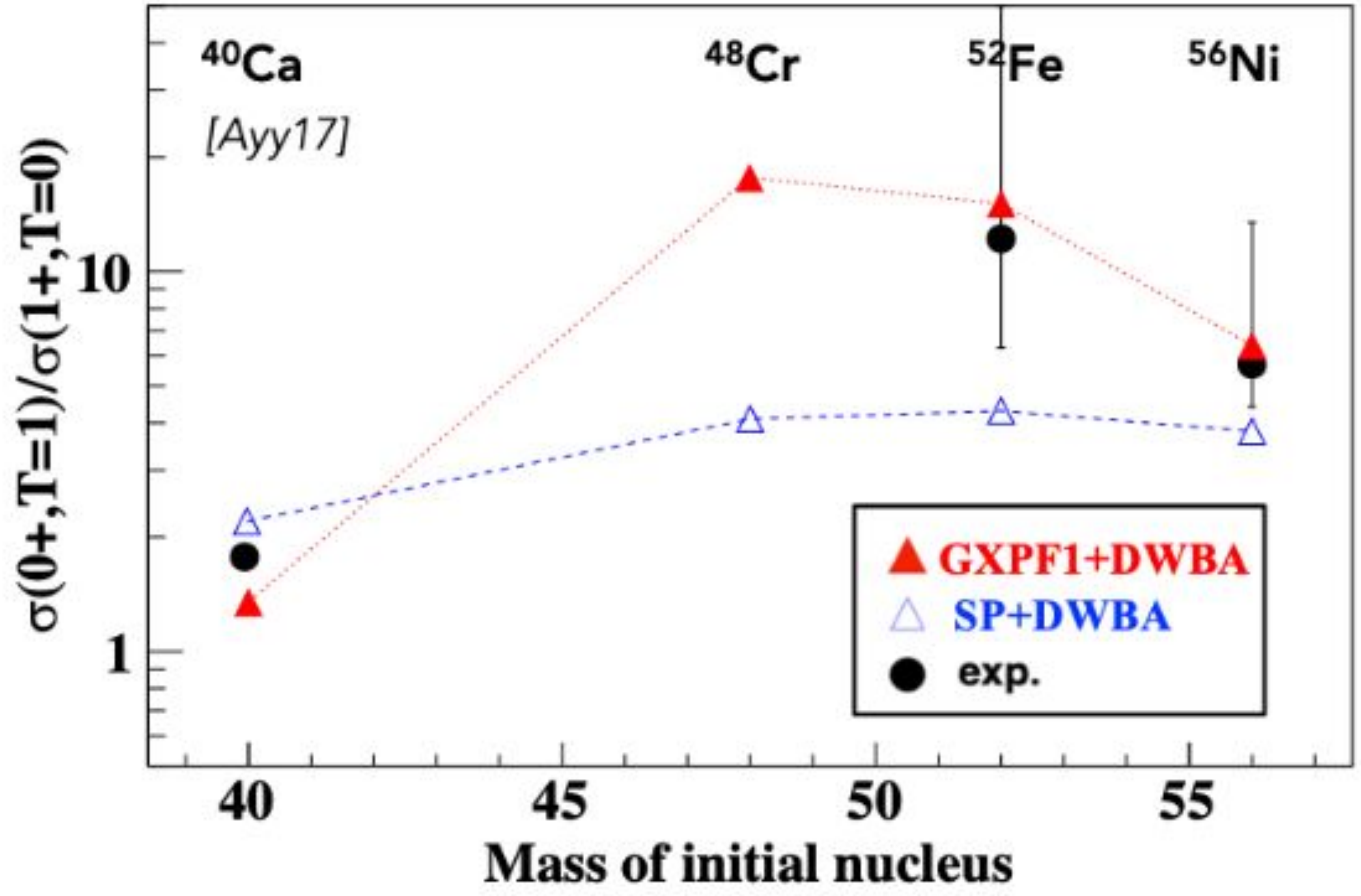
Ex (MeV)





Previous results

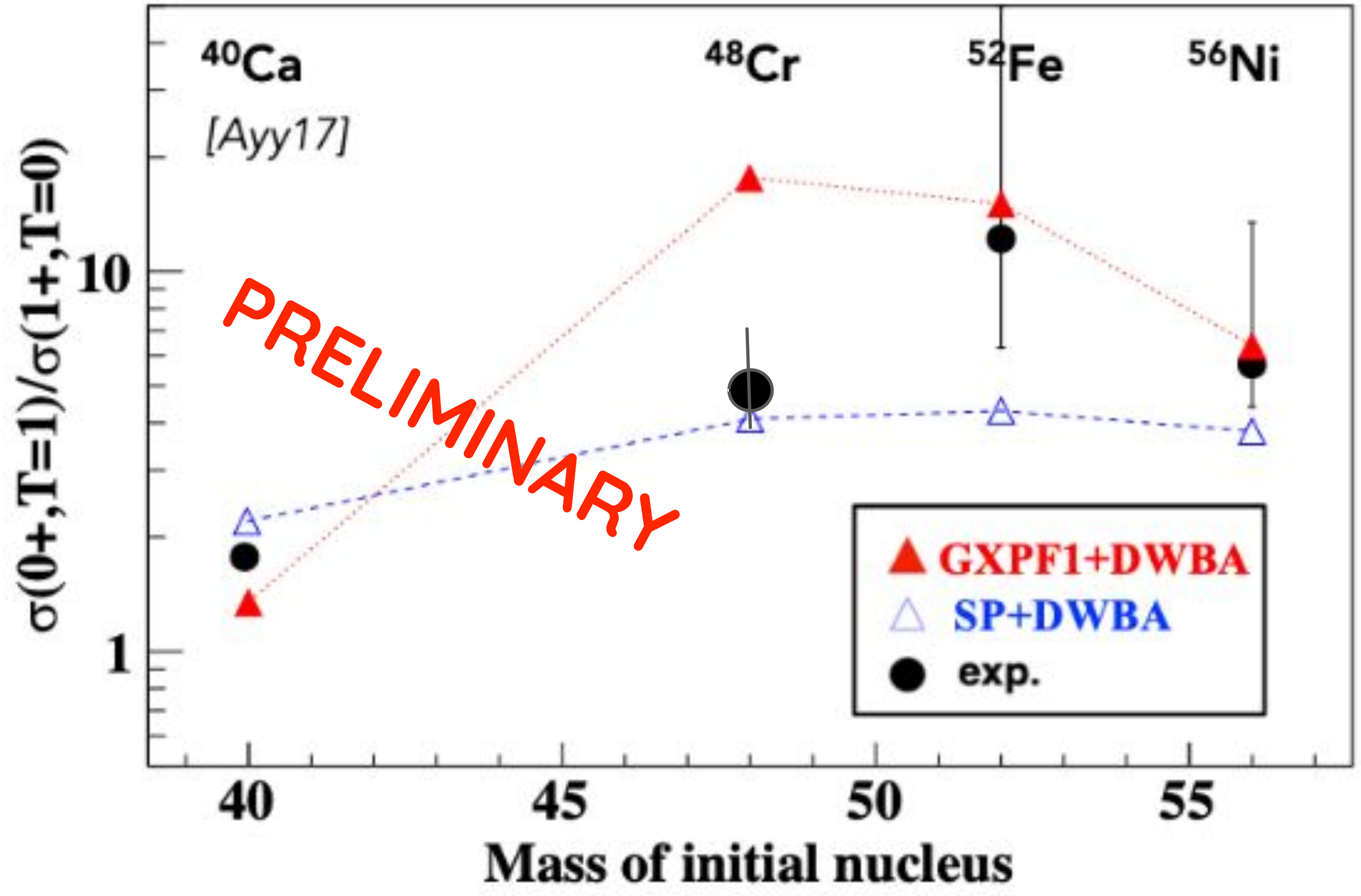
Cross section ratio



B. Le Crom, M. Assié, *et al.*, Physics Letters B **829** (2022) 137057

Preliminary results

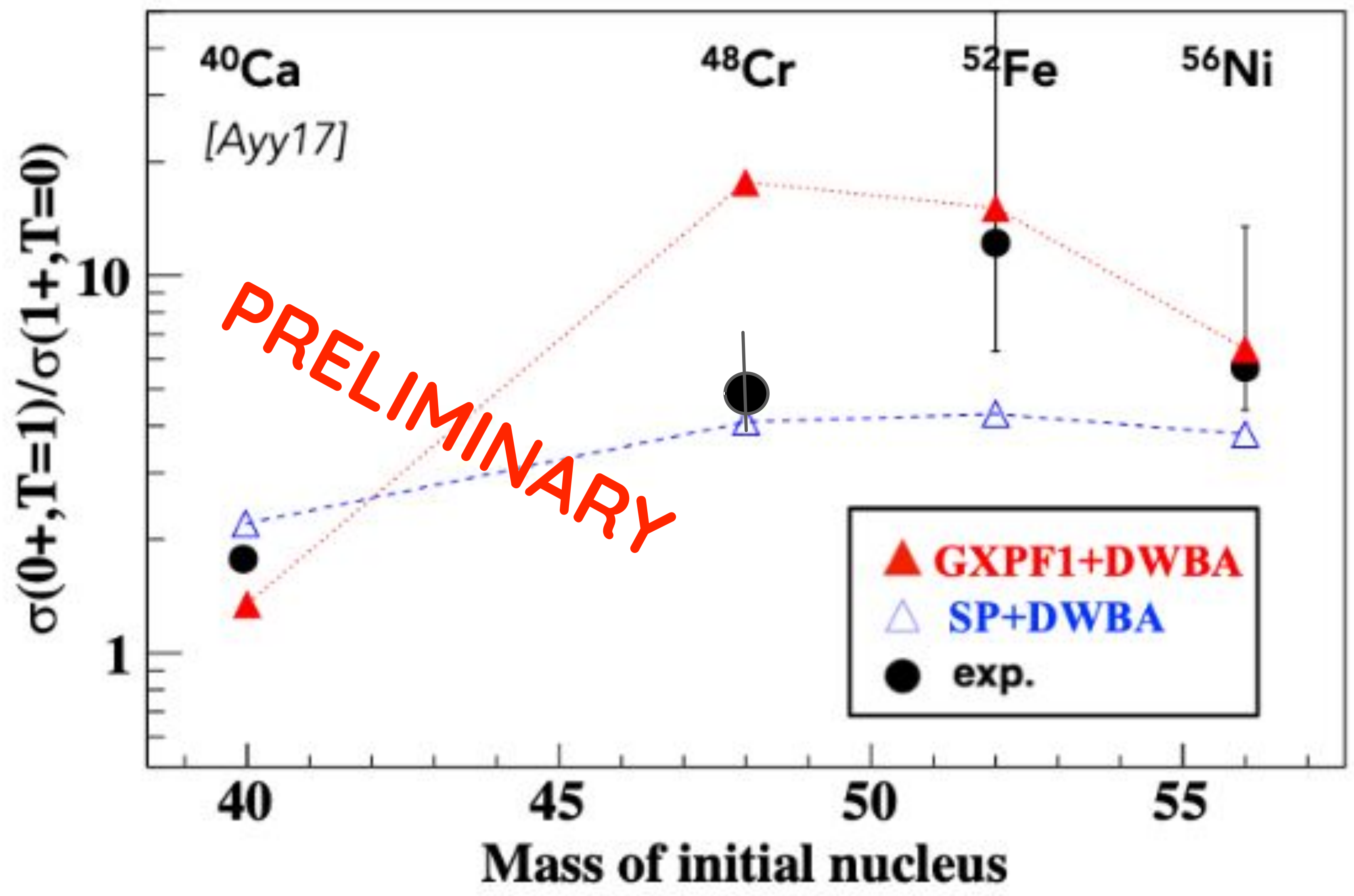
Cross section ratio



B. Le Crom, M. Assié, *et al.*, Physics Letters B **829** (2022) 137057

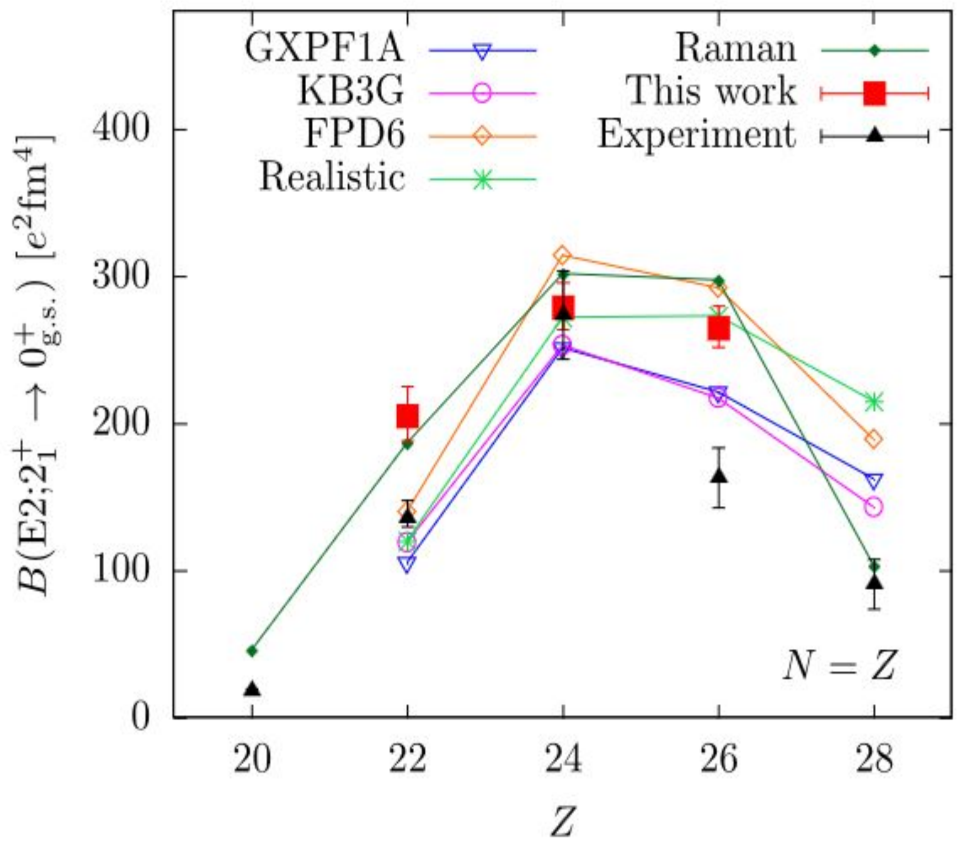
Preliminary results

Cross section ratio



B. Le Crom, M. Assié, *et al.*, Physics Letters B **829** (2022) 137057

Deformation in N=Z nuclei ($f_{7/2}$ shell)



Preliminary results

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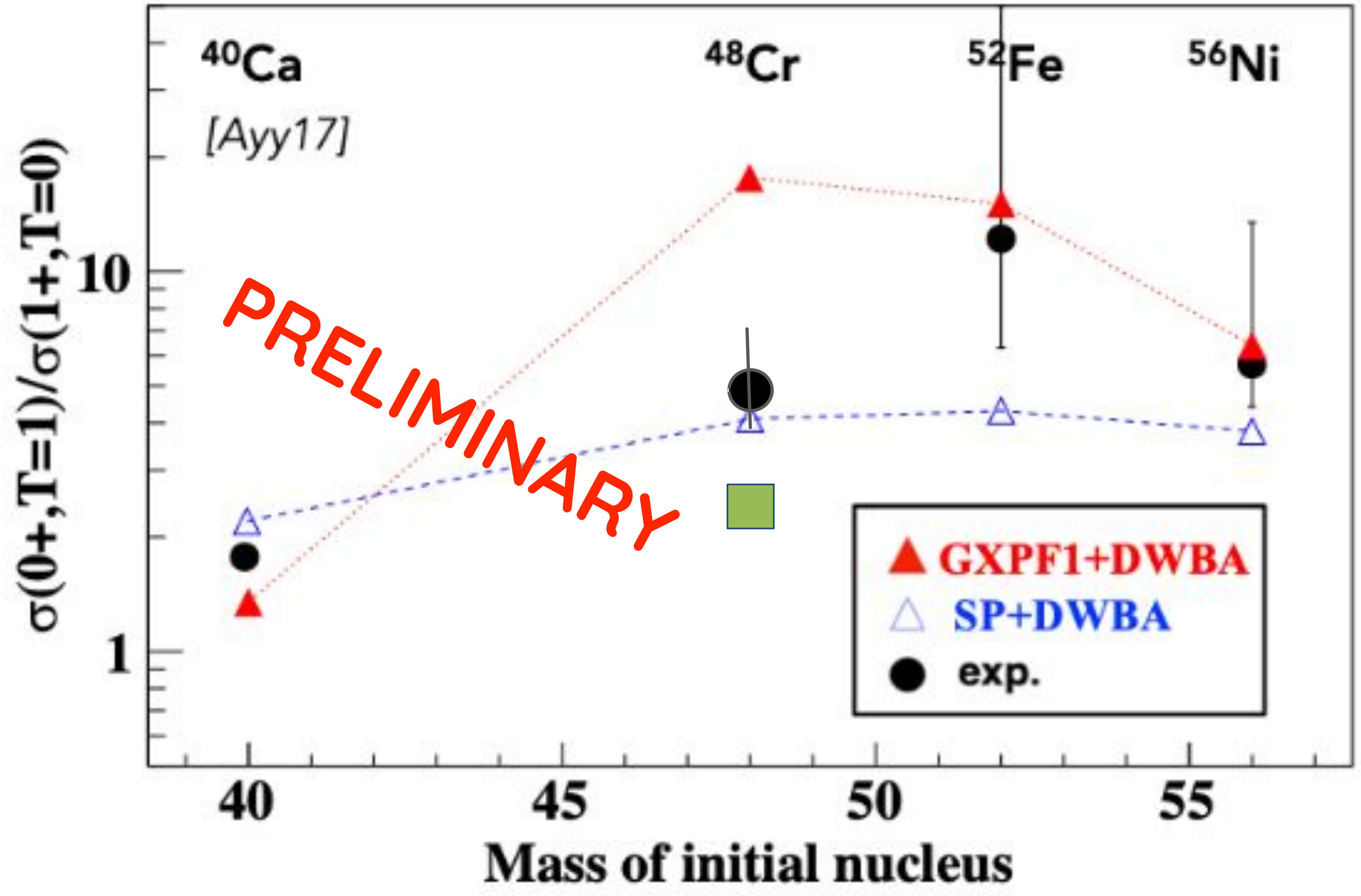

B. Le Crom, M. Assié, *et al.*, Physics Letters B **829** (2022) 137057

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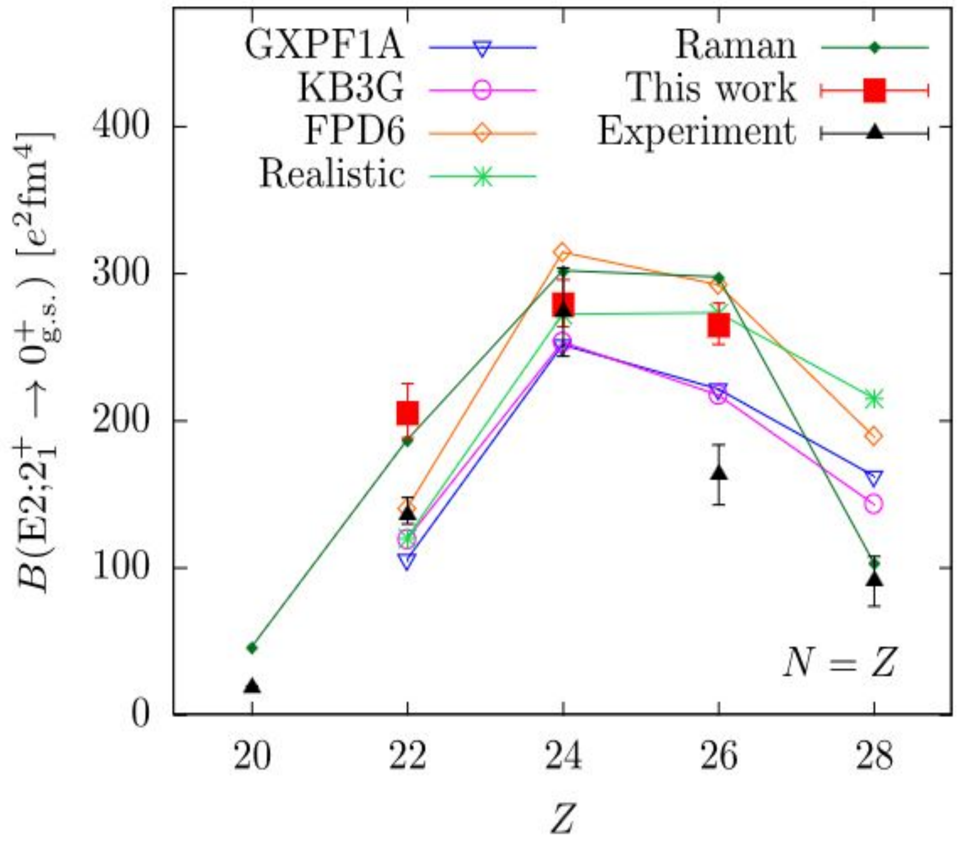
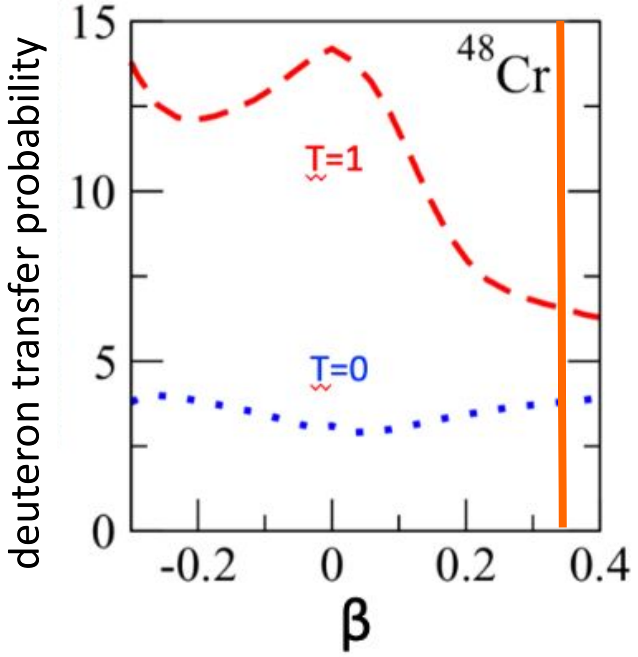
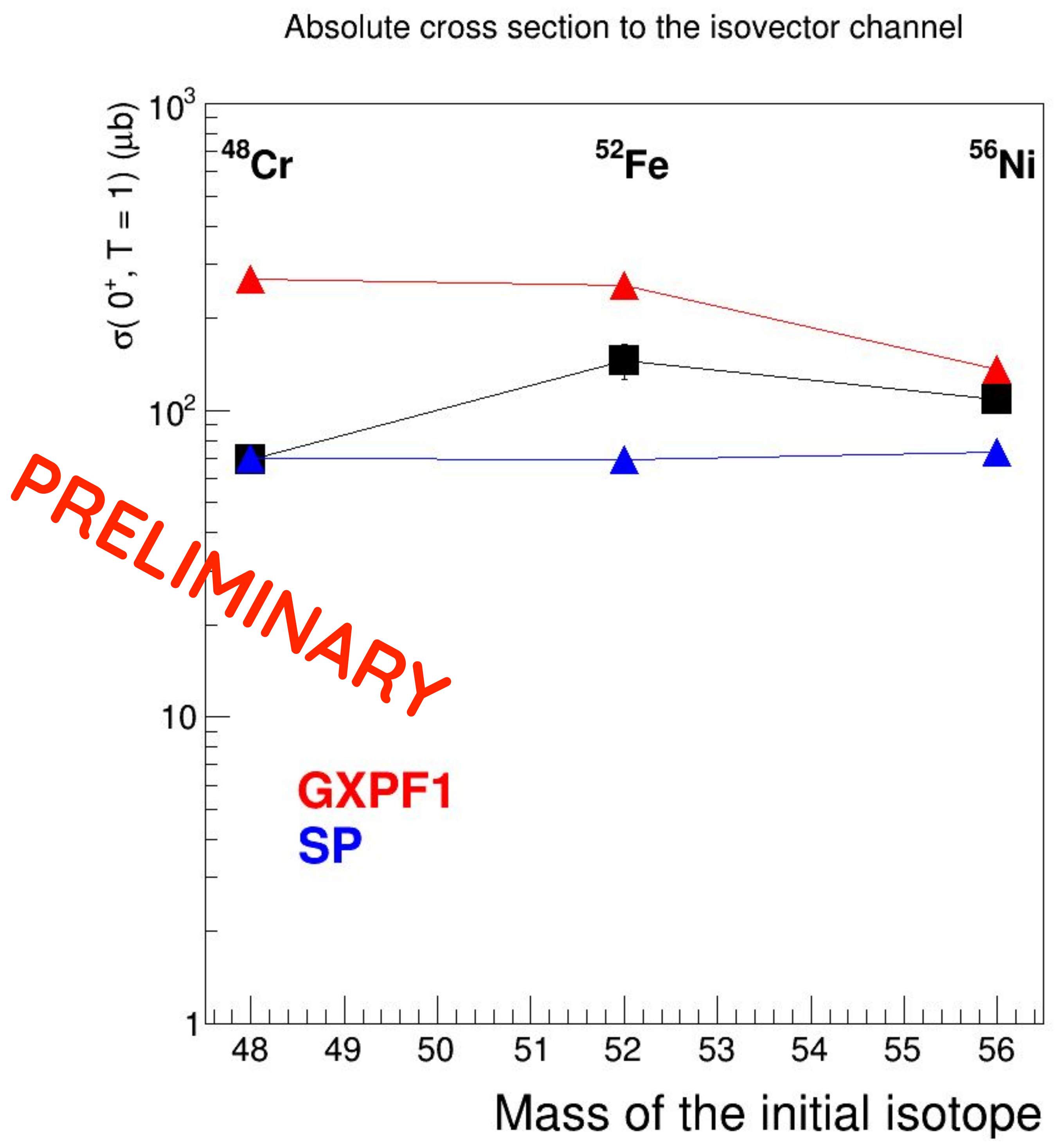
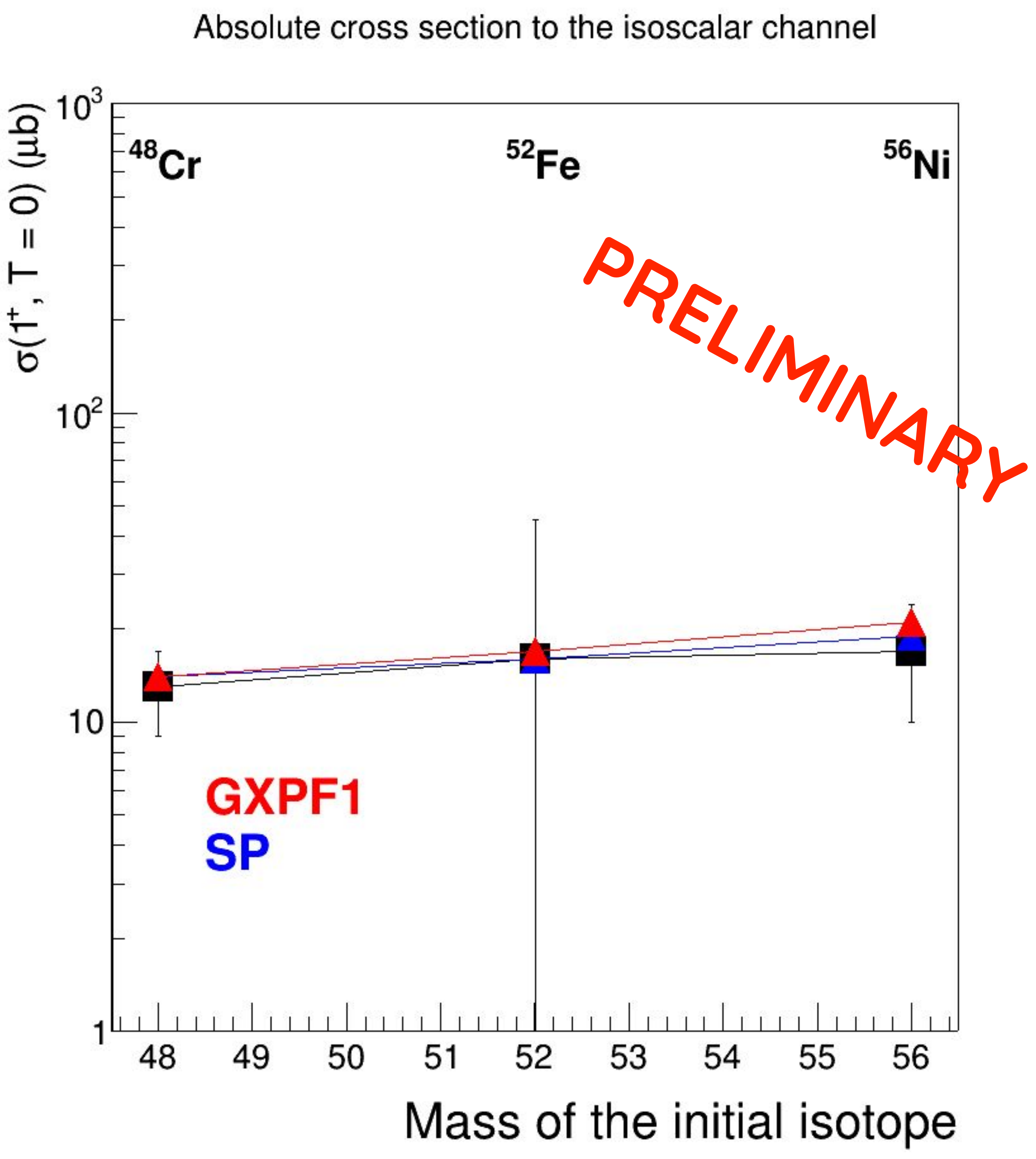




D. Gambacurta, D. Lacroix, Phys. Rev. C 91 (2015) 014308 and D. Lacroix private communication

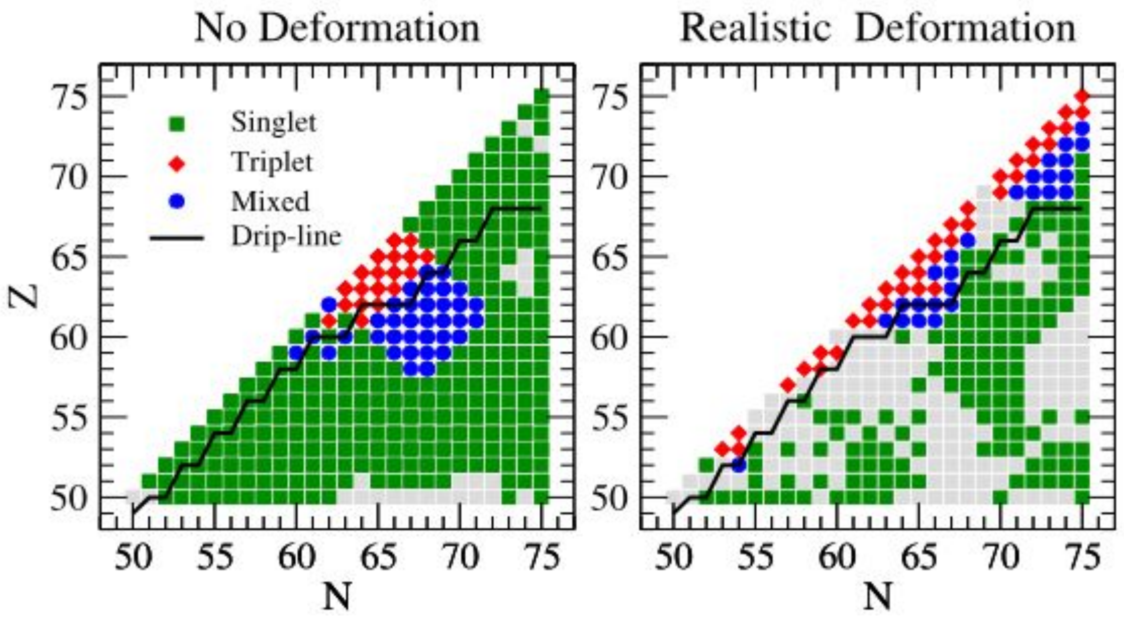
Absolute cross sections





Conclusions

- Proton-neutron pairing is strongly hindered in the middle of the $f_{7/2}$ shell
- The isoscalar pairing channel has generally a low contribution in this shell
- Possible explanation: strong deformation of ^{48}Cr
- Perspectives: exploring proton-neutron pairing in high seniority shells and alpha clustering in N=Z nuclei



G. Palkanoglou, M. Stuck and A. Gezerlis, PRL 134, 032501 (2025)

Deformation modifies both pairing correlation energy and the condensate nature

Thank you !

Collaboration:

- IJCLAB: H. Jacob, M. Assié, Y. Blumenfeld, V. Girard-Alcindor, D. Beaumel, F. Hammache, N. de Séréville, I. Stephan, S. Franchoo, I. Matea, O. Nasr, M. Kaci
- GANIL: G. de France, A. Lemasson, O. Sorlin, J.-C. Thomas, T. Roger, O. Aktas, S. Koyama, E. Clément, F. de Oliveira
- LP2IB: Q. Delignac, S. Grévy
- Surrey: C. Paxman
- Edinburgh: R. Sidhu
- INFN: D. Mengoni, A. Gottardo, S. Bottoni, L. Zago, S. Pigliapoco, F. Galtarossa
- IFIN: F. Rotaru, M. Stanoiu
- USG: M. Lozano Gonzalez