Study of proton-rich Ne isotopes with the ISOLDE Solenoidal Spectrometer

J.L. Aguado[1], P. Butler[2], J. Cederkäll[3], G. De Angelis[4], S. Freeman[5], L. Gafney[2], C. García[1], D. Joss[2], N. Keeley[6], K. Kemper[7], M. Labiche[8], I. Lazarus[8], I. Martel[1], R. Page[2], R. Raabe[9], K. Rusek[10], J. Sánchez[1], D. Sharp[5].

[1] Department of Applied Physics, University of Huelva, 21071 Huelva, Spain.
[2] Department of Physics, University of Liverpool, Liverpool L69 7ZE, United Kigndom.
[3] Department of Physics, Lund University, 223 63 Lund, Sweden.
[4] Laboratori Nazionali di Legnaro, INFN, 35020 Legnaro PD, Italy
[5] Department of Physics, University of Manchester, Manchester M13 9PL, United Kingdom.
[6] National Centre for Nuclear Research, 05-400 Otwock, Poland.
[7] Department of Physics, The Florida State University, Tallahassee, FL 32306 Florida, USA.
[8] STFC Daresbury, Sci-Tech Daresbury, Warrington WA4 4AD, United Kingdom.
[9] Department of Physics and Astronomy, KU Leuven, 3001 Leuven, Belgium.
[10] Heavy Ion Laboratory, University of Warsaw, 02-093 Warsaw, Poland.

Spokesperson: I. Martel

Local contact: Bruno Olaizola

PHYSICS CASE

Study the evolution of proton spectroscopic factors close to the proton drip line, using (d,^{3}He) transfer reactions in inverse kinematics with the Isolde Solenoidal Spectrometer.

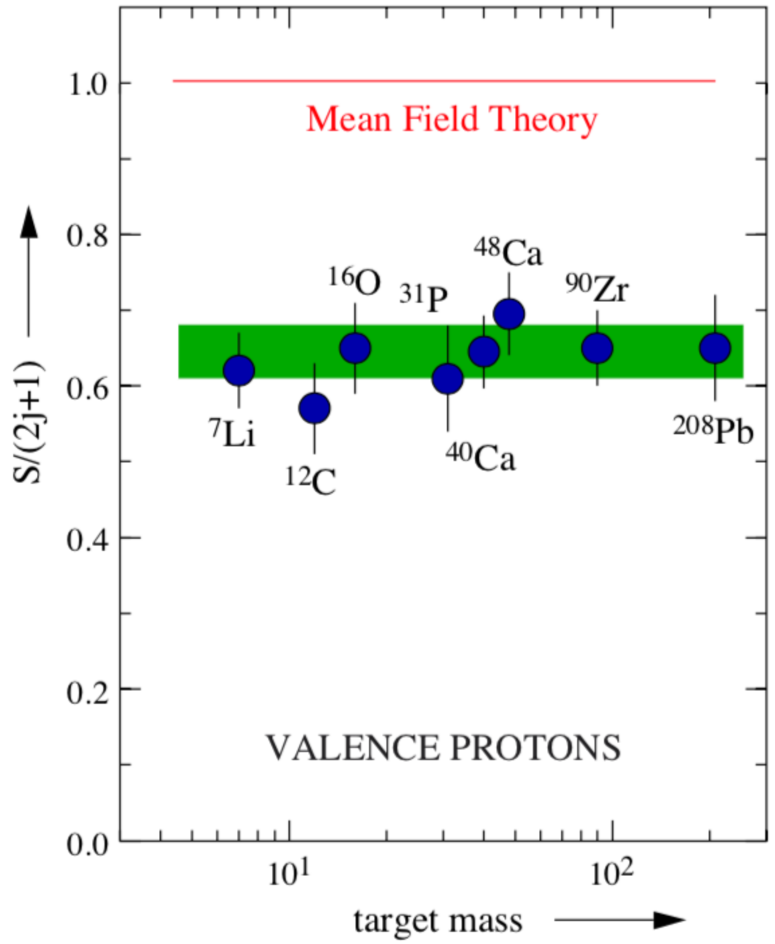
- The ideal shell model considers the nucleus composed of states fully occupied by nucleons.
- In a real nucleus the single-particle strength is fragmented due to correlation effects → configurations mixing.

  → quenching of the spectroscopic factors.

For stable nuclei the (e,e'p) data reveals a quenching factor around ~ 0.6 with respect to the shell model predictions.

The quenching is due to the role played by short and long range correlations:

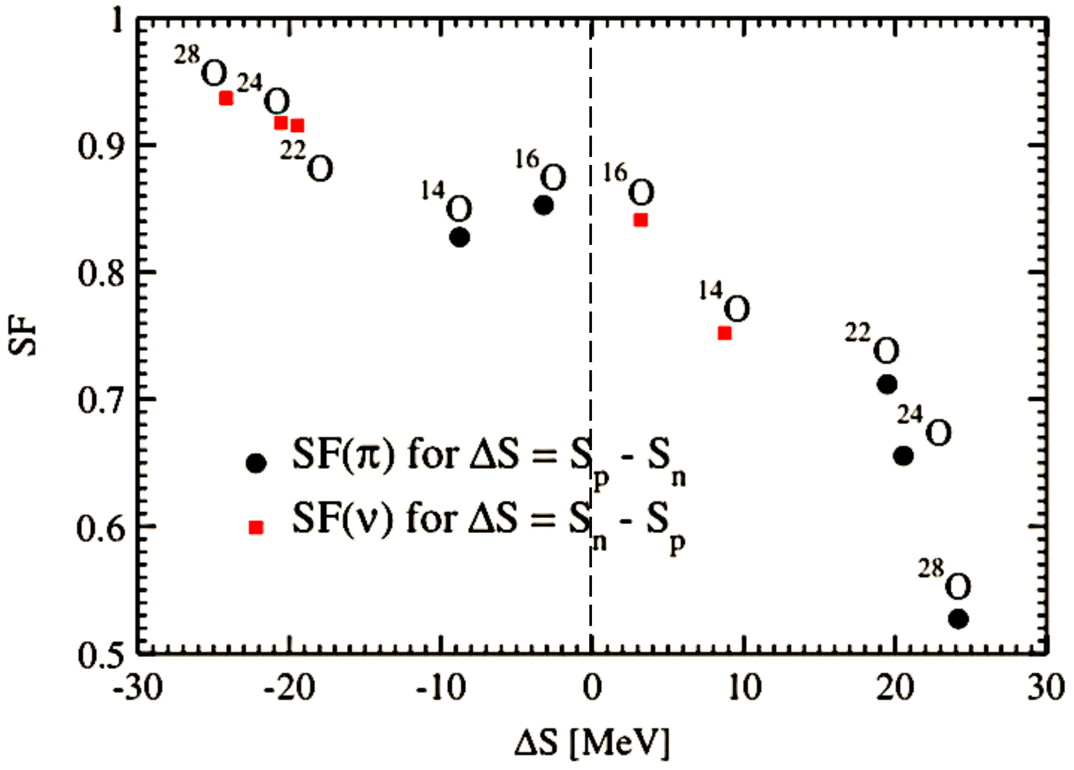
- Tensor interaction
- Particle vibration
- Pairing correlations



Spectroscopic factors from the (e, e′ p) reaction as a function of target mass. Data have been obtained at the NIKHEF facility.

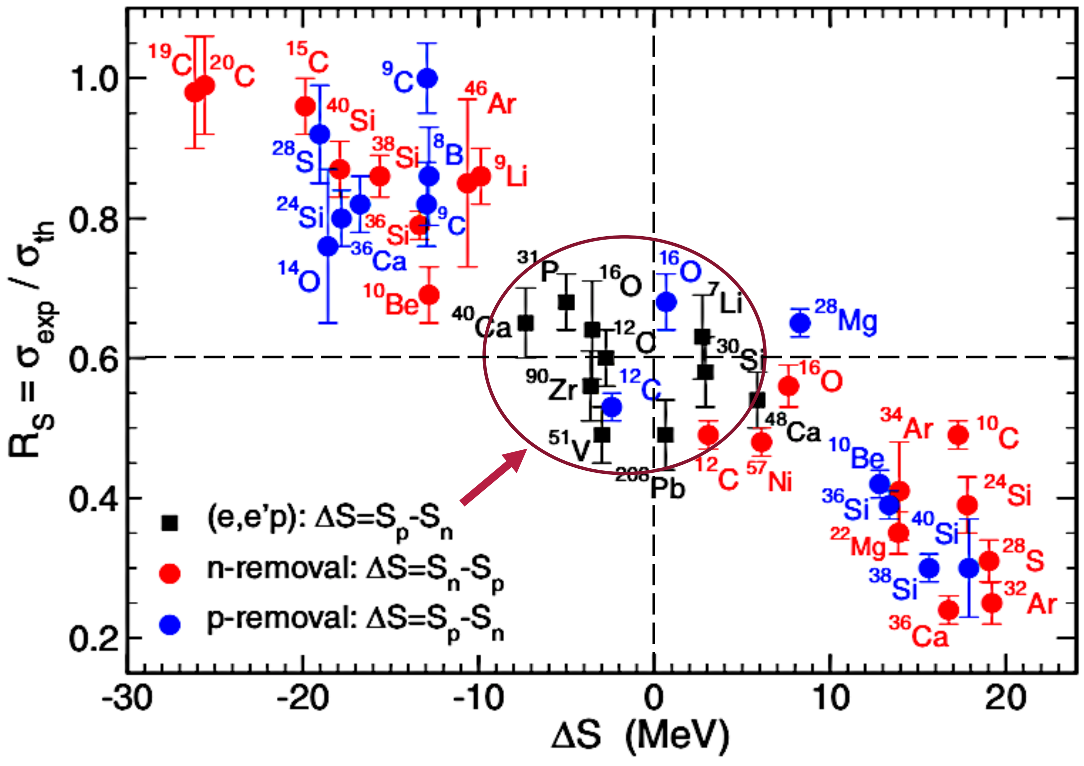
W. Dickhoff, C. Barbieri, Prog. Nucl. Part. Sci. 52 (2004) 377

SF change with n/p: State-of-the-art *ab-initio* calculations show a large SF variation with ΔS = (Sp-Sn) or (Sn-Sp) for n/p removal ~ difference of n/p fermi levels



O. Jensen, G. Hagen, M. Hjorth-Jensen, B.A. Brown, A. Gade. PRL107 (2011) 032501. Coupled-cluster method.

SF quenching: knockout reactions data show a strong dependence on the proton–neutron asymmetry. → effect of LRC on minor p/n component



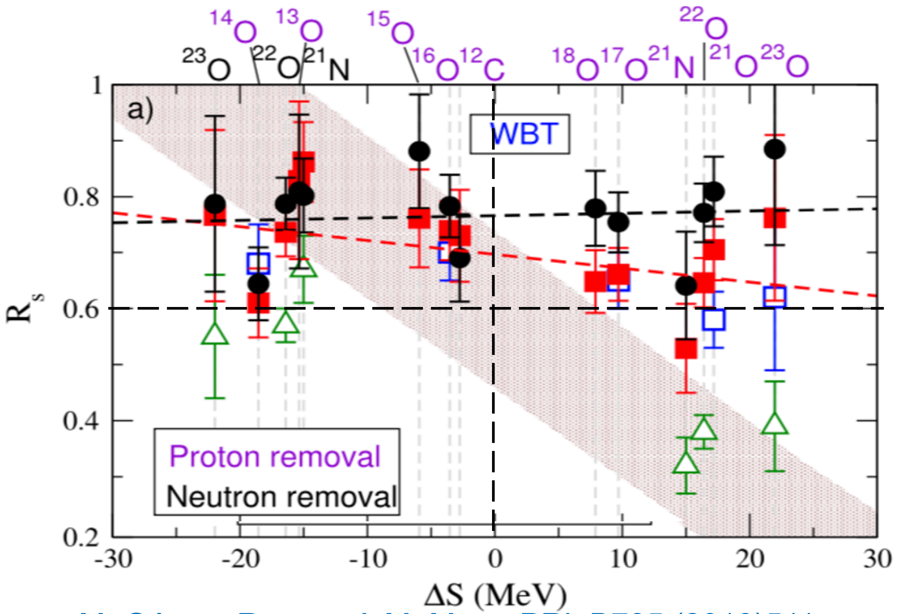
J. A. Tostevin and A. Gade, Phys. Rev. C 90, 057602 (2014). Hartree-Fock (HF) method.

Recent re-analysis of knockout and transfer reactions **show no ΔS dependence, transfer/knockout results basically agree.**

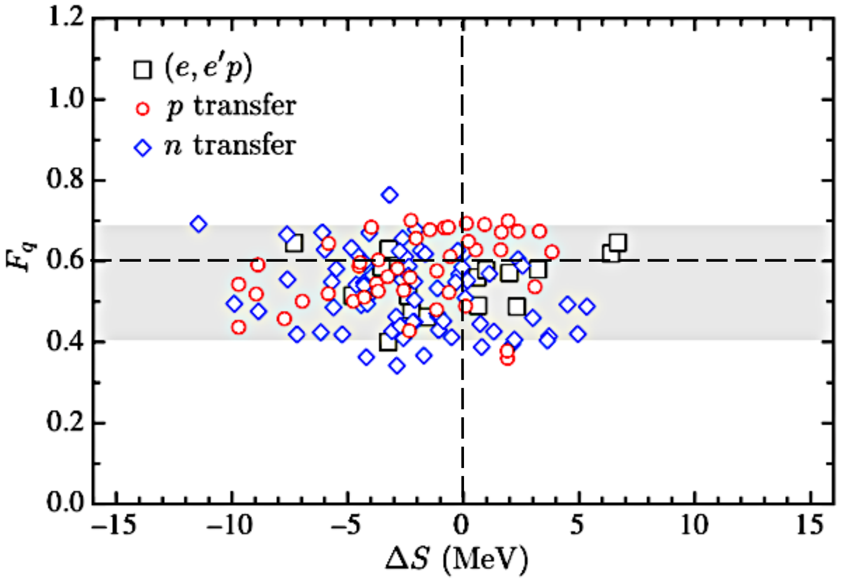
- knockout reactions → all excited states of residues
- transfer reactions → selected single-particle states

→ To extract the spectroscopic information all relevant channels must be included and to use **proper reaction models.**

However there is very few data of proton rich nuclei **using transfer reactions** to test these models.



M. Gómez-Ramos, A.M. Moro. PRL B785 (2018)511

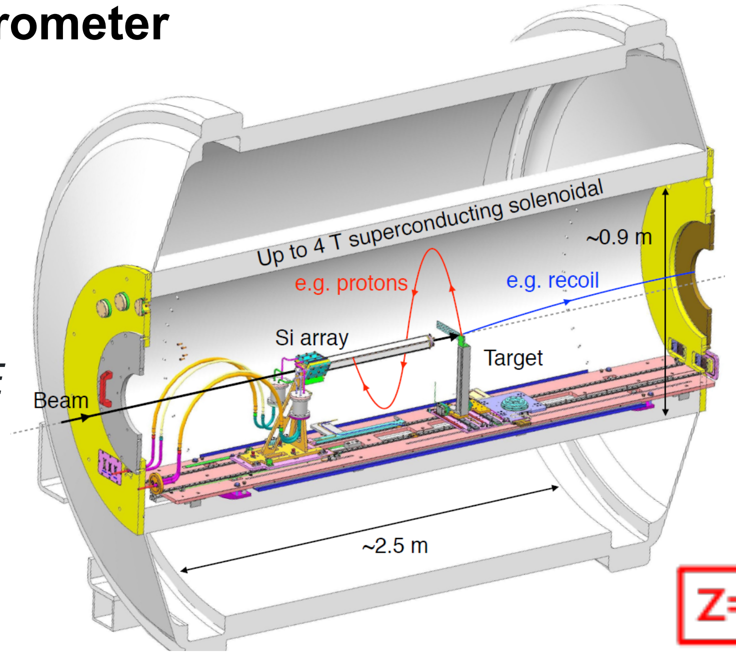


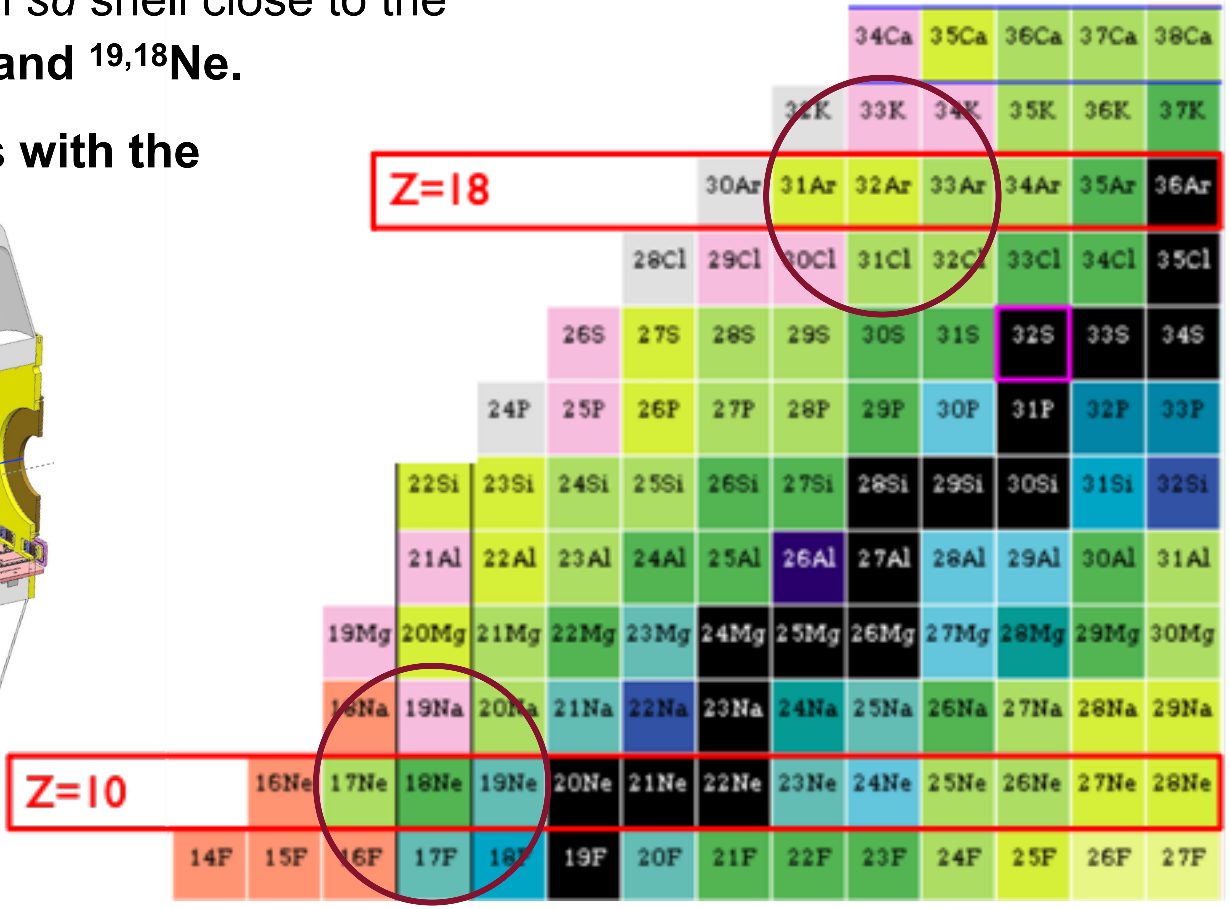
B. P. Kay, J. P. Schiffer, and S. J. Freeman PRL 111, 042502 (2013)

At **ISOLDE** there are two interesting regions on the proton *sd* shell close to the drip lines (large ΔS), experimentally accessible: **^{35,34,33}Ar and ^{19,18}Ne.**

→ Study $1d_{3/2,5/2}$, and $2s_{1/2}$ components of proton orbitals **with the Isolde Solenoidal Spectrometer**

Schematic of the ISOLDE Solenoid Spectrometer.

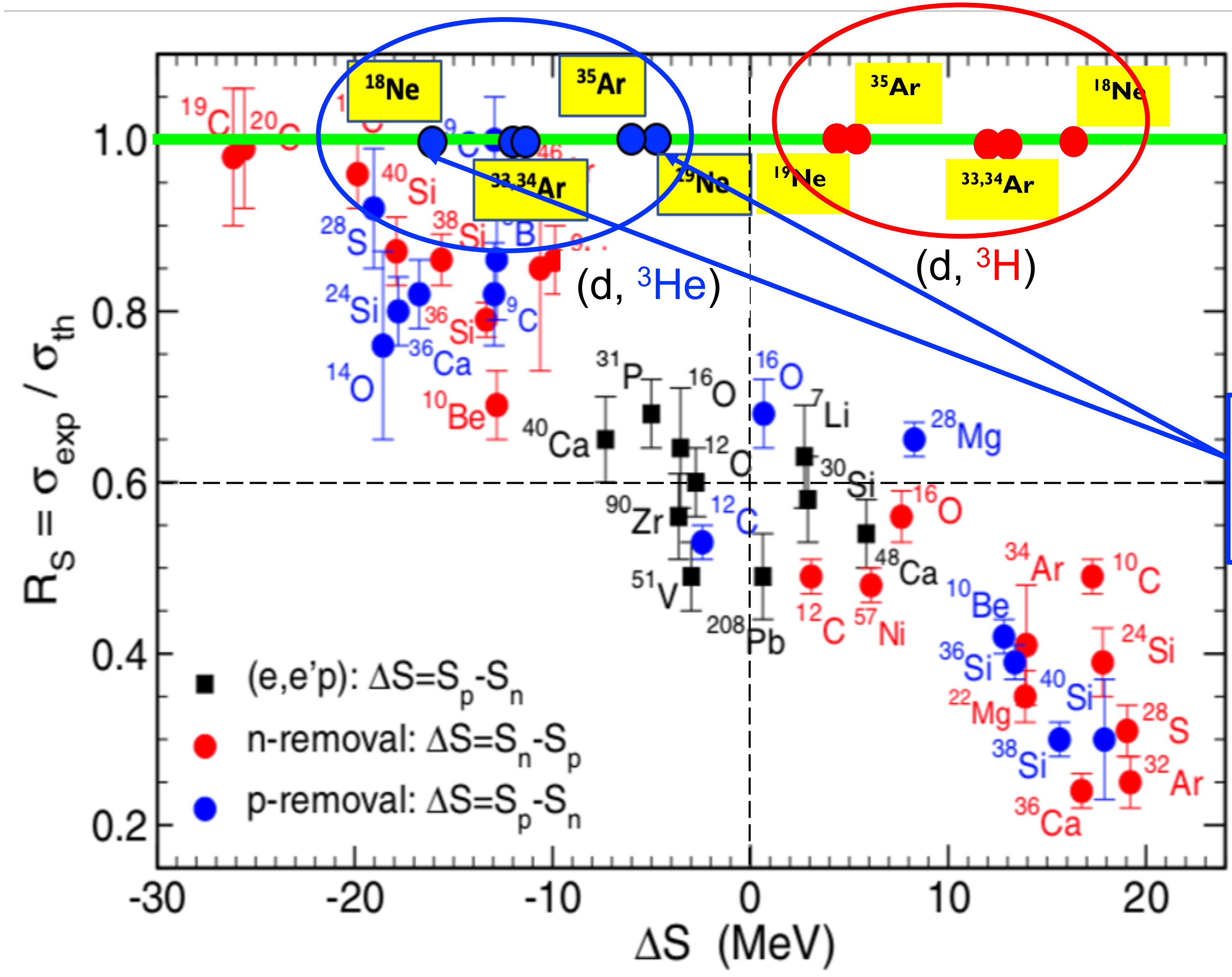




Studies:

- Quenching factors & SP fragmentation
- Correlation between SF(p) and SF(n)
- Isospin dependence
- Coupling to the continuum
- Formation of proton halo/skin towards ^{17}Ne,^{31}Ar
- Test/improve reaction models – beyond DWBA→ coupling effects

PROPOSED PROGRAM



The proposed experiment will focus on **^{18,19}Ne ground states** using (d, ^{3}He) reactions.

WHAT DO WE KNOW ABOUT PROTON SFs OF $^{18}Ne_{gs}$ AND $^{17}Ne_{gs}$?

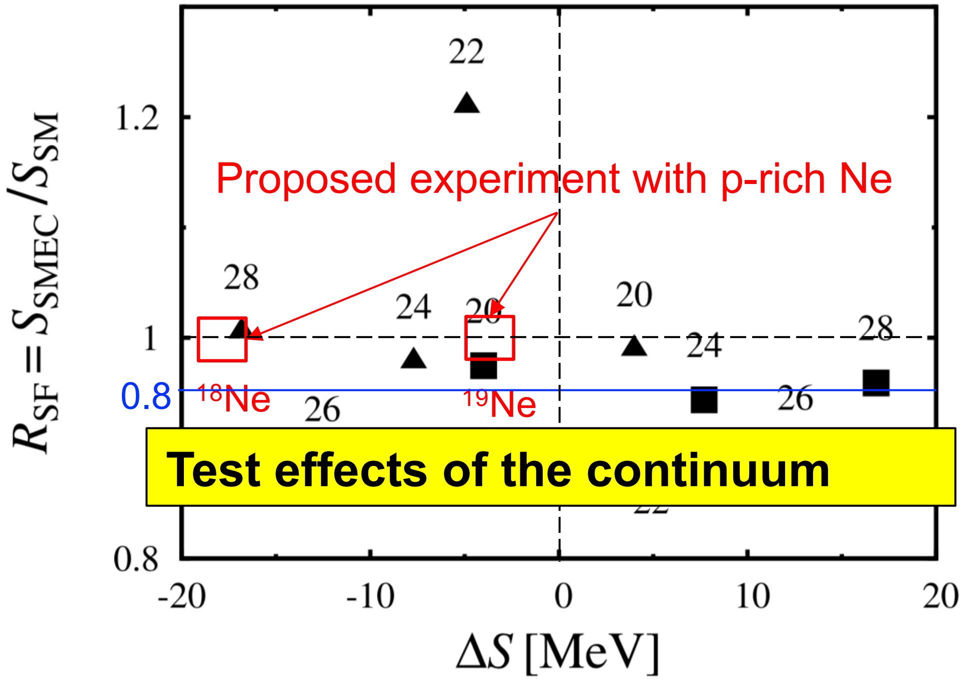
There is **no experimental information on ground states**, but only for states above proton separation threshold (relevant for astrophysics).

Relevant theoretical studies:

N.K. Timofeyuk, I.J. Thompson, PRC78 (2008):
Mirror SF of ^{18}Ne & ^{18}O using three-body model and Hartree-Fock calculations.

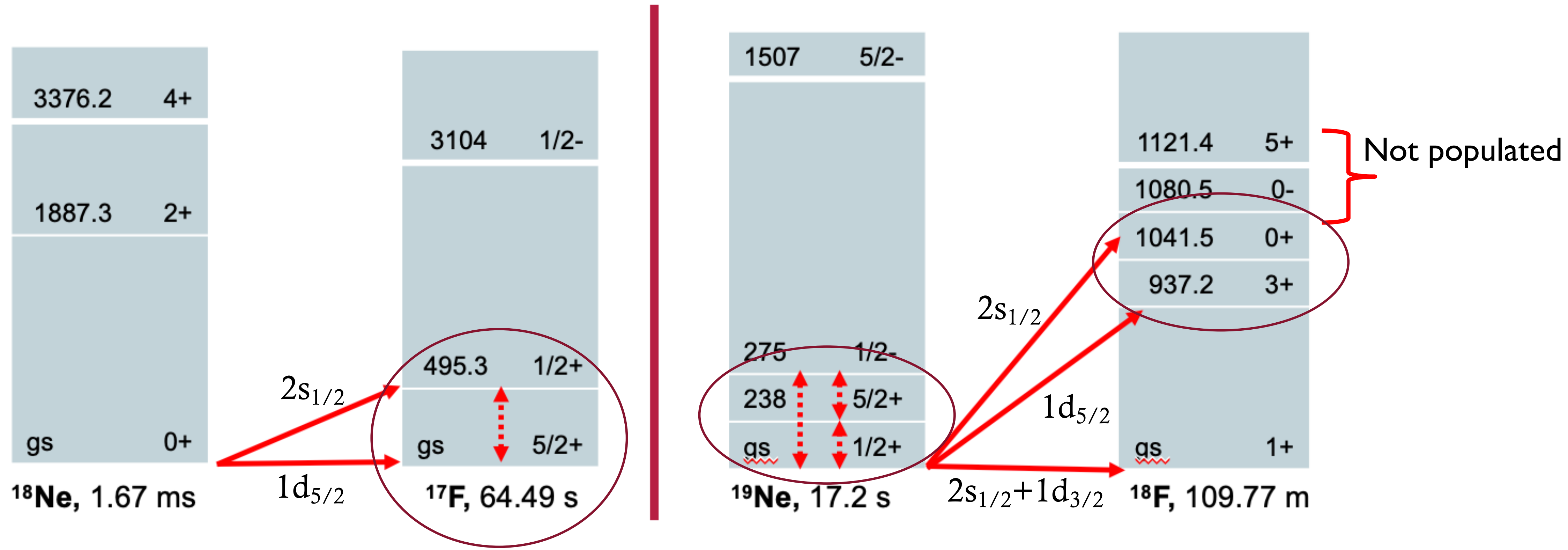
J.Okołowicz et al., PLB757 (2016):
Calculate ratio of SMEC and SM ground state spectroscopic factors in the chain of **Ne rich isotopes** (20 ≤ *A* ≤ 28). → effects of the continuum.

Ne rich isotopes (20 ≤ *A* ≤ 28)



Ratios SMEC/SM.
Proton(squares), neutron (triangles).
J.Okołowicz et al., PLB757 (2016).

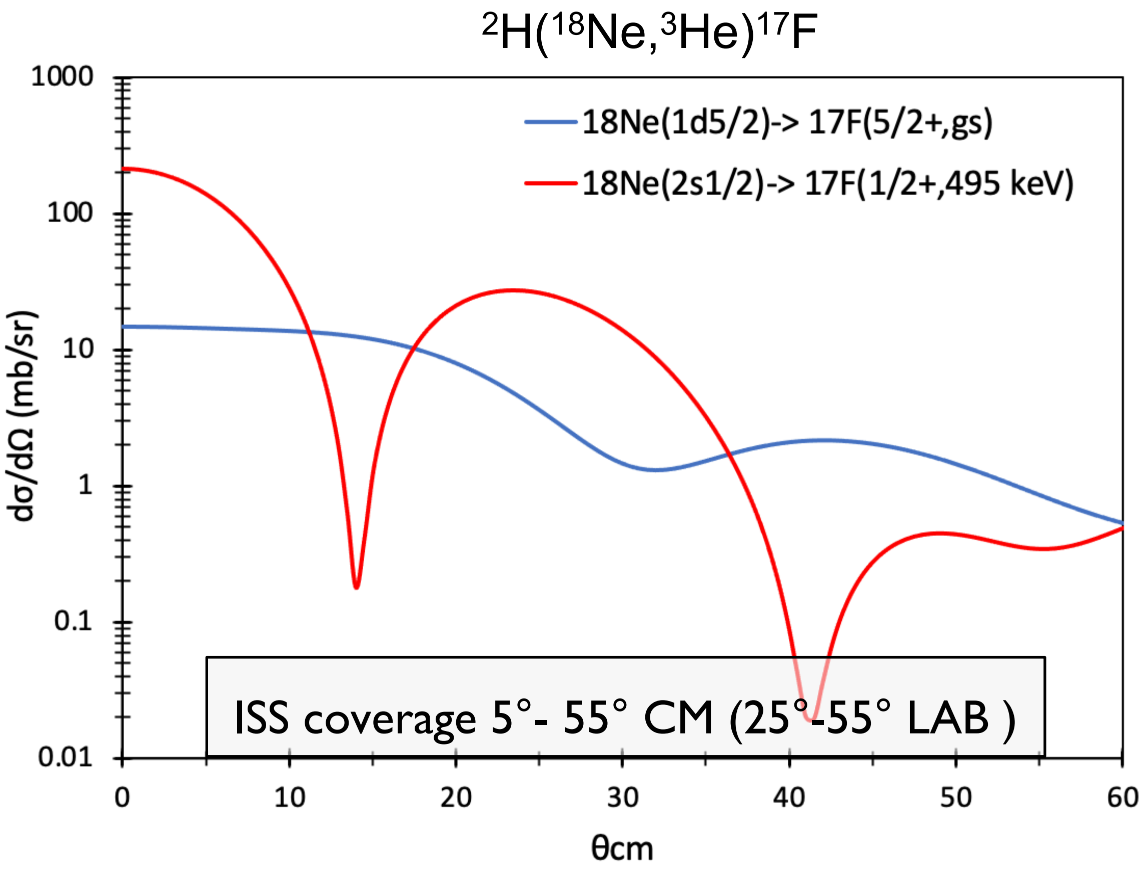
REACTION MODELS: COUPLING EFFECTS

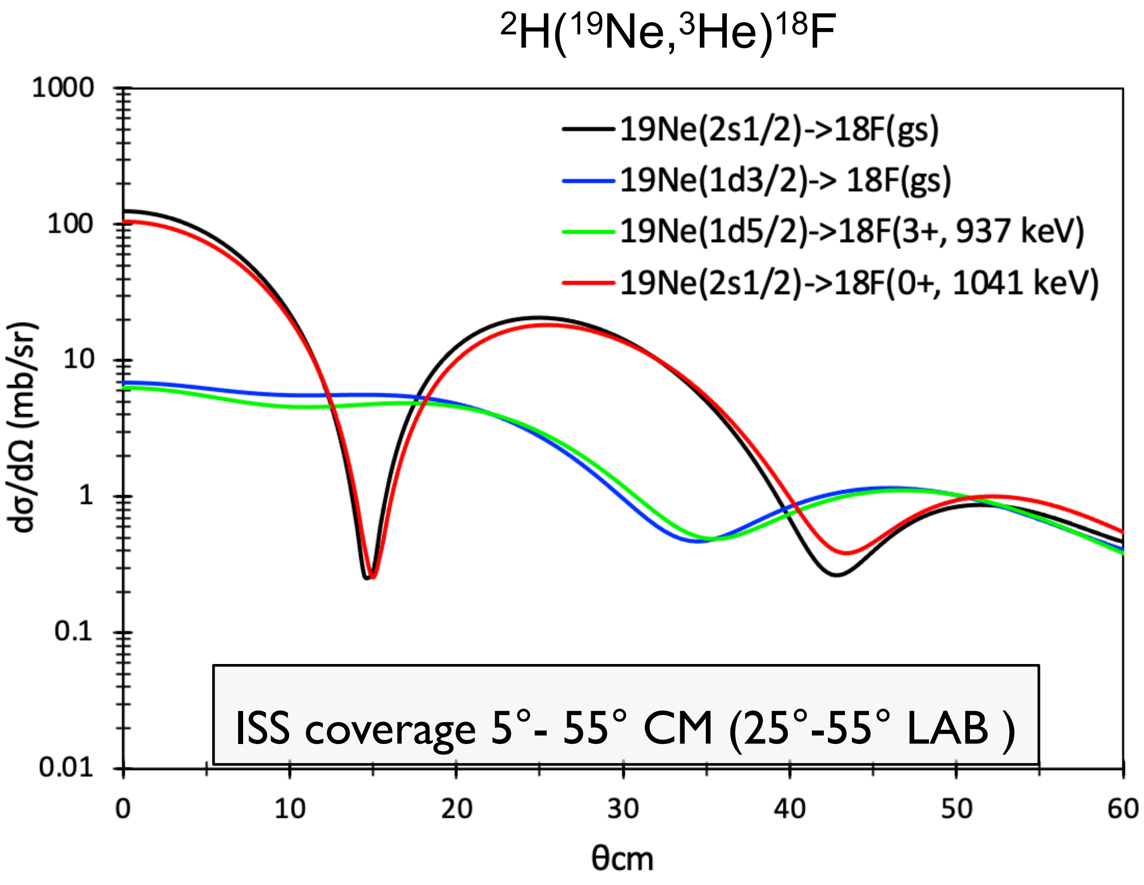


- DWBA first approach
- CRC to include coupling to excited states (FRESCO)
- Tune reaction models close to the drip lines
- Investigate evolution of SF and quenching factors

DWBA CALCULATIONS

DWBA calculations for 3He transfer from $2s_{1/2}$ and $1d_{3/2}$, $1d_{5/2}$ single-particle components to ground and excited states of the recoiling nucleus. Totals cross sections ~ 5 – 30 mb.

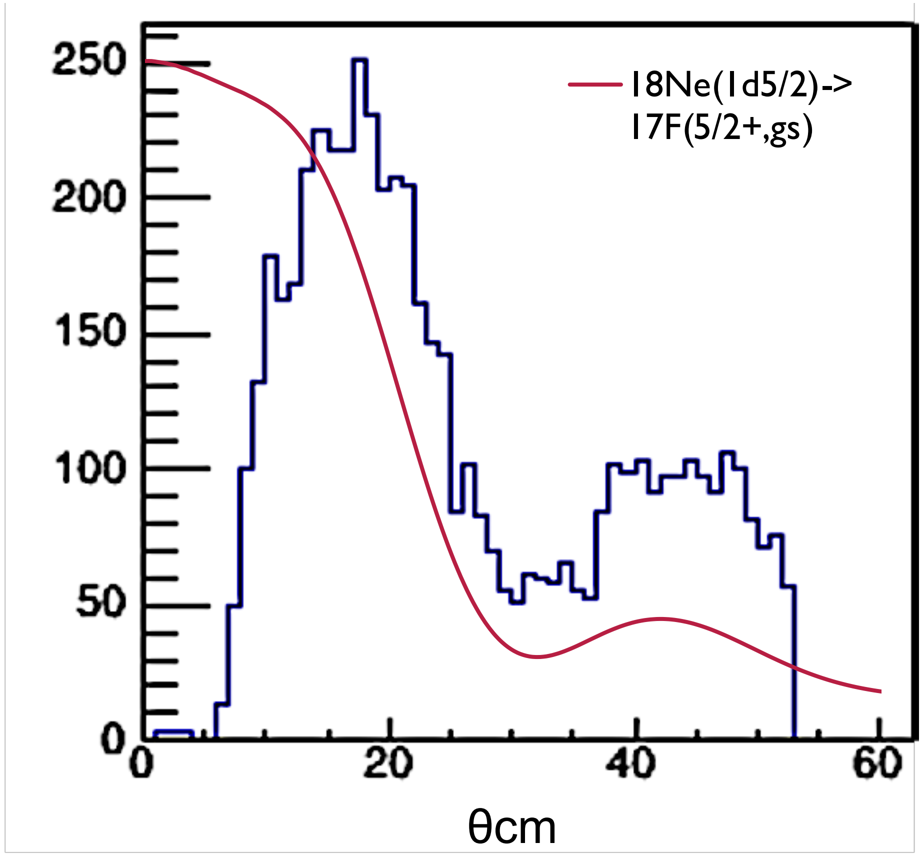




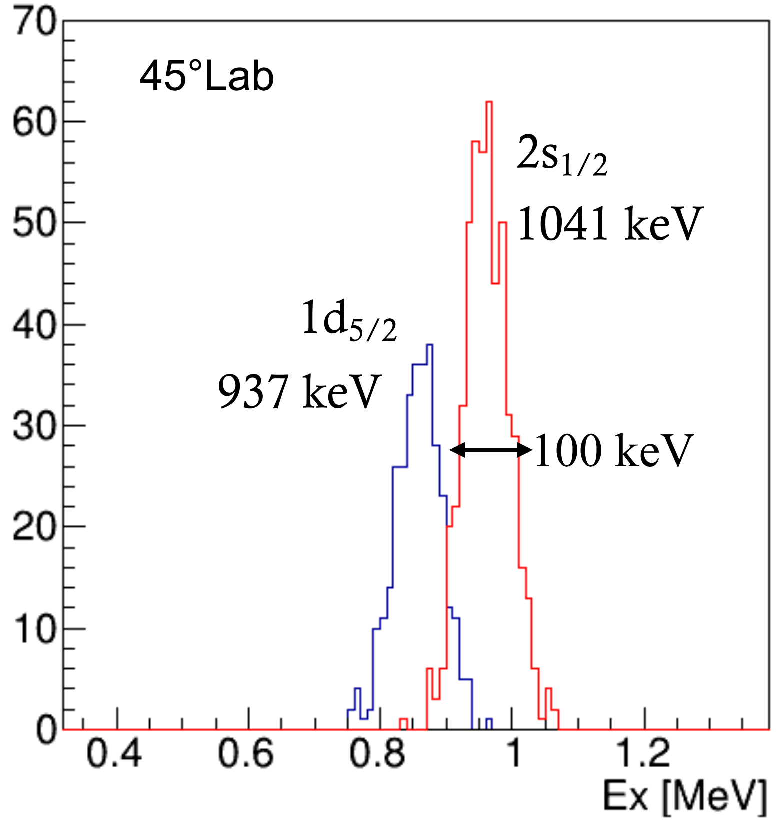
SIMULATIONS

ISS: detector array at forward angles (25 cm from target)

$^{18}Ne(d,^{3}He)^{17}F_{gs}$ @ 10 MeV/u



$^{19}Ne(d,^{3}He)^{18}F^{*}$ @ 10 MeV/u



- **Good intensity**

→ T ~ 200 μg/cm²

→ E_{res} ~ 100 keV

→ Peak fit

- **Lower intensity**

→ 300 μg/cm²

→ E_{res} ~ 200 keV

→ Integrate $2s_{1/2}$+$1d_{5/2}$

Courtesy of Marc Labiche

BEAM TIME REQUEST

- 10% overall transmission to target
- Yields from CaO production target
- CD_2 reaction target, (200 ~ 300 μg/cm^2)
- Estimated Xsec ~ 5 - 30 mb
- ~ 10% statistical uncertainty

  SF ~ 15% uncertainty

	TOTAL CROSS SECTION (mb)		
TRANSFER PROCESS	$2s_{1/2}$	$1d_{3/2}$	$1d_{5/2}$
$^{19}Ne_{gs} \rightarrow {}^{18}F_{gs}$ (1+)	23.01	6.49	-
$^{19}Ne^* \rightarrow {}^{18}F^*$ (937 KeV, 3+)	-	-	7.74
$^{19}Ne^* \rightarrow {}^{18}F^*$ (1041 KeV, 0+)	20.96	-	-
$^{18}Ne_{gs} \rightarrow {}^{17}F_{gs}$ (5/2+)	-	-	11.02
$^{18}Ne_{gs} \rightarrow {}^{17}F^*$ (495 keV, 1/2+)	28.63	-	-

Isotope	Production CaO	Intensity at target	Minimum events expected	Shift request
^{19}Ne	9.6 10^6 pps	9.6 10^5 pps	10000-20000	2.5
^{18}Ne	6.9 10^5 pps	6.9 10^4 pps	5000-10000	18.5
Beam change	-	-	-	2
			TOTAL	**23**

1 additional shift of stable ^{20}Ne for tuning the experimental setup