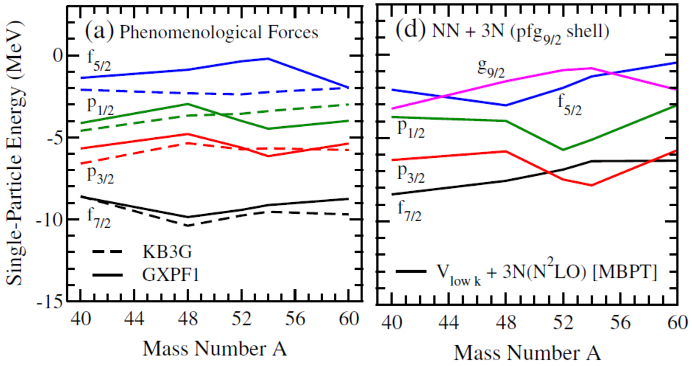
Spectroscopic factors from transfer and knockout reactions

Freddy Flavigny

Single-particle structure

Single-particle energies

- Pillar of our understanding
- Crucial to investigate shell evolution



[J.Holt, T.Otsuka, Jour. Phys. G**39**, 08111 (2012)]

Single-particle structure and SF

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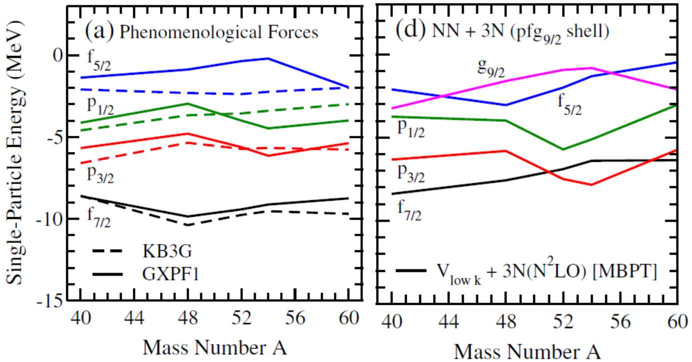
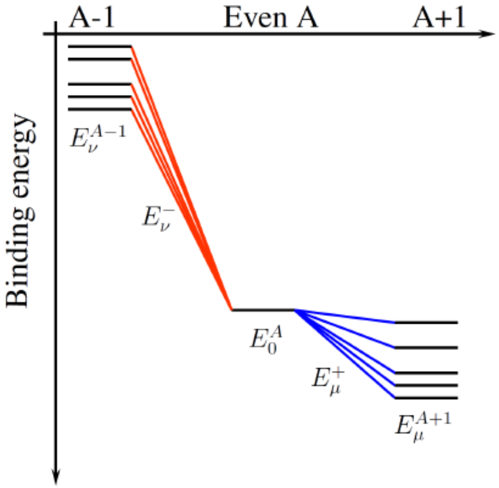


[J.Holt, T.Otsuka, Jour. Phys. G**39**, 08111 (2012)]



[T.Duguet, G. Hagen, PRC85 034330 (2012)]

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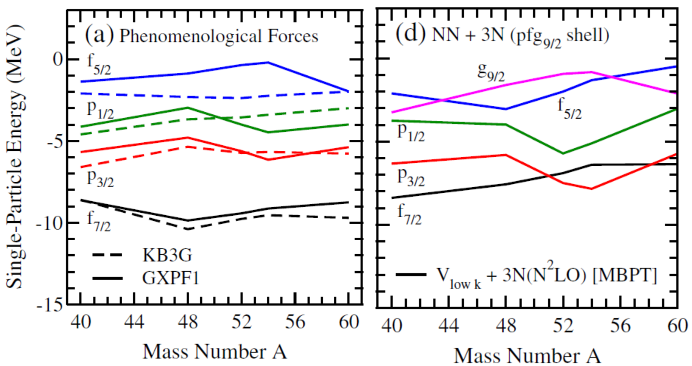

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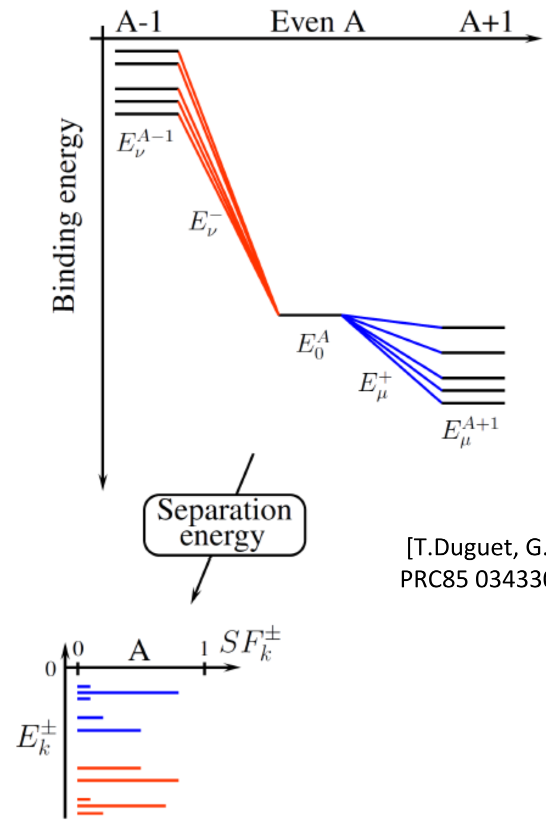

[T.Duguet, G. Hagen, PRC85 034330 (2012)]

$$SF_\mu^+ = \sum_{p \in H_1} \left| \left\langle \varphi_\mu^{A+1} \middle| a_p^+ \middle| \varphi_0^A \right\rangle \right|^2$$

$$SF_n^- = \sum_{p \in H_1} \left| \left\langle \varphi_n^{A-1} \middle| a_p \middle| \varphi_0^A \right\rangle \right|^2$$

Single-particle structure and SF

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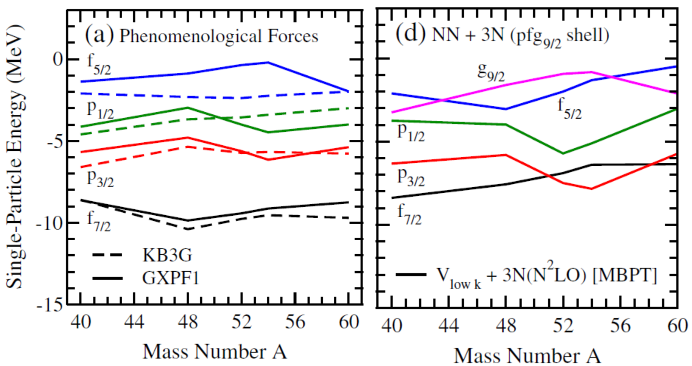
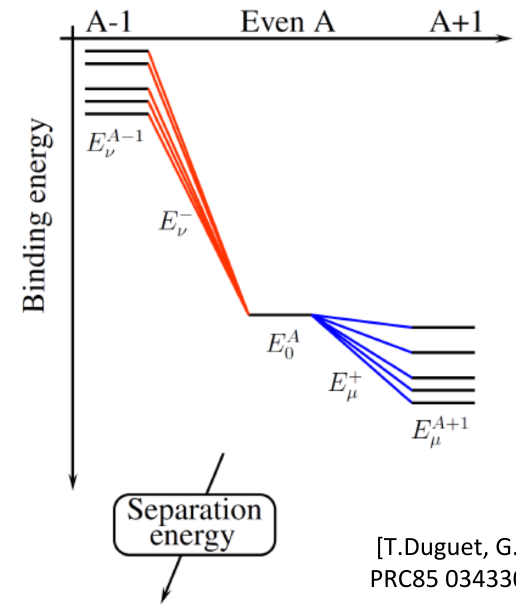


[J.Holt, T.Otsuka, Jour. Phys. G**39**, 08111 (2012)]

Baranger Sum Rule

$$e^{cent}{}_p = \sum_{\mu \in H_{A+1}} SF_\mu{}^+ E_\mu{}^{A+1} + \sum_{n \in H_{A-1}} SF_n{}^- E_n{}^{A-1}$$

[M. Baranger, Nucl. Phys. A**149**, 225 (1970)]



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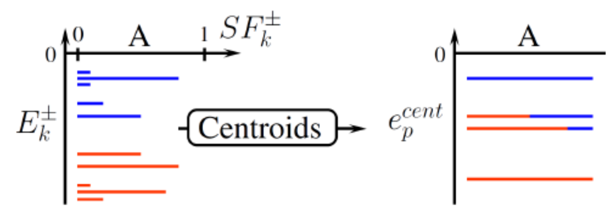

$$SF_\mu{}^+ = \sum_{p \in H_1} \left| \langle \varphi_\mu{}^{A+1} | a_p{}^+ | \varphi_0{}^A \rangle \right|^2$$

$$SF_n{}^- = \sum_{p \in H_1} \left| \langle \varphi_n{}^{A-1} | a_p | \varphi_0{}^A \rangle \right|^2$$

Non-observability

Baranger sum rule:

$$e_p^{\text{cent}} \equiv \sum_{\mu \in \mathcal{H}_{A+1}} S_\mu^{+pp} E_\mu^+ + \sum_{\nu \in \mathcal{H}_{A-1}} S_\nu^{-pp} E_\nu^-$$

Full expansion:

$$\underbrace{\overset{\text{many-body observable}}{E_\mu^+}}_{\text{invariant under } U(\lambda)} \equiv \underbrace{\overset{\text{single-particle components}}{\sum_p s_\mu^{+pp}(\lambda)\, e_p^{\text{cent}}(\lambda)}}_{\text{varies under } U(\lambda)} + \underbrace{\overset{\text{correlations}}{\sum_{pq} s_\mu^{+pq}(\lambda)\, \Sigma_{qp}^{\text{dyn}}(E_\mu^+;\lambda)}}_{\text{varies under } U(\lambda)} \,,$$

SFs are **not observable** – modified through Unitary Transforms

For an extended discussion , see:

- T. Duguet, H. Hergert, J. D. Holt, and V. Somà, PRC **92** 034313(2015)
- T.Duguet., G.Hagen, PRC **85** 034330 (2012)
- R.J. Furnstahl and H.W. Hammer, PLB **531**, 203 (2002)

Direct reactions: a probe for nuclear structure

Reason of interest / belief: sensitive to shell occupancy / overlap from initial to final states

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Major assumption in treatment : separation of reaction mechanism and structure inputs

Cross section
to populate a final state μ

$$\sigma_\mu = \sum_{p\, \in H<H_1} \underbrace{\left| \left\langle \varphi_\mu{}^{A-1} \middle| a_p{}^- \middle| \varphi_0{}^A \right\rangle \right|^2}_{\text{Structure}} \times \underbrace{\sigma_p}_{\text{reaction}}$$

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reaction

Structure (C²S)

In practice:

1) Measure σ^{exp}_{if} the cross section to populate a given final state

2) Calculate $\sigma^{sp}(nlj)$ with a reaction model suited for the direct reaction you used

3) Extract C^2S^{exp}:

$$C^2 S^{\exp} \propto \frac{\sigma^{\exp}}{\sigma^{th}_{sp}}$$

4) Compare with structure model value C^2S^{th}

→ Experimental Spectroscopic factors are reaction model dependent

Direct reactions: a probe for nuclear structure

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Cross section
to populate a final state μ

$$\sigma_\mu = \sum_{p\,\in H<H_1} \left|\left\langle \varphi_\mu{}^{A-1} \middle| a_p{}^- \middle| \varphi_0{}^A \right\rangle\right|^2 \times \sigma_p$$

reaction

Structure

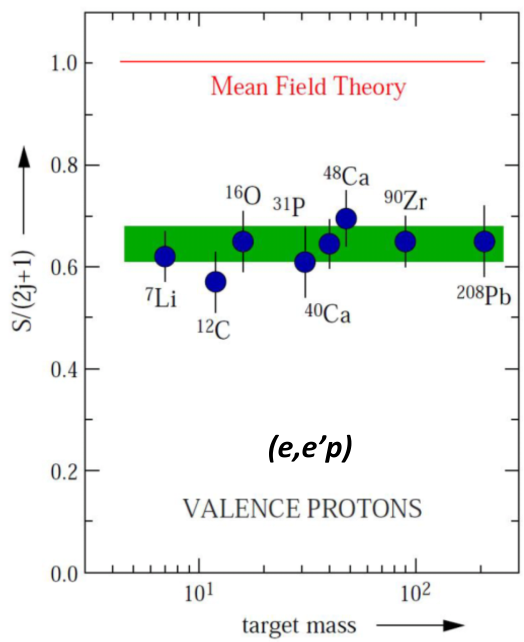
What should be done:

- ✓ Consistent approach of reaction and structure (same Hamiltonian)
- ✓ Clearly assess which theoretical framework is used (which Hamiltonian)

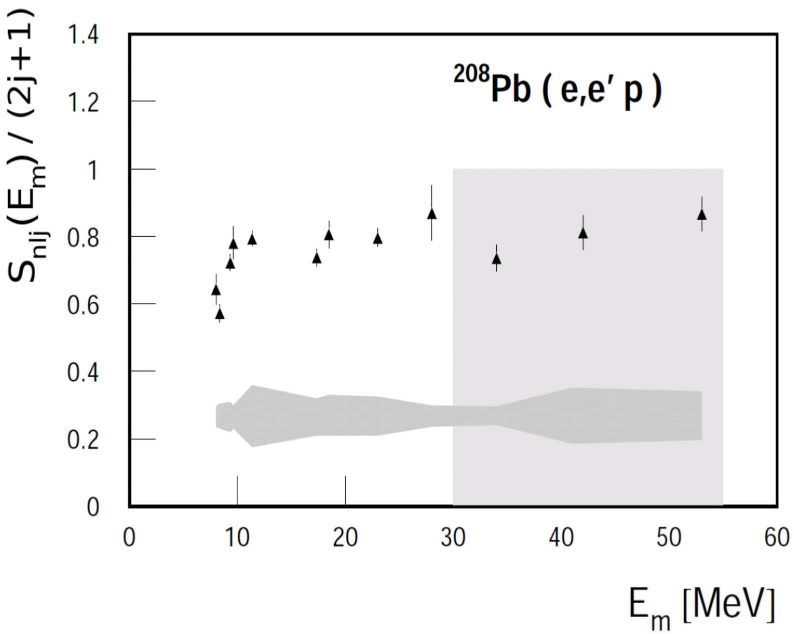
What is done (*i.e.* what *can be done* today):

- ✓ Inconsistent treatment of structure and reaction mechanism
- ✓ Most often highly-truncated model space (shell model)

(e,e'p) on stable nuclei



L. Lapikás, Nucl. Phys. A 553 (1993) 297
[W. Dickhoff, C. Barbieri, PNP**52**, 377 (2004)]



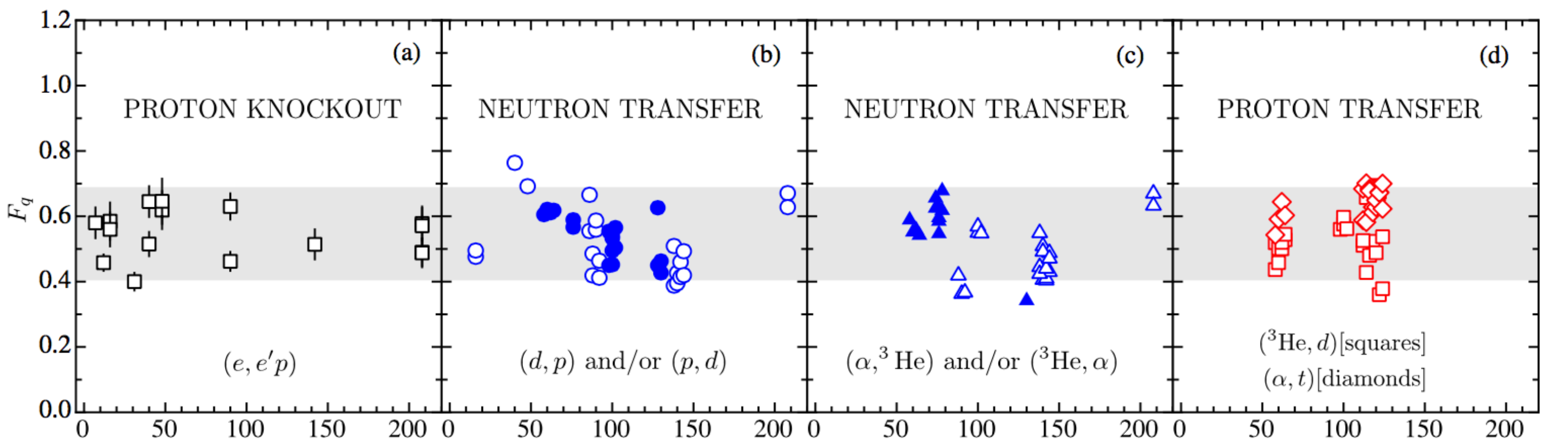
M.F. Van Batenburg, PhD thesis (2001)
University of Utrecht, NIKHEF data

- 30-40 % reduction
- Beyond mean-field correlations
  Short and Long range
- Little binding energy dependence
- Agreement with (d,He³)
  [G.J. Kramer et al., NPA**679**, 267 (2001)]

Consistent re-analysis of transfer data on stable nuclei:

B. P. Kay et al., PRL **111** (2013) 043502.

$$F_q \equiv \frac{1}{(2j+1)}\left[\Sigma\left(\frac{\sigma_{\rm exp}}{\sigma_{\rm DW}}\right)_j^{\rm add} + \Sigma\left(\frac{\sigma_{\rm exp}}{\sigma_{\rm DW}}\right)_j^{\rm rem}\right],$$



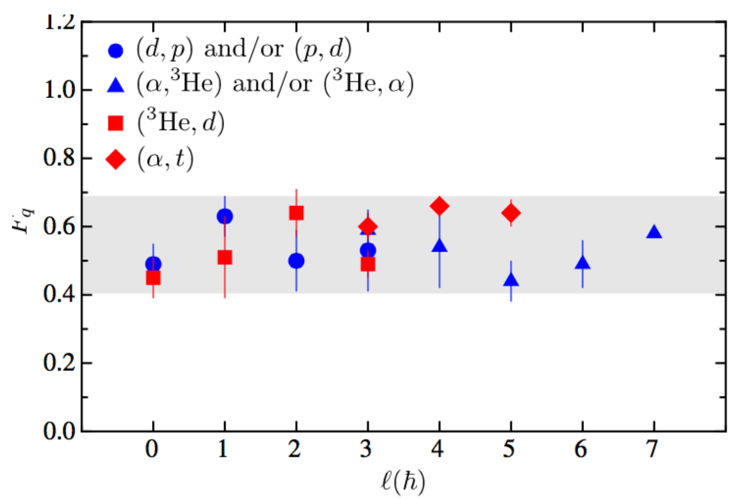


TABLE I. Mean quenching factor by reaction type.

Reaction, ℓ transfer	Number of determinations	F_q	rms spread
(e,$e'p$), all ℓ	16	0.55	0.07
(d,p), (p,d), $\ell = 0$–2	40	0.53	0.09
(d,p), (p,d), $\ell = 0$–3	46	0.53	0.10
(α,^{3}He), (^{3}He,α), $\ell = 4$–7	26	0.50	0.09
(α,^{3}He), (^{3}He,α), $\ell = 3$–7	34	0.52	0.09
(^{3}He,d), $\ell = 0$–2	18	0.54	0.10
(^{3}He,d), $\ell = 0$–4	26	0.54	0.09
(α,t), $\ell = 4$–5	14	0.64	0.04
(α,t), $\ell = 3$–5	18	0.64	0.04
All transfer data[a]	124	0.55	0.10

[a]Rows 3, 5, 7, and 9.

Transfer on stable nuclei

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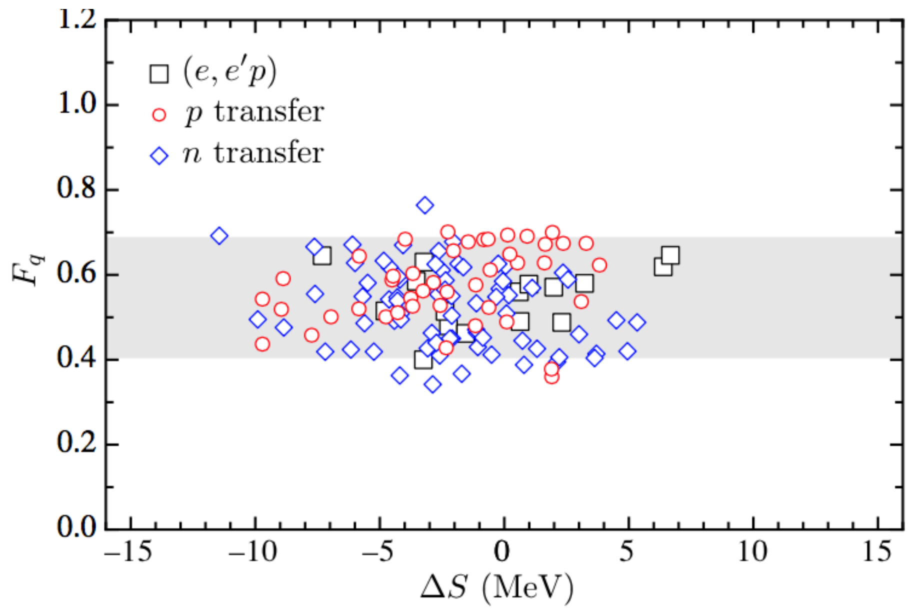
B. P. Kay et al., PRL **111** (2013) 043502.

$$F_q \equiv \frac{1}{(2j+1)}\left[\Sigma\left(\frac{\sigma_{\exp}}{\sigma_{\mathrm{DW}}}\right)_j^{\mathrm{add}} + \Sigma\left(\frac{\sigma_{\exp}}{\sigma_{\mathrm{DW}}}\right)_j^{\mathrm{rem}}\right],$$



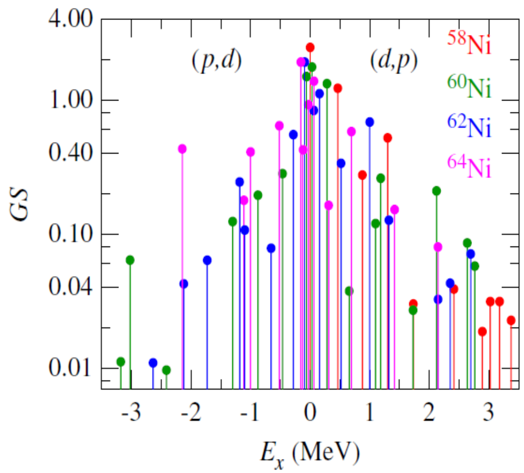
$\Delta S = \varepsilon\,|S_n - S_p|$ (MeV)

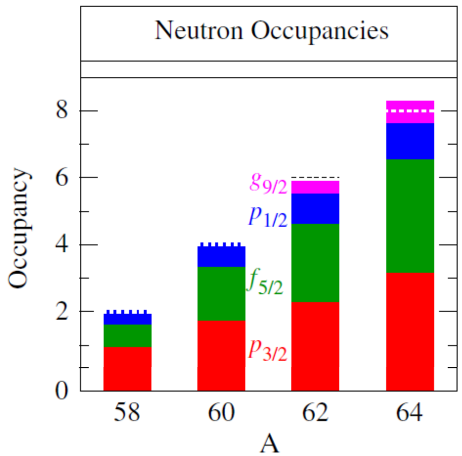
Quenching:

- No clear mass dependence
- No clear l-transfer dependence
- No clear ΔS dependence in [-10;6] MeV

All compatible with (e,e'p)

Transfer on stable nuclei (ex: Ni isotopes)





Global renormalization by 0.55 for correlations beyond shell model

J.P. Schiffer *et al.,* Phys. Rev. Lett. **108**, 022501 (2012).

Quantitative test of sum rules using nucleon transfer reactions:

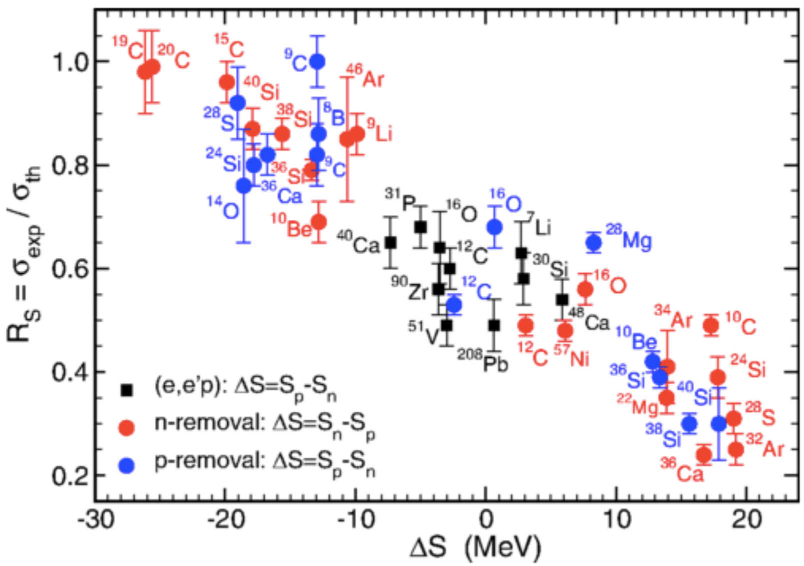
For a given angular momentum: $$N_{particles} + N_{holes} = 2j+1$$

(MacFarlane and French 's sum-rule) $$\sum G^{+}S_{addition} + \sum G^{-}S_{removal} = 2j+1$$

Nucleon removal from exotic nuclei

Intermediate energy Knockout

J.A. Tostevin and A. Gade, Phys. Rev. C **90**, 057602 (2014)



- **Disagreement between theory and experiment**

$$\sigma_{th} = \Sigma\, C^2 S_{th}\ \sigma_{sp}$$

2 possible sources: (structure or reaction)

Nucleon removal from exotic nuclei

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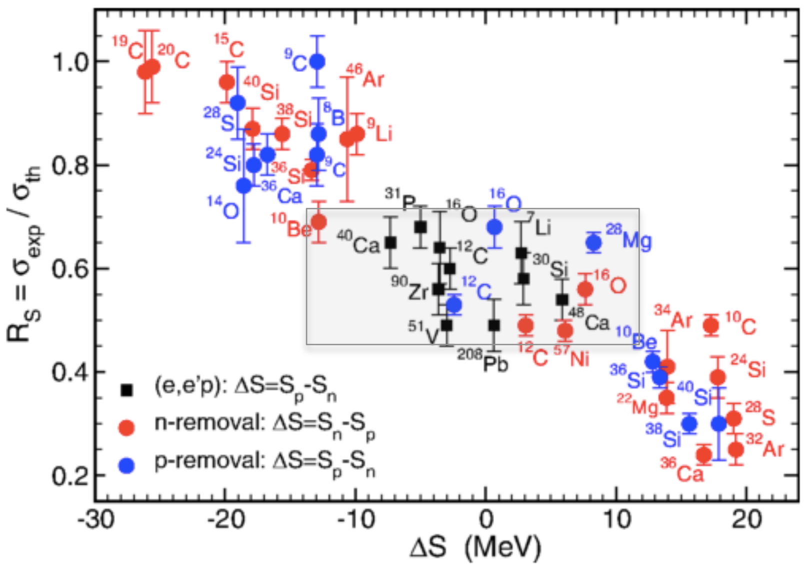
J.A. Tostevin and A. Gade, Phys. Rev. C **90**, 057602 (2014)



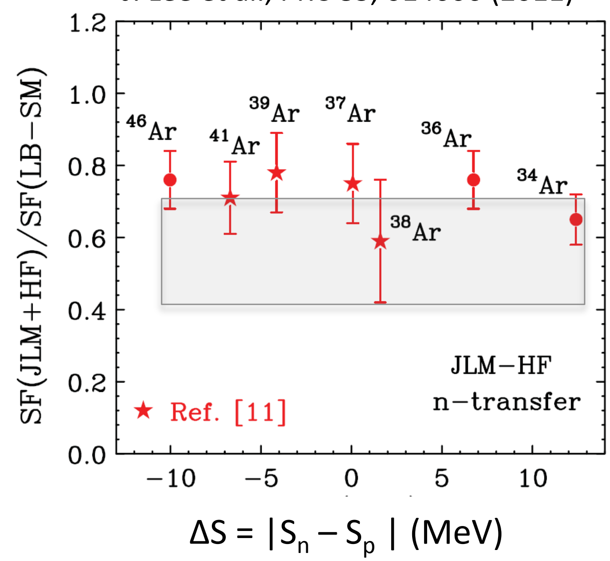
- **Disagreement between theory and experiment**

$$\sigma_{th} = \Sigma C^2 S_{th}\ \sigma_{sp}$$

2 possible sources: (structure or reaction)

Transfer (d,p)

J. Lee et al., PRC 83, 014606 (2011)



Low-energy (p,d) transfer

- Constant reduction~30%
- Data for ΔS up to [-13,13] MeV

Applicability of reaction models to deeply-bound nucleon stripping?

Experimental program

Question : Are spectroscopic factors from knockout and transfer consistent for high ΔS ?

Experimental Program

- $^{14}O + {}^{9}Be \rightarrow {}^{13}O$ ou $^{13}N + X$
- $^{16}C + {}^{9}Be \rightarrow {}^{15}C$ ou $^{15}B + X$

53 MeV/u
75 MeV/u
@ NSCL

[F.Flavigny et al., Phys. Rev. Lett **108**, 252101 (2012)]

- $^{14}O + d \rightarrow {}^{13}O + t$
- $^{14}O + d \rightarrow {}^{13}N + {}^{3}He$
- $^{14}O + d \rightarrow {}^{14}O + d$

18 MeV/u @ SPIRAL-GANIL

[F.Flavigny et al., Phys. Rev. Lett. **110** 122503 (2013)]

Reaction Models

Knockout:

- *Medium effects (Pauli principle)*
  [*F. Flavigny , A. Obertelli et I. Vidana, PRC* ***79****, 064617 (2009)*]
- *Intra-nuclear Cascade Model*
  [C.Louchart et al., PRC **83**, 011601 (R) (2011)]
- *Transfer to the continuum model*

Transfer:

- *Coupled-Channel calculations (FRESCO)*
- *Use of standard and* ***ab-initio*** *overlaps*

Ideal case: ^{14}O

✓ Large value ΔS = 18.6 MeV
✓ Closed-shell nucleus, well described in SM calculations
✓ Beam intensity high enough for (d,^{3}H) (d,^{3}He) transfer measurements

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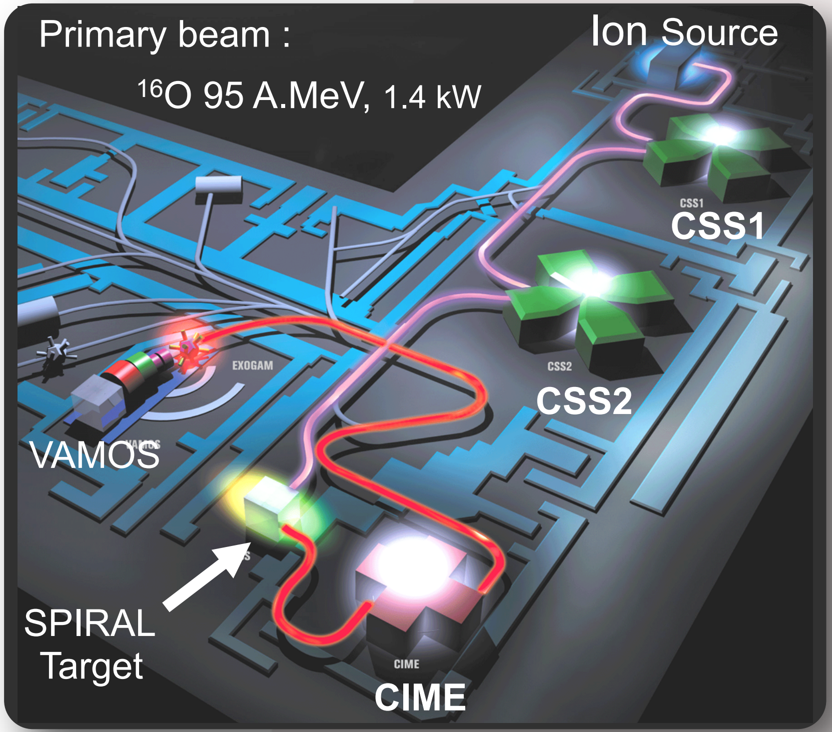
Transfer

Beam production, acceleration, detection setup



SPIRAL Beam: $^{14}O^{8+}$

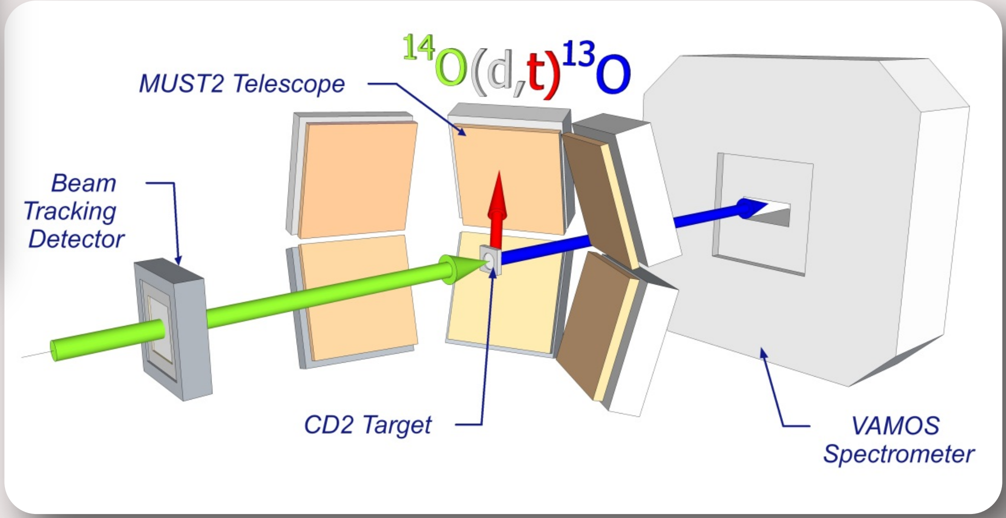
Intensity: 6.10^4 pps

Energy: 18.1 A.MeV

CD2 targets: 0.5,1.5 and 8.5 mg.cm^{-2}

Reactions: (d,d), (d,^{3}H) and (d,^{3}He)

- *6 MUST2 Telescopes:*
  10x10 cm^2 300μm DSSSD + SiLi or CsI
- *VAMOS spectrometer in dispersive mode*



Fully exclusive measurement

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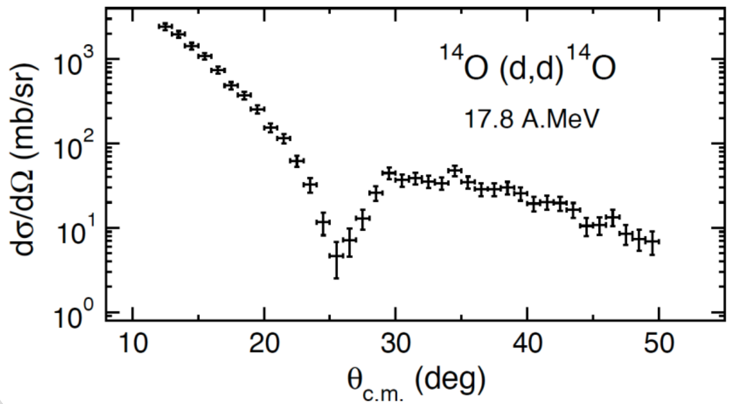
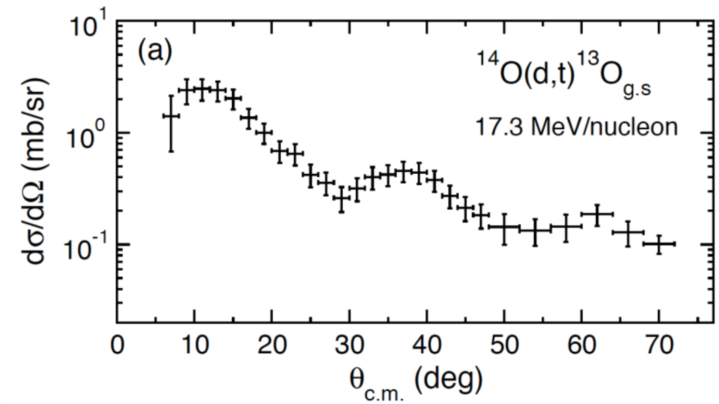
Experimental Data Set

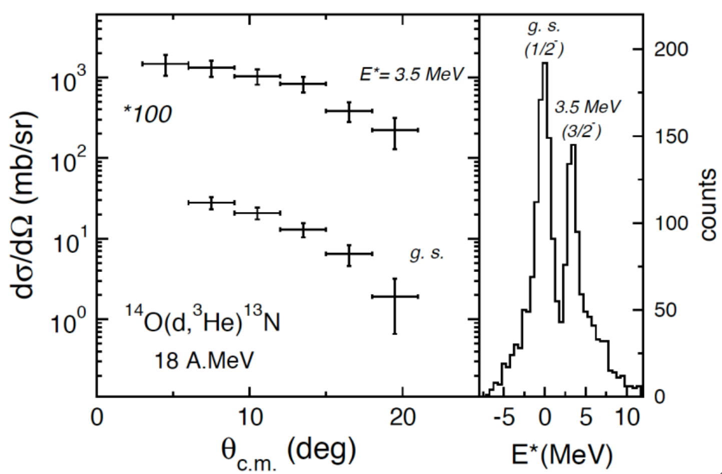
Elastic channel



One-neutron pickup channel



One-proton pickup channel



+

Published Data on ^{16}O and ^{18}O

[V. Bechtold et al., Phys. Lett. B **72**,169 (1977)]
[M. Gaillard et al., Nucl. Phys. A **119**, 161 (1968)]
[D. Hartwiget al., Z. Phys. **246**, 418 (1971)]

[D. Suzuki et al., Phys.Rev. Lett. **103**, 152503 (2009)]

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Reaction Framework

Input Potential:

- ✓ $^{14}O + ^{2}H$
  - → A.J. Koning et J.P. Delaroche, NPA 713, 231 (2003)
  - → Validated on elastic data

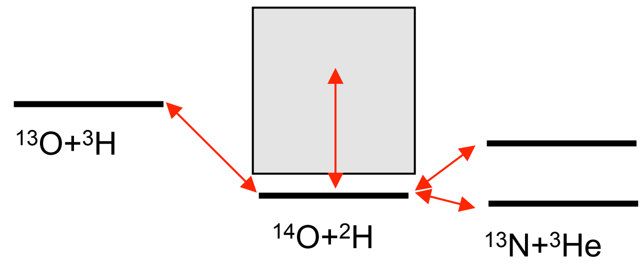
Output potentials:

- ✓ $^{13}O + ^{3}H$ and $^{13}N + ^{3}He$
  - → D. Y. Pang et al., PRC 79, 024615 (2009)
  - → C. M. Perey and F. G. Perey, ADNDT 17,17,1 (1976)

Form factors:

- ✓ $\langle ^{3}H | d + n\rangle$ and $\langle ^{3}He | d + p\rangle$
  - → B. A. Watson et al., PR 182,977 (1969)
- ✓ $\langle ^{14}O \mid ^{13}O + n\rangle$ and $\langle ^{14}O \mid ^{13}N + p\rangle$
  - → Woods Saxon, **Hartree Fock constrained**

Coupling scheme



- Coupled Reaction Channel analysis (CRC)
- Coupled discretized continuum channel (CDCC) for deuteron breakup

Test case : stable ^{16}O

Form factors

~~X Standard arbitrary value:~~

~~(r_0,a_0) : (1.25 fm , 0.65 fm)~~

✓ r_{rms} from $^{16}O(e,e'p)^{15}N_{gs}$:
[M. Leuschner et al., PRC 49, 955 (1994)]

r_{rms} = 2,943(30) fm

✓ WS parameters to reproduce r_{rms} and Sp:

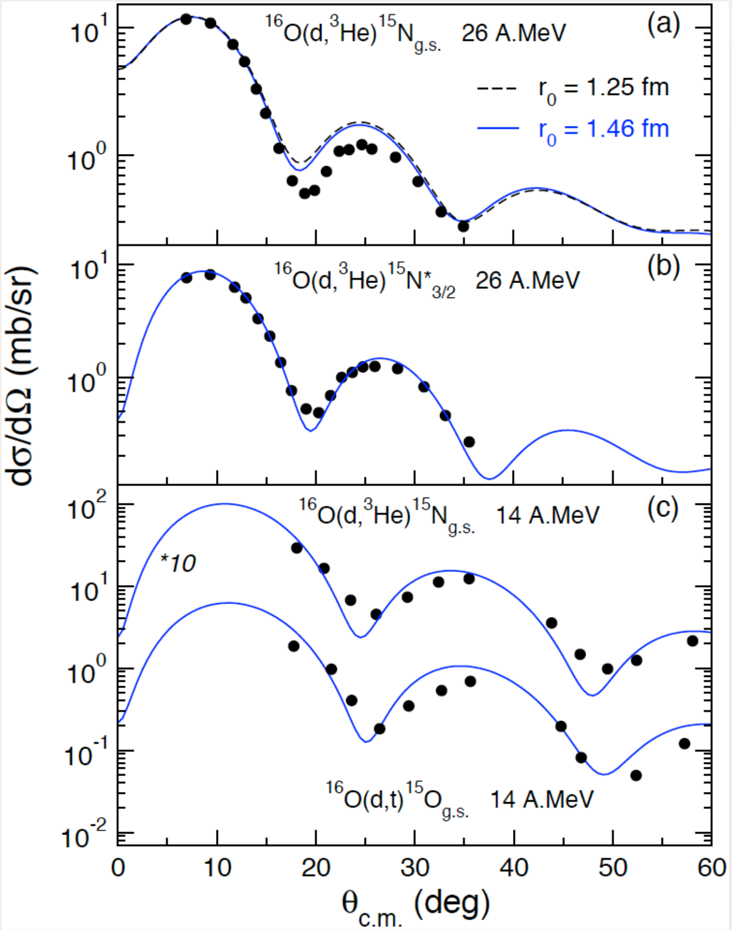
r_0 = 1,46 fm

C^2S_{exp} =0,91(9)

✓Single-particle HFB w.f. with Sly4 interaction:

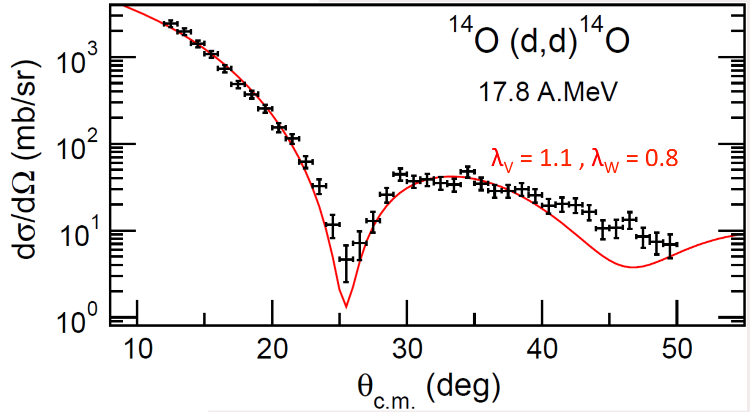
r_{rms}(HFB) = 2,95 fm

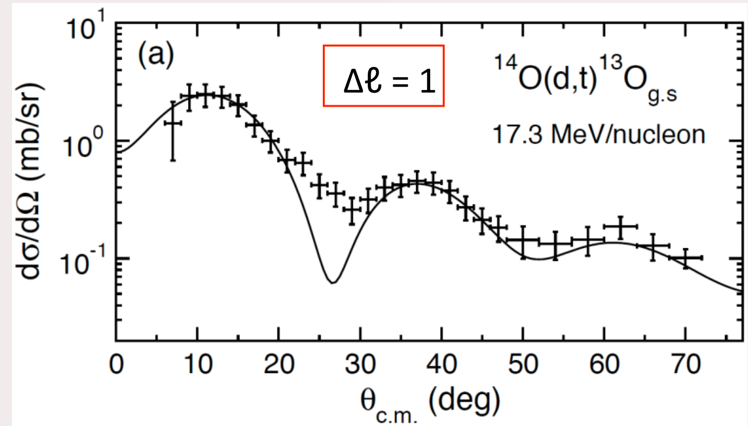
HFB RMS (fm)	$\pi 0p_{3/2}$	$\pi 0p_{1/2}$	$\nu 0p_{3/2}$	$\nu 0p_{1/2}$
^{14}O	2.77	3.03	2.69	2.72
^{16}O	2.80	2.95	2.78	2.91
^{18}O	2.81	2.91		
$^{16}O(e,e'p)^{15}N$	2.719(24)	2.943(30)		

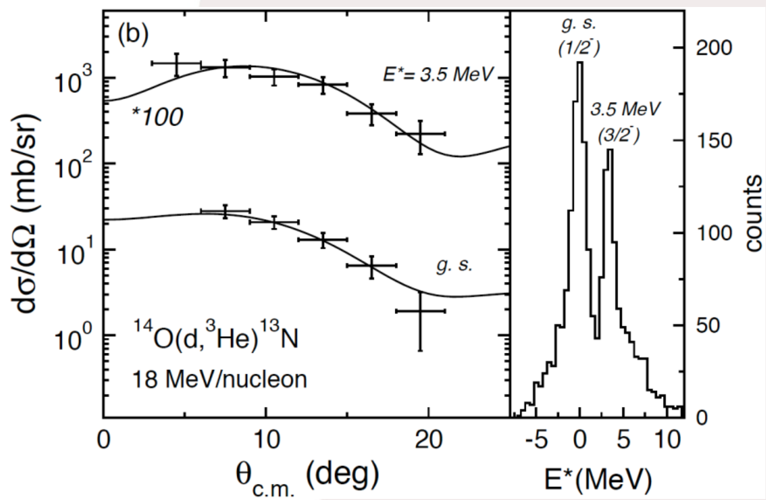


Data points from :
[V. Bechtold et al., Phys. Lett. B **72**,169 (1977)]
[M. Gaillard et al., Nucl. Phys. A **119**, 161 (1968)]

^{14}O results

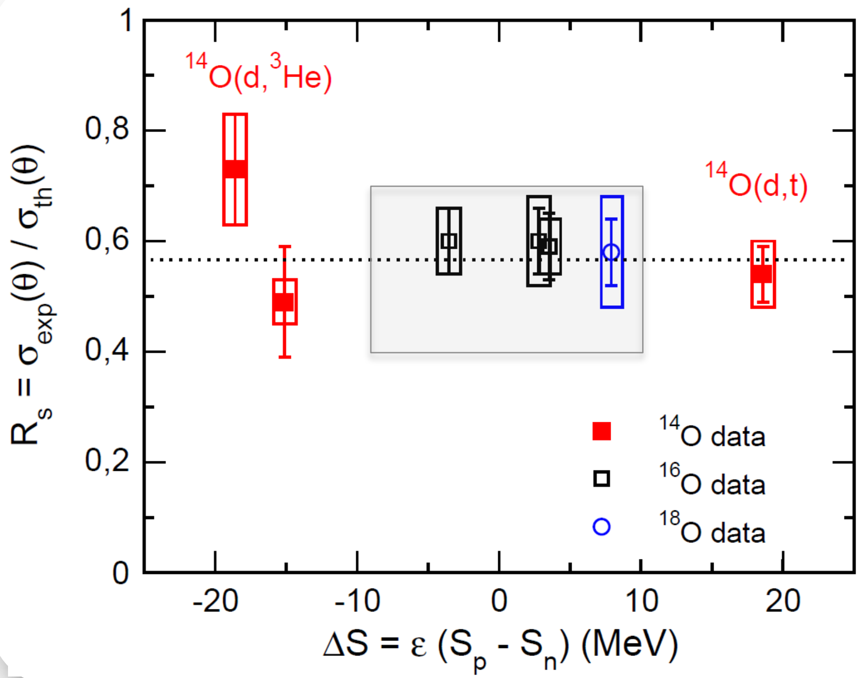






Reaction	E^* (MeV)	J^π	R^{HFB}_{rms} (fm)	r_0 (fm)	C^2S_{exp} (WS)
^{14}O (d, t) ^{13}O	0.00	$3/2^-$	2.69	1.40	1.69 (17)(20)
^{14}O (d, ^{3}He) ^{13}N	0.00	$1/2^-$	3.03	1.23	1.14(16)(15)
	3.50	$3/2^-$	2.77	1.12	0.94(19)(7)
^{16}O (d, t) ^{15}O	0.00	$1/2^-$	2.91	1.46	0.91(9)(8)
^{16}O (d, ^{3}He) ^{15}N [19,20]	0.00	$1/2^-$	2.95	1.46	0.93(9)(9)
	6.32	$3/2^-$	2.80	1.31	1.83(18)(24)
^{18}O (d, ^{3}He) ^{17}N [21]	0.00	$1/2^-$	2.91	1.46	0.92(9)(12)

Results with WS overlap functions



δ (RMS) → δr$_o$ → box

Error bars due to exp. Uncertainties

OFs : WS (HFB constrained)
C^2S_{th}: Shell model with WBT interaction

$$\sigma_{th}(\theta) = C^2S_{th}\, \sigma_{sp}(\theta)$$

48 analysis:

- **2 sets of C^2S_{th}:**
  - WBT Interaction 0p shell + 2ħΩ
  - Utsuno int. 0p1s0d space
- **3 HF calculations** for radii
- **8 combinations of optical potentials** for entrance and exit channels

χ^2_{min}

$$R_s = \alpha \, . \, \Delta S + \beta$$

$\boxed{\alpha = +0.0004(24)(12)\ \text{MeV}^{-1}}$

$\beta = R_s(0) = 0.538(28)(18)$

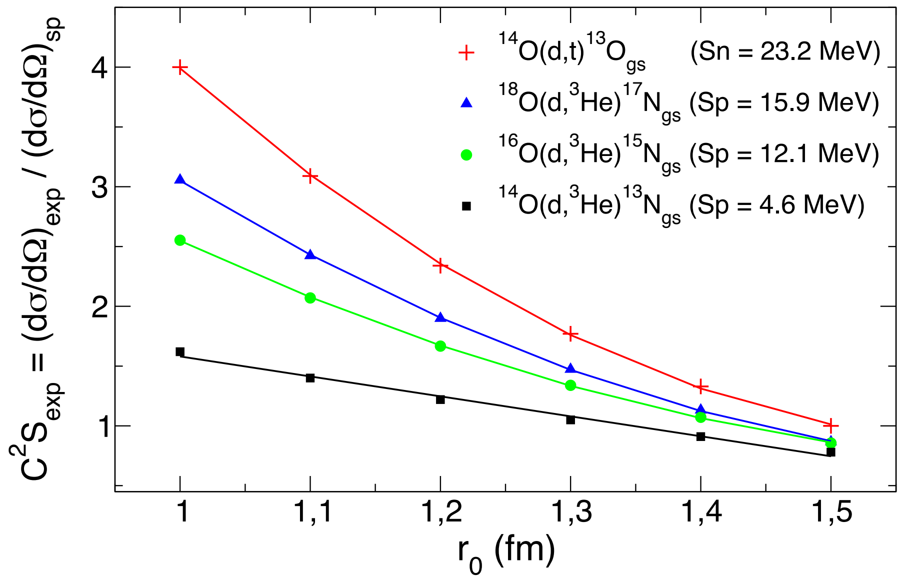
Exp. Error (1 set)

Stdrd. error from 48 data sets

Choices to be made

- **Potentials**
  - Input channels
  - Output channels
- **Framework**
  - DWBA
  - ADWA
  - CCBA
  - CRC
- **Overlaps**
  - Woods Saxon geometry
    - ~~Historical (1.25; 0.65) fm~~
    - HF constrained
  - Ab-initio

r_0 dependence



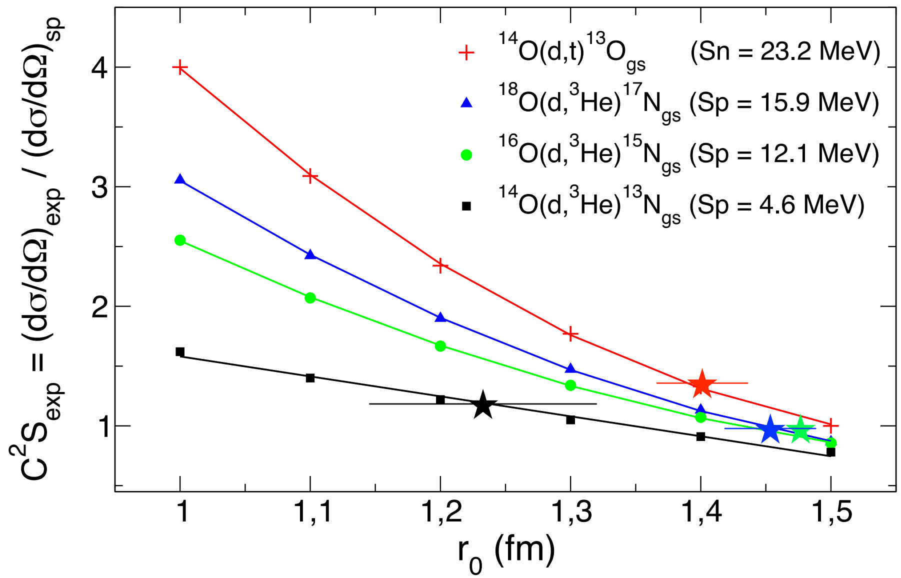
Potentials used: (KD+GDP08)

Linear fit (a*r0+b) between 1.3 fm and 1.5:

Reaction	$S_{n,p}$ (MeV)	a (slope)
$^{14}O(d,t)^{13}O$	23.2	-3.85
$^{18}O(d,^3He)^{17}N$	15.9	-3.00
$^{16}O(d,^3He)^{15}N$	12.1	-2.4
$^{14}O(d,^3He)^{13}N$	4.6	-1.35

- The $C^2S_{exp}(r_0)$ dependence is enhanced if the transfer nucleon is more bound
  - For r_0 in [1; 1.25] fm, this effect becomes even larger (non linear)

r_0 dependence



Potentials used: (KD+GDP08)

Linear fit (a*r0+b) between 1.3 fm and 1.5:

Reaction	$S_{n,p}$ (MeV)	a (slope)
$^{14}O(d,t)^{13}O$	23.2	-3.85
$^{18}O(d,^{3}He)^{17}N$	15.9	-3.00
$^{16}O(d,^{3}He)^{15}N$	12.1	-2.4
$^{14}O(d,^{3}He)^{13}N$	4.6	-1.35

- The $C^2S_{exp}(r_0)$ dependence is enhanced if the transfer nucleon is more bound
  - For r_0 in [1; 1.25] fm, this effect becomes even larger (non linear)

<u>Ex. for 14O(d,t):</u> for r_0= 1.40 fm ⇒ $C^2S_{exp} \approx 1.3$
for r_0= 1.25 fm ⇒ $C^2S_{exp} \approx 2.1$

(≈ 11% change) (≈ 60% change)

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Choices to be made

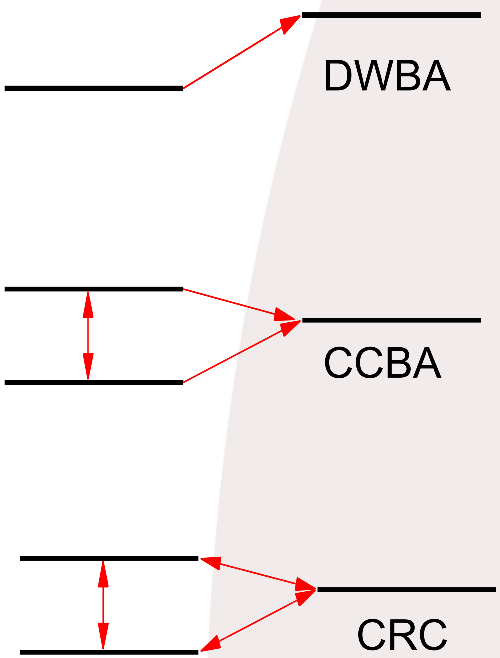
Potentials
- Input channels
- Output channels

Framework
- DWBA
- ADWBA
- CCBA
- CRC

Overlaps
- Woods Saxon geometry
  - ~~Historical (1.25; 0.65) fm~~
  - HF constrained
- Ab-initio

Framework

Four main reaction approaches for transfer reactions:



1) The **D**istorted **W**ave **B**orn **A**pproximation (**DWBA**)

- the simplest : assumes direct, one-step process that is weak

2) The adiabatic model:

- modification of DWBA for (d,p) and (p,d) reactions
- deuteron breakup effects included in an approximate way

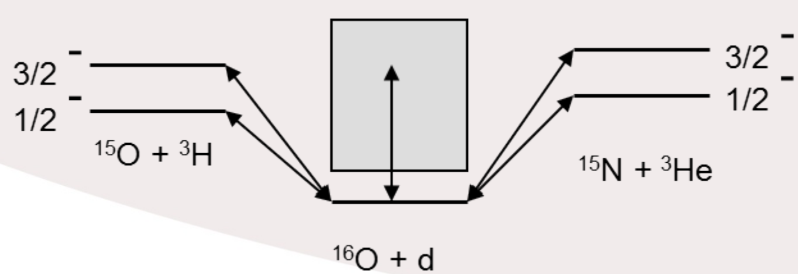
3) The **C**oupled **C**hannels **B**orn **A**pproximation (**CCBA**) :

- used when the assumption of a one-step transfer process breaks down
- strong inelastic excitations modelled with coupled channels theory
- transfers still with DWBA

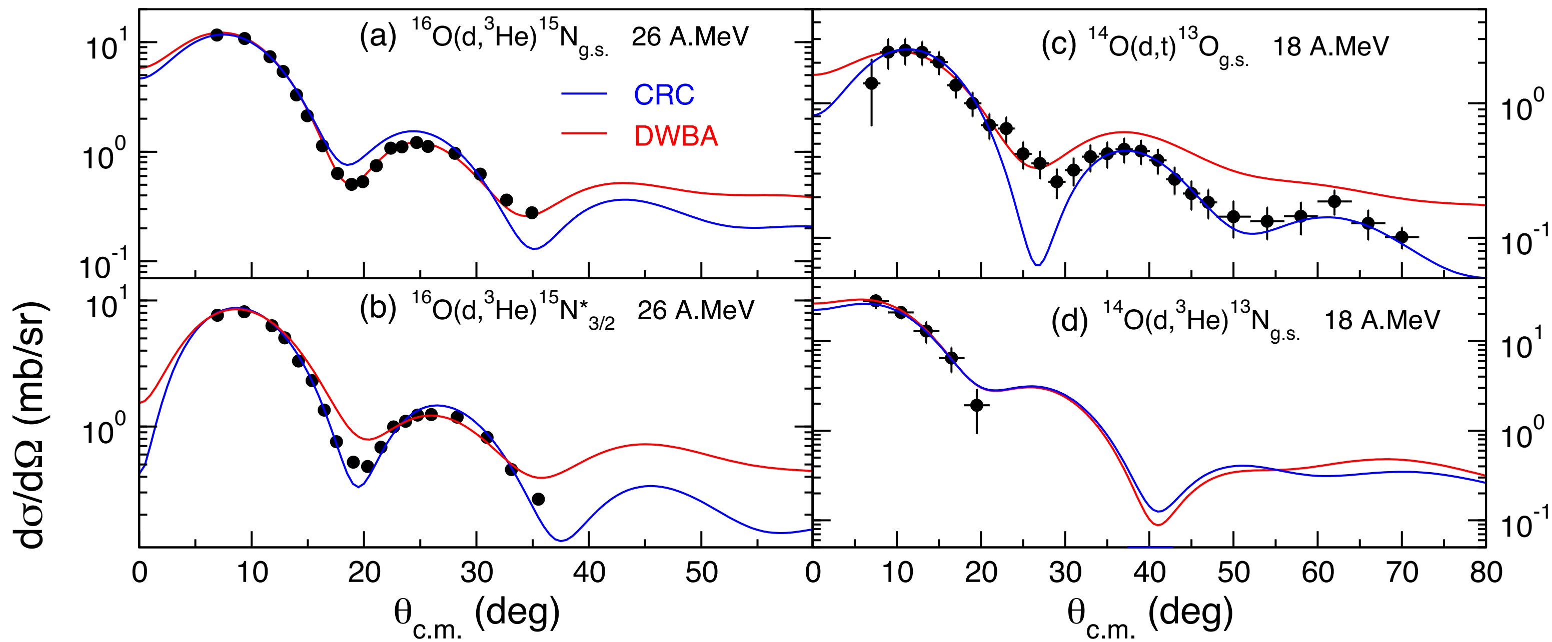
4) **C**oupled **R**eaction **C**hannels (**CRC**):

- does not assume one-step or weak transfer process.
- All processes on equal footing;
- (complex) rearrangements of flux possible

Example for ^{16}O:



Framework: CRC Vs DWBA



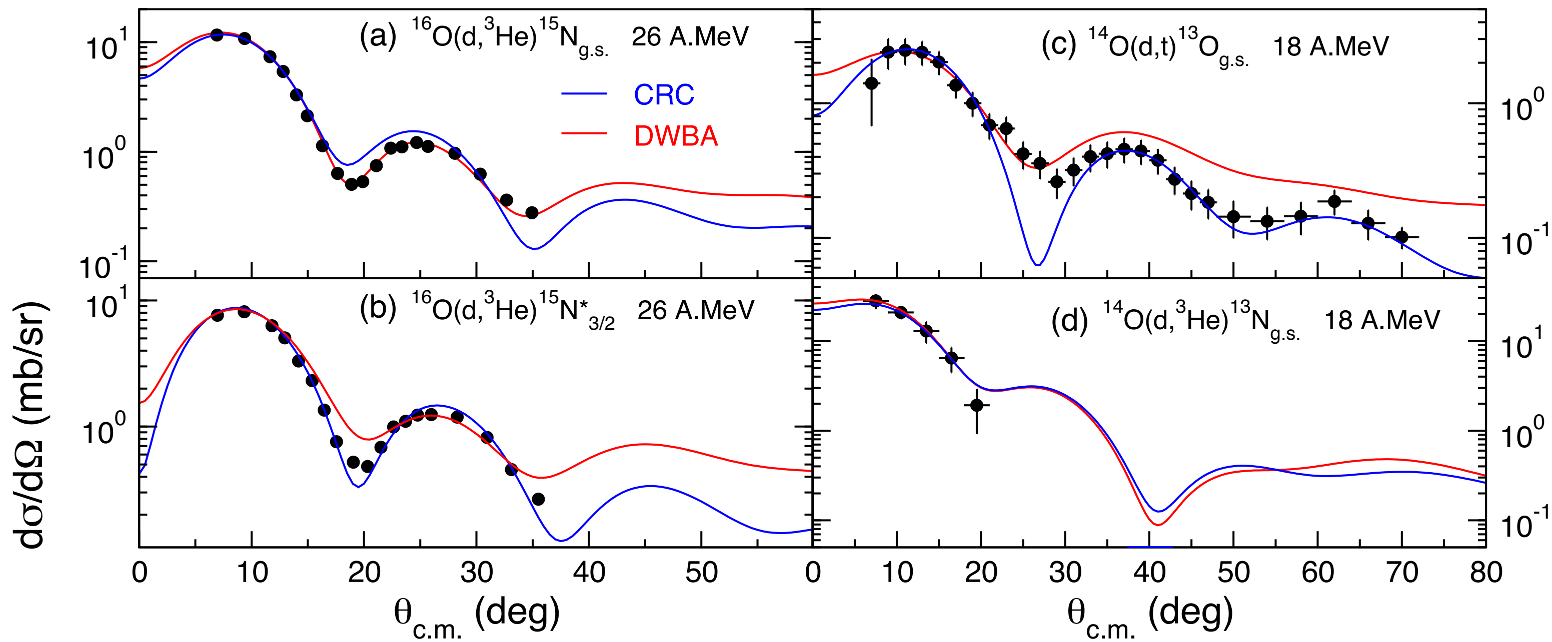
Parameters:

- One fixed set of potentials (KD+GDP08)
- Constrained Woods Saxon overlap functions

Shapes

- Better described by CRC (in general)
- But DWBA works rather well too
  (especially for small angles)

Framework: CRC Vs DWBA



Reaction	E* (MeV)	r_0 (fm)	C^2S_{exp} CRC	C^2S_{exp} DWBA	$\delta(C^2S_{exp})$ %
^{14}O(d,^{3}H)^{13}O	0	1.40	1.35	1.00	35
^{14}O(d,^{3}He)^{13}N	0	1.23	1.15	1.31	-12
	3.5	1.12	1.02	0.90	12
^{16}O(d,^{3}He)^{15}N	0	1.46	0.94	0.94	0
	6	1.31	2.00	1.70	18

$$\delta = (C^2S_{\exp}^{CRC} - C^2S_{\exp}^{DWBA}) / C^2S_{\exp}^{DWBA}$$

Normalisation and C^2S_{exp}

- **Reaction dependent** effect
- Up to **35%** difference for ^{14}O(d,t)

→ **Systematic error**

Choices to be made

Potentials
- Input channels
- Output channels

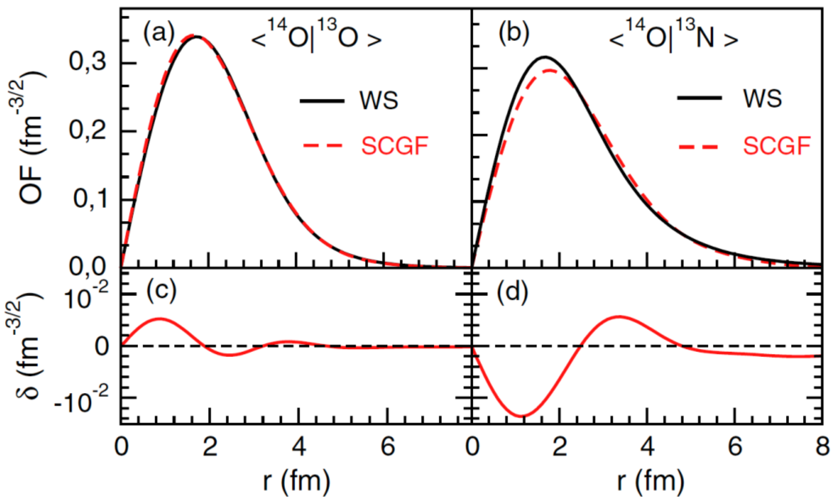
Framework
- DWBA
- ADWA
- CCBA
- CRC

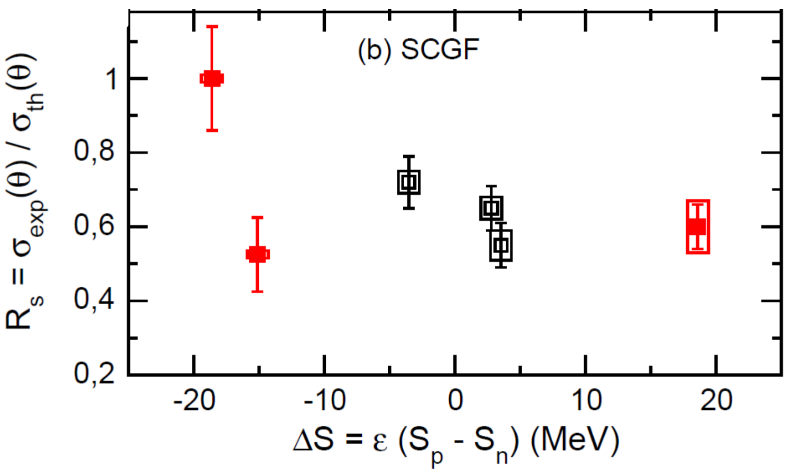
Overlaps
- Woods Saxon geometry
  - ~~Historical (1.25; 0.65) fm~~
  - HF constrained
- Ab-initio

Results with ab-initio overlaps

Ab-inito SF_{th} and overlaps (from C. Barbieri and A. Cipollone)

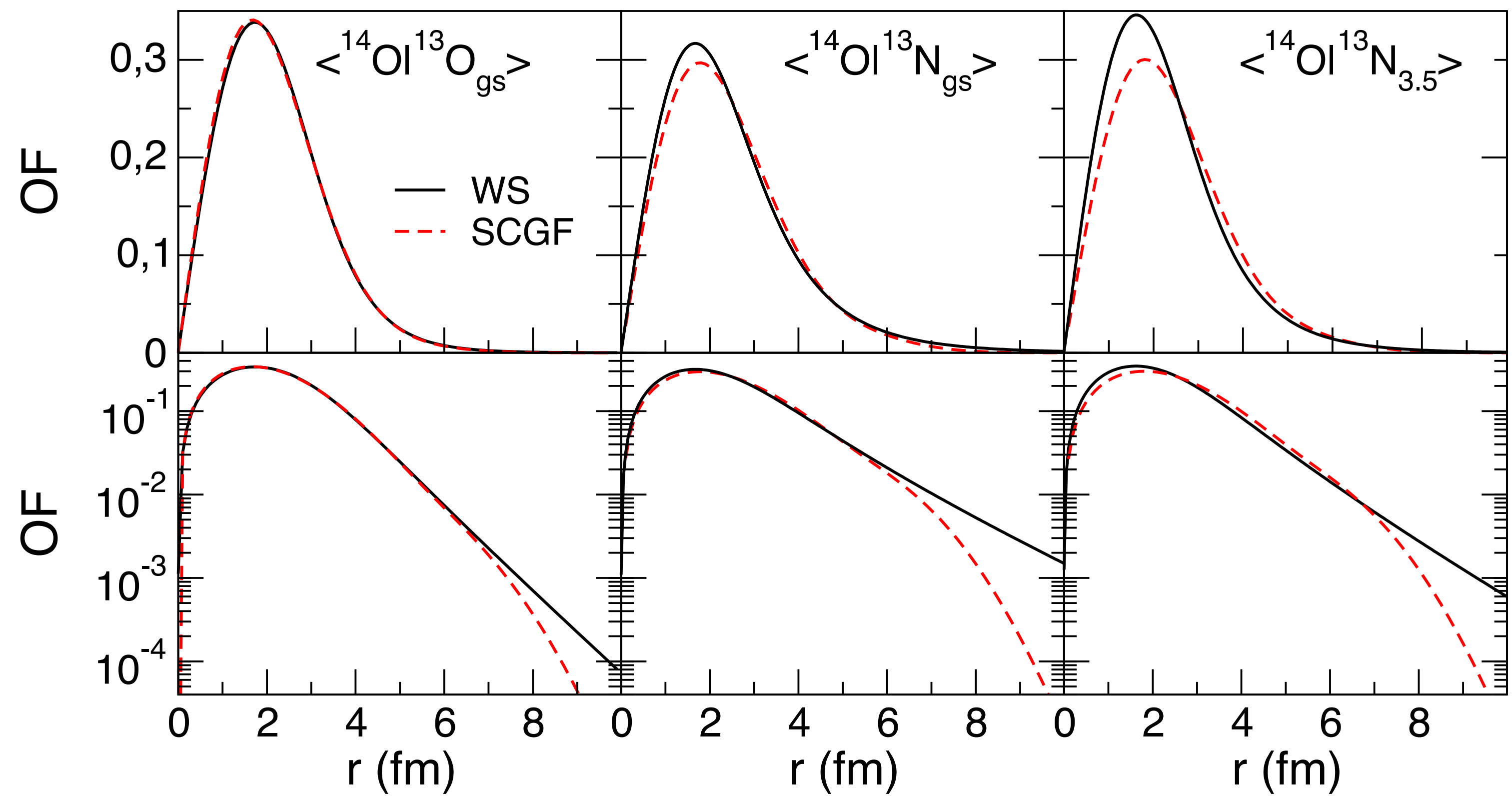
- Single-particle Green's function (third order diagrammatic construction method)
- Chiral two-body + three-body interactions (cutoff λ=1.88 fm^{-1})





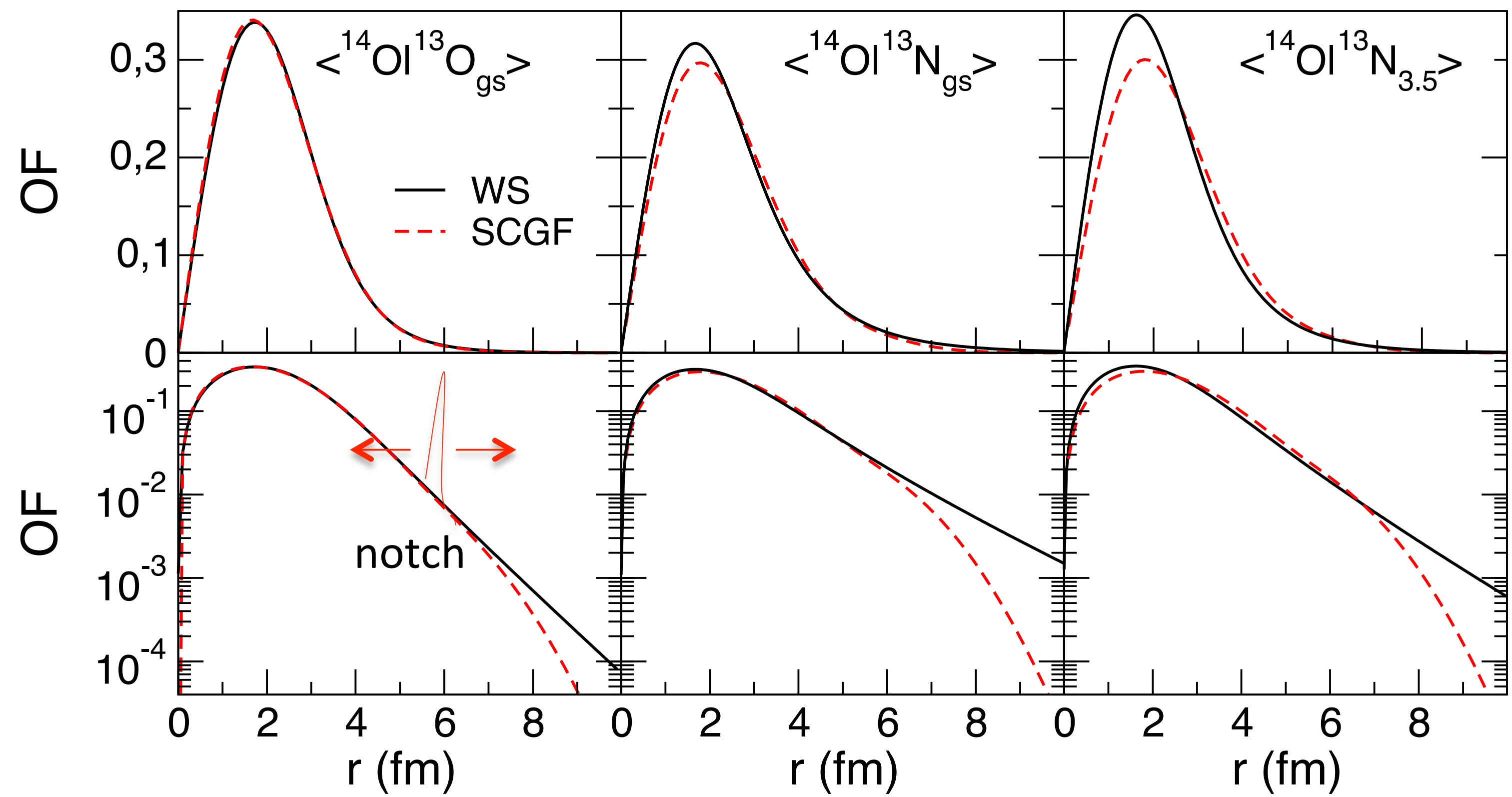
$\sigma_{th}(\theta) = C^2 S_{th}\, \sigma_{sp}(\theta)$

Radial sensitivity – Asymptotic tails



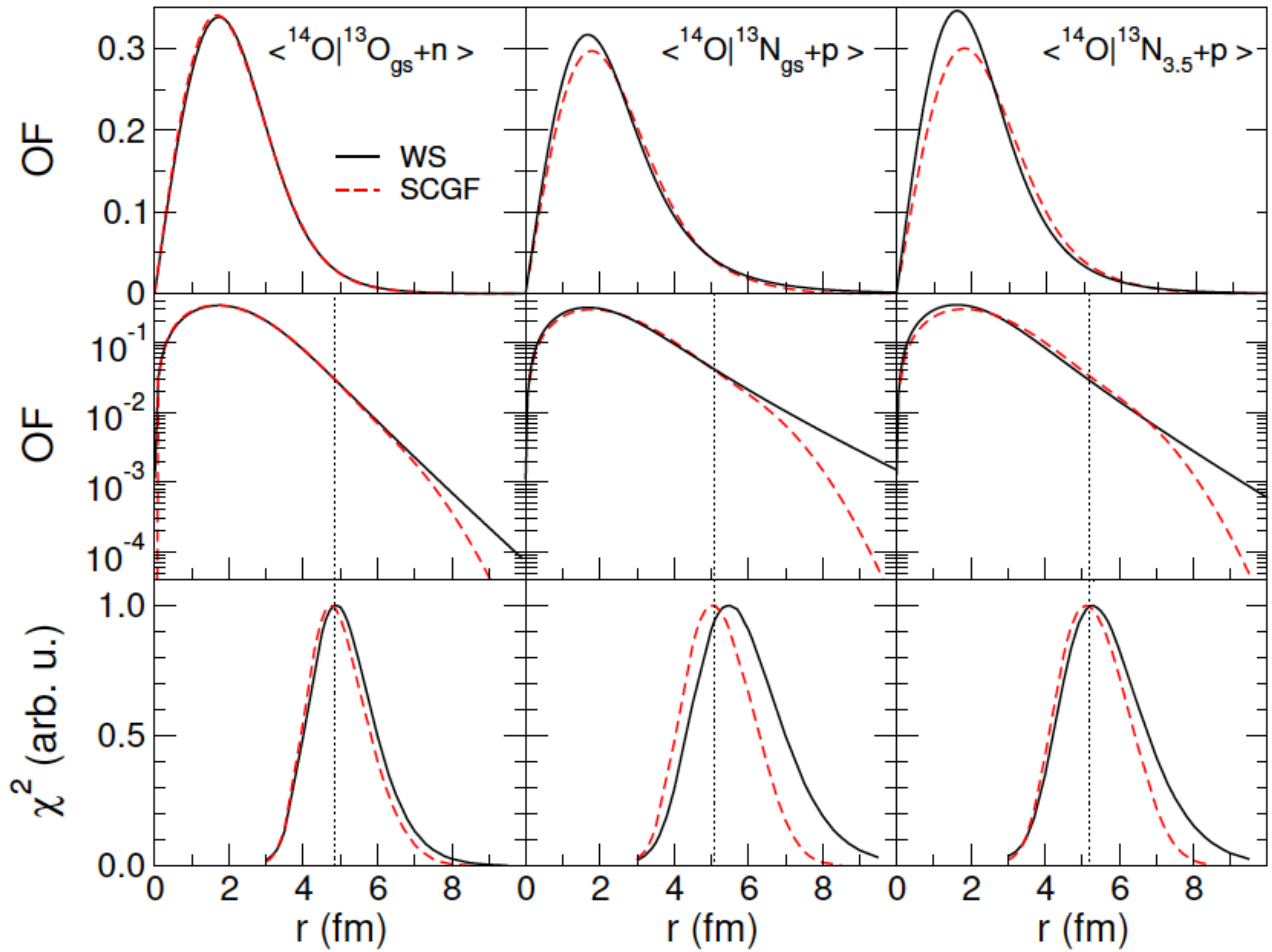
→ After (6-7) fm: **differences** between WS and ab-initio overlaps

Radial sensitivity – Asymptotic tails



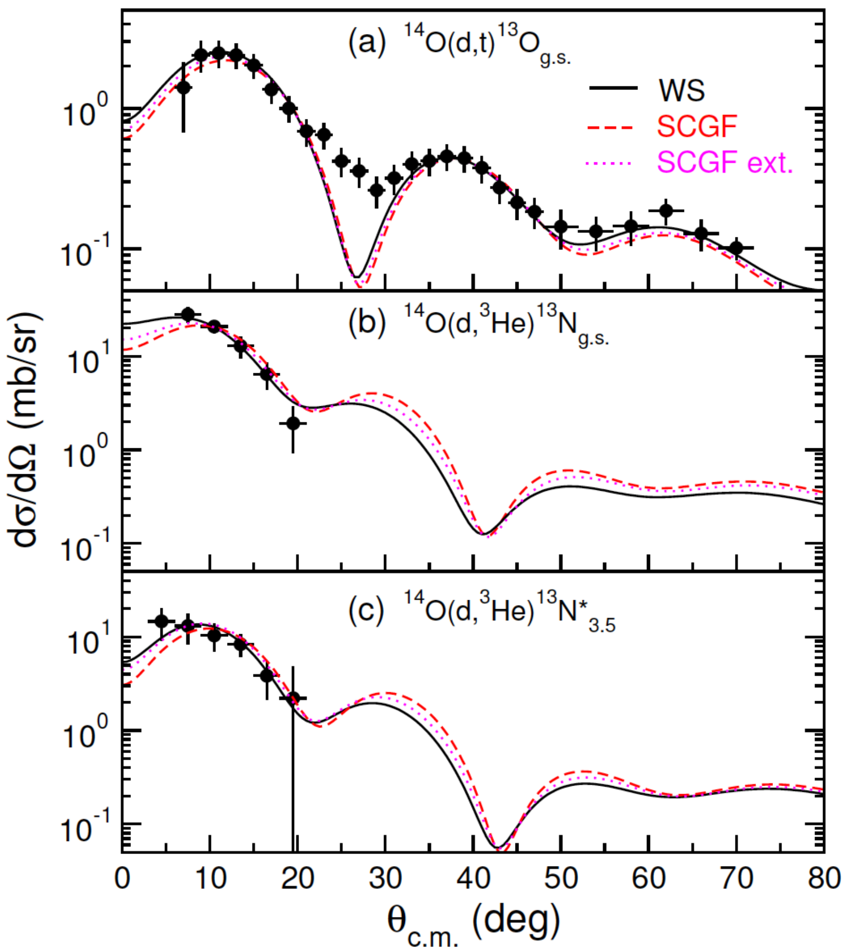
→ Notch test: $\chi^2 = \Sigma((d\sigma/d\Omega)_{pert} - (d\sigma/d\Omega)_{un})^2/(d\sigma/d\Omega)^2_{un}$

Radial sensitivity – notch test



Radial sensitivity – Asymptotic tails

With extrapolated ab-initio OFs (after 7fm)



Small shape changes (within exp. errors)

C^2S_{exp}	1 (SCGF)	2 (SCGF ext.)	(2/1)
^{14}O(d,t)^{13}O	2.41	2.28	**0.95**
^{14}O(d,^{3}He)^{13}N	1,58	1.42	**0.90**
^{14}O(d,^{3}He)$^{13}N_{3/2-}$	1.01	0.86	**0.85**

Effect on

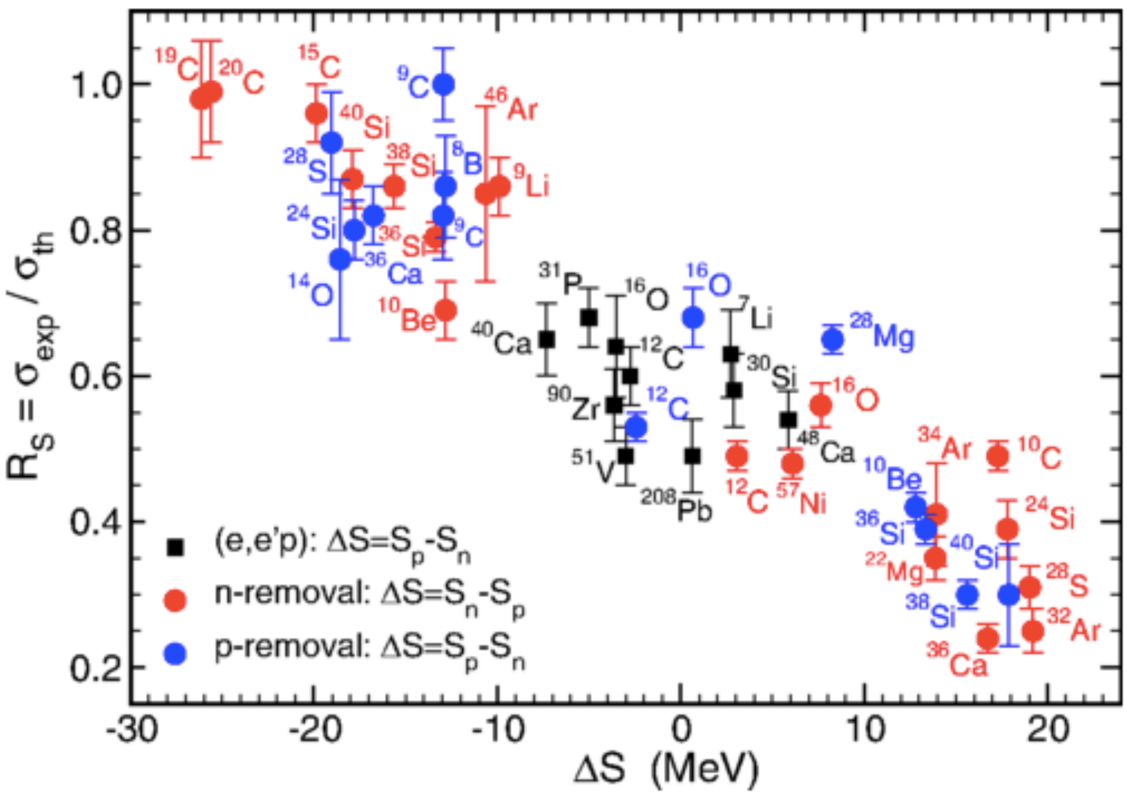
$Rs = C^2S_{exp}/C^2S_{th}$

Rs(1)	Rs(2)
0.60(6)(7)	0.57
1.00(14)(1)	0.90
0.53(10)(1)	0.45

Knockout at intermediate energies

Knockout on exotic nuclei

J.A. Tostevin and A. Gade, Phys. Rev. C **90**, 057602 (2014)

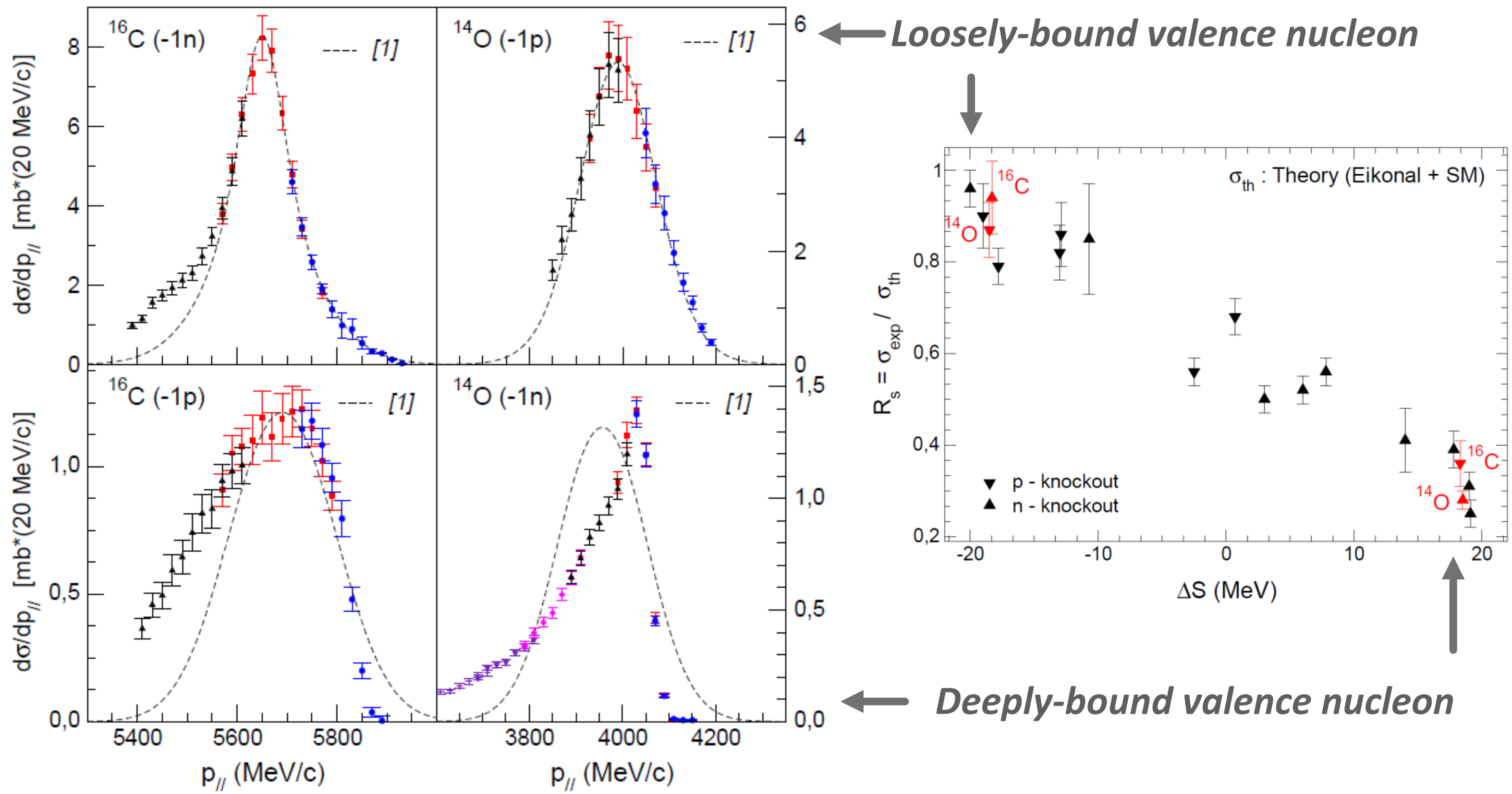


Knockout results

F. Flavigny *et al.*, Phys. Rev. Lett. **108**, 252501 (2012)

^{14}O: 53 MeV/u, ^{16}C: 70 MeV/u, NSCL

Loosely-bound valence nucleon



Deeply-bound valence nucleon

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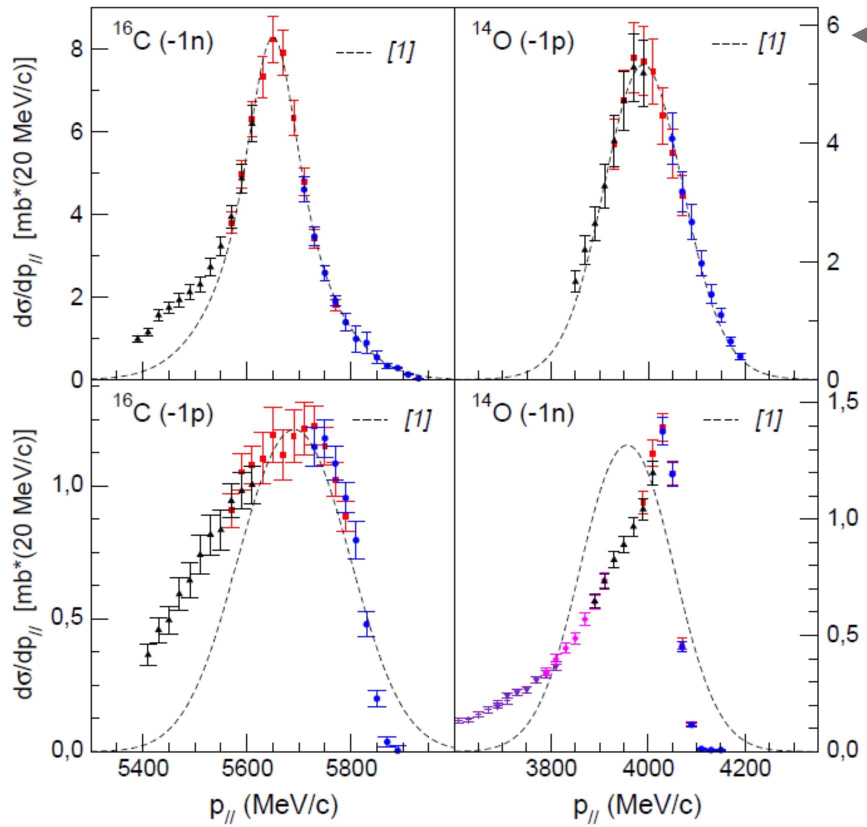
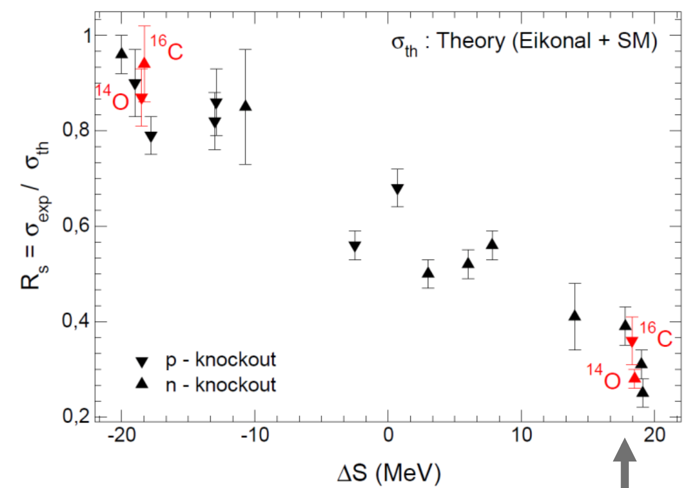


Loosely-bound valence nucleon



Deeply-bound valence nucleon

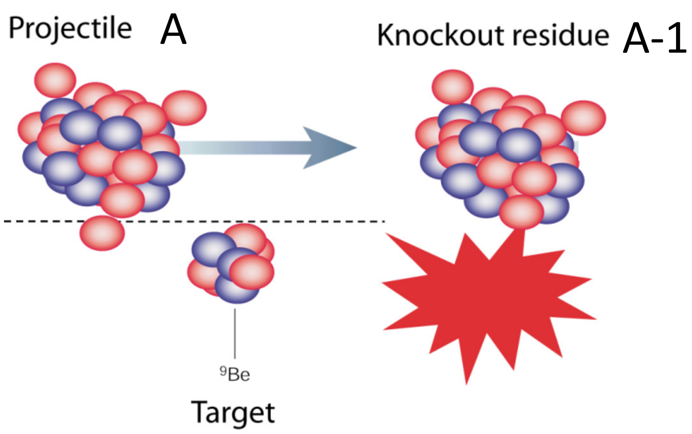
Open questions

- Microscopic origin of the observed **dissipative processes**
- **Incident-energy** dependence of the reaction process

Inelastic core-target processes

Projectile energy large enough to consider
that the intrinsic degrees of freedom are frozen

Eikonal / sudden approximation



Probability to leave the core intact

Probability to remove the nucleon

$$\sigma_{st} = 2\pi \int bdb\,|\phi_0|^2 \boxed{|S_C|^2}(1-|S_N|^2)$$

$$\boxed{\hat{S}_C(b)} = exp(i\boxed{\chi_C(b)})$$

$$\boxed{\chi_C(b)} = -\sigma_{NN}(E)\int d^2\vec{r_\perp}\,\boxed{\bar{\rho}_C(\vec{r_\perp})}\,\bar{\rho}_T(|\vec{b}-\vec{r_\perp}|)$$

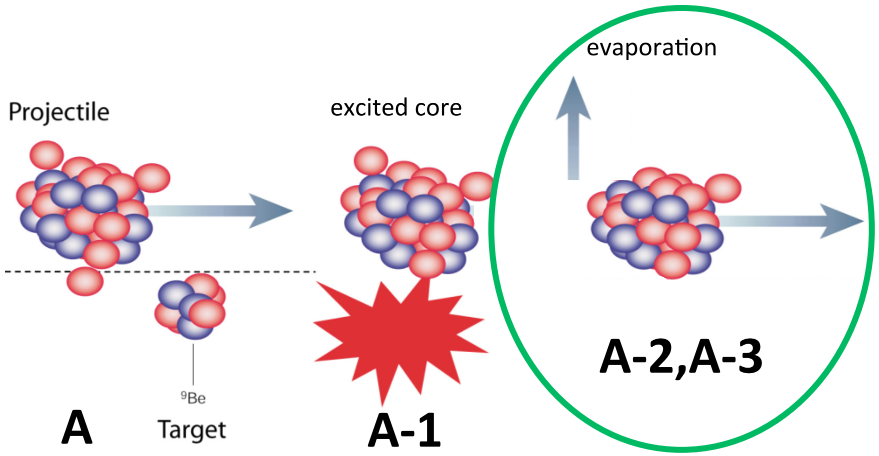
NN cross section

Core density

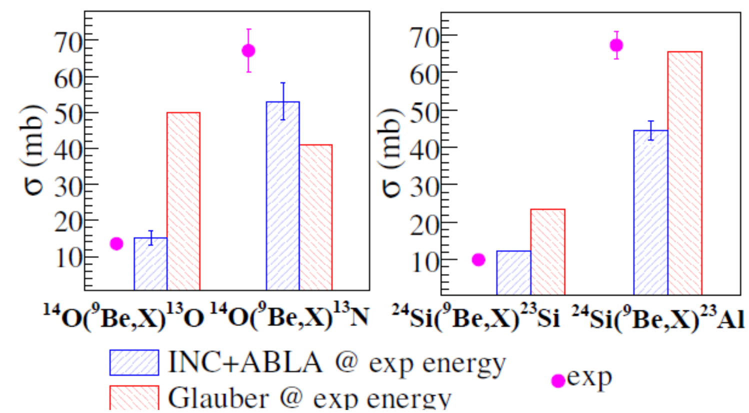
No explicit treatment of core excitations

Questionning the « inert core » approximation

Intranuclear Cascade Model (*INC*)
(*with nuclear-structure input)*



Reduction of the -1 nucleon removal cross section



⇒ Importance of **core excitations** for loosely-bound cores and deeply-bound nucleons?

C. Louchart *et al.,* Phys. Rev. C **83**, 011601 (R) (2011).

Recent results for deeply-bound nucleon removal

1) Details on the reaction mechanism?

$^{14}O(^{12}C,X)^{13}N+p,^{13}O$ at 60 MeV/nucleon
exclusive measurement at RCNP, J. Lee (HKU)

2) Energy and isospin dependence?

$^{14\text{-}22}O(p,2p)$ at 700 MeV/nucleon
GSI, R3B collaboration

3) Energy dependence ?

$^{14}O,^{20}O,^{22}O(p(pol)2,p)$ at 250 MeV/nucleon
RIBF, T. Uesaka *et al.* (RIKEN Nishina Center)

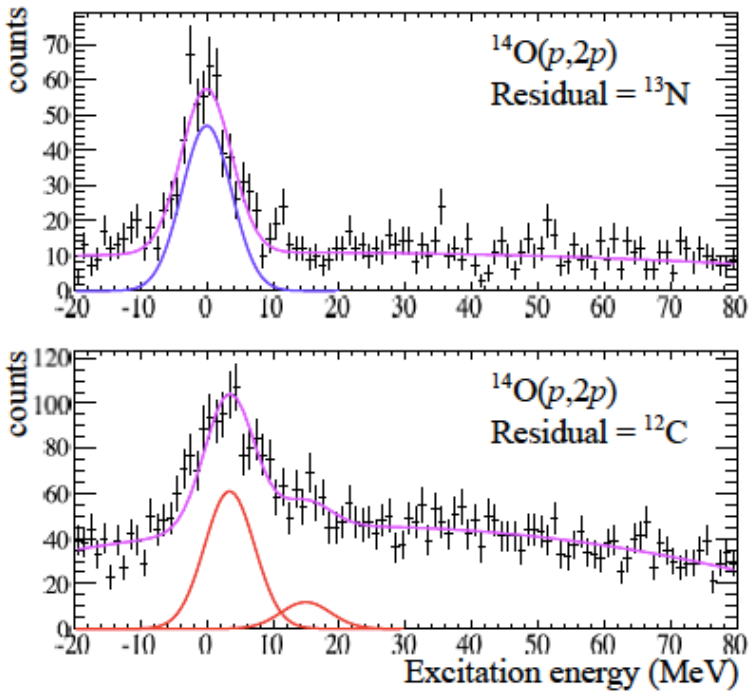
$^{14}O(p,2p)$ @ 250 MeV/nucleon

E_x (MeV)	J^π	yield	σ_{exp} (μb)	σ_{DWIA} (μb)	C^2S
0	$1/2^-$	445(25)	251(14)	166	1.51(8)
3.5	$3/2^-$	576(38)	326(22)	161	2.02(14)
15	$3/2^-$	111(31)	63(18)	97.1	0.65(19)

Σ C^2S / 6 p-wave nucleons = 4.2(3) / 6 = 0.70(5)

➔ Consistent with stable nuclei reduction
and with transfer results from GANIL

S. Kawase *et al.*, ARIS 2014 proceedings,
to be published (2015)



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Conclusions

- **Discrepancy** between experimental and eikonal theory + shell-model SFs for well-bound valence nucleon removal from a heavy-ion target at E ~ 60 - 100 MeV/nucleon
  A. Gade *et al.,* Phys. Rev. C **77**, 044306 (2008).
  F. Flavigny *et al.,* Phys. Rev. Lett. **108**, 252501 (2012).
  J.A. Tostevin and A. Gade, Phys. Rev. C **90**, 057602 (2014).

- **No effect** from deeply-bound proton quasi-free scattering from ***(e,e'p)***

- **No effect for low-energy transfer**
  J. Lee *et al.,* Phys. Rev. C. **83**, 014606 (2011).
  F. Flavigny *et al.,* Phys. Rev. Lett. **110**, 122503 (2013).

- Hypothesis for a **strong core-target inelastic excitation in asymmetric nuclei** in case of intermediate-energy stripping of deeply bound nucleons
  C. Louchart *et al.,* Phys. Rev. C **83**, 011601(R) (2011).

- Similar discrepancy with intra-nuclear cascade for high-energy nucleon stripping cross sections
  L. Audirac *et al.,* Phys. Rev. C **88**, 041602 (2013).
  D. Mancusi *et al.*, Phys. Rev. C **91**, 034602 (2015).

- First **quasifree scattering** data soon available (RIBF, R3B)
  $^{14}O(p,2p)^{13}N$ at 250 MeV/nucleon shows similar results than GANIL transfer
  S. Kawase *et al.,* ARIS 2014 proceedings, to be published.