Analysis of isospin dependence of "quenching factors" for (p, pn) and $(p, 2p)$ reactions via the Transfer to the Continuum formalism

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June 7, 2018

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Quenching factors

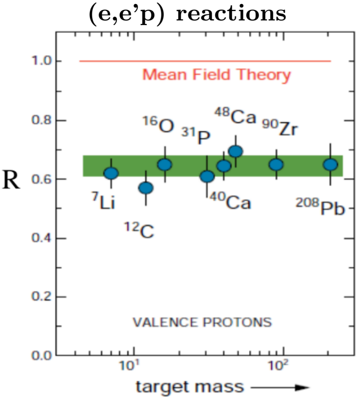
- SF from IPM or shell-model
- Can be related to experiment through:

$$\sigma_{\text{th}} = C^2 S \times \sigma_{s.p.}$$

- Quenching of spectroscopic factors:

$$R_s = \frac{\sigma_{\text{exp}}}{\sigma_{\text{th}}}$$

- Related to correlations beyond IPM

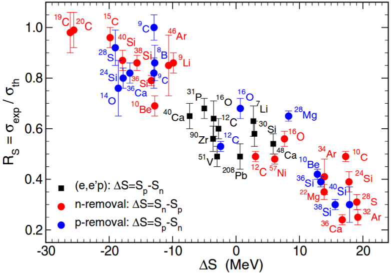


H. Dickhoff, C. Barbieri, Prog. Part. Nucl. Phys. 52, 377 (2004)
NIKHEF data: L. Lapikas Nucl. Phys. A 553, 297c (1993)

Quenching factors

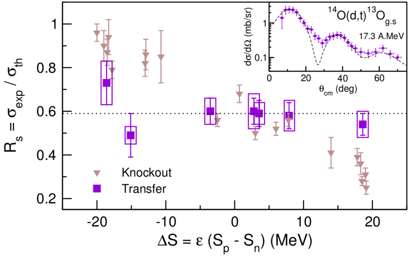
With respect to SM

- Knockout reactions



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

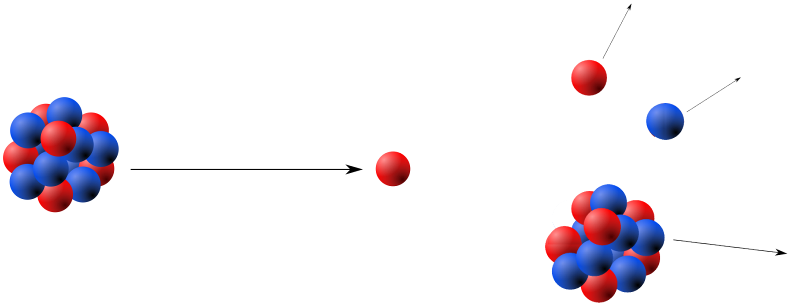
- Transfer reactions



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

Different trends: reaction description in question?

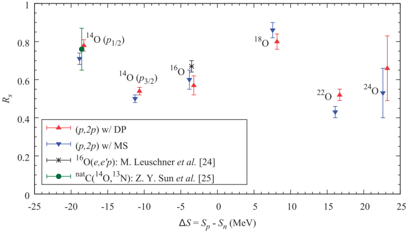
(p, pN) reactions



- A proton and a nucleus collide in such a way that a proton or neutron is removed and the residual nucleus remains.
- High energies ($\sim$ 200-400 MeV) to increase mean free path of nucleon in nucleus.
- Used to obtain single-particle information of nuclei.
- It is sometimes referred to as "quasifree" because the main interaction can be modelled as if it were a free collision between the incoming proton and the removed nucleon.

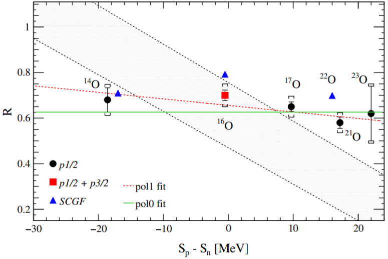
Quenching factors

RIKEN+RCNP



S. Kawase *et al*, Prog. Theor. Exp. Phys. 2018 (2) (2018), 021D01

R^3B (GSI)



L. Atar *et al*, Phys. Rev. Lett. 120, 052501 (2018)

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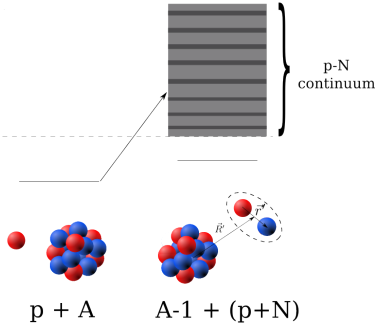
Reaction formalism: Transfer to Continuum

- We consider a calculation without explicit IA, including interaction with residual nucleus in matrix element and without factorization approximation.

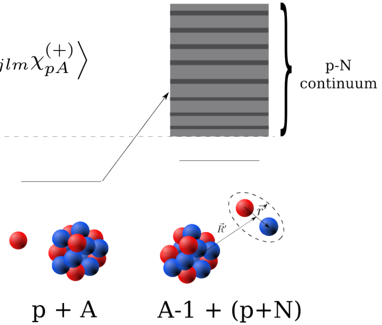


Reaction formalism: Transfer to Continuum

- We consider a calculation without explicit IA, including interaction with residual nucleus in matrix element and without factorization approximation.

- Prior representation of the T-matrix for the process $p + A \to p + N + C$, approximating the exact wf $\Psi_f^{(-)}$ by a 3-body CDCC wf $\psi_f^{3b-CDCC(-)}$

$$\mathcal{T}_{if}^{3b} = \left\langle \psi_f^{3b-CDCC(-)} | V_{pN} + U_{pC} - U_{pA} | \psi_{jlm} \chi_{pA}^{(+)} \right\rangle$$



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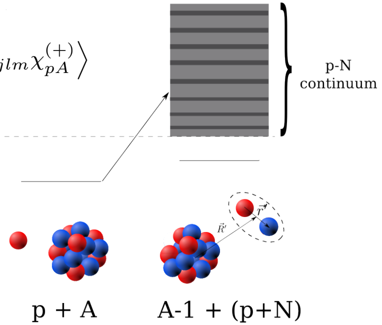
- p-N continuum states discretized in energy bins
  Deuteron included for (p, pn)

$$\phi_n^{j,\pi}(k_n, \vec{r}') = \sqrt{\frac{2}{\pi N}} \int_{k_{n-1}}^{k_n} \phi_n^{j,\pi}(k, \vec{r}') \mathrm{d}k$$

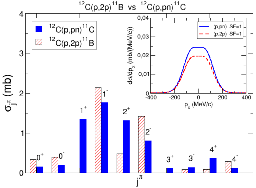


- 3-body final state wavefunction expanded in proton-nucleon states

$$\psi_f^{3b-CDCC(-)} \approx \sum_{n,j,\pi} \phi_n^{j,\pi}(k_n, \vec{r}') \chi_{n,j,\pi}^{(-)}(\vec{K_{pn}}', \vec{R}')$$

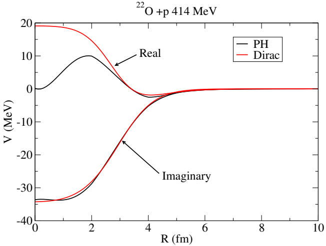
Inputs of the calculation

- Nucleon-nucleon interaction: Reid93



- Bound states from Woods-Saxon
  - $a = 0.7$ fm
  - r_0 chosen to reproduce HF rms (SkX)

- Distorting potentials
  - Folding from Paris-Hamburg g-matrix effective interaction and HF density (SkX)
  - Phenomenological Dirac parametrization (EDAD2)



- SF obtained using WBT interaction

Contents

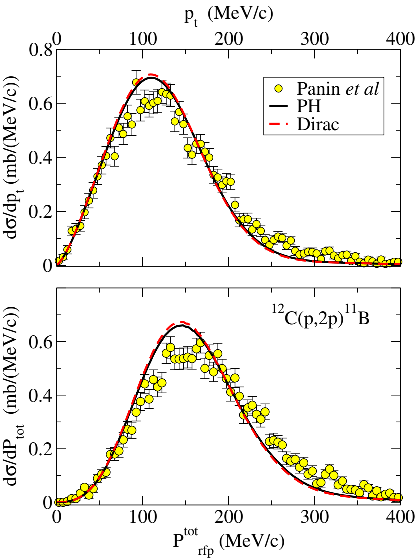
Experimental data

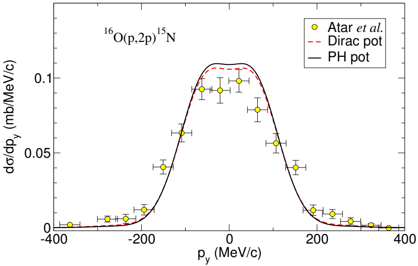
We use recent experimental data from R^3B collaboration (GSI)

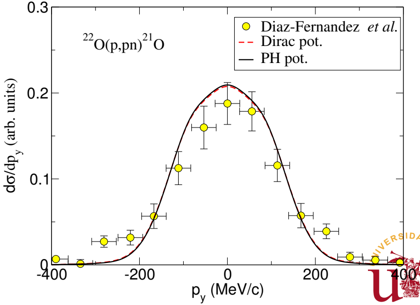
Reaction	E/A	Ref	Reaction	E/A	Ref
$^{13}O(p,2p)$	401	1	$^{21}O(p,2p)$	449	1
$^{14}O(p,2p)$	351	1	$^{21}N(p,pn)$	417	2
$^{15}O(p,2p)$	310	1	$^{21}N(p,2p)$	417	2
$^{16}O(p,2p)$	451	1	$^{22}O(p,pn)$	414	2
$^{17}O(p,2p)$	406	1	$^{22}O(p,2p)$	414	2
$^{18}O(p,2p)$	368	1	$^{23}O(p,pn)$	445	2
$^{12}C(p,2p)$	398	3	$^{23}O(p,2p)$	445	2

1: L. Atar *et al* Phys. Rev. Lett. **120**, 052501 (2018)
2: P. Díaz-Fernández *et al* Phys. Rev. C **97**, 024311 (2018)
3: V. Panin *et al* Phys. Lett. B **753**, 204 (2016)

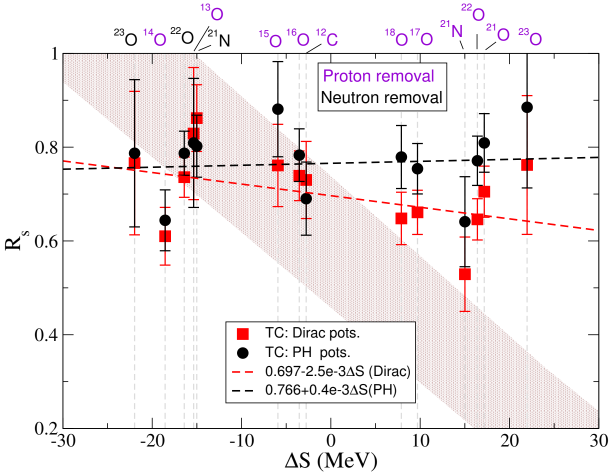
Momentum distributions





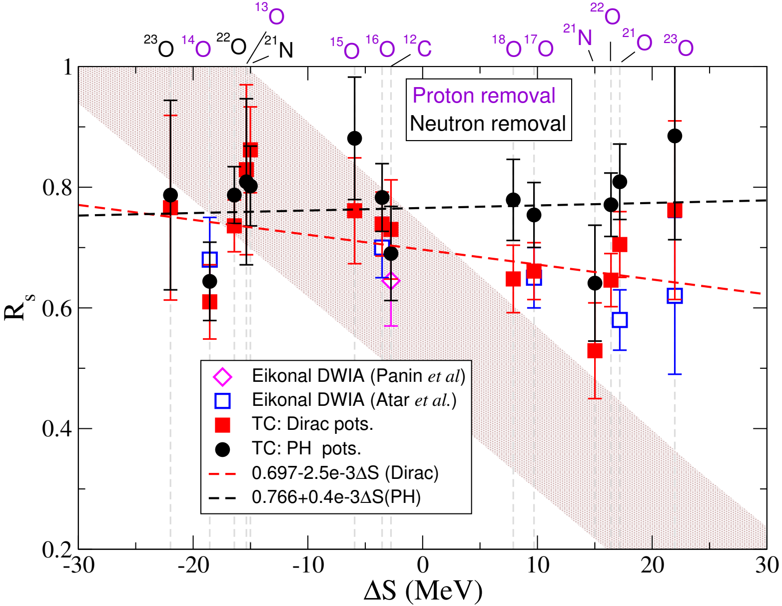


Quenching factors



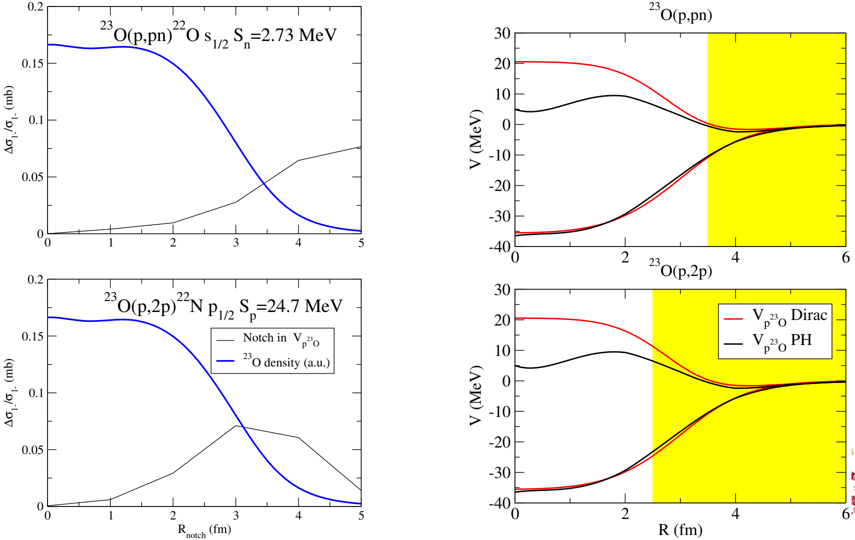
- Small ΔS dependence
- $R_s \sim 0.7 - 0.77$

Quenching factors

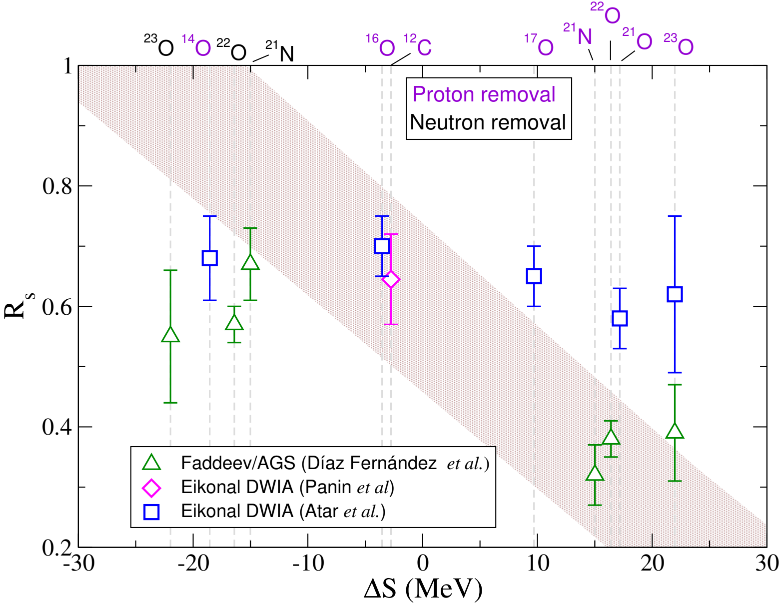


Peripherality of (p, pN) reaction

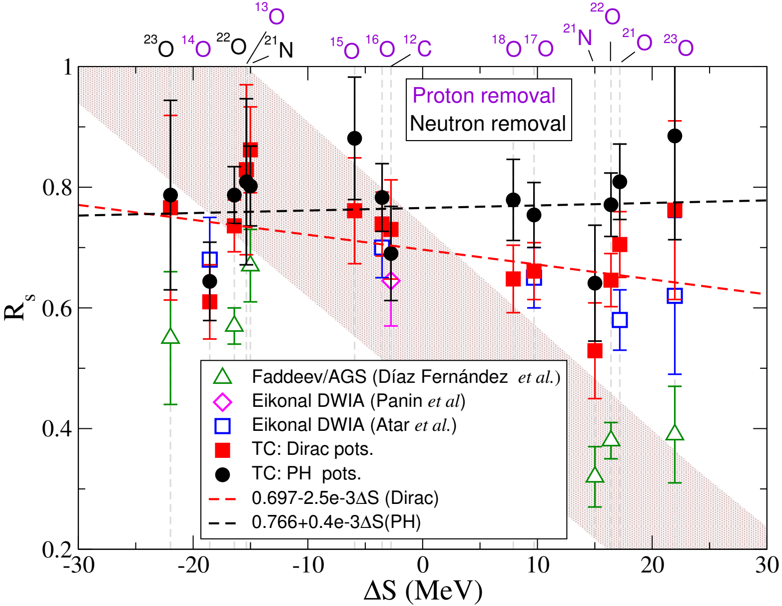
We perform a "notch test" (introducing a narrow peak in the potential at R_{notch}) to study the sensitivity of the reaction with R.



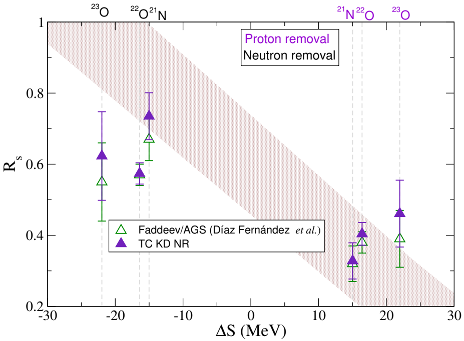
Quenching factors



Quenching factors



Quenching factors. KD potentials



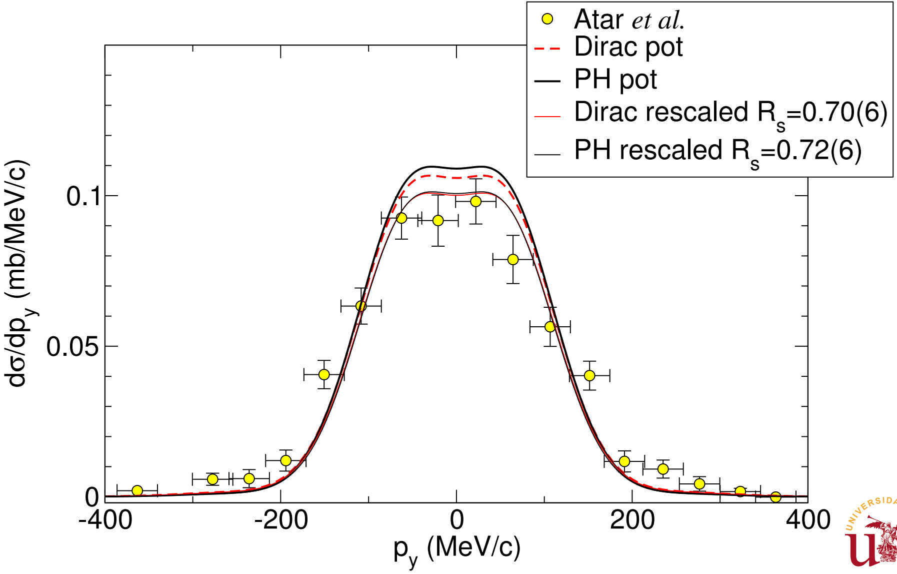
- Köning-Delaroche potentials at 200 MeV
- No relativistic modifications
- WS geometry: $r_0 = 1.25$ fm $a = 0.65$ fm

Contents

Summary

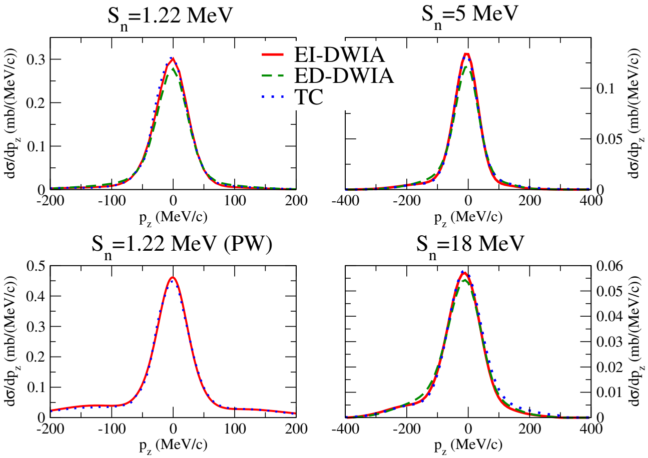
- Transfer to Continuum (TC) developed for the study of (p, pN) reactions at high and intermediate energies.
- "Quenching factors" obtained from all published R^3B data show a systematic reduction ($R_s \sim 0.7 - 0.77$) with a small dependence on ΔS
  - Agreement with transfer experiments
  - Disagreement with mid-energy knockout reactions
- Reasonable agreement with published eikonal DWIA R_s for small binding energies, but increased disagreement for larger binding energies
- Agreement with Faddeev/AGS results when using the same input parameters.

Fitting of momentum distribution (Backup)



Benchmark with DWIA: ^{15}C$(p, pn)^{14}$C @ 420 MeV/A (Backup)

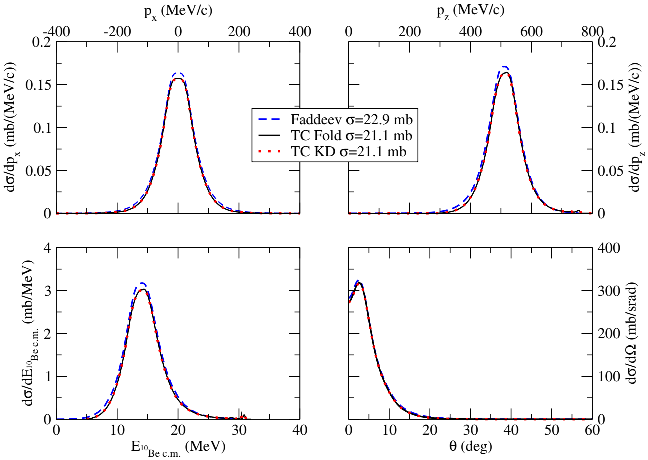
- In collaboration with K. Yoshida and K. Ogata (PRC **97** 024608 (2018))



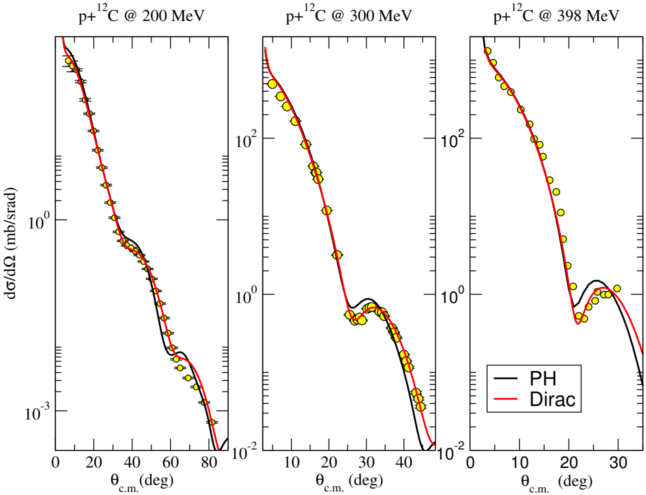
See talk by K. Yoshida

Benchmark with Faddeev: ^{11}Be$(p, pn)^{11}$Be @ 200 MeV/A (p wave) Reid93 (Backup)

- In collaboration with A. Deltuva



Dirac and PH potentials (Backup)



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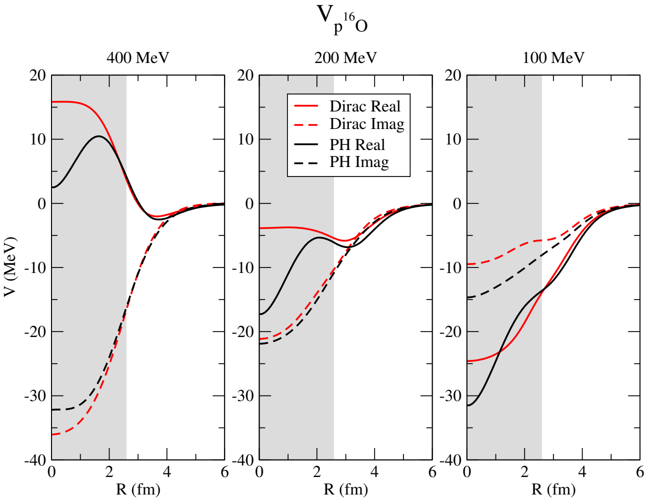

IPM Spectroscopic factors (Backup)

Reaction	$\sum$SF	R_s	$R_s(IPM)$	R_s (Atar *et al*)
$^{14}O(p, 2p)$	1.97	0.61(6) 0.64(6)	0.60(6) 0.63(6)	0.68(7)
$^{16}O(p, 2p)$	6.09	0.74(5) 0.78(6)	0.75(5) 0.79(6)	0.70(5)
$^{17}O(p, 2p)$	2.07	0.66(5) 0.75(5)	0.68(5) 0.78(6)	0.65(5)
$^{21}O(p, 2p)$	1.88	0.71(5) 0.81(6)	0.67(5) 0.76(6)	0.58(4)
$^{23}O(p, 2p)$	1.99	0.76(15) 0.89(17)	0.76(15) 0.89(17)	0.62(13)