Ground-state configuration of ^{23}O investigated via Coulomb breakup

Chiara Nociforo
for the LAND collaboration

presently *INFN-LNS, Catania*

ECT* Trento, 2nd-12th March 2004

Contents

Studies of light neutron-rich nuclei spectroscopy at FRS/LAND:

- Electromagnetic excitations as spectroscopic tool

  → theoretical description
  → experimental method

Results on single particle properties of the ground state of neutron-rich nuclei :

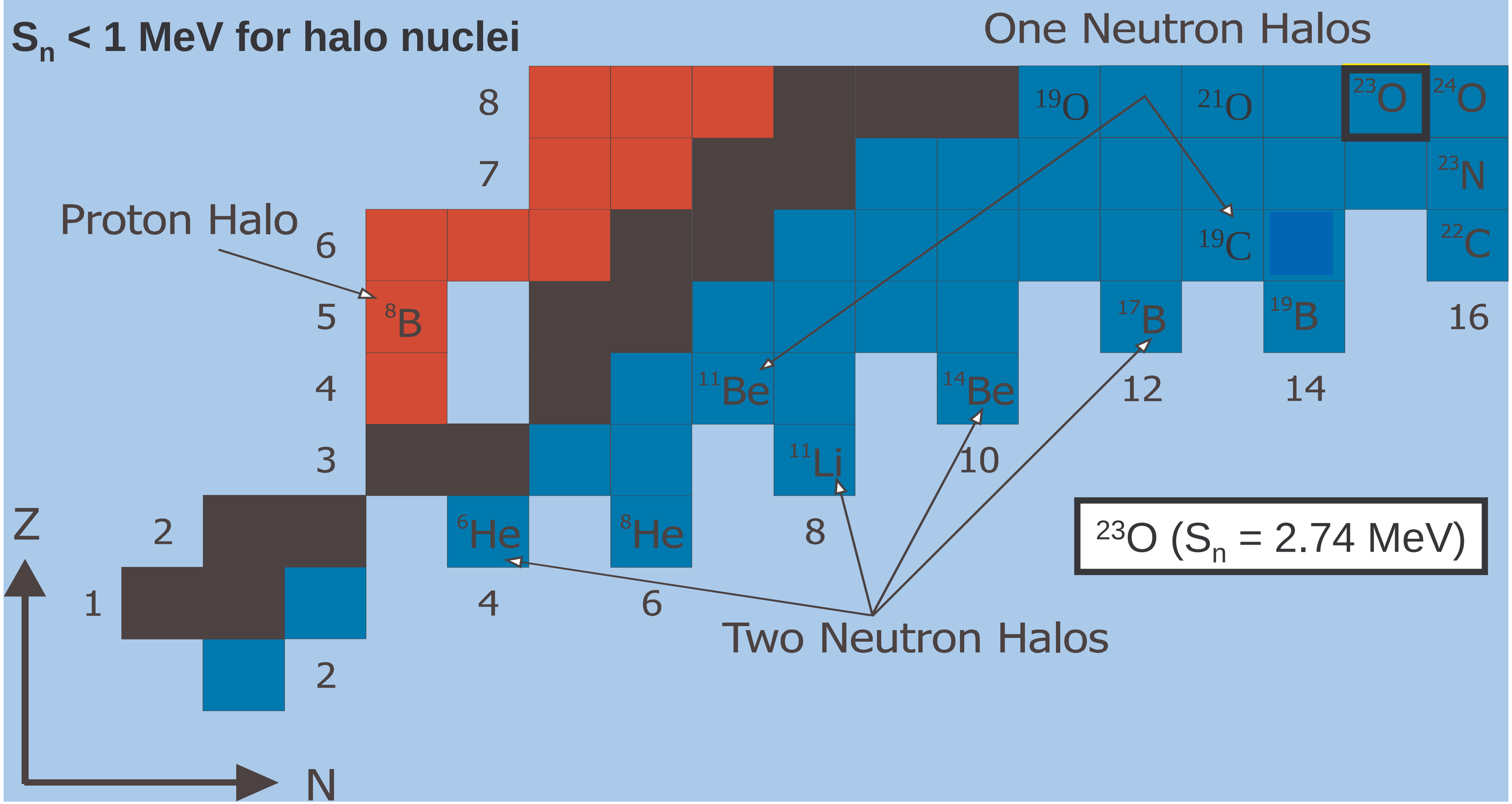
- Discussion of experimental results and comparison with the models

  → ^{23}**O** case

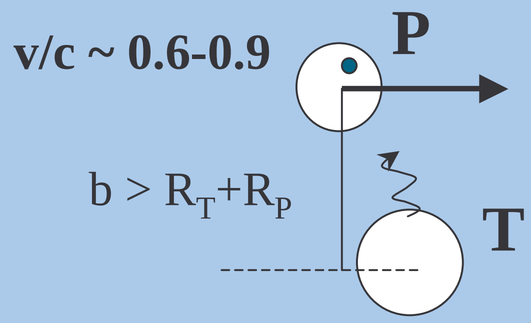
Approaching the neutron drip line

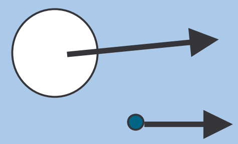
Unusual combination of **large isospin** and **weak binding energy**
→ large diffuseness of nuclear surface (*Halo*)

S_n < 1 MeV for halo nuclei



Electromagnetic dissociation





^{208}Pb + A $\longrightarrow$ (A-1) + **n** + (γ)

Spectrum of *virtual photons* up to $E_{\max} = \gamma \, v \, \hbar / b \approx 25\,\mathrm{MeV}$

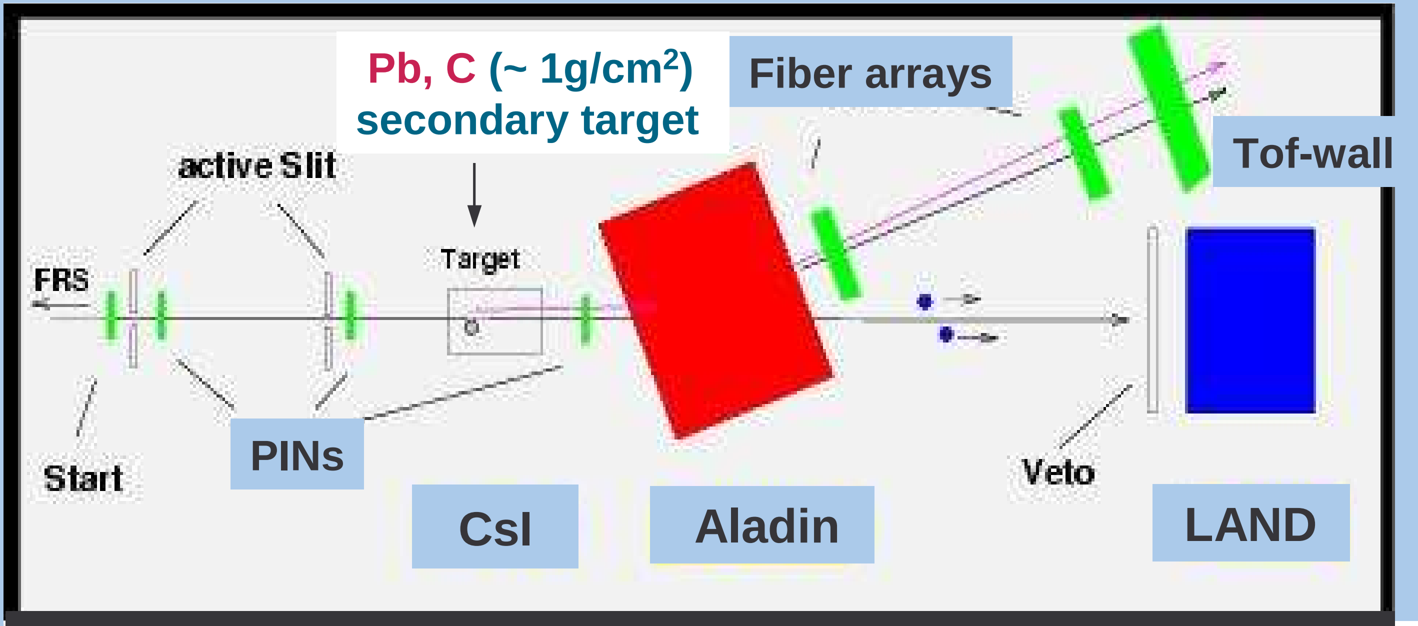
- **Small nuclear contribution to the cross section** (estimated with C target runs) → $\sigma_{e.m.} = \sigma_{tot} - \sigma_{nucl}$

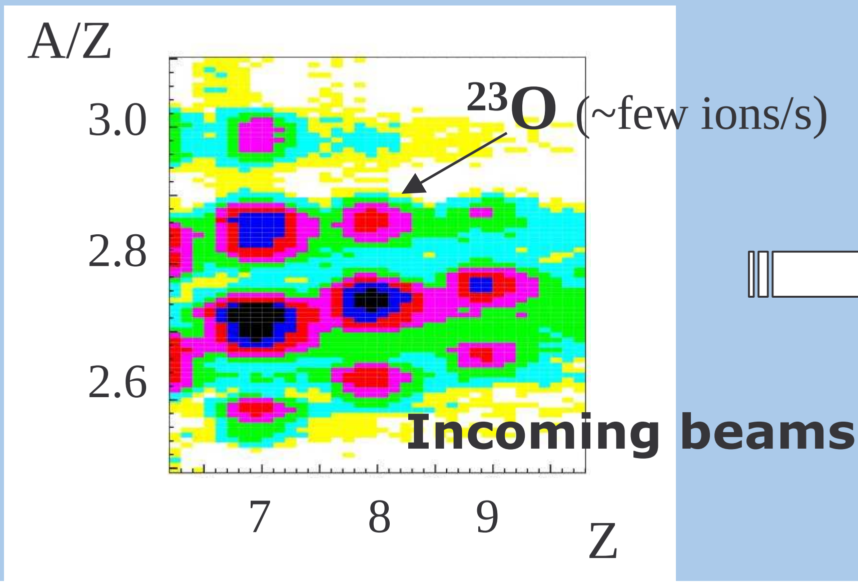
- E1 **is dominating over other multipolarities due to the small effective charge** *(S. Typel and G. Baur, PRC 64(2001)024601)*

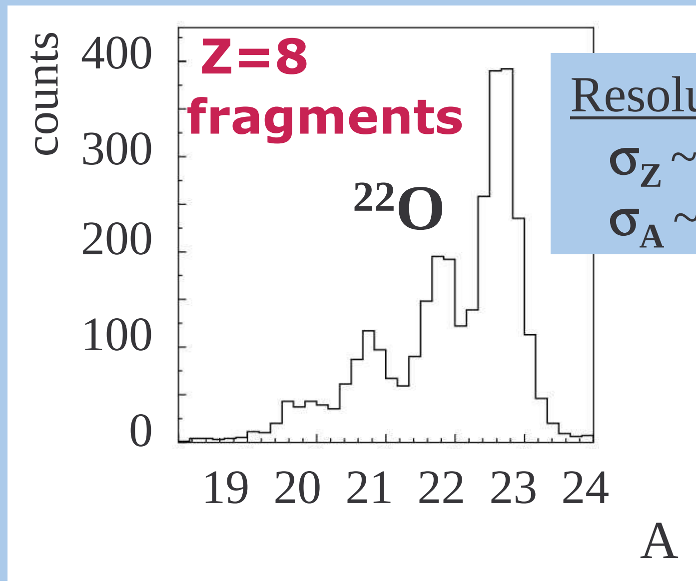
Determination of photon energy (excitation energy) via kinematically complete measurement of the momenta of all outgoing particles (**invariant mass method**)

LAND experimental setup

At E_{inc} =422 MeV/u







Resolution:

$\sigma_Z \sim 0.2$

$\sigma_A \sim 0.3$

Direct breakup model

After projection on *core* states $\mathbf{I}_c^{\pi}$, identified by means of *γ-ray coincidences* :

E1 matrix element

$N_{E1}(E^*)$ calcultated in semiclassical approx.

$$\frac{d\sigma}{dE^*}(I_c^{\pi}) = \frac{16\pi^3}{9\hbar c} N_{E1}(E^*) \sum_{nlj} C^2 S(I_c^{\pi}, nlj) \sum_m \left| \left\langle \mathbf{q} \left| \frac{Ze}{A} r Y_m^1 \right| \psi_{nlj}(\mathbf{r}) \right\rangle \right|^2$$

spectroscopic factor

The differential cross section for e. m. excitations can provide information on the quantum numbers and spectroscopic factors of ground state configuration

Advantages

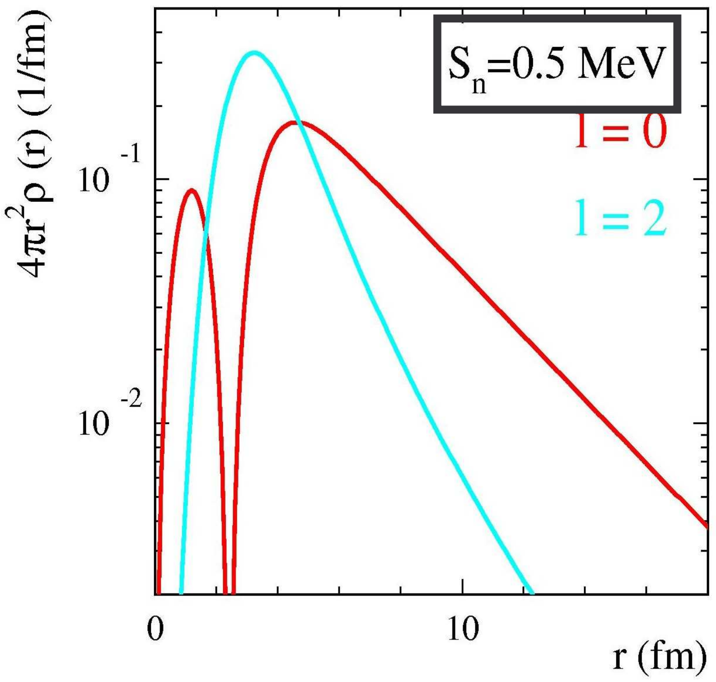
- interaction is well known
- high energy approx.
- sensitivity to low l values

Limitations

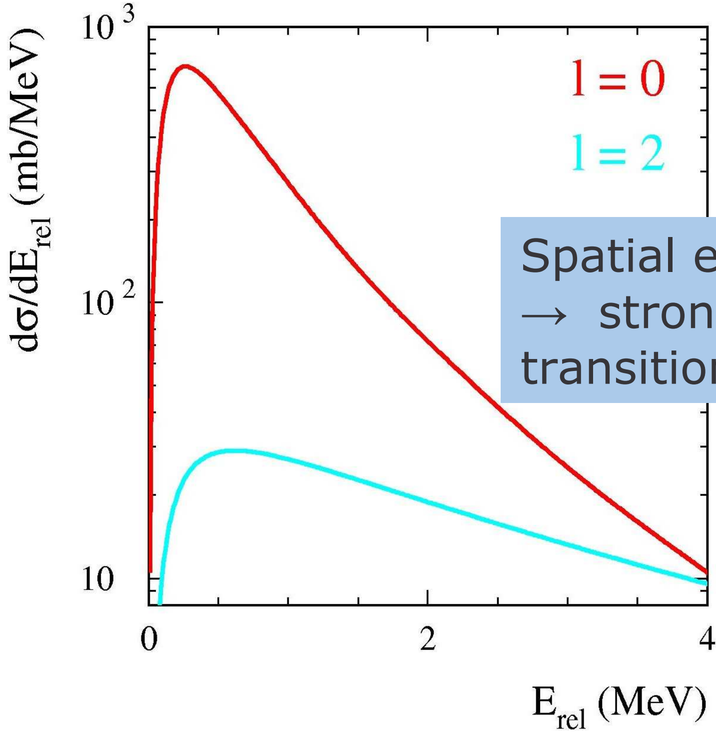
- core excited states to be identified
- in case of not so weakly bound breakup systems ?

Low-lying E1 strength as spectroscopic tool

Density distribution



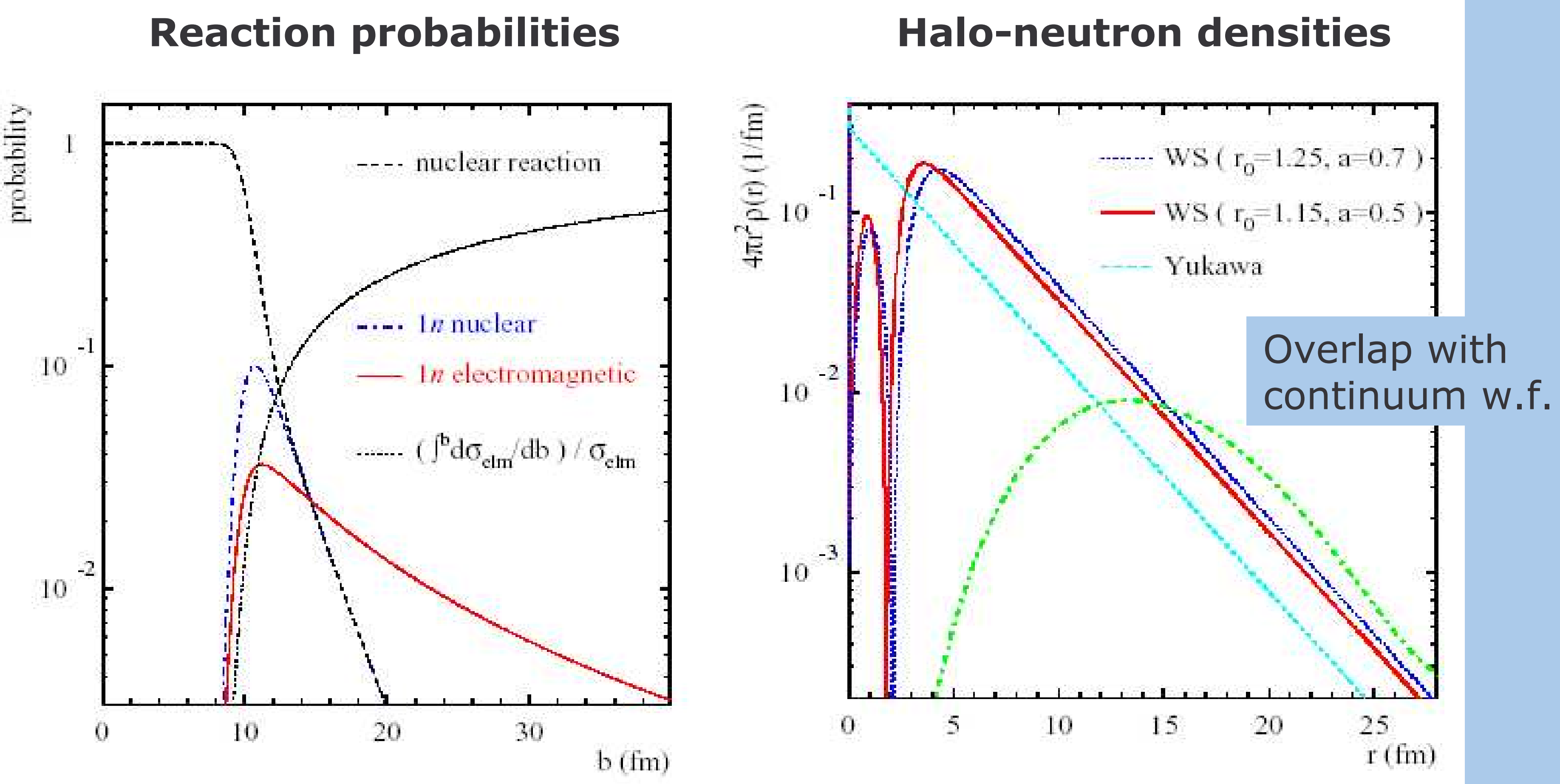
Differential cross section



Spatial extension (*Halo*)
→ strong non-resonant transition (~100mb/MeV)

shape of differential cross section → orbital angular momentum *l*
γ-ray coincidences → identification of core state
cross section → spectroscopic factor

Sensitivity of Coulomb breakup



R. Palit et al., PRC 68(2003)034318

Sensitivity to low-density tail of the wave function

Information available on ^{23}O nucleus

s-wave g.s. configuration

Narrow **$p_{//}(^{23}O \rightarrow ^{22}O)$** distribution → halo-like tail of the w. f. (***s***-wave neutron)

Experiments of **^{22}O** γ-spectroscopy *(P. Thirolf et al., PLB 485(2000) , O. Sorlin et al., NPA 685(2001)186c)* → **2^+** state in ^{22}O at **3.2 MeV** → **N=14 sub-shell closure**

d-wave g.s. configuration

$p_{//}(^{23}O \rightarrow ^{21}O)$ distribution → ***$(s_{1/2})^2 d_{5/2}^{-1}$*** configuration (in conflict with shell model prediction)

Large **^{23}O interaction cross section** → modification of the ^{22}O core structure *(R. Kanungo et al., PRL 88(2002)142502)*

Theory :

Prediction of shell closure at N=16 rather than at N=20 for O isotopes

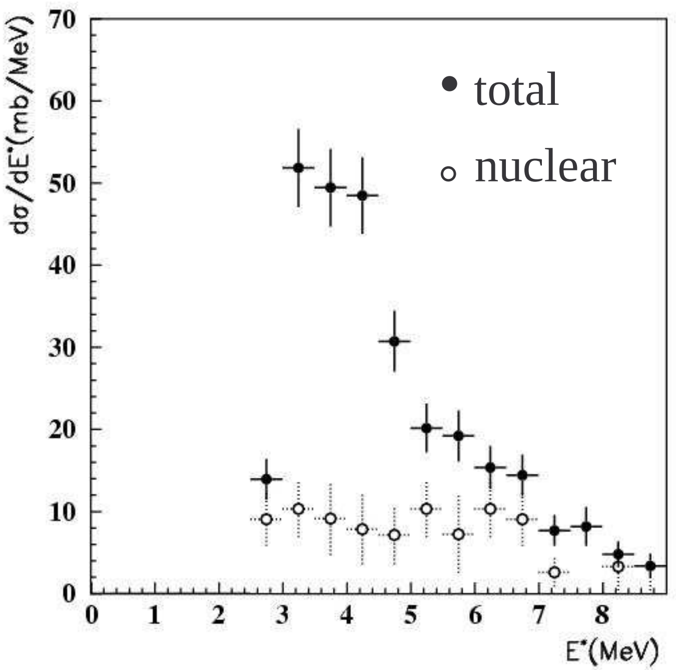
(T. Otsuka, present meeting)

Coulomb breakup of ^{23}O

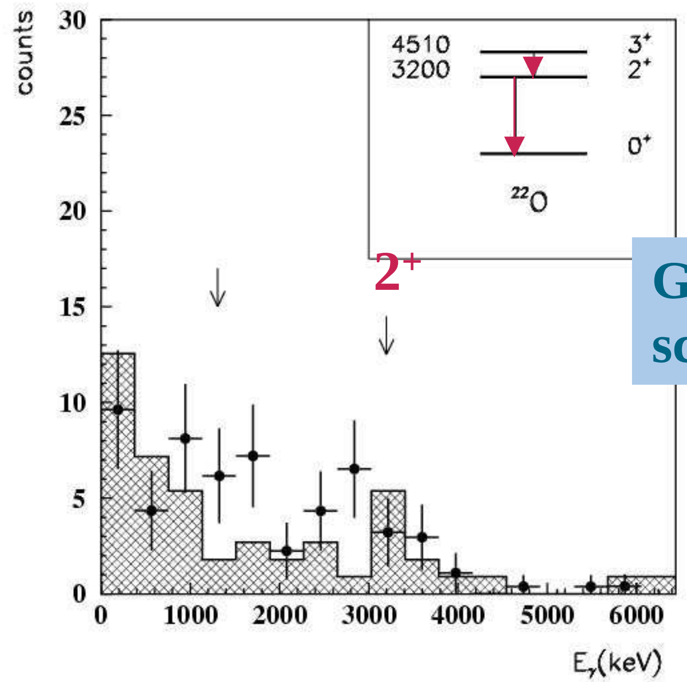
At E_{inc} =422 MeV/u

	σ_{tot}(mb)	σ_{nucl}(mb)	$\sigma_{e.m.}$(mb)
Pb	131±8	37±6	94±10
C	12±2	12±2	-

Differential cross section



^{208}Pb (^{23}O,^{22}O+n+γ) X



GANIL scheme

At most 30% ^{22}O in excited states

According to the γ-analysis, the quantum numbers of the valence neutron uniquely determine spin and parity of $^{23}O_{g.s.}$

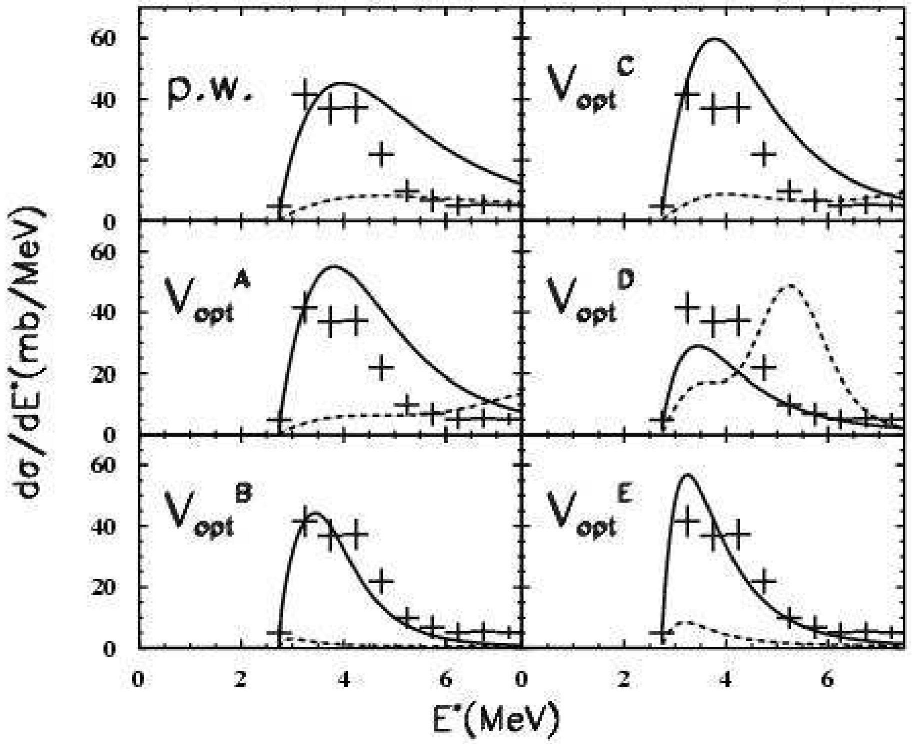
Comparison with models

Differential e. m. cross section

$\sigma_{e.m.} = 94 \pm 10$ mb

—— $|2s_{1/2}\nu \otimes {}^{22}\mathrm{O}(0^+)>,\ C^2S=1$

.... $|1d_{5/2}\nu \otimes {}^{22}\mathrm{O}(0^+)>,\ C^2S=1$



Using distorted waves :

		V_0 (MeV)	$\sigma^{th}(0^+)$mb	C^2S
S.Typel calc.	A	42	149	0.52 ±0.10
	B	**55**	**73**	**1.05 ±0.21**
Perey & Perey	C	49§	154	0.50±0.10
	D	47§	63	1.22 ±0.24
Chadwick &Young	**E**	**49**	**89**	**0.87 ±0.17**

§ values quoted for E_n=0

V_0 depth of the real part of optical potentials

corrected for ^{22}O core excited states

Proposed J^π=1/2$^+$ for $^{23}O_{g.s.} \rightarrow (2s_{1/2})^2 1d_{5/2}^{-1}$ configuration not supported

Summary

Spectroscopic results for $^{23}O_{g.s.}$ via exclusive measurements of one-neutron e. m. breakup :

- Contribution of core excited states at most 30%

- Proposed $J^{\pi} = 1/2^{+}$ for $^{23}O_{g.s.}$ $\rightarrow$ $(2s_{1/2})^2 1d_{5/2}^{-1}$ configuration not supported

$C^2S \sim 1$ for $|2s_{1/2}\nu \otimes {}^{22}O(0^+)>$ $\rightarrow$ support proposed N=14,16 shell closure for O isotopes

LAND-FRS collaborators :

P. Adrich[d], T. Aumann[b], K. Boretzky[a], D. Cortina-Gil[b], U. Datta Pramanik[b], Th.W. Elze[c], H. Emling[b], H. Geissel[b], M. Hellström[b], N. Iwasa[b], K. L. Jones[b], J. V. Kratz[a], R. Kulessa[d], Le Hong Khiem[a], A. Leistenschneider[b], G. Münzenburg[b], R. Palit[c], P. Reiter[e], H. Scheit[f], C. Scheidenberger[b], H. Simon[g], K. Sümmerer[b], S. Typel[b], E. Wajda[d], W.Walus[d], H.Weick[b]

[a]*University of Mainz, Germany*
[b]*GSI, Darmstadt, Germany*
[c]*University of Frankfurt, Germany*
[d]*University of Kraków, Poland*
[e]*University of Köln, Germany*
[f]*MPI Heidelberg*
[g]*TU Darmstadt, Germany*