Direct Reactions with Exotic Beams

Yorick Blumenfeld
Direct Reactions with Exotic Beams

<table>
<thead>
<tr>
<th>Experimental method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Search for the tetra-neutron</td>
</tr>
<tr>
<td>Doubly magic oxygen isotopes: proton scattering from the O isotopic chain</td>
</tr>
<tr>
<td>Shell gaps far from stability: the power of transfer reactions</td>
</tr>
<tr>
<td>Improved beams and detectors: Towards lower cross sections.</td>
</tr>
</tbody>
</table>
A Typical Direct Reaction Experiment with RIB

MUST: Y. Blumenfeld et al., *NIM A366* (1999) 298

CATS1  |  CATS2

CH₂ target

RIB²²O

**CH₂ target**
The $^{14}\text{Be}$ break-up experiment

**FIG. 3.** Distribution of the ratio of proton energy, $E_p$ (MeV), to the energy derived from the flight time, $E_n$ (MeV/nucleon), for data from the reaction ($^{14}\text{Be}$, $^{12}\text{Be}+n$)—histogram—and for simulations of elastic scattering of $^{1,3,4}n$—solid, dashed, and dotted lines, respectively—on protons. The experimental resolution has been included in the simulations.

**FIG. 6.** Scatter plot and the projections onto both axes of the particle identification parameter PID defined in Eq. (1) vs $E_p/E_n$ for the data from the reaction ($^{14}\text{Be},X+n$). The PID projection is displayed for all neutron energies. The dotted lines correspond to $E_p/E_n=1.4$ and to the region centered on the $^{10}\text{Be}$ peak.

F. Marques et al, PRC 65; 044006 (2002)
“ I show that it does not seem possible to change modern nuclear Hamiltonians to bind tetraneutron without destroying many other successful predictions of those Hamiltonians. This means that, should a recent experimental claim of a bound tetraneutron be confirmed, our understanding of nuclear forces will have to be significantly changed…”

S. C. Pieper, PRL 90, June 2003
No evidence for a bound tetraneutron
- correlations between the 4 neutrons
**Oxygen isotopic chain**

Can we prove that these effects are due to a neutron shell closure? Through a proton scattering experiment. Protons are more sensitive to Neutrons.

P.G. Thirolf et al. PLB 485 (2000)16
M. Belleguic et al. NP A682, 136c (2001)
Results

$E_{2+} = 3.2 \pm 0.2 \text{ MeV}$

1000 pps
Phenomenological analysis

\[ \beta_{(p,p')} = 0.26 \ (4) \]

\[ \beta_{(p,p')} = 0.55 \ (6) \]

\[ \beta_{(p,p')} = 0.37 \ (3) \]

E. Becheva PhD and PRL 96 (2006) 01250
$M_n/M_p$ ratio

$Z=8$ closed shell
$^{46}$Ar(d,p)$^{47}$Ar at 10 AMeV with SPIRAL
Excitation energy spectrum for $^{47}$Ar

N=28 gap : 4.47(8)MeV

$L. Gaudefroy (PhD)$ and O. Sorlin

C$^2$S$_{p_{3/2}}$ = 0.61
C$^2$S$_{p_{1/2}}$ = 0.85
C$^2$S$_{f_{7/2}}$ = 0.17
C$^2$S$_{f_{5/2}}$ = 0.64
C$^2$S$_{g_{9/2}}$ = 0.34

Experimential
SM calcul.
Decrease of the \( f \) and \( p \) spin-orbit splittings not predicted by mean field calculations.

The \( N=28 \) gap has decreased by 330(80) keV between Ca and Ar.

Decrease of the \( f \) and \( p \) spin-orbit splittings not predicted by mean field calculations.

First evidence of the tensor force in nuclei!

Courtesy of Olivier Sorlin
The MUST2 Array

Collaboration: IPNO, SPbN/Saclay, GANIL

**MUST2: a major upgrade of MUST**
- Increased angular coverage
  - Better efficiency
  - Measure several reactions in one shot
- Increased granularity (multiparticle events)
- New ASIC based electronics: more compact

ASICS 16 channels
E and T

DSSD 128+128
300μm

Si(Li) 4.5mm

CsI(PD) 4cm
**MUVE II**

- Plan Basics
  - Exp. Method
  - Inv Kinematics
  - MUST II
  - Geometry
  - MATE (ASIC)
  - Signals process
  - Slow Control
  - Data Acquisition
  - Trigger
  - Dead-Time

**WHO**

- 288 Energy Spectra
  - 150 KeV Threshold
  - 40 KeV FWHM

- 288 Time Spectra
  - 500 psec FWHM

**MUVE**

- 2.3K parameters
- 16 ADC14 bits
- Slow Control I2C
- 2 MHz

**288 Energy Spectra**

- 150 KeV Threshold
- 40 KeV FWHM

**288 Time Spectra**

- 500 psec FWHM
DEXON 2006 - 2012

Short-Term

BT D

ExoGam

TIARA

MUST II

VAMOS

E. C. Pollacco CEA Saclay
Neutron-proton pairing in N=Z nuclei through n,p transfer

- n-p pairing can occur in 2 different states: $T=0$ and $T=1$.

$^{56}\text{Ni}$, $^{48}\text{Cr}$ (p,t) $\Delta T = 0, 1$

$^{56}\text{Ni}$, $^{48}\text{Cr}$ (d,α) $\Delta T = 0$

Study of $^{68}\text{Ni}$ (d,p)

Study of $^{60}\text{Fe}$ (d,p) for astrophysics
The EURISOL Road Map

• Vigorous scientific exploitation of current ISOL facilities: EXCYT, Louvain, REX/ISOLDE, SPIRAL

• Construction of intermediate generation facilities: MAFF, REX upgrade, SPES, SPIRAL2

• Design and prototyping of the most specific and challenging parts of EURISOL in the framework of EURISOL_DS.
The EURISOL_DS proposal in the 6th framework

- Detailed engineering oriented studies and technical prototyping work
- 21 participants from 14 countries
- 21 contributors from Europe, Asia and North America (including SOREQ)
- Total Cost : 33 M€
- Requested contribution from EU : 9.16 M€
The EURISOL Concept

One possible schematic layout for a EURISOL facility