Probing the structure of neutron-rich N=12-16 F, O and Ne isotopes using deep-inelastic collisions

- the proposal
- set-up PRISMA-CLARA
- details about our experiment

(28th beam prep.) 29th Nov - 3rd Dec (finishing 4th morning)
LNL Legnaro (Pd)
Aim of the project:
Population of n-rich Ne, F and O nuclei

Information on reaction dynamics in light nuclei using MNT and deep-inelastic reactions

Gamma spectroscopy of n-rich
• O isotopes
• F isotopes
• Ne isotopes
binary reactions with the mass of the products in a narrow distribution around the projectile and target masses

**DIC**
energies well above the Coulomb barrier. Most of the beam energy is absorbed in the process, the reaction products emerge with low kinetic energy

**QE- Multi Nucleon Transfer**
energies around the Coulomb barrier. Population of Multiparticle-Multihole states with limited excitation energy and therefore limited particle evaporation

---

Oxygen isotopes

Experimental info for N = 12 and 14


Need to firmly establish these transitions
VAMOS+EXOGAM exp:

$^{24}\text{Ne} @ 7.923 \text{ MeV/A} + ^{208}\text{Pb} (10.9 \text{ mg/cm}^2)$

$^{24}\text{Ne}^5+ , I_{\text{beam}} \sim 1.5 \times 10^5 \text{ pps}$

**Neon isotopes**

**Oxygen isotopes**

<table>
<thead>
<tr>
<th></th>
<th>Counts</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>$1.416 \times 10^5$</td>
<td>100</td>
</tr>
<tr>
<td>Neon</td>
<td>$1.377 \times 10^5$</td>
<td>97.2</td>
</tr>
<tr>
<td>Fluorin</td>
<td>2101</td>
<td>1.5</td>
</tr>
<tr>
<td>Oxygen</td>
<td>664</td>
<td>0.47</td>
</tr>
</tbody>
</table>

$2^+ \rightarrow 0^+ \ ^{20}\text{O}$

1.6 MeV

-2p-2n
CLARA-PRISMA setup

Angular range
- $30^\circ$ +$130^\circ$

$\Delta \Omega = 80$ msr
$\Delta Z/Z \approx 1/60$
(Measured)
$\Delta A/A \approx 1/190$
(Measured)
Energy acceptance
$\pm 20\%$
$B_\rho = 1.2$ T.m
CLARA: CLOVER ARRAY at PRISMA

Composite HPGe detectors CLOVER:
• 4 crystals
• 1 BGO shield (AC)
• 1 criostat

Beam-out

3 signals from each crystal:
• Energy (ADC 4MeV)
• Energy (ADC 20MeV)
• Time

24 to 25 Clovers setup
Efficiency ~ 3 %
Peak/Total ~ 50 %
Position $\theta = 104^\circ-156^\circ$
FWHM ~ 10 keV for $E_\gamma = 1.3$MeV at $\nu/c = 10 %$

“in-beam” $\gamma$-ray spectroscopy
CLARA-PRISMA setup

Start detector

Quadrupole

Dipole

MWPPAC

IC

E-ΔE

X-Y, time

6m (TOF)
Optical Elements

- **Quadrupole**: a singlet, focuses vertically the ions towards the dispersion plane.

- **Dipole**: bends horizontally the ions with respect to their magnetic rigidity ($B\rho$).
PRISMA Detectors

- **Entrance Position**
  - position \(x_s - y_s, \text{time}\)

- **Focal Plane Position**
  - position \(x_f - y_f, \text{time}\)

- **Ionization Chambers**
  - energy loss, total energy

Physical Event:
\((x_s, y_s, x_f, y_f, \text{TOF}, \Delta E, E)\)
Entrance Position Detector: MCP

- Micro Channel Plate
- 8x10 cm² sensitive area ($\Omega=80$ msr)
- Timing resolution for TOF ~ 350 ps

- $d_{\text{TARGET}}=25$ cm
- C-foil 20mg/cm² thick
- $E_{\text{acc}}=30-40$ kV/m
- $B\approx120$ Gauss

- 3 signals
- Hole diameter 1 mm
- 1.1 mm FWHM
MCP is located here

Beam in
Focal Plane Position Detector

- **MWPPAC**
- Active area 1m x 13 cm
- 10 independent sections (horizontal plane)
- $\Delta X \sim 1\text{mm}, \Delta Y \sim 2\text{mm (FWHM)}$
- Stop signal for TOF

Filling gas: $C_4H_{10}$
Filling pressure: 7 mbar

10 x 3 signals ($X_l$, $X_r$, timing)
2 signals ($Y_u$, $Y_d$)

Lower efficiency for light nuclei (60-70 %)

1000 Wires
Entrance Window

to Ionization Chambers
Ionization Chambers

- **10x4 sections** (10x25 cm²)
- $\Delta E/E < 2\%$

Filling gas: $CH_4$ or $CF_4$
Working pressure: 20-100 mbar

40x2 signals
How to reconstruct the different incoming particles???

- **Optical elements + TOF** → **Magnetic rigidity:**
  \[
  B \rho = \frac{p}{q}
  \]

- **Energy loss in IC + residual energy** →
  \[
  \frac{m}{q} \approx B \rho \times TOF
  \]

Bethe-Bloch for non-relativistic heavy particles:

\[
\frac{dE}{dx} \propto \frac{M Z^2}{E}
\]

\[\downarrow\]

\[E \Delta E \approx M Z^2\]
DANTE
(Detector Array for multi Nucleon Transfer Ejectiles)

• Limited efficiency of the PRISMA-CLARA setup ⇒ No γ-γ coincidences.
• DANTE (heavy ion detector based on MCP) reveals the position interaction of the recoils ⇒ Doppler correction.
• DANTE placed at the grazing angle, has a high efficiency ⇒ γ-γ coincidences ⇒ No need of an extra GASP experiment to build up a level scheme.
Trigger conditions:

- Dante \( \text{AND} \) \( 2\gamma \) (Sumbus =2)
- MCP \( \text{AND} \) \( \gamma \) (Sumbus =1)
- PPAC \( \text{AND} \) \( \gamma \) (Sumbus =1)
- PPAC \( \text{AND} \) MCP

OR

Master Trigger

There can be events WITHOUT CLARA
Or events of DANTE and CLARA and no PRISMA
References for Prisma-Clara set-up:

- NPA 701 (2002) 217c-221c A.M.Stefanini ➔ array description
- NIM A547(2005) 455-463 G.Montagnoli ➔ MCP detector
- NIM A551(2005) 364-374 S.Beghini ➔ Focal plane detectors
- Proceeding of 5th Italy-Japan Symposium (world scientific 2005) E.Fioretto + A.Gadea ➔ overview of PRISMA e CLARA
- LNL annual report 2000-2005 ➔
  - PRISMA-CLARA installation and description
  - First results
  - DANTE array description
- LNL web site www.lnl.infn.it ➔ research ➔ PRISMA-CLARA
What to check on-line....

• **rates** ➔ Note on the LOGBOOK:
  
  ✓ **PRISMA rates**: i.e. PPAC, PPAC-Ge, MCP, DANTE
  
  ✓ **CLOVER rates**: singles,
  
  ✓ **ACQ rate** (kBytes/s on tape)

• **On-line spectra monitoring**
  
  ✓ **PRISMA spectra**: use the on-line display “d”

  Important RAW spectra:
  
  • MCP X,Y and MATRIX
  
  • PPAC_X for each section
  
  • PPAC_Y
  
  • IC raw and E/dE for each section and summed
  
  • TOF spectra
  
  ✓ **CLARA spectra**: XmSpecview (usually on different pc)
    
    ➔ clear frequently RAW spectra

• **alarms** ➔ beam beeper + HV in PPAC
Numbers for our experiment

• **Beam:** $^{22}\text{Ne} @ \sim 150 \text{ MeV} \Rightarrow \text{highest possible, possibly 155 MeV}
• **Target:** - $^{238}\text{U}$ 0.5 mg/cm² evaporated on $^{12}\text{C}$ foils (0.2 mg/cm²) stack of 2
  - $^{208}\text{Pb}$ 0.5 mg/cm² evaporated on $^{12}\text{C}$ foils (0.2 mg/cm²) stack of 2
• **Positioning of Prisma:** $\sim 70^\circ$ (depending on target used $\theta_{\text{gra}}=68.5^\circ$ with U)
• $E_{\text{coulomb}}=112.4 \text{ MeV} \Rightarrow \sim 35\%$ above Coulomb barrier
• $E_{\text{exc}} \sim 5\text{-}10 \text{ MeV}$ (depending on specific channel)
• Expected population of isotopes (GRAZING code)

\begin{figure}
\centering
\includegraphics[width=\textwidth]{oxygen_isotope_diagram}
\end{figure}

\begin{table}
\centering
\begin{tabular}{|c|c|c|}
\hline
$\langle E_{\text{exc}} \rangle$ & U target & Pb target \\
\hline
$^{20}\text{Ne}$ & 4.5 & 5.1 \\
$^{22}\text{Ne}$ & 5.6 & 6.6 \\
$^{20}\text{O}$ & 7.6 & 7.4 \\
\hline
\end{tabular}
\end{table}
Shift organization:

2 staffs, PRISMA (staff 1) and CLARA (staff 2)

- We will be included in staff 2
- Always 2 people on shift: 1 from staff1 and 1 from staff2
- Shifts schedule for staff2 on blackboard in GASP ACQ. Room
- Need to guarantee 1 person/shift
- 3 shifts a day, 8 hours each (0-8; 8-16; 16-24)
- Local people on call in nights and w-ends
- Try not to leave un-experienced people alone

Reminder:

(28th beam prep.) 29th Nov – 3rd Dec (finishing 4th morning)
LNL Legnaro (Pd)

You find this file in: http://lxmi.mi.infn.it/~benzoni/download/exp_LNL/pre Esp.ppt(pdf)