High energy resolution spectroscopy with K600 magnetic spectrometer at iThemba LABS – FD Smit
Beginning of 0° mode for K600 at iTL

- Invitation by Peter von Neumann-Cosel to take part in an RCNP experiment
- Meet Yoshi at RCNP in May 2002
- Yoshi strongly advises that 0° at iTL is possible
- Biggest worry is that weekends only beam time would make it impossible
- Return home to considering

Oct’ 2006 – First beam in new 0° beam dump
The K600 at iThemba LABS

A kinematically corrected QDD magnetic spectrometer for light ions

Since 1993

Indiana University Cyclotron Facility design

**Finite angle measurements** ($\theta_{\text{scat}}>5^\circ$)

- Medium dispersion focal plane $B(D1)=B(D2)$
- Large momentum range: $p_{\text{max}}/p_{\text{min}}=1.097$
- Resolving power: $\Delta p/p = 1/28000$
- Horizontal magnification $M_x = -0.52$
- Vertical magnification $M_y = -5.5$
- Dispersion: 8.4 cm/%

Since 2009

**Zero degree measurements** ($\theta_{\text{scat}}<2^\circ$)

- High dispersion focal plane $B(D1)/B(D2)=1.49$
- Momentum range: $p_{\text{max}}/p_{\text{min}}=1.05$
- Horizontal magnification $M_x = -0.74$
- Vertical magnification $M_y = -7.05$
- Dispersion: 10.9 cm/%
- Solid angle: 3.5 msr
• Fine structure seems to be a global phenomenon: different targets, different resonances
• Wavelet analysis: scales characterize the fine structure
• Use scales to study dissipative mechanisms of GR

iTL K600 zero degrees

Special thanks:
Y Fujita
H Fujita
K Hatanaka
G Berg
Clustering - Recent $^{20}$Ne results from iThemba LABS

- $^{22}$Ne(p,t)$^{20}$Ne at 60 MeV
- 0°, 7°, 16°, 27°, gas target
- Discovered 6 new, narrow, states in $E_x = 17$–23 MeV
  - 17.67, 18.84, 20.59, 21.16, 21.80, 22.5 MeV
- Low spin values: J=0–2
- Only state at 22.5 MeV could not be interpreted by shell–model calculations
Do as well or better than RCNP at \((\alpha, \alpha')\)

ISGMR Data -- Spin Dependence of Level Densities

\[ ^{58}\text{Ni}(\alpha,\alpha) \text{ at } 0^\circ \]

Counts/

Excitation Energy / MeV

Being Analyzed – 75 keV
Add a Coincidence DSSSD array: CAKE

- 4 × MMM-400 Double Sided Silicon Strip Detectors (DSSSD)
- Lampshade configuration
- 400 μm thick (7 MeV p, 28 MeV α)
- 16 rings, 8 sectors
- θ range: 114° - 166°
- total solid angle: 21% of 4π; 0.66 msr/DSSSD
- target to detector separation: 100–110 mm
- rates during experiment <5kHz/DSSSD
Clustering: the \(^{16}\text{O}\) nucleus

Natural parity states (NNDC)

0\(^+\) state at 15.097:
- Few hundred keV above 4 \(\alpha\) threshold

\(S_{4\alpha} = 14437\) keV

0\(^+\) state at 15.097:

\(E_x\) the weighted mean of 4 studies:

<table>
<thead>
<tr>
<th>Reference</th>
<th>Energy (MeV)</th>
<th>Width (MeV)</th>
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<tbody>
<tr>
<td>NPA 180 (1972) 282</td>
<td>15.17 ± 0.05</td>
<td>190 ± 30</td>
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<tr>
<td>NPA 294 (1978) 161</td>
<td>15.10 ± 0.05327 ± 100</td>
<td>12(^\text{C}(\alpha,\alpha)), (p, p_0)</td>
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<tr>
<td>NPA 305 (1978) 63</td>
<td>15.103 ± 0.005</td>
<td>-</td>
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<tr>
<td>PRC 25 (1982) 729</td>
<td>15.066 + 0.011</td>
<td>166 ± 30</td>
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Width from Ames (PRC 25)

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<tr>
<td>11260?</td>
<td>(0+)(0+)</td>
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<td>11600</td>
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Li$_2$CO$_3(\alpha, \alpha')$ coincidence results @ 200 MeV, 0°

Search for Hoyle–like state in $^{16}$O

Characterize decay of $0^+_6$ at 15.097 MeV
$\text{Li}_2\text{CO}_3(\alpha, \alpha')$ coincidence results @ 200 MeV
Particle Separation via Time-of-Flight to Si detectors

DSSSD PID:

proton

α
Coincidence results: Li$_2$CO$_3$
15.097 MeV not one state?

\[ p_0 \]

\[ \alpha_0 \]

\[ \alpha_1 \]
Test cases: $2^+ 11.52$ MeV & $0^+ 12.049$ MeV

$0^+ 12.049 \, \alpha_0$ extracted branching ratio: 97%

$0^+ 12.049 \, \alpha_0$  

$2^+ 11.52 \, \alpha_0$
15.097 MeV results

$0^+ \ 15.097 \ \alpha_0$ angular distribution

$0^+ \ 15.097 \ \alpha_1$ angular distribution

If isotropic distribution assumed …

$0^+ \ 15.097 \ \alpha_0$ branching ratio

$\text{counts}(\alpha_0)/\text{counts(singles)}*\text{SA} = 0.89 \pm 0.06$

$0^+ \ 15.097 \ \alpha_1$ branching ratio

$\text{counts}(\alpha_1)/\text{counts(singles)}*\text{SA} = 0.35 \pm 0.05$
15.097 MeV results

$0^+ 15.097 \alpha_0$ angular distribution

This work

$15.090(1) \alpha_0$ – Width 164 ± 5 keV

$0^+ 15.046(3) \alpha_1$ – Width 216 ± 10 keV
Prospect of benefit for fine structure Giant Resonance

$^{24}\text{Mg}(\alpha,\alpha')$ at 0° with K600 and CAKE

Counts / 100 keV

$E_x / \text{MeV}$

Singles
- $\alpha_0 \text{ gs } ^{20}\text{Ne}$
- $\alpha_1 \text{ 1st } ^{20}\text{Ne}$
Add a Coincidence HPGe array: BAGEL

Beautiful Array of GErmaniums for L-value determination
BAGEL array: soon to be assembled

Assembly start
February 2016
GATEAU – Gaseous Active-TargEt Ancilliary Unit
Contributors and support

- Y Fujita, H Fujita, K Hatanaka, A Tamii
- A Richter, P von Neumann-Cosel
- J Carter, E Sideras-Haddad, I Usman
- G Berg
- P Papka
- R Fearick
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- L Pellegrini – Wits Univ. & iTL
- D Marin-Lambarri – Univ. West. Cape & iTL
- V Pesudo – Univ. West. Cape & iTL

Students MSc work

$^{16}$O – KCW Li – Univ. Stellenbosch
GATEAU – JW Brümmer – Univ. Stellenbosch
Thank You