Investigations of Heavy Ion Reactions at Low energy with Diamond Detectors

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Motivation

The typical setup for reaction studies

CORSET + DIAMOND

First experimental results

Summary
- Identification of Low Energy Reaction Products
- Production of Heavy Ions

- Fusion Reactions in Heavy Systems
- Multi-Nucleon Transfer Reactions in Damped Collisions of Heavy Ions
The typical setup for reaction studies: ToF-E-telescope
ΔE-E-ToF telescope

{ΔE, t₁} \{E_r, t₂\}

\begin{align*}
\text{ToF} &= t₁ - t₂ \\
E &= \Delta E + E_r \\
Z &\sim (\Delta E)^{1/2} \cdot f(E) \\
A &\sim (\text{ToF})^2 \cdot f(E)
\end{align*}
### Comparison of ranges in CVDD and Si detectors

<table>
<thead>
<tr>
<th>Range</th>
<th>$\alpha$ (5.5MeV)</th>
<th>Fission Fragments $^{140}$Ba (100MeV)</th>
<th>Deep inelastic transfer products $^{205}$Tl (800MeV)</th>
<th>Elastic scattering of $^{238}$U+$^{238}$U (1.6GeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVDD (µm)</td>
<td>12</td>
<td>10</td>
<td>25</td>
<td>44</td>
</tr>
<tr>
<td>Si (µm)</td>
<td>24</td>
<td>18</td>
<td>48</td>
<td>82</td>
</tr>
</tbody>
</table>

Thickness of "$\Delta E$/Start" detector should be less then 10 µm.
$E_\alpha \approx 5.5$ MeV

\[
\begin{align*}
\text{ToF} & \\
E_r & \\
\Delta E & \\
\end{align*}
\]

$L = 14\text{mm}$

"$\Delta E/\text{Start}$" scCVDD$_1$

"$E_r/\text{Stop}$" scCVDD$_2$

"$\Delta E/\text{Start}$" detector

[Image of a detector with dimensions:]
- 4µm
- 50µm
- 1 mm
- 2 mm
- 4.5 mm
Two-dimensional $\Delta E$ vs $E_r$ spectrum of $\alpha$-particles

$E_{1\text{line}} = 5156.59 \text{ keV}$
$E_{2\text{line}} = 5485.56 \text{ keV}$
$E_{3\text{line}} = 5804.82 \text{ keV}$
Energy and time of flight spectra of α-particles

\[ E_{\text{tot}} = \Delta E + E_r \text{(event by event)} \]

3 line α source

\[ \Delta E \]

\[ E_r \]

L = 14 mm

ToF

Gaussian

\[ x_c = 0.96 \text{ ns} \]

\[ \sigma = 0.21 \text{ ns} \]

\[ \text{fwhm} = 0.42 \text{ ns} \]

\[ \text{tof}_{1 \text{line}} = 1.01 \text{ ns} \]

\[ \text{tof}_{2 \text{line}} = 0.97 \text{ ns} \]

\[ \text{tof}_{3 \text{line}} = 0.93 \text{ ns} \]
ToF-E detector system CORSET + Diamond = Z+A

Start, Stop: MCP-detectors
E: Si-detectors

Projectile
$^{36}\text{S } E = 160 \text{ MeV}$

Target
$^{186}\text{W}$

For HI
$\Delta t(\text{FWHM}) = 150 \text{ ps}$
$\Delta E(\text{FWHM}) = 6 \text{ MeV}$
$\Delta M(\text{FWHM}) = 2-3 \text{ amu}$
$^{36}\text{S}(160\text{MeV}) + ^{186}\text{W}$ at $20^0$ (Dubna, October 2013)
$^{36}\text{S}(160\text{MeV})+^{186}\text{W at } 20^0$ (Dubna, October 2013)

$\sigma^S_{\text{Ruth}} = 7.7 \times 10^4 \text{mb/sr}$

$\sigma^W_{\text{Ruth}} = 4.9 \times 10^2 \text{mb/sr}$
Summary

• $\Delta E$-E-ToF telescope to obtain A and Z in heavy ion reactions at Coulomb barrier energy
• First successful application of very thin diamond detector (4 $\mu$m) with $\alpha$-particles
• First successful application in reaction $^{36}\text{S}+^{186}\text{W}$ at 4.4MeV/u
• Further experiment planned for 2014 {U+U}
Acknowledgments

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- Michal Pomorski

Thank You for Attention!