Mass measurements with (d,p) transfer reactions

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06/10/05
Experimental Program

- Measure the Mass of $^{64}$Ge and $^{65}$As to calculate the Q-Value of $^{64}$Ge(p,$\gamma$)$^{65}$As
- Use (p,d) Transfer Reactions in Inverse Kinematics
  - Produce $^{66}$As and $^{65}$Ge Beams.
- CH$_2$ Target for Protons
- Magnetic Spectrometer to separate reactions products.
- Measure Deuterons from (p,d) in Charged Particle Array
- Measure Reaction Angle with Position Sensitive Beam Tracking Detectors
How Do We Measure These Nuclear Masses?

Using Inverse Kinematics: (p,d)

Use Heavy Beam Particle.

Heavy Fragment Which Has An Unknown Mass

The Proton is in a CH$_2$ target or a Frozen Hydrogen Target

\[
M_{65\text{As}}^2 = M_{66\text{As}}^2 + M_p^2 + M_d^2
\]

\[
+ 2 \left( E_{66\text{As}} M_p - E_d M_p - E_{66\text{As}} M_d + \sqrt{E_{66\text{As}}^2 - M_{66\text{As}}^2 \sqrt{E_d^2 - M_d^2}} \cos(\alpha) \right)
\]
Inverse Kinematics

\[
\begin{align*}
V_{d}^{\text{Lab}} & \quad \theta_{\text{lab}} \\
V_{c}^{\text{cm}} & \quad V_{d}^{\text{cm}} \\
V_{\text{beam}}^{\text{Lab}} & \quad V_{H}^{\text{cm}} \\
\theta_{\text{cm}} & \\
\end{align*}
\]
Cross Section in Inverse Kinematics

$^{65}\text{Ge}(p,d)^{64}\text{Ge}$
At 60 MeV/u
Generating the Radioactive Beam
The S800 Spectrograph
Dispersion Matching

Only 3 keV/mm Effect From Beam Energy using Dispersion Matching in S800
Resolution Effects

Slope of these lines:
1.8 keV\textsubscript{mass}/keV\textsubscript{deu}
61 keV/mm or
16 keV/mrad
Target Effect

Slope

71 keV/mg/cm²
Laser Based Alignment System

• Designed for precision measurement of detector positions relative to target.
• Adaptable to various configurations and other devices.
• Computer controlled.

Resolution:
• ±0.005° for angular stages.
• 100 microns for distance.
Beam Tracking Using Micro Channel Plate Detectors

Schematic Construction and Operating Principle of MCP

- Primary Electron
- anode
- MCP
- e-
- Beam
- Magnet
- Foil

INPUT ELECTRON
INPUT SIDE ELECTRODE
CHANNEL WALL
OUTPUT ELECTRODE
OUTPUT ELECTRONS
V_D

CHANNEL

STRIP CURRENT
Resolution of MCP Tracking System

Position: \( \sim 0.35 \text{ mm FWHM} \) - \( \sim 0.74 \text{ mm FWHM} \)

Time: \( \sim 600 \text{ ps FWHM} \)

Beam Rates up to 1 MHz

Efficiency \( \sim 90\% \) at 1 MHz
The High Resolution Array (HiRA)

- 20 Independent Telescopes
Silicon Detectors

- Bulk material is n type
- Interstrip on junction side is 25 μm
- Interstrip on ohmic side is 40 μm
  - P+ implant for better interstrip isolation
- Depletion voltage for 1.5 mm detector < 500 V
- 10 guard ring structure on periphery (2mm dead area region)

- 62.3 x 62.3 mm² Active Area
- Pitch 1.95 mm
- 1024 Pixels per telescope
Silicon Energy Resolution

HiRA global resolutions

DE global resolution = 30.9 keV
EF global resolution = 33.8 keV
EB global resolution = 34.0 keV
Particle Identification

Particle ID using EF vs DE

- $^4\text{He}$
- $^3\text{He}$
- $t$
- $d$
- $p$

DE Energy (MeV) vs EF Energy (MeV)
Electronic Readout
developed at Washington University (St. Louis)

With 2000 channels to readout, cost of “traditional” readout is prohibitive.

Design Includes:
- Multiple Preamps
- Shapers
- Discriminator
- Time to amplitude converters

Application Specific Integrated Circuit

This chip board + one VME module replaces 32 pre-amp’s, 32 Shapers, 32 TDCs and 32 ADCs
2 different gain internal Charge Sensitive Amplifiers (CSA)

- 100 MeV & 500 MeV dynamic range
- Bypass internal CSA for use with higher gain external CSA
- Pseudo CFD - Leading edge trigger zero cross discriminator
  - Computer controlled threshold for each strip
  - Positive and negative signals
  - On off for each channel

TVC 150 ns & 1 µs
- Unity gain Shaper with 1 µs shaping time for both positive and negative signals
- 3 computer controlled Inspection points, shown with red dot
- Multiplexed output of E & T signals through differential Amp into LVDS flash ADC.
- Sparse readout based on hit register, or forced readout of all channels
- Pulser inputs, even or odd channels
HiRA Electronics Setup Behind Detectors in Vacuum Chamber
Signal Traces from Differential Amplifier to ADC
Chip High Gain Pre-Amplifier

$^{228}\text{Th~}\alpha$ source
FWHM=50 keV
External 60 mV/MeV Pre-Amplifier + ASIC Chip

$^{249}$Cf $\alpha$ source
FWHM=30 keV
Simulated $^{64}\text{Ge}$ mass spectrum from $^{65}\text{Ge}(p,d)^{64}\text{Ge}$

FWHM = 190 keV

$\frac{\text{FWHM}}{\sqrt{N}} = 5.5$ keV
Status and Outlook

• Final Test of Entire system July 10th
• Initial Test of (p,d) experiment July 18th
• Measurement of $^{65}$As and $^{64}$Ge August
• Breakup Measurement of $^{69}$Br
• Measurements of $^{72}$Kr, $^{73}$Rb in the future
Collaborators

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