The Focal-plane Detector Package at the TUNL Split-pole Spectrograph

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Triangle Universities Nuclear Laboratory
Outline

1. Triangle Universities Nuclear Laboratory
2. The TUNL Enge Splitpole Spectrograph
3. Focal-plane Detector
4. Results
5. Future Upgrades
The Triangle Universities Nuclear Laboratory

- Four-university consortium
  - Duke University
  - The University of North Carolina at Chapel Hill
  - North Carolina State University
  - North Carolina Central University

- Three accelerator facilities
  - The Tandam accelerator laboratory
  - The Laboratory for Experimental Nuclear Astrophysics
  - The High Intensity γ-ray Source

- Nuclear astrophysics groups form a tight collaboration between UNC and NC State
- Revolves around a general research pipeline
Triangle Universities Nuclear Laboratory

- Beam capabilities
  - $p, d$
  - $^3\text{He}, ^4\text{He}$
  - Heavier species with SNICS
  - Chopping/Bunching capabilities
  - Polarized ion source
- 10 MV Tandam accelerator

- Scientific programs
  - General purpose scattering chambers
  - Neutron time-of-flight
  - Shielded source area
  - Detector characterization for neutrino physics
  - Nuclear astrophysics with the Enge Split-pole Spectrograph
The TUNL Enge Split-pole Spectrograph

- First installed at NSCL
- Moved to TUNL in 1990s
- Now one of two/three such spectrometers for astrophysics in North America
- Only one currently in operation
- Acceptance 2 – 5 msr
- Maximum field 1.5 T
- Zero and 180 degree capabilities with mid-pole faraday cup

Previous flagship experiments:

- $^{22}\text{Ne}(^3\text{He},d)^{23}\text{Na}$ - Hale, S. et al., PRC 65 (2002) 015801
- $^{40}\text{Ca}(^3\text{He},t)^{40}\text{Sc}$ - Hansper, V. Y., et al., PRC 61 (2000) 028801
- $^{14}\text{N}(^3\text{He},d)^{15}\text{O}$ - Bertone, P. et al., PRC 66 (2002) 055804
The TUNL POE-SPS

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Timeline

Aug. 2014  
R. Longland hired at NCSU

Jan. 2015  
First beam on target

2015  
Rebuilding focal-plane detector

Build DAQ

Vacuum systems

Pressure systems

Apr. 2016  
Reliable beam-on-target

Calibration runs

Nov. 2016  
First science run

Spring 2017  
Focal-plane detector upgrades

Science runs!

2018  
First $\gamma\gamma$-coincidence runs

DAQ upgrades

...
Focal-plane Requirements

- 1 mm beam spot and magnification $\sim 0.34 \rightarrow 0.34$ mm resolution
- Particle identification
- Focusing corrections

- Assume:
  - 12 MeV deuteron beam
  - 40 $\mu$g/cm$^2$ target
  - TRIM calculation says:
    - 3 keV energy resolution
      (0.1 mm at 0°)
      (1 mm at 40°)
The Focal-Plane Detector Package on the TUNL Split-Pole Spectrograph

Caleb Marshall, Kiana Setoodehnia, Katie Kowal, Federico Portillo, Arthur E. Champagne, Stephen Hale, Andrew Dummer, and Richard Longland
Focal-plane Detector

PhD Student: Caleb Marshall
Postdoc: Kiana Setoodehnia
REU: Katie Kowel

• Four independent sections
  ▶ Two Position sections
  ▶ $\Delta E$ Energy loss section for particle ID
  ▶ Total energy scintillator for further particle ID

• Anodes in plane of particle trajectories

• 200-tap delay line
• Time difference between signals provides position
• Electric discharge etching re-developed!
• Position resolution: $\sim 0.5$ mm
• Traditional TFA + CFD for timing information

• Position sections function independently of $\Delta E$
• Maximum resolution corresponds to $\Delta(\rho) \sim 0.2$ mm ($2$ in $10,000$)
• Proportional counter
• Cremat preamplifiers
• In-house, carefully engineered preamplifier circuits

• Well separated ΔE spectra
• Can also be used in conjunction with full-energy scintillator
• Detector subsystems operate independently
**Focal-plane Detector Performance - Delta-E**

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- Added scintillating fiber readout to the total-energy scintillator.
- More compact design
- More sturdy design
- Performance still being optimized
Focal-plane Detector Performance - E

PhD Student: Federico Portillo

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Can this be used for heavy ions?
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Probably not (but it’s pretty good up to alphas)
• $^{27}\text{Al}(d,p)^{28}\text{Al}$
• Commissioning Run
Results

- $^{40}\text{Ca}(^{3}\text{He},\alpha)^{39}\text{Ca}$
- Important for identifying states relevant for nova nucleosynthesis
- K. Setoodehnia et al., Excited states of $^{39}\text{Ca}$ and their significance in nova nucleosynthesis, PRC 98 (2018) 055804
Results

- $^{32}\text{S}(\alpha,p)^{35}\text{Cl}$
- Important for identifying states relevant for nova nucleosynthesis
- K. Setoodehnia et al., Submitted for publication in PRC
• How does this compare?
  ▶ Unnamed experiment to supplement some data from the Q3D in Munich
• DAQ Upgrades
  ▶ MIDAS Data acquisition
  ▶ Custom Python data viewer

• Digitizer upgrades
  ▶ CAEN V1730 500 GHz digitizer
  ▶ Couple with MIDAS
  ▶ Use firmware for energy and times
Thank you!
DOE Award Number DE-SC0017799
Contract No. DE-FG02-97ER41041
Position Reconstruction

Target

Beam

q
Shapira et al. NIM 129 (1975) 123

\[ x' = \frac{H + S \cos(\alpha) P_2 / (P_1 - P_2)}{S \cos(\alpha) / (P_1 - P_2) - \sin(\alpha)} \]
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Position Reconstruction

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Position Reconstruction
Comparisons

- How does this compare?
  - Top secret target tests
  - Compare with photographic plate data from the 1970s