

Investigating excitation and nucleon correlation in ${}^8\text{He}$ using reactions with a solid hydrogen target

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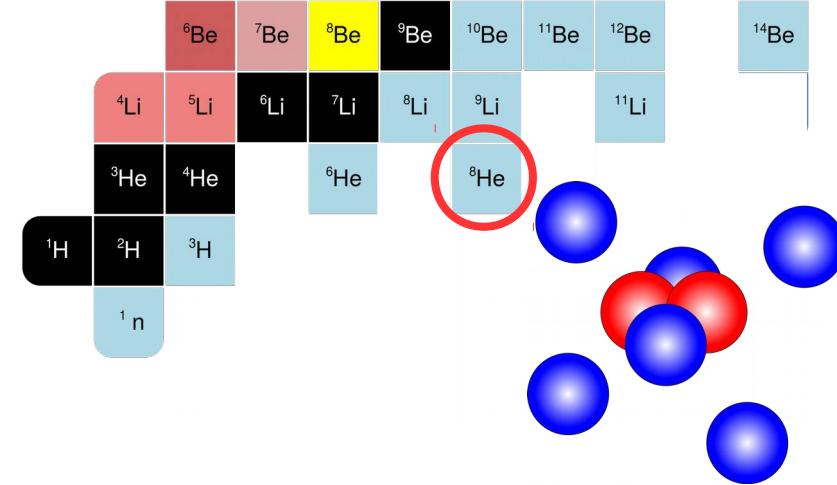
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Introduction and Outline

^8He

- Most neutron-rich bound nucleus ($A/Z=4$)
- Most often described as $^4\text{He} + 4\text{n}$
- Overlap with $^6\text{He} + 2\text{n}$



Outline

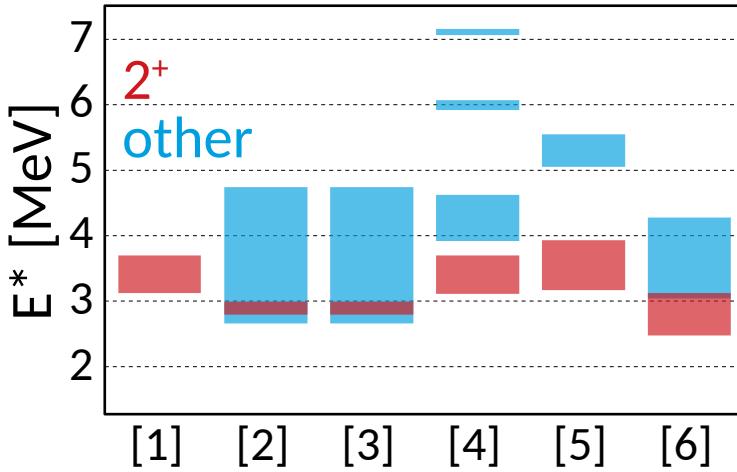
- Overview of previous measurements
- The IRIS setup at TRIUMF
- Elastic scattering

Investigate exact structure through optical potential analysis

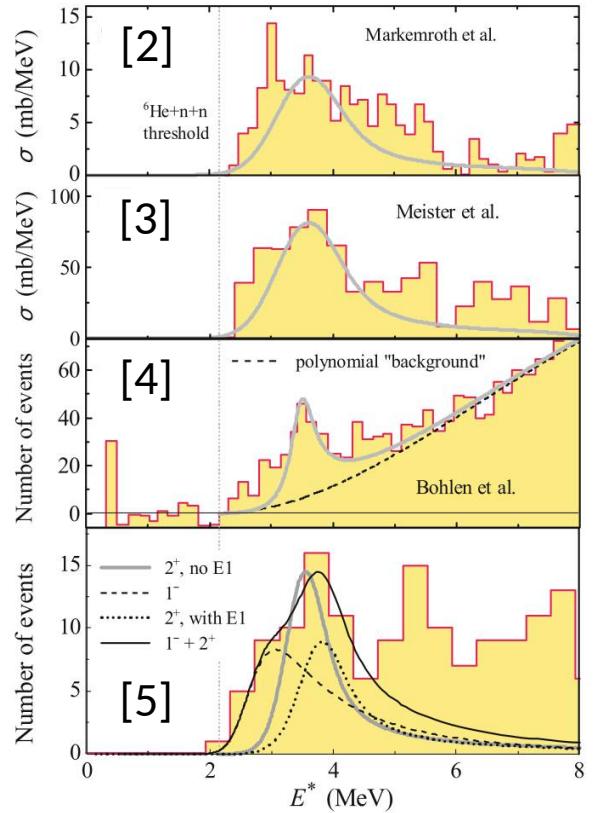
- Inelastic scattering
Characterize resonances in ^8He

- Two-neutron Transfer
Understand $^6\text{He} + \text{n} + \text{n}$ structure of ^8He

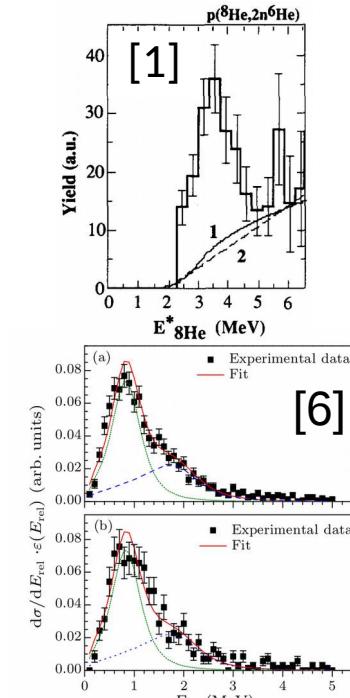
Excited States in ${}^8\text{He}$: Published Results



| | Lab | Reaction Type | E [AMeV] |
|-----|-------|---|----------|
| [1] | RIKEN | (p,p') | 72 |
| [2] | GSI | Coul.Ex. | 227 |
| [3] | GSI | Fragmentation | 227 |
| [4] | JINR | ${}^{10}\text{Be}({}^{15}\text{N}, {}^{17}\text{F}){}^8\text{He}$ | 16 |
| [5] | JINR | ${}^6\text{He}(t,p){}^8\text{He}$ | 25 |
| [6] | RIKEN | Breakup | 82 |

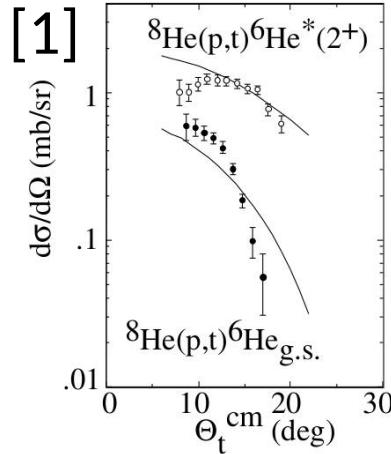


Fornichev et al., Eur. Phys. J. A 42 465 (2009)

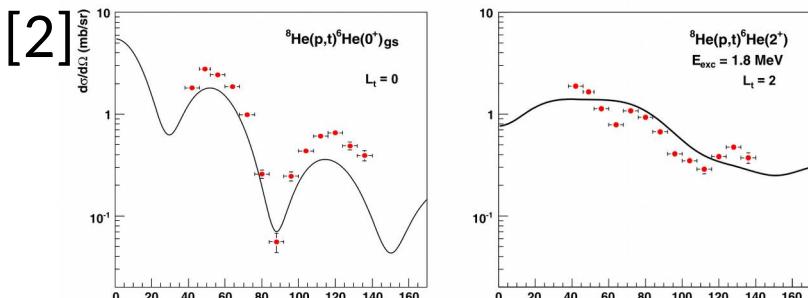


- [1] Korsheninnikov et al., Phys. Lett. B 316 (1993) 38
- [2] Markenroth et al., Nucl. Phys. A679 (2001) 462
- [3] Meister et al. Nucl. Phys. A 700 (2002) 3
- [4] Bohlen et al., Prog. Part. Nucl. Phys. 42 (1999) 17
- [5] Fornichev et al., Eur. Phys. J. A 42 465 (2009)
Golovkov et al., Phys. Lett. B 672 (2009) 22
- [6] Xiao et al., Chin. Phys. Lett. 29 8 (2012) 082501

Two-Nucleon Transfer from ${}^8\text{He}$



Korsheninnikov et al., Phys. Rev. Lett. 90 (2003) 082501



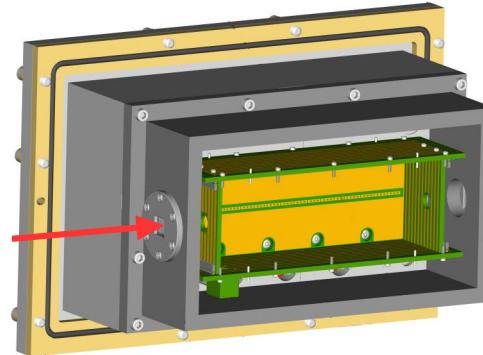
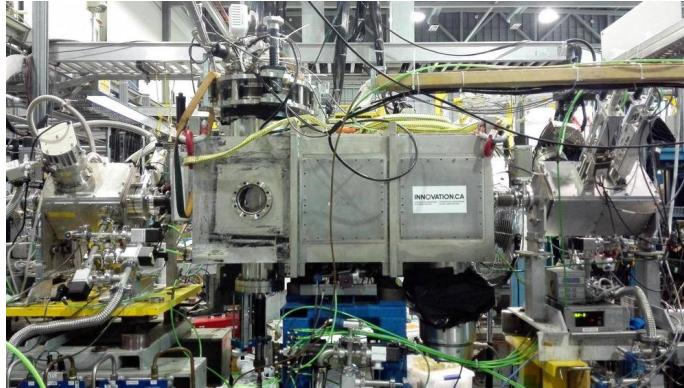
Mougeot et al., Phys. Lett. B 718 (2012) 441-446

- Ratio of ${}^6\text{He}(0^+)$ and ${}^6\text{He}(2^+)$ gives insight into $1p_{1/2}$ component of ${}^8\text{He}$ ground state
- Widely different results reported:

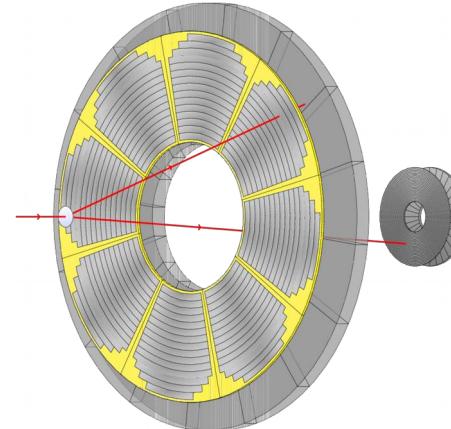
[1] RIKEN/JINR
 $C^2S(0+)/C^2S(2+) \approx 1/1$

[2] GANIL
 $C^2S(0+)/C^2S(2+) = 1.0/0.014$

IRIS @ ISAC-II



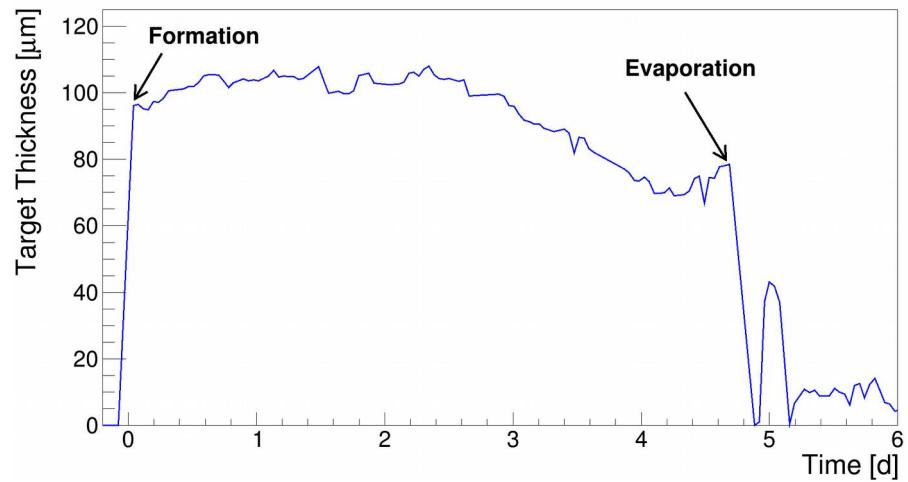
- IRIS: Charged particle spectroscopy at ISAC-II at TRIUMF
- Designed to allow studies of direct reactions with low intensity beams with solid H₂/D₂ target
- Low pressure ionization chamber used to identify beam contaminants with minimal energy loss
- Particle identification using 2 ΔE-E telescopes
 - Light particles: 100 μm segmented Si detector + 1.2 cm CsI array, covering 21°-46°
 - „Heavy“ particles: 60 μm + 1 mm Si detectors, covering ~3°-10°



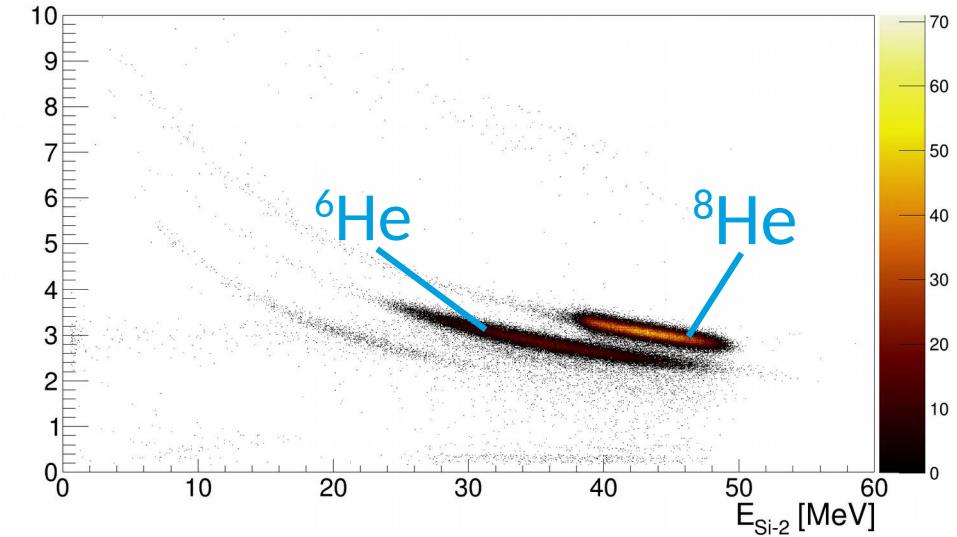
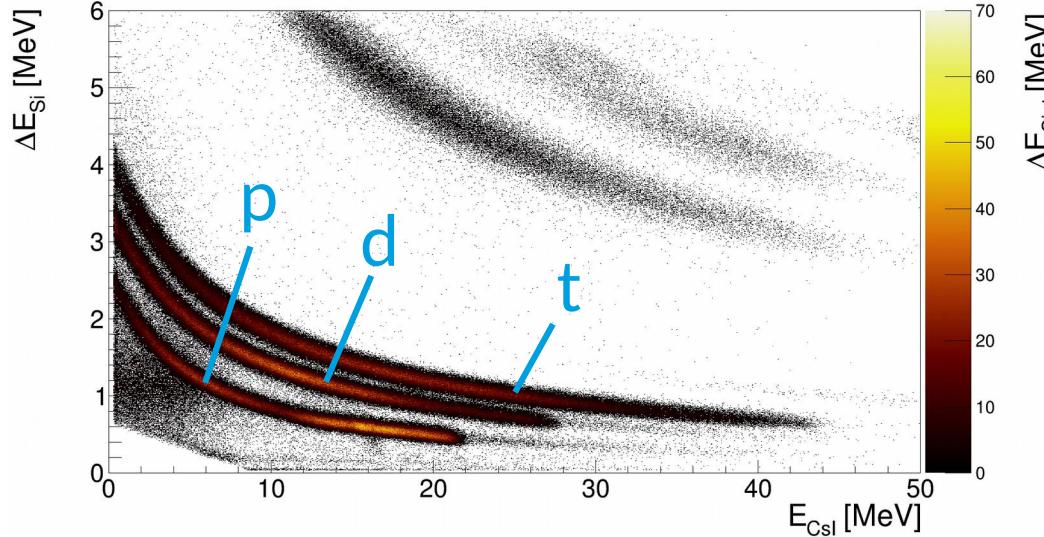
IRIS Solid Hydrogen Target



- 100 μm solid H_2 target
- Formation: H_2 gas sprayed onto a 4.5 μm silver foil at $T < 4 \text{ K}$
- Energy difference of nuclei scattered elastically off the silver foil with and without H_2 used to continuously measure thickness

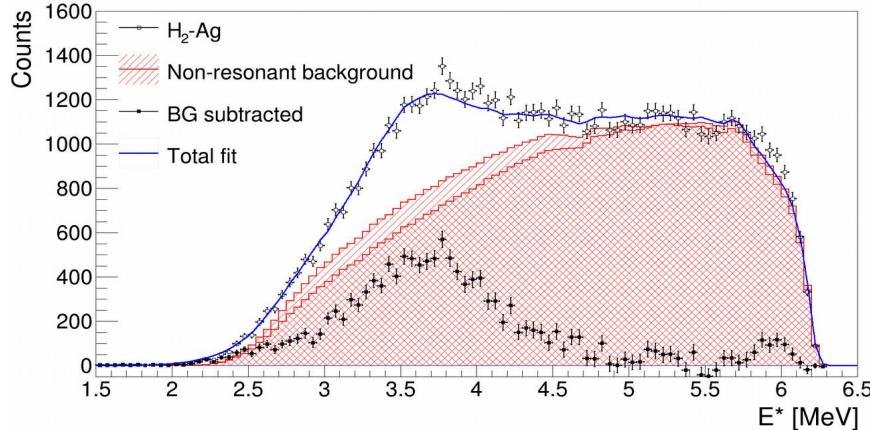
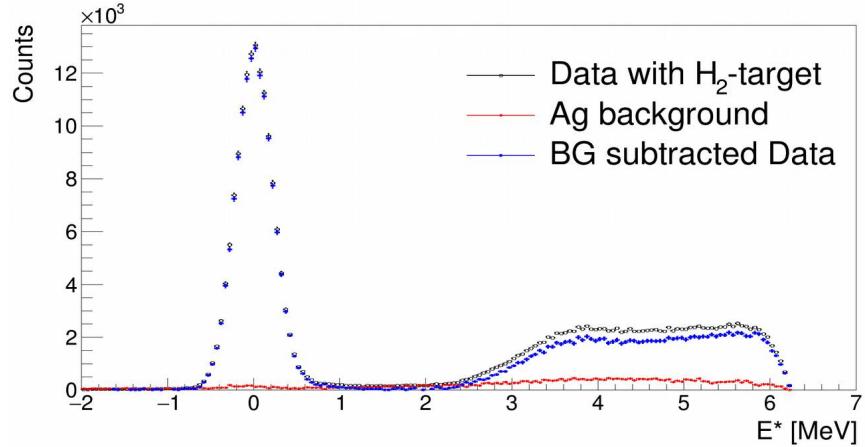


Particle ID



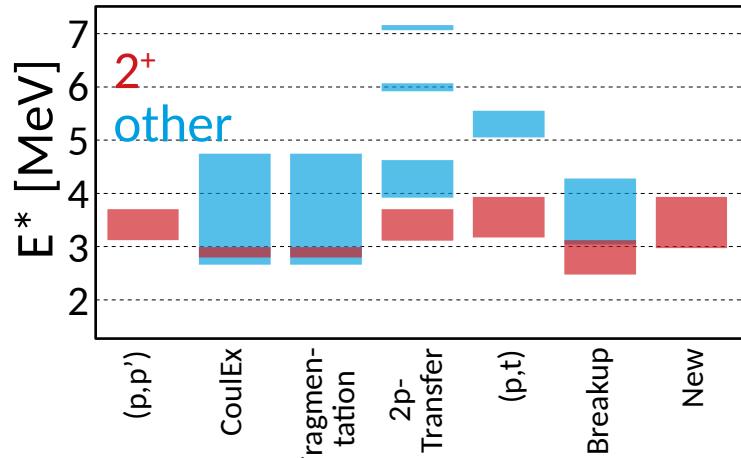
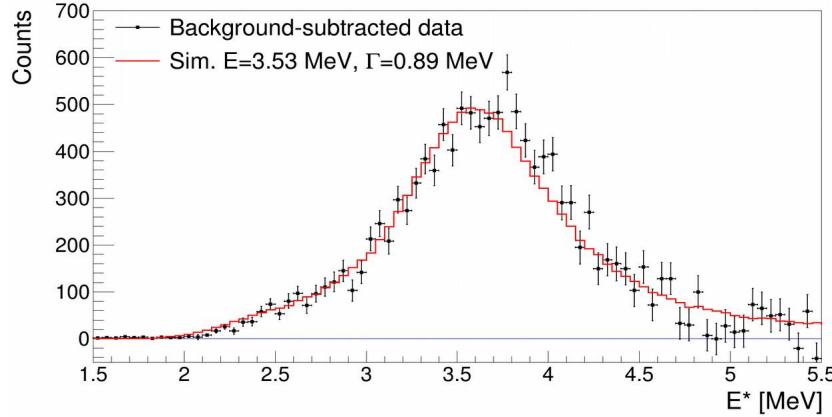
- ^8He beam from ISAC-II, 8.25 AMeV, ~10000 pps
- ^8Li contamination 10-20 %, identified in IC
- Light and heavy reaction products identified using ΔE - E

Excitation Energy Spectrum



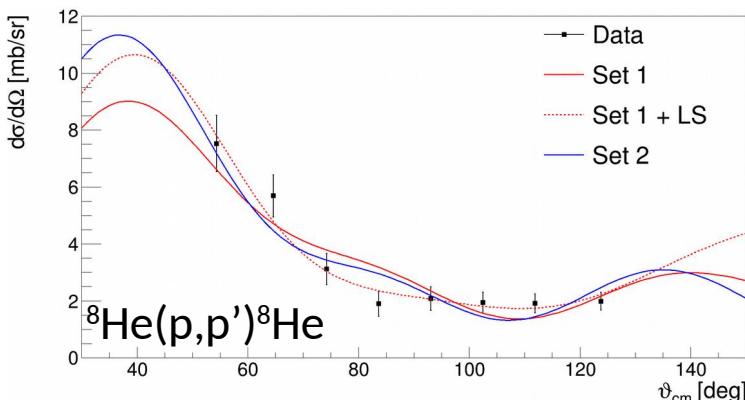
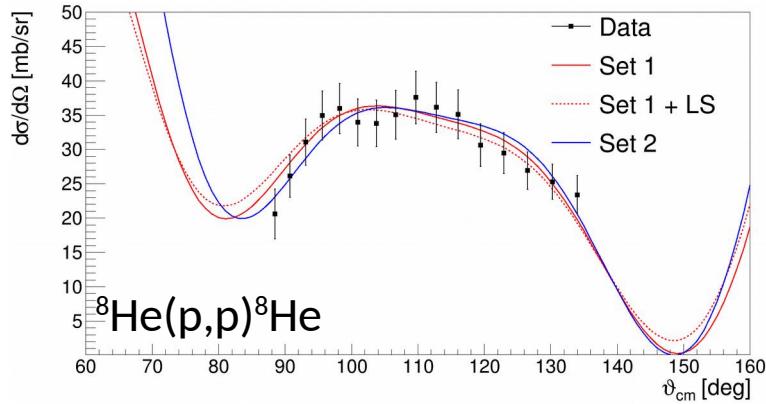
- Elastic scattering analysed by gating on ground state
- Inelastic scattering: Excitation spectrum above neutron threshold dominated by non-resonant reactions
- Fit to data including background from non-resonant reactions
 - $p + {}^8He \rightarrow p + {}^6He + n + n$
 - $p + {}^8He \rightarrow p + {}^7He + n$

Resonance in ${}^8\text{He}$



- Data can be described by non-resonant background + single resonance
- $E^* = 3.53(4) \text{ MeV}$
 $\Gamma = 0.89(11) \text{ MeV}$
- Position and width of resonance consistent with previous (p,p') and transfer measurements

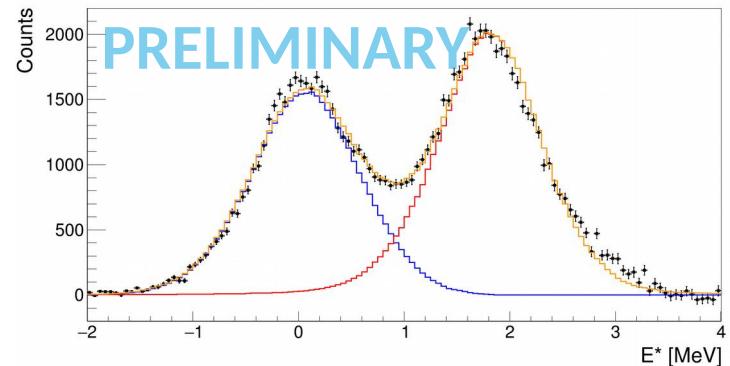
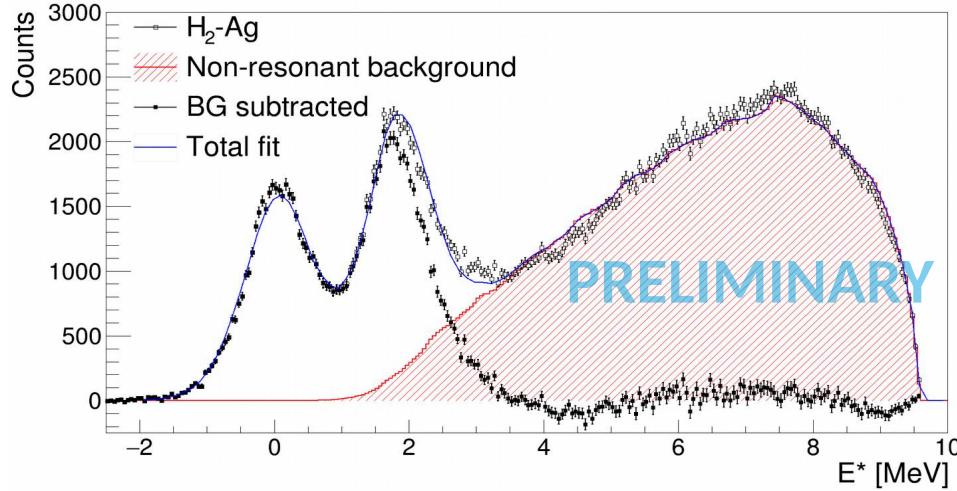
Differential Cross Sections



- Optical potentials determined with SFRESCO
- Simultaneous fit to elastic and inelastic channel with resonance assigned 2^+
- Included real volume and imaginary surface potential
- Large deformation necessary to describe inelastic $d\sigma/d\Omega$ ($\beta_2=0.6\pm0.2$)
- Ab initio calculations including 3N-force in preparation

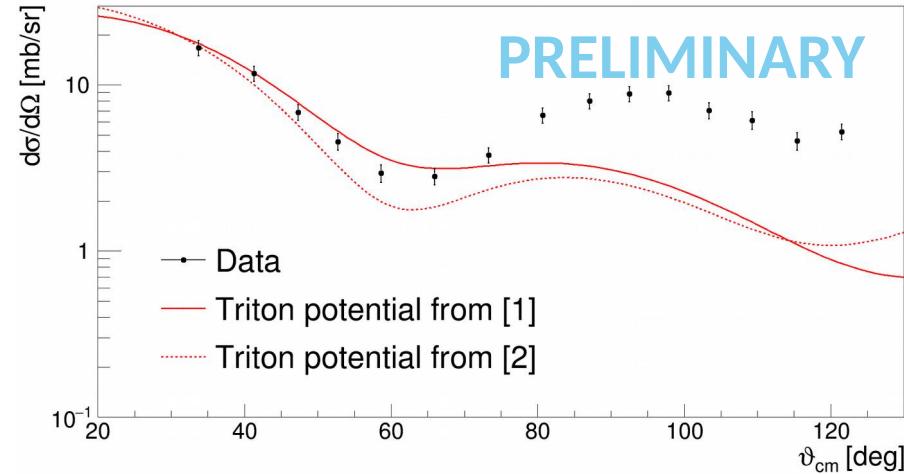
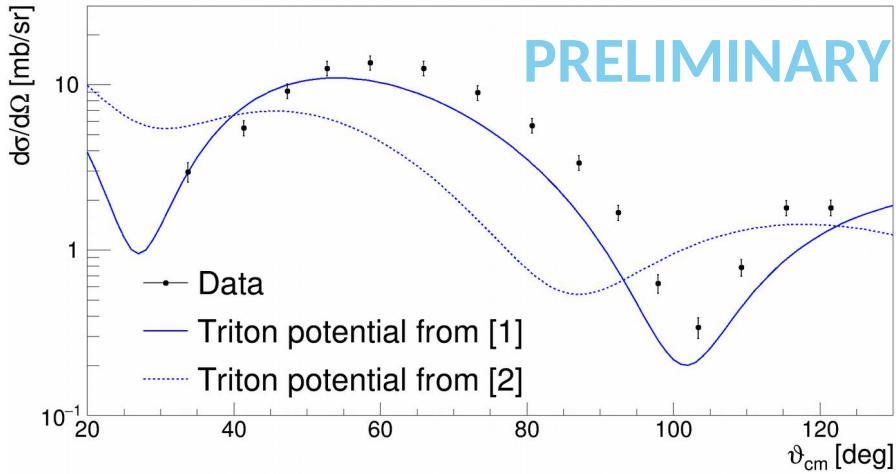
| | V [MeV] | r [fm] | a [fm] | W_s [MeV] | r_s [fm] | a_s [fm] | δ [fm] | χ^2/N |
|-------|---------|--------|--------|-------------|------------|------------|---------------|------------|
| Set 1 | 33.0 | 1.51 | 1.23 | 20.3 | 1.31 | 0.34 | 1.51 | 0.93 |
| Set 2 | 29.3 | 1.62 | 1.21 | 21.3 | 1.28 | 0.37 | 1.71 | 0.90 |

${}^8\text{He}(\text{p},\text{t})$: Excitation Energy Spectrum



- Data fitted using non-resonant background, ground state and first excited state
- Included background channels:
 - $\text{p} + {}^8\text{He} \rightarrow \text{t} + {}^4\text{He} + \text{n} + \text{n}$
 - $\text{p} + {}^8\text{He} \rightarrow \text{t} + {}^5\text{He} + \text{n}$

Differential Cross Sections



[1] Li et al., Nucl. Phys. A 789 (2007) 103

[2] Pang et al., Phys. Rev. C 79 (2009) 024615

- Data compared to FRESCO calculations using shell model transition amplitudes and global optical triton potentials
- Strong population of 2^+ state observed

Summary

- Measurements of ${}^8\text{He}(\text{p},\text{p})$, ${}^8\text{He}(\text{p},\text{p}')$, and ${}^8\text{He}(\text{p},\text{t})$ at IRIS
- The excitation spectrum of ${}^8\text{He}$ can be described using non-resonant background and a single resonance
- Large cross section of ${}^8\text{He}(\text{p},\text{t}){}^6\text{He}(2+)$ observed

Thank you for your attention!

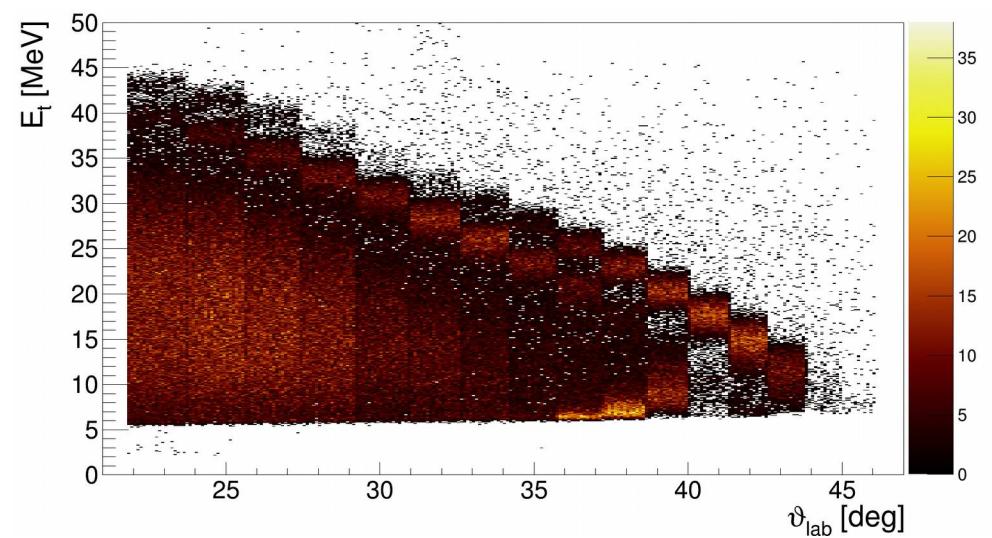
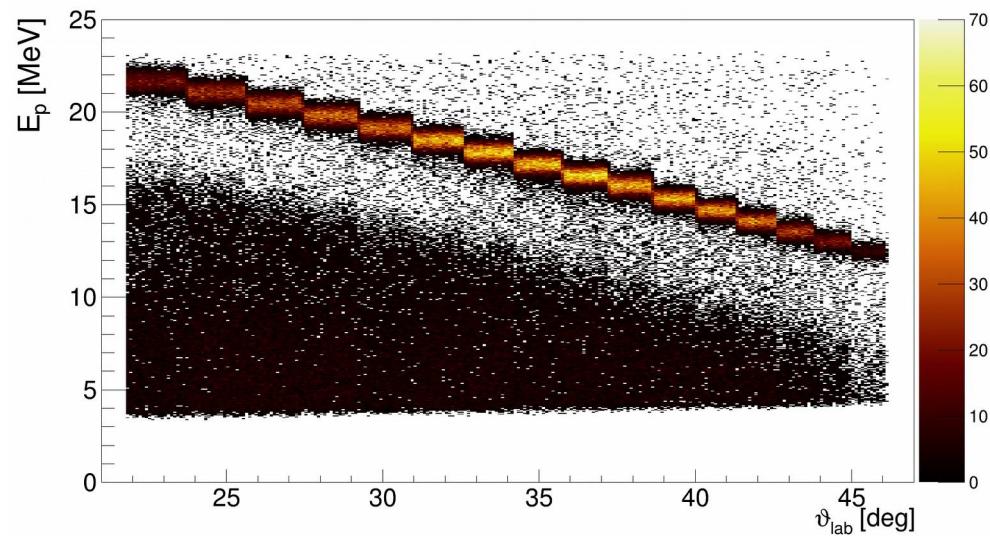
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Kinematics



Q vs Theta

