Experiment e06006

Precise study of the diffractive components in two-proton knockout reactions

Two-proton knockout on neutron-rich nuclei

- Direct process
  - Path through sequential process energetically forbidden
  - See J. A. Tostevin et al., PRC 70, 064602 (2004)
- Spectroscopic information can be obtained from this type of reaction
  - Reaction drives towards more neutron-rich species

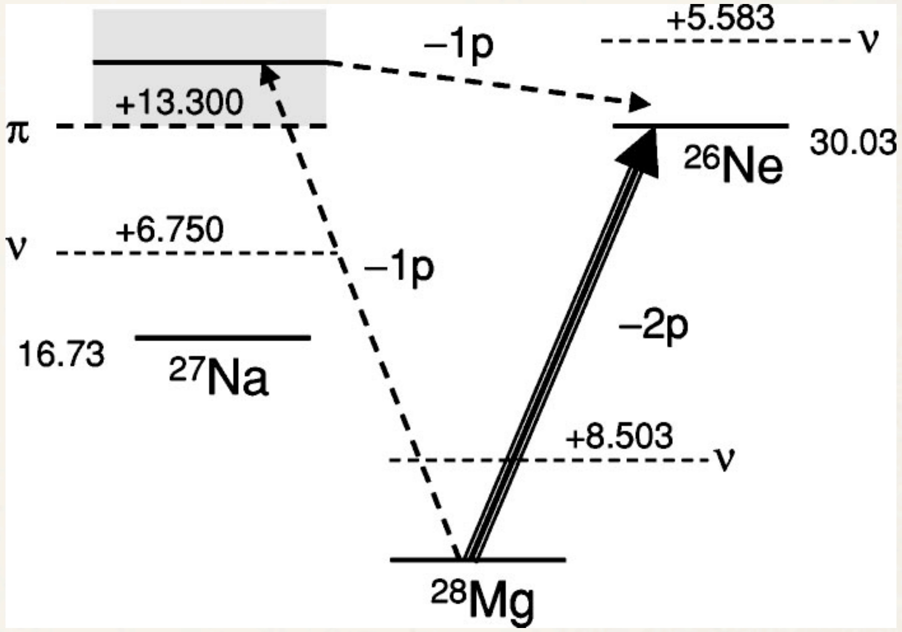


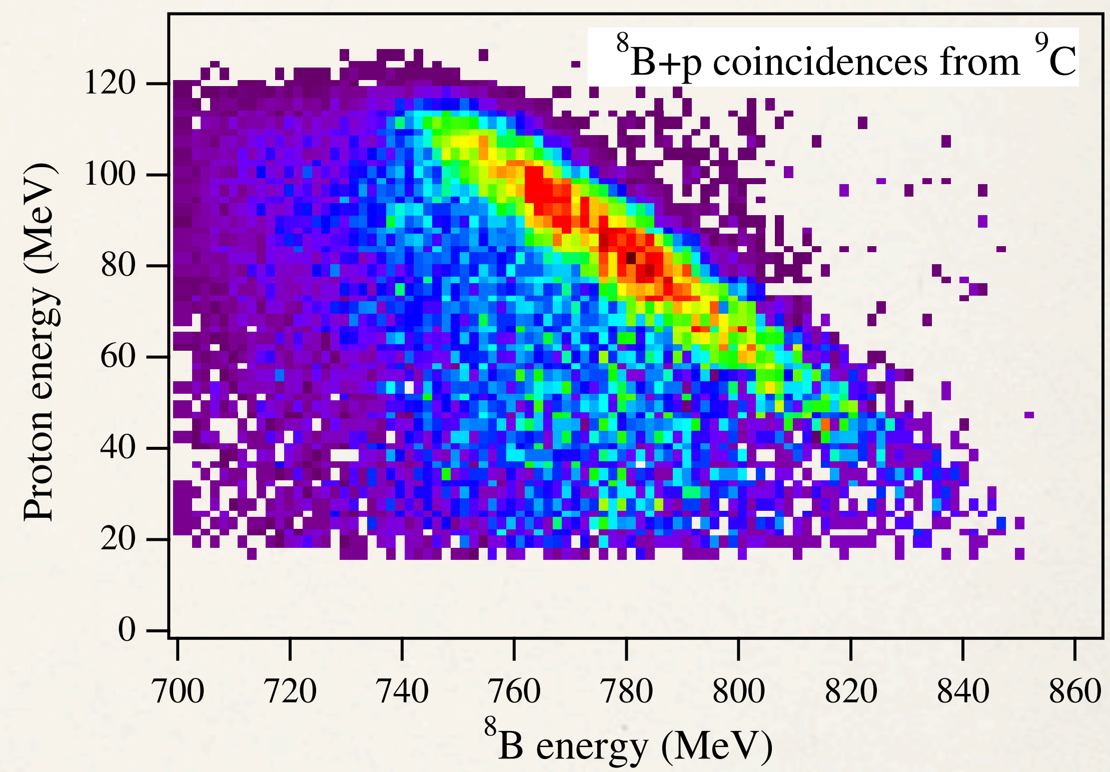
FIG. 2. Energy diagram of the neutron-rich $N=16$ isotones ^{28}Mg, ^{27}Na, and ^{26}Ne, showing the single-neutron (ν) and proton (π) separation energies for each nucleus. The diagram shows that nondirect population of the bound states of ^{26}Ne, by one-proton removal to excited ^{27}Na followed by proton evaporation, would involve states high above the (much lower) neutron evaporation threshold and so is expected to be negligible.

Knockout reactions

- Surface dominated collision with a light target
  - Stripping or inelastic breakup: removed nucleon absorbed - target is excited or even broken
  - Diffraction or elastic breakup: removed nucleon elastically scattered - target stays in its ground state
  - Heavy residue detected at forward angles
  - Residue final state measured from in-flight γ-ray decay
- Fast projectile
  - Momentum of residue directly related to momentum of removed nucleon
  - Longitudinal momentum free of Coulomb deflection and diffractive scattering, directly related to angular momentum of removed nucleon
  - Sudden/adiabatic approximation and eikonal model

Previous experiment: ^{9}C and ^{8}B

- Study of elastic and inelastic parts of cross section
  - One-proton knockout on ^{9}C and ^{8}B
  - HiRA array used in coincidence with S800
  - Clear kinematical differences between elastic and inelastic breakup
  - Proportions calculated with eikonal model agrees with observations very well
  - See D. Bazin et al., PRL 102, 232501 (2009)



Proj.	$\%_{\rm diff}$ [a]	$\%_{\rm diff}$ [b]	$\%_{\rm diff}$[9]	$\sigma_{\rm th}$ (mb)	R_S [a]	R_S[9]	R_S[11]
^{9}C	25(2)	26.8	26(10)	62.90	0.84(5)	0.82(6)	-
^{8}B	38(3)	37.1	28(14)	144.28	0.88(4)	0.86(7)	0.88(4)

[a] This work
[b] Calculated (from Table I)

Goal of experiment e06006

- Study proportions of elastic breakup in two-proton reaction
  - 3 scenarios possible
    - Both protons removed inelastically
    - One proton elastically removed, the other not (times two)
    - Both protons elastically removed
  - Eikonal model calculates cross sections for each scenario
    - See J. Tostevin & B. A. Brown, PRC 74, 064604 (2006)
    - Branching ratios already measured from experiment 01013 using S800+SeGA
    - Expected cross section for double diffraction channel: 0.1 mb

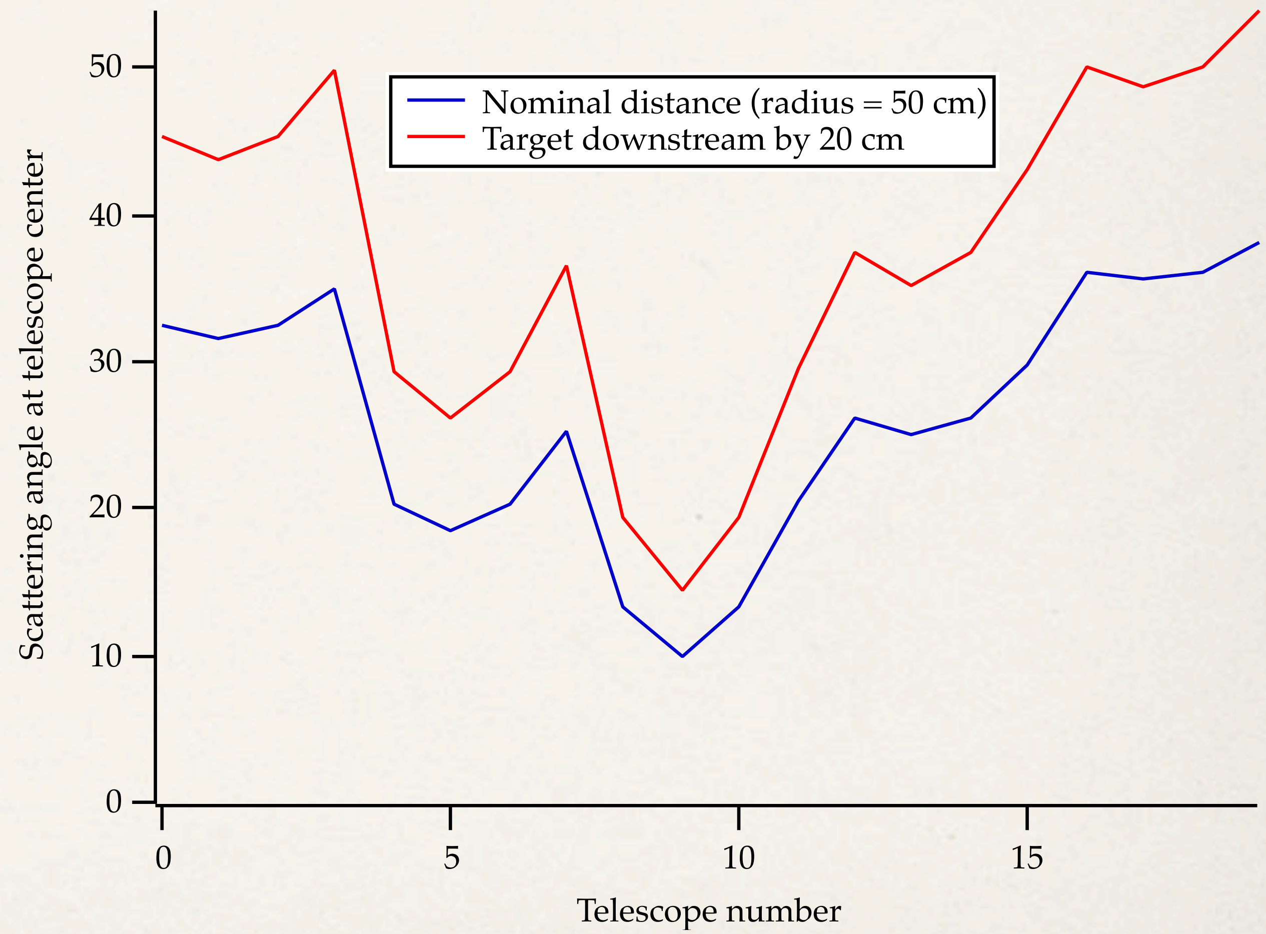
TABLE I. Calculated and measured two-proton knockout reaction partial cross sections $\sigma^{(f)}$ from ^{28}Mg and ^{54}Ti on a ^{9}Be target showing their stripping, $\sigma^{(f)}_{\rm str}$, stripping-diffraction, $\sigma^{(f)}_{\rm str-diff}$, and diffraction, $\sigma^{(f)}_{\rm diff}$, components. All cross sections are in mb. $R_s(2N) = \sigma_{\rm expt}/\sigma^{(f)}$ is the ratio of the experimental and the theoretical total partial cross section $\sigma^{(f)}$.

J^{π}_{f}	E (MeV)	$\sigma^{(f)}_{\rm str}$	$\sigma^{(f)}_{\rm str-diff}$	$\sigma^{(f)}_{\rm diff}$	$\sigma^{(f)}$	$\sigma_{\rm expt}$ [4]	$R_s(2N)$
^{28}Mg $\rightarrow$ ^{26}Ne	83.2 MeV						
0^+	0.0	0.63	0.47	0.09	1.19	0.70(15)	0.59(13)
2^+_1	2.02	0.18	0.12	0.02	0.32	0.09(15)	0.28(47)
4^+	3.50	0.59	0.37	0.06	1.02	0.58(9)	0.57(9)
2^+_2	3.70	0.25	0.17	0.03	0.45	0.15(9)	0.33(20)
Incl.					2.98	1.50(10)	0.50(3)
^{54}Ti $\rightarrow$ ^{52}Ca	72.0 MeV						
0^+	0.0	0.21	0.15	0.03	0.38	0.21(3)	0.55(8)

0.84 0.58 0.1

Experimental setup

- S800
  - Collect and identify ^{26}Ne residues
  - Two rigidity settings necessary to cover full parallel momentum distribution
- HiRA
  - Detect high energy protons in coincidence
  - Use ΔE-E with DSSD + CsI to identify protons
  - Angular coverage between 10° and 50°, by moving target forward 15 cm (3 holes on table)



Rate estimation

- Target thickness compromise
  - Increase reaction rate - reduce energy broadening due to differential energy loss
  - Choice: ^{9}Be 100 mg/cm^{2}
  - Differential energy loss between ^{28}Mg and ^{26}Ne: 22 MeV (similar to width obtained during the ^{9}C experiment)
- Expected rate
  - Expected rate of ^{28}Mg radioactive beam on target: 3.10^{5} pps
  - Expected rate for double diffraction channel (cross section of 0.1 mb): 0.2 pps
  - Solid angle efficiency of HiRA for two protons: ~ 5% (need real value for new geometry)
  - Rate for double diffraction events: 36 / hour
  - 72 hours give about 2,500 counts

Precise measurement on one-proton knockout

- Use thin ^{9}Be target (9 mg/cm^{2})
  - Reduce width of diffraction peak to ~ 1 MeV
  - Eikonal calculation of one-proton knockout cross section to ^{27}Na g.s. (remove valence proton from $d_{5/2}$ orbital)
    - Stripping (inelastic): 10.9 mb
    - Diffraction (elastic): 2.4 mb
- Rate estimation
  - Diffraction channel: 0.5 pps
  - HiRA solid angle efficiency: ~ 20%
  - Estimated rate for diffraction events: 360 / hour
  - 12 hours give about 4,000 counts

Experiment planning

Goal	Beam	Target	Time
Calibrate CsI	^{1}H	^{197}Au 20 mg/cm^2	6 hours
one-proton knockout	^{28}Mg	^{9}Be 9 mg/cm^2	12 hours
two-proton knockout	^{28}Mg	^{9}Be 100 mg/cm^2	72 hours

To-Do list

- Scattering chamber configuration
  - Remove MCP detectors and collimators
  - Move target drive downstream by 15 cm (3 holes on table)
  - Mount targets and target ladder
  - Position camera for new target location and check image
  - Check target drive control
- Trigger
  - Need OR from DSSD for coincidence (good timing)
  - Trigger in S800 trigger box (FPGA) sent back to HiRA electronics

To-Do list (continued)

- Readout
  - Same readout code as for previous experiments e07037 and e06035
  - HiRA readout with only DSSD + CsI
  - Install software on account e06006 (readout, SpecTcl, eLog)
  - Test it! (beware of recent upgrades from computer department)
- Run organization
  - Read and acknowledge experimenter responsibilities
  - Need one HiRA specialist and one S800 specialist per shift
  - Sign up for shifts in Data-U6