THE FLORIDA STATE UNIVERSITY

The First Experiments with ANASEN

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Collaboration

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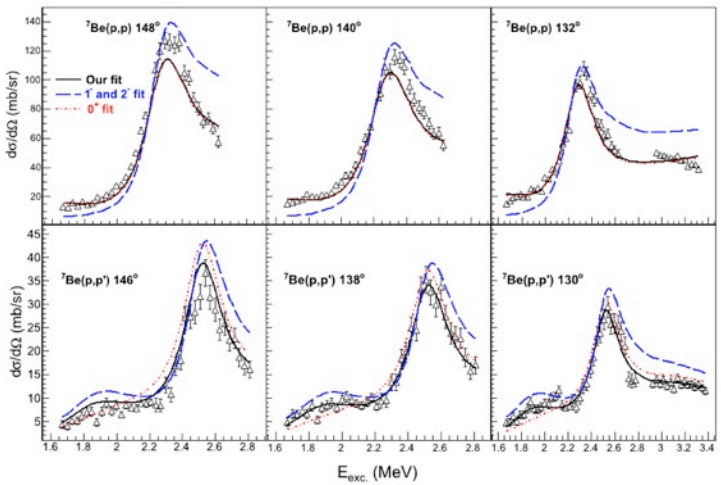
Outline

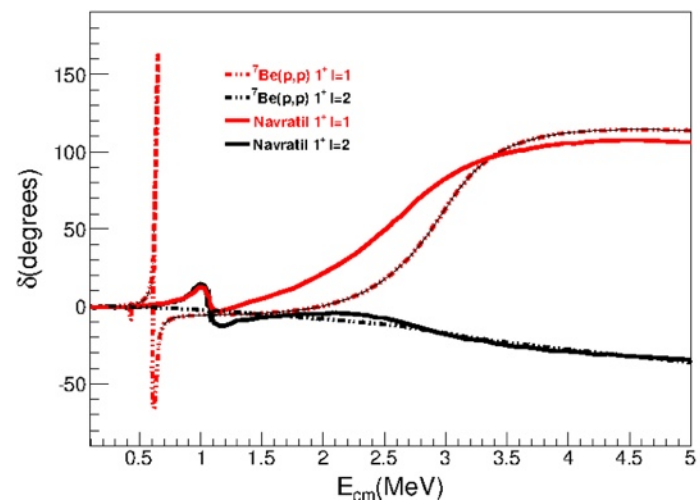
- Physics with ANASEN
- Overview of ANASEN and its main components
- First results
  - Cluster states in ^{10}Be using α+^{6}He resonance scattering
  - Structure of ^{9}C in p+^{8}B resonance scattering
  - Test run for (α,p) reactions - ^{14}N(α,p) excitation function
  - Structure of ^{20}O using ^{19}O(d,p) reaction

Physics with ANASEN

- Structure of light exotic nuclei through res. scattering
  - ★ Development of *ab initio* models
  - ★ Coupling of structure calculations to the continuum (NCSM/RGM, TDCSM, RCCSM). *(Talk of K.M. Nollett, NS2012, Monday, Aug. 13, "Ab Initio widths and Asymptotic Normalizations)*



^{7}Be+p elastic and inelastic excitation function [J. Mitchell, et al., PRC (2010)]

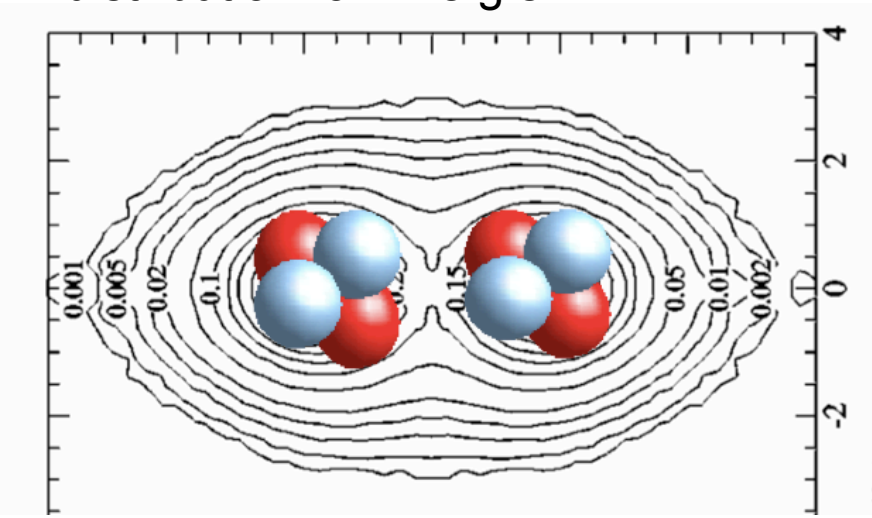


Comparison of the experimental phase shift to the ab initio NCSM/RGM calculations [P. Navratil, et al., Phys. Lett. (2011); J. Mitchell, et al., to be submitted]

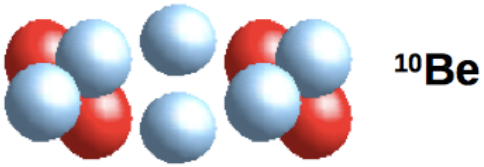
Physics with ANASEN

- Clustering in light nuclei

GFMC nuclear matter density distribution for ^{8}Be g.s.

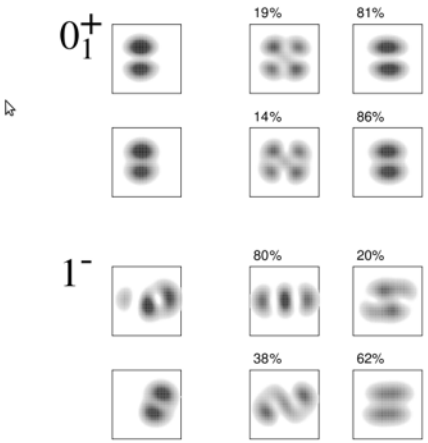


R.B. Wiringa, et al., PRC 62 (2000)



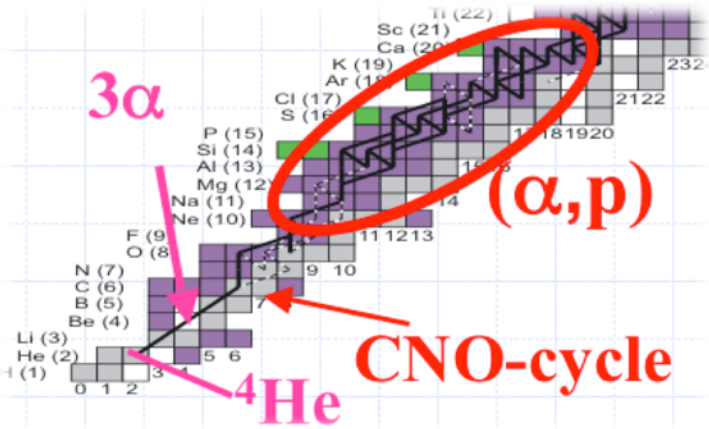
W. von Oertzen, Z. Phys. A354 (1996)

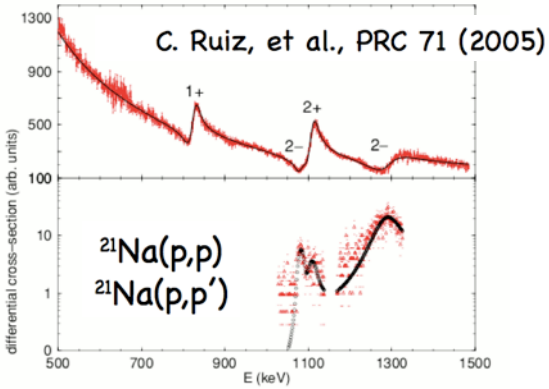
Y. Kanada-En'yo, H. Horiuchi Prog.Th.Phys. 142 (2001), Supl.



Astrophysics

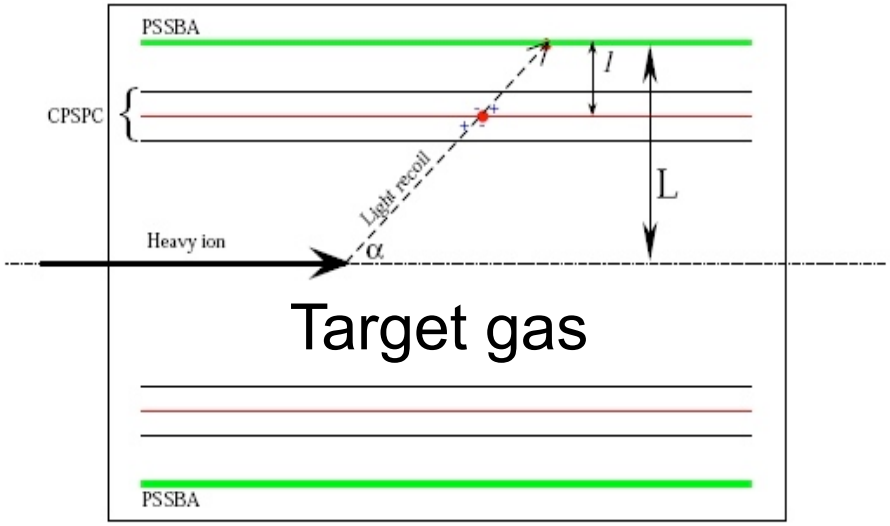
- (α,p) and (p,γ) rates with light proton-rich isotopes are important in stellar explosions
- Properties of resonances determine reaction rates
  - Excitation energies
  - Spin-parity
  - Partial widths
- These properties can be established in resonance scattering experiments with rare isotope beams; (p,p), (p,p'), (α,α), (α,α')...
- Direct measurements of (α,p) reactions

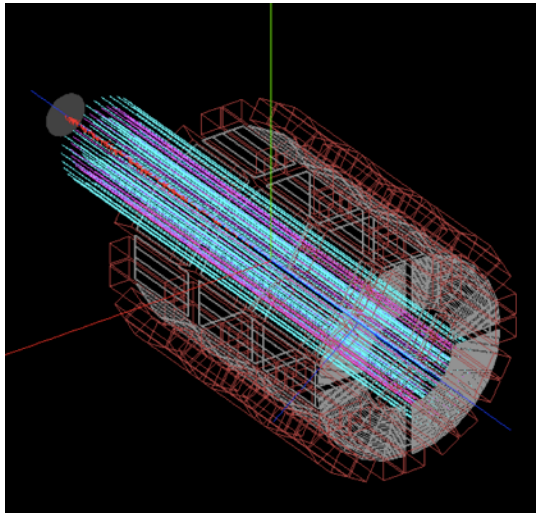


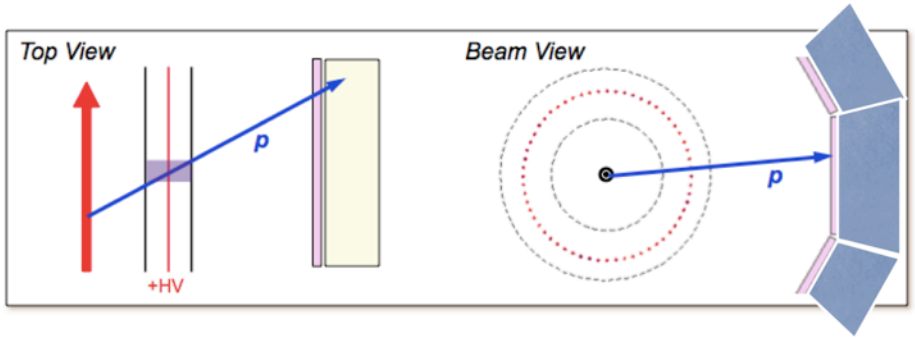


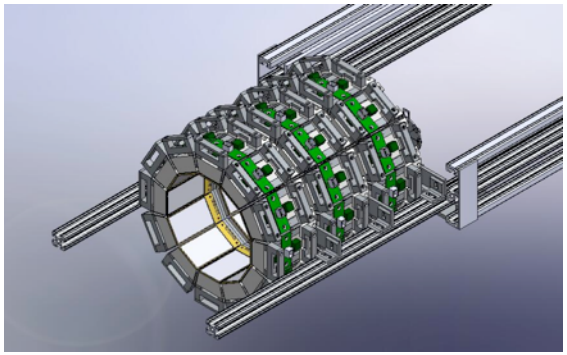
Main features of ANASEN

Array for Nuclear Astrophysics Studies with Exotic Nuclei

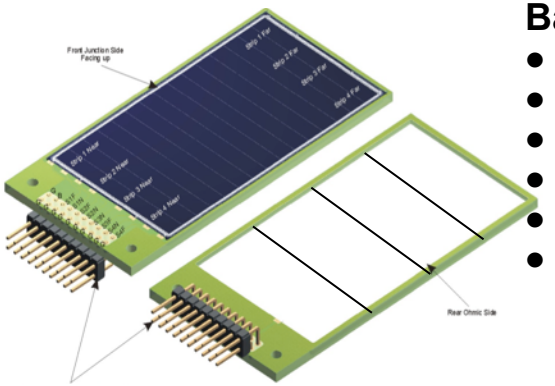






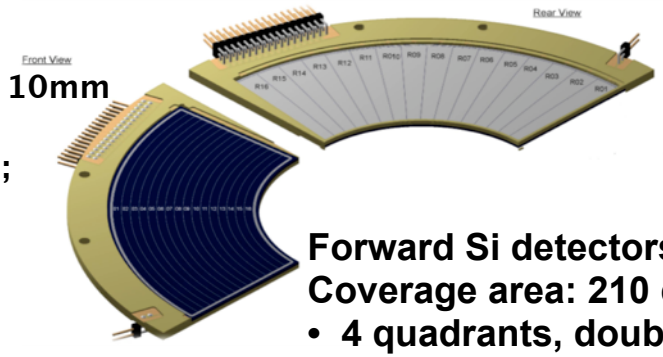


Major components of ANASEN



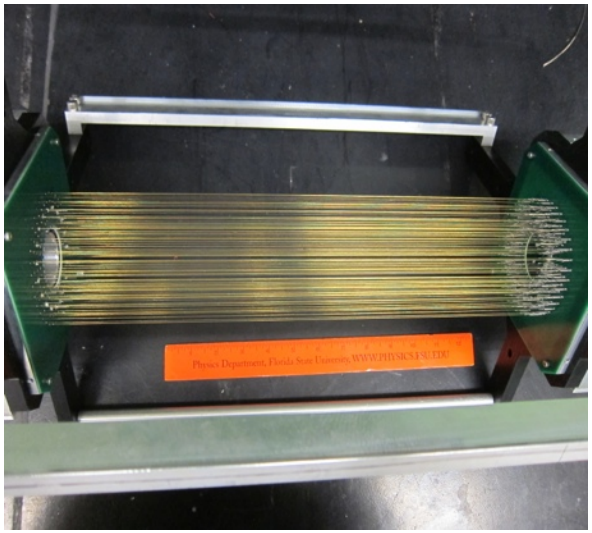
Barrel Si detectors

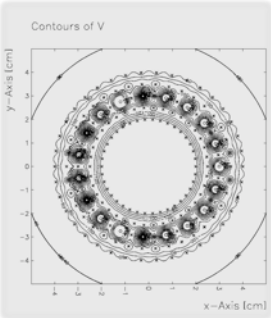
- Double-sided detectors
- 4 Res. front strips 75mm x 10mm
- 4 back strips 18x40mm
- 0.6-0.8% energy resolution;
- 1.5 mm position resolution
- Charge division



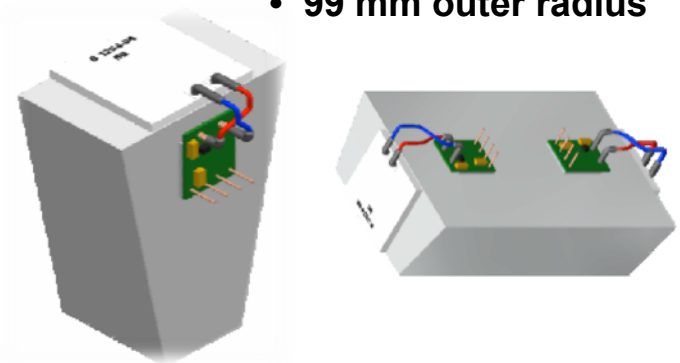
Forward Si detectors
Coverage area: 210 cm^2

- 4 quadrants, double-sided
- 16 strips X 16 segments
- 50 mm inner radius
- 99 mm outer radius



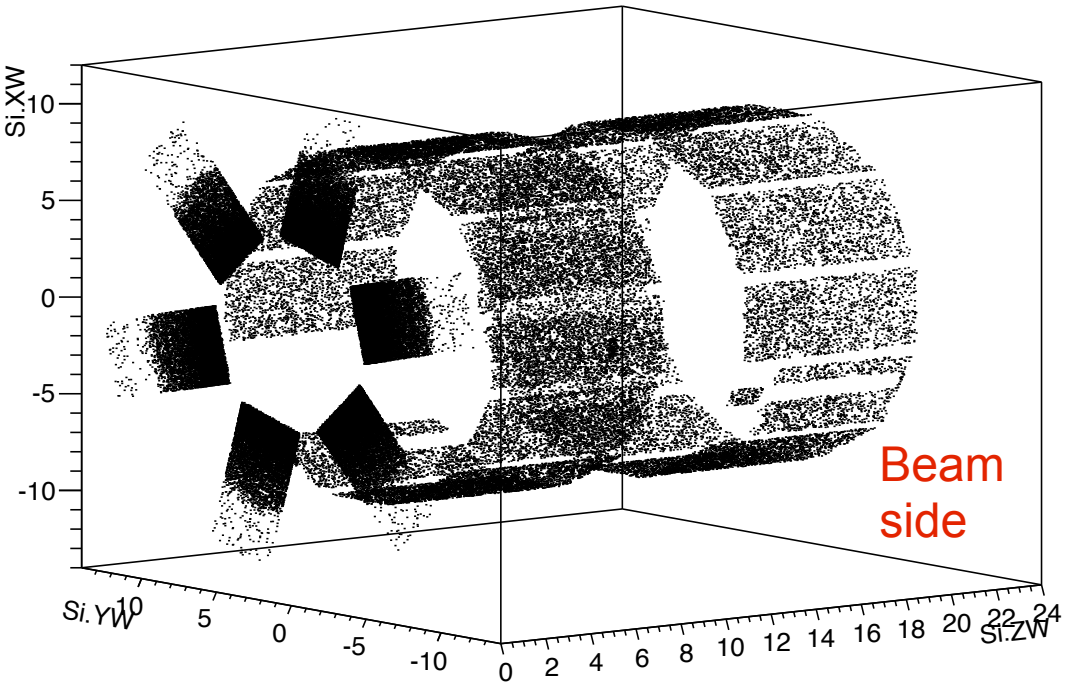


- Wires arranged to make 19 cells
- Carbon fiber anodes

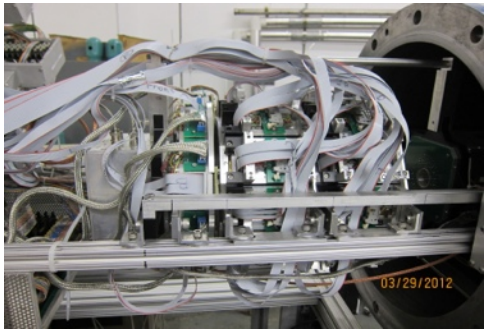


CsI(Tl) detectors backing both forward and barrel Si. Thickness - 25 mm.

Major components of ANASEN

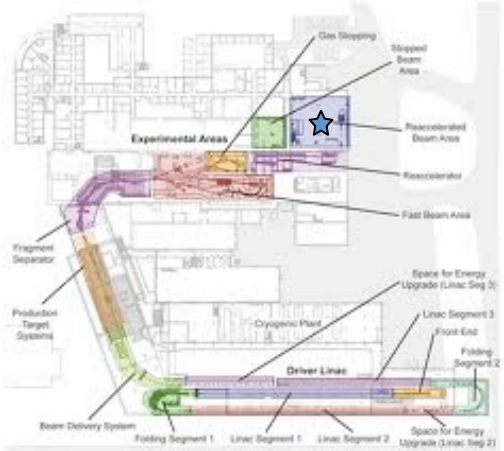


- ANASEN provides ~90% coverage (1300 cm^2)
- Min scattered angle: 5°
- Barrel telescopes:
  3 rings x 12 telescopes (1000 mm position sensitive SuperX3 Si + CSI(Tl)
- Forward telescopes:
  4 annular double sided quadrance QQQ3 Si strip detectors or 6 SuperX3 Si detectors + 16 trapezoid CSI(Tl) detectors
- Expected number of channels
  590 channels total: 488 Si (ASICs) , 64 CsI & 38 PC (conventional electronics)
- Actual number of channels
  462 channels total (360 Si, 64 CsI, 38 PC)
- Gas target
- HI beam

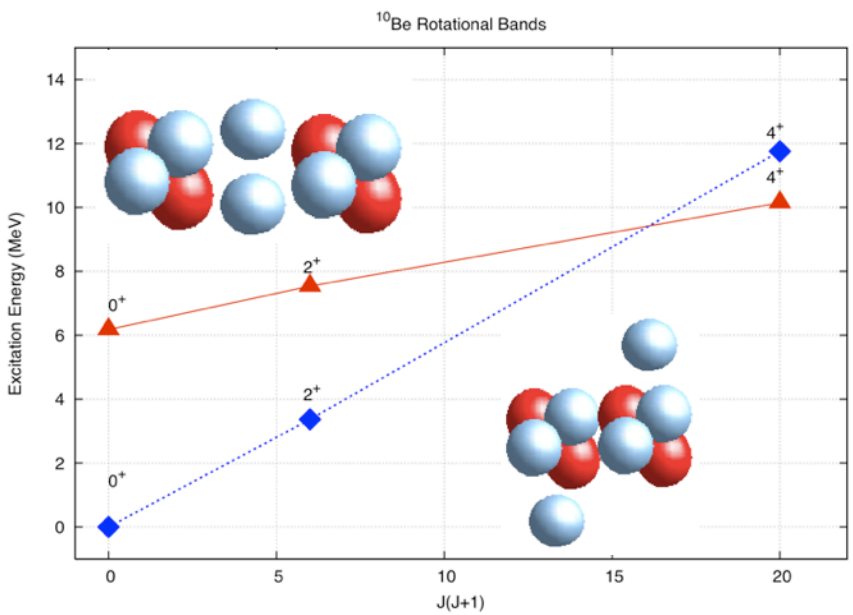


ANASEN's current home:
RESOLUT facility at FSU

ANASEN's future home:
ReA3 facility at MSU



Clustering in ^{10}Be



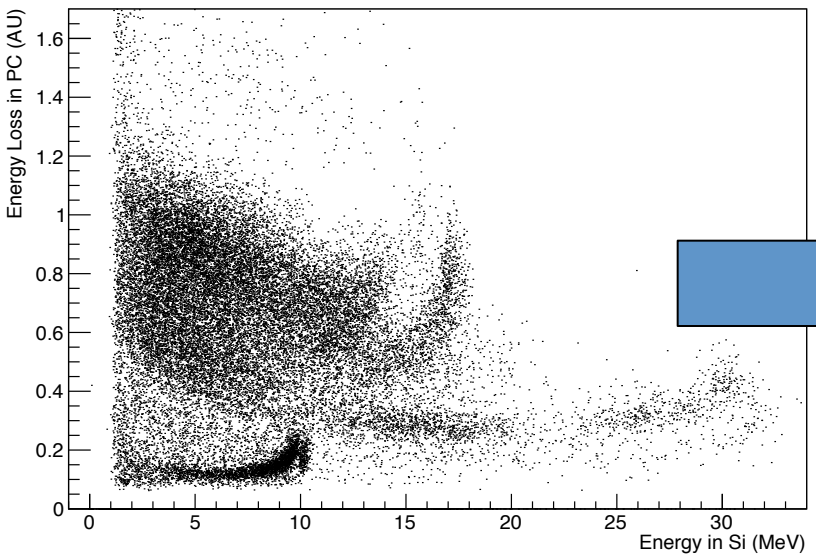
- Rotational band with high moment of inertia built on 0^+ at 6.18 MeV
- 10.15 MeV state reported to be extremely clustered [1]
- Believed to be associated with α-2n-α molecular rotational band.
- Disagreement in spin-parity assignment for 10.15 MeV
  - ★ 4^+ in [1,2]
  - ★ 3^- in [3]

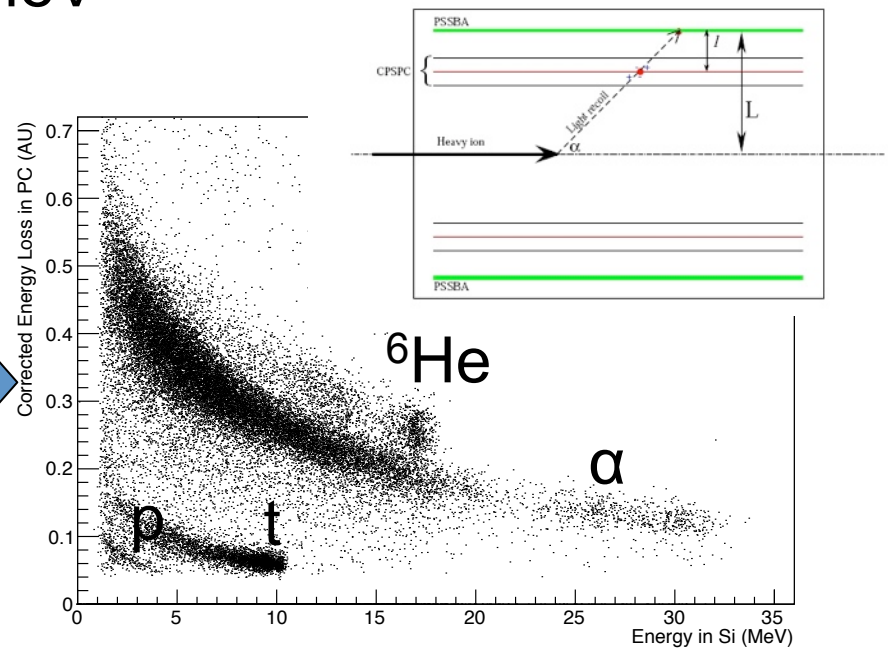
Goal: search for *molecular* states in ^{10}Be
[Yu.Chuvil'sky et al. Phys.At.Nuc 73 (2010)]

[1] M. Freer, et al., PRL 96, 042501 (2006)
[2] M. Milin, et al., NPA 753, 263 (2005)
[3] N. Curtis, et al., PRC 64, 044604 (2001

Elastic scattering experiments

Excitation function of **^{6}He + α** resonance scattering was measured between 9.1 and 17 MeV ^{10}Be excitation energy in 7 steps, each covering 0.5 - 1.5 MeV



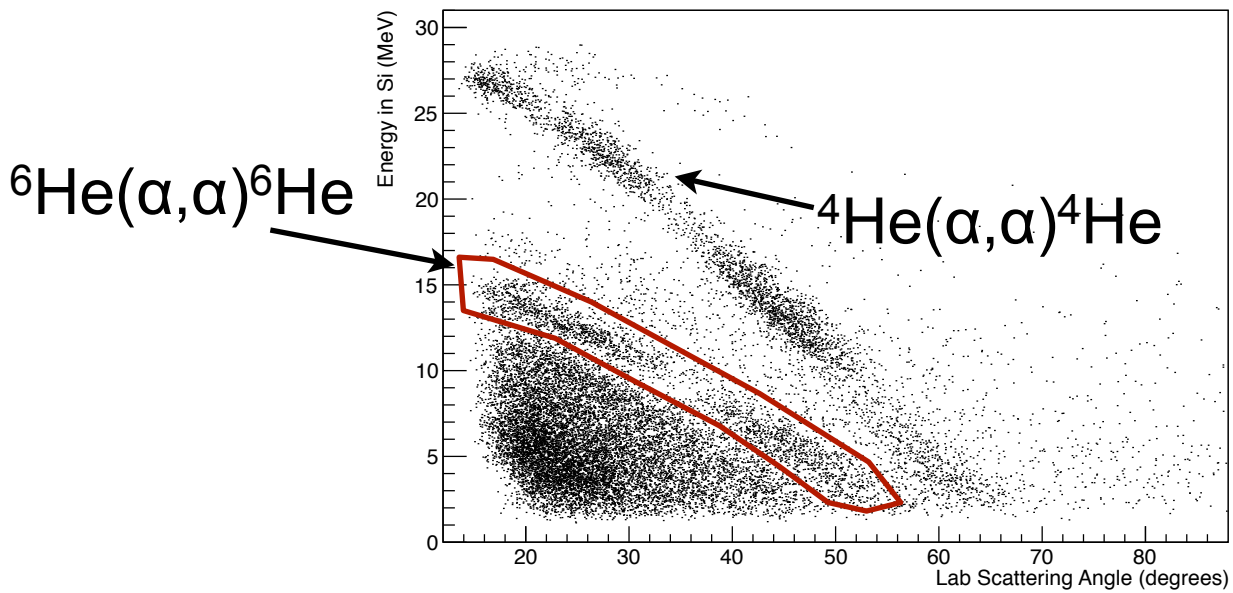


No correction for path in PC

With correction for path in PC

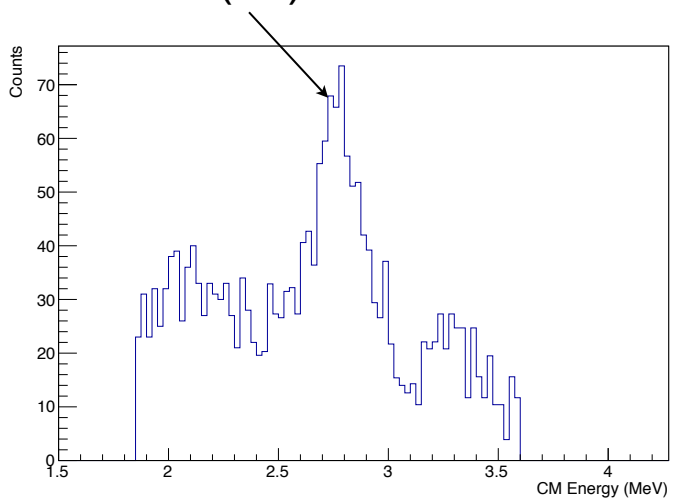
Elastic scattering experiments

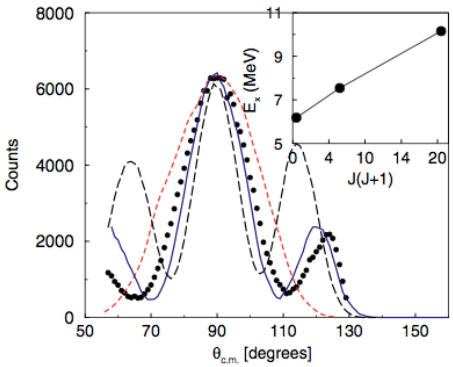
Identification of $^{6}He(\alpha,\alpha)^{6}He(g.s.)$ events using energy - scattering angle plot



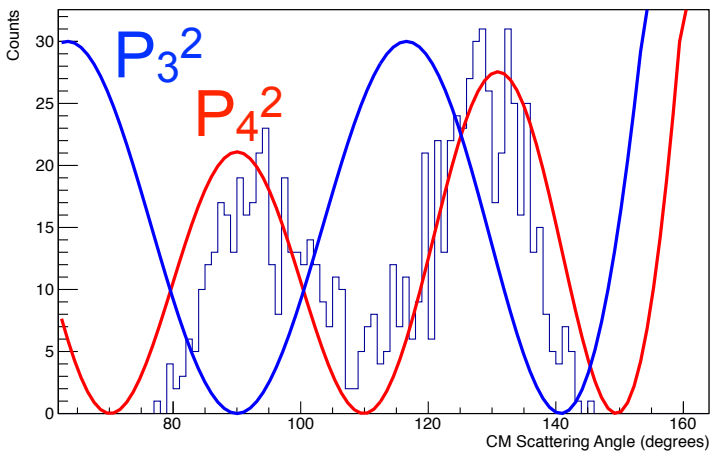
Elastic scattering experiments

The peak is at 10.16(2) MeV of ^{10}Be excitation energy; Γ_{tot}=270(30) keV





M. Freer, et al., PRL 96 (2006)

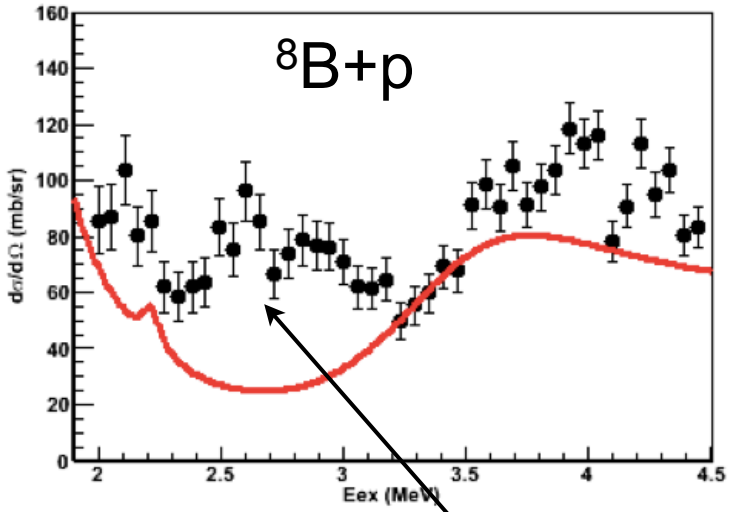


Angular distribution if gated around 2.75+/-0.1 MeV

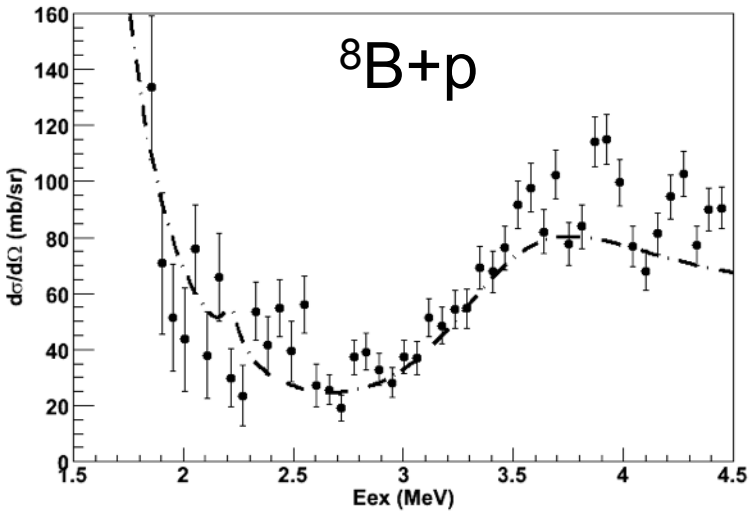
Elastic scattering experiments

Structure of ^{9}C was studied using ^{8}B+p elastic scattering

Talk of S.T. Marley; NS2012, Aug 14th (Tuesday), 9:25pm "Structure of ^{9}C from the $^{10}C(d,t)^{9}C$ Reaction..."

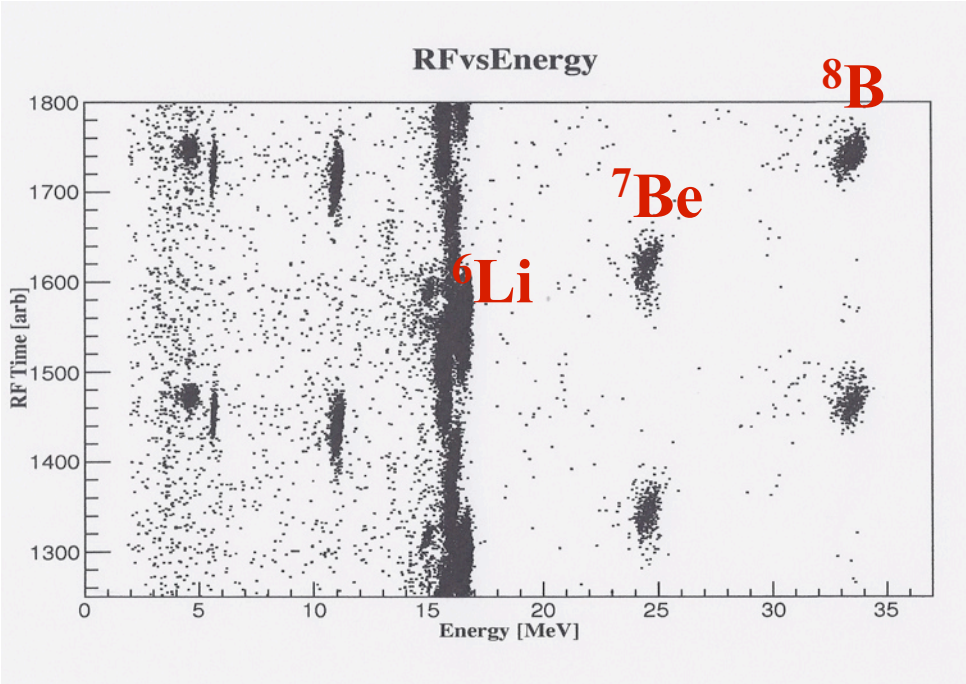


$^{8}B(p,p')^{8}B^{*}$->p+^{7}Be



GR, et al., PRC (2007)

Elastic scattering experiments

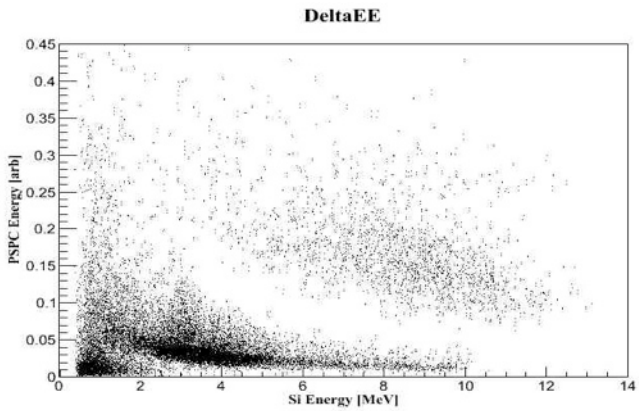


RESOLUT
Target: ^{3}He
Production: ^{3}He(^{6}Li,^{8}B)n
E(^{6}Li)=40 MeV, I=200 nA

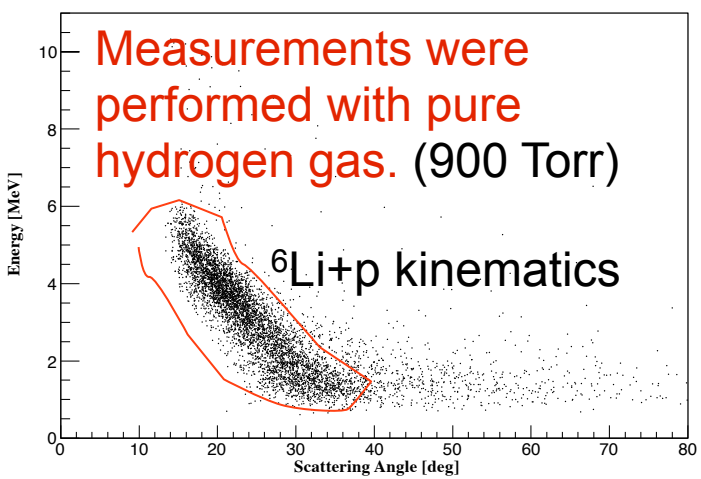
Rates:
^{8}B (35.6 MeV): ~4 p/s/nA
^{7}Be (26 MeV): ~3 p/s/nA
^{6}Li (17 MeV): ~100 p/s/nA
^{3}He (15.1 MeV): ~80 p/s/nA
^{4}He (11.4 MeV): ~4-5 p/s/nA

Measurements were performed with pure hydrogen gas.
900 Torr

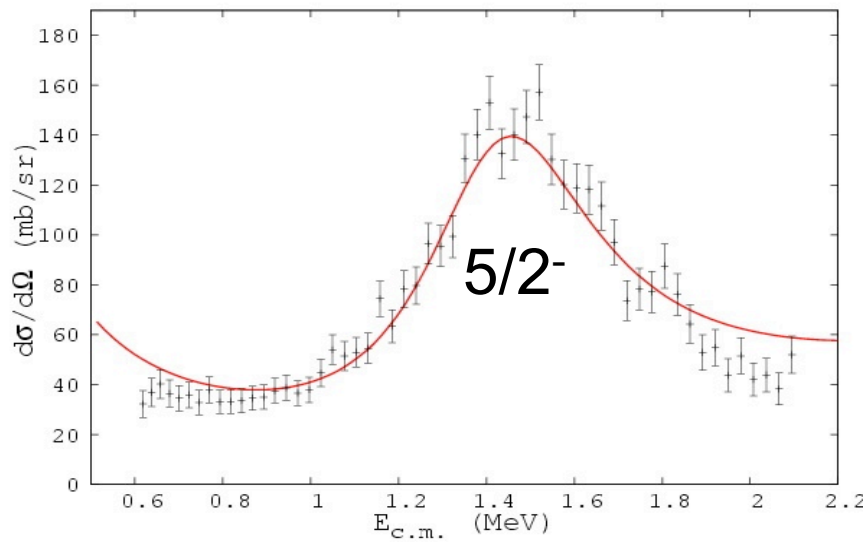
Elastic scattering experiments



Energy Vs Scattering Angle



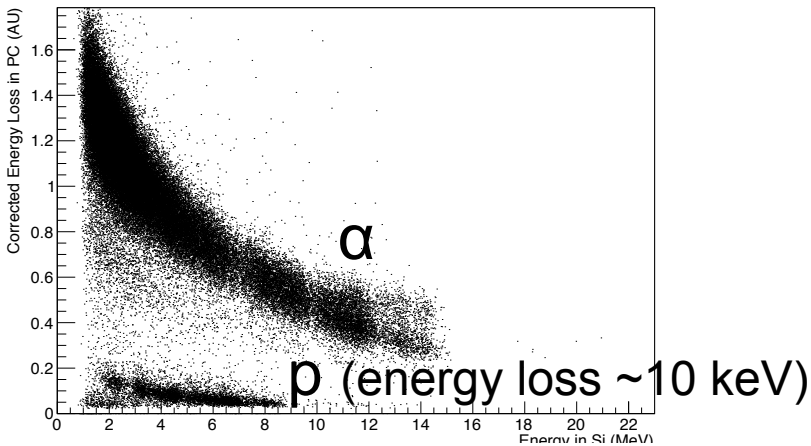
Excitation function for ^{6}Li+p elastic scattering



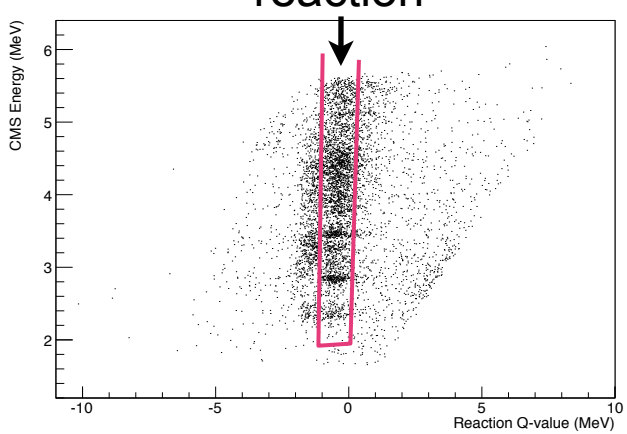
The peak is a known $5/2^-$ state at 7.2 MeV in ^{7}Be

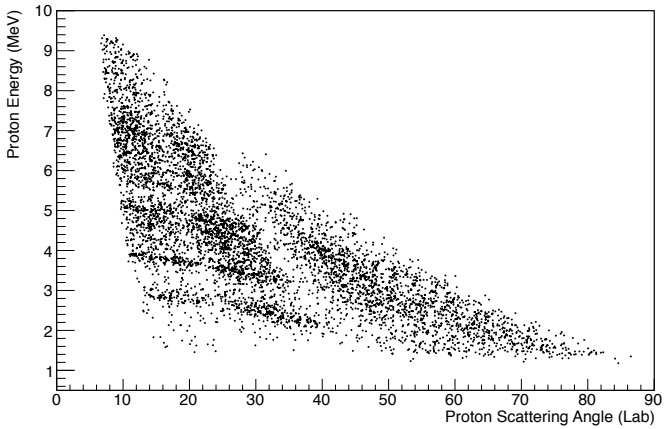
Direct (α,p) measurements

- Possibility for direct measurement of (α,p) excitation function was demonstrated using $^{14}N(\alpha,p)$
- ^{14}N beam energy - 35.6 MeV
- Target - Helium gas + 1% CO_2



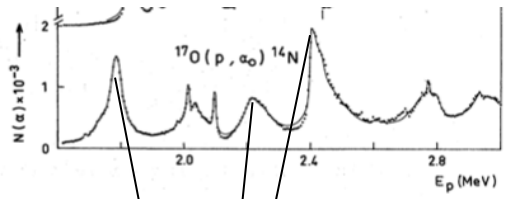
Q of $^{14}N(\alpha,p)$ reaction



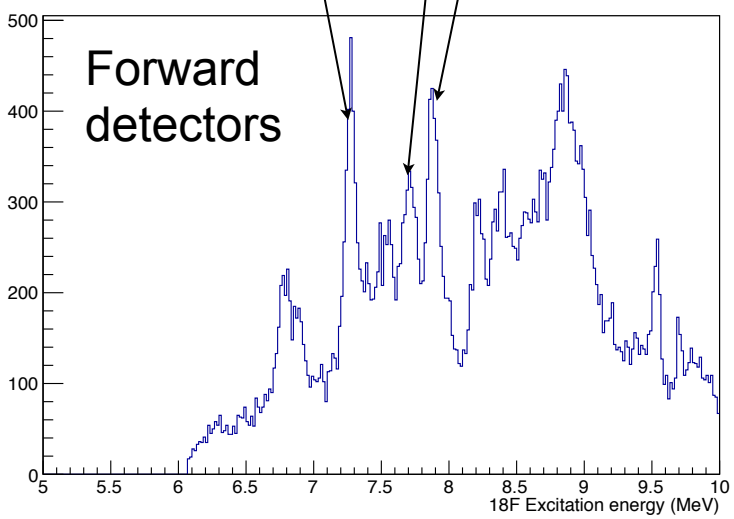


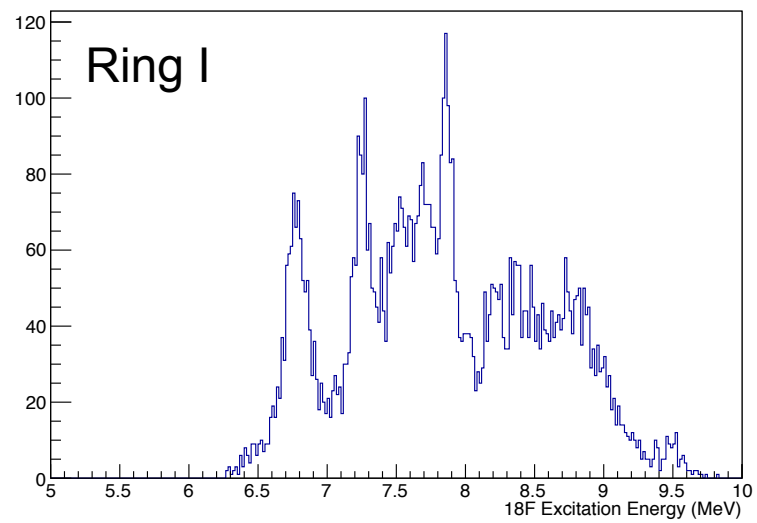
Direct (α,p) measurements

$^{17}O(p,\alpha)$ J.C. Sens, et al., PRC 76 (1978)



- The spectra were accumulated over 6 hours.
- Intensity of ^{14}N beam was ~5×10^5 pps (35.6 MeV).



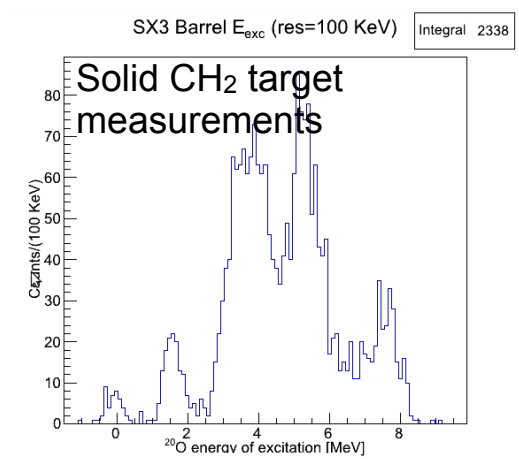


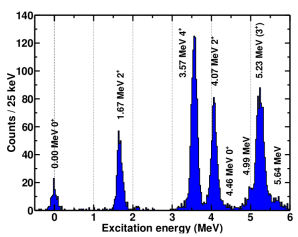
Excitation function for $^{14}N(\alpha,p)^{17}O$

Nucleon transfer reactions

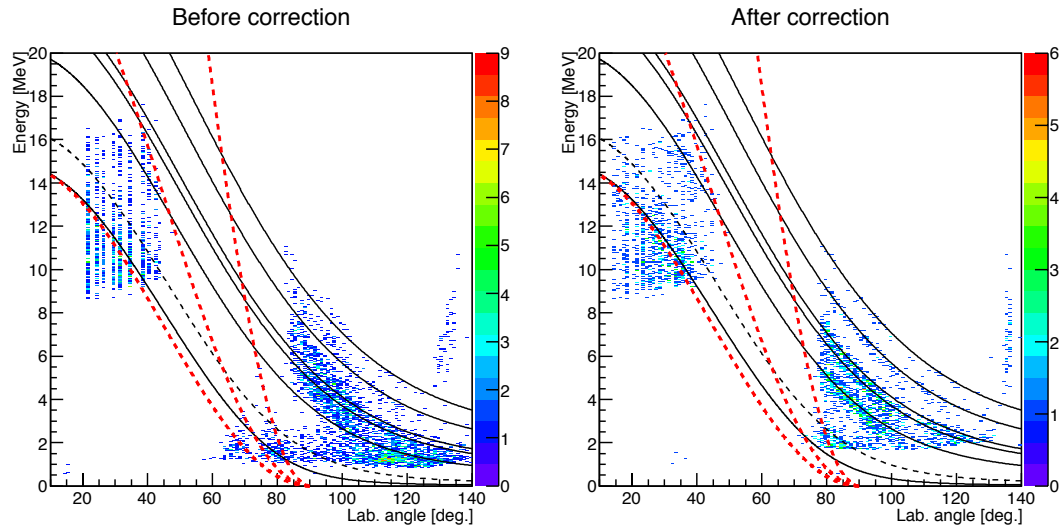
^{20}O states populated in $^{19}O(d,p)$ reaction

Talk of C. Hoffman; NS2012, Monday, Aug 13, 9:55 pm





C. Hoffman, et al., PRC 85 (2012)

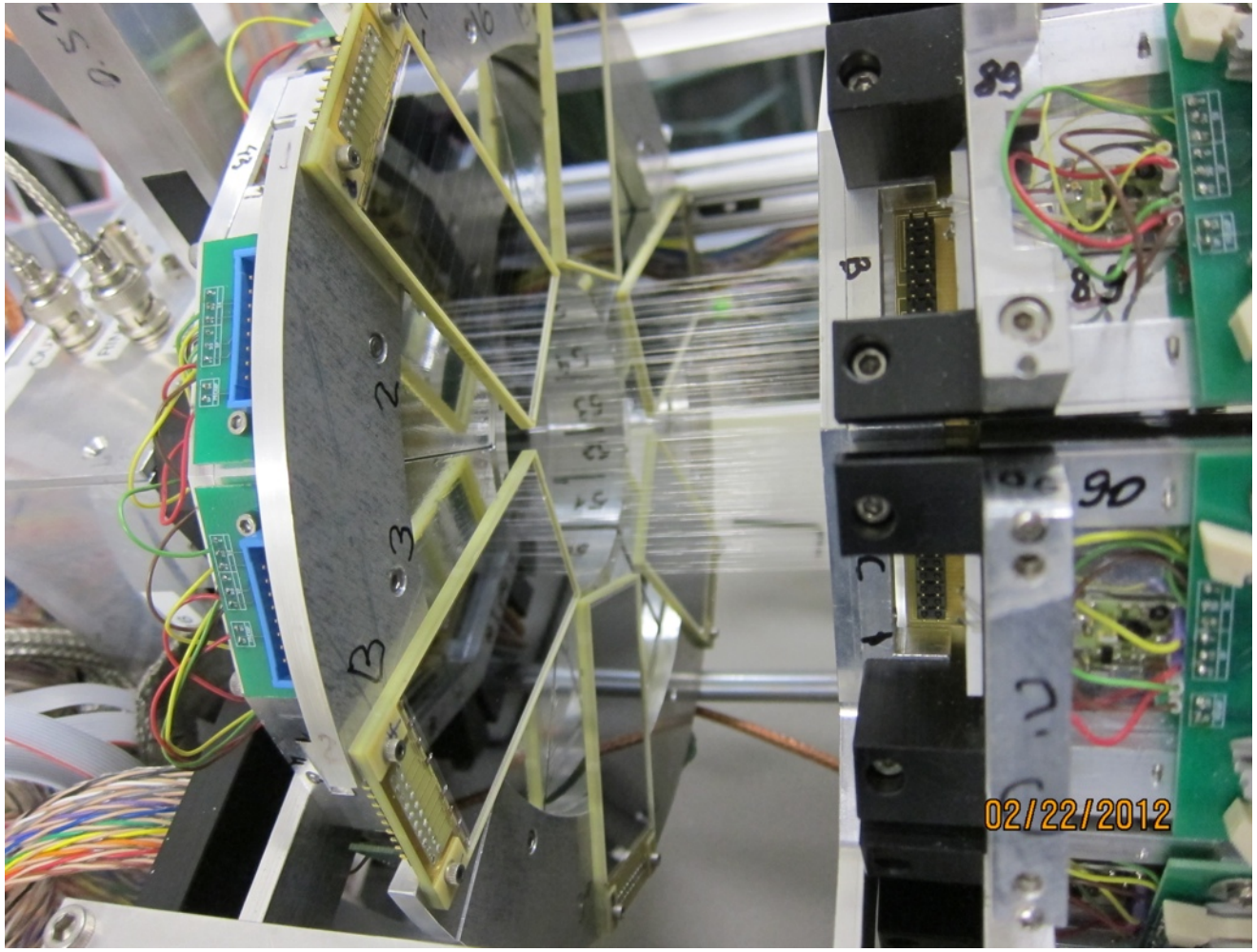


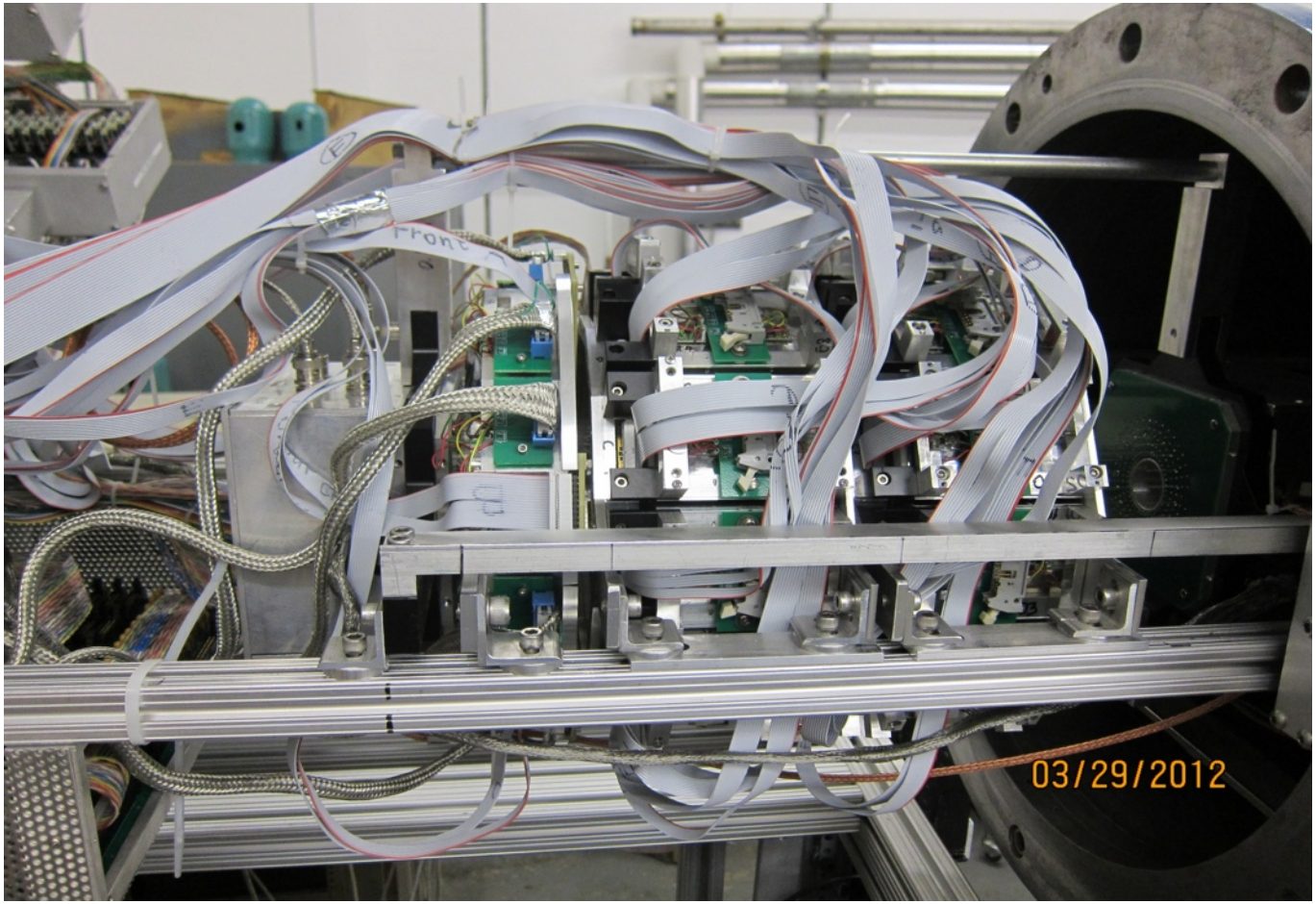
ANASEN can be used for nucleon transfer reaction in active target mode with pure deuterium or hydrogen gas:

- reduced background
- measurements with low intensity (very exotic) beams are possible due to thick target

Summary

- ANASEN demonstrated expected performance in the test runs and first experiments
- Excitation functions for resonance scattering p+^{8}B and α+^{6}He were measured
- Possibility for direct measurement of (α,p) excitation function with radioactive beams was demonstrated using ^{14}N(α,p) reaction.
- Exciting possibility to use ANASEN for nucleon transfer (d,p), (d,^{3}He), (p,d) and (p,t) reactions.


02/22/2012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