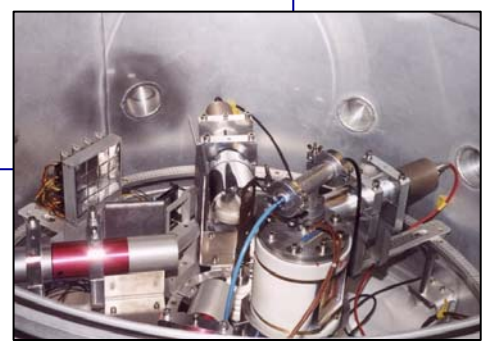
Evidence for a $(1d_{5/2})^2$ component to the ^{12}Be ground state

Steven Pain

CHARISSA & DeMoN Collaborations

Nuclei at the Limits 2004

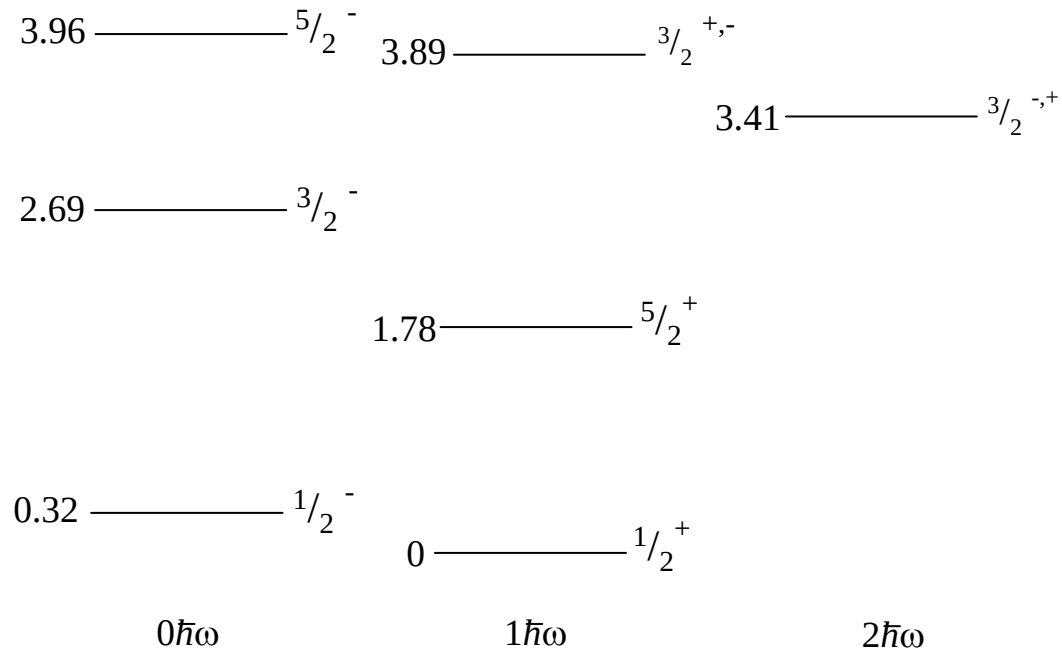


Knockout Reactions with Radioactive Beams

- Probe of single particle structure
- Beam of nuclei of interest
- Low Z target
- Core survival ensures peripheral reaction
- Medium to high energy
  - Simple reaction mechanism – adiabatic approximation
  - Forward focused
  - Thick targets
- Bound states in the residual are identified with γ ray tagging, the residual being detected in a high resolution spectrograph
- Unbound states which break up into core + n require neutron detectors - complicated by the presence of the spectrometer

^{12}Be Ground State Structure

- Simple spherical shell model: $\nu(1p_{1/2})^2$
- ^{11}Be g.s. -> $2s_{1/2}$
- MSU experiment[1]: ~equal mixture of *s* and *p* components. Shell model analysis suggested a significant $1d_{5/2}$ component to the g.s. structure
- Various calculations give different admixtures

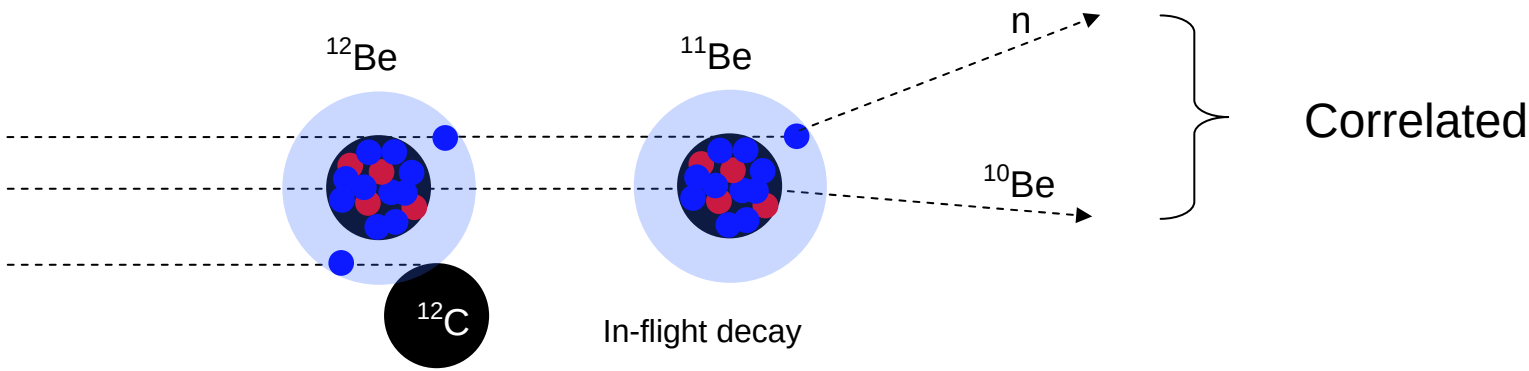


States in ^{11}Be separated by shell model classification[2]

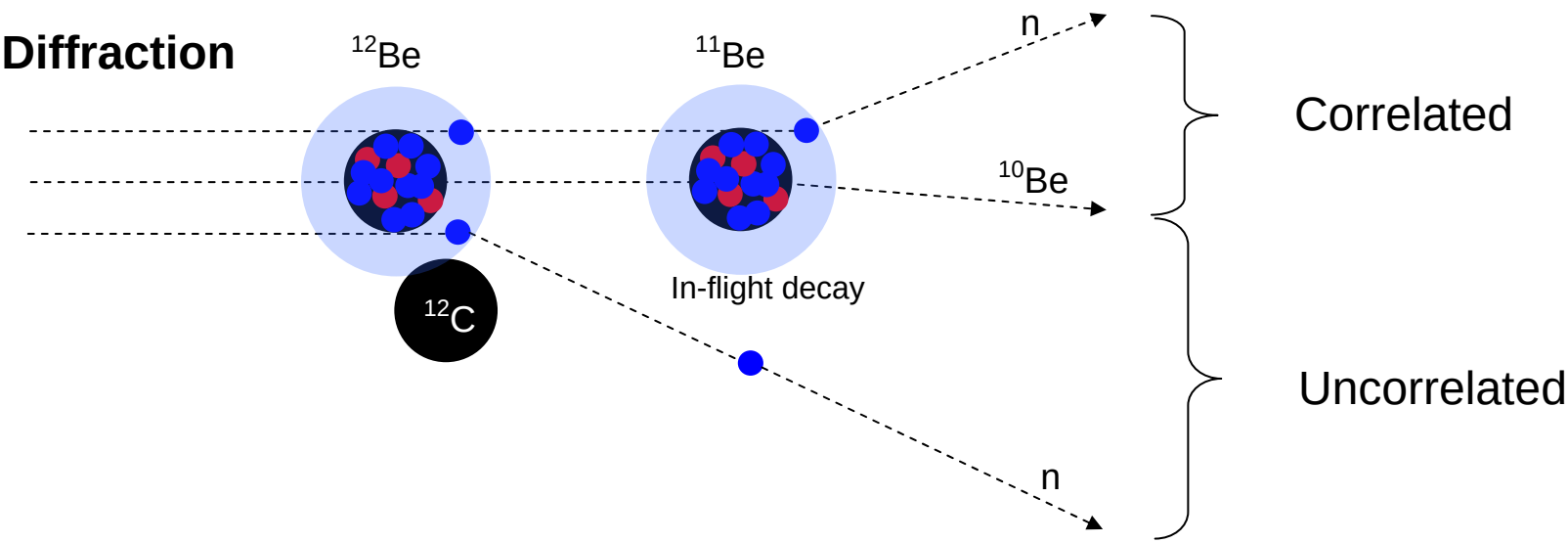
[1] A. Navin *et al*, PRL 85, 266 (2000)

[2] D.J. Millener, NPA 693, 394 (2001)

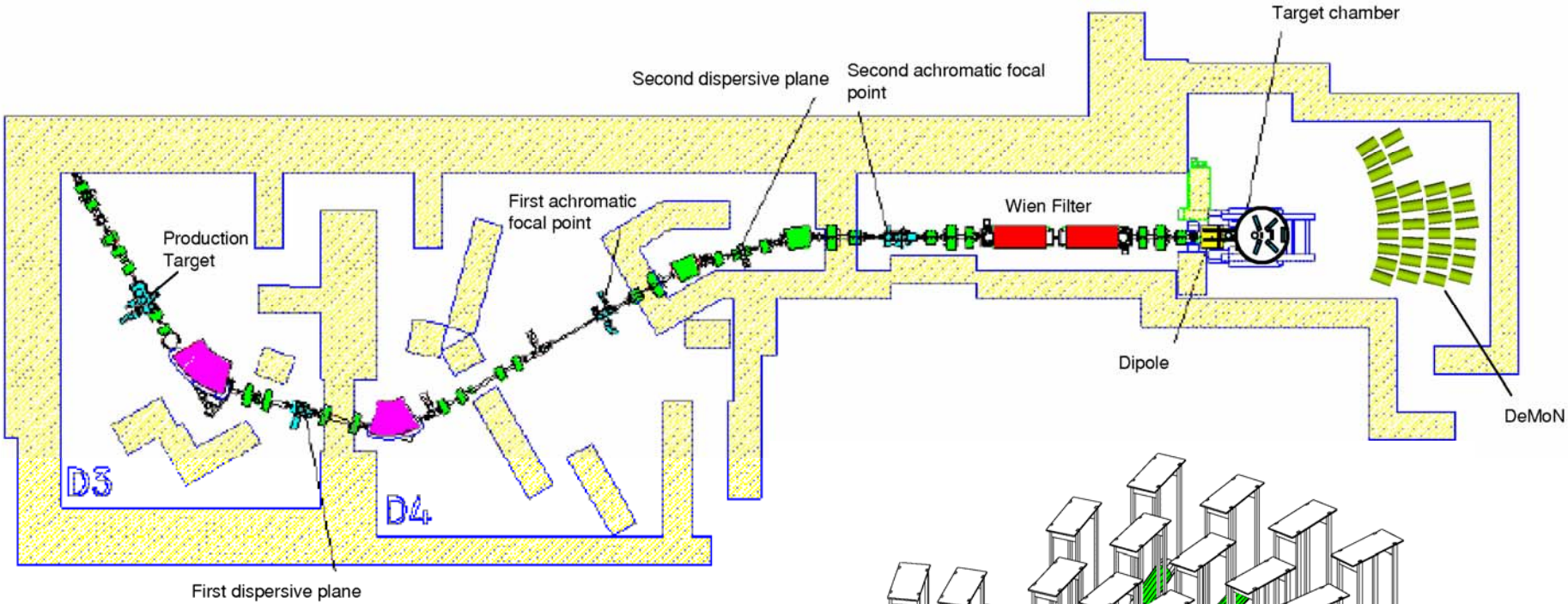
Stripping

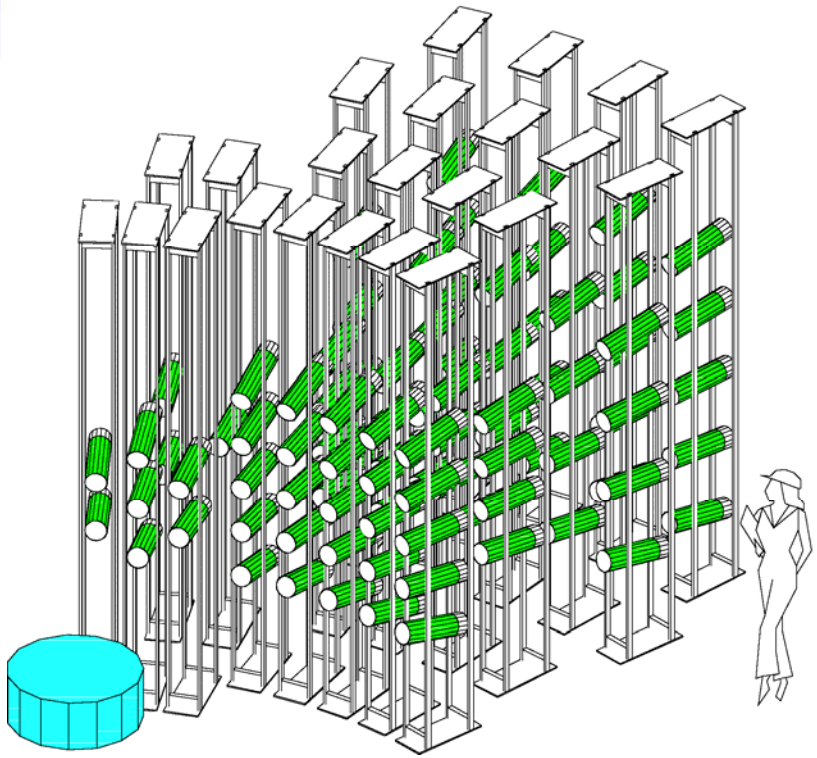


Diffraction



Experimental Set-up

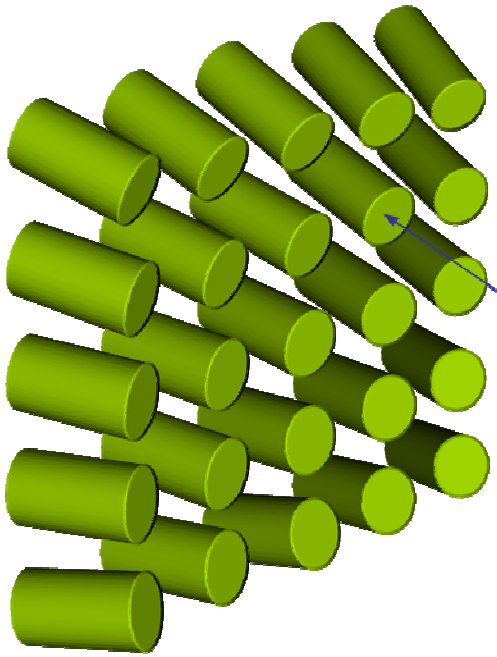


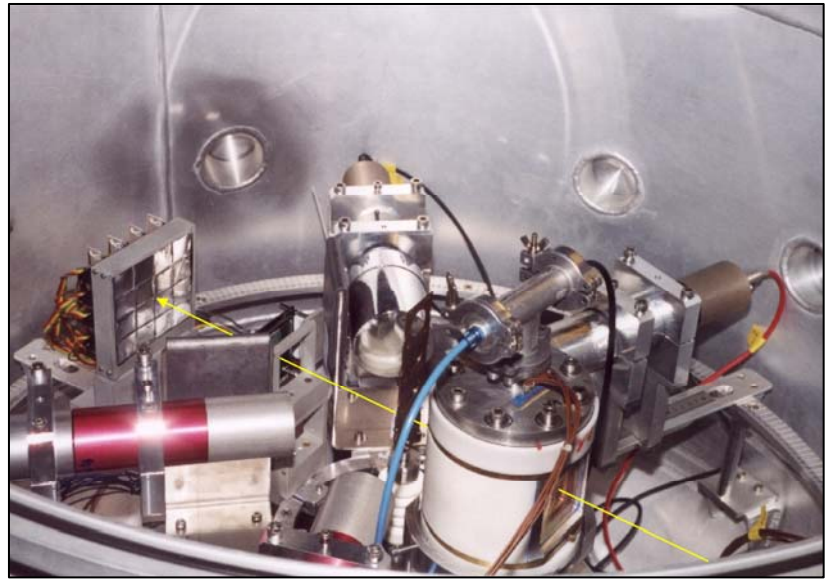


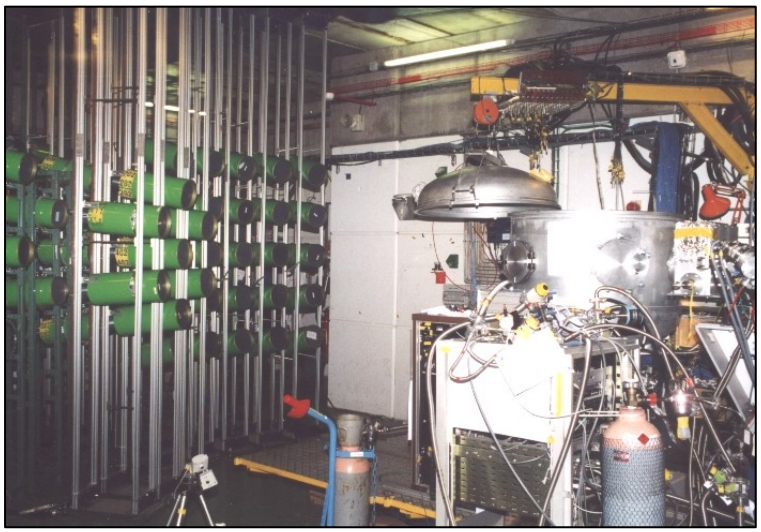
10^4 pps ^{12}Be (95% pure)

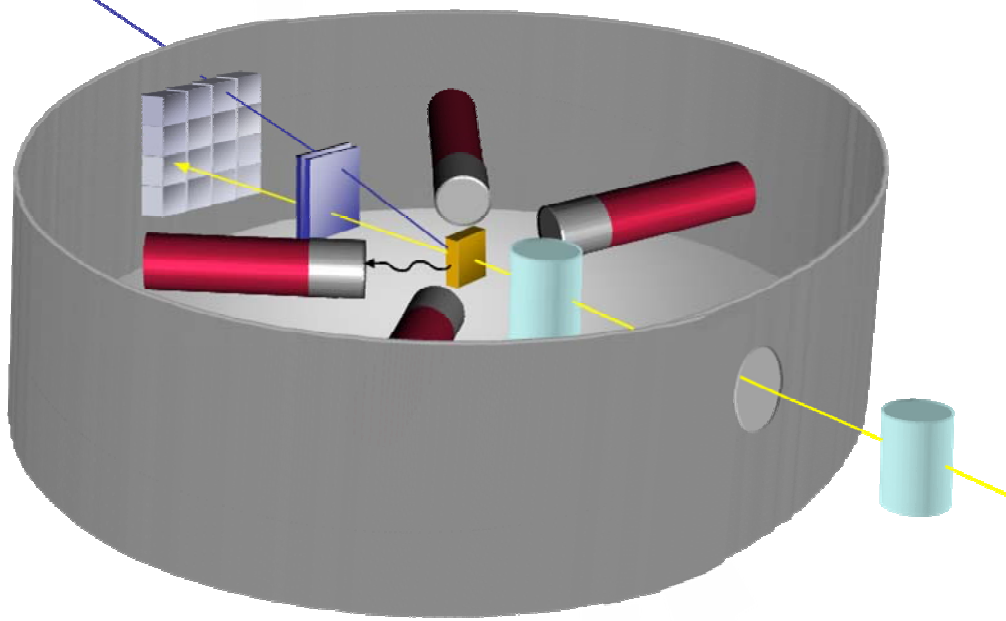
41 MeV/A

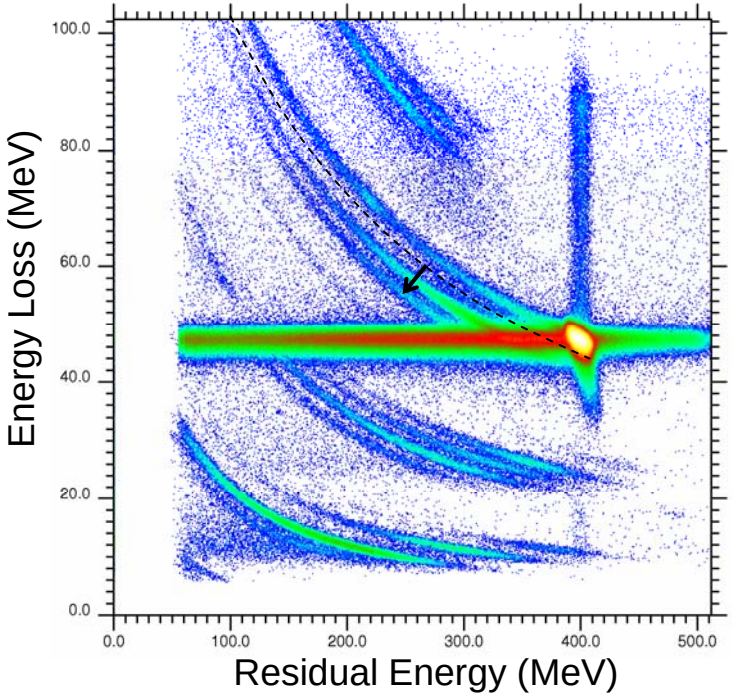
Experimental Set-up

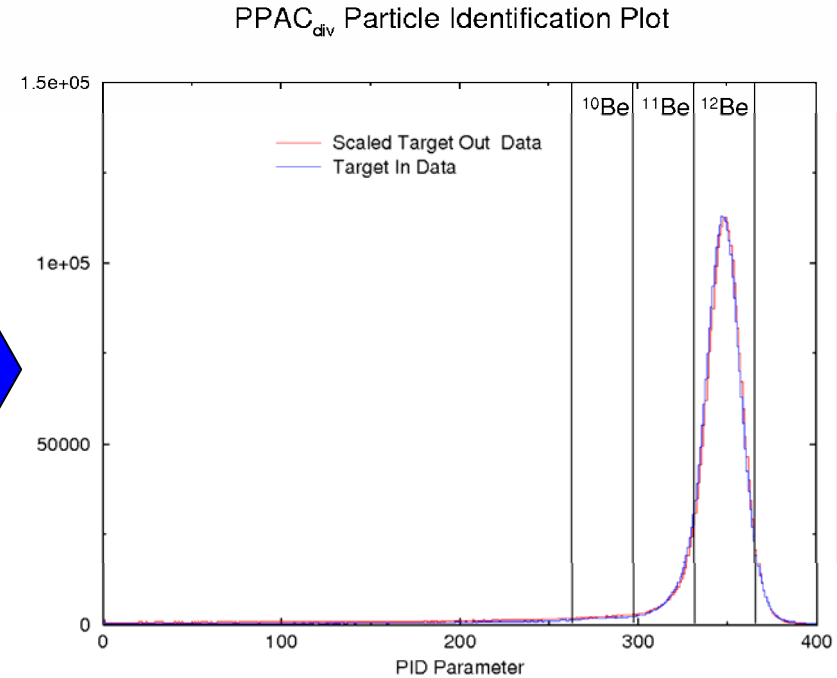


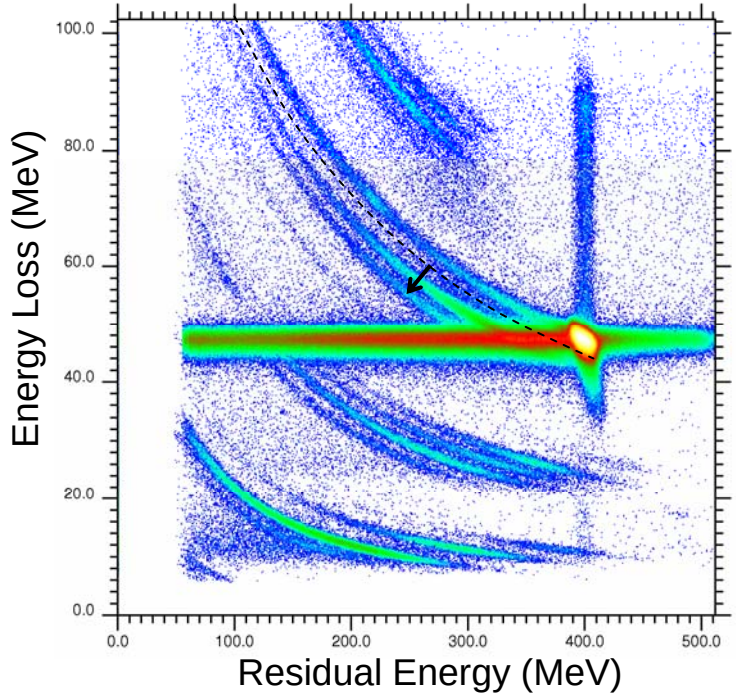


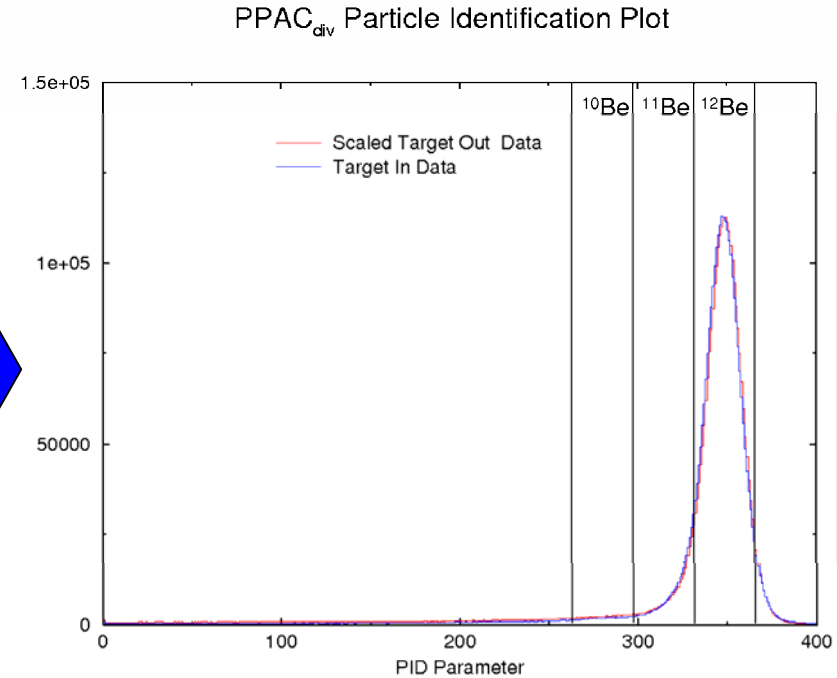


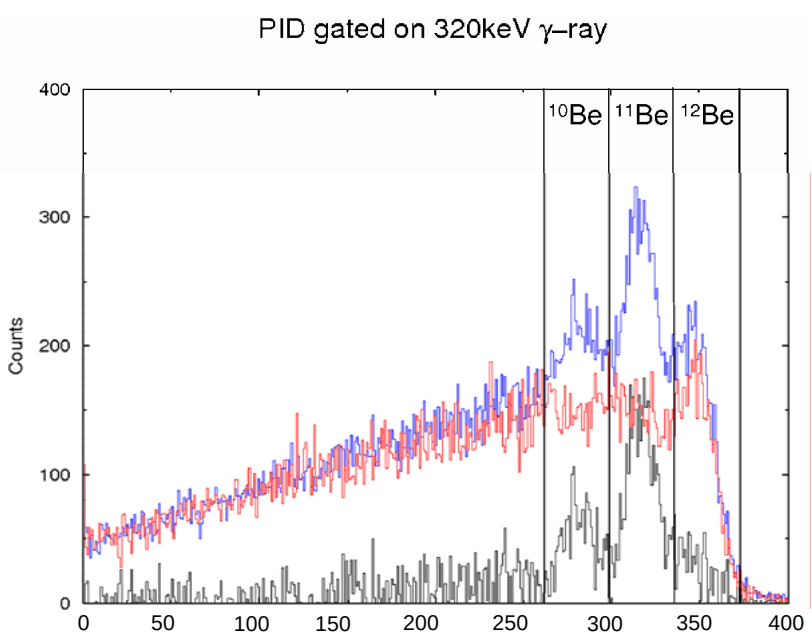


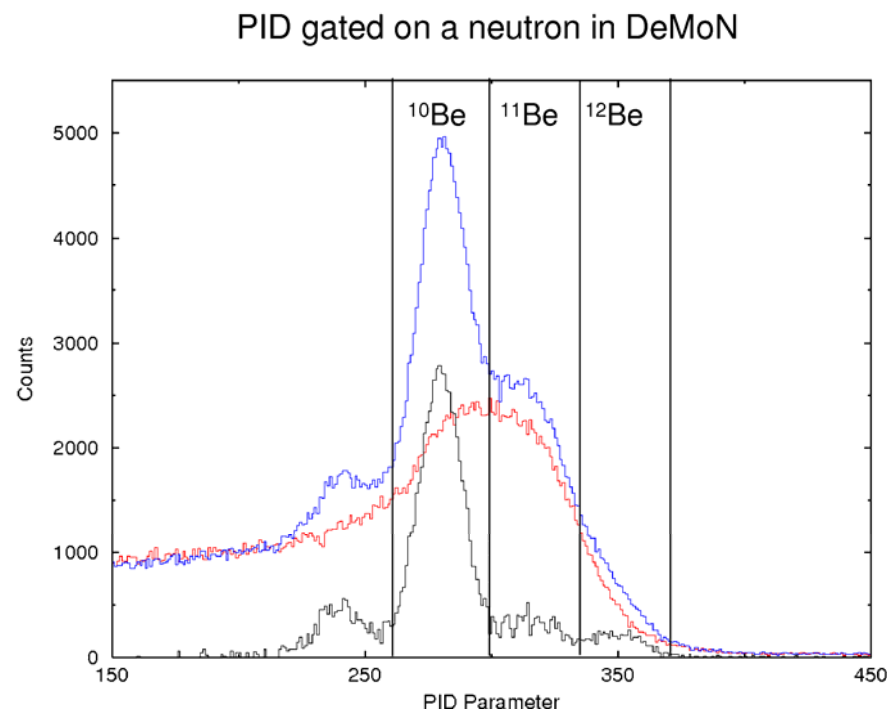

Energy Loss (MeV)
Residual Energy (MeV)
100.0
80.0
60.0
40.0
20.0
0.0
0.0
100.0
200.0
300.0
400.0
500.0


PPAC$_{div}$ Particle Identification Plot
^{10}Be
^{11}Be
^{12}Be
Scaled Target Out Data
Target In Data
1.5e+05
1e+05
50000
0
0
100
200
300
400
PID Parameter


Energy Loss (MeV)
Residual Energy (MeV)
100.0
80.0
60.0
40.0
20.0
0.0
0.0
100.0
200.0
300.0
400.0
500.0


PPAC$_{div}$ Particle Identification Plot
^{10}Be
^{11}Be
^{12}Be
Scaled Target Out Data
Target In Data
1.5e+05
1e+05
50000
0
0
100
200
300
400
PID Parameter

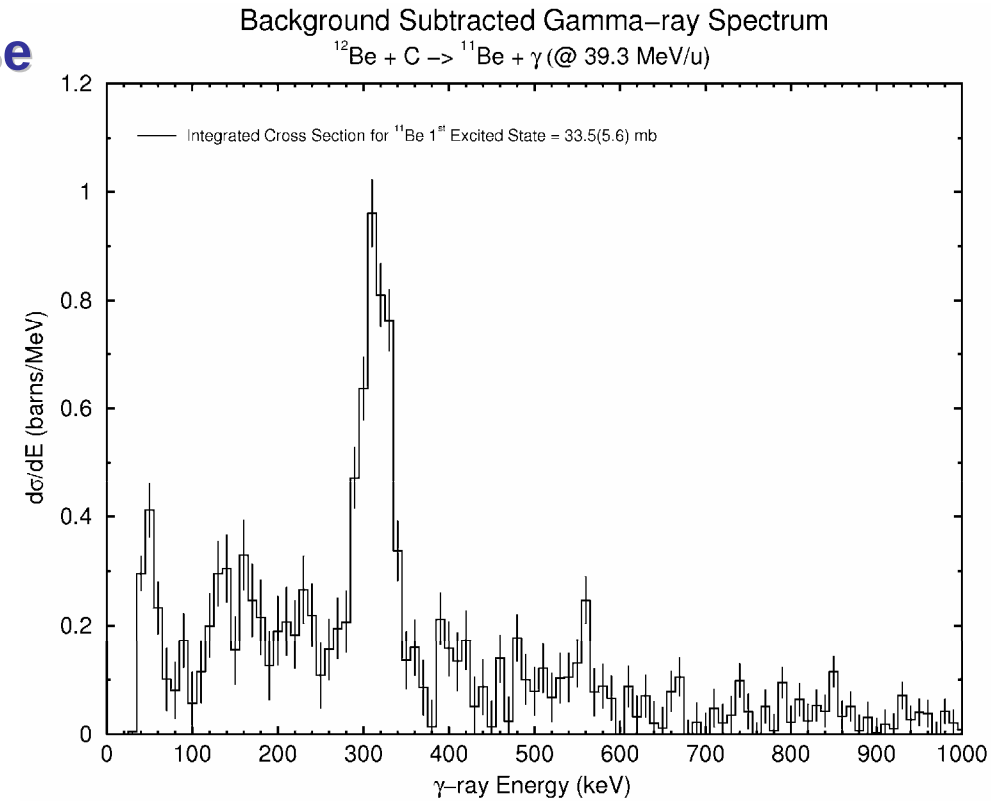

PID gated on 320keV γ–ray
^{10}Be
^{11}Be
^{12}Be
Counts
400
300
200
100
0
0
50
100
150
200
250
300
350
400


PID gated on a neutron in DeMoN
^{10}Be
^{11}Be
^{12}Be
Counts
5000
4000
3000
2000
1000
0
150
250
350
450
PID Parameter

Detection of the $^1/_2^-$ State in ^{11}Be

σ = 33.5 (5.6) mb [MSU = 17.5 (2.6) mb]

$P_{||}$ = 137 (21) MeV/c [MSU = ~150 mb]



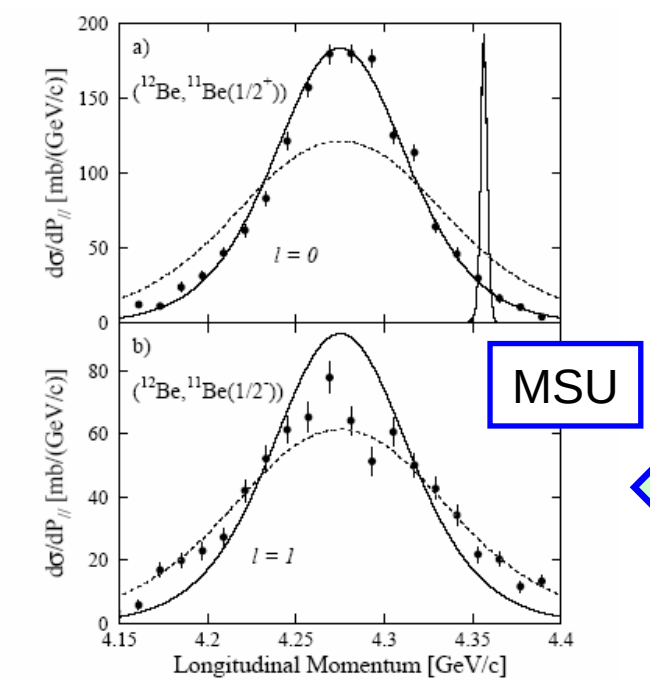
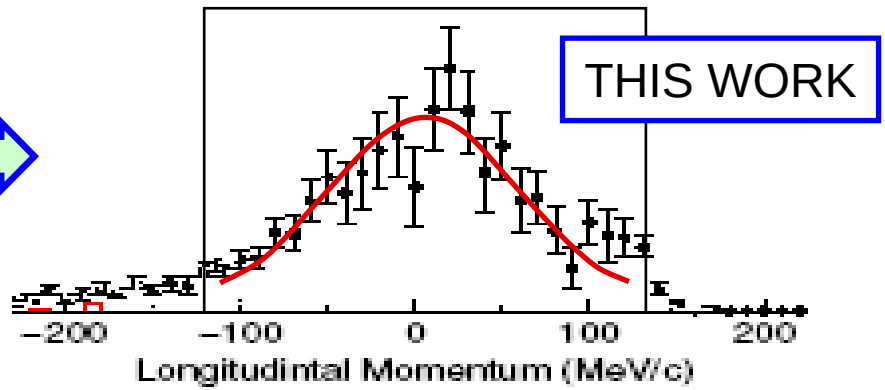


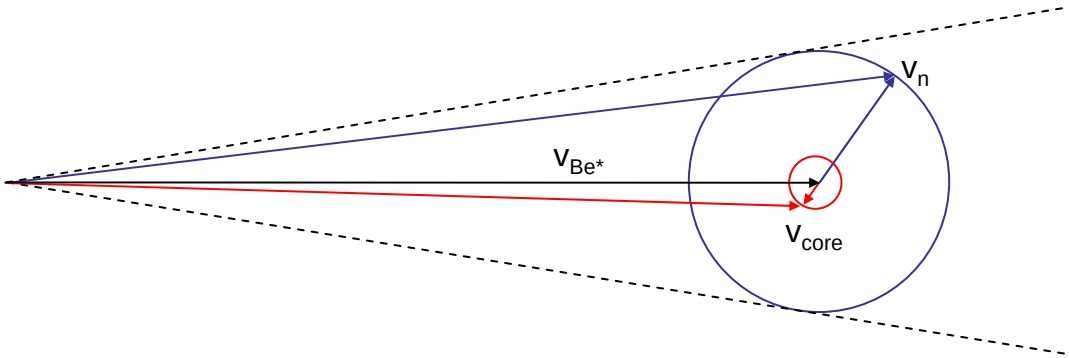
FIG. 2. Laboratory frame longitudinal momentum distributions for ^{11}Be residues in the ground (a) and excited (b) states. The solid (dashed) curves are calculated for $l = 0$ (1) neutron removal. The narrow line in (a) illustrates the line profile of the spectrograph.

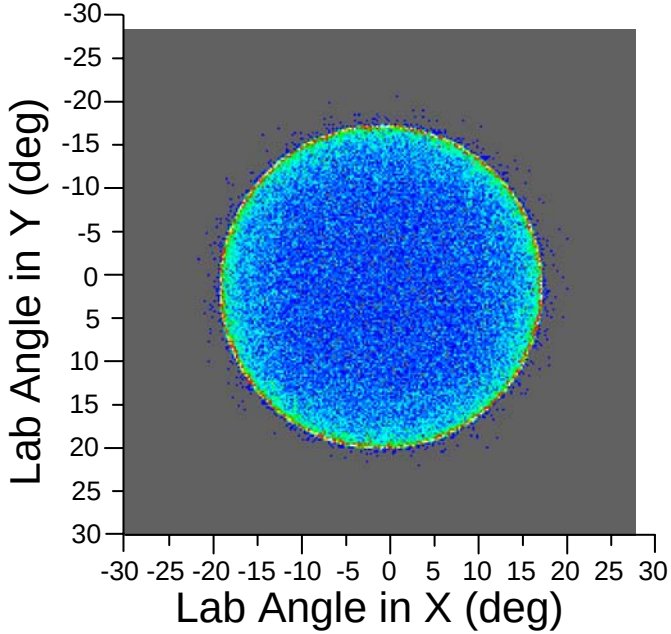
MSU

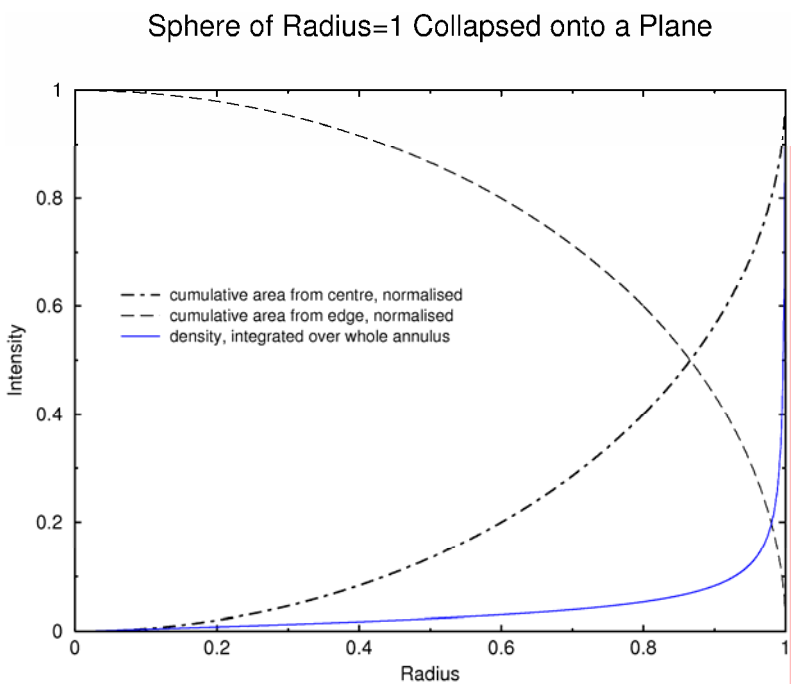
1/2$^-$ γ-ray tag

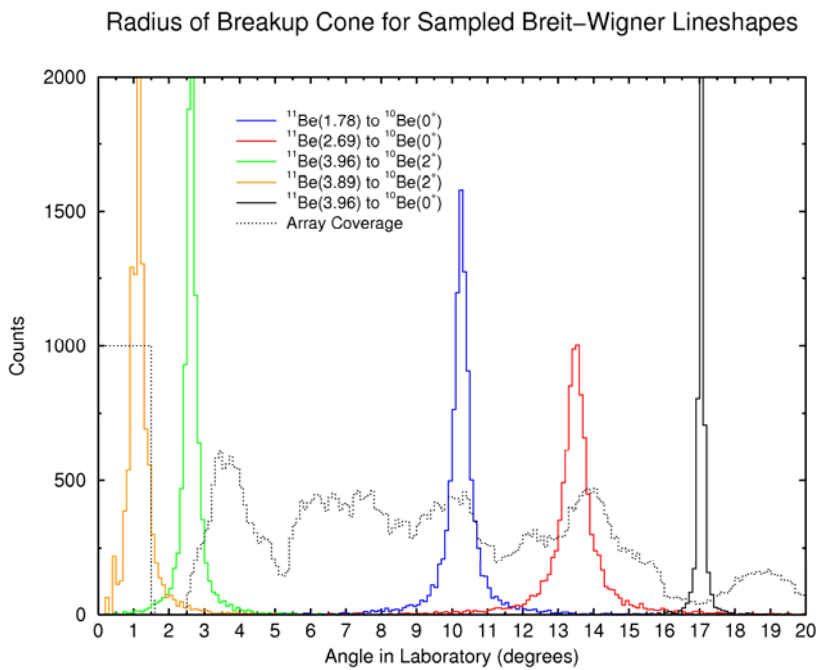


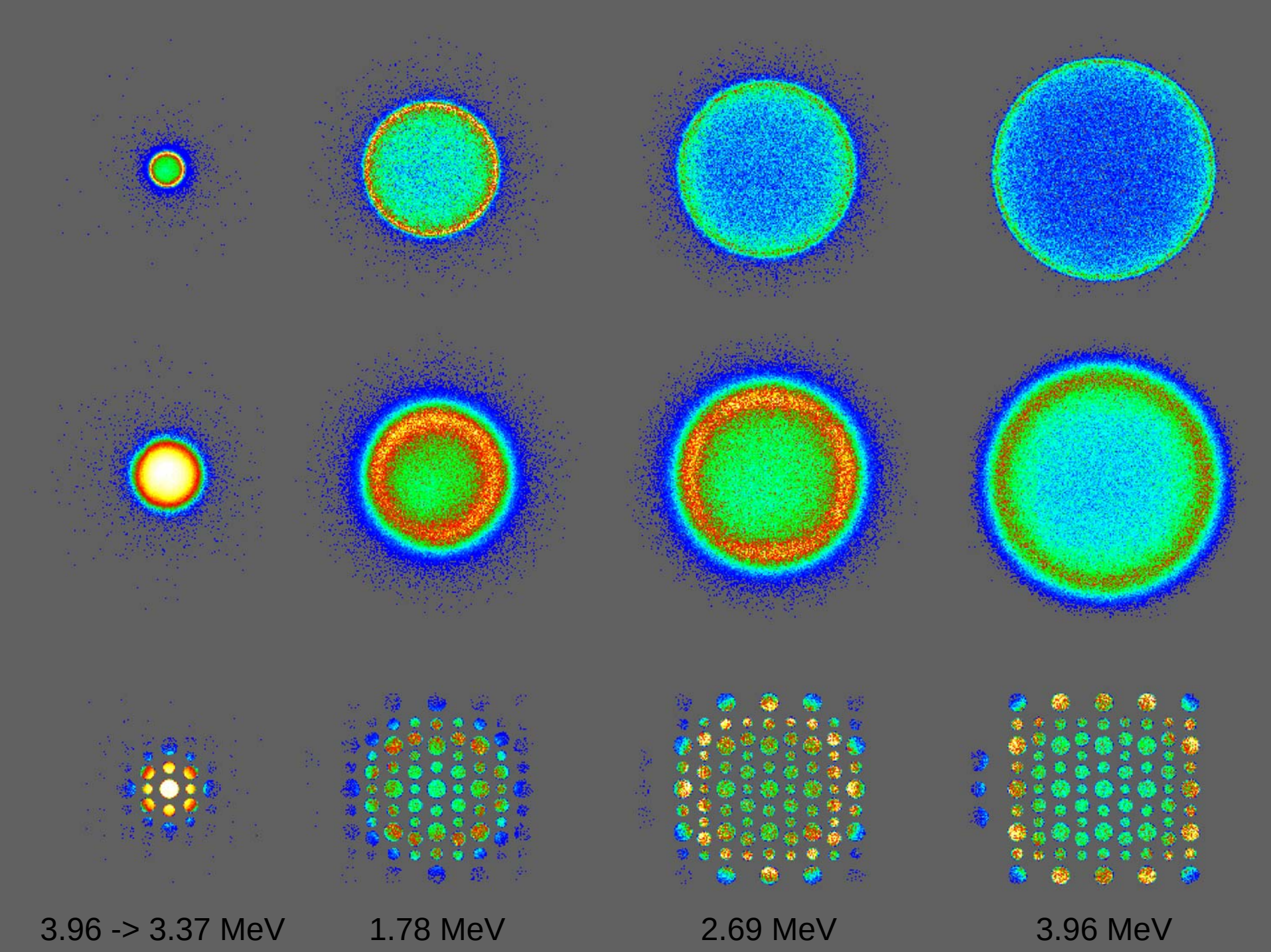
Detection of Unbound States in ^{11}Be



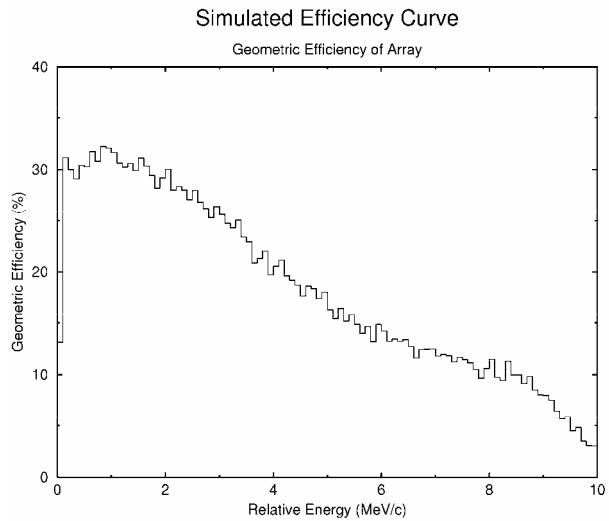


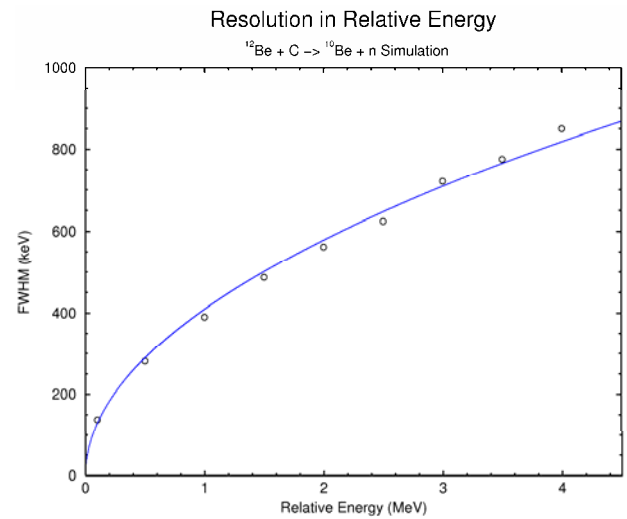


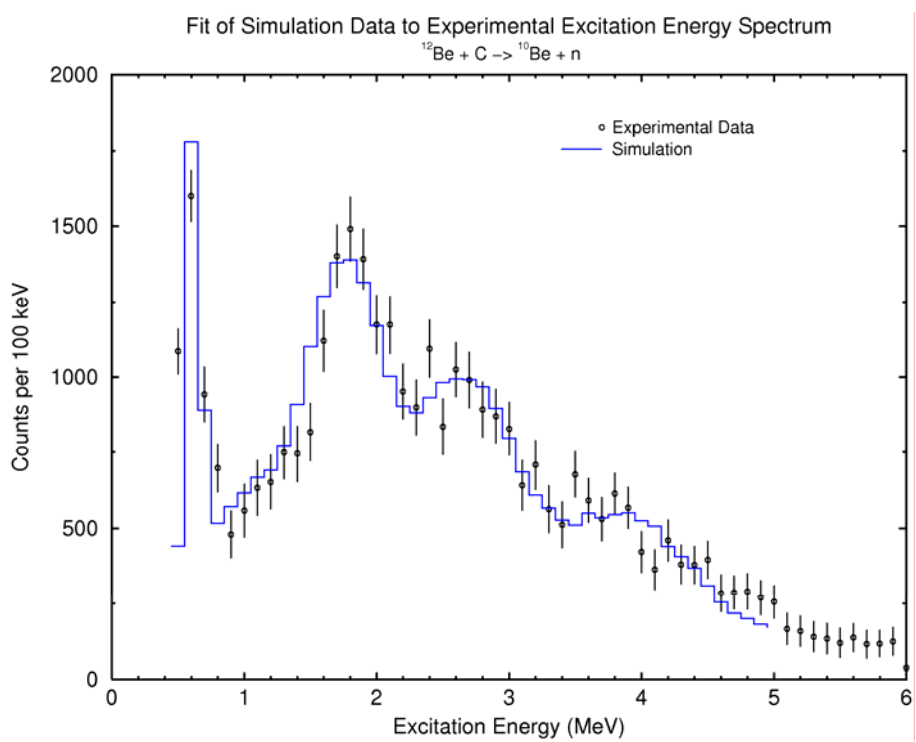


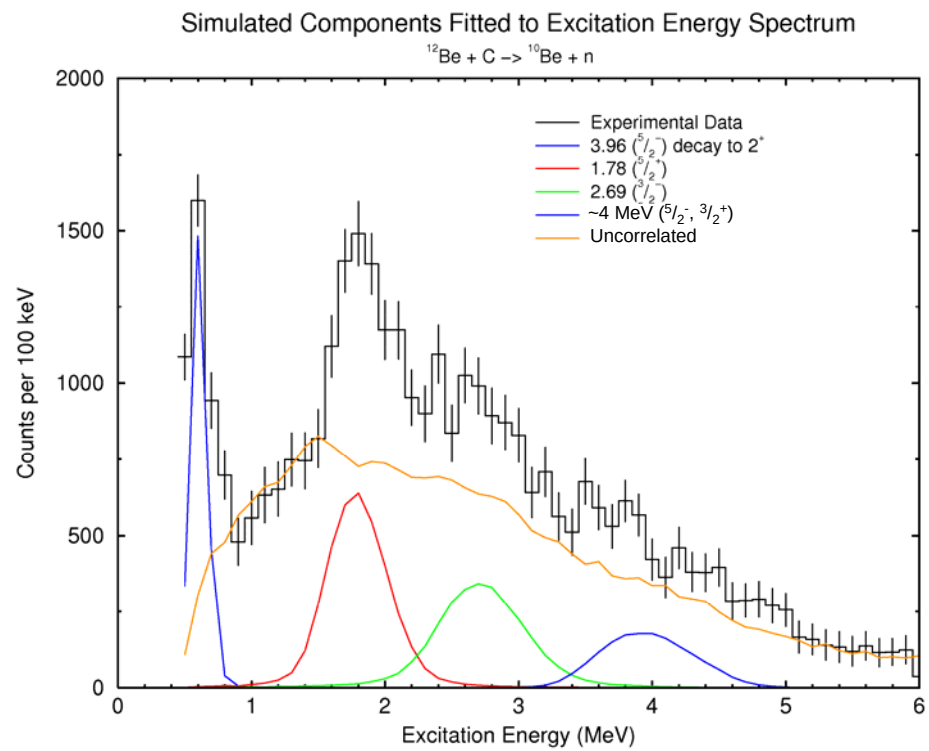

3.96 -> 3.37 MeV
1.78 MeV
2.69 MeV
3.96 MeV

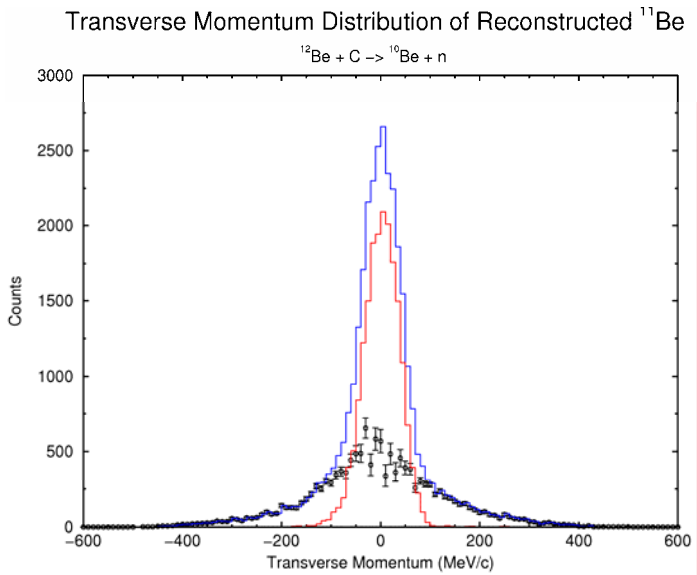
Reconstructed ^{11}Be Excitation Energy

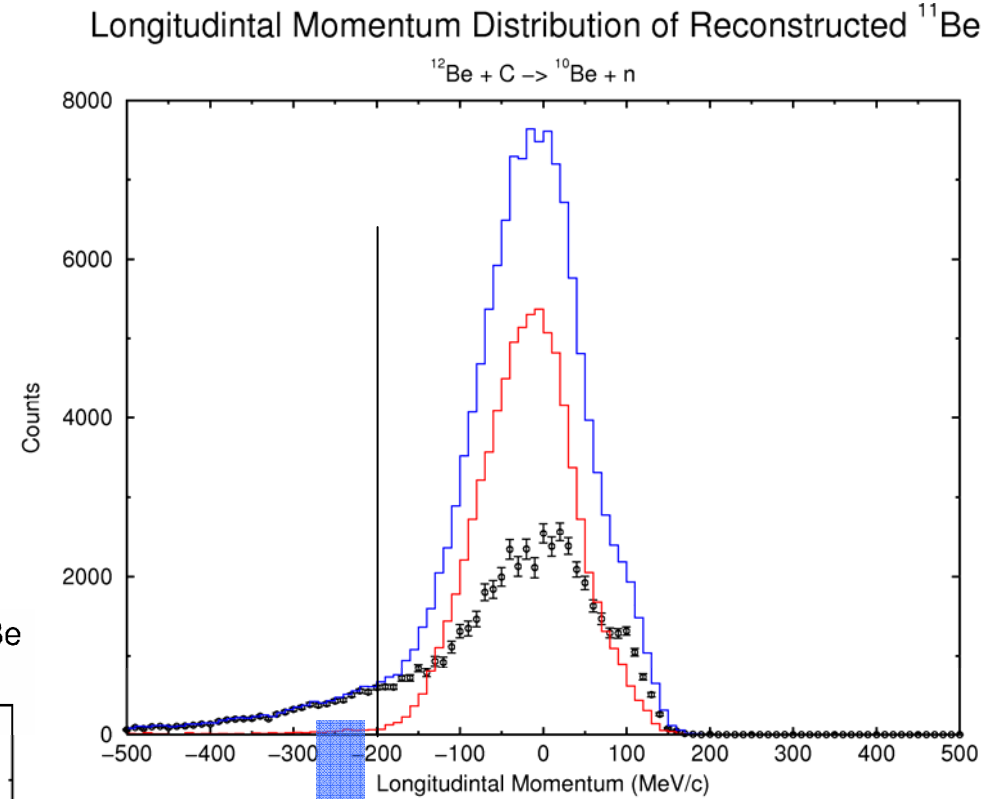


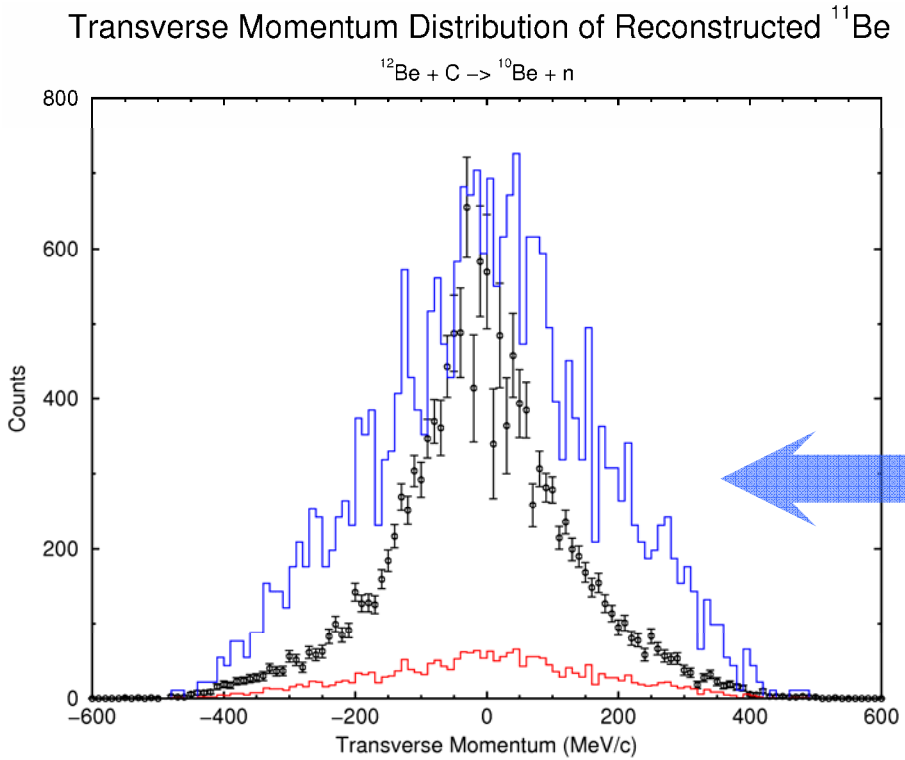


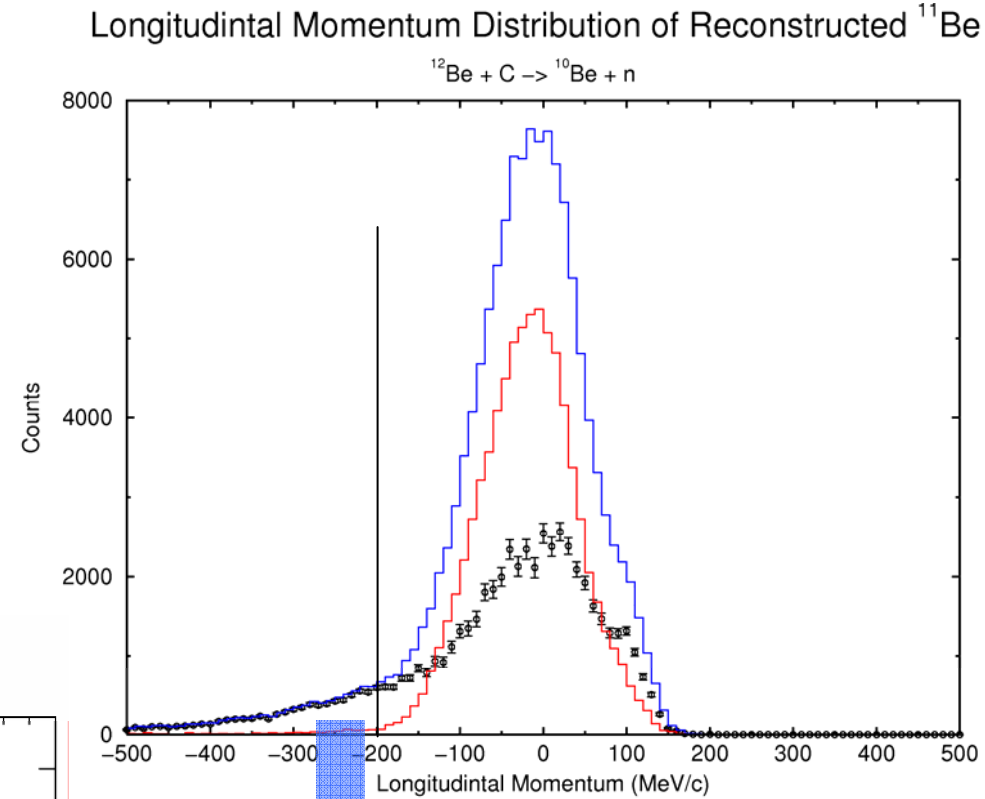


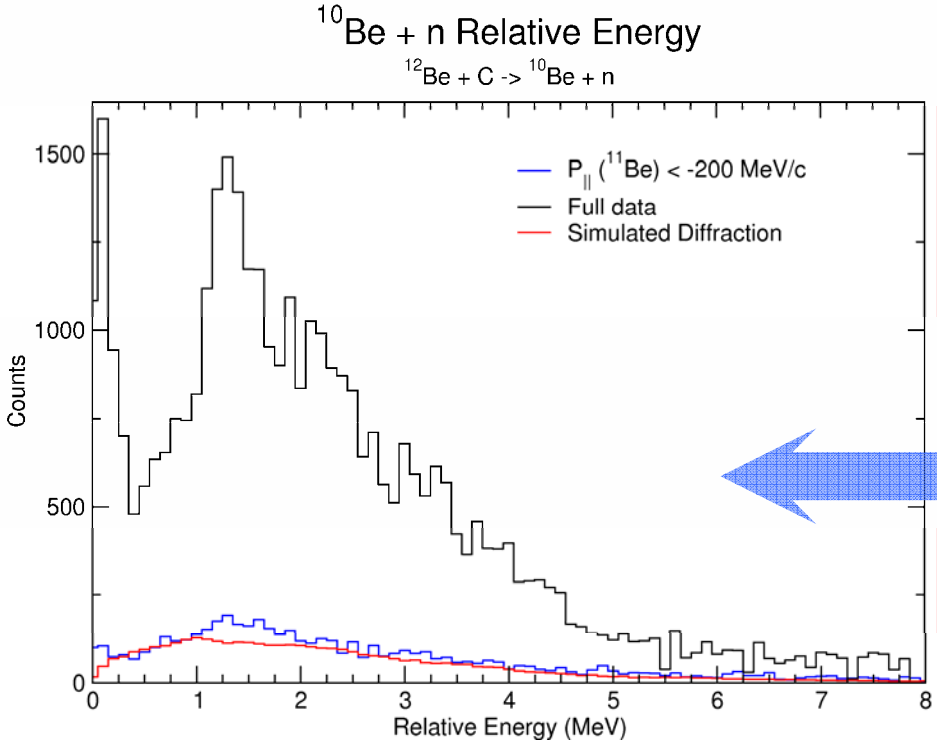



Transverse Momentum Distribution of Reconstructed ^{11}Be
^{12}Be + C –> ^{10}Be + n
Counts
Transverse Momentum (MeV/c)


Longitudinal Momentum Distribution of Reconstructed ^{11}Be
^{12}Be + C –> ^{10}Be + n
Counts
Longitudinal Momentum (MeV/c)


Transverse Momentum Distribution of Reconstructed ^{11}Be
^{12}Be + C –> ^{10}Be + n
Counts
Transverse Momentum (MeV/c)


Longitudinal Momentum Distribution of Reconstructed ^{11}Be
^{12}Be + C –> ^{10}Be + n
Counts
Longitudinal Momentum (MeV/c)


^{10}Be + n Relative Energy
^{12}Be + C -> ^{10}Be + n
$P_{||}$ (^{11}Be) < -200 MeV/c
Full data
Simulated Diffraction
Counts
Relative Energy (MeV)

Cross Sections (Preliminary)

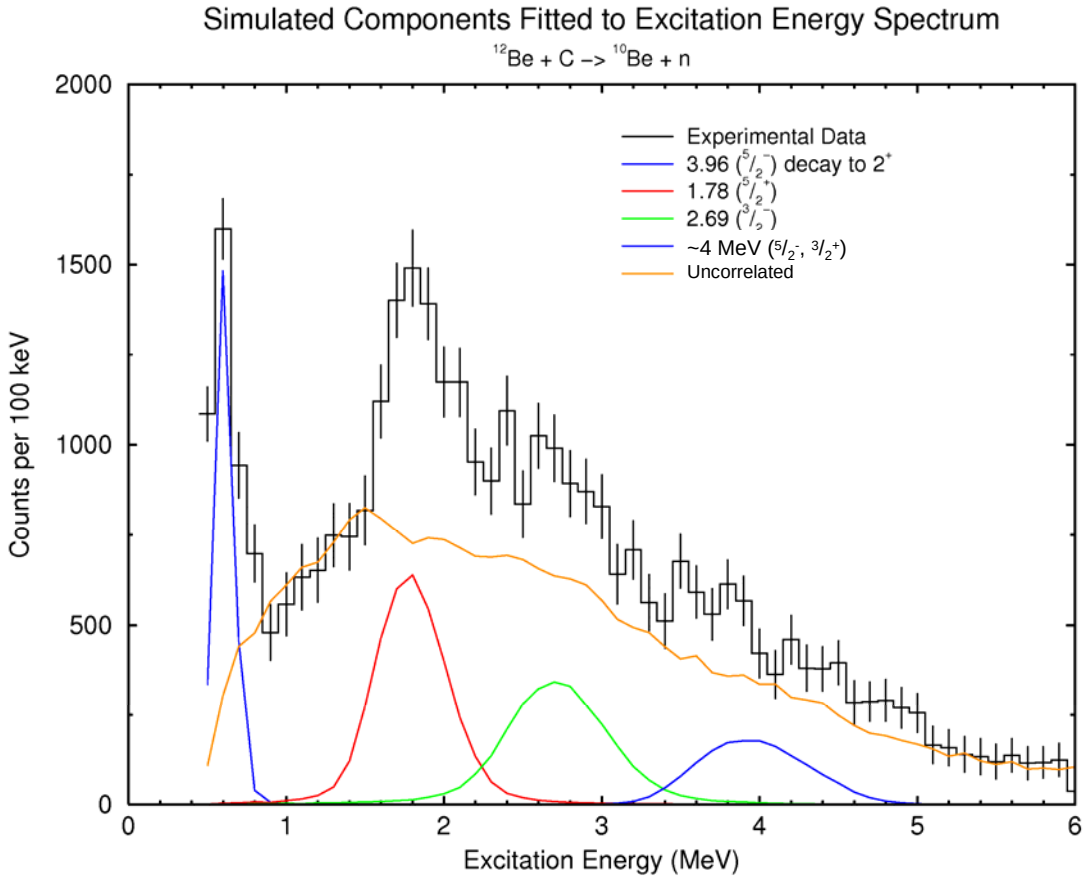
σ(0.32 MeV $^1/_2^-$) = 33.5 (5.6) mb

σ(1.78 MeV $^5/_2^+$) = 22.4 (4.4) mb

σ(2.69 MeV $^3/_2^-$) = 18.3 (5.2) mb

σ(~4 MeV) = 12.8 (6.0) mb

σ(~4 MeV$\rightarrow 2^+$) = 13.7 (0.9) mb



Spectroscopic Factors (Preliminary!)

Single particle removal cross sections

J^{π}	Stripping (mb)	Diffraction (mb)	Sum (mb)
$^{1}/_{2}^{+}$	61.28	57.69	118.96
$^{1}/_{2}^{-}$	42.59	30.72	73.31
$^{5}/_{2}^{+}$	39.78	22.77	62.55

Spectroscopic Factors

J^{π}	MSU	Current Work
$^{1}/_{2}^{+}$	0.42(10)	-
$^{1}/_{2}^{-}$	0.37(10)	0.46(12)
$^{5}/_{2}^{+}$	-	0.36(10)

Preliminary calculations by Jeff Tostevin

Summary

- Knockout experiments leading to n-unbound states performed with zero degree charged particle telescope
- Previous experiment identified approximately equal *s* and *p* components to the ^{12}Be ground state
- Current experiment was sensitive to *p* and *d* components
- Measured comparable cross sections for the $^{1}/_{2}^{-}$ state and the $^{5}/_{2}^{+}$ state – indicating significant $d_{5/2}$ component to ^{12}Be g.s.
- Preliminary calculations performed by Jeff Tostevin suggest spectroscopic factors of 0.46(12) and 0.36(10) for the $^{1}/_{2}^{-}$ and $^{5}/_{2}^{+}$ states.
- Further work required on understanding broad component to the reconstructed ^{11}Be energy spectrum

Collaborators

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& J.A. Tostevin[1] (Theory)