AARHUS
UNIVERSITET

August 2014

Probing resonances in ^{12}C above the triple-alpha threshold

A.M. Howard, H.O.U. Fynbo, O.S. Kirsebom, K.L. Laursen, K. Riisager

Motivation

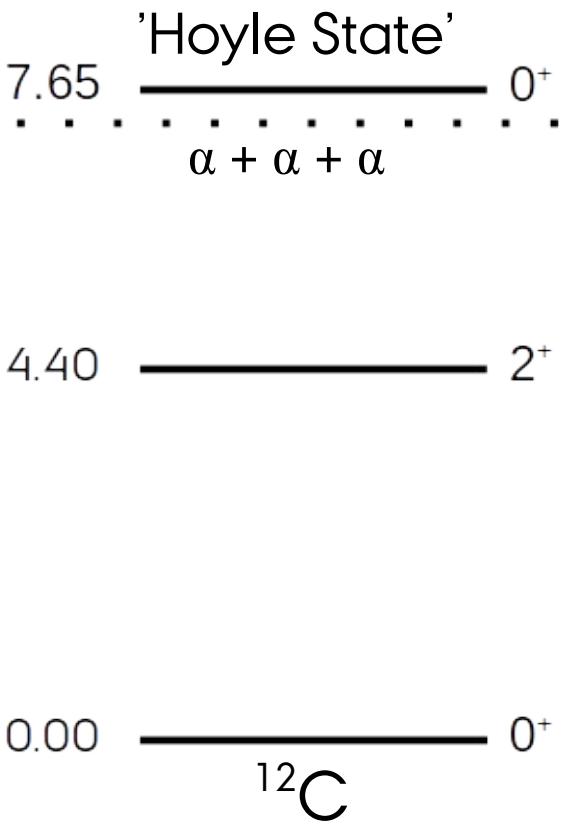
???

Interest in ^{12}C resonance structure since the 1950s – proposal and discovery of 'Hoyle State'

Speculation regarding nature of state followed – still very much relevent today

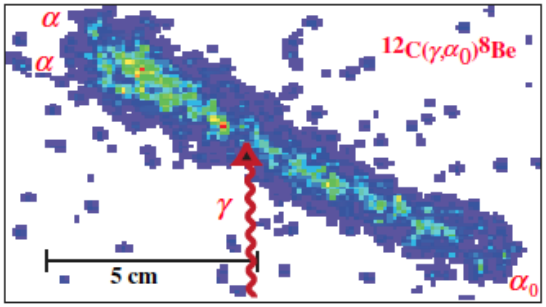
Excitations of the Hoyle State should give insight – search for second 2^+ state begins

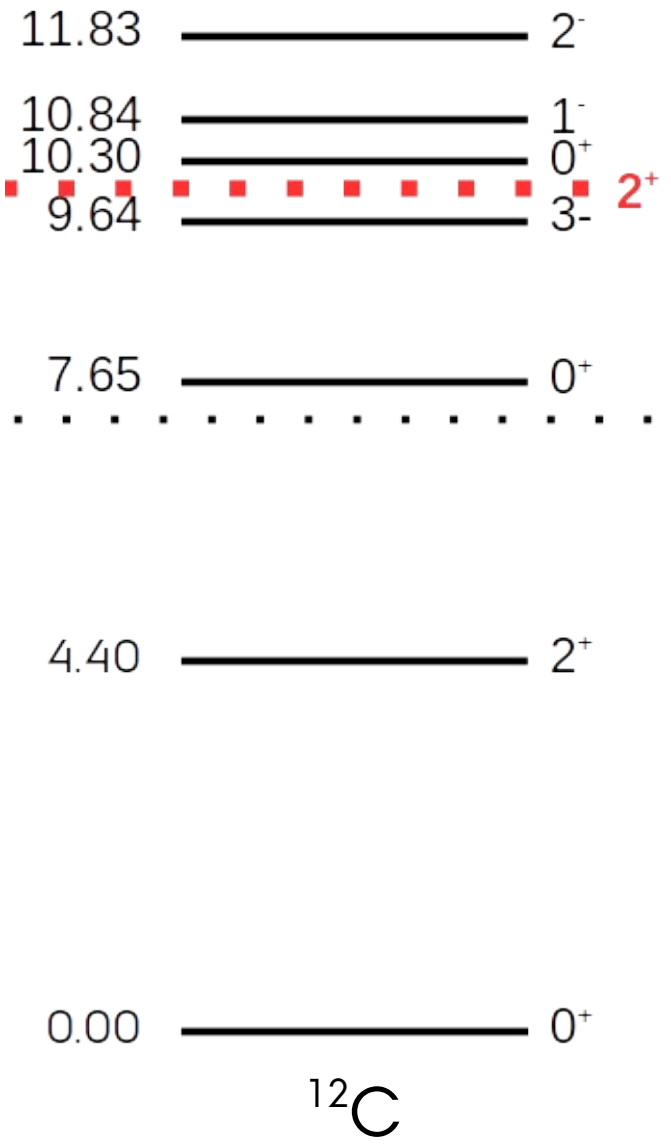
M. Freer & H. O. U. Fynbo, Prog. Part. Nucl. Phys., **78** (2014) 1-23



AARHUS
UNIVERSITET

Motivation





Observation of the second 2^+ state only in recent years

Proton- and alpha-scattering data: Freer *et al.*, Phys. Rev. C **86**, 034320 (2012)

Photo-excitation of ^{12}C: W. R. Zimmerman *et al.*, Phys. Rev. Lett. **110**, 152502 (2013)

Experimentally challenging – highly selective probes required

AARHUS
UNIVERSITET

Motivation

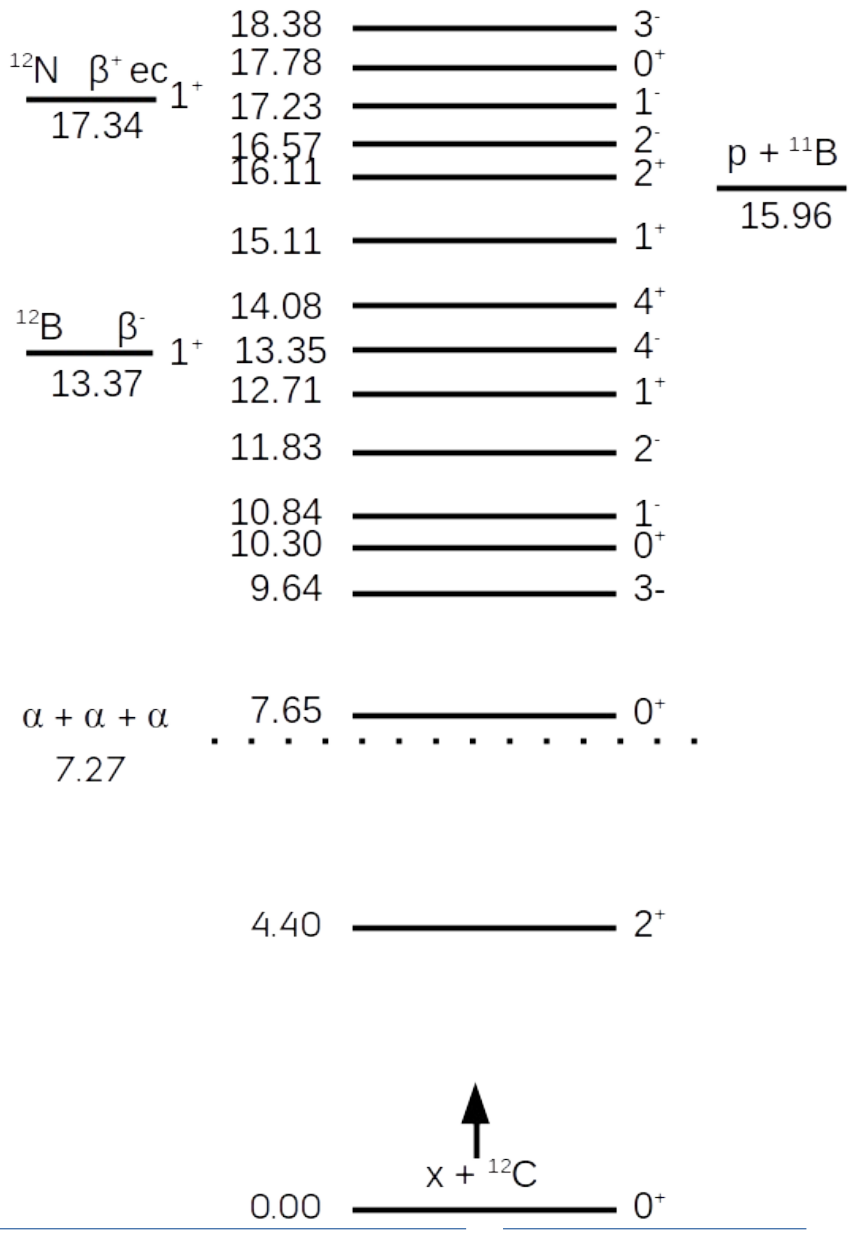
An alternative probe – gamma decay between resonances

Pro: Excellent selectivity

Con: Branching ratio typically small (10^{-5} – 10^{-6})

Direct measurement of gamma-rays problematic (E. Adelberger *et al.* , Phys. Rev. C**15** , 484 (1977))

Indirect measurement instead?



AARHUS
UNIVERSITET

Complete kinematics

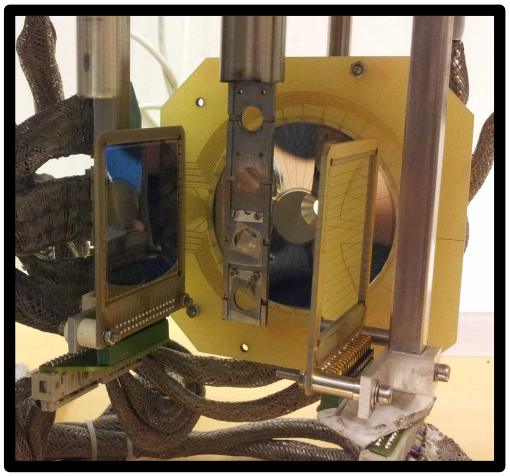
Double Sided Silicon Strip Detector array (16x16 or 24x32)

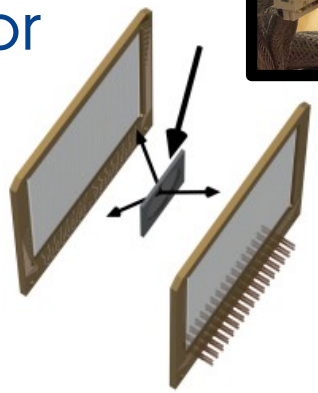
Large solid angle coverage with good angular sensitivity

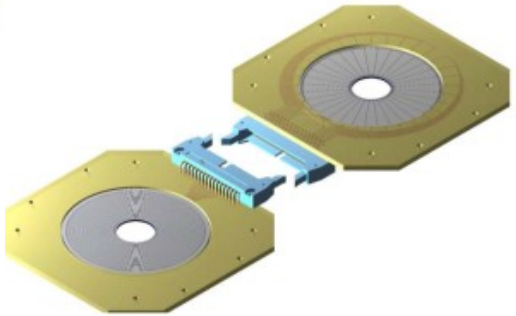
Granularity reduces issues associated with summing or pileup

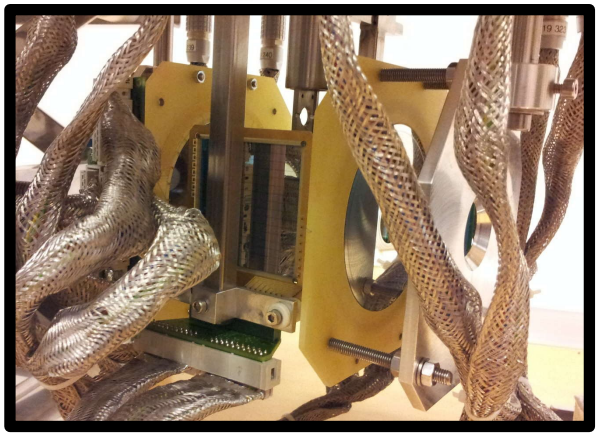
Solid angle coverage ~40%

Triple-alpha efficiency ~6%









Beam requirements

Energy: ~100 keV → ~4 MeV

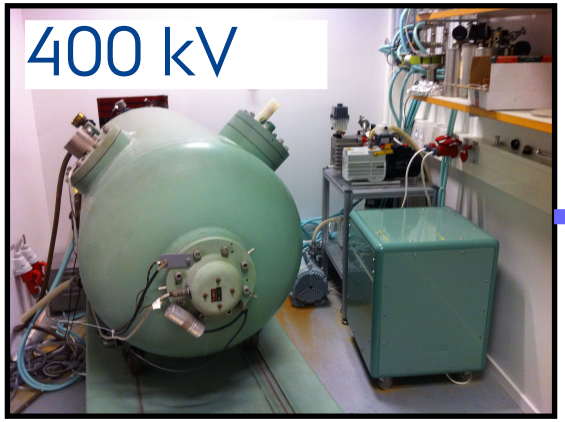
Current: ~1 nA

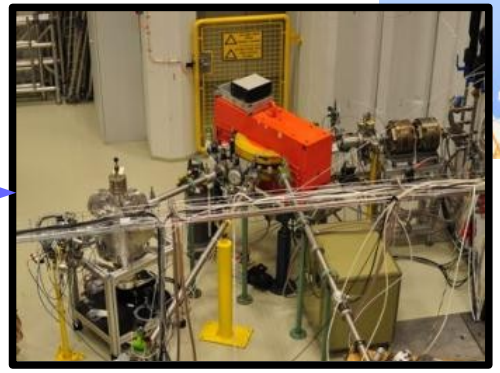
Running time: Many weeks

Two old Van de Graaf acclerators at Aarhus – mainly used for teaching and materials analysis in recent years

AARHUS
UNIVERSITET

Beam requirements





AARHUS
UNIVERSITET

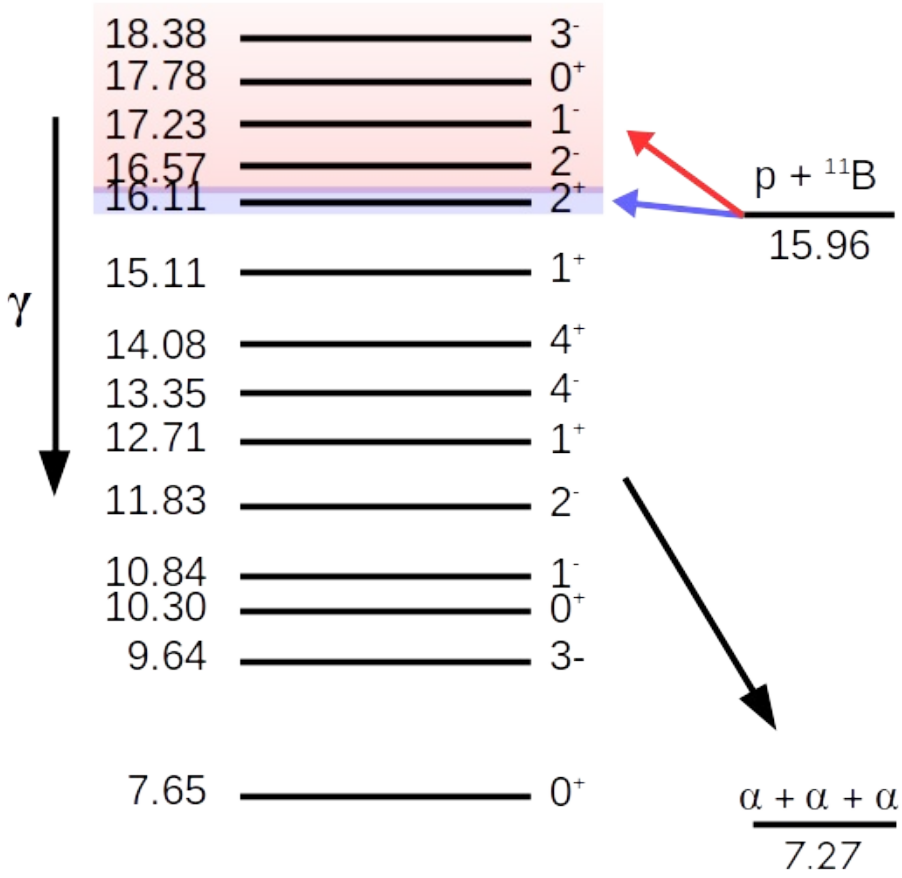
Experimental aims

Use ^{11}B + p to populate resonances

Observe triple-alpha final state

Several resonances energetically accessible

Test runs on multiple resonances to verify technique



AARHUS
UNIVERSITET

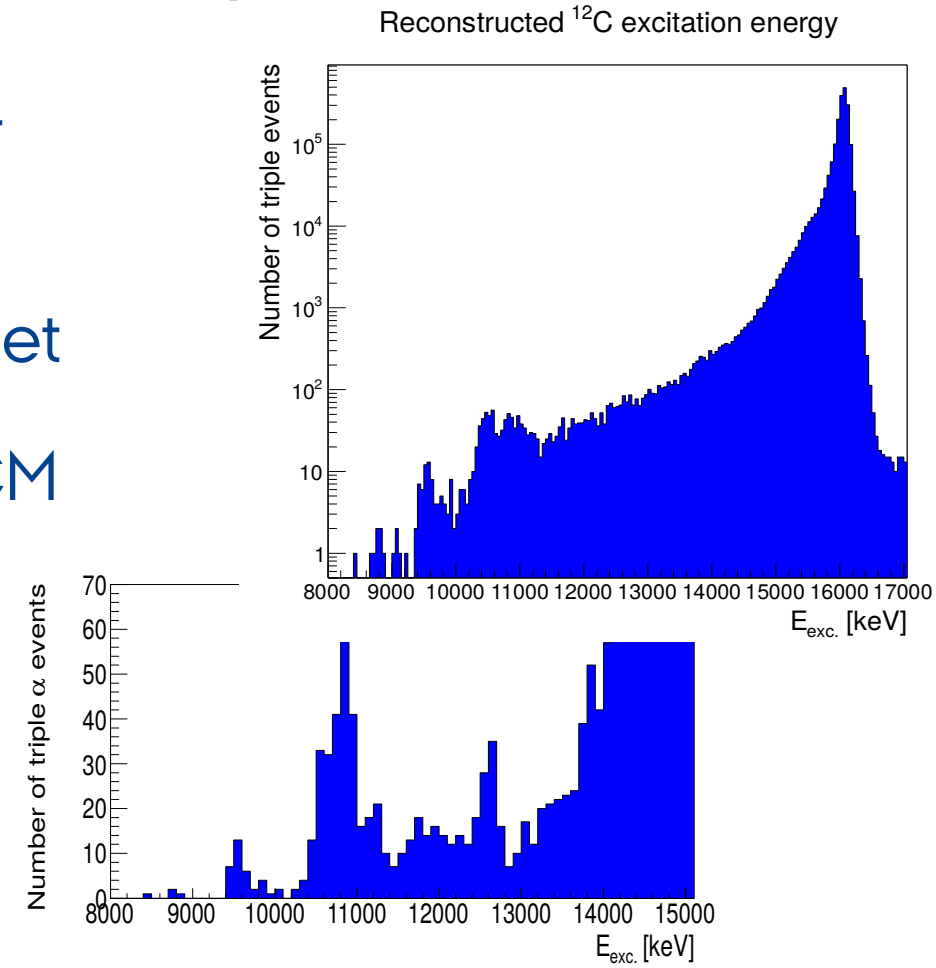
Reconstructing triple-alpha events

Gate on common timing for each DSSD

Detection in plane with target

Sum momentum = zero in CM

$$\mathrm{E_{exc.}} = \sum_{i=0}^{3} \mathrm{E}_{\alpha}^{\mathrm{CM}} + 7.275\,\mathrm{MeV}$$



Preliminary findings

First test using 16.11 MeV 2^+ resonance

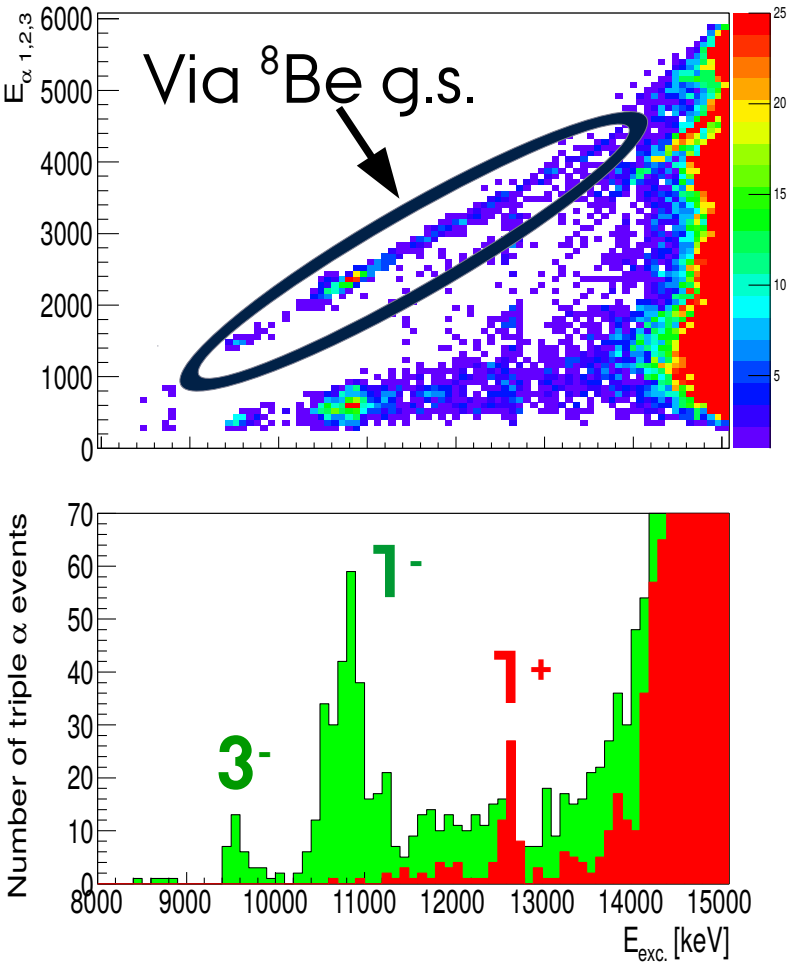
Gate on ^{8}Be g.s. discriminates natutal parity states

Known transitions to 1^+ and 3^- states observed

Transition to broad 1^- state previously unobserved

K. L. Laursen, Aarhus University

$p + {}^{11}B \rightarrow {}^{12}C(16.11, 2^+)$



Preliminary findings

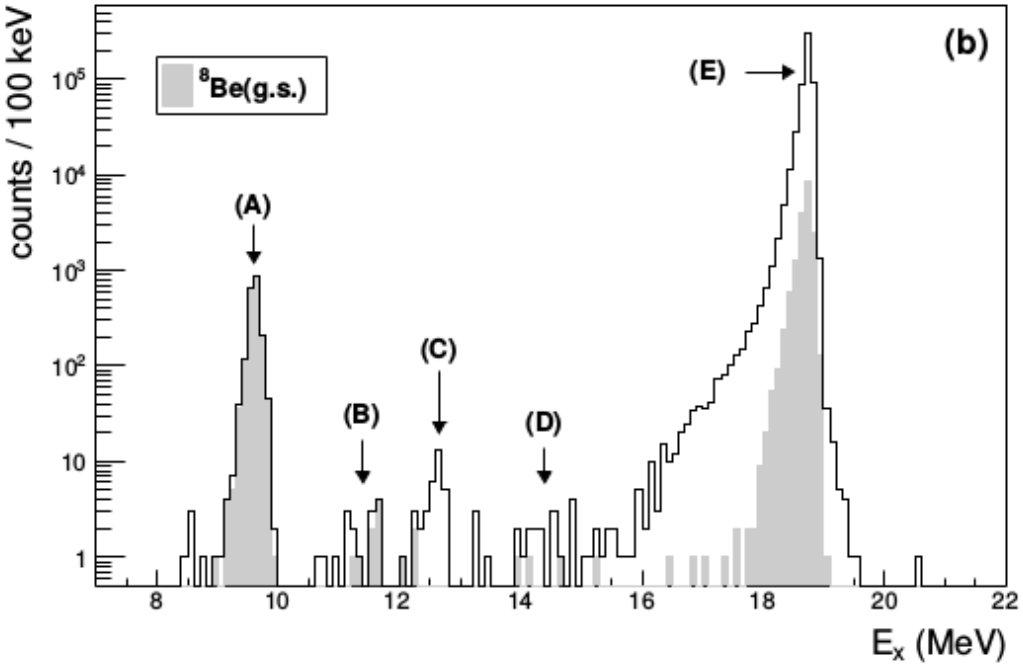
Additional data on 0^+, 2^+ and 3^- resonances

~30 hours of data each

Evidence for new transitions

(e.g. 18.81→ 12.71)

$p + {}^{11}B \rightarrow {}^{12}C(18.81, 2^+)$



Future

Run with an enriched ^{11}B target – reduce ^{10}B induced background

Improve timing resolution – reduce background from random coincidences

Simulations essential to fully understanding any remaining background and efficiency calculations

Long duration (>1 week) runs to increase statistics

Explore additional reaction channels – e.g. $^{11}B(^{3}He,d)$

Summary

Simple setup for studies of reactions in complete kinematics operational at Aarhus

Indirect detection of gamma-rays possible – sensitivity to transitions leading to broad resonances demonstrated

Analysis underway on several preliminary data sets

More complete results soon ….

Thank you for your attention!