Is (d,pγ) a surrogate for neutron capture?

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Motivation

- (n,γ) cross sections on unstable nuclei are important
  - Nuclear Astrophysics
  - Stockpile stewardship science

- Limitations for direct measurements
  - Need a radioactive target
  - $t_{1/2}$ must be a couple of hundred days or greater

(d,pγ) as a surrogate

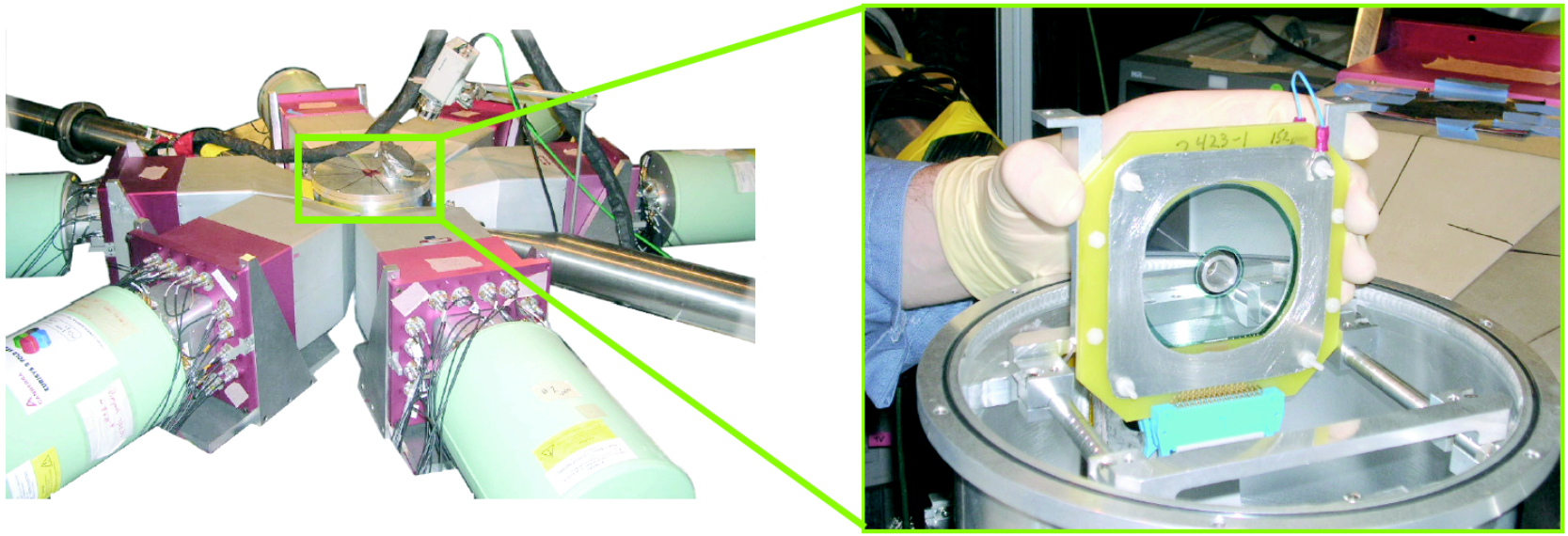
The (d,pγ) reaction:

- can be used to populate the same compound nucleus as (n,γ)
- In opposite to (n,γ) it can be measured in inverse kinematics with radioactive beams

To test the feasibility of a (d,pγ) surrogate a benchmarking experiment is needed:

- Using the surrogate ratio method
- Direct kinematics, stable targets with known cross sections
- The goal is to reproduce the cross section ratio of ^{171}Yb(n,γ) and ^{173}Yb(n,γ) (both have been measured directly)

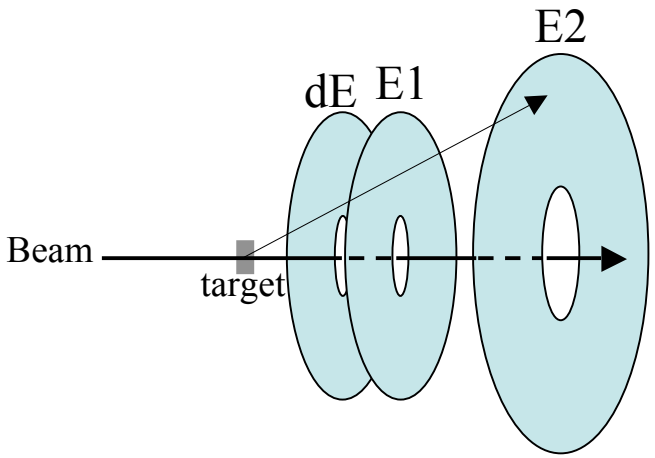
Experimental Setup



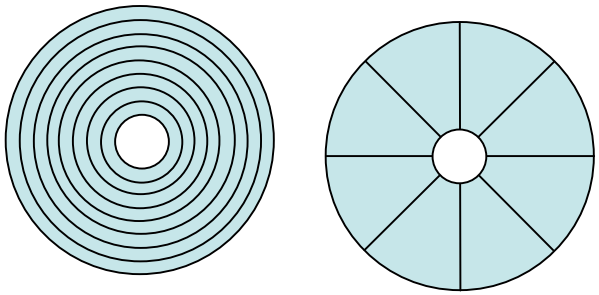
Target chamber surrounded by 6 Ge-Clover detectors to detect γ-rays

Si detector array in the chamber detects reaction protons.

STARS detector arrangement



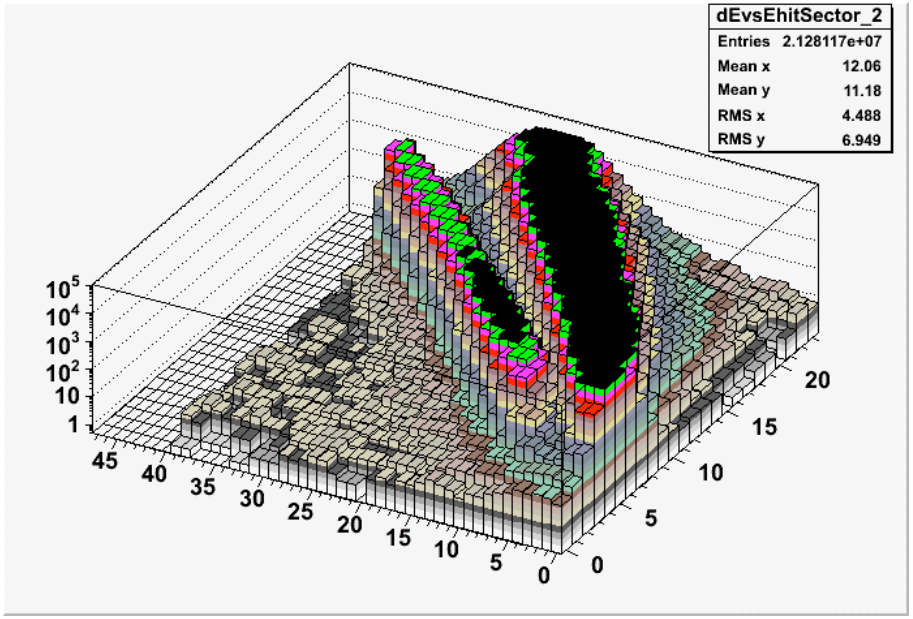
Front side divided into rings



Back side divided into sectors

- Targets: two isotopically enriched metallic foils of ^{171}Yb (0.981 mg/cm^2) and ^{173}Yb (0.502 mg/cm^2)
- Beam: 18.5 MeV deuterons of the 88" Cyclotron at LBNL
- 3 Si detectors for particle detection (STARS)
  - dE: 500 μm with 48 rings 16 sectors
  - E1: 1000 μm with 24 rings and 8 sectors
  - E2: 1000 μm with 16 rings and 16 sectors
  - Angular range covered: 44° to 73°
- 6 Ge clover detectors to detect coincident γ -rays (LIBERACE)

STARS properties

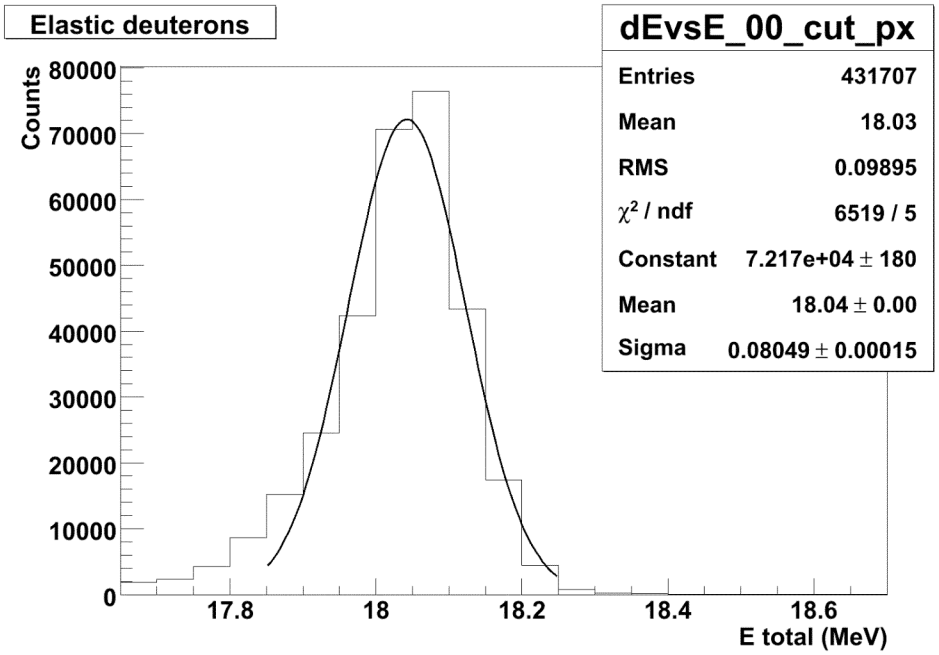


• Using the ring hit-pattern in both dE and E detector the particle can be ray-traced to the target.

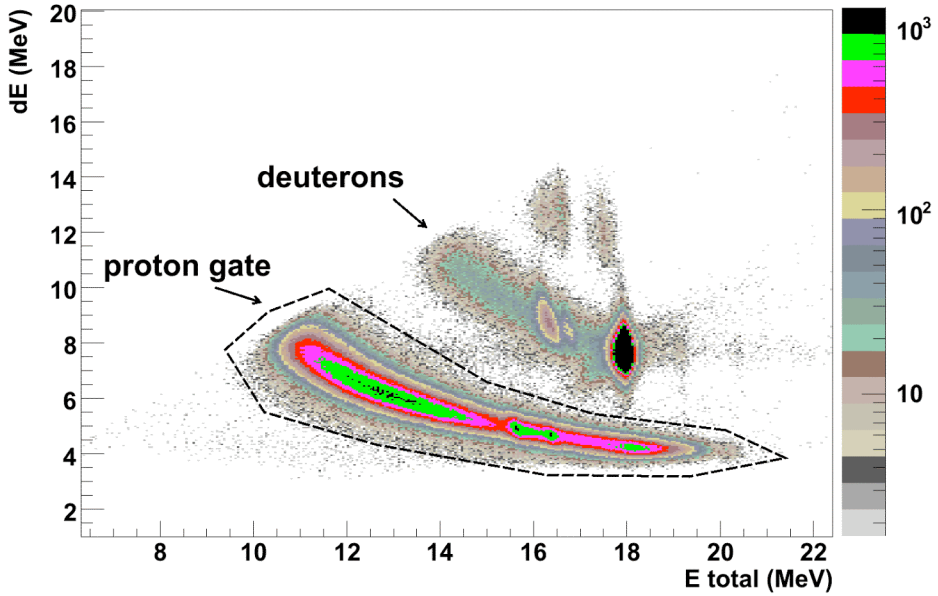
Elastic deuteron peak:

• Used to check energy calibration

• Shows resolution of array

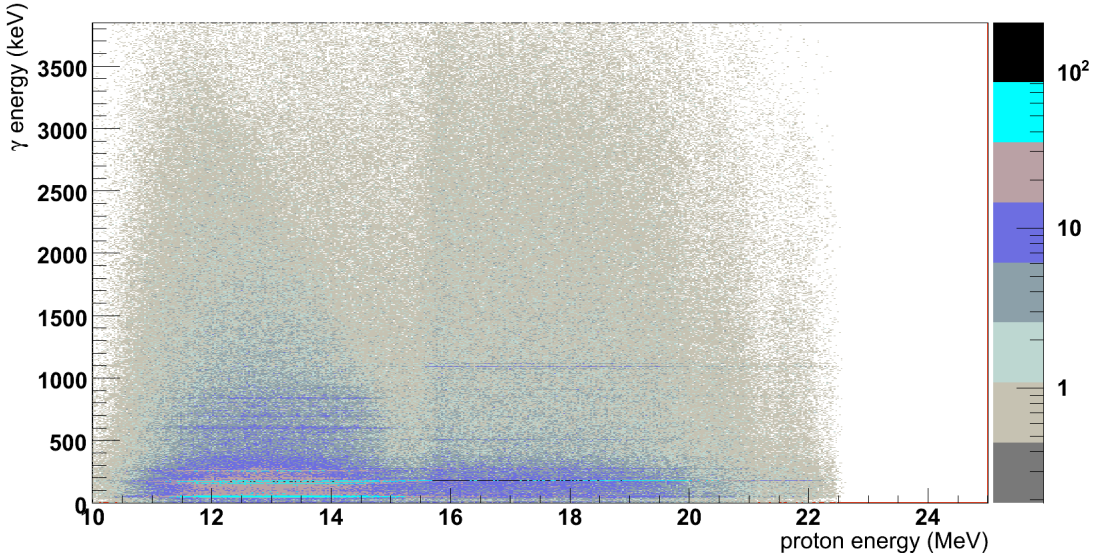


Particle ID

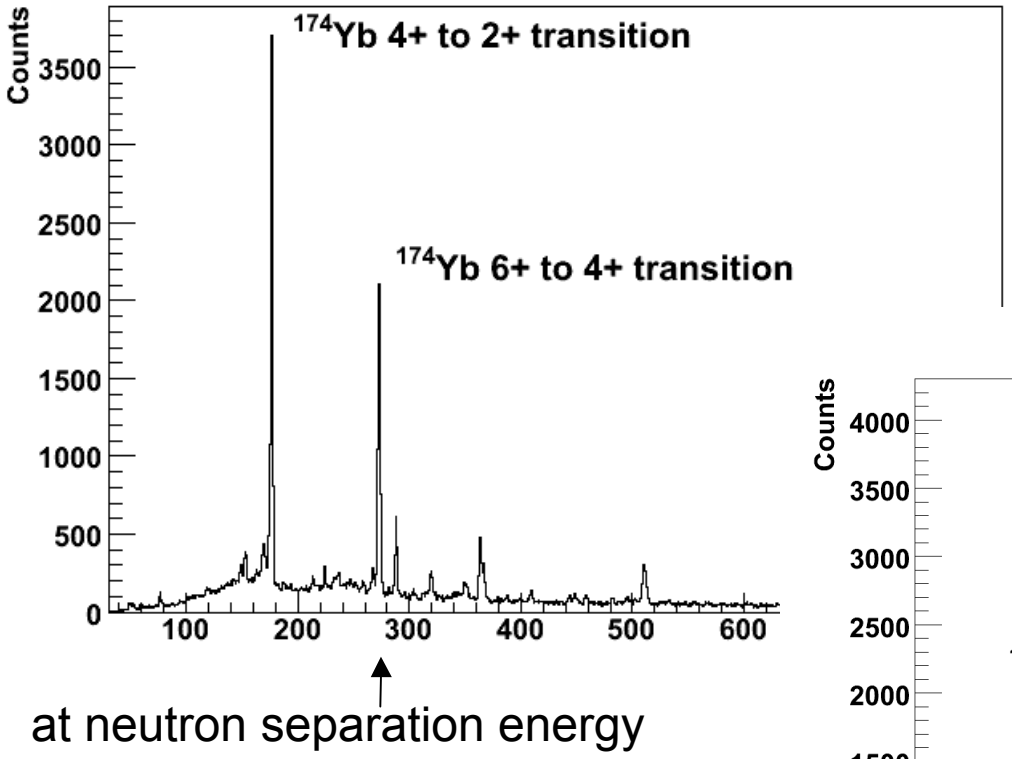


- The left figure shows particle identification using dE vs E of event
- One can gate on protons using a polygon cut

- Right figure shows proton energy vs γ-energy
- The proton energy region of interest is from 15 to 16.2 MeV

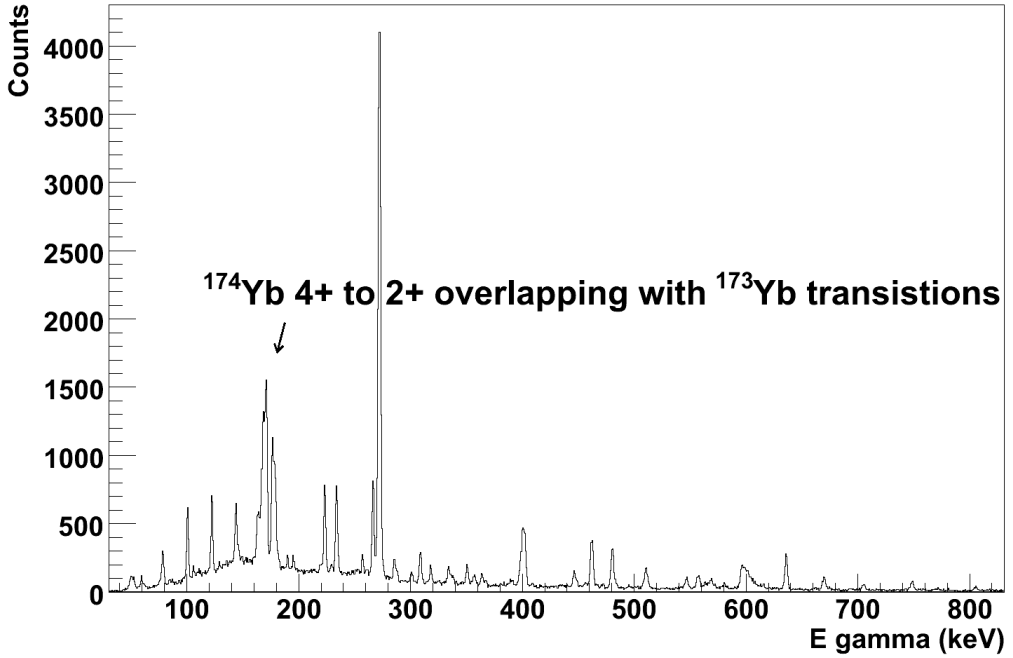


γ-ray spectrum

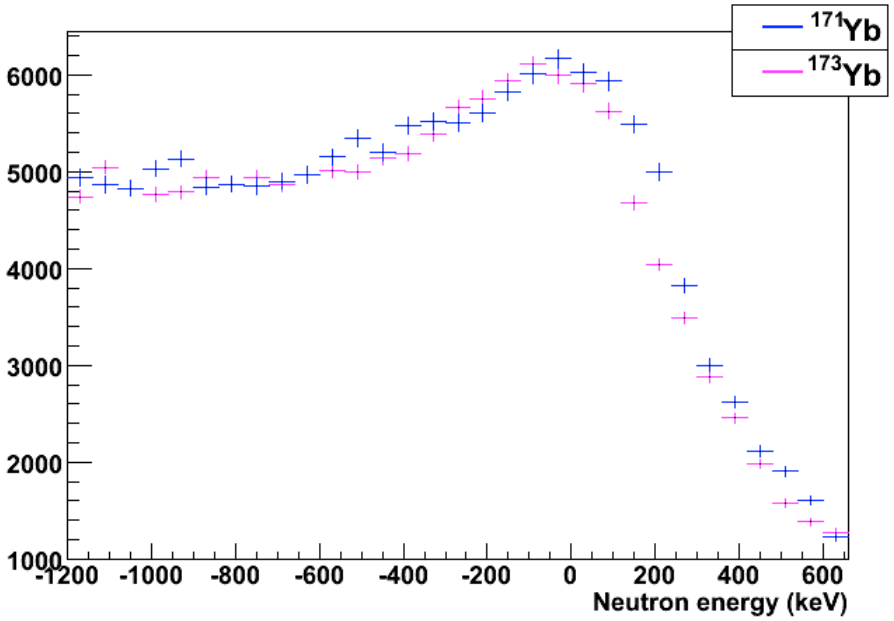


at neutron separation energy

at 1 MeV equivalent neutron energy



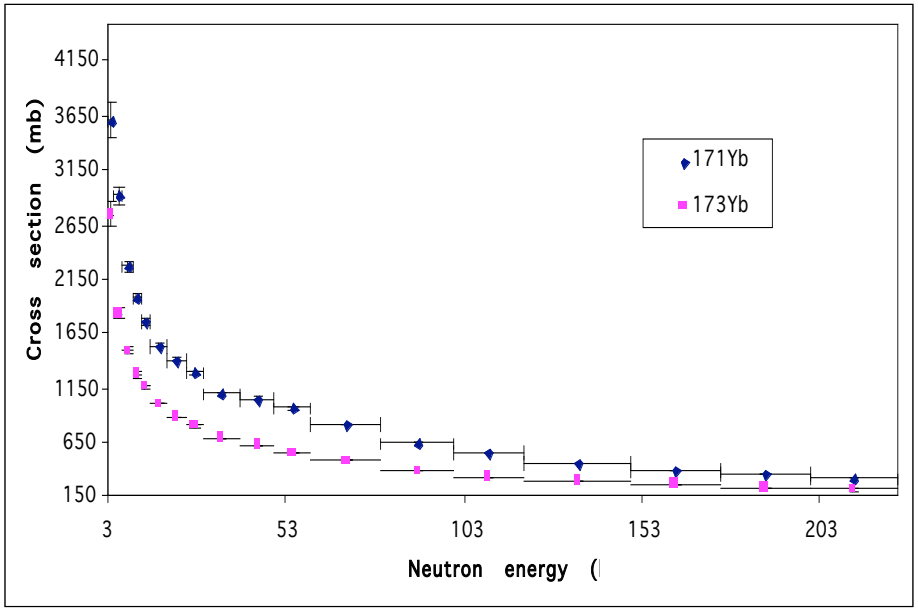
Count rate comparison



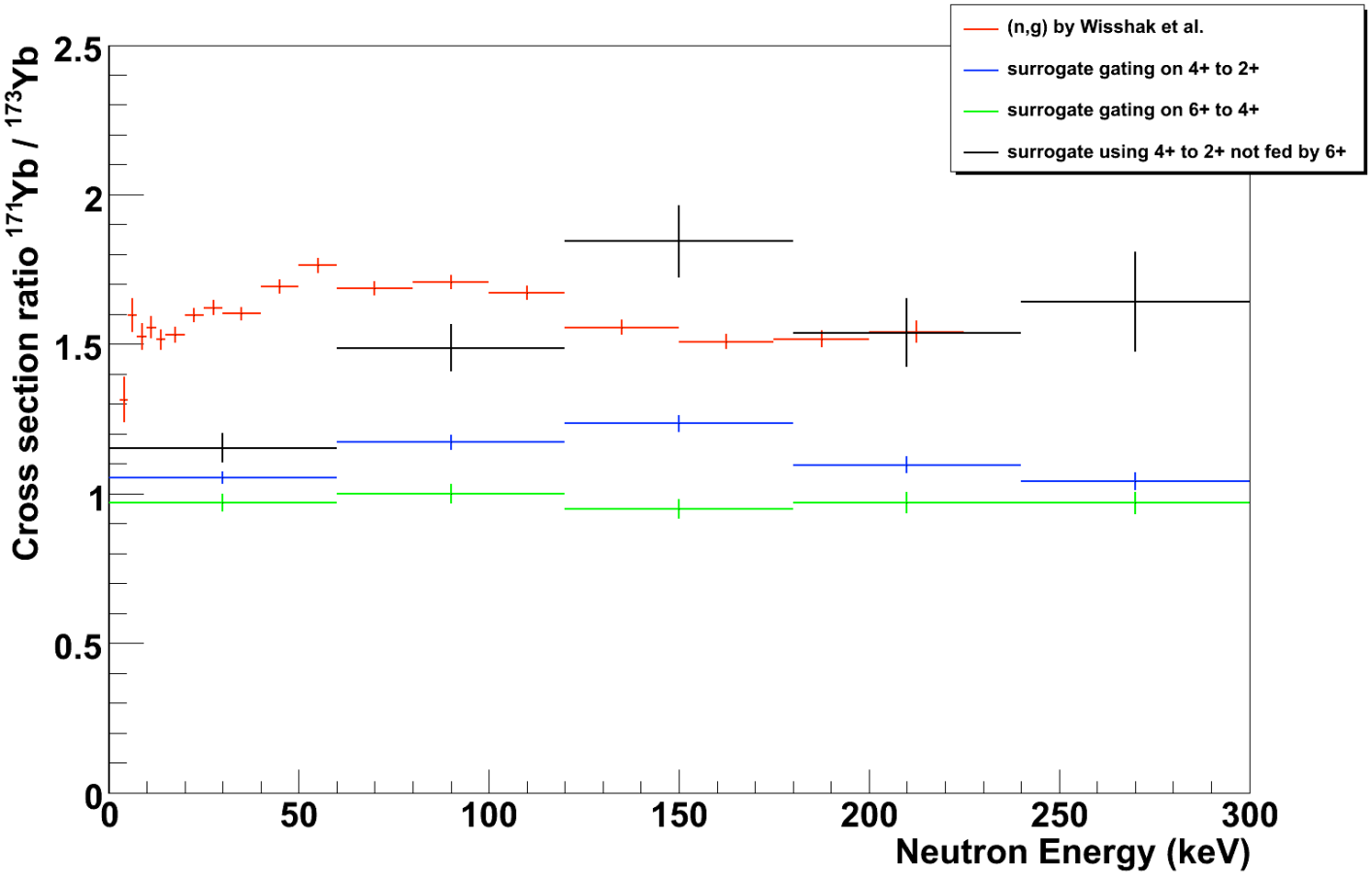
- Count rates obtained by gating on 4+ to 2+ transition
- higher energy is problematic for Yb isotopes, since levels of target isotope are overlapping with 4+ level of interest

Neutron capture cross sections for ^{171}Yb and ^{173}Yb

from K. Wisshak et al, Phys Rev C 61, (2000) 065801.



Preliminary cross section ratio results



Summary

- A (d,pγ) measurement in inverse kinematics is a potential candidate for a surrogate to determine neutron capture cross sections on radioactive nuclei.
- A ratio experiment reduces systematic uncertainties by a large factor.
- To test the feasibility of such an attempt a surrogate experiment in direct kinematics on the stable isotopes ^{171,173}Yb has been performed.
- Preliminary results show a discrepancy of about 35-15% to (n,γ) data, depending on the transition gated.
- Biggest problem is spin mismatch: both target had different ground state spin and (d,p) transfers more angular momentum than (n,γ)

Collaborators

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