$^{18}\text{F}(p,\alpha)^{15}\text{O}$ reaction at astrophysical energies

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What’s a Nova?

Stellar explosion that take place in binary systems:

**Cataclysmic variable:**
- WD + Main Sequence
- Roche lobe overflow

**Symbiotic system:**
- WD + Red Giant
- Accretion from a red giant wind
Nova explosion

- White Dwarf accretes mass through the Roche lobe Lagrangian point
- Red Giant accretes it radius
- In the H-rich zone starts the p-p chain
- When $T \approx 2.4 \cdot 10^7 k$ the CNO cycle starts \(\rightarrow\) end of accretion phase
- Hot phases
The synthesis of $^{18}$F in nova outbursts takes place within the hot-CNO cycle.

A. Coc et al. (2000)

**Hot CNO cycle**

Dashed and dotted circles represent beta unstable and proton unbound nuclei respectively. Dashed arrows represent reactions of negligible influence in novae.
So... why we have to study the reaction $^{18}\text{F} + \text{p} \rightarrow ^{15}\text{O} + \alpha$?

The amount of radiation emitted from classical novae strongly depends on the $^{18}\text{F}$ content of the envelope. The electron-positron annihilation, resulting from the beta decay of radioactive nuclei, produces Gamma-ray radiation (emitted after the explosion at 511 keV). The main contribution comes from the decay of $^{18}\text{F}$. 
The synthesis of $^{18}\text{F}$ is essentially controlled by five proton-capture reactions:

- $^{16}\text{O}(p, \gamma)^{17}\text{F}$
- $^{18}\text{F}(p, \gamma)^{19}\text{Ne}$
- $^{18}\text{F}(p, \alpha)^{15}\text{O}$
- $^{17}\text{O}(p, \gamma)^{18}\text{F}$
- $^{17}\text{O}(p, \alpha)^{14}\text{N}$

The $^{18}\text{F}(p, \alpha)^{15}\text{O}$ reaction is one of the main $^{18}\text{F}$ destruction channels. The study of the $^{18}\text{F}+p \rightarrow ^{15}\text{O} + \alpha$ reaction at astrophysical energy regions!
Experiment:
thick target method
(RIKEN, Japan)
Thick target method

We study the excitation function of the $^{18}\text{F}(p,\alpha)^{15}\text{O}$ in the center of mass energy region 370-630 keV.

- Experimental spectra were compared to calculated ones;
- The thick target was ideally divided in many thin slices;
- For each slice, we will assume that the interaction energy corresponds to its value at the middle of the slice, calculating the energy loss of the beam up to that point;
- The energy loss of outgoing particles in the rest of target and in the detector dead zone is also taken into account subtracted;
- Multiple scattering of the beam and outgoing particles in the target introduced a kinematical broadening that has to be simulated;
- The yield obtained from the experiment is hence the convolution of many contribution here;
- Calculated spectra have to be fitted to the experimental ones to fix the relevant parameters in the model/theory.
We used a secondary $^{18}$F beam (13.5 MeV) produced in the CRIB set-up by means of the $^{18}$O(p,n)$^{18}$F reaction.

Primary target (F0): $\text{H}_2$ gas-filled cell.

Thick target (F3): $\text{CH}_2$. 
Detection setup

**PPAC**: parallel plate avalanche counters

**DPSSD**: double position sensitive silicon detectors

**DSSSD**: double sided silicon strip detectors
We wrote the “Two-B-Monte” Monte Carlo to simulate the experiment.

The beam profile from two body “Two-B-Monte” Monte Carlo and from an analytical formula fitted to experimental data are compared.

Sigma-theo=1.1489 MeV
Mean-theo=13.3 MeV
Kinematics (kin2) and "Two-B-Monte" are compared
The spectra shows the correspondence between experimental energy distribution and Monte Carlo simulation for elastic scattering of $^{18}\text{F}$ on gold target.
Rutherford scattering of $^{18}$F+ $^{197}$Au.

The angular dependence of the outgoing particles beam is reproduced reasonably well by the two-body Monte Carlo simulation.
We need to make cuts in phase space in order to recognize events and select the particles that come from events of interest for us.
What next?
After we select the events of interest, the next steps will be:

- reconstruct the experimental spectra of interest;
- fit these spectra with a model/theory in order to fix the relevant parameters.

We are working on this!!!

Thanks for your attention!