

# CROSS-SECTION MEASUREMENTS FOR $^{nat}\text{Zn}(n, p)^{64, 67}\text{Cu}$ REACTION

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# Abstract



hola

This is for me.



# Acknowledgements

THANKS

Thank you grandmother, for being my safe place, even now.

*Nora Irene Jensen Pettersen*

DATO





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# Chapter 1

## Introduction

*“Count only the good days.”*

— Irene Jensen, Ahus 2017

A short introduction to nuclear medicine



# Chapter 2

## Theory

*quote*

— by,

### 2.1 Background of Nuclear medicine

- why does it work
- how we have been doing nuclear medicine
- what isotopes are we currently using in clinics
- problems with it
- my work

### 2.2 Radioactive decay

- what is it

### 2.3 Decay modes

- why are these useful for nuclear medicine (therapy and diagnostics)

#### 2.3.1 $\beta$ -decay

Decay by  $\beta$  can happen by  $\beta^-$ , EC (see Auger electrons) or  $\beta^+$  decay.  
 $\beta^-$ :

$$n \rightarrow p + e^- + \bar{\nu}_e \quad (2.1)$$

$\beta^+$ :

$$p \rightarrow n + e^+ + \nu_e \quad (2.2)$$

For therapy,  $e^-$  will travel longer in a medium than  $e^+$  (will annihilate fast). **WHY?**  $e^-$  will ionize matter on its path and we want to take advantage of that. Therefore, it is  $\beta^-$  decay we are interested in when we treat a patient.  $\beta^+$  decay are used in diagnostic. If we want to take a picture of the biological activity in a patient,  $e^+$  is the source of interest for usage of PET scans, which I will discuss in section 4.1.

Compared to  $\alpha$  particles,  $\beta$  particles travels a lot further and creates less ionization to the surrounding medium on its path. This is important when the biological effect matters. There are however, difference in the range of various of isotopes that undergo  $\beta$  decay. Short range  $\beta$ -particle emitters have a relatively short range, a couple of  $\mu m$ , in tissue that is suitable for treatment of small tumor metastases. The  $\beta$ -emitters with long range in tissue can penetrate with an average of more than 2 mm and can be used to treat i.e. rheumatoid arthritis, which is an autoimmune disorder that often affect joints.

The energy of  $\beta$  particles are not distinct, but rather more spread out in a spectrum.

The spectrum in figure shows how the energy are divided between the electron and the anti neutrino. The electrons of beta particles will interact with the surrounding electrons by dismissing the it from its orbit and producing a ion pair or cause excitation. Since the amount of damage tissue is related to LET and  $\beta$  particles penetrates further in to a medium than  $\alpha$  particles,  $\beta$  particles has lower LET than  $\alpha$  does. Exposure to  $\beta$  results therefore in less damage.

$^{90}Y$  is one popular long range isotope used in therapy, it has a mean range of 3.900  $\mu m$  and an average energy of 935 KeV, while a widely used short range beta emitter is  $^{131}I$ . It has a mean range of 910  $\mu m$  and an average energy of 182 KeV. The energy will vary from almost zero to the maximum energy, and the average energy is approximately one third of the maximum energy. For therapy, the mean energy dependent mean and maximum range in tissue for beta emitters.

### **2.3.2 Electron capture, Internal conversion and Auger electrons**

### **2.3.3 $\gamma$ -decay and X-rays**

### **2.3.4 Theranostic**





# Chapter 3

## Cu64,67

*“- The idea that everyone is supposed to buy into stuff without questioning it, is the reason why we are 51 year old 16 year olds.  
- Dude, I agree. ”*

— Joe Rogan and Duncan Trussel

### 3.1 what can we do to make the nuclear medicine better?

- medical prespecctive: we wan to introduce a new theragnostic pairs to use in hospitals
- how wonderful Cu64,67 are
  - properties
  - papers
  - better than a lot of the studff we are already using
  - motivation for my work
- can adjust ratio for 64,67 Cu by tuning the energy of the beam

#### 3.1.1 My motivation

#### 3.1.2 Physics motivation

- cu64,67 are amazin but now, we have not a good way for making them. tell about my way of create them
  - deuterium breakup (n,-) way
  - how we are doing it



# Chapter 4

## The experiment

*quote*

— by

### 4.1 The facility

- tuning of beam

### 4.2 Cyclotron

- k-value (discuss energies for hospital cyclotrons and what energies for Cu64,67), what is it, how does it work
- no more than a page or two (look at other theses to see how deep you should go)

### 4.3 Deuterium breakup process

- and how it is useful for creating neutrons (broad energy spectrum that we can tune in terms of energy, intense neutron source (makes a lot of neutrons) focused beam of neutrons)
- moulders paper and other

### 4.4 Stack design

- photos and stuff
- monitor foils

### 4.4.1 Radiation

- how long time
- beam current
- beam monitor to measure the
- plot the beam current as a function of time to justify that we can make the math that we do

### 4.4.2 Counting

- after each radiation, we removed the foils to the counting room (how long did this take?) hvor lang ti tok det fr vi begynte telle etter EOB?

## 4.5 Gamma spectroscopy

- Detector
- forklare hvor dypt jeg skal g inn i physics (doping, n-p junction)
- pair production, Compton og photoelectric effect

## 4.6 Gamma spectra

- deadtime, og alt det der

## 4.7 Calibrating

- detector efficiency
- curves at different position

# Chapter 5

## Analyse

*“If you ever start thinking too seriously, just remember that we are talking monkeys on an organic spaceship flying through the universe”*

— Joe Rogan

### 5.1 Fitz peak

- Data to activity ( the math). Peak counts to activity
- i - Aktivit t to A\_EOB
- Production physics (Analyse eller Resultater?) - how we calculate cross-section, the work with John to use the monitor data to neutron fluxes that I'm going to use for calculate the cross section for my isotopes

#### 5.1.1 Regression process

### 5.2 Production physics



# Chapter 6

## Results and dscussion

- Cross sections for all the isotopes
- experimentall data with the data that has been meassured so fare

### 6.1 TALYS

- tolking av resultat. Hvilke energier er best i forhold til hva vi ser?
- Verdien av dette i fremtiden?
- how can we desien target for kunne produsere mer Cu67. hvilke cyclotrons can we use for that?





# Chapter 7

## Summary and outlook

### 7.1 Future work

*quote*

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