

ICTR-PHE 2016



Differential cross sections measurements for hadrontherapy: 50 MeV/A ^{12}C reactions on H, C, O, Al and ^{nat}Ti targets.

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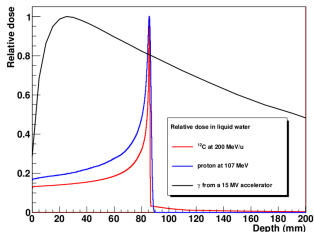
ENSICAEN, Université de Caen, CNRS/IN2P3, Caen, France

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PhD. Thesis supervised by Daniel Cussol, Marc Labalme and Samuel Salvador.

Introduction

Hadrontherapy



- ▶ Better control of dose deposition
 - ▶ The heavier the ion, the less lateral scattering
 - ▶ Better Relative Biological Effectiveness (Efficiency to kill cells)
- ⇒ But nuclear interactions → fragmentation.
- Attenuation of beam ions at Bragg Peak
 - Delocalisation of the dose (*fragmentation tail*)
 - Mixed irradiation field

More accurate treatment planning → Cross-section measurement on thin targets

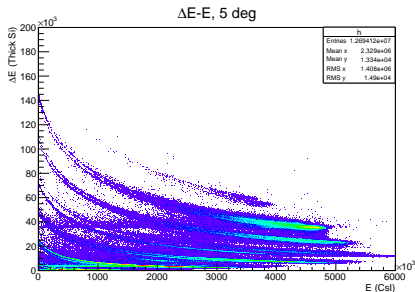
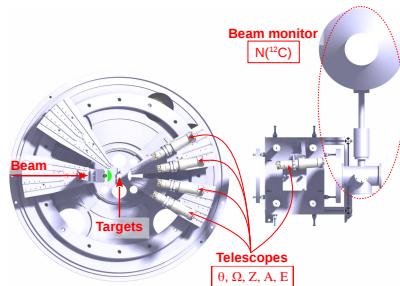
- ▶ 95 MeV/A ^{12}C at GANIL in 2011 and 2013
- ▶ 50 MeV/A ^{12}C at GANIL in 2015 → PhD. subject

Targets : C, CH₂, Al, Al₂O₃, ^{nat}Ti ⇒ C, H, O, Ca (95% of human body)

March 2015: 50 MeV/A experiment (FRANCE HADRON beam time)

Experiment set-up

- ▶ 50 MeV/A ^{12}C beam
- ▶ 5 Telescopes (Si-Si-CsI)
 - $3^\circ + 5-39^\circ$
- ▶ Different targets of medical interest (C, CH_2 , Al, Al_2O_3 , ^{nat}Ti)

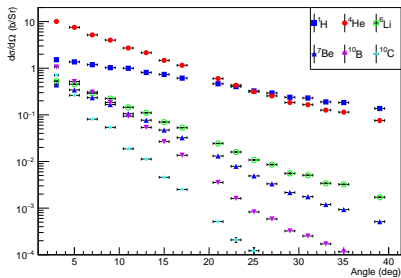


Analysis

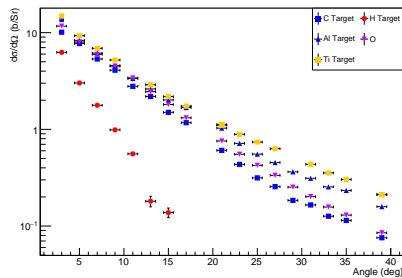
- ▶ Particle identification ($\Delta E - E$ plots)
 - ▶ Z, A, E, θ
- ⇒ Double differential cross-sections $\frac{d\sigma^2}{dE d\theta}$

50 MeV/A: Angular Distributions - Results

Carbon target for several isotopes



^4He on several targets (H, O reconstructed)



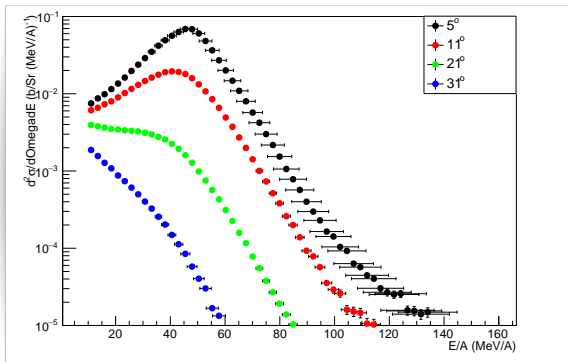
- ▶ Predominance of ^4He up to $\sim 20^\circ$
- ▶ Isotope mass hierarchy \sim respected
- ▶ The more massive, the more peaked

- ▶ Target mass hierarchy respected
- ▶ No contribution of $Z \geq 2$ for H target at large angles

Available for every isotope (^1H to ^{12}C) and every target

50 MeV/A: Energy Distributions

Energy Distribution for ^4He and various angles



- ▶ Energy threshold:
~10 MeV/A
- ▶ Peaked at the beam energy (small angles)

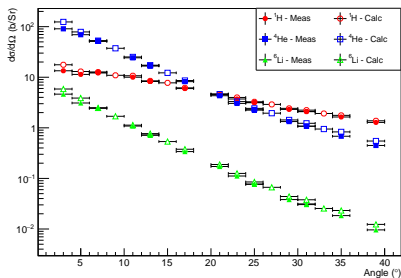
Available for every isotope, every angle and every target

50 MeV/A: Reconstructed PMMA target

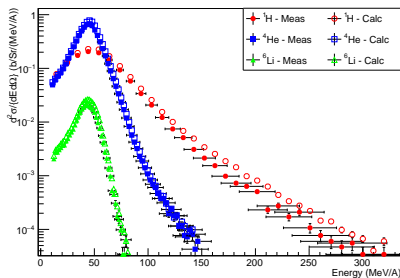
PMMA: $\text{C}_5\text{H}_8\text{O}_2$

$$\frac{d\sigma}{d\Omega}(\text{C}_5\text{H}_8\text{O}_2) = 5 \times \frac{d\sigma}{d\Omega}(\text{C}) + 8 \times \frac{d\sigma}{d\Omega}(\text{H}) + 2 \times \frac{d\sigma}{d\Omega}(\text{O})$$

Angular distribution



Energy distribution

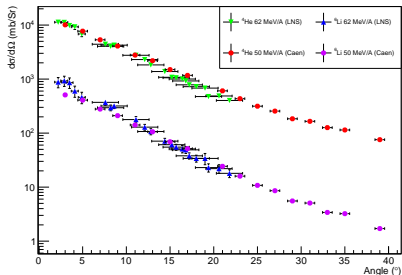


► Good agreement

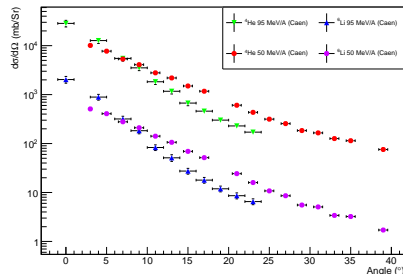
⇒ Possibility to reproduce most of organic tissues

50 MeV/A: Angular Distributions - Comparisons

Comparison with LNS Data (62 MeV/A)¹



Comparison with 95 MeV/A experiment²



- ▶ Similarities expected
- ▶ Good agreement

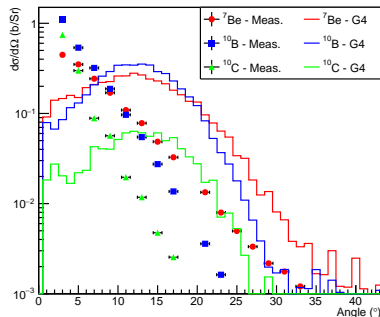
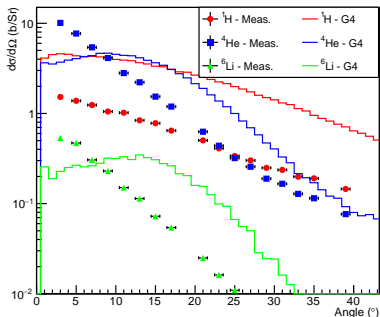
- ▶ Less forward focused distributions
- ▶ "Flatter" distributions

¹Phys. Med. Biol. 57 (2012) 76517671

²Phys. Rev. C 88, 024606 Published 12 August 2013

50 MeV/A: Simulations

Comparison between GEANT4.10 (QMD) and data



- ▶ Large differences
- ▶ Peaked distributions at $\sim 15^\circ$
- ▶ Also observed at 95 MeV/A

Conclusion

Data analysis almost completed

- ▶ All targets analyzed
- ▶ Systematic errors estimation ongoing
 - ▶ Full simulation of the experiment
- ▶ Benchmark of available models
- ▶ Will soon be submitted for publication

Cross sections measurements

- ▶ 50 MeV/A & 95 MeV/A (last 2 cm of the range)
- ▶ Up to 400 MeV/A → ARCHADE center

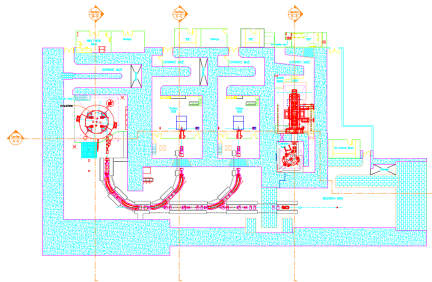
- ▶ Data will be available online with free access:
<http://hadrontherapy-data.in2p3.fr/>

- ▶ Constrain models or use as input data in simulations

Outlook: Future cross-sections measurement

ARCHADE

- ▶ Research facility in Caen (FR) for carbon therapy
- ▶ Construction begun on December 4th 2015
- ▶ First ^{12}C beam: ~ 2021
- ▶ 100 to 400 MeV/A ^{12}C beam (and all $A/Z = 2$)
- ▶ LPC: design & development of FRACAS



FRACAS

- ▶ **FRACAS: FR**agmentation of **CA**rbon and **Cross Sections**
- ▶ Large acceptance mass spectrometer
- ▶ $\Delta E - \text{ToF}$ technique

