# Validation of Geant4 fragmentation models in <sup>4</sup>He ion therapy

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## Helium ion therapy

- Growing interest in helium ion therapy in recent years
  - Patients treated at GSI
- Presents middle ground between proton and carbon ion therapy
- Monte Carlo becoming more widely used in medical physics including treatment dose planning verification
- Critical to know the behaviour of models used for medical physics applications
  - This study presents the validation of Geant4 for helium ion therapy in terms of it fragment production and distributions (angular and energy)



## Comparison to experimental data

- Comparisons performed using version 11.00 of Geant4
- Evaluated the following hadronic models:



## Results



#### Angular distributions – Rovituso et al.



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### Angular distributions – Marafini et al.

	Model	$111 > 0^{\circ}$	$211 > 0^{\circ}$	$311 > 0^{\circ}$	🕂 Exp 🕚 BIC 📕 QMD 🔺
≥0		$H = >0^{-1}$	$-H = >0^{-1}$	$H = >0^{-1}$	– . 102 MeV/u . 125 MeV/u
	102MeV/u	4710	45 1 10	05115	
	BIC	$47\pm6$	$45 \pm 12$	$65\pm17$	
	QMD	$47 \pm 7$	$46 \pm 12$	$78 \pm 38$	200 500
	INCL	$30{\pm}4$	$34\pm24$	$84\pm20$	
	$125 \mathrm{MeV/u}$				
	BIC	$56 \pm 6$	$34 \pm 5$	$73 \pm 44$	
	$\operatorname{QMD}$	$59 \pm 7$	$42 \pm 8$	$75 \pm 42$	
	INCL	$42 \pm 5$	$38 \pm 9$	$82\pm55$	
	145 MeV/u				
	BIC	$49 \pm 8$	$32 \pm 13$	$75 \pm 31$	— <u>≥10<sup>-3</sup> Angle (deg)</u> Angle (deg) 350 — 1
	QMD	$57 \pm 9$	$53 \pm 19$	$73 \pm 17$	300 <sup>2</sup> <sup>2</sup> H
	INCL	$39 \pm 5$	$40 \pm 17$	$78 \pm 24$	
>10	Model	$^{1}{\rm H} => 10^{\circ}$	$^{2}H => 10^{\circ}$	${}^{3}\mathrm{H} => 10^{\circ}$	
	102 MeV/u				
	BIC	$30{\pm}4$	$36 \pm 16$	$53 \pm 17$	
	QMD	$28 \pm 6$	$36 \pm 16$	$73 \pm 50$	50
	INCL	$6\pm1$	$23 \pm 34$	$80 \pm 26$	0 10 15 20 25 30 35 0 5 10 15 20 25 30 0 Angle (deg) Angle (deg)
	125 MeV/u				
	BIC	$35 \pm 4$	$13 \pm 6$	$70 \pm 59$	- 400 H
	QMD	$39 \pm 5$	$21 \pm 10$	$73 \pm 56$	
	INCL	$17 \pm 2$	$25 \pm 13$	$77 \pm 75$	
	145 MeV/u				
	BIC	24±4	$11 \pm 18$	$73 \pm 44$	
	OMD		20107	CO + 01	
	QMD	$36 \pm 6$	$38 \pm 27$	$09\pm 21$	
	INCL	$\frac{36\pm6}{13\pm2}$	$38\pm27$ $31\pm25$	$69\pm21$ 70±30	



6

Angle (deg)

## Comments on angular distribution

- More forward angles (~10 degrees) agree very poorly
- Simulation has better agreement with Rovituso than Marafini
  - Rovituso measurements performed at approximately half thickness of BP
  - Marafini measurements just after BP
  - Model compounds
- INCL gives best agreement for <sup>1</sup>H (most abundant fragment)



7

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## Fragment build up curves

Rovituso et al. 2017, PMB





## Summary

- Validation of Geant4 for helium ion therapy in terms of it reproducing three fragment measurements
- Angular distributions
  - All three models evaluated in Geant4 give very poor agreement with experiment for forward angles
  - Improvements to models desirable
  - INCL best reproduces <sup>1</sup>H fragments (most abundant fragment)
- Fragment yields
  - Must be very careful when comparing fragment yields

