Therapeutic Helium Beams in Magnetic Fields: Measurements of Corrections Factors for Cylindrical Ionization Chambers

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Purpose

Helium ions are a promising alternative to protons and carbon ions in particle therapy (PT) due to their intermediate physical and biological characteristics. In MR-guided PT, Lorentz force in magnetic fields (MF) influence the response of ionization chambers (ICs). While such effects were studied for protons and carbon ions, this work addresses the gap by investigating the MF-dependence of cylindrical ICs in helium beams.

Materials & Methods

Setup: Effective point of measurement (EPOM) of ICs positioned at water-equivalent depth of 2 cm [1].

Detectors: Six thimble-type chambers, all from PTW, Freiburg, Germany (Table 1).

Source: 10 x 10 cm^2 helium ions (99.5, 220.8 MeV/u).

Correction factors: polarity correction k_{pol}, ion-recombination k_{s}, magnetic-field correction $k_{\vec{B},M,Q}$.

Magnetic field: perpendicular to detector and beam axis, 1 T for k_{pol} and k_{s}; ± 0.25, ± 0.5, ± 1 T for $k_{\vec{B},M,Q}$.

Evaluation protocol: IAEA TRS-398 formalism [2].

Results

k_{pol}: No dependence on energy, MF or chamber volume is observed. The largest deviation from unity occurred for the Semiflex 31010 at 0 T. Results are summarized in Table 1.

k_{s}: No MF dependence was observed, but a clear energy dependence of ~ 0.7 % was found, with larger corrections at the higher energy. This is attributed to a more spatially concentrated beam for the 220.8 MeV/u primaries, which results in a higher peak dose rate. No dependence on chamber volume was observed. Results are summarized in Table 1.

$k_{\vec{B},M,Q}$: The largest IC (Farmer 30013) showed minimal effect below 0.5 % (Figure 1), with smaller chambers exhibited a stronger MF-influence (deviations up to 1.5 % at ±1 T). An anti-symmetrical response was observed upon MF polarity reversal. No clear energy dependence was resolved within the measurement uncertainty.

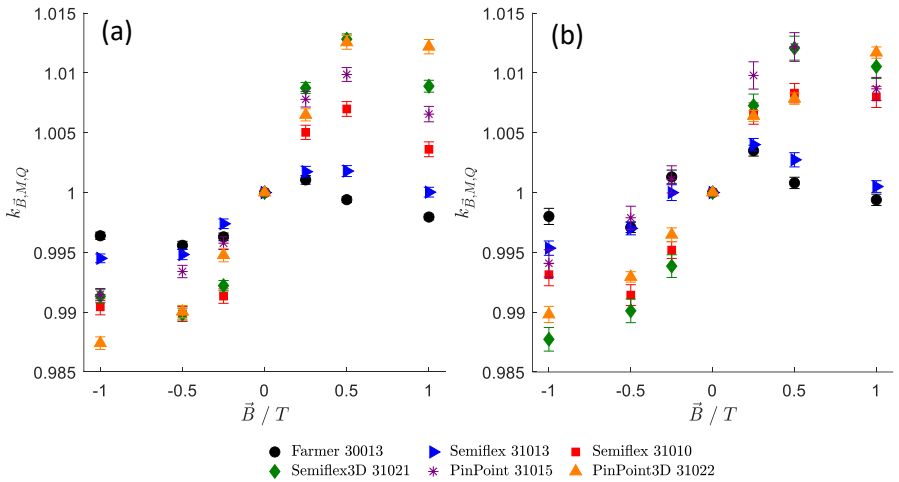

Figure 1. $k_{\vec{B},M,Q}$ for six detectors at two beam energies: (a) E = 99.5 MeV/u and (b) E = 220.8 MeV/u. ICs are ordered by decreasing sensitive volume from top left to bottom right (see legend).

Conclusion

For helium beams, k_{pol} and k_{s} are unaffected by MF strength of 1 T, indicating stable chamber response for all tested ICs. $k_{\vec{B},M,Q}$ results suggest an increased sensitivity of small-volume chambers to MF-induced effects, warranting further investigation of the role of sensitive volume in MF-dependency.

Detectors	E / MeV/u	B / T	k_{pol}	k_{s}
Farmer 30013	99.5	0	1.00037(14)	1.00360(6)
		1	1.00035(16)	1.00415(4)
	220.8	0	0.9997(36)	1.0055(10)
		1	1.0002(36)	1.0065(10)
Semiflex 31013	99.5	0	1.0006(2)	1.00305(4)
		1	1.0009(2)	1.00323(7)
	220.8	0	1.0008(3)	1.00518(7)
		1	1.0008(3)	1.00235(5)
Semiflex 31010	99.5	0	1.0068(4)	1.00235(5)
		1	1.0064(3)	1.00236(5)
	220.8	0	1.0068(7)	1.00308(12)
		1	1.0066(11)	1.00324(16)
Semiflex 31021	99.5	0	1.0012(2)	1.00373(8)
		1	0.9997(3)	1.00374(5)
	220.8	0	1.0017(5)	1.00553(11)
		1	1.0032(7)	1.00552(10)
PinPoint 31015	99.5	0	0.9999(2)	1.00097(3)
		1	1.0002(4)	1.00095(5)
	220.8	0	0.9989(5)	1.00127(6)
		1	0.9995(6)	1.00121(8)
PinPoint 31022	99.5	0	0.9974(5)	1.0006(1)
		1	0.9979(3)	1.0011(1)
	220.8	0	0.9954(9)	1.00122(17)
		1	0.9930(7)	1.00117(20)

Table 1. k_{pol} and k_{s} for six detectors, ordered by decreasing sensitive volume (top to bottom). Values in the parentheses indicates the standard type-A uncertainty in the last digit(s).

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References

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