

Development of water equivalent phantoms for the measurement of FWHM and penumbra in Gamma Knife using GafChromic film

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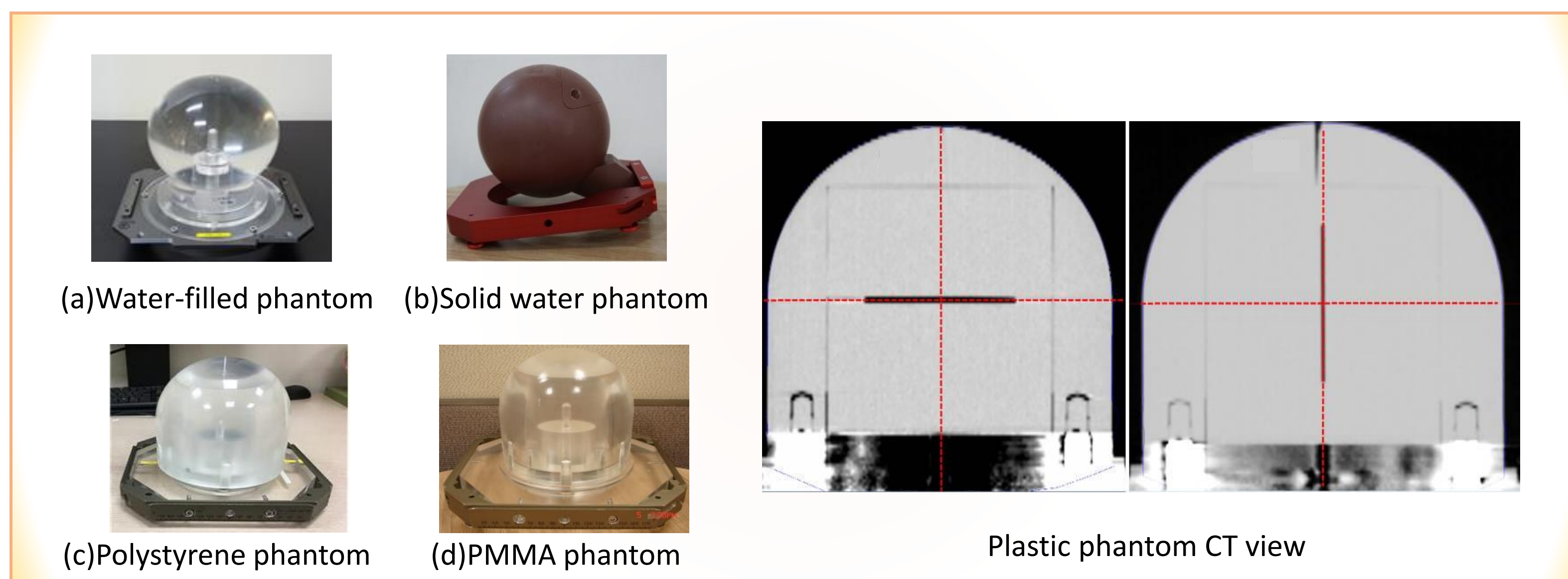
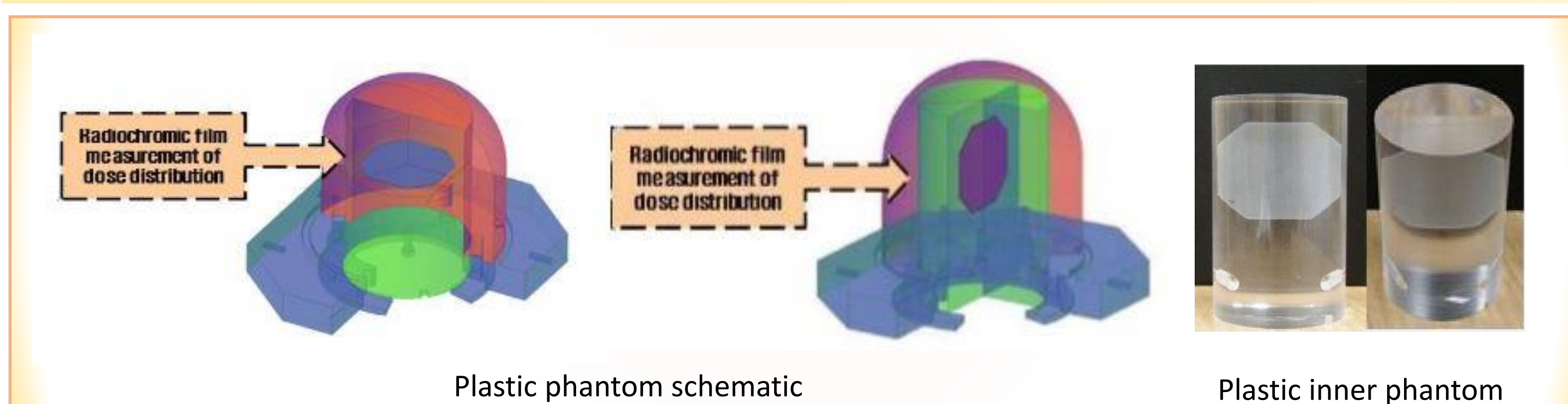
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Purpose

To investigate the scattered photon contribution of the three plastic (Polystyrene, PMMA, Solid Water) phantom to the absorbed dose profile in Gamma Knife radiosurgery facility by determining full width half maximum (FWHM) and the physical penumbra using EBT3 GafChromic film and three plastic phantoms

Material and Methods



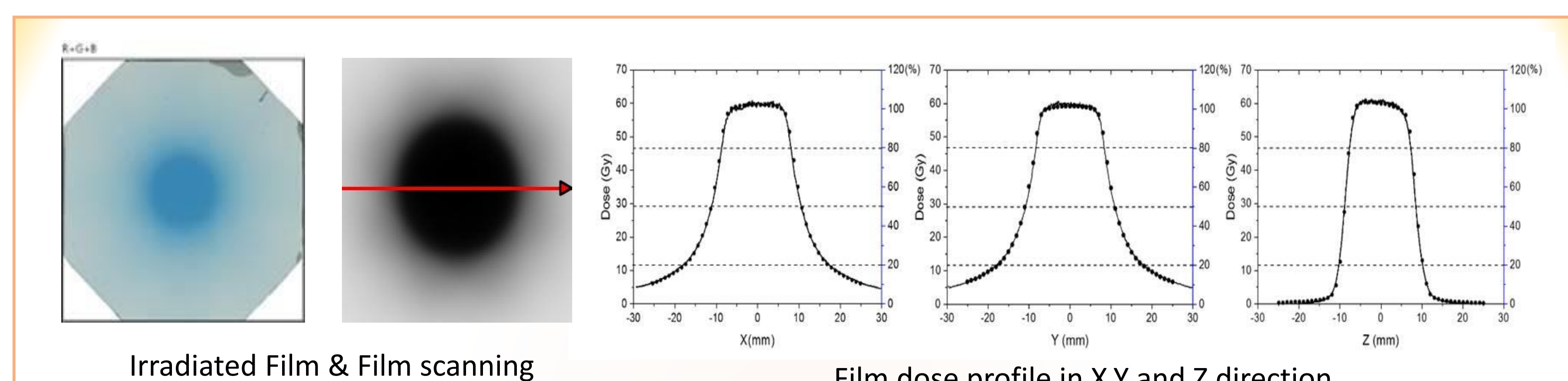
Component	f _i	Z/A	$\rho_{e, \text{Polystyrene}}$	$\rho_{e, \text{Polystyrene}} / \rho_{e, \text{water}}$	Component	f _i	Z/A	$\rho_{e, \text{PMMA}}$	$\rho_{e, \text{PMMA}} / \rho_{e, \text{water}}$
H	0.078	0.992162	0.5626	1.0156	H	0.081	0.992162	0.6393	1.1547
C	0.919	0.499542			C	0.595	0.499542		
O	0.002	0.500031			O	0.317	0.500031		
N	0.001	0.49975			unknown	0.007	0.500		

Polystyrene material components

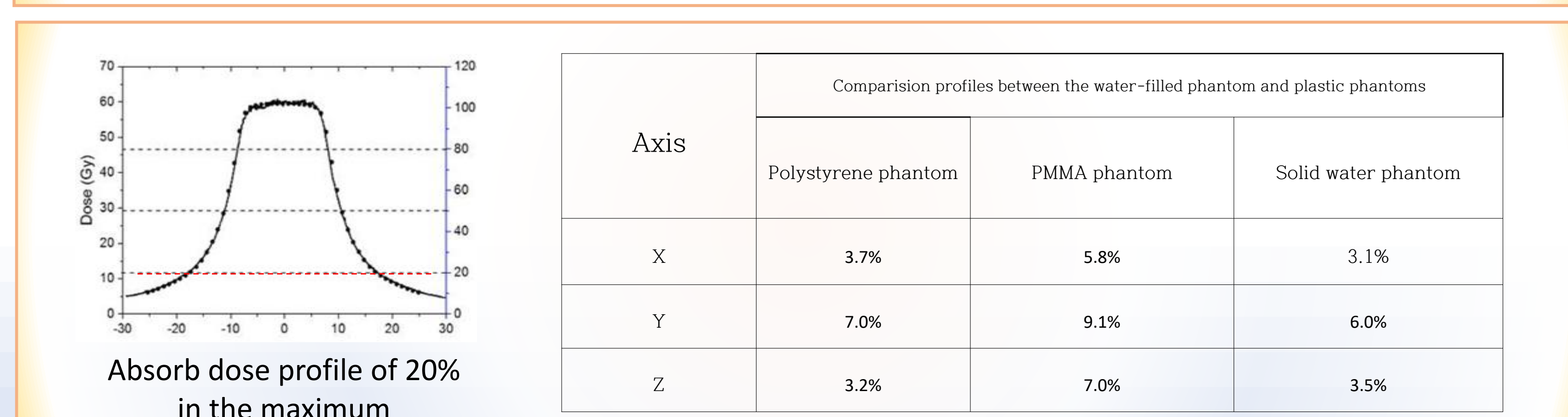
PMMA material components

- A hemispherical shaped Polystyrene plastic phantom and PMMA plastic phantom were developed to measure the absorbed dose distribution of Gamma Knife.
- The radii of Polystyrene phantom and PMMA phantom were determined considering the electron density of Polystyrene and PMMA such that they correspond to 8 g/cm² water depth, which is the reference depth of the absorbed dose measurement of Gamma Knife.
- A spherical water-filled phantom with the same water equivalent depth was constructed as a reference phantom.
- The dose distributions at the center of a circular field delimited by a 16-mm collimator were measured with the Polystyrene phantom, PMMA phantom and Solid Water phantom at Seoul National University Hospital Gamma Knife Center.
- The beam profiles along X-, Y- and Z-axis using 16 mm collimator were measured using EBT3 GafChromic films.
- The irradiated films were scanned using an EPSON Expression 10000XL scanner with a transparency unit.
- The scanned images then were analyzed with Doselab (6.80 Version) software to convert the image data into optical density distribution of the film and then to convert the optical density into absorbed energy on the film.
- Full width half maximum (FWHM) values and the physical penumbra, which is defined as the distance from the dose level of 80% to the dose level of 20% ($=d_{20} - d_{80}$) were measured.

Results & Conclusions



Axis	FWHM(mm)				Penumbra(mm)			
	Water-filled phantom	Polystyrene phantom	PMMA phantom	Solid water phantom	Water-filled phantom	Polystyrene phantom	PMMA phantom	Solid water phantom
X	21.55±0.41	21.60±0.29	21.79±0.22	21.49±0.33	8.64±0.54	8.79±0.18	9.15±0.22	8.92±0.14
Y	21.62±0.35	21.57±0.15	21.68±0.18	21.56±0.27	8.73±0.26	8.84±0.18	9.30±0.31	8.99±0.27
Z	17.30±0.05	17.41±0.04	17.48±0.08	17.41±0.17	2.58±0.05	2.73±0.18	2.78±0.4	2.67±0.08



- The FWHM and the penumbra measured with the Polystyrene phantom and Solid Water phantom showed similar differences compared with those with the reference phantom (spherical water-filled phantom).
- Comparison of the absorbed dose profile at the dose level of 20% between the plastic phantoms and the reference phantom showed that Solid Water phantom was 3.1%, the Polystyrene was 3.7%, and the PMMA phantom was 5.8% higher than the reference phantom for the X-axis.
- For the Y-axis, at the dose profile at the dose level of 20%, the Solid Water phantom was 6.0%, the Polystyrene 7.0% larger, and the PMMA phantom was 3.5% larger than the reference phantom. For the Z-axis, Solid Water phantom was 3.2%, the Polystyrene was 3.7%, and the PMMA phantom was 5.8% larger than the reference phantom.
- As a result, these differences were due to the wider width of the 20% dose line in these three plastic (Polystyrene, PMMA and Solid Water) phantoms, which can be explained by the greater scattering contribution in these phantoms compared to that in the reference phantom.
- The FWHM and penumbra values measured using the plastic phantoms showed the evidence of scattering effect of the plastic material to the low level of the dose profile, but more sophisticated approach of the scattered photon contribution is necessary to explain the wider penumbra in the measured beam shape.
- The plastic phantoms developed in this study represents an acceptable and practical alternatives for Gamma Knife film dosimetry.

