

Plastic Scintillation Detectors: Principle and Application to Radiosurgery

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Disclosure

- Université Laval, together with MD Anderson, has licensed a plastic scintillation technology to Standard Imaging
- Luc Beaulieu is the holder of a research contract with Standard Imaging

Learning Objectives

- 1** Understanding the basic principal of scintillation dosimetry.
- 2** Knowledge of the various components of PSDs.
- 3** Application of PSDs to radiosurgery dose measurements.



**NSERC
CRSNG**



PSD work

Researchers and Collaborators

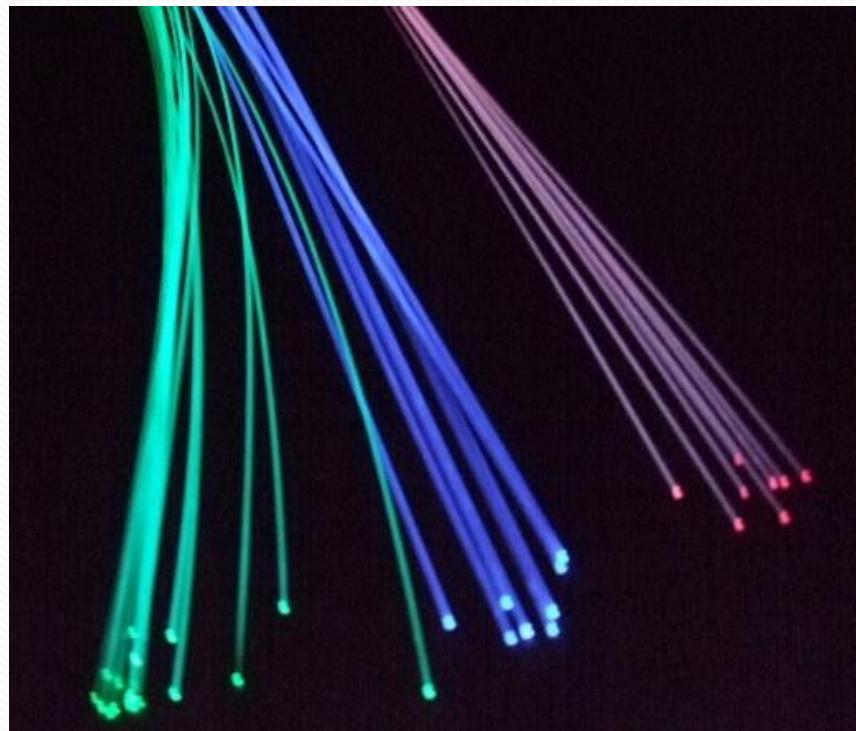
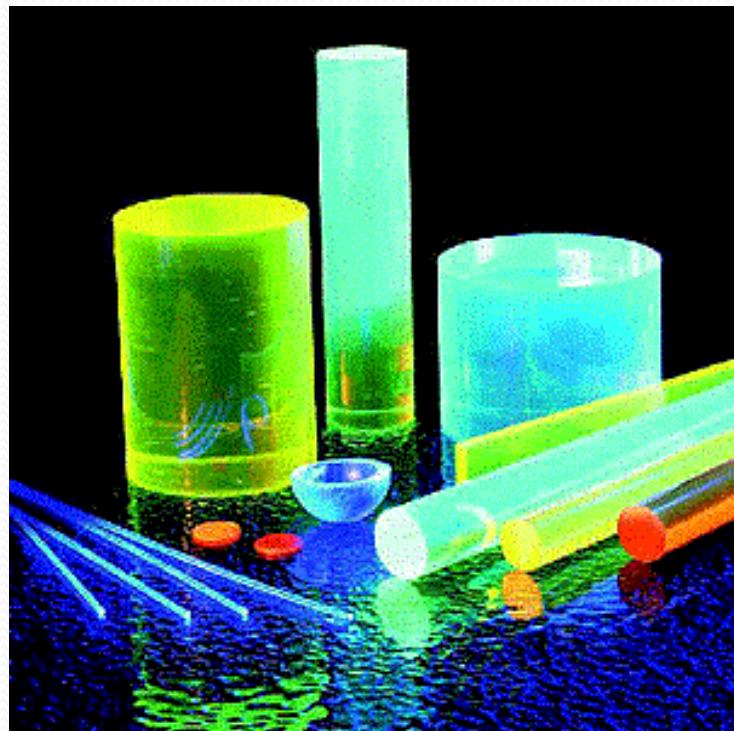
- Luc Beaulieu
- Sam A Beddar (MD Anderson)
- Louis Archambault
- Luc Gingras
- M McEwen and C Cojocaru from NRC, Ottawa
- M Lepage, Sherbrooke



Grad. Students

- François Lessard (2010 -)
- Jonathan Morin (2010 -)
- Mathieu Goulet (2009 -)
- François Thériault-Proulx (2008 -)
- Mathieu Guillot (2007-)
- J-C Gagnon (2008-2010)
- Nicolas Tremblay (2007-2009)
- Maxime Villeneuve (2006-2008)
- Frédéric Lacroix (2005-2007)
- Louis Archambault (2002-2006)

Scintillators?



Two types of scintillators:

A. Inorganic materials

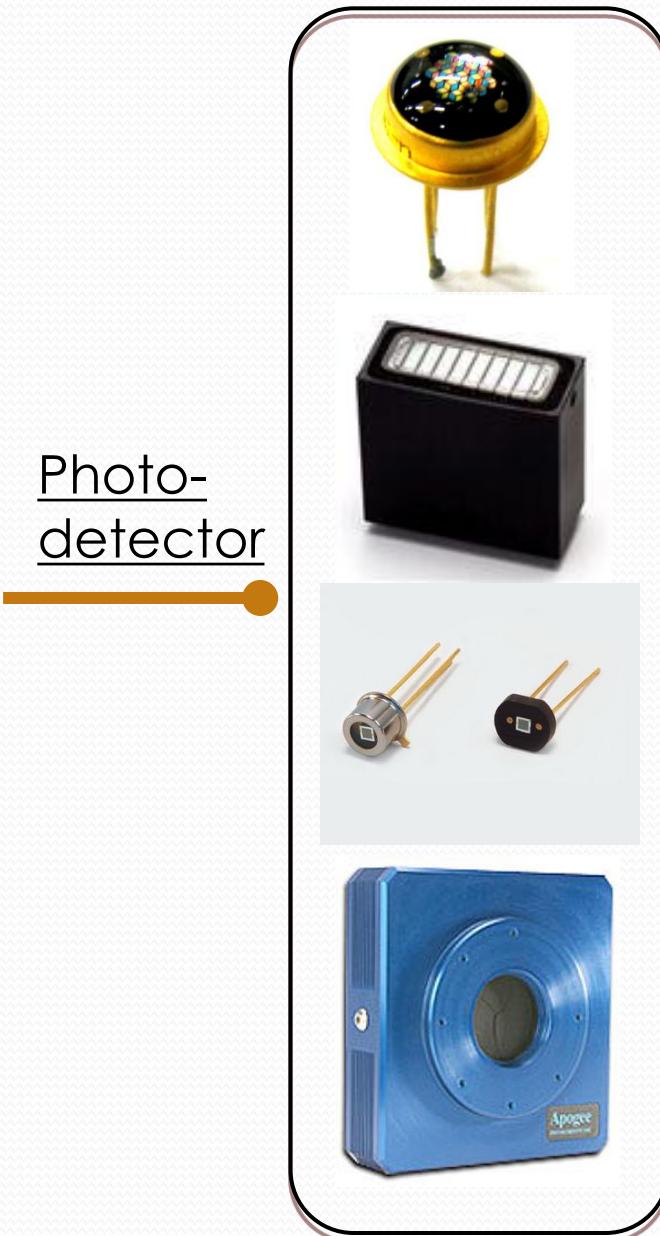
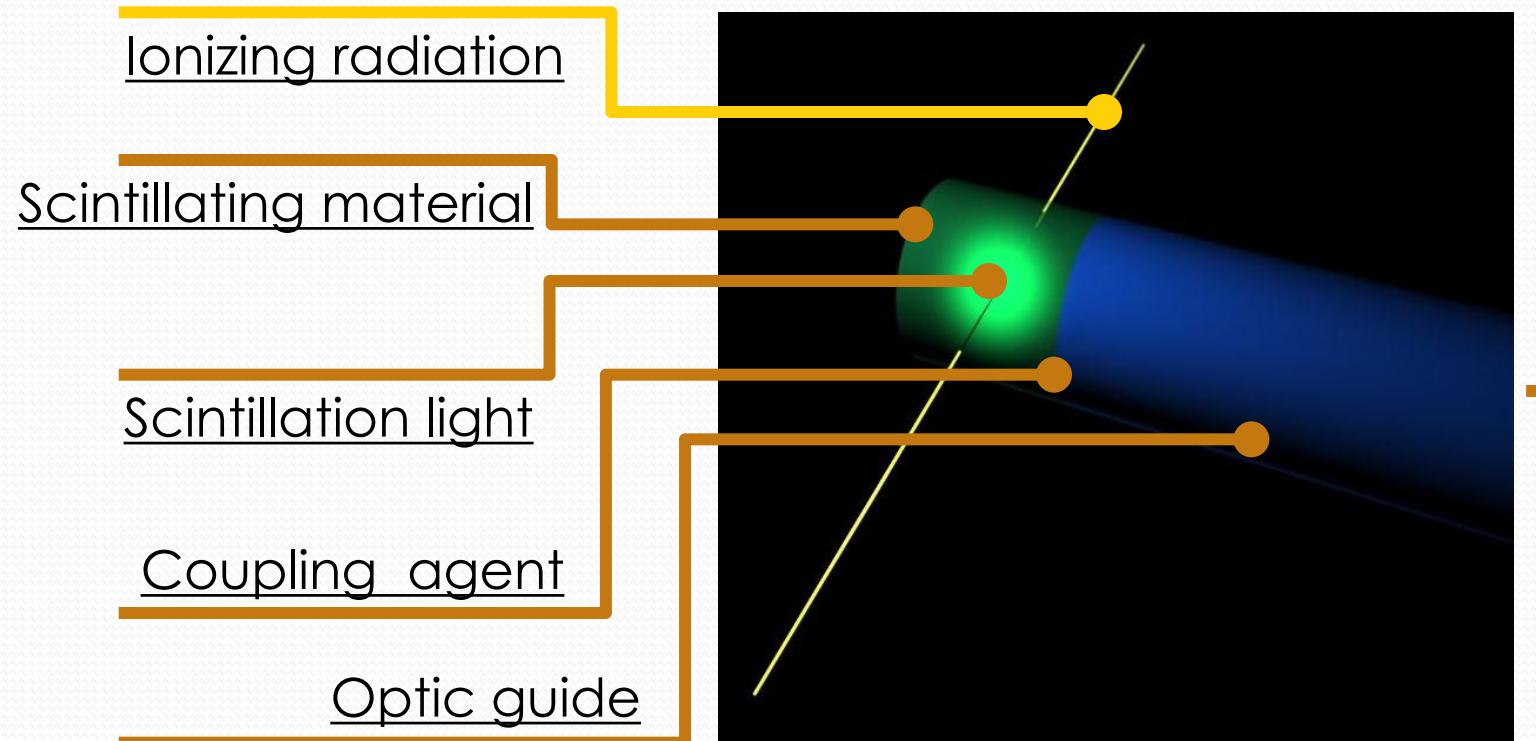
B. Organic materials (e.g. plastics)

- Lower density ... and (!!!) nearly equivalent to water
 - Density on the order of 1.03-1.06 g/cm³
 - (Generally) No high Z materials content.
- Excitation and emission spectra are similar in solid, liquid or vapor states

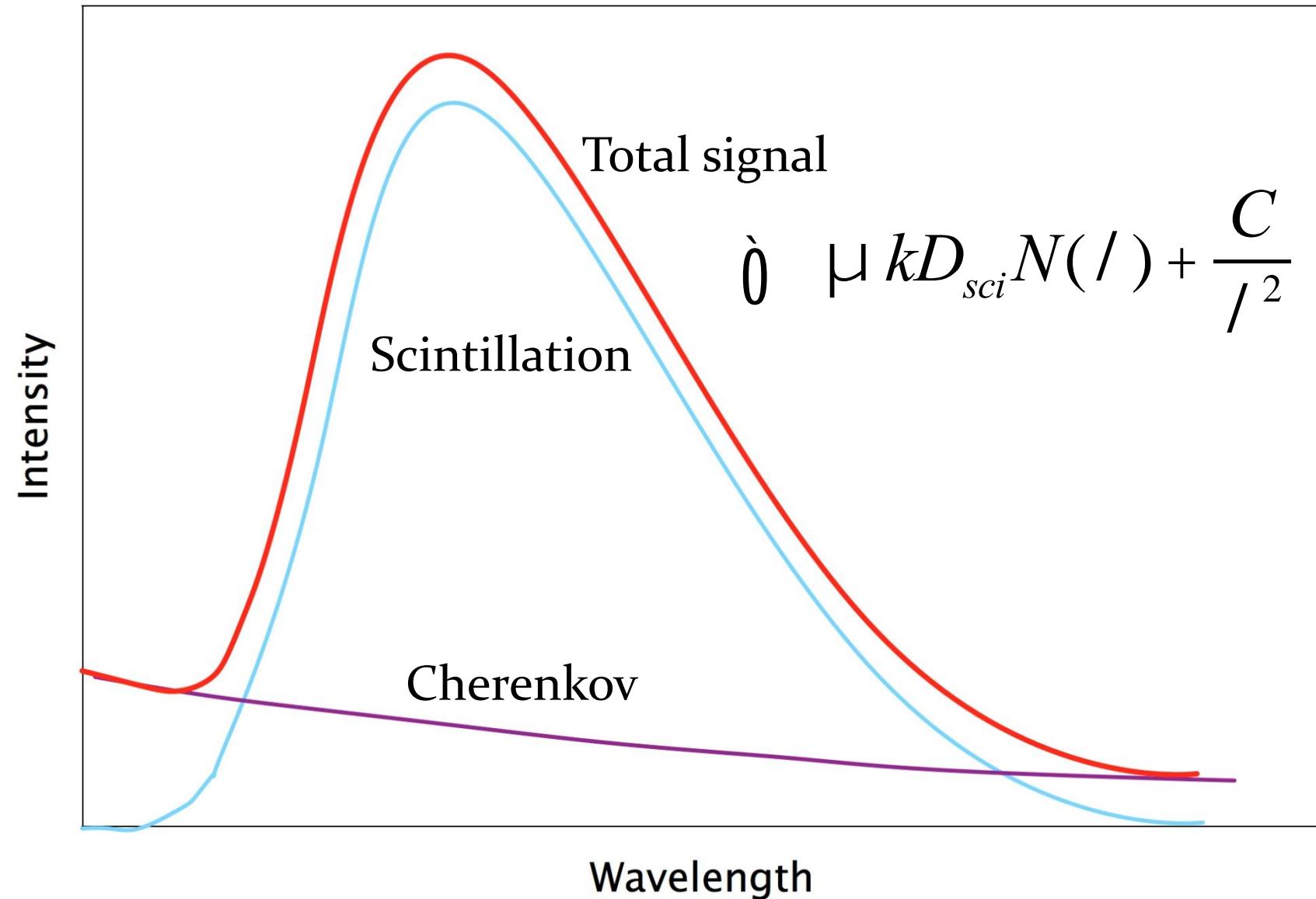
Physics of plastic scintillation detectors

- Scintillation detectors:
 - Impinging particles will excite atoms or molecules of the scintillating medium.
 - The decay of these excited states will produce photons in the visible part of the spectrum.
 - These photons will be guided to a photodetector and converted in an electric signal.

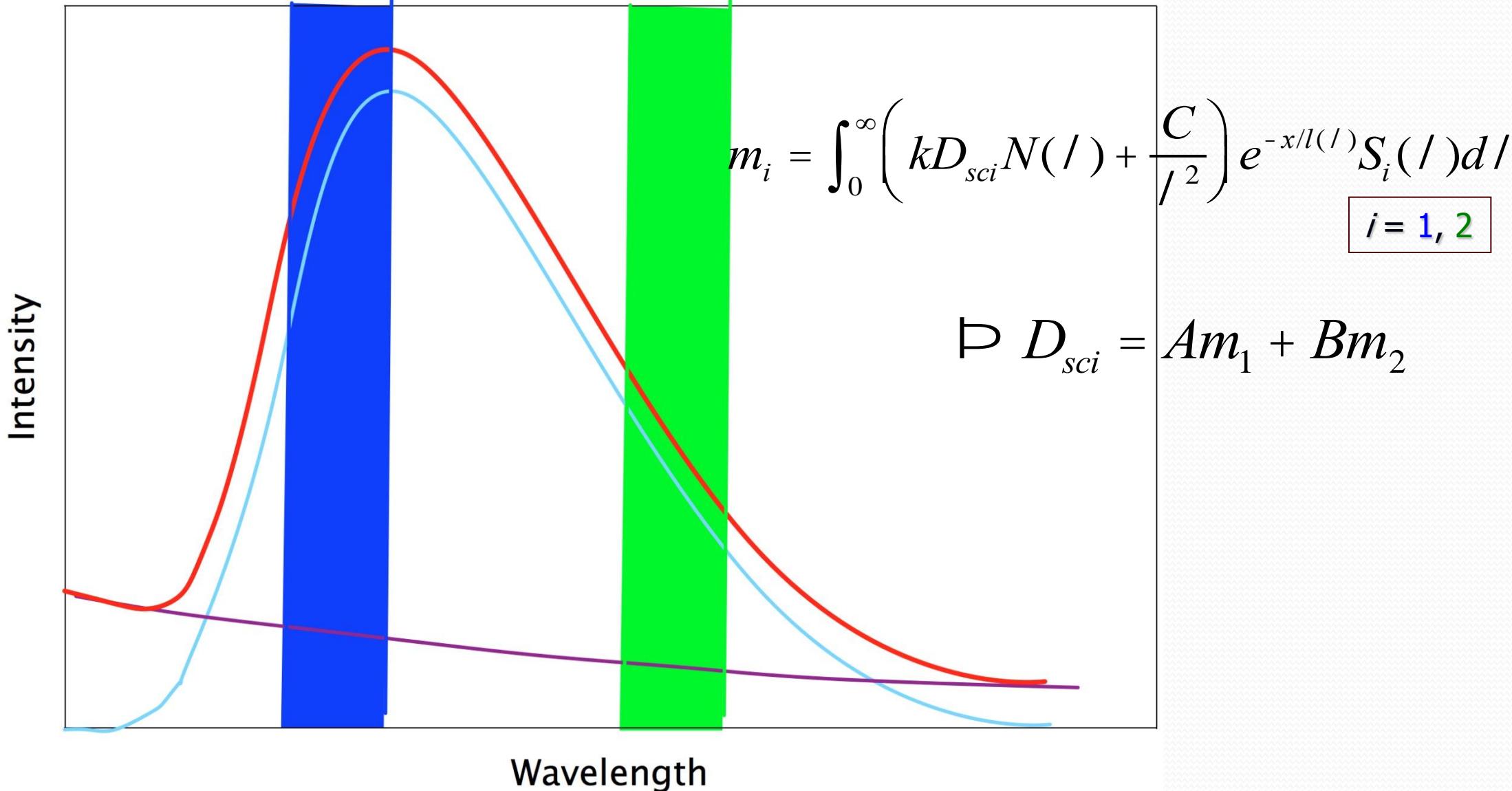
Light Production and Collection



Stem Effect Removal: Cherenkov



Stem Effect Removal: Cherenkov



Fontbonne et al, IEEE, 2002; M Guillot et al, Med Phys. 38 (2011)

PROPERTIES of PLASTIC SCINTILLATORS

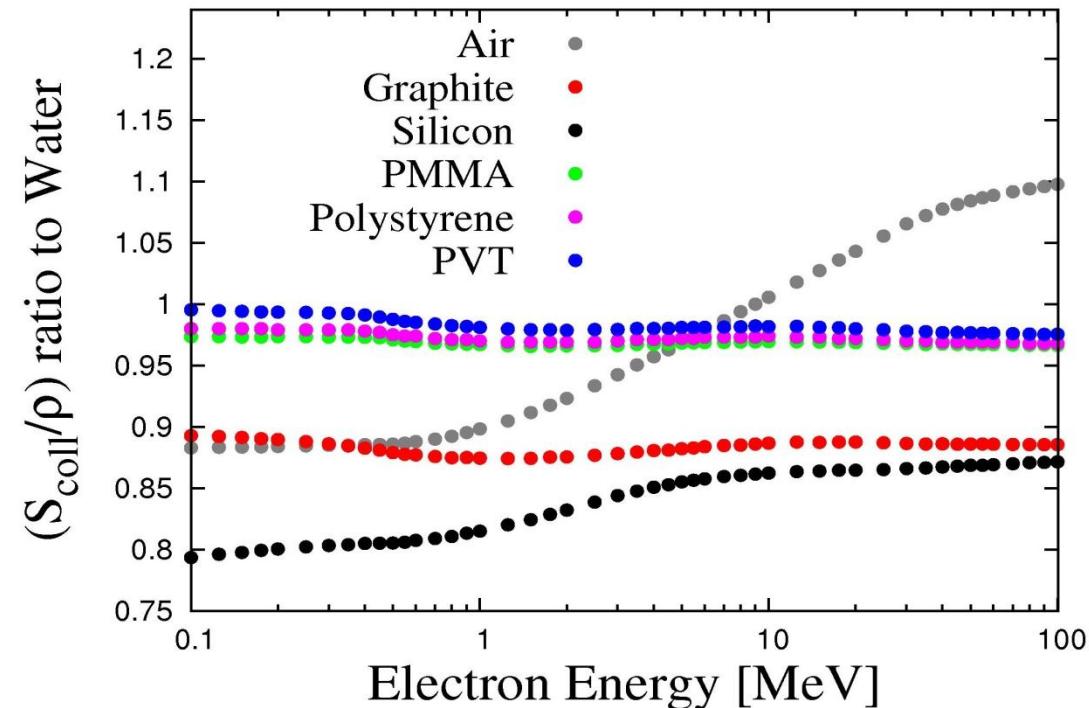
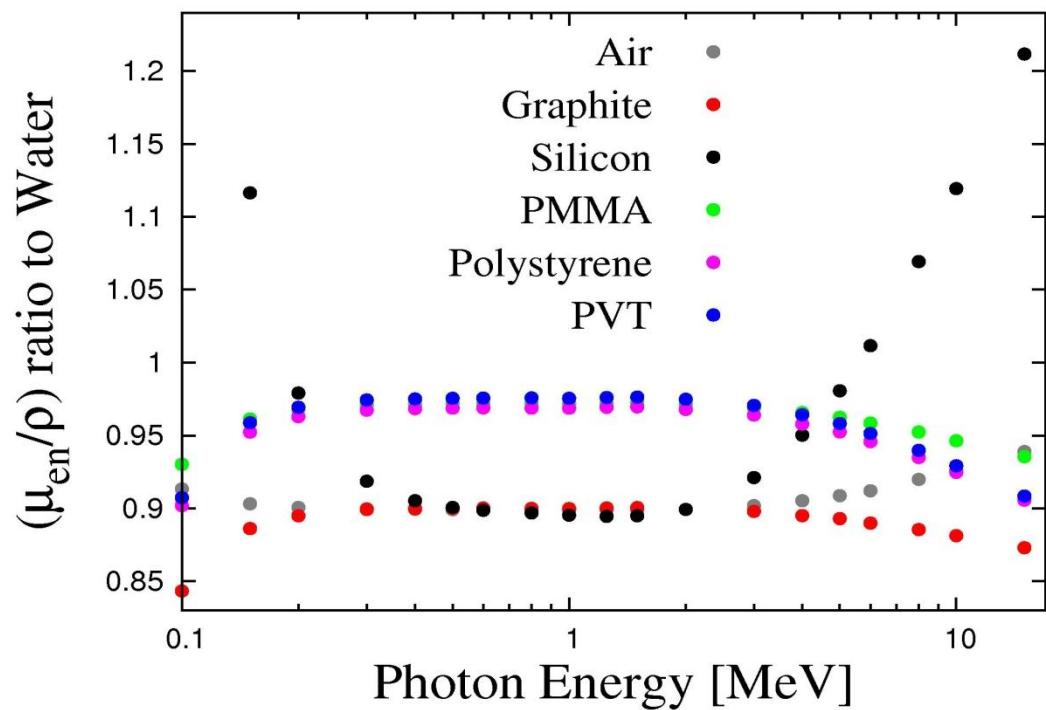
- Linear response to dose
- Dose rate independence
- Energy independence
 - Particle type independence (clinical electrons and photons beam energy range)
- Pressure independence
- Spatial resolution

WATER EQUIVALENCE

- W-E is achieved by:
 - Media-matching (walls and sensitive volume)
- W-E depends on:
 - Mass energy-absorption coefficients
 - Mass collision stopping powers
 - Size of the sensitive volume (according to Burlin cavity theory)

Parameter	Scintillator	Polystyrene	Water
Density (g/cm ³)	1.032	1.060	1.000
Electron density (10 ²³ e ⁻ /g)	3.272	3.238	3.343
Composition (by weight %)	H: 8.47 C: 91.53	H: 7.74 C: 92.26	H: 11.19 O: 88.81

WATER EQUIVALENCE

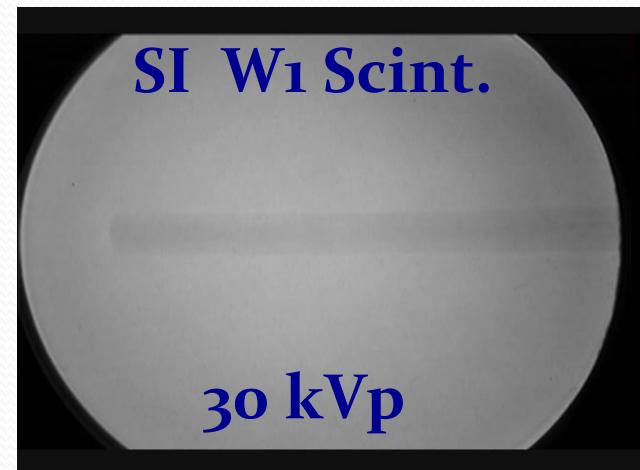
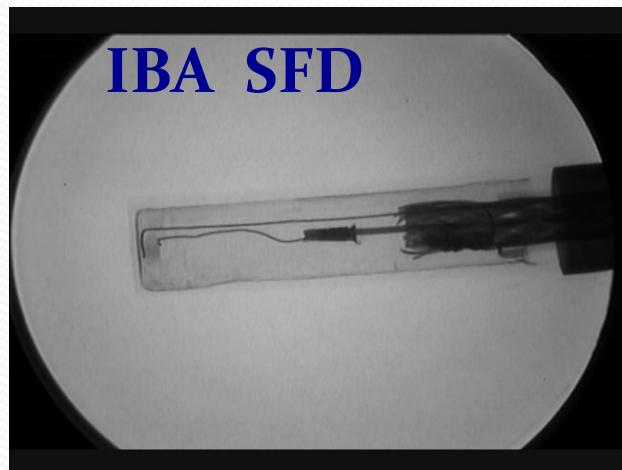
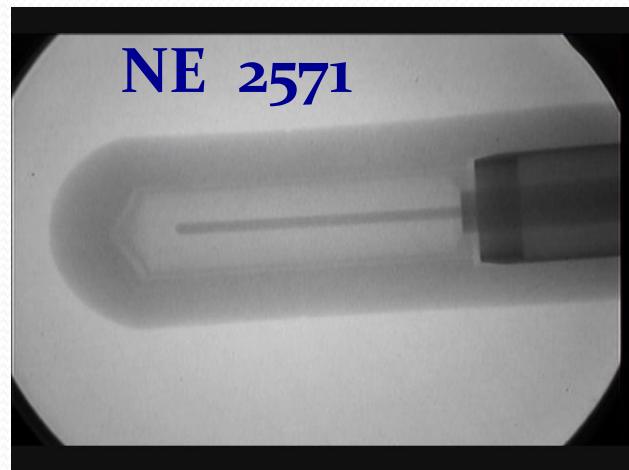
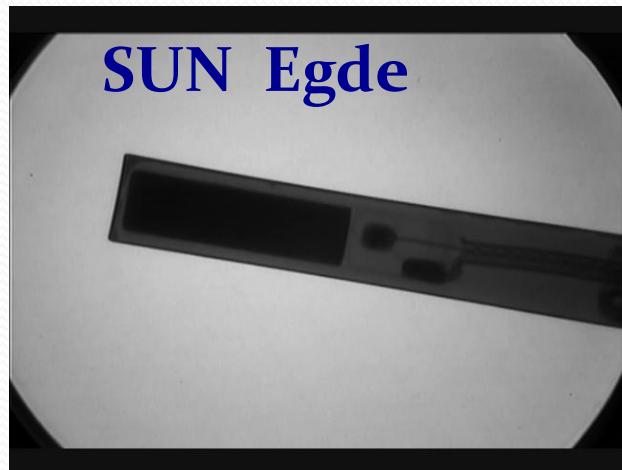
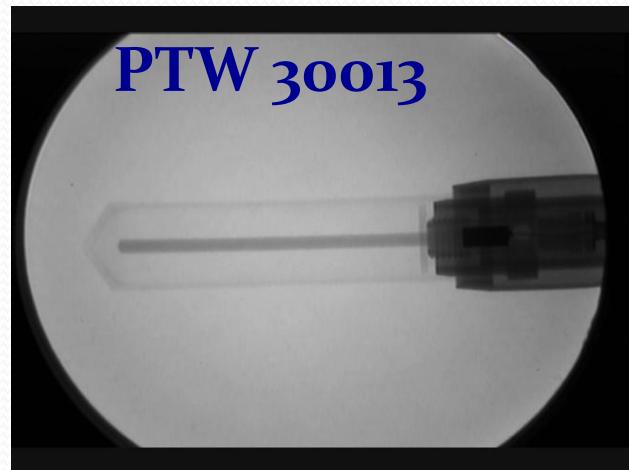


According to Burlin cavity theory, above 125 keV:

$$\frac{\bar{D}_{sci}}{\bar{D}_{med}} = 0.980 \pm 0.005$$

Beddar A S et al, PMB 2002

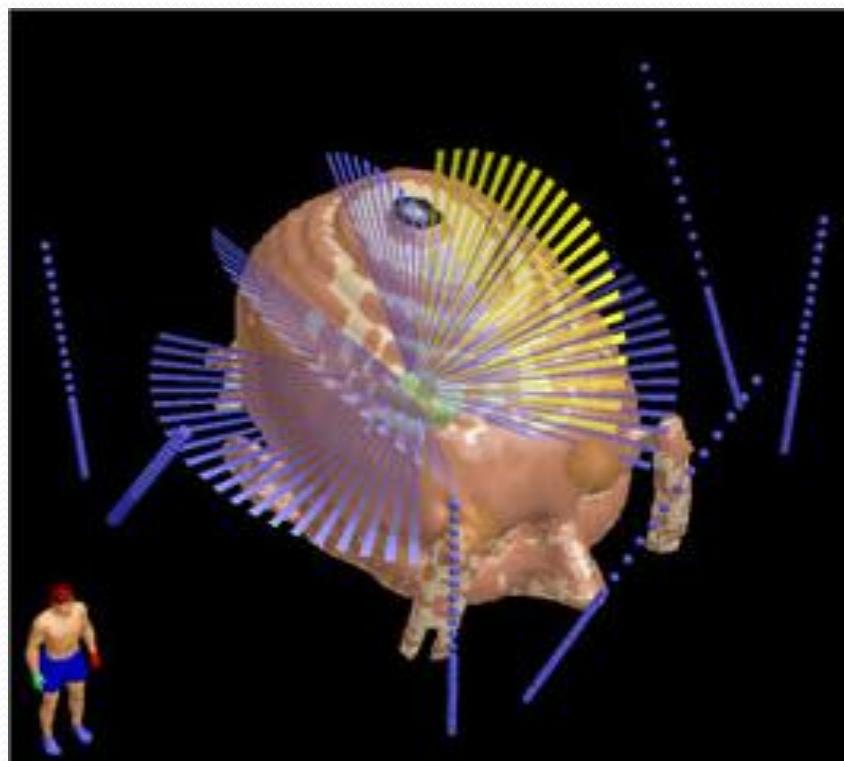
WATER EQUIVALENCE : 80kVP x-ray in water



Plastic Scintillation Dosimeters or PSDs

- PSDs are the most water-equivalent of the potential real-time dosimeters .
 - Can be stacked – no perturbation!
 - Guillot et al, Med Phys 38 (2011) 6763-74
 - Mixed-beam dosimetry (photons and electrons)

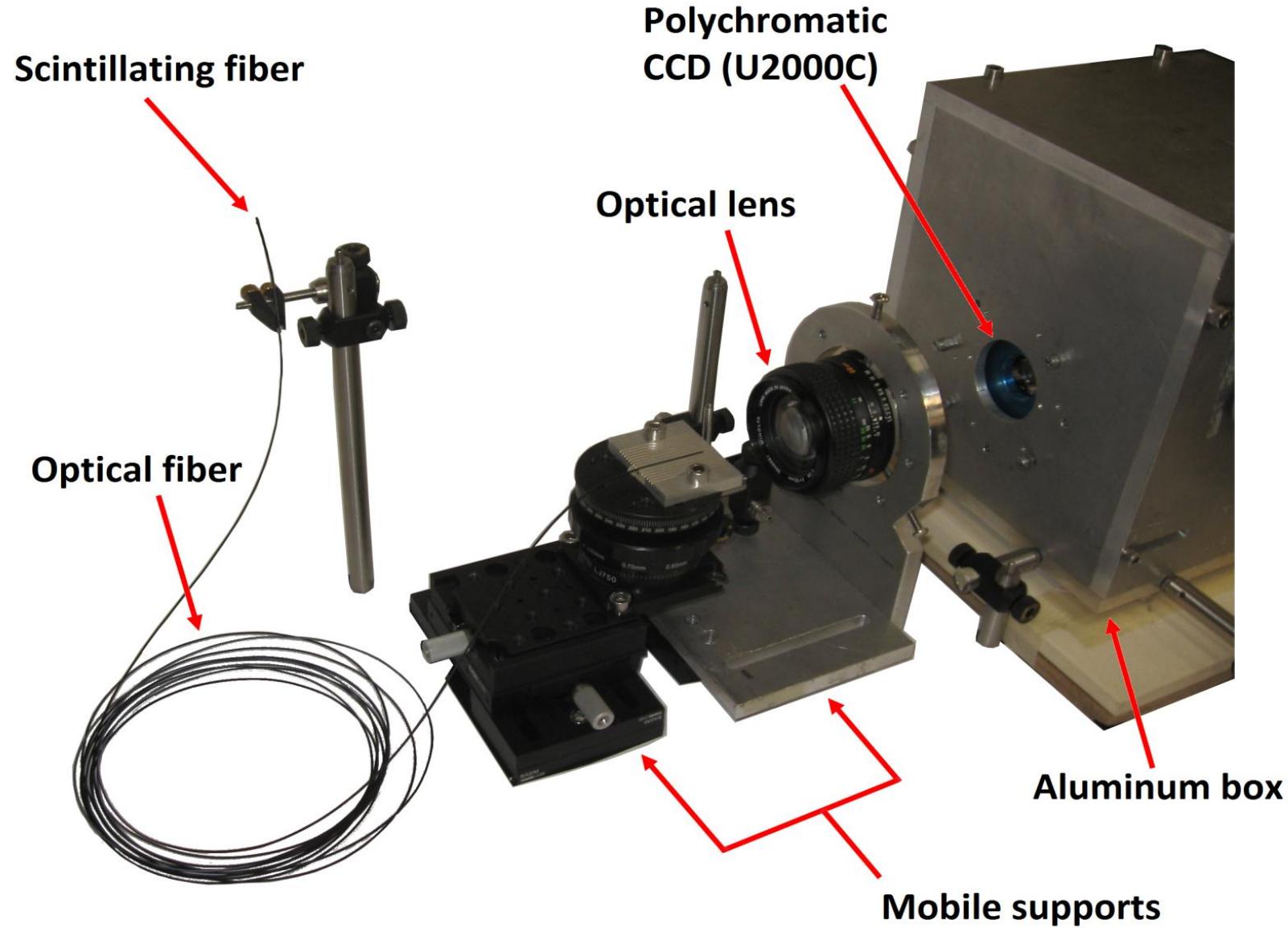
Radiosurgery



Why PSDs?

- For small field dosimetry (≤ 20 mm)
 - High spatial resolution
 - Water equivalence
 - Energy independence
 - Dose rate independence
 - Real-time measurements

Lab PSD system used



Total scatter factors

- Total scatter factors
 - Collimator diameters used: 5, 7.5, 10, 12.5, 15, 20, 30, 40, 50, 60 mm
 - Stem parallel to the beam axis with all detectors



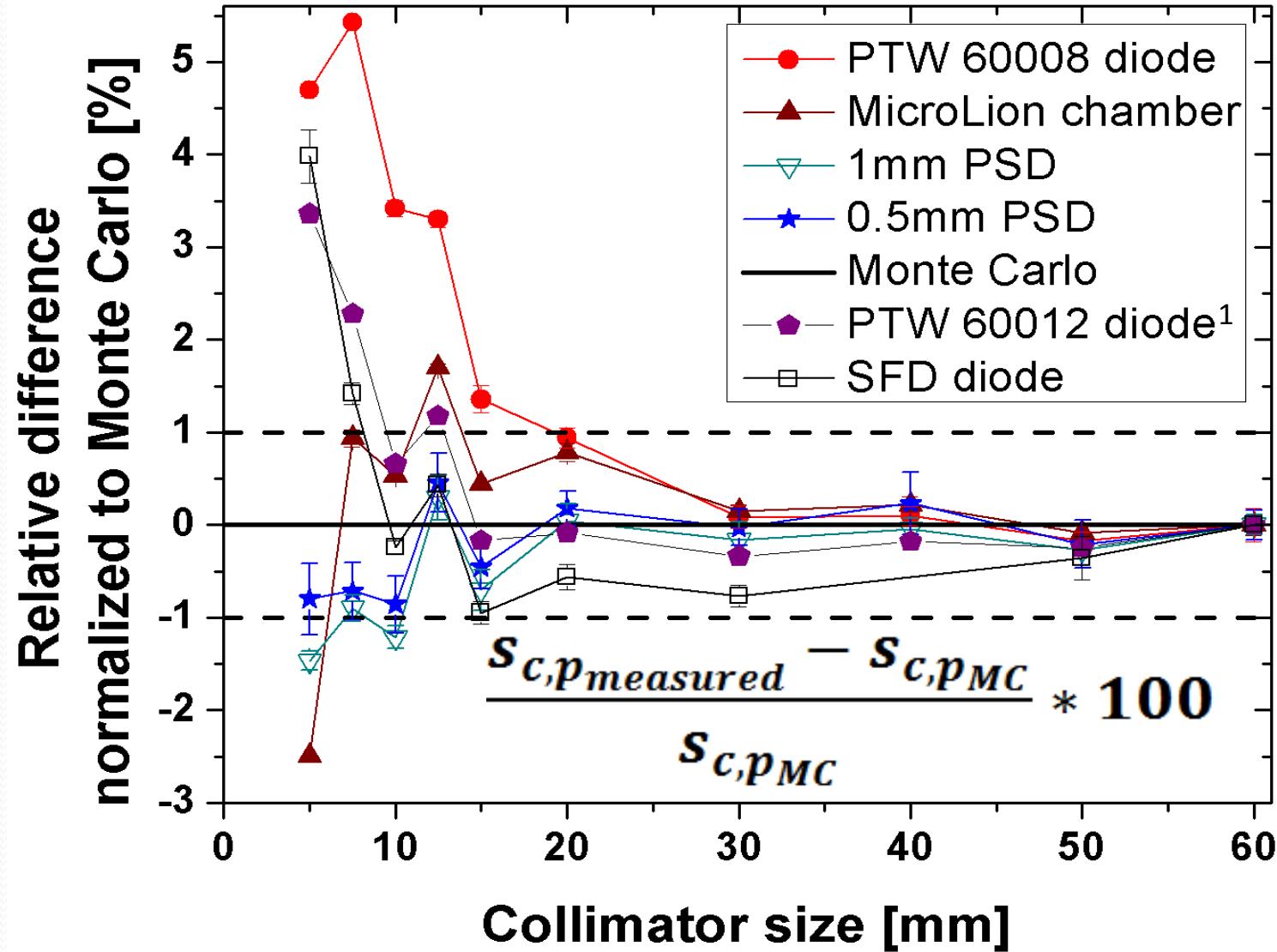
Total scatter factors

- Comparison with two independent Monte Carlo studies
 - Araki (3.2 mm and 6.7 MeV)¹
 - Francescon (2.2 ± 0.1 mm and 6.6 ± 0.1 MeV)²

¹ Araki, Med. Phys. **33** (2006)

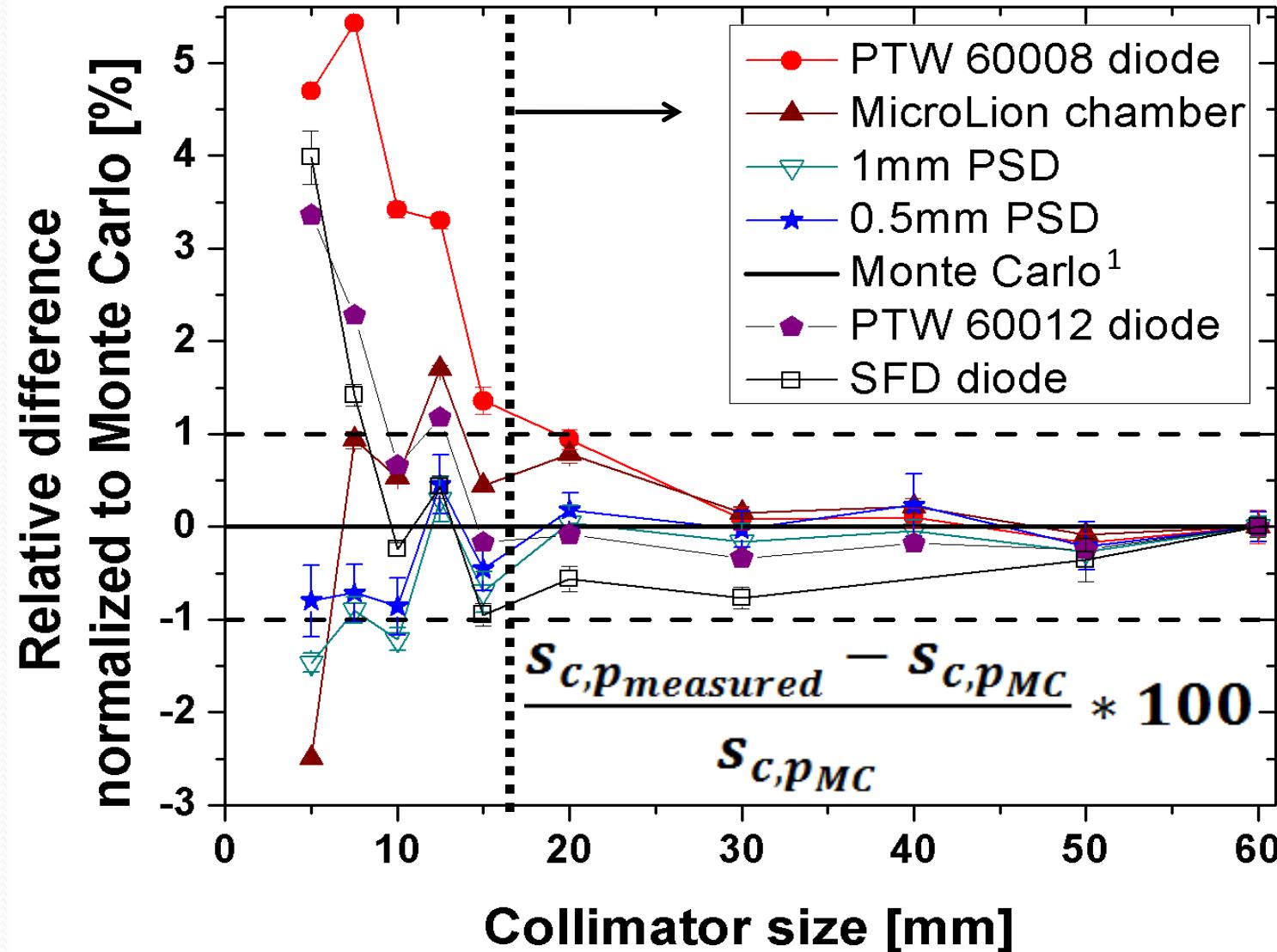
² Francescon et al., Med. Phys. **35** (2008)

Total scatter factors



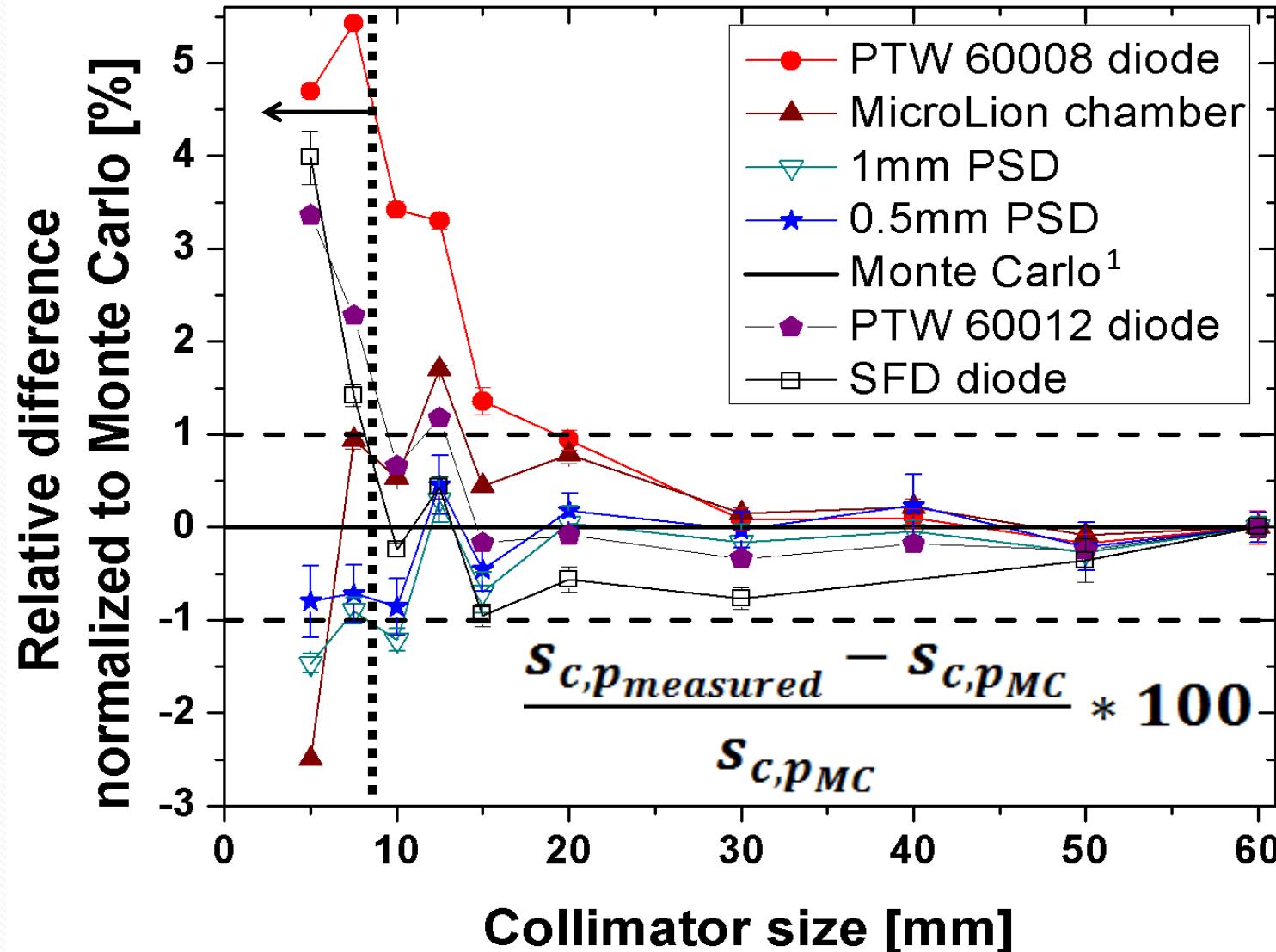
¹ Araki, Med. Phys. 33 (2006)

Total scatter factors



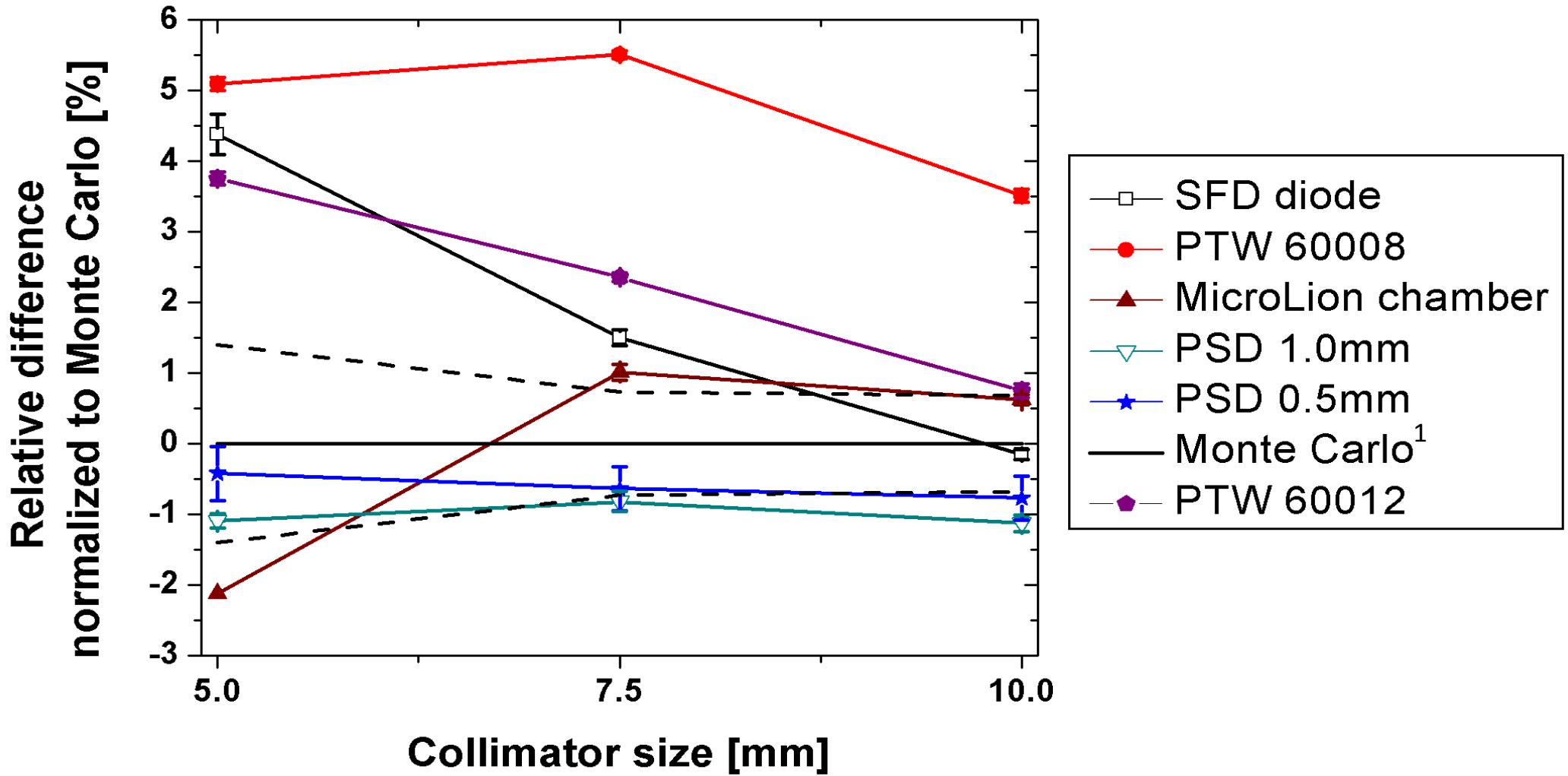
¹ Araki, Med. Phys. 33 (2006)

Total scatter factors



¹ Araki, Med. Phys. 33 (2006)

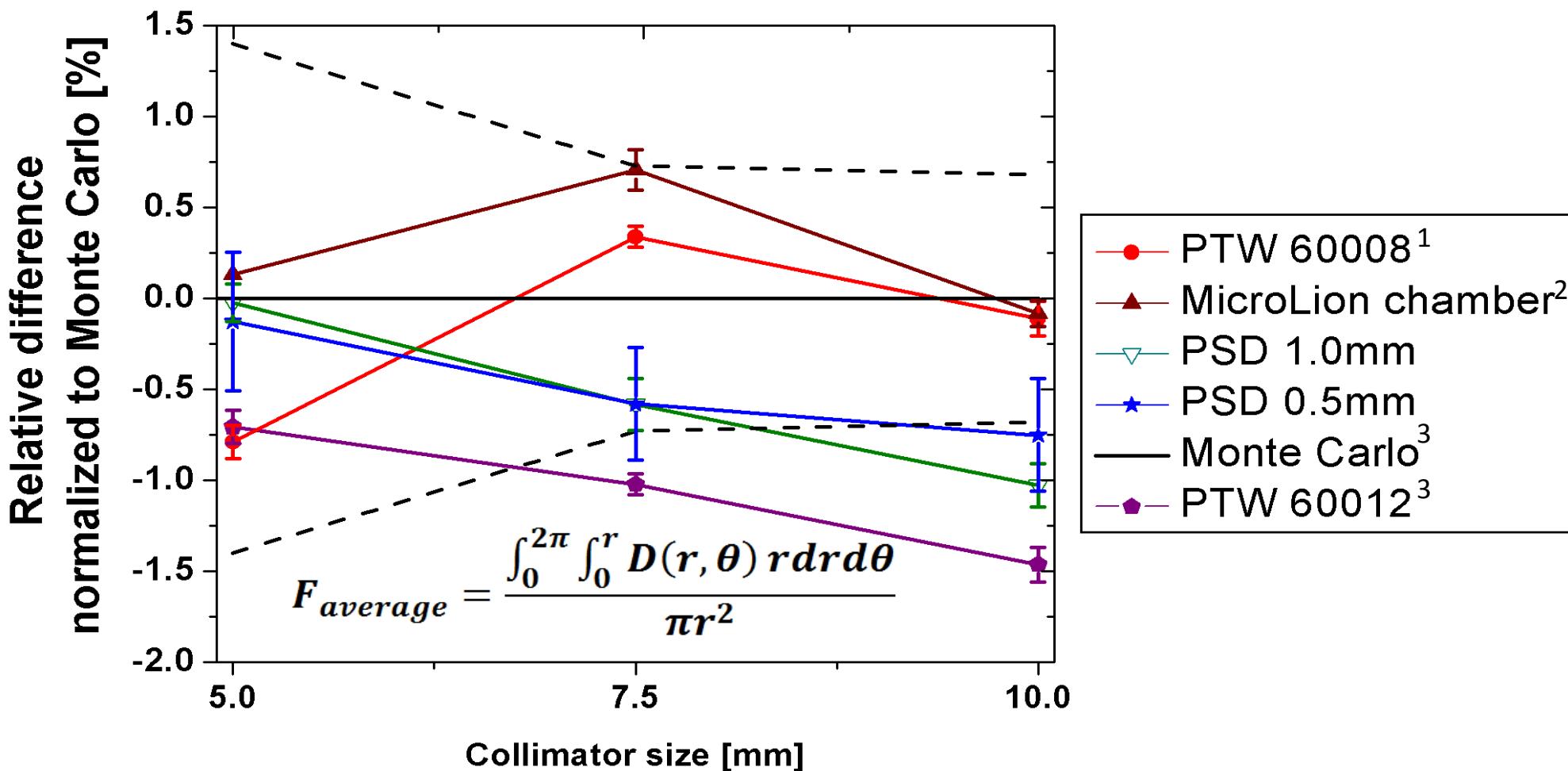
Total scatter factors



¹Francescon et al., Med. Phys. **35** (2008)

Total scatter factors

Corrected for composition and volume averaging effect



Correction factors extracted using PSD!

Detectors	Collimator diameter [mm]	Correction factors	Literature	Difference [%]
PTW 60008 diode	5	0.950	0.944 ¹	0.6
	7.5	0.942	0.951 ¹	0.9
PTW 60012 diode	5	0.963	0.957 ²	-0.6
	7.5	0.971	0.967 ²	-0.4
SFD diode	5	0.957	0.952 ³	-0.5
	7.5	0.980	0.976 ³	-0.4
MicroLion chamber	5	1.020	1.023 ⁴	0.3
	7.5	0.984	0.997 ⁴	1.3

¹Francescon et al., J. Appl. Clin. Med. Phys. **10** (2009)

²Francescon et al., Med. Phys. **35** (2008)

³Araki, Med. Phys. **33** (2006)

⁴Francescon et al., Med. Phys. **38** (2011)

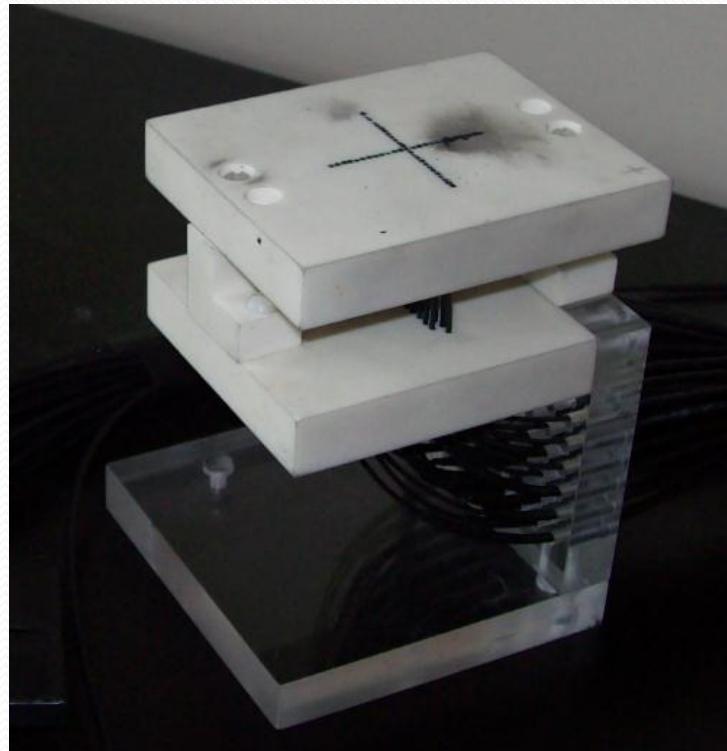
What we have learned

- Current commercial dosimeters provide accurate results once corrected
- PSDs need no corrections
 - Worst case scenario for 1 mm diameter PSD is a 1% underestimation for the 5 mm cone
- PSDs perfect for small field / radiosurgery

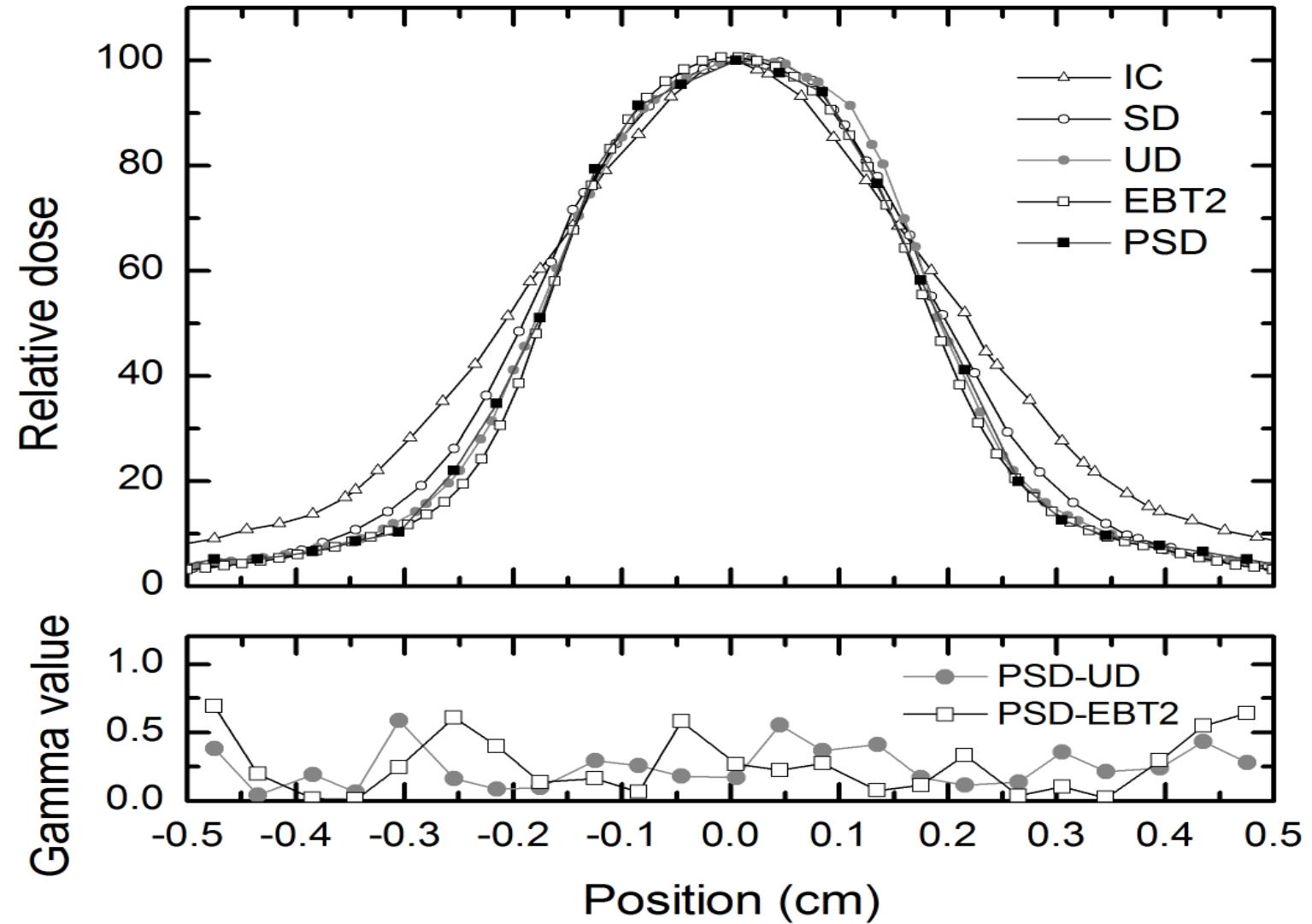
Cross-Hair Matrix for SRS/SRT

Closely pack array of 49 PSDs

J.-C. Gagnon et al, Med Phys 39 (2012) 429-36



4 mm cone



Merci!

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<http://physmed.fsg.ulaval.ca>



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