Energy Monitoring Device for Electron Beam Facilities

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Introduction

The electron beam energy in commercial radiation processing is one of the critical parameters for quality assurance and quality control since it determines the size of the product box that can be processed and a variation of the energy affects the absorbed dose distribution in the product under irradiation.

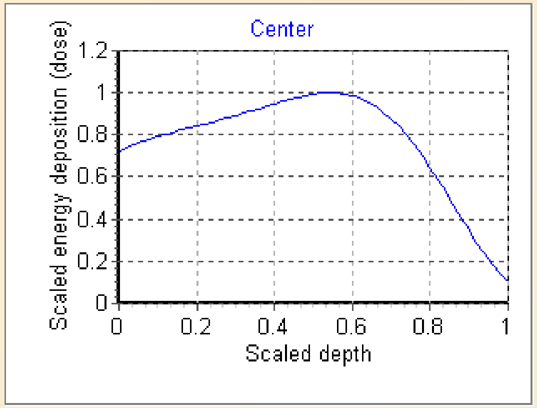
Standards procedures require that the beam energy be:

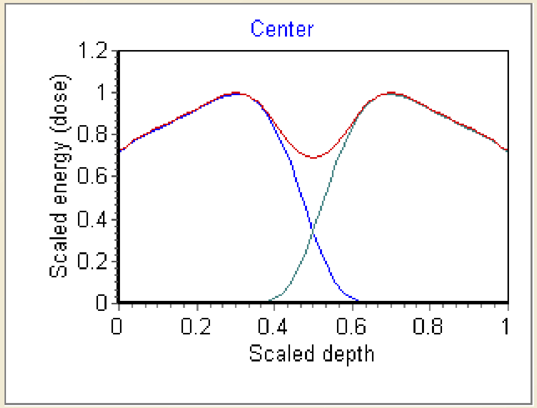
- determined during the facility qualification;

- monitored and controlled during routine irradiation.

Examples of dose distribution in uniform material:

10 MeV

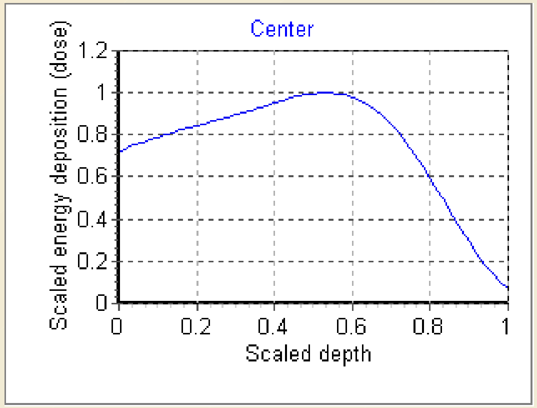


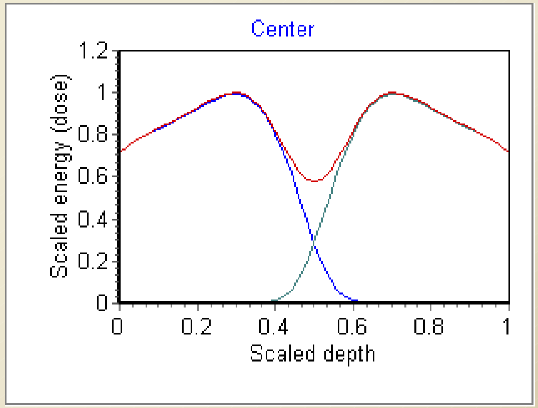


Single side irradiation
(water, 5 cm)

Double side irradiation
(water, 9 cm)

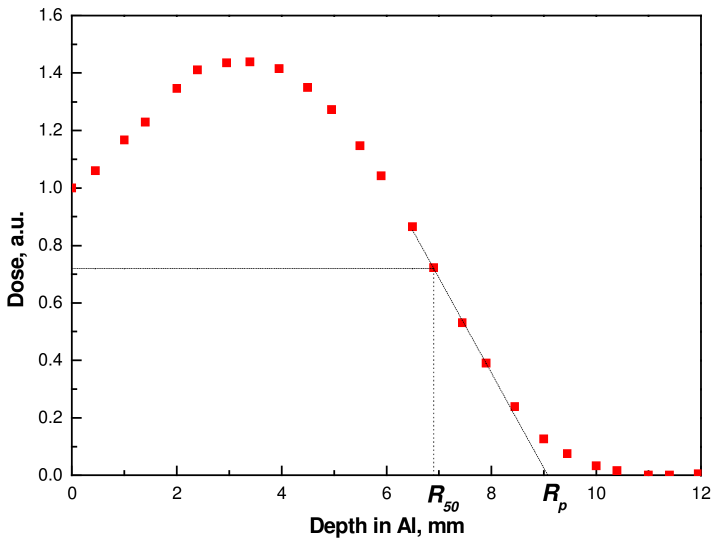
9.8 MeV





Simulations obtained with the software ModeRTL, Version 2.6.

Amongst different methods for measuring the electron beam energy, the study of the *depth-dose distribution* in a homogeneous reference material is the widely used technique.



Empirical energy-range relations for

mean electron energy:

E_a = (2.33 MeV•cm^{-1}) • (R_{50} cm)

(5 MeV ≤ E_a ≤ 35 MeV, in H_2O phantom)

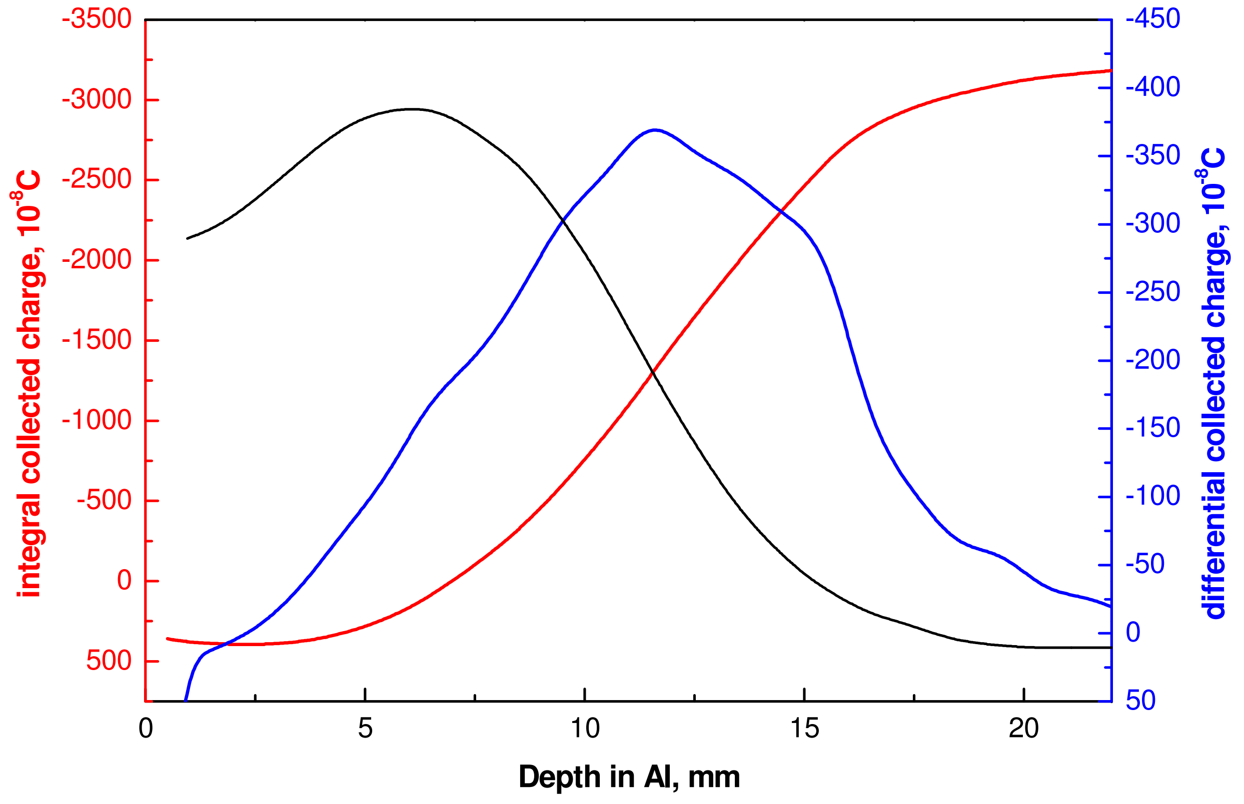
most probale electron energy:

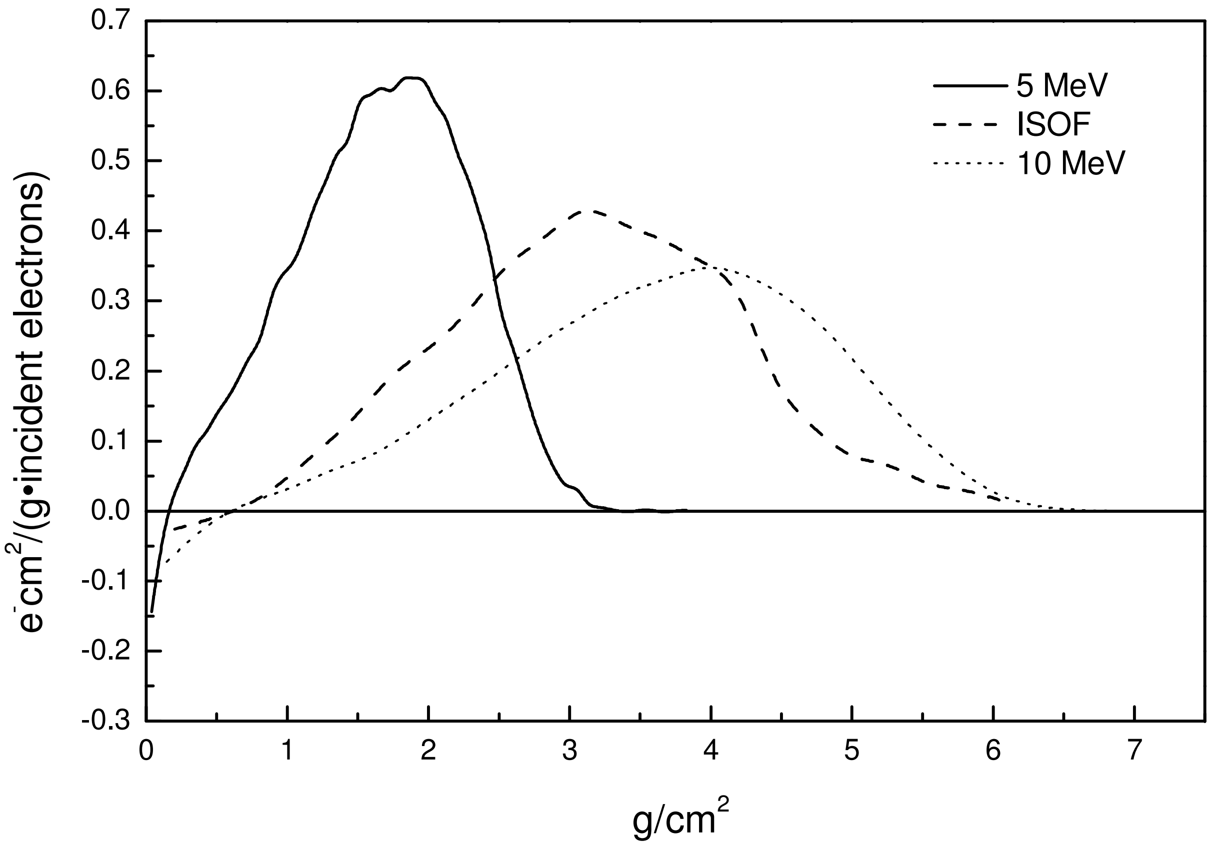
E_p = (5.09 MeV•cm^{-1}) • (R_p cm) + 0.20 MeV

(5 MeV ≤ E_p ≤ 25 MeV, in Al phantom)

(examples from ICRU, 1984. *Radiation dosimetry: Electron beams with energy between 1 and 50 MeV, Report No. 35.* International Commission on Radiation Units and Measurements, Bethesda, MD, USA.)

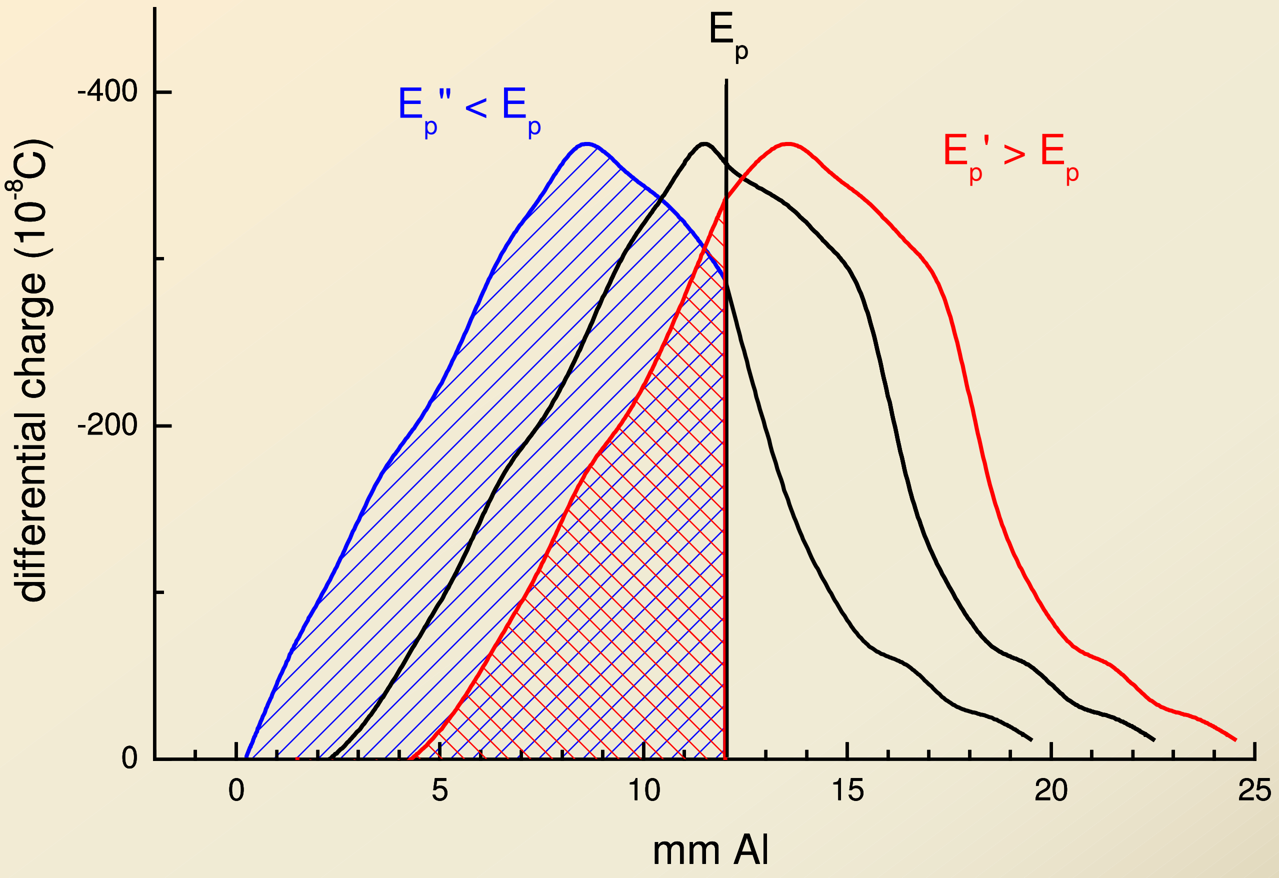
Another possible method, which is the subject of this work, is the study of the influence of the electron beam energy on the *charge distribution with depth* in homogeneous absorbers.





Differential charge-deposition distributions in aluminium for ISOF LINAC beam (experimental, 8 MeV), and for 5 and 10 MeV mono-energetic beams (calculated, from Andreo, P., Ito, R., Tabata, T., 1992. *Tables of charge- and energy-deposition distributions in elemental materials irradiated by plane-parallel electron beams with energies between 0.1 and 100 MeV, Report* ISSN 0917-8015, Res. Inst. Adv. Sci. Tech., Univ. Osaka Pref., Japan.).

The basic idea:



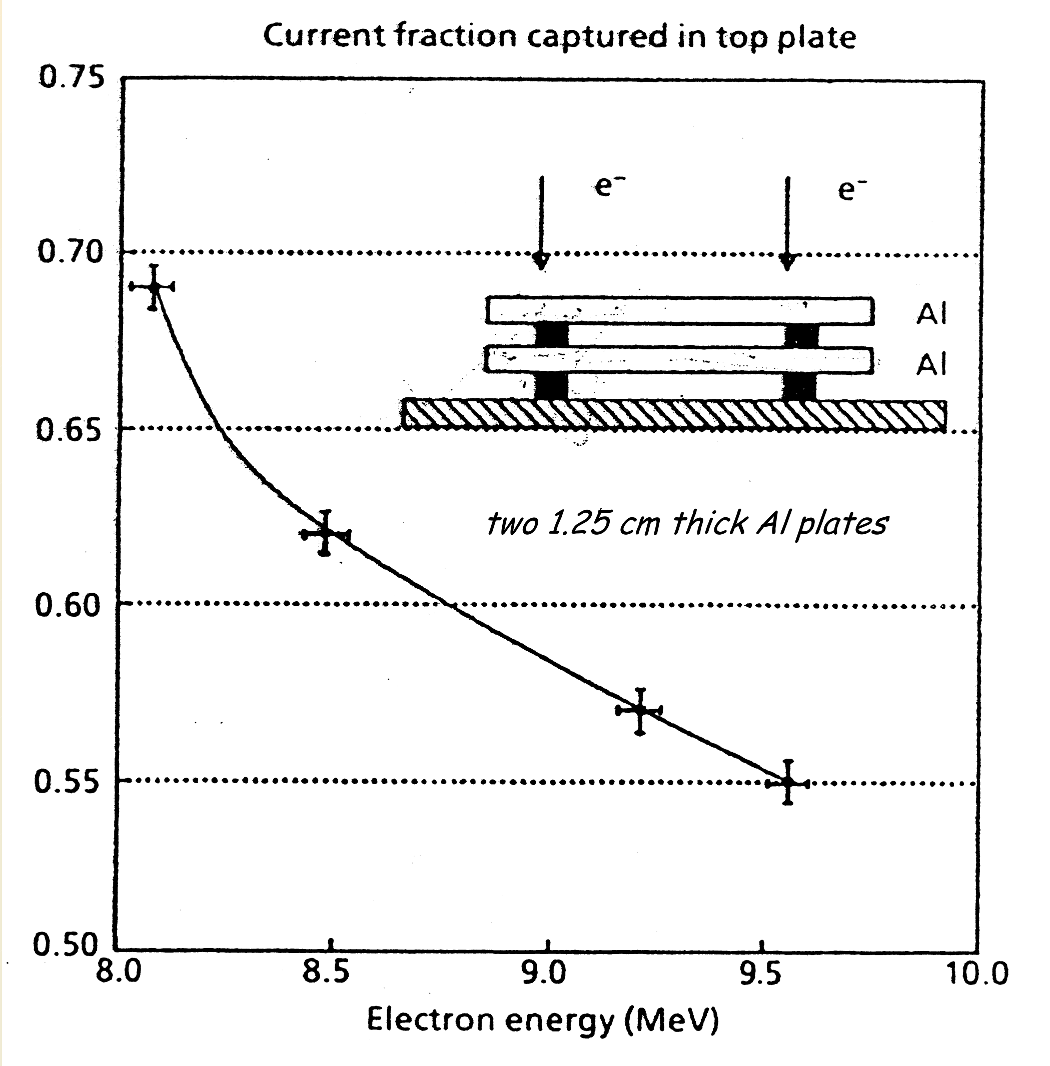
The first device:

K. Mehta, J. Barnard, W. Stanley and A. Unger

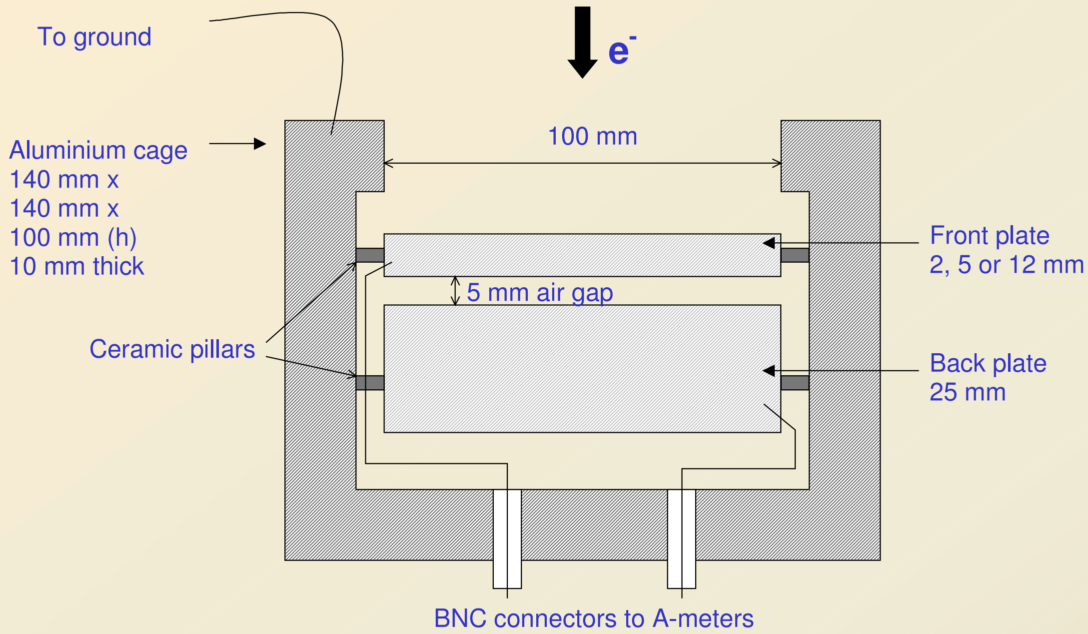
Experience with e-beam process dosimetry at the Whiteshell Irradiator

International Symposium on High Dose Dosimetry for Radiation Processing Vienna 5-9 November 1990

Proceedings Series STI/PUB/846, 1991, ISBN 92-0-010291-3, 28 June 1991, 451-458.



The actual device:



Definition of the "energy ratio" (*E.R.*):

$$E.R. = \frac{I_1}{I_1 + I_2}$$

where:

I_1 is the current from the front plate

I_2 is the current from the back plate

The previous tests

Location	Beam characteristics	Thickness of the front absorber *(the back absorber was always 25 mm)*	Energy range MeV
ISOF-CNR Bologna (Italy)	Research L-band LINAC 0.2 – 5 μs pulses at 50 Hz *energy varied changing the pulse length and the beam current*	12 mm	6.5 – 11.5
Institute of Isotopes Budapest (Hungary)	Research Tesla LPR-4 LINAC 2.6 μs pulses at 50 Hz *energy varied changing the beam current*	5 mm	4 – 6
FE-MA Co. Ltd. Budapest (Hungary)	Commercial LUE-8 LINAC 3.6 μs pulses at 50 Hz beam scanned at 5 Hz *energy varied changing the magnetron high voltage and the beam current*	5 mm	4 – 6.5
Gambro-Dasco Medolla (Italy)	Commercial Rhodotron TT-100 "continuous" beam, 0.5 – 2.7 mA beam scanned at 100 Hz *energy does not vary*	12 mm	10

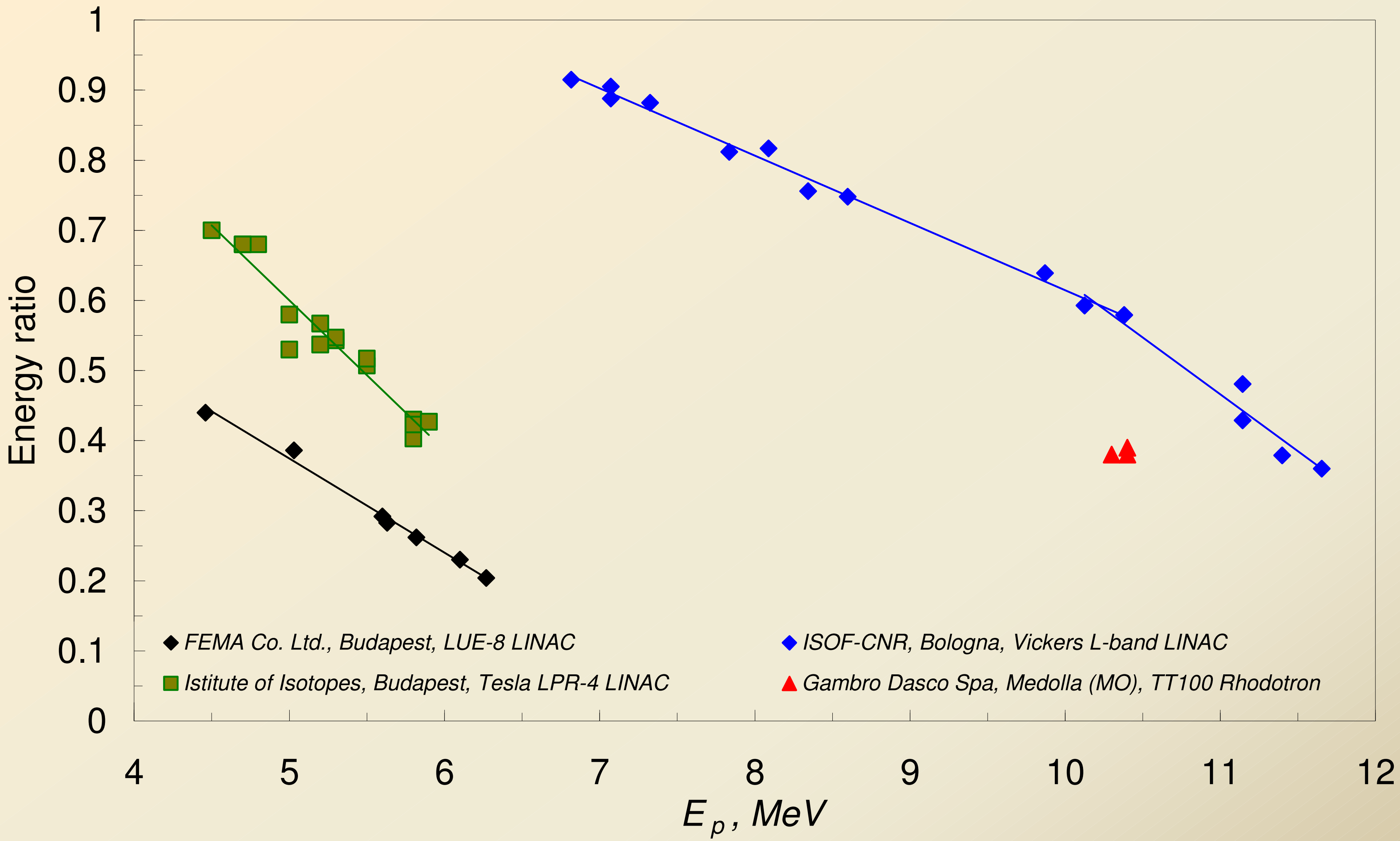
Several measuring techniques adopted:

- measurement of the charge deposited into the absorbers through the integration of the current for a fixed time, using digital current integrators (EG&G ORTEC 439) [ISOF, LINAC]

- measurement of the currents using EG&G ORTEC 439, used as current monitor [Gambro Dasco Spa, Rhodotron]

- dedicated measuring instrument realized using an integrated circuit, with ultra low bias and fast slew rate, selected so that its offset voltage and its temperature drift were as low as possible, hardwired in the current amplifier configuration [Institute of Isotopes, LINAC and FE-MA Co. Ltd., LINAC]

The previous results



Aim of the actual work:

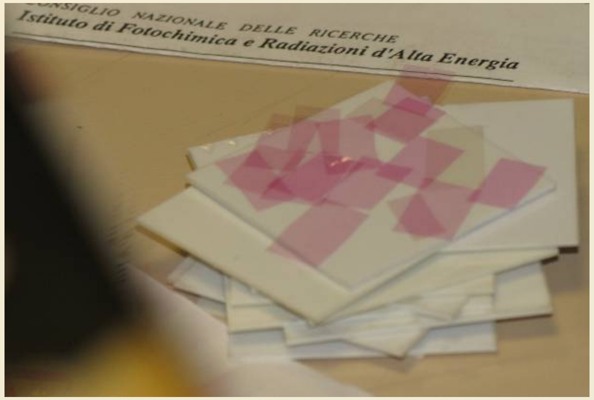
- extension of the method to a lower energy region (around 2 MeV)
- tests on the sensitivity performances of the device

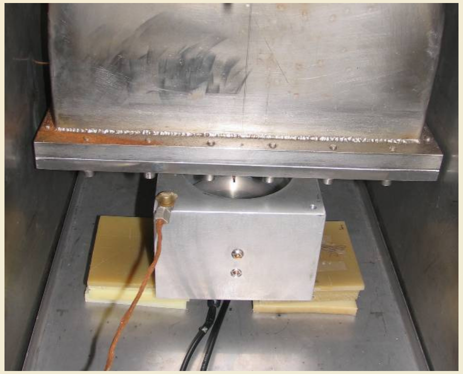
Experimental:

Electron beam source:
0.5 - 2.4 MeV; 1 - 125 μA Van De Graaff electron accelerator
Aérial (Strasbourg, France)

Energy monitoring device:
Thickness of front absorber plate: 2 mm
Measurement of the currents: electrometer Keithley 610B or multimeter (ITT Metrix MX512)

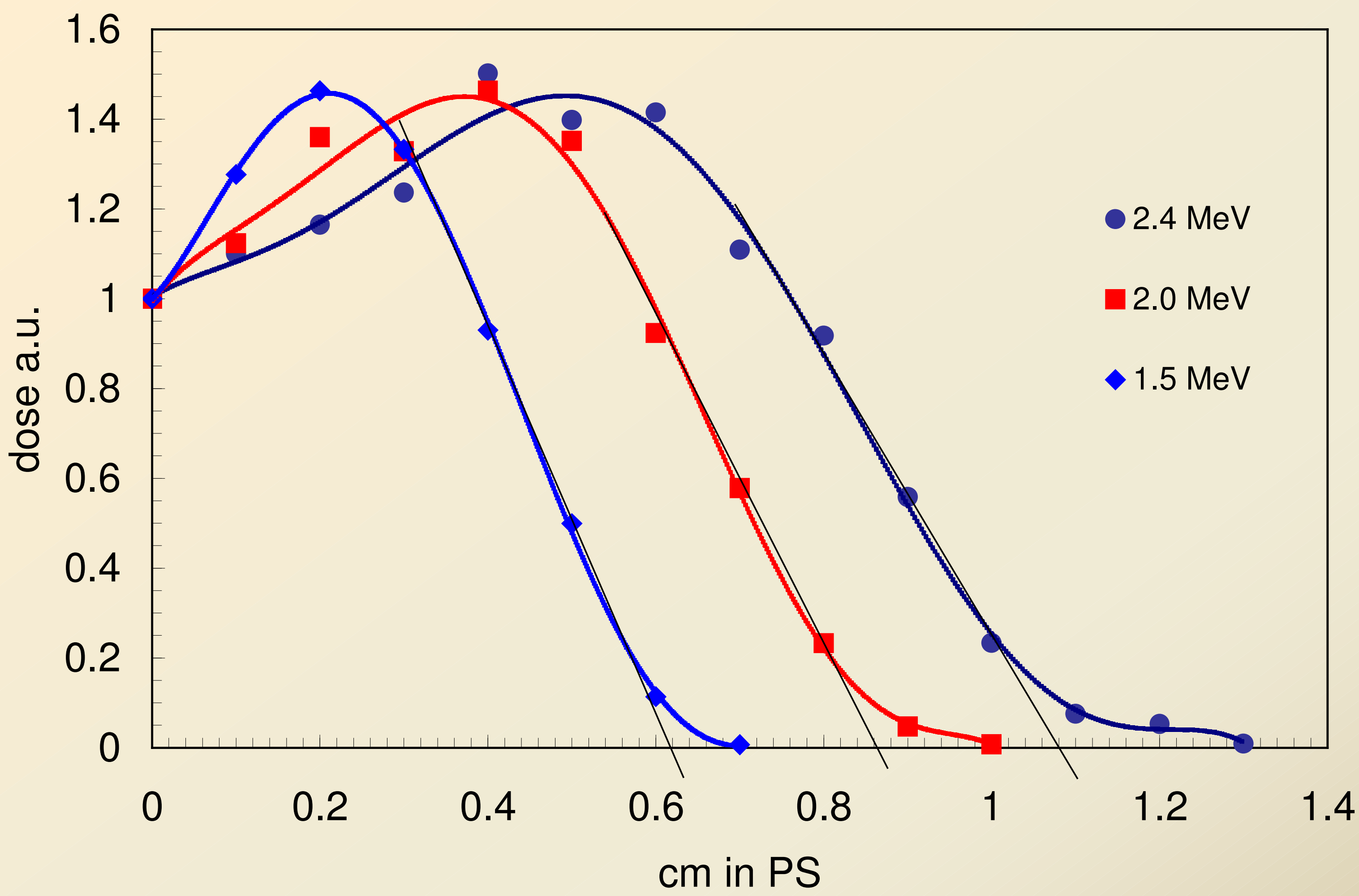
Energy measurement:
E_p: B3 radiochromic film dosimeters placed in within several polystyrene foils (stack technique)


ONSIGLIO NAZIONALE DELLE RICERCHE
Istituto di Fotochimica e Radiazioni d'Alta Energia




610B ELECTROMETER
KEITHLEY INSTRUMENTS


- 07.4
ITT INSTRUMENTS
metrix
MX 512

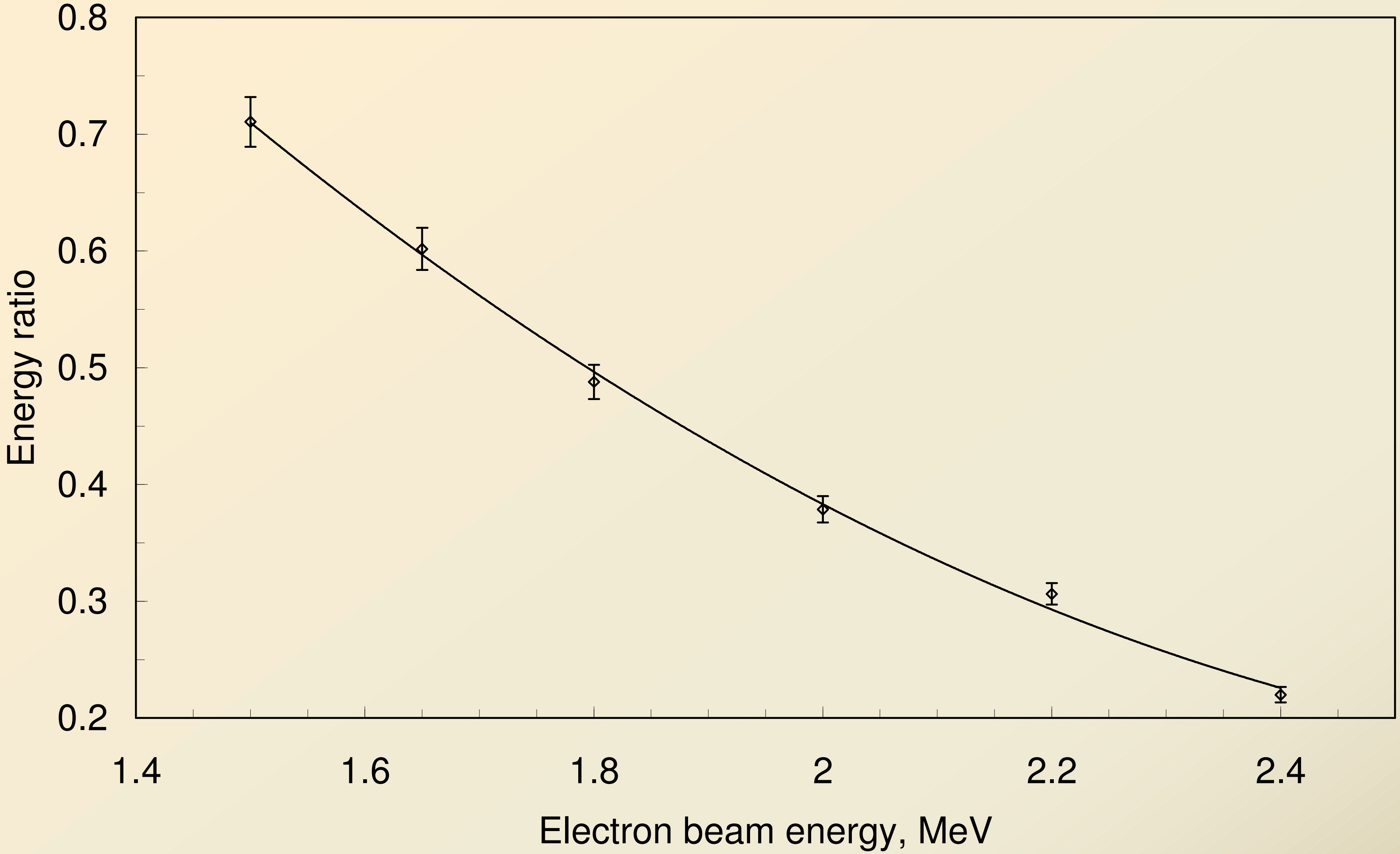


Depth-dose curves in polystyrene (PS).

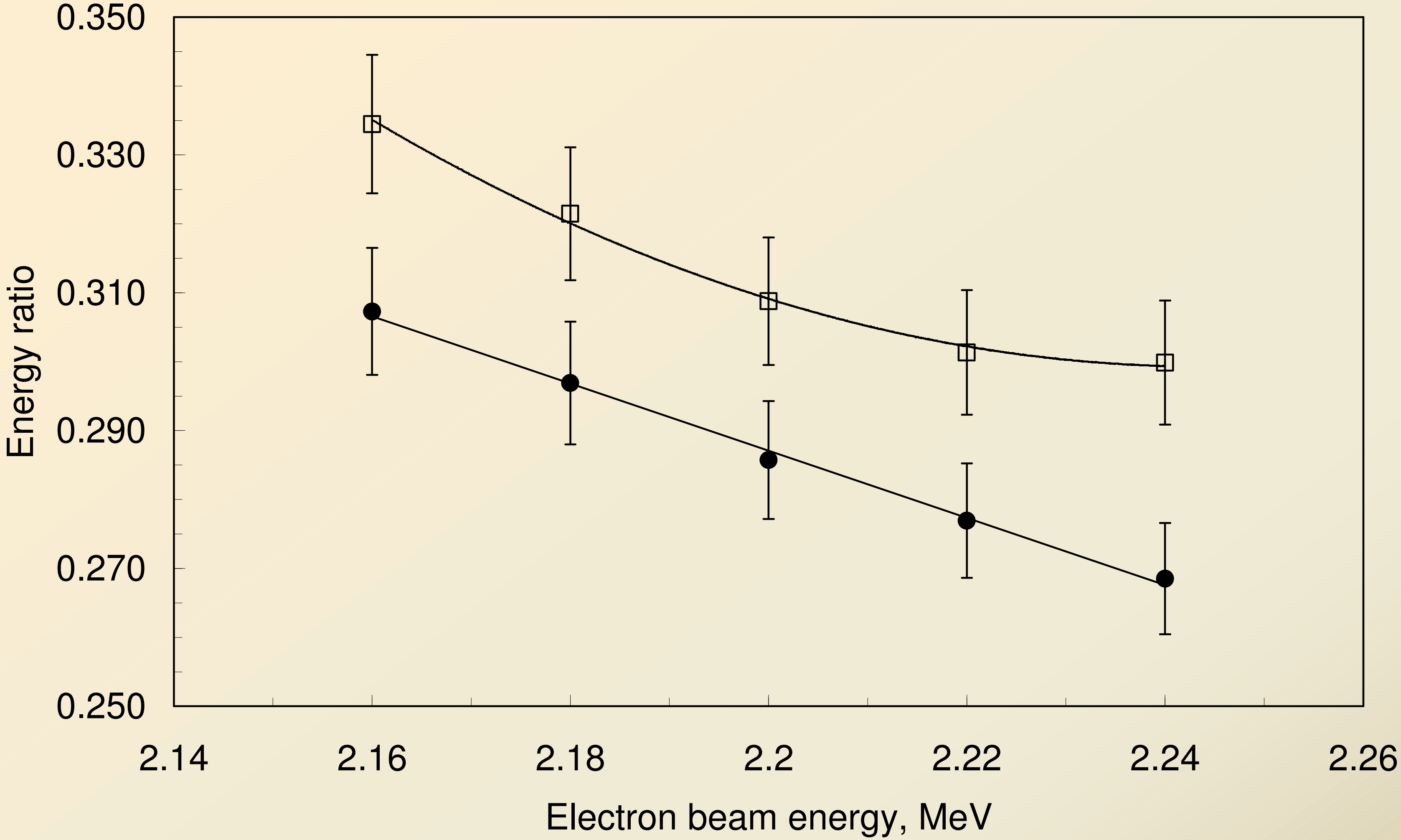
Nominal electron beam energy vs. the most probable electron beam energy:

Nominal electron beam energy* *(as set by the high voltage control)* MeV	Practical electron beam range measured in PS *(ρ = 1.06 g·cm^{-3})* cm	Practical electron beam range scaled to water *(ρ = 1 g·cm^{-3})* cm	Calculated most probable energy E_p MeV
1.5	0.62	0.64	1.5
2.0	0.86	0.88	2.0
2.4	1.08	1.11	2.4

**Calibrated during the facility installation using the technique of foil activation*



Response of the energy monitoring device
using the electrometer.



Test of the sensitivity of the energy monitoring device; measurements with electrometer (•) and multimeter (□).

Conclusions

The energy monitoring device:

- able to monitor variations in the electron beam in the range of 1.5 - 2.4 MeV (2 mm front absorber)

- sensitivity of at least 40 keV

- robust and immediate response: easy integration in the control system of an electron beam irradiation facility

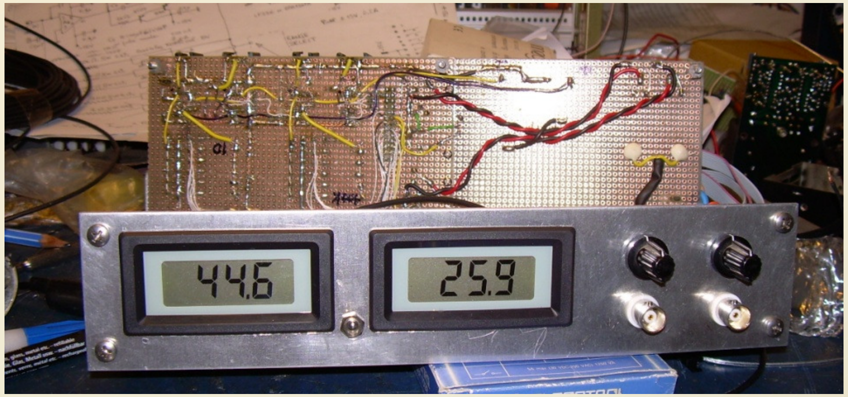
- the range of possible beam energy can be easily accommodated by properly selecting the thickness of the two absorber plates

- a variety of techniques can be adopted to measure the currents (or the charges) generated by accumulated electrons in the absorber plates

- for accurate measurements, either an electrometer or a dedicated circuit is needed

Future developments:

integration of a dedicated energy monitoring device, equipped with dedicated electronic, in research or industrial facilities for on-line monitoring of the electron beam energy. (Aérial, Strasbourg)



Acknowledgements

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Thank you !