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Continuum hard x-ray spectrum emitted from a Plasma Focus: a radiographic method

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Continuum hard x-ray spectrum emitted from a Plasma Focus: a radiographic method

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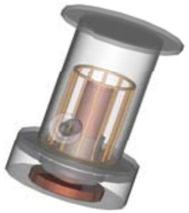


Outline

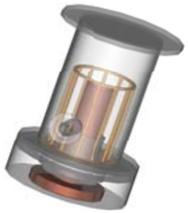
1) Experimental device

2) Applications of the hard x-rays

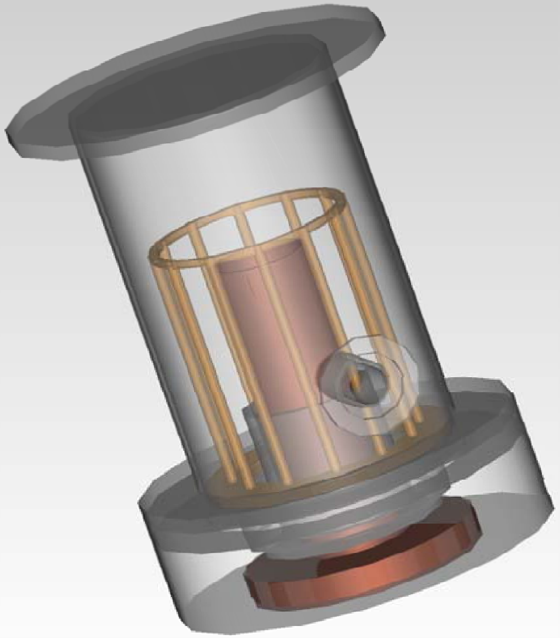
3) The method to measure the continuum hard x-rays

4) Results

5) Final remarks

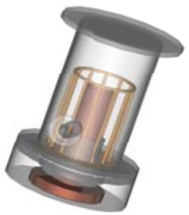


Experimental device

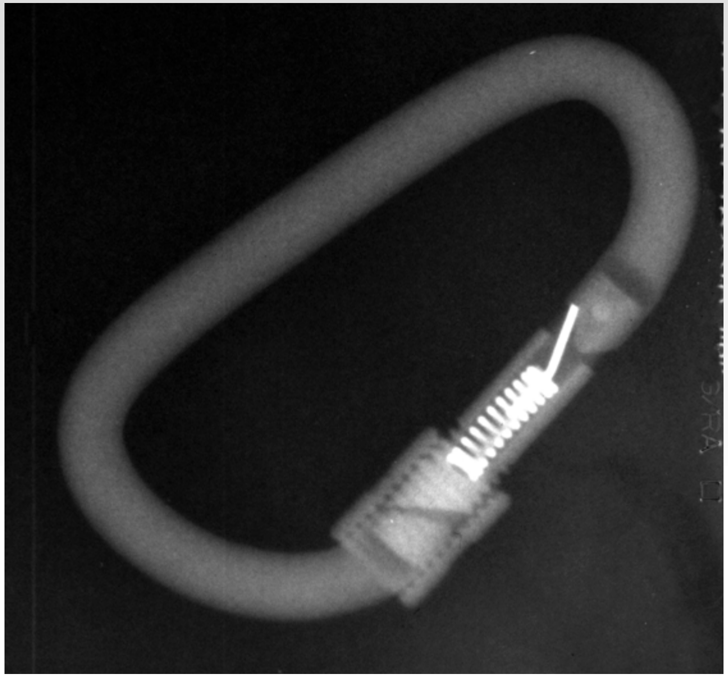


Anode radius	19 mm
Cathode radius	36 mm
Capacitance	10.5 μF
Energy	4.7 kJ
Pressure	3-6 mbar
Gas	D_2 + 0-5% Ar
Target	Pb

Diagnostics: Rogowski coil, PMT.

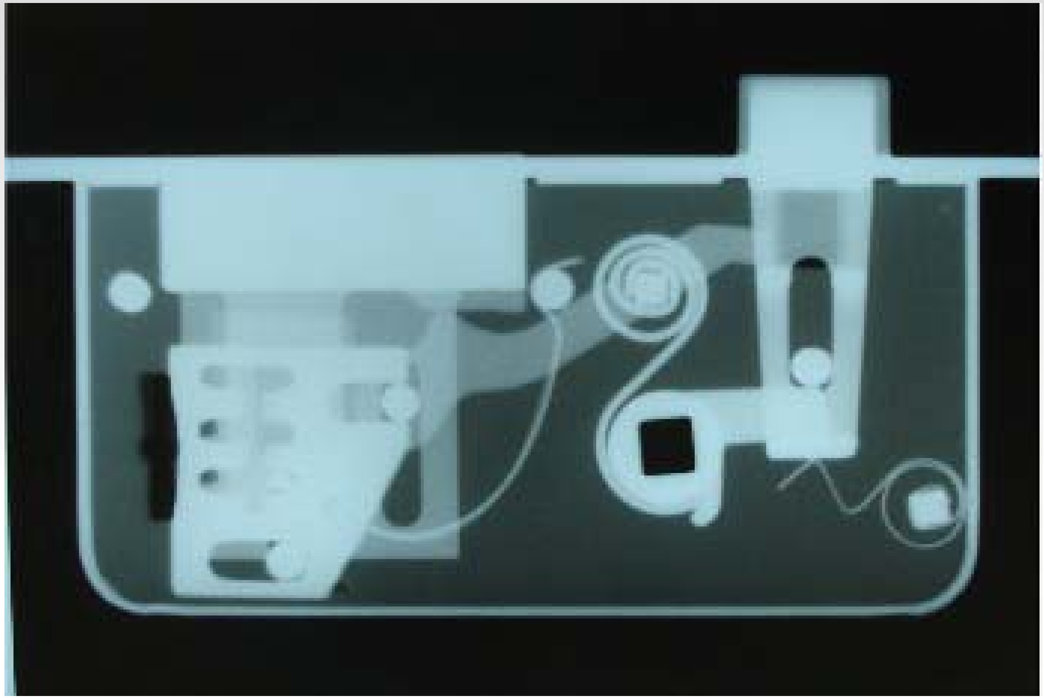


Applications



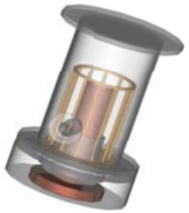
Hard x-ray introspective image of a metallic climbing carabiner.

C. Moreno, V. Raspa, L. Sigaut, R. Vieytes and A. Clausse.
Applied Physics Letters, 89, (9), 091502-1 to -3, (2006).



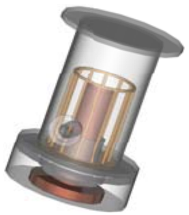
Single shot radiography of a standard door lock made on steel and brass.

V. Raspa, P. Knoblauch, F. Di Lorenzo, and C. Moreno
Physics Letters A, 374 (46), 4675-4677, (2010).

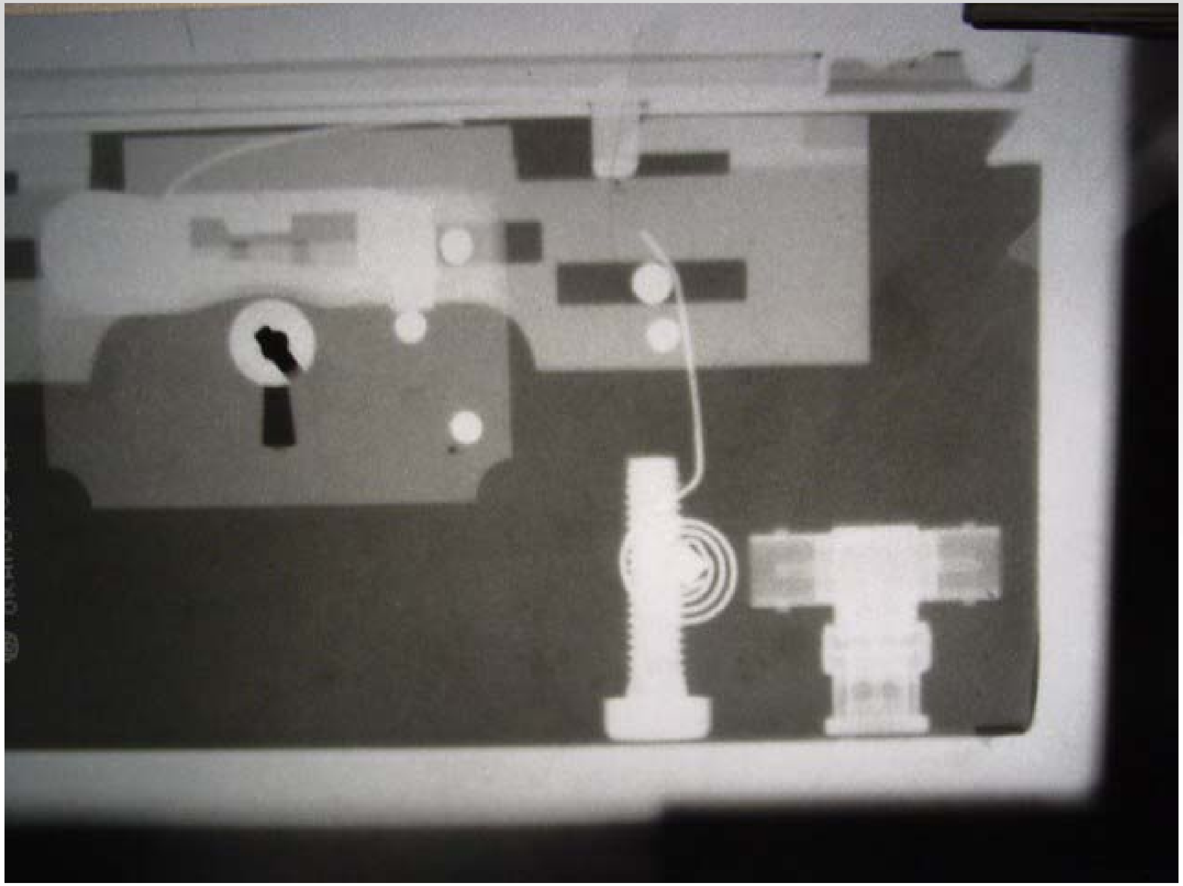


Applications

Snapshot of a strongbox containing a BNC tee and a brass bolt.



Applications



Radiography of the strongbox.

V. Raspa, F. Di Lorenzo, P. Knoblauch, A. Lazarte, A. Tartaglione, A. Clausse, and C. Moreno. PMC Physics A, 2:5, Oct (2008).

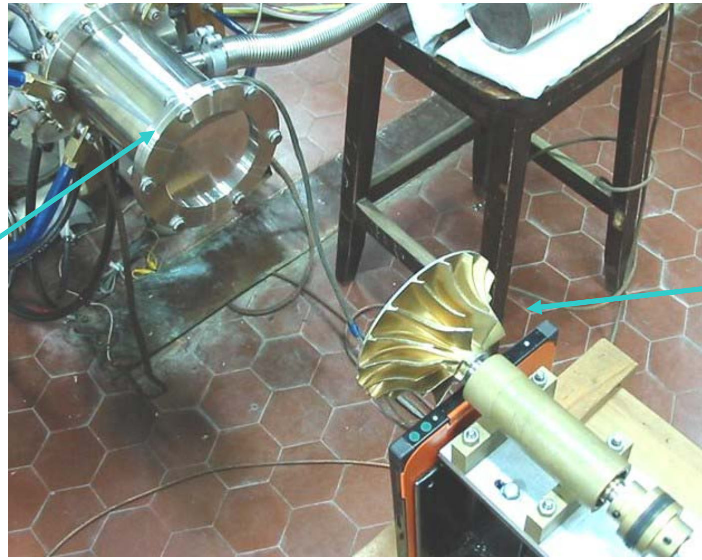
Applications

Front view

Side view

Turbine blade

Notch

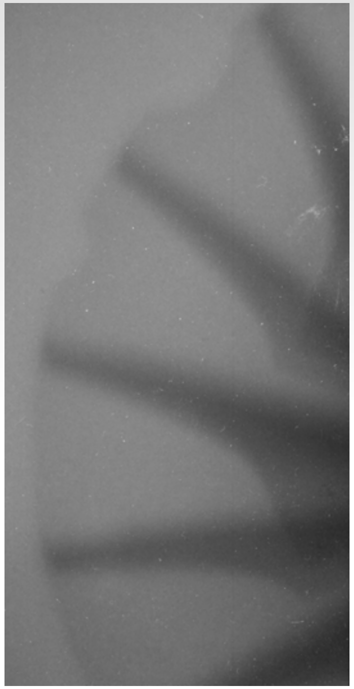


Discharge chamber

Turbine

Applications

W = 6100 rpm



Static turbine

Rotating turbine

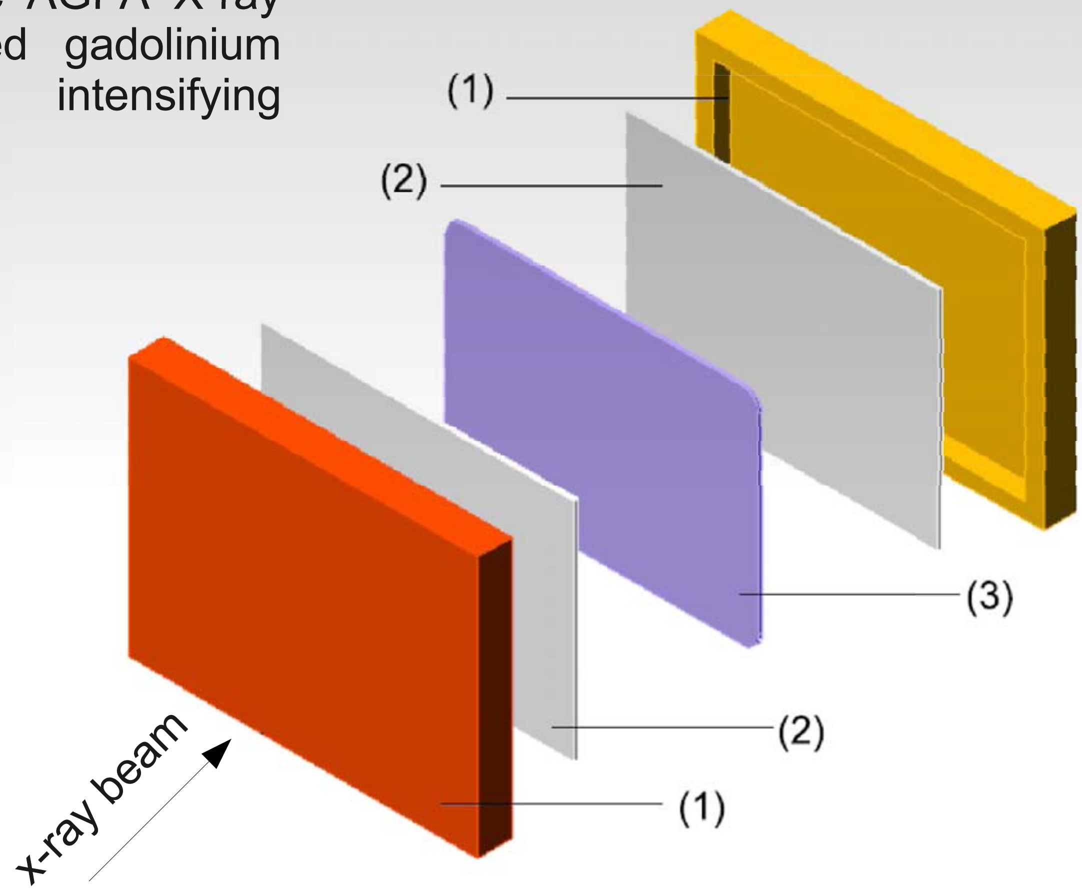
C. Moreno, V. Raspa, F. Di Lorenzo, A. Lazarte, P. Knoblauch, and A. Clausse
AIP Conference Proceedings 875, ISBN: 978-0-7354-0375-8, J. Julio E. Herrera Velázquez Ed., 438-441, 4 Dec (2006).

Radiographic image of a BNC tee connector with a single plasma focus shot, through a 9-mm-thick iron flange.

V. Raspa, C. Moreno, L. Sigaut, and A. Clausse
Journal of Applied Physics,102,(12),123303, Dec (2007).

The detector

High sensitivity orthochromatic AGFA X-ray film along with terbium-doped gadolinium oxysulphide (Gd_2O_2S:Tb) intensifying screens.



Exploded sketch of the detector. Refs.: (1) light-tight plastic cassette body, (2) intensifier screen, (3) X-ray film.

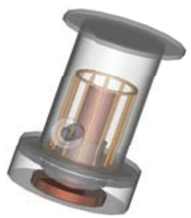
The method

The amount of visible photons per unit area impressing the film due to the transmission of the hard X-ray polychromatic beam through an arbitrary metallic sample of thickness d is defined as

$$I(d) \equiv \int_0^{\infty} A\,\eta(E)\,S(E)\,e^{-k(E)d}\,dE$$

- A: Number of photons
- $\eta(E)$: the screen conversion efficiency
- $S(E)$: continuum part of the unknown hard X-ray spectrum
- $e^{-k(E)d}$: linear attenuation coefficient, k(E), depending on the sample material

V. Raspa and C. Moreno. Physics Letters A 373 (2009) 3659–3662



The method

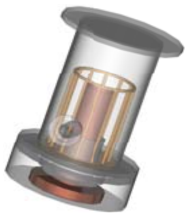
To get rid off the unknown quantity A, the following transmission coefficient T(d) can be considered

$$T(d) \equiv \frac{I(d)}{I(0)} = \frac{\int_0^\infty \eta(E) S(E) e^{-k(E)d} dE}{\int_0^\infty \eta(E) S(E) dE}$$

For a set of metallic samples made of different materials and thicknesses

$$T_{ij} = \frac{\int_0^\infty \eta(E) S(E) e^{-k_i(E)d_{ij}} dE}{\int_0^\infty \eta(E) S(E) dE}$$

V. Raspa and C. Moreno. Physics Letters A 373 (2009) 3659–3662

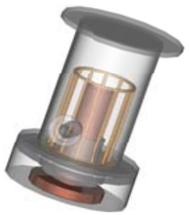


The method

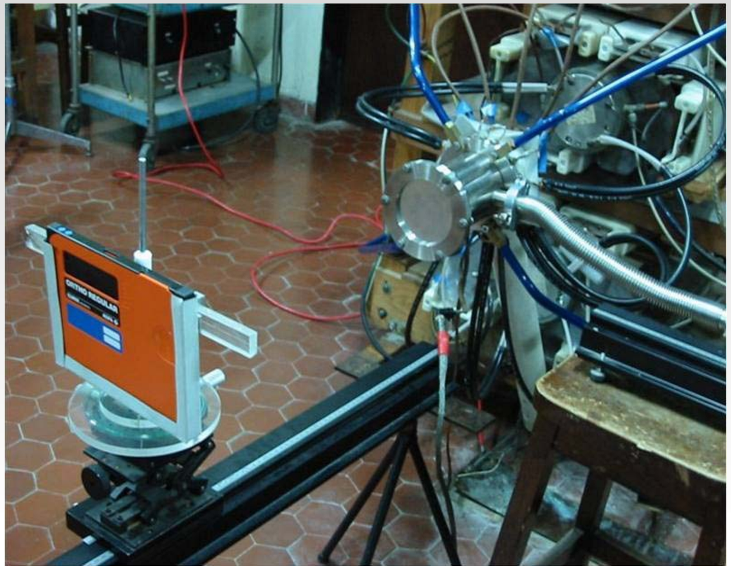
The standard weighted least-squares method can be used to infer a point-defined function S(E) by minimizing the functional X^2 defined as

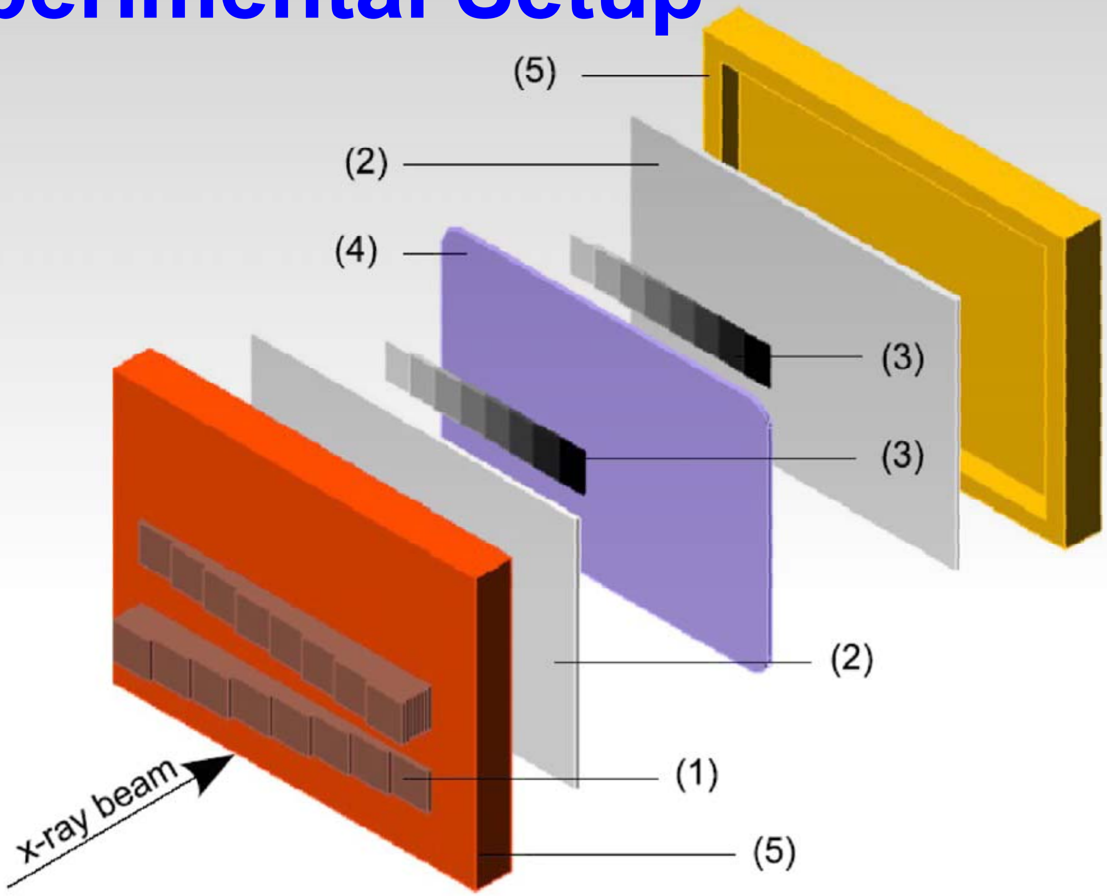
$$X^2 = \sum_{i,j} w_{ij} \left(T_{ij}^{meas} - T_{ij} \right) \qquad w_{ij} = \sigma_{ij}^{-1}$$

Transmission measured



The method: Experimental Setup

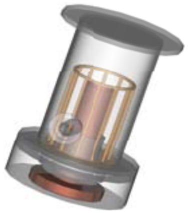




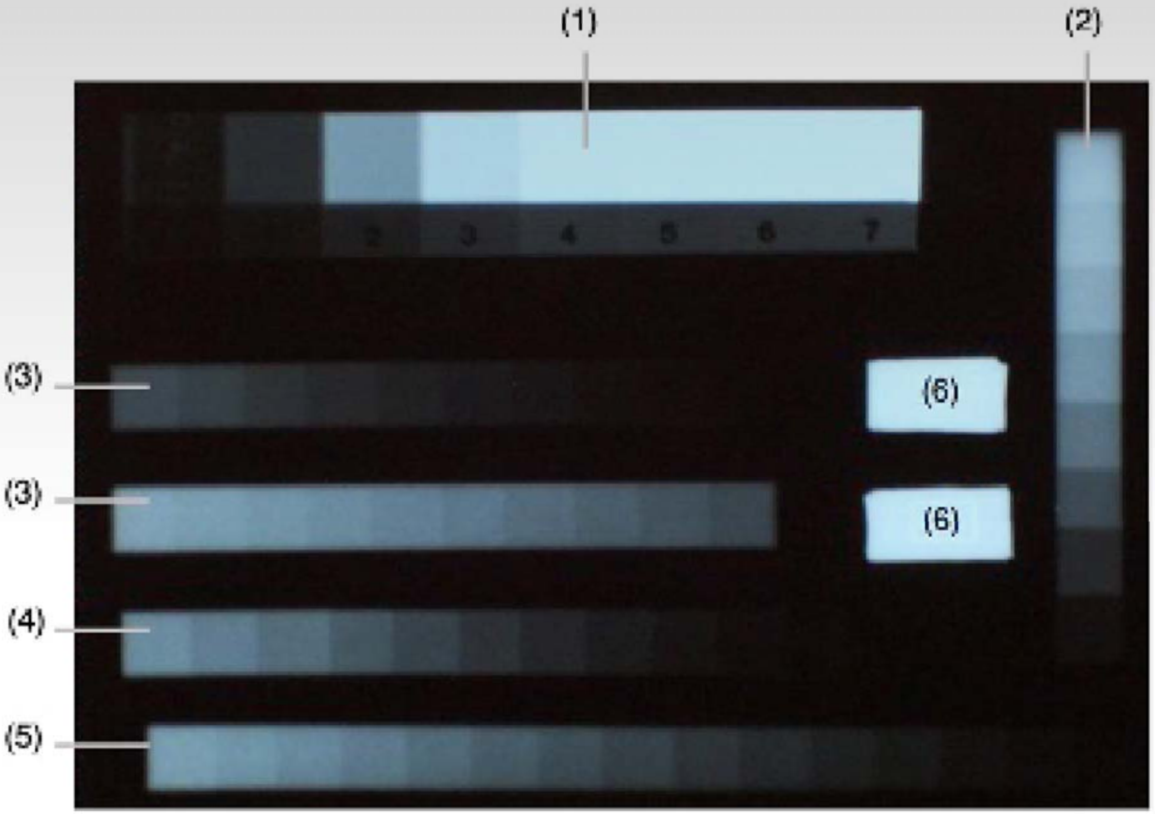
The screen-film detection system gives no direct information on T_{ij}^{meas} but rather on optical densities, we propose to place, between each intensifier screen and the film, a set of calibrated gray filters for the visible light emitted by the screens.

Refs: (1) metallic plates, (2) intensifier screen, (3) calibrated transmission set, (4) X-ray film, (5) light-tight plastic cassette body.

V. Raspa and C. Moreno. Physics Letters A 373 (2009) 3659–3662



The method: Radiographic image



Material	Thicknesses [mm]
silver	from 0.10 to 0.80, in eight 0.10 steps
titanium	from 0.89 to 9.79, in eleven 0.89 steps
copper	from 0.20 to 3.00, in fifteen 0.20 steps
nickel	from 0.15 to 3.00, in twenty 0.15 steps
lead	14.00 and 18.80

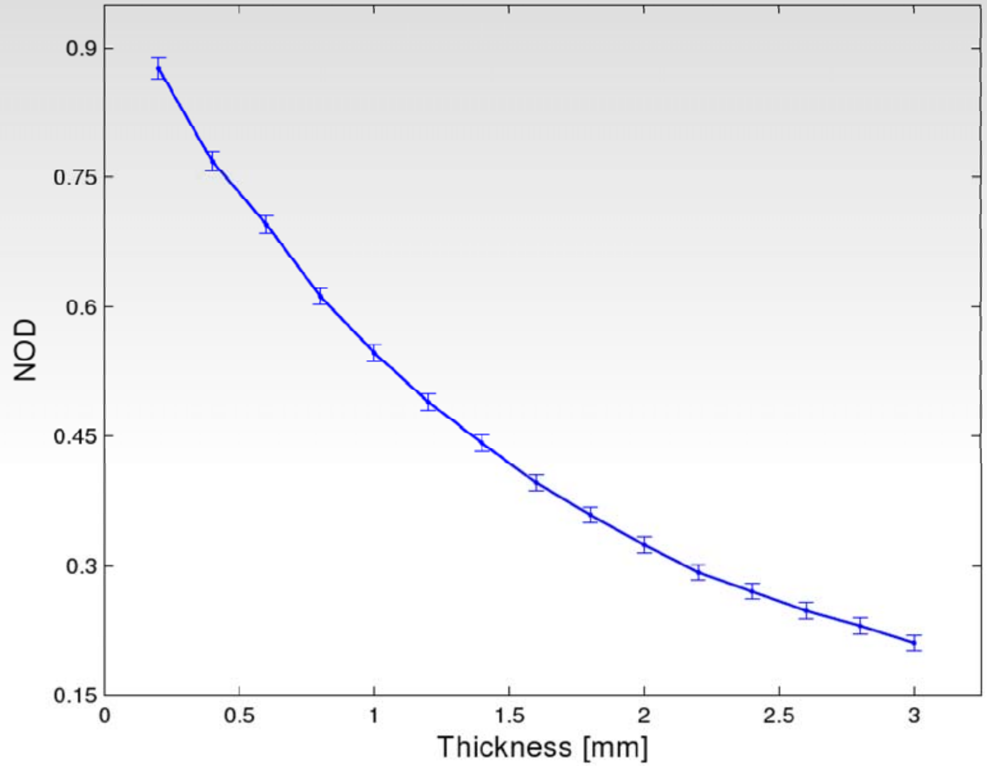
Single-shot radiographic image of the plates set used to determine the radiation spectrum.
Refs.: (1) calibration image, (2) silver, (3) nickel, (4) titanium, (5) copper and (6) fog level reference.

The method: Optical density

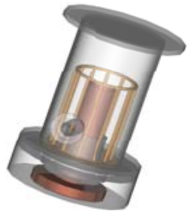
To take eventual film inhomogeneities into account, it is defined the normalized optical density (NOD)

$$NOD_{ij} = \frac{OD_{ij}}{OD_{ij}^{B}}$$

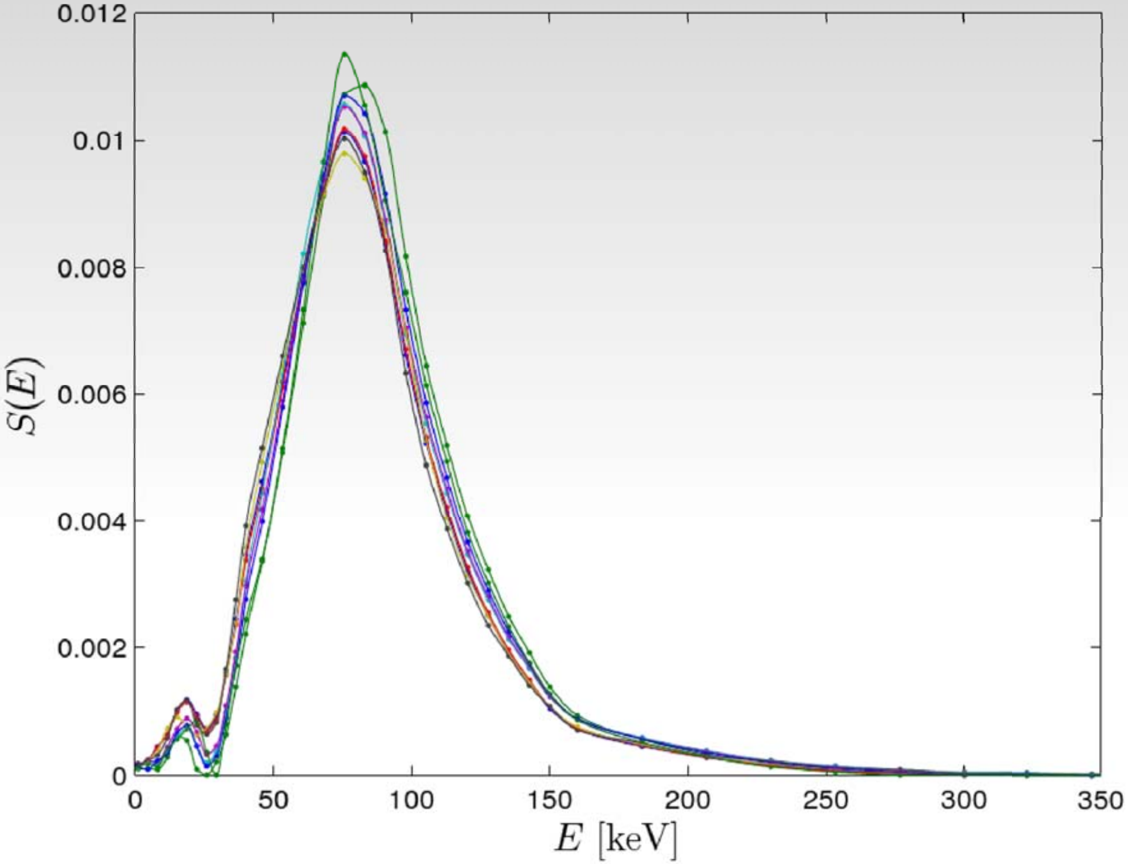
where OD_{ij} is the optical density measured for sample ij and OD_{ij}^{B} is the optical density of the nearby background.



Normalized film optical density for the copper metallic samples as a function of the sample thickness.



Results



- Single dominant peak around 75 keV.
- A spectral bandwidth covering the 40–150 keV region.
- The spectral amplitudes decay for increasing energies greater than 75 keV until becoming negligible beyond 250 keV.

d = 70 cm
p = 3.5 mbar (D2 + 2.5% Ar)

Hard X-ray continuum spectra obtained from the analysis of different radiographies taken under the same experimental conditions.

V. Raspa, P. Knoblauch, F. Di Lorenzo and C. Moreno.
Physics Letters A 374 (2010) 4675–4677

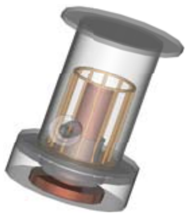
Final remarks

• The examined radiation proved to be well suited for good contrast radiography of different materials.

•The resulted spectrum presents a maximum around 75 keV, and a spectral bandwidth covering the 40–150 keV region.

• Filter materials and thicknesses and/or calibrated transmission sets can be adapted to explore the hard X-ray output of other devices having, for instance, different spectral characteristics and/or emission intensities.

• Since only the use of standard materials and numerical procedures are required, the presented method is inexpensive and easy to be applied.



Thank you for your kind attention