PAUL SCHERRER INSTITUT

PSI

Emilio Andrea Maugeri

&

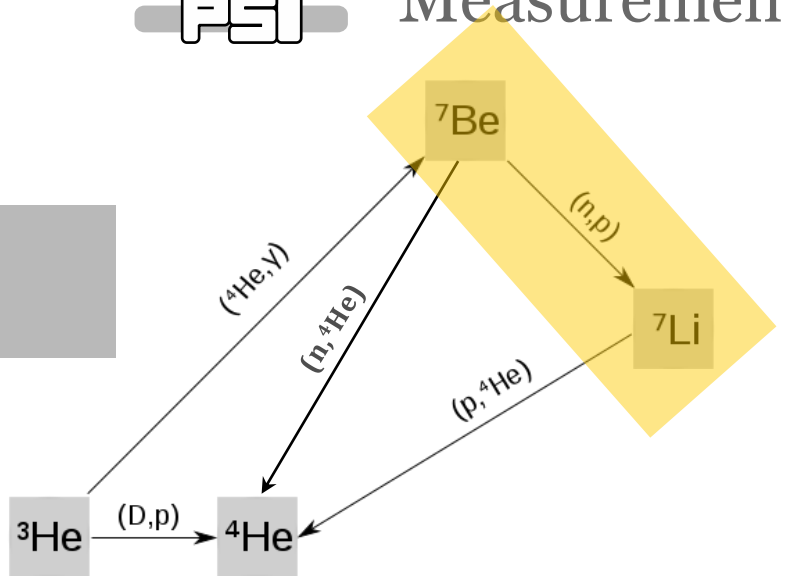
the PSI crew

Characterization of the ^{7}Be target used for the measurement of the ^{7}Be(n, p)^{7}Li reaction cross sections

Isotope and Target Chemistry :: Paul Scherrer Institut

n_TOF Collaboration meeting, 11-12 December, 2017. Madrid, Spain

Measurement of the $^{7}Be(n,p)^{7}Li$ cross section



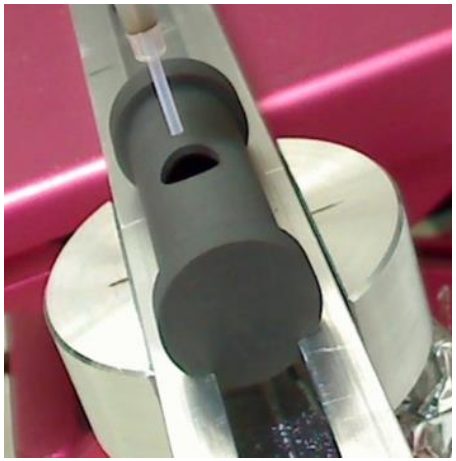
$^{7}Be(n,p)^{7}Li$ (1.64 MeV)

Target:

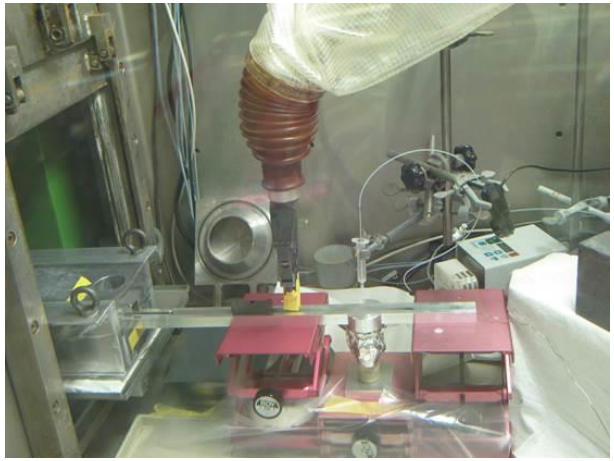
- ≈ 100 ng of ^{7}Be (≈ 1.3 GBq)
- Off-line mass separation at ISOLDE
- Implantation on backing

Two targets of 20 MBq and 1.1 GBq of ^{7}Be, respectively

Preparation of the starting ^{7}Be material



About 90 GBq of ^{7}Be were loaded into a cylindrical graphite crucible



transferred to the shielded container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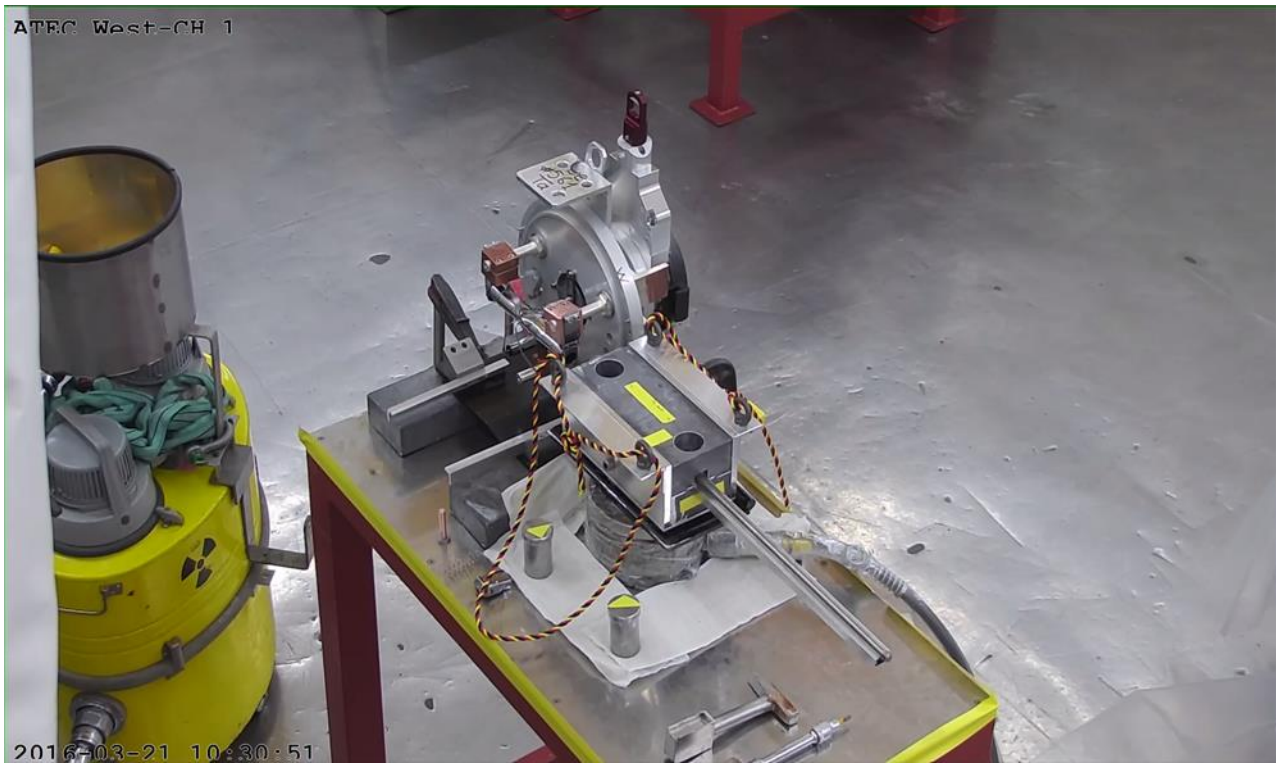
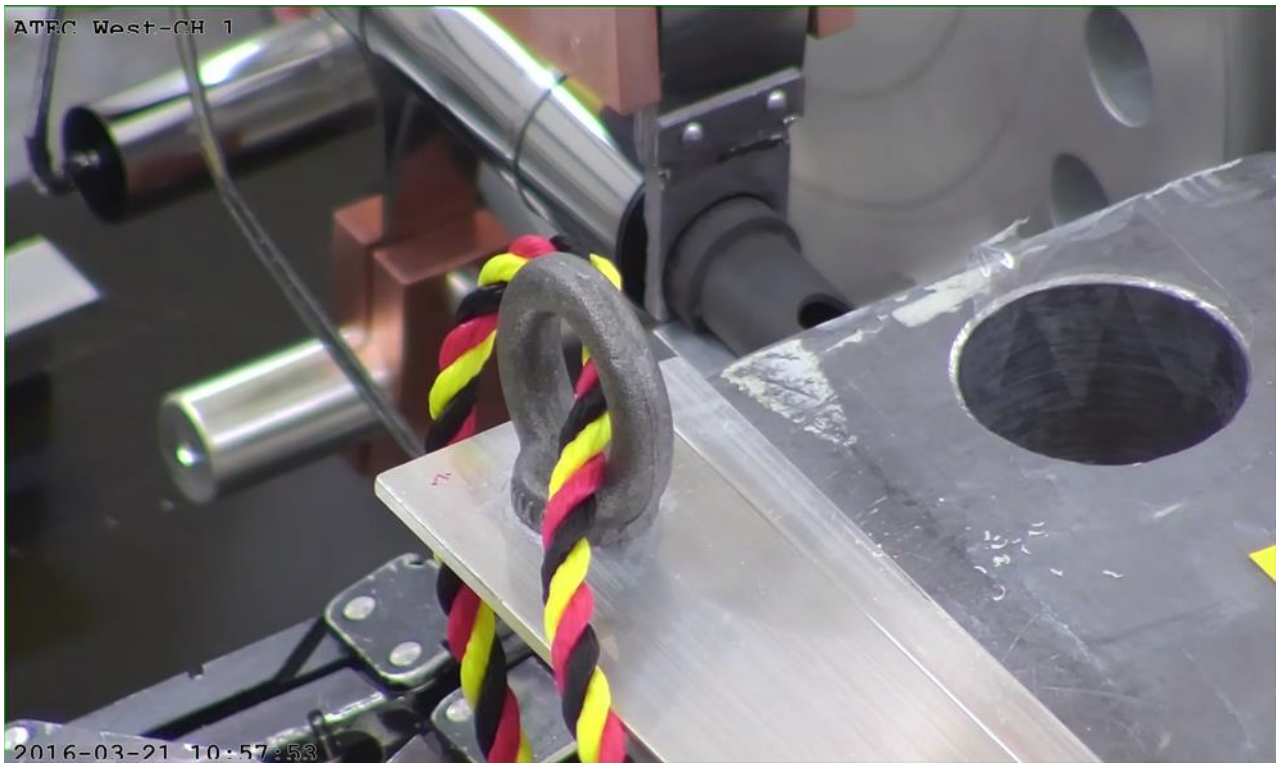


it was inserted into the empty tantalum target container (20 mm inner diameter and 200 mm length) connected to a FEBIAD ion source unit equipped with a tantalum ionizer tube (3 mm inner diameter, 30 mm length).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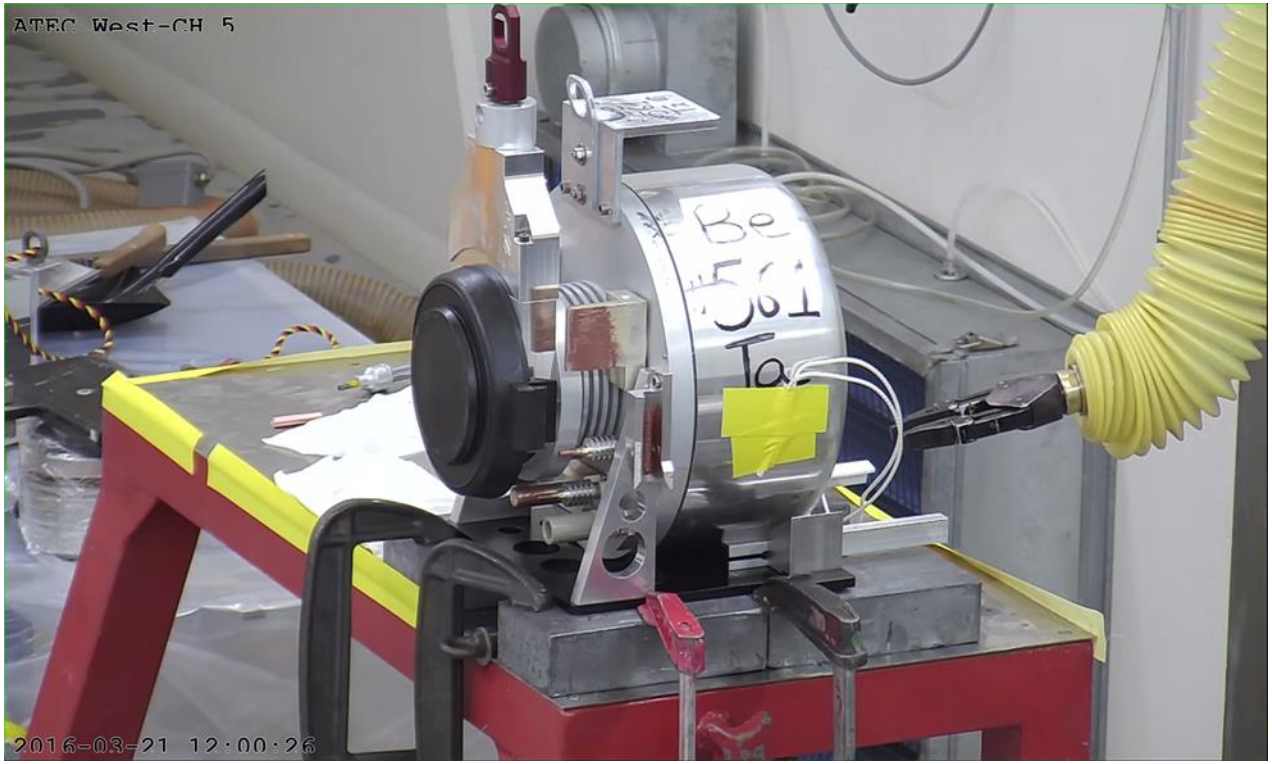
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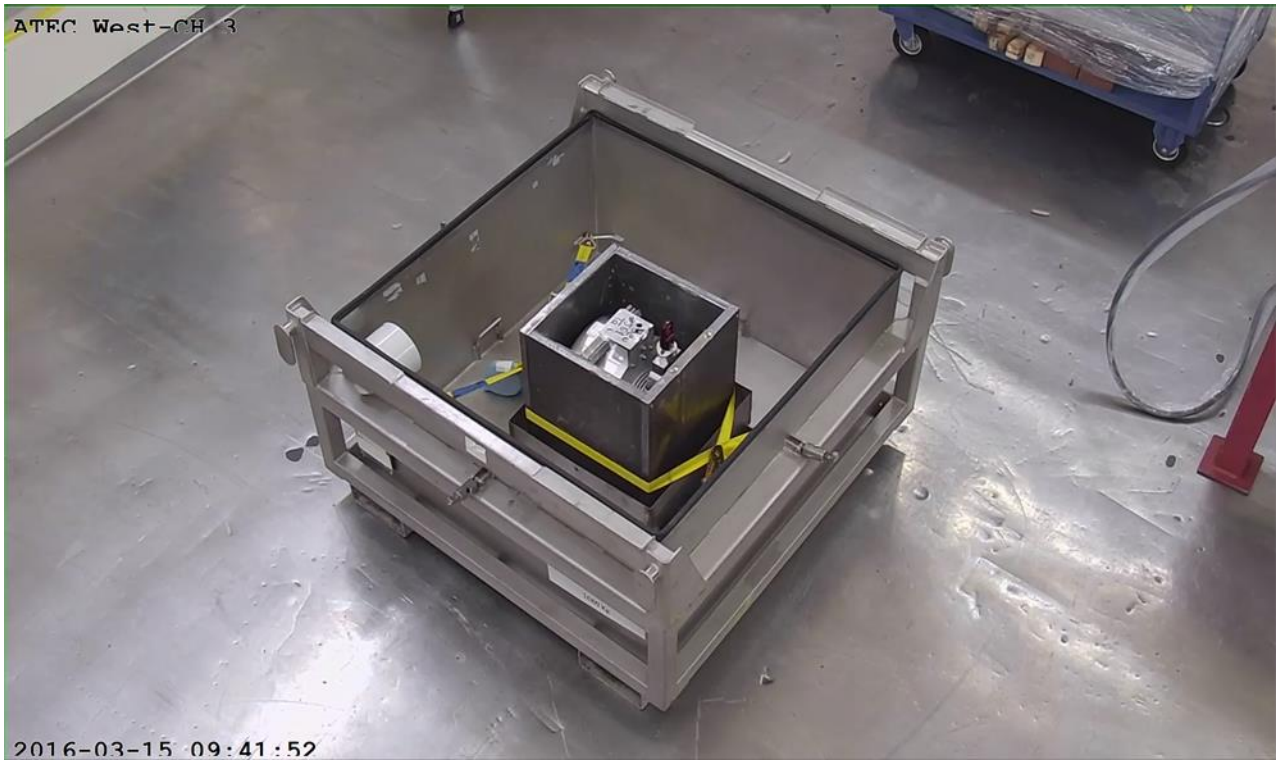
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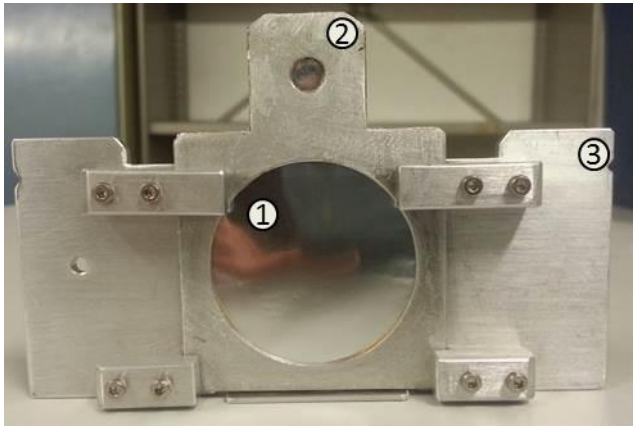
ATEC West-CH 1
2016-03-21 09:34:42

Target assembly



(1) aluminium backing; (2) aluminium frame, (3) target holder.

Al backing dimensions h × w × d: (50 × 50 × 0.018) mm

Frame dimensions h × w × d: (50 × 50 × 1) mm, with a 40 mm diameter central hole

Implantation of ^{7}Be

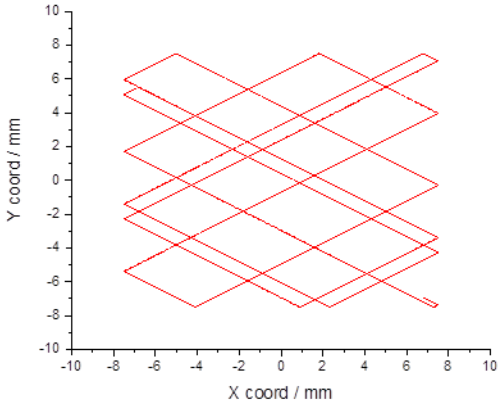
Lissajous curve

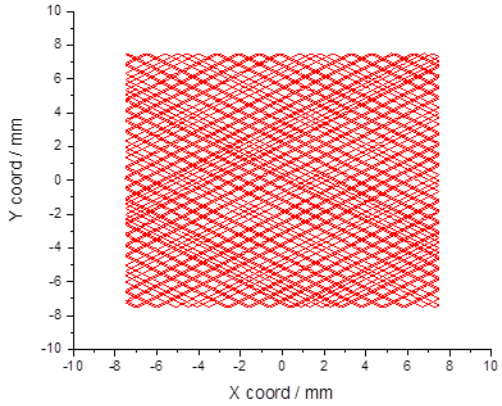
$$x = A_x\, f(\varpi_x t + \phi_x)$$

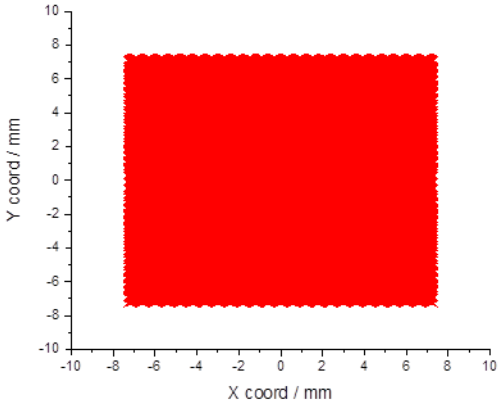
$$y = A_y\, f(\varpi_y t + \phi_y)$$

A_x and A_y are the amplitudes
ϖ_x and ϖ_z are the frequencies
ϕ_x and ϕ_y are the phases

$A_x = A_y$
ϖ_x = 241 Hz; ϖ_z = 150 Hz
$\phi_y = 0.125$







7.2×10^{15} ions, corresponding to an activity of about 1 GBq, were estimated to be implanted over 10 hours. The ^{7}Be beam intensity was between 5 nA and 44 nA

Cross section measurement

$$\sigma = \frac{C}{\Phi\, N \sum f_t}$$

Where C is experimental counts (number of interactions per cm^2 per second), and Φ is the flux of beam particles passing through the target, N is the target nuclei density, $\sum f_t$ is the sum of correction factors.

$$\sigma = \frac{C}{C_{ref}} \frac{N_{ref}}{N} \sigma_{ref}\, BIF$$

Where *BIF is the beam interception factor, i.e. the fraction of the neutron beam intercepted by the target nuclei

BIF depends on the beam profile and target size. It very important when the target is smaller than the beam profile, since it interacts with only a fraction of it.

$$BIF = \frac{BIF_{ref}}{BIF_{target}}$$

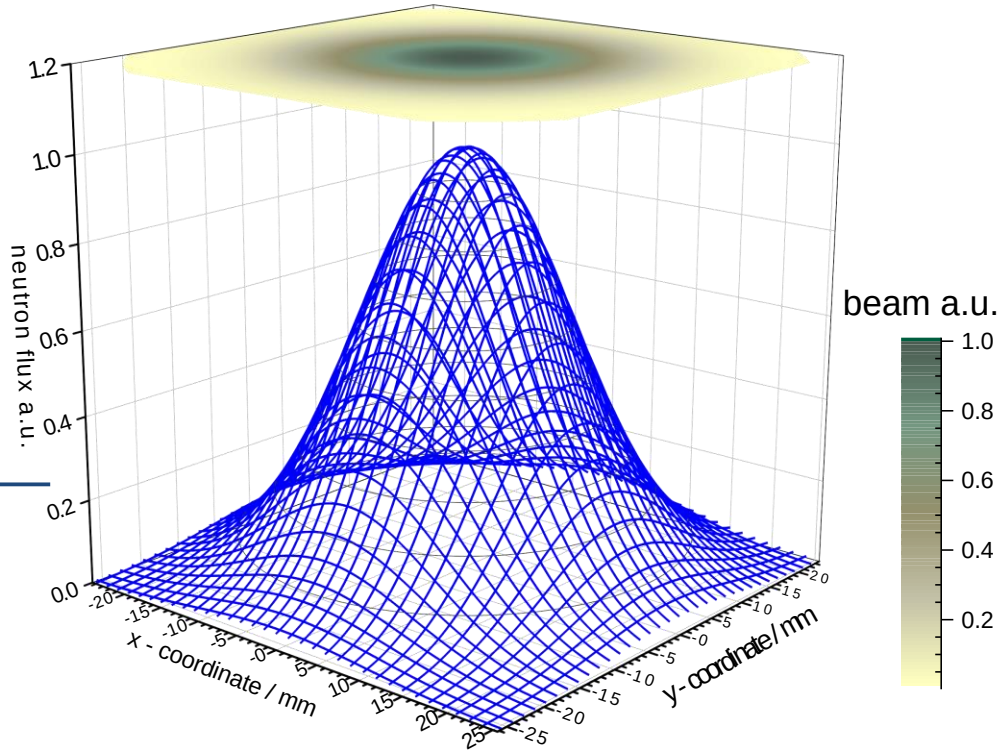
**ratio of the number of neutrons hitting the target nuclei to the number of neutrons in the whole beam*

Spatial beam profile

Results EAR2

E	PX (mm)		PY (mm)	
(eV)	mean	sigma	mean	sigma
1e-3 – 1e-2	19.50	9.92	25.18	10.09
1e-2 – 1e-1	19.52	10.11	25.25	10.28
1e-1 – 1	19.12	10.08	25.57	10.26
1 – 1e1	18.76	10.08	25.93	10.34
1e1 – 1e2	18.62	10.08	26.03	10.83
1e2 – 2e2	18.51	10.23	25.17	10.62

Expected target radius ~ 20 mm



M. Barbagallo, n_TOF Analysis Meeting, CERN, February 2015

Distribution of ^{7}Be in implanted targets

Radiographic imaging method:

GE Typhoon™ FLA 7000 is laser scanner with spatial resolution down to 25 μm was used in combination with reusable Fujifilm imaging plates.

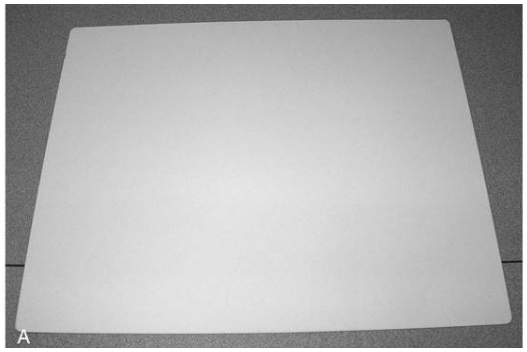
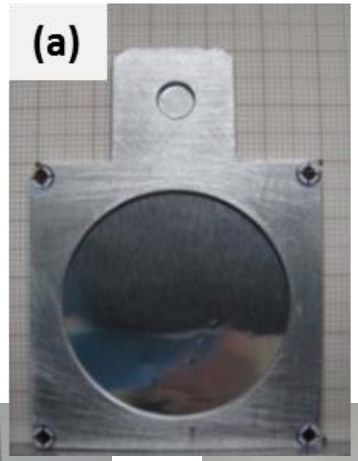


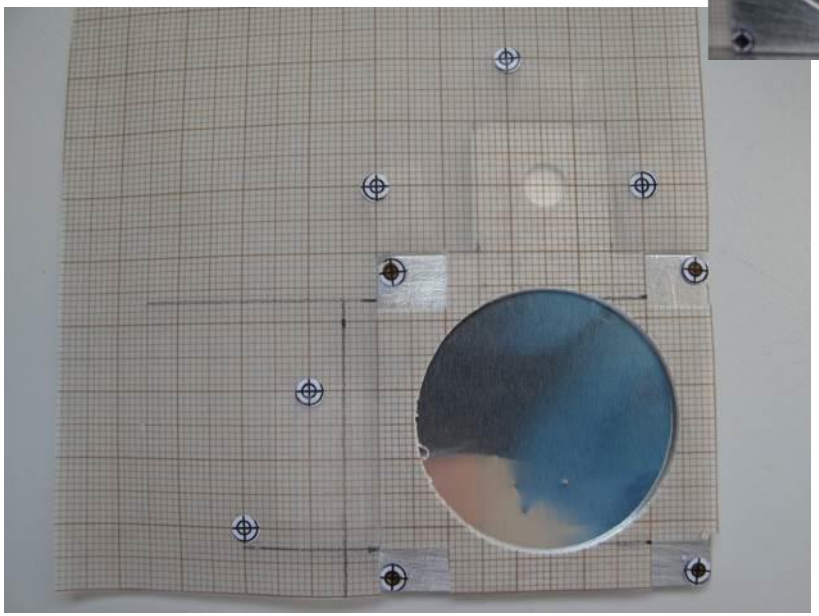
Table 1 Thickness, density, and material of each layer.

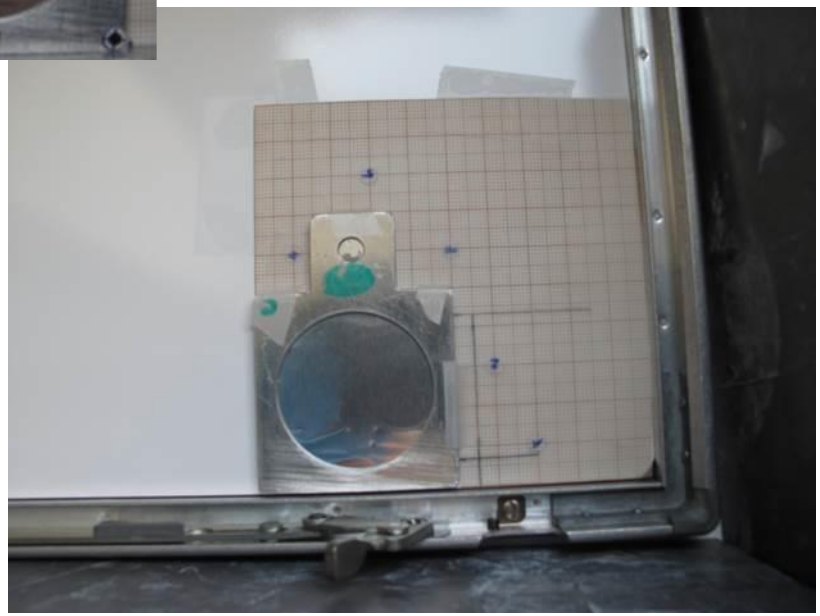
Layer type	Thickness (μm)	Density (g/cm^3)	Material
Surface layer	9	1.4	polyethyleneterephthalate
Phosphor layer	115	3.3	phosphor* : urethane = 25 : 1 *Ba : F : Br : I (atomic number ratio 1 : 1 : 0.85 : 0.15, density 5.2 g/cm^3)
Back layer	12	1.4	plastic
Base layer	190	1.4	polyethyleneterephthalate
Ferrite layer	80	3.0	MnO, ZnO, Fe_2O_3 + plastic
Back protective layer	25	1.4	polyethyleneterephthalate

- Imaging Plate is a two-dimensional radiation detector with a phosphor layer of photostimulable barium fluorobromide usually doped with europium ($BaFBr:Eu^{2+}$).
- This layer trap and store the radiation energy.
- The stored energy is stable until scanned with a laser beam, which releases the energy as luminescence.
- The emitted light is collected and transformed to an electrical signal by a photomultiplier tube.
- The electrical signal is then converted into digital information by A/D conversion for image display and analysis.

Distribution of ^{7}Be in implanted targets



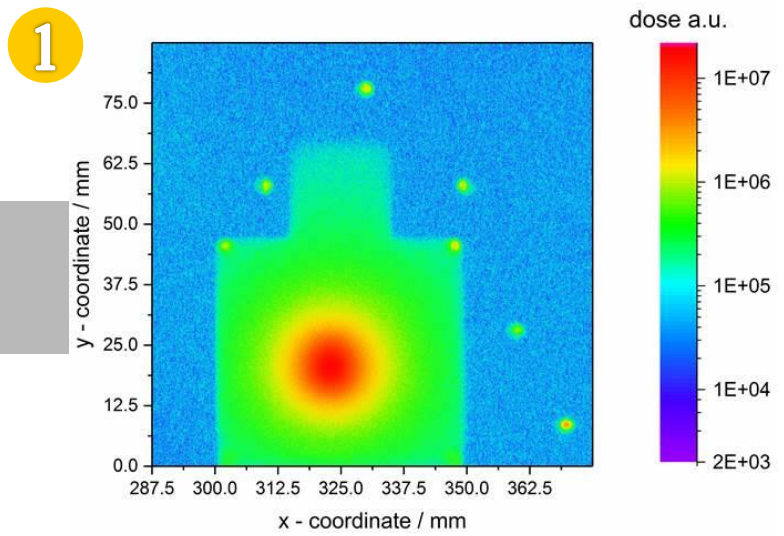




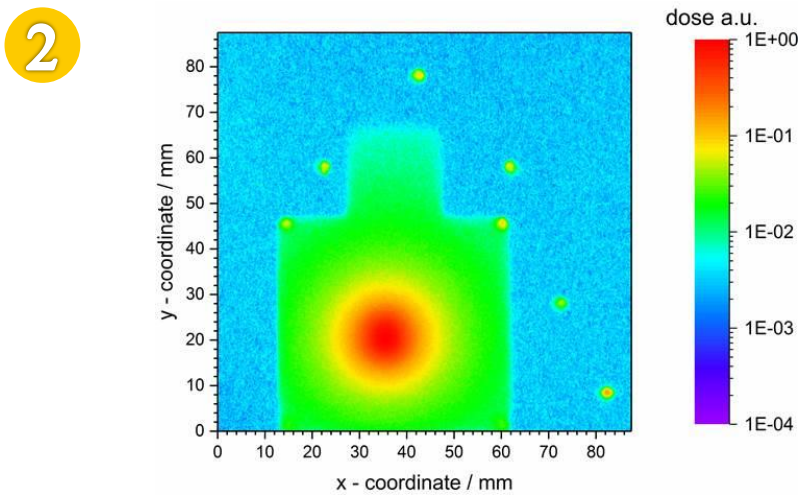
The target was placed on a millimetre graph paper with openings corresponding to the central hole of the aluminium frame and to the four ^{44}Ti markers,

The implanted area of the targets was placed facing the IP in a light-tight aluminium case.

Raw image from the ARIP. Resolution: 0.025 mm

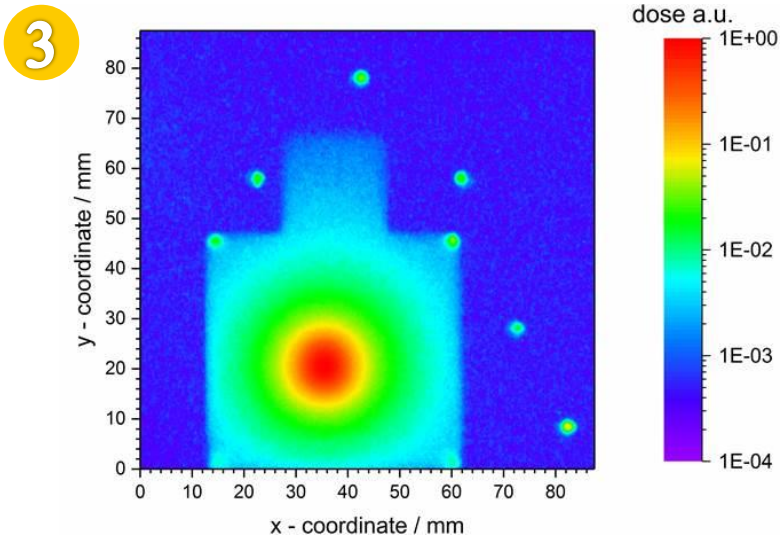


Re-binning to shrink the size of the picture to dimension we can handle with our software. Resolution: 0.25 mm

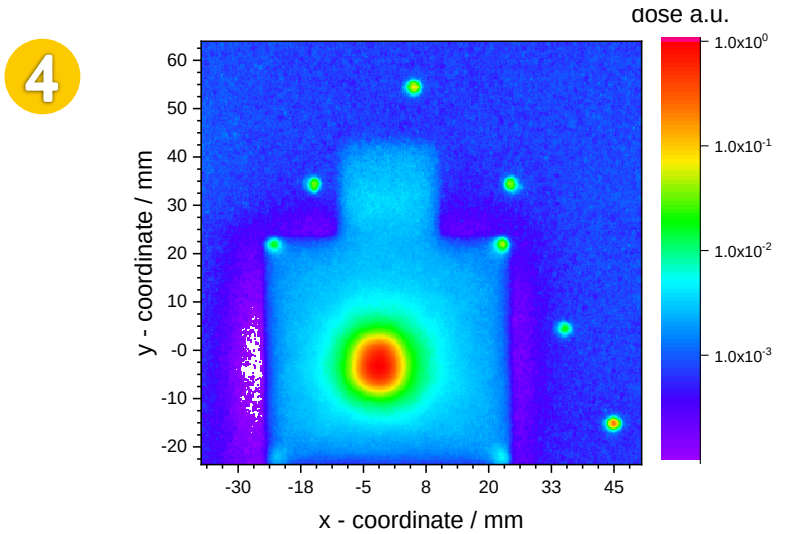


x-centre [mm]	x-width [mm]	y-centre [mm]	y-width [mm]
2.017 ± 0.183	**3.273 ± 0.011**	-2.980 ± 0.112	**3.607 ± 0.012**

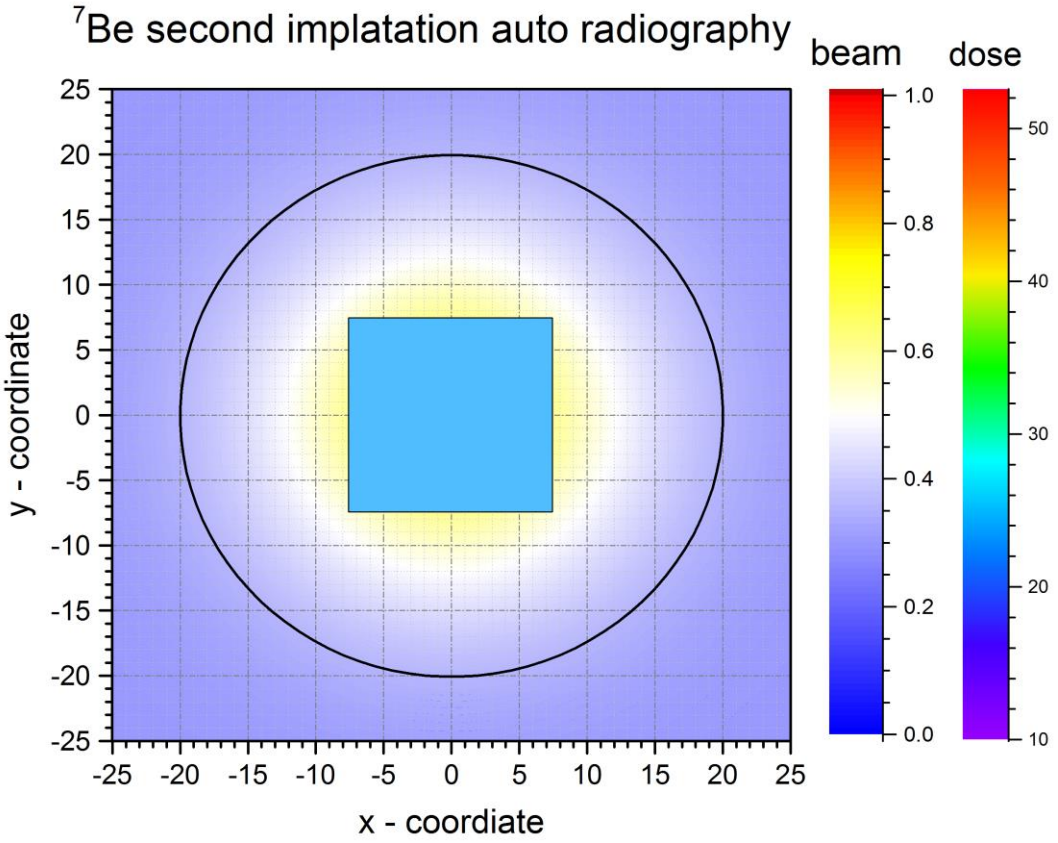
A "Total Variation Filter" using a Poisson noise model was applied to improve the signal to noise ratio.



De-blurring using the Richardson-Lucy-method with 25 iterations and no additional preconditioning of the data.



x-centre [mm]	x-width [mm]	y-centre [mm]	y-width [mm]
2.017 ± 0.183	**2.074 ± 0.002**	-2.980 ± 0.112	**2.518 ± 0.002**

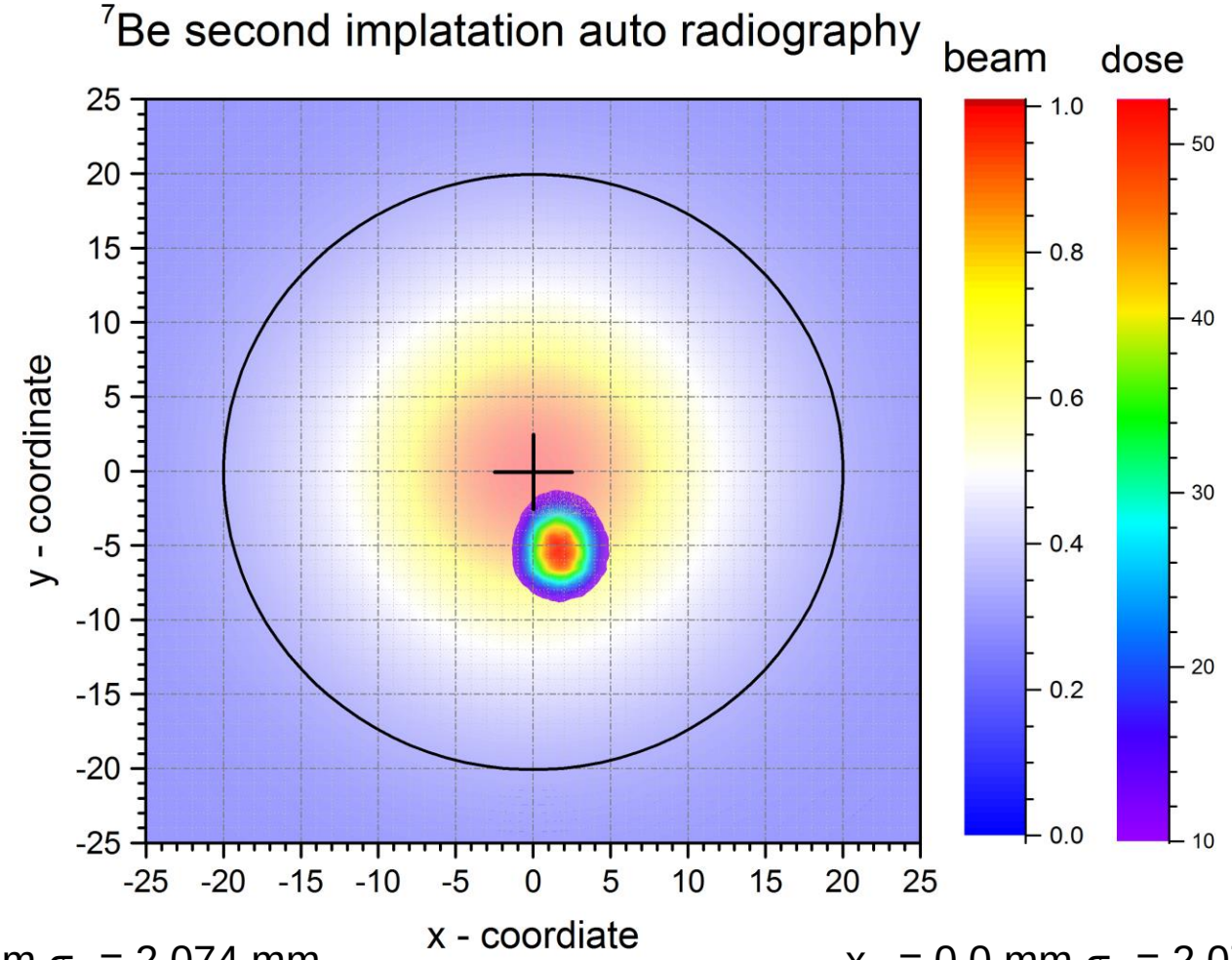


Homogenious square

d = 15 mm

BIF = 0.689

Distribution map of ^{7}Be in implanted targets



x_C = 2.017 mm σ_x = 2.074 mm

y_C = -2.980 mm σ_y = 2.518 mm

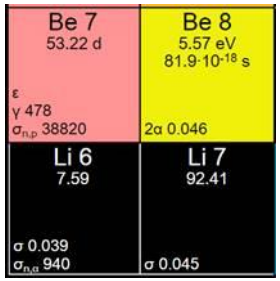
BIF = 1.108

x_C = 0.0 mm σ_x = 2.074 mm

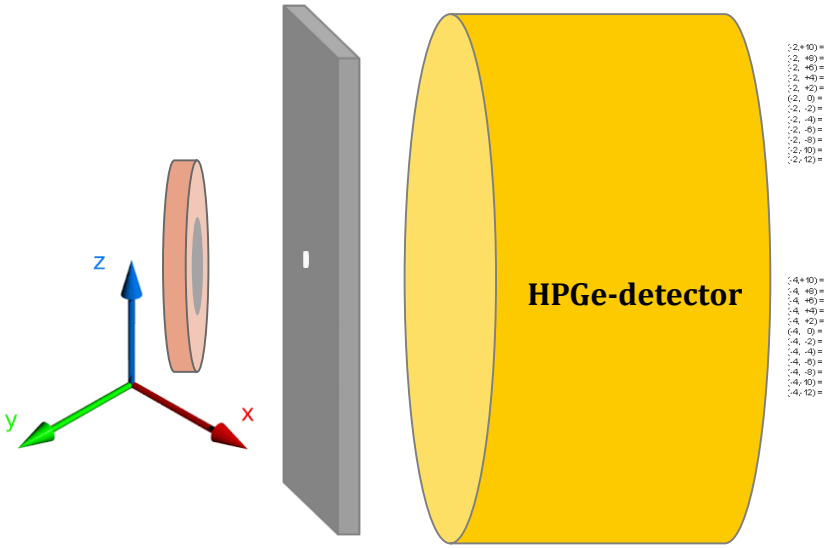
y_C = 0.0 mm σ_y = 2.518 mm

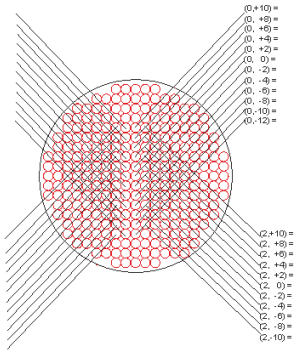
BIF = 1.137

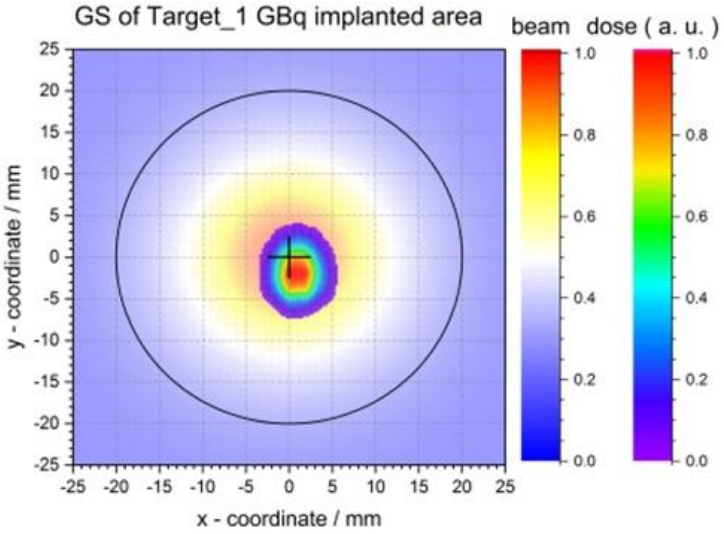
Distribution map of ^{7}Be in deposited target



Screening of small sections of the target using a standard γ-spectrometry with a 10 cm thick lead collimator with a 2 mm diameter hole in front of a coaxial HPGe-detector







x_C = 0.940 mm σ_x = 1.861 mm

y_C = -1.880 mm σ_y = 2.375 mm

Wir schaffen Wissen – heute für morgen

Acknowledgement

- Vögele Alexander
- Laboratory of Radiochemistry
- n_TOF Collaboration

Distribution map of ^{7}Be in implanted targets

samples that are perfectly aligned with the beam line