# Boron Imaging with a microstrip silicon detector for applications in BNCT

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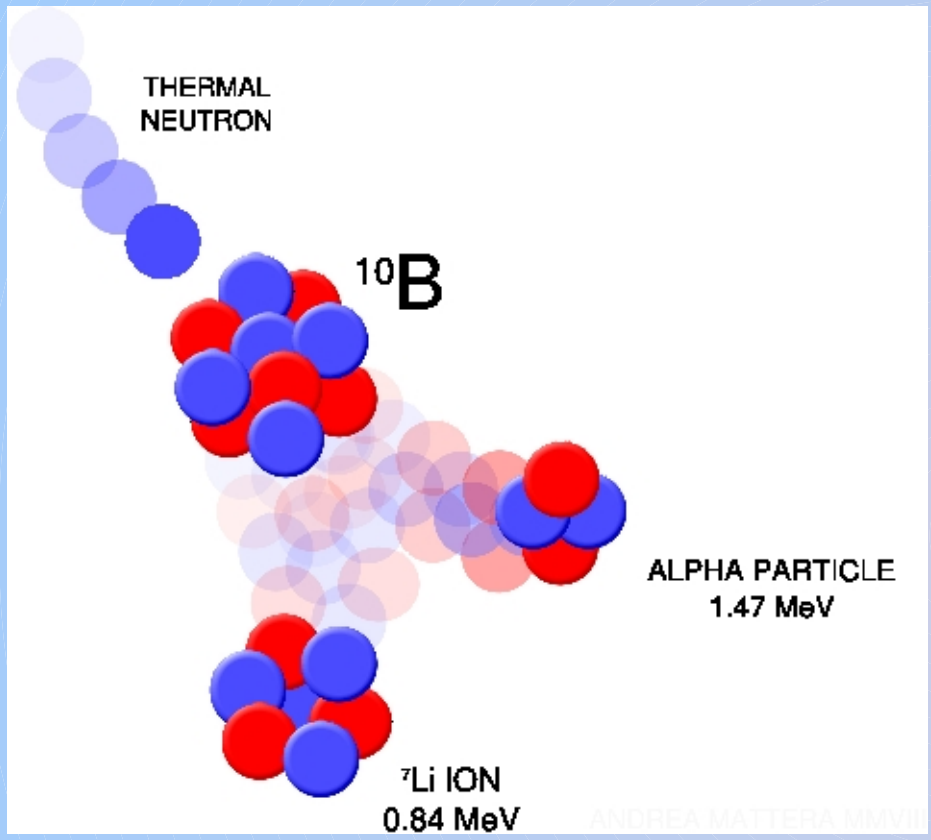
# Summary

- Boron Neutron Capture Therapy (BNCT): a new chance against cancer.
- The INFN PhoNeS project
- Boron imaging in BNCT
- A microstrip silicon detector to measure $^{10}B$
- Measurements and Results
- Conclusions and Outlooks

# Boron Neutron Capture Therapy

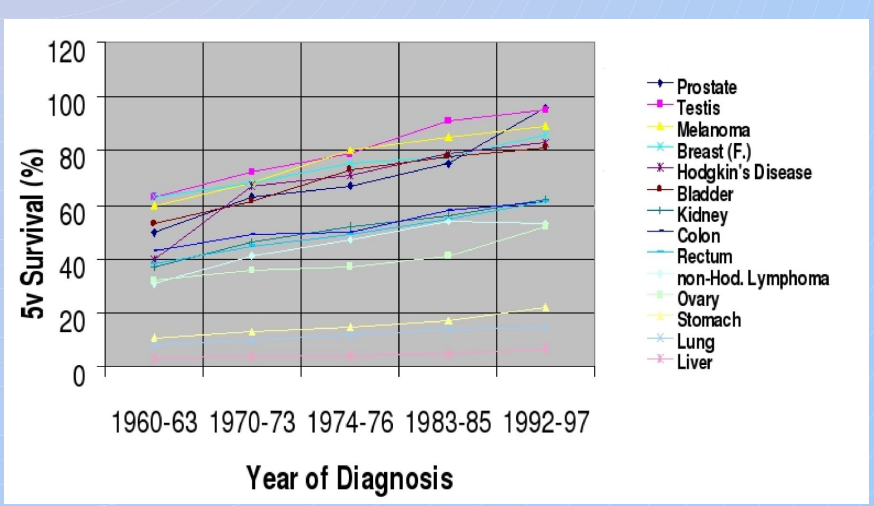



## BINARY TREATMENT:

- $^{10}B$ is introduced in the tumour by **dedicated molecules** (boron carriers)

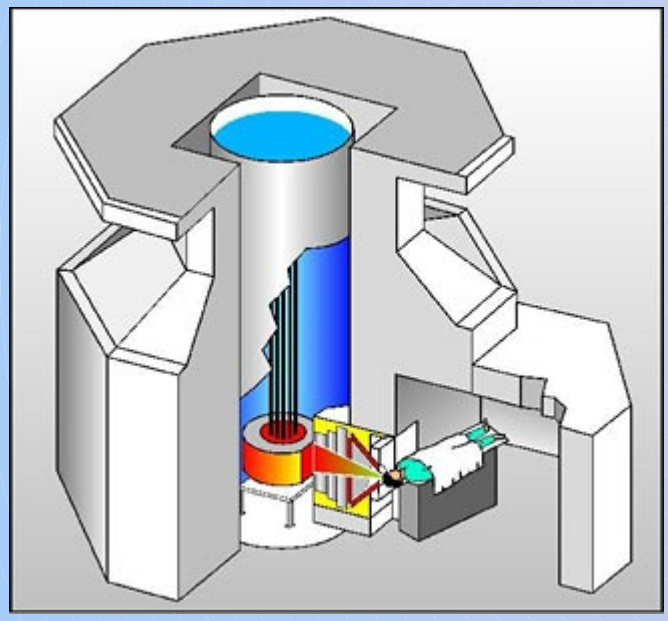
- The patient is irradiated with a **thermal neutron beam** to induce the capture reaction of boron

Combining radiotherapy effectiveness and chemotherapy selectivity, BNCT could be an answer to treat radioresistent (melanoma), extended (liver metastases) or located near vital organs (Glioblastoma multiforme) tumours.



# Why is BNCT not available at my hospital?

## NEUTRON SOURCES



- Thermal neutron flux of 5 x $10^{8}$ n $cm^{-2}$ $s^{-1}$
- Gamma contamination lower than 2 x $10^{-13}$ Gy $cm^{2}$ $neutron^{-1}$

## BORON CARRIERS

- Low toxicity
- High specificity
- Non-persistence in the bloodstream

**BSH**
(sulfhydryl borane)

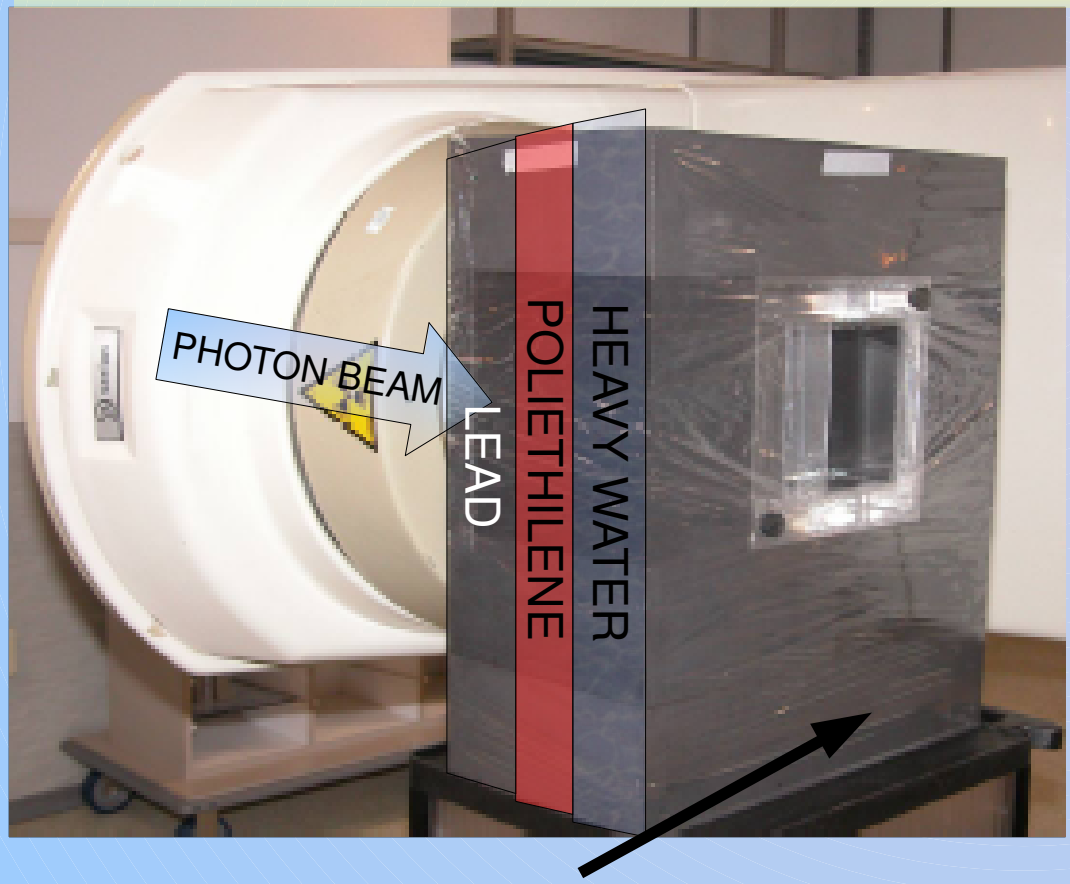
**BPA**
(boron phenylalanine)

# The PhoNeS project

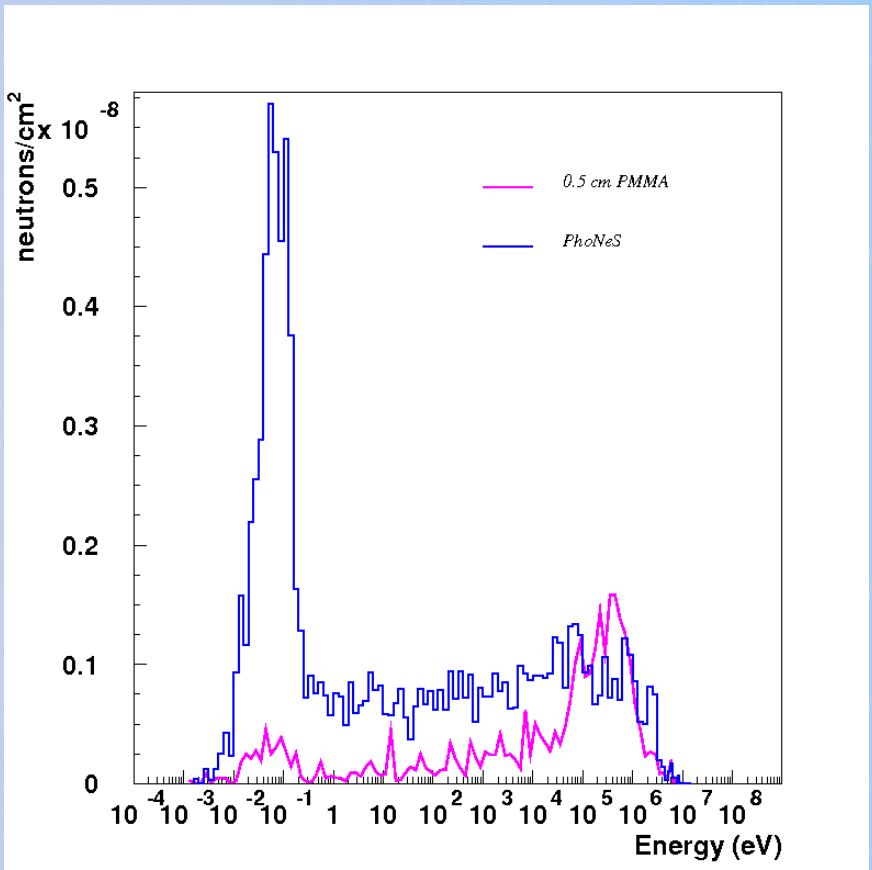
BNCT in a hospital environment

**The PhoNeS prototype**

First BNCT neutron source in a hospital




GRAPHITE STRUCTURE




NEUTRON FLUX IN THE TREATMENT CAVITY

$(1.3 \pm 0.1) \times 10^{7}$ n $cm^{-2}$ $s^{-1}$

# Boron Imaging in BNCT

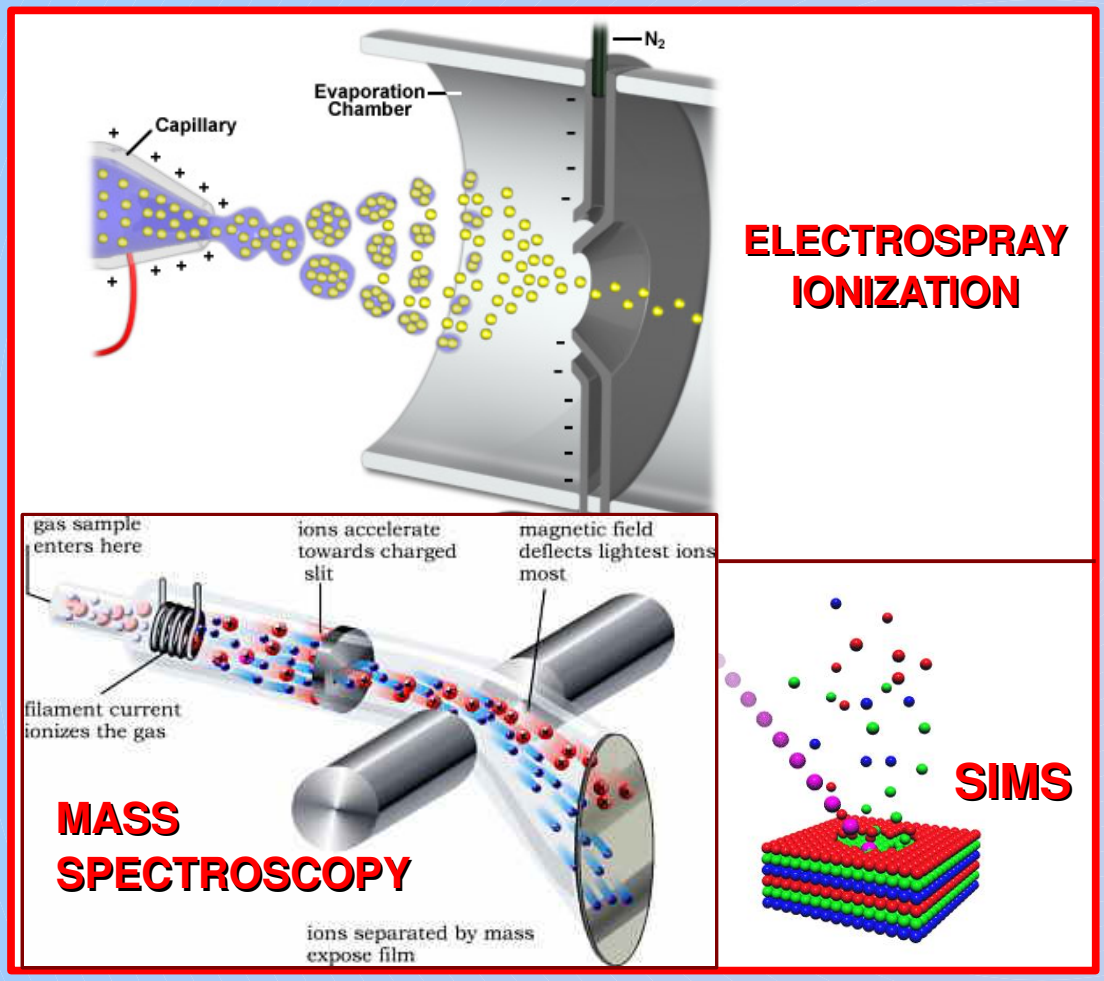
**WITHIN BNCT TREATMENT**

- Fast and accurate determination of $^{10}B$ concentration in blood and urine
- Production of kinetic curves to have informations on boron concentration in tumour and blood.

**IN BORON CARRIERS RESEARCH**

- Localization of $^{10}B$ in tissue
- Analysis of kinetic curves to study the carriers metabolism.

# Techniques of boron imaging

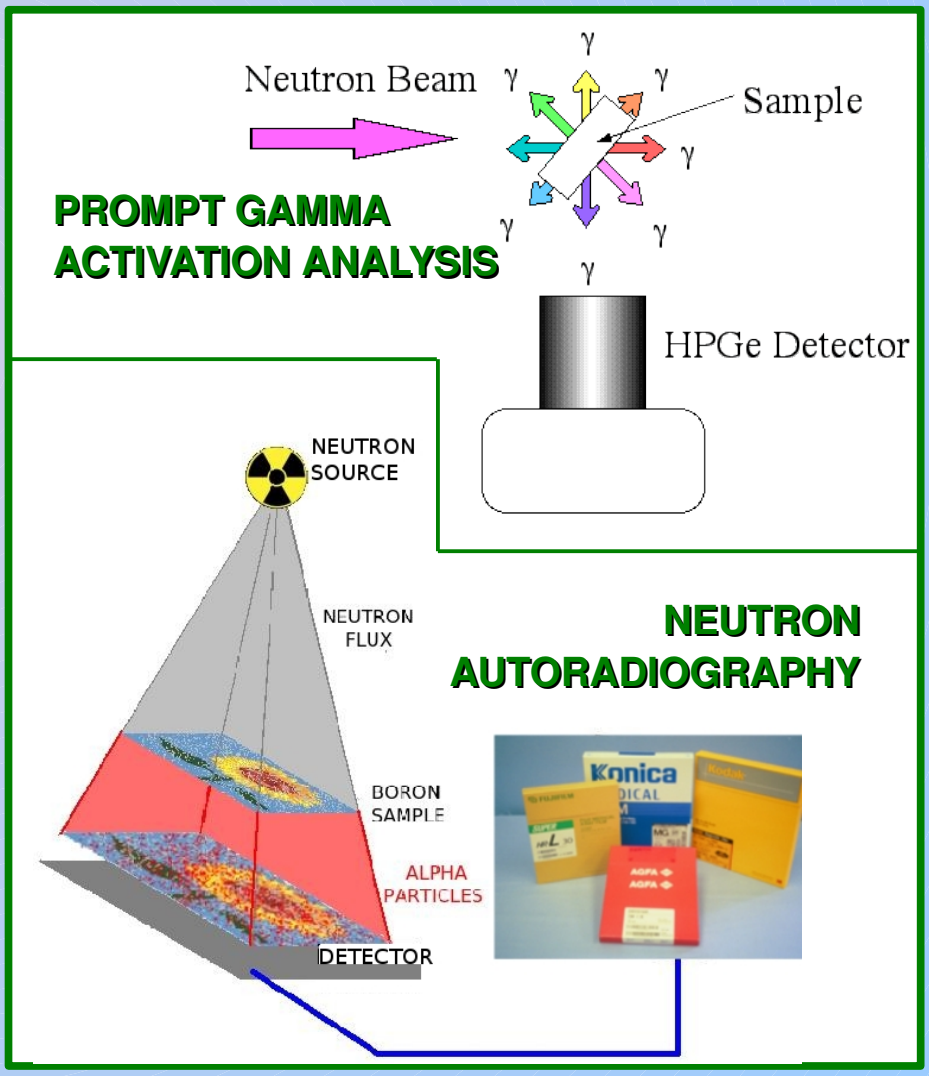



**CHEMICAL ANALYSIS**

sensitive to molecules used as boron carriers

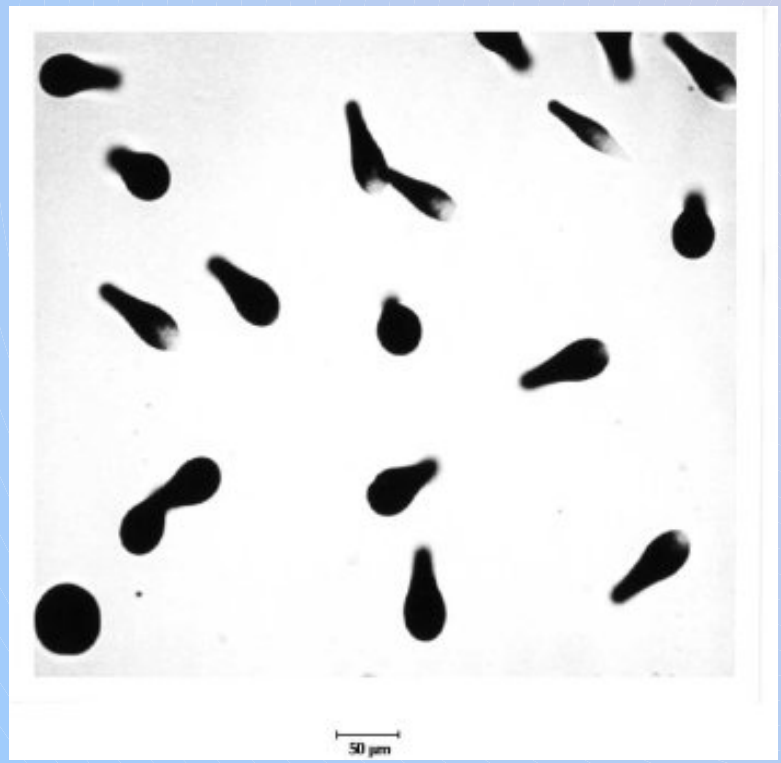
**PHYSICAL ANALYSIS**

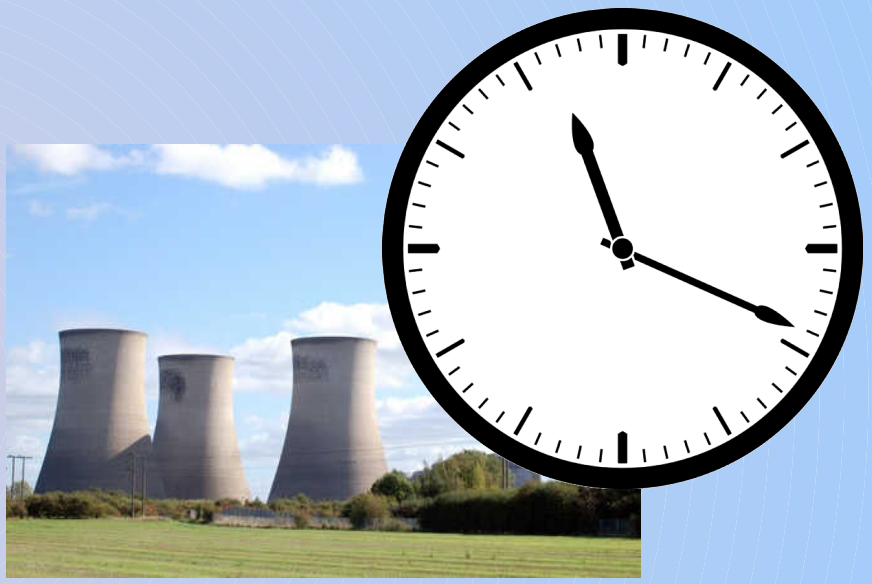
measure $^{10}B$ by inducing the capture reaction



# Neutron autoradiography in BNCT

Detects the alpha particles from the neutron capture reaction on a film (CR39)

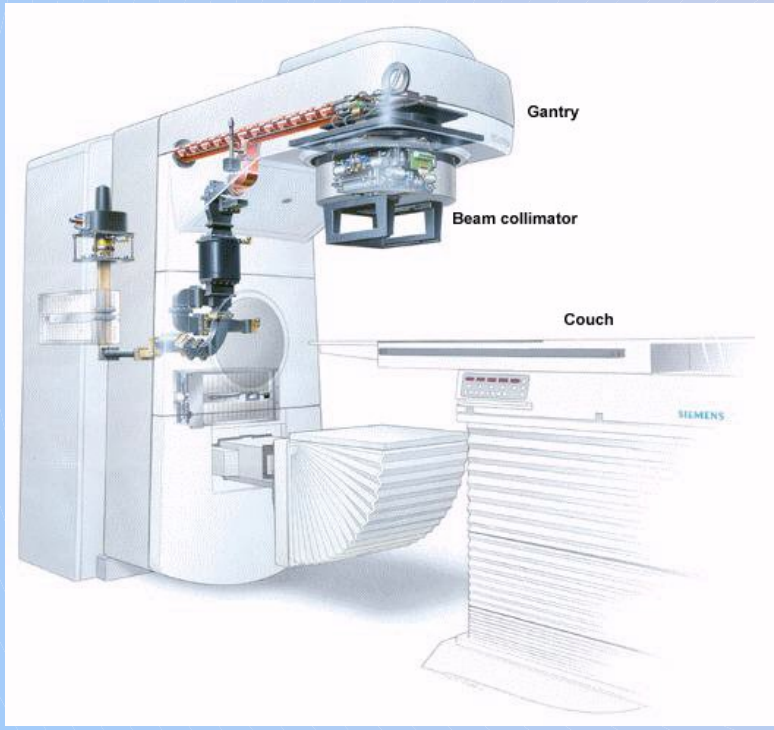


Usually needs some time to get the result and a nuclear reactor to produce the neutrons

# A new approach to neutron autoradiography

BNCT RESEARCH IN A
**HOSPITAL ENVIRONMENT**




Neutron production with a radiotherapy LINAC

Clinac 2100C/D of “S.Anna” Hospital in Como, Italy

**REAL-TIME** ANALYSIS

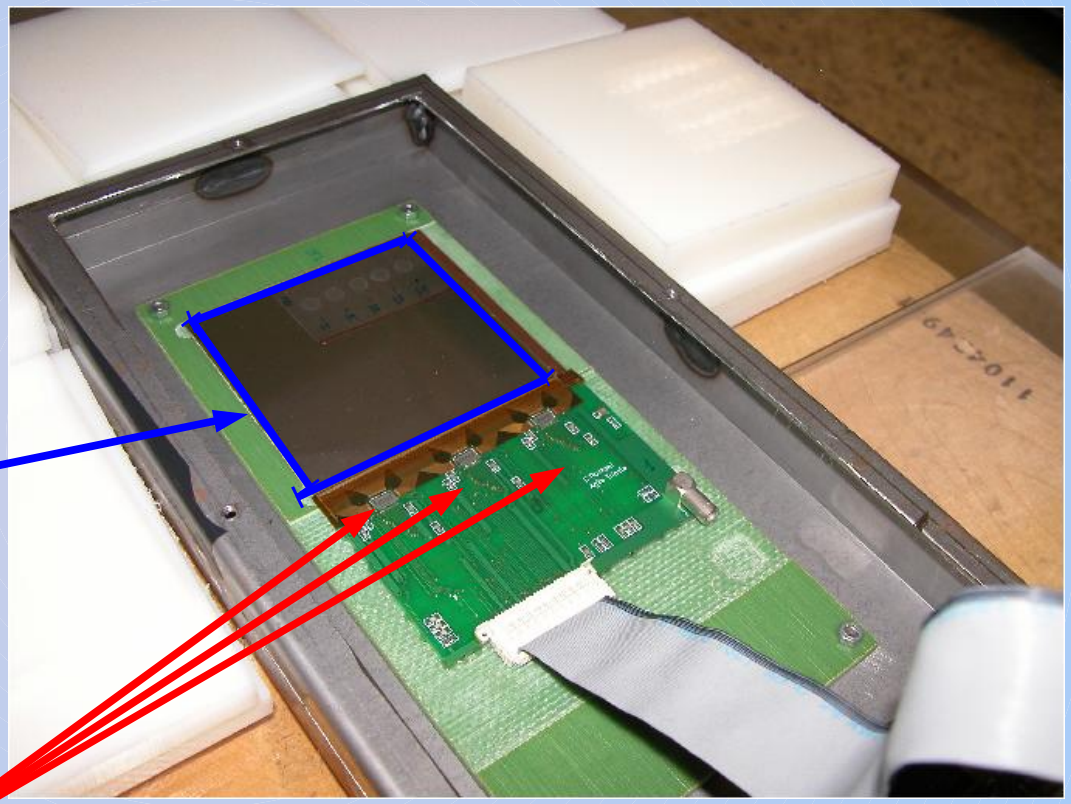
**NO films** – analysis in less than 60 minutes (average time of analysis = 10 mins)

# The imaging detector

HAMAMATSU
MICROSTRIP
SILICON DETECTOR
768 strips

SILICON DIMENSIONS:
9.5 x 9.5 $cm^2$
READOUT PITCH: 242um

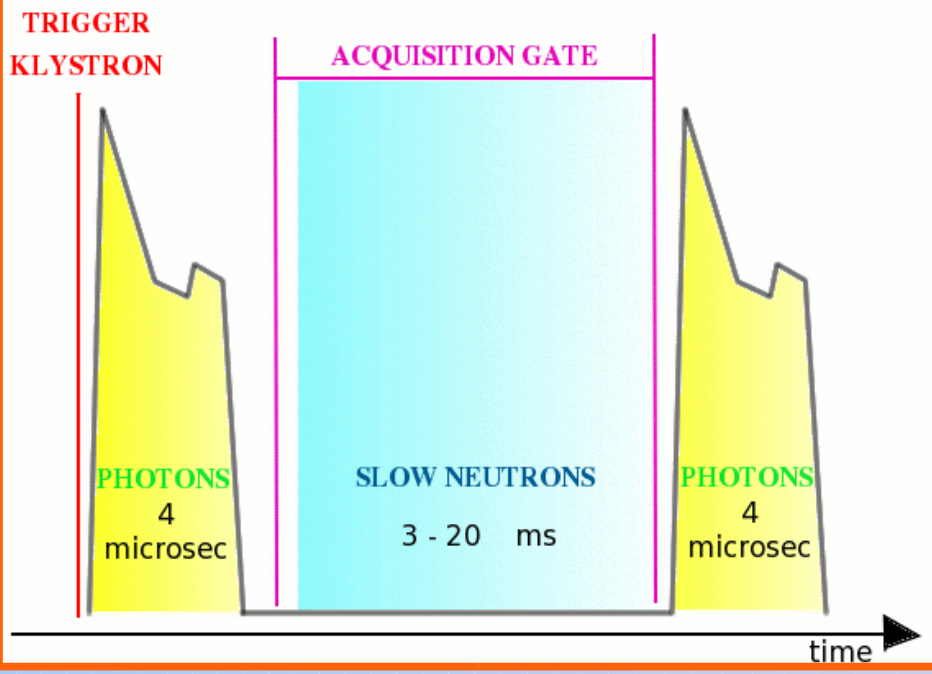
READOUT by
3 TAA1 IDEAS ASICs
SELF TRIGGERING



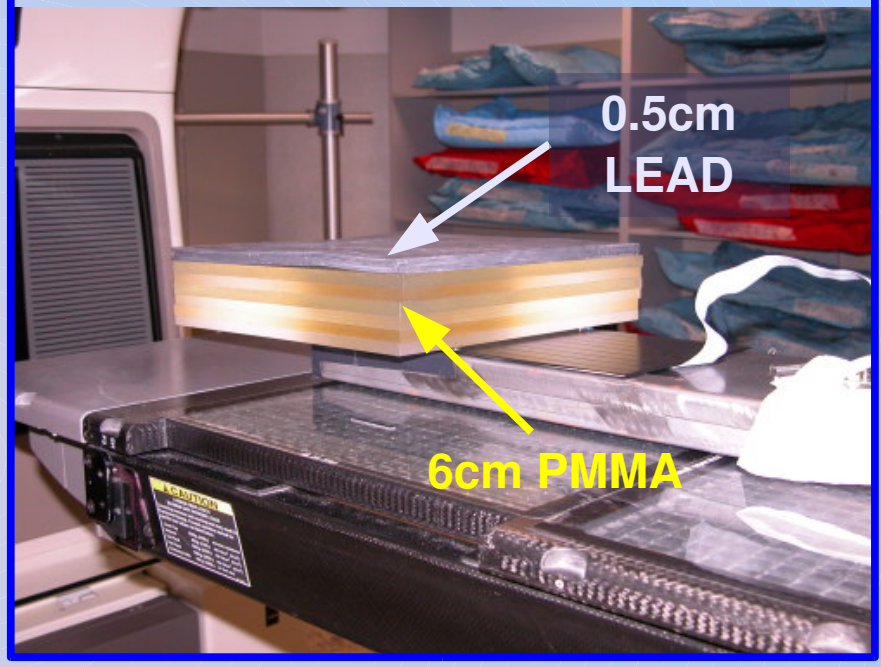
1D $^{10}B$ DISTRIBUTION

# Setup

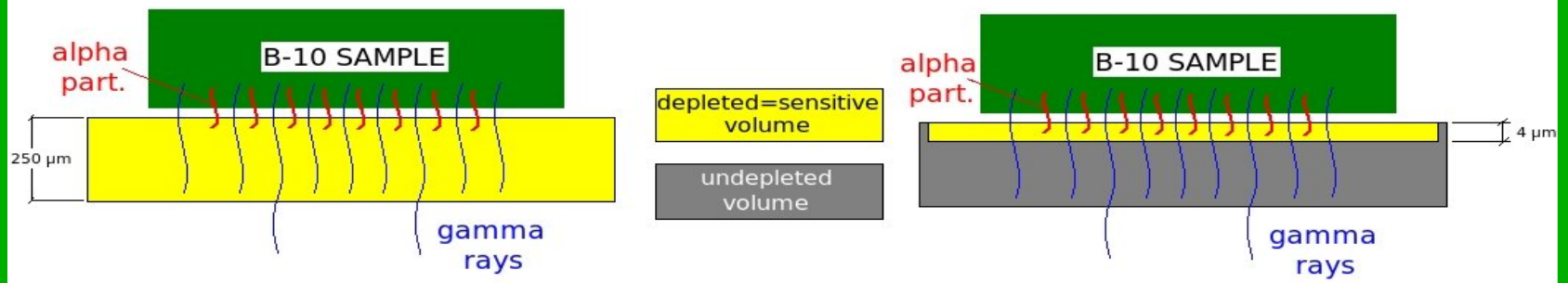
## INTER-BUNCH ACQUISITION




## SIMPLIFIED PhoNeS PROTOTYPE

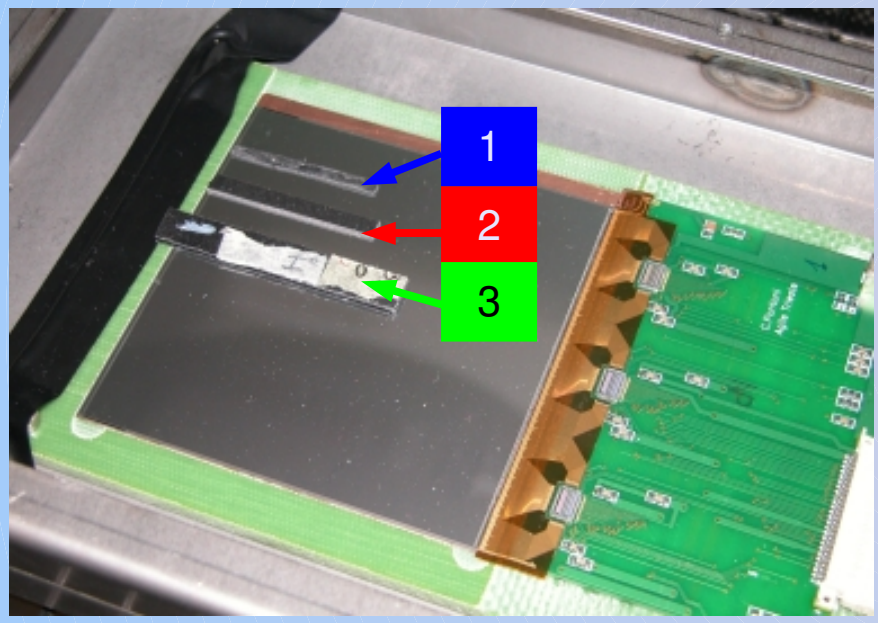



## UNDEPLETED SILICON DETECTOR

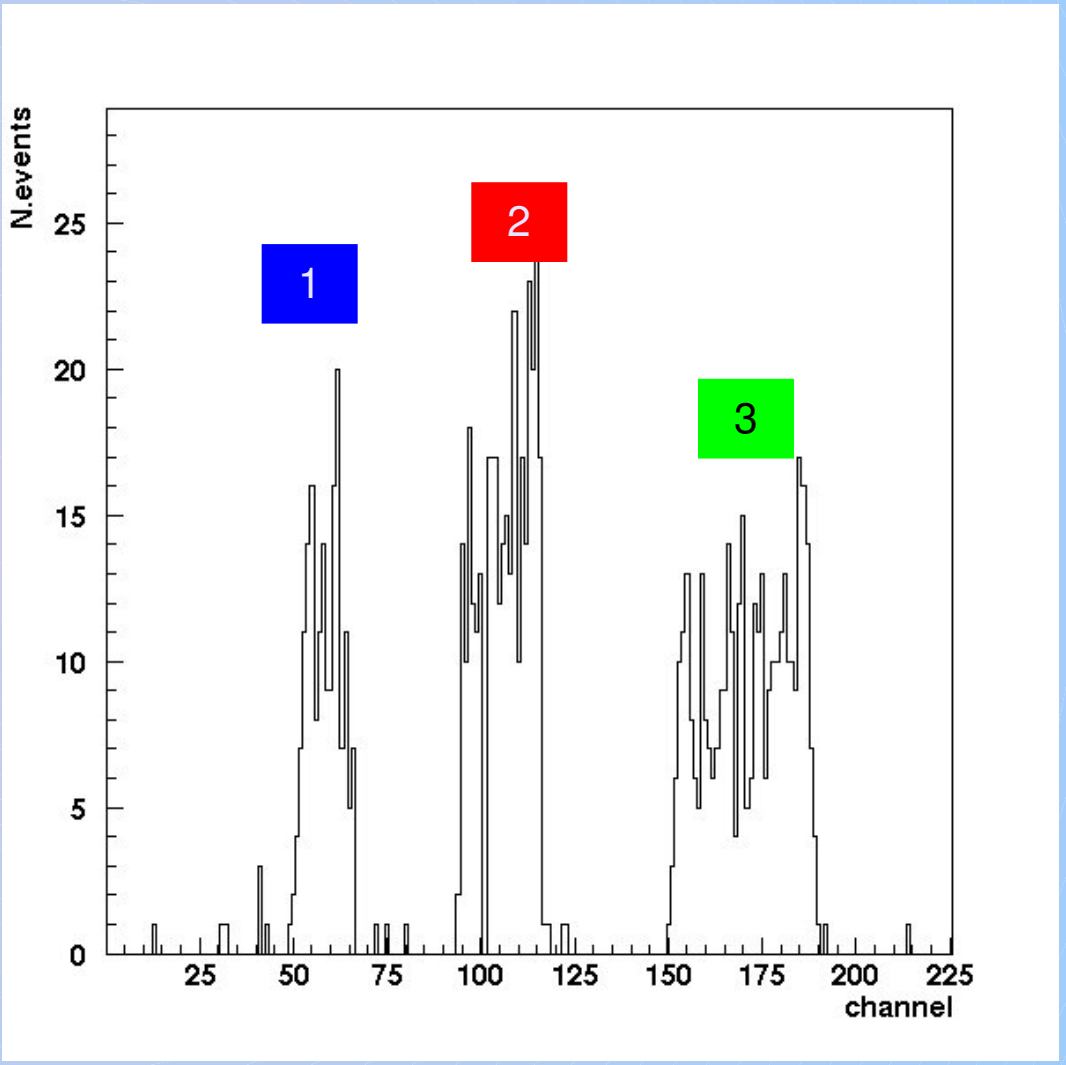


# Feasibility study

HIGH $^{10}$B CONTENT RESINS




SAMPLES' DIMENSIONS
PERFECTLY REPRODUCED



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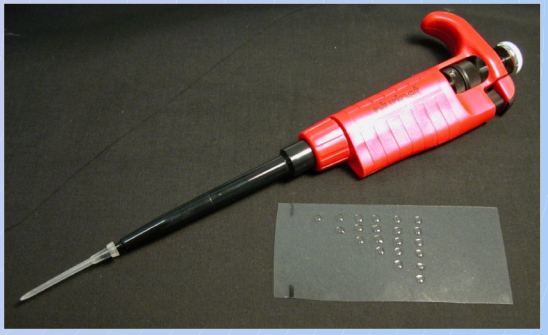
# The puzzle of the Samples

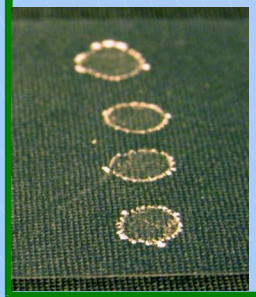
Toward a calibration with $H_3BO_3$

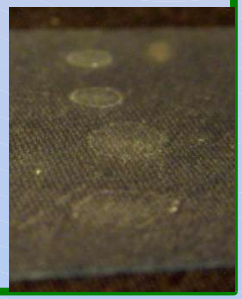
SPECIMEN SUPPORT
evaporate the liquid solution on a plastic support not able to absorb it

PRODUCING SAMPLES of KNOWN VOLUME to evaluate $^{10}B$ concentration



SOLUTION HOMOGENEITY
to prevent crystallization and self-absorption of the α particles by the sample itself



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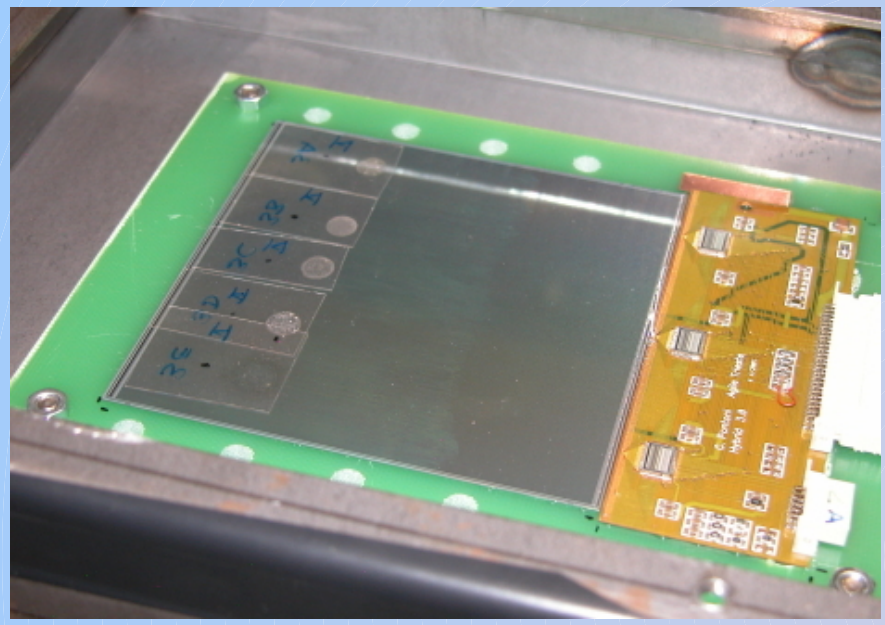
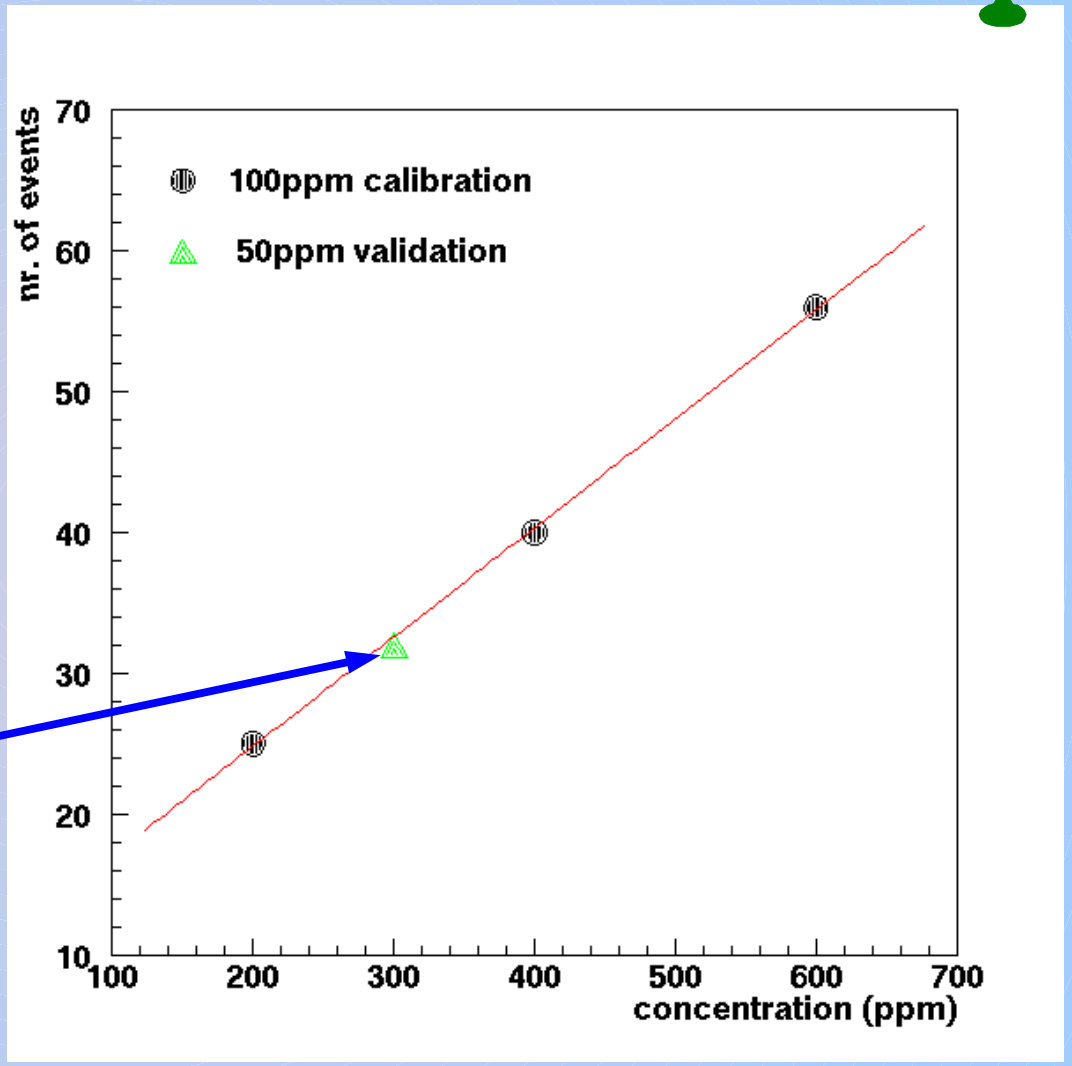
# Calibration with $H_3BO_3$





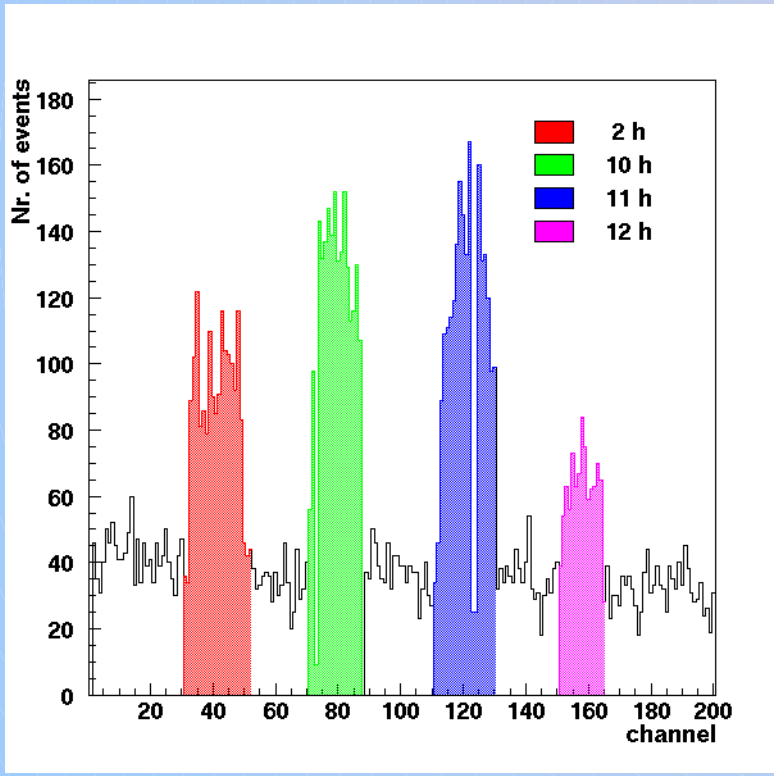

Calibration validated with a different standard solution of $H_3BO_3$

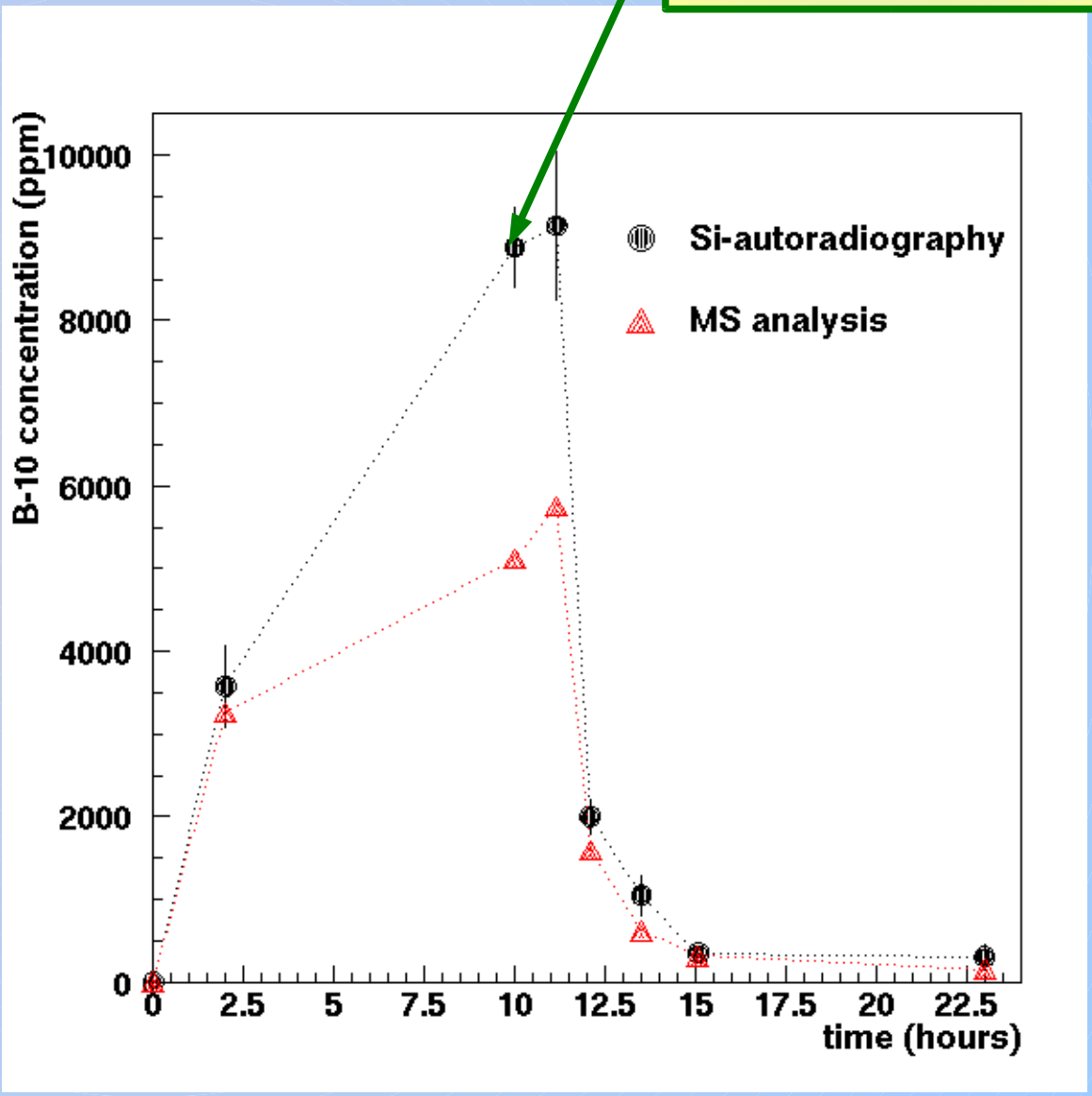
# Kinetic Studies

URINE of a patient administered BSH

This trend is confirmed by other physical analysis

Comparison of real-time autoradiography with a MS analysis (sensitive to BSH)



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# Future Applications ...

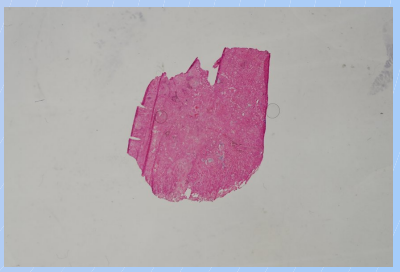
Lung treated with BPA

Therapeutic explantation of a lung suffering from mesothelioma

## BNCT to treat lung mesothelioma

in cooperation with “S. Luigi” Hospital in Orbassano (TO), Italy

Imaging of $^{10}B$ in biological tissues





FUTURE ... milestones

# Conclusions & Outlooks

**AUTORADIOGRAPHY** in a **HOSPITAL ENVIRONMENT**

**REAL-TIME IMAGING** optimized to perform **pharmacokinetic studies**: **research on new BNCT molecules**

New measurements are scheduled to detect boron in biological tissues

**Setup UPGRADEs**

**New PhoNeS prototype**
to increase the neutron flux (faster analysis)

**Vacuum system**
to allow a non-destructive analysis for samples

# Boron Imaging with a microstrip silicon detector for applications in BNCT

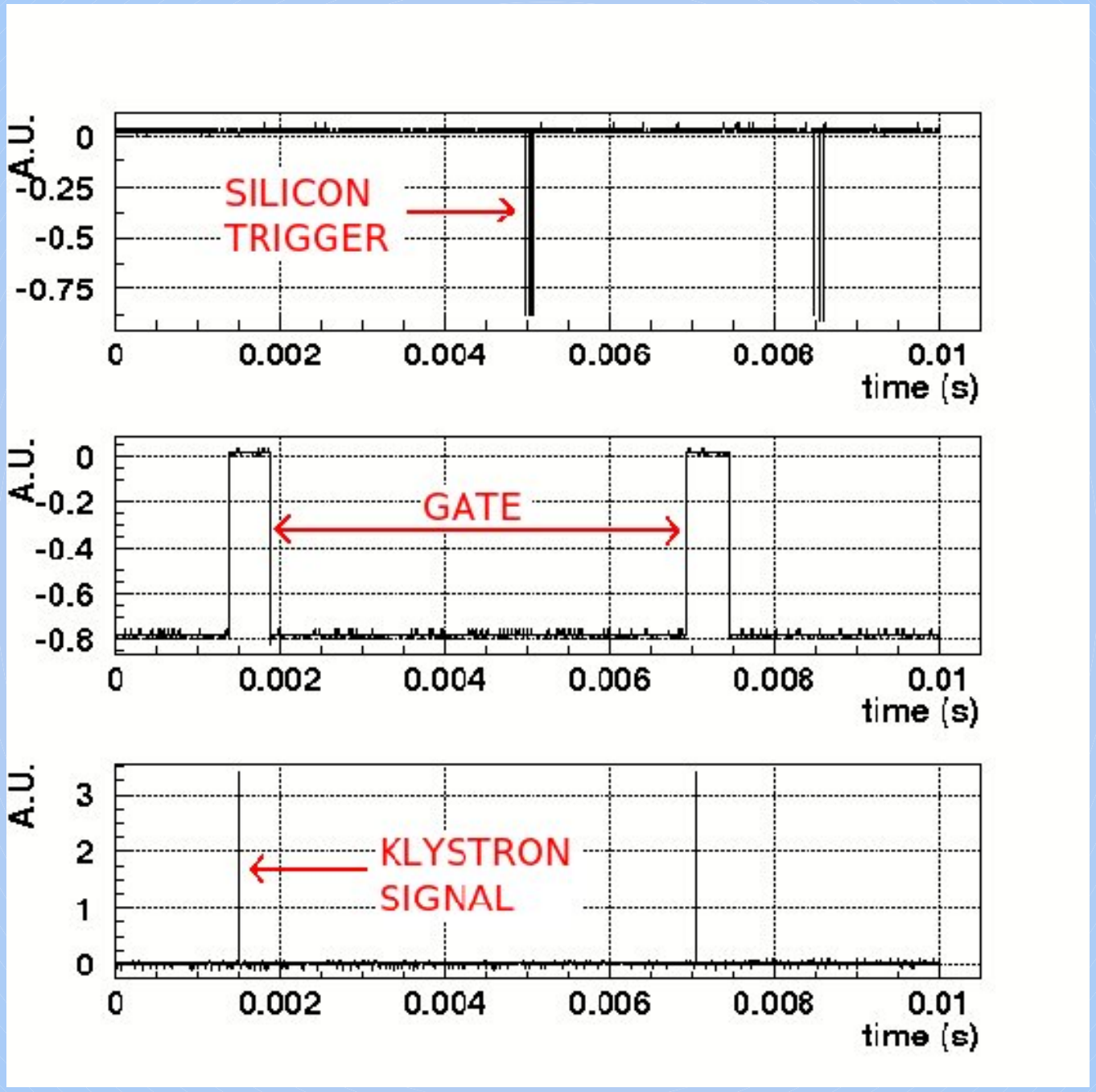
Thank you for your attention ...



# BACKUP SLIDES

# BNCT around the world

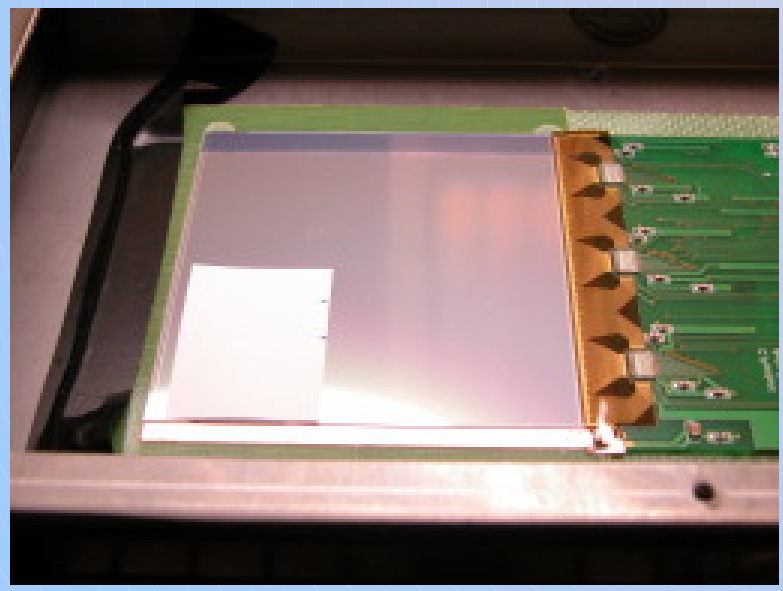
| Country | Nr. Patients | CARRIER | Tumour | YEAR |
|---|---|---|---|---|
| Japan | 207 | BSH/BPA | Astrocitoma | 1968 |
| Japan | 23 | BPA | Melanoma | 1968 |
| US-BNL | 54 | BPA-F | GBM | 1994 |
| US-MIT | 26 | BPA-F | GBM/melanoma | 1994 |
| Petten | 26 | BSH | GBM | 1997 |
| Finland | 21 | BPA | GBM | 1999 |
| Sweden | 17 | BPA | GBM | 2001 |
| Czech Rep. | 5 | BSH | GBM | 2001 |
| Argentina | 3 | BPA-F | Melanoma | 2003 |
| Italy | 2 | BPA | Liver | 2001 |

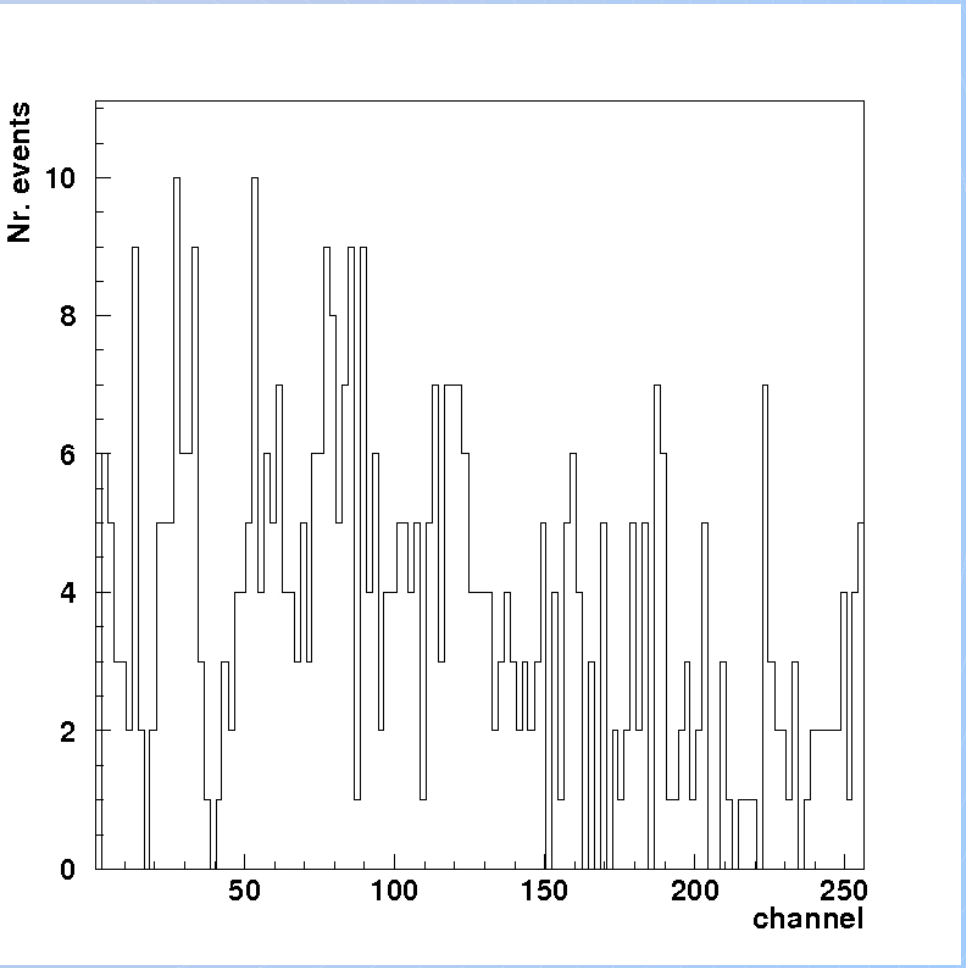

A.U.
0
-0.25
-0.5
-0.75
SILICON
TRIGGER
0
0.002
0.004
0.006
0.008
0.01
time (s)
A.U.
0
-0.2
-0.4
-0.6
-0.8
GATE
0
0.002
0.004
0.006
0.008
0.01
time (s)
A.U.
3
2
1
0
KLYSTRON
SIGNAL
0
0.002
0.004
0.006
0.008
0.01
time (s)

# Qualitative measurements

INORGANIC LIQUID SAMPLES
(boric acid)

PAPER SUPPORT NOT SUITABLE FOR THIS KIND OF ANALYSIS





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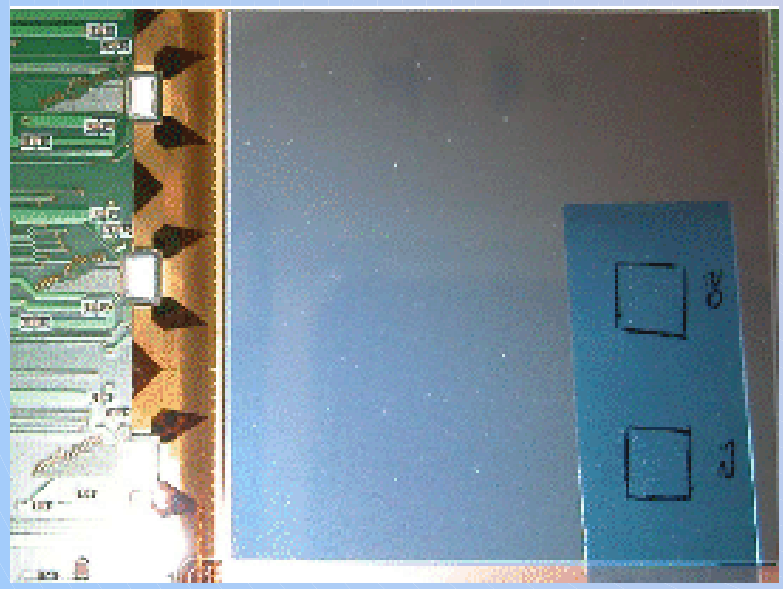
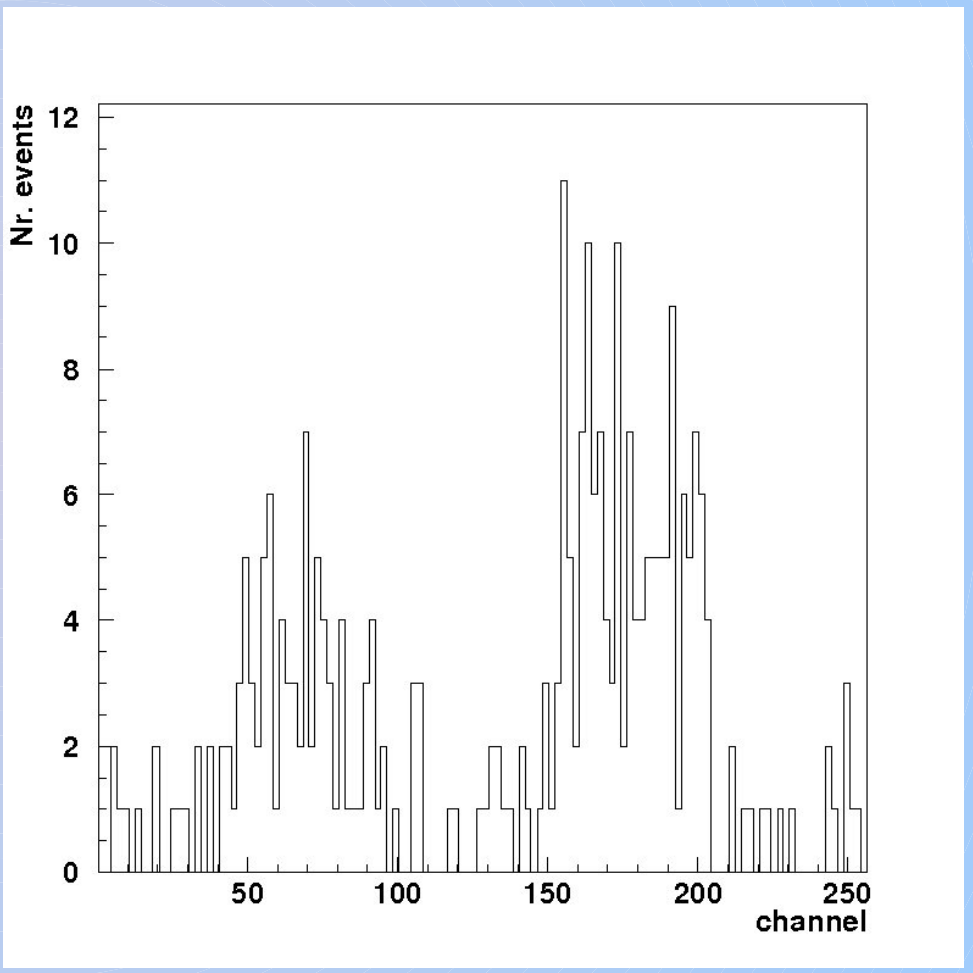
# Qualitative measurements

INORGANIC LIQUID SAMPLES
(boric acid)

LIQUID SAMPLES
EVAPORATED ON
PLASTIC SUPPORTS





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