

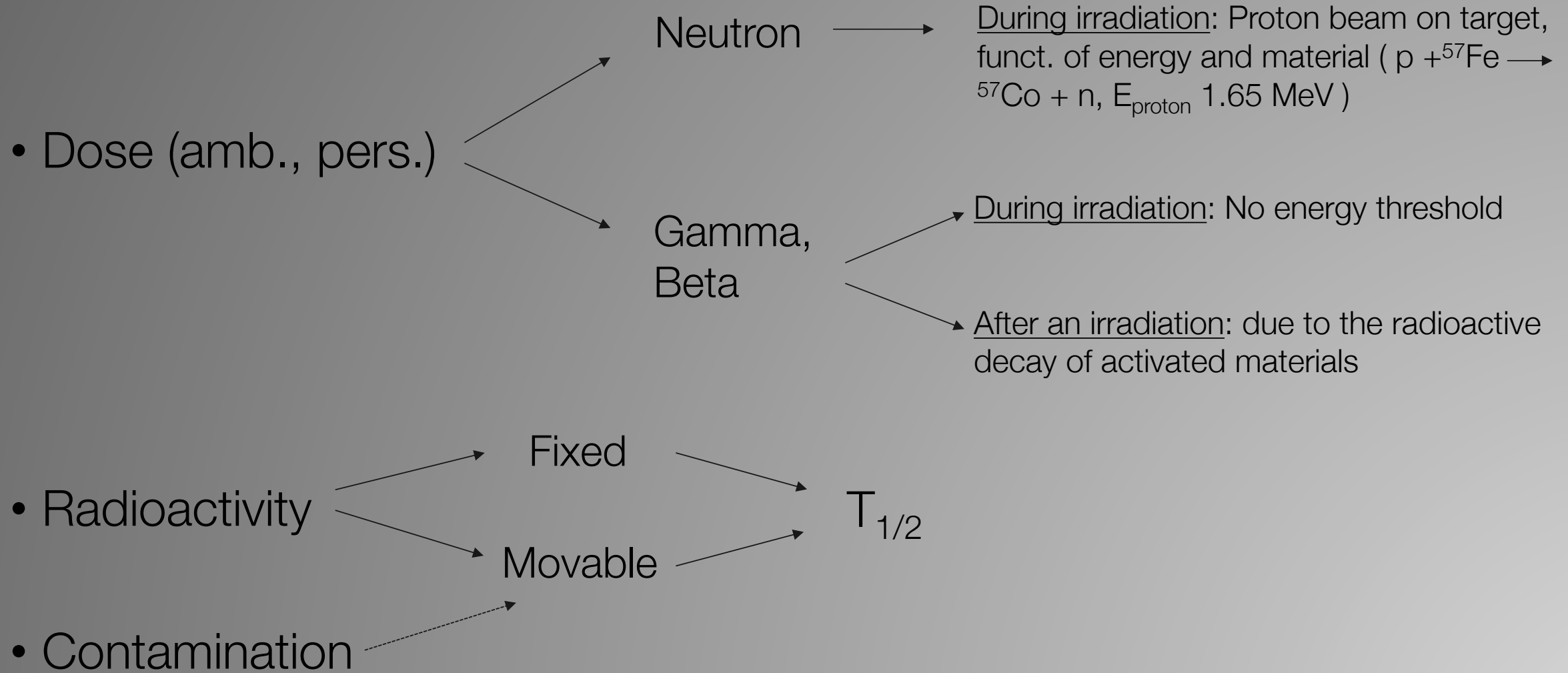
# Radiometric Survey at the LNL Cyclotron

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Istituto Nazionale di Fisica Nucleare – INFN*

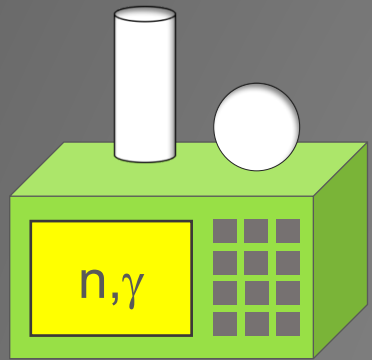
✉ [Lucia.Sarchiapone@lnl.infn.it](mailto:Lucia.Sarchiapone@lnl.infn.it)

☎ +39 049 8068 394



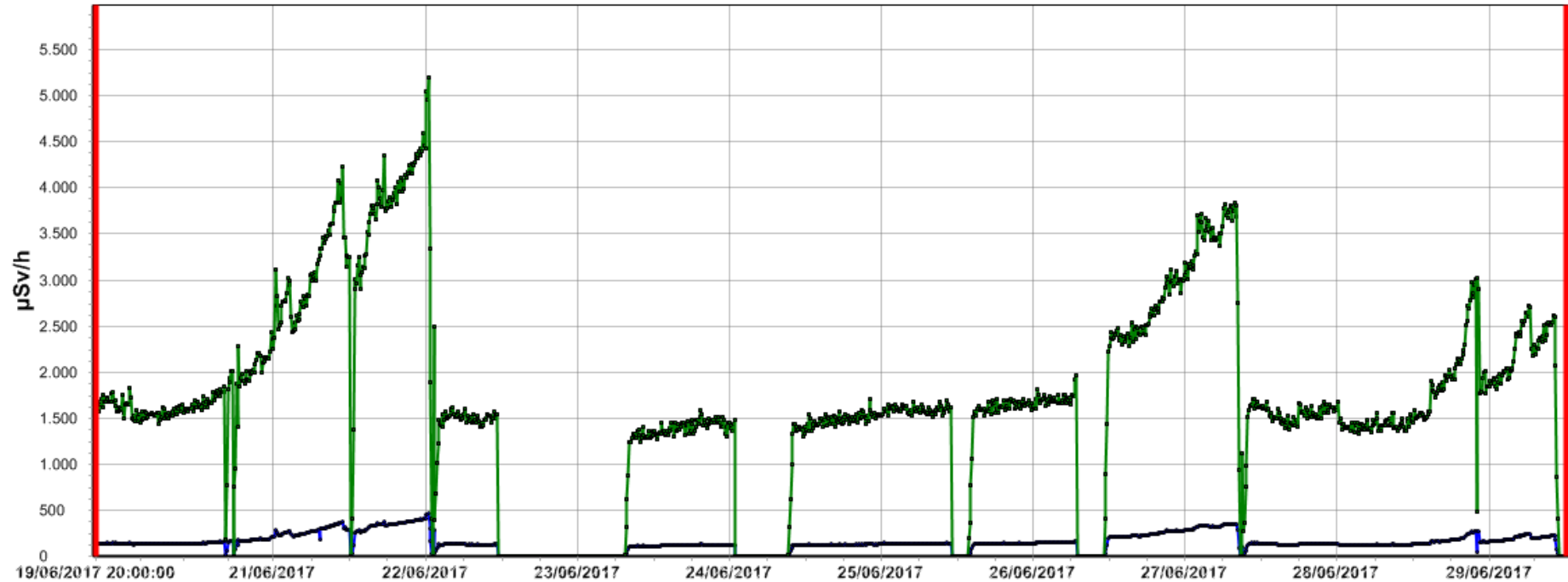


# *The monitoring plan and instrumentation*



## Misure AreaMonitor - Serial Number : 232

## Misure AreaMonitor - Serial Number : 232

☒ Sonda 1 - GAMMA ( $\mu\text{Sv/h}$ ) ☒ Sonda 2 - NEUTRONI ( $\mu\text{Sv/h}$ )☐ Indicatori Ratei Grafico

Inizio Calcolo Dose Integrata

19/06/2017 20:00:00

Fine Calcolo Dose Integrata

29/06/2017 12:00:00

Calcola Dosi Integrate

Dose Totale

Disponibilità  
Dati DoseRisoluzione Temporale  
Grafico Asse X

Sonda N.1

33.884,18  $\mu\text{Sv}$ 

100 %

Sonda N.2

385.413,90  $\mu\text{Sv}$ 

100 %

10 Minuti

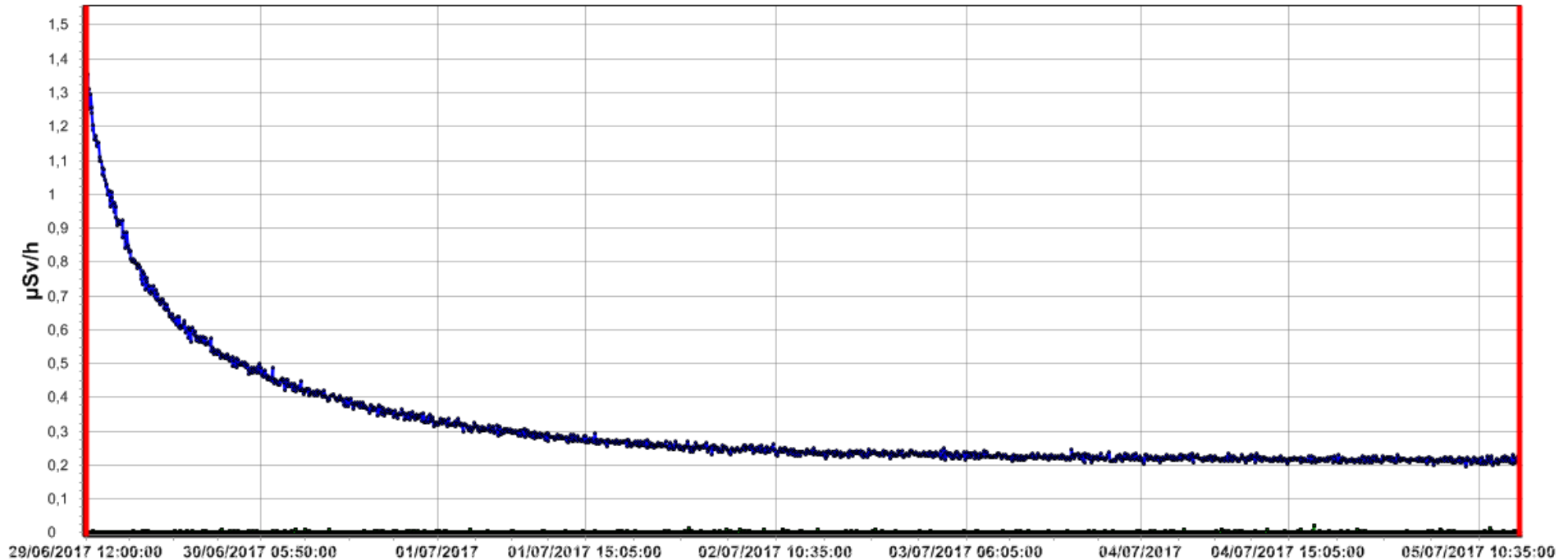
Stampa Grafico

Esci



## Misura AreaMonitor - Serial Number : 232

## Misura AreaMonitor - Serial Number : 232

☒ Sonda 1 - GAMMA ( $\mu\text{Sv/h}$ ) ☒ Sonda 2 - NEUTRONI ( $\mu\text{Sv/h}$ )☐ Indicatori Ratei Grafico

Inizio Calcolo Dose Integrata

29/06/2017 12:00:00

Fine Calcolo Dose Integrata

05/07/2017 14:40:00

Calcola Dosi Integrate

Dose Totale

Disponibilità  
Dati DoseRisoluzione Temporale  
Grafico Asse X

5 Minuti

Stampa Grafico

Esci

Sonda N.1

46,08  $\mu\text{Sv}$ 

100 %

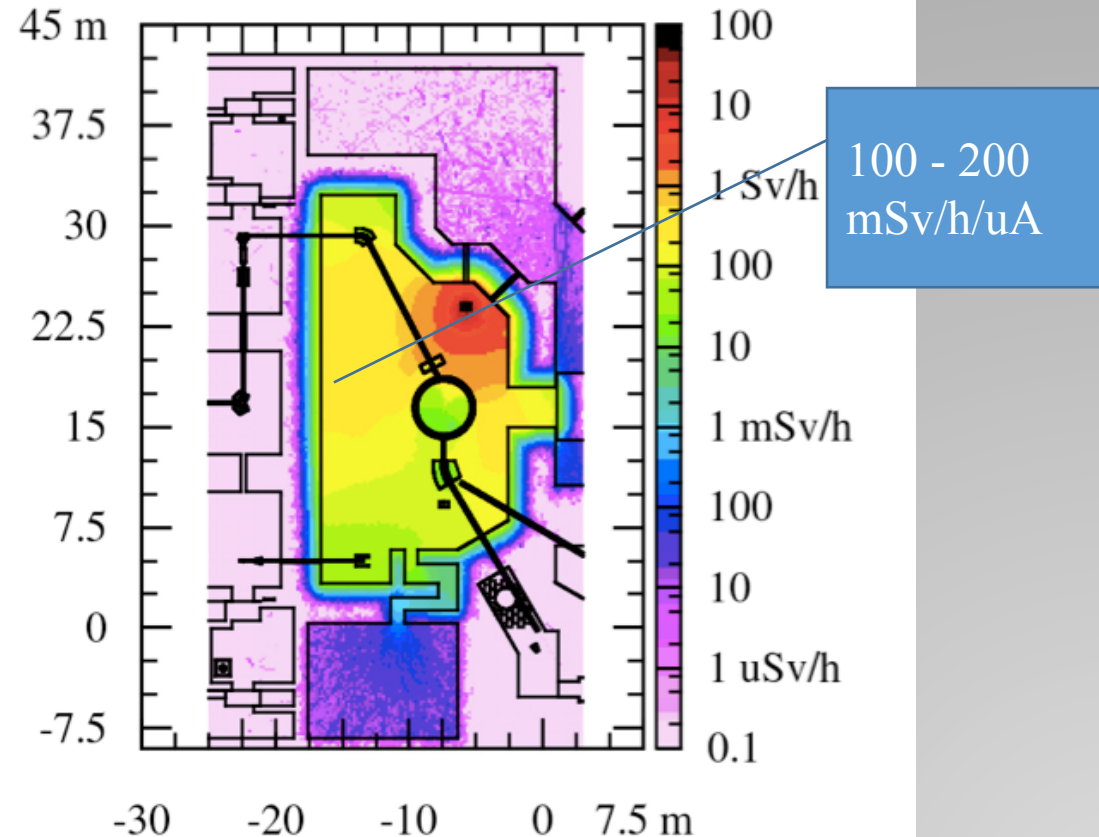
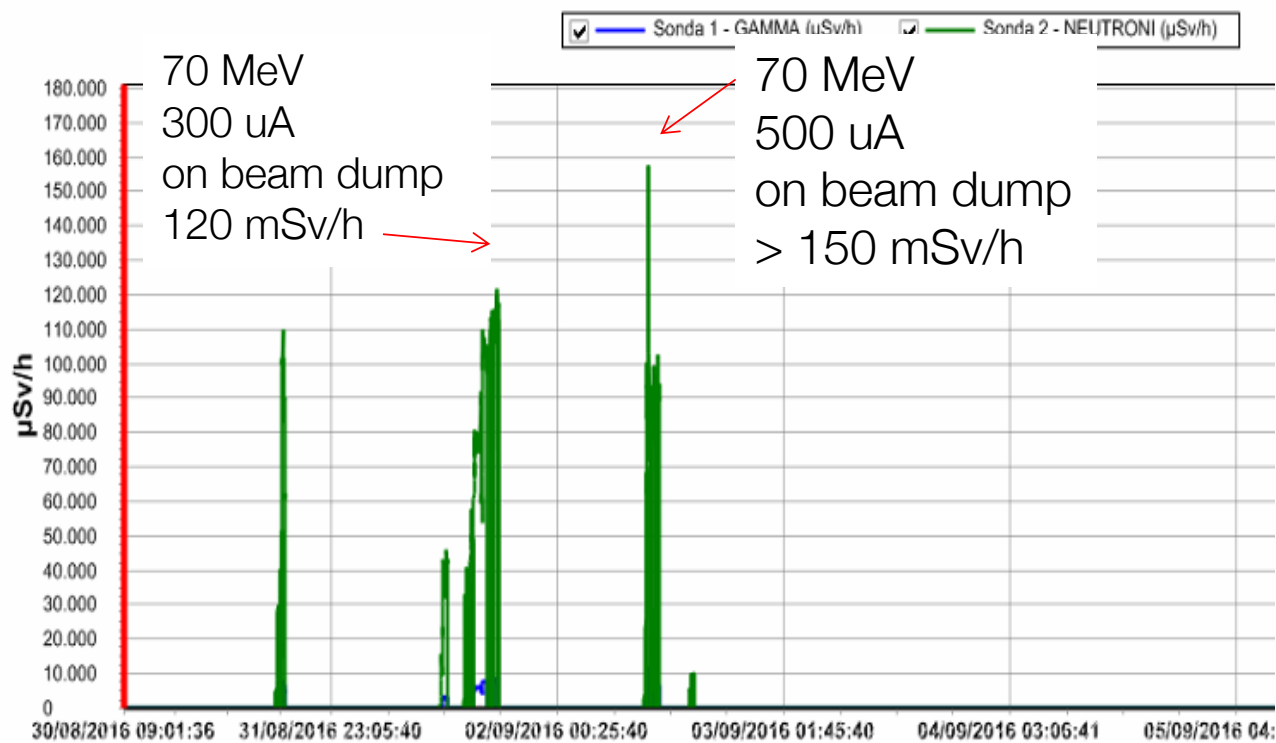
Sonda N.2

0,13  $\mu\text{Sv}$ 

100 %

## Doses and dose rates during beam extraction

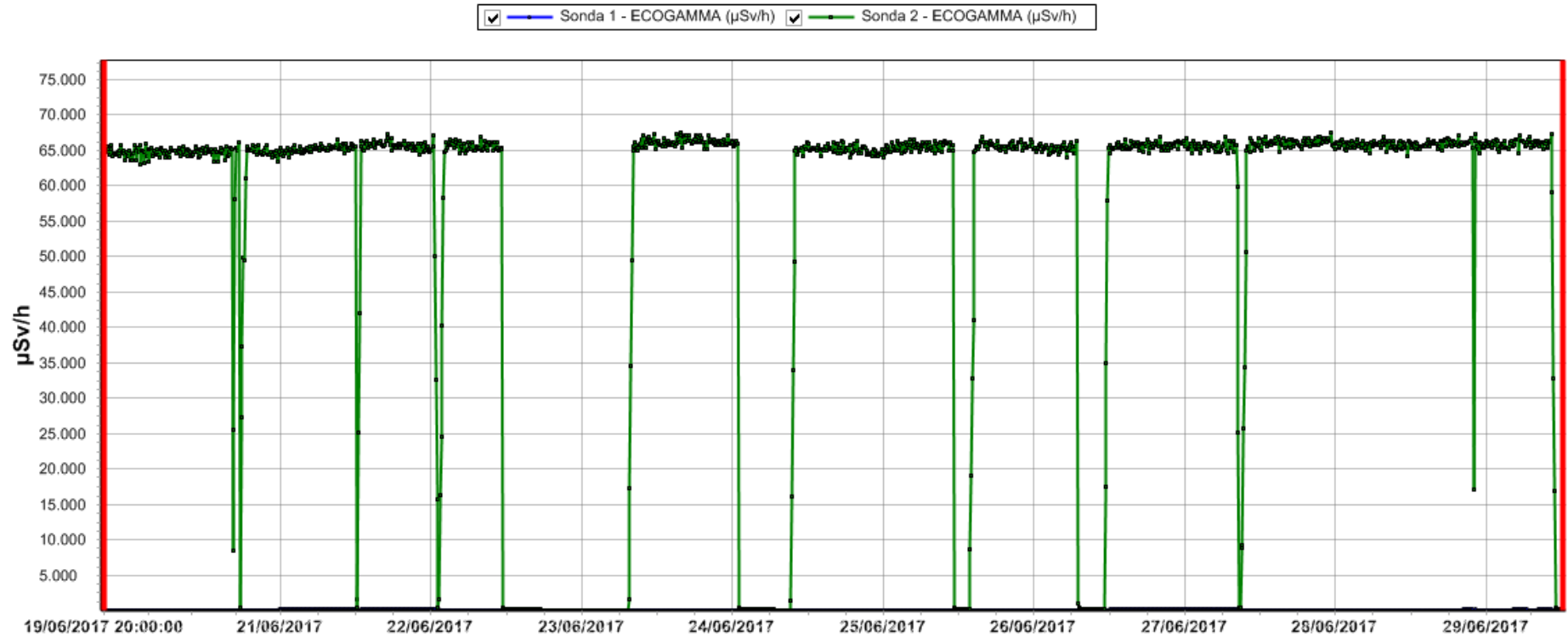
Beam Energy	Beam current	Measurement	Simulation
40 MeV	200 uA on target	1.5 mSv/h in A1	
70 MeV	500 uA on target	150 mSv/h in A1	
70 MeV	1 uA on FC		150 mSv/h in A1





## Misure AreaMonitor - Serial Number : 241

## Misure AreaMonitor - Serial Number : 241

☐ Indicatori Ratei Grafico

Inizio Calcolo Dose Integrata

19/06/2017 20:00:00

Fine Calcolo Dose Integrata

29/06/2017 12:00:00

Calcola Dosi Integrate

Dose Totale

Disponibilità  
Dati DoseRisoluzione Temporale  
Grafico Asse X

10 Minuti

Stampa Grafico

Esci

Sonda N.1

16.204,73  $\mu\text{Sv}$ 

100 %

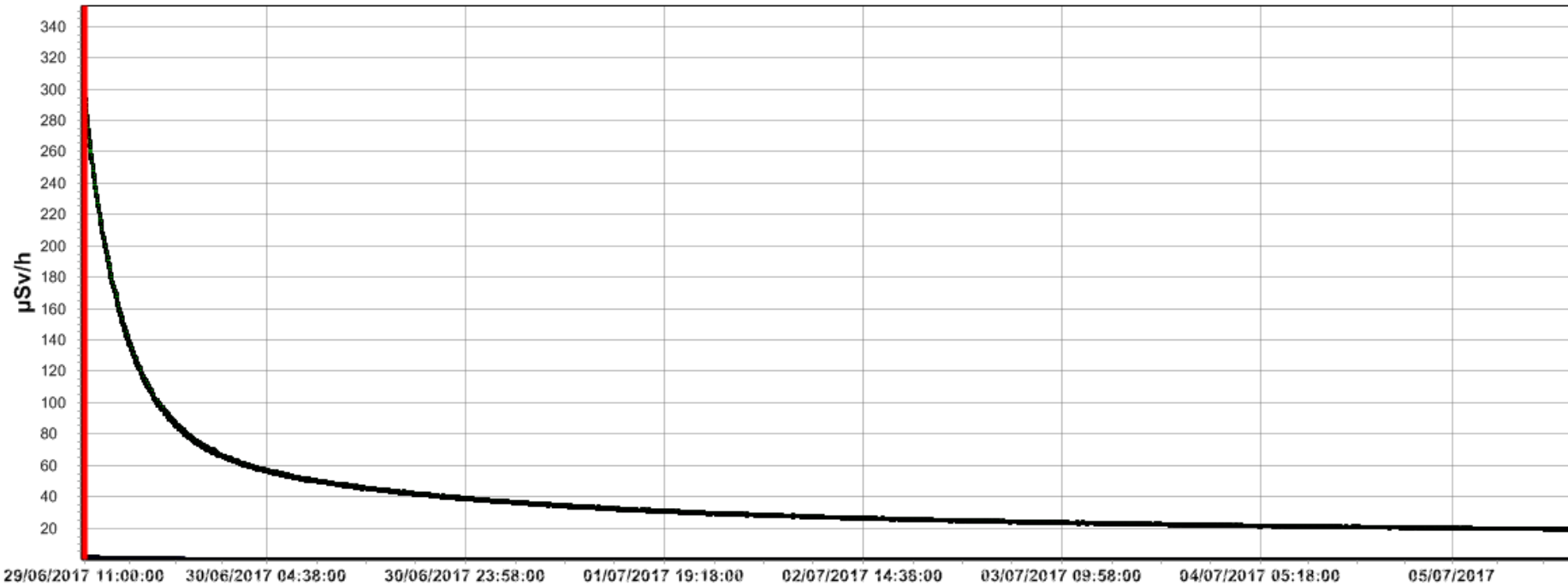
Sonda N.2

12.440.120,00  $\mu\text{Sv}$ 

100 %

## Misura AreaMonitor - Serial Number : 241

## Misura AreaMonitor - Serial Number : 241

☒ Sonda 1 - ECOGAMMA ( $\mu\text{Sv/h}$ ) ☒ Sonda 2 - ECOGAMMA ( $\mu\text{Sv/h}$ )☐ **Indicatori Ratei Grafico**

Inizio Calcolo Dose Integrata

29/06/2017 11:00:00

Fine Calcolo Dose Integrata

05/07/2017 12:00:00

Calcola Dosi Integrate

Dose Totale

Disponibilità  
Dati DoseRisoluzione Temporale  
Grafico Asse X

1 Minuto

Stampa Grafico

Esci

Sonda N.1

32,33  $\mu\text{Sv}$ 

100 %

Sonda N.2

5.573,15  $\mu\text{Sv}$ 

100 %

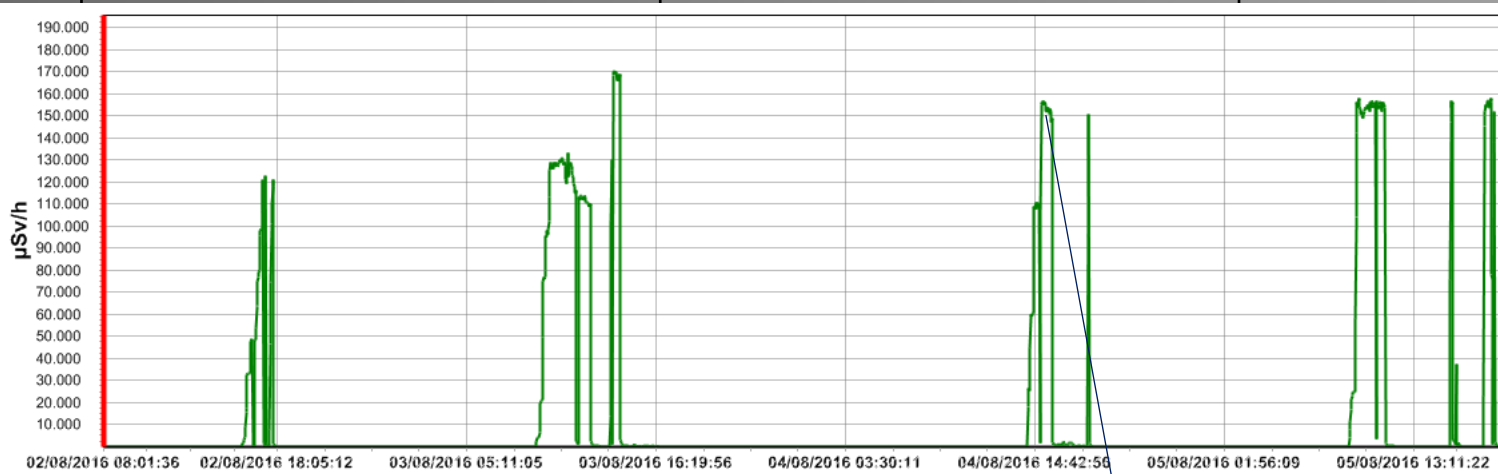


# Doses and dose rates during beam extraction

Beam Energy	Beam current	Measurement	Simulation
70 MeV	100 uA on target	160 mSv/h in A6	100-200 mSv/h
70 MeV	1 uA on FC		150 mSv/h

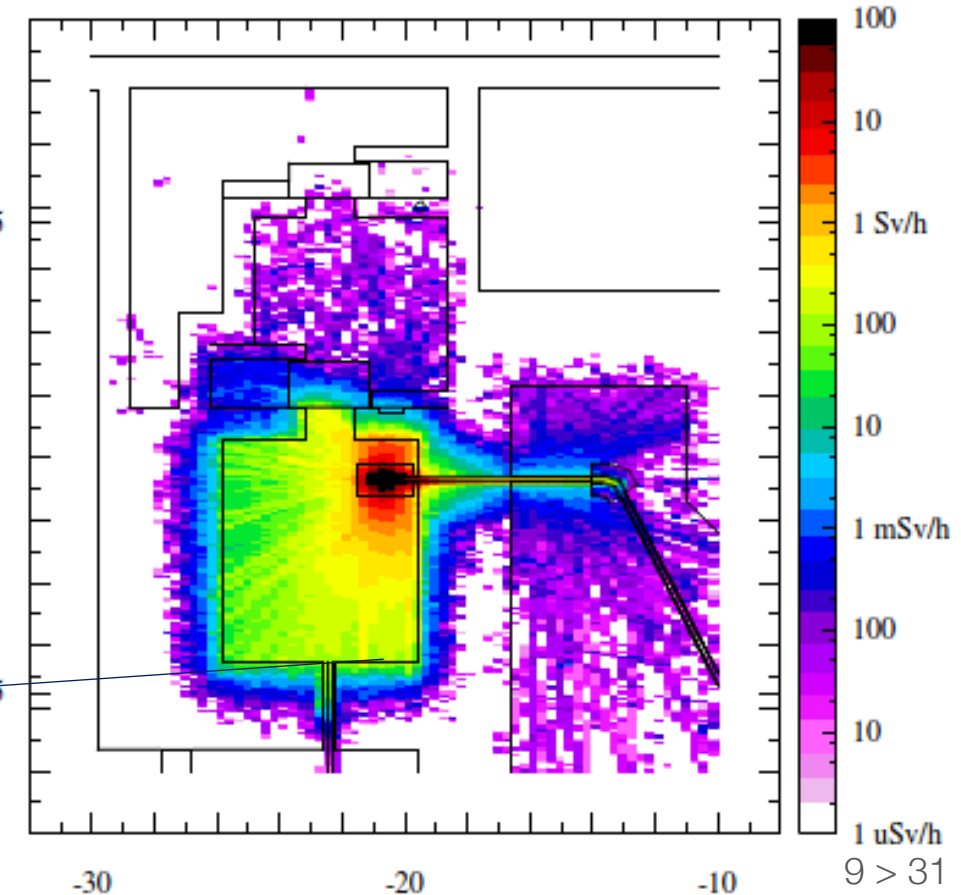
gamma

neutron

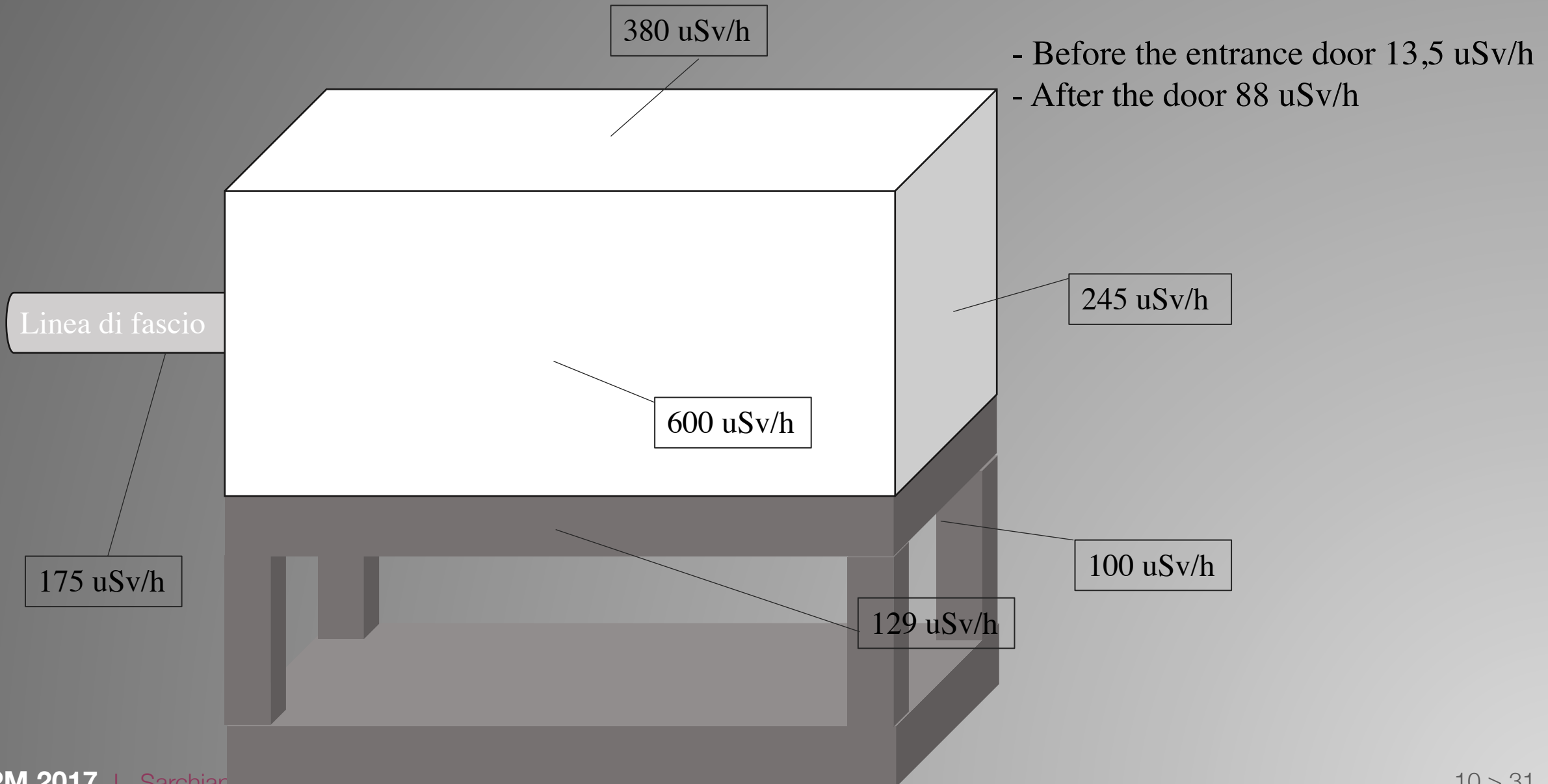


Gamma dose rate inside the target irradiation cave, 70 MeV 100 uA

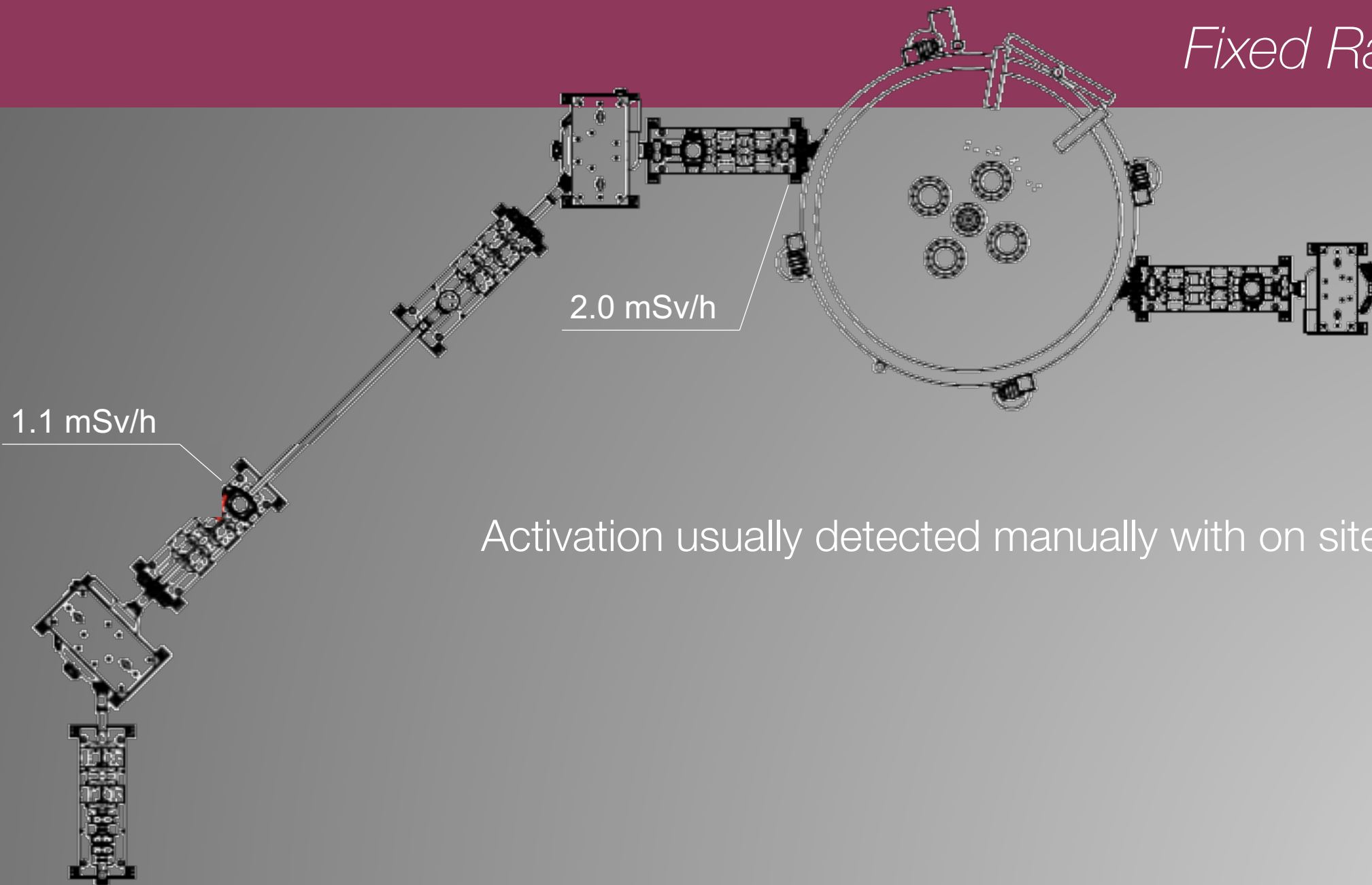
160 mSv/h @ 5,4 m from the beam dump



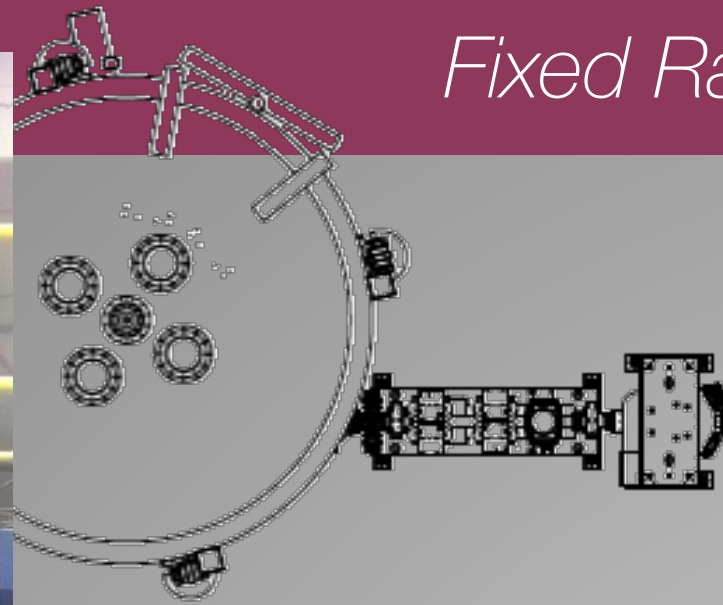
# Doses and dose rates after the EOB







1.1 mSv



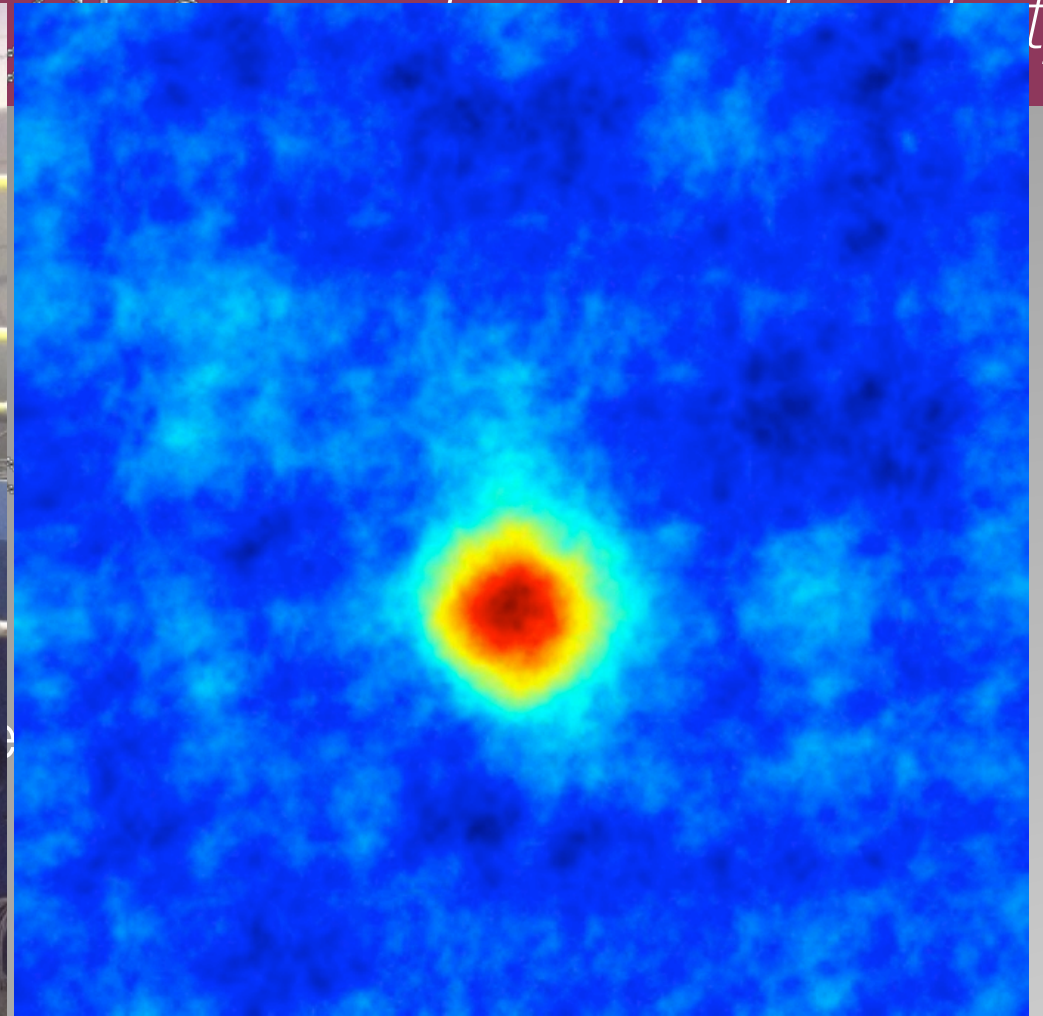
ected manually with on site-survey



iPix: GAmPpix photon detector  
CdTe, 1 mm thick, placed on a pixilated chip CMOS – sensor Timepix  
made at CERN plus a mini optical camera

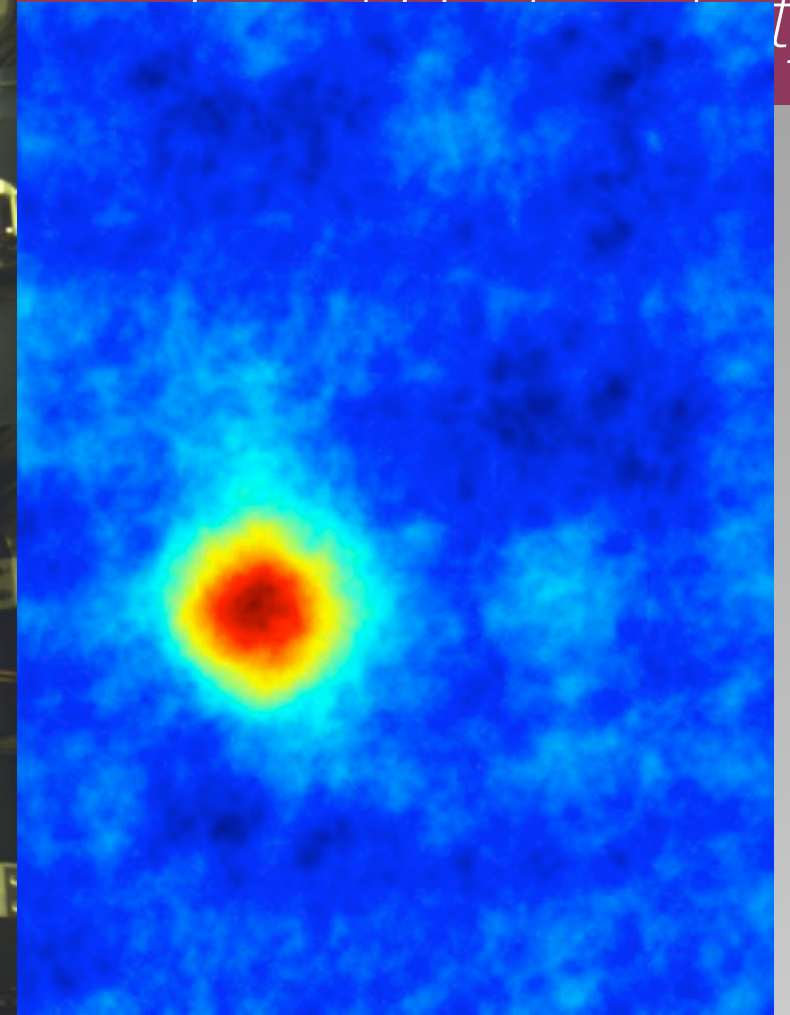
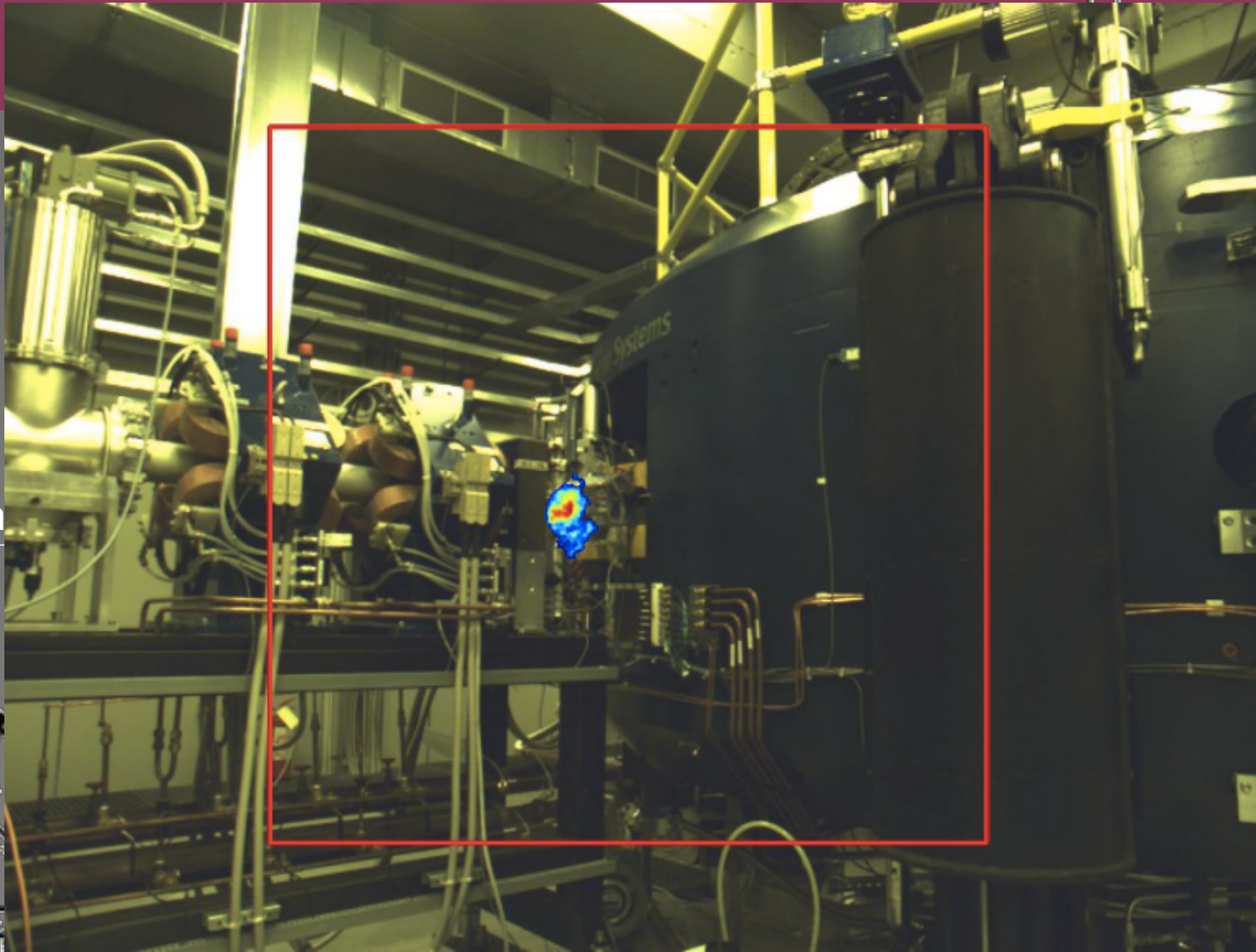


1.1 mSv



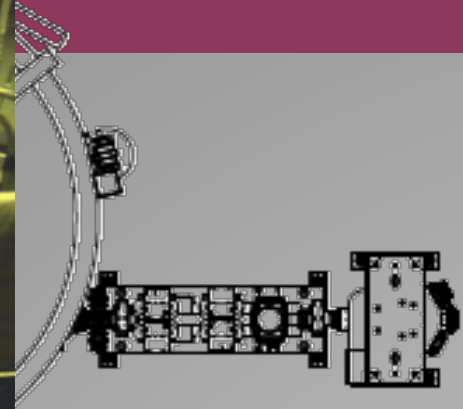
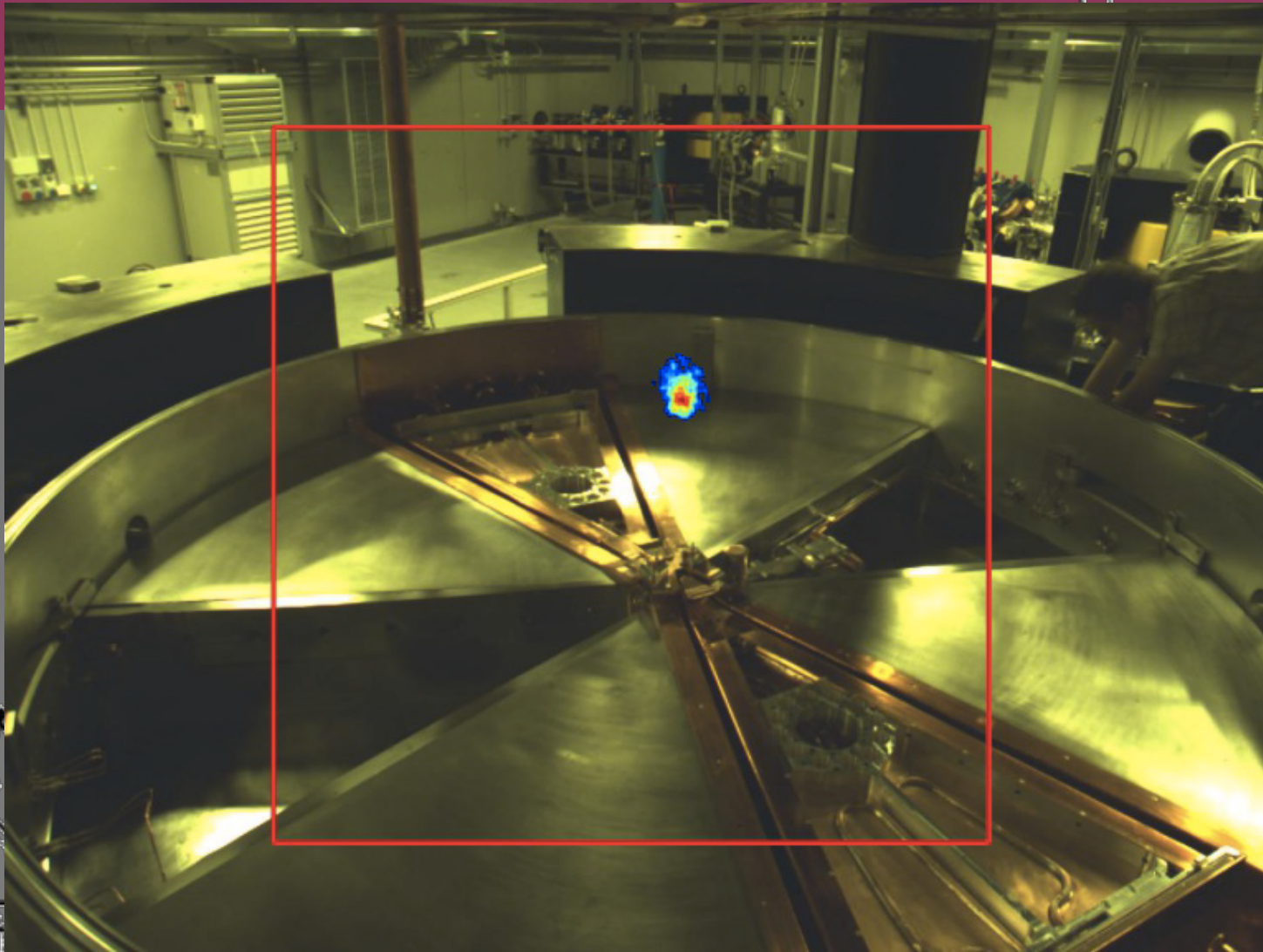


1.1 m



iPix: GAmPix photon detector  
CdTe, 1 mm thick, placed on a pixilated chip CMOS – sensor Timepix  
made at CERN plus a mini optical camera





# *Doses and dose rates after the EOB*

380  $\mu\text{Sv/h}$

- Before the entrance door 13,5  $\mu\text{Sv/h}$
- After the door 88  $\mu\text{Sv/h}$

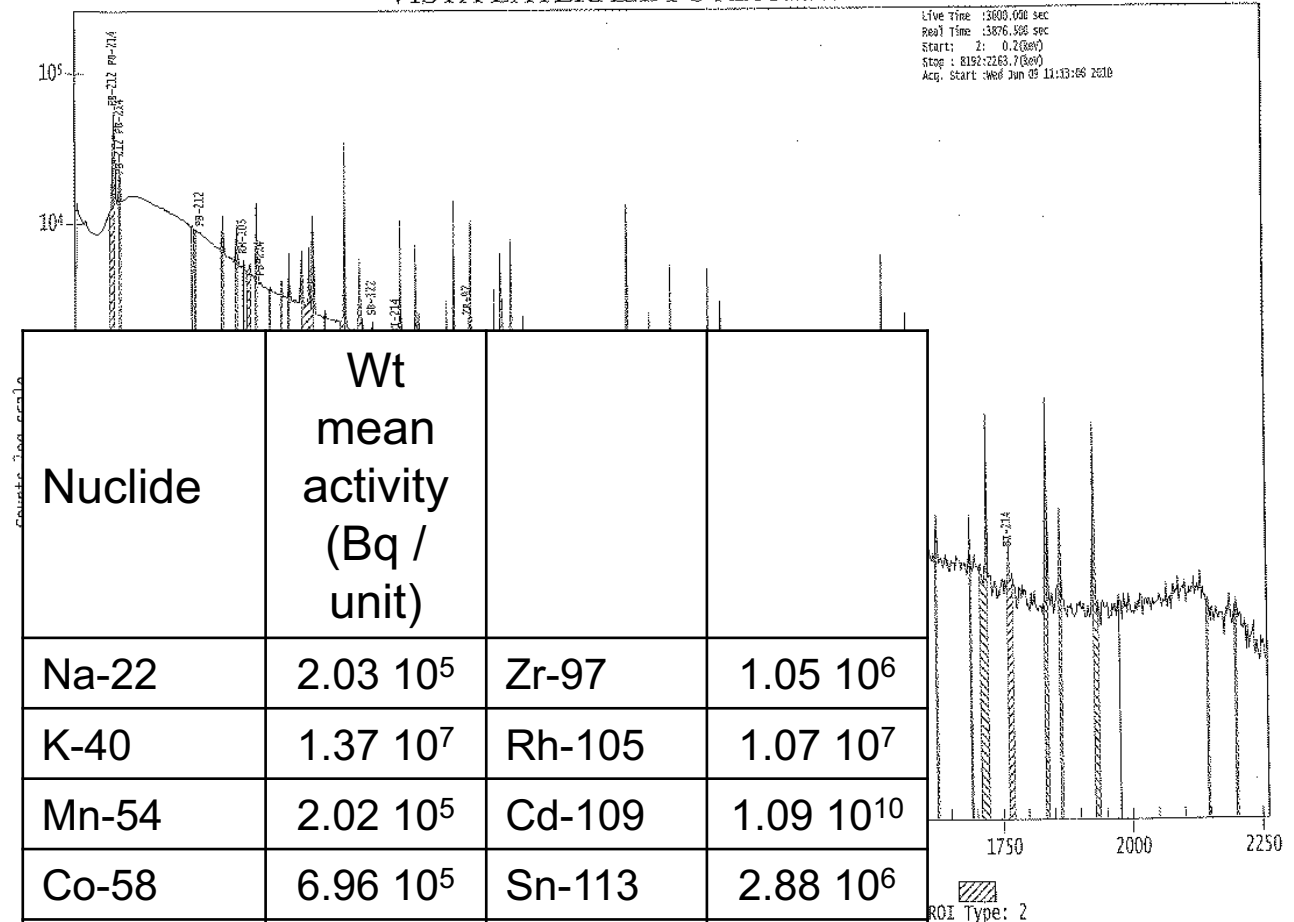
Linea di fascio

175  $\mu\text{Sv/h}$

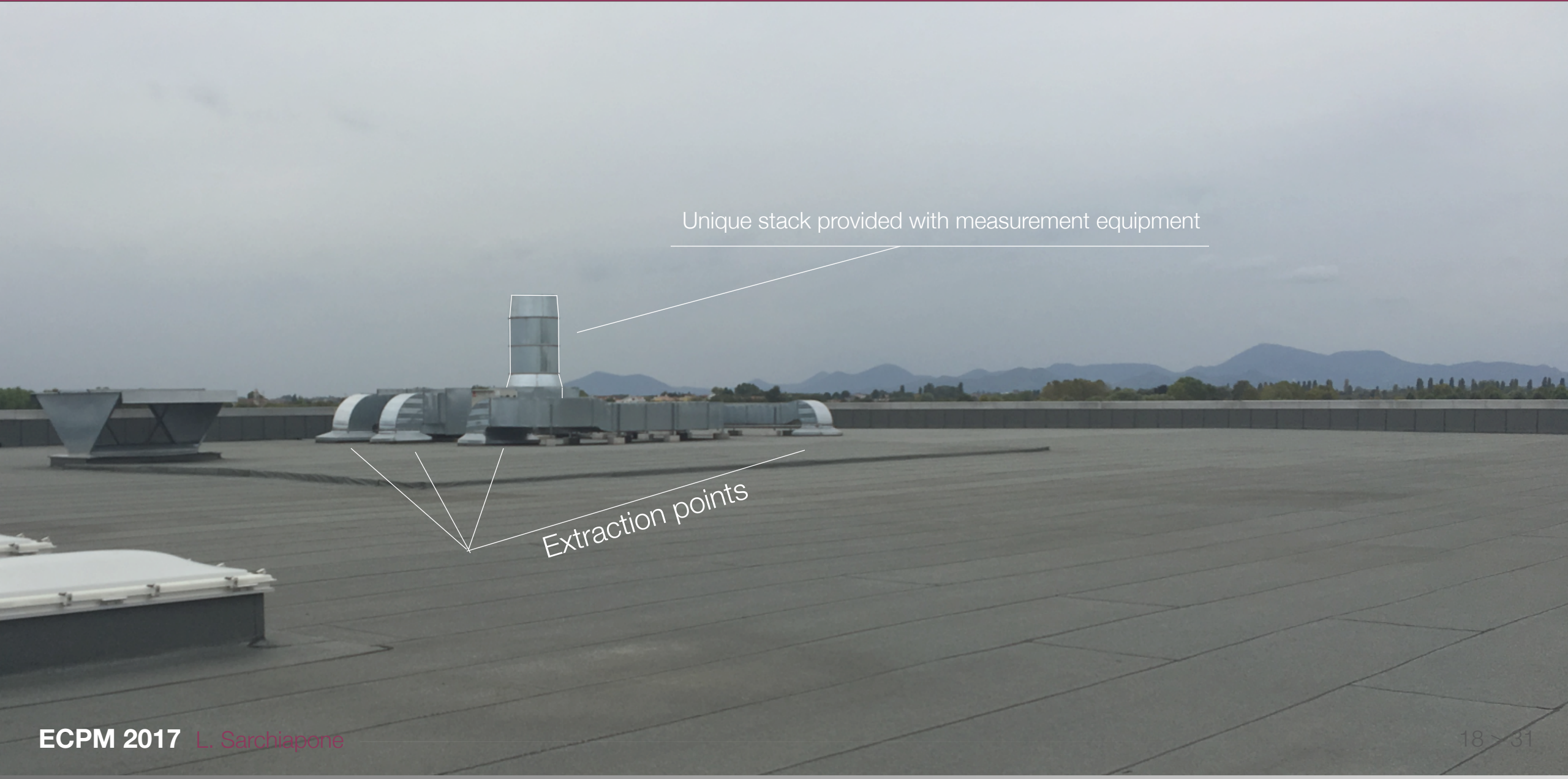




VISTA LATERALE FC ARGENTO.CNF







Unique stack provided with measurement equipment

Extraction points



# Movable Radioactivity: Air

Air continuously sampled through a NaI spectrometer.

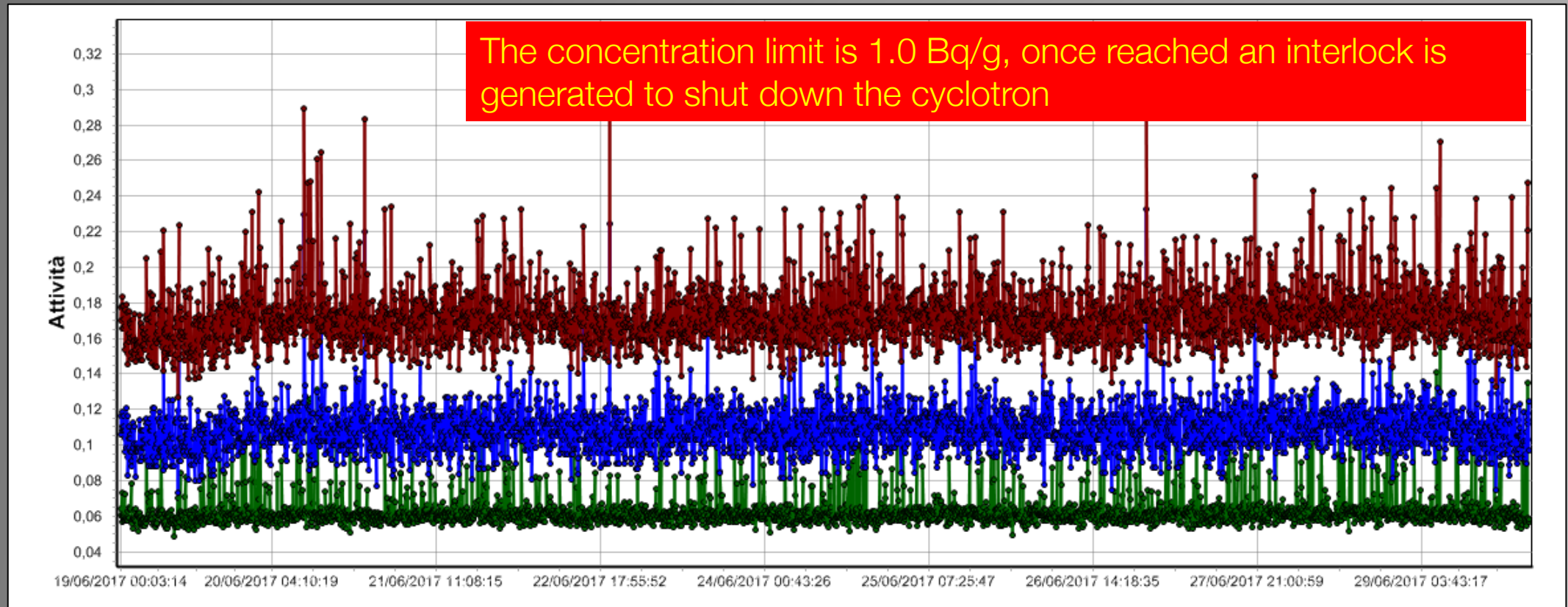
Direct activation of air components,  $\beta^+$  (511 keV),  $^{41}\text{Ar}$  (1293.64 keV)

Sensitivity,  $fz(t_{\text{sampling}})$ : 0.1-0.5 Bq/g<sub>air</sub>



Low sensitivity achieved by compression, in order to obtain a measurable sample despite the low density of air

Radioactivity Concentration (Bq/g) measured at the stack (green  $\beta^+$  and blue  $^{41}\text{Ar}$ )



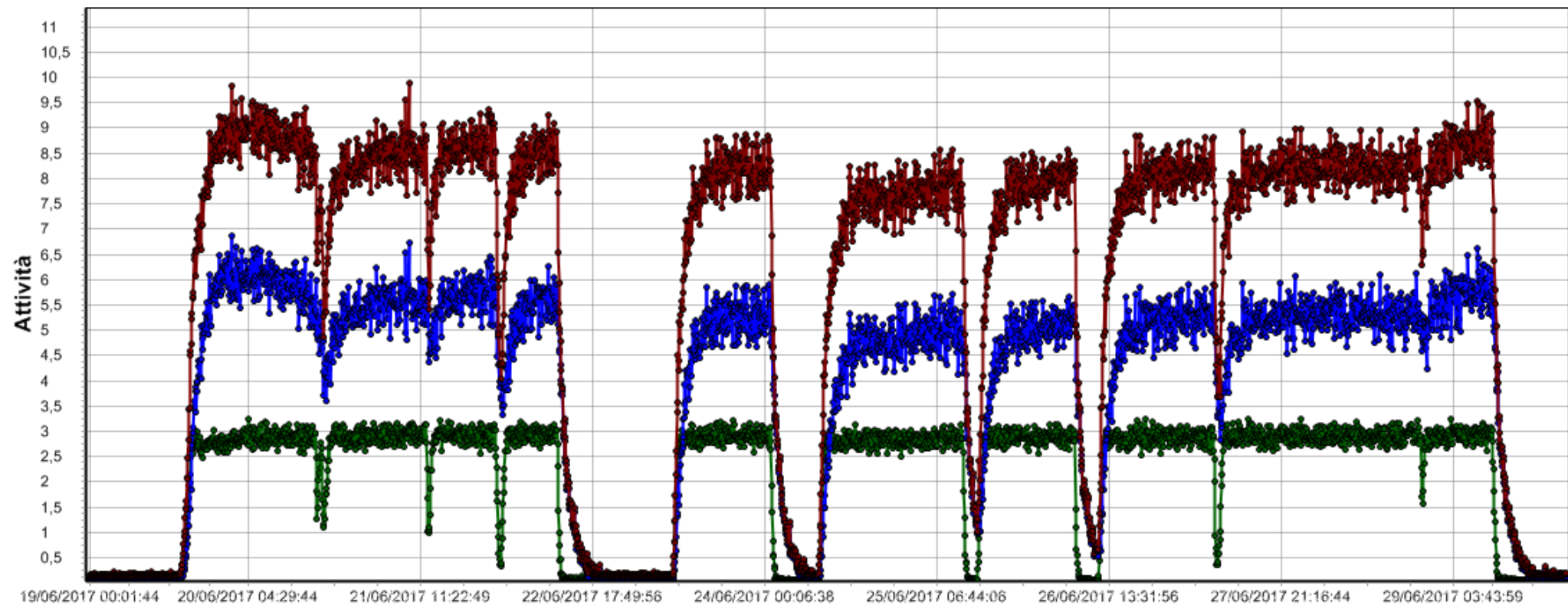
$\beta^+$  emitters:  $^{11}\text{C}$  ( $T_{1/2}$  20.4 min),  $^{13}\text{N}$  (9.9 min),  $^{15}\text{O}$  (122 sec)

$^{41}\text{Ar}$ , 109.3 min

Average (on the sum of the 2 peaks) 0.18 Bq/g with peaks of 0.28 Bq/g



Radioactivity Concentration (Bq/g) measured inside the irradiation bunker (green  $\beta^+$  and blue  $^{41}\text{Ar}$ )

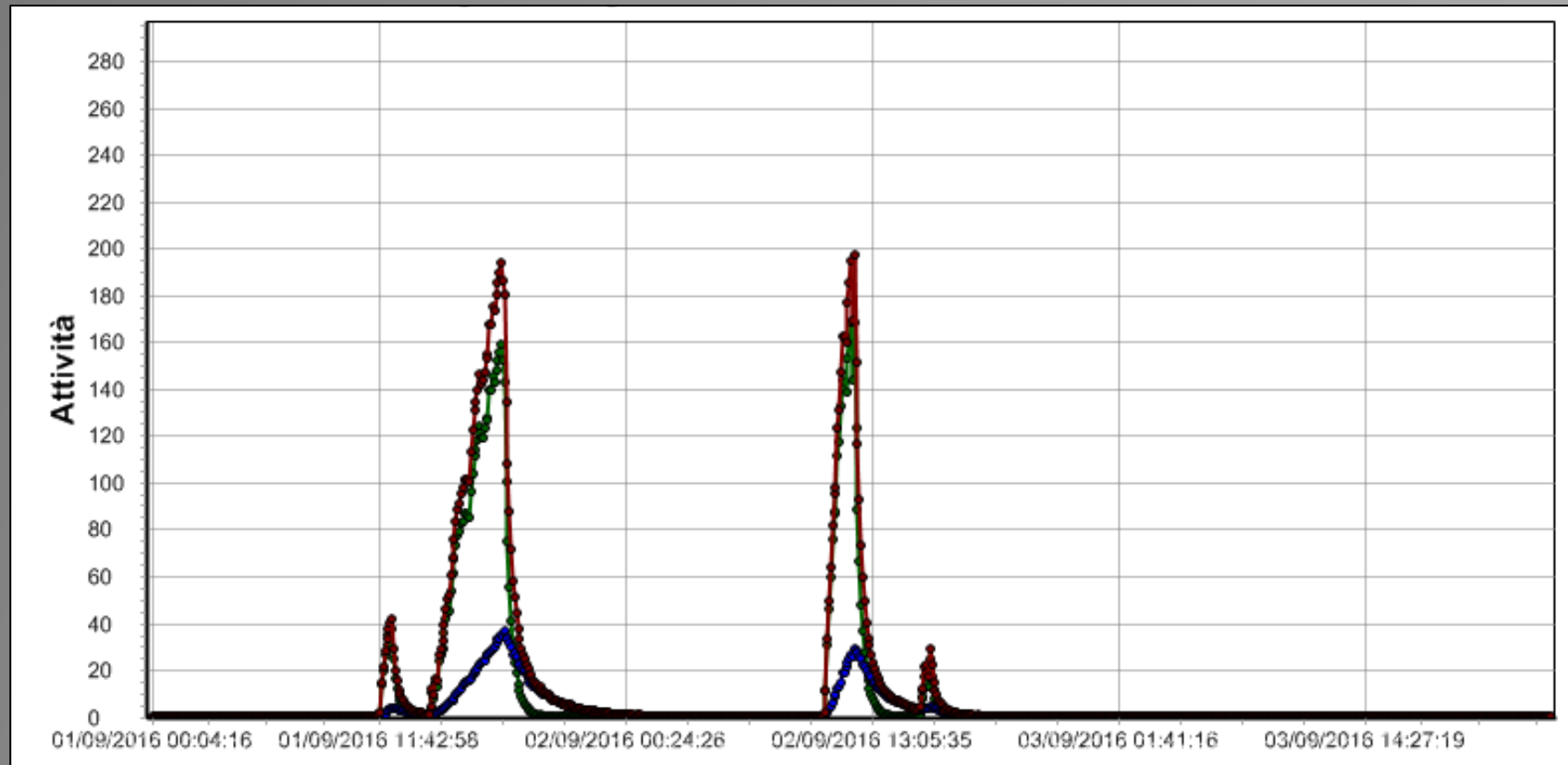


$\beta^+$  emitters:  $^{11}\text{C}$  ( $T_{1/2}$  20.4 min),  $^{13}\text{N}$  (9.9 min),  $^{15}\text{O}$  (122 sec)

$^{41}\text{Ar}$ , 109.3 min

Average (on the sum of the 2 peaks) 8.5 Bq/g with peaks of 10 Bq/g

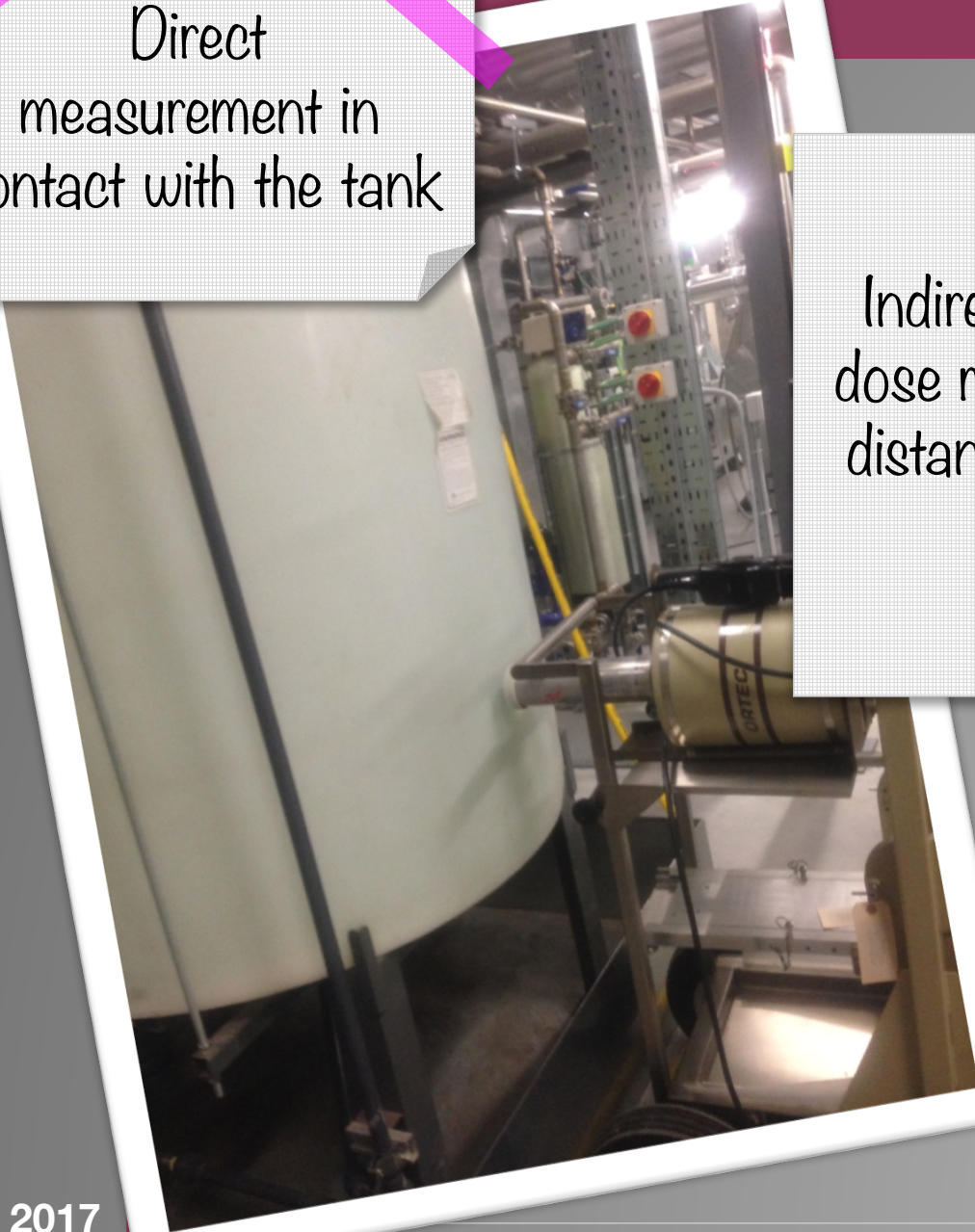
Radioactivity Concentration (Bq/g) measured inside the irradiation bunker (green  $\beta^+$  and blue  $^{41}\text{Ar}$ )



Air activity measured inside the irradiation cave: 200 Bq/g at maximum power tested on the beam dump.

From FLUKA calculation + build up in presence of ventilation: about 500 Bq/g

Direct  
measurement in  
contact with the tank

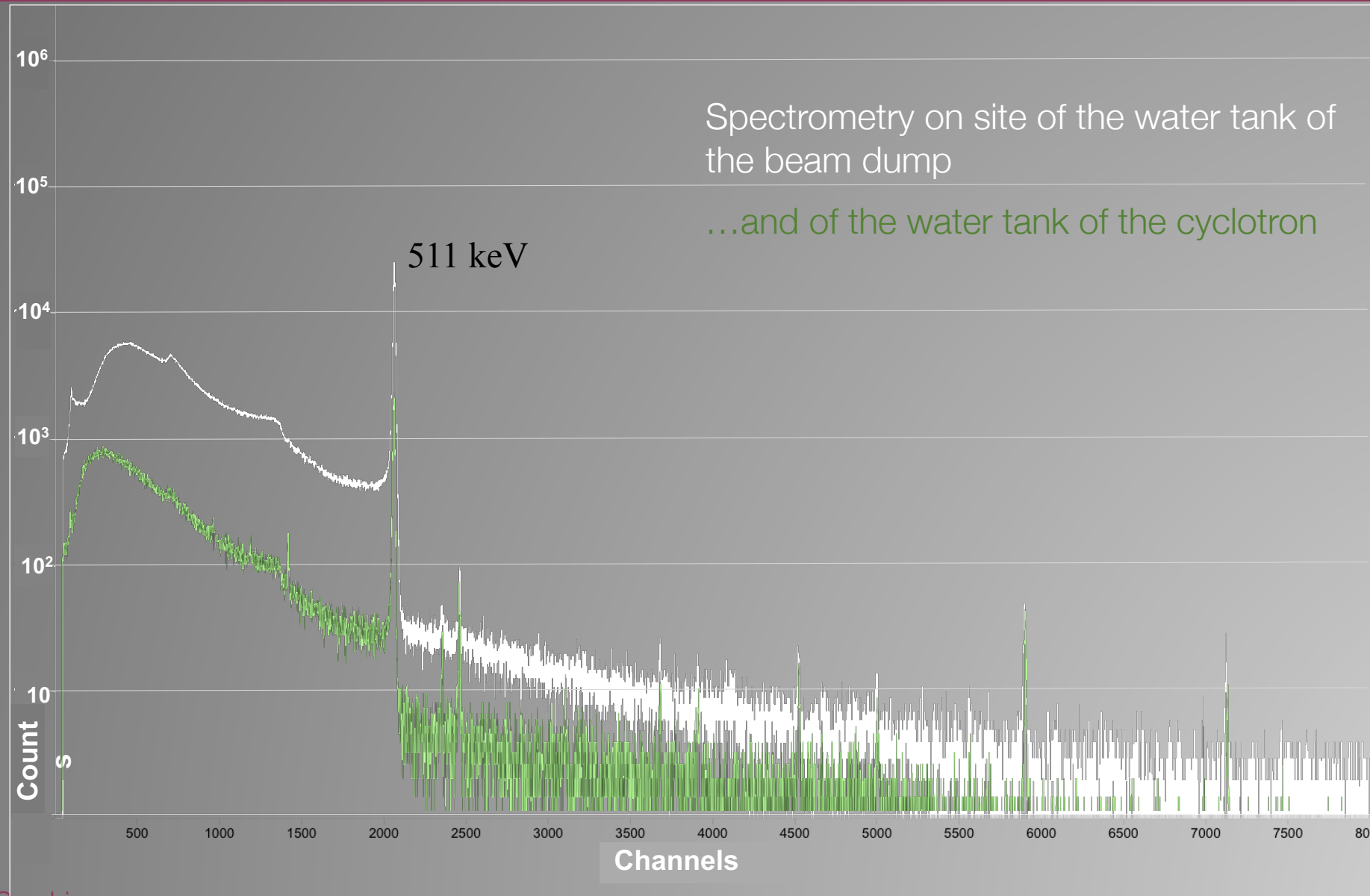


Indirectly through  
dose rate at several  
distances from the  
tank

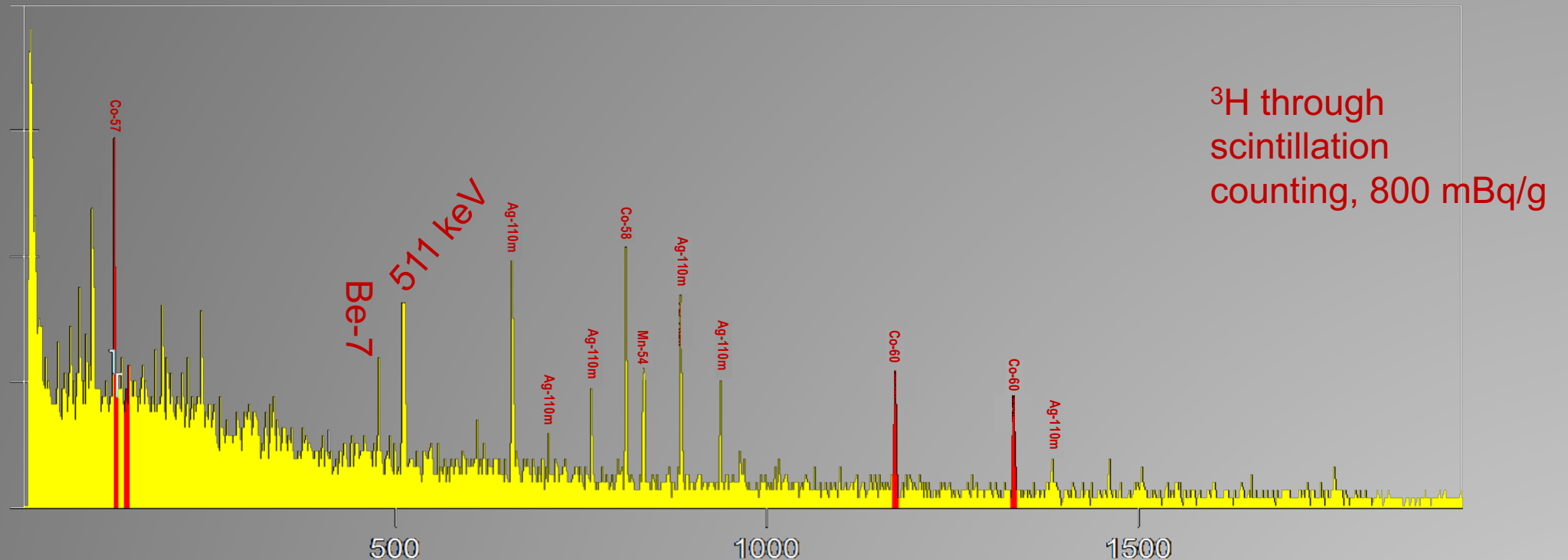


Direct  
measurement from  
sample gathering



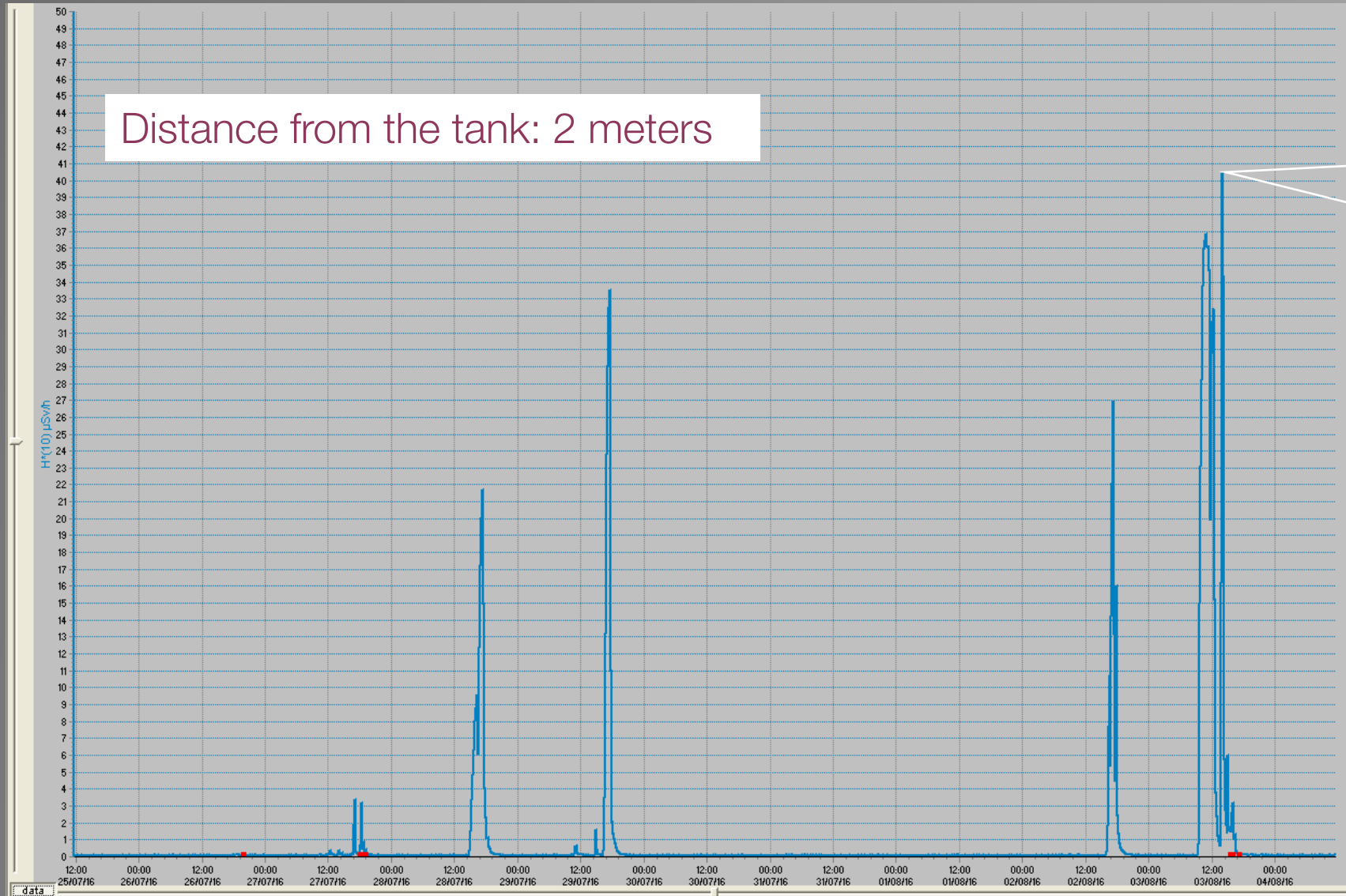


# Movable Radioactivity: Water



Identified Nuclide	Wt Mean Activity (mBq/g)	Uncertainty (mBq/g)
$^{54}\text{Mn}$	8.8	1.0
$^{57}\text{Co}$	2.5	0.4
$^{58}\text{Co}$	12.6	1.2
$^{60}\text{Co}$	9.8	0.9
$^{110\text{m}}\text{Ag}$	20.3	1.1

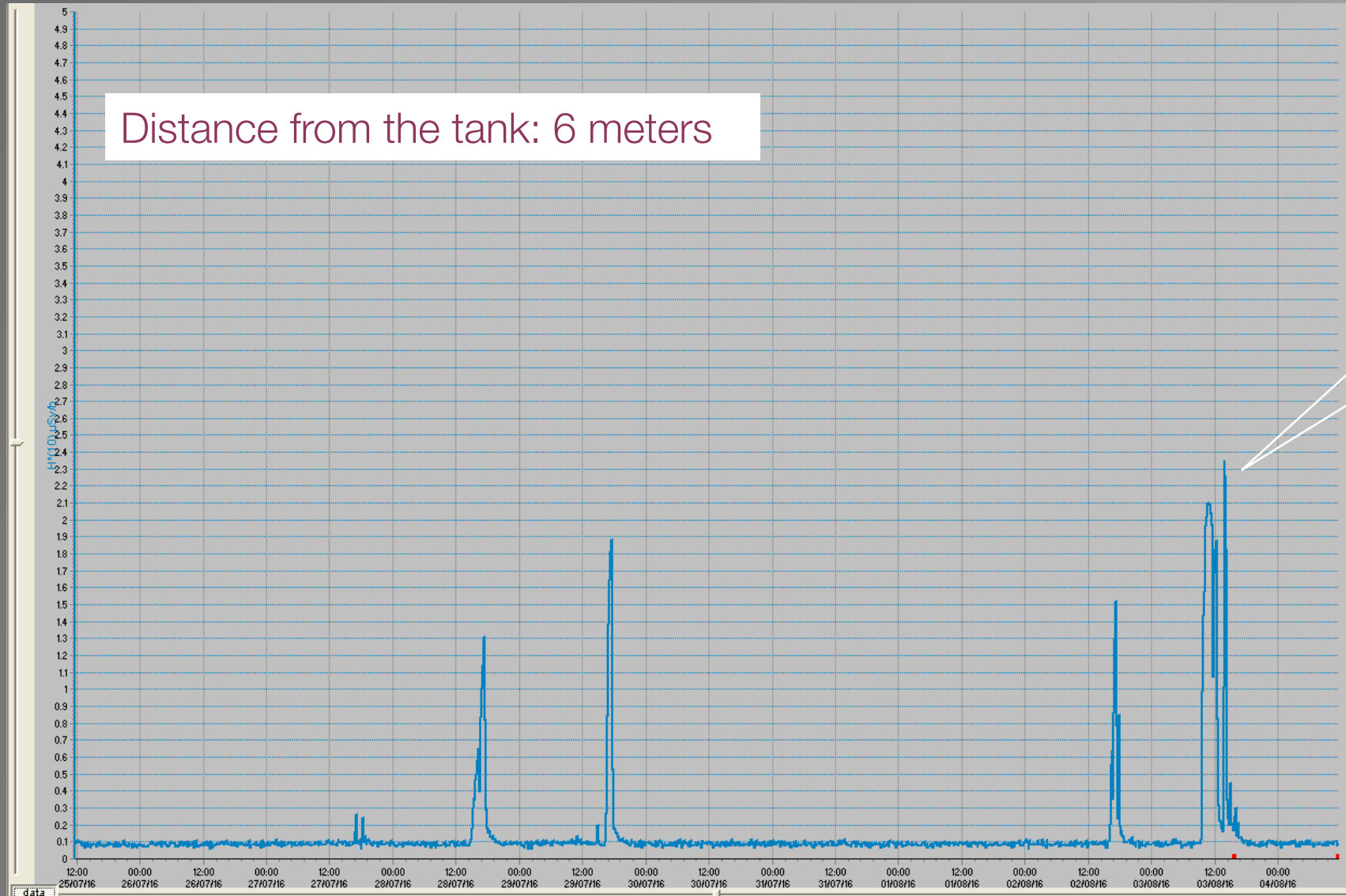
# Movable Radioactivity: Water



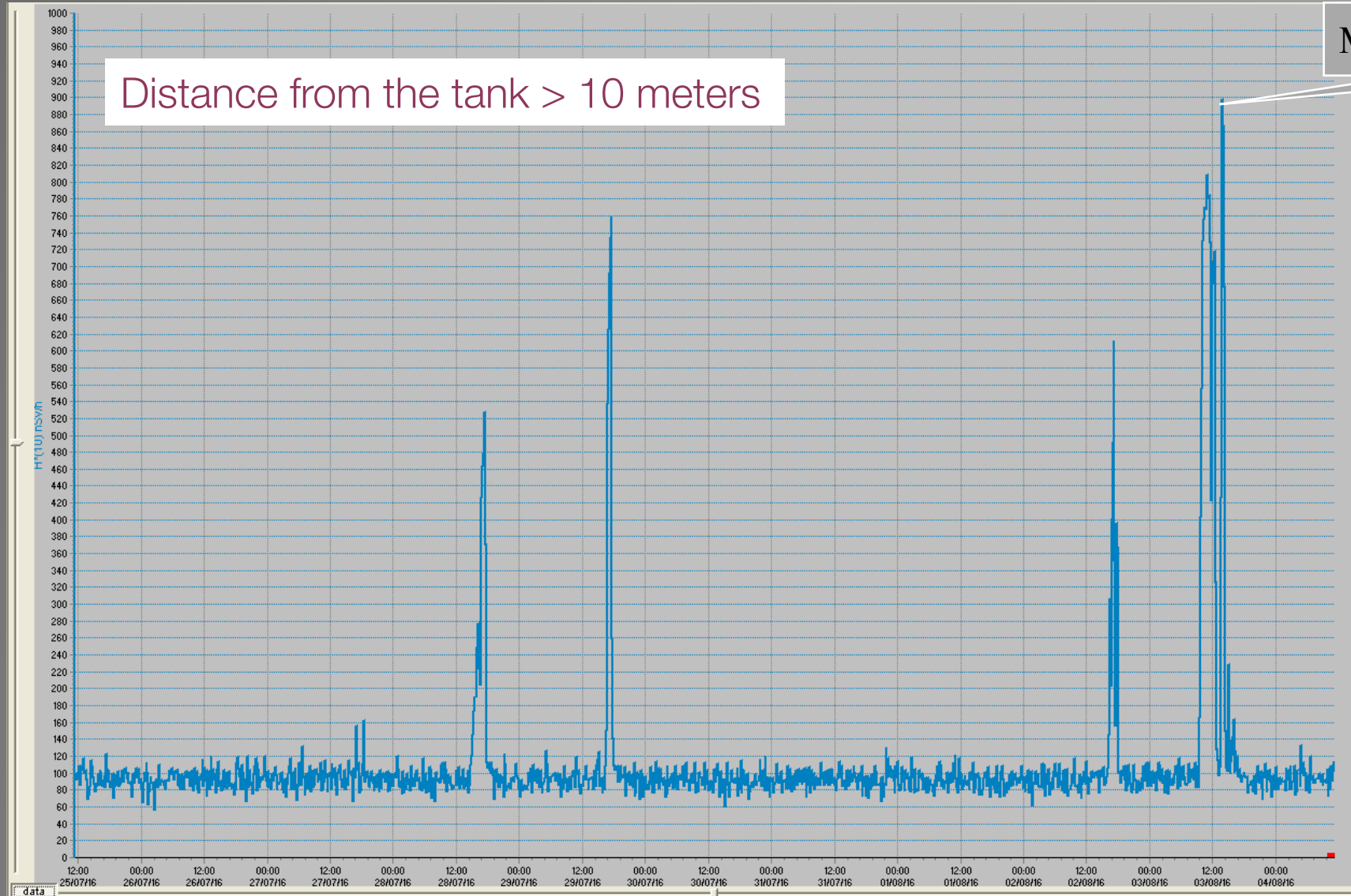
Maximum 40 uSv/h  
corresponding to a current  
extraction of 100 uA

Each peak decays with an  
half life of about 15  
minutes (beta+ emitters  
have half lives in the  
range 2-20 min)

# Movable Radioactivity: Water



# Movable Radioactivity: Water

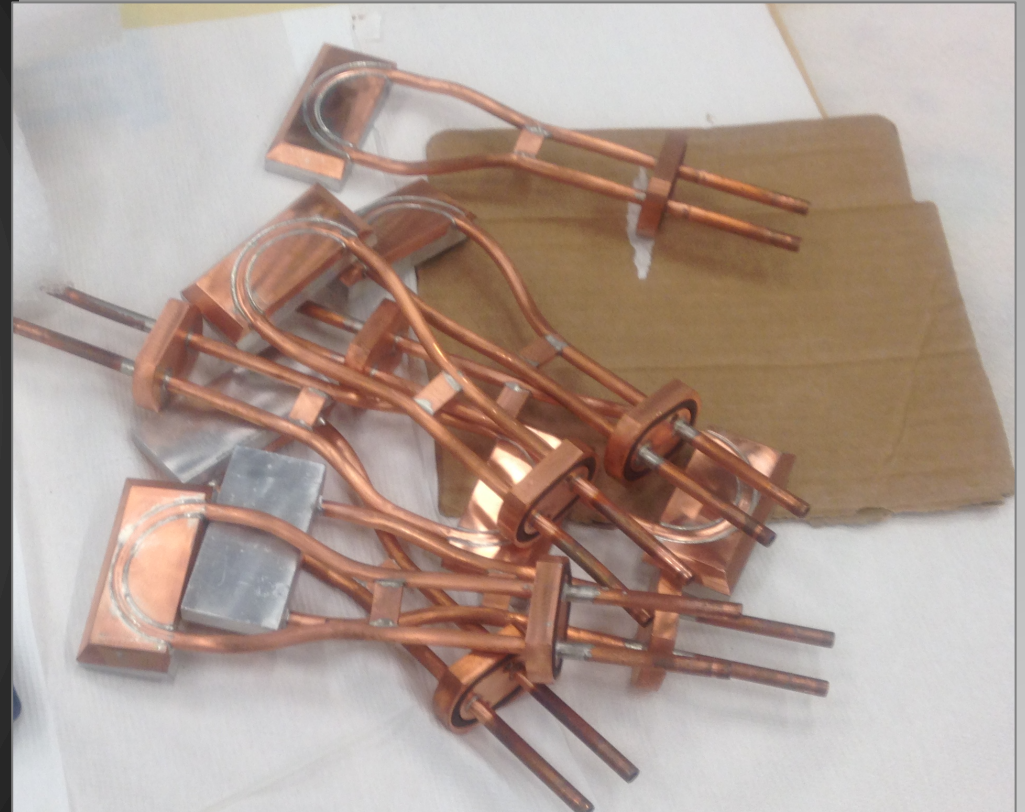
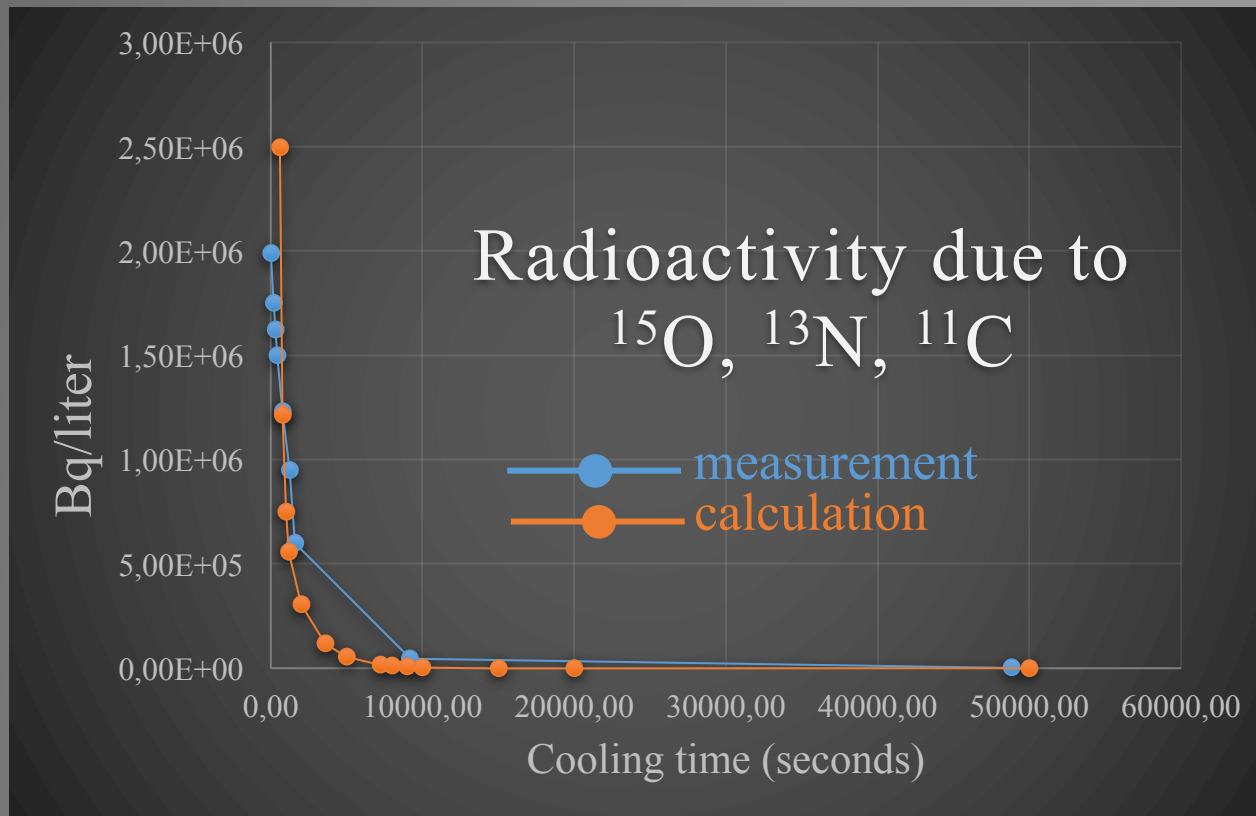


Distance from the tank > 10 meters

Max 0.9 uSv/h



Cyclotron cooling water after a few days of operation, high power



Be-7 measured 830 Bq/liter, calculated 50 Bq/liter. Some effects – other than direct irradiation – such as leaching from the cooling pipes, not included in the calculation.



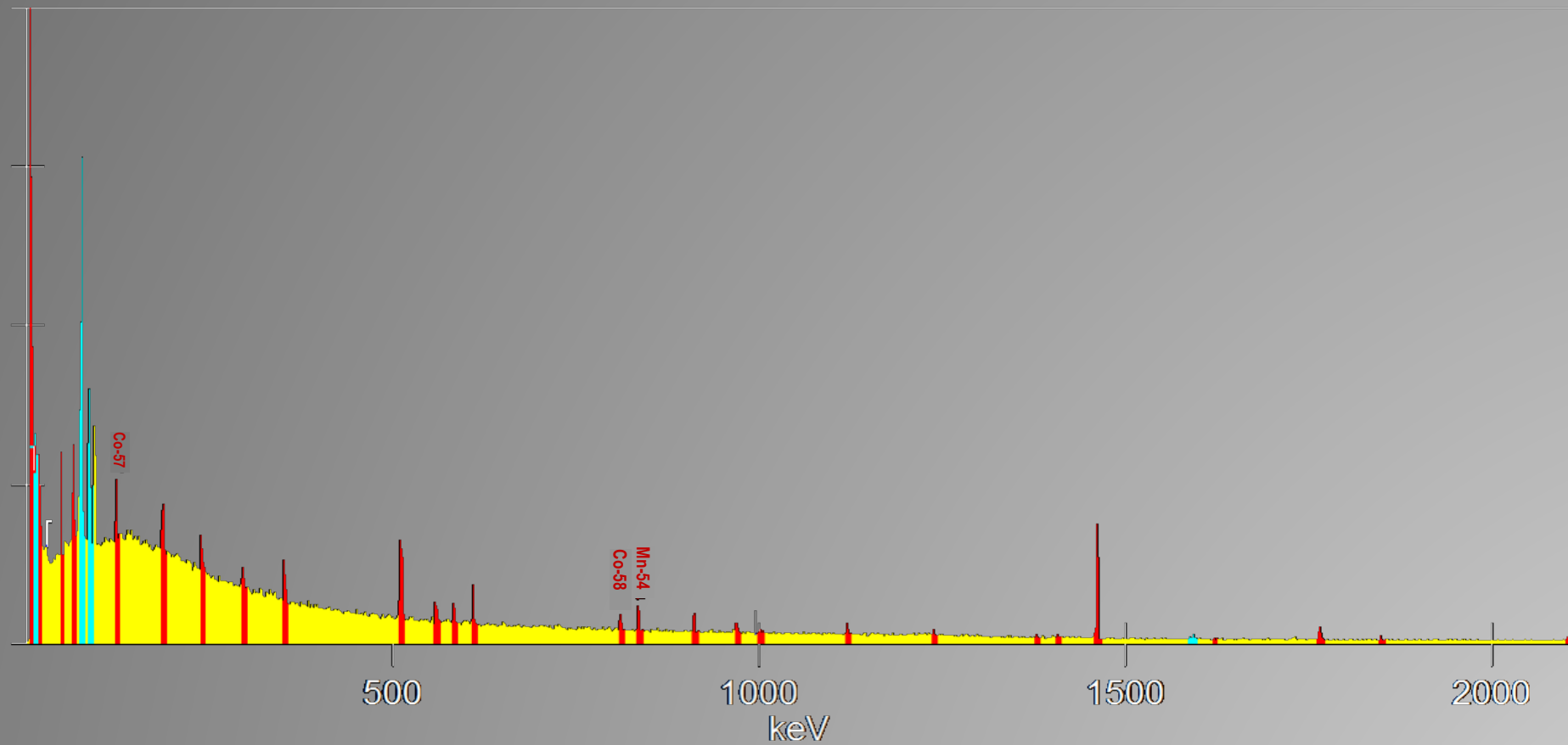
# Movable Radioactivity: Dust

- 2 hours irradiation
- 70 MeV proton energy
- 100 uA proton current on the copper beam dump
- The sample has been measured immediately after the irradiation

Despite the limited duration of the irradiation, it has been possible to identify some radionuclides of medium half life

Nuclide	$T_{1/2}$	Measured Radioactivity (Bq)	Err (Bq)
$^{24}\text{Na}$	15 h	144	5
$^{56}\text{Mn}$	2.6 h	160	4
$^{42}\text{K}$	12.3 h	16	1.4





Identified Nuclide	Wt Mean Activity (mBq/g)	Uncertainty (mBq/g)
<sup>54</sup> Mn	125	9.5
<sup>57</sup> Co	64	7
<sup>58</sup> Co	85.6	7.7



- Monitors are placed in the whole SPES installation to provide as complete as possible survey during operations, for RP purposes
- ... not only RP purposes!
- During the commissioning the measurements have confirmed what expected by the calculation
- The beam line survey is actually done on site and manually, in the future it may cause significant dose commitment to the operator. Instruments for the remote control are available and they will be routinely put in operation.
- Already important activation levels have been observed, especially in water: care to be paid for tank shielding (external irradiation) and for maintenance (introduction).



To err is human – and to  
blame it on a computer is  
even more so

Robert Orben





# Thank you for your attention

L. Sarchiapone

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