Advanced Radiation Dosimetry European Network Training

POLITECNICO DI MILANO





LUPIN A neutron detector for pulsed mixed fields: preliminary measurements

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Pulsed neutron fields (PNF)

It is well-known that neutron detectors, based on neutrons counting, generally suffer from dead-time effects and have strong limitations when measuring in pulsed radiation fields.

This is a major issue at particle accelerators, where pulsed neutron and gamma fields are present because of beam losses at e.g. targets, collimators and beam dumps.

Pulsed neutron fields (PNF)

An ideal neutron survey meter for PNF should meet the following requirements:

1. capability to withstand very high instantaneous neutron fluxes with little or no saturation;

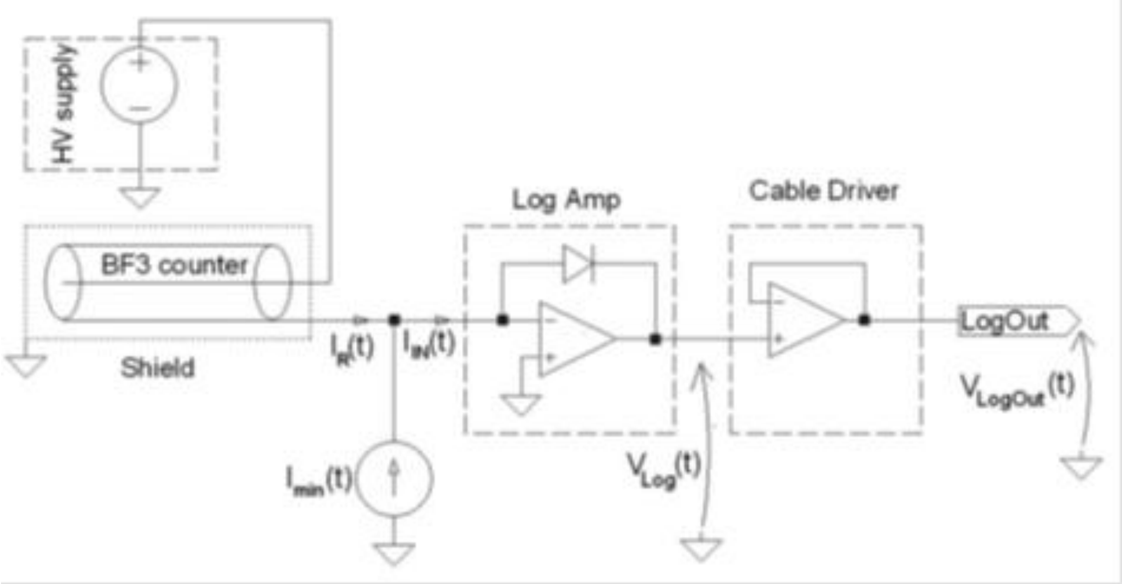
2. sensitivity comparable to that of commercially available rem counters;

3. capability to measure correctly the intensity of a single neutron burst;

4. capability to reject the photon contribution that accompanies the neutron field.

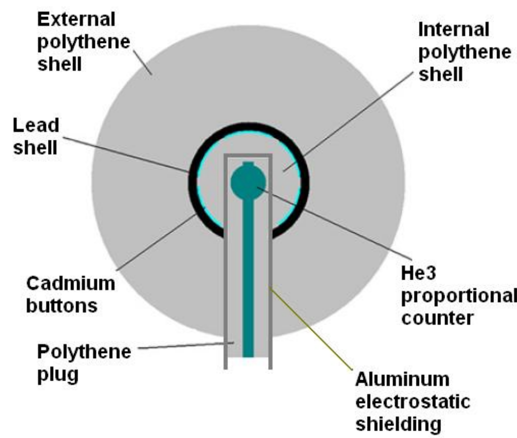
At present there is no instrument capable to fulfill all the requirements

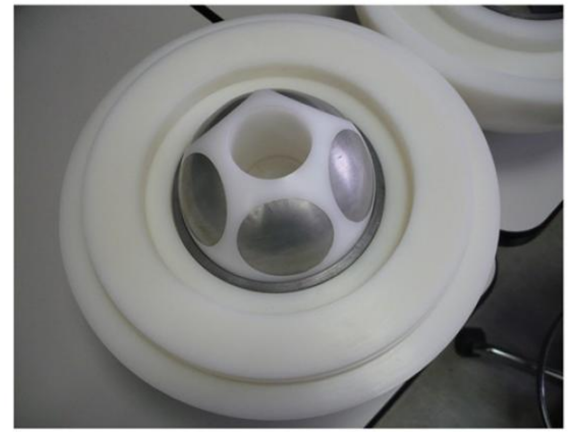
LUPIN (Long interval Ultra wide dinamic Pile-up free Neutron detector)

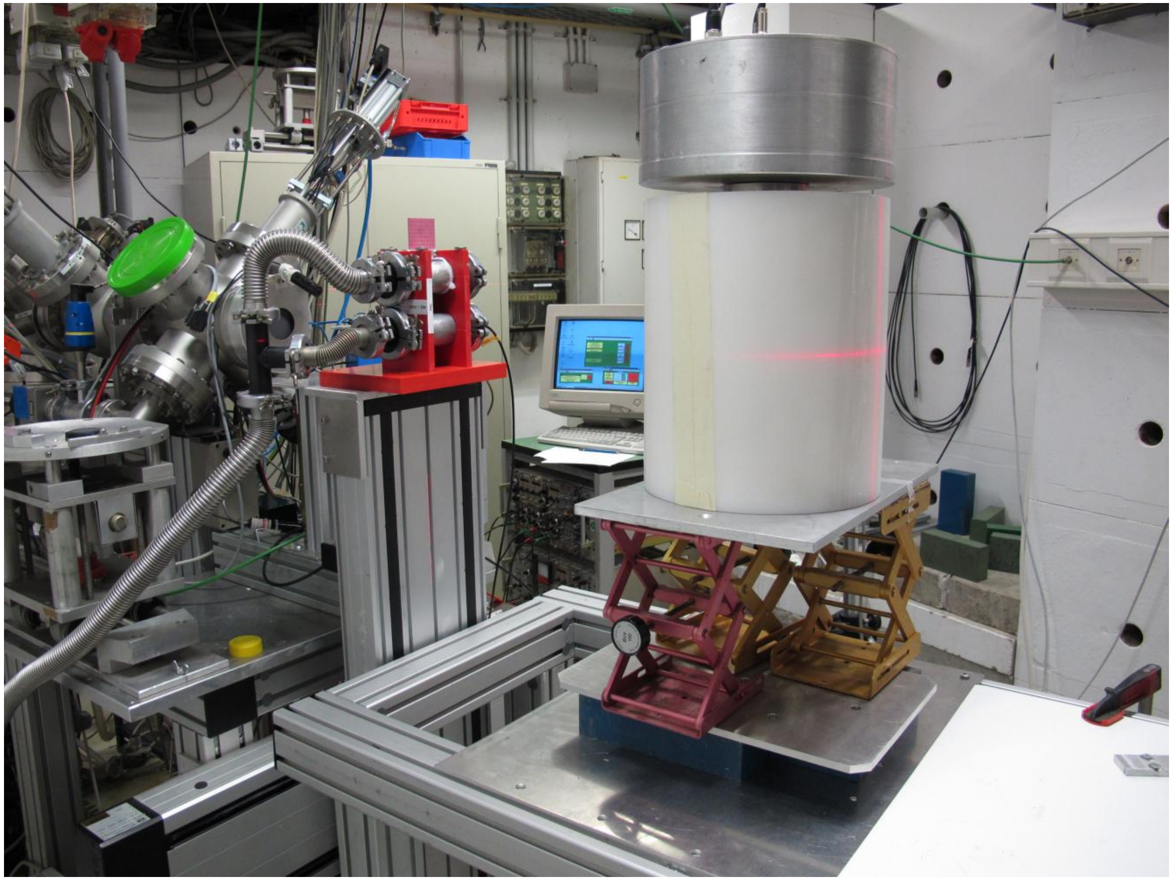


The BF3 detector is placed inside a cylindrical polyethylene moderator with a diameter of 35 cm.

The signal LogOut is acquired with an ADC (12.5 MHz) and processed via software (current integration over a user settable timebase). The system measures the charge generated by a neutron interaction

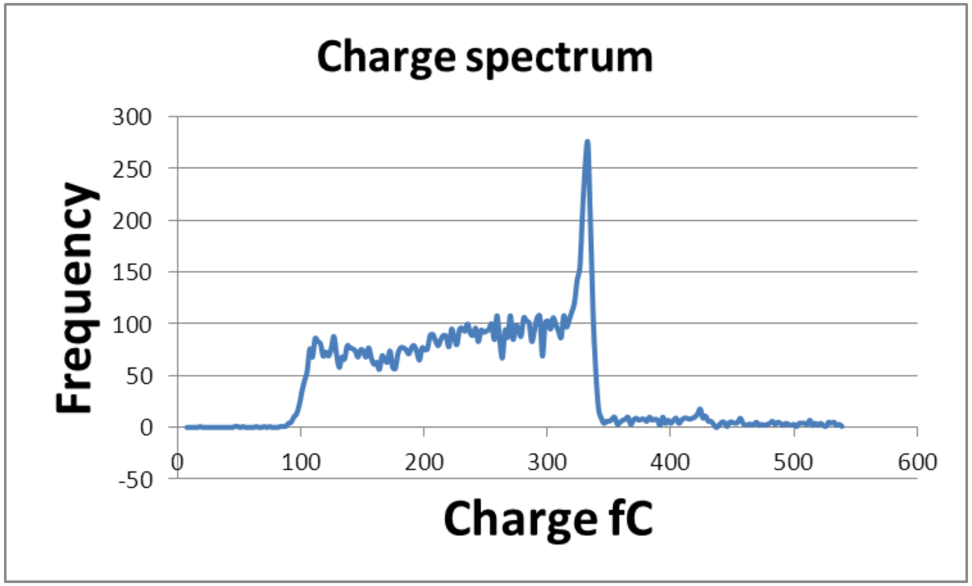

External polythene shell
Internal polythene shell
Lead shell
Cadmium buttons
He3 proportional counter
Polythene plug
Aluminum electrostatic shielding





Charge calibration

The charge calibration is the measurement of the mean collected charge (MCC) expected from a single neutron interaction, expressed in fC/n



The total charge, measured during the interaction of a radiation burst involving several neutron interaction, divided by MCC is the number of neutron interactions

MCC = 247 fC with HV=2400V

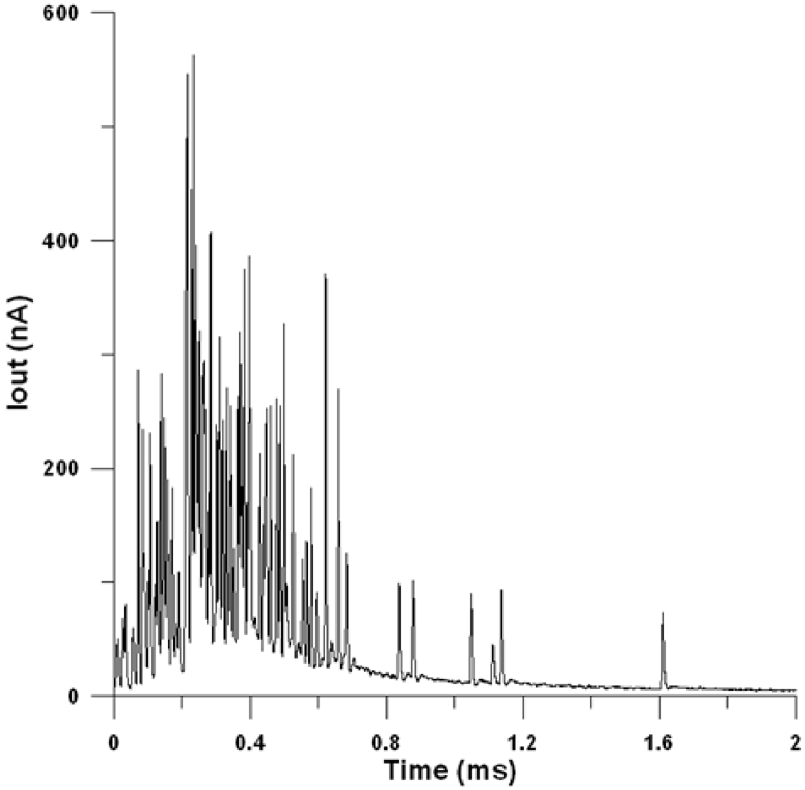
Measurement at CNAO

A beam of 7 MeV protons was accelerated by a LINAC and impinged on a copper Faraday cup. Each proton pulse had a current of 500 μA and a length of 200 μs. The detector was placed at 4.5 m from the target in the mixed neutron-gamma field generated by the interaction of the protons in the Faraday cup.

The total charge generated inside the detector is 93.2 pC. By dividing this value for the MCC calculated before, one obtains 378 neutrons.

The interaction rate is:

$3.8 \cdot 10^5\ s^{-1}$

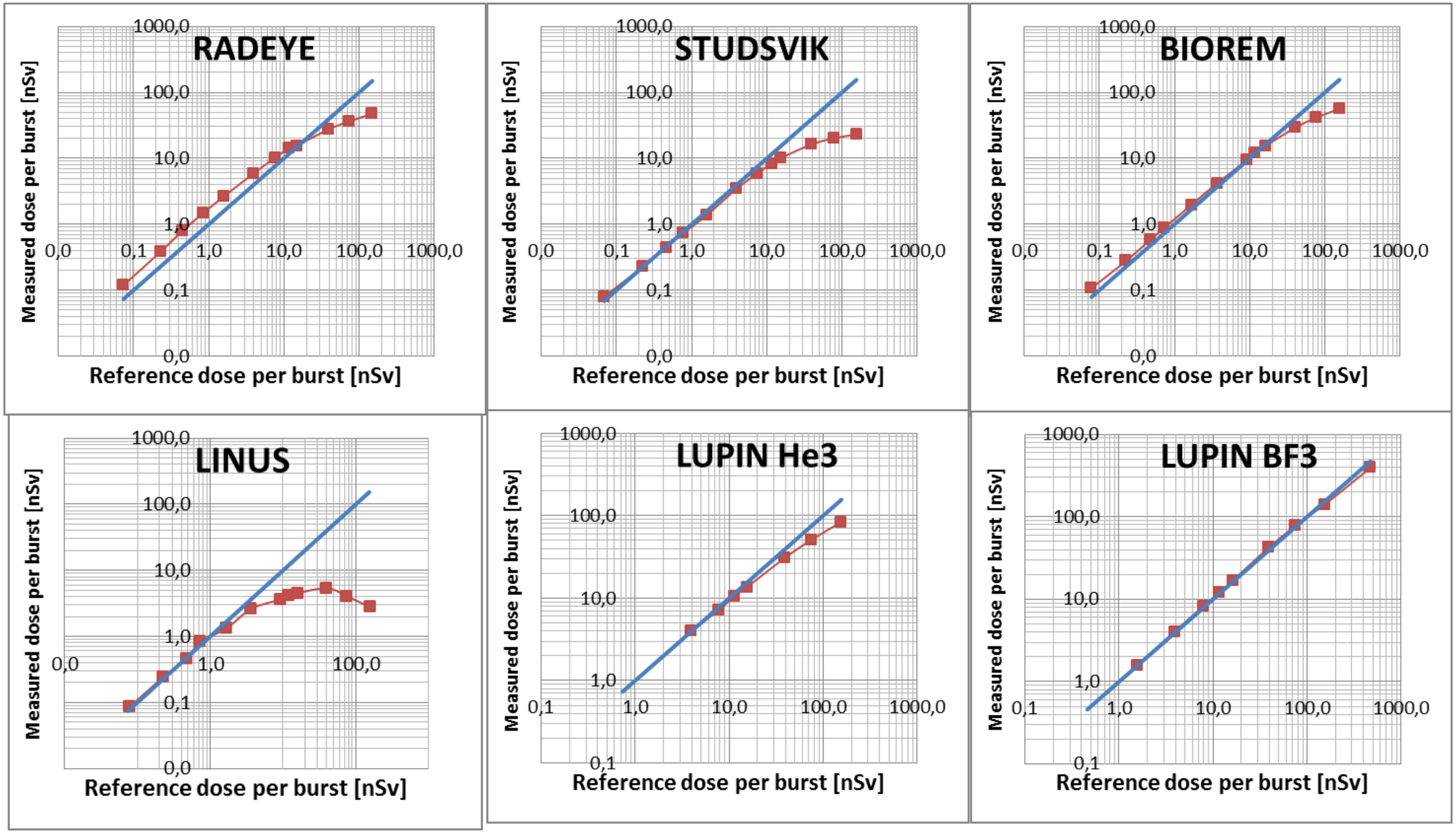


A burst suppressor deflects the beam and sends it to the target only for the desired time. This technique permits to generate radiation bursts with time duration ranging from 50 ns to 1 ms with 100 kHz as a maximum repetition rate. The beam current can vary in the range from 0.5 pA to 300 nA.

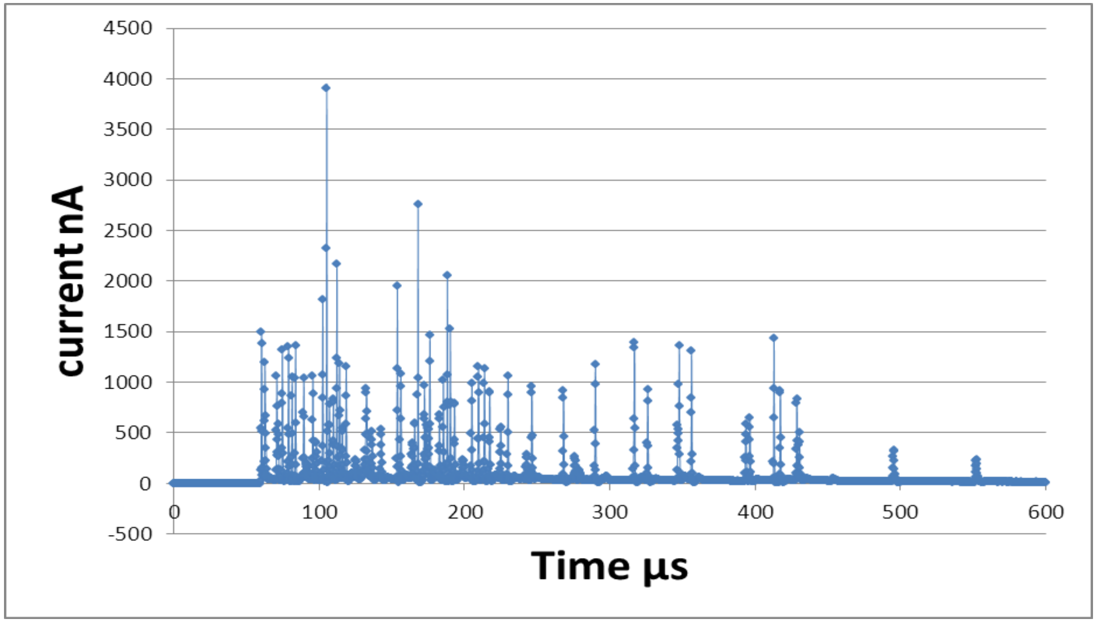
Measurements at HZB

Setting number	Ion current [pA]	Burst current [nA]	Burst length [µs]	Burst charge Qi [fC]	Reference burst intensity nSv per burst	Average dose rate µSv·h^{-1}	Burst dose rate Sv·h^{-1}
1	0.5	5	1	5	0.077	27.72	0.28
2	1.5	15	1	15	0.231	83.16	0.83
3	3	30	1	30	0.462	166.32	1.66
4	5	50	1	50	0.770	277.2	2.77
5	10	100	1	100	1.540	554.4	5.54
6	25	250	1	250	3.850	1386	13.86
7	50	500	1	500	7.700	2772	27.72
8	75	750	1	750	11.550	4158	41.58
9	100	1000	1	1000	15.400	5544	55.44
10	250	250	10	2500	38.500	13860	13.86
11	500	500	10	5000	77.000	27720	27.72
12	1000	1000	10	10000	154.000	55440	55.44
13	3000	800	40	32000	492.800	177408	44.35

Measurements at HZB



Measurements at HZB



Acquisition of a single burst with the LUPIN BF3 (setting 10, 38 nSv/burst) about 80 neutrons/burst were measured. The TDT spreads the signal over a time of hundreds of µs. Interaction rate 200kHz.

Linearity up to an interaction rate about 2 MHz

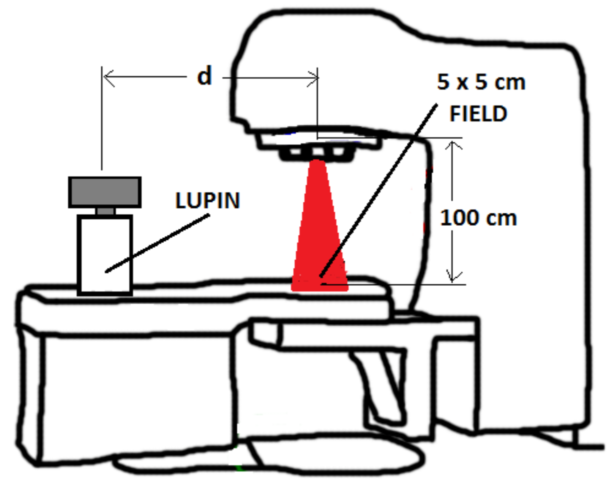
Measurement at S. Raffaele hospital

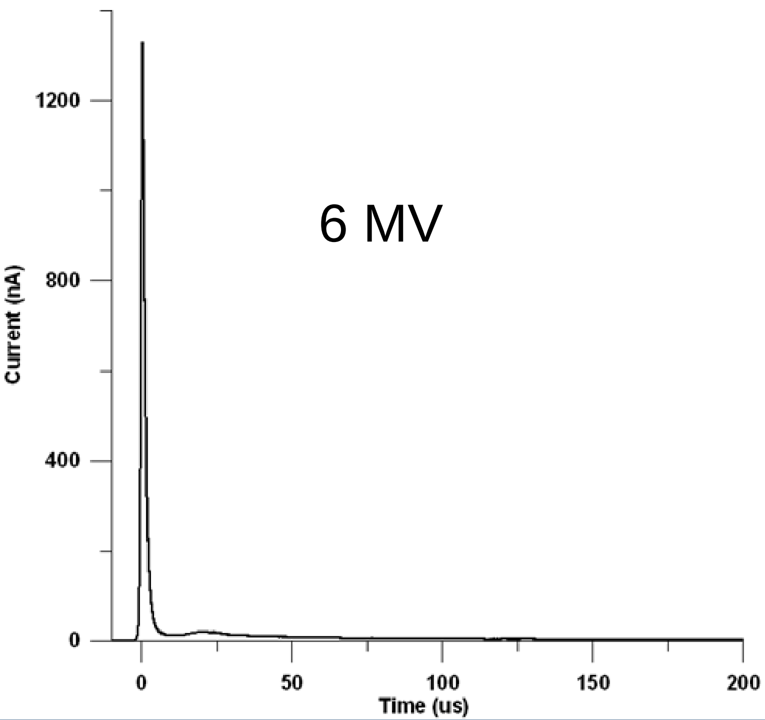
Electron radiotherapy LINAC: Varian Clinac® DHX - Dual energy

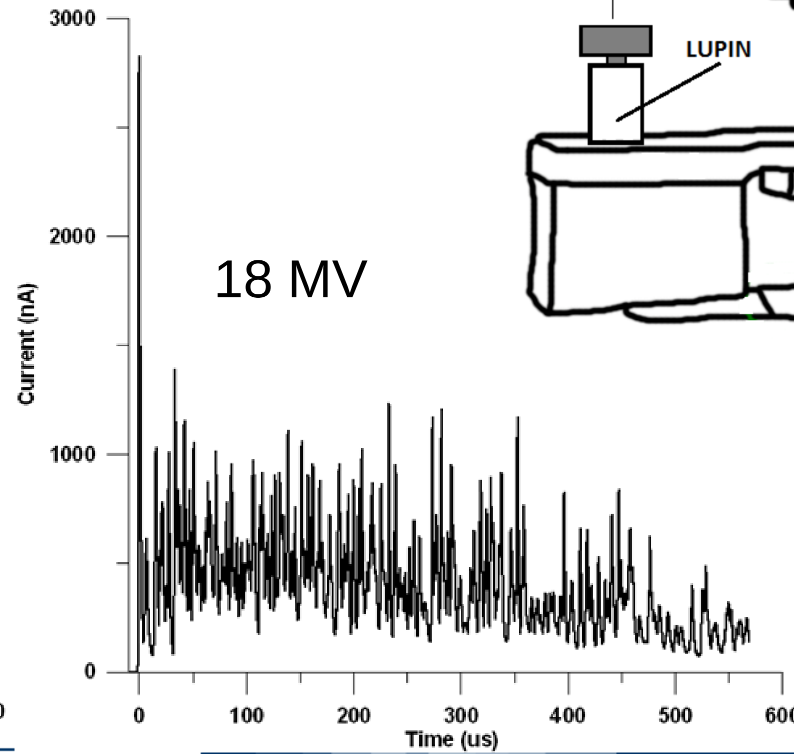
beam directed on the treatment couch, irradiation field of 5 x 5 cm^2.

The detector was placed on the therapy couch at 100 cm from the isocenter.

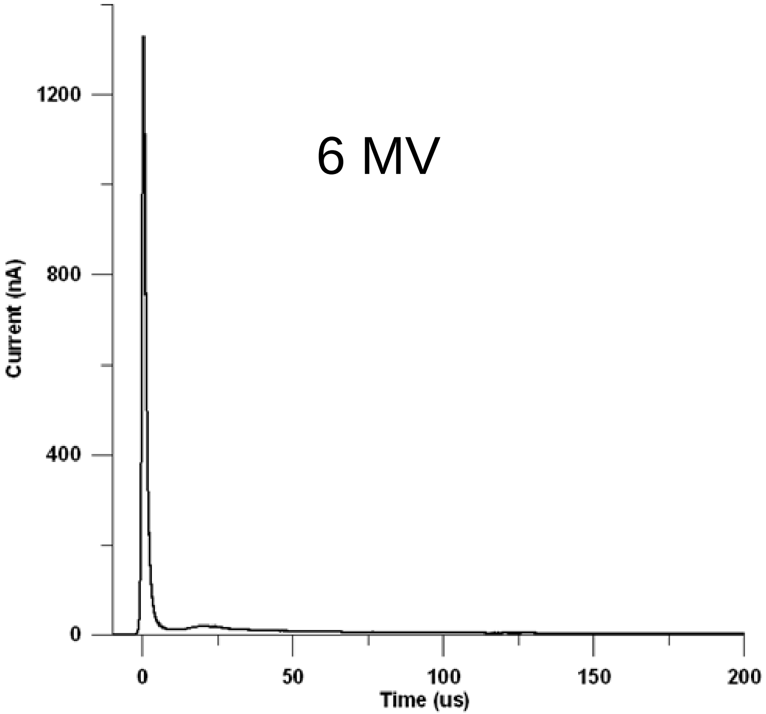
LINAC was operating 6 MV or 18 MV.

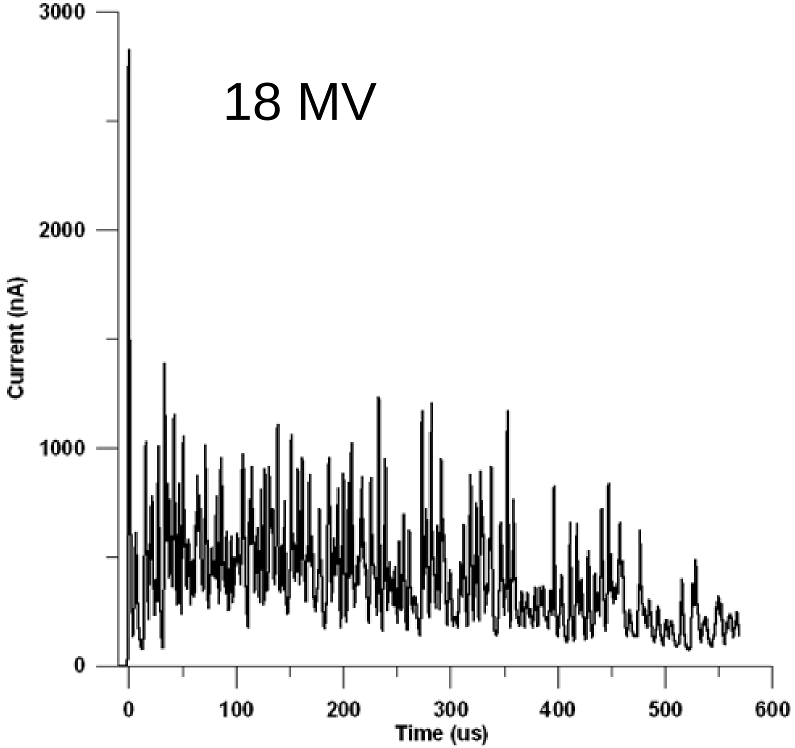






Measurement at S. Raffaele hospital





the gamma contribution is limited to the first 10 μs and can easily be rejected by excluding the first 10 μs of the signal from the calculation.

The total charge generated inside the detector is 219.7 pC, the charge generated in the first 10 μs is 6.4 pC. The difference corresponds to 890 neutrons

The reaction rate is $1.5 \cdot 10^6$ s-1

Conclusions

The characterization of the LUPIN permits to conclude that the instrument performs very well in pulsed neutron fields, when compared to classical rem counters

the detector operating principle allows rejecting efficiently the gamma component unavoidably present in neutron fields, when this component is very intense and strongly pulsed.

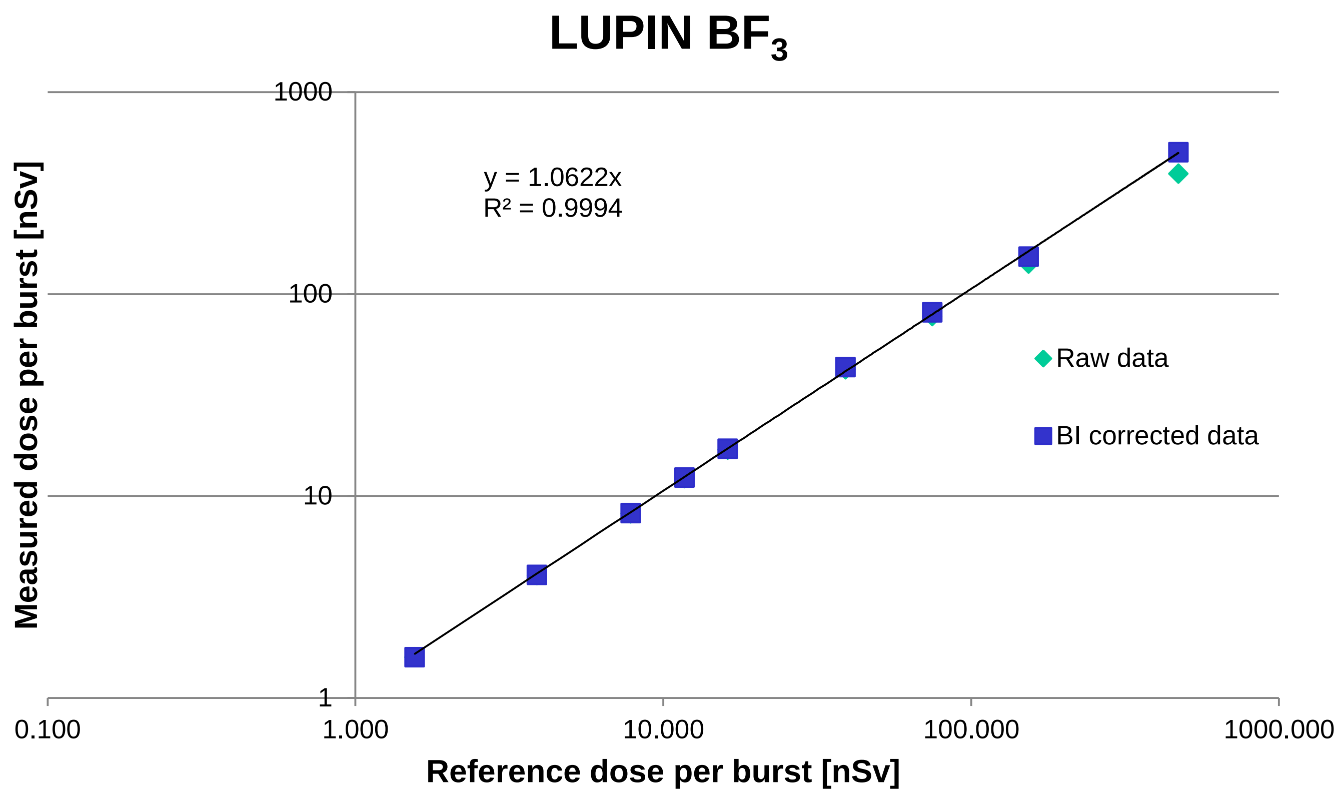
Conclusions

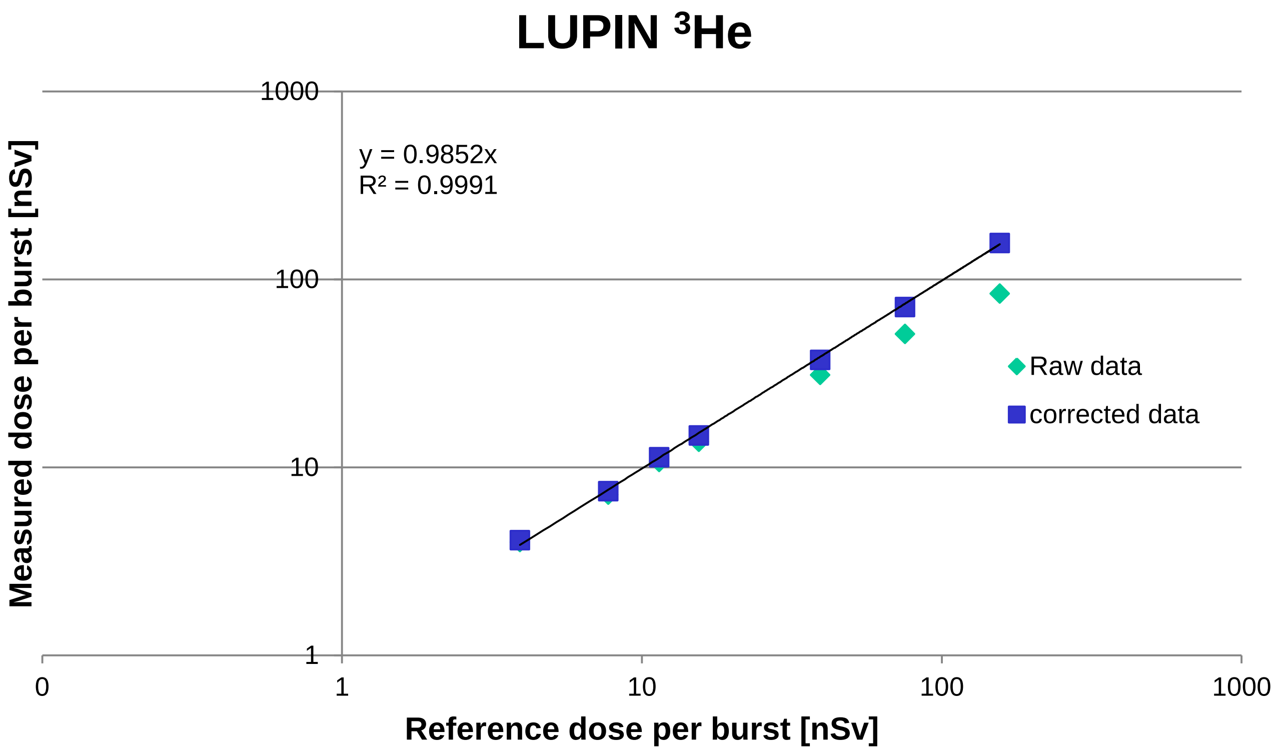
Our interest is to evaluate the instrument response in workplace pulsed neutron fileds that are present around the CNAO accelerator and in the treatements rooms.

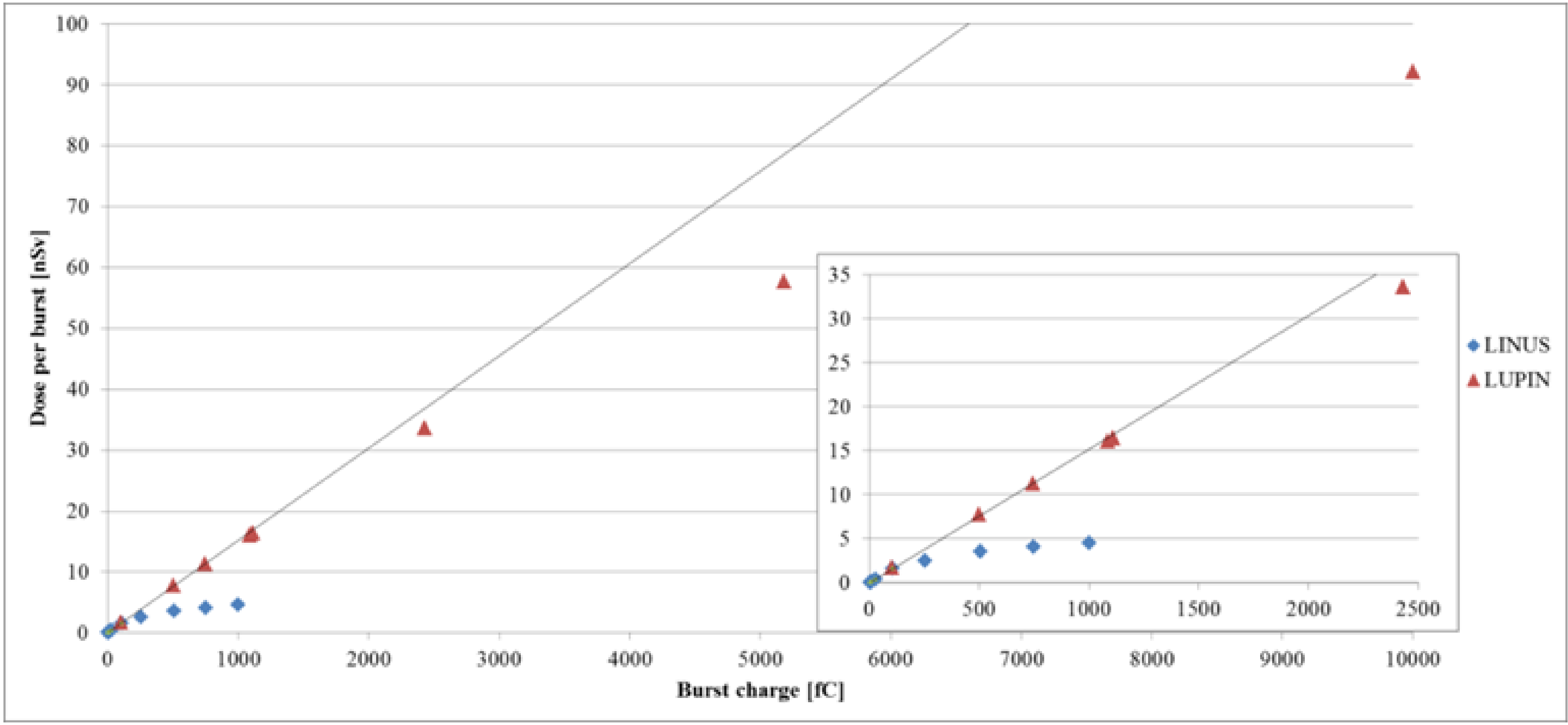
Evaluation of the undue neutron dose to the patient?

Beam loss monitors?

Thank you for your kind attention


LUPIN BF3
1000
100
10
1
0.100
1.000
10.000
100.000
1000.000
y = 1.0622x
R² = 0.9994
Raw data
BI corrected data
Measured dose per burst [nSv]
Reference dose per burst [nSv]


LUPIN ^{3}He
y = 0.9852x
R² = 0.9991
Raw data
corrected data
Measured dose per burst [nSv]
Reference dose per burst [nSv]
1000
100
10
1
0
1
10
100
1000


Dose per burst [nSv]
Burst charge [fC]
LINUS
LUPIN
0
10
20
30
40
50
60
70
80
90
100
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
0
5
10
15
20
25
30
35
0
500
1000
1500
2000
2500