

EURADOS Webinar

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General characteristics of pulsed and mixed
radiation fields

Marco Caresana

Outline

1. The problem
2. Definition pulsed fields
3. Focus on neutron pulsed fields

The problem

*“One of the outstanding trends in the present phase of research is the use of increasingly large and complex machines... A feature common to all machines giving particles of the highest energies is that their output is not continuous but occurs in **bursts** or ‘**pulses**’ separated by long intervals during which the machine gives no output... During the pulse, particles must be arriving at a mean rate of a million per minute.” (C.H. Westcott, **A study of expected loss rates in the counting of particles from pulsed sources, 1948**)*

The problem

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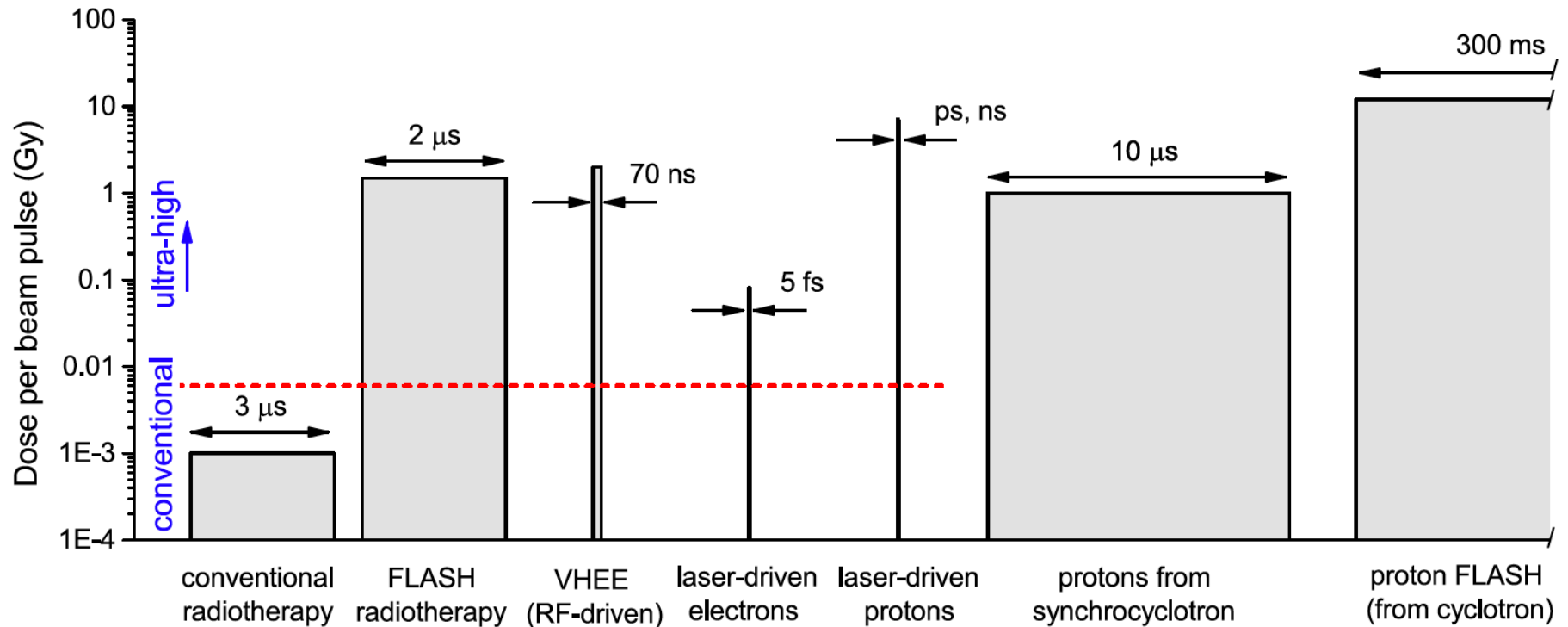
Application of detectors and instruments in pulsed neutron fields

Modern proton therapy accelerators such as synchrocyclotrons or laser-induced proton beams produce high intensity, micro- or nano-second pulses, which complicates dosimetry with active instruments. New detectors and associated electronics should be developed.

Improved secondary neutron dosimetry, mixed field dosimetry within the treatment room and inside the patient

Current dosimetric techniques are not sufficiently developed to enable full discrimination between neutron and photon components of the secondary irradiation fields. New methods should be developed which properly measure these components at the therapeutic dose-rates.

The problem

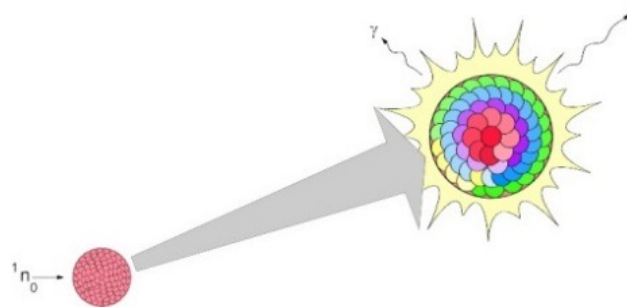


Pulsed radiation facilities

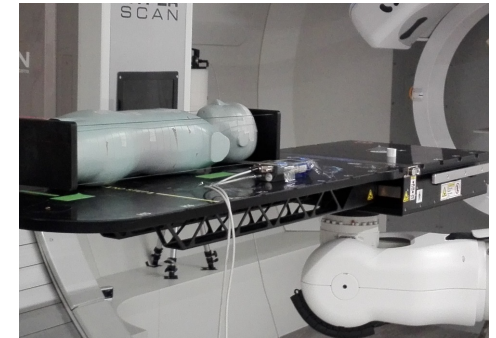
Particle accelerators



Material testing



Proton therapy synchrocyclotron

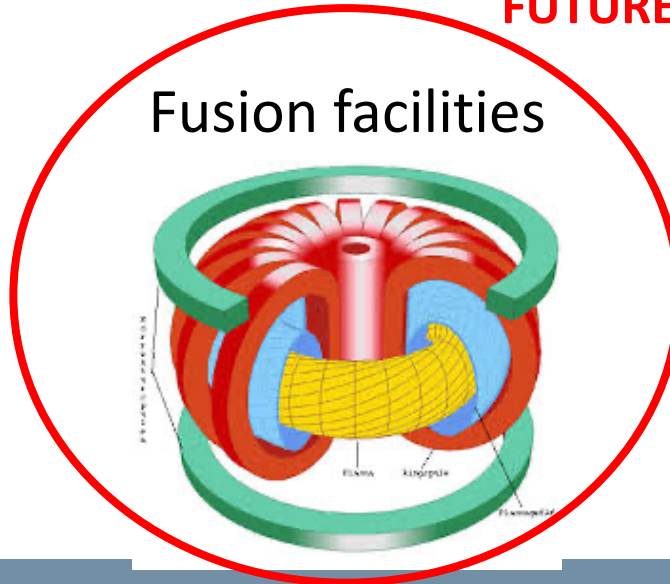


Radiation therapy

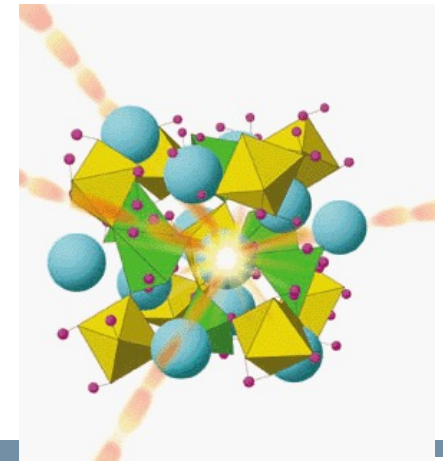


FUTURE?

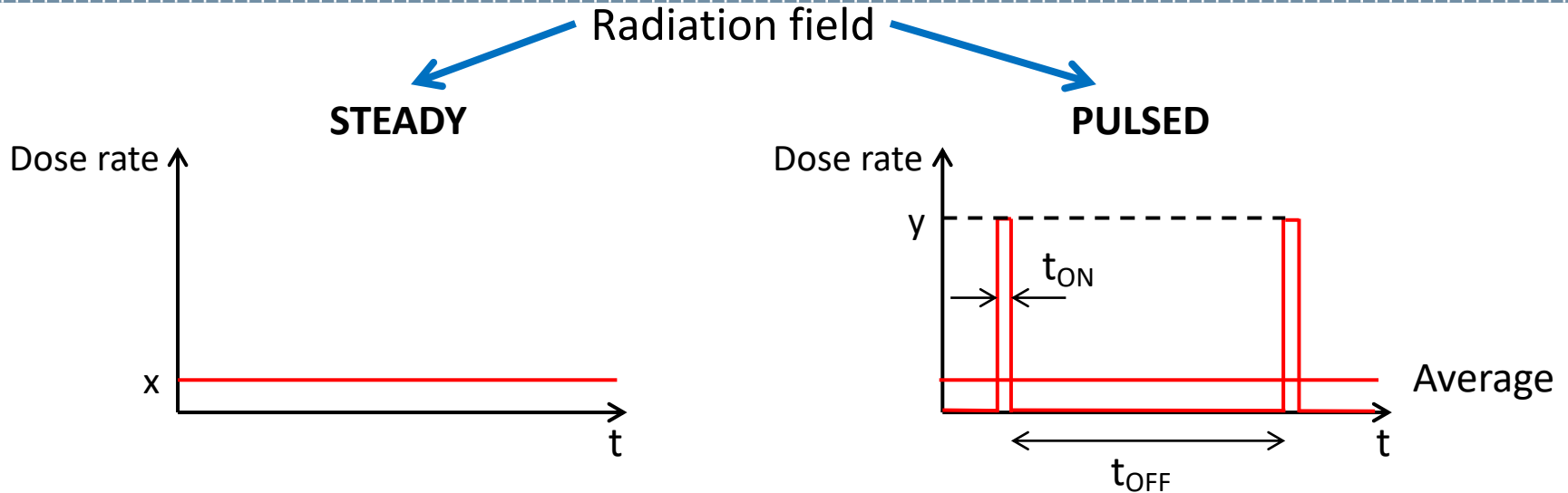
Fusion facilities



Spallation sources



Definition



Same averaged dose rate but
different instantaneous dose rates

$$x = y \cdot \frac{t_{ON}}{t_{ON} + t_{OFF}} \quad \text{DUTY FACTOR}$$

Small DUTY FACTORS ($\Rightarrow$ high instantaneous dose rates)
impose severe limitations on the survey meters to be employed

Nomenclature

Pulse: indicates the output of the shaping or counting circuit

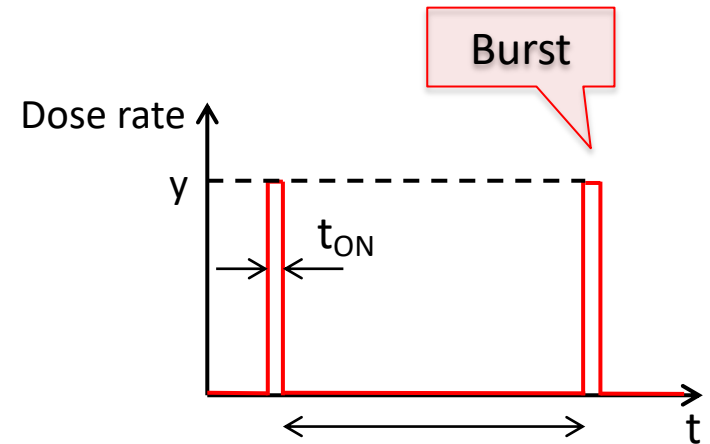
Burst: indicates a radiation pulse from an accelerator.

Burst duration: time length of the burst

Burst dose: burst intensity expressed in Sv, Gy or other suitable quantities

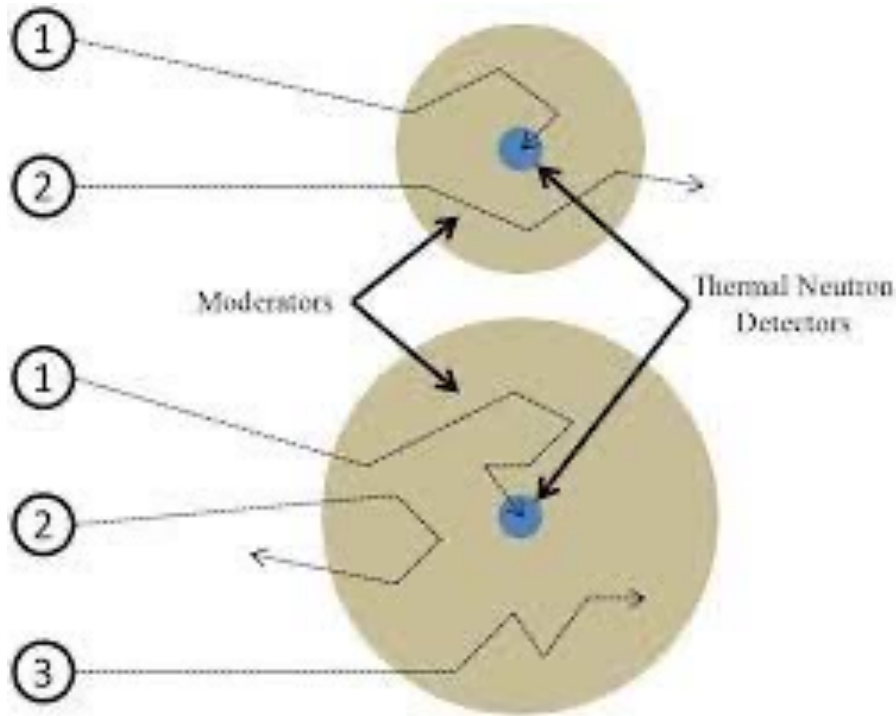
Burst dose rate: Burst dose divided by the burst duration

Repetition rate: number of burst per second



Focus on neutron fields

Pulsed fields and instrument time response



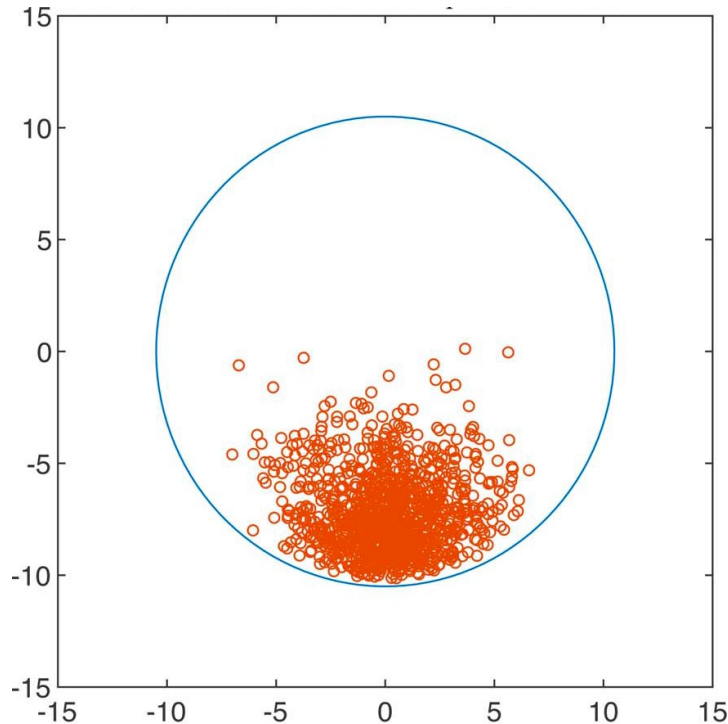
Fast neutrons thermalize in the moderator and, once thermal, takes some time to drift to the inner neutron detector.

The thermalization time is very fast (ns) while the drift time is longer (tens or hundreds μs) Thus, the thermalization and drift time (TDT) spreads out the time of arrival of neutrons to the thermal neutron detector.

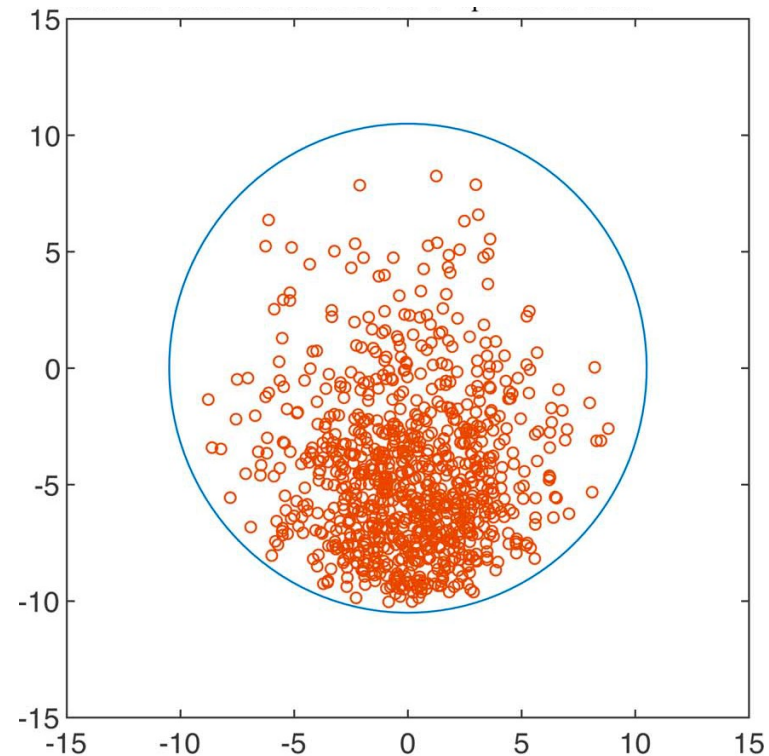
Focus on neutron fields

Pulsed fields and instrument time response

Neutron thermalization position for a 8'' sphere at different neutron energies

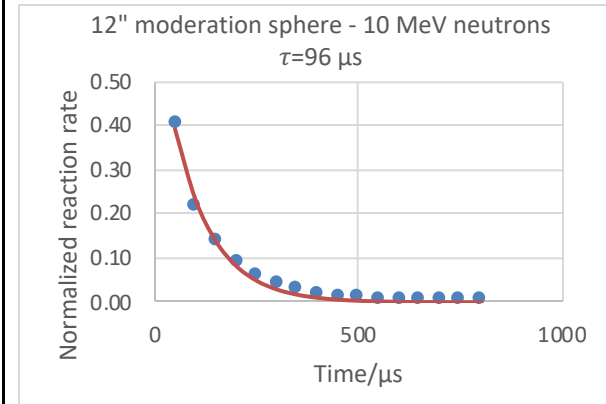
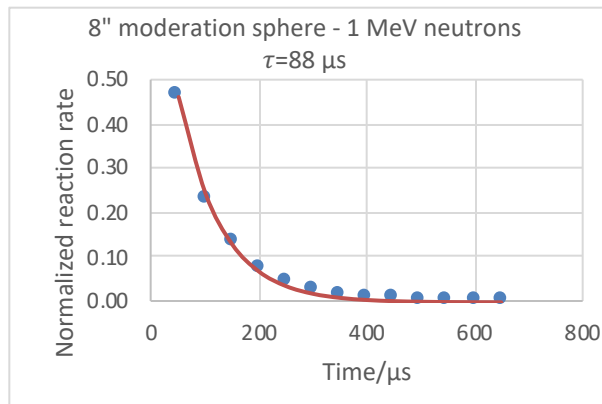
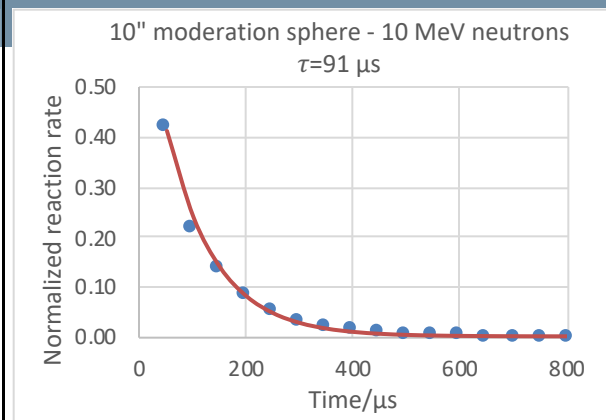
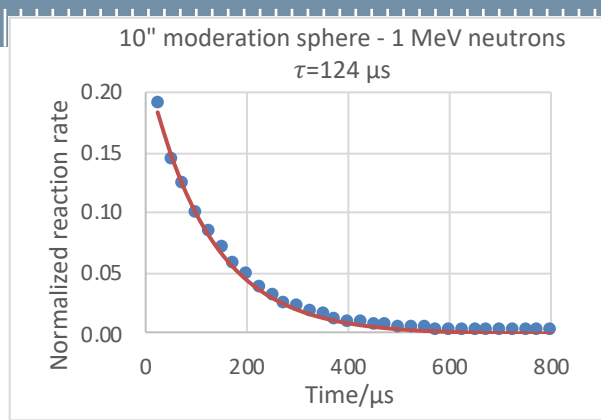


(a) 100 keV



(b) 1 MeV

Time response of moderation spheres



The TDT depends on the neutron energy and on the sphere dimension and can be modelled by a decreasing exponential (red line) with a time constant τ of several tens/hundred μs

Independently on the original time duration of the burst (fs to μs), the neutron time of arrival is defined by the TDT.

Simulation with MCNP6.2, assuming an instantaneous irradiation and scoring the reaction rate in the inner detector.

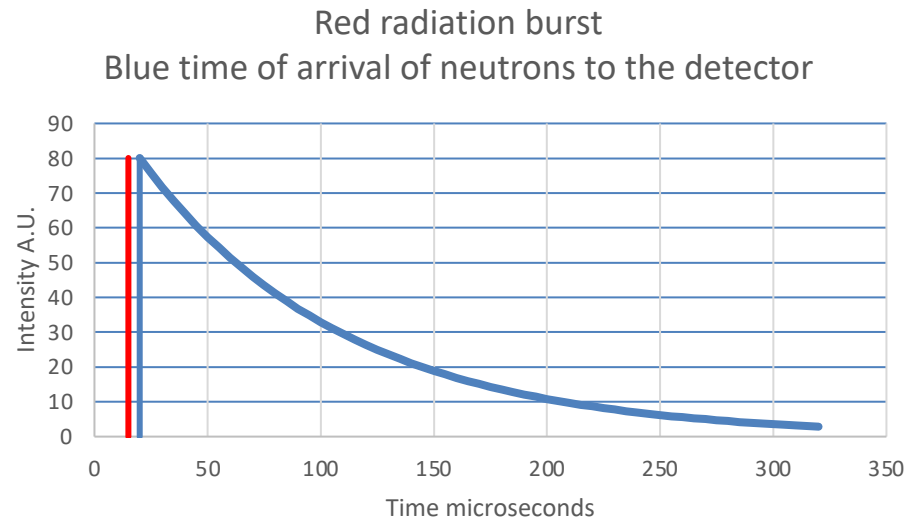
Time response of moderation spheres

Sphere (inches)	τ / μ s @ 1MeV	τ / μ s@ 10MeV
2	11	9
3	24	22
5	51	50
8	88	78
10	123	91
12	154	96

Consequences of the TDT

1) The definition of pulsed fields depends on the TDT

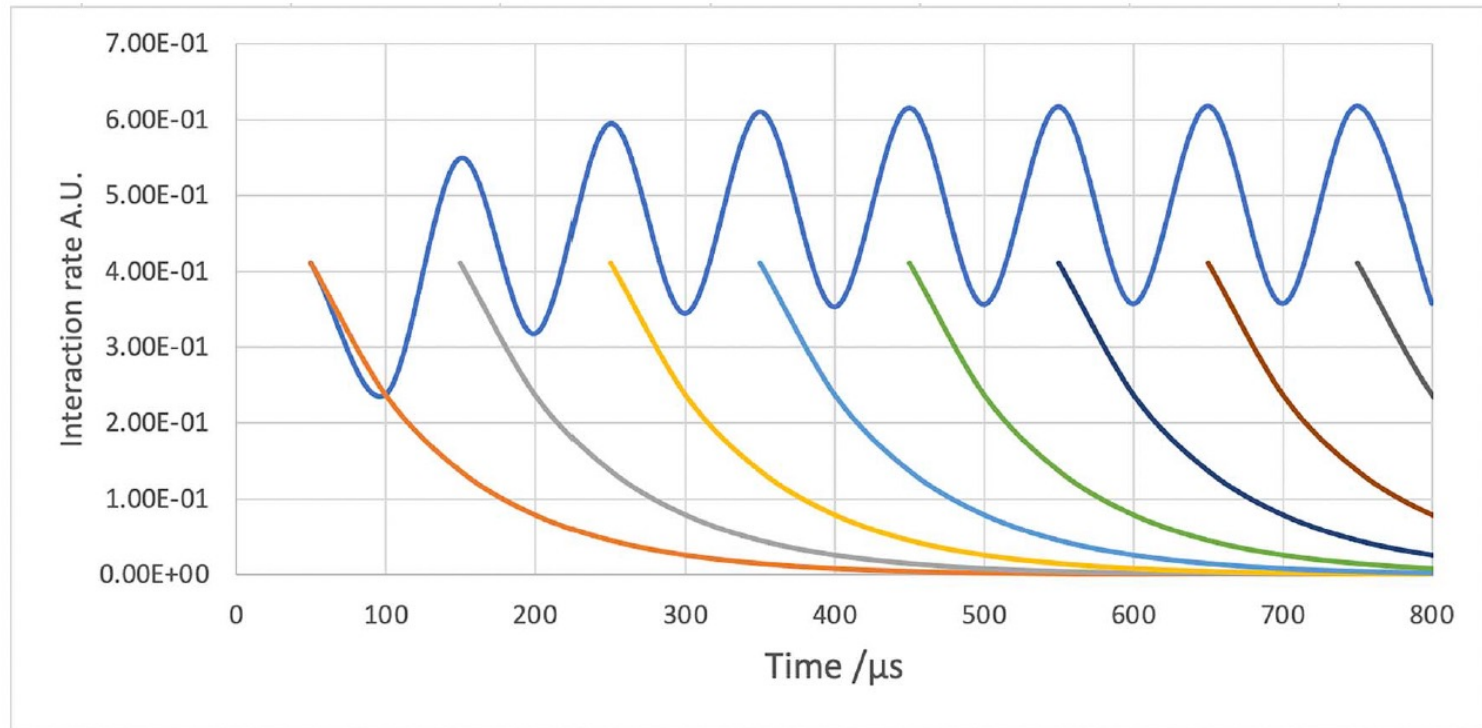
$$\tau = 90 \mu\text{s}$$



Burst duration $\ll \tau$

Consequences of the TDT

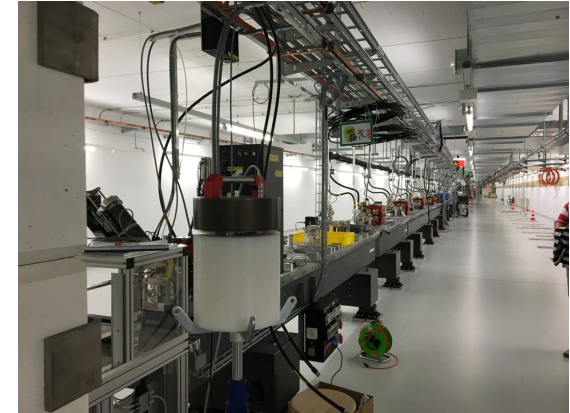
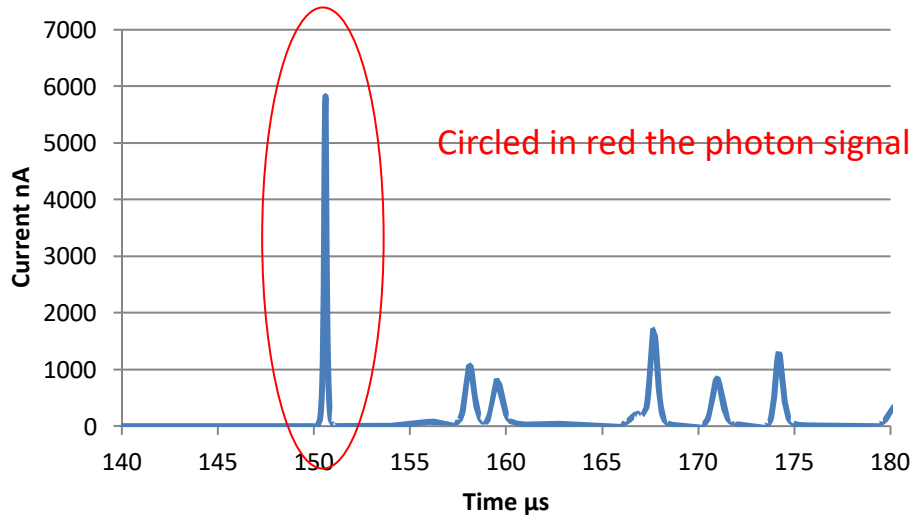
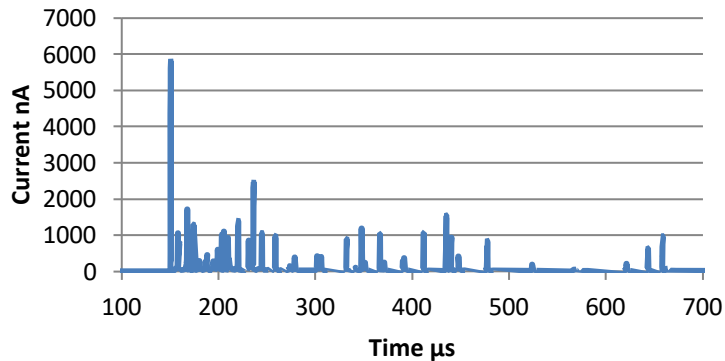
2) The definition of pulsed fields depends on the repetition rate



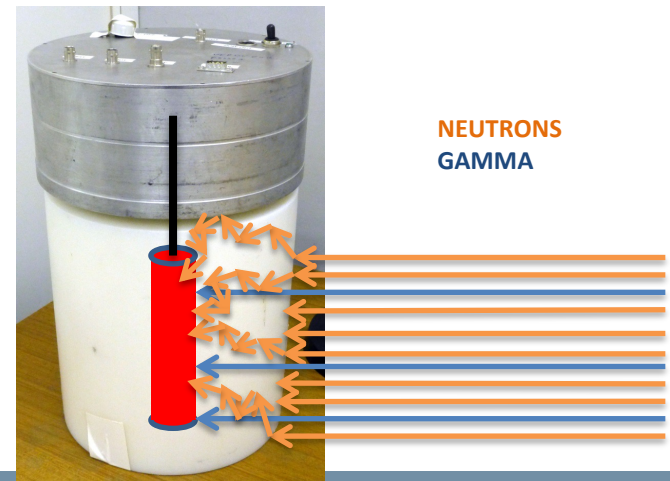
Repetition rate 10 kHz

Consequences of the TDT

3) n - γ discrimination on time basis



Neutrons are delayed respect to the photon signal



Conclusions

Main remarks

1. In pulsed field standard rem counters suffer of dead time losses
2. A neutron field is considered pulsed if the pulse duration $<$ TDT (Thermalization and Drift Time, hundreds of μ s)
3. Gamma discrimination can be done on time discrimination.
4. **At present a reference facility for pulsed neutrons is not available. A metrological effort to fill this gap is needed.**

Thanks for your attention