Instrument intercomparison in the stray radiation field around the CERN proton synchrotron

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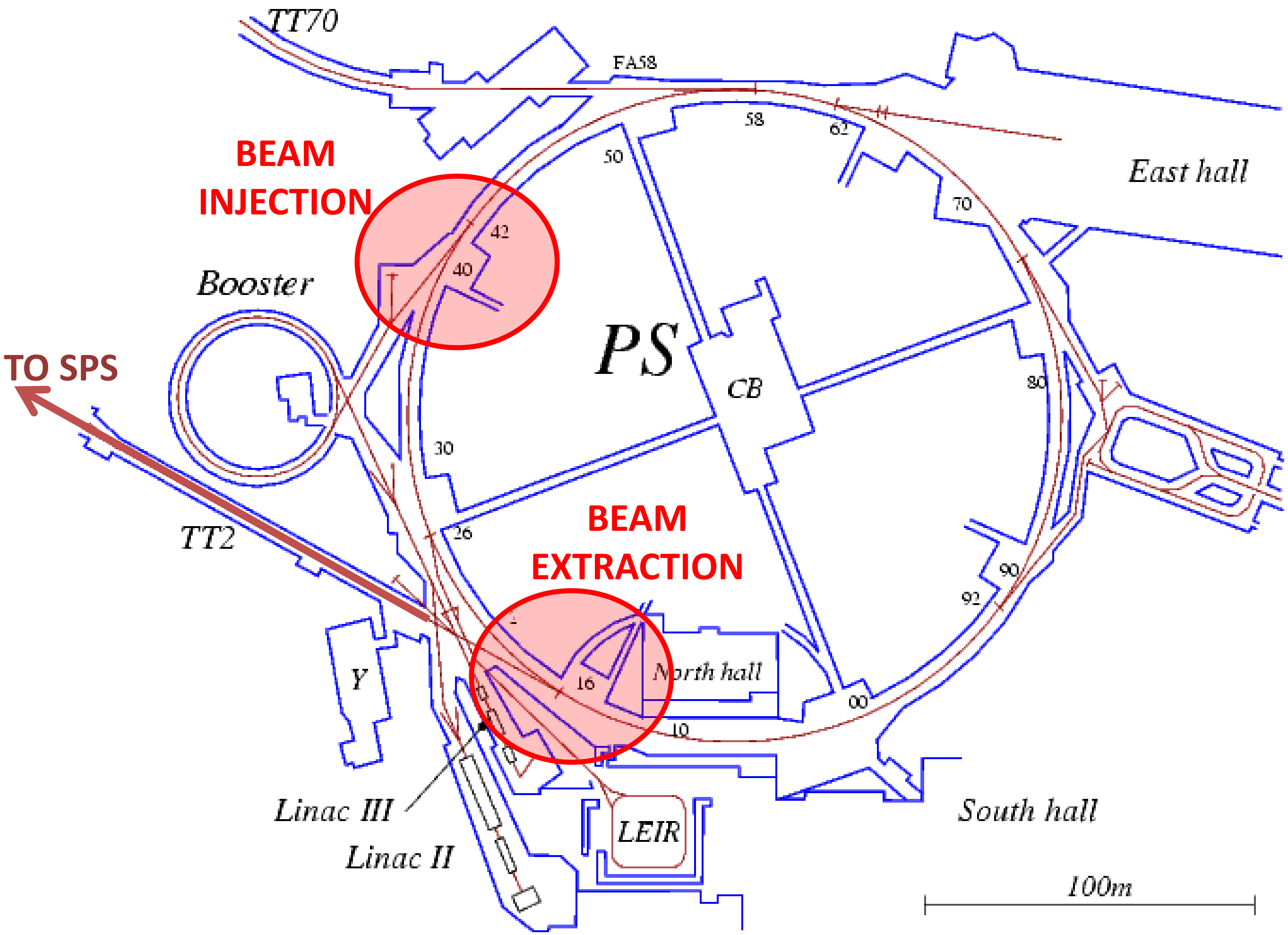
3rd June 2013, Aix-en-Provence

12th NEUtron and ion DOSimetry symposium

THE PS COMPLEX



Beam accelerated from 1.4 GeV to 26 GeV

100 combined-function magnets interleaved by 100 straight sections (SS)

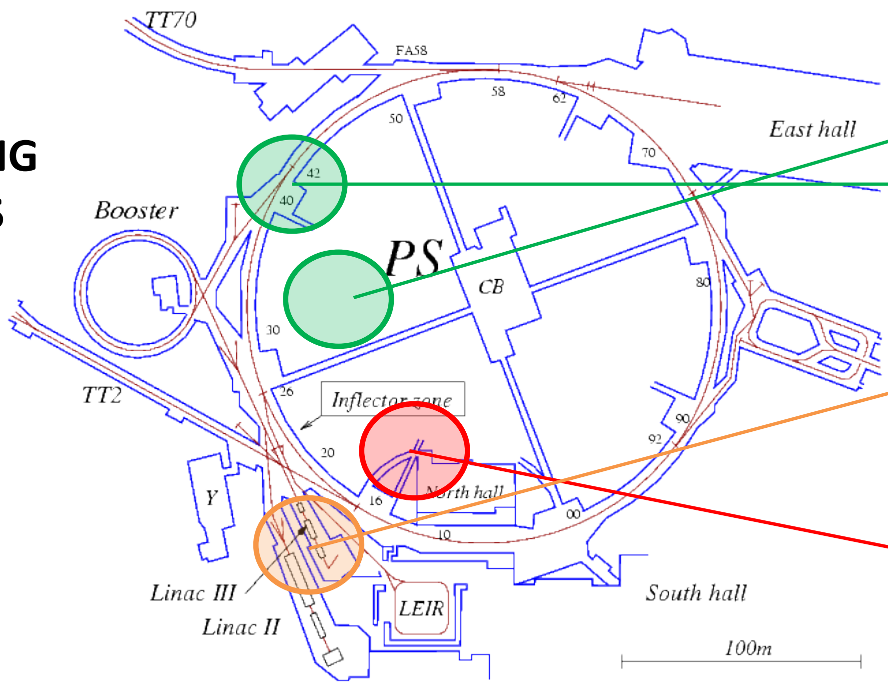
Major losses due to beam injection and extraction

THE MEASUREMENT CAMPAIGN

Aim of the measurements: evaluate the difference in the responses of 6 active neutron detectors in different stray field conditions.

Focus: difference in the responses due to **dead time losses**.

4 MEASURING POSITIONS



Non-pulsed losses (200-300 μs), smoothed by 6-10 meters of ground shield

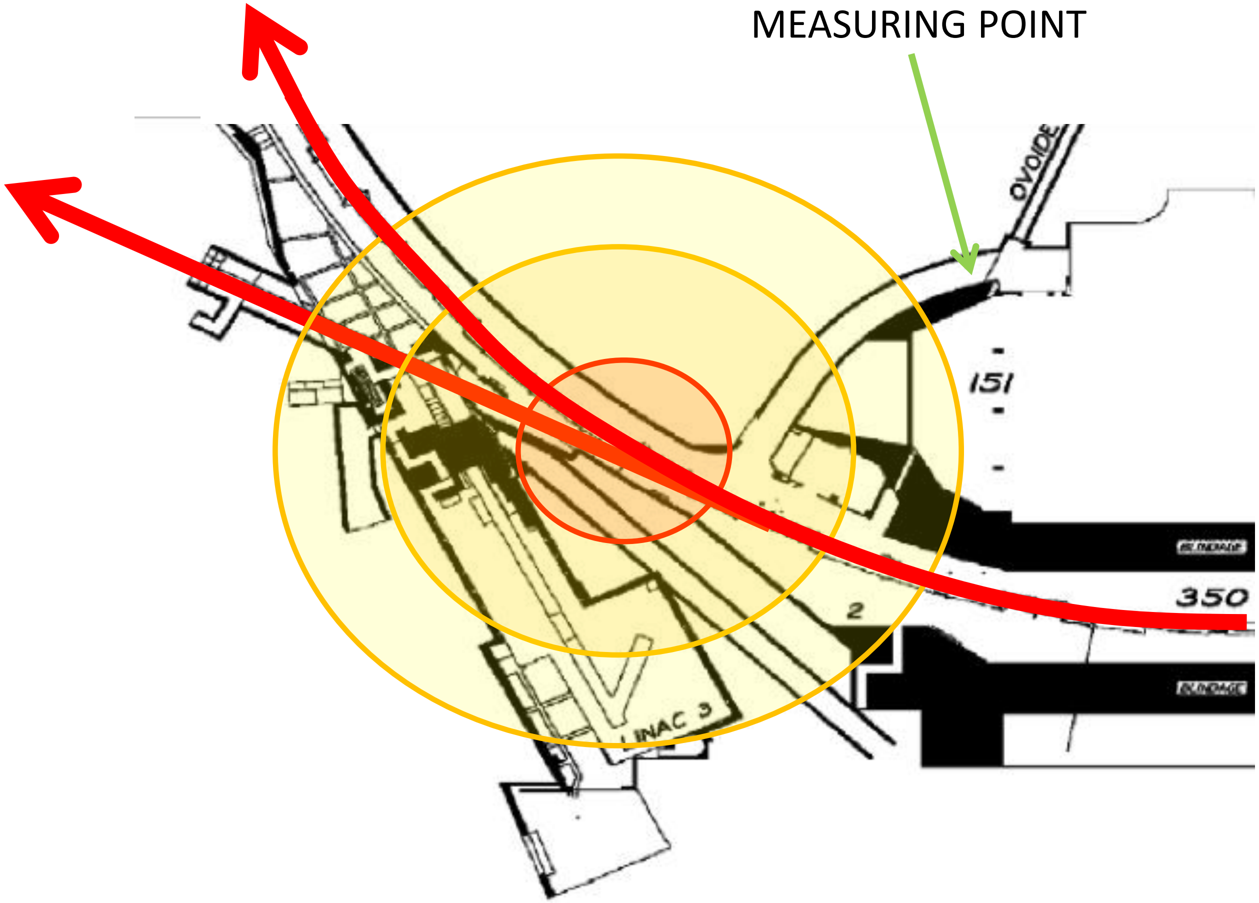
Pulsed losses, low intensity (quite far from the extraction septum)

Pulsed, intense losses (access tunnel to the extraction septum, limited shielding)

Several measurements carried out in 4 the positions
Systematic intercomparison at the **access tunnel of SS16**

THE INTERCOMPARISON

MEASURING POINT



Beam extracted with Continuous Transfer (CT) technique

1% lost beam in the area: losses due to particles scattered by the electrostatic septum used to slice the beam

Beam extracted in 5 turns: each turn lasts 2.2 μs => length of the losses: **11 μs**

6 detectors installed and rotated in reference positions at the beginning of the access tunnel

THE DETECTORS (I)

3 classes of instruments employed:

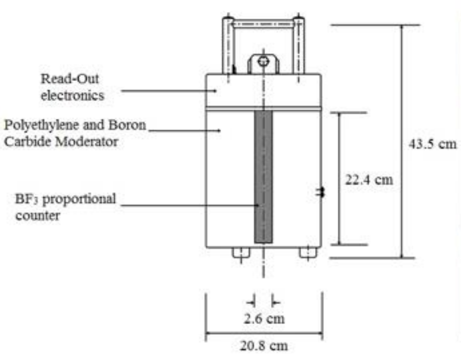
I) Conventional and extended range rem counters

Used for RP routine measurements

II) Ionization chambers

Employed in ***RAMSES*** *(CERN RAdiation Monitoring System for the Environment and Safety)*

III) Prototype extended range rem counter (**LUPIN**)



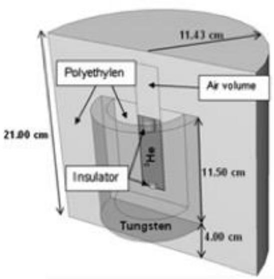
Thermo BIOREM (BF_3)

Conventional rem counter

Good sensitivity up to 20 MeV

CERN LINUS (^3He)

The original extended range rem counter

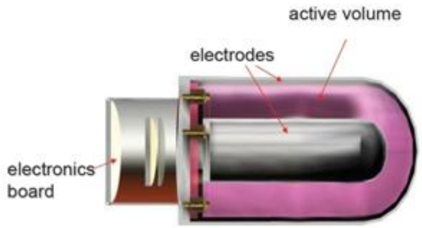


Thermo Wendi-2 (^3He)

Extended range rem counter

Good sensitivity up to 5 GeV

THE DETECTORS (II)



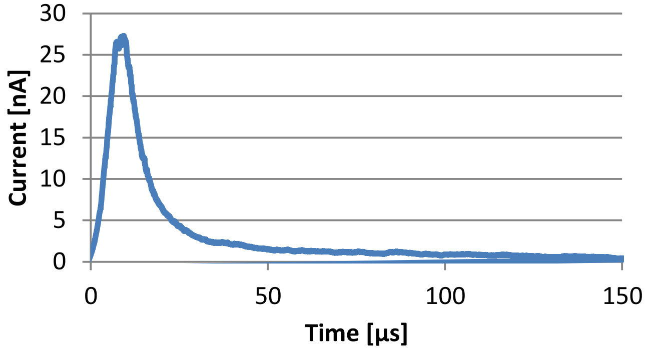
Pressurized (20 atm) Centronic ionization chambers (Ar and H)

Good sensitivity up to 20 MeV

LUPIN prototype (BF_3)

Extended range rem counter

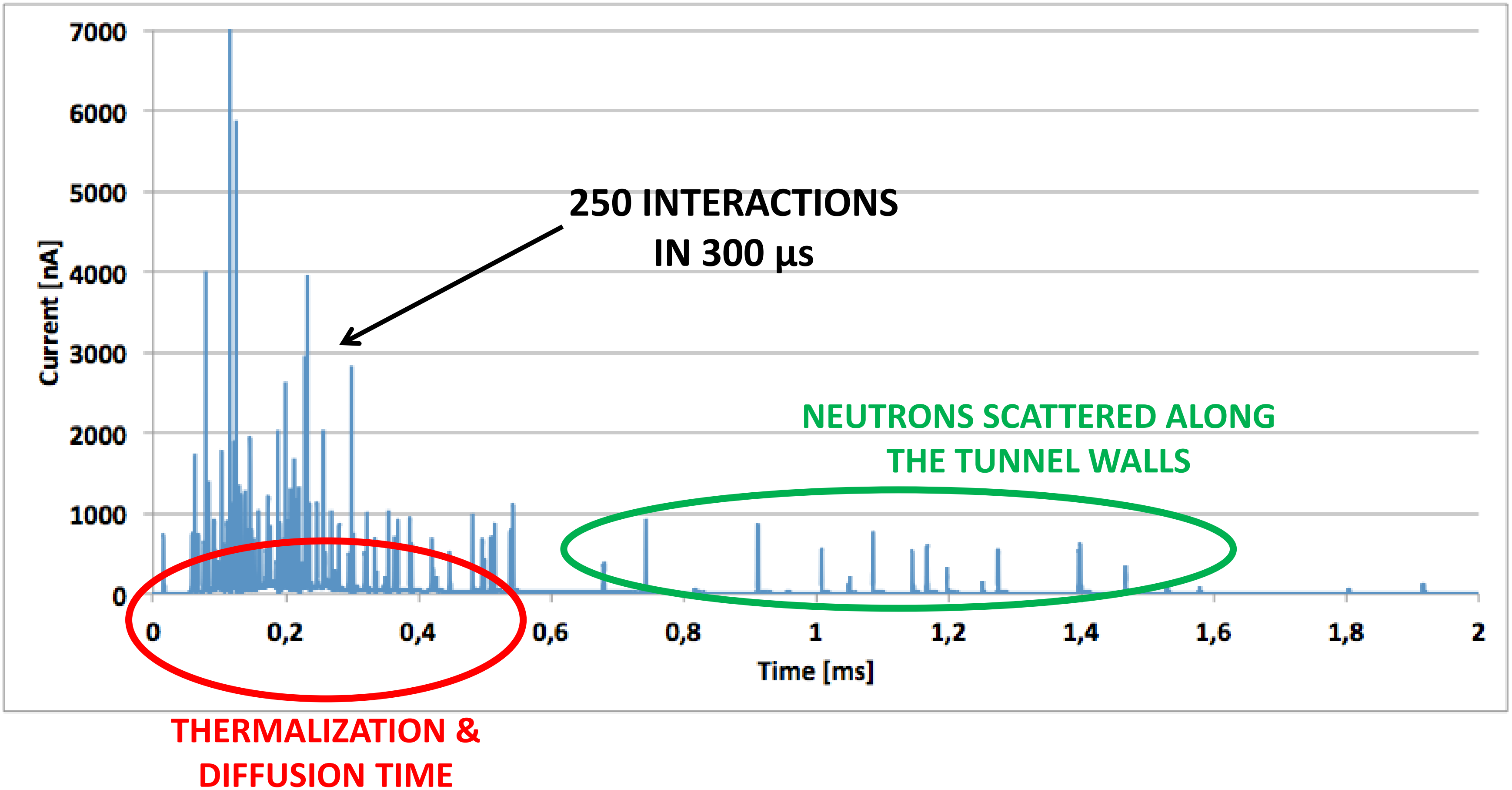
Specifically conceived to work in pulsed neutron fields



It uses the integration of the total electric charge as a measure of the number of neutron interactions in the gas

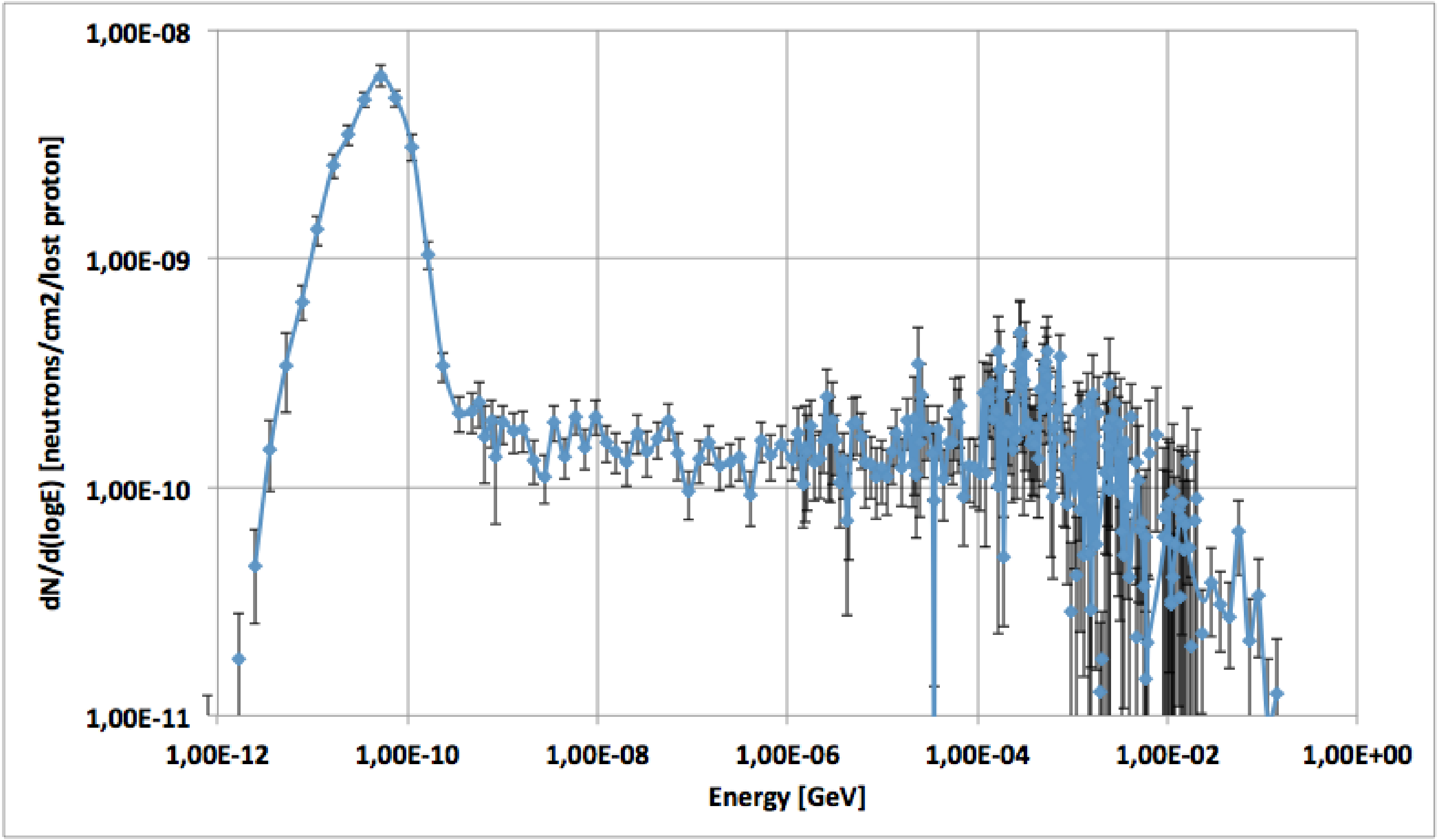
THE STRAY FIELD

Example of signal acquired with the LUPIN in one of the reference positions



THE NEUTRON SPECTRUM

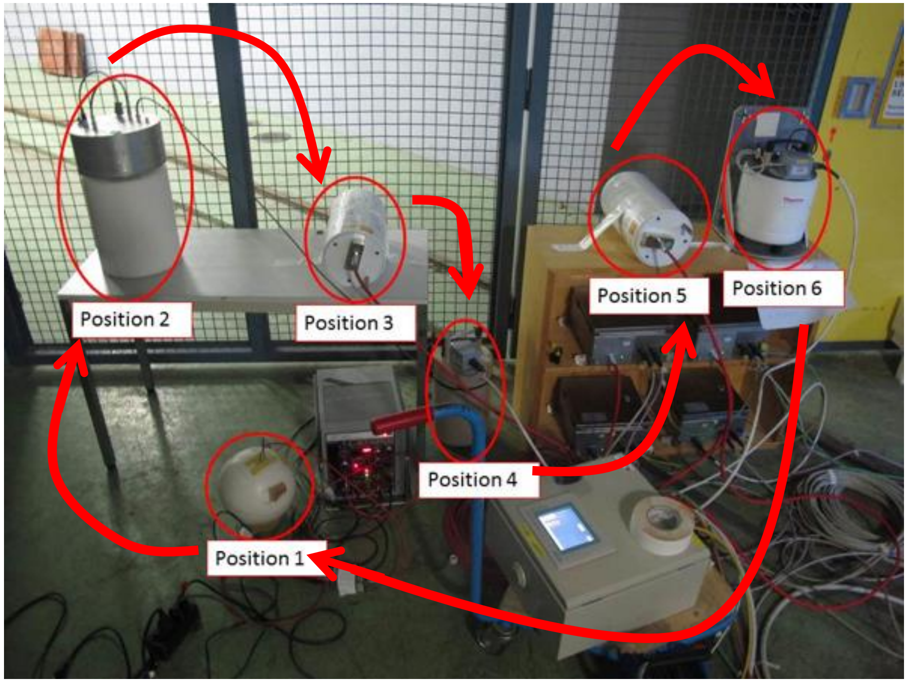
Expected neutron spectrum at the beginning of the access tunnel (FLUKA simulations)



Expected neutron H*(10) rate = 95% of the total H*(10) rate

Max neutron energy < 20 MeV => Same response for conventional and extended range RC

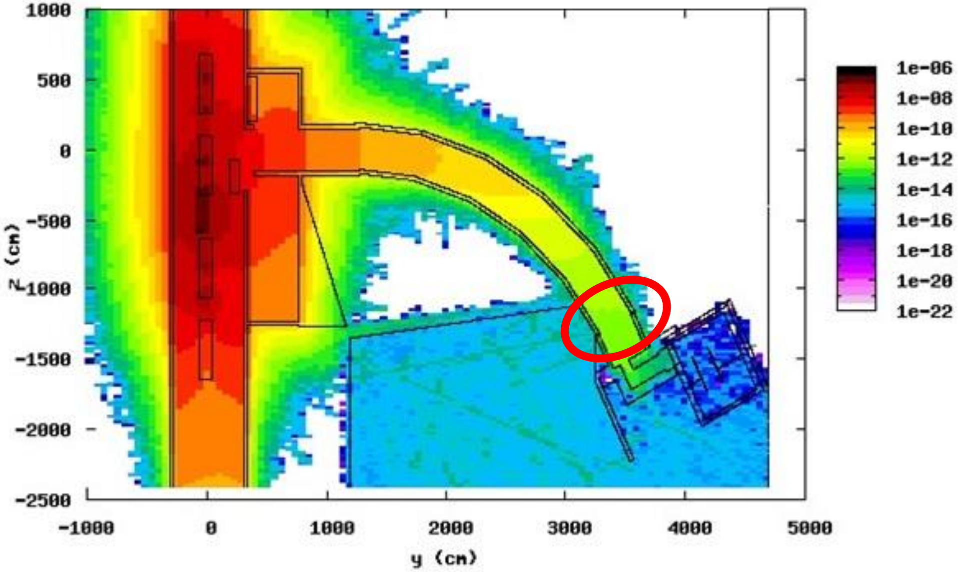
THE COMPARISON PROCESS



Detectors turned in the 6 reference positions (high H*(10) rate gradient in the area)

Comparison of the integrated H*(10) (30 minutes) in each positions

EXPECTED H*(10) [μSv/lost primary]



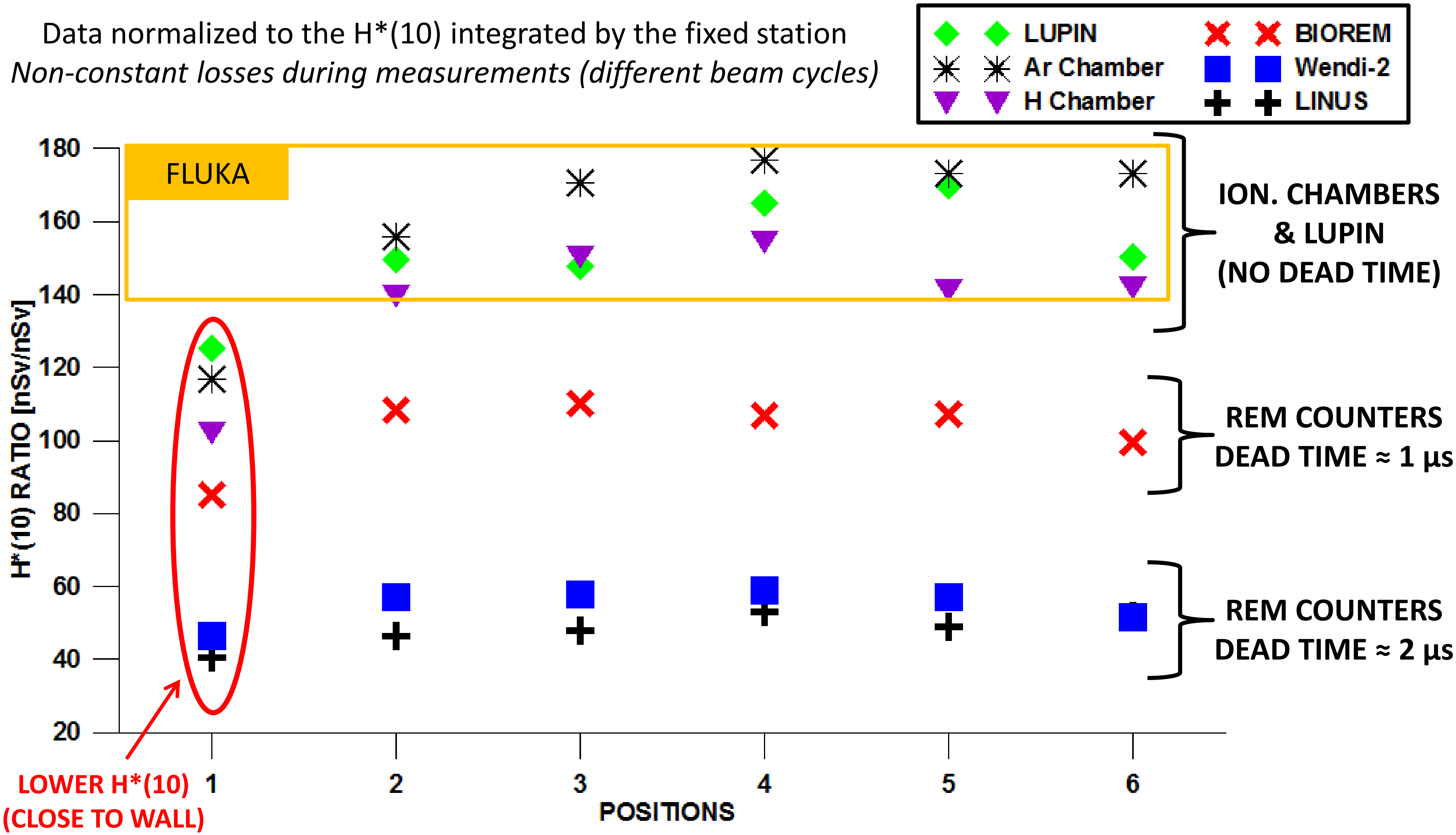
Normalization of the H*(10) to:

I) Integrated proton fluence in the PS

II) H*(10) integrated by a fixed monitoring station installed in the area

THE RESULTS

Data normalized to the H*(10) integrated by the fixed station
Non-constant losses during measurements (different beam cycles)



REMARKS

1) Ionization chambers & LUPIN (no dead time)

Results compatible within the range of uncertainty and with FLUKA simulations.

2) BIOREM (dead time ≈ 1 µs)

30% underestimation if compared to the average results of group 1 and FLUKA

1) Wendi-2 & LINUS (dead time ≈ 2 µs)

60% underestimation if compared to the average results of group 1 and FLUKA

From the dead time correction formula: $$n = \frac{m}{1 - m\tau}$$

- n = expected counting rate ≈ $8.3 \cdot 10^{5}\ s^{-1}$ (from LUPIN signal)
- m = measured counting rate
- τ = dead time ≈ 1 or $2 \cdot 10^{-6}$ s

Expected underestimation due to the dead time effects:

45% for BIOREM; 65% for Wendi-2 & LINUS

CONCLUSIONS

LUPIN and IONIZATION CHAMBERS (H/Ar)

No underestimation of the expected H*(10)

Can be used in every working conditions, even with strongly pulsed fields.
Employed at CERN in all critical positions (pulsed, high energy losses).

LUPIN has the advantage of being portable (rem counter) and (unlike the ionization chambers) does not need the setting of a different calibration factor in each measuring position as a function of the neutron spectrum.

CONVENTIONAL REM COUNTERS (BIOREM, LINUS, Wendi-2)

Huge underestimations due to dead time

Real underestimation slightly lower than what calculated with the DT correction formula (stray field partly scattered)
Used at CERN for environmental measurements or outside accelerator shieldings where radiation field is not strongly pulsed.

THANK YOU FOR YOUR ATTENTION

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DEAD TIME CALCULATIONS

To derive the dead time for each detector the "two-source method" **[Knoll]** was applied to the data acquired in a dedicated experiment.

Method based on observing the counting rate from two sources individually and in combination. Applied by taking three different values of expected and measured counting rates, i.e. EXP_1, EXP_2, EXP_{12} and $MEAS_1$, $MEAS_2$, $MEAS_{12}$, where $EXP_{12} = EXP_1 + EXP_2$, and by evaluating them individually and in combination.

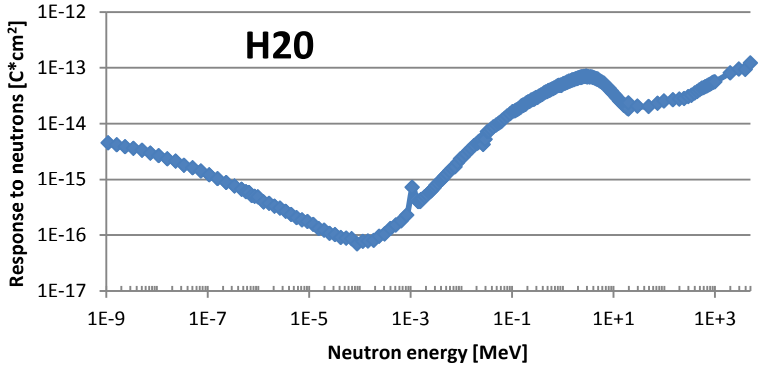
The dead time could be calculated from the discrepancy between the measured rate $MEAS_{12}$ and the sum of $MEAS_1 + MEAS_2$.

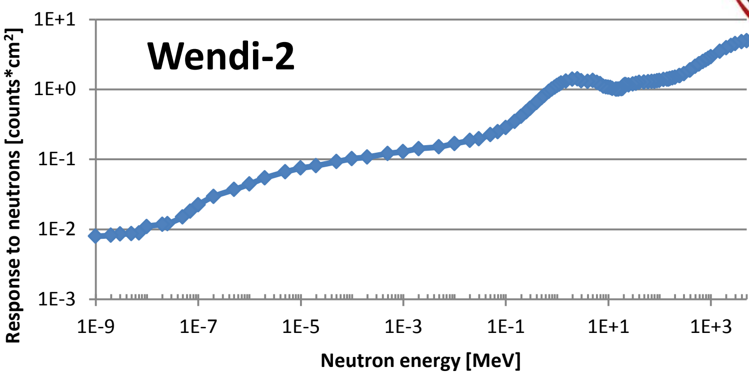
(1.02 ± 0.10) μs for the BIOREM

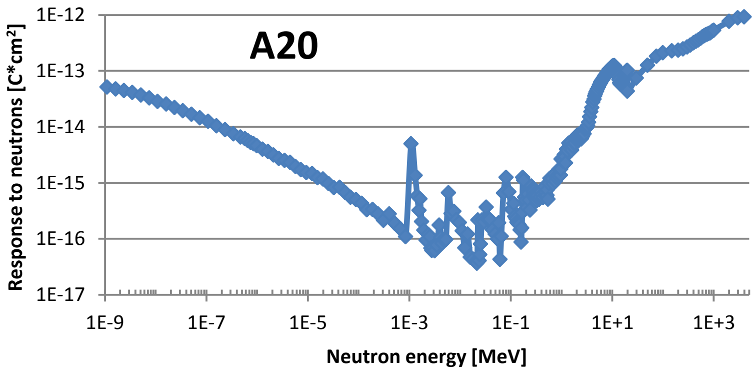
(very close to the TTL pulse width declared by the manufacturer, 1.2 μs **[Thermo]**)

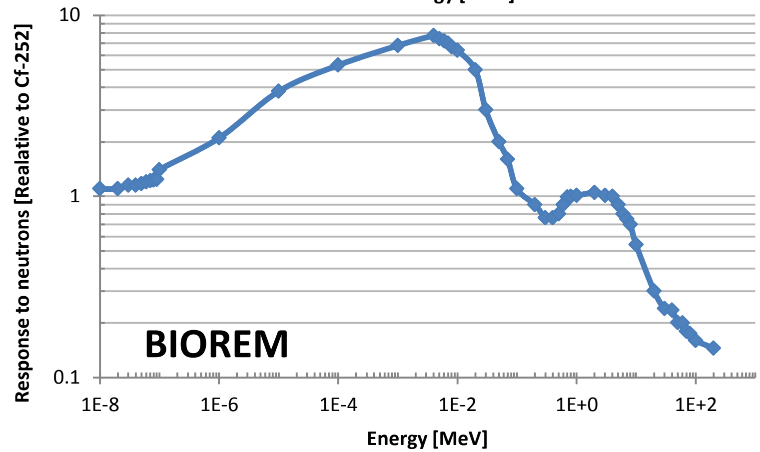
(1.74 ± 0.17) μs for the Wendi-2

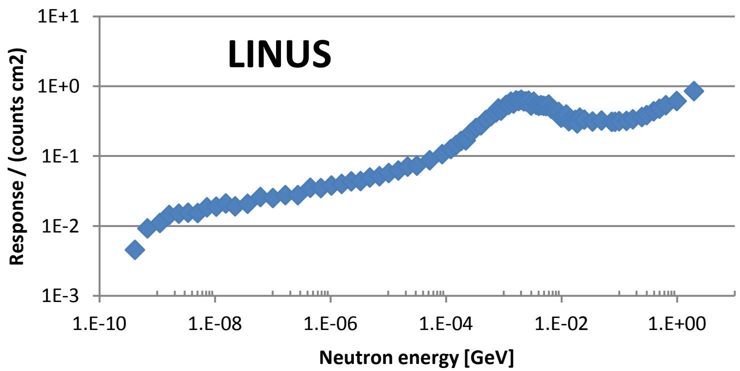
RESPONSE FUNCTIONS

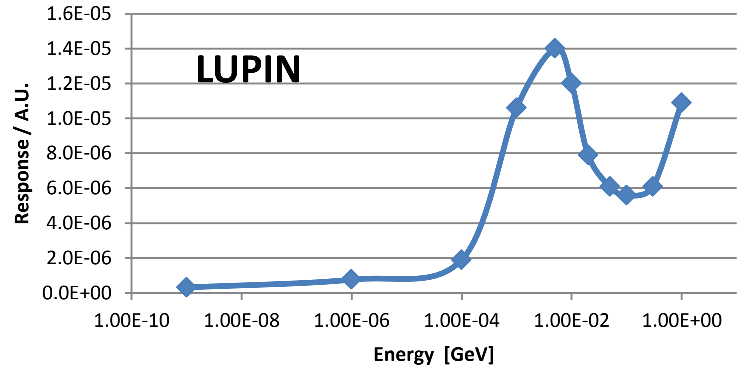












NORMALIZATION TO PS FLUENCE

Data normalized to integrated proton fluence in the PS