Imitation of the inverse beta-decay reaction in the neutrino scintillator detectors with the controllable UV/visible LED flasher

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LNGS Seminars

07.06.2018

Motivation

1) Imitation of the inverse beta-decay reaction and other processes in the organic liquid scintillator detectors

2) Calibration at high energies (10-50 MeV)

Two complementary approaches to simulation

1) Computer simulation (Monte Carlo and so on)

2) Simulation events inside the detector with a UV sources

The second approach necessarily requires three ingredients:
a) nanosecond LED driver (flasher)
b) monitoring line to control the energy of the simulated event
c) special diffuser that increases the isotropy of the outgoing UV radiation

Historical overview

1985

Original idea: the electrical scheme of nanosecond LED flasher

Kapustinsky's driver: Kapustinsky J S *et al.* 1985 *Nucl. Instrum. Meth.* A 241 612–13

1990s, 2000s

Some implementations (not all!):

> 1997 the Baikal experiment NT-200

Belolaptikov I A *et al.* 1997 *Astropart. Phys.* 7 263–82

> 2001 the ANTARES underwater neutrino telescope

McMillan J E *et al.* 2001 *Proc. of 27th ICRC* (Hamburg) p 1287

2006

Upgrade the driver for using with ultraviolet and blue LEDs:

Lubsandorzhiev B K and Vyatchin Y E 2006 *JINST* 1 T06001 (*Preprint* arXiv:physics/0410281v1)

2015, 2016

The first prototypes for online calibration of neutrino liquid scintillator detectors at energies above 10 MeV:

Chepurnov A S, Gromov M B and Shamarin A F 2016 J. Phys.: Conf. Series 675 012008

Chepurnov A S, Gromov M B *et al.* 2017 J. Phys.: Conf. Series 798 012118

2017

The UV LED calibration system for Borexino

It has not been applied because the calibration campaign is postponed for indefinite period

Main ideas

- Mimic of real events in any neutrino liquid scintillator detector with a controllable UV double-LEDs flasher

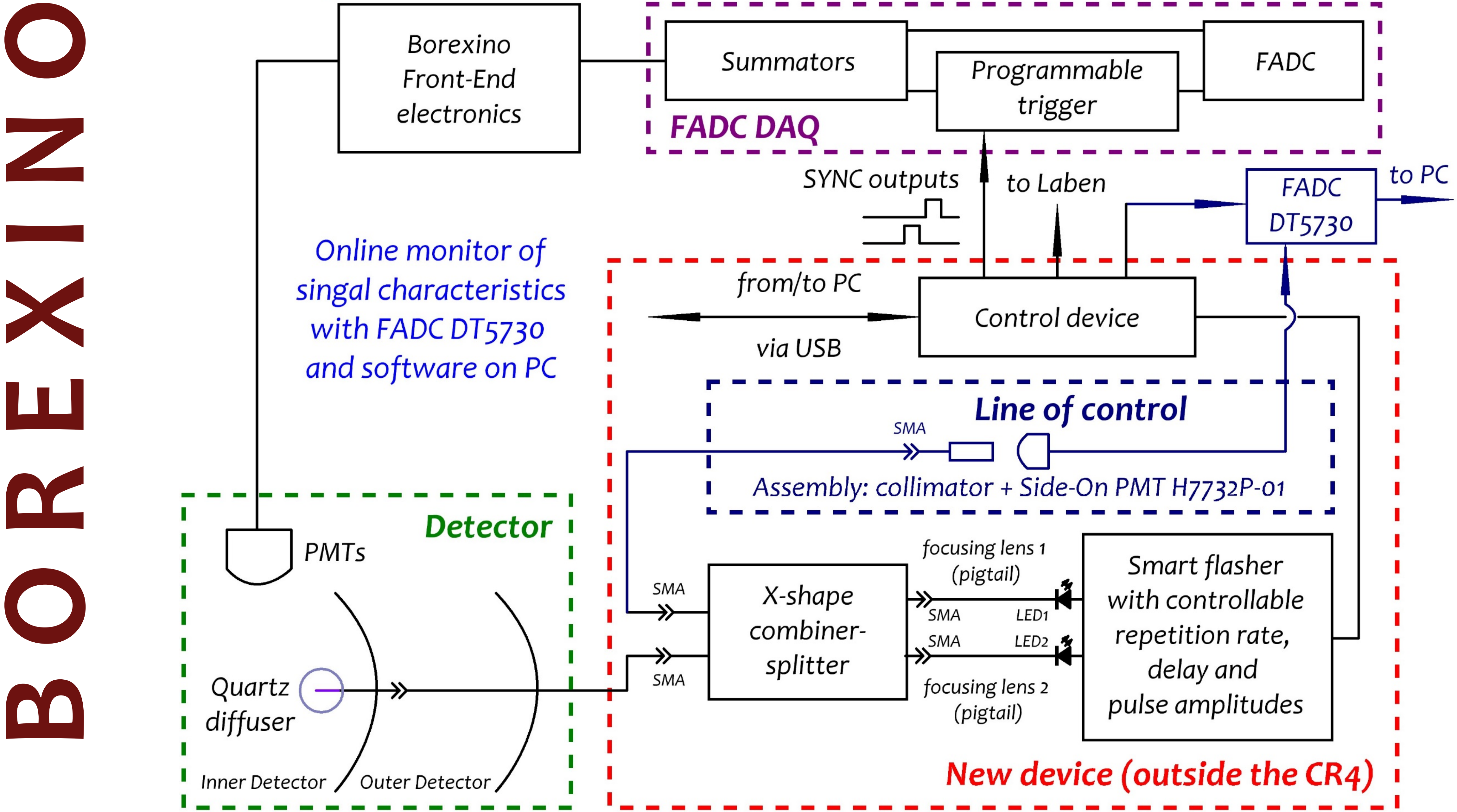
- The energy of the imitated signal is directly proportional to the number of emitted photons but depends on the source position

Foundations of the conception

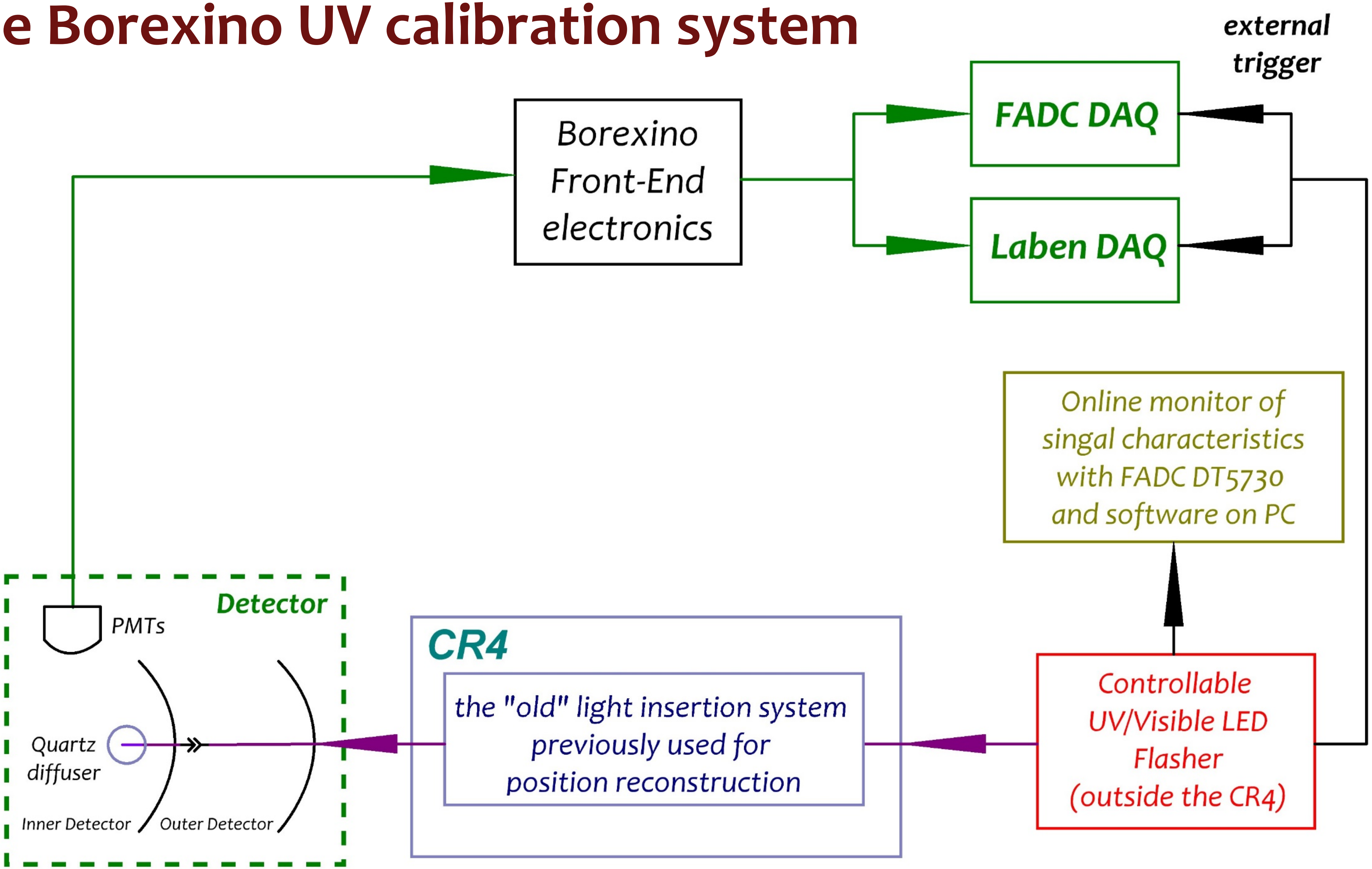
1) Adjustable level of the output power of the LED flashers
2) Double-LEDs scheme
3) Remote control
4) Pulse to pulse monitoring of the flasher output
5) All components except the end of the fiber with diffuser can be placed outside a cleanroom
6) To increase the isotropy of the UV radiation the diffuser is mounted at the tip of the fiber inside the detector
7) Hot swapping
8) UV or/and Visible LEDs

The Calibration System Based On the Controllable UV/Visible LED Flasher

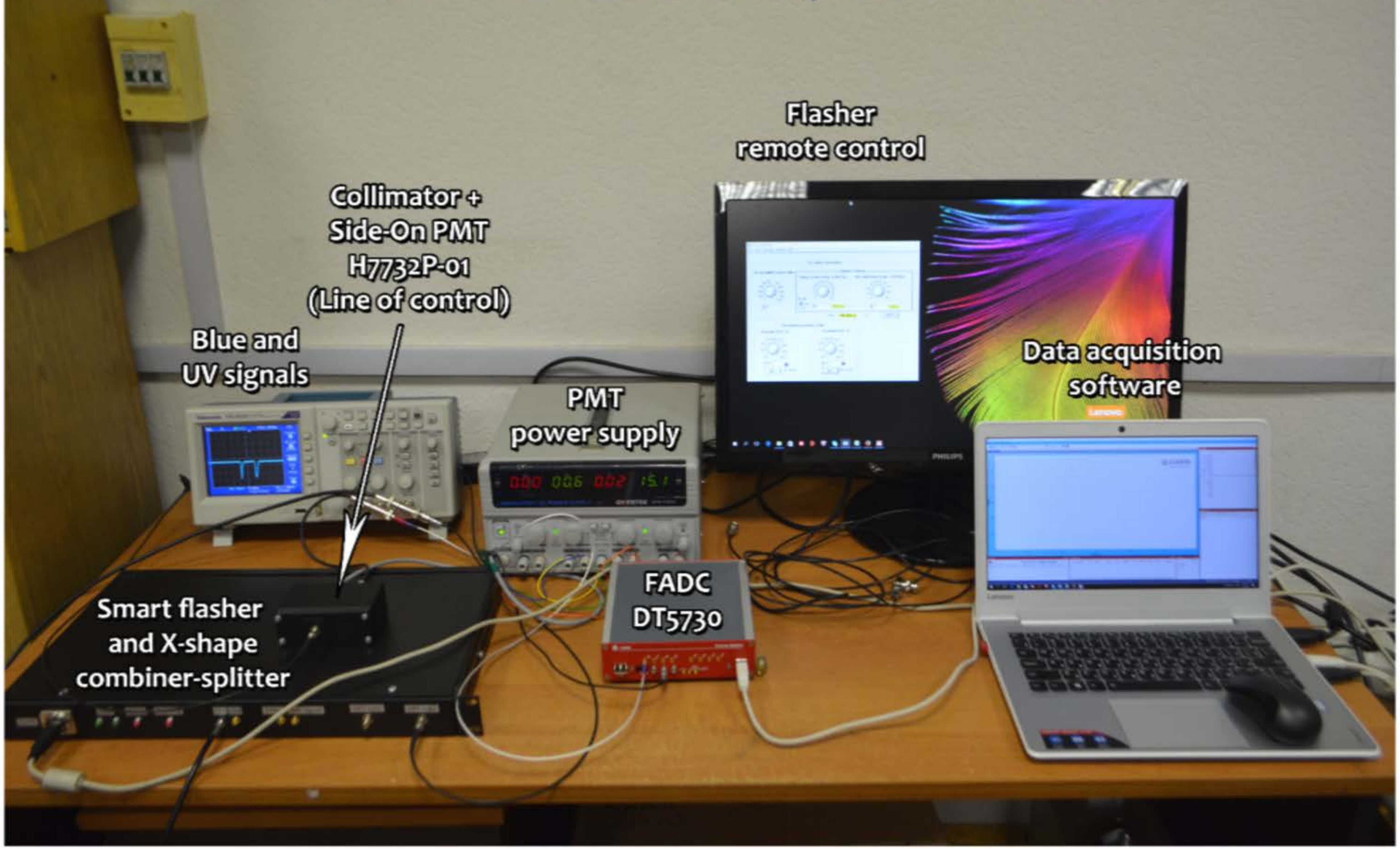
simplified scheme



General overview of the Borexino UV calibration system



Setup for testing @ SINP MSU



UV LED power (for τ = 20 ns, λ = 260 nm)

The number of UV photons

in Borexino (MC simulation): $m_{bx} \sim 10^4$/MeV

Attenuation: $n_{exp} \sim 10^2 - 10^3$ (based on tests)

The number of photons

emitted by the UV LED: $m \sim 10^7$/MeV

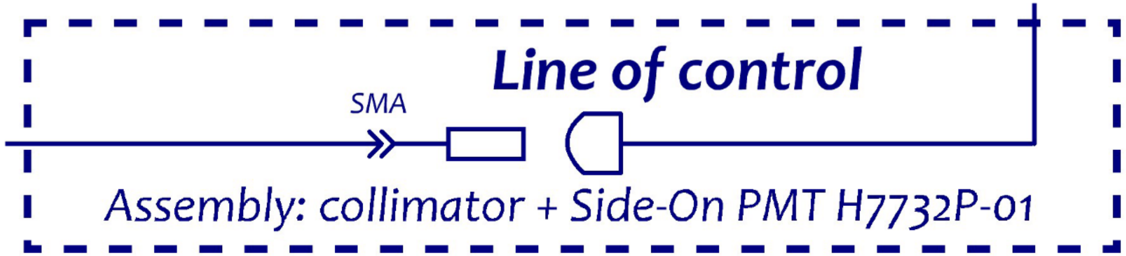
The UV LED power: $P \sim {}^{mhc}/_{\lambda\tau} \sim 4$ mW (for 10 MeV)

The standard UV LED power: P ~ (0.1 – 1.0) mW

UV LED in pulse mode (high current mode)

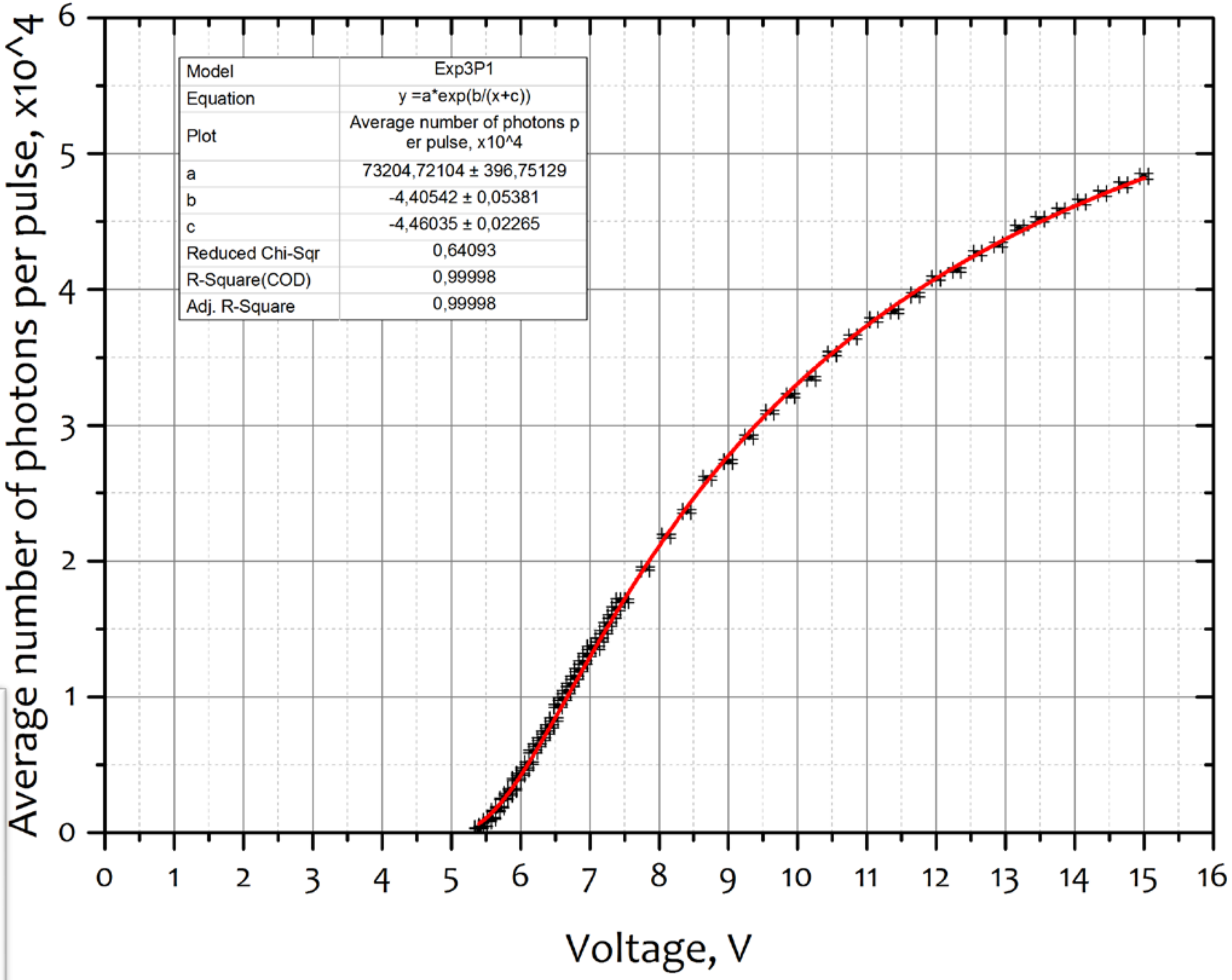
Line of control

Side-On PMT
With adjustable sensitivity



Number of photons emitted by the UV LED as a function of the voltage applied to the diode (empirical dependence)

$$< k_\gamma >= a \exp\left(\frac{b}{V_{\mathrm{d}} + c}\right)$$



Line of control:
side-on PMT VS photodiode + preamplifier

- The characteristics of both monitoring system are practically the same
- The system based on a photodiode and preamplifier was applied initially
- A good optical system for focusing radiation in case of the control line with a photodiode is difficult to manufacture
- Instead of manufacturing the system can be purchased but it’s quite expensive
- It’s easier to apply a side-on PMT

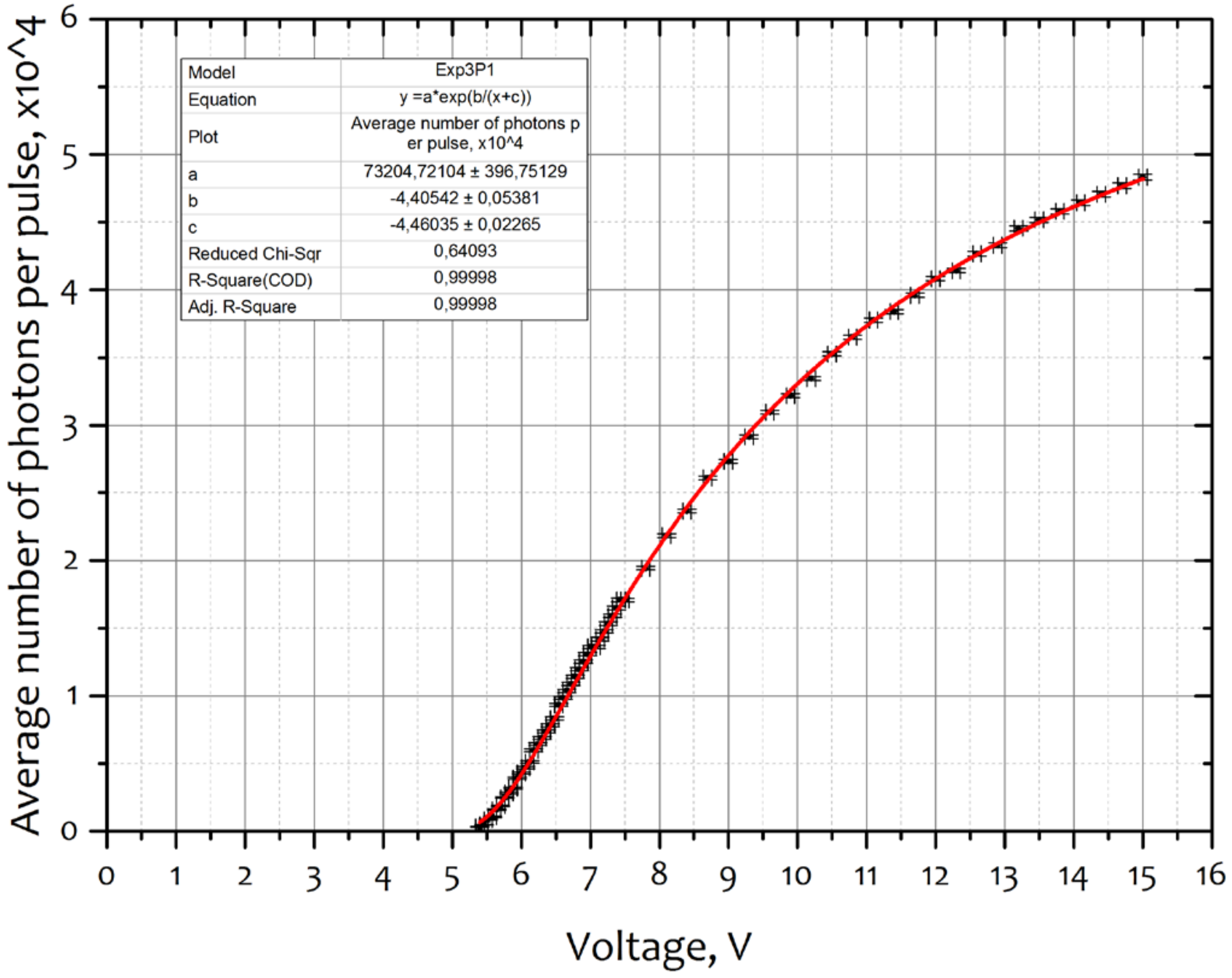
Measurement features

All measurements are relative

So that the calibration with γ source

(E ~ a few MeV)

can be required in each position in the detector

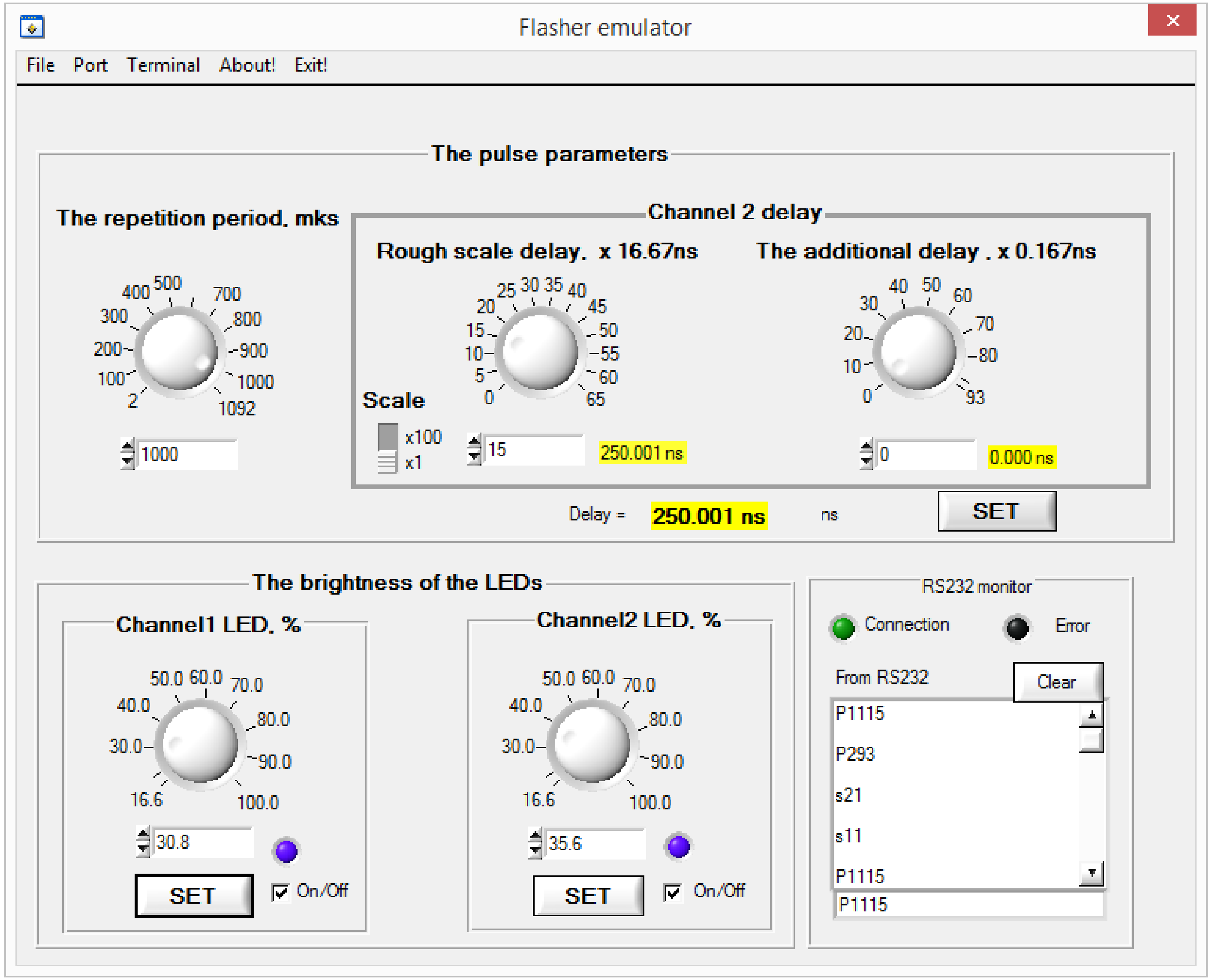


Windows application for control

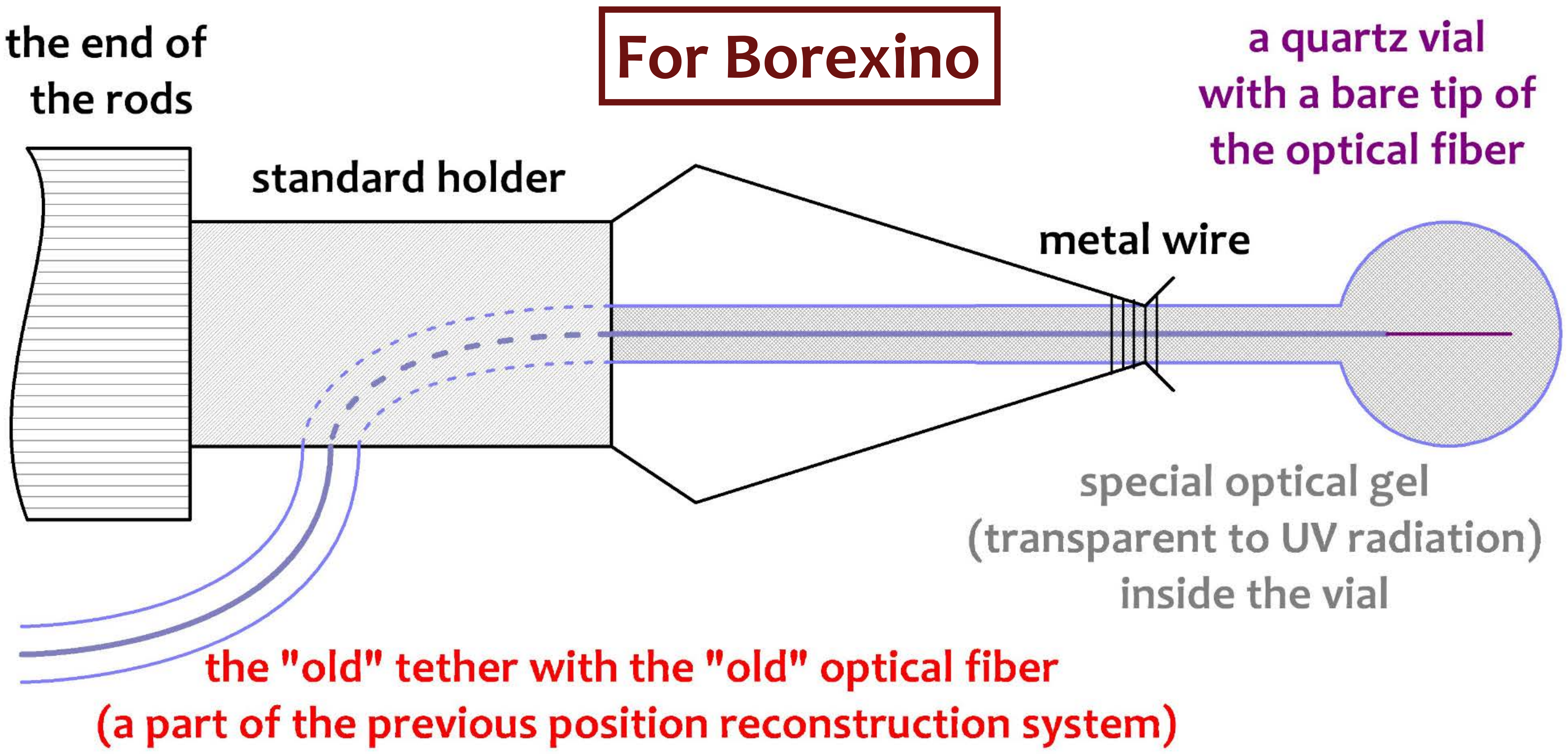
Adjustable parameters:

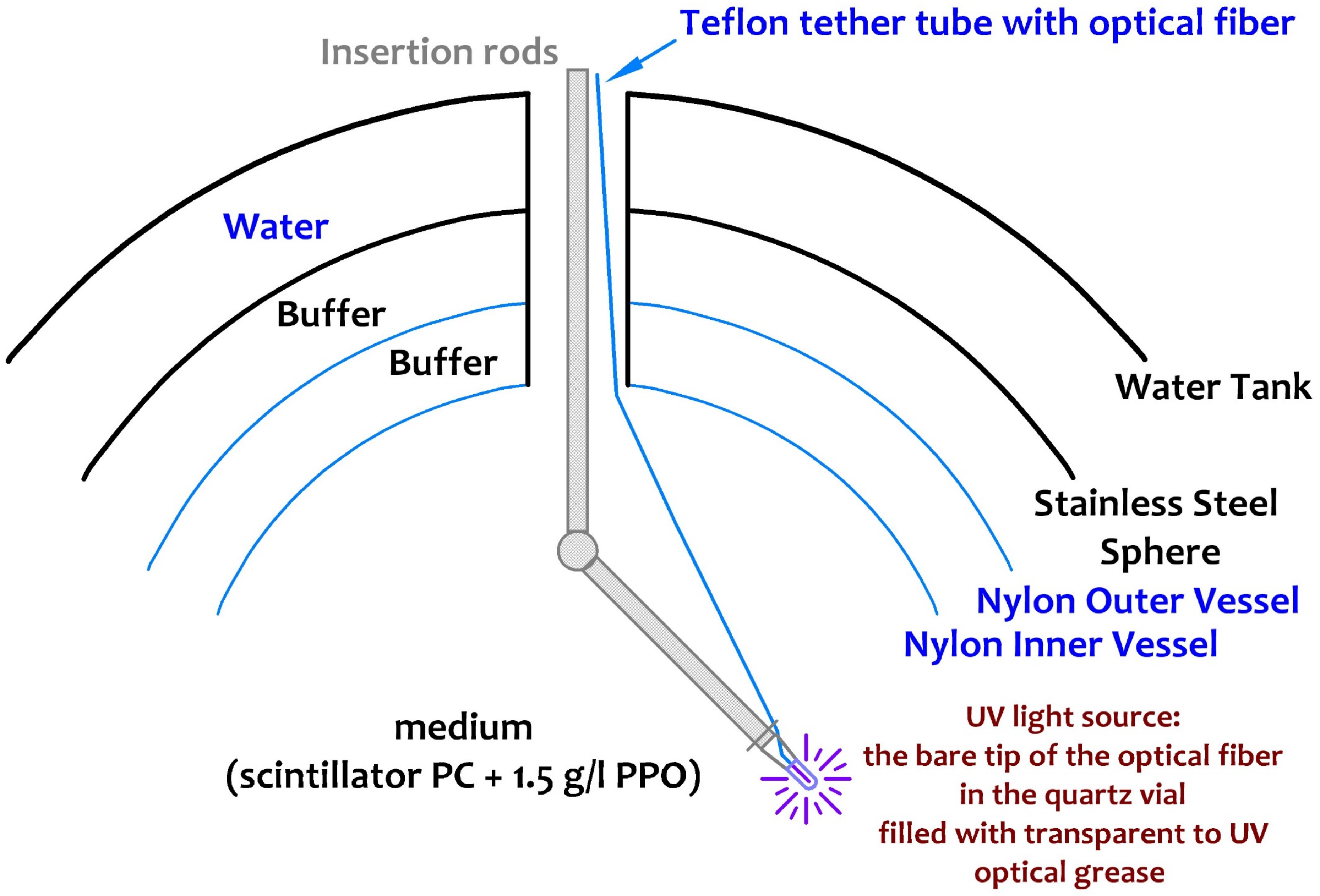
- simulated energy
- delay time between two continuous pulses
- repetition rate

Simulation physical event in the detector, moreover physical spectra



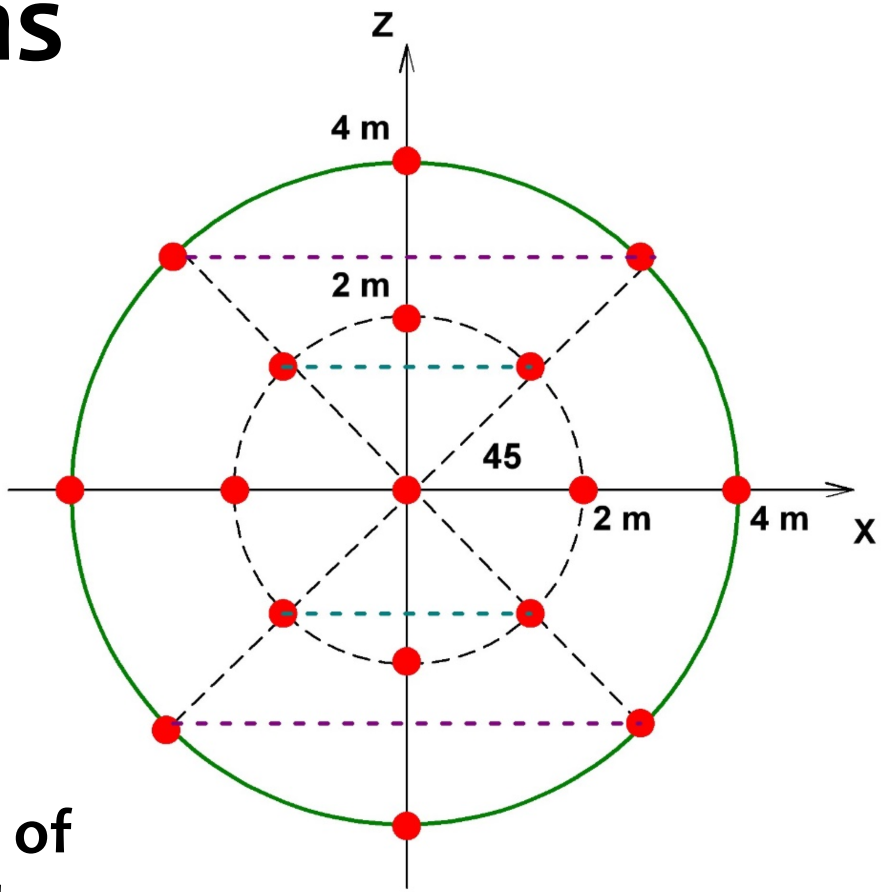
Diffuser and its holder

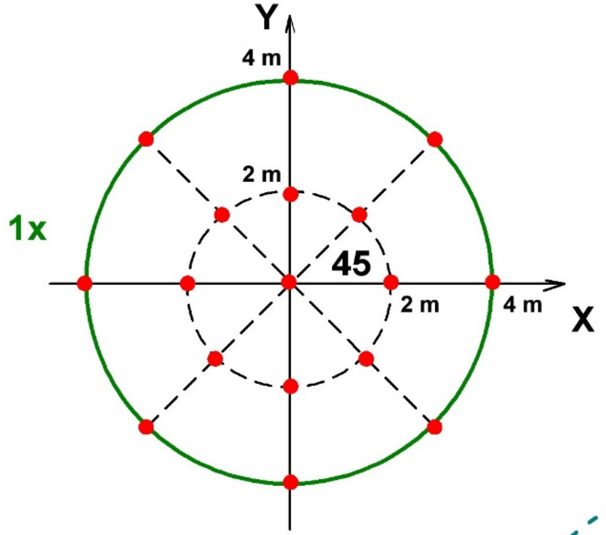


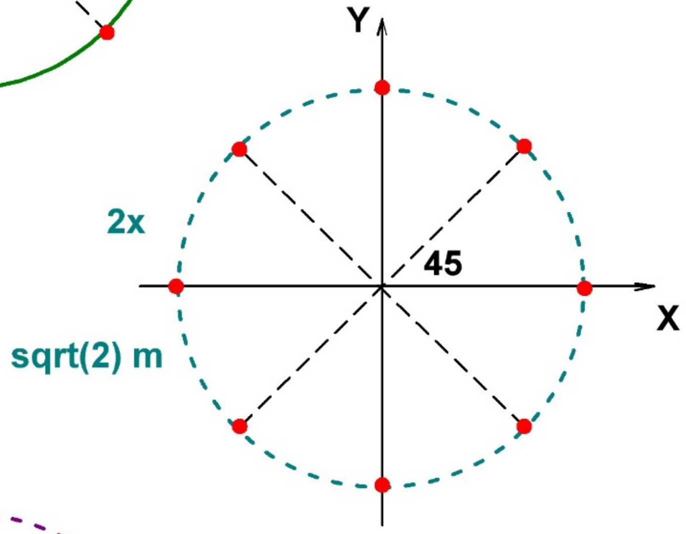


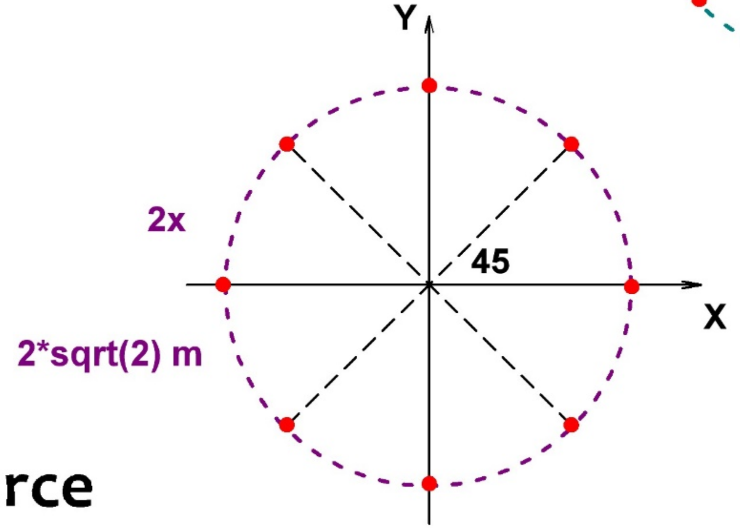
Principle scheme of the Borexino off-axis calibration

Positions









example of
a simple scheme
for energy calibration of Borexino

53 positions of the UV source

Advantages

- ➢ A non-radioactive source
- ✓ safety for experimenters and technical staff
- ✓ safety for low background environment
- ✓ no papers
- ✓ it calms and save nerves
- ✓ it saves time

- ➢ Wide range of energies (100 keV – 50 MeV)
- ➢ A cheap calibration source

Advantages

- Easy operation and control

- Mounted along with other systems
(using infrastructure of other calibration systems)

- Possible fast calibration campaign:
  simultaneous calibration measurements
(a few different sources at the end of the insertion rods)

In conclusion: other possible applications

1) Updating and correction of the energy scale
   in the range 1 - 10 MeV
2) Study of the scintillator properties
3) Reference information for different spatial
   reconstruction algorithms
4) Pile-up study
5) Additional detector hardware and
   software checks

Thank you for your attention!