Portable LAr Scintillation Analyser

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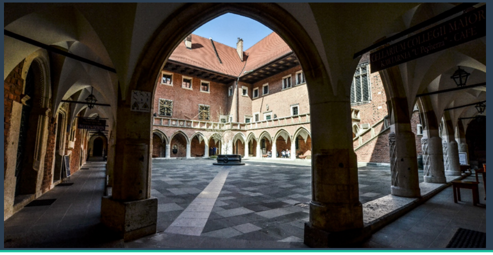
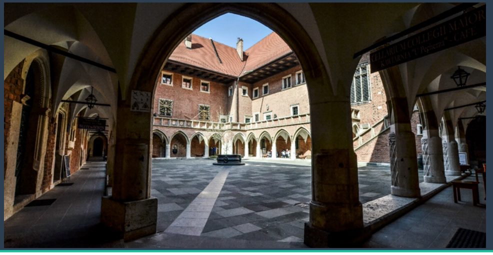
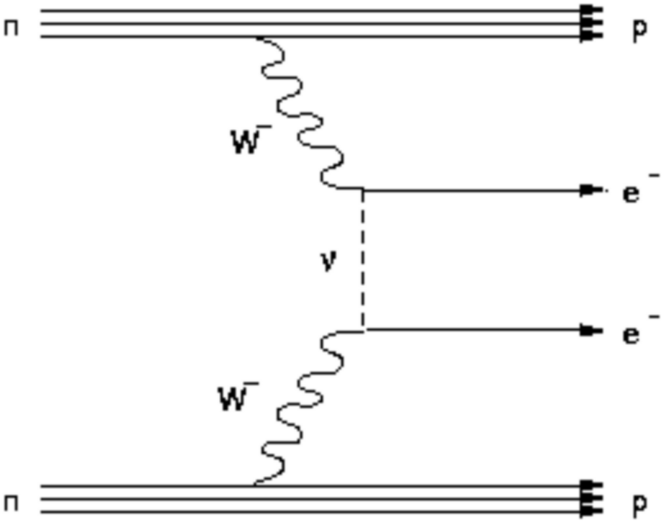


Outline

- Motivation to build Scintillation Analyser
- Design of Portable LAr Scintillator Analyser
- Performance
- Conclusions



MOTIVATION



Feynman diagram for 0νββ decay driven by a light Majorana mass exchange.

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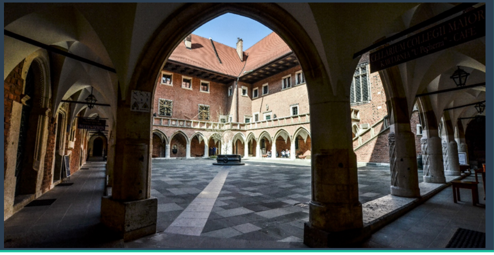
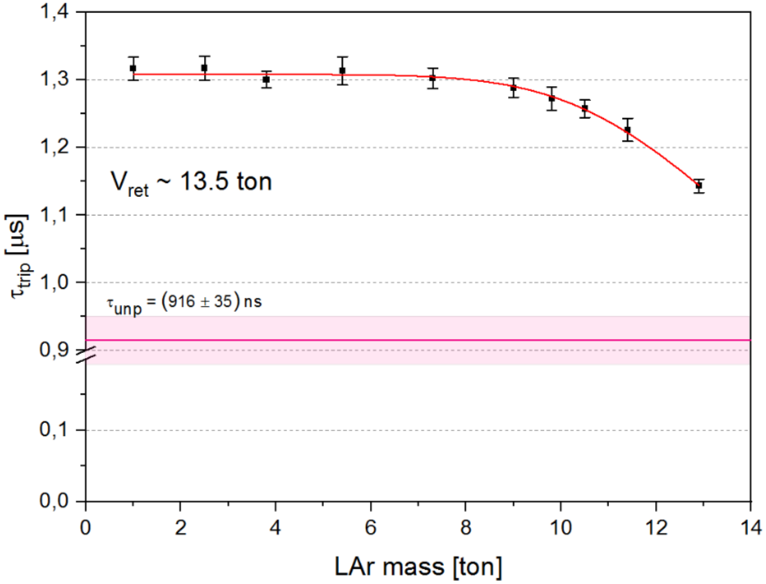


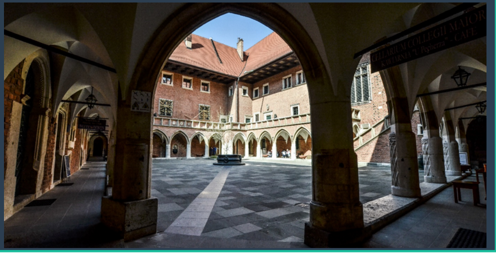
● Motivation to build Scintillation Analyser:

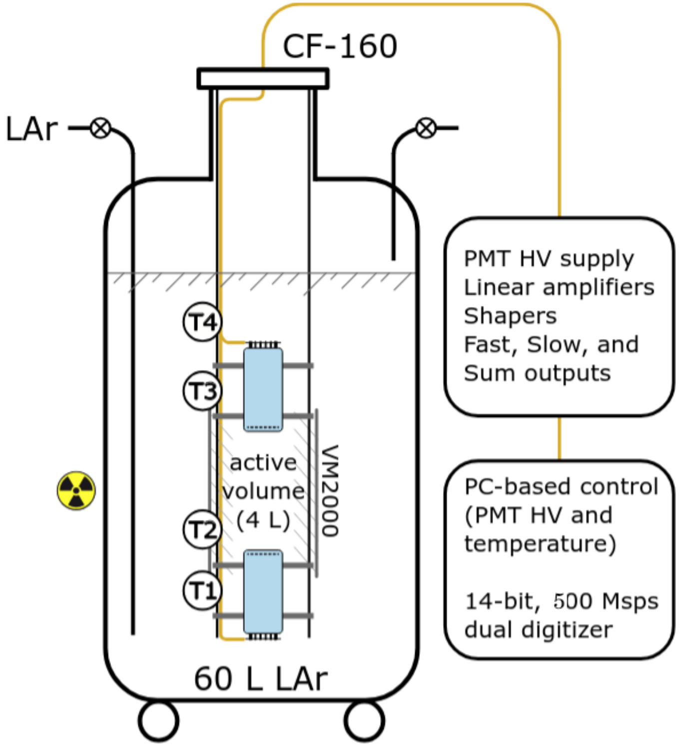
- During filling of the LEGEND-200 cryostat LAr was purified (in liquid phase) from the initial 5.5 quality.
- Continuous monitoring of nitrogen, oxygen and water down to 0.1 ppm in purified gas was performed (using dedicated gas analyzer).
- **Simultaneously, we tested the LAr quality by measuring directly the triplet lifetime (other impurities than O_2, N_2 and H_2O could affect LAr scintillation)**
- Measurements were performed in a quasi real-time mode by using dedicated Scintillation Analyzer
- Recent upgrades: new TPB coating of PMTs, voltage dividers, new digitizer card (14 bit, 500 MHz sampling rate), new software for DAQ and fitting



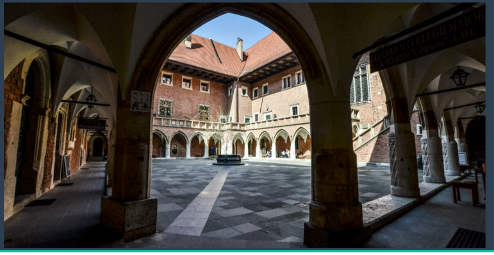
- Triplet lifetime measured with SA as a function of the mass of LAr processed in the LEGEND-200 purification system.
- Performance of the system starts to drop after purifying about 10 t (regeneration was needed).
- About 91 t of purifies LAr was filled into the LEGEND-200 cryostat.

Design of the PLSA: scintillation analyser





- SA based on 60-L full metal-sealed customized
- CF-160 top flange holds the support structure with PMTs and provides feedthroughs for HV/signal and temperature sensors
- 2” TPB-coated PMTs facing each other register Ar scintillation
- PMTs equipped with cold voltage dividers
- ~ 4 L of LAr surrounded by VM2000 (multi-layer reflector foil coated with TPB) viewed by two 2” TPB-coated PMTs
- Filling level controlled with four PT100 sensors
- Electronics module: provides HV for PMTs, ultra-fast linear amplifiers, slow/fast/sum outputs to allow for application of various (slower) digitizers
- Default digitizer: 2-channel 14 bit, 500 MHz PCIe card
- Data can be collected from both PMTs simultaneously

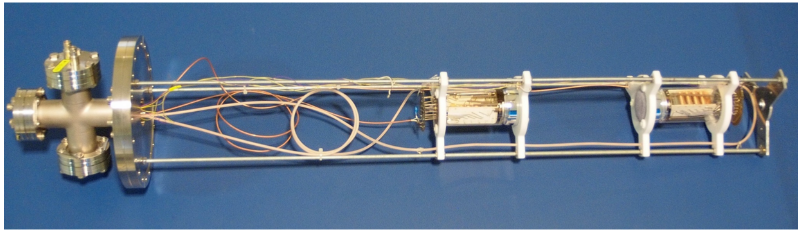


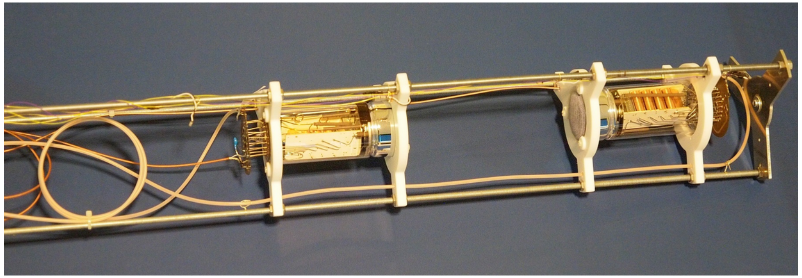
PMTs support structure

- Cryogenic photo-multiplier assembly: two 2-inch Hamamatsu TPB-coated PMTs placed 20 cm apart off and facing each other

- Equipped with dedicated bias high voltage (HV) dividers

- Four temperature sensors (T1 - T4) are located above/below the voltage dividers





Electronics module

- A dedicated electronic unit has been built to provide High Voltage (HV) to both PMTs and amplify their signals
- Each channel has two electronic paths: 1) for fast linear amplification of the pulses , 2) with a “semi gaussian shaper” to allow for operation with slower digitizers.
- A sum of “slow” pulses from both PMTs is also available.

HV 1 out

HV 2 out

Ch 1 in

Ch 1 fast

Ch Sum

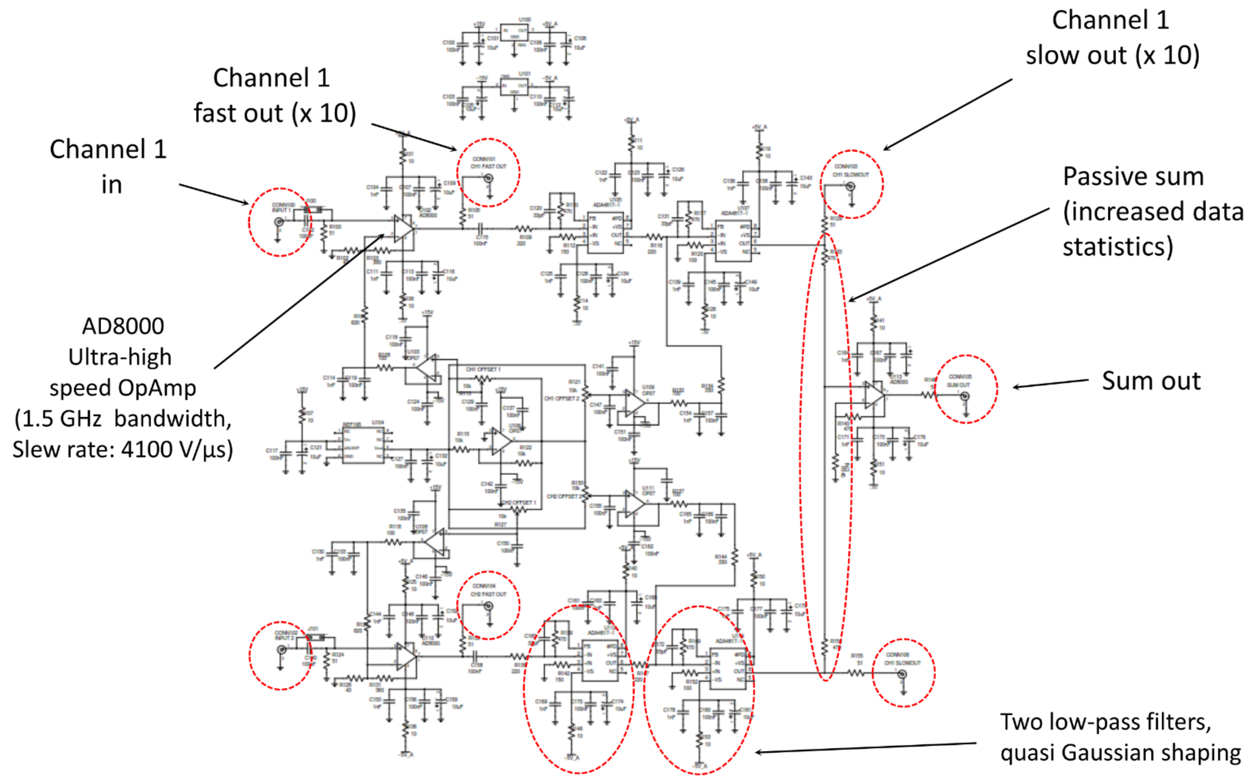
Ch 2 slow

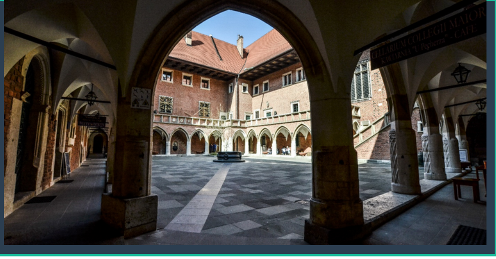
HV supply programming:

- HV set
- HV ramp up
- HV ramp down

Both channel independent

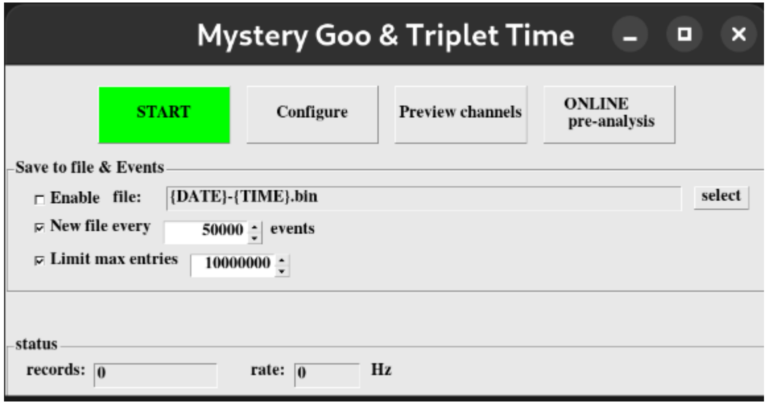
Electronics module – signal processing





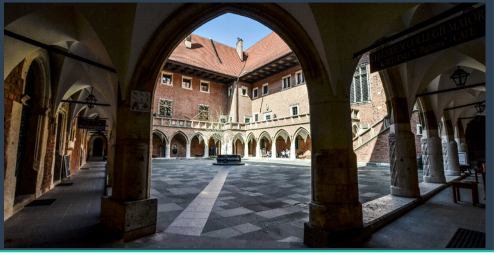
Software design

● **Design of the PLSA:** as a part of recent upgrade of PLSA new acquisition and analysis software has been prepared. It allows for **real-time estimates** of the triplet lifetime



A custom acquisition software was developed in the C++ built with the Cern ROOT framework,

- simultaneously acquire, write and analyse (fitting τ) data,
- operates under Linux and MS Windows,
- drivers provided by FADC card manufacturer, (ADQ14DC-2A-PCIe)
- τ reaches a stable value after collecting about 3 000 events.
- The outcome of the fitting process is displayed on the screen, giving the user a real-time update of the estimated value of τ as new entries are added.



System operations

- Cleaning (~30 min): Pumping to pre-vacuum and filling the dewar with the gas to be measured, 5 cycles.

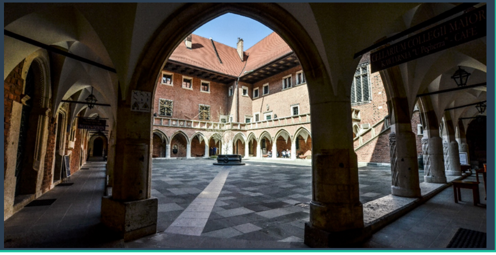
- Filling (~30 min): LAr filled into the dewar through the inlet tube (reaches the bottom of the dewar).
- LAr filtered by a $3 \mu m$ metal filter.

- Analysis (~20 min): when T4 covered with LAr (located above the top PMT voltage divider) HV
- is switched ON, data are acquired and analyzed.

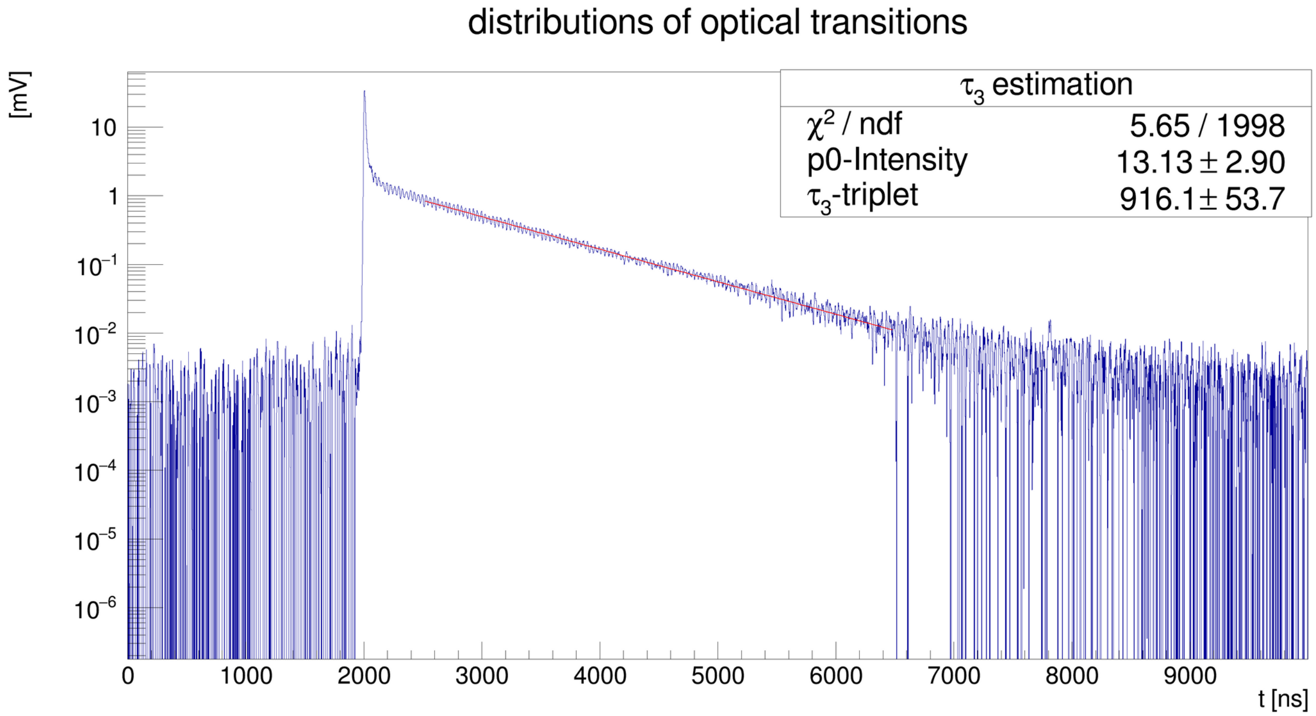
- Drainage (~20 min): LAr pushed from the dewar through the inlet tube.

- Full measurement cycle takes up to 100 min.

Fast outputs



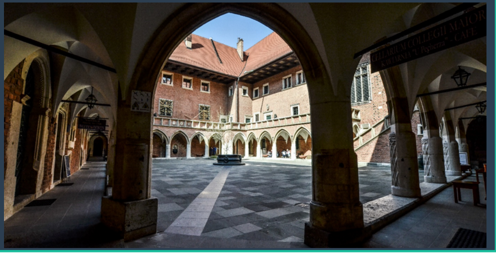
New DAQ system based on a 2-channel 500 MHz, 14 bit card. For the fast outputs (amplification $\times$ 10) no further manipulation on the traces (except BL subtraction) need.



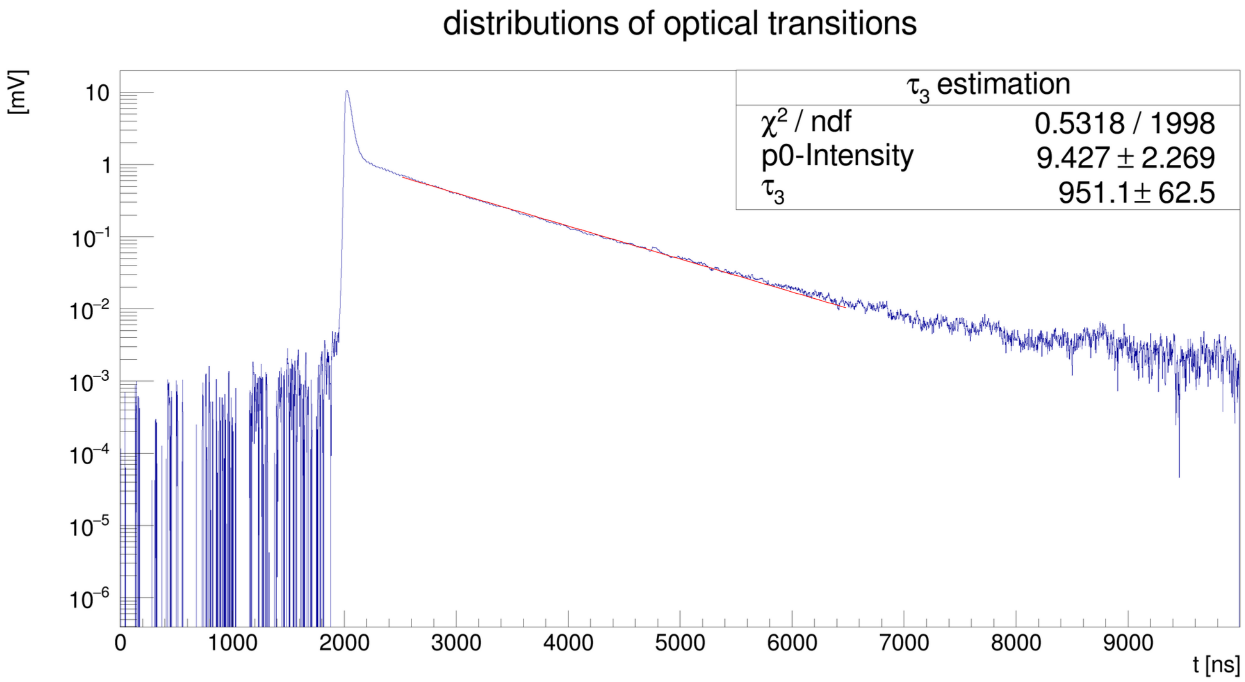
τ_{fast} = **(916 ± 54)** ns

$$f(t) = p_0 \cdot e^{-t/\tau_3}$$

Slow outputs



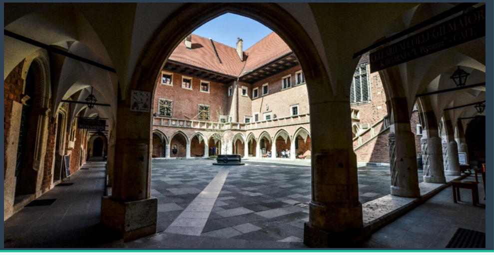
Gaussian shaping of the pulses causes deformation of the summed shape - needs to be corrected using quasi pole-zero function.



τ_{fast} = **(951 ± 63)** ns

$$f(t) = p_0 \cdot e^{-t/\tau_3}$$

Sum output



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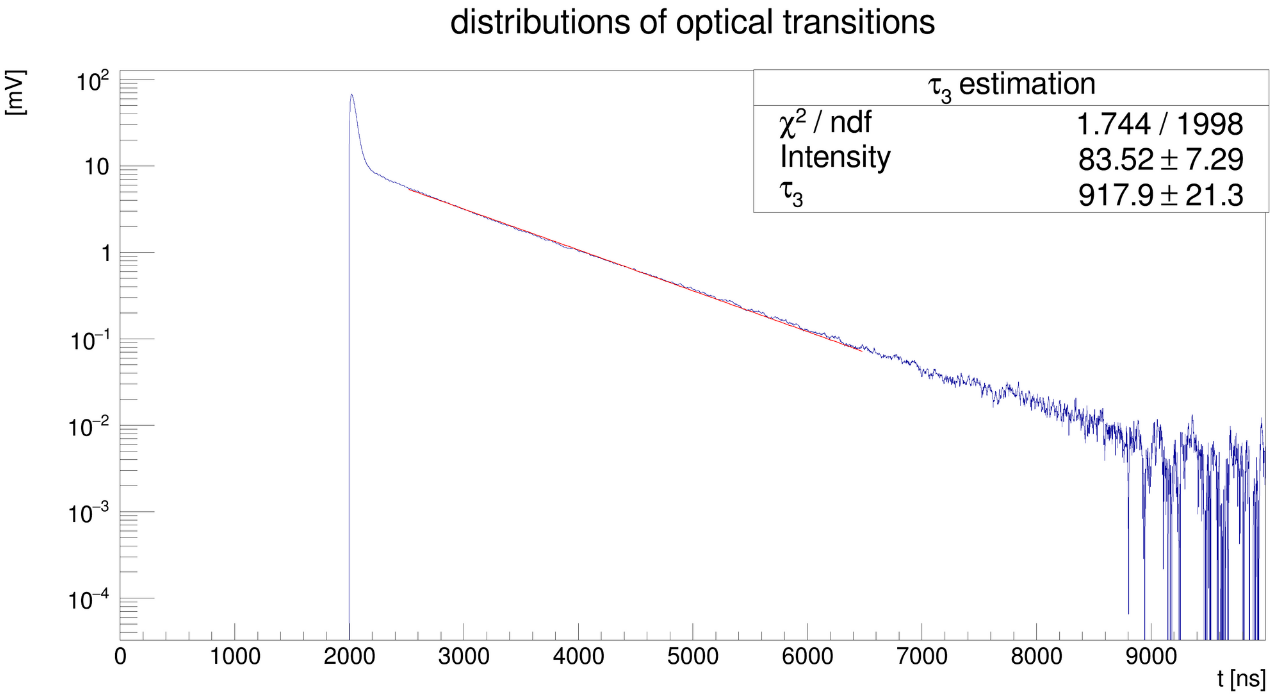
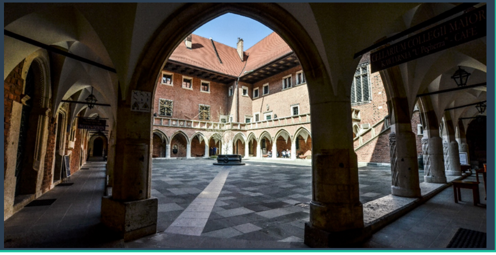


τ_{fast} = **(918 ± 21)** ns

$$f(t) = p_0 \cdot e^{-t/\tau_3}$$



● Conclusions

- The SA well understood (possibility to use independently all outptus for analysis)
- Recent upgrade of the system included renewal of the PMTs TPB layers, voltage dividers and a new digitizer with dedicated acquisition/fitting software
- Various digitizers can be applied for DAQ (also slower using the slow/sum outputs)
- Relatively short measurement cycle – quasi real-time operation (~100 min „time resolution”)
- Short determination time of the triplet life time even from one PMT: about 20 min (~10 000 traces needed)
- High portability (relatively compact system)
- High reliability: two PMTs, various signal channels available for analysis
- Various applications possible but the main goal is to use the system to monitor the LAr quality during purification and filling of the LEGEND-1000 cryostat (new purification system able to process up to 30 t in one go under construction)
- Paper describing the PLSA in preparation

Thank you