# Investigation of WLS techniques for the LAr-detector in the COHERENT experiment

Rudik Dmitrii Gennadyevich

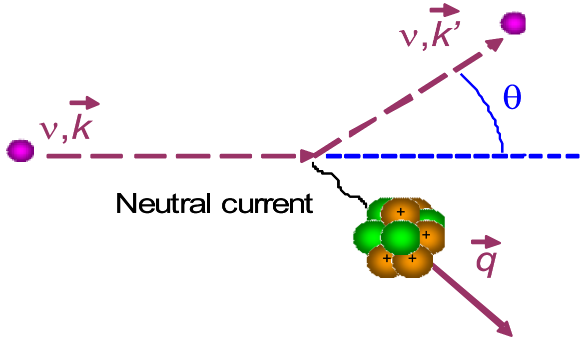
NRC "KURCHATOV INSTITUTE” - ITEP,
MEPhI,
COHERENT coll.

# Outline

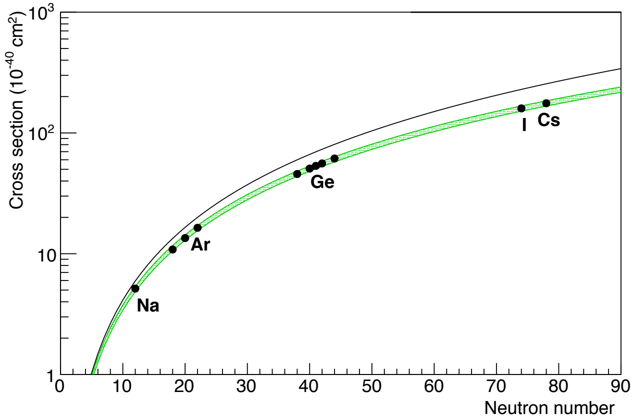
- Motivation
  - Coherent elastic neutrino-nucleus scattering (CEvNS)
  - LAr detector for CEvNS registration: CENNS-10
- CENNS-10 WLS improvements
- Investigation of WLS @ ITEP test chamber
  - ITEP test chamber
  - TPB
  - Volume-distributed WLS (Xe-dopant)
- Conclusion

# Motivation

- CEvNS is observed by the COHERENT collaboration!*
- Different types of detecting substance allow to determine parameters of this process

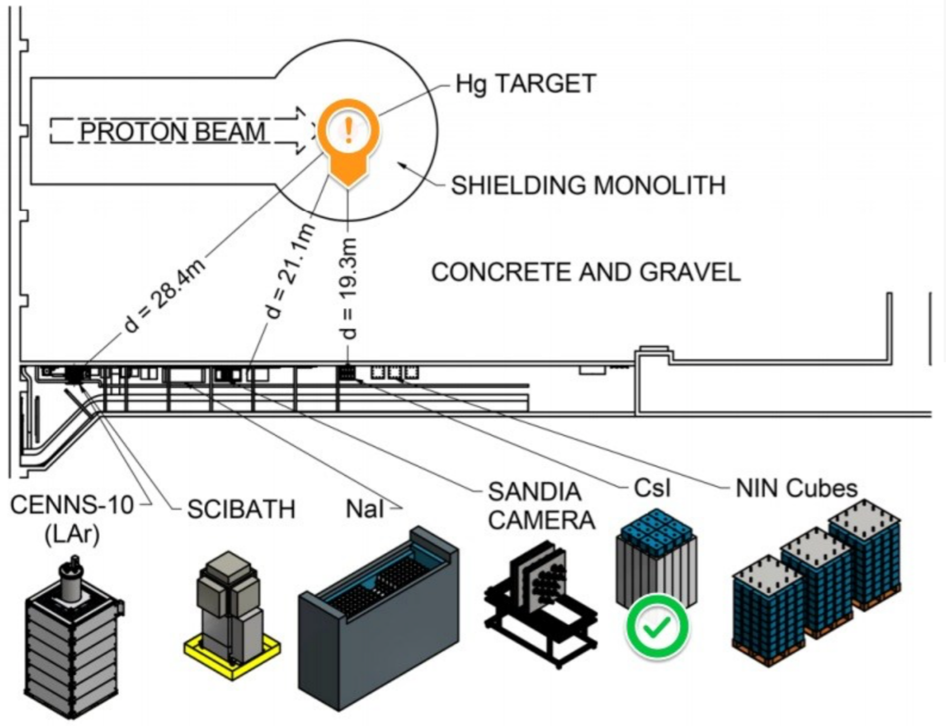

$$\sigma_{elastic} = \frac{G_F^2}{4\pi} N^2 E_\nu^2 \approx 0.4 \times 10^{-44} \mathrm{cm}^2 N^2 E_\nu (\mathrm{MeV})^2$$

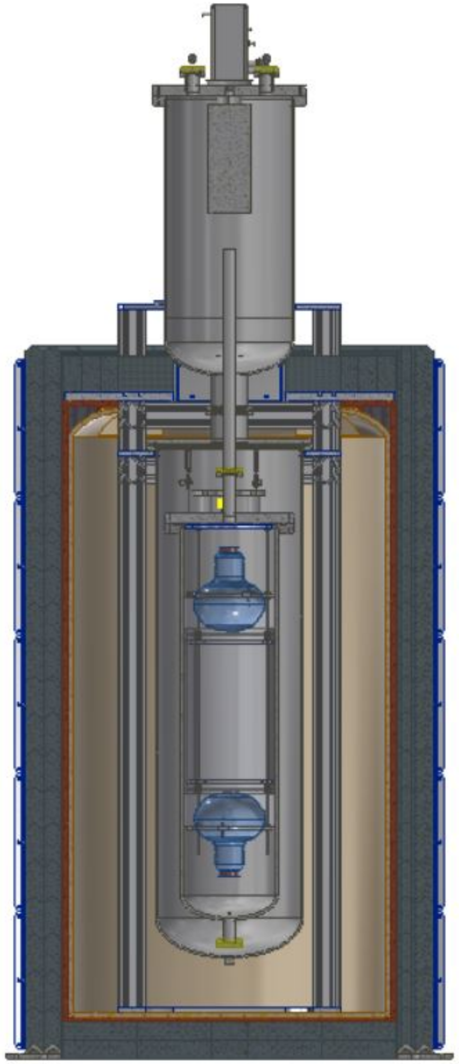



* Observation of Coherent Elastic Neutrino-Nucleus Scattering
COHERENT coll. **Science (2017)** DOI: 10.1126/science.aao0990

# Motivation CENNS-10

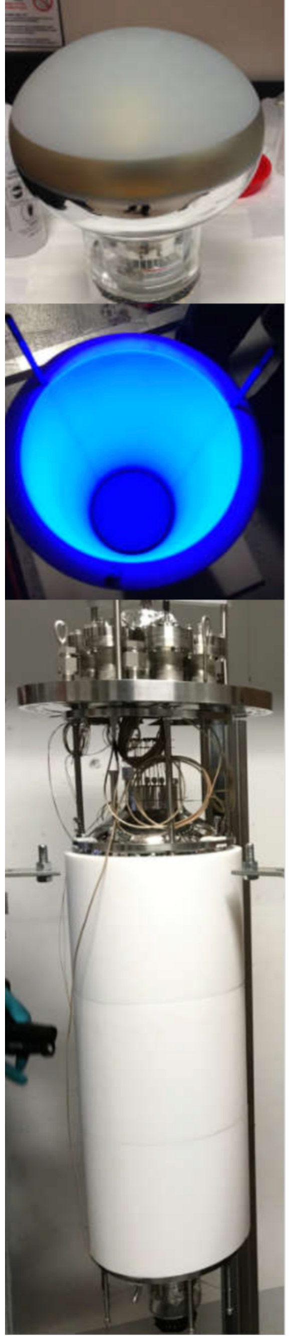
- CENNS-10 is LAr detector made by IU group @ SNS, Oak Ridge, USA
- Two PMTs: R5912
- WLS technology:
  - First mod: acrylic + tetraphenyl butadiene (TPB) only 0.3 PE/keVee
  - Second mod: PMT's covered by TPB; Teflon reflector covered by TPB current run ~ 2.2 PE/keVee
  - Future: studying of WLS techniques for more (5 - 10) PEs per keVee
- Upgrading for 1-tonne detector… New WLS techiques?

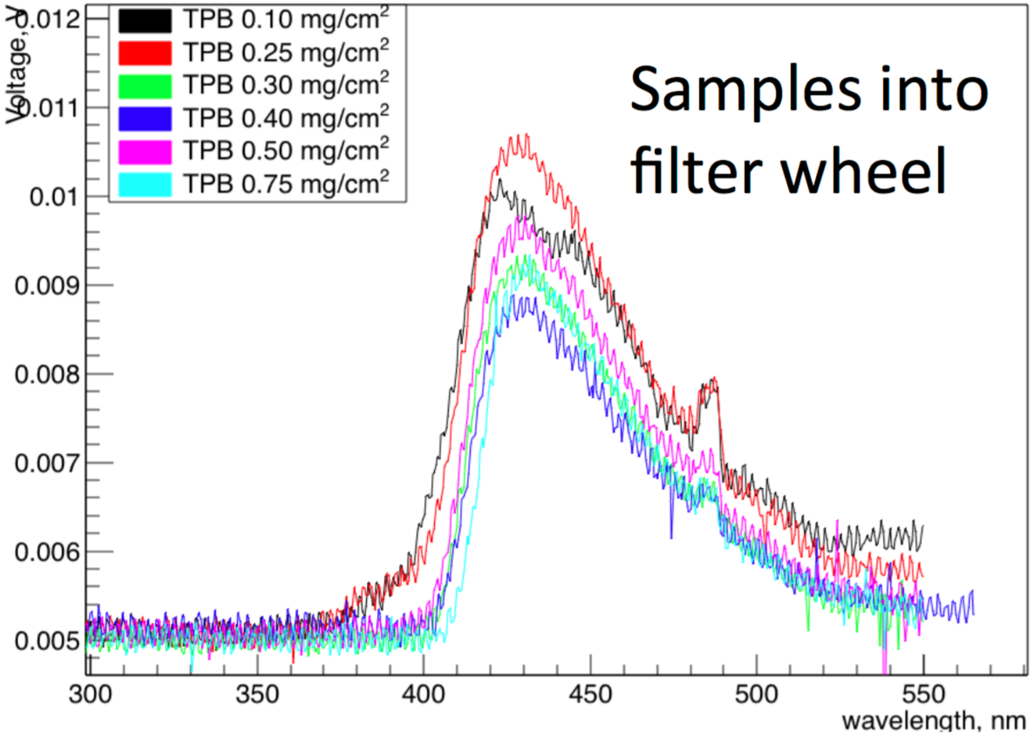


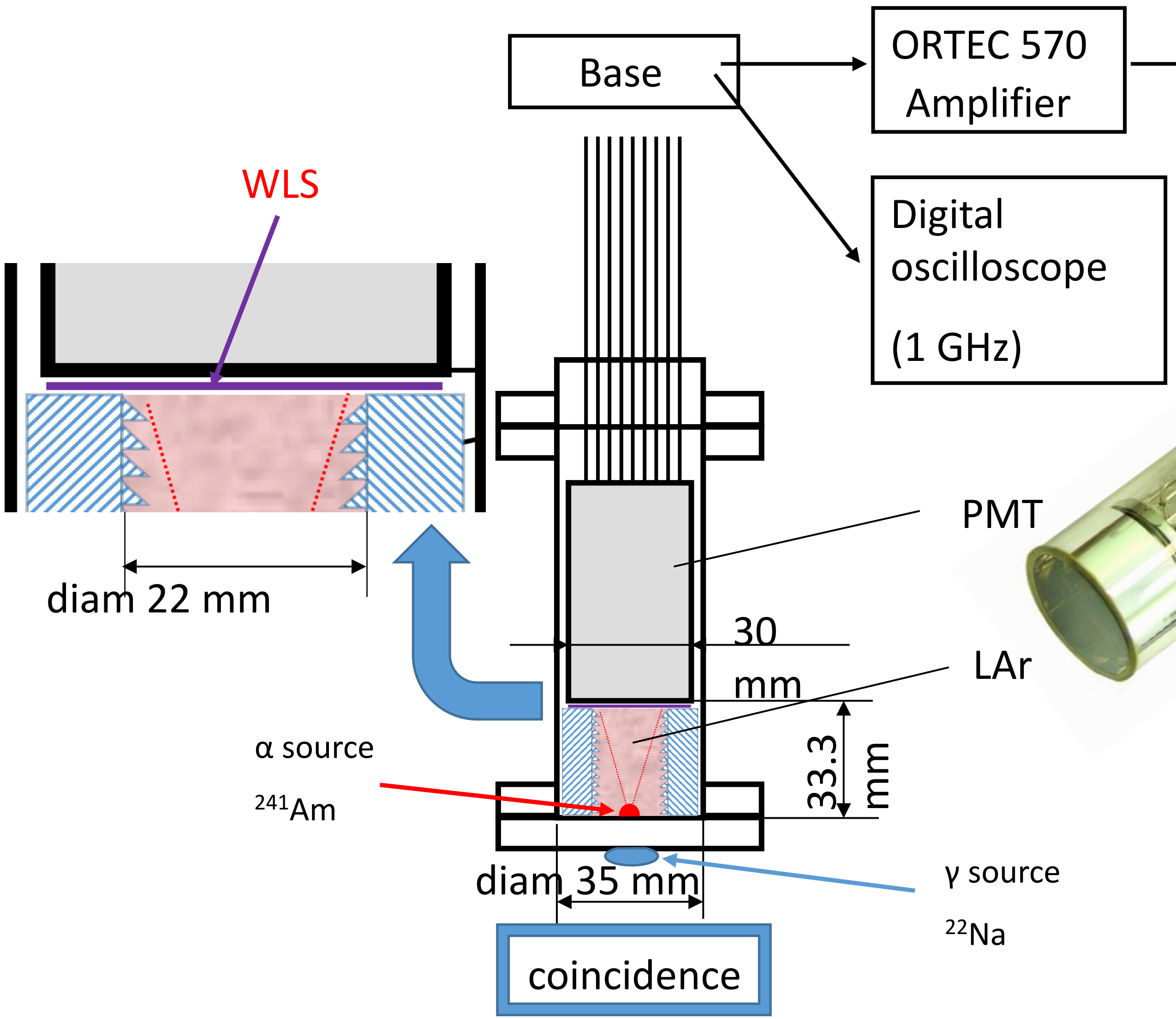
# CENNS-10

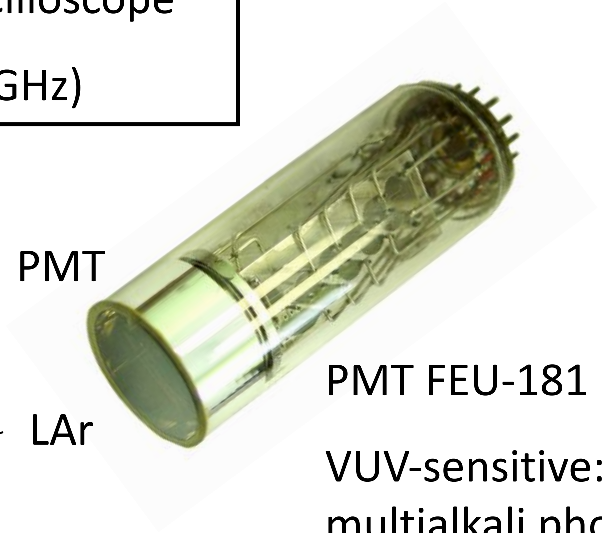
- Teflon reflector
- Two PMTs: R5912 covered by TPB
- Vacuum monochromator: the beginning of operation
- Upgrading:
  - Set of PMT or new PMT?
  - Xe-dopant?
  - Another variant of WLS?





# ITEP Test Chamber & scheme of measurements



PMT FEU-181 MELZ (Moscow)

VUV-sensitive: $MgF_2$ window multialkali photocathod

Can operate at cold (down to $LN_2$ temp.)

# TPB investigation

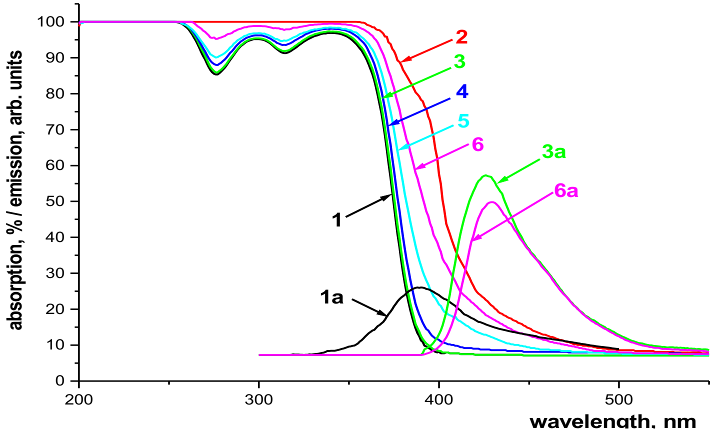
- Investigation with monochromator (by Enikolopov inst. group)
  - “literature” best thickness is 0.2 mg/sm$^2$
  - Big reabsorption for 0.2 mg/sm$^2$
  - TPB has polycrystalline structure, that’s why there is the minimum thickness of TPB layer
- TPB degradation:
  - 38 % during 5 month storage and short-term tests
  - 17% during 1 month under vacuum
- TPB has slow component: 336 ± 43 ns. May influence on the slow LAr-scintillation component parameters!
  -

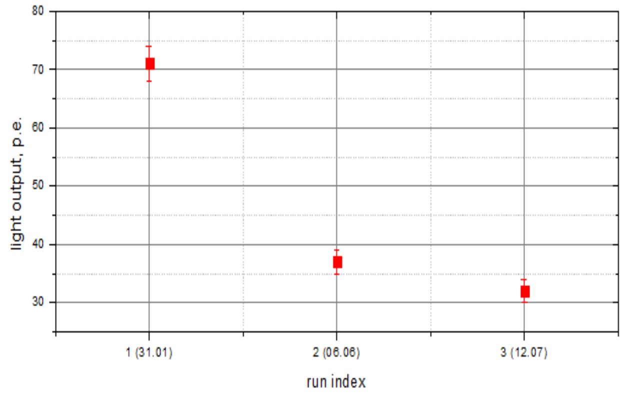
| | decay time (nsec) | abundance (%) |
|---|---|---|
| Instantaneous component | 1-10 | 60 ± 1 |
| Intermediate component | 49 ± 1 | 30 ± 1 |
| Long component | 3550 ±500 | 8 ± 1 |
| Spurious component | 309 ± 10 | 2 ± 1 |

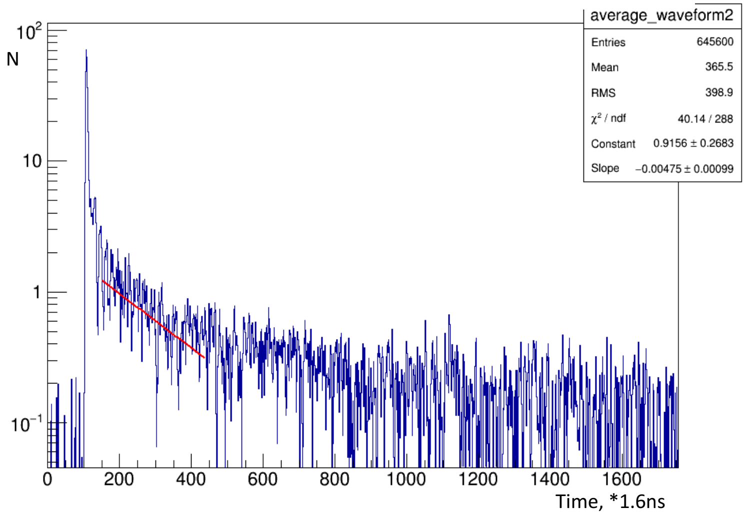
*

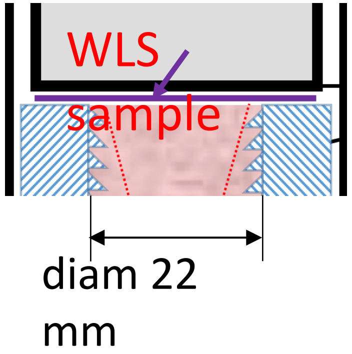
- New type of WLS with TPB molecules is under investigation by Enikolopov inst. group.

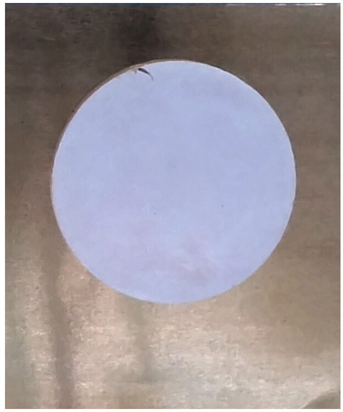
* arXiv:1411.4524v2 by E. Segreto



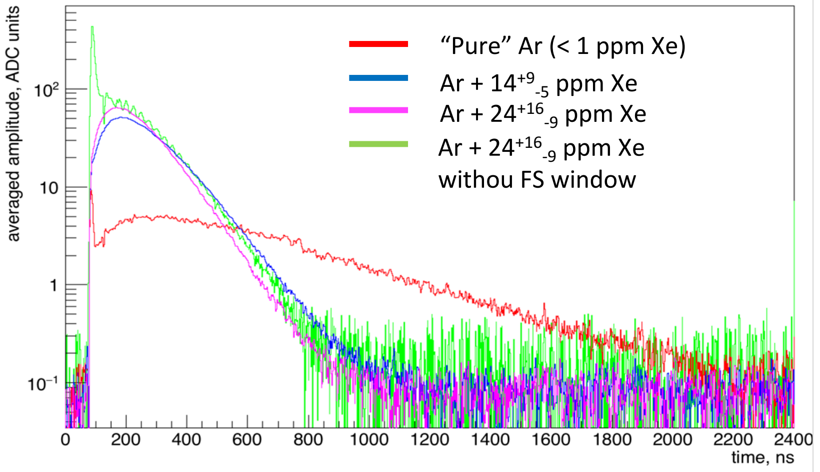



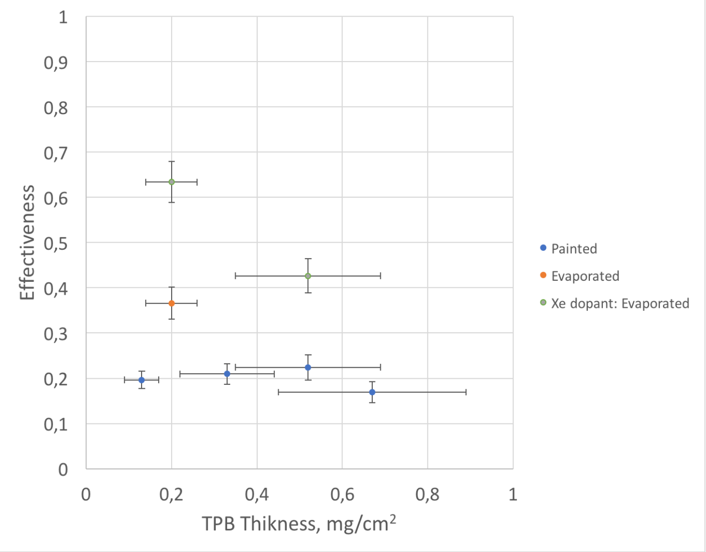



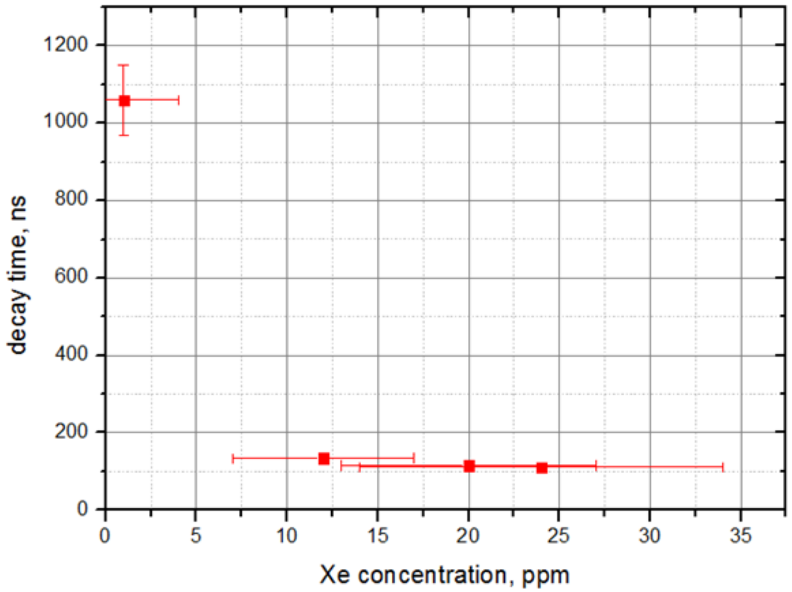



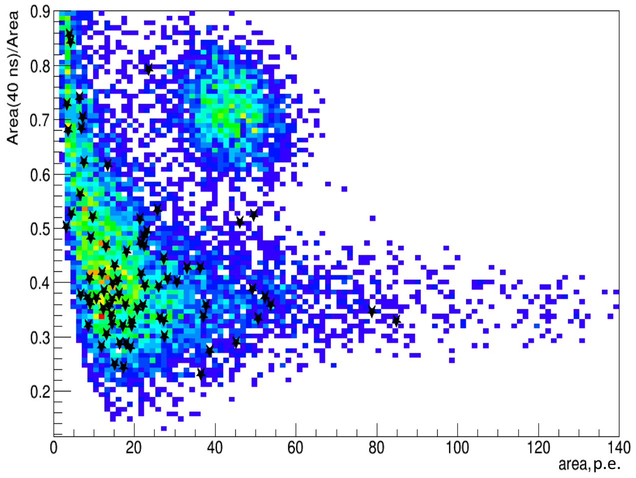
# Volume-distributed WLS

- Xe-dopant in LAr works like distributed WLS
  - Reemission is occurred only for slow component!
  - Have to use combined method (TPB or another film WLS) to obtain the fast component.
- The decay time of slow component decrease with Xe concentration increasing
- The amount of collected light increasing with Xe concentration
- LAr+Xe mixture is stable during the long continuous run
- Concentration of Xe changing with cryogenic manipulations with mixture
- PSD?



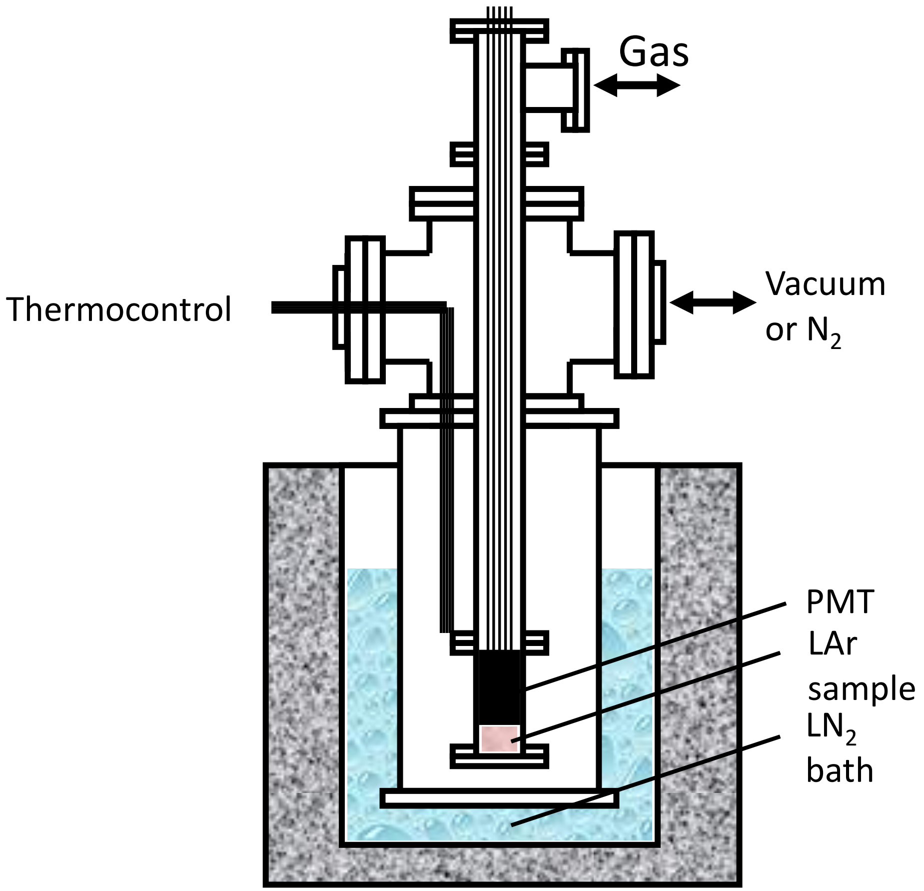



# Conclusion

- We are conducting R&D on different types of WLS for LAr detectors
- More knowledge about TPB
- Trying to use TPB-covered teflon as a reflector
- Different characteristics of volume-distributed WLS (Xe-doping) were experimentally investigated
- We have shown stability of LAr+Xe mixture and possibility of usage this type of WLS
- Some things are still in our ToDo list:
  - New type of film-WLS test
  - Further LAr+Xe investigation: possibility of PSD analysis

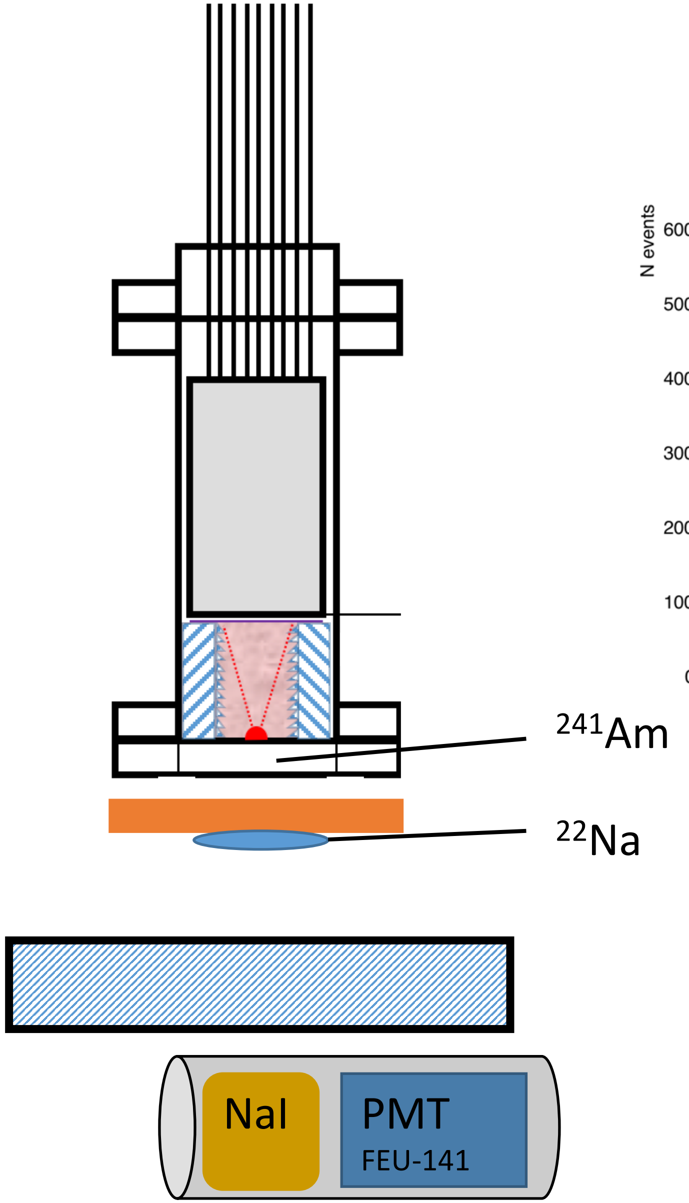
Thank you for your attention!

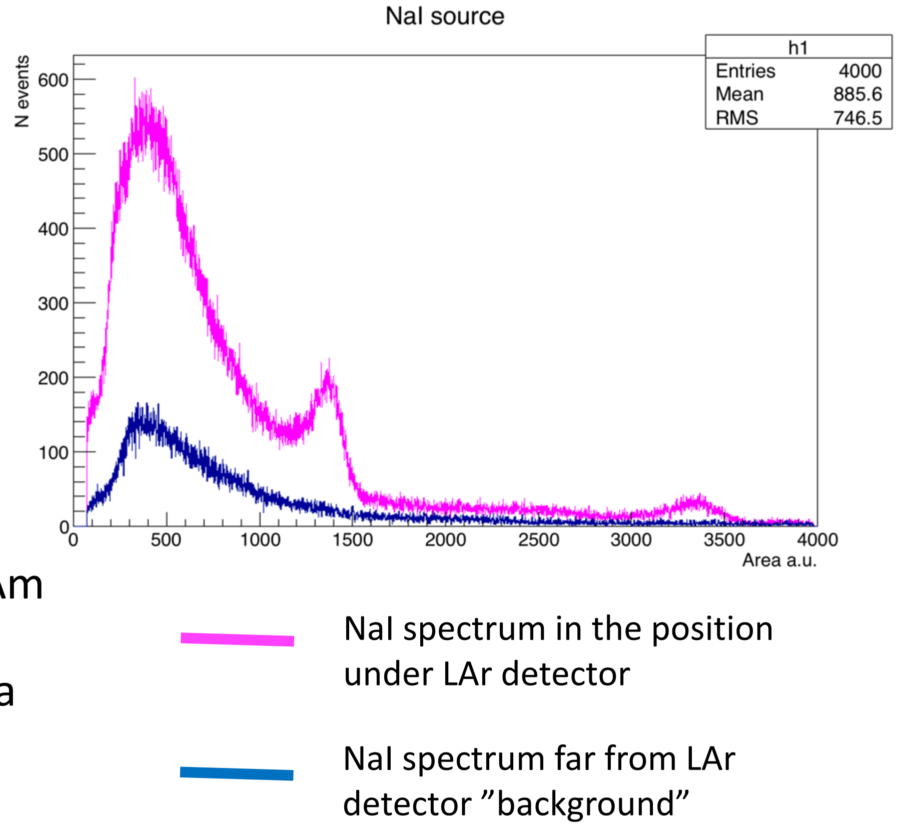
# ITEP Test chamber




# ITEP test chamber, scheme of measurements

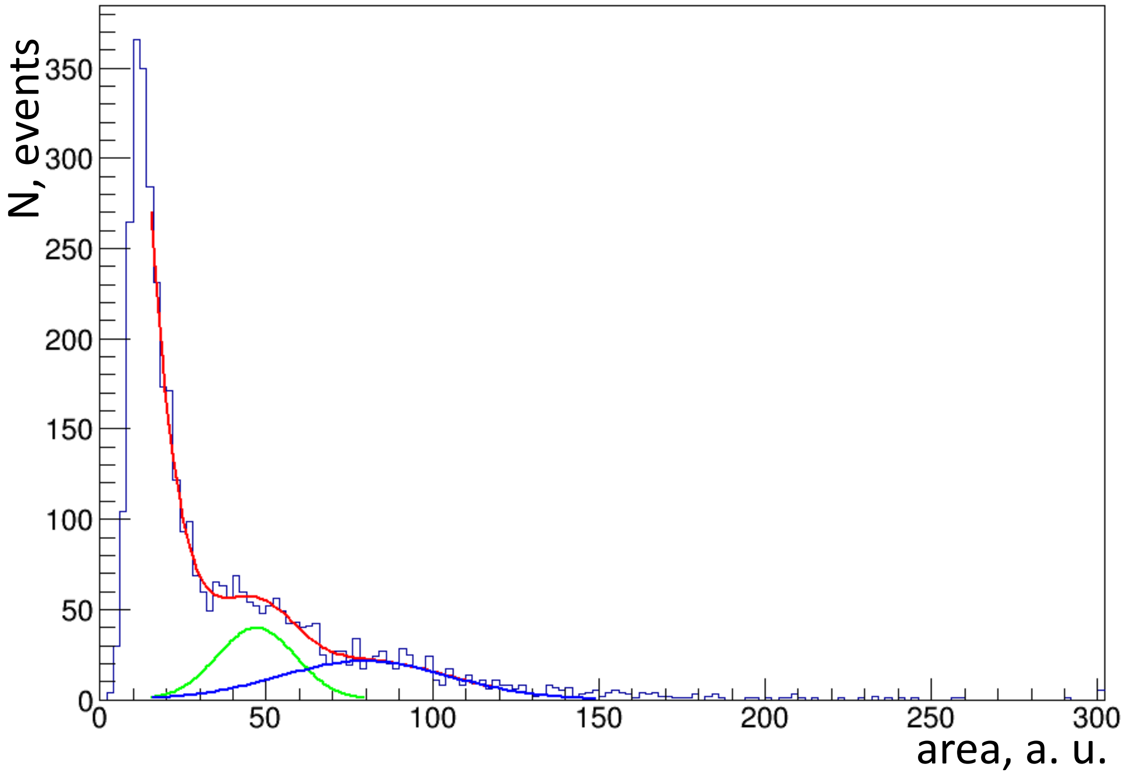
- $^{22}$Na => 2 γ in opposite direction (511 keV) 1.2 MeV γ
- Coincidence scheme
- $^{241}$Am => α-particles 5.6 MeV



# LAr test chamber, SPE calibration

- SPE calibration
- Approximately 0.03 p.e./keV in case of LAr + ORNL sample



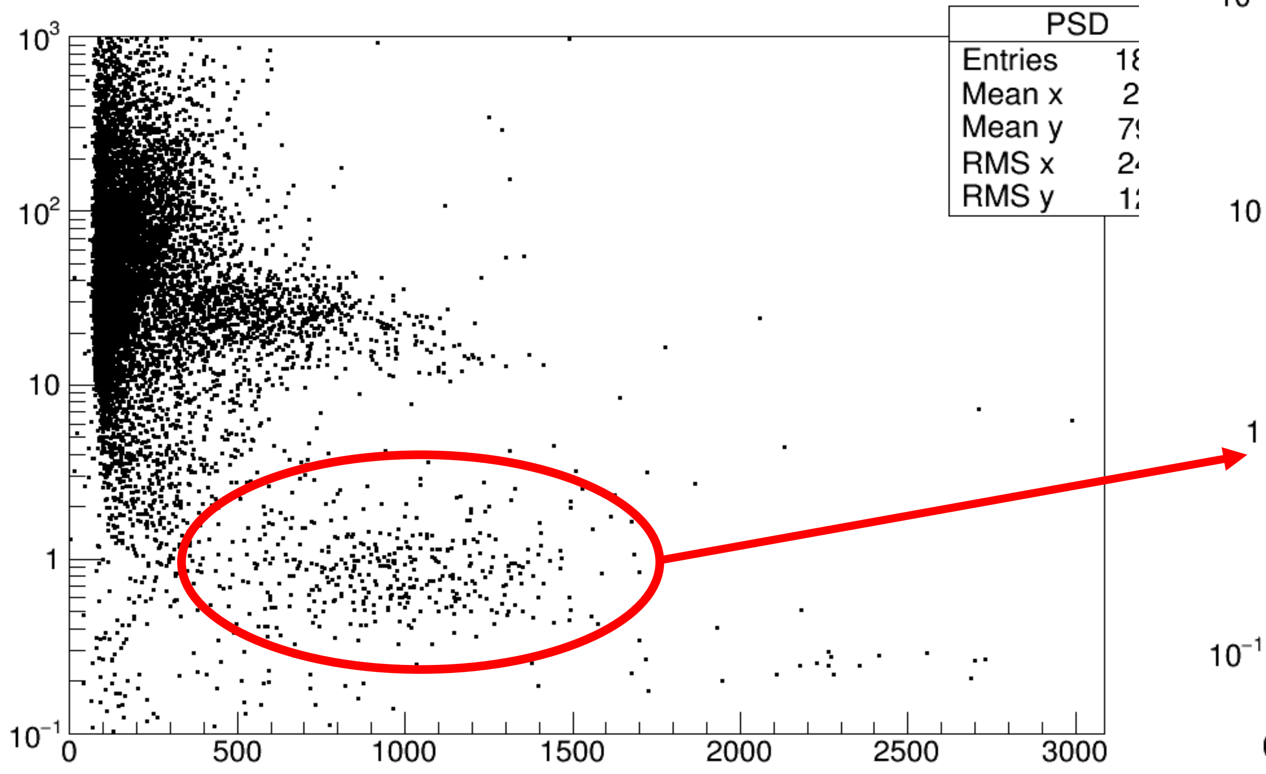
# Xe-doping work
# Energy transferring

- See for example: C.G. Wahl et al ***Pulse-shape discrimination and energy resolution of a liquid-argon scintillator with xenon doping*** 2014 JINST 9 P06013
- $Ar_2^*$ can be either singlet or triplet state
- Singlet states decay quickly (No time for Energy transferring)
- Triplet excimer decay as follows (with Xe doping)
  - $Ar_2^* + Xe + \text{migration} \rightarrow (ArXe)^* + Ar$
  - $(ArXe)^* + Xe + \text{migration} \rightarrow Xe_2^* + Ar$
- (ArXe)* state can decay with IR light emitting (see A. Neumeier et al ***Intense vacuum ultraviolet and infrared scintillation of liquid Ar-Xe mixtures*** EPL, 109 (2015) 12001)

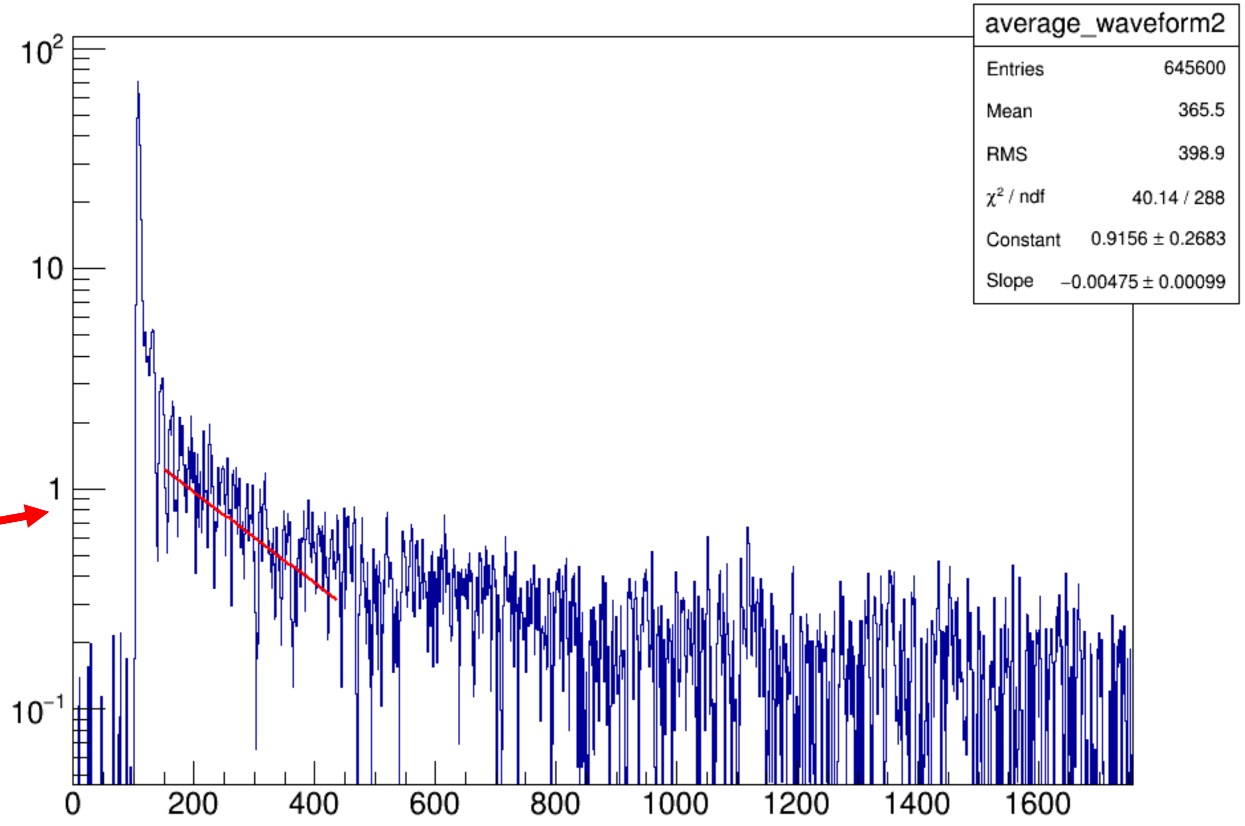
# TPB investigation
# Slow component

PRELIMINARY

~F10

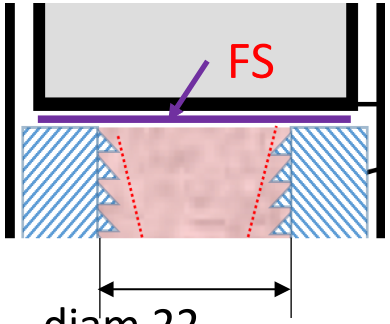



Area a.u.

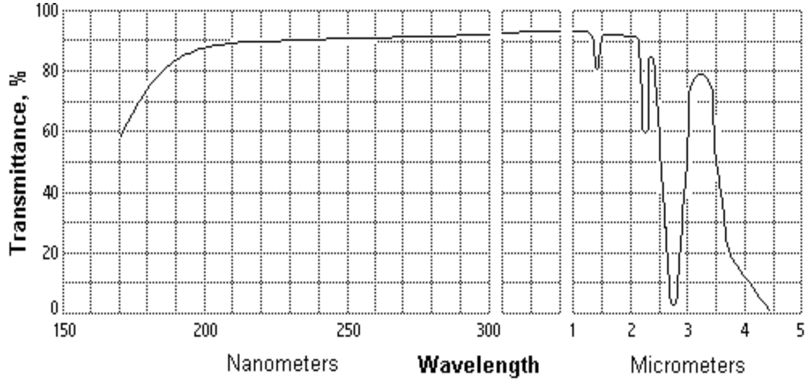


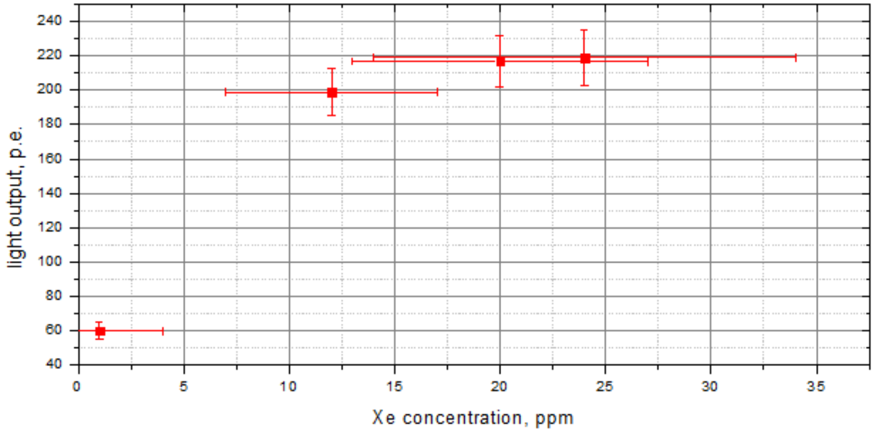

Time: *1.6 ns

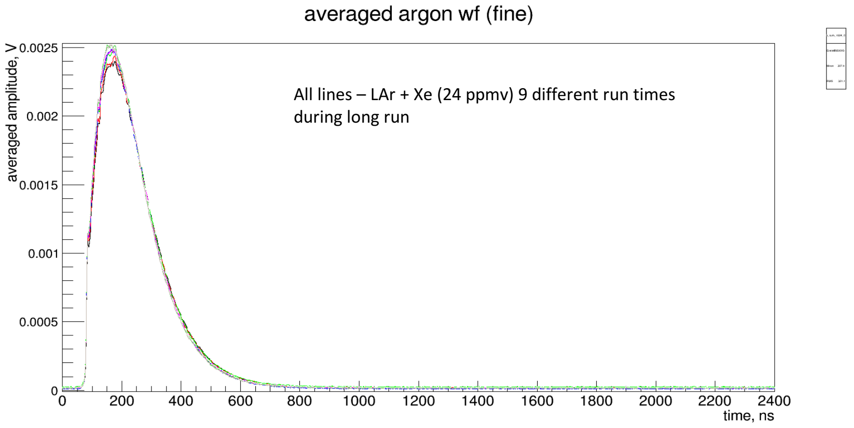
# Xe-doping
# Volume-distributed WLS




- Xe-dopant in LAr works like distributed WLS
  *O. Cheshnovsky, B. Raz, J. Jortner, J. Chem. Phys. 57 (1972) 4628.*
- The amount of collected light increasing with Xe concentration
  *A. Neumeier, et al., Nucl. Instrum. Meth. A 800, 70-81 (2015)*



# LAr+Xe mixture degradation