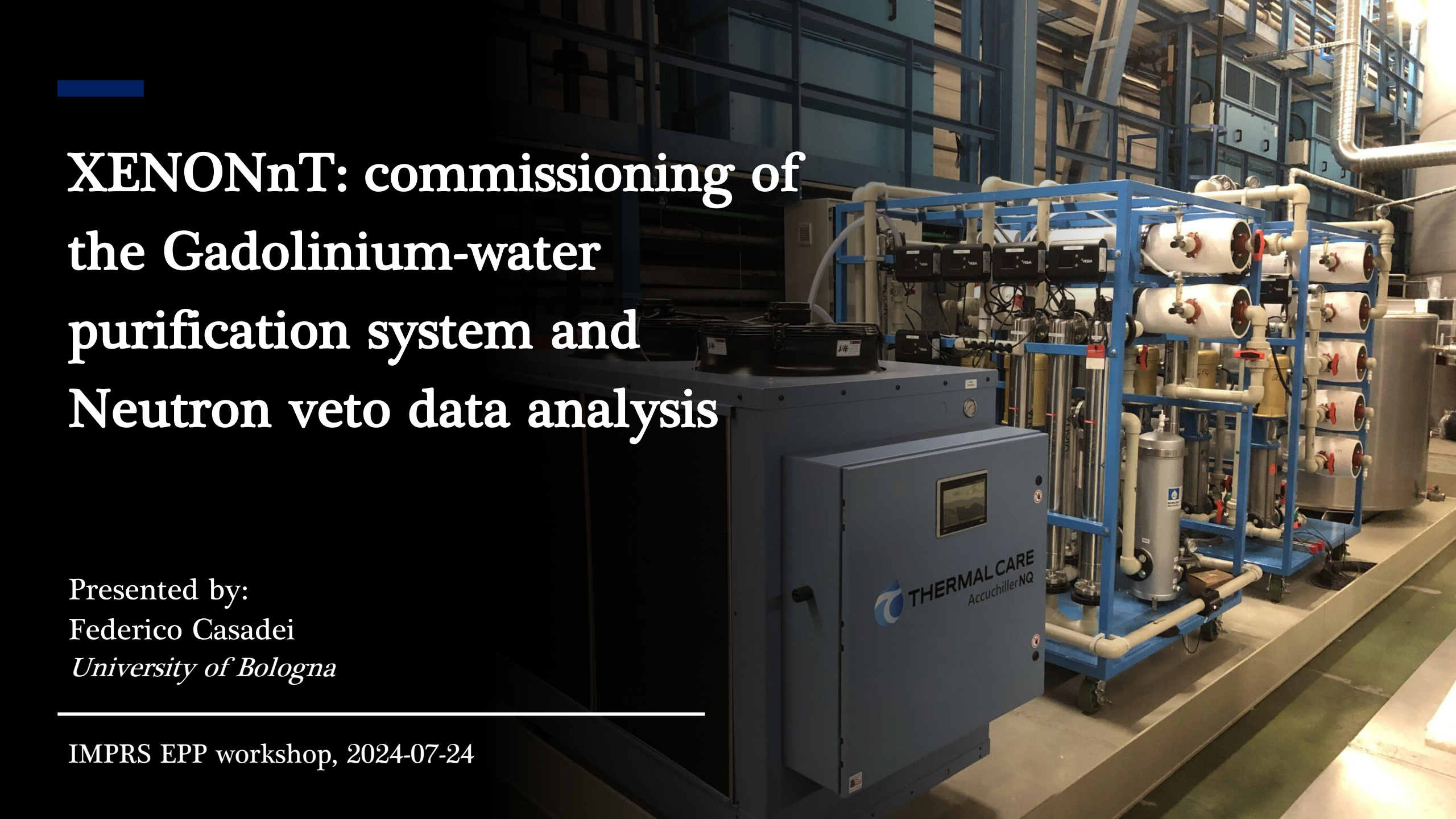
XENONnT: commissioning of the Gadolinium-water purification system and Neutron veto data analysis



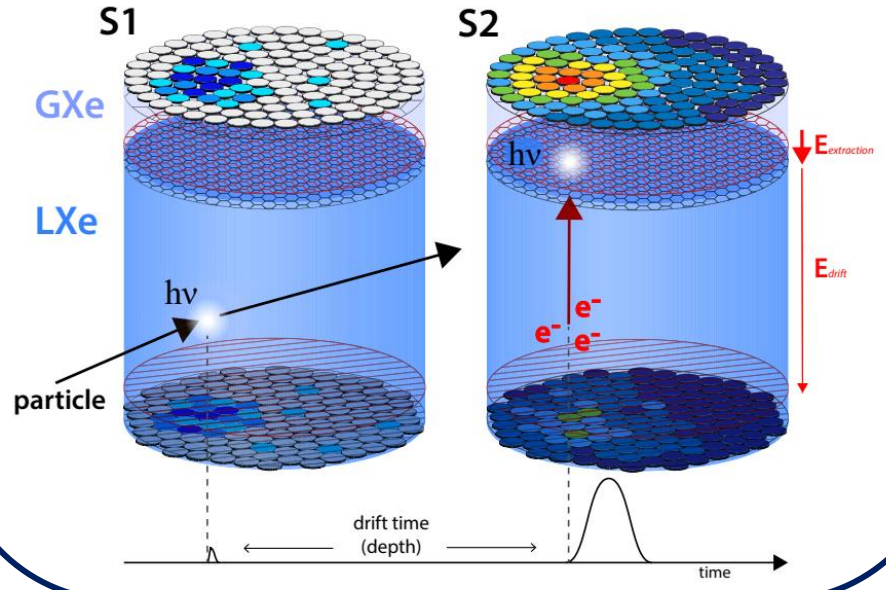
Presented by:
Federico Casadei
University of Bologna

IMPRS EPP workshop, 2024-07-24

Dark Matter search with XENONnT

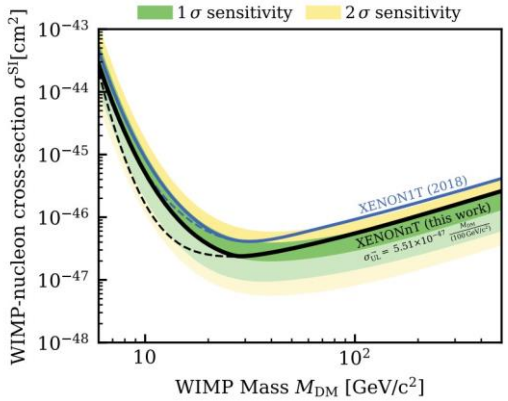
XENON project:

double-phase Xenon Time Projection Chamber
[hosted at INFN Laboratori Nazionali del Gran Sasso]

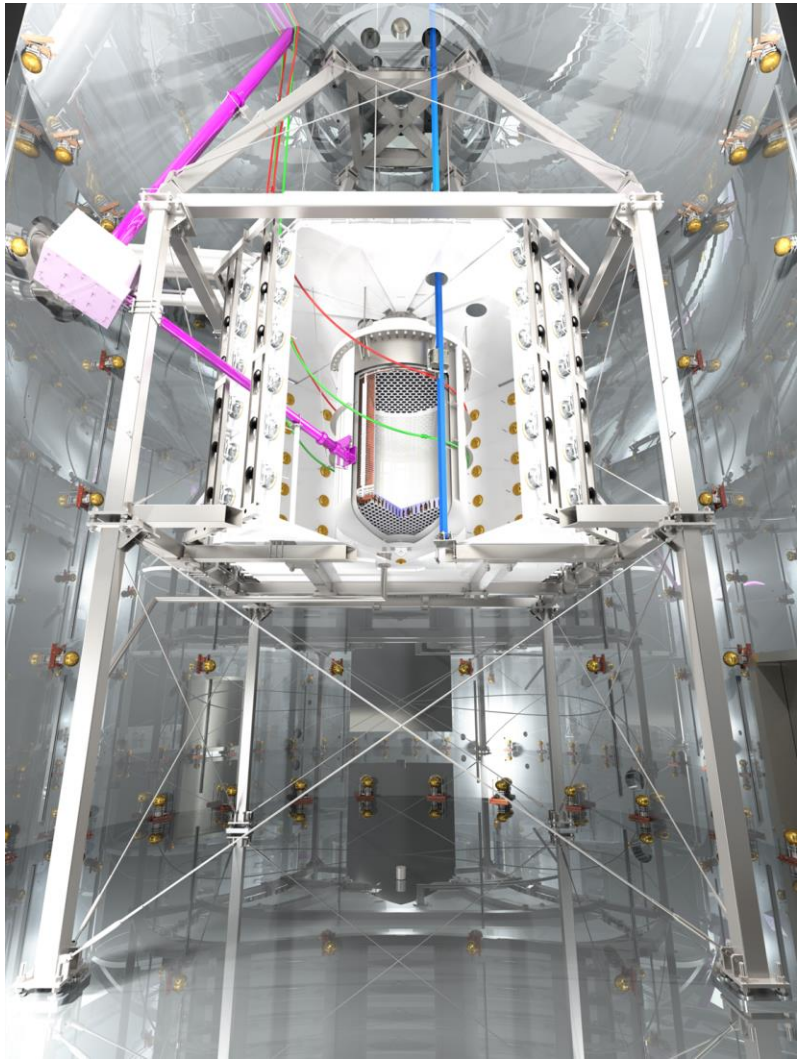


XENONnT

- 8.5 tons of liquid Xenon (5.9 tons active target)
- Nuclear Recoil / Electronic Recoil discrimination
- active Muon Veto and **Neutron Veto** systems
- search for **WIMPs**, axions, rare decays and solar neutrino



The Neutron Veto (NV) of XENONnT



- **Gadolinium-doped** water Cherenkov detector
- neutron capture followed by Cherenkov emission
- light detected by 120 PMTs used for neutron tagging
- **ultra pure water and reflective panels**, crucial for light collection

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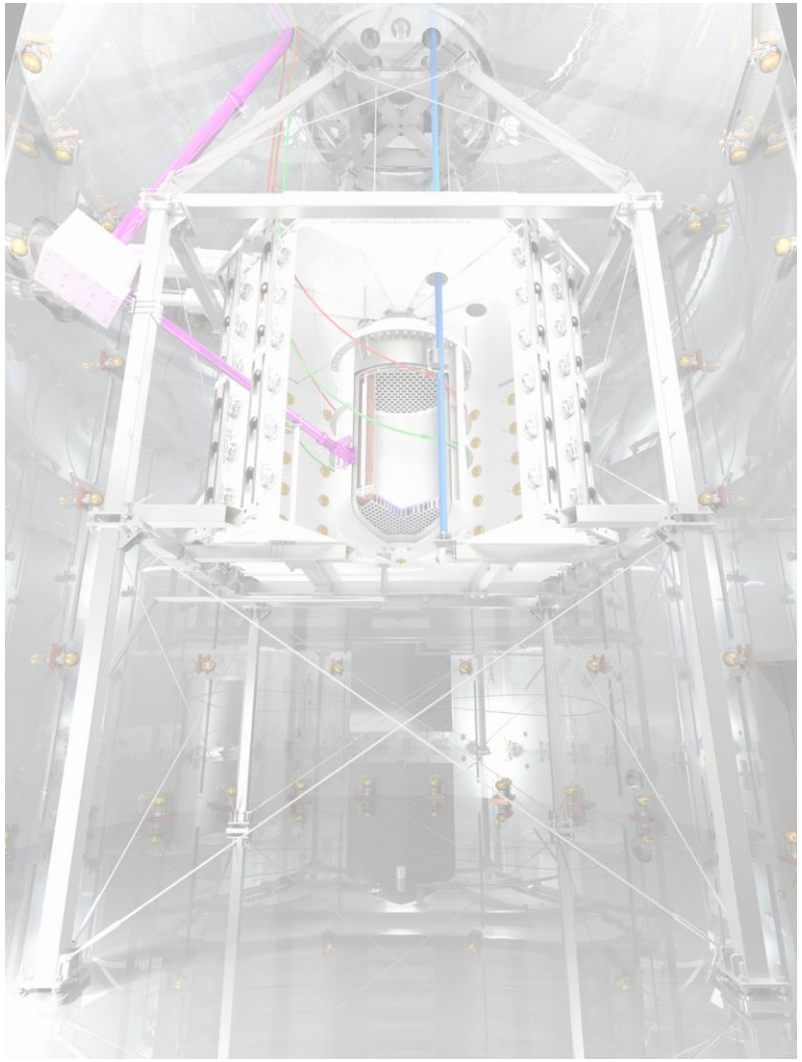

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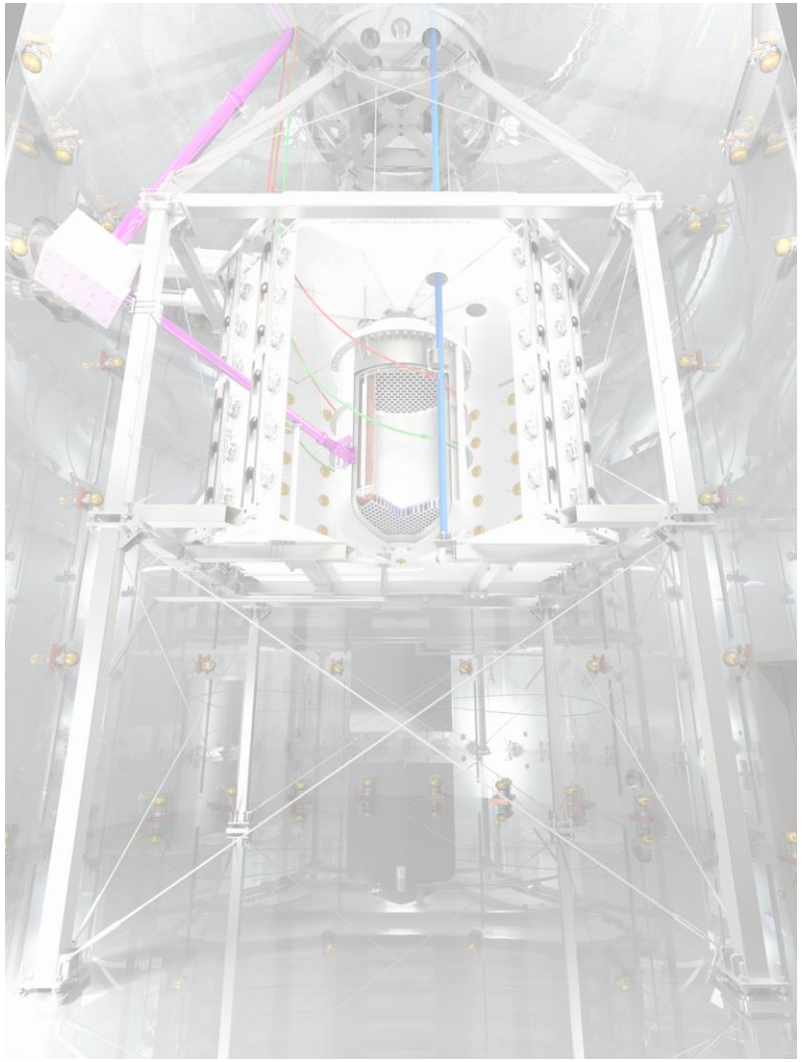

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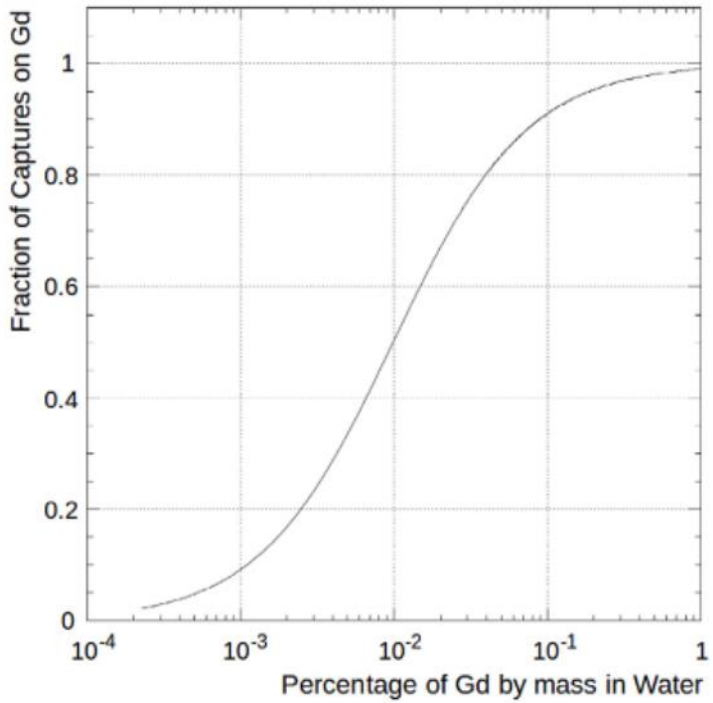
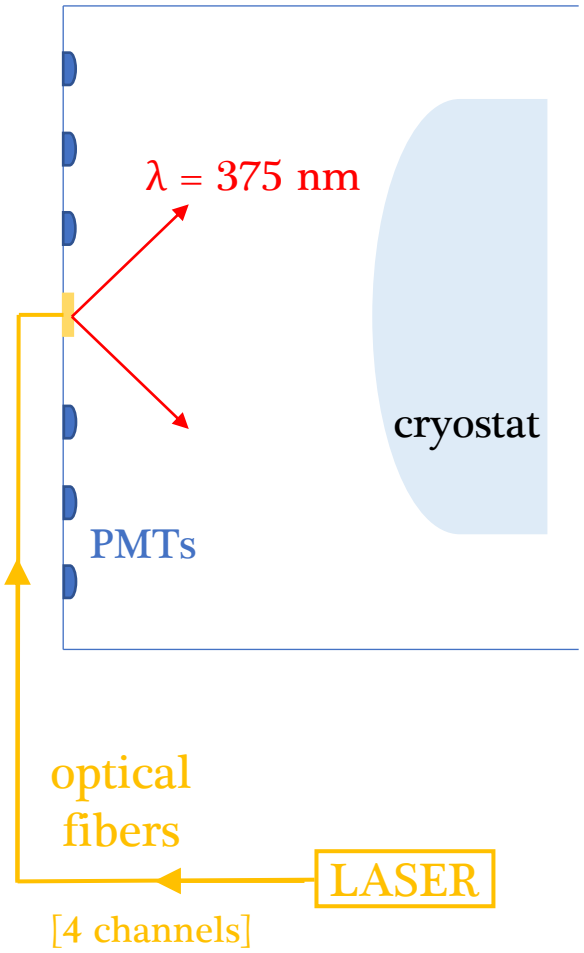
(n,γ) on Gd results in:

- lower veto dead time
- larger tagging efficiency



Neutron Veto Reflectivity Monitor



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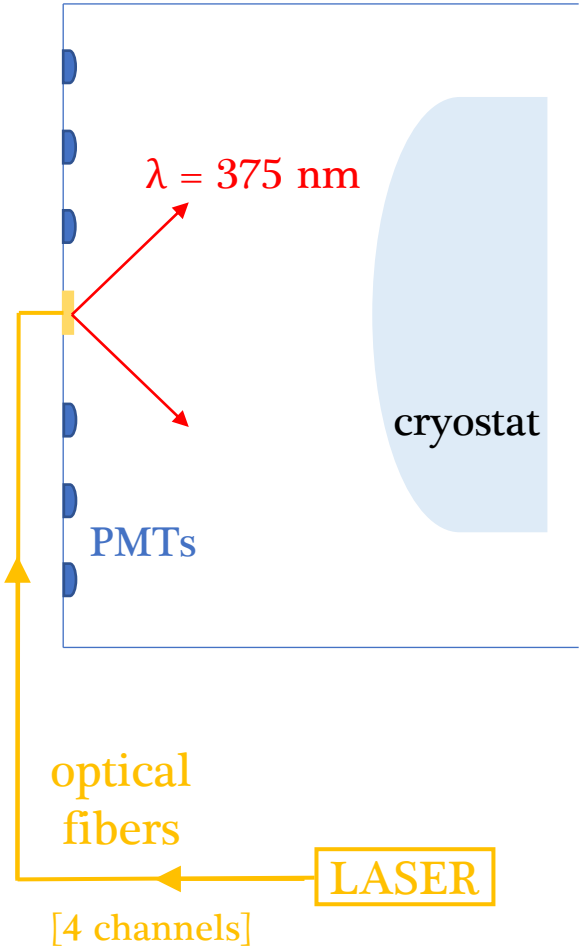
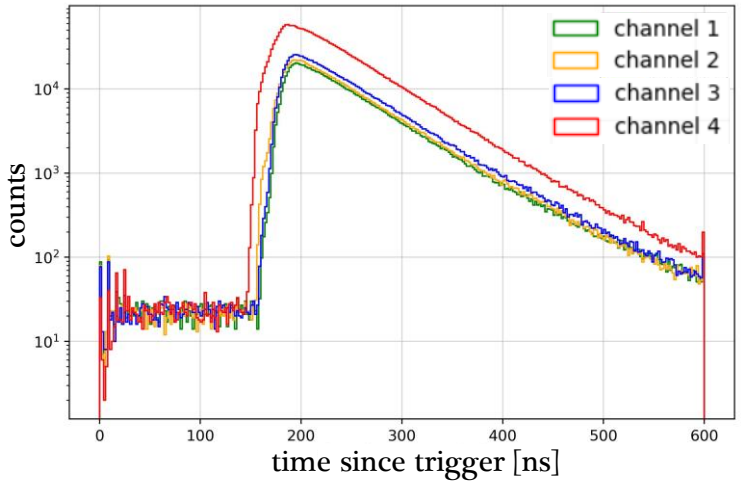


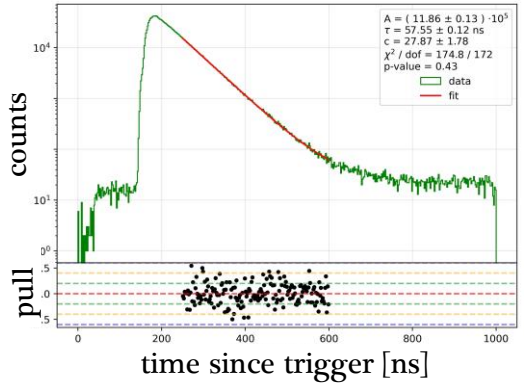
PMT hits timings are recorded; the distribution is **exponential:**



Selection cuts in:

- number of PMTs
- hits area in photoelectrons

3-parameter **fit**: $f(t) = Ae^{-t/\tau} + c$



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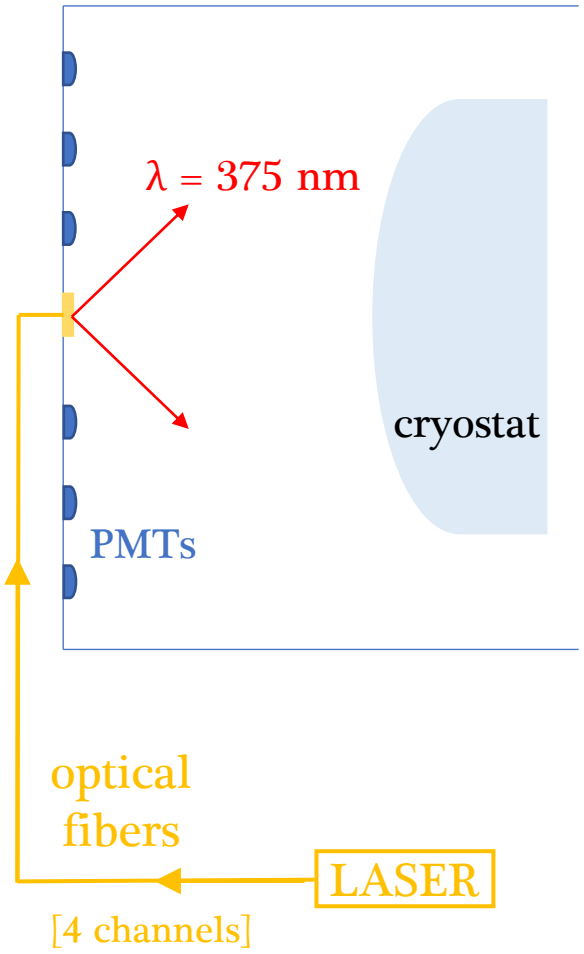

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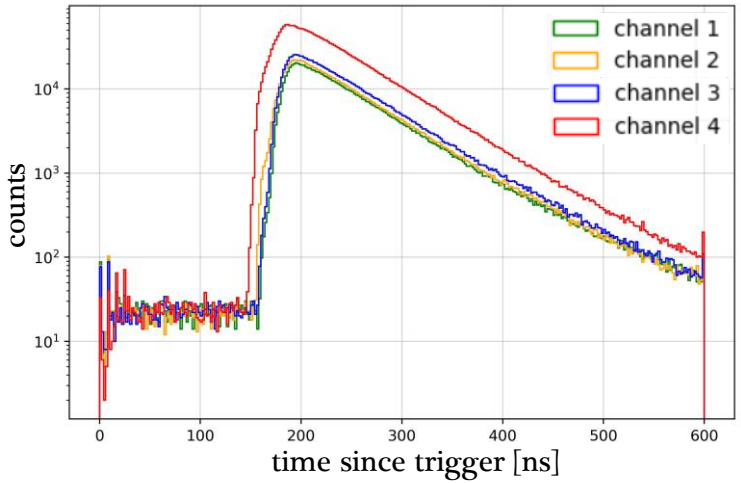

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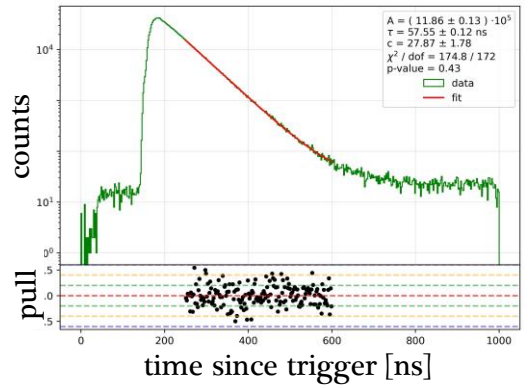
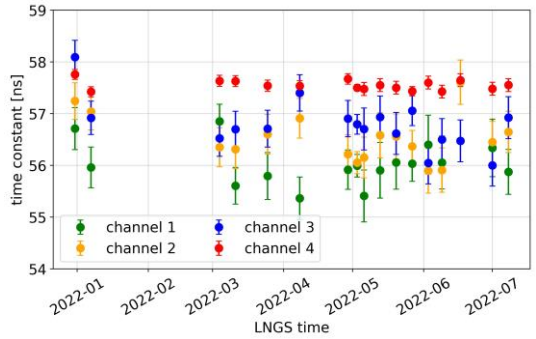


Time constant τ

(57 ± 1) ns (around 13 m path length)

- measure of the NV **optical properties**
- depends on water **transparency** and wall **reflectivity**



Simulations and background data analysis

Monte Carlo simulations

Reflectivity Monitor with background data

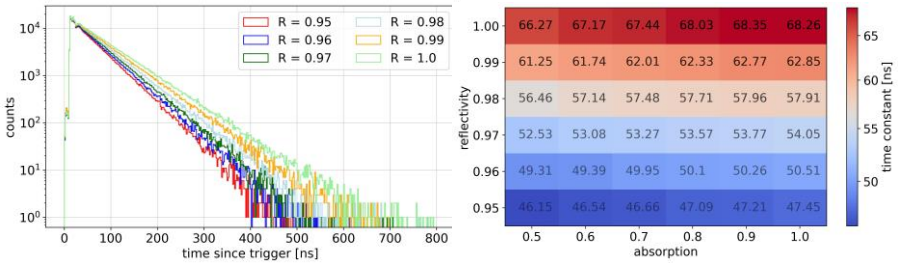
Simulations and background data analysis

Monte Carlo simulations

The time constant has three main contributions:

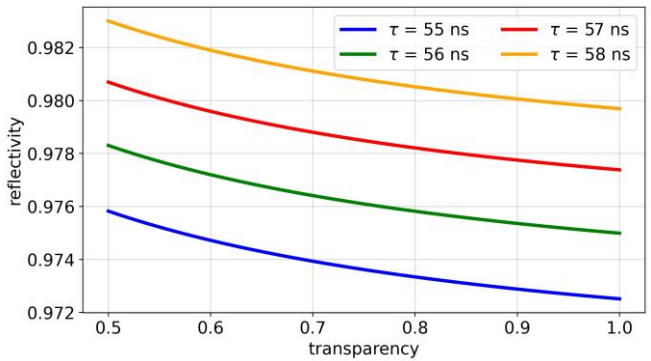
$$\frac{1}{\tau} = \frac{1}{\tau_{abs}} + \frac{1}{\tau_{ref}} + \frac{1}{\tau_{geom}}$$

Reflectivity Monitor simulations varying transparency and reflectivity



Main results:

- time constant mainly affected by reflectivity
- estimation of τ_{geom}: (70.69 ± 0.05) ns [with perfect transparency and reflectivity]



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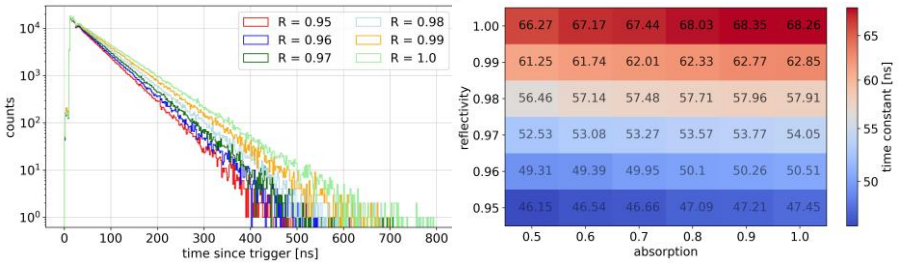

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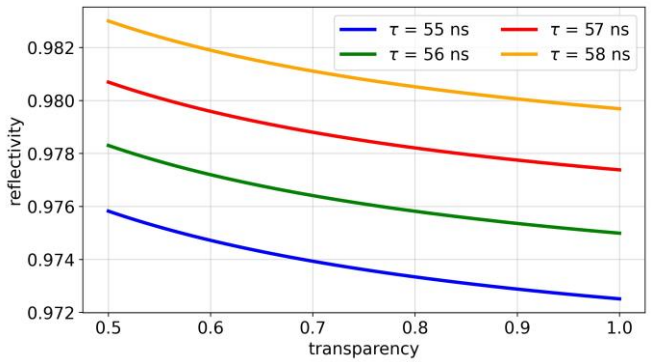
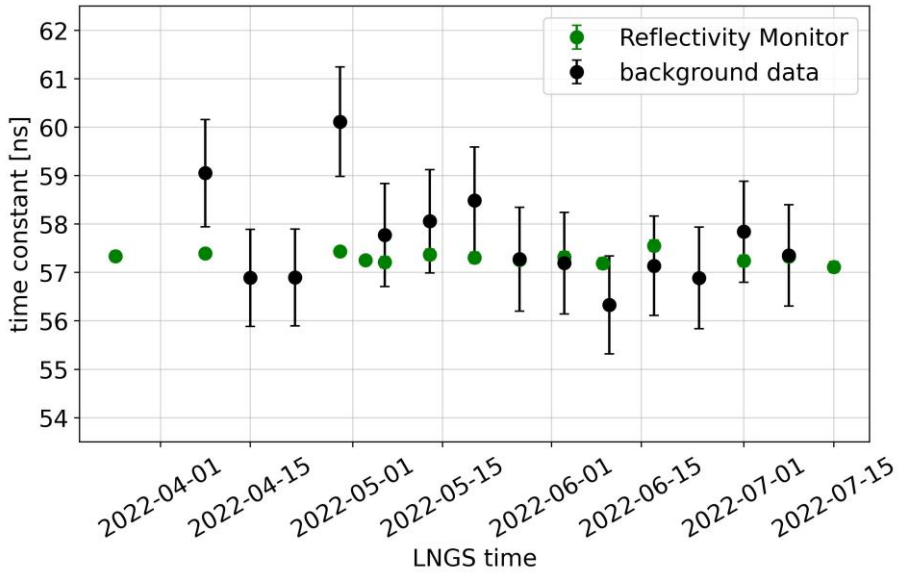


Reflectivity Monitor with background data

Important to validate the results with actual Neutron Veto data



In agreement with the Reflectivity Monitor

Gd-water purification system (GdWPS)

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Main purposes:

- **insert, dissolve** and keep a constant **concentration** of Gd sulfate
- **purify** the solution from other impurities, preserving **transparency**

Main components:

- **circulation elements** (pumps, valves, chiller, etc.)
- **Gd insertion elements**
- **purification elements** (filters, resins, etc.)
- **sensors** (pressure, density, etc.)

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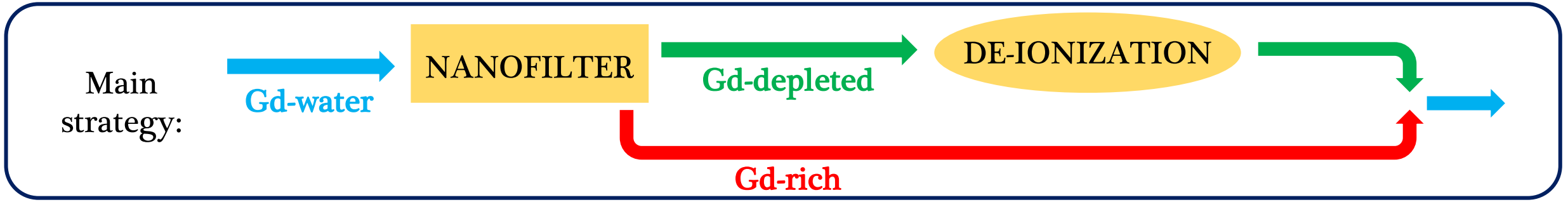


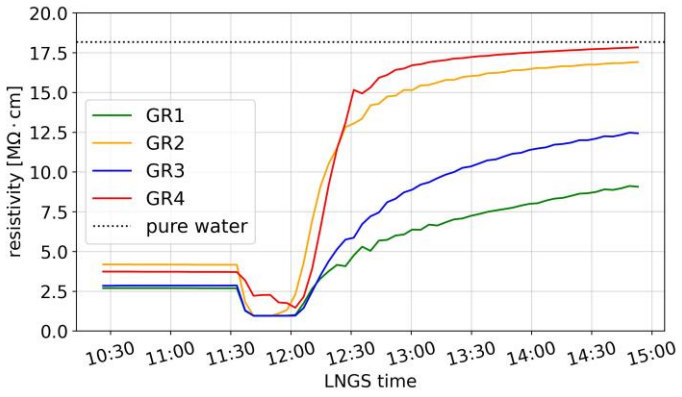
GdWPS: operation with demi water

Demi water phase

During 2022 the GdWPS operated with **demi water**:

- tests
- calibrations
- adjustments

The system reached **resistivity** close to the one of pure water (18.18 MΩ cm):



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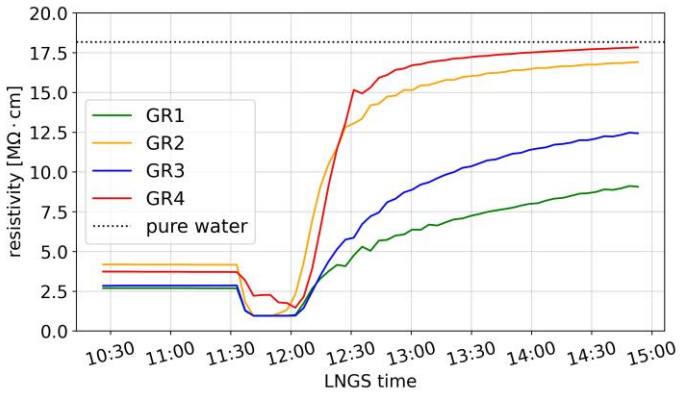
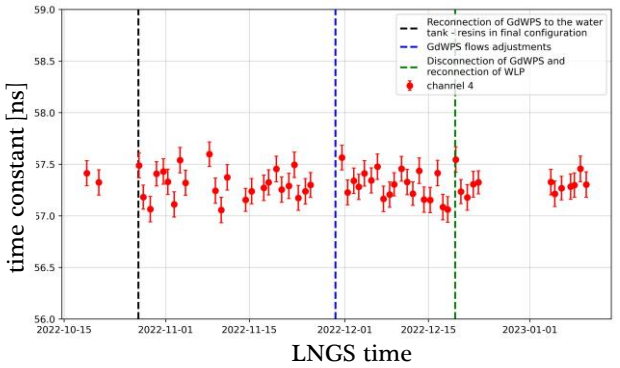
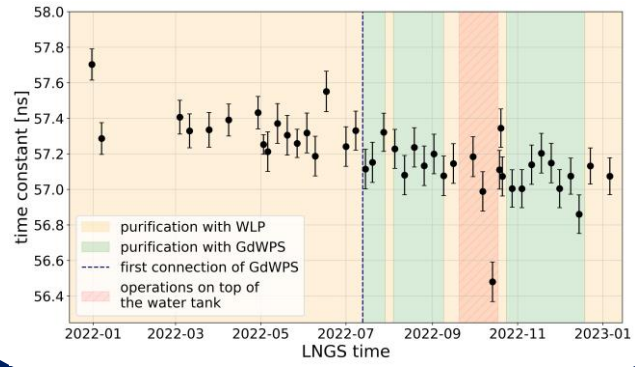


Reflectivity Monitor

Reflectivity Monitor runs detected a ~ 0.3 ns (0.5%) time constant decrease over a year





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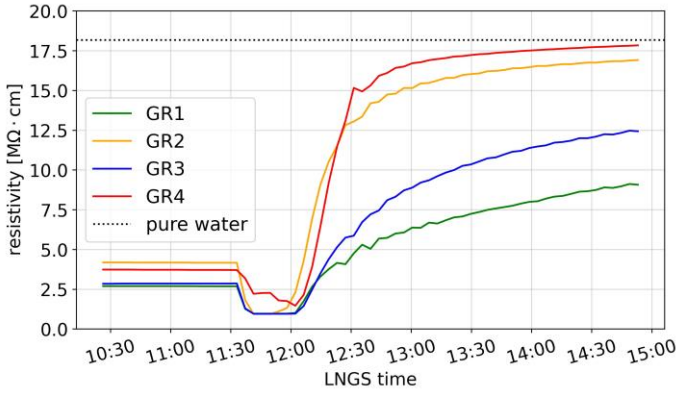

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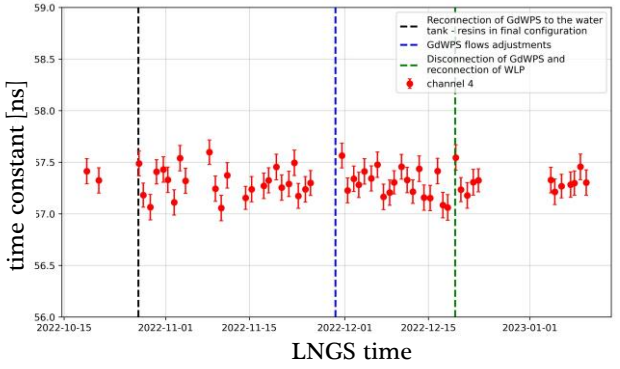
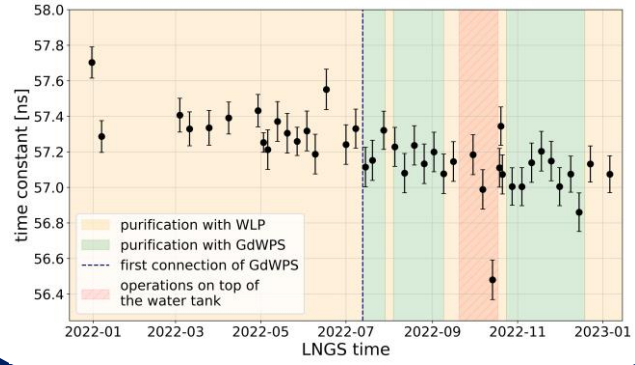
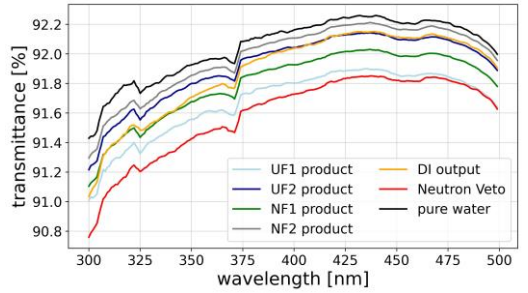
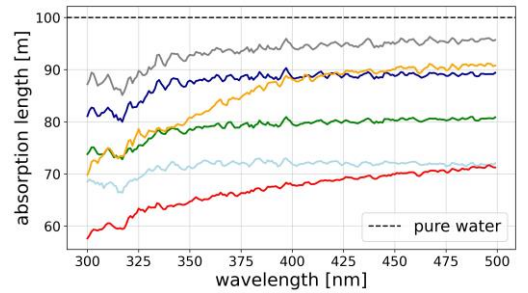




Transparency measurements

Absorption lengths > tens of meters





GdWPS: first Gadolinium insertion test

Purposes:

- test the **insertion system**
- monitor the **Gd concentration**
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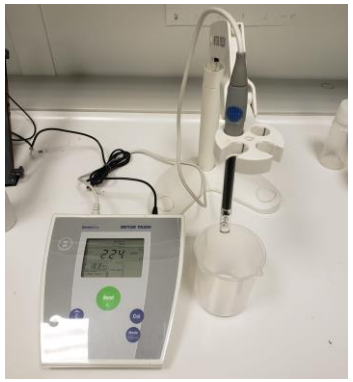
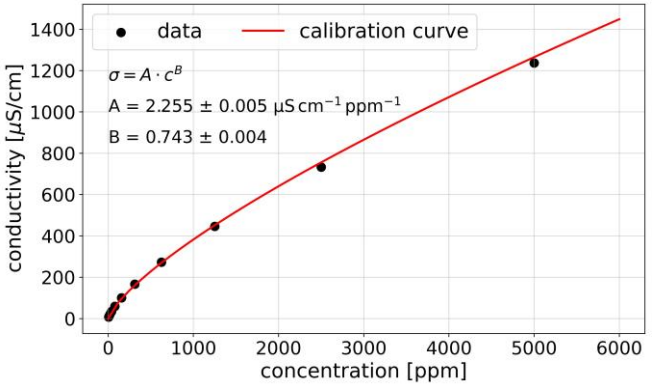
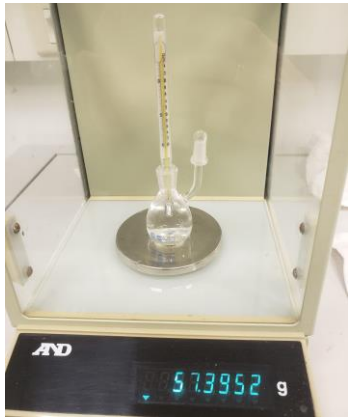
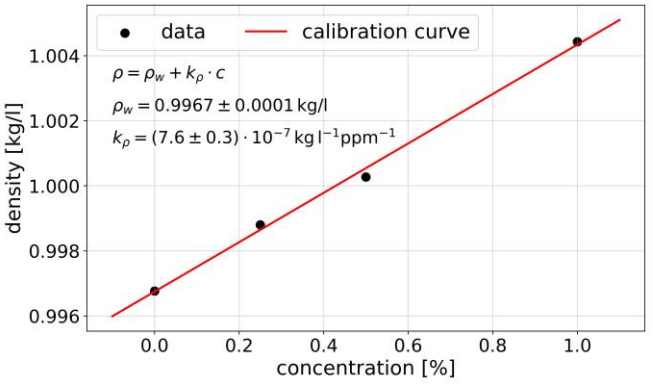




- **density:**





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Purposes:

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Plan:

insert 10 kg of Gd sulfate in three steps; an additional insertion of 5 kg has been made to reach the goal of **0.5% mass concentration**

Preliminary measurements of:

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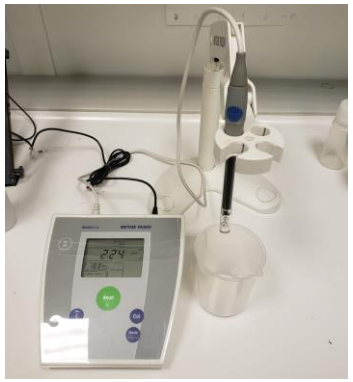

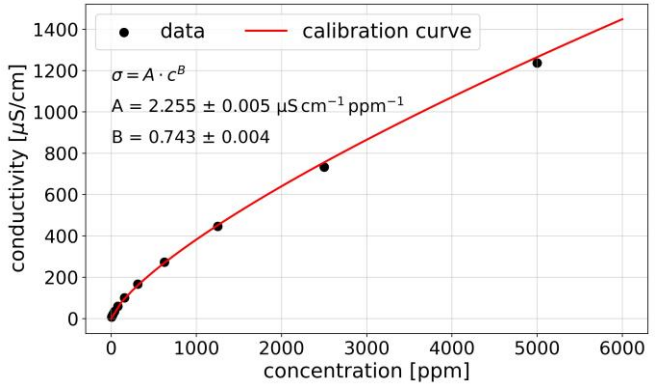

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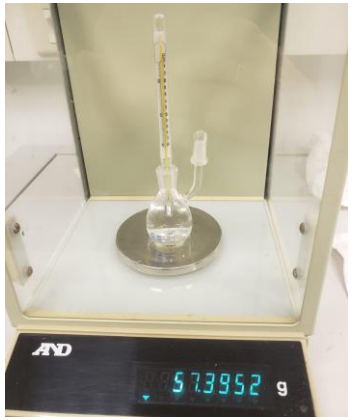

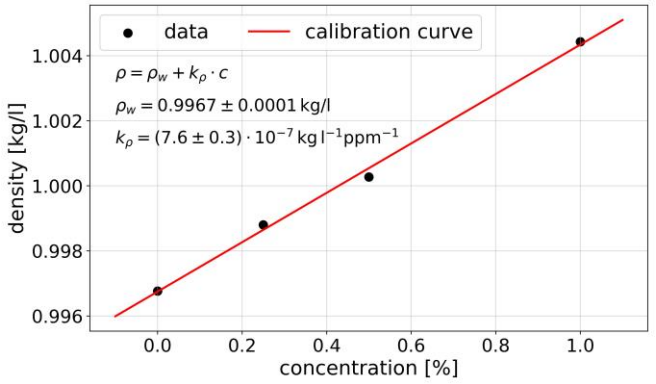

Gd insertions

Transport system connection

Gd insertions

Transport system connection → Salt insertion

Gd insertions



Transport system connection → Salt insertion → Stirrer activation

Gd insertions

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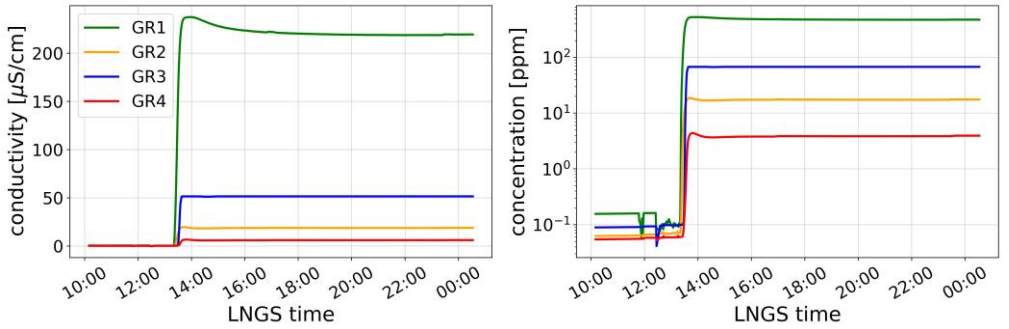
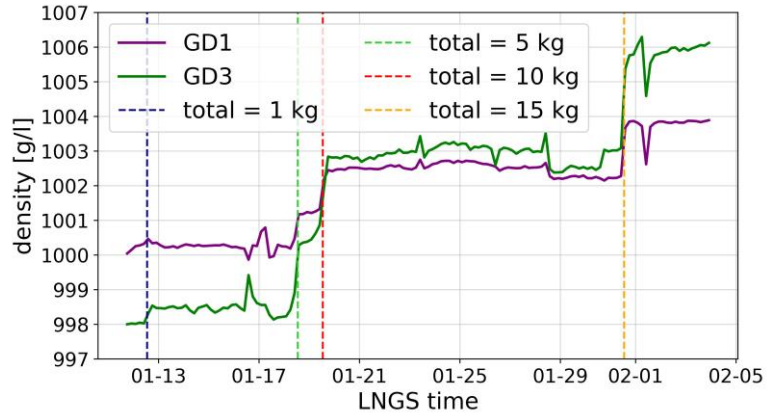
First insertion [1 kg]



conductivity increase

online concentration estimations



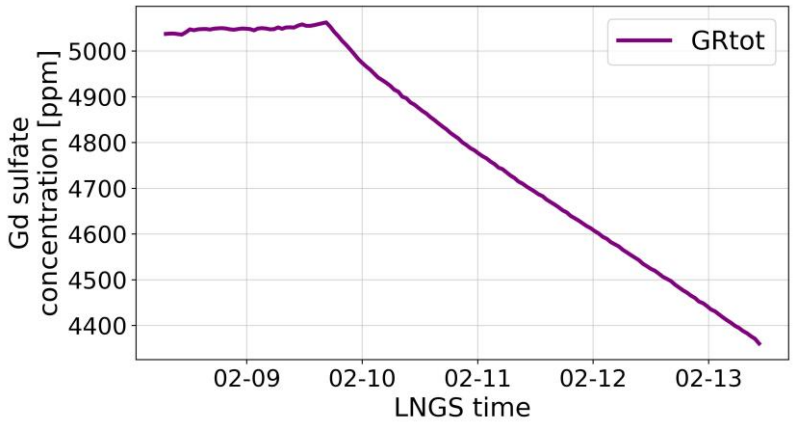
Overall density increase

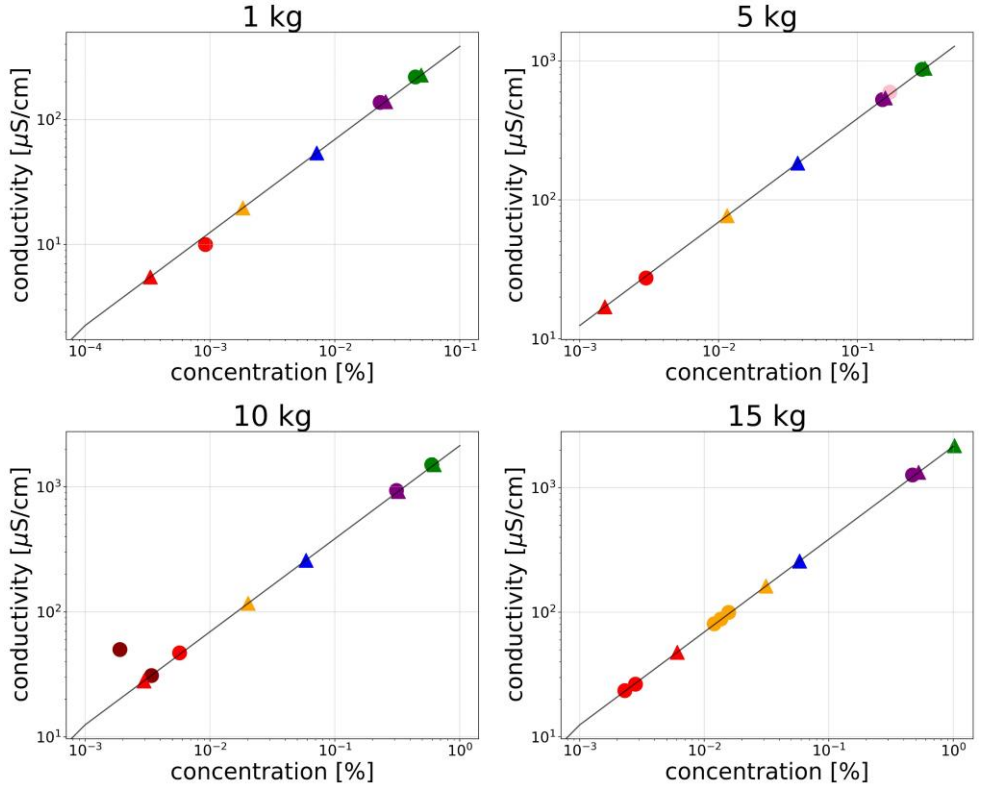
ICP-MS concentration measurements

Gd concentration measurements

- **directly**: Inductively Coupled Plasma-Mass Spectrometry (**ICP-MS**) ●
- **indirectly**: from conductivities ▲

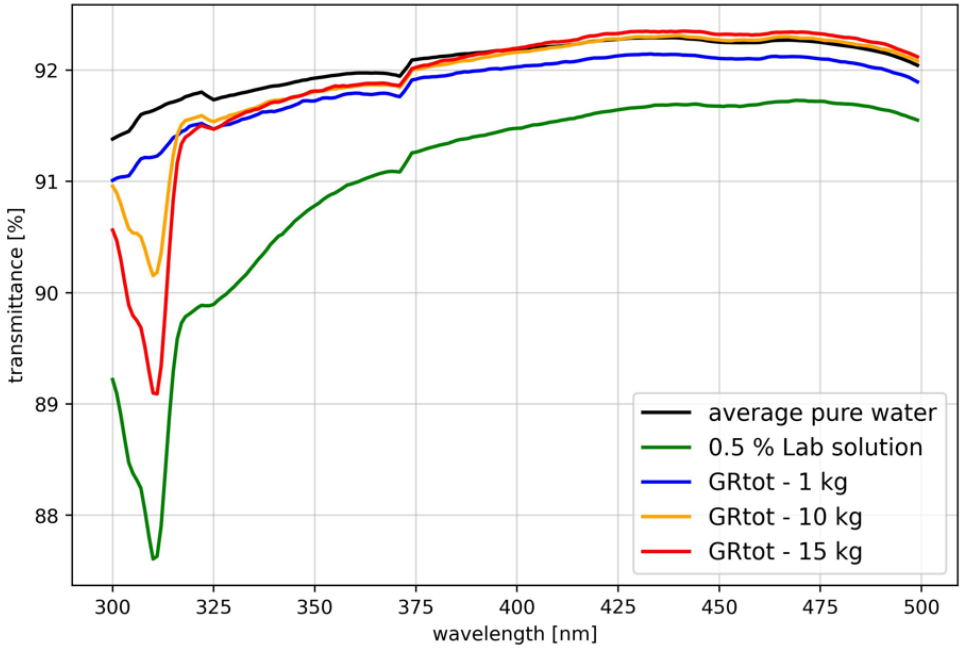
- Separation efficiency estimation: **99.6% - 99.85%**
- Gadolinium loss after De-Ionizing resin connection: **~ 600 g/day**



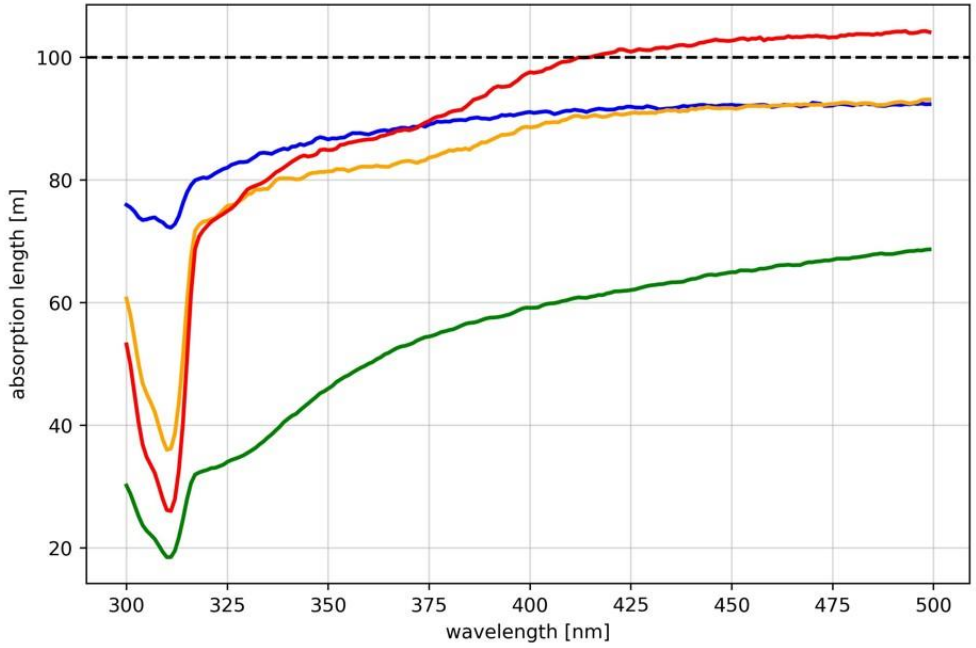


Gd-water transparency measurements

[Range of interest: 300 nm – 500 nm]



Gd-water samples from GdWPS are more transparent than solutions prepared in laboratory



The absorption lengths are still > tens of meters

Conclusions

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Reflectivity Monitor

- **photon absorption time** (in demi water) measure
- **Monte Carlo simulations** estimating the **geometric time constant**
- analysis on **NV background data** to validate the results

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- efficient purification, reaching **resistivities** close to the one of pure water
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First Gd insertion test

- efficient **insertion and dissolution systems**
- online **concentration** estimation
- **acceptable Gd loss rate**
- **transparency** still in agreement with Neutron Veto requirements

Presented by:
Federico Casadei

Alma Mater Studiorum – University of Bologna