Naples LEGEND Group
Activities foreseen in 2025

2024, Sep 5th

N. Canci on behalf of Naples LEGEND Group

LEGEND Experiment

LEGEND-Experiment: Activities foreseen at INFN-Naples

Main Involvement in the Experiment

- LEGEND-1000 detector is provided of an instrumented outer liquid argon veto to reject cosmogenic backgrounds
- Based on the expertise and the know-how the Naples group will be mainly involved on the Instrumentation and Characterization of the Outer Liquid Argon Detector of the LEGEND-1000 Experiment
- Liquid argon VUV scintillation light needs to be converted to be detected
- Xe-doping argon represents a viable and efficient solution to this purpose
- Activities on study of features of Xe-doped LAr are foreseen at INFN-Naples
- Multi-phase approach will be perfomed towards the integration of a Xe-doping system on the LEGENDArY prototype and then to the full detector
- Procurement of equipment and devices are needed to commission the system and perform tests and measurements

- Participation to LEGEND-200 experiment with duties agreed within the Collaboration: theoretical studies, shifts, analysis

LEGEND-1000 Experiment

LEGEND-Experiment: Activities foreseen at INFN-Naples

Main People Involved

Name	Position	Main Skills	FTE
N. Canci	INFN Technologist	Liquified noble gases technology, WLS coating, cryogenics and purification, photosensor characterization	0.5
G. De Gregorio	Researcher UniCampania	Phenomenological and theoretical aspects of double beta decay with Germanium detectors	0.2
F. Di Capua	Associate Professor UniNA	Liquid argon technology, photosensor characterization, radiation hardness	0.3
L. Favilla	PhD Student Sc Sup Merid	Data analysis and data taking	0.2
A.O.M. Iorio	Associate Professor UniNA	Data analysis, statistics, simulations	0.2
B. Rossi	INFN Researcher	Liquified noble gases technology, photosensor characterizazion at room and low temperature, data analysis	0.2
			Total 1.6

Other colleagues already expressed some interest in collaborating

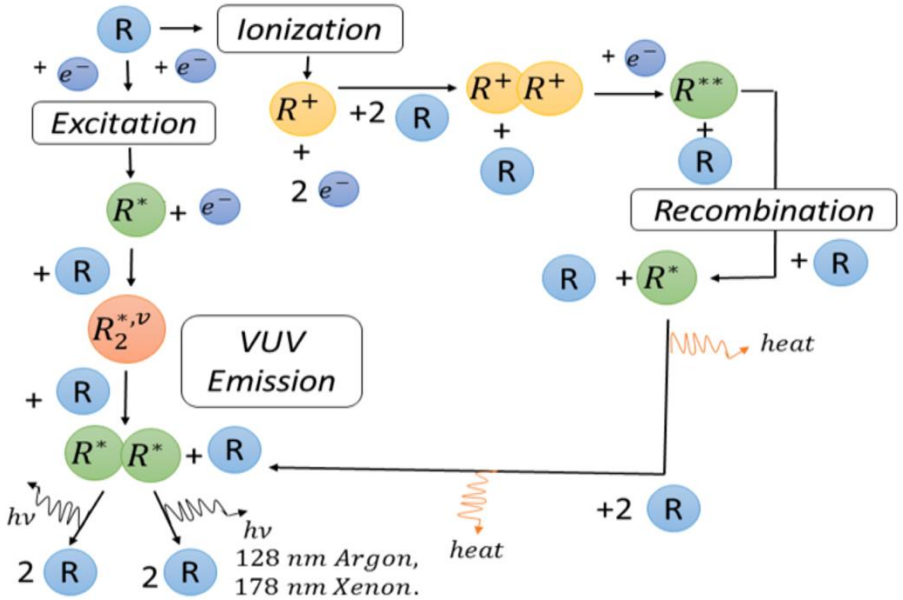
LEGEND-1000 Experiment

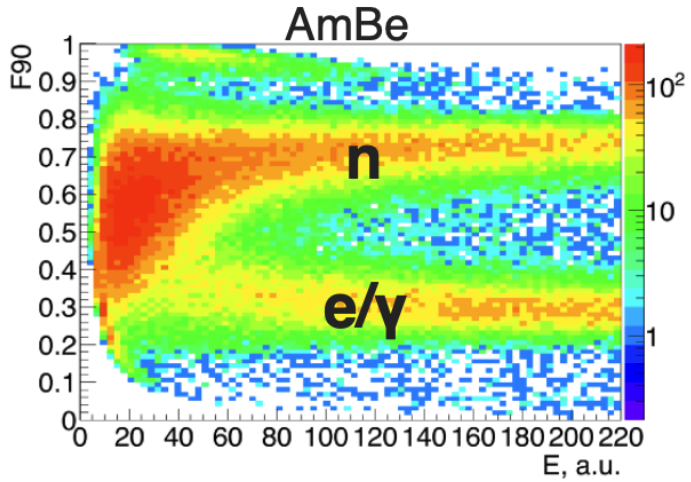
LEGEND-1000: Activities foreseen at INFN-Naples

Studies on scintillation light of the Xe-doped Liquid Argon

- Liquid argon used as detection medium in particle physics and rare-event searches
- High stopping power for ionizing radiation and high photon yield ~50 γ/keV
- Scintillation time structure with a fast emission component (singlet state excimer decay) of 6-10 ns and a slow component (decay of triplet state excimers) of 1300-1600 ns
- Excellent pulse shape discrimination (PSD) performance between electronic and nuclear recoils

- Scintillation light in the VUV range at 128 nm
- VUV light needs to be converted
- Use of wavelength-shifter (WLS) materials (TPB, PTP, PEN, etc.) from VUV to Vis





LEGEND-1000 Experiment

LEGEND-1000: Activities foreseen at INFN-Naples

Xe used as WLS for Liquid Argon Scintillation Light

- Detection improvement of primary scintillation light
- Good volume uniformly distributed WLS
- Re-emission at the point of interaction
- Pure gas and re-purified
- Reduction of LAr sensitivity to scintillation quenching by impurities
- Increase of Rayleigh scattering length
- Shorter scintillation time
- Improved LY
- Better resolution
- Charge yield increase (10–15%)
- PSD restored with high Xe concentrations

- No additional constructions inside the detector
- Common reflectors and photodetectors

- T_{LAr}=87 K T_{LXe}=165 K

Property	Argon	Xenon
Scintillation wavelength	128 nm	178 nm
Kinetic Match to Light Particles	A = 39.95	A = 131.29
Liquid phase ionization energy	14.3 eV	9.28 eV
Excitation Energy	11.8 eV	8.4 eV
Scintillation lifetime	1.5 us	22 ns
Price	Cheap	Expensive

Pure Argon Time Evolution

$$r = I_1 e^{-t/T_f} + I_2 e^{-t/T_s}$$

Xenon-doped Argon Time Evolution

$$r = I_1 e^{-t/T_f} + I_2 e^{-t/T_s} - I_3 e^{-t/T_{df}} - I_4 e^{-t/T_{ds}}$$

LEGEND-1000 Experiment

LEGEND-1000: Activities foreseen at INFN-Naples

Xe-doped Liquid Argon Scintillation Light: processes

Fast e- + Ar → slow e- + Ar*

Threshold 11.8 eV

Fast e- + Xe → slow e- + Xe*

Threshold 8.4 eV

Example: Electrons inelastically colliding with xenon or argon

$Ar^* + Ar \rightarrow Ar_2$

$Ar^* + Xe \rightarrow ArXe$

$Xe^* + Xe \rightarrow Xe_2$

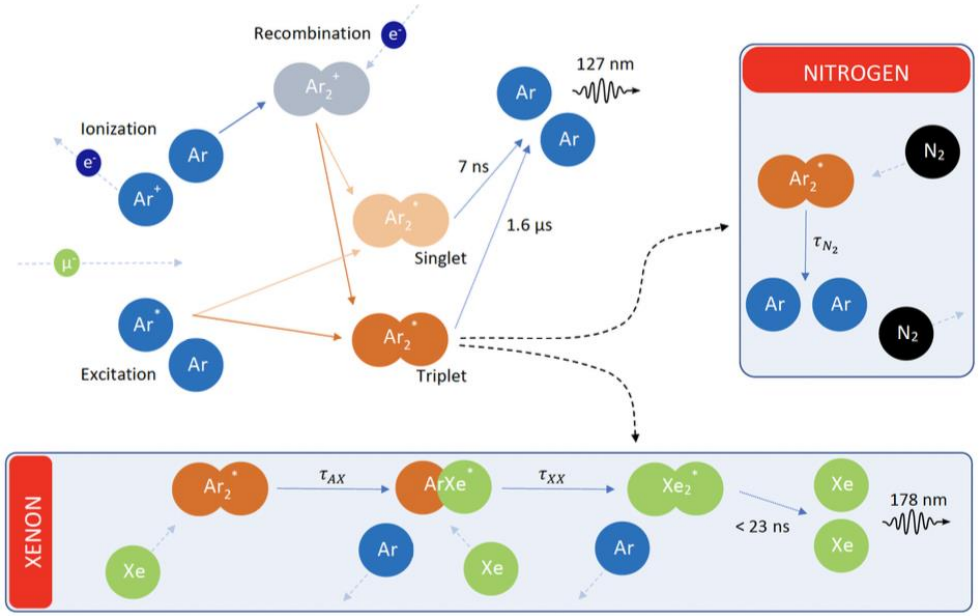
Argon and xenon form metastable excimers

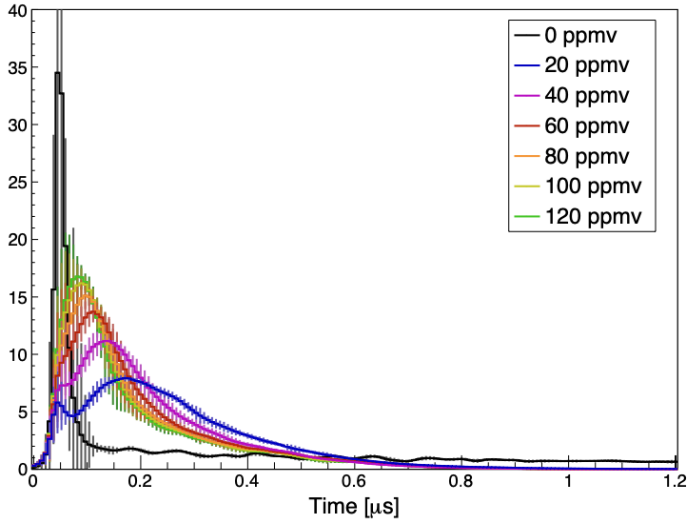
$Ar_2 \rightarrow 2\,Ar + h\nu$ (128 nm, 1.6 us)

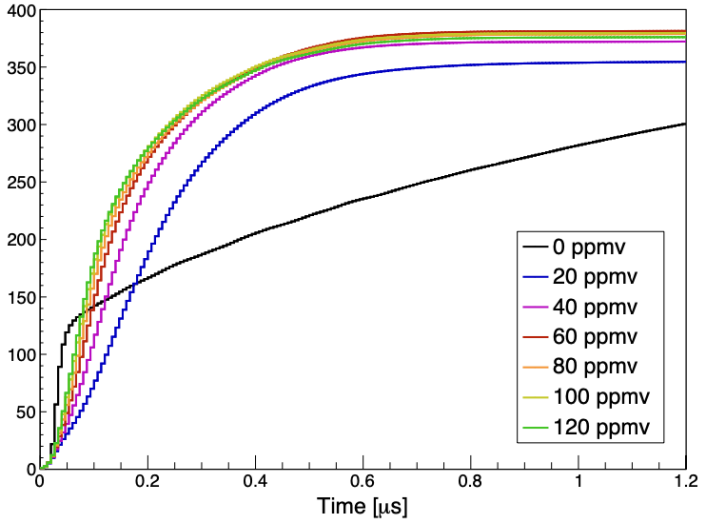
$ArXe \rightarrow Xe + Ar + h\nu$ (147 nm, ~300 ns(?))

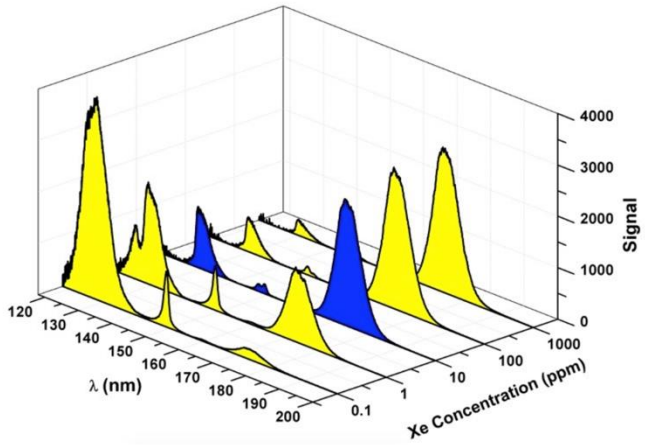
$Xe_2 \rightarrow 2\,Xe + h\nu$ (178 nm, 22 ns)

Excimers decompose and release scintillation light









Neumeier et al., EPL 109 12001 (2015)

Several measurements perfomed with the aim to study the Xe-Ar process

LEGEND-1000 Experiment

LEGEND-1000: Activities foreseen at INFN-Naples

Xe-doped Liquid Argon Scintillation Light: phases of the study

Phase 1:
Study of the Parameters of purified LAr

Decay time constants
Relative intensities
Light Yield
Purity

Phase 2:
Design and put in operation of Xenon doping system

Production and assembly of Xe injection system
Checking for thermodynamics and solubility
Monitoring of doping amount with capacitance and RGA

Phase 4:
Long term stability Xe-doped LAr

Decay time constants
Pulse shape discrimination
Light Yield stability
Purity

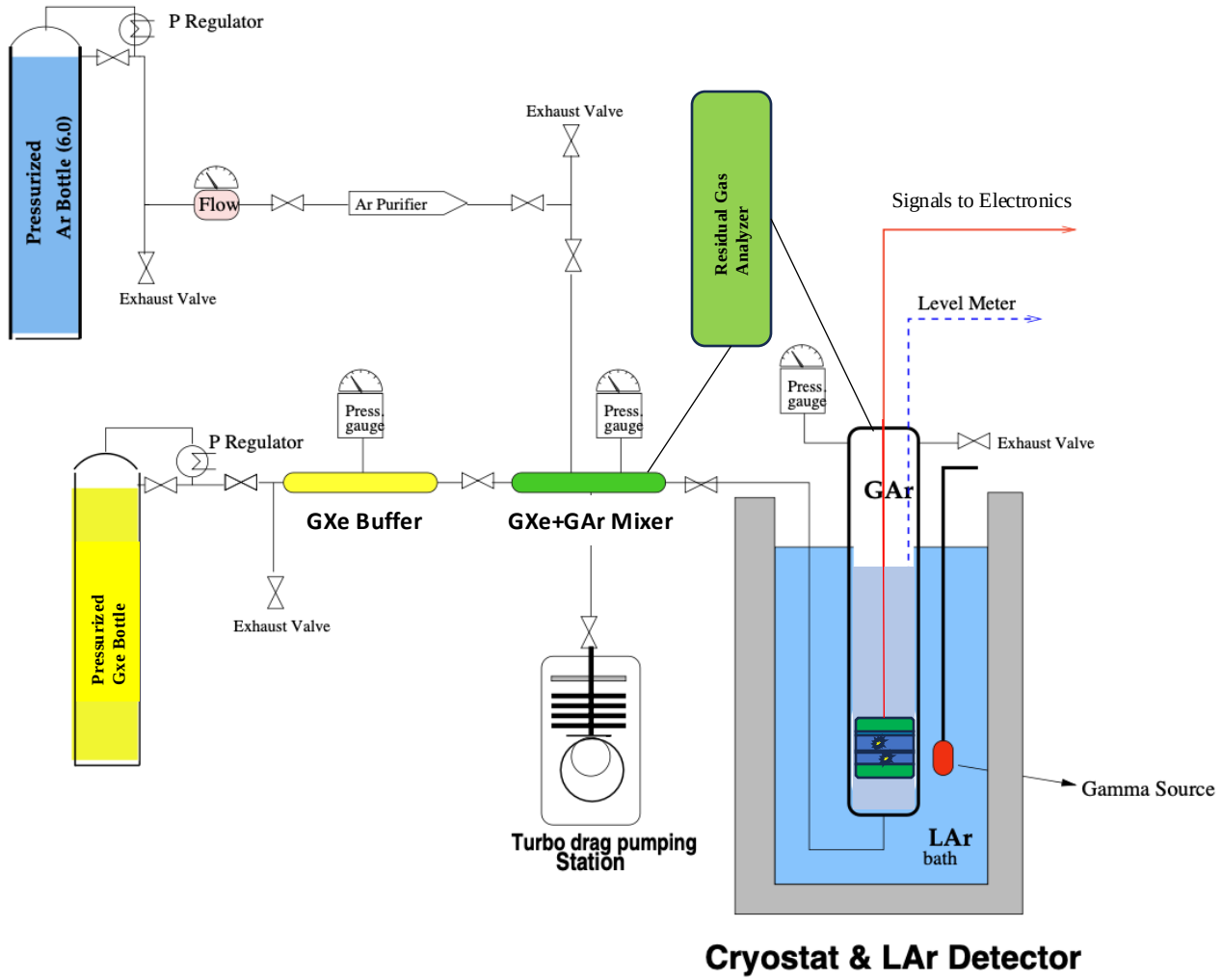
Phase 3:
Xenon doping and measurement of concentration in LAr

Concentration through LAr/LArXe
Decay time constants modification
Relative intensities due to the doping
Light Yield improvement
Purity

LEGEND-1000 Experiment

LEGEND-1000: Activities foreseen at INFN-Naples

Xe-doped Liquid Argon Scintillation Light: concept design of the system



Different Condensation Temperatures:

- Need of a dedicated cryogenic system
- Avoid Xe freezing

Measurements of [Xe] concentration:

- Use of Residual Gas Analyzer to measure the [Xe] content in the mixer and evaporated gas mixture
- Measurement of pure LAr/Xe-doped LAr capacitance

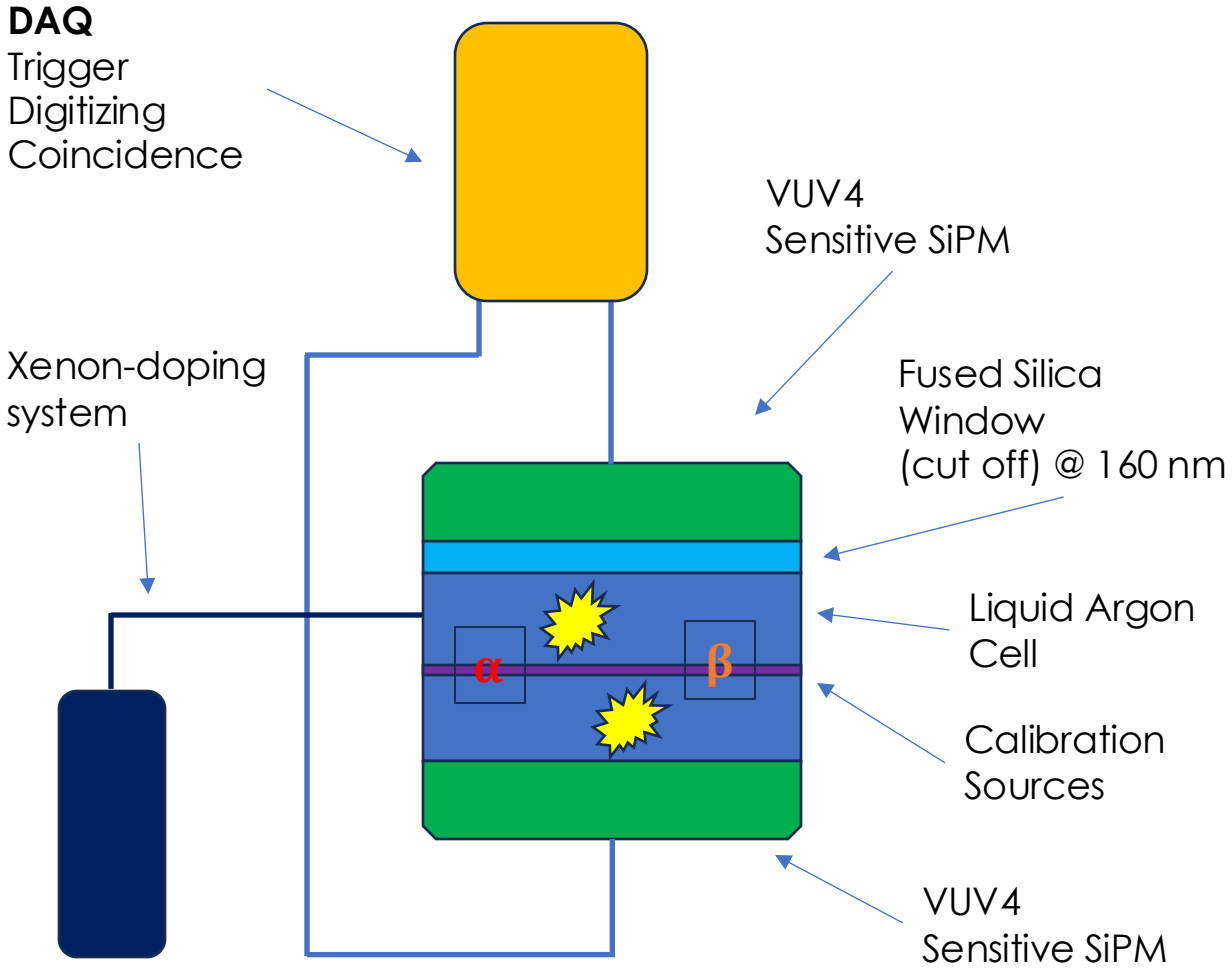
Other types of inspections:

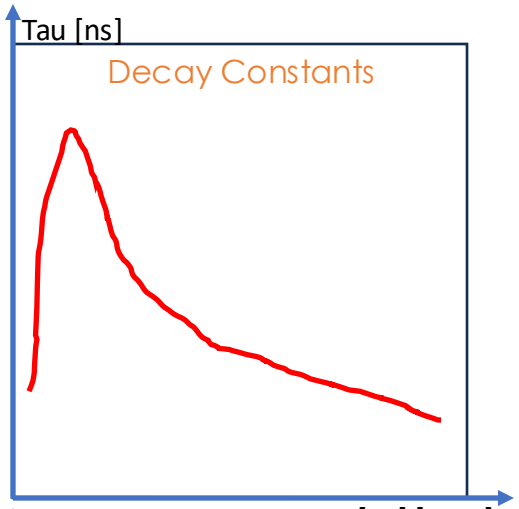
- Use of camera inside the detector
- Measurement of temperature gradient profiles

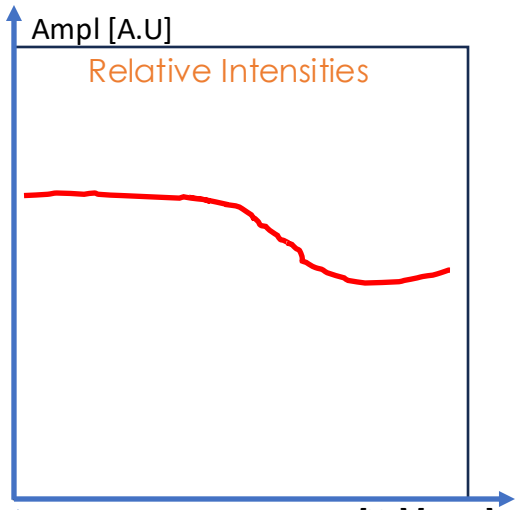
LEGEND-1000 Experiment

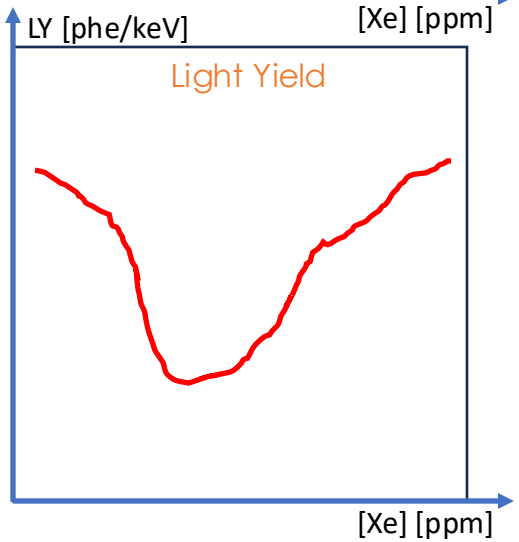
LEGEND-1000: Activities foreseen at INFN-Naples

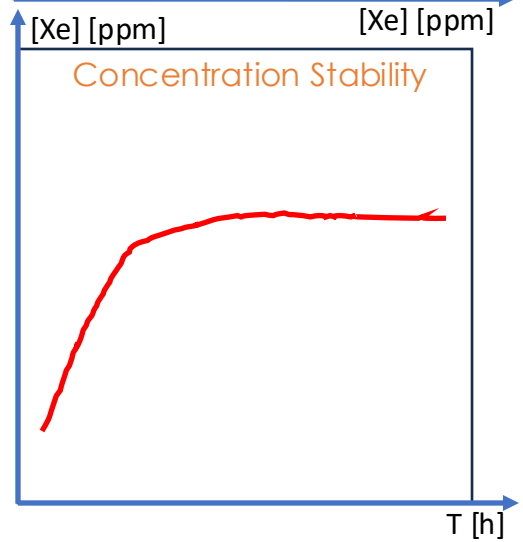
Xe-doped Liquid Argon Scintillation Light: concept design of the system and measurements











LEGEND Experiment

LEGEND-Experiment: Activities foreseen at INFN-Naples

Request of funds to CSN2 for the year 2025

Construction of the system to perform studies and tests (Phase 1 and preliminary Phase 2)

- Study and optimization of the liquid argon scintillation properties and comparison with xenon-doped liquid argon
- Design, production and operations of a dedicated criogenic system for liquid argon mainly composed by:
  - Cryostat
  - Gas panel for argon purification and recirculation
  - Small test chamber
  - Pumping station
  - Pressure transducers, vacuum gauges and pressure and vacuum monitors
  - Liquid argon (low purity < 5.0)
  - Gaseous argon (high purity 6.0)
  - Gasoues xenon
- Preliminary studies of the xenon concentration in liquid argon

- Theoretical studies on double beta decays with germanium

- Participation to LEGEND Meetings and working groups
- Participation to test activities on prototypes and test runs

LEGEND-1000 Experiment

LEGEND-1000: Activities with participation of INFN-Naples

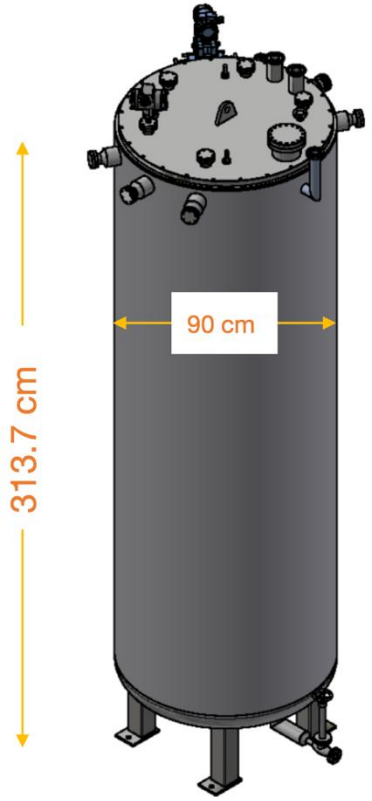
Xe-doped Liquid Argon Scintillation Light: Integration in the LEGENDArY Prototype

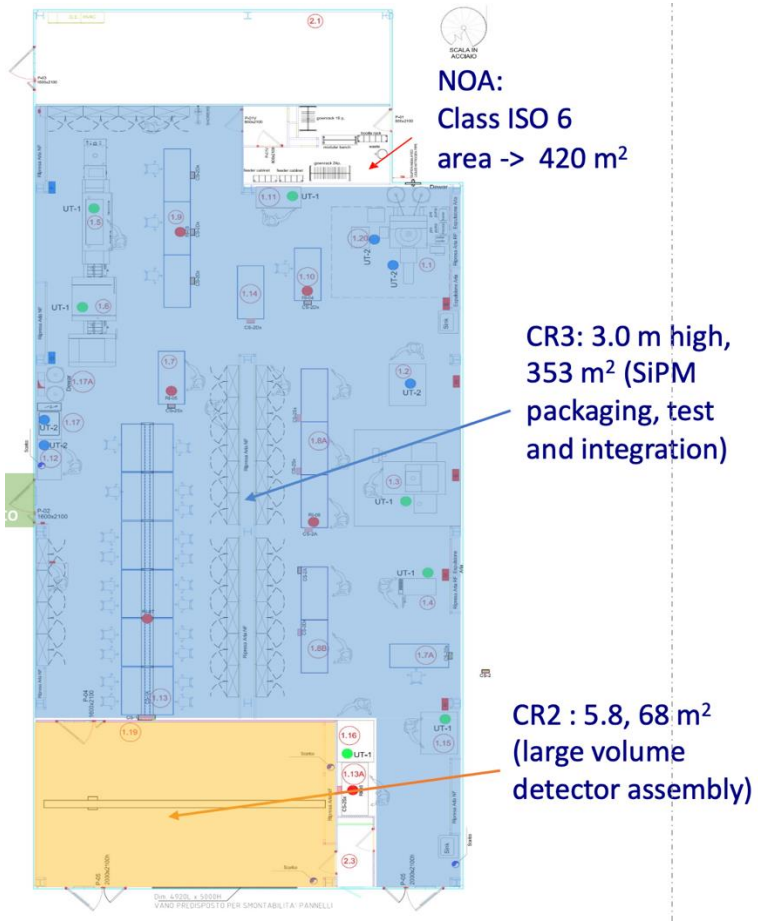
Test stand at INFN-LNGS for production and quality test:

Neutron moderator panels
- Radioassay
- Moderation power tests with neutron beams
- Crioresilience, outgassing, thermal expansion

Light readout system
- Radioassay
- SiPM test & characterization
- Light guides development and quality tests

Xe-doping system
- Integration of the injection and recirculation system
- Long term stability Xe-doped LAr
- Purity measurements





LEGEND-1000 Experiment

LEGEND-Experiment: Other Activities with participation/contribution of INFN-Naples

Test Stand Systems and Facilities

LEGENDArYno Prototype at INFN-LNGS
Characterization of Light Guides coupled with SiPMs in cold environment

Evaporation at INFN-LNGS
TPB coating of light guides

LEGEND-1000 Experiment

LEGEND-Experiment: Activities foreseen at INFN-Naples

Request of funds to CSN2 for the year 2025

Capitolo	Descrizione	Parziali (k€)		Totale (k€)	
		Richieste	SJ	Richieste	SJ
consumo	R&D LEGEND-1000 (LAr Instrumentation): Fornitura di argon liquido in serbatoi mobili per test a bagno aperto	5.00	0.00	48	0
	R&D LEGEND-1000 (LAr Instrumentation): meccanica varia per poter approntamento sistemi di prove meccaniche	5.00	0.00		
	R&D LEGEND-1000 (LAr Instrumentation): Produzione di gas panel provvisto di valvole e regolatori con linea elettropulita per gestione condensazione e ricircolo di argon	23.00	0.00		
	R&D LEGEND-1000 (LAr Instrumentation): Fornitura di flange, tubazioni, raccorderia e guarnizioni e valvole con diversi standard per connessione degli apparati ai sistemi da vuoto e al gas panel	10.00	0.00		
	R&D LEGEND-1000 (LAr Instrumentation): Fornitura di argon gassoso 6.0 ad elevata purezza per test di luce di scintillazione (Sinergico con DRD2-WP2.2 e DRD2-WP3.2)	3.00	0.00		
	R&D LEGEND-1000 (LAr Instrumentation): Fornitura di xenon gassoso per test di dopaggio dell'argon per la misura dei parametri della luce di scintillazione (Sinergico con DRD2-WP2.2 e DRD2-WP3.2)	2.00	0.00		
missioni	MEETING: partecipazione al meeeting LEGEND ai LNGS: 6 persone per 7 giorni	6.00	0.00	20	4
	MEETING: partecipazione al meeting di LEGEND all'estero (tipicamente USA): 2 persone per 7 giorni	5.00	0.00		
	MEETING: incontri con i gruppi italiani per lo sviluppo di LEGEND-1000	3.00	0.00		
	TEST: partecipazione ai tests dell'Outer LAr Instrumentation: 2 persone per 3 settimane ai LNGS	6.00	0.00		
	MEETING DRD2-WP2.2: incontro con gruppi italiani e/o europei per test e misure di WLS dell'argon: 2 persone x per 3 giorni ad incontro (2 incontri plausibili)	0.00	4.00		
inventario	R&D LEGEND-1000 (LAr Instrumentation): stazione di pompaggio composta da pompa primaria e turbomolecolare	20.00	0.00	45.5	0
	R&D LEGEND-1000 (LAr Instrumentation): Sensori di vuoto, trasduttori di pressione con lettore ed accessori per sistema di test in argon liquido	14.00	0.00		
	R&D LEGEND-1000 (LAr Instrumentation): Criostato con flangia per test in argon liquido addizionato con xenon (Sinergico con DRD2-WP2.2 e DRD2-WP3.2)	11.50	0.00		
trasporti	R&D LEGEND-1000 (LAr Instrumentation): Trasporto e/o trasferimento di SiPM e materiali riflettenti e convertenti di lunghezza d'onda da caratterizzare	2.50	0.00	2.5	0
Totale				116	4