TANGO_RD
Toward A New Generation Of RPC Detectors

TANGO_RD: (1)Why?

Resistive Plate Chambers (RPCs) are gas detectors with planar, resistive electrodes, characterized by excellent time resolution (< 1.5 ns) and excellent detection efficiency (> 98%), with ad hoc spatial resolution over large areas and simple construction [1]. The transition from streamer to saturated avalanche operation [6] has allowed rate capability of 1 kHz/cm^2 to be achieved. By lowering the electronics' threshold on the induced signal (New FE), increasing the fraction of induced signal (thinning the electrode thickness), and narrowing the gas gap (charge quenching), the new generation of RPCs has achieved rate capability of 10 kHz/cm^2 with time resolution < 0.5 ns and efficiency > 95%.
These developments have enabled the detector to be applied in modern HEP upgrades

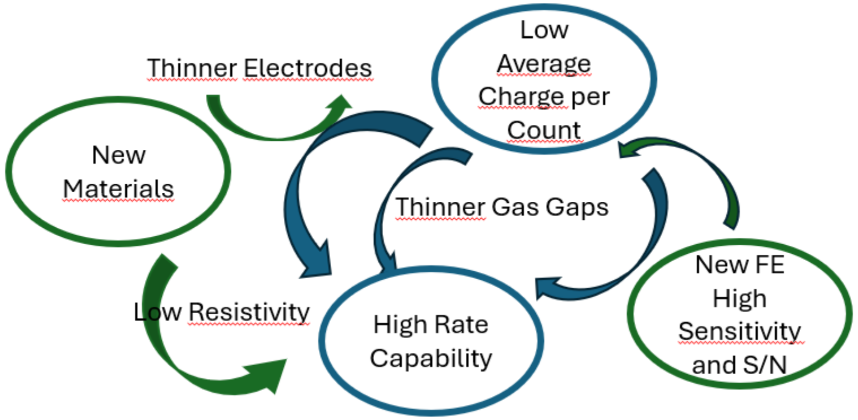
Future HEP experiments (FCC-ee and MuColl) present challenges in terms of performances.

RPCs have the following potential: Simple construction – Low cost - Active part separated from the readout - High efficiency and time resolution - Low sensitivity to neutrons and gamma rays. For future use, however, limitations must be addressed and overcome.

TANGO_RD: (2)Why...Not?

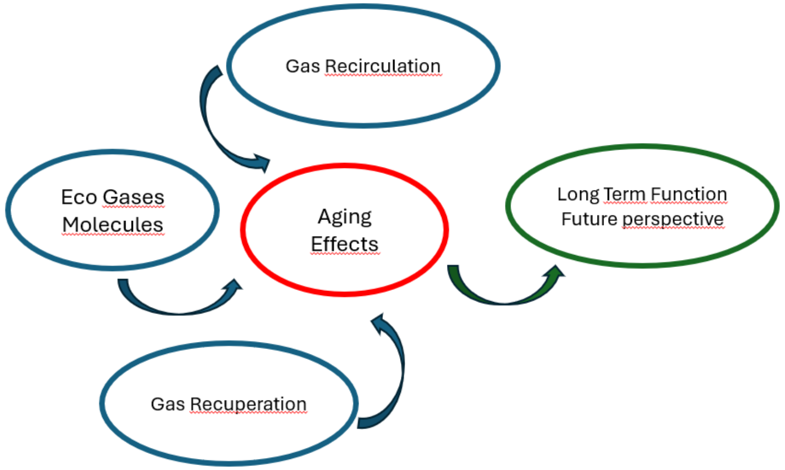
❖ Rate Capability -> R&D Lines:

- Research into new materials with lower resistivity [14],
- Development of thin electrode configuration that maximize the induced signal [15],
- Fast front-end electronics with a very low physical threshold and optimal signal-to-noise ratio [24]



❖ Gas mixtures with high environmental impact (as for other gaseous detectors!) -> R&D lines:

- Search for new environmentally friendly gases (low GWP) based on new molecules, replacement of TFE (TetraFluorethane) and SF6 (Sulfur HexaFluoride)[9,10],
- Study of performance and possible ageing effects on the detector[12,16] and materials
- Development of gas recirculation or recovery systems with filters, and studies to reduce the overall flow of gas emitted into the atmosphere[25].



TANGO_RD: Innovative RCC

Recently, the Resistive Cylindrical Chamber (RCC) has been proposed as an innovative extension of the RPC planar detector to the cylindrical geometry [16,17].

This technology could help to overcome some of the open issues in gaseous detectors, and its potential needs to be extensively explored.

The innovation in the cylindrical geometry is due to the gradient in the electrical field and to the much higher mechanical stiffness.

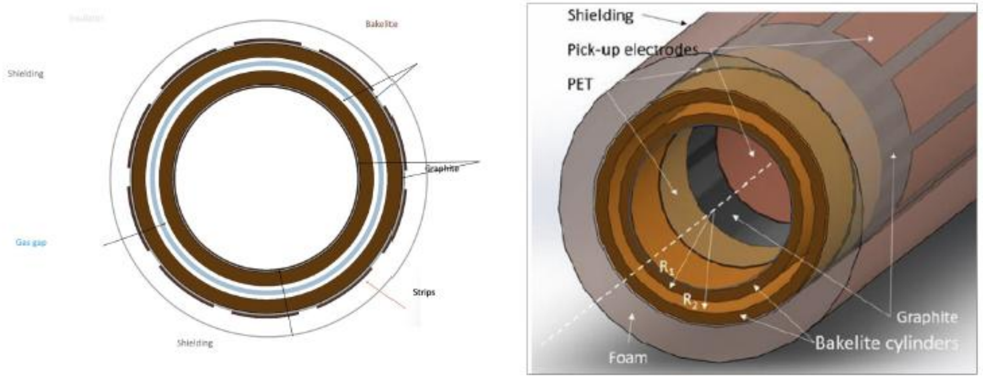


Figure 1. Schematic view of a RCC

$$E(r) = \frac{V}{r\,ln\frac{R_o}{R_i}} \approx \frac{V}{R_i ln\frac{R_o}{R_i}} - \frac{V}{R_i ln\frac{R_o}{R_i}}\,\frac{r-R_i}{R_i}$$

$$R_o - R_i \ll R_i$$

Figure 2. Equation for the cylindrical electric field

TANGO_RD: (1) How?

- The cylindrical geometry of the RCC adds an electric field correction with intensity dependent on the ratio between the gas gap width and the inner radius of the cylinder.
- The field gradient changes the avalanche development during its drift, in different ways for opposite polarities, and contributes to the quenching of the avalanche charge and to its shape distribution.
- Preliminary results confirm the asymmetry for the field effect (for gas gap 1mm and gas gap 0,3 mm)

- **This effect could help in reducing the amount of fluorine components in gas mixtures, reducing average charge, and sustaining higher rate capability.**

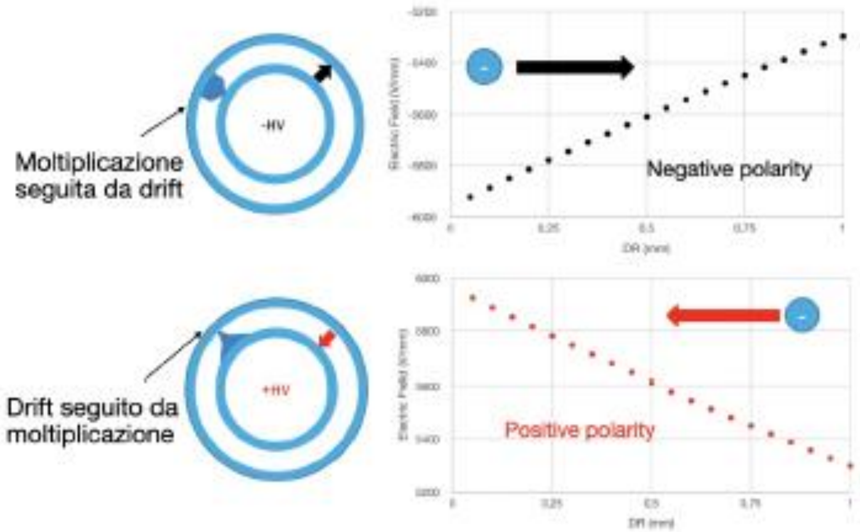
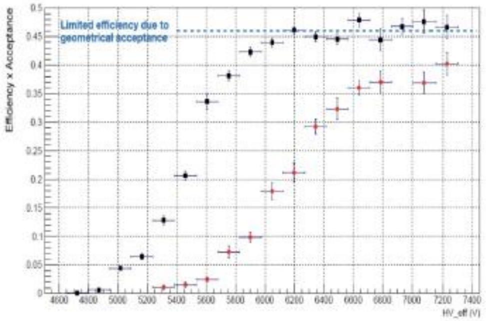
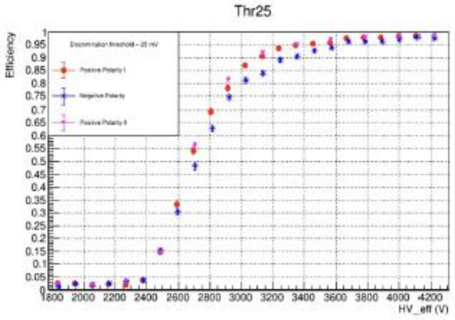


Figure 3. Diagram of the RCC operation in the two polarities and the trend of the electric field as a function of the distance from the inner electrode.





TANGO_RD: (2) How?

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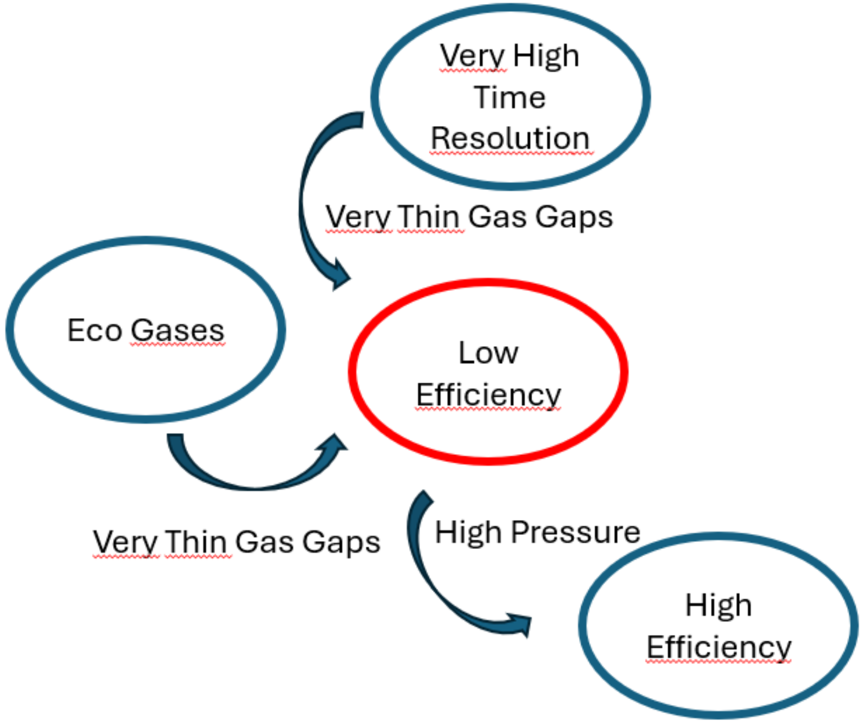
- Moreover, the mechanical stiffness of cylindrical geometry will allow working with overpressure with respect to atmosphere and with very thin gas gap, keeping the gap thickness uniformity with high precision.

- Working with overpressure will increase the gas target density,   increasing the primary ionisation efficiency, even with very thin gas gaps and with ecological gas (CO2 low density).

- **These aspects will preserve high detection efficiency and excellent time resolution typical of planar RPCs, with a more ecological gas mixture.**



TANGO_RD: (3) How?

The TANGO_RD project aims to bring the RCC technology to a maturity level to be used for future experiments and to demonstrate that the RCC technology could overcome some of the open issues of gaseous detectors.

The main objectives (work packages) are:

1) to systematically characterise the working principles of the RCC detector as a function of geometrical construction parameters
2) to study the performance with different ecological gas mixtures and at high overpressure
3) to explore innovative materials to enhance the rate capability
4) to study the scalability of the technology for large-scale applications, at ‘Low’ and ‘High Performance’.

- **WP1: characterization of the physical principle and performance as a function of construction parameters**
  A set of glass RCC detectors will be produced to accurately control the construction parameters and surface smoothness of the detector. The prototypes will be built with inner radii ranging approximately from 5 to 20 mm and with gas gap thicknesses between 0.3 mm and 2 mm, in order to characterize the detector physics, quantify the quenching principle and the asymmetry between positive and negative polarities, with various ratios between gas gap thickness and inner radius. Performance will be tested with a standard gas mixture ($C_2H_2F_4$ / i-C_4H_10 / SF_6 in the ratios 95.2% / 4.5% / 0.3%) by measuring operating currents, noise rate, efficiency, and time resolution, initially with cosmic rays and subsequently with an electron beam at the BTF. Results will be compared with those of traditional planar RPCs with the same gas gap thickness and with those from dedicated simulations.

- **WP2: simulation of RCC operation**
  The goal is to simulate primary and secondary ionization as a function of the electric field in various cylindrical geometries, to quantify the charge distributions generated inside the detector and to derive information on performance in terms of efficiency, rate capability, and time resolution. In a s
  in order to compare r

- **WP3: performance characterization with eco-friendly mixtures and under over-pressure**
  The performance of RCCs with different geometries will be analyzed using gas mixtures with reduced fluorine content and completely eco-friendly mixtures (e.g., pure CO_2). In a second phase, detector performance will be studied as a function of applied over-pressure. For the various mixtures, the effect of over-pressure on detection efficiency, time resolution, and streamer probability will be evaluated. These tests will be carried out with cosmic rays and for the most promising mixtures later with beam tests, too.

- **WP4: characterization of new electrode materials**
  Achieving rate capabilities beyond 10 kHz/cm^2 for these detectors depends, among other factors, on the use of materials with suitable and controllable resistivity. Alternative materials to those traditionally used, will be evaluated, considering both the ease of processing for RCC production, and performance in terms of rate capability on planar RPCs and on RCCs. Some of the materials to be considered include: phenolic glass, phenolic laminates, PEEK reinforced with MWCNT, and GaAs. To test the performance of different types of planar RPCs with various materials, a reconfigurable RPC will be built using non-glued components, allowing both maximum flexibility in test geometries and post-irradiation analysis of material samples. Initial tests can be conducted using the X-ray guns available at the Frascati labs, followed by irradiation tests at GIF++ at CERN.

- **WP5: construction of prototypes by assembling multiple tubes with geometries selected from WP1 results and materials from WP4, and beam testing**
  The final goal of the project is the design and construction of two chamber prototypes, each made by assembling multiple tubes into a single structure with dimensions on the order of 10-20 × 40 cm^2. One prototype (LP type) will prioritize ease of construction and low production cost and will feature gas gap thicknesses ≥ 0.5 mm and low readout segmentation. The second prototype (HP type) will aim to push the device performance to its limits. Its gas gap thickness will be < 0.5 mm and the readout segmentation will be finer. For both prototypes, the final choice of geometric parameters will be based on the results of WP1. For the second prototype, materials studied in WP4 will be considered, while the first prototype will be made with HPL. Both detectors will be tested with beam at the BTF in Frascati and at GIF++ at CERN to evaluate their performance and rate capability.

TANGO_RD: Work Package Milestones

WP1	Date	
D1.1	June 2026	Material procurement for a complete set of tubes with different geometries (thicknesses, gas gap, radii)
D1.2	December 2026	Construction of a complete set of tubes with different geometries (thicknesses, gas gaps, radii)
M1	June 2027	Validation of the quenching principle and Characterization of performance vs geometric parameters with std mix for RCC
WP2	Date	
D2.1	June 2027	Simulation of charge development in cylindrical geometry
D2.2	June 2028	Geometric simulation of prototypes with extended layout
M2	December 2028	Comparison of the data obtained with the simulations carried out
WP3	Date	
D3.1	December 2026	Definition and purchase of gases and mixtures for standard atmospheric pressure studies
D3.2	June 2027	Performance characterization of low fluorine mixtures at std pressure
D3.3	December 2027	Characterization of performance as a function of overpressure
M3	December 2028	Validation of eco-friendly mixtures for RCC
WP4	Date	
D4.1	June 2026	Identification of alternative materials for construction: costs, ease of processing, characteristics
D4.2	December 2026	characterization of selected materials
D4.3	December 2026	Flexible chamber design for housing different electrodes
D4.4	June 2027	flexible chamber construction for housing different electrodes
M4	December 2028	Characterization of RPC and RCC made with the different materials in terms of resistivity, currents, noise, rate capability
WP5	Date	
D5.1	June 2027	Layout and mechanical design of two prototypes: LP type and HP type
D5.2	December 2027	purchasing material for LP and HP prototypes
D5.3	June 2028	Building small chamber prototypes by aligning multiple tubes: LP and HP type
M5	December 2028	LP and HP prototype test results under beam

Figure 9. Milestones and deliverables of the project

TANGO_RD: Who and Where?

The project is based on a detector concept developed within INFN by R. Cardarelli [16] and first prototyping efforts have been proven successful by A. Rocchi [17](one of the proponents of this project).
The results have also been presented in international conferences (RPC and IFD Workshops) and within the DRD1 working groups at CERN, attracting interest in the international scientific community.
At present, there are no collaborations with other INFN committees or with institutions outside INFN.
We strongly believe that it is important to maintain this active and productive R&D within INFN.

The research groups involved in the project are:
INFN Roma Tor Vergata, Laboratori Nazionali di Frascati (LNF), INFN Bari.
All groups have extensive experience in the design and use of RPC detectors and are involved in the main experiments at the LHC

These groups have also been promoters of the ECOGas@GIF++ Collaboration for the study of alternative eco-friendly gas mixtures for RPCs under irradiation. Currently, all project participants contribute in various forms within the WGs and WPs of the DRD1 collaboration on gas detectors.

The project will be developed in the RPC Laboratories of Tor Vergata, LNF and Bari. At LNF, the group has access to X-ray guns, which will be used for rate capability studies, and to the Beam Test Facility (BTF) for dedicated beam tests. Moreover, prototypes will be tested at GIF++ Facility for high background rate studies.

TANGO_RD: Participants and FTE

ROMA ToV	FTE		LNF			Bari	
B. Liberti R.N.	0,7		**D. Piccolo R.L.**	0,3		**A. Pastore R.L.**	0,1
A. Rocchi	0,5 *		A. Paoloni	0,1		M. Abbrescia	0,1
M. Vallocchia	0,5		S. Bianco	0,2		M. De Serio	0,1
			S. Meola	0,3			
			G. Saviano	0,2			
			C. Vendittozzi	0,2			
			S. Colafranceschi	0			
Tot Roma ToV	**1,7 ***		**Tot LNF**	**1,3**		**Tot Bari**	**0,3**
* waiting for nulla osta from ENEA for INFN association							
			Tot FTE TANGO_RD	**3,3**			

Figure 10. Project participant engagement in terms of FTE.

TANGO_RD: Conclusions

- The TANGO_RD project is focused on advancing the Resistive Cylindrical Chamber (RCC) technology to a level of maturity that would enable its deployment in a variety of demanding applications.
- The project aims to characterise a detector that could be a real advancement for gaseous devices: high rate capability (>10 kHz/cm^2), excellent time resolution (<200 ps), robust, modular design suited for intense radiation and background environments, and operating with low and hopefully zero environmental impact.
- The studies on innovative materials and alternative gas mixtures are expected to have a broad impact beyond the RCC itself, influencing the development of traditional Resistive Plate Chambers (RPCs).

The advancement in RCC technology could be applied to several key domains: in the **muon detection systems for future collider experiments like the Muon Collider and the FCC**. Similarly, in **high-granularity hadronic calorimetry**, the RCC improved charged particle detection efficiency—maintaining excellent timing and neutron discrimination—could meet the stringent requirements of Particle Flow Algorithms, offering a significant performance boost over existing detectors. Beyond high-energy physics, RCC could also pave the way for its use in **the space experiment or muon tomography for industrial and geophysical applications**.

TANGO_RD: Timeline

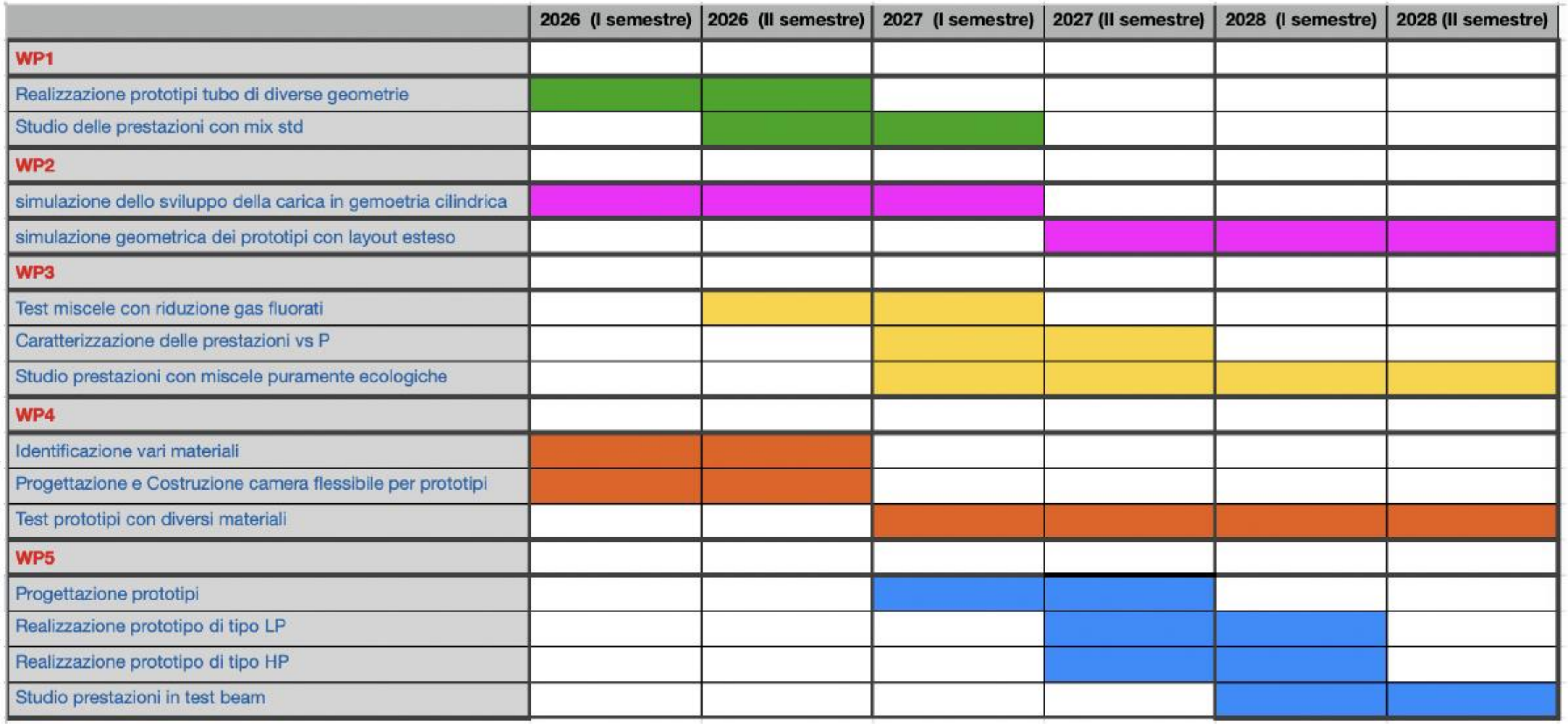


Figure 8. timeline of the project

TANGO_RD: (2026) Financial budget request

	2026					
		ROMA 2	LNF	Bari	Tot (KEuro)	di cui s.j.
Consumi	Tubi in vetro	5			5	
	Bombole gas premix			5	5	
	Meccanica RPC apribile	3			3	2
	Prototipi con nuovi materiali		5		5	4
Totali consumi 2026					18	
Inventariabile	DAQ TDC picosecond	7			7	
	disc. 16 ch	3			3	
Totali inventariabile 2026					10	
Missioni	Scambio tra laboratori	1	1	2	4	
Totali missioni 2026					4	
Totale 2026					**32**	

TANGO_RD: (2027) Financial budget request

	2027					
		ROMA 2	LNF	Bari	Tot (KEuro)	
Consumi	Materiale per prototipi LP e HP				10	5
	Gas per test beams su singoli tubi				3	
Totali consumi 2027					13	
Inventariabile	Alimentatore HV +30 kV				1,5	1,5
Totali inventariabile 2027					1,5	
Missioni	Test singolo tubo e prototipi con nuovi materiali a BTF				3	
	Test singolo tubo e prototipi con nuovi materiali a GIF++				10	
Totali missioni 2027					13	
Totale 2027					**27,5**	

TANGO_RD: (2028) Financial budget request

	2028					
		ROMA 2	LNF	Bari	Tot (KEuro)	
Consumi	Sviluppo readout per prototipi LP e HP				2	
	Gas per test beams su prototipi LP e HP				3	
Totali consumi 2028					5	
Missioni	Test prototipo LP e HP a BTF				3	
	Test prototipo LP e HP a GIF++				10	
Totali missioni 2028					13	
Totale 2028					**18**	

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