

# Commissione Scientifica Nazionale IV

## Gruppo Teorico LNF

GENNARO CORCELLA

1. Informazioni su gruppo ed anagrafica
2. Attività sigle locali CSN4

*Al momento: Iniziative Specifiche sotto valutazione esterna*

## Anagrafica Provvisoria 2023-24 – dipendenti e associati senior

Nome	Posiz.	Qual.	AMPLITUDES	ENP	TASP	TIME2QUEST	DOT4	CSNIII	Tot
Bagnaschi Emanuele	Dip.	Ric.		50	50				100
Bellucci Stefano	Dip.	I Ric.				100			100
Benfatto Maurizio	Ass.	Ass.Sen.				30		70	100
Corcella Gennaro	Dip.	I Ric.		100					100
Del Duca Vittorio	Dip.	I Ric.	100						100
Gionti Gabriele	Ass.	I Ric.					50		50
Nardi Enrico	Ass.	Ass.Sen.			100				100
Pancheri Giulia	Ass.	Aff.		0					0

### Assegnisti di ricerca

A. Plascencia (Cabibbo fellow, TAsP): LNF sino a Ottobre 2023, poi INFN Roma I

D. Sengupta (Cabibbo fellow, ENP): LNF sino a Novembre 2024

F. A. Aragón: da Ottobre 2023 Cabibbo fellow in TAsP (2+1 anni)

I. Gnilitzky e C. Vacacela (Time2Quest)

Assegnista PRIN 2022 'AxionOrigins' da Novembre 2023 (TAsP)

Associato: A. Maffucci (Prof. Ordinario U.Cassino, Time2Quest)

## IS Exploring New Physics (ENP) – Nodi: LNF, RM1, RM2, NA, PG

Responsabile Nazionale: G. Corcella (2024-26)

Nodo LNF:

G. Corcella (100%, Ric. II Livello), E.A. Bagnaschi (50%, Ric. III Livello),  
D. Sengupta (100%, assegnista 'Cabibbo')  
G. Pancheri (0%, affiliata)

Attività di ricerca su vari aspetti di fenomenologia dei collider:

- Test di precisione del Modello Standard: fenomenologia dei quark pesanti e Higgs, implementazione Monte Carlo a NLO, SMEFT
- Fisica BSM: modelli e scenari non ancora esclusi, e.g., 331, supersimmetria nel top, materia oscura

Organizzazione: 'B.Touschek' Spring School (G.C.), Linear and Future Colliders 2022-24 (G.C. e G.P.), Amplitudes (V.D.D.), MWDays23, Future Colliders for Early-Career Researchers, (g-2) days, IRN Terascale '24 a LNF (E.B.)

Gennaro Corcella:

1. Fisica dei quark pesanti (top e bottom) in MS e sue estensioni

ACE per l'analisi di ATLAS sulla misura della massa del top da muoni soffici:

$t \rightarrow bW, W \rightarrow \ell\nu, b \rightarrow B \rightarrow X\mu \Rightarrow m_t = (174.41 \pm 0.80) \text{ GeV}$  da  $M_{\mu\ell}$

G.C. and ATLAS, JHEP 06 (2023) 019

Frammentazione del bottom in  $t \rightarrow bW + ng$  ( $b \rightarrow B, B \rightarrow J/\psi X$ ) a NNLL: risommazione soffice/collineare di  $\ln(m_b/m_t)$  e  $\ln(1-x)$  ( $x \sim E_b/m_t$ ), tuning di modelli di adronizzazione a LEP/SLD e impatto sull'incertezza sulla massa del top

Effetti di stop (MSSM) in  $m_{bt}$ :  $pp \rightarrow \tilde{t}\tilde{t}^* \rightarrow (\tilde{\chi}^+b)(\tilde{\chi}^-\bar{b}) \rightarrow (\tilde{\chi}^0\ell^+\nu_{\ell}b)(\tilde{\chi}^0\ell^-\bar{\nu}_{\ell}\bar{b})$

2. Bileptoni  $Y^{\pm\pm}$  ( $L = \pm 2$ ) e quark esotici  $Q$  di massa  $\mathcal{O}(\text{TeV})$  e carica  $5/3$  o  $4/3$  da vari modelli, come il 331, basato sulla simmetria  $SU(3)_C \times SU(3)_L \times U(1)_X$

$pp \rightarrow Y^{++}Y^{--} \rightarrow (T\bar{b})(\bar{T}b) \rightarrow (b\bar{b}\mu^+\mu^+)(b\bar{b}\mu^-\mu^-)$  con  $Q(T) = 5/3$  in 331 visibile a FCC-hh (100 TeV,  $\mathcal{L} = 3000 \text{ fb}^{-1}$ ,  $m_Y \simeq 1.3 \text{ TeV}$ ), ma statistica insufficiente a LHC

(G.C., C.Corianò, A.Costantini, P.H.Frampton, PLB'22)

In corso: bileptoni a LHC (ATLAS Bologna):  $pp \rightarrow Y^{++}Y^{--} \rightarrow (\ell^+\ell^+)(\ell^-\ell^-)$

Produzione di quark pesanti nel 331:  $pp \rightarrow T\bar{T} \rightarrow Y^{++}bY^{--}\bar{b} \rightarrow b\bar{b}\mu^+\mu^+\mu^-\mu^-$

Chairman di Spring/Summer School 'Bruno Touschek' (LNF) e Linear and Future Colliders 20XX (con G.Pancheri a ECT\*)

# Dibyashree Sengupta (INFN, Laboratori Nazionali di Frascati)

## 1. New strategies to search for new physics at the LHC

The Large Hadron Collider (LHC), being a “top quark factory”, helps in precise measurement of various properties of the top quark. Deviation from the SM prediction in measuring these properties of the top quark can, very efficiently, shed light on new physics signal.

## 2. Constraining the masses of supersymmetric particles in the current and upcoming runs of the LHC

LHC searches for Weak scale supersymmetry (SUSY) has pushed the mass limits on sparticles well beyond the early upper limits from naturalness and gives rise to the question whether SUSY is now unnatural. The older notions of naturalness can be updated based on the more conservative electroweak naturalness measure. Such natural SUSY models can give rise to several smoking gun signatures at the LHC. A detailed phenomenological study of these models in the current and upcoming runs of the LHC can help us to derive  $5\sigma$  reach and 95 % CL on masses of various sparticles.

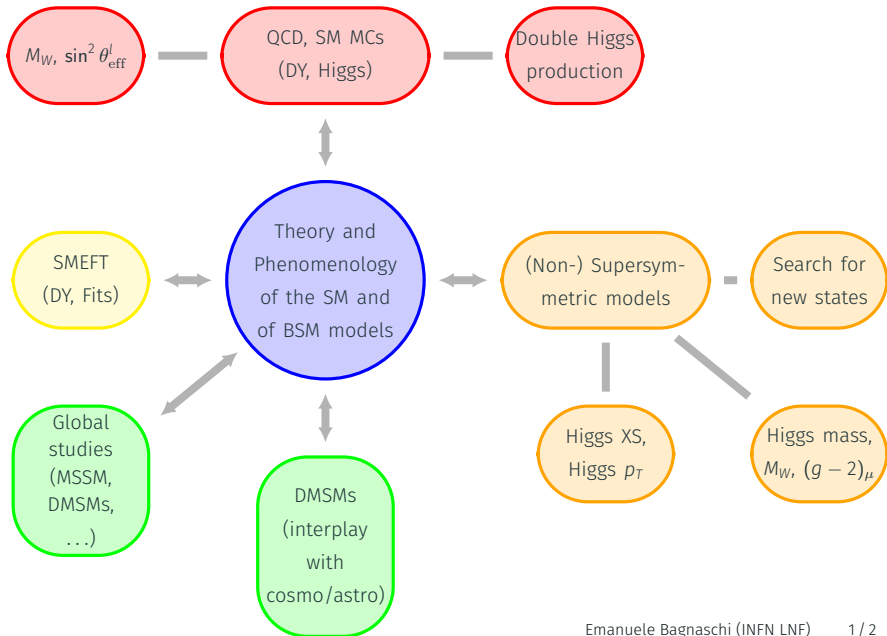
## 3. Axion phenomenology

Axions can very effectively solve the strong CP problem as well as serve as a good cold dark matter candidate. I plan to study the interactions between axions and various standard model particles to seek a potential smoking gun signal that can lead to axion discovery.

## 4. New physics at muon colliders

Muon colliders are extremely advantageous as leptons are fundamental and hence entire beam energy is available for the hard collision whereas in hadron collider only a fraction of the proton-beam energy that is carried by the colliding partons is available for collision thereby yielding higher physics reach in muon colliders. Also since muons are heavier than electrons, therefore in muon colliders synchrotron radiation is much suppressed as compared to that in electron colliders.

# Overview of the research lines



# Selection of currently active projects

## TAsP related

- Study of the Dark Matter Simplified Models (DMSMs) with t-channel mediators in the context of a Dark Matter Working Group (DMWG) White Paper (Monte Carlo studies at colliders, NLO-QCD corrections, recast of existing analyses, interplay with cosmo/astro bounds)
- Global likelihood study of s-channel leptophilic vector mediated models

## ENP related

- Double Higgs production at NLO+PS in the POWHEG approach using 2-loop virtual ME computed using expansion techniques
- Dilepton production in SMEFT at NLO-QCD/NLO-EW in the POWHEG approach and related phenomenology
- Running effects in SMEFT fits
- $M_W$  in the MSSM in light of current constraints (study of EFT approximation)
- Stop production and detection in top mass related observables

## Publications

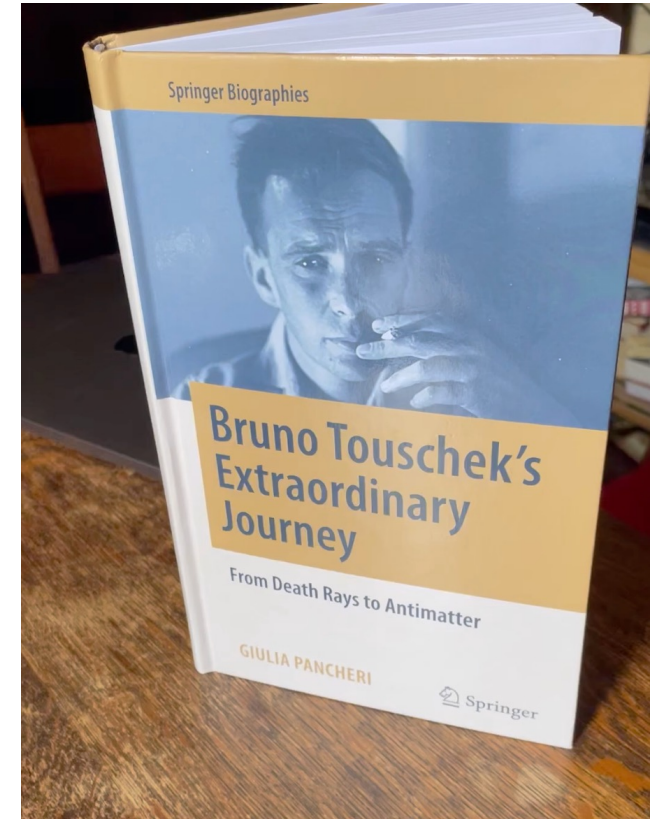
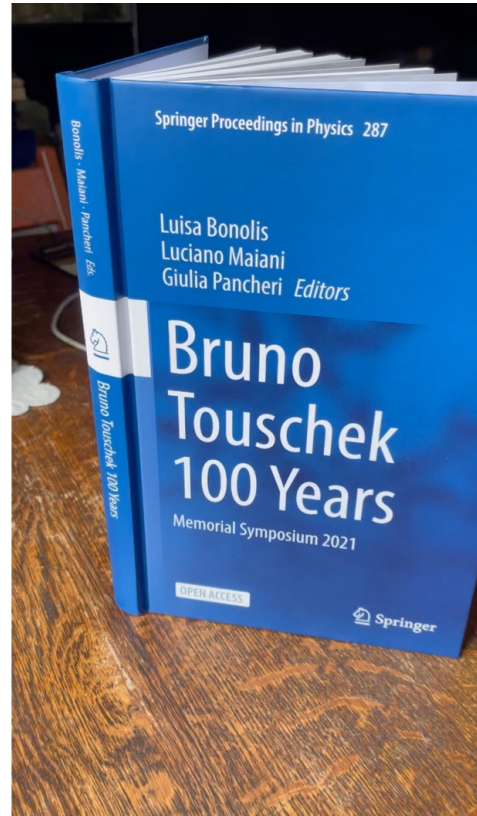
- [Bruno Touschek Extraordinary Journey](#)  
*G. Pancheri*, Springer, 2022
- [Bruno Touschek 100 years](#)  
*L. Bonolis, L. Maiani G. Pancheri*, 2023
- [L'eredità di Bruno Touschek a cent'anni dalla nascita](#)  
*L. Bonolis, G. Pancheri*  
DOI: [10.1393/qsf/i2023-10117-5](https://doi.org/10.1393/qsf/i2023-10117-5)  
Quaderni di Storia della Fisica,  
pp. **121-157**, online 25 May 2023

## Presentations at

- Centro Fermi, Rome, 25 November 2022
- Forum Austriaco di Cultura, Rome, 25 May 2023
- Planned at Austrian Academy of Science, Vienna, February 2024

## Work in progress on

“Touschek resummation method for soft graviton emission”





# Relazione sull'attività di ricerca

Vittorio Del Duca

## Linee di ricerca

- migliorare l'accuratezza teorica nella produzione di Higgs in associazione con 1 jet.  
[1] rappresenta il primo conto esatto al NLO, che includa le masse dei quark top e bottom, e la dipendenza da una massa dinamica
- sviluppare uno schema per il calcolo di sezioni d'urto al NNLO in  $\alpha_s$  e oltre in modo indipendente dal particolare processo [2], usando l'universalità delle divergenze infrarosse

[1] R. Bonciani, V. Del Duca, H. Frellesvig, M. Hidding, V. Hirschi, F. Moriello, G. Salvatori, G. Somogyi, F. Tramontano  
"NLO QCD Corrections to Higgs Production in association with a Jet", Phys.Lett.B 843 (2023) 137995  
[arXiv:2206.10490 [hep-ph]].

[2] V. Del Duca, C. Duhr, F. Guadagni, P. Muckerjee, G. Somogyi, F. Tramontano  
"Colour singlet production in hadron collisions in NNLO subtraction methods"  
to appear soon

# Una nuova Iniziativa Specifica: Amplitudes

dall'abstract della proposta:

“Modern amplitude methods have made a huge impact on our understanding of quantum field theory and our ability to make precise predictions for physical observables. Their remarkable mathematical structure has led to new results in an enormous range of subjects from gravitational waves, condensed matter systems and collider experiments.

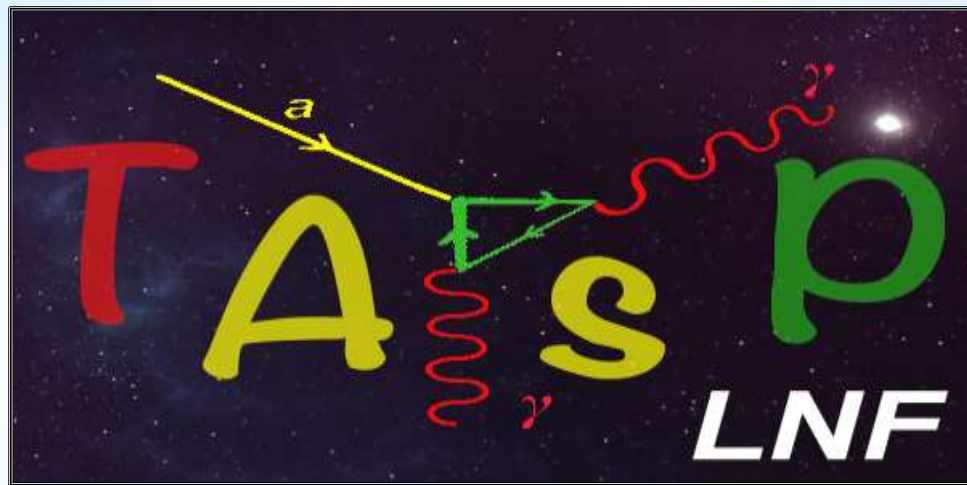
Our team members have contributed to cutting-edge computations of amplitudes, and our aim is to keep INFN to the forefront of amplitude evaluations both for collider and for gravitational-wave observables.”

## **Responsabile Nazionale**

- V. Del Duca (INFN LNF)

## **Responsabili Locali**

- S. Badger (U. Torino)
- R. Bonciani (U. Roma La Sapienza)
- P. Mastrolia (U. Padova)
- T. Peraro (U. Bologna)
- F. Tramontano (U. Napoli)
- V. Del Duca (INFN LNF)



# Theoretical Astroparticle Physics

[Activity 2022-23]

**CSN4 Linea 5 (Astroparticle Physics)**


Resp. Loc. Emanuele Bagnaschi

- E. Bagnaschi 50% (Ric. INFN)
- E. Nardi 100% (Senior Ass. INFN)
- A. Plascencia Contreras 100% (Ass. Cabibbo, until Oct. 2023)
- F. Arias Aragón 100% (Ass. Cabibbo, from Oct. 2023)
- ?? [PRIN2022 “AxionOrigins”] 100% (Ass. PRIN2022, from Nov. 2023)

## PRIN 2022:

*AxionOrigins: towards a complete theory for the origin of the axion*

Progetto finanziato (MUR)

<u>Units:</u>	<u>Proposal (March 2022)</u>	<u>After approval (June 2023)</u>
INFN	Enrico Nardi (local resp.)	Luca Di Luzio (PI - INFN Ric.)
Padova U.	Luca Di Luzio (PI - RTDA) 	Paride Paradisi (local resp.)
Sapienza U.	Marco Nardecchia (loc. resp.)	Marco Nardecchia (loc. resp.)

PRIN2022: One two-years postdoctoral position for TAsP-LNF

# AXIONS@GGI

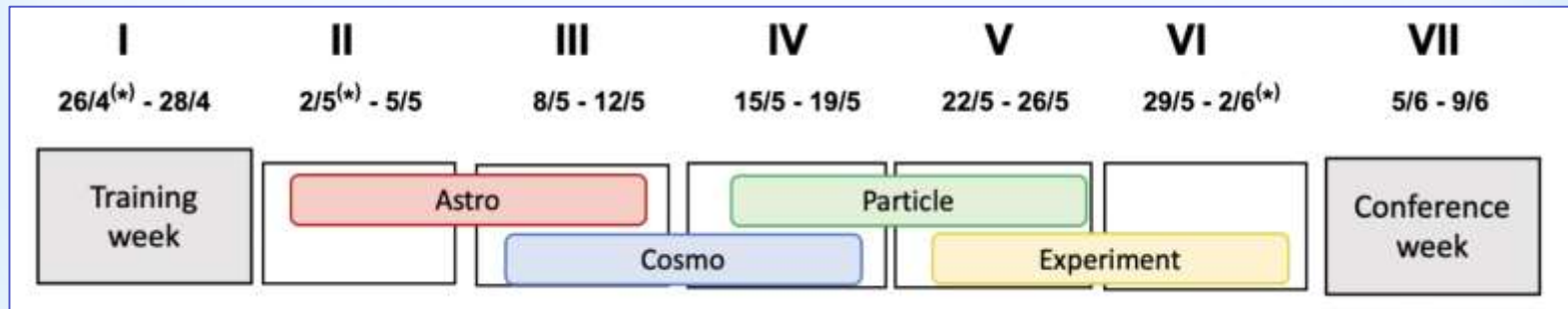
Long Workshop for the GGI 2023 Program, concluded the past June 9

***Axions across boundaries*** between Particle Physics, Astrophysics, Cosmology and forefront Detection Technologies [www.ggi.infn.it/showevent.pl?id=437](http://www.ggi.infn.it/showevent.pl?id=437)

**Apr 26, 2023 - Jun 09, 2023**

Contact person: [enrico.nardi@lnf.infn.it](mailto:enrico.nardi@lnf.infn.it)

Multidisciplinary scientific program (7 weeks):



The workshop had a strong resonance in the community.... more than 180 applications, 125 participants in total.

The scientific program included:

9 lectures (week I), 24 Seminars, 8 Young researchers talks, 2 Topical discussions, 24 Contributions to the conference and virtually unlimited time for discussions/collaboration

# TAsP-LNF: Argomenti di Ricerca 2022-2023

- ➔ Physics of the Axions: theory and phenomenology  
Theoretical models (generation of  $U(1)_{PQ}$ ), Astrophysics, Cosmology
- ➔ Feebly Interacting Particles (FIPs) (dark photons, ALPS, LDM)  
Connections with searches at PADME, Jlab, etc... Effects on  $(g-2)_{\mu,e}$
- ➔ The muon  $(g-2)$  puzzle  
Connections with GeV-scale feebly interacting particles
- ➔ Phenomenology of two Higgs doublet model  
Connections with quark-lepton unification and DM.

# Axion theory and phenomenology

## The axion quality problem

The axion-flavour connection

*L. Darmé, E. Nardi, C. Smarra* [JHEP 02 (2023) 201]

## Renormalization Group effects on axion couplings to matter

Renormalization group effects in astrophobic axion models

*L. Di Luzio, F. Mescia, E. Nardi, S. Okawa* [Phys.Rev.D 106 (2022) 5]

Running into QCD axion phenomenology

*L. Di Luzio, M. Giannotti, F. Mescia, E. Nardi, S. Okawa, G. Piazza* [e-Print: [2305.11958](https://arxiv.org/abs/2305.11958)]

Stellar evolution confronts axion models

*L. Di Luzio, M. Fedele, M. Giannotti, F. Mescia, E. Nardi* [JCAP 02 (2022) 035]



# Phenomenology of Feebly Interacting Particles

## Feebly interacting particles and the $(g-2)_\mu$

The muon  $g-2$  anomaly confronts new physics in  $e^\pm$  and  $\mu^\pm$  final states scattering

*L. Darmé, G. Grilli di Cortona, E. Nardi* [JHEP 06 (2022) 122]

The  $(g-2)_\mu$  window discrepancy: a GeV-scale new physics explanation

*L. Darmé, G. Grilli di Cortona, E. Nardi* [e-Print: 2212.03877]

## Light mediators

Probing light vector mediators with coherent scattering at future facilities

*E. Bertuzzo, G. Grilli di Cortona, L. Magno D. Ramos* [JHEP 06 (2022) 075]

Probing light mediators at the MUonE experiment

*G. Grilli di Cortona, E. Nardi* [Phys.Rev.D 105 (2022) 11, L111701]

## The X17 anomaly

Resonant search for the X17 boson at PADME

*L. Darmé, M. Mancini, E. Nardi, M. Raggi* [Phys.Rev.D 106 (2022) 11, 115036]

Shedding light on X17: community report

*D. S. M. Alves et al.* [Eur.Phys.J.C 83 (2023) 3, 230]

# Theoretical constructions beyond the Standard Model

## Extensions of the Standard Model Higgs Sector

On the  $W$  mass and new Higgs boson

*P. Fileviez Perez, H. H. Patel, A. D. Plascencia* [Phys.Lett.B 833 (2022) 137371]

Two-Higgs-doublet model and quark-lepton unification

*P. Fileviez Perez, E. Golias, A. D. Plascencia* [JHEP 08 (2022) 293]

Enhancing  $B_s \rightarrow e^+e^-$  to an observable level in the two-Higgs-doublet model

*M. Black, A. D. Plascencia, G. Tetlalmatzi-Xolocotzi* [Phys.Rev.D 107 (2023) 3, 035013]

Probing quark-lepton unification with leptoquark and Higgs boson decays

*P. Fileviez Perez, E. Golias, A. D. Plascencia* [Phys.Rev.D 105 (2022) 7, 075011]

Advanced Theoretical methods for emerging 2D materials in Quantum Information

Technology Studies: Time2Quest

- S. Bellucci (Resp. Naz.) Unical (gruppo CS, A. Sindona), RM2 (G. Stefanucci), UNIMI (G. Onida)

CSN4 research line: statistical physics and field theory

Main research issues

Spectroscopies, Electron correlations, Density Functional Theory, Modeling-Simulations and low-dimensional systems

*Richiesta 2023 7.5 KE Missioni*

Personnel associated in 2023, as of today

S. Bellucci (100%), M. Benfatto (30%), Iaroslav Gnilitskyi (AR, 100%),

Antonio Maffucci (PO, 100%), Cristian Vacacela (AR, 100%)

**FTE** 4.3

**Time2Quest** started 2021 evaluated AAA by referees

# Advanced Theoretical methods for emerging 2D materials in Quantum Information Technology Studies: Time2Quest

- *S. Bellucci (Resp. Naz.) Unical (gruppo CS, A. Sindona), RM2 (G. Stefanucci), UNIMI (G. Onida), continued*

## Collaborations in 2023

HPSWFood, High Pressure Sanification of Water for Foodborne Virus removal  
Progetto Regione Lazio per Organismi di Ricerca, 2021-2023, directed by  
S. Bellucci, with Univ. Roma Tor Vergata and Istituto Superiore di Sanità

AU-EU Collaborative Research and Innovation projects on renewable energy,  
"RCLIB: Recycling of the cathodes, based on carbon nanotubes and conducting polymers,  
from spent rechargeable Li batteries", 2023-2025, S. Bellucci, head of INFN team

## Publications by the LNF unit in 2023

17 papers su rivista: Advances in High Energy Physics, Scientific Reports, Frontiers in Physics, Crystals, Nano and Medical Materials, International Journal of Geometric Methods in Modern Physics, Separations, Microchemical Journal, Molecules, Minerals, Inorganics (2), Catalysts, Materials Chemistry and Physics, Journal of Functional Biomaterials (2), Journal of Composites Science

# Advanced Theoretical methods for emerging 2D materials in Quantum Information Technology Studies: Time2Quest

- *S. Bellucci (Resp. Naz.) Unical (gruppo CS, A. Sindona), RM2 (G. Stefanucci), UNIMI (G. Onida), continued*

## Talks in 2023

LNF 14 April 2023, U.Cassino@LNF Lectures

S. Bellucci: **Nanomaterials for sensors and electronics applications**

LNF 19 May 2023, U.Cassino@LNF Lectures

S. Bellucci: **Nanocomposite materials for electromagnetic compatibility**

LNF 1 June 2023 XXII International Conference on Nanoscience and Nanotechnology

S. Bellucci: **Summary talk on n&n 2023**

Gaeta - Angevin Castle 13 July 2023, U.Cassino SUMMER COURSE

on Nanotechnology and Sensing Technologies

S. Bellucci: **Advanced 2D materials for sensing**

Cluj-Napoca, Romania 19 – 22 September 2023, 4th International Conference

Processes in Isotopes and Molecules (PIM 2023)

S. Bellucci: **Nanoelectronics, Molecular Sensing, Optical Properties, Pollutants Removal**

## Conclusioni

Eccellente produzione scientifica del gruppo teorico dei LNF

Collaborazioni internazionali e locali con gruppi ai LNF e dell'area romana (PRIN, Assegni Cabibbo)

Responsabili nazionali di Iniziative Specifiche di LNF

Continua interazione con gruppi sperimentali di Gruppo I e II in loco e non (ATLAS, PADME, DarkSide, JLAB)

Assegno di ricerca Cabibbo (collider o astroparticelle) ben consolidato

**Nuovo ricercatore dopo circa 12 anni**

Ulteriore rafforzamento del gruppo necessario con ricercatori a tempo indeterminato necessario, anche alla luce dei pensionamenti nel 2023/24

Si prevede coi nuovi membri del gruppo e rientri una più regolare ripresa di workshop (tipo JRW) e institutes, per i quali si chiederanno a Div.Ric. e Direzione qualche finanziamento e supporto di segreteria