LNF Theory Group– July 2014

- Human Capital

6+1 Ten. Res. [Bellucci, Benfatto, Corcella, Del Duca, Lombardo, Nardi, (Isidori)]

- Four yrs. ago we were 12 (10 TRs + 2 NTRs)...
- ALL TR above 40
- Two of the above 7 TR are returning from mobility elsewhere (Del Duca, Lombardo); Isidori at University of Zurich, probably for good

+

6 Postdocs [1 supported by external funds (Fermi Inst.)] + 2 PhD + 1 laurea students

4 Senior Associates +

14 Associates from outside LNF (Univ. Tor Vergata, Pavia, Marche, CERN)

~15 frequent visitors from outside LNF, supported by INFN invitation funds and by many new EU Curie Projects

LNF Theory Group– July 2014

- Research activity

Theory Nat. projects (Iniziative Specifiche) at LNF

I.S.	Loc. (**Nat.**) Spokesperson	FTE	Topics
SEMS	**Bellucci**	16.1	[Complex systems] Methods in Cond. Mat. Phys.,
GSS	Bellucci	5.3	[Fields/Strings] Supersymmetry, supergravity, BH
PHENOLNF	Isidori	1.9	[Phenomenology] Flavor Physics, Physics@LHC
TASP	Nardi	3.0	[Astroparticles] Leptogenesis, neutrino physics
FTECP	Lombardo	1.0	[Fields/Strings] Lattice, QCD at finite T

SEMS Spectroscopies, Electron correlations, Modeling-Simulations and low-dimensional systems - S. Bellucci (nat. spokesperson) + M. Benfatto, M. Cini, K. Hatada, K.Hayakawa, C.Natoli, L.Pierantoni, F.Palumbo,G.Stefanucci, A.Tagliacozzo

Main research issues

Spectroscopies, Electron correlations, Modeling-Simulations and low-dimensional systems

LNF activities in 2015

The project uses tools from field theory, quantum mechanics, modeling and simulations, to analyze spectroscopies, electron correlations and various properties of low-dimensional systems in condensed matter physics:

* Electron spectroscopy of magnetic systems;
* Magnetic properties of quantum rings;
* NanoElectromagnetics (microwave/RF/photonics);
* Multiple scattering theory for non-local and multichannel potentials;
* Quantum effects in nanoparticles;
* Collective response of low dimensional, many body systems to abrupt perturbations;
* Electronic properties and plasmon excitations in graphene and doped graphene;
* Ab initio simulations and spectroscopy of Graphene/Metal interfaces.

The interdisciplinary and multidisciplinary character of the project ranges from the fusion of classical electrodynamics with novel methods and approaches of condensed matter physics; to methods allowing elucidating local properties of magnetic systems; to understanding the 2D character of the interface collective excitation in the electronic structure of graphene sheets deposited on metal surfaces; to the elaboration of a theoretical framework, providing a unified description of the electronic ground state as well as the excited states of a physical system, taking into account correlation effects, at least at a local level, beyond what can be reached in a description based on Density Functional Theory.

SEMS - S. Bellucci (nat. spokesperson) + M. Benfatto, M. Cini, K. Hatada, K. Hayakawa, C. Natoli, L. Pierantoni, F. Palumbo, G. Stefanucci

LNF collaborations in 2015

- - University of Lorraine, and Belarus State University, Institute for Nuclear Problems, through the 7th FRAMEWORK PROGRAMME, International Research Staff Exchange Scheme "Nano-thin and micro-sized carbons: Toward electromagnetic compatibility application (NAmiceMC)", Proposal Number: 610875, Grant Agreement Number: PIRSES-GA-2013, 2013-2017. S. Bellucci

- - Laboratory for Solid State Physics at the Department of Physics of matter and radiations University of Namur, Nanostructures Department from the Research Institute for Technical Physics and Materials Science of the Hungarian Academy of Sciences in Budapest, Institute for Biochemical Physics at the Russian Academy of Sciences in Moscow, Institute of Physics of the National Academy of Sciences of Ukraine in Kiev, Department of Radiophysics of the Faculty of Physics in Vilnius University, and Belarus State University, Institute for Nuclear Problems, through the 7th FP International Research Staff Exchange Scheme "Fundamental and Applied Electromagnetics Of Nanocarbon (FAEMCAR)", Proposal Number: 318617, Grant Agreement Number: PIRSES-GA-2012, 2012-2015. S. Bellucci

SEMS - S. Bellucci (nat. spokesperson) + M. Benfatto, M. Cini, K. Hatada, K. Hayakawa, C. Natoli, L. Pierantoni, F. Palumbo, G. Stefanucci

LNF collaborations in 2015

- - CNRS Université de Rennes, Ludwig-Maximilians-Universität München, Université de Bourgogne, Institute of Physics in Prague of the Academy of Sciences of the Czech Republic, Southern Federal University at Rostov-on-Don, University of Science and Technology of China of the Chinese Academy of Sciences, Chiba University in Japan, Birla Institute of Technology and Science at Pilani in India, through the 7° FP International Research Staff Exchange Scheme "A Multiple Scattering Computing Platform For (Nano) Materials (MSNano)", Grant Agreement Number: 2012-317554, 2012-2016, M. Benfatto

- - Yerevan State University, Armenia, through EMERGING SECURITY CHALLENGES DIVISION SCIENCE FOR PEACE AND SECURITY (SPS) PROGRAMME PROJECT PROPOSAL - Multi-Year Science for Peace (SfP) "Development of Biosensors using Carbon Nanotubes", NATO Grant SPS EAP SFP 984537 2014-2016, S. Bellucci.

SEMS - S. Bellucci (nat. spokesperson) + M. Benfatto, M. Cini, K. Hatada, K. Hayakawa, C. Natoli, L. Pierantoni, F. Palumbo, G. Stefanucci

LNF collaborations in 2015

- - Grant ASI Italian Space Agency: 2014-2017 "SHAPE- A New Theoretical Framework of the Microgravity-Cell Interaction" , S. Bellucci: Definire il modello teorico capace di spiegare l'interazione tra campo gravitazionale ed organismi viventi.

- Graphene-Based Revolutions in ICT And Beyond GRAPHENE Flagship Grant agreement n. 604391 CP-CSA."Multi-layered sandwich graphene devices (MILESAGE)", 2015-2017, S. Bellucci.

- Italian Ministry for Health, Research Project PE-2011-02347026 (Ricerca Finalizzata, "Delivery and imaging of miRNAs by multifunctional carbon nanotubes and circulating miRNAs as innovative therapeutic and diagnostic tools for pediatric pulmonary hypertension", 2014-2017, S. Bellucci.

GSS Gauge Theories, Supergravity and String Theory (ex MI12) - S. Bellucci (loc. spokesperson) + S. Ferrara (ass.), G. Gionti (ass.), A. Yeranyan (Fermi Inst. PostDoc)

Main research issues

I) String Theory, Supergravity.
II) Perturbative and non perturbative properties of Gauge Theories.

String Theory seems the best candidate to describe in one framework both Quantum Gravity and the usual Quantum Field Theory models of the Fundamental Interactions. Because of this, String Theory has become an efficient theoretical laboratory to explore the limits of our understanding of the fundamental forces. Indeed, the most plausible models for new physics beyond the Standard Model have been inspired by ideas developed in the context of String Theory.

Supergravity emerges as the low energy limit of String Theory. The study of Supergravity in its many forms is crucial for understanding the perturbative and non-perturbative dynamics of String Theory, the landscape of vacua, compactifications and the issue of supersymmetry breaking. It is also important for a better understanding of black holes and their microstates, which is is a central problem in Quantum Gravity.

In the last decades a considerable progress has been obtained in the investigation of non perturbative properties and different dualities between strong and weak coupling regimes in Gauge and String Theory. Integrability and a better understanding of the structure of scattering amplitudes has shed new light on the quantum properties of certain gauge theories.

GSS - S. Bellucci (loc. spokesperson) + S. Ferrara (ass.), G. Gionti (ass.), A. Yeranyan (Fermi Inst. PostDoc)

Main research issues (continued)

A major role as a candidate bridge between line I and line II is played by D-branes, extended objects in String Theory, whose low energy dynamics is described by supersymmetric gauge theories. Analysis of D-brane configurations therefore provides non- perturbative information on gauge theories and leads to a framework that unifies string theory, supergravity and gauge theory. An analogous role is played by the AdS/CFT duality, which, emerged from string theory, has been centered on the analysis of strongly interacting gauge field theories by mapping them to classical gravity and it has been recently extended to the description of the quark-gluon plasma and to condensed matter.

Important and acknowledged results. The IS includes internationally known experts in gauge theories, supergravity, D-branes, compactifications and the AdS/CFT correspondence whose competences are naturally complementary. Many collaborations are active with international Institutions. The future research activity will be devoted to the study of some of the main open problems in the fields of:

1) The AdS/CFT correspondence, with an eye to three, four and possibly higher dimensional theories, the relation with integrability and the holographic description of realistic systems.
2) Supergravity and Black Holes, with attention to the classical and quantum properties of supergravity and the properties of BPS and non-BPS black-holes and their microstates.
3) Properties of supersymmetric Gauge Theories, with attention to integrability and the properties of scattering amplitudes, the study of protected quantities in various dimensions, topological theories and the (brane) instantonic calculus.
4) String Theory, compactifications and string vacua, with an eye to the most tractable vacua, the supersymmetric ones, and to the deepening of our knowledge of semi-phenomenological models.

IS – PhenoLNF [Particle physics phenomenology]

Gruppo LNF (2013/14):
Dipendenti LNF: G. Corcella, V. Del Duca, G. Isidori [Resp. Loc.]
Ass. Senior: G. Pancheri
Borsisti: M. Gonzales-Alonso [A.R. PRIN (1yr)], G. Bevilacqua [bors. INFN (2yrs)]

Campi di ricerca:

- Modelli di Nuova Fisica
- Higgs Physics
- Stime di precisione in fisica del sapore [*Fisica dei K e B*]
- Sviluppi formali in QCD
- Calcoli di precisione e simulazioni Montecarlo per l'LHC

- Attività fortemente collegata a molte delle attività di GR.I dei LNF [ATLAS, CMS, LHCb, KLOE, NA62, Belle-II, …]

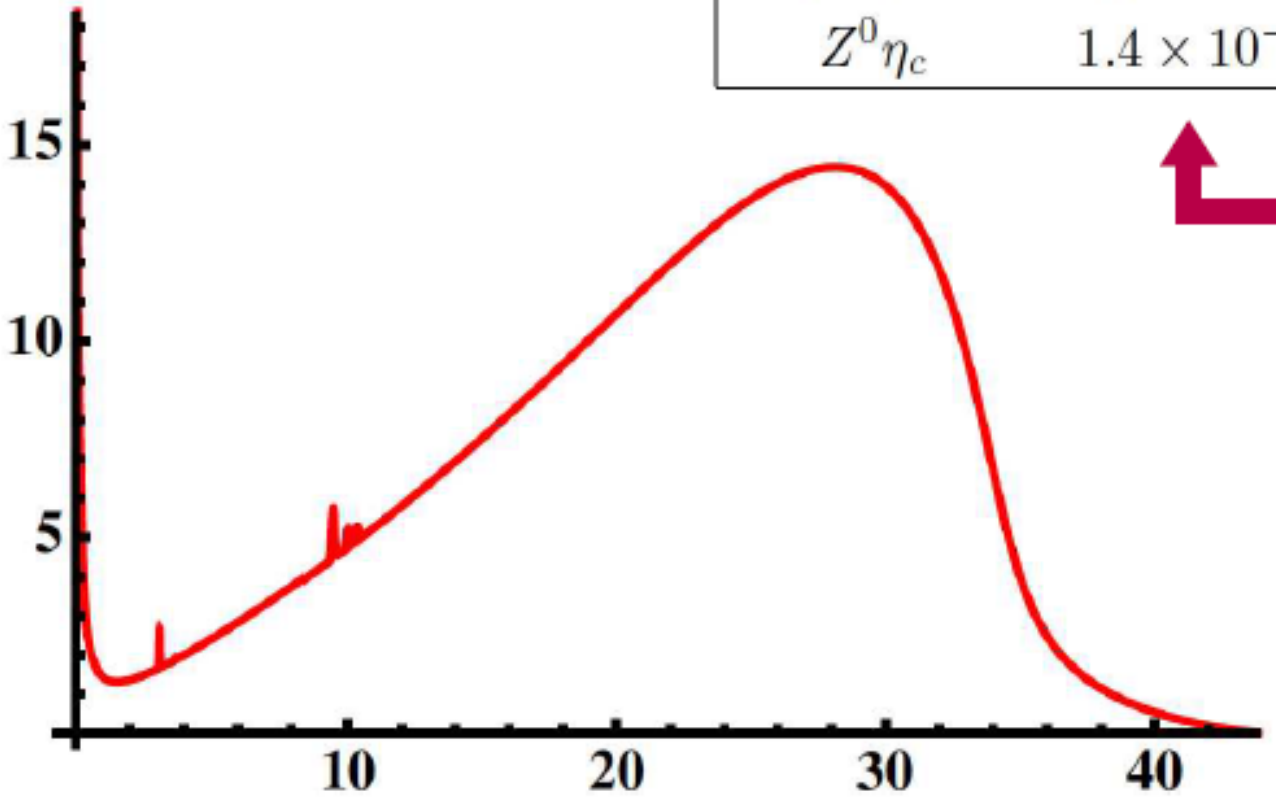
- 22 papers on the arXive in the last 12 months

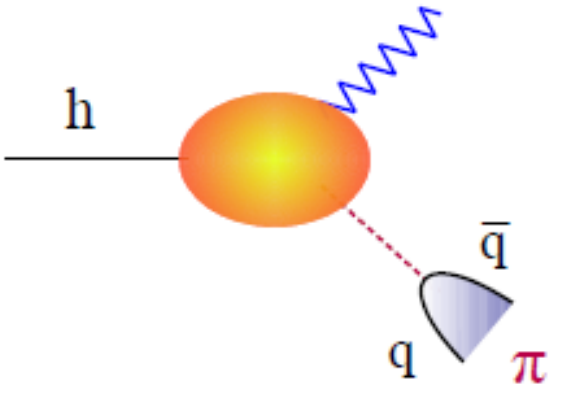
PhenoLNF Highlights: Higgs Physics

First th. analysis of the dilepton mass spectrum in Higgs $\longrightarrow$ 4l decays including SM resonance effects

VP mode	$\mathcal{B}^{\rm SM}$	VP^* mode	$\mathcal{B}^{\rm SM}$
$W^-\pi^+$	0.6×10^{-5}	$W^-\rho^+$	0.8×10^{-5}
W^-K^+	0.4×10^{-6}	$Z^0\phi$	2.2×10^{-6}
$Z^0\pi^0$	0.3×10^{-5}	$Z^0\rho^0$	1.2×10^{-6}
$W^-D_s^+$	2.1×10^{-5}	$W^-D_s^{*+}$	3.5×10^{-5}
W^-D^+	0.7×10^{-6}	W^-D^{*+}	1.2×10^{-6}
$Z^0\eta_c$	1.4×10^{-5}	Z^0J/ψ	2.2×10^{-6}

First th. predictions of the rare semi-hadronic Higgs decays within SM





Gonzales-Alonso & Isidori, '14

Isidori, Manohar, Trott, '13

Vittorio Del Duca

Calcoli di precisione nel Modello Standard e in QCD perturbativa

- migliorare la comprensione dell'universalità delle divergenze infrarosse in QCD perturbativa[a]

- completare uno schema per il calcolo di sezioni d'urto al NNLO in α_S in modo indipendente dal particolare processo, usando l'universalità delle divergenze infrarosse[b]

- potenziare il calcolo di ampiezze di scattering a molti loop in teorie di gauge mediante l'uso di concetti avanzati di algebra moderna, come la *symbol map*[c]

a VDD, G. Falcioni, L. Magnea, L. Vernazza, *Phys. Lett.* B732 (2014) 233 [arXiv:1311.0304 [hep-ph]]

b VDD, G. Somogyi, Z. Trocsanyi, *JHEP* 1306 (2013) 079 [arXiv:1301.3504 [hep-ph]]

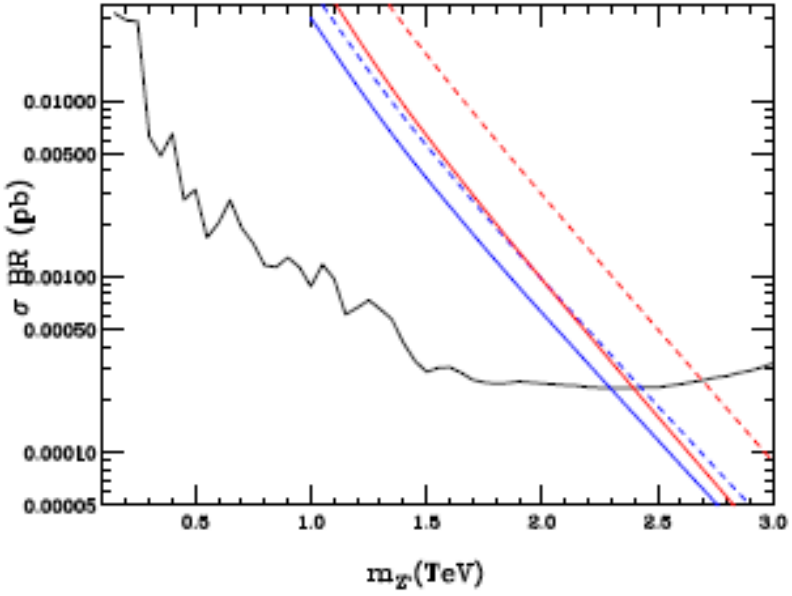
c VDD, L.J. Dixon, C. Duhr, J. Pennington, *JHEP* 1402 (2014) 086 [arXiv:1309.6647 [hep-ph]]

G.Corcella: Fenomenologia dei collider adronici nel Modello Standard e sue estensioni

Produzione di bosoni vettori Z' in supersimmetria e fenomenologia del quark top a LHC

1. Gli attuali limiti sulla massa della Z' a LHC sono $m_{Z'} > 2.22 - 2.90$ TeV nel Modello Standard Sequenziale (SSM) e $m_{Z'} > 2.51 - 2.62$ TeV per i modelli $U(1)'$ ispirati dalle Teorie di Grande Unificazione

Ricerca di coppie di leptoni a grande massa invariante; l'apertura di canali supersimmetrici in coppie di sleptoni, squark e gaugini ($Z' \to \tilde{\ell}^+\tilde{\ell}^-, \tilde{\chi}_i^+\tilde{\chi}_j^-, \tilde{\chi}_i^0\tilde{\chi}_j^0$) abbassa limiti di esclusione e dà spazio a nuove analisi (leptoni+MET)



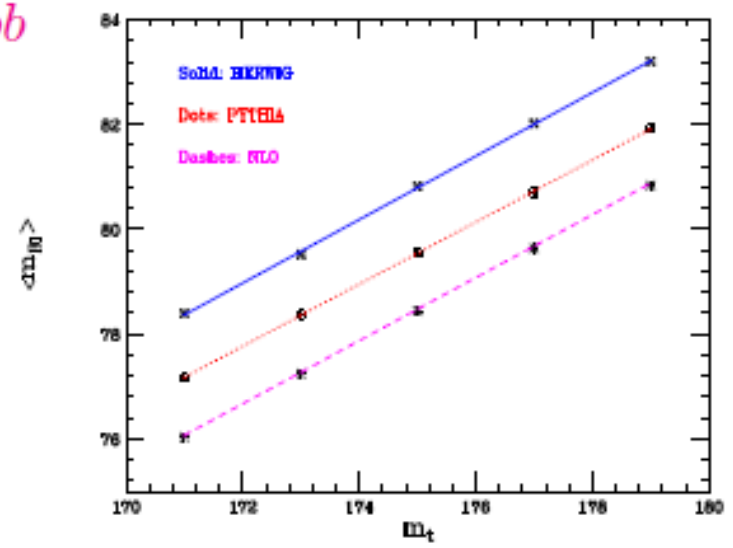
Black: ATLAS data on $\sigma(pp \to Z') \times B(Z' \to e^+e^-)$
Red: SSM; solid: SM+BSM decays, dashes: SM
Blue: Z'_ψ; solid: SM+BSM decays, dashes: SM
$\Delta m_{Z'} \simeq 300$ GeV rispetto alle analisi standard
in un punto nello spazio dei parametri Z'/SUSY

References: G.C., EPJ 60 (2013) 18011; G.C. and S.Gentile, NPB 866 (2013) 293

2. Contributo di adronizzazione all'errore sistematico sulla massa del top (m_t)

2.1 Frammentazione del quark bottom nel decadimento del top ($t \to bW$, $W \to \ell\nu$)

Case study: massa invariante $m_{B\ell}$ nel canale dileptonico predetta da generatori Monte Carlo (HERWIG e PYTHIA) e calcoli NLO, con fit di modelli di adronizzazione a dati di LEP e SLD su $e^+e^- \to b\bar{b}$



Incertezza $\Delta m_t \simeq 1.5$ GeV; in prospettiva uso di codici NLO+showers o in C++

2.2 Relazione tra massa del top estratta da simulazioni MC (LO+showers) e definizioni teoriche di massa (pole, $\overline{\rm MS}$ mass) che richiedono calcoli almeno NLO

Strategia: simulare stati adronici $T^{0,\pm}$ e farli decadere con il modello spettatore

Connessione tra massa ricostruita quando il top decade prima (m_t) o dopo (m_T) l'adronizzazione: $m_T = m_t + \Delta m$ (G.C. and M.L.Mangano, work in progress)

Relazione tra massa di mesone e quark (pole o $\overline{\rm MS}$) con metodi di reticolo o NRQCD

TAsP: Theoretical Astroparticle Physics

Afferenti :

Gaetana Anamiati (Studentessa Dottorato, U. Cosenza – 100%)
Martin Krauss (Assegnista LNF – 100%)
Aurora Meroni (Assegnista LNF & Roma 3 – 100%)
Enrico Nardi (Responsabile, 1^0 ricercatore INFN – 100%)
Eduardo Peinado (Borsista INFN – 100%)
Un nuovo Assegnista da Ottobre 2014 (Concorso in svolgimento)

TAsP-LNF Main Research Topics:

- Dark Matter models & detection
- Baryogenesis & Leptogenesis
- Majorana neutrinos & neutrinoless double beta decay
- Models for ν masses & mixings
- Lepton Flavor (LF) & LF violation
- Spont. Flavor Symmt. Breaking & theories for Yukawa couplings

Some representative topics in more detail:

Theory of Yukawa couplings from Spont. Flavor Symmt. Breaking

Main idea: the $SU(3)^3$ quark-flavor symmetry is spontaneously broken by VEVs of `Yukawa fields' which minimize the symmetry invariant scalar potential at configurations corresponding to the observed quark masses and mixing angles. A Yukawa potential that reproduces correctly V_{CKM} and m_Q in: Fong & Nardi, PRD89 (2014)

Theory of neutrino masses after the Planck limit: $\Sigma m_\nu < 0.23$ eV

Main idea: An analysis of Majorana mass matrix textures in the light of neutrino oscillation data and of the Planck result on the sum of the neutrino masses allows to rule out a set of possibilities, in: Meloni, Meroni & Peinado, PRD89 (2014)

Higher dimensional effective operators and direct DM detection

Main idea: The extremely feeble interactions of DM might be explained by the fact that only (dimensionally suppressed) effective operators couple DM to the SM particles. An analysis of all possible completions for dimension six operators with extra fermions and extra scalars, and their consequences at the LHC, in: Krauss, Morisi, Porod & Winter, JHEP 1402 (2014).

Baryogenesis at the TeV scale

Main idea: A Cosmological Baryon Asymmetry can be obtained even when Baryon and Lepton numbers remain perturbatively conserved, if equal in magnitude and opposite in sign B & L asymmetries get produced in the SM sector and in a new (hidden) secluded sector. In: "Cloistered Baryogenesis", Aristizabal Sierra, Fong, Nardi & Peinado, JCAP 1402 (2014).

Collaborations

Université de Liège	(D. Aristizabal Sierra)
Sao Paulo U.	(Chee Sheng Fong)
Univ. Roma 3	(D. Meloni)
SISSA – Trieste	(S. Petkov, M. Spinrath, I. Girardi)
Colima U.	(A. Aranda)
Stony Brook	(M.C. Gonzalez-Garcia)
Wurzburg U.	(S. Morisi, W. Winter, W. Porod)
Valencia U.	(J.W.F. Valle, C. Bonilla, M. Hirsch)
Southampton U.	(S.F. King)
Orsay, LPT	(A. Vicente)
Tata Institute	(Ketan M. Patel)
U. Antioquia	(D. Restrepo, O. Zapata)

FTECP - M.P. Lombardo (loc. spokesperson) + F. Palumbo

Main research issues

Lattice Field Theories and Phase Transitions in Particle Physics.

Link with the Center for Mathematics and Theoretical Physics (CMTP)

http://cmtp.uniroma2.it/index.php

With 'FASTSUM Collaboration' : Frascati, Argonne, Seoul, Trinity, Swansea, Utah, Maynooth

BOTTOMONIUM IN QGP

HIGHLIGHTS 2013/2014: P-STATES AND ALGORITHMIC DEVELOPEMTNS.

With tmft collaboration:

Frascati, Dubna, Berlino

QCD Transition and QGP Physics:

Highlights 2013/2014:

Observation of the effects of a dynamical charm mass on QCD thermodynamics

With Groningen and Nagoya

Strong interactions with many fundamenta fermions

Highlights 2013/2014:

Observation of scale separation and hints of anomalou dimension needed for BSM models.

Requests to LNF services:

Normal secretarial help

Financial request to CSN4:

Not ready (We are discussing as many think that the IS scheme should be adapted in case of international activities (will be glad to add details))