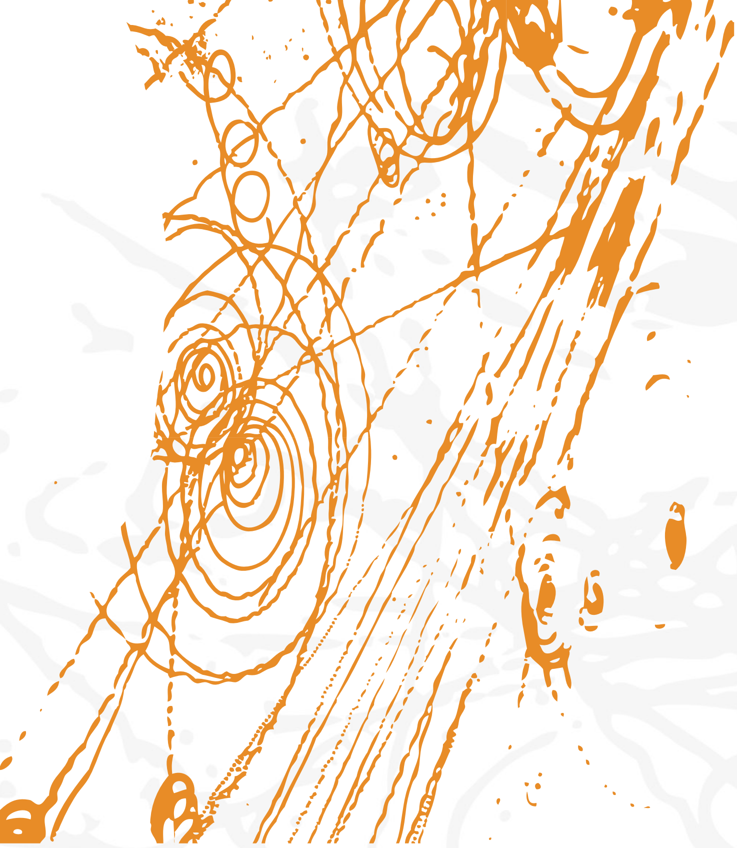
2014

LNF Highlights

INFN
Istituto Nazionale
di Fisica Nucleare
Laboratori Nazionali di Frascati



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Laser alignment system of detectors at BTF (courtesy: F. Burkart, CERN)

One year of Physics at LNF: 2014

Foreword

Following a long period devoted to hardware maintenance and to the installation of new equipment, in the fall of 2014 the DAΦNE accelerator has restarted delivering luminosity to the KLOE-2 detector. This is an important achievement for LNF, aimed at keeping and strengthening the long standing tradition of the Laboratory in building and operating high energy electron-positron colliders. After this successful start, a few years of hopefully rich data taking efforts are now in front of the KLOE-2 Collaboration.
Important results have also been produced at the SPARC_LAB facility, where, among other things, innovative and potentially revolutionary acceleration techniques are being tested.
Several external experimental groups have accessed our research facilities. At the same time, LNF researchers, engineers and technicians have contributed to some of the major scientific enterprises held in many laboratories in the world, in particular at CERN.
This booklet aims at giving a short review of the major achievements of the Laboratory during the year, in all these fields. It is a tribute to the passion and to the ingenuity of LNF personnel, at all levels.

Umberto Dosselli
LNF Director

KLOE-2 searches for the Dark Light

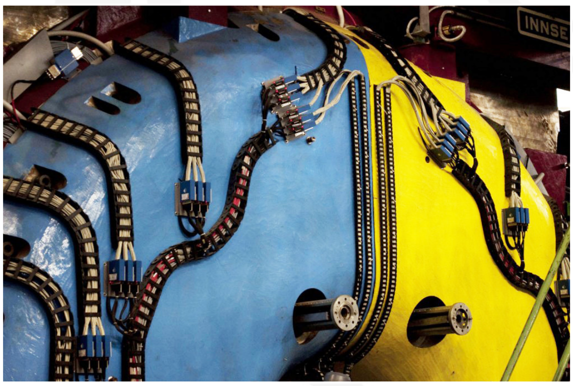
There is compelling astrophysical evidence that the vast majority of the matter of which our Universe is made of is not the "ordinary" matter described by the Standard Model of Particle Physics (SM). Unfortunately, we know very little about this new type of matter: it must be massive, because we know of its existence by gravitational effects, stable since we do not observe appreciable differences in its presence along time, and electrically neutral, since it does not emit radiation at any wavelength (hence the name of Dark Matter). During the last two or three decades many theoretical and experimental efforts have been put in place to try to give an explanation to this fascinating puzzle, however no conclusive evidence exists.

Among the various hypothesis taken into consideration there is the idea that Dark Matter (DM) constitutes the stable component, similar to the proton and the electron for SM particles, of a large set of possible new states which are sensitive to new types of interactions, different from those described by the SM. The mediators of these new forces might be several, however for simplicity physicists refer to only one of them, often dubbed as the "dark photon" or γ'. As for DM particles, there is no firm prediction about the nature of the dark photon. Its mass, for instance, might be any. However there are phenomenological reasons to believe that it can be relatively light, with a mass between 1 MeV and a few GeV. Moreover it is also often postulated that, although SM particles are "blind" to the new interactions, they might still couple to the γ' through special mechanisms allowed by quantum mechanics. The strength of this coupling is often described by a single factor "ε" which parametrizes the coupling between SM particles and the dark photon compared to that between the same particles and the ordinary photon. Obviously, the "mixing parameter" ε must be consistently lower than 1, and in general it is postulated to be in the range 10^{-2} – 10^{-8}. Based on these arguments, many scientists in the world have tried to find evidence for the existence of dark photons, searching for their signals in accelerator based experiments. The basic idea is that a γ' can be produced any time there are allowed processes that produce an ordinary photon, with the only difference that the former event is rarer by a factor ε^2 with respect to the latter one. Fortunately, however, the dark photon immediately decays into a pair of SM particles with an invariant mass corresponding to the mass of the γ', while the standard processes show a continuum invariant mass spectrum. Therefore the common strategy of all of these searches is to look for a peak rising over an otherwise continuum invariant mass distribution, a technique that in the physicists' slang is often called "bump hunting".

In a series of papers published between 2012 and 2014, the KLOE-2 Collaboration of LNF, has searched for such resonant processes looking into the data collected between 2002 and 2005 by the KLOE detector [1][2][3]. Two reactions were taken into consideration:

1. the decay of a φ meson into an η meson and a γ', with the subsequent decay of the dark photon into an electron-positron pair;
2. the production of a γ-γ' pair in e^+e^- collisions, with the subsequent decay of the γ' into a muon-antimuon ($\mu^+\mu^-$) pair.

In the first case the presence of the η meson in the final state was tagged by its decays into either three neutral pions or into $\pi^+\pi^-\pi^0$. The choice of the γ' decay channel into e^+e^- allows one exploring dark photon masses down to few MeV; on the other hand the allowed mass range is limited upwards by the difference between the masses of the φ and the η meson, approximately 450 MeV. In the second case, the choice of the $\mu^+\mu^-$ final state limits downwards the explorable region to ~210 MeV, but the allowed range extends up to the maximum available energy, 1020 MeV.



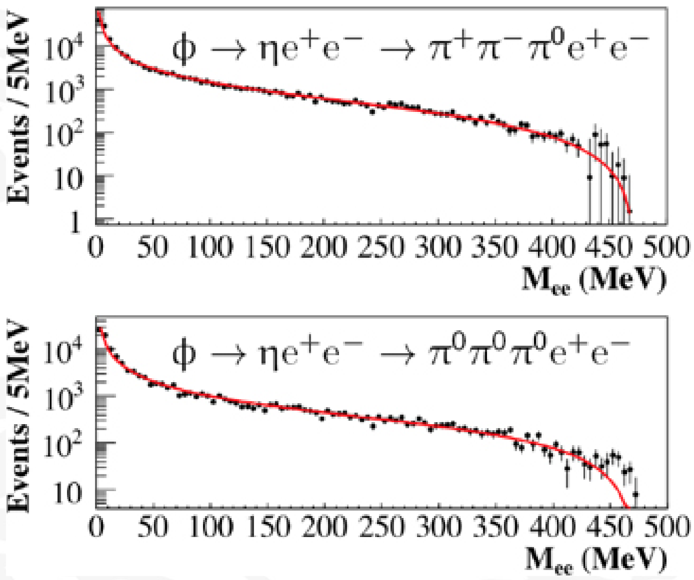
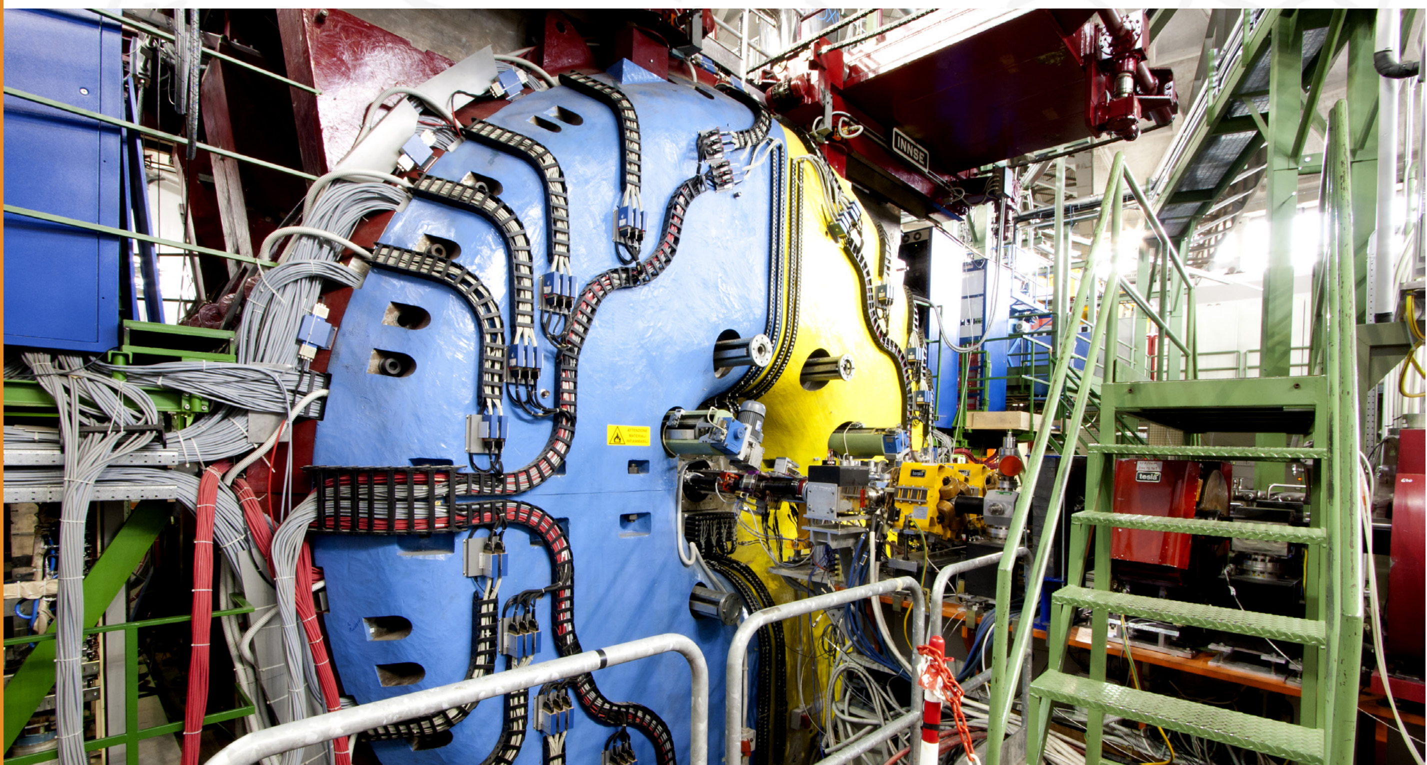


Fig. 1: Invariant mass distribution for $\varphi \to \eta e^+e^-$ events. Plot taken from reference [2].

In both cases, the analysis could profit of the excellent mass resolution, ~ 1 MeV, provided by the KLOE Drift Chamber. The invariant mass distributions for the first type of reactions are shown in fig 1: no evident bump is seen in the plots for any invariant mass value. Similarly, no positive signal is seen for the second type of reaction, so that KLOE-2 could in the end exclude the existence of the dark photon in the mass region between 30 MeV and 1 GeV, for ε values as low as 10^{-3}.
At the same time, other experiments have performed similar searches although with different techniques, all of which with null result.
At present, no evidence for the existence of a dark photon, decaying into SM particles has been obtained. New experiments are being planned to increase the sensitivity to lower couplings as well as to different, non-standard decay channels.



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DAΦNE starts a new run for KLOE-2

On November 17 2014, after a long period of maintenance and hardware upgrade, DAΦNE, the LNF e^+e^- collider, has started providing new collision data to the renewed KLOE-2 detector.
This is the first time that the new interaction scheme of DAΦNE, which was successfully operated with the SIDDHARTA experiment, is used with a magnetic detector such as KLOE-2.
In the short run before the Christmas shutdown very encouraging results have been obtained. A peak luminosity of 1.8×10^{32} cm^{-2}s^{-1} was observed, exceeding by a factor 13% the best luminosity ever achieved at DAΦNE while operating in the presence of a high field detector solenoid. The backgrounds, one of the major concerns with the new interaction scheme, have been kept at a level acceptable for the operation of KLOE-2.
Storing a test pattern of contiguous 10 bunches, the peak luminosity has reached 2.5×10^{31} cm^{-2}s^{-1}, demonstrating that 2.5×10^{32} cm^{-2}s^{-1} might be achieved using 100 bunches if the e-cloud effect is controlled at the best and the dynamical vacuum is optimized.
KLOE-2 aims at collecting a minimum of 5 fb^{-1} of data within a couple of years. The results of these first days of run are suggesting that this goal can be successfully reached.

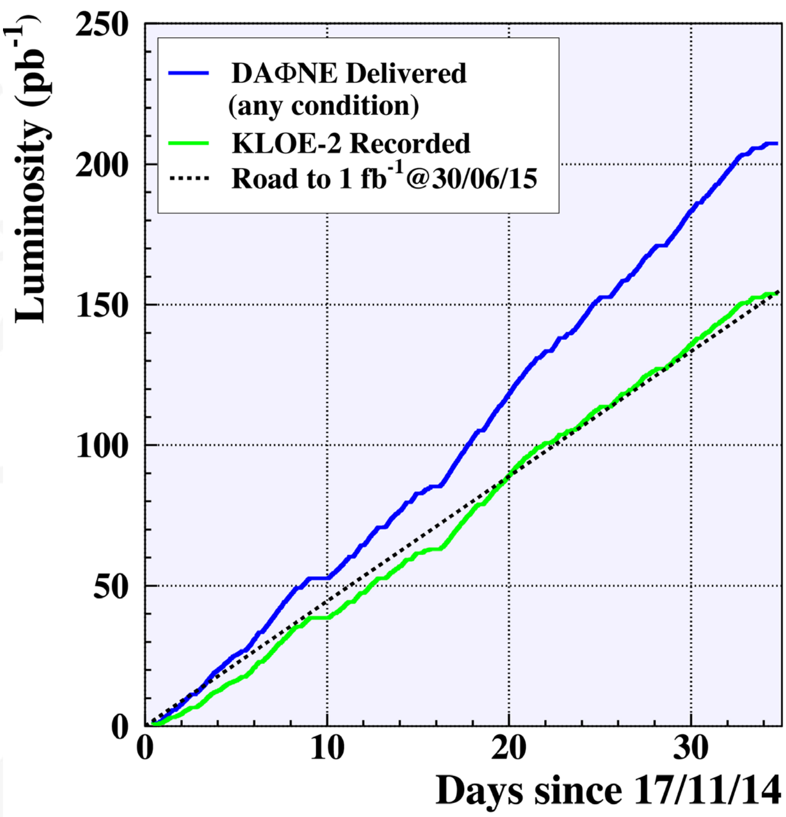

Fig. 1: Integrated luminosity in the last 30 days of 2014.
The dotted line shows the rate required to accumulate 1 fb^{-1} by the end of june 2015.

Single and multi-bunches high brightness generation for plasma acceleration experiments

Plasma-based accelerators are the new frontier of the acceleration technology thanks to their capability to sustain extremely large accelerating gradients [1,2]. Unlike conventional Radio-Frequency (RF) structures, plasma-based ones can sustain electron plasma waves with electric fields several orders of magnitude higher than those achievable with present technologies, i.e. hundreds GV/m. However, lower beam quality than conventional accelerators has been achieved so far, due to the dynamic nature of the plasma structures, whose gradient can be tuned by adjusting the plasma density.

Plasma-based accelerators are usually grouped according to the excitation mechanism of the electron plasma wave: Laser Wakefield Accelerators (LWFA) if driven by laser pulses [3], or Particle-driven Wakefield Accelerators (PWFA) if driven by particle bunches [4]. A high power driving pulse can excite a plasma wave in which electrons are trapped and gain energy as long as they are in phase with the accelerating and focusing field. The SPARC_LAB team is currently investigating external injection schemes, driven by either a hundreds TW laser (FLAME) or a train of electron bunches, to accelerate in a plasma capillary a high brightness electron beam. The choice of the plasma density determines the wavelength of the accelerating plasma wakefield and the matched beam size to be injected in the plasma-based accelerator (Fig. 1). In case of a 10^{16} cm^{-3} plasma density, the plasma wavelength is about 300 μm, demanding micrometer and femtosecond scale electron bunches to be injected in the plasma capillary, in order to minimize emittance growth, due to betatron oscillations, and final energy spread.

As a matter of fact, the production and control of fs scale and low emittance electron bunches is mandatory to accelerate in the plasma a high brightness electron beam, which can serve as active medium for Free-Electron Lasers (FELs), to drive advance radiation sources (e.g. X-rays and THz radiation) and to allow the staging of plasma structures for compact TeV linear colliders. In this framework, the preparatory phase of plasma-based experiments has started at the SPARC_LAB test facility [5]. Experimental beam dynamics studies have demonstrated the great flexibility of the SPARC photoinjector to generate and manipulate high brightness electron bunches by fine-tuning the photocathode laser pulse shape and the RF linac settings. At this regard, a bunch with 50 pC charge has been compressed by a factor 20 through the Velocity Bunching [6], resulting in 50 fs rms length at the exit of the linac at 81 MeV with 0.5% rms energy spread, and 1 mm mrad normalized average rms emittance.

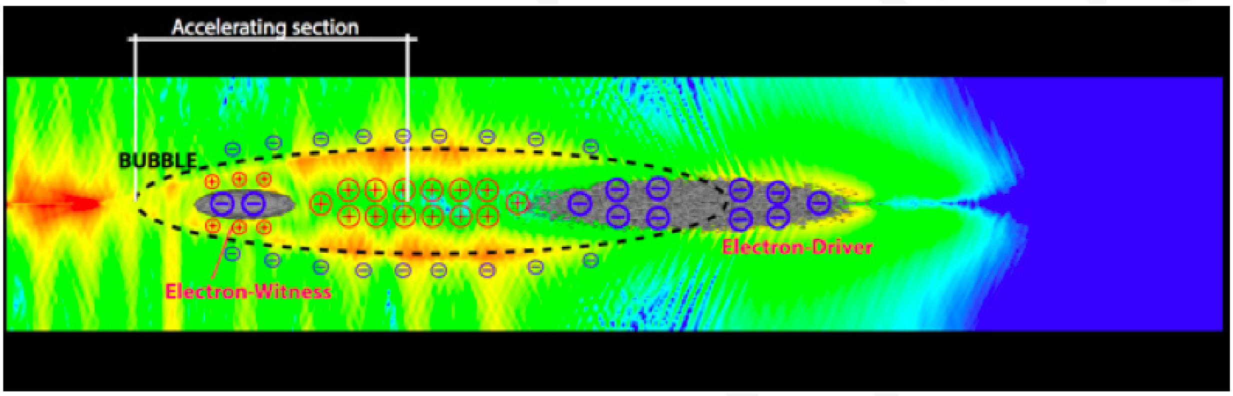

Fig. 1 Bubble of electrons displaced by a driver beam. The witness bunch is injected at the phase of accelerating field (Particle-in-Cell simulation code).

Afterwards, the beam has been transported through the dog-leg beam line up to the Electro Optical Sampling diagnostic station [7], which measured a final rms bunch length of 90 fs. This result has been also confirmed through the measurement of coherent transition radiation spectrum [8], extending up to higher frequencies in the THz range, as shown in Fig.2.
In addition, a train of short bunches with variable and tunable distance, as the one required by the beam driven plasma acceleration experiment, has been characterized. Two drivers (40 pC) and one witness (20 pC) bunch have been successfully produced by the so-called laser comb technique [9]. The train at the linac exit has been over-compressed and accelerated up to 116.5 MeV, the final distance between drivers was 1.16 ps with the witness at 1.55 ps distance as the one required by matching with a ~300 µm plasma wavelength. The witness bunch has a measured time duration as low as 30 fs and an rms normalized emittance of 1 mm mrad.

These results are a significant step forward external injection experiments, foreseen at SPARC_LAB, in both schemes of plasma acceleration, i.e. laser and particle driven ones.

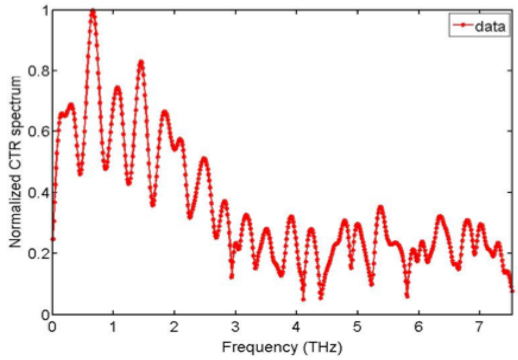

Fig. 2 Normalized spectrum of coherent transition radiation (CTR) as produced by an electron bunch as short as 90 fs rms. The spectrum is retrieved by Fourier transformation of the autocorrelation function of CTR as measured through a Michelson interferometer.

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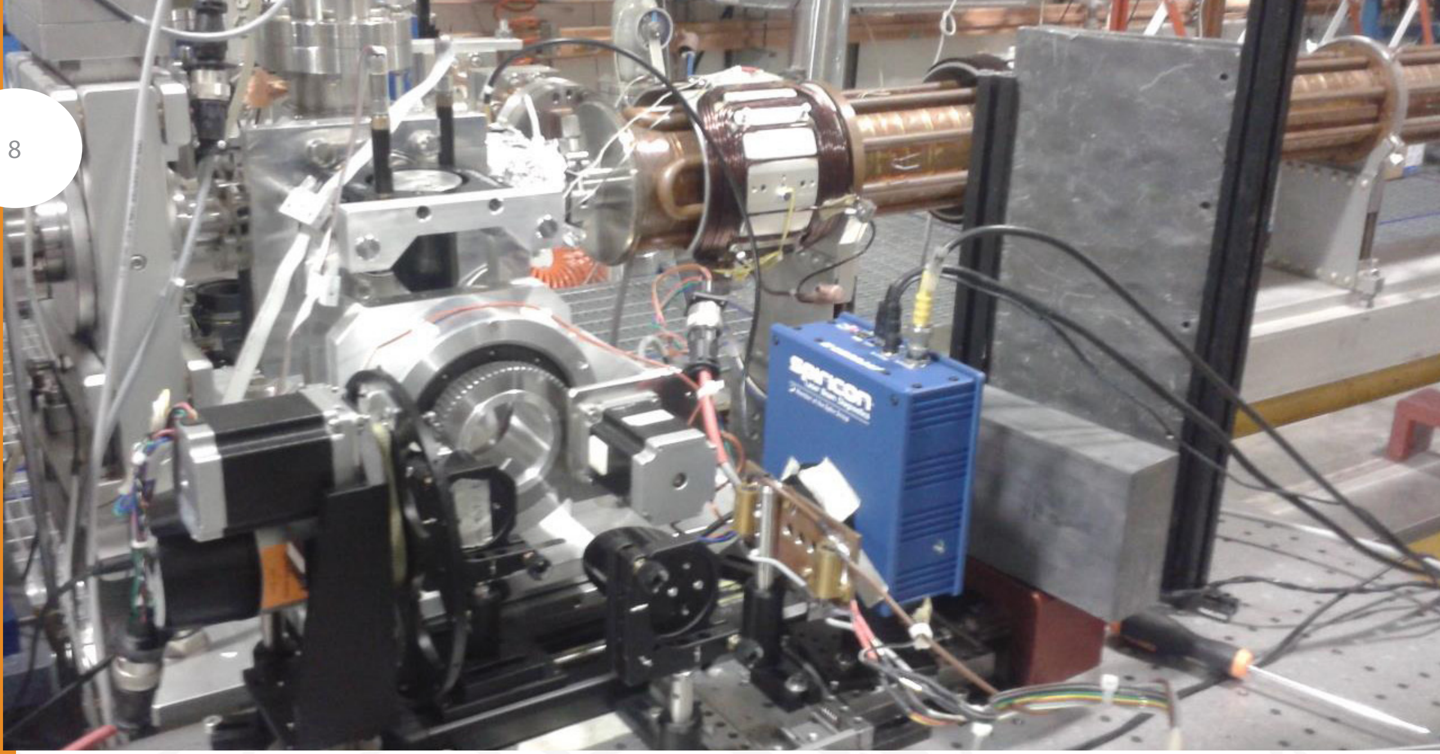

Electromagnetic Induced Trasparency in TI materials observed for the first time

Dirac electrons, i.e. massless electrons characterized by a linear energy/momentum dispersion have been discovered in Condensed Matter Physics only recently [1]. Indeed, they characterize the low-energy electrodynamics of Graphene [2] and its spectacular properties like electric tunability, Quantum Hall effect and very strong electromagnetic field-matter interaction are a direct consequence of the presence of Dirac electrons. More recently, Dirac electrons have been discovered also in other exotic electronic quantum materials: the Topological Insulators (TIs).

These materials are quantum systems characterized by an insulating electronic gap in the bulk, whose opening is due to strong spin-orbit interaction, and gapless surface states at the edge and interface [3]. Surface states in TIs are metallic, characterized by a Dirac dispersion, showing a chiral spin texture, and protected from backscattering by time-reversal symmetry [4].

Since their discovery, TIs have attracted a growing interest due to their potential application in quantum computing, Terahertz (THz) detectors, and spintronic devices. Moreover, TIs have been proposed as a Condensed Matter realization of axionic electrodynamics.

Recently, theoretical models have predicted a strong nonlinear terahertz behavior in Topological Insulators which has been estimated to be ten orders of magnitude larger than massive (Schrödinger) electron plasma in conventional metals. This nonlinearity which corresponds to a strong dependence of the electromagnetic properties of TIs vs. the applied THz electric field, implies an effective harmonic generation and can be used for frequency conversion and optical rectification, and for a technological implementation of new optical devices, in particular in the THz range (50 GHz – 10 THz). This part of the electromagnetic spectrum which separates the microwaves region from the infrared, is indeed extremely important and it has seen in recent years a tumultuous developing of basic researches and technologies. However, in order to test a nonlinear optical behavior one should measure the THz optical properties of Topological Insulator materials in a very broad range of THz electric field: from a few V/cm, which correspond to a standard electric field associated with conventional electromagnetic source, to several MV/cm, electric field values characteristic of the atomic limit. These electric fields cannot be achieved with a conventional THz source

while they are routinely produced at SPARC_LAB through the Coherent-Transition-Radiation emission mechanism [5].
A picture of the THz installation at SPARC_LAB is shown in Fig.1 and in Fig.2 we show a scheme of the experimental set-up.
The ultra-short electronic bunches coming from SPARC_LAB photoinjector interacting with a metallic screen produce highly intense sub-picosecond Coherent Transition Radiation THz pulses. THz radiation, emitted at 90° with respect to electron vacuum pipe, is transmitted by a z-cut Quartz window and collected and collimated by means of an off-axis parabolic mirror. A further flat mirror was used to reflect the THz radiation up to the optical table where a second off-axis parabolic mirror focalized the THz pulses on TI samples.
One can see that harmonic generation corresponds to an electromagnetic induced transparency in the THz range [6]. Indeed, most of the electromagnetic energy associated with the THz field in a given spectral range is converted at high frequency corresponding to an enhanced transparency. In other words, a Topological Insulator sample irradiated with THz radiation becomes more and more transparent for an increasing electric field associated with the THz pulses. In Fig. 3 we show this effect, which has been measured at SPARC_LAB, for THz electric fields spanning seven orders of magnitude from 0.1 V/cm to 1.5 MV/cm [6].
The transmittance of a Topological Insulator sample integrated over a frequency range from 500 GHz to 2 THz is plotted vs. the THz electric field. At low-field the transmittance is nearly flat corresponding to the linear response regime. For increasing electric fields the Topological Insulator sample starts to be more transparent and this corresponds to the harmonic generation effect.
This is the first experimental evidence of electromagnetic induced transparency in the Topological Insulator materials and could open the way towards the possibility to control light by light in the THz regime which is a subject of intense study to implement compelling applications in THz technology, like ultrafast THz tabletop sources, quantum cascade lasers and ultrafast THz communications based on optical bistability.

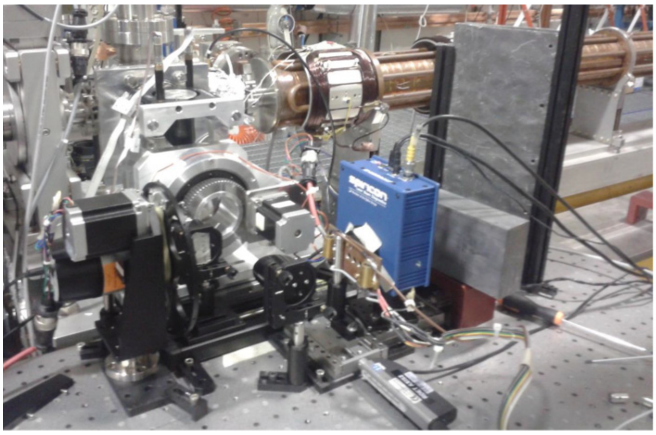

Fig. 1 Picture of the SPARC_LAB THz installation.

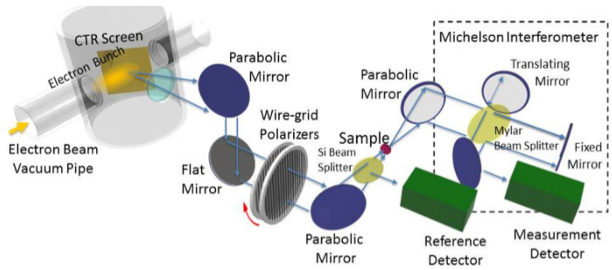

Fig. 2 Scheme of experimental setup at SPARC THz source

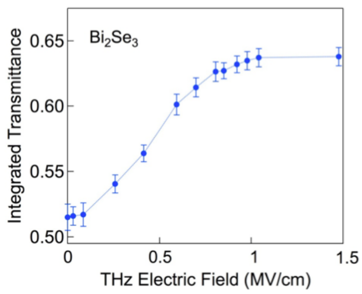

Fig. 3 Experimental Data.

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First Thomson back-scattered photons observed at SPARC_LAB

Many research fields from biology to medicine, to materials science require the availability of tunable and quasi-monochromatic X radiation sources with large spectral intensity. One of their most important applications is the advanced imaging where new research techniques in the investigation of matter, which need a coherent illumination of the samples with a large flux of photons of high energy, permit in fact to reach spatial resolution of the order of the molecular and atomic scales, probing nano-structured, inorganic and organic objects. Besides the synchrotron radiation (SR) facilities, radiation sources based on the Thomson backscattering effect have become more and more attractive due the large variety of applications and compactness of the whole apparatus. Even though their fluence rate is lower compared to those typically achievable by SR sources, it can be still compatible with the requirements of a wide range of experiments.
The Thomson backscattering (TS) [1–3] is the electromagnetic process in which each electron absorbs one (linear scattering) or more (nonlinear scattering) photons from (typically) a laser pulse, emitting one photon. If the electrons are ultrarelativistic the scattered radiation looks frequency upshifted and is emitted in the forward direction with respect to the motion of particles, in a small cone of aperture roughly given by the inverse of their Lorentz relativistic factor, see Fig 1.

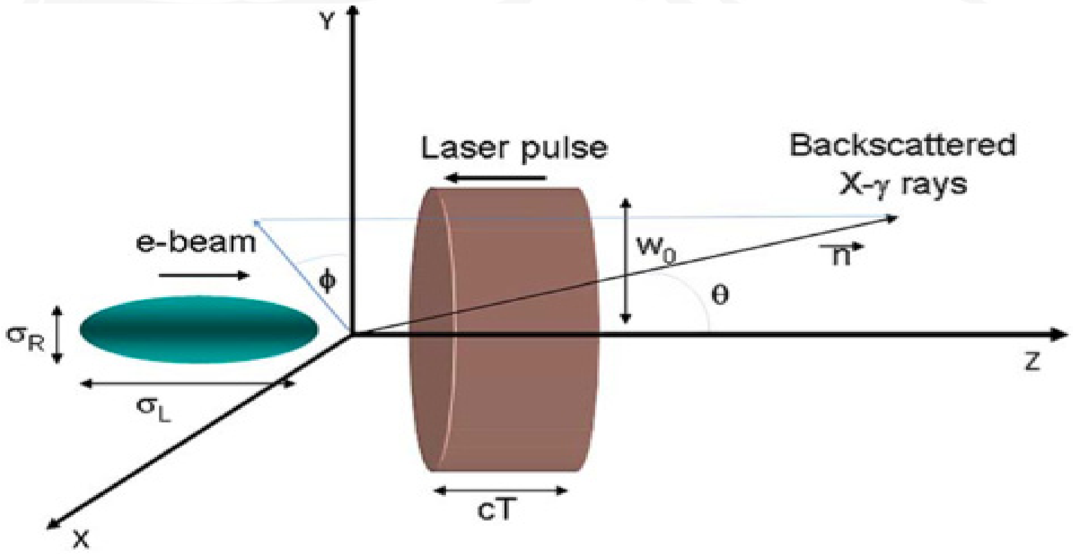

Fig. 1 Thomson backscattering geometry.

The electron beam of longitudinal and transverse size σ_L and σ_R, respectively, is moving at a relativistic speed from left to right, colliding with a photon beam of waist size w_0 and duration T, thus emitting scattered radiation mainly in the direction of motion of the electron beam. At the Frascati INFN-SPARC_LAB [4] the opportunity has been used to couple the SPARC High Brightness photoinjector with the 250 TW FLAME laser system [5] in order to provide a X-ray Thomson source in the range of 20-500 keV. A 20 m double dogleg carries the electron beam output from the SPARC photoinjector down to the Thomson Interaction Point where the FLAME laser pulse is brought by a 20 m in vacuum optical transfer line. The parameters of the electron and laser beams, have been optimized in view of the first planned experiment with the Thomson radiation: the X-ray imaging of mammographic phantoms with phase contrast technique [6], requiring high flux of photons and moderate monochromaticity.
The electron beam is provided by the SPARC photoinjector where a 1.6 cell S-band RF gun is equipped with a Cu photocathode driven by a 50 μJ Ti:Sapphire laser and a four coils solenoid for the emittance compensation.

The beam is then accelerated by three TW SLAC type S-band linac sections (S1-S3) up to the desired energy. For the commissioning phase a low charge working point has been set up for electron beam with Q= 200 pC and energy E= 50 MeV.

The laser pulse used to drive the Thomson back scattering process with the SPARC electron beam is provided by the FLAME laser system [6]. This nominal 300 TW laser system uses 11 YAG pump lasers and 5 titanium-sapphire multi-pass amplifiers to produce linearly polarized pulses with a central wavelength λ_0=0.800 µm in a 60÷80 nm bandwidth. The pulse duration ranges between 25 fs ≤ τ_L ≤ 10 ps, and the maximum energy is E= 7J that corresponds to a maximum energy on target E_t ~ 5J, at 10 Hz repetition rate. The laser pulse is optically transported from the FLAME laser system in a shielded underground area where the compressor is located and that is adjacent to the SPARC hall. From here an optical transfer line in vacuum, (P=10^{-6} Torr), carries the beam up to the parabolic mirror of the Thomson interaction chamber that focuses the beam in a 10 µm diameter (FWHM) spot at the interaction point.

The synchronous arrival of electrons and photons at the IP is obtained by locking precisely the oscillators of the photo-cathode laser and interaction laser systems, and the phase of the RF accelerating fields to a common Reference Master Oscillator (RMO).

For the commissioning 200 pC electron beam at 50 MeV the measured normalized transverse emittance at the Linac exit was ε_{x-y} = 1.5 - 2.2 ± 0.2 mm mrad, with an energy spread σ_δ= 0.1 ± 0.03 %, and a rms length σ_z = 3.1 ± 0.2 ps. The minimum electron beam size reached was σ_{x-y} ~ 90 ± 3 µm, nevertheless a clear Thomson photon production signature has been obtained with an electron spot size σ_{xy} ~ 240-160 ± 10 µm.

In Fig. 2 the results of the multichannel acquisition of the signal from the x-ray detector are shown as a histogram of the signal intensities acquired over 120 s; it is possible to distinguish the signal due to background (without interacting laser FLAME) and that due to Thomson backscattering. The pulse-to-pulse variation is due to fluctuations of the overlap region of the two beams, the relative temporal jitter between electrons and photons is ~150 fs.

The energy distribution of the Thomson radiation was reconstructed by CAIN simulation of the interaction and the average energy of the photons reaching the detector was 60 keV. We can then calculate that the number of photons per each pulse, and interacting with the detector sensitive area, is on average 6.7x10^3. In the next runs a full characterization of the source is planned, including also the measurement of the energy distribution and the spatial distribution of the radiation produced.

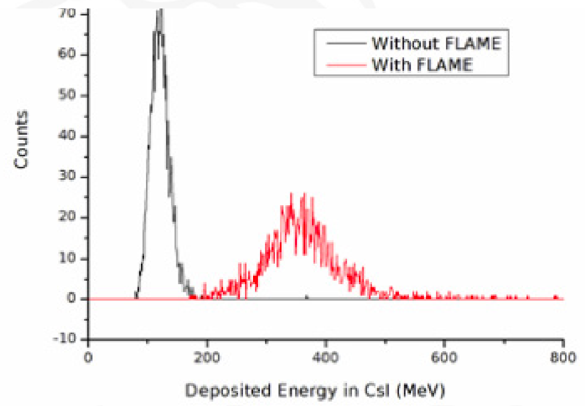

Figure 2 Thomson x-rays signal in red, in black the electron background signal (without FLAME laser), integrated over 120 s (1200 pulses).

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Another successful year of operations for the Beam Test Facility

In 2014 the BTF (DAΦNE Beam-Test Facility) has been providing electrons, positrons, photons and neutrons for a grand-total of 261 beam-days (including some co-user) to a large scientific community, mainly in the High Energy and Astro-particle Physics fields.

The BTF is composed by an extraction line, beam attenuation and energy selection through a 42° dipole magnet plus collimator system, and a transport line. Electron and positrons accelerated by the Linac, and extracted to the BTF line, can be tuned easily both in energy, from 50 to 750 MeV, and intensity, from 10^{10} down to the single particle regime. The focussing and steering of the 1-2 mm beam spot can be optimized on the needs of the users. In addition, a tagged photon beam can be produced, and a experimental photo-production neutron source has been recently commissioned.

In the last ten years of operation, the DAΦNE Beam-Test Facility has delivered an average of 220 beam-days/year, providing access to a large number of experimental teams, with a 30% of scientists coming from foreign institutions (see Fig. 1).

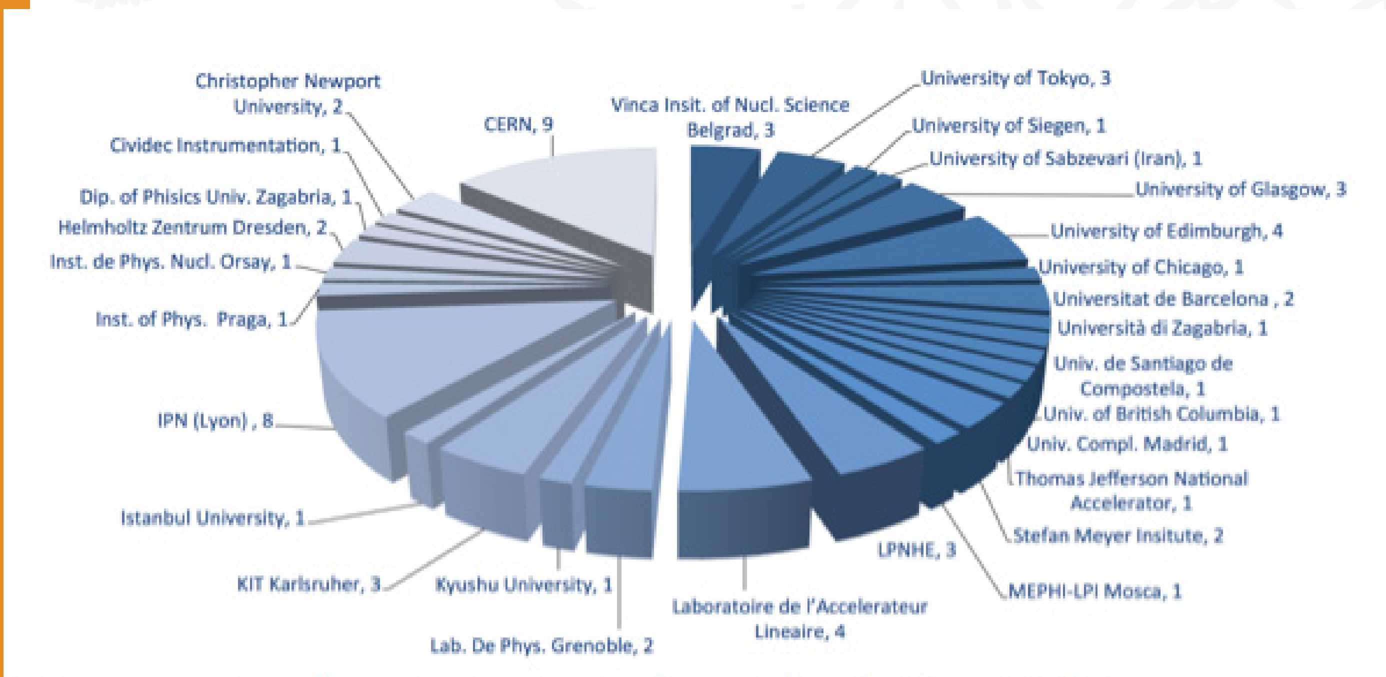


Figure 1 BTF users from foreign institutions, in the period mid 2011–mid 2013.

BTF uses can be grouped in two main categories:
1. beam-test of detectors, covering practically all possible user cases: calorimeters, scintillators, fibers, drift chambers, micro-pattern gas detectors (GEM, MSGC), RPC, diamond, silicon pixels, silicon micro-strips, fluorescence detectors, Cerenkov, RICH, and more;
2. experiments using the electron or positron beam, aimed at measuring a wide spectrum of physics phenomena, like the thermo-acoustic expansion of materials due to ionizing particles, the absolute air and Nitrogen fluorescence yield, the microwave emission from electromagnetic showers, the electron and positron channeling, parametric radiation, etc.

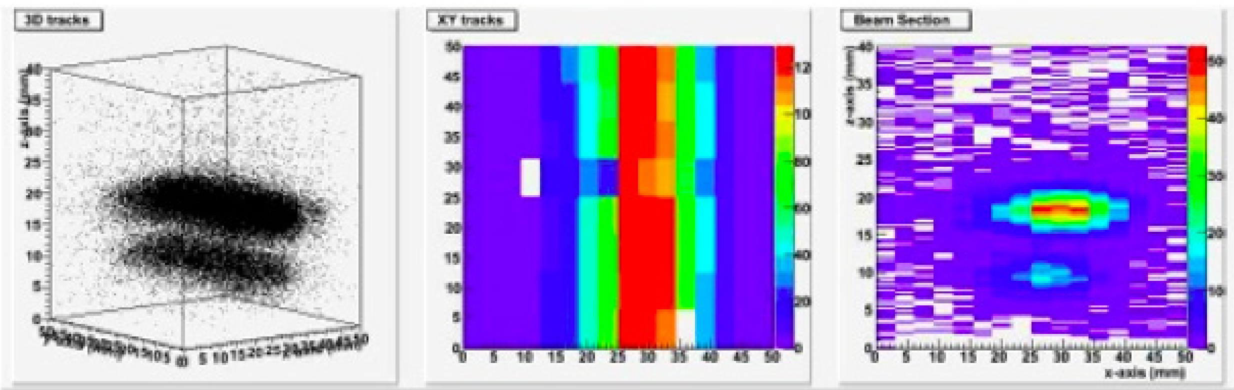
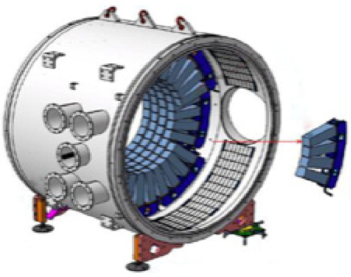


Figure 2 Example of GEM TPC tracking for channeling experiments: the 3D tracking capability of the detector, with ≈100 μm resolution on the drift coordinate, allows to clearly separate the channelled and un-channeled positron beam on a bent crystal.

Approximately 75% of the beam-time has been delivered in parallel to the operation of the DAΦNE collider, thanks to the possibility of selecting individual bunches, in the 25 Hz or 50 Hz time-structure of the Linac beam. While one bunch per second is driven on a magnetic spectrometer for the monitoring of the Linac energy, the remaining 24 or 49 bunches/s can be either all extracted to the BTF line, or – during the injections to the DAΦNE collider – only the portion of pulses not delivered to the damping ring can be deviated to the BTF. In this configuration, the maximum energy is fixed at 510 MeV and the pulse length at 10 ns. When running without the collider, the Linac settings can be optimized for the BTF operation: it is possible to raise the maximum electron energy to about 750 MeV, and to tune the beam charge from 0.1 to >10 nC/pulse. Since 2014, also the beam pulse length can be easily adjusted from 1 to 40 ns, in 1 ns steps.
Many other improvements of the facility were implemented in 2014:
The GEM compact TPC tracker has been commissioned and fully integrated in the BTF diagnostics (in the framework of the AIDA European Commission project): a typical user application of the GEM tracker is shown in Fig. 2;
A high resolution beam spot diagnostics, based on FITPIX detector, has been added;
The acquisition and data handling system has been upgraded, and is now running in a completely virtualized computing environment, integrating all diagnostics devices in a memcached storage;
New rotational and linear stages have been installed.
In May 2014, the first BTF Users Workshop took place at LNF, with the participation of more than 30 experimental groups, with several presentations on the results – mainly obtained in the previous two or three years – and with one session dedicated to future developments and upgrades of the facility. The discussions were very lively and interesting, especially from the point of view of improving the quality of the facility, in order to match as much as possible the users needs. Also a very interesting new proposal came up, for a new experimental research activity using the BTF extraction line and the Linac positron/electron beam for dark matter searches, in particular for the hunt of the so-called hidden or dark photon.

LNF Detectors Installed at CERN

The Standard Model of particle physics (SM), is an effective theory, which is able to describe precisely almost every observed phenomenon. Nevertheless it does not foresee a mechanism that explains some important experimental observations such as dark matter, baryon asymmetry of the universe, neutrino masses, and many others.
There are many different models that expand the SM to take into account the phenomena mentioned before, but how to disentangle among them?
The term "new physics" is used to describe such phenomena. There are two ways to search for new physics. One way is to make available higher and higher energies for the production and observation of new particles, as is it done by the LHC at CERN. The other way is to look for physical processes so rare that they have never before been observed, or alternately, to measure with higher and higher precision the parameters that describe known processes. For this second approach to be useful, the processes must be predicted precisely by the SM, so that a deviation from the prediction constitutes an unambiguous sign of new physics.
NA62 is the 62nd experiment to be conducted in the North Area of the Super Proton Synchrotron at CERN, in Geneva. The goal of the experiment is to measure the branching ratio, or probability of occurrence, of an extremely rare decay: that of a positively charged kaon into a positive pion, a neutrino, and an anti-neutrino. This probability is predicted very precisely by the SM (about one over 10 billion), while it has been measured experimentally only once on the basis of 7 candidates only.



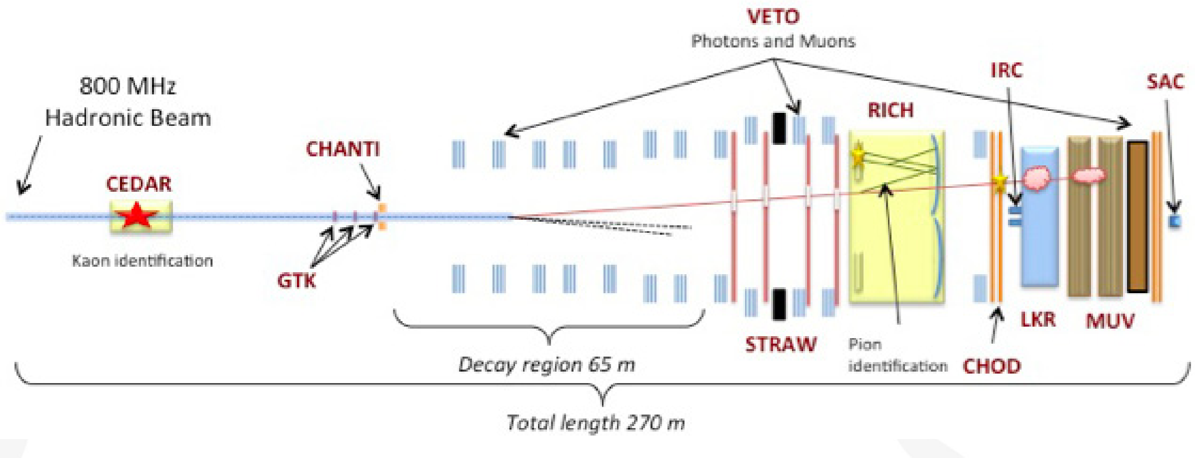
NA62 is collecting data from 2014, and at the end of the data acquisition, it will have collected 5000 billion of kaon decays. Out of these, only 1000 would have decayed into the interesting channel, meanwhile the vastly larger number of kaons will decay into other particles and will most often produce at least one photon (γ) or muon (μ). By spotting these other particles, the scientists of NA62 will be able to recognize and count the interesting kaon decays. To enclose as many kaon decays as possible, the NA62 experiment is very long—270 meters. Powerful pumps maintain the inside of the decay tube at high vacuum (10^{-6} mbar). The NA62 experiment is composed of many different detectors, each of which serves a different purpose in distinguishing decays from the others. The primary kaon is identified using the CEDAR, a detector that makes use of the Cerenkov effect, and tracked by the gigatracker (GTK), a silicon pixel detector. The secondary particles are tracked in the straw chambers and identified as pions by another Cerenkov detector, the RICH. In addition, all decays containing at least one photon (γ) must be rejected with a high degree of confidence by the photon veto system. This system is composed of large-angle vetoes (LAV), the liquid krypton calorimeter (LKr), and the small vetoes: the intermediate ring calorimeter (IRC), and small-angle calorimeter (SAC). Likewise, redundancy for the precise rejection of the enormous number of decays containing muons (μ) is provided by the muon vetoes (MUV) and the charged-particle hodoscope (CHOD).
The researchers and technicians of the NA62 group of LNF are responsible for the construction of the LAVs together with IRC and SAC.
On the 30th of July 2014, the construction of the last large-angle photon veto detector was completed. During the past six years, 12 detectors have been constructed and shipped to CERN. Each detector is a cylindrical steel vacuum vessel lined with four or five rings of lead-glass blocks, with each block coupled to a photomultiplier tube, as seen in the figure.

The different detectors contain from 160 to 256 blocks, are from 2.2 to 3.1 m in diameter (the downstream detectors are larger) and weigh from 10 to 15 tons. The lead-glass blocks of the dimension of 40x10x10 cm^3 and weighting 23 Kg, were obtained from OPAL, a decommissioned LEP experiment at CERN. About 4000 blocks were shipped to Frascati, polished, wrapped, tested, and characterized one by one by a team of researchers and technicians, in strict collaboration with the laboratory's services. LAV blocks operate in vacuum, for this reason particular attention was put on the material choice (e.g cables, electronics, wrapping) and on the behavior of the phototubes.

Lead glass is regular glass, with a high percentage of lead. The well-known Swarovski's crystals are indeed lead-glass, in fact the high density confer them a high refraction index thus a higher reflectivity ad shininess. LAV blocks are similar to them but they contain an even higher percentage of lead.

When a charged particle passes through the lead glass, it emits light via the Cerenkov effect. This light is reflected onto the photomultiplier tube and converted into an electrical signal. The signals from all 2496 tubes are converted into digital signals by specialized electronic circuits. Finally, these signals are recorded and processed by a high-speed computer network, and combined with information from the other NA62 detectors.

When a sufficient number of events has been acquired, the NA62 scientists will analyze them, and using advanced computing techniques, will determine the branching ratio for the decay , hopefully shedding new light on physics beyond the Standard Model.



Affiliation agreement between NASA and INFN

On September 15th 2014 NASA signed an agreement with the Italian National Institute for Nuclear Physics — Istituto Nazionale di Fisica Nucleare (INFN) — to become an Affiliate Member of the Solar System Research Virtual Institute (SSERVI). Being the first Italian partner of SSERVI, INFN will participate in SSERVI programs on a no-exchange-of-funds basis.

The agreement was signed by the president of INFN, Fernando Ferroni, and the SSERVI Deputy Director Gregory Schmidt, on behalf of Yvonne Pendleton.

“This is a special moment for INFN,” said the President Fernando Ferroni. “Making our researchers available for a collaboration with NASA, the most prestigious space agency in the world, is a source of pride and great satisfaction for all of us. Furthermore, this demonstrates that technologies developed in “curiosity driven” research can be applied even in fields which are very different from the original ones,” concludes Ferroni.

The INFN proposal, SPRINGLETS (Solar system Payloads of laser Retroreflectors of INfn for General reLativity, Exploration and planeTary Science), submitted by Principal Investigator Dr. Simone Dell’Agnello, of LNF-INFN, was selected for Affiliate Membership after it was determined that the INFN carries out complementary research activities that will help NASA achieve its goals for human exploration of the solar system.

“INFN is devoted to fundamental research in nuclear, sub-nuclear, astroparticle physics, and related technological developments, and we look forward to collaborative scientific discoveries from this partnership,” said Yvonne Pendleton, Director of SSERVI. “These results will be important for NASA to conduct successfully the ambitious activities of exploring the solar system with robots and humans.”

The new scientific collaboration between the two institutes will enable the development of joint activities, the exchange of scientists involved in studies for space exploration and the shared use of respective research laboratories.

This Affiliation is intended to allow INFN and NASA to jointly exchange information about the Laser Retroreflector Array (LRA) development and characterization in order to maximize laser positioning accuracy, laser orbit coverage and laser return strength for future missions involving laser ranging, laser altimetry and laser communication throughout the Solar System.

This work is done through the laser time-of-flight techniques called Satellite Laser Ranging (SLR) and Lunar Laser Ranging (LLR).

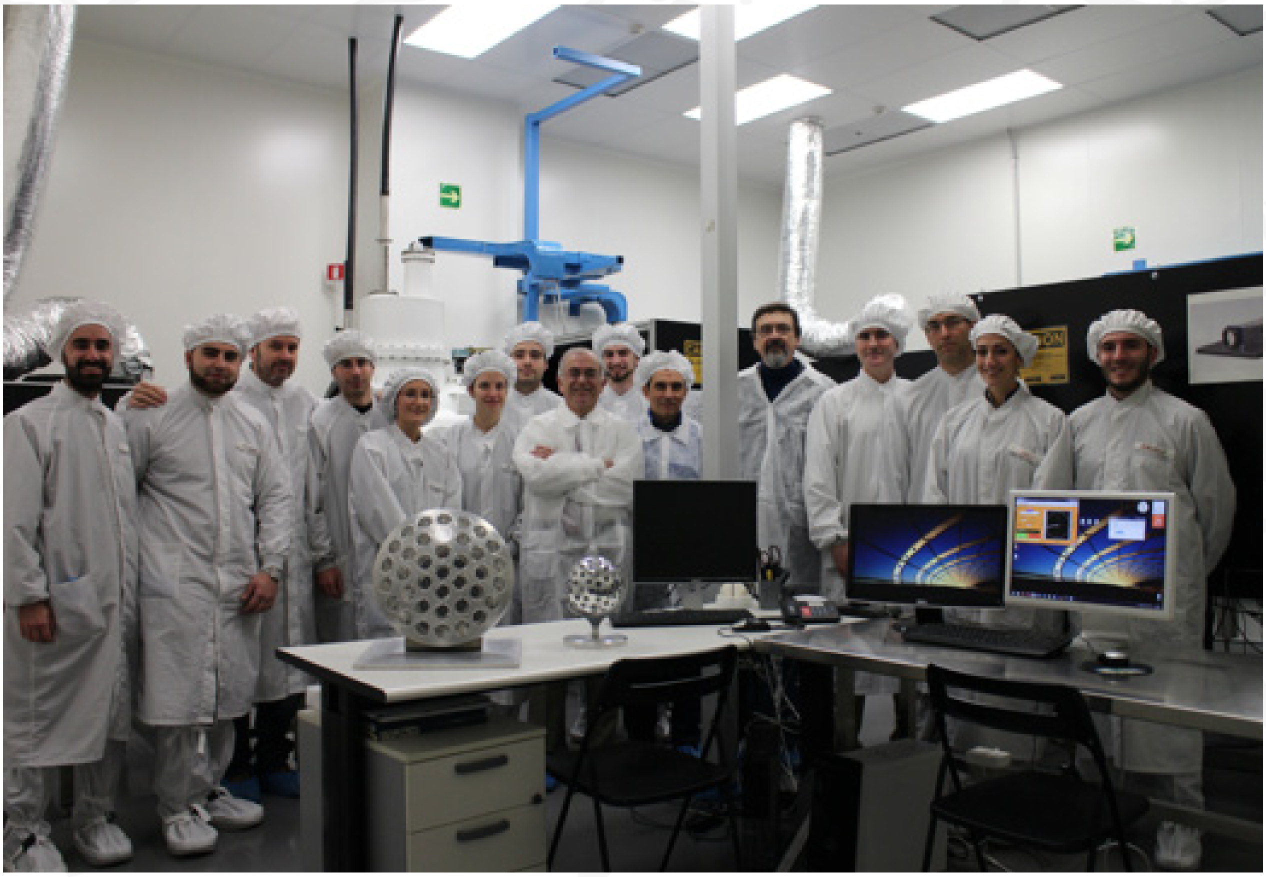
The short laser pulses of light fired from ground stations of the International Laser Ranging Service (ILRS) hit a satellite equipped with Cube Corner Retroreflectors (CCR), that reflect light back in the same direction of the incident one. In this way we have the possibility of making measurements with a precision at the level of the millimeter that can be accumulated to provide accurate measurement of orbits and important scientific data.

The characterization of the space segment of this technique, i.e. the LRA of CCRs, is carried out at the LNF-INFN, where there is a dedicated and unique infrastructure: the SCF_Lab (Satellite/lunar/GNSS laser ranging/altimetry and Cube/microsat Characterization Facilities Laboratory), that includes two Optical Ground Segment Equipment (OGSE) facilities (SCF and SCF-G for the optimization of GNSS) in a Clean Room to perform the integrated thermal-optical-vacuum characterization of LRAs in representative, accurately simulated space conditions and altitudes. Thermal, orbital, optical and structural software simulations are part of the work program. SCF_Lab activities include: the ETRUSCO program for GNSS (also supported by ASI) and Earth Observation (EO, also supported by the Italian Ministry of Defense) and the MoonLIGHT program (Moon Laser Instrumentation for General relativity High accuracy Tests), for the LLR test of General Relativity and new gravitational physics, carried out in collaboration with Professor Douglas Currie of the University of Maryland.

The design, modeling, development, validation, diagnostics, optimization and data analysis (in one word the "Characterization") of LRAs of CCRs are important to provide accurate positioning for GNSS satellites (like GPS and Galileo), and for EO and geodesy satellites. This work is also important to understand the orbit and the interior structure of Moon and Mars (i.e. of their planetary geophysical networks).

The main activities to be developed, as specified in the SPRINGLETS proposal, are:

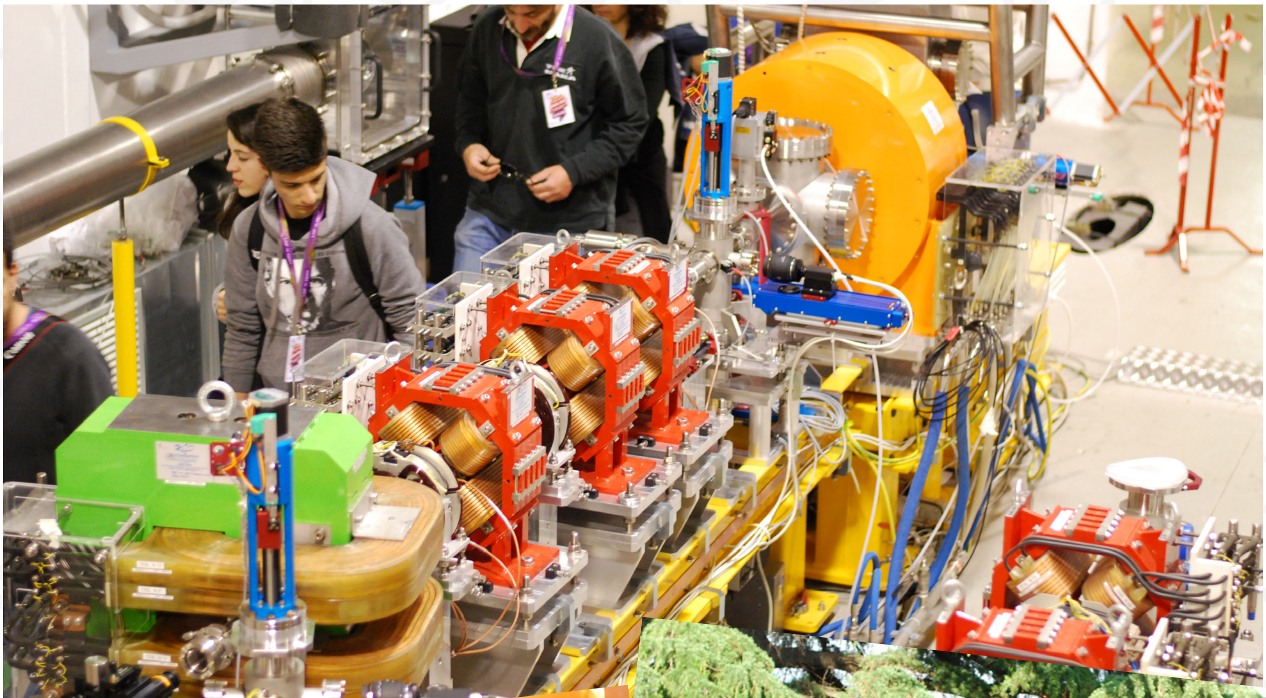
1. the Moon as a laser-ranged test body for General Relativity, that allows us to make precise test of General Relativity and study of new gravitational physics. The importance of Lunar Laser Ranging is demonstrated by 45 years of operation, started in 1969 with Apollo and Lunokhod, respectively USA and Russian missions;
2. laser retroreflectors for Mars exploration that contribute to the creation of Mars Geophysical Network;
3. Europa/Enceladus laser cube corner reflectors for exploration/exolife up to Saturn;
4. International Laser Ranging Service payload standards in Earth Orbits;
5. connecting the International Terrestrial Reference System (ITRS) and International Celestial Reference System (ICRS), via laser communication and ranging throughout the Solar System;
6. Near Earth Asteroids, in order to support their laser tracking.



For more information about SSERVI and about the research activity of the SCF_Lab visit:
http://sservi.nasa.gov
http://www.lnf.infn.it/esperimenti/etrusco/index.html

LNF is open !

Every year LNF hosts on site educational activities for about 5000 people and reaches a web of connections of about 10000 people. The Open Day is the most relevant of these activities. This year, "LNF is open!" for the first time took place on a Saturday, hosting more than 1300 participants.
The program featured the following activities:
-10 conferences;
-7 shifts of guided tours for 700 visitors;
-video projections;
-12 open experimental sites, with surveillance
The Communication and Scientific Education's Service staff organized the event in collaboration with researchers, technicians and administrative personnel of LNF, and with the extra support provided by an additional staff of 60 high school students.



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