Monitoring the EMC generated with VEGA at the Spanish Pulsed Lasers Center (CLPU)

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At the Spanish Pulsed Laser Center, the so-called VEGA-2 laser (200TW; 6J@30fs) is already in operation. The beam is delivered to the Target Area and first experiments are being commissioning. On the other hand, the beam transport of the VEGA-3 laser (1PW; 30J@30fs) is currently being setting, and first laser shots in the Target Area are expected this year. In order to apply the appropriate protection measures to mitigate the impact of the EMP from the PW laser system, we are preparing an exploratory and initial data capture of the EMP at the VEGA-2 interaction chamber and its surroundings. A systematic monitoring of the EMC generated with the VEGA laser system is under consideration with the participation of ITAINNOVA which is a public Technology Centre in Spain that has a large experience in electromagnetic compatibility in High Energy Physics Experiments.

Generation of extreme currents at an interaction of relativistic intense laser pulses with nanostructure targets

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Particle acceleration in different nanostructured targets irradiated by UHI laser pulses has been studied here with analytical model and PIC simulations. It is possible to manufacture such targets for example, as a thin substrate with "brash" consisted from long thin wires. The absorption of laser energy in such target is close to 100%. Such targets also generate effectively a big current of relativistic electrons, propagating along the wires and following their curvature. It follows that the optimal wire thickness should be of several lengths of the skin layer of the electrical field and has to be in the order of magnitude of tens of nanometers. The distance between wirers can vary between several Debye radiuses up to values of a few laser wavelengths. Collecting all wirers in only one allows to reduce the transverse size of fast electron cloud. The density of the energy flux of the hot electrons in such bunch, propagating along one nanowire exceeds several times the intensity of the laser pulse. By means of analytical and numerical modeling are constructed the dependences of numbers and temperatures of hot and cold electrons from the parameters of a relief targets irradiated by a short laser pulse of relativistic intensity. It is shown, that changing of a relief size, period and a thickness of a target substrate, it is possible to manipulate parameters of electron energy distribution function and to increase selectively transformation of laser energy into short wavelength radiation or into proton acceleration. The results of the simulations were compared with the experimental data and have shown a good coexistence.

EMC strategies to control the noise issues in High Energy Physics Experiments

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Electromagnetic interference (EMI) has been a major concern during the electronics integration of the CMS experiments at CERN (Switzerland) and Belle II experiment at KEK (Japan). Grounding and shielding problems and electromagnetic compatibility (EMC) issues have arisen during the integration of the LHC and SuperKEKB experiments in different sub-detectors requiring time and important number of tests and studies to solve them. This talk presents a general overview of the EMC plan and tests that have been applied to a two high energy physics experiment (CMS and Belle II) before the installation and commissioning of the electronics system. This talk shows several techniques to control the noise emissions as well as how to deal with them. Also, the impact of different FEE topologies in the final sensitivity to electromagnetic interference of the subsystem is analysed to improve the EMC of the detectors in view of the future challenging electronics topologies.

Vulcan Petawatt EMP studies

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Measurements of EMP made in the Vulcan target area are presented. Time-frequency analysis shows frequencies below 100 MHz to appear tens of nanoseconds after the laser interaction and are sustained for hundreds of nanoseconds while higher frequencies promptly appear and fade away after 150ns. Previous results indicated weak scaling of EMP with changes in the laser energy and pulse duration. New results show EMP signal changes linearly with target size in the range of 0.5mm to 4mm range. A copper shielding box designed to house a PC to protect it from EMP, a solution copied from the Phelix laser facility, has been tested and the signal reduction measured. The EMP inside the box is found to be reduced to 12% of the original signal..

Polaro-interferometric measurements of spontaneous magnetic fields in laser-produced plasmas

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Spontaneous magnetic fields (SMF) in laser-plasma interaction is an important object being extensively studied both experimentally and theoretically. Many phenomena in space and technology may become clearer due to the better understanding of the SMF physics. This paper presents the latest results of the direct the space-time resolved spontaneous magnetic fields (SMF) measurements performed at the PALS (Prague Asterix Laser System) facility in the series of experimental campaign with two-channel polaro-interferometer irradiated by the Ti:Sa laser pulse with the wavelength of 808 nm and 40 fs pulse duration. The experiments were performed by using of the 1ω single beam of the iodine laser (1.315 μm) with linear polarization, focused to the focal spot radius R_L=50 μm at the Cu planar massive target. By the obtained space-time distributions of SMF we calculated the current density distributions, ~~in~~ the magnetic field of the ablative plasma and to estimate the electron energy for different expansion times during the laser-target interaction. Additionally, measurements of the total current through the target were carried out with current probes. The polaro-interferometry shows that the axial current, is mainly located near the symmetry axis within 100 μm diameter cylinder. The number of electrons in the cylinder is in range of 3.5 - 8% of the total electron number in ablated plasma and has the maximum energy in the range from tens to hundreds of keV. Both the polaro-interferometric and the current probe measurements demonstrate that the total current on target surface is around several kA level. Maximum conversion efficiency of the laser beam energy to the SMF energy is about 2% and is reached at to the end of the laser pulse. Obtained quantitative data of the current density distributions are consistent with the fast electron emission. The results show that the polaro-interferometry appears to be unique useful diagnostic tool for SMF studies fast electron transport in the inertial confinement fusion (ICF) concept and in other applications of the laser produced plasma.

Two-axis electro-optic measurements of intense electromagnetic pulses in the radiofrequency-microwave regime generated by nanosecond laser-plasma interaction

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Electromagnetic pulses (EMPs) are commonly characterized by means of conductive probes, where information is conveyed by electric currents. This is cause of some well-known disadvantages and in many contexts limits the possibility to determine the associated electric fields. In a previous work[1] we proposed to detect single components of EMPs from laser-plasma by dielectric probes, where birefringence is induced by external electric fields because of the electro-optic effect, and we demonstrated that hundreds-of-kV fields were generated with the nanosecond ABC laser at energies of some tens of Joules. Here we describe the first simultaneous two-dimensional measurements of intense EMP fields by electro-optic effect, in experiments performed with the same laser, at focused laser intensities 10^{14}-10^{15} W/cm^2, for λ = 1054 nm. Measurements and particle-in-cell simulations indicate that signals match the emission of charged particles detected in the same experiment, and suggests that anisotropic particle emission from target, X-ray photoionization and charge implantation on surfaces exposed to plasma, could be important EMP contributions.[2]

1 F. Consoli et al, “Time-resolved absolute measurements by electro-optic effect of giant electromagnetic pulses due to laser-plasma interaction in nanosecond regime”, Scientific Reports **6**, 27889 (2016)

2 This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Measurements of EMP fields generated by interaction of the Vulcan petawatt laser with solid thin foil targets.

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We report on the preliminary analysis of electromagnetic pulses (EMPs) produced during the interaction of a picosecond laser beam of order 400 Joules with various targets in the Vulcan Petawatt facility. In this experimental campaign EMPs have been monitored in several locations around the target area and with a range of sensor systems. Here we concentrate mainly on the data recorded for thin (micron to sub-micron) plastic targets from calibrated probes placed inside and outside the vacuum chamber, from which the absolute value of the electric fields is accurately inferred.

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.
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Electromagnetic pulse (EMP) radiation by interaction of laser pulse with ^{2}H ice ribbon

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The radio-frequency (RF) emission from plasmas produced with a laser within a vacuum chamber can be smaller in power and shorter in time duration if a low density target is exposed to the laser radiation in comparison with solid density targets. The strength and temporal characteristics of electromagnetic (EMP) pulses are found to be dependent on the characteristic of the bulk target matter. If an entire target is ionized during the laser-target interaction and no ionized species are flowing between melted target surface and expanding plasma, as such a phenomenon was observed by Drouet and Pépin, Appl. Phys. Lett. 28, 426 (1976) for a thick solid target, the EMP is weaker in strength and shorter in time duration. A numerical simulation of resonant frequencies occurring within the vacuum target chamber (cavity) elucidates the peaked structure of frequency spectra of the EMP radiation in the GHz domain.

On the road to PETAL: the challenge of measuring the strong laser-induced EMP

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To study and understand of the laser-induced EMP, we performed experiments. We measured the current between the target and the chamber and the magnetic field inside the chamber during a short laser pulse shot. Until 2015, these campaigns were realized mainly on the CELIA's eclipse facility, a 100 mJ and 30 fs laser. In 2015-2016, we did again these experiments but on higher energy lasers (GSI / PHELIX 100 J – 0.5 ps and LULI / PICO 50 J – 0.5 ps). We had to adapt our measure to deal with this strong step in energy. We present the issues and the solutions that we developed to perform this measurement of a high-energy facility. We also present a direct application of this work, the newly arrived LMJ's EMP diagnostic.

Reduced EMP from High Intensity Laser Matter Experiments Using Optically Levitated Targets

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We report on the development of a unique feedback controlled optical levitation trap for use in low EMP laser matter experiments. The optical trap has proven capable of holding both solid (glass beads) and liquid (silicon based oil) micro-targets (~3-10um) in vacuum. The trap has been successfully fielded in two high-intensity laser interaction experiments; one at Imperial College using the Cerberus laser system, and a second using the Vulcan Petawatt laser system at the Rutherford Appleton Laboratory. Experiments established several key results; firstly, an x-ray source size of 10-15um with very good spherical symmetry when compared to wire targets, secondly very low, almost negligible, EMP signal from isolated levitated targets when compared to traditionally solid mounted targets. We were also able to record a proton energy spectrum which produced peak proton energies of 35MeV.

EMP - Related Issues at ELI-NP

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At ELI-NP in Bucharest-Magurele [1], [2] will operate soon a very high intense laser with two beams of 10 PW and less than 30 fs, focused onto very small target, giving intensities up to 10^{24} W/cm^2. Nuclear physics experiments performed with very intense (10^{23} gammas/second) brilliant gamma-ray beam, with 0.1% bandwidth and energy between 0.2 and 19 MeV will also run simultaneously in facility. Equally, combined laser-gamma beams experiments are planned. An impressively strong EMP of tens or hundreds of kV/m, ringing transient in the MHz- THz frequency range can be generated within the vacuum chamber containing the target, as a result of interactions of high-power laser with matter. In this context, the protection of human beings and electronics to the damaging effects induced by EMP is mandatory. Besides that, the unique physical phenomena to be studied at the ELI-NP facility should not be hampered by EMP pick-up. In the meantime, electromagnetic interference induced by EMP should be avoided. This means that any experiments running in parallel in building, such as the experiments with gamma-ray beams, should not be disturbed by EMP. Our current understanding on EMP generation mechanism, based mainly on information available in literature, will be presented. Based on these data, an estimate of the magnitude of EMP produced by the laser beams, in correlation with the limits of exposure for electronic equipment and personnel, is done. An overview of shielding strategy applied at ELI-NP is presented. The current status of implementation EMP shielding for building well be reviewed. A special care should be paid inside of the experimental area, were a considerable EMP is spread mainly from interaction chambers by conductive and radiative emission. However, some key experimental equipment must be placed inside and thus being directly exposed to EMP. In certain situations the cables and wires between components of these equipment will also contribute to the EMP emission. Despite the extremely complex approach, some important aspects, which should be considered in design of experimental setups, in order to obtain and maintain the overall integrity of electromagnetic shield, are pointed out.

References:
[1]. N.V. Zamfir, Romanian Reports in Physics, Vol. 68, Supplement, P. S3–S4, 2016
[2]. S. Gales, Romanian Reports in Physics, Vol. 68, Supplement, P. S5–S10, 2016

Characteristics of magnetic field induced by target current driven by interaction of the PALS laser with solid targets

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The emission of transient electromagnetic pulses (EMP) and the current balancing the target charging driven by interaction of a focused 1.315-µm iodine 300-ps PALS laser with metallic and plastic targets will be reported. Experiments have shown that three phases of the target current can be distinguished. During the first (ignition) phase, the target current is driven by the laser pulse. At post-pulse times, a peaked waveform of the target current is typical for the second (active) phase of the plasma. It implies that the duration of return target currents is much longer than the duration of laser-target interaction mainly when a thick solid target is irradiated. The third (afterglow) phase is related to a residual ionized target vapour. The rise time, full width at a half maximum and frequency spectrum of EMPs and of target currents will be compared.

The P3 installation of ELI-Beamlines as a potential EMP research platform

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Large electro-magnetic pulse (EMP) fields produced during laser matter interaction experiments on PW class lasers pose a significant risk to the diagnostics. These fields are modelled to be driven by the hot electrons from the target, which excite wave modes corresponding to the resonances of the target chamber. The Plasma Physics Platform (P3) at ELI Beamlines is a large vacuum chamber (approximately 50 m^3) for experiments with beams with wide range of parameters – (a) 1 PW with 30 fs duration, (b) 10 PW with 150 fs duration, and (c) ns scale 1.5 kJ. Thus it provides an exciting prospect for EMP measurements with a variety of beam parameters in the same experimental chamber. This presentation will describe the P3 installation as a prospective EMP research platform. It will also briefly describe the grounding schemes at the facility to limit the effects of EMP and ground loops.

Relativistic electron beam guiding by using two consecutive laser pulses

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A scheme using two consecutive intense laser pulses has recently been proposed to optimize electron transport and collimation in dense matter. The two laser pulses, of different intensities, are focalized in a solid target at a given delay to generate two successive co-axial electron populations [1]. It has been shown that the azimuthal magnetic field generated by the first electron beam can guide the second beam. Previous experimental results have confirmed the general validity of the scheme: optimum delay time and intensity ratio yielding the best guiding effect [2]. Simulations pointed out the importance of the ratio between the pre-formed magnetic field extension and the diameter of the second electron beam, as this parameter plays a major role in determining the guiding efficiency [3]. A systematic investigation of the scheme, exploring the role played by the radial extension of the seed magnetic field, was recently carried out on the LULI-ELFIE Facility. The main improvements of the campaign compared to previous experiment were the use of two different parabolas, allowing to choose independently the focal spot size, and the implementation of a coherent transition radiation (CTR) diagnostics allowing to estimate collimation effects on the MeV electron population. The preliminary experimental results showed a clear collimation of fast electrons in the optimum conditions. This collimation scheme can provide an efficient energy transport in dense matter, which is relevant for several applications such as ion-beam sources and fast ignition inertial fusion.

[1] A.P.L. Robinson, et al., Phys. Rev. Lett. 100, 025002 (2008)
[2] R.H.H. Scott, et al. Phys. Rev. Lett. 109, 015001 (2012)
[3] L. Volpe, et al., Phys. Rev. E. 90, 063108 (2014)

Escaping electrons and EMP scaling at VULCAN in the 1-20 ps experimental region

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The escaping electron population from metallic foil targets and the EMP fields generated simultaneously were measured as a function of pulse length in the range 1-20 ps, which is of interest to Ion acceleration and Inertial Confinement Fusion experiments and simulations. This measurements were carried out using the Vulcan PW laser in an experimental chamber of 2x2x5 m^3. The absolute flux of escaping “hot” electrons from the rear of the targets were characterised by a wraparound absorption stack in the 2-25 MeV spectral range and the electric and magnetic fields were characterised in the 0.01-4 GHz frequency range. The scaling of the electron flux, temperature and EMP will be presented and observations of the source of noise pickup on diagnostics and simple techniques for avoidance will be presented.

Preliminary EMP estimates and facility grounding @ ELI-alps

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During laser pulse target interaction, a large amount of charge escapes from the target leaving the target charged behind. The remaining charge on target is neutralized by a large return current propagating through the solid target and target holder thereby inducing a large electromagnetic pulse (EMP). In this presentation an overview of the most recent estimates for the different laser systems at ELI-ALPS is given. Furthermore, we will present an overview of the grounding strategy at ELI-ALPS. A proper grounding is considered as one of the important mitigation tools against electromagnetic interference (EMI).

Target charging modeling: evolution of the charging current with thin targets

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We recently demonstrated that the EMP produced by short laser impulsion are closely linked to the target charging during the laser matter interaction. The bigger is the charge, the stronger is the resulting EMP [1,2]. In this context, we developed a short model named ChoCoLaT.f90, which predicts of the magnitude order of the charge, but also enhances the understanding of this target charging: how does the system parameters such as the target diameter or the laser pulse duration affect the final charge [3]? In this presentation, we show the new version of this model which include the target thickness and the energy repartition of ejected electrons. The results are compared to dedicated experiments. En bonus, we will make an excursion toward the ns pulses which are not producing EMP despite some target charging.

[1] J.-L. Dubois et al., Target charging in short-pulse-laser plasma experiments, Phys. Rev. E 89, 013102 (2014)
[2] A. Poyé et al., Physics of giant electromagnetic pulse generation in short-pulse laser experiments, Phys. Rev. E 91, 043106 (2015)
[3] A. Poyé et al., Dynamic model of target charging by short laser pulse interactions, Phys. Rev. E 92, 043107 (2015)

Characterization of the EMP generated with a high-intensity fs laser interacting with a thin foil target

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One of the topical problems in the area of EMP assessment is the EMP generation in short pulse laser interaction with thin targets. This is a very important issue from the point of view of practical applications of laser-driven ion acceleration, but so far not a very thoroughly investigated one. To elucidate this topic, dedicated EMP measurements were performed on the ECLIPSE laser at CELIA and a 10TW laser at IPPLM, with pulse duration 40 fs and the energy on target in the range of 100 mJ and 200 mJ, respectively. A special type of target was used to facilitate comparison with the EMP measurements for a thick target, and a variety of EMP probes was utilized. We briefly report on the results of these measurements.
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Electro-optical measurement of electromagnetic pulses from petawatt-regime laser-matter interactions

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Strong electromagnetic pulses (EMP) produced by intense laser-matter interactions are often problematic in high-power laser facilities, however they can also be used as a complementary diagnostic to give insight into charged particle dynamics. EMP is usually characterised with conductive probes; even with shielding, these are troubled by electrical noise pickup from EMP coupling to oscilloscopes or conductive cabling, hence it is challenging to obtain good signal-to-noise ratios. Using a fundamentally different probing mechanism can mitigate these issues, in our case the electro-optic Pockels effect in dielectric crystals. Here, we report on the first petawatt-regime electro-optic EMP measurements carried out at the Vulcan Petawatt facility, using thin plastic foils of varying thicknesses and levitated silicone oil microdroplets as targets. By using polarising optics along with "probe" crystals, local electric fields can be mapped onto intensity modulations on a continuous-wave laser. Using several crystals allows multi-axis measurement with minimal local field disturbances (compared to conductive probes), while optical techniques are advantageous for noise-reduction, as signal transport to the readout system can be via fibre-optic cables. This ensures high inherent electrical noise immunity, as the oscilloscopes and photodetectors recording data can be located in a Faraday Cage outside the target area. The crystals were not required to be close to the target, enabling such diagnostics to be mobile within interaction chambers.

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Charge separation and self-generated currents in short pulse laser experiments

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The interaction of intense, short laser pulses with three dimensional solid structures cause charge separation, the onset of transient fields and the emission of high frequency e-m radiation. The evolution of the charge separation and the strength of the fields can be used as a guiding principle for accelerated particles, but also constitute a hazard to close by diagnostics. We report on experiments and simulations of the evolution of self-generated e-m fields in complex target structures and the effort to shield diagnostics for experiments at laser systems in the US and Europe. The target surface also alters the interaction of the laser with the probe, which can be used to maximize laser beam absorption and transfer into energetic electrons. We have started to build structured targets for maximizing the laser absorption using fs surface structuring of semiconductors in ambient environments.

Quasi-stationary magnetic fields generation with capacitor-coil targets

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Recent experiments are showing possibilities to generate strong magnetic fields exceeding 100 T with high energy laser pulses in a compact setup of a capacitor connected to a single turn coil. Hot electrons ejected from the capacitor plate (cathode) provide the source of current in a coil. However, the physical processes leading to generation of currents exceeding 100 kA with a nanosecond pulse are not sufficiently explained. Here we present a critical analysis of previous estimates and propose a self-consisted model for the magnetic field generation in the laser-driven capacitor coil target. Its validity is confirmed by a comparison with the available experimental data.

Strong electromagnetic pulse effects observed in experiments on interaction of ultra-short laser pulses with gas puff targets.

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Interaction between ultrashort laser pulses and gas targets allows to produce short wavelength radiation and in some case strong electromagnetic interference. In two experiments using our devices, strong electromagnetic pulses, EMP, was observed. First experiment was performed in Czech Technical University in Prague and concerned interaction of femtosecond laser with cluster target. The second experiment was performed by Hyung Taek Kim teams in APRI, Korea and concerned electron accelerations in dense gases. Interaction of this targets with PW laser system also produce strong electromagnetic pulse. In both experiments, strong electromagnetic pulse cause damage of valve or controls systems.

The High Power Laser Laboratory at IPPLM

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The High Power Laser Laboratory (HPLL) at the Institute of Plasma Physics and Laser Microfusion is an unique laboratory in Poland, devoted to studies of ultra-intense laser interaction with matter. In particular it enables to study phenomena related to inertial confinement fusion, laser particle acceleration and generation of corpuscular and electromagnetic radiation. The laboratory is equipped with a femtosecond laser Pulsar 10 TW, two experimental vacuum chambers and diagnostics devices. The main parameters of laser system are as follows:

- peak power 10 TW
- pulse duration 44 fs
- spot diameter in focal plane 10 µm
- pulse repetition 10 Hz
- central wavelength 812 nm
- power density $10^{18} – 10^{19}$ W/cm^2

During the experiments performed in the laboratory the various type of targets are used: thin foils (aluminum, mylar or with gold or silver coats), solid targets (aluminum, copper), as well as gas puff. The set of diagnostics includes: ion collectors, electrostatic ion analyzer, Thompson spectrometer, track detectors, fast four-frame camera, fast detectors of hard and soft X-ray radiation, polaro-interferometer and broadband digital oscilloscopes. This is the first laboratory of this kind in Poland, opened for both domestic and foreign scientists interested in the above and related topics.

EMP experience and mitigation at PHELIX

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With the high-intensity upgrade of the PHELIX target area in 2013, EMP issues became relevant to the level of influencing both laser and experiment control and diagnostics equipment. Since then, a number of mitigation measures have been implemented which limit the EMP impact to an acceptable level. In addition, several loop probes connected to a 1 GHz storage oscilloscope have been installed inside and outside the target chamber for a long-term assessment of the EMP levels caused by different targets and setups. An overview of the mitigation measures and preliminary analysis of the loop probe measurements will be given.