

# EMP generation at Centro de Laseres Pulsados

**Massimo De Marco<sup>1</sup>, Kwinten Nelissen<sup>2</sup>, Giancarlo Gatti<sup>1</sup>, Michael Liszi<sup>3</sup>, Valeria Ospina<sup>1</sup>, Istvrot Drotr<sup>3</sup>, Christos Kamperidis<sup>2</sup> and Luca Volpe<sup>4</sup>**

<sup>1</sup>Centro de Láseres Pulsados (CLPU), Calle del Adaja 8, Villamayor 37185, Salamanca, Spain

<sup>2</sup>ELI-ALPS, ELI-HU Non-Profit Ltd., Dugonics t ' er 13, Szeged 6720, Hungary

<sup>3</sup>Radiofrequency Test Laboratory (RFTL) - Szchenyi Istvn University, Egyetemtr 1, Gyr 9026, Hungary

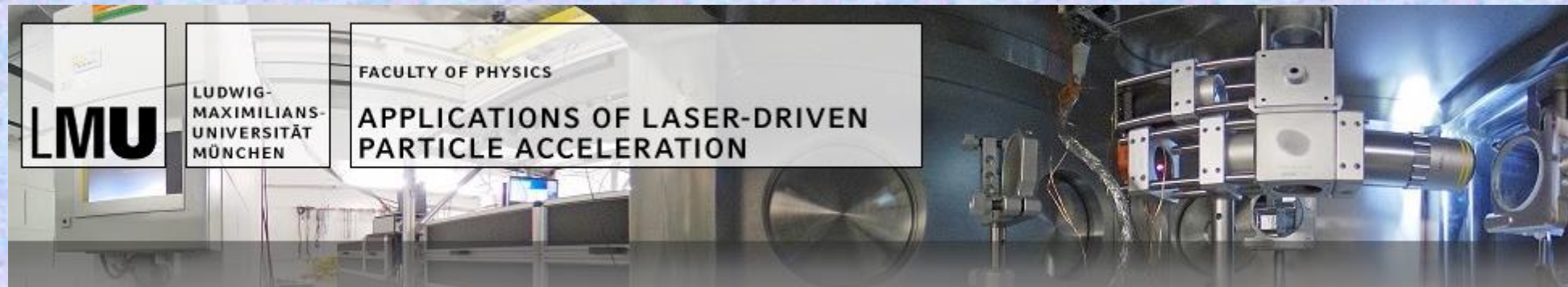
<sup>4</sup>Laser-Plasma Chair at the University of Salamanca, Salamanca, Spain

**BLIN4 workshop, Garching, 29th June 2020**



**VNiVERSIDAD  
D SALAMANCA**

CAMPUS DE EXCELENCIA INTERNACIONAL

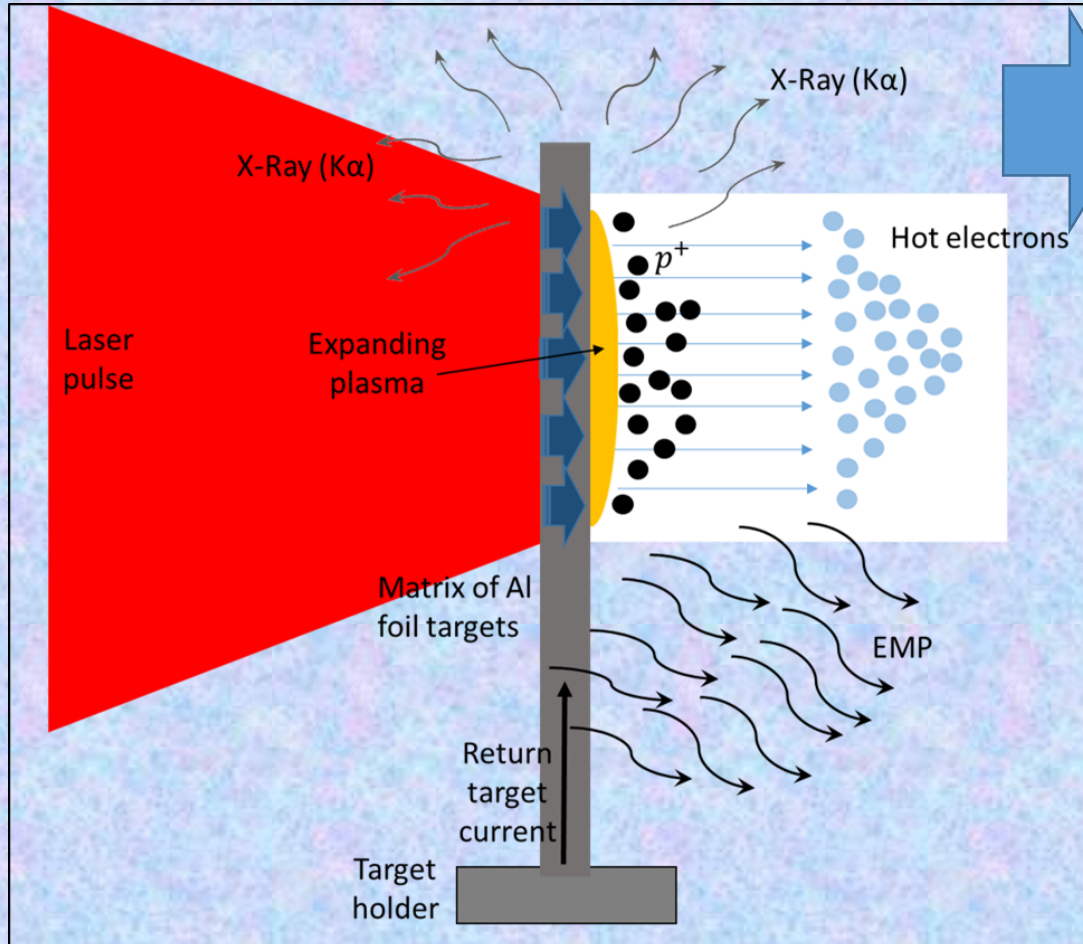


# Contents

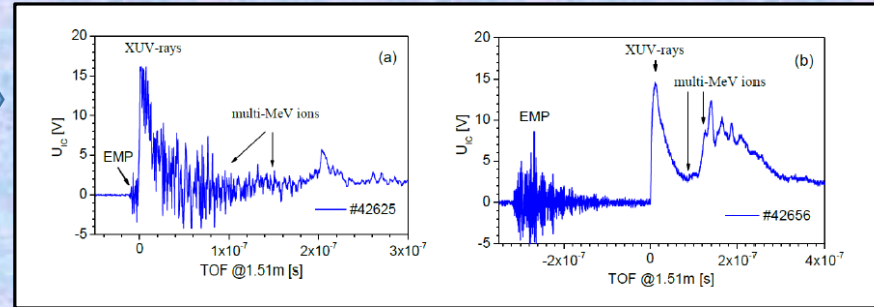
- Motivations
- State of art of EMP
- Work done at CLPU
- Conclusions

# Motivations

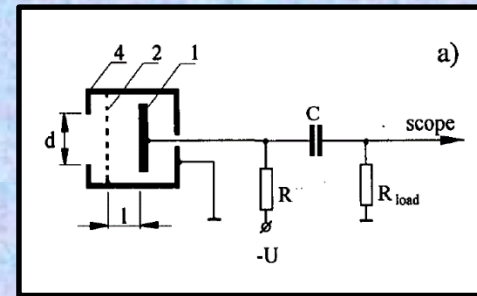
Strong EMP effects on electronic equipment inside and outside the experimental chamber



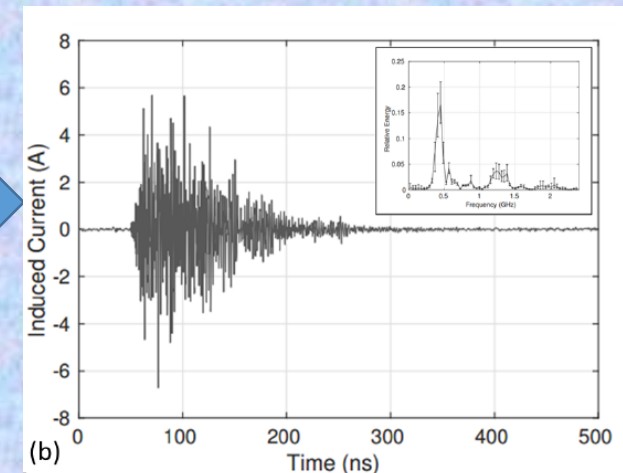
Kwinten et al. Characterisation and Modelling of Ultrashort Laser-Driven Electromagnetic Pulses submitted to Scientific report



M. De Marco et al. Journal of Physics: Conference Series 508 (2014) 012007



E. Woryna et al. Corpuscular diagnostics and processing methods applied in investigations of laser-produced plasma as a source of highly ionized ions *Laser and Particle Beams* (1996)



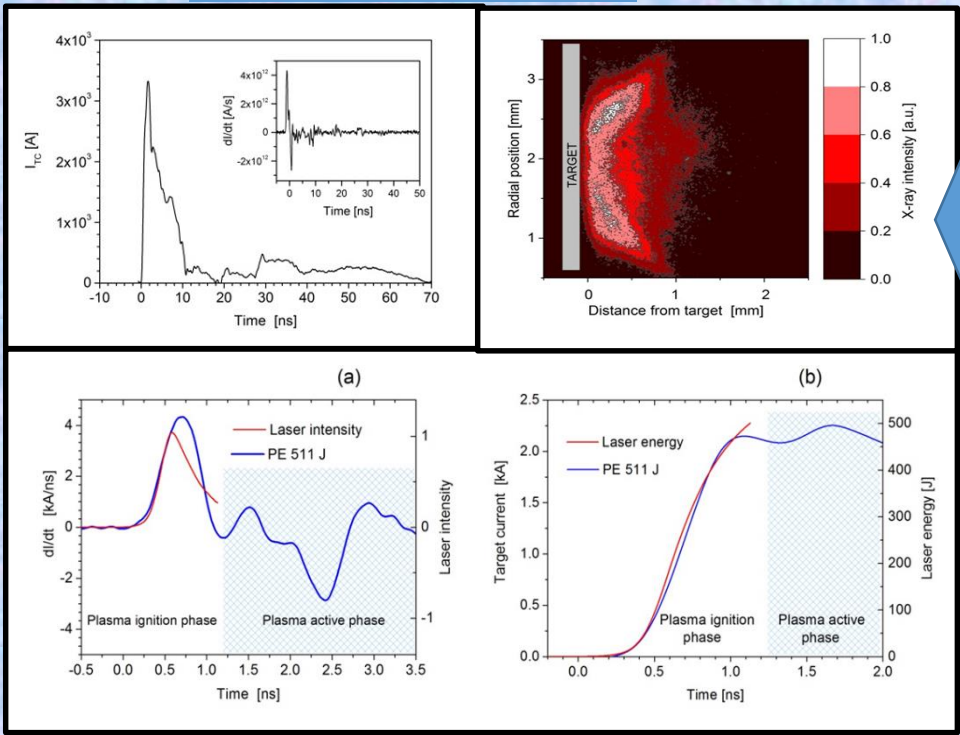
K.Nelissen et al. Characterisation and Modelling of Ultrashort Laser-Driven Electromagnetic Pulses submitted to Scientific report

- Usage of voltage supplier unit
- Oscilloscope Faraday Cage

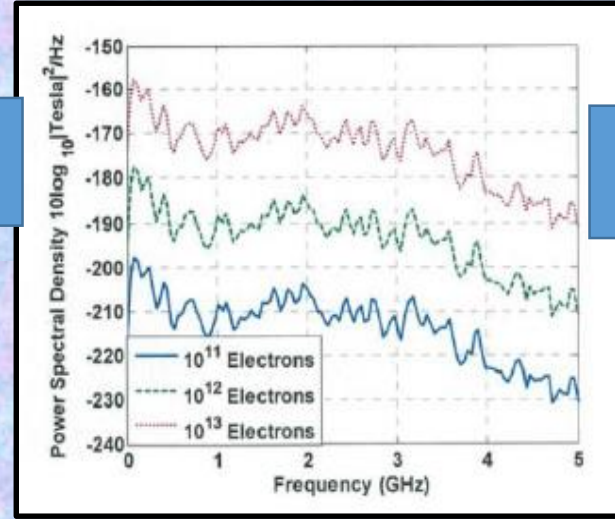
# EMP in literature

## Different kind of regimes

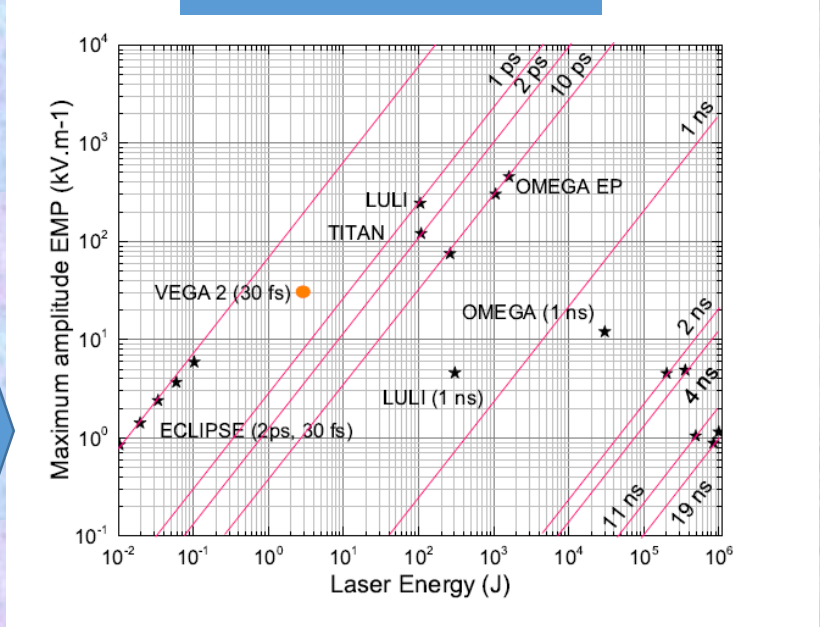
### Two plasma phases



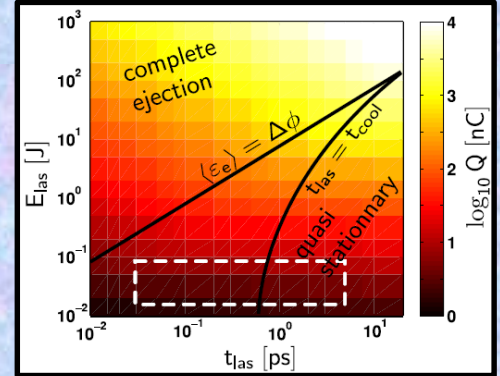
Krásá et al. Spectral and temporal characteristics of target current and electromagnetic pulse induced by nanosecond laser ablation, Plasma Physics Control. Fusion (2017) 10.1088/1361-6587



C G Brown Jr. Electromagnetic Pulses at Short-Pulse Laser Facilities Journal of Physics: Conference Series 112 (2008) 032025

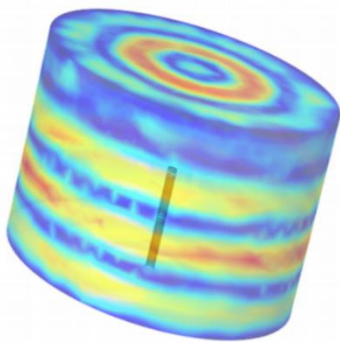
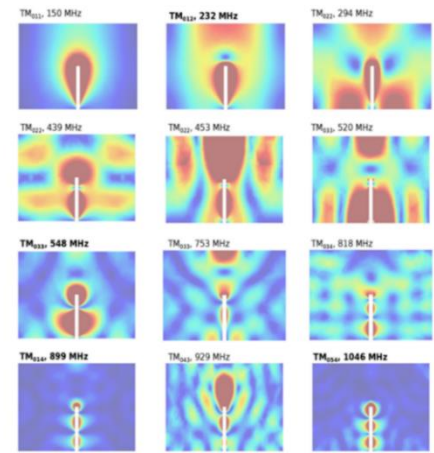
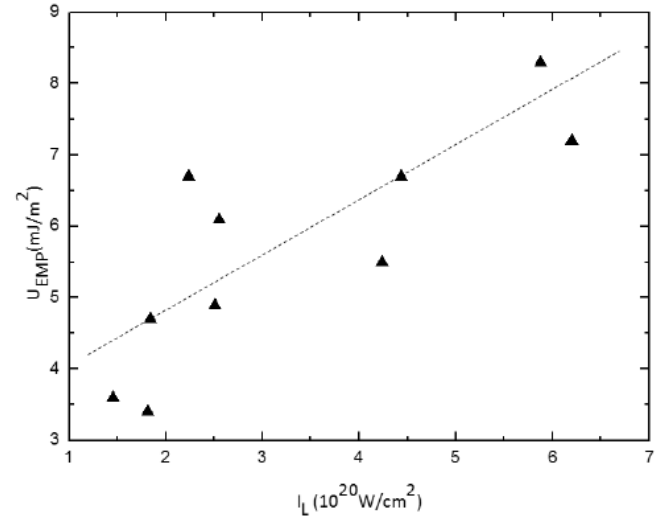
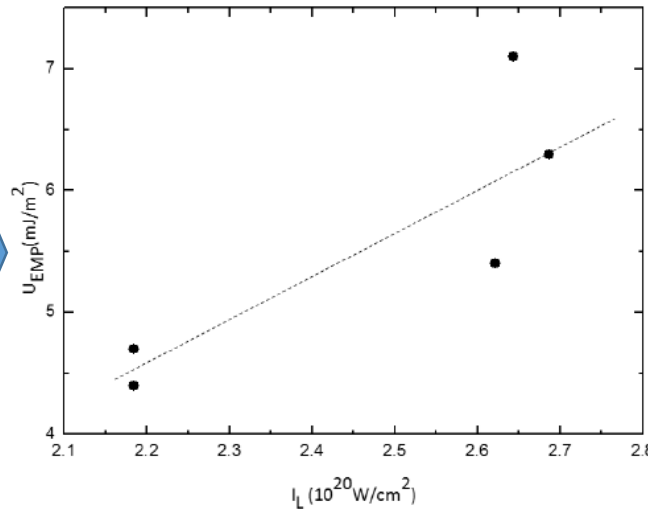
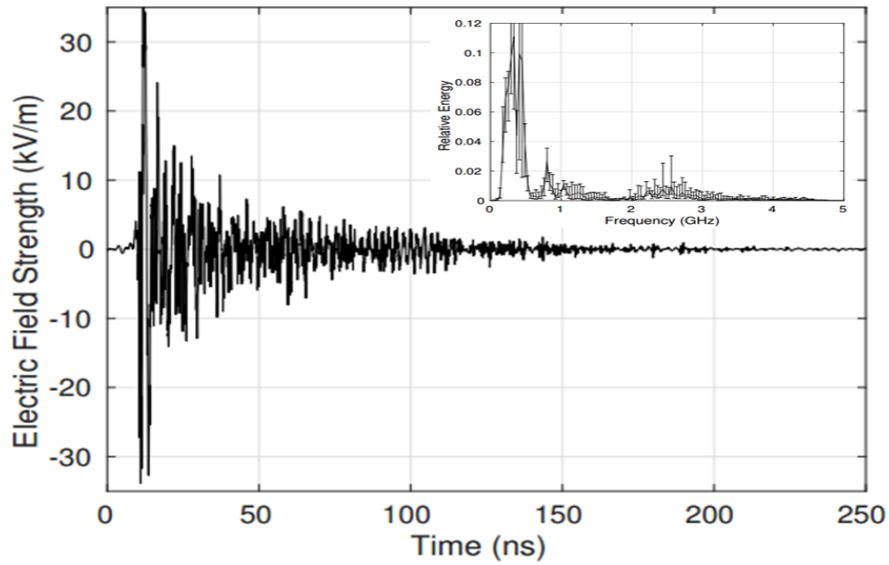


Kwinten et al. Characterisation and Modelling of Ultrashort Laser-Driven Electromagnetic Pulses submitted to Scientific report

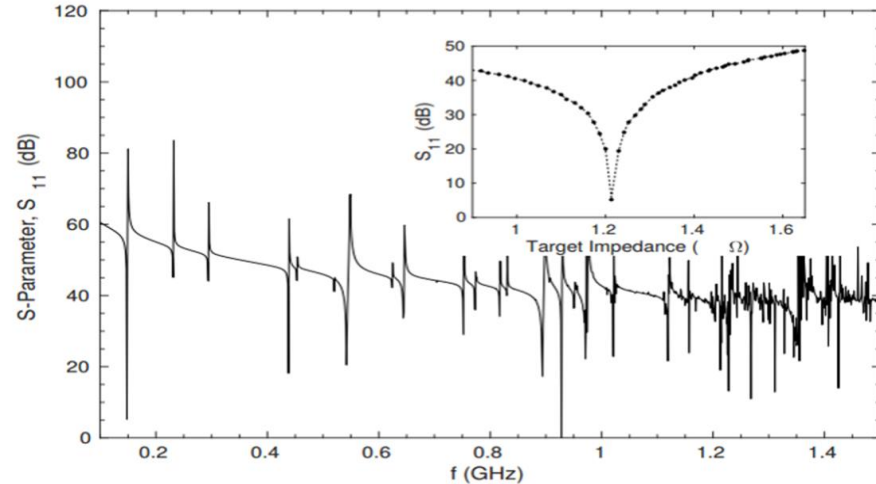


A.Poyé et al. Physics of giant electromagnetic pulse generation in short-pulse laser experiments PHYSICAL REVIEW E 91, 043106 (2015)

# EMP measurements at CLPU and simulations



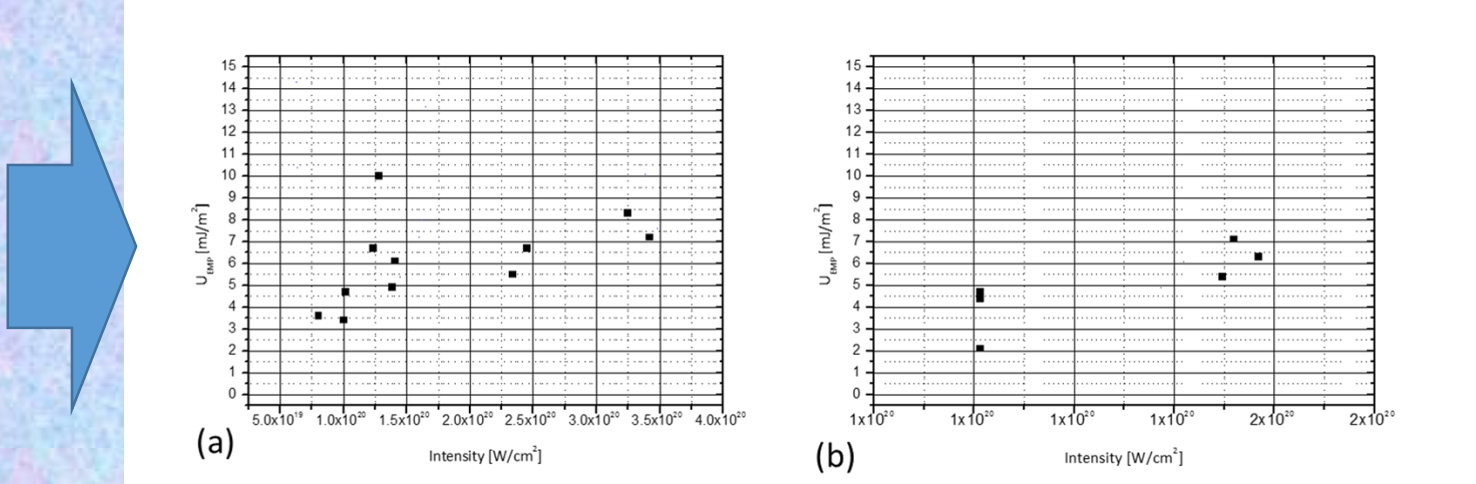
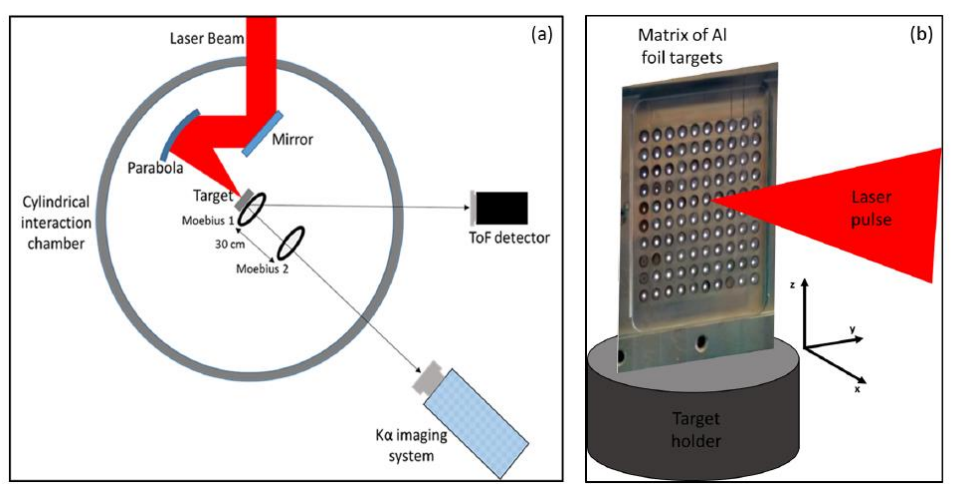
(a) (b)



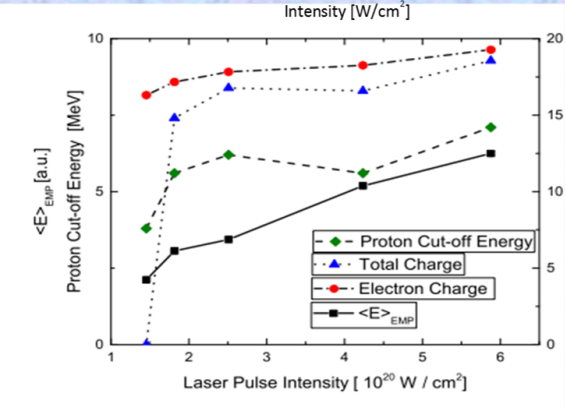
Kwinten et al. Characterisation and Modelling of Ultrashort Laser-Driven Electromagnetic Pulses submitted to Scientific report

Kwinten et al. Characterisation and Modelling of Ultrashort Laser-Driven Electromagnetic Pulses submitted to Scientific report

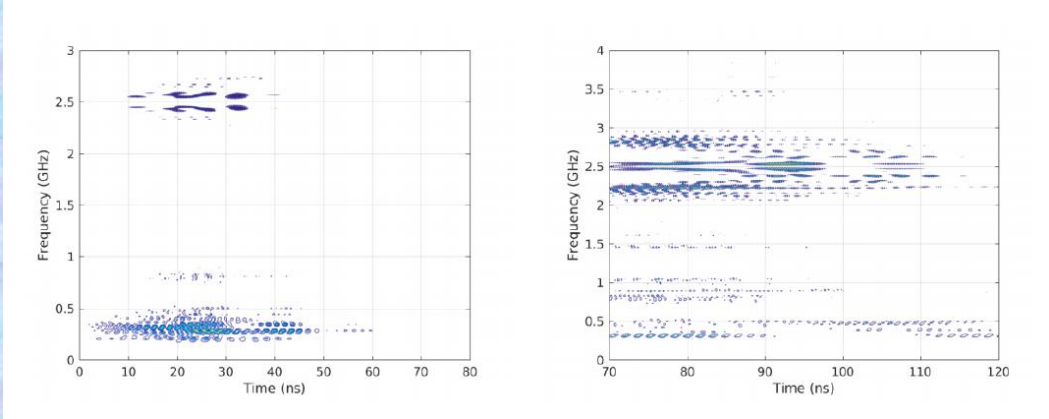
# EMP measurements at CLPU



# Proton generation



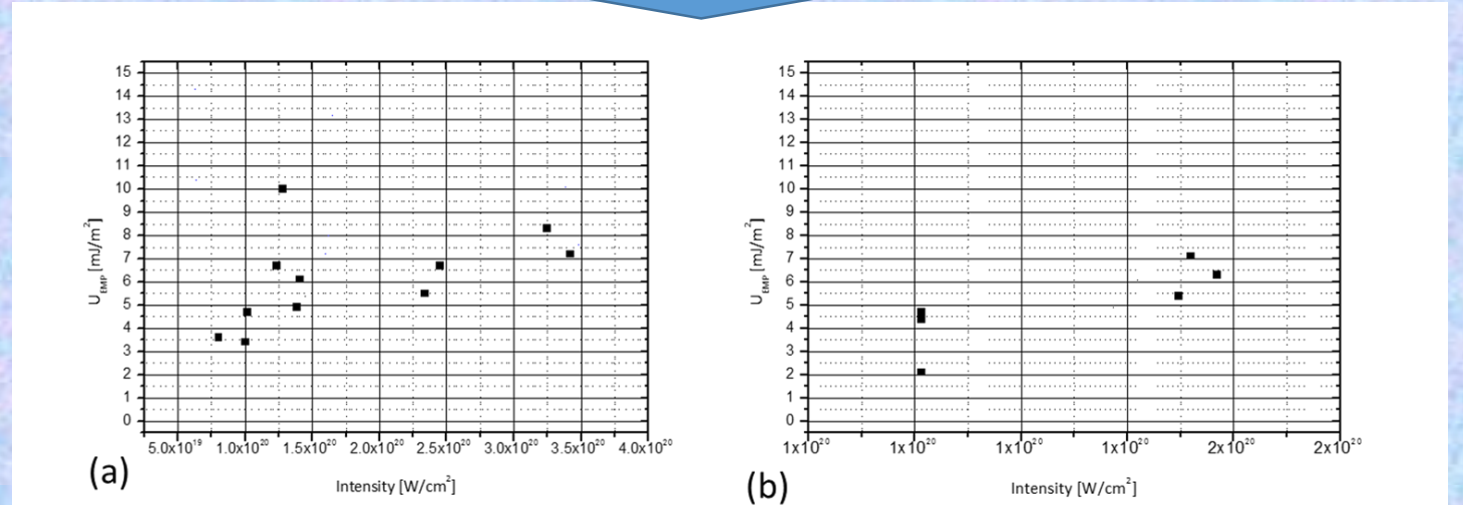
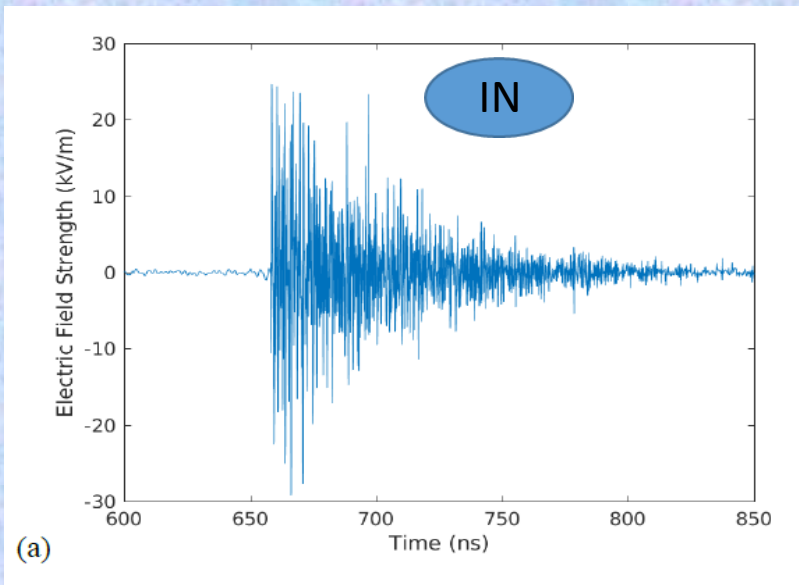
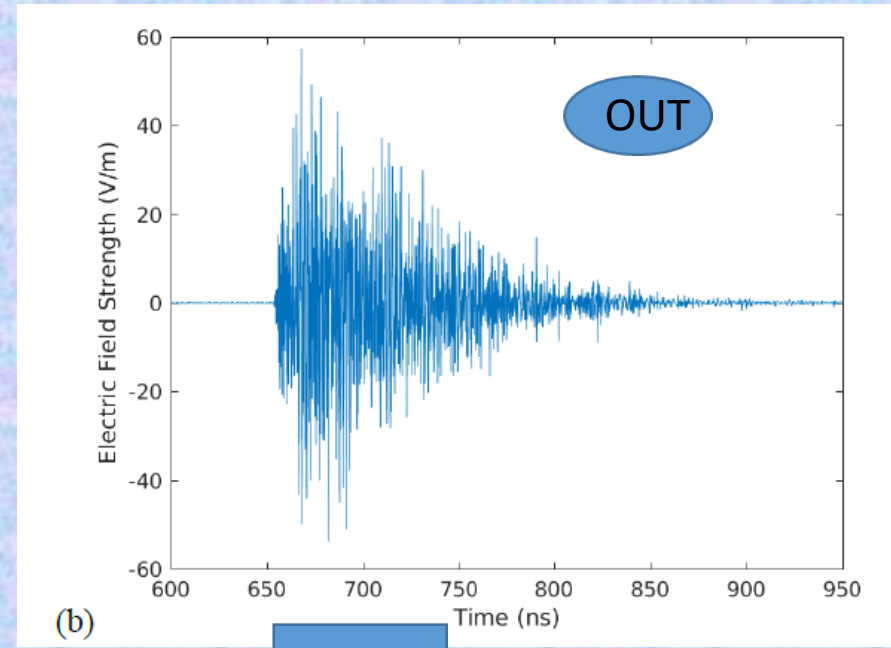
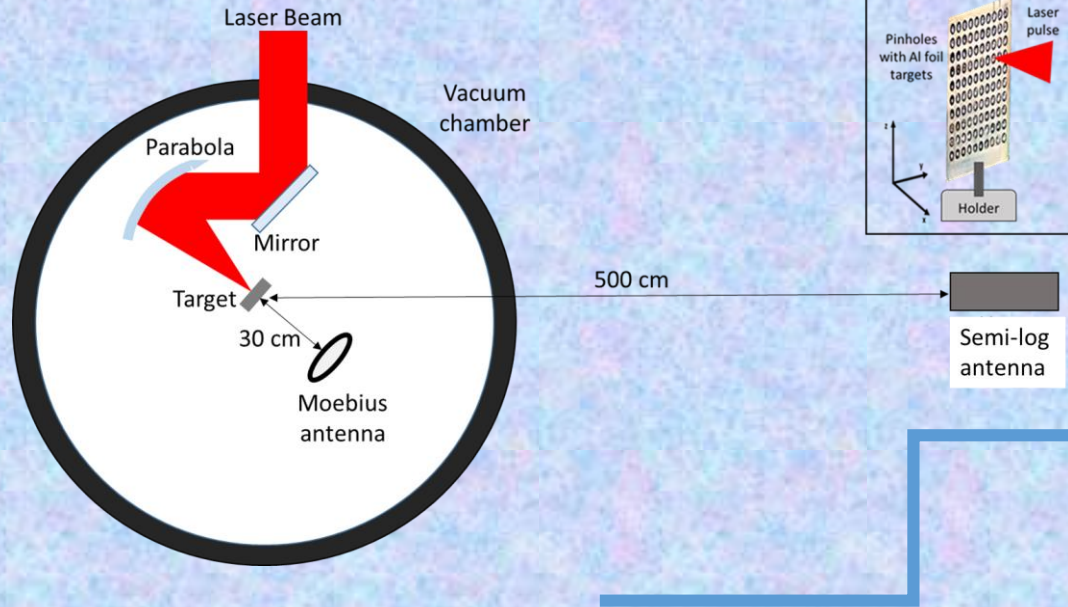
# EMP FFT in time



Kwinten et al. Characterisation and Modelling of Ultrashort Laser-Driven Electromagnetic Pulses submitted to Scientific report

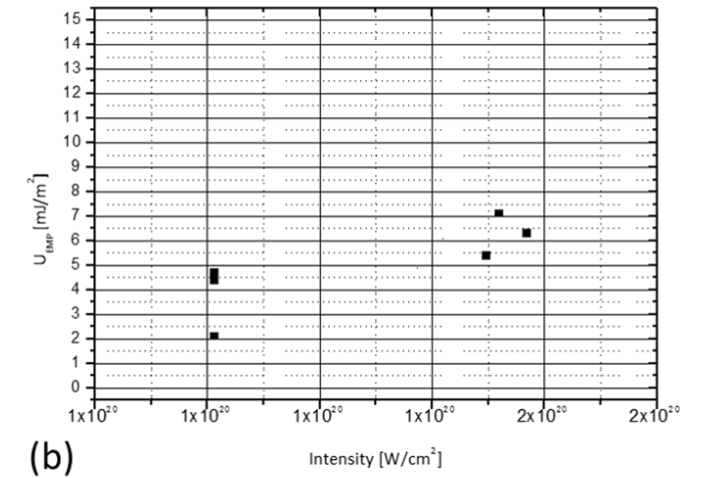
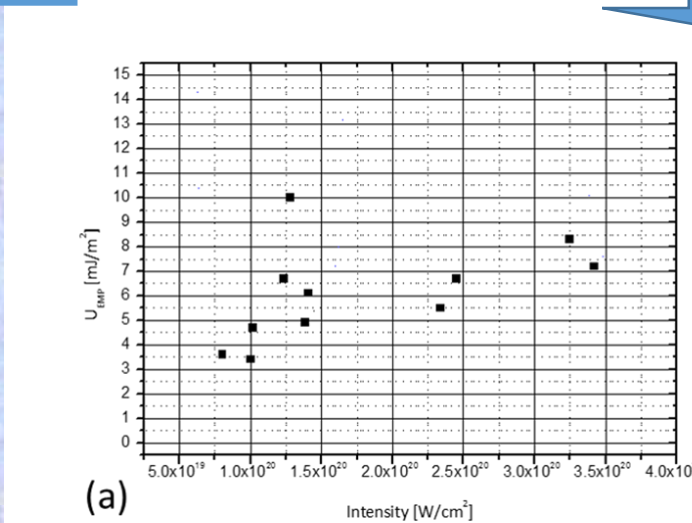
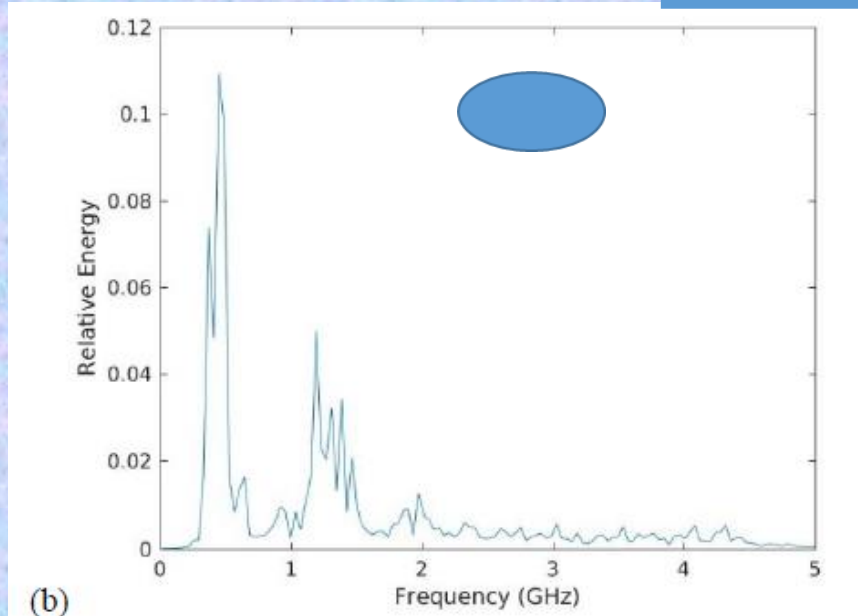
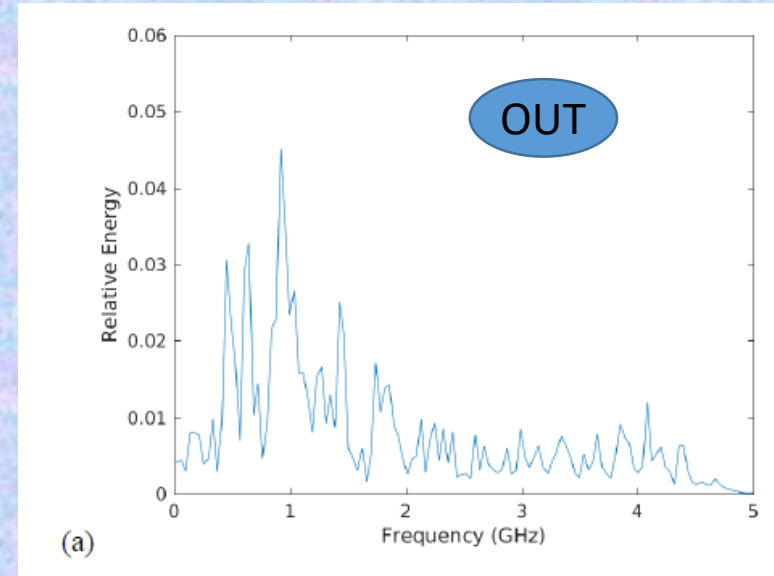
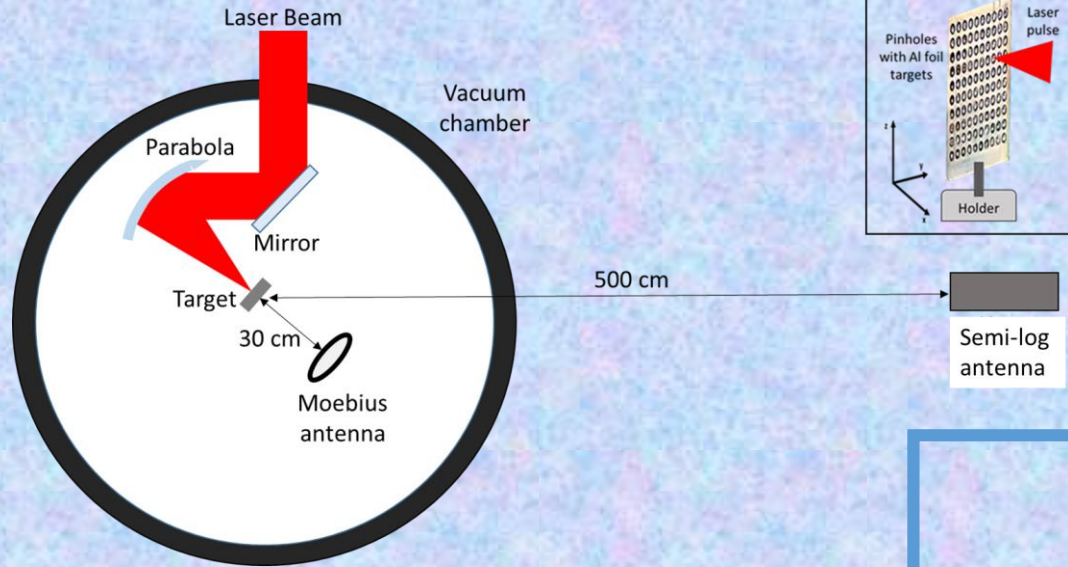
Kwinten et al. Characterisation and Modelling of Ultrashort Laser-Driven Electromagnetic Pulses submitted to Scientific report

# EMP measurements in TA at CLPU



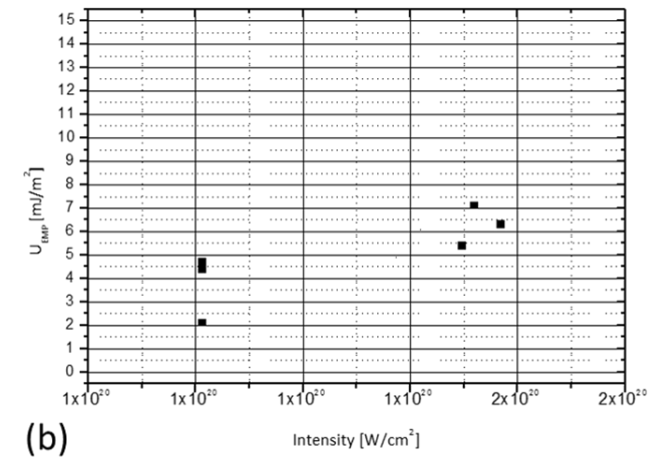
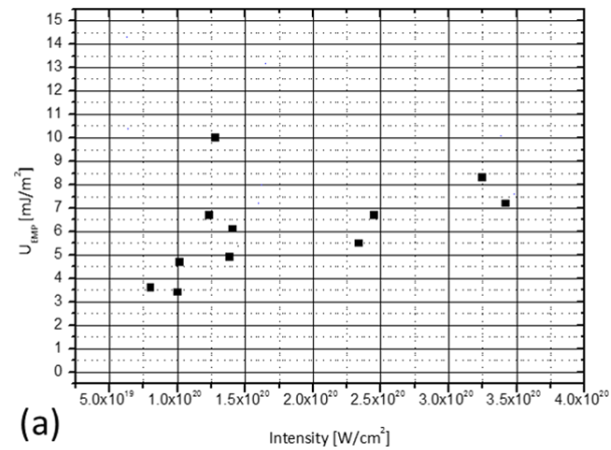
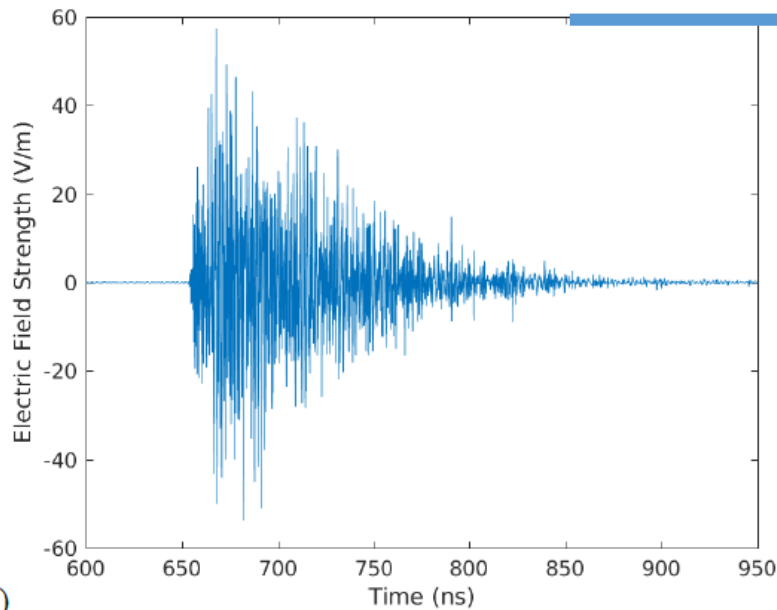
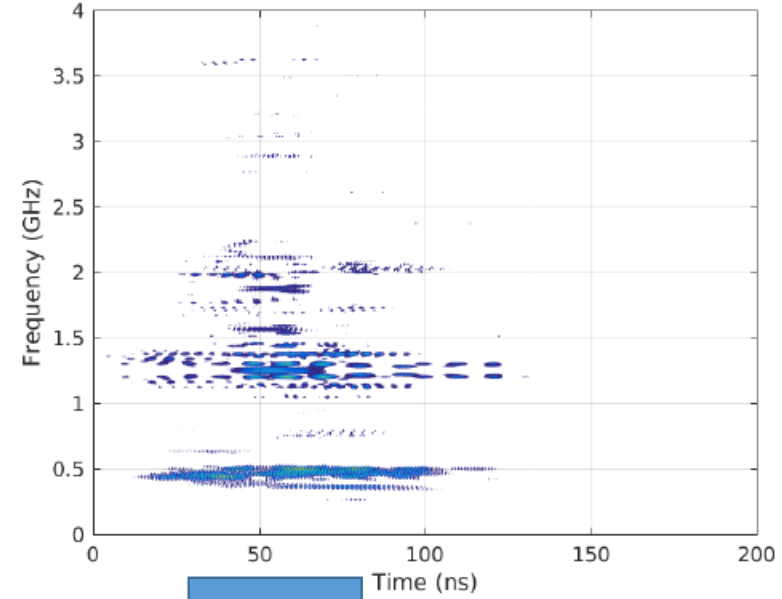
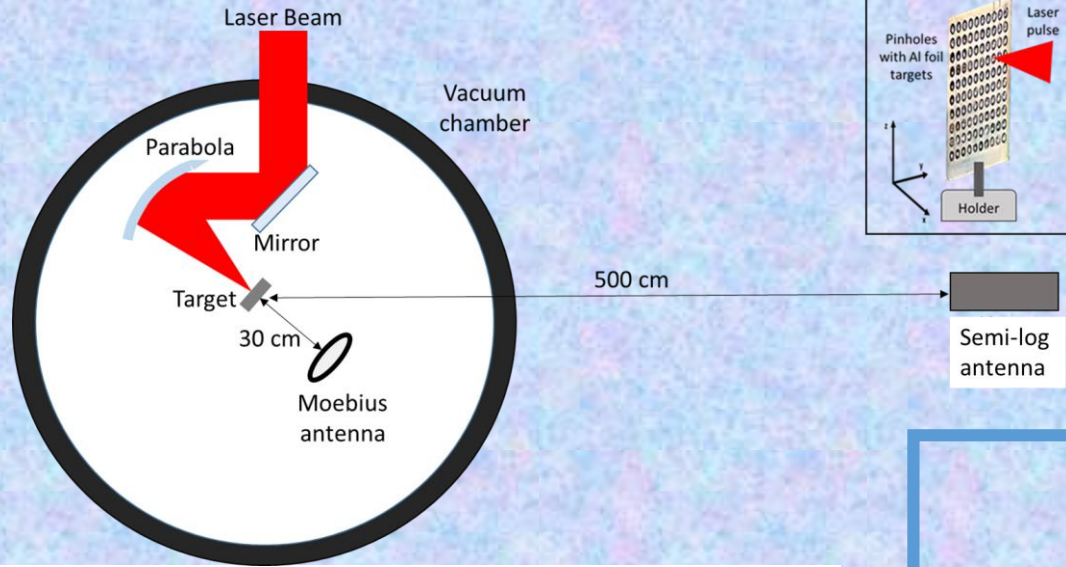
Kwinten et al. Characterisation and Modelling of Ultrashort Laser-Driven Electromagnetic Pulses submitted to Scientific report

# EMP measurements in TA at CLPU



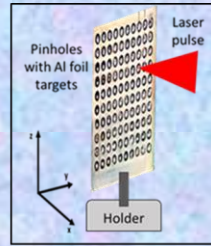
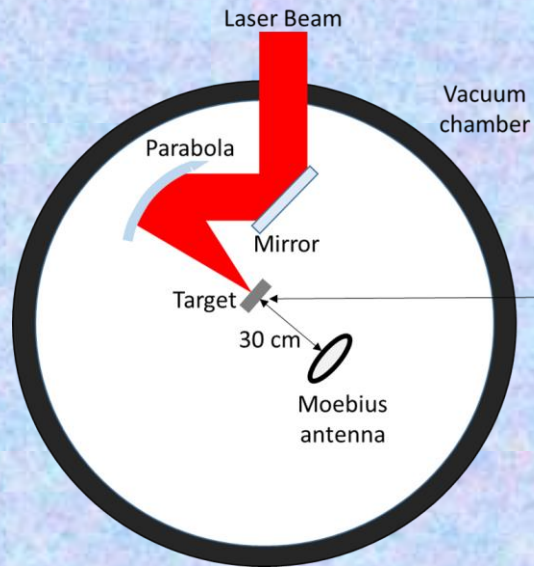


# EMP measurements in TA at CLPU

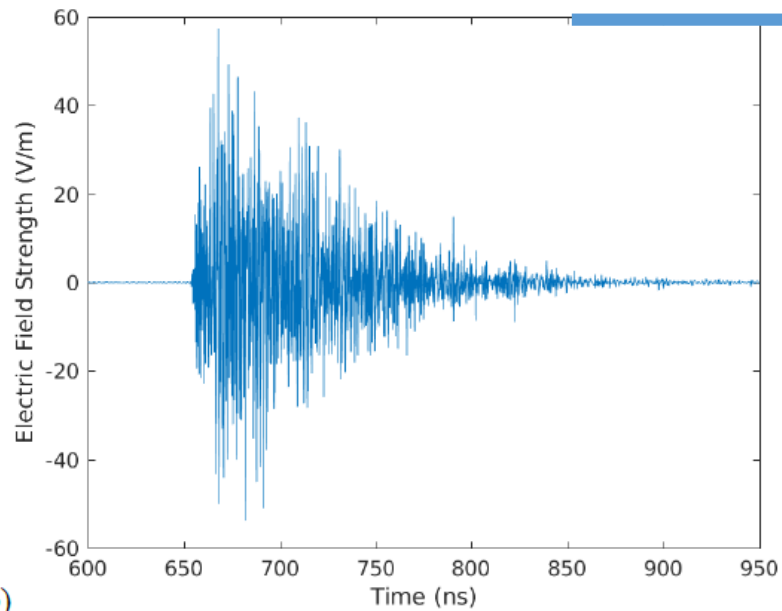
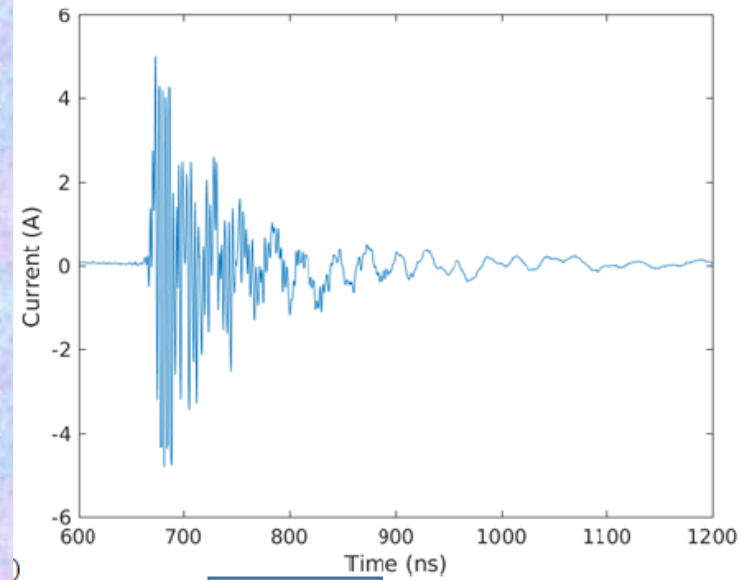


Kwinten et al. Characterisation and Modelling of Ultrashort Laser-Driven Electromagnetic Pulses submitted to Scientific report

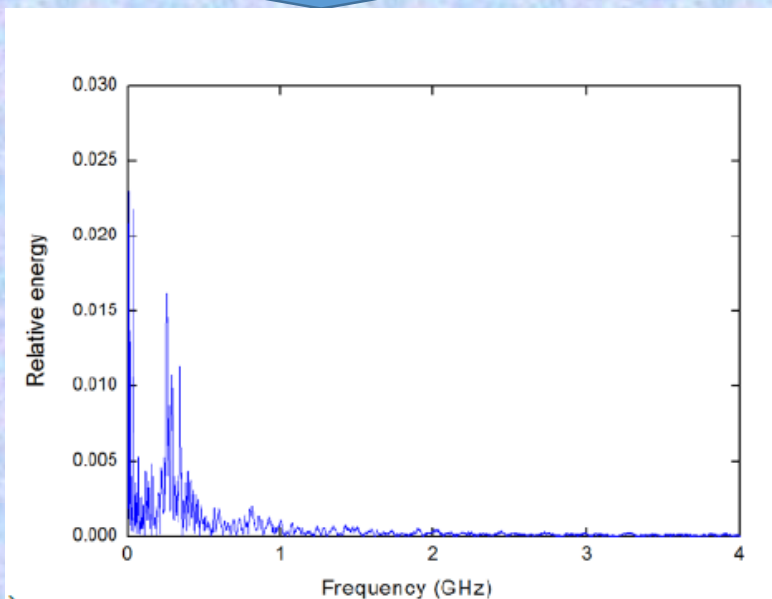
# EMP measurements in TA at CLPU



Semi-log antenna

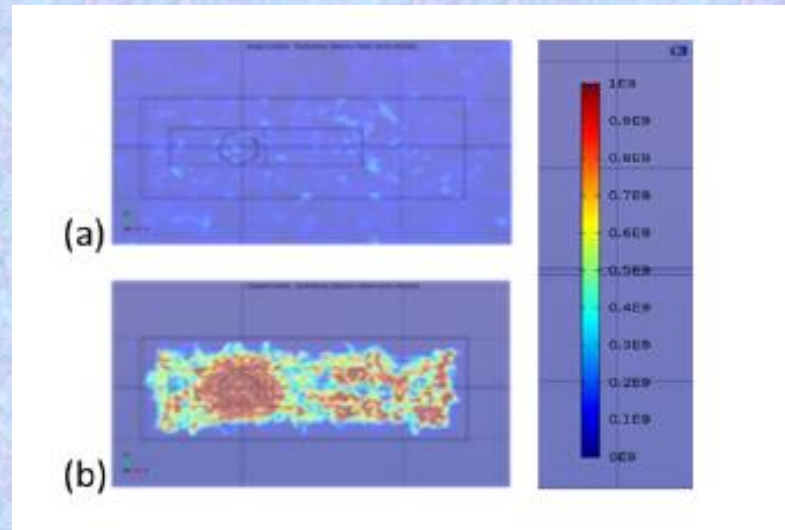
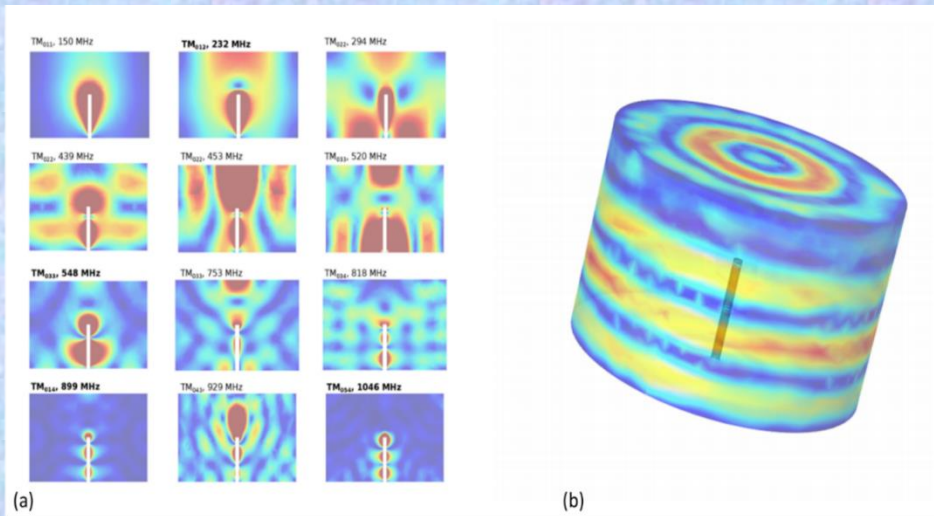
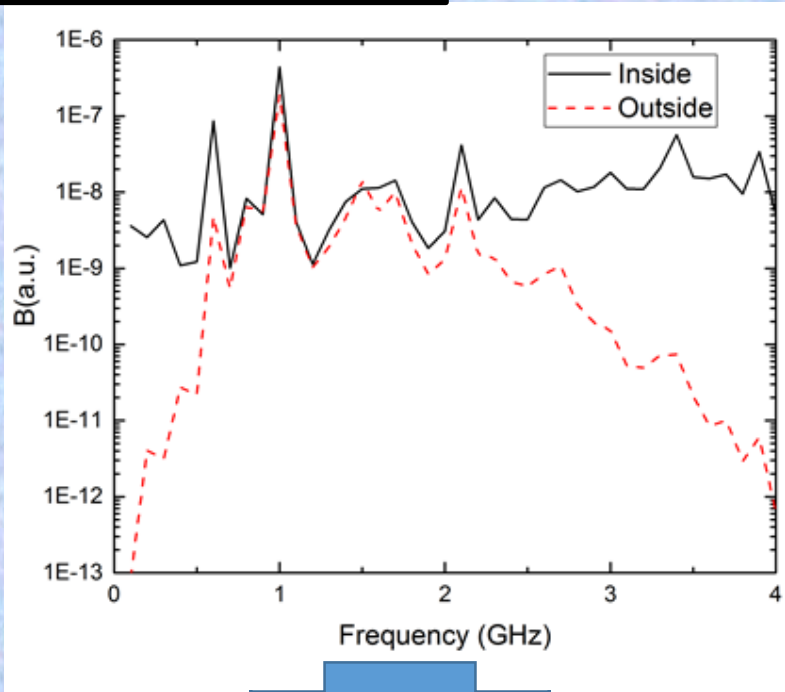
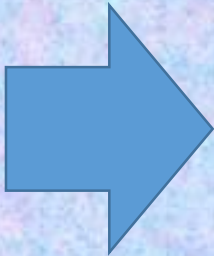
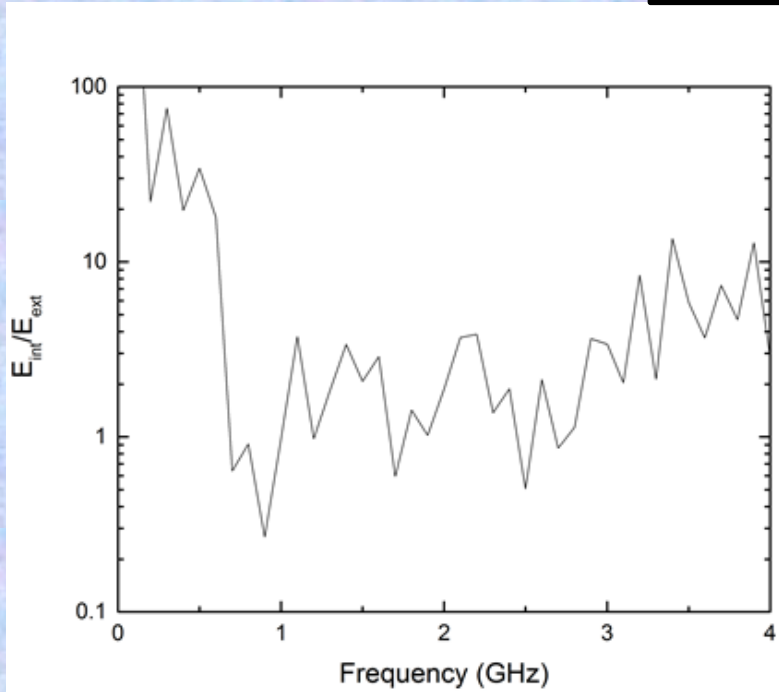


(b)



(c)

# Simulations of TA EMP



# Conclusions

- EMP is due to the escaping electrons and return current flowing on the system target-target holder compensating the unbalance of charges.**
- EMP strongly depends on different laser regimes and on different target material and sizes as well as target chamber structure.**
- Relatively high current induced in cables and electronics**
- Electric field inside the interaction chamber in the level of 10' kV/m**
- Interaction chamber works as a bandpass filter**

# Thank you for your attention

## List of references

**1)** M. De Marco, M.Pfeifer, E.Krousky, J.Krasa, J.Cikhardt, D.Klir, and V.Nassisi, **Basic features of electromagnetic pulse generated in a laser-target chamber at 3-TW laser facility PALS**, Journal of Physics: Conference Series 508 (2014) 012007

Author's contribution: participation in experiment set up, proposing diagnostics, data acquisitions, data analysis, interpretations of results, drafting of the paper, drawing pictures for paper

**2)** M. De Marco, J.Cikhardt, J.Krasa, A.Velyhan, M.Pfeifer, E.Krousky, D.Klir, K. Řezáč, J.Limpouch, D.Margarone, J.Ullschmied, **Electromagnetic pulses produced by expanding laser-produced Au plasma**, 2015 Nukleonika 60 239-243

Author's contribution: participation in experiment set up, proposing diagnostics, data acquisitions, data analysis, interpretations of results, drafting of the paper, drawing pictures for paper.

**3)** M. De Marco, J. Krása, J. Cikhardt, M. Pfeifer, E. Krouský, D. Margarone, H. Ahmed, M. Borghesi, S. Kar, L. Giuffrida, R. Vrana, A. Velyhan, J. Limpouch, G. Korn, S.

Weber, L. Velardi, D. Delle Side, V. Nassisi and J. Ullschmied **Measuring of electromagnetic pulses generated during interactions of high power lasers with solid targets**, 2016 JINST 11 C06004

Author's contribution: participation in experiment set up, proposing diagnostics, data acquisitions, data analysis, interpretations of results, drafting of the paper, drawing pictures for paper, numerical simulations with Comsol Multiphysics 5.2a.

**4)** J. Krása, D. Klír, A. Velyhan, K. Rezac, J. Cikhardt, L. Ryc, E. Krouský, M. Pfeifer, M. De Marco, J. Skála, R. Dudžák and J. Ullschmied **Generation of fast neutrons through deuteron acceleration at the PALS laser facility**, 2016 JINST 11 C03050

Author's contribution: participation in experiment set up, proposing diagnostics, data acquisitions, data analysis, interpretations of results.

**5)** J. Krása, D. Klír, M. De Marco, J. Cikhardt, A. Velyhan, K. Řezáč, M. Pfeifer, E. Krouský, L. Ryc, J. Dostál, J. Kaufman, J. Ullschmied **Semiconductor detectors for observation of multi-meV protons and ions produced by lasers (submitted in the Plasma Physics and Technology 2016 Conference)**

Author's contribution: participation in experiment set up, proposing diagnostics, data acquisitions, data analysis, interpretations of results.

**6)** J.Cikhardt, J.Krásá, M.De Marco, M.Pfeifer, A. Velyhan, E.Krouský, B. Cikhardtová, D. Klír, K. Řezáč, J.Ullschmied, J. Skála, P. Kubeš, and J. Kravárik **Measurement of the target current by inductive probe during laser interaction on terawatt laser system PALS**, *Rev. Sci. Instrum.* **85**, (2014) 103507.

Author's contribution: participation in experiment set up, proposing diagnostics, data acquisitions, interpretations of results

**7)** J. Krása, J. Cikhardt, M. De Marco, D. Klír, A. Velyhan, K. Řezáč, M. Pfeifer, E. Krouský, J. Skála, R. Dudžák, J. Dostál, J. Kaufman, J. Ullschmied **Magnetic field induced by laser-driven target current, (Proceeding at EPS Conference 2016)**

Author's contribution: participation in experiment set up, proposing diagnostics, data acquisitions, data analysis, interpretations of results, drawing pictures for paper.

**8)** D. Margarone, A. Velyhan, J. Dostal, J. Ullschmied, J.P. Perin, D. Chatain, S. Garcia, P. Bonnay, T. Pisarczyk, R. Dudzak, M. Rosinski, J. Krasa, L. Giuffrida, J. Prokupek, V. Scuderi, J. Psikal, M. Kucharik, M. De Marco, J. Cikhardt, E. Krousky, Z. Kalinowska, T. Chodukowski, G.A.P. Cirrone, G. Korn **Proton Acceleration Driven by a Nanosecond Laser from a Cryogenic Thin Solid-Hydrogen Ribbon**, *Phys. Rev X* **6**, 041030 (2016)

Author's contribution: participation in experiment set up, proposing diagnostics, data acquisitions, data analysis.

**9)** J. Krása, M. De Marco, J. Cikhardt, M. Pfeifer, A. Velyhan, D. Klír, K. Řezáč, J. Limpouch, E. Krouský, J. Dostál, J. Ullschmied, R. Dudžák **Spectral and temporal characteristics of target current and electromagnetic pulse induced by nanosecond laser ablation (2017)** *Plasma Phys. Control. Fusion* <https://doi.org/10.1088/1361-6587/aa6805>

Author's contribution: participation in experiment set up, proposing diagnostics, data acquisitions, data analysis, interpretations of results, drafting of the paper, drawing pictures for paper, numerical simulations with Comsol Multiphysics 5.2a.

**10)** M. De Marco, J. Krása, J. Cikhardt, A. Velyhan, M. Pfeifer, R. Dudžák, J. Dostál, E. Krouský, J. Limpouch, T. Pisarczyk, Z. Kalinowska, T. Chodukowski, J. Ullschmied, L. Giuffrida, D. Chatain, J-P. Perin, D. Margarone **Electromagnetic pulse (EMP) radiation by laser interaction with a solid H2 ribbon**, submitted to *Physics of Plasma*

Author's contribution: participation in experiment set up, proposing diagnostics, data acquisitions, data analysis, interpretations of results, drafting of the paper, drawing pictures for paper, numerical simulations with Comsol Multiphysics 5.2a.

**11)** I.Prencipe, J.Fuchs, S.Pascarelli, D.Shumacher, R.Stephens, N.Alexander, R.Briggs, M.Cernaianu, M.De Marco, G.Fiquet, P.Fitzsimmons, C.Gheorghiu, J.Hund, L.Huang, M.Harmand, N.Hartley, A.Irman, T.Kluge, Z.Konopkova, D.Kraus, V.Leca, D.Margarone, J.Metzkes, W.Nazarow, P.Lutoslawski, A.Pelka, J.P.Perin, J.Schulz, C.Spindloe, S.Steinke, R.Torchio, M.Tolley, G.Schaumann, M.Buescher, Fiedorowitz, K.Nagai, Papp, M. Passoni, A.Shukurov, Tabeling, Vass, R.Zaffino, T.Tschentscher, and T.E. Cowan **Targets for high repetition rate advanced laser facilities: needs, challenges and perspectives** Article submitted to: *High Power Laser Science and Engineering*, 2016

Author's contribution: participation in experiment set up, proposing diagnostics, data acquisitions, data analysis, interpretations of results, drafting of the paper, drawing pictures for paper.