Queen's University Belfast

Apollon

Apollon FIRE user meeting

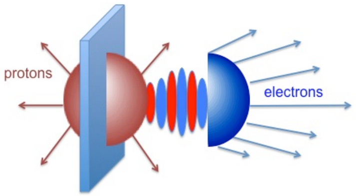
Laser Energised travelling wave accelerator a miniature, modular device for guided post-acceleration of laser driven ions

Satya Kar

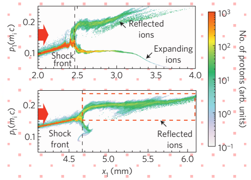
Queen's University Belfast, UK.

Current motivations in the field of laser ion acceleration

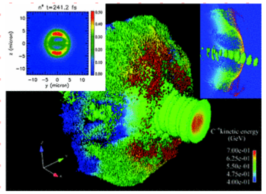
Energy increase



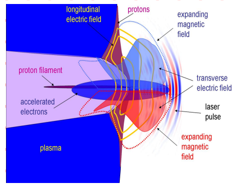
Coulomb explosion



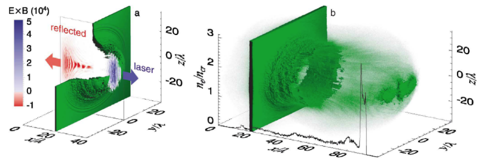
Shock acceleration



BOA

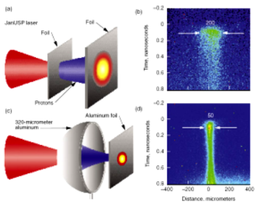


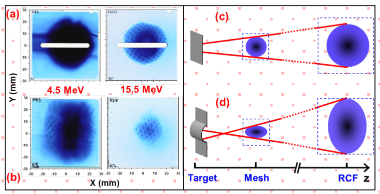
Magnetic vortex

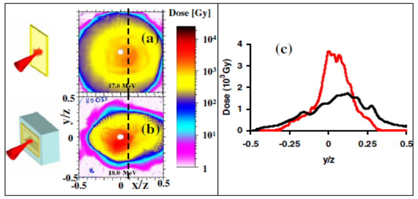


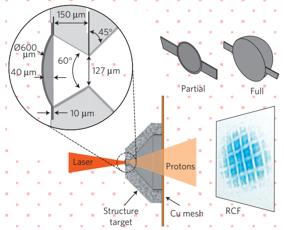
Radiation pressure acceleration

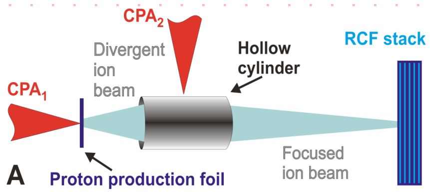
Focusing and Energy selection

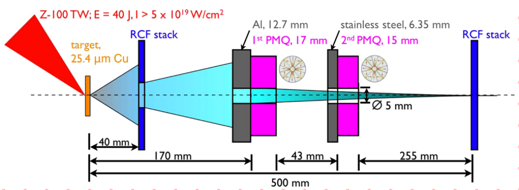


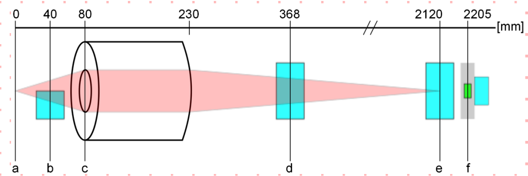






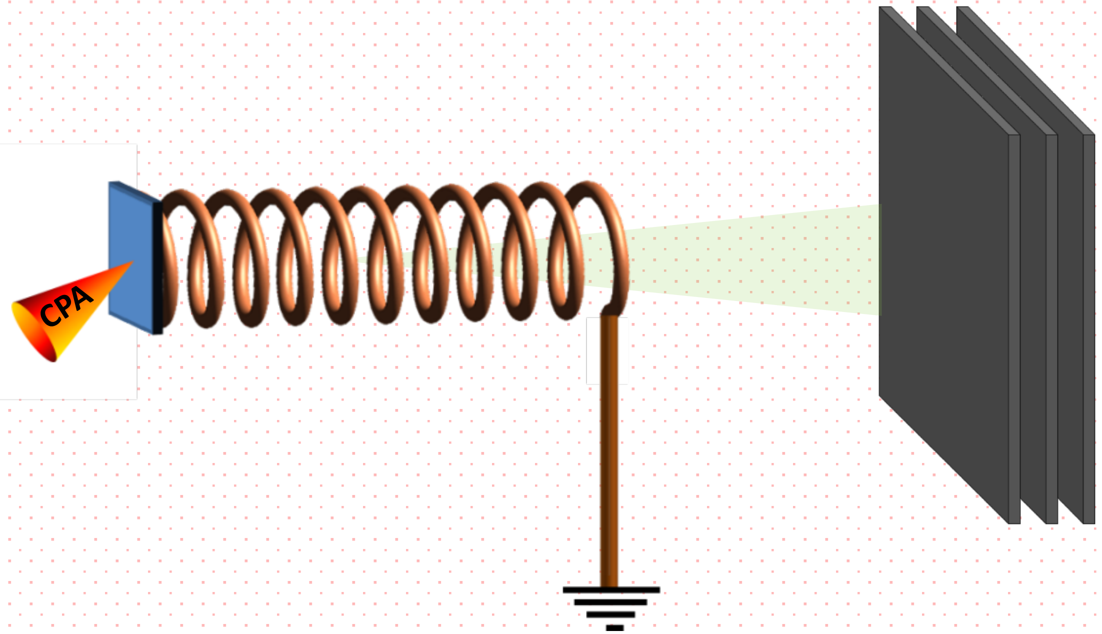






One device –
focusing, energy selection, re-acceleration !

Laser energized travelling charge accelerator



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Pioneering research and skills

S. Kar, PCT Patent-1400727.2, 2014

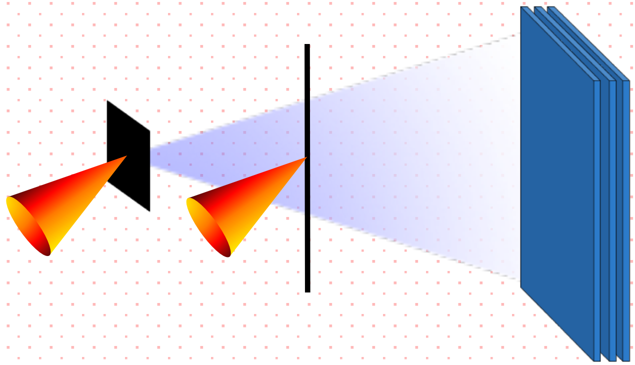
Invest Northern Ireland

Outline

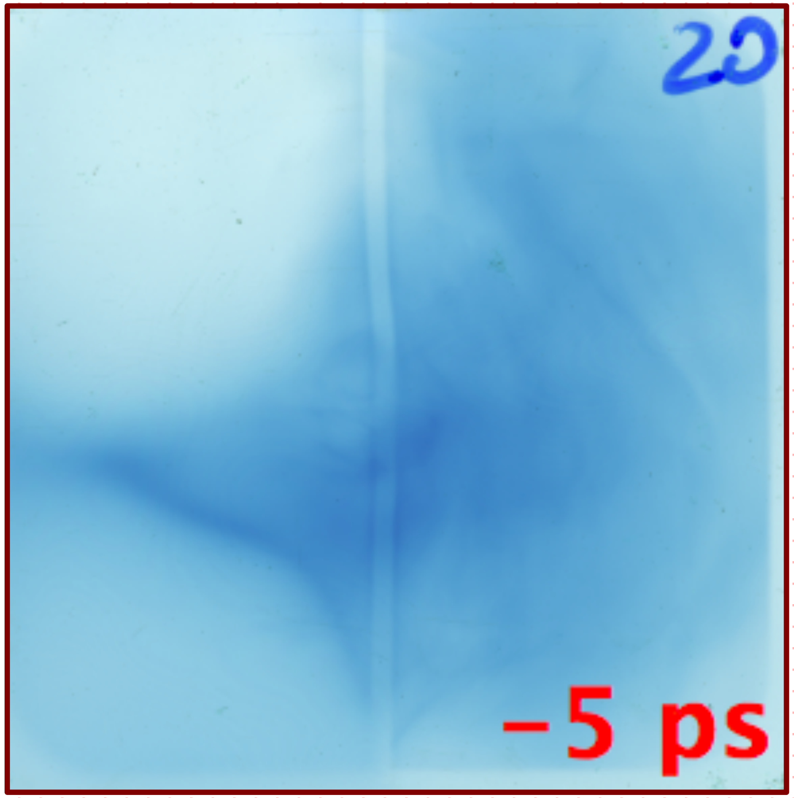
- Ultra-short current pulse generation
- How it works
- Experimental results (Dusseldorf, CLF)
- LETCA for upcoming laser intensities and STAGING

Charging and discharging following laser interaction

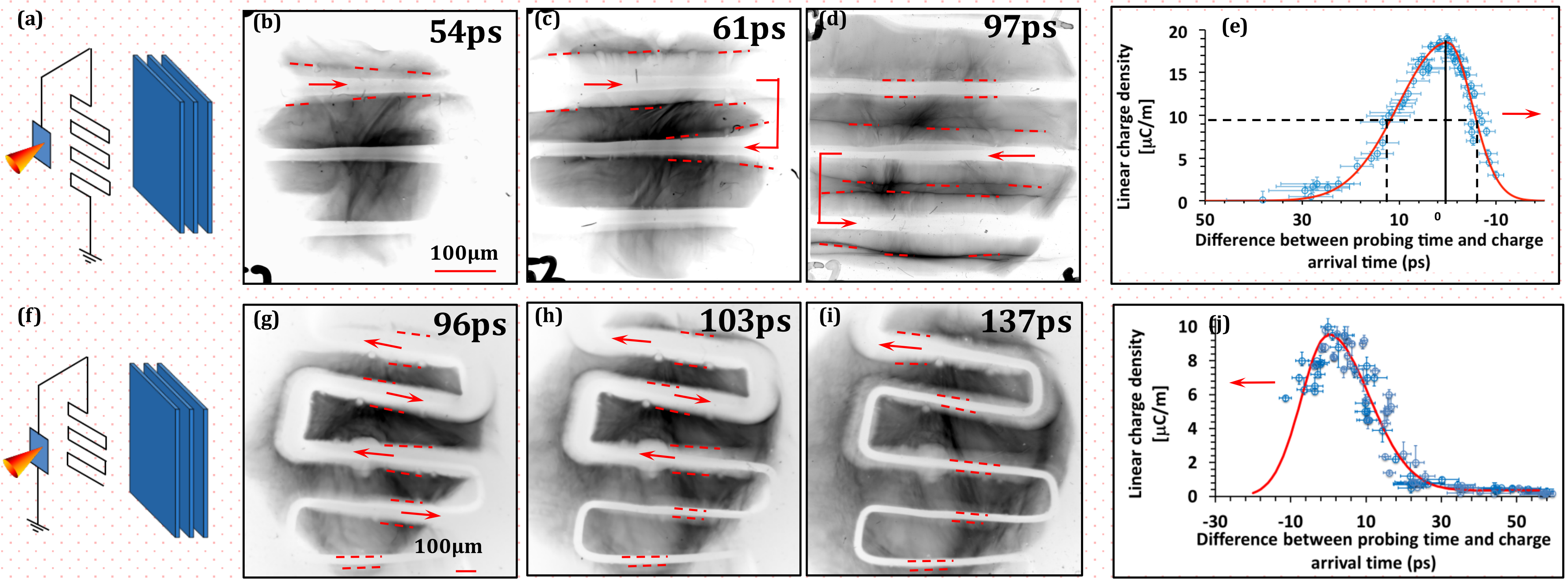
Proton imaging of laser irradiated wire



Multi-frame snapshot from a single shot



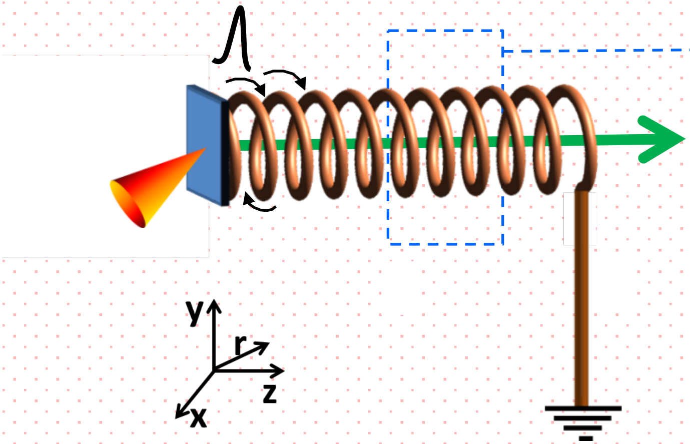
And, what we saw is very interesting!

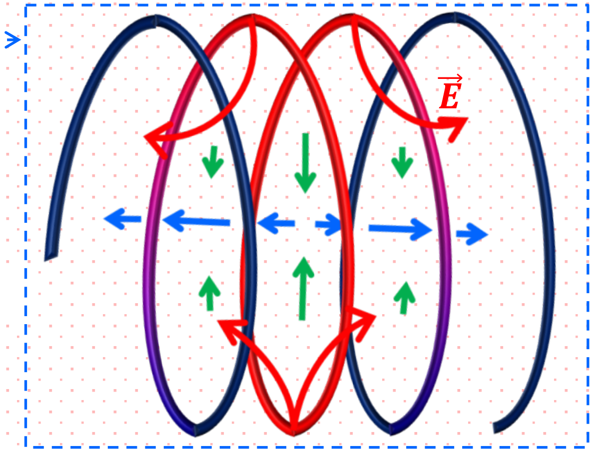


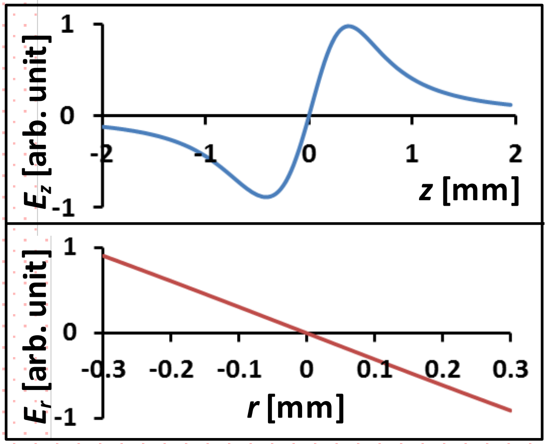
Not only the current pulse travels over the bends,

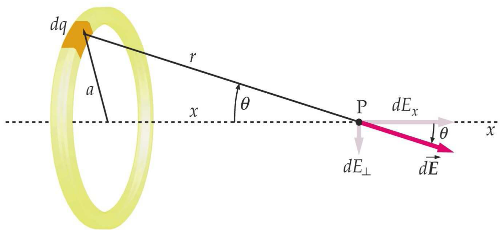
reflects from an open end.

Laser Energised Travelling charge Accelerator



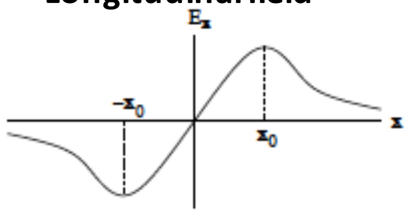






Analogy with the field of a charged ring

Longitudinal field



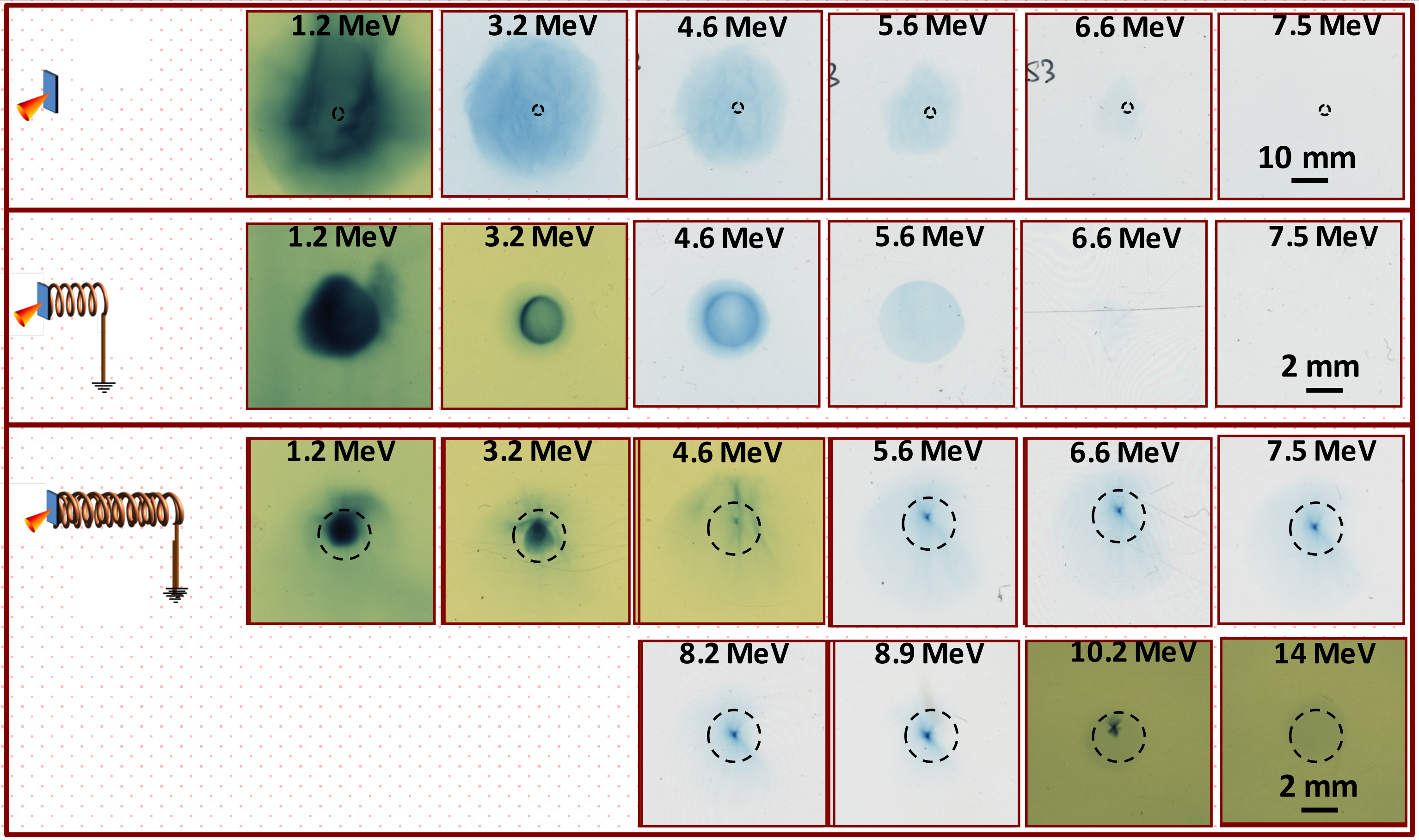
$$x_0 = \frac{a}{\sqrt{2}}$$

$$E_{\max} = \frac{Q}{2\pi\varepsilon_0 a^2}\frac{\sqrt{2}}{3\sqrt{3}}$$

Q~ 60 nC, a =0.4 mm → E~ MV/mm

Proof-of-principle at University-scale laser (ARCTURUS)

S. Kar et. al., Nature Communications, in press (2016)



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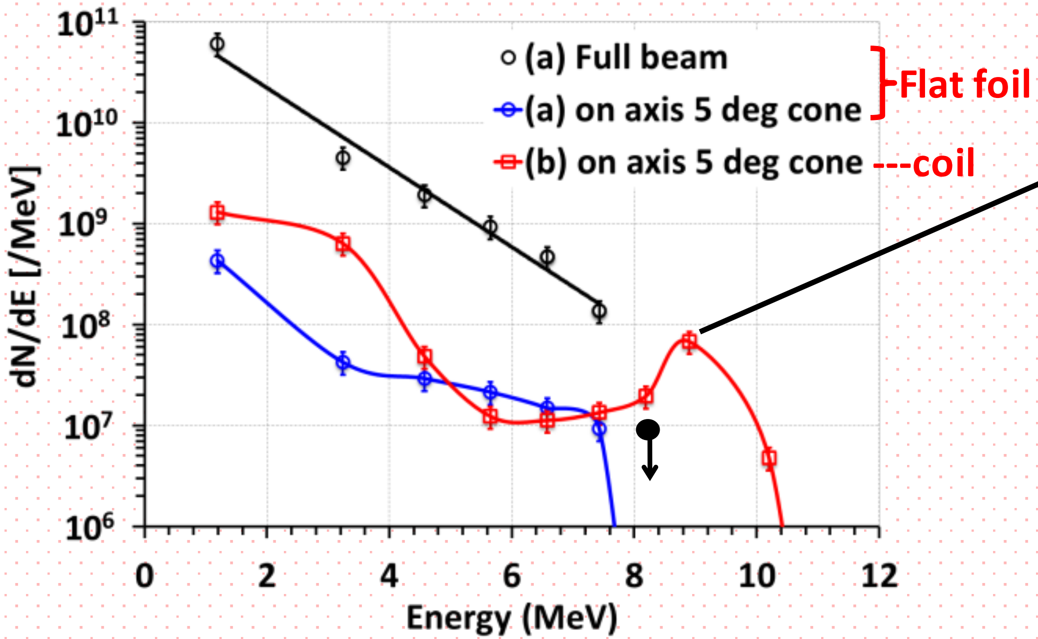
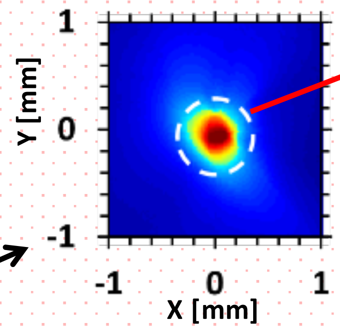
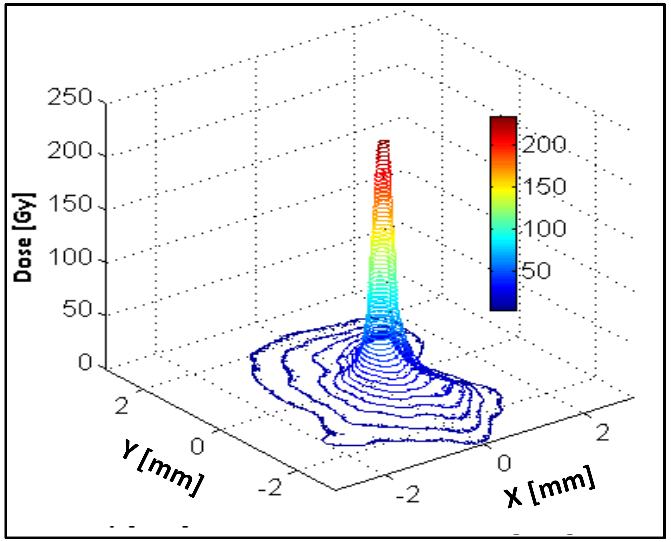




Inner diameter of the coil

⇒ Divergence < 1°
measured at 35 mm
from the target



LETCA for Higher Intensity lasers
&
staging

Scaling to higher power laser

Typical electron spectrum from laser solid interaction:

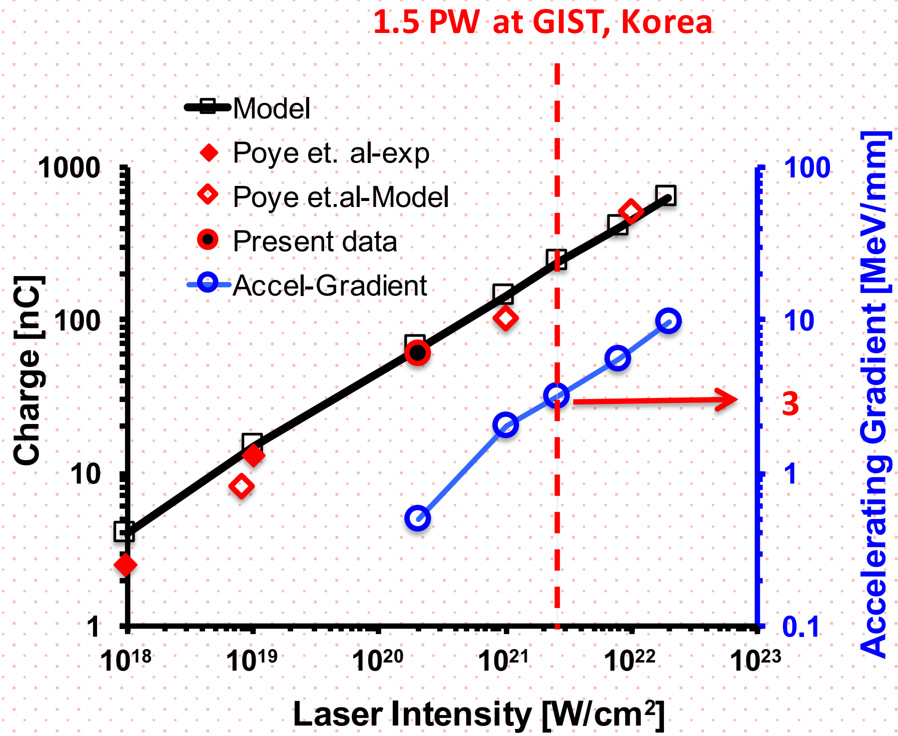
$$\frac{dN}{dE} = \frac{N_0}{U_p} e^{-E/U_p}$$

where $U_p = 0.511\left(\sqrt{1 + a_0^2/2} - 1\right)$

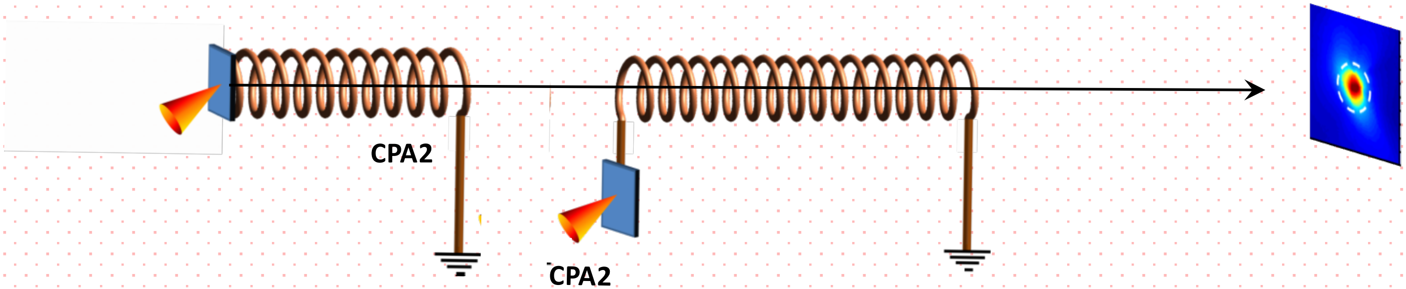
Temporal evolution of target charge is controlled by target capacitance :

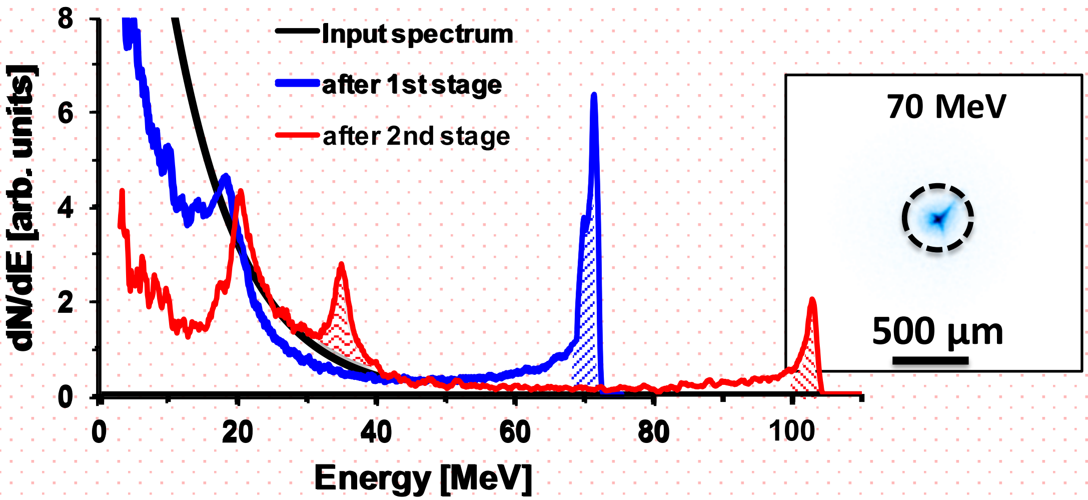
$$N_{es}(t) = N_0\, e^{-E_{cutoff}/U_p}$$

where $eN_{es}(t)/C_T = E_{cutoff}$



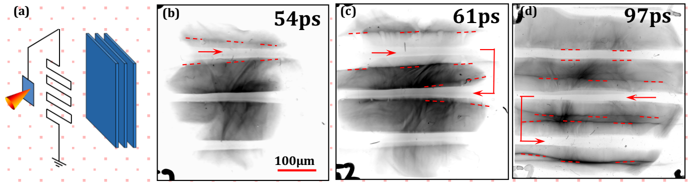
Scaling to higher power laser + STAGING



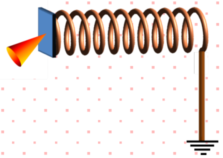


Summary

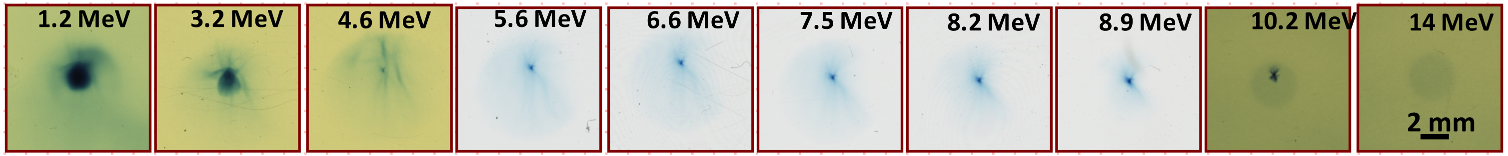
- Transient charging of laser irradiated target generates ultra-short charge pulse propagating along the supporting wire.



- The unique properties of the charge pulse is exploited to create a device for simultaneous focussing, energy selection and re-acceleration of proton beams.



- Promising data obtained experimentally using university scale laser, which opens of possibility of optimising ion beam parameters with currently available higher power lasers.



Acknowledgements

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  Dr. A. Macchi

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Thank you very much for your attention.