Laser wakefield acceleration of electrons

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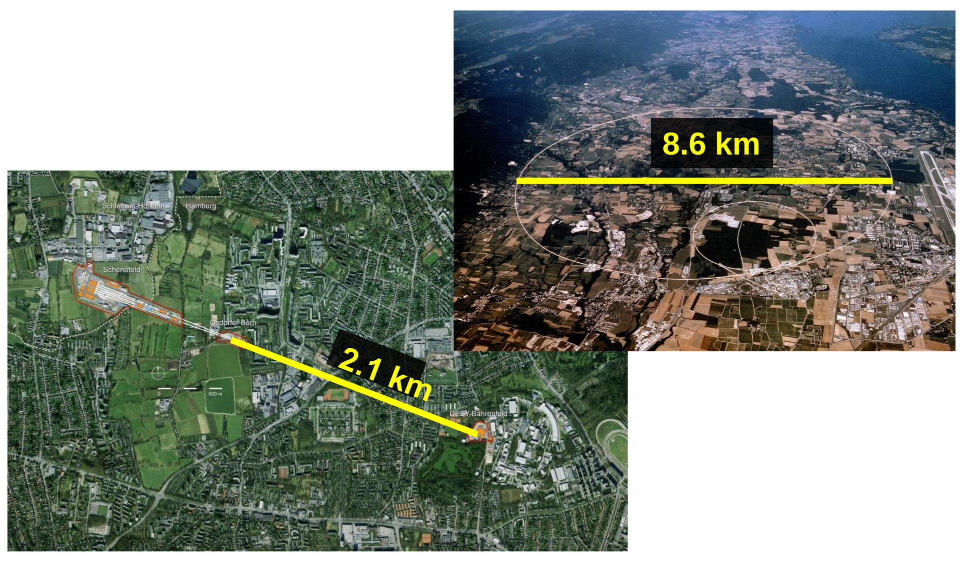
Acceleration of electrons

- Acceleration of electrons is done by placing an electron (negative charge) in an electric field and accelerating them to almost the speed of light
- Conventional accelerators are huge and expensive. Using Laser Wakefield Acceleration (LWFA) we can scale down these machines by 3 orders of magnitude

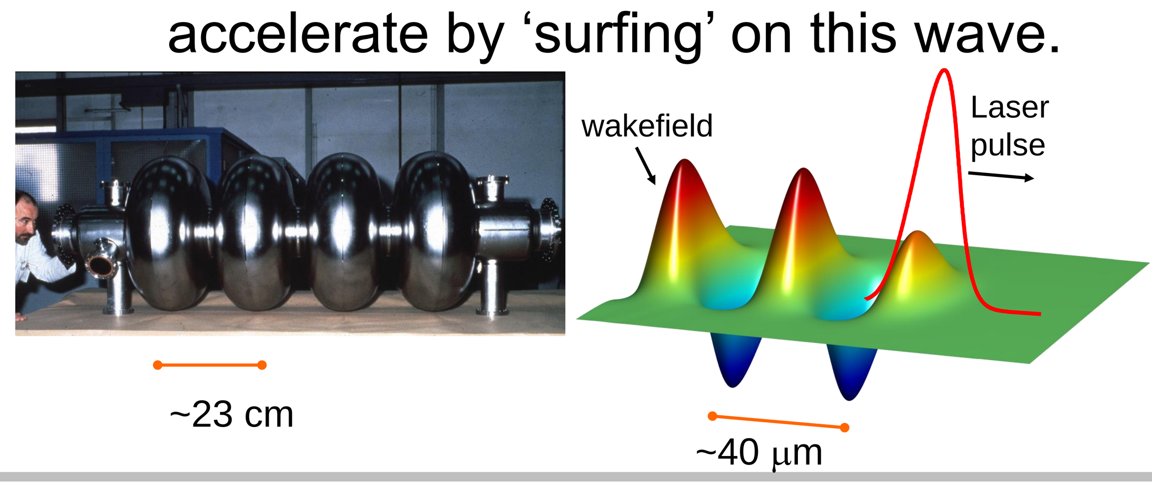
Kinetic Energy	Speed
25 keV	0.30 c
100 keV	0.55 c
1 MeV	0.94 c
10 MeV	0.9988 c
100 MeV	0.99998 c
1 Gev	0.9999999 c

~25 keV electron accelerator



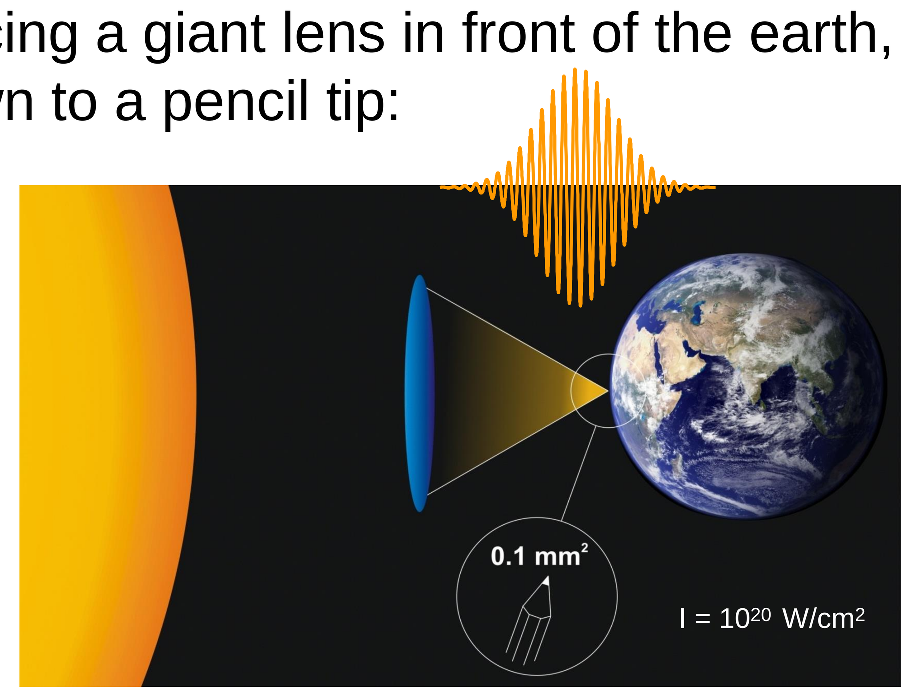
XFEL electron accelerator (17.5 GeV, left) and CERN LHC (7 TeV, right)

- Conventional accelerators (left) use macroscopic radiofrequency accelerating structures. (max. 100 MeV/m)
- In LWFA (right) a travelling laser creates a microscopic acceleration gradient (up to 100 GeV/m). Electrons accelerate by 'surfing' on this wave.

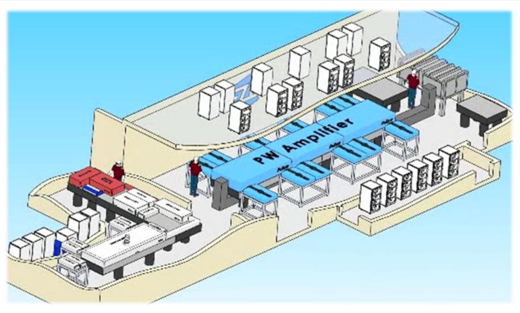


How to create fast LWFA electrons

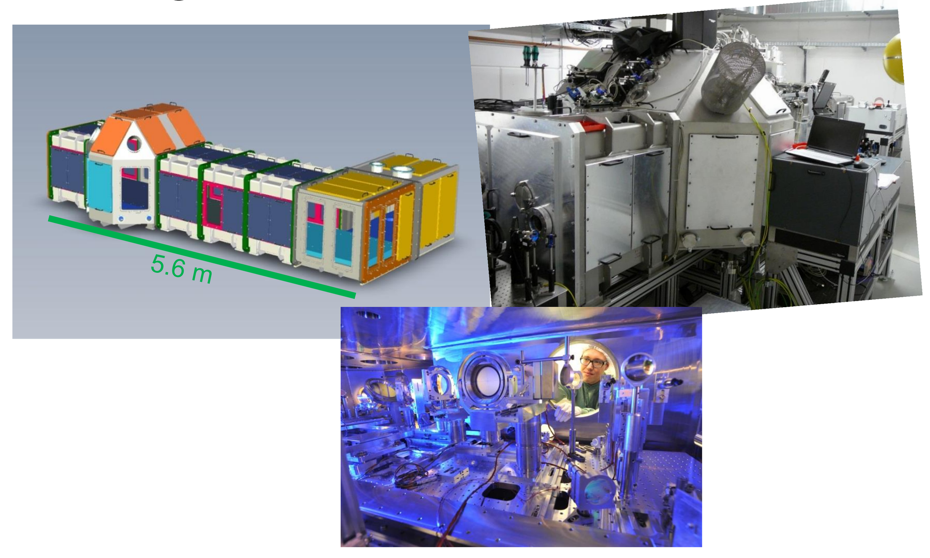
- The intensity required for LWFA is comparable to placing a giant lens in front of the earth, focussing down to a pencil tip:

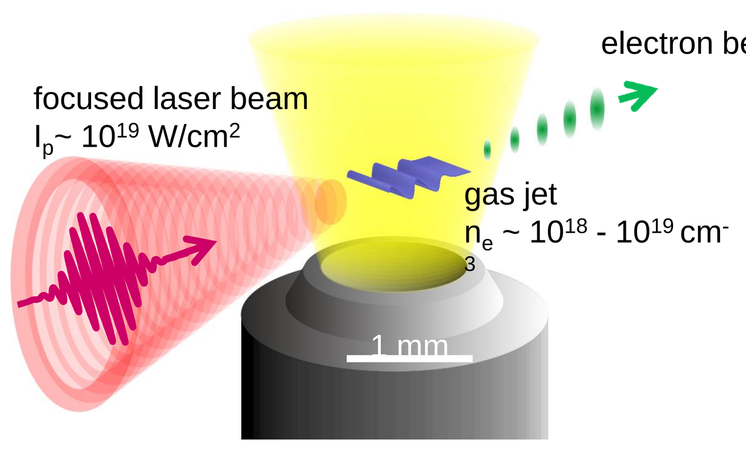


- These kind of intensities can be produced by some of the biggest laser systems in the world. Our laser system, DRACO, fills one big room (~100m² / 1000 ft²)

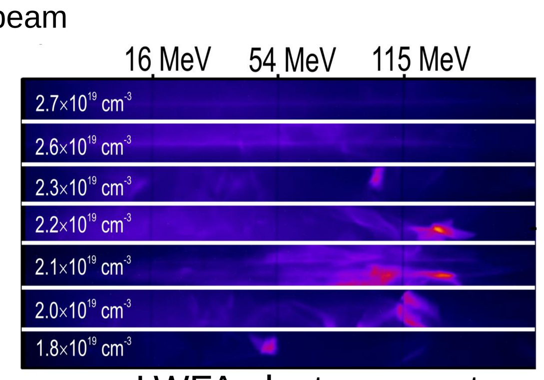


- The LWFA electron acceleration takes place in a large vacuum chamber, producing 100s of MeVs within a mm





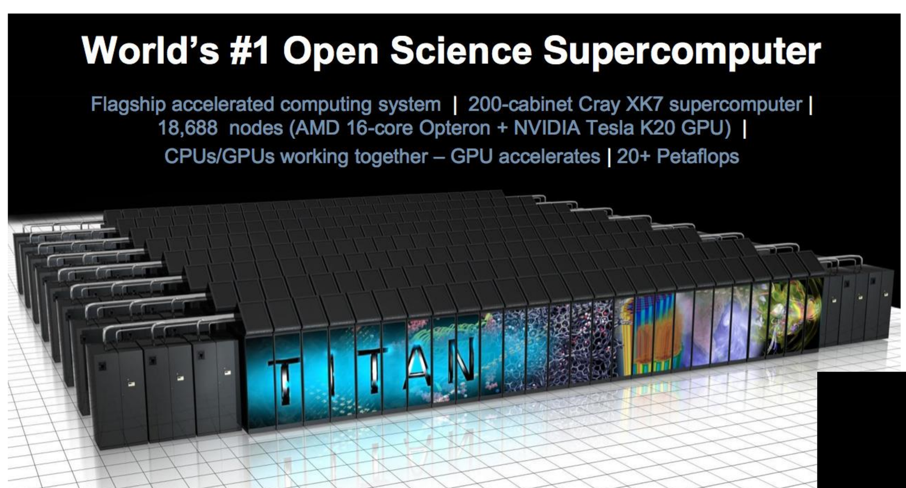
Supersonic de Laval nozzle



LWFA electron spectra
DRACO laser parameters on target:
1.4 J, 30 fs, 9 µm (1/e²), a_0=3.9

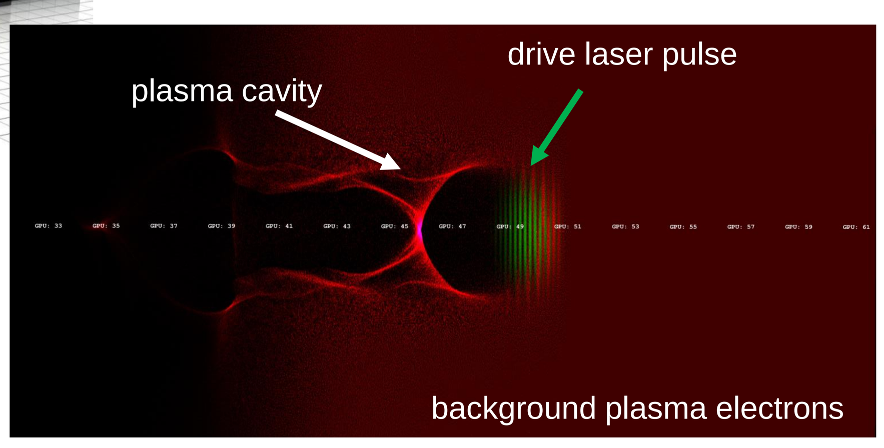
Simulations

- The physics behind this process is so complicated that it can not be done mathematically on a piece of paper.



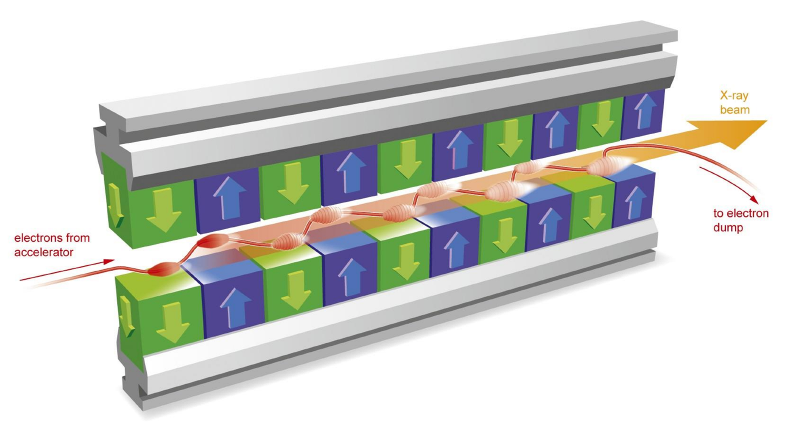
- To better understand the physics, simulations are performed on supercomputers

PIConGPU
Scan for video

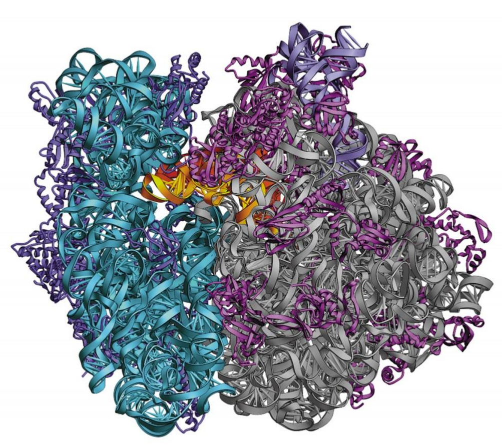


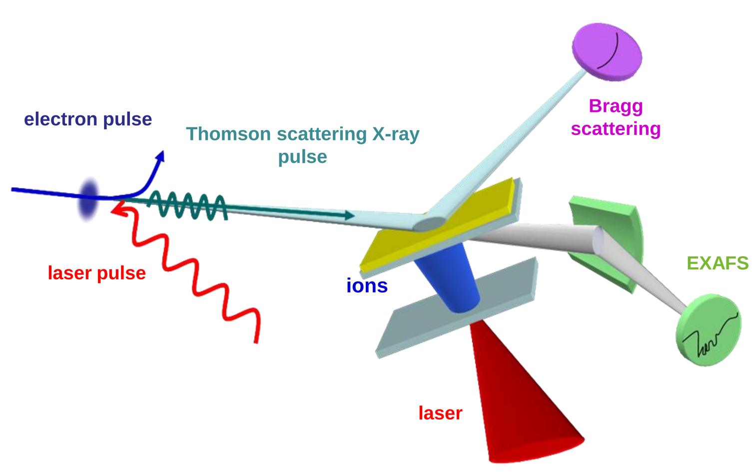
PIConGPU simulation (64 NVIDIA Fermi GPUs) of wakefield formation in the bubble regime. One 3D simulation requires only 45 minutes of simulation time.
H Burau, et al, IEEE Trans. on Plasma Sc. 38(10), 2831-2839

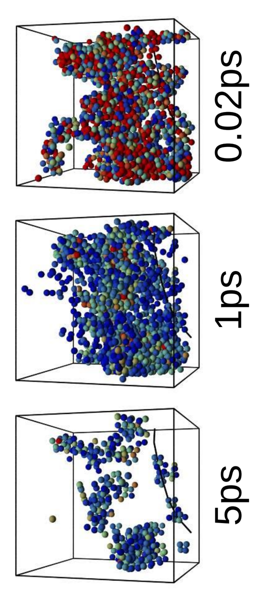
Why fast electrons?



- If an electron travels through alternating fields, it will wiggle. At every curve it will emit a x-ray photon (action = reaction)
- Because of the short wavelength of x-rays, very small details can be studied. Like Ribosomes (our cells' protein factories), or matter under extreme conditions







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