Advanced accelerator concepts for future accelerators

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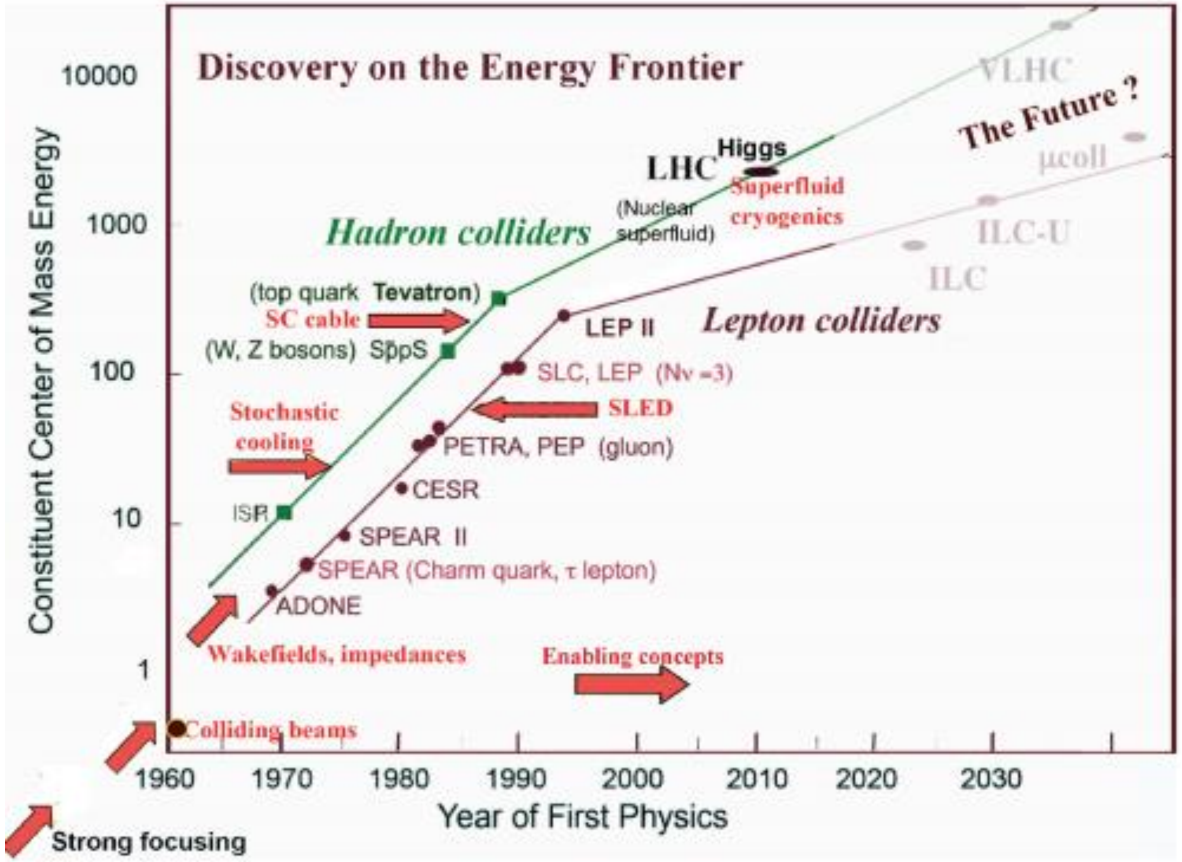
Outline

- Review of existing concepts and facilities
- Novel accelerator techniques
  - Plasma wakefield acceleration (PWFA)
  - Dielectric accelerating structures
  - Metallic millimeter wavelength accelerating structures
- Conclusion

Existing facilities and achieved energies

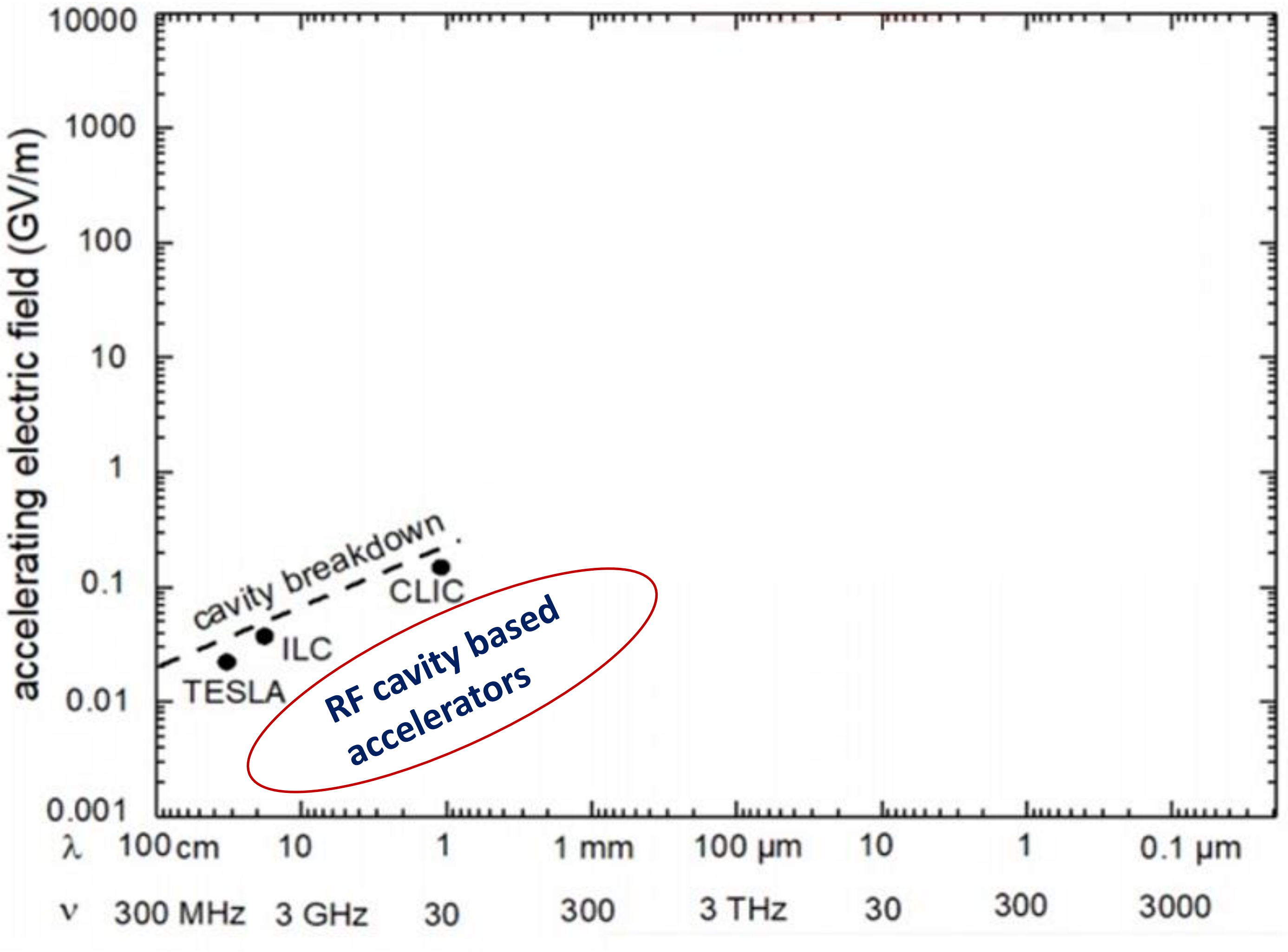


Updated Livingston curve [1]

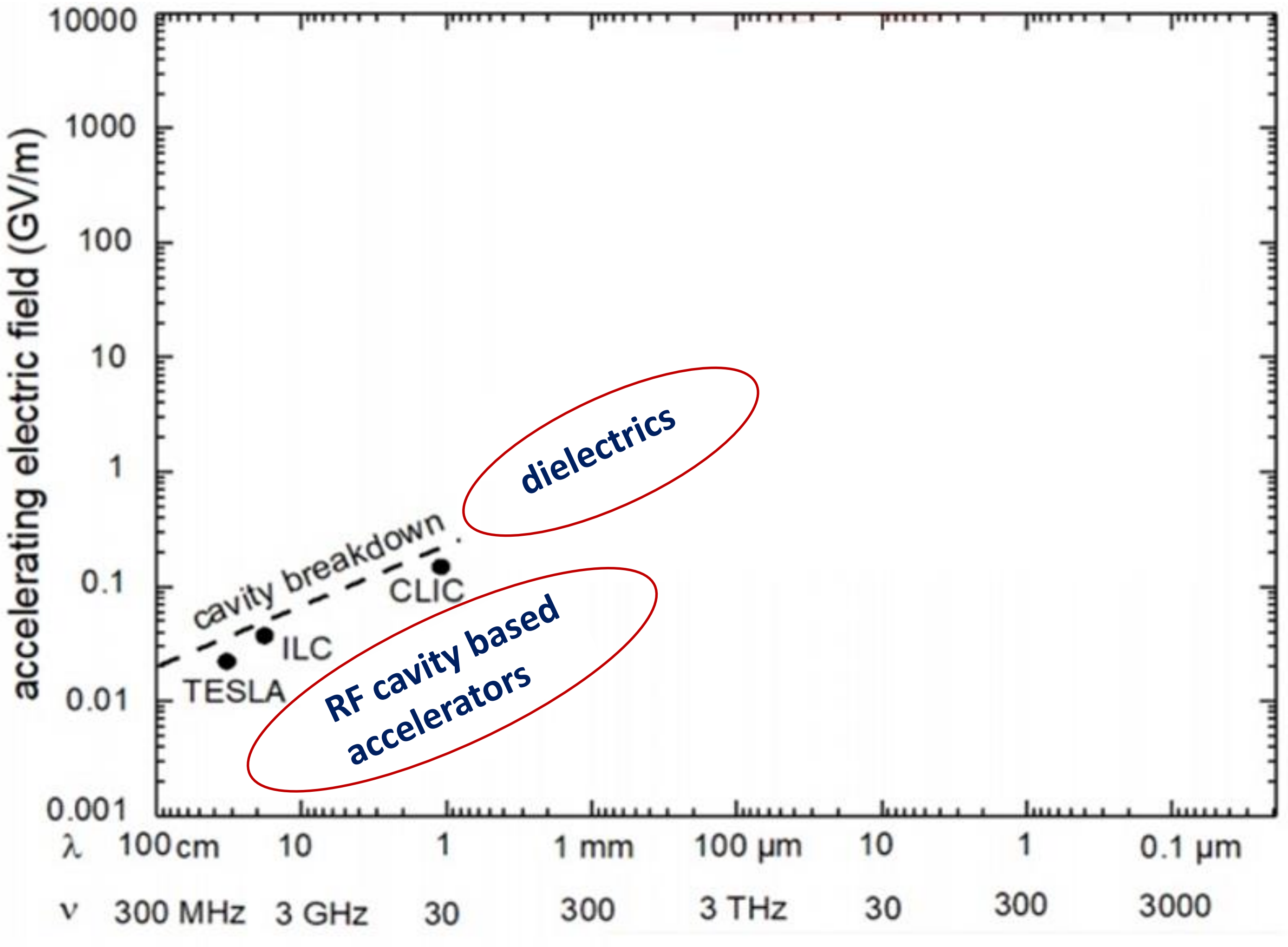
Limitations

- Accelerating structure breakdown
- Radiation losses in lepton machines
- Magnetic field limitation in circular machines
- Lack of space for linear accelerators

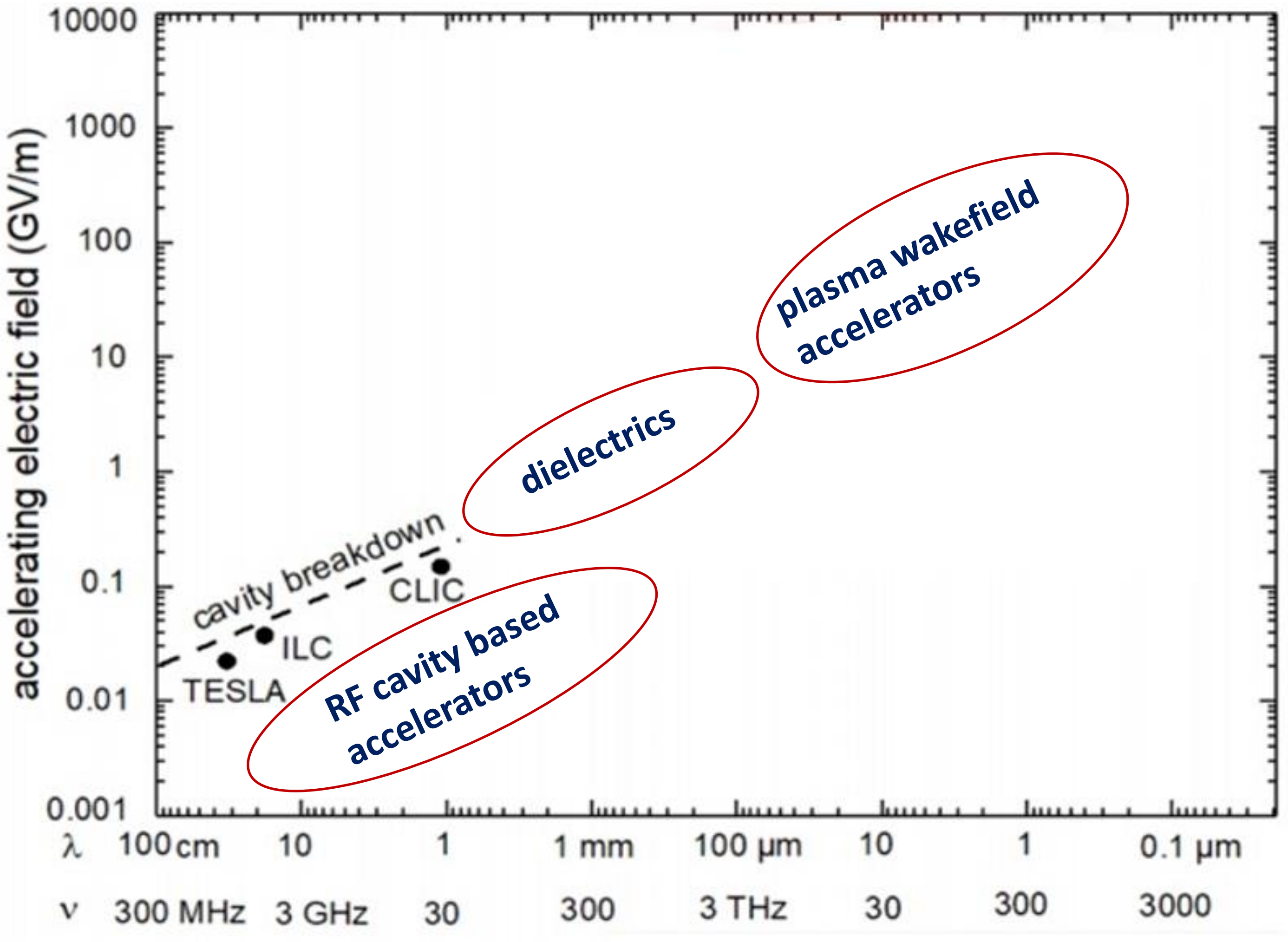
Advanced accelerator concepts



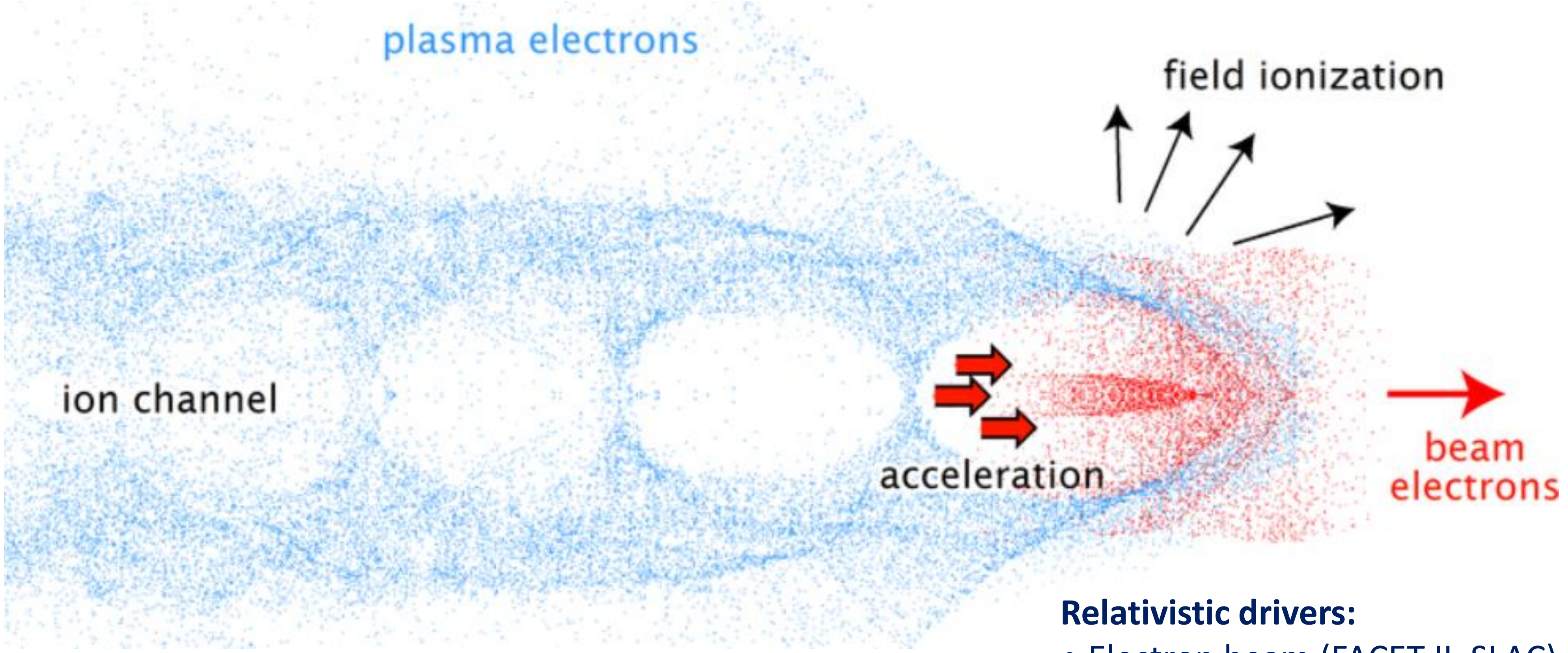
Advanced accelerator concepts



Advanced accelerator concepts



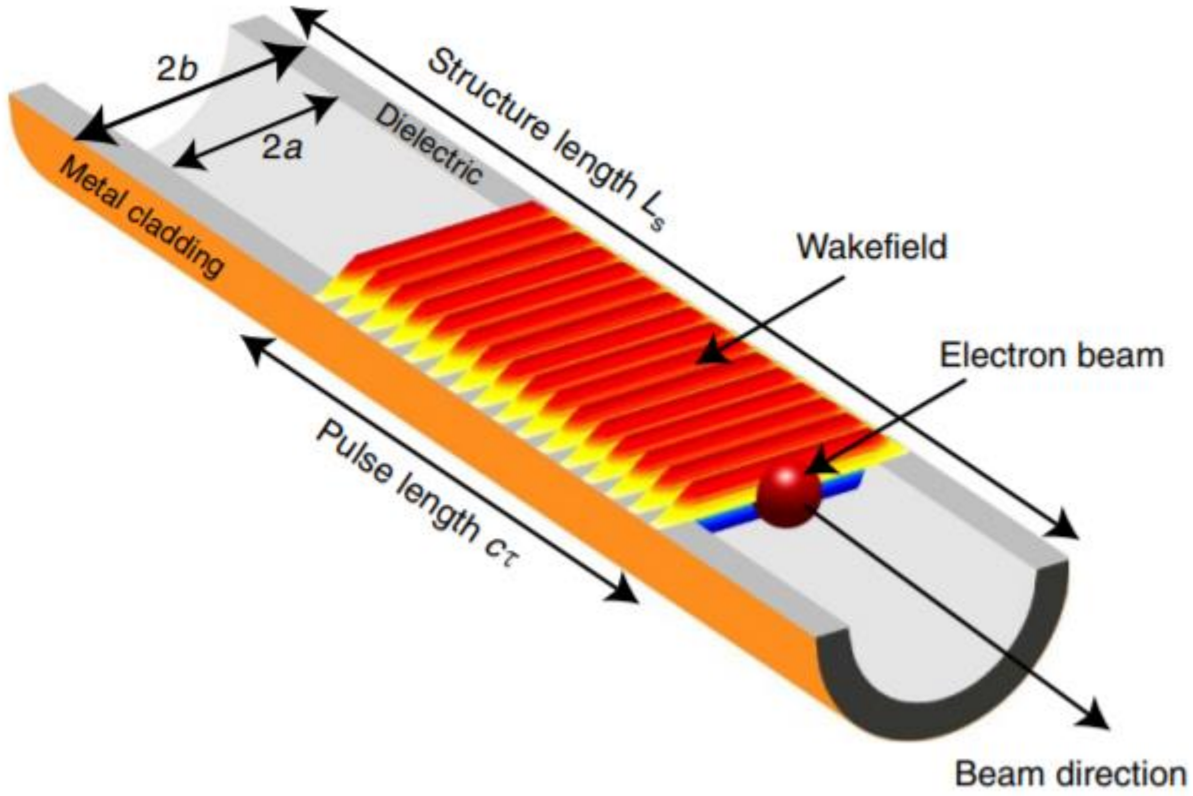
Plasma wakefield acceleration (PWFA)



Relativistic drivers:

- Electron beam (FACET II, SLAC) – $E_z \approx 150$ GeV/m
- Proton beam (AWAKE, CERN) – $E_z \approx 0.2$ GeV/m
- Laser pulse (numerous) – $E_z \approx 300$ GeV/m

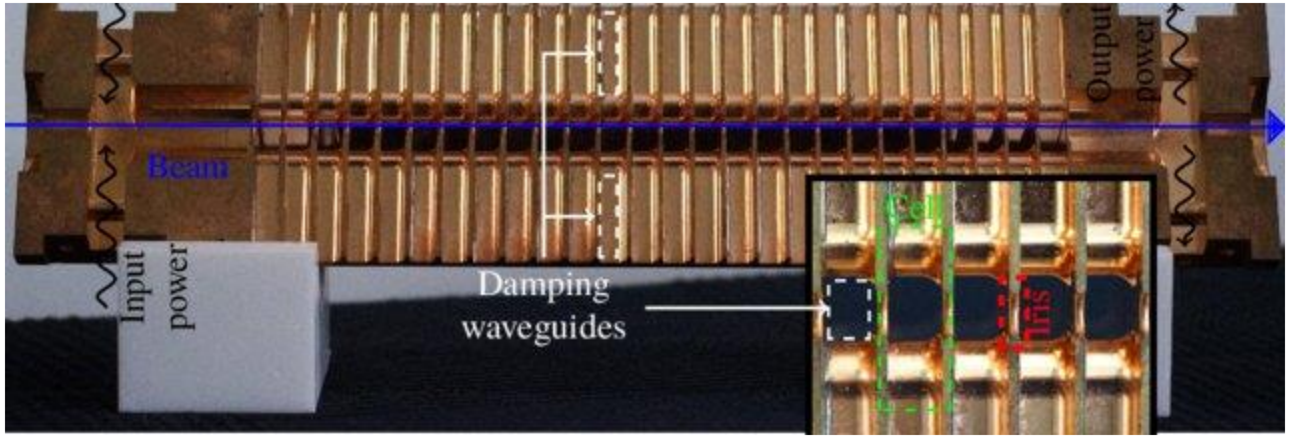
Dielectric structures



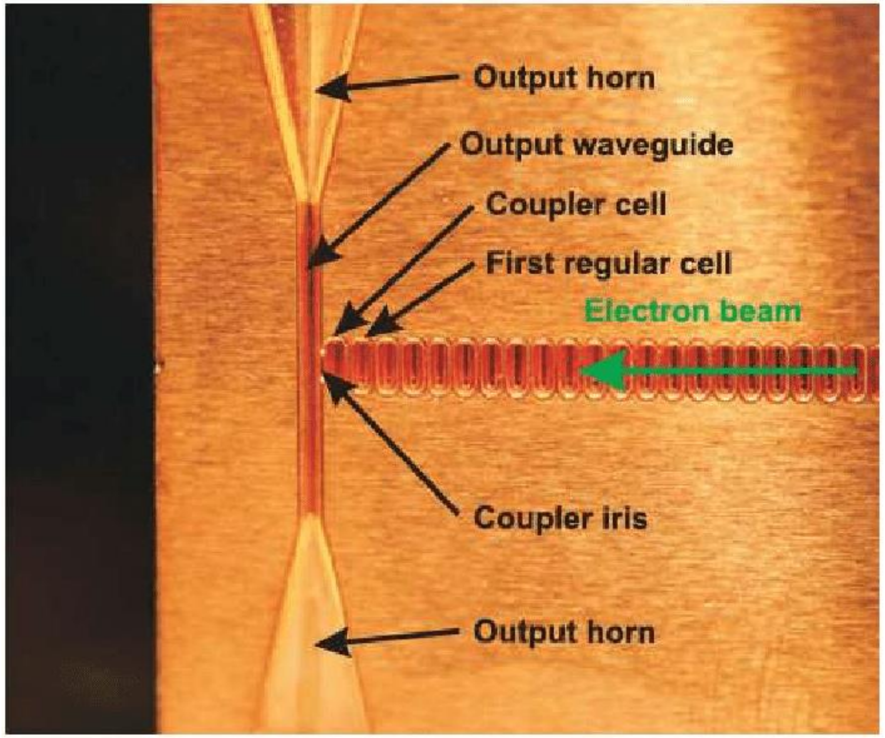
Accelerating gradient – 1.3 GeV/m

Cutaway view with the dielectric (grey) and metal cladding in copper. The beam (dark red) travels along the structure in the vacuum region, leaving an accelerating longitudinal wakefield (colour intensity map, red to blue) [2]

Metallic millimeter wavelength accelerating structures

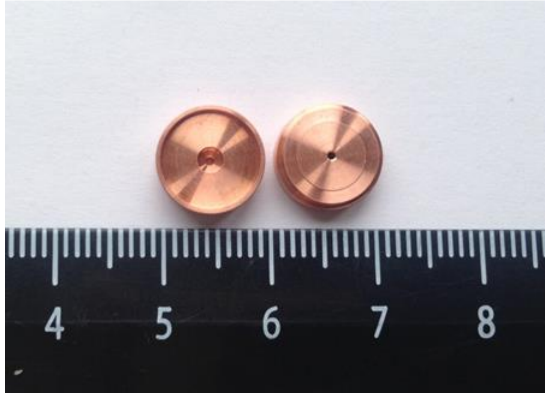


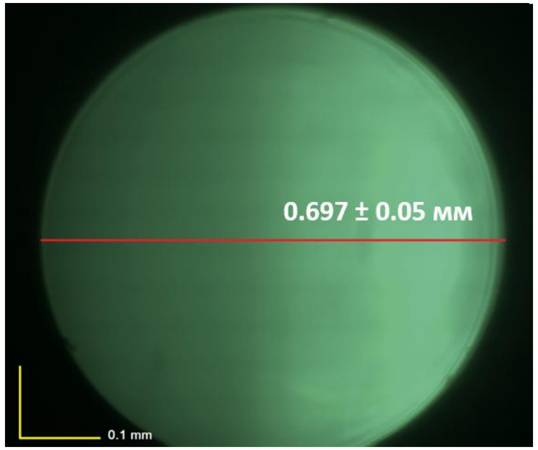
12 GHz accelerating structure for Compact Linear Collider (CLIC), CERN
Accelerating gradient – 100 MeV/m [3]

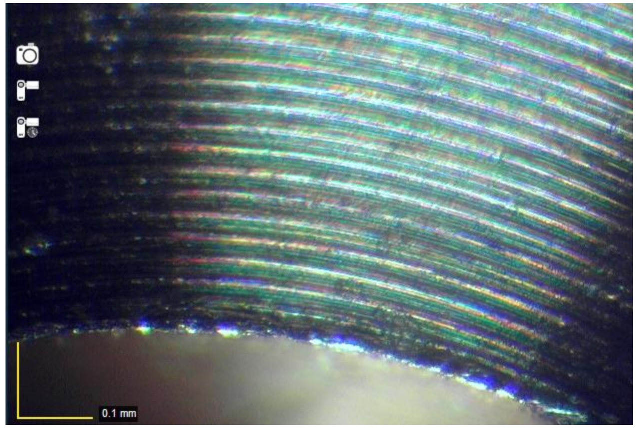


140 GHz accelerating structure at SLAC
Accelerating gradient – 300 MeV/m [4]

Metallic millimeter wavelength accelerating structures at BINP







First prototype at BINP, frequency of 96 GHz
Experimental accelerator gradient will depend on the exiting beam parameters [5]

Conclusion

- Conventional accelerator techniques are close to their limit, there is need in novel accelerator techniques
- Promising advanced concepts (plasma wakefield acceleration, both beam or laser driven): challenge of the usable beam quality
- Metallic millimeter wavelength accelerating structures: limitations related to fabrication tolerances

References

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2. B. D. O'Shea, G. Andonian, S. K. Barber, K. L. Fitzmorris, S. Hakimi, J. Harrison, P. D. Hoang, M. J. Hogan, B. Naranjo, et al., *Observation of acceleration and deceleration in gigaelectron-volt-per-metre gradient dielectric wakefield accelerators*, *Nat Commun* **7**, (2016) 12763.

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5. M. V. Arsentyeva, A. M. Barnyakov, A. E. Levichev and D. A. Nikiforov, Development of the Millimeter-Wave Accelerating Structure, Phys. Part. Nuclei Lett. 16, (2019) 885.