MANCHESTER 1824

The University of Manchester

A flavour of (not an exhaustive list)

Accelerator Technologies for Future Colliders

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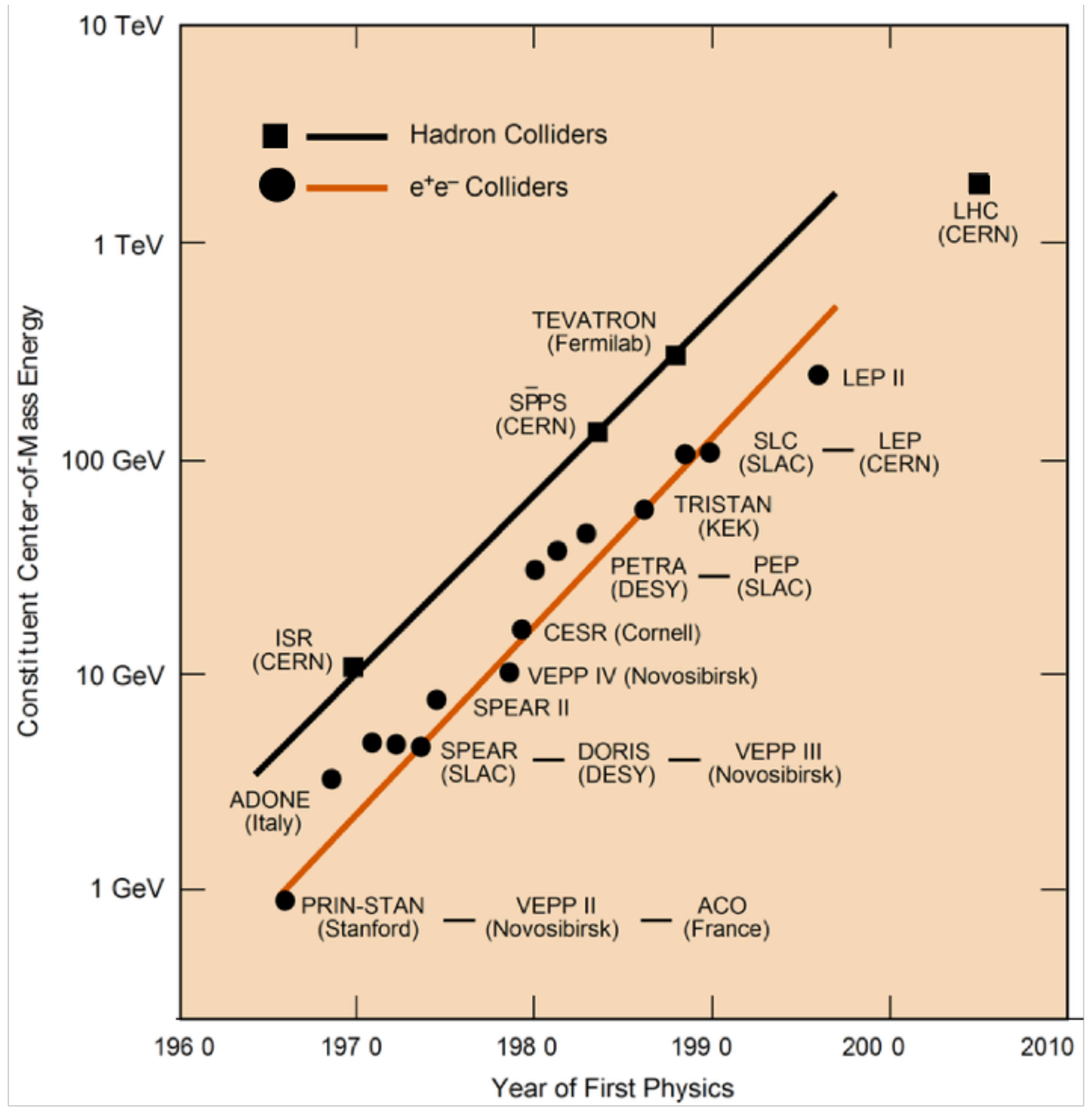
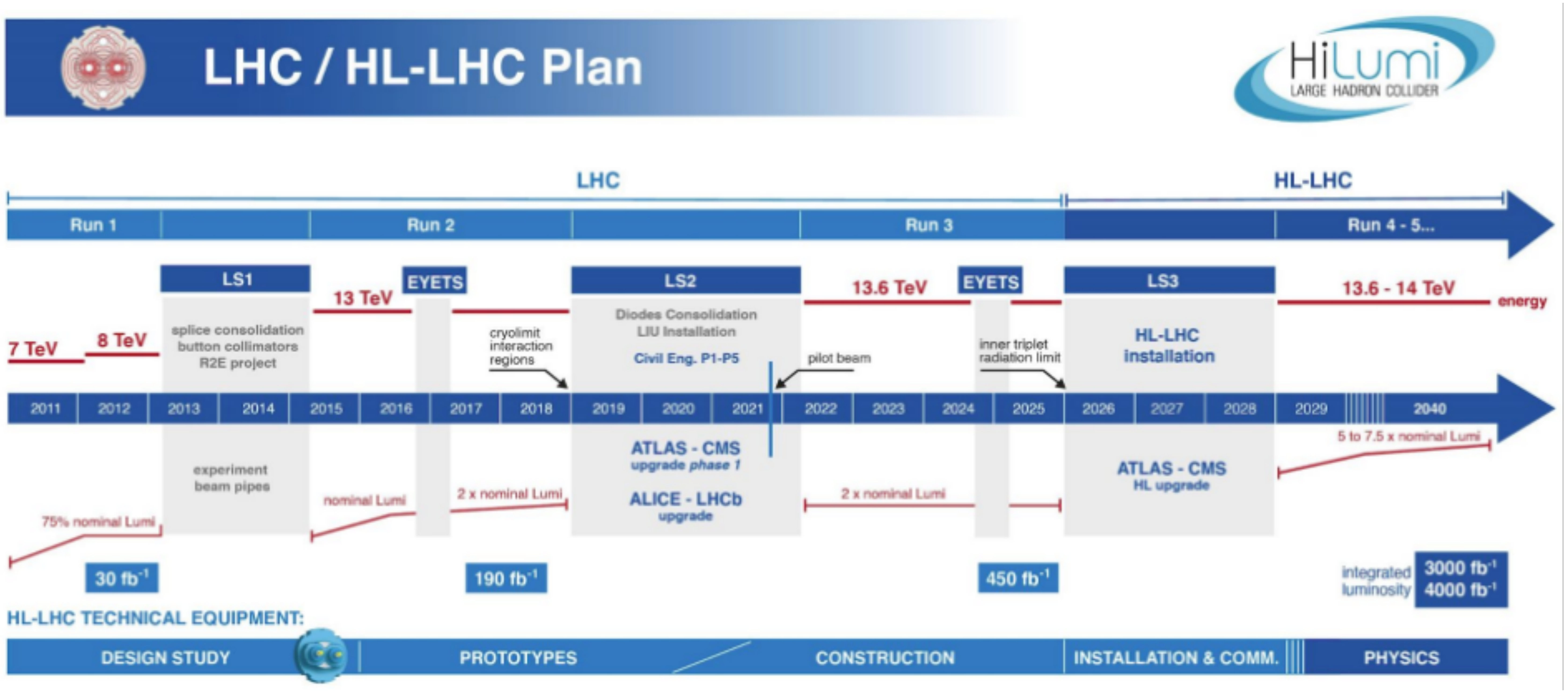
The University of Manchester, Department of Physics and Astronomy

Accelerator Physics Group

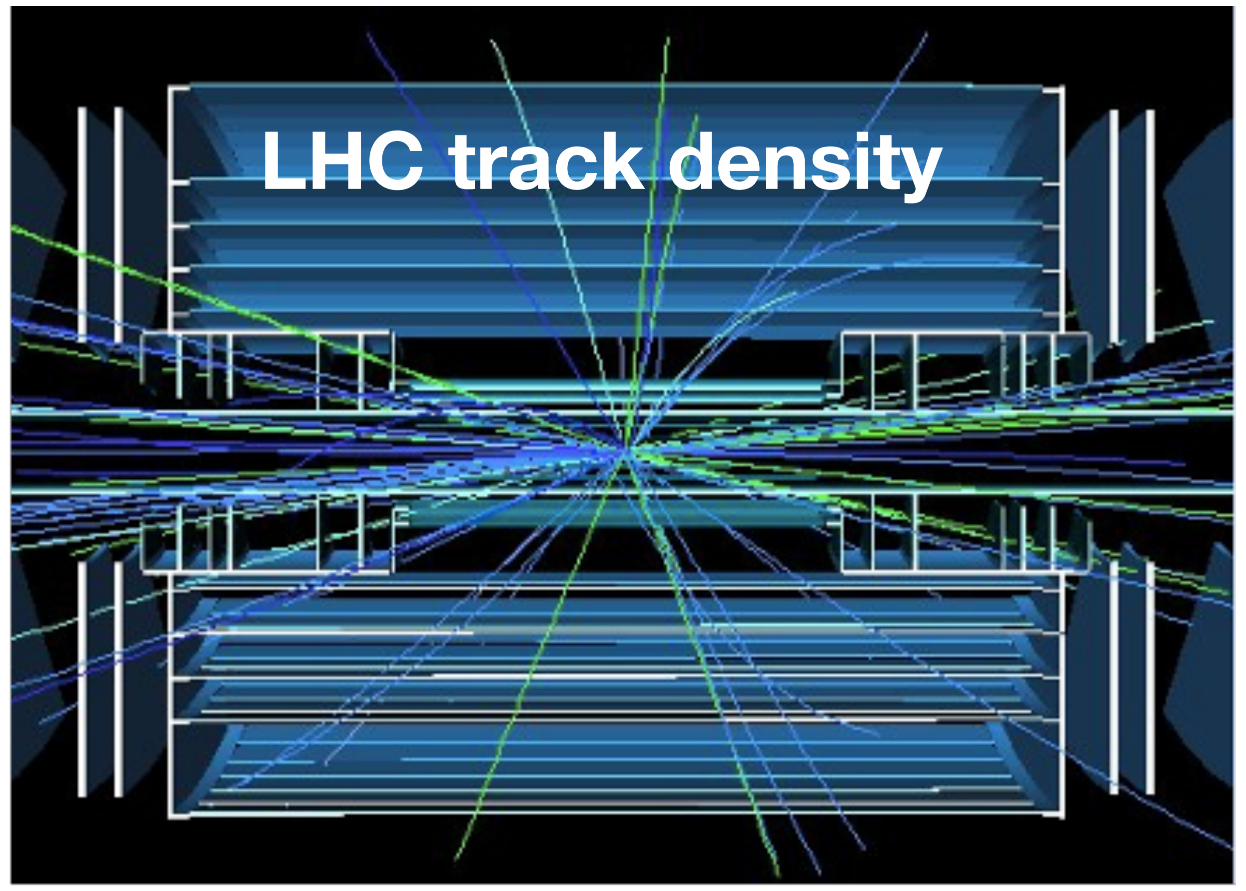
with input from Prof Erik Adli (University of Oslo) and Dr Peter Williams (ASTeC)

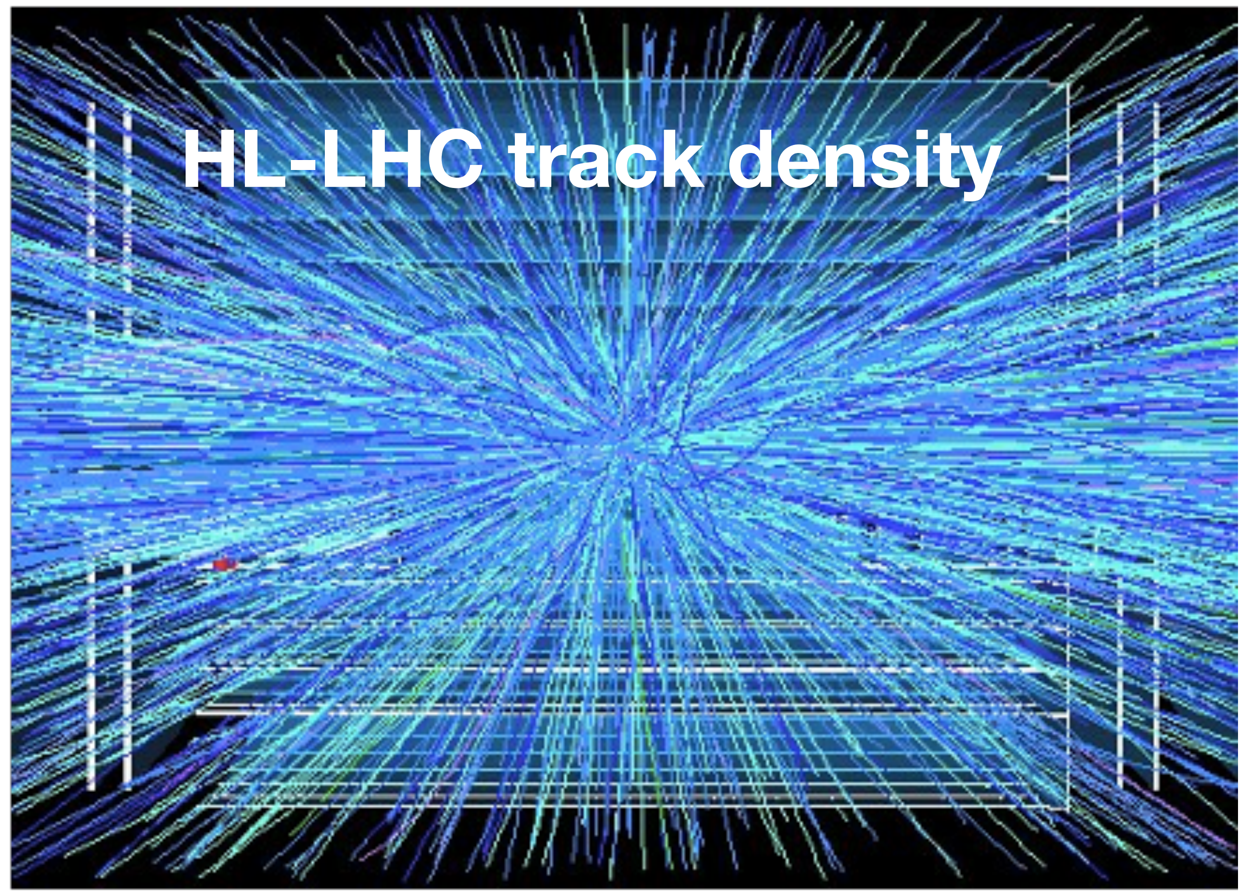
What is imminent?



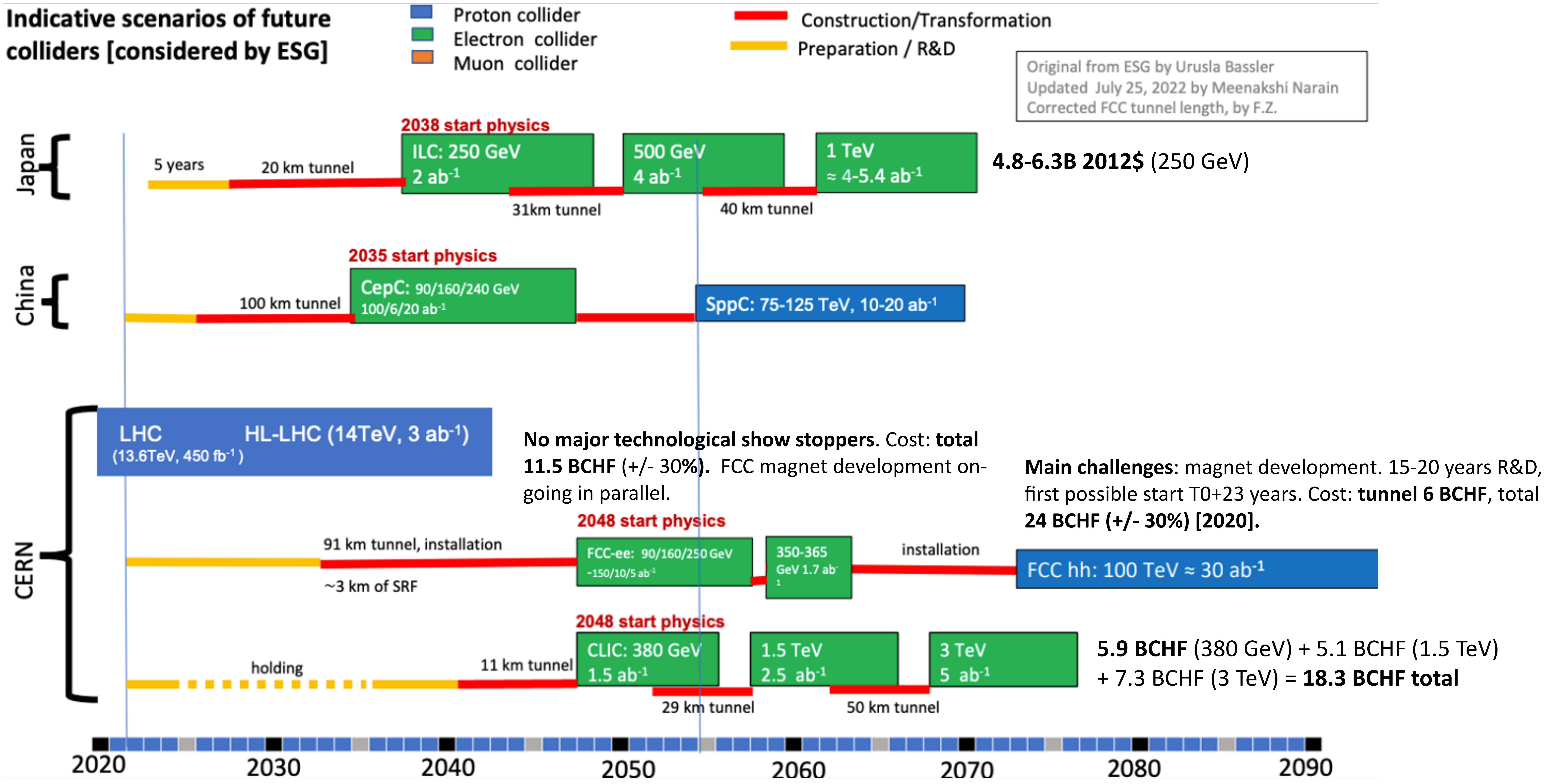


- HL-LHC will provide factor of 5-10 luminosity.
- What's next?





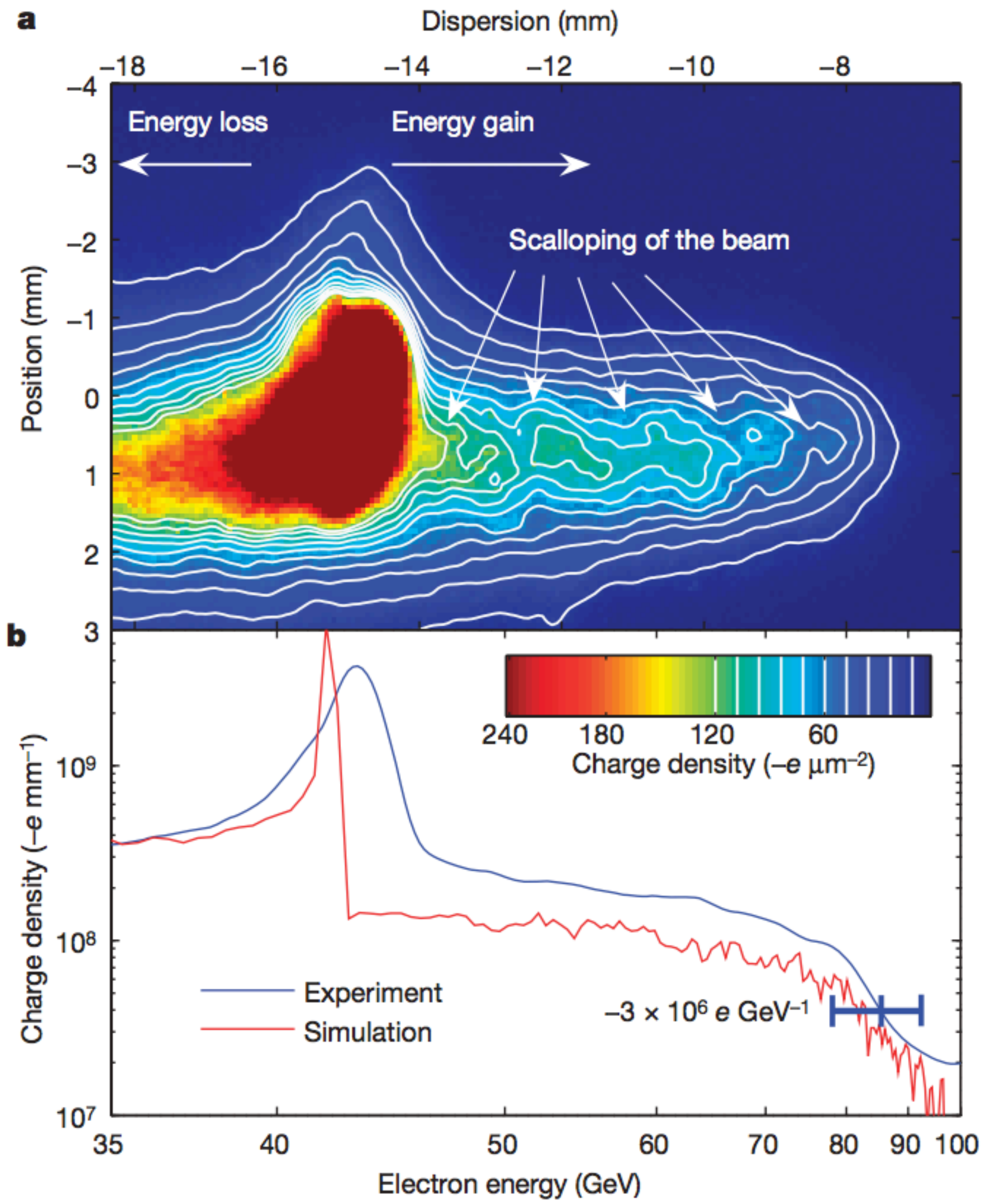
Proposed projects at the energy frontier



From European Strategy Update meetings (2022)

Energy doubling

Driver: 42 GeV **e⁻ beam**

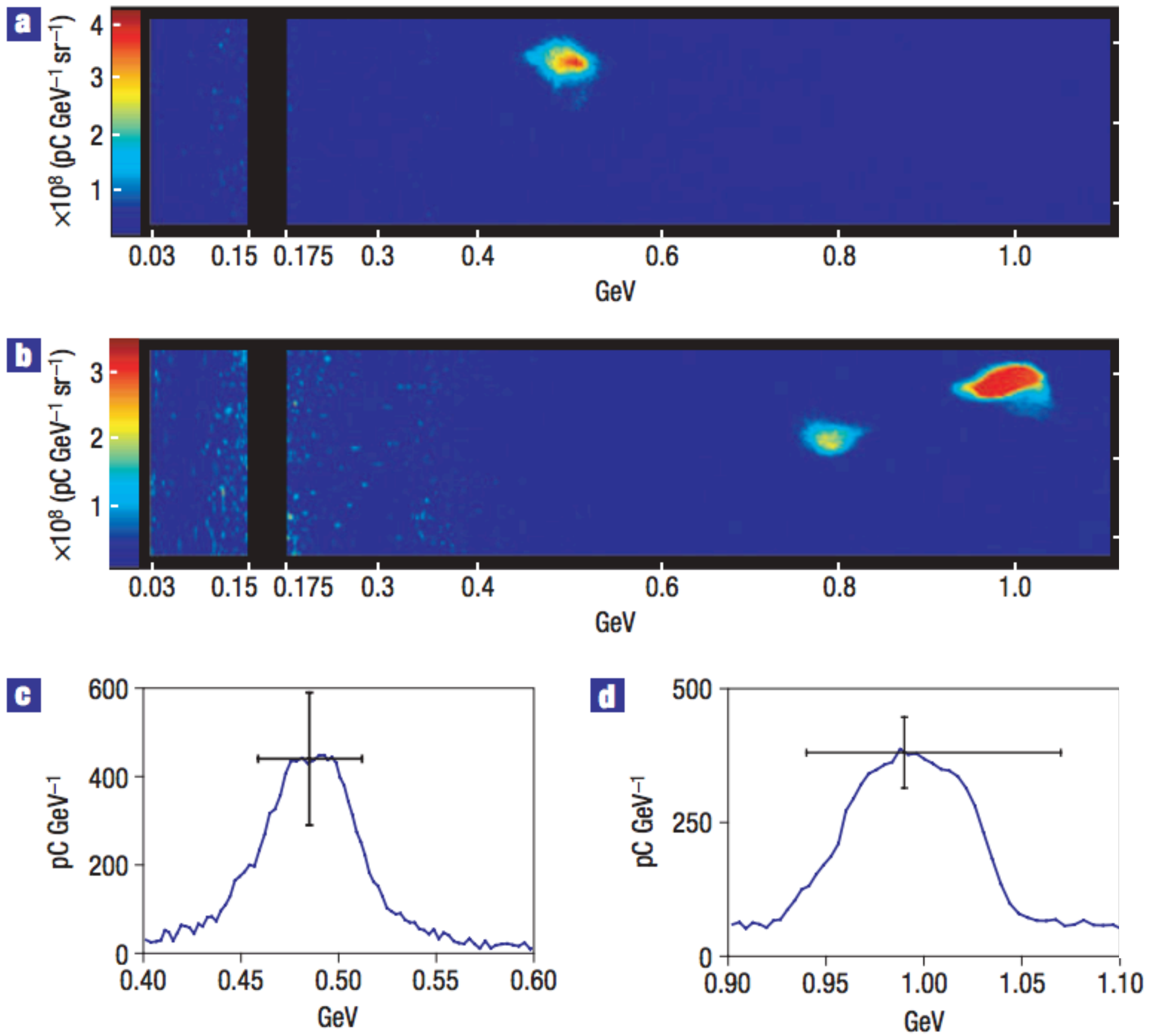


I Blumenfeld et al., Nature 445, 741 (2007)

SLAC

GeV electrons from a cm scale accelerator

Driver: 40TW **laser pulse**

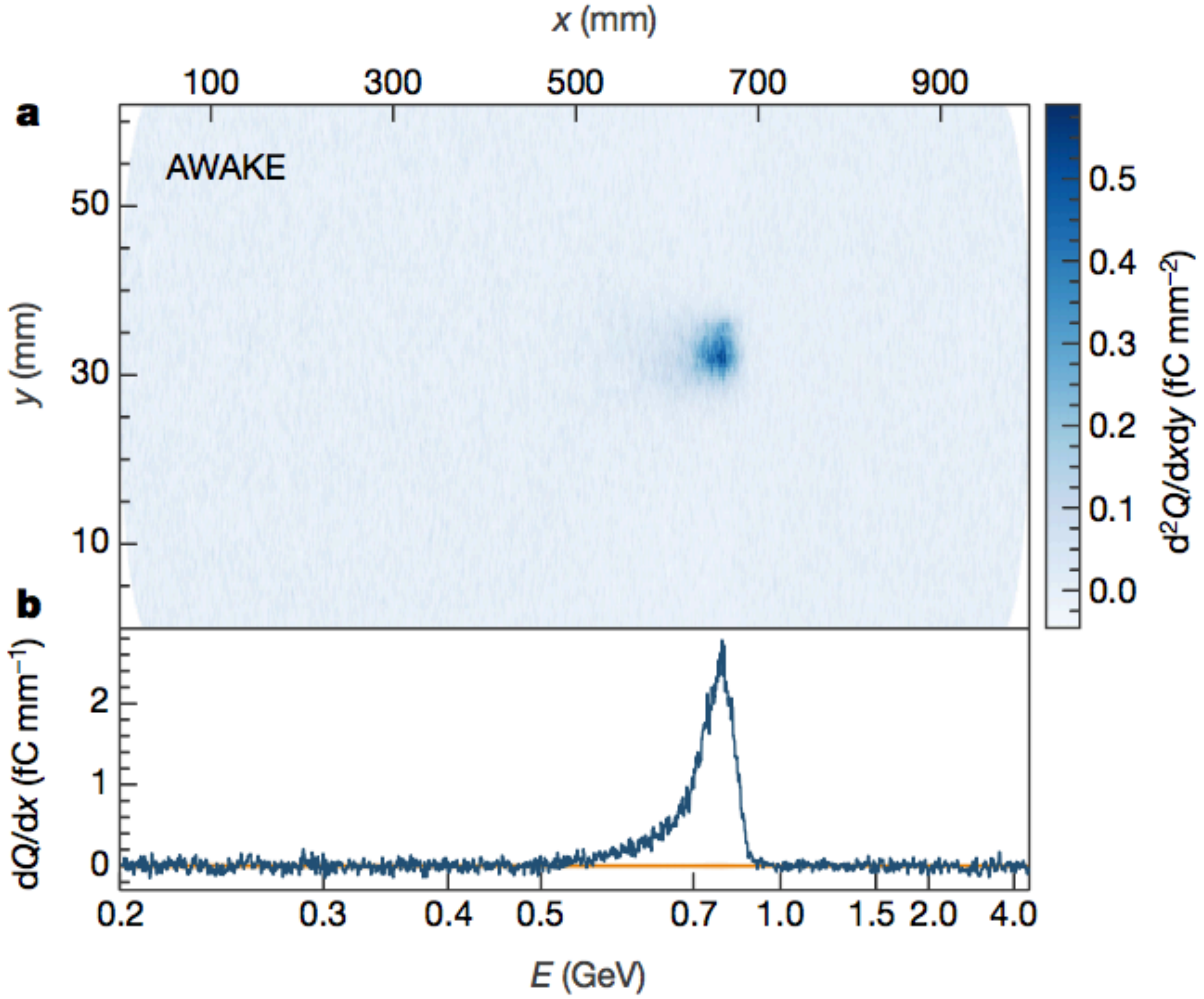


W. P. Leemans et al.,Nature 2, 696 (2006)

BELLA

Acceleration in proton wake

Driver: 400 GeV **p⁺ beam**

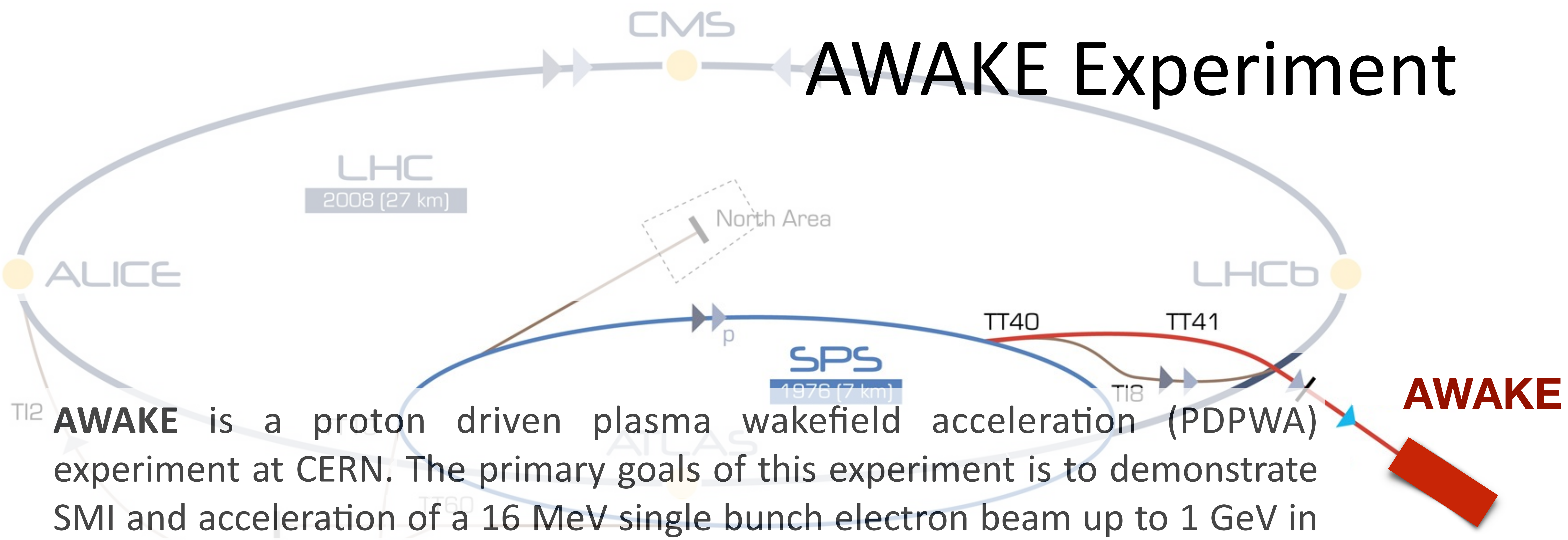


E. Adli, et al., Nature 561, 363 (2018)

CERN

A. J. Gonsalves et al., Phys. Rev. Lett, 122, 084801 ← **8 GeV along ~20 cm**

AWAKE Experiment

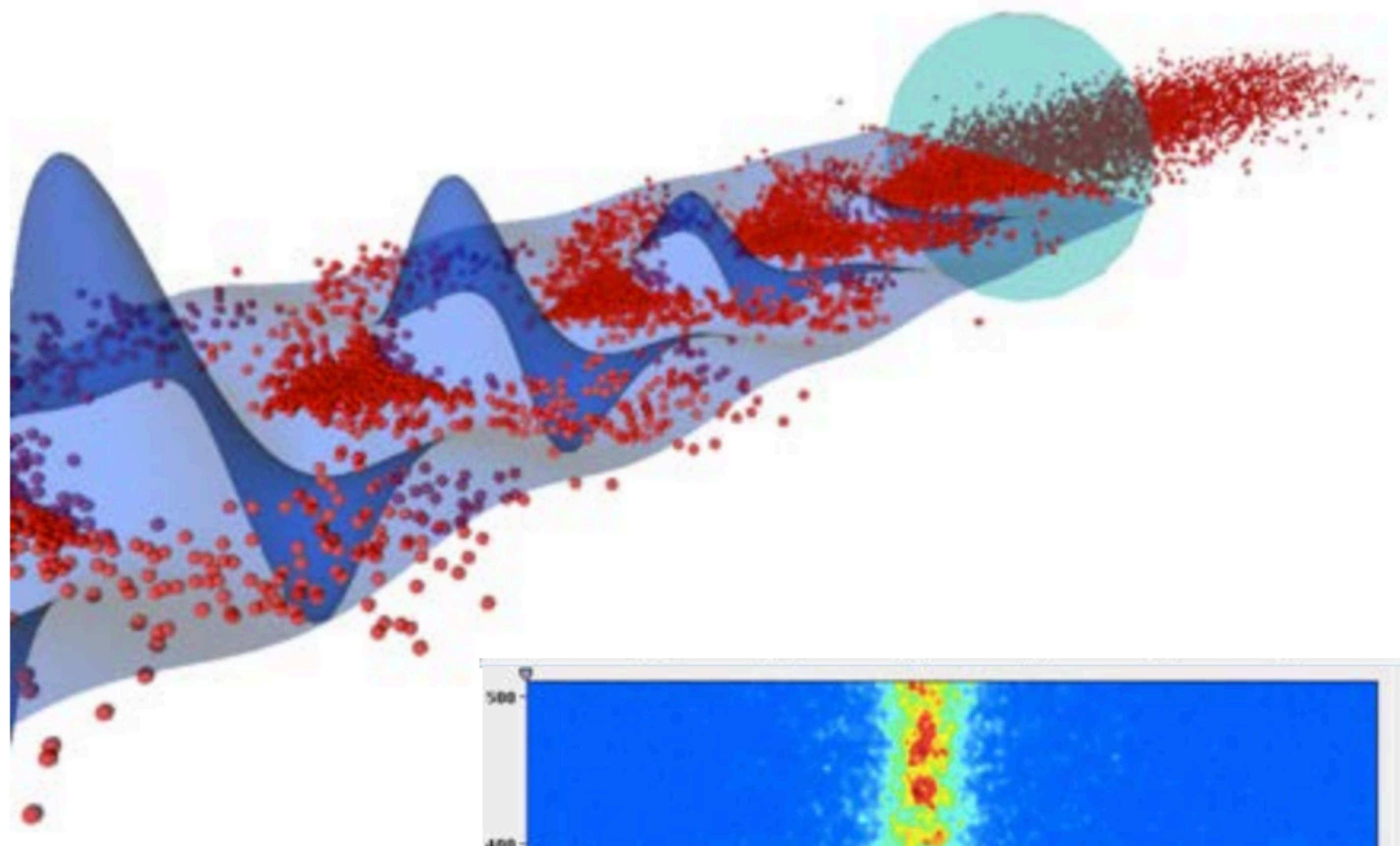


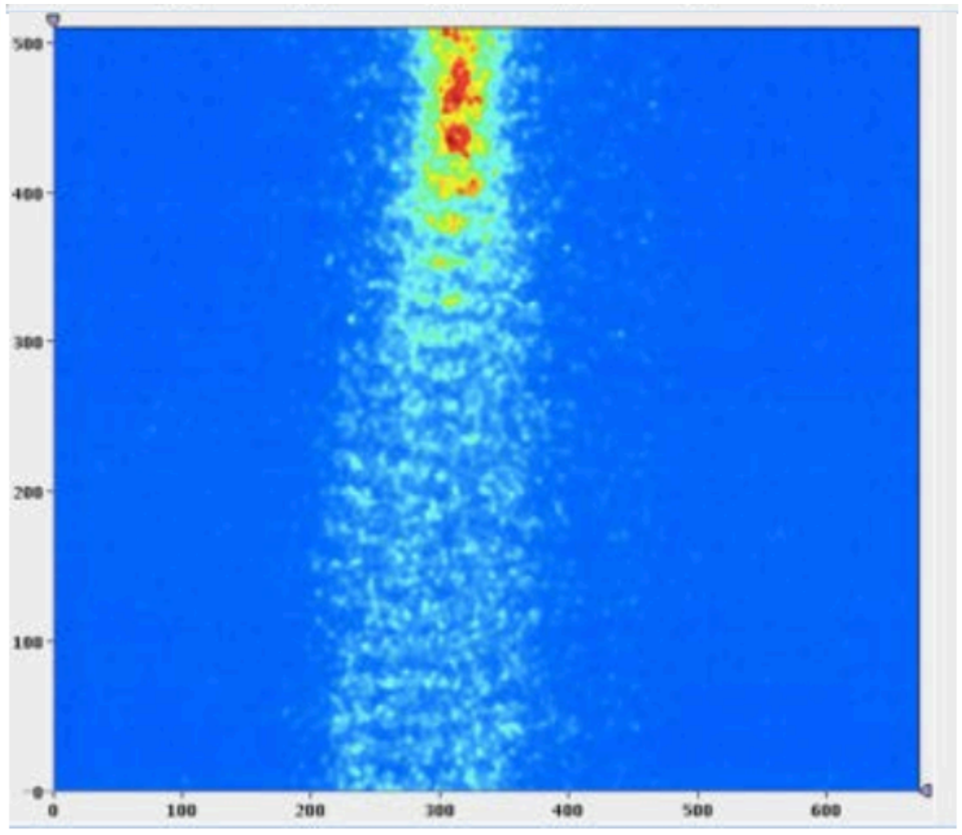
AWAKE is a proton driven plasma wakefield acceleration (PDPWA) experiment at CERN. The primary goals of this experiment is to demonstrate SMI and acceleration of a 16 MeV single bunch electron beam up to 1 GeV in a 10m of plasma driven by SPS protons.

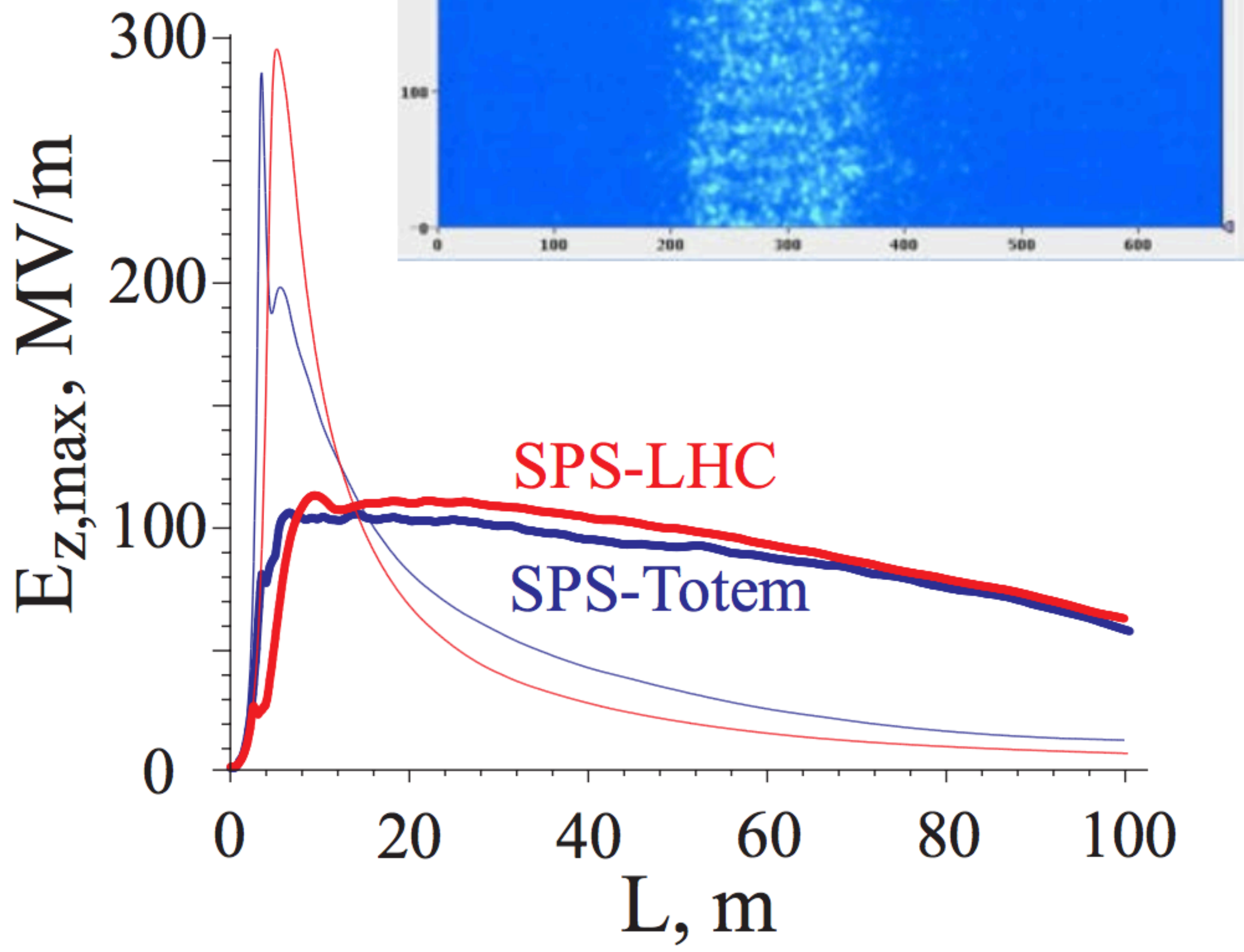
Physics potential:

- fixed target experiments with O(3GeV) electrons: hidden sector like dark photons,
- electron-laser collisions: unmeasured region of strong fields at values of the Schwinger fields,
- ultimately, electron (O(3TeV))-proton (LHC).

Particle physics experiments based on the AWAKE acceleration scheme.
Phil. Trans. R. Soc. A 377: 20180185.
http://dx.doi.org/10.1098/rsta.2018.0185



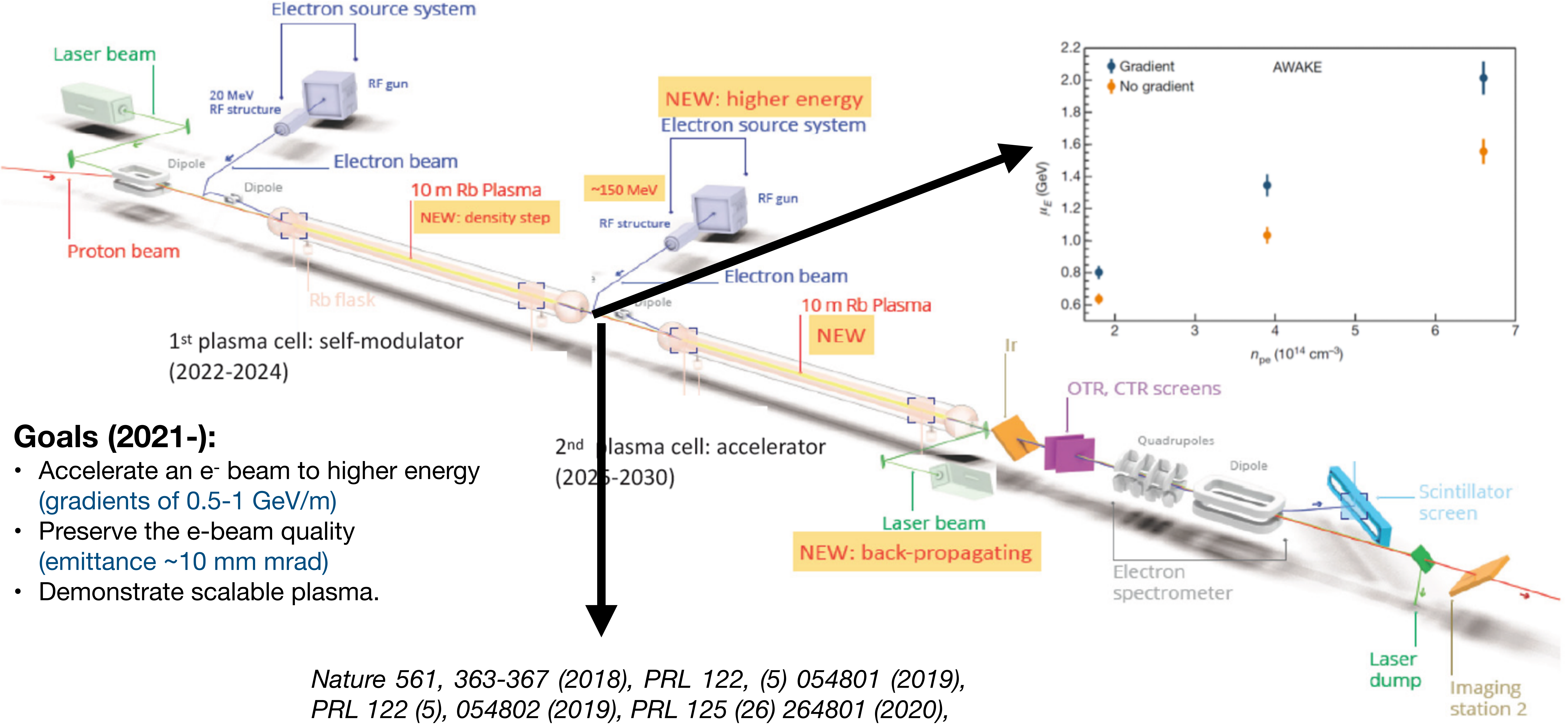




Modulated proton bunch through stepped-up plasma.

A. Caldwell, K. V. Lotov, Physics of Plasmas 18, 103101 (2011).

AWAKE

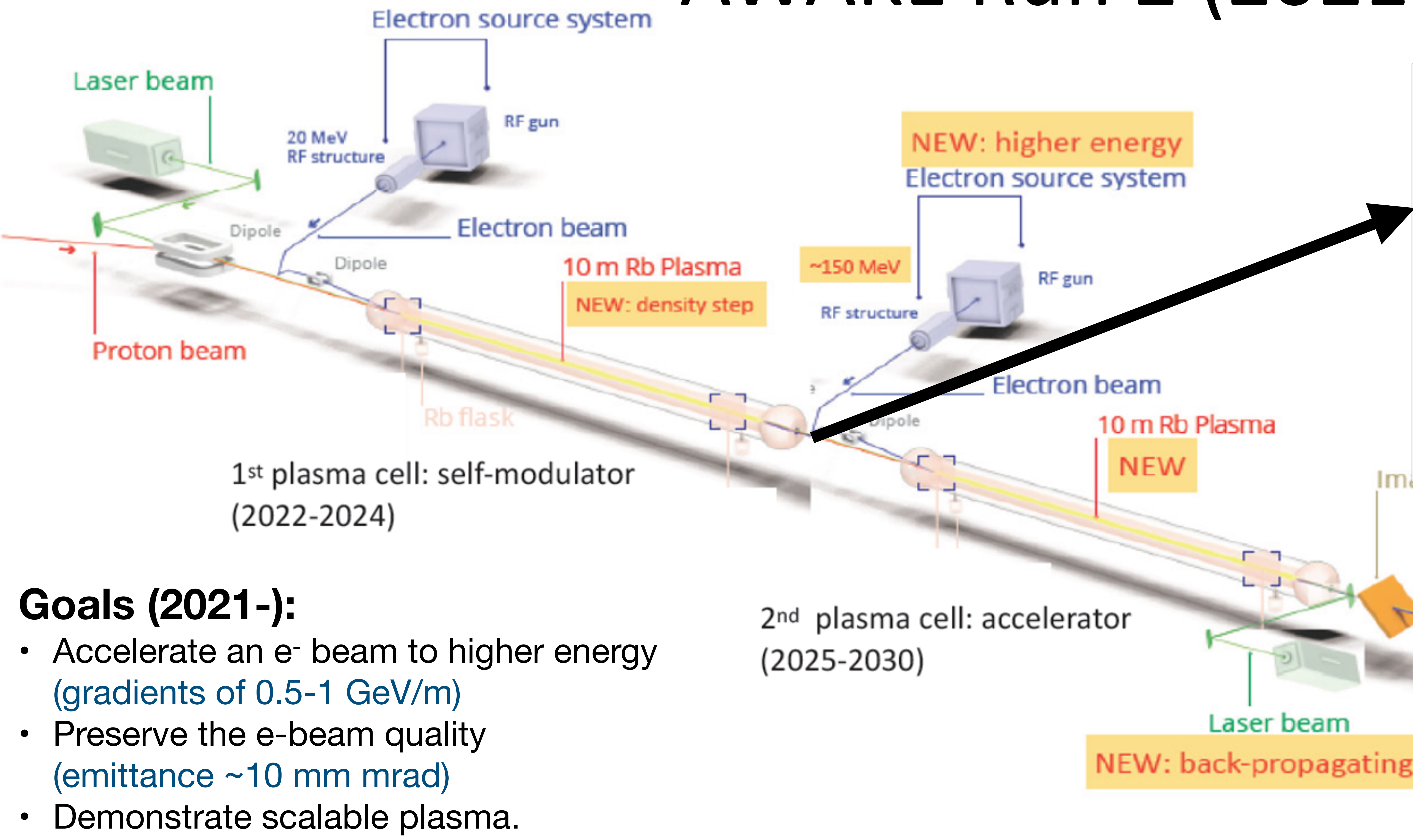


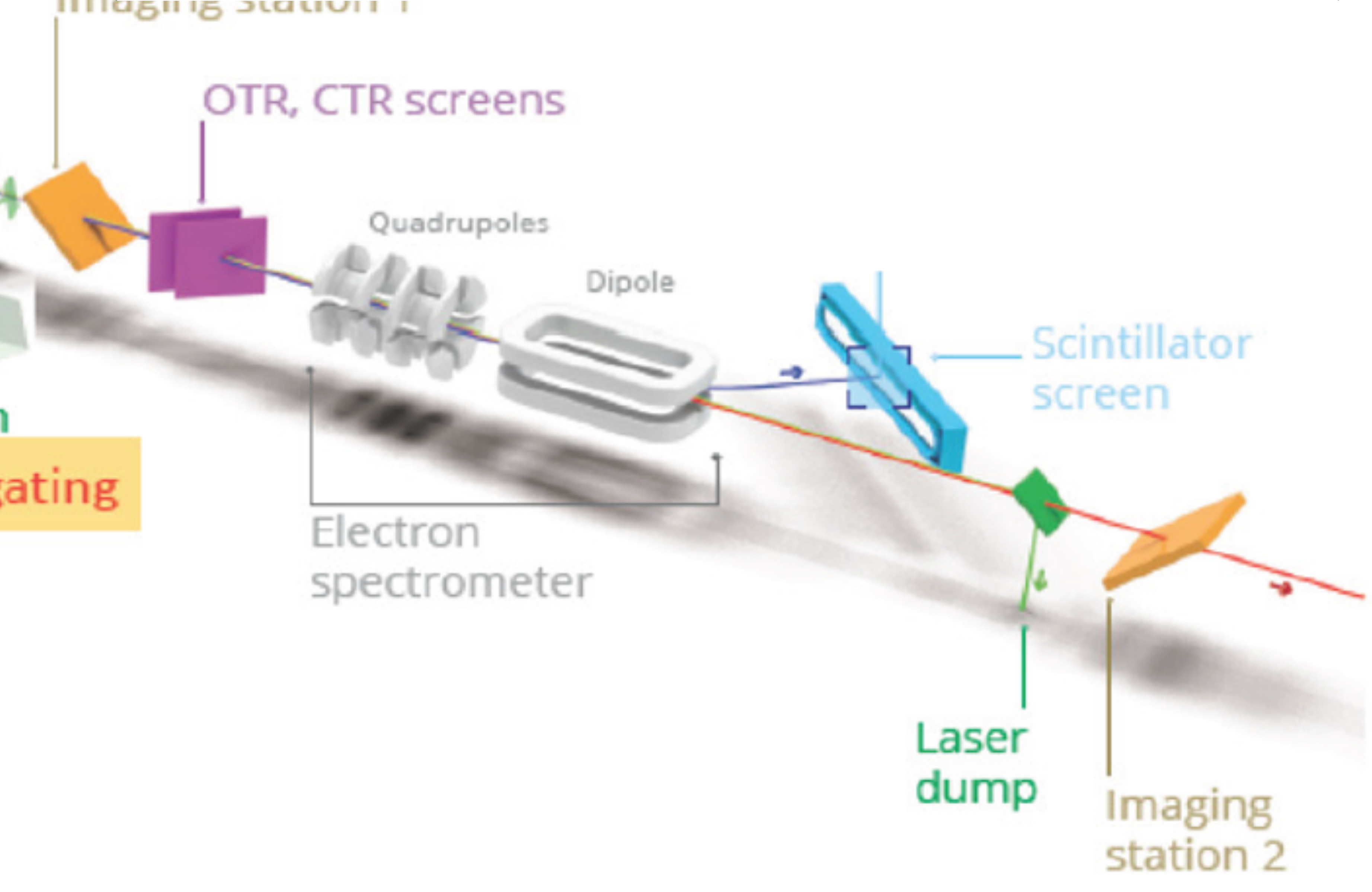
Goals (2021-):

- Accelerate an e^- beam to higher energy (gradients of 0.5-1 GeV/m)
- Preserve the e-beam quality (emittance ~10 mm mrad)
- Demonstrate scalable plasma.

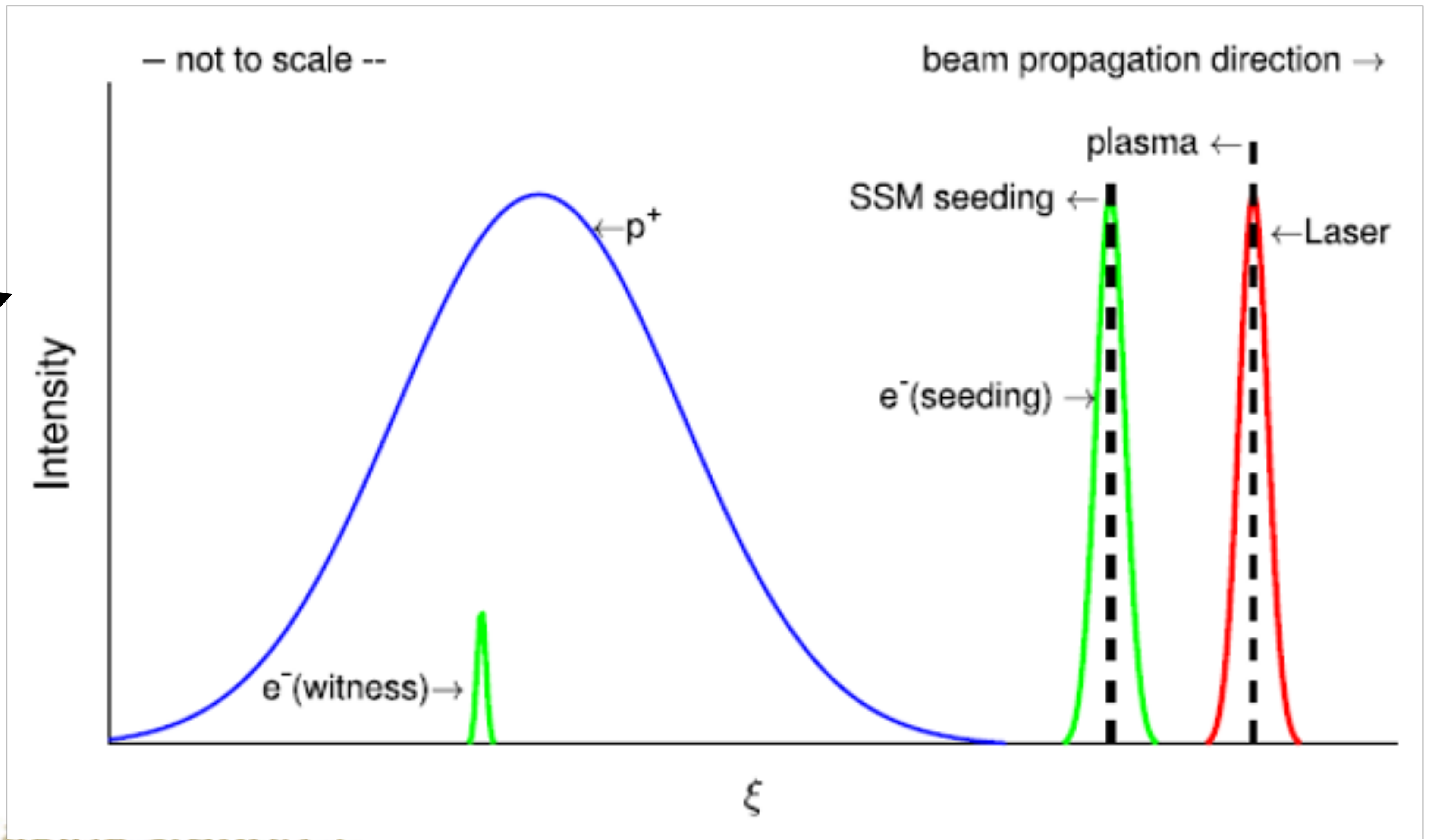
Nature 561, 363-367 (2018), PRL 122, (5) 054801 (2019), PRL 122 (5), 054802 (2019), PRL 125 (26) 264801 (2020), PRL 126 (16) 164802 (2021), PRL 129 (2), 024802 (2022)

AWAKE Run 2 (2021-)





Electron seeded self modulation



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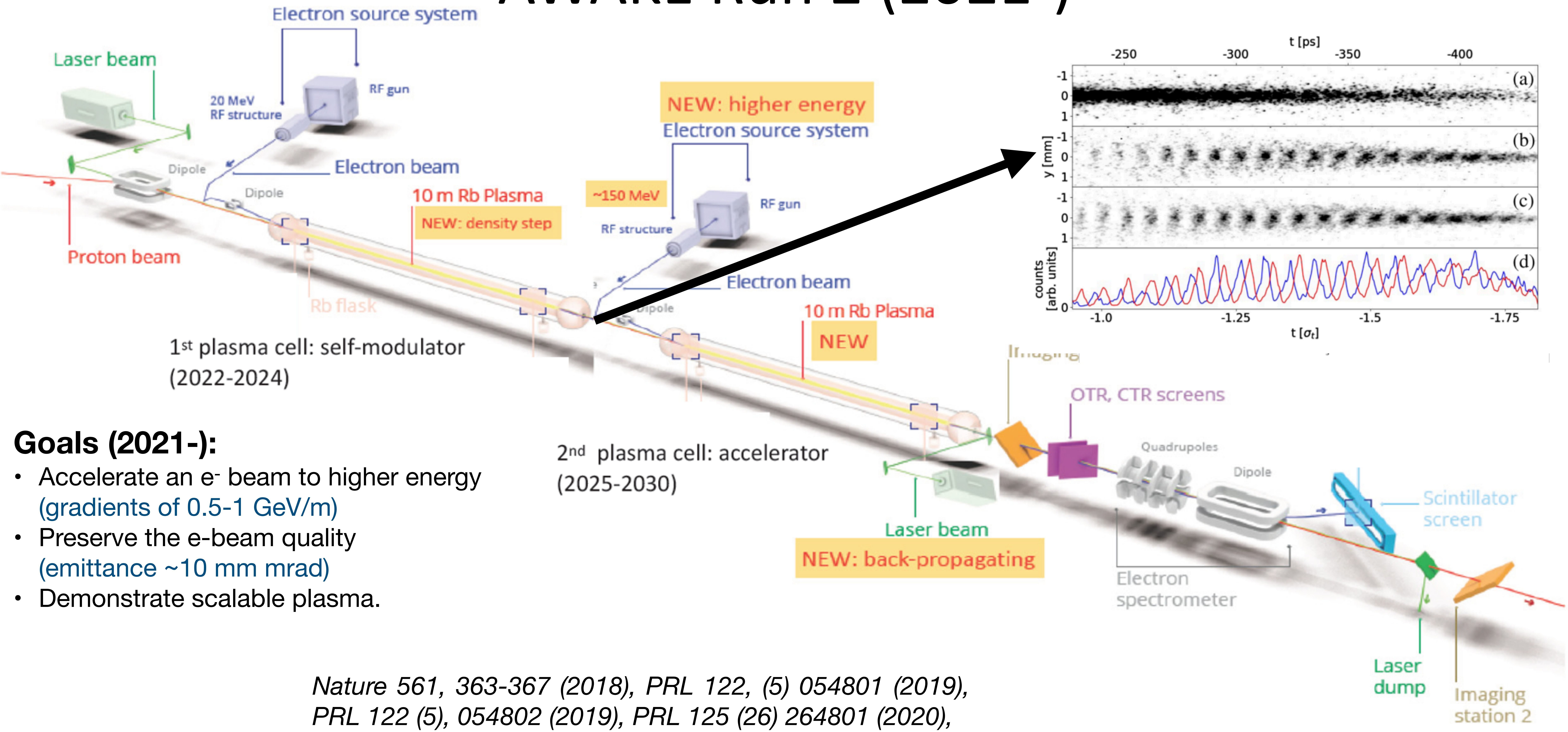

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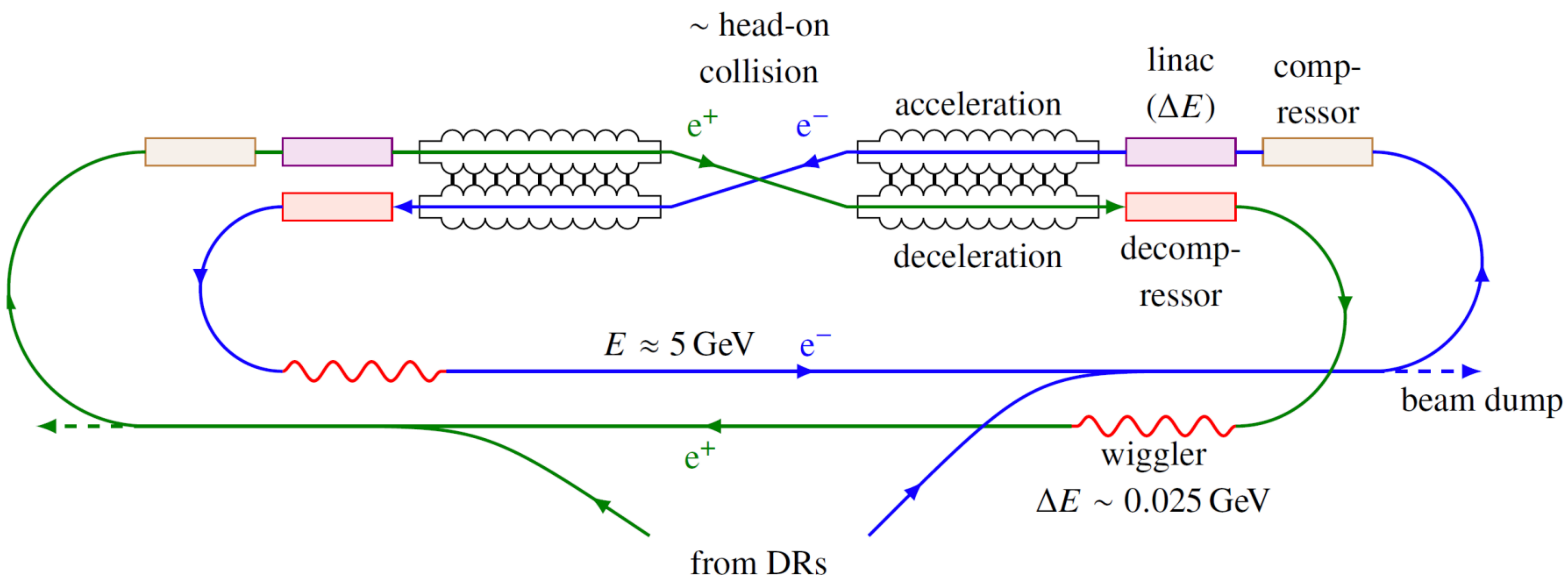
HALHF: Hybrid Asymmetric Linear Higgs Factory

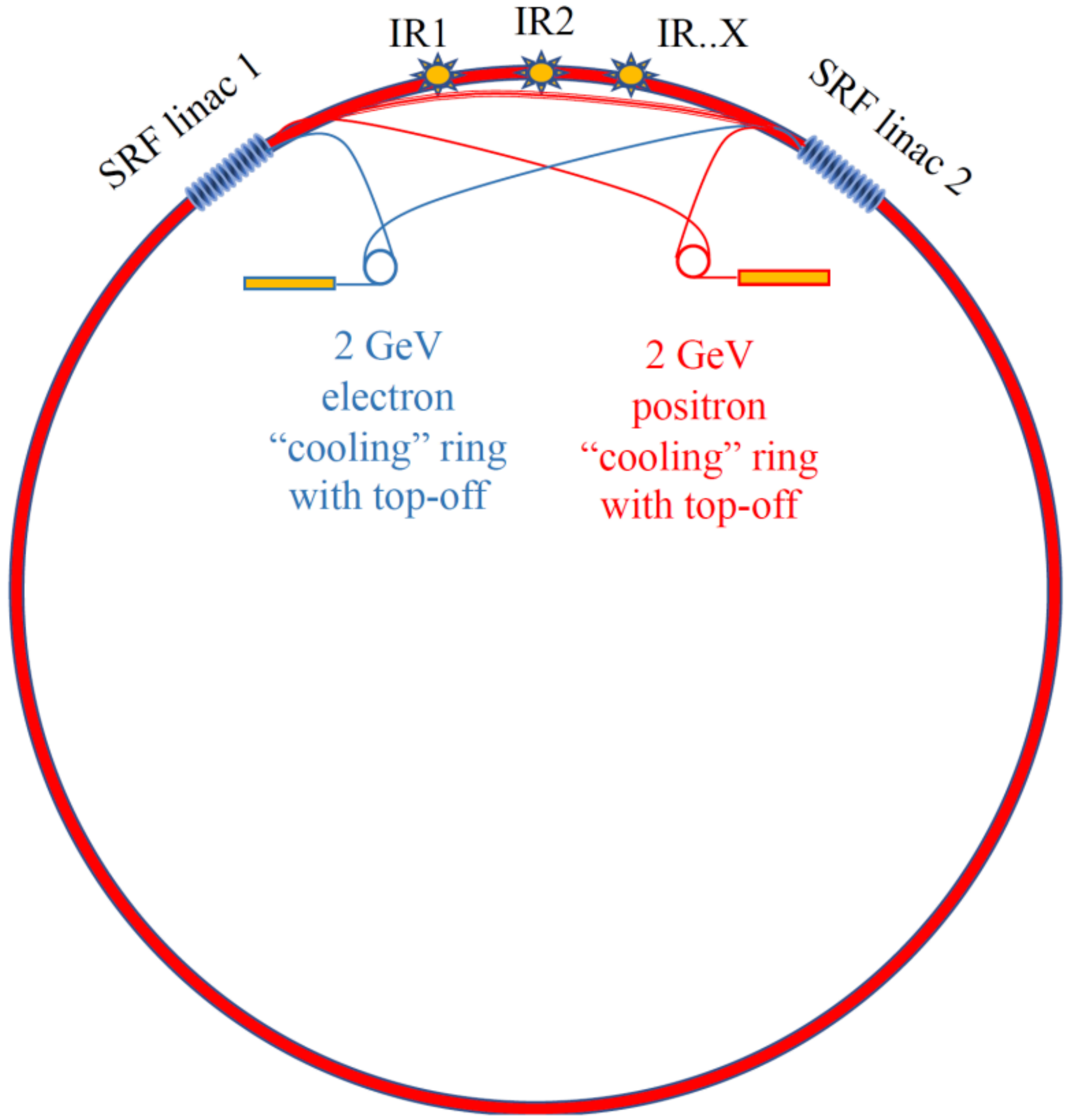
Brian Foster, Richard D'Arcy, **Carl Andreas Lindstrøm**, https://arxiv.org/2303.10150

Energy recovery linacs for future colliders

- ERLs can also be applied to e+e- colliders in addition to e-p colliders (LHeC) and cooling for EIC.
- In particular that achievable luminosities using ERLs can exceed those at FCC-ee, ILC etc by orders of magnitude.
- Please see, https://www.ipac23.org/preproc/author/peter-williams-cockcroft-institute/index.html, for details.



ERLC: A re-imagining of the ILC as an ERL.



CERC: A re-imagining of FCC-ee as an ERL.

P.S. I haven’t included the status with the muon colliders.
See the talk from Monica tomorrow.

Thanks for your attention.

Next collider: Higgs factory

- Community (through Snowmass and Alegro processes) agrees that the next collider should be a **Higgs factory** e^+e^- collider with 250-380 GeV centre of mass energy. Advantages of an e^+e^- collider

  - **Cleanliness**, reduced detector background with respect to hadron collisions through improved momentum and energy resolution.

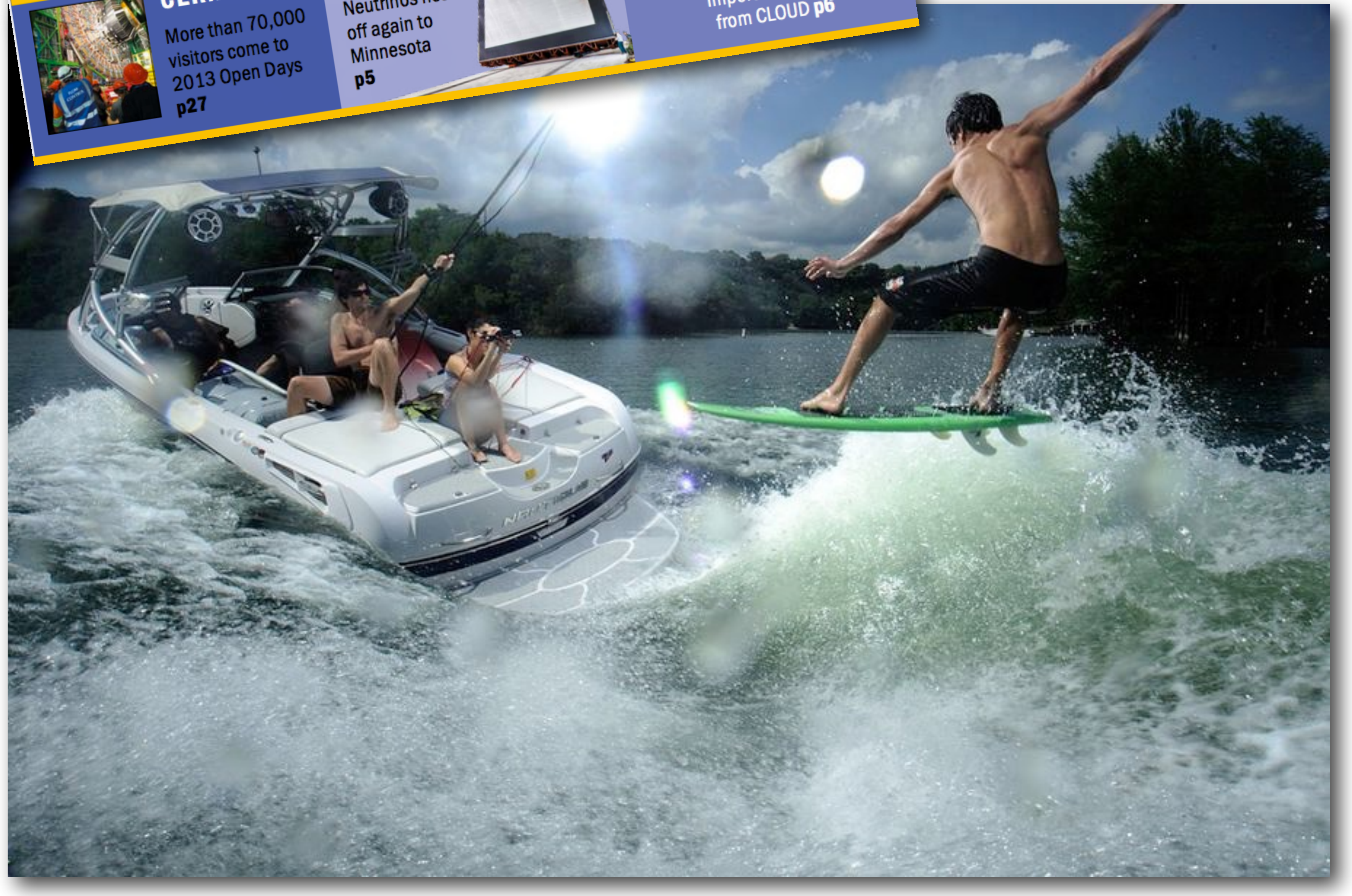
  - **Democracy**, e^+e^- annihilation produces pairs of all species at similar rates. Unlike LHC, can measure absolute branching ratios and total width.

  - **Calculability**, radioactive corrections are more precise for EW interactions (LC) than QCD interactions (LHC).

  - **Detail**, Reconstruction of complete events, direct measurement of spin-dependence of production and decay processes possible.

Plasma Wakefield Acceleration

- Driven by high-power lasers or particle beams, plasmas can generate very large amplitude wakefields - orders of magnitude larger than the state-of-art metallic cavities.
  - Plasma consists of ions and electrons
  - Driven by a laser pulse, plasma electrons oscillate under ponderomotive force
  - Driven by a particle beam, plasma electrons oscillate due to Coulomb force
- A charged particle beam can ride these wakefields to gain energy.



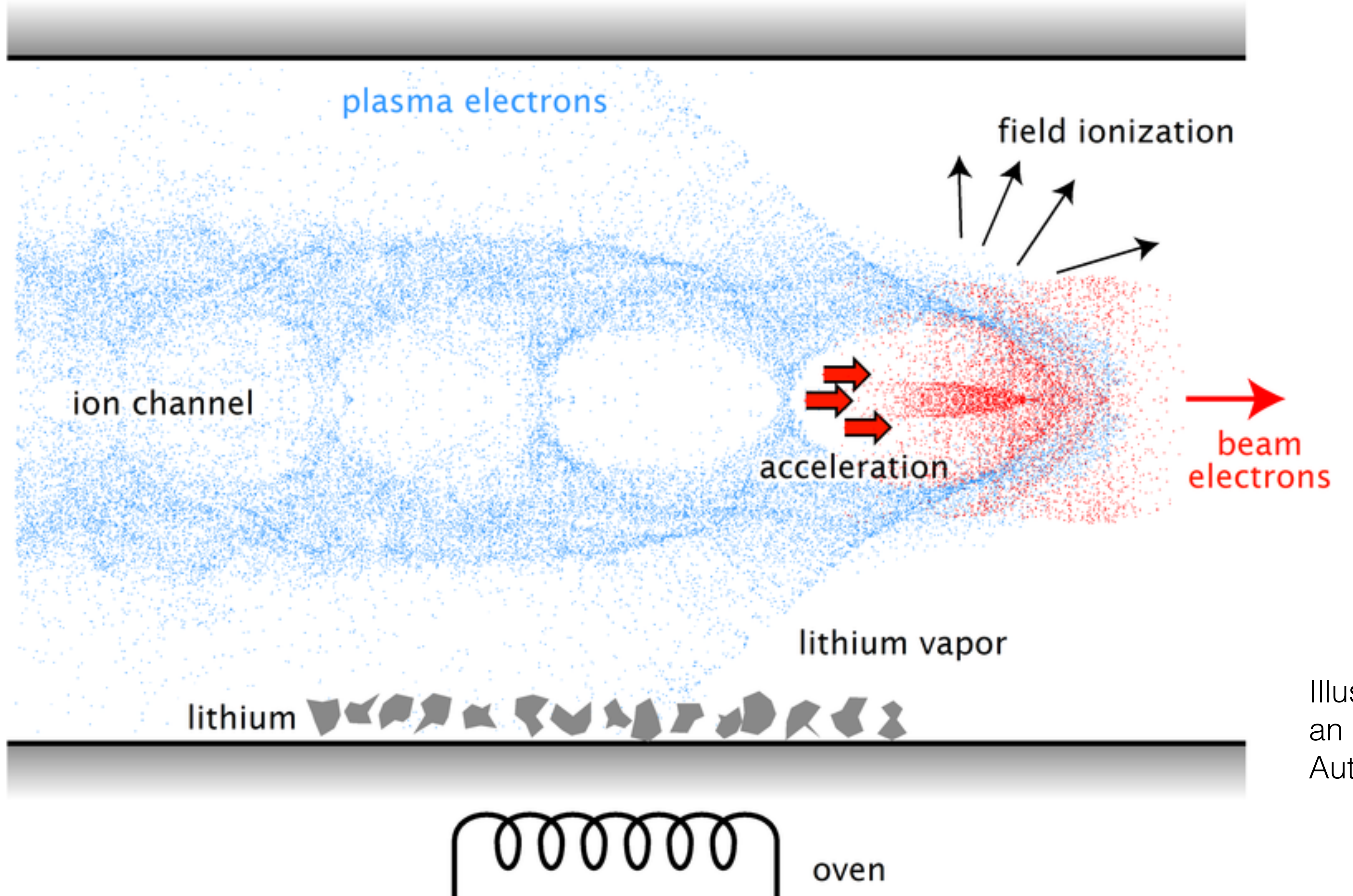
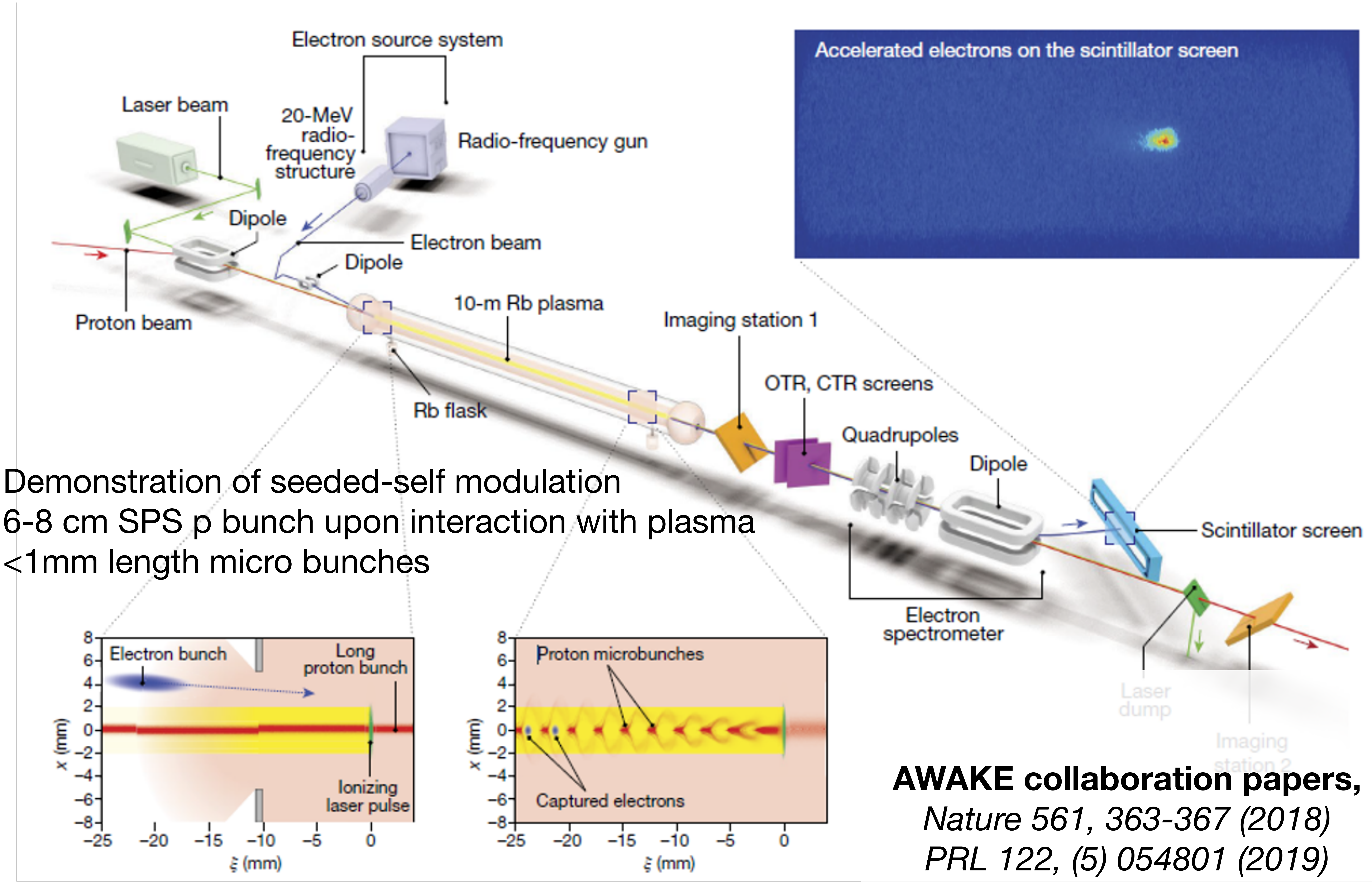


Illustration of the wake created by an electron beam in a plasma. Author: Rasmus Ischebeck.

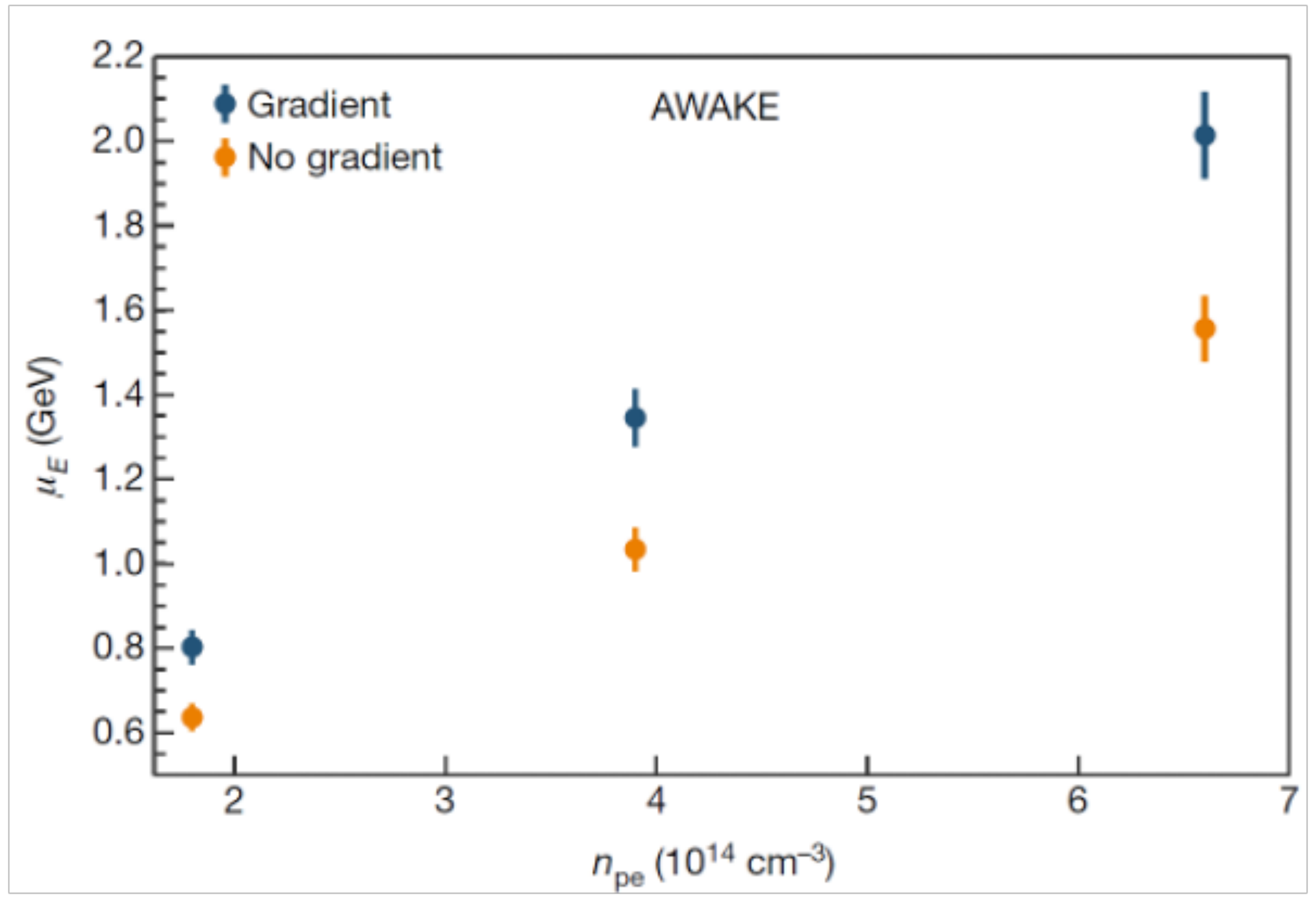
AWAKE Run 1 (2016-2018)



- Demonstration of seeded-self modulation
- 6-8 cm SPS p bunch upon interaction with plasma
- <1mm length micro bunches

AWAKE collaboration papers,
Nature 561, 363-367 (2018)
PRL 122, (5) 054801 (2019)
PRL 122 (5), 054802 (2019)
PRL 125 (26) 264801 (2020)
PRL 126 (16) 164802 (2021)

Witness e-beam energy gain



- Acceleration from 20 MeV to 2.0±0.1 GeV was achieved
- with a plasma density of 6.6 x 10^{14} cm^{-3} over 10 m.
- Avg. acceleration gradient ~200 MV/m.