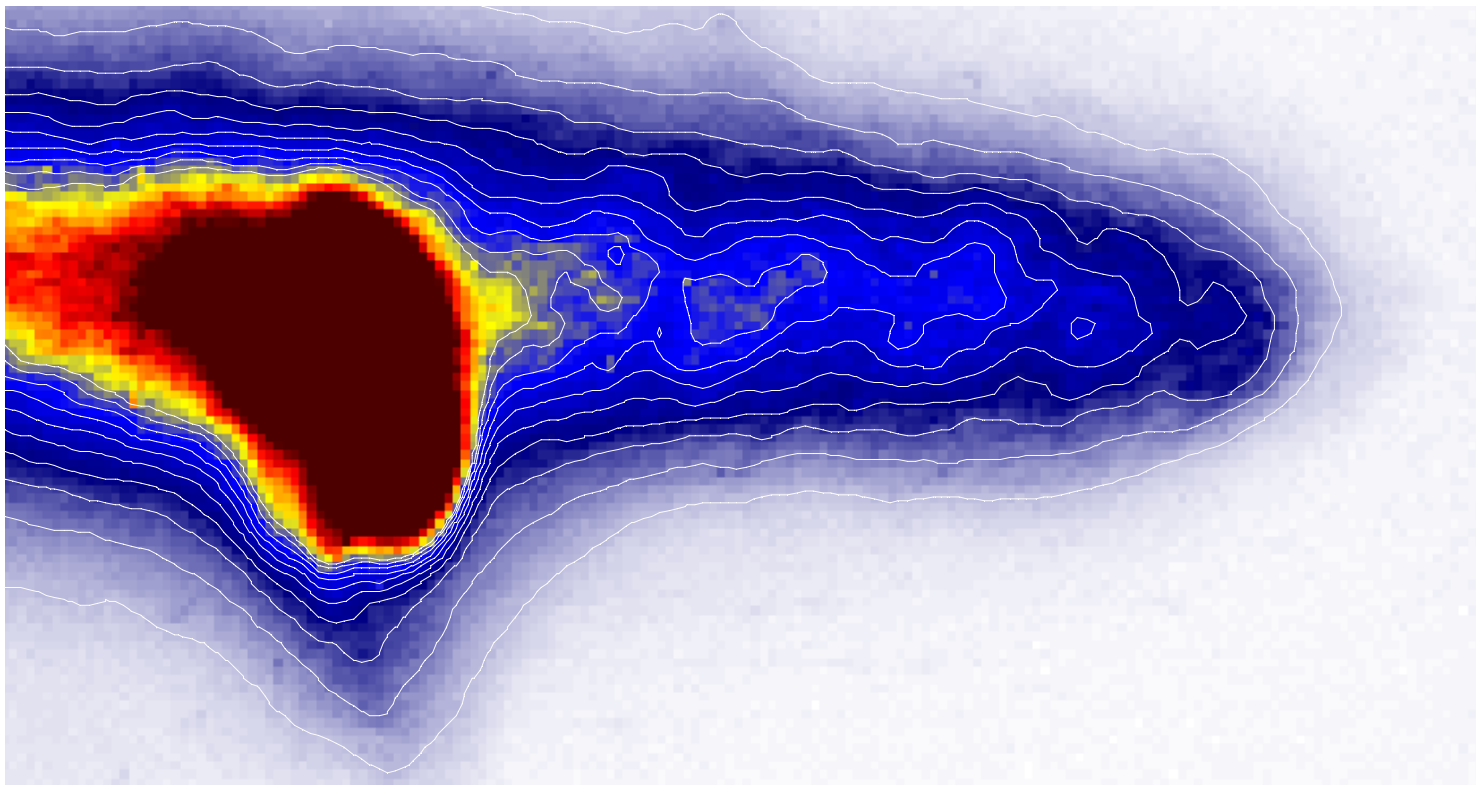
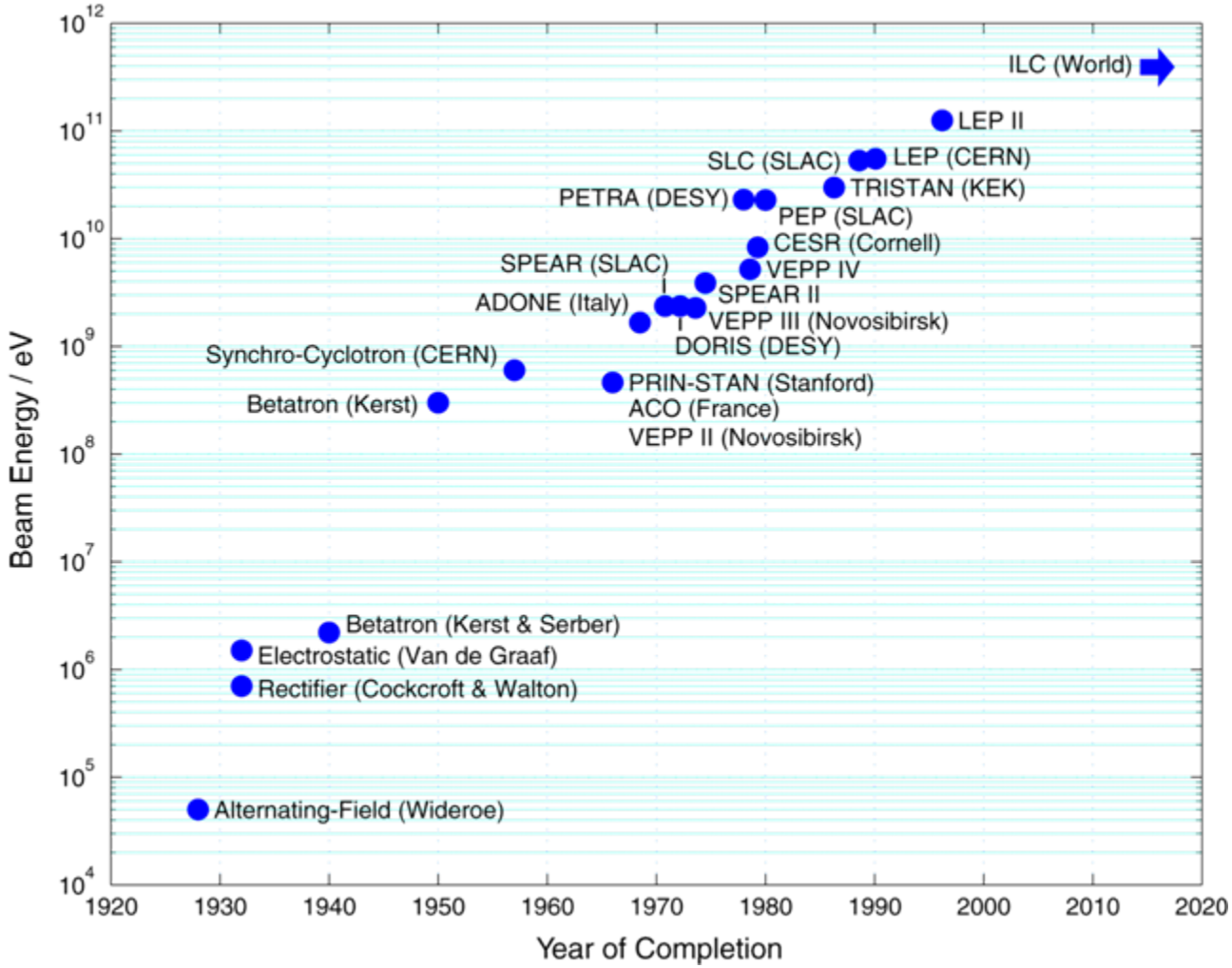
Energy Doubling of 42 GeV Electrons

Rasmus Ischebeck, for the E-167 Collaboration



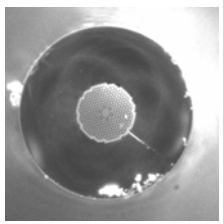
Evolution of Electron Accelerators (Livingston Plot)



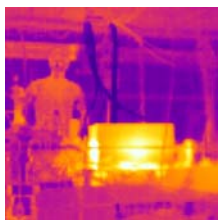
Advanced Accelerator Technologies

- In conventional accelerators, the accelerating fields are limited by the damage threshold of the cavities
  - 20 MV/m (SLAC Linac)
  - 35 MV/m (ILC)
- Options for higher damage thresholds:

  - RF structures at higher frequencies
    - about 300 MV/m



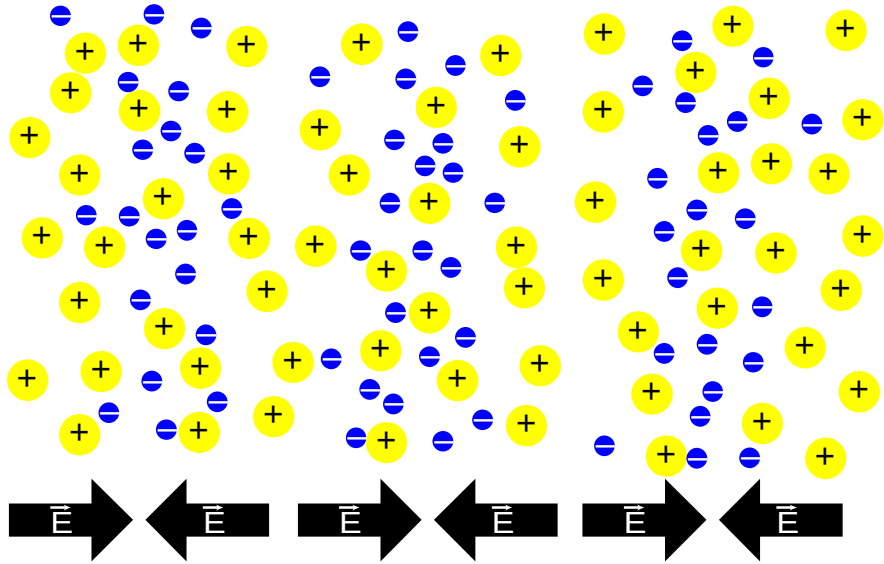
  - Dielectric structures at optical frequencies
    - about 1 GV/m



  - Plasma-based accelerators
    - about 50 GV/m

Plasma Wakes – Theory

- Unlike electromagnetic waves in vacuum, plasma wakes can have a longitudinal electric field



- Linear plasma wake:

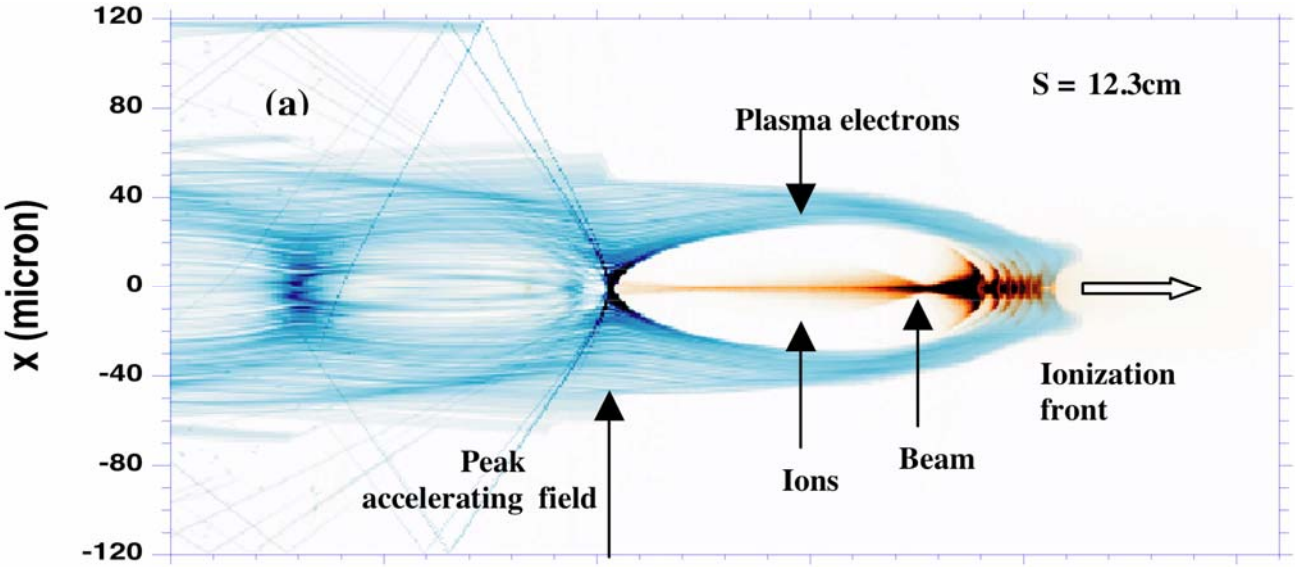
$$\lambda_p \approx \sqrt{\frac{10^{15}\mathrm{cm}^{-3}}{n_p}} \quad \mathrm{mm}$$

  - Limit:

$$E_0 = \frac{4\pi\,\varepsilon_0\,c\,m_e}{e}\,\omega_p \quad \approx \sqrt{\frac{n_p}{\mathrm{cm}^{-3}}} \quad \frac{\mathrm{V}}{\mathrm{cm}}$$

Plasma Wakes – Theory

- Above this limit: non-linear wakes, "Blow-out regime"
- Fields can be calculated only with numerical methods

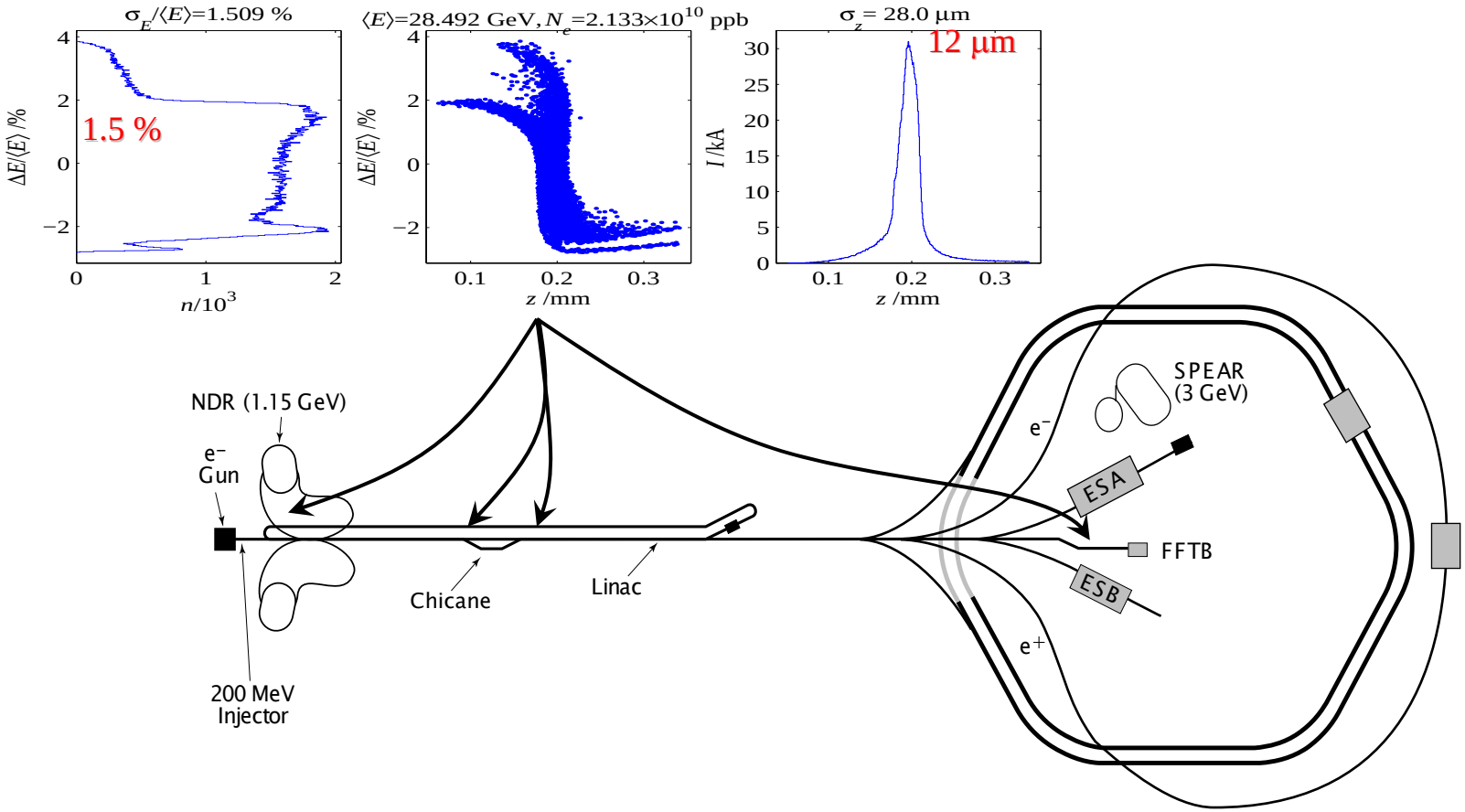


- Typical wavelength: 50 μm
- Accelerating fields up to 50 GV/m

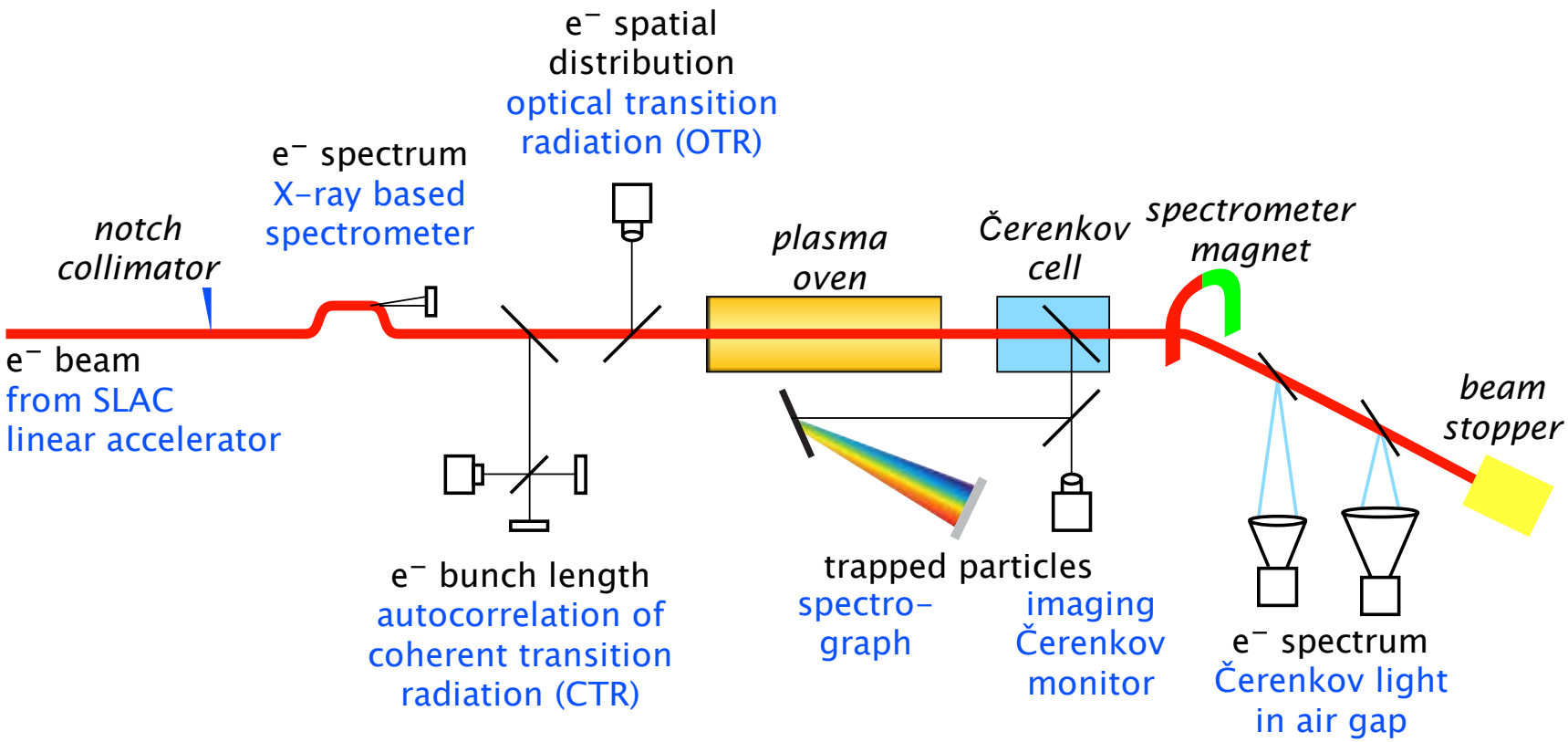
Drive the Plasma Wake

- Typical drive beam power: $\sim 10^{15}$ W = 1 TW
- Power density: $\sim 10^{24}$ W/m^2 =1 YW/m^2
- Drive the plasma wake:
  - Photons
  - Electrons

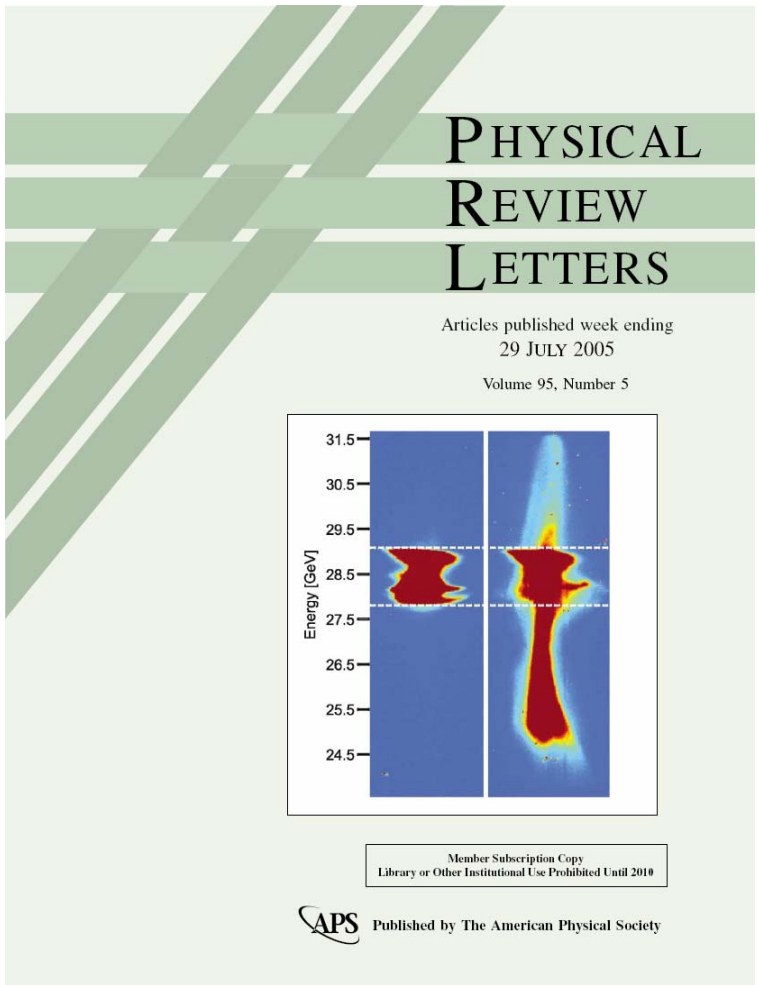
Generation of Short Electron Bunches



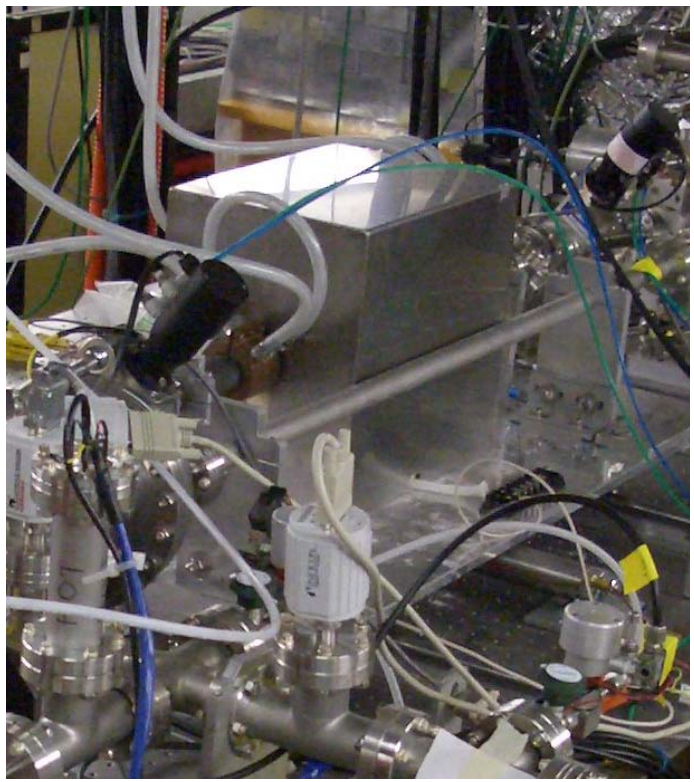
Experimental Setup



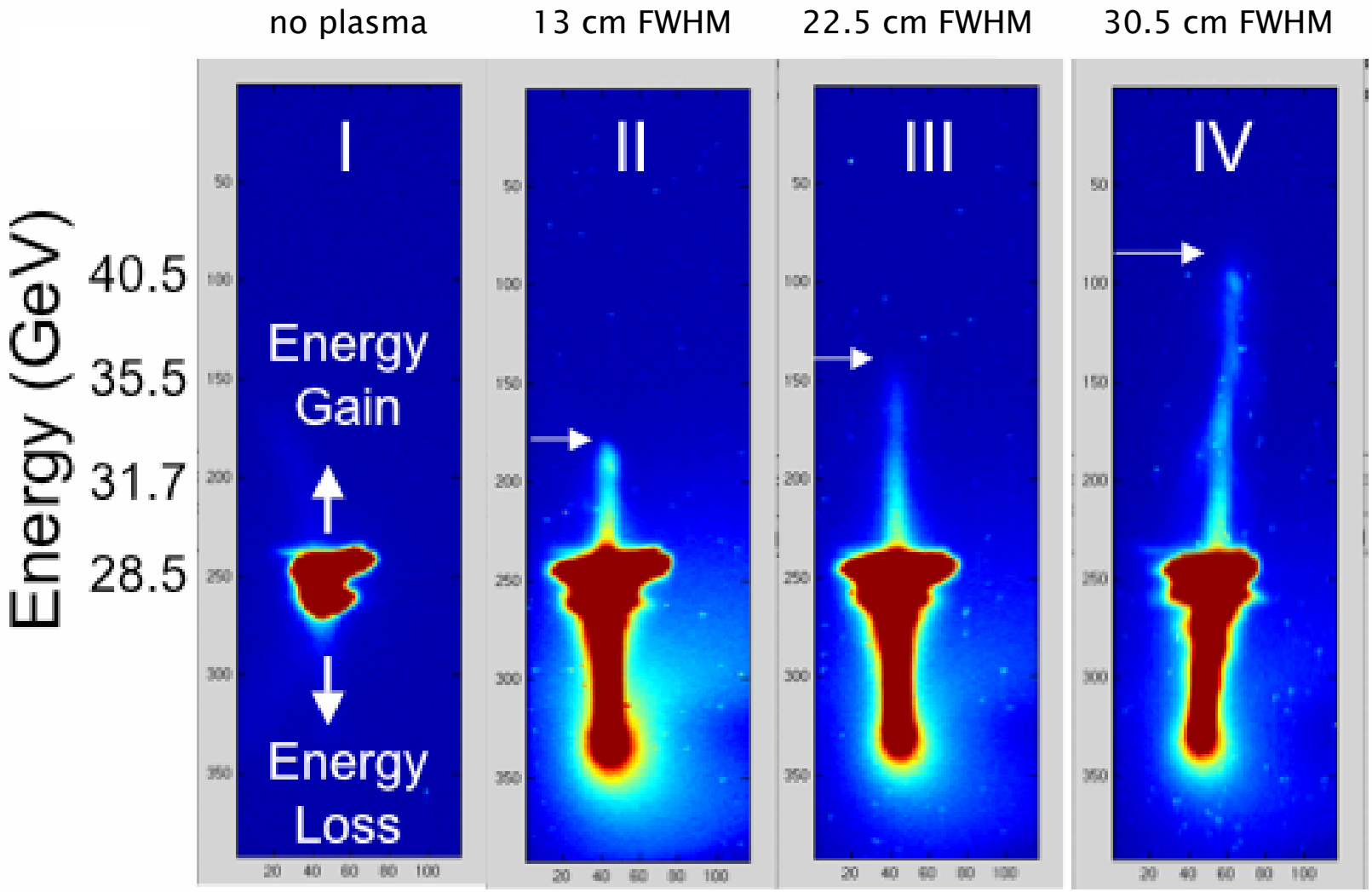
Previous Results



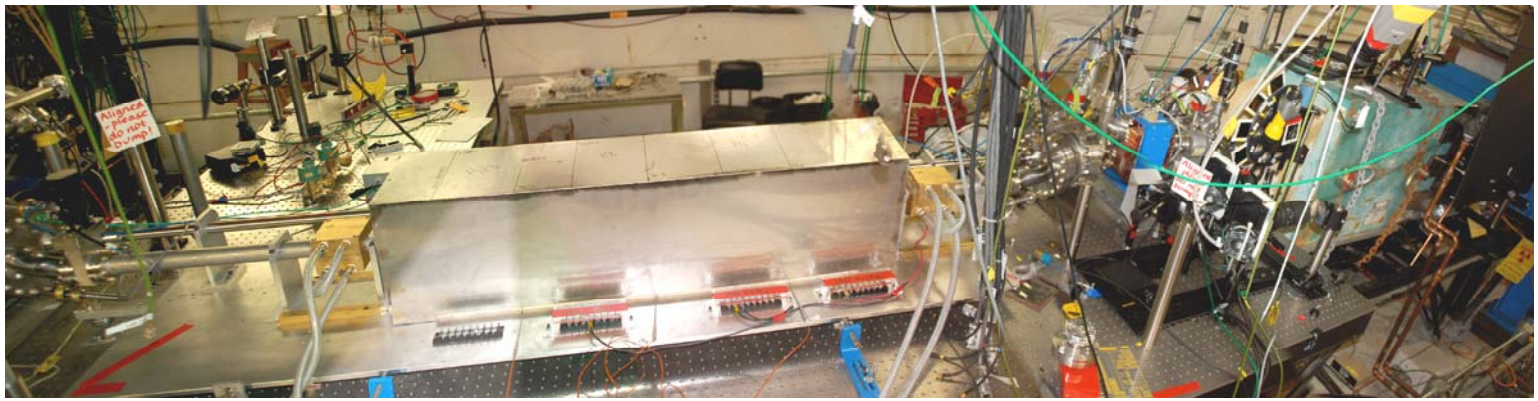
More than 3 GeV energy gain in 10 cm plasma length



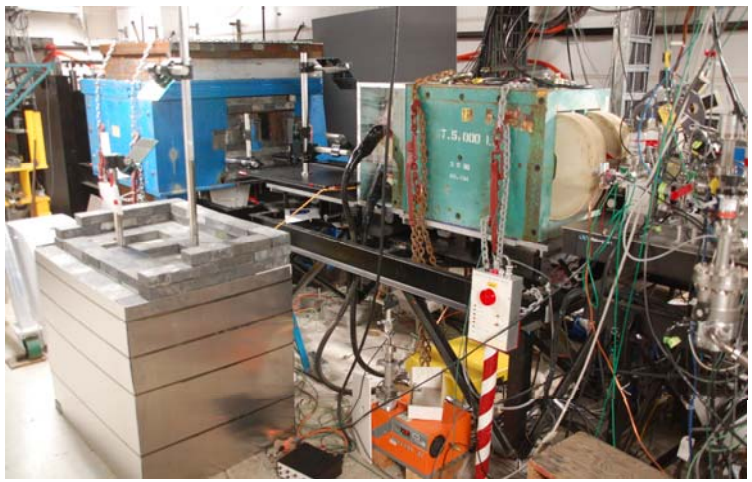
Increasing the Plasma Length to 30.5 cm



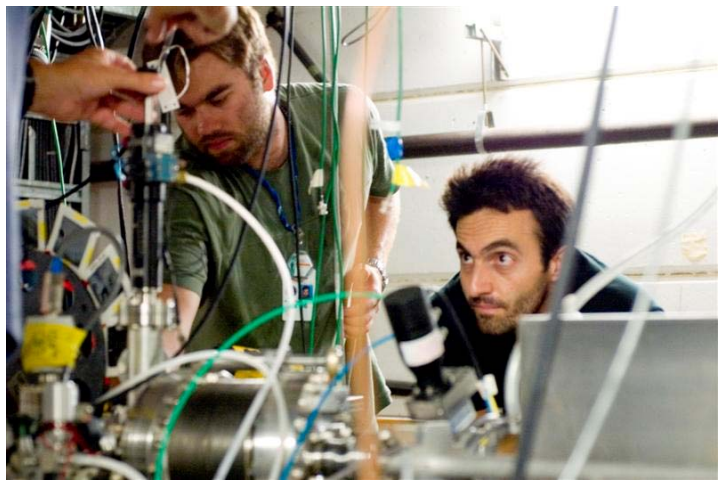
Changes to the Experimental Setup



Longer plasma oven



New spectrometer

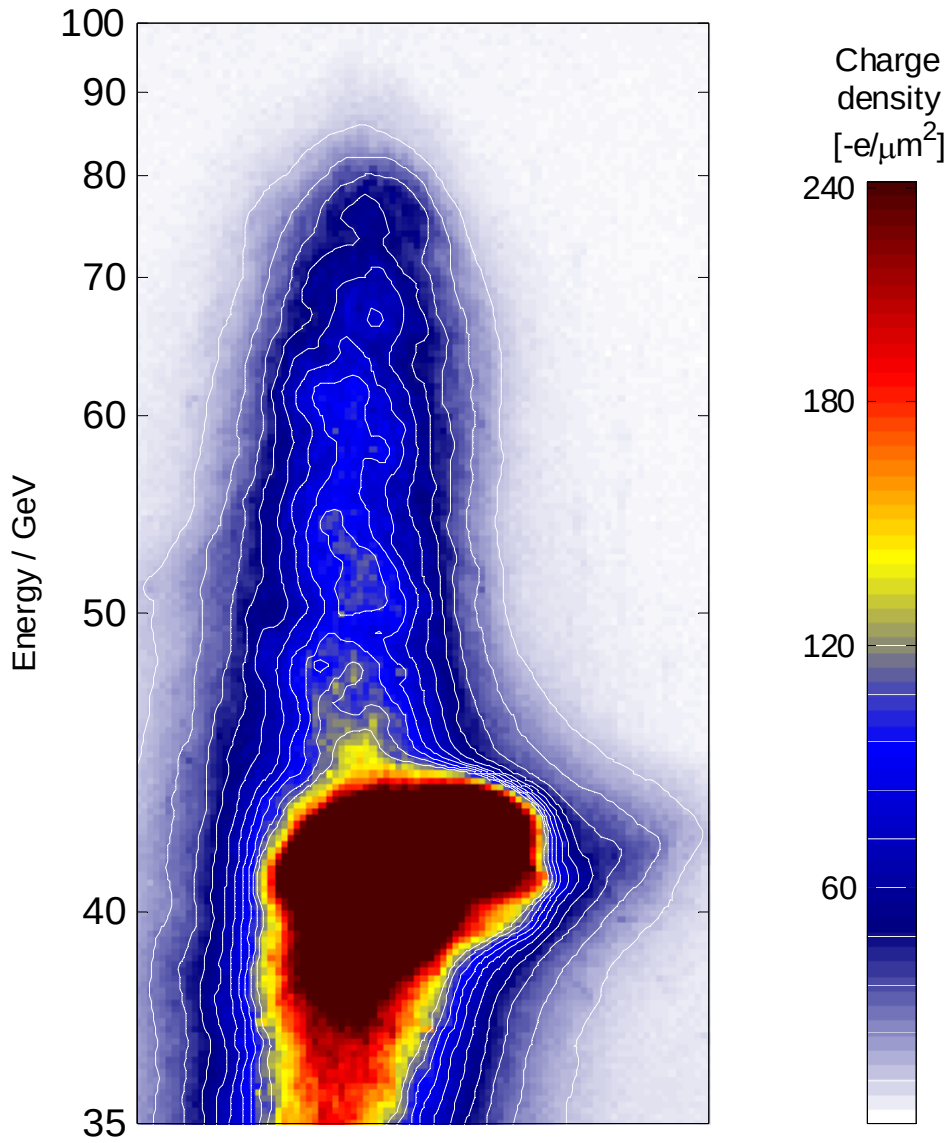


Diagnostics for low-energy particles

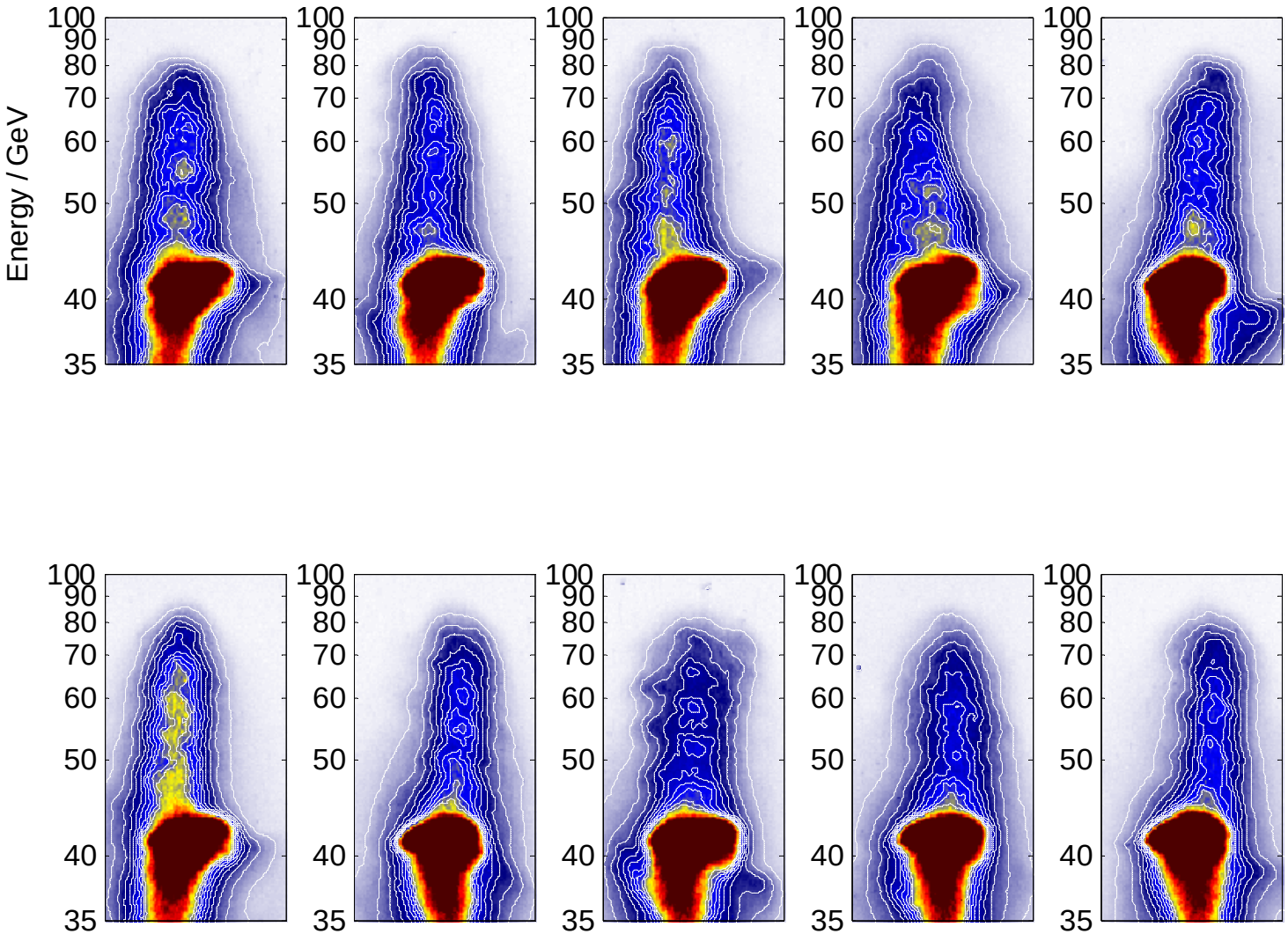
Increased the energy in the drive beam

Energy Doubling

- Plasma length: 85 cm
- Density: $2.7 \cdot 10^{23}\ \mathrm{m}^{-3}$
- Incoming energy: 42 GeV
- Peak energy: 85 ± 7 GeV



Stability

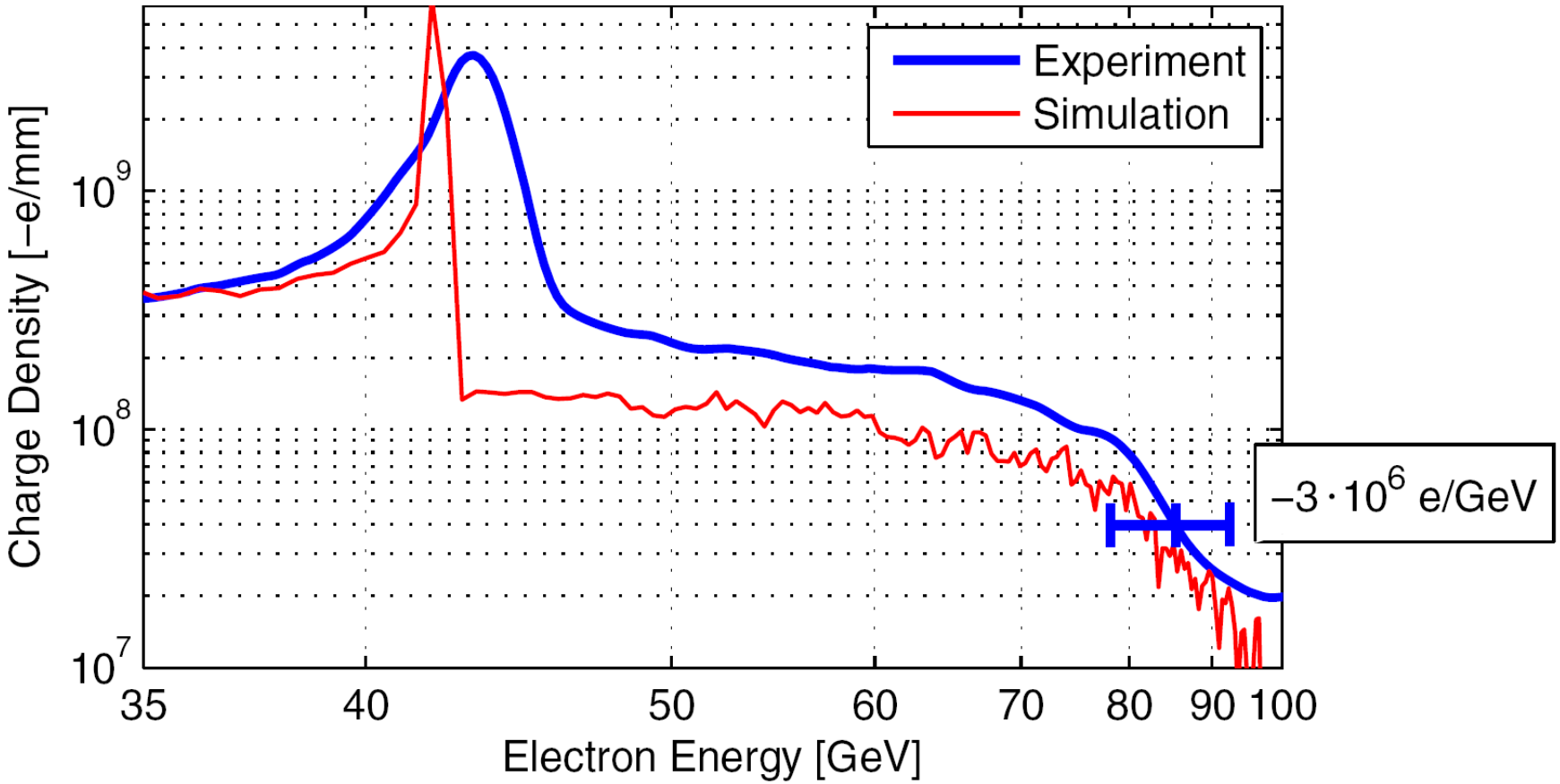


Simulations

- Match the phase space from LiTrack simulation to the measured energy spectrum before the plasma
- Use the corresponding longitudinal bunch profile
- Particle-In-Cell codes:
  - full PIC code: approximately 132,000 CPU hours for 85 cm plasma
  - QuickPIC: quasi-static approximation, 2760 CPU hours

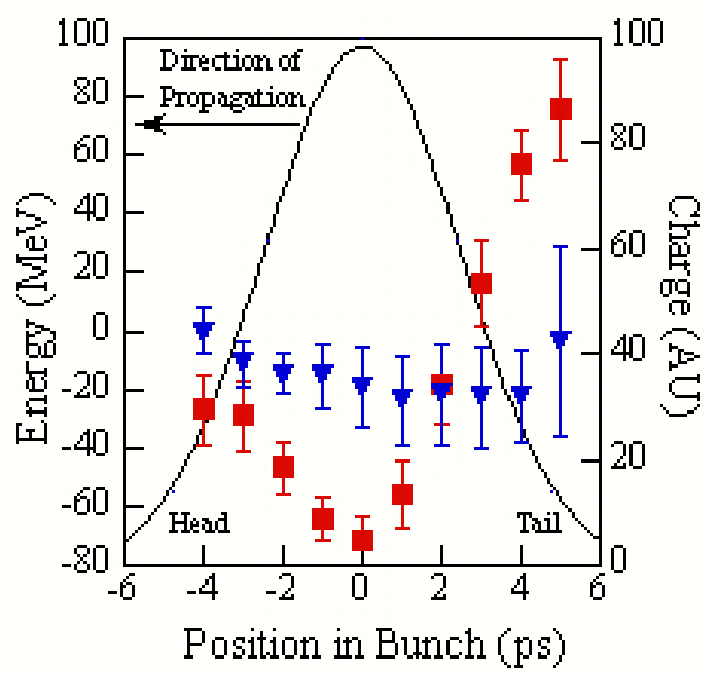
- Simulation of
  - ⇒ field ionization
  - ⇒ motion of beam and plasma electrons
  - ⇒ wake formation
  - ⇒ acceleration
  - ⇒ energy spectrum

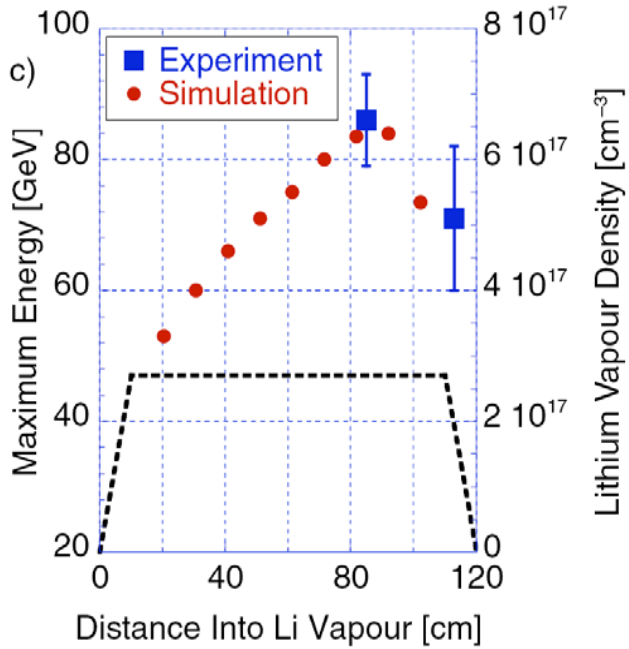
Comparison to Simulations



Future Experiments at SABER

- Studies on self-injected particles
- Positron acceleration with short bunches
- Possibilities to overcome head erosion





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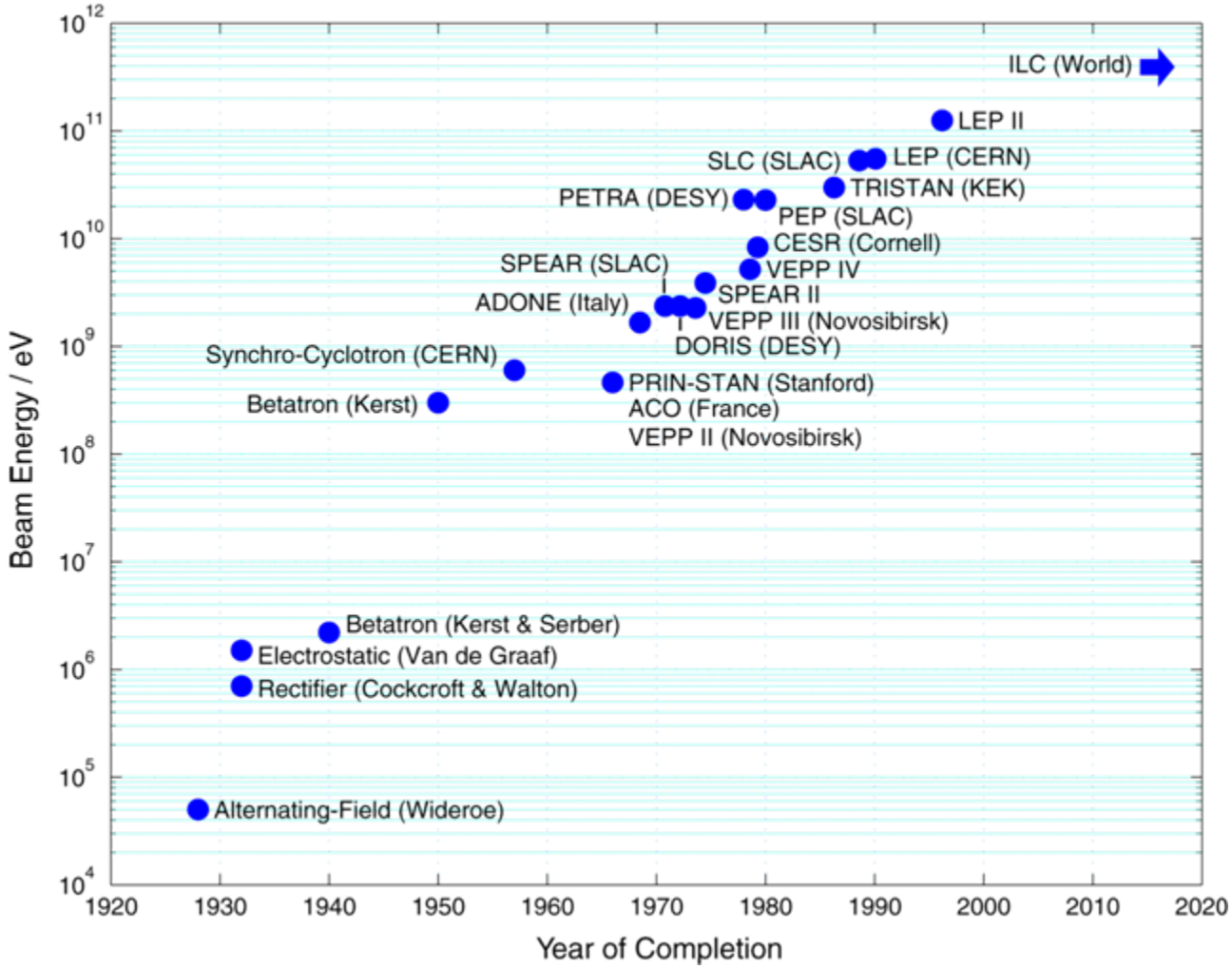
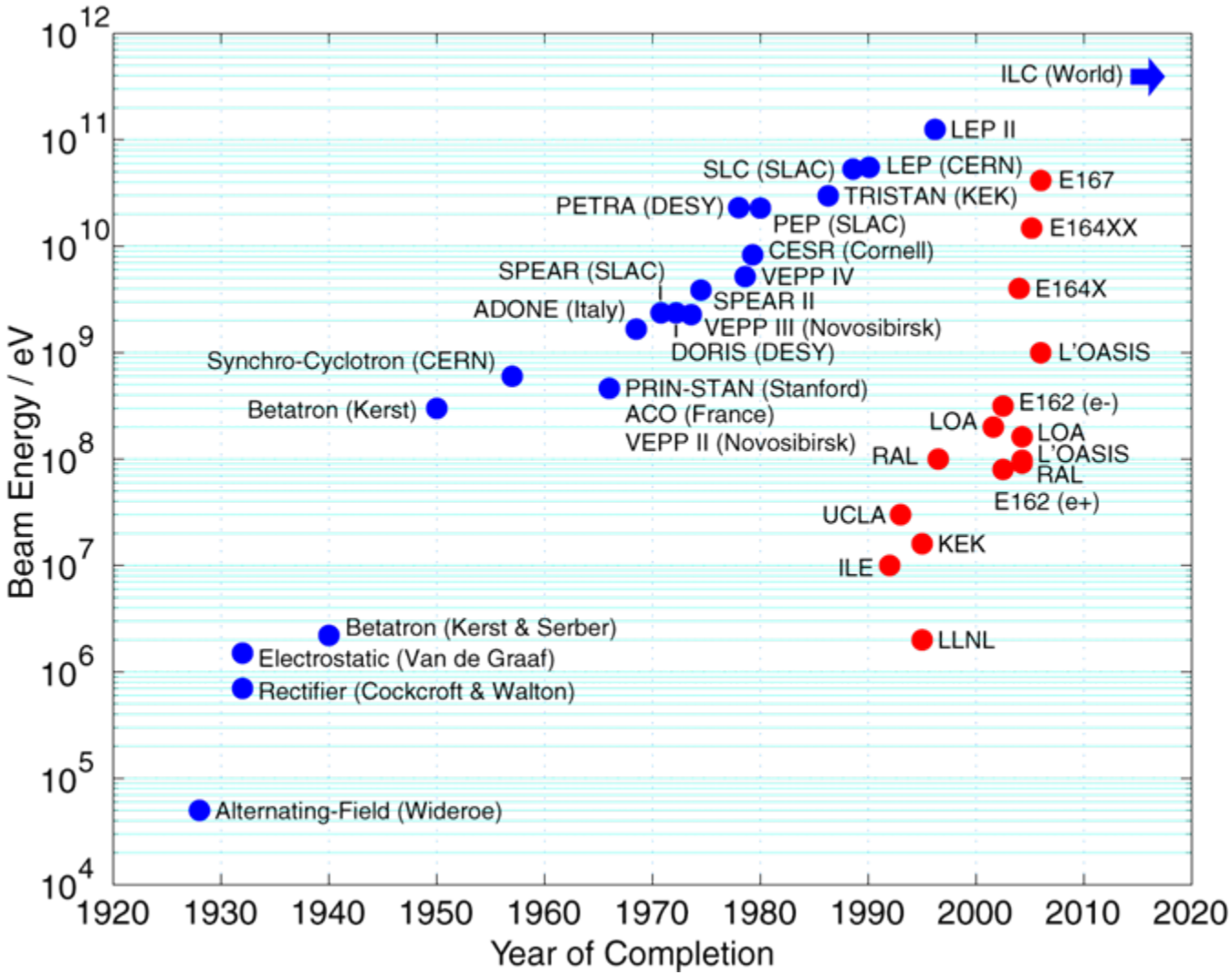


An Unfair Comparison



Presented by the E-167 Collaboration

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