

Effects of a plasma ramp on an electron bunch seeding self modulation of a proton bunch

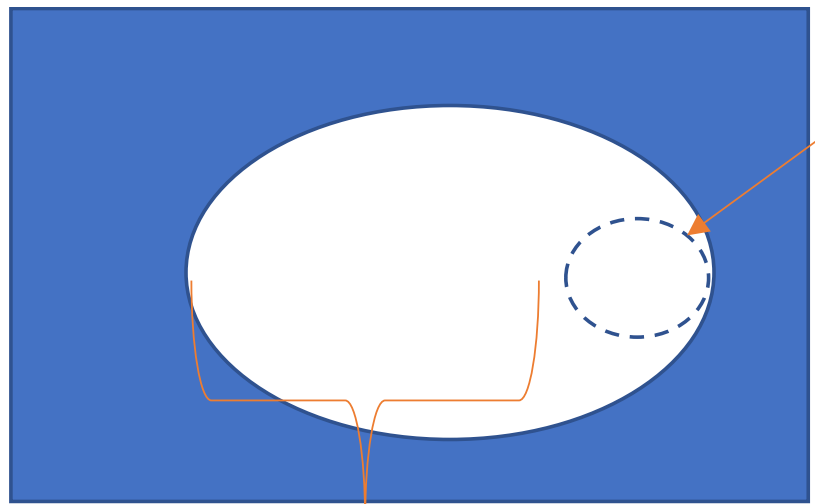
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Abstract:

We study the propagation of an electron bunch travelling within a proton bunch through a plasma density ramp. The proton bunch charge density in the ramp is higher than the plasma density. In this nonlinear regime the bunch generates a high density, on-axis plasma electron filament. The filament sustains defocusing fields for the externally injected electron witness bunch that can therefore be lost along the ramp. At AWAKE we have measured this effect by changing the relative timing between electron and proton bunches. When the electron bunch propagates in front of the proton bunch, the electron bunch seeds self-modulation and reaches the energy spectrometer, downstream of the plasma. When propagating within the proton bunch, seeding stops and the electron bunch does not reach the spectrometer. These results indicate that the presence of a plasma density ramp could prevent on axis injection of an electron witness bunch into a following acceleration plasma. We will present latest experimental data.

Plasma ramp ($n_{\text{driver}} \gg n_{\text{pe}}$):

Laser/electron driver



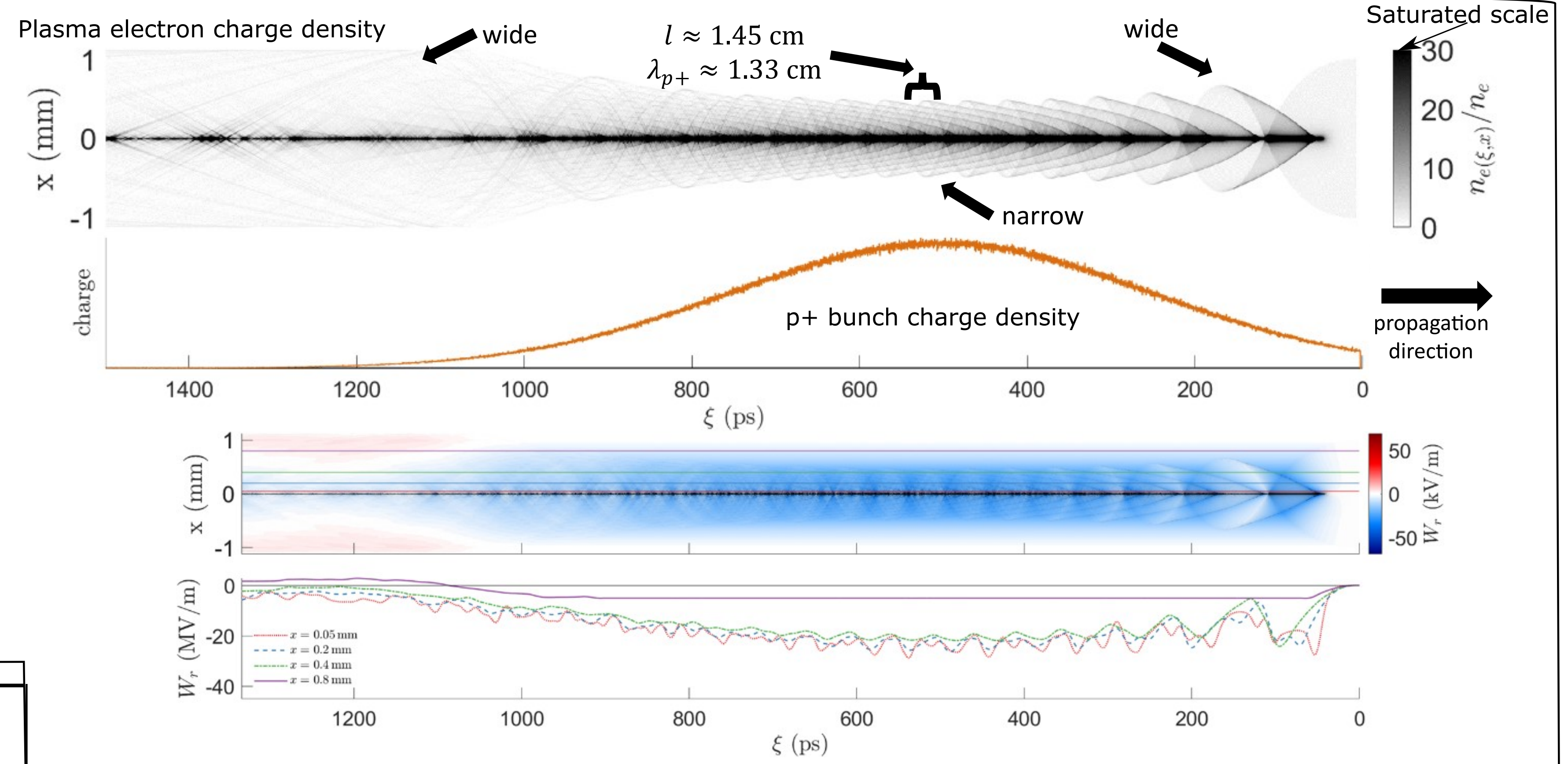
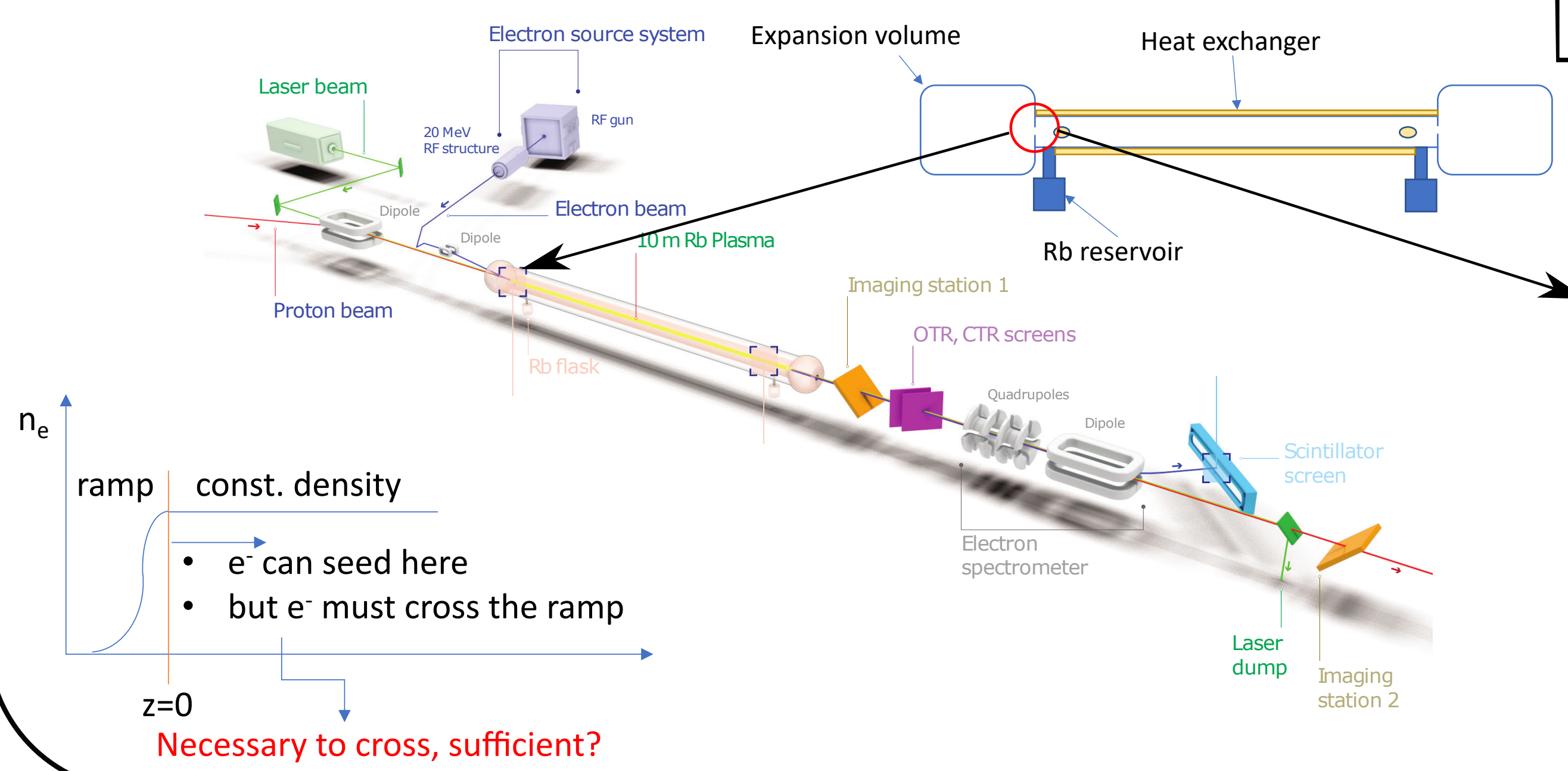
- Driver repels plasma electrons off axis creating an ion column
- Inside the electron depleted region electron witness bunch is focused

Possible positions for e⁻ witness bunch

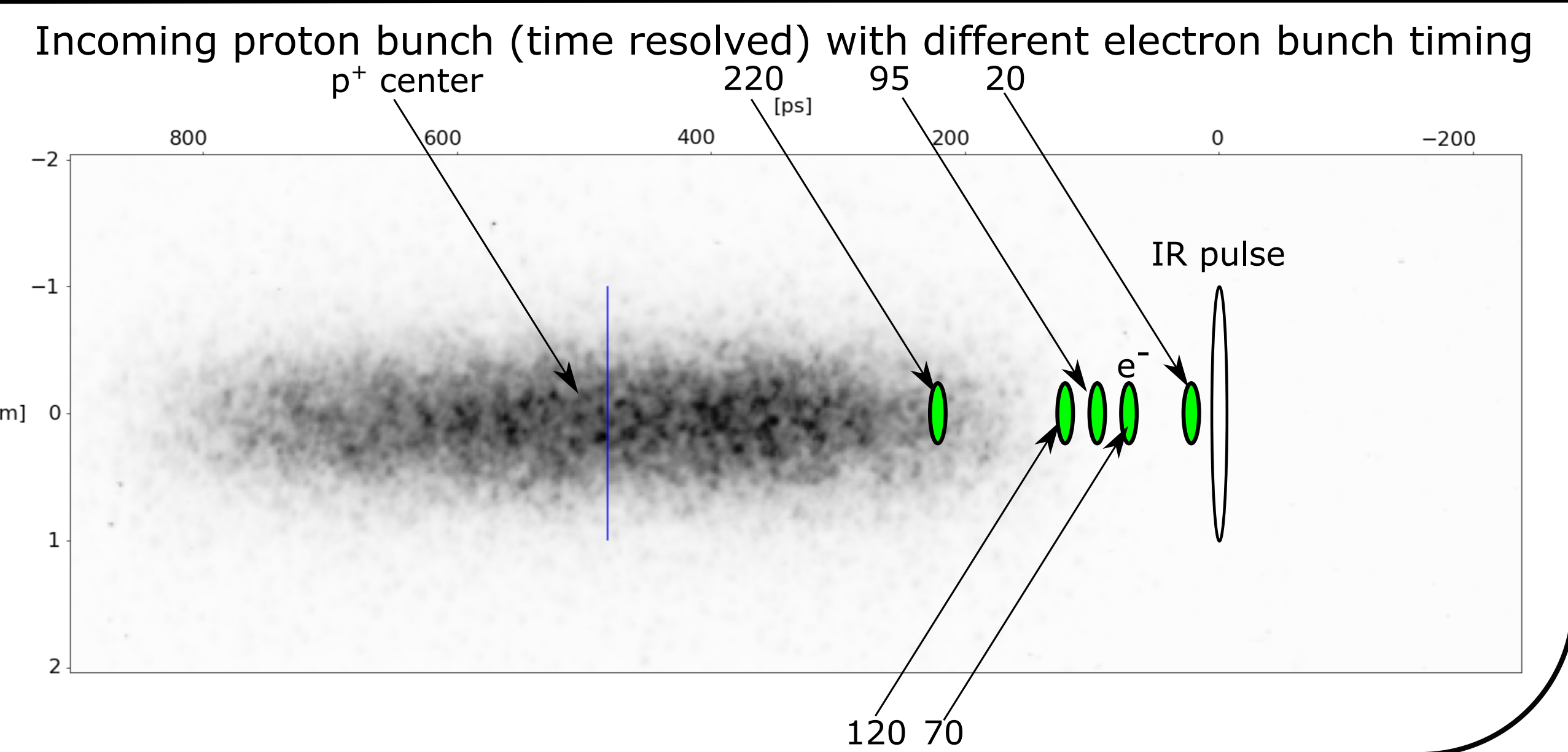
Proton driver

- Attracts plasma electrons
- Plasma electrons form filament
- Filament sustains defocusing fields for electrons

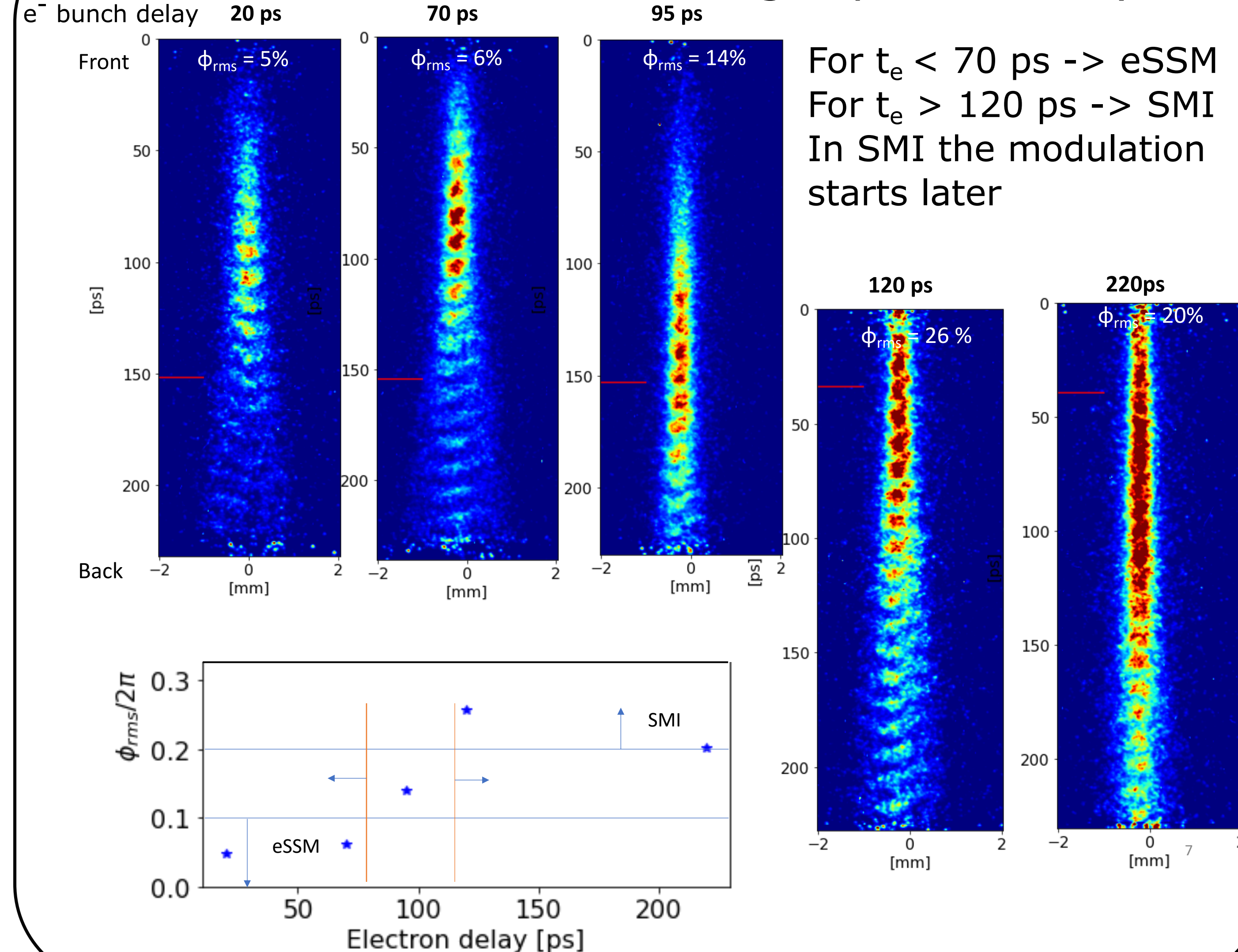
Experimental setup:



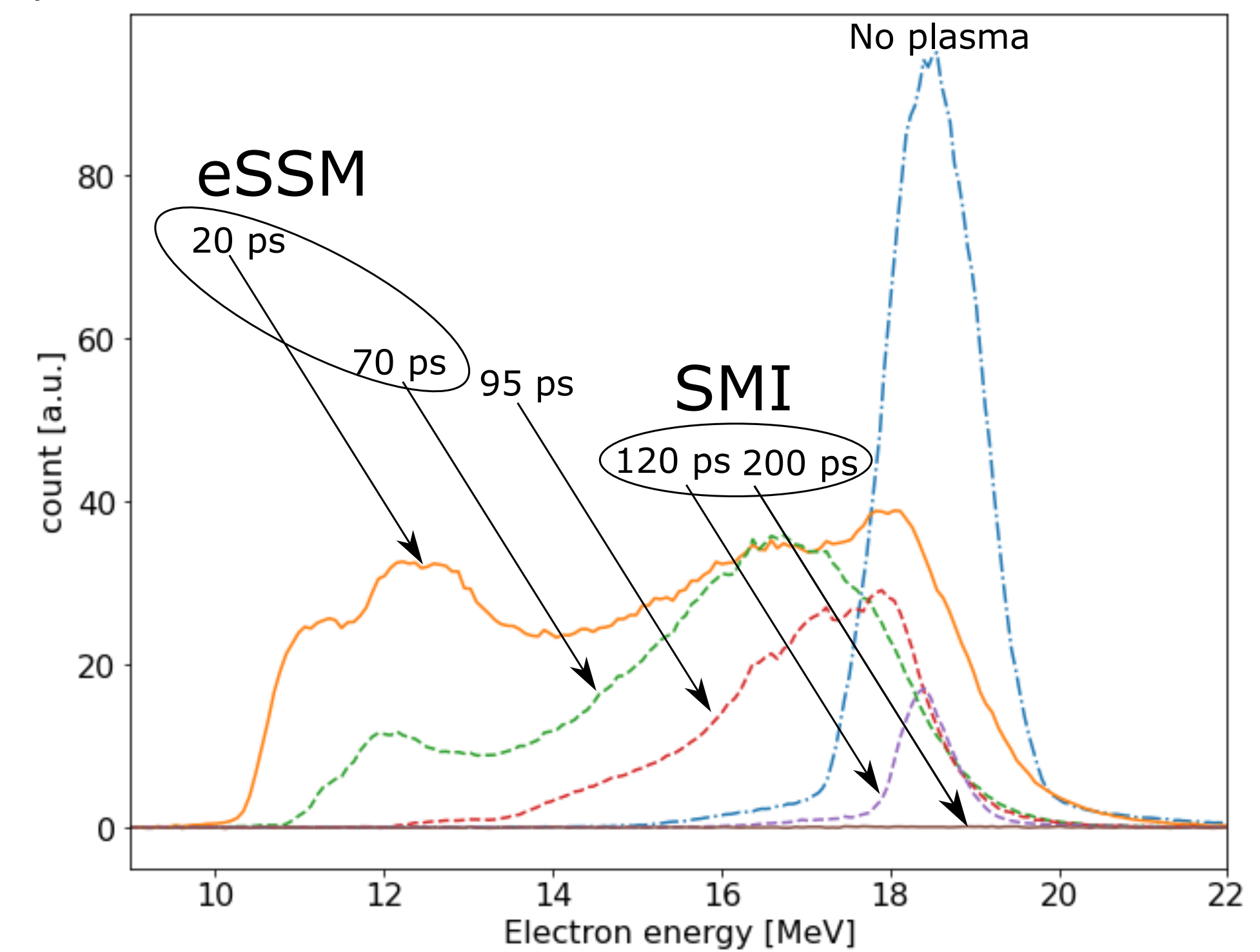
Courtesy of P. Guzman



Proton microbunch timing reproducibility:



Electron energy spectrum: after plasma



Q_e decreases as t_e increases
 $Q_e > 0$ but $\Phi_{rms} > 20\%$

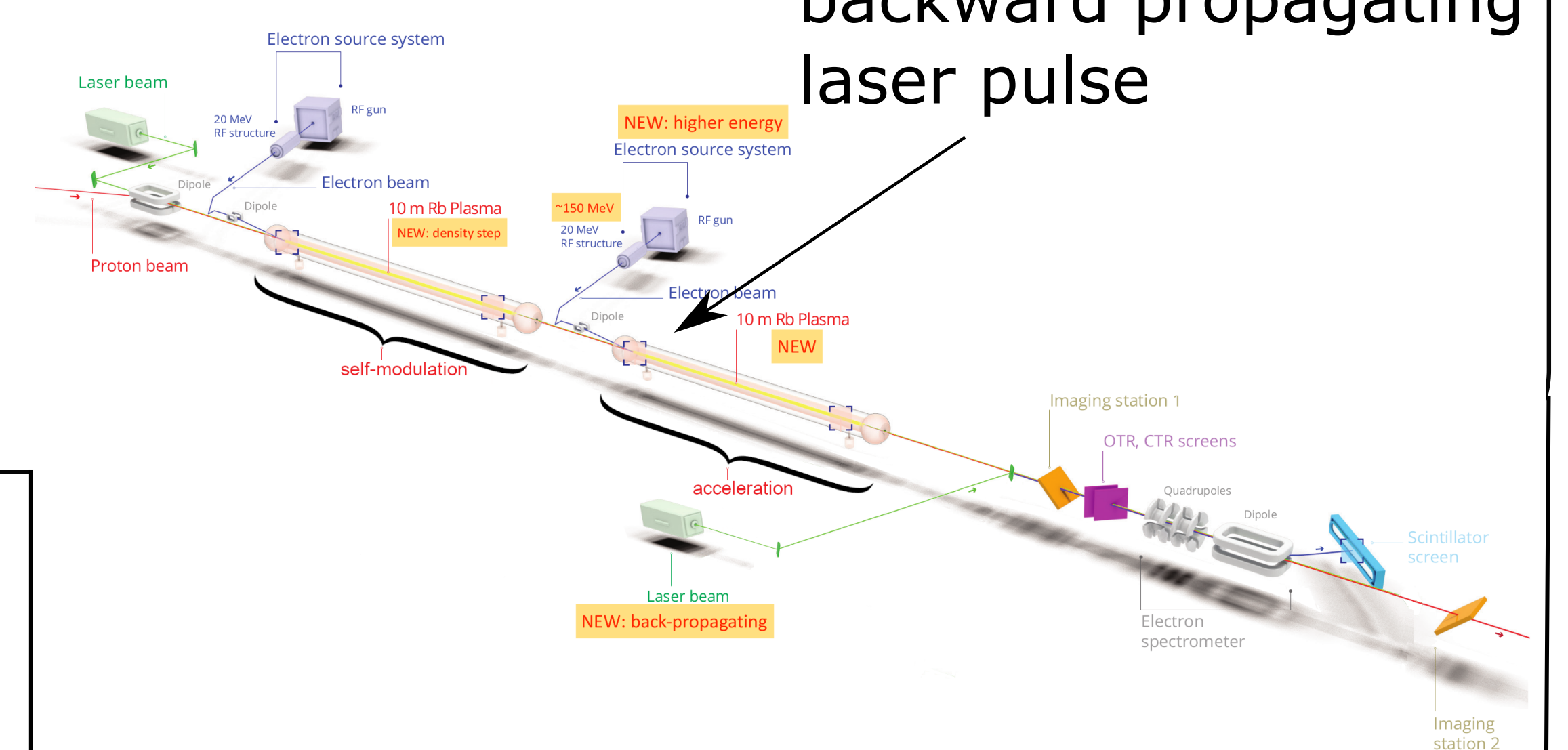
Charge at initial energy survives, but does not seed
When no charge seen on spectrometer -> SMI

Summary:

- Plasma density ramp prevents on-axis electron injection for acceleration
- Problem for RUN2c? NO
- Measurement is consistent with numerical simulations (LCODE)

RUN2c:

No plasma ramp, backward propagating laser pulse



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