Run II Planning

Goals:

Internal - learn what we need to learn so we can seriously propose a particle physics project once Run II is done.

- How to inject a bunch of electrons successfully
- Parameters of electron bunch for stable emittance during acceleration
- Determine if deleterious effects show up (hosing ? …)
- pre-protons under control (not affecting the microbunches, phase stability, …)
- simulations correctly reproduce data (emittance, energy gain, captured charge, …)
- best would be to also demonstrate a scalable plasma cell technology

External - need some numbers that grab peoples attention/imagination

- 10 GeV energy gain ?
- 1 GV/m accelerating field ?
- 1 nC accelerated charge ?
- 10 mm-mrad emittance after acceleration

Need to plan to meet all these goals by end of Run II.

→ **fix design & fix work schedule**

Run 2 Organization

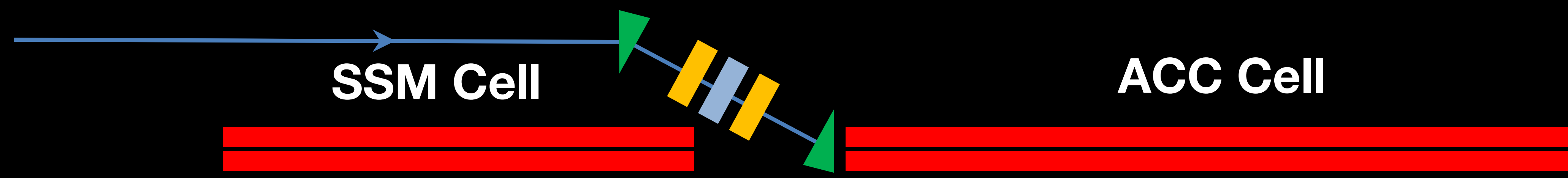
1. **Agree on Run plan and basic parameters**
   - Extract decision points (e.g., when need to decide on e source/energy, when do we need to decide on integrated versus separated plasma cell ?)
   - Fix basic design (integrated versus separated cells)
   - Fix electron injector parameters

2. **Break out main tasks for different aspects**
   - design, test, build, commission new plasma source
   - design, test, build, commission diagnostics
   - simulation studies to fix parameters of SSM source
   - improved proton beam line (transverse jitter, window, bunch parameters)
   - …

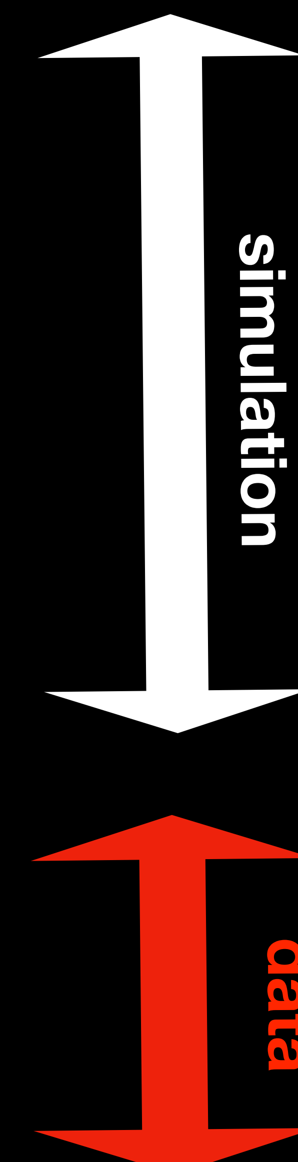
3. **Assign/find responsible for carrying out main tasks**
   - institute responsibilities
   - individual responsibilities for coordination packages
   - New task groups & organizational chart for AWAKE
   - goal: assignments at next Collaboration Meeting (April 1-3)

4. **Tracking & updating where we are:**
   - fix TB & PEB schedule for 2019

Lessons

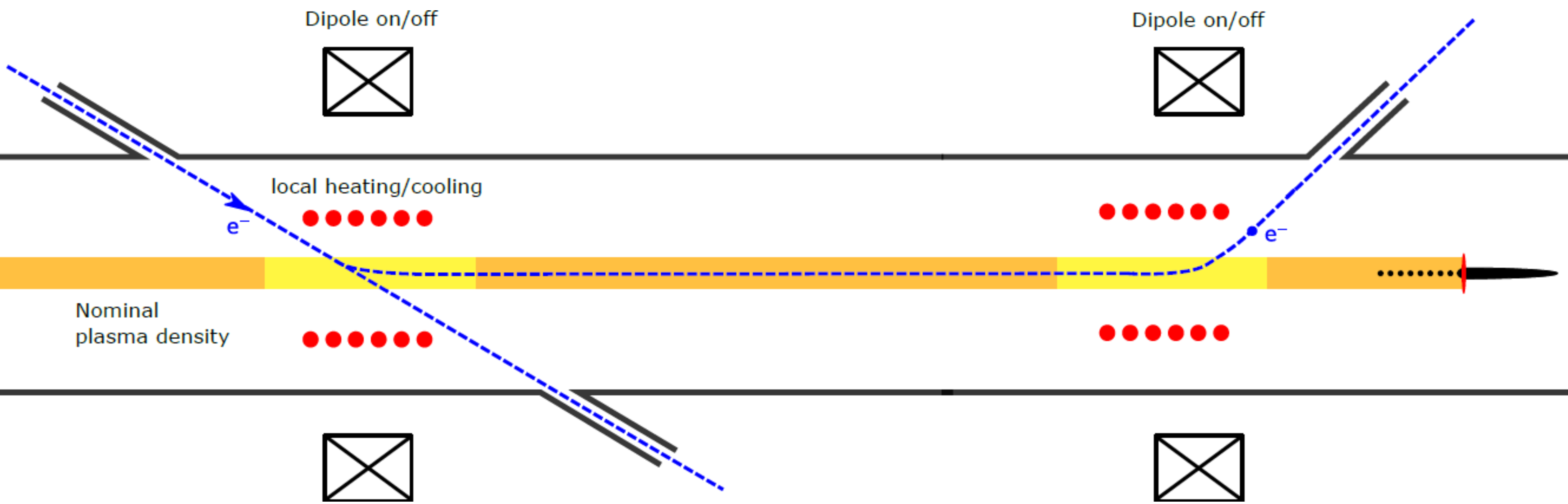


- Minimize gap: important for high gradient & shape of potential well
- Density step in SSM cell to preserve strong accelerating fields
- Match density of SSM and ACC cells to <1%, stable to 0.2%
- Sharp density step at entrance to ACC cell - ramp defocuses electrons
- beam loading from witness needs to be taken into account - important for correct simulation of emittance growth
- initial parameters of electron bunch important for final emittance
- electron injection in complicated/not well understood plasma should be avoided
- SSM not phase stable if seed too early in proton bunch. Electron bunch helps?



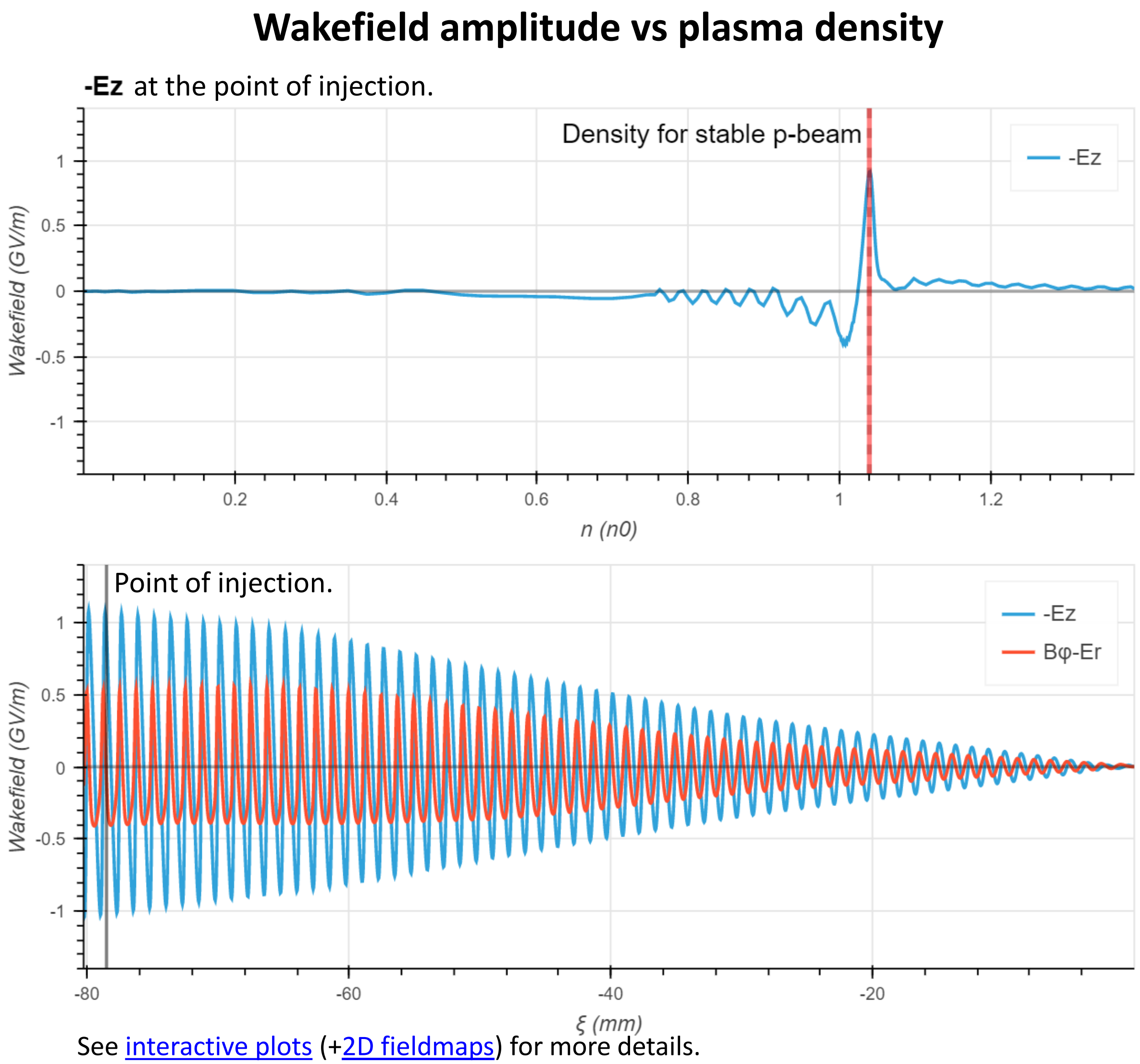
Proposed Run 2 injection scheme:

A.Petrenko et al.



Main advantages of this approach to electron injection:

1) The gap between the two plasma sections can be reduced to several cm.
2) Electron beam can be optionally extracted shortly after injection – i.e. injection and acceleration can be separated.
3) When the dipole is turned off the electron beam can be used for the transmission electron microscopy of plasma wakefields.
4) Flexibility in the longitudinal plasma profile can be useful for low-energy electron injection.

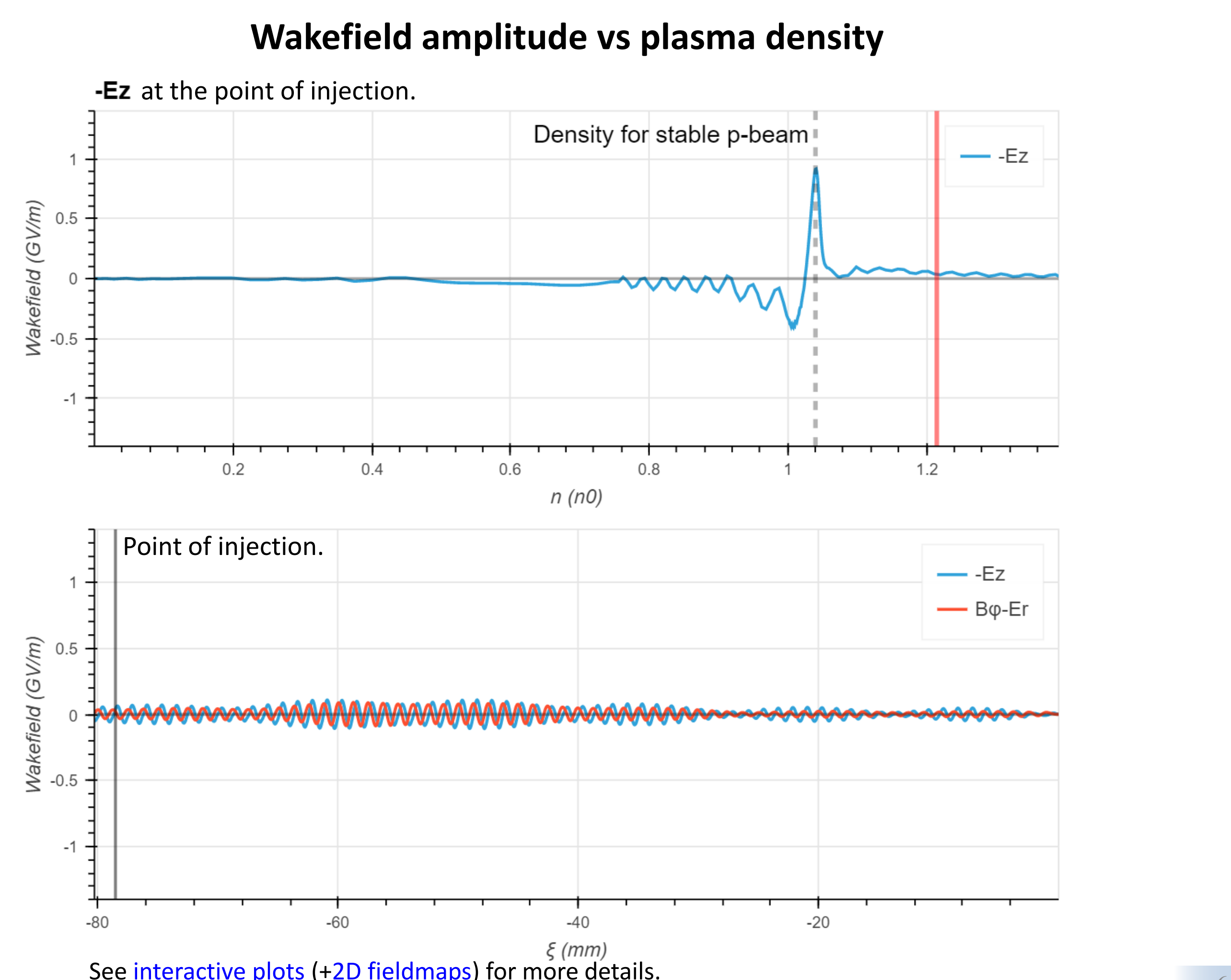


Detune plasma density in injection region. Fields much weaker - electron injection possible (in simulation)

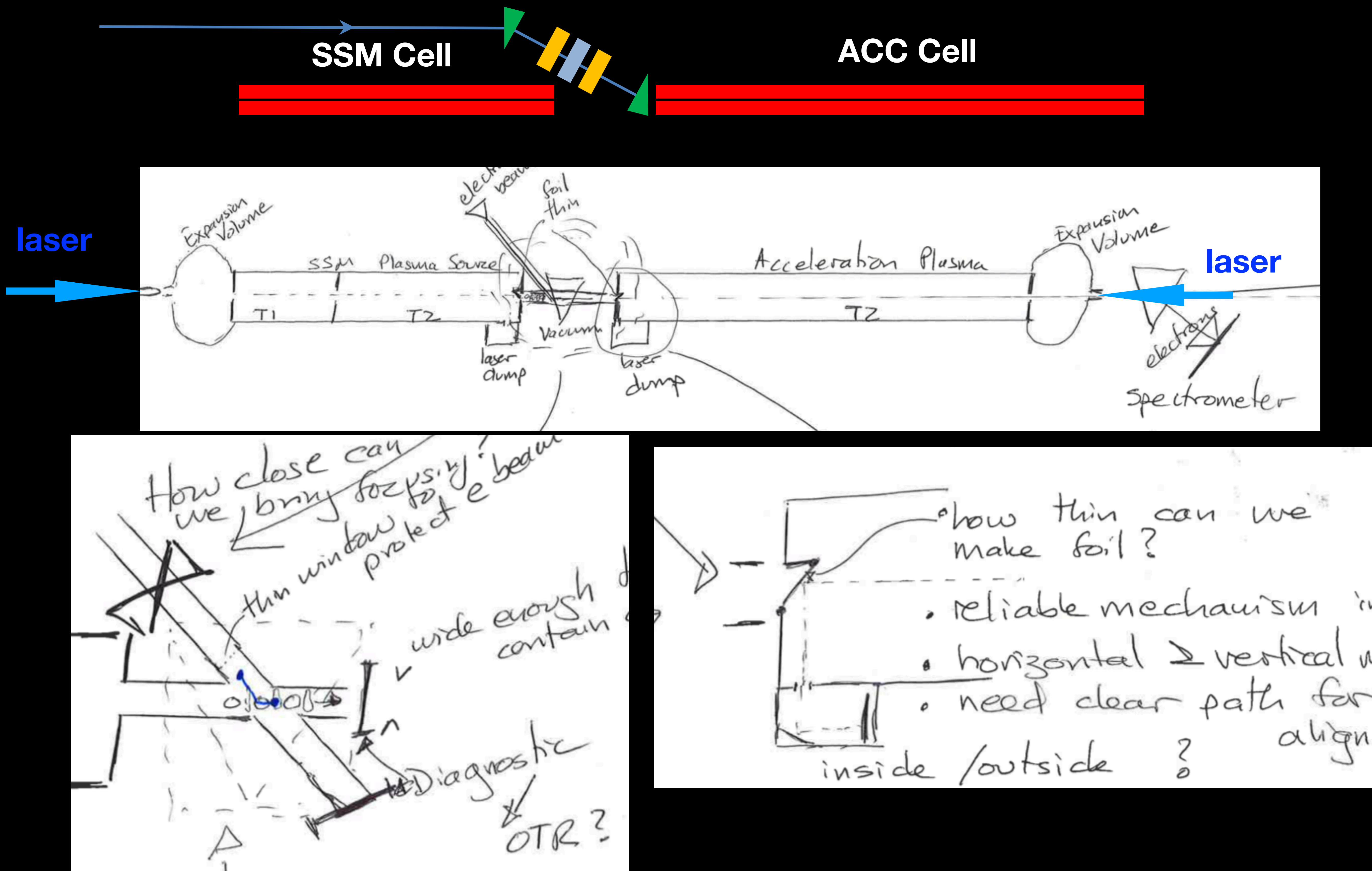
complicated plasma source

- **several temperature zones**
- **integration of magnetic elements in plasma source**
- **limited flexibility because 'all-in-one'**

Still have plasma density ramps: effect on electron emittance ?

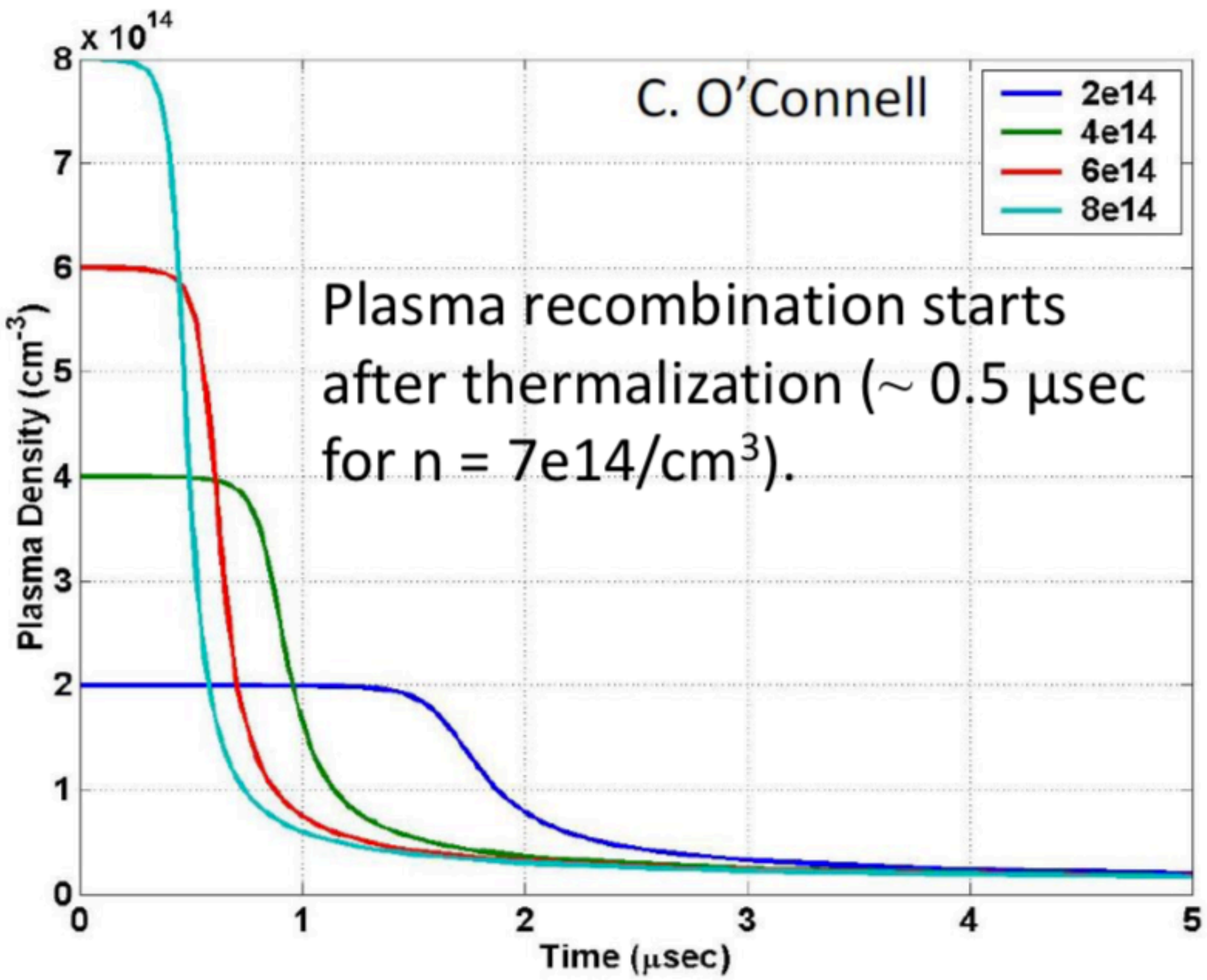


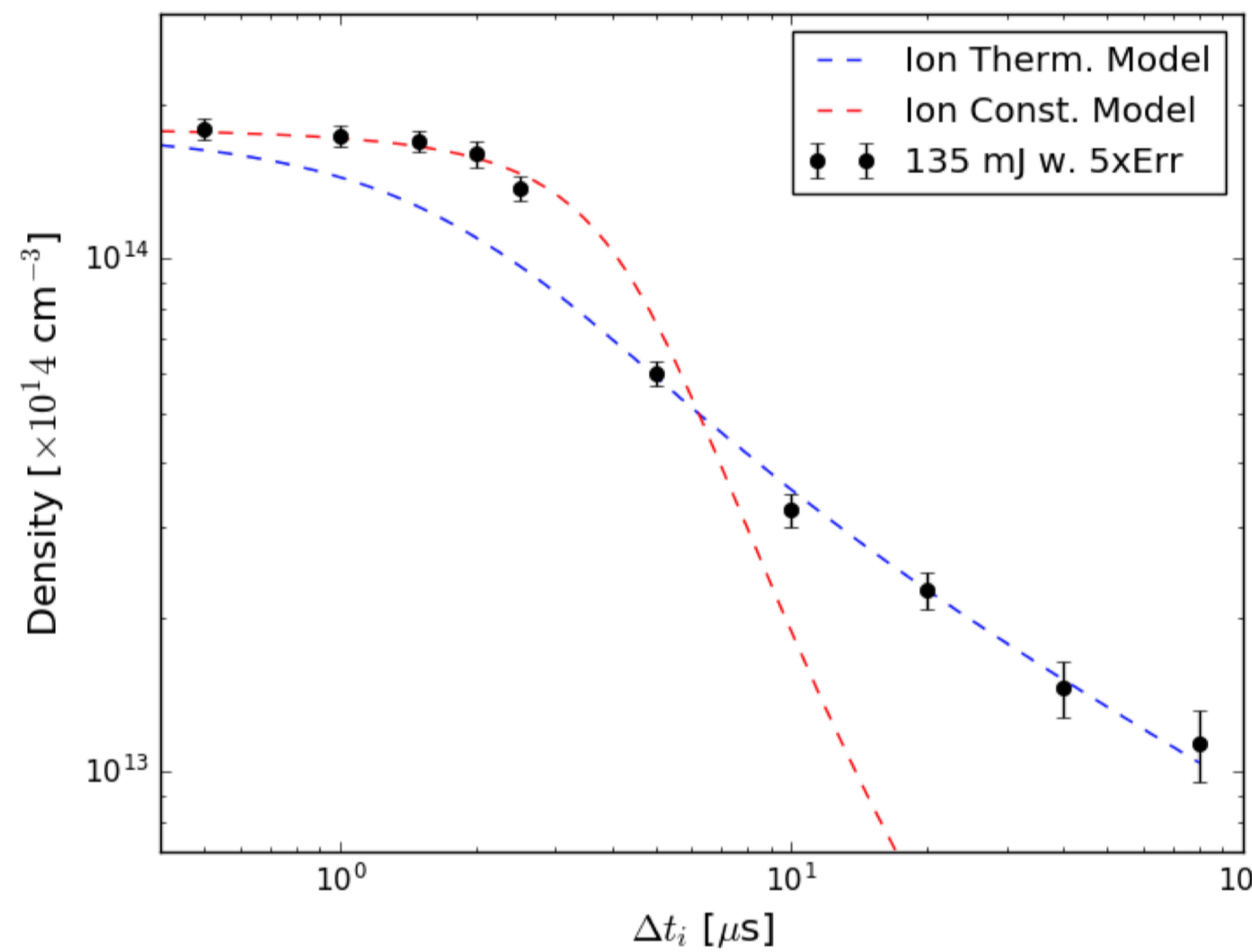
Alternative



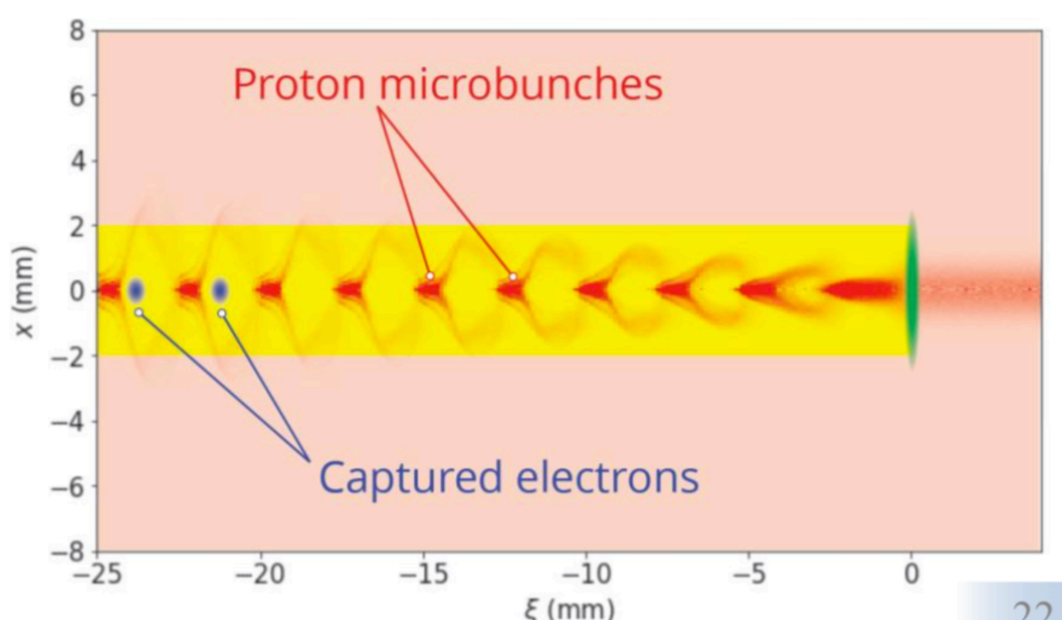
Consider pre-ionized Rb vapor for ACC cell

S. Gessner, PEB, June 2018





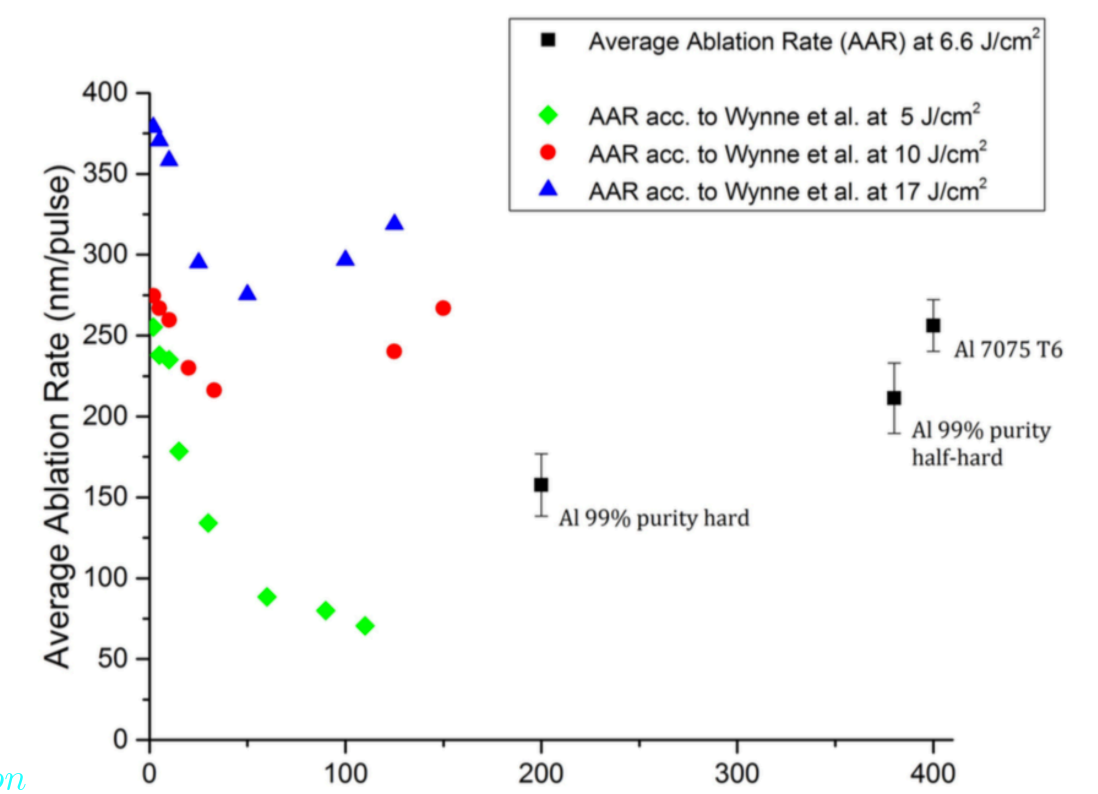
How important is the p-beam head interaction with plasma for micro-bunch stability?



$$0.1J/(0.2cm)^2 = 2.5J/cm^2$$

$$0.5J/(0.2cm)^2 = 12.5J/cm^2$$

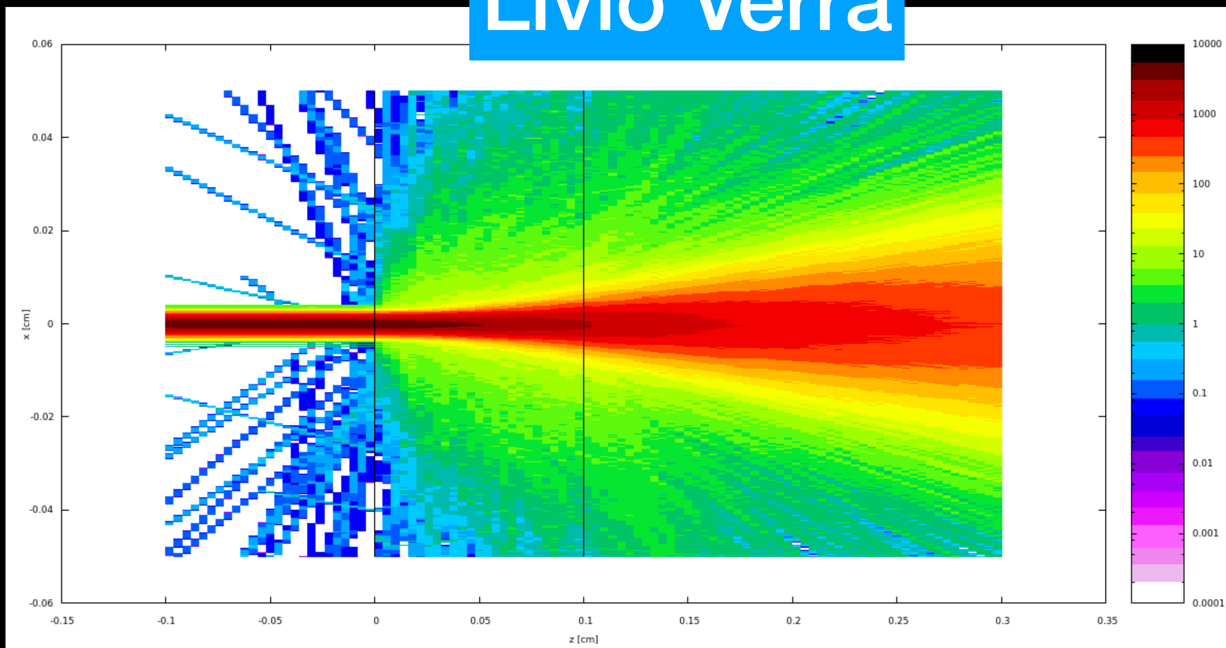
$$\frac{20\mu m}{250nm/pulse} = 80 pulses/position$$

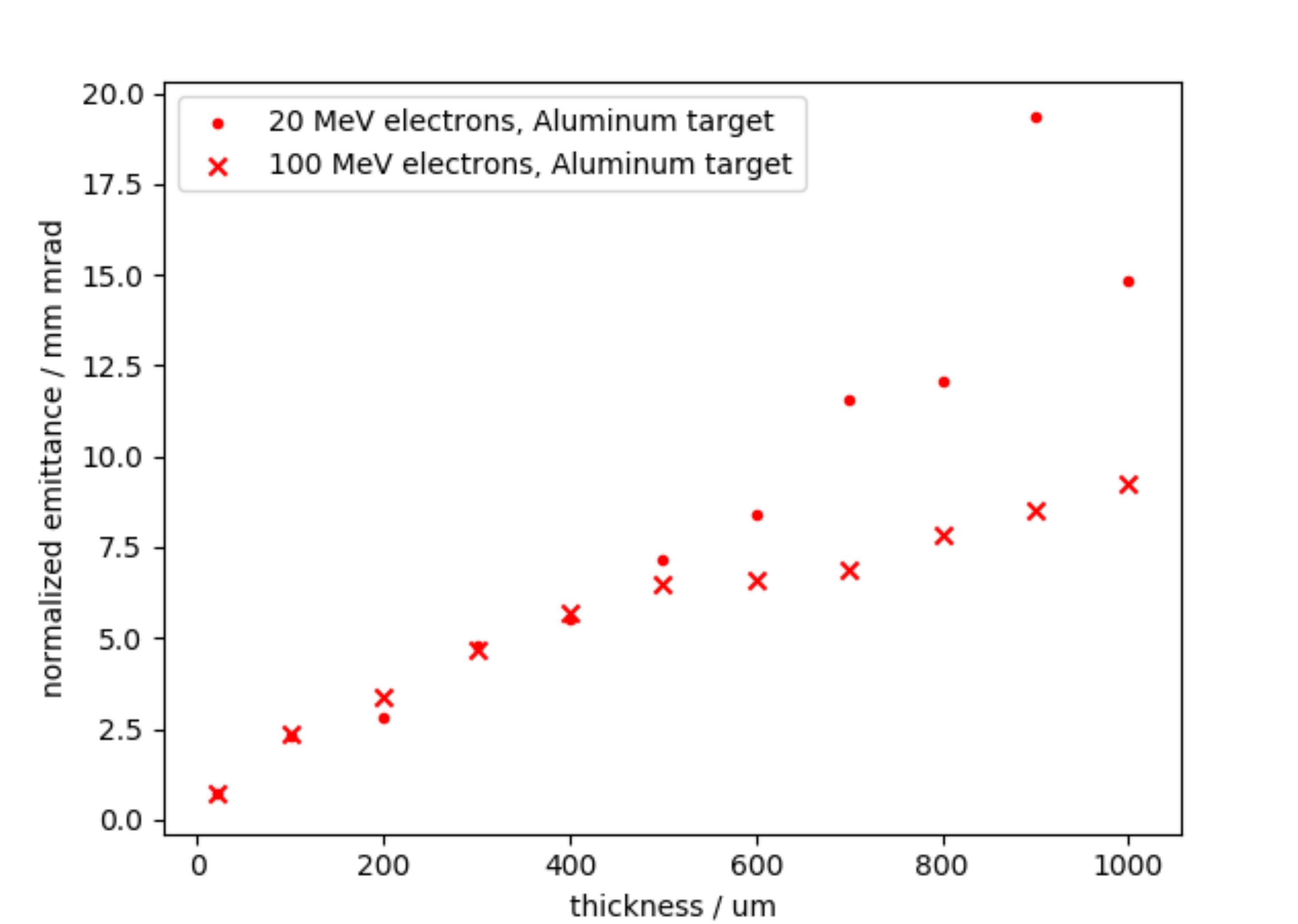


Mathias Hüther

I run simulations for the different materials, thicknesses and energies you asked me.
I set an incoming beam of zero emittance and 10 um sigma. Simulations return sigma and rms angle of the beam coming out of the target. From these values I calculate the normalized emittance.

Livio Verra





Polymer foil windows for gas-vacuum separation in accelerator applications

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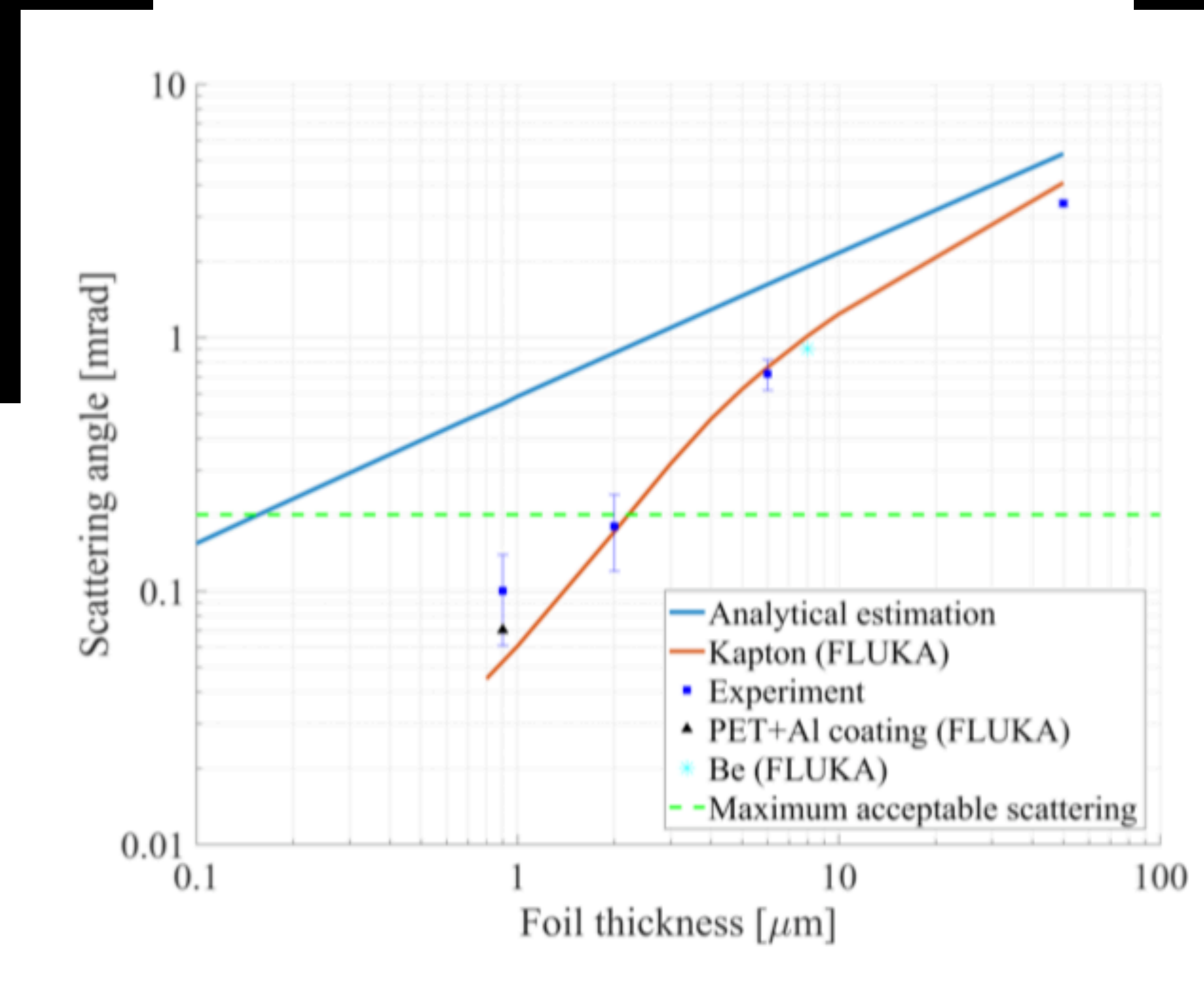
Helmholtzzentrum Berlin, Albert-Einstein-Str. 15, 12489 Berlin, Germany

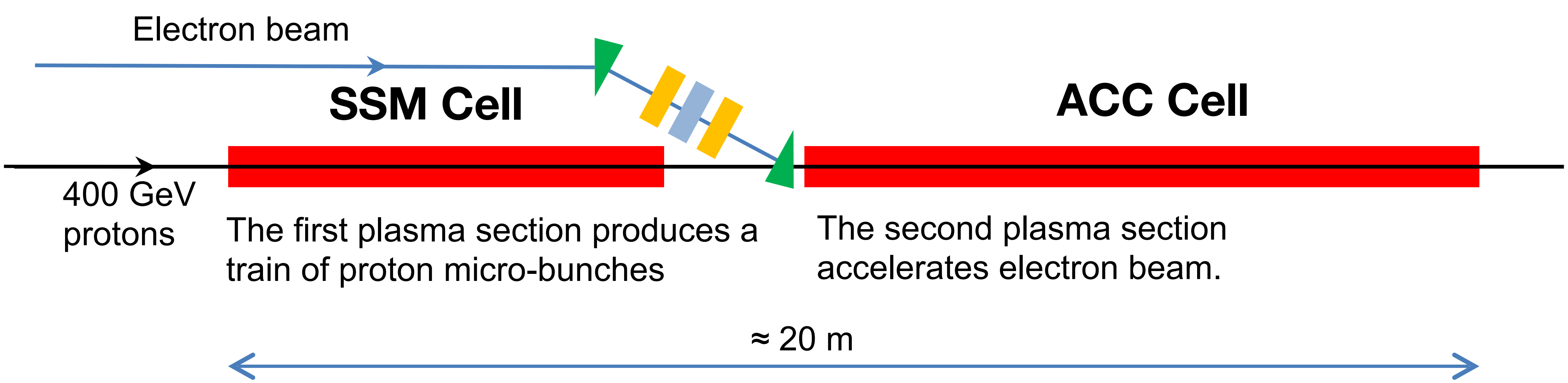


Pros and Cons

All in one plasma source	split plasma source
electron beam line integrated in plasma source	electron beam line standalone
no pre-plasma in acceleration cell	pre-plasma in acceleration cell
electron injection in plasma	electron injection in vacuum
ACC: soft plasma density start	ACC: sharp plasma density start
one laser path	two laser paths+dump inside plasma source
no emittance blow-up in foils	emittance blow-up in foils

Run 2 Planning

We need nominal scheme - limited manpower to study multiple schemes in parallel
Need to eventually solve pre-seed proton issue anyway
Propose to focus on split plasma cell - more flexibility



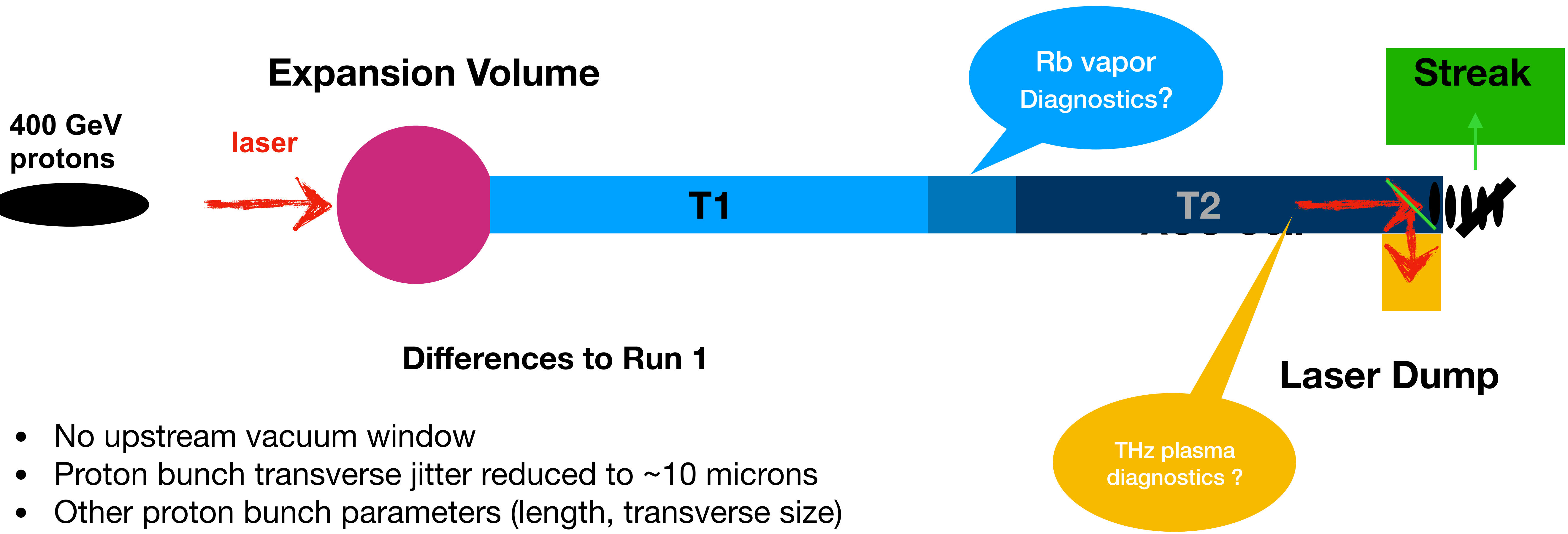
Possible Run Plan - four phases

Phase 1 - only SSM plasma source
Phase 2 - add e beam
Phase 3 - add Rb ACC plasma source
Phase 4 - alternative plasma ACC plasma source

(Phases 2 ↔ 3:) If need to test effect of pre-seed protons

Planning and implementation should be organized with final goal in mind !

Phase 1 SSM Cell Studies



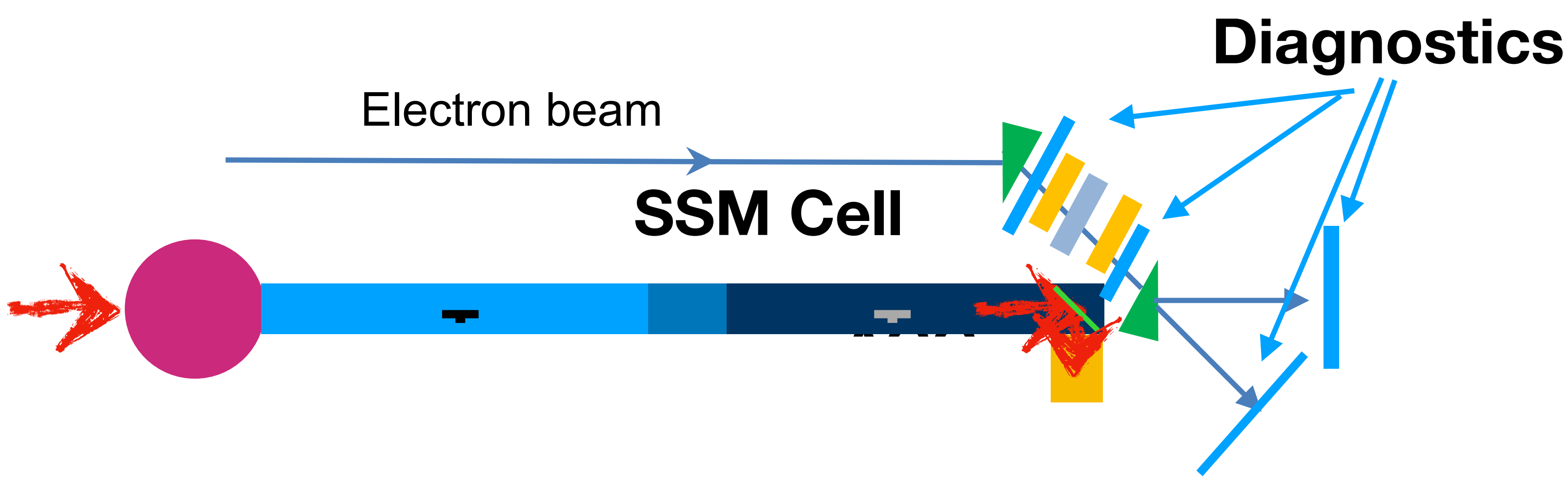
Differences to Run 1

- No upstream vacuum window
- Proton bunch transverse jitter reduced to ~10 microns
- Other proton bunch parameters (length, transverse size)
- density step in plasma source
- only one expansion volume
- laser dump integrated in plasma source
- diagnostics directly at exit of plasma source

Questions

- what to measure to confirm effect of density step?
- how to implement variability of density step location & size?
- how to implement laser dump?
- length of Rb plasma source ?
- laser diagnostics?
- proton diagnostics upstream & downstream (novel diagnostics)?
- move upstream relative to Run 1?

Phase 2 Option1: Electron Studies



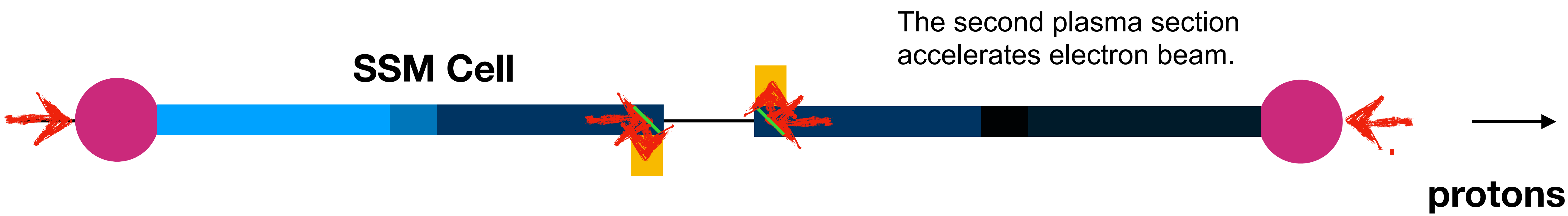
Differences to Run 1

- Very different e bunch parameters
- diagnostics near merge point
- measure e,p bunch simultaneously

Questions

- How compact can merge region be?
- how does it depend on e energy?
- required e bunch parameters?
- what type of electron diagnostics needed?
- concurrent e,p beam diagnostics?
- how long needed to install source & beam line?

Phase 2 Option-2: test effect of pre-seed protons

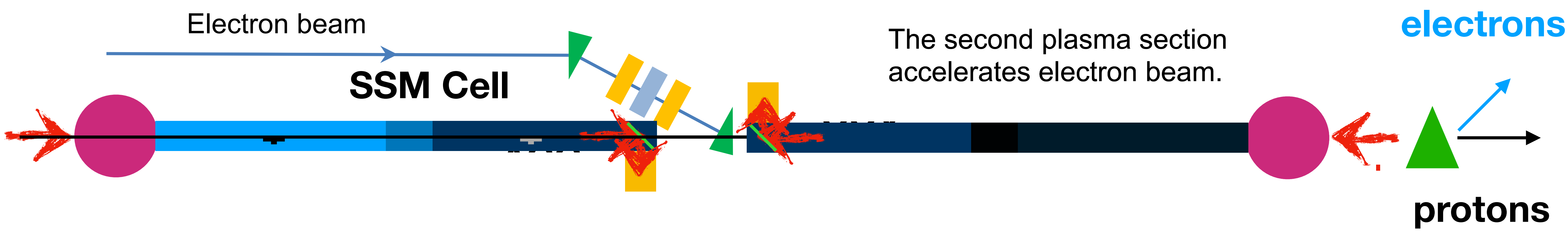


Questions

- understand effect of pre-seed protons on phase stability, etc
- understand effect of plasma density evolution
- understand effect of laser dump if any

could be part of Phase 1

Phase 3 Acceleration Studies with Rb ACC cell



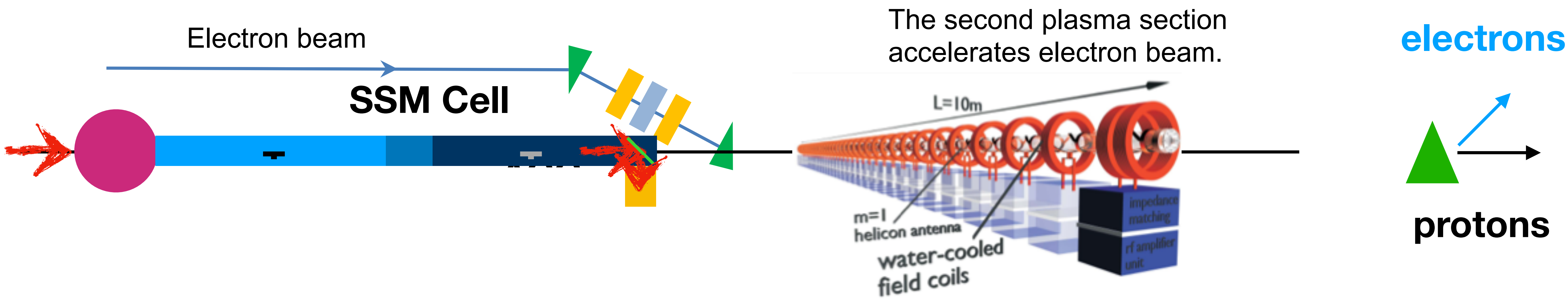
Differences to Run 1

- electrons merged in vacuum
- electrons pass through laser dump
- plasma pre-formed (ps-ns ahead of p bunch)
- second laser beam line

Questions

- effect of laser dump- on e beam?
- effect of pre-seed protons on wakes?
- what diagnostics still needed in merge region ?
- emittance diagnostics downstream?
- stronger dipole for e beam?
- laser beam line alignment?
- laser optics in proton beam?

Phase 4 Acceleration Studies alternative technology ACC cell



Goal: demonstrate that we have scalable plasma cell technology

- uniformity acceptable ?
- injection/density ramp at entrance ?
- how long do we need to set up infrastructure ?
- …