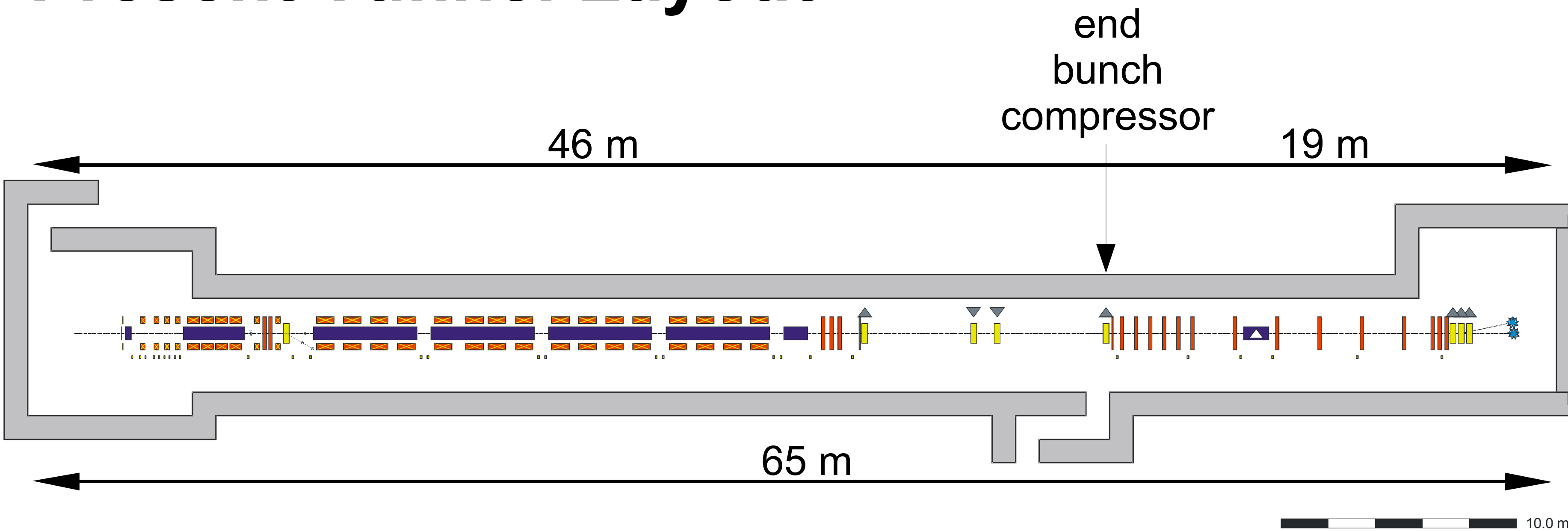
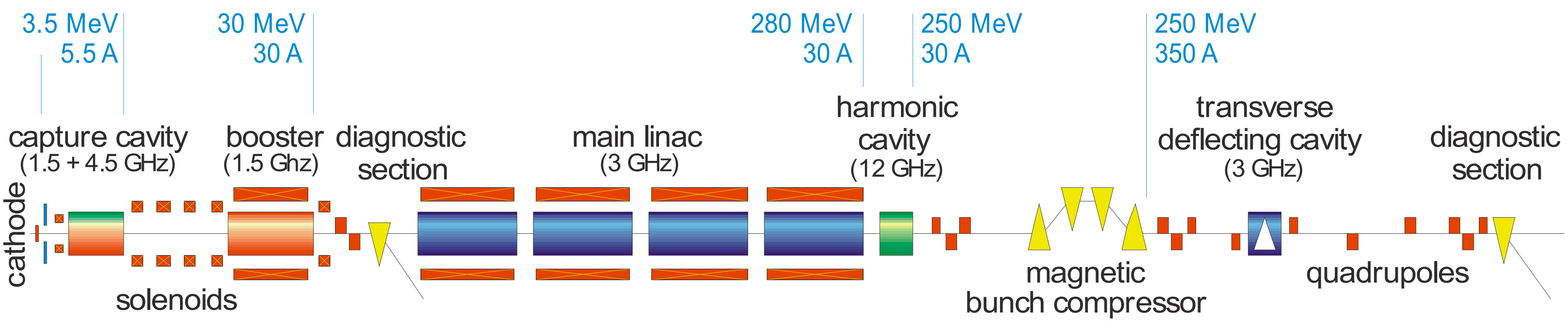
Issues

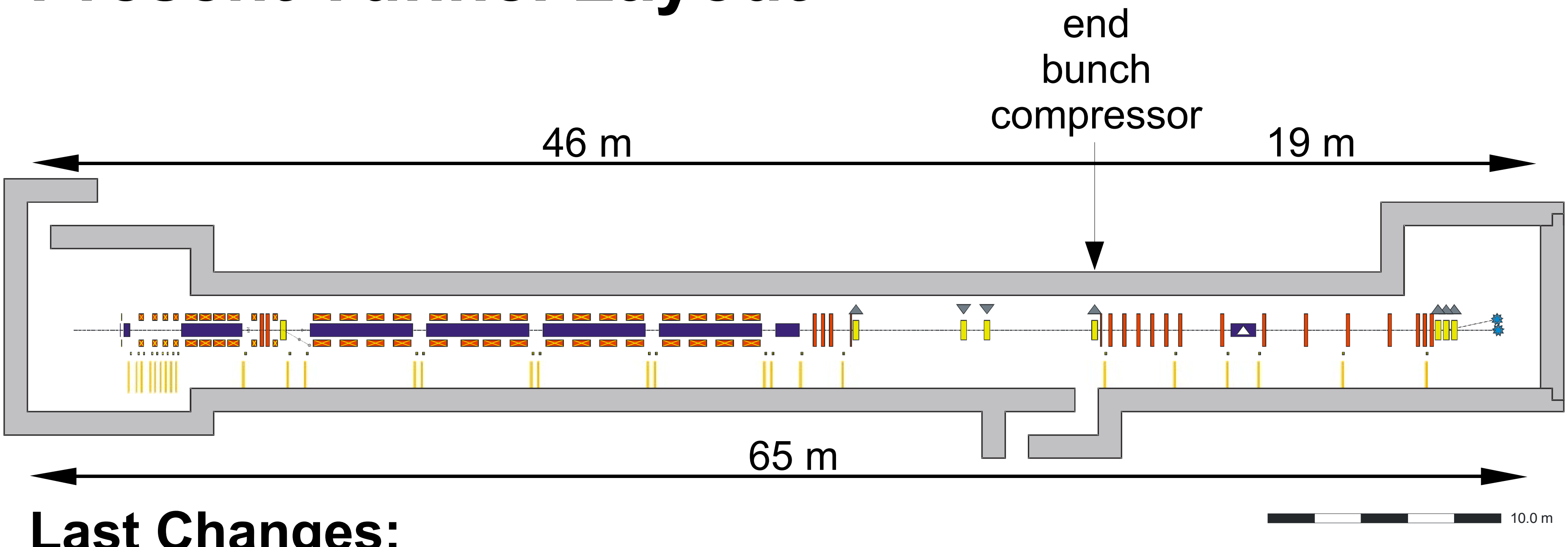
- Changes in the base layout
- Operational difficulties
- Alternative Sources and Topics to Investigate

Present Tunnel Layout





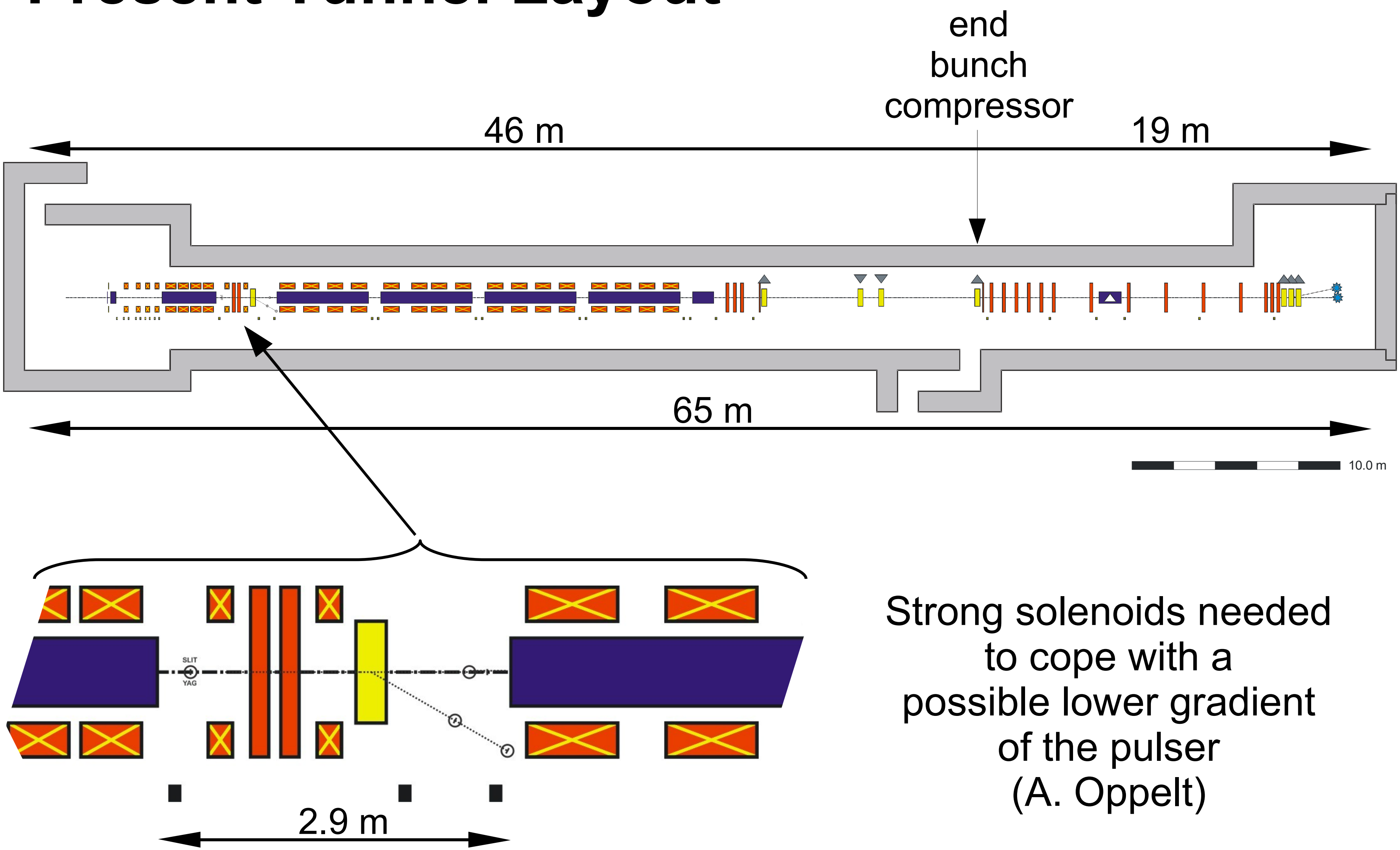
Present Tunnel Layout



Last Changes:

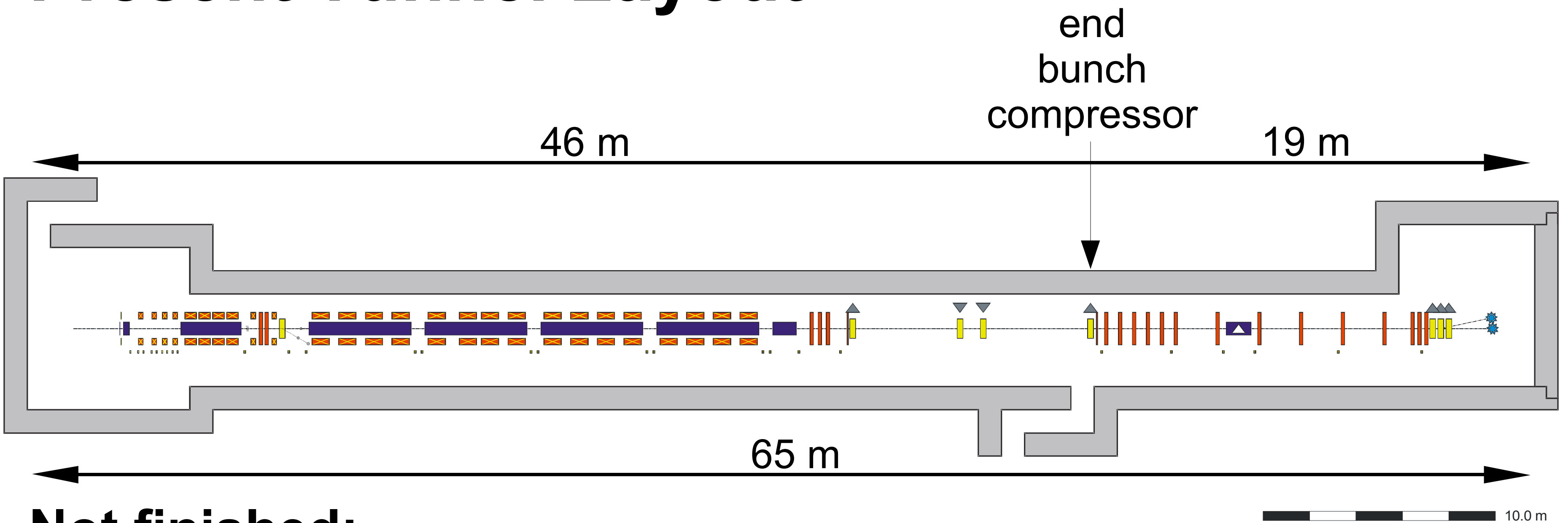
- Length of linac sections
  - 37 cell, 1.5 GHz TW linac
  - 132 cell, 3.0 GHz TW linac (internal load)
  - ~0.55 m between sections
- Corrector coils
  - 36 horizontal correctors
  - 28 vertical correctors
- Length of 30 MeV diagnostics (originally not included)

Present Tunnel Layout



Strong solenoids needed to cope with a possible lower gradient of the pulser (A. Oppelt)

Present Tunnel Layout



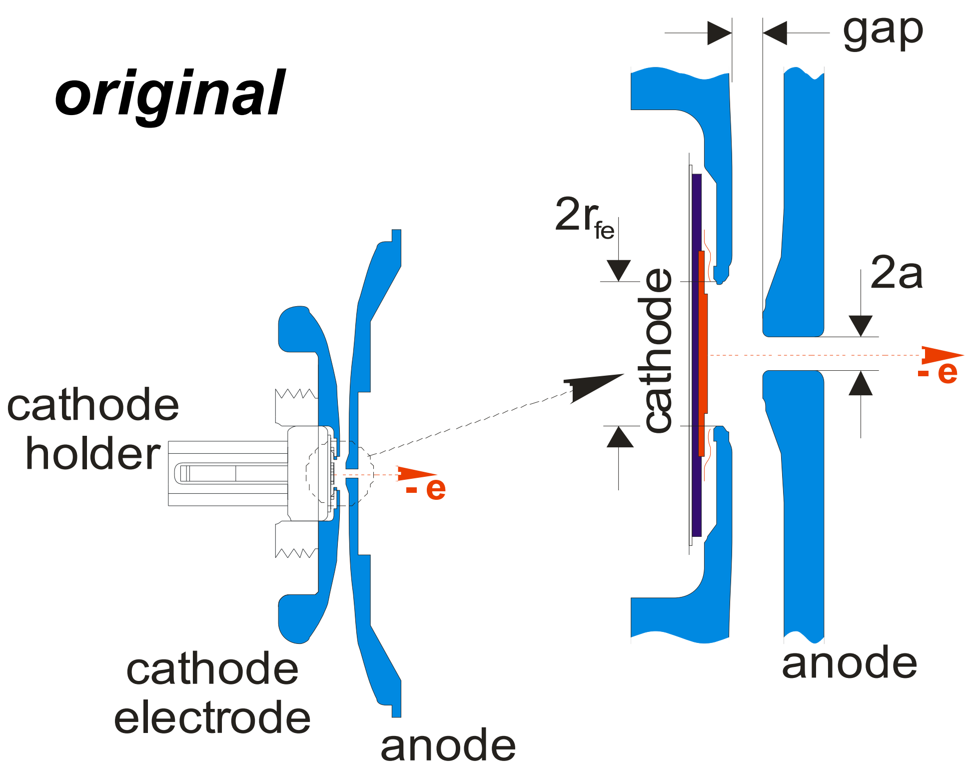
Not finished:

- 250 MeV diagnostic section
  - base design on paper
  - length and specs pending

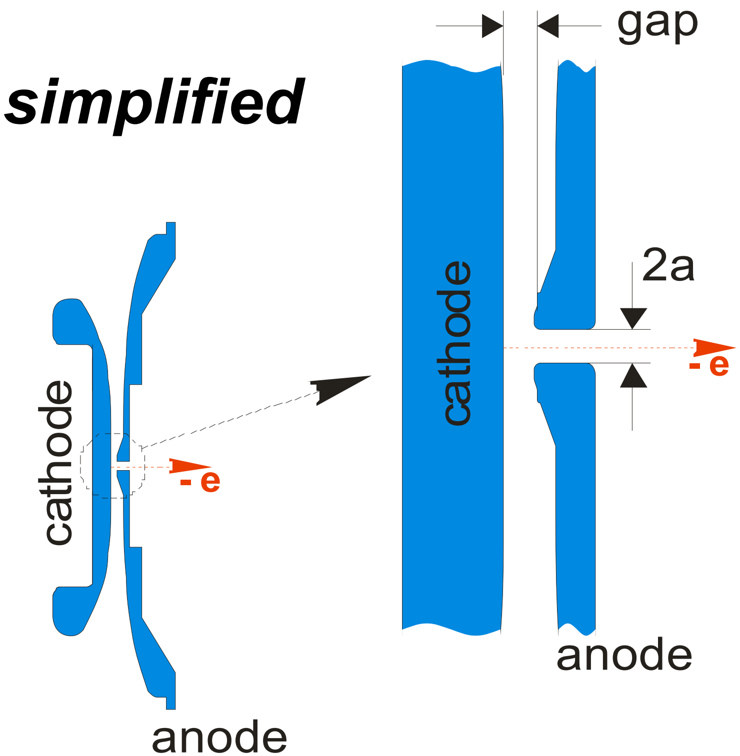
Previous Changes (1)

Cathode – Anode Geometry

original



simplified

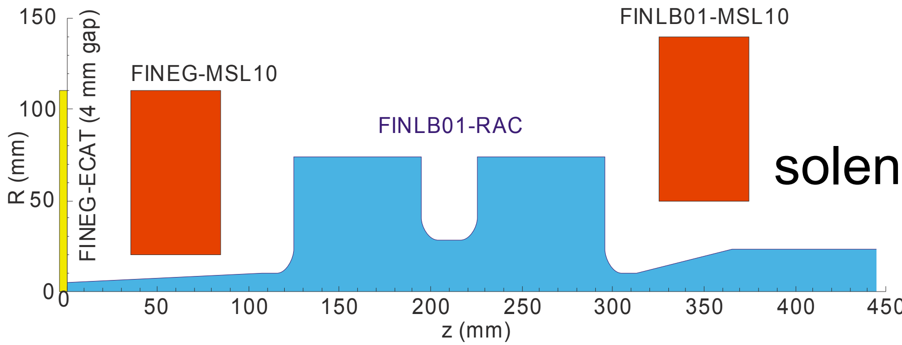


flat cathode → less focusing

Previous Changes (2)

2-cell standing wave cavity

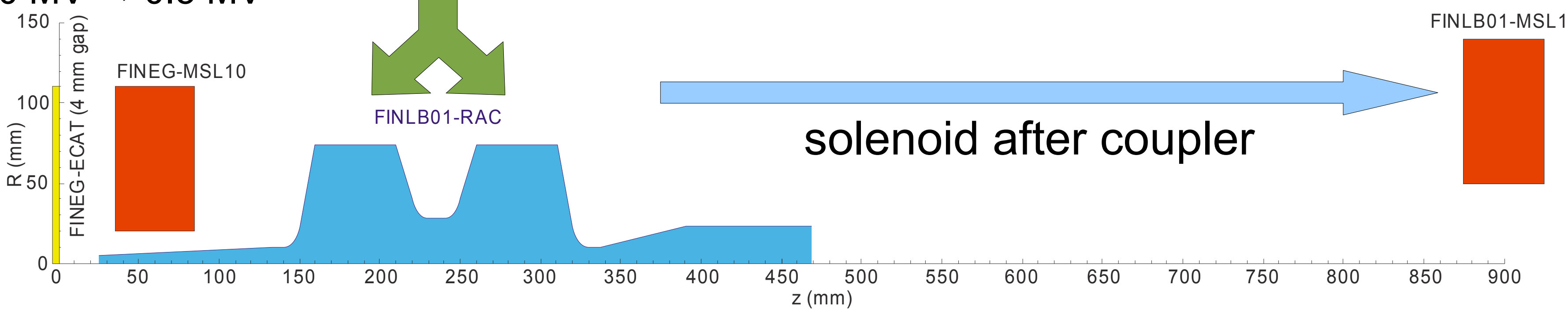
- less focusing
- reduced control over the longitudinal bunch-shape



solenoid around coupler

pulser voltage
1.0 MV → 0.5 MV

limit to harmonic field strength



solenoid after coupler

longer drift: 7.5 cm ► 12.5 cm ► 15.0 cm

Consequence of Changes:

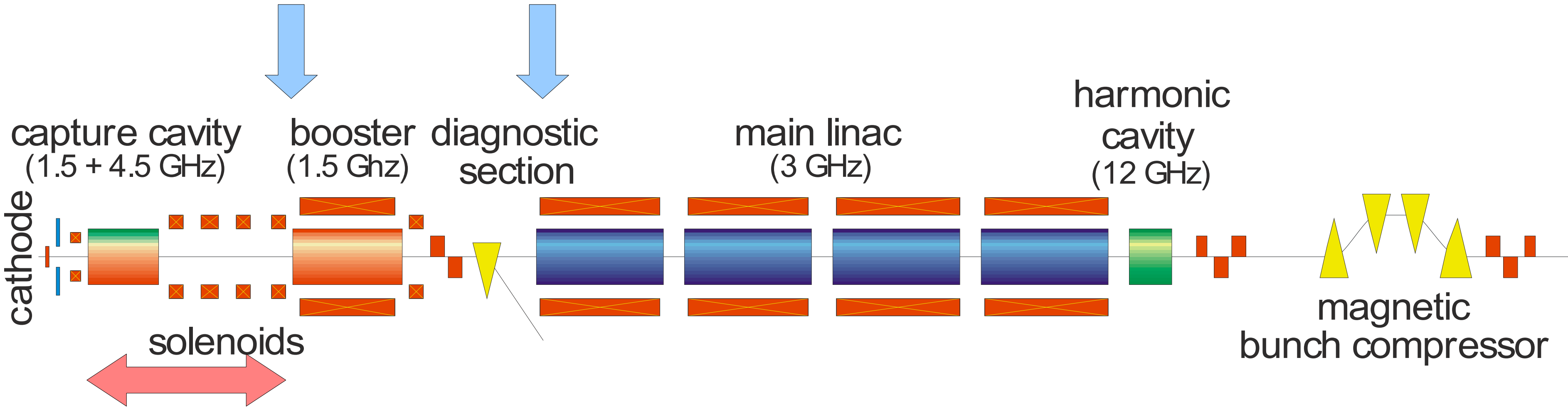
Difficult solution for the required beam-optics:

- 1 MV pulser @ 250 MV/m
  solution still OK

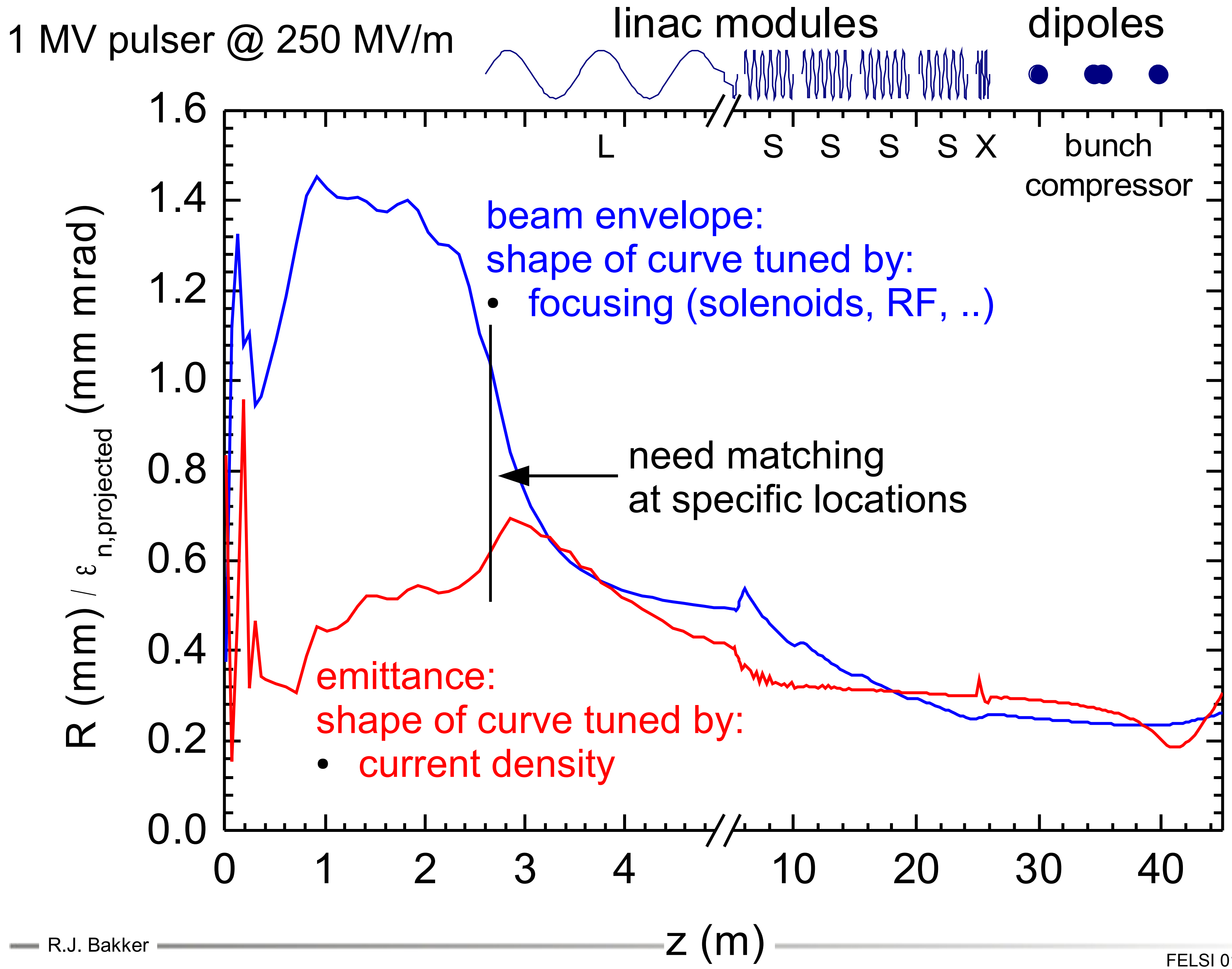
- 500 kV pulser @ 125 MV/m &
  500 kV pulser @ 90 MV/m (modified cathode)
  academic solution

Boundary Conditions
for a High Brightness Accelerator

emittance compensation
specific beam waist
emittance evolution



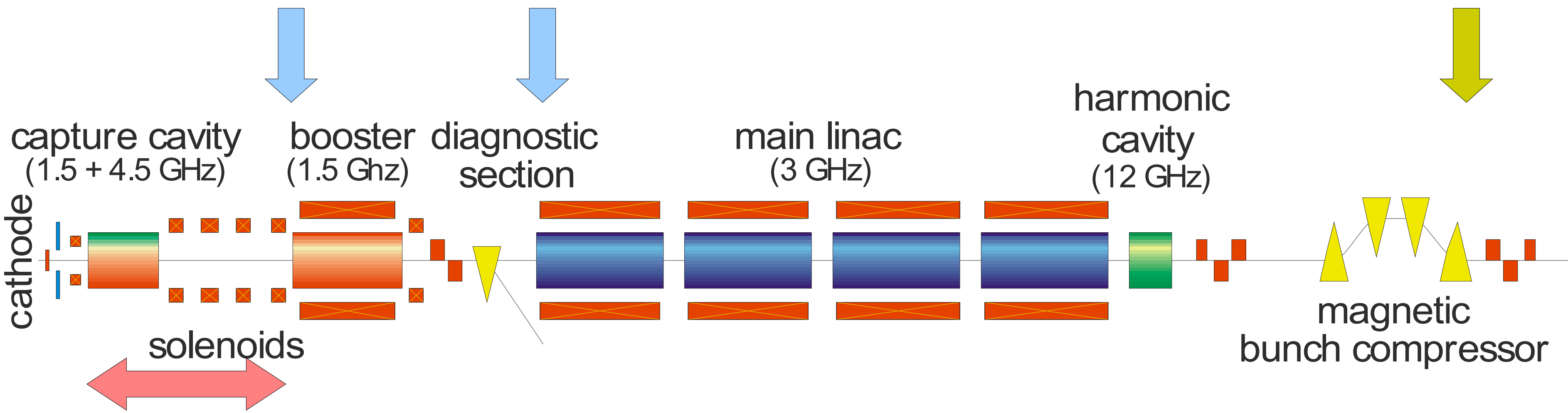
velocity bunching
beam energy
length


1 MV pulser @ 250 MV/m
linac modules
dipoles
L
S S S S X
bunch compressor
beam envelope:
shape of curve tuned by:
• focusing (solenoids, RF, ..)
need matching
at specific locations
emittance:
shape of curve tuned by:
• current density
R (mm) / $\varepsilon_{n,projected}$ (mm mrad)
z (m)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
10
20
30
40

Boundary Conditions
for a High Brightness Accelerator

emittance compensation
specific beam waist
emittance evolution

CSR
beam waist



velocity bunching
beam energy
length

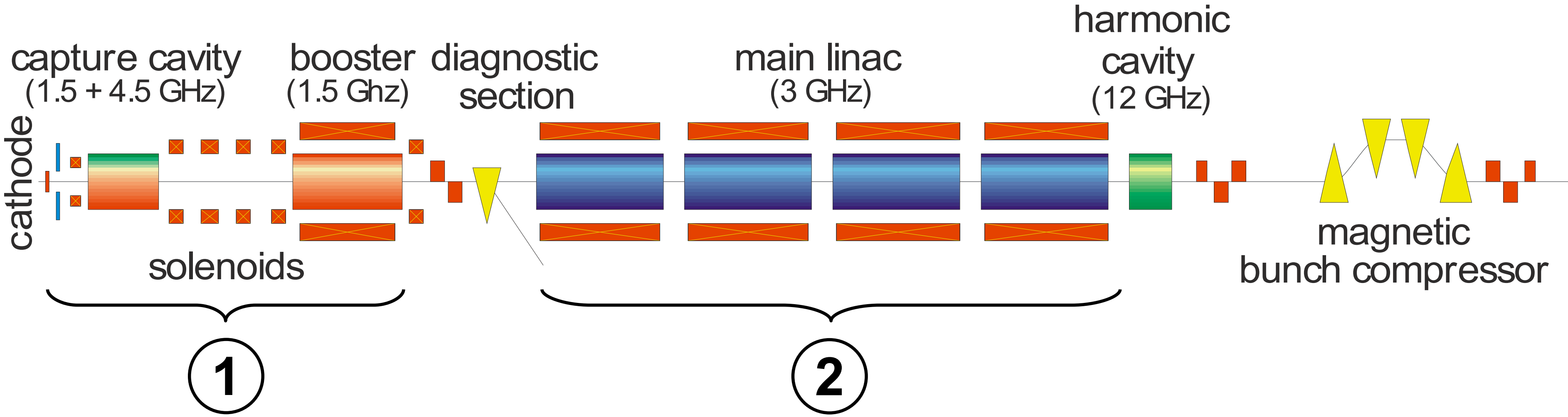
low emittance
tight window of permitted beam diameters

Approach

for the PSI XFEL 250 MeV Injector

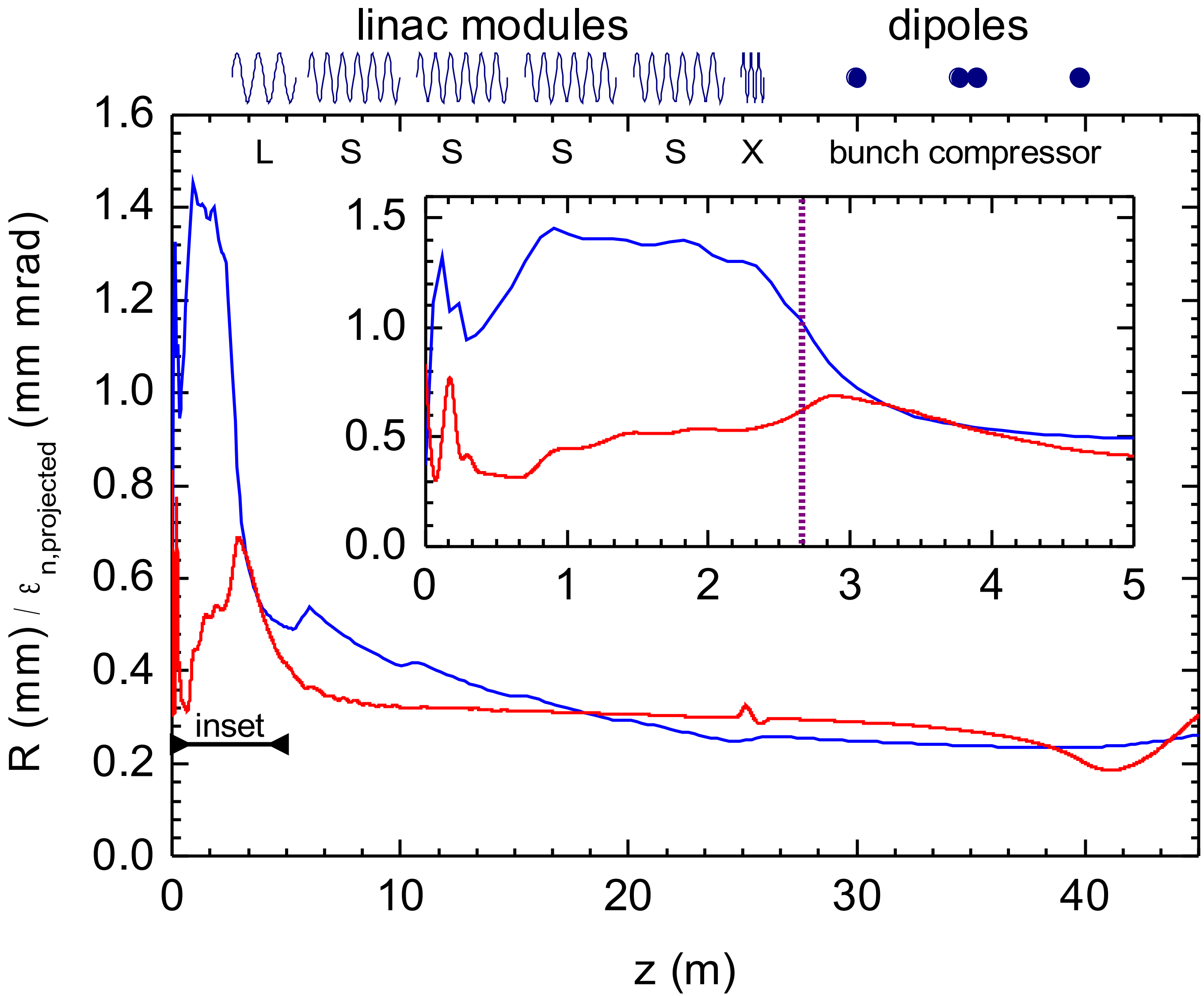
tune the beam optics to:

- a solution, which is close enough to the optimum solution (ε-comp.)
- still permits sufficient fine-tuning down-stream (CSR)

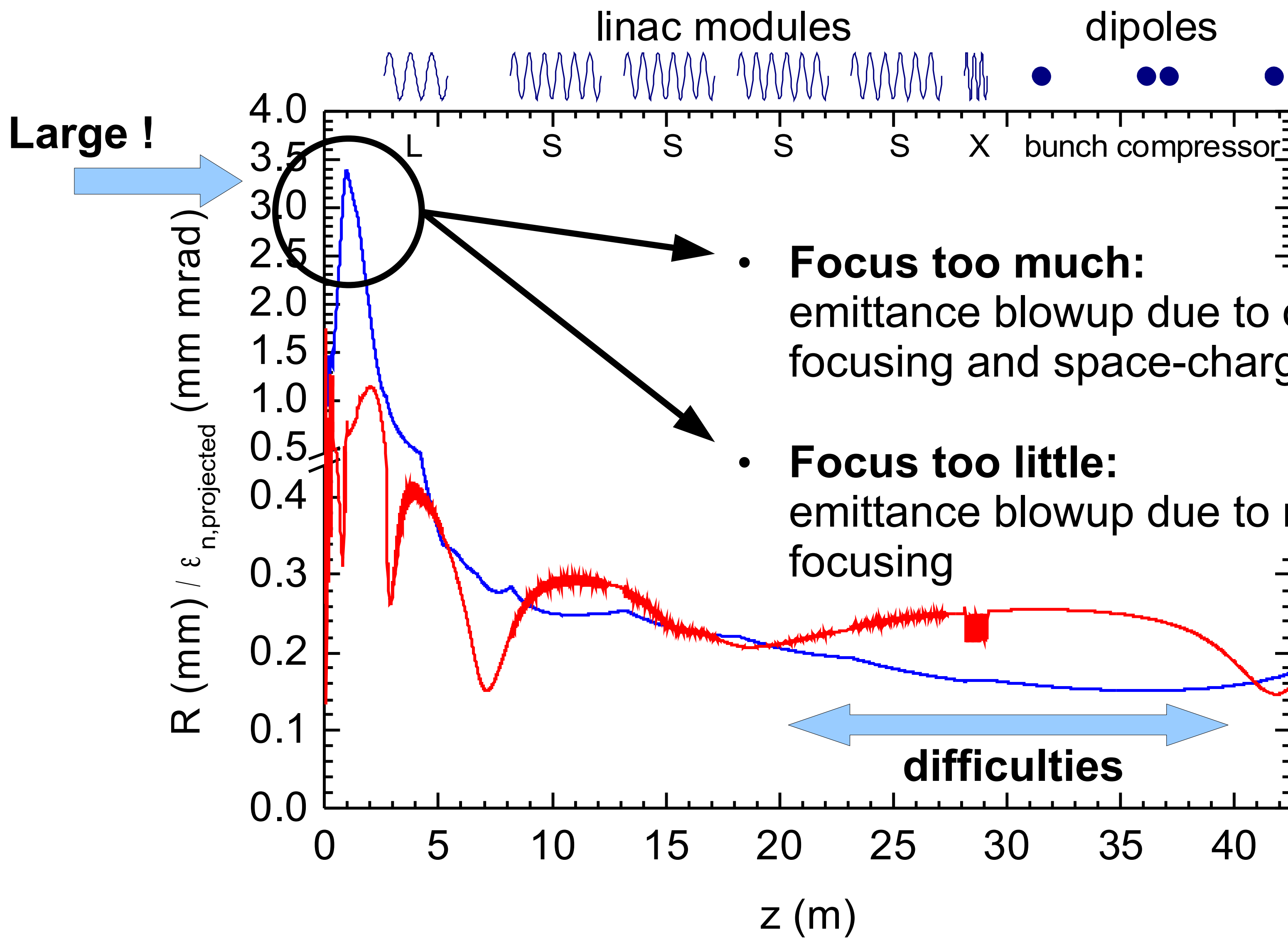


→ Approach is restrictive to the beam diameter close to the gun

Solution Oct 2007, 1 MV pulser @ 250 MV/m

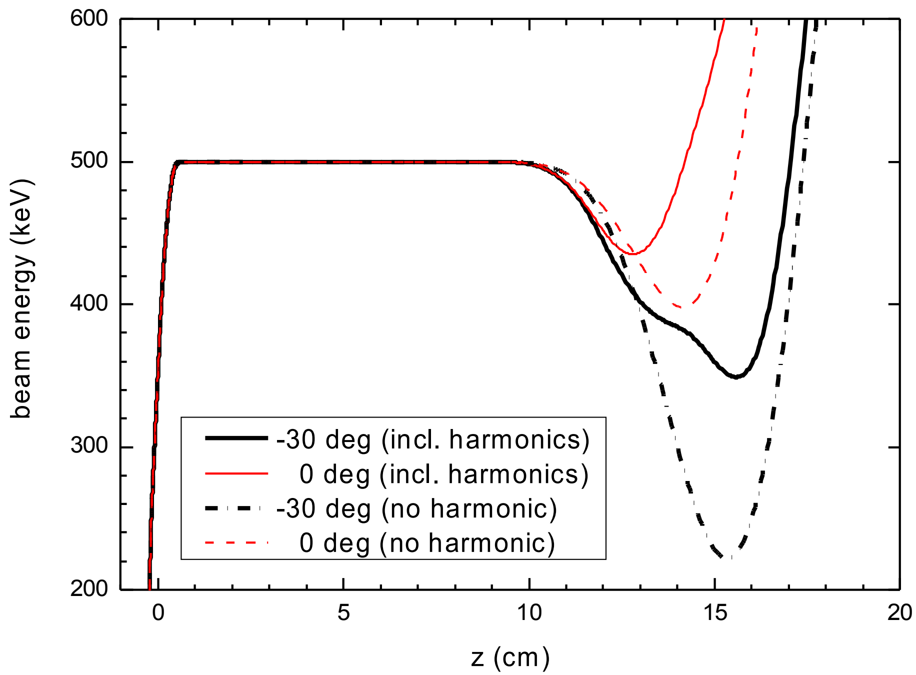


Solution March 2008: 500 kV @ 90 MV/m



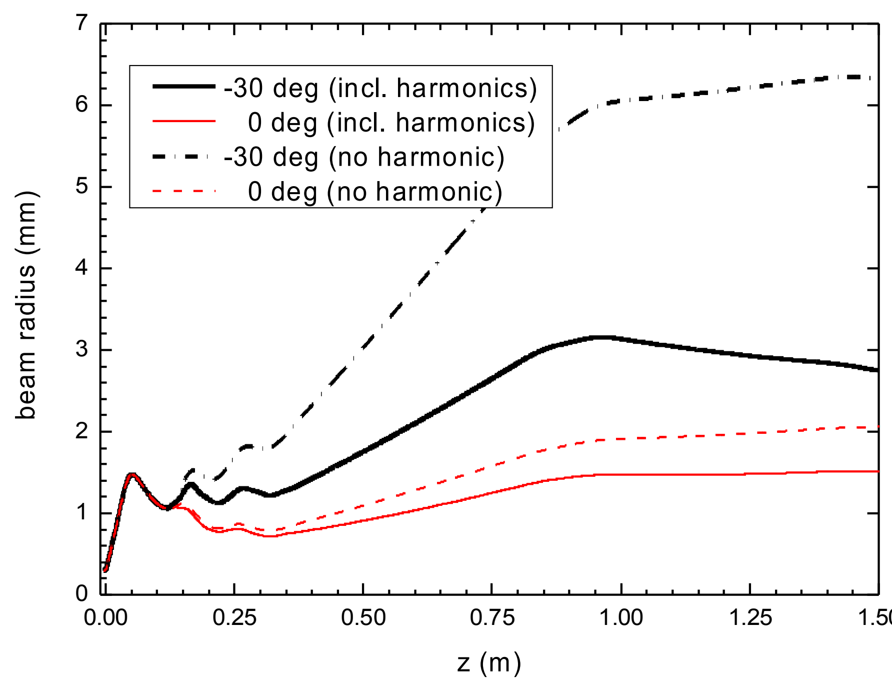
- **Focus too much:** emittance blowup due to over-focusing and space-charge
- **Focus too little:** emittance blowup due to non-linear focusing

Cause: Low Beam Energy after Pulser

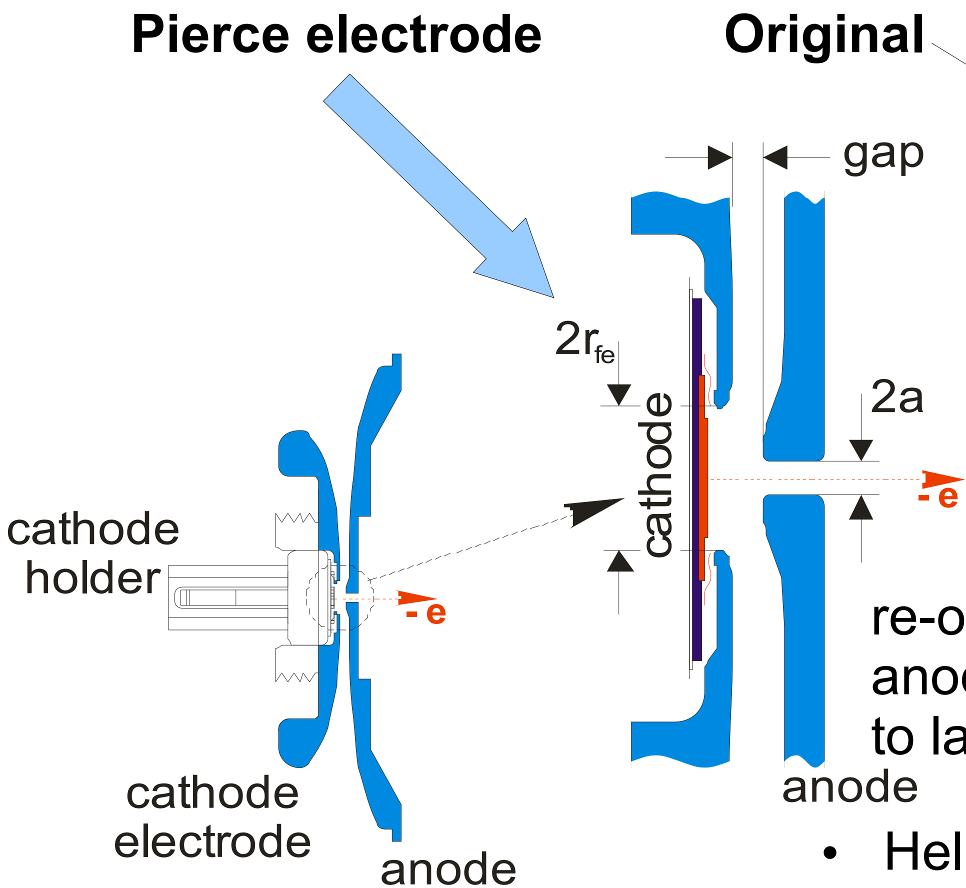


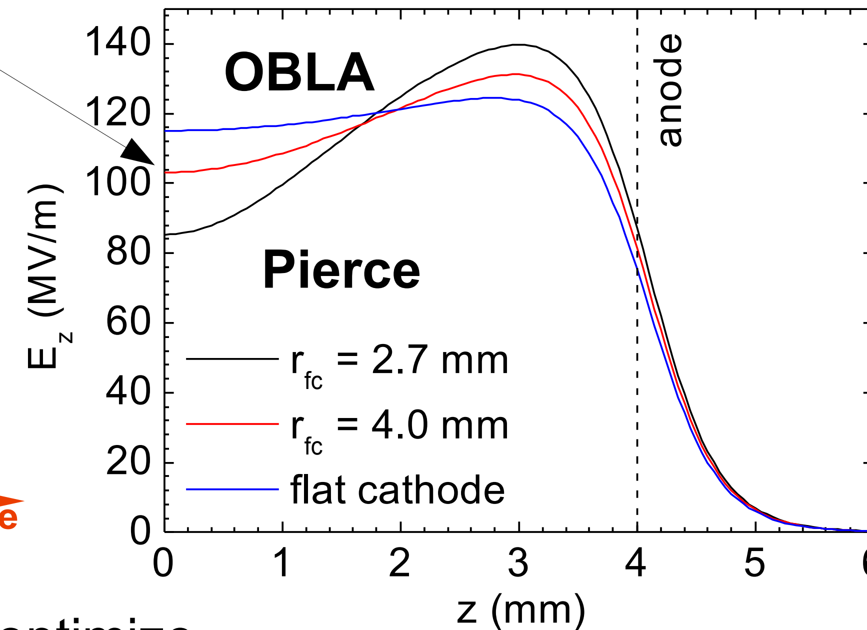
Difficult to compensate divergence since the first main solenoid is far downstream

Suggest to increase the voltage of the pulser to 1 MV, such that the effect is smaller on the relative scale (irrespective of gradient)



Coping with Lower Gradients

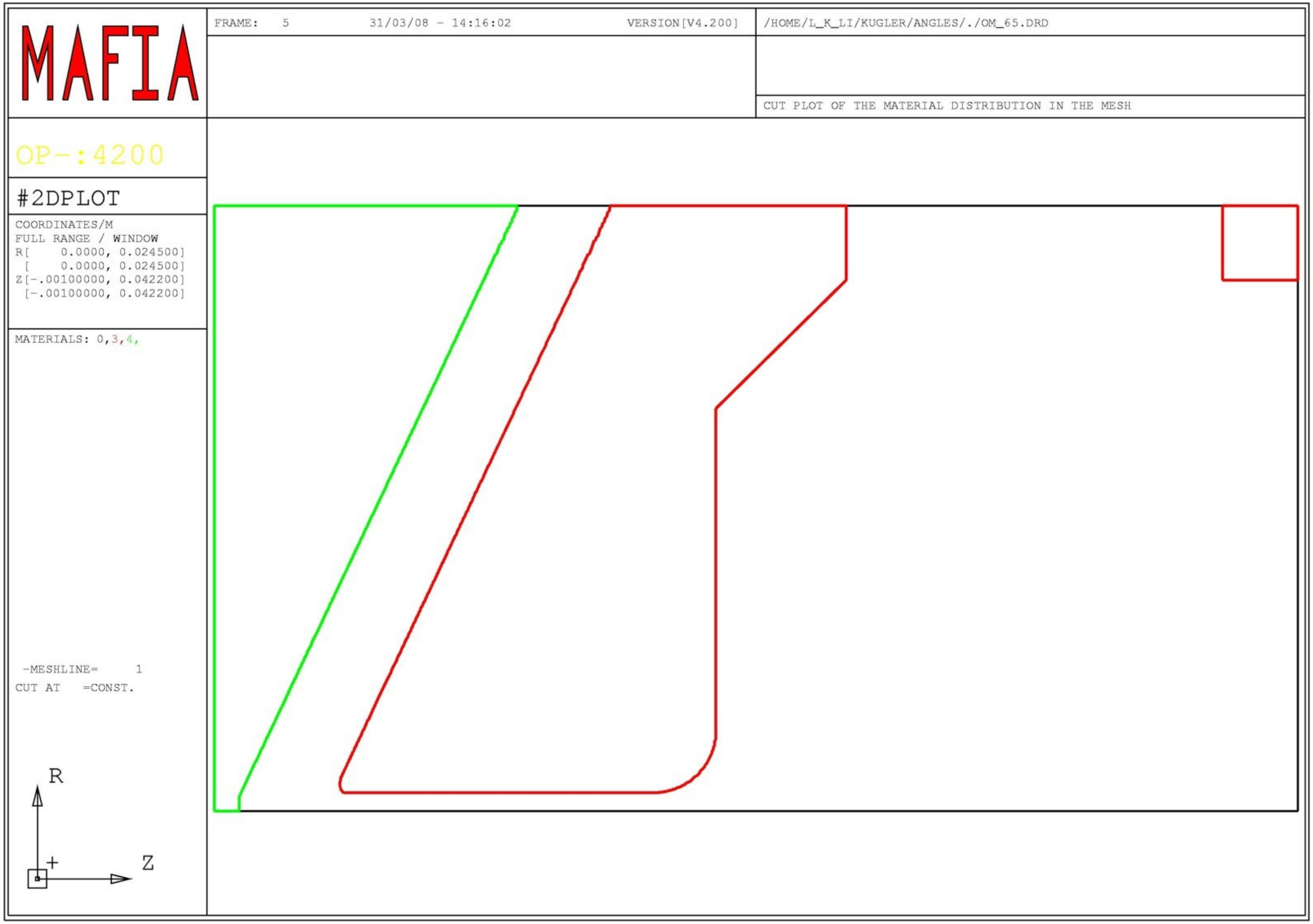


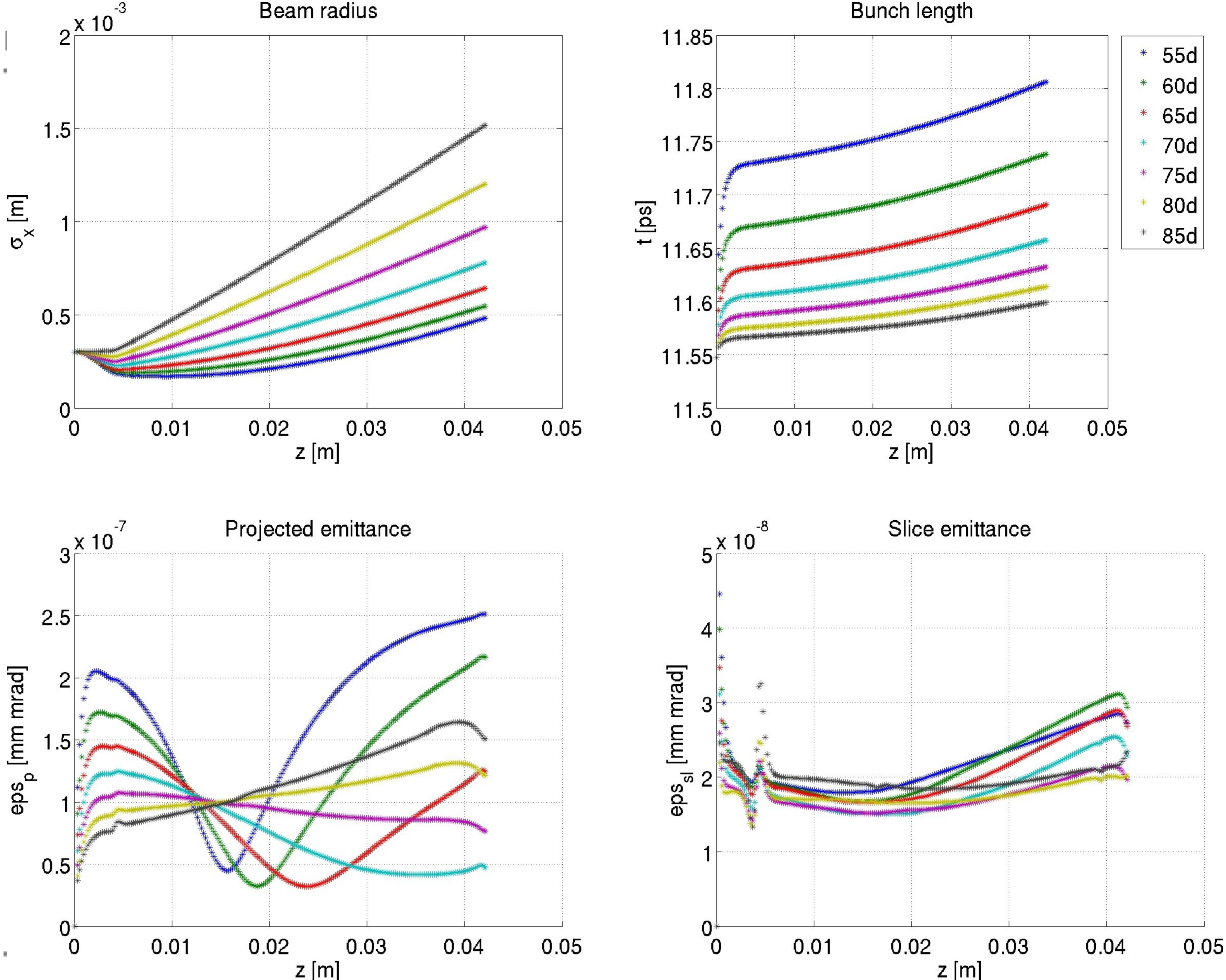


re-optimize anode iris to larger gap

- Helps to match the electron beam to the 2-cell RF cavity
- Still needs of pulsed solenoid behind the anode

More Detailed Studies (Kevin Li)





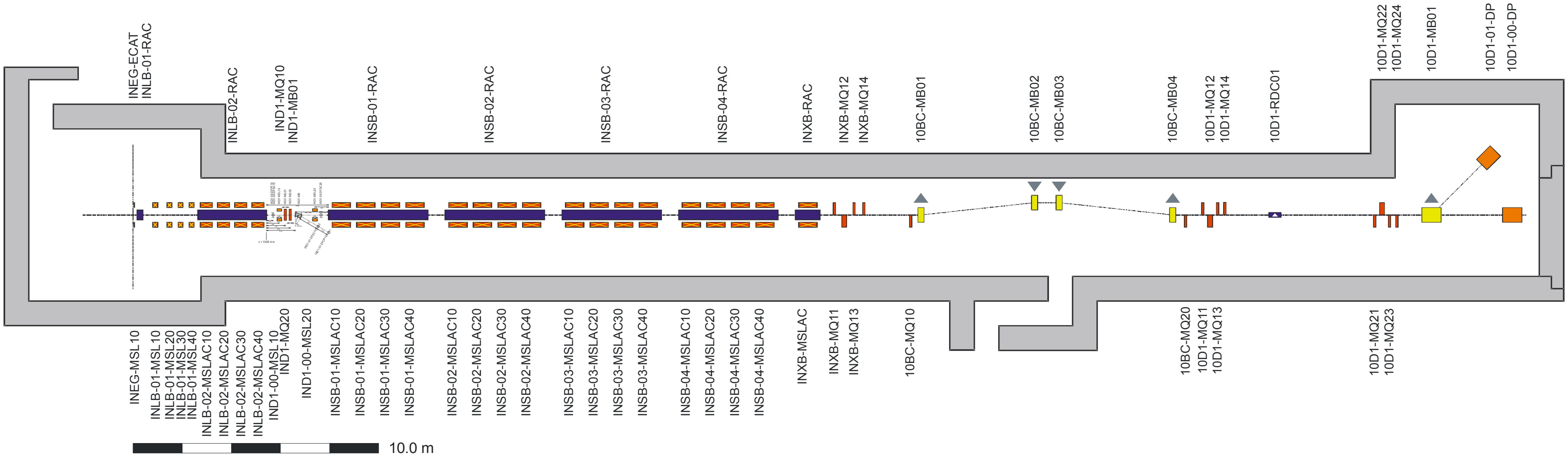
Beam radius
x 10^-3
σ_x [m]
z [m]
Bunch length
t [ps]
z [m]
55d
60d
65d
70d
75d
80d
85d
Projected emittance
x 10^-7
eps_p [mm mrad]
z [m]
Slice emittance
x 10^-8
eps_sl [mm mrad]
z [m]

Possible Solutions (Electron Source)

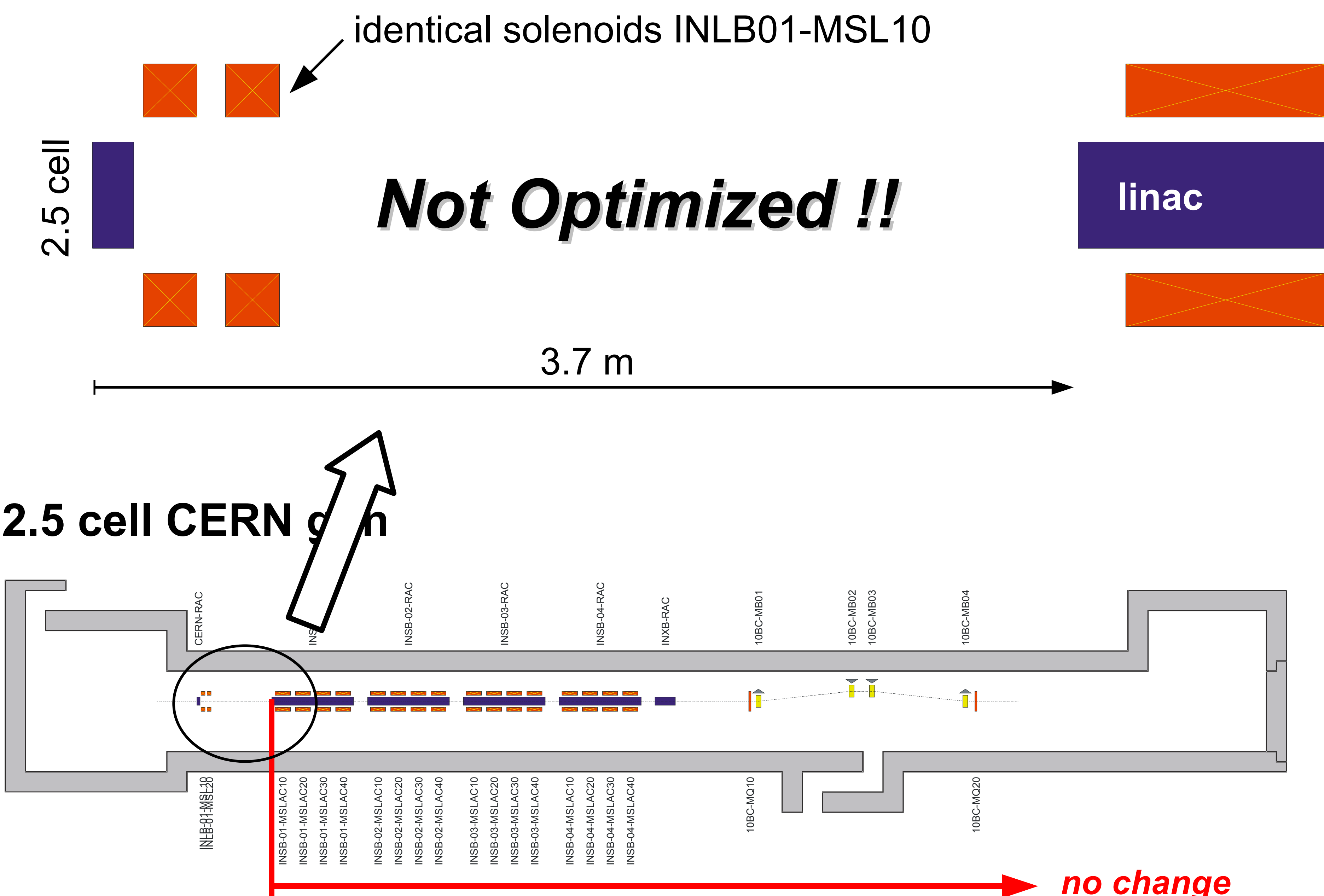
subject to discussion

- Present design with the pulser:
  - upgrade to 1 MV.
  - redesign of the anode/cathode geometry, based on a realistic gradient.
- RF photo-cathode
  - 2.5 cell S-band (CERN design, available)
  - 1.5 cell S-band (copy of LCLS, SPARC, Elettra ......)
  - 1.5 cell 2-frequency (J-Y. Raguin)

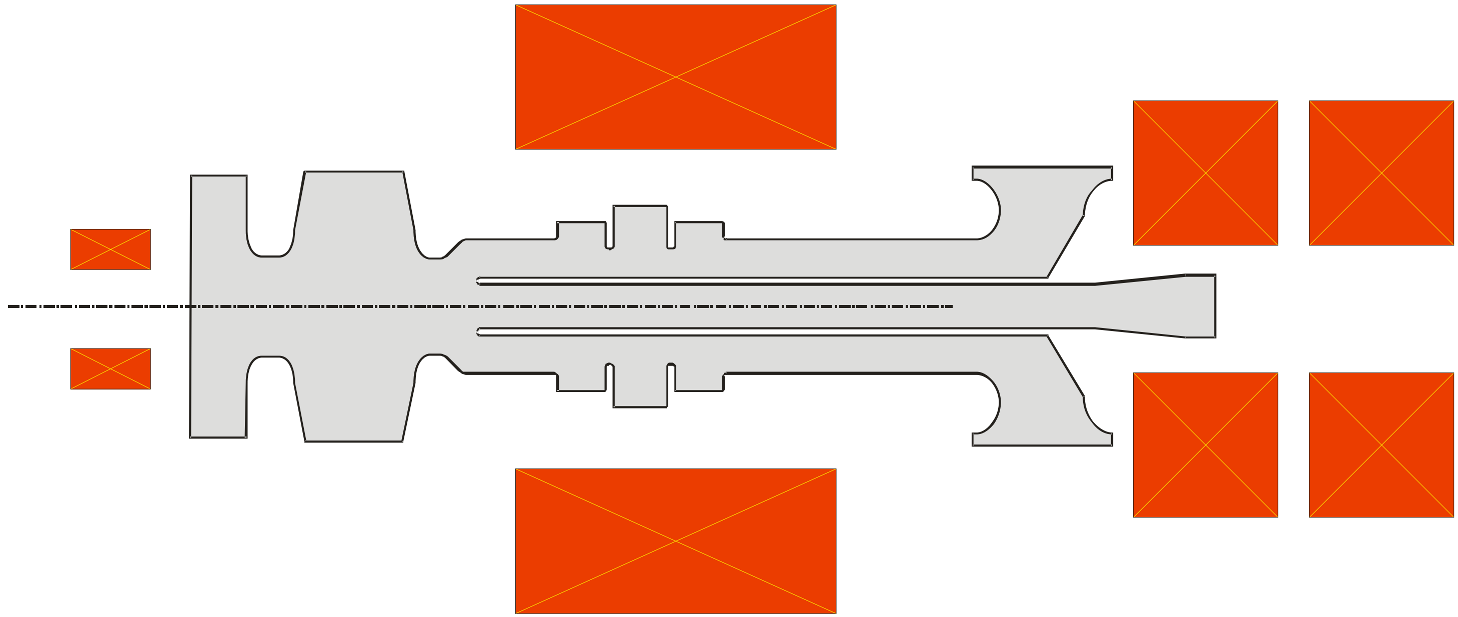
Default Design & 1.5 cell, 2-frequency design

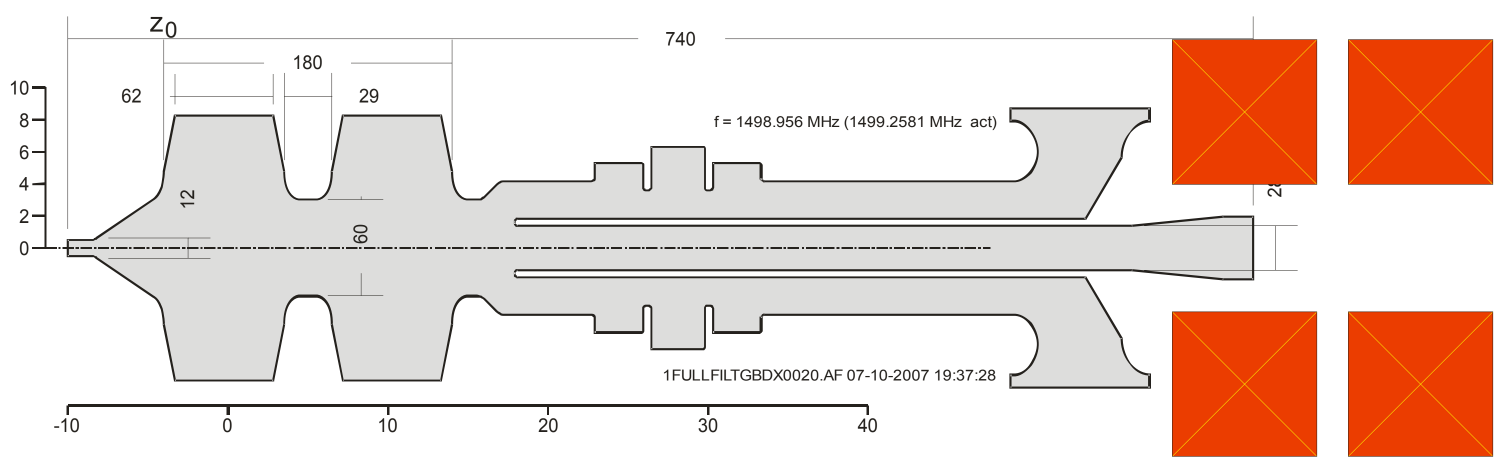


2.5 cell CERN gun


identical solenoids INLB01-MSL10
2.5 cell
Not Optimized !!
linac
3.7 m
2.5 cell CERN gun
CERN-RAC
INS
INSB-02-RAC
INSB-03-RAC
INSB-04-RAC
INXB-RAC
10BC-MB01
10BC-MB02
10BC-MB03
10BC-MB04
INLB-01-MSL10
INLB-01-MSL20
INSB-01-MSLAC10
INSB-01-MSLAC20
INSB-01-MSLAC30
INSB-01-MSLAC40
INSB-02-MSLAC10
INSB-02-MSLAC20
INSB-02-MSLAC30
INSB-02-MSLAC40
INSB-03-MSLAC10
INSB-03-MSLAC20
INSB-03-MSLAC30
INSB-03-MSLAC40
INSB-04-MSLAC10
INSB-04-MSLAC20
INSB-04-MSLAC30
INSB-04-MSLAC40
10BC-MQ10
10BC-MQ20
no change

1.5 Cell, 2-Frequency Gun





Source Specifications (Pulser)

500 kV

- Source
  - Q = 200 pC
  - I = 5.5 A
  - R = 0.30 mm
  - ε_n = 0.1 mm mrad
- Pulser
  - G = 90 - 125 MV/m
- RF
  - 1.5 GHz: 40 MV/m
  - 4.5 GHz: <u>15 MV/m</u>

1000 kV

- Source
  - Q = 200 pC
  - I = 5.5 A
  - R = 0.30 mm
  - ε_n = 0.1 mm mrad
- Pulser
  - G = 70 - <u>250 MV/m</u>
- RF
  - 1.5 GHz: 35 MV/m
  - 4.5 GHz: <u>15 MV/m</u>

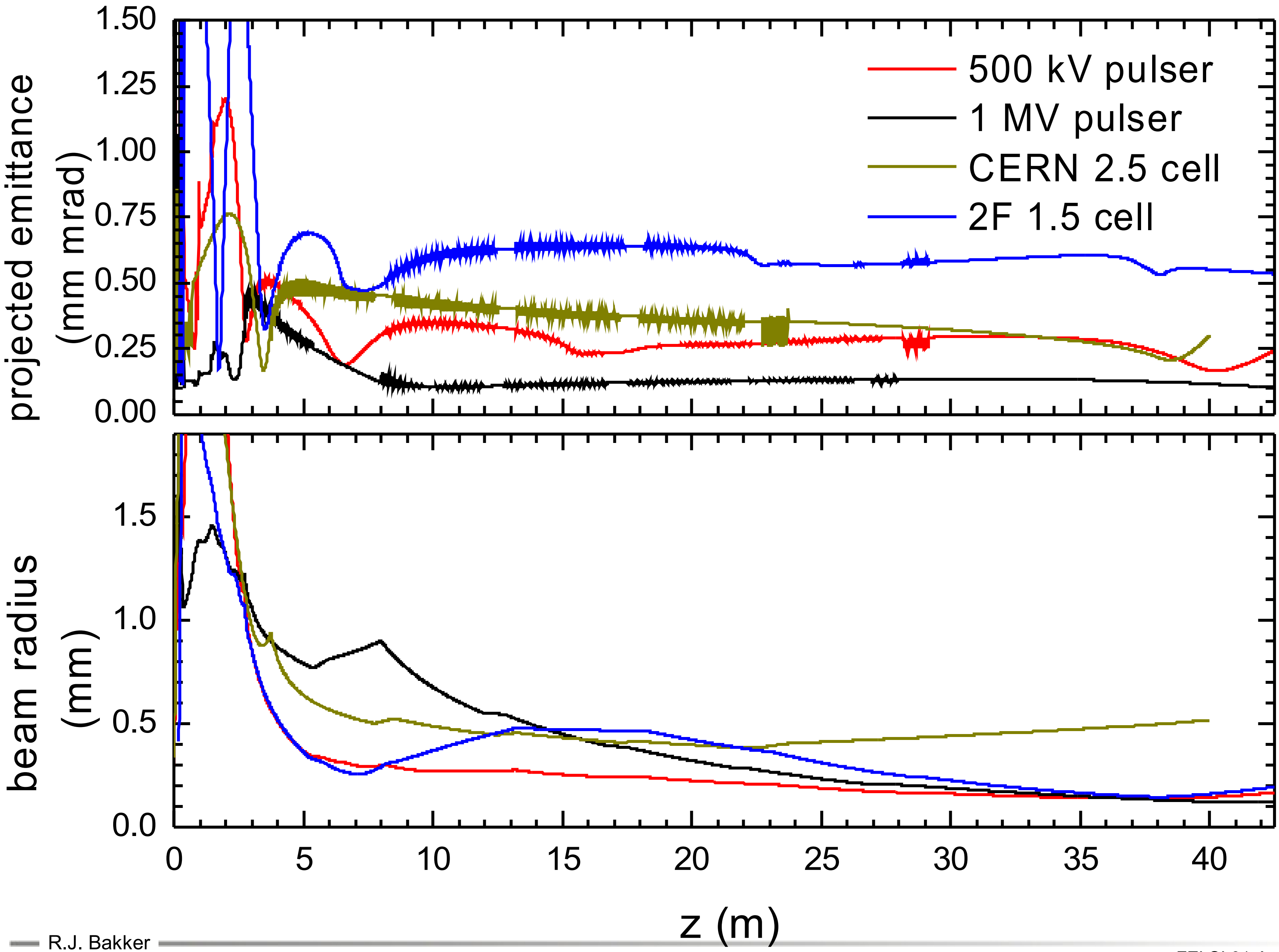
Source Specifications (RF Photo Cathode)

1F Cavity

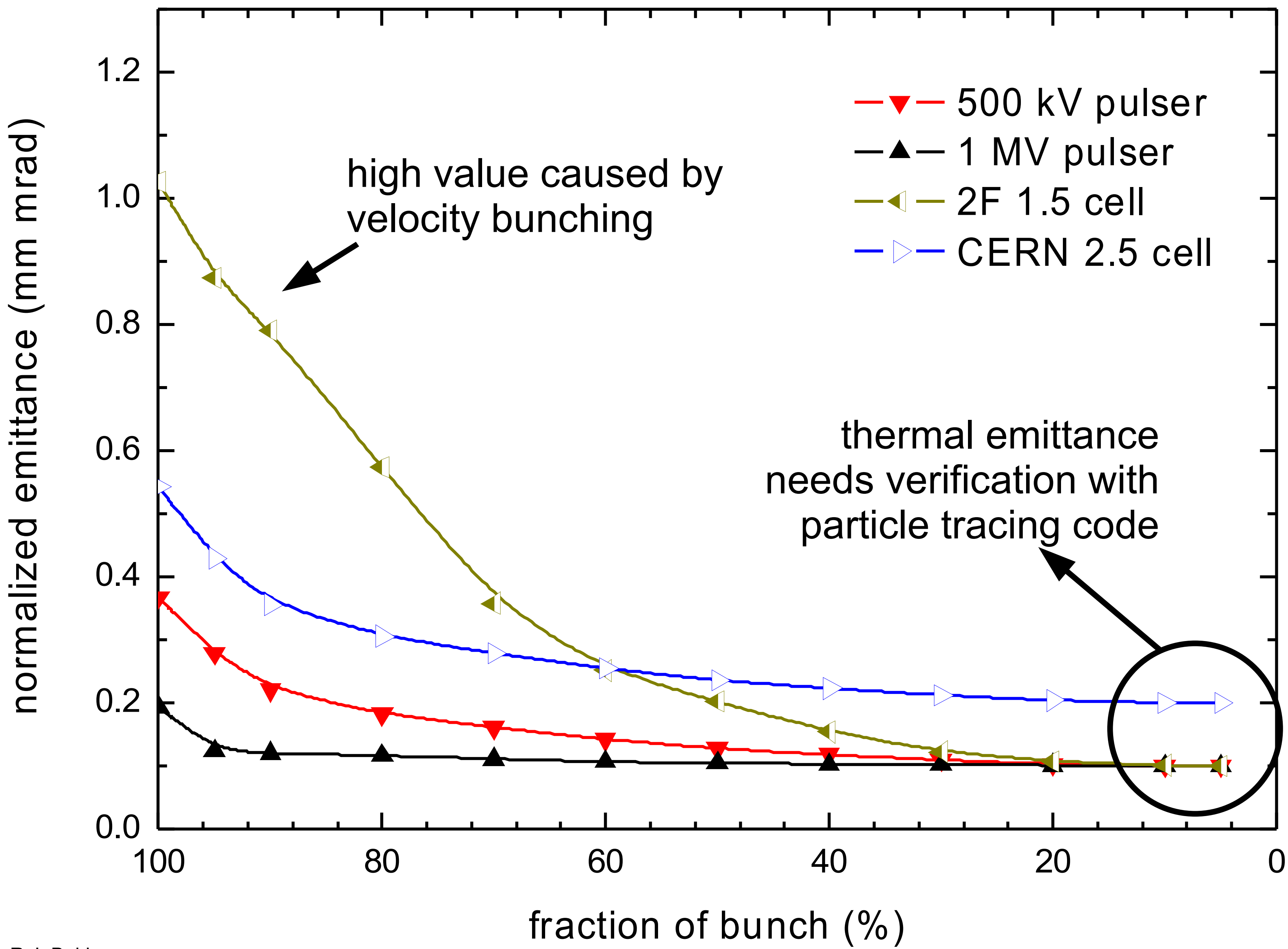
- Source
  - Q = 200 pC
  - I = 20 A
  - R = 0.50 mm
  - ε_n = 0.2 mm mrad
- Existing design
- RF
  - 3.0 GHz: 100 MV/m

2F Cavity

- Source
  - Q = 200 pC
  - I = 7.0 A
  - R = 0.30 mm
  - ε_n = 0.1 mm mrad
- Preliminary design
- RF
  - 1.5 GHz: 60 MV/m
  - 4.5 GHz: 30 MV/m



1.50
1.25
1.00
0.75
0.50
0.25
0.00
projected emittance
(mm mrad)
500 kV pulser
1 MV pulser
CERN 2.5 cell
2F 1.5 cell
1.5
1.0
0.5
0.0
beam radius
(mm)
0
5
10
15
20
25
30
35
40
z (m)


normalized emittance (mm mrad)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
100
80
60
40
20
0
fraction of bunch (%)
500 kV pulser
1 MV pulser
2F 1.5 cell
CERN 2.5 cell
high value caused by velocity bunching
thermal emittance needs verification with particle tracing code

Pulser vs. RF Photo-Cathode

Pulser	1F RF photo-cathode	2F RF photo-cathode
✔ large flexibility in beam manipulation	✔ availability	✔ thermal emittance (velocity bunching)
✔ projected emittance relatively close to slice emittance	✔ stability	✔ longitudinal bunch-shape
✔ low thermal emittance	• projected emittance not too far from slice emittance	✗ no field-emitters
		✗ projected emittance
✗ availability (needs 1 MV)	✗ no field-emitters	✗ availability
✗ stability ?	✗ thermal emittance (no velocity bunching)	✗ stability ?

limited simulation results (1F and 2F RF photo-cathode)

Strategy under Consideration

- Development of two injector designs, to be tested in WLHA in sequential order:
  - Intermediate emittance source, possibly with a charge up to 1 nC (for 10 – 1 nm FEL):
    - 2.5 Cell CERN gun?
  - Ultimate low-emittance gun
    - 1 MV pulser + 2 cell, 2-frequency cavity
      - availability ?
      - wakes < 30 MeV ?
    - 1.5 cell, 2-frequency cavity
      - real performance analyses
      - availability and design ?