A LINAC DRIVER FOR BRAFEL

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BRAFEL Beam Requirements

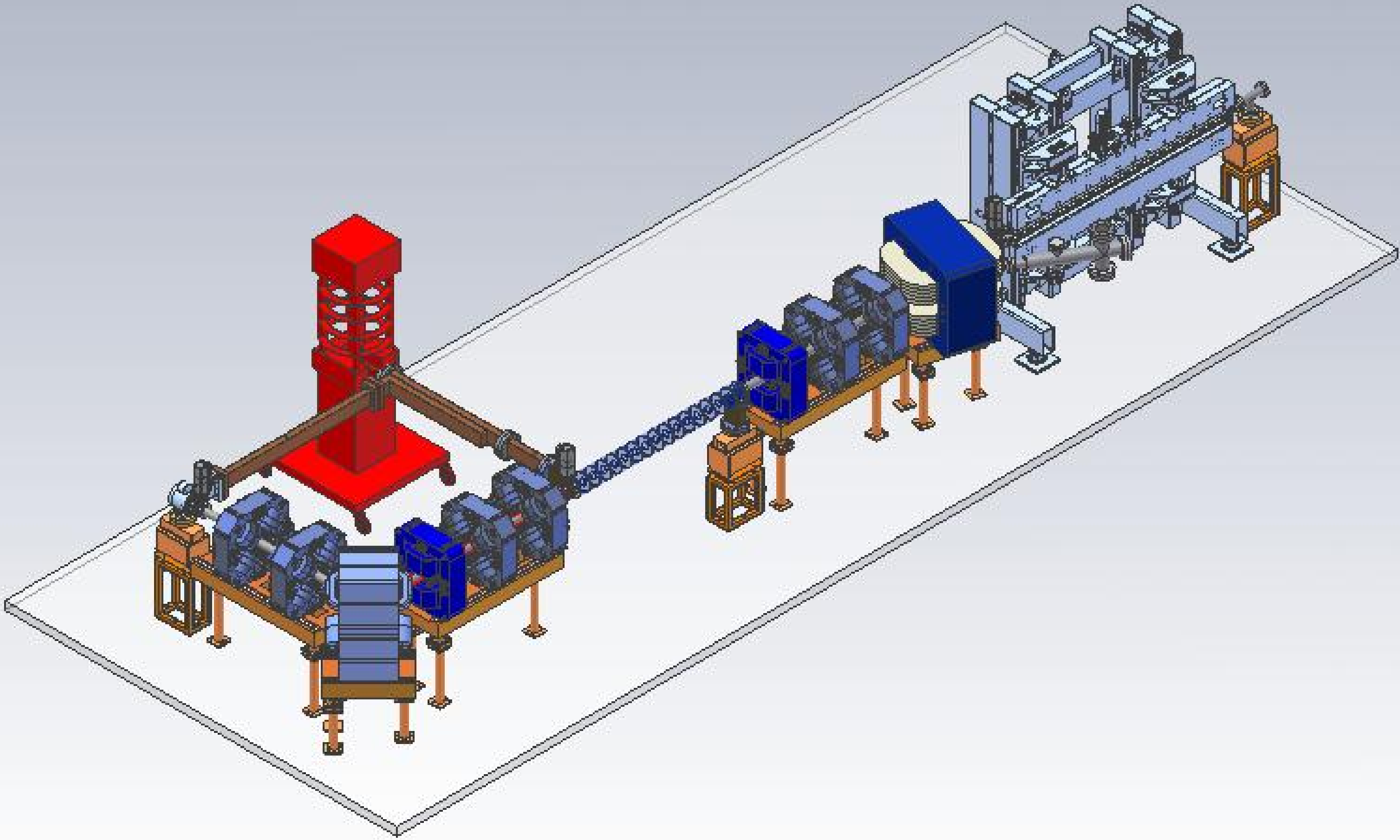
- The following beam parameters:
  - Beam Energy: 8.5 MeV
  - Bunch Length : 100 fs
  - MicroPulse Current: > 70 A
  - Relative momentum spread: <1%
  - Transverse Emittance: 40 mm mrad
- Will produce radiation at 100 μm from an undulator with 3 cm long period and 0.47 T peak field.

Here we present a preliminary proposal of a linear accelerator that can produce such a beam

Overall Machine Concept

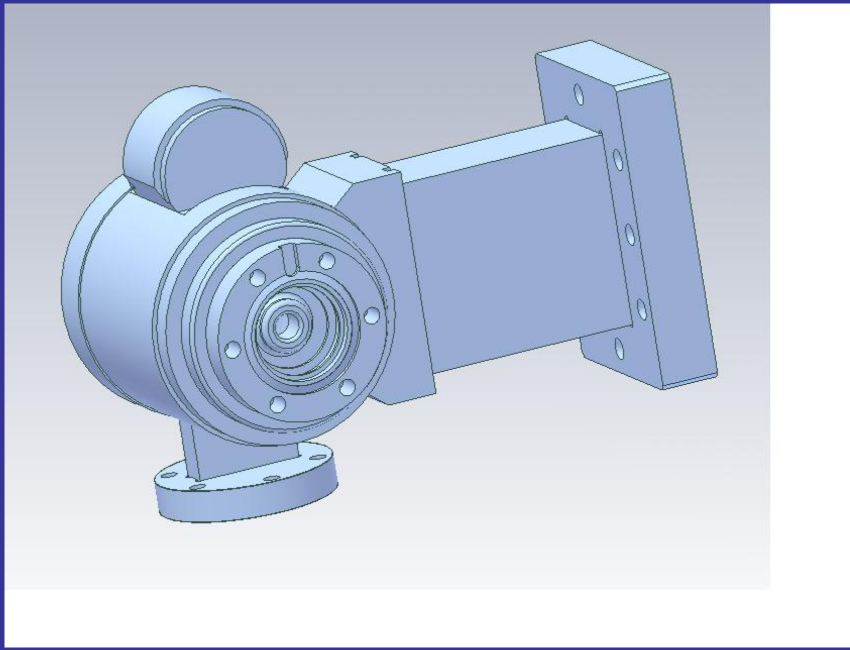
- Electron source: RF gun with thermionic cathode: ***simple, cheap***
- Compression System: Alpha Magnet: ***adequate for low energy, moderate intensity beams.***
- Accelerator: Travelling Wave LINAC:

Machine LayOut

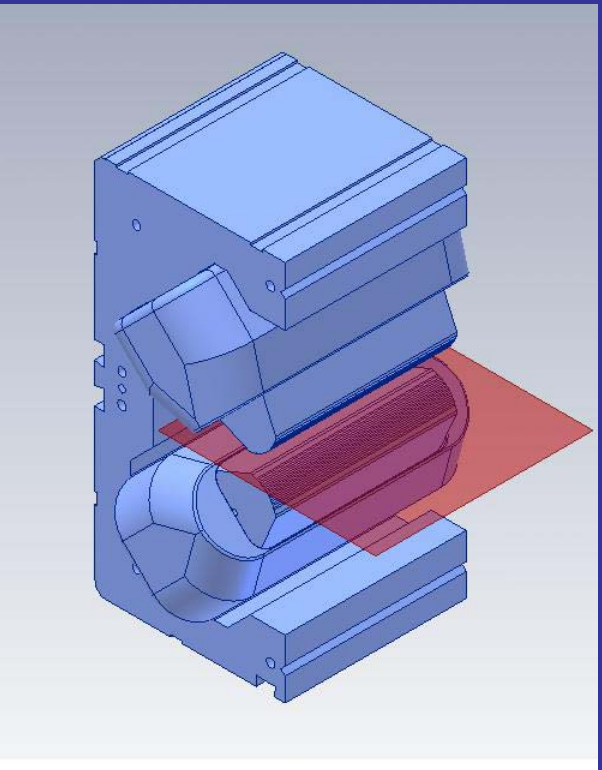


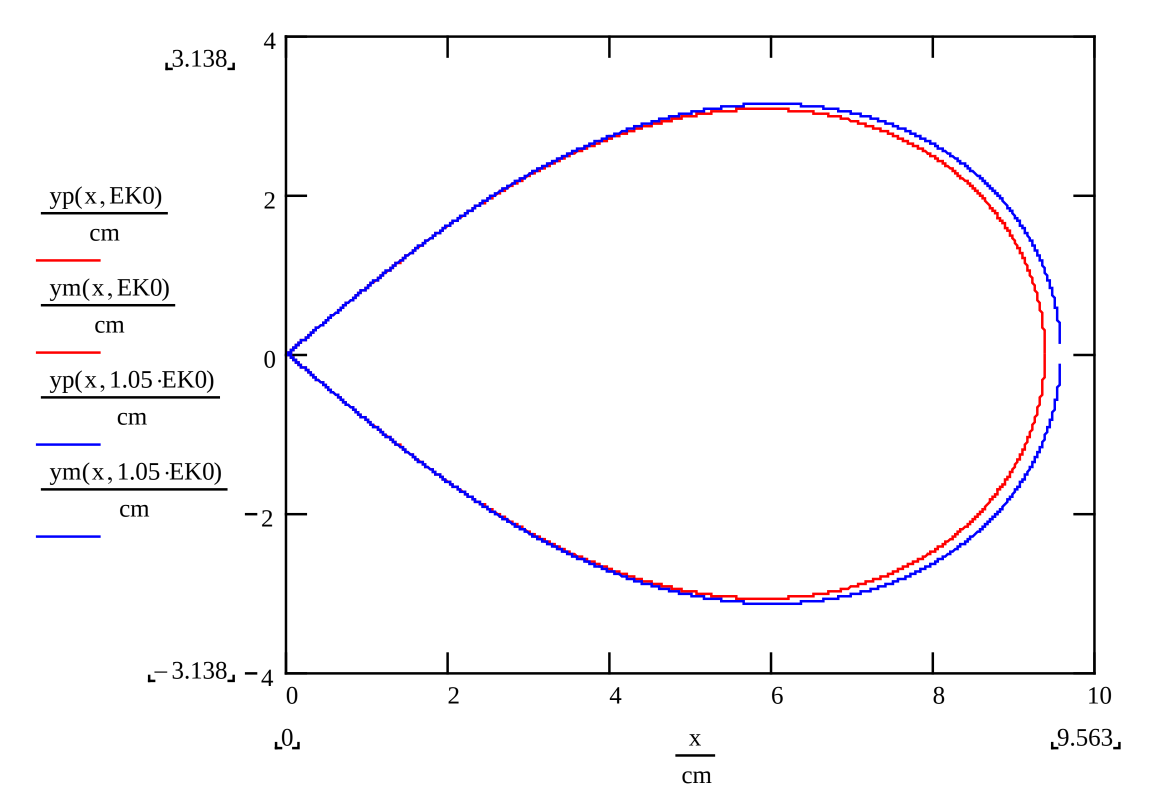
The RF Gun

Electron RF Gun		
Cathode Type	Thermionic Dispenser Cathode (no grid)	
Cathode Radius	3	mm
Gun Type	1+1/2 cavity standing wave RF Gun with side coupling (pi/2 mode)	
Gun Input Peak RF Power (no beam)	0.40	MW
Nominal Field amplitude in first cell	29.2	MV/m
Nominal Field amplitude in second cell	67.6	MV/m
First Cavity Effective Length	1.5	cm
Second Cavity Effective Length	2.7	cm
Energy Gain (first cavity)	0.4	MeV
Energy Gain (second cavity)	1.8	MeV
Quality factor (first cavity)	15000.0	
Quality factor (second cavity)	13000.0	
Shunt Impedance (first cavity)	3.9	Mohms
Shunt Impedance (second cavity)	9.7	Mohms
Output Kinetic Energy	2.3	MeV
Relativistic gama	5.4	
Output momentum	5.4	m0c
Output Total Energy	2.8	MeV
MacroPulse Length	3	microsec
Maximum Gun Repetition Rate	10	Hz



Bunch Compression
The Alpha Magnet

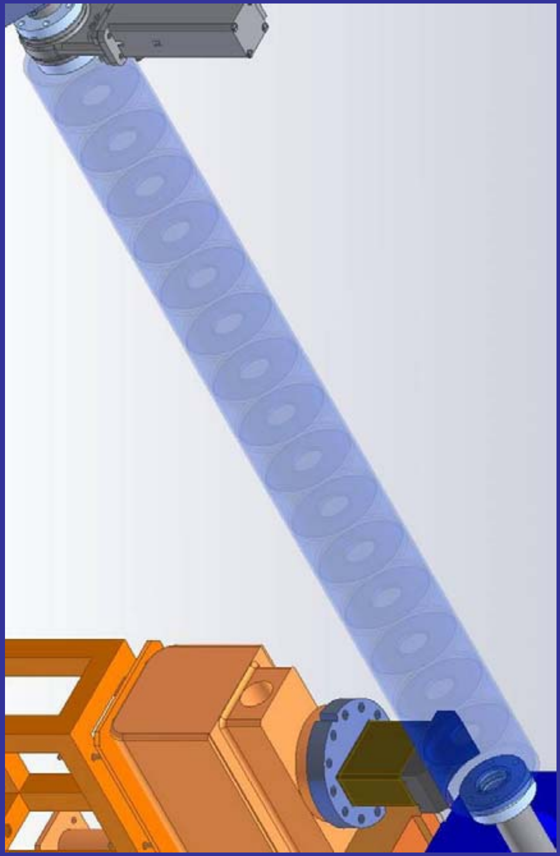




ALPHA MAGNET		
Nominal Gradient	347	gauss/cm
Maximum Gradient	500	gauss/cm
Bore Radius	100	mm
Magnet width		
Magnet Length		
Trajectory Width	3.1	cm
Trajectory Height	9.5	cm
Trajectory Length	24.4	cm
Cooling	by air	

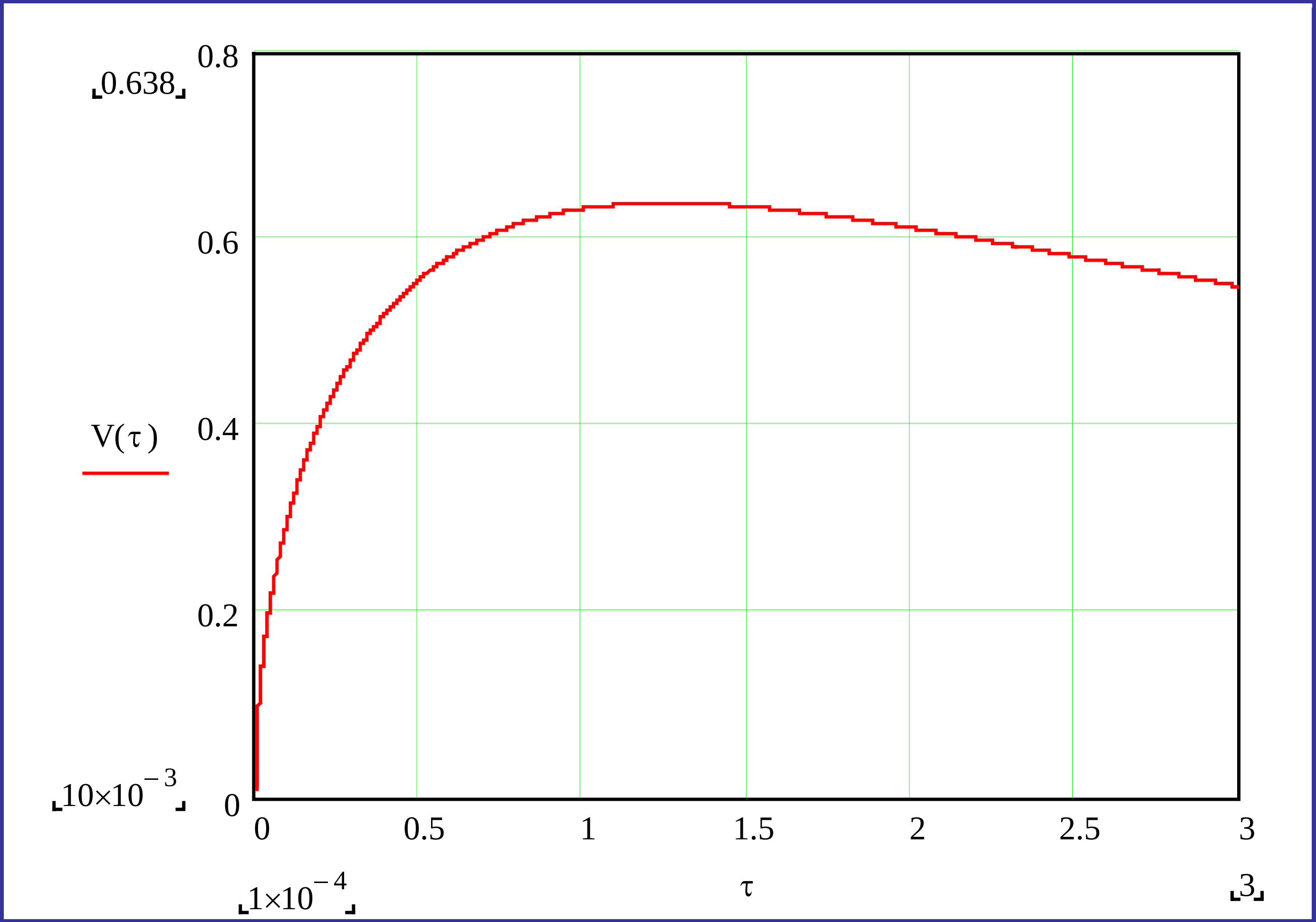
Acceleration

Accelerating Structure		
Structure Type	Travelling Wave 2pi/3 beta=1, constant impedance, iris loaded	
Shunt impedance per unit length	53	Mohms/m
Quality factor	15000	
Attenuation Coefficient	0.19	m**-1
Group velocity	3.2E+06	m/s
Input Peak RF power	2.4	MW
Attenuation Constant	0.17	neper
Structure Filling Time	0.28	microseg
Structure Length	90	cm
Number of cavities	27	
Maximum energy gain	5.7	MeV
Maximum Output Energy	8.5	MeV
Average Maximum accelerating Field	6.3	MV/m
Nominal Output Energy (Total)	8.5	MeV
Nominal Energy spread	1	%
Gun-To-Structure Transfer Efficiency	50	%
Micropulse peak Current	70	A
Micropulse repetition period	350	picosec
Macropulse peak current	20	mA
Average current	0.6	microA
Micro-Pulse length	100	fs



Structure Length

Energy Gain vs Structure Attenuation



Beam Line Parameters Optimization

- Choosing drift spaces and Alpha Magnet strength: *optimum trajectory length inside the alpha depends on the position where a short bunch is desired. A simple first-order formalism gives:*

$$s_{opt} = \frac{2}{1-\frac{2}{\gamma_0^2}}\left(\frac{D}{\gamma_0^2} + \frac{\gamma_0 \beta_0 L}{\Delta\gamma}\left(\frac{1}{\gamma_0^2} - \frac{1}{\gamma_f^2}\right) - \frac{\delta s_0}{\delta p / p_0}\right)$$

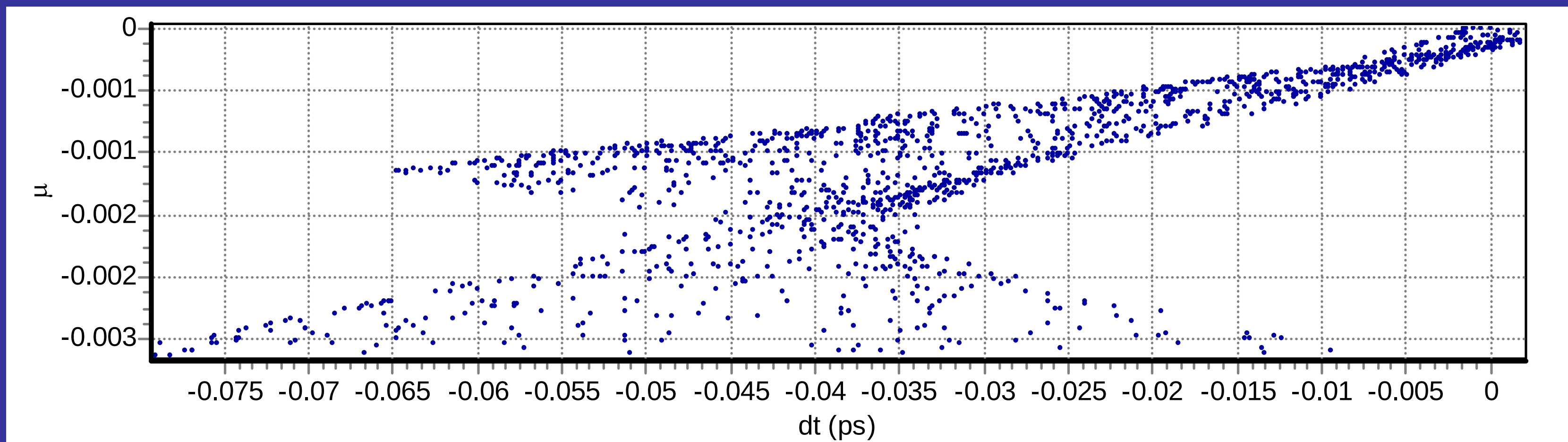
Simulations

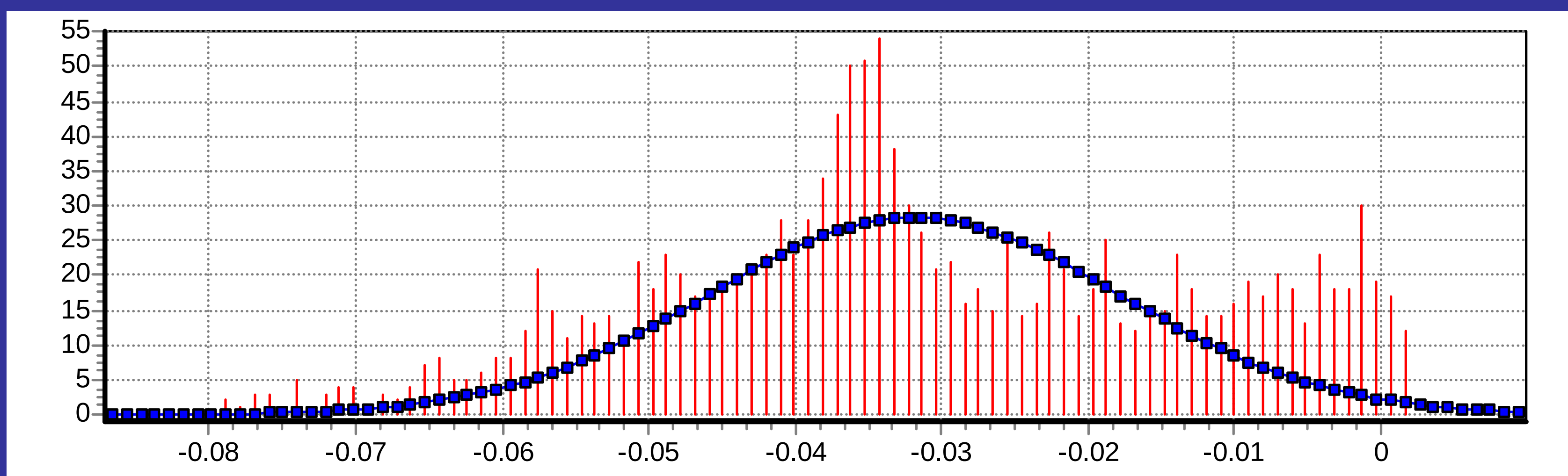
- Full 3-D inside the gun(includes space charge).
- Longitudinal dynamics inside alpha magnet and accelerating structure (no space charge).
- Allows parameter optimization.
- Must choose a location for minimum bunch length.

Simulation Results

- Given
  - g=347 gauss/cm
  - Drift gun to alpha = 50 cm
  - Drift alpha to LINAC = 52 cm
- We obtain (for +/- 0.4% energy dispersion)
  - @ 50 cm from the LINAC: 270 fs; 40 pC
  - @ 100 cm from the LINAC: 70 fs; 48 pC
  - @ 150 cm from LINAC: 90 fs; 30 pC

Example Plots



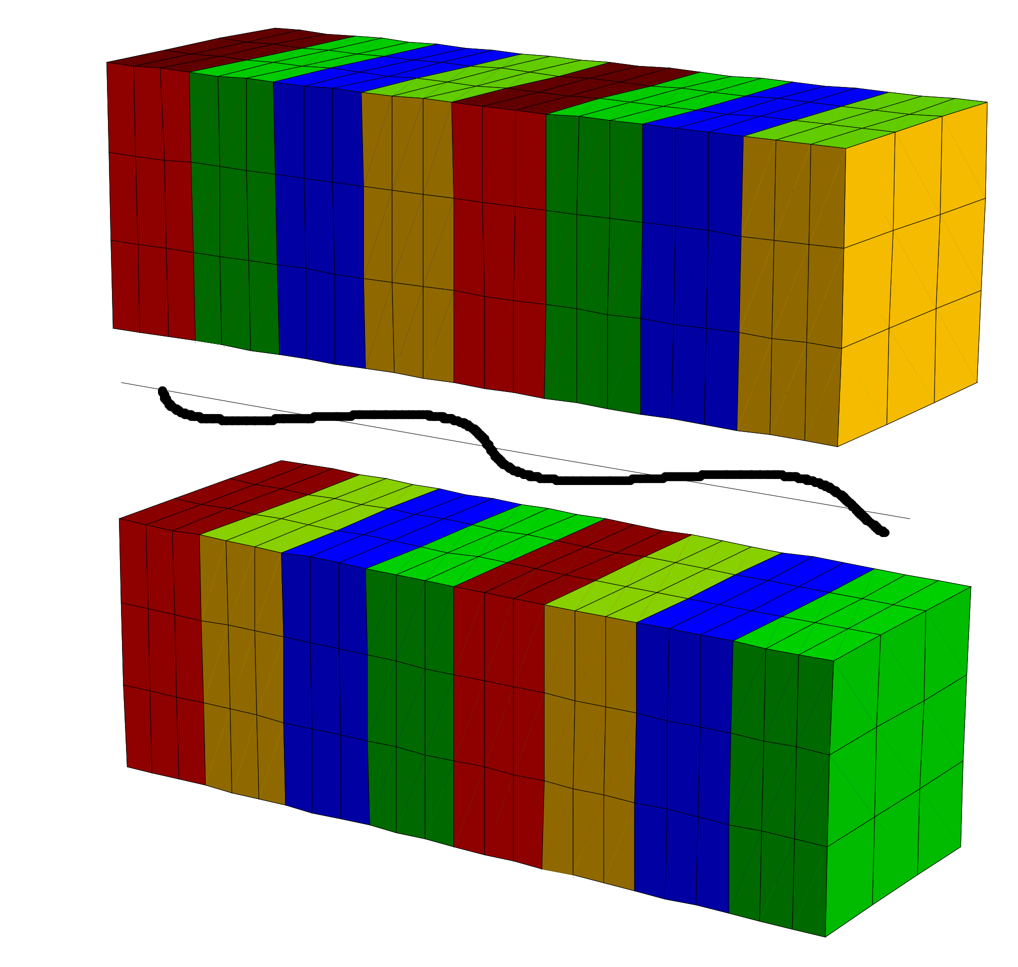


Accelerator Subsystems

- RF Gun.
- Magnets and power supplies: quads, correctors, spectrometer, alpha.
- Accelerating Structure.
- RF High Power system: klystron, modulator
- RF low power system: generator, diagnostics, feedback.
- Controls.
- Diagnostics.
- Interlocks.
- Timing.
- Cooling (for klystron collector) and temperature control for accelerating structure and RF gun.
- Shielding.

Undulator

- Preliminary 3D Design Calculations (RADIA)
- NdFeB magnets
- Peak Field:0.47 T
- Period:3 cm
- Gap:14 mm



Some (of the many) open issues

- Cathode Backbombardment.
- Standing wave vs travelling wave. structures.
- Beam loading and bunch length variations along the macropulse.
- Space-Charge along the beamline (not only inside the gun).
- Divergence effects.
- Coherent synchrotron radiation.

Standing Wave vs Travelling Wave

Ratio of energy gain in SW vs TW for a fixed power and attenuation