The Mixed SPL Architecture

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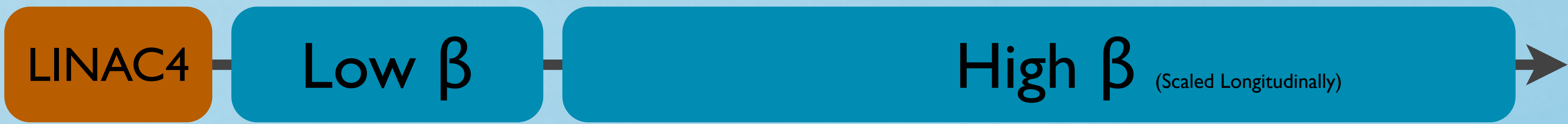
What SPL is?

SPL, Superconducting Proton LINAC, is accelerating H- ions from 160 MeV to 4-5 GeV.

The SPL can be the proton driver for a radioactive ion beam facility, or a neutrino factory.

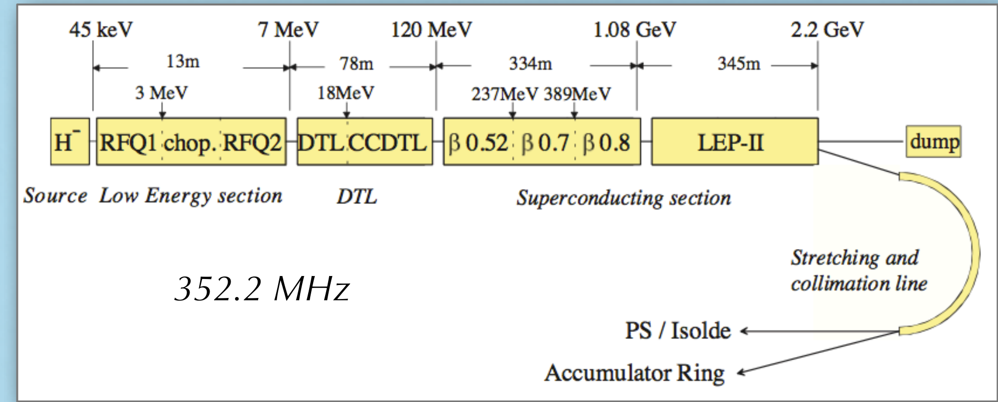
The SPL *could* replace the low-energy part of the CERN proton accelerator complex.



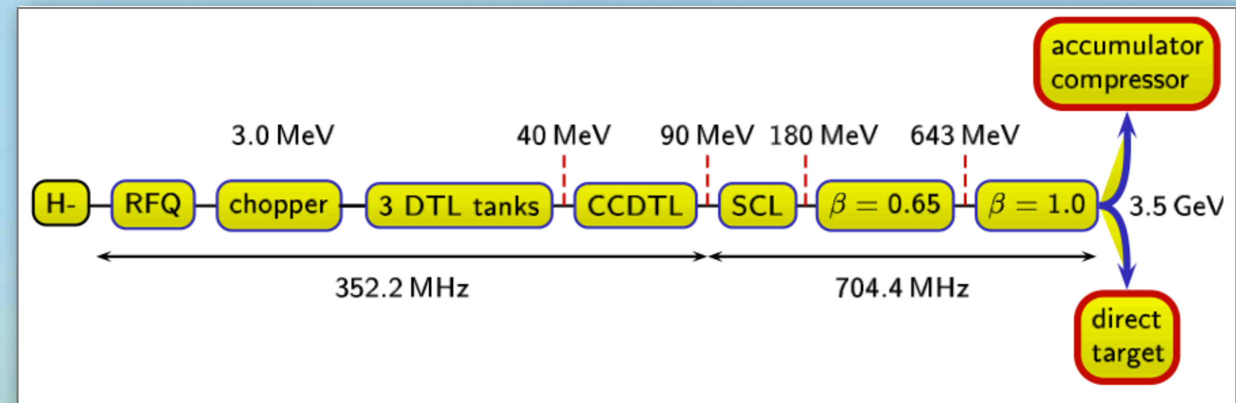
There are studies on using the High β section of SPL to accelerate electrons.

Life of SPL

In its 1st CDR, SPL is a complicated 630 m, 2.3 GeV LINAC.



Later in the 2nd CDR SPL starts from 180 MeV, after LINAC4, and brings the beam to 3.5 MeV in 430 m.

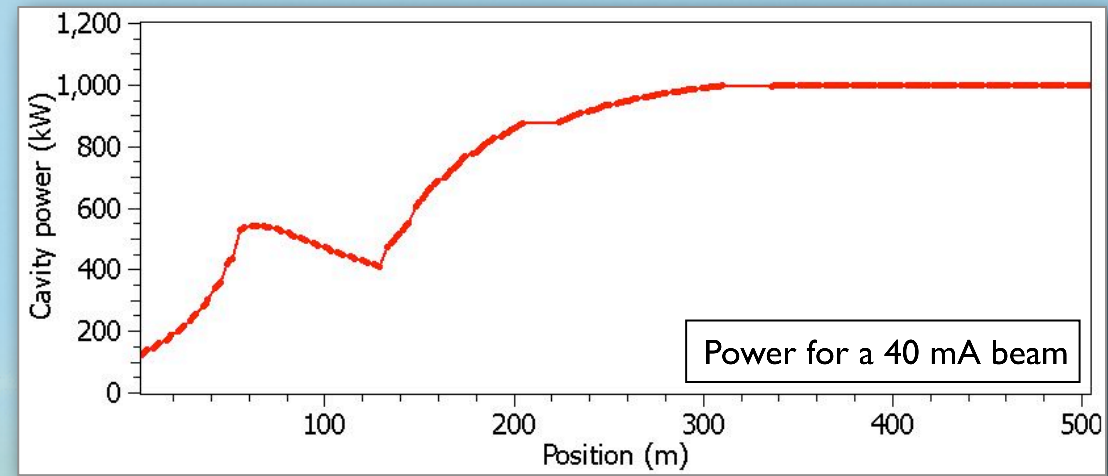


Cavities of SPL

LINAC4 → $\beta = 0.6x$ → $\beta = 0.9x$ $(0 \leq x \leq 10)$

SPL now extends to 4-5 GeV and uses two families of 5-cell elliptical cavities optimized for its current & range of energy.

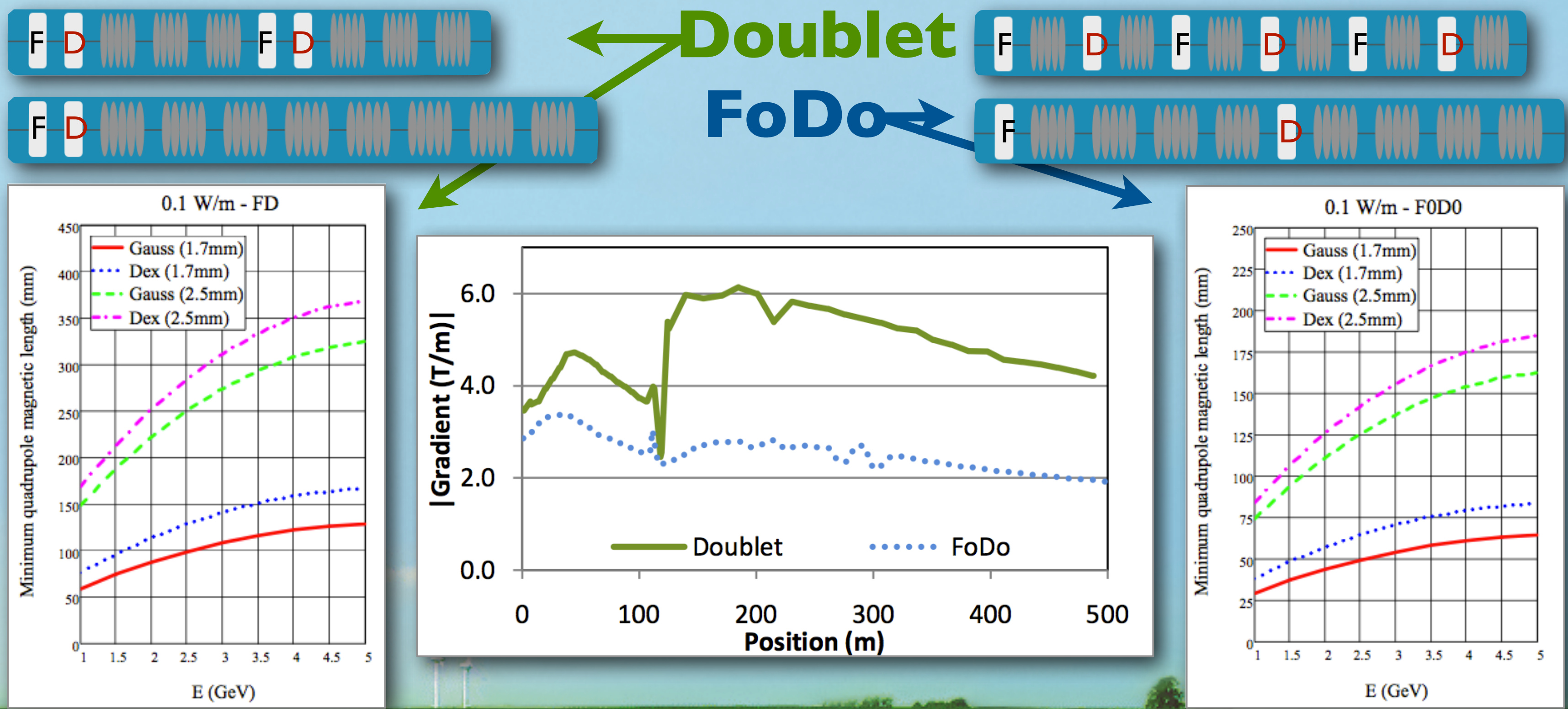
Low beta region uses cavities with $\beta_{Geo} = 0.65$ and high beta region uses $\beta_{Geo} = 1$ cavities.



Architectures

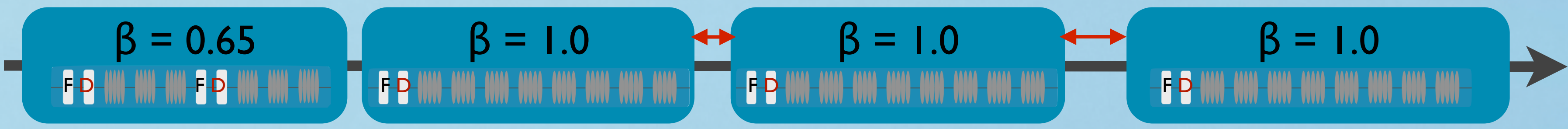
The baseline SPL uses a quadrupole doublet focusing, it has the advantage of being more flexible for cryo-sectioning.

A FoDo interlacing is studied. Its advantage is it needs weaker quadrupoles to achieve the same focusing.



Obstacles & Openings

Two branchings are needed at SPL, at 1.4 and 2.5 GeV each requiring a drift space of 13.6 and 21 m respectively in the periodic structure of LINAC.



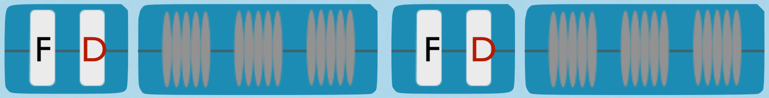
Each time the focusing structure changes, beam settles to a new equilibrium, this process is always accompanied by emittance growth and halo formation,

BUT

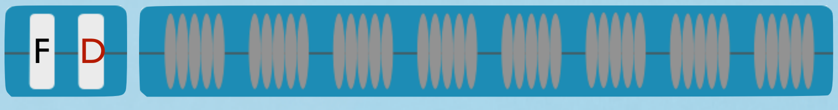
If there has to be a 21m drift, why not change the focusing?

A New Hope

Low beta cavities / doublets are used from 160 to 750 MeV

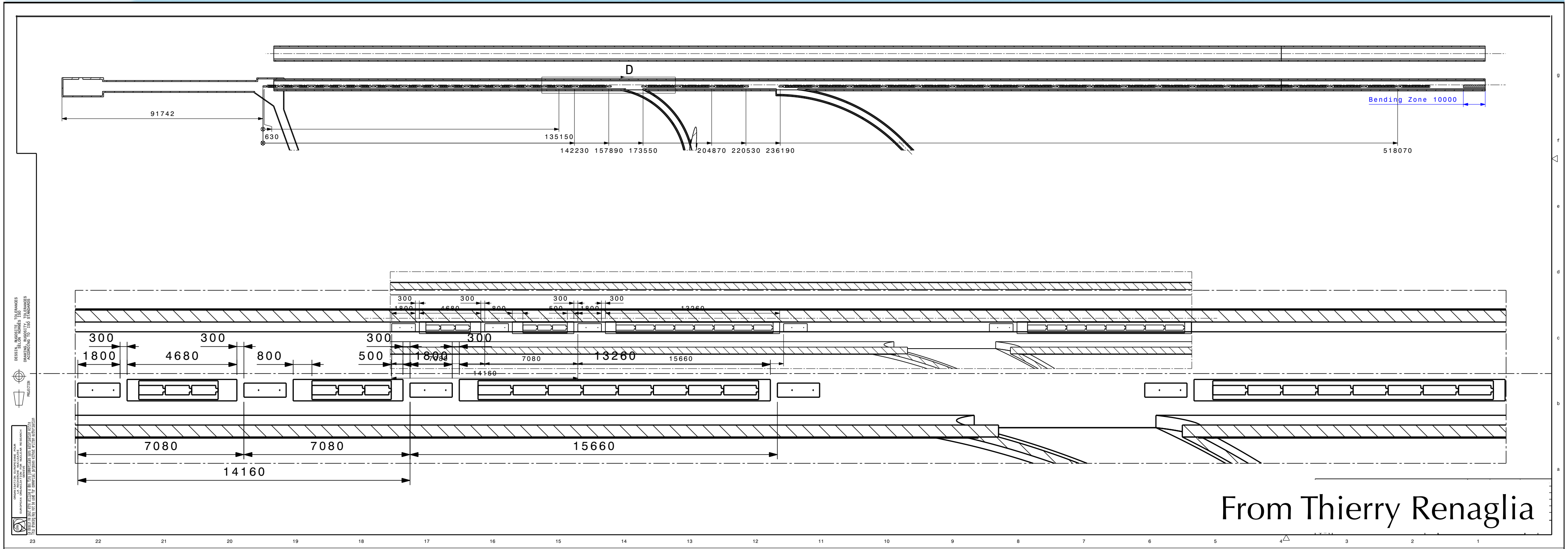


From 750 to 2500 MeV high beta cavities are used.
One period in the middle is skipped to house 1 x L_p branching.
1.5 x L_p at the end leaves enough space for 2.5 GeV bends.



Long FoDo periods, have the advantage of requiring weaker quadrupole as well as simple and flexible cryo-modules.

Spacings



From Thierry Renaglia

Box to Quad	Quad to Quad	Quad to Box	Box to Cryo	Cryo to Cavity	Cavity to Cavity	Cavity to Cryo	Cryo to Box
300	400	300	300	800	277 / 207	500	300

Design Criteria

When the space charge is not negligible, i.e. $\sigma / \sigma_0 < 1$, zero current phase advance, σ_0, should be smaller than 90^o.

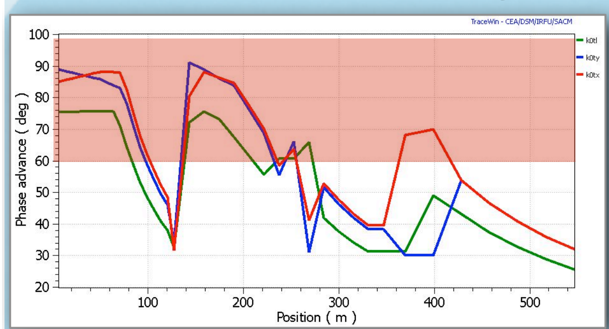
The average external force on the beam, $(\sigma_0/L_p)^2$, has to be smooth and continuous.

Special care has to be taken to avoid the parametric as well as the space charge resonances.

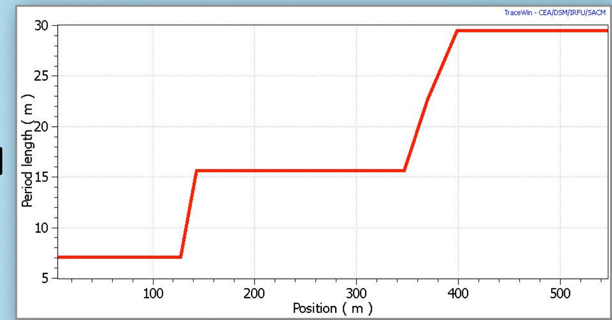
Implementation!

... of these criteria

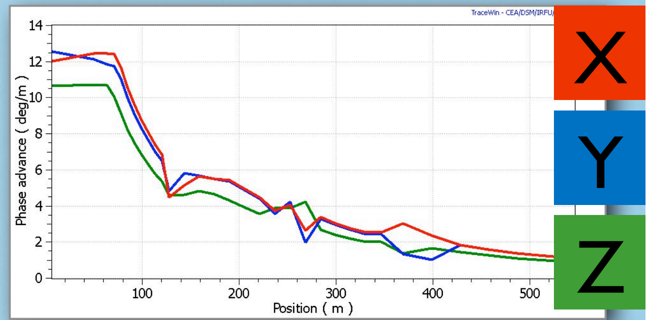
Phase Adv. (Deg)

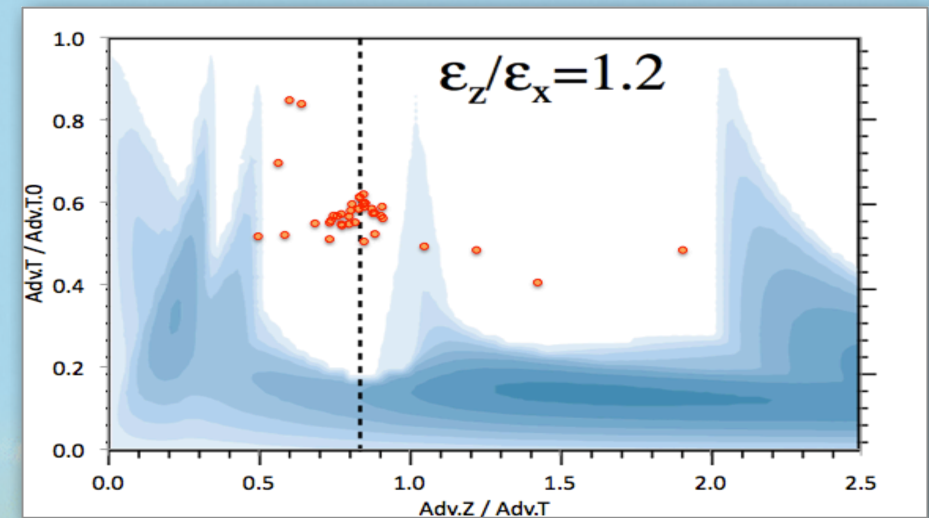


L. period (m)



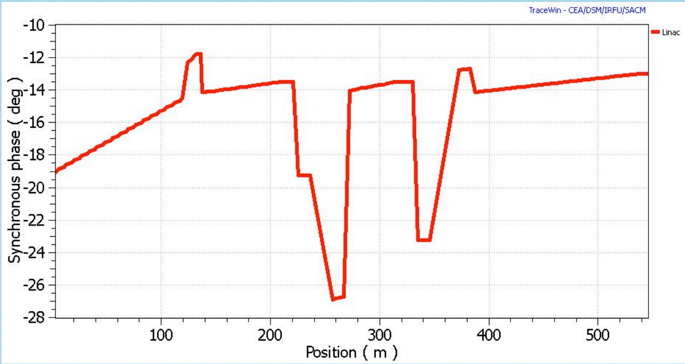
Phase Adv/m (deg/m)



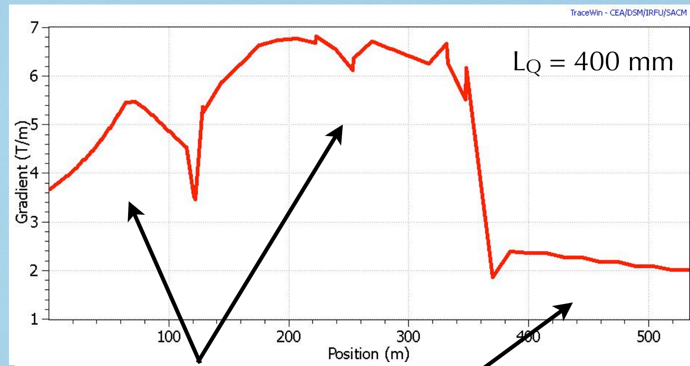


Phase, Grad and Power

Sync Phase (Deg)

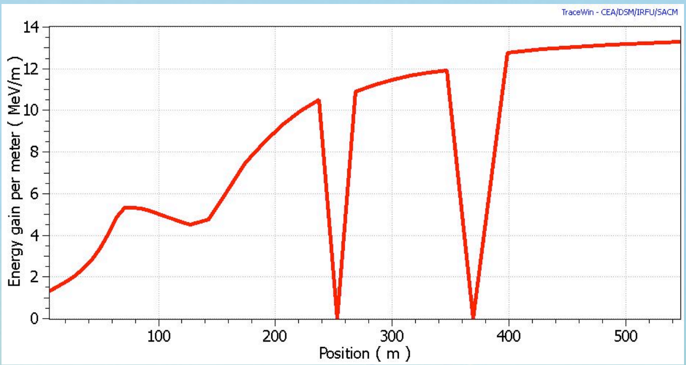


Quad. Grad (T/m)

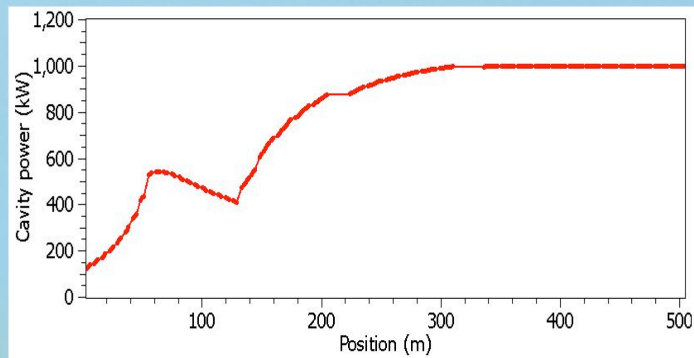


$$G = \frac{\gamma\, m\, v\, \sigma}{q\, l \sqrt{L\, D}} \qquad G = \frac{\gamma\, m\, v\, \sigma}{q\, l\, L}$$

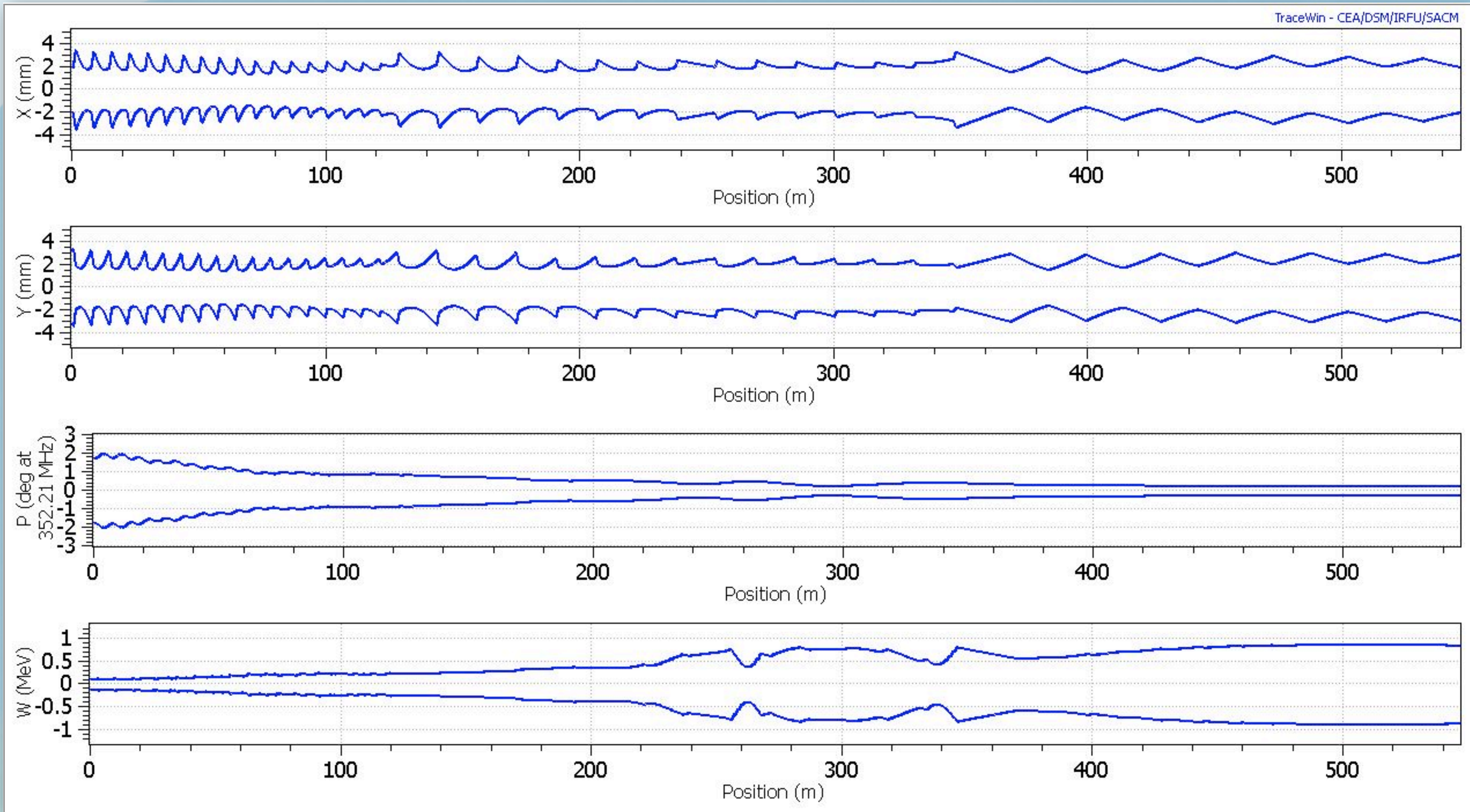
REG (MeV / m)



Power/Cavity (kW)



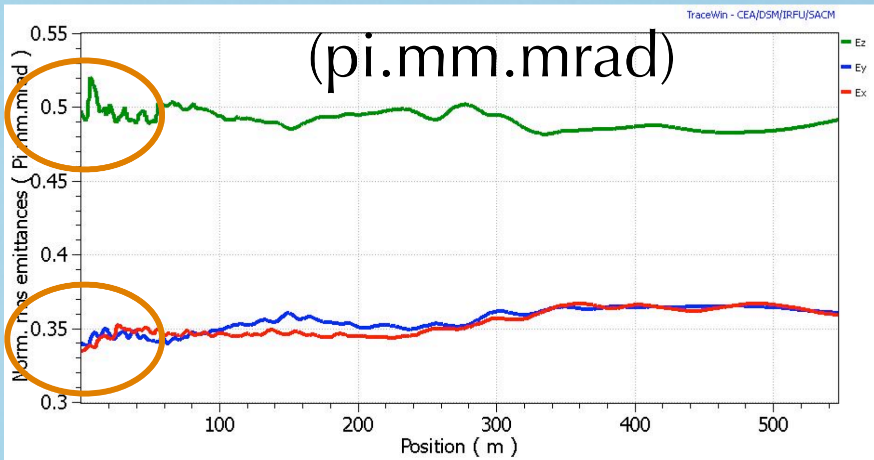
Envelopes


TraceWin - CEA/DSM/IRFU/SACM
X (mm)
Position (m)
Y (mm)
Position (m)
P (deg at 352.21 MHz)
Position (m)
W (MeV)
Position (m)

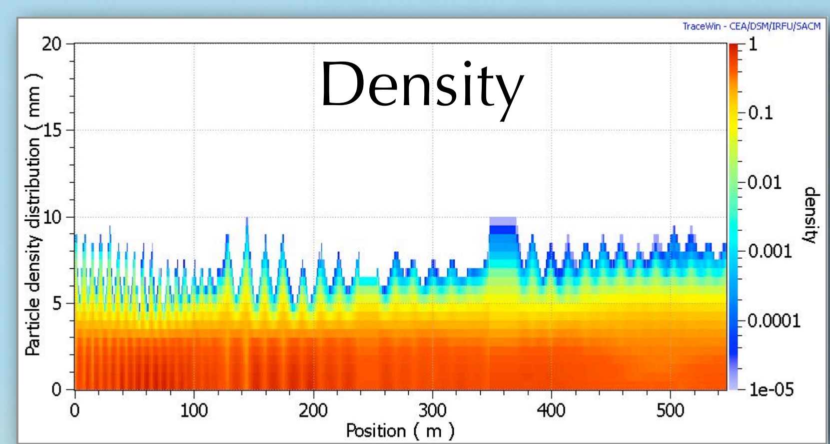
Density, Halo & ϵ

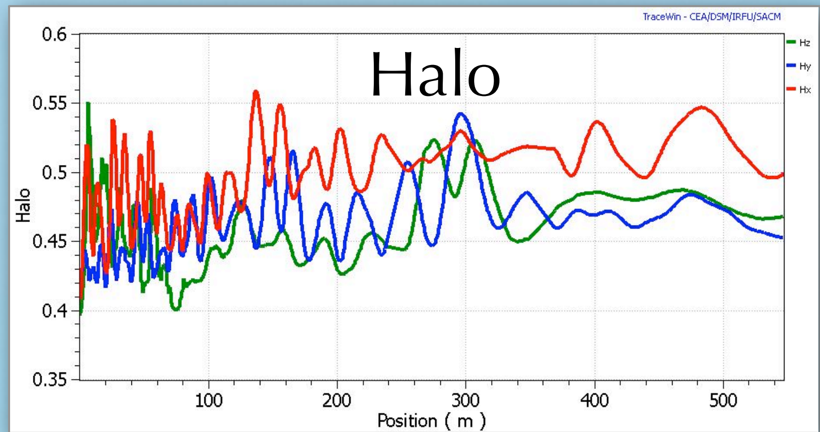
Redistribution

norm. rms. emit.
(pi.mm.mrad)



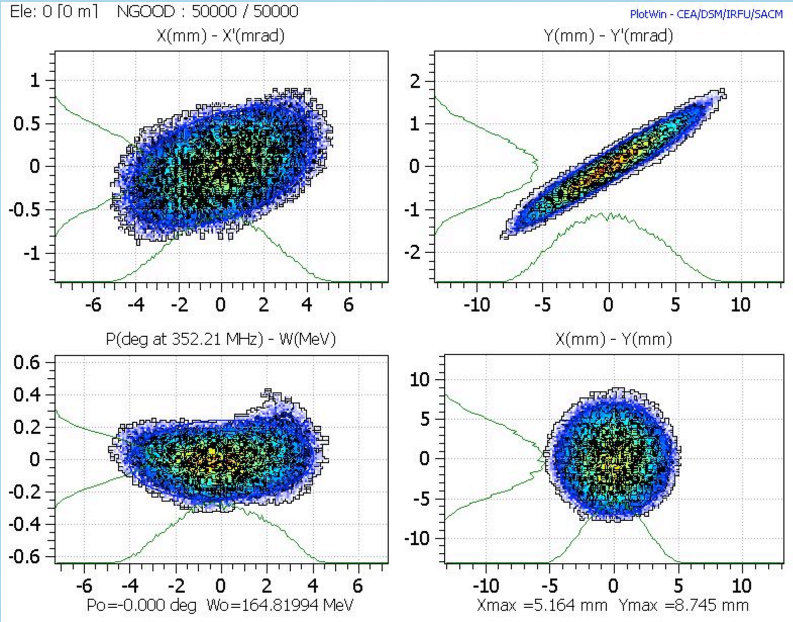
X	7.4%
Y	6.2%
Z	-1.0%



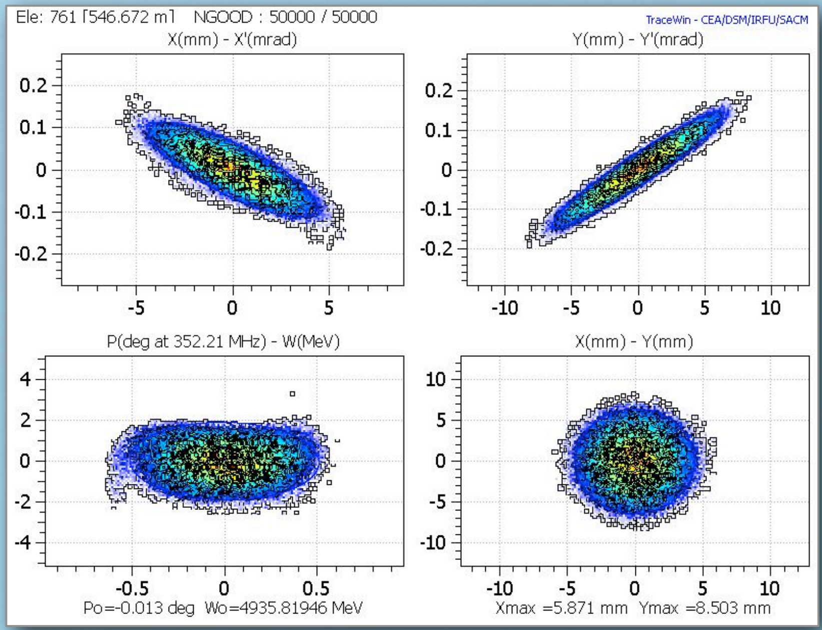


Beam In / Beam Out

Input beam, 165 MeV



Output beam, 4.93 GeV



Mixed vs. Doublet

Inventory comparison

	L (m)	E (MeV)	No. Period	Cav. / per	No. Quads	No. Cav.
Doublet	550	786 / 4989	20 / 23	3 / 8	90	244
Mixed	546	654 / 4936	18 / 15 / 6	3 / 8 / 16	78	254*

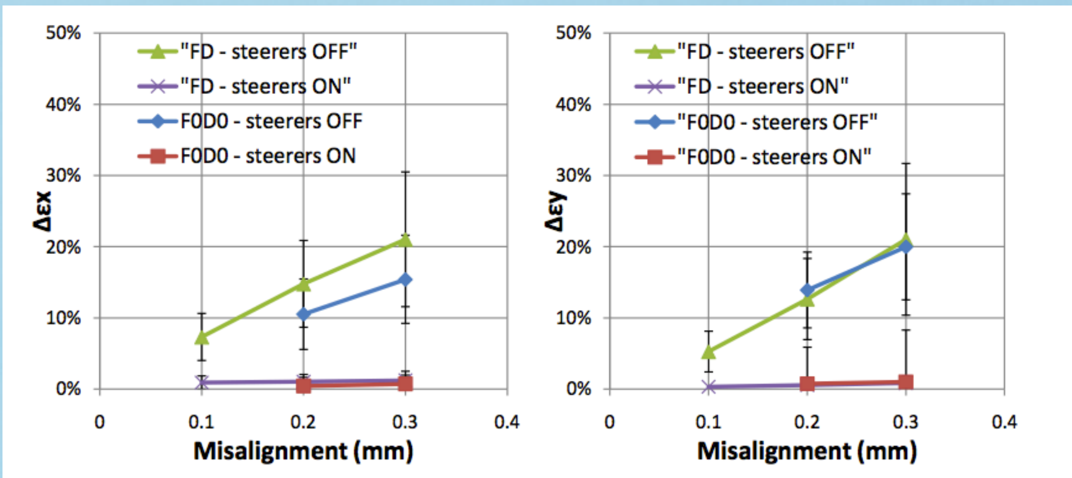
* Power limited to 1 MW/cavity and gradients are 19 and 25 MV/m

Performance comparison

	$\epsilon_{n.rms.x}$	$\epsilon_{n.rms.y}$	$\epsilon_{n.rms.z}$	$\Delta \epsilon_x$ %	$\Delta \epsilon_y$ %	$\Delta \epsilon_z$ %
Doublet	0.369	0.356	0.517	11.2	5.0	4.2
Mixed	0.359	0.361	0.492	7.4	6.2	-1

Required Correction

Quadrupoles equipped with dipoles can correct the beam center, and maintain the emittance.



The multipoles have to be considered, since steerers may induce the m=3 component in the magnet, dangerous when $\sigma_0 > 60$, as detected in SNS*.

* PAC09, Beam Transverse Issues at the SNS LINAC, Y. Zhang, C.K. Allen, J.D. Galambos, J. Holmes, J.G. Wang,

Summary

A new architecture, based on the highly segmented design, is proposed for SPL to avoid the magnetic stripping of H- ions.

This structure uses the base line doublet (FDO) focusing till 2.5 GeV and long (16 Cav./Period) singlet (FODO) focusing afterwards.

Steerer equipped quadrupoles can correct the beam center, however, their multipoles have to be considered seriously.