Using ELEGANT for FFAG and RLA tracking

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Neutrino Factory IDS

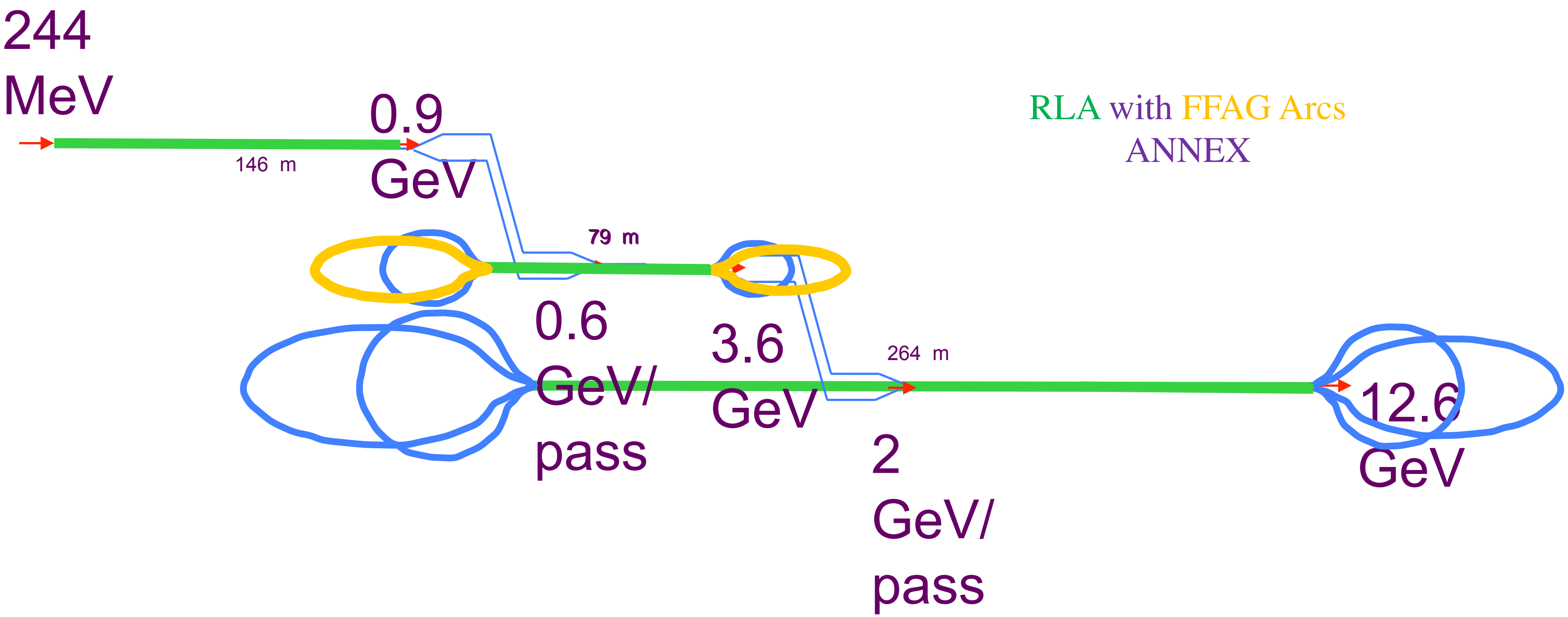
- Design that will be in the IDS document is RLA with traditional return arcs (for first part of acceleration)

- We are also exploring an alternate option with FFAG arcs.

- Need for a good start to end simulation to explore and study all options.

- Wide range of energy, large emittance, large phase space

Neutrino factor IDS



Requirements for tracking

- Code needs to exhibit Symplecticity (large emittance and phase space)
- Need to be able to handle large dp/p swings (several times initial momentum)
- No small angle approximation
- Field maps (for 3D field maps of complex magnet poles)
- Fringe fields

ELEGANT

- ELEGANT started as an electron ring code. Developed by M. Borland at Argonne. It has been benchmarked and is a proven code in this community.

- Jefferson Lab beam physics and operations groups have been using ELEGANT both in and out of the control room.

- Planning to invest in the development necessary to equip ELEGANT with all that is needed.

- Very extendable, vast amount of data manipulation utilities, good optimizer.

Hamiltonian for ELEGANT

$$H = -\frac{e}{pc}A_s(x,y) + \frac{x}{\rho} + \frac{x^2}{2\rho^2} - (1+\frac{x}{\rho})\sqrt{(1+\delta)^2 - p_x^2 - p_y^2}$$

$$A_s(x,y) = -\Re(\sum_{n=1} \frac{1}{n}(b_n + ia_n)(x+iy)^n)$$

Exact at all momenta.

No small ring approximation.

Integrated with 4th order symplectic integrator

Field maps integration

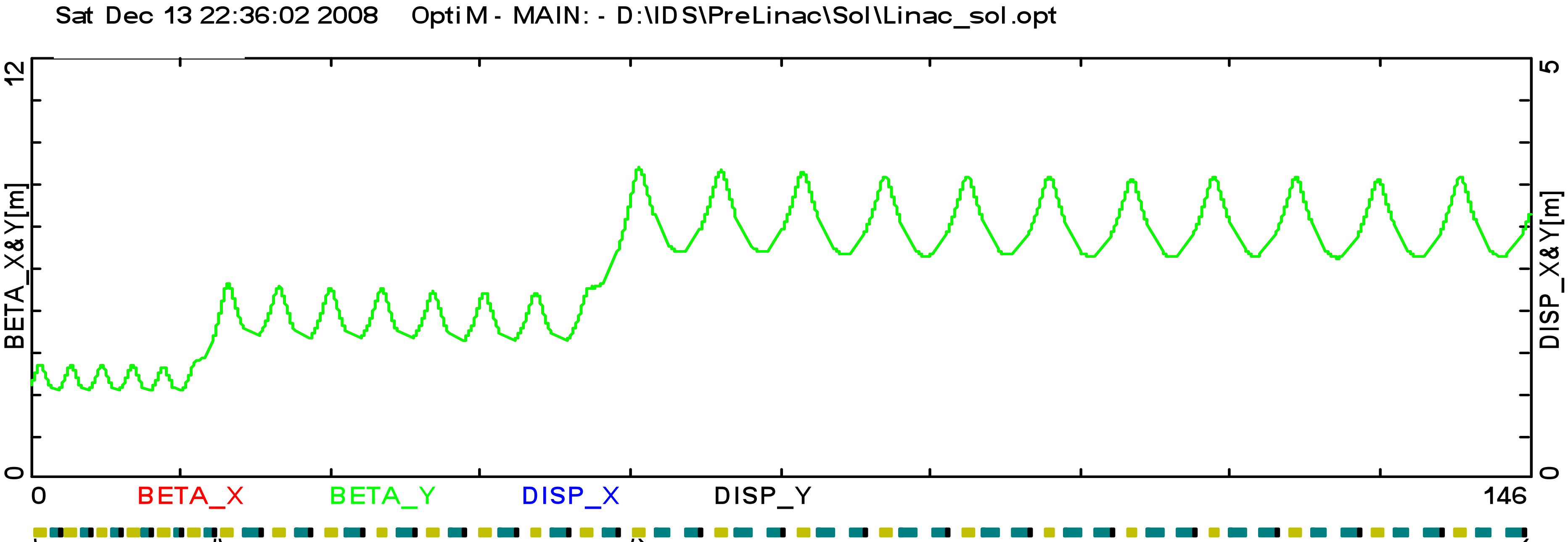
Currently:

- cylindrical r,Br, Bz,z maps for solenoids
- Ez vs Z for cavities with possibility of giving wake fields
- 2D Bx,By field map
- All integrated via non-symplectic methods (Runge-Kutta)

Field maps (cont)

- Currently effort underway at Argonne to have a generic 3D field map integrator.
- Symplectic scaling techniques to include fringe fields under study
- Treatment of synchrotron radiation.
- Effort at Jefferson Lab to provide better cavity models.

Linear Pre-accelerator – 244 MeV to 909 MeV



6 short cryos

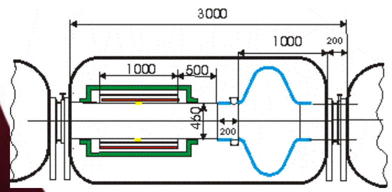
15 MV/m

8 medium cryos

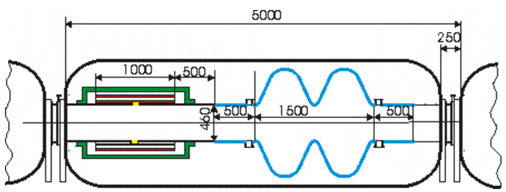
17 MV/m

11 long cryos

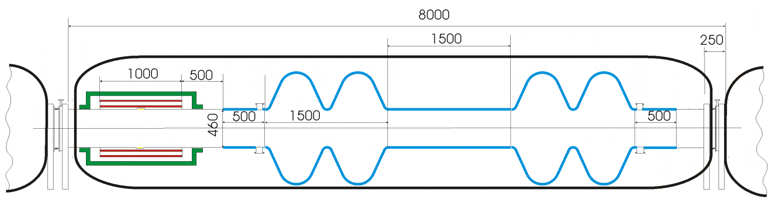
17 MV/m



1.1 Tesla solenoid



1.4 Tesla solenoid



2.4 Tesla solenoid

Courtesy of A. Bogacz

Initial conditions after cooling channel

ISS/IDS		ε_{rms}	$A = (2.5)^2\ \varepsilon$
normalized emittance: $\varepsilon_x/\varepsilon_y$	mm·rad	4.8	30
longitudinal emittance: ε_l $(\varepsilon_l = \sigma_{\Delta p}\ \sigma_z/m_\mu c)$ momentum spread: $\sigma_{\Delta p/p}$ bunch length: σ_z	mm mm	24 0.07 165	150 ±0.17 ±412

Courtesy of A. Bogacz

Tracking thru first RLA linac

- Field maps for Solenoids and cavities from Imperial College

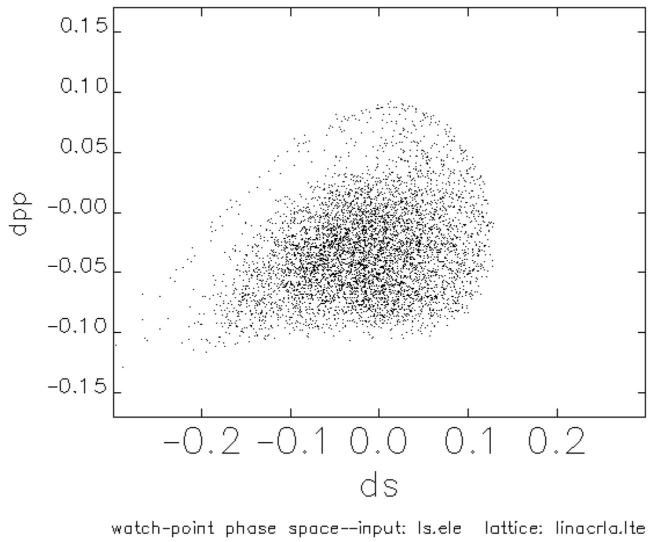
- initial beam characteristics taken from simulations/ estimates of the cooling channel efficiency

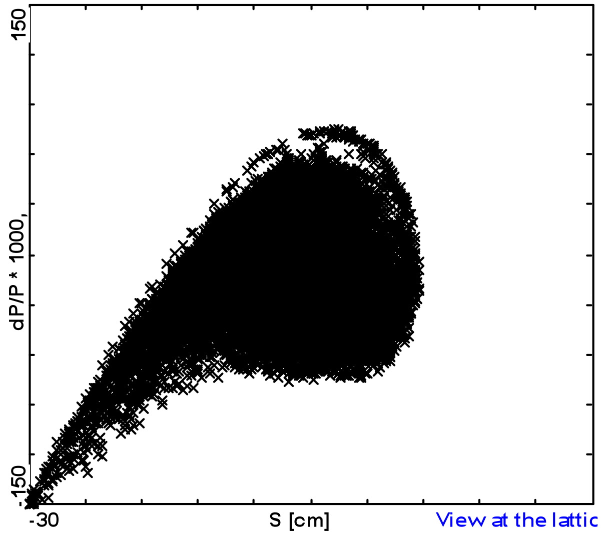
- Aperture restrictions in model.

Longitudinal optics

- Phase profile is adjusted to produce adequate bunching and rotation in the linac
- Acceptance is about 17 % in dp/p
- Bucket size is about 93 degrees (f=201.25 Mhz)
- Initial bunch of 16.5 cm .

Longitudinal phase space end of linac1



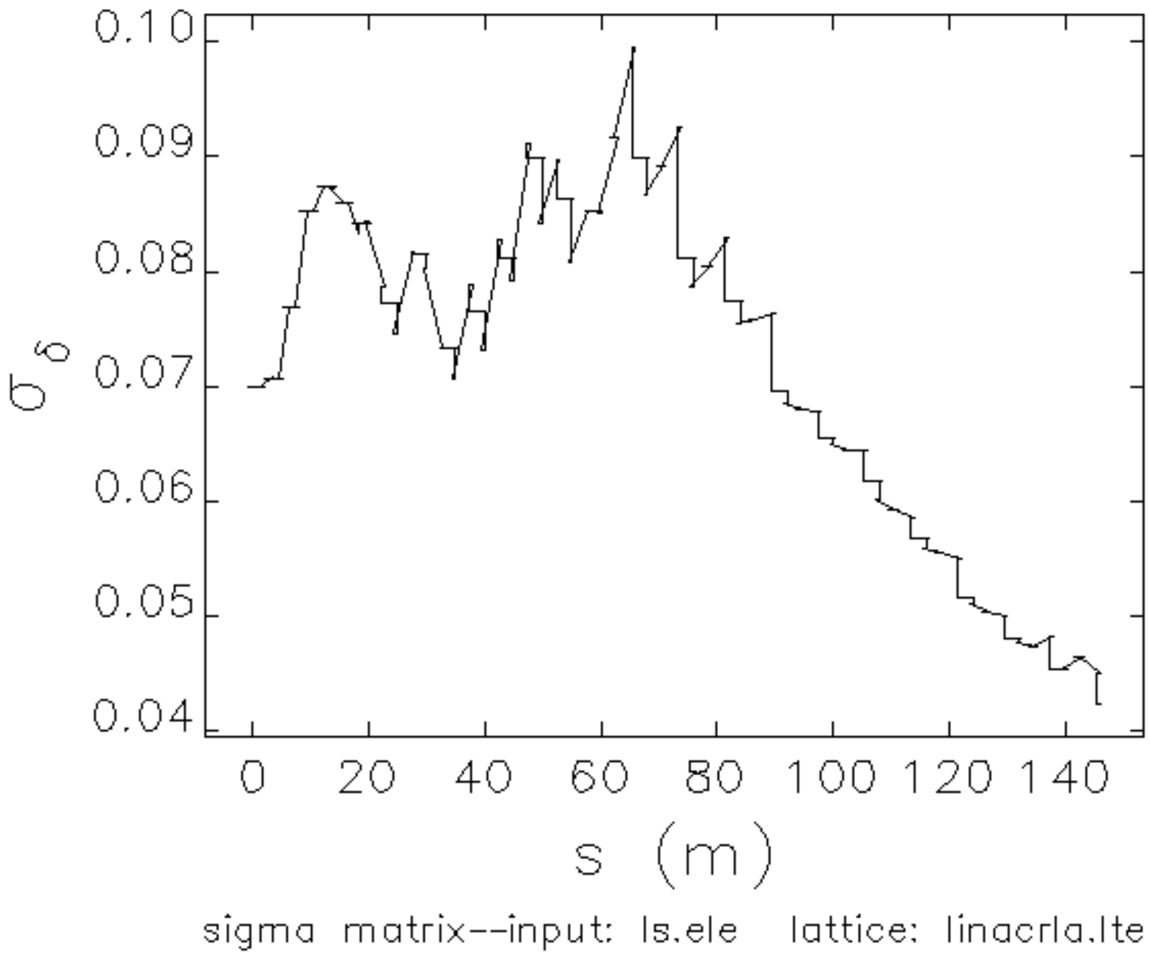


ELEGANT

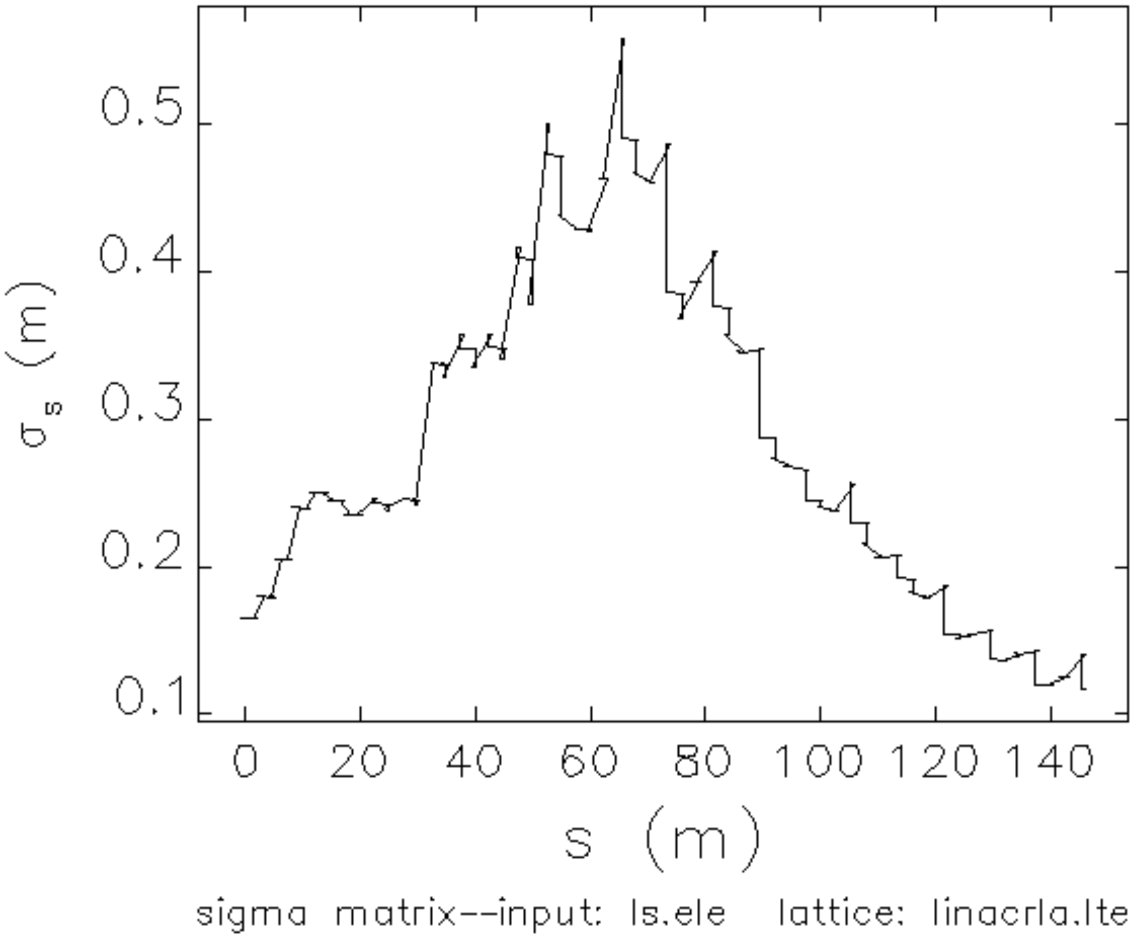
Better bunching, smaller tail

OPTIM

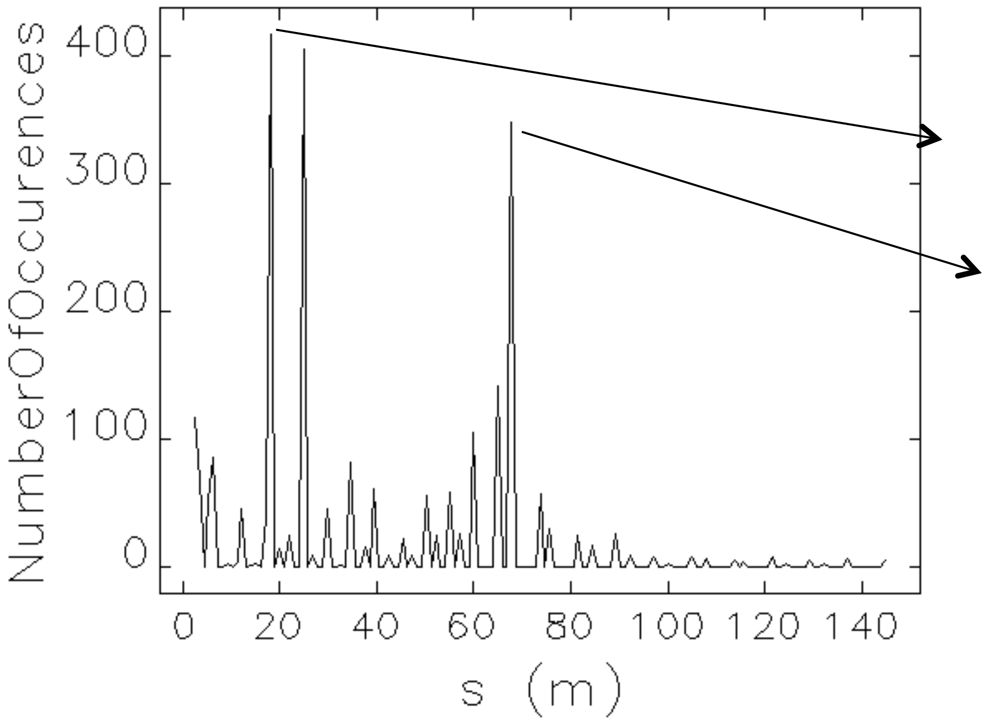
Longitudinal phase space (cont)



Longitudinal phase space (cont)

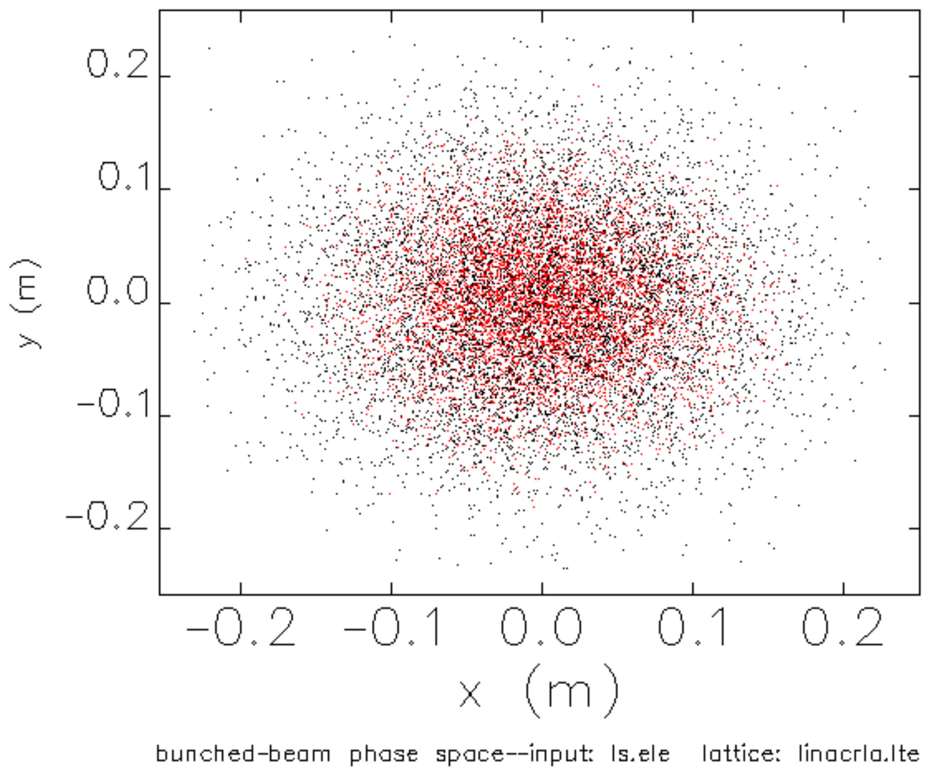


Beam losses



Match between sections
Is not optimal

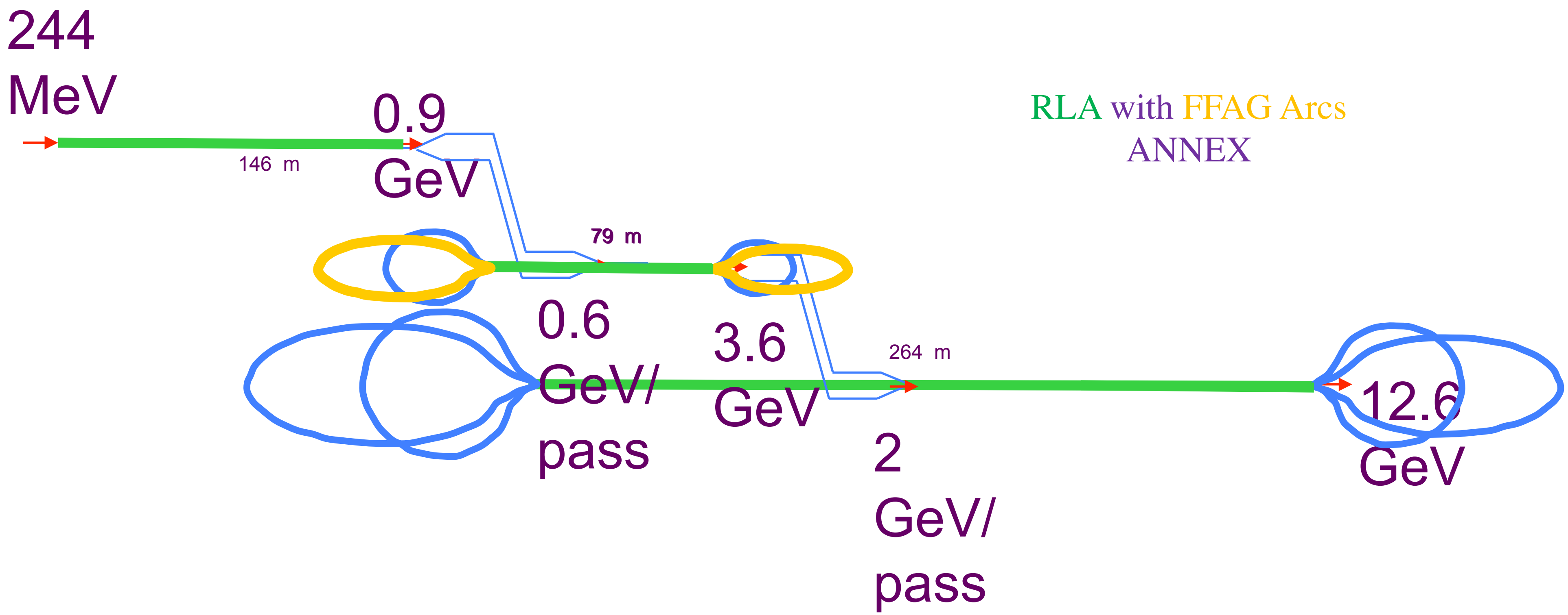
Transverse dynamics in linac1



Red is final distribution

About 70 % transmission

Neutrino factor IDS

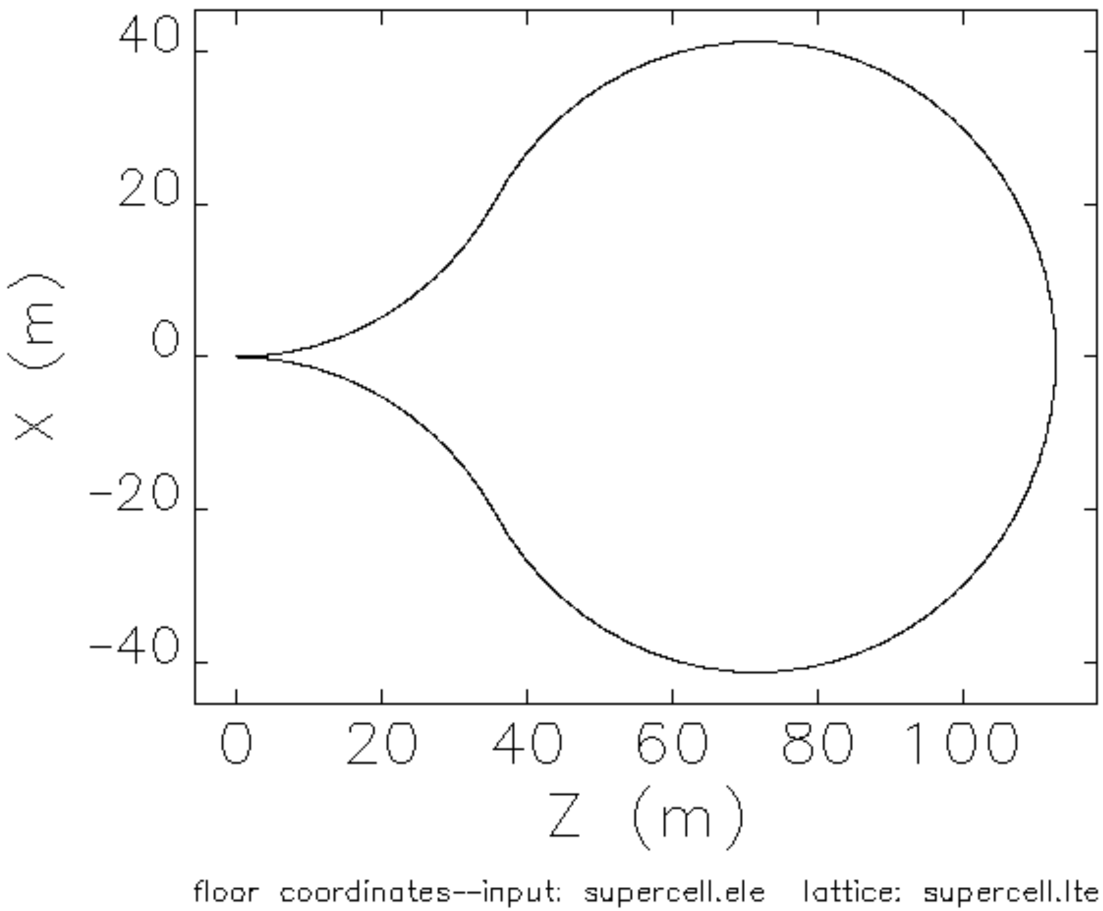


RLA with FFAG Arcs
ANNEX

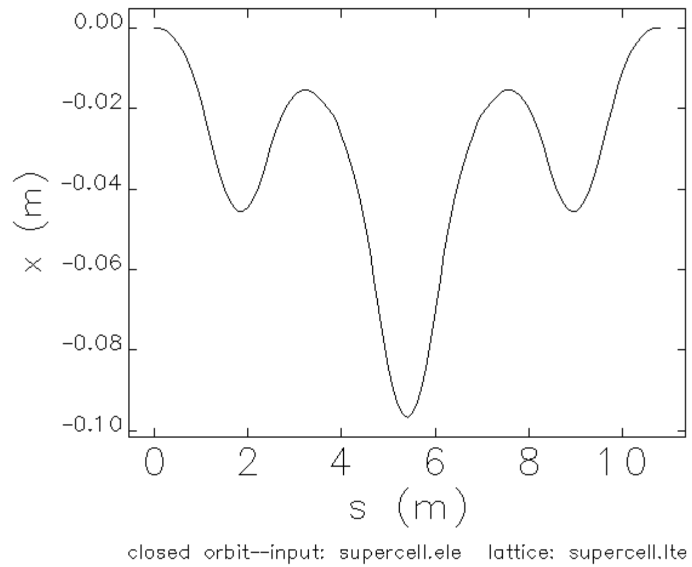
Linear Non-Scaling FFAG droplet

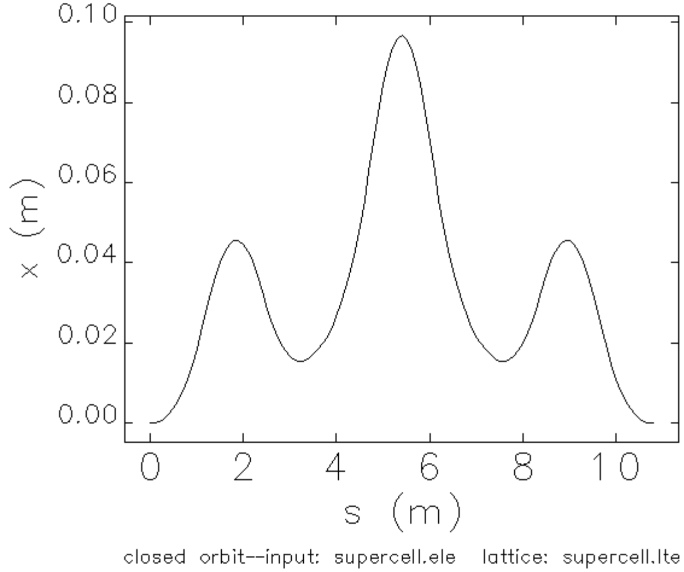
- Proposed by V. Morozov, D. Trbojevic,A. Bogacz.
- Only has to transport two energies.
- ELEGANT reproduces MAD-XP study.
- Next step is to shape the beam in order to maximize transmission through the FFAG droplet. (available sextupoles and octupoles)
- Chromatic corrections, bunch compression
- Initial design was single particle dynamics.

FFAG droplet layout



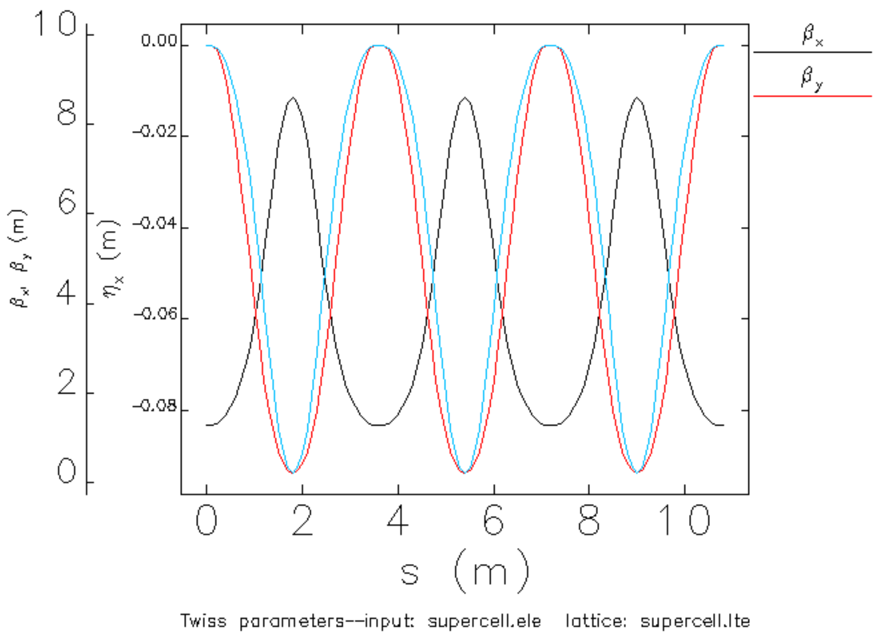
FFAG droplet closed orbit

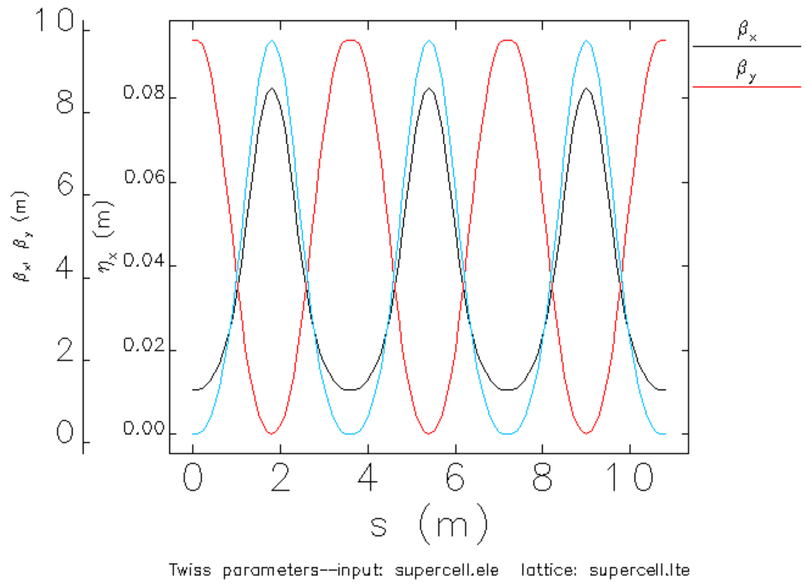




Closed orbit for 2.4 GeV muons in inward and outward bending cells

Off –momentum twiss functions





Future Developments

- Match between linac and arcs being worked on

- Better models/improvements for ELEGANT under way (cavity models, 3D field map tracking. Etc..)

- Work is being started on adding features needed in ELEGANT to be able to carry out FFAG studies beyond the initial design phase (fringe field models, 3D field maps imports and normalization, symplectic tracking in fields, TPSA/DA ?)