Muon RLA – Design Status and Simulations

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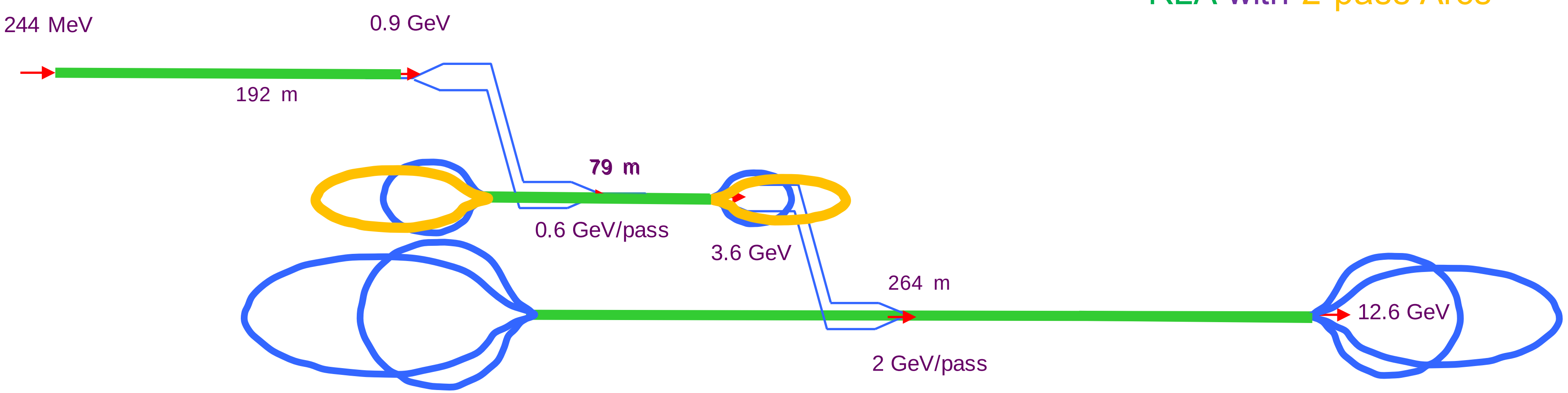
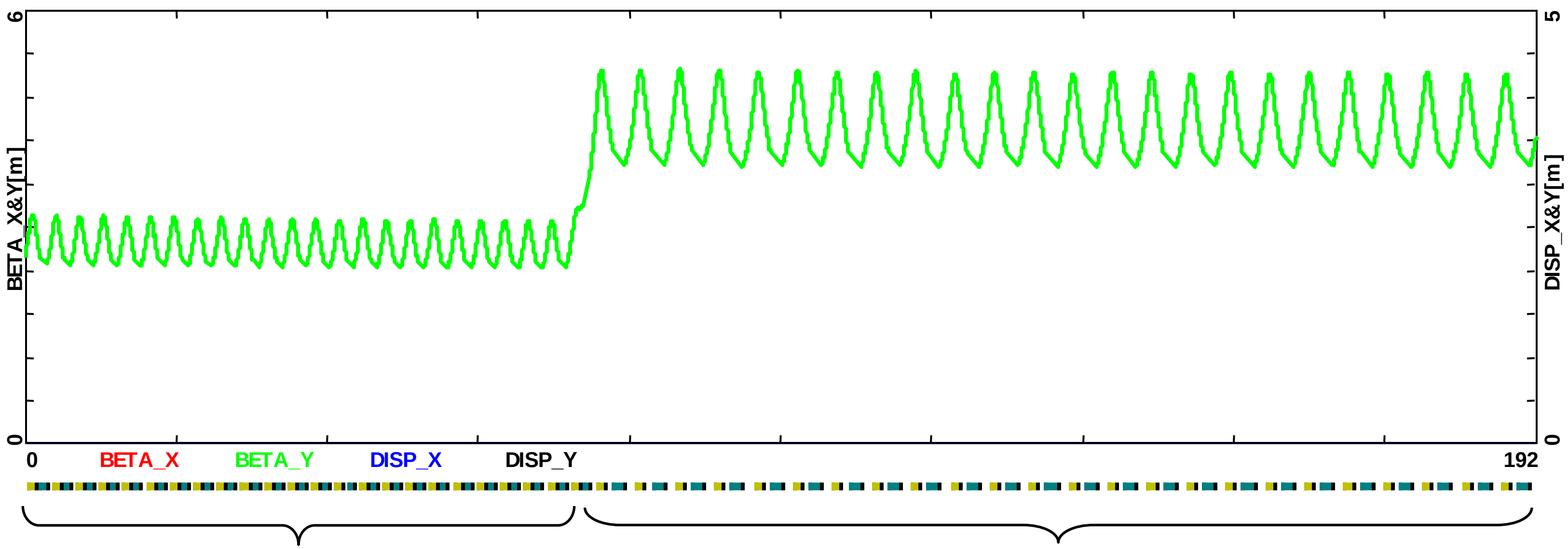
Linac and RLAs – IDS



- IDS Goals:
  - Define beamlines/lattices for all components
  - Matrix based end-to-end simulation (machine acceptance) (OptiM)
  - **Field map based end-to-end simulation: ELEGANT, GPT and G4Beamline**
  - Error sensitivity analysis
  - Component count and costing
  - Two regular droplet arcs replaced by one two-pass combined function magnet arc

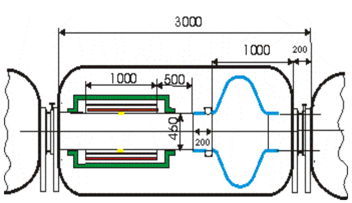
C. Bontoui

Linear Pre-accelerator – 0.9 GeV

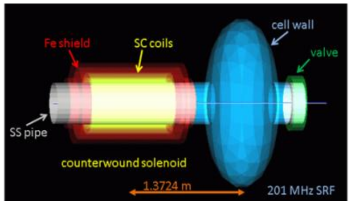


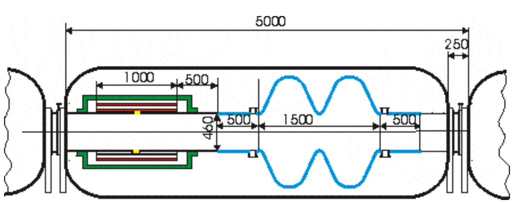
24 short cryos

24 medium cryos



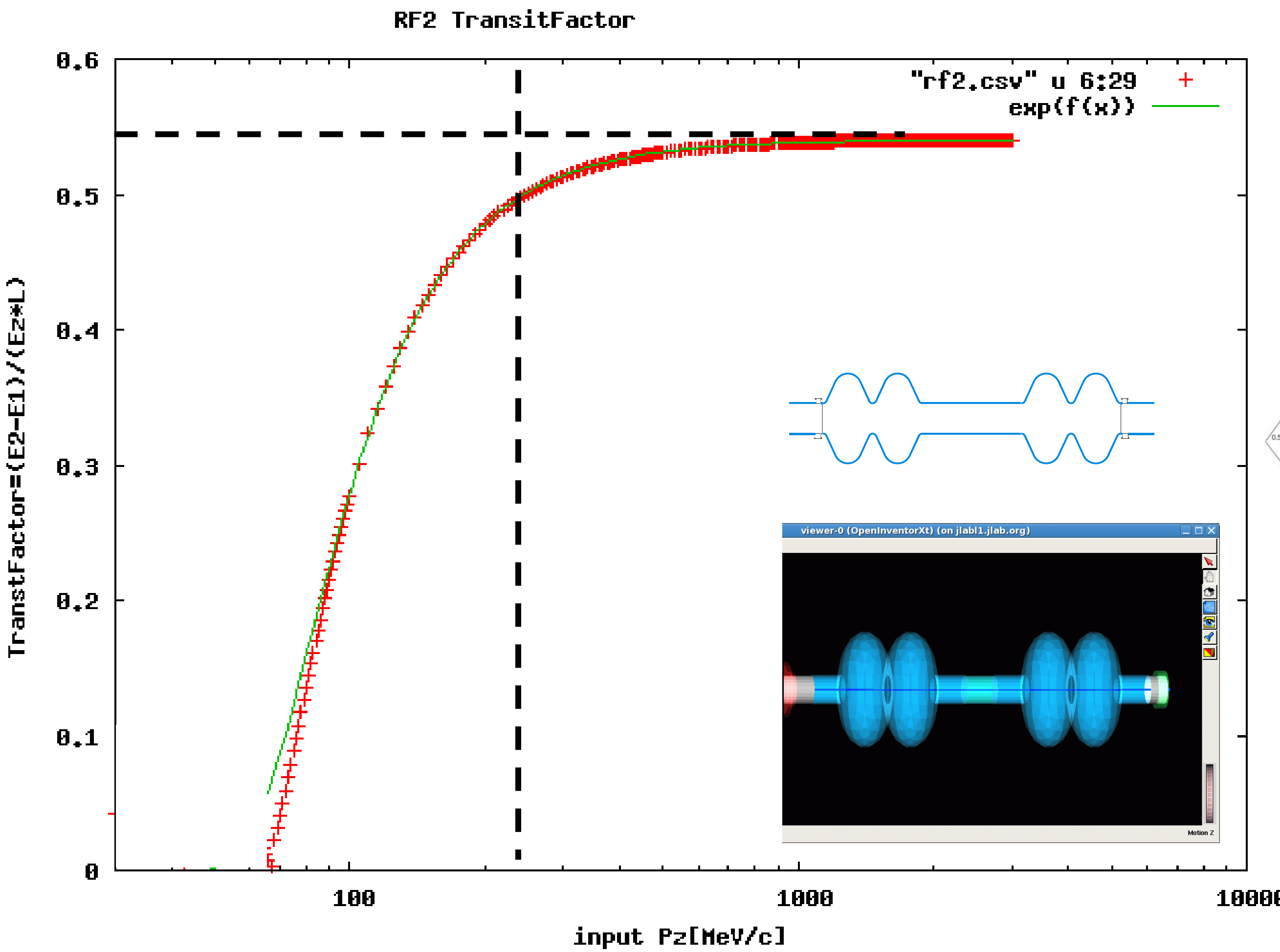
1.5 Tesla solenoid

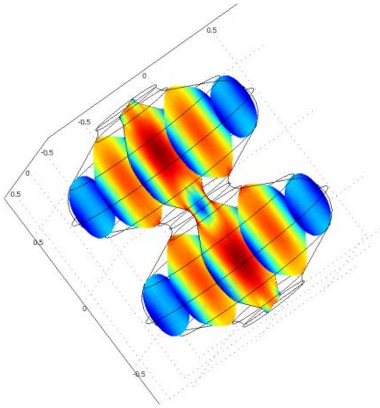




2 Tesla solenoid

Transit time effect – G4BL

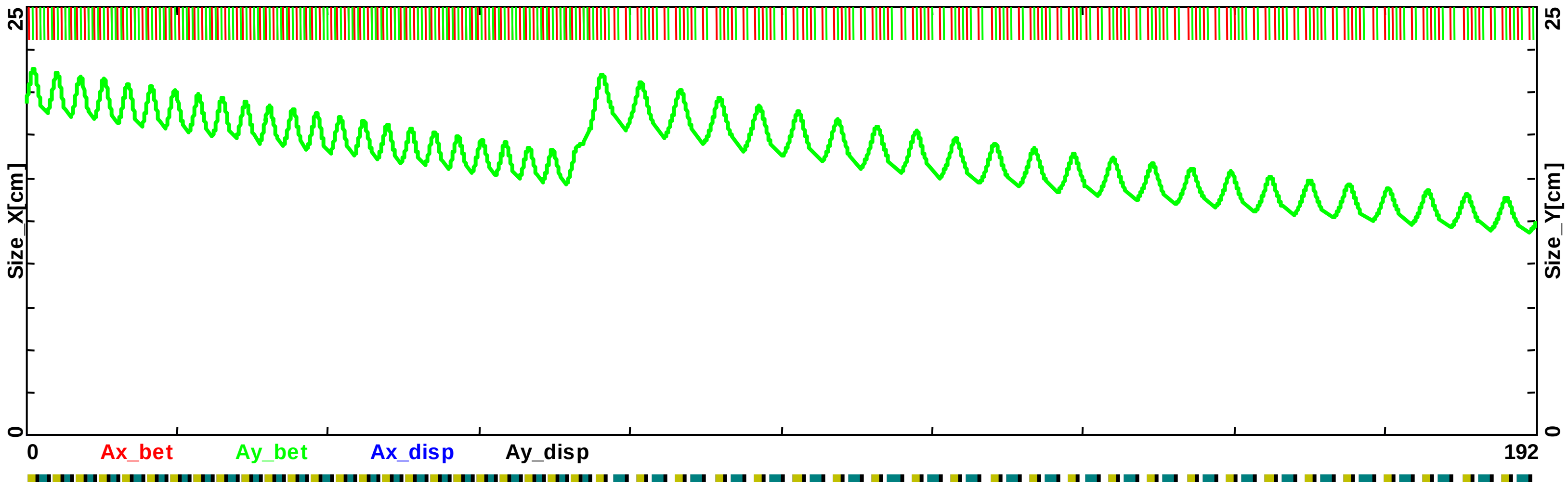


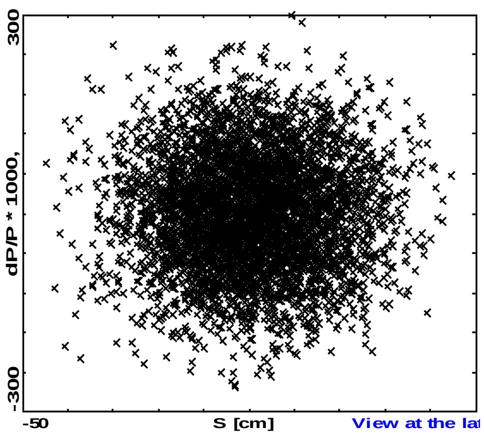


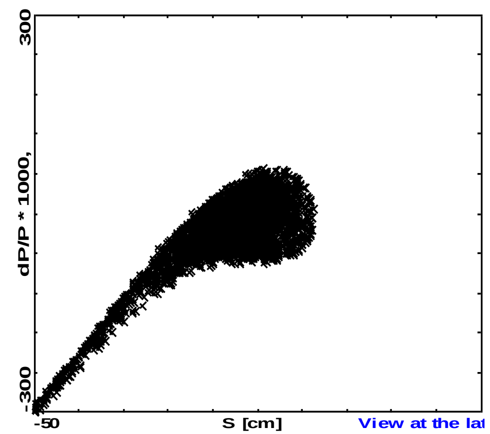
C. Bontoiu
M. Aslaninejad

Linear Pre-accelerator – Longitudinal dynamics

72° before crest | on crest





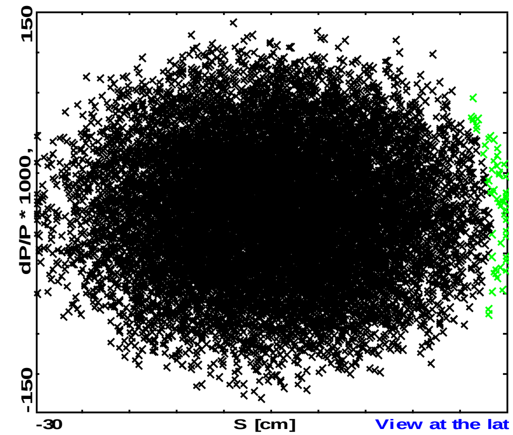


Longitudinal phase-space (s, $\Delta p/p$) **axis range: s = ±50 cm, $\Delta p/p$ = ±0.3**

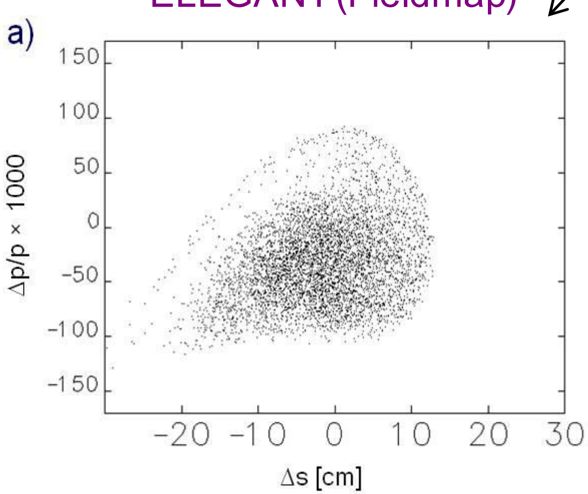
Pre-Linac - Longitudinal phase-space

Initial distribution

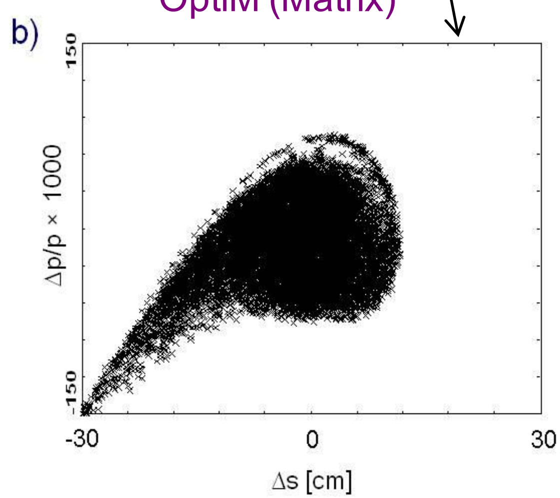
$\varepsilon_x/\varepsilon_y$ = 4.8 mm rad
$\varepsilon_l = \sigma_{\Delta p}\, \sigma_z / m_\mu c$ = 24 mm



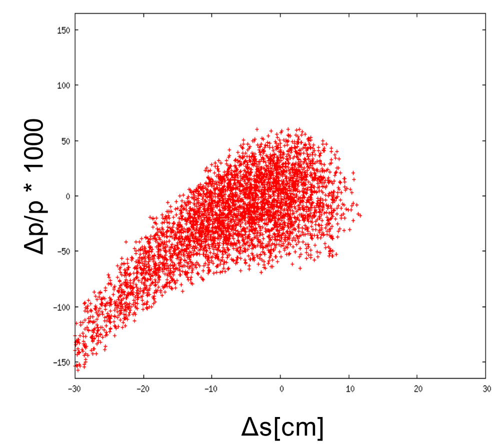
ELEGANT (Fieldmap)



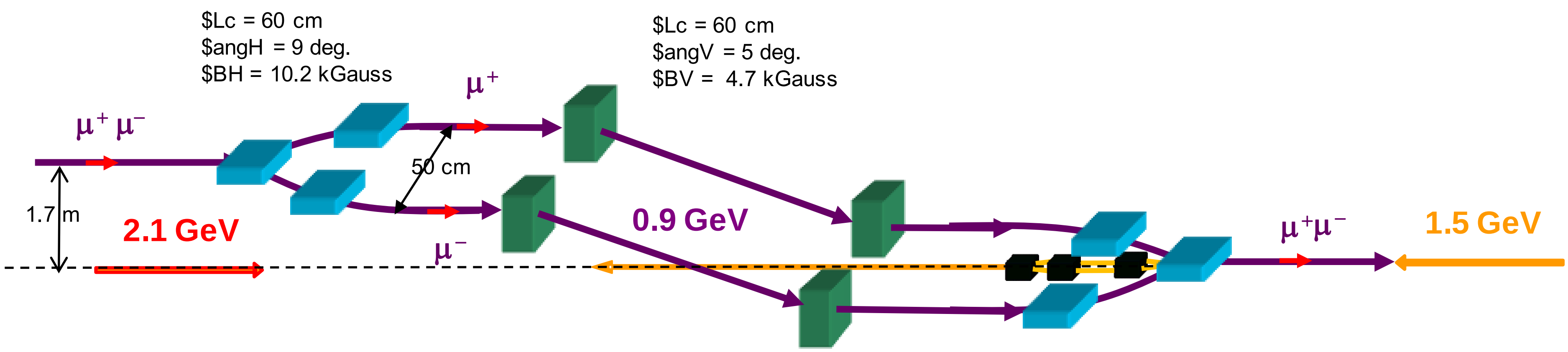
OptiM (Matrix)

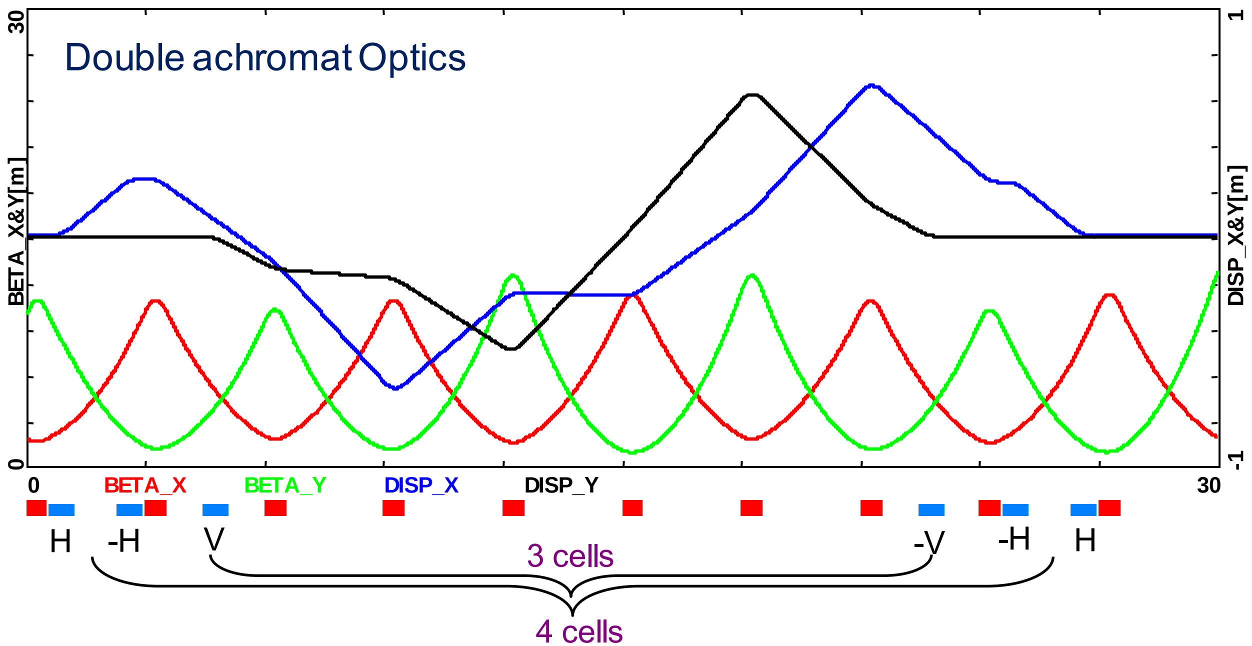


G4beamline (Tracking)



Injection/Extraction Chicane





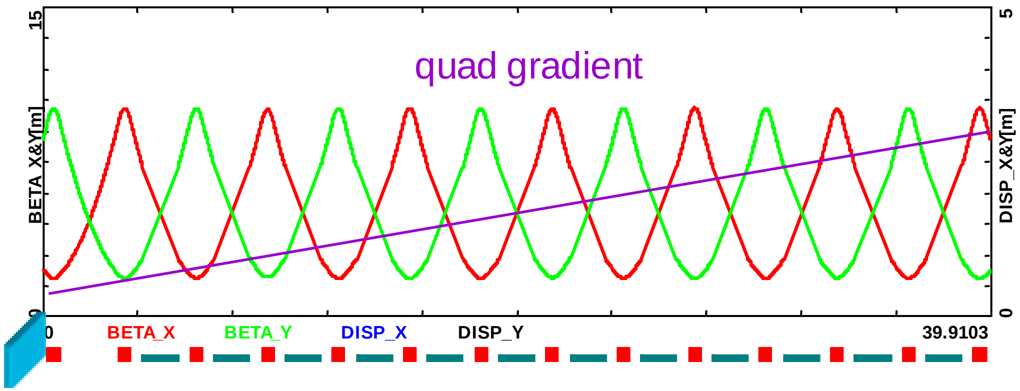
FODO lattice:

$90^0/120^0$ (h/v) betatron phase adv. per cell

Multi-pass Linac Optics – Bisected Linac

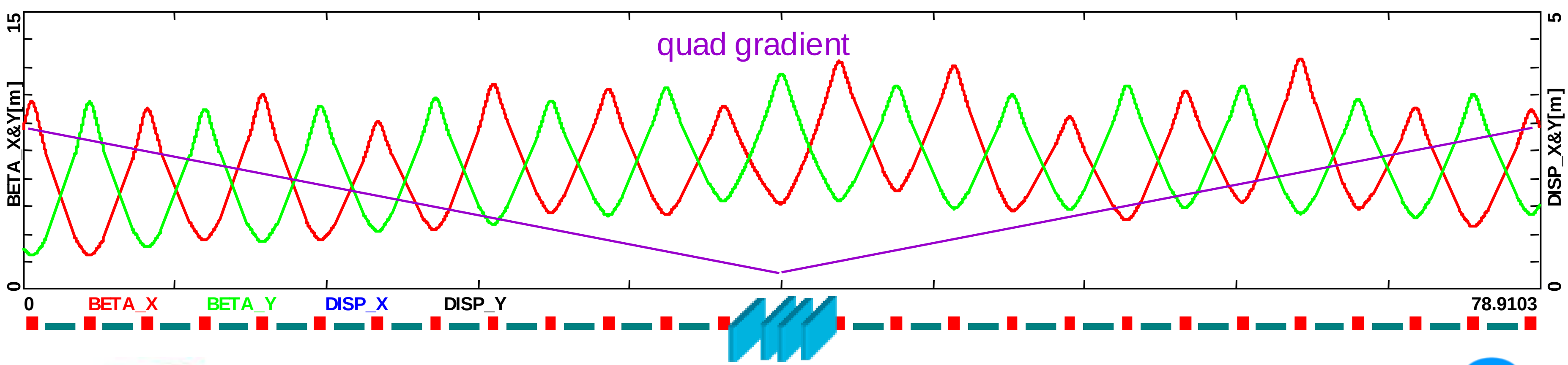
'half pass' , 900-1200 MeV

initial phase adv/cell 90 deg. scaling quads with energy

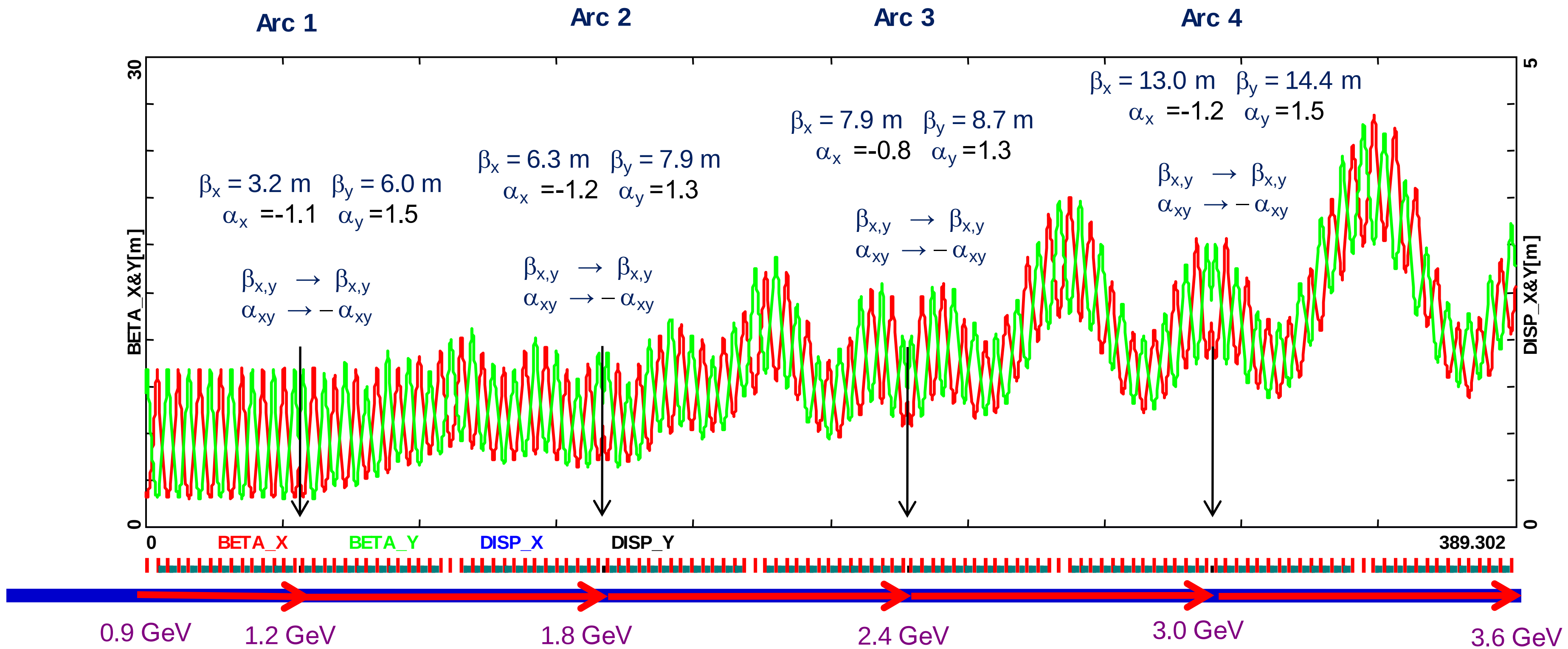


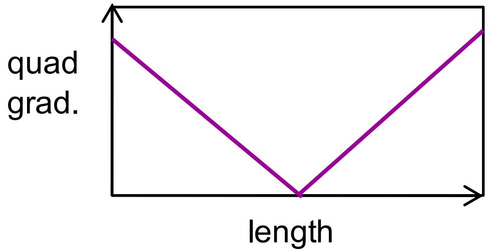
1-pass, 1200-1800 MeV

mirror symmetric quads in the linac

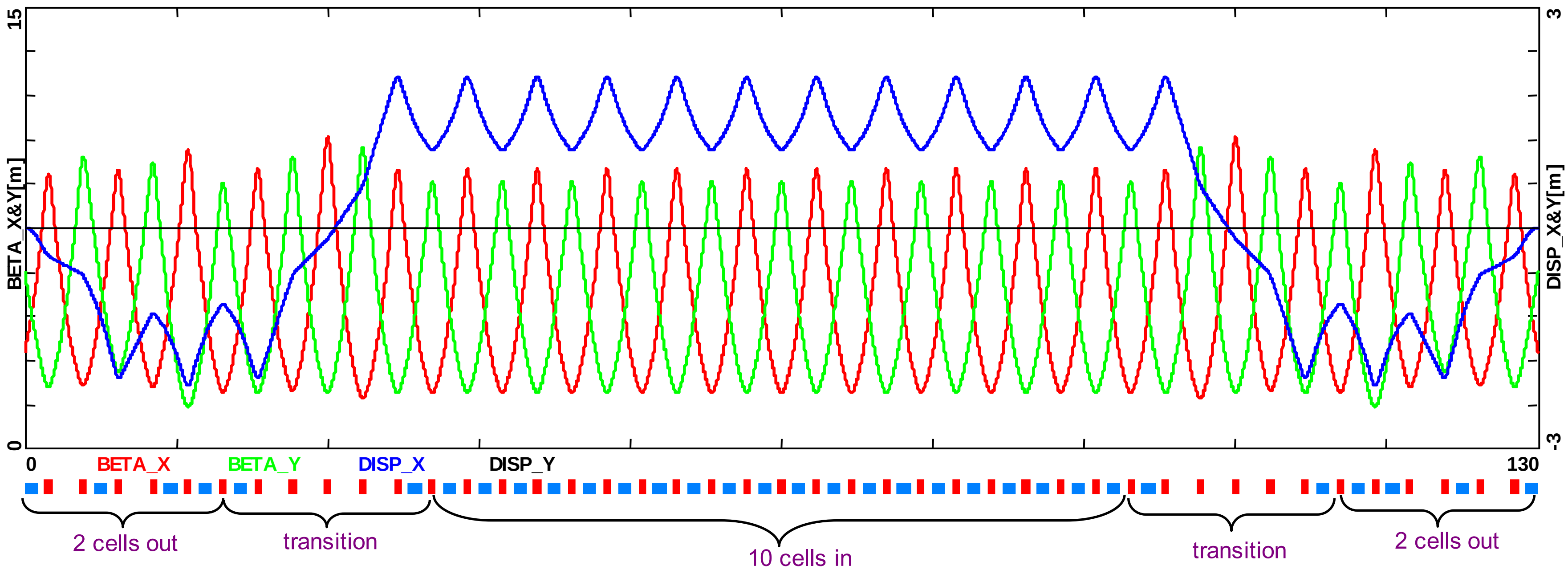


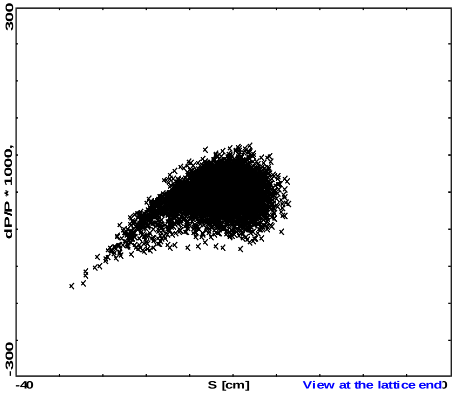
Multi-pass bi-sected linac Optics

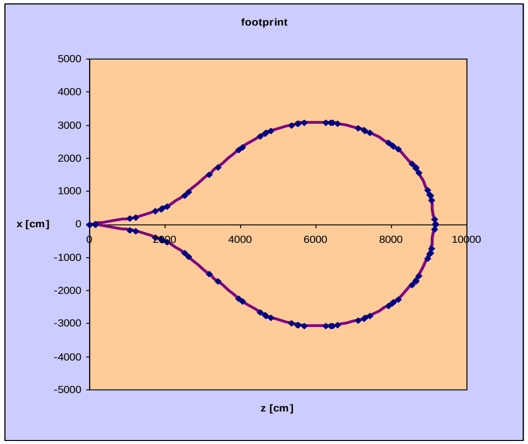


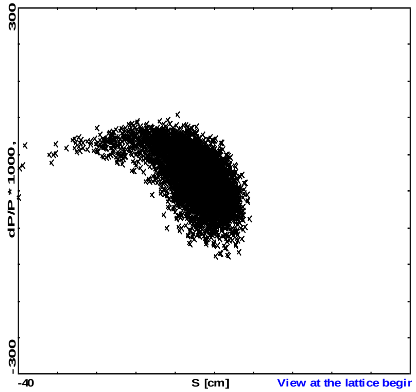


Mirror-symmetric 'Droplet' Arc – Optics

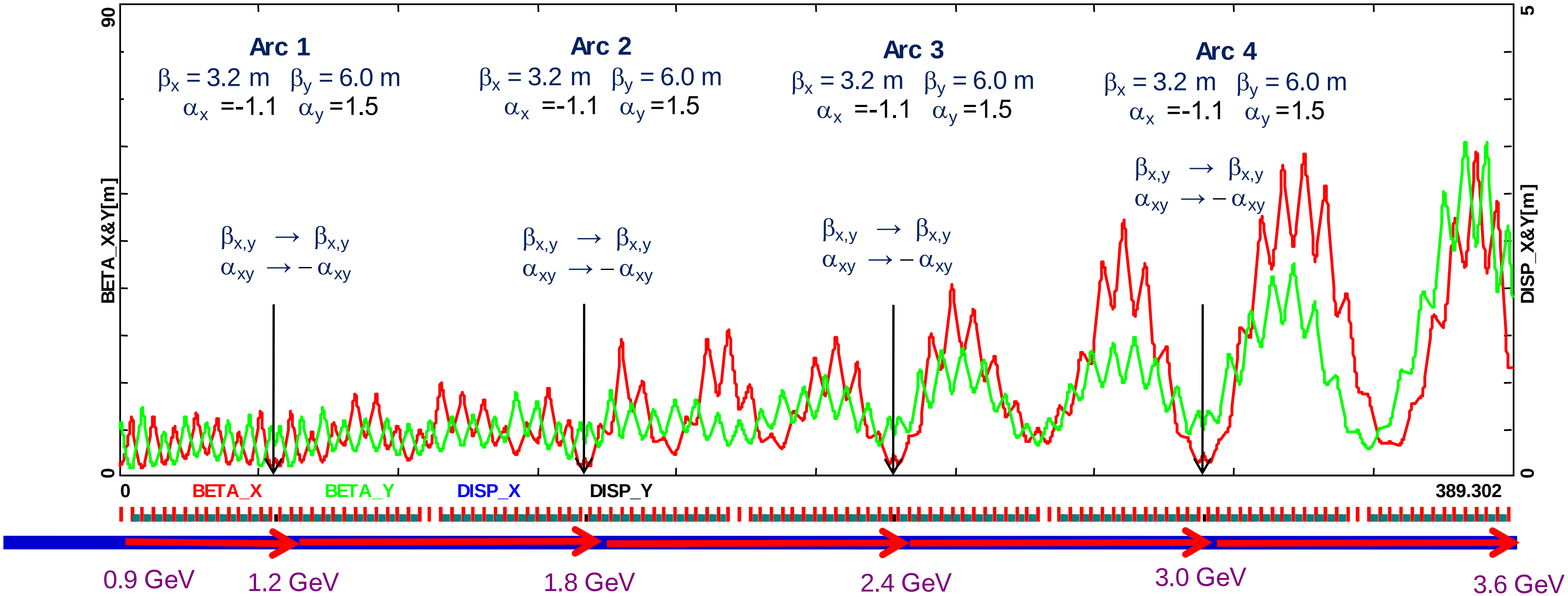


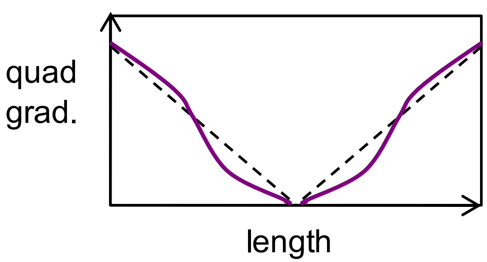




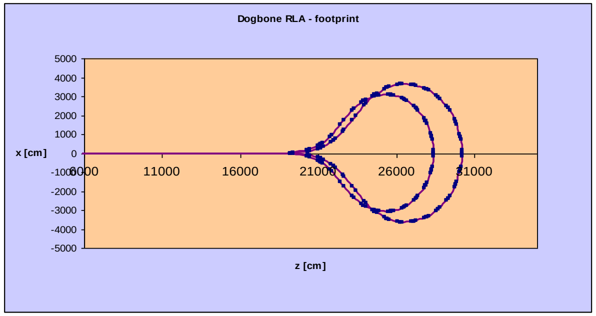


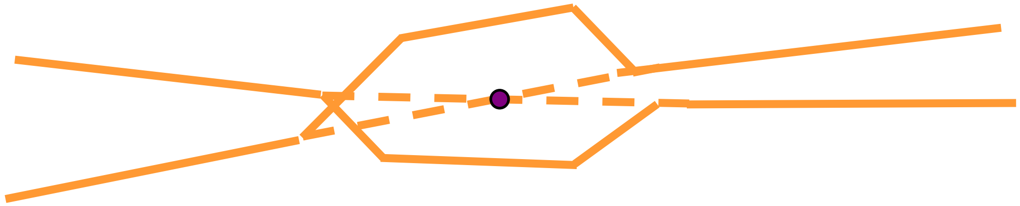
Alternative multi-pass linac Optics

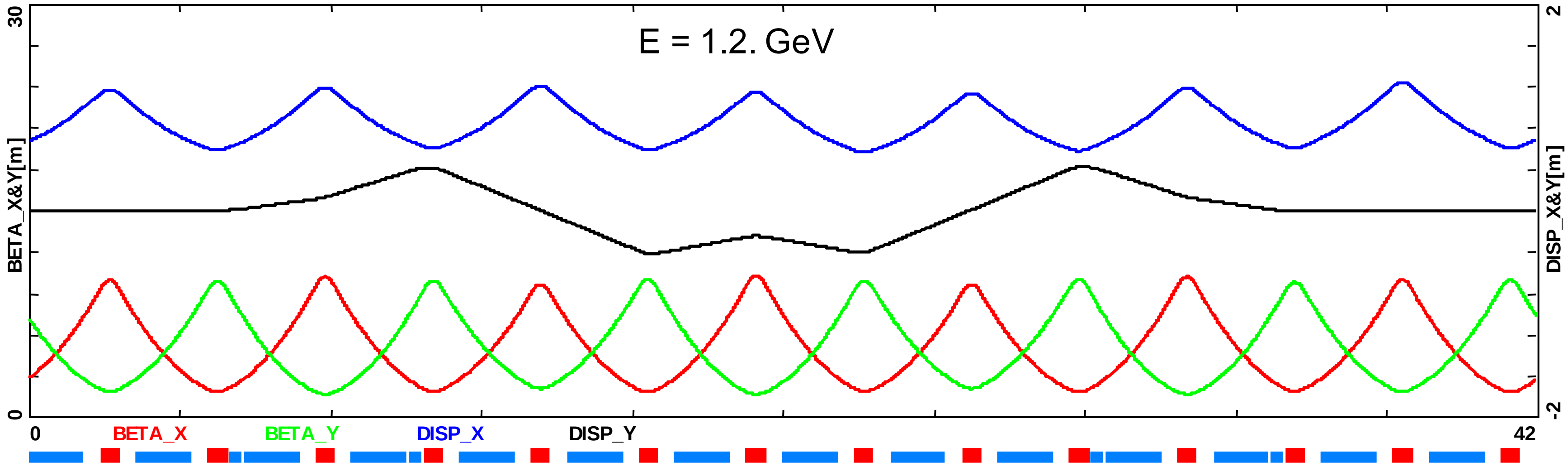


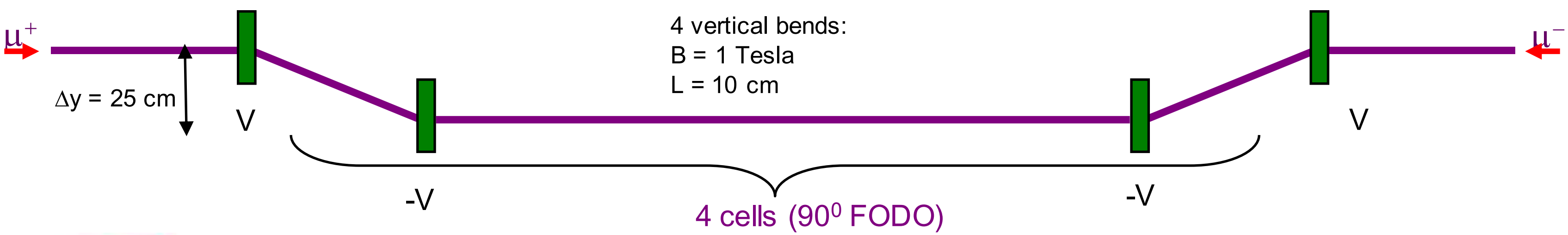


Arcs 'Crossing' - Vertical Bypass



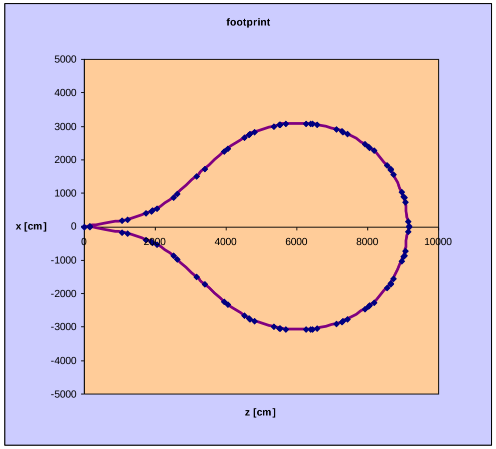






'Droplet' Arcs scaling – RLA I

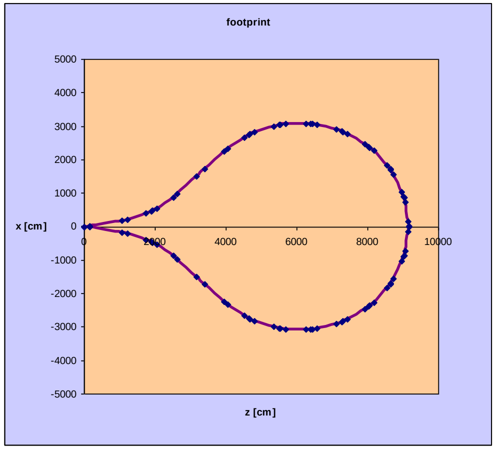
i = 1…4	E_i [GeV]	p_i/p_1	cell_out	cell_in	length [m]
Arc1	1.2	1	2×2	10	130
Arc2	1.8	1.43	2×3	15	172
Arc3	2.4	1.87	2×4	20	214
Arc4	3.0	2.30	2×5	25	256



- Fixed dipole field: B_i =10.5 kGauss
- Quadrupole strength scaled with momentum: $G_i = \frac{p_i}{p_1} \times 0.4$ kGauss/cm
- Arc circumference increases by: (1+1+5) × 6 m = 42 m

'Droplet' Arcs scaling – RLA II

i = 1…4	E_i [GeV]	p_i/p_1	cell_out	cell_in	length [m]
Arc1	4.6	1	2×2	10	260
Arc2	6.6	1.435	2×3	15	344
Arc3	8.6	1.870	2×4	20	428
Arc4	10.6	2.305	2×5	25	512



- Fixed dipole field: B_i = 40.3 kGauss
- Quadrupole strength scaled with momentum: $G_i = \frac{p_i}{p_1} \times 1.5$ kGauss/cm
- Arc circumference increases by: (1+1+5) × 12 m = 84 m

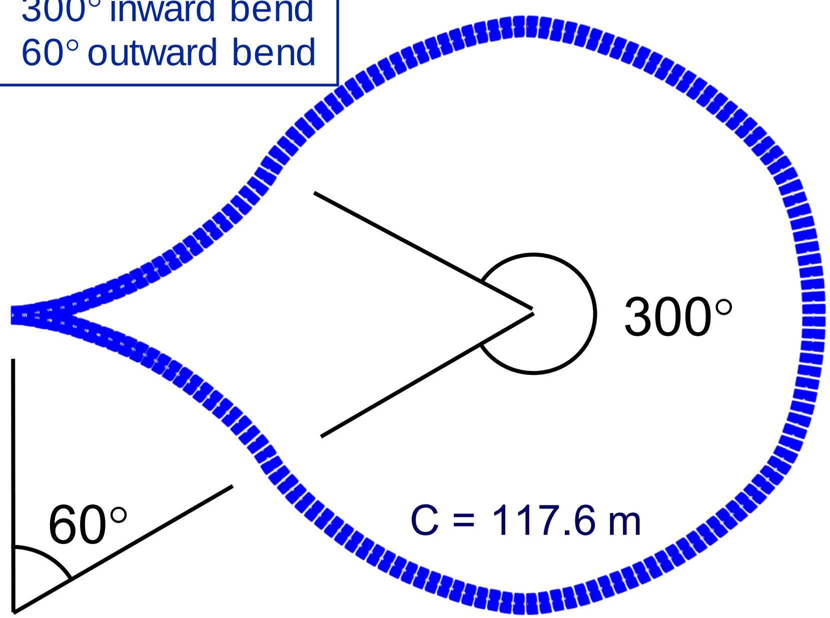
Component Count

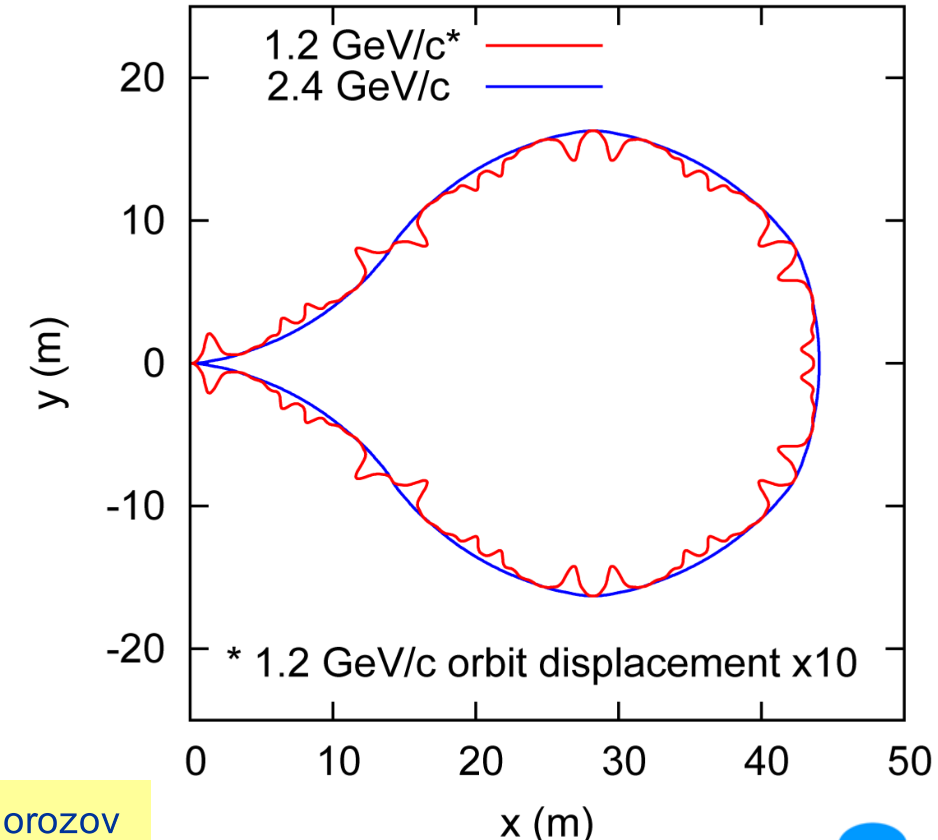
beamline	RF cavities		solenoids	dipoles	quads	sext
	1-cell	2-cell				
pre-accelerator	6	62	25			
inj-chic I				8+3	16	3
RLA I						
linac		24			26	
arc1				35	43	
arc2				49	57	
arc3				63	71	
arc4				77	85	
inj-chic II				8+3	16	3
RLA II						
linac		80			42	
arc1				35	43	
arc2				49	57	
arc3				63	71	
arc4				77	85	
Lambertson				1		

Two-pass Arc Layout

- Simple closing of arc geometry when using similar super cells
- 1.2 / 2.4 GeV/c arc design used as an illustration can be scaled/optimized for higher energies preserving the factor of 2 momentum ratio of the two passes

Droplet arc:
- 60° outward bend
- 300° inward bend
- 60° outward bend



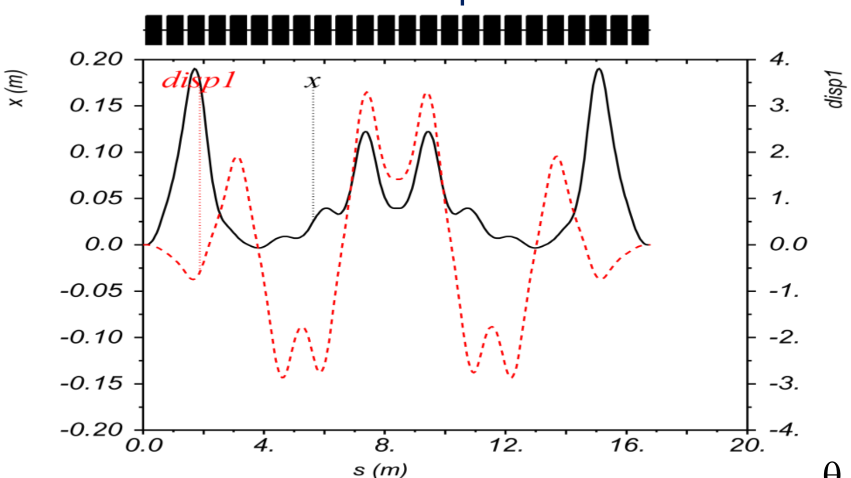


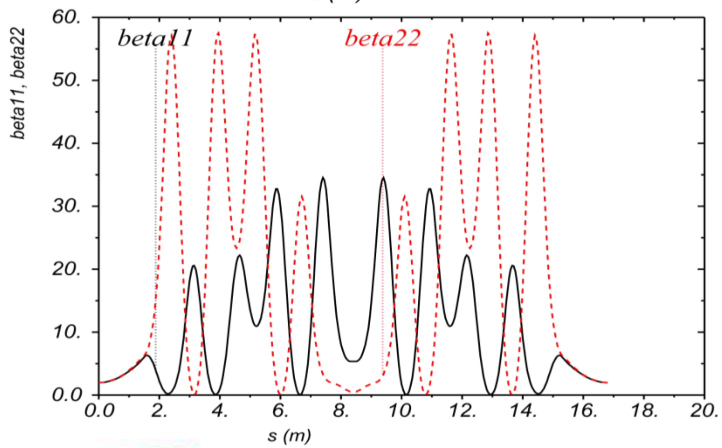
Vasiliy Morozov

Large Acceptance Super-cell (2 passes)

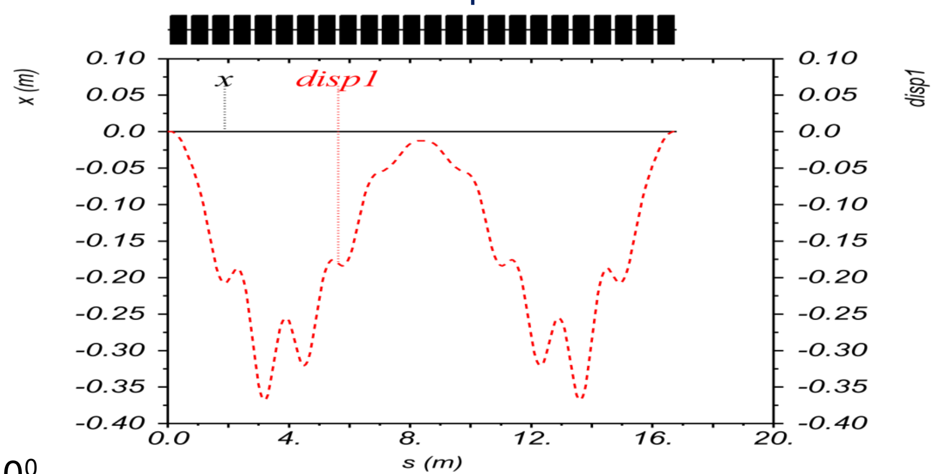
- Each arc is composed of symmetric super cells consisting of linear combined-function magnets (each bend: 2.5^0)

1.2 GeV Optics

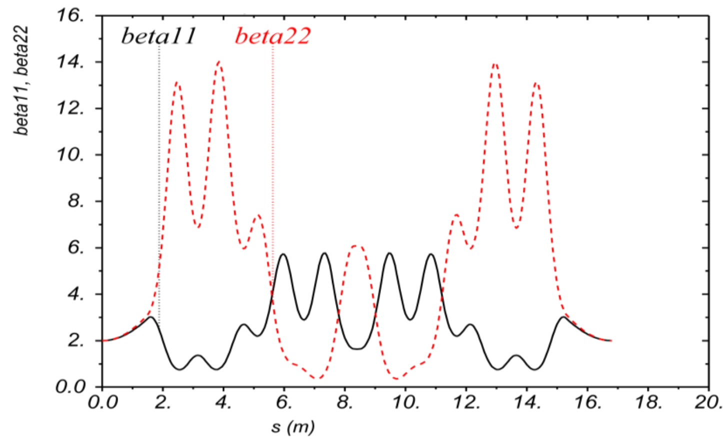




2.4 GeV Optics

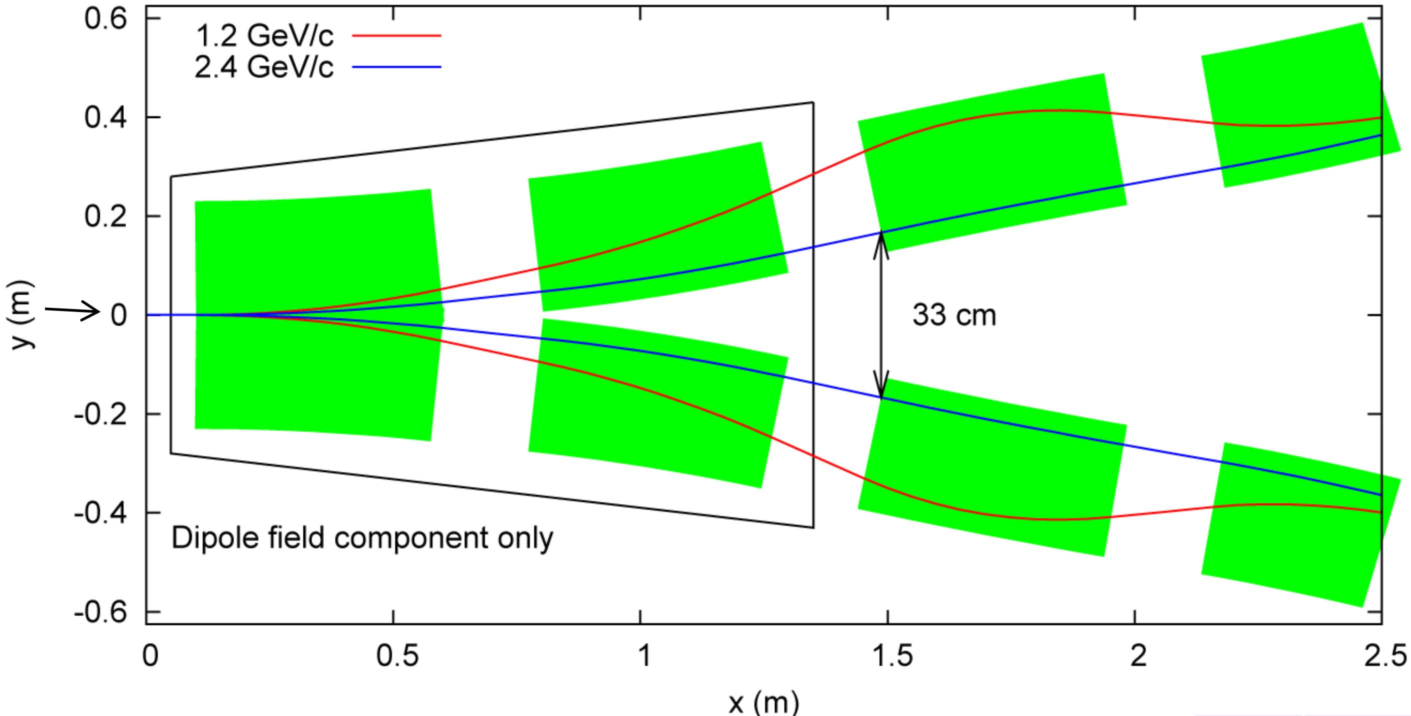


$\theta = 60^0$



‘Droplet’ Arc – Spreader/Recombiner

- First few magnets of the super cell have dipole field component only, serving as Spreader/Recombiner



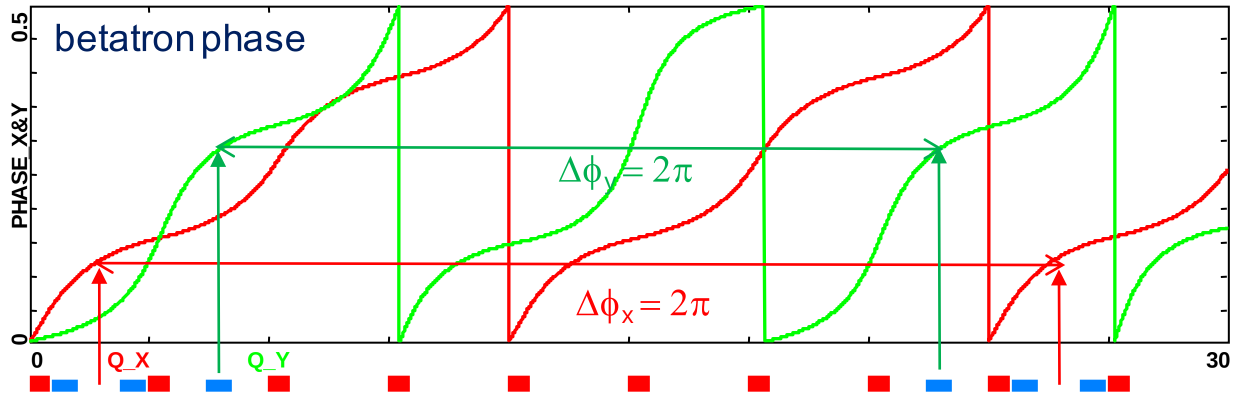
* Trajectories are shown to scale

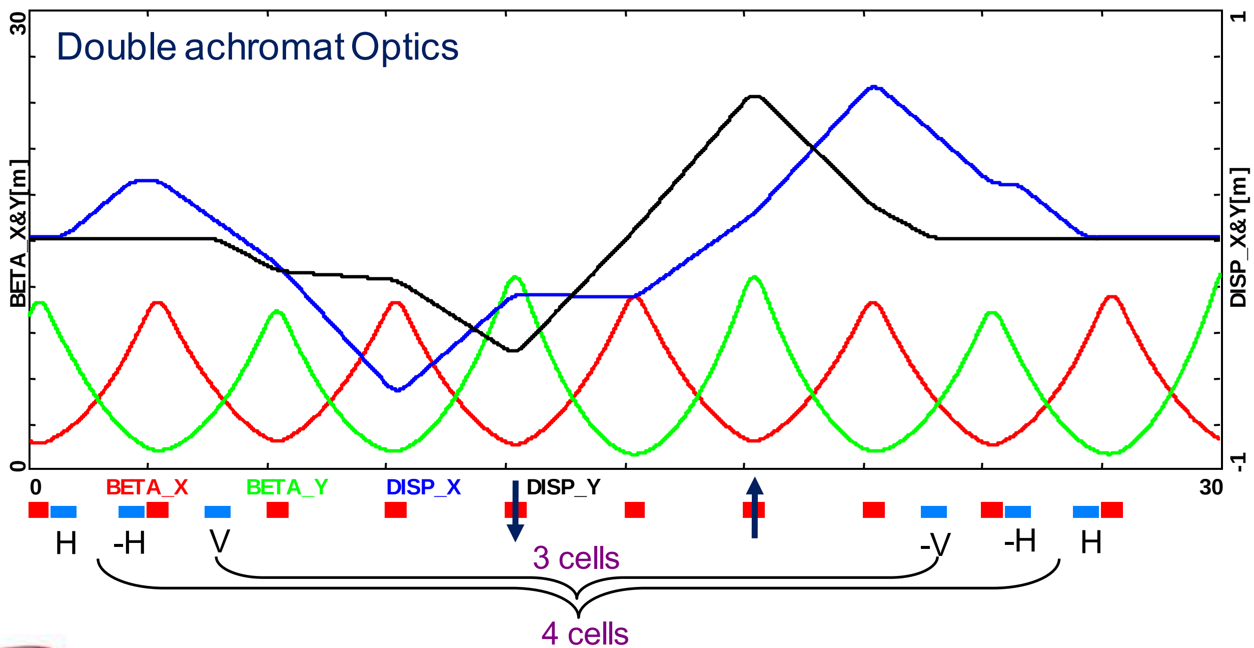
B	1 .7 Tesla
G	28 Tesla/m

Summary

- Piece-wise end-to-end simulation with OptiM/ELEGANT (transport codes)
  - Solenoid linac
  - Injection chicane I (new more compact design)
  - RLA I + Injection chicane II + RLA II
- Alternative multi-pass linac optics
- Currently under study… GPT/G4beamline
  - End-to-end simulation with fringe fields (sol. & rf cav.)
  - Engineer individual active elements (magnets and RF cryo modules)
  - μ decay, background, energy deposition
- Strong synergy with muon collider program

Chicane - Double Achromat Optics





FODO quads:

L[cm] = 50

F: G[kG/cm] = 0.322

D: G[kG/cm] = -0.364

sextupole pair to correct vert. emittance dilution