PERLE – Beam Optics Design

Alex Bogacz

PERLE – Newly Proposed Test Facility

arXiv.org > physics > arXiv:1705.08783v1

CDR

Search or / (Help | Advan

Physics > Accelerator Physics

PERLE: Powerful Energy Recovery Linac for Experiments – Conceptual Design Report

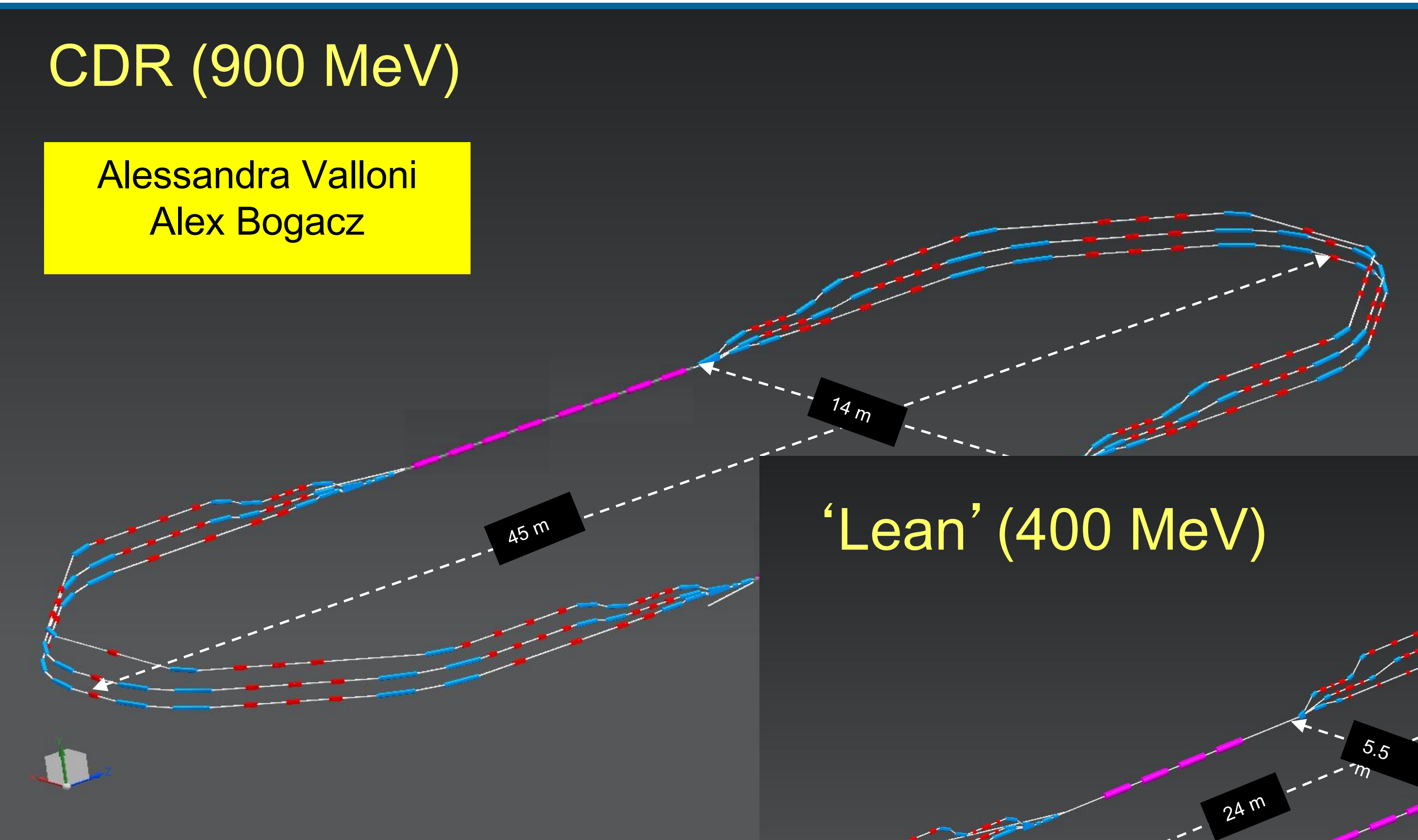
D. Angal-Kalinin, G. Arduini, B. Auchmann, J. Bernauer, A. Bogacz, F. Bordry, S. Bousson, C. Bracco, O. Brüning, R. Calaga, K. Cassou, V. Chetvertkova, E. Cormier, E. Daly, D. Douglas, K. Dupraz, B. Goddard, J. Henry, A. Hutton, E. Jensen, W. Kaabi, M. Klein, P. Kostka, F. Marhauser, A. Martens, A. Milanese, B. Militsyn, Y. Peinaud, D. Pellegrini, N. Pietralla, Y.A. Pupkov, R. A. Rimmer, K. Schirm, D. Schulte, S. Smith, A. Stocchi, A. Valloni, C. Welsch, G. Willering, D. Wollmann, F. Zimmermann, F. Zomer

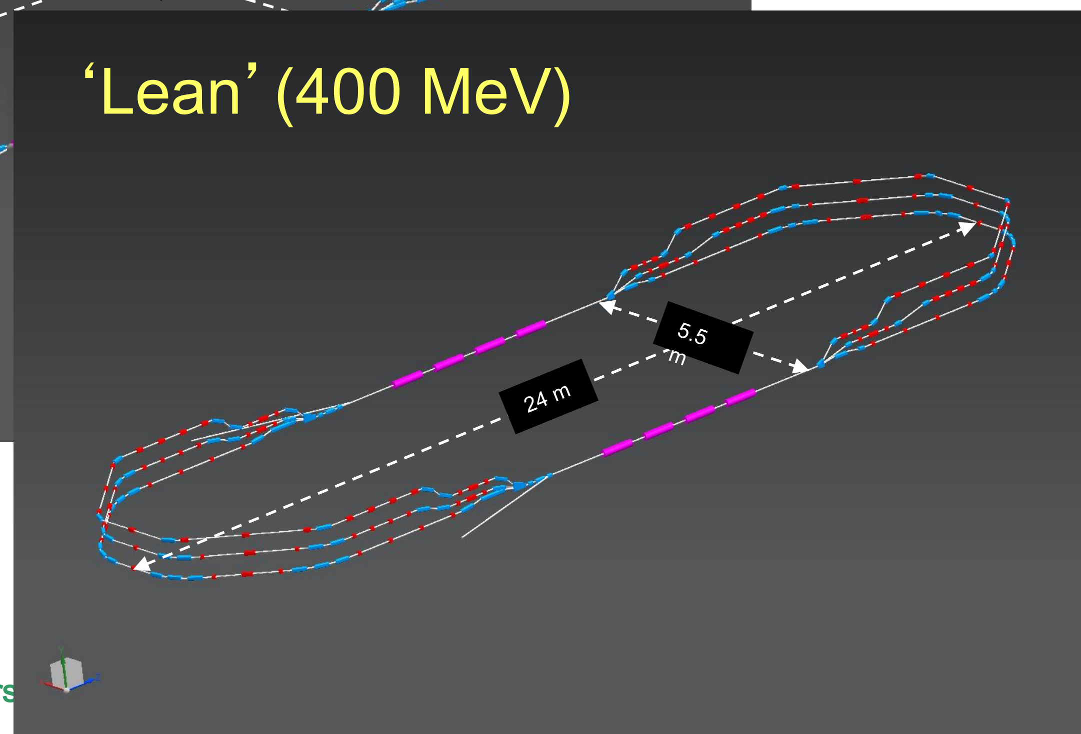
(Submitted on 24 May 2017)

CELIA Bordeaux, MIT Boston, CERN, Cockcroft and
ASTeC Daresbury, TU Darmstadt, U Liverpool, Jefferson Lab
Newport News, BINP Novosibirsk, IPN and LAL Orsay

More on PERLE@Orsay from Walid Kaabi, tomorrow morning

PERLE Downsizing

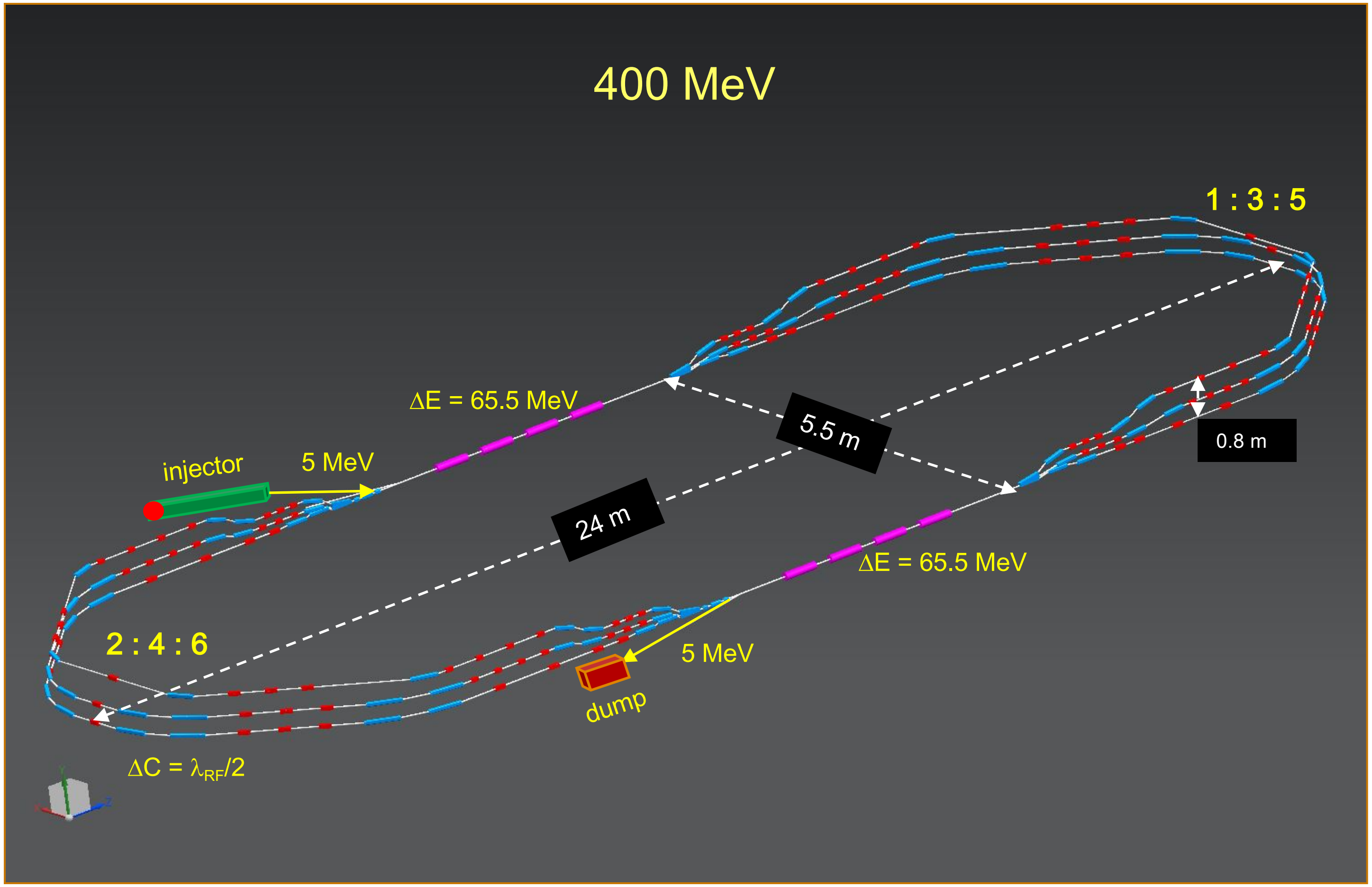




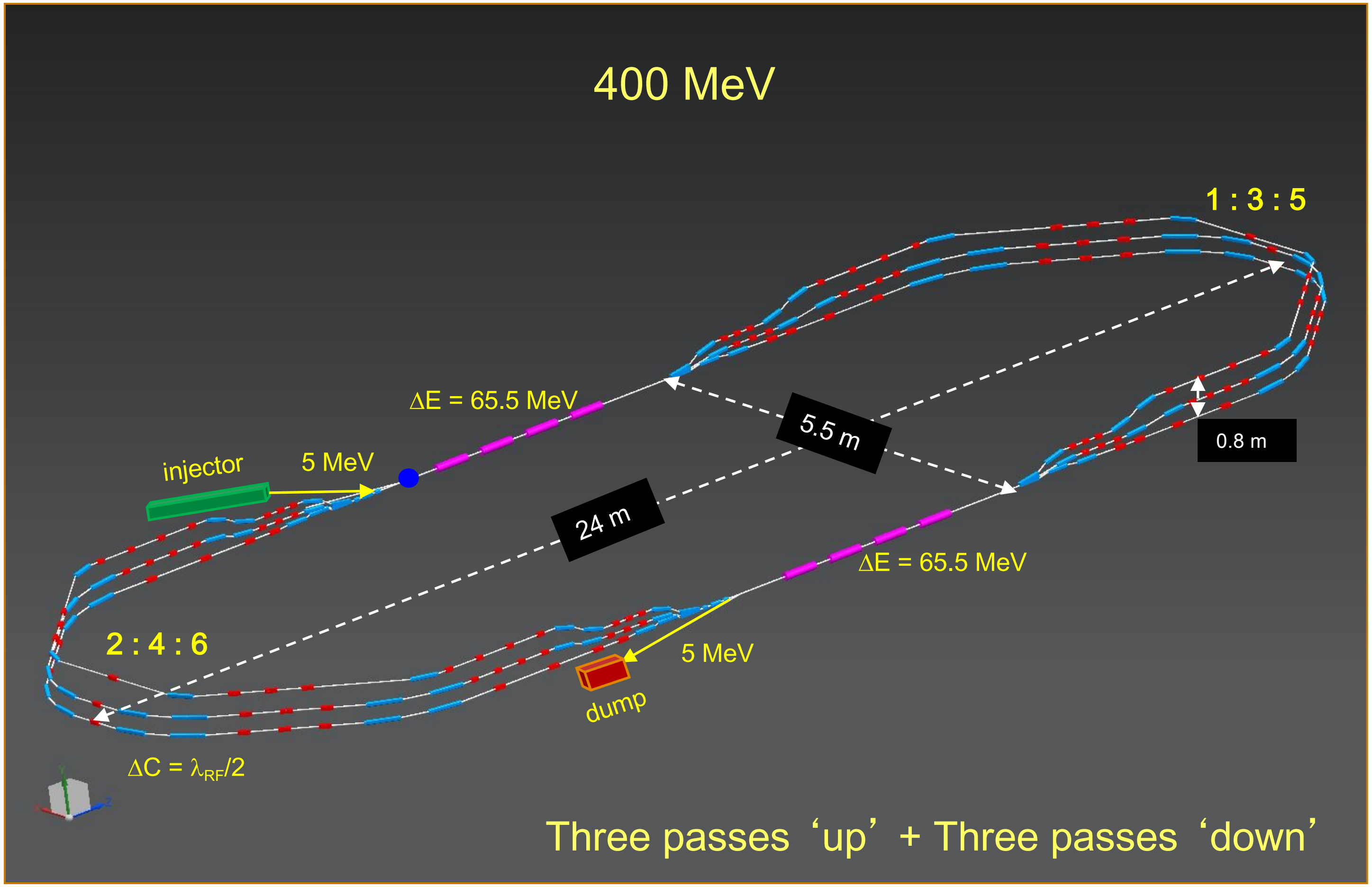
Overview

- PERLE@Orsay (400 MeV) – Layout
  - Compact footprint (24 m × 5.5 m × 0.8 m)
- Multi-pass linac Optics in ER mode
  - Choice of symmetric 'drift linac' Optics: 3-pass 'up' + 3-pass 'down'
- Arc Optics Architecture
  - Isochronous Arcs with Flexible Momentum Compaction (FMC) Optics
  - Configured with two styles of 1.2 Tesla 'curved bends'
- Switchyard
  - Two-step, Vertical Spreaders/Recombiners with matching sections: Linacs-Arcs
- 'First cut' lattice design for PERLE@Orsay
  - Magnet inventory (Dipoles and Quads)
- Outlook – Future R&D

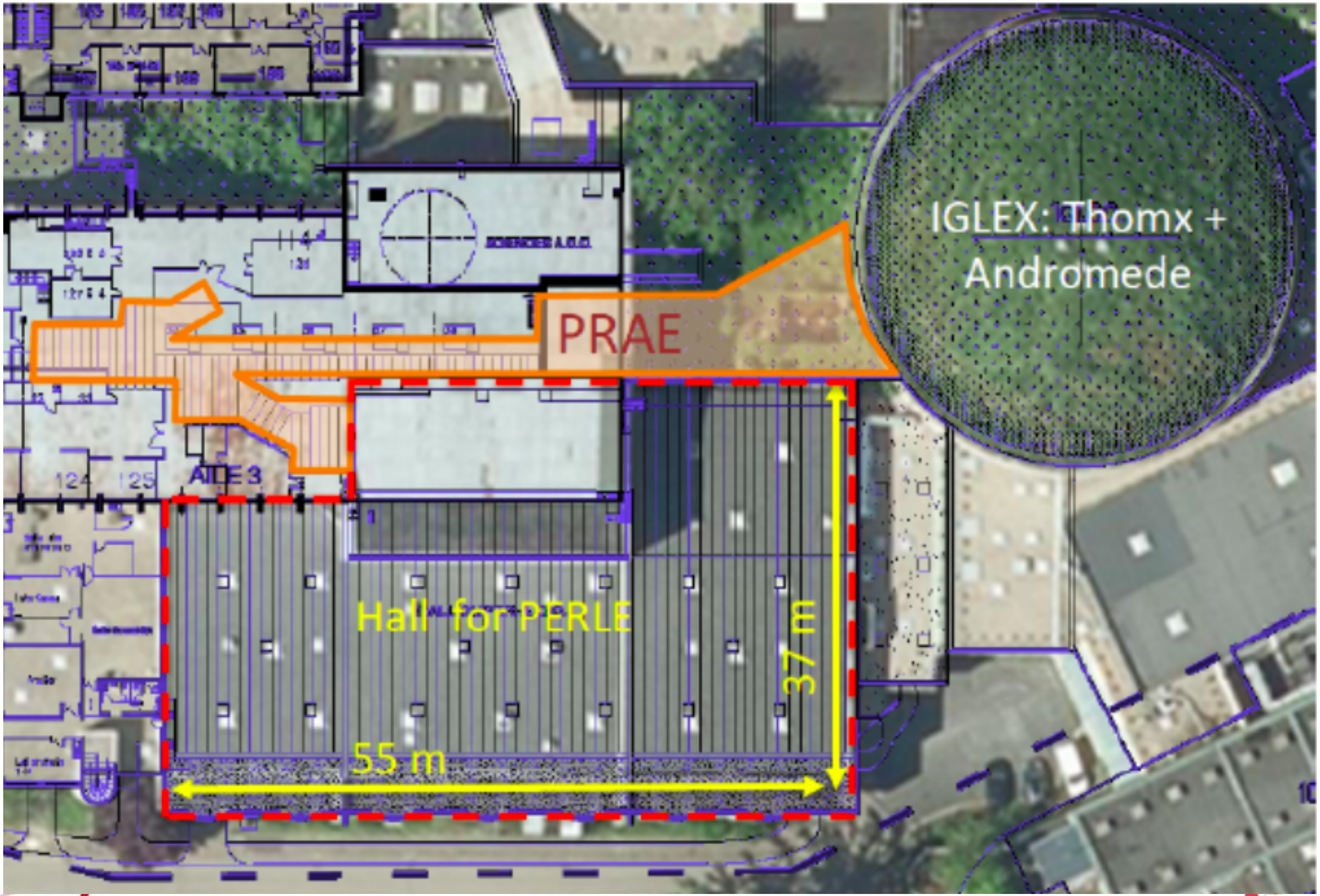
PERLE@Orsay – Layout



PERLE@Orsay – Layout



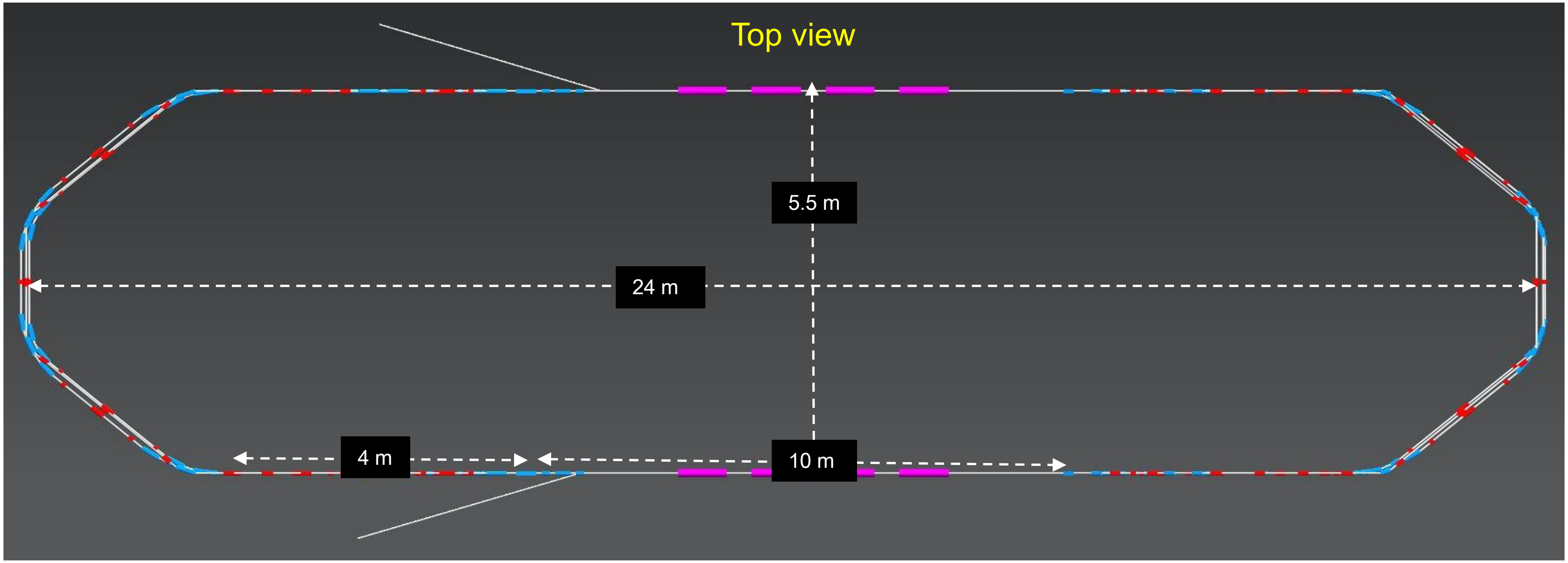
PERLE@Orsay – Site

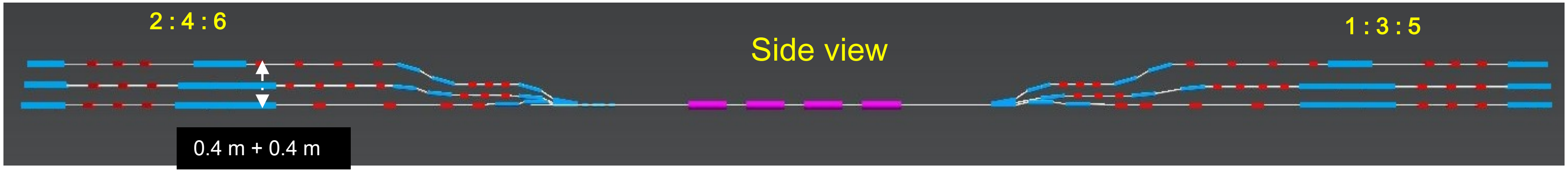


PERLE@Orsay – Baseline Parameters

TARGET PARAMETER	VALUE	
Injection energy [MeV]	5	
Maximum energy [MeV]	400	
Normalised emittance $\gamma\varepsilon_{x,y}$ [mm mrad]	6	
Average beam current [mA]	15	(300
Bunch spacing [ns]	25	(20-th sub harmonics)
Bunch length (rms) [mm]	3	
RF frequency [MHz]	801.58	
Duty factor	CW	

PERLE@Orsay – Layout





Cost-effective Magnet Solution

- Longer and curved bending magnets
- 2 different magnet types with same cross section (only the length changes)
- Only 1 magnet per bend with a deflection of 45°
- Reduction of magnet number (24 compared to 48), could help to reduce cost

Arc	Energy [MeV]	Count	angle [deg]	B [T]	L [mm]	Curv. radius [mm]	Pole gap [mm]	GFR width [mm]	
#1	80	4	45	0.45	456	596	±20	±20	MBA
#2	155	4	45	0.87	456	596	±20	±20	
#3	230	4	45	1.29	456	596	±20	±20	
#4	305	4	45	0.85	912	1191	±20	±20	MBB
#5	380	4	45	1.06	912	1191	±20	±20	
#6	455	4	45	1.27	912	1191	±20	±20	

PERLE Magnet Design (dipoles and quads)

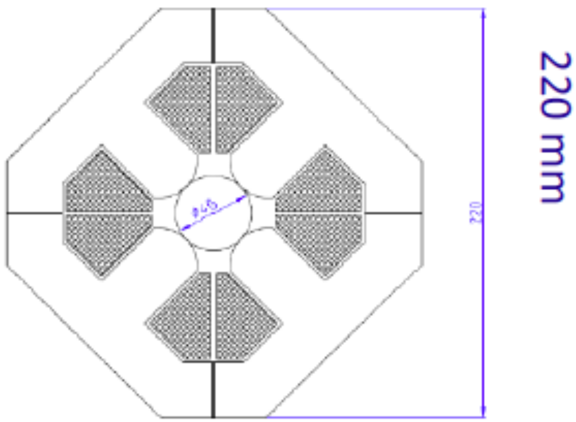
70 dipoles 0.45-1.29 T

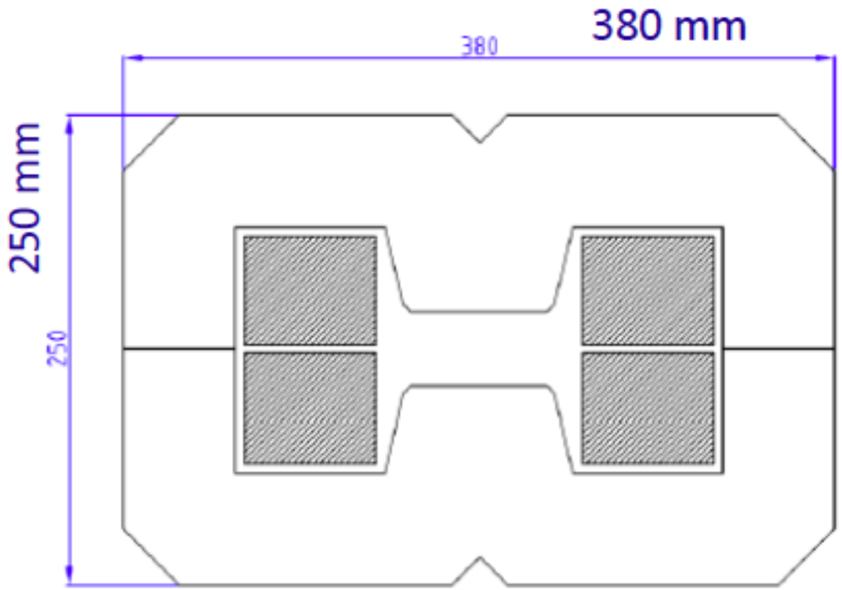
+- 20 mm aperture, l=200,300,400 mm

May be identical for hor+vert bend

7A/mm2 (in grey area) water cooled

DC operated





114 quadrupoles max 28T/m

Common aperture of 40mm all arcs

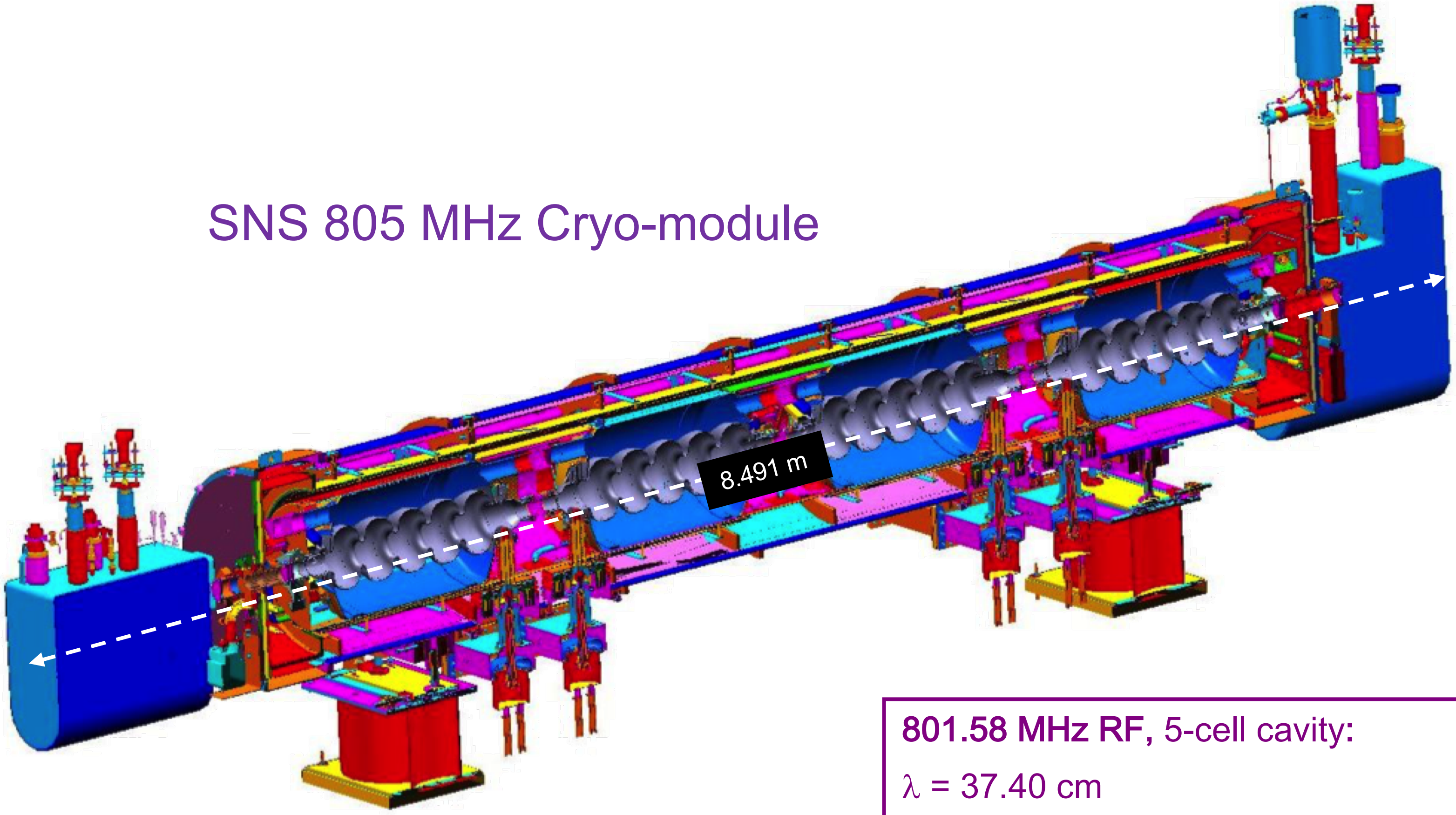
Two lengths: 100 and 150mm

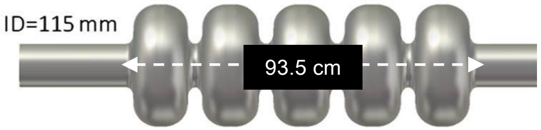
DC operated

P Thonet, A Milanese (CERN), C Vallerand (LAL), Y Pupkov (BINP)

Cryo-module – Layout and Cavity Specs

SNS 805 MHz Cryo-module





801.58 MHz RF, 5-cell cavity:

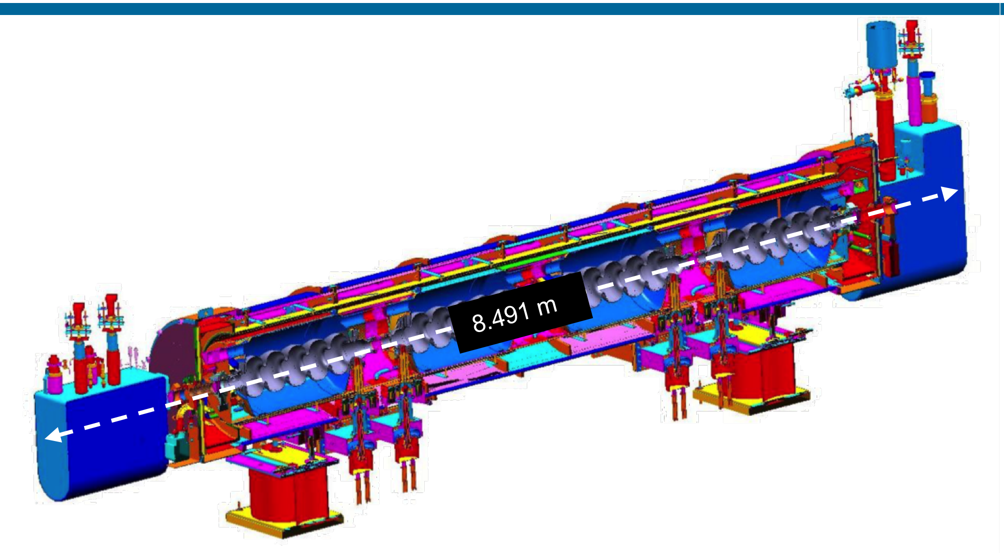
λ = 37.40 cm

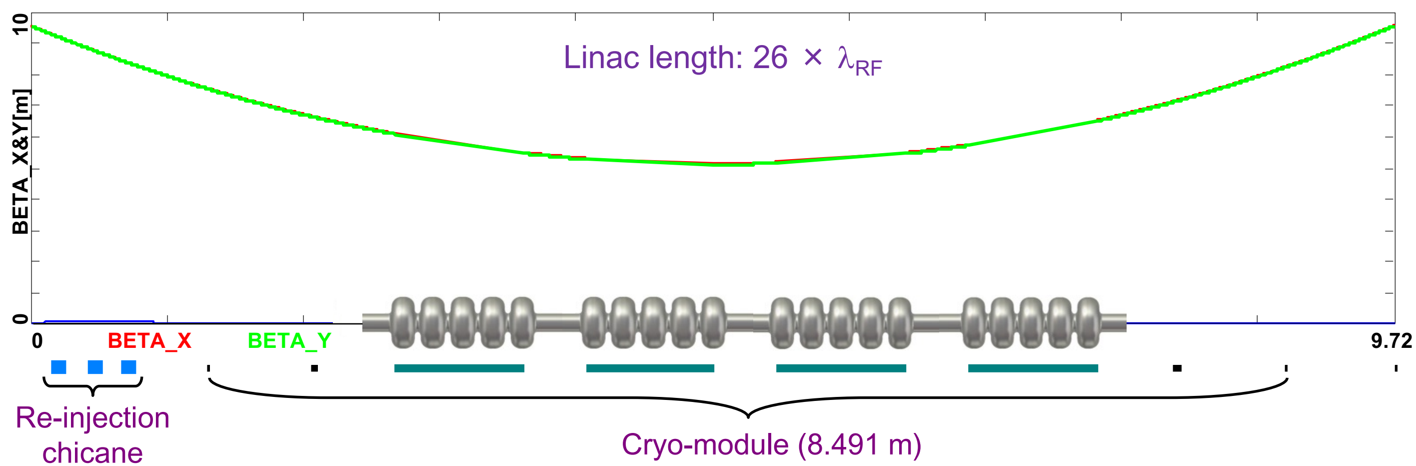
$L_c = 5\lambda/2 = 93.50$ cm

Grad = 17.5 MeV/m (16.4 MeV per cavity)

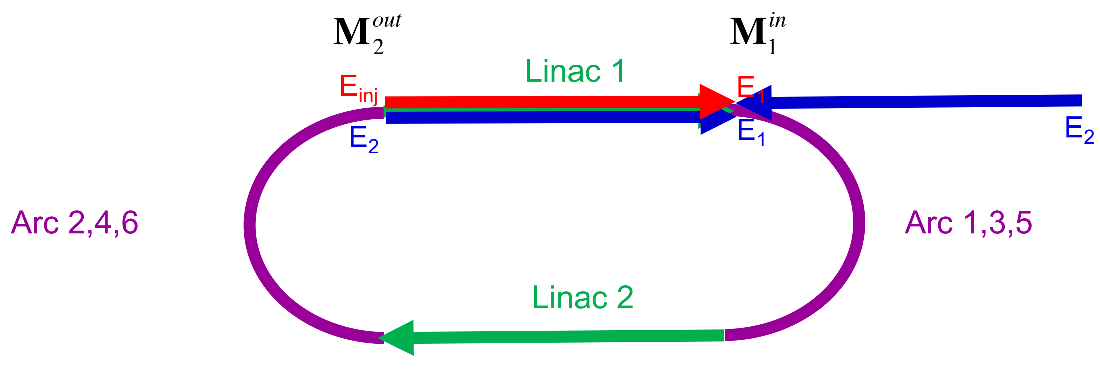
ΔE= 65.5 MeV per Cryo-module

Linac – Layout

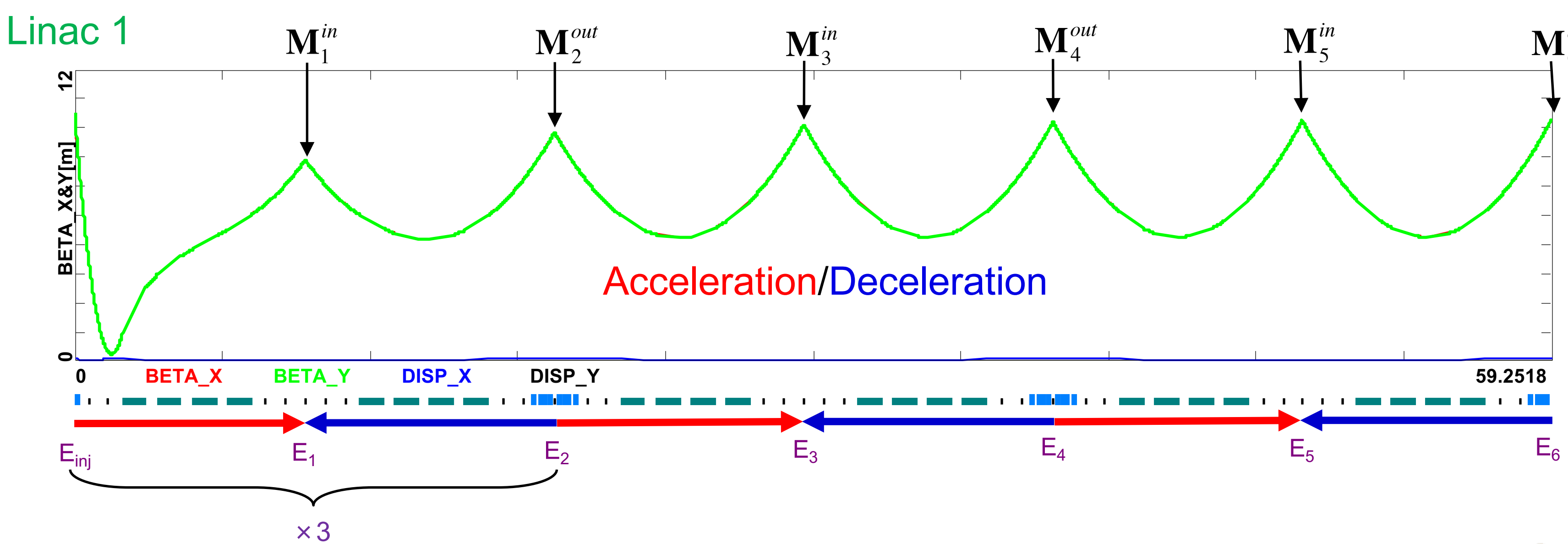




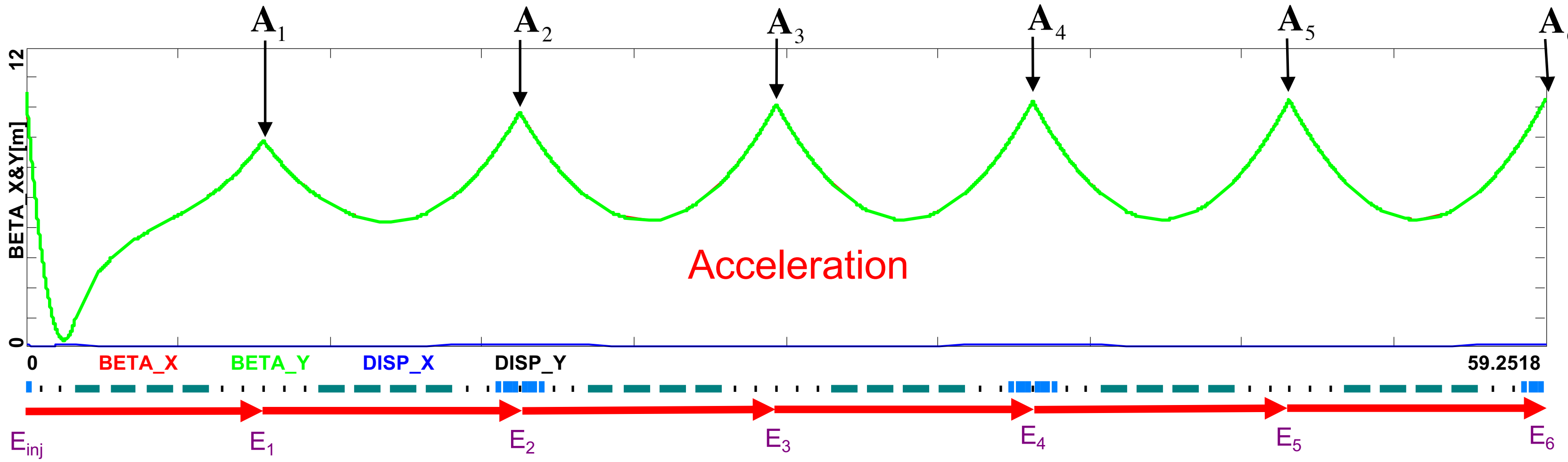
Multi-pass Linac ER Optics

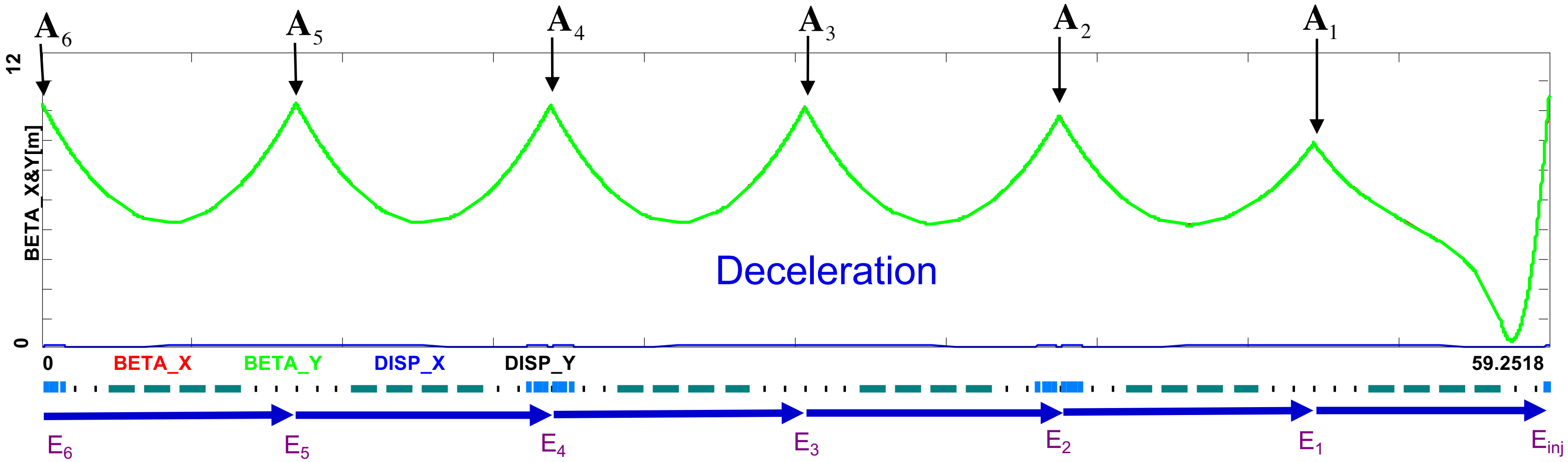


$$\mathbf{M} = \begin{bmatrix} \beta_x \\ -\alpha_x \\ \beta_y \\ -\alpha_y \end{bmatrix}$$

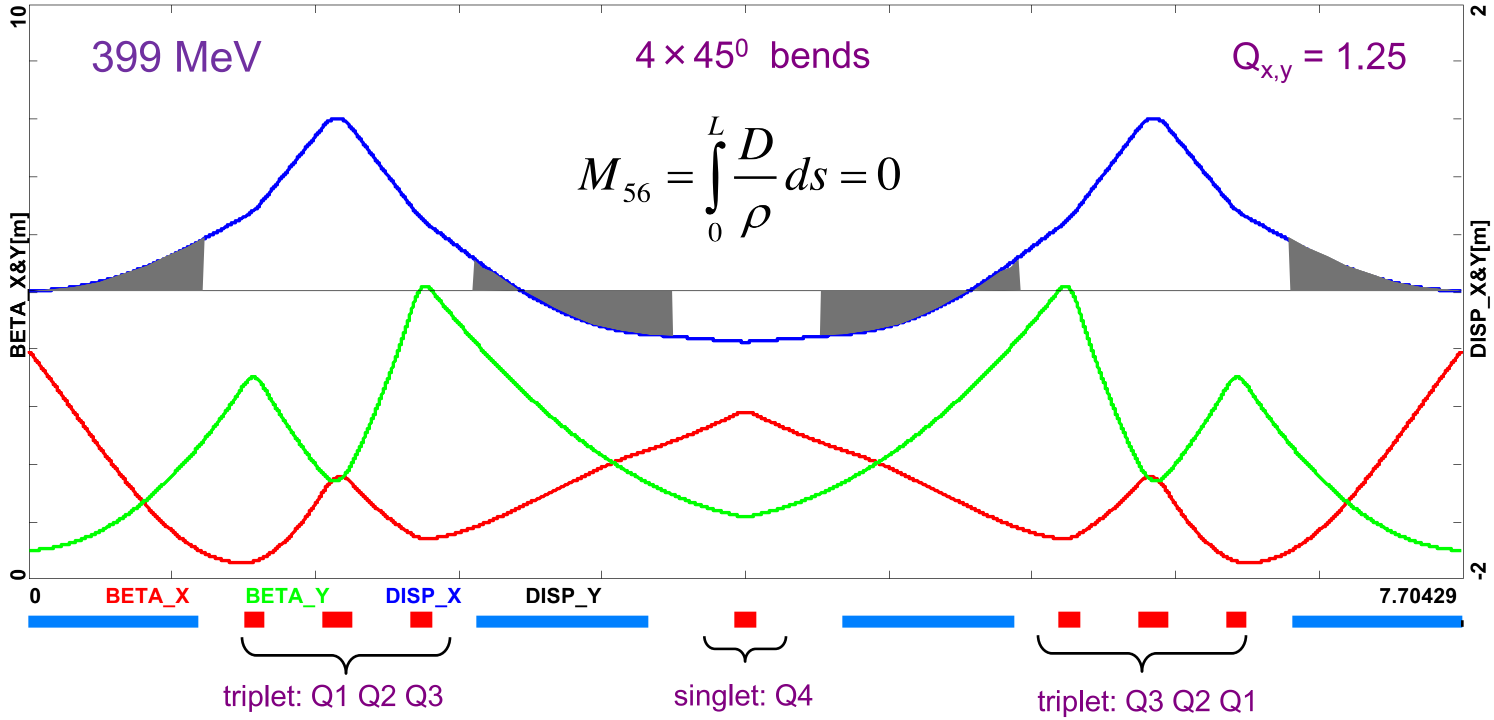


Multi-pass ER Optics





Arc 6 Optics – FMC Lattice



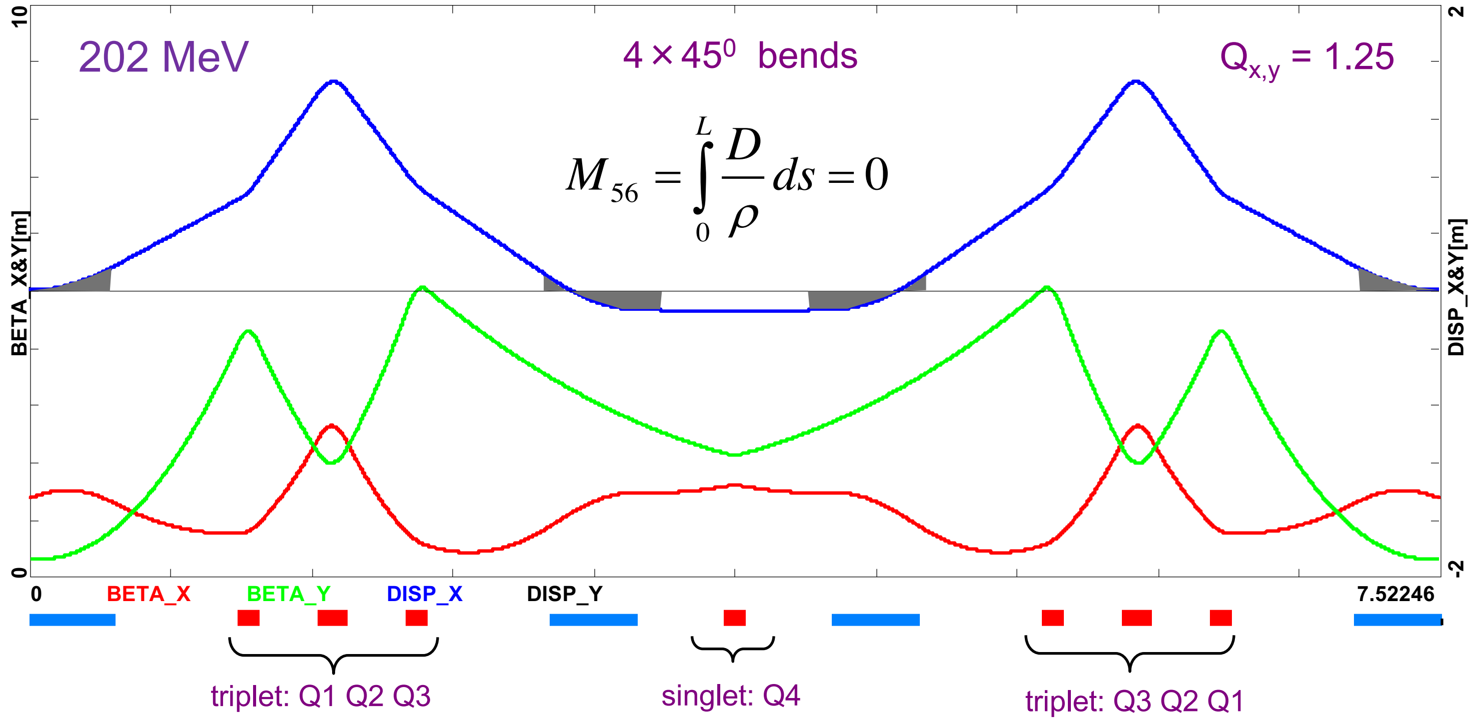
Dipoles: (91.2 cm long)

B = 1.2 Tesla

Quadrupoles:

Q1	L[cm] =10	G[T/m] = - 23.6
Q2	L[cm] =15	G[T/m] = 28.2
Q3	L[cm] =10	G[T/m] = - 22.4
Q4	L[cm] =10	G[T/m] = 8.6

Arc 3 Optics – FMC Lattice



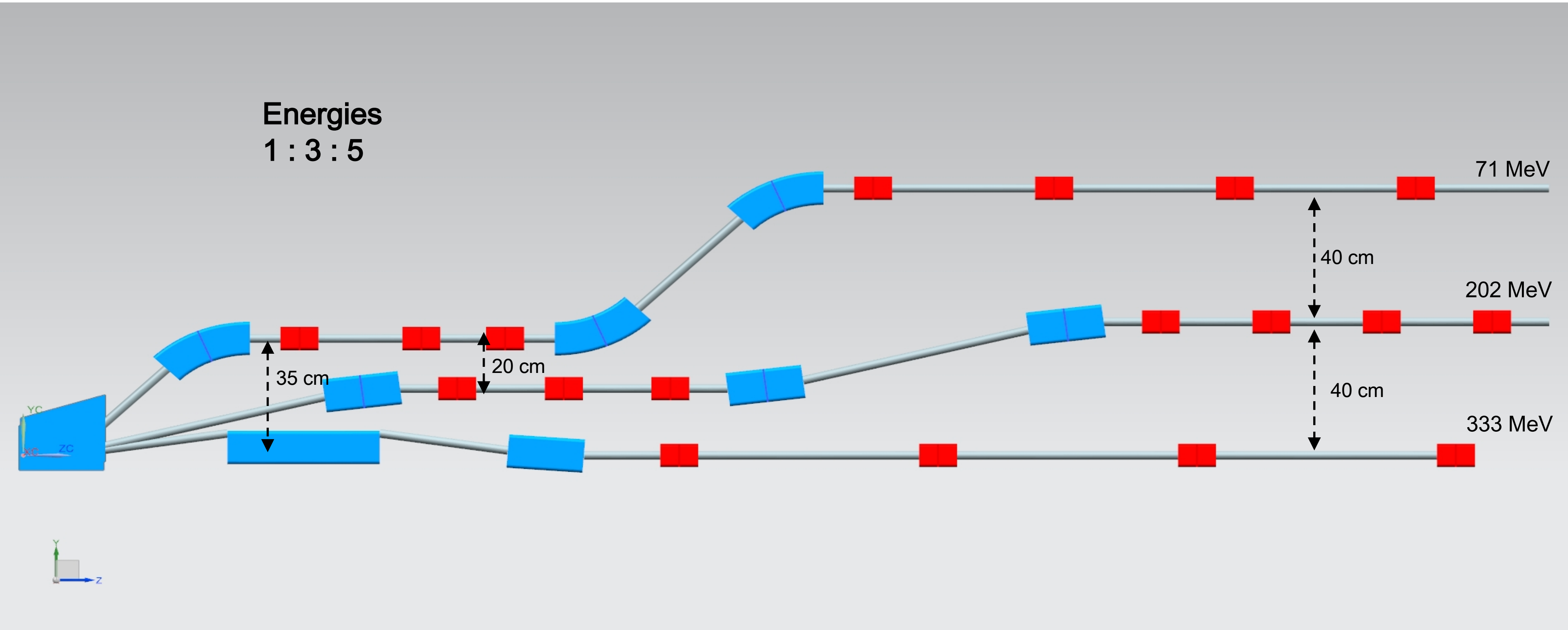
Dipoles: (45.6 cm long)

B = 1.2 Tesla

Quadrupoles:

Q1	L[cm] =10	G[T/m] = - 13.2
Q2	L[cm] =15	G[T/m] = 13.1
Q3	L[cm] =10	G[T/m] = - 9.3
Q4	L[cm] =10	G[T/m] = 3.1

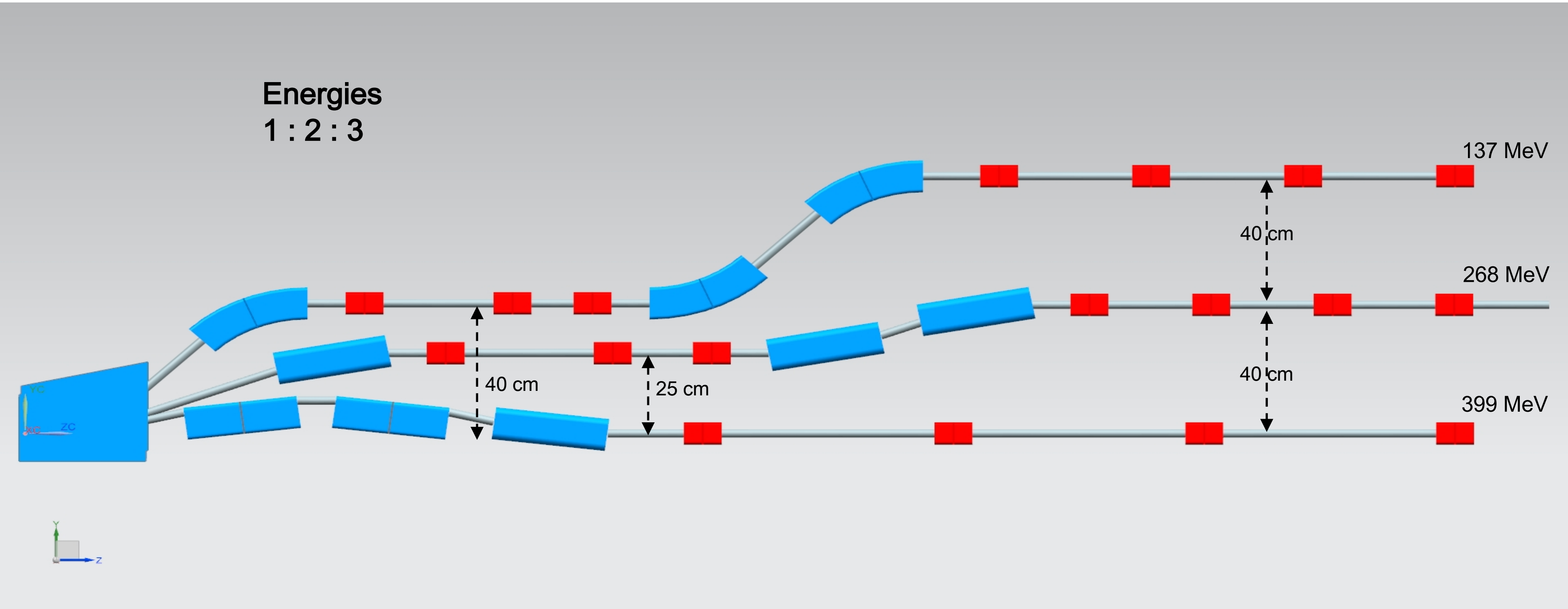
Switchyard – Vertical Separation of Arcs (1, 3, 5)



Dipoles: (20 and 40 cm long)

B = 0.8 Tesla

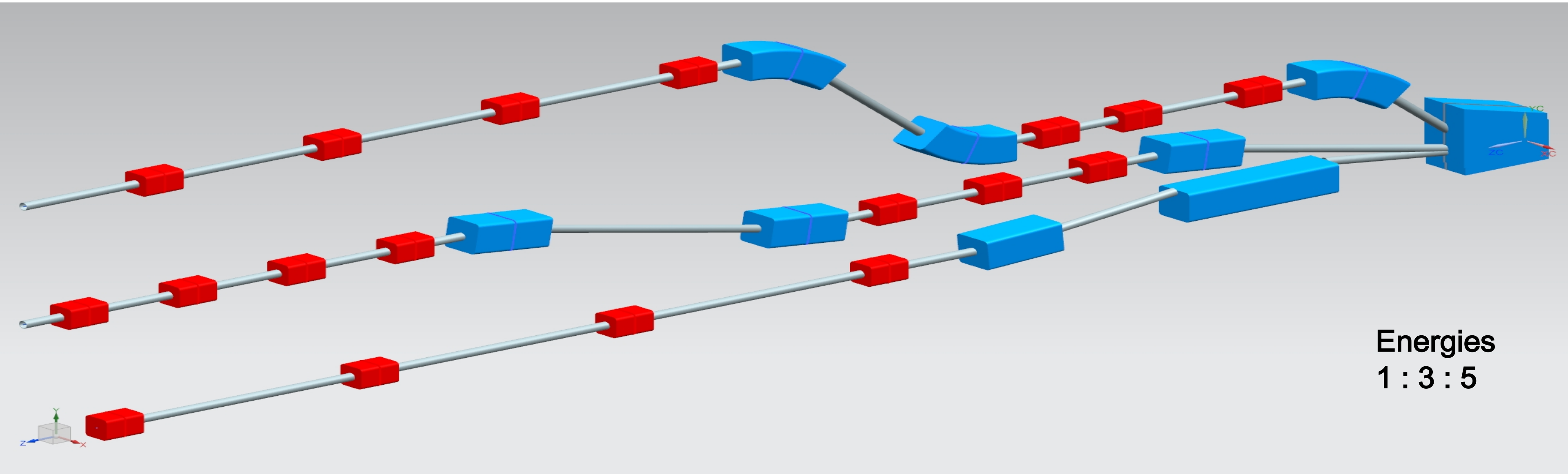
Switchyard – Vertical Separation of Arcs (2, 4, 6)

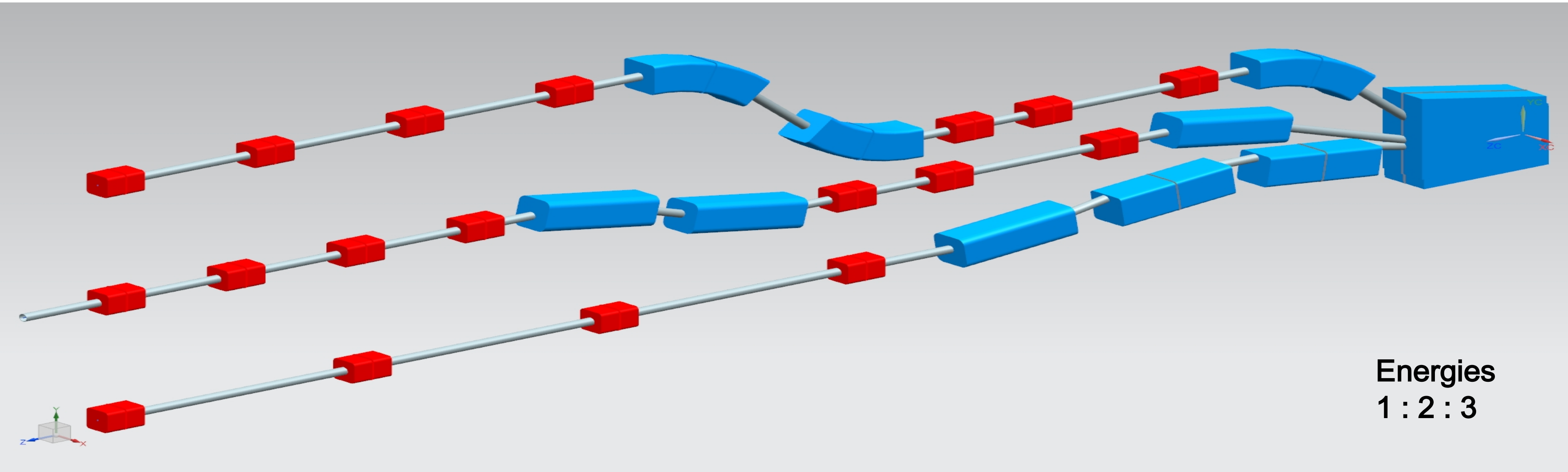


Dipoles: (30 cm long)

B = 1.2 Tesla

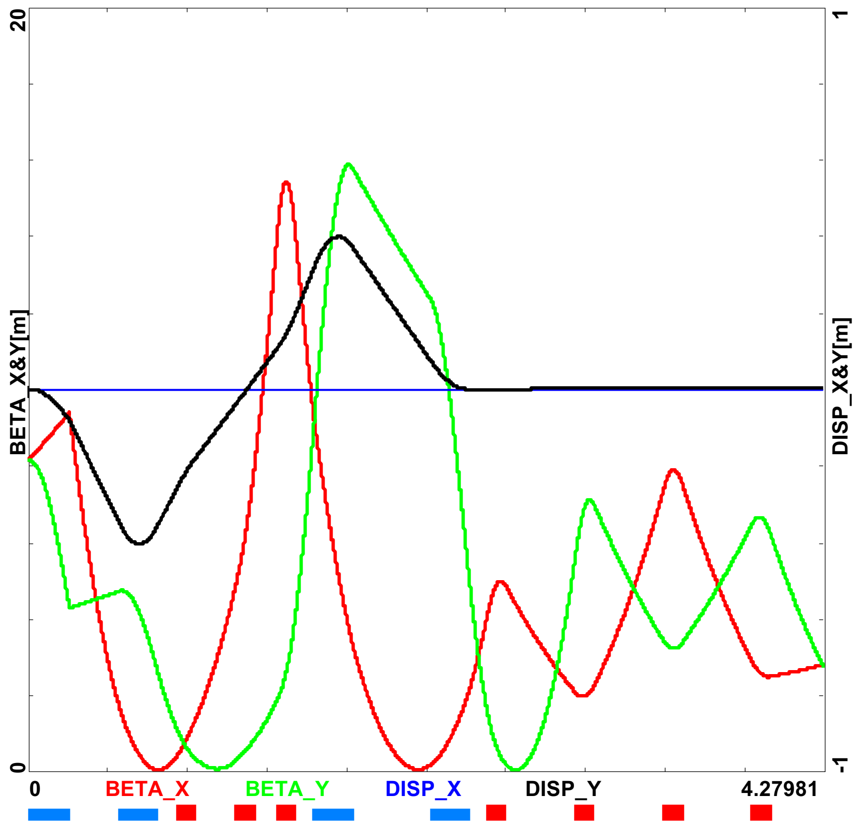
Switchyard – Layout





Vertical Spreaders – Optics

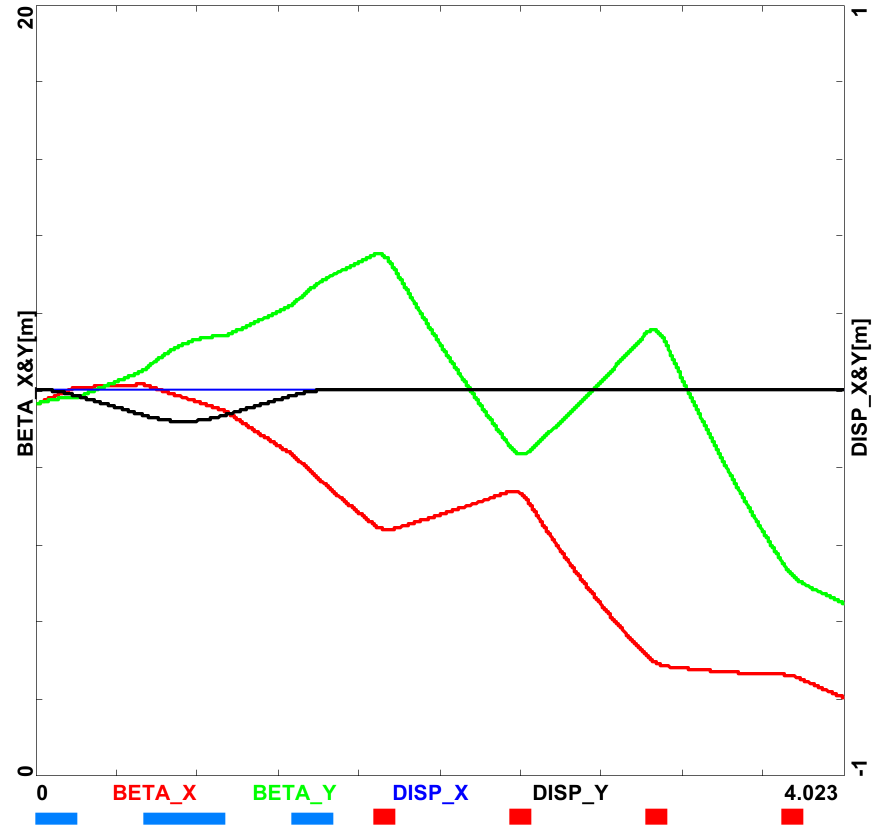
Spr. 1 (71 MeV)



vertical step I

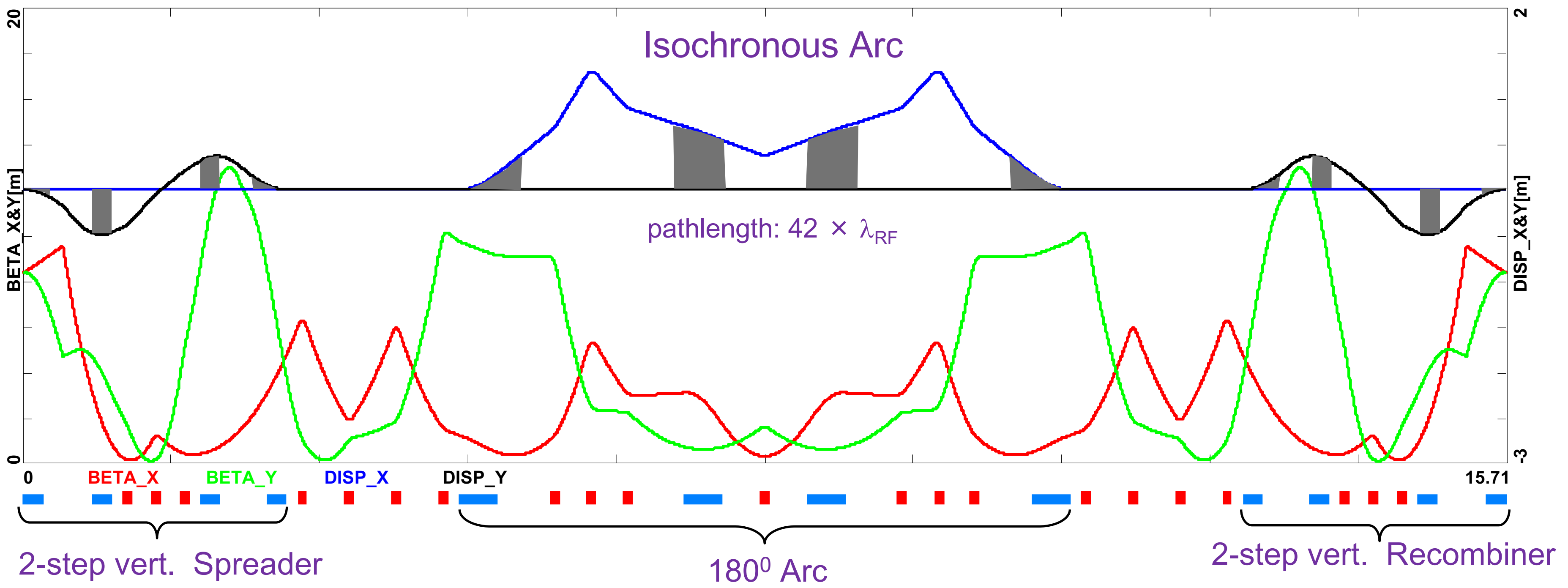
vertical step II

Spr. 5 (333 MeV)



vertical chicane

Arc 1 Optics (71 MeV)



Spr. dipoles:

4× 45⁰ bends

L = 20 cm

B = 9.5 kGauss

Arc dipoles :

4×45⁰ bends

L = 45.6 cm

B = 4.5 kGauss

Rec. dipoles:

4× 45⁰ bends

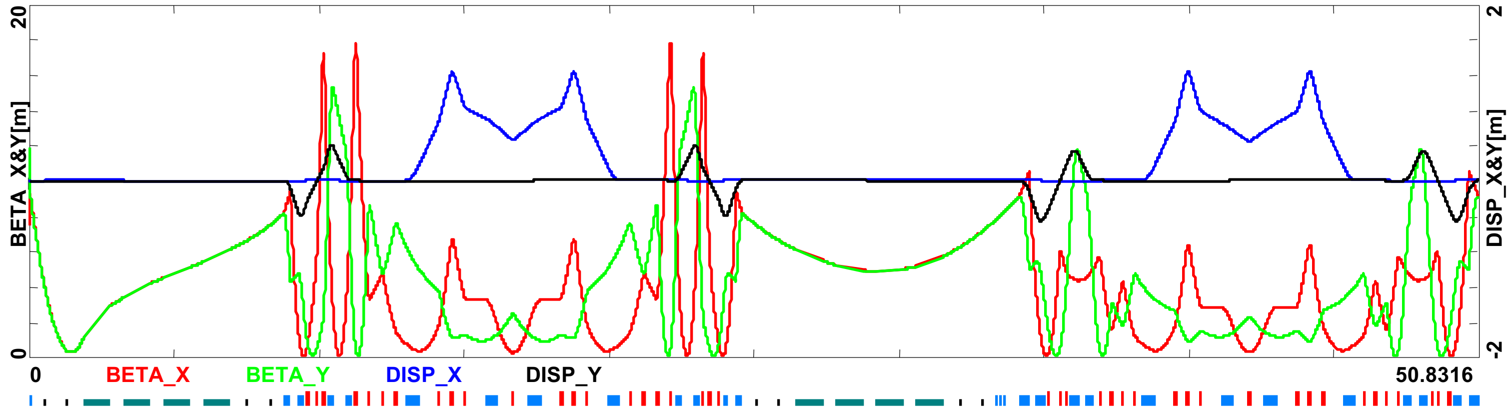
L = 20 cm

B = 9.5 kGauss

quads: L = 10 cm G ≤ 1 kGauss/cm

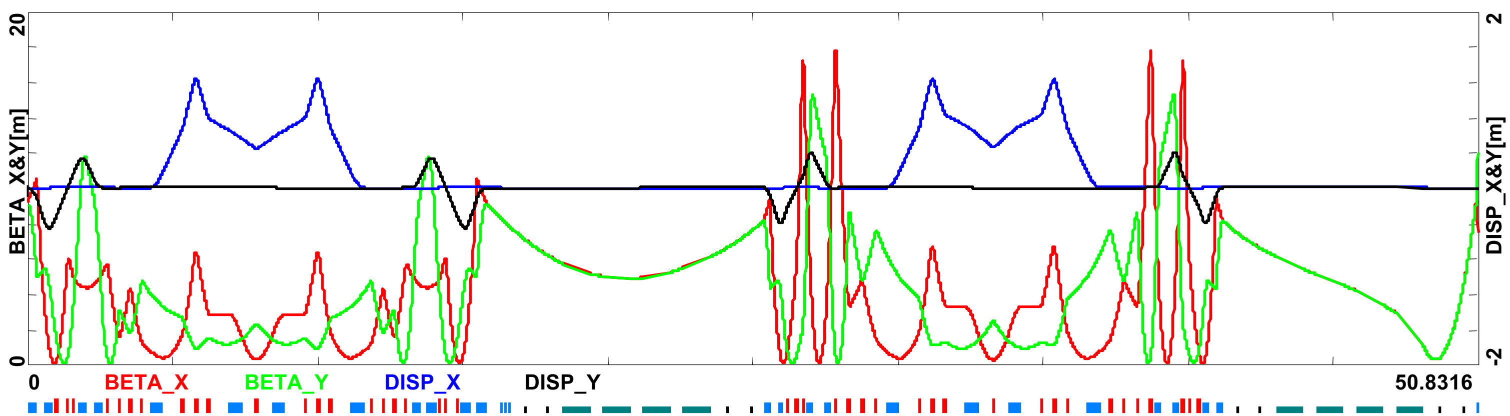
Pass up + Pass down

Pass-1 'up'



5 MeV 71 MeV 137 MeV

Pass-1 'down'



137 MeV 71 MeV 5 MeV

Magnet Inventory

Magnet Type	Single Hor. Bend	Double Hor. Bend	Short B-com	Medium-Bcom	Short Ver. Bend	Medium Ver. Bend	Long Ver. Bend	Chicane Bend	Short Quad	Longer Quad
Length [cm]	45.6	91.2	20	30	20	30	40	5	10	15
Field [kGauss]	11.6	11.5	8.3	10.7	8.3	11.5	8.3	1.6		
Gradient [kGauss/cm]									2.5	2.5
S/R 1					6				14	
Arc 1	4								5	2
S/R 2						6			14	
Arc 2	4								5	2
S/R 3					6				14	
Arc 3	4								5	2
S/R 4						6			14	
Arc 4		4							5	2
S/R 5					2		2		8	
Arc 5		4							5	2
S/R 6						6			8	
Arc 6		4							5	2
Linacs								8		
Total	**12**	**12**	**2**	**2**	**14**	**18**	**2**	**8**	**102**	**12**

Bends:	**70**
Quads:	**114**

Outlook – R&D Program

- Liner lattice optimization Initial magnet specs ★
- Momentum acceptance and longitudinal match ★
- End-to-End simulation with synchrotron radiation, CSR micro-bunching (ELEGANT)
- Correction of nonlinear aberrations (geometric & chromatic) with multipole magnets (sext. octu.?)
- RF cavity design, HOM content BBU studies (TDBBU)
- Injection line/chicane design Space-charge studies at injection
- Diagnostics & Instrumentation
- Multi-particle tracking studies of halo formation
- Final magnet specs
- Engineering design

Summary

- PERLE@Orsay (400 MeV)
  - 'lean design', fewer magnet varieties, 1.2 Tesla curved bends
- Multi-pass linac Optics in ER mode
  - Linear lattice: 3-pass 'up' + 3-pass 'down'
- Arc Optics Choice
  - Flexible Momentum Compaction Optics
- Modular Arc Architecture
  - Vertical switchyard
  - Matching sections: Linac-Switchyard-Arc
- 'First cut' linear lattice design
  - Magnet inventory
  - Dipole and Quad design
- Vigorous R&D Program Ahead…

Thank you!

Special Thanks to:

Oliver Brüning

Erk Jensen

Max Klein

and

Alessandra Valloni