CERN

Alessandra Valloni

Initial LHeC Coordination Group meeting

TEST FACILITY
STAGES AND OPTICS

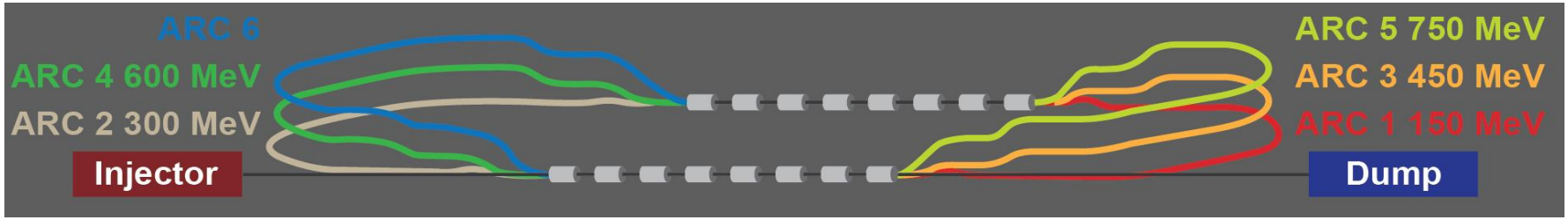
CERN, 5th February

Goals of a CERN ERL Test Facility

- Test facility for SCRF cavities and modules
- Test facility for multi-pass multiple cavity ERL
- Test facility for controlled SC magnet quench tests
- Injector studies: DC gun or SRF gun
- Study reliability issues, operational issues!
- Could it be foreseen as the injector to LHeC ERL?

TARGET PARAMETER*	VALUE
Injection Energy [MeV]	5
Final Beam Energy [MeV]	900
Normalized emittance $\gamma\varepsilon_{x,y}$ [μm]	50
Beam Current [mA]	10
Bunch Spacing [ns]	25 (50)

*in few stages



Outline

1. **STAGES OF BUILDING DESIGN**
   - LAYOUTS
   - BASELINE PARAMETERS

2. **ARC OPTICS ARCHITECTURE**

3. **TEST FACILITY FOR SC MAGNET TESTS**

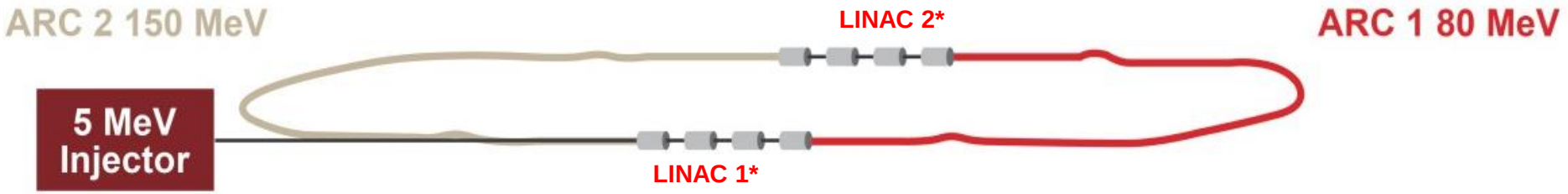
Planning for each stage

STEP 1

SC RF cavities, modules and e^- source tests

- Injection at 5 MeV
- 1 turn
- 75 MeV/linac
- Final energy 150 MeV

ARC	ENERGY
ARC 1	80 MeV
ARC 2	155 MeV



*4 SRF 5-cell cavities at 802 MHz

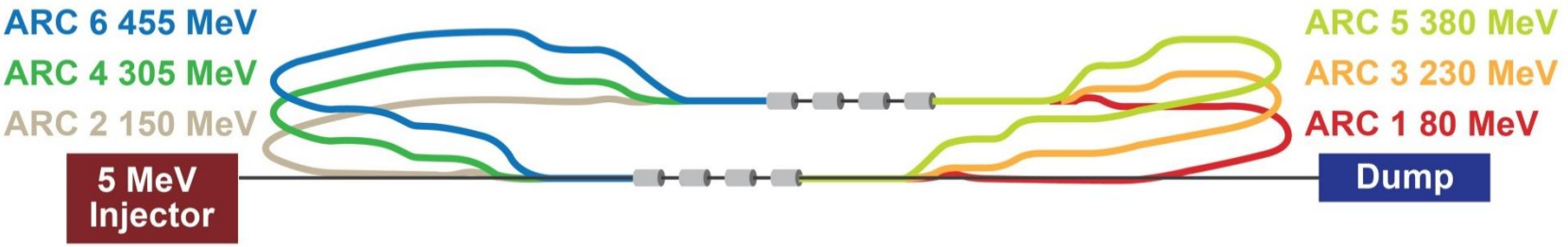
Planning for each stage

STEP 2

Test the machine in Energy Recovery Mode

- Injection at 5 MeV
- 3 turns
- 75 MeV/linac
- Final energy 450 MeV

ARC	ENERGY
ARC 1	80 MeV
ARC 2	155 MeV
ARC 3	230 MeV
ARC 4	305 MeV
ARC 5	380 MeV
ARC 6	455 MeV



Recirculation realized with vertically stacked recirculation passes

Planning for each stage

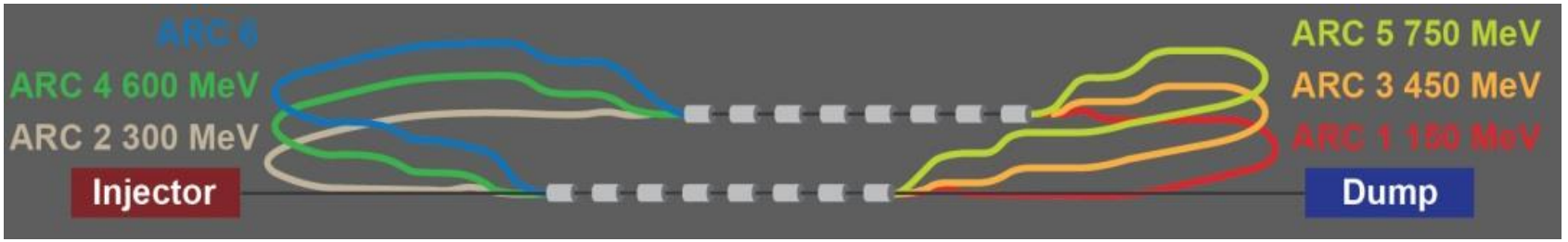
STEP 3

Additional SC RF modules test

Full energy test in Energy Recovery Mode

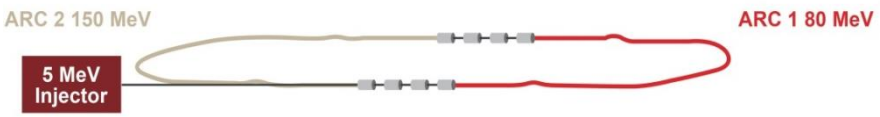
- Injection at 5 MeV
- 3 turns
- 150 MeV/linac
- Final energy 900 MeV

ARC	ENERGY
ARC 1	150 MeV
ARC 2	300 MeV
ARC 3	450 MeV
ARC 4	600 MeV
ARC 5	750 MeV
ARC 6	900 MeV

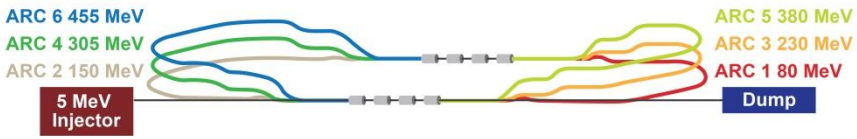


Planning for each stage

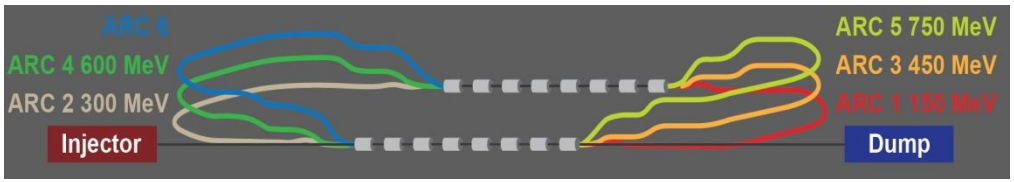
Step 1



Step 2



Step 3



ARC	Step 1	Step 2	Step 3
ARC 1	80 MeV	80 MeV	155 MeV
ARC 2	155 MeV	155 MeV	305 MeV
ARC 3		230 MeV	455 MeV
ARC 4		305 MeV	605 MeV
ARC 5		380 MeV	755 MeV
ARC 6		455 MeV	905 MeV

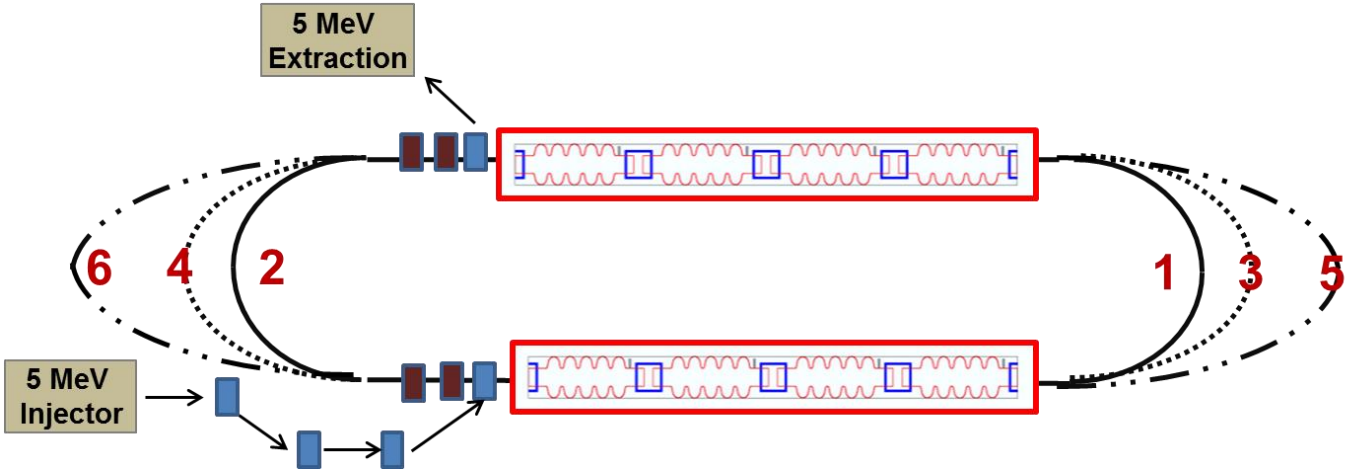
Outline

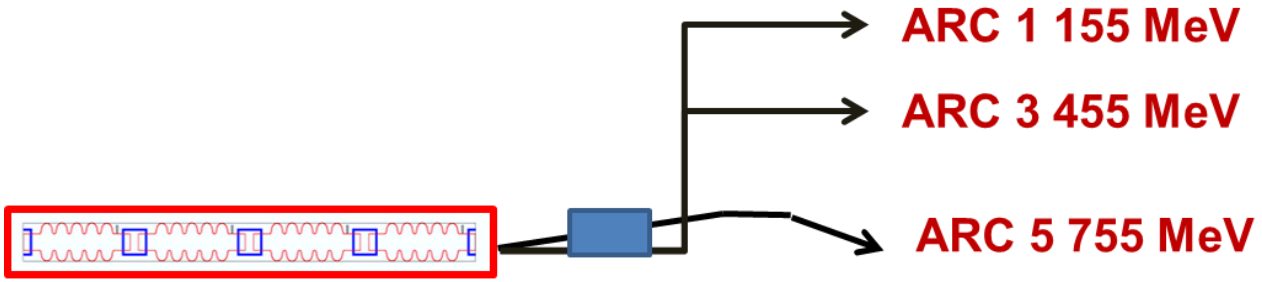
1. STAGES OF BUILDING DESIGN
   - LAYOUTS
   - BASELINE PARAMETERS

2. ARC OPTICS ARCHITECTURE FOR STEP 3

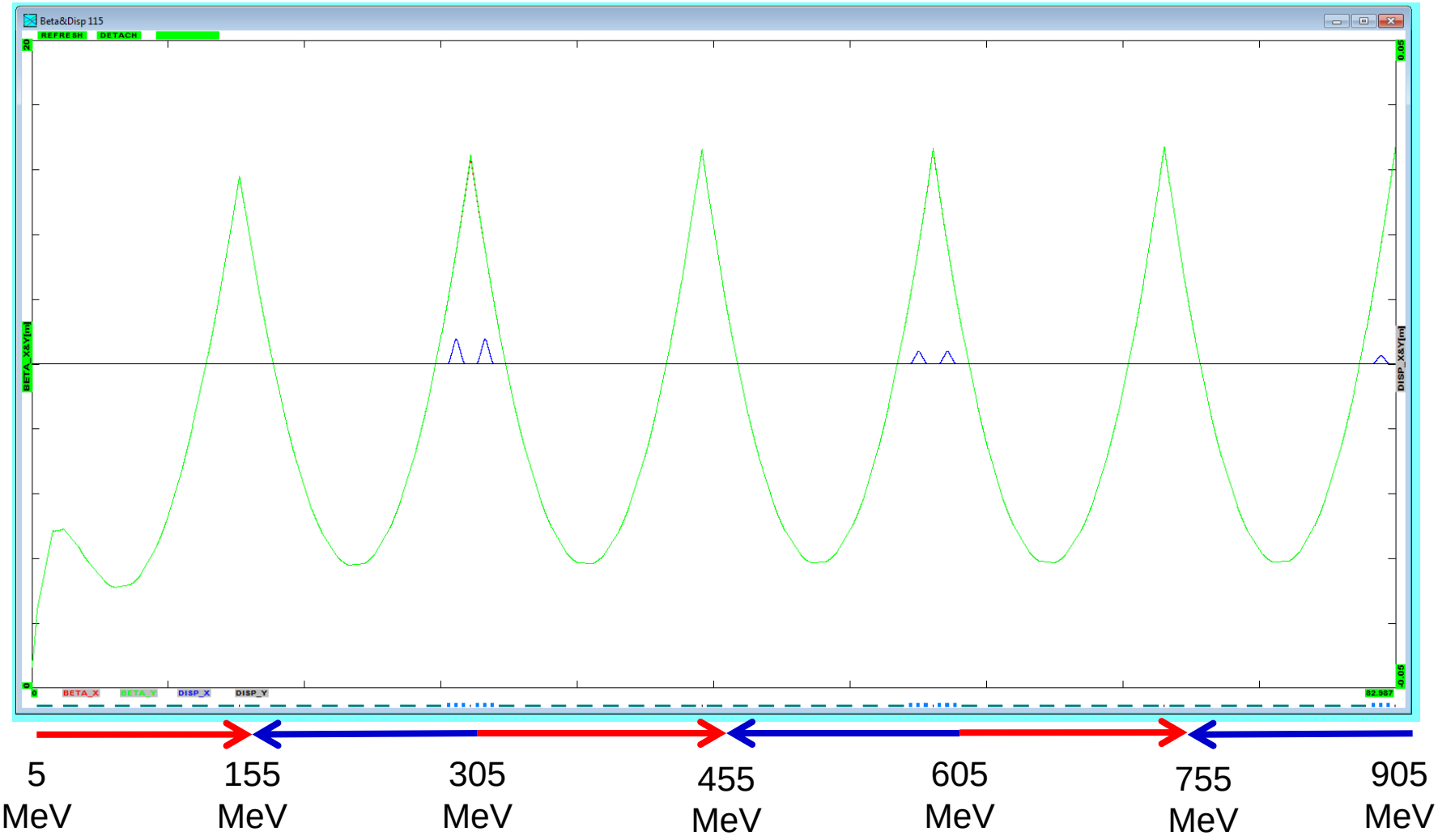
3. TEST FACILITY FOR SC MAGNET TESTS

Layout

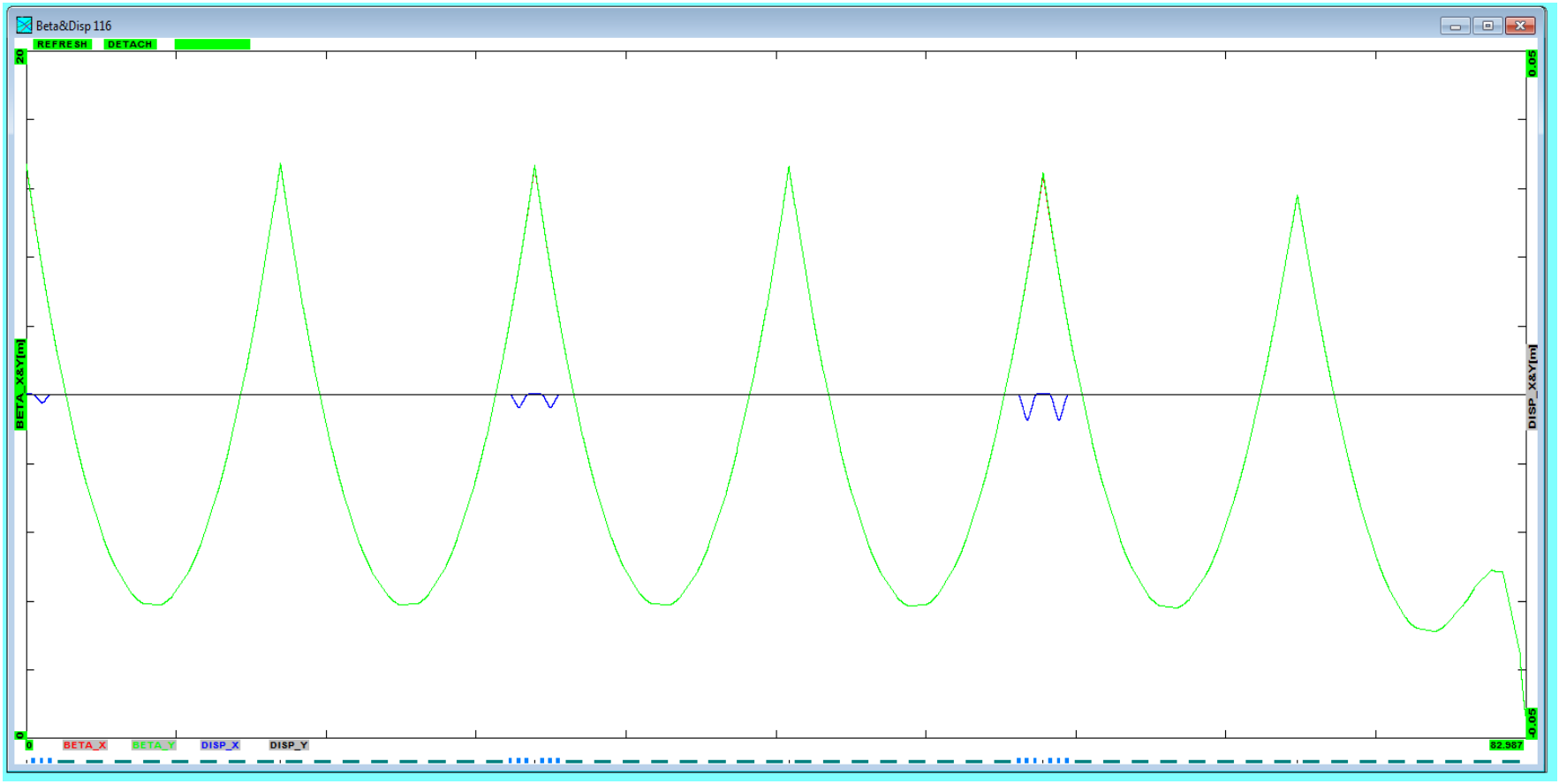

5 MeV
Extraction
6
4
2
1
3
5
5 MeV
Injector


ARC 1 155 MeV
ARC 3 455 MeV
ARC 5 755 MeV

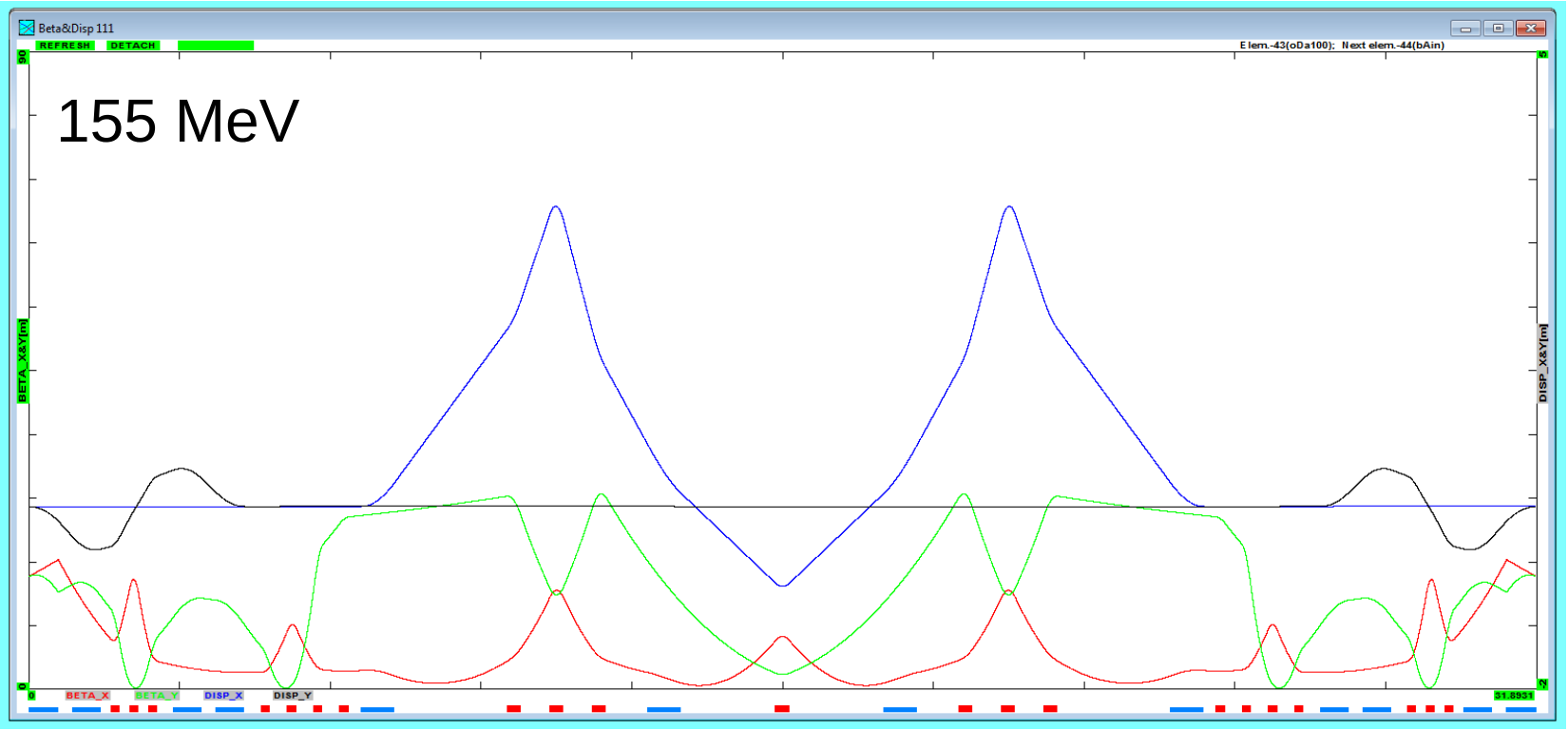
Linac 1 Multi-Pass Optics



Linac 2 Multi-Pass Optics



Arc 1 optics



2-step vert. Spreader

30^0 bends

(1 rec. + 3 sec.)

4×45^0 sector bends

Arc dipoles :

Ldip = 71.8 cm

B = 5.67 kGauss

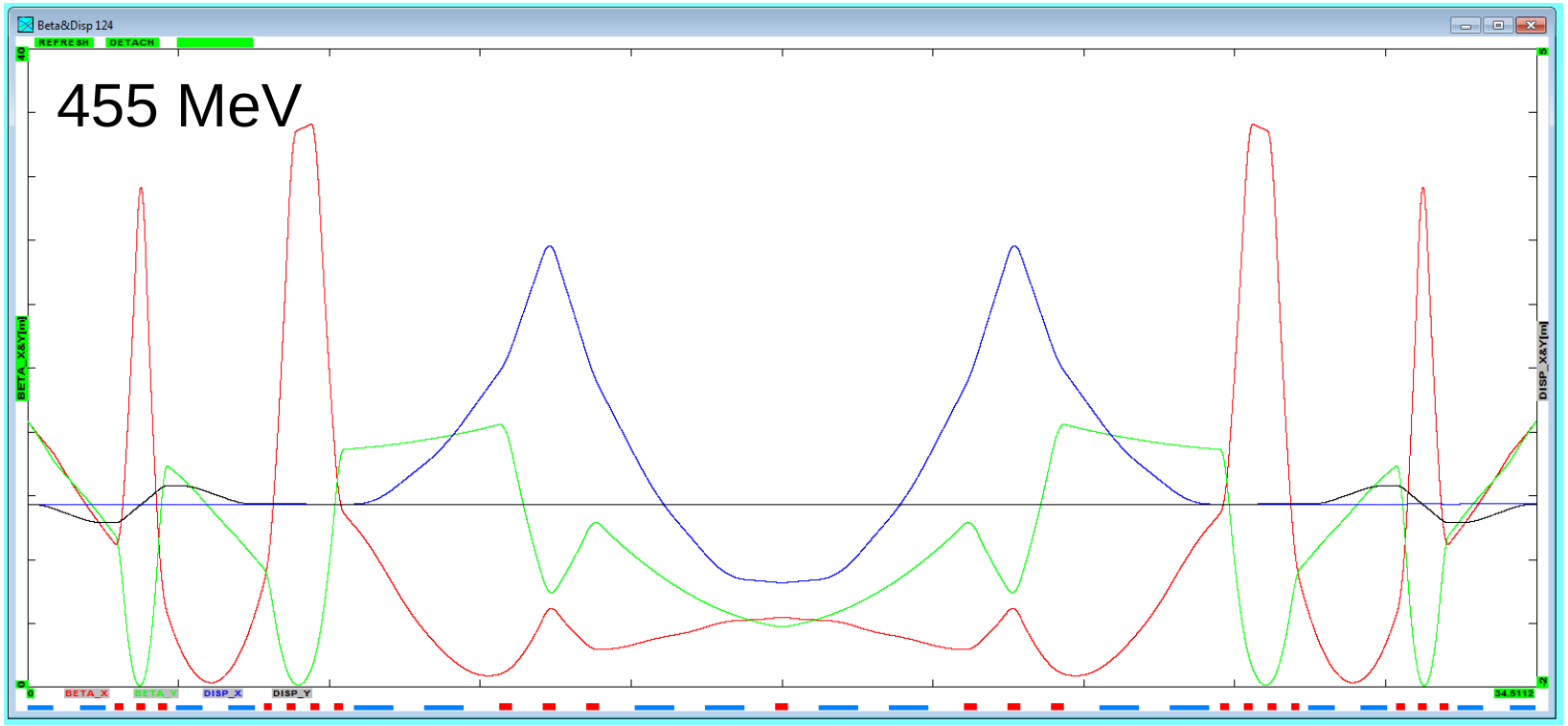
ρ = 91.45 cm

2-step vert. Combiner

30^0 bends

(1 rec. + 3 sec.)

Arc 3 optics



2-step vert. Spreader

8×22.5^0 sector bends

2-step vert. Combiner

9.8^0 bends (1 rec. + 3 sec.)

Arc dipoles :

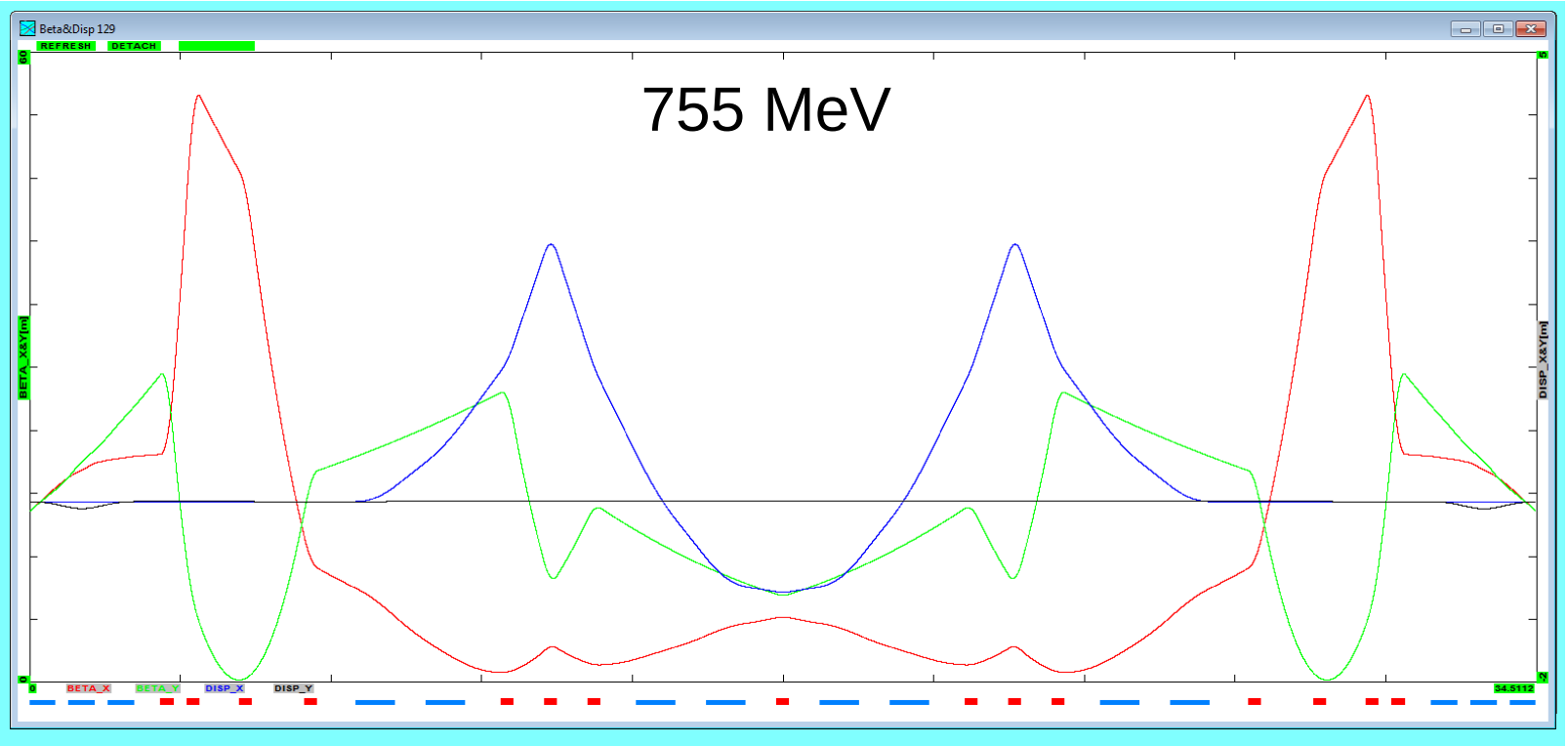
Ldip = 90.58 cm

B = 6.58 kGauss

ρ = 230.66 cm

9.8^0 bends (1 rec. + 3 sec.)

Arc 5 optics



Vertical chicane

8×22.5^0 sector bends

Vertical chicane

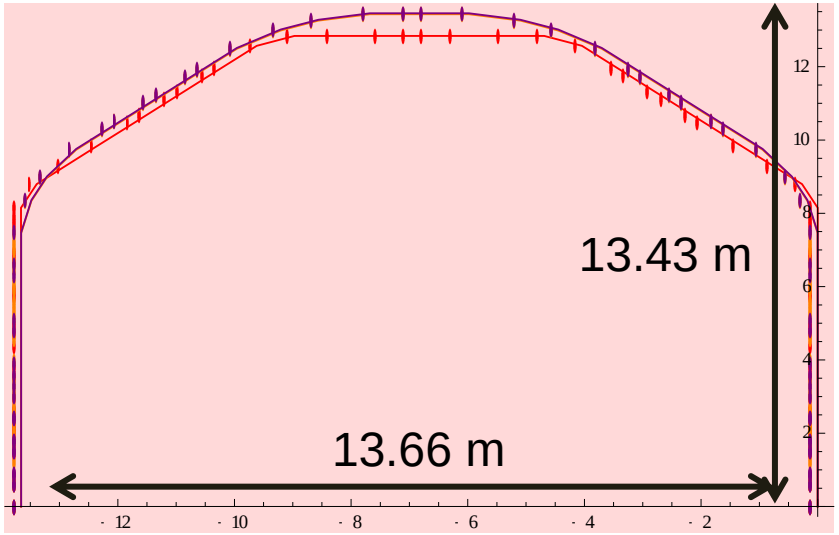
Arc dipoles :

Ldip = 90.58 cm

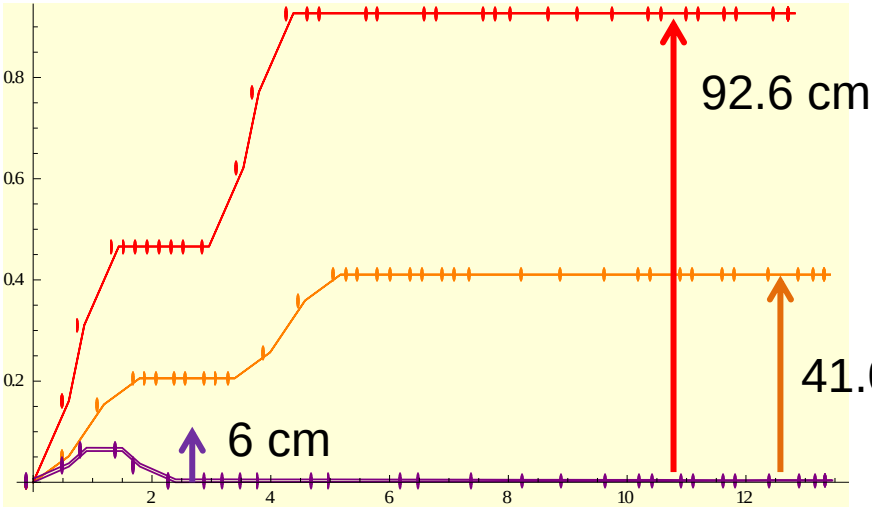
B = 10.92 kGauss

ρ = 230.66 cm

Arc 1,2,3 layout

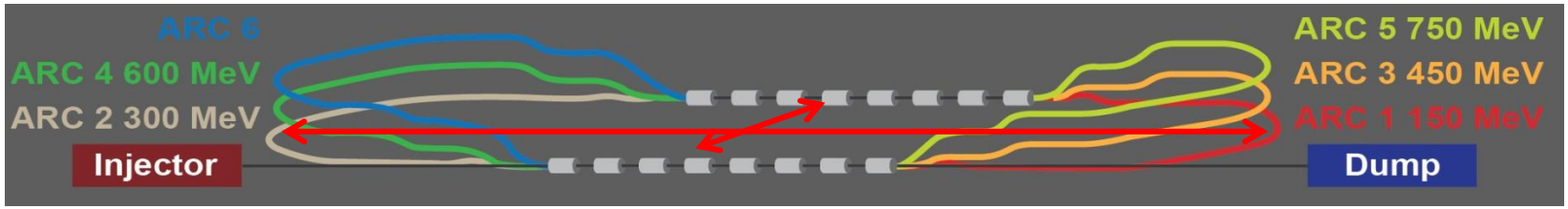


- Synchronous acceleration
  Isochronous arcs
- Achromatic arc
- FMC optics



Total Arc length for Arc 1,2,3
34.5112 m
94 x λrf

Footprint



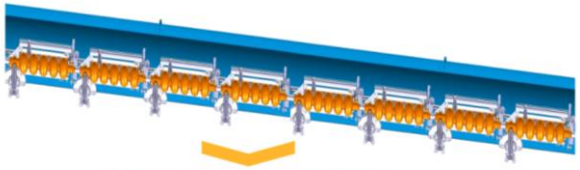
ARCS

Total length for Arc 1,2,3
34.5112 m
94 x λrf
(last cavity linac1 to first cavity linac 2)

Total length for Arc 2,4
34.2704 m
101 x λrf
(last cavity linac1 to first cavity linac 2)

Total length for Arc 6
3445.74 m
101.5 x λrf
(last cavity linac 1 to first cavity linac 2)

LINAC



ONE CRYOMODULE: 8 RF CAVITIES

PARAMETER	VALUE
Frequency	801.58 MHz
Wavelength	37.4 cm
Lcavity= 5λ/2	93.5 cm
Grad	20.02 MeV/m
ΔE	18.71 MV per cavity

Total length ~ 13 m

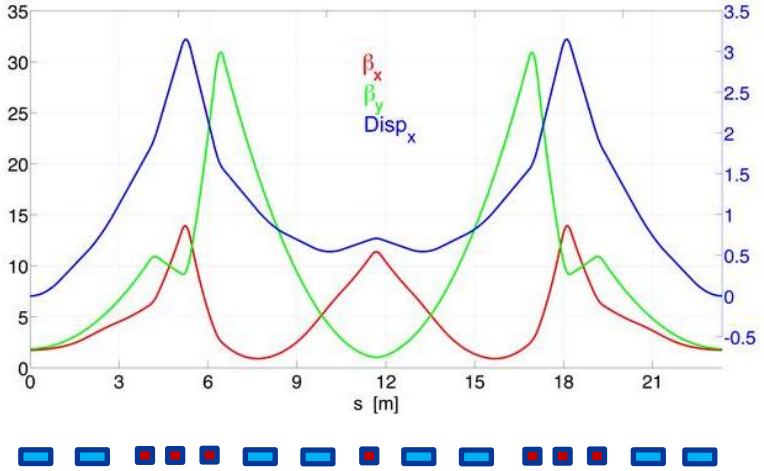
CHICANE INJ/EXTR

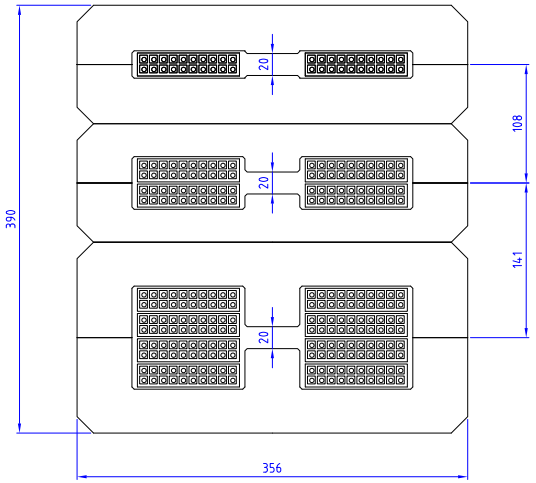
Length ~ 1.75 m

TOTAL DIMENSIONS
42 m x 13.7 m

Arc optics OPTION 2

SAME OPTICS LAYOUT FOR ALL THE ARCS 900/750/600/450/300/150 MeV





3 DIPOLES ON TOP OF EACH OTHER

*Attilio Milanese

Arc dipoles :

8×22.5^0 bends

Ldip = 100.6 cm

ρ = 256.3 cm

	1GeV	750MeV	600MeV	450MeV	300MeV	150MeV
B FIELD	1.30 T	0.97 T	0.78 T	0.58 T	0.39 T	0.19 T

Arc quadrupoles

Lquads = 30 cm

	Q1	Q2	Q3	Q4
Kq[m^{-2}]	-1.01	2.91	2.09	1.19

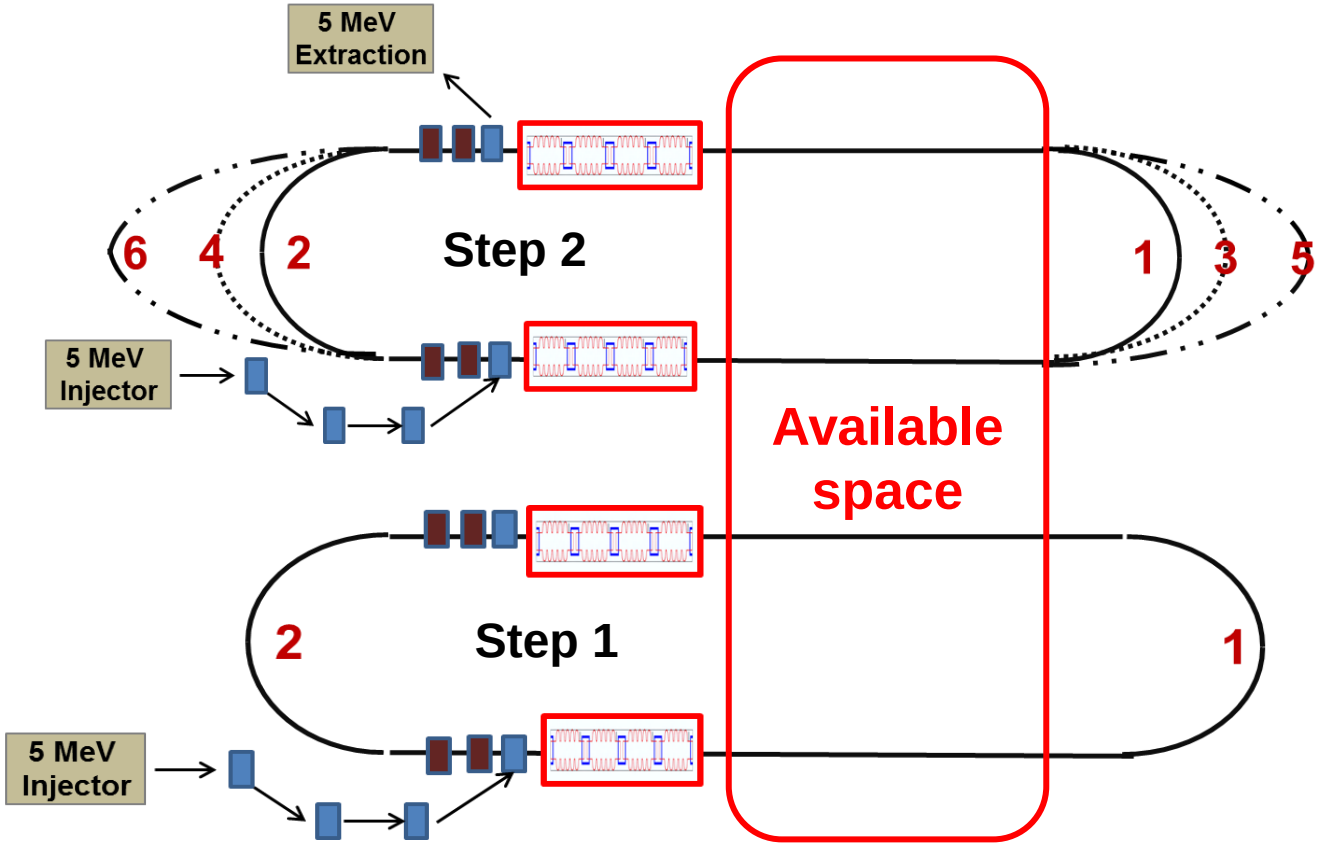
Incoherent Synchrotron radiation in return arcs

ARC	E [MeV]	ΔE [keV]	σE/E [%]
1	150	0.0087	0.00000387
2	300	0.139	0.00002199
3	450	0.708	0.0000621
4	600	2.239	0.000132
5	750	5.467	0.00024
6	900	11.337	0.00039
7	750	5.4667	0.00052
8	600	2.239	0.00066
9	450	0.708	0.00089
10	300	0.139	0.00135
11	150	0.0087	0.0027

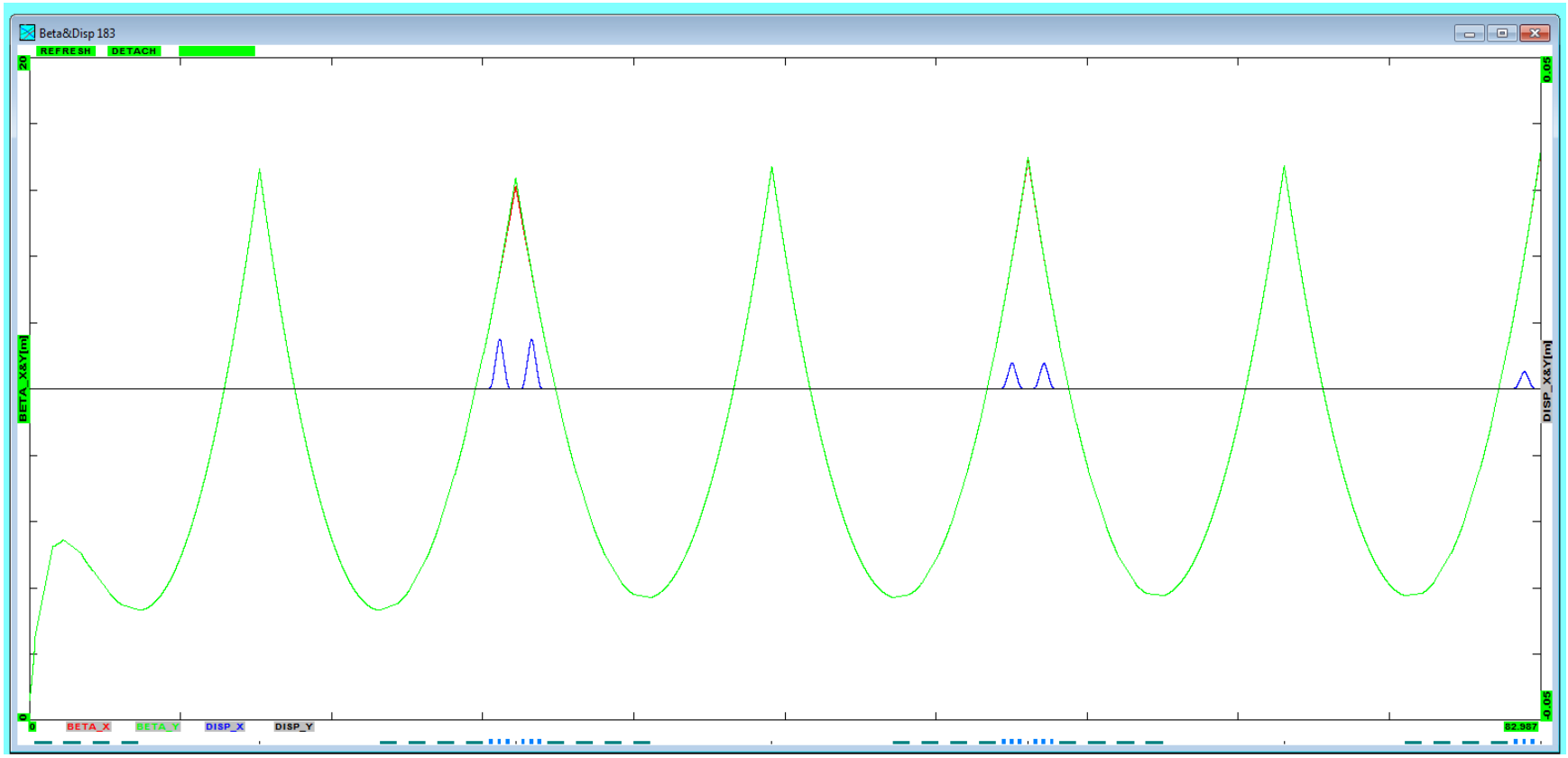
- Beam Energy loss $\Delta E = \int P_\gamma dt = P_\gamma \frac{\pi\rho}{\beta c}$ $\Delta E(GeV) = C_\gamma \frac{E^4}{\rho}\frac{1}{2}$
- Beam Energy Spread $\frac{\sigma_E}{E} = \sqrt{1.4397 * 10^{-27}\frac{\pi\gamma^5}{\rho^2}}$

Next steps

- Complete Step 2 and Step 1configuration and optics layout



Linac 1 - Step 2



5 MeV | 85 MeV | 155 MeV | 235 MeV | 305 MeV | 380 MeV | 455 MeV

Outline

1. STAGES OF BUILDING DESIGN
   - LAYOUTS
   - BASELINE PARAMETERS

2. ARC OPTICS ARCHITECTURE

3. TEST FACILITY FOR SC MAGNET TESTS

Controlled quench tests of SC magnets

WE ARE INVESTIGATING THE POSSIBILITY OF USING THE TEST FACILITY FOR SC MAGNET TESTS

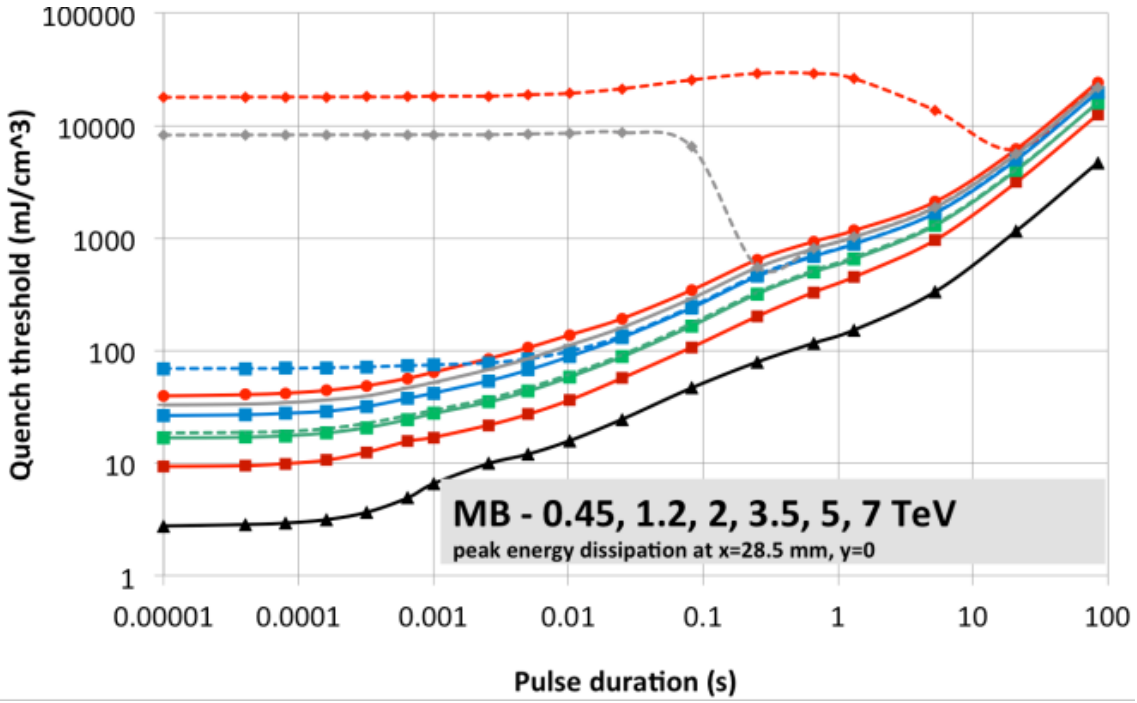
Requirements in terms of:

- Beam energy, intensity and pulse length (energy deposition)
- Space for the magnets installation (possible tests of cable samples and full cryo magnets)
- Cryo requirements
- Vacuum requirements
- Powering needs

Controlled quench tests of SC magnets

Study beam induced quenches (quench thresholds, quenchino thresholds) at different time scales for:

- SC cables and cable stacks in an adjustable external magnetic field
- Short sample magnets
- Full length LHC type SC magnets



Quench limits of LHC dipole as expected from QP3 simulations for different pulse durations

Courtesy A. Verweij

Beam parameters to generate a given amount of energy deposition

CALCULATIONS AND FLUKA SIMULATIONS

Beam

Copper target
(no magnetic field)

Cylinder of copper
Radius = 50cm
Length = 100cm

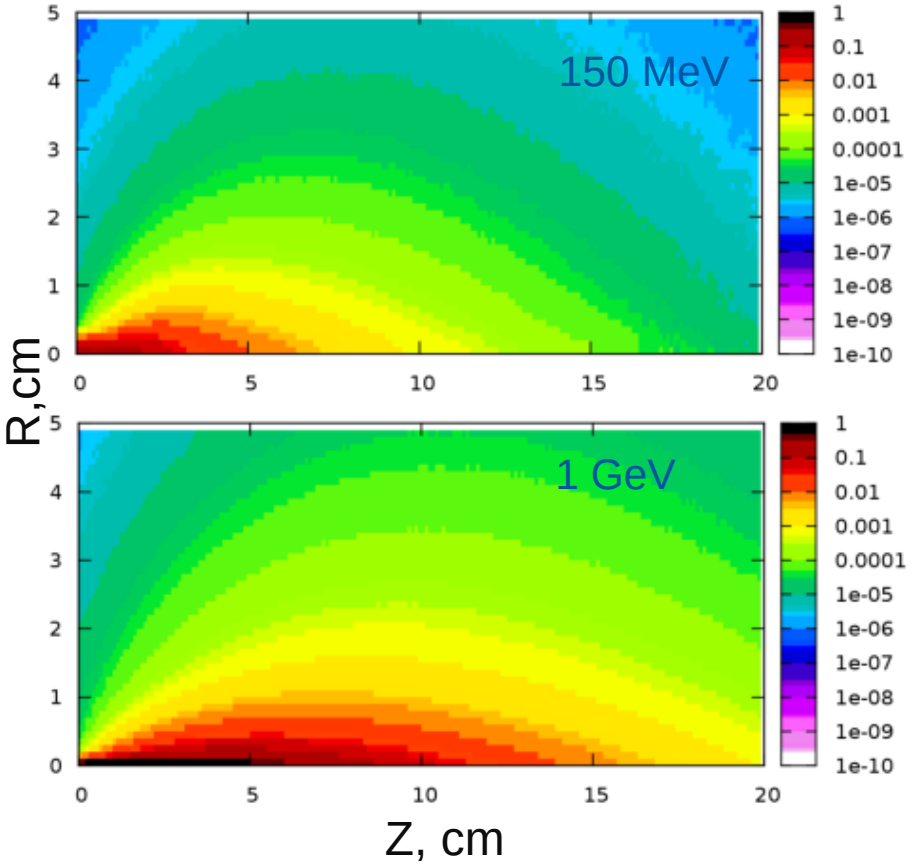
Beam parameters

Energy, MeV	Emittance, m	Sigma, cm	FWHM, cm
150	1.70E-07	0.092	0.22
300	8.52E-08	0.065	0.15
450	5.68E-08	0.053	0.13
600	4.26E-08	0.046	0.11
750	3.41E-08	0.041	0.10
900	2.84E-08	0.038	0.09
1000	2.55E-08	0.036	0.08

Results are given for half of bulky target because of symmetry

Binning: 1 mm^3 bins

Energy deposition, GeV/cm^3/e^-



Beam parameters to generate a given amount of energy deposition

CALCULATIONS AND FLUKA SIMULATIONS

Beam

Copper target
(no magnetic field)

Cylinder of copper
Radius = 50cm
Length = 100cm

Beam parameters

Energy, MeV	Emittance, m	Sigma, cm	FWHM, cm
150	1.70E-07	0.092	0.22
300	8.52E-08	0.065	0.15
450	5.68E-08	0.053	0.13
600	4.26E-08	0.046	0.11
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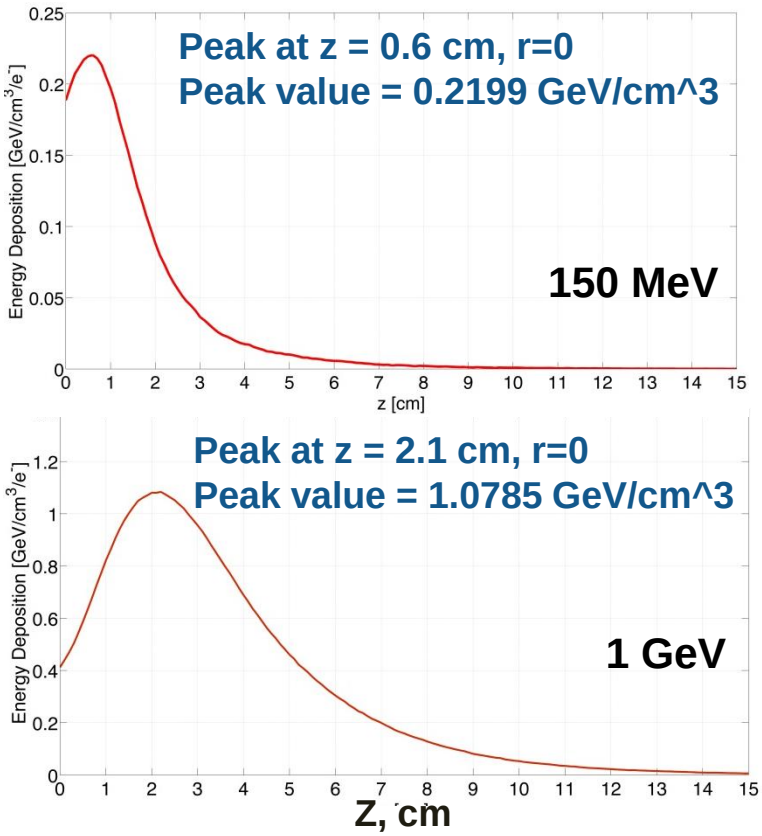
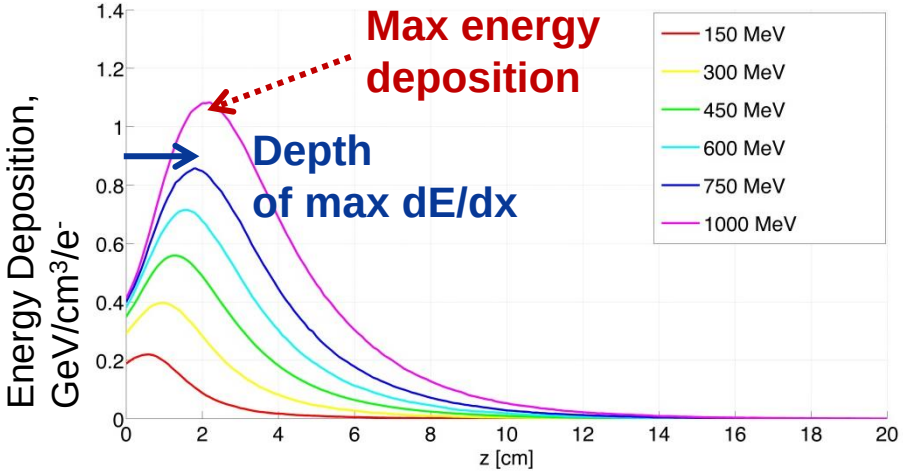
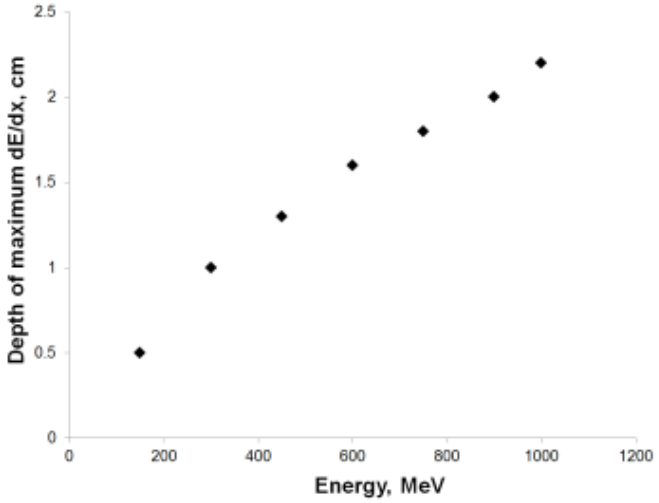


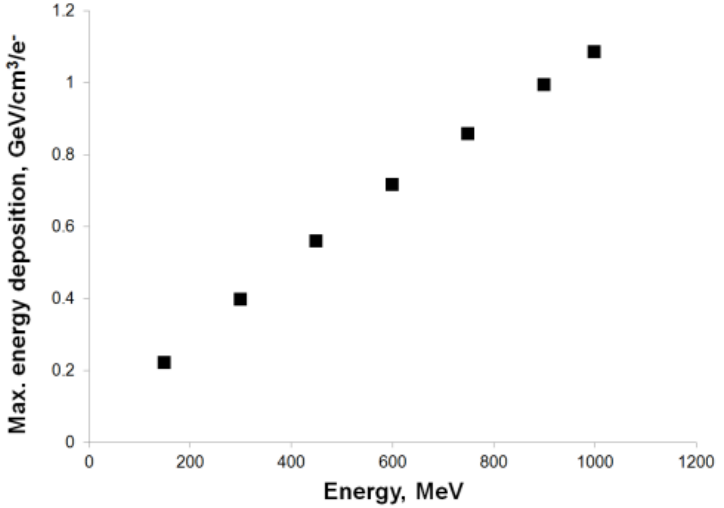
Beam parameters to generate a given amount of energy deposition



Depth of max dE/dx



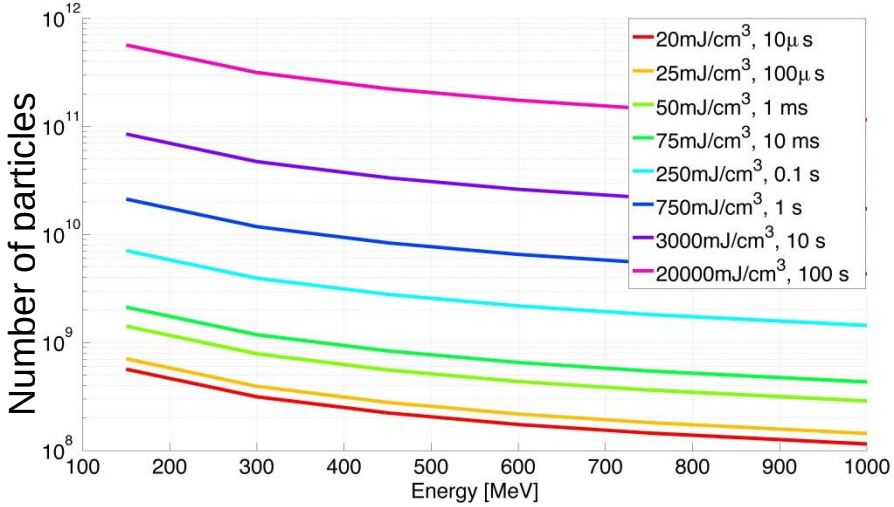
Max energy deposition

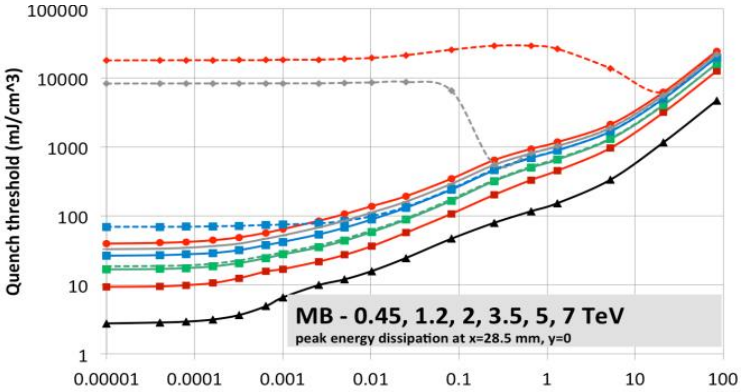


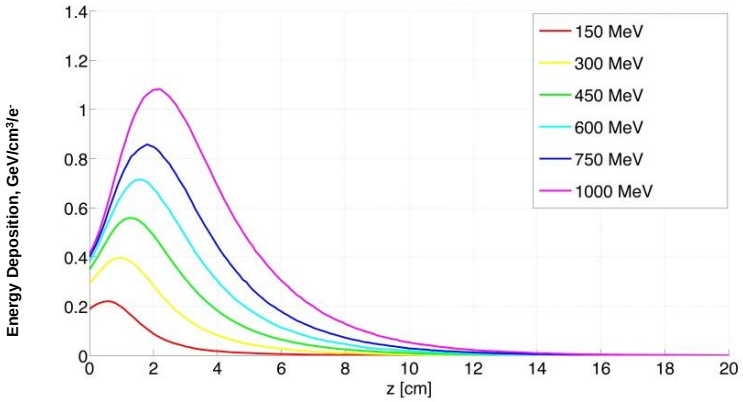
Beam parameters to generate a given amount of energy deposition

electrons needed to quench the magnet = Quench threshold / Maximum value for the energy deposition

MB quench limit 3.5 TeV







1 GeV = 1.602 x 10^{-7} mJ

MB quench limit 450 GeV is 140mJ/cm^3 in 10ms:
~2.2 x 10^9 e^- @ 1GeV necessary

MB quench limit 7 TeV is 16 mJ/cm^3 in 10ms:
~2.6 x 10^8 e^- @ 1GeV necessary

Summary

- The concept of the ERLTF is designed to allow for a staged construction with verifiable and useful stages for an ultimate beam energy in the order of 1 GeV
- A sketch of the ERLTF optics configuration is provided and other options are under investigation
- First analysis of having controlled quench tests of next generation superconducting magnets has been carried out. Beam parameters seem to match the requirements….further investigation is required!
- Complete the optics layout for Steps 2 and 3 and make a second-order analysis

Thank you for your attention

www.cern.ch