



Alessandra Valloni

Future Circular Collider Study Kickoff Meeting

CERN ERL TEST FACILITY STAGES AND OPTICS

12–15 February 2014, University of Geneva



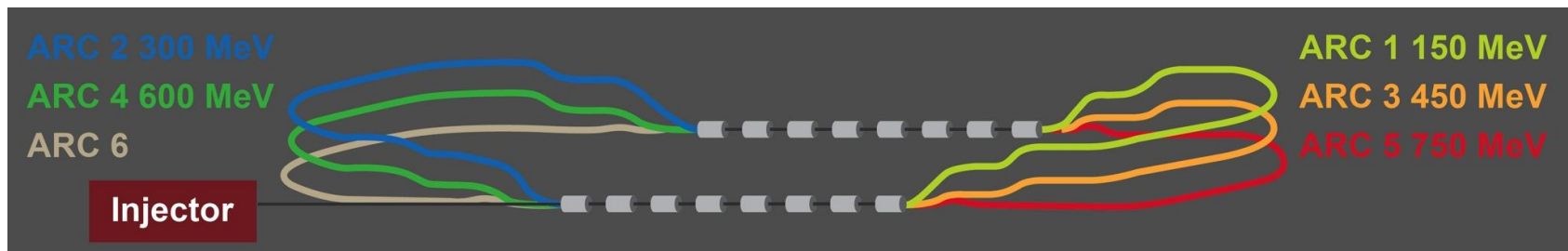
Future Circular Collider Study Kick-off Meeting

Goals of a CERN ERL Test Facility

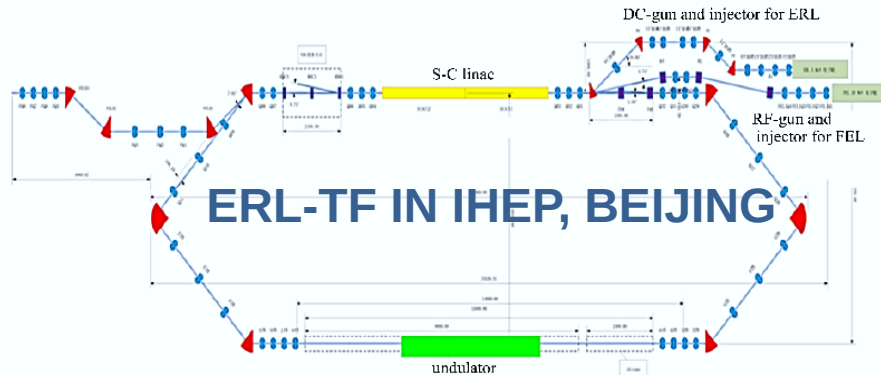
- Test facility for SCRF cavities and modules
- Test facility for multi-pass multiple cavity ERL
- Test facility for controlled SC magnet quench tests
- Injector studies: DC gun or SRF gun
- Study reliability issues, operational issues!
- Could it be foreseen as the injector to LHeC ERL?

TARGET PARAMETER*	VALUE
Injection Energy [MeV]	5
Final Beam Energy [MeV]	900
Normalized emittance $\gamma\epsilon_{x,y}$ [μm]	50
Beam Current [mA]	10
Bunch Spacing [ns]	25 (50)
Passes	3

*in few stages



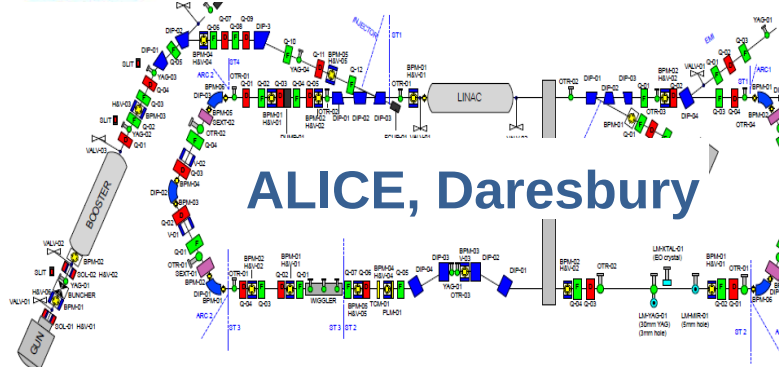
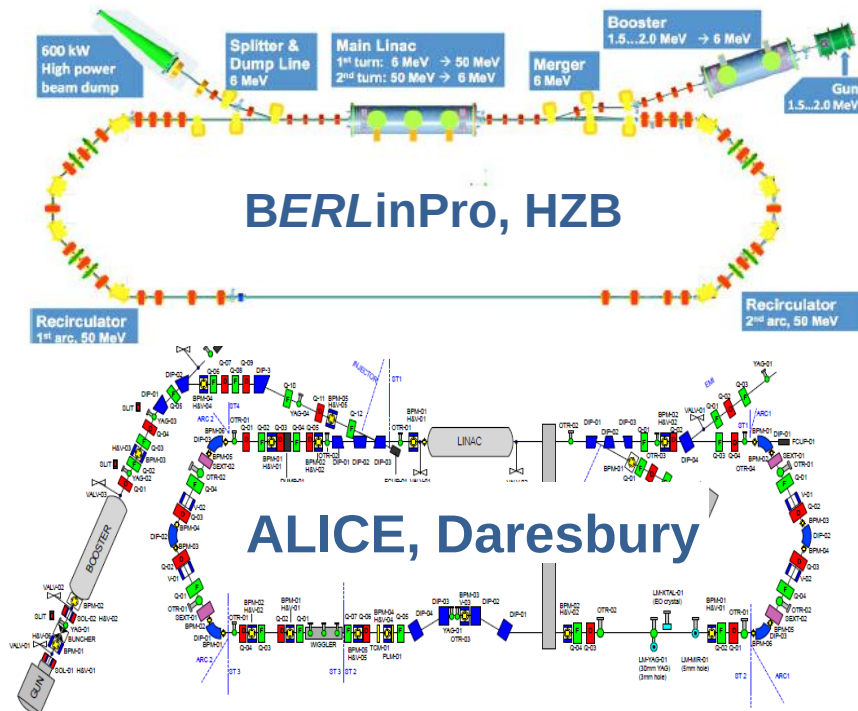
ERL Test Facility worldwide (1/2)



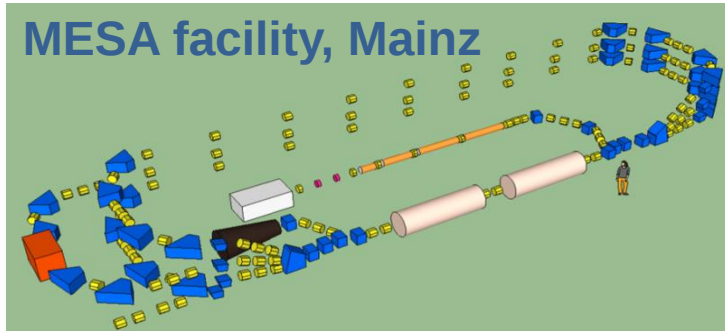
Beam Energy	35 MeV
Beam Current	10 mA
Bunch charge	77 pC
RF frequency	1300 MHz
Passes	1

Beam Energy	50 MeV
Beam Current	100 mA
Bunch charge	77 pC
RF frequency	1300 MHz
Passes	1

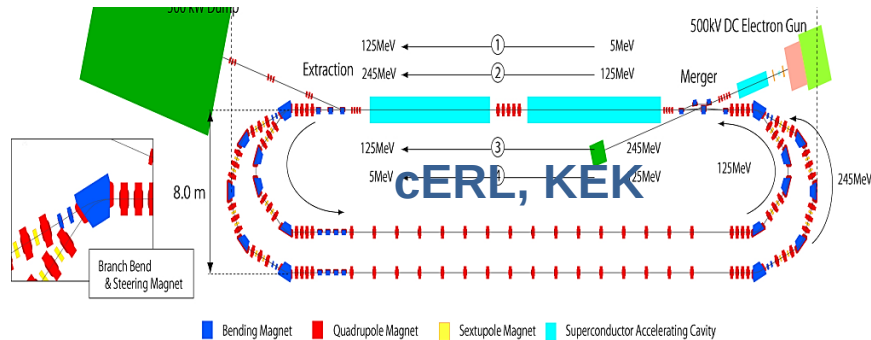
Beam Energy	12-26 MeV
Bunch charge	40-60-200 pC
RF frequency	1300 MHz
Passes	1



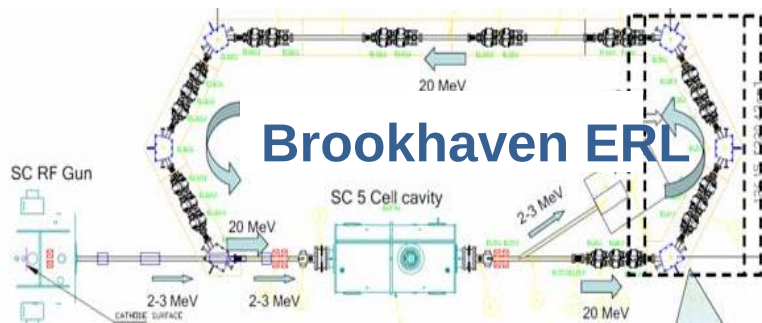
ERL Test Facility worldwide (2/2)



Beam Energy	105 MeV
Bunch charge	0.77 pC
RF frequency	1300 MHz
Passes	2-3



Beam Energy	35-125-250 MeV
Beam Current	10mA (100mA)
Bunch charge	7.7pC- 77pC
RF frequency	1300 MHz
Passes	1- 2



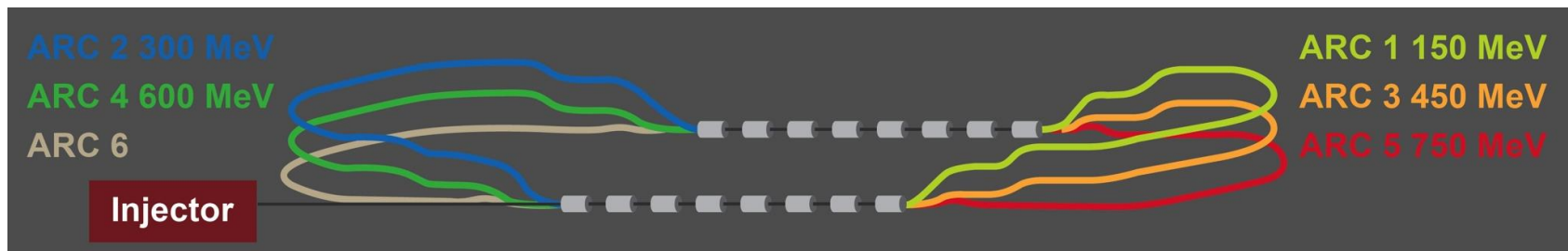
Beam Energy	20 MeV
Bunch charge	0.5-5 nC
Bunch current	300 mA
RF frequency	704 MHz
Passes	1

Goals of a CERN ERL Test Facility

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- Test facility for controlled SC magnet quench tests
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- 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 $\gamma\epsilon_{x,y}$ [μm]	50
Beam Current [mA]	10
Bunch Spacing [ns]	25 (50)
Passes	3

*in few stages



Outline

1. STAGES OF BUILDING DESIGN

- LAYOUTS
- BASELINE PARAMETERS

2. ARC OPTICS ARCHITECTURE

3. TEST FACILITY FOR SC MAGNET TESTS

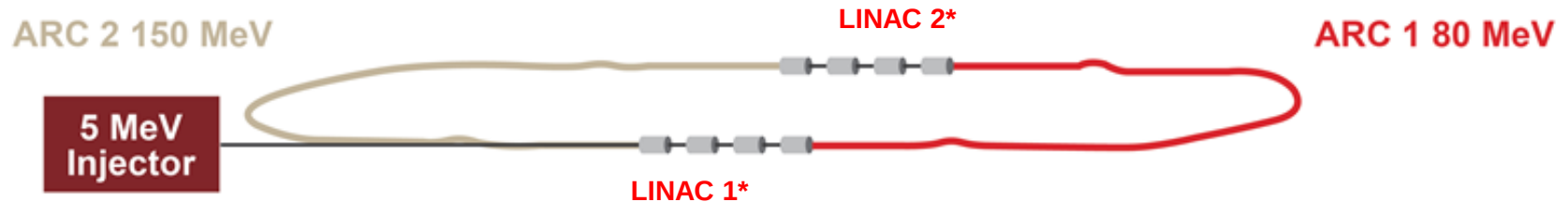
Planning for each stage

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

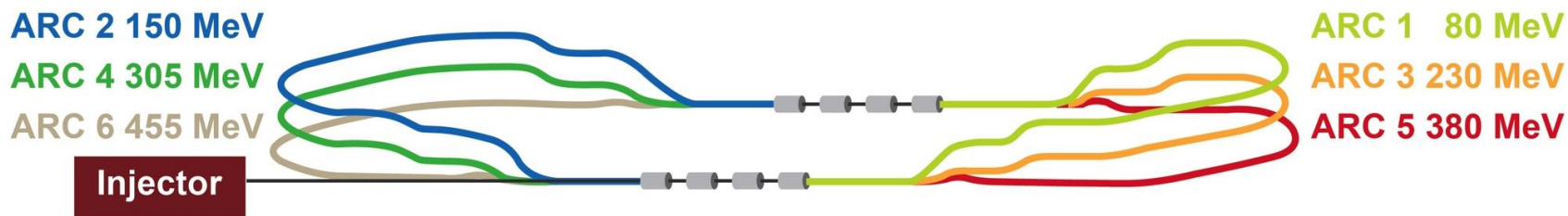
Planning for each stage

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

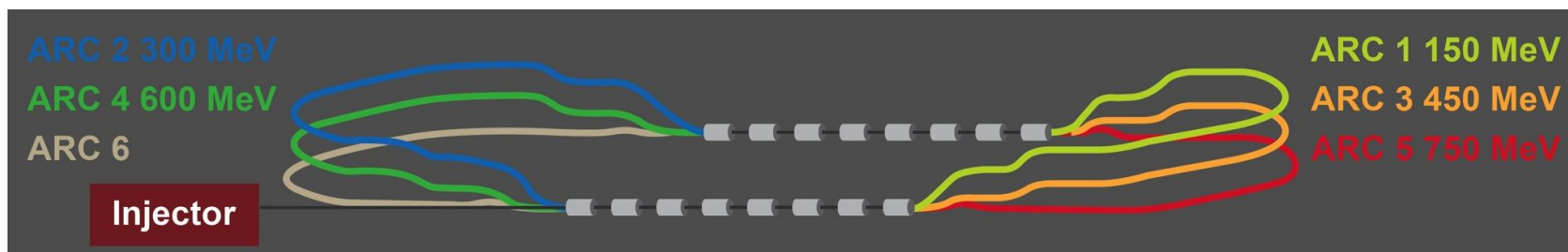
STEP 3

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



Outline

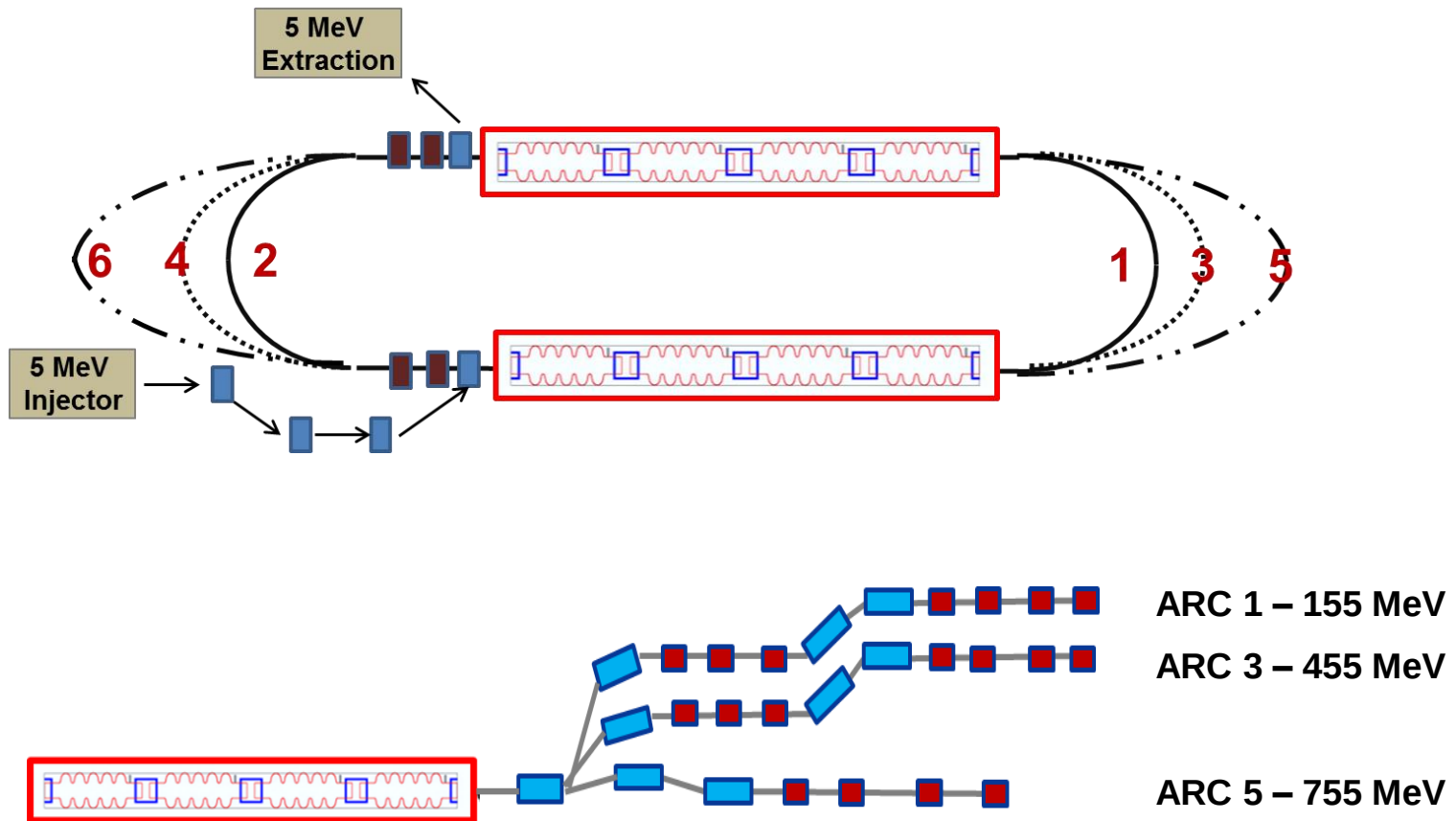
1. STAGES OF BUILDING DESIGN

- LAYOUTS
- BASELINE PARAMETERS

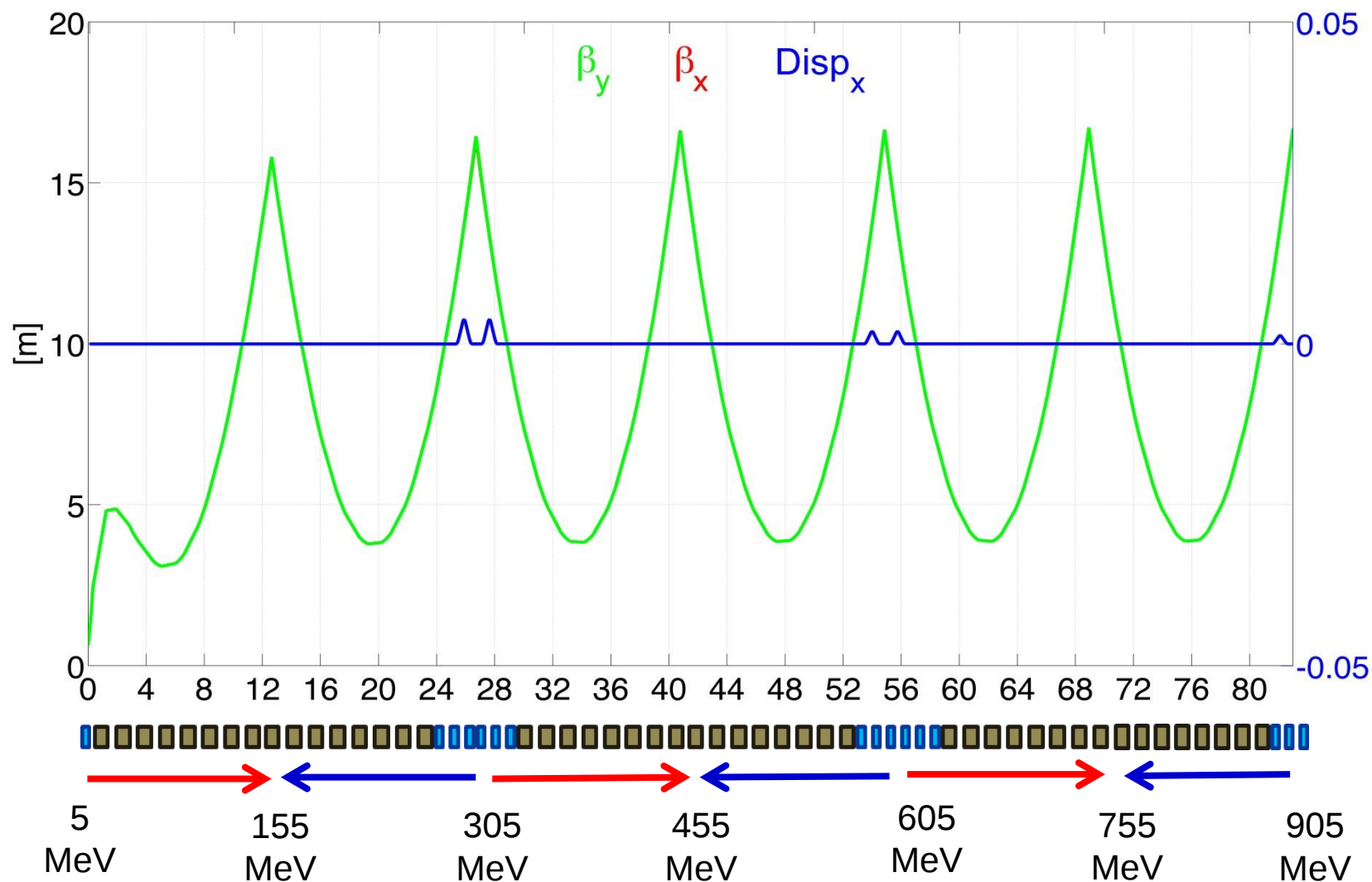
2. ARC OPTICS ARCHITECTURE FOR STEP 3

3. TEST FACILITY FOR SC MAGNET TESTS

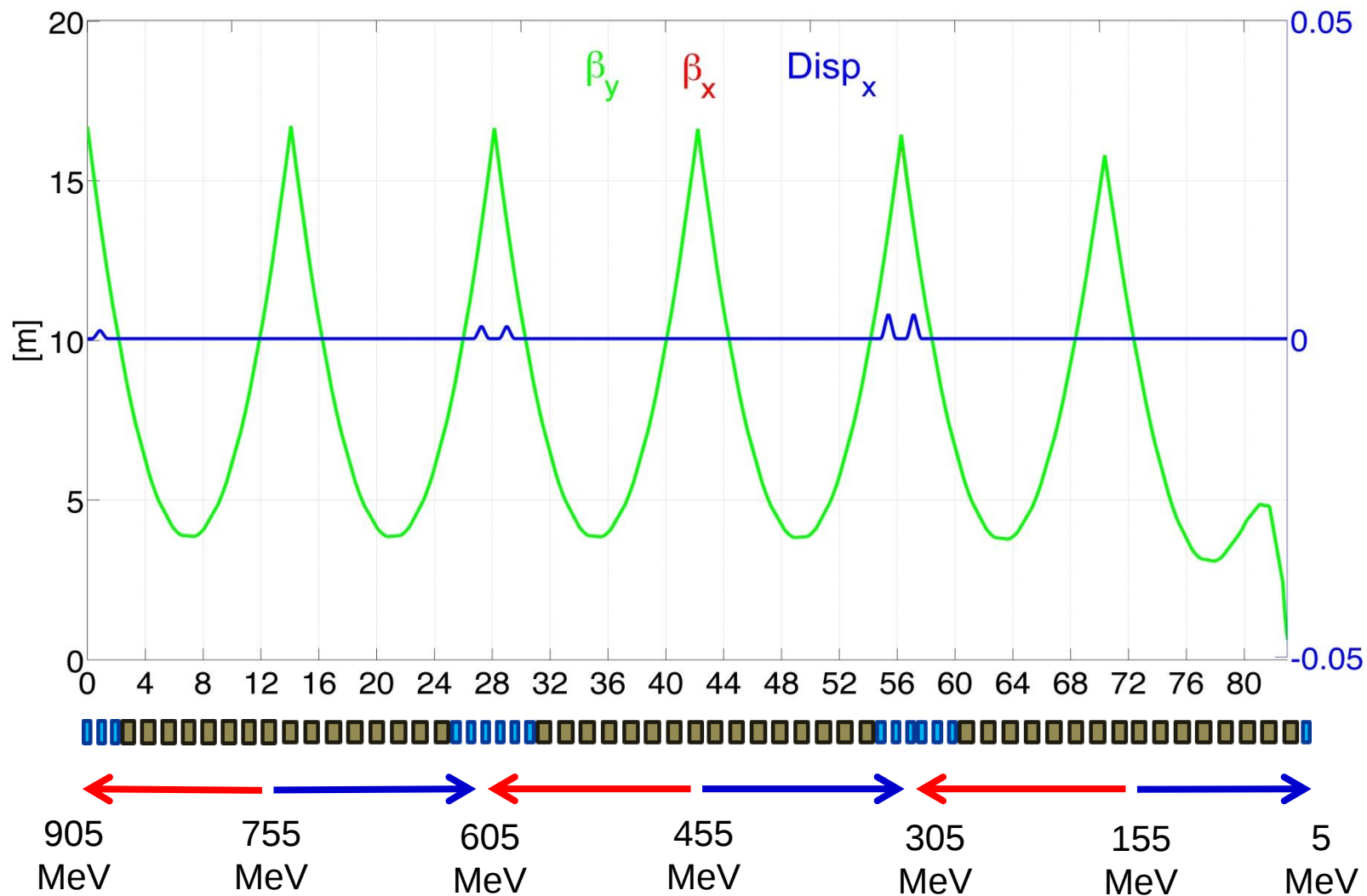
Layout



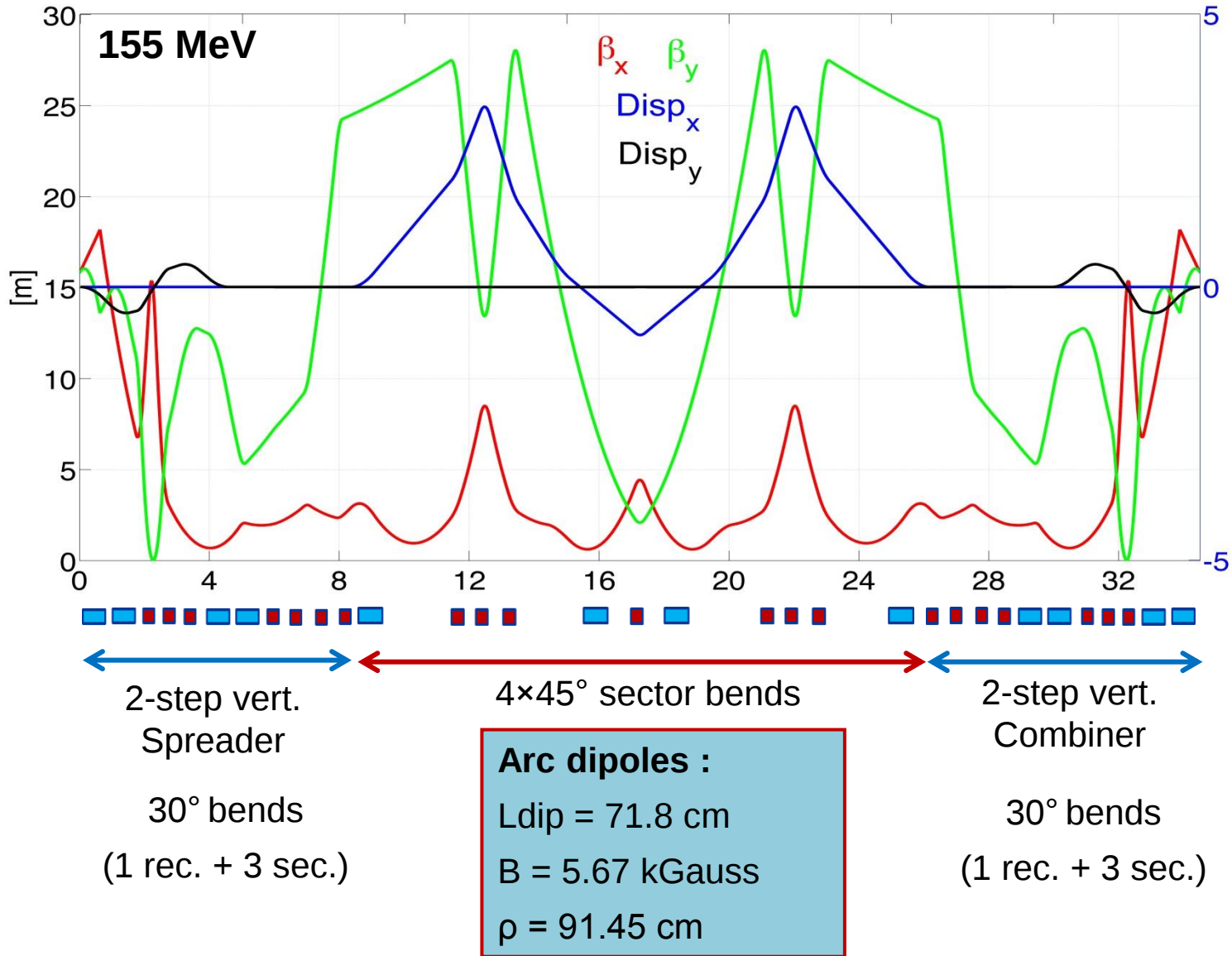
Linac 1 Multi-Pass Optics



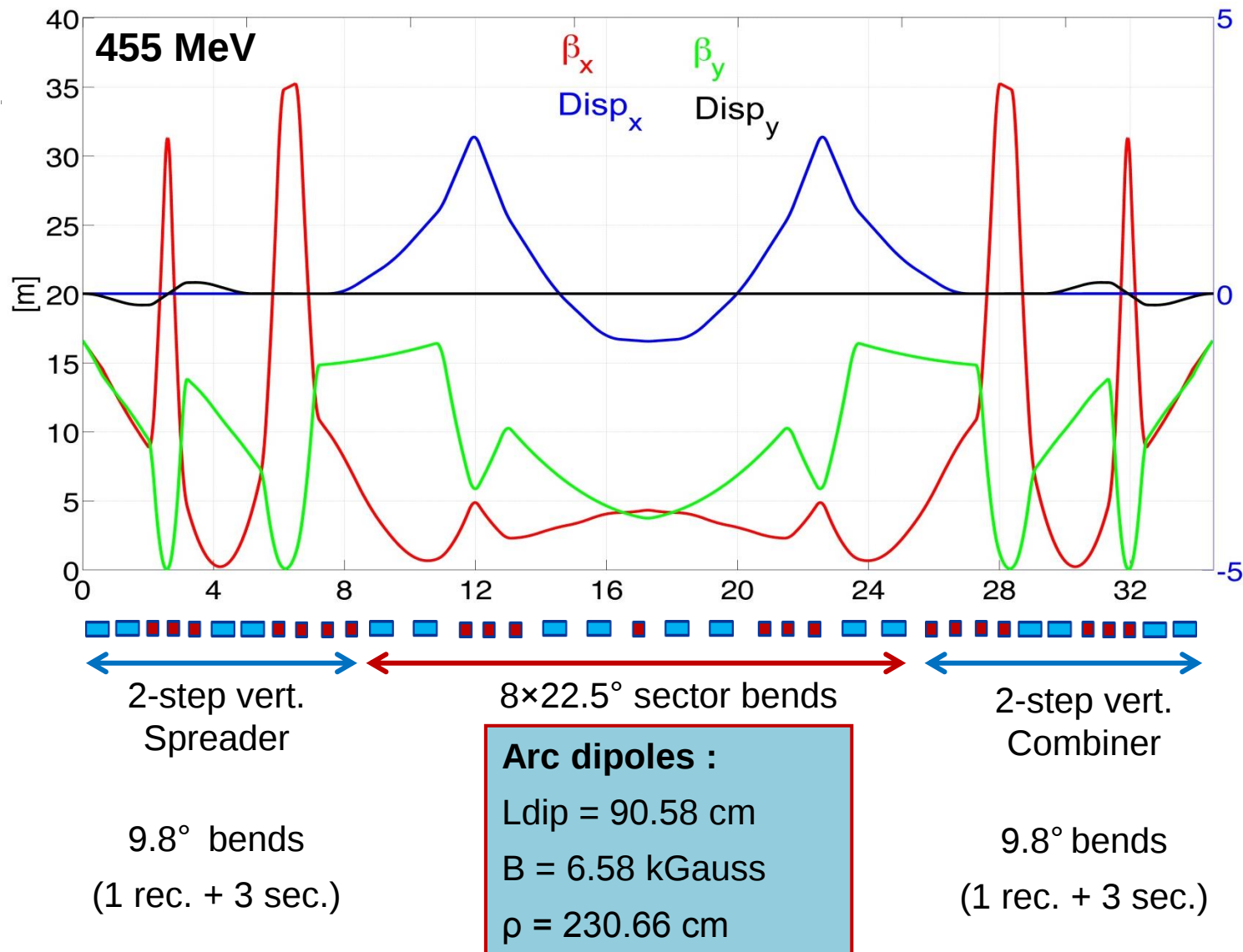
Linac 2 Multi-Pass Optics



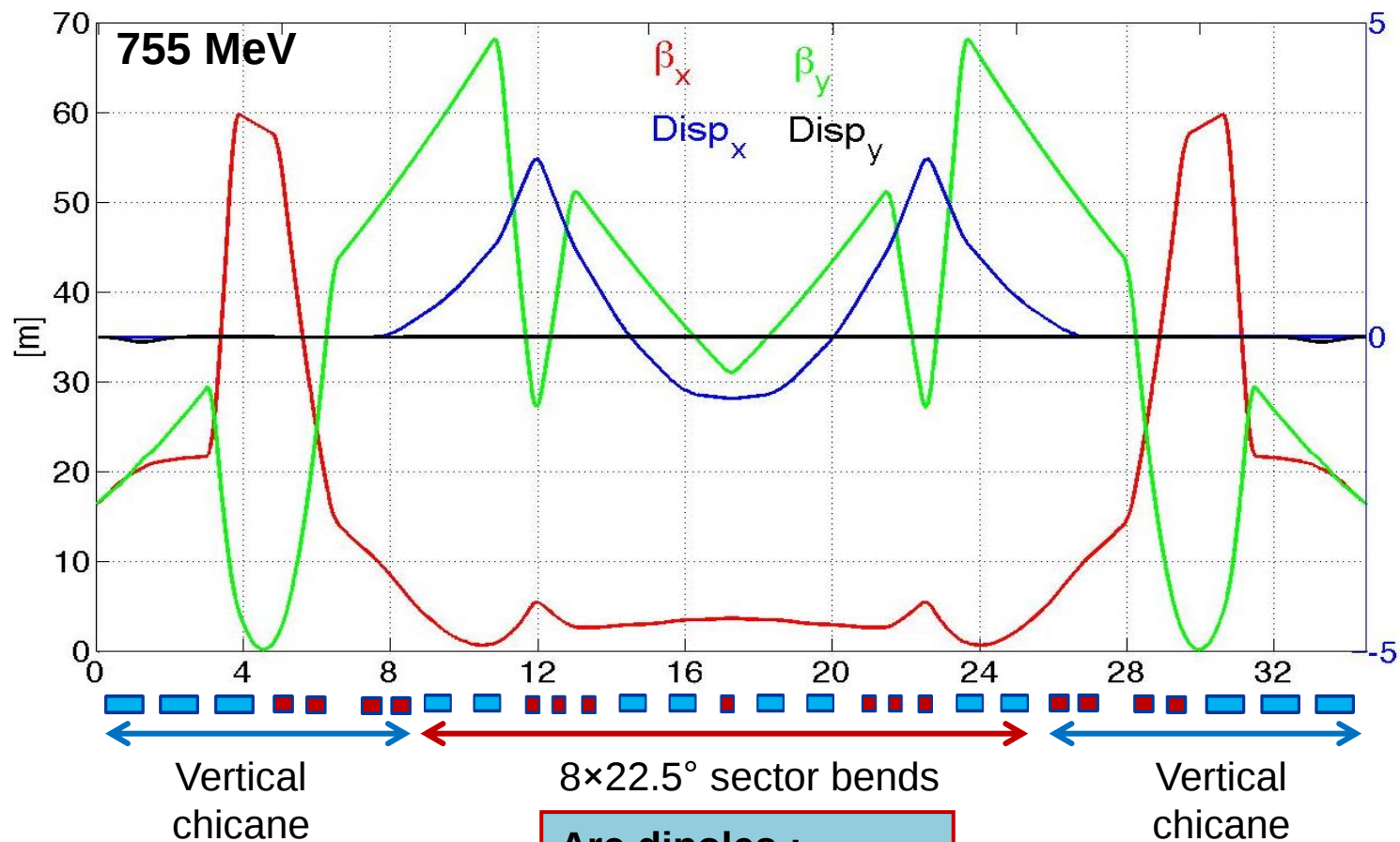
Arc 1 optics



Arc 3 optics



Arc 5 optics



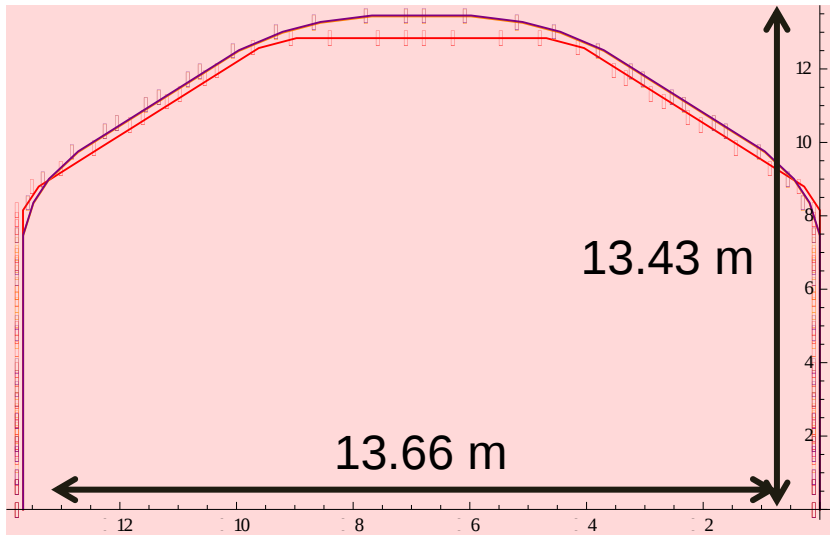
Arc dipoles :

$L_{\text{dip}} = 90.58 \text{ cm}$

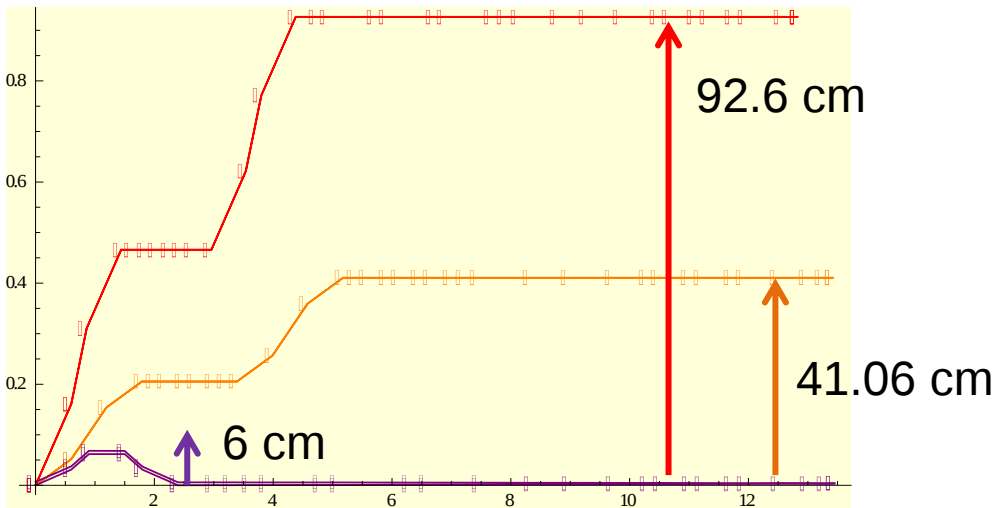
$B = 10.92 \text{ kGauss}$

$\rho = 230.66 \text{ cm}$

Arc 1,3,5 layout



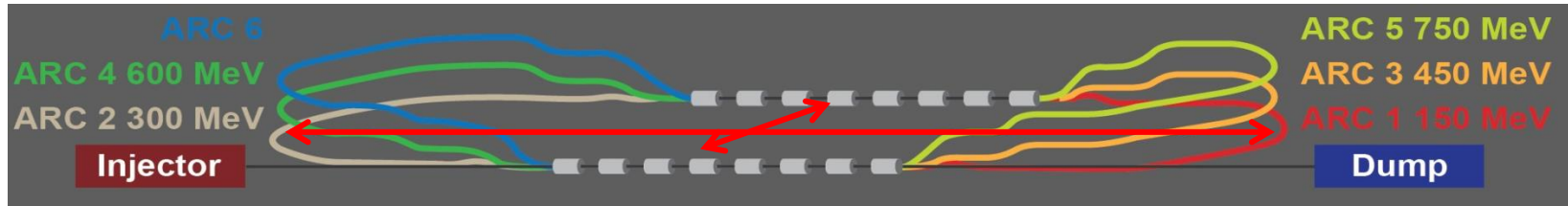
- Synchronous acceleration
Isochronous arcs
- Achromatic arc
- FMC optics



Total Arc length for Arc 1,2,3
34.5112 m
 $94 \times \lambda_{rf}$

For 6 arcs:
84 DIPOLES
114 QUADRUPOLES

Footprint



ARCS

Total length for Arc 1,2,3

34.5112 m

$94 \times \lambda_{rf}$

(last cavity linac1 to first cavity linac 2)

Total length for Arc 2,4

34.2704 m

$101 \times \lambda_{rf}$

(last cavity linac1 to first cavity linac 2)

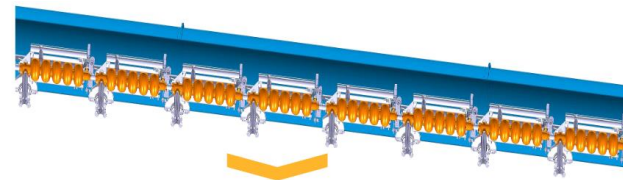
Total length for Arc 6

34.4574 m

$101.5 \times \lambda_{rf}$

(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
$L_{cavity} = 5\lambda/2$	93.5 cm
Grad	20.02 MeV/m
ΔE	18.71 MV per cavity

Total length ~ 13 m

CHICANE INJ/EXTR

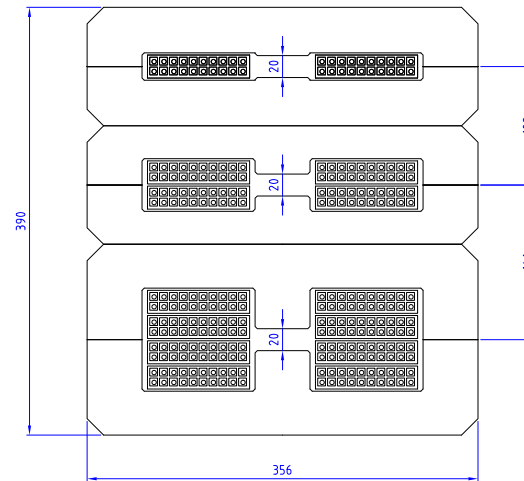
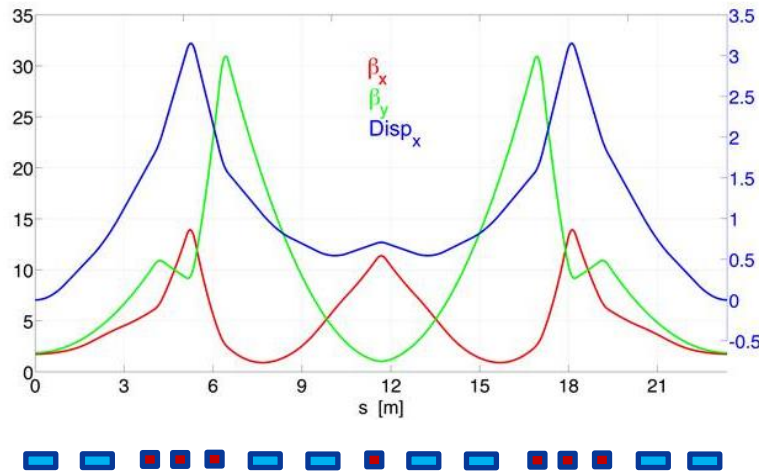
Length ~ 1.75 m

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° bends

Ldip = 100.6 cm

$\rho = 256.3$ 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

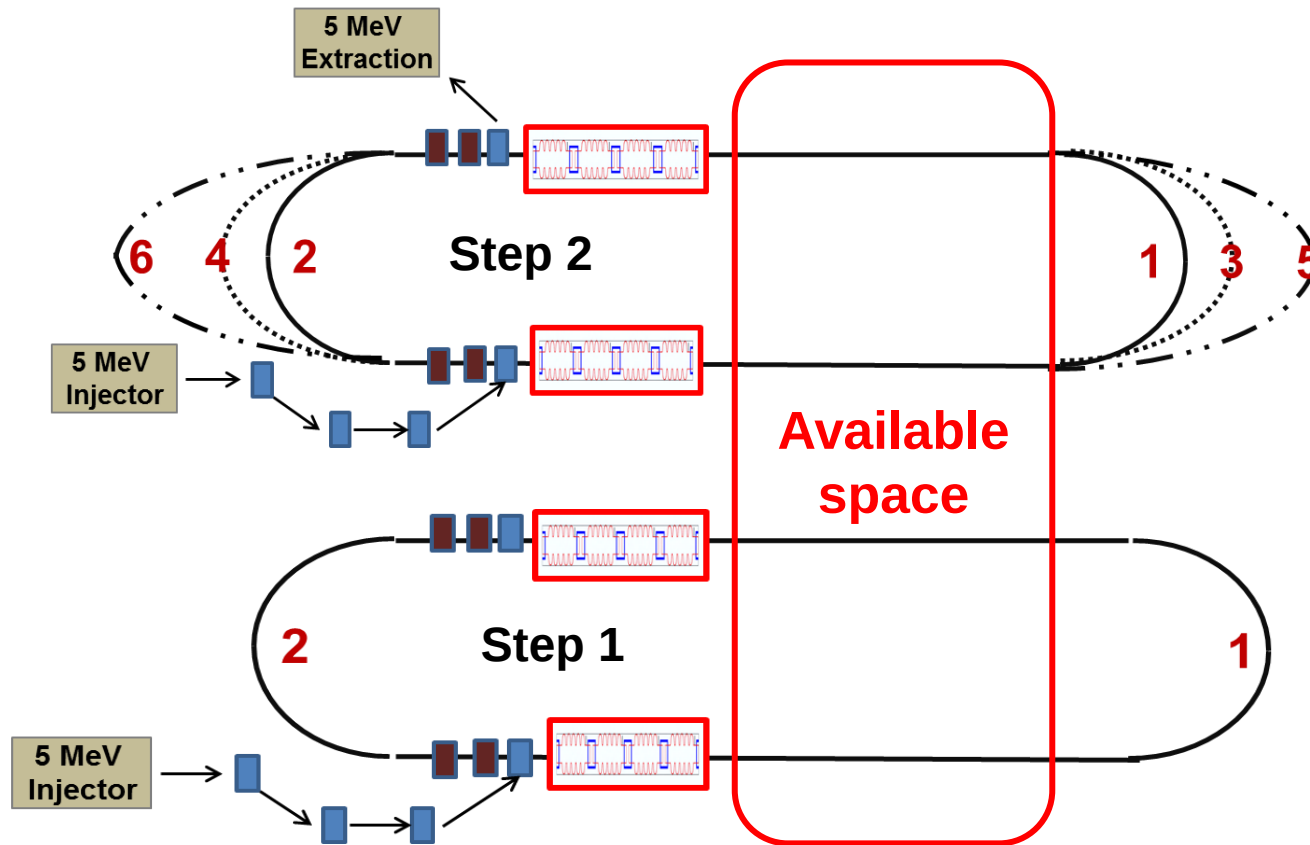
ARC	E [MeV]	ΔE [keV]	$\sigma E/E$ [%]
1	150	0.0087	0.00000387
2	300	0.139	0.00002199
3	450	0.708	0.0000621
4	600	2.239	0.000132
5	750	5.467	0.00024
6	900	11.337	0.00039
7	750	5.4667	0.00052
8	600	2.239	0.00066
9	450	0.708	0.00089
10	300	0.139	0.00135
11	150	0.0087	0.0027

➤ Beam Energy loss $\Delta E = \int P_\gamma dt = P_\gamma \frac{\pi \rho}{\beta c} \quad \Delta E (GeV) = C_\gamma \frac{E^4}{\rho} \frac{1}{2}$

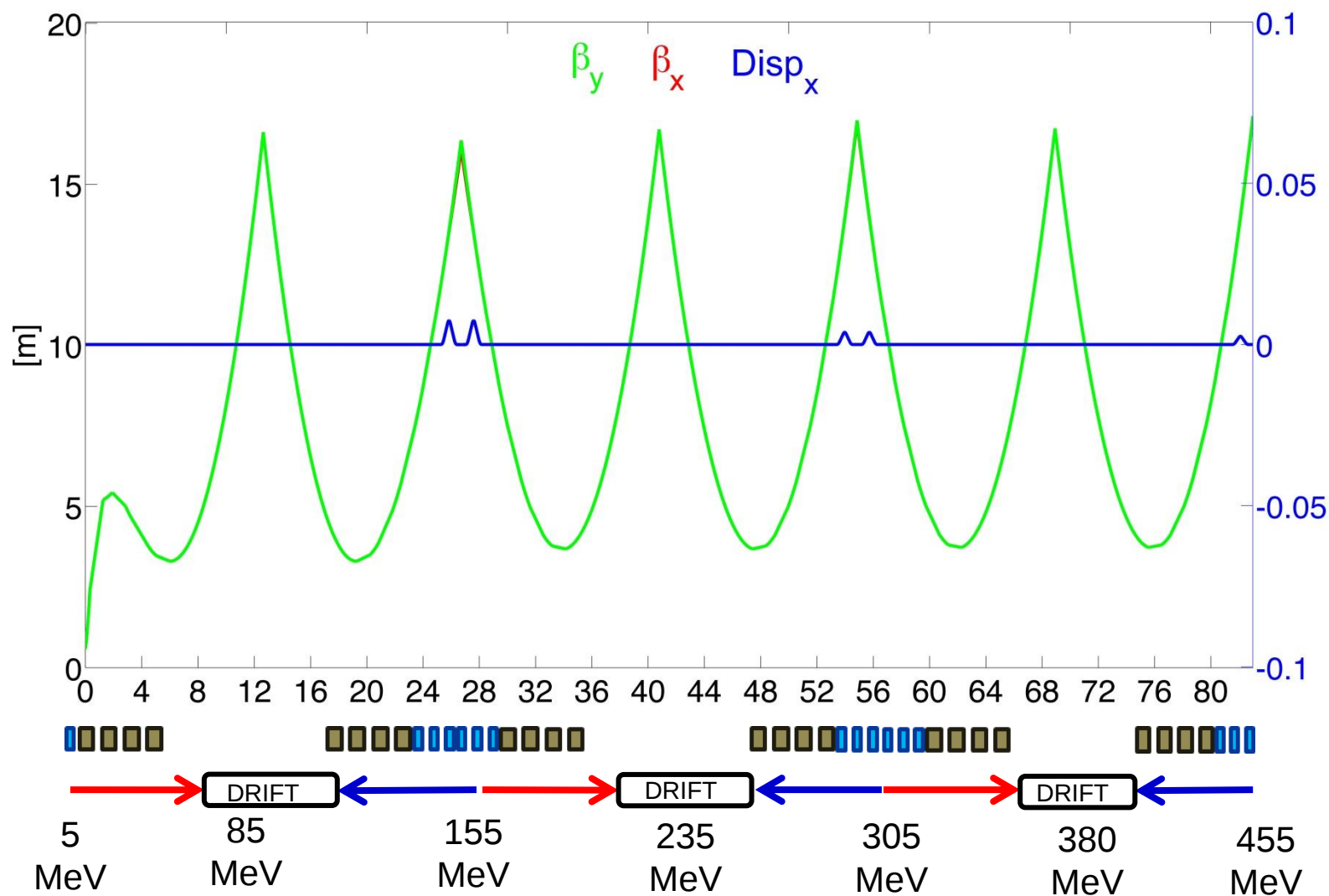
➤ Beam Energy Spread $\frac{\sigma_E}{E} = \sqrt{1.4397 * 10^{-27} \frac{\pi \gamma^5}{\rho^2}}$

Next steps

- Complete Step 2 and Step 1 configuration and optics layout



Linac 1 - Step 2



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Controlled quench tests of SC magnets

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

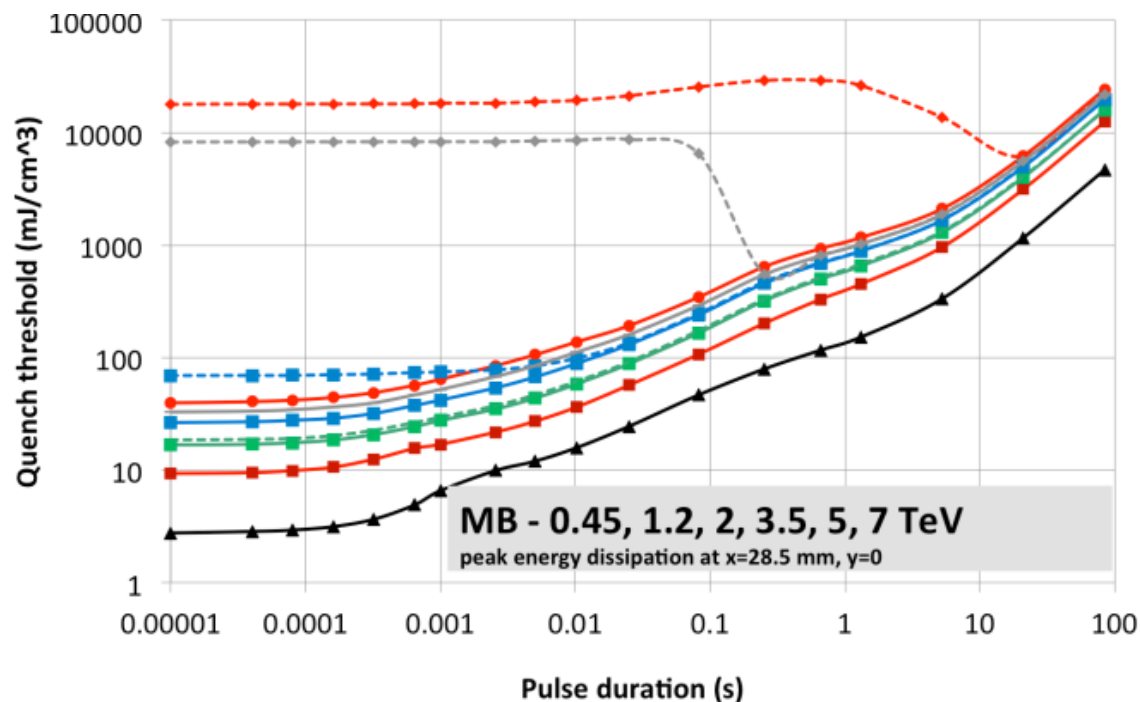
Requirements in terms of:

- 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

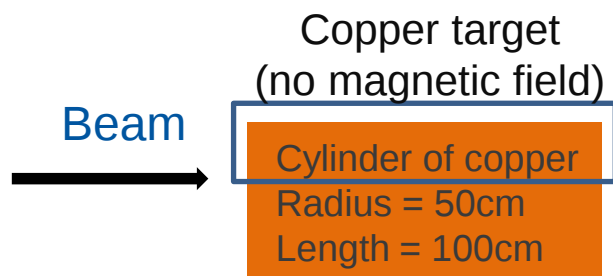


Quench limits of LHC
dipole as expected from
QP3 simulations for
different pulse durations

Courtesy A. Verweij

Beam parameters to generate a given amount of energy deposition

CALCULATIONS AND FLUKA SIMULATIONS

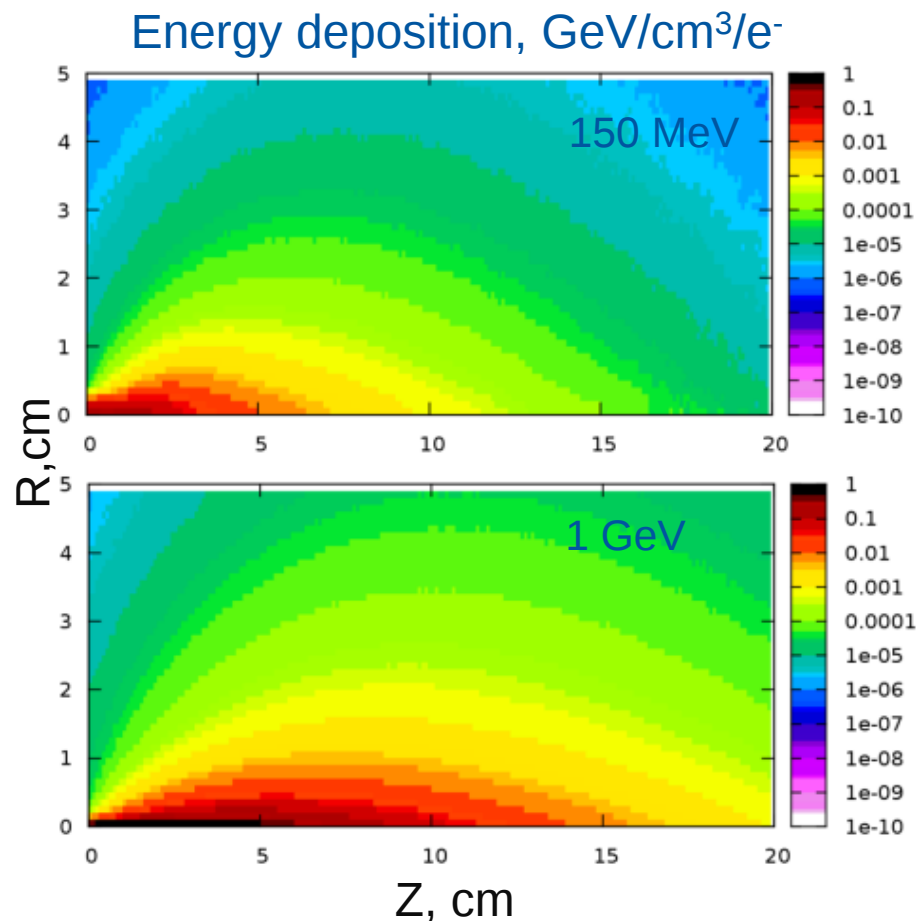


Beam parameters

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

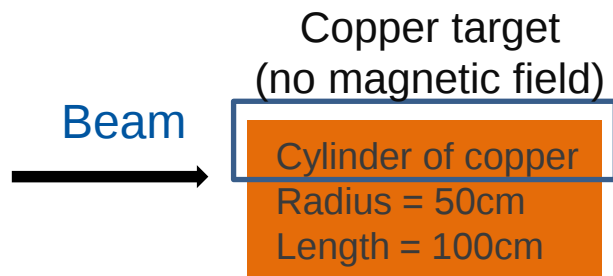
Results are given for half of bulky target
because of symmetry

Binning: 1 mm³ bins



Beam parameters to generate a given amount of energy deposition

CALCULATIONS AND FLUKA SIMULATIONS



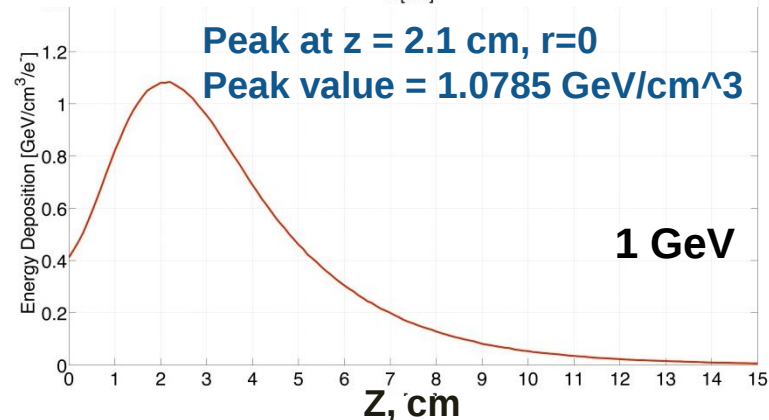
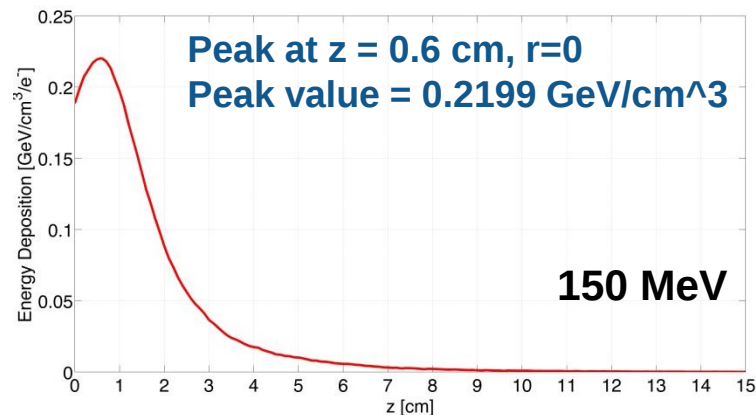
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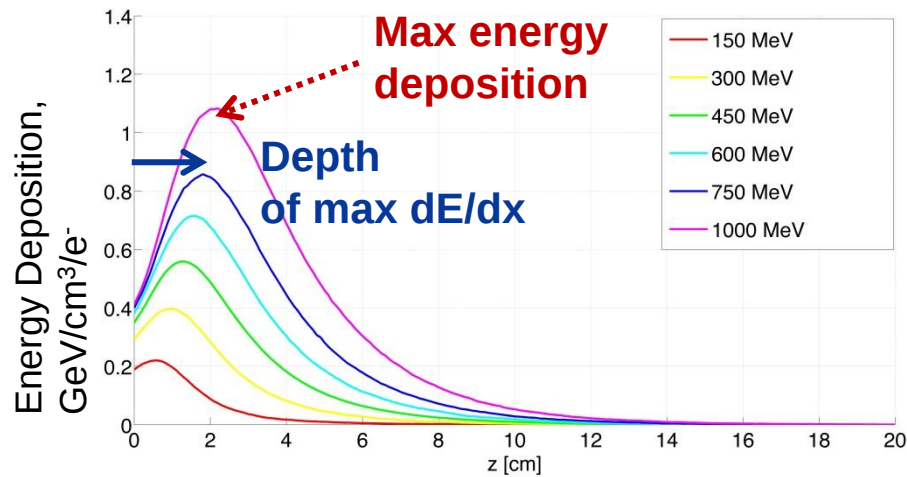
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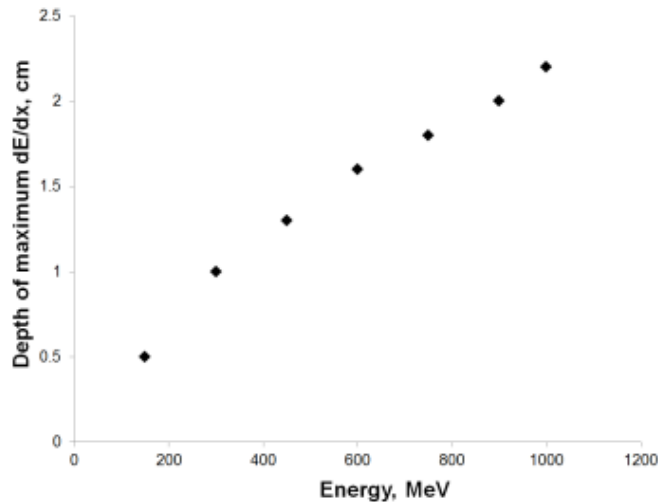
Energy deposition, GeV/cm³/e⁻



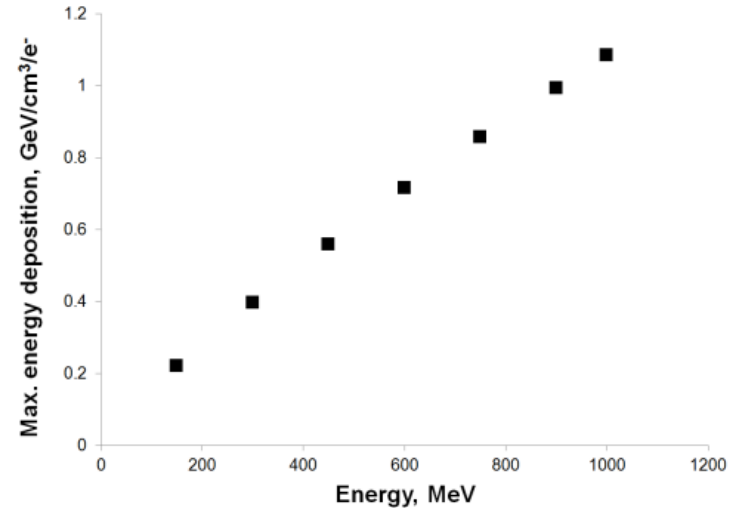
Beam parameters to generate a given amount of energy deposition



Depth of max dE/dx



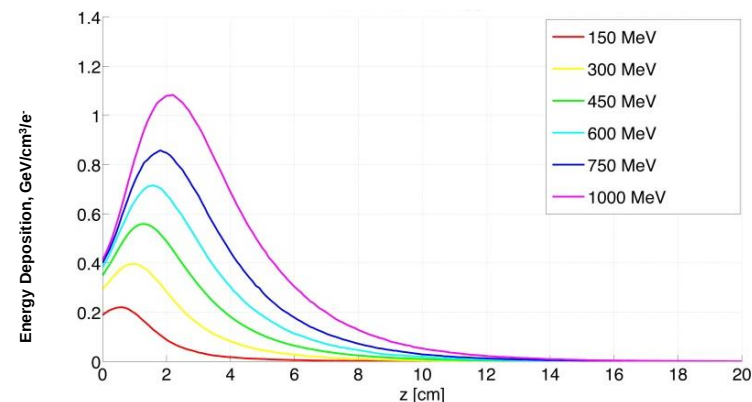
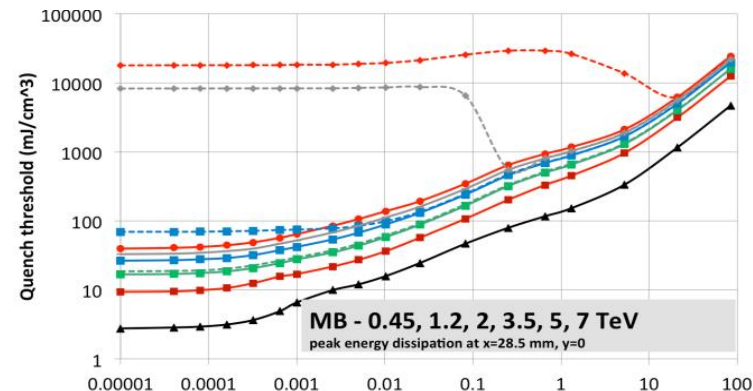
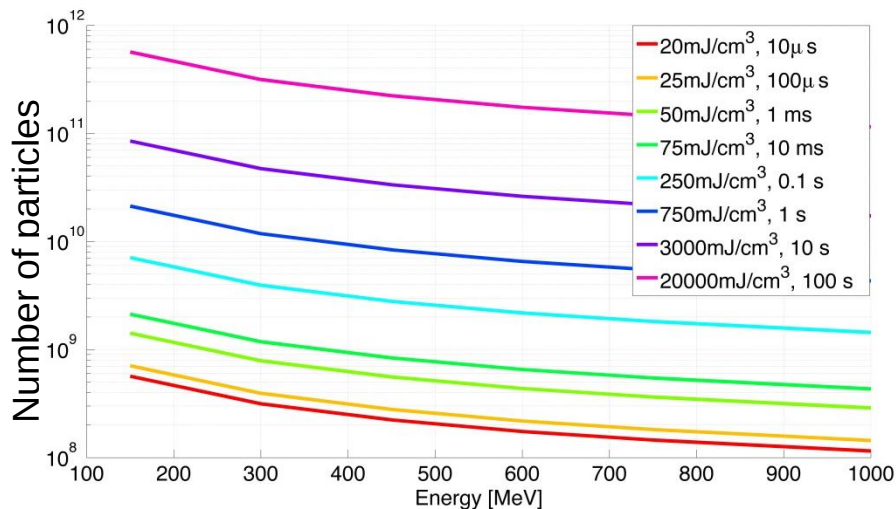
Max energy deposition



Beam parameters to generate a given amount of energy deposition

electrons needed to quench the magnet = $\frac{\text{Quench threshold}}{\text{Maximum value for the energy deposition}}$

MB quench limit @ 3.5 TeV



1 GeV = 1.602×10^{-7} mJ

MB quench limit 450 GeV is 140 mJ/cm³ in 10ms:

$\sim 2.2 \times 10^9$ e⁻ @ 1GeV necessary

MB quench limit 7 TeV is 16 mJ/cm³ in 10ms:

$\sim 2.6 \times 10^8$ 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.
- Design complementary to & synergetic with other proposals
- A Design Study of the ERL-TF has started (a sketch of the optics configuration is provided and other options are under investigation) in collaboration with other institutes (as JLAB)
- 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!
- Completion of Conceptual design study of an ERL-TF at CERN by the end of 2014

Thank you for your attention





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