eRHIC electron injection and storage ring

Cost estimate
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- Ring
  - Parameters
  - Costs
  - Power, Length, Scaling
- Linac
  - Costs
  - Various Injection Options

All estimates include:

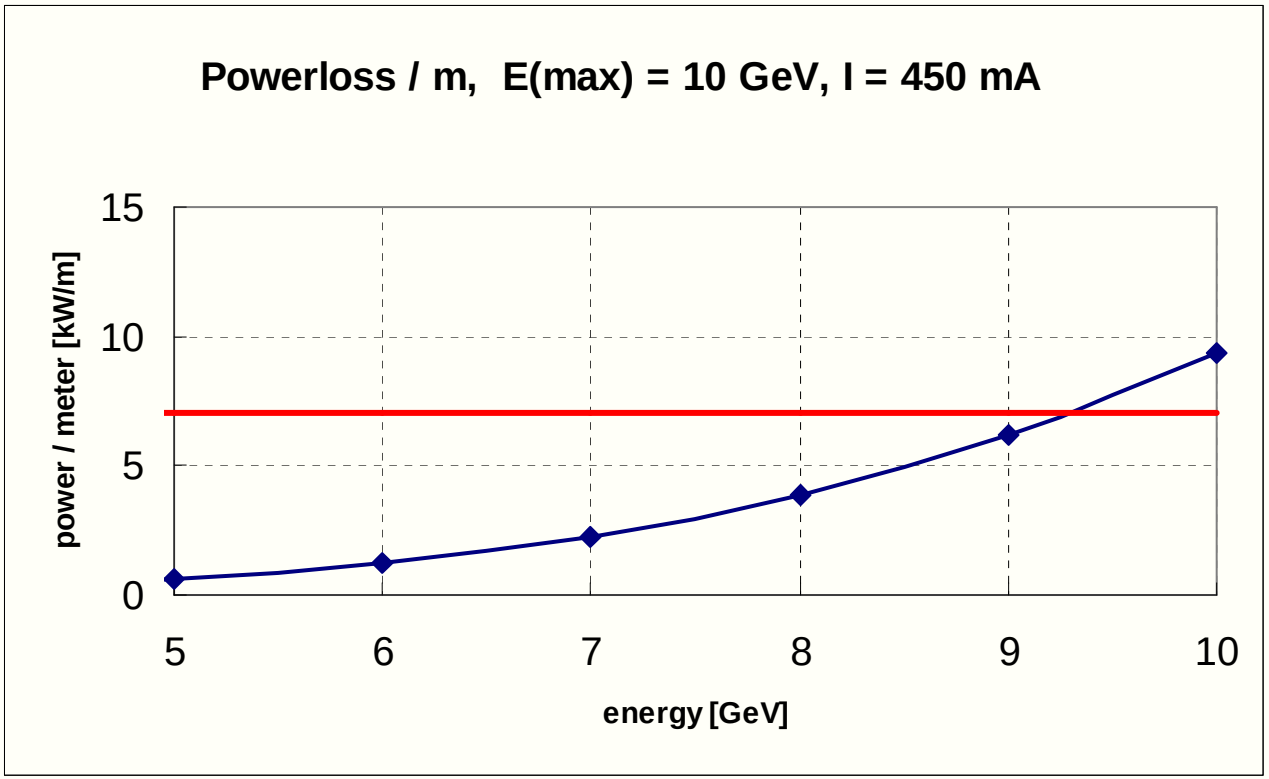
- E D & I, Engineering, Design and Inspection
- M & S, Material and Service + Labor
- NO contingency

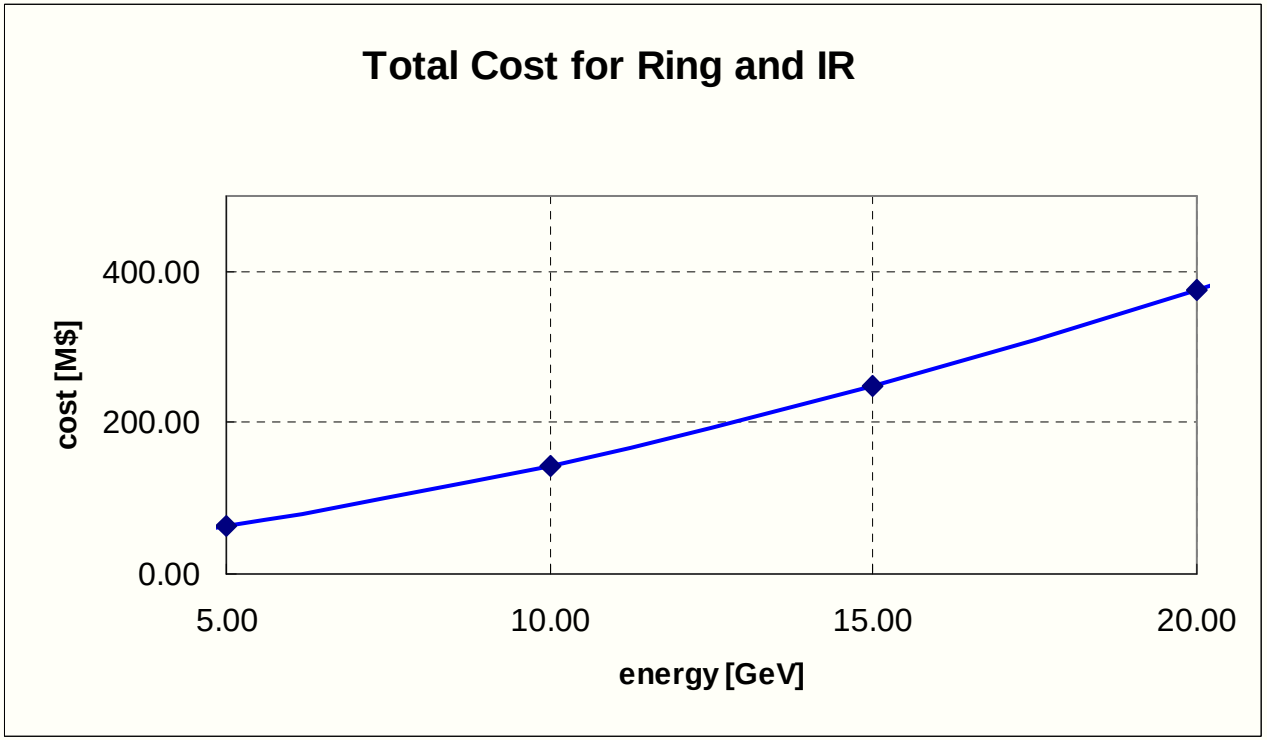
Electron storage ring for eRHIC

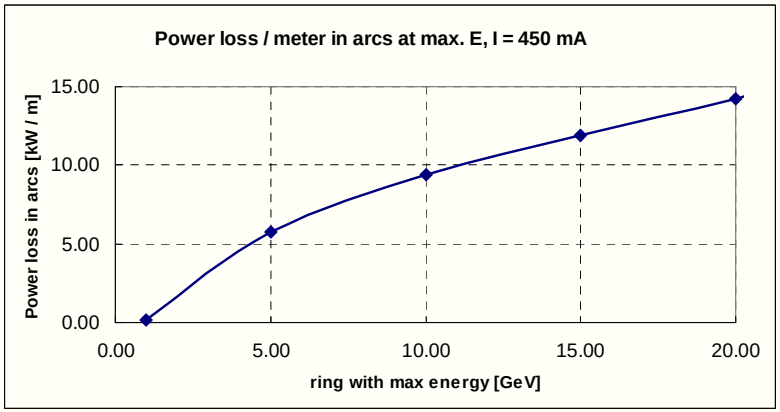
Main parameters for the RF system

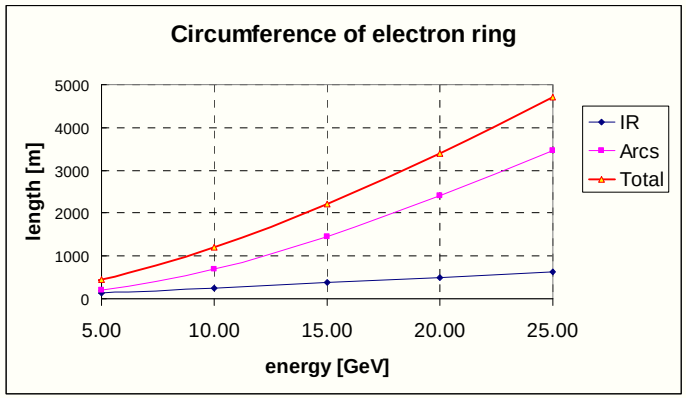
	Storage ring	
Circumference	1199	m
Energy	10	GeV
Rf frequency	364	MHz
Energy loss / turn	13	MeV
Gap voltage	30	MV
# of Cavities	20	
# of Klystrons	10	
Klystron power	10	MW

Storage Ring			
	Tunnel		13.9
	Magnets (incl. measurements)		53.2
	Support/Stands		2.5
	Installation		5.2
	Vacuum		21.5
	Power conversion		8.5
	RF		13.7
	Feedback (transv. + long.)		3.7
	Diagnostics		3.1
	Control System		8.0
	Subtotal Ring		***133.3***
Interaction Region			
	Magnets		4.5
	Power conversion		1.8
	Support/Stands		0.6
	Installation		1.2
	Vacuum		1.6
	Diagnostics		0.6
	Subtotal Interaction Region		***10.3***
Total Ring			**143.6**

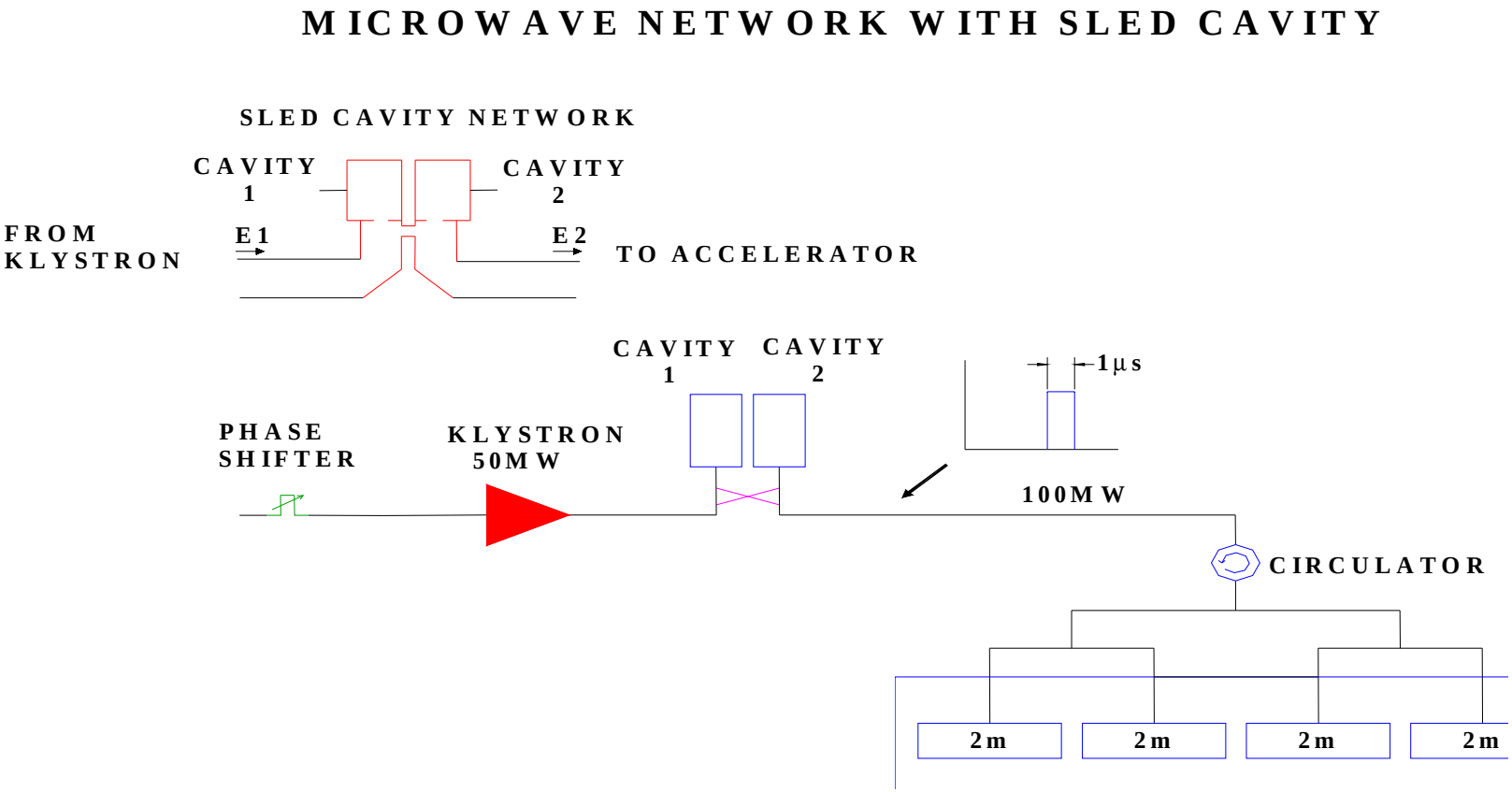

Powerloss / m, E(max) = 10 GeV, I = 450 mA
power / meter [kW/m]
15
10
5
0
5
6
7
8
9
10
energy [GeV]


Total Cost for Ring and IR
cost [M$]
400.00
200.00
0.00
5.00
10.00
15.00
20.00
energy [GeV]


Power loss / meter in arcs at max. E, I = 450 mA
Power loss in arcs [kW / m]
15.00
10.00
5.00
0.00
0.00
5.00
10.00
15.00
20.00
ring with max energy [GeV]


Circumference of electron ring
length [m]
5000
4000
3000
2000
1000
0
5.00
10.00
15.00
20.00
25.00
energy [GeV]
IR
Arcs
Total

SLED cavities



Copper Linac (1 – 10 GeV) Costs

	Estimated Cost for eRHIC Electron Linac					
					15MV/m	
Copper Electron Linac energy [GeV]		**1**	**2**	**5**	**5**	**10**
		M$	M$	M$	M$	M$
Injector						
	Polarized injector	0.7	0.7	0.7	0.7	0.7
	Injector RF	0.6	0.6	0.6	0.6	0.6
	diagnostics & Install	0.3	0.3	0.3	0.3	0.3
	Subtotal Injector	***1.6***	***1.6***	***1.6***	***1.6***	***1.6***
RF System						
	Klystrons	1.6	3.2	7.9	11.1	15.8
	Modulators	2.2	4.4	11.1	15.5	22.1
	Waveguides	0.8	1.6	3.9	5.5	7.8
	Power Conversion	2.5	5.0	12.6	20.6	25.2
	Subtotal RF System	***7.1***	***14.2***	***35.5***	***52.7***	***70.9***
Accelerator System						
	Accelerator Structure	2.8	5.7	14.2	20.0	28.4
	RF cavities (SLED)	0.8	1.6	4.0	0.0	7.9
	High Power Loads	0.2	0.4	1.1	1.5	2.2
	Subtotal Acc. System	***3.9***	***7.7***	***19.3***	***21.5***	***38.5***
Miscellaneous						
	Tunnel	1.1	1.8	3.7	5.0	6.9
	Supporst/Stands	0.3	0.6	1.5	2.1	3.0
	Magnets	0.7	0.9	1.5	1.8	2.4
	Vacuum system	0.8	1.2	2.2	2.8	3.8
	Diagnostics	0.6	0.7	1.0	1.2	1.5
	Installation	1.4	1.8	3.0	3.8	5.0
	Control System	2.3	2.6	3.4	4.0	4.8
	Subtotal Miscellaneous	***7.2***	***9.5***	***16.2***	***20.7***	***27.4***
Total Accelerator		**19.8**	**33.0**	**72.5**	**96.5**	**138.4**

SLAC cavities > 6 μs rf pulse allows recirculation

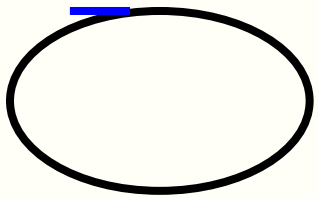
SC Linac (1 – 10 GeV) Costs

SC Electron Linac energy [GeV]		1	2	5	10
		M$	M$	M$	M$
Injector					
	Polarized injector	0.7	0.7	0.7	0.7
	Injector RF	0.6	0.6	0.6	0.6
	diagnostics & Install	0.3	0.3	0.3	0.3
	Subtotal Injector	***1.6***	***1.6***	***1.6***	***1.6***
RF System					
	Klystrons	1.2	2.4	6.0	12.0
	Modulators	0.5	1.0	2.5	5.0
	Waveguides	0.8	1.6	3.9	7.8
	Power Conversion	2.5	5.0	14.4	25.2
	Subtotal RF System	***5.0***	***10.0***	***26.8***	***50.0***
Accelerator System					
	Cavities incl Quads & BPMs	17.5	35.0	87.5	175.0
	Cryo	0.4	0.8	2.0	4.0
	Subtotal Acc. System	***17.9***	***35.8***	***89.5***	***179.0***
Miscellaneous					
	Tunnel	1.1	1.8	3.7	6.9
	Supporst/Stands	0.3	0.6	1.5	3.0
	Magnets	0.7	0.9	1.5	2.4
	Vacuum system	0.8	1.2	2.2	3.8
	Diagnostics	0.6	0.7	1.0	1.5
	Installation	1.4	1.8	3.0	5.0
	Control System	2.3	2.6	3.4	4.8
	Subtotal Miscellaneous	***7.2***	***9.5***	***16.2***	***27.4***
Total Accelerator		**31.7**	**56.9**	**134.1**	**258.0**

Booster Ring (10 GeV) Costs

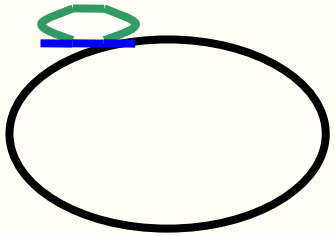
Booster Ring		
	Tunnel	5.0
	Magnets (incl. meas.)	14.0
	Support / Stands	1.5
	Installation	3.0
	Vacuum	9.0
	Power conversion	8.5
	RF	38.6
	Feedback (transv. + long.)	2.0
	Diagnostics	1.5
	Control System	2.5
Total Booster		***85.6***

2 GeV Copper Linac
2-10 GeV Ramping Ring



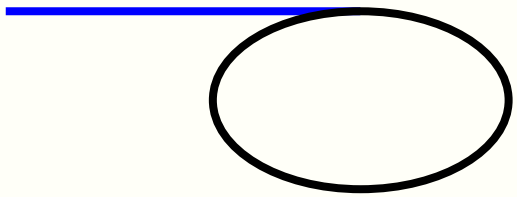
Injector & Linac	33
Ring & IR	144
Radiation & Damping Wigglers	15
Total	192

1 GeV Copper Linac
One Recirculation
2-10 GeV Ramping Ring



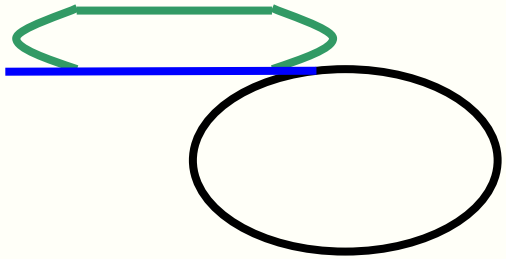
Injector & Linac	20
Recirculator	10
Ring & IR	144
Radiation & Damping Wigglers	15
Total	189

10 GeV Copper Linac
5-10 GeV Static Ring



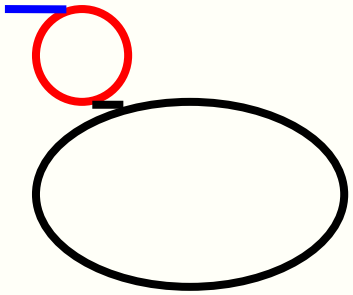
Injector & Linac	138
Ring & IR	144
Total	282

5 GeV Superconducting Linac
One Recirculation
5-10 GeV Static Ring



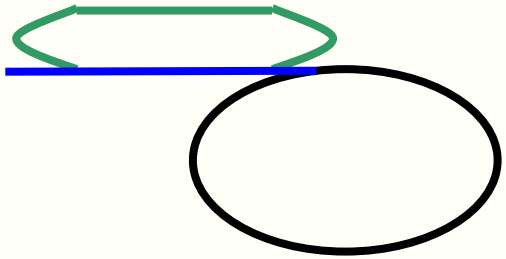
Injector & Linac	134
Recirculator	15
Ring & IR	144
Total	293

2 GeV Copper Linac
2-10 GeV Ramping Booster Ring
5-10 GeV Static Ring



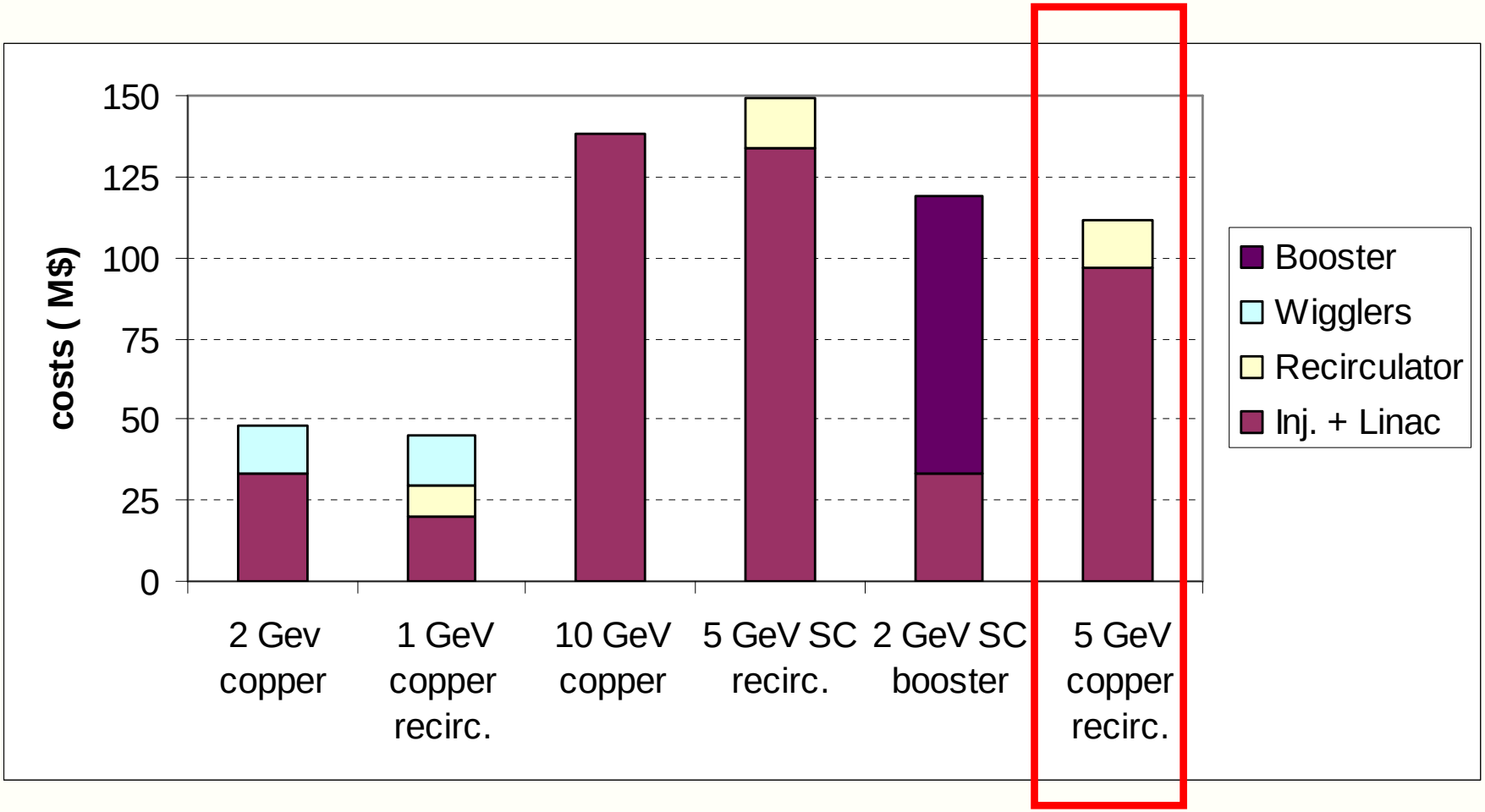
Injector & Linac	33
Booster	86
Ring & IR	144
Total	263

5 GeV Copper Linac
One Recirculation
5-10 GeV Static Ring

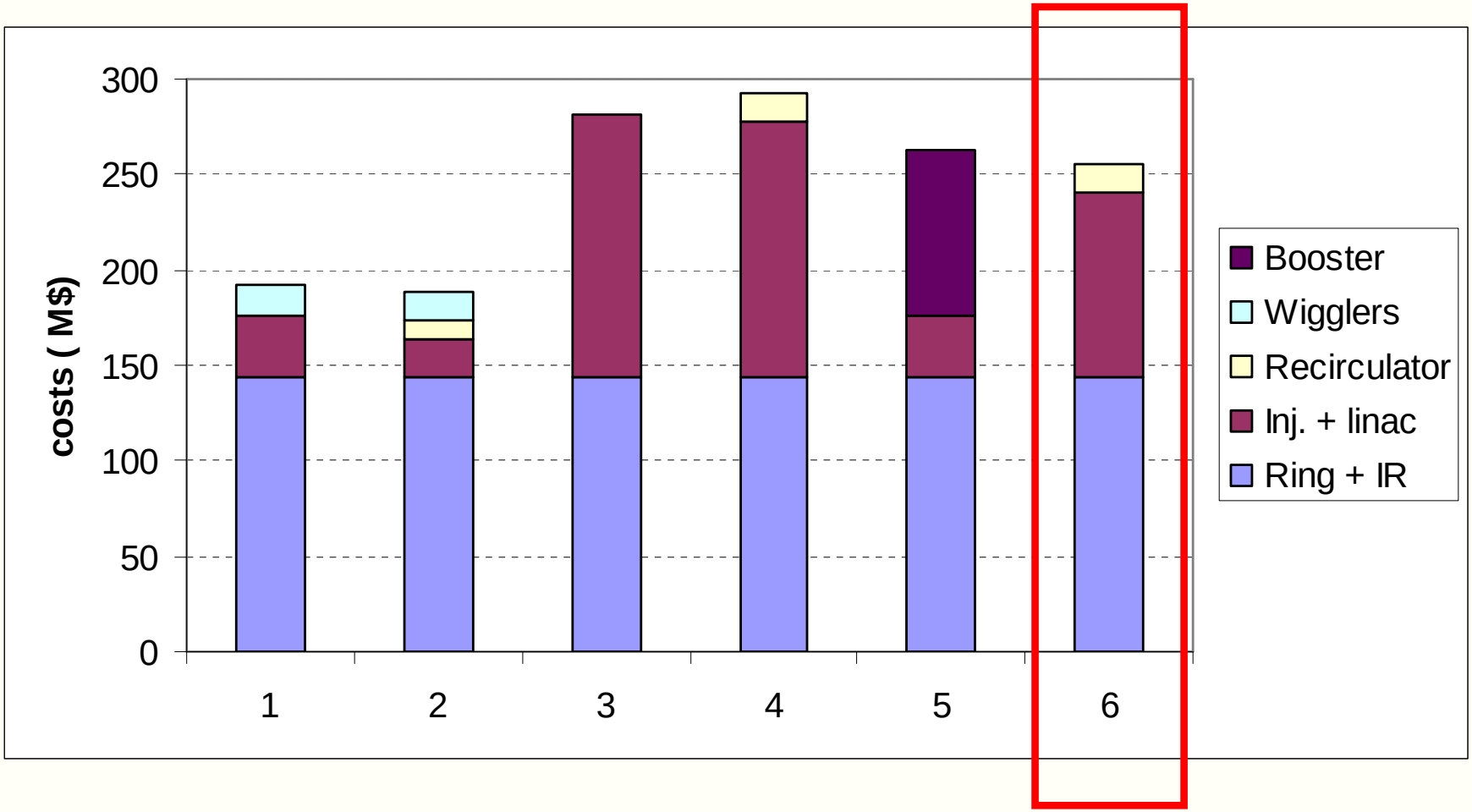


Injector & Linac	96
Recirculator	15
Ring & IR	144
Total	255

Injection Costs



Injection + Ring Costs



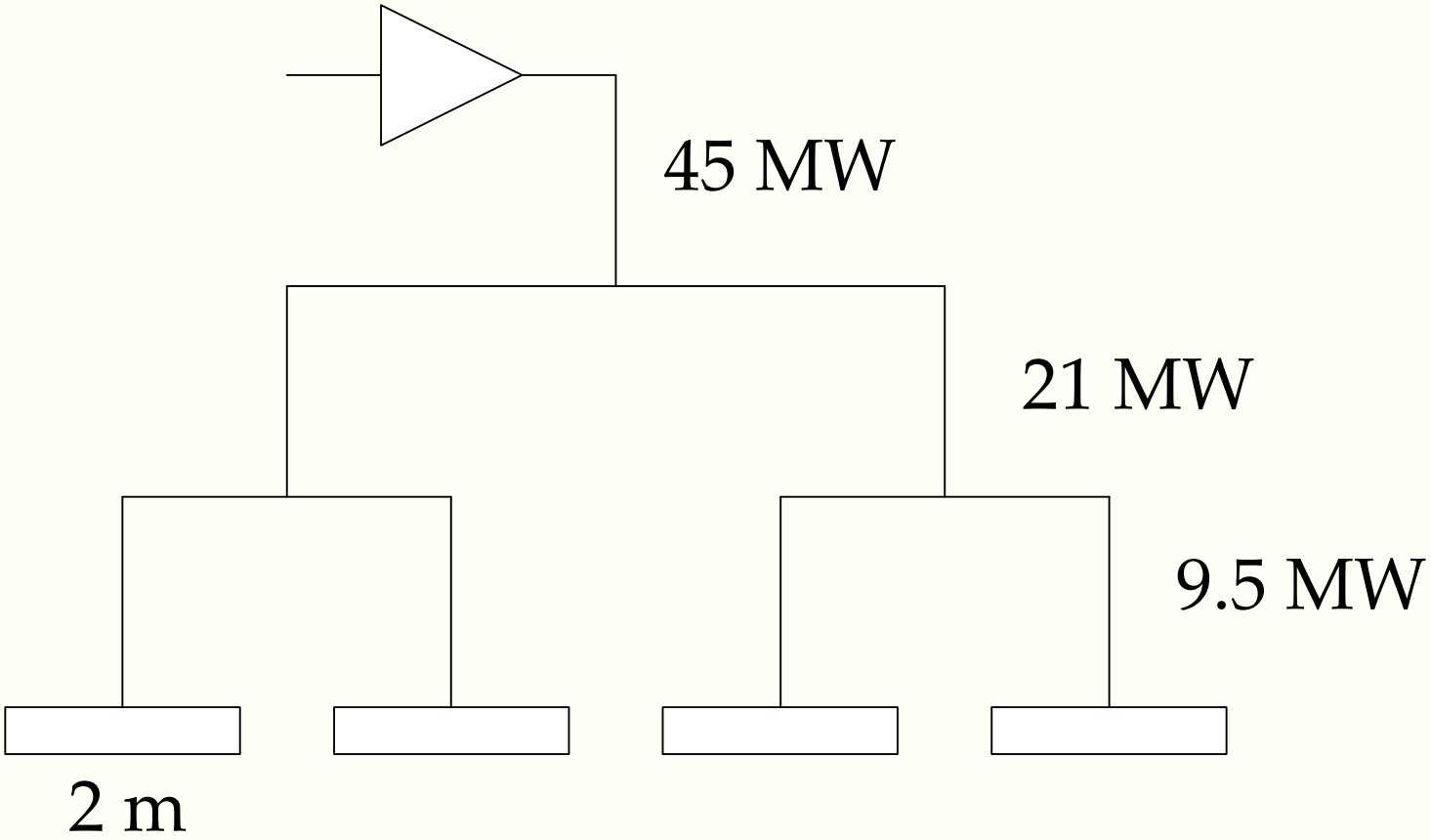
5 GeV copper linac, SLAC cavities

- 2865 Mhz
- 60 Hz
- 8 μs macropulse

Recirculation to 10 GeV

- head-to-tail operation
- e^- two passes
- e^+ three passes

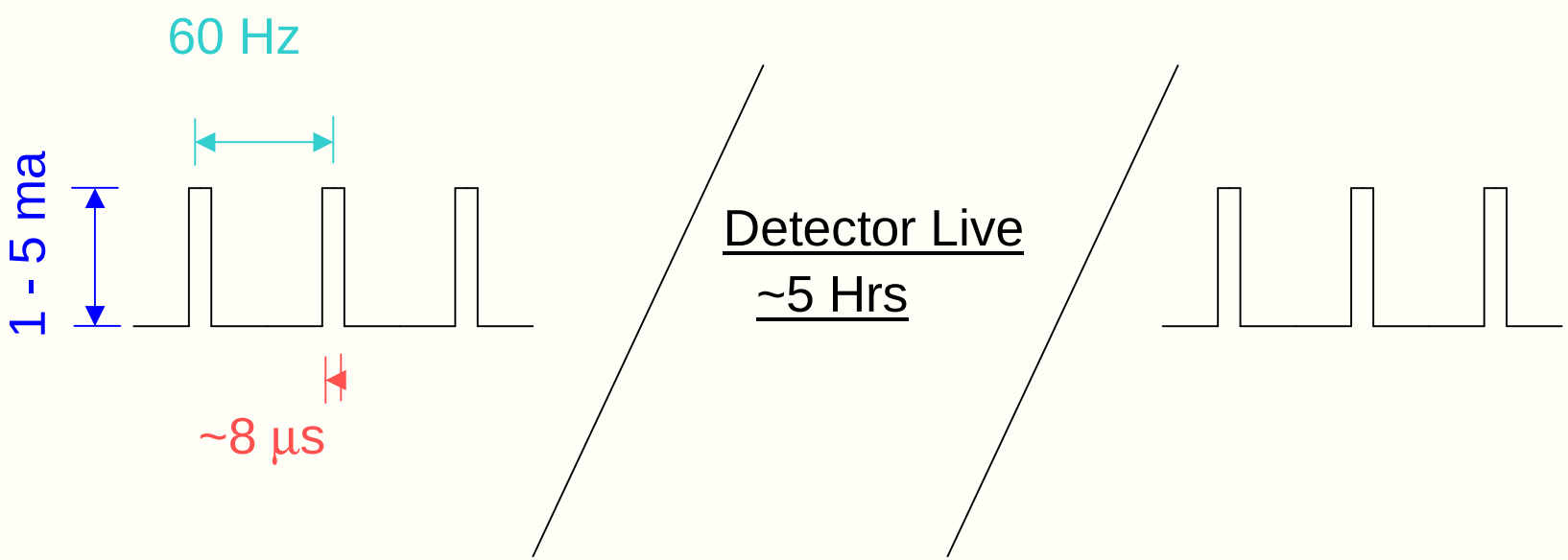
Accelerator Section, 4 cavities, L = 11 m.

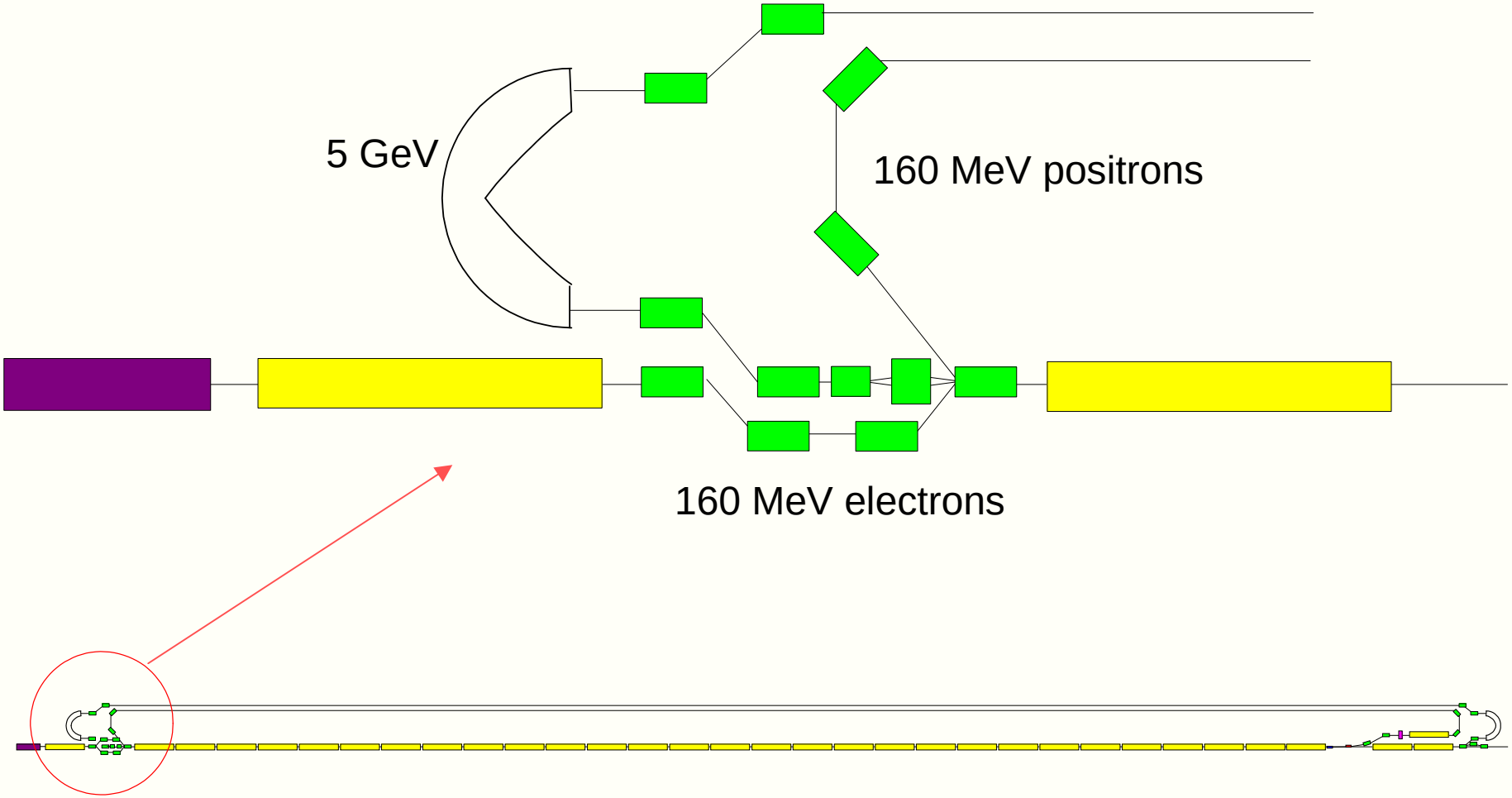


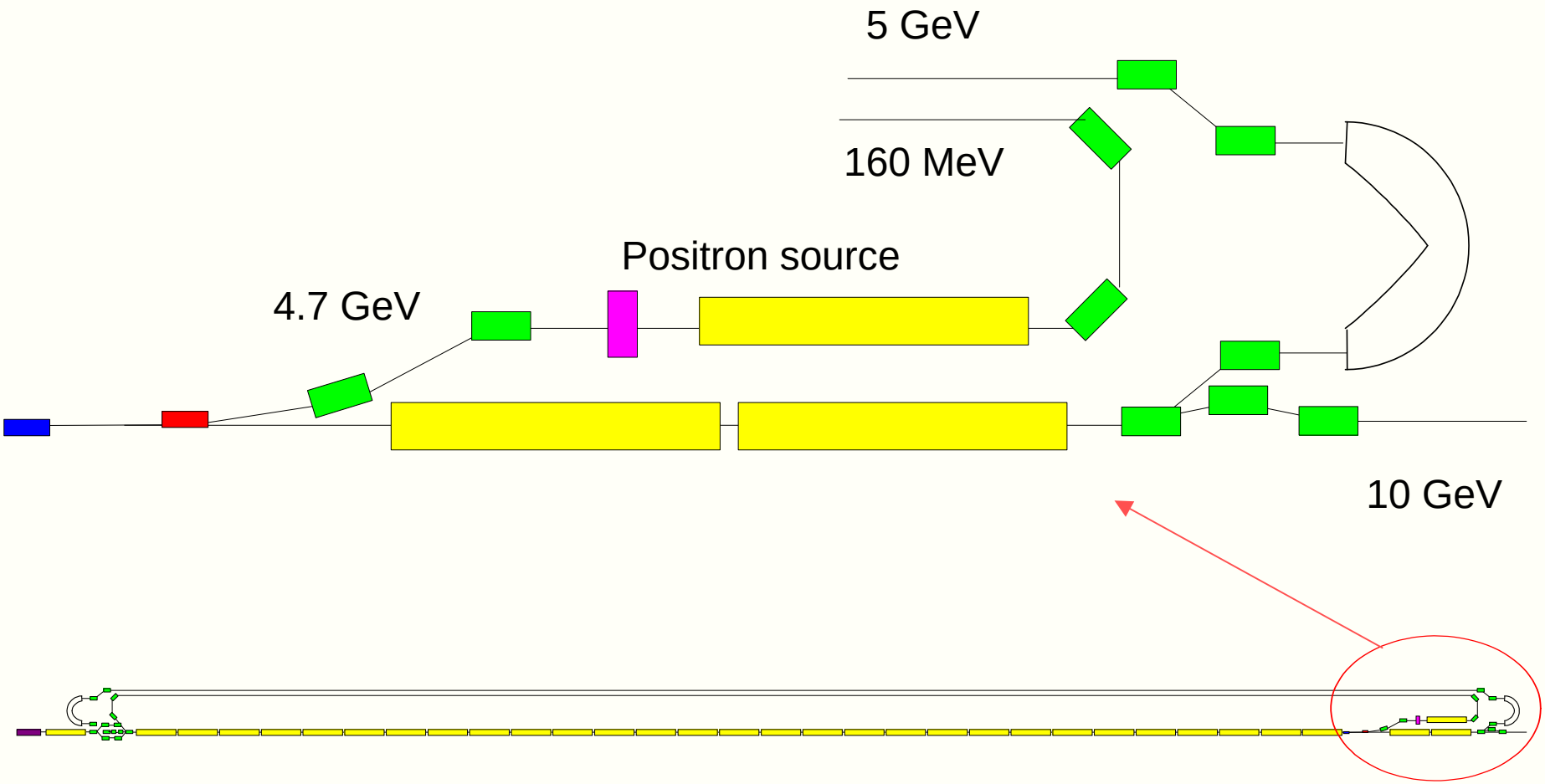
21 MV/m, 8 m ->168 MeV

Injector macropulse timing

Ring fill: >~70% pol., <~ 5 minutes




5 GeV
160 MeV positrons
160 MeV electrons


5 GeV
160 MeV
Positron source
4.7 GeV
10 GeV