LHeC Injection and Beam Dump

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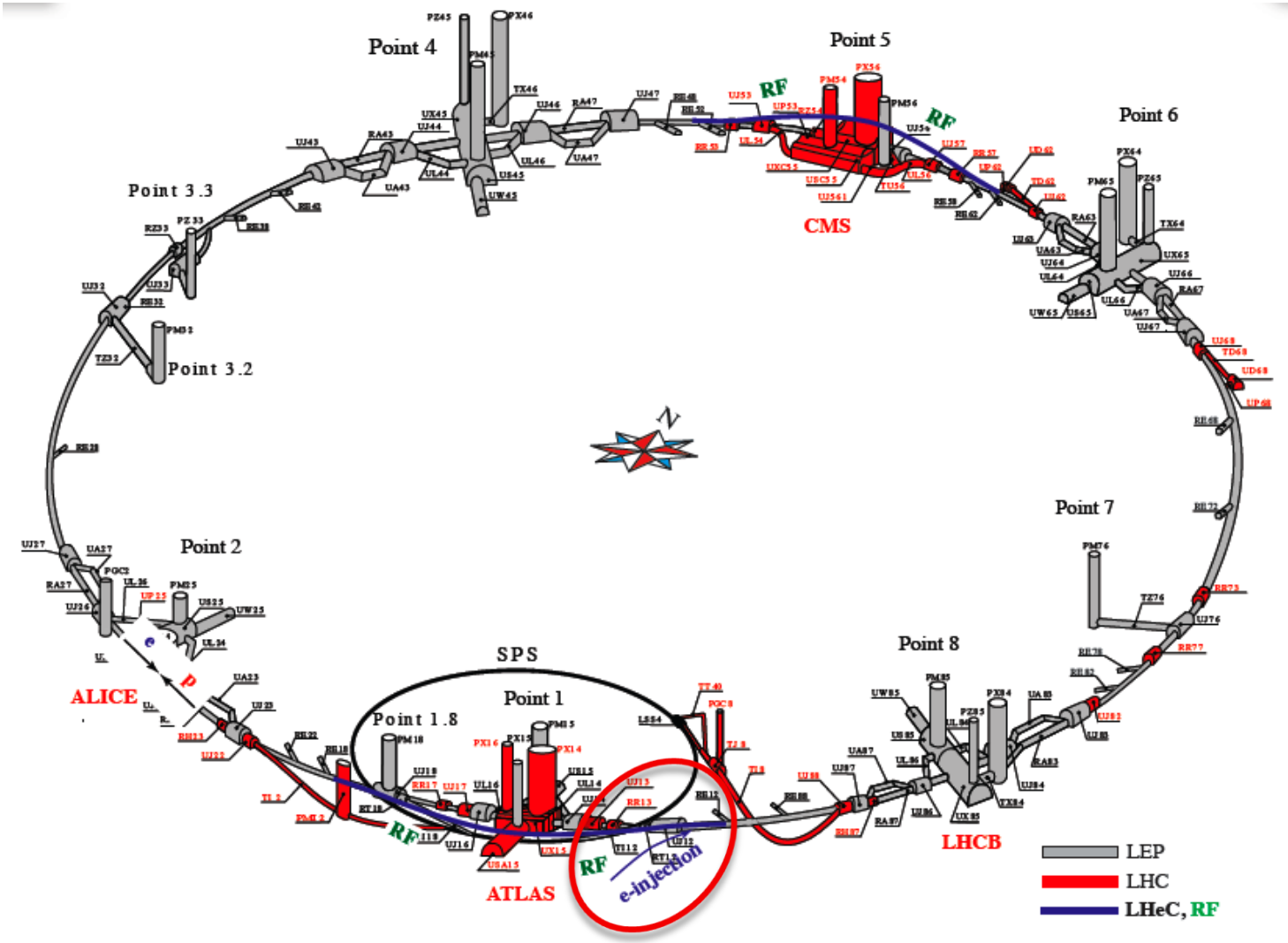
Outlines

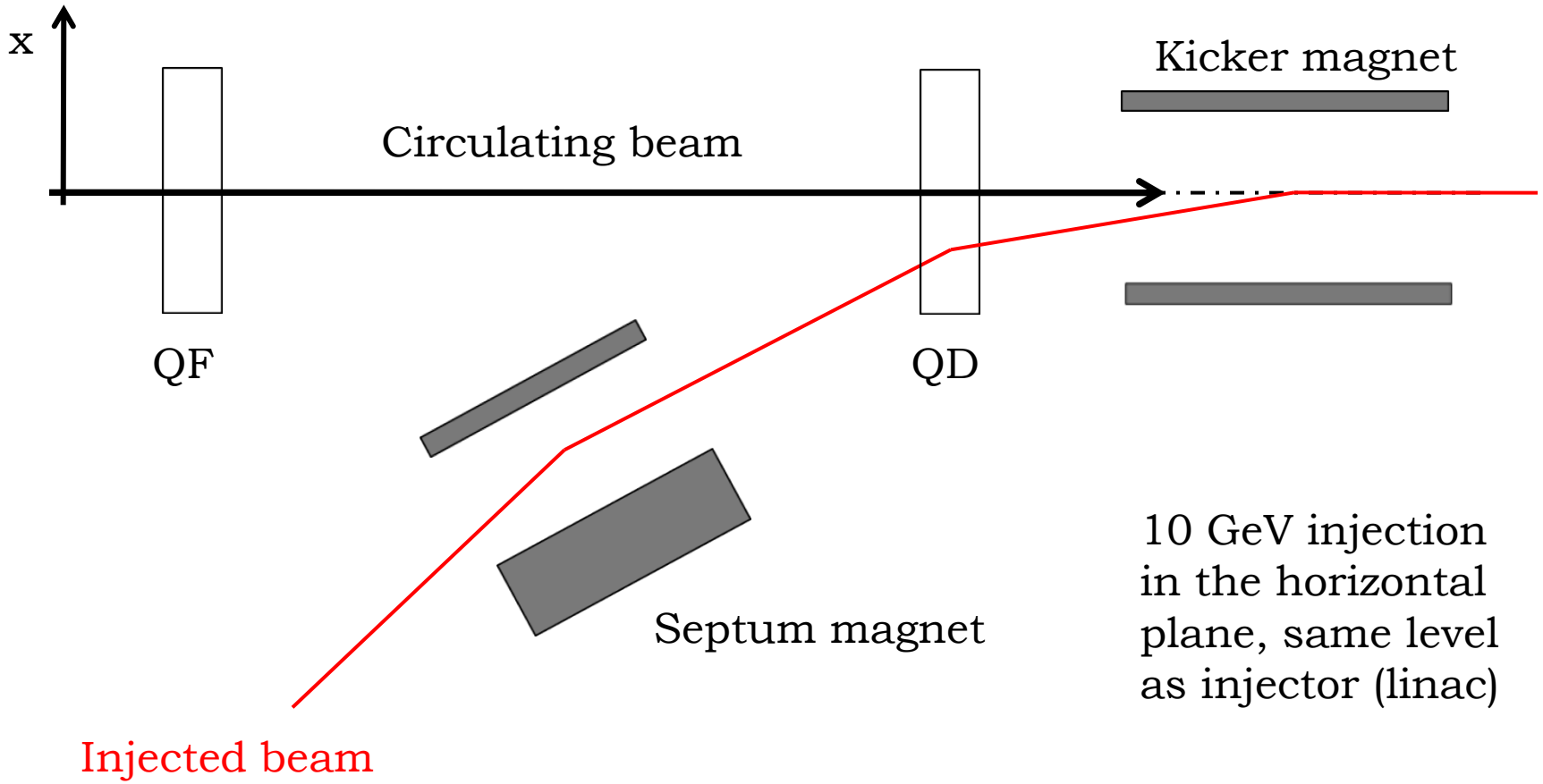
- Ring-Ring option:
  - 10 GeV TL and injection region (optics and magnet parameters)
  - 60 GeV internal dump
- Linac-Ring 140 option:
  - 50 MW dump: possible solutions
  - Dump size
  - Dump window
- Linac-Ring ERL option:
  - Nominal and setup beam dump

Ring-Ring Option

Injection into the Bypass Region

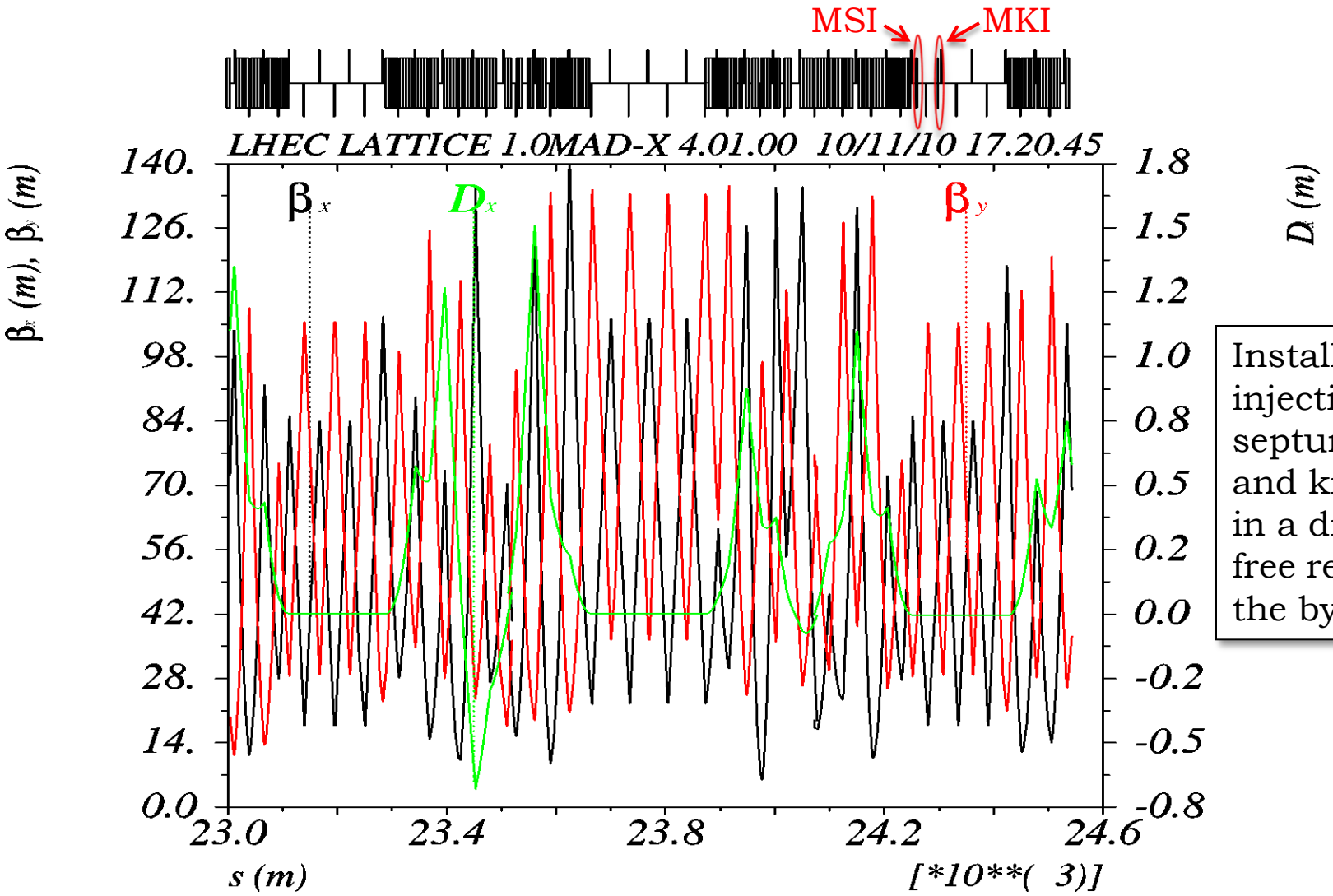


Injection Scheme: Bunch to Bucket



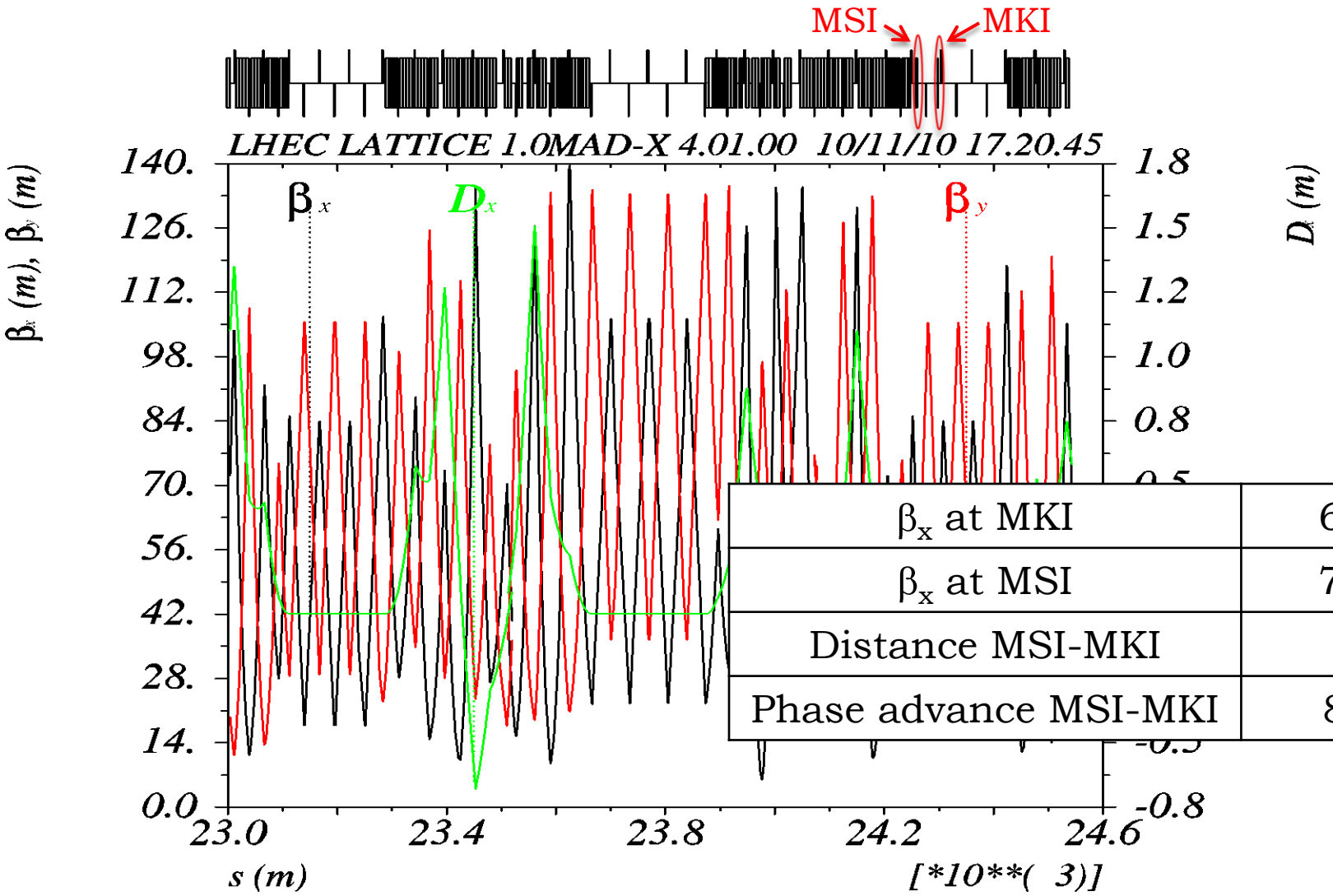
10 GeV injection in the horizontal plane, same level as injector (linac)

Bypass Optics



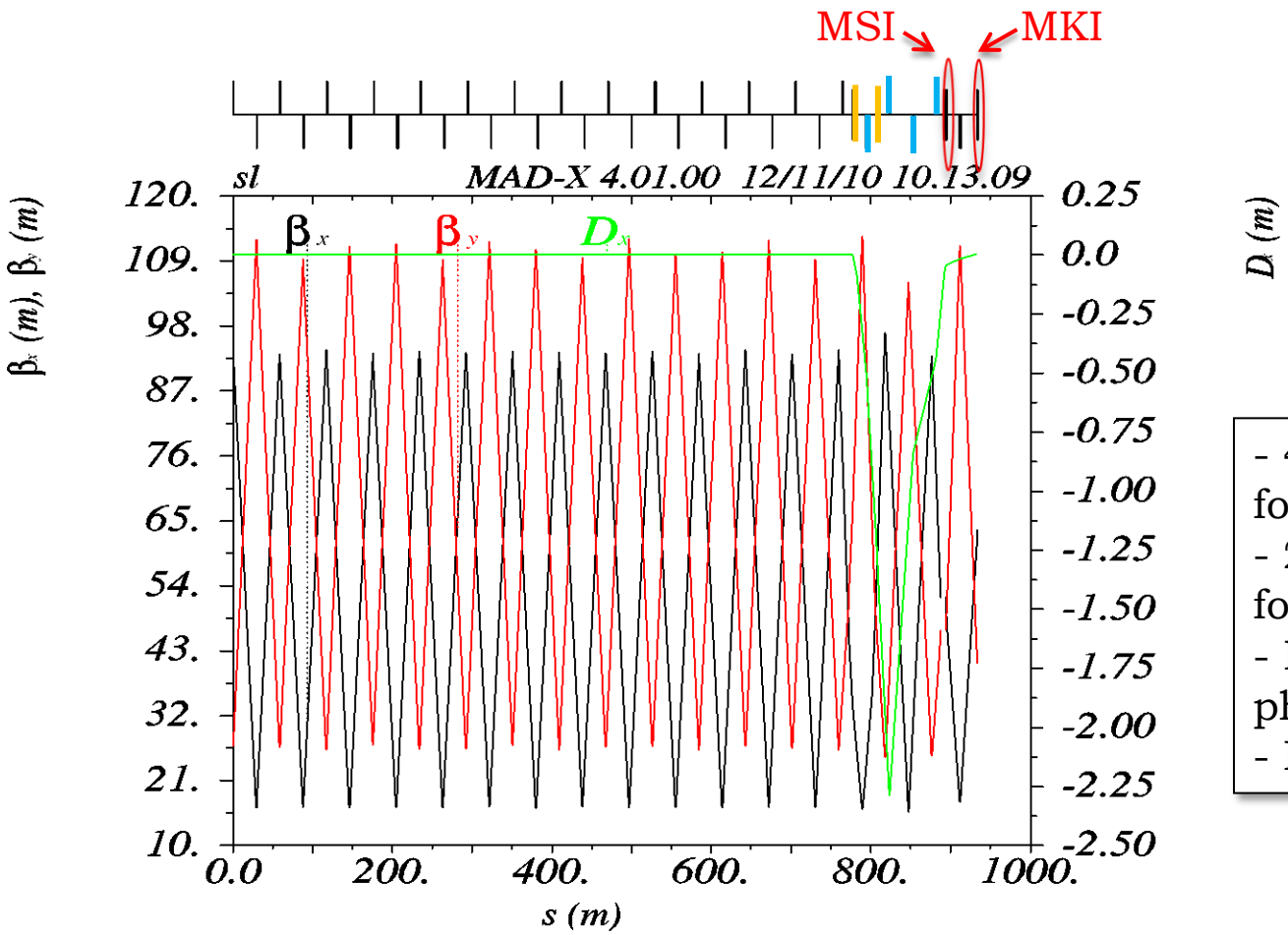
Installed injection septum (MSI) and kicker (MKI) in a dispersion free region of the bypass

Bypass Optics



β_x at MKI	63.4 m
β_x at MSI	71.5 m
Distance MSI-MKI	40 m
Phase advance MSI-MKI	83 deg

TL Optics



- 4 QUADS (1 m long) for matching β_x and β_y
- 2 RBEND (5 m long) for matching D_x
- FODO cell: 97.5 deg phase advance
- Max Dx = -2.3 m

Aperture for Injection Kicker Gap

- Parameters (generous):
  - Emittance: ε_{nx} = 0.58 mm (ε_x= 4.94e-9m), ε_{ny}= 0.29 mm (ε_y =2.47e-9 m)
  - Injection precision: ± 3 mm
  - Orbit ± 4 mm
  - Mechanical/alignment tolerance ± 1 mm
  - Beta function: β_x = 63.4 m, β_y = 38.4 m
  - Number of sigma: 6
  - Injection mismatch (on emittance): 100%

- X_{min} full gap: 40 mm
- Y_{min} full gap: 29 mm

Aperture for Injection Septum Gap

- Parameters (generous):
  - β at kicker and septum: 63.4 m, 71.5 m
  - Phase advance kicker-septum: 83°
  - Septum thickness: 4 mm
  - Orbit: ±4 mm
  - Mechanical tolerances: ±1 mm

- Opening at the septum: 41 mm

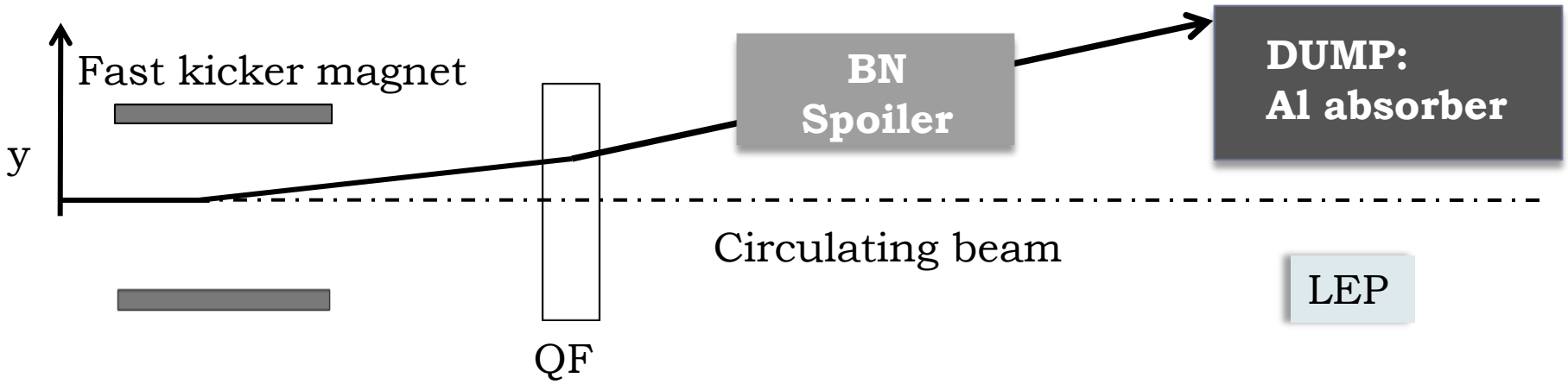
Kickers and Septum Parameters

	Septum	Kicker
Angle [mrad]	34.7	0.86
Field [T]	0.38	0.1
Rise/Fall time [μs]	~1000	0.8
Flat top length [μs]	~1000	10

e- bunch structure matches that of LHC

60 GeV Internal Beam Dump

- Internal dump looks possible

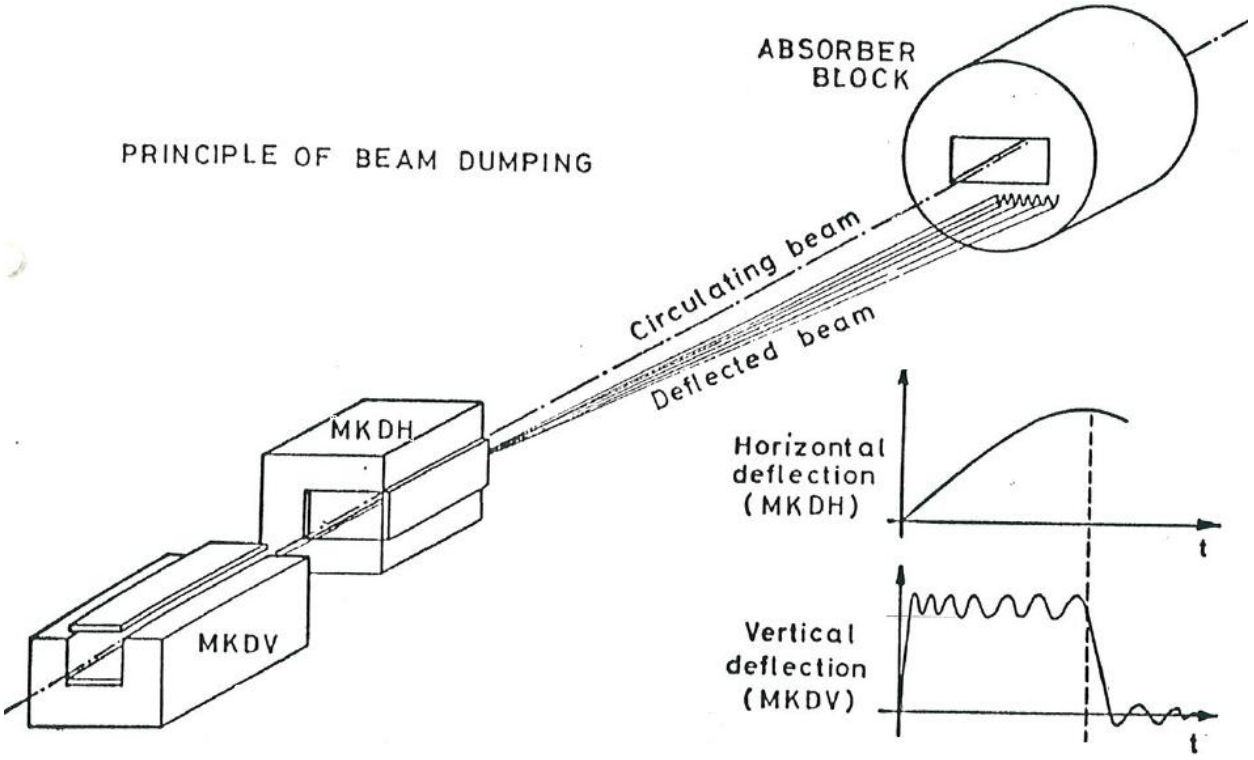


	Kicker
Drift to DUMP [m]	9
Length [m]	3.3
Angle [mrad]	3.8
Field [T]	0.1
Rise/Fall time [ns]	800
Flat top length [us]	90

- Kicker with dump blocks in beam aperture
- LEP dump size: 40×40×210 cm
- Instantaneous temperature rise for Al dump $\Delta t = 165^{o}$ for 8 LEP bunches (8.3×10^{11} e^{-} per bunch) at 100 GeV.

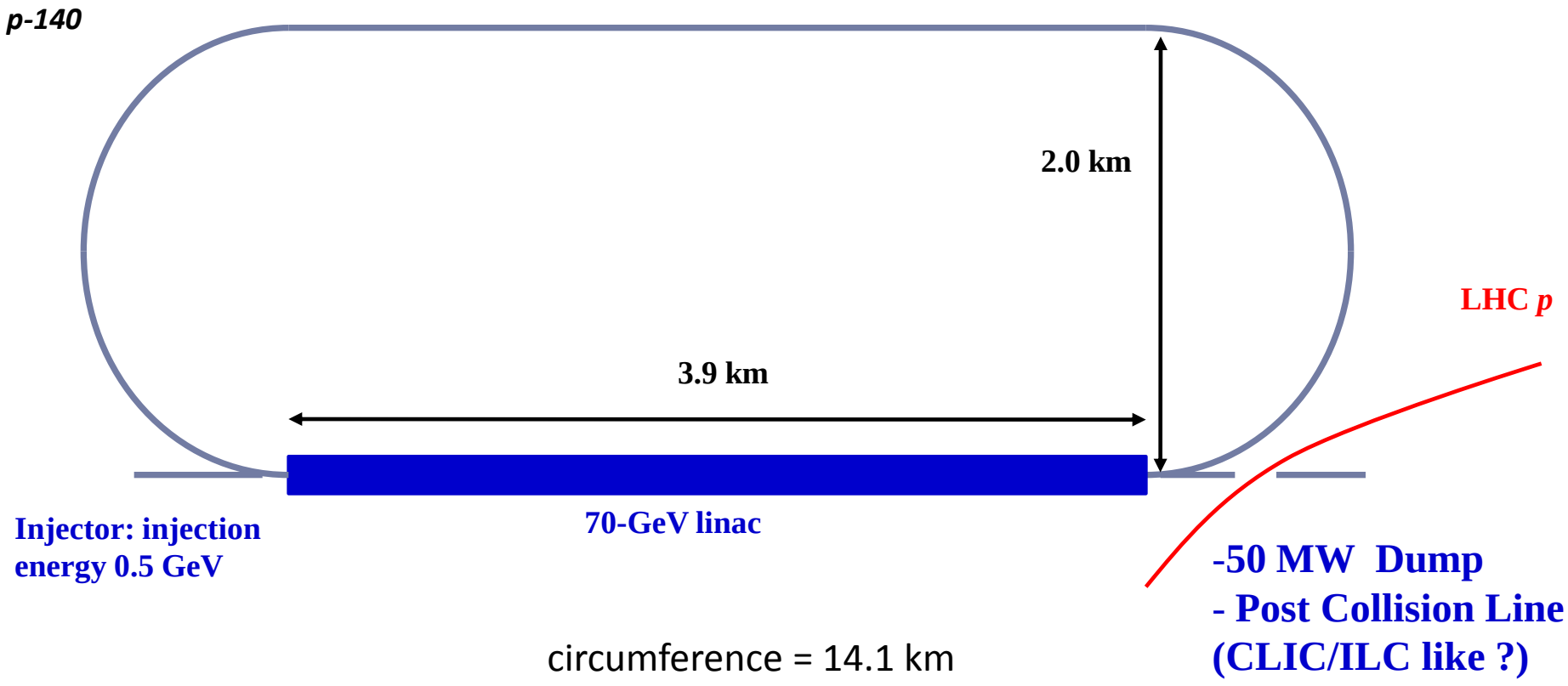
Active dilution

Even with graphite block as spoiler, LHeC will need active dilution (SPS internal dump)



Linac-Ring 140 Option

Linac-Ring: 140 Option



circumference = 14.1 km

50 MW Dump

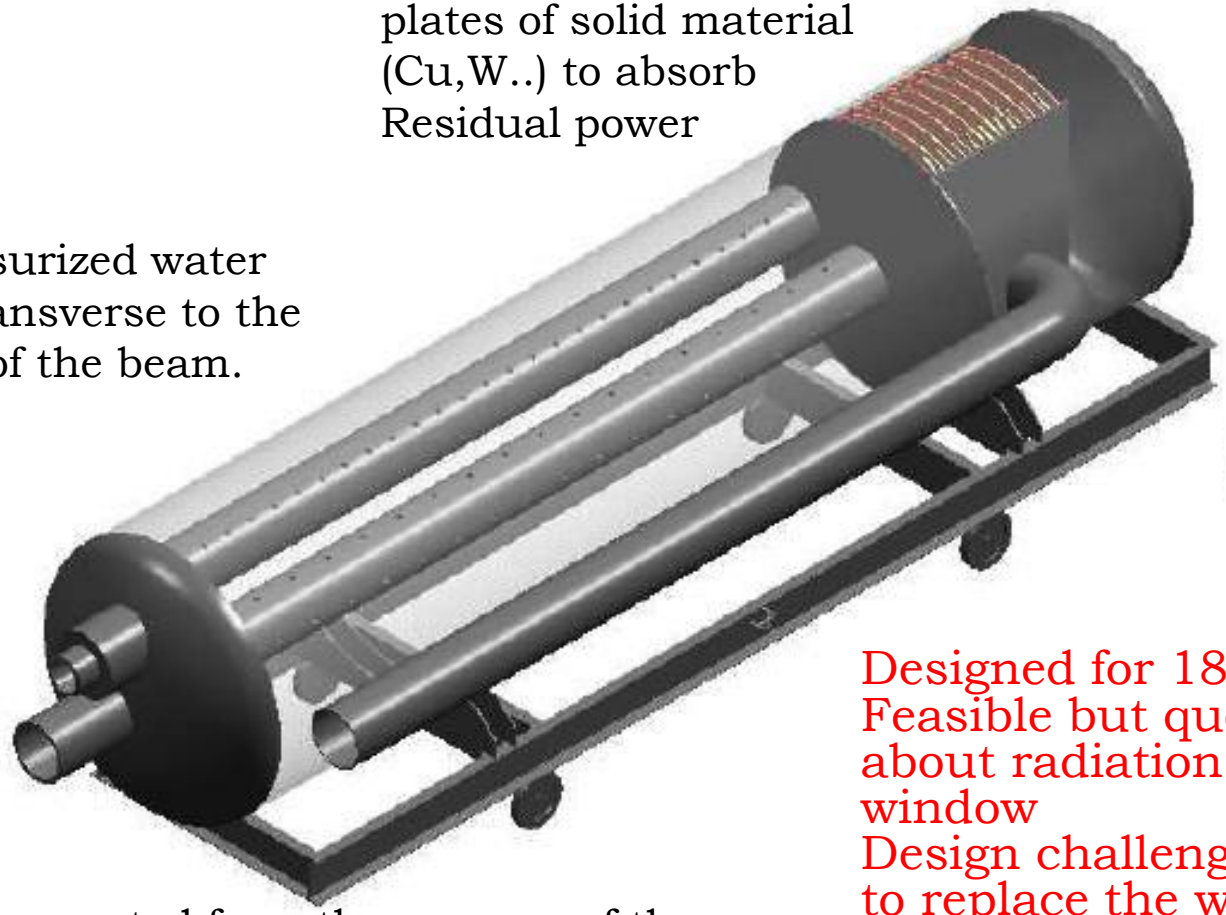
- Scaling from ILC dump – acceptable concept?
- “EcoDump” – power recovery and reuse should be investigate (50 MW = average energy consumption of 69’000 Europeans)
- Radiation issues (tritium production and handling)

Concept of ILC Water Dump

plates of solid material (Cu,W..) to absorb Residual power

Solid material cooled by air natural convection and thermal radiation to ambient + many meters of shielding.

Cold pressurized water flowing transverse to the direction of the beam.



Water is separated from the vacuum of the extraction line by a thin Ti window

Designed for 18 MW!!
Feasible but questions remain about radiation damage to window
Design challenges remain how to replace the window, dump shell and cooling water.

ILC Water Dump

- Volume: 18 cubic meter of water at 10 bar.
- Max ΔT in water: 30^o
- Max T in water: 155^o (boiling temperature 180^o)
- Size (including shielding): 25m longitudinally, 15 m transversely

Ref.I "DESIGN OF AN 18 MW BEAM DUMP FOR 500 GEV ELECTRON/POSITRON BEAMS AT AN ILC*" Walz et al. IPAC 2010
Ref.II "THE INTERNATIONAL LINEAR COLLIDER BEAM DUMPS" R. Appleby et al. 2005 ALCPG & ILC Workshops

LHeC Water Dump

Scaling linearly wrt ILC dump:

- Volume: 36 cubic meter of water
- Max ΔT in water: 90^o
- Max T in water: 215^o → higher pressure needed: ~ 35 bar (to keep 25^o margin from boiling point) .
- Size (including shielding): 36 m longitudinally, 21 m transversely

ILC Dump Window

- The spot size of the undisrupted beam must be sufficiently large to prevent window damage.
  - ILC: Beam size σ_x = 2.42 mm, σ_y = 0.27 mm
  - Extraction line length ➔170 m drift
  - Beam dilution and sweeping ➔ sweep radius: 6 cm

Window:

- Hemispherical shape, 1 mm thick made of a high strength titanium alloy (Ti- 6Al- 4V).
- FLUKA study results: 25 W of beam power with maximum heat source of 21 W/cm^3 deposited on the window ➔ T max. 77°, ΔT max. 9° (minimum ionization particle: dE/dx=2MeV cm^2/g)

LHeC Dump Window

Window:

- Titanium window.
- To have T max. < 100° ➔ $\sigma_{min\ x,y}$ = 1.8 mm
- Beam emitance:
  - Undisrupted beam: $\varepsilon_{x,y}$=0.37E-9 m
  - Disrupted beam: $\varepsilon_{x,y}$=0.74E-9 m
- Minimum β at window: 8877 m
  - LHC dump has ~4 km β, with ~700 m drift.
  - Dilution is needed: strong quads or active kickers for sweep?
- Cooling…?
- FLUKA studies are needed.

LHeC Dump Window

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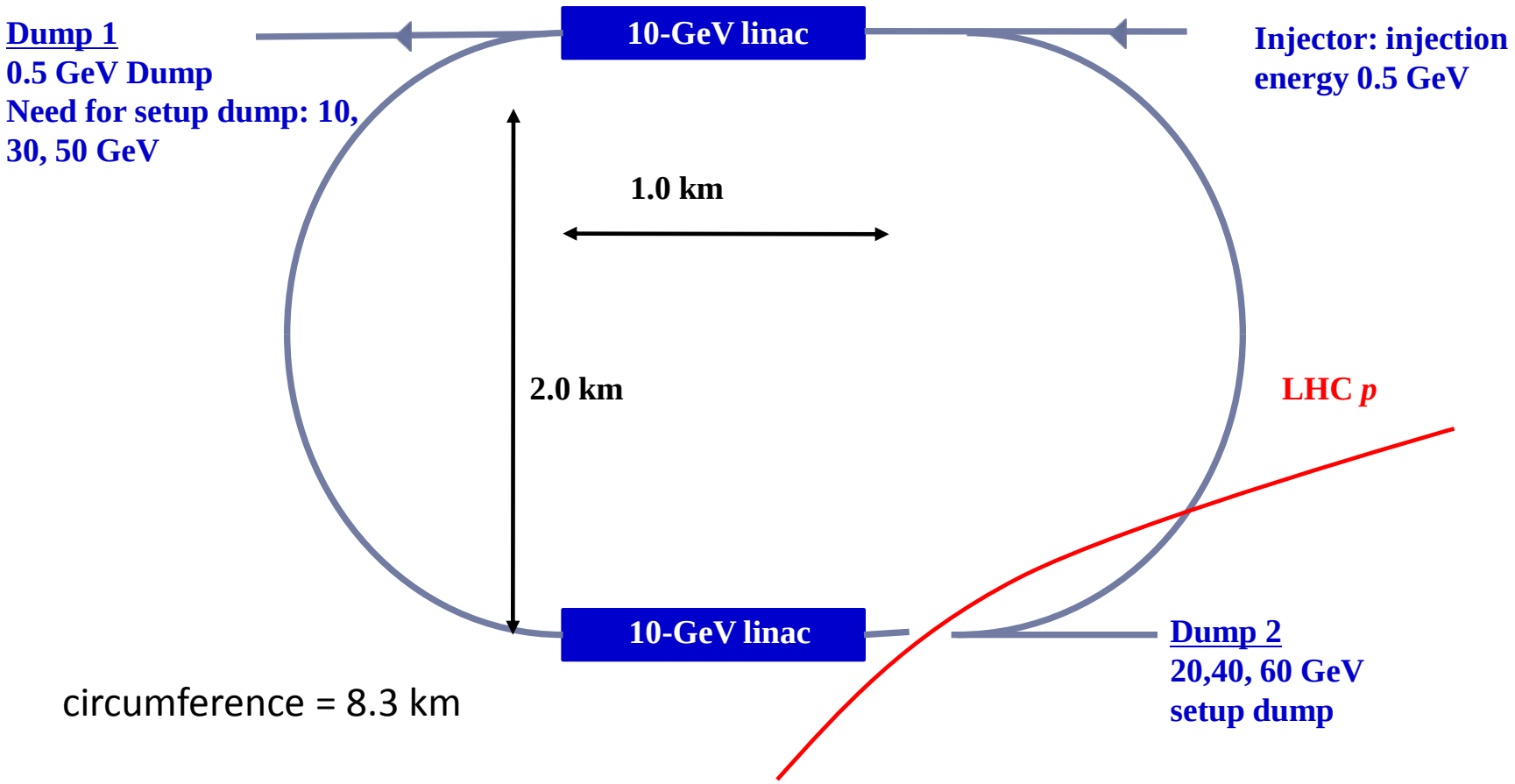
Under Investigation!

Linac-Ring ERL Option

Linac-Ring: ERL Option



Power Requirements

- Maximum e^- current: 0.5 mA

Energy [GeV]	Power [MW]	
0.5	0.25	→ Nominal Operation
10	5	
20	10	
30	15	→ Beam Setup
40	20	
50	**25**	Dump 1
60	**30**	Dump 2

- Lower the current? Problem with diagnostic if current is too low!

Conclusions

- Ring-Ring option:
  - TL and injection region optics have been defined and matched wrt bypass optics (zero dispersion)
  - Aperture and hardware requirements and parameters have been defined
  - 60 GeV internal dump (LEP like) feasible, active dilution is needed.
- Linac-Ring 140 option:
  - 50 MW eco dump possible?
  - ILC type dump and window: preliminary estimate of size and energy deposition have been presented → dilution system required and detailed FLUKA studies are needed
- Linac-Ring ERL option:
  - Nominal dump: no major issues for nominal 0.5 GeV beam dump.
  - Setup dump: similar problem as for 140 GeV option → lower beam current?