MADEIT

MAchine **DE**veloped for **I**nterest in **T**op quarks

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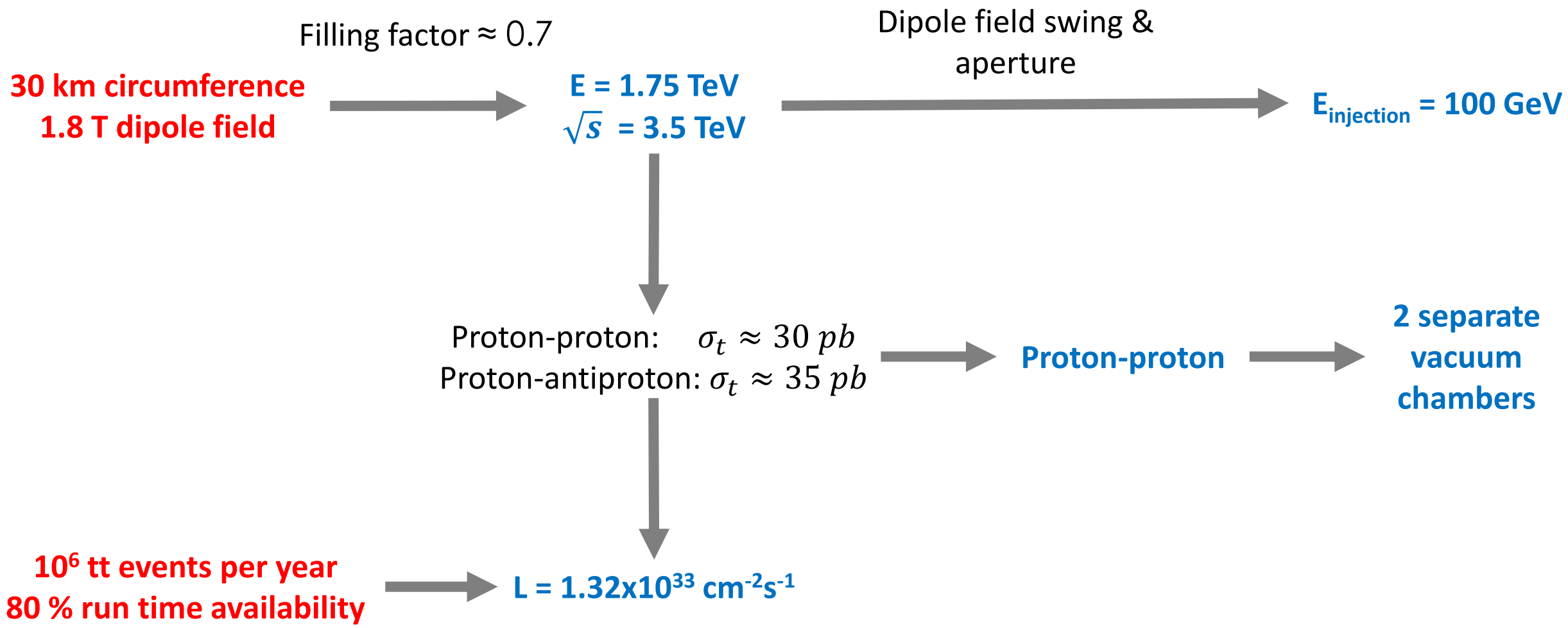
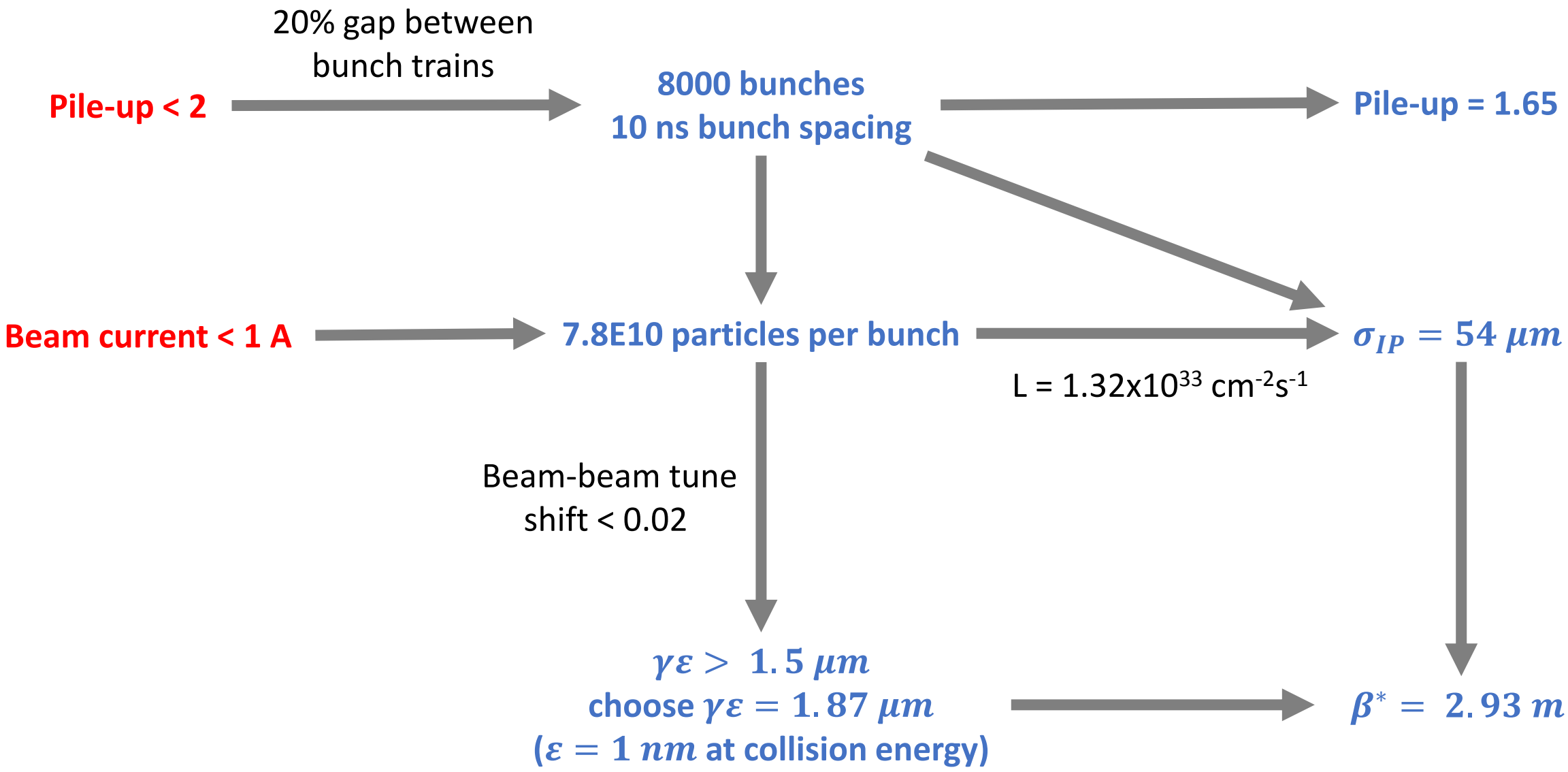
Design task

- Design a top factory yielding 10^6 tops per year.
- Choice of p-p or p-pbar collisions.
- Normal conducting (max. dipole field = 1.8T)
- Max length 30 km
- Pile-up less than 2

Design choices

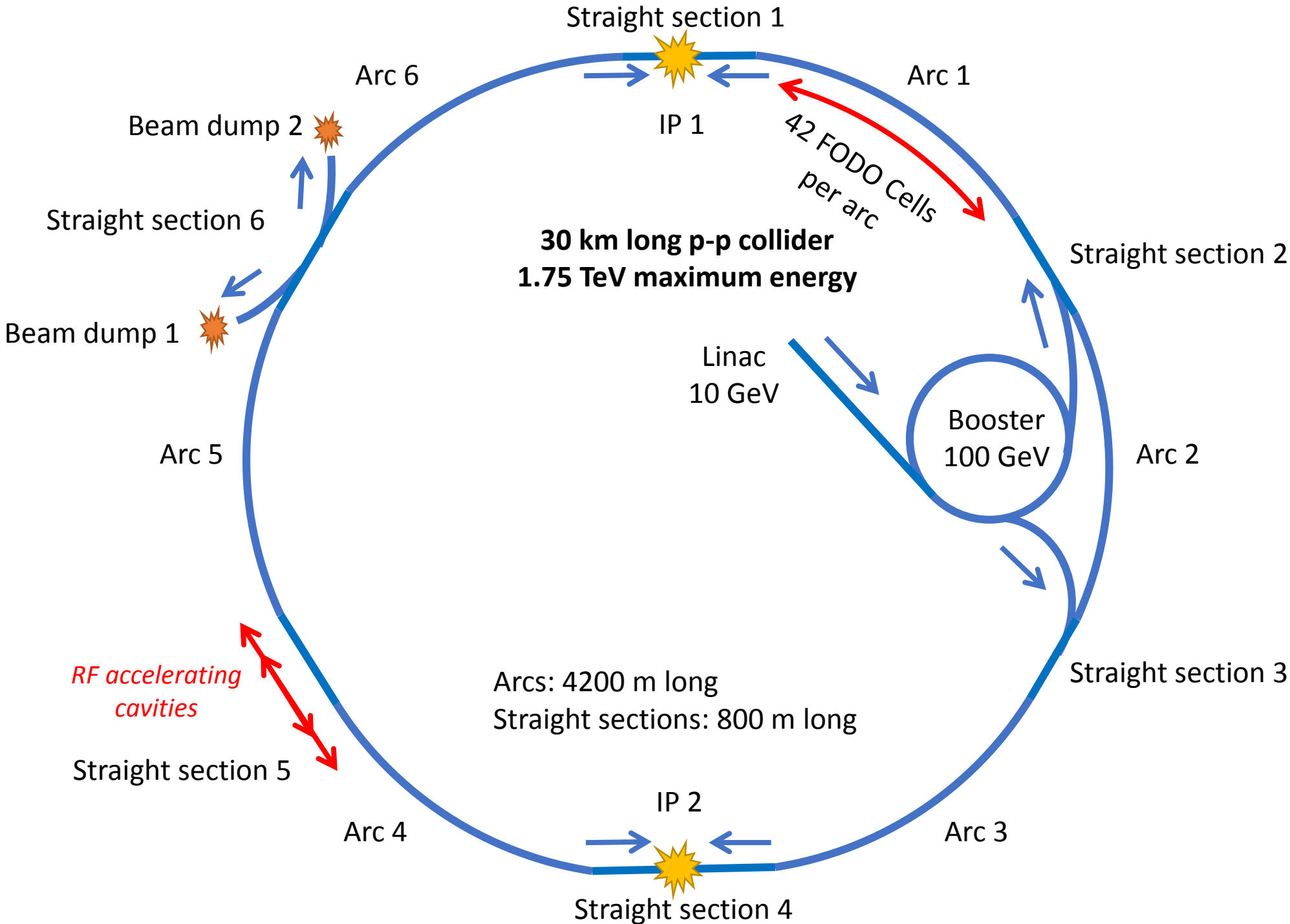


Design choices

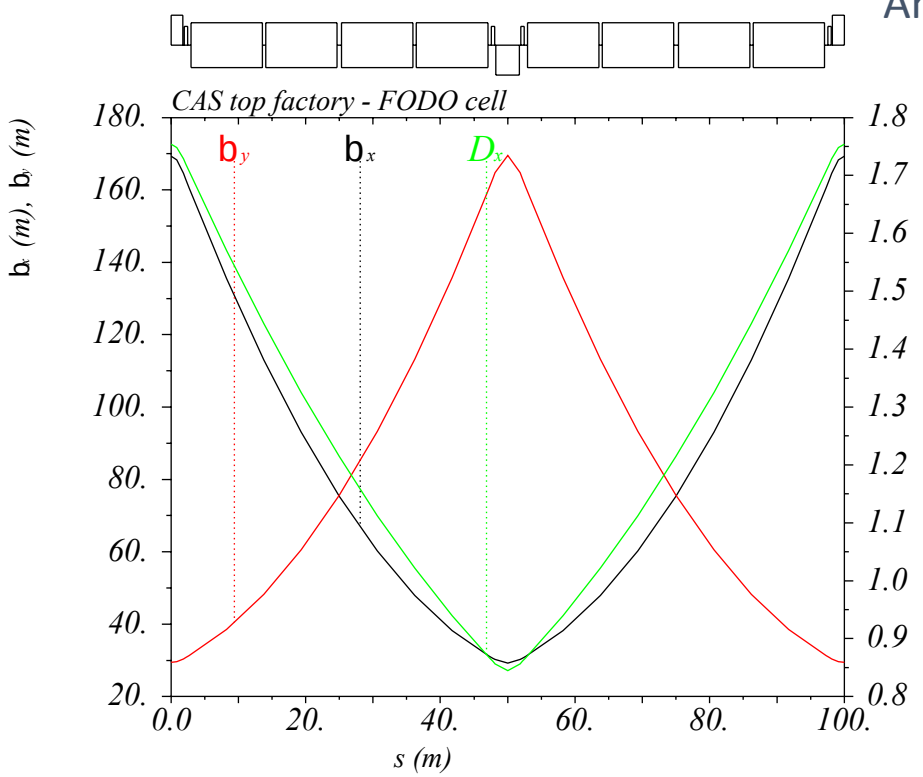


Parameter table

Parameter	LHC	MADEIT
Collision energy per beam	7 TeV	1.75 TeV
Injection energy per beam	450 GeV	100 GeV
Dipole field	8 T	1.8 T
Circumference	27 km	30 km
Number of IPs	2 & 2	2
Beam current	0.58 A	1 A
Bunch intensity	1E11	7.8E10
Bunch spacing	25 ns	10 ns
β^*	0.55 m	2.9 m
Luminosity at each IP	1E34 $cm^{-2}s^{-1}$	1.3E33 $cm^{-2}s^{-1}$
Pile-up	27	1.65
Stored energy per beam	0.36 GJ	0.18 GJ
Normalized emittance	3.75 μm	1.87 μm


Straight section 1
Arc 6
Arc 1
Beam dump 2
IP 1
42 FODO Cells per arc
Straight section 6
30 km long p-p collider
1.75 TeV maximum energy
Straight section 2
Beam dump 1
Linac
10 GeV
Booster
100 GeV
Arc 5
Arc 2
RF accelerating cavities
Straight section 3
Arcs: 4200 m long
Straight sections: 800 m long
Straight section 5
IP 2
Arc 4
Arc 3
Straight section 4

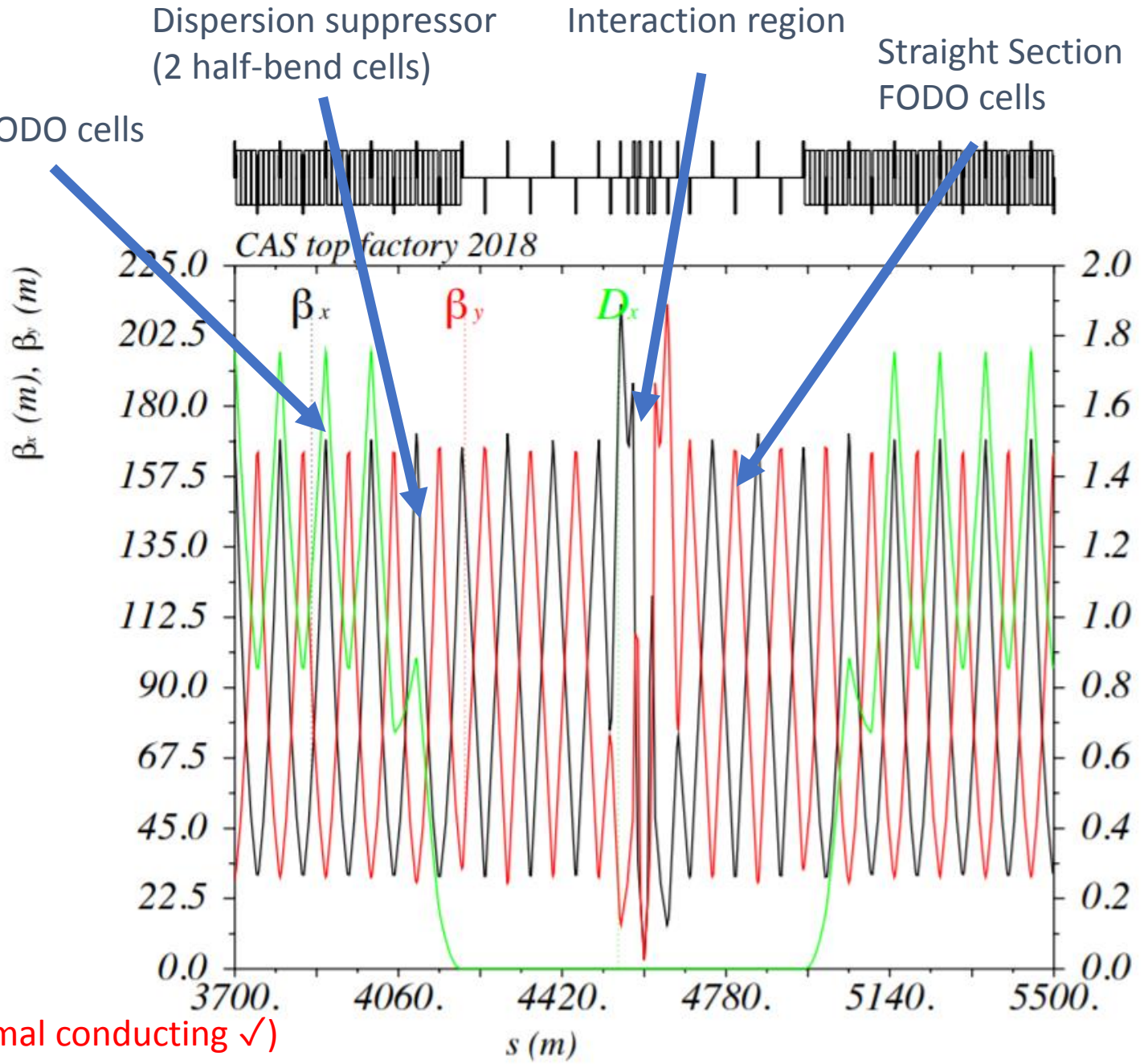
Lattice



- 90° phase advance per cell (both planes)
- L_B = 10.6 m: dipole filling factor: 84.8 %
- L_Q = 3.5 m

$$k_1 = \frac{p}{e}\frac{dB}{dx} = 0.0083\frac{1}{m^2}$$

→ Pole tip field of B = 1.45 T at 3 cm radius (normal conducting ✓)

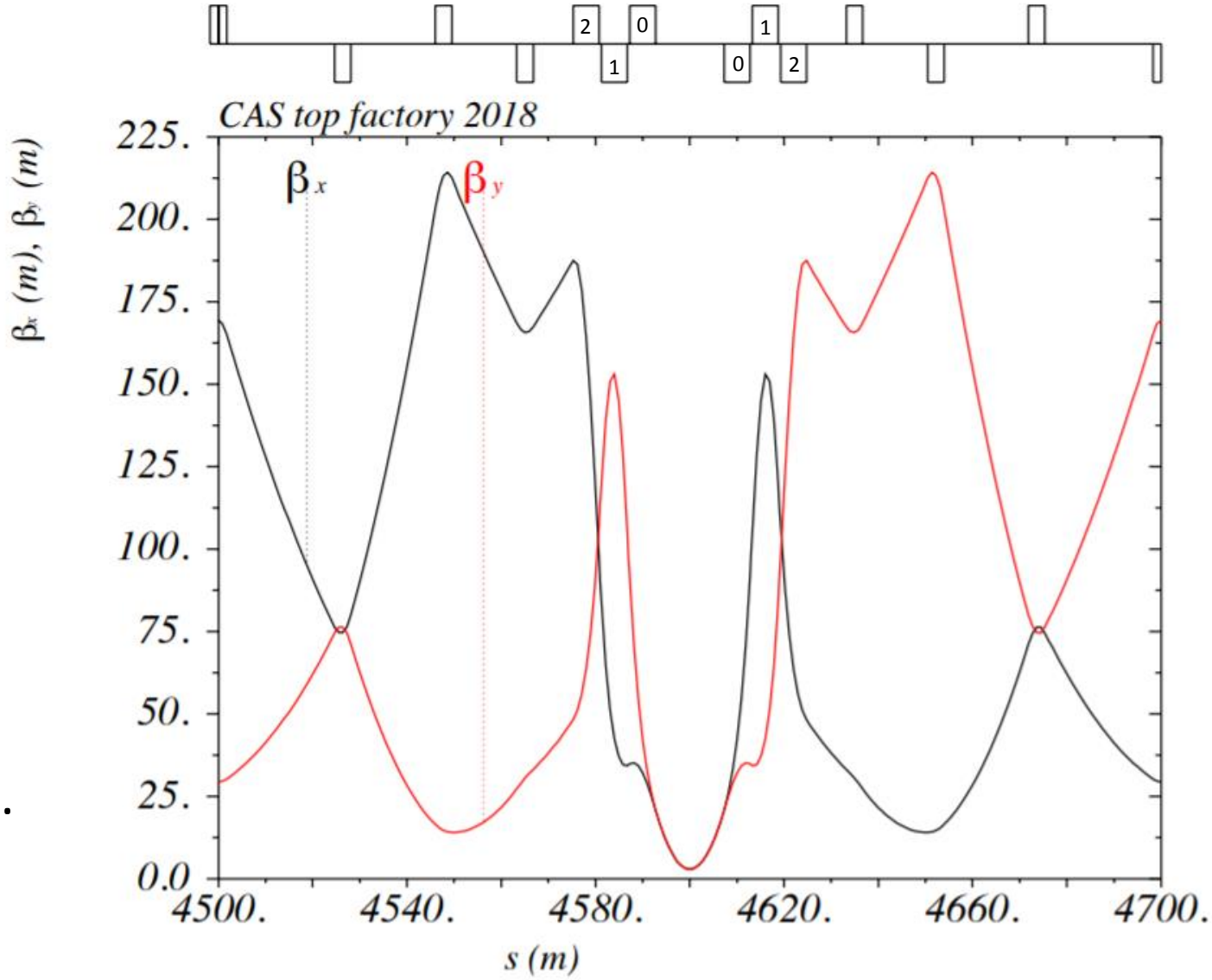


Final Focus

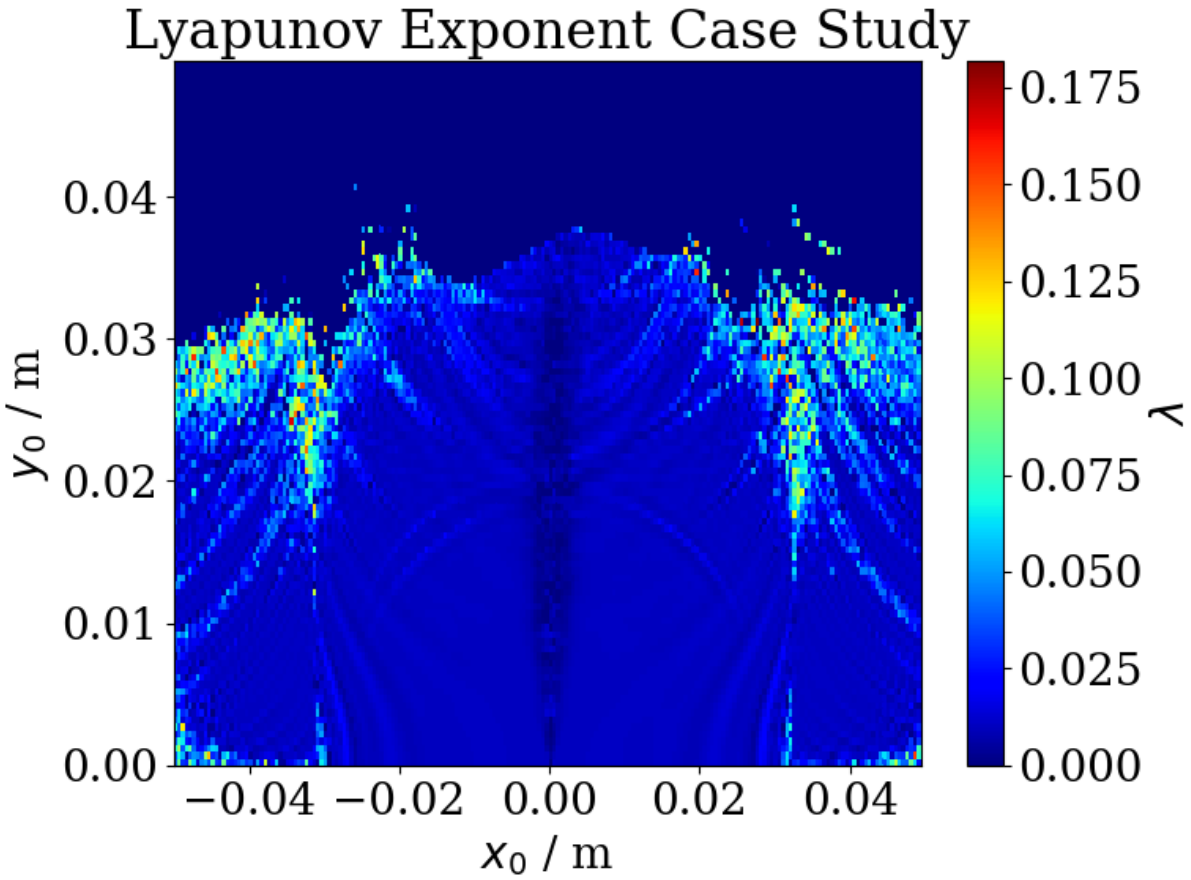
- $\beta^* = 2.93$ m
- $L^* = 10.0$ m

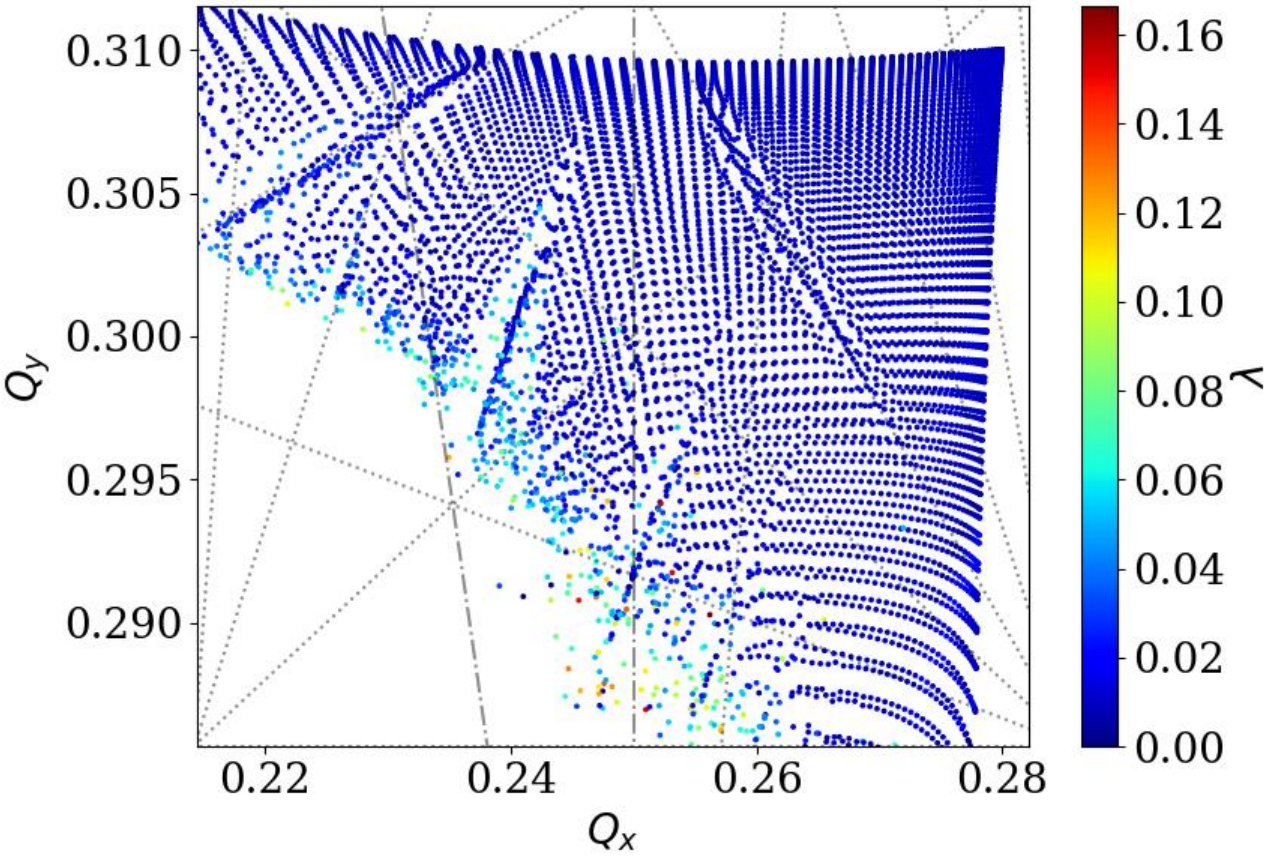
- Point to parallel focusing triplet:
- $k_{qff0} = k_{qff2} = 0.0218 \frac{1}{m^2}$
  $\triangleq 127.28 \frac{\mathrm{T}}{\mathrm{m}}$ @ 1.75 TeV

- $k_{qff1} = -0.0390 \frac{1}{\mathrm{m}^2}$
  $\triangleq -227.43 \frac{\mathrm{T}}{\mathrm{m}}$ @ 1.75 TeV
- Superconducting final focus quads.



Dynamic aperture estimate (no field errors etc.)





Injector Chain

10 GeV H^- Linac

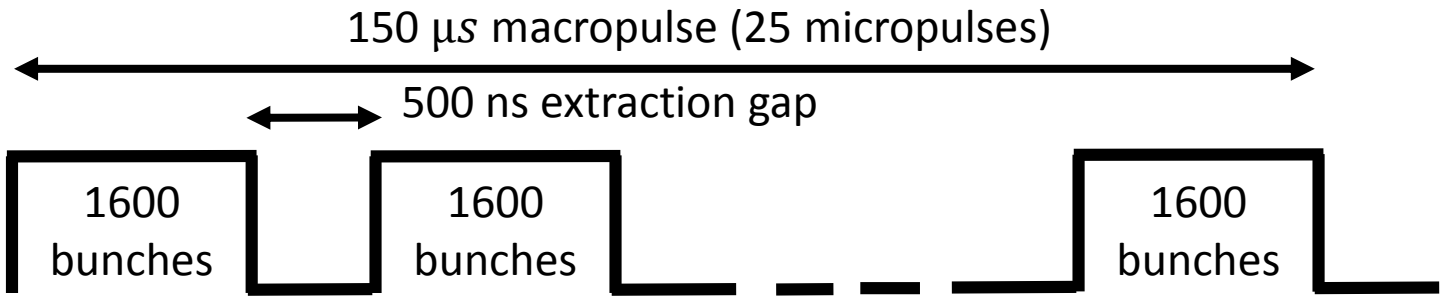
Parameter	Value
E_{max}	10.0 GeV
Normalised emittance	1.8 μm
Max. gradient	30 MV/m
Length	800 m
Bunch intensity	1E9
Bunch frequency	400 MHz
Pulse length	150 μs

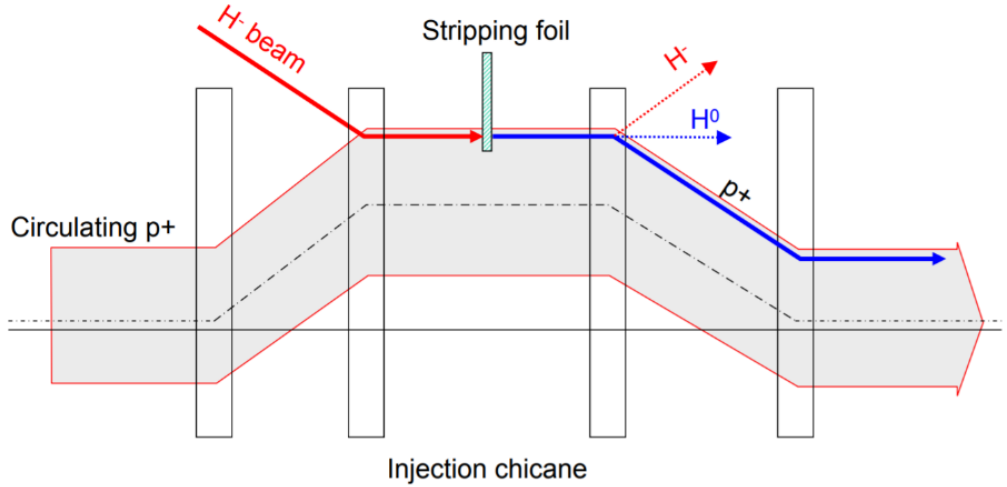
100 GeV Booster

Parameter	Value
E_{max}	100 GeV
Circumference	1800 m
Bunch intensity	1E11
No. bunches	400
Harmonic number	600
RF Frequency	100 MHz

- 4 linac bunches combined longitudinally into 1 booster bunch
- Booster ring filled over 25 turns in 1 linac pulse.
- 20 booster cycles to fill collider ring (8000 bunches)
- Ensure bunch length small enough to fit in 400 MHz RF in collider ring – harmonic cavities?

Bunch structure from linac:





Collective effects

Beam-beam tune shift $= -\frac{r_0 N}{4\varepsilon_n}$

$dQ_{bb} = -0.016$
acceptable to avoid major resonances

Space charge tune shift $= \frac{dQ_{bb}}{2\gamma^2}$

Negligible

Resistive-wall instability:

$$N_{turns} = \frac{8\sqrt{\pi} m_0 \gamma Q c}{e^2 NM * Re\{Z_{y,eff}\}}$$

$$Re\{Z_{y,eff}\} = -\frac{Cc}{\pi b^3}\sqrt{\frac{\mu_0 \rho}{2\omega}}$$

$$\omega = \left(1 - Q_{frac}\right) * 2\pi f_{rev}$$

300 turns growth rate at injection – manageable by feedback