FUTURE CIRCULAR COLLIDER

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POWER CONVERTERS R&D - POWERING OF MAGNET CONCEPT & REQUIREMENTS

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M. Parodi, CERN Electrical Group
J.-P. Burnet, CERN

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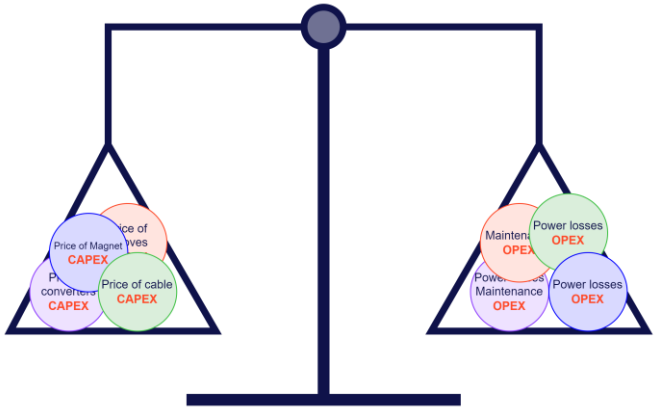
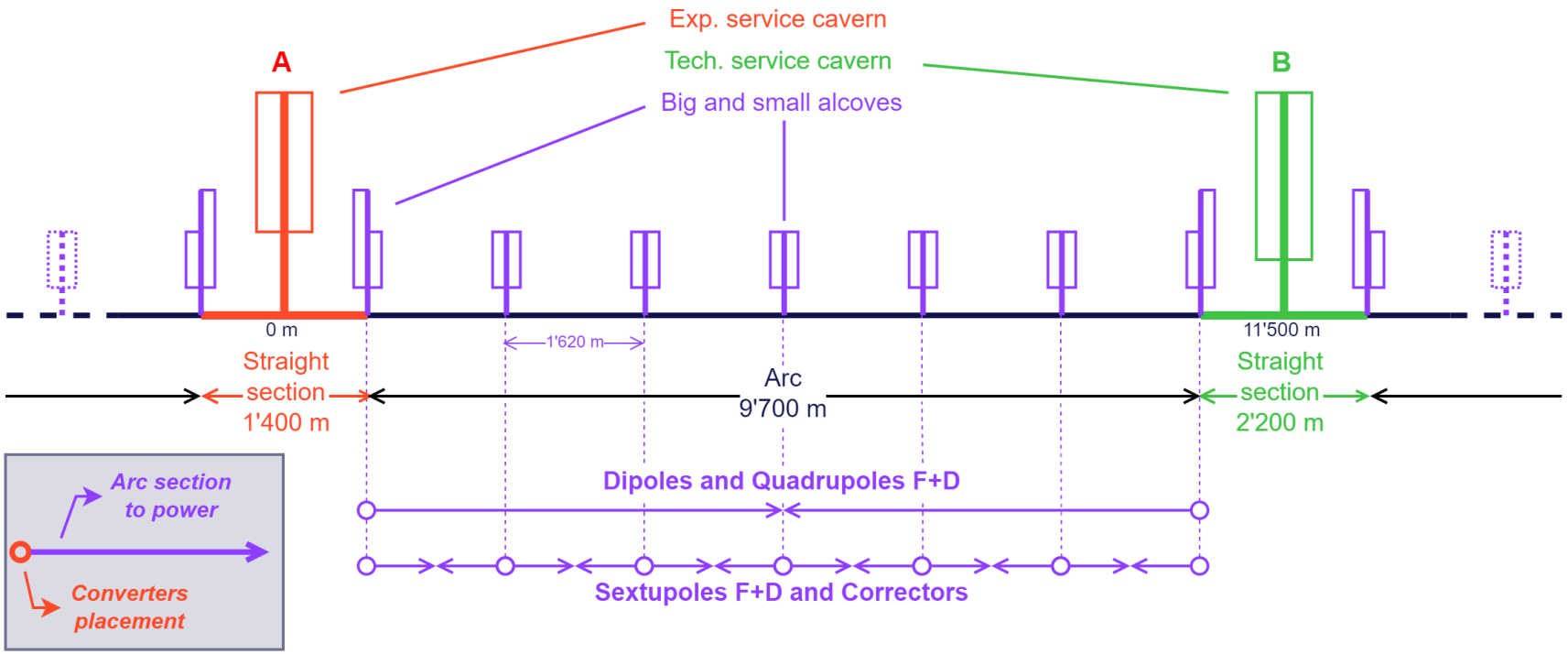
Introduction

What it takes to power a magnet



General layout of an arc section



Example - Collider Sextupole

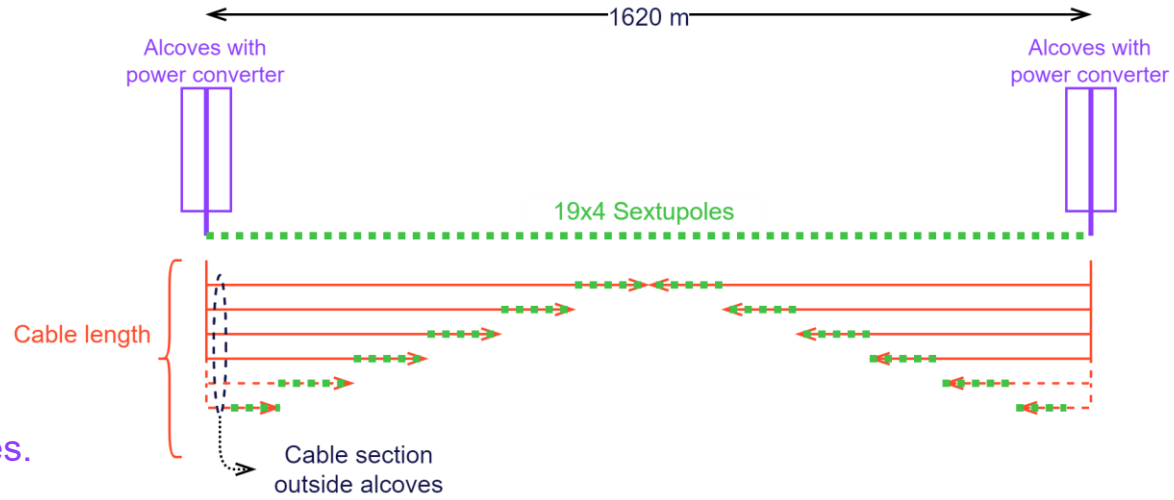
7 alcoves each ~1620 m apart

7120 Sextupoles are powered by all alcoves in groups of 4.

One side of alcoves cover ~810 m
→12x 810 m per arc

7120/4 = 1780 circuits

One side of the alcove cover
~810 m of ~19 circuit of 4 sextupoles.



$$L_{cables,alcoves} = 2x \sum_{i=1}^{19} i * \frac{810}{19} = 16.2\ km$$

$$L_{cables,tot} = 16.2 * 8 * 12 = 1'555\ km$$

Example - Collider Sextupole

7 alcoves each ~1620 m

7120 Sextupoles are powered by all alcoves in groups of 4.

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→12x 810 m per arc

7120/4 = 1780 circuits

One side of the alcove cover ~810 m of ~19 circuit of 4 sextupoles.

Sextupoles cable needs to carry 330 A

- at 0.8 A/mm2
  - 19x2 x 400 mm2
  - 165.2 kW per alcoves
    → 7.93 MW total

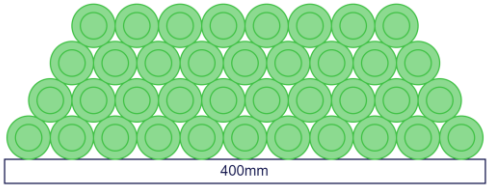
÷3.3

- at 2.8 A/mm2

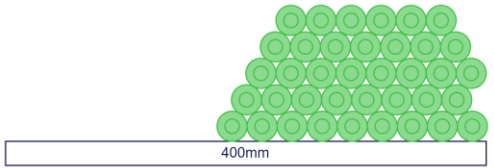
x3.3

  - 19x2 x 120 mm2
  - 550.6 kW per alcoves
    → 26.43 MW total

Collider Sextupoles
(2x19)x400mm^2
330A@ 0.8 A/mm^2
1591km
7.93MW



Collider Sextupoles
(2x19)x120mm^2
330A@ 2.8 A/mm^2
1591km
26.43MW



$$L_{cables,alcoves} = 2x \sum_{i=1}^{19} i * \frac{810}{19} = 16.2\ km$$

$$L_{cables,tot} = 16.2 * 8 * 12 = 1'555\ km$$

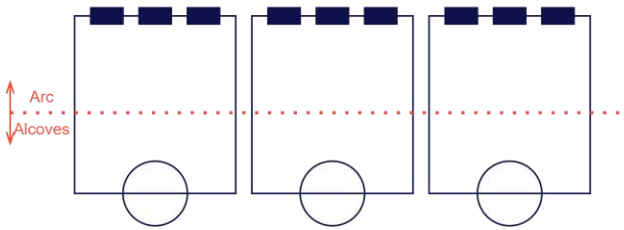
CAPEX –
OPEX +

Example - Collider Sextupole

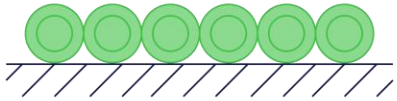
Other powering solution depending on controllability

Controllability : -100% to +100%

Polarity of group can be reversed during run



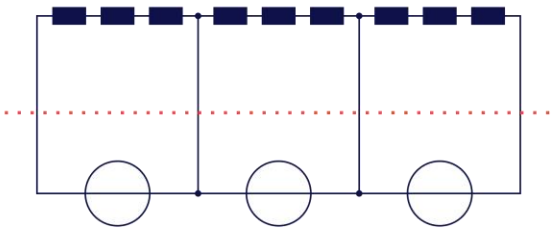
$N_{cable} = 2N_{circ}$



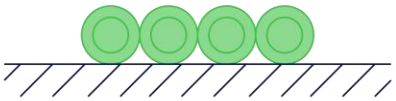
Power converters are too big to be put in the arcs.

Controllability : 0% to +100%

Polarity of group not reversed during run



$N_{cable} = N_{circ} + 1$



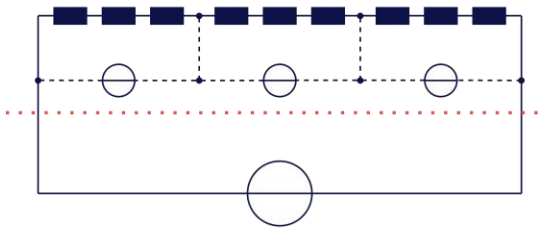
Close to half the space by using cable sharing.

CAPEX –

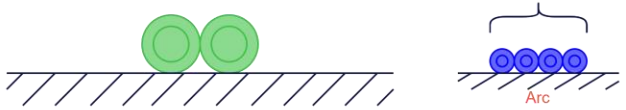
OPEX –

Controllability : 0% to +10%

Polarity of group not reversed during run
+ lower change percentage



$N_{cable} = 2$ $+(N_{circ} + 1)$



Only one converter in the alcoves.

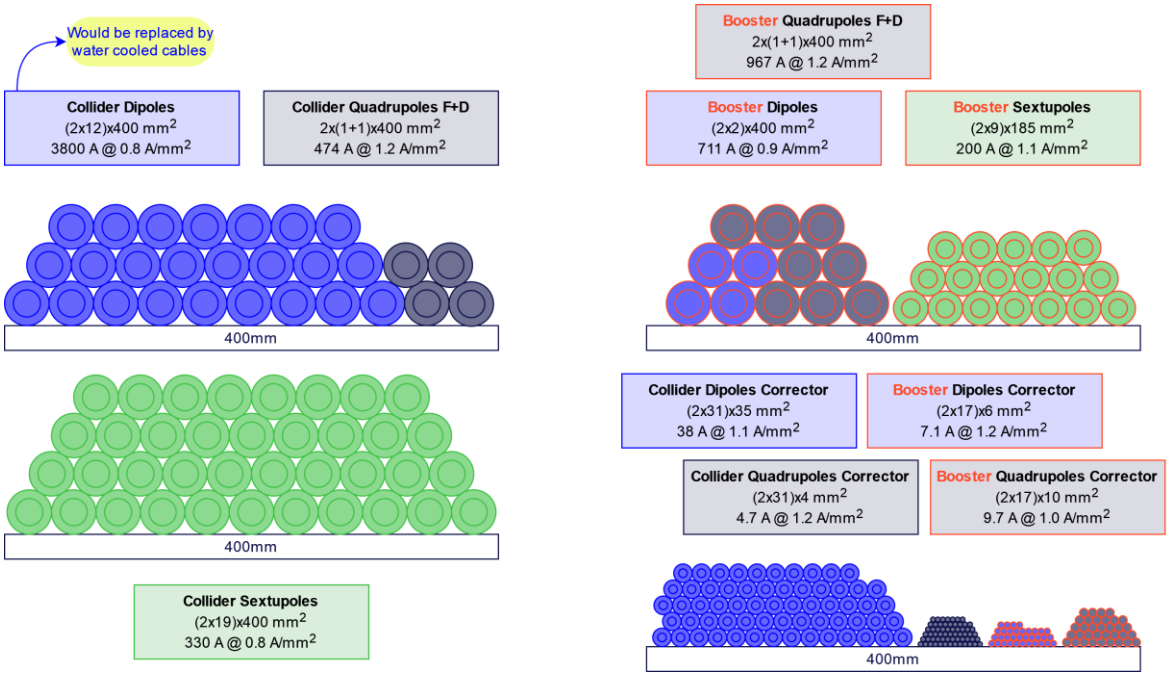
The trimmers + cabling in the arc section, closest to magnets

CAPEX – – –

OPEX – – –

Example - Global Optimisation

If we do the same exercise for the other magnet @ ~1 A/mm2

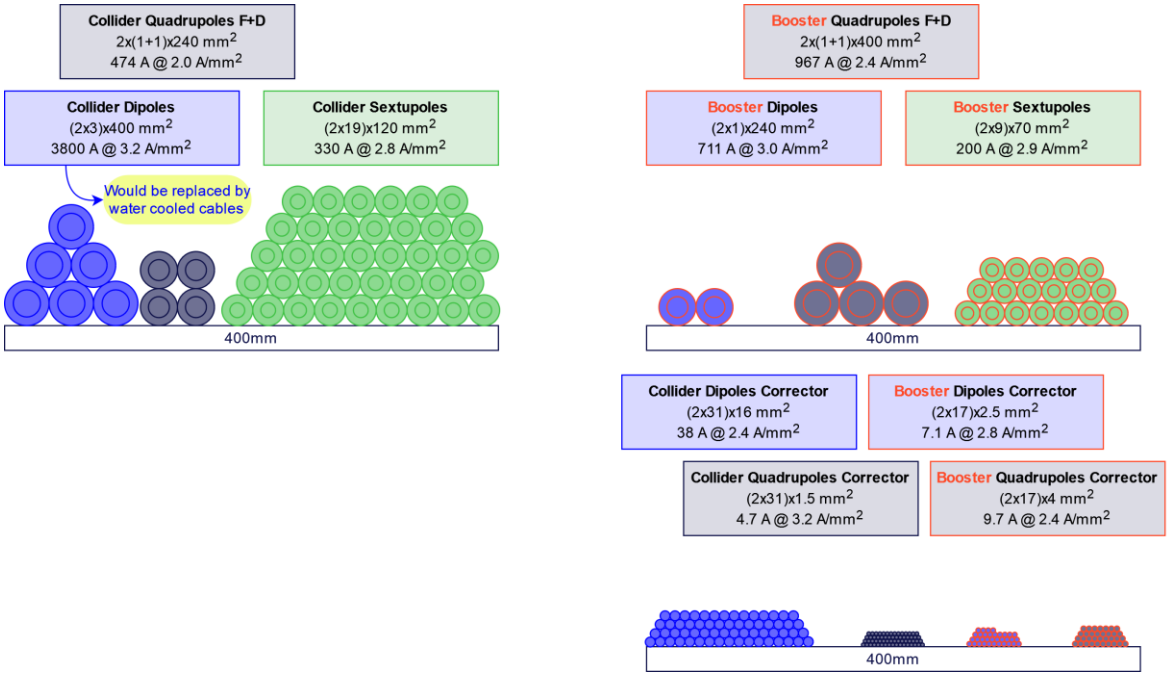


Collider Dipoles	45.3 km	2.49 MW
Collider Quadrupoles F+D	232.5 km	2.39 MW
Collider Sextupoles	1591 km	7.93 MW
Booster Dipoles	48 km	0.26 MW
Booster Quadrupoles F+D	237.2 km	5.07 MW
Booster Sextupoles	796 km	3.15 MW
Collider Dipoles Corrector	2529 km	1.91 MW
Collider Quadrupoles Corrector	2529 km	0.26 MW
Booster Dipoles Corrector	1423 km	0.22 MW
Booster Quadrupoles Corrector	1423 km	0.22 MW

1A/mm^2 : Total cable power losses : 23.9 MW

Example - Global Optimisation

If we do the same exercise for the other magnet @ ~3 A/mm2



Collider Dipoles	45.3 km	9.98 MW
Collider Quadrupoles F+D	232.5 km	3.98 MW
Collider Sextupoles	1591 km	26.43 MW
Booster Dipoles	48 km	0.85 MW
Booster Quadrupoles F+D	237.2 km	10.14 MW
Booster Sextupoles	796 km	8.32 MW
Collider Dipoles Corrector	2529 km	4.18 MW
Collider Quadrupoles Corrector	2529 km	0.69 MW
Booster Dipoles Corrector	1423 km	0.53 MW
Booster Quadrupoles Corrector	1423 km	0.61 MW

~~1A/mm² : Total cable power losses : 23.9 MW~~ → ~3A/mm² : Total cable power losses : 65.7 MW

CAPEX –

OPEX +

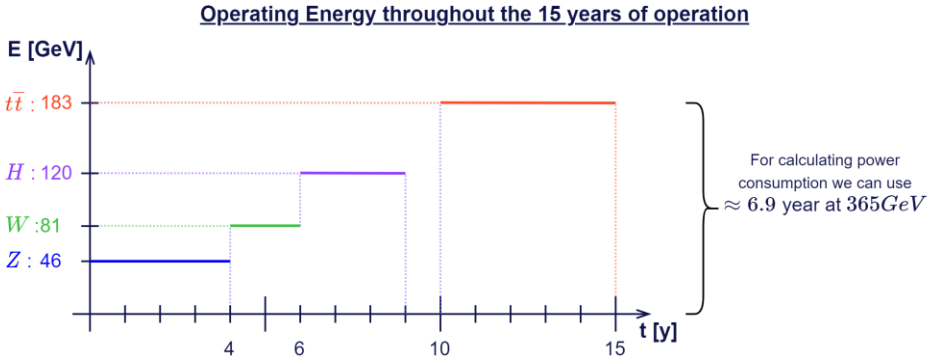
Example - Global Optimisation

To calculate operational cost;

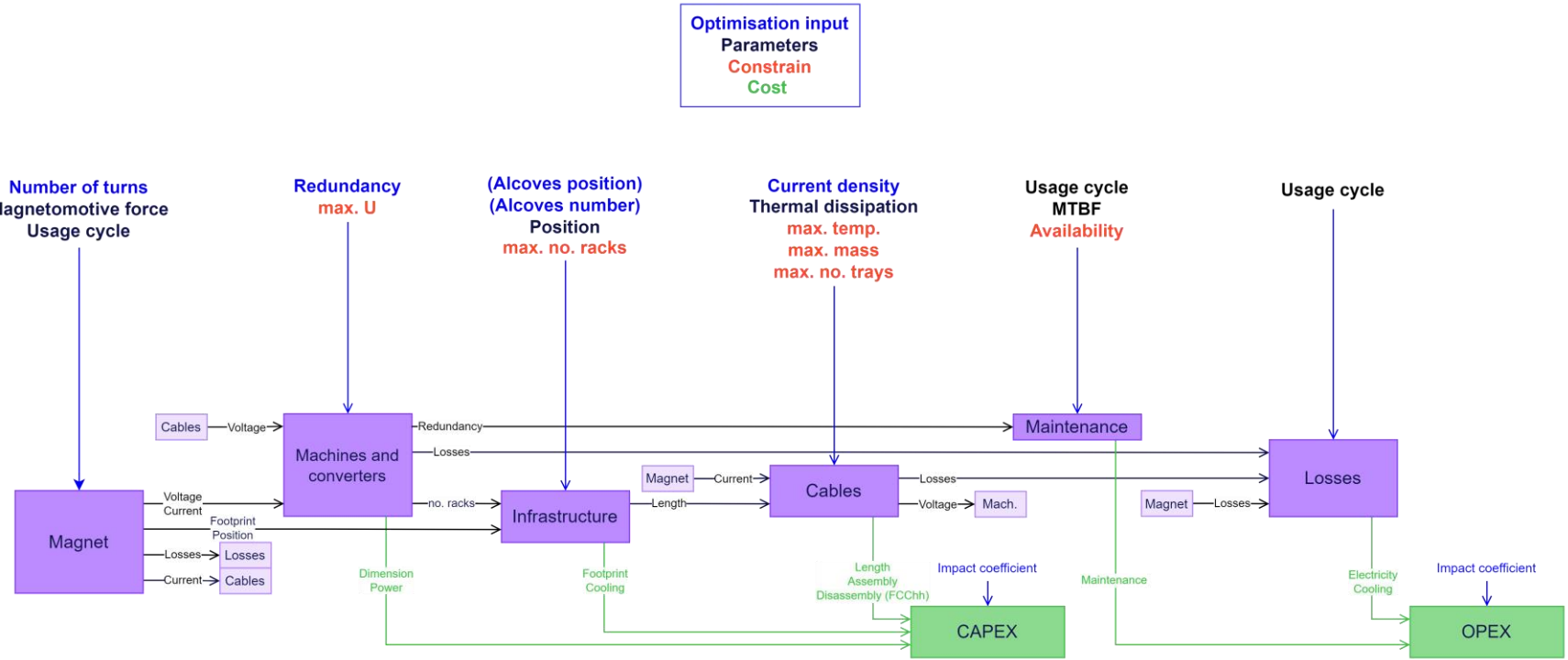
We need to take into account the effective operation energy level throughout the 15 years of operation.

And for the booster, the cycle's RMS to peak ratio.

All of this adds to the challenge of finding the right balance between OPEX and CAPEX.



Global Optimisation



Conclusion

We don't have yet any electrical specification on correctors, booster sextupoles, straight sections, insertions, specific application magnets, …

The missing information concerns the converters that are smallest in power but many in number ! They represent a big portion of the total powering cost – CAPEX & OPEX

To manage the cable quantities, a study on sextupoles (among others) circuit controllability is needed

We need precise data and requirements to be able to construct and optimise the global costing for the midterm review.