Magnet Design

JUAS 2022 : Course 2

Exercise 1 : Analytical Design

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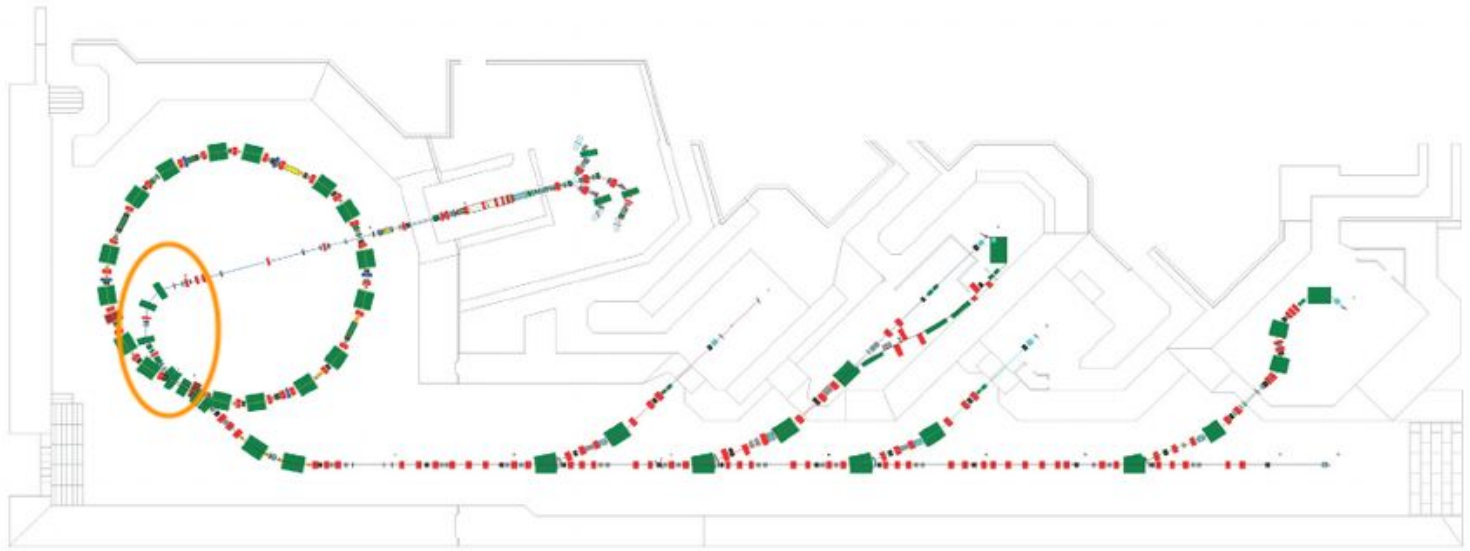
Marvin Noll
Abhishek Panchal
Sophie Morard
Gael Craveiro
Katyayni Tiwari

Coordinated by
Jérémie Bauche

Introduction

❖ Outline :

1. Magnet type
2. Magnetic Measurements
3. Coil parameters
4. Cooling



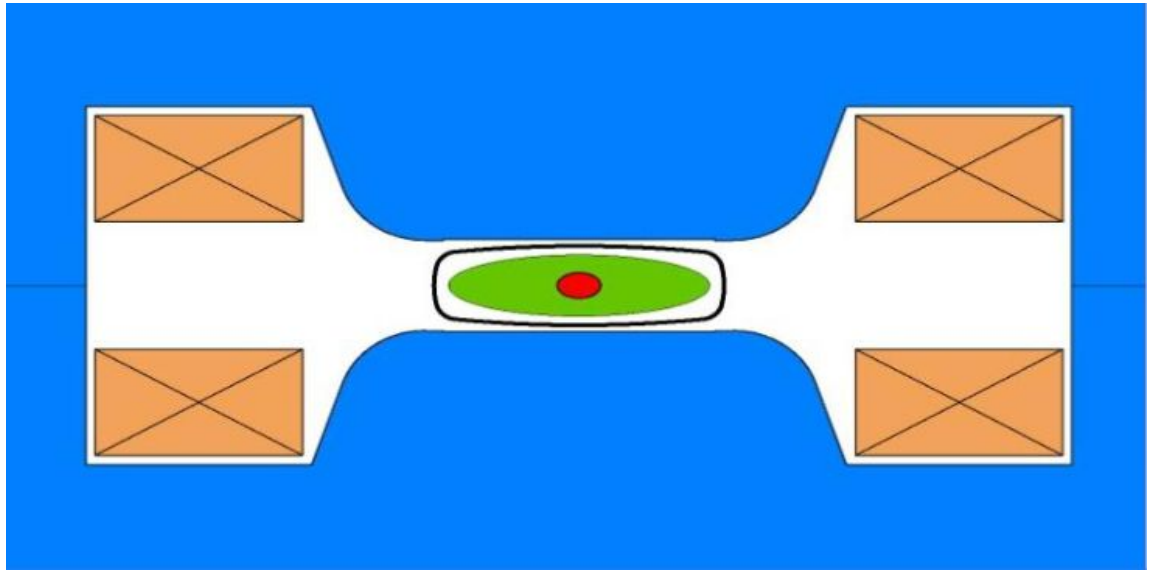
MedAustron accelerator layout

Magnet type

❖ Magnet type selection → H-type

Because,

- It is symmetrical
- Mechanical rigid
- less iron
- size of the yoke smaller

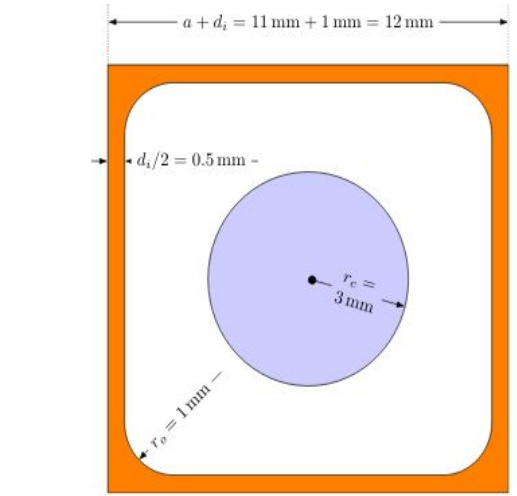


Geometric Parameters

- Aperture height, $h = h_{GFR} + 2.d_{vaccum} + d_{tolerance}$ ⟶ 52 mm

- Magnetic length of the dipole magnets, $l_{mag} = l_{iron,max} + 2hk$ ⟶ 397.2 mm

- Taking saggita into account, we got *pole width* approx. 140.13 mm.



1: Cross section of the copper winding showing insulation(■) and water channel(■)

unoptimized $x_{\text{unoptimized}} = 1.5898$

- Copper conductor cross-section = $a^2 - r_0{}^2(4 - \pi) - \pi r_c{}^2$

area of water channel

area of rounded edge

91.8 mm^2

Magnetic Parameters

★ Calculated magnetic strengths,

$$B_{\min} = \frac{(B\rho)_{\min}}{\rho} = \frac{0.383\,\mathrm{T\,m}}{0.642\,\mathrm{m}} = 0.596\,\mathrm{T}$$
$$B_{\max} = \frac{(B\rho)_{\max}}{\rho} = \frac{0.766\,\mathrm{T\,m}}{0.642\,\mathrm{m}} = 1.19\,\mathrm{T}$$

❑ calculated excitation currents,

$$(NI)_{\text{dipole, min}} = \frac{B_{\min}\,h}{2\,\mu_0} = \frac{0.596\,\mathrm{T}\cdot 52\,\mathrm{mm}}{2\cdot\mu_0} = 12.331\,\mathrm{kA}$$
$$(NI)_{\text{dipole, max}} = \frac{B_{\max}\,h}{2\,\mu_0} = \frac{1.19\,\mathrm{T}\cdot 52\,\mathrm{mm}}{2\cdot\mu_0} = 24.621\,\mathrm{kA}$$

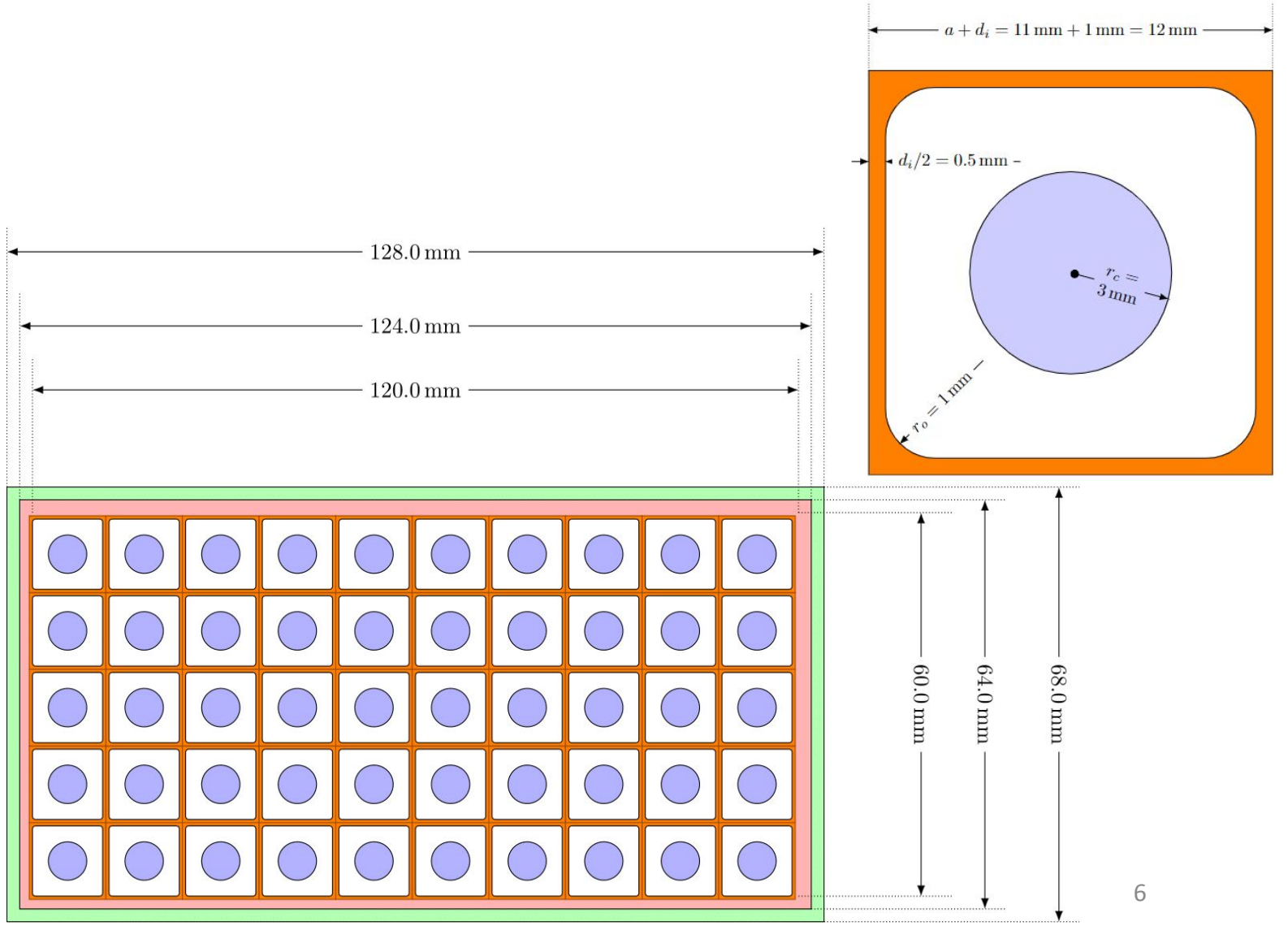
Parameters	Values
★ Flux density B	B_min≈0. 6 T B_max ≈ 1.2 T
❑ Excitation current NI (ampere-turns)	min-12.33 A max-24.66 A
● Nominal current I	Max possible current ~ 492.4 A
❖ Number of turns	min- 23 max- 45

< max. current of power supply 600 A

❖ N= N_horizonta*N_vertical = 50; we are choosing, 50 no. of turns.

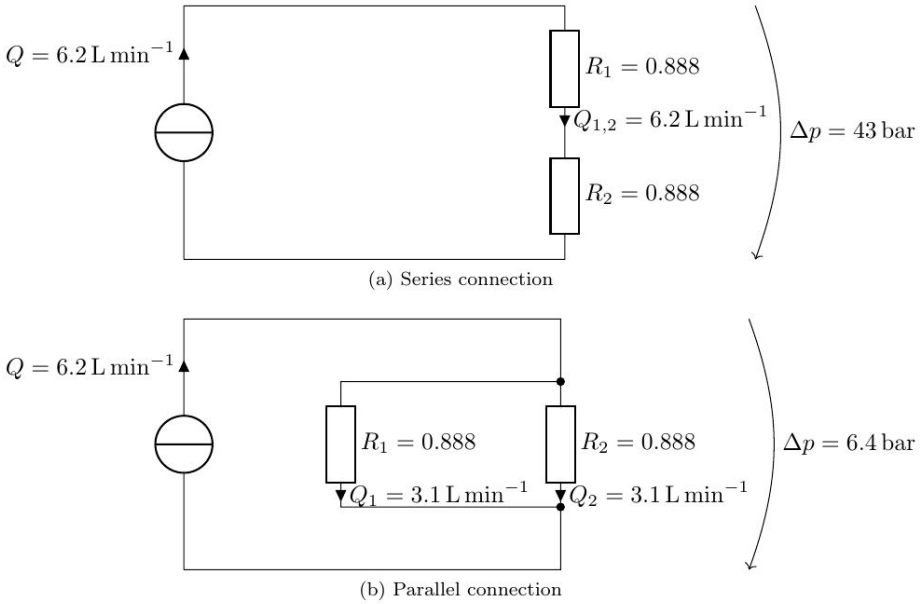
Coil Parameters

width	128	mm
height	68	mm
pole perimeter	960	mm
avg turn length	1472	mm
R_c	13.4	mΩ
V_m	13.2	V
V_{total}	39.6	V
P_m	6.5	kW



Cooling

❖ First try with cooling system in series, led to a pressure drop around 40 bar -> Not good !

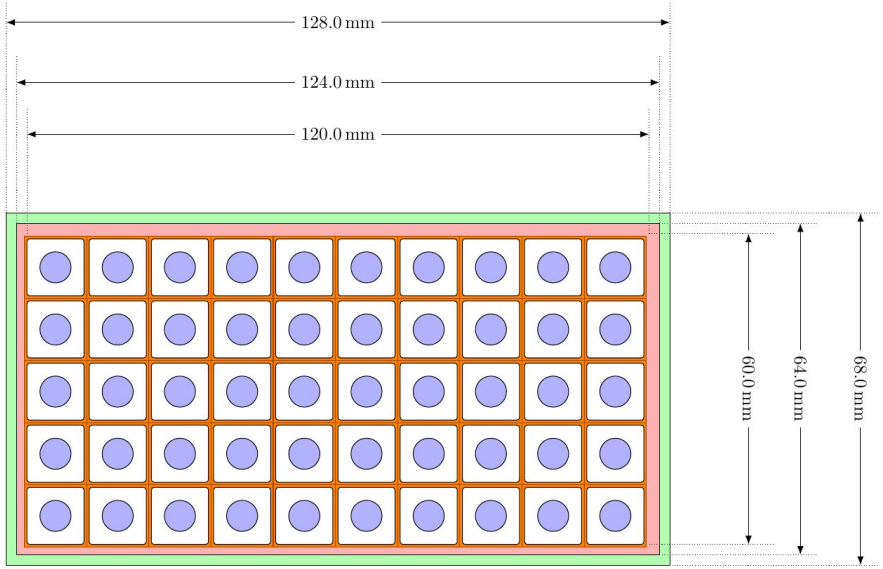


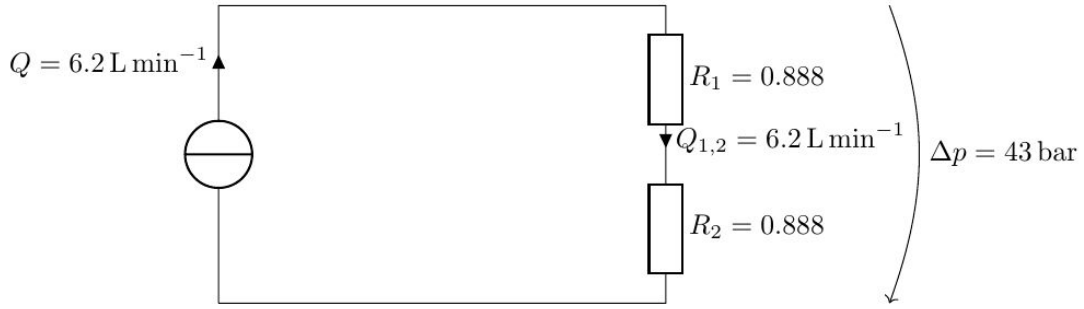
Parameter	Value	Unit
Water flow	3.098	L/min
Average flow velocity	1.827	m/s
Cooling circuit length	73.6	m
Pressure drop	6.43	bar
Reynold number	16 600 Turbulent flow !	dimensionless

Conclusion and Discussion

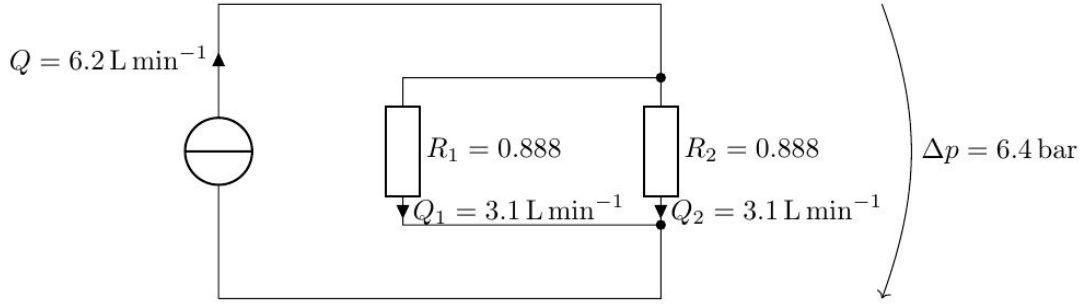
$$N_{B_{\min}} = \left\lceil \frac{(NI)_{\min}}{I_{\max}} \right\rceil = 23$$

$$N_{B_{\max}} = \left\lceil \frac{(NI)_{\max}}{I_{\max}} \right\rceil = 45$$





(a) Series connection



(b) Parallel connection

$$\Delta p = \underbrace{\frac{60 \cdot l}{d^{4.75}}}_{R} \cdot Q^{1.75} = R \cdot Q^{1.75}$$