Joint Universities Accelerator School

JUAS 2012

Archamps, France

Analytical & numerical design of a normal-conducting, iron-dominated electro-magnet

Mini Workshop - Case study

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Introduction

- The goal is to practice elements learned during the lectures
- Students are invited to design and specify a ‚real‘ magnet
- Sample case: Bending magnet for the MedAustron medium-energy beam transfer line
- Work in groups of 3 persons during 2 half-days
- At the end, students are expected to deliver a short written report

Programme

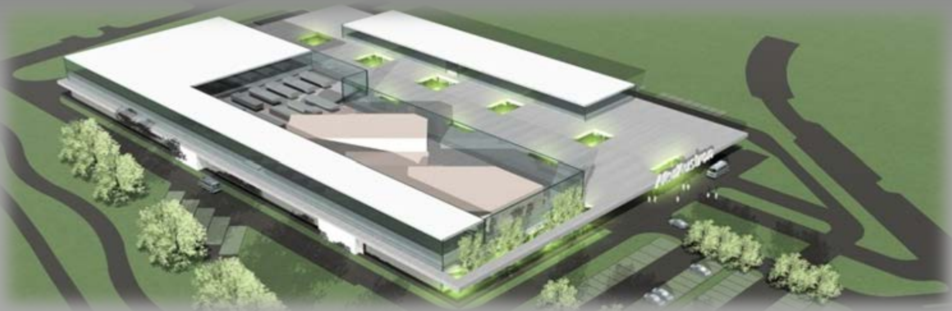
- Short introduction to MedAustron
- Magnet input parameters, requirements and constraints
- Part I:
  - Wednesday, 22. Feb., 16:00 – 17:30
  - Analytical design (on paper) to derive the main parameters
  - Expected results: detailed parameter list, magnet cross-section (yoke & coils) ready for numerical computations
- Part II:
  - Thursday, 23. Feb., 9:00 – 12:15
  - Numerical field computations and optimization of the pole profile
  - Expected results: final report (1 – 2 pages)

Deliverables

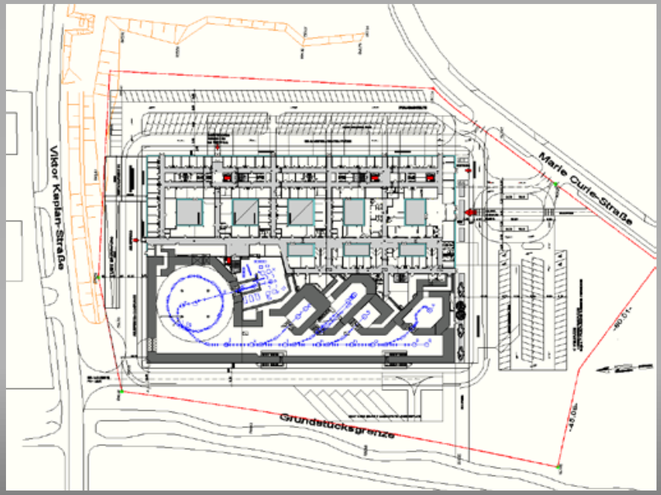
- Students are expected to deliver a short written report which should include at least:
  - detailed magnet parameter list summarizing the outcome of the analytical design
  - magnet cross-section based on analytical calculations with yoke and coil shape
  - optimized cross-section (pole profile) based on numerical computations fullfilling the field quality requirements

Introduction to MedAustron

- MedAustron is located in Wiener Neustadt (50 km north of Vienna) next to the future site of the new hospital

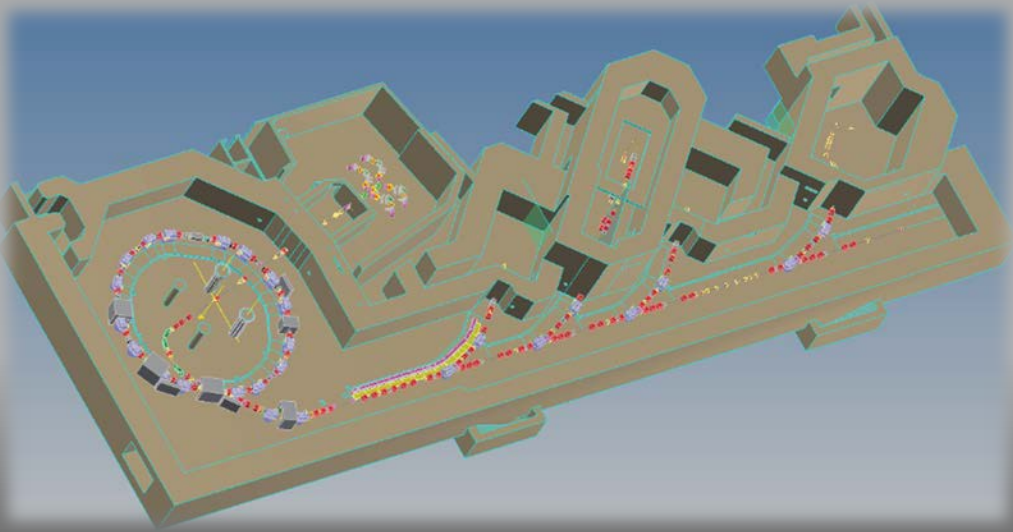


- Medical Treatment
  - Tumour treatment
  - Clinical research
- Non-clinical Research (NCR)
  - Medical Radiation Physics
  - Radiation biology
  - Experimental physics



Accelerator Main Parameters

- Synchrotron based (circumference 76 m)
- Ion species: protons and carbon ions
  - Optionally and at a later stage other ions with q/m>1/3 are possible
- Energy range
  - Proton: 60-250 MeV (medical)
    - Higher proton energy provided for experimental physics: up to 800 MeV
  - Carbon: 120-400 MeV/n
- Cycle time > 1 second



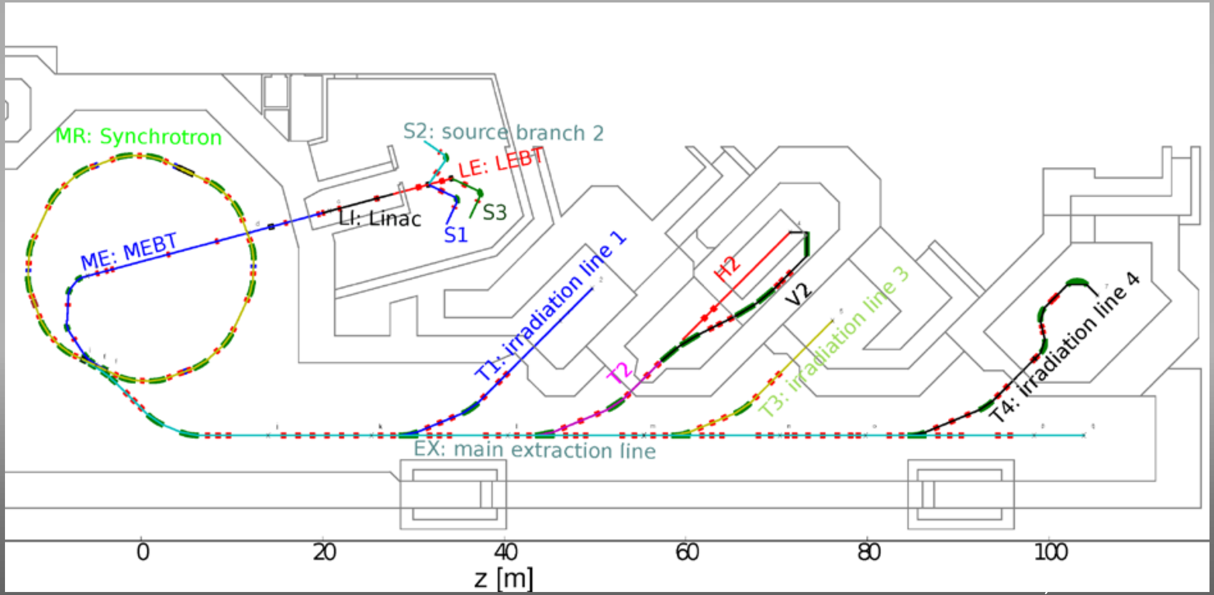
Irradiation rooms

Medical facility:

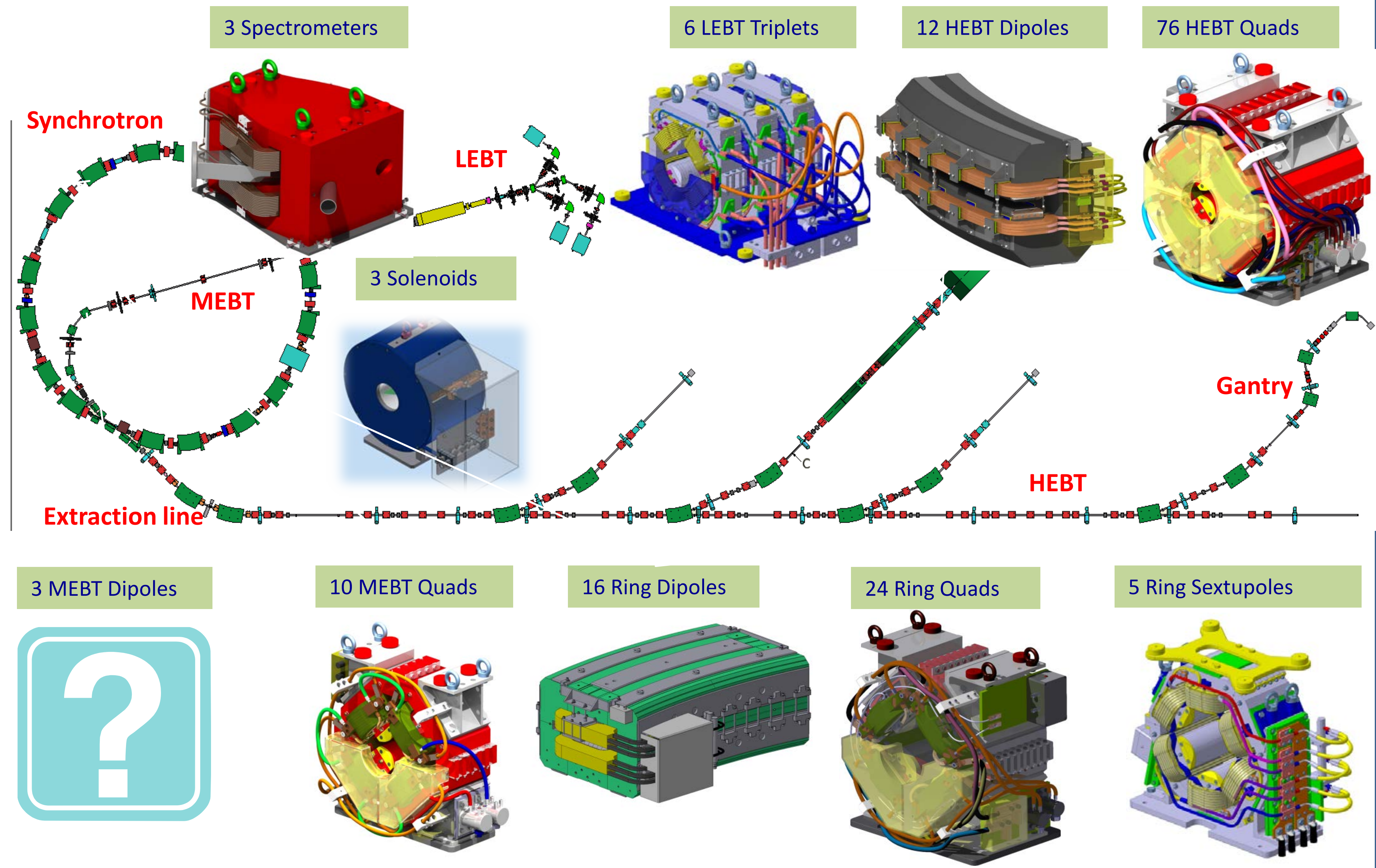
- IR2
  - Horizontal and vertical beam
  - Protons and carbon ions
- IR3
  - Horizontal beam
  - Protons and carbon ions
- IR4
  - Gantry
  - Protons

Non-clinical research facility:

- IR1
  - Horizontal beam line
  - Protons (up to 800 MeV) and carbon ions

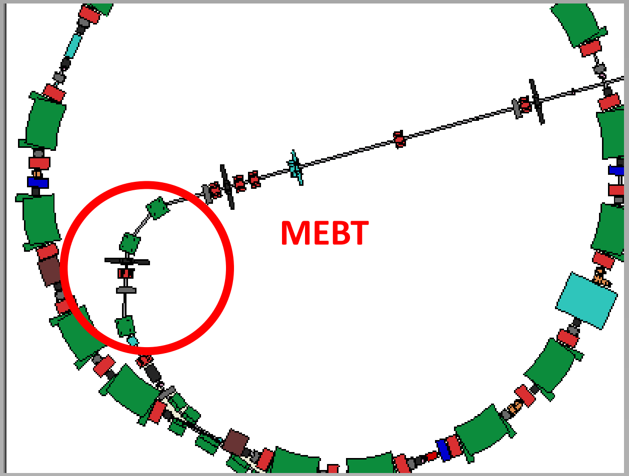


Magnet families



Beam parameters

Required: Three C-shape bending magnets for the medium-energy beam transfer line between the Linac and the Synchrotron



Parameter	Value	Unit
Particle type	Protons, C^{6+}	
Beam energy	7	MeV/u
Operation mode	quasi DC	
Length of beam line	40.9	m
Beta function β_x, β_y	~10	m
Beam size σ_x, σ_y	+/- 10	mm
Margin for closed orbit distortions	+/- 10	mm

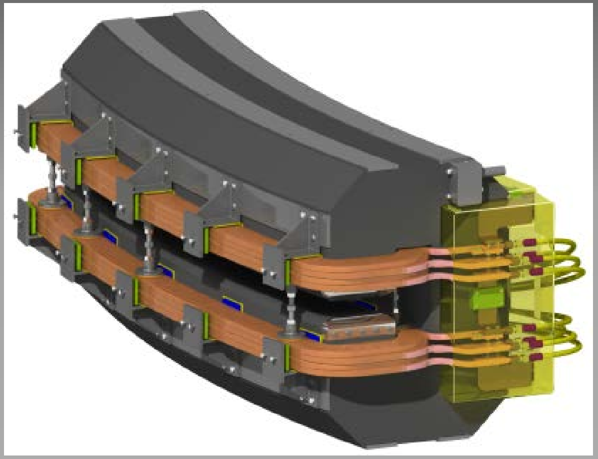
Functional specification

Parameter	Value	Unit
Number of magnets	3	
Bending angle	36	deg
Beam entry/exit angle	18	deg
Operation mode	quasi DC	
Ramp rate	0.3	T/s
Horizontal good field region	+/- 20	mm
Vertical good field region	+/- 23	mm
Integrated field quality inside GFR $\Delta\int Bdl/\int B_0 dl$	$< \pm 1\cdot 10^{-3}$	
Max. overall magnet length	0.8	m
Max. available water pressure drop	0.8	MPa
Inlet water temperature	25	°C
Max. converter current	650	A
Max. converter voltage	160	V

Analytical design

The following parameters should be defined or derived:

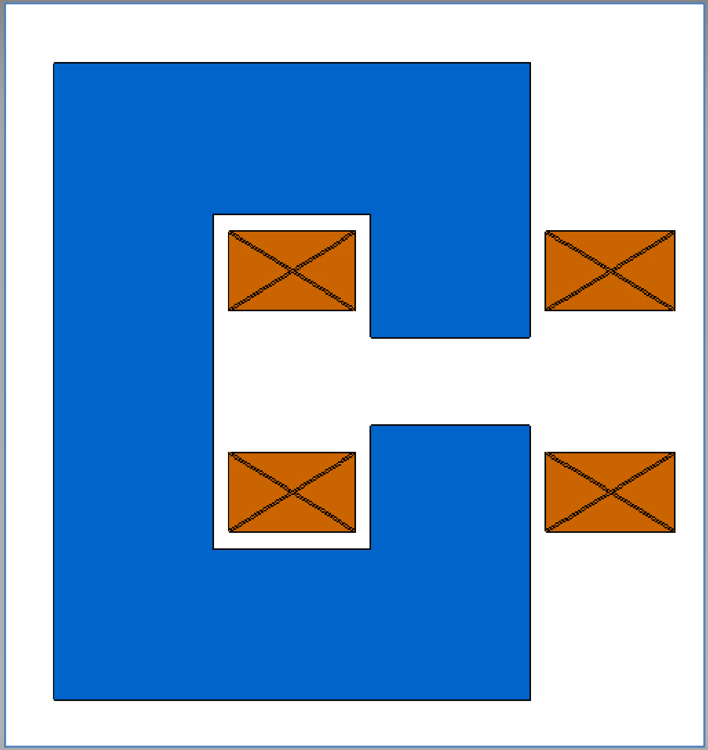
- Yoke shape (straight/curved)
- Aperture height *h*
- Flux density *B*
- Excitation current *NI* (ampere-turns)
- Magnetic length l_{mag} and iron length l_{iron}
- Pole width and yoke thickness
- Current density *j*, nominal current *I* and number of turns *N*
- Dissipated power *P*, coil resistance *R*, dc voltage *V*
- Coil size (width, height) and conductor material
- Pressure drop Δp, Temperature rise ΔT,
- Conductor size (height, width, cooling hole diameter) and insulation thickness
- Coolant flow *Q* and flow velocity u_{avg}, Reynolds number RE



Numerical input

For the computer work with ROXIE tomorrow morning, you will need the following design variables:

- Aperture height
- Pole width
- Yoke width (horizontal and vertical)
- Coil window width and height
- Coil size (width and height)
- Coil position wrt to beam axis
- Coil excitation (ampere-turns)



Good luck.....!