Magnets for the ELENA ring and injection line

ADUC and ELENA Meeting
28 – 29 September 2011

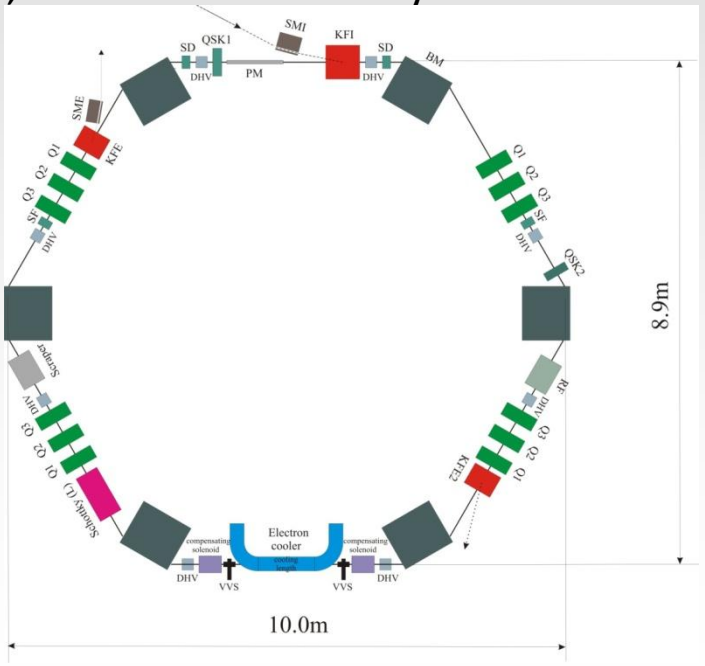
M. Buzio, A. Vorozhtsov, T. Zickler

History

- 2006: First contact with ELENA project
- March 2007: preliminary magnet design by T. Zickler
- Outcome summarized in AT Technical Note (EDMS: 823968)
- Since then several changes in the optics layout
- 2010: Conceptional magnet design started in 2010 by A. Vorozhtsov
- Latest results summarized in TE Technical Note (EDMS: xxxxxx)
- Not a final design, but a solid baseline for discussions: costs, water and electricity
- Further design iterations are expected with the advancement of the project towards the TDR

General

- 48 magnets (incl. spare) of 8 types
- Normal-conducting magnets
- Water and air (convection) cooled
- Mostly iron-dominated; laminated yokes
- Cooling designed for dc-operation



Ring magnets

Type	Number	Aperture [mm]	GFR [mm]	Field error	Magn./mech. length [m]	Nominal field strength	Cooling
Bending BM0.36	6 + 1	91	45 x 41	$\pm 2 \cdot 10^{-4}$	0.97 / 1.25	0.36 T	Water
Quadrupole Q1.4	12 + 1	91	36	$\pm 5 \cdot 10^{-4}$	0.25 / 0.35	1.4 T/m	Water
Sextupole X13	4 + 1	91	43	$\pm 2 \cdot 10^{-3}$	0.15 / 0.23	13 T/m^2	Air
H/V Corrector C1	8 + 1	91	43	$\pm 1 \cdot 10^{-2}$	0.15 / 0.21	$\pm 2 \cdot 10^{-3}$ Tm	Air
Skew Quadrupole SQ0.4	2 + 1	91	40	$\pm 1 \cdot 10^{-2}$	0.15 / 0.23	0.4 T/m	Air
Solenoid SOL	2 + 1	100	38	$\pm 3 \cdot 10^{-4}$	0.4 / 0.5	0.0147 T	Air

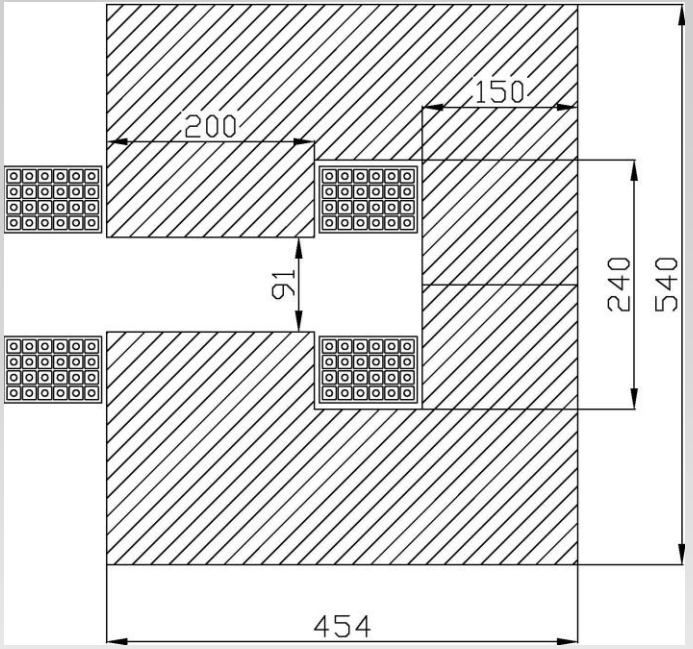
Injection line magnets

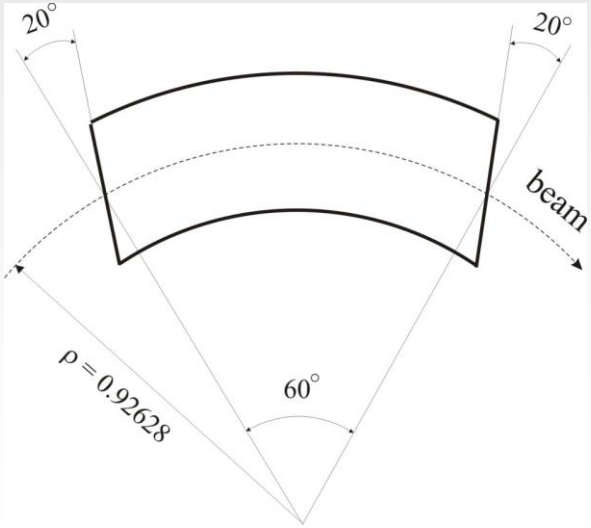
Type	Number	Aperture [mm]	GFR [mm]	Field error	Magnetic length [m]	Nominal field strength	Cooling
Bending BM0.32	3 + 1	71	45 x 40	$\pm 5 \cdot 10^{-4}$	0.522	0.32 T	Water
Quadrupole Q1	2 + 1	71	50	$\pm 1 \cdot 10^{-3}$	0.4	1.0 T/m	Water
H/V Corrector C1	1 + 0	91	43	$\pm 1 \cdot 10^{-2}$	0.15	$\pm 2 \cdot 10^{-3}$ Tm	Air

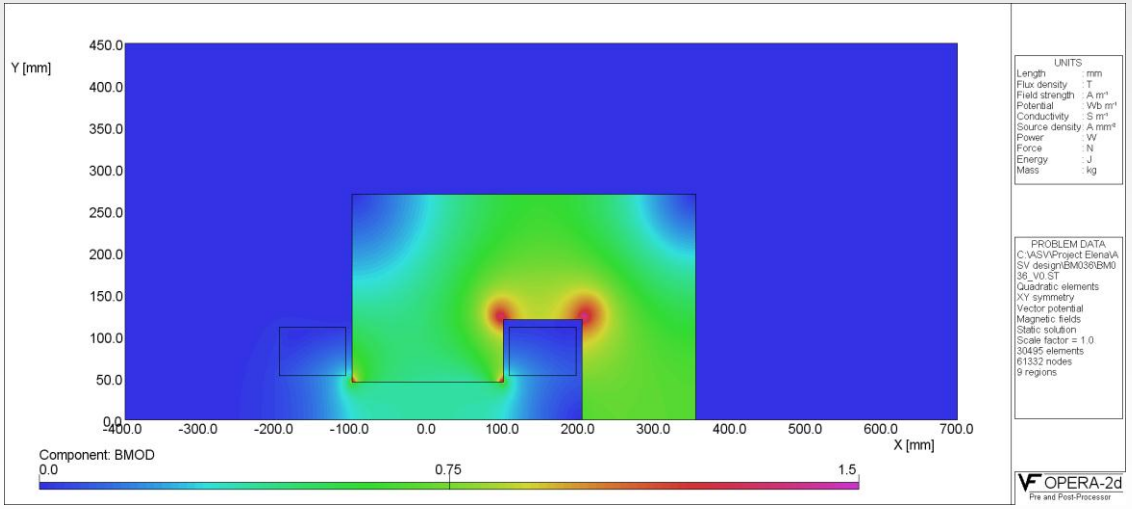
Note: the injection line will use the same corrector type as foreseen for the ring

Bending magnets

- Dynamic range: 5.6 MeV → 100 keV
  - Low fields down to 50 mT
  - Residual field due to coercive force in the iron yoke
  - Steel properties and quality important
- High field quality (± $2 \cdot 10^{-4}$)
  - careful study of end-effects
- Ramp time > 1 s
  - Laminated yokes
- Curved C-shape magnets with 20° edge angles







ELENA Ring dipoles

- Combination of strong 60° bend, very low field (50 mT flat-bottom), possible saturation effects due to edge focusing → challenging measurement
- At the moment, the development of a suitable curved fixed-coil integral fluxmeter (CNAO- and MedAustron-style) looks like the best option (~9 months lead time)
- Equipment for additional standard measurements (e.g. 3D Hall probes scanners for fringe fields) is already available
- Environmental field mapping in the tunnel can be carried out if needed

Real-time field control (B-train)

- Upgraded system with new electronics and an FMR-based field marker is being developed for the PS (installation foreseen in the 2013/14 shutdown)
- The system can be easily adapted to ELENA in case of external reference magnet, re-using the integral fluxmeter for improved accuracy
- In-ring reference magnet: different sensor layout and performance, feasibility study needed
- B(t) distributed on a new fast serial line, completely different from current pulse train system; Details to be discussed well in advance with all users

Other Ring and TL magnets

- All testable with existing instrumentation

Cost estimate

Type	Number	Position	Cost per unit [kCHF]	Total cost [kCHF]
Bending BM0.36	7	Ring	78	546
Quadrupole Q1.4	13	Ring	20	260
Sextupole X13	5	Ring	16	80
H/V Corrector C1	10	Ring + Transfer line	18	180
Skew Quadrupole SQ0.4	3	Ring	15	45
Solenoid SOL	3	Ring	18	54
Bending BM0.32	4	Transfer line	64	256
Quadrupole Q1	3	Transfer line	23	69
Total	**48**			**1490**

Note: the cost estimate includes raw materials, tooling, manufacturing and assembling of the magnets

Packages for possible contributions

Basic (‚in-kind‘)	Advanced (‚full supply‘)	Full (‚turn-key‘)
Package 1 **800 kCHF** Ring bending magnets + Transfer line bending magnets	**Package 1+** **800 kCHF + MP** Ring bending magnets + Transfer line bending magnets	
Package 2 **330 kCHF** Ring quadrupoles + Transfer line quadrupoles	**Package 2+** **330 kCHF + MP** Ring quadrupoles + Transfer line quadrupoles	**Package 2++** **>330 kCHF + MP** Ring quadrupoles + Transfer line quadrupoles + Design & Mag. measurements
Package 3 **360 kCHF** Ring sextupoles + Ring skew quadrupoles + Solenoids + H/V Correctors	**Package 3+** **360 kCHF + MP** Ring sextupoles + Ring skew quadrupoles + Solenoids + H/V Correctors	**Package 3++** **>360 kCHF + MP** Ring sextupoles + Ring skew quadrupoles + Solenoids + H/V Correctors + Design & Mag. measurements

Summary

- The ELENA project requires in total 48 magnets
- Magnets to be produced in industry
- Preliminary design available
- Most critical items: laminated, curved C-shape bending magnets
  - Challenging in design, production and measurements
  - Prototype to study hysteresis effects
- Overall magnet production costs 1.5 MCHF
- Several packages for possible contributions proposed
- Contributions can be either ‘in-kind’ or more collaboration-like

We are looking for competent partners who want to share this challenge with us…

… and we hope that you will be one of them!