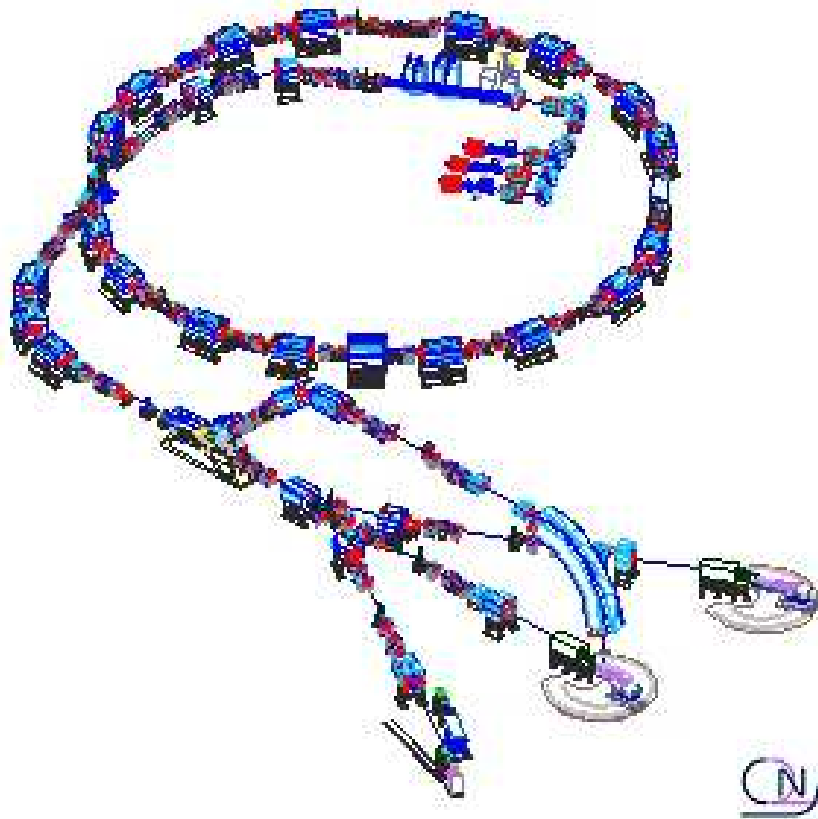


# Synchrotron and Transfer Lines Magnets

ASG was the main contractor for the construction of the magnets for the synchrotron and the beam transfer lines of the “**Centro Nazionale di Adroterapia Oncologica**” (CNAO – National Centre for hOncologic hAdrotherapy). CNAO is devoted to therapy using proton and carbon ions with energies in the range of 250-400 MeV respectively. The centre is presently under construction in Pavia, Italy. The supply included 26 bending dipoles, 25 quadrupoles, 7 sextupoles and 20 corrector magnets (horizontal and vertical).

The medium energy transfer line (MEBT) is equipped with n. 2 bending dipoles, 10 quadrupoles and 8 “both plane” corrector magnets, while the high energy transfer line (HEBT) from the ring to the treatment station is equipped with 42 quadrupoles, 1 switching dipole, 21 “both plane” corrector magnets, supplied by ASG Superconductors.

Moreover 2 monitoring magnets, a skew quadrupole and an air core quadrupole, were supplied.



CNAO Synchrotron system

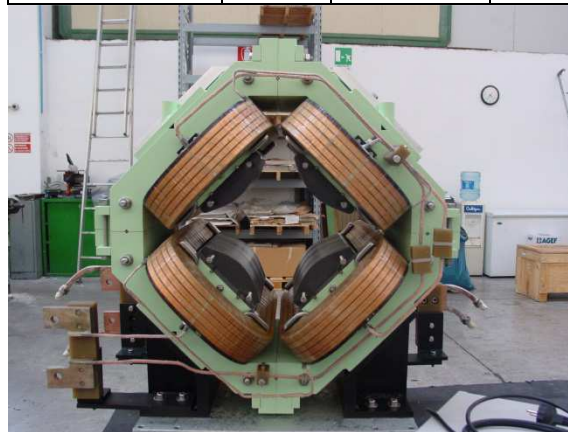
**Synchrotron**



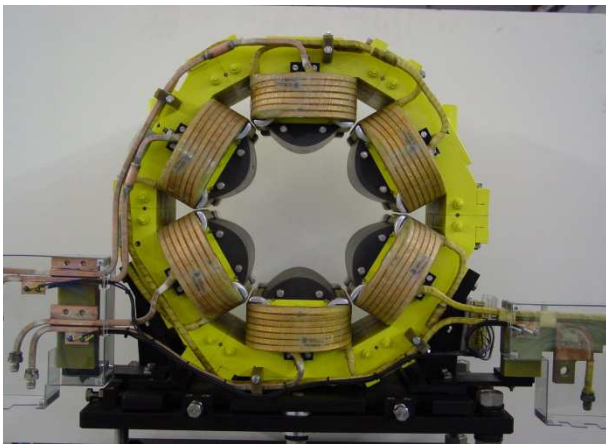
Vertical and horizontal corrector magnets

		Horizontal	Vertical
Quantity		10+1	8+1
Nominal Max Field	T	0.0412	0.0179
Magnet Gap	mm	106	180
Int. Field Quality	$\Delta BI/BI$	$\pm 1 \cdot 10^{-2}$	$\pm 1 \cdot 10^{-2}$
Nominal Current	A	14.6	27.1
Copper Conductor	mm*mm	3*3.8	3*7
Dimensions W*L*H	mm	448*286*620	384*300*630
Weight	Kg	~95	~85

Quantity	24+1	
Nominal Max Field Gradient	T/m	3.965
Magnet Bore Radius	mm	85
Int. Field Quality	$\Delta GI/GI$	$\pm 5 \cdot 10^{-4}$
Nominal Current	A	580
Copper Conductor	mm*mm	10*11 $\phi$ 5
Dimensions W*L*H	mm	625*462*795
Weight	Kg	~310



Quadrupole magnet



Sextupole magnet

Quantity	5+2	
Nominal Max Field Gradient	T/m	59.6
Magnet Bore Radius	mm	100
Int. Grad. Field Quality	$\Delta GI/GI$	$\pm 4 \cdot 10^{-3}$
Nominal Current	A	566.4
Copper Conductor	mm*mm	8*8 $\phi$ 4
Dimensions W*L*H	mm	990*320*704
Weight	Kg	~300

**Synchrotron**


Dipole magnets

Quantity	26	
Nominal max field	T	1.5
Magnet Gap Height	mm	72 (71.6)
Field Quality	$\Delta B/B_{nom}$	$\pm 2 \cdot 10^{-4}$
Nominal Current	A	2800
Copper Conductor	mm*mm	12.5*50 $\phi$ 6*2
Dimensions W*L*H	mm	1900*1300*1030
Weight	Kg	~10500

**Transfer Line**
**HEBT**

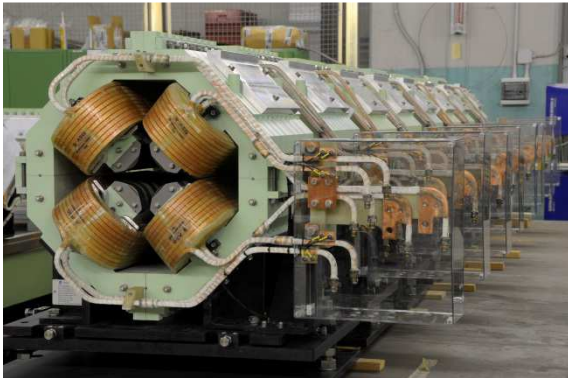
Quantity		21
Nominal max field	T	0.0604
Magnet Gap	mm	206
Int. Field Quality	$\Delta B/B$	$\leq \pm 1 \cdot 10^{-2}$
Nominal Current	A	140.1
Copper Conductor	mm*mm	5*7 $\phi$ 3
Dimensions W*L*H	mm	656*420*747
Weight	Kg	~470



HEBT e MEBT corrector magnets

**MEBT**

Quantity		8
Nominal max field	T	0.023
Magnet Gap	mm	200
Int. Field Quality	$\Delta B/B$	$\leq \pm 3 \cdot 10^{-3}$
Nominal Current	A	46.1
Copper Conductor	mm*mm	4.5*4.5 $\phi$ 2.5
Dimensions W*L*H	mm	620*216*745
Weight	Kg	~220


**HEBT quadrupole magnet**

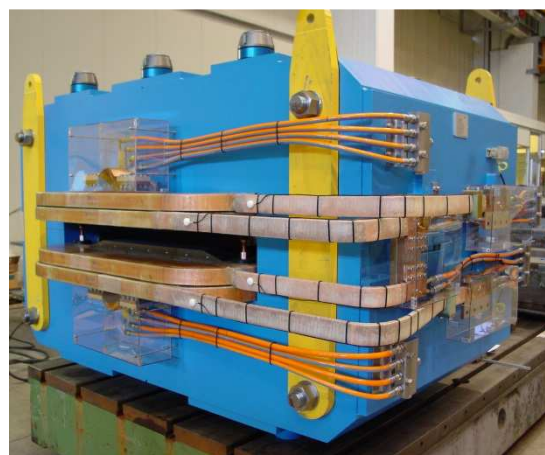
Quantity	42	
Nominal max field grad.	T/m	18.67
Magnet Bore Radius	mm	37
Int. Field Grad. Quality	$\Delta GI/GI$	$\leq \pm 4 \cdot 10^{-4}$
Nominal Current	A	286.25
Copper Conductor	mm*mm	10*10 $\phi$ 6
Dimensions W*L*H	mm	1088*598*790
Weight	Kg	-870

**Transfer Line**

**MEBT quadrupole magnet**

Quantity	9+1	
Nominal max field grad.	T/m	8.18
Magnet Bore Radius	mm	37
Int. Field Grad. Quality	$\Delta GI/GI$	$\leq \pm 1.3 \cdot 10^{-4}$
Nominal Current	A	112.4
Copper Conductor	mm*mm	10*10 $\phi$ 6
Dimensions W*L*H	mm	930*361*790
Weight	Kg	-310

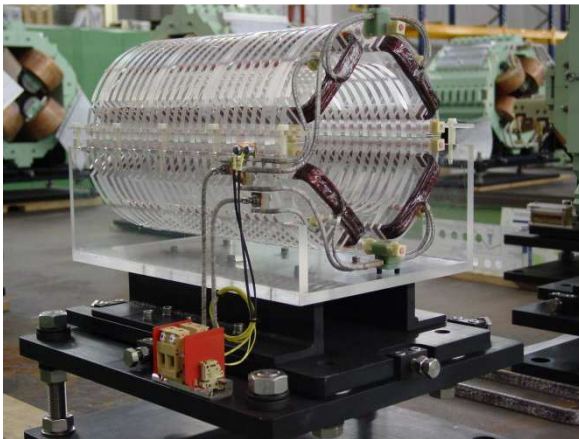
Quantity	1	
Nominal max field	T	1.5
Magnet Gap Height	mm	64
Int. Field Quality	$\Delta BI/BI_{nom}$	$\leq \pm 5 \cdot 10^{-4}$
Nominal Current	A	1795.3
Copper Conductor	mm*mm	12.5*50 $\phi$ 6*2
Dimensions W*L*H	mm	2180*1650*1431
Weight	Kg	-21000


**HEBT switching dipole**




**MEBT dipole magnets**

Quantity	2	
Nominal max field	T	0.4041
Magnet Gap Height	mm	54
Int. Field Quality (at nom. field)	$\Delta B/B_{nom}$	$\leq \pm 2 \cdot 10^{-4}$
Nominal Current	A	242.5
Copper Conductor	mm*mm	10*10 $\phi$ 6
Dimensions W*L*H	mm	956*1532*692
Weight	Kg	~2800

**Air Core and Skew quadrupoles**


Quantity	1	
Nominal max field grad.	T/m	0.01349
Magnet bore radius	mm	85
Int. Grad. Quality	$\Delta GI/GI$	$\leq \pm 3.2 \cdot 10^{-2}$
Nominal Current	A	9.75
Copper Conductor	mm*mm	4.5*2
Dimensions W*L*H	mm	430*556*536
Weight	Kg	~110

**Air Core Quadrupole**

Quantity	1	
Nominal max field grad.	T/m	0.1232
Magnet bore radius	mm	85
Int. Grad. Quality	$\Delta GI/GI$	0.0125
Nominal Current	A	19.72
Copper Conductor	mm*mm	4.5*2
Dimensions W*L*H	mm	784*298*770
Weight	Kg	~310


**Skew quadrupole**