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PANDA Solenoid (Rev.1)

1 - Introduction

The magnet for PANDA Experiment is a thin superconducting solenoid housed into an octagonal laminated iron flux return joke.

The main parameter of the PANDA Solenoid are the following:

- inner diameter 2090 mm
- outer diameter 2190 mm
- central field: 2T
- 2635 mm length

The double layer coil is internally wound on an about 50 mm thick 5083-0 aluminum alloy support mandrel. Cooling pipes are welded to the outer diameter of the support mandrel forming part of the thermo-siphon system.
Electrical insulation consists of dry wrap fiberglass cloth and epoxy vacuum impregnation.

2 – The Conductor

The conductor is composed of a superconducting Rutherford type cable co-extruded in a pure aluminum matrix (99.996 %). The estimated RRR is better than 100 for the strand and better than 1000 for the Al matrix.
In order to have the field homogeneity required the current density in the winding is graded: lower in the central region and higher at the coil ends.
The gradation is obtained by using conductor of two different heights.
Overall dimensions shall be estimated into 24 x 2.5 mm (high density) and 24 x 4 mm (low density) while the Rutherford wires diameter will be about 0.84 mm.
At present six lengths of S/C conductor are forecast and five internal joints will be realized.
As PANDA is an indirect cooled magnet, the stability against thermal disturbances is a severe task:
to establish the minimum energy required to have a quench propagation, computer codes, both analytical and 3-D numerical for transient thermal analysis will be adopted. In order to have a good stability margin the conductor will be chosen to have a pure Al section ranging around 50-60 mm^2 and a quite big ratio between the operating and the critical current (in between 1/3 and 1/2).

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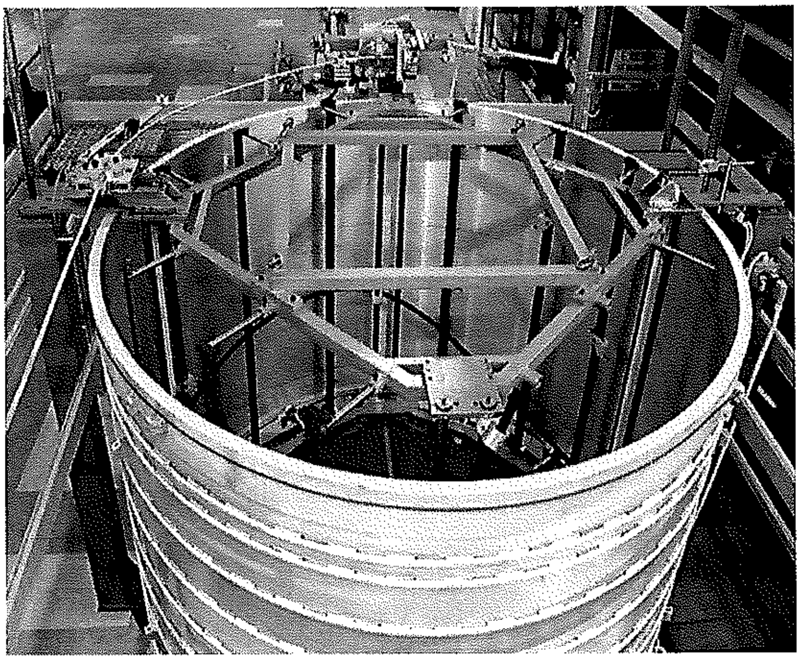
3 – The coil

The superconducting cable will be wound inside an Aluminum alloy 5083-0 cylinder having the length of about 2735 mm and the inner diameter of 2190 mm while the cylinder thickness estimated is 50 mm.
The constrain cylinder will ensure the Lorentz force supporting and, by means of the Aluminum pipes welded on the external surface, it will provide the L-He path for the indirect cooling.
The Al-pipes are connected to two manifolds where the inlet and outlet helium lines are connected to close the self regulating thermo-siphon loop.
The winding of the solenoid will be carried out by using a properly designed automatic machine. The plant will be mainly composed of a synchronized rotating table, a taping station for the cable insulation, a tool for the tensioning of the insulated cable and several rollers to properly route the cable inside the cylinder itself.
The junctions between the different cable lengths shall be performed by using both the TIG welding and soft soldering techniques (estimated length around 2 meters each).
For the winding the cable is deformed in a helical shape and pushed against the inner surface of the cylinder.
The conductor is pre-bent on a radius bigger than the design one, before its disposition in the cylinder, in order to have a good pressing against the ground insulation.
The axial pressing of the turns will be performed for the glass compaction.
After the winding the solenoid will be vacuum impregnated by using Araldite epoxy.
This potted monolithic structure will ensure good thermal conduction and good bonding among the Aluminum support structure and the cable.
The total weight of the cold mass is estimated to be about 4100 kg.
The quench behavior of the PANDA magnet will be analyzed including also the quench back effect due to the induced current on the external Al cylinder.
On the basis of similar coils it is possible to state that the final temperature of the conductor after a discharge on the dump resistor is quite low, about 30°K even if a conservative value of RRR 500 for the Al matrix is commonly considered in the calculations.



Babar Thin Solenoid Winding Line

4 – The cryostat

The vacuum vessel will be realized in AISI 304L stainless steel.
Its overall estimated dimensions will be:

- inner diameter 1900 mm
- outer diameter 2720 mm
- overall length 3100 mm

The cryostat has to support the external pressure, its own weight, the weight of the solenoid inside, the weight of the detectors and the loads due to axial and radial misalignment.
The cryostat flange will also be the closure flange for the turret, where the electrical and hydraulic connections are housed.
On the top of the turret, outside the joke, an integrated box will be used for the current leads and the control valves.
The electrical bus bars, vacuum pump connections and cryogenic transfer line couplings are all connected to this box.
The cryostat plus turret total weight estimated is 5000 kg.
The cold mass (winding plus containment cylinder) will be supported by 16 radial tie rods and 6 axial tie rods.
The tie-rods material forecast shall be or titanium alloy or income alloy.

The thermal shielding forecast will be an annular chamber realized by an aluminum plates reinforced by Al-rings for increasing their strength.
The two walls will be connected by two end flanges.

The shield cooling will be performed by the return helium gas flow at about 50°K inlet/60°K outlet in order to make the system independent from the liquid nitrogen.

5 –The iron joke

At present the iron joke forecast has an octagonal structure realized in black steel Fe360.
The assumption is to assembly the joke by using steel plates having thickness around 100 mm.
The weight estimated is about 120 tons. It will be possible to open the door by means of rollers sliding onto a beam fixed onto the outer wall of the iron joke. (see the picture related to FINUDA solenoid)

6 – Orientation System

The magnet and its iron joke, inside the experimental pit, shall have to be translated into the beam axis by means of a dedicated truck fixed to the iron joke.
It is possible to choose the orientation in one direction or in two perpendicular directions like the FINUDA one.
The positioning precision within the beam axis could be in the order of one millimeter.

Here below are reported the main parameters of the thin solenoids realized at ASG premisis:

1 – ZEUS (1989)

The thin superconducting solenoid was designed (on the basis of the conceptual study carried out by INFN) and built at Ansaldo Componenti.
This detector was installed on 1989 in the HERA ring accelerator (DESY, Hamburg) with its own Cryostat/vacuum chamber, 5.5 meters transfer line, current leads cryostat, current leads, power supply, dump resistors, breakers and computer control system

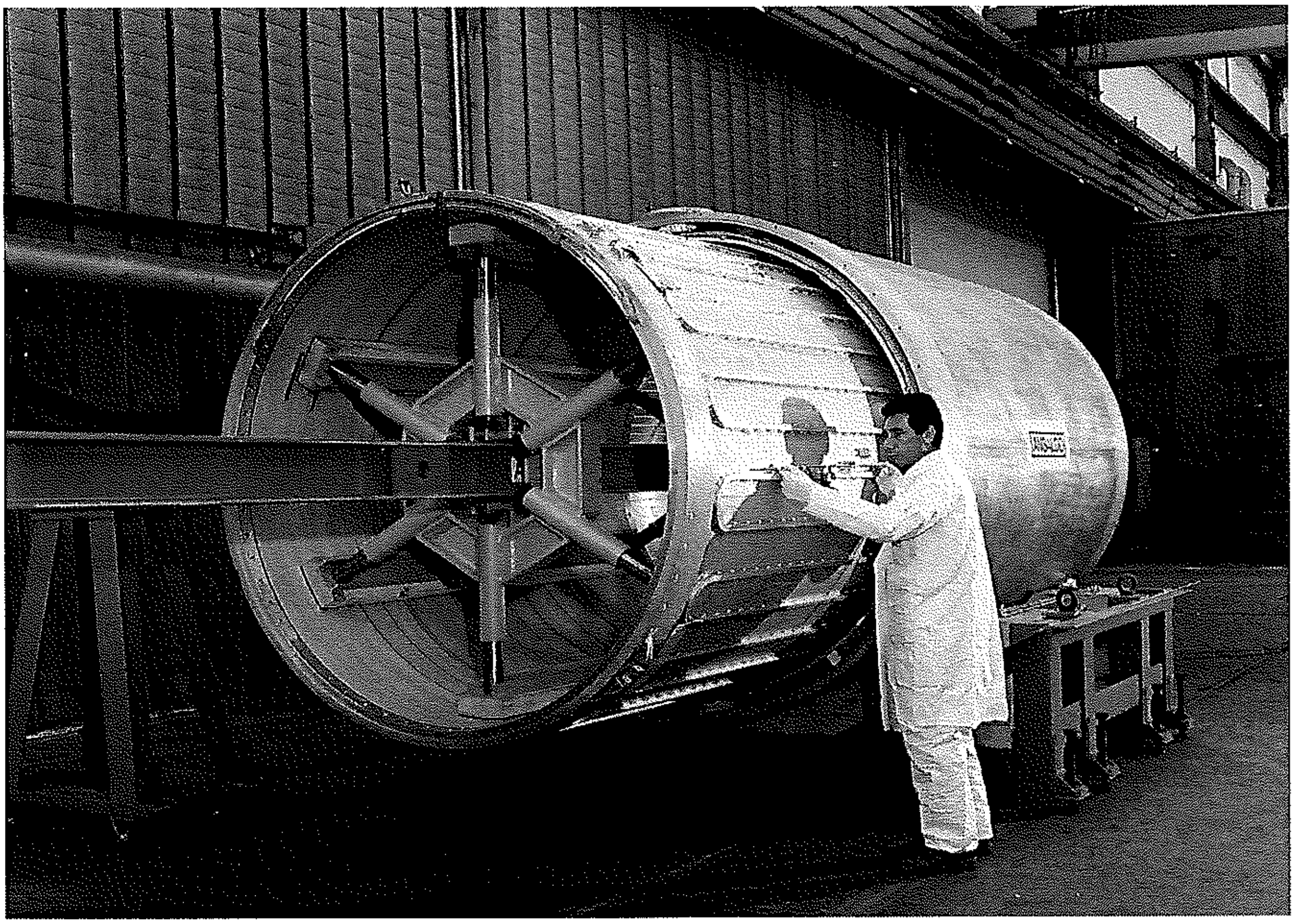
2 - FINUDA (1996)

The Finuda magnet, one of the two detectors for DAΦNE, the Frascati Φ factory has been realized under general specifications granted by INFN.
Ansaldo designed the complete magnetic system including cryostat, the shaped iron joke, the data acquisition, the safety and controls, the translation trolleys for the magnet displacement out of the beam axis.
The Ansaldo order is completed with the acceptance tests at his own premises and the installation in the experimental site in Frascati.

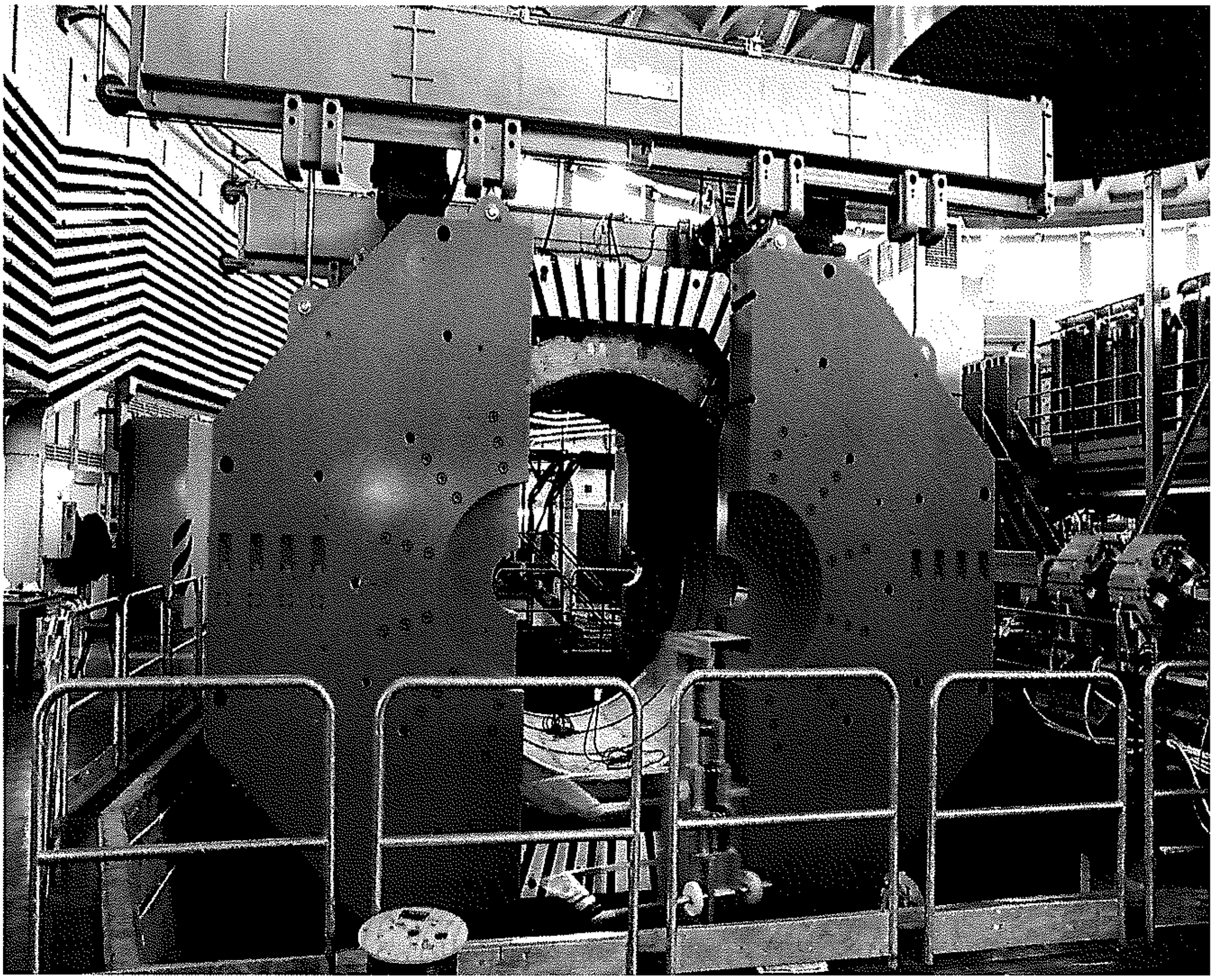
3 – BABAR (1997)

The BaBar Detector for the PEPII B-factory at SLAC is a thin solenoid housed into a hexagonal laminated iron flux return.
Ansaldo designed the complete magnetic system including the cryostat.
The Factory acceptance test was successfully carried out in 1997 while the final commissioning took place at SLAC starting from Jan, 1998.

Here below is reported the ZEUS Solenoid during the assembly inside the cryostat phase at ASG premises



FINUDA Magnet System positioned outside the beam line at I.N.F.N. (Frascati-I)



ASG "Thin Solenoids" Magnet System main parameters:

Magnet	**ZEUS**	**FINUDA**	**BABAR**
Assembly year	1989	1996	1997
Place	DESY Hamburg GERMANY	I.N.F.N. DAΦNE Frascati Labs. ITALY	SLAC California USA
Superconducting Solenoid			
Coil Inner Diameter [mm]	1849	2929	3038
Coil Outer Diameter [mm]	1914	2993	3082
Coil Length [mm]	2487	2241	3512
Cable layers	2	2	2
Turns number	907	753	1067
Inductance [H]	0.84	2.2	2.5
Central Field [T]	1.8	1.1	1.5
Operating Current [A]	4987	2845	4650
Stored Magnetic Energy [MJ]	10.5	8.1	27
S/C Cable Cooling	indirect	indirect	indirect
Winding Technique	Inner removable mandrel Al5083	Outer mandrel Al5083	Outer mandrel Al5083
Cable			
Superconductor type	Rutherford config. Cu/Nb-Ti 10 strands with 99.996% Al-stabilizer	Rutherford config. Cu/Nb-Ti 7 and 8 strands with 99.996% Al-stabilizer	Rutherford config. Cu/Nb-Ti 16 strands with 99.996% Al-stabilizer
Cu/NbTi Ratio	1.1/1	1.1/1	1.1/1
Total S/C length required [m]	6000	8250	10000
Cross section dimensions [mm]	15 x 4.3 (coil ends) 15 x 5.56 (central region)	14.4 x 4.13 (coil ends) 14.4 x 6.03 (central region)	20 x 4.93 (coil ends) 20 x 8.49 (central region)
Cryostat			
Material	Aluminum alloy 5083	Stainless steel AISI 304L	Aluminum alloy 5083
Inner Diameter [mm]	1720	2790	2840
Outer Diameter [mm]	2280	3360	3540
Length [mm]	2820	2540	3850
Inner cylinder thk. [mm]	5	7	10
Outer cylinder thk. [mm]	12	12	25
End flanges thk. [mm]	30	30	40