International Linear Collider ILD/ILC part 2

Karsten Buesser (DESY)
Yasuhiro Makida (KEK)

Contents

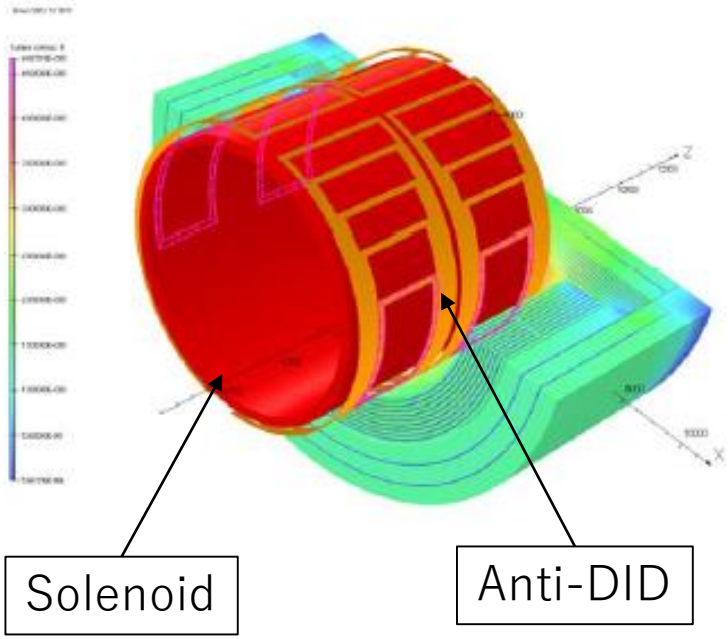
Conceptual Design of the ILD Detector Magnet System

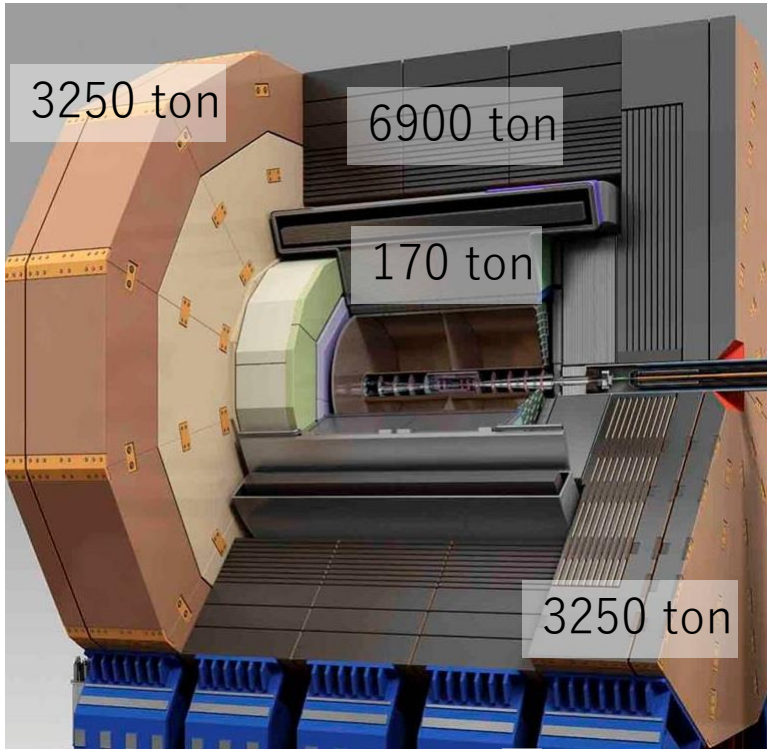
Magnetic Field Requirement for Physics

- ILD detector design asks for
  - **solenoidal** magnet field of **3.5 T and 4 T in maximum** central field in a warm aperture **of 6.88 m in diameter and 7.35 m in length**.
  - Anti-DID (Detector Integrated **Dipole**) horizontal magnetic field of **0.035 T in maximum within Z=0.3 m**.
  - No stringent field homogeneity is required, but **an accurate field mapping will be requested** before installation of the sub-detectors inside the solenoid. Mainly **for the TPC** as main tracking detector.
  - For safety reasons, **constraints** have been put on the **fringe field should be less than 50 Gauss at 15 m from the interaction point (IP)** in the radial direction.
  - Iron yoke, besides **returning and shielding the solenoidal magnetic field**, will be instrumented to be used for **the detection of muons and for measuring showers** .

ILD Magnet General Design

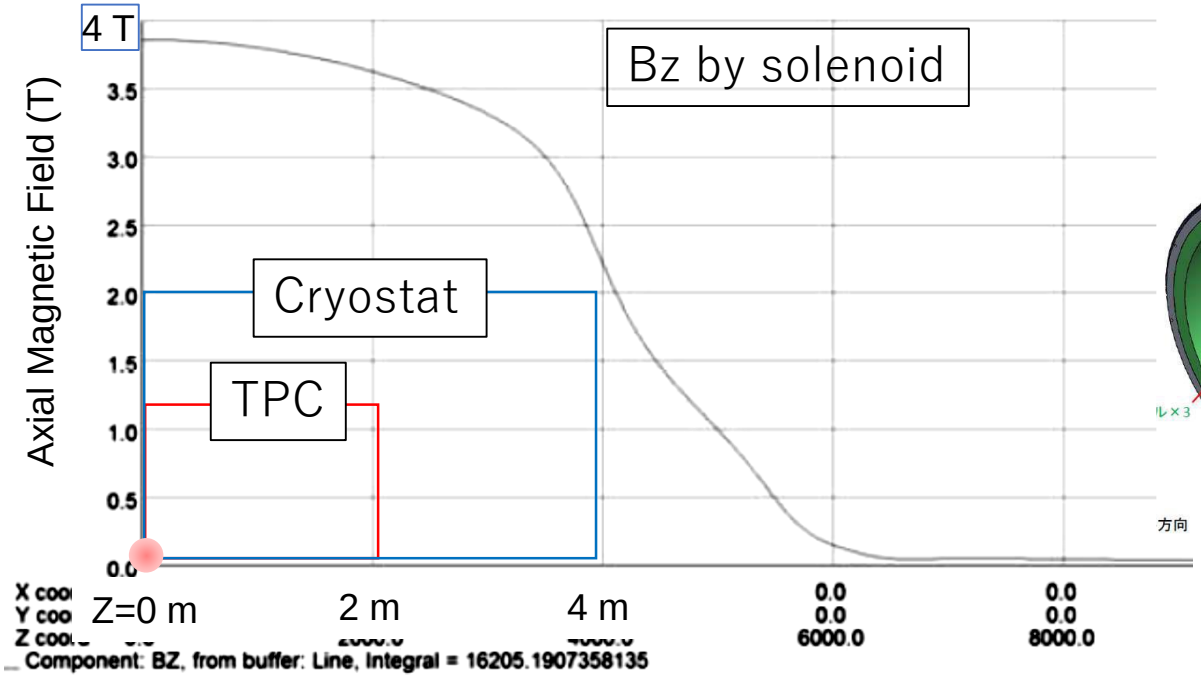
- Many technical solutions successfully used for CMS are proposed for the design of the ILD magnet.
  - Solenoid coil, made of 3 modules, mechanically and electrically connected.
  - A multi-layer coil geometry is required to obtain the 4 T.
- Presence of anti-DID complicates coil design.

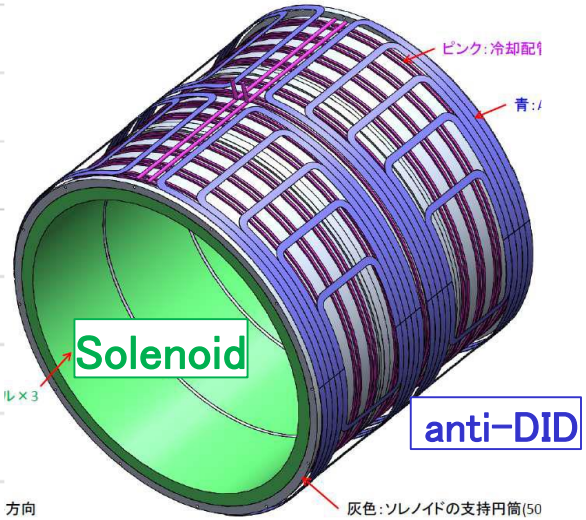


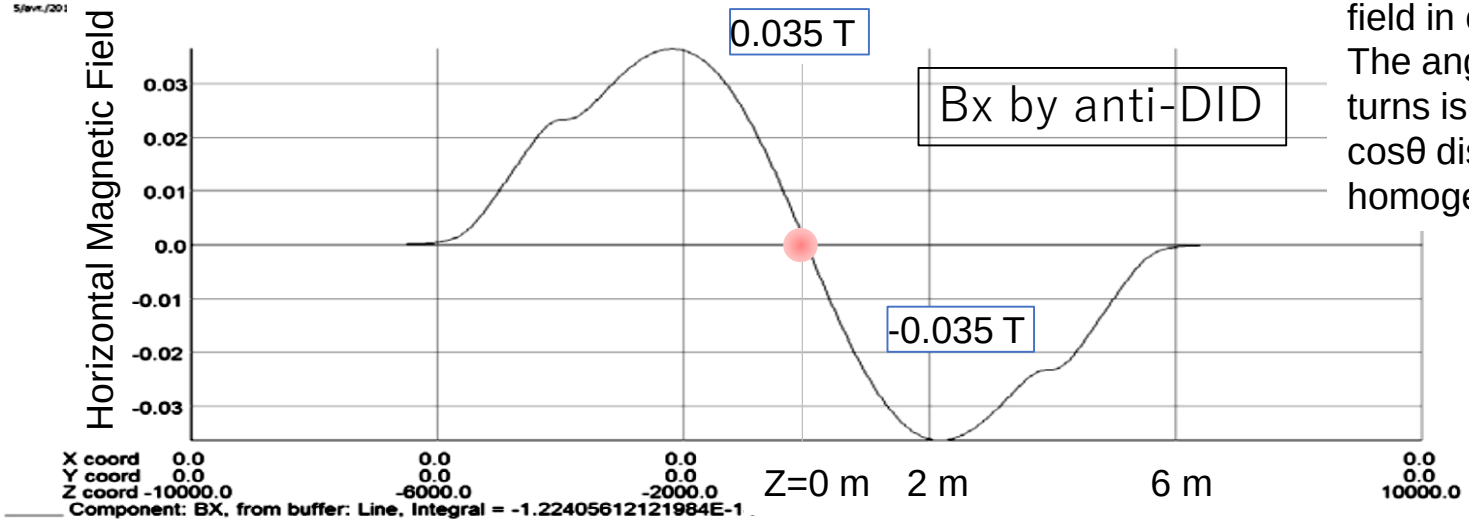


Cut illustration of ILD magnet

ILD Magnetic Field







The anti-DID coil is formed with two dipoles centered on the beam axis with magnetic field in opposite direction. The angular distribution of the turns is such as to get an cosθ distribution to obtain a homogeneous dipole field.

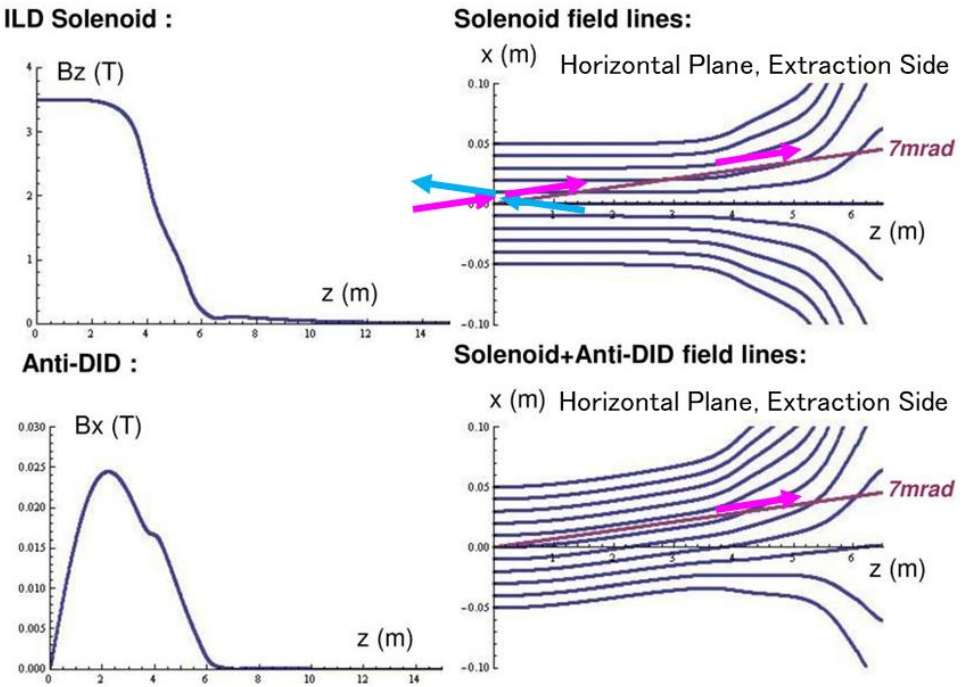
ILD Solenoid Design

Coil Inner Radius (mm)	3615
Coil Outer Radius (mm)	3970
Coil Length (mm)	7350
Cold Mass Weight (ton)	**170**
Turn × Layer	309 X 4
Nominal Current (kA)	22.4
Current Density (A/mm^2)	10.6
Central Field (T)	4.0
Maximum Field (T)	4.6
Inductance (H)	9.2
Stored Energy (GJ)	2.3
S.Energy / Cold Mass (kJ/kg)	13
Support Shell Thickness (mm)	50
Cryostat I. R. (mm)	3440
Cryostat O. R. (mm)	4400

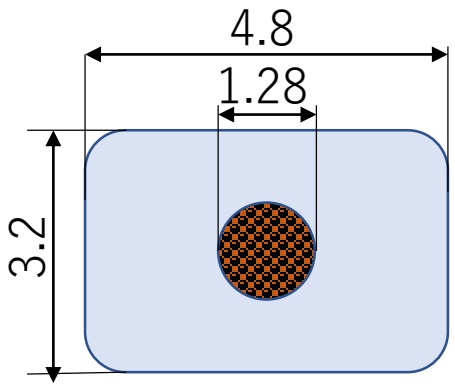
- A multi-layer coil geometry is required to obtain the 4 T.
- Similarly to CMS, a 4-layer coil was retained, with a nominal current in the range of 20 kA.
- The 7.35 m length of ILD coil enables to make it in **3 modules**, each 2.45 m long.
  Odd number of module is preferable , because in case of even number, an interface between modules is set at the coil mid-plane where the axal compressive forces are at a maximum and delamination risk in the module-to-module coupling region should be reduced.
- **Each conductor length** of 1 layer, 103 turn, in 1 module is **2.6 km**, that is fine for conductor fabrication..
- The coil is wound with inner winding technique, where **aluminum alloy support cylinder of 50 mm thickness** is used as an external mandrel.

ILD anti-DID (Detector Integrated Dipole) Design

Design Max. Dipole Central Field on Beam Axis (T)	0.035
Position of max Bx within Z (mm)	3000
Maximum Field on Conductor (T)	2.0
Anti DID I.R. (mm)	4160
Anti DID Length (mm)	6820
Nominal Current (A)	615
Current Density (A/mm^2)	40
Conductor size (mm x mm)	4.8 x 3.2
Inductance (H)	23
Stored Energy (GJ)	4.4

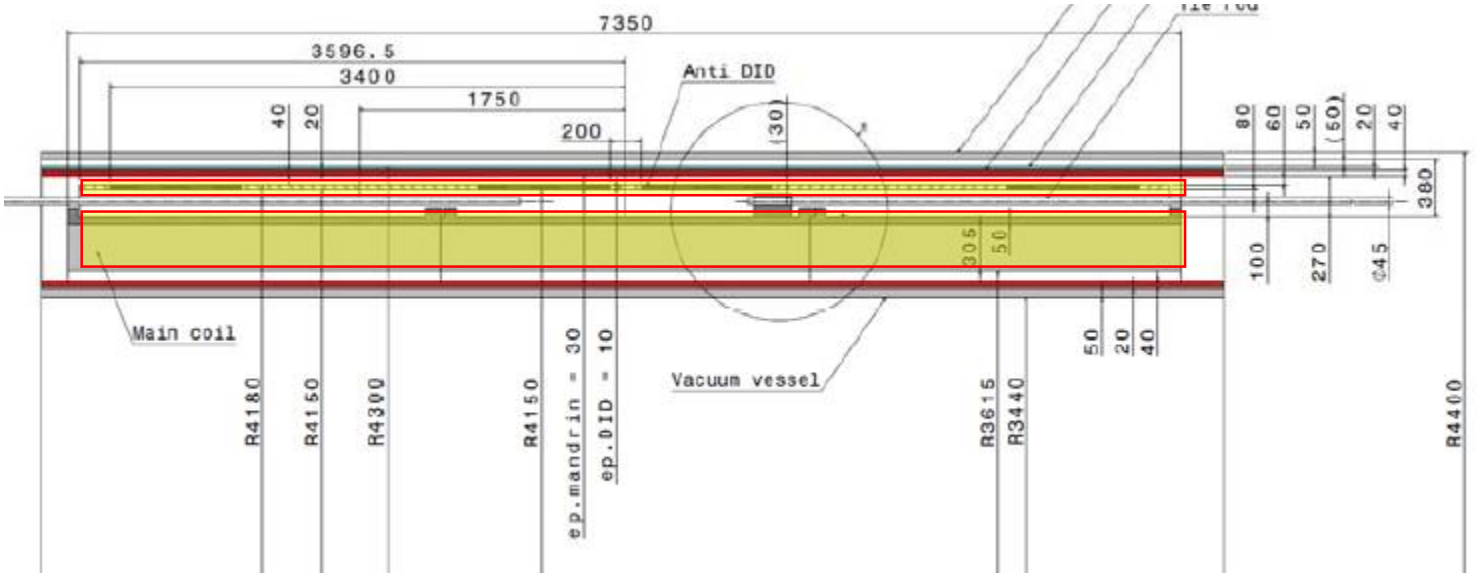


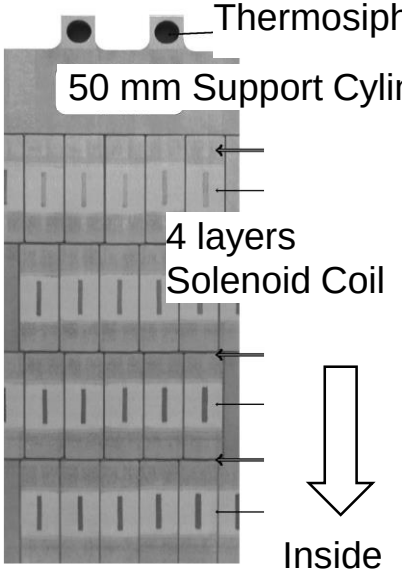
Anti-DID makes improved flux direction along the beam line. Low energy electrons & positrons, background, are kept inside the beam pipe.

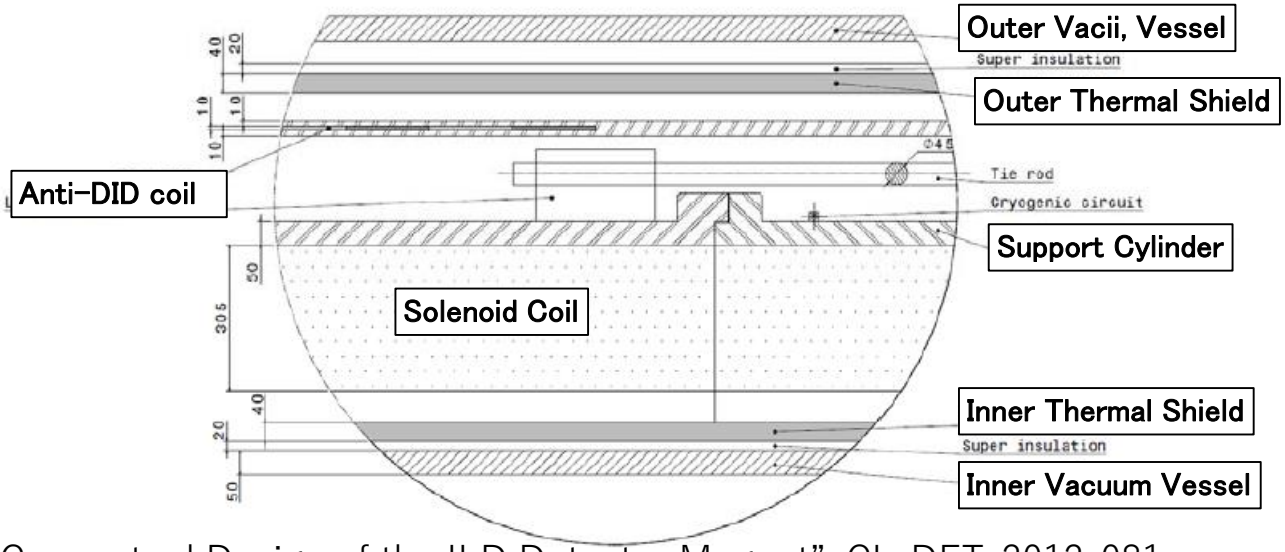


The anti-DID is located within **the same cryostat** as the main solenoid, and benefits from the cryogenics of the main coil. It will be fixed on the mandrel of the solenoid .

ILD Cryostat Configuration



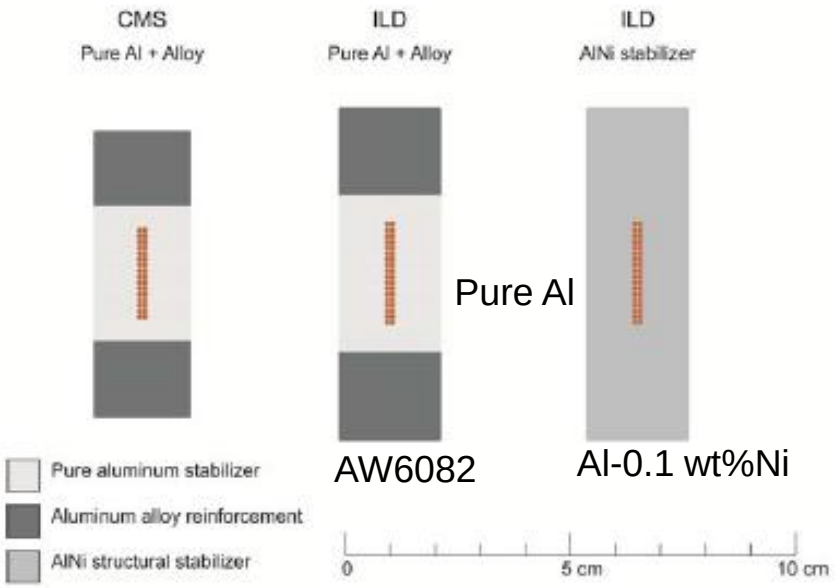


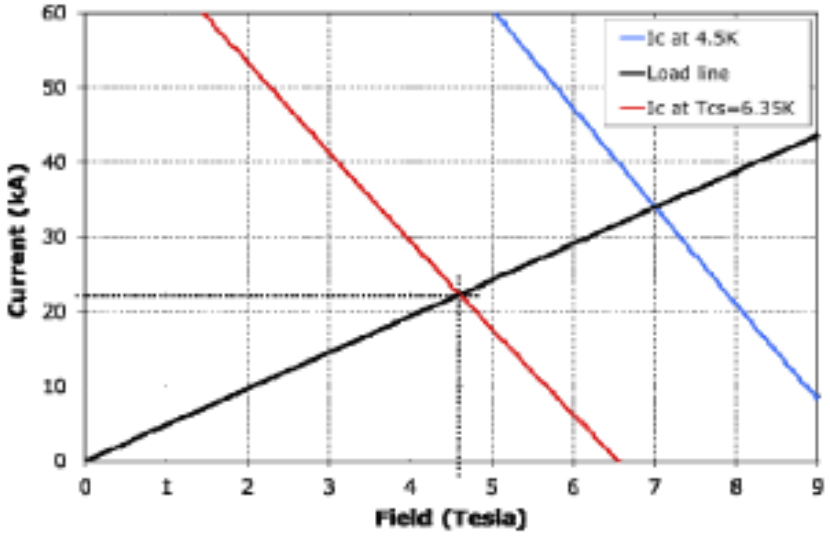


From F. Kircher etc., " Conceptual Design of the ILD Detector Magnet", CL-DET-2012-081

ILD Superconducting Conductor

Superconducting Strand in virgin state	
Strand diameter (mm)	1.28
Cu matrix / NbTi	1.1 ± 0.1
Jc (A/mm^2) @ 4.2 K, 5 T	3300
Rutherford Cable	
Number of Strand	36
Cable Transposition Pitch(mm)	185
Final Conductor (AL clad)	
Overall Dimensions (mm x mm)	**74.3 X 22.8**
Total Length (km)	**32**
Spool #, Length (km) per spool	**12, 2.6**
Al/NbTi	≈75
Critical Current (A @ 4.2 K, 5T)	67500

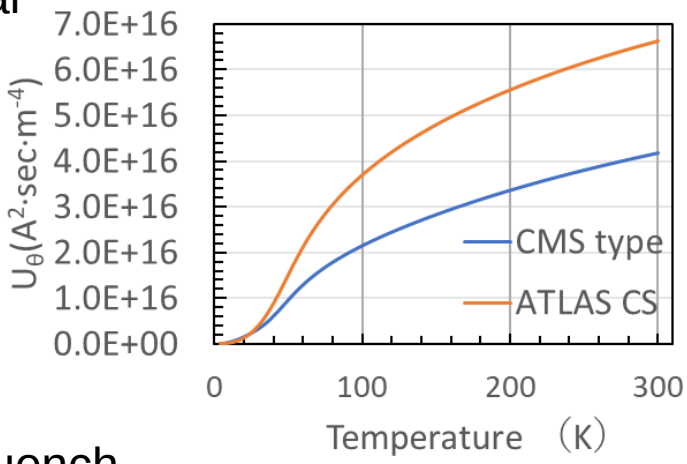




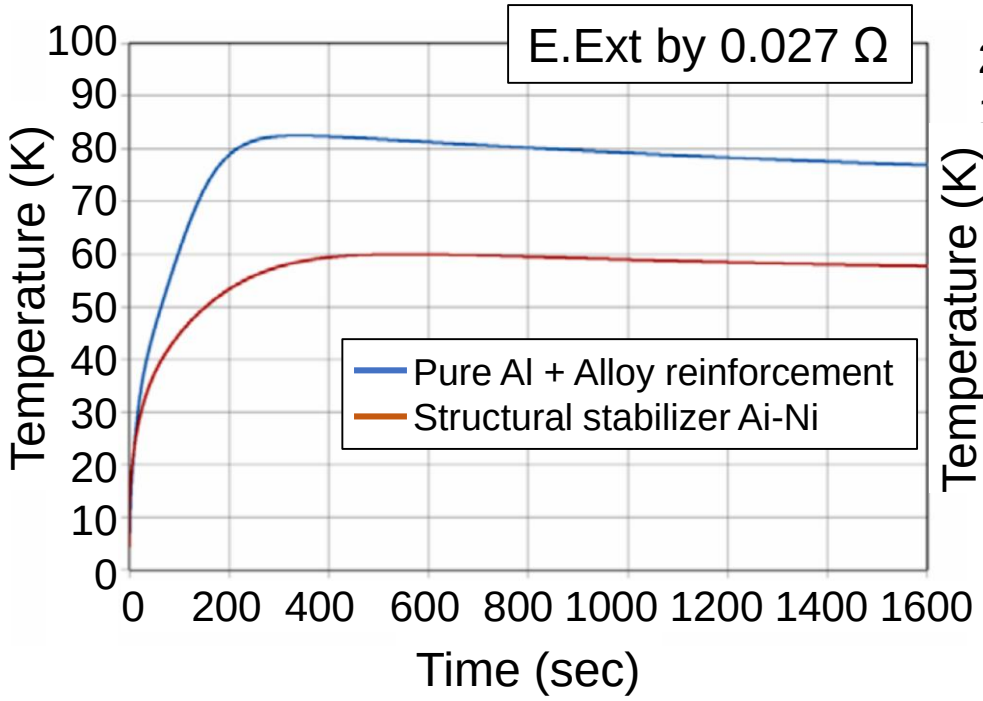
- Conductor consists of a superconducting Rutherford cable, sheathed in a stabilizer and mechanically reinforces.
- Two solutions are considered for the reinforcement. ATLAS CS type or CMS

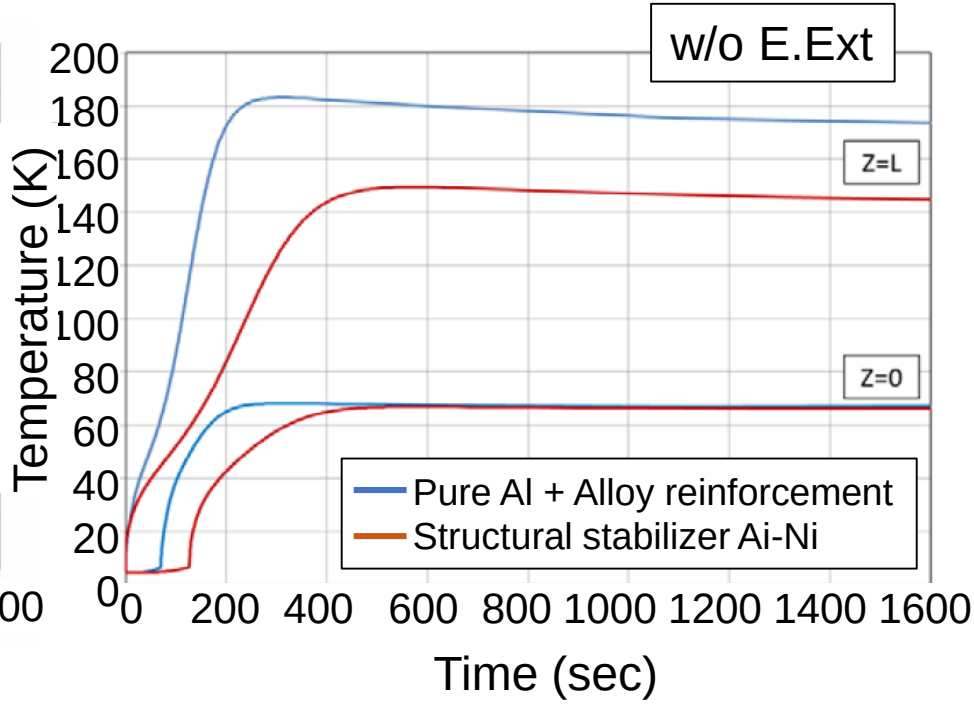
Coil Quench Protection

- In a classical way, the coil protection uses an external dump circuit. A dump circuit with 600 V terminal voltage extracts 56 % of the stored energy.
- In unlikely case that external dump process is not activated, quench propagation and temperature rise are estimated. The temperature reaches 185 K for CMS type conductor (resp. 150 K ATLAS CS type) and minimum temperature is about 65 K. ΔT< 120 K.



Temperature Rise after Quench





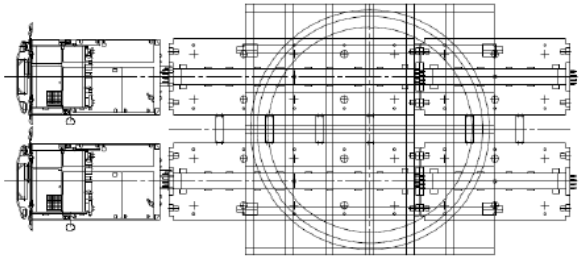
Transportation of coils from factory

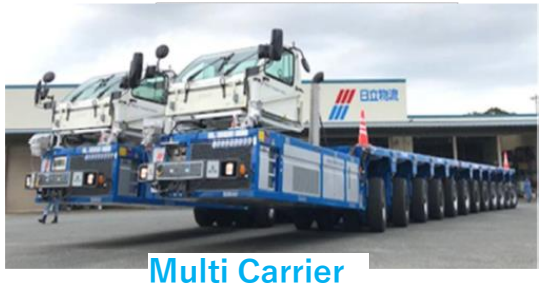
Coil Module Transportation

	Solenoid	Support Cylinder	Anti DID
ID(mm)	7230	7940	8300
OD(mm)	7940	8100	8360
L(mm)	7350	7350	6820
Density (g/cc)	2.7	2.7	2.7
Weight (ton)	168	40	14
1/4(ton)			3.7
1/3 (ton)	56	70	14

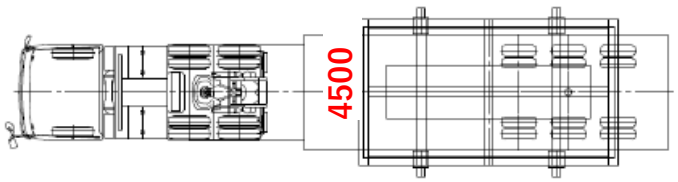
1/3 Solenoid Coil Package	
Dimension	8500 × 8500 × 3608 mm^3
Weight	**90.0** ton (module **70** ton)
Package No.	3

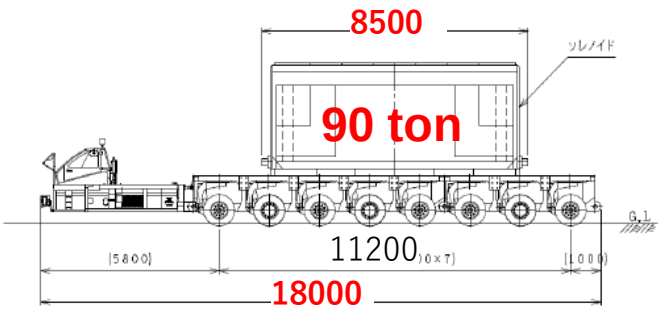
1 Anti-DID coil Package	
Dimension	8500 × 4500 × 3500 mm^3
Weight	16.0 ton (coil **3.7** ton)
Package No.	4

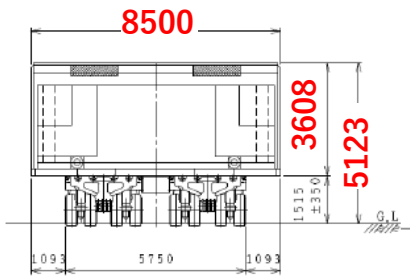


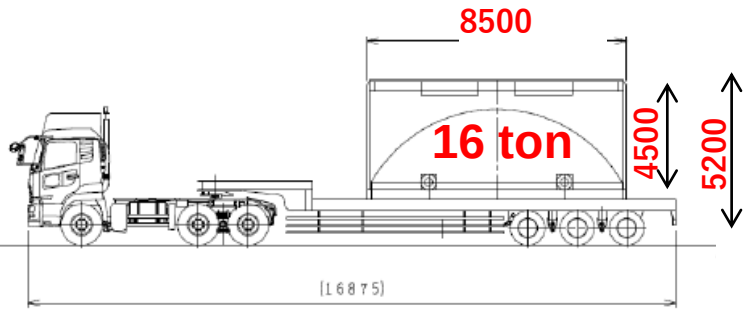


Multi Carrier



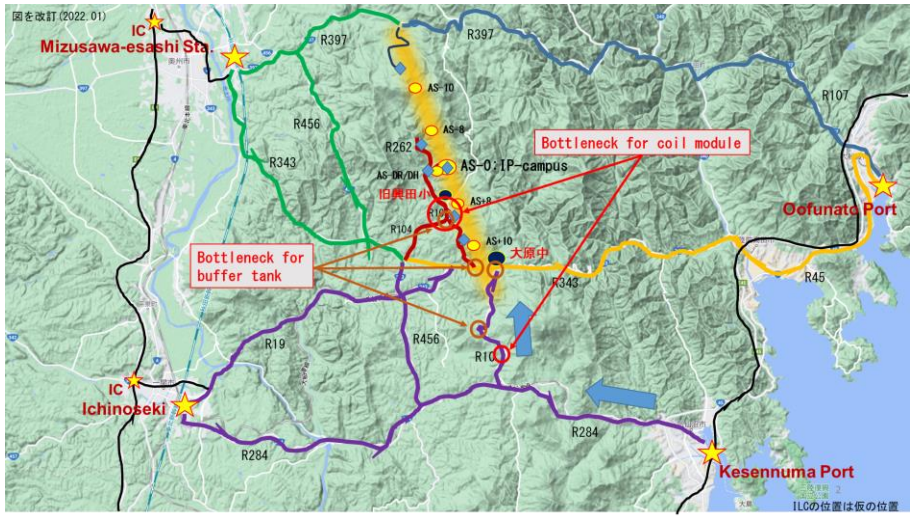






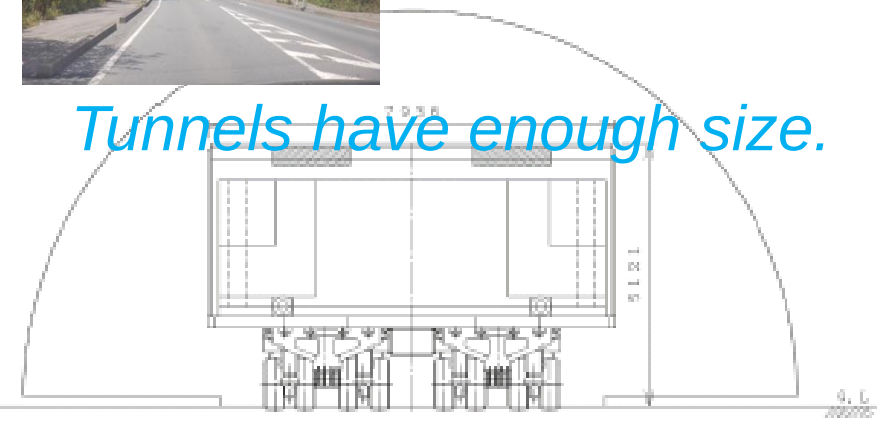
Land Transportation from a port to IP

Land Transportation is not impossible, but



- There are many traffic signs, signals, poles, lights and fences to be temporally removed.
  - 154 points (upper obstacle 60 points)
  - Trees are not counted.
  - Preparation and recovery cost may be comparable with transportation fee.
- Some bridges must be reinforced.
  - Reinforcement cost may be huge.
- Permissions and public approvals are necessary to occupy the road and removing road instruments.

Tunnels have enough size.



Keeping stacking height less than GL4.9 m, number of obstacles is reduced to about 100. Keeping stacking width less than 6.0 m is more effective. So, smaller package size should be considered.

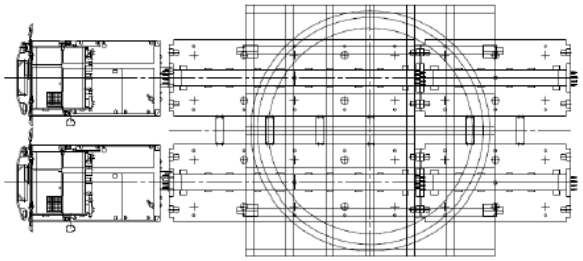
SiD Coil Module Transportation

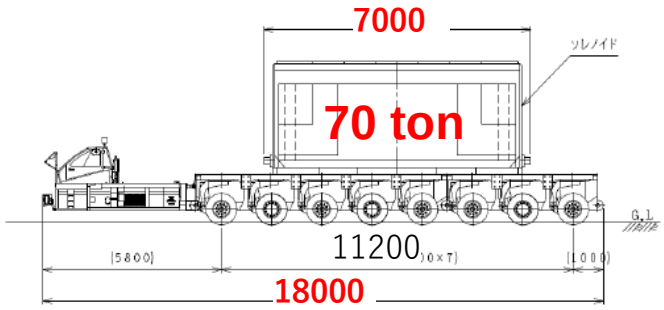
	Solenoid	Support Cylinder	Anti DID
ID(mm)	5462	6224	6324
OD(mm)	6224	6324	6404
L(mm)	5586	5586	5586
½ L (mm)	2793		
Density (g/cc)	2.7		
Weight (ton)	133		
½ Weight(ton)	70		

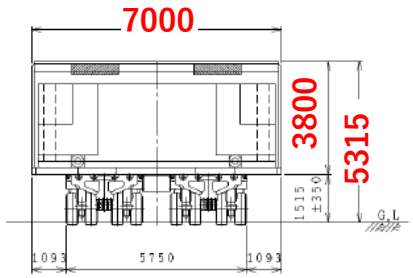
½ Solenoid Coil + 1 anti – DID coil Package	
Dimension	7000 × 7000 × 3800 mm^3
Weight	90.0 ton (module **70** ton)
Package No.	2

Keeping stacking height less than GL4.9 and width less than 6.0 m is desirable.

So, SiD modules transportation is costly and need public agreement.







Onsite manufacture of cold mass

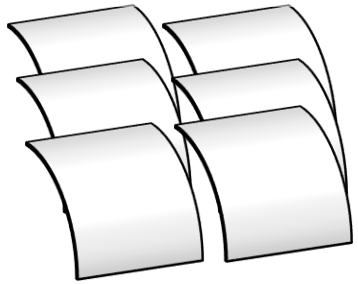
Outline of ILD Coil manufacturing process
Onsite winding and assembly

SC conductor
From Factory

In Assembly Hall (AH)
or Winding factory
neighboring AH
Coil Winding

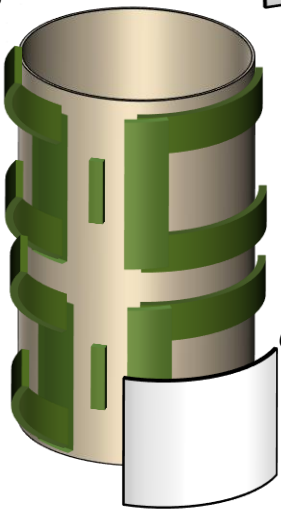
From P. Fabbricatore, I
EEE Trans. Appl. Super., Vol. 12, p.358

Thermal shield
From Factory

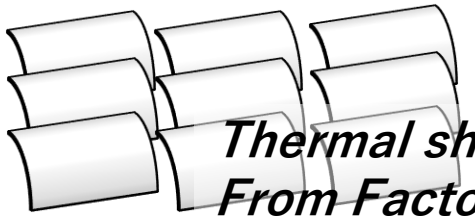


Support cylinder
welded in AH

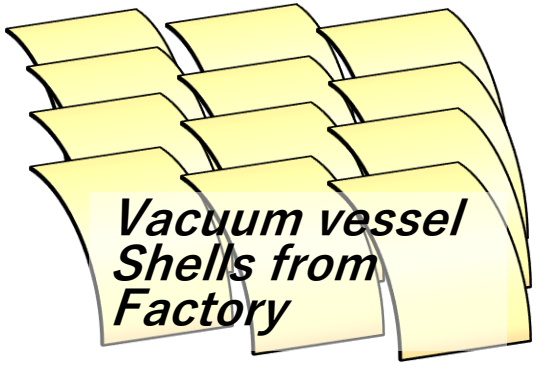
In AH
Cold mass
assembly



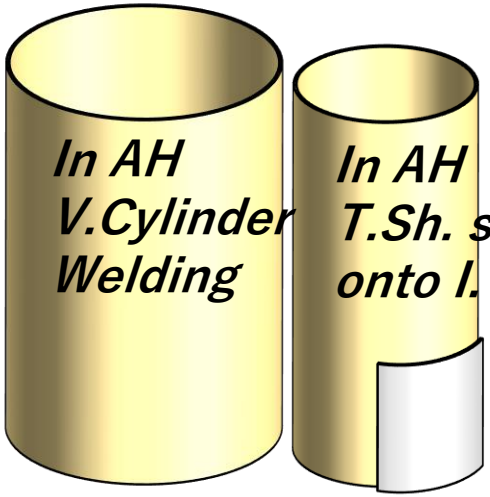
T.Sh. setting
onto C.Mass



Thermal shield
From Factory



Vacuum vessel
Shells from
Factory

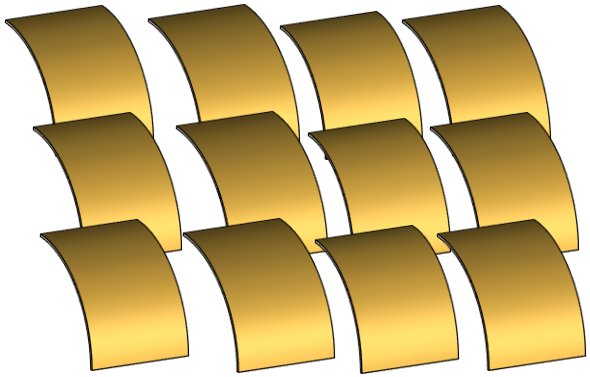


In AH
V.Cylinder
Welding

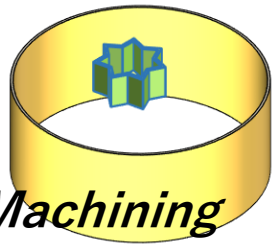
In AH
T.Sh. setting
onto I.V.V.

In AH
Cryostat
Assembly

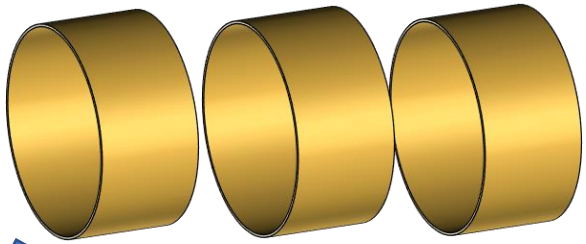
Onsite manufacture of cold mass (solenoid coil)



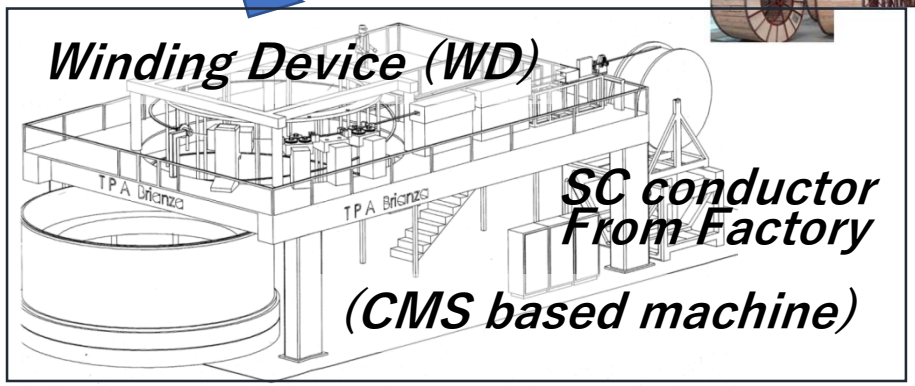
Welding shells *to support cylinder*

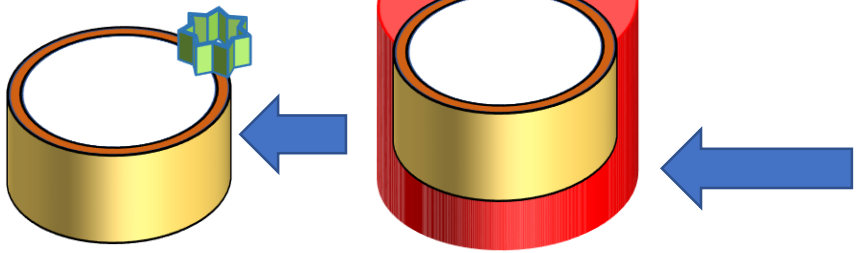


Machining
to make smooth surface for winding
GND Insulation



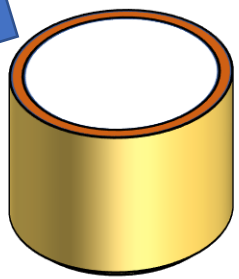
Set support cylinder onto WD



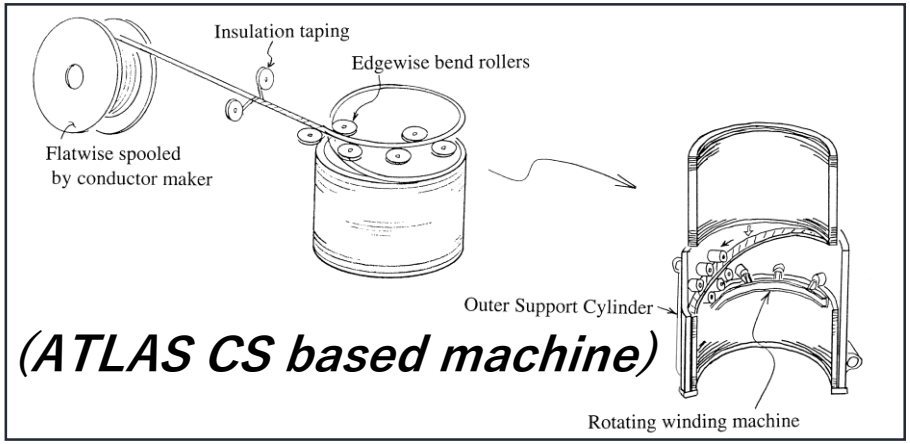


Auto clave

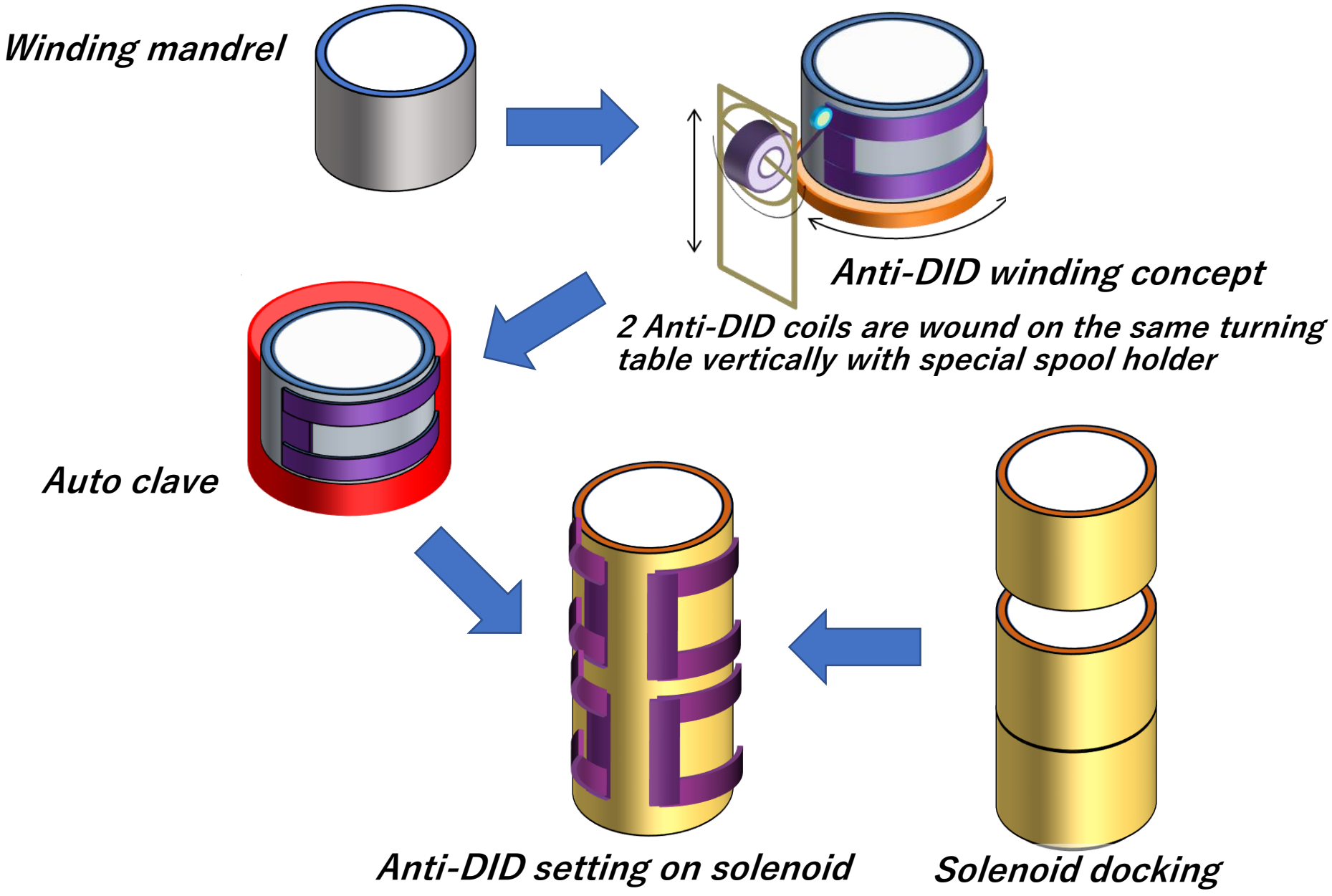
Lathe
to make flat surface for stacking



Complete
1/3 solenoid

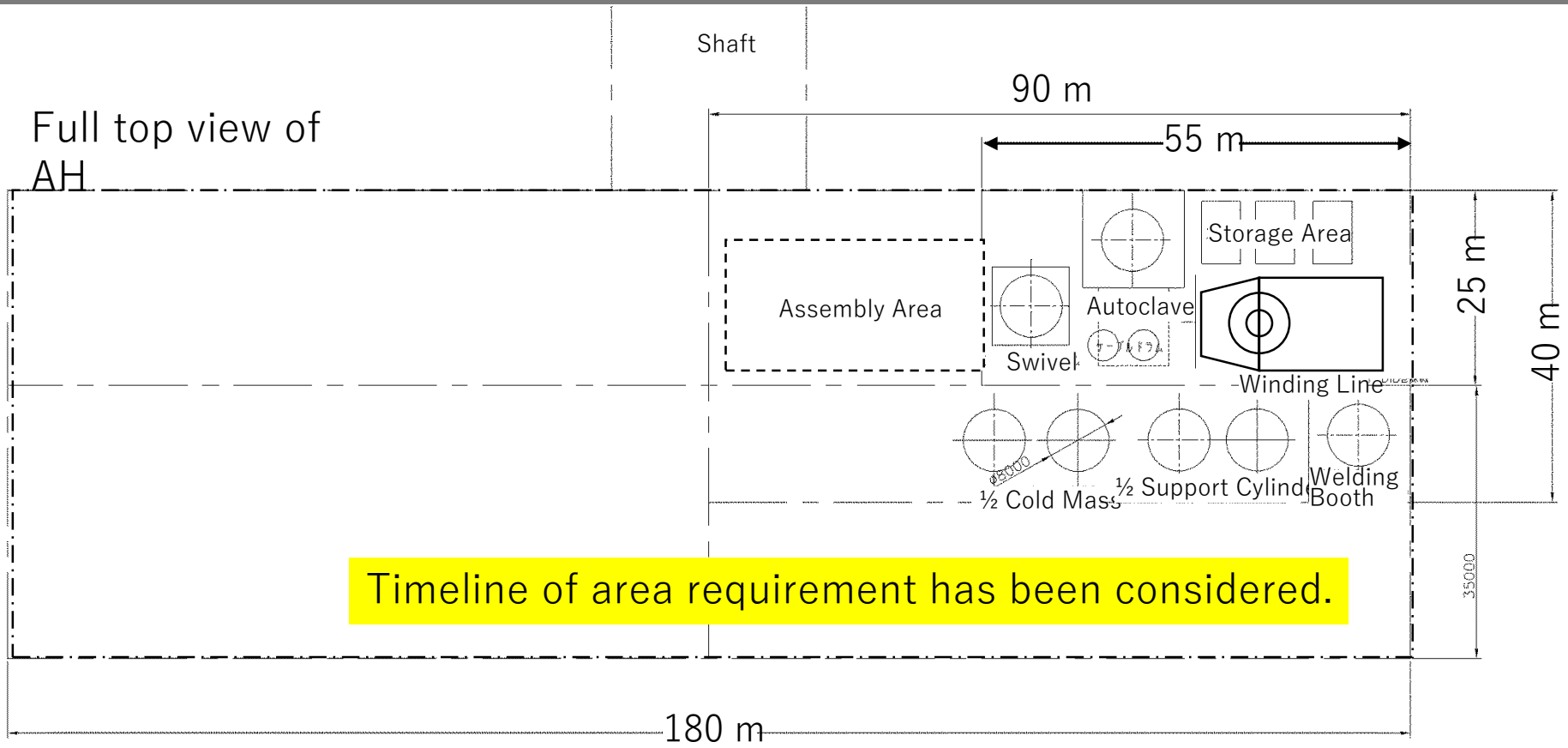


Onsite manufacture of cold mass (Anti-DID)



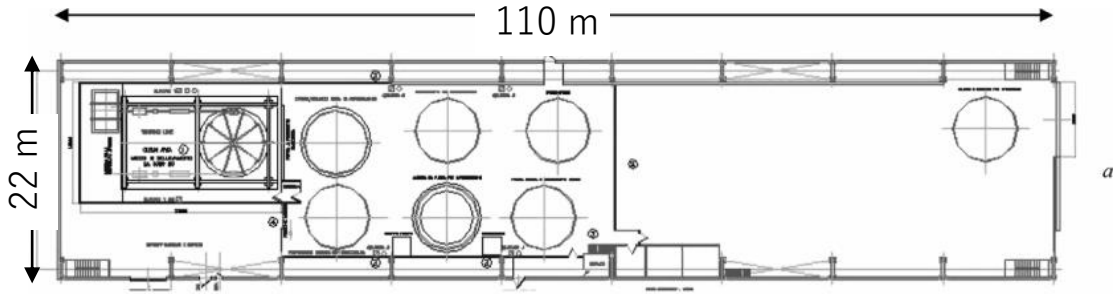
Workplace in AH for SC Magnet

Full top view of AH



Timeline of area requirement has been considered.

CMS Case

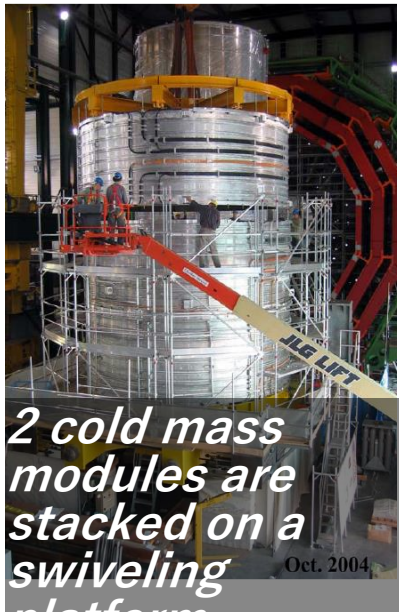


Conclusion

- Technical design of ILD magnet is summarized.
  - **solenoidal** magnet field of **3.5 T and 4 T in maximum** central field in a warm aperture **of 6.88 m in diameter and 7.35 m length**.
  - Anti-DID (Detector Integrated **Dipole**) horizontal magnetic field of **0.035 T in maximum in Z=0.3 m**
- Conductor consists of a superconducting Rutherford cable, sheathed in a stabilizer and mechanically reinforces.
  - It has the overall dimensions of **74.3 X 22.8** mm^2. Length demand is 32 km, breakdowns 2.6 km x 12 spools.
  - Two solutions, CMS type, ATLAS CS type, has been considered.
- Magnet manufacture procedure has been investigated with the cooperation by magnet makers, forwarding agents and local support organizations.
  - In the CMS experience, the coil modules were manufactured in the factories and were transported to the experimental site.
  - It is not impossible for ILD coil module to be transported on surface, but its cost and getting public agreement to occupy regional traffic has been promoting its onsite winding.
  - Anyway many technical methods, direct-internal-multilayer winding

Back Up Slide

Cryostat Assembly (Learning by CMS experience)



2 cold mass modules are stacked on a swiveling


Setting outer thermal shield Horizontal


Inserting the cold mass + O.Th.S
Inserting Inner V.V + I.Th.S


Descent to cavern


Cryostat


Setting Outer Vacuum V


ke Center

These photos are copied from CMS web s