ILC – GENERAL INSTALLATION EQUIPMENT

Presentation to LCWS Workshop in Beijing 27 March 2010

Outline

- General issues
- ILC cryo-modules
- Underground transport and handling solutions
- Conclusion
- *(Slope facts and issues)*

Need to consider all phases

- Delivery of components
- Assembly
- Test
- Storage (LHC experience –this will be needed)
- Transfer to shaft (road transport)
- **Lowering (crane or lift ?)**
- **Loading underground**
- **Transport along tunnel (co activities)**
- **Unloading / Transfer onto supports (time constraints)**
- **Removal for repair**

Integration issues

- Space for transport , unloading and transfer
  - With guidance error margin
  - Allow co-activity (passage next to transport zone)
- Space for power rail
- Space for loading lowered items
- Consider logistics (parking and passing places)
- Integration should include space for removal
- Try to integrate transport and handling design issues into equipment and infrastructure design at an early stage.

CIVIL ENGINEERING TOLERANCES

- Important to know how much space is available for transport.
- LHC experience – LEP tunnel moves with respect. to beam line – this can make up to 100mm difference to space available at junction floor to tunnel wall
- Assumption after discussion with J Osborne: Space available will be as shown on theoretical drawings (CE tolerances will be specified accordingly)
- Tunnel floor is always much more stable and more exact than tunnel ceiling. Preferable to install heavy machine components on the floor.

SLOPES…

Effect of slope on vehicle design:

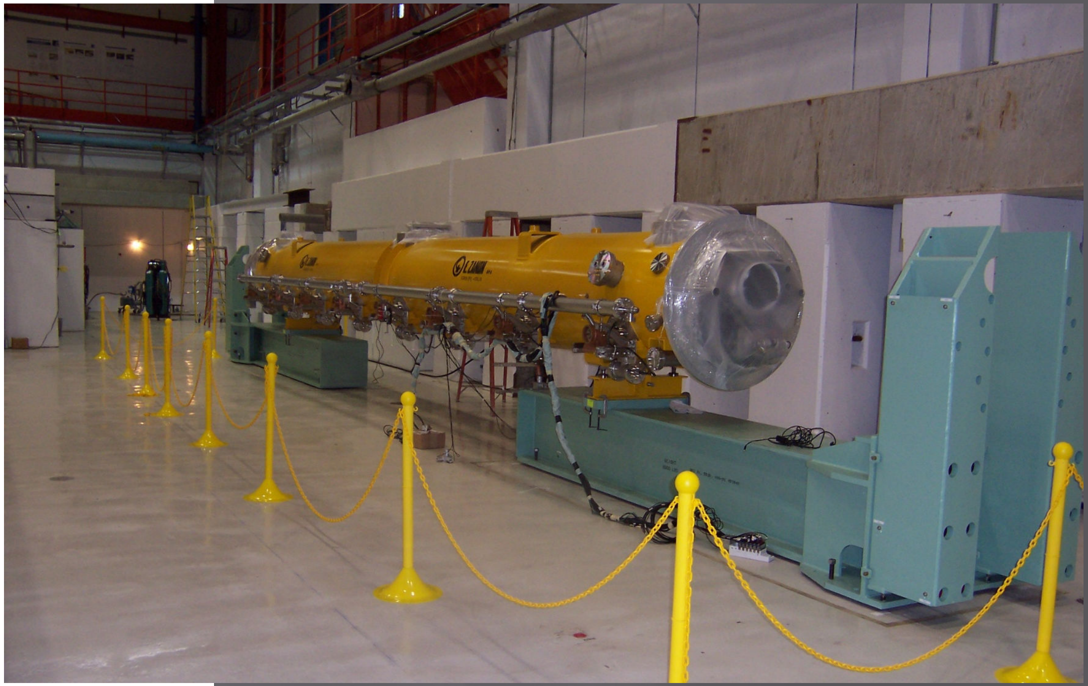
- Need more traction force
- Need more braking force
- Cooling of motors (duty factor)
- Cooling of brakes
- Bigger vehicle (integration)

ILC - Transport Study Specification Sheet

FNAL, Dec. 10, 2008

ILC Cryomodules

Equipment Description	Value	Unit	Source of Information/Comments
Length	12.65	Meters	This is the length given in the ILC RDR of a future ILC-type cryomodule. The length of the "Type 3+" used at DESY TTF, XFEL, and Fermilab NML Test Facility is 11.98 meters. The length of the "Type 4" design developed at Fermilab is 12.35 meters (See "Cryomodule Dimensions" drawing).
Width	1.67	Meters	This is the total transport width of the Type 3+ and Type 4 crymodule, including the survey arm and attached coupler motor (See "Cryomodule Dimensions" drawing). At one time, there was some discussion of moving the survey arm to the other side of the cryomodule to reduce the width.
Height	1.34	Meters	This is th total transport height of the Type 3+ and Type 4 cryomodule, without any support feet or transportation device (See "Cryomodule Dimensions" drawing).
Weight	16260	Pounds	Actual measured weight of the Type 3+ cryomodule with interconnect bellows attached. An ILC-type cryomodule will be slightly heavier due to exta 0.67 meter length.
Support Points	8.30 x 0.64	Meters	This the distance between the support points on the bottom of the Type 3+ cryomodule (along the beamline, and transverse to the beamline, respectively). See "Cryomodule Attachment Points" drawing for details. The details of the support stand currently used at DESY and Fermilab are shown on the "Adjustable Support Assembly" drawing. A new support stand will most likely be designed for the ILC.
Lifting Points	6.80 x 0.64	Meters	This the distance between the attachment points for the lifting fixture on the top of the Type 3+ cryomodule (along the beamline, and transverse to the beamline, respectively). See "Cryomodule Attachment Points" drawing for details.
Lifting Fixture Weight	4940	Pounds	The lifting fixture is used to lift the Type 3+ cryomodule with an overhead crane. It has a load capacity of 10-tons (20,000 pounds).
Transportation Fixture	2840	Pounds	The transportation fixture was designed at Fermilab by Mike McGee to minimize vibration of the cryomodule while transporting it on a truck. Details of this system have been well documented and tested and can be provided, if needed.
Maximum Acceleration	1.5	G	The conservative maximum value of acceleration for the Type 3+ cryomodule in the vertical, transverse, and longitudinal direction. This value was provided by Mike McGee of Fermilab and comes from a published report by Babcock Noell, who was contracted by DESY to study this. It has been determined through actual transport studies that somewhat higher accelerations are safe. More detailed information can be provided, if needed.
Natural Frequencies	9-11 13-15 19 21-23	Hz (x, y, and z) Hz (x and z) Hz (x, y, and z) Hz (x, y, and z)	These frequencies are results of actual measurements during transport studies. There are also calculated frequencies from Finite Element Analysis (FEA) modeling that agree very well with these measurements. Details can be provided, if needed. (x is transverse, y is vertical, and z is longitudinal)
Quantity to be Transported & Installed	1680	Cryomodules	This it the quantity of cryomodules given in the ILC RDR for the Main Linac.
Cryomodule String			The ILC is broken up into a number of cryogenic strings. Each string has support "girders" at each end to counteract the cryogenic vacuum loads, with a string of cryomodules in between. At this time, it is unclear as to how long each of these strings will be. The "Cryomodule Attachment Points" drawing shows a schematic of a cryogenic string.
Interconnection Details			The interconnects between each cryomodule within a cryogenic string consist of several cryogenic pipes, a vacuum beamline, and a large interconnect bellows. At the ends of each cryogenic string is a cryogenic end/feed cap and a warm vacuum section. The details of these interconnects are very complicated and require detailed discussions.
Tunnel Size	4.5	Meters	This is the inner diameter of the Main Linac Beam tunnel given in the ILC RDR. See "4.5M Service and Beam Tunnel Plan & Elev." drawing.
Position in Tunnel Cross-Section			See "4.5M Service and Beam Tunnel Plan & Elev." drawing.
Time Available for Transport & Installation			Unknown



Picture of the first cryo-module on its green support girders at Fermilab (cryogenic components not installed).

Reason for the 860 mm clearance underneath the ILC cryo-modules

Response from Jerry Leibfritz, FNAL

- This is what is used at DESY for FLASH and CMTS, and also at the Fermilab ILCTA.
- It is based on the large support girder that sits underneath the first and last cryo-modules of a string to counteract the large vacuum load and prevent movement of the cryo-module. The support stand sits on top of this girder.
- The cryogenic feedbox and endcaps are designed for this elevation and it would have been too expensive for us at Fermilab to redesign this, so we used basically the same design as DESY.
- When we were initially laying out the ILC tunnel, we tried to maximize the use of space, so we set the elevation of the cryo-module to be in the widest part of the diameter of the tunnel, allowing us to move it as close to the wall as possible.
- For a machine as big as the ILC, these components could be redesigned, so the cryo-module sits lower, but it would require some engineering effort.
- THE CURRENT BEAM POSITION IS HIGH ENOUGH TO ALLOW THE USE OF TRANSPORT VEHICLES WHICH INCLUDE THEIR OWN TRANSFER CAPABILITY; IT IS THEREFORE INTERESTING TO LEAVE IT WHERE IT IS!

Further discussions with Jerry Leibfritz

- 860mm (700 mm?) clearance underneath confirmed
- Interconnect clearance about a couple of cm.
- Lateral transfer OK (vertical OK for interconnects)
- Support anywhere (except bellows retraction space)
- Space under cryo-module can be left clear (cabling etc can be on floor on wall side of cryo-module)
- Assume a waveguide crossing tunnel at each cryo-module (headroom during operation).

LHC installation

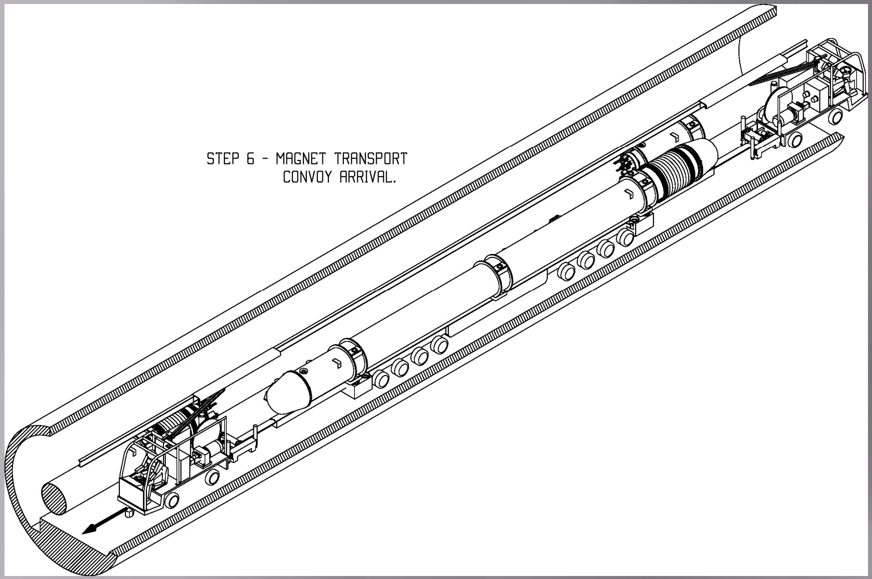
LHC	n°	Length (incl. protection covers)	Dimension	Weight	
Cryo-dipoles	1232 (+16)	16.4 m	Ø 1.1 m	34 t	42' 432
Cryo-quadropoles	360 arc 64 DS 90 LSS	7.5 m 9 – 10.5 m 7.5 – 15 m	Ø 1.1 m	8.5 t 5 – 23 t 5 – 23t	3'060 760 1'373
Resistive	205	1.2 - 6.4 m	max width 1.1m max height 1.1m	3 – 18t	1'025 (est.)
Total					48'650 t

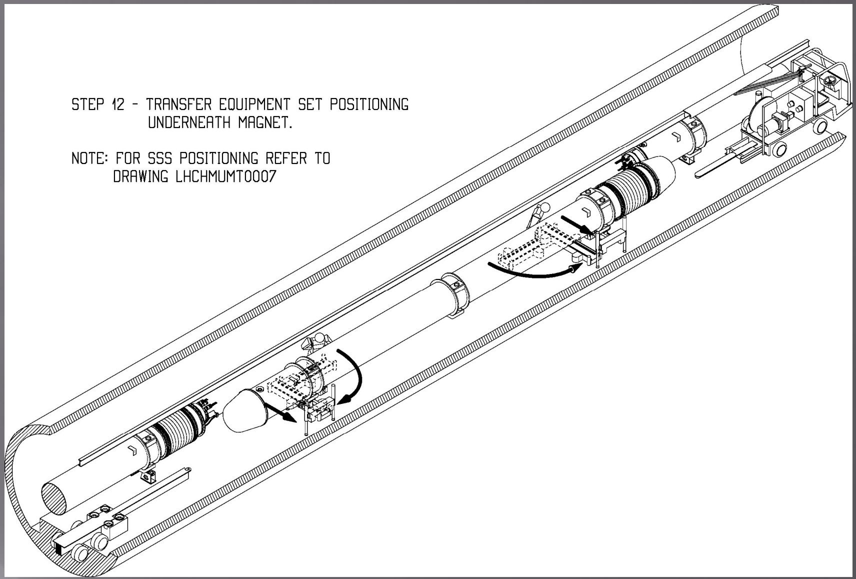
Difficulties for LHC cryodipole tunnel transport / installation

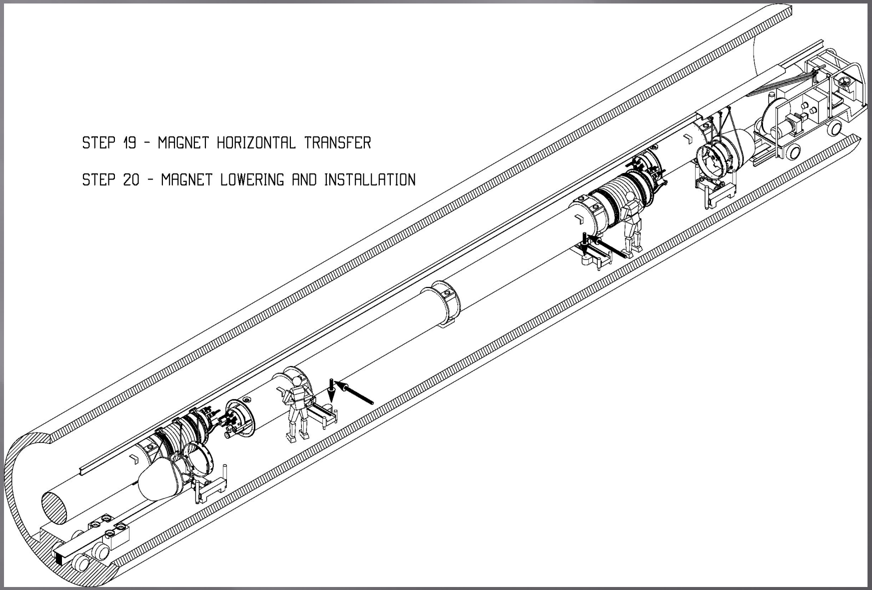
- Space
  - Laterally during transport and unloading
  - Underneath when placing on supports
  - Transport and installation blocks tunnel
- Overlapping interconnects (horizontal transfer)
- Fragility (cold feet)
- Proximity of support and lifting points
- Precise positioning needed to put on jacks
- One lowering shaft for whole ring

Implications

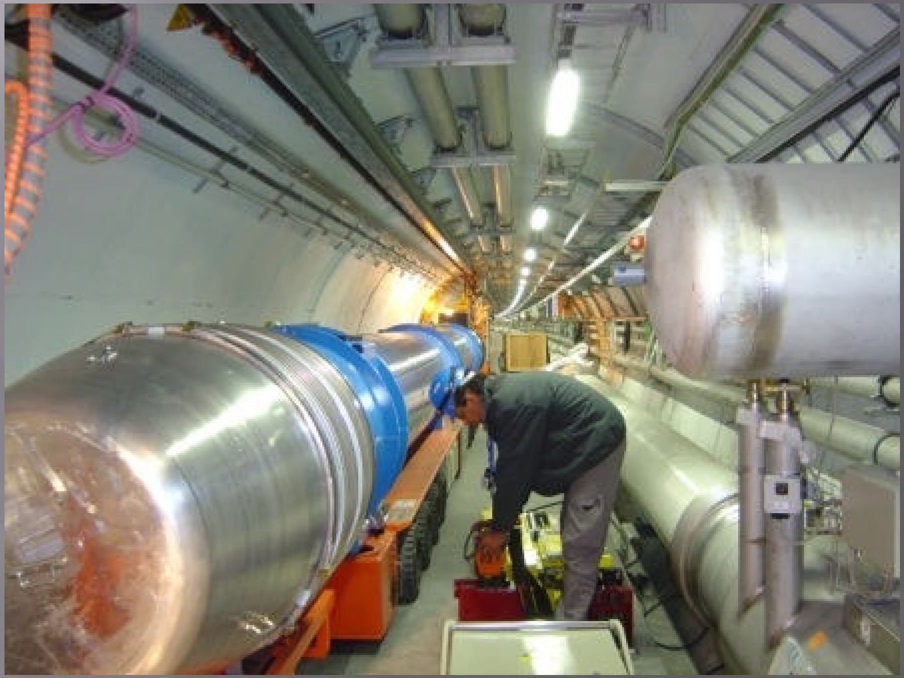
- Separate transport, unloading and transfer equipment
- Complex (prototype) very compact equipment
- Shock-log monitoring of each magnet
- Approx 2 hours to unload
- Complicated logistics


STEP 6 - MAGNET TRANSPORT
CONVOY ARRIVAL.

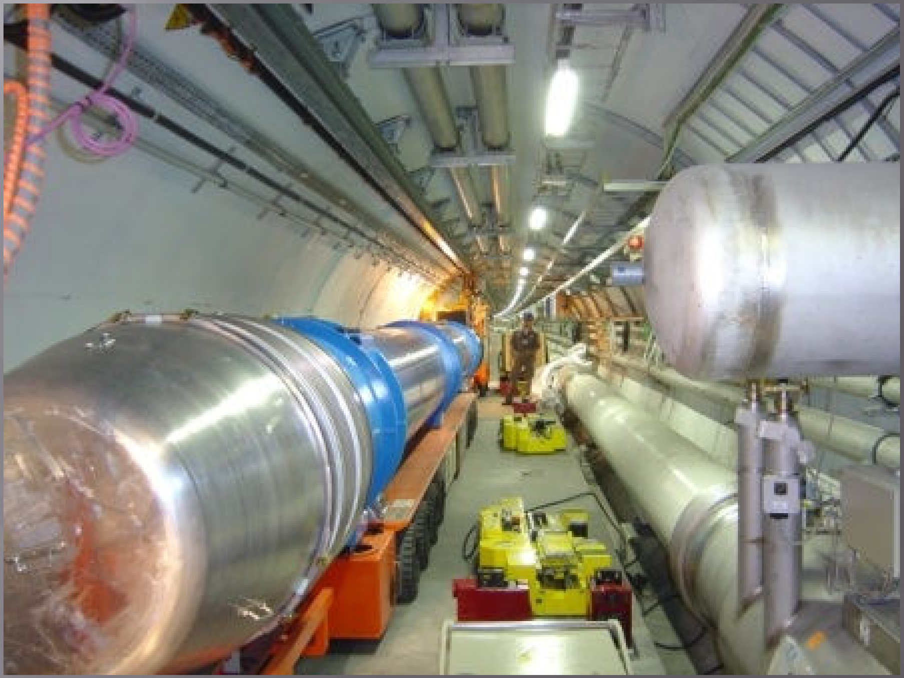

STEP 12 - TRANSFER EQUIPMENT SET POSITIONING
UNDERNEATH MAGNET.
NOTE: FOR SSS POSITIONING REFER TO
DRAWING LHCHMUMT0007


STEP 19 - MAGNET HORIZONTAL TRANSFER
STEP 20 - MAGNET LOWERING AND INSTALLATION

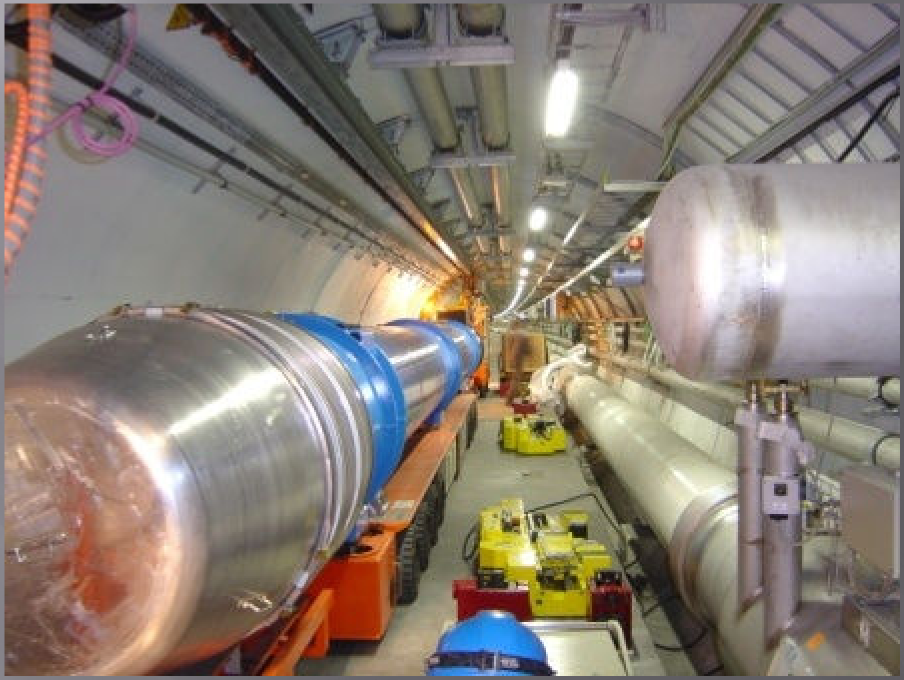
LHC Cryodipole installation sequence

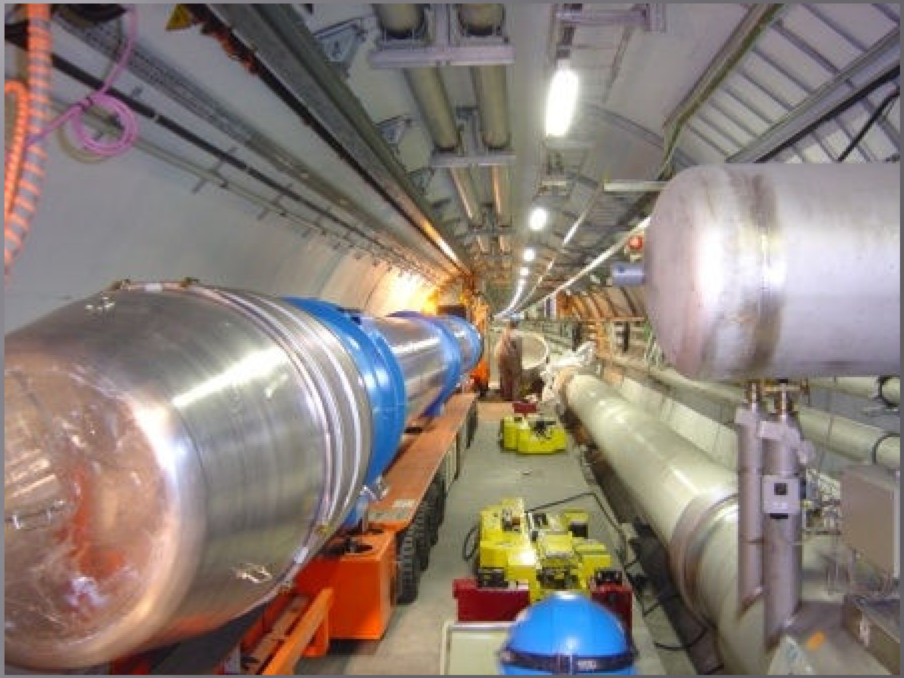


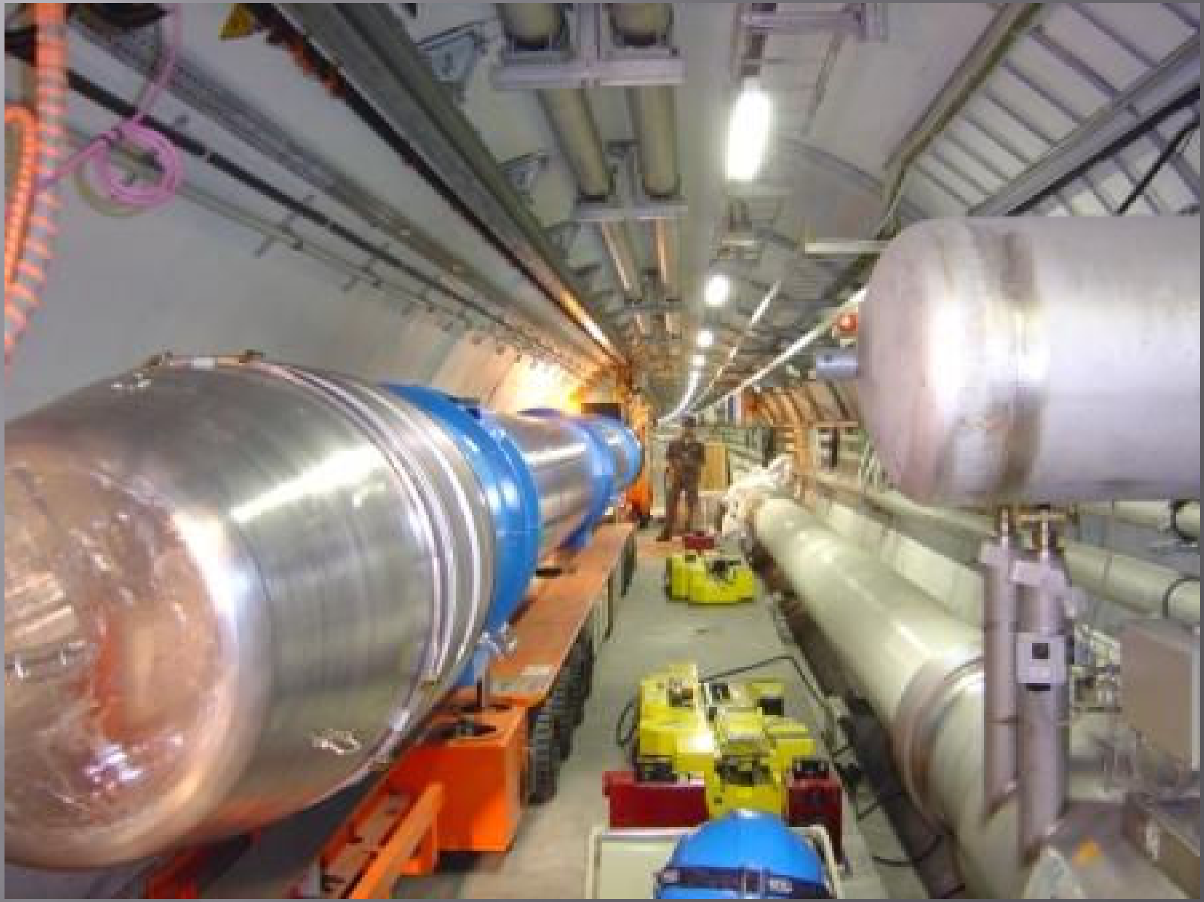
Lift magnet



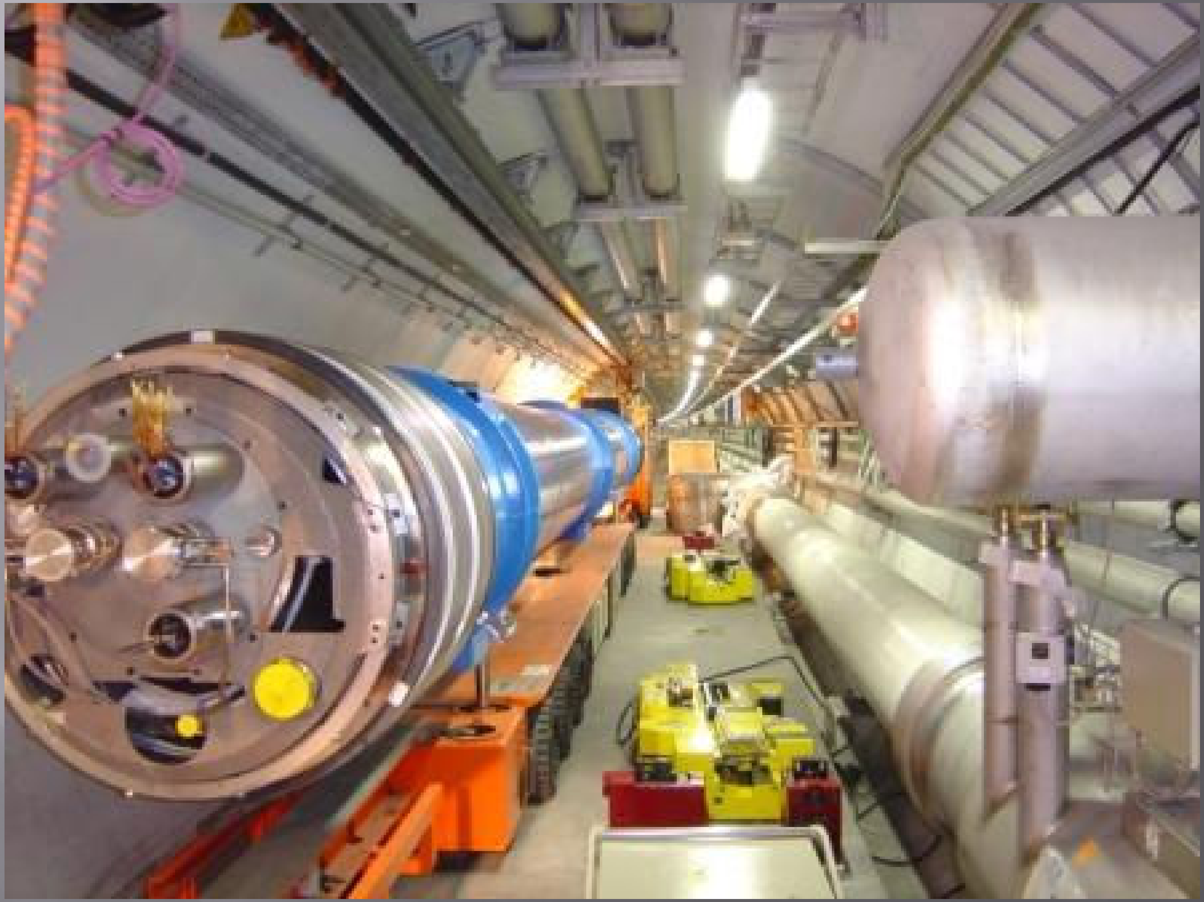
Trailer height 530 mm resp. 500 mm

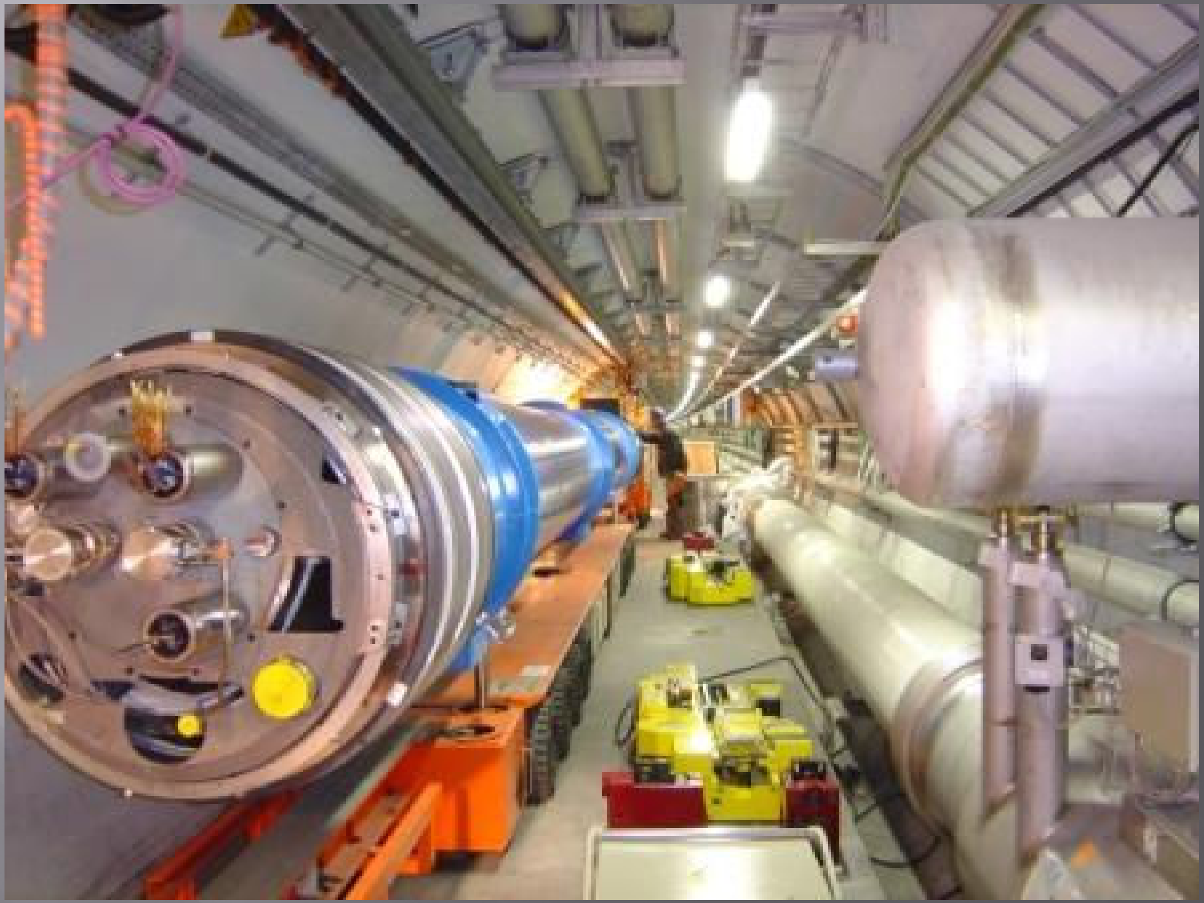


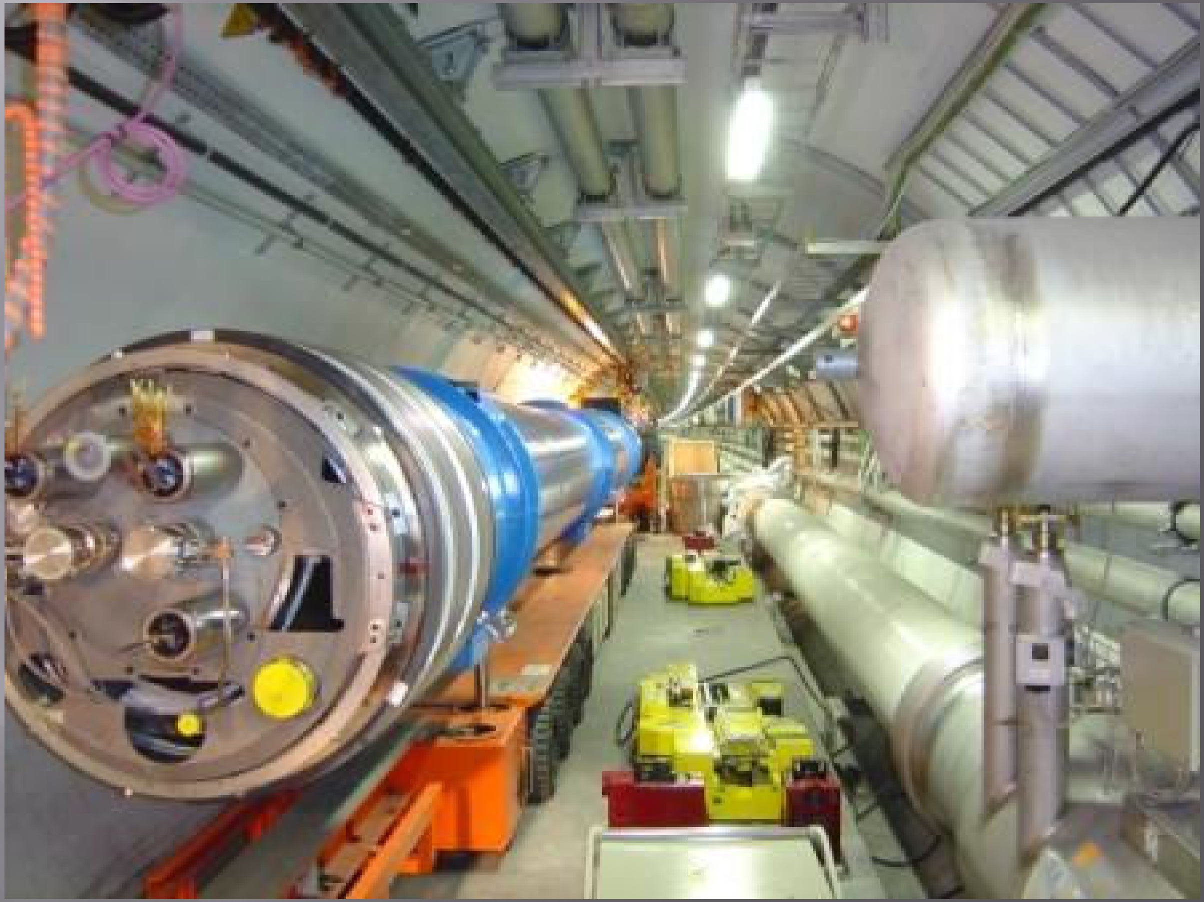


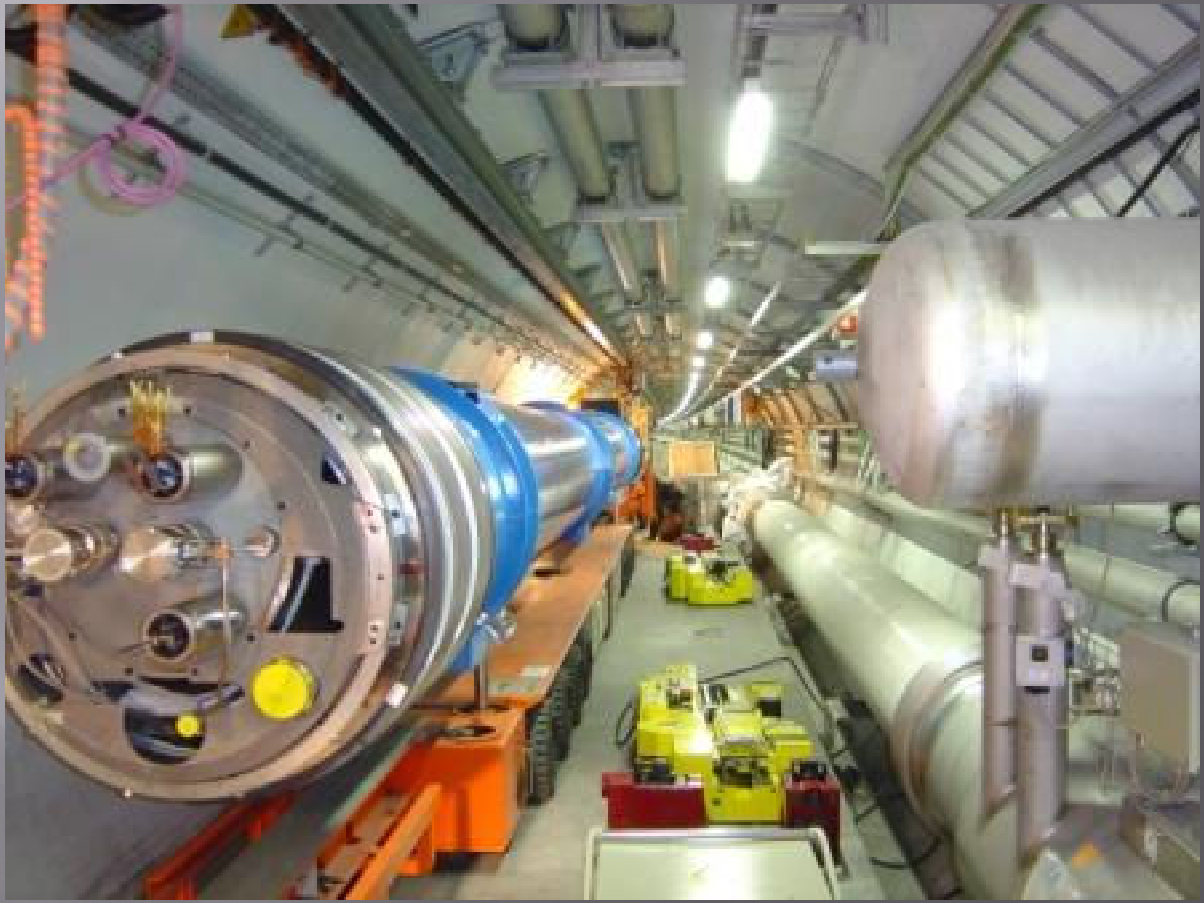


- Lifting stroke 250 mm

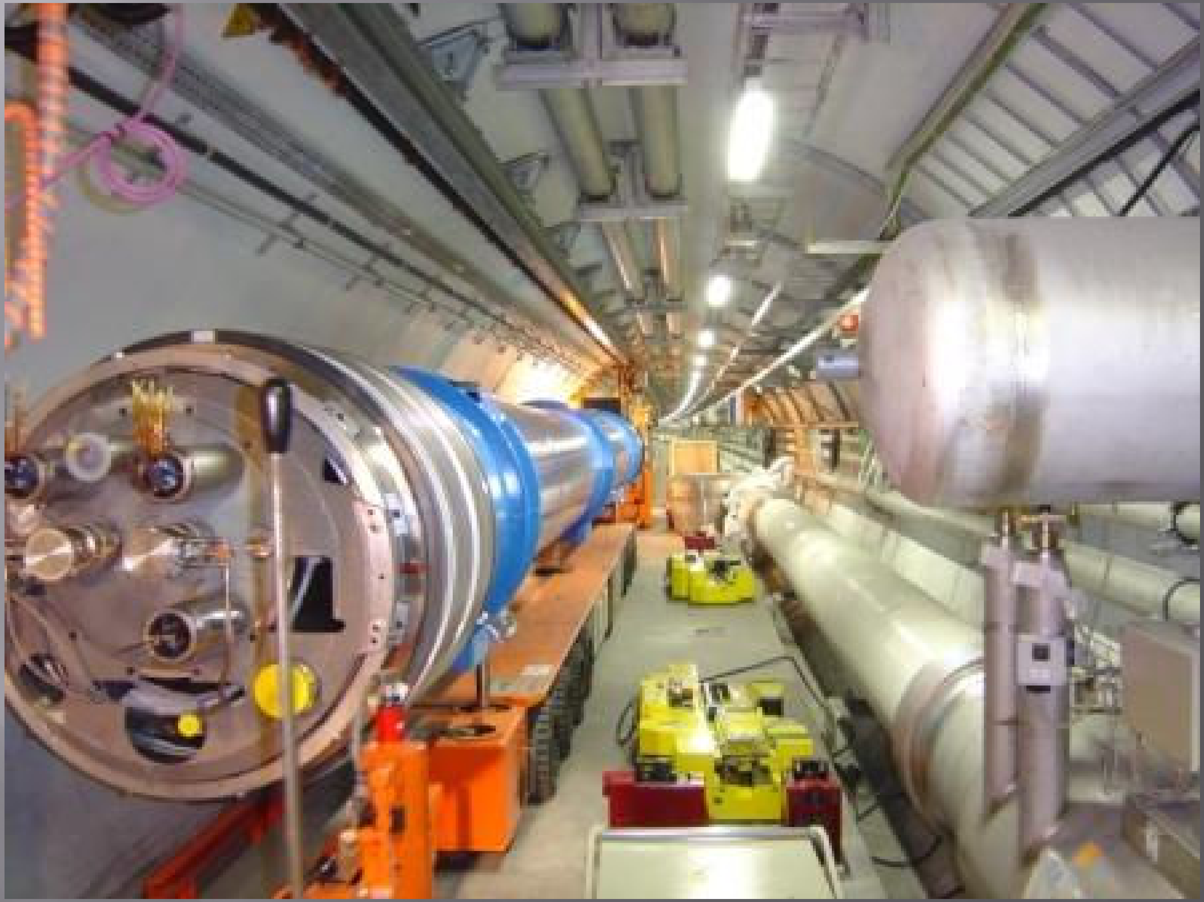


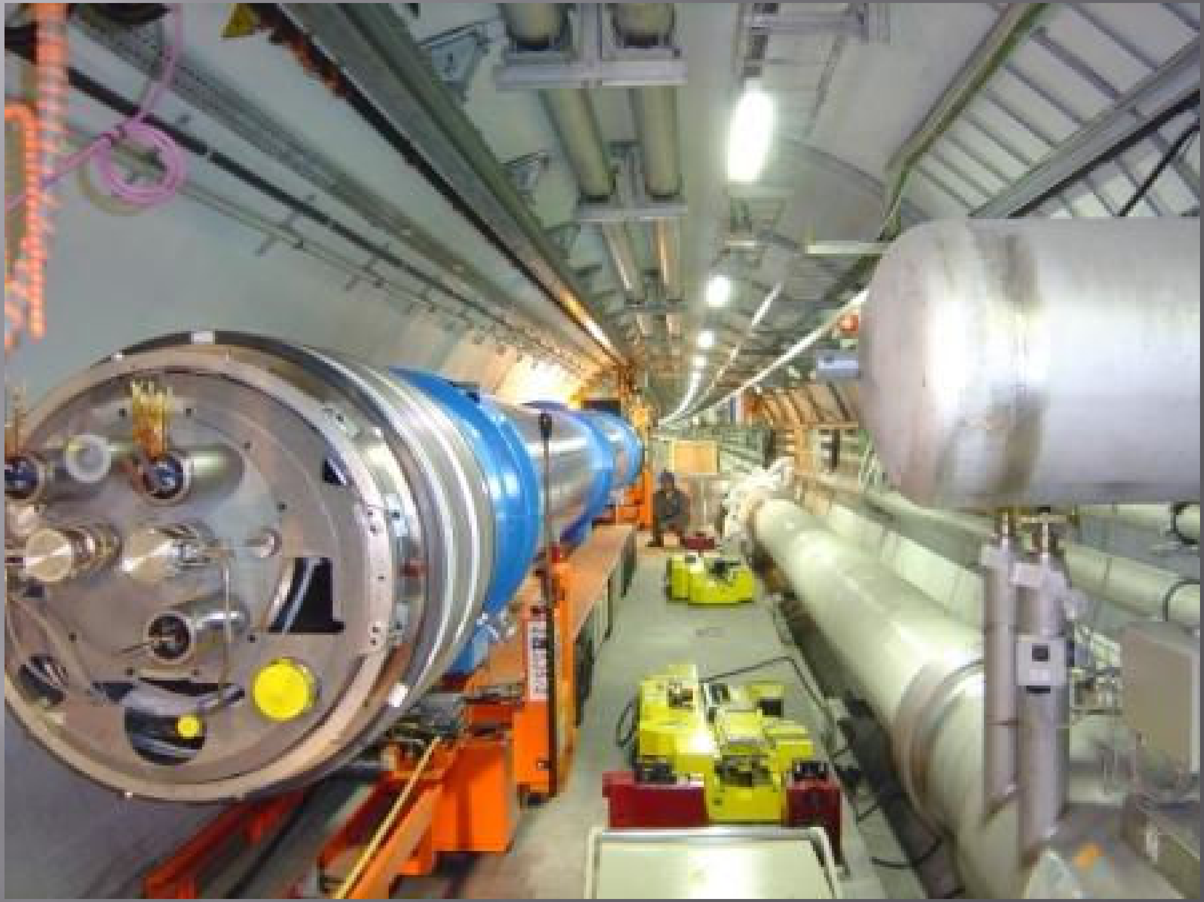


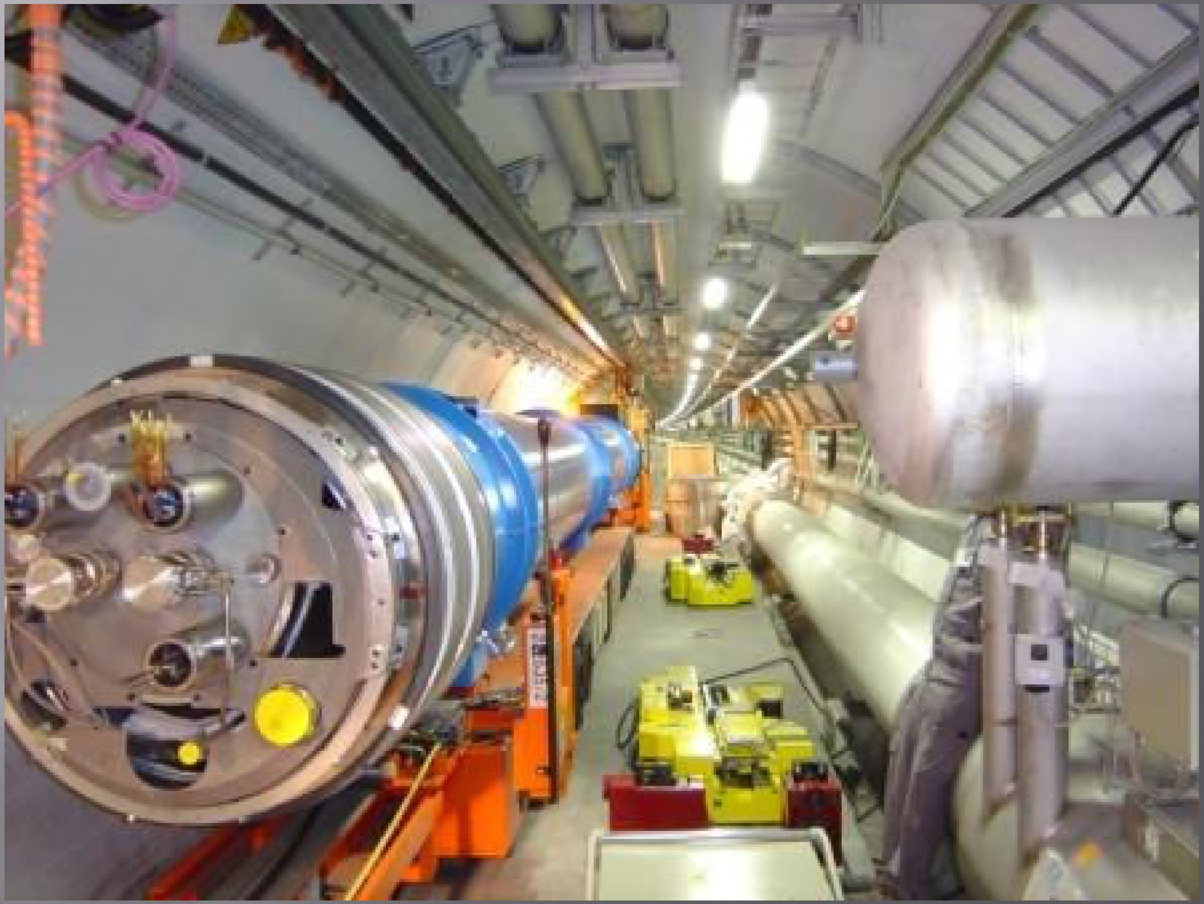


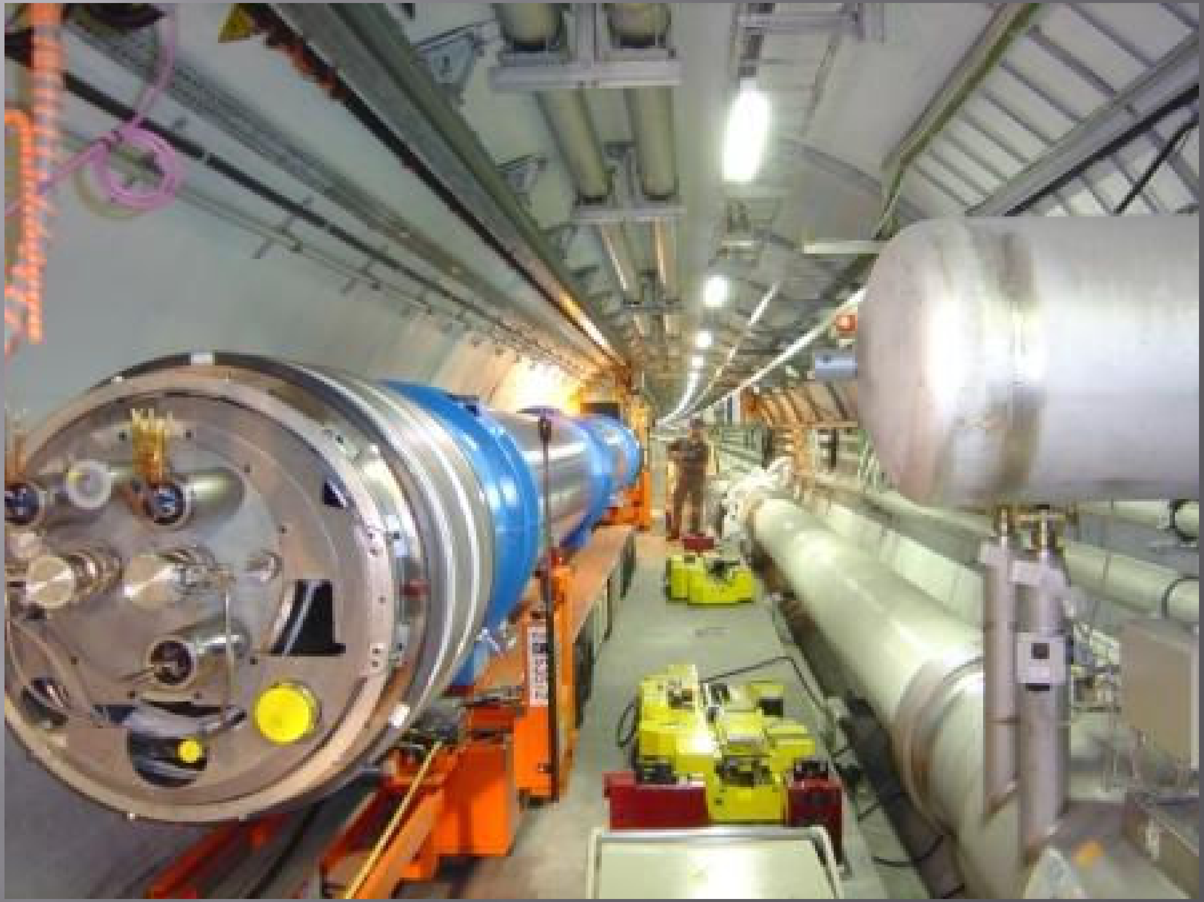


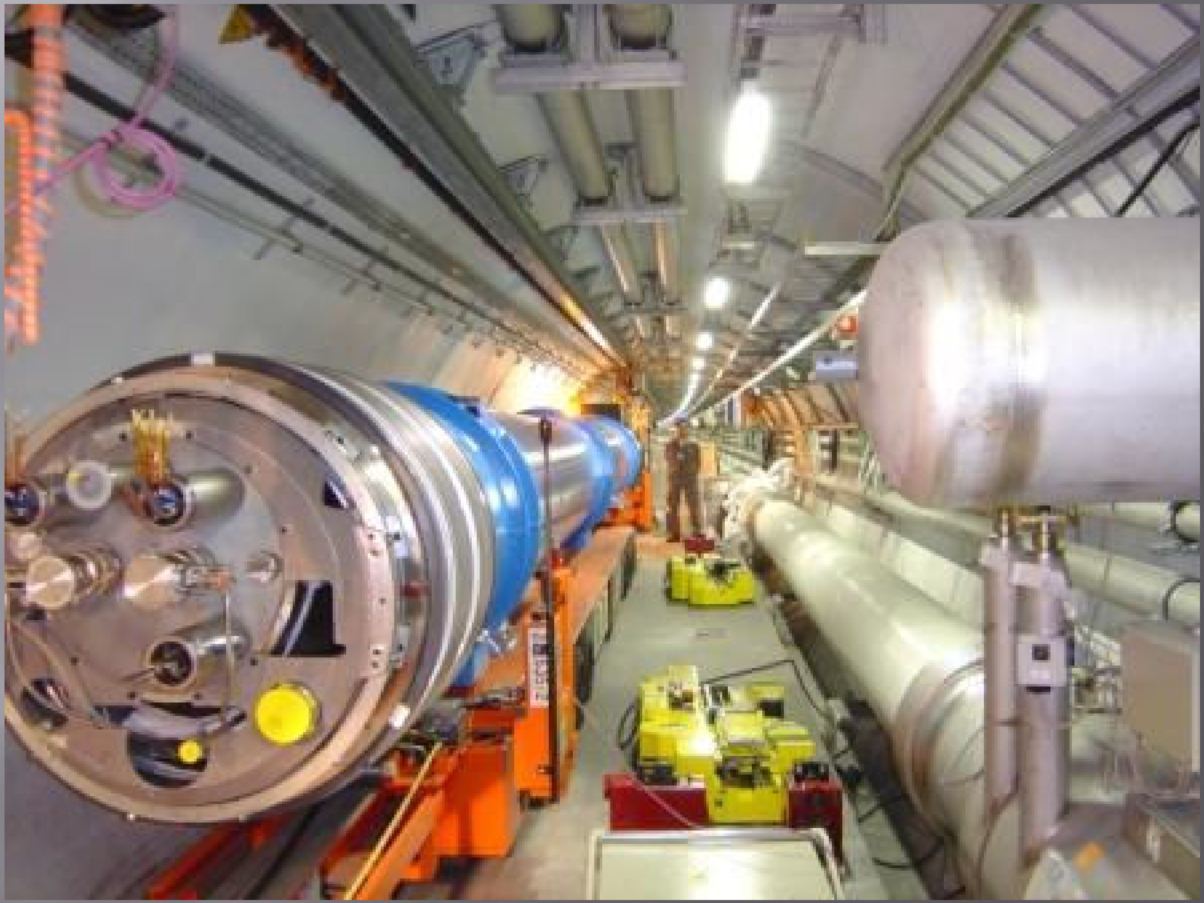
Roll unloading equipment under magnet

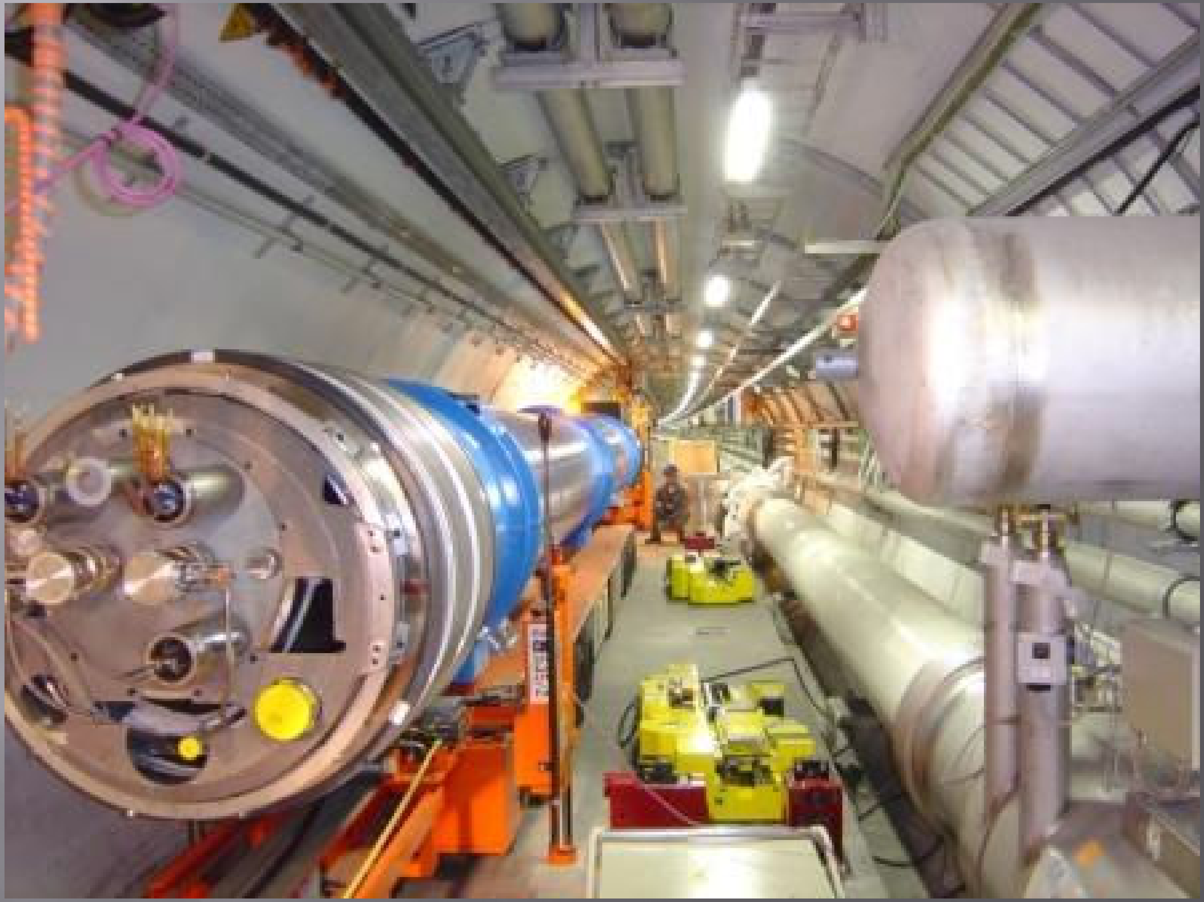


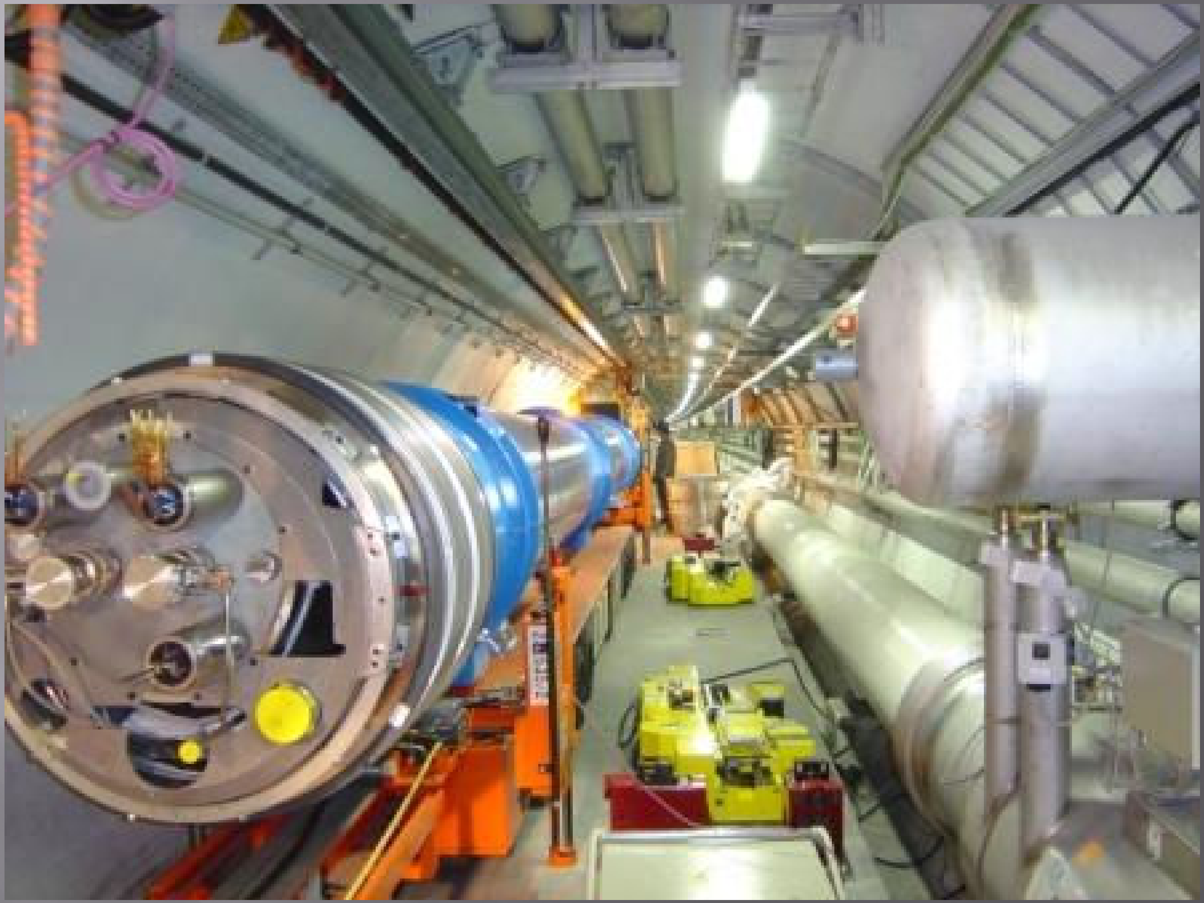




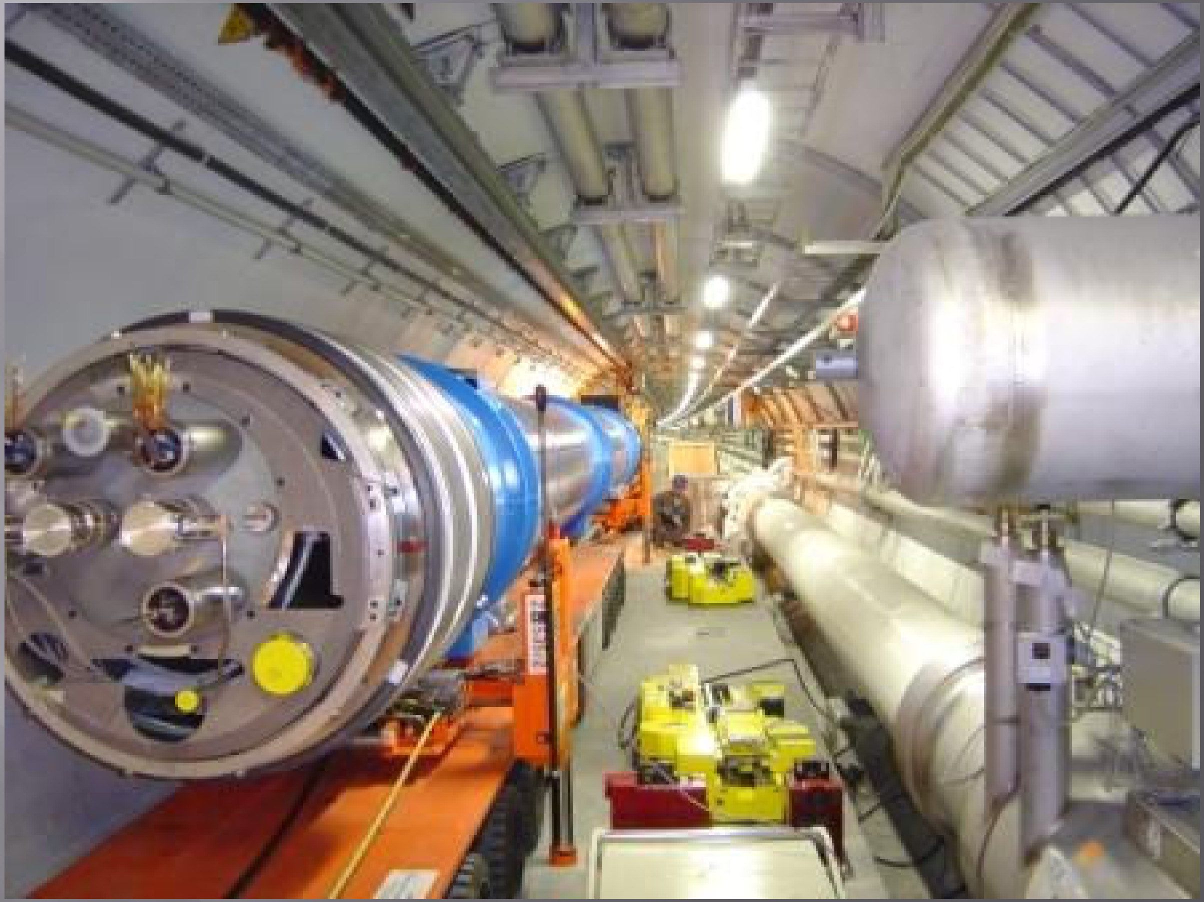




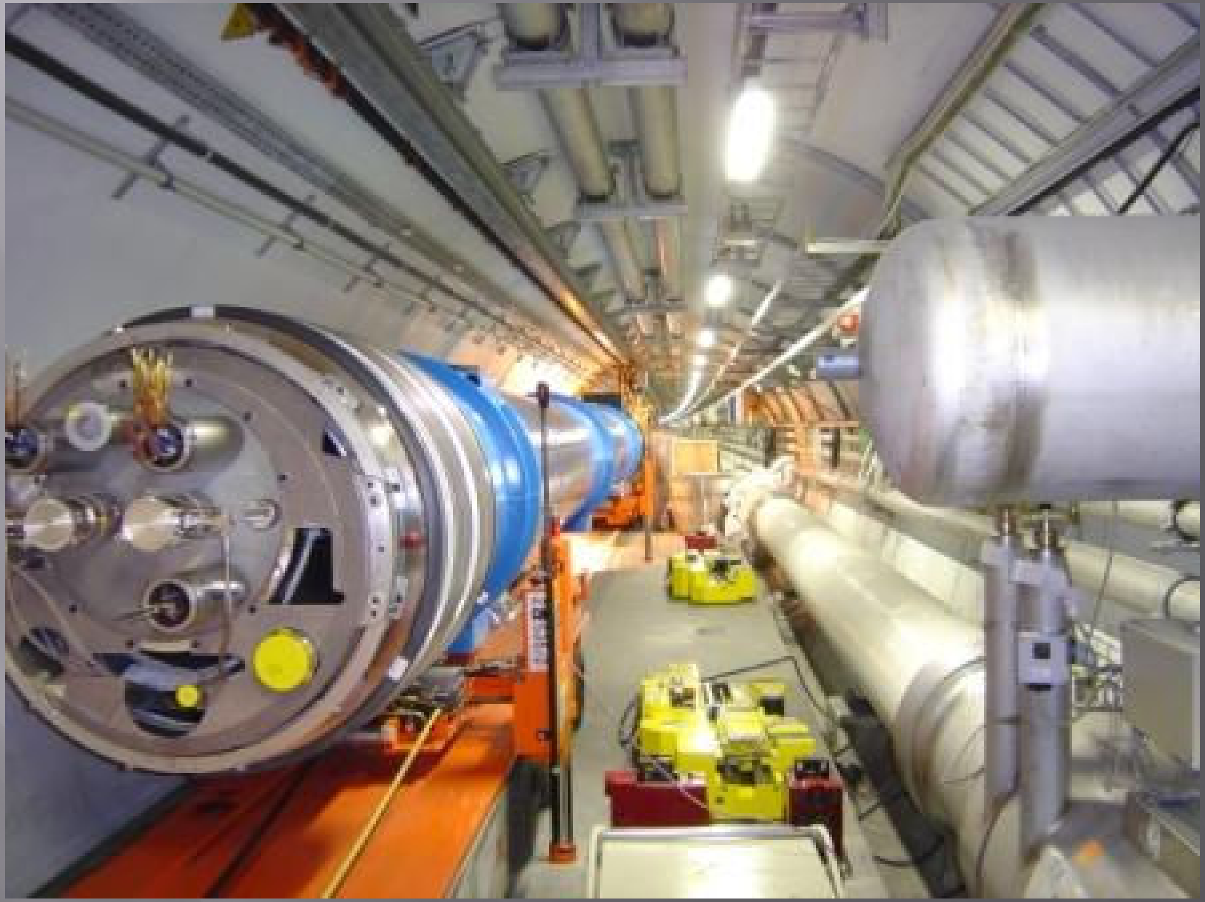


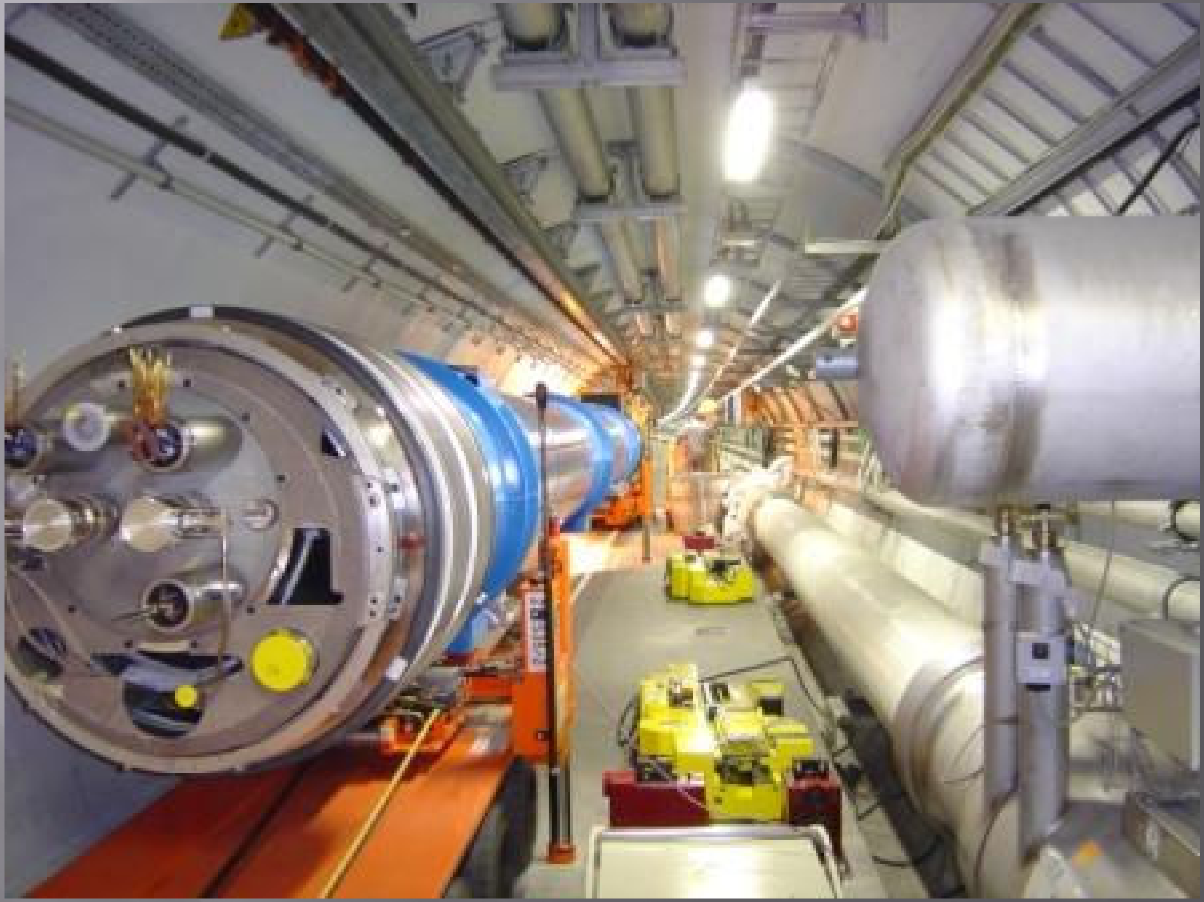


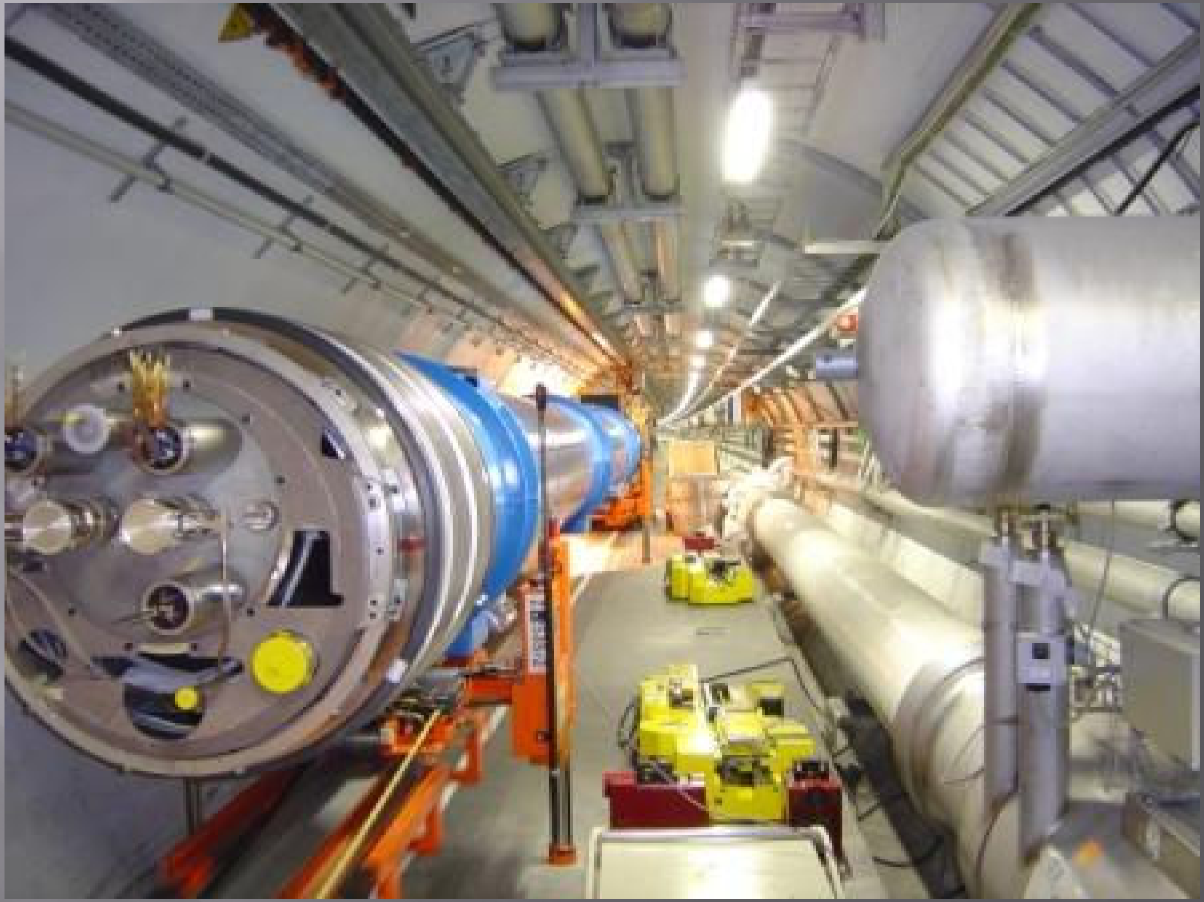
Lift magnet



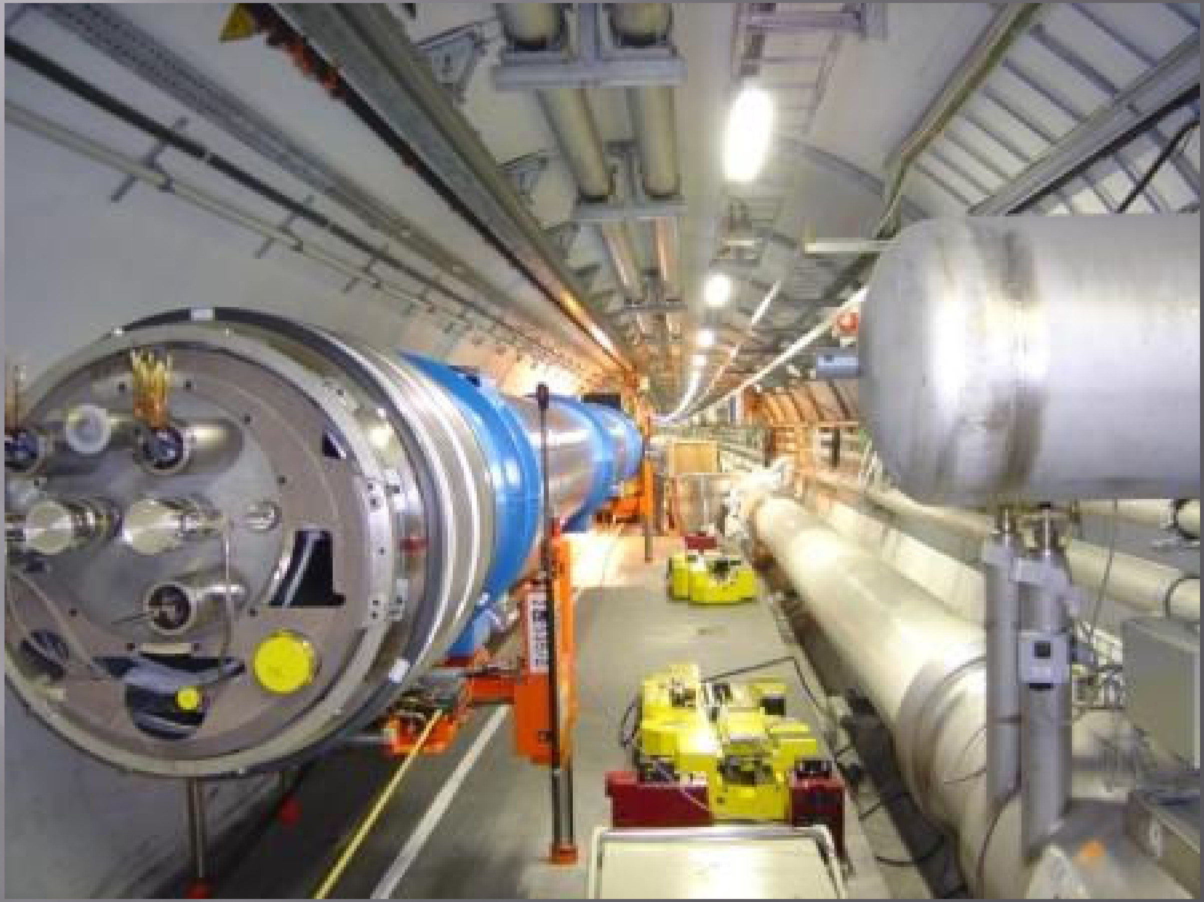
Withdraw trailer

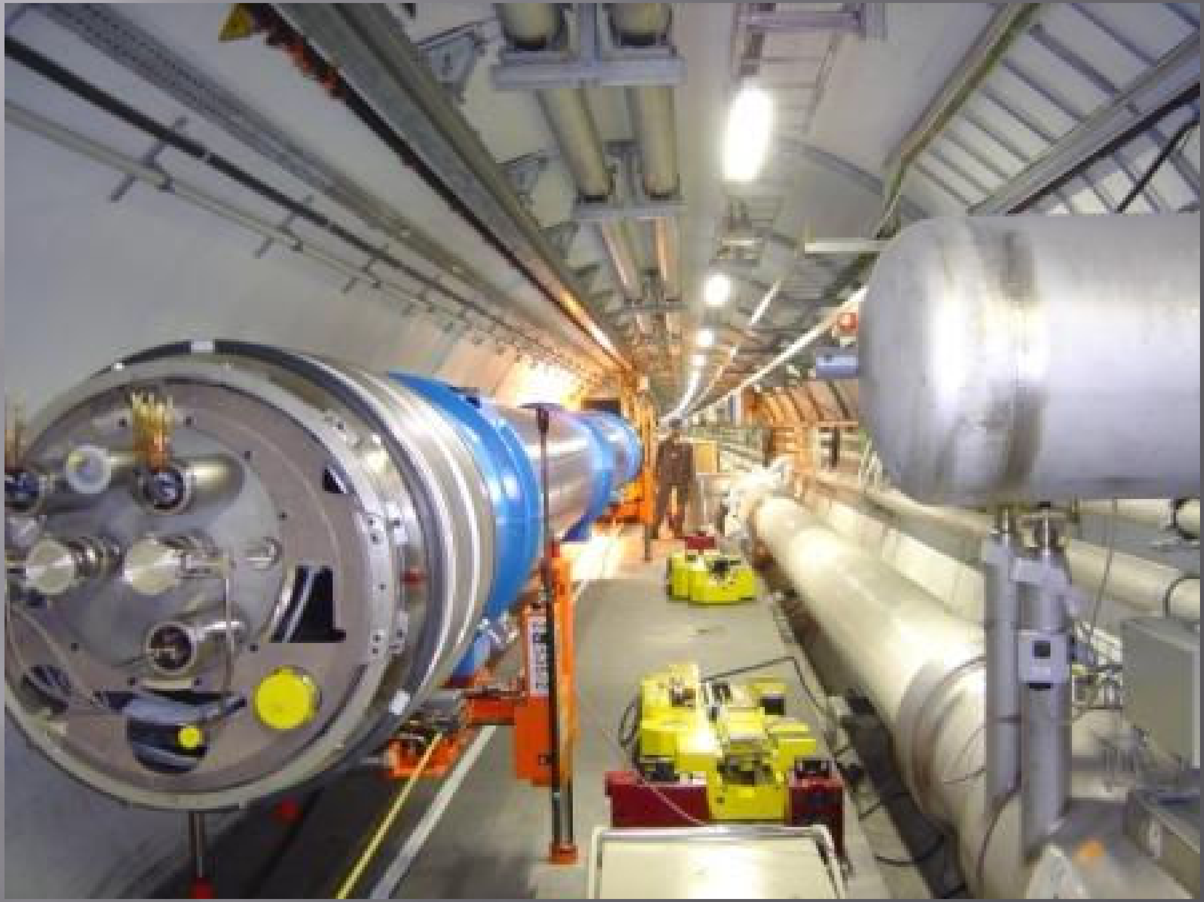


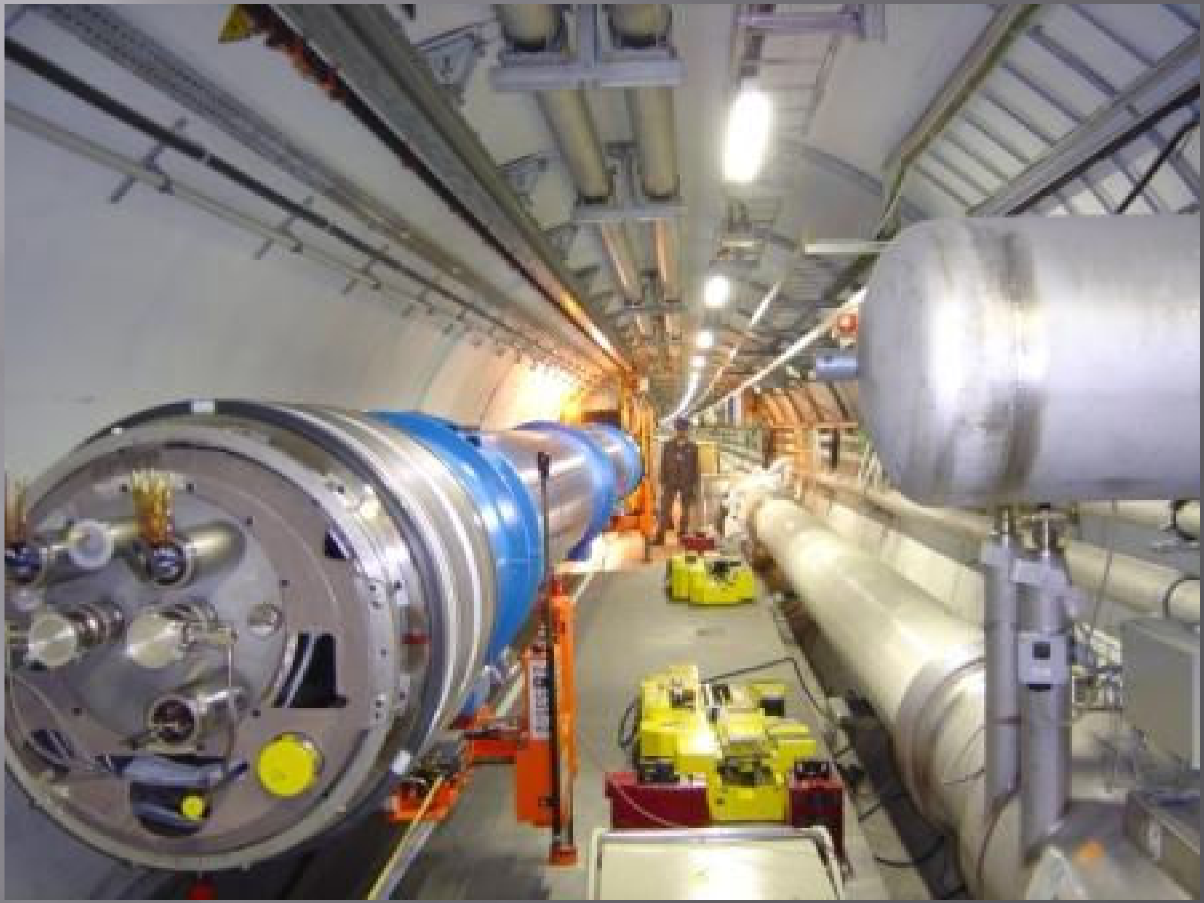


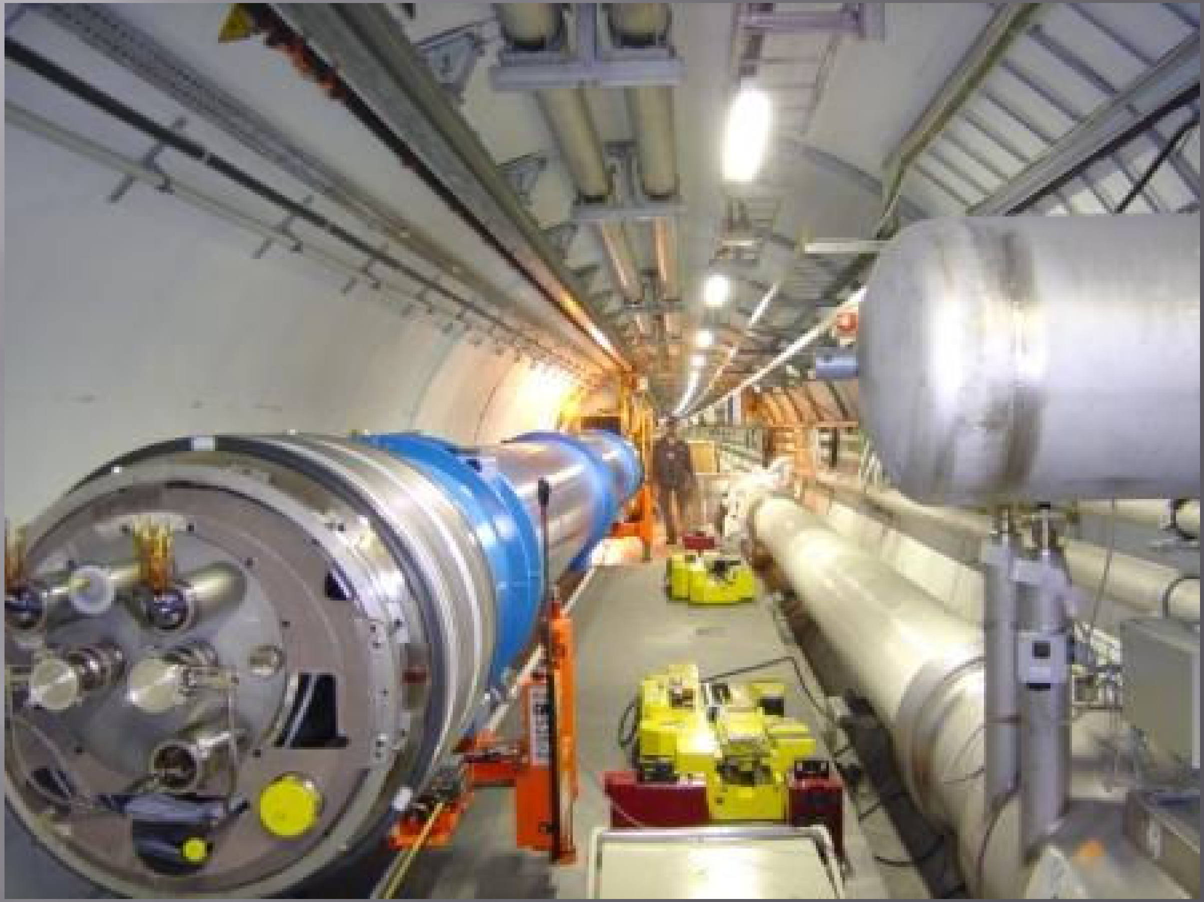


Lower magnet









Install transfer tables

Withdraw unloading equipment

Measure positions

Transfer onto supports

Re-connect convoy

Go to get the next one

LHC trailer and transfer tables

- Advantages
  - Allows installation with very limited clearance (250 to 300 mm) underneath the cryo-module
  - Transfer tables allow small longitudinal corrections during resp. after lateral movement
- Disadvantages
  - Very sophisticated, complex and consequently maintenance intensive
  - *Tunnel almost entirely blocked during transport operation*
  - Collisions possible despite optical guiding system, anti collision system, low speed of max 3 km/h and two operators -> For safety reasons transports >250 kg are not allowed next to 'cold' LHC machine! Installation of solid barriers all along the LHC would be required.

LHC Buggies can move at 180 deg to transport direction

Capacity:	9 t per buggy
Equipment height:	560 mm


ELIN


ELIN


ELIN


ELIN

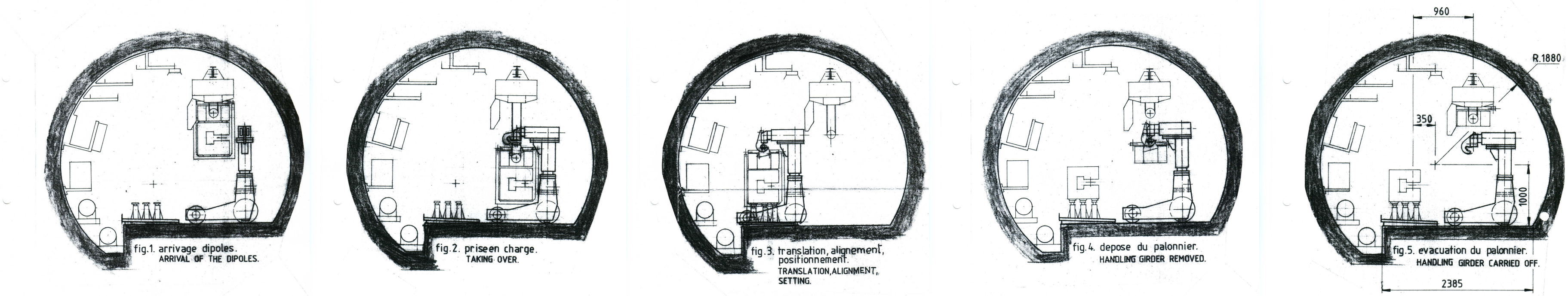

LEFT

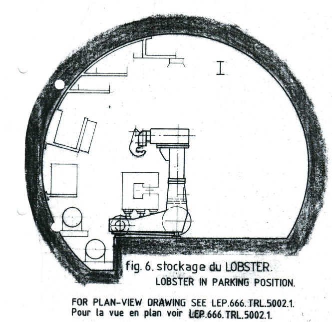

LEFT
LEFT

LHC buggies

- Advantages
  - All-in-one solution for longitudinal transport and lateral transfer
  - No longitudinal offset when wheels turn 180°
  - Can operate within a limited time on slopes up to 7%
  - Operator friendly
- Disadvantages
  - Require considerable clearance (>500 mm) underneath the cryo-module
  - Require very exact positioning since the jacks can only compensate for a very slight misalignment
  - *Tunnel almost entirely blocked during transport operation*
  - Collisions possible despite optical guiding system, anti collision system, low speed of max 3 km/h and two operators -> For safety reasons transports >250 kg are not allowed next to 'cold' LHC machine! Installation of solid barriers all along the LHC would be required.

LEP monorail system

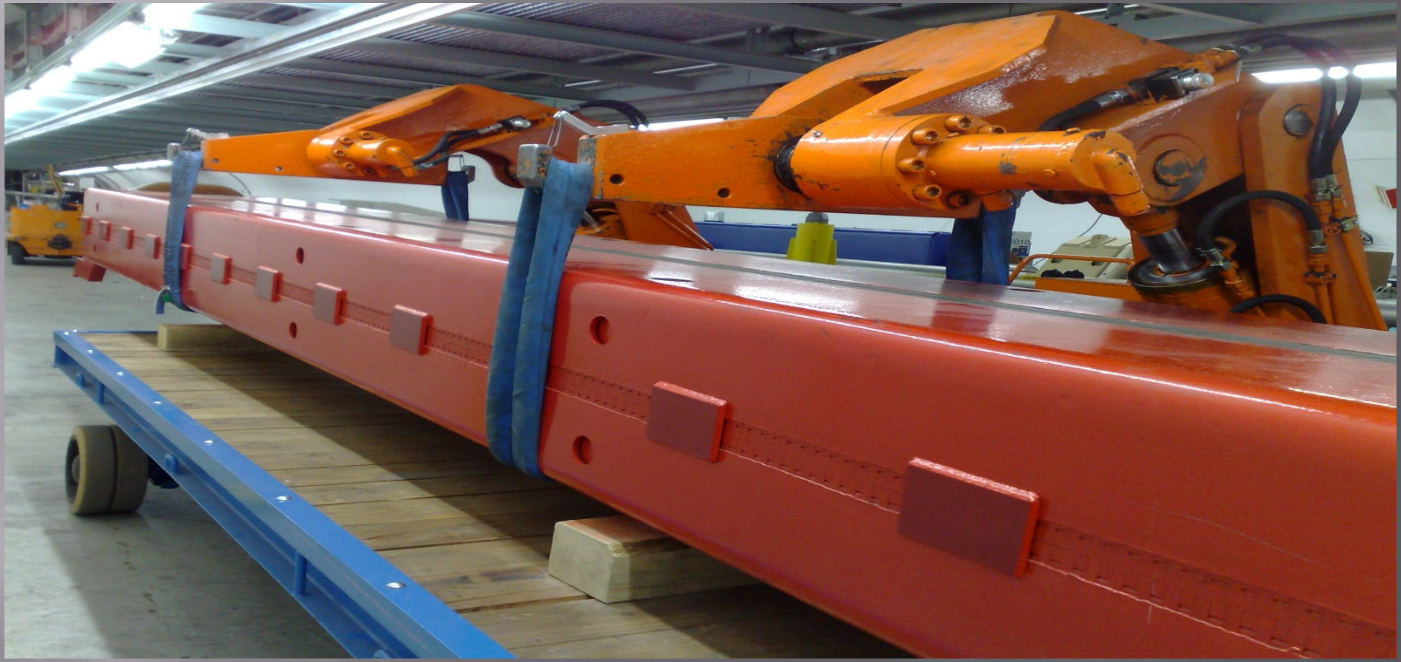




Suspended monorail train

- Advantages
  - Fixed mechanical guiding system
  - Not depending on floor conditions
  - No or very limited risk of collisions with installed machine components during transport operation -> big advantage when machine is 'cold'
  - Rail also used for fixation of power feed rail
  - Tunnel not entirely blocked during transport operation
  - Remote controlled operation easily feasible
  - Could be configured to operate on slopes
  - Can transport several cryo-modules at once
  - Can transport all kind of equipment
- Disadvantages
  - Integration issue – may conflict with waveguides or other overhead installations?
  - Lateral transfer solution to be assessed i.e. transfer table.

SPS TRAILER CRANE UNIT

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SPS trailer / crane unit

- Advantages
  - All-in-one solution for longitudinal transport and lateral transfer
  - Operator friendly
  - Requires clearance only for the outriggers
- Disadvantages
  - Require very exact positioning since the jacks can only compensate for a very slight misalignment
  - Tunnel almost entirely blocked during transport operation
  - *Collisions possible - no optical guiding system, no anti collision system but more space than in LHC*

DESY – Trailer transfer table unit

Equipment height 1m

DESY trailer / transfer table unit

- Advantages
  - All-in-one solution for longitudinal transport and lateral transfer
  - Operator friendly
  - Requires clearance only for the outriggers
- Disadvantages
  - Require very exact positioning since the jacks can only compensate for a very slight misalignment
  - *Collisions possible - no optical guiding system, no anti collision system but more space than in LHC*




http://adweb.desy.de/~meyners/xfel/WP33/XFELexpress056gekuerzt.avi

http://adweb.desy.de/~meyners/xfel/WP33/XFELexpress057gekuerzt.avi

Capacity: 6 t per lifting platform
Lifting height: 2.4 m

DESY trailer / lifting table unit

- Advantages
  - All-in-one solution for longitudinal transport and lateral transfer
  - No or very limited risk of collisions with installed machine components during transport operation -> big advantage when machine is 'cold'
- Disadvantages
  - Require very exact positioning since the ceiling support frames can only compensate for a very slight misalignment
  - More difficult to install overhead
  - Civil Engineering tolerances more problematic
  - Longitudinal forces, vibrations, oscillations etc.?
  - LHC incident scenario?
  - Handling/storage rule: Light staff up, heavy stuff down

Discussion – Buggies

- The 700 mm clearance below cryo-modules allows the use of a combined transport and transfer vehicle such as the LHC buggies.
- The LHC buggies were designed for slope of 8% but did overheat after intensive use on slopes
- The transfer using buggies is carried out by rotating the wheels through 90 degrees . The space between ends of LHC warm magnets when being installed is approx 7cm – longitudinal alignment relied on the operators' skill and care.
- The space between the ends of ILC cryo-modules is approx 2cm – this would lead to risk of damage using buggy –type solution relying on operator skill for large numbers (1600) modules unless some automated alignment is provided.
- The LHC buggies were used for transporting warm magnets – less delicate than cryo-modules.

CONCLUSION

- All presented underground transport and handling solutions offer some advantages but also disadvantages.
- Considering the dimensions and characteristics of the cryo-module an ‘All-In-One’ type equipment seems to be the most adapted.
- The LHC buggies are 560mm high: for ILC the 860mm clearance underneath cryo-modules will allow incorporation of cradles, load suspension, additional cooling and precise positioning tables to allow accurate longitudinal (and vertical?) alignment during lateral transfer onto jacks.
- A suspended monorail train system offers the safest and fastest transport solution but may create important integration problems.

NOTES ON SLOPES

Standard electric vehicles

- Typically 1.5-2% slope for continuous use at full rated load
  with increased slope the load capacity or the use factor reduces. (see performance chart)

Encyclopedie de la Manutention

- "rampe ≥ 7% = problème délicate" (this is with unbraked trailers)
- Effect of 2% slope is to double traction force needed compared with horizontal surface.

MAFI
Transport-Systeme GmbH

Specification "Eidechse" EFZ 302 AC

431,099,0001-A

Layout plan for industrial trucks acc. to VDI 2198 Tractors

Characteristics	1.1	Manufacturer (Abbreviation)		MAFI
	1.2	Type (Manufaturer' s designation)		EFZ 302 AC
	1.3	Drive		Electric
	1.4	Operation		from driver's seat
	1.5	Load capacity	t	
	1.7	Nominal tractive force	N	4000
	1.9	Wheel base	mm	1365
Weights	2.1	Dead weight (incl. battery)	kg	2500
	2.2	Axe load with load at front/at rear	kg	-
	2.3	Axe load without load at front/at rear	kg	1000 / 1500
Wheels, Chassis	3.1	Tyres		Air
	3.2	Tyre size, front		6.00-9
	33	Tyre size, rear		6.00-9
	3.5	Wheels numbers at front/rear (x = powered)		2/2x
	3.6	Wheel track, at front	mm	888
	3.7	Wheel track, at rear	mm	888
Basic dimensions	4.7	Height with cabin	mm	2375
	4.8	Seat height (SIP as per ISO 5353)	mm	1320
	4.12	Coupling height	mm	330
	4.13	Platform level without load	mm	-
	4.16	Length of loading platform	mm	-
	4.17	Projecting length	mm	550
	4.18	Width of loading platform	mm	-
	4.19	Overall length	mm	2360
	4.21	Overall width	mm	1060
	4.32	Road clearance (with nominal load)	mm	150
	4.35	Turning radius	mm	2690
	4.36	Smallest distance between the centers of rotation	mm	1005
Output data	5.1	Driving speed with/without load	km/h	ca. 10 / 20
	5.5	Traction force with/without load	N	- / 4400
	5.6	Max. traction force with/without load	N	- / 15000
	5.7	Gradability with/without load	%	- / 27
	5.8	Maximun gradability with/without load	%	- / 55
	5.10	Service brake		hydraulic
E-motor	6.1	Drive motor, power output S2, 60 min	kW	15,6
	6.3	Battery acc. to DIN 43536 A		5PzS
	6.4	Battery voltage, nominal capacity	V/Ah	80/400L
	6.5	Battery weight	kg	1049
	6.6	Energy consumption	kWh/h	-
Others	8.1	Type of drive control		AC Inverter
	8.4	Sound level, driver's ear	dB (A)	-
	8.5	Trailer coupling, kind/type DIN		three-stage

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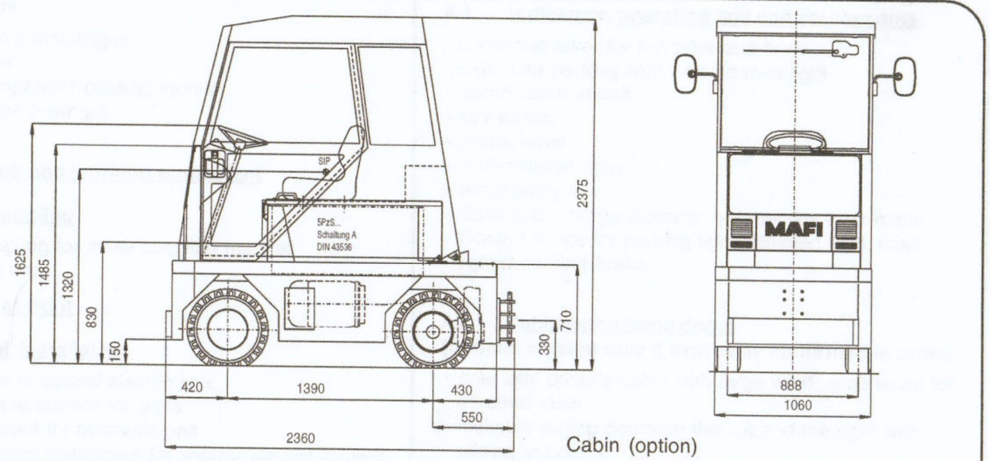
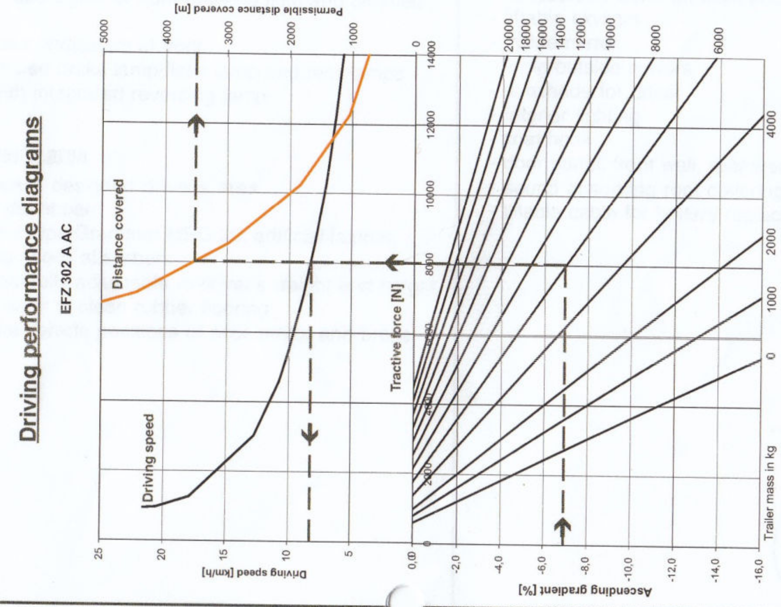


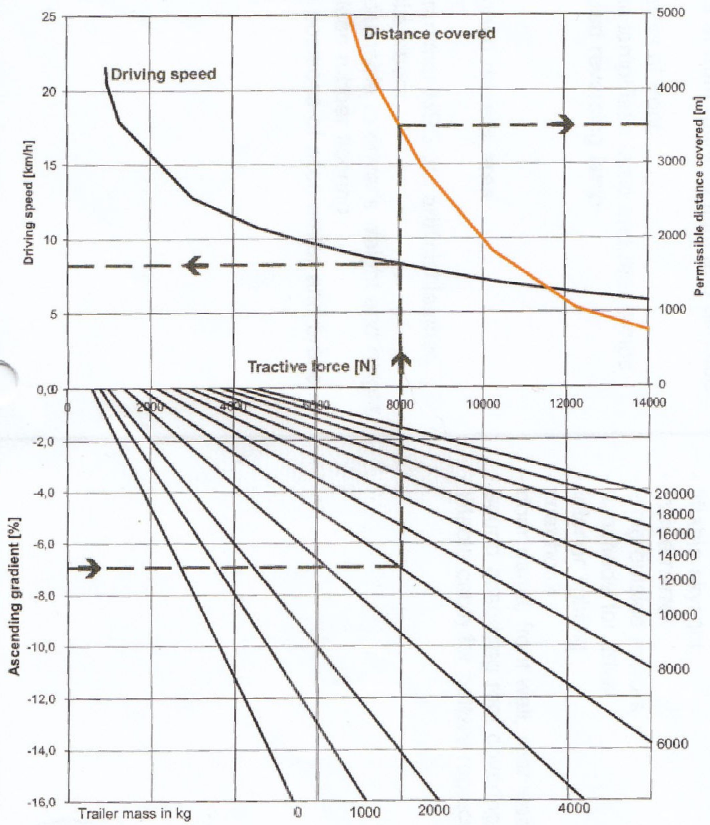
Cabin (option)



Example:
A tractor with a trailing load of .... 6000 kg
drives on an ascending gradient of 7%
The speed to be obtained is .... 8 km/h
The permissible distance covered per hour is .... 3500 m

Driving performance diagrams

EFZ 302 A AC



Example:
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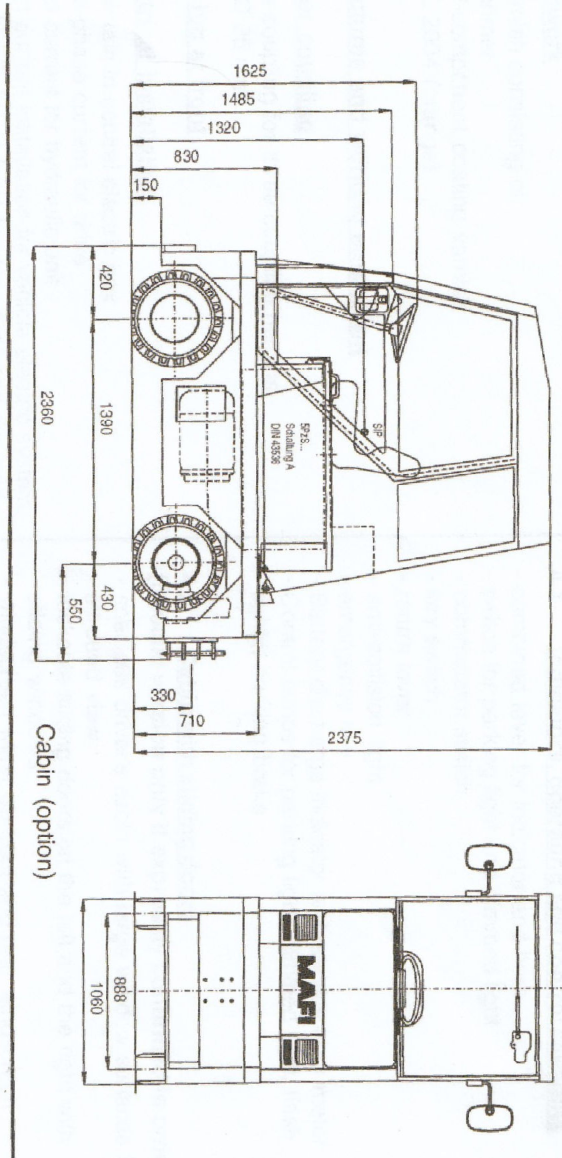

Example on effect of slope

- In the example a tractor with a nominal towing capacity of 20 tonnes can be used on a 7% slope to tow a 6 tonne trailer a maximum of 3500m in one hour.

Other slope experience at CERN

Buggies for LHC warm magnet installation:

- Design for max slope 8%.
- During testing on 7% slope (several passes) overheated after approx 1hour.

Special purpose fork lift:

- customized for 14% slope (needed continuous forced ventilation for brakes and motors)
- Difficult to find supplier willing to do this.

Slope general comments

at this stage:

- 1.5 - 2% slope means can use standard vehicles (lowest cost most reliable solution)
- Up to 7 or 8% slope achievable by reducing standard vehicle capacity to approx one third of nominal (space issues?).
- Any steeper slopes will mean that it becomes more difficult to use standard equipment –this will have cost and reliability implications.
- In any case equipment for installing cryo-modules will be specially designed and built - but what about other equipment?

THANK YOU!

Any questions?

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- …