ILD TPC

TPC Requirements

Oliver Schaefer on behalf of the LCTPC Collaboration

Mini-Workshop on ILC Infrastructure and CFS for Physics and Detectors

Sunday 27th October 2019, Ichinoseki

(Contains Discussion Slides from Mini Workshop 2018 by Volker Prahl)

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Over view

- TPC Gas System
- TPC support structure
  - Requirements of the TPC support structure
  - Pros and cons of various fixing point
  - Various designs of the support structure
  - Dimensions of the support structure
  - Design of the support structure
  - Alignment of the TPC ect.

- HV-Cable and routing
- Cathode design
- Cabling and cooling of the TPC Module
- Estimated acceleration and forces ???
- TPC installation
  - TPC assembly
  - TPC insertion
- Conclusion and outlook

ILD TPC Gas System

Slides from LCTPC CM 2017/2018

Oliver Schäfer at the Mini-Workshop on Infrastructure and CFS for Physics and Detectors, Ichinoseki, 27th October 2019

Boundary Conditions

- Physics related requirements
- Technical
- Economical
- Legal

- Almost no parallels to LPTPC gas system at the moment
- We can learn from LEP (esp. Aleph), LHC (standardized), HERA-B, HERMES, T2K.

Basic Parameters

- TPC Volume = 24 … 39 m³ (ILD small/large)
- ALEPH: 6 Volume changes for flushing sufficient → Purge Rate = 16 … 26 m³/h; 9 hours for purging
- Requires many or large diameter tubes for low overpressure in TPC (ALEPH: 75 mm for 8...15 mbar)
- If compression is feasible underground, thinner lines can be used to surface.
- Large volume calls for mixing from components, also more flexible for other systems (Muon chambers, …)
- System is larger than T2K → new problems

Influences on TPC Physics

- Pressure
- Temperature (Simu by P. Schade, D. Bhattacharya?)
- Composition (Ionization, Attachment, Drift Velocity, Gain, Diffusion)
  - Impurities
  - Aging
- Secondary p, T effects on field cage geometry → electric field

- → What needs to be controlled or measured to what precision to reach physics goals?

Gas Analytics

- Conventional sensors need to sample the gas, partly contaminate it (oxygen electrolytic cell)
- Spectro-photometric sensors can operate very fast and on full tube diameter, but need to be specially developed (Oxygen, Water, other components)
- Gas chromatograph, mass spectrometer desirable to monitor impurities
- Qualitative sensors (monitoring chambers, …)

Purifying

- Absorbers
  - one way
  - cyclic operation
- Kryo distillation
- Cold traps
- Membrane separation

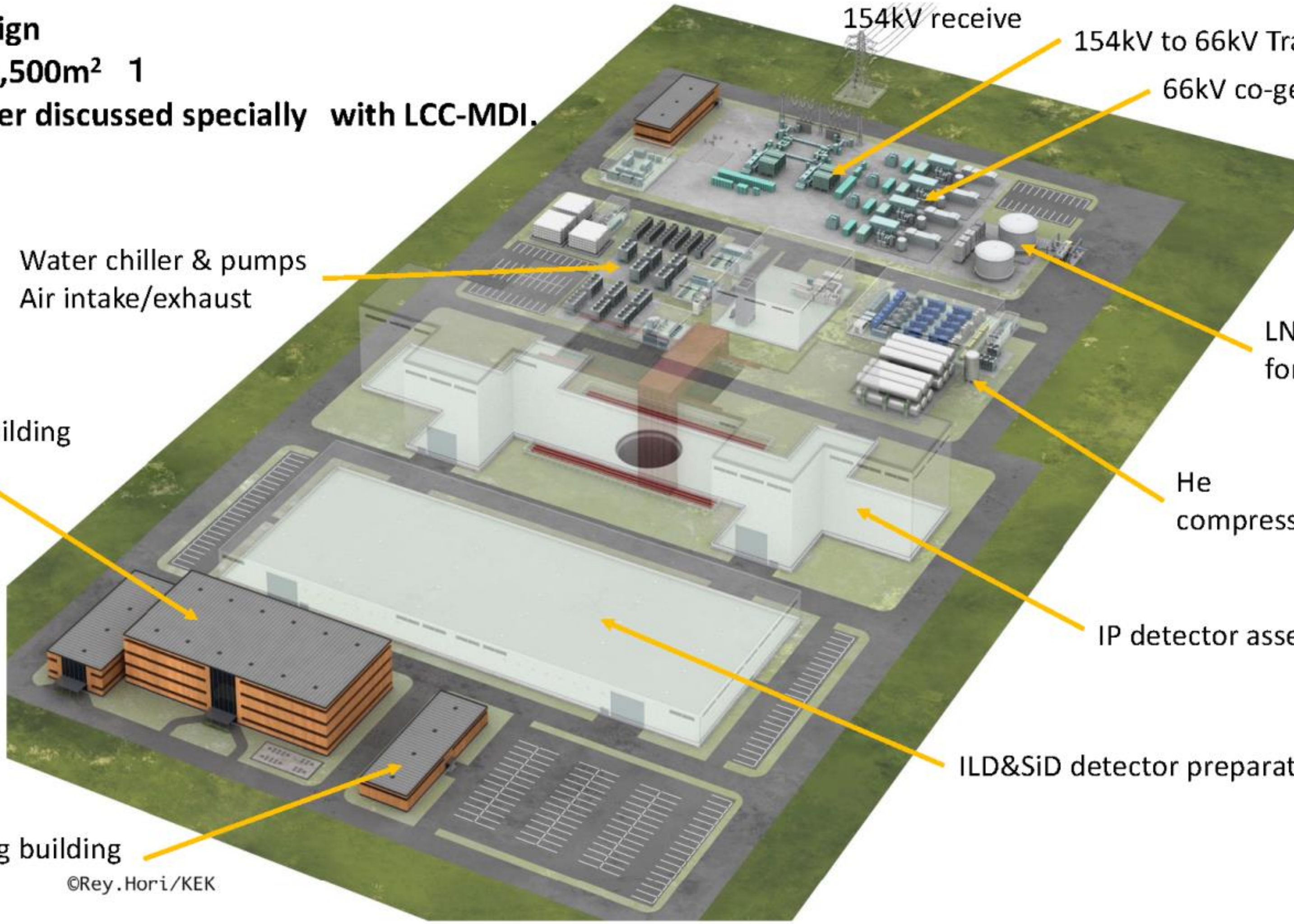
Exhaust Gas Treatment

- CF_4 can’t be released into atmosphere at ILD scales
- Green house gas 7390x CO_2, no ozone killer
- Usual way in industry is to decompose at high temperature in a furnace and generate CO_2 and HF or CaF_2
- Standard at CERN, T2K: purify and refill into bottles or recirculate.
- Did RD51 find eco-friendly alternatives?
- For climate change skeptics: CF_4 is quite expensive → regeneration

surface design

IP area 78,500m² 1

to be further discussed specially with LCC-MDI.



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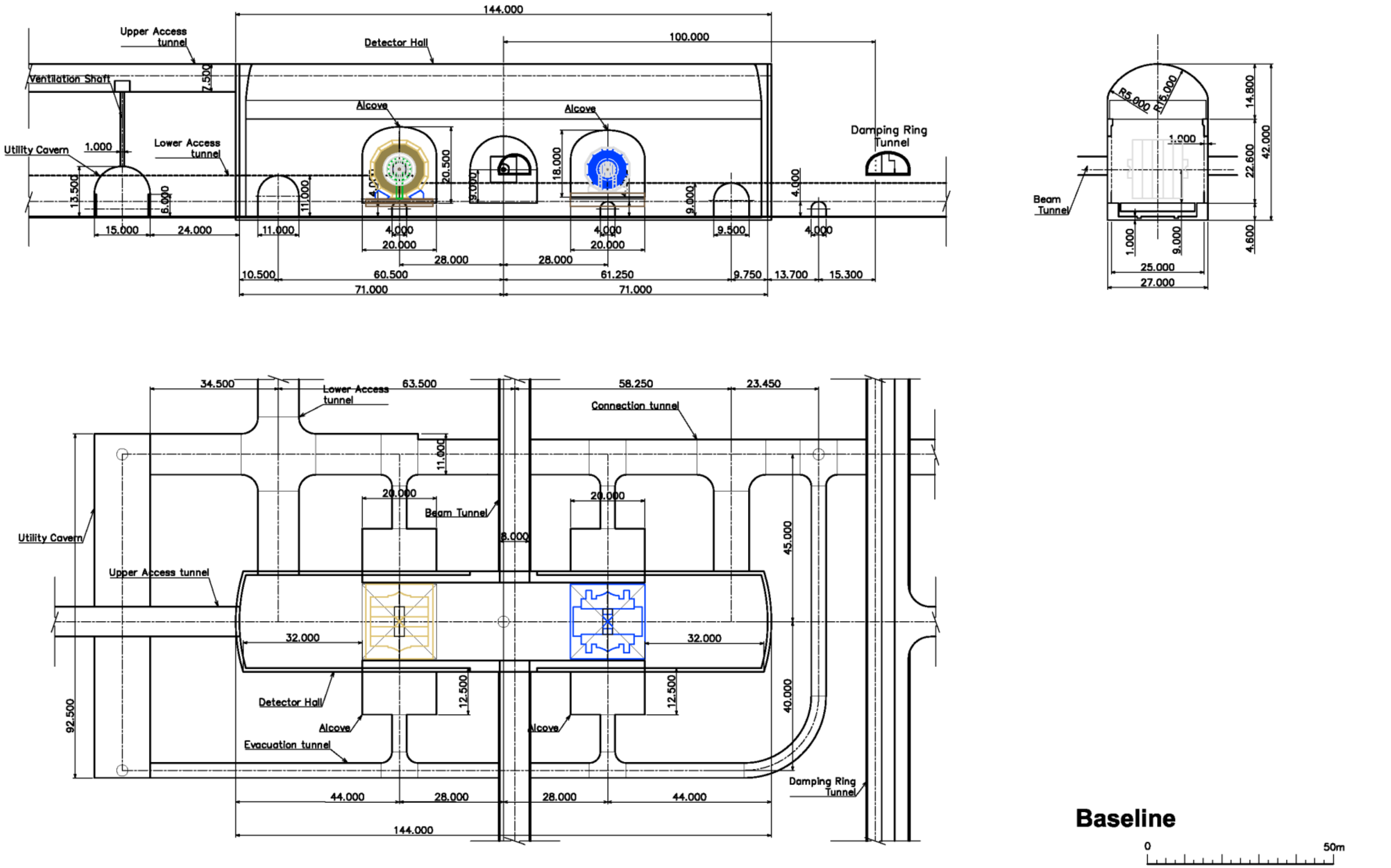
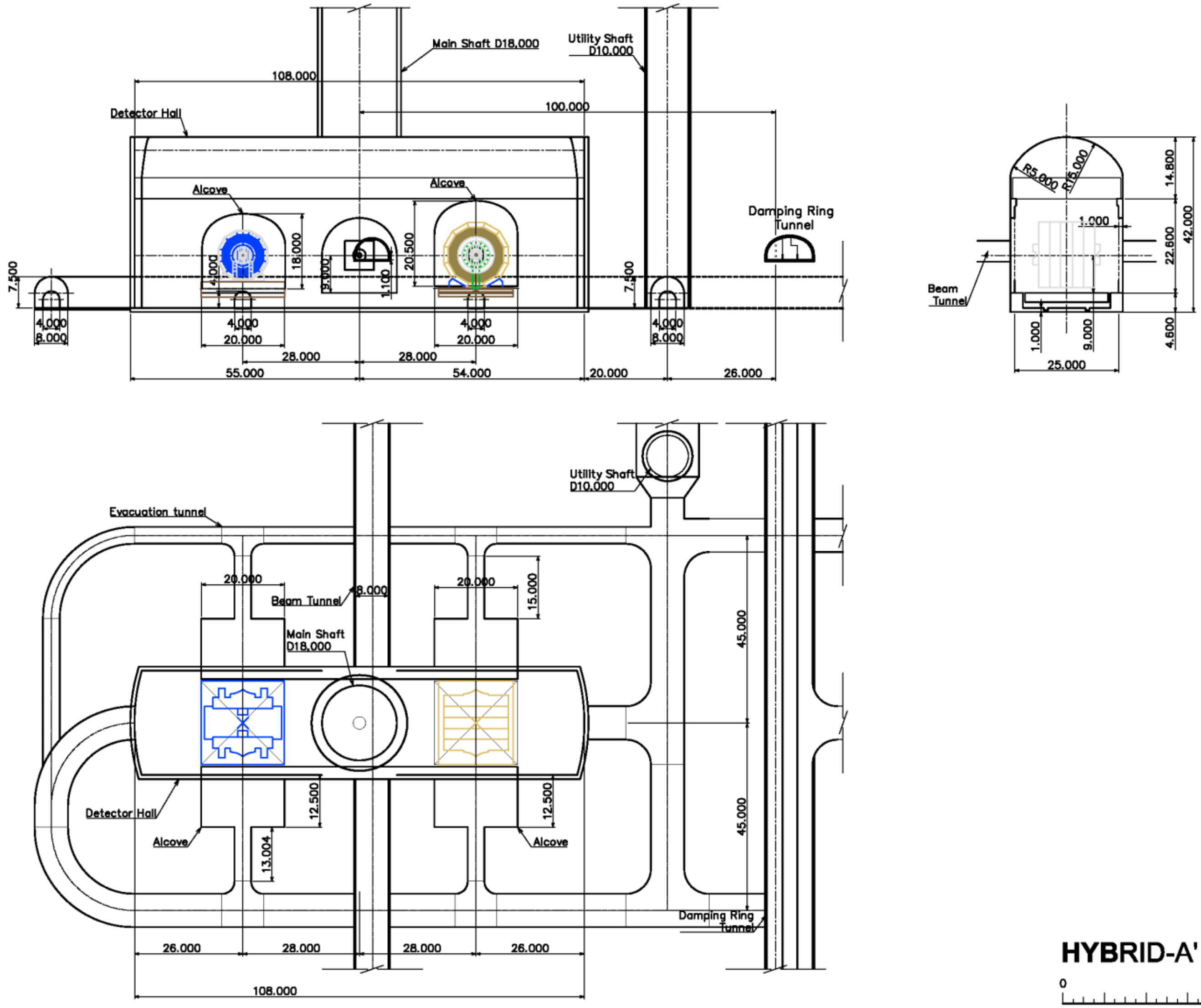
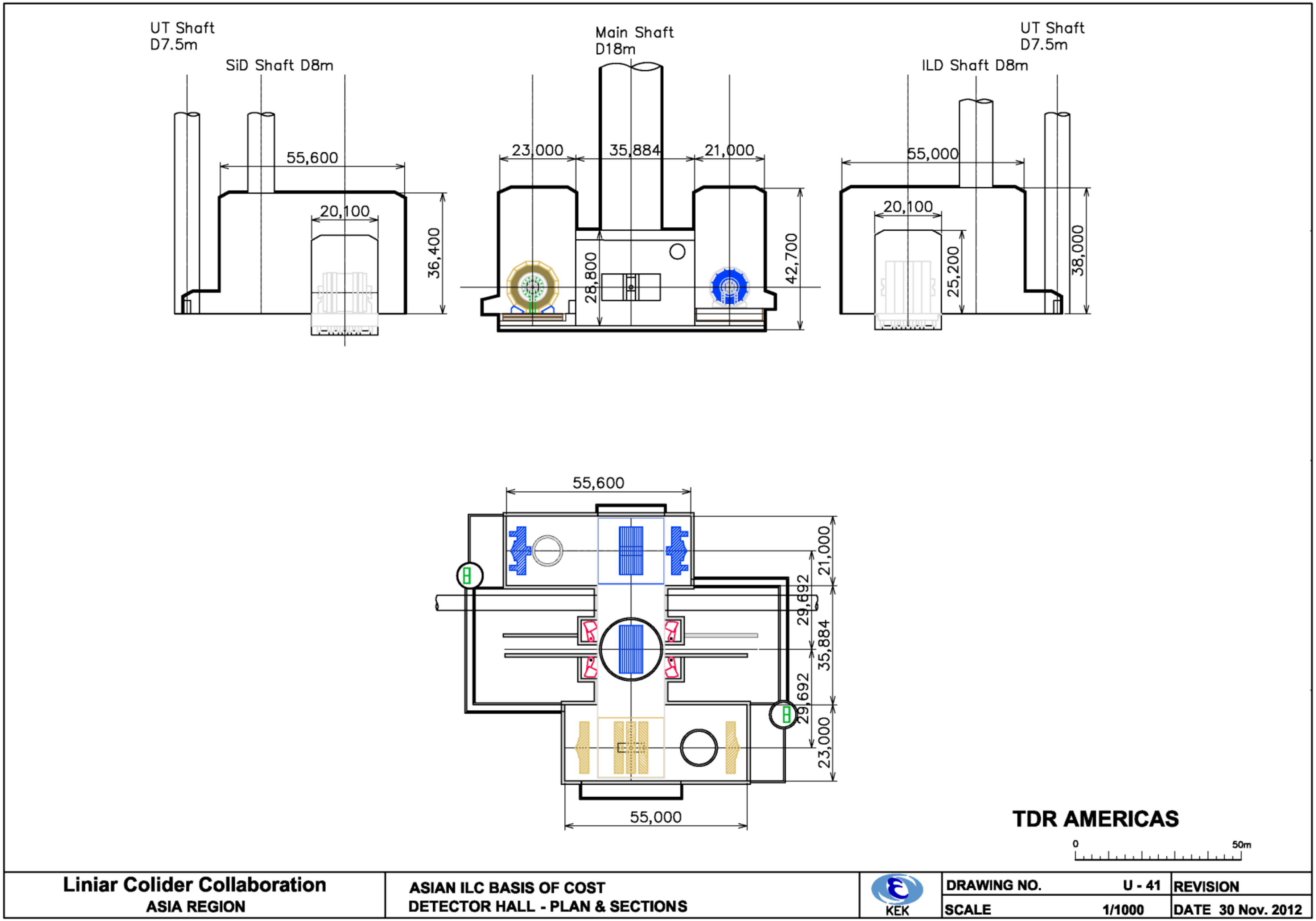


Liniar Colider Collaboration ASIA REGION	CFS Detector Hall Access Study Baseline	KEK	DRAWING NO. SCALE shown on drawing	REVISION DATE 12 Jun 2014

EDMS Nr.: D00000001093215 Rev: A Ver: 3 Status: Released - for internal reference Dat.: 7. Jan 2015



Liniar Colider Collaboration ASIA REGION	CFS Detector Hall Access Study Hybrid Option	KEK	DRAWING NO.	REVISION
			SCALE shown on drawing	DATE 4 Sep 2014


UT Shaft
D7.5m
SiD Shaft D8m
Main Shaft
D18m
UT Shaft
D7.5m
ILD Shaft D8m
55,600
20,100
36,400
23,000
35,884
21,000
28,800
42,700
55,000
20,100
25,200
38,000
55,600
21,000
29,692
35,884
29,692
23,000
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TDR AMERICAS
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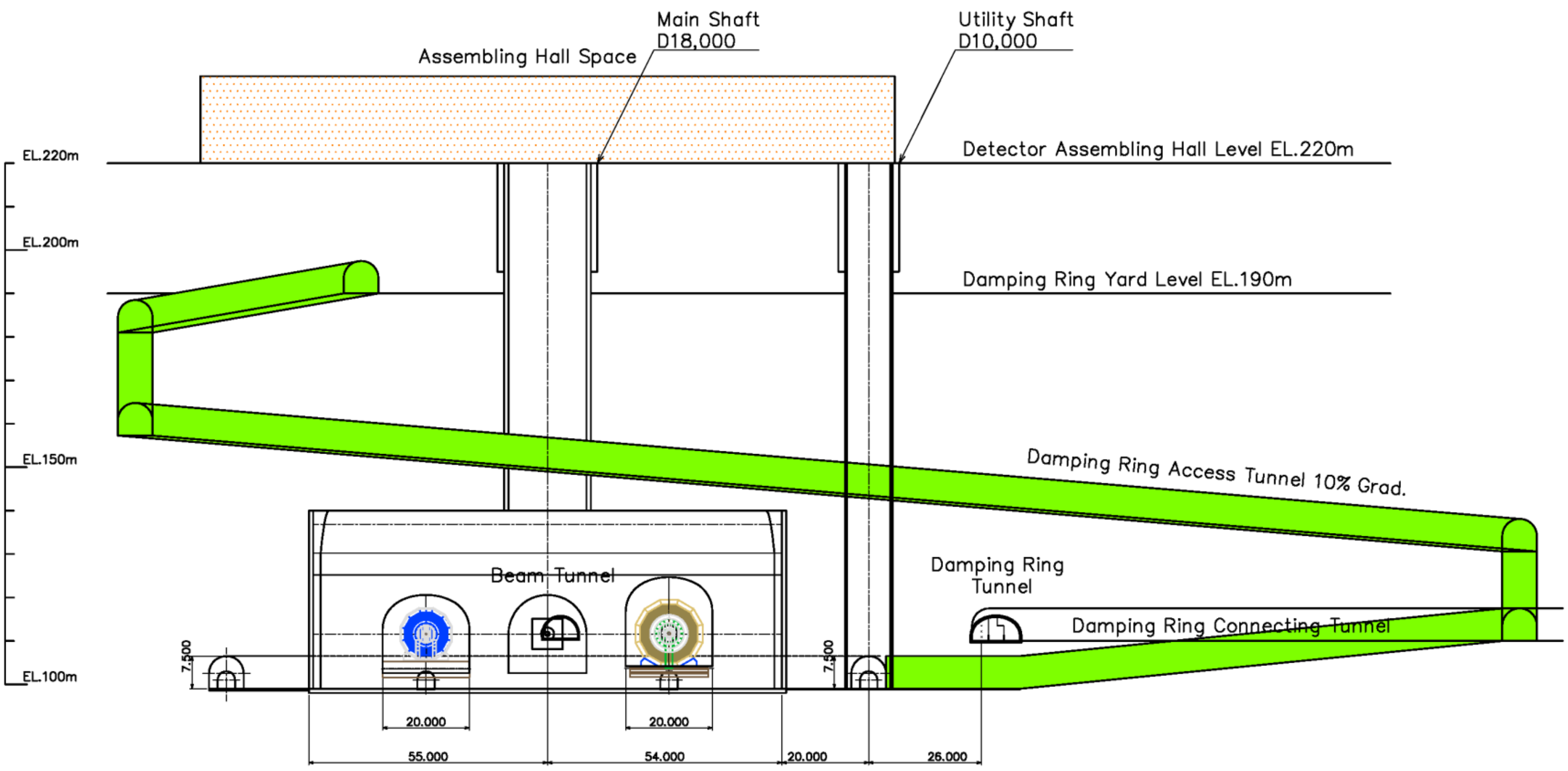
50m
Liniar Colider Collaboration
ASIA REGION
ASIAN ILC BASIS OF COST
DETECTOR HALL - PLAN & SECTIONS
KEK
DRAWING NO. U - 41
SCALE 1/1000
REVISION
DATE 30 Nov. 2012



HYBRID - A'

EDMS Nr.: D00000001093215 Rev: A Ver: 3 Status: Released - for internal reference Dat.: 7. Jan 2015

TPC Support Structure

TPC support structure

- Requirements of the TPC support structure

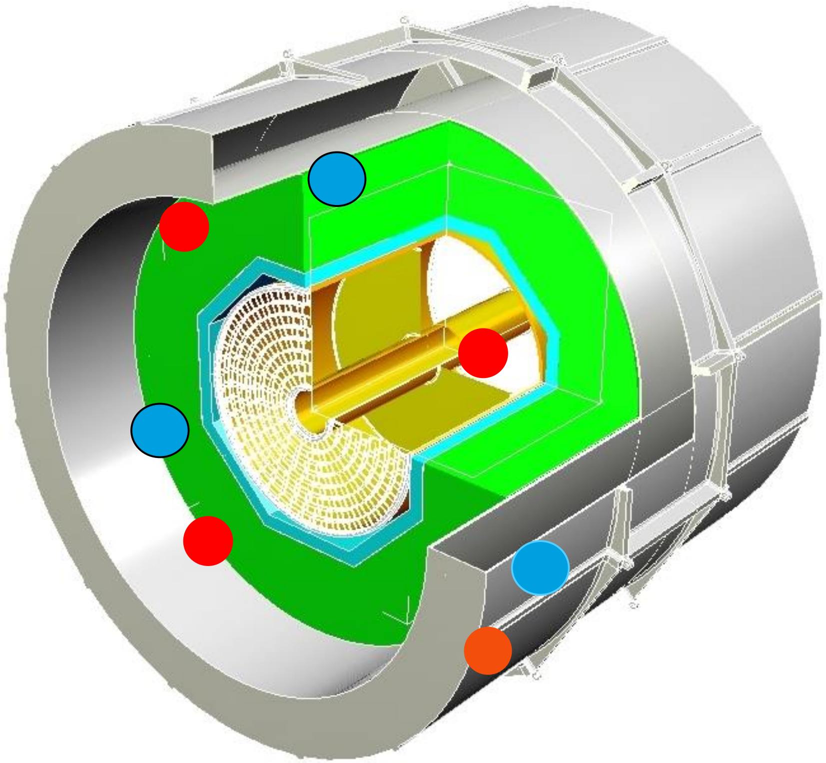
- Non-magnetic material
- Low thermal expansion coefficient

  } Carbon fiber structure preferred (applies to the two items above)

- Robust system in x,y,z,
- Accuracy and stability has to be constant over the lifetime
- Earthquake-safe system
- Short support structure (more a wish than a realistic option)
- Vibration absorption in Z direction
- Required accuracy 100 µm or better for Vertex, SIT, FTD !, realistic?
- Min free space of 10 mm in all directions ! Gaps ! I guess it is to less

TPC Support Structure

Requirements of the TPC support structure

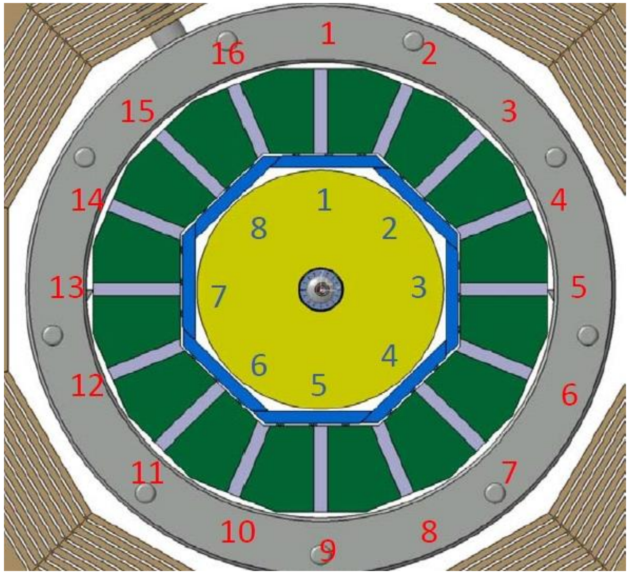


Main dimensions of the TPC (outside)

Ø Od = 3616, r=1808

Ø Id = 658, r=329

Length = 4700 incl. endplate and cabling



3 Point 3x120°, preferred gaps: 1,12, 6

4 Point 4x90°, preferred gaps: 3, 15, 11, 7 but this gaps filled 100%

Only the cryostat is foreseen to support the TPC

TPC Support Structure

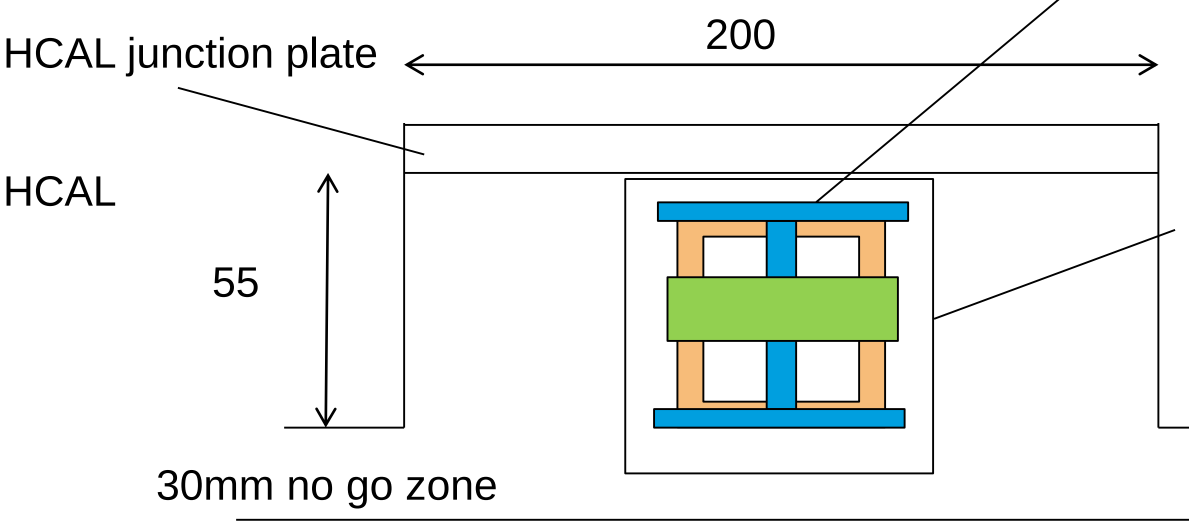
Pros and cons of various fixing points

	HCAL	Cryostat
3x120°	- Accuracy + Shorter support structure - HCAL deformation - Seismic stability	+ Accuracy - Longer support structure + Cryostat deformation - Seismic stability
4x90°	See above + Seismic stability - More space required	See above + Seismic stability - More space required

TPC support structure

Gap size: in Z direction = 55mm, circular = 200
The 30mm “ no go zone” will be used only in a worst case

Necessary gap for adjustment and support systems



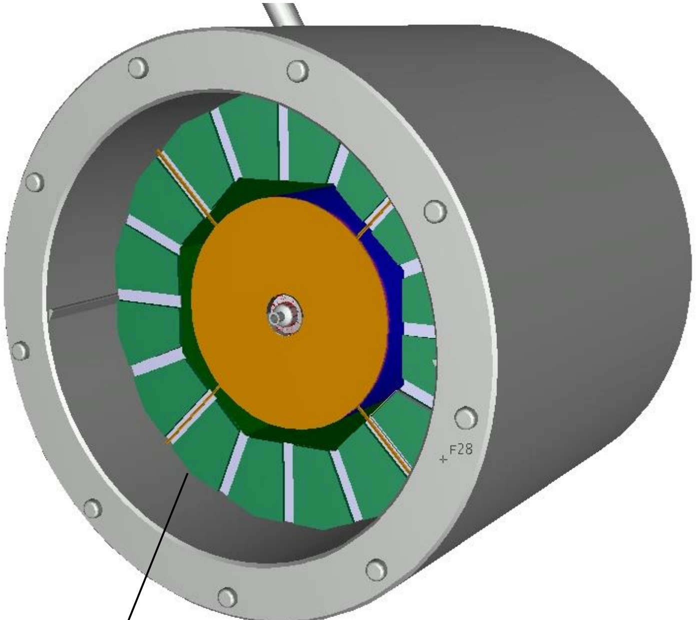
Support bar cross sections

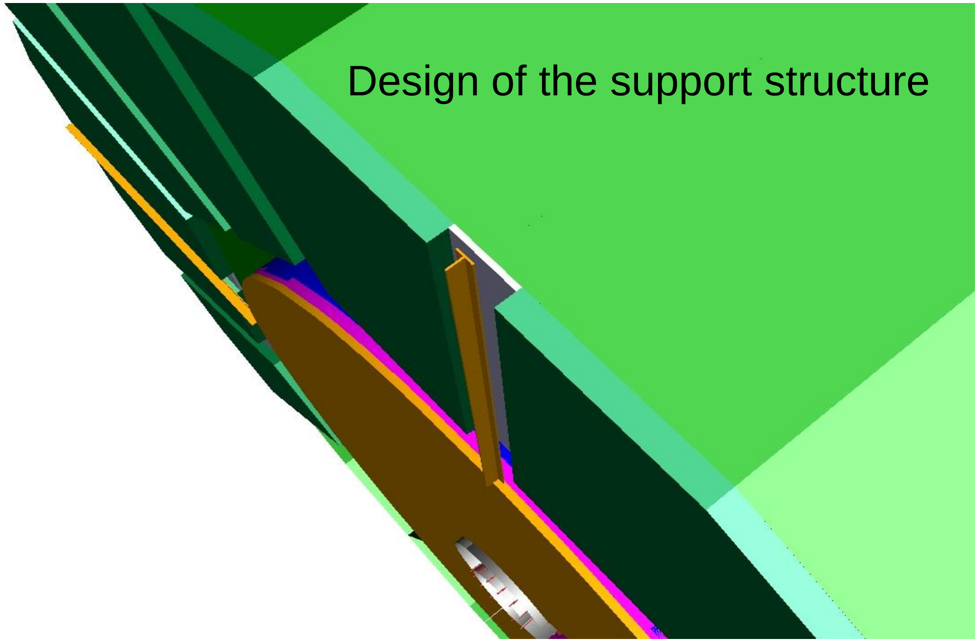
- Square profile
- Double T bar
- Band system

Note: all different profiles are drawn not in scale and not calculated

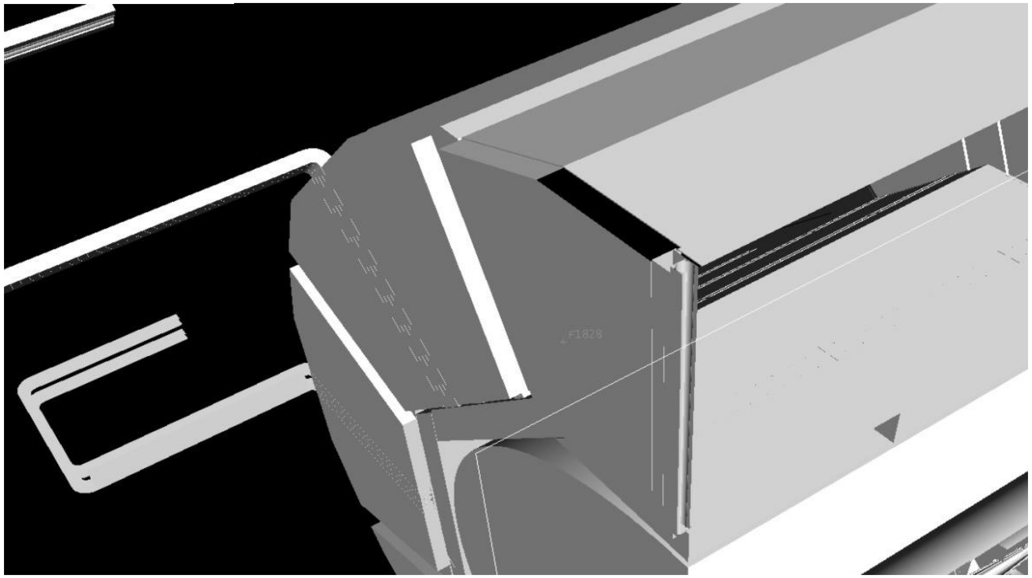
Expected each kind of support system required an separate support in Z direction

TPC support structure

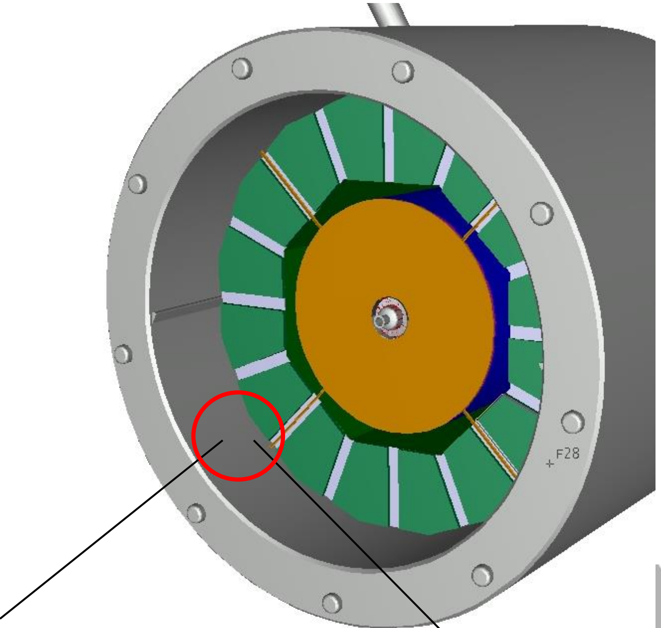


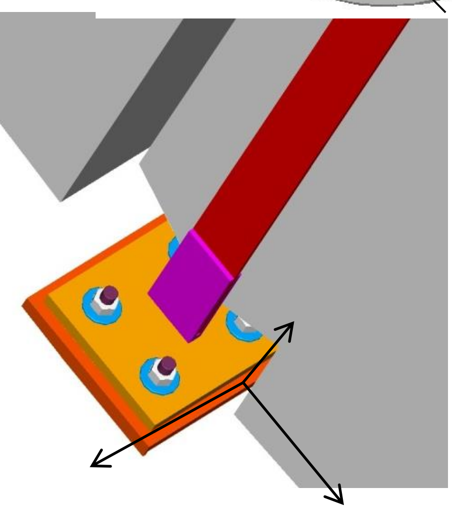


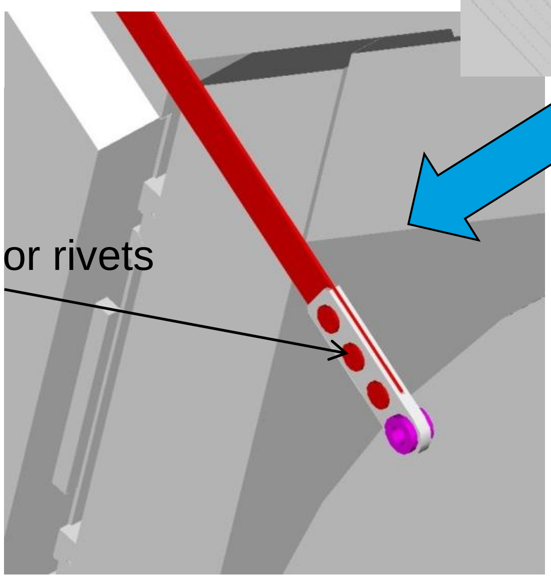
4 Cantilever arms or
4 Ropes



Flat ribbon support







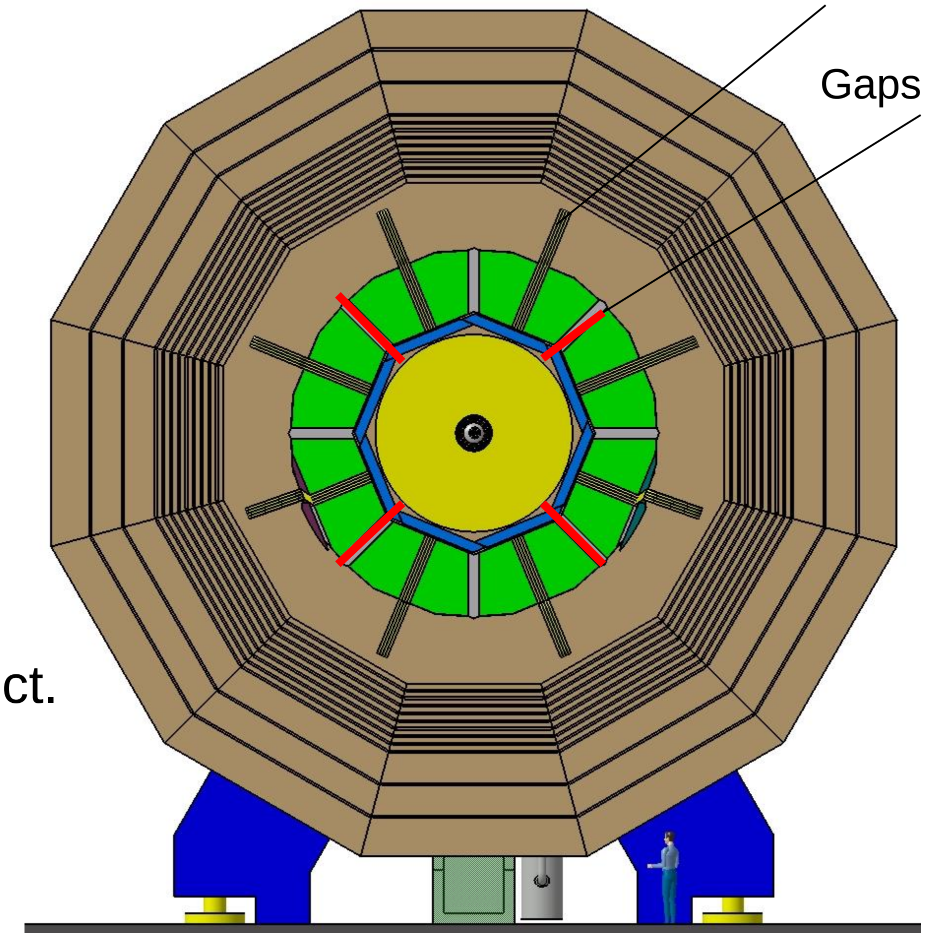
Screws or rivets

Adjustable in x,y,z

An ribbon support takes the smallest space, but a separate support in Z has to be defined

HV-Cable and routing

- Gap for the HV-Cable (two, incl. one spare?)
- TPC services
- TPC cooling lines
- TPC Support
- Cooling systems of



A lot of cables, coolling lines ect. touting at the same space

Cathode design

Typical cathode design:

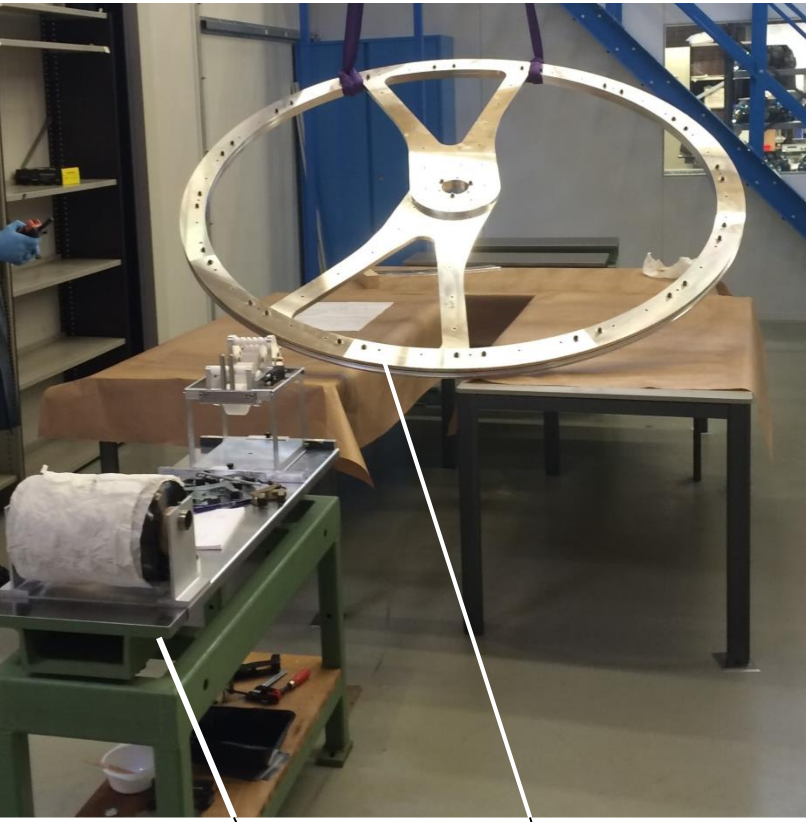
Tensioned foil (mylar, CFC, …) supported by inner and outer ring

STAR-TPC

Design goals and problems:

- Light weight, thin
- Mechanically stable and robust (inaccessible)
- Supply of HV non trivial
- Studies in laboratory support this design: load is about 2kg/10cm outer radius
- HV supply through special HV cable, OD about 14mm for 100 kV

Cathode design



Part of the wetting tool

Mold

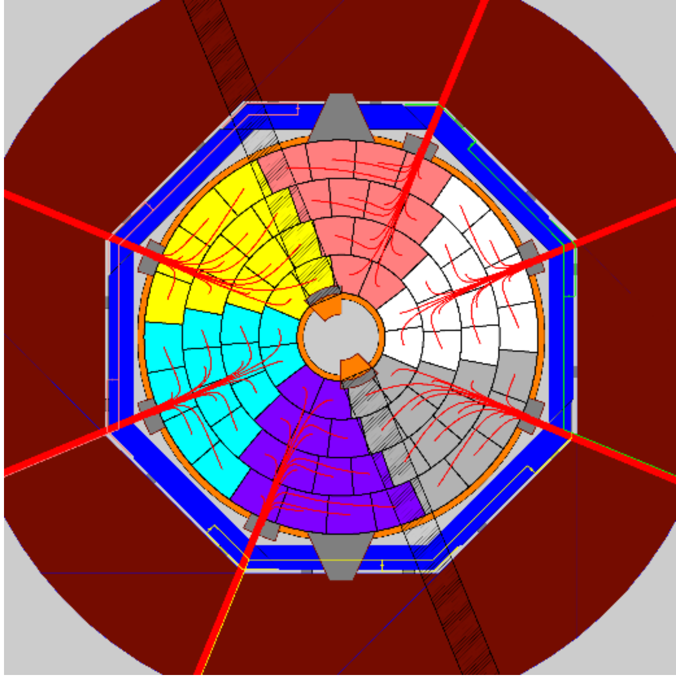
Wetting tool and mold for an T-Shape cross section rim from NIKHEF, designed for the Atlas Endcap 2m outer dia

Instance of the outer / inner wheel of the Cathode

Carbon Roving

HV Cable and routing

Interface with the SET: the radial reservation made for the SET is currently 35mm for two planes of strip sensors. There are no information on the structure, the power consumption, the cabling.
The SET can be an autonomous structure resting on the TPC endplates or sensor planes
fastened to the Ecal front face. This has an impact on the Ecal: to be known



Patch panels for the Ecal barrel

The Ecal/Tpc interface concerns the passage of the TPC “ribbons” and the services between end cap and barrel as well as patch-panels.

Such an interface exists also with the inner detectors.

Henri Videau LLR. Integration Meeting February 2018   Orsay

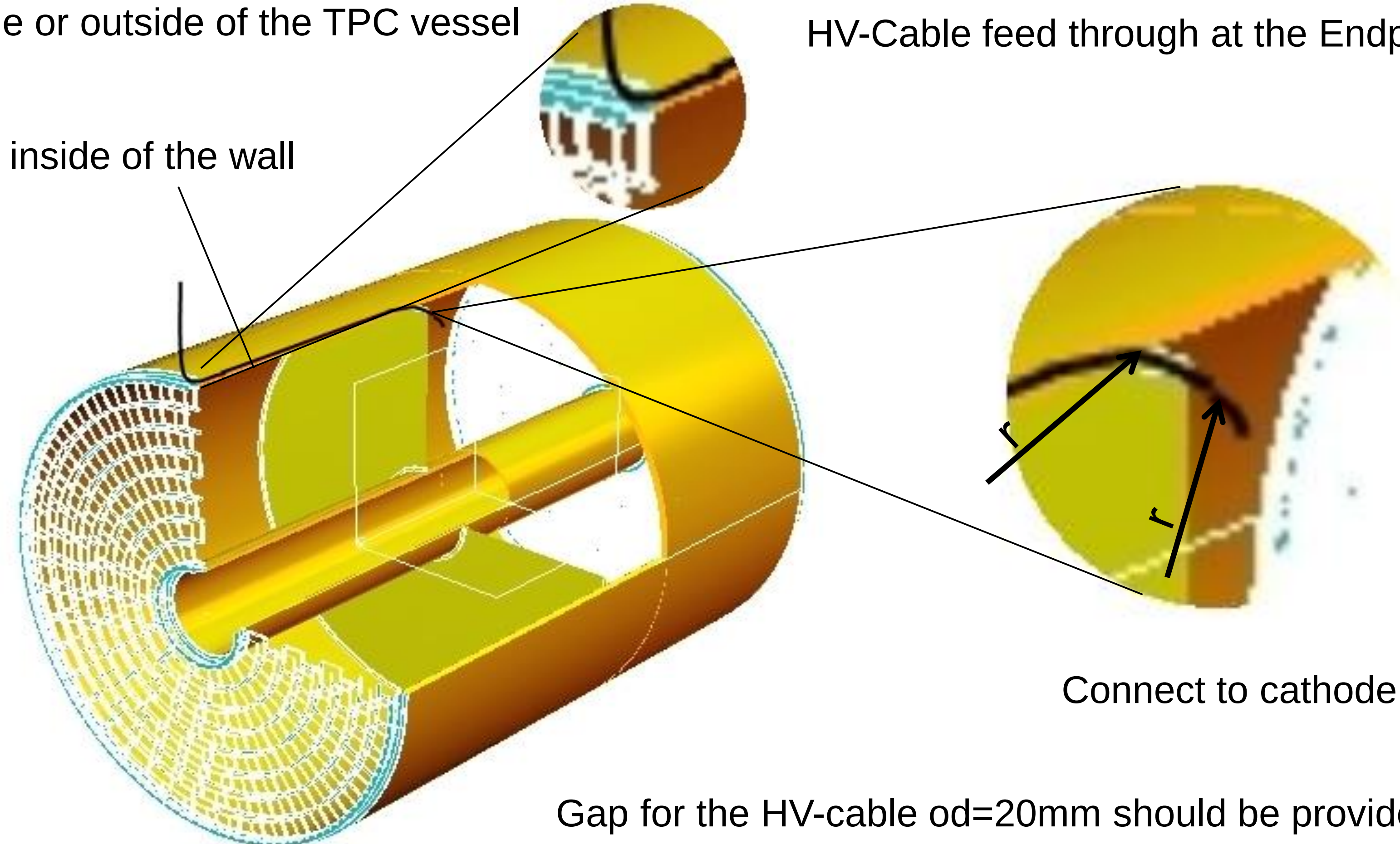
HV Cable and routing

Overview of an first idea of the HV-cable routing

Inside or outside of the TPC vessel

HV-Cable feed through at the Endplate

Laying inside of the wall



Connect to cathode

Gap for the HV-cable od=20mm should be provide, the bending radius maybe an issue

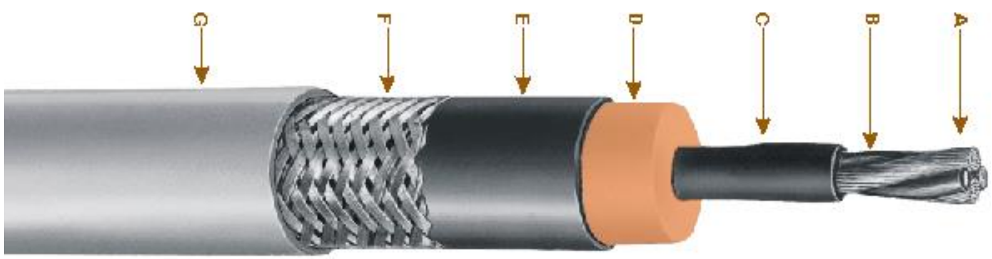
HV Cable and routing

Samples of HV-cables

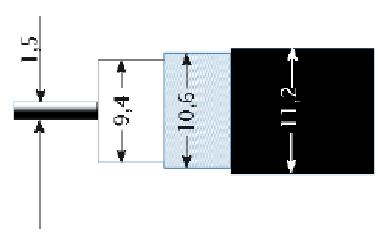
Okonite Hi-Voltage Cable: www.okonite.com

100kV, od= 16,76mm,

bending radius = 4*od > 70mm



A Coated Stranded Copper Conductors
B Polyester Insulation
C Extruded Semiconducting Layer
D Primary Insulation – Okoguard
E Extruded Insulation Shield
F Coated Copper Braid
G Jacket – Okoseal

C 2124	Mat.- Nr.: 0502032124			
Capacitance/m: Impedance: Ambient temperature: Bending radius: Max. current:	99pF 61Ω -50°C ... +60°C 15,2cm max. 27A		**100kV DC**	HVS 65 65kV HVS 100 100kV

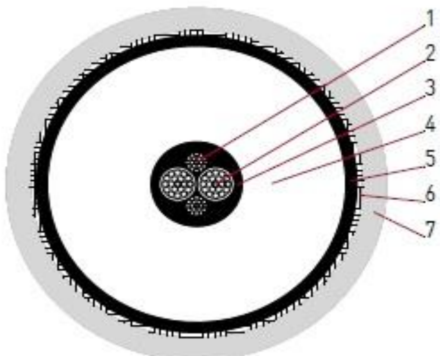
HV Cable and routing

X-Ray HV Cable

hivolt.de

2212

100kV$_{DC}$ – EPR Dielectric

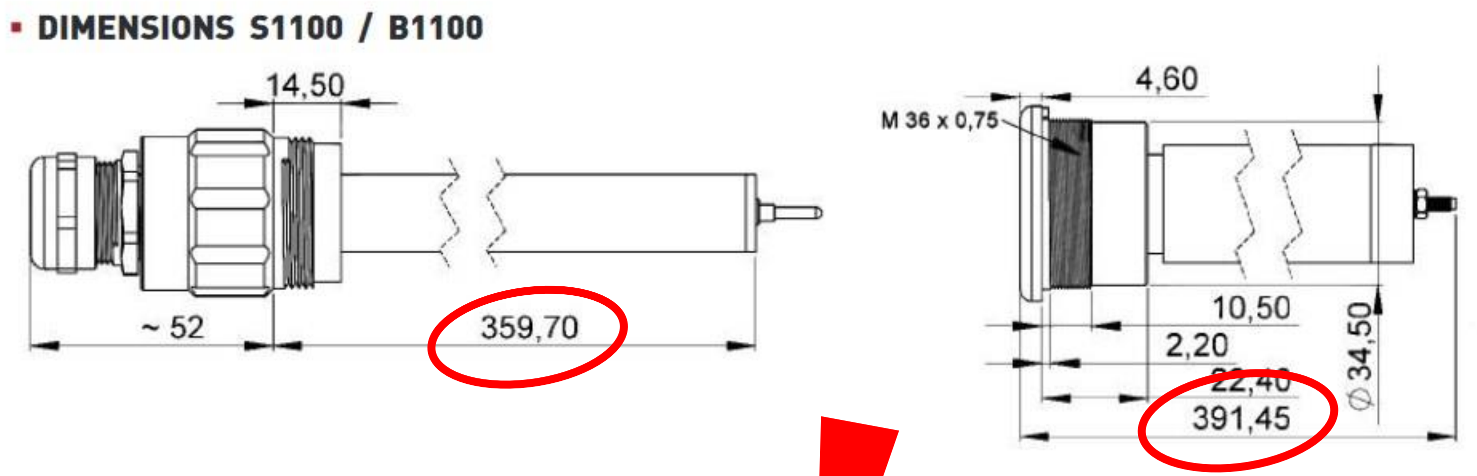


1. Conductor	2x bare Cu/Sn AWG18 (19x0.24mm, t.p.c.), AWG15 in total	
2. Conductor	2x Cu/Sn AWG15,(19x0.33mm, t.p.c.), Polyester Tape Insulation, Rated Voltage: 1kV$_{DC}$	
3. Semicon	Semiconductive EPR (black)	Ø 4.8mm
4. Dielectric	EPR	Ø 15.8mm
5. Semicon	Semiconductive EPR (black)	Ø 16.9mm
6. Braid	Cu/Sn (Coverage ≥ 80%)	Ø 17.5mm
7. Jacket	PVC	Ø 19.9mm

▪ **TECHNICAL DATA**

Number of Conductors	3
Rated Voltage	100kV$_{DC}$ / 30kV$_{AC}$
Impedance	53Ω
Capacitance	131pF/m
min. Bend Radius (static)	101mm
Operating Temperature	-51°C - +60°C
RoHS Compliant	Yes
Weight	0.49kg/m
Color	grey
Status	P (Preferred)

HV Cable and routing



Commercial 100kV connector from Highvolt male and female roughly 750mm long

TPC installation

Thomas Schörner-Sadenius
Volker Prahl
Paris, 8/9 October 2015

Some basic assumptions – all to be argued

No (long) transport of full TPC, field cage or fully equipped end-plates → need to assemble TPC at IP campus

- Our assumption here: TPC assembly in the AH. Compatible with Yasuhiro's overall plan assuming realistic TPC time scales?
- Then space in AH necessary
- Do it in research office building? But then where full TPC system test (gas!)?
- No TPC assembly in DH.

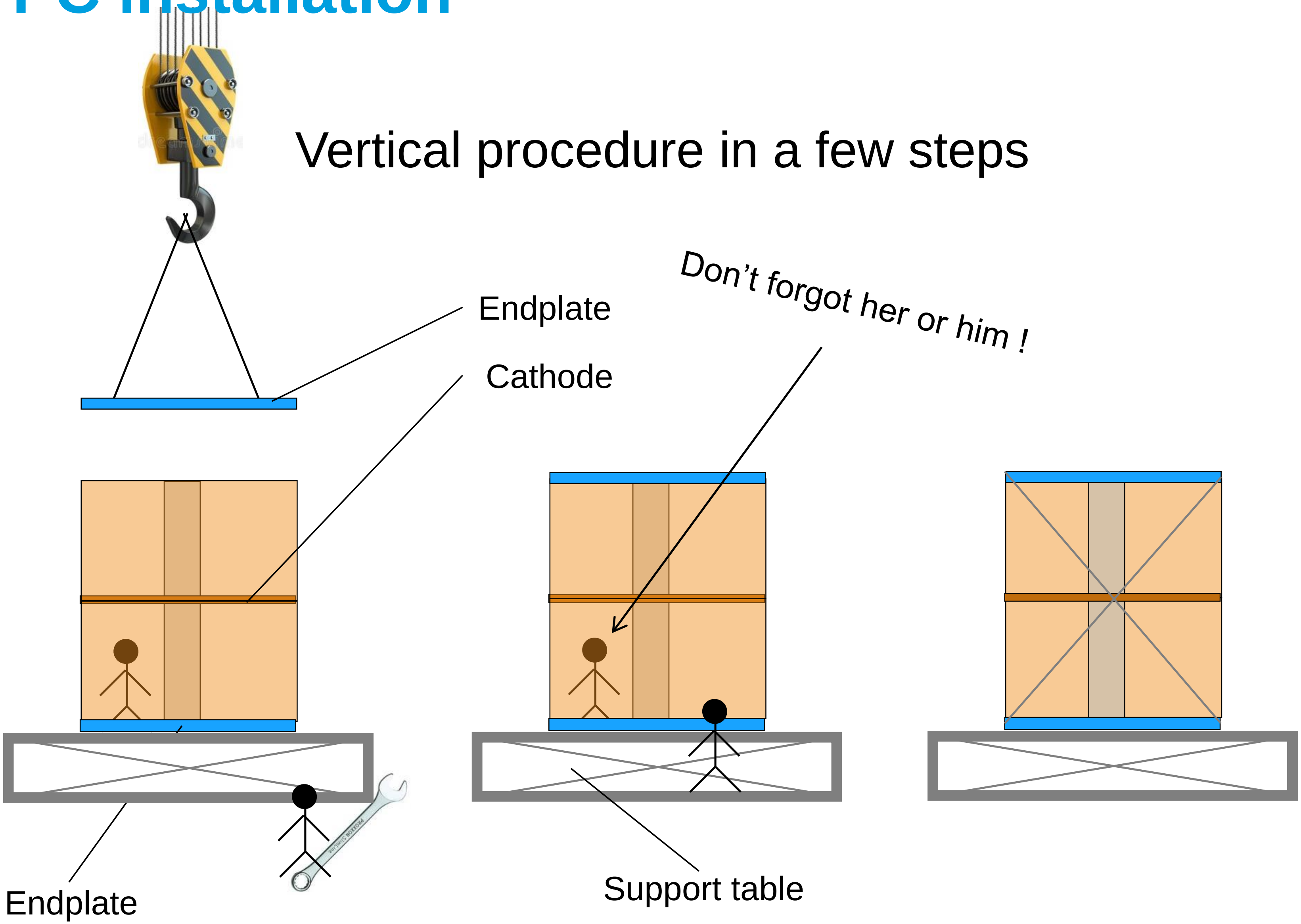
No TPC assembly in DH – sufficient space and possibility to work in parallel with yoke construction, but probably bad timeslot?

Current scenario therefore:

- Horizontal or vertical assembly in AH hall (exact position tbd)
- Space requirement: 100 m^2 (probably 60 m^2 enough, but some contingency), plus storage space (for modules) and test area for modules
- Field cage delivered in one or two big pieces and assembled in AH
- Necessity to create grey-room / ISO7 characteristics around TPC assembly place

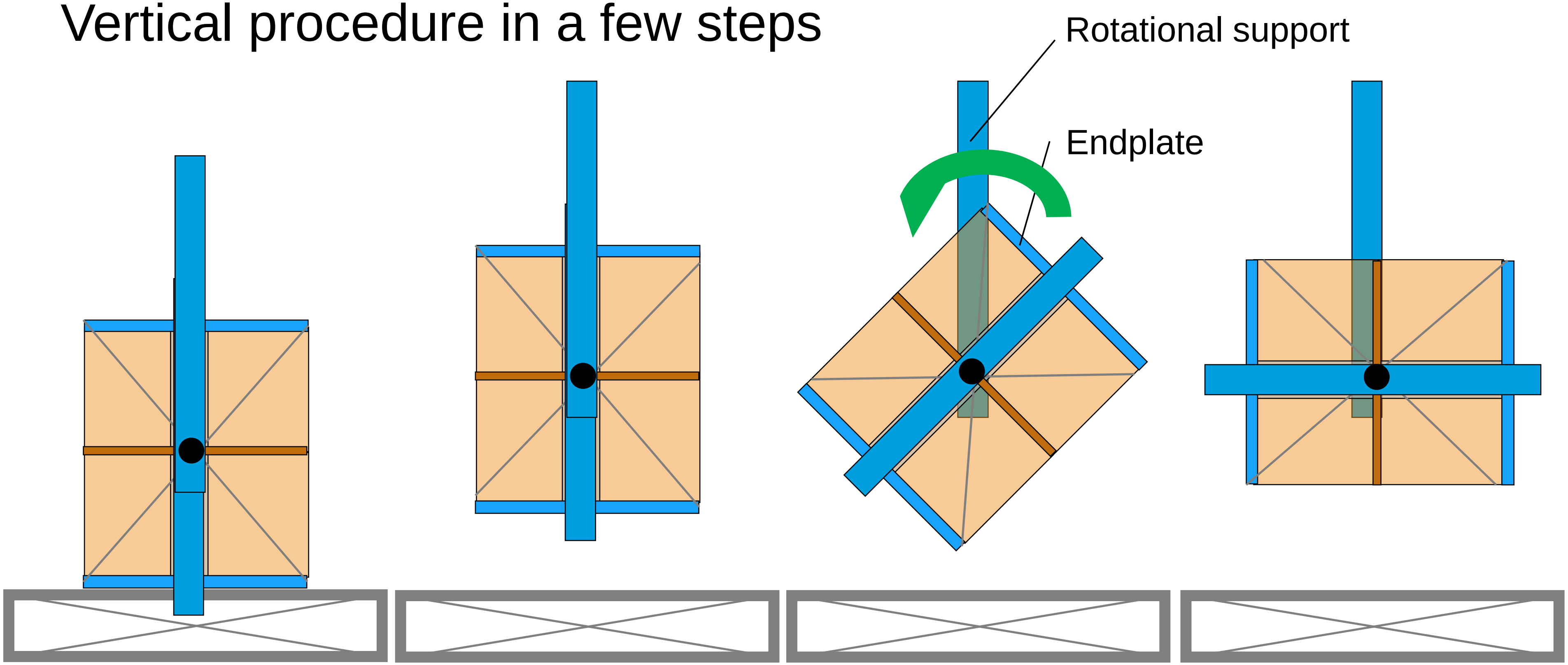
TPC installation

Vertical procedure in a few steps



TPC assembly

Vertical procedure in a few steps



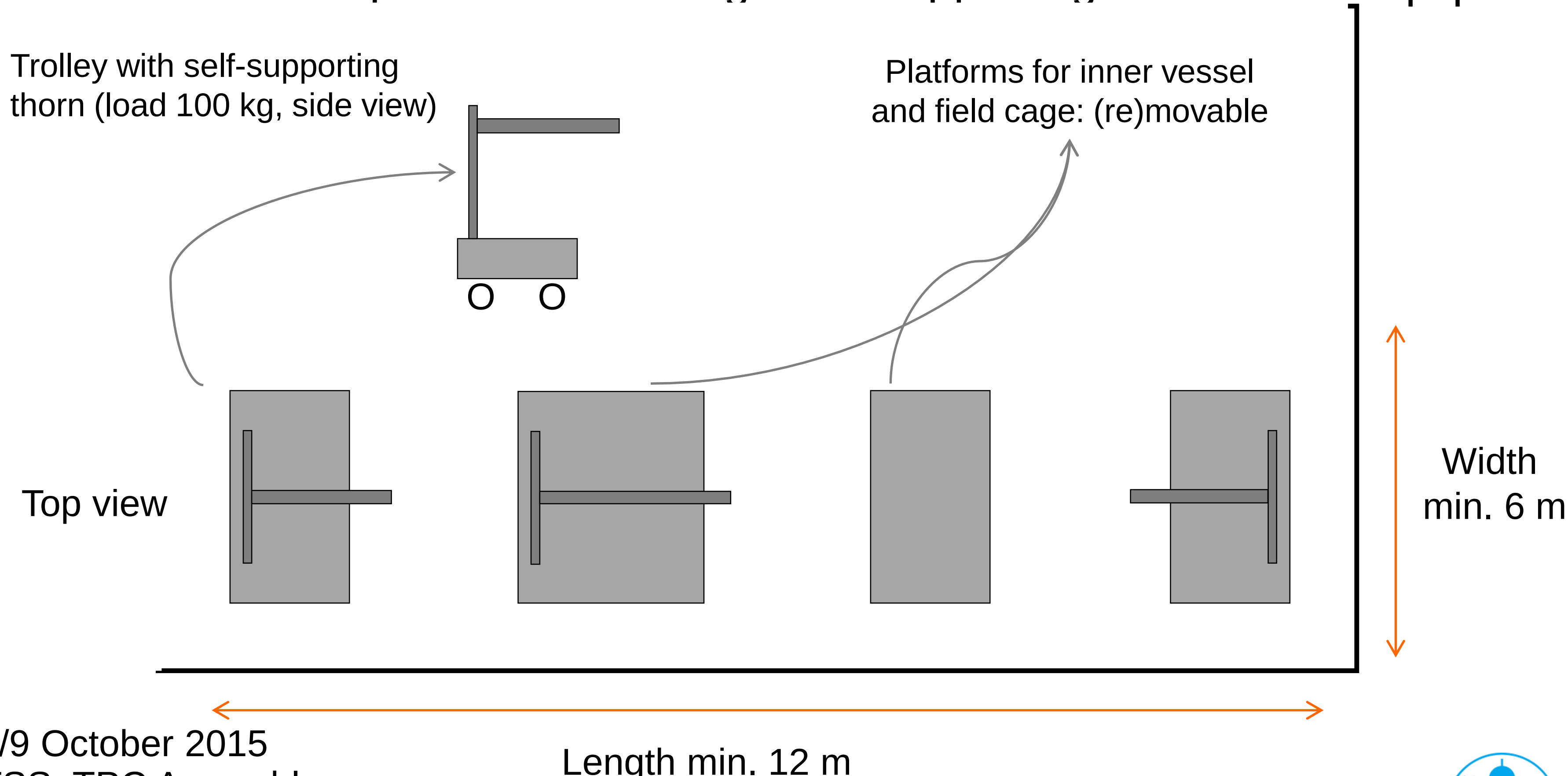
Then

- Cleaning of field cage
- Construction of grey/clean room around TPC field cage (ISO 7)
- Equipping of end-plates with tested modules using robot (petal-like structures in EP quadrant holes).
- System test (in AH)

TPC assembly

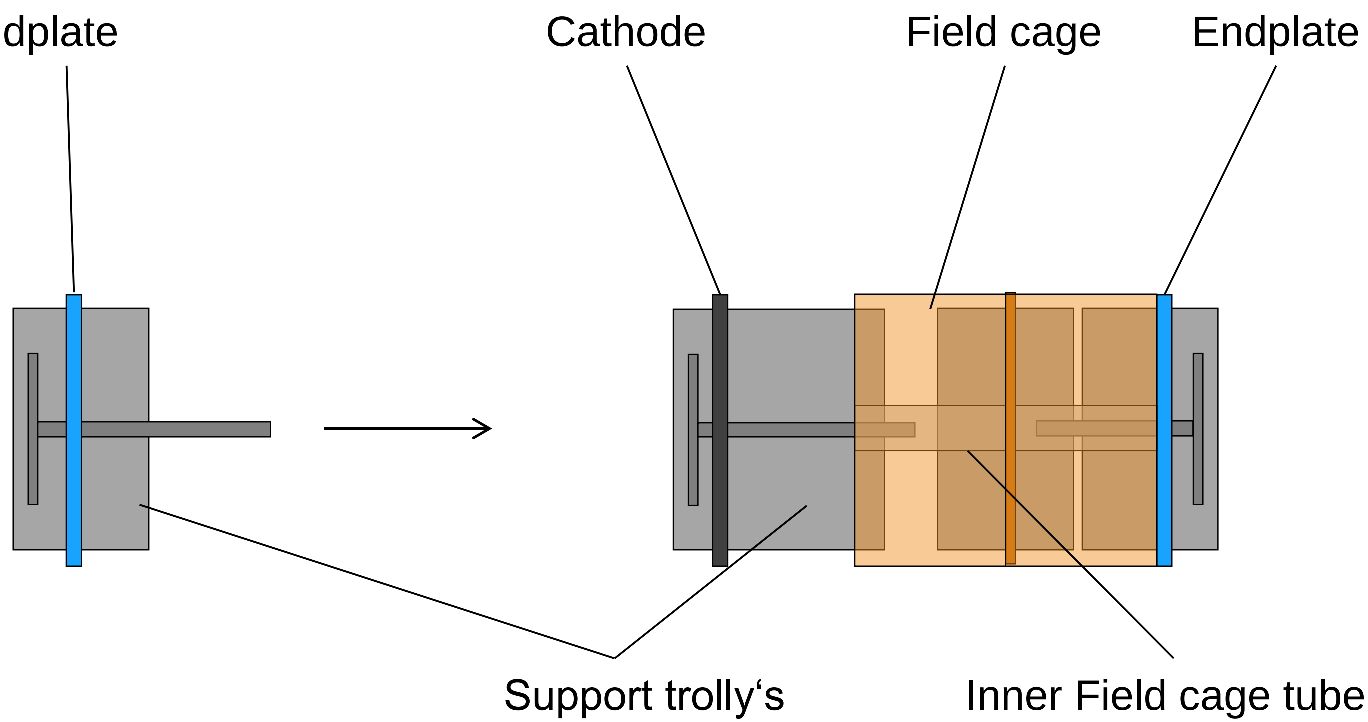
Horizontal procedure in a few steps

Note: – Grey room / ISO7 with stable T and FFUs needed from start.
– Access to grey room through sliding gate with air lock
– Assumption that field cage self-supporting and first EP equipment



TPC assembly

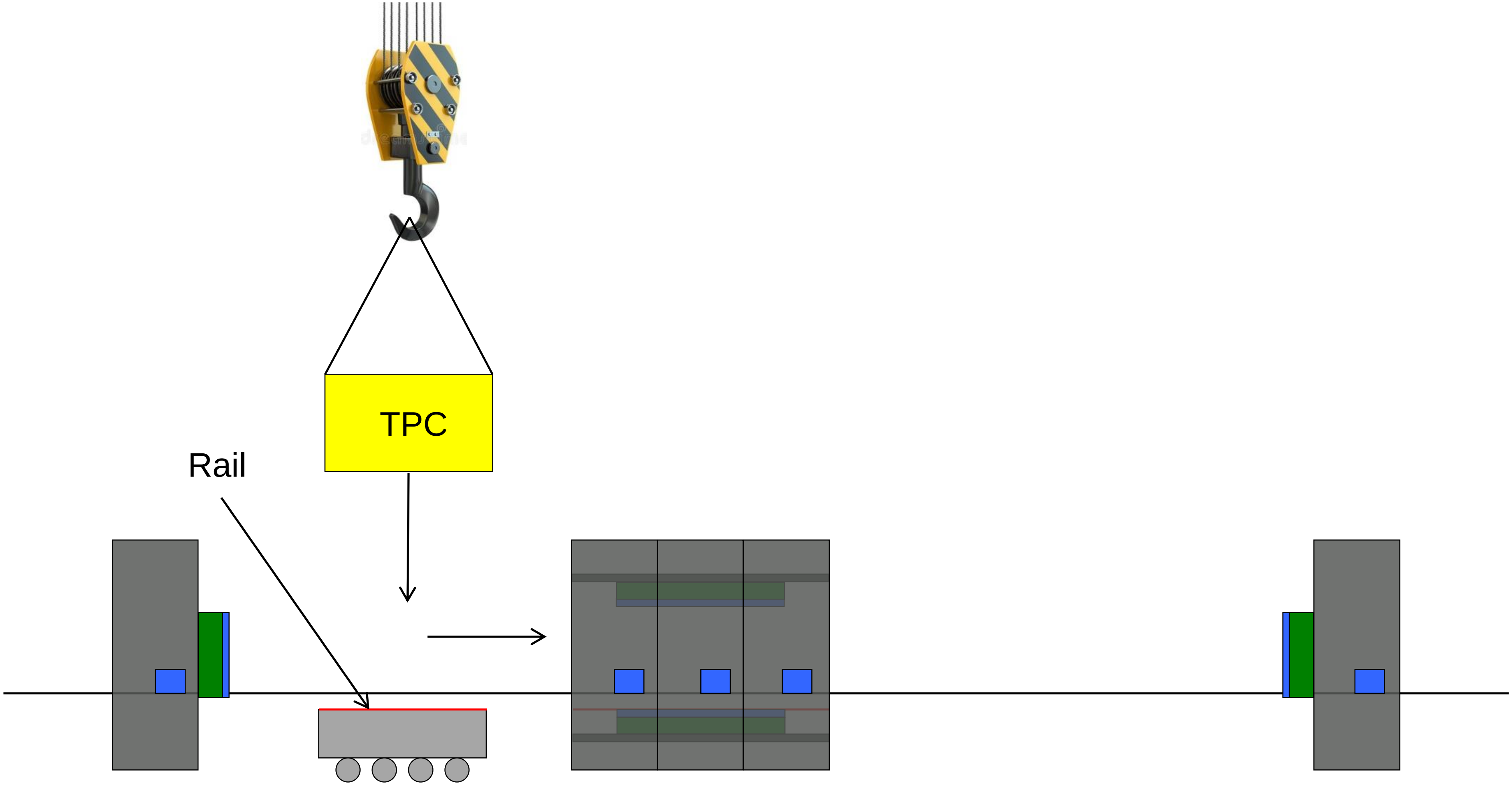
Horizontal procedure in a few steps



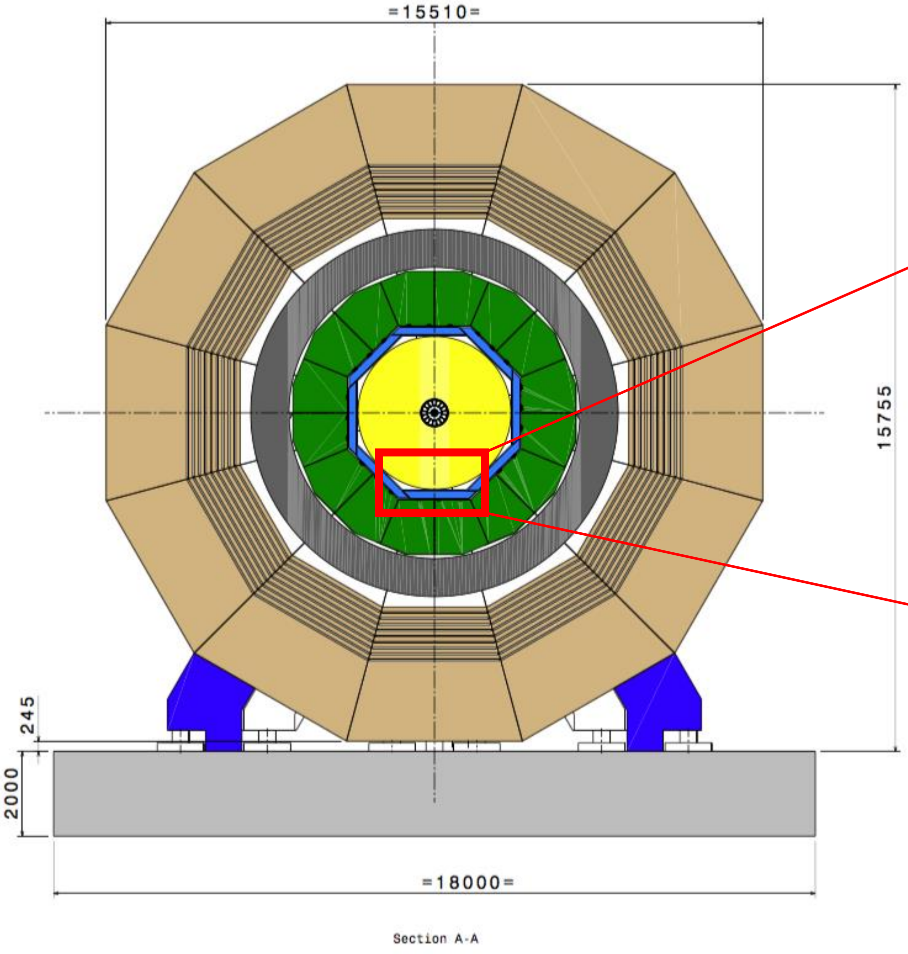
Top view of TPC assembly

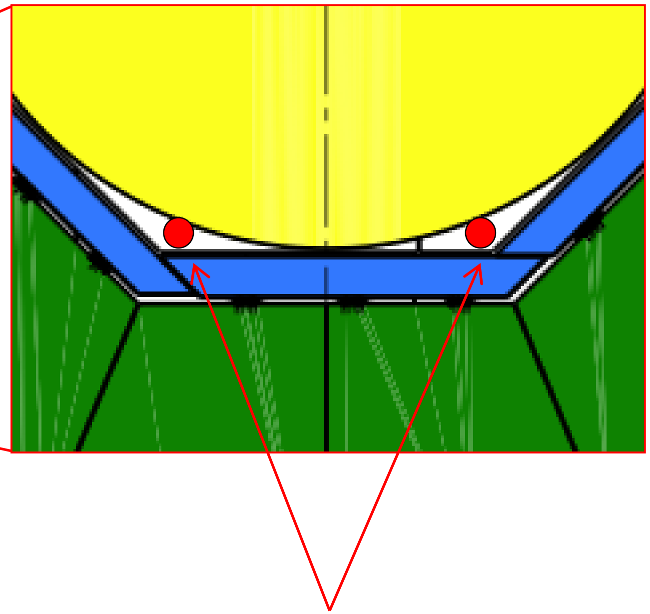
Alternative: First fixing of inner vessel in field cage, then installation / spanning of cathode.

TPC inserting



TPC inserting





Conclusion and outlook

Conclusion

- Support system with min. 4 bars necessary
- Required space is an issue with the infrastructure and gaps between and in the middle of the HCAL / ECAL octagons
- Alternative approaches have to be considered
- Various cross sections and materials of the support bars will be calculated
- Alternative system design maybe required

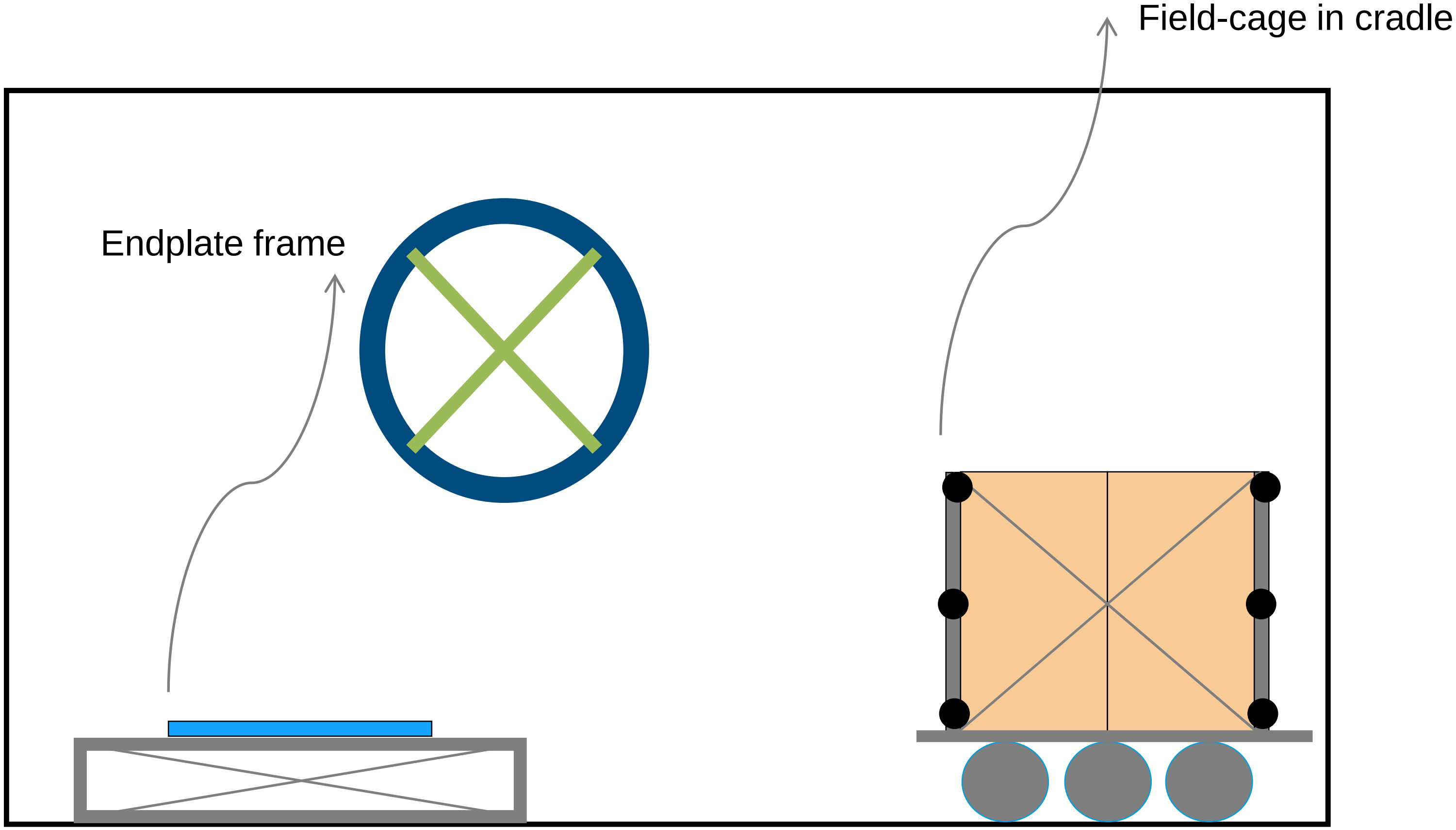
Conclusion and outlook

Outlook

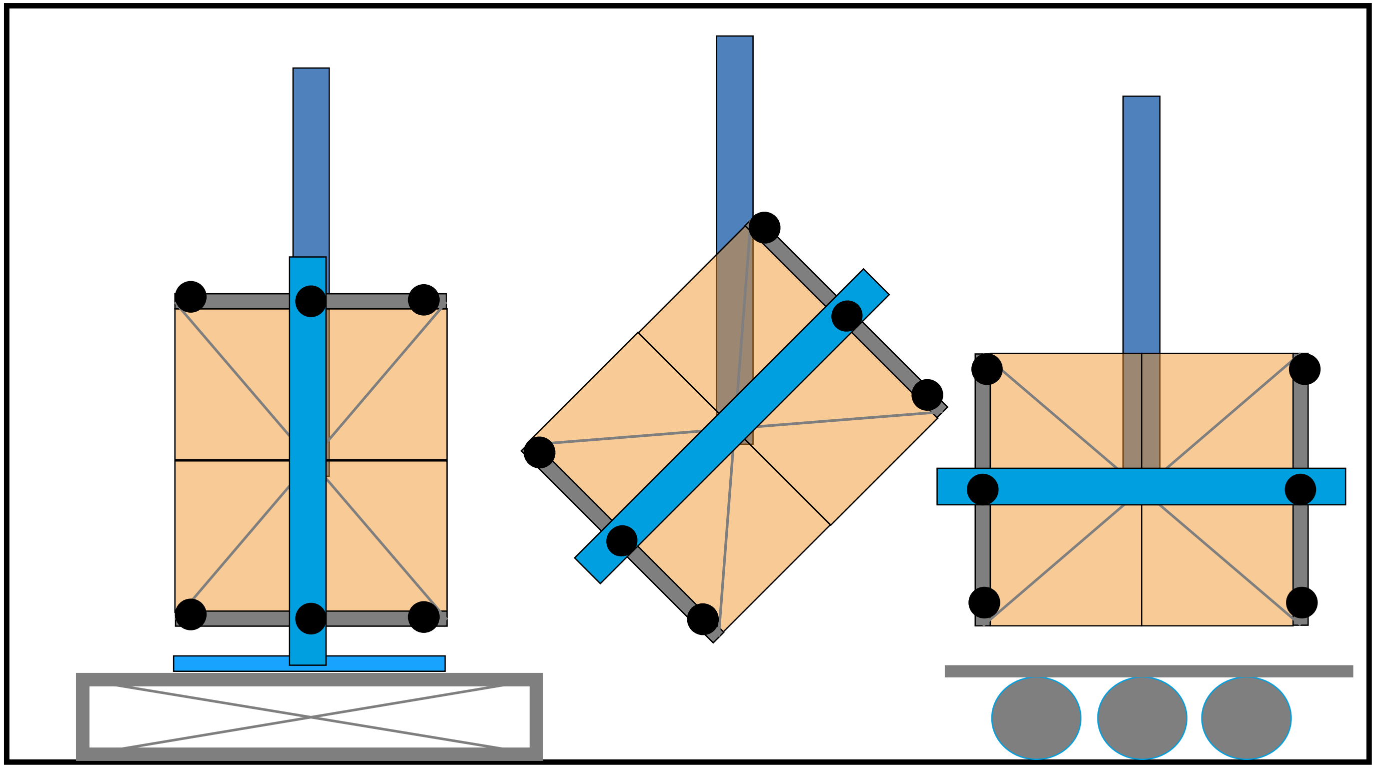
- Availability of space in the gaps has to be evaluated
- More FEA studies
- Minimize the cross section of the support bars
- HV-Cable routing
- Field cage electrical insulation
- Cathode, design and inserting
- TPC Assembling and mounting, services
- TPC insertion
- Local regulations (Gas, HV, …)
- And many more…

Backup slides

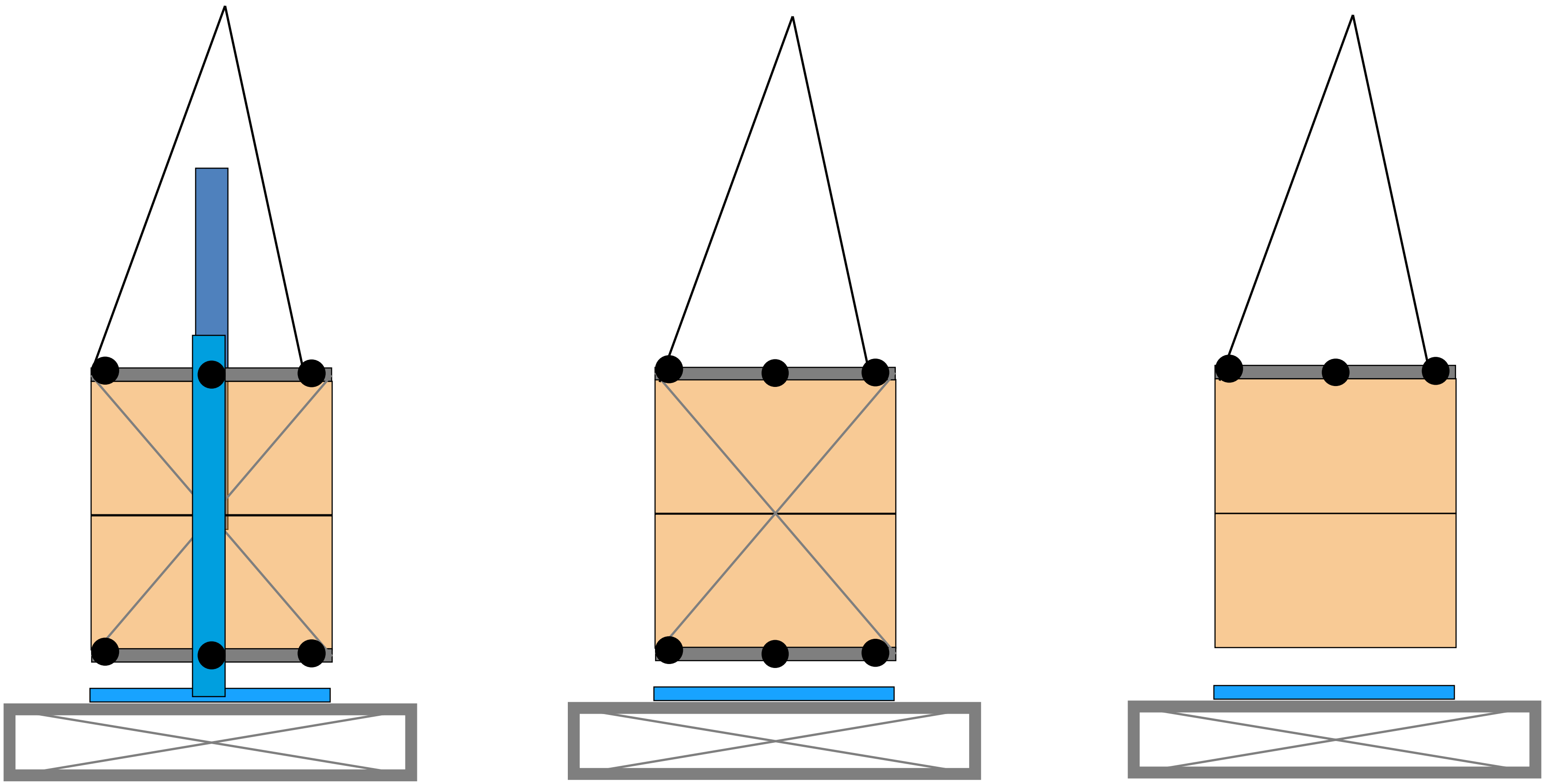
Vertical procedure in a few steps



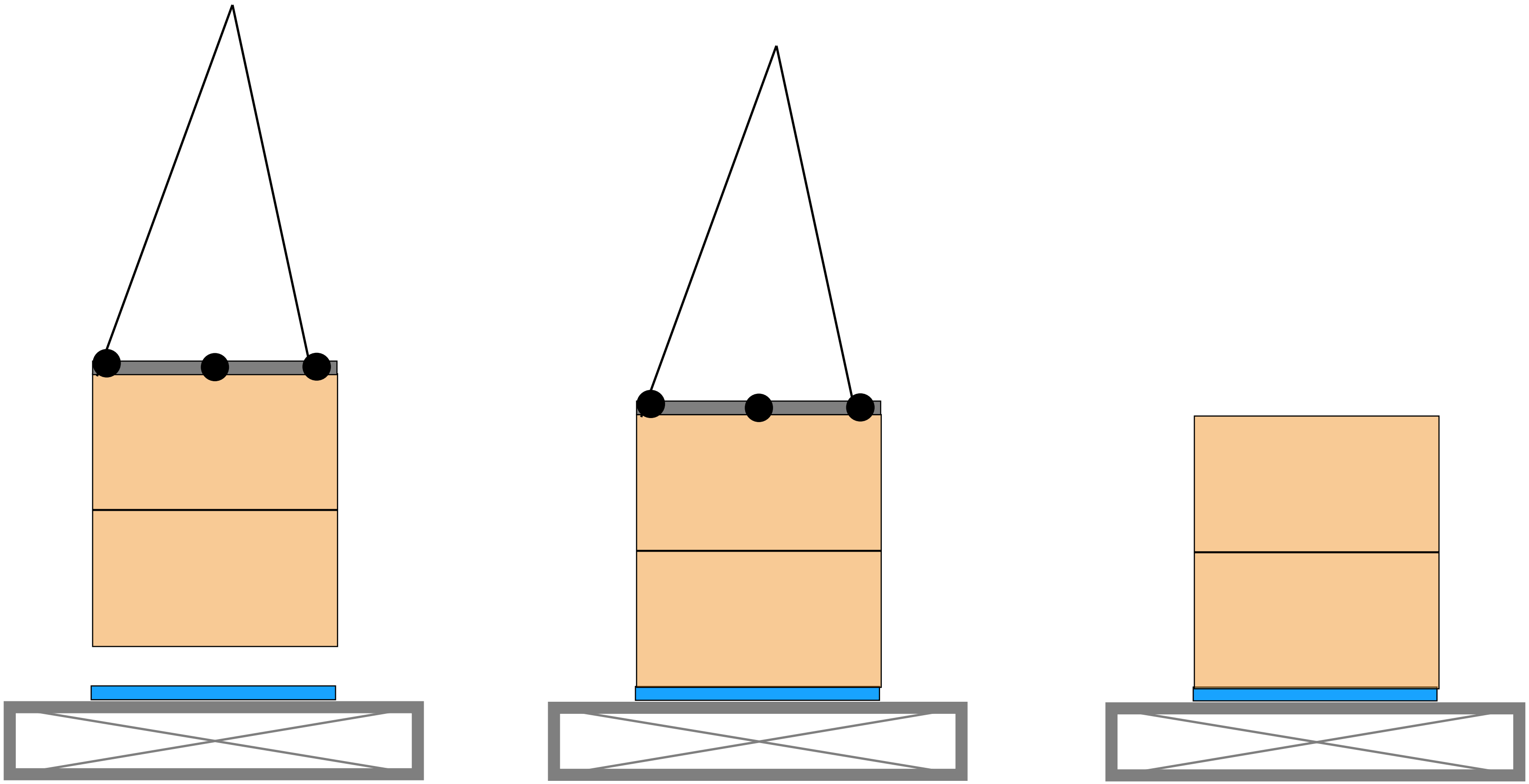
Vertical procedure in a few steps



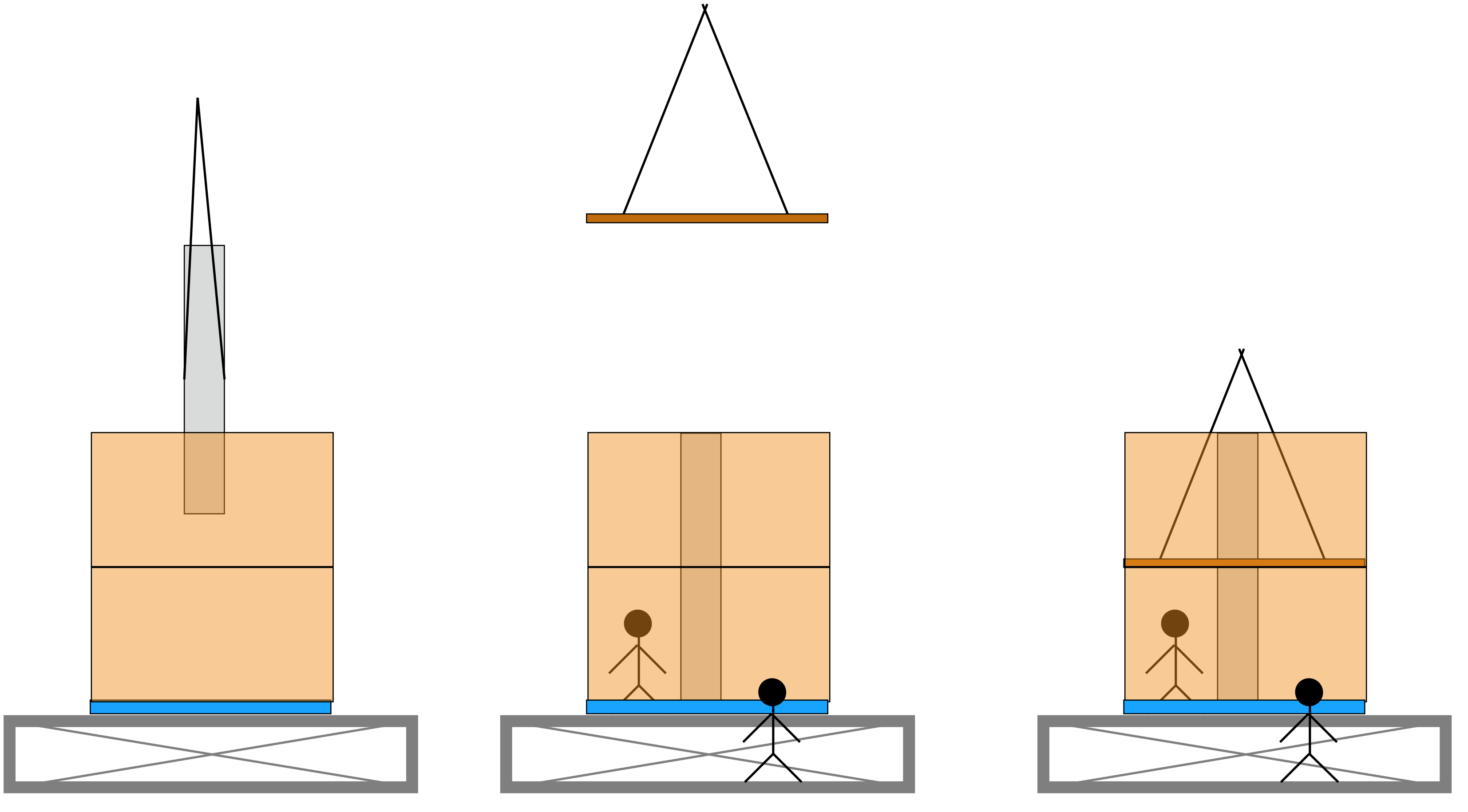
Vertical procedure in a few steps



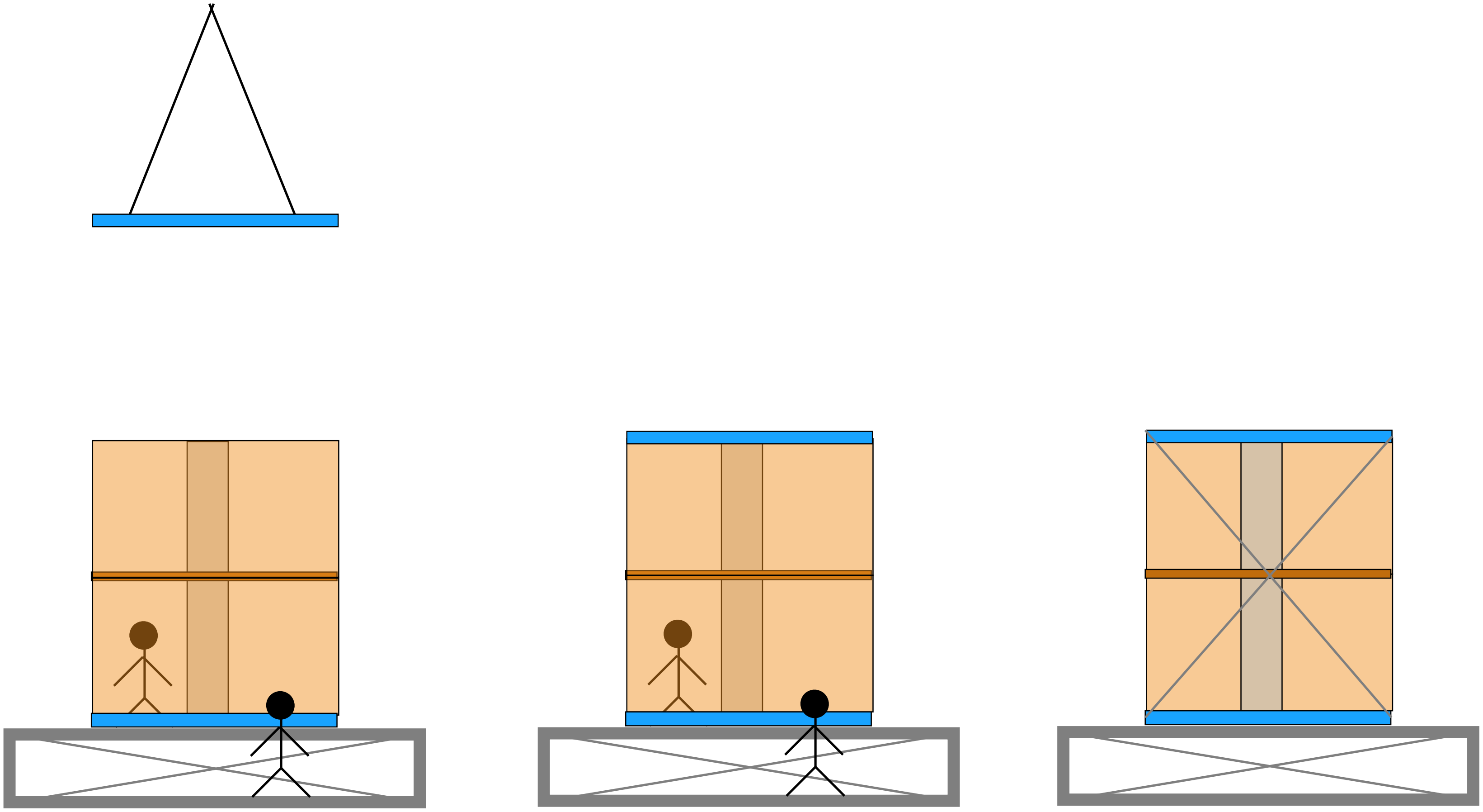
Vertical procedure in a few steps



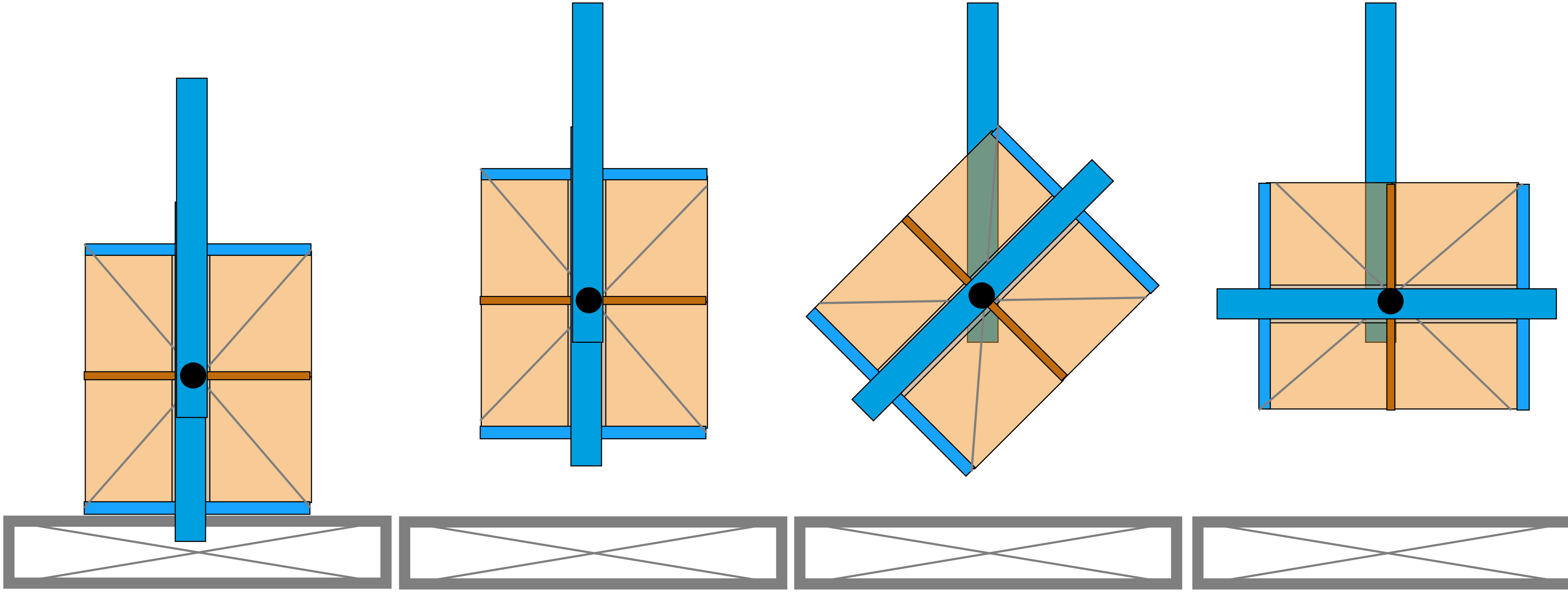
Vertical procedure in a few steps



Vertical procedure in a few steps



Vertical procedure in a few steps

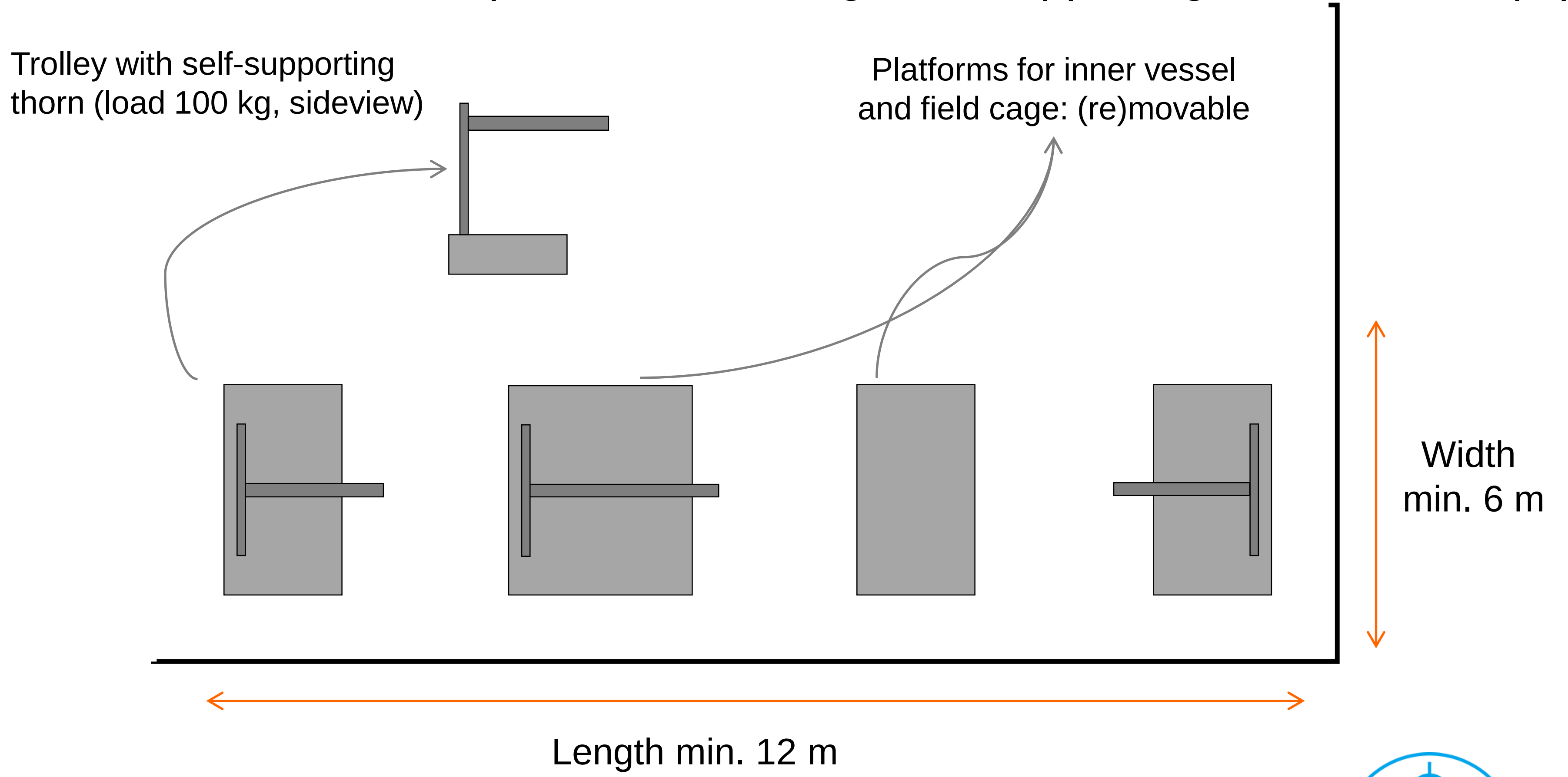


Then

- Cleaning of field cage
- Construction of grey/clean room around TPC field cage (ISO 7)
- Equipping of end-plates with tested modules using robot (petal-like structures in EP quadrant holes).
- System test (in AH)

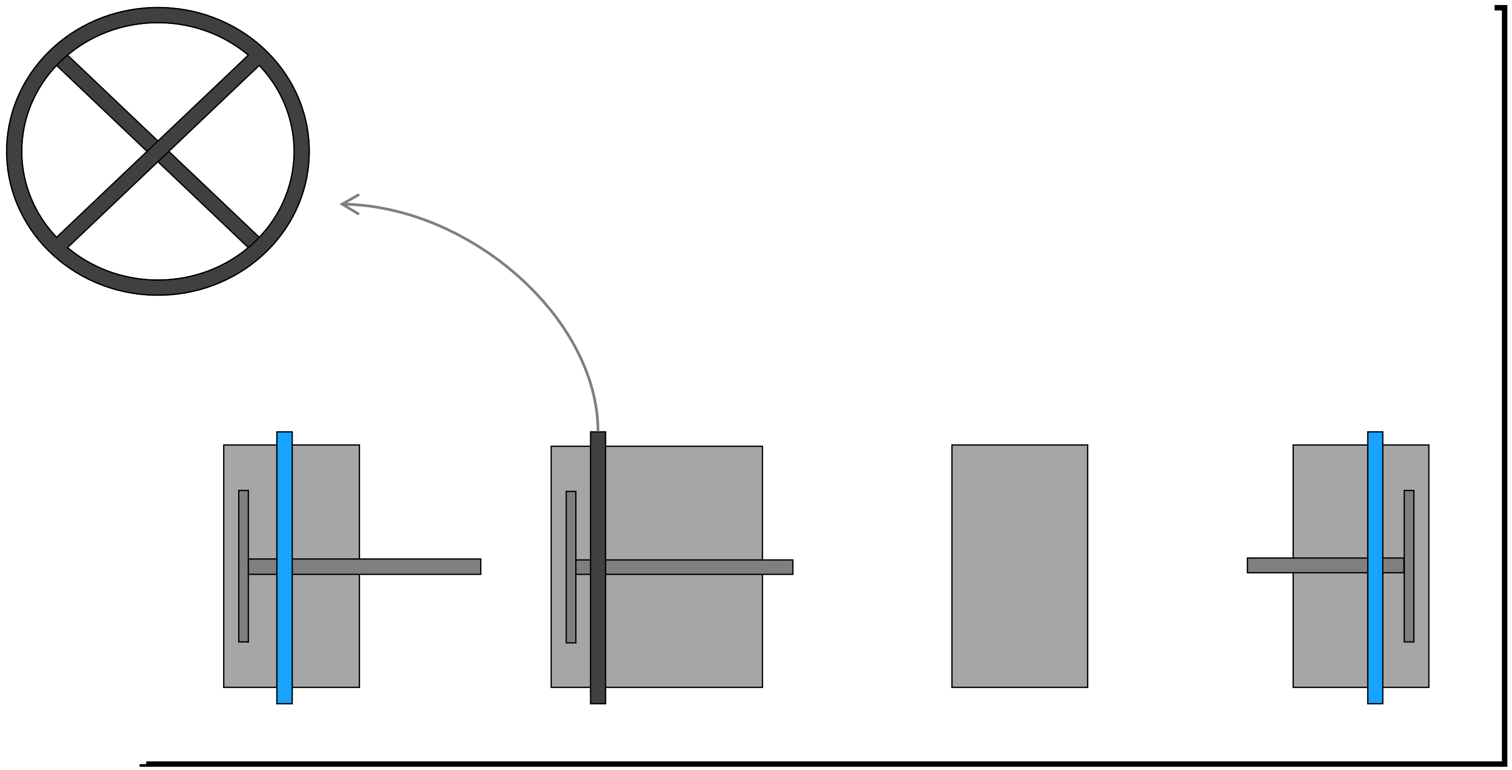
Horizontal procedure in a few steps

Note: – Greyroom / ISO7 with stable T and FFUs needed from start.
– Access to greyroom through sliding gate with air lock
– Assumption that field cage self-supporting and first EP equip



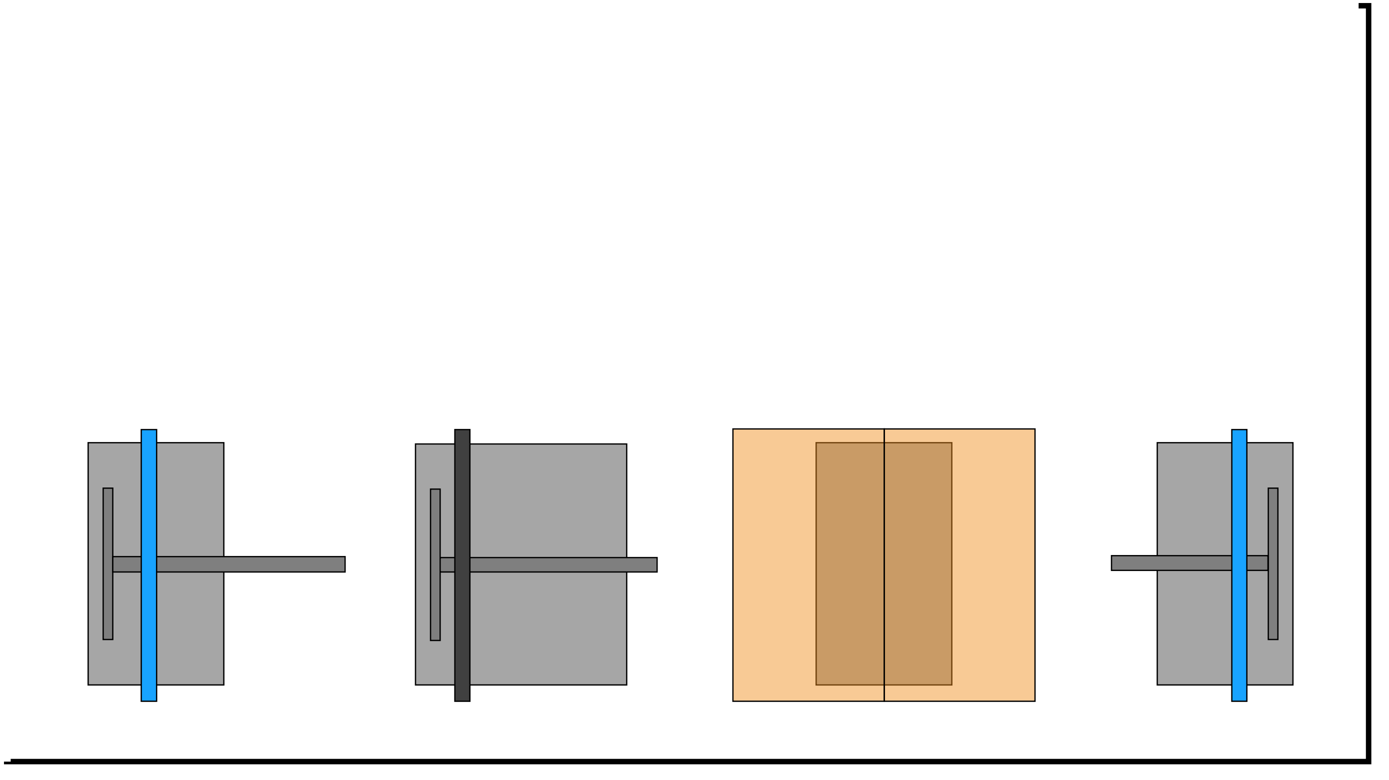
Horizontal procedure in a few steps

End-plate structures on trolleys and beginning of end-plate equipping (R); supporting star on inner-vessel platform



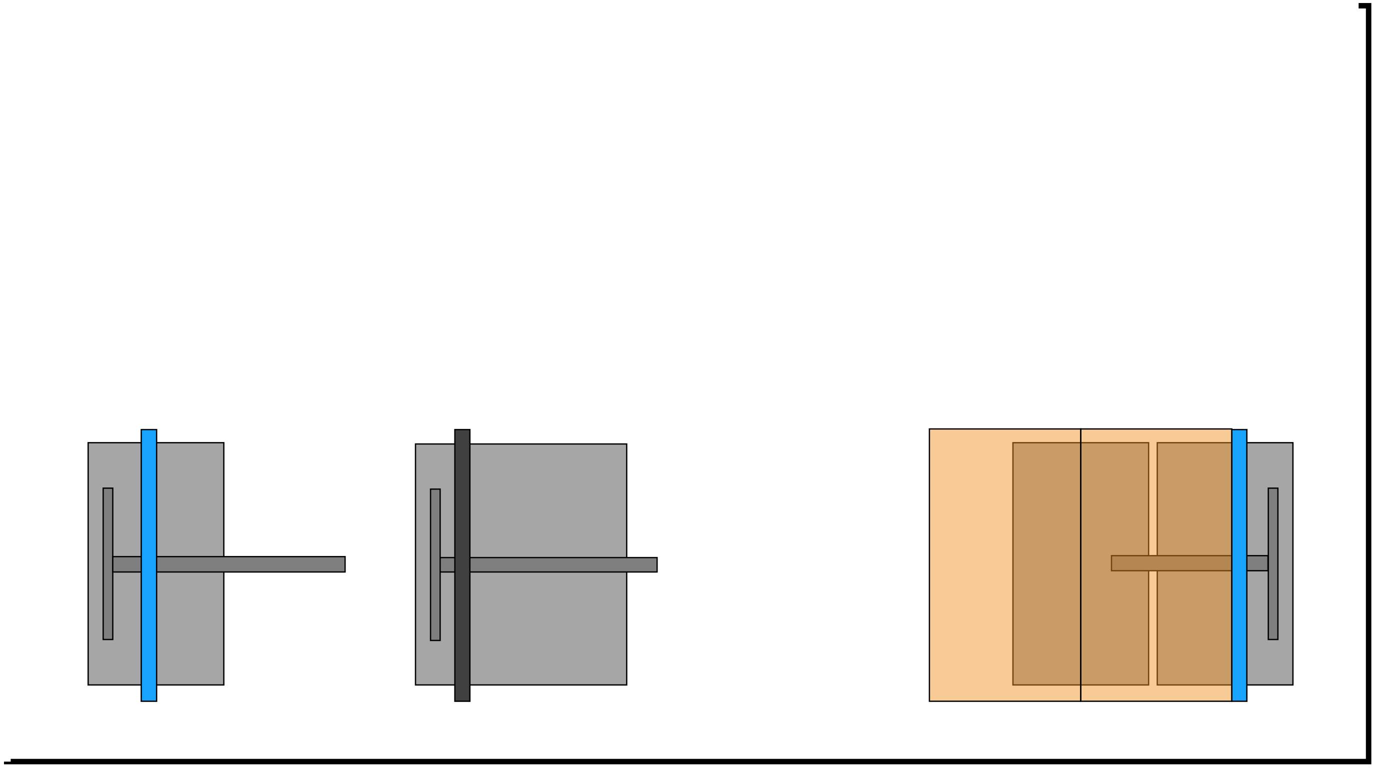
Horizontal procedure in a few steps

Field-cage assembly



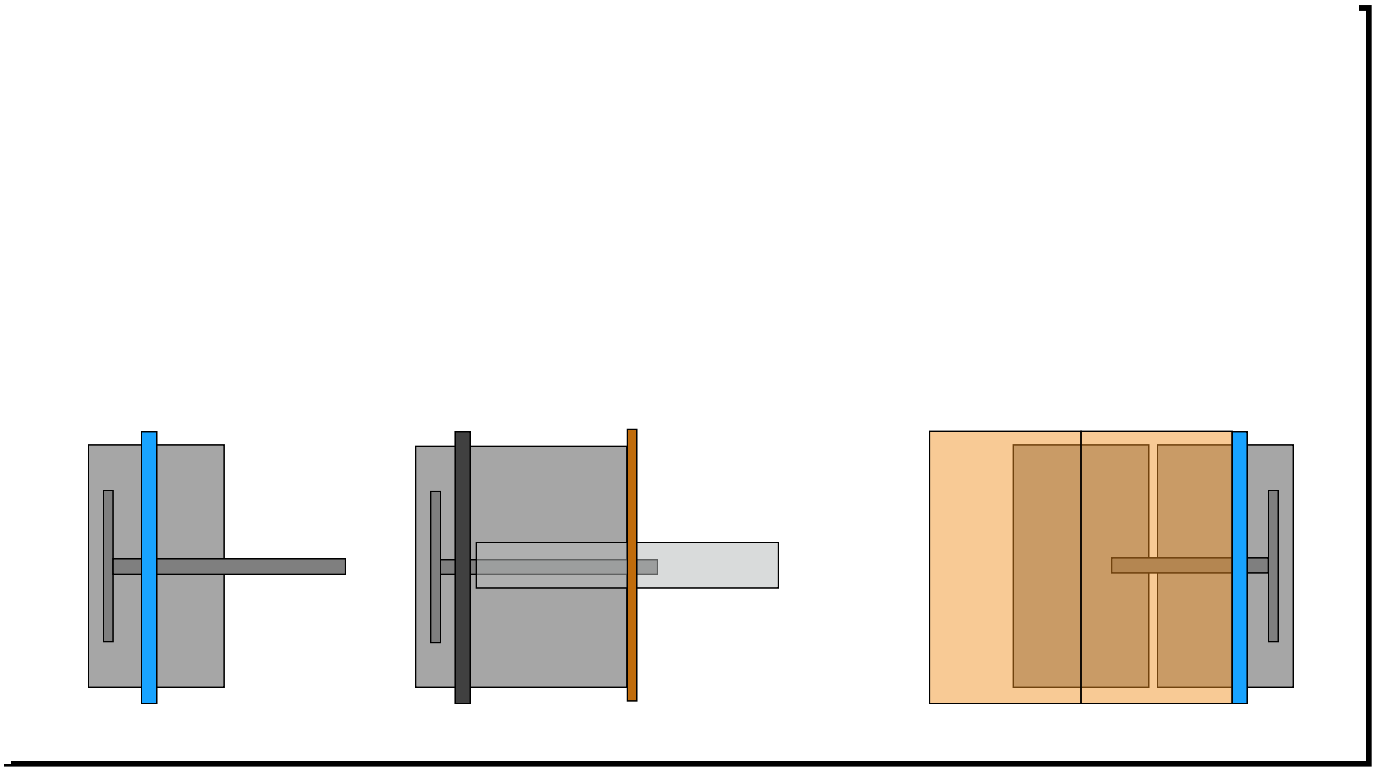
Horizontal procedure in a few steps

Marriage of field-cage and end-plate R



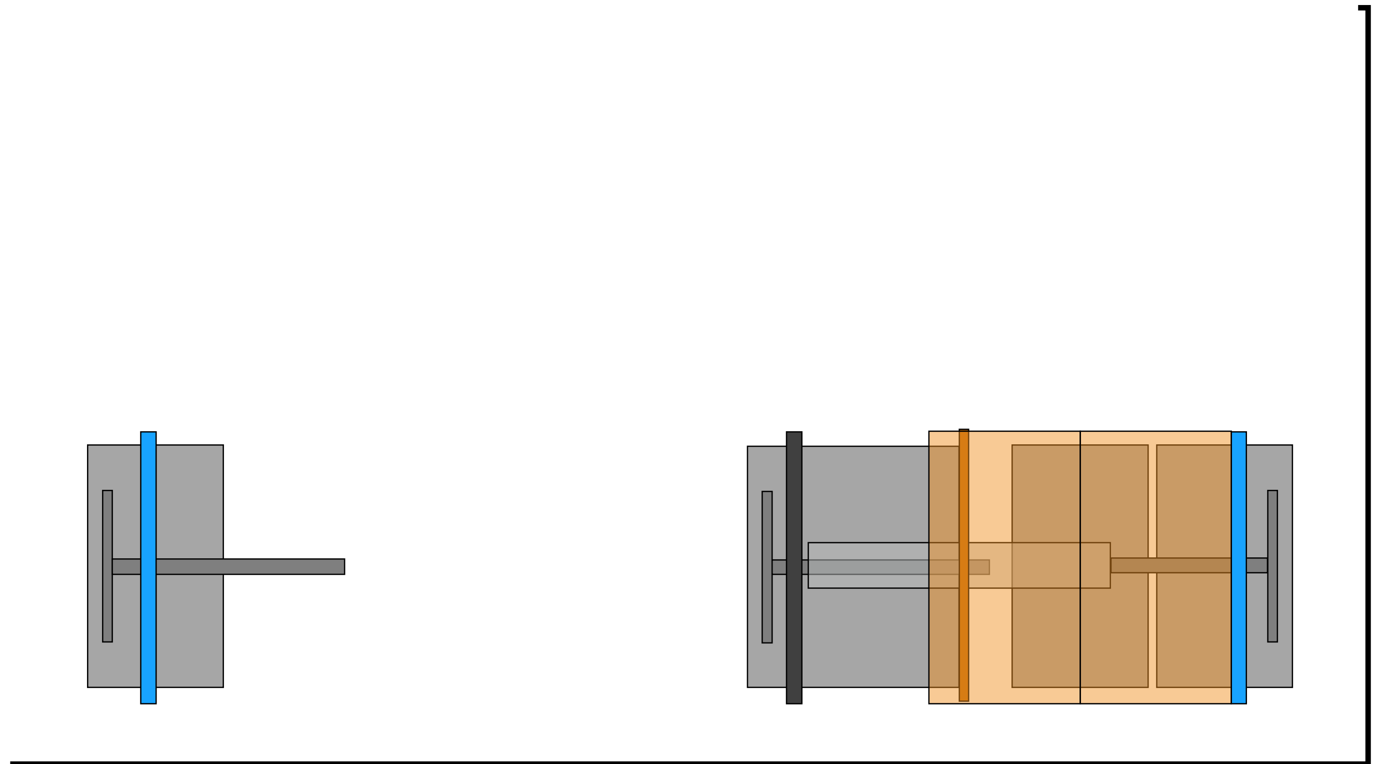
Horizontal procedure in a few steps

Set-up of inner vessel with cathode ("sail")



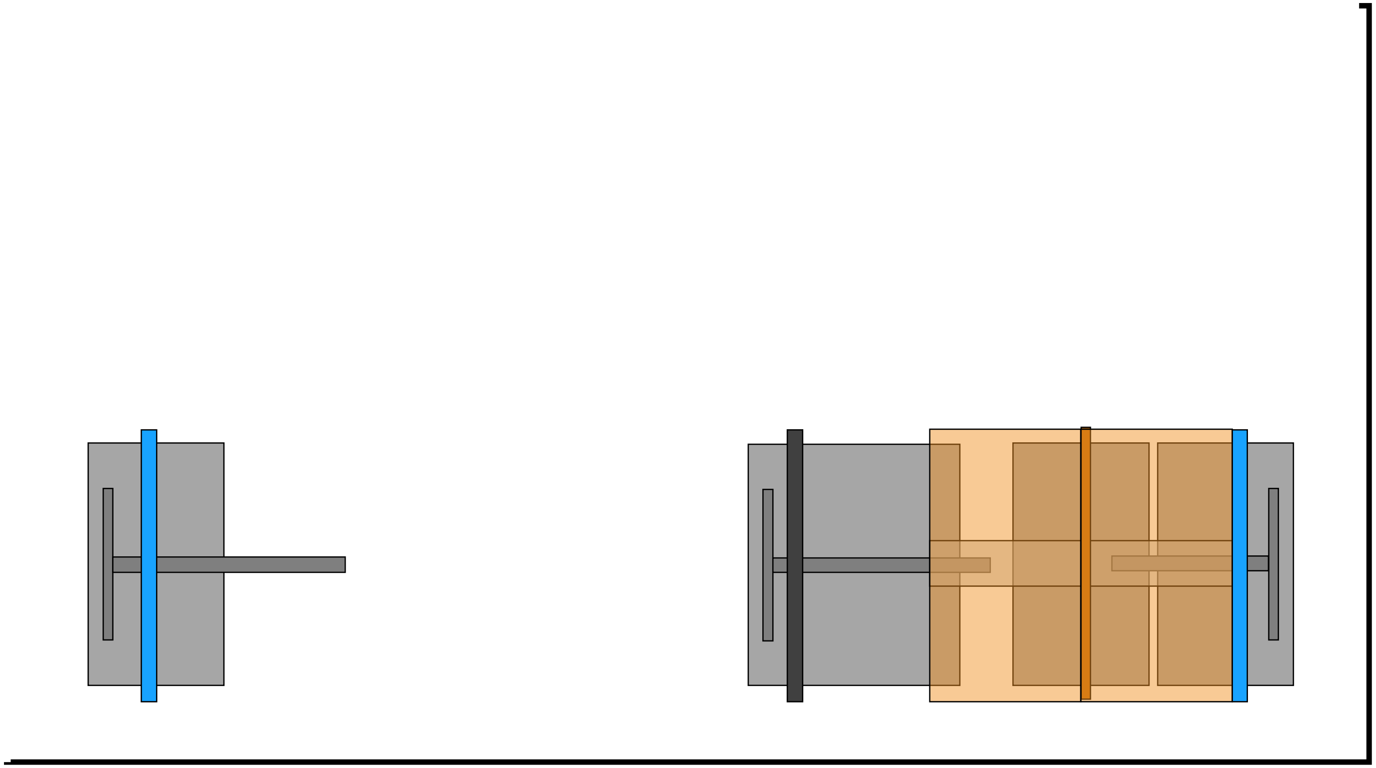
Horizontal procedure in a few steps

Marriage of inner vessel with cathode and field cage



Horizontal procedure in a few steps

Marriage of inner vessel with cathode and field cage

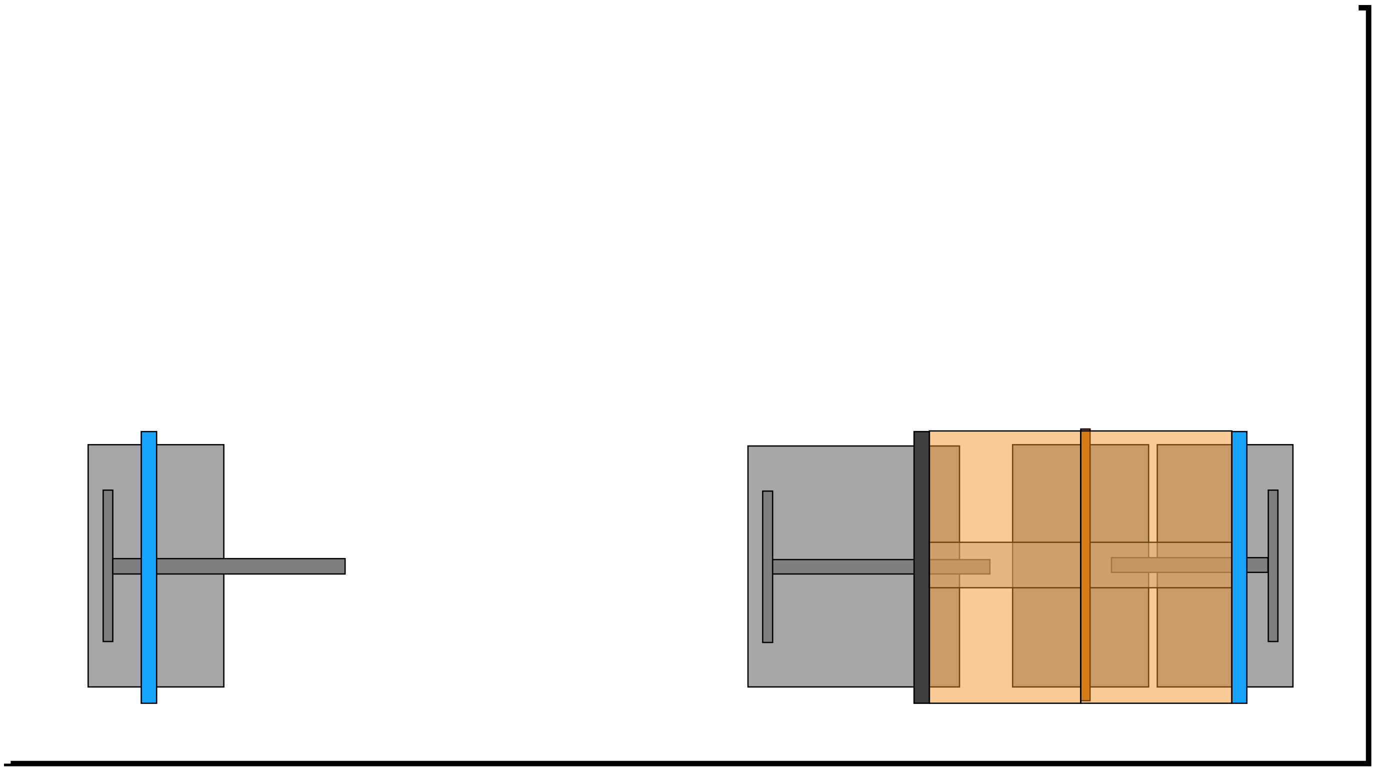


Alternative: First fixing of inner vessel in field cage, then installation / spanning of cathode.

Horizontal procedure in a few steps

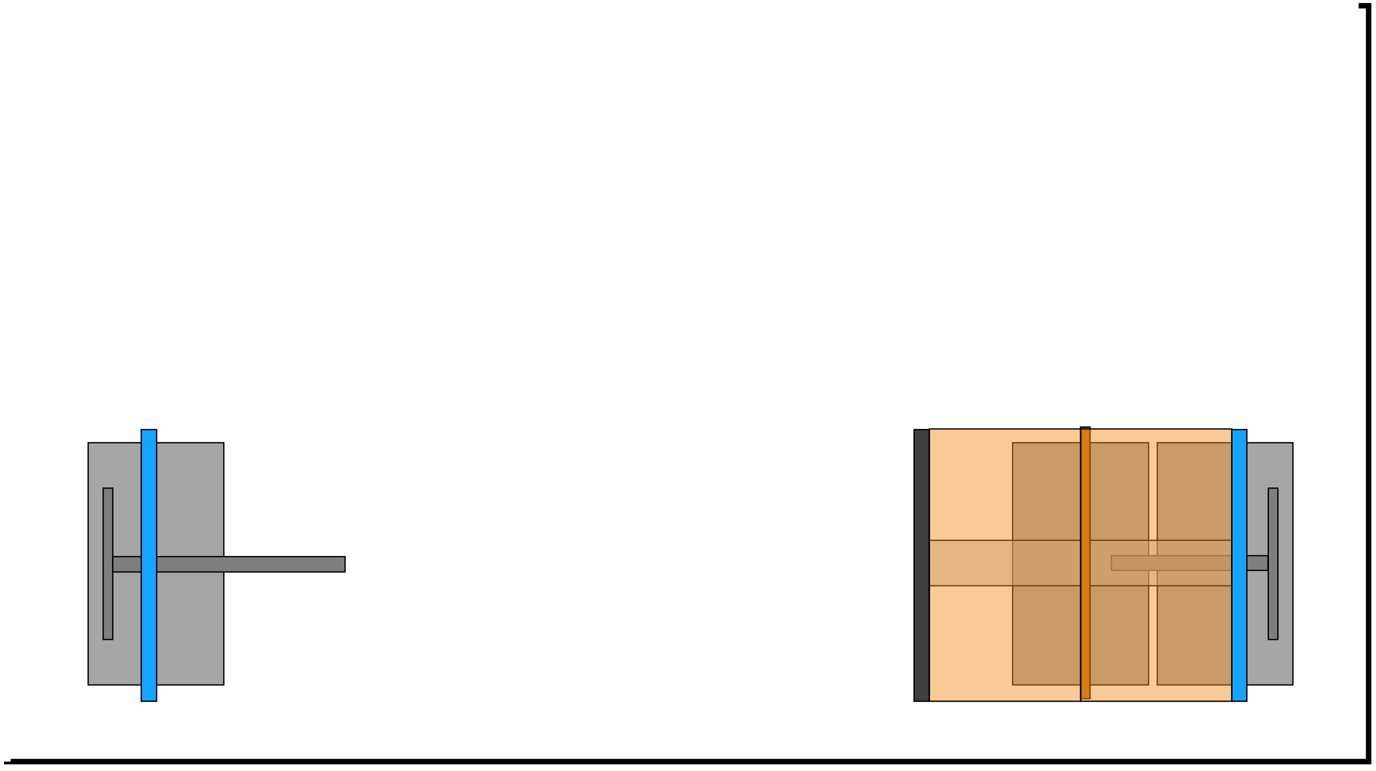
Marriage of inner vessel with cathode and field cage.

Fixing the supporting “star” supporting the inner vessel and the sail



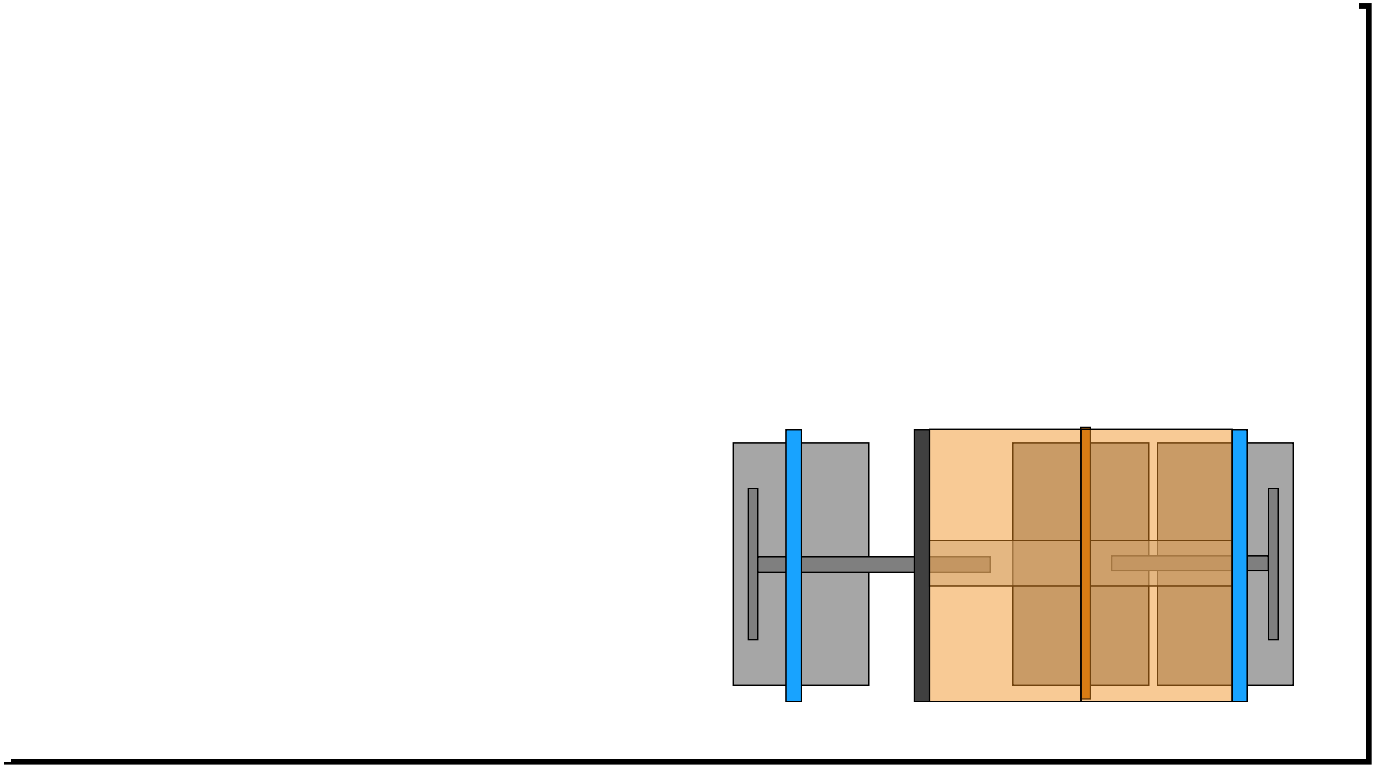
Horizontal procedure in a few steps

Removing inner-vessel platform and finalisation of end-plate L



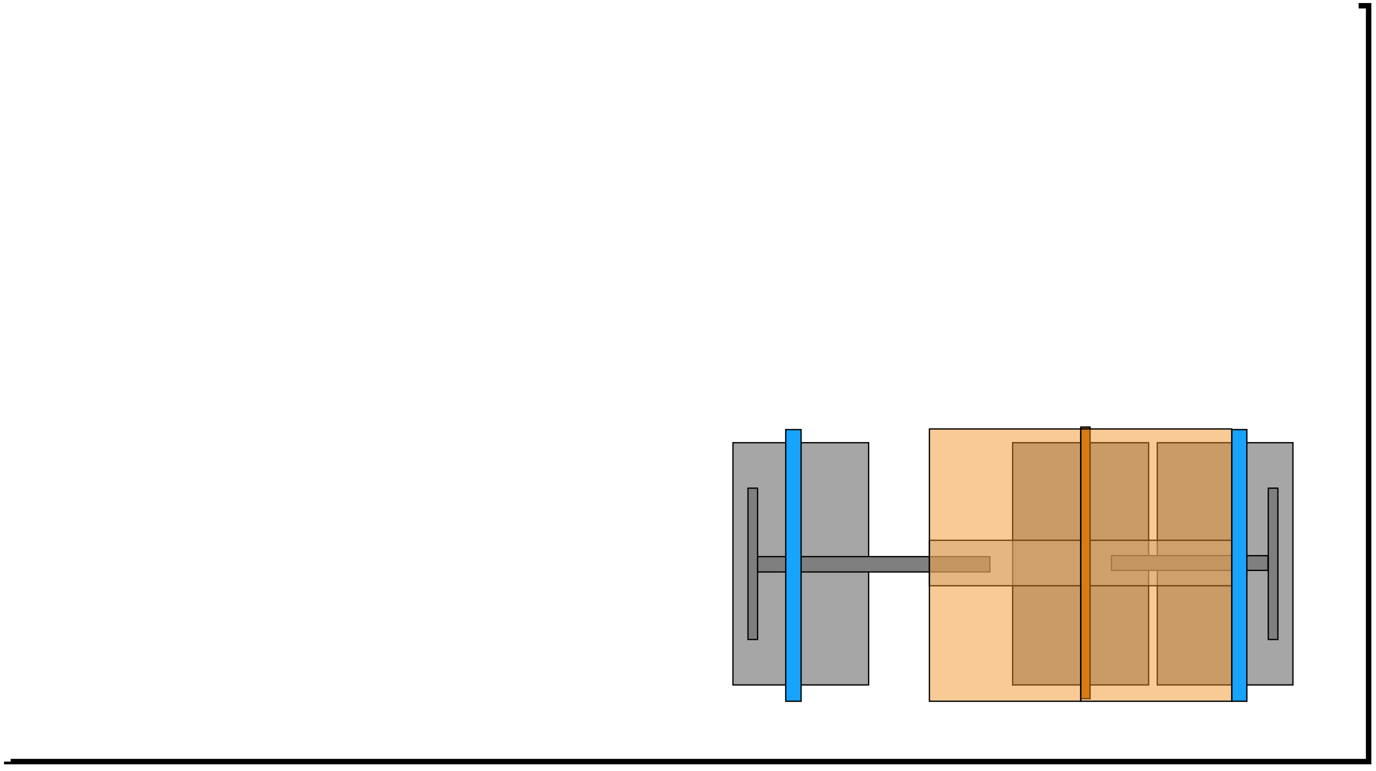
Horizontal procedure in a few steps

Inserting end-plate L: approaching the field cage …



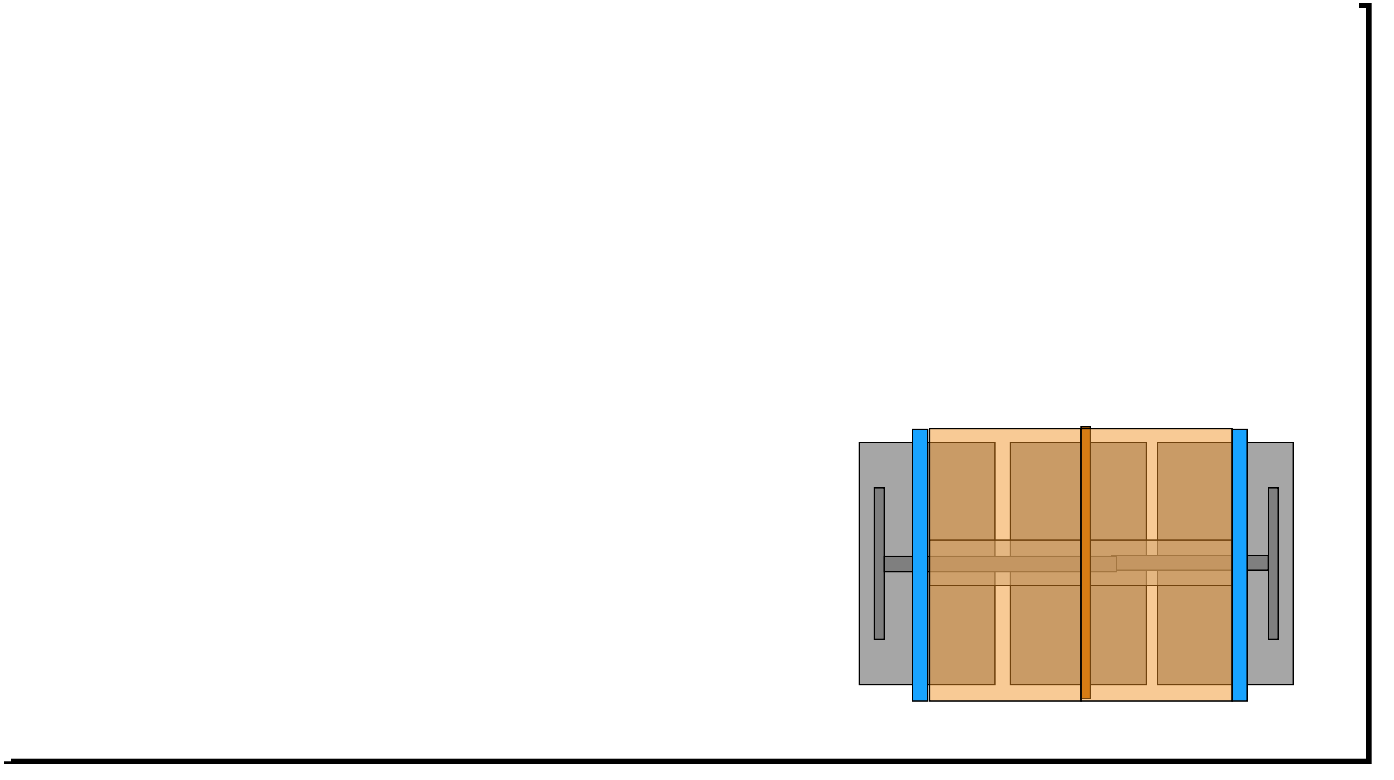
Horizontal procedure in a few steps

Inserting end-plate L: approaching the field cage, supporting the inner vessel and removing the supporting star, …



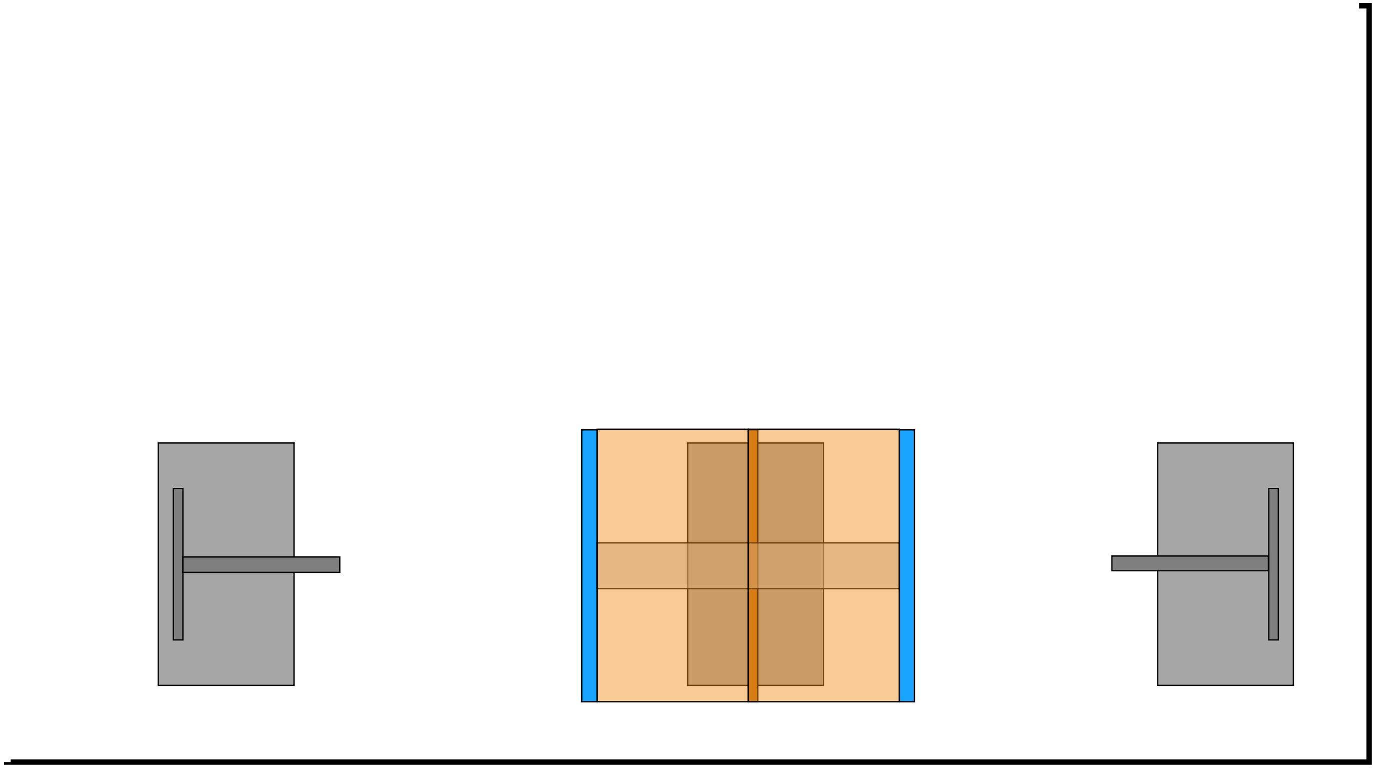
Horizontal procedure in a few steps

Inserting end-plate L: approaching the field cage, supporting the inner vessel + removing the supporting star, pushing in end-plate L



Horizontal procedure in a few steps

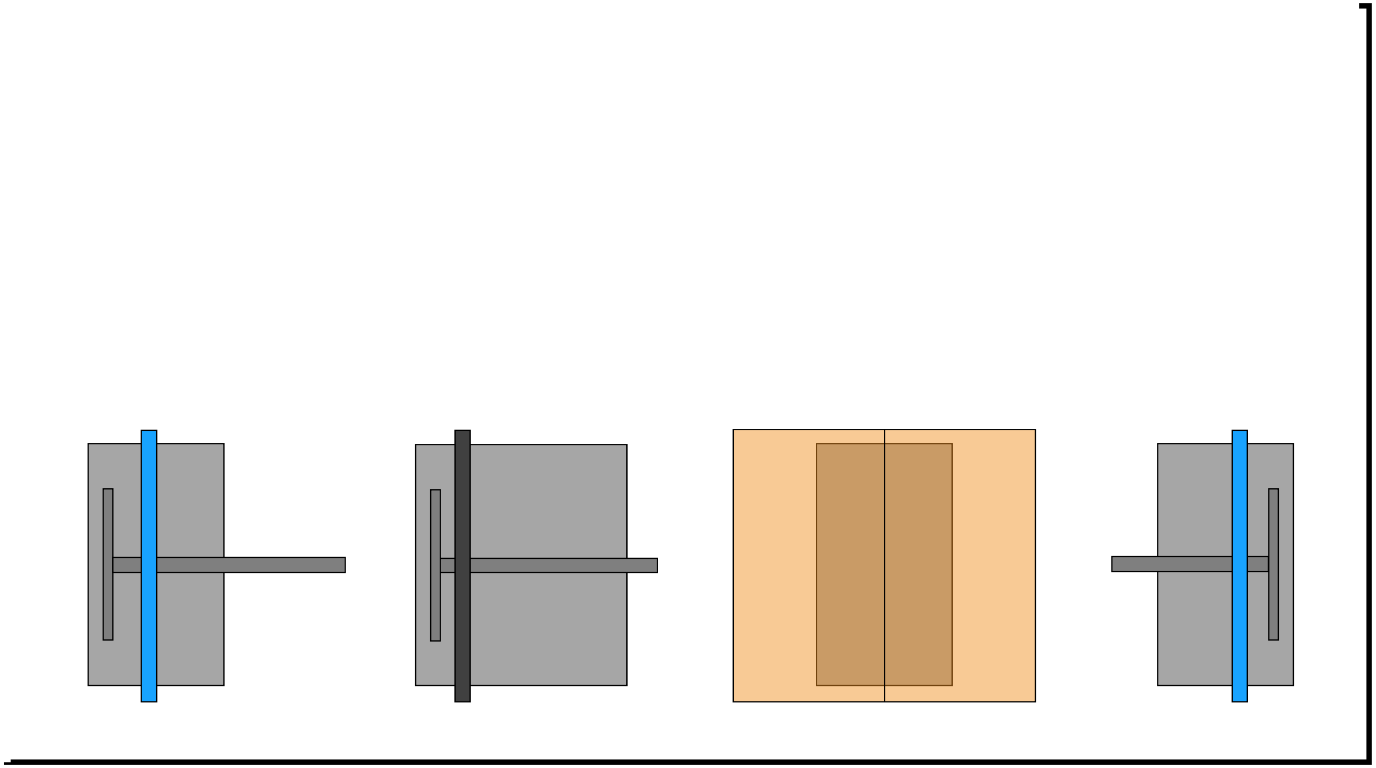
Ready



Alternative horizontal procedure

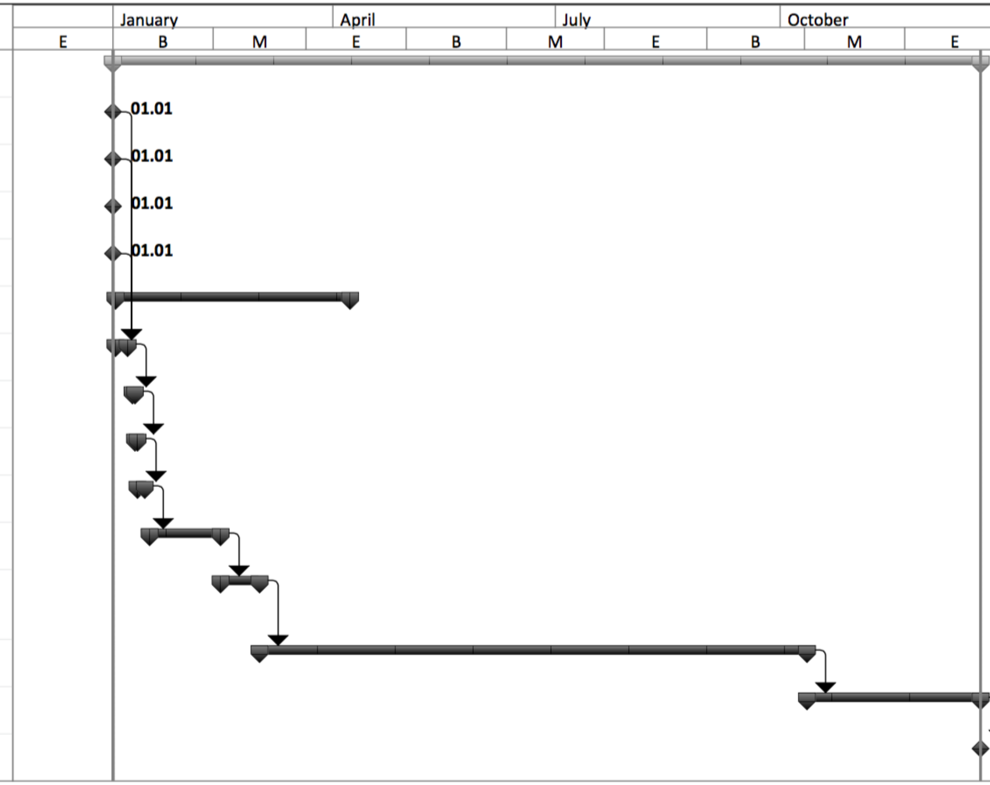
Assumptions: Similar as before, but …

- EP equipment at the end with robot
- Question of overall time planning (end-plate equipment the most time-consuming item



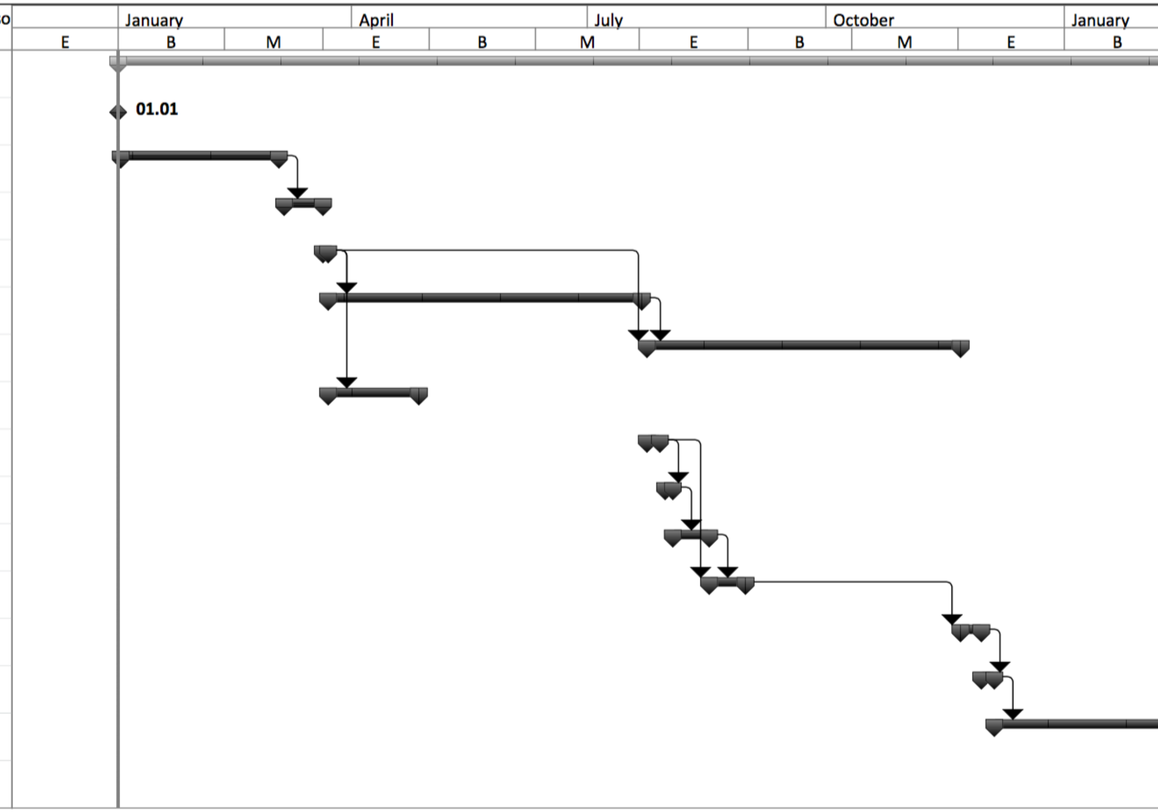
Vertical procedure – time estimate

ID	Task Name	Duration	Start	Finish	Predecesso	Resource Names
0	**TPC Assembly**	**254 day...**	**Sun 01.01.17**	**Thu 21.12.17**		
1	Platform setup	0 days	Sun 01.01.17	Sun 01.01.17		
2	End-plate delivery	0 days	Sun 01.01.17	Sun 01.01.17		
3	Inner vessel delivery	0 days	Sun 01.01.17	Sun 01.01.17		
4	Field cage delivery to hall	0 days	Sun 01.01.17	Sun 01.01.17		
5	**Module testing**	**70 days**	**Mon 02.01.17**	**Fri 07.04.17**		
8	**Placing field cage on end-plate**	**5 days?**	**Mon 02.01.17**	**Fri 06.01.17**	**1;2;4**	
14	**Installation of inner vessel**	**1 day?**	**Mon 09.01.17**	**Mon 09.01.17**	**8**	
16	**Installation of cathode**	**1 day?**	**Tue 10.01.17**	**Tue 10.01.17**	**14**	
18	**Installation of top end-plate**	**3 days?**	**Wed 11.01.17**	**Fri 13.01.17**	**16**	
22	**Cleaning and greyroom installation**	**21 days**	**Mon 16.01.17**	**Mon 13.02.17**	**18**	
25	**Cabling of field cage, inner vessel and cathode**	**12 days**	**Tue 14.02.17**	**Wed 01.03.17**	**22**	
28	**Installation of Modules**	**160 days**	**Thu 02.03.17**	**Wed 11.10.17**	**25;6**	
31	**Final test of TPC**	**51 days**	**Thu 12.10.17**	**Thu 21.12.17**	**28**	
34	TPC ready	0 days	Thu 21.12.17	Thu 21.12.17	31	

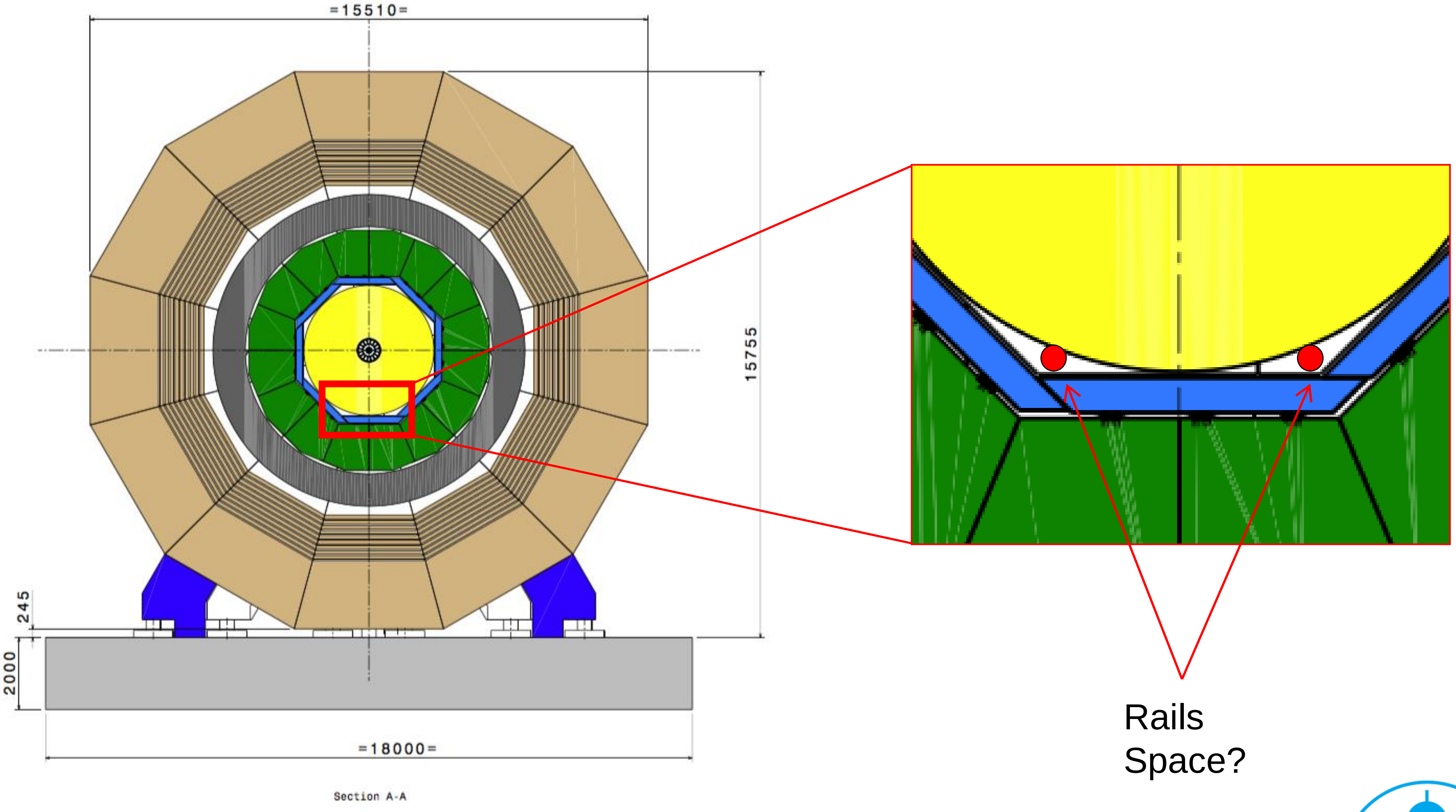


Horizontal procedure – time estimate

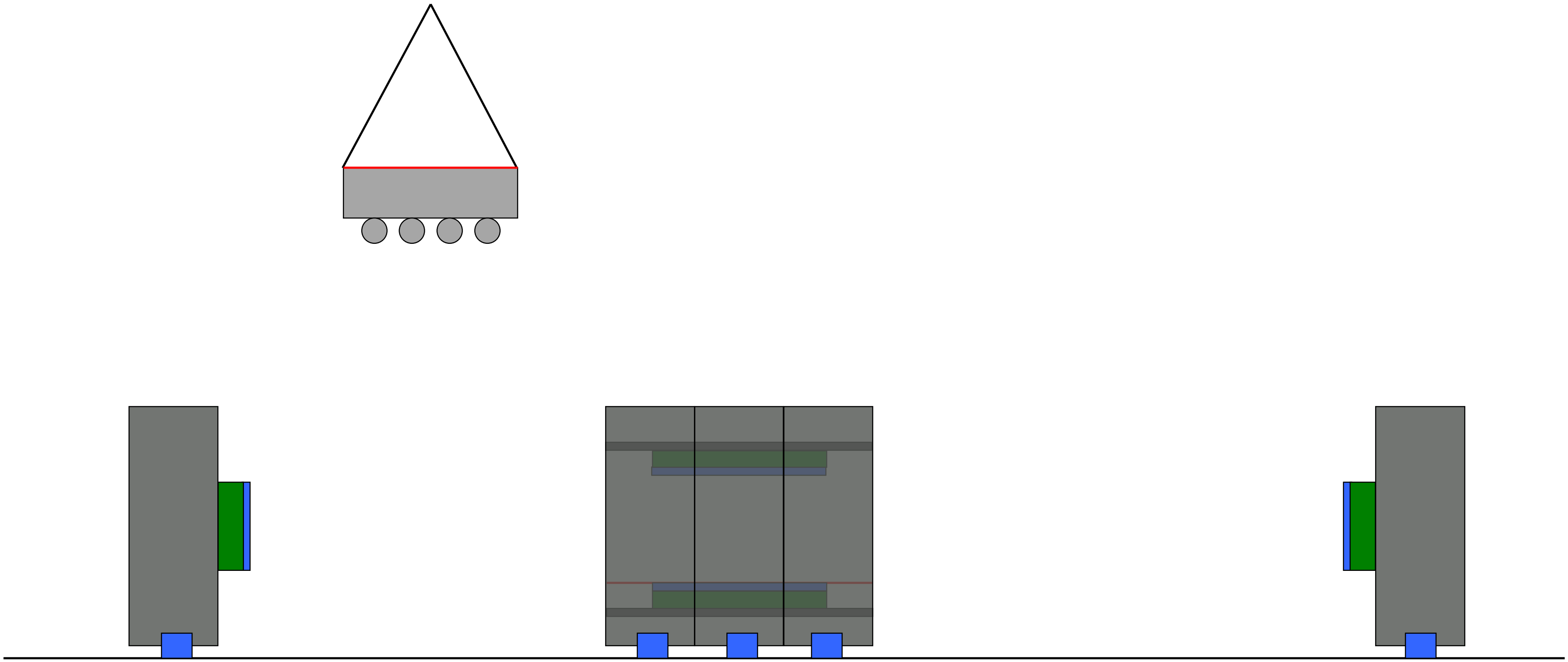
ID	Task Name	Duration	Start	Finish	Predecesso
0	**TPC Assembly**	**292 day...**	**Sun 01.01.17**	**Tue 13.02.18**	
1	Start of Assembly	0 days	Sun 01.01.17	Sun 01.01.17	
2	**Greyroom setup**	**45 days**	**Mon 02.01.17**	**Fri 03.03.17**	
6	**Trolley installation and test**	**11 days?**	**Mon 06.03.17**	**Mon 20.03.17**	**2**
13	**End-plates on trolleys**	**2 days?**	**Tue 21.03.17**	**Wed 22.03.17**	**12**
16	**End-plate mounting R**	**87 days**	**Thu 23.03.17**	**Fri 21.07.17**	**13**
20	**End-plate mounting L**	**87 days**	**Mon 24.07.17**	**Tue 21.11.17**	**13;16**
24	**Field cage assembly**	**25 days**	**Wed 22.03.17**	**Wed 26.04.17**	**13**
31	**Marriage field cage + end-plate R**	**5 days?**	**Mon 24.07.17**	**Fri 28.07.17**	**19;30**
35	**Inner vessel setup on platform**	**3 days?**	**Mon 31.07.17**	**Wed 02.08.17**	**31**
39	**Marriage of inner vessel + sail**	**10 days?**	**Thu 03.08.17**	**Wed 16.08.17**	**35**
44	**Marriage of inner vessel / sail + field cage**	**10 days?**	**Thu 17.08.17**	**Wed 30.08.17**	**31;39**
50	**Marriage of end-plate L + field cage**	**6 days?**	**Wed 22.11.17**	**Wed 29.11.17**	**44;23**
55	**Removal of trolleys**	**3 days**	**Thu 30.11.17**	**Mon 04.12.17**	**50**
60	**TPC tests**	**51 days**	**Tue 05.12.17**	**Tue 13.02.18**	**55**
63	TPC ready	0 days	Tue 13.02.18	Tue 13.02.18	62

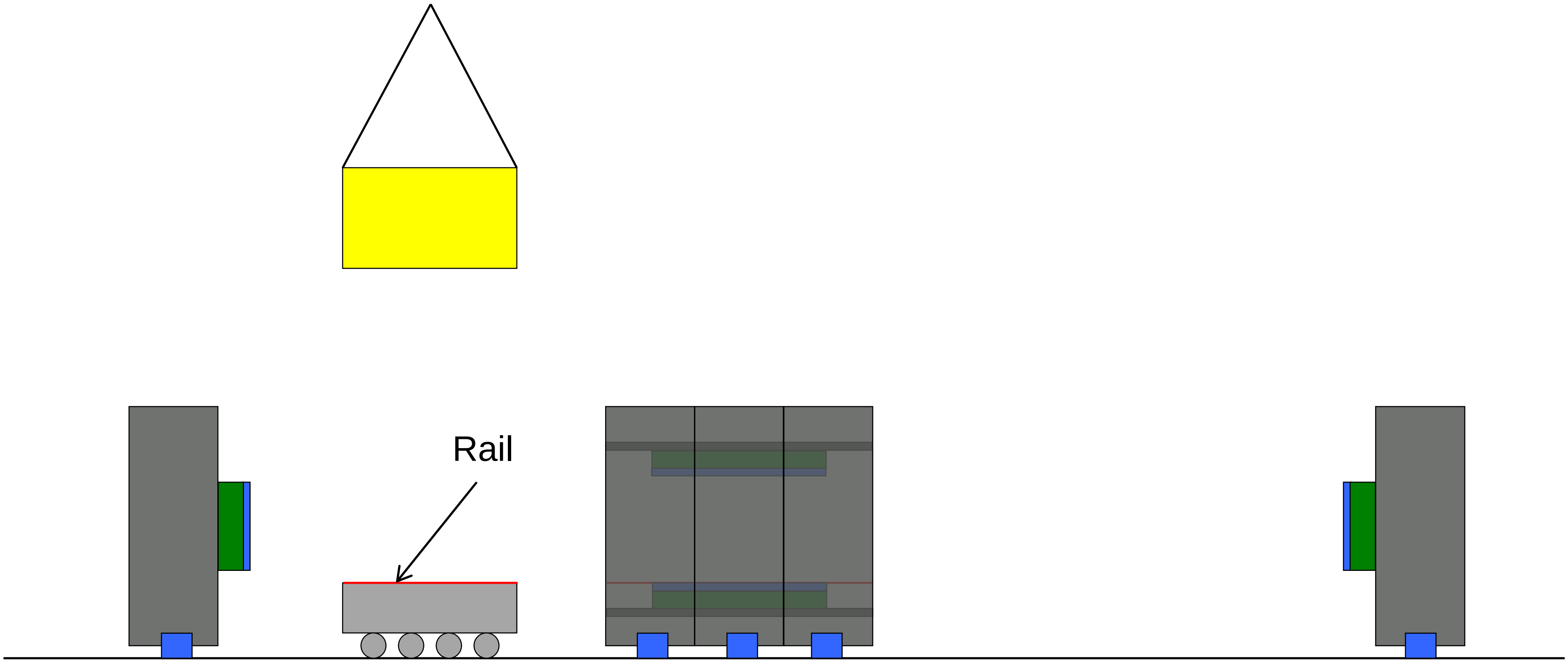


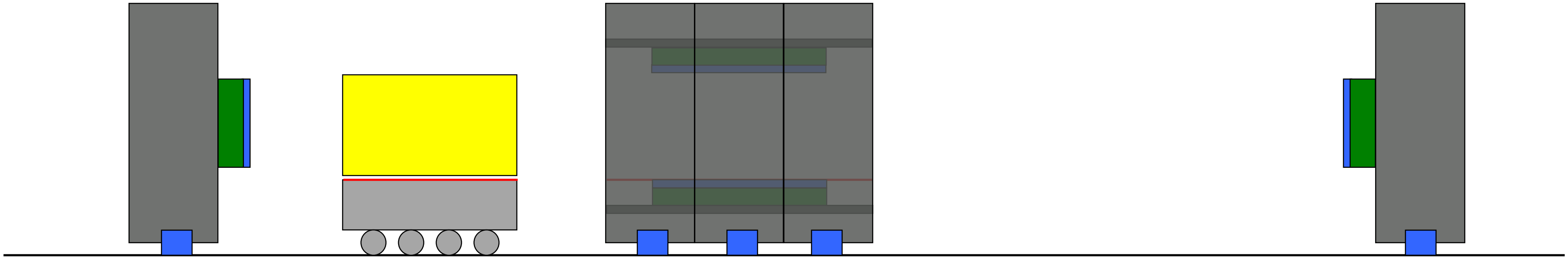
TPC insertion – mechanism?

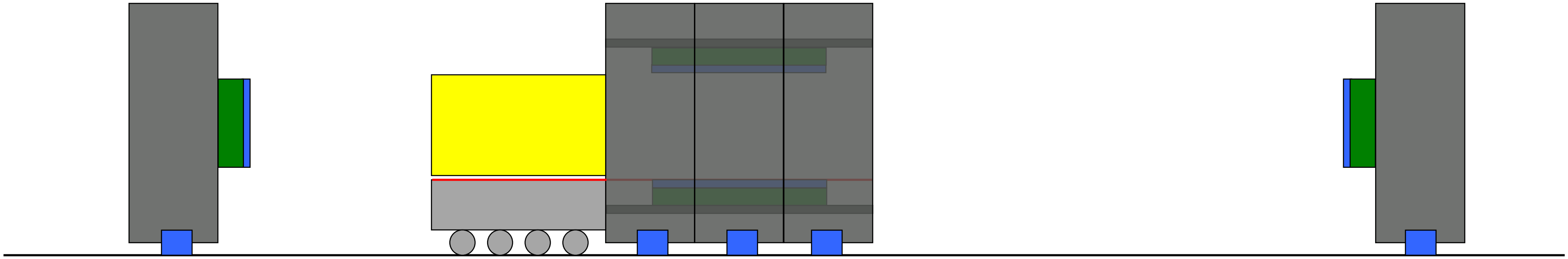


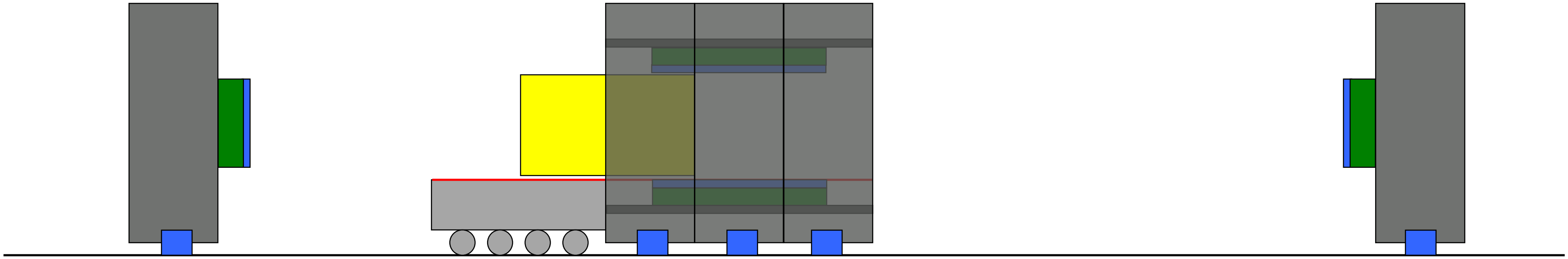
Rails
Space?

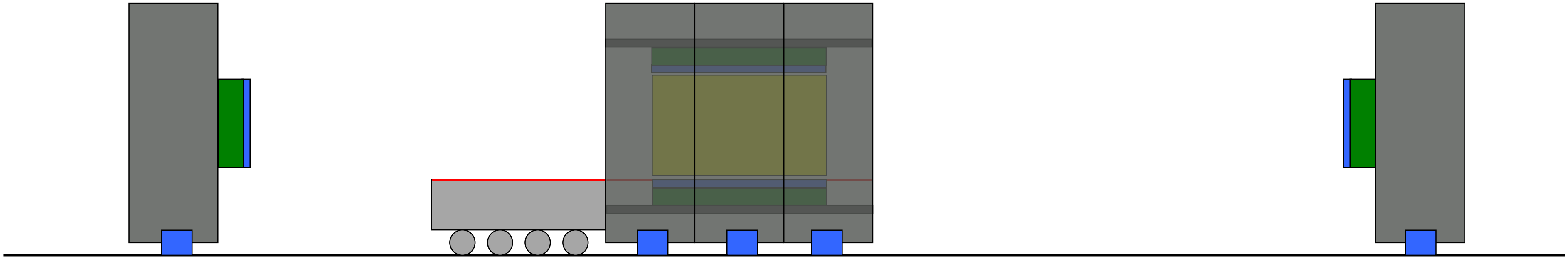


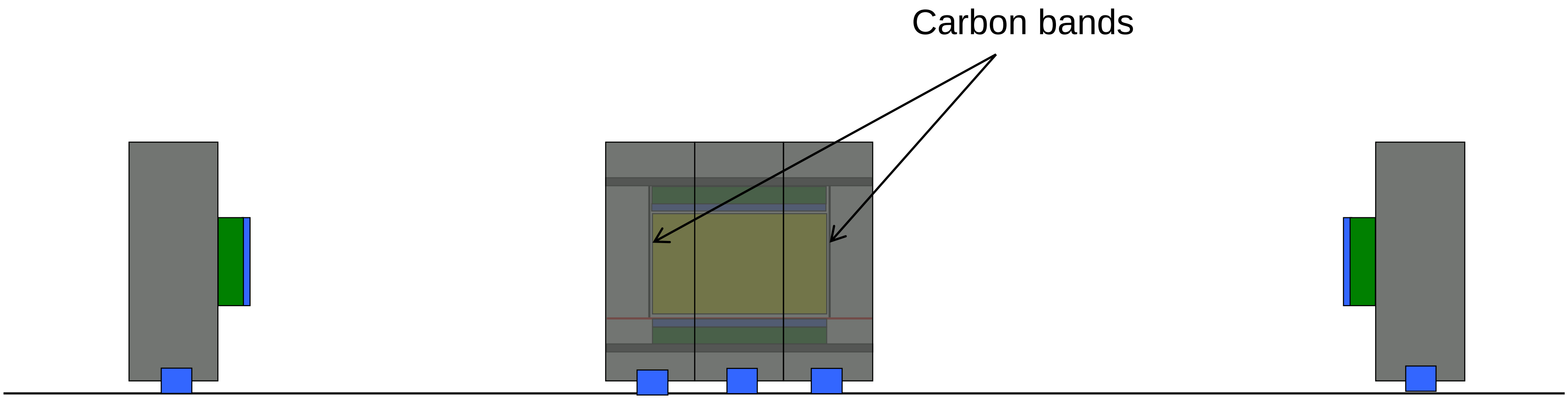

Rail





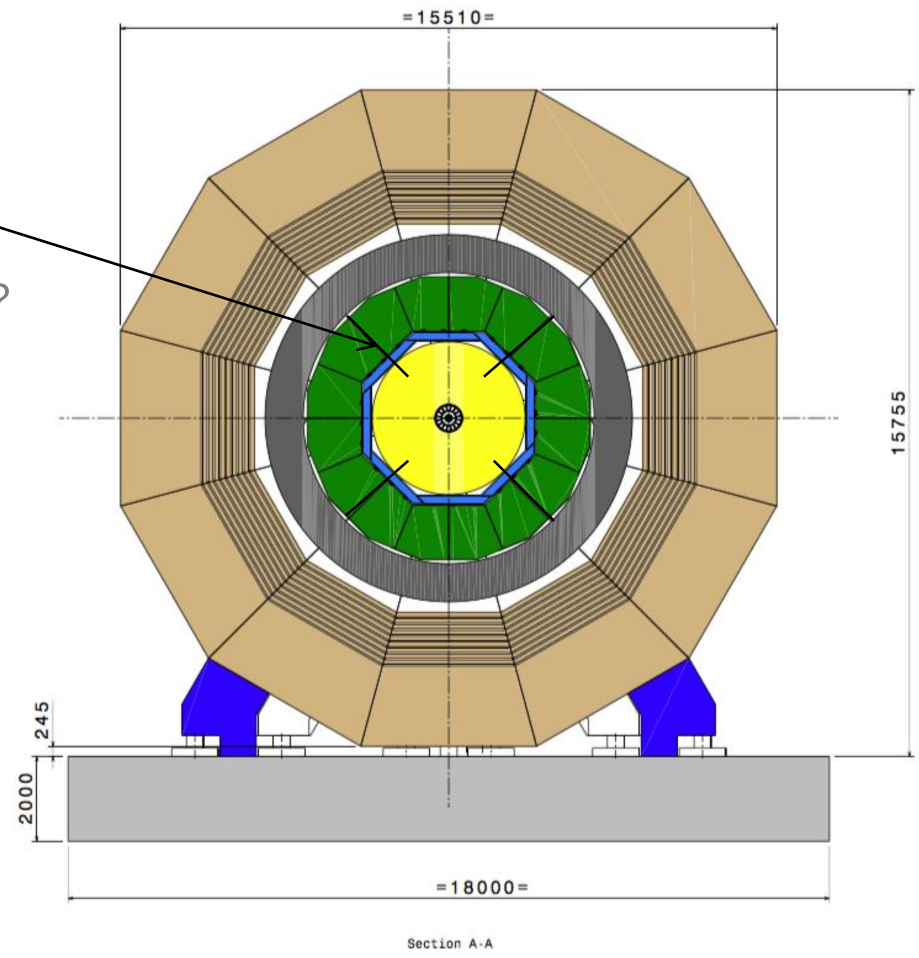


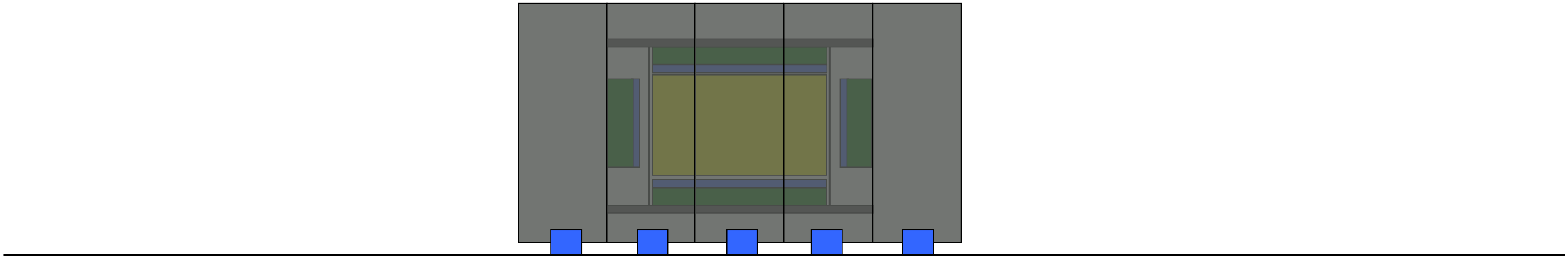



Carbon bands

Carbon bands

- How many?
- Size?
- How about longitudinal strain?





Veeeeery preliminary conclusions

Currently, more in favour of vertical assembly:

- Space requirements
- Time requirements
- Ease of access / logistics
- …

But many steps need thorough planning, and many engineering solutions are still missing.

- Also for insertion of TPC into ILD, and for mounting and suspension

Nevertheless – best current guess:

- Assembly requires one year after delivery of field cage
- Space requirements: 100 m^2 (ISO 7 / grey room quality)
- Plus space for module storage and testing, plus services

Some near-future steps

Continue to work on the models, assumptions and their consequences

- Principal procedures, needs and requirements
- Some important topics:
  - Support of TPC in ILC?
  - Prevention of longitudinal movement?
  - Cathode design?
  - End-plate design?
  - Space and infrastructure in DH (gas, power, electronic hut etc.)

To be decided soon: Where to assemble TPC?

- AH or research office building?
- If research office building, then still full TPC system test before lowering in AH?

Draw on previous experience

- Specifically ALICE → meeting in November at CERN

Get in touch with global integration efforts

- Hope to intensify contact to Yasuhiro