

LCTPC Collaboration Meeting

TPC Mechanics

9-11 January 2019, DESY

[Volker Prahl on behalf of the TPC Collaboration](#)

Most of the slides presented at:

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

Friday 23 Feb 2018, KEK Tsukuba Campus

[https://agenda.linearcollider.org/event/7804/
overview](https://agenda.linearcollider.org/event/7804/overview)

R.P. is indebted to many authors from whom I have reused their material

Over view

- TPC support structure (AHCAL)
 - 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



TPC support structure

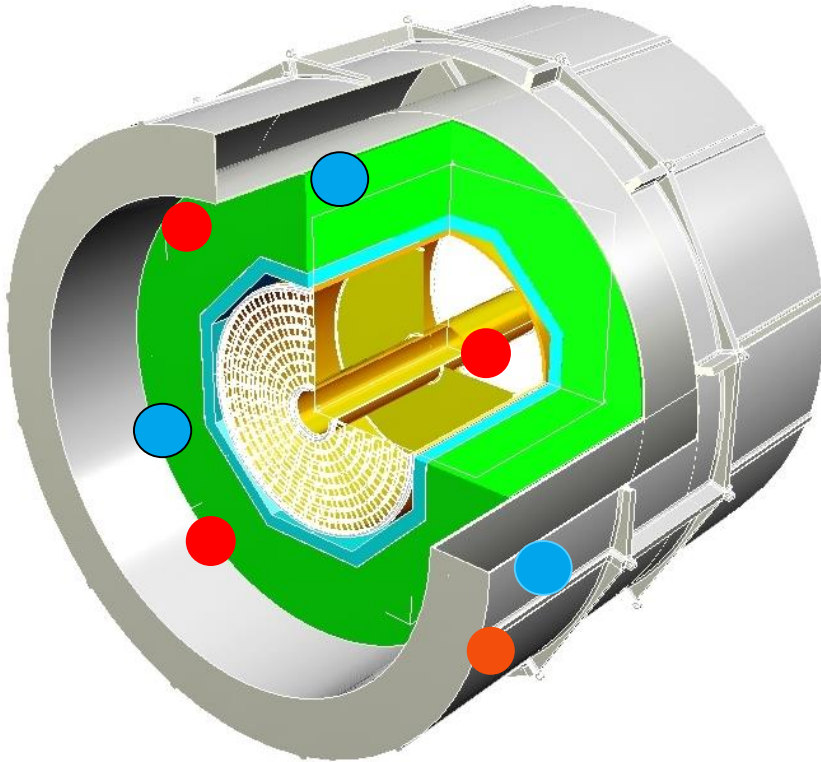
Requirements of the TPC support structure

- > Non-magnetic material
 - > Low thermal expansion coefficient
 - > 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
- Carbon fiber structure preferred

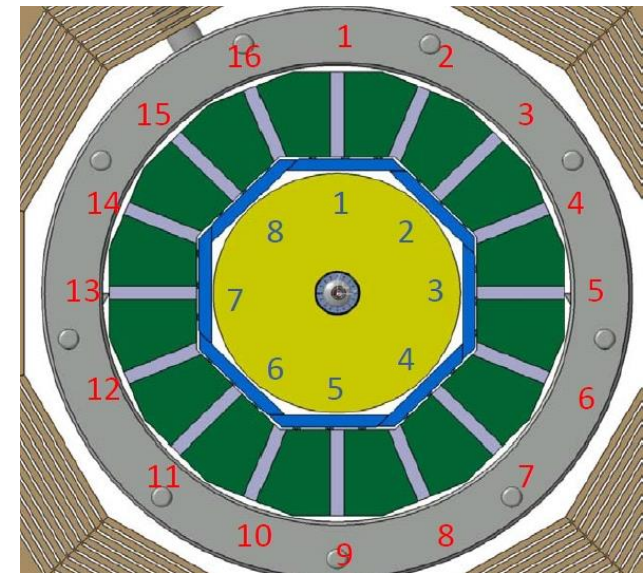


TPC Support Structure

Requirements of the TPC support structure, AHCAL around !



Main dimensions of the TPC (outside)
 \varnothing Od = 3616, r=1808
 \varnothing 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

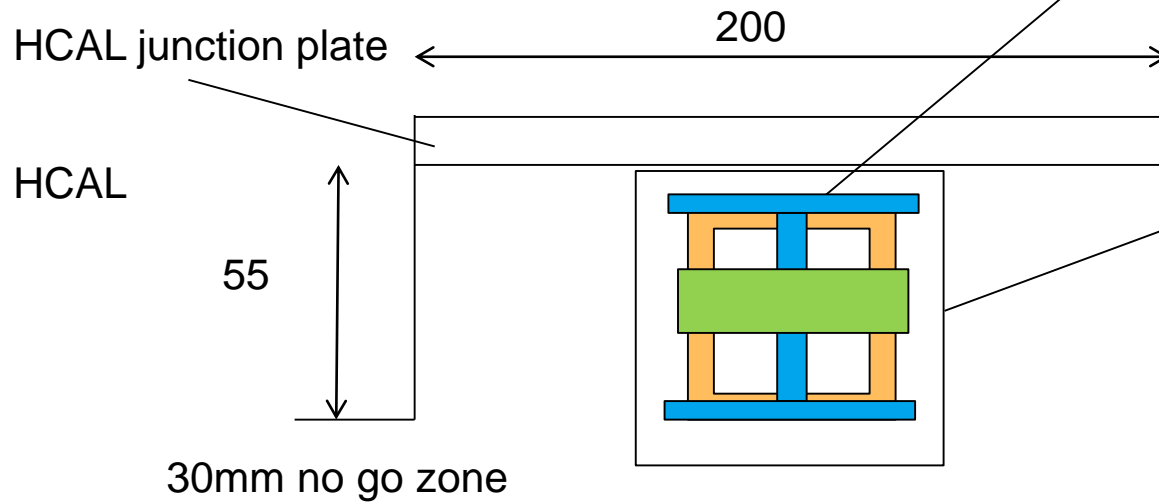
Pros and cons of various fixing points

	AHCAL	Cryostat
3x120°	<ul style="list-style-type: none">- Accuracy+ Shorter support structure- HCAL deformation- Stability under seismic conditions of the AHCAL	<ul style="list-style-type: none">+ Accuracy- Longer support structure+ Cryostat deformation+/- Seismic stability
4x90°	<ul style="list-style-type: none">See above- More space required	<ul style="list-style-type: none">See above- 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

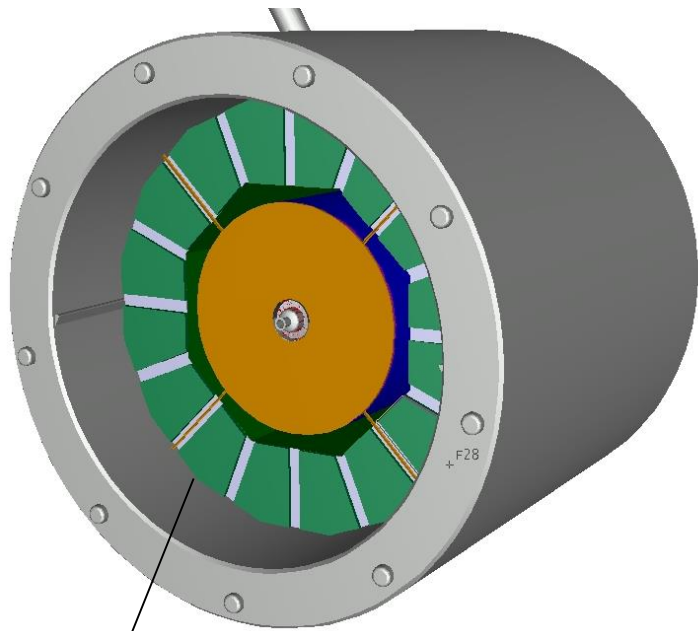
Support bar cross sections

- Square profile
- Double T bar
- Band system

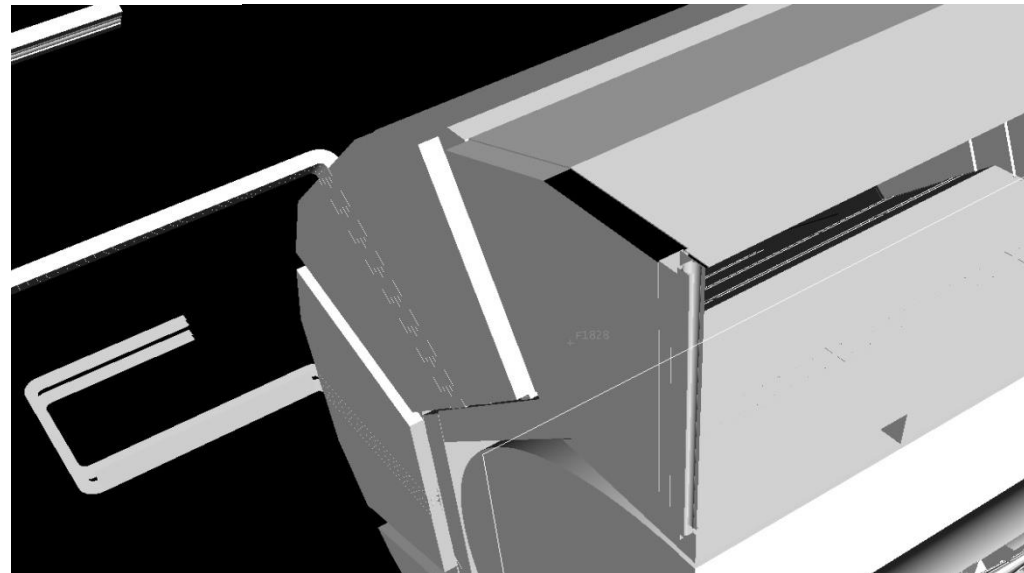
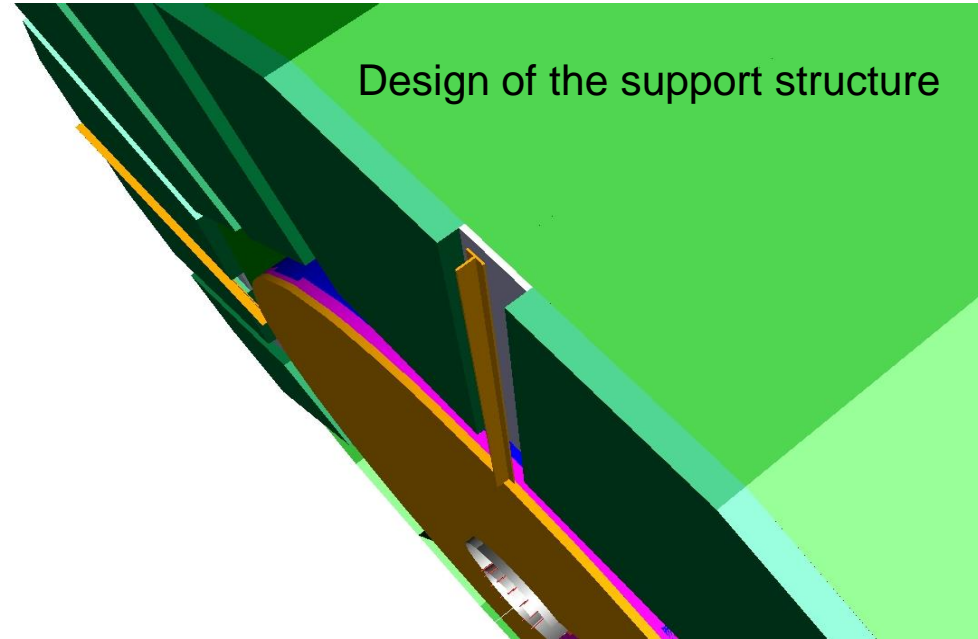
Note: all different profiles are drawn not in scale and not calculated

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

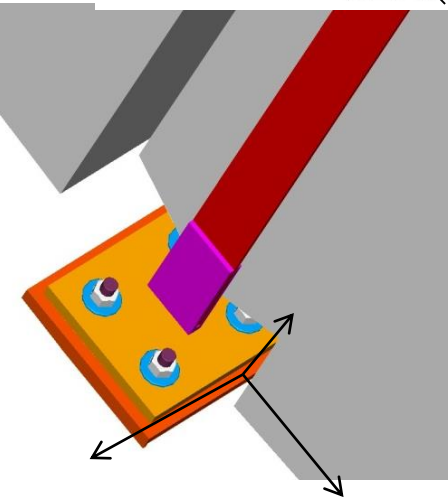
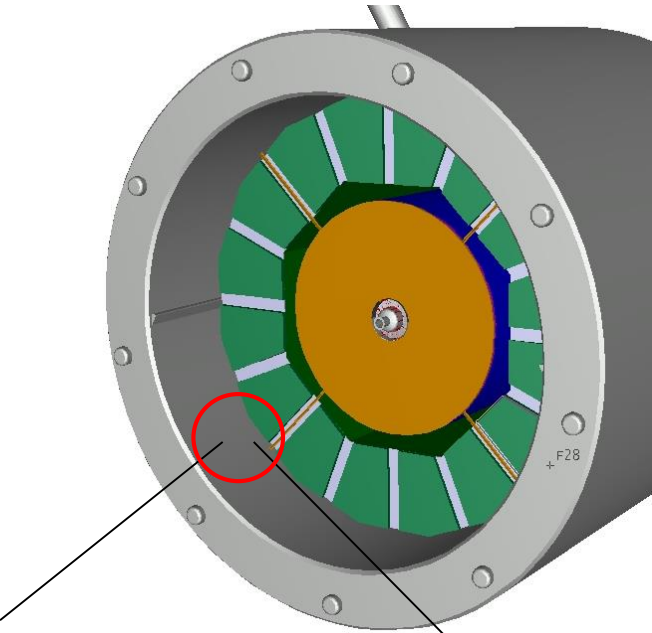
TPC support structure



4 Cantilever arms or
4 Ropes

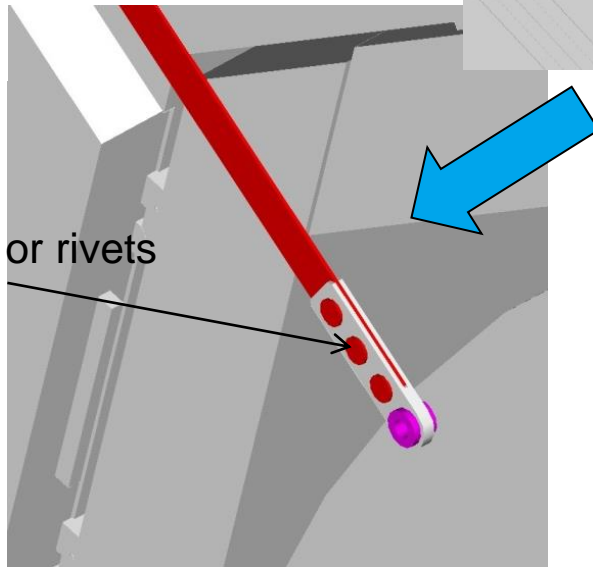


Flat ribbon support



Adjustable in x,y,z

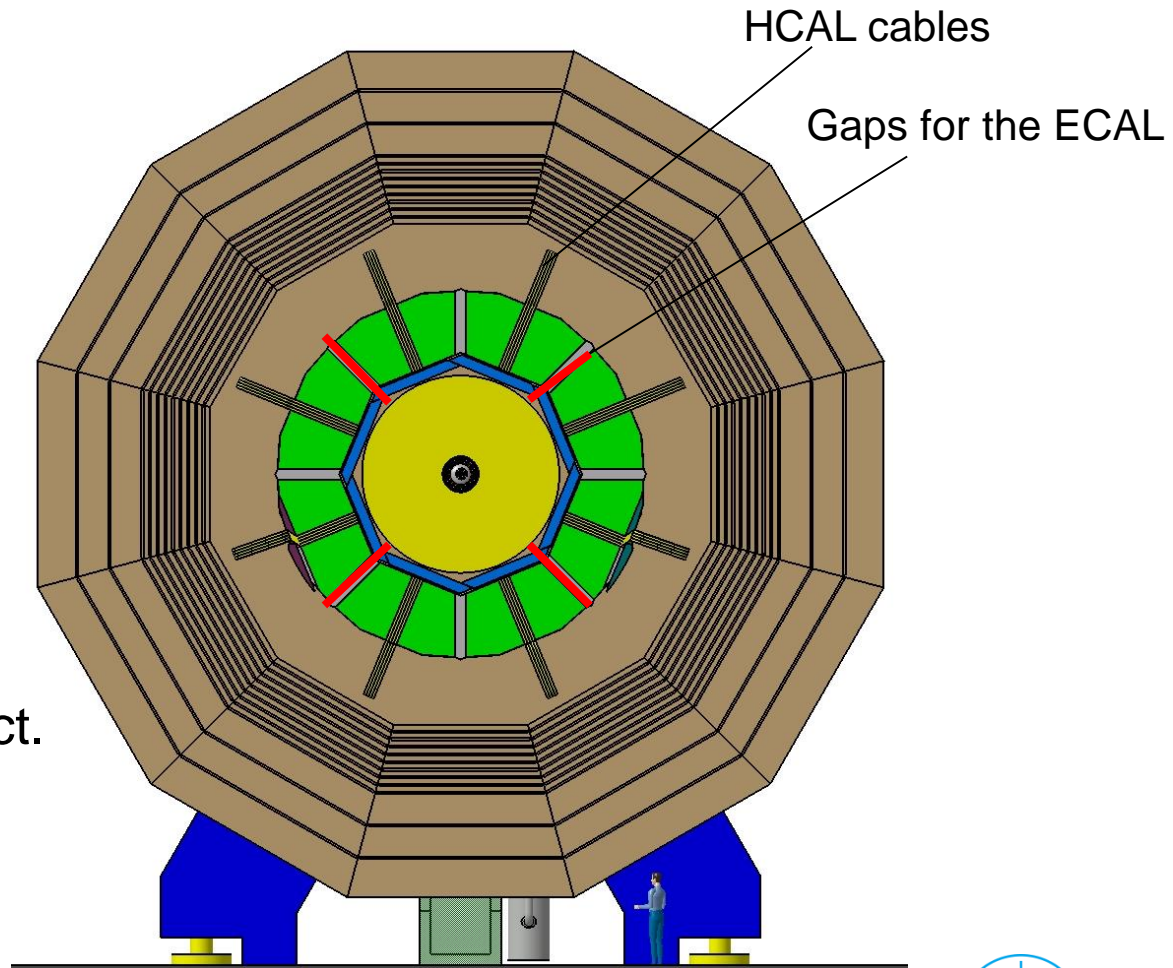
Screws or rivets



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, cooling lines ect.
touting at the same space

Cathode design

Typical cathode design:

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

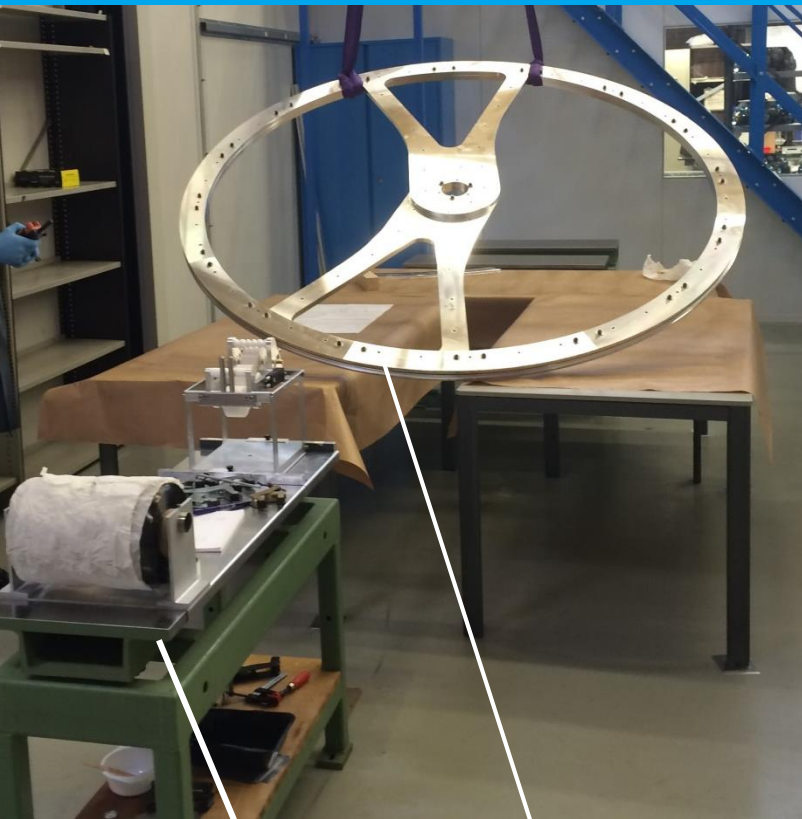


Design goals and problems:

- 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

STAR-TPC

Cathode design



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



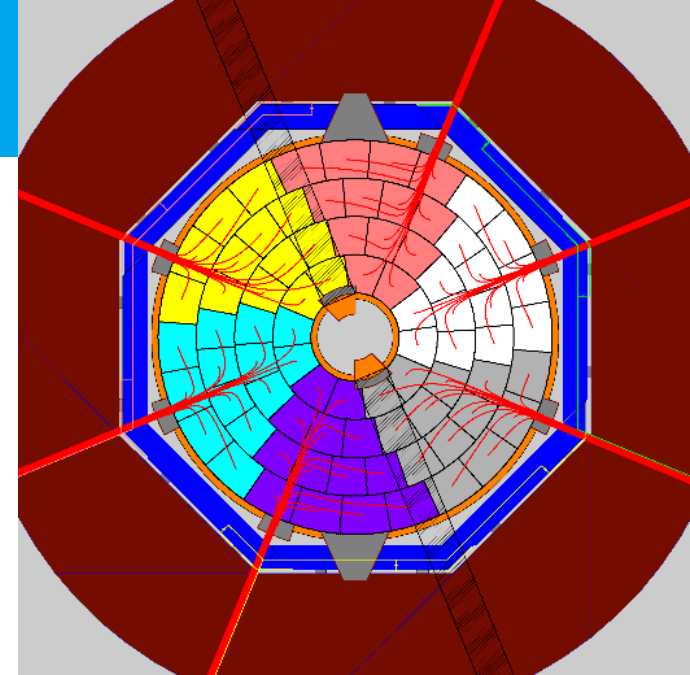
Part of the wetting tool

Mold

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

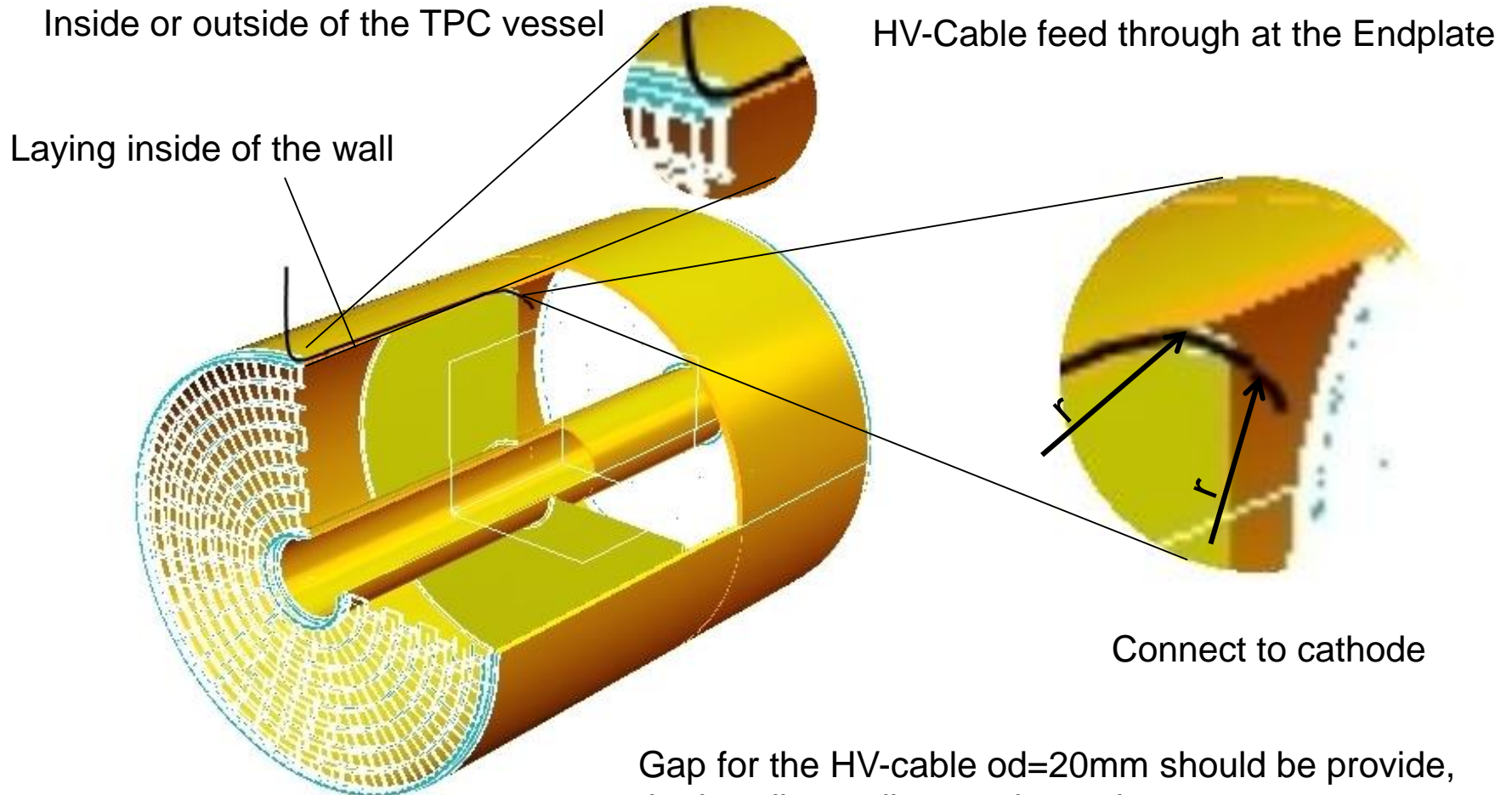
The Ecal/Tpc interface concerns the passage of the TPC “ribbons” and the services between end cap and barrel as well as patch-panels.

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



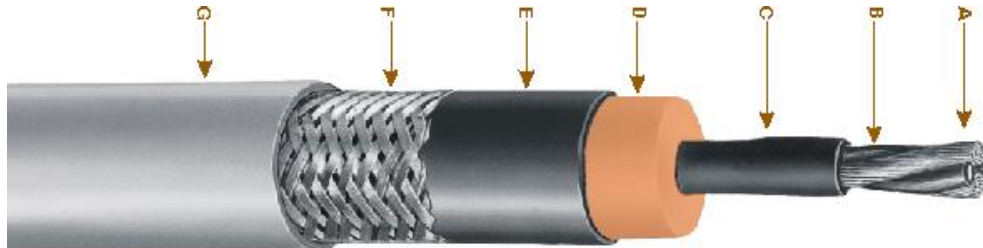
HV Cable and routing

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:	99pF		100kV DC
Impedance:	61Ω		
Ambient temperature:	-50°C ... +60°C		
Bending radius:	15,2cm		
Max. current:	max. 27A		
		HVS 65 65kV	HVS 100 100kV

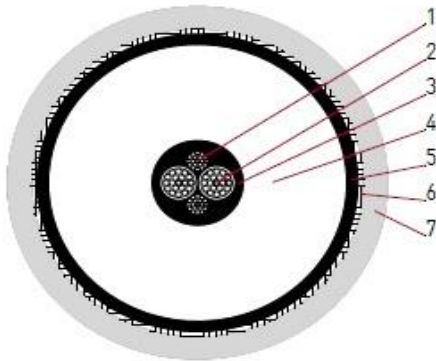


X-Ray HV Cable

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

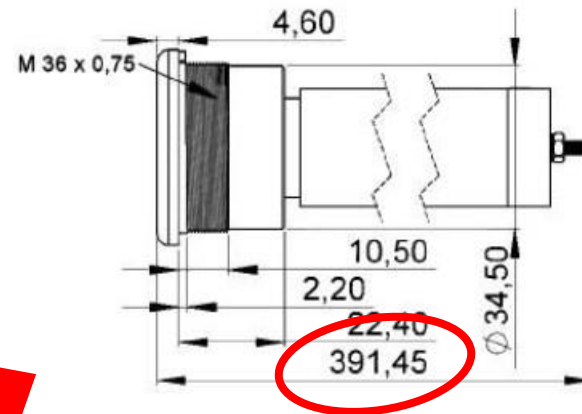
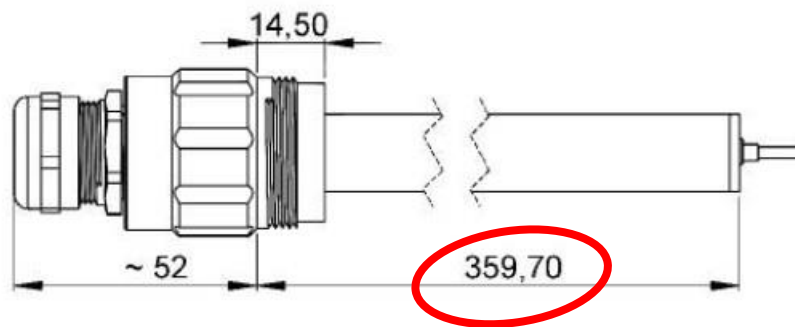
▪ TECHNICAL DATA

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

▪ DIMENSIONS S1100 / B1100



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

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.

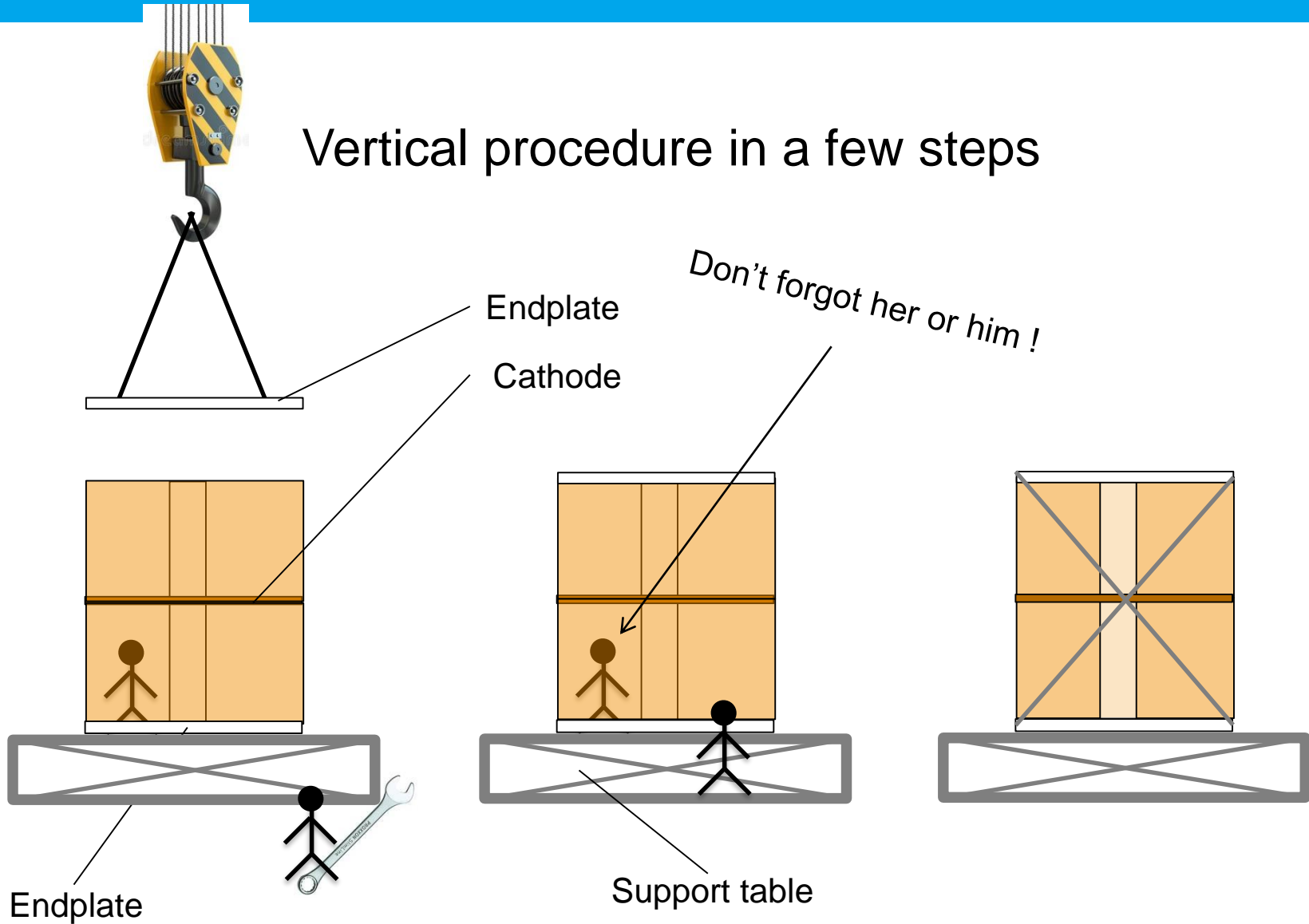
No TPC assembly in DH – sufficient space and possibility to work in parallel with yoke construction, but probably bad timeslot?

Current scenario therefore:

- Horizontal or vertical assembly in AH hall (exact position tbd)
- Space requirement: 100 m² (probably 60 m² 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

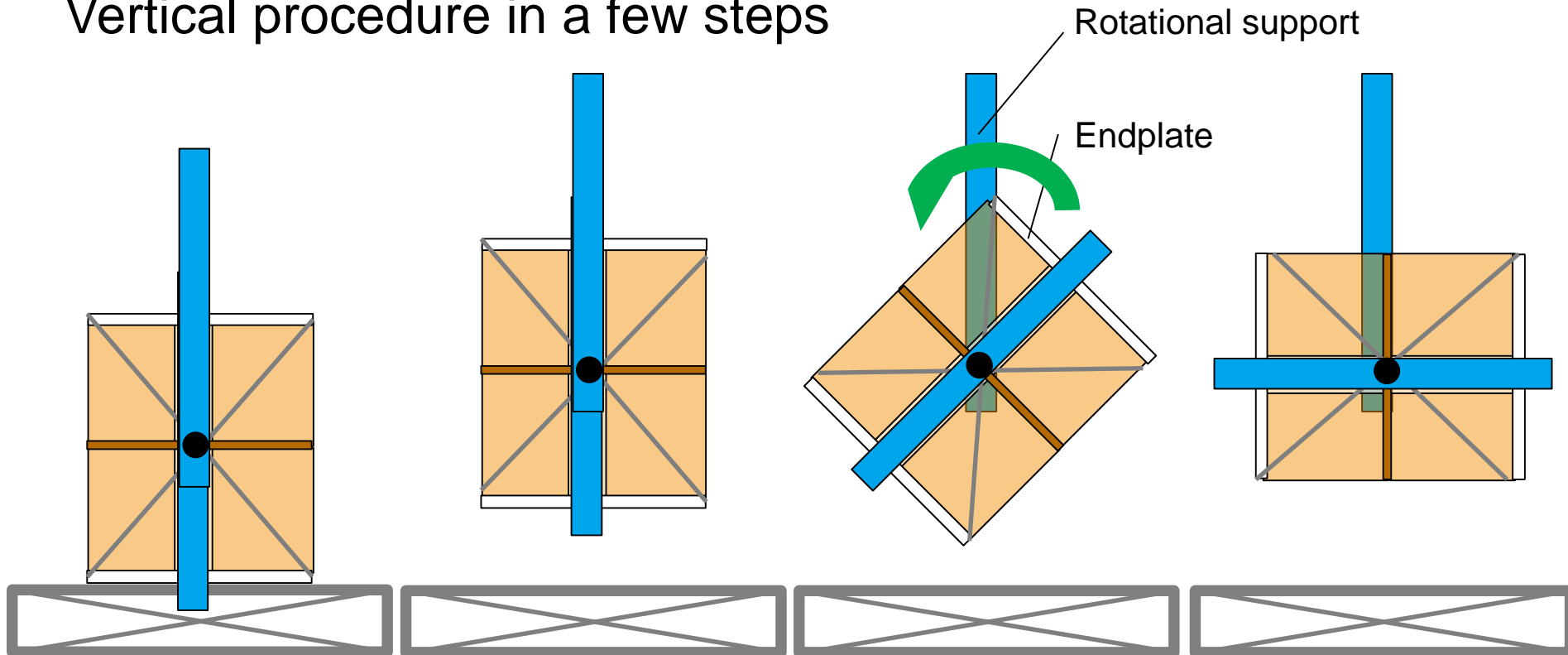


TPC installation



TPC assembly

Vertical procedure in a few steps



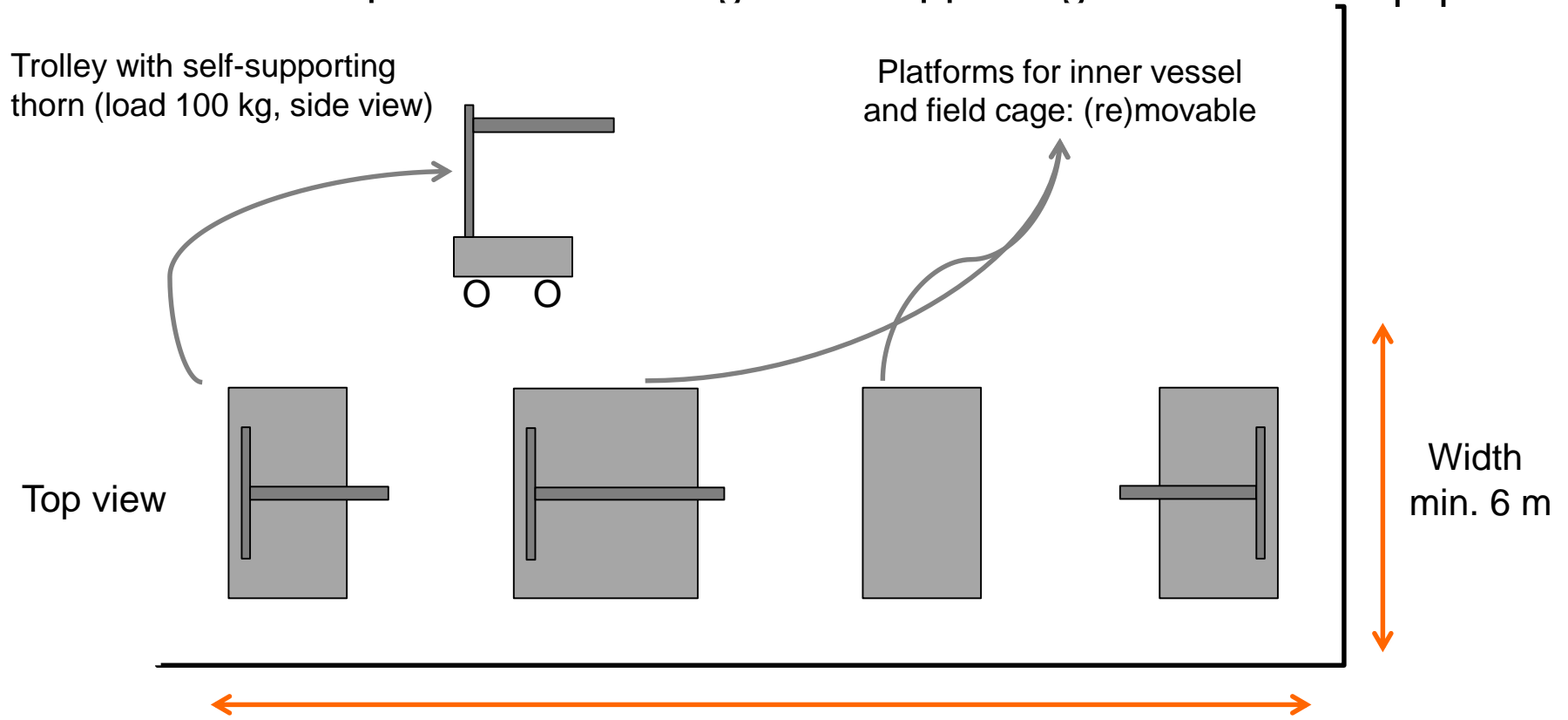
Then

- 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



8/9 October 2015
TSS: TPC Assembly

Length min. 12 m

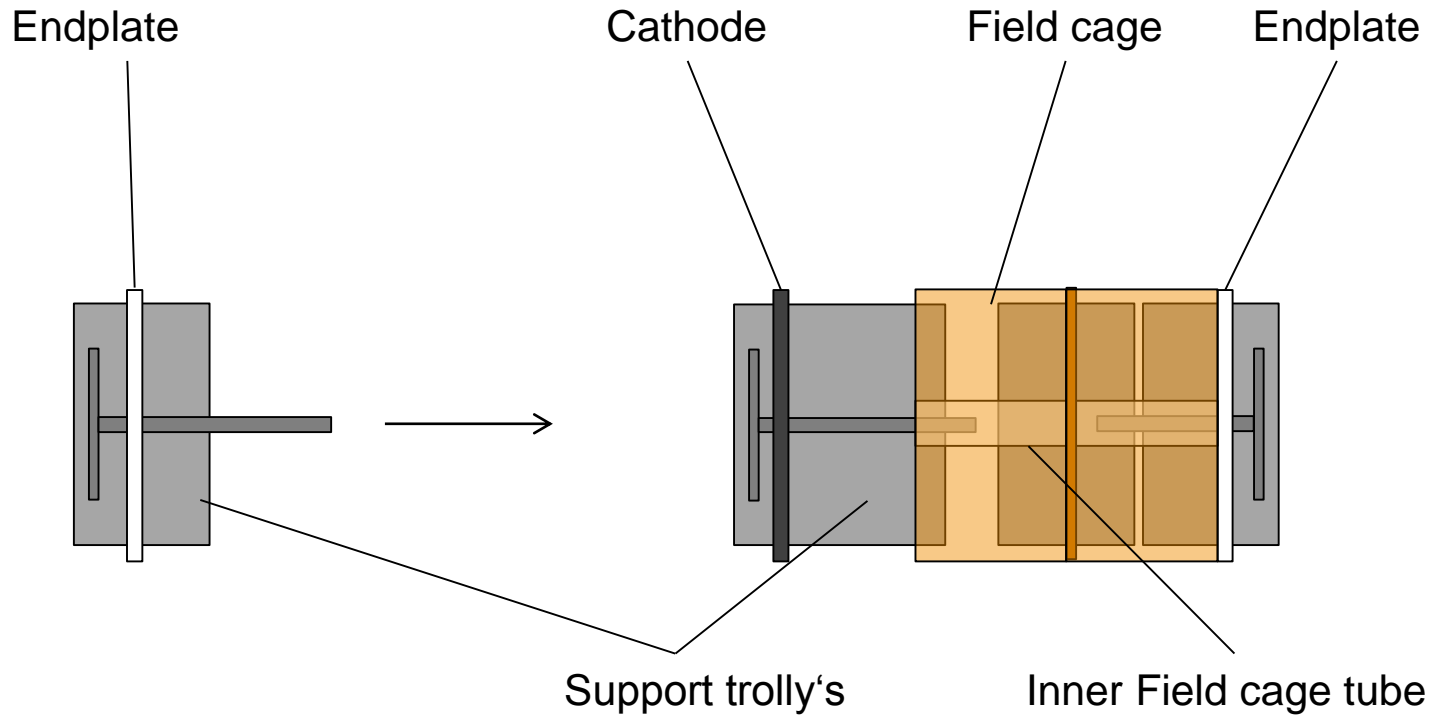
Volker Prah, LC TPC Collaboration Meeting, TPC Mechanics I

| 10.01.2019 | Page 20



TPC assembly

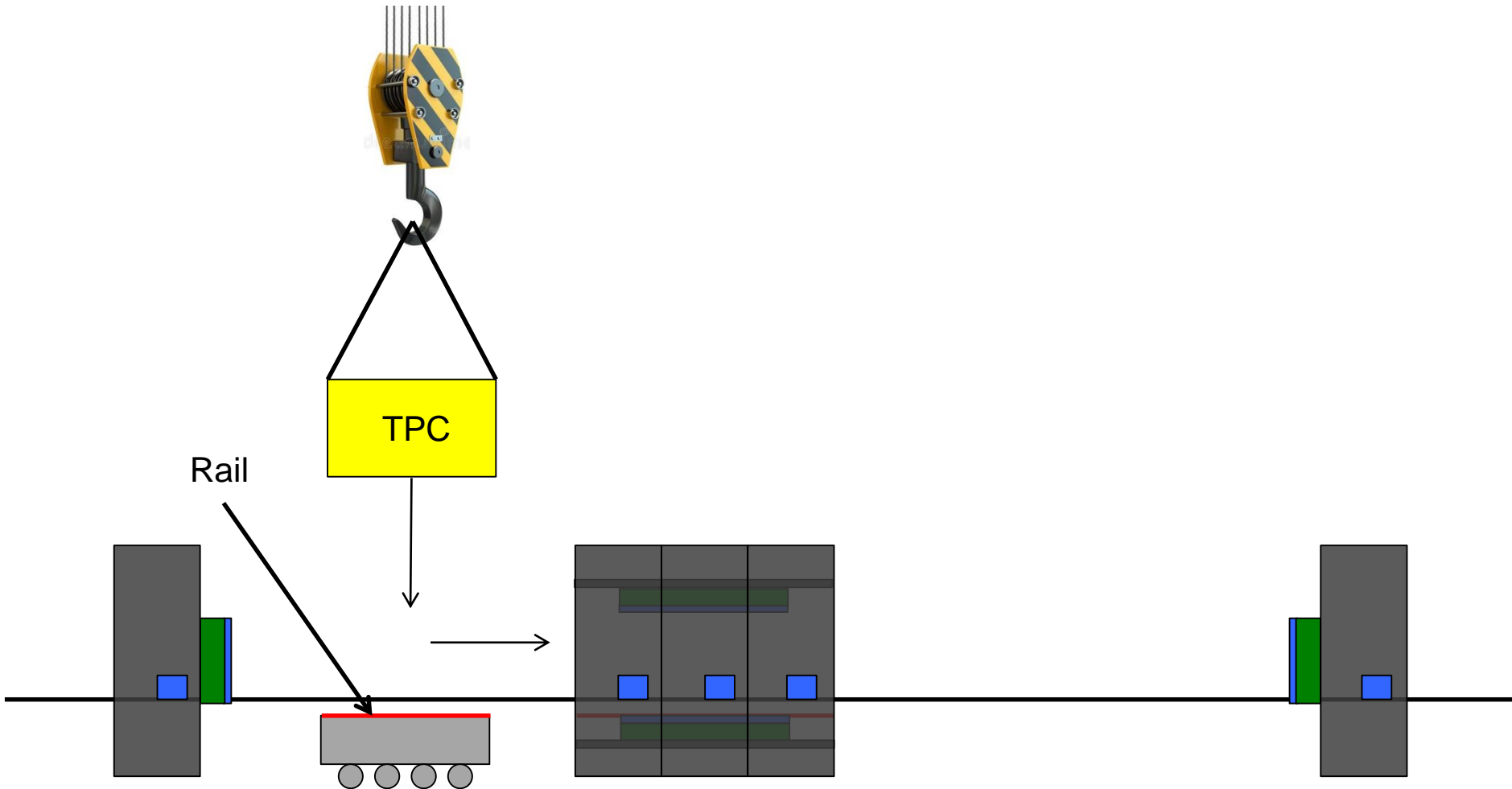
Horizontal procedure in a few steps



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

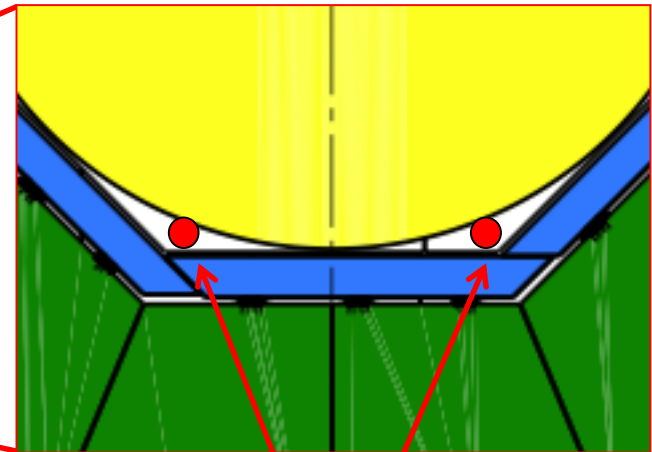
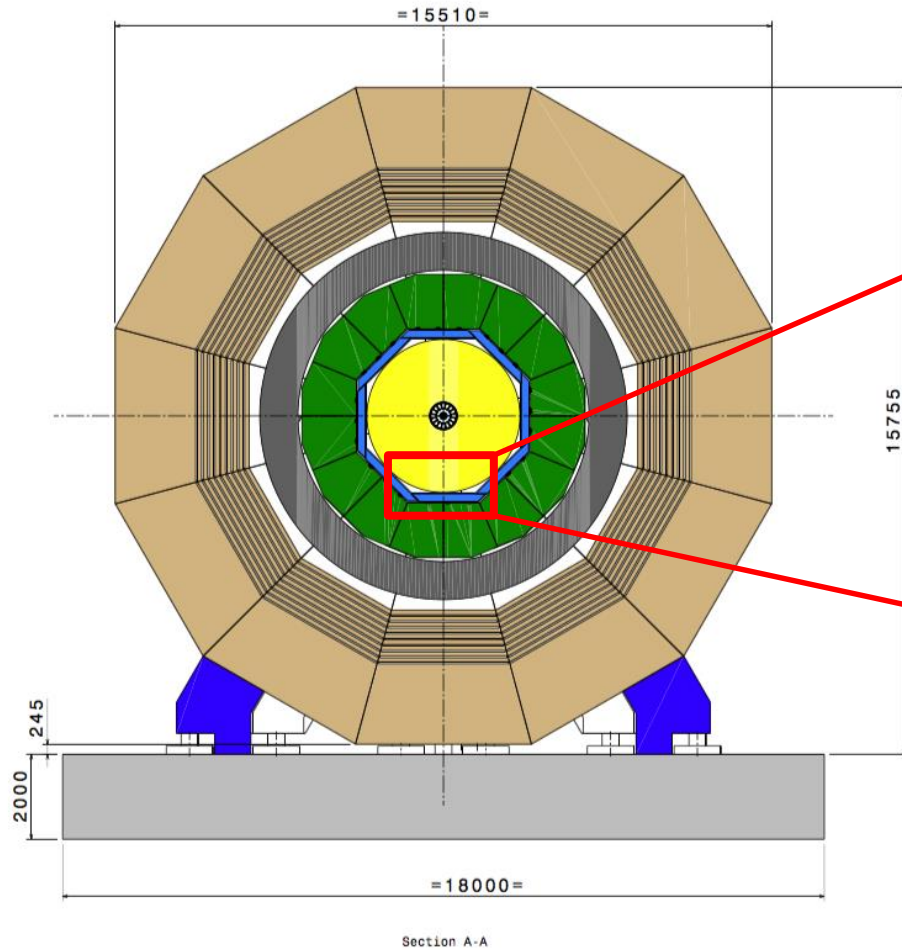
Top view of TPC assembly

TPC inserting



8/9 October 2015
TSS: TPC Assembly

TPC inserting



Rails
Space?

8/9 October 2015
TSS: TPC Assembly

Volker Prael, LC TPC Collaboration Meeting, TPC Mechanics I

| 10.01.2019 | Page 23

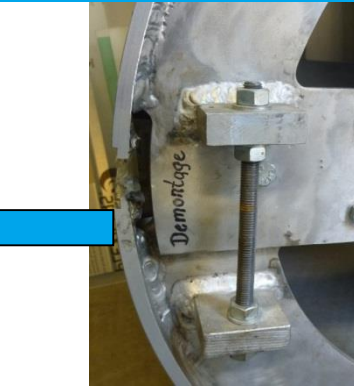
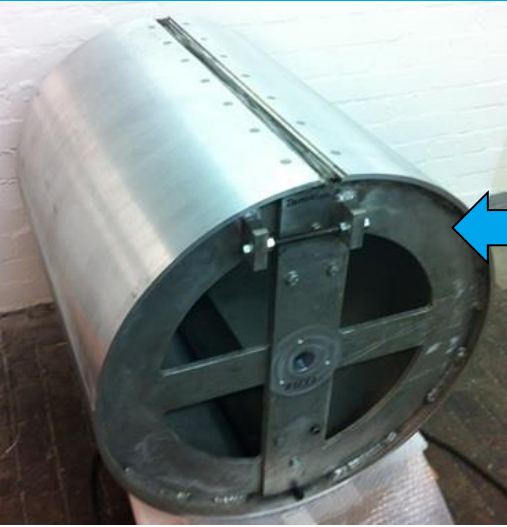


Preparation of the second LPTPC

- Fabrication of the new mandrel
 - Reusable mechanics to build more than one FC
 - Lower mechanical tolerances
 - Focus on the parallelism of the flanges and perpendicular axis / flanges
- Preparation of the curing area for the second field cage
- New field strip foil in preparation
- Honeycomb test part for bending test in preparation
- Improvements of the connection of the filed cage shielding in design progress
- Redesign of the connection of the first and seven field strip
- TPC support rails at the PCMAG planed
- PCMAG cooldhead maintenance in January 2019



LP TPC Activities in 2018 and 2019...



Alignment screw



New mandrel
(Ole Bach)

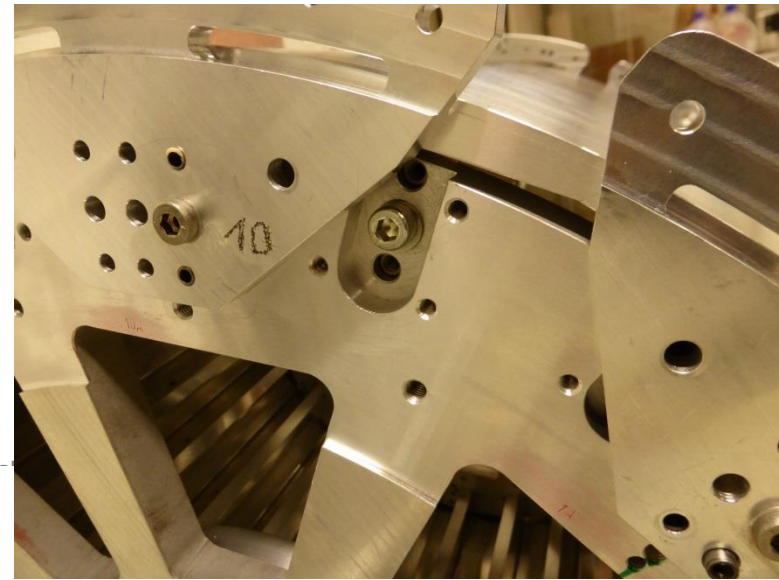
First mandrel

Challenge of a high-precision TPC field cage:

- Low material, high HV stability, high mechanical precision

Why a new LPTPC ?

- Current field cage built by external company:
Skewed by ~ a factor 10 too much
→ field homogeneity not within specs
- Want to gain experience for building the big
ILD TPC
- Good to have a spare one



LP TPC Activities in 2018 and 2019...



„Gluing“ room, preparation table
incl. end flanges of the new field cage
(Bernd Beyer)

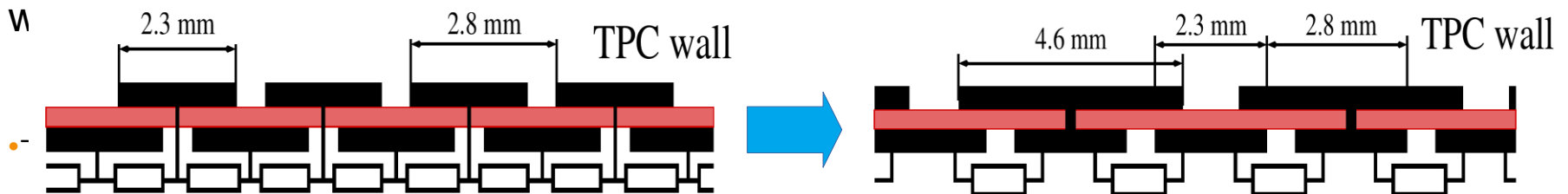
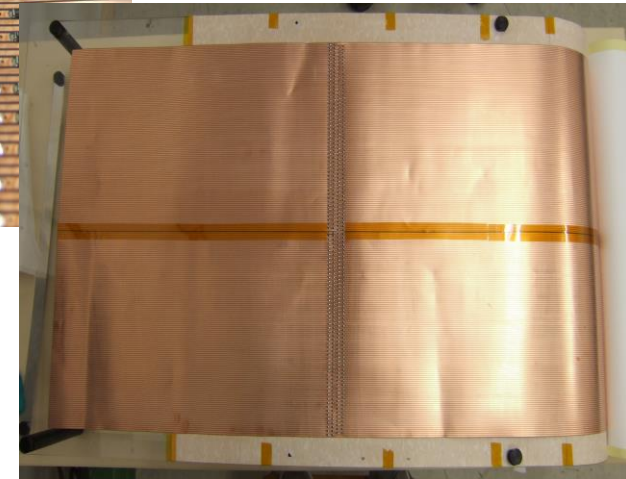
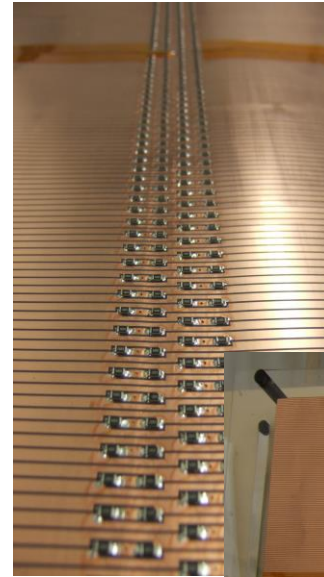


Mandrel connect to the
table

Large TPC Field Cage - V2

Field Strip Foil

- Available “old” foil collected some “damages” during storage
- First field cage: No production site could do a two sided foil of that size (61 cm x ~226 cm)
- Now: full size seems possible (i.e. @CERN)
- Possible sizes seem to match just what we need
- Developed a simpler field strip pattern → minimal worse field: distortion reach ~7 mm instead of ~5 mm from



Conclusion

- More studies of the support system required
- Required space is an issue with the infrastructure and gaps between and in the middle of the AHCAL / 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



Outlook

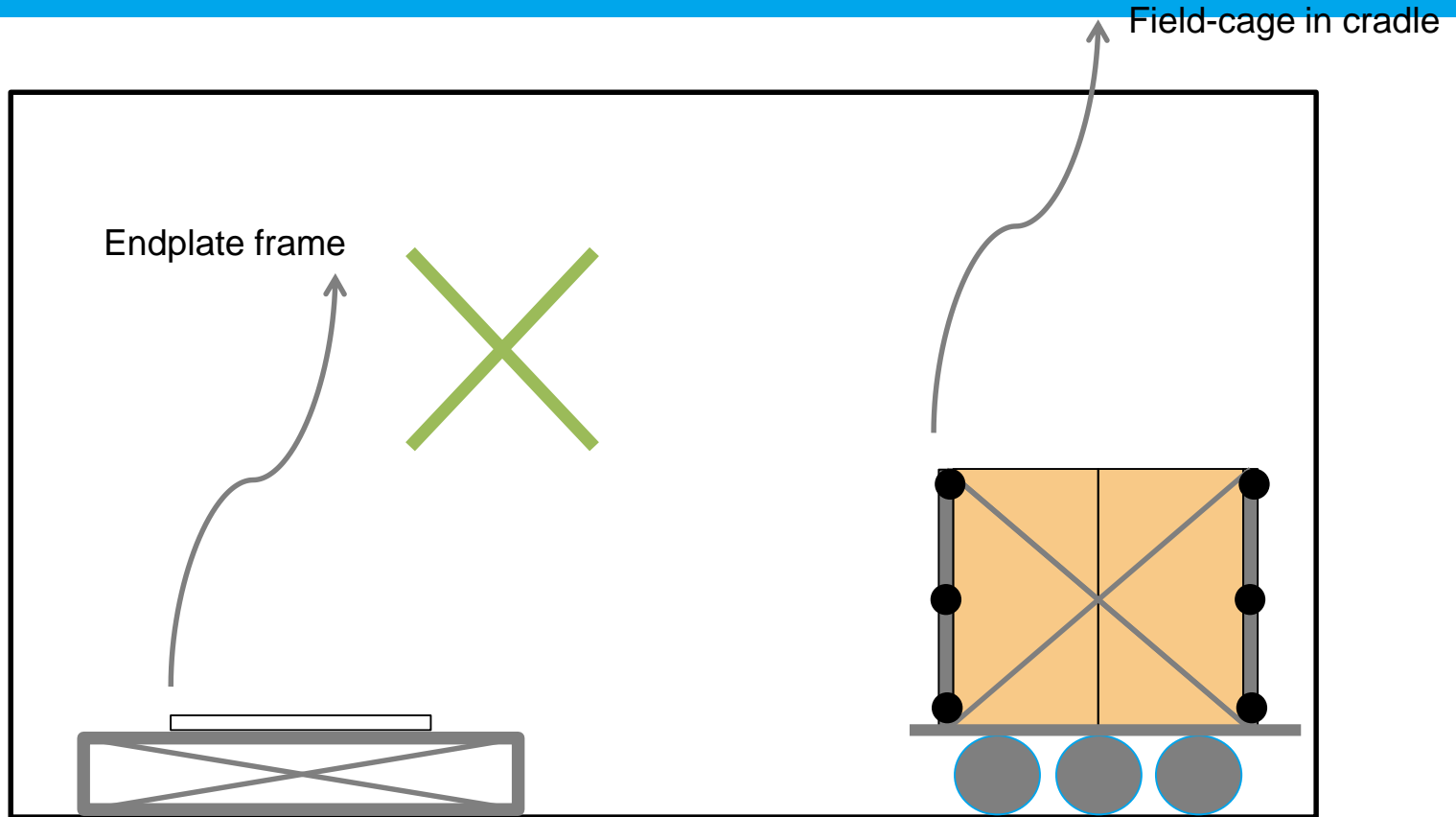
- Build the second field cage
- Availability of space in the gaps has to be evaluated
- More FEA studies
- Minimize the cross section of the support bars
- HV-Cable routing
- Field cage electrical insulation
- Cathode, design and inserting
- TPC Assembling and mounting, services
- TPC insertion
- Local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



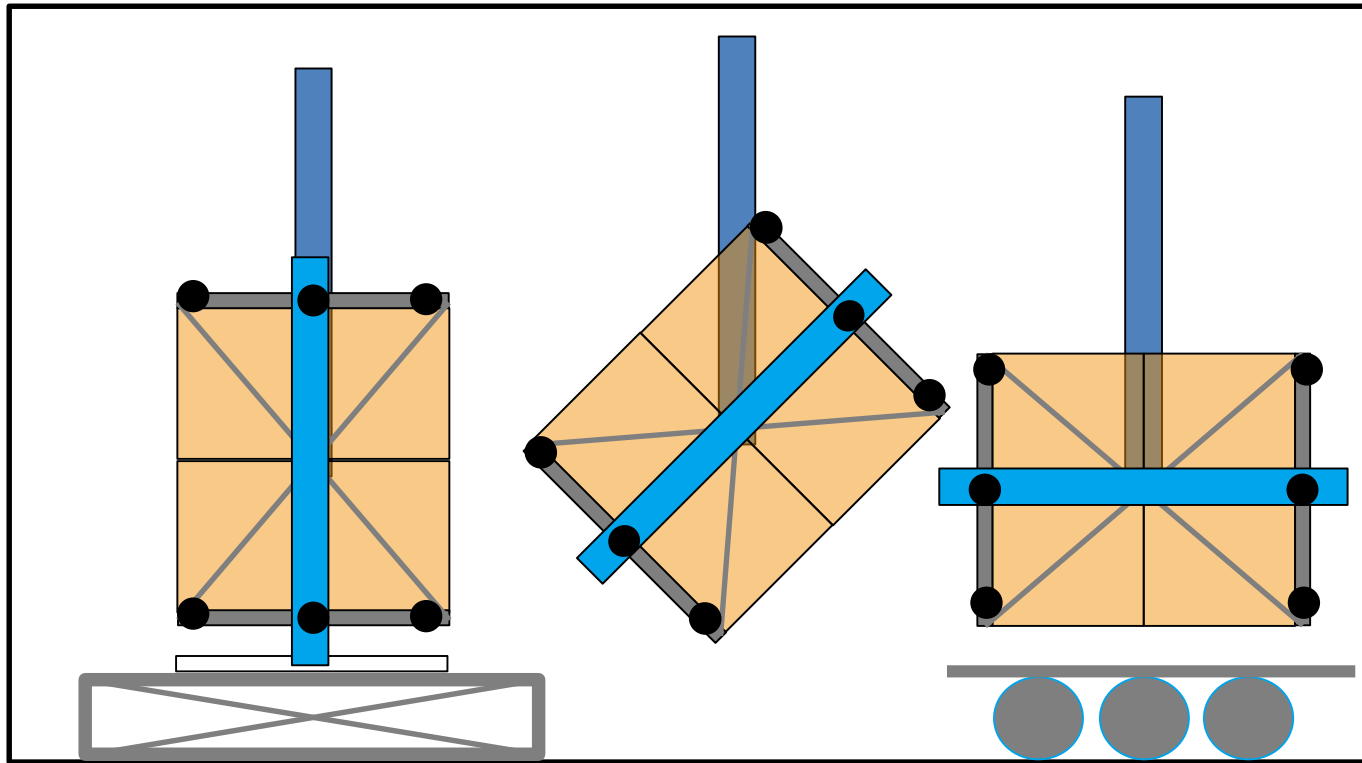
TPC assembly and inserting steps
some ideas from Thomas Schörner-Sadenius, Volker Prah



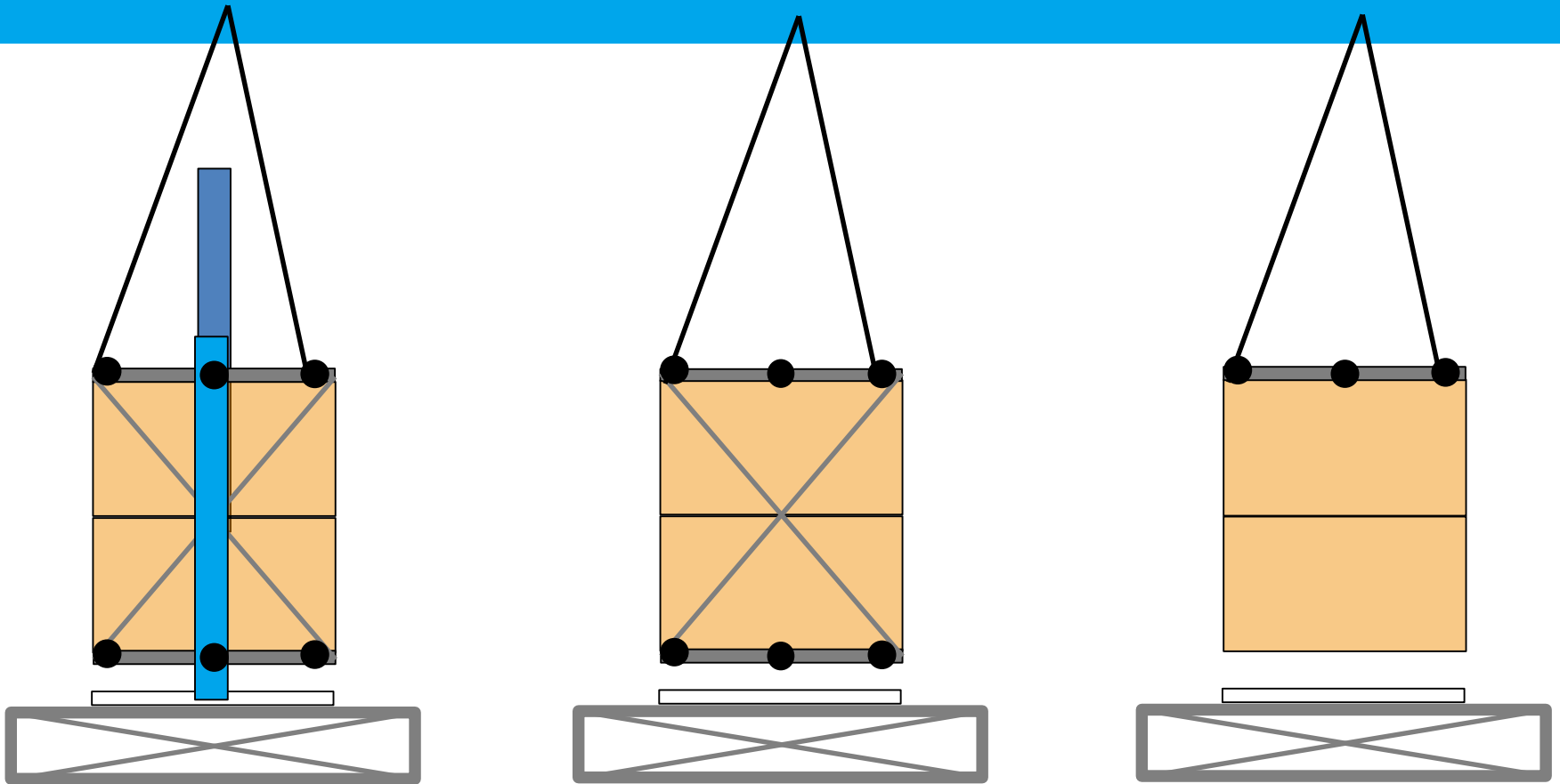
Vertical procedure in a few steps



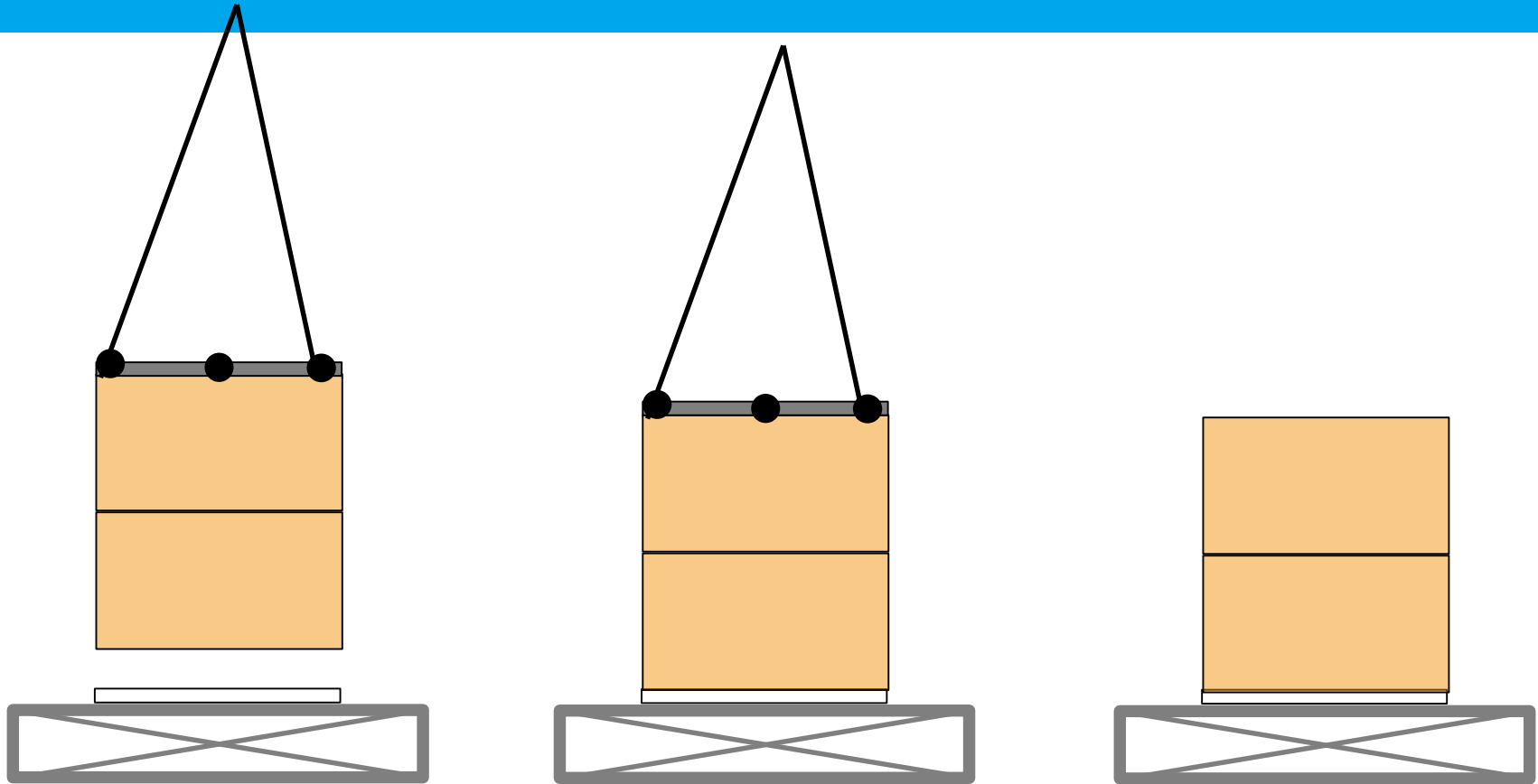
Vertical procedure in a few steps



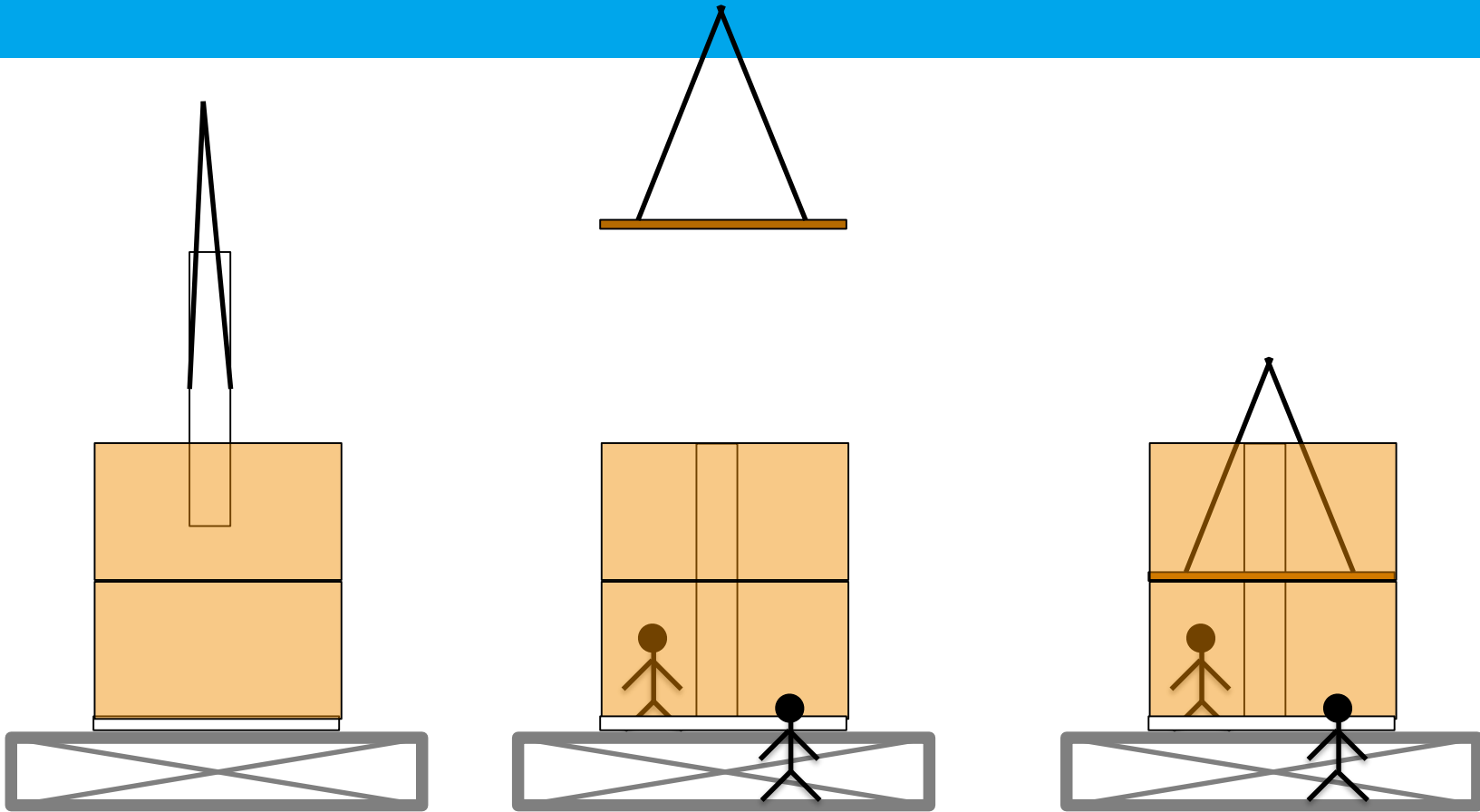
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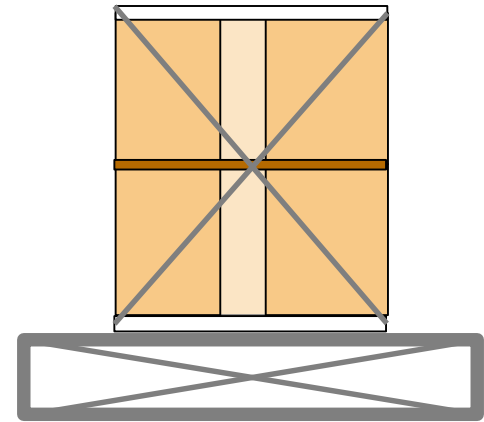
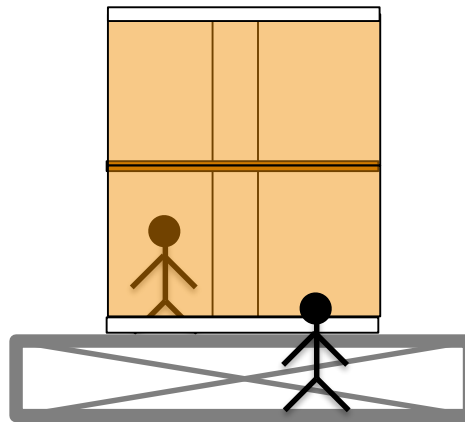
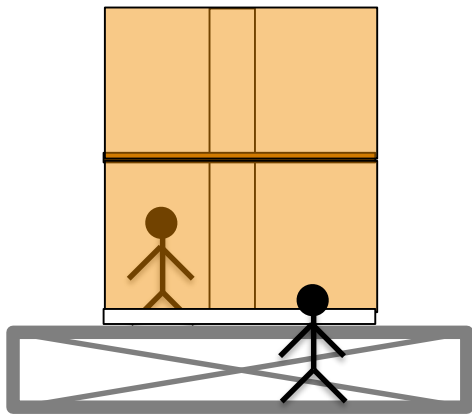
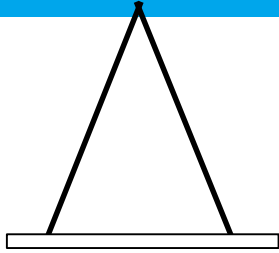
Vertical procedure in a few steps



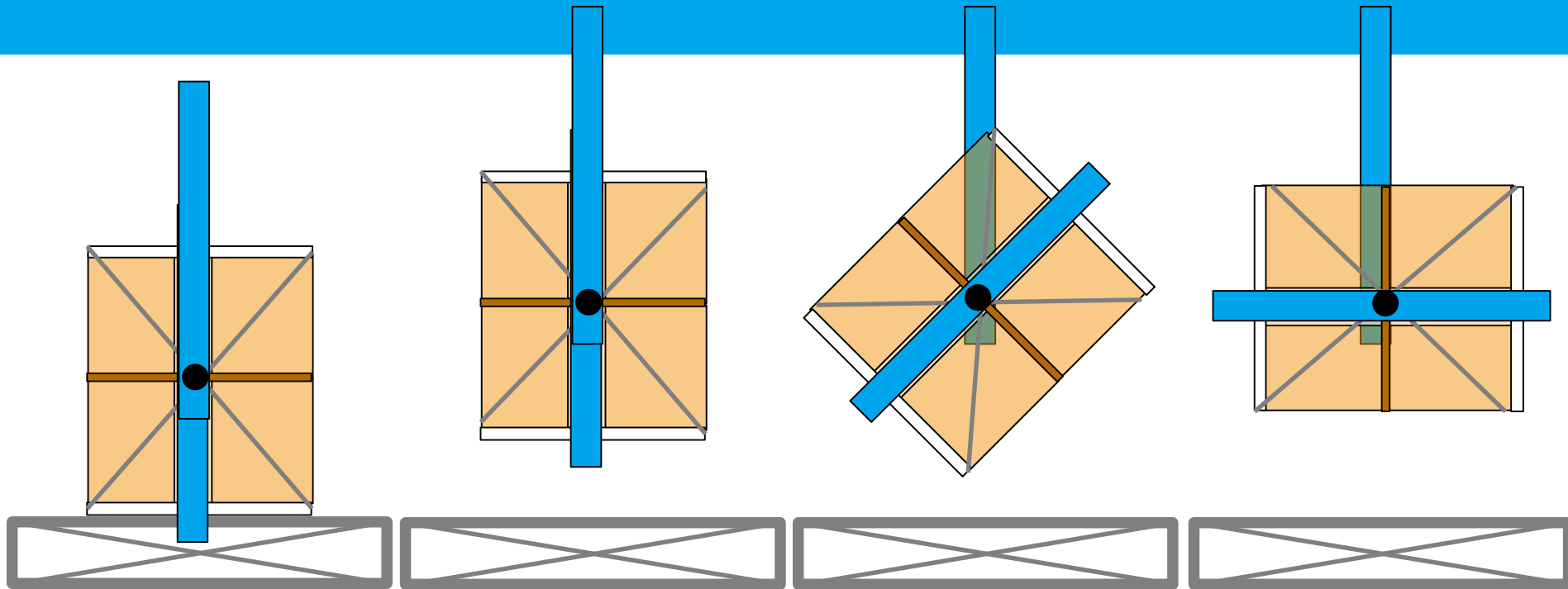
Vertical procedure in a few steps



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).

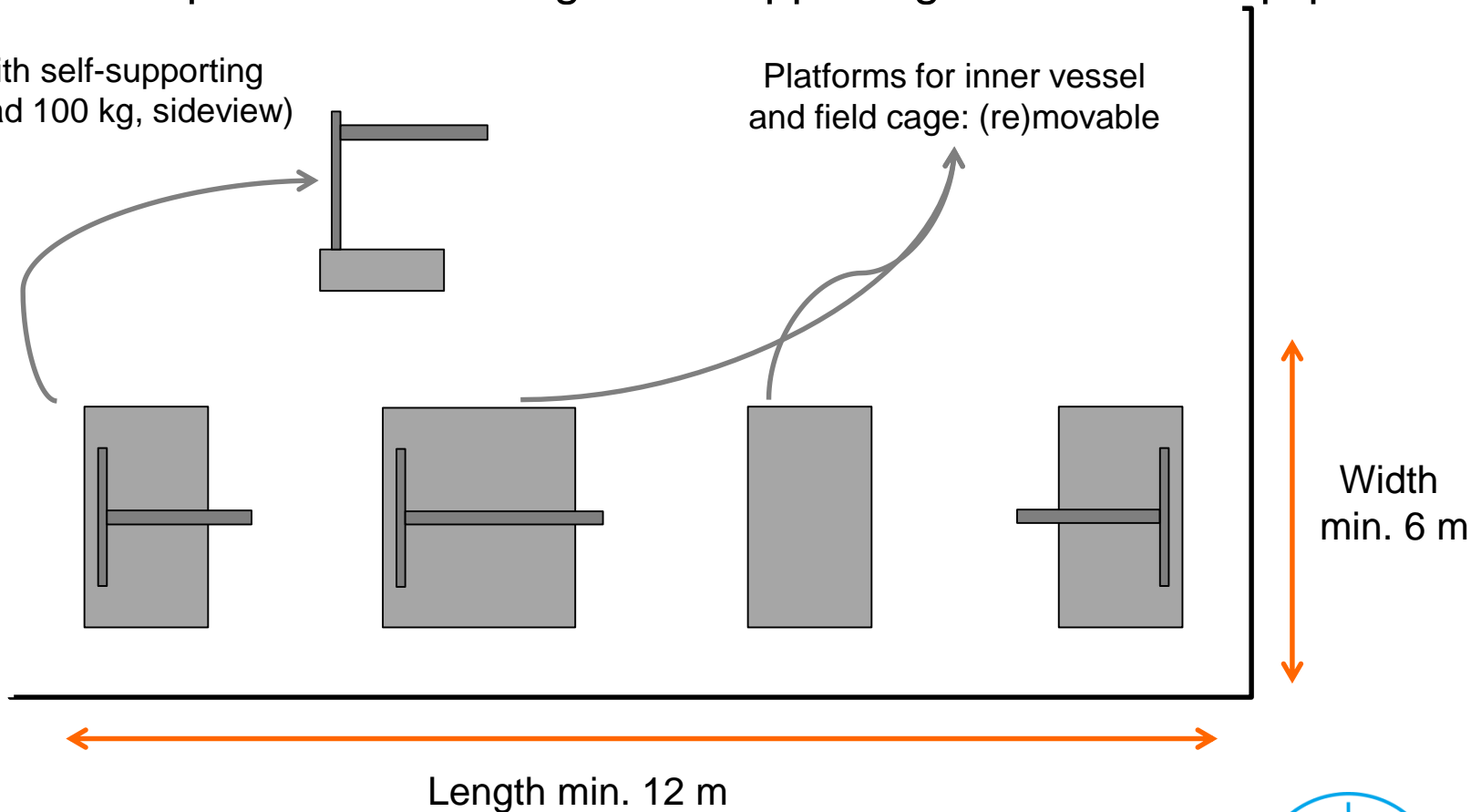
▪ System test (in AH)

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 equipment

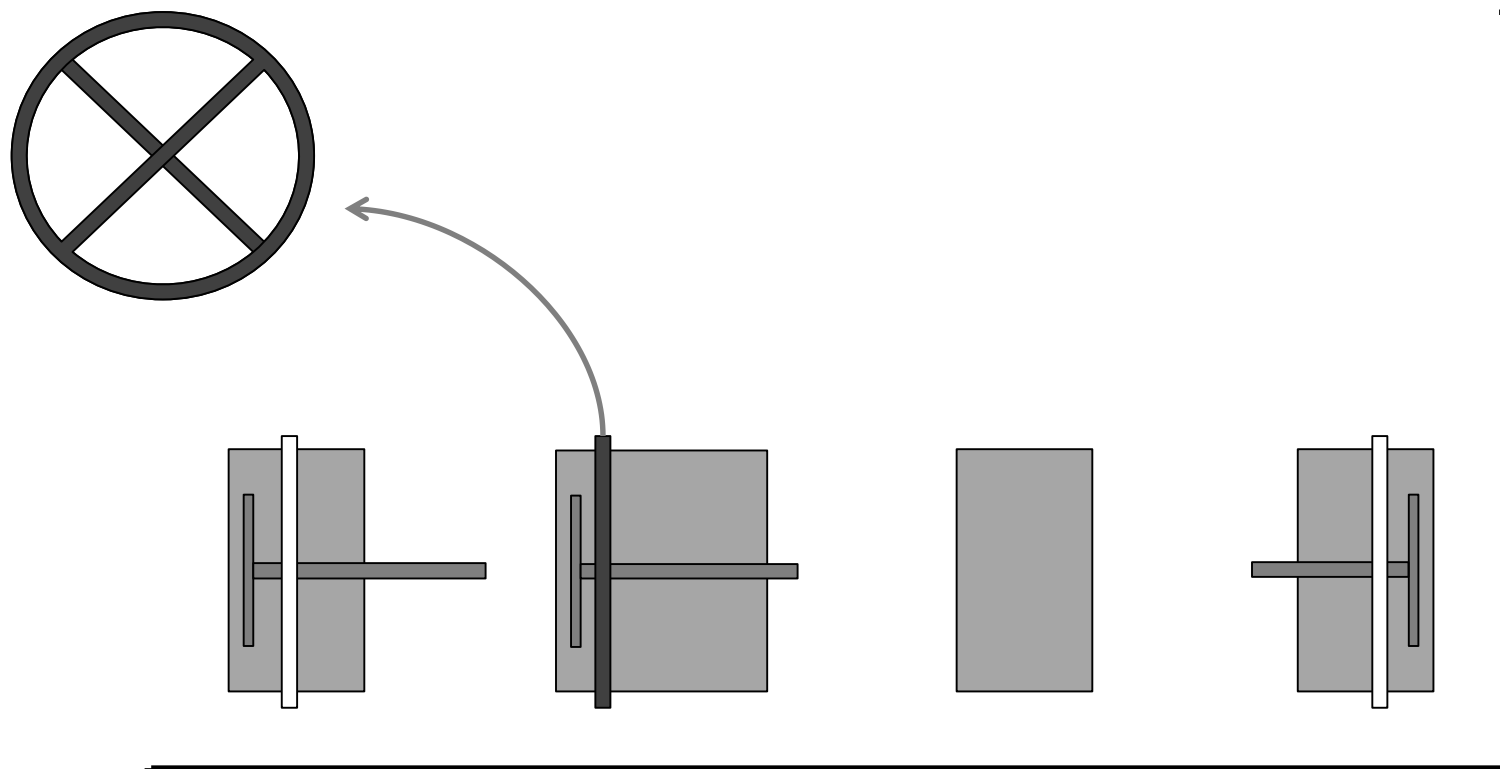
Trolley with self-supporting thorn (load 100 kg, sideview)

Platforms for inner vessel and field cage: (re)movable



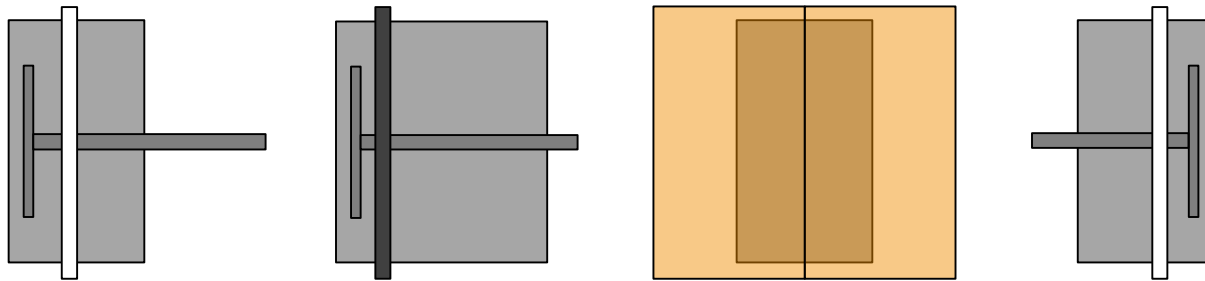
Horizontal procedure in a few steps

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



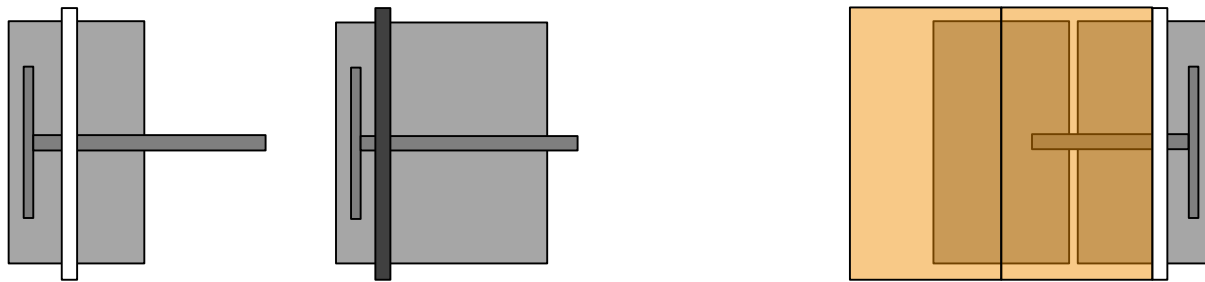
Horizontal procedure in a few steps

Field-cage assembly



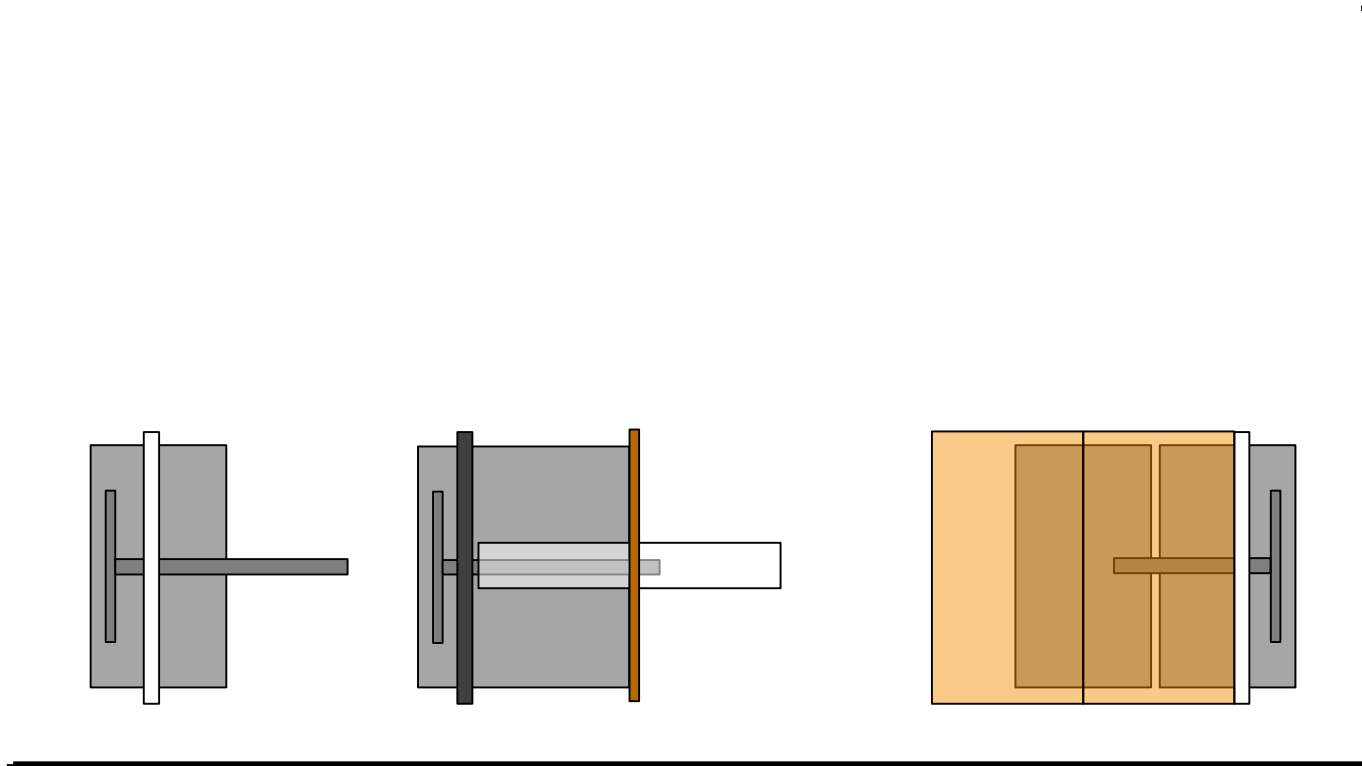
Horizontal procedure in a few steps

Marriage of field-cage and end-plate R



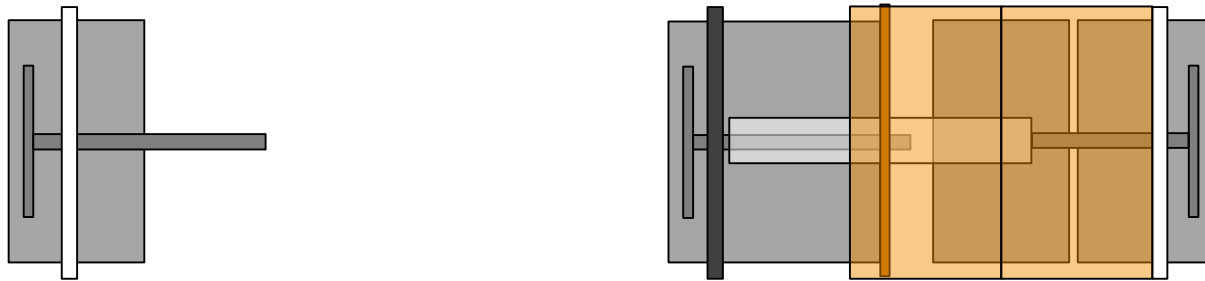
Horizontal procedure in a few steps

Set-up of inner vessel with cathode (“sail”)



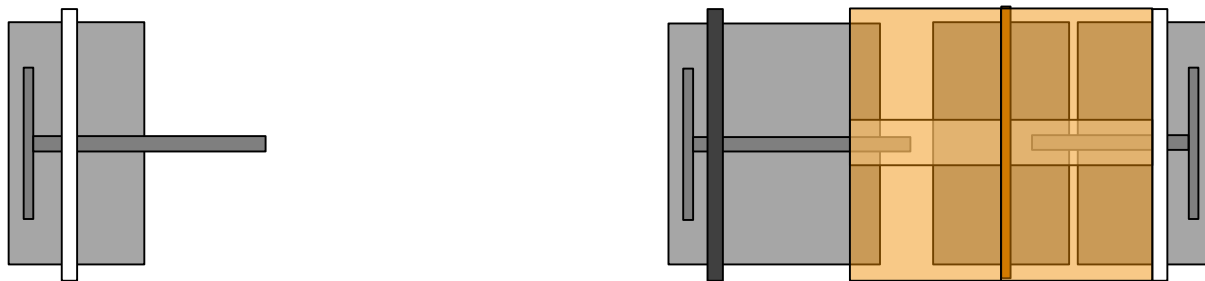
Horizontal procedure in a few steps

Marriage of inner vessel with cathode and field cage



Horizontal procedure in a few steps

Marriage of inner vessel with cathode and field cage

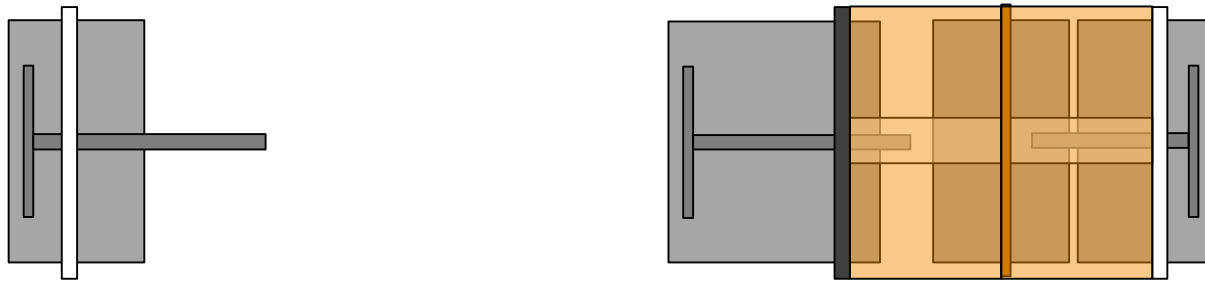


Alternative: First fixing of inner vessel in field cage,
then installation / spanning of cathode.

Horizontal procedure in a few steps

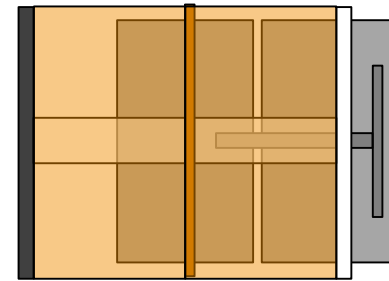
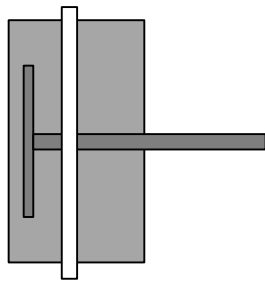
Marriage of inner vessel with cathode and field cage.

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



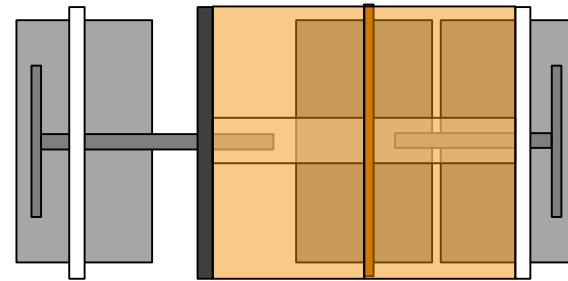
Horizontal procedure in a few steps

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



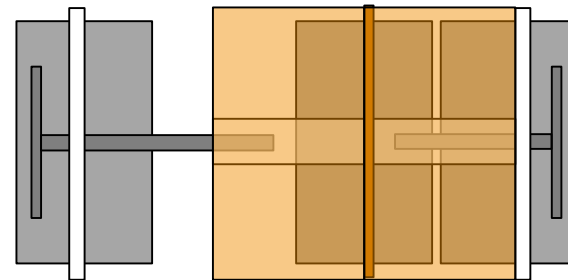
Horizontal procedure in a few steps

Inserting end-plate L: approaching the field cage ...



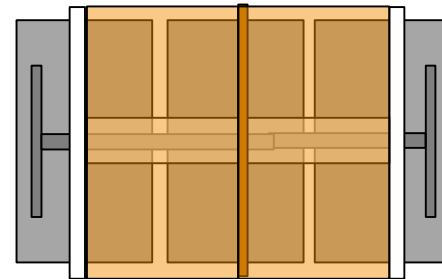
Horizontal procedure in a few steps

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



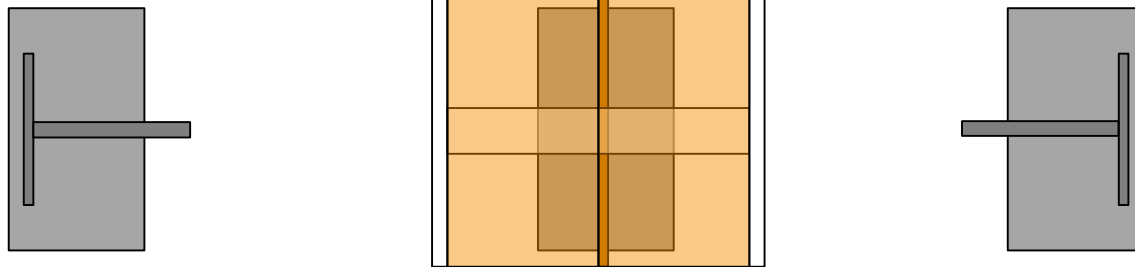
Horizontal procedure in a few steps

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

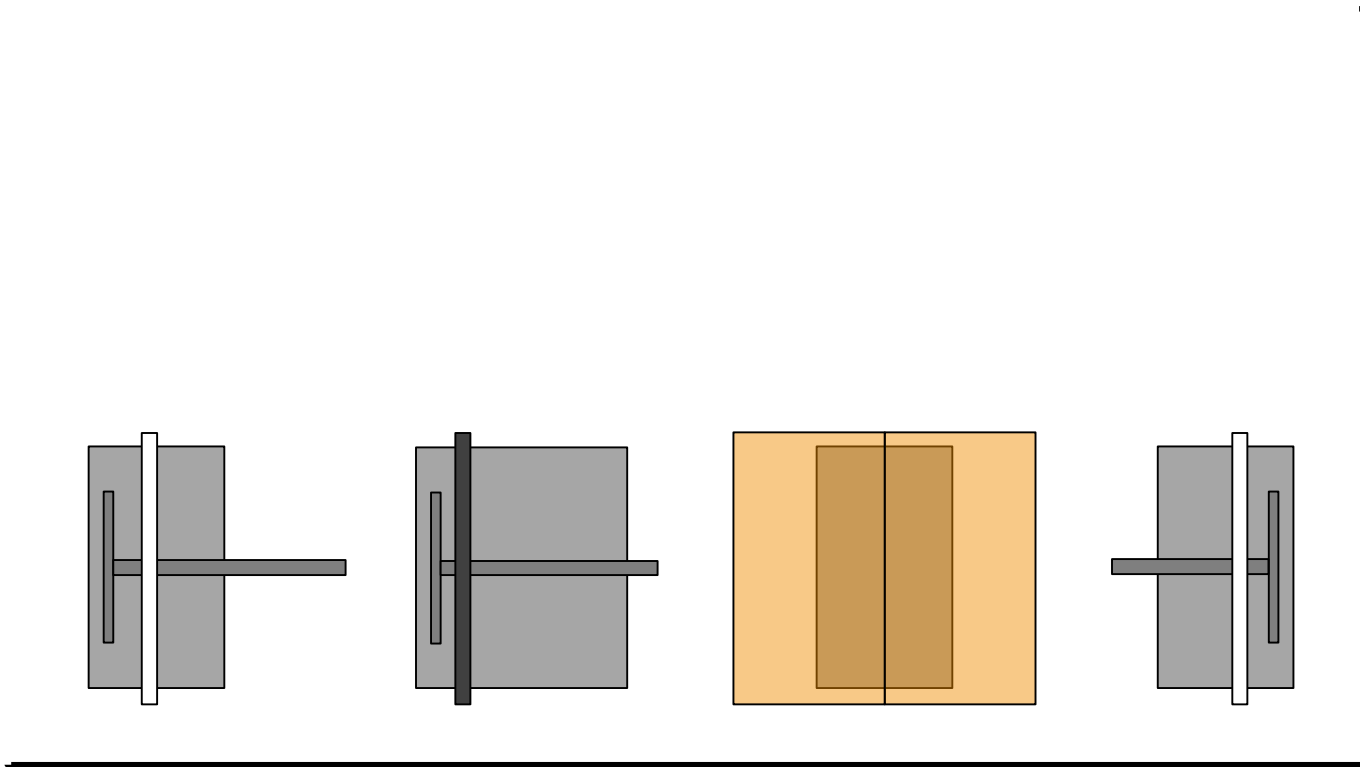
Ready



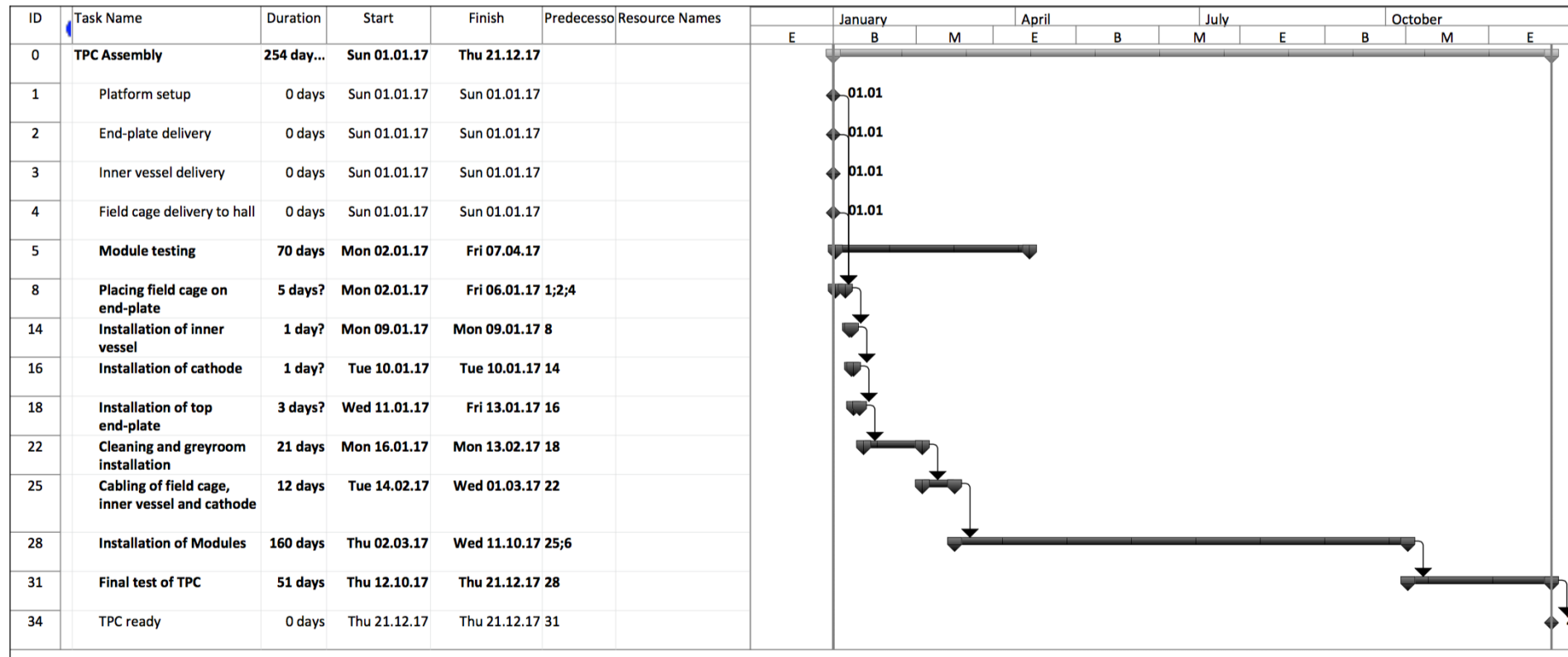
Alternative horizontal procedure

Assumptions: Similar as before, but ...

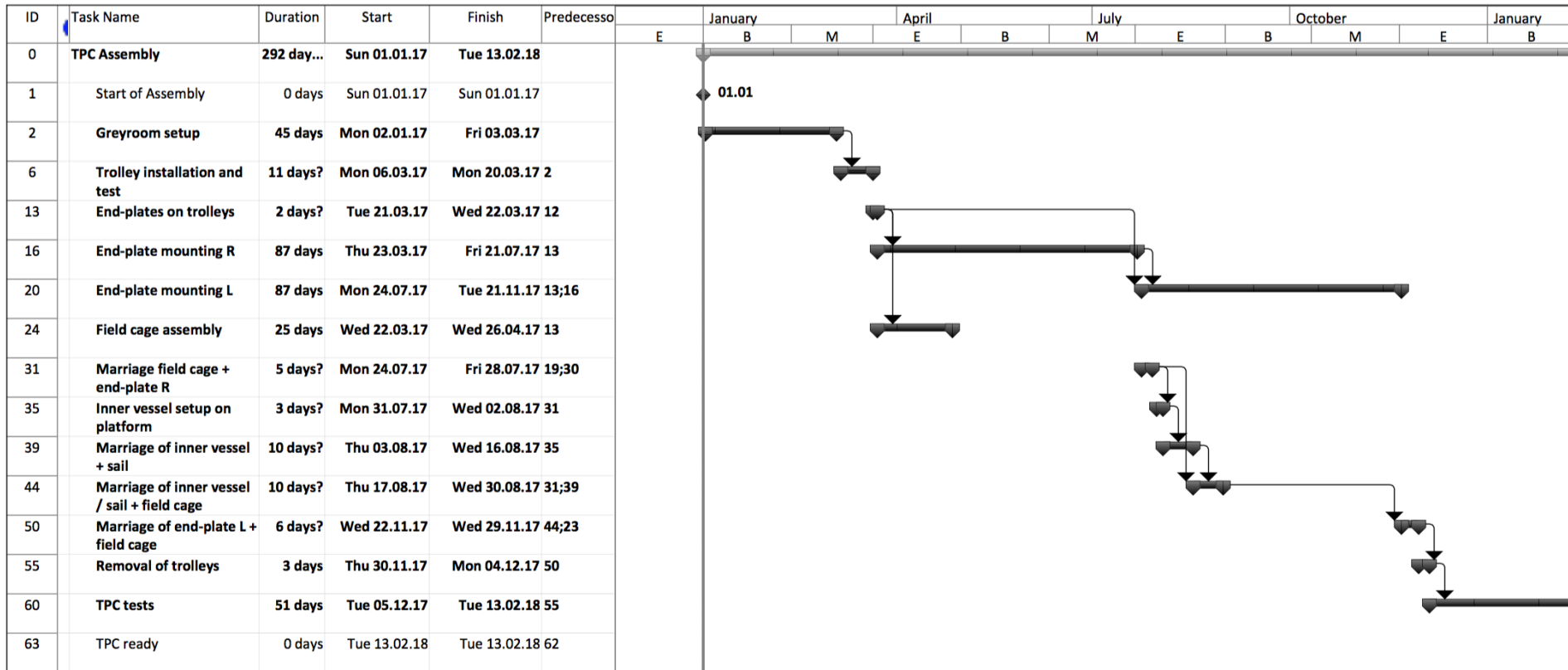
- EP equipment at the end with robot
- Question of overall time planning (end-plate equipment the most time-consuming item)



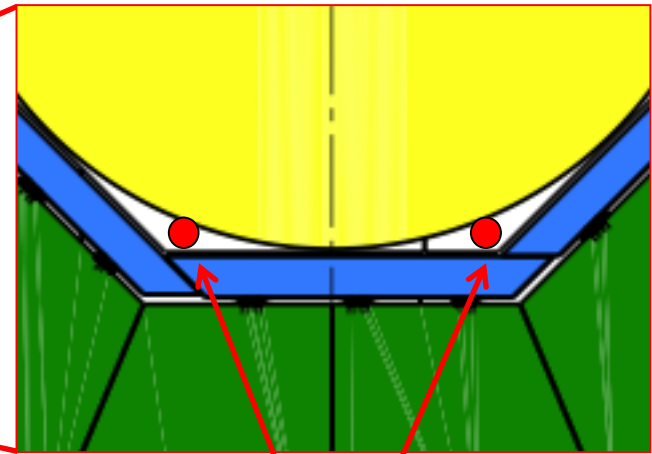
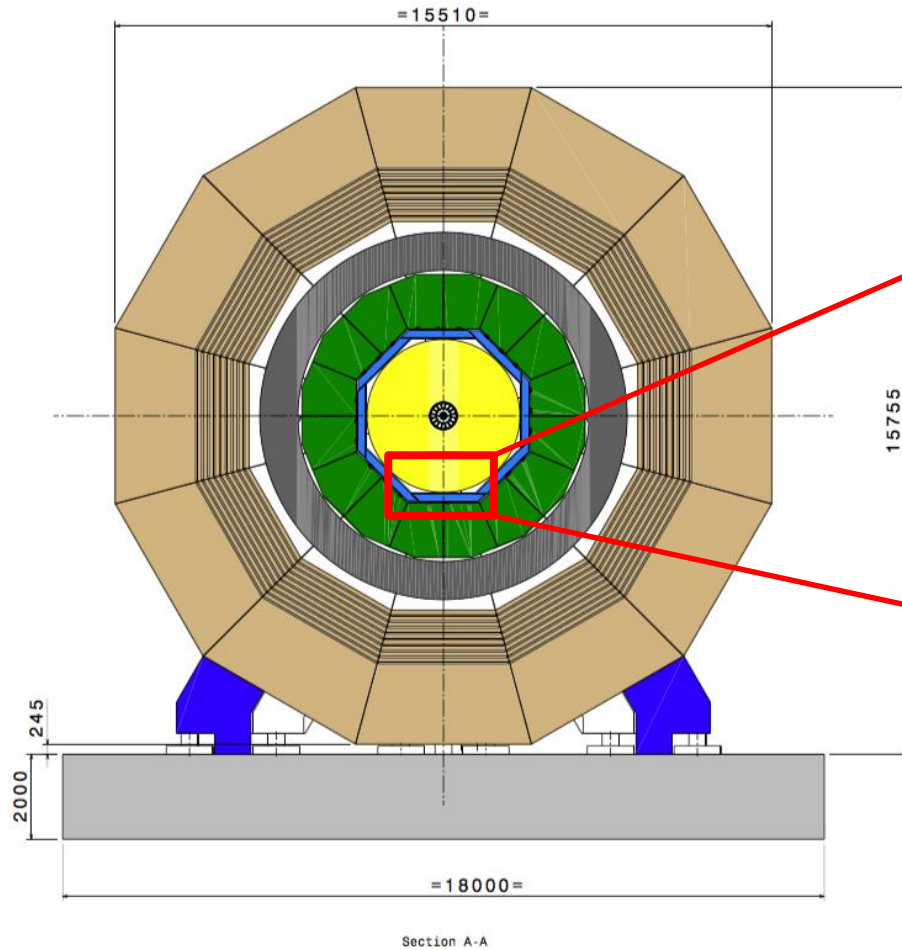
Vertical procedure – time estimate



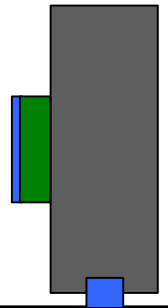
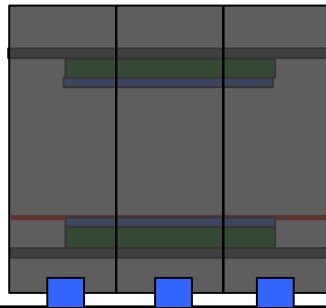
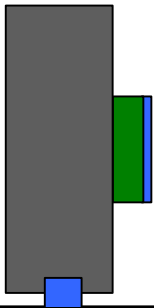
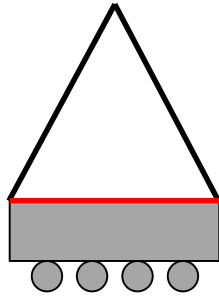
Horizontal procedure – time estimate

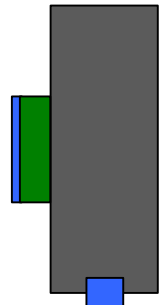
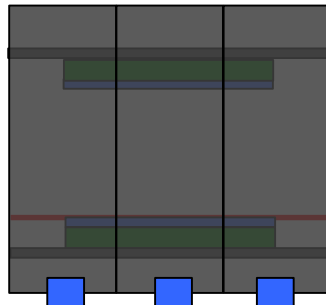
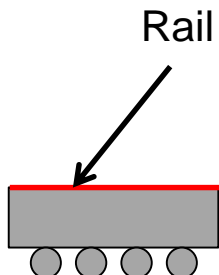
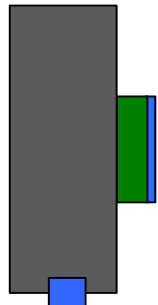
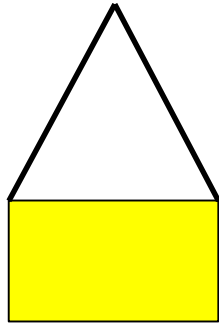


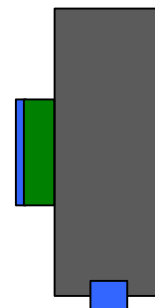
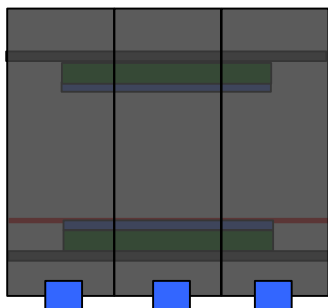
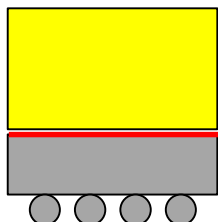
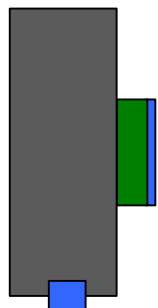
TPC insertion – mechanism?

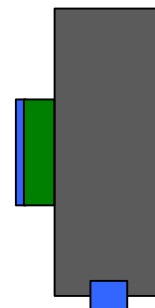
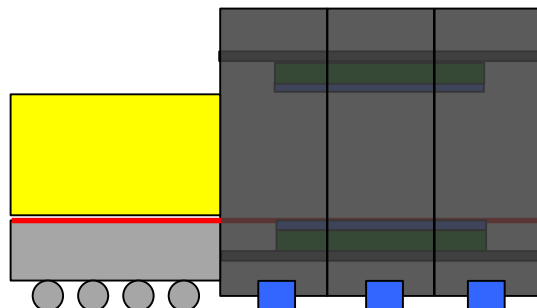
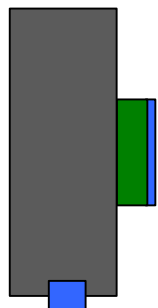


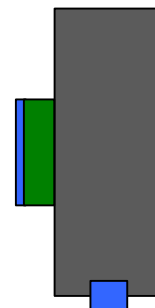
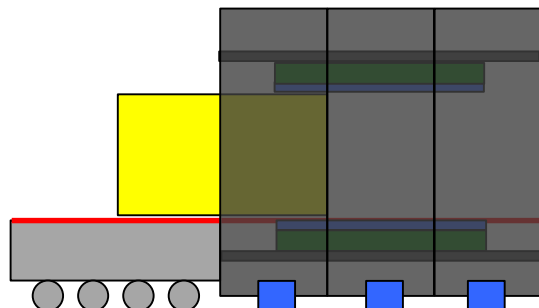
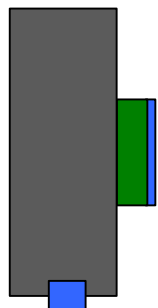
Rails
Space?

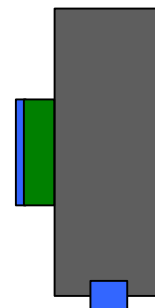
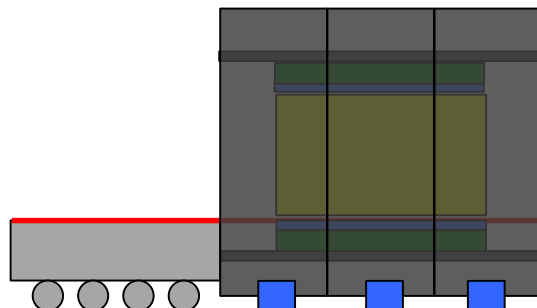
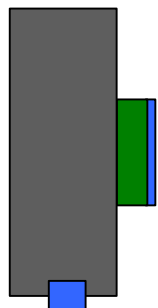


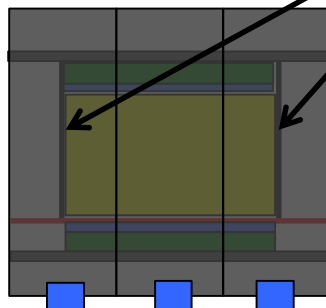
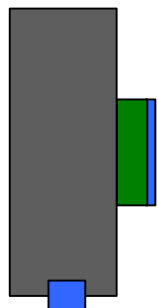




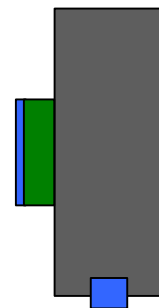






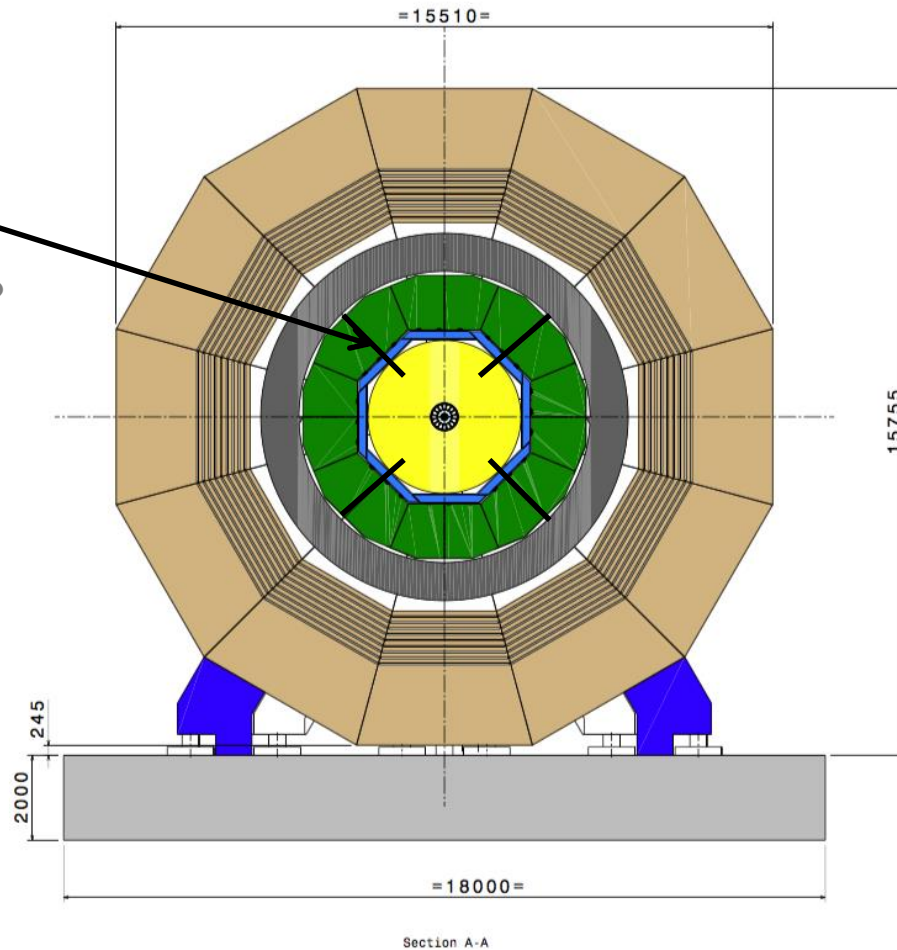


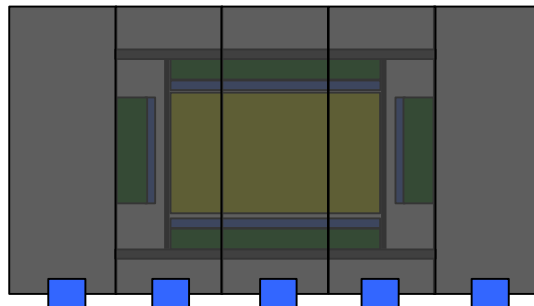
Carbon bands



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 m² (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

