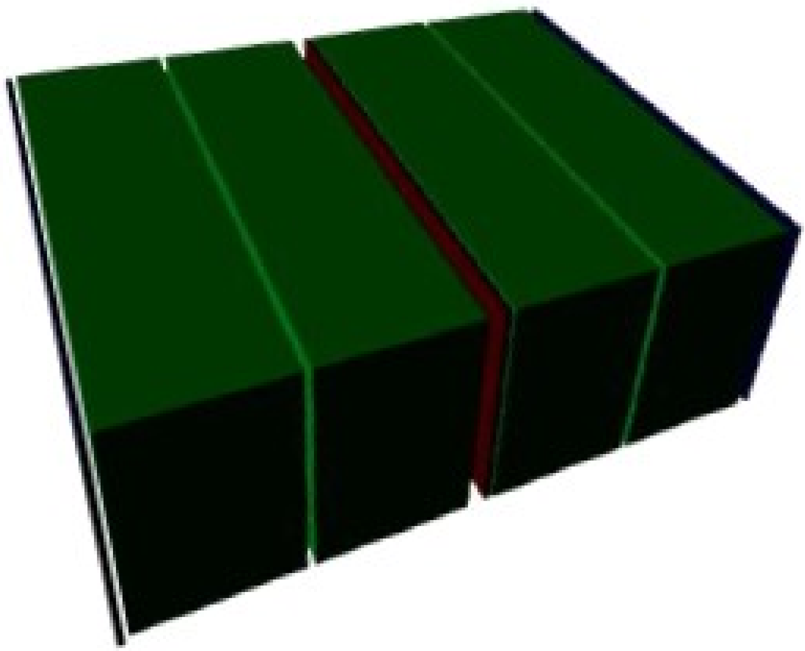
ND280 Upgrade Workshop - 20180416

TPC field cage design and prototype - status report



Overview

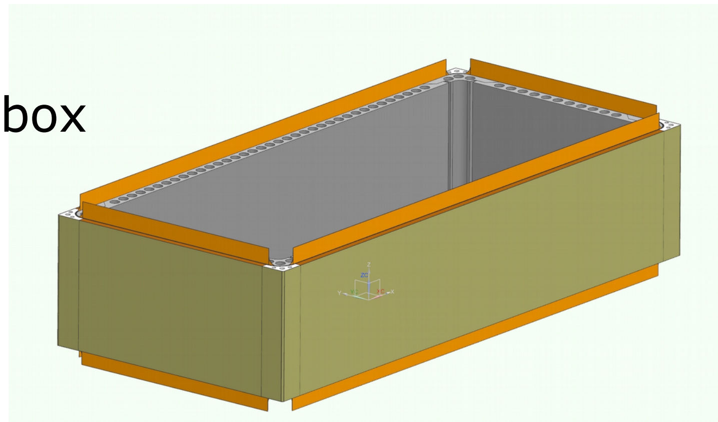
1. TPC **design concepts**
2. **Prototype** for testing
   issues of the building process

IFAE: T.Lux, J.Mundet, C.J.Valls
INFN Bari: L.Magaletti, E.Radicioni
INFN Legnaro Labs: F.Gamegna, T.Marchi
INFN Padova: G.Cogo, G.Collazuol, A.Longhin, A.Pepato, M.Romanato

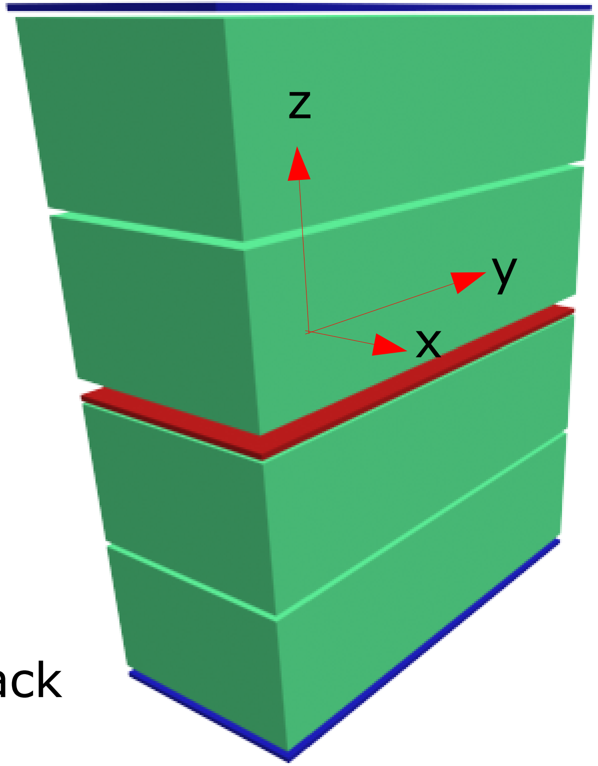
1 - TPC design concepts – Concept and specs

Basic design idea is to build the new thin wall TPCs by piling up boxes made of composite material walls

single box



boxes in astack



Walls composite structure to define active gas volume and to provide mechanical support to electrodes. Main specs:

→ gas tightness, for keeping O_2 level below O(1ppm)

→ electric insulation against breakdown with cathode V max of O(40kV)

→ internal surfaces (E field shaping strips) flatness better than O(100μm) considering O(5mbar) overpressure (and gravity)

→ alignment of strips plane (x-y) || end-plates || cathode better than O(100μm)

1 - TPC design concepts – Box structure

- Rectangular TPC of 200 (B field / drift dir.) x 180 (beam dir.) x 85 (height) cm^3
- Aiming at thin wall (~3cm) made of low Z composite material (few % X_0)

Carbon Fiber based layer stack

	Material	Thickss (mm)
	Copper coated polymide film	*~ 0.15*
	Carbon Fiber	*1.20*
	Aramide HoneyComb panel	*15.00*
	Carbon Fiber	*1.20*
	Aramide HoneyComb panel (insulation)	*10.00*
	Polymide film (insulation)	*~ 0.10*
	Strips (double later) on Kapton foil	*~ 0.15*
	TOTAL RADIATION LENGHT **~ 2% X_0**	*~27.5*

Aramide Fiber fabric based layer stack

	Material	Thickss (mm)
	Copper coated polymide film	*~ 0.15*
	Aramid Fiber Fabric (Kevlar)	*4.00*
	Aramide HoneyComb panel	*15.00*
	Aramid Fiber Fabric (Kevlar)	*4.00*
	Polymide film (insulation)	*~ 0.10*
	Strips (double later) on Kapton foil	*~ 0.15*
	TOTAL RADIATION LENGHT **~ 4% X_0**	*~23.5*

Note: aiming at a thin and low Z composite wall:
- peels symmetry about Honeycomb (HC) core to minimize deformations (overpressure 5mbar)

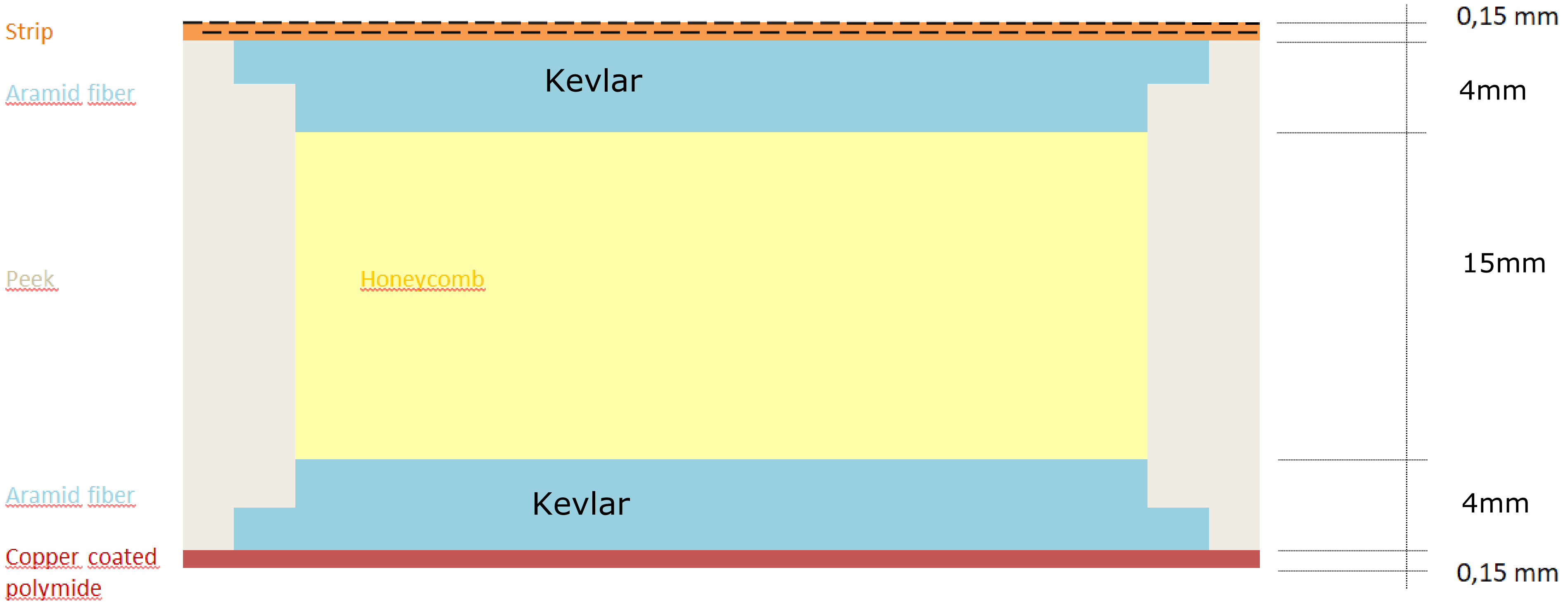
- Carbon Fiber (CF) provides best stability, simulations tells: max deform. < O(150μm)
  - CF is low Z material (radiation length ~20cm)
  - CF has low resistivity → additional electric insulaiton required

(*) mechanics simulation by J.Mundet

- Aramid Fiber (or Kevlar) (AF) allows much simplified stack:
  - AF has larger rad. length (~ 28cm)
  - AF provides very good insulation and stability: simulation tells deformation < O(150μm)

1 – Box wall cross section - example

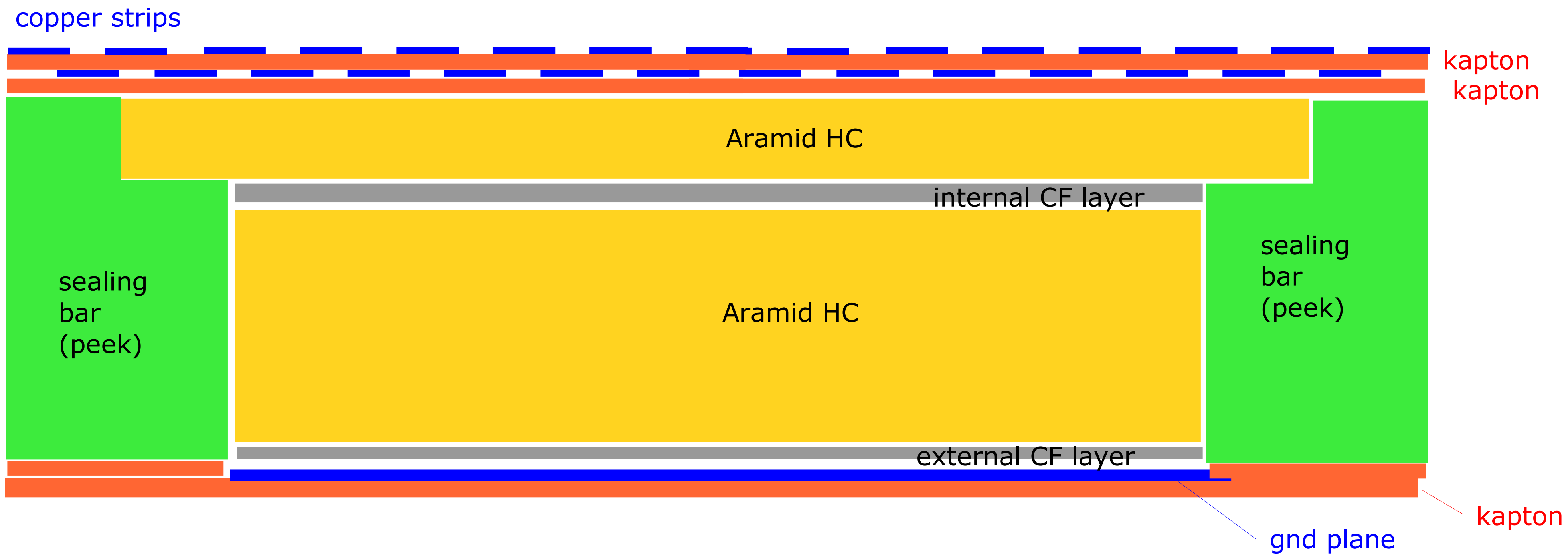
Option 1 → **full aramide** wall structure



M.Romanato – G.Cogo (INFN-PD)

1 – Box wall cross section - example

Option 2 → **carbon fiber** based wall structure



1 – Box wall cross section – impact on physics

César Jesús Valls (IFAE)

ND280-Upgrade

TPC-FC Simulation Status

Objectives:

Three possible Models for the TPC FC: Nexus, GF, Solid.

I worked on a Geant4 simulation to study:

- The relative momentum loss.
- The angle spreading.

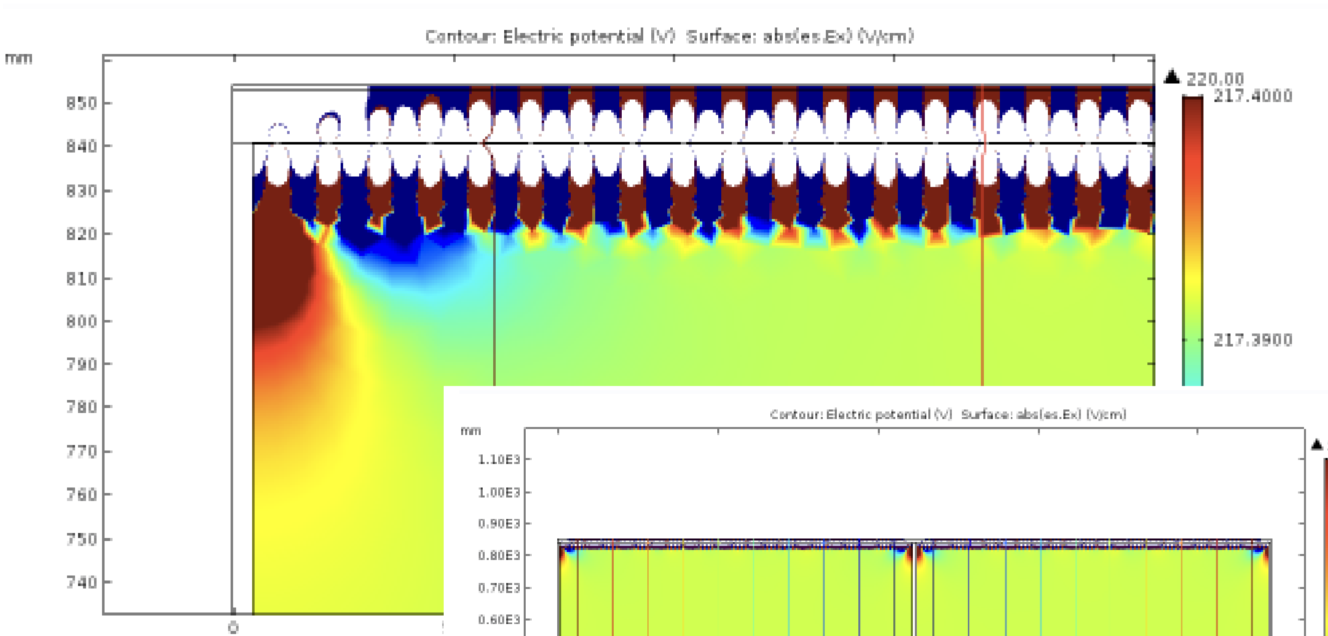
Simulation overview:

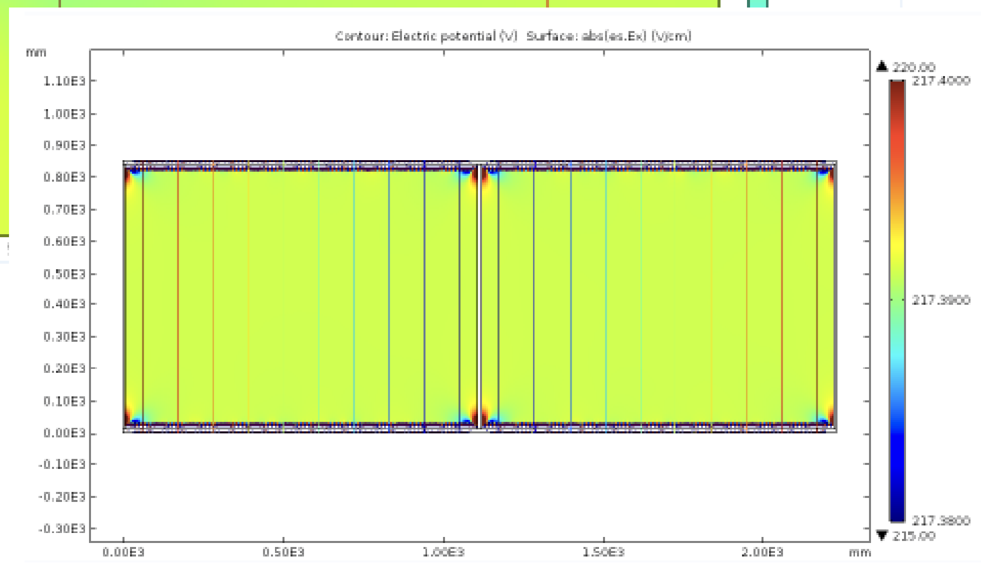
The simulation is made using different logical volumes (one per layer). Each volume has a precise thickness, and material.

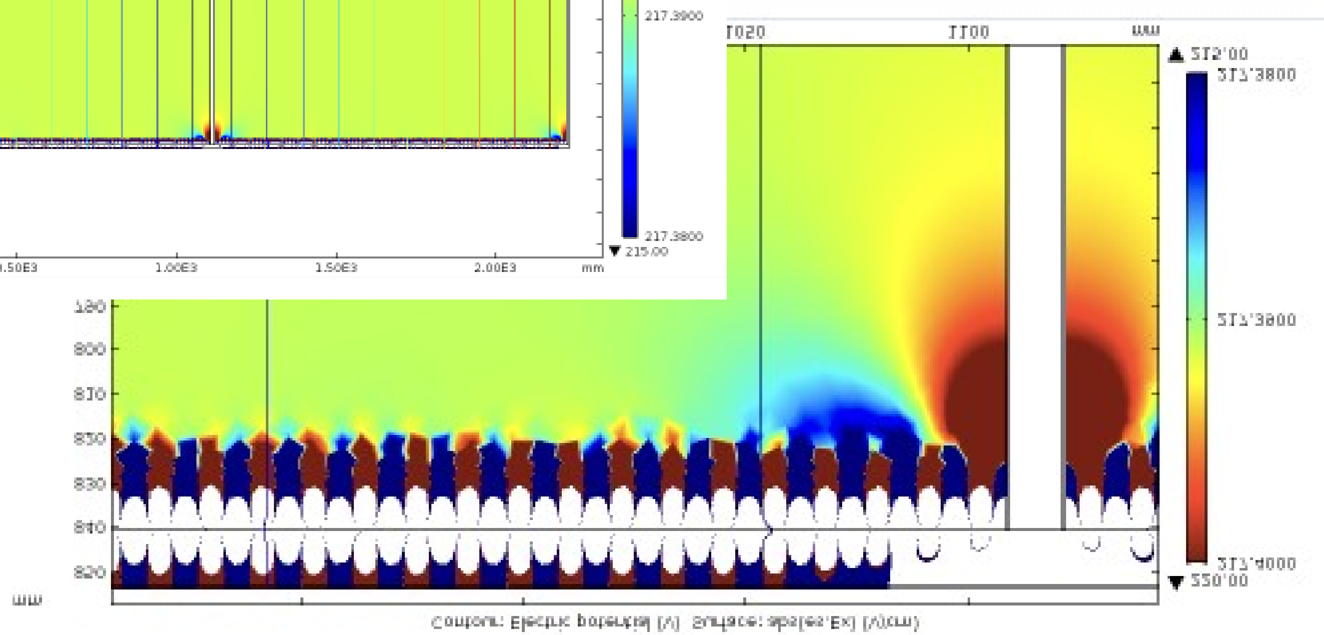
To simulate particles I used Particle Gun (Either Muon or Electron).
Energy for the Particle Gun in the range of 0.2 - 2.0 GeV in steps of 0.2 GeV.
The angle of the Particle Gun has been tuned in from 0° to 75° in steps of 15°. (0° is ⊥).

1 - TPC design concepts – Simulation work

Thanks to simulation work by Lorenzo (COMSOL)

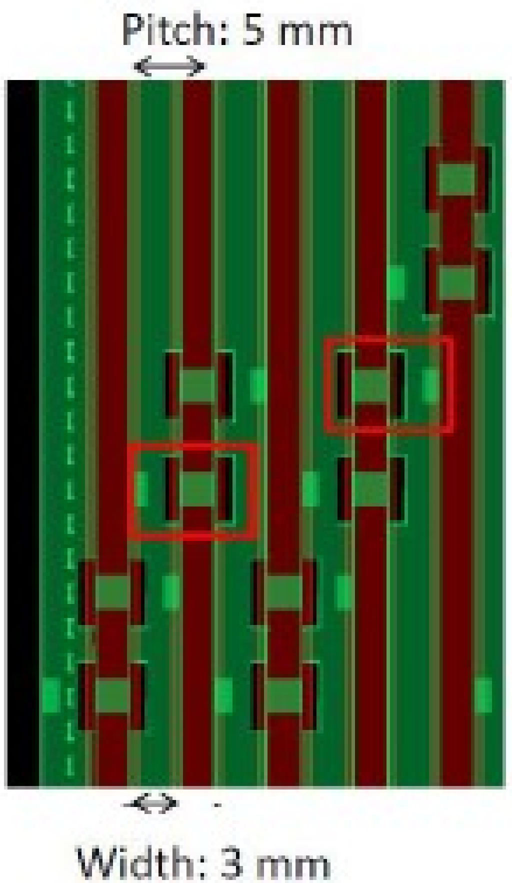






- strip geometry defined (see next slide)
- E field details @Anode, @Cathode and @ corners -> under study

1 - TPC design concepts – Strip design



- double sided
- mirror strips
- all resistors on inner side
- cut marks all 5 cm on inner side
- cross marks for alignment on mirror strip
- foil dimensions currently: ~55x220 cm

ILC TPC Design

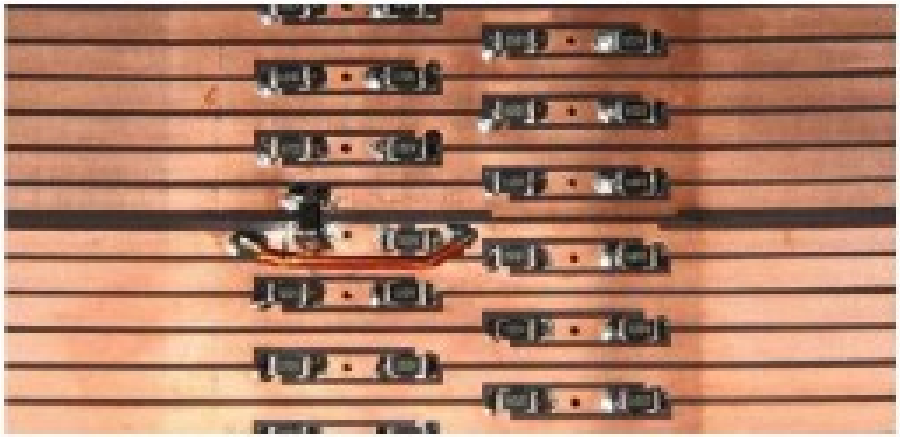
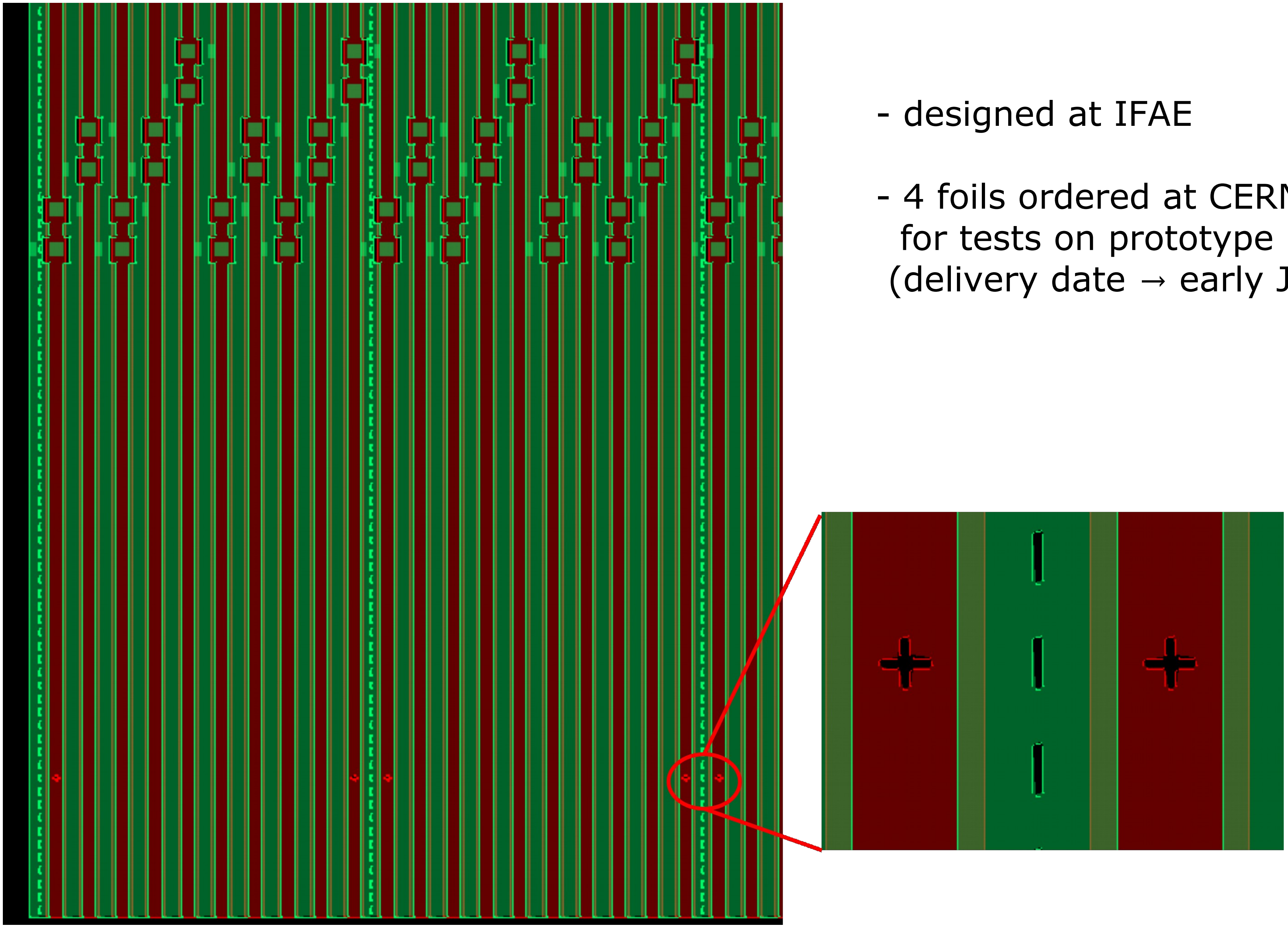


Figure 5.13: *Resistor chain in the field cage at the central connection between the half boards*

1 - TPC design concepts – Strip design



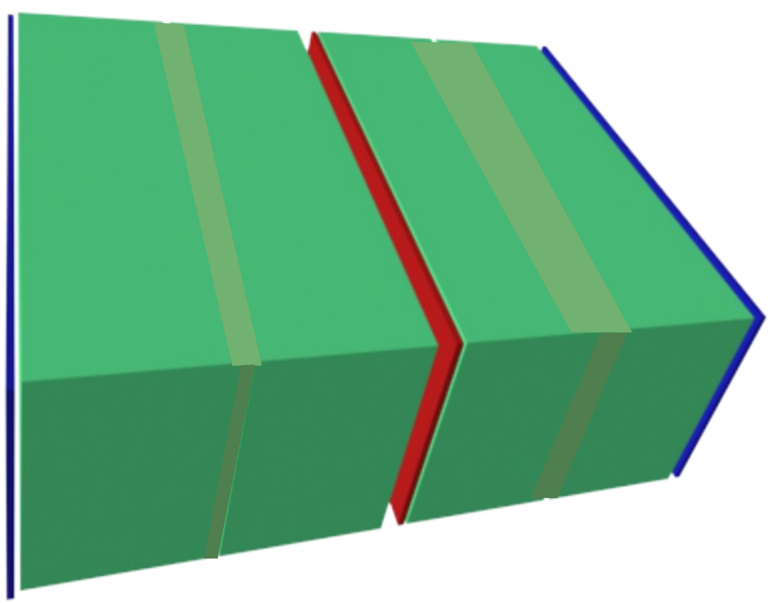
- designed at IFAE

- 4 foils ordered at CERN
  for tests on prototype
  (delivery date → early June)

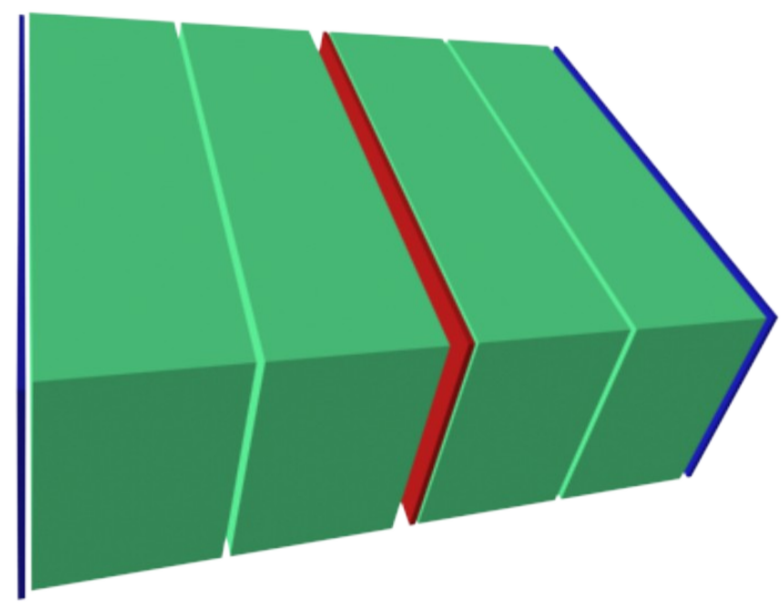
1 - TPC design concepts – Overview

Rectangular TPC assembled either in 2 or 4 boxes:

- 2 boxes (100cm in height) solution apparently simpler than 4 (50 cm) but…
  → composite material process for boxes 50cm in height might be simpler
  → cost estimations will play a role in choice of the final concept design



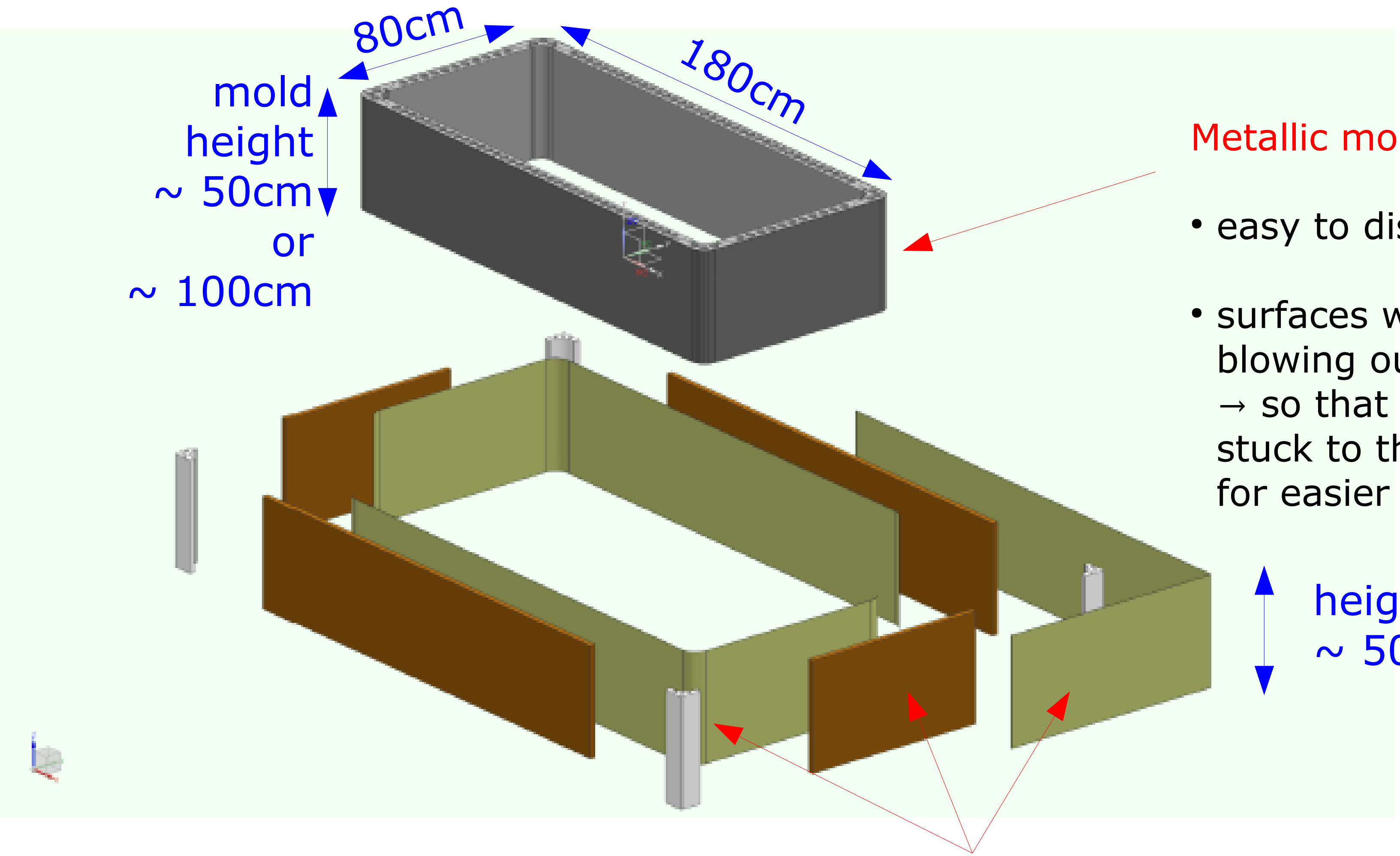
either 2 boxes
each 180 x 85 x **100** cm^3



or 4 boxes
each 180 x 85 x **50** cm^3

→ prototype useful for **testing box composite material building procedure**

1 - … details about how to build a box

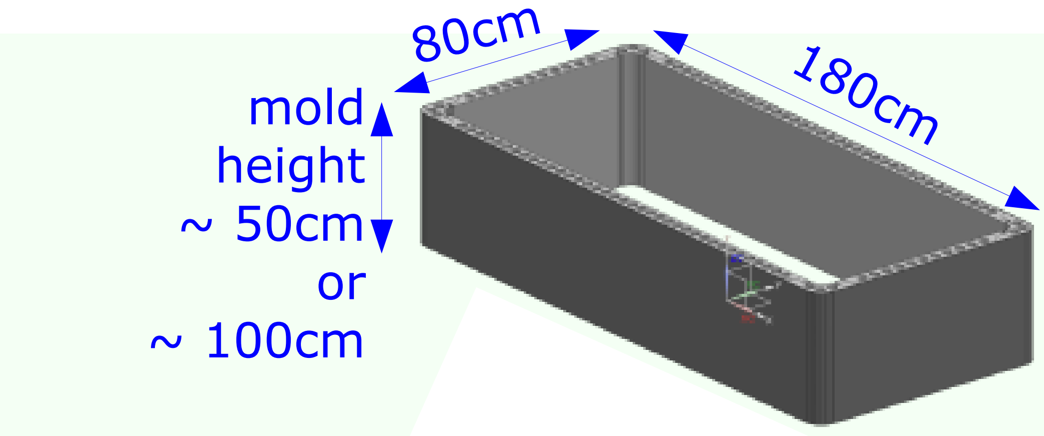


- easy to disassemble
- surfaces with holes for blowing out air → so that first layer can be stuck to the mold (w/o glue) for easier alignment

Various layers to be wrapped around the mold one by one

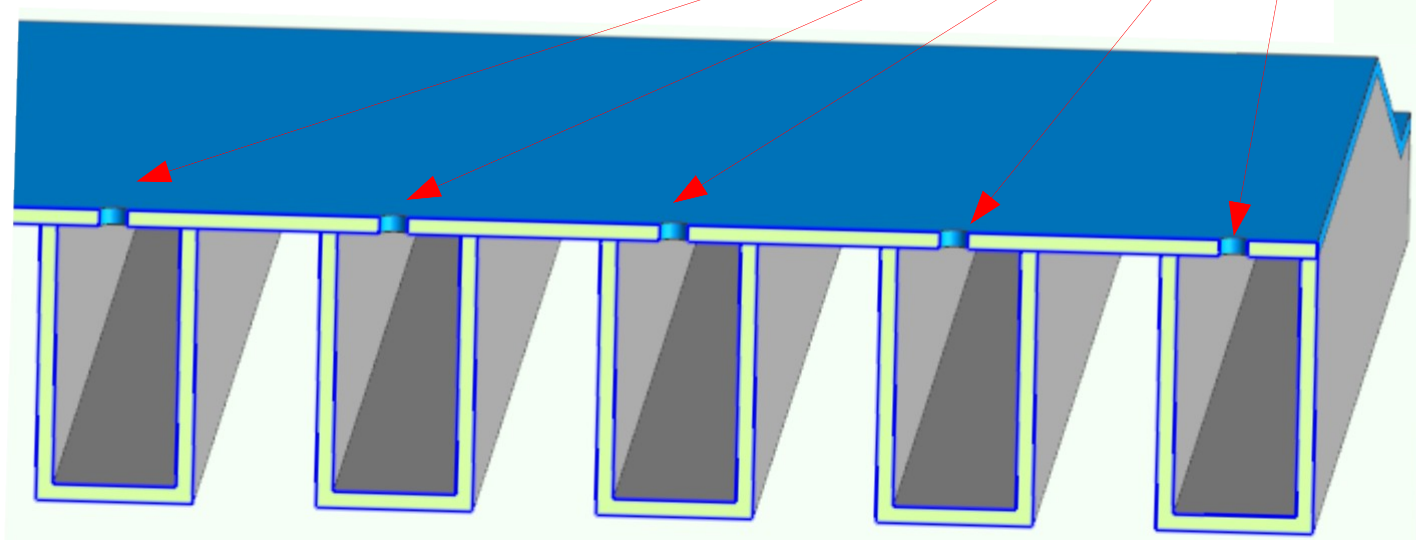
- the following layers should be continuos
  - foils w/ strips → minimizing strip junctions
  - kapton foils → better insulation but ok w/ joints
  - structural peels (carbon-fiber or kevlar) → mechanical properties
- discontinuos layers
  - panels (HC)
  - corners (PEEK) + bars at edges (PEEK)

1 - … details about the mandrel/mold



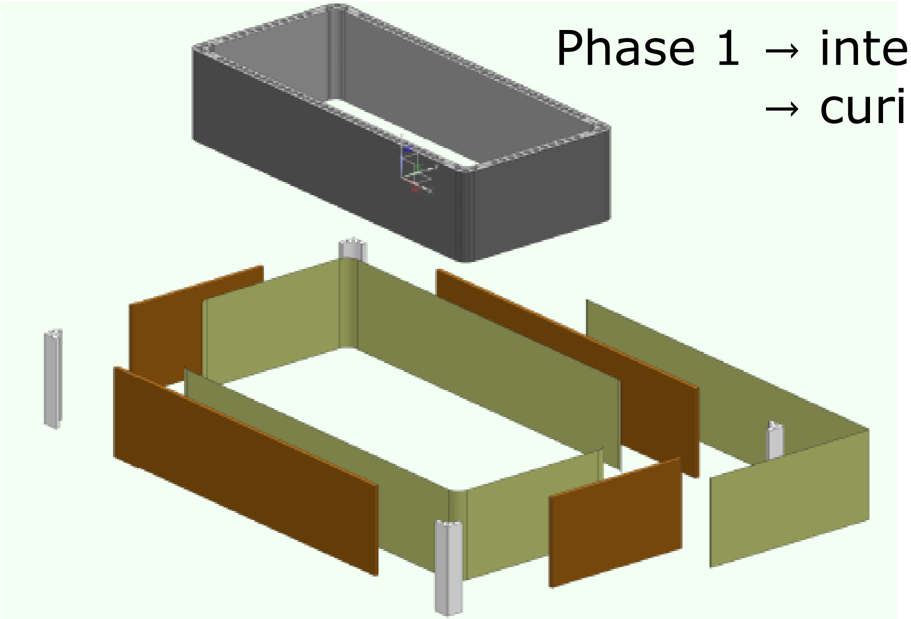
Metallic mold (core)

- easy to disassemble
- surfaces with holes for blowing out air → so that first layer can be stuck to the mold (w/o glue) for easier alignment

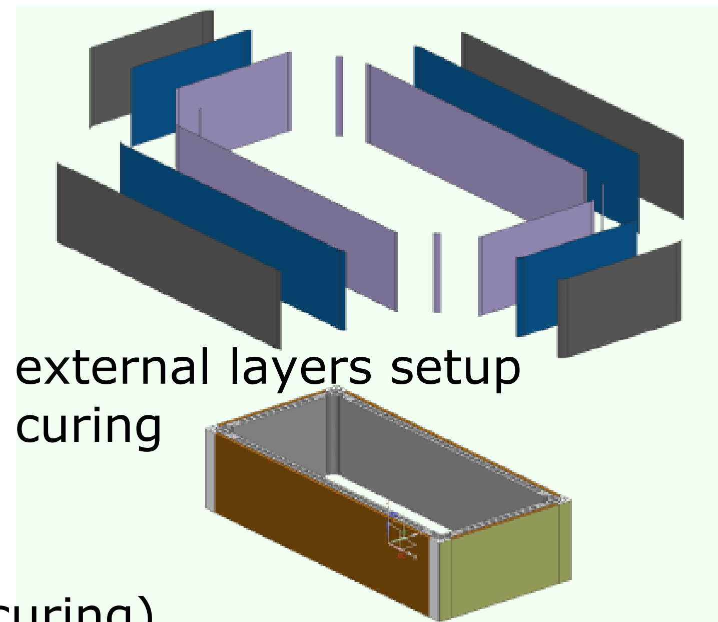


Mandrel concept and design → M.Romanato and G.Cogo (INFN-PD)
(technical design – work in progress → end by mid May)

1 - … details about how to build a box



Phase 1 → internal layers setup
→ curing (autoclave)



Phase 2 → external layers setup
→ curing

Note: about alignment and positioning of layers
(before curing)

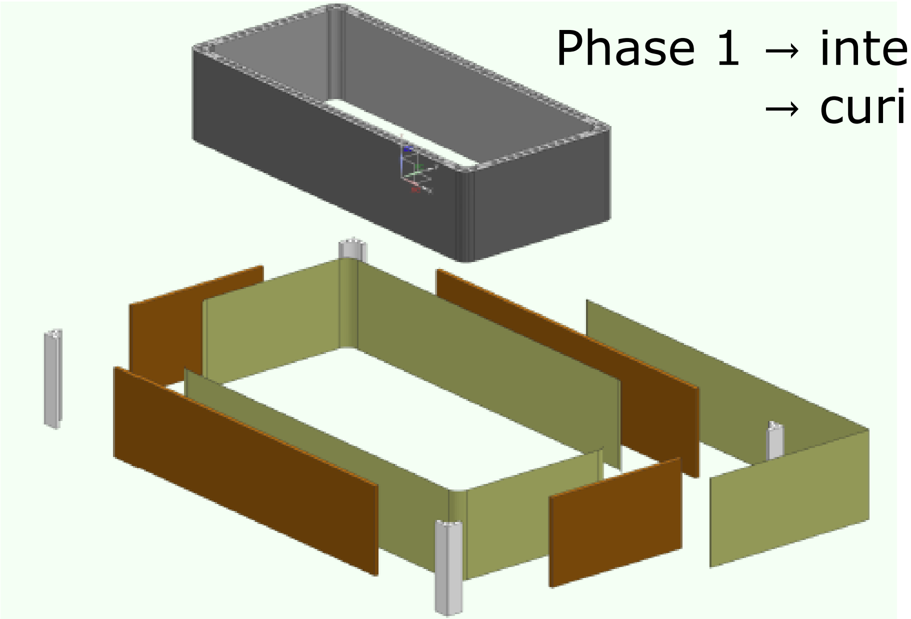
1) use of holes for blowing air trough mold walls
→ positioning of first (internal) layer (strips)

2) use of 3M AF163 type adhesive film
→ layers where no glue is possible/needed

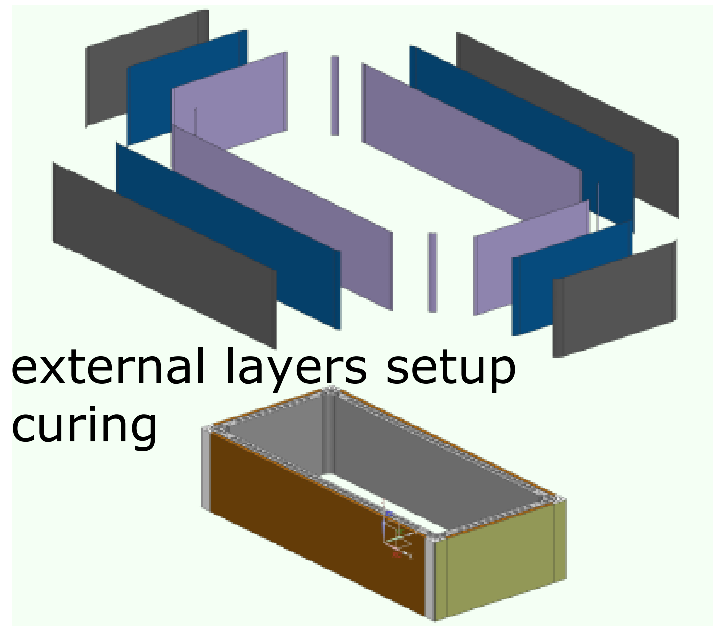
3) use of prepreg Carbon Fiber or Aramid (Kevlar) layers

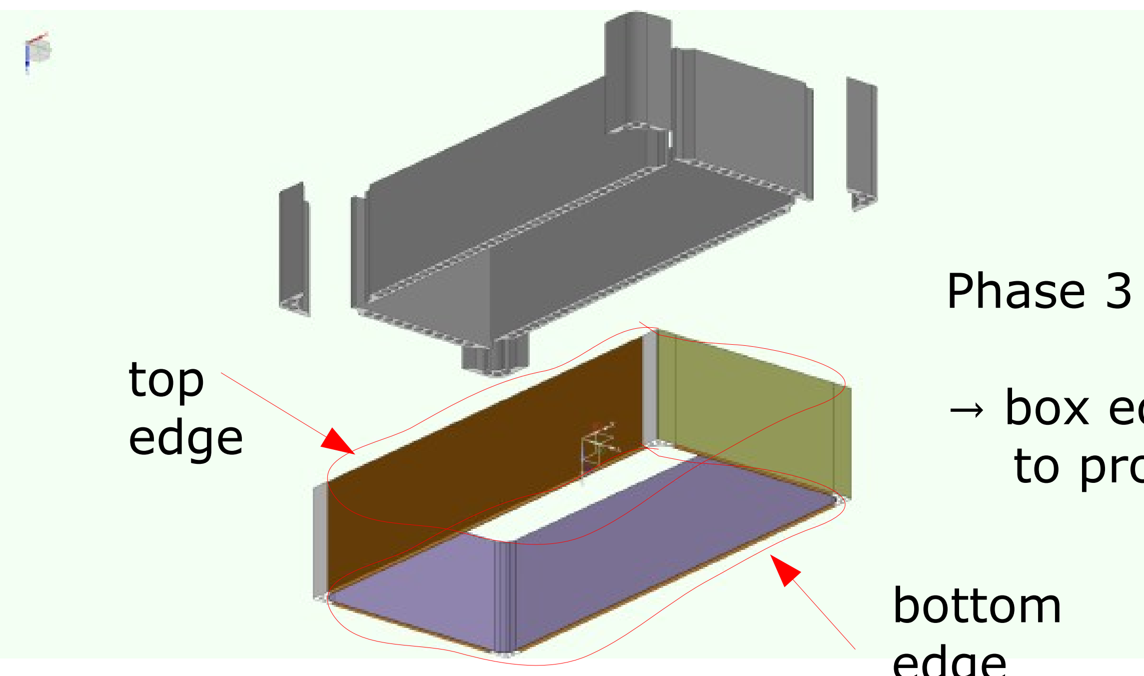
1 - … details about how to build a box

Phase 1 → internal layers setup
→ curing (autoclave)



Phase 2 → external layers setup
→ curing



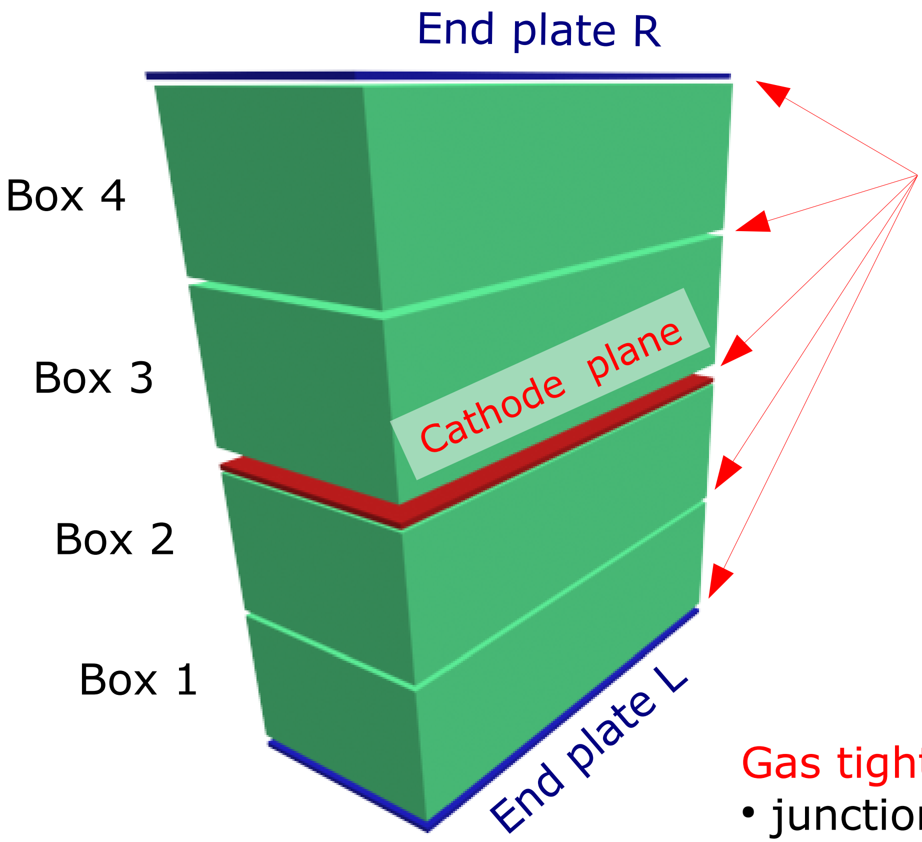


Phase 3 (Mold dismantled)

→ box edges must be "terminated " by bars to provide:

- precision machining
- sealing
- mechanincal

1 - TPC design concepts – mechanical stiffness, gas tightness, electrical insulation



5 junctions at box edges...

Mechanical point of view

- junctions B1-B2 and B3-B4
- Mechanical stiffness given by proper joints on the **corner structures** (made by keramic material – Peek)

→ not critical

Gas tightness point of view

- junctions B1-B2, B2-CP-B3 and B3-B4 externally sealed by **gluing a kapton band** wrapped all around

→ must be tested (but not expected to be critical)

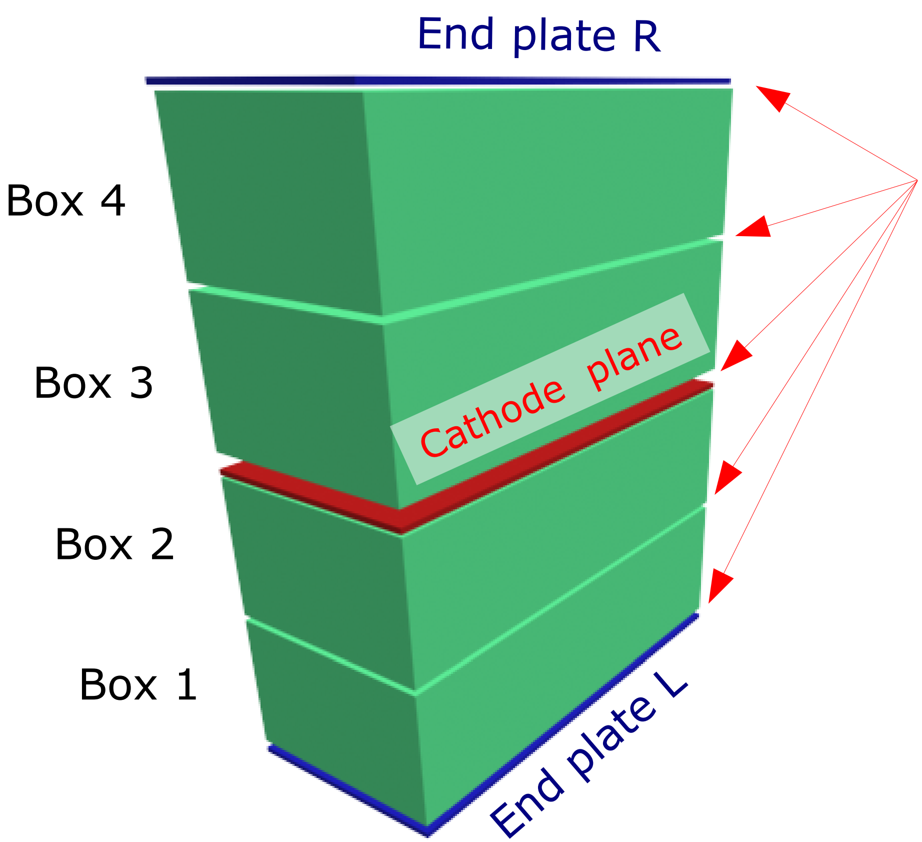
(C) Electrical point of view

- **box edges should be "sealed" by dielectric material** against dangerous current paths to conductive layers (in case of Carbon Fiber option)

Note: presence of internal Carbon Fiber layer might be critical (should think to set its potential at which level)

1 - TPC design concepts –

- mechanical stiffness
- gas tightness
- electrical insulation



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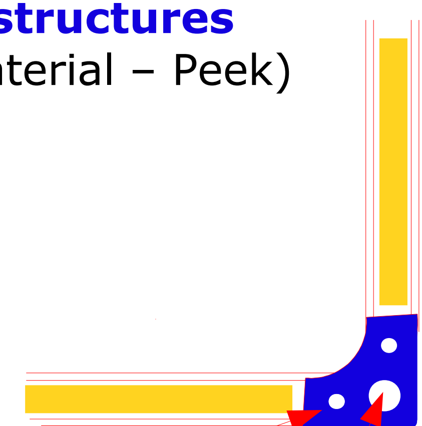
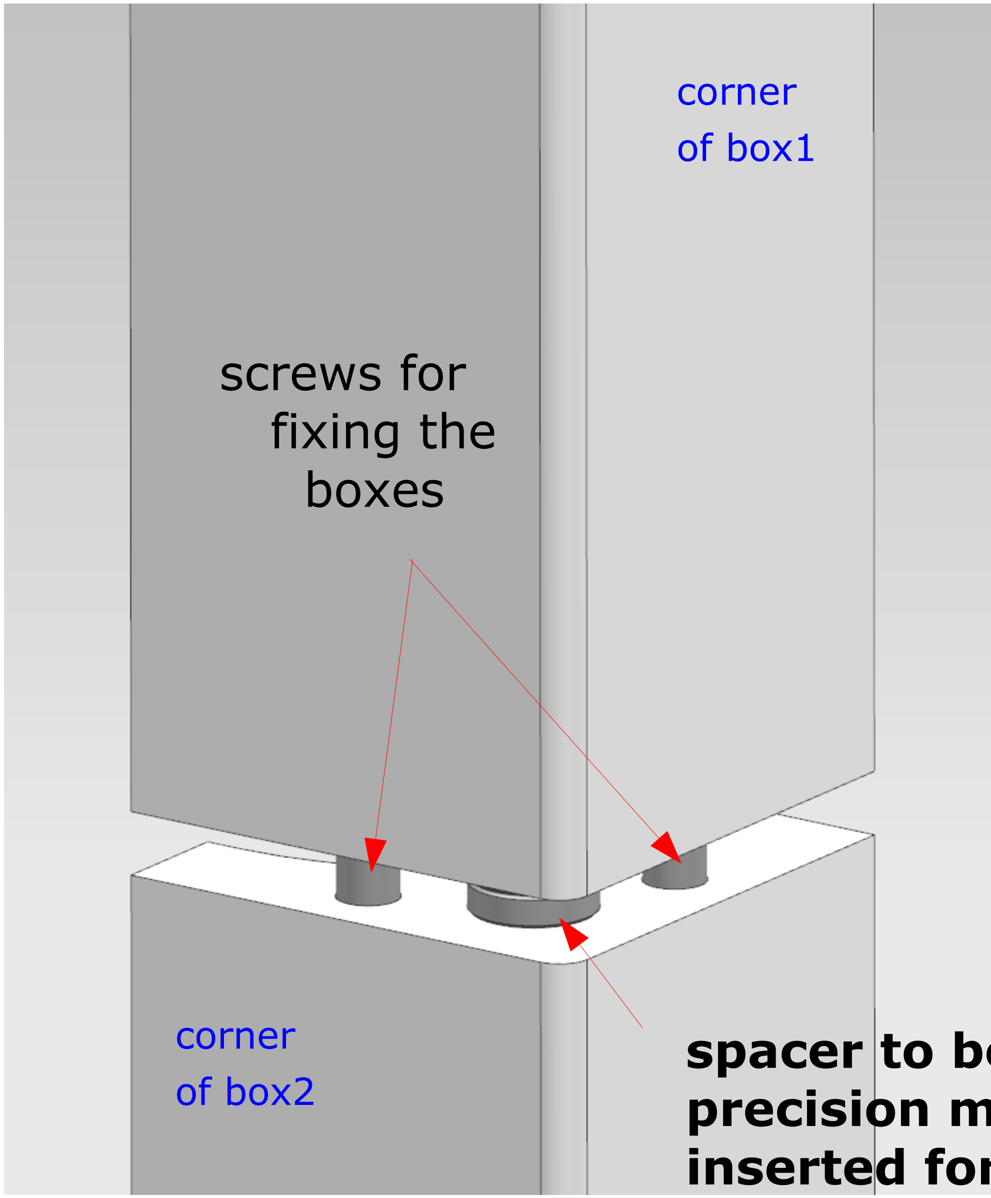


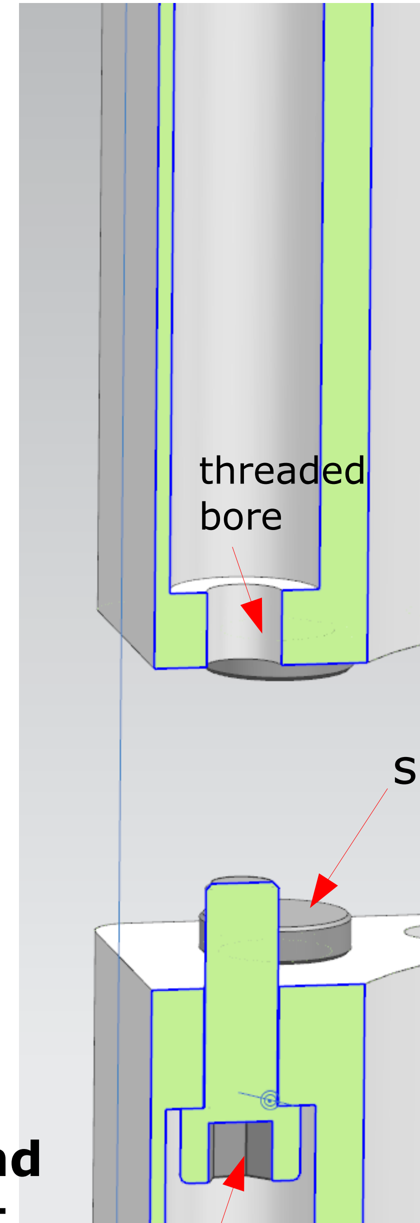
bores for
joining boxes

Note: inserts here for alignment
Indeed due to solution below the edges will not be machinable → we should rely only on corner structures for aligment

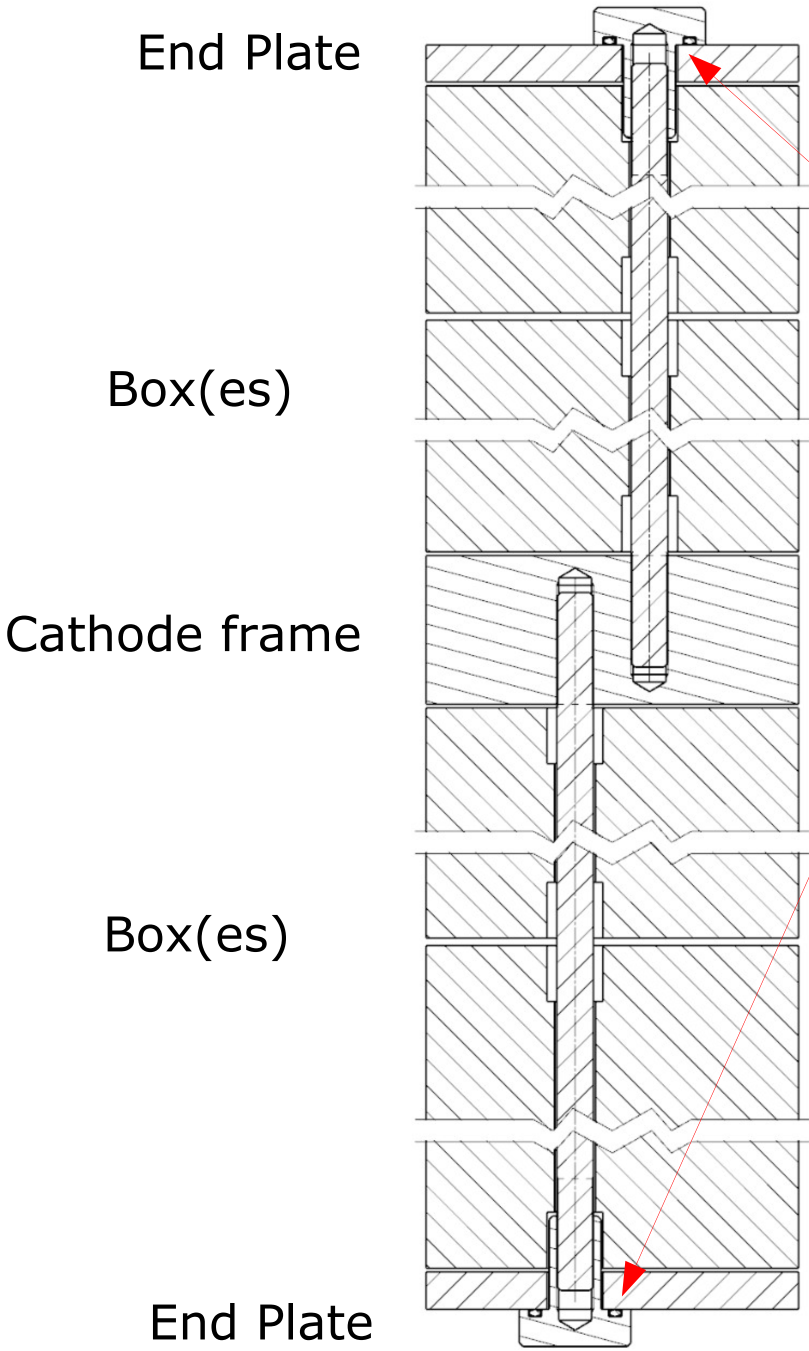
Note: corner structure to be easility machined → Peek

Joining 2 boxes – by the angular structures





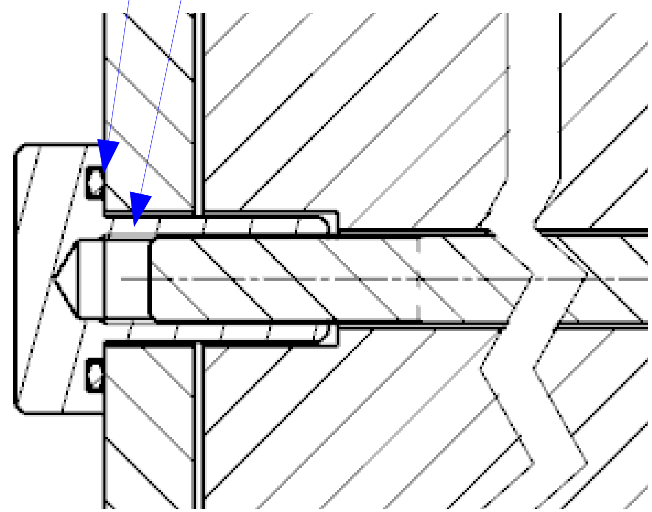
Joining 2 boxes – by the angular structures



Mechanical junction by (1m) **long** (insulating) **rods** at each corner would allow mechanical stiffness

Note:

- gas sealing → o-ring
  - bore on EP to allow thermal expansion (Alu vs Peek)



Note, BTW: no relevant problem in joining End-Plate Al frame to Field-Cage edge/corner Peek parts

MODULE FRAME (ALUMINIUM) / TPC BOX FLANGE (PEEK) - Thermal loads

Δtmax = 5ºC

ΔTmin = -5ºC

DEFORMATION DUE TO THERMAL LOAD

		Module Frame	Frame	Assembly	Screw	Difference	
Material		Al7075-T6	PEEK	-	SS	-	
Coefficient thermal expansion	CTE [1/K]	2,14E-05	4,68E-05	-	1,80E-05	-	
Length	L [mm]	15	15	30	30	-	
Deformation due to ΔTmax	xmax [mm]	-0,0016	-0,0035	-0,0051	-0,0027	0,0024	INCREASE
Deformation due to ΔTmin	xmin [mm]	0,0016	0,0035	0,0051	0,0027	-0,0024	DECREASE

LOAD DUE TO THERMAL LOAD

Screw Young's Modulus	E [Mpa]	200000
Screw Equivalent section	As [mm2]	14,18
Screw Length	L [mm]	30
Screw Rigidity	k [N/mm]	94552
Deformation due to ΔTmax	xmax [mm]	0,0024
Deformation due to ΔTmin	xmin [mm]	-0,0024
Force in the screw due to ΔTmax	Pdtmax [N]	228
Force in the screw due to ΔTmin	Pdtmin [N]	-228

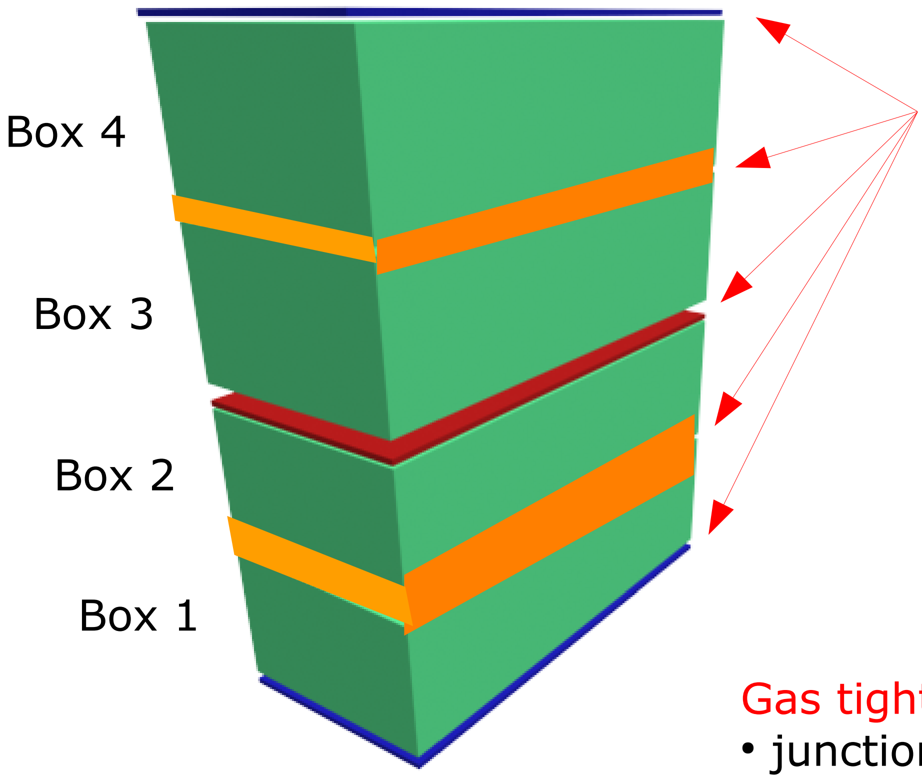
Preload on M5 = 5000 N

→ Increase of 4% preload (OK)

→ Loss of 4% preload (OK)

Calculations by Juli; OK also by Adriano

1 - TPC design concepts – mechanical stiffness / gas tightness / electrical insulation

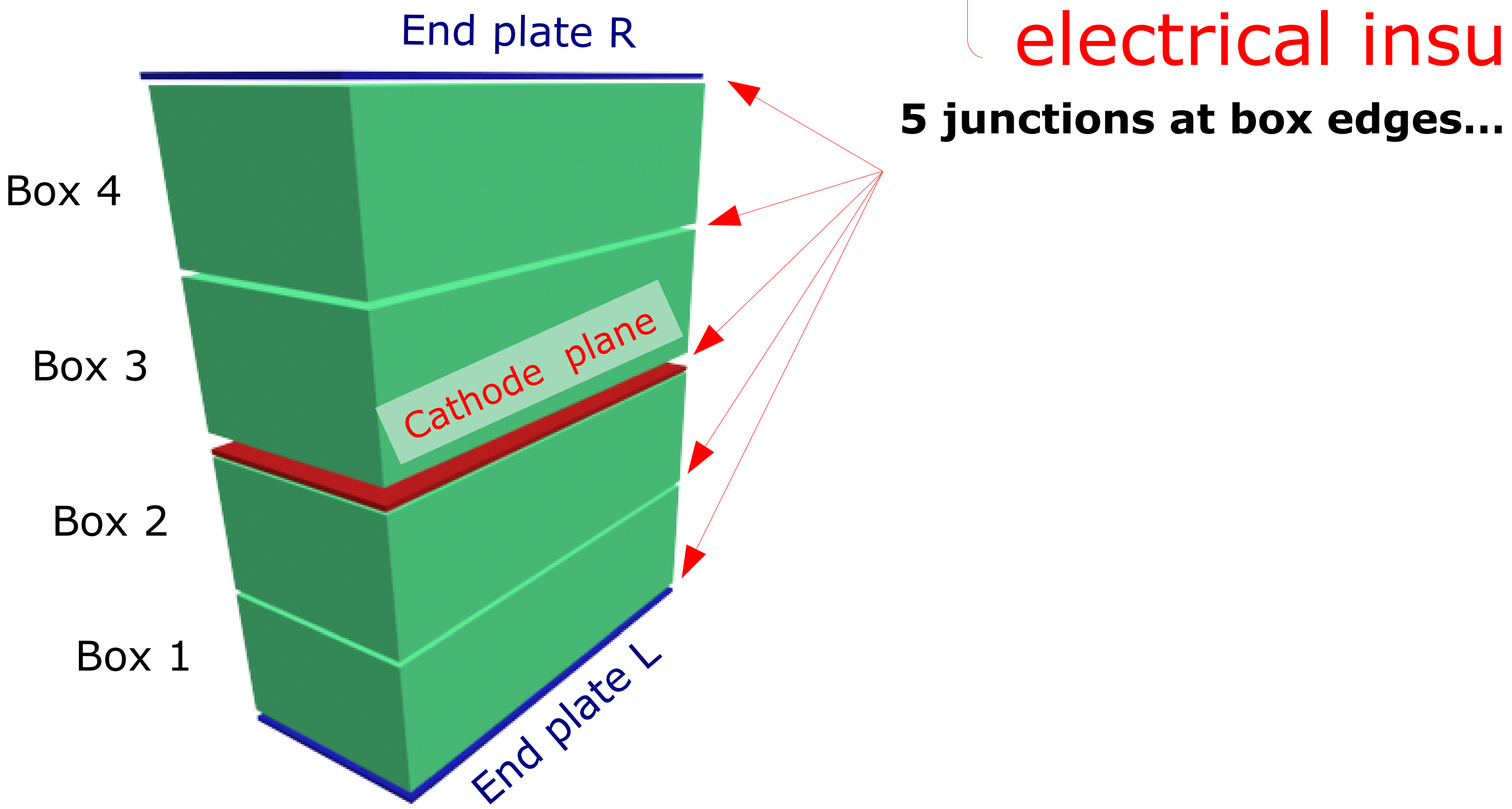


5 junctions at box edges…

Gas tightness point of view

- junctions B1-B2, B2-CP-B3 and B3-B4 externally sealed by **gluing a kapton band** wrapped all around
  → must be tested (but not expected to be critical)

1 - TPC design concepts – mechanical stiffness / gas tightness / electrical insulation



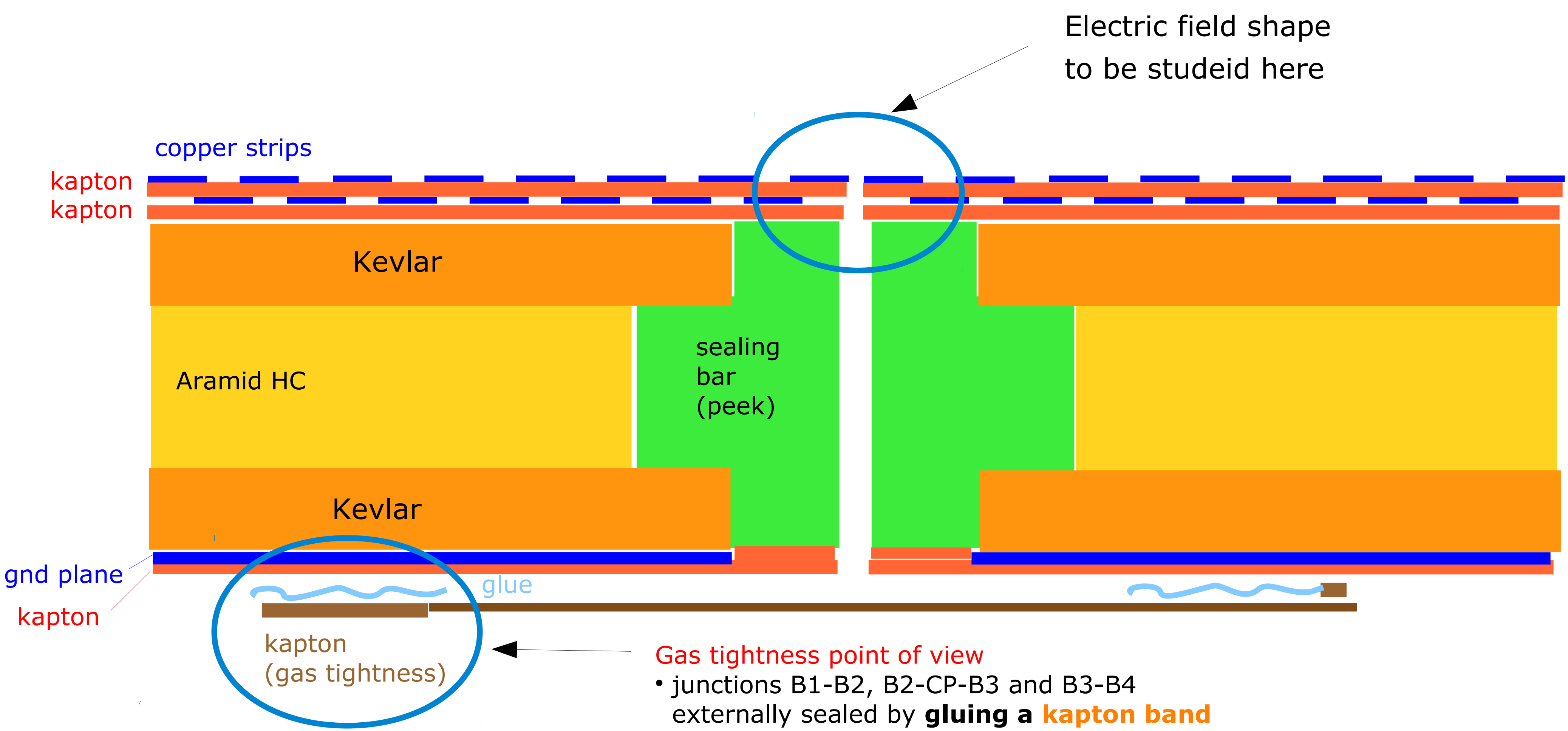
(C) Electrical point of view

- **box edges should be "sealed" by dielectric material**
  against dangerous current paths to conductive layers

  Note: presence of internal Carbon Fiber layer might be critical
  (should think to set its potential at which level)

Dielectric and gas "sealing" at Box edges

Option 1 → **full aramide** wall structure



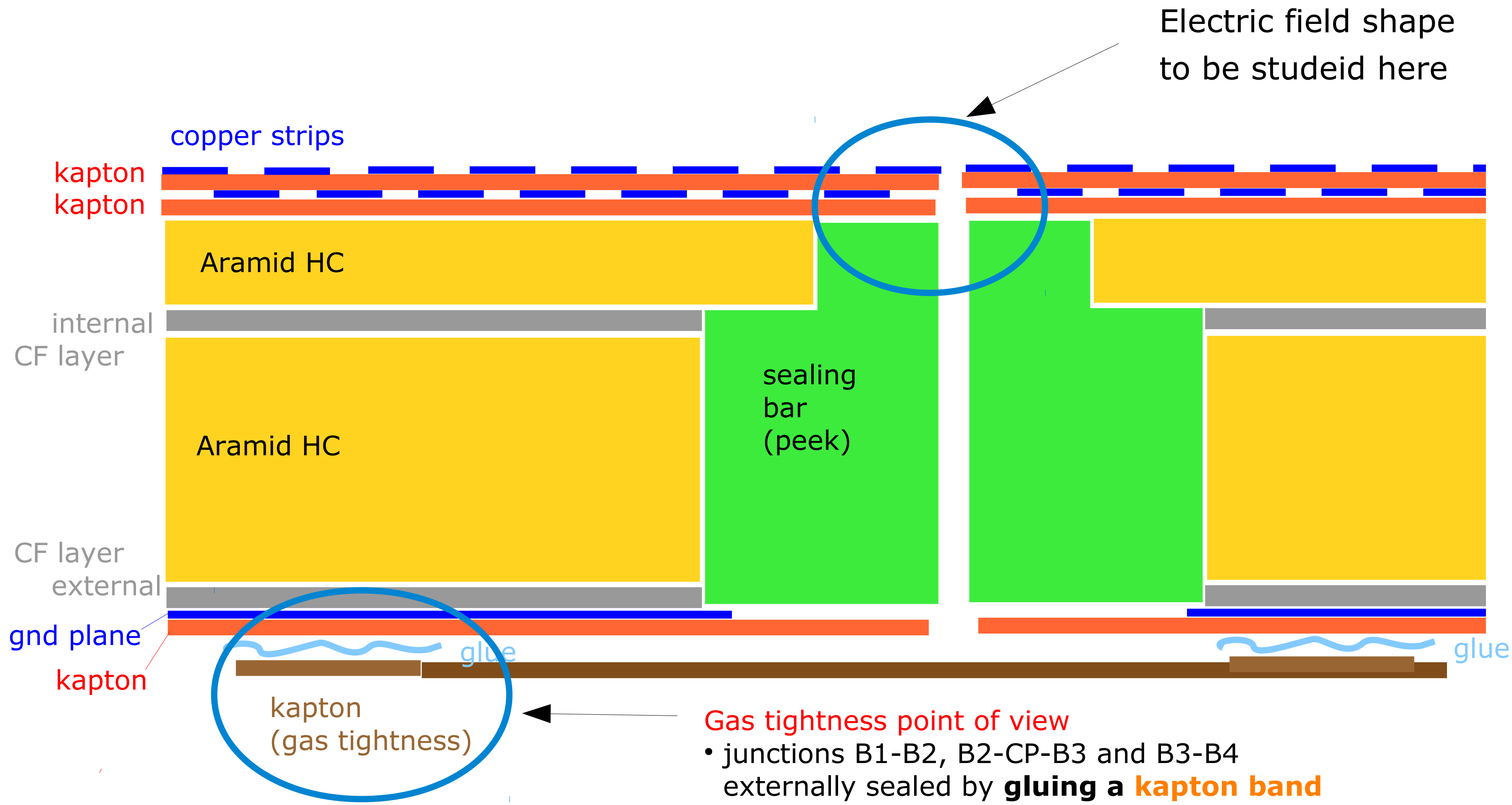
Gas tightness point of view

- junctions B1-B2, B2-CP-B3 and B3-B4 externally sealed by **gluing a kapton band** wrapped all around not expected to be critical

→ **will be proved with mockup structure**

Dielectric and gas "sealing" at Box edges

Option 2 → **carbon fiber** based wall structure



Gas tightness point of view

- junctions B1-B2, B2-CP-B3 and B3-B4 externally sealed by **gluing a kapton band** wrapped all around not expected to be critical

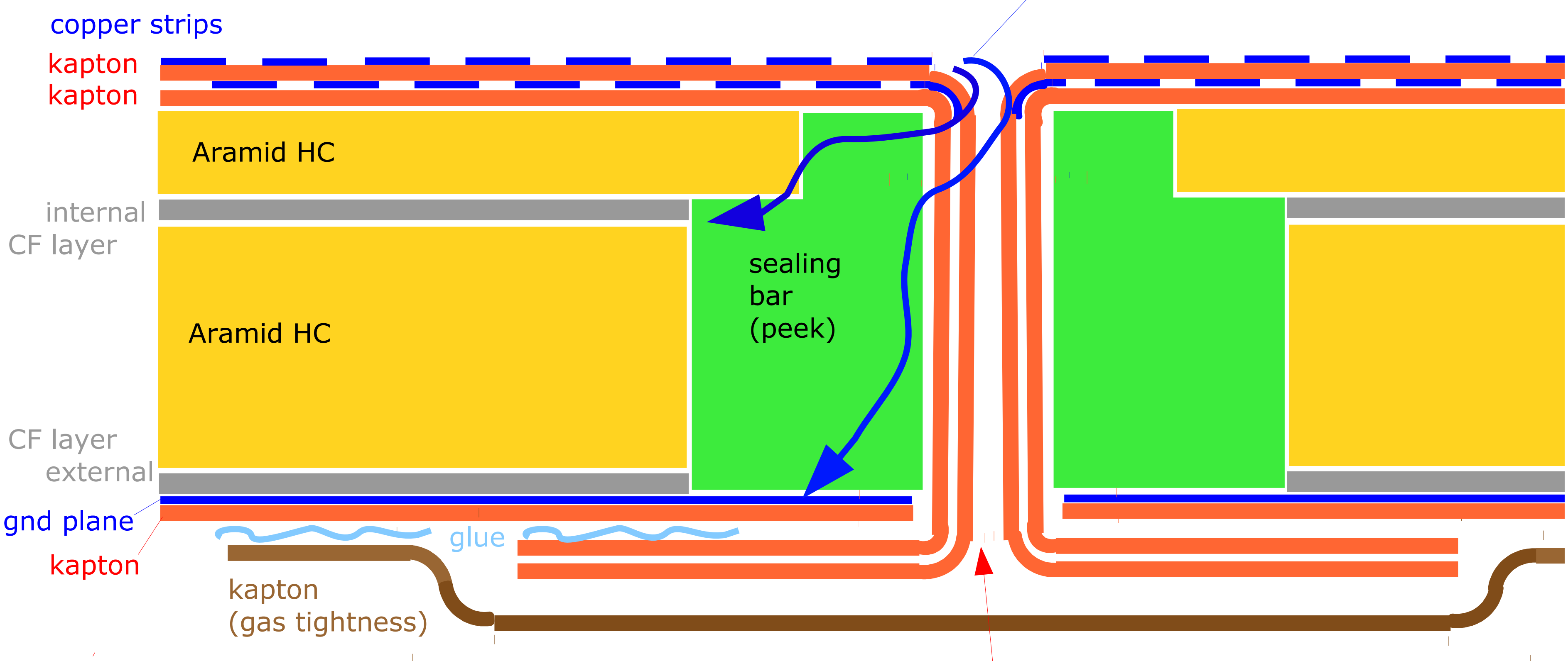
Dielectric and gas sealing at box edges – CF problems

Carbon fiber seems to add more complications
due enhanced probability of breakdown

Electrical point of view

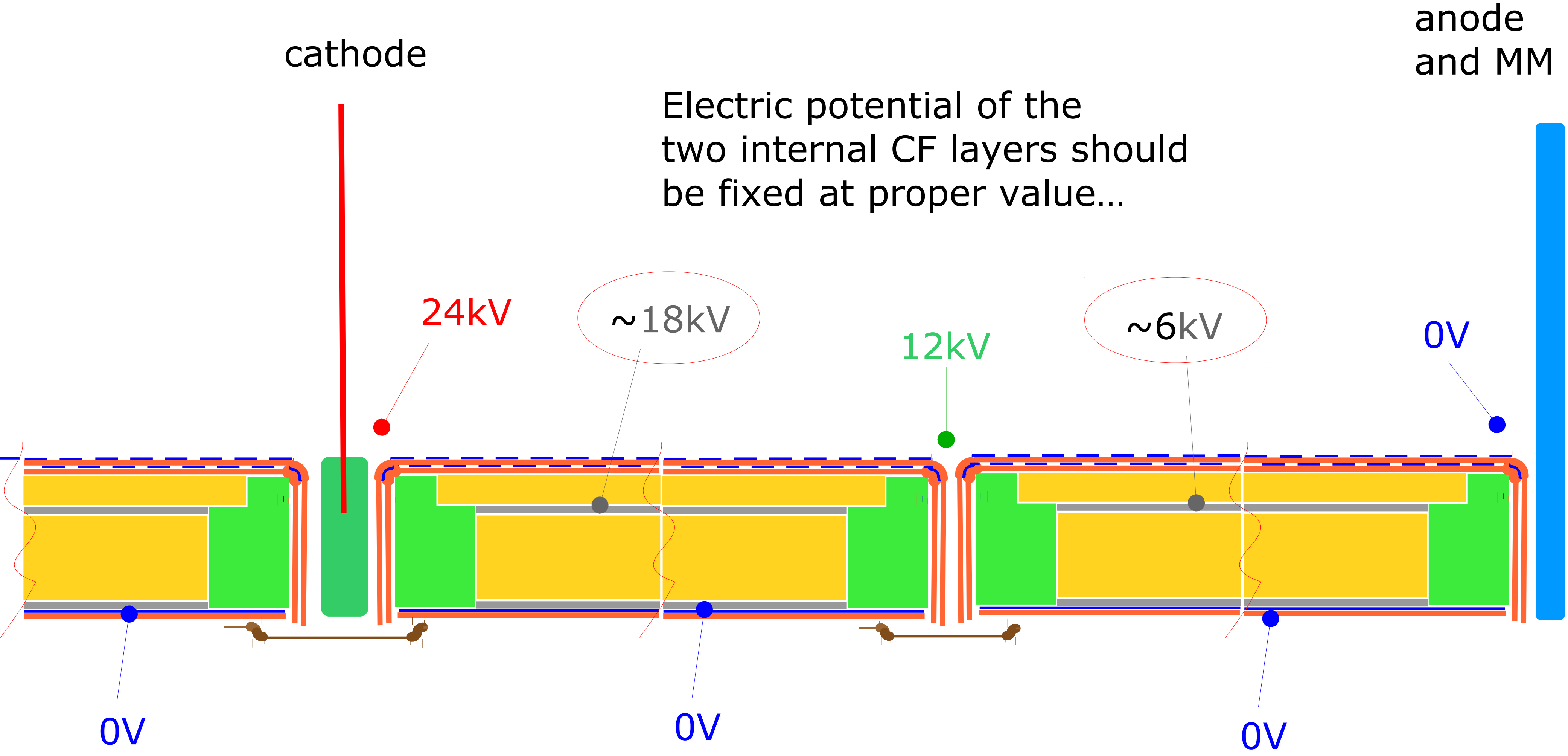
will be tested with sample structure ←

- box edges should be “sealed” by dielectric material against dangerous **current paths** to conductive layers



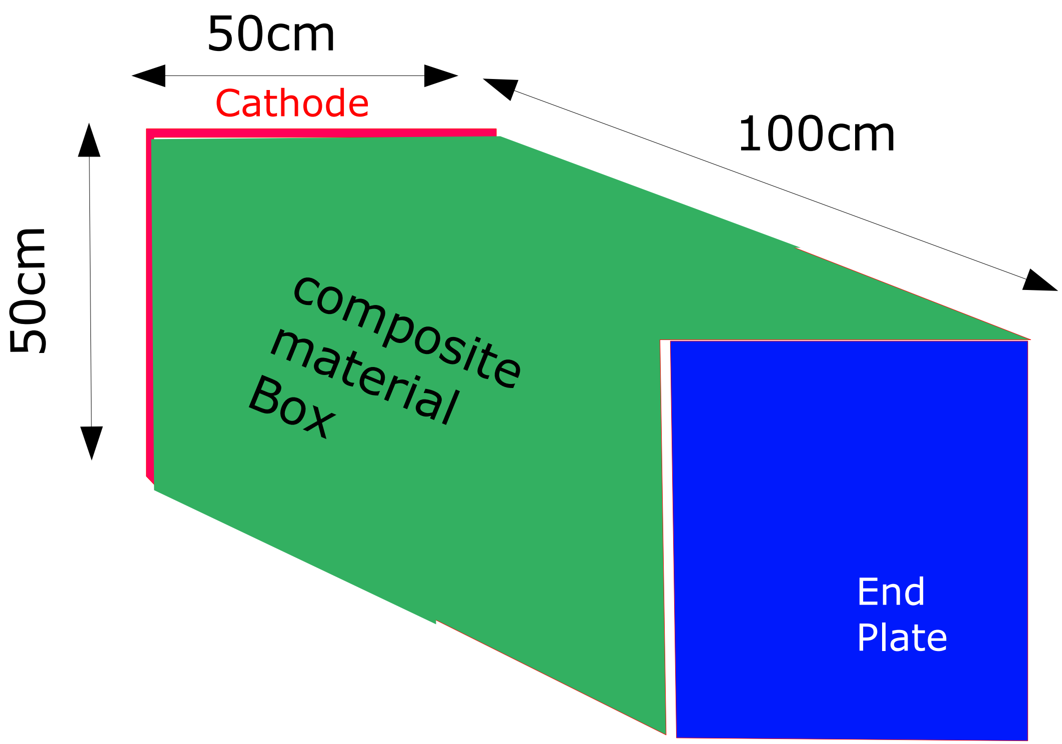
This wall structure might require additional insulation
(by Kapton later folded outward)

Dielectric and gas sealing at box edges – CF potential



Note: presence of internal Carbon Fiber layer might be critical
(should think to set its potential at which level)

2. Prototype and tests



TPC concept design tests by buiding the prototype

1. building the box
→ 100cm in height (baseline)

2. mechanical properties of walls
→ deformation
→ planarity of internal wall plane
→ bubbles affecting internal wall side
→ building box edges

3. electrical breakdown at edges
→ edge termination structure

4. gas tightness solution (O_2)
→ gas sealing by kapton band gluing
(in vacuum w/ mass spectrometer)

Composite samples to be produced at 2 facilities:

1. NEXUS company (Barcelona)
2. CERN composite matrerial lab

2. Prototype Tentative Time schedule

Test structures

- test structures at CERN: by end of May
  - → mechanical and electrical tests (Padova) by end of June
  - → gas sealing and outgassing test (Padova) be end of June

- test structures by NEXUS: by mid May

Prototype:

- mandrel design (INFN Padova): by mid May
- mandrel building (INFN Bari): by mid July
- mandrel at NEXUES (Barcellona): by end July

- building of the boxes: still to be agreed with NEXUS

… dead line for prototype assembly at CERN → late October ?

Conclusions

- Design of the new thin TPCs by exploiting composite material techniques
- Two main options for composite structure under evaluation:
  Carbon Fiber vs Full Aramid
- Building by Boxes approach: box length (drift direction) under evaluation
- Electric field: details at the Anode, Cathode corners under study
- Mechanical and Electrical breakdown tests: samples in preparation
- Prototype not ready for August TB, but plans are still to have it ready for tests with particles at CERN in Fall 2018

Additional material

1 - TPC design concepts – Box structure

- Rectangular TPC of 200 (B field / drift dir.) x 180 (beam dir.) x 85 (height) cm^3
- Aiming at thin wall (~3cm) made of low Z composite material (few % X_0)

Carbon Fiber based layer stack

	Material	**Thickss (mm)**
	Copper coated polymide film	*~ 0.15*
	Carbon Fiber	*1.20*
	Aramide HoneyComb panel	*15.00*
	Carbon Fiber	*1.20*
	Aramide HoneyComb panel (insulation)	*10.00*
	Polymide film (insulation)	*~ 0.10*
	Strips (double later) on Kapton foil	*~ 0.15*
	TOTAL RADIATION LENGHT ~ **4,0 % X_0**	~27.5

Glass Fiber based layer stack

	Material	**Thickss (mm)**
	Copper coated polymide film	*~ 0.15*
	Glass Fiber	*0.30*
	Aramide HoneyComb panel	*20.00*
	Glass Fiber	*0.30*
	Polymide film (insulation)	*~ 0.10*
	Strips (double later) on Kapton foil	*~ 0.15*
	TOTAL RADIATION LENGHT **~ 6.5 % X_0**	*~21.5*

Note: aiming at a thin and low Z composite wall:
- peels symmetry about Honeycomb (HC) core to minimize deformations (overpressure 5mbar)

- Carbon Fiber (CF) provides best stability, simulations (*) tells: baseline structure max deform. < O(150μm)
- CF is low Z material (radiation length ~20cm)
- CF has low resistivity → additional electric insulaiton required

(*) mechanics simulation by J.Mundet

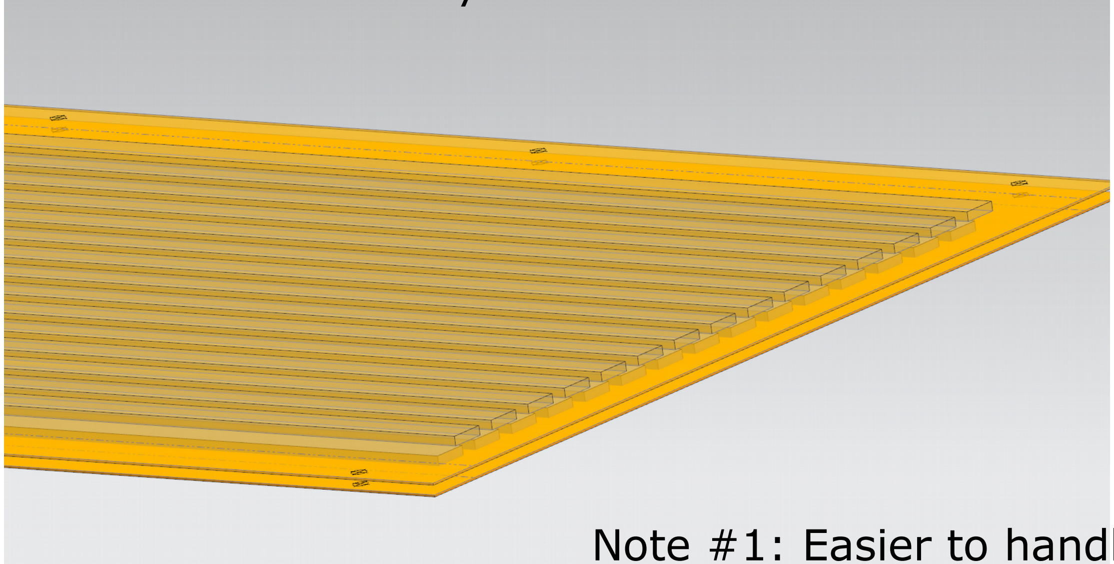
- Fiber Glass (GF) allows much simplied stack;
- GF has lower rad. length (~ 13cm)
- GF provides worser stability: simulation tells deformation < O(400μm)

Possible procedure for

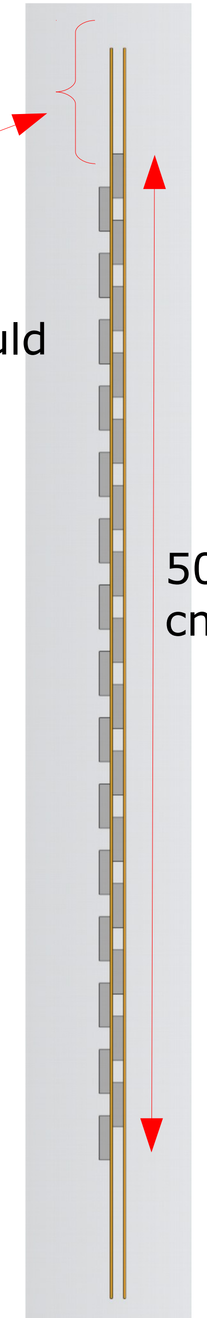
- bulding the boxes in 3 phases and
- assembling them

Phase I – preparing the inner layer on a flat table

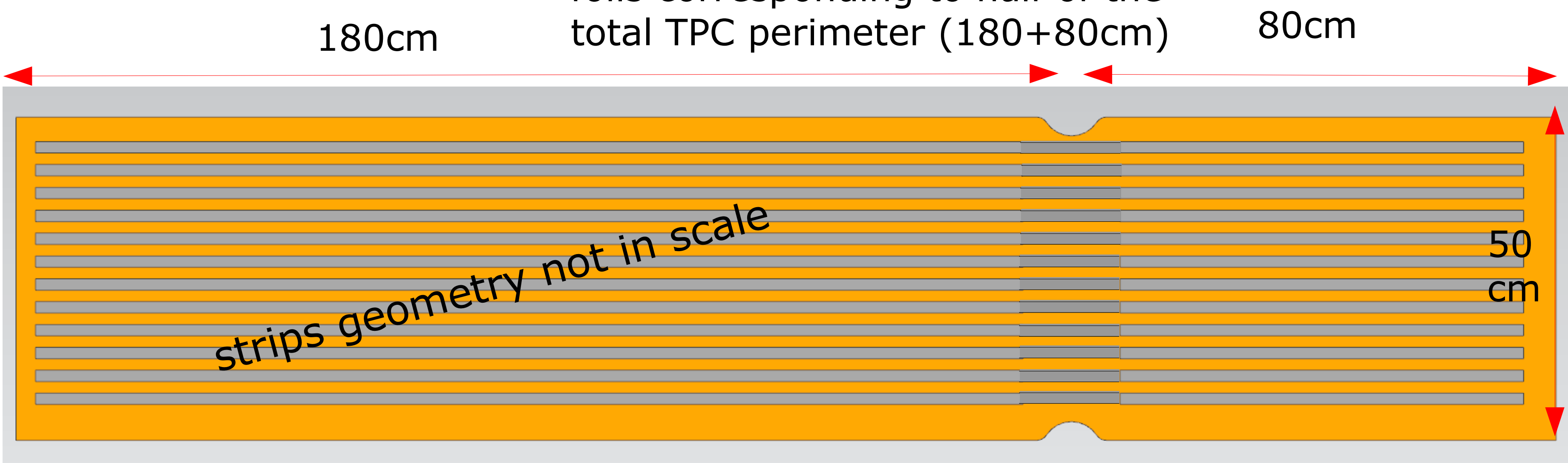
On top of a flat table the strip double layer + the kapton layer are glued together (possibly with a no flaw adhesive thin film)
→ we call it “inner layer” in what follows



Note #2: extra foil length beyond strips region for two reasons:
1) aligment (markers should be there)
2) to be folded for sealing edges of the box

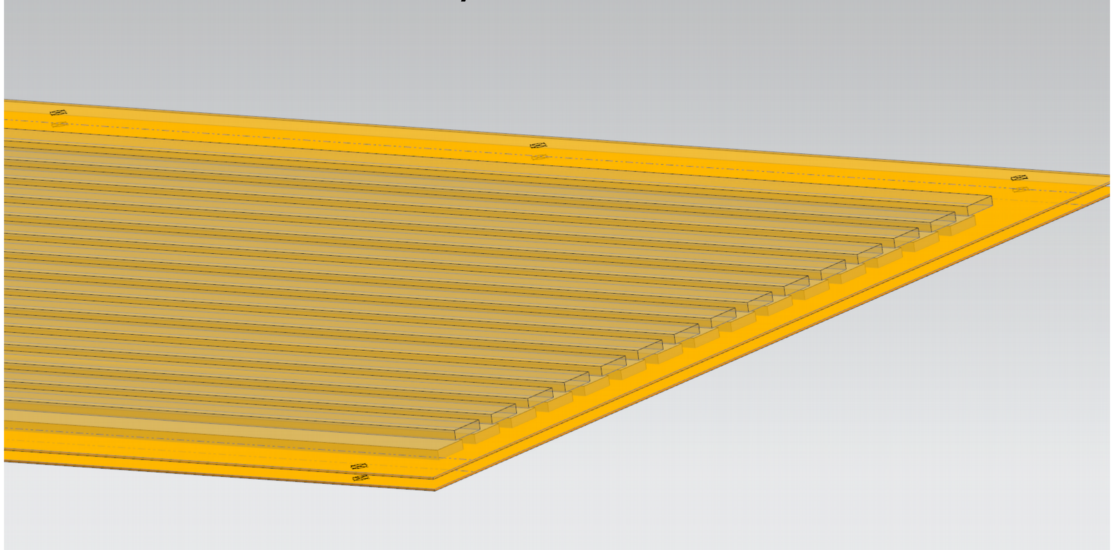


Note #1: Easier to handle two foils corresponding to half of the total TPC perimeter (180+80cm)

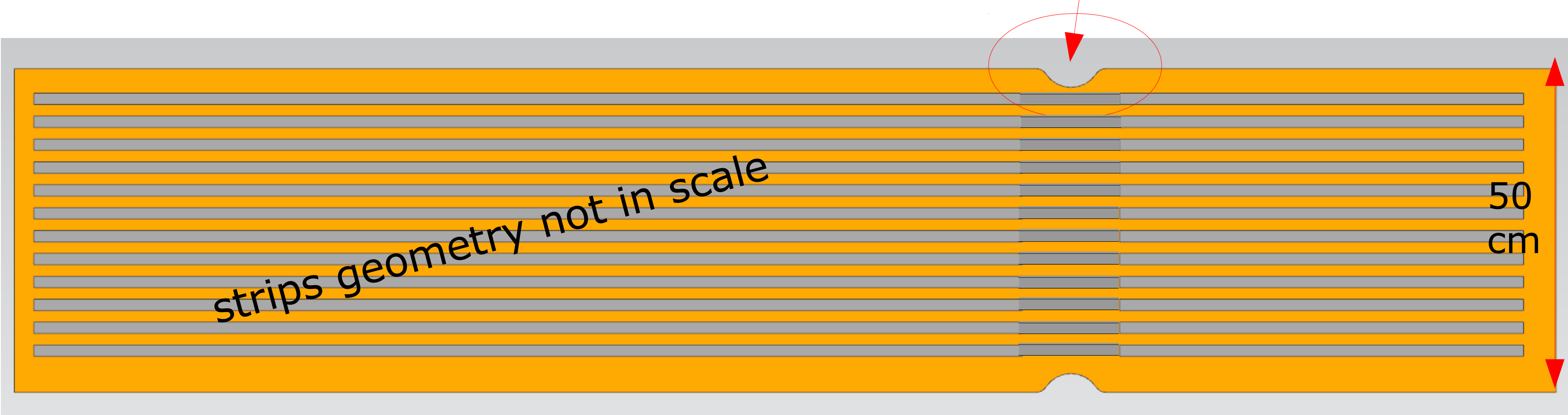


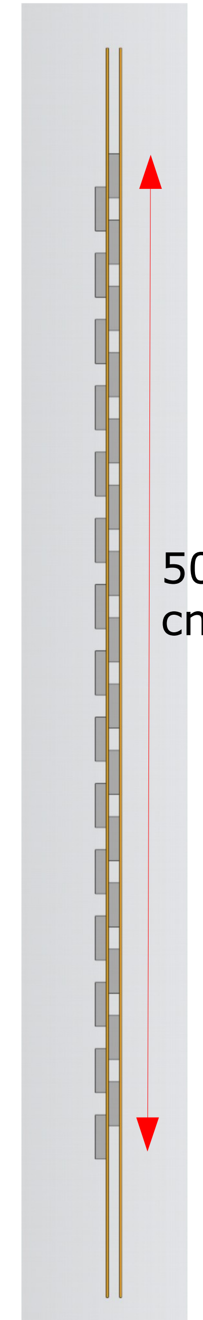
Phase I – preparing the “inner layer” on a flat table

On top of a flat table the strip double layer + the kapton layer are glued together (possibly with a no flaw adhesive thin film) → we call it “inner layer” in what follows



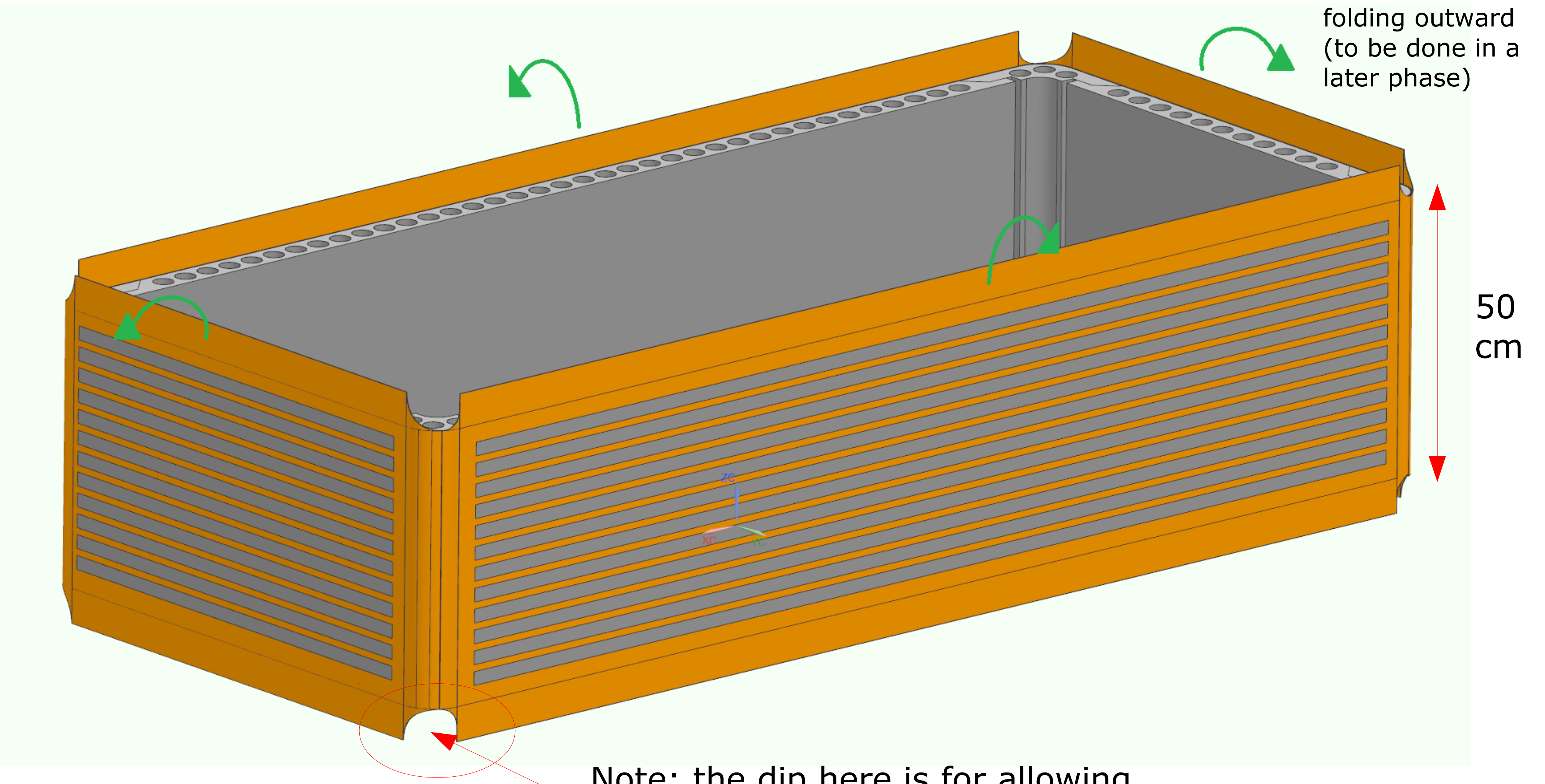
Note #3: the dip here is for allowing proper folding outward of the extra region of the foil (see 3D view next slide)





Phase II – the “inner layer” is wrapped around the mold

The Inner layer is aligned (with markers markers) on the mold
Blowing out air simplifies a lot the procedure



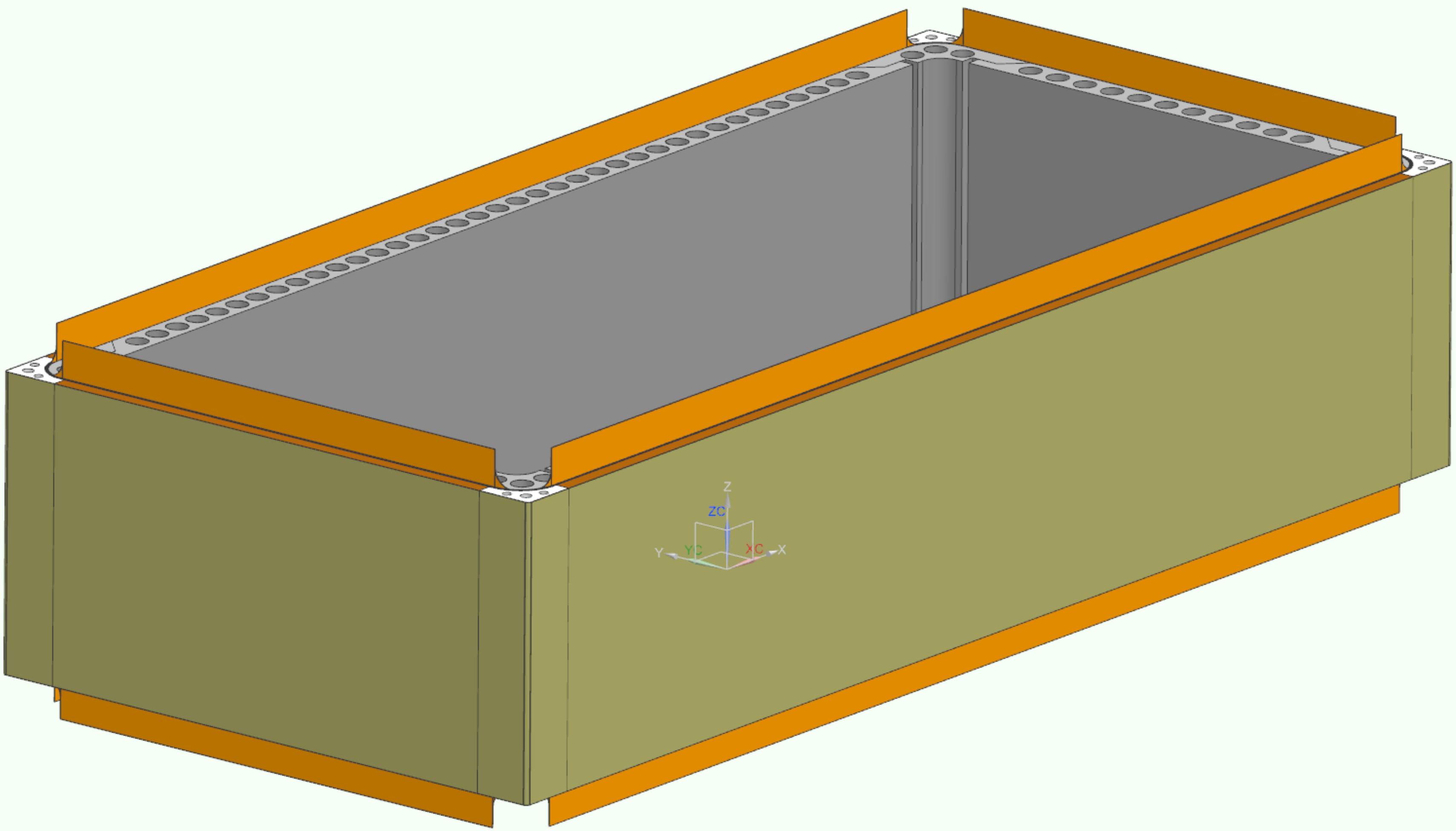
Note: the dip here is for allowing
proper folding outward of the
extra region of the foil

Phase II – the other layers are applied around the mold

Layers are applied according to the stack sequence (going outward):
1. inner layer – 2. HC (6mm) – 3. CF – 4. HC (16mm) – 5. CF – 6. (outer layer)

Note #1: the use of thin (160um) adhesive film layers (no flow) simplify the stack preparation

Note #2: intermediate curing phases might be needed

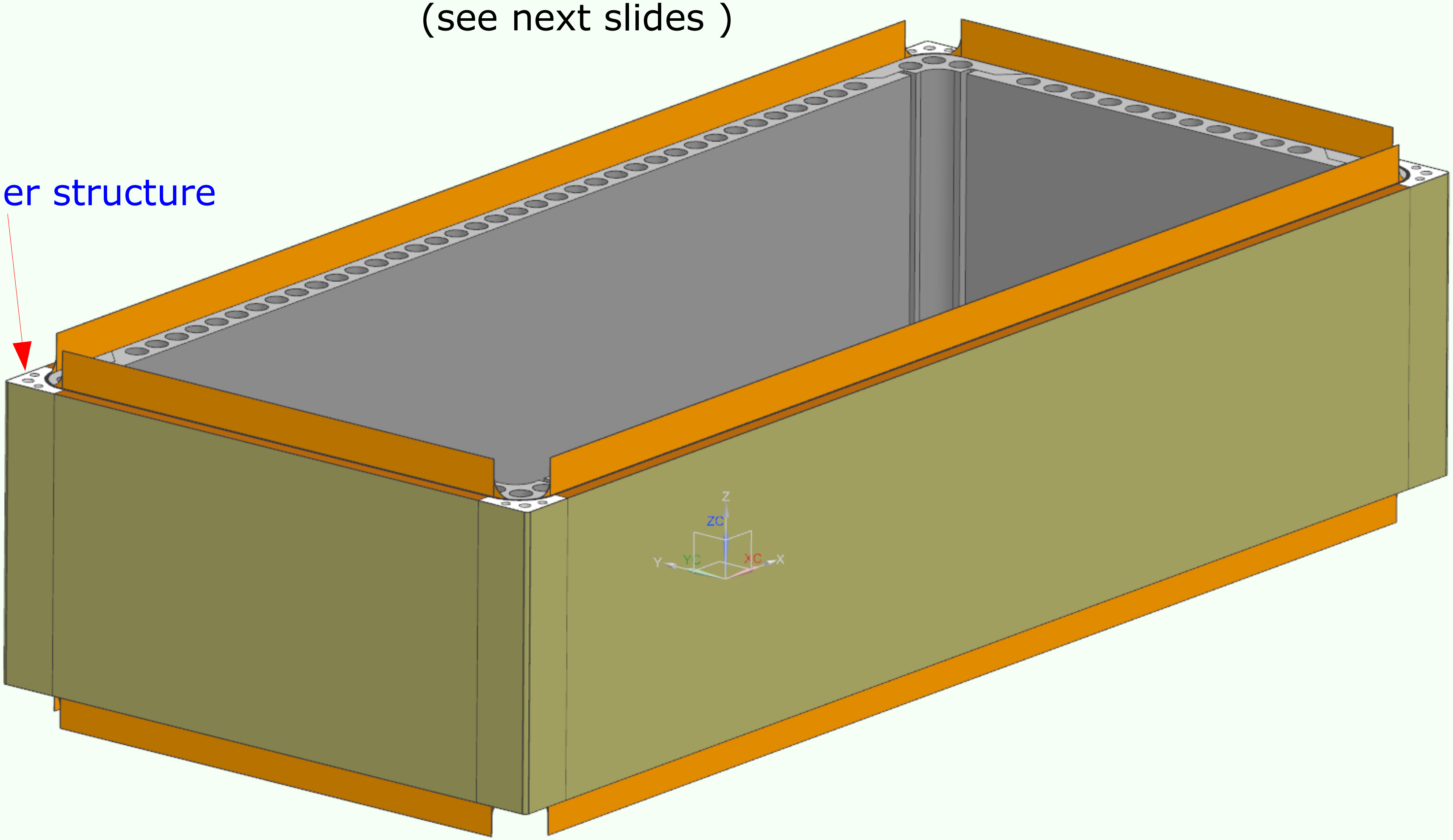


Phase II – the other layers are applied around the mold

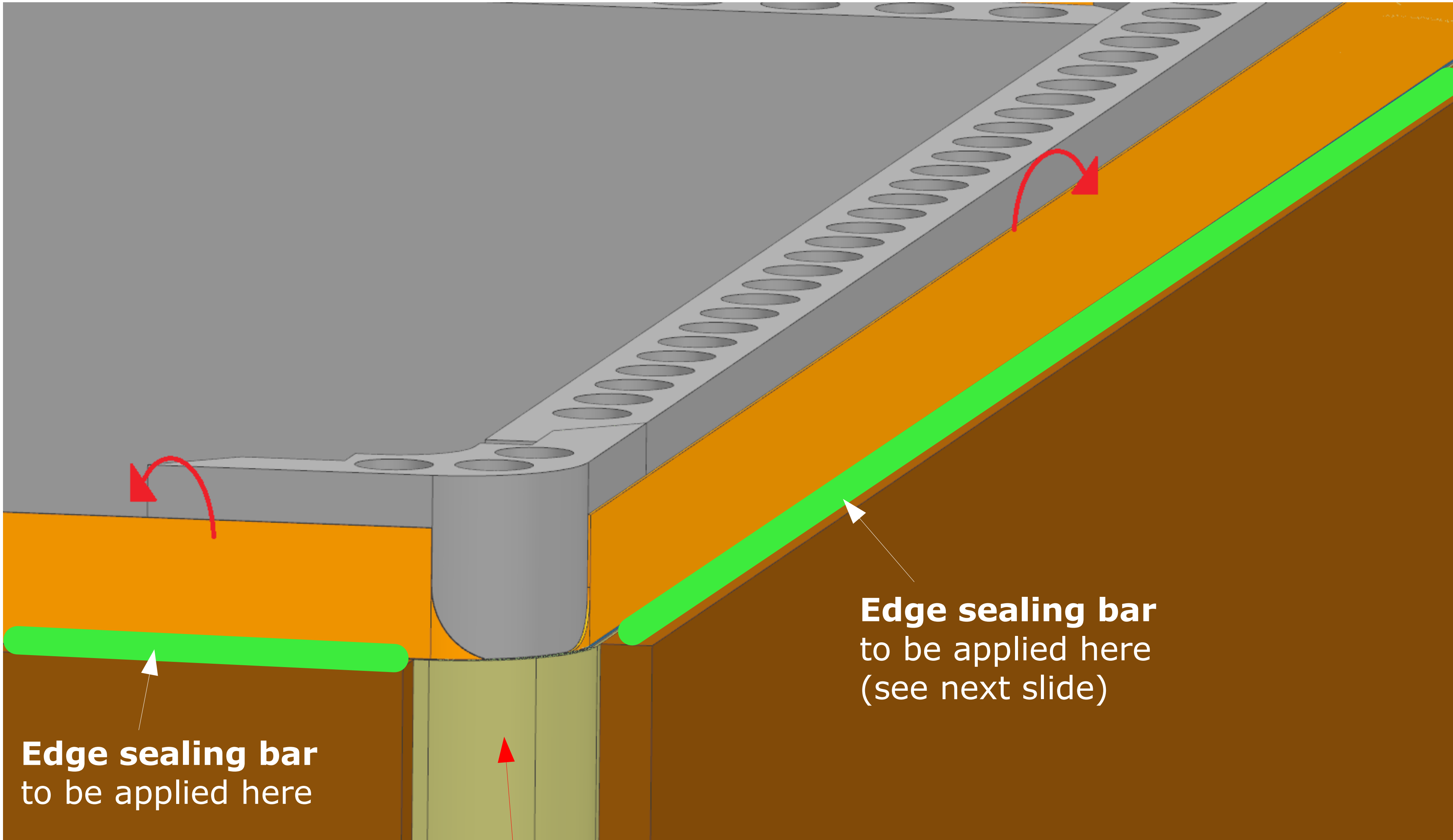
Layers are applied according to the stack sequence (going outward):
1. inner layer – 2. HC (6mm) – 3. CF – 4. HC (16mm) – 5. CF – 6. (outer layer)

Note #3: Before subphases 5. and 6. (wrapping 5.CF and 6.outter_layer)
Corner structures and **Edge Sealing Bars** will be applied
(see next slides)

Corner structure



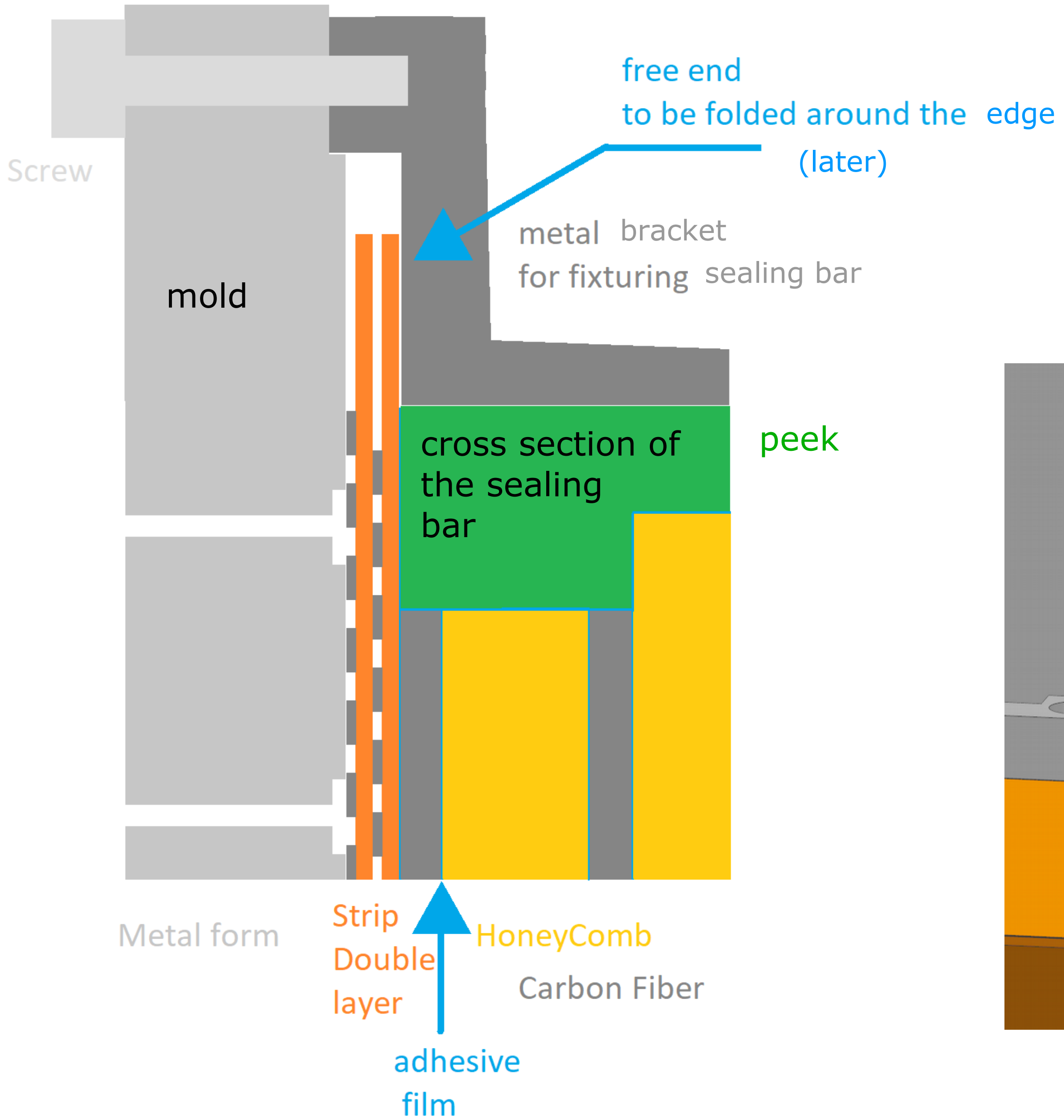
Phase II – the other layers are applied around the mold

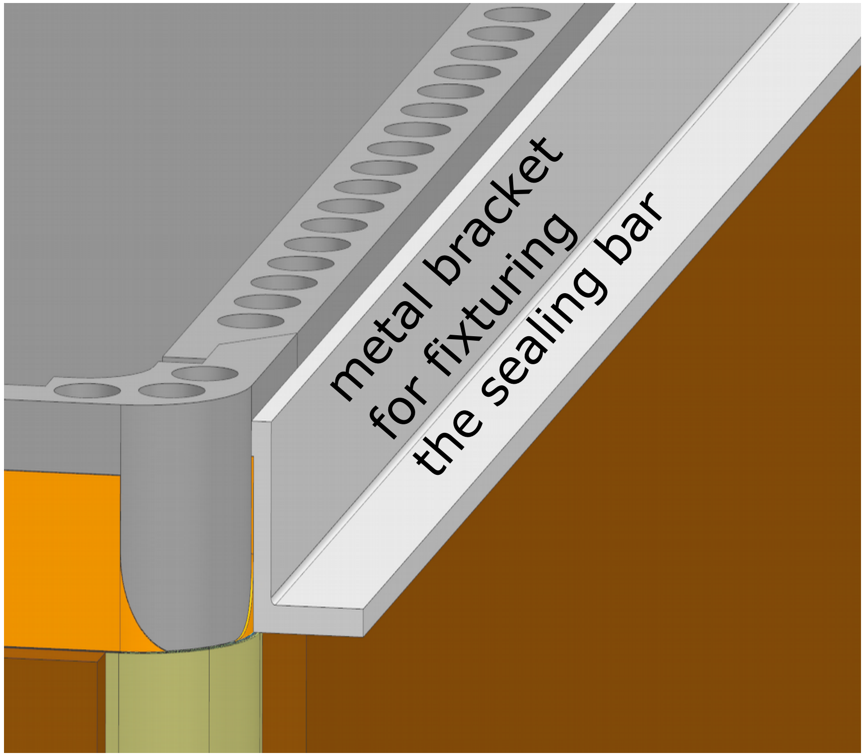


Corner structure
to be applied here

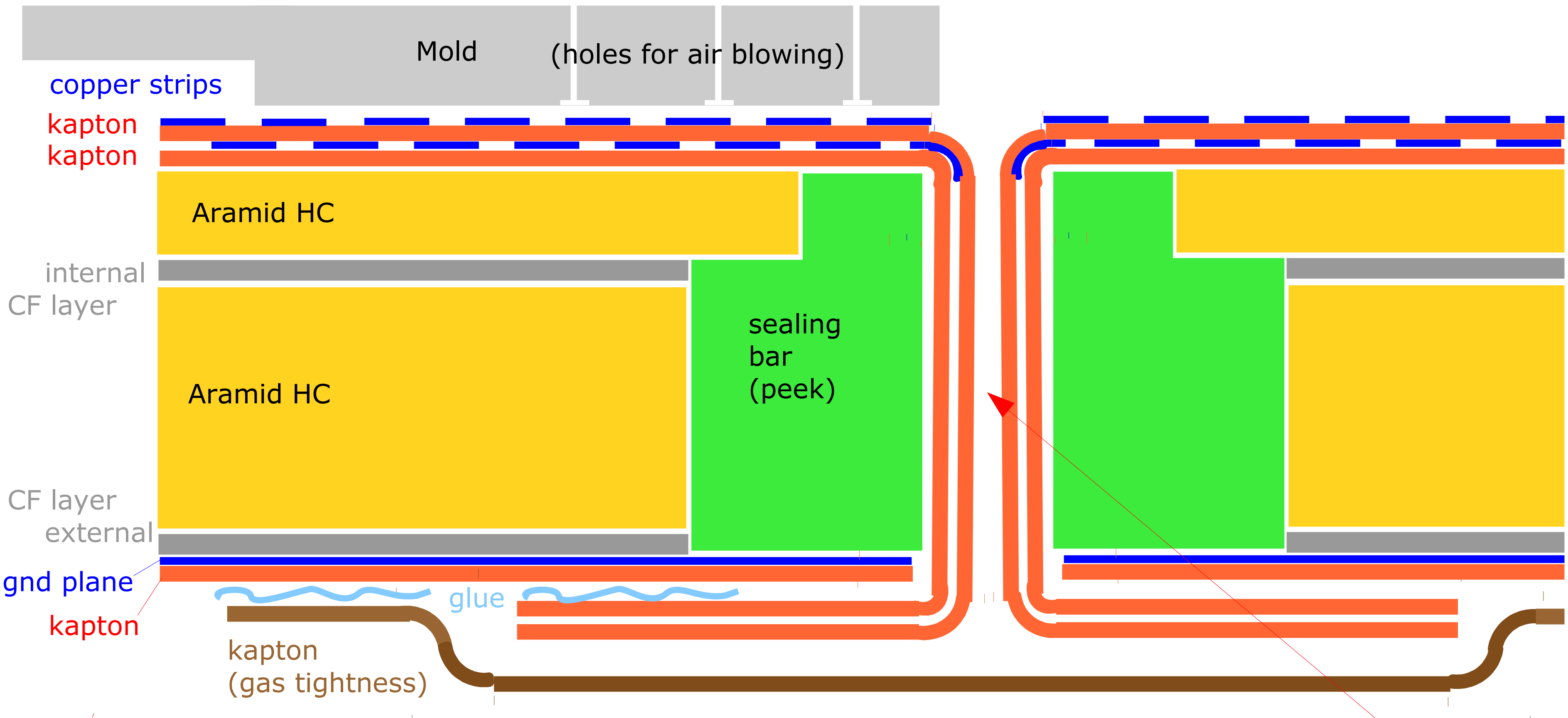
Phase III – completion of the composite layers stack including edge sealing bar

Vertical cross section of the stack @ box edge





Dielectric and gas sealing at box edges – Note #1



"soft" gas sealing (illustrated in picture) vs "hard" sealing (by gluing here)

To be discussed… tested

→ "soft" sealing appears more convenient for various reasons (including it allows to rework the chamber

→ if "soft" sealing OK → it might be applied also at Box-cathode and Box-end_Plate junctions !!!

Dielectric and gas sealing at box edges – “soft” sealing