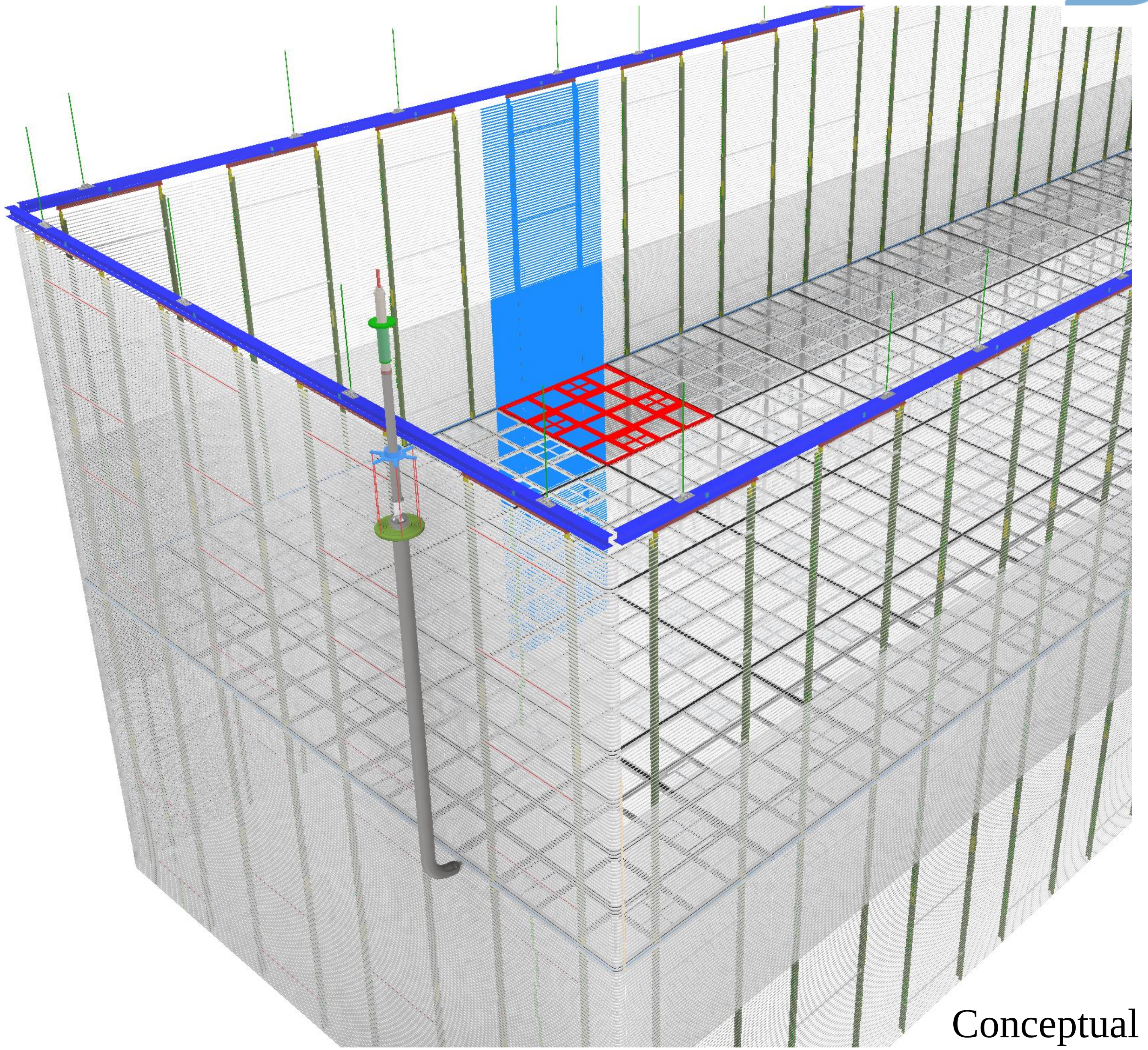
Vertical Drift Cathode

- **Requirements and Interactions with other consortia**
- **Cathode Frame and Suspension**
- **Cathode Mesh**
- **Arapuca Integration**
- **Installation plan**



Conceptual Design Review
Fabien Cavalier, June 14th 2021

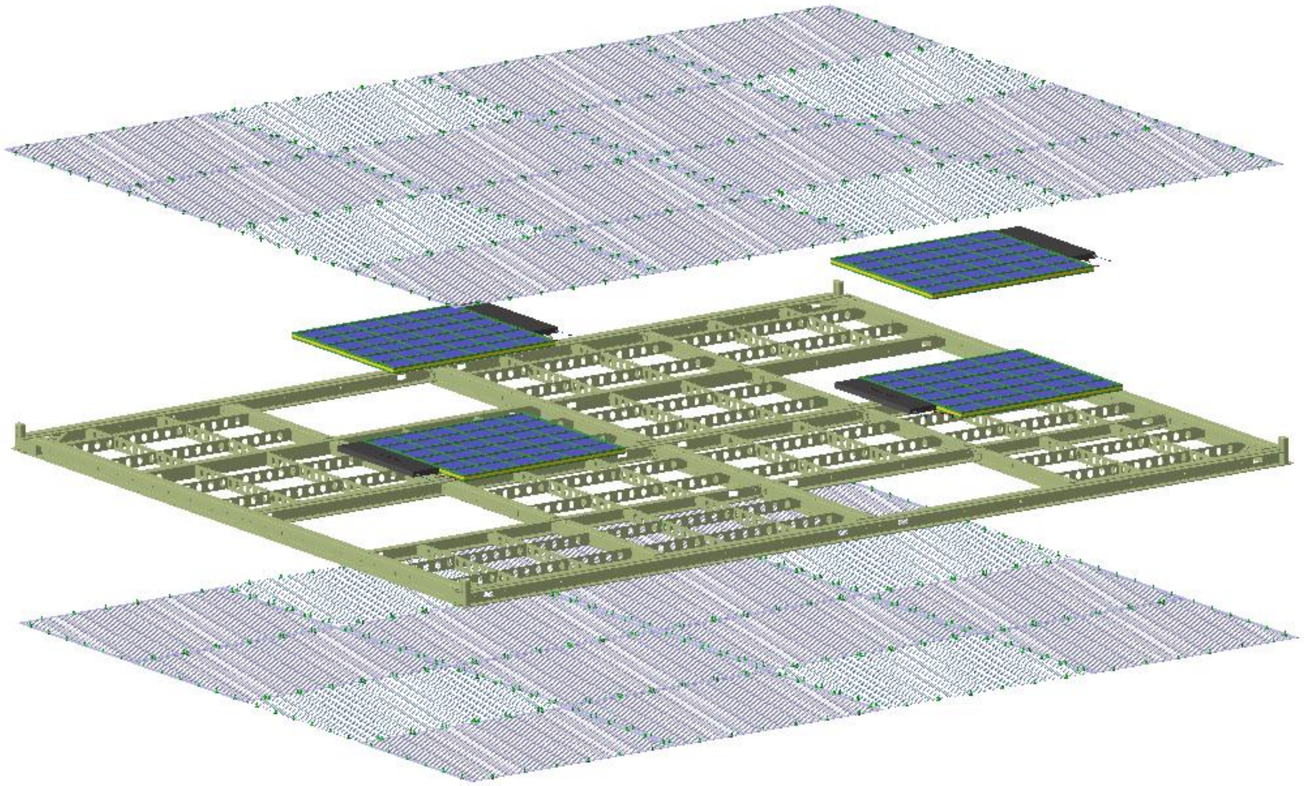
The Requirements

- Nominal Drift Field: **500 V/cm** => Cathode at **-325 kV**
- Drift Field **uniformity < ±1%** [in 99.8% volume]
- **Local** electric field **< 30 kV/cm**

- **Cathode Resistivity** : **> 1 GΩ/sq**. (lower limit 1 MΩ/sq., upper limit 10 TΩ/sq.)

- **Dimension : 3000 mm x 3375 mm x 50 (max) mm** (footprint of **CRP**)
- **Weight < 100 kg in air** (including **Photon Detector** to minimize deformation of **CRP**)
- **Bending < 20 mm in Lar**

- Mesh **transparency > 85%** over **Photon Detector** and **> 60%** elsewhere for LAr flow
- Mesh **pitch < 30 mm** for field uniformity

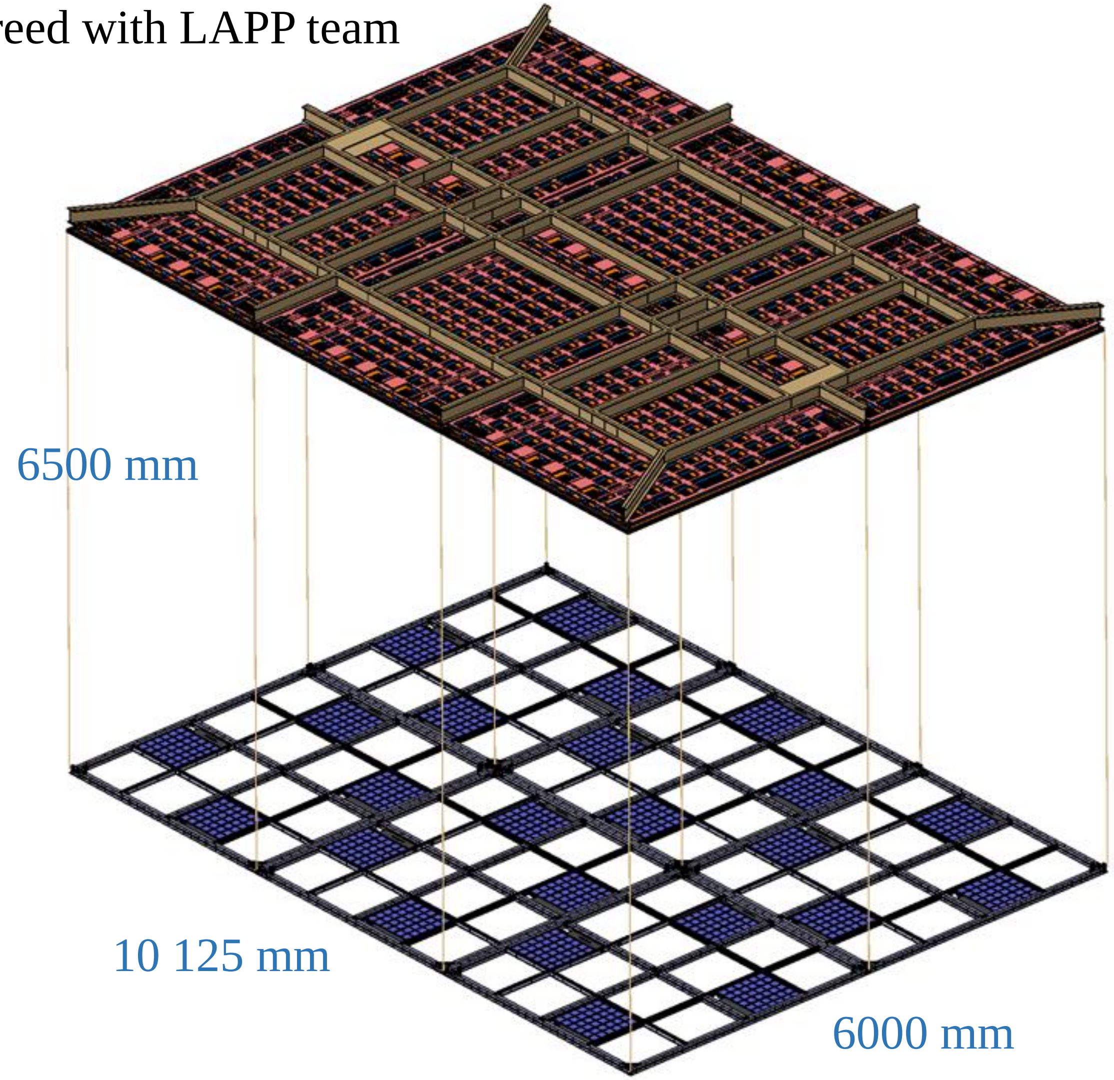


The Cathode and the CRP

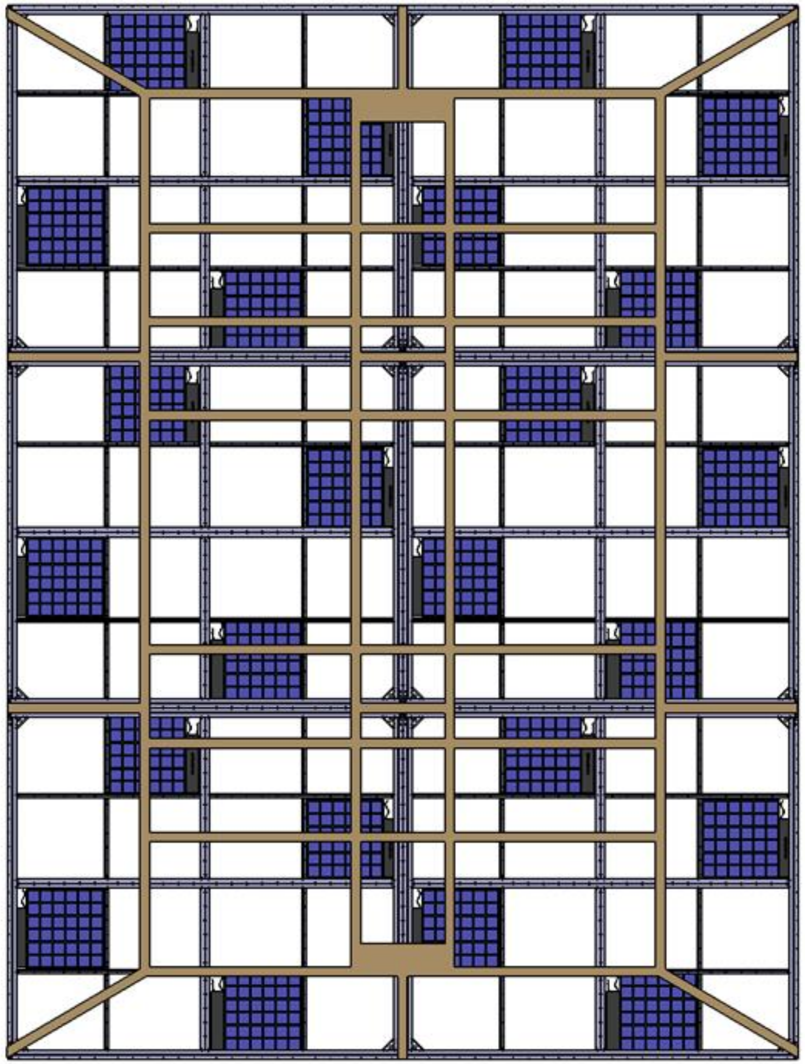
- **6 cathodes to be attached** to the SuperCRP
- All wires to be vertical

=>

- **12 ropes** made in Dyneema (details after)
- Position of the wires agreed with LAPP team



Top view

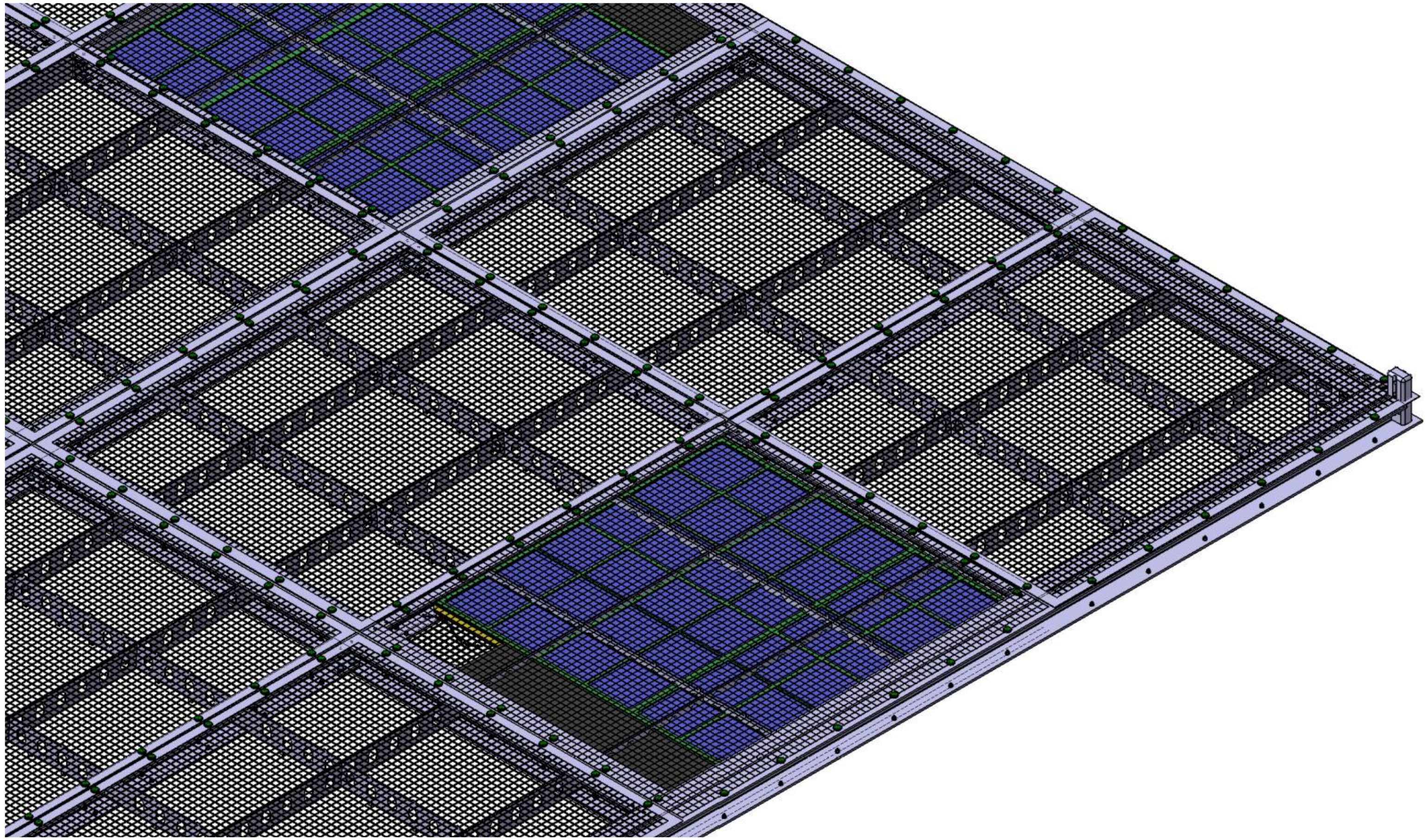


The supporting frame

- Polyester **glass fiber**
- 50 mm height
- **U/I profile**
- Reinforcement with **crossribs** above the mesh to insure mesh planarity
- Total weight (without Arapuca and mesh) : **62.5 kg in air, 8.3 kg in LAr**

⇒ Available **Payload : 37,5 kg**

- Arapuca : about ~7x4=28 kg in air
- ~10 kg available for the “electrical” part of the cathode



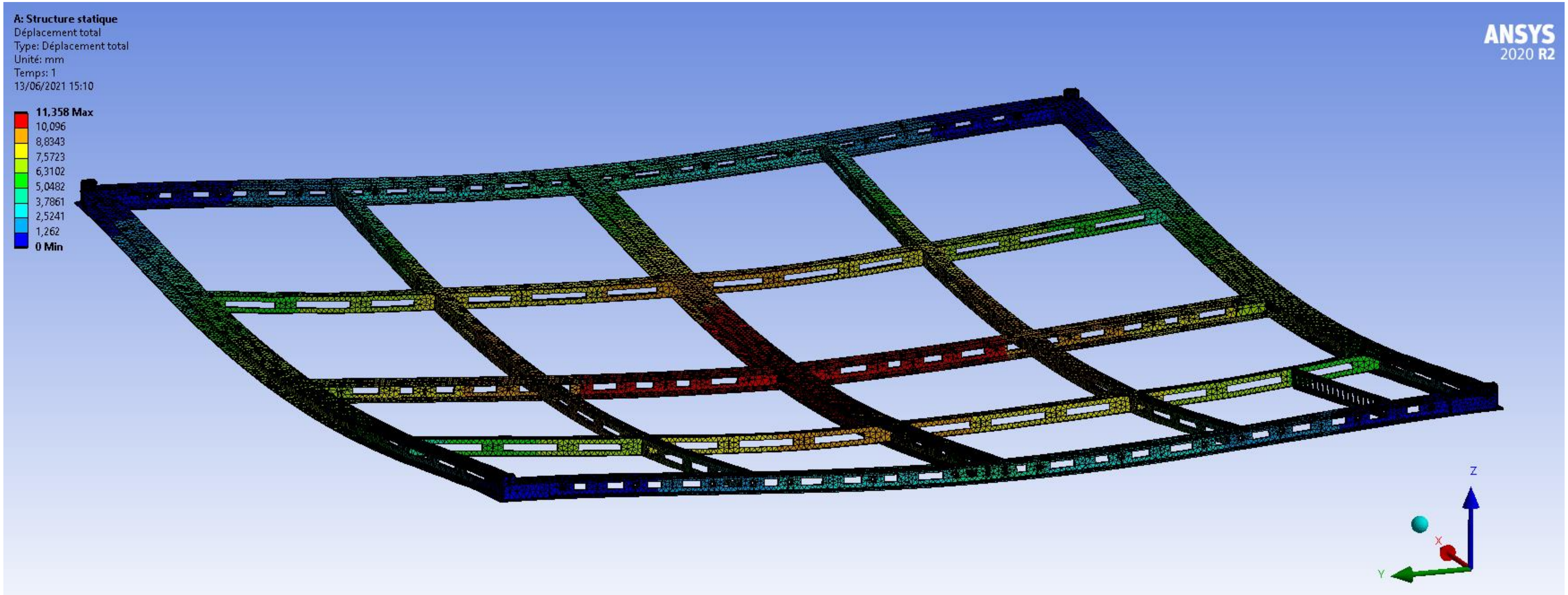
The supporting frame

- **Prototype Design Completed** (P.Rosier)

- **Simulated performances**

over the whole cathode:

  - Distortion below **32 mm in Air**
  - Distortion below **15 mm in LAr**



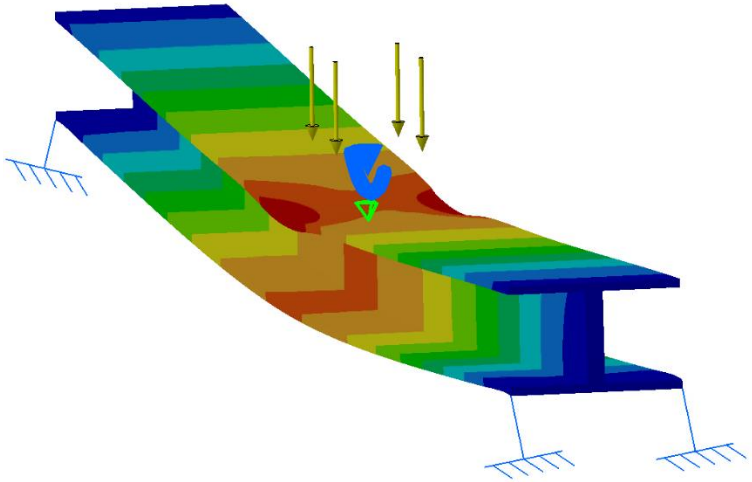
The supporting frame

- **Production** of **2 frames:**
  - Pb (bad composition of the fiber glass) with first batch
  => one month of delay but still in time
  - Sample of bad batch received this morning: Young Modulus / 2 !!!
  - One frame to be delivered **this summer** at CERN for ColdBox tests
  - The second will stay at Orsay for tests (creep, deformation …)

- **Impact** of **transport** to be taken into account

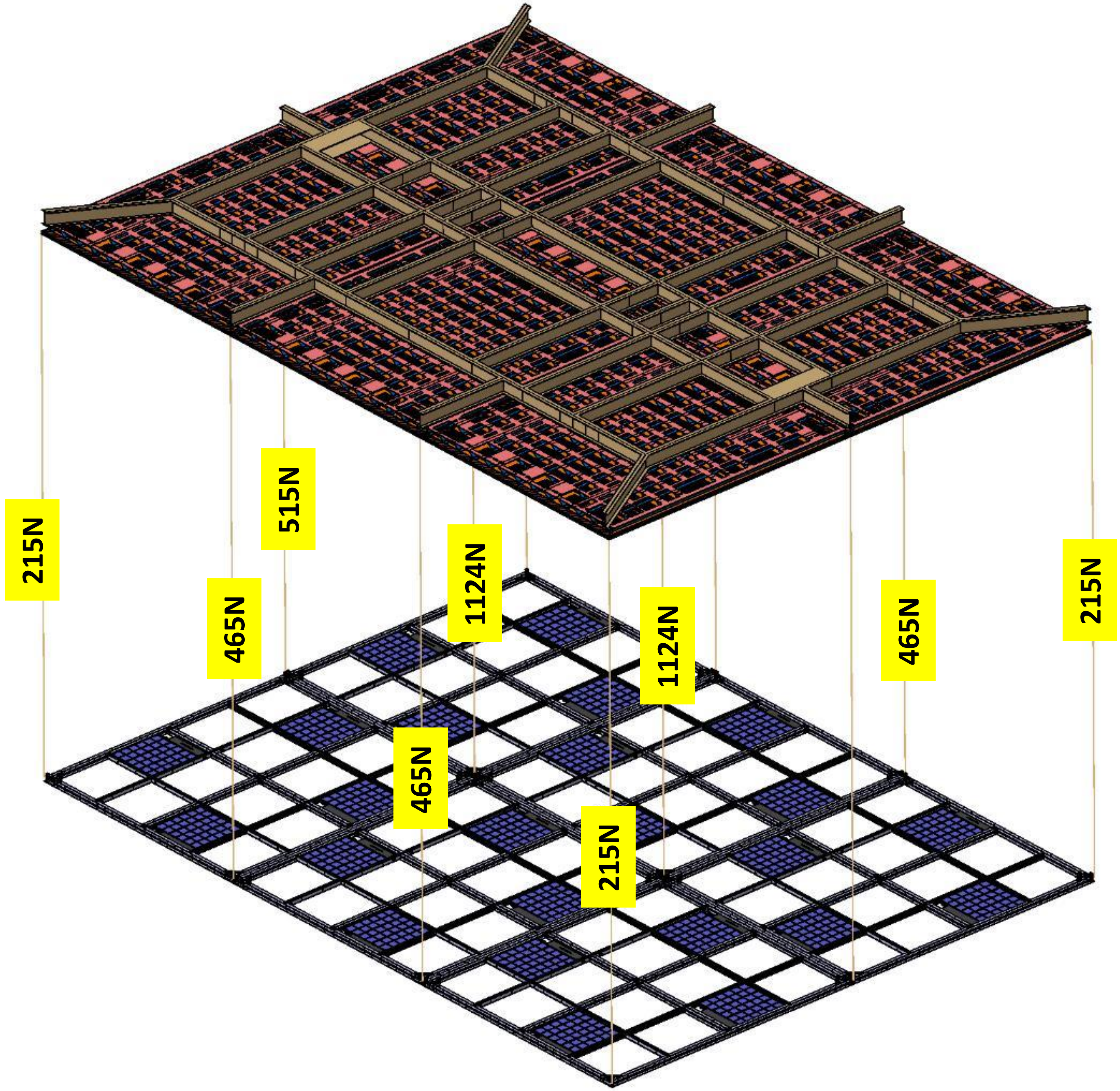
⇒ **New design** to be performed for **½ frames** with easy reconnection at SURF: some ideas to be developed, simulated and tested

⇒ **No major difficulties** foreseen for final design



The suspension system

- **6 cathodes** attached to the same **SuperCRP**
- Total load in **Air ~ 600 kg**
- Total load in **LAr < 250 kg** depending on mesh and Arapuca material
- Tension wire from 200 N to 1100 N



The suspension system

M-Rig Max Standing Rigging

Wires made with **Dyneema**:

- **High resistance** with small diameter (**3 mm** is our choice for minimal dead zones)
- **Low creep**:
  - Creep at 300MPa = 0.00007%/day
  - **10 years =>** 0.25% => **15 mm**

  - In our case, we are at 142 Mpa max in air and 100 Mpa in LAr

=> **Measurements** to be done in **cold condition**. Expected in NP02

M-Rig Max

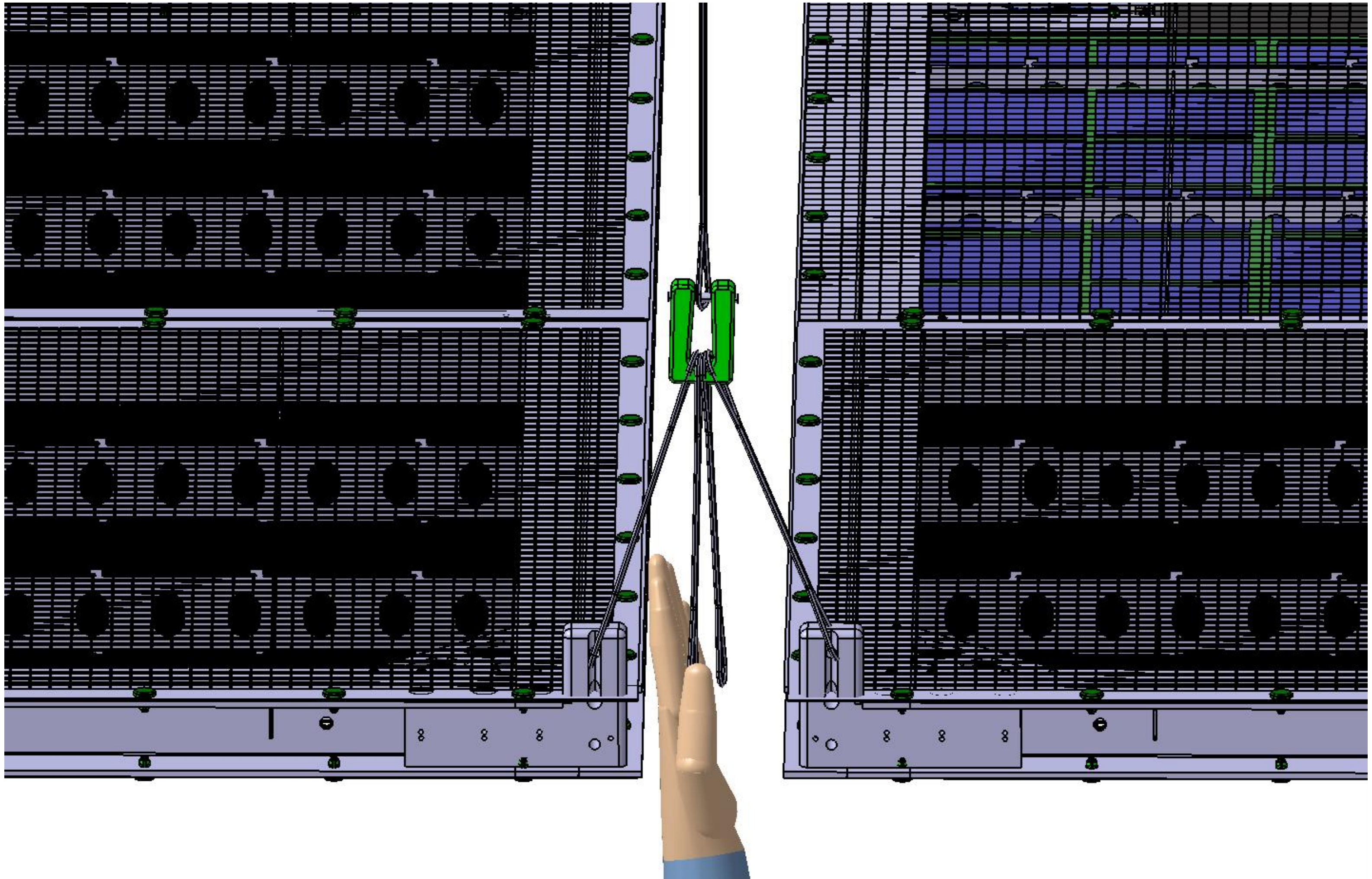
Part Nos: TV**** JTV***

-DM20 for Zero Creep
-Construction optimised for strength
-Colour coated with Polyurethane for improved abrasion resistance
-Heat set and super pre-stretched for zero constructional stretch
-Super Lightweight
-Higher strength than wire of the same diameter
-Good resistance to UV and Chemicals
-Easily Terminated with locking D12 Splice

Diameter mm	Mass g/m	Average strength kg	Min strength (spliced) kg	Stretch mm/mm/1000kg
2.5	4.5	902	839	0.04709
3	6.8	1353	1259	0.03141
4	11.1	2224	2069	0.01911
5	15.6	2874	2672	0.01479

The suspension system

- **One wire** will support **one, two or four cathode corners** according to its position
- A **single long wire** and **1/2/4 short wires** at the end
- **Connection device** between wires **to be designed**



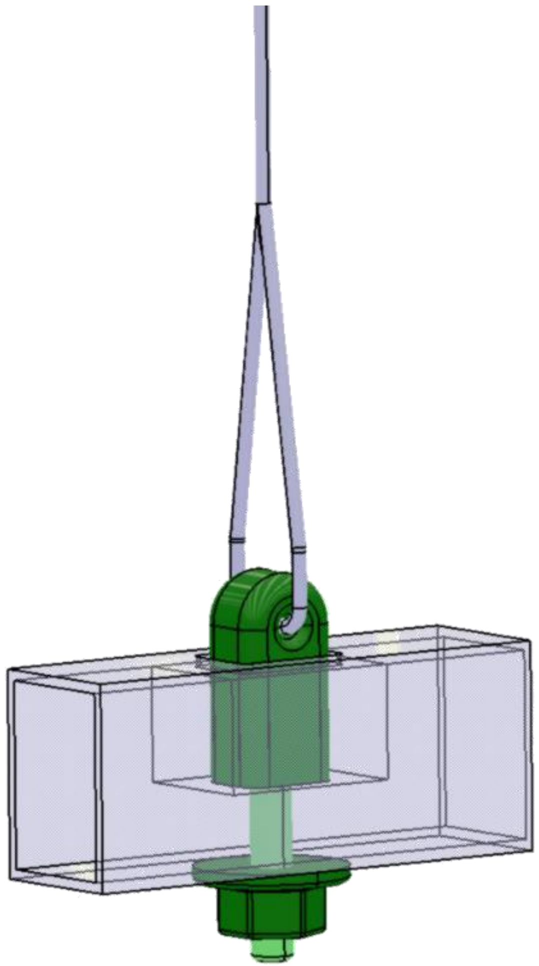
The Length Adjusting Device

- System located in a **cathode frame corner**, integrated inside the H beam and **accessible from below**.

- Rope tension from 215 N to 1125 N
- **Rope elongation** due to load **from 2 mm to 9 mm**
- Rope **thermal expansion 14 mm** (negative CTE). To be measured

- **Different initial lengths** for the ropes to take it into account (16 to 23 mm)

- Final adjustment with the length adjusting device +/- 10 mm



The Cathode Mesh

- More than **100 J stored** in the cathode

- In case of discharge:
  - if fully metallic, the energy is released in **few nanoseconds** => **severe damage** is possible
  - initial solution with **Stainless Steel mesh connected by resistive material** (release time increased to few seconds) but big risk of arching in LAr which will short-circuit the resistive part => back to previous situation

⇒ Move to **fully resistive mesh** to slow down the discharge

The Cathode Mesh

Current Design

- Commercial **Metallic mesh over Arapuca** to easily insure **transparency above 85%**
- **FR4 laminated with Kapton** elsewhere (similar to FD1 Cathode) and **machined** to create a mesh with **transparency above 60%**
- **Mechanical behavior** after machining to be **measured and tested** for resistive mesh:

Information:
the providers were doubtful to get a satisfactory result starting from a **too thin panel** which will be machined to reach a 60% transparency because the amount of resin is **not sufficient to insure a correct mechanical** behavior (some fibers are not surrounded by enough resin to insure cohesion)

⇒ Manageable increase of weight ?
(with 3.5 mm thickness and 80% transparency, the 2 meshes **weight 27 kg (54kg for 60%)**)

=> Need for more crossribs to compensate the weak mechanical behavior ?

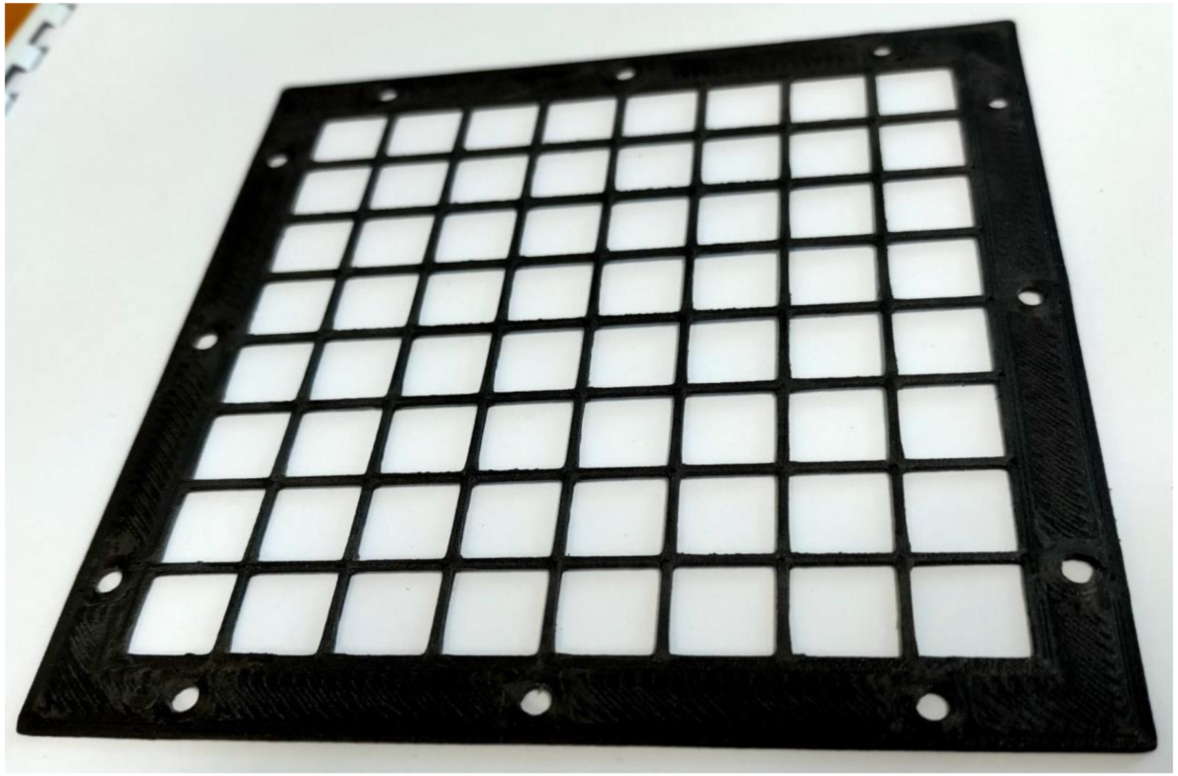
Put 3.5

Backup solutions under investigation with CERN team:

- **Resistive FR4** (Vetronit), machined for transparency: same pb of mechanical behavior ?

- **Kapton foil** alone with eventually additional crossribs for planarity:
    - Preliminary tests after punching 200 holes (80% transparency) on a standard Kapton A3-size foil seems promising: object still difficult to tear (main fear about Kapton), limited bending when put on a frame

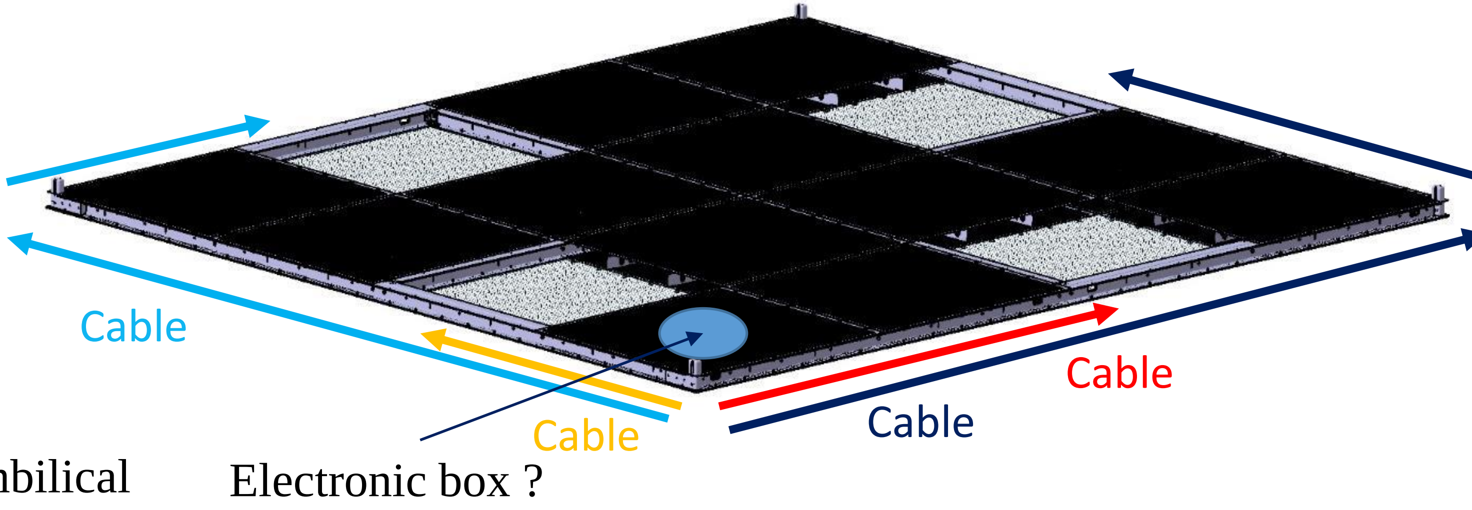
- **Peek loaded with Carbon** fibers using a 3D printer:
    - 1 mm thickness mesh produced
    - Resistance above 100 GΩ, difficulty to measure it



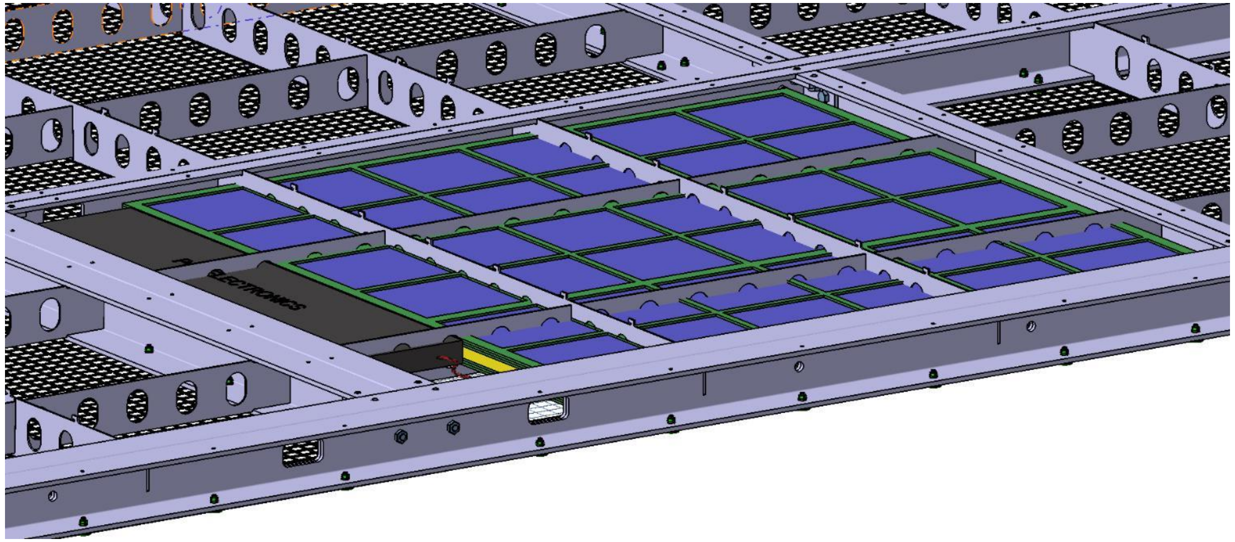
Costs for each solution (material, machining, printer …) to be better evaluated but **first estimates** gives **similar amounts**

Arapuca Integration

- **Weight limit agreed** with Arapuca team
- **Routing of cables** in the **edge** of the cathode frame
- Holes already implemented to go through the frame
- Possibility to **easily plug** external cables (fibers, umbilical …) to the electronic box from **below** to be investigated (minor issue)



- **Impact on Arapuca interconnections** to be clarified due to shortcuts introduced by copper wires



⇒ Is only one electronic box for the 4 Arapucas reasonable ?
⇒ Should we go in the direction of 4 electronic boxes ?
⇒ **How to protect Arapuca from discharges?**

Integration Plan

Guideline: maximize work in the lab, minimize actions at SURF

At the lab:

- **Reception** of the frames **produced in the industry**
- **Installation** of **Arapuca electronics** and **cable routing** in the frame
- **Mounting** of **all mesh elements** (except the four above Arapuca tiles)

At SURF:

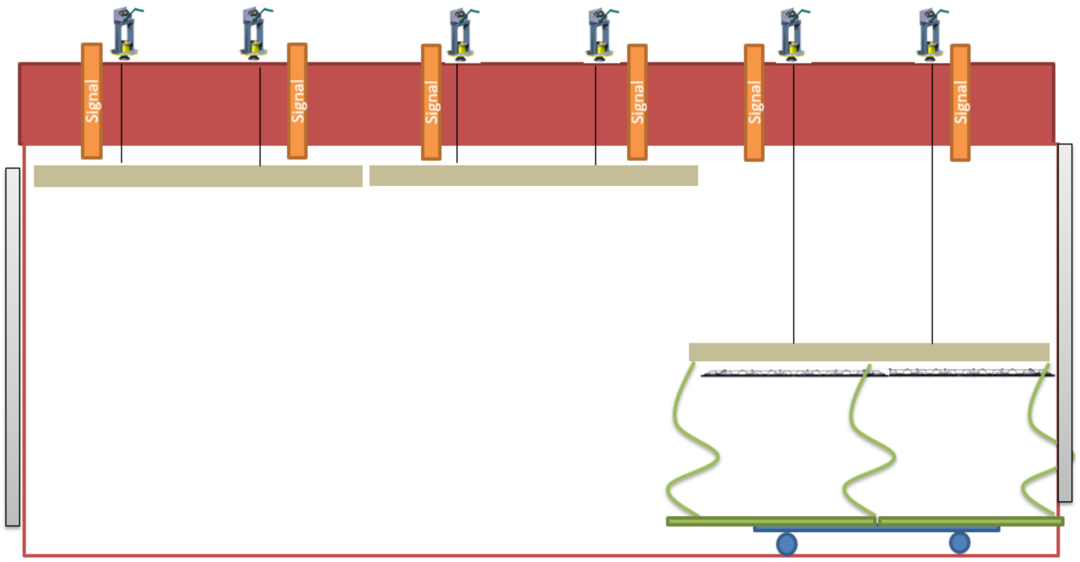
- **Connection** of the **2 ½ frames**
- **Installation** of **the 4 Arapuca tiles**, **connection** to its electronics
- **Mounting** of the **4 missing meshs**

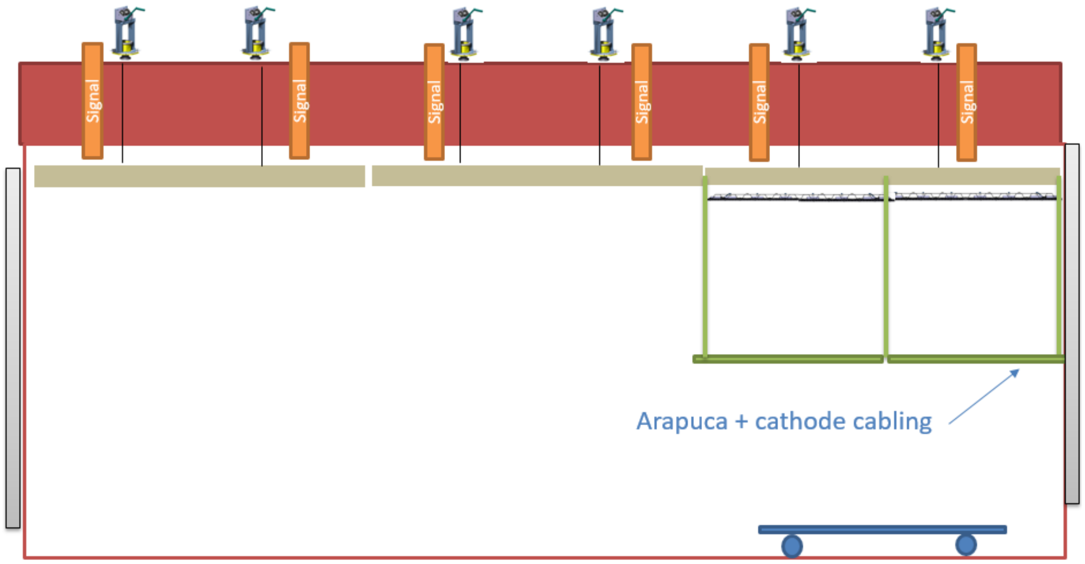
=> **Full cathode ready to be installed**

The current scheme

- **Sequence** proposed in agreement **with CRP installation** (LAPP team)

- **Wires** installed on **SuperCRP**
- **SuperCRP lowered** using its winches around 6m to **attach the 6 cathodes at human height**
- **SuperCRP raised** at nominal position with the **6 cathodes attached** to it
- **Connection to HV**
- **Connection of Arapuca electronics**
- **Final tuning** of the cathodes **alignment**





Pros:

- **No cathode** or set of 6 cathodes **to be lifted by external means at 6 m**
- **Minimal activity** on the cathode **at 6m height**

Cons:

- **Cabling of CRP** more tricky

Open questions:

- Impact on **Field Cage mounting**
- How the **Arapuca** will be **connected up to flanges**?
- Is there any connector to plug or everything is already connected to electronic box (or elsewhere (patch panel)) ?

Conclusion

- **Suspended cathode is a "new object"** in the Vertical Drift concept

- Advanced **mechanical design** (with simulations) for the **supporting frame**
  - Under production
  - Available for ColdBox tests
  - Ideas for ½ frame to be implemented

- **Suspension system** under design
  - Tuning device
  - Attachment system
  - **Wire behavior at cold to be measured**

- **Reference solution for the mesh** but mechanical behavior to be tested

- **Installation scheme to be agreed** with all involved activities (CRP, FC, Arapuca)

- **Significant impact of Arapuca** design on cathode design
  - HV protection
  - Connectors
  - Cabling
  - Integration and Installation