

Dual Phase Drift Cage Production QA/QC & Installation

protoDUNE Design and Production Review
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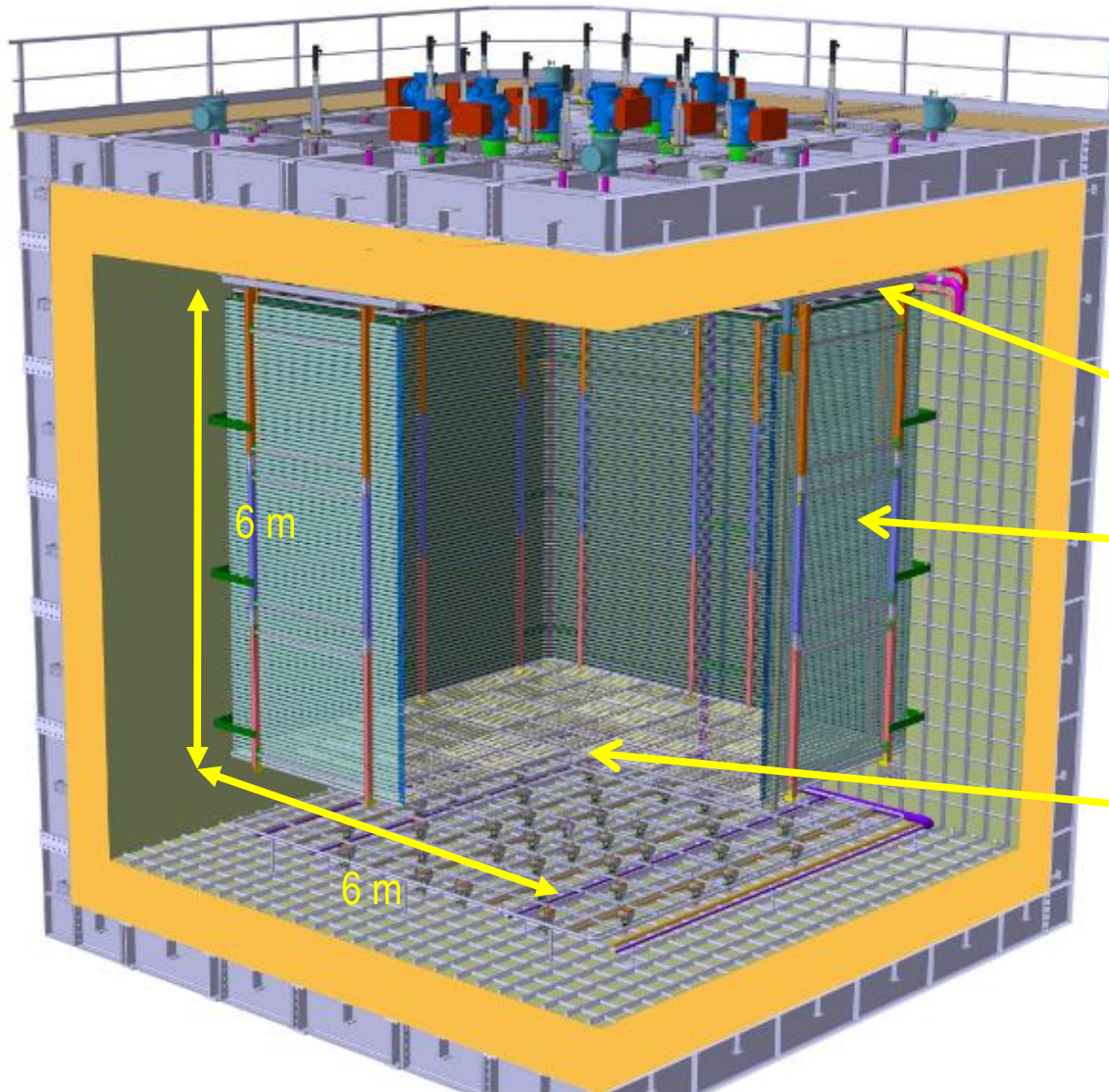
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Drift Cage in protoDUNE DP



- Drift Cage and cathode hangs off of the ceiling
- Essential to have light yet sturdy structure
- Based on modular concept as SP

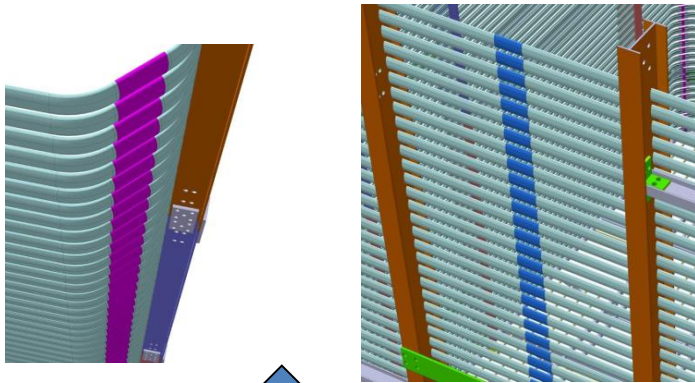
Charge Readout Planes

Drift Cage (common structural elements with SP)

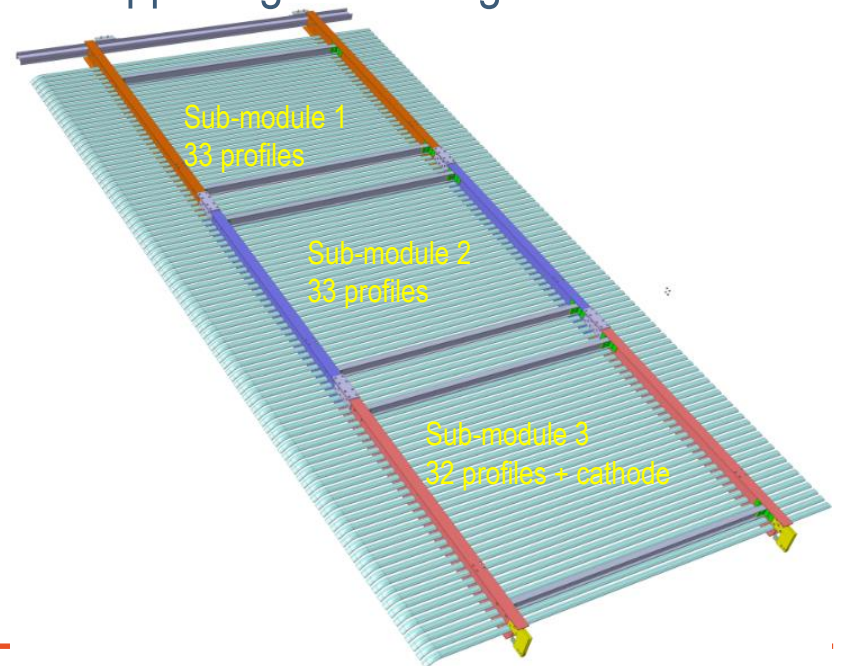
Cathode

Drift Cage Design

- Shares common basic structural elements w/ ProtoDUNE-SP
- Consists of 8 vertical modules of 6310 x 3010 mm² (2 modules per detector face)
- Each module is assembled out of 3 distinct sub-modules
- 11 profiles with one end bent at 45 degrees are electrically connected by 1 HV divider board
- 98 electrically continuous rings in 60mm pitch using straight aluminum clips
- Three distinct types of sub-modules with 33, 33, and 32 profiles each held by a frame with two 6" and two 3" horizontal FRP I-beams
- Inter-module connections made with FRP plates connected with FRP threaded rods
- Each profile is made of extruded aluminum with a supporting rib running in the middle



Continuity at center and borders w/ Al clips



DC Production Procedure Overview

- This procedure is based on the SP DC End plate group's (LSU group) and is included in the QC Doc
- Production & QC procedure is as follows:
 1. Receipt inspection of the parts for QA
 2. Cleaning of the parts
 3. Pre-assembly of the DP-DC sub-modules
 4. Disassembly
 5. Packaging and Shipping

DC Production – Receipt Inspection/QA

- Inspect profiles, I-beams and other FRP parts for their dimensional and functional qualification
- Visual Inspection for dimensions and structural damages and categorize them by the severity of defects
- Al profiles: deformation or surface damages and bend angle
- FRP I-beams and connecting plates
 - Visual inspection
 - Cracks & Fractures
 - Delamination
 - Dry fiber
 - Burn or thermal decomposition
 - Blisters
 - Dimensional inspection
 - Cross sectional dimensions and lengths
 - straightness, flatness and camber

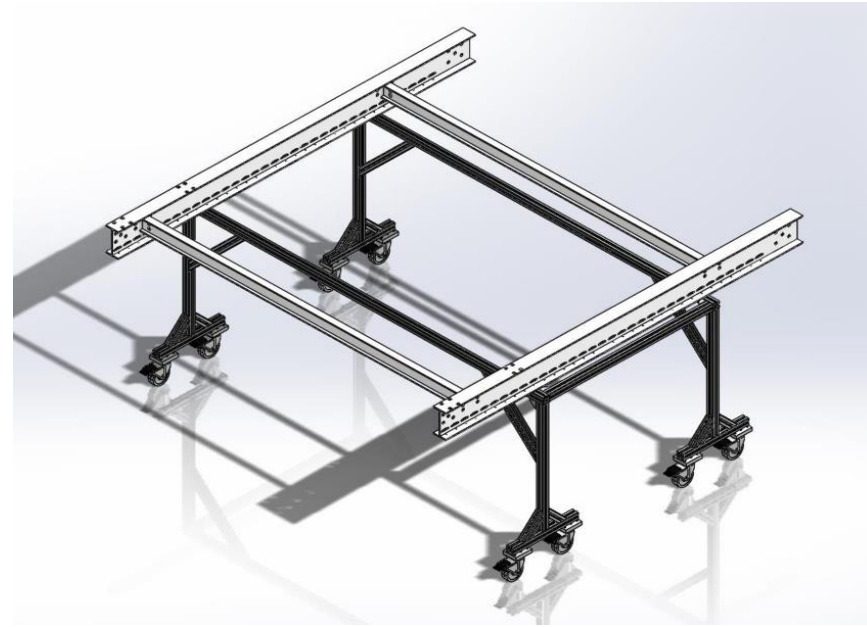
DC Production – Parts Cleaning

- This step will be done in a clean and lockable secure area
- All members will wear disposable lab coats, masks, hairnets and powderfree gloves
- Deburr and defiber the machined holes of the FRP parts with fine sandpaper, vacuuming the fiber as sanding
- Clean FRP I-beams and connecting plates with simple green without color and de-ionized water, using Kimwipes
- Dry and remove moisture from I-beams w/ hot air heat gun
- Clean small parts – threaded rods, nuts, screws, slip-nuts and inserts –in an ultrasonic cleaner w/ ethanol
- Inspect cleanliness of each part after the above processes
- Store cleaned parts on the shelf in the cleanroom



DC Production – Assembly

- This process will be done in a class 100,000 clean room. All members of the assembly team will wear disposable lab coat, mask, hairnet and power-free gloves
- Connect two 6” primary I-beams w/ two 3” horizontal ones using the L-brackets and FRP threaded rods and nuts on the A-frame based assembly stand
- Slides the aluminum field shaping profiles through the corresponding cutouts one at a time and secure each using slip-nut to one side of the frame near the bent part
- Check the alignment, straightness and part fitness of the submodule



Production – Disassembly

- This process will be done in a class 100,000 clean room. All members of the assembly team will wear disposable lab coat, mask, hairnet and powerless gloves
- For shipping, we will disassemble the DC in the following order:
 - Unscrew the profiles one at a time, collecting all screws and slip nuts in a bag, and store the removed profiles on the shelf
 - Unscrew FRP nuts from the threaded rods to disassemble the horizontal I-beams from the primary ones, collecting all threaded rods and nut in a bag
 - Clean all small parts in ethanol in an ultrasonic cleaner to ensure cleanliness and dry off the ethanol and put them in ziplock bags
 - Inspect the I-beams for cleanliness and any damages

Production – Packaging & Shipping

- This process will be done in a class 100,000 clean room. All members of the assembly team will wear disposable lab coat, mask, hairnet and powerless gloves
- Packaging process will be done as follows:
 - Collect zip-lock bags for screws and slip-nuts for profile mounting
 - Collect zip-lock bags for FRP threaded rods and nuts
 - 10% spare parts will be included in the package to ensure the assembly of the sub-module in case they are lost
 - Stack 6” I-beams and 3” I-beams as small a packing factor as possible and mount zip-lock bags for small parts and shrink wrapped multiple layers to ensure isolation from moisture during storage → as small as 165mmx160mmx2000mm
- Each package will contain the list of included parts and be clearly tagged w/ the type of the sub-module (top, middle and bottom) and to ensure proper identification of the locations of the specific sub-module
- The package is then moved into a separate semi-clean room with a lock for storage until shipping

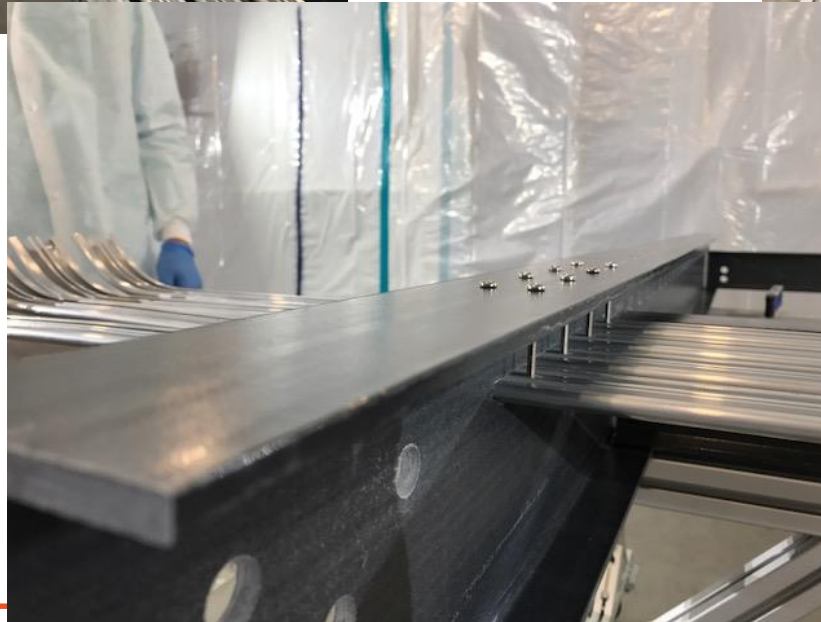
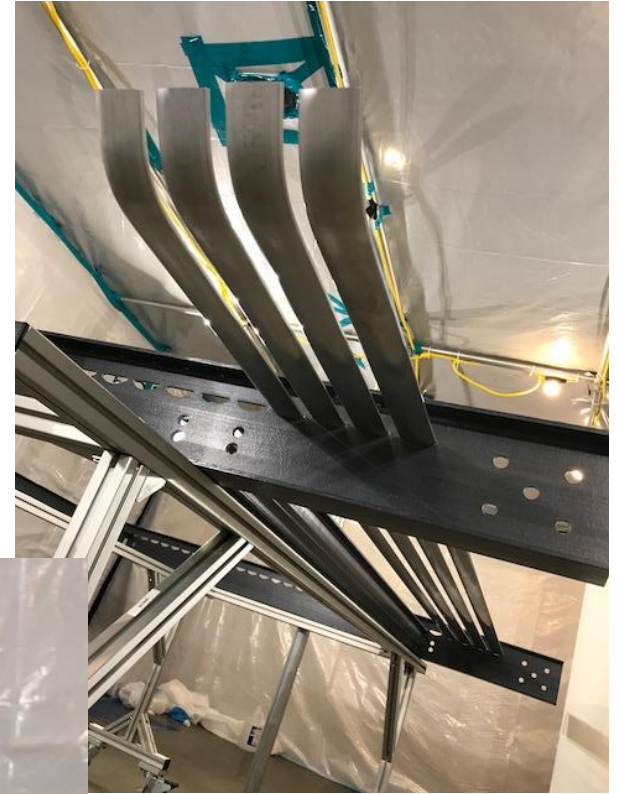
Sub-module Construction Sequence

- In order to prepare strategically for installation into the cryostat, we will build the three sub-modules for one module at a time
- Each sub-module package in shrink wrap will be stored in a clean and secured area
- Ship out to CERN four module worth of sub-modules – 12 sub-modules - at a time, ideally one in early September and in mid to late October 2017
 - The actual shipping dates could be adjusted based on the situation at CERN but the shipping must complete prior to the Thanksgiving to avoid holiday rush and to ensure the safe arrival at CERN prior to the holiday shutdown

DP DC Production Status

- Production readiness documents in review
 - QC Procedure
 - QC Checklist
 - Hazard analysis
 - Vendor documents
- Production readiness review scheduled on May 15 but requested an earlier visit to begin production of I-beams earlier to avoid delays of production I-beams delivery
- Assembly facility preparation complete
- All parts for module-zero delivered
 - Two I-beam vendors identified
- 40 Aluminum profiles with 45 degree bend at hand
- All members of production team in place
- Module-zero in production in progress with initial QC measurements
 - Initial flatness inspection looks good, and the hole dimensional measurements are within the 1mm tolerance
 - All I-beams cleaned but requires a deburring and defibering process
 - Profiles are being cleaned
 - Four profiles put into the slots and screwed in for a trial fit

DC Module Zero Production

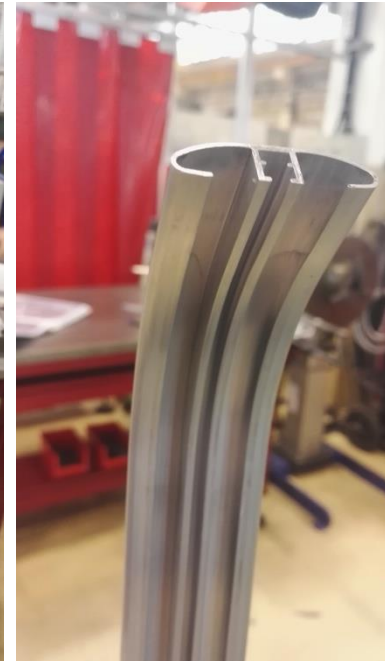
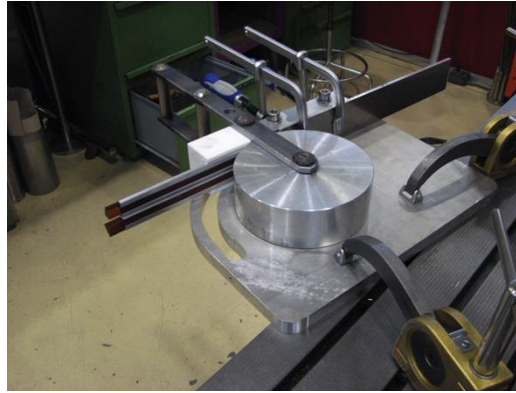


Production of Bent Profiles (FP)

- Two production chains identified:
 - Full production by manufacturer, MIFA (NL)
 - Extrusion, bending, conductive coating
 - Slightly more expensive than Alexia: ~25-30 Euros/profile
 - Less risky: defects and mistake absorbed by manufacturer, included in cost.
 - Different manufacturers for each production stage
 - Extrusion: Alexia (Italy); bending: CERN; coating (Finland)
 - Less expensive: 5 Euros/profile (extrusion), ~10 Euros/profile (bending: manpower), 3 Euros/profile (conductive coating); + some transport costs
 - Additional risks due to transport requires more spare parts (to be evaluated)
- Choice to be evaluated on quality of prototypes:
 - Extrusions (MIFA, Alexia):
 - Very similar profile shape accuracy and surface finish
 - Bending procedure tested at CERN on 50 profiles (4 man-days):
 - No loss, ~mm accuracy on straight section ~1 degree bending accuracy,
 - waiting for MIFA prototypes (mid May) for comparison
 - Conductive coating (SURTEC) is a well established process:
 - Company selected based on best offer

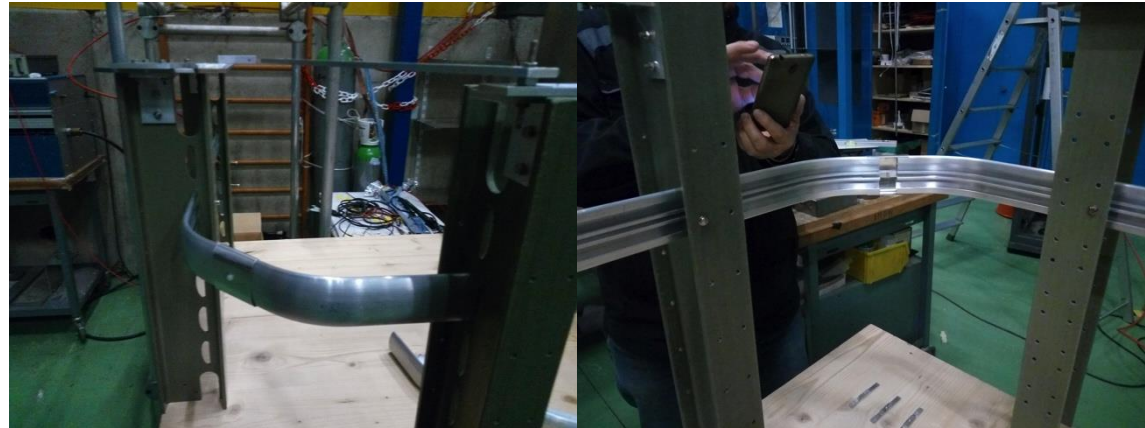
Al Profile Bending

- Dedicated bending tool designed constructed and tested at CERN main workshop guaranteeing ~ 1 mm accuracy in straight segment length and ~ 1 degree accuracy in bent angle
- Al profile end heated for few minutes to make it locally (10 cm) malleable
- Polymer strips (density and elasticity accurately tuned) matching the profile shape are inserted to ensure that profile keep the shape during bending.
- ~ 50 profiles per day can be bent by two people



Test stand at CERN

- 50 3m long profiles bent at CERN
- One corner assembly tested at CERN few elements using home roll formed clips and home made joining bars
 - profile alignment and bending angles successfully checked
- Full set of profiles sent to Texas to be used for Module 0 and pre-constructions of I-beam structures



Clips/Profiles production schedule

- Clips production by MIFA:
 - Prototypes ready and being sent to CERN for evaluation (present week)
 - Final production in ~ 1 month from our green light
 - 800 pieces + 400 spares (large spare number driven by the requirement on shape accuracy that can be degraded during assembly: to be verified bin prototype assembly)
- Bent profiles:
 - Preferred choice is full production by MIFA:
 - if prototypes quality is similar or better than those bent at CERN
 - Full production available at CERN by early September (tbc):
 - 800 pieces + 5% of spares
 - Alternative production chain has similar schedule, but requires CERN manpower (~2 people fully dedicated to bending for one month) during summer:
 - Possible clash with single phase drift cage assembly
 - Extrusion and coating time: < 1+1 months including transport

DP FC Assembly Facilities @ CERN

- DP field cage modules assembly can be performed in EHN1:
 - In the clean room buffer (CRB) in front of the TCO
 - Vertically in a dedicated clean area (class 100000) at the ground level
- Alternatively the clean room in Bdg. 182 is being refurbished for the assembly of the 28 SP Field cage modules 3.6m long and 2.3/1.5m wide :
 - Assembled horizontally on optical table for best planarity and QA/QC tests
 - Stored and transported vertically in appropriate clean bags.
 - SP module assembly scheduled during July/August
 - All these facilities could be re-used for the assembly/storage/transport of the DP field cage modules starting from September.
- Man-power:
 - CERN will provide adequate man-power as for the SP case:
 - At least 3 people fully dedicated to field cage assembly for 1 month (1 module/day).

Material Reception and Assembly QA/QC

- Procedures described for pre-production will be strictly replicated at CERN
 - See slides 6-to-8.
 - In particular AI profiles will be inspected for deformations, surface damage, bend angle, straight segments length.
 - Conductive coating (few microns) is invisible: handling care to avoid outer surface scratches
 - Clips will be inspected for uniformity of surface shape and matching with AL profile shape
 - No cleaning required (but it will be done as described on small components in case of need).
- QC after assembly:
 - Module planarity
 - Bent segment alignment
 - Bent angle uniformity
 - Mechanical locking of profiles on supporting beams
- Transport (in case of assembly in bdg 182):
 - Dedicated supporting structures and protective bags.

Conclusions

- The protoDUNE DP DC uses the same modular concept using the same extruded aluminum profiles
- Slightly different design from SP due to the fact that field cage and the cathode hang from the ceiling
- Production/QC/QA facility at UTA is in operation
- Production readiness review documents ready
- Module-zero production in progress
- Bent profiles are being prepared at CERN for the final assembly before the installation in the cryostat
- Two final assembly facilities identified