DUνE dual-phase FD: CRP procurement

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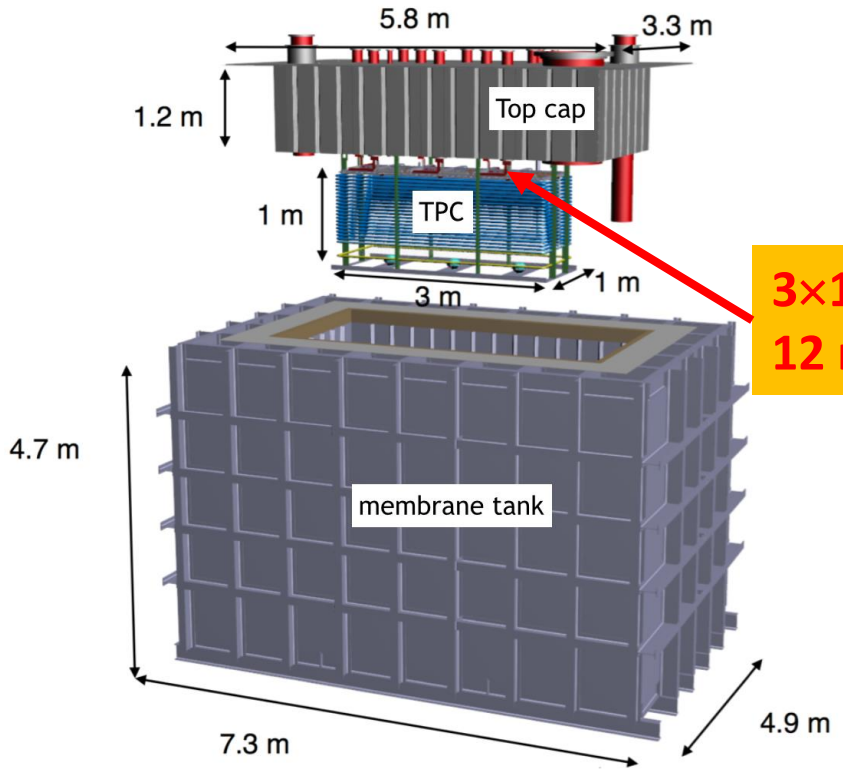
The WA105 CRP

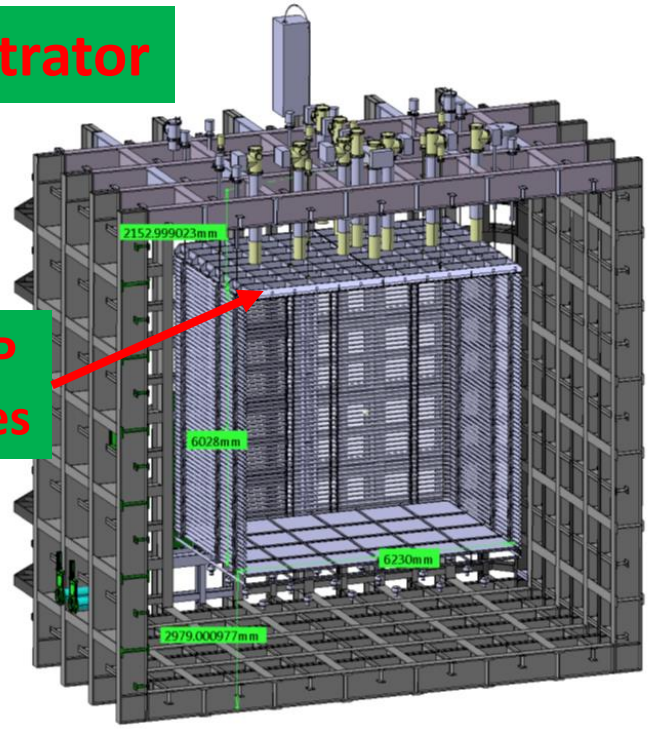
50 × 50 cm² LEM + ANODE sandwiches (2 mm gap)

The 3×1×1 m³ prototype

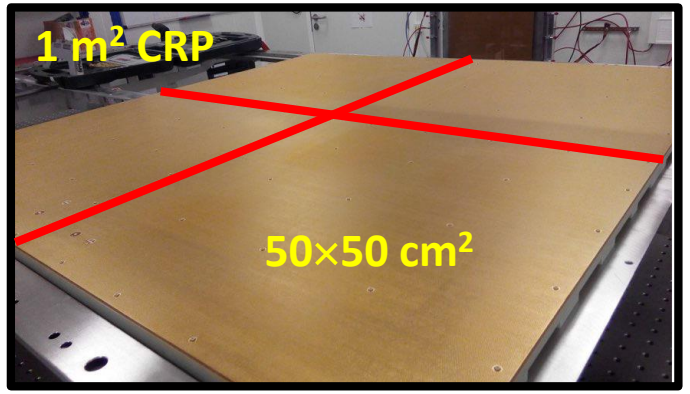


3×1 m² CRP
12 modules

WA105 demonstrator

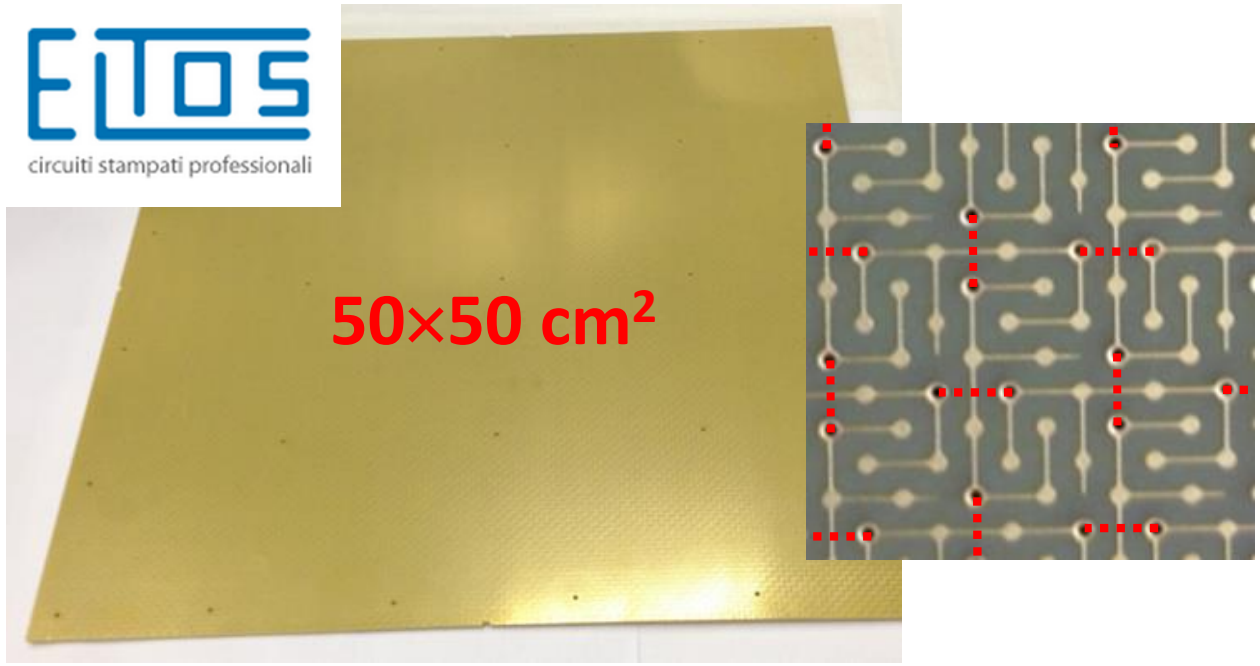


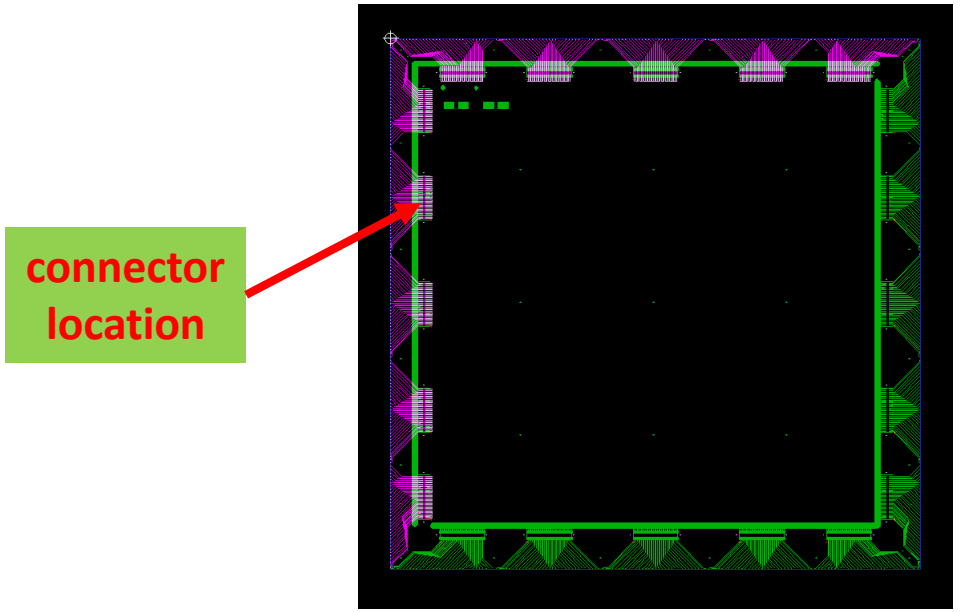
6×6 m² CRP
144 modules



The WA105 anode

- 4-layer 3.4 mm thick PCB
- X-Y symmetric readout strips
- 3.125 mm pitch
- 5×32 channels in X and in Y
- low capacitance : ~ 150 pF/m
- 6 anodes bridged together to form 3m long strips



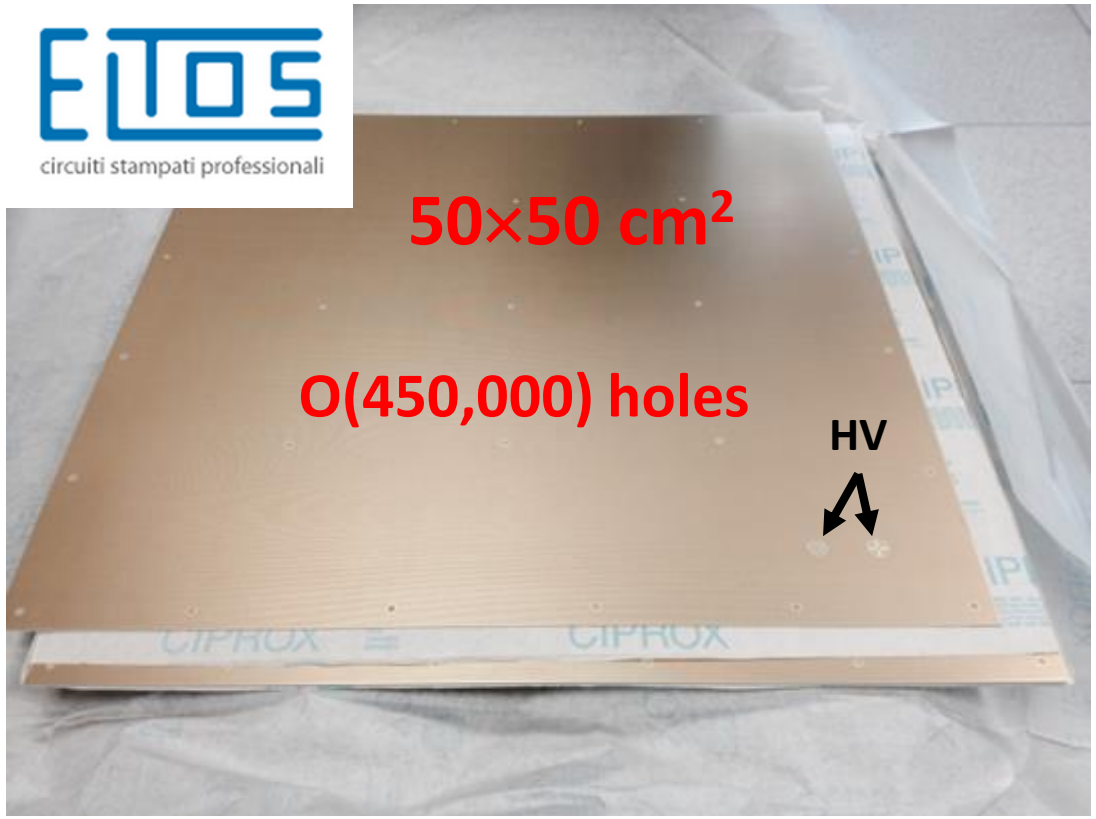


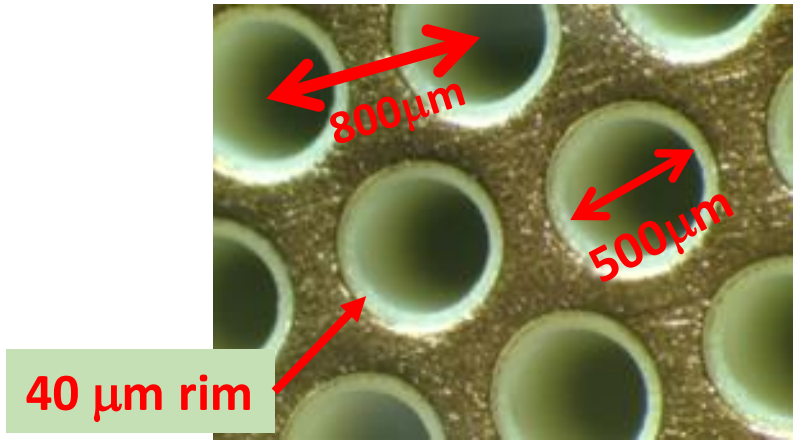
Rather standard to manufacture

The WA105 LEM

- 1 mm thick FR4 plate double-sided cladded with a passivated copper layer
- ~ 450k holes with ϕ = 500 µm
- hexagonal pattern with 800 µm pitch
- 40 µm rim to minimize discharges
- > 3kV operating HV in dual-phase LAr conditions (E > 30 kV/cm)

Careful handling and testing required





LEM QA / QC

LEMs are the most delicate part of the CRP :

- need specific and detailed QA/QC procedure during the manufacturing process in close collaboration with the industry

- several manufacturers around the world (Europe, U.S.A., India, China, etc..) can produce LEMs

WA105 experience with a 20 LEM pilot series :

By ELTOS (Italy):

1) PCB procurement
2) CNC (Computer Numerical Control) drilling
3) Polishing
4) Permanganate bath (remove residual glass fibers from holes
5) Chemical etching for rims
6) Copper passivation (chromic acid) and NI/Au plating

At CERN :

1) Ultrasonic bath with demineralized water
2) Bath at 60°C with soap to remove residual greases
3) Rinsing with demineralized water
4) 3-hour baking at 180°C
5) HV test in air @ 4kV across the 1 mm gap (< a few nA required)

None of the 20 produced LEMs was rejected

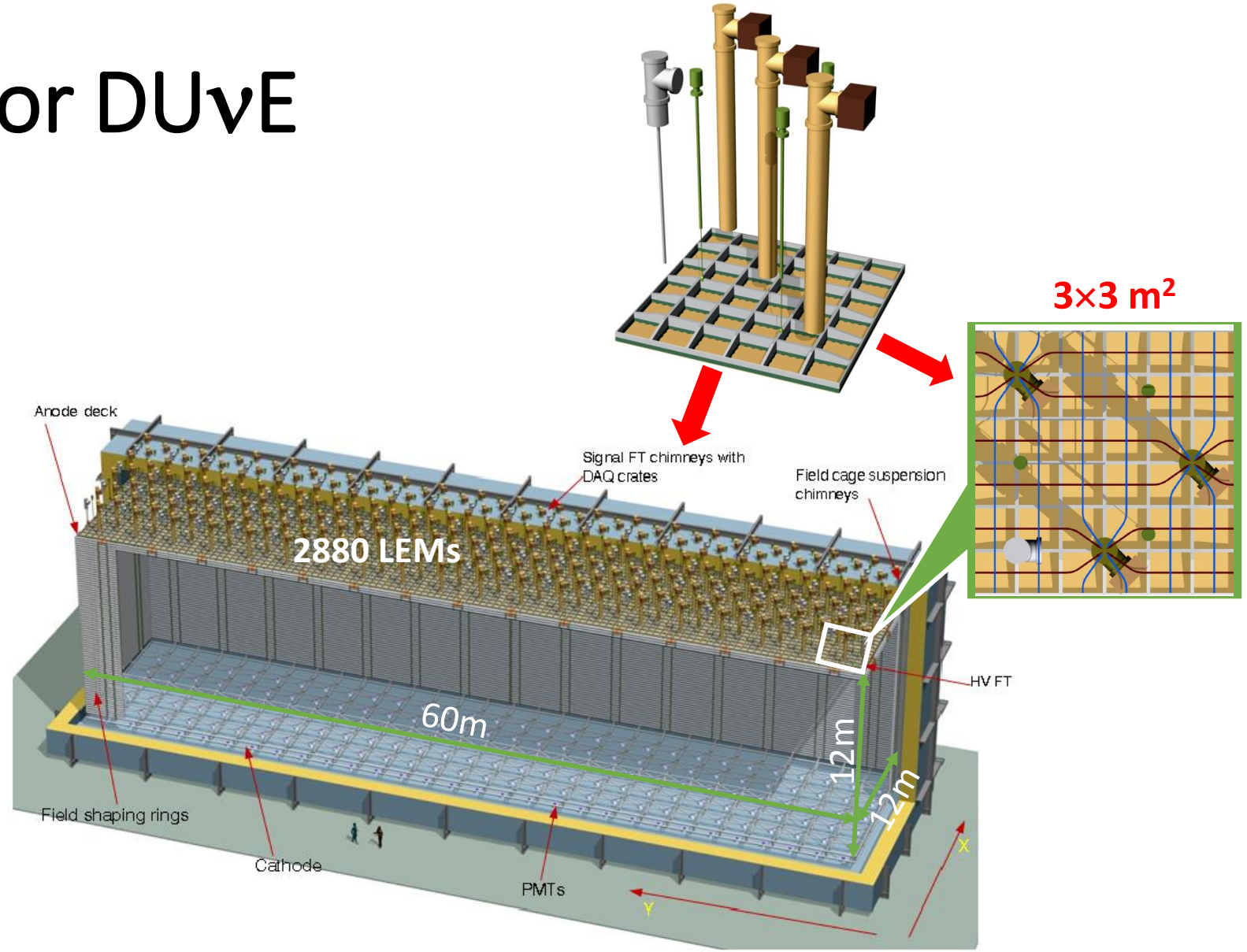
Could steps 1 to 5 above be done by manufacturer?

Additional QC Tests @CERN :

- HV tests in a clean room (air, Ar, Ar/CO_2), discharge rate measurements
- LEM thickness and 3D optical survey of holes on a few LEM samples

CRP procurement for DUνE

- 2880 LEMs for a 720 m^2 active area
- Several manufacturers needed to minimize risks
- QA/QC procedures to be set up with LEM industrial partners
- Acceptance tests in tendering process
- Search process of industrial partners for LEM production may last several months
- WA105 tendering experience for 6×6 m^2 CRP will be useful to DUνE



Production Cost and Time

- Based on ELTOS estimate for WA105 :
  - 150 anodes : 389€ / unit
  - 200 LEMs : 775€ / unit
  - total production time is about 5-7 months
- Extrapolation to a 10kt detector :
  - 3.4 M€ (without losses, pre-series, spares, …) but for a very large production of several thousands of modules, prices are likely to be significantly lower
- Current maximum production capability of ELTOS :
  - 36 modules/week based on 1 CNC drilling machine with 6 heads operating simultaneously
- With 2 or 3 PCB manufacturers, full production for a 10kt detector could realisticaly be completed in less than 2 years

A possible scenario for DUνE

- Use of several dedicated assembly sites working in parallel (Europe, USA, etc..)
- Each site assembles and tests 3×3 m^2 «super-modules» made of 36 modules mounted on a frame
- 80 super-modules for a 10 kt FD
- Assuming 4 assembly sites and a total assembly time of 2 years, then average number of super-modules to be produced is 20 at a rate of about 1 / month
- Super-modules are then shipped to SURF where they are tested and mounted on the FD detector (sealed packaging needed to protect modules from dust)
- Infrastructures needed at each site (including SURF) : storage rooms, cleaning stations, climatized clean rooms, test stations
- QC at assembly sites:
  - metrology : rim size, LEM thickness
  - HV tests in air, Ar or Ar based gas mixtures
  - test benches : cosmic rays, X-rays or radioactive sources
  - test of module samples in dual-phase LAr conditions