Politecnico di Bari

The electric field in the T2K TPC

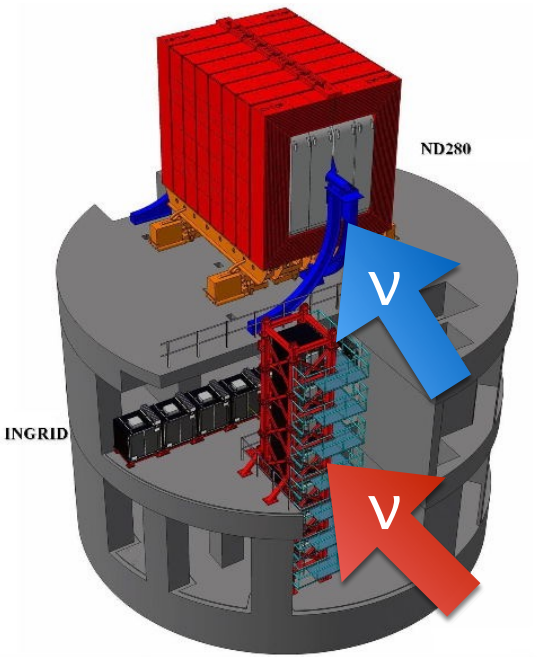
L. Magaletti, E. Radicioni

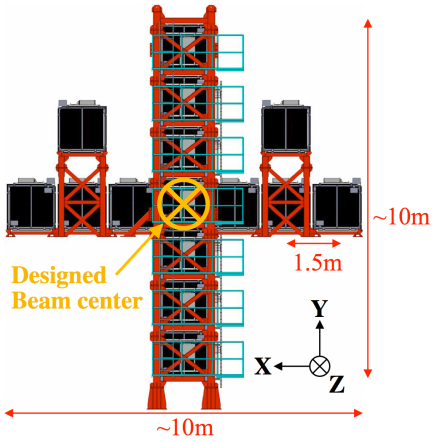
INFN Istituto Nazionale di Fisica Nucleare Sezione di Bari

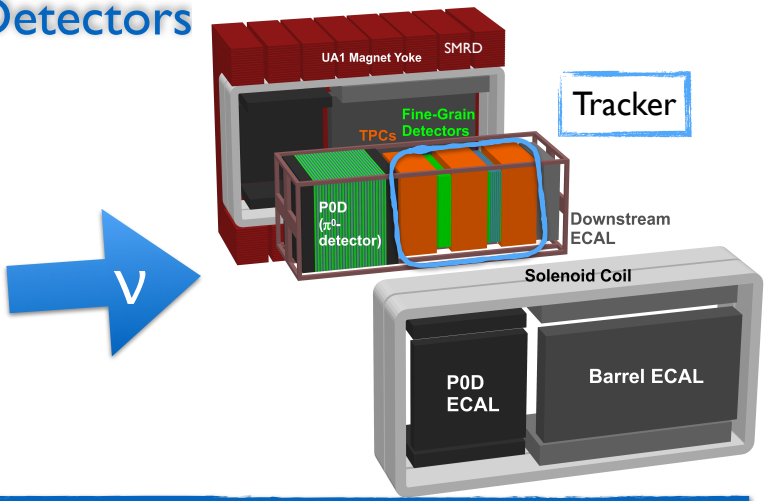
Overview

- The ND280 detector and its upgrade
  - The "Old" T2K field-cages
  - The "new" field-cages
- E field simulations with COMSOL
- Main goals for the new field cages:
  - **E field uniformity up to 10^{-4}**
  - **E field dis-uniformity $\leq$10 mm from field strips**

Near Detectors







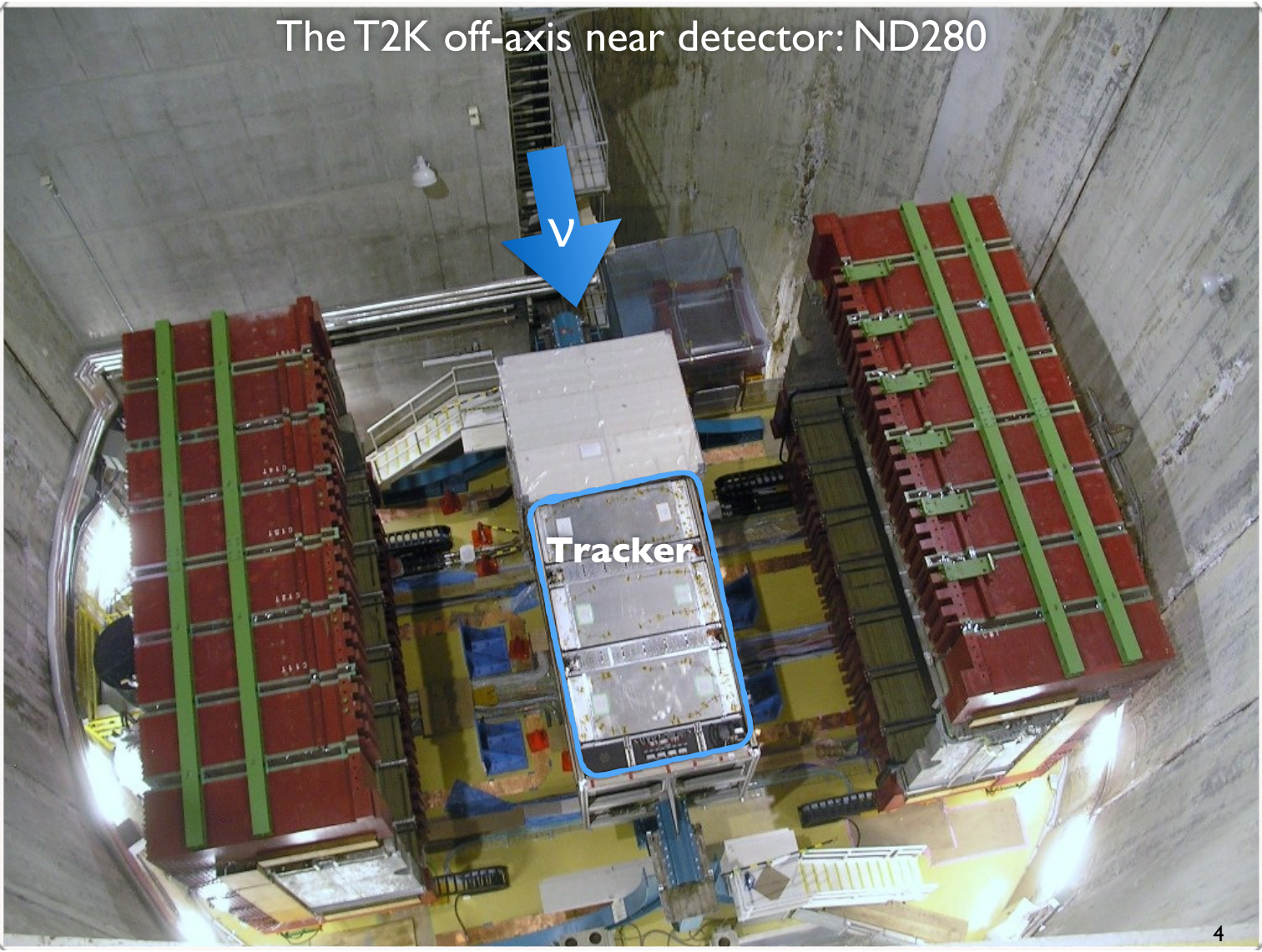
ND280 (off-axis)

- **Magnet:** B = 0.2 T
- **TPC:** p measurement + particle-ID with dE/dx
- **FGD:** Fine-grained detectors (2 x 0.8 t) → FGD1 (C), FGD2 ($C+H_2O$)
- **SMRD:** magnetized muon range detector
- **P0D:** pi-zero detector (Pb/brass-H_2O-scintillator)
- **ECal:** electromagnetic calorimeter

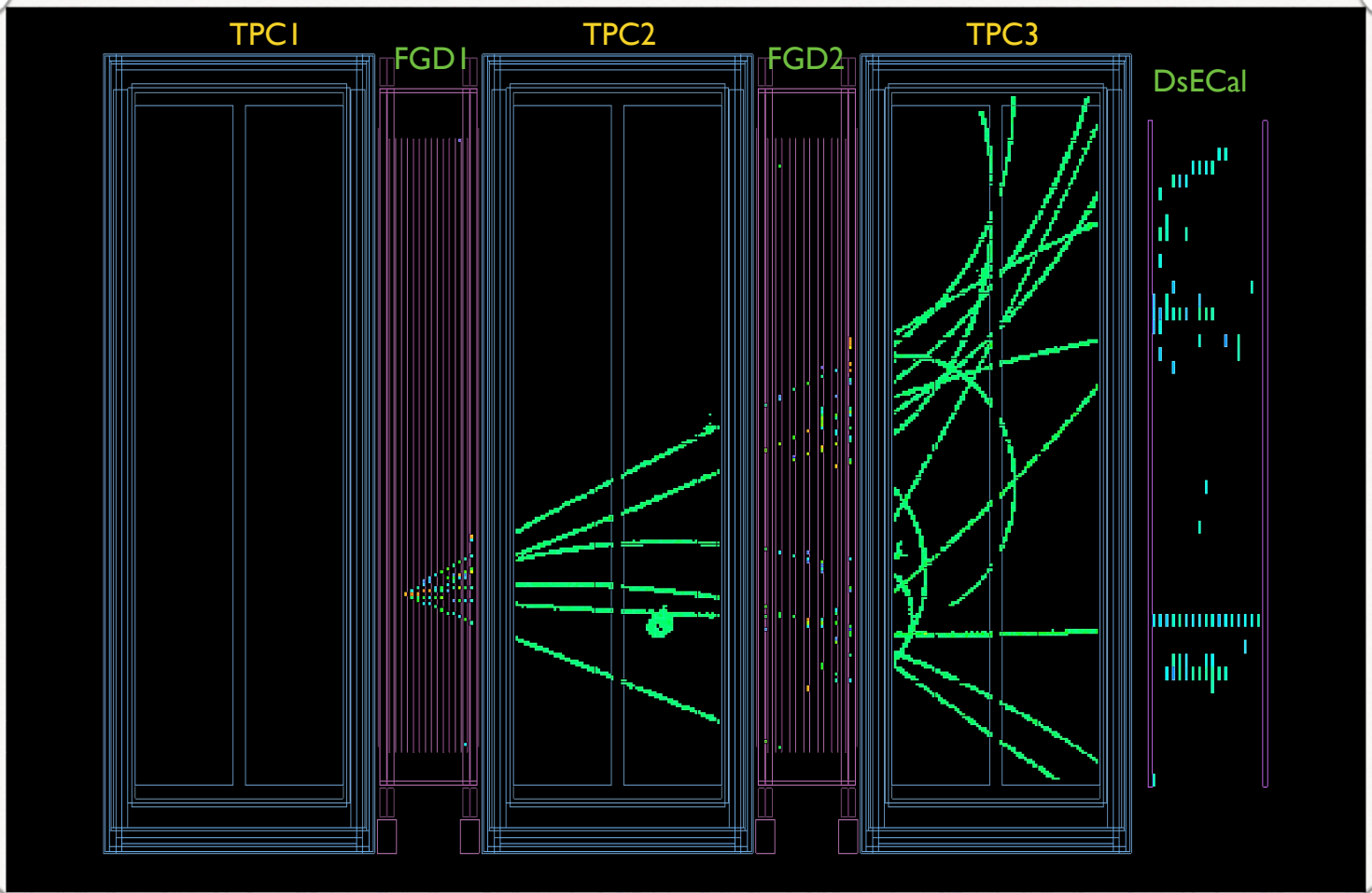
INGRID (on-axis)

- **ν_μ CC rate → monitor beam profile and stability**
- **Fe/Scintillator tracking calorimeter** (16 Fe/Scint modules + 1 central one made of scintillator only)

The T2K off-axis near detector: ND280



The ND280 tracker



The "Old" T2K field-cages

- create panels from rohacell + Cu-clad G10 foils and G10 bars
- cut field-shaping strips by milling the Cu surface
  - only 1 strip layer → larger volume wasted because of distorted field
  - ... but easy construction

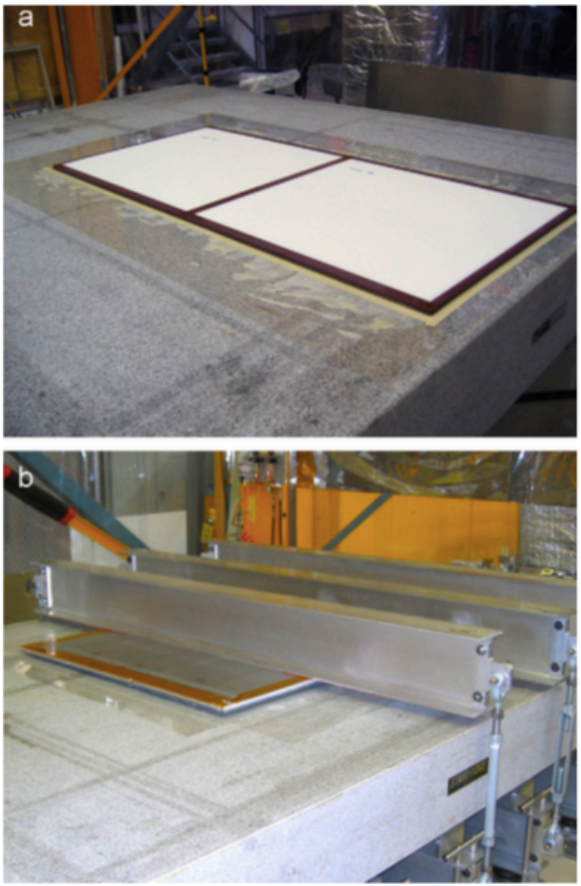
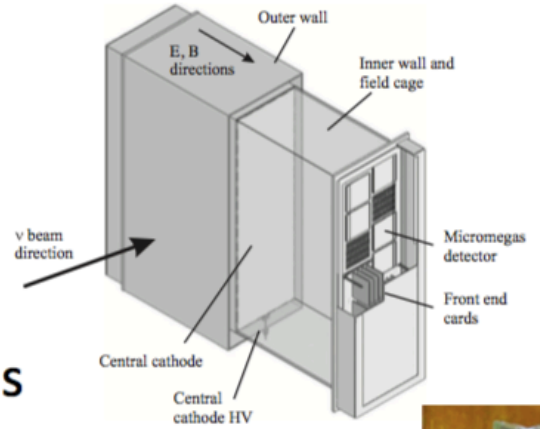
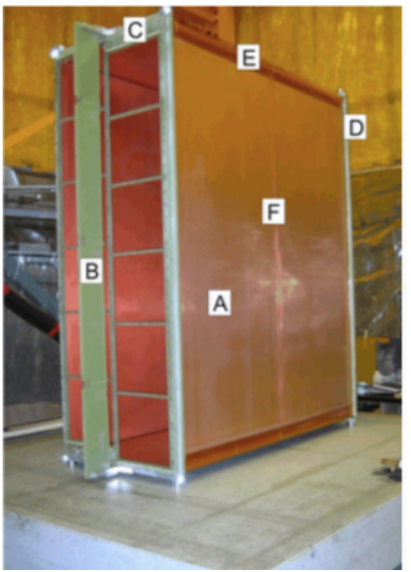


Fig. 4. An inner box panel being laminated. The central FR5 bar provides a solid mounting point for the cathode.

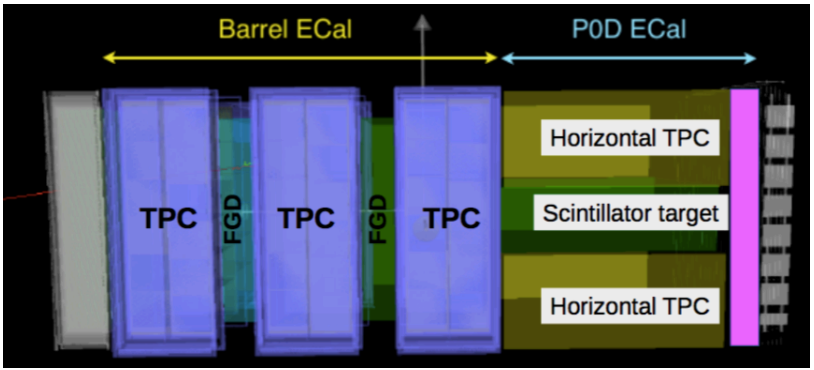
The "Old" T2K field-cages

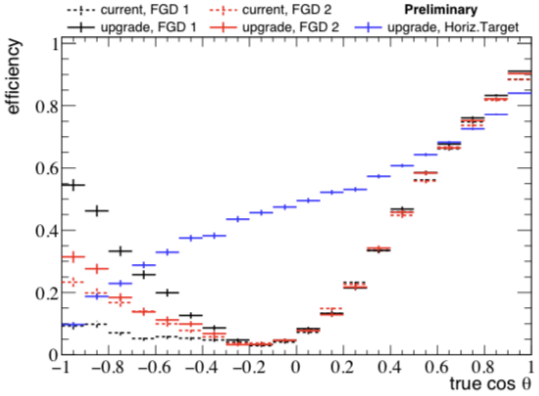
- dual gas volumes
  - outer: CO_2 for insulation
  - inner: active
  - inner field-cage panels must not
    - degrade the E field
    - provide gas tighness
    - stand overpressure



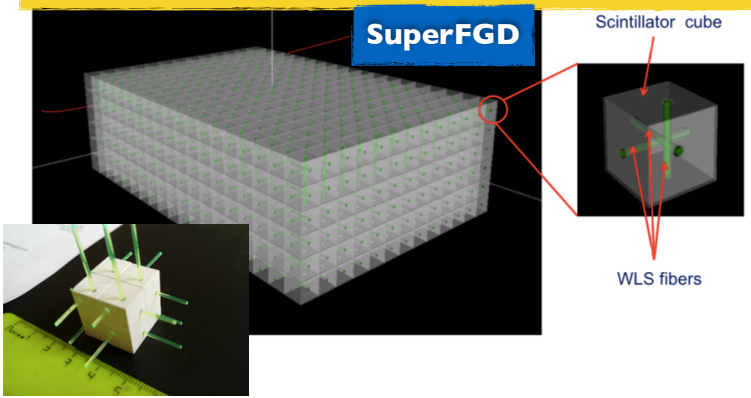


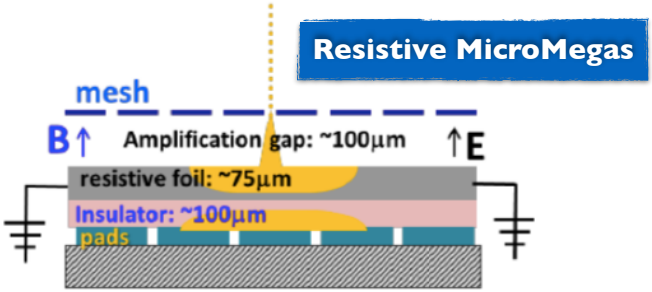
ND280 upgrade design



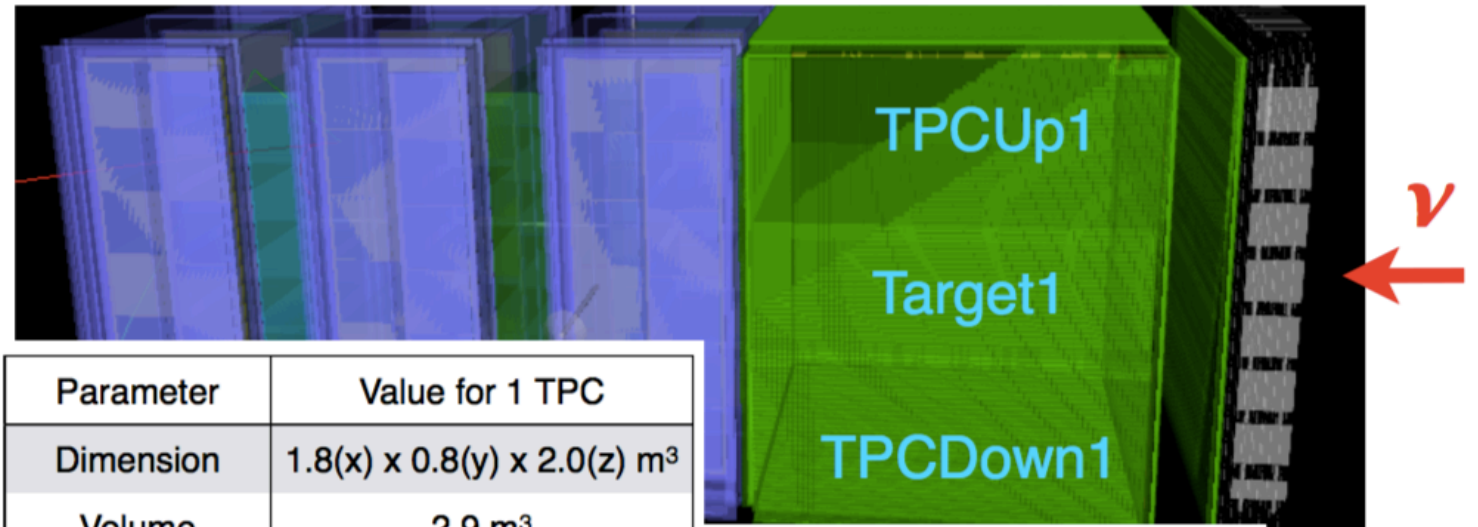


- Goal of the upgrade project: replace the P0D with an **horizontal totally active target** (SuperFGD) and **2 horizontal TPCs** equipped with resistive MicroMegas by 2021
- Increase the current phase-space and reduce the cross-section systematics
- Currently working on R&D and prototypes + simulations

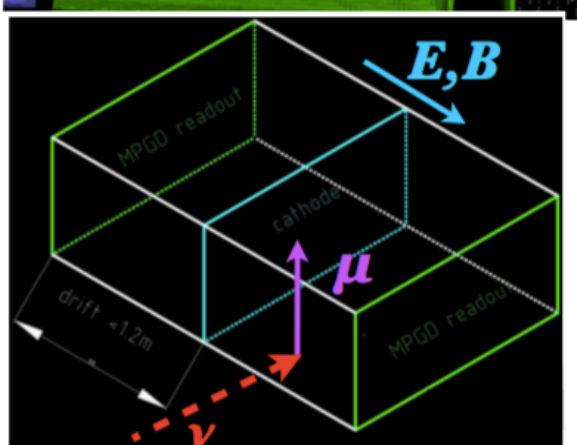




"New" field-cages



Parameter	Value for 1 TPC
Dimension	1.8(x) x 0.8(y) x 2.0(z) m^3
Volume	2.9 m^3
Drift Length	90 cm
Pad area	~1 cm^2 (~2 cm^2 resistive MM)
Sensitive area	3.2 m^4
# MM	16 (50x50 cm^2 each MM)
# channels	$3.2x10^4$



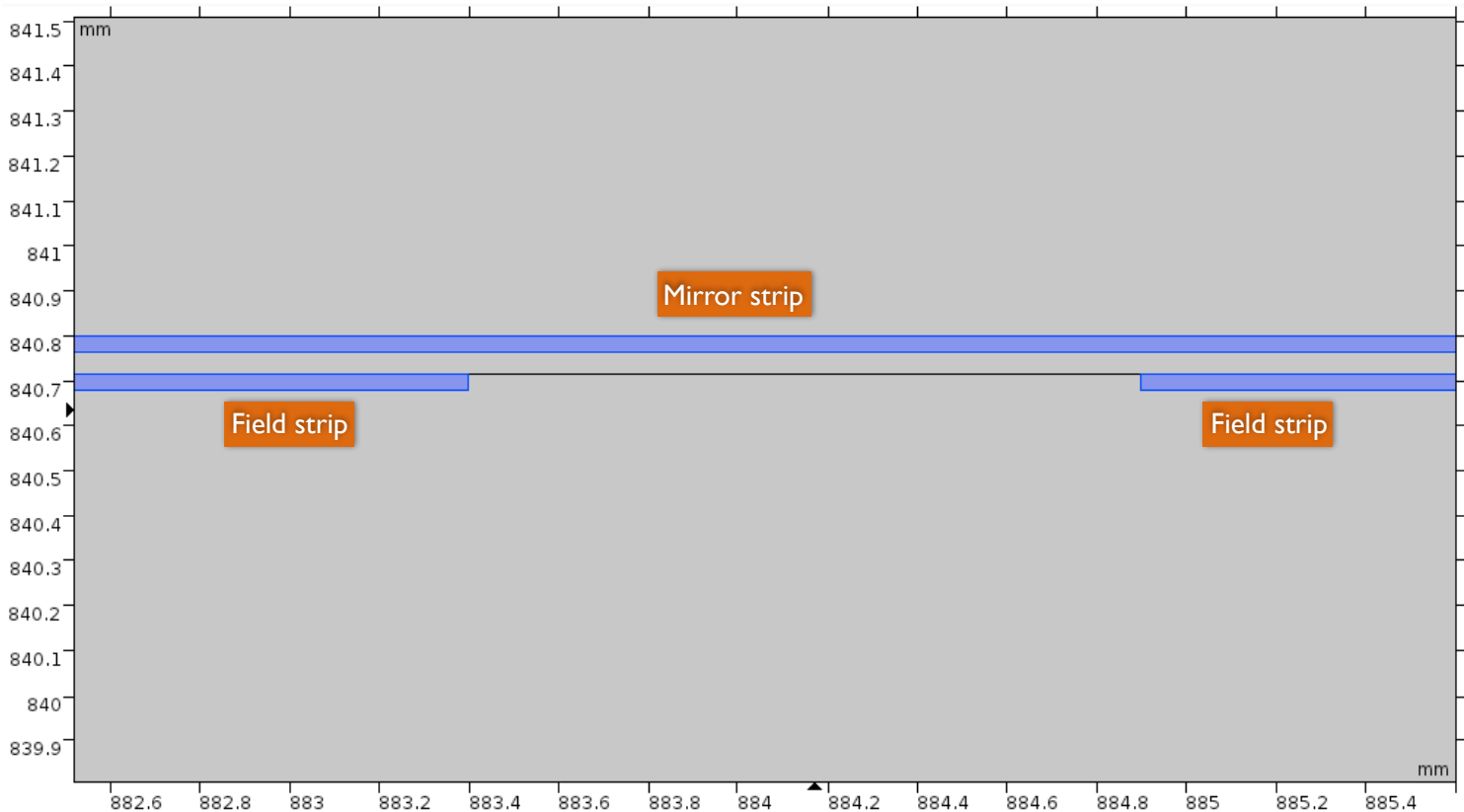
"New" field-cages

- no outer volume: one structure must do:
  - Electrostatic insulation
  - gas tightness
  - overpressure
- with minimal wasted volume
  - thin
  - light
  - multiple strip layers
- light + thin + overpressure + own weight → panel deformation → E-field dis-uniformity

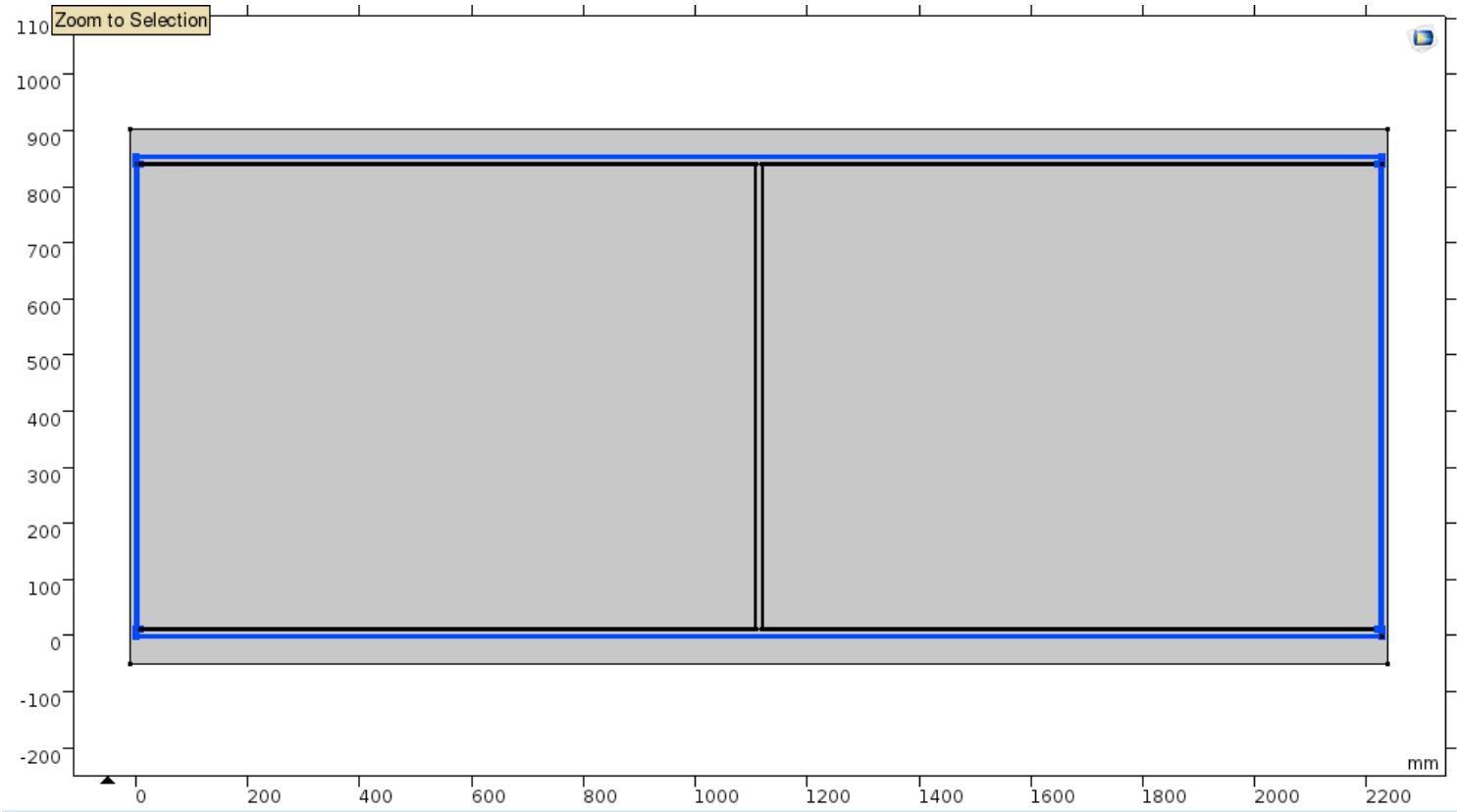
Parameters used

- Field cage wall thickness: 13.2 mm (inner box of current TPCs)
- Strips length: 10mm
- Strips pitch: 11.5 mm
- Strips width: 35 µm
- Resistors between strips: 20 MΩ
- Number of field strips on each side: 95 (97 with the half strips at the cathode and anode)
- Number of mirror strips on each side: 96
- $V_{cathode}$ = -24 kV
- V_{anode} = 0 V
- R_{TOT} = ~1900 MΩ
- i = ~13 µA
- Voltage drop between neighbour field strips = 250 V
- Voltage drop between neighbour mirror strips = 250 V
- Voltage drop between neighbour field strip and mirror strip = 125 V

Field cage design: mirror strip



Grounds


Zoom to Selection
1100
1000
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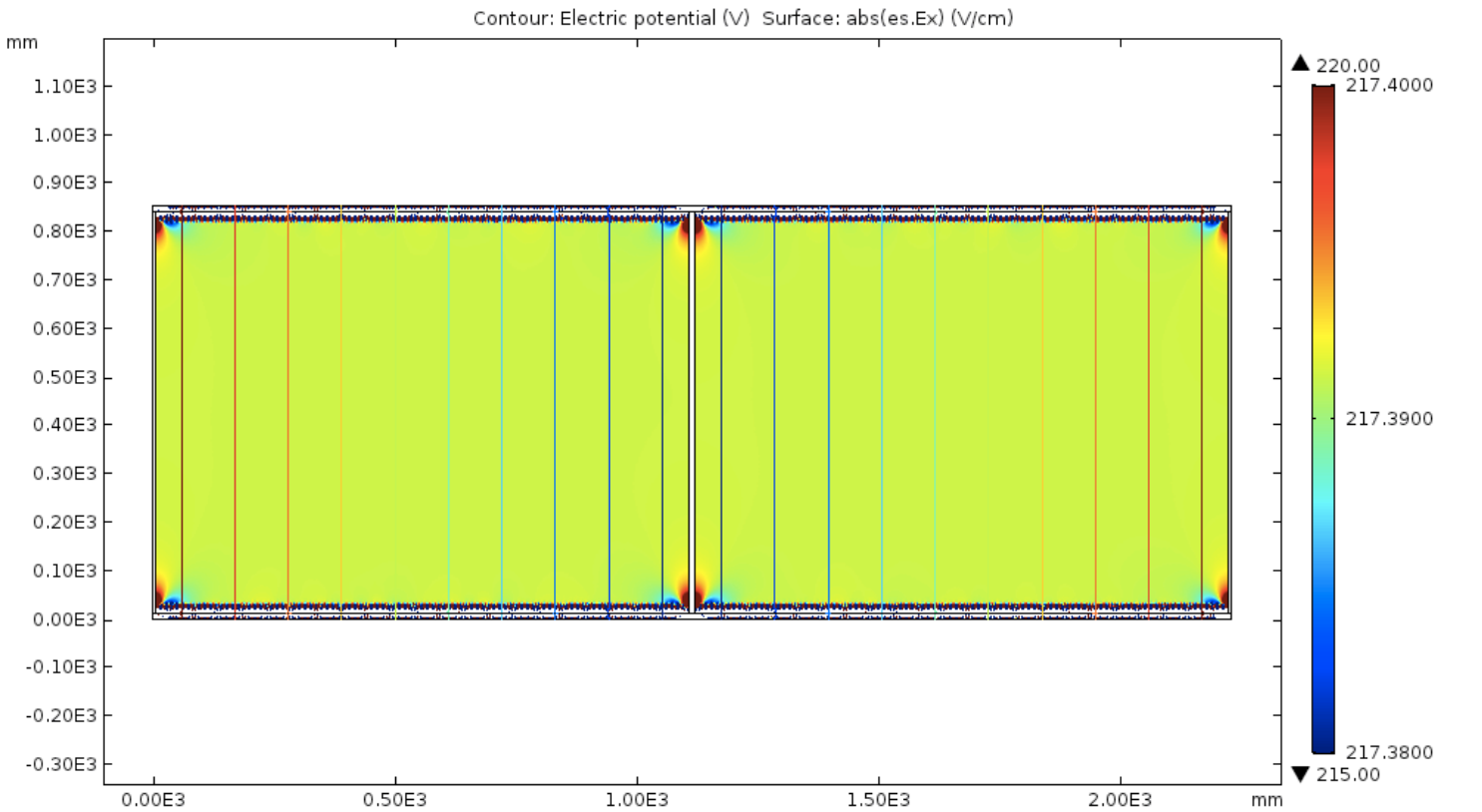
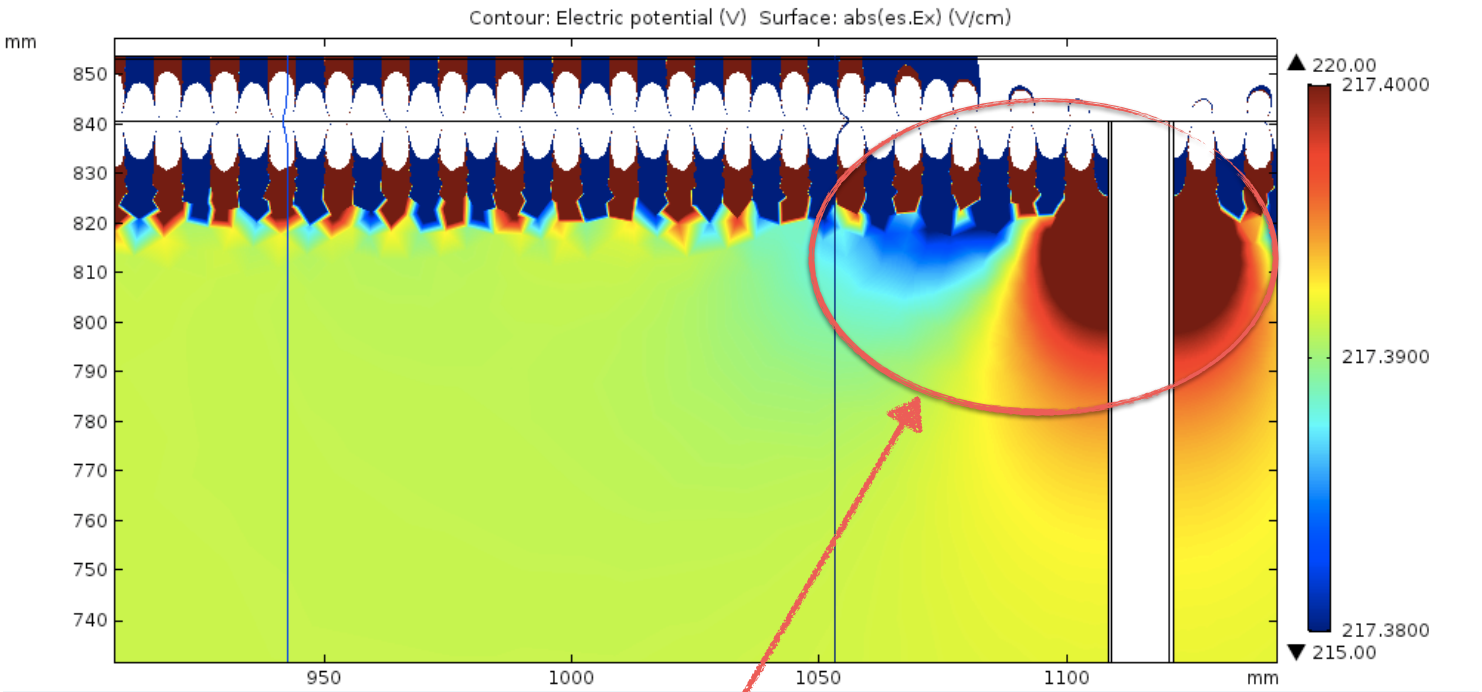
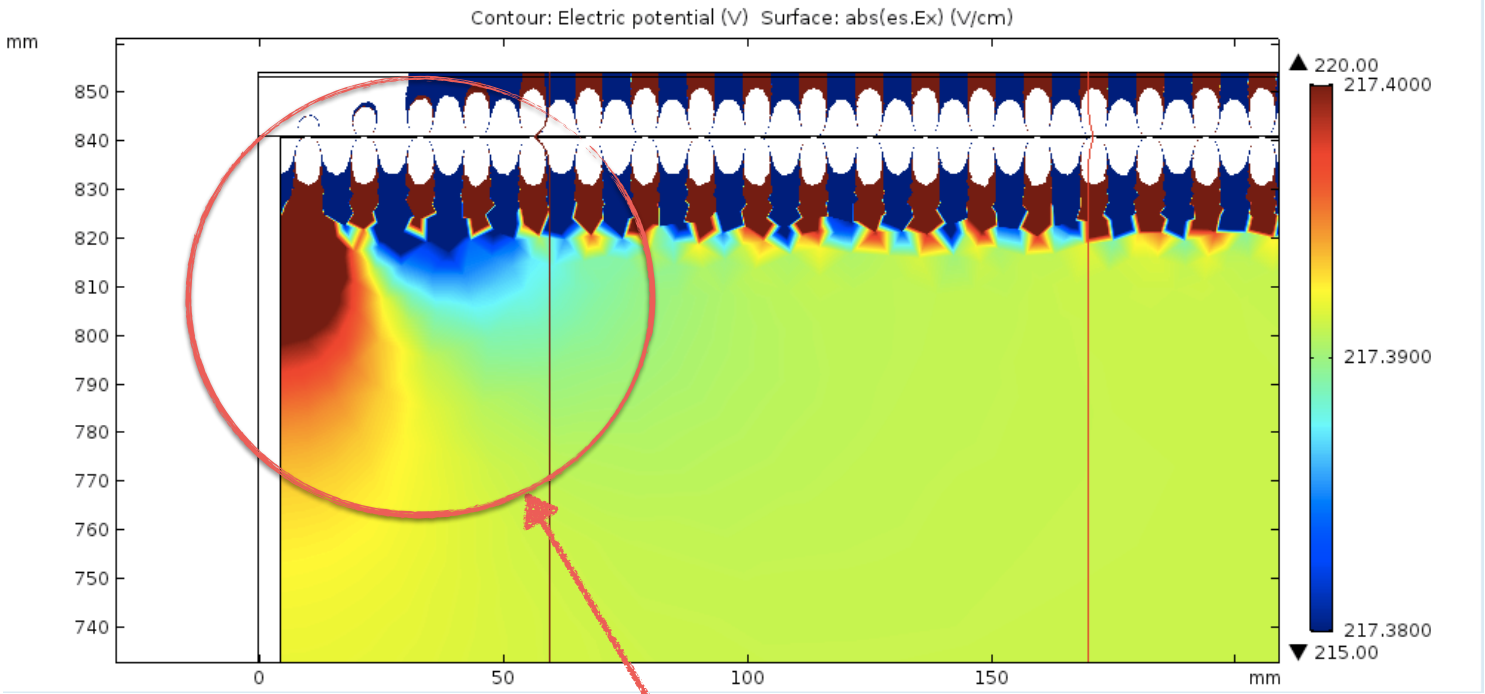
1600
1800
2000
2200
mm



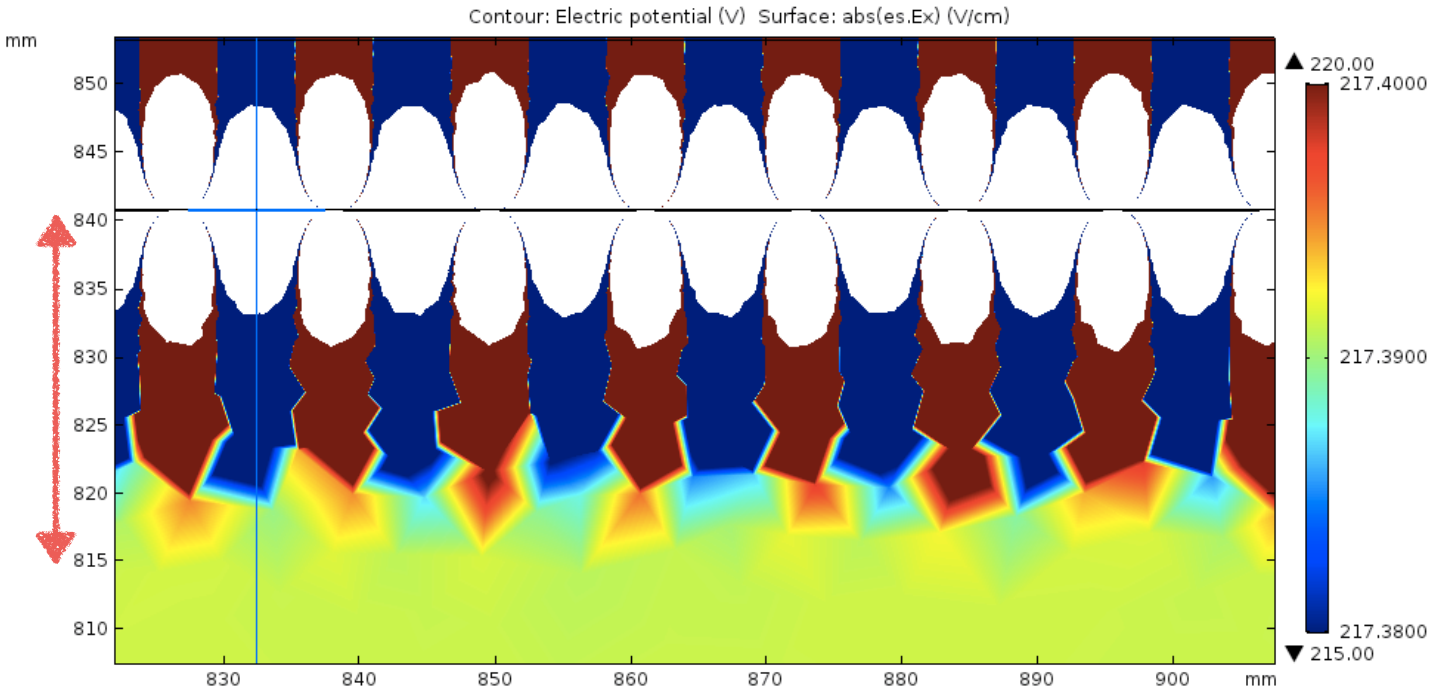
Good E field uniformity up to 10^{-4} in the middle



Huge E field distortion near the cathode as expected



Huge E field distortion near the anode as expected

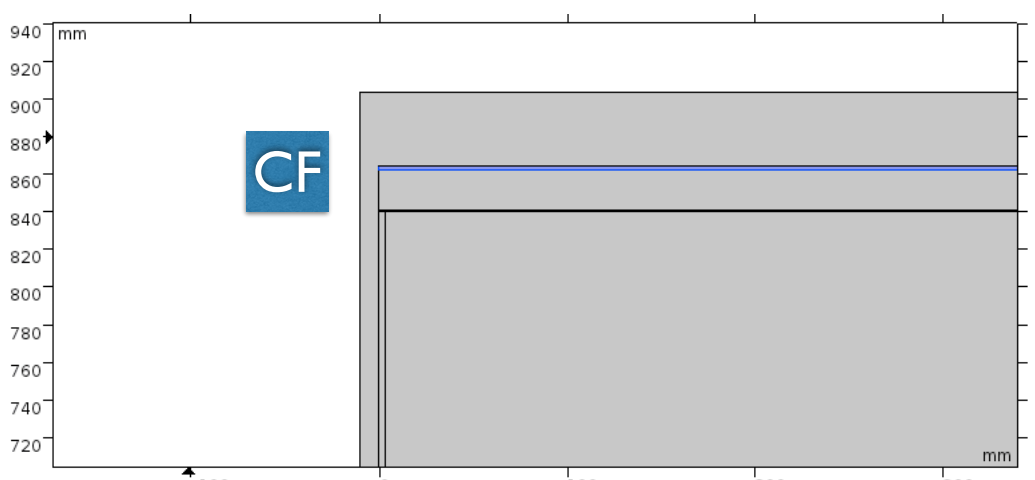


E field not uniform up to ~ 25 mm from the field strips!
(in agreement with T2K TPC TDR)

ILC-TPC like + 2 mm of CF layer with decreased strip pitch

Field cage wall parameters

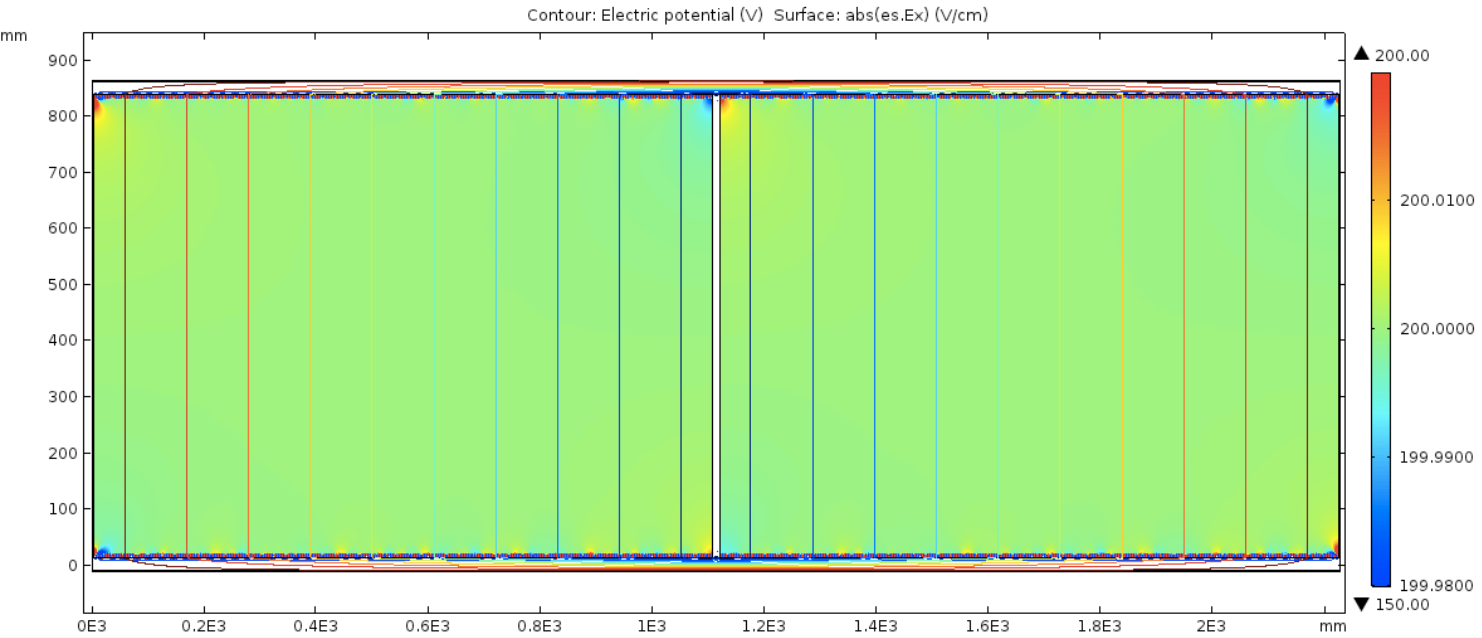
Wall Layers	Thickness	Relative permittivity
Copper shielding	0.01	$1e^{10}$
Polyimide substrate	0.05	3.4
CF prepreg fabric 0/90	2	2.7
Honeycomb	21.5	3.6
GRP	0.3	4.5
Polymide insulation	0.125	3.4
Mirror strips	0.035	$1e^{10}$
Polyimide substrate	0.05	3.4
Field strips	0.035	$1e^{10}$



Parameters used

- **Strips length: 4 mm**
- **Strips pitch: 5 mm**
- Strips width: 35 μm
- Number of field strips on each side: **220** (**222** with the half strips at the cathode and anode)
- Number of mirror strips on each side: **221**
- $\mathbf{V_{cathode} = -22100\ kV}$
- $\mathbf{V_{anode} = 0\ V}$
- Voltage drop between neighbour field strips = 100 V
- Voltage drop between neighbour mirror strips = 100 V
- Voltage drop between neighbour field strip and mirror strip = 50 V

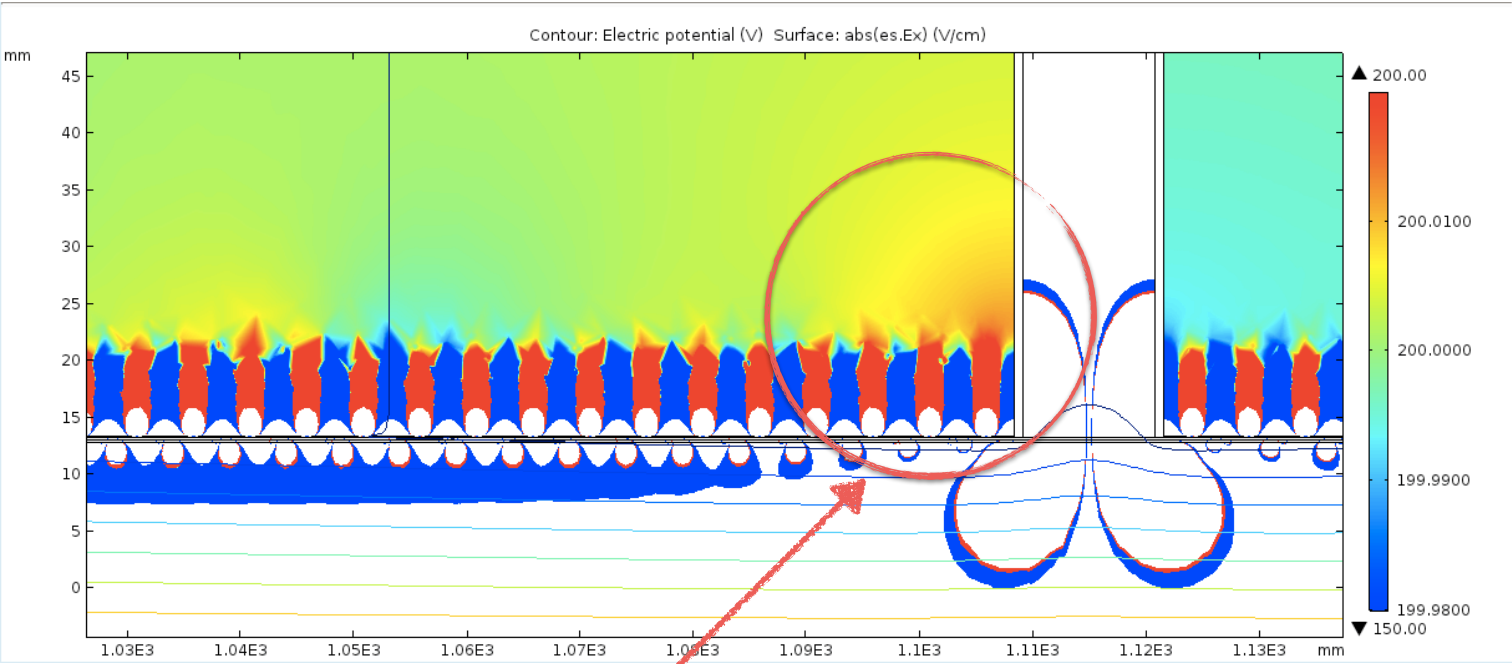
Results



Equipotential lines perfectly aligned!

Good E field uniformity up to 10^{-4} in the middle

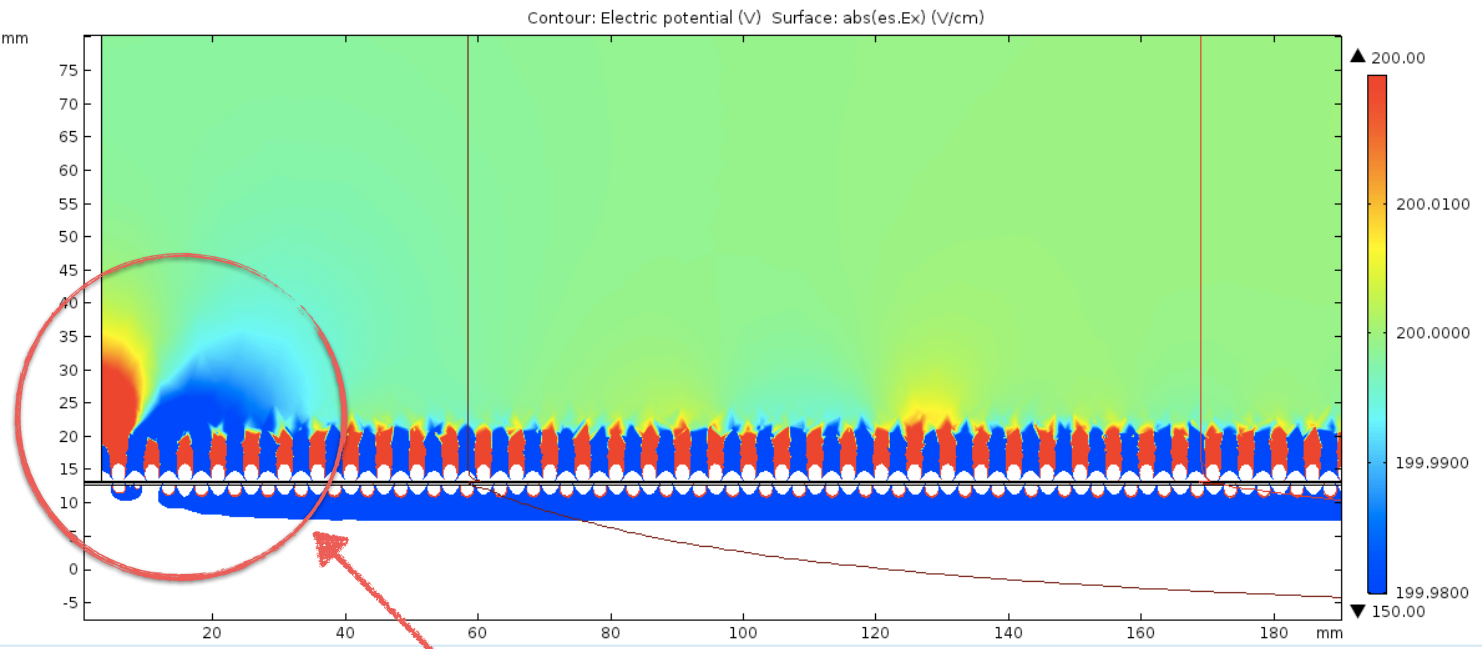
E Field near the cathode



Large E field distortion near the cathode as expected

But already lower than previous configuration!

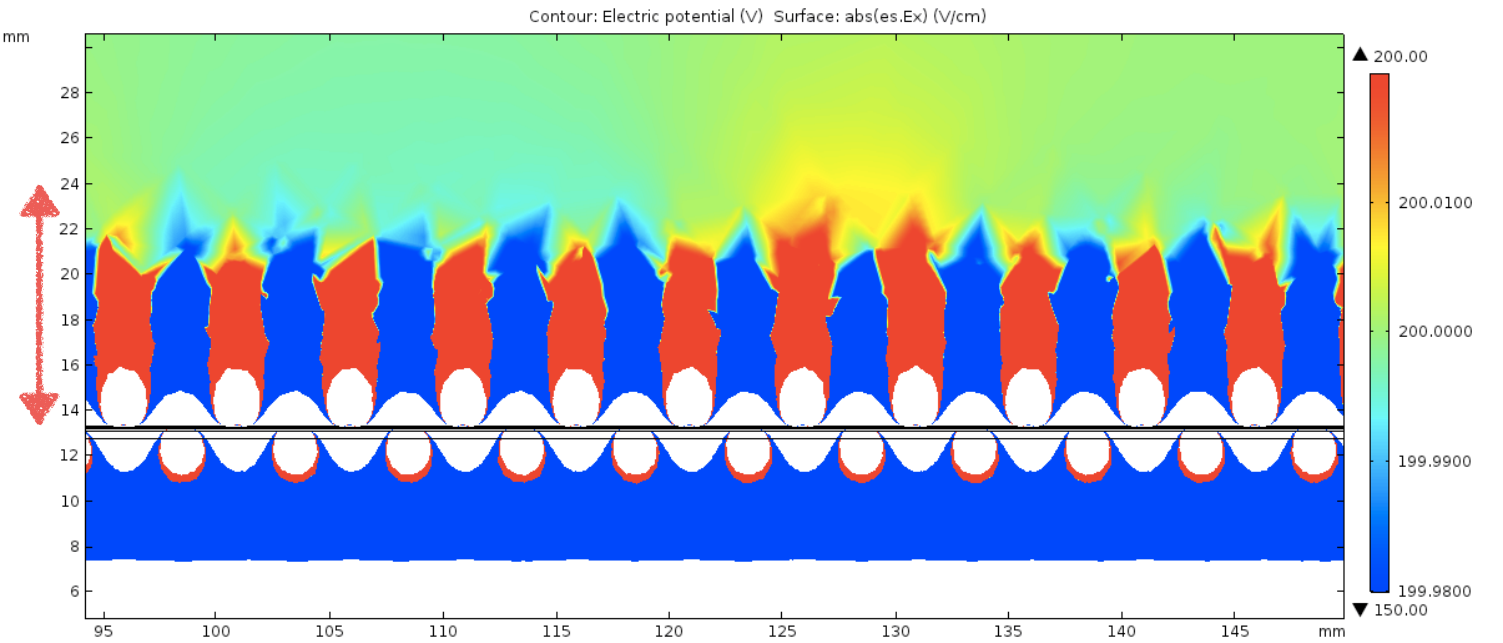
E Field near the anode



Large E field distortion near the anode as expected

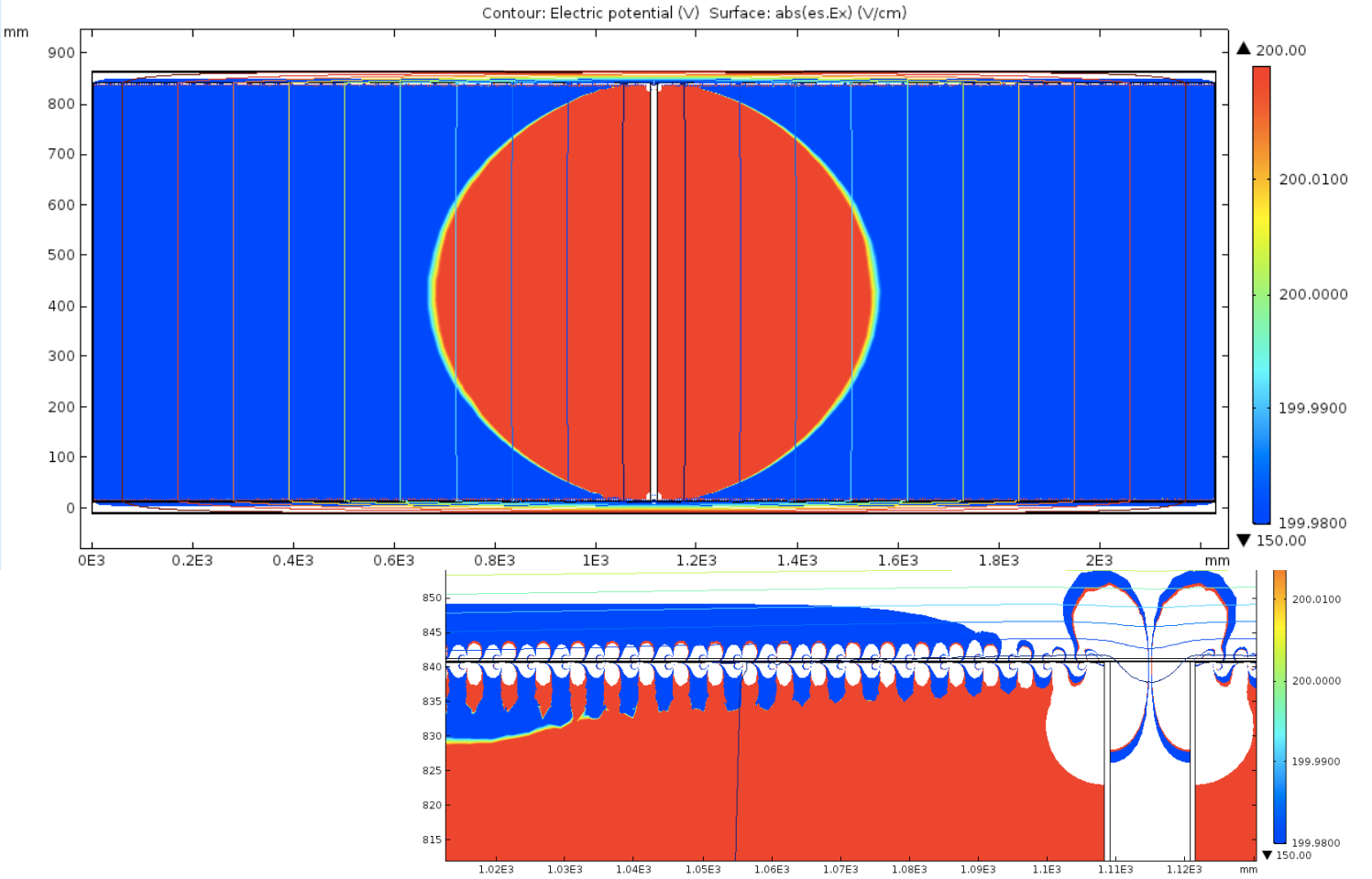
But already lower than previous configuration!

E Field close to the field cage wall



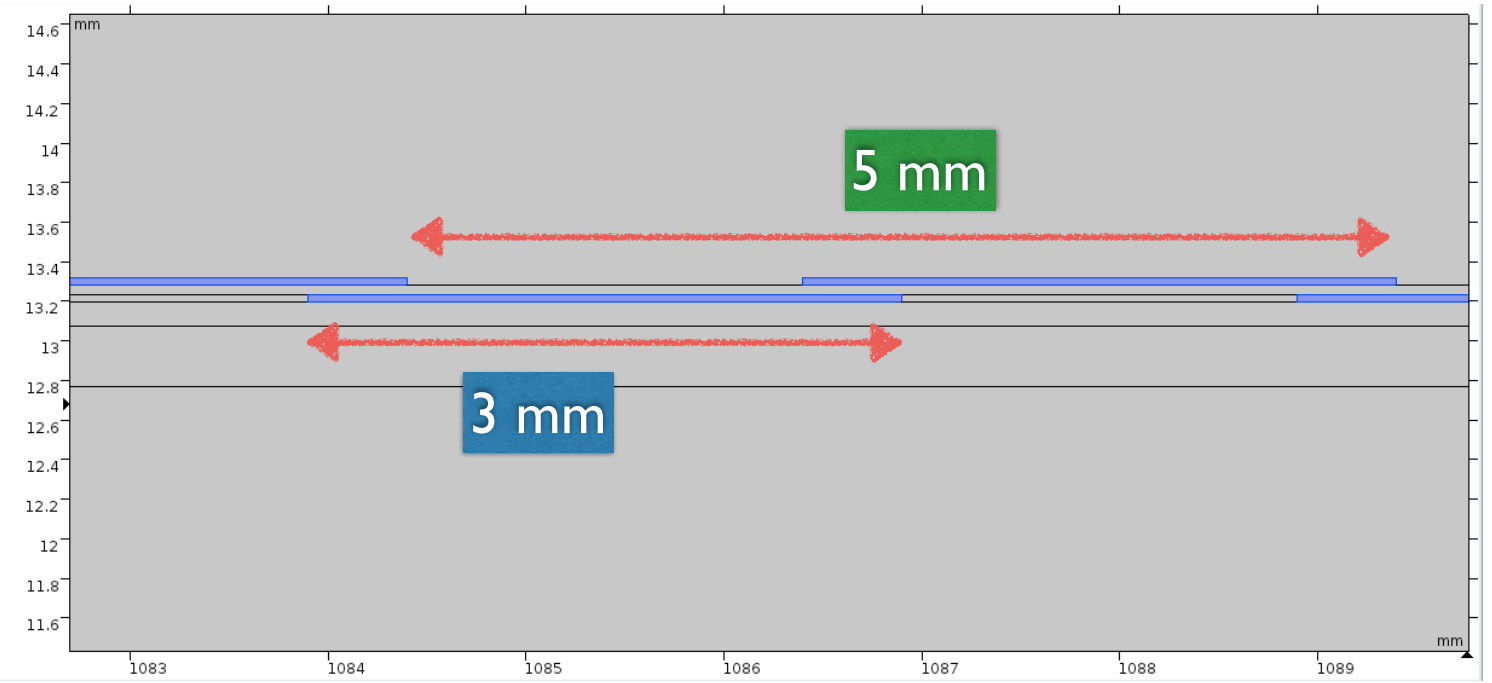
E field not uniform up to ~ 10 mm from the field strips much better than previous configuration!

What happens if we don't use mirror strips

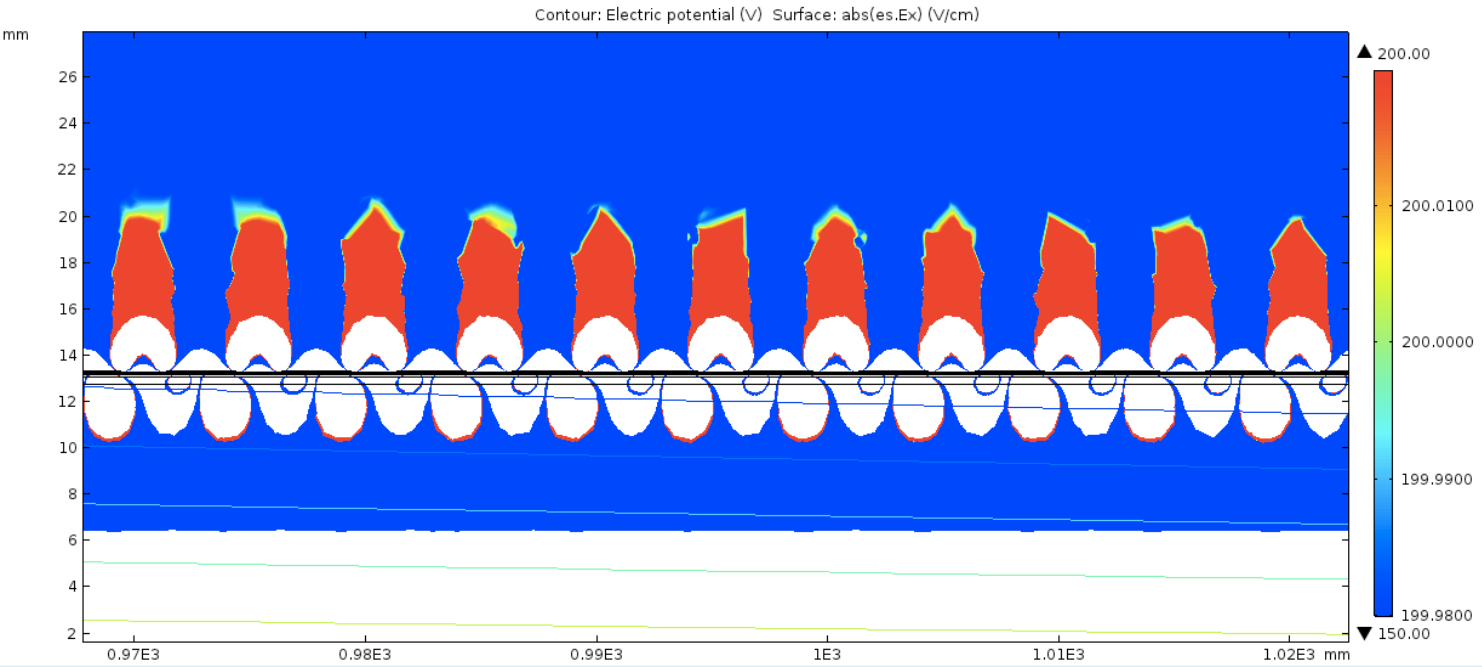


Huge E field distortion is expected

3mm Strip width (same 5 mm pitch)


mm
14.6
14.4
14.2
14
13.8
13.6
13.4
13.2
13
12.8
12.6
12.4
12.2
12
11.8
11.6
5 mm
3 mm
1083
1084
1085
1086
1087
1088
1089
mm

New Results



E field not uniform lower than 10 mm from the field strips!
Very promising configuration!

Conclusions

- Tested modified strips width and pitch for the new T2K field-cages
  - E field non uniformity region **decreased from ~25 mm to ~10 mm** near the field strips if we use **5 mm pitch (4 mm strip width)**
  - Probably **better results (non uniformity region lower than 10 mm)** can be achieved if we use **5 mm pitch (3 mm strip width) => Study ongoing**
- Different Field cage wall structures tested
  - **no significant changes observed** if we change GRP (from the ILC-like design) to CF (backup)
- next steps on this work: **3D corners simulations** => Crucial in order to study how much can be decreased the E field dis-uniformity in that region
- Test beam foresee for August-September 2018