Status and plans for the anode and LEM for CRP 3 and 4

ETHZ group

WA105

ETH Zürich

Summary from last meeting

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1) ETHZ will get in touch with ELVIA in order to produce two LEMs CFR-34 and two LEMs of a new design.

2) Electrostatic simulations will be reported during a Vidyo meeting to be held on January 19th. If possible, results from the LEM-anode sandwich surveys leading to an optimization of the number of pillars will also be presented (pending availability of the CERN metrology group). Based on this, ETHZ will propose modifications to the anode (taking into account experience from the 3x1x1) and LEM designs.

The minutes on EDMS from last meeting are incorrect and need to be updated

Motivation

Due to the limitations of the 3x1x1 pulsing system, a calibration of all the channels was not possible:

- Only able to pulse in groups of 32 channels
- The cabling of the pulsing system introduced additional electronic noise inside the detector.
- The pulsing system installation was difficult, time consuming and it is not easily extrapolated to a 3x3 m^2 CRP (for example, would need an extra patch panel that distributes the signal to all together 60 KEL connectors on the anodes).

What do we want?

A system that does an absolute calibration and test the linearity.

The 3x1x1 pulsing system schematics

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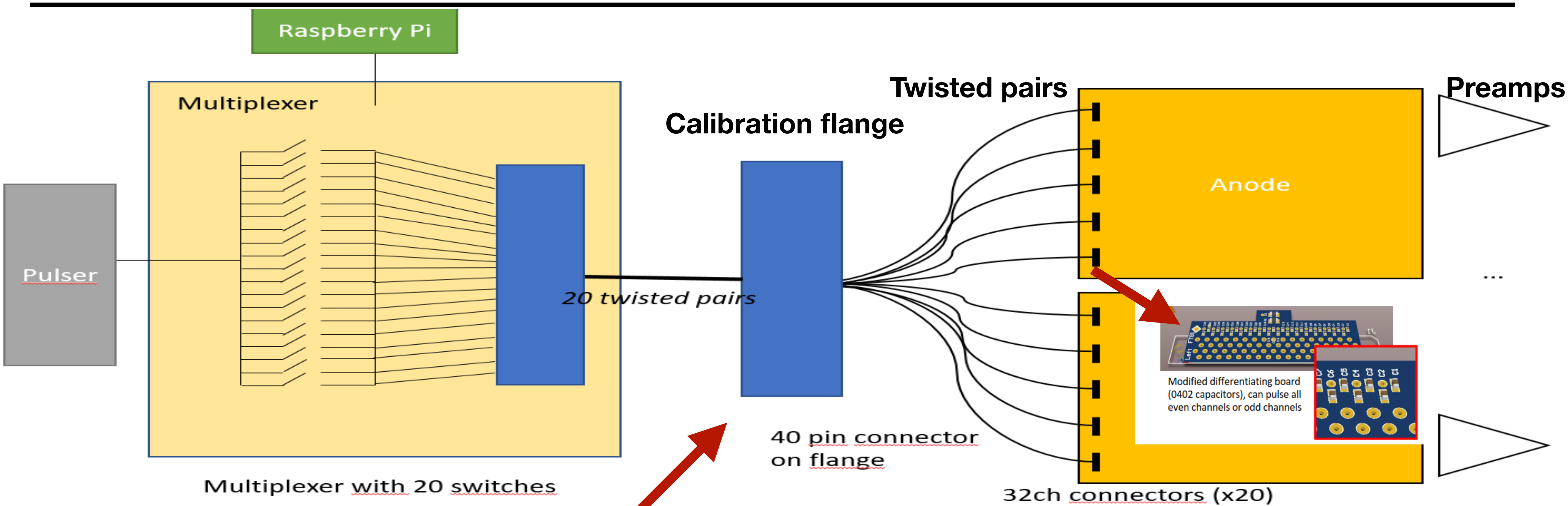
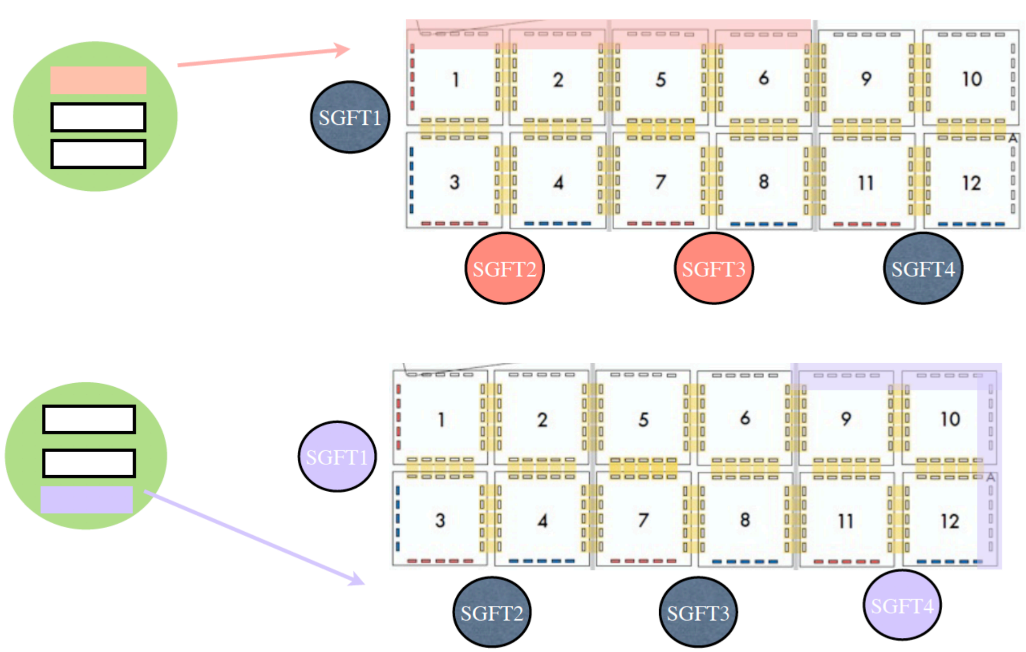
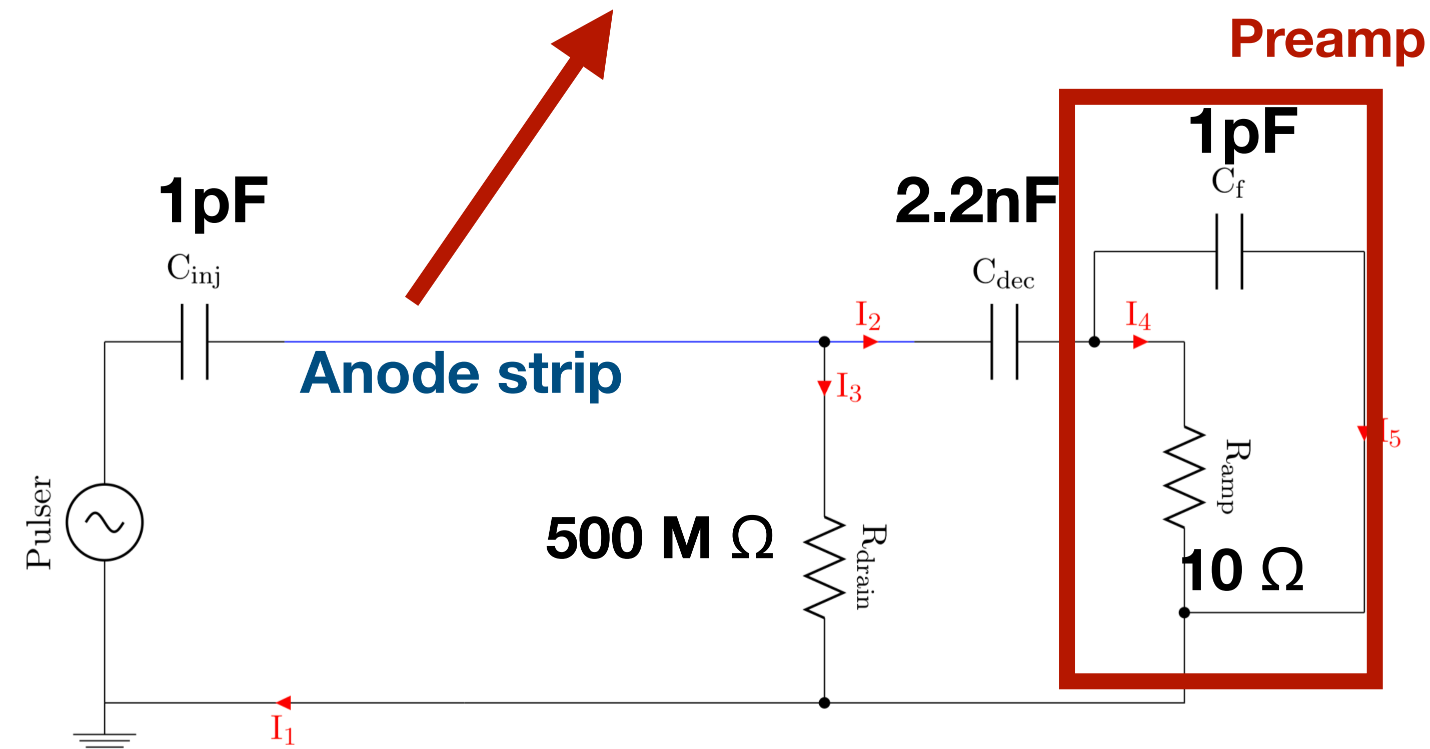


Calibration flange distribution





Simplified pulsing equivalent circuit to one anode strip

A new improved pulsing system

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- **The system implemented on the 3x1x1 was not optimal:**
  - By pulsing simultaneously 32 channels, a channel by channel calibration can not be performed.
  - The external cabling of the pulsing system (even though shielded) was introducing an important source of electronic noise.

Minimal requirements

- The possibility to independently pulse the odd and even channels of each connector.

In order to implement these modifications with a 3x1x1 pulsing system design we would need additional cables from the feedthrough, modify the PCB, doubling cables to pulse odd and even…

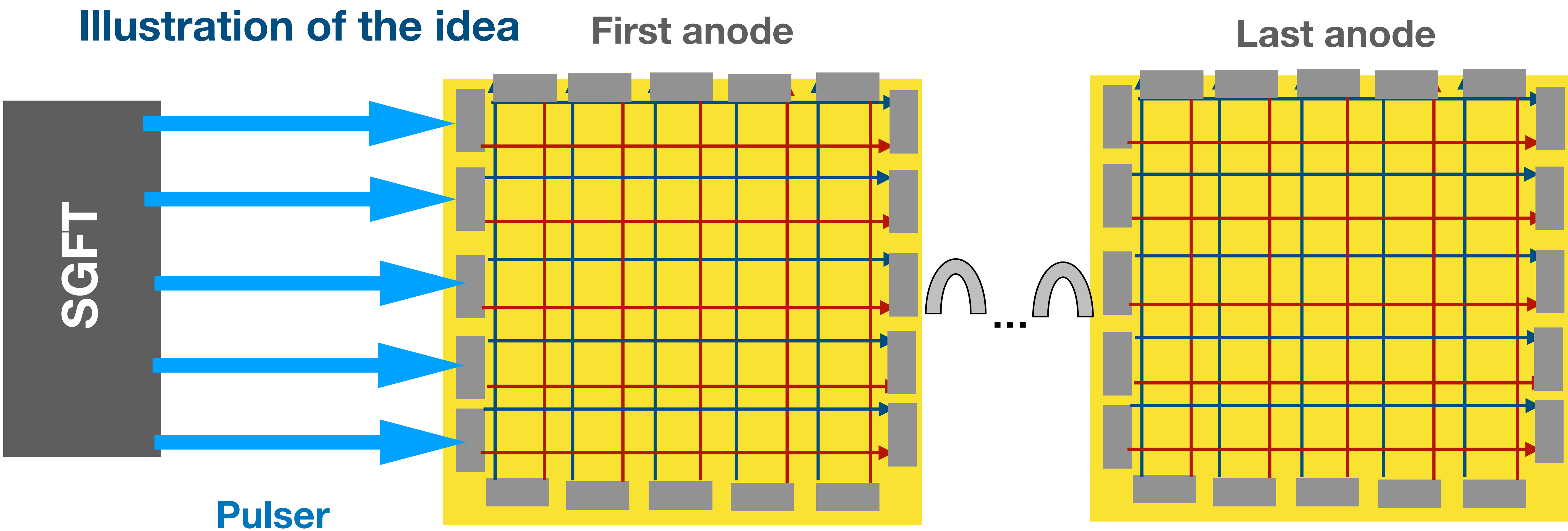
Solution

Design a new system

New test pulse system design

- **The test pulse comes from the signal feedthrough.**
- **It is distributed across the anode, using the spare channels of the signal connector (in the 3x1x1 these channels are spare grounds).**
- **It is needed to connect the two sides of the anode:**
  - Use twisted pairs wires across the anode to connect the two sides.
  - Add lines on the top layer of the PCB (the cross-talk needs to be verified).

Illustration of the idea



5 X 2 X 2 connections per anode

Plans for the anode

- The modifications to the anode are minimal: remove the connection to ground of four pins.
- The anode new Gerber files have been produced.
- We are ordering a prototype from ELTOS.
- Foreseen timescale: February

ETHZv1 LEM qualification tests

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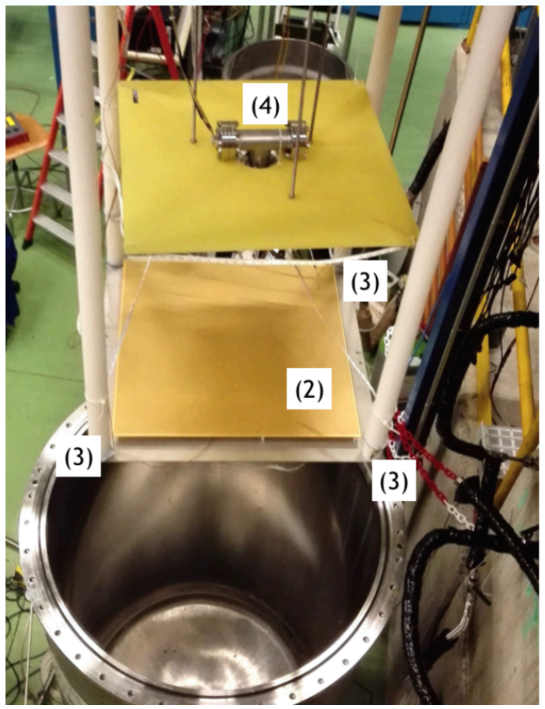
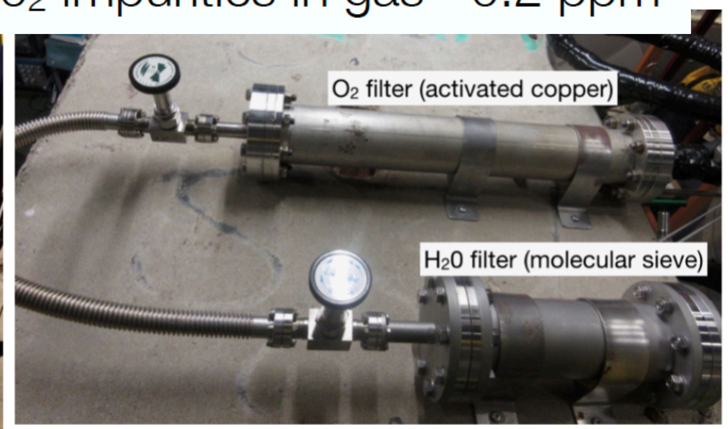
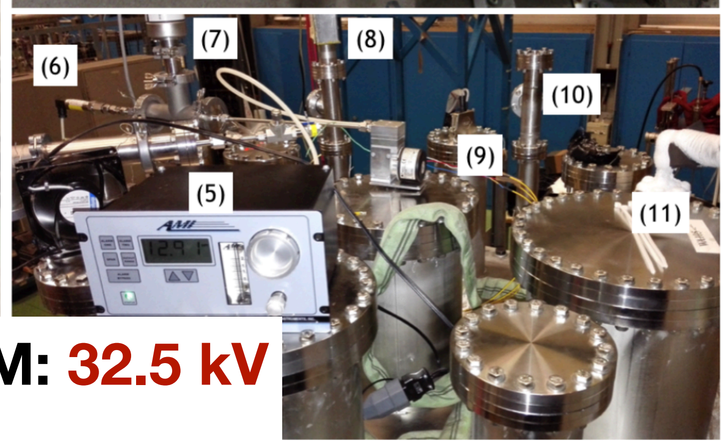
single 50x50 cm² with anode and grid (no measurement of gain)

P=980 mbar, T_{LEM} ~ 90 K, O_2 impurities in gas ~0.2 ppm

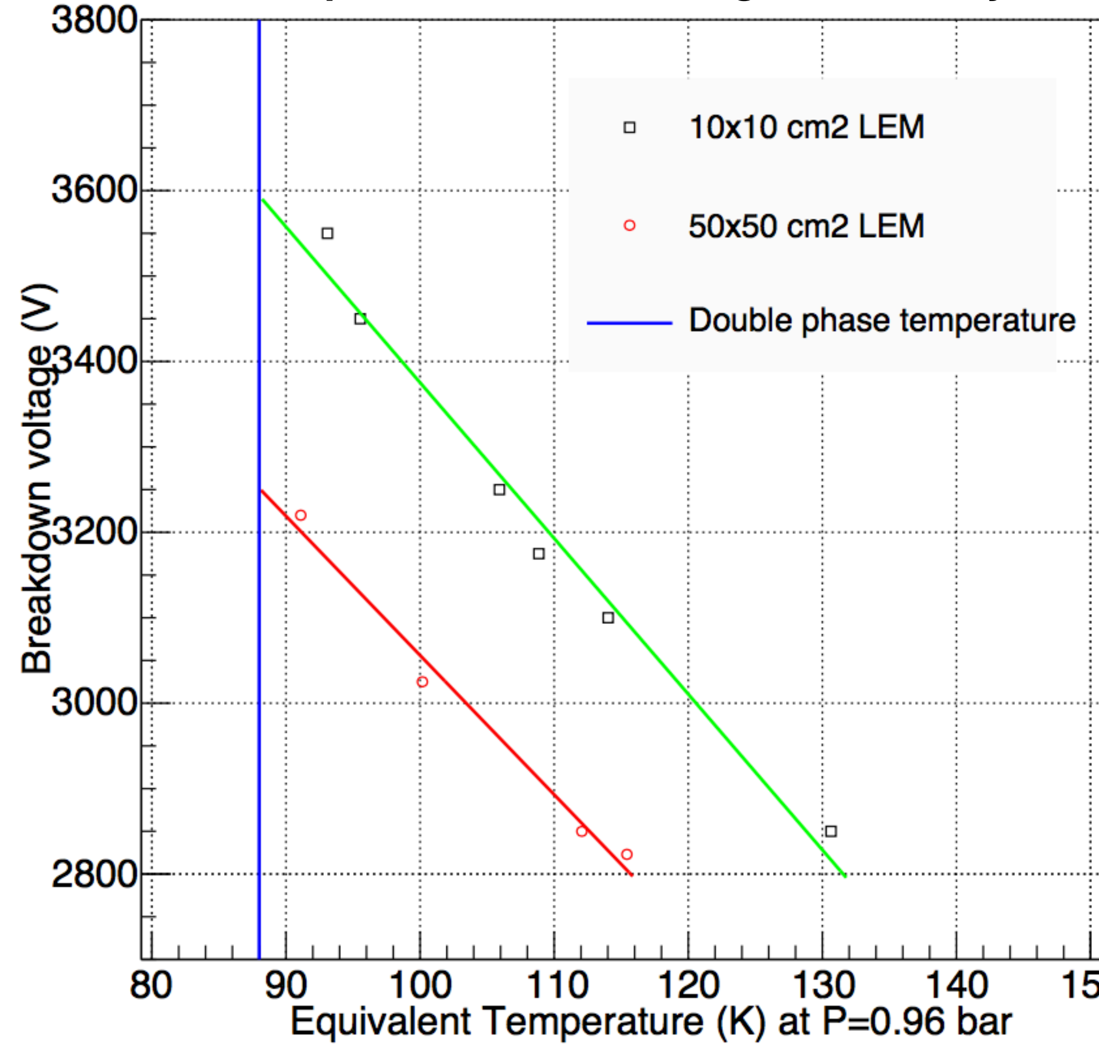


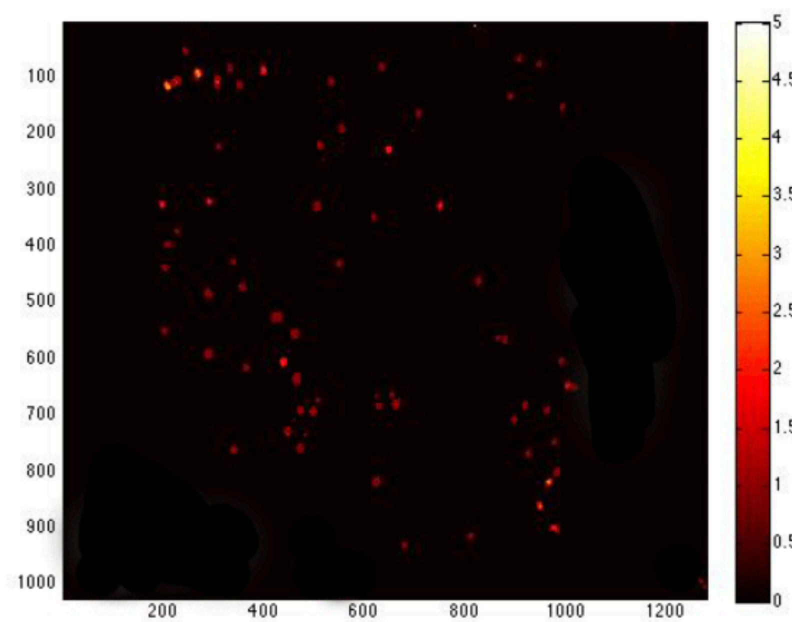




- **V_{max} standalone LEM: 32.5 kV**
- **V_{max} LEM in CRP configuration** with nominal induction and extraction (5 kV/cm and 2 kV/cm resp.): **32 kV (Gain 45 before charging up and 15 after charging up).**
- Discharges uniformly distributed.

Shouxing Wu ETHZ PhD thesis
Study of alternative double phase LAr TPC charge readout systems





Extrapolated $V_{Breakdown}$ ~ 3250V at T 88K and P 0.96 bar for 50x50 LEM

- **Lower breakdown voltage** observed on the 50x50 cm² than in the 10x10 cm².

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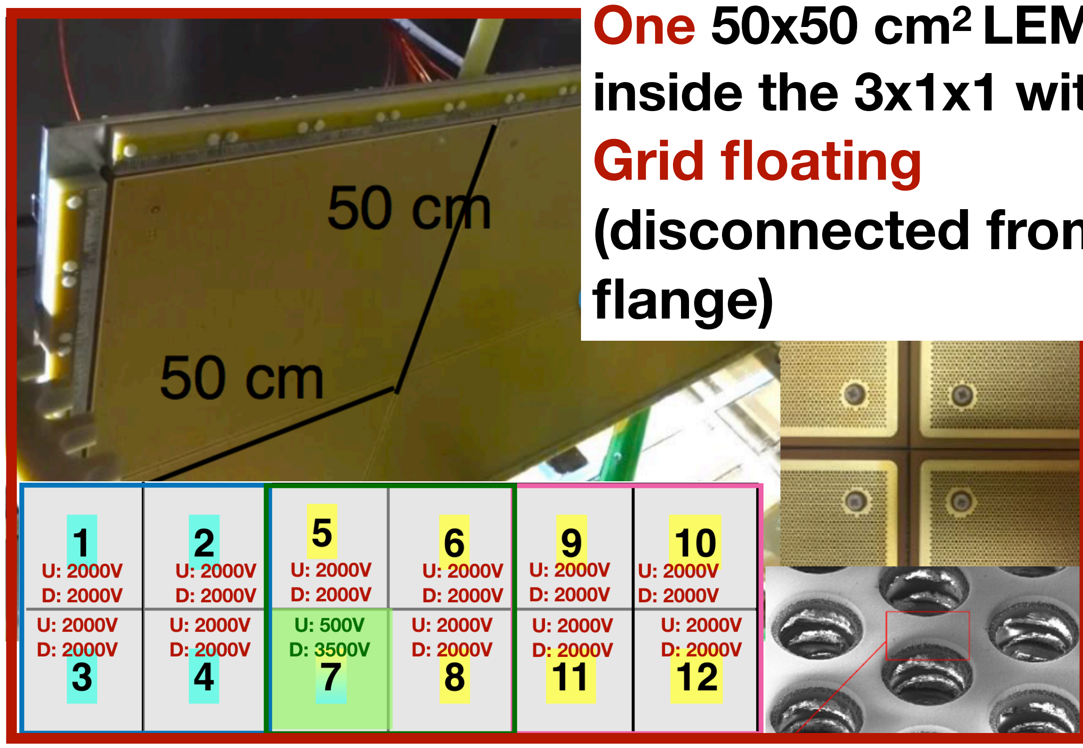
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Summary from 3x1x1 operations

From the 3x1x1 operations we have learnt there are additional effects when moving from individual to multiple LEMs due to capacitive couplings and potential domino effects.
The 3x1x1 results are the only ones obtained in nominal thermodynamic conditions.

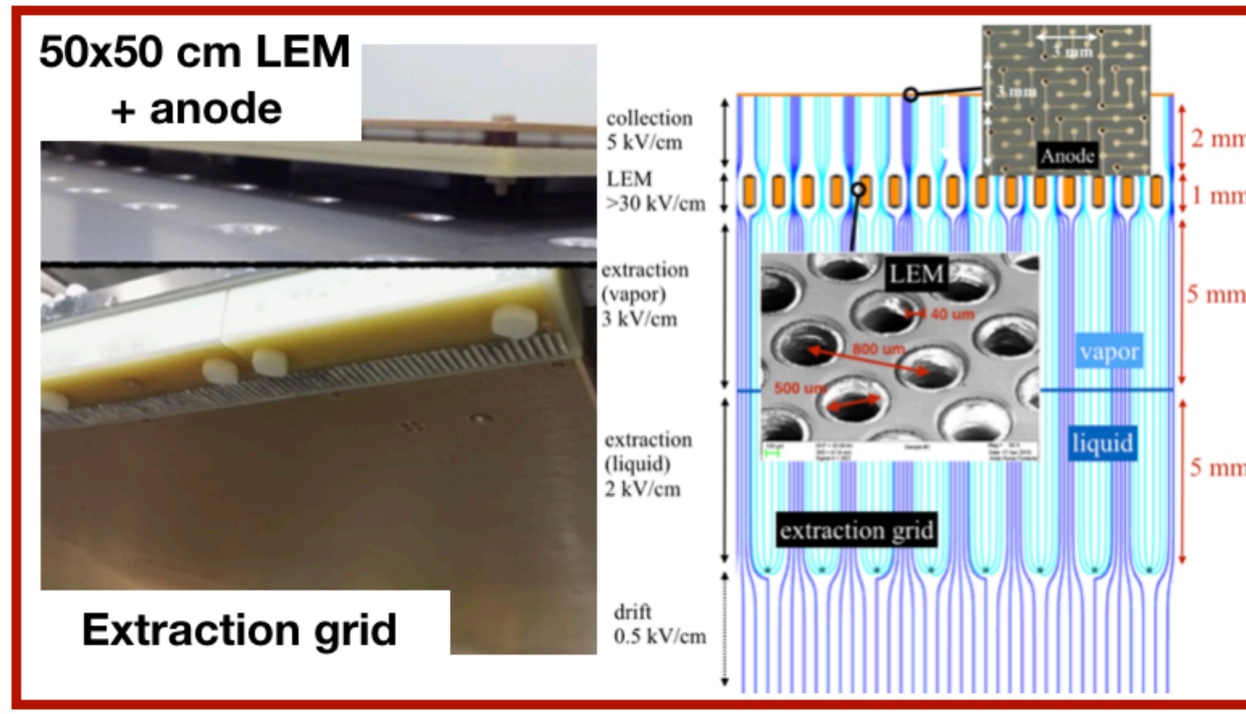
Single LEM without extraction

One 50x50 cm^2 LEM inside the 3x1x1 with the Grid floating (disconnected from the flange)



- Single LEM-anode inside the 3x1x1 reach 32 kV/cm (gain of ~45)

Multiple LEMs with extraction



- The LEMs in the corners were not able to reach the same voltage as the others.
- Maximum LEM field 31 kV/cm.

LEM max. Field inside the 3x1x1

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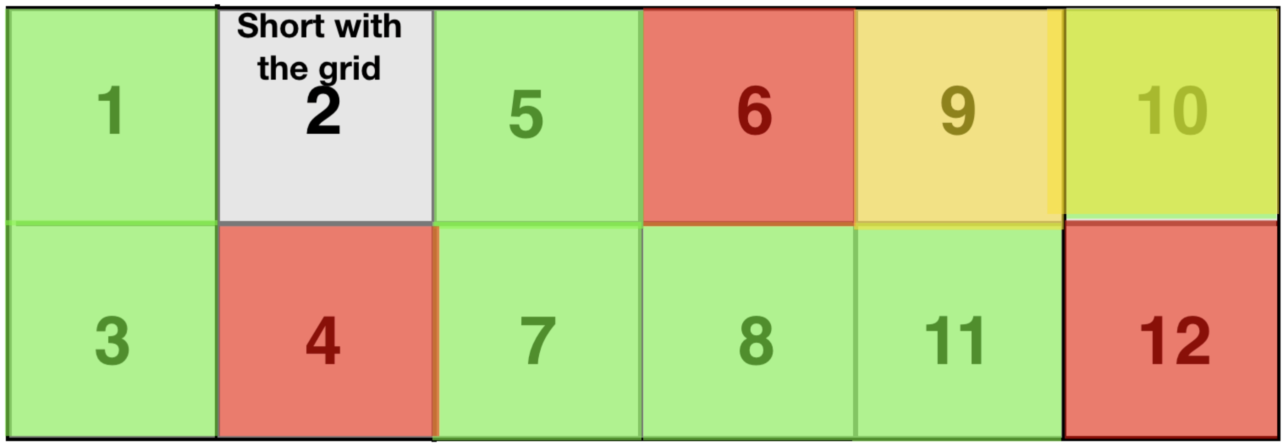


Individually powered inside the 3x1x1 with the grid floating

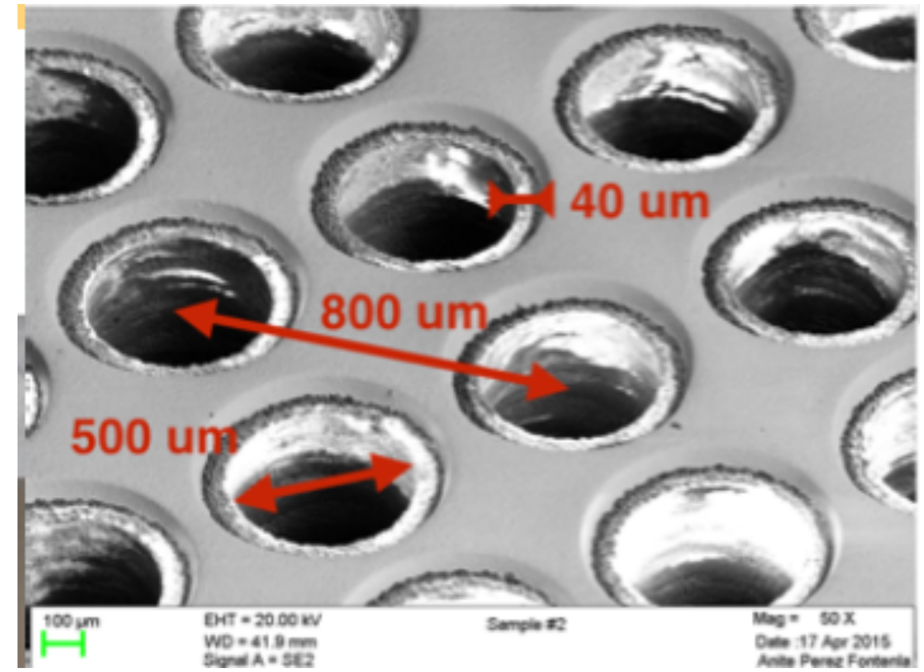
Trip definition:	Time 1 s	Date: 14.11.2017
	Current 1uA	
LEM	**Max LEM field [kV/cm]**	**Spark rate**
1	32	< 1 per hour
3	32	< 1 per hour
4	24	< 1 per hour
5	32	< 1 in 12 h
6	24	< 1 per hour
7	32	< 1 per hour
8	32	< 1 per hour
9	30	< 1 per hour
10	31	< 1 per hour
11	32	< 1 per hour
12	24	< 1 per hour

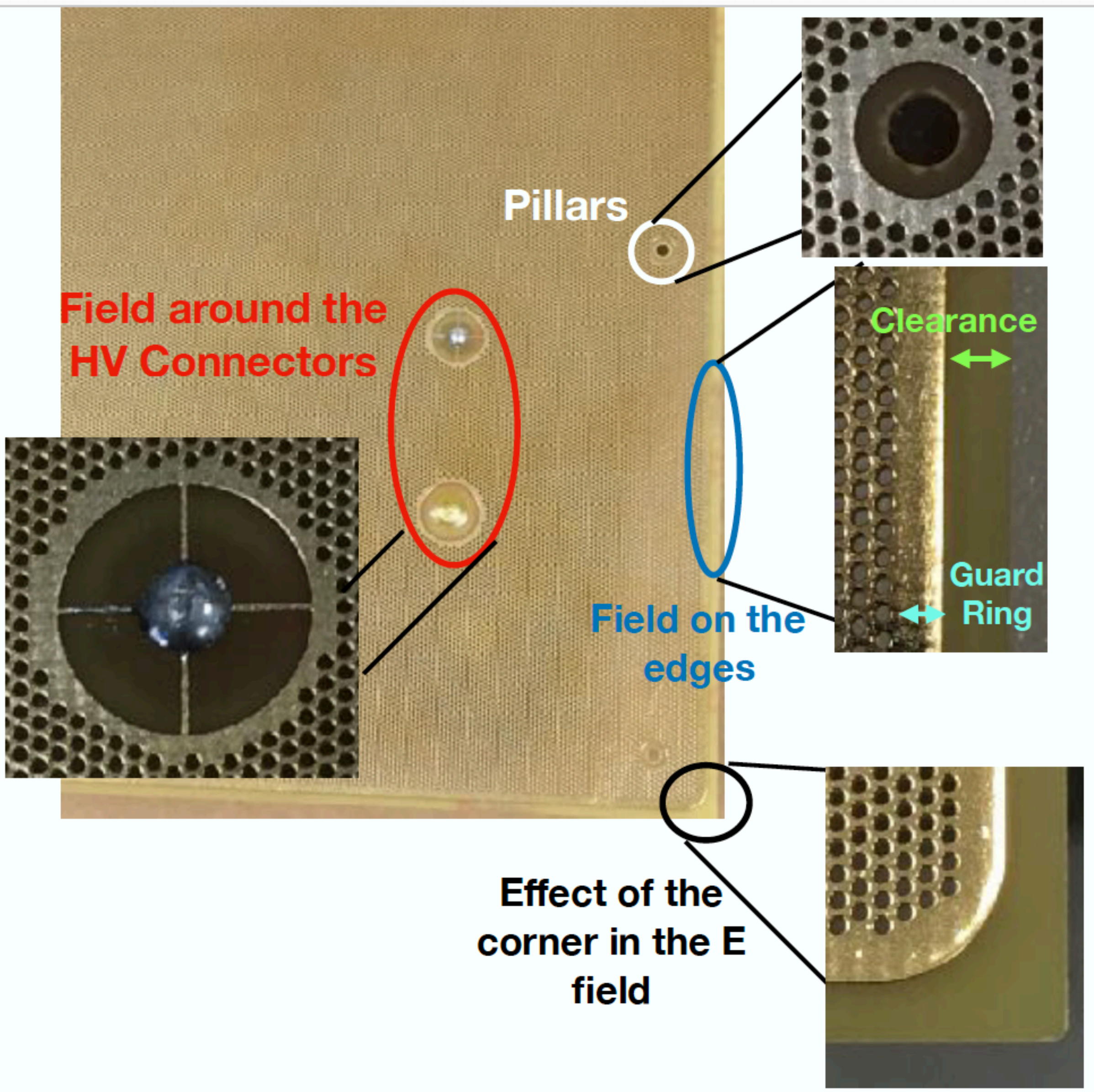
- **All the LEMs were tested during one hour except LEM 5 which was tested 12 hours.**
- **Stable means that no spark was observed during the duration of the test.**

Spark rate less than one hour.
When the LEM can be recovered in a minute this corresponds to less than 2 % dead time.

The **LEM parameters** such as the **hole size**, the **hole pitch** and the **rim size** have been optimised by ETHZ after many years of R&D**.**

JINST 8 (2013) P04012 JINST 9 (2014) P03017 JINST 10 (2015) P03017





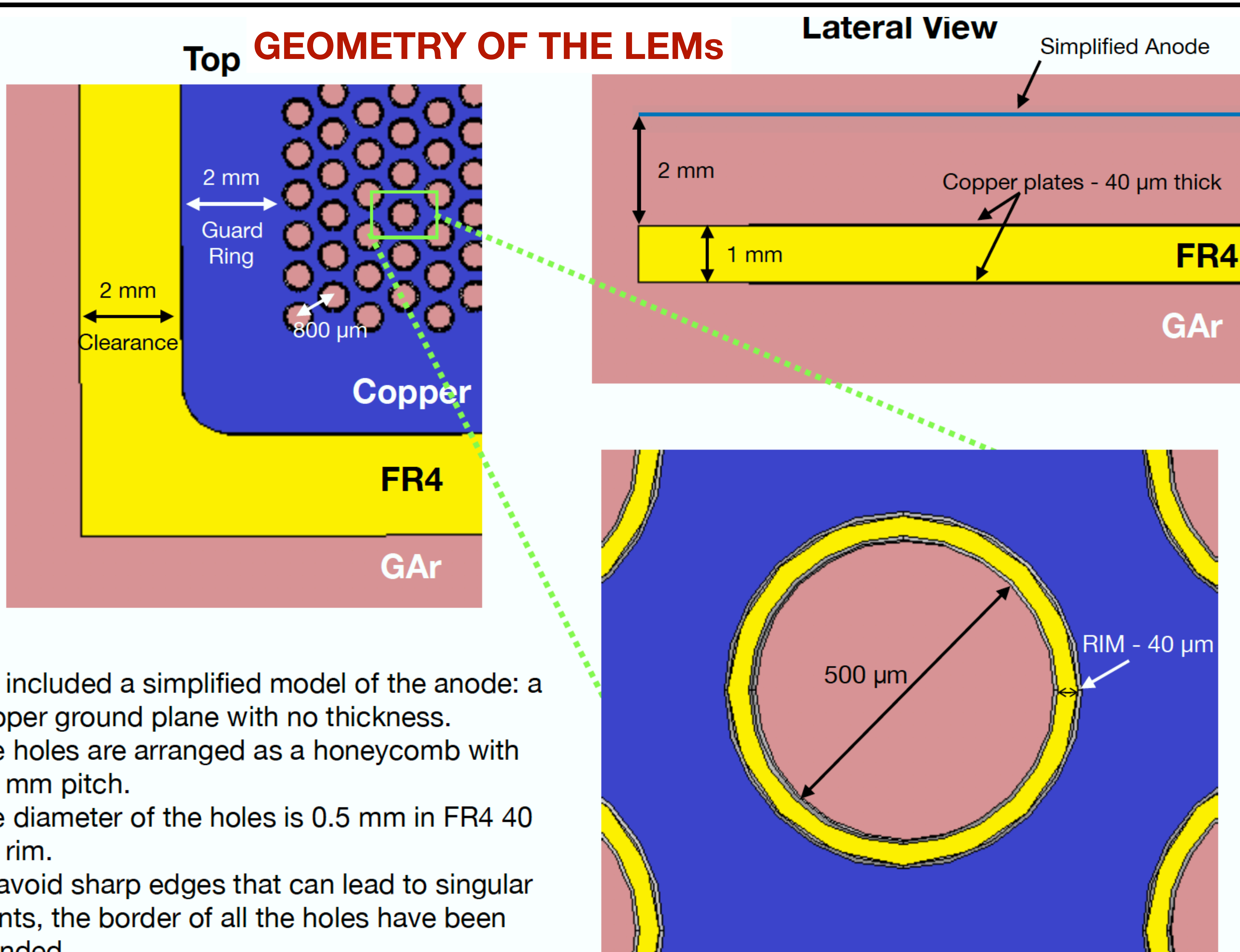
GOAL

- **Electrostatic simulations at geometrical boundaries:** identify the most potentially sensitive areas and understand the effect of the different boundary parameters on the electric field configuration.
- In this first attempt, we have studied the impact on electric field configuration of the variation of the **Guard Ring (GR)** and the **Clearance (Cl)**.

See all details in Carlos Moreno presentation.

Electrostatic simulations at LEM geometrical boundaries

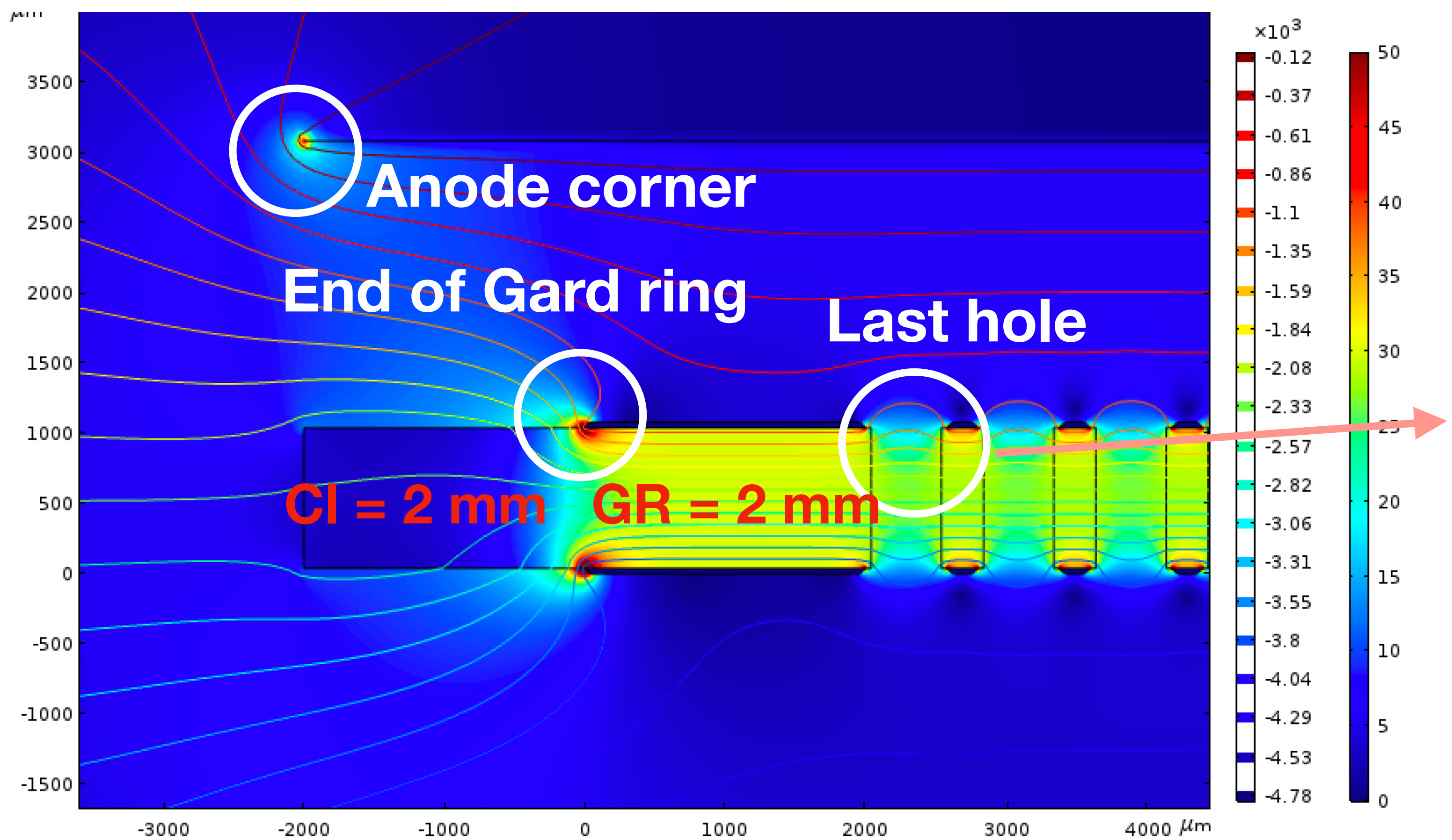
GEOMETRY OF THE LEMs



- We included a simplified model of the anode: a copper ground plane with no thickness.
- The holes are arranged as a honeycomb with 0.8 mm pitch.
- The diameter of the holes is 0.5 mm in FR4 40 μm rim.
- To avoid sharp edges that can lead to singular points, the border of all the holes have been rounded

2D cross-section of the 3x1x1 LEM-anode design

Three sensitive regions identified: Anode corner, end of Cu Gard ring and LEM last hole



- We considered the effect of the Gard ring and clearance on the electric field reached on those regions.

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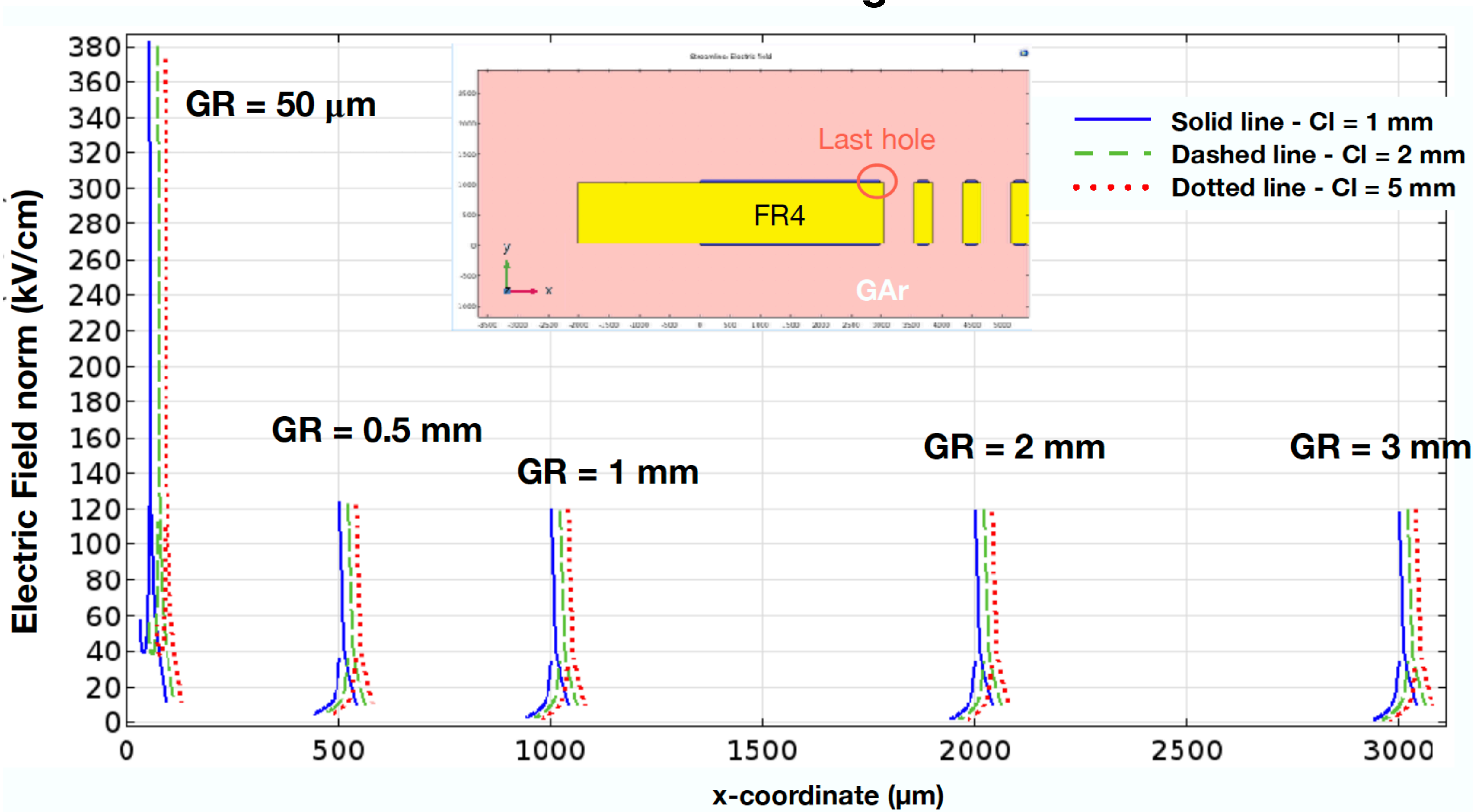
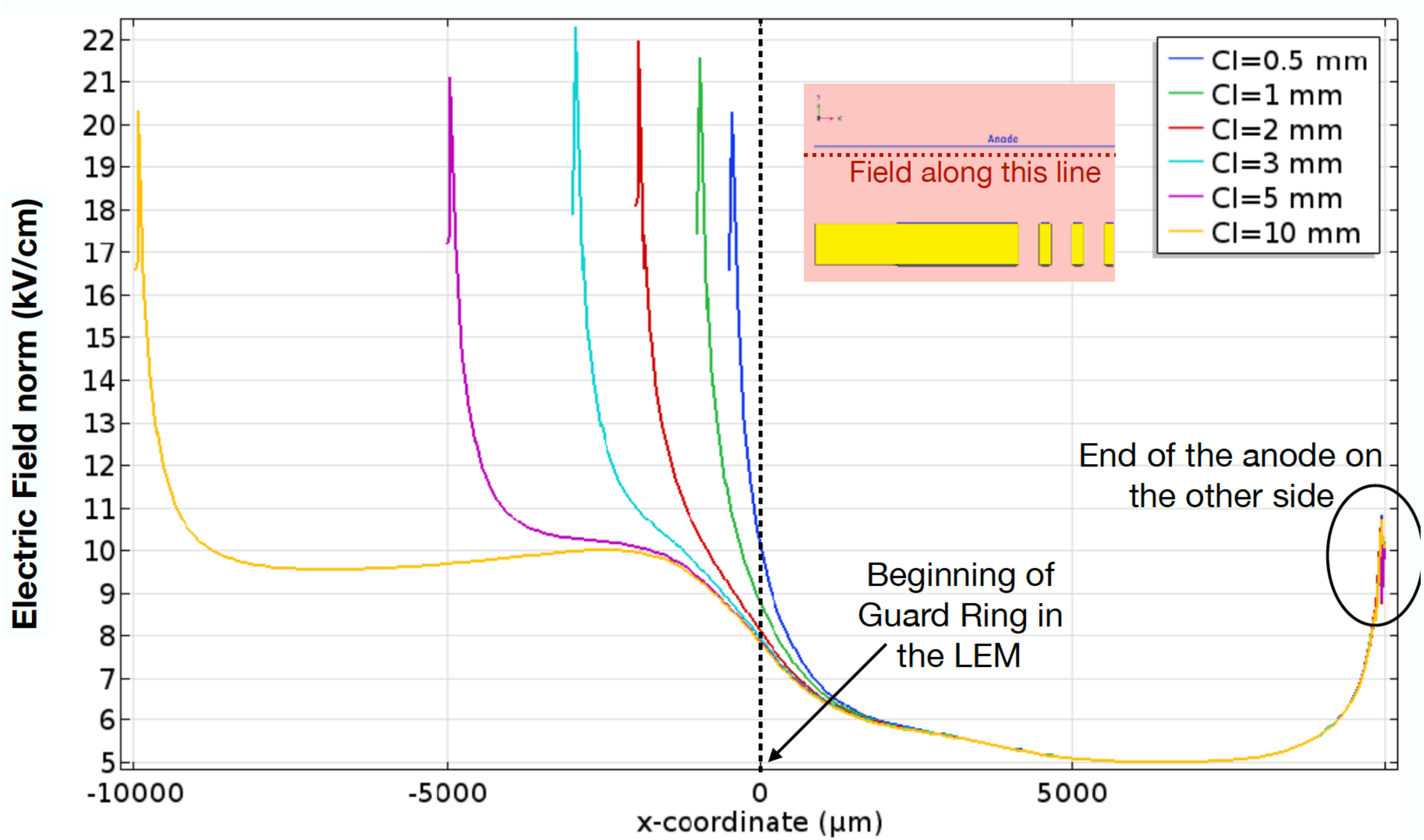
Effect of the Guard Ring in Last Hole



- The field in the last hole decreases as we increase the GR for values GR < 1 mm.
- Above 1 mm the field in this region does not change with the GR for Clearance above 2 mm.
- For Cl < 2 mm the field shows a slight decrease from GR = 2 mm to GR = 3 mm.

Effect of the Clearance in the Field near Anode Surface



- For clearance up to 3 mm, the maximum field increases when we increase the Clearance. For values above 3 mm the maximum field decreases with Cl, but a constant field of ~10 kV/cm appears in the region between FR4 and anode.

CONCLUSIONS

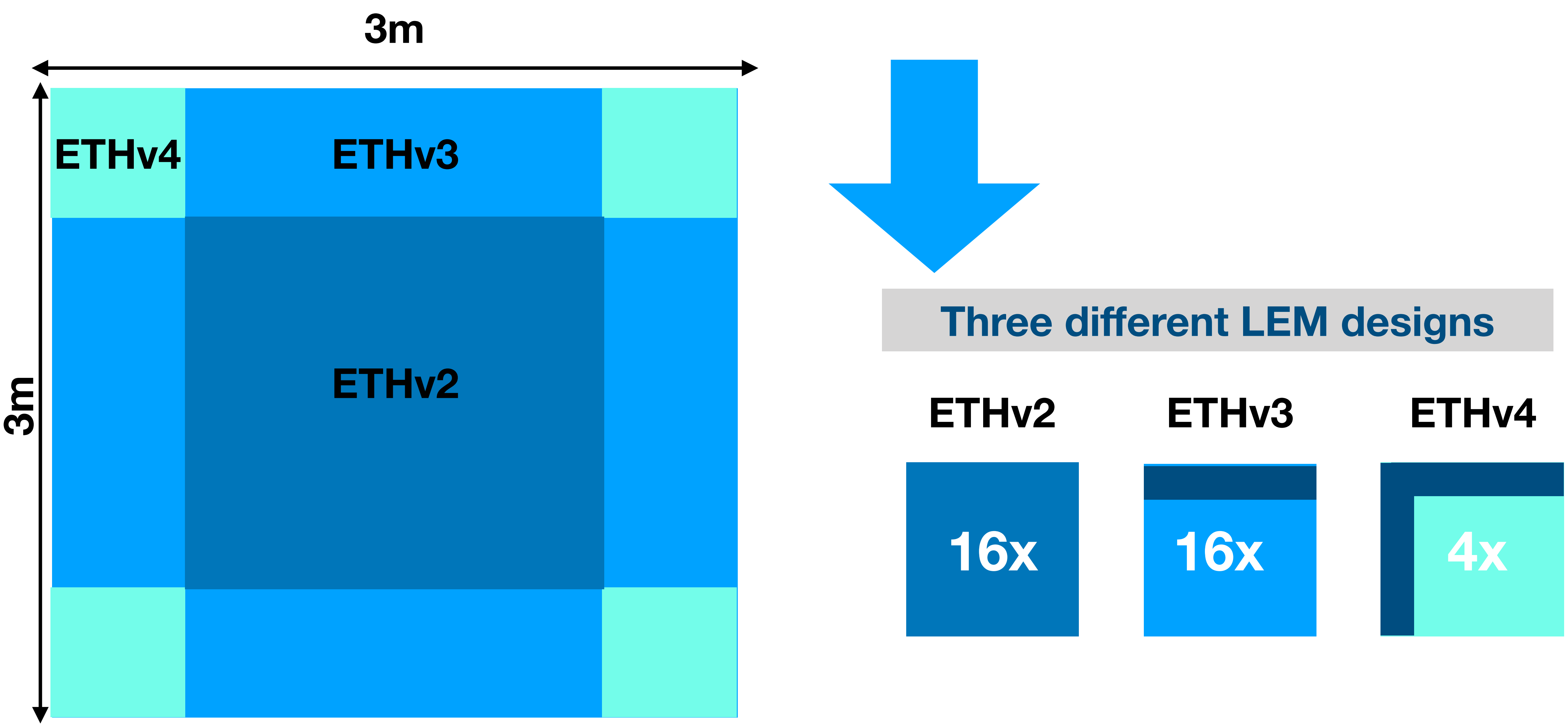
- The Clearance barely affects the field in the beginning of the Guard Ring or the Last hole.
- For Clearance above 1 mm, the field in the Last hole reaches its minimum value with Guard Ring of 1 mm, and stays the same for higher values of GR.
- A guard ring above 1mm guarantees the minimum electric field on the last hole and on the end of the guard ring.

Electrostatic simulations of multiple LEM-anode side by side is work in progress and preliminary results will be ready in 2 weeks from now.

LEM configuration in a 3x3 m² CRP

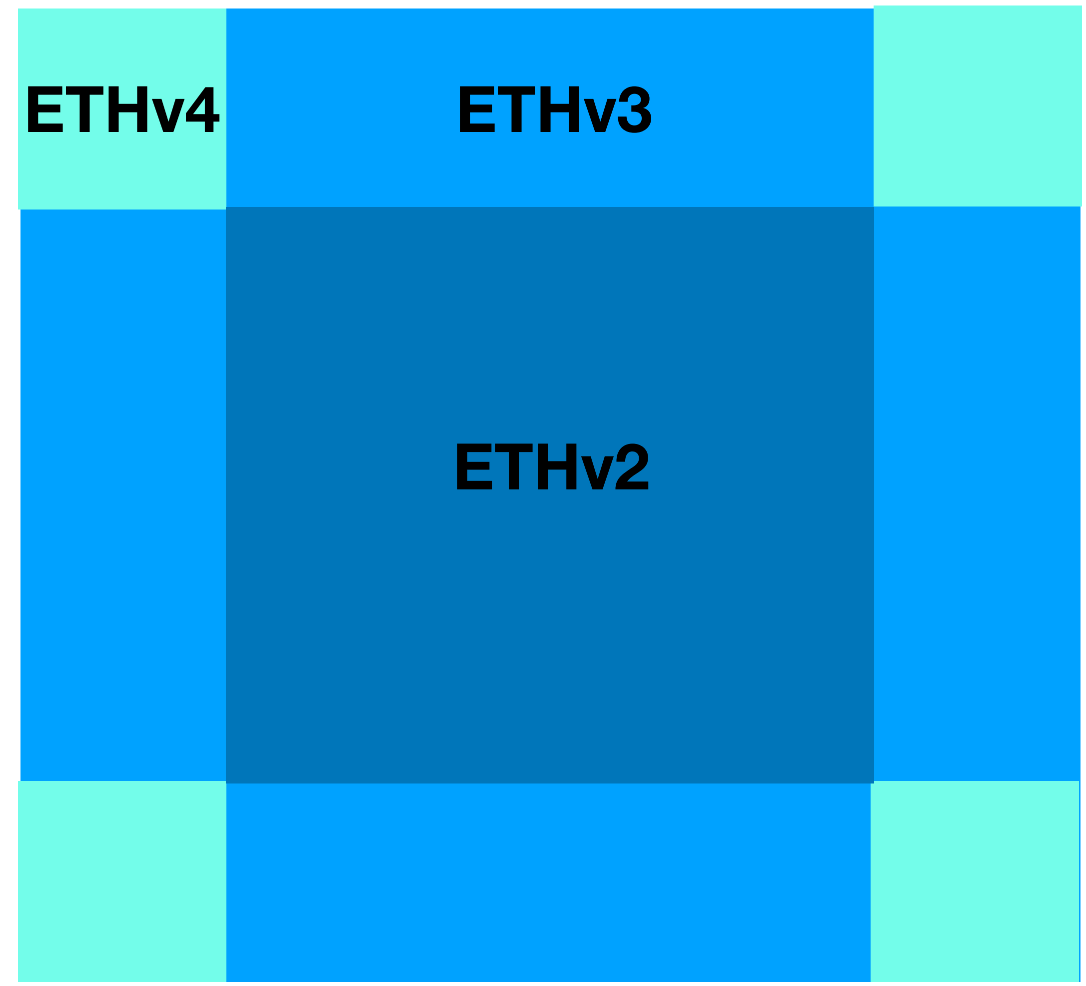
How do we optimise the LEM design for the 3x3m² CRP?

- Maximise the active area
- Avoid too high fields on the border/corners of the 3x3 m² CRP.
- Minimise the FR4 area to avoid charging-up.



LEM configuration in a 3x3 m² CRP

CRP with one type of LEMs Vs CRP with multiple LEM design



Active area:

ETHv2 97%

To be compared with:

CFR 35 85%

FR4 area:

ETHv2 2%

CFR 35 8%

Active area:

ETHv2
ETHv3
ETHv4
96%

FR4 area:

2%

LEM geometrical boundaries optimisation

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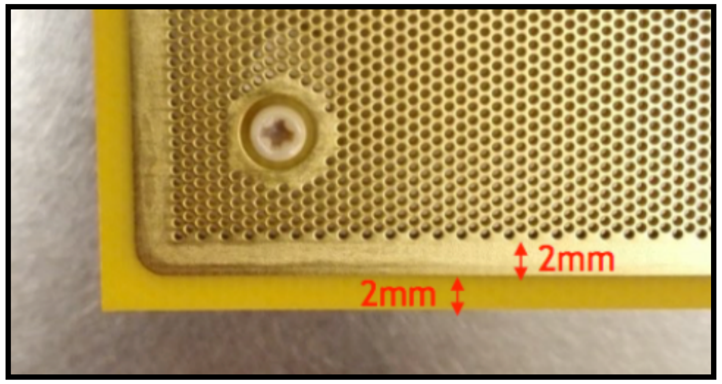
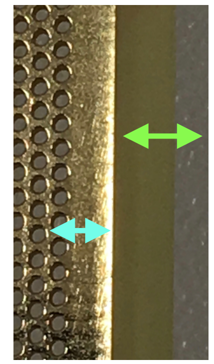
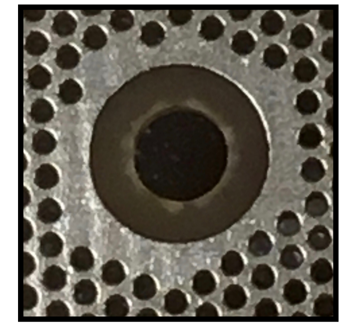
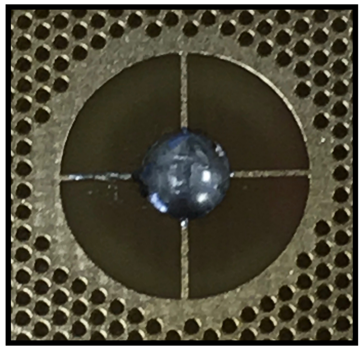


Clearance



Guard Ring



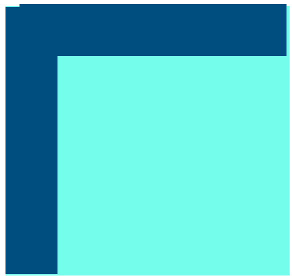


Design	LEM borders		Screws			HV contacts			Active Ares
	FR4 clearence [mm]	Cu guard [mm]	FR4 clearence [mm]	Cu guard [mm]	Spacers	FR4 clearence [mm]	Cu guard [mm]	Contacts	Percentage
ETHv1	2	2	2	3	29	5	1	2	97,0
ETHv2	2	2	3	2	29	5	2	2	97,0
ETHv3	5	5	3	2	29	5	2	2	95,0
ETHv4	5	5	3	2	29	5	2	2	94,0

ETHZv1

ETHZv2: Larger guard ring and clearance on the outside border

ETHZv3: Larger guard ring and clearance on the corner, in an L-shape



Ongoing activities

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- Metrology measurements of the anode-LEM distance (being done this week, waiting for results by week 4)
- Electrostatic simulations of two or several LEMs side by side (work in progress, results by week 6).
- We expect the delivery of the female connector pins by middle of February.

LEM plans and tests

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GOAL

Test one by one a LEM-anode sandwich.
Measure the spark rate, spark distribution, gain and stability.

PLANS

- **Order the new LEMs**
- **Test in cold to be performed using the Dec.2015 setup in the ArDM clone dewar in blg. 182.**
- **Timescale: March 2018.**

Conclusions

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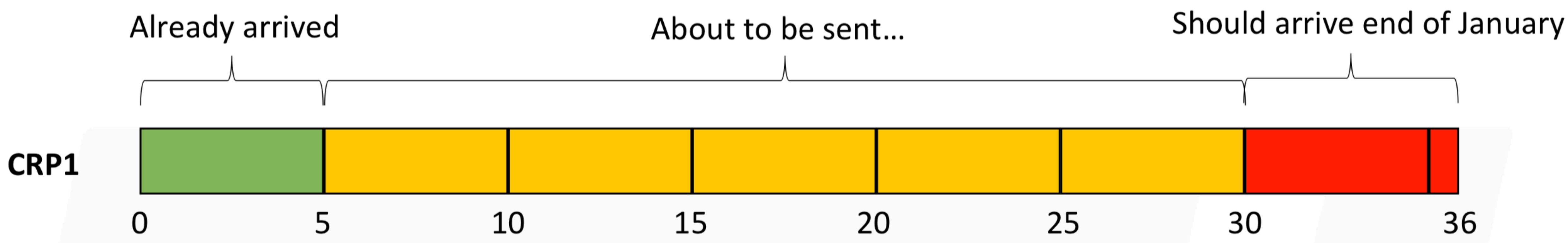
- **If we want a calibration and linearity system we need to implement a new pulsing system.**
- We have a qualitative understanding of the performance of the anode-LEM in the 3x1x1. An effort is still needed for quantitative results.
- Based on the 3x1x1 feedback and the baseline electrostatic simulations:
  - The **LEM parameters** such as the **hole size**, the **hole pitch** and the **rim** are sound and **do not need to be changed**.
  - An **optimisation of the LEM geometrical boundaries such as Gard ring and various clearances** can be considered. However, the total coverage should remain above 95%.
- We intend to continue along these lines of investigation in the coming months.

Back-up

Pre-production for CRP#1

36 anodes per 3x3 m² CRP



December 2017

We received 5 new anodes visually conform

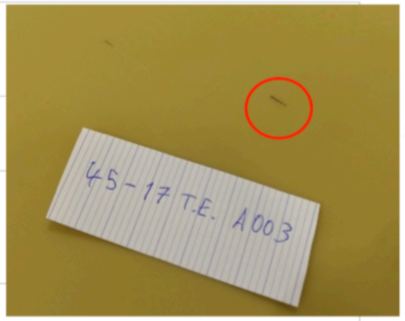
(Still need to be electrically tested by us)

October 2017

We received 5 anodes but conformity was visually not OK

(Broken corner interrupted tracks…)

45-17 T.E. A001	• light discolorations on metal back strip • light scratches on metal back strip • light small scratches on non-strip side • a few fingerprints on strip side
45-17 T.E. A002	• light scratch on non-strip side • slight discoloration of metal back strip • very small scratch on strip side
45-17 T.E. A003	• medium scratches on non-strip side in multiple places • very small slight discoloration on metal back strip • slight discolorations on strip side in multiple places • 1 cm scratch on strip side • fingerprints on strip side
45-17 T.E. A004	• discoloration of metal back strip in multiple places • discolorations on ends of strips on non-strip side • slight scratches on non-strip side • fingerprints on strip side
45-17 T.E. A005	• small scratch on non-strip side • small discolorations and very small scratches on strip side



https://photos.app.goo.gl/P2Q000oe33scTeIn2

See Caspar presentation