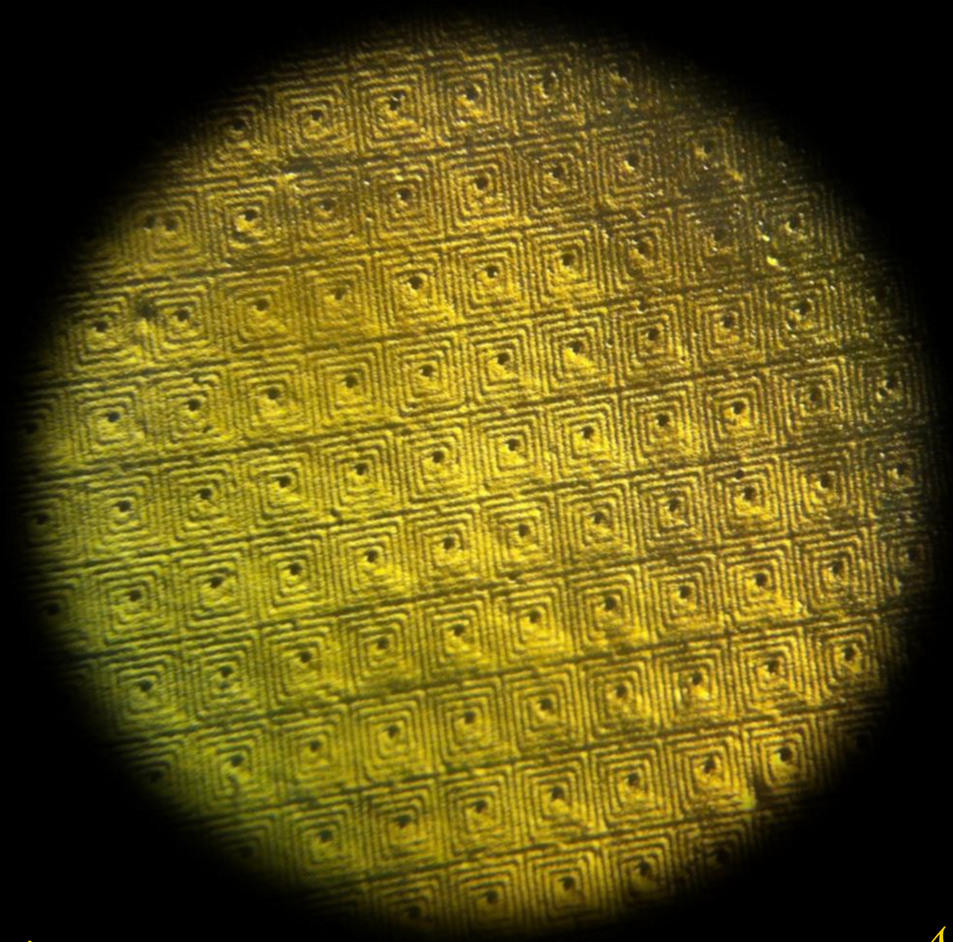
Micro-Pattern Gas Detectors: State of the Art and R&D



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Outline

❖General Introduction
- Classical Gas Detectors

❖State of the Art
- MicroMesh Gaseous Structure and Gas Electron Multiplier

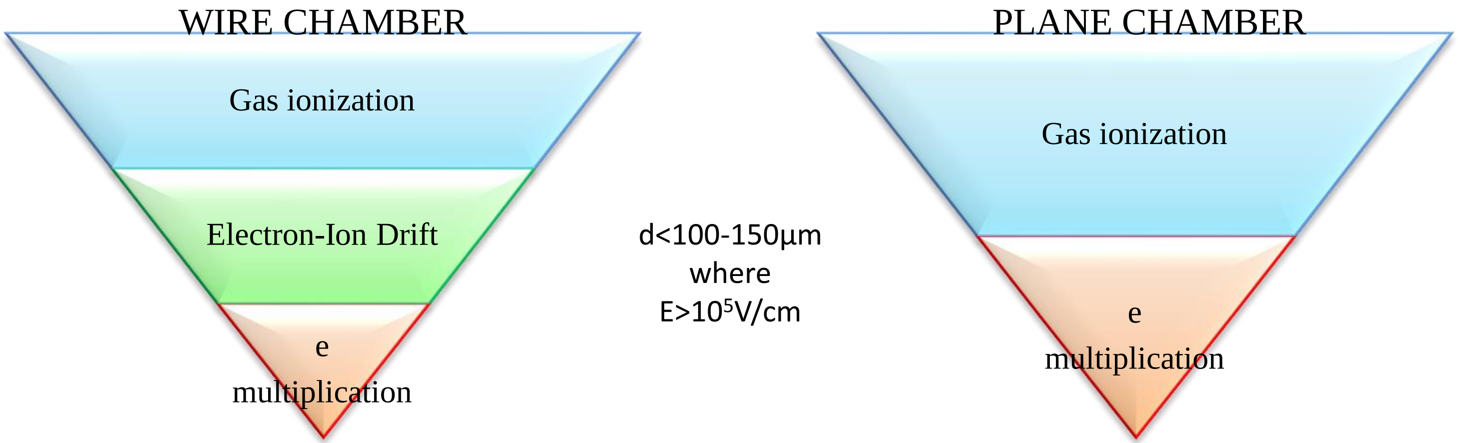
❖Research & Development
- Spiral Detector

Classical Gas Detectors

WHAT ARE THEY?

Gaseous detectors are **radiation detection instruments** designed:

- to **point out** the **presence** of ionizing particles (p, e, μ, …);
- to **measure** together with B-field, dE/dx, etc., their **properties** (momentum, charge, …).



HOW DO THEY WORK?

They use the **ionizing effect** produced by the **incoming ionizing particle** onto a **gas-filled sensor**. The charged particle, passing through the gas, loses a small fraction of its energy producing various collateral effects, such as the ionization of the gas atoms or molecules.

The resulting electrons and ions, moving in an external electrical field, cause a **current flow** which can be measured.

Classical Gas Detectors

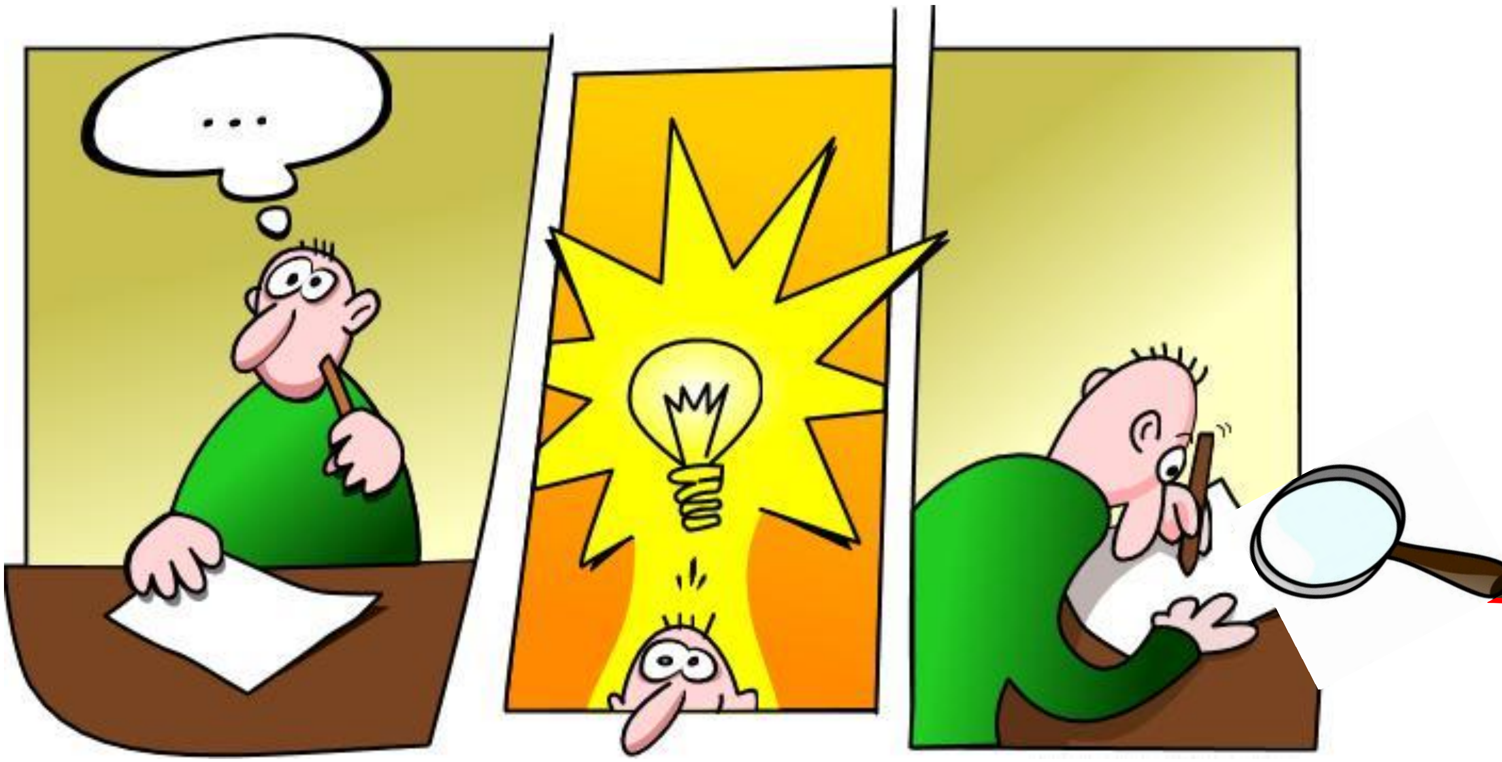
ADVANTAGES

- Large areas at low prices;
- Flexible geometries;
- Good spatial and energy resolution.

LIMITATIONS

- Rate capabilities <10 kHz/cm^2 (due to the long ion drift time and the space charge density which reduces the effective electric field);
- Reduction of the gain;
- Distortion of the drift path.

SOLUTIONS?



Micro-Pattern Gas Detector

- Plane geometry with electron multiplication close to its electron drift direction in both directions of the chamber plane
- E-field shape in drift regions similar to classic plane chambers (constant drift velocity)

Micro-Pattern Gas Detector

Introduced at the end of 1980s,
the **Micro-pattern Gas Detectors (MPGD)**
perform better than classic wire chambers.

They allow to achieve both
very good localization accuracy
and
high rate capability
that make this technology attractive for charged particle tracking at high luminosity colliders.

During its evolution, Micro-Pattern Gas technology gave raise to many different types of devices such as **Micro-Strip Gas Chambers (MSGC)**.

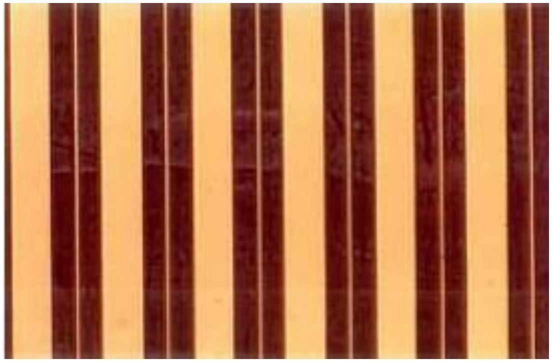
Micro-Strip Gas Chamber

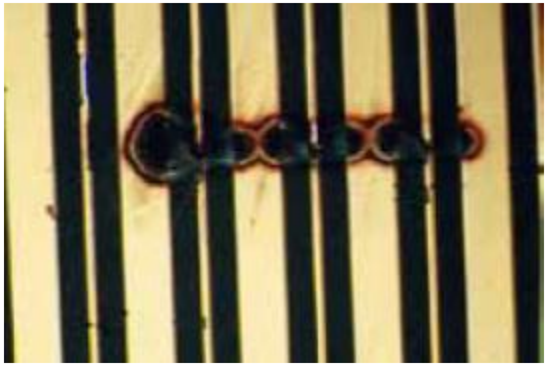
MSGCs, having a small pitch between anode and cathode strips, are characterized by:

- fast ions collection;
- spatial resolution ~50μm;
- two track resolution ~500 μm;
- high rate capability ~10^6 Hz/mm.

But… MSGCs are subjected to:

- slow degradation under sustained irradiation;
- rare but devastating occurrence of discharges.

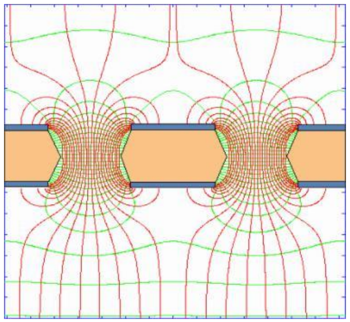




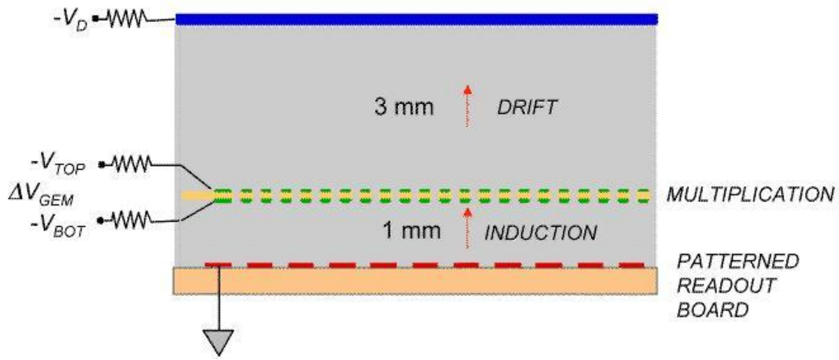
Gas Electron Multiplier

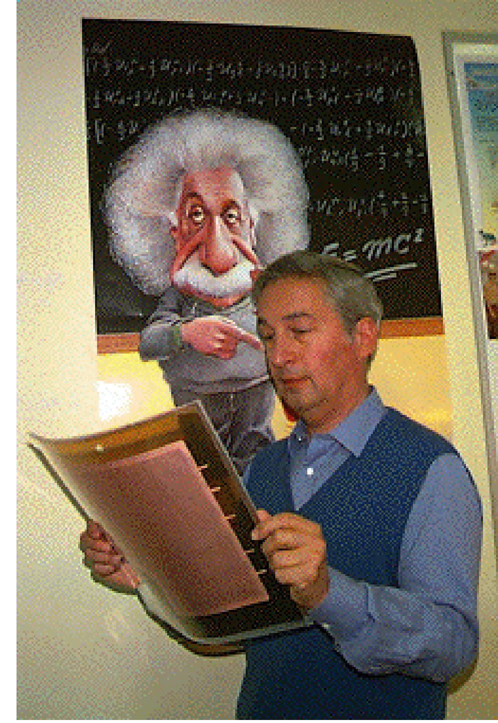
Initially developed as a preamplifier stage for an MSGC, the **G**as **E**lectron **M**ultiplier (**GEM**) became soon a detector on its own.

E field



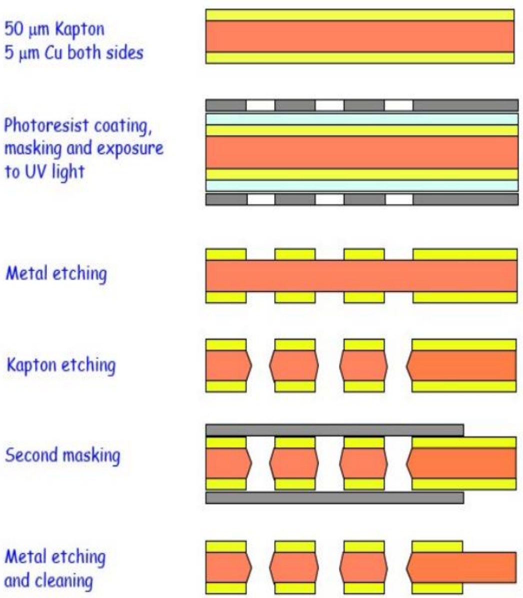
Structure

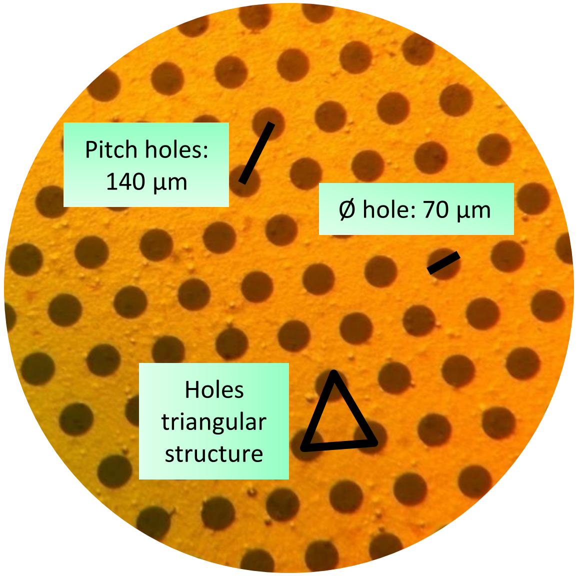




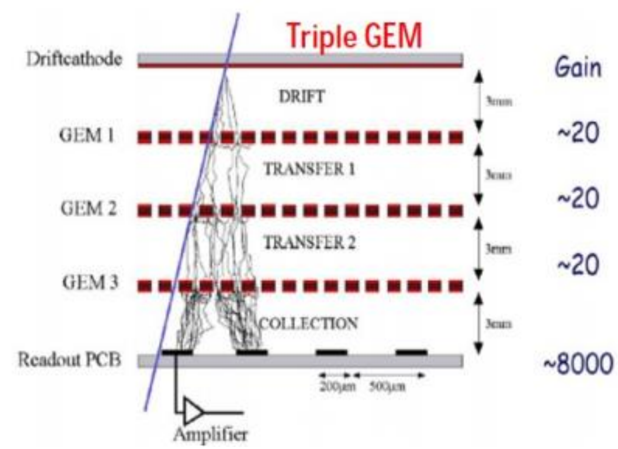
(1999, F.Sauli)

Production steps



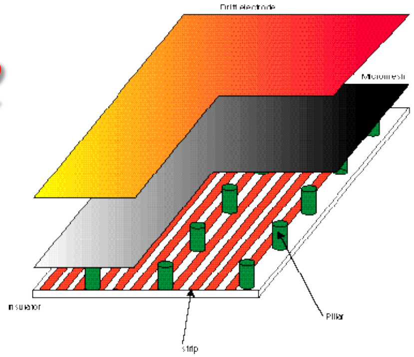


Improved GEM



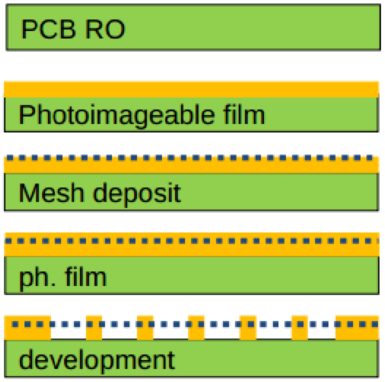
Spread of the avalanche over many active holes → reduction of spark probability

MicroMesh Gaseous Structure

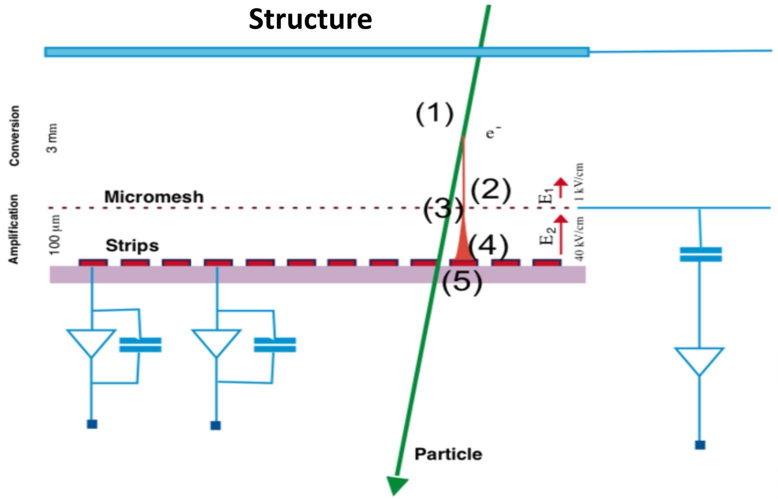


Parallel plate chamber where the amplification takes place in a thin gap, separated from the conversion region by a fine metallic mesh.

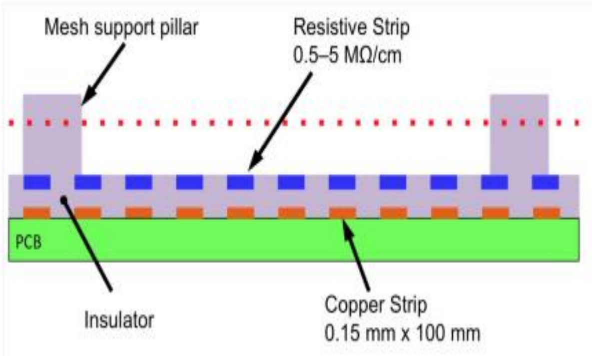
Production steps



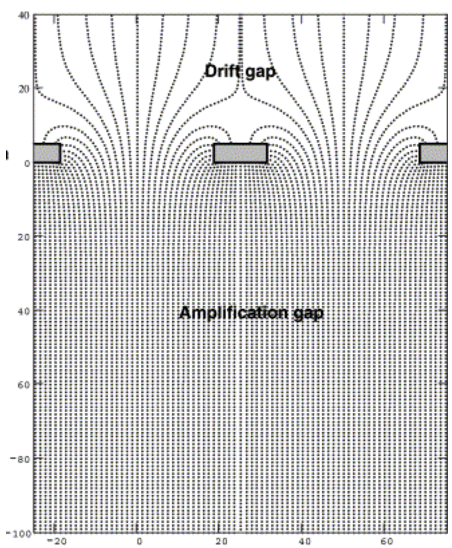
Structure

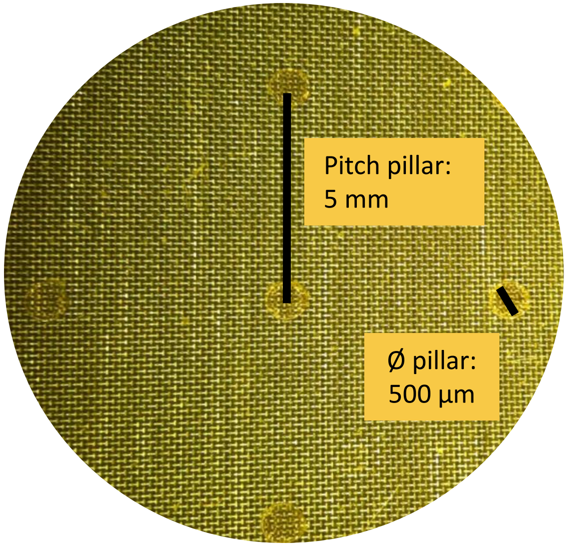


Improved MM



E field





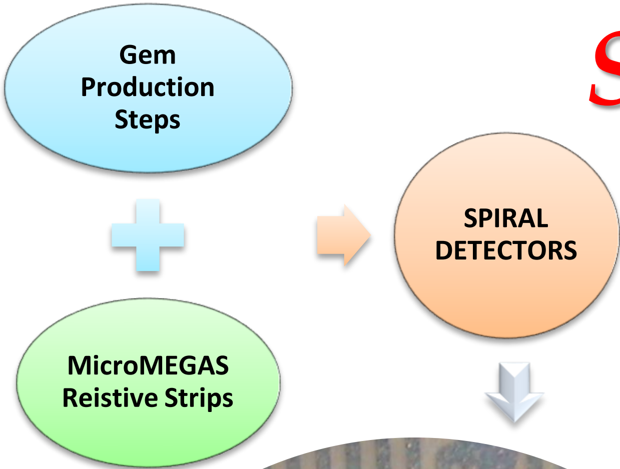
Resistive material:
not reduction of sparks but limit their impact on performance of the detector (HV drops become insignificant).

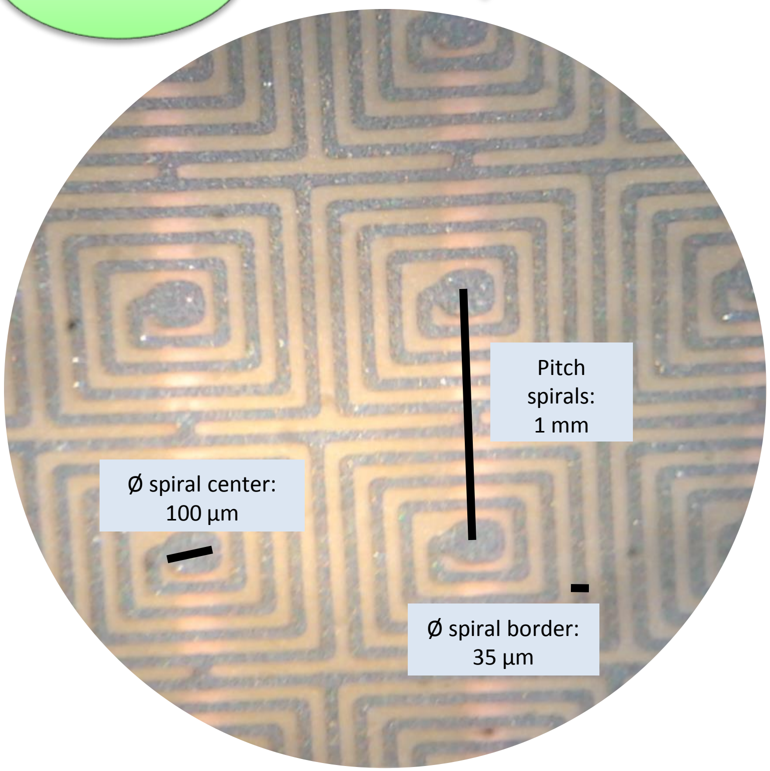
Strips instead of layer:
to avoid charge spreading and to keep the area affected by discharges as small as possible.

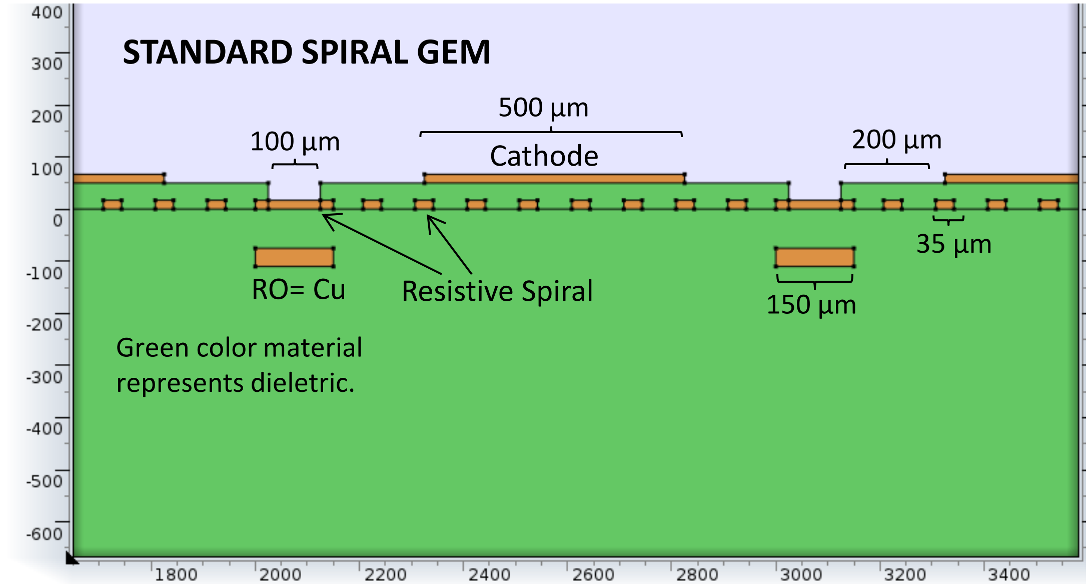
GEM and MicroMEGAS spark…

What can we do?

Spiral Detector



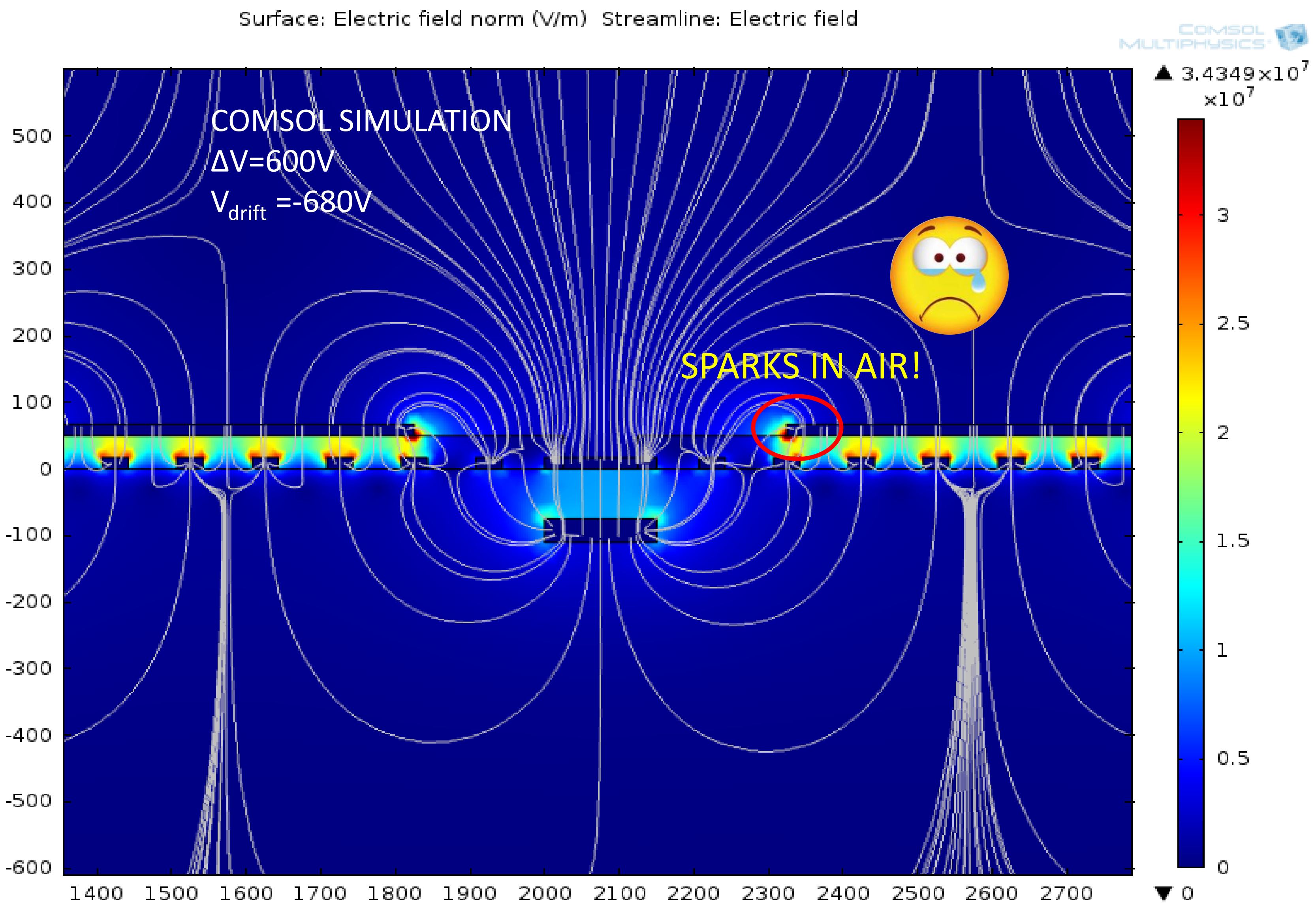




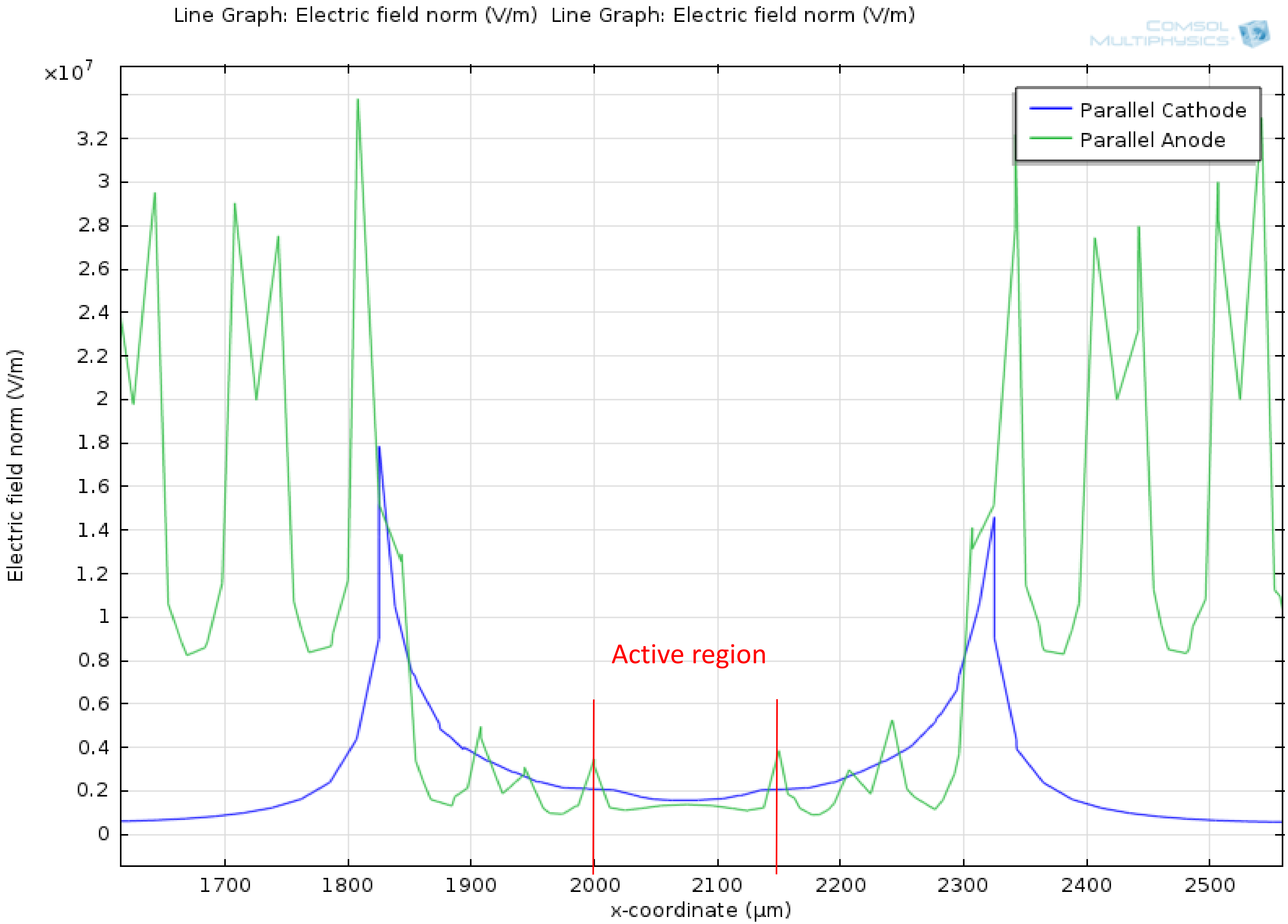
The spirals are connected all togheter and the presence of resistive material on the whole path allow us to obtain very high electrical resistance R ~ 3 GΩ.

$V_{tot} = V_0 - RI$,
so if R is very high,
when there is a current I
(and this happens just in the sparks),
the value RI is subtracted to V_0 and the potential V_{tot} (from which we obtained the electric field E) slows down,
so the spark is stopped
and the detector is safe.

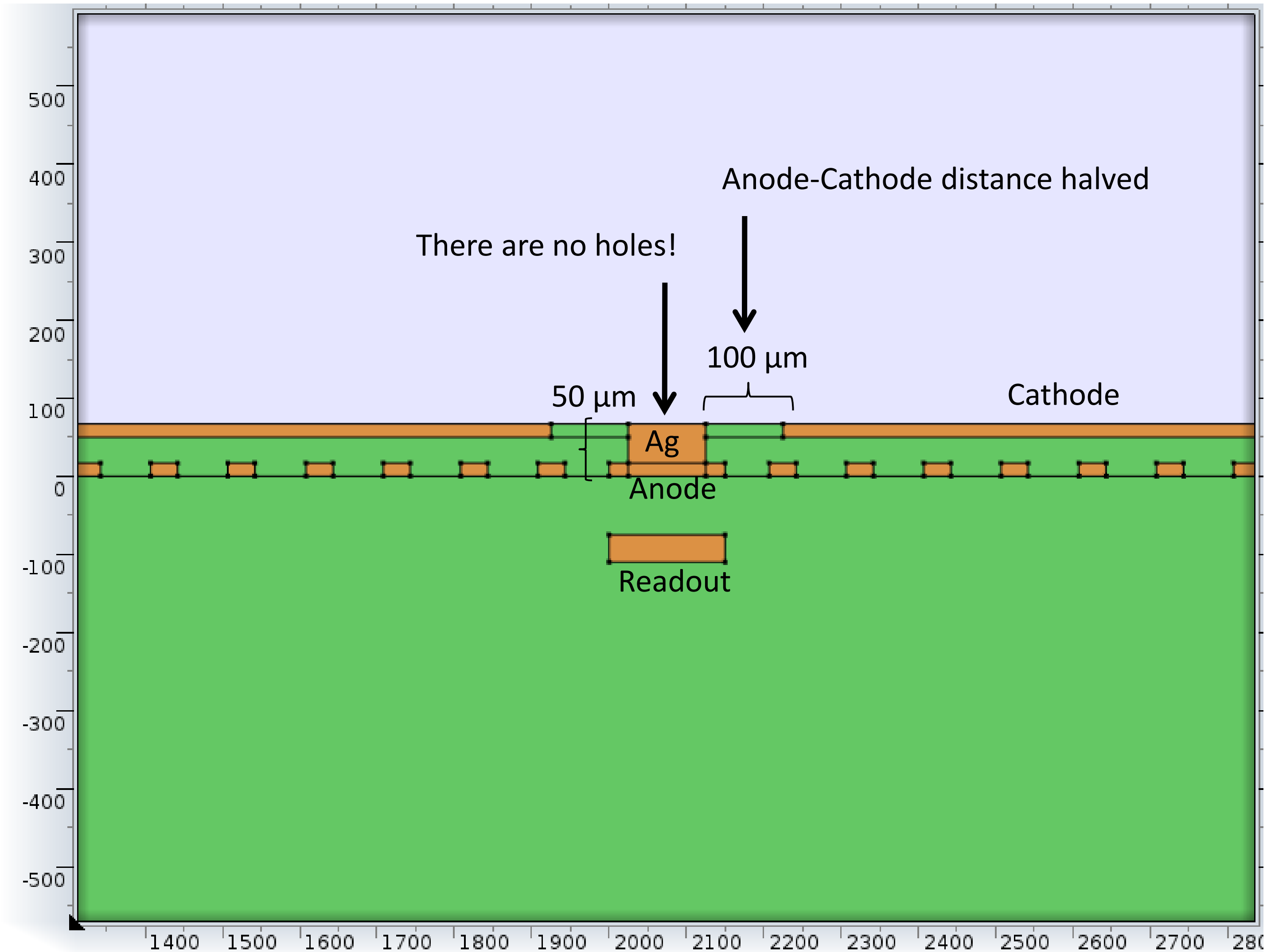
Spiral Detector



Spiral Detector



Spiral Detector –First Improvement-



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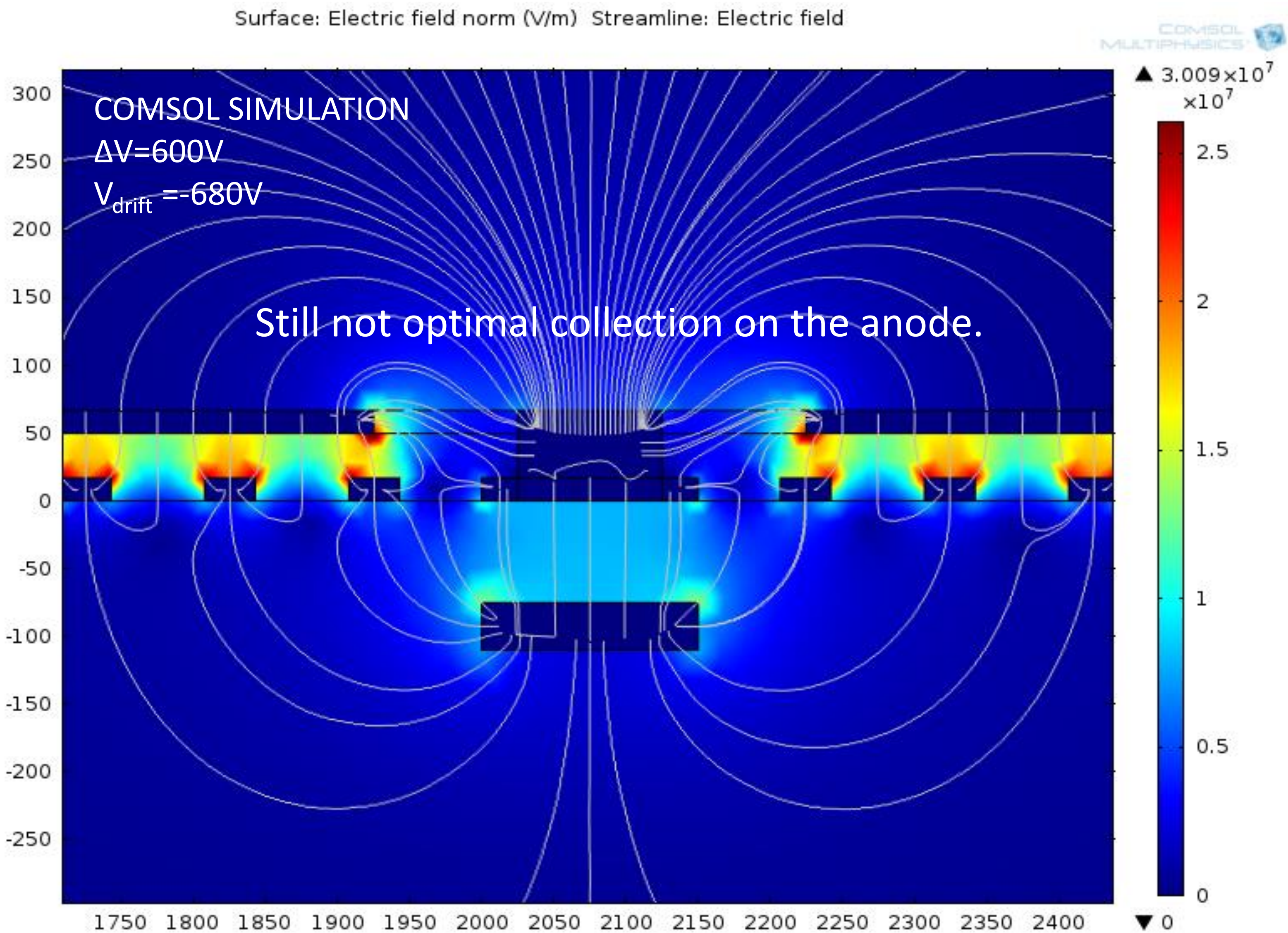

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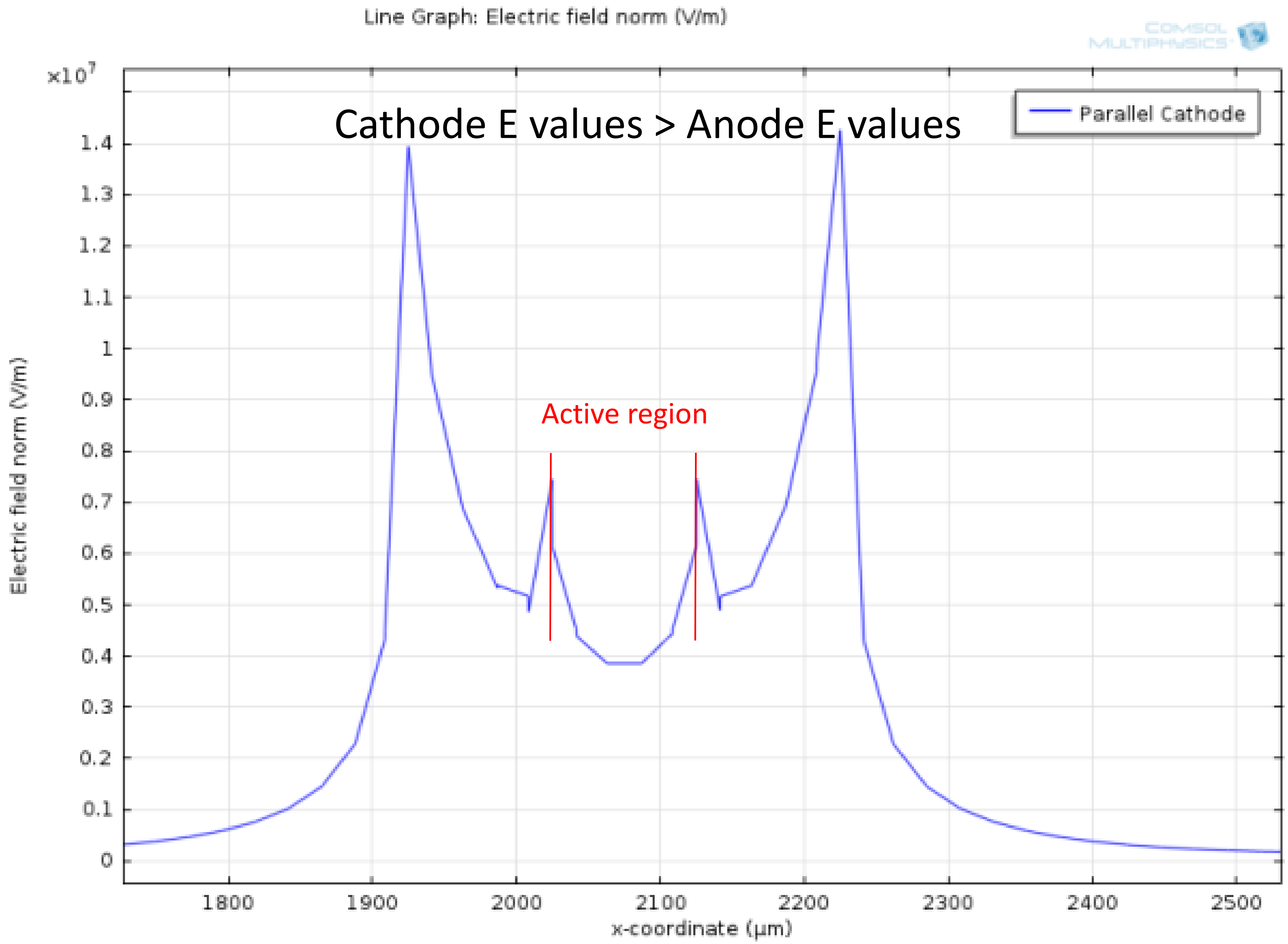
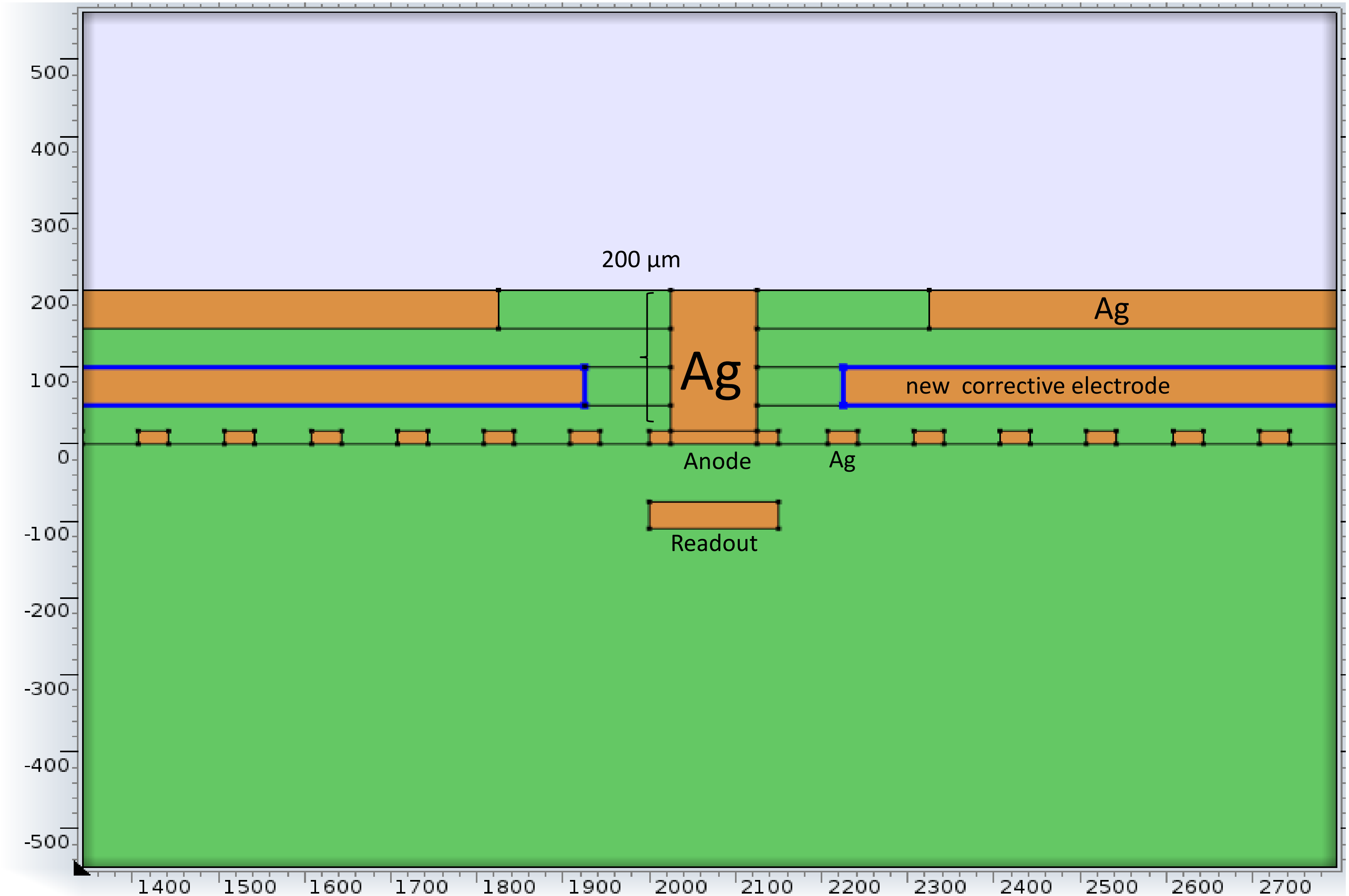


Spiral Detector –Second Improvement-



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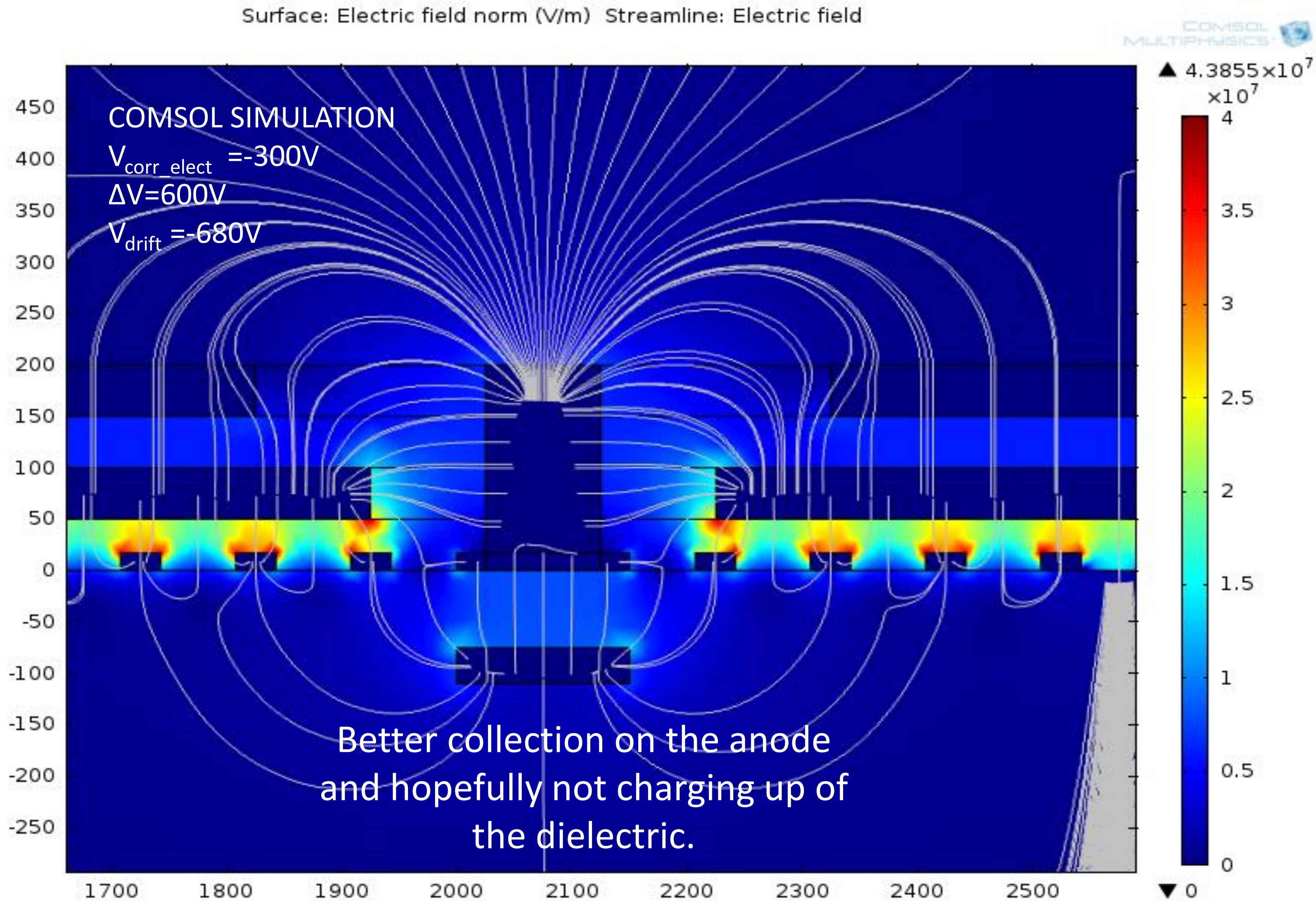
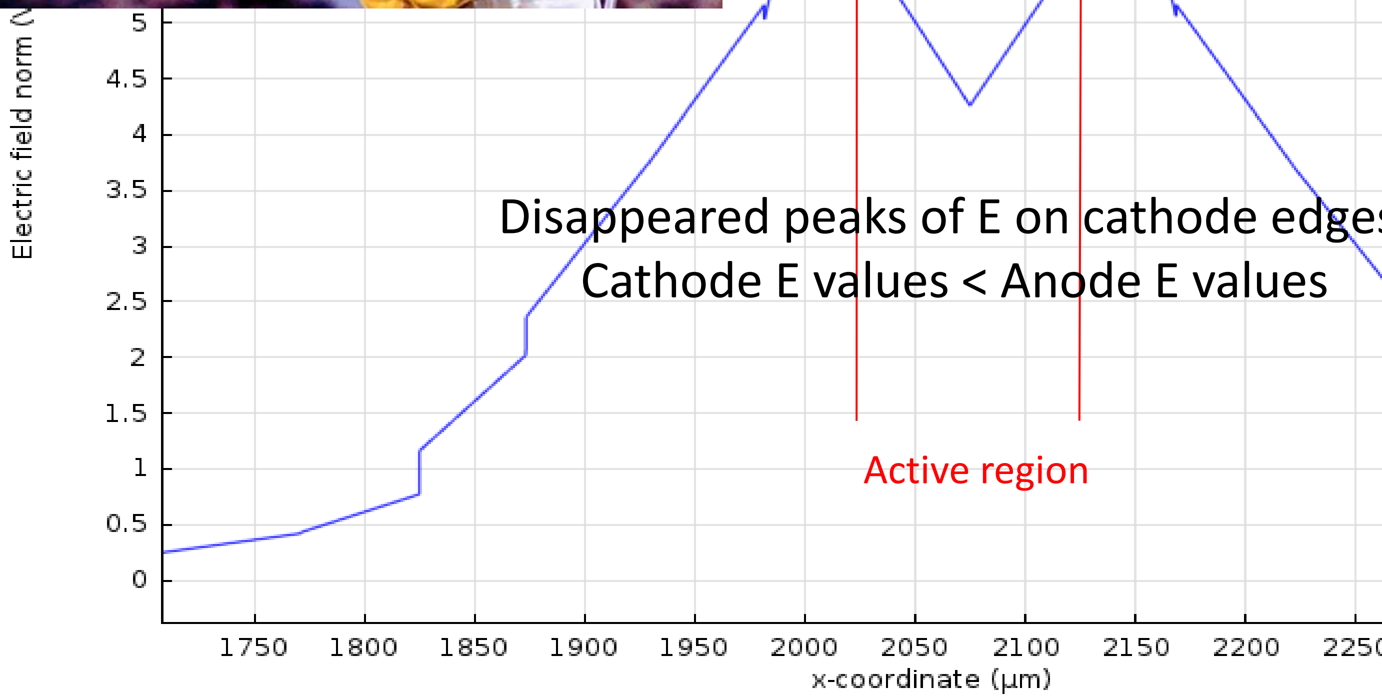
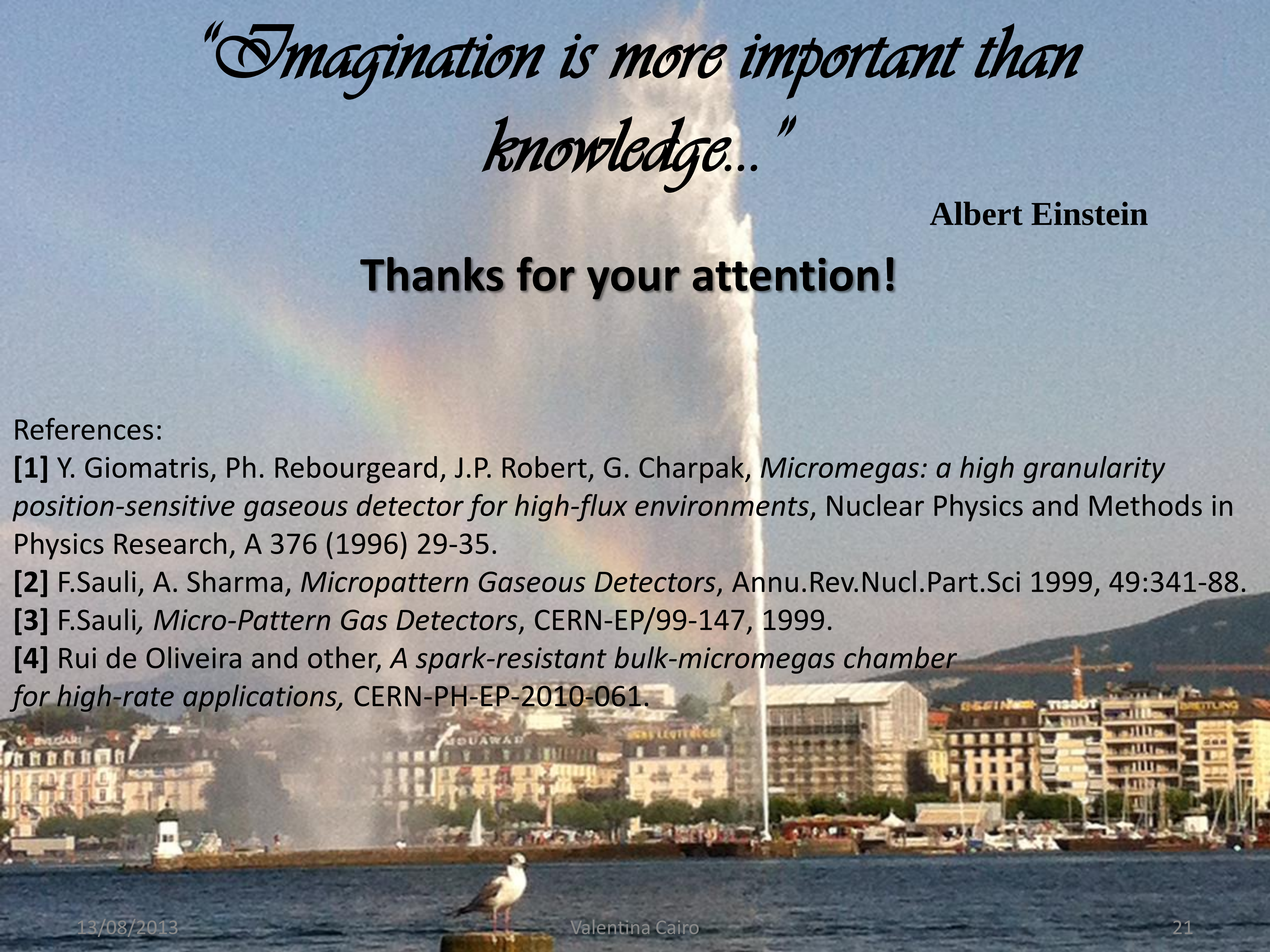


Spiral Detector –Second Improvement-



Disappeared peaks of E on cathode edges,
Cathode E values < Anode E values



"Imagination is more important than knowledge…"

Albert Einstein

Thanks for your attention!

References:

[1] Y. Giomatris, Ph. Rebourgeard, J.P. Robert, G. Charpak, *Micromegas: a high granularity position-sensitive gaseous detector for high-flux environments*, Nuclear Physics and Methods in Physics Research, A 376 (1996) 29-35.

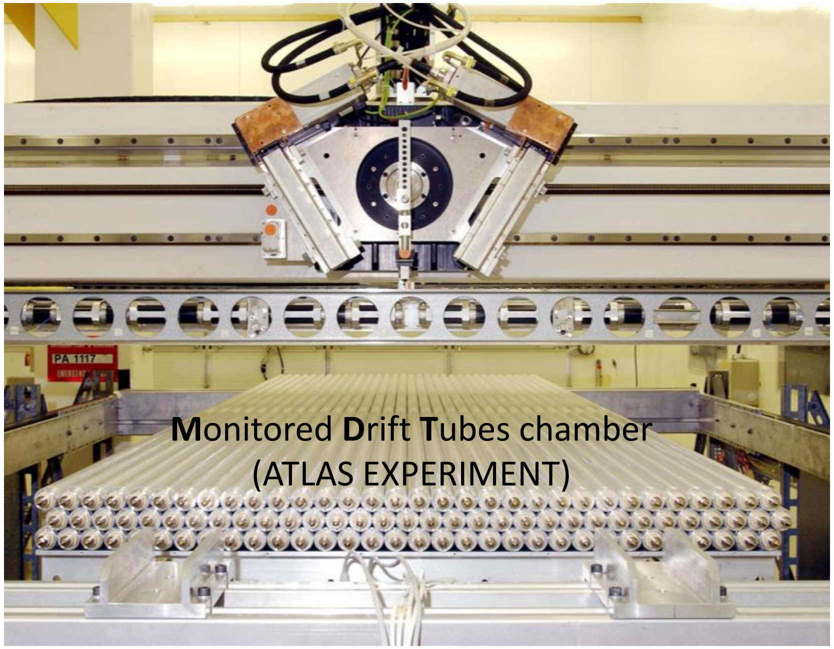
[2] F.Sauli, A. Sharma, *Micropattern Gaseous Detectors*, Annu.Rev.Nucl.Part.Sci 1999, 49:341-88.

[3] F.Sauli*, Micro-Pattern Gas Detectors*, CERN-EP/99-147, 1999.

[4] Rui de Oliveira and other, *A spark-resistant bulk-micromegas chamber for high-rate applications,* CERN-PH-EP-2010-061.

EXTRA SLIDE

Classical Gas Detectors



Monitored **D**rift **T**ubes chamber
(ATLAS EXPERIMENT)

ATLAS/MDT : 1 kHz / cm² → 10% gain loss