Multi-Wire gas-filled Electron Multiplier (MWEM)
Crossing Wire – CWEM
Parallel Wire – PWEM

Presented by **S.Movchan** (JINR)

A.Kashchuk[a], V.Bayev[b], O.Levitskaya[a] , S.Movchan[c] ,

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ВВЕДЕНИЕ

Известна конструкция колодезного электронного умножителя, в которой ликвидирован индукционный зазор – the WELL detector.

Появилось множество разновидностей, в частности, μRWELL .

Одни авторы рассматривают этот прибор, как разновидность GEM без индукционного зазора, другие – как разновидность ММ со спейсером из каптона, выполненном травлением.

В конструкции μRWELL в качестве анода введено резистивное покрытие из алмазоподобного углерода (DLC) толщиной ~100 нм.

В этом приборе в выходном сигнале доминирует ионный ”хвост”, который ограничивает быстродействие. Без специальных мер практически до уровня MWPC снижается быстродействие, т.к. в длительности выходного импульса на считывающем электроде может доминировать даже не время транзита положительных ионов через зазор умножения, как в ММ, а время стекания заряда электронов Q- с резистивной поверхности анода на землю.

Конструкция μRWELL длительное время совершенствовалась с целью повышения быстродействия, пока не была достигнута загрузочная способность $\sim 10^{7}$ $с^{-1}см^{-2}$, на два порядка превышающая возможности MWPC. Предложенные технические решения довольно сложные с двумя резистивными слоями.

Ниже – иной подход к повышению загрузочной способности WELL (μWELL) с резистивным анодом из DLC, нанесенном на густую печатную решетку.

The Well* (micro-Well) Electron Multiplier with the DLC anode — a key element of the robust 2D-position sensitive MPGD for high rates

2020 JINST 15 C09018 2020 JINST 15 C09041

Presented by **S.Movchan** (JINR)

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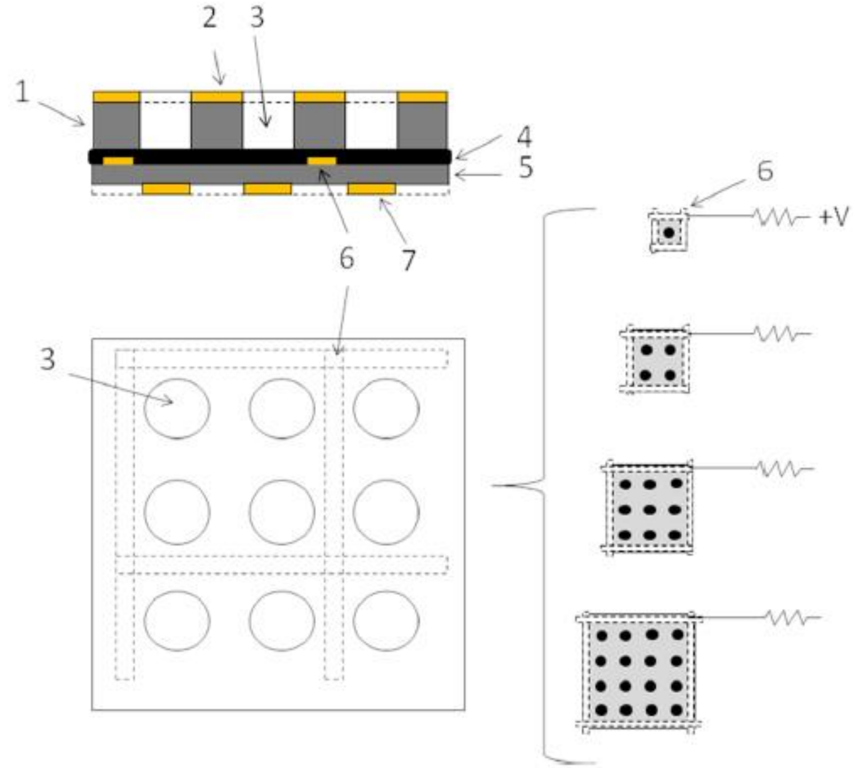
[e] *Joint Institute for Nuclear Research, Russia*

*) The WELL detector» R.Bellazzini et al., NIM A 423 (1999) 125

a)



b)

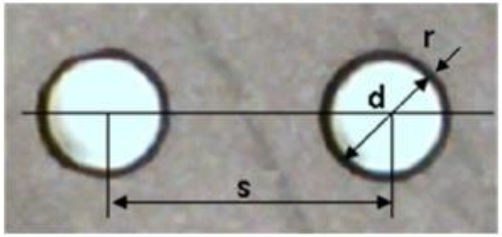
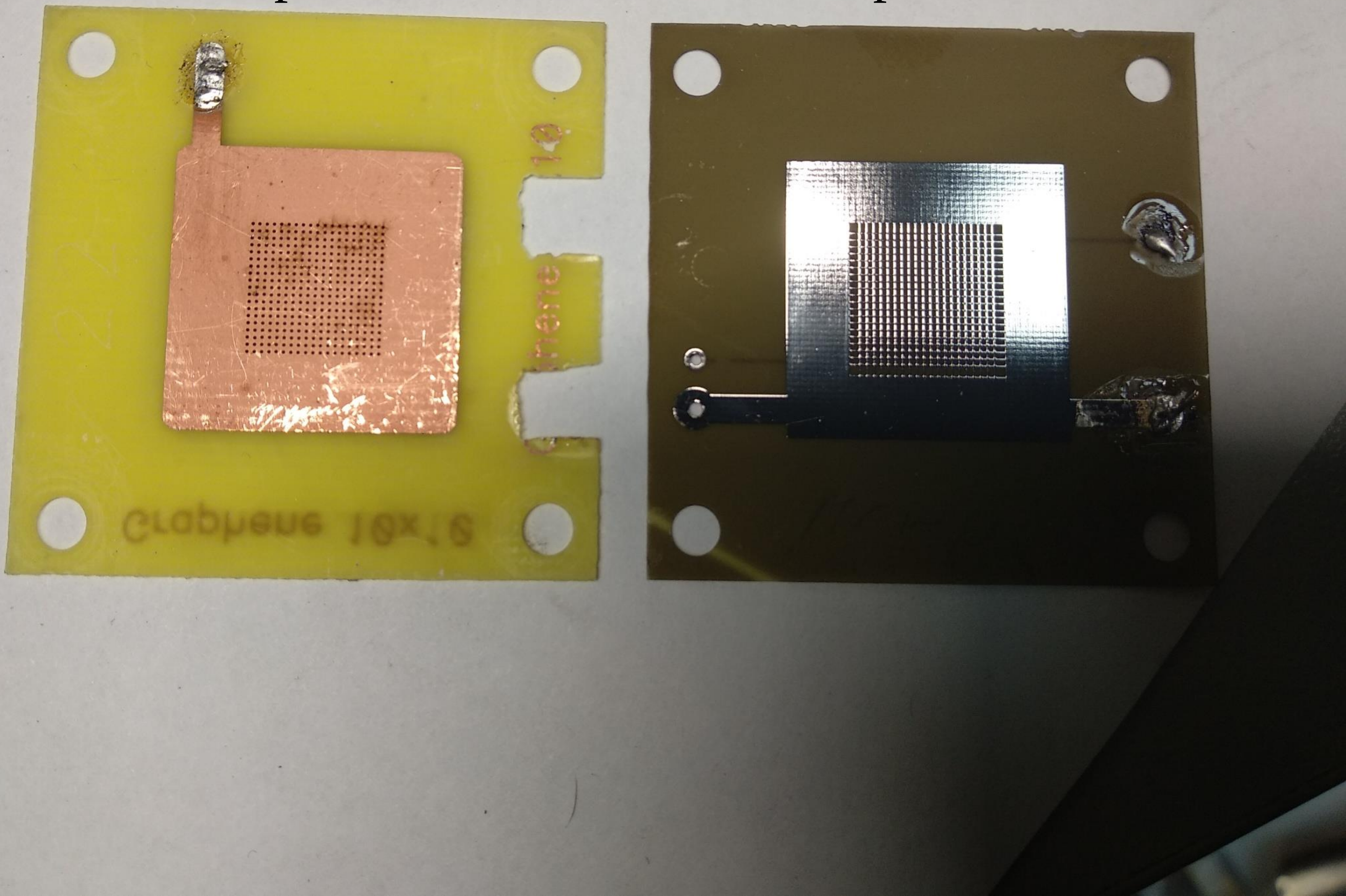


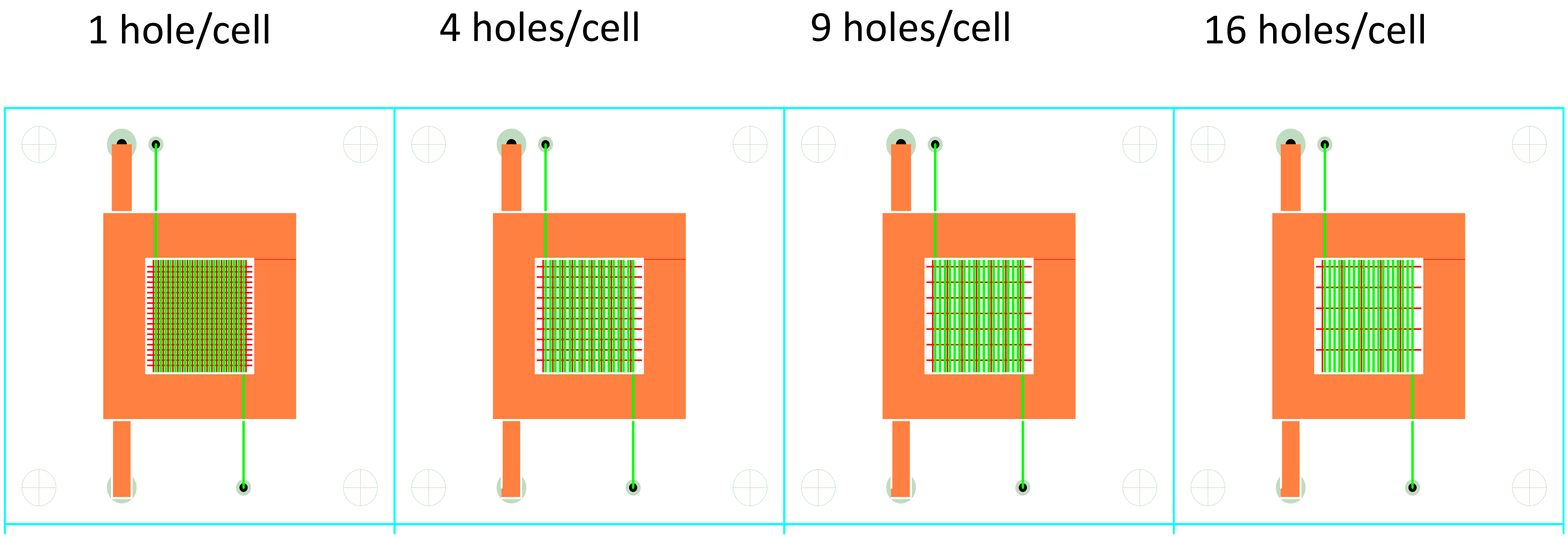
Figure 1. The Well Electron Multiplier in cross-section (*a*) and top view (*b*):
1 dielectric substrate with copper on one side (board 1)
2 1st electrode
3 blind well-like hole d = 200 μm, s = 500 μm, r~15 μm, board thickness 500 μm
4 resistive DLC layer (anode)
5 dielectric substrate with copper on both sides (board 2)
6 2nd electrode: copper mesh at various configurations of conductors surrounding either 1 hole (grid 1), or 4 = 2 × 2 (grid 2), 9 = 3 × 3 (grid 3), 16 = 4 × 4 (grid 4)
7 3rd electrode (strip/pad/pixel readout elements).

1st board
Top view

2nd board
Top view

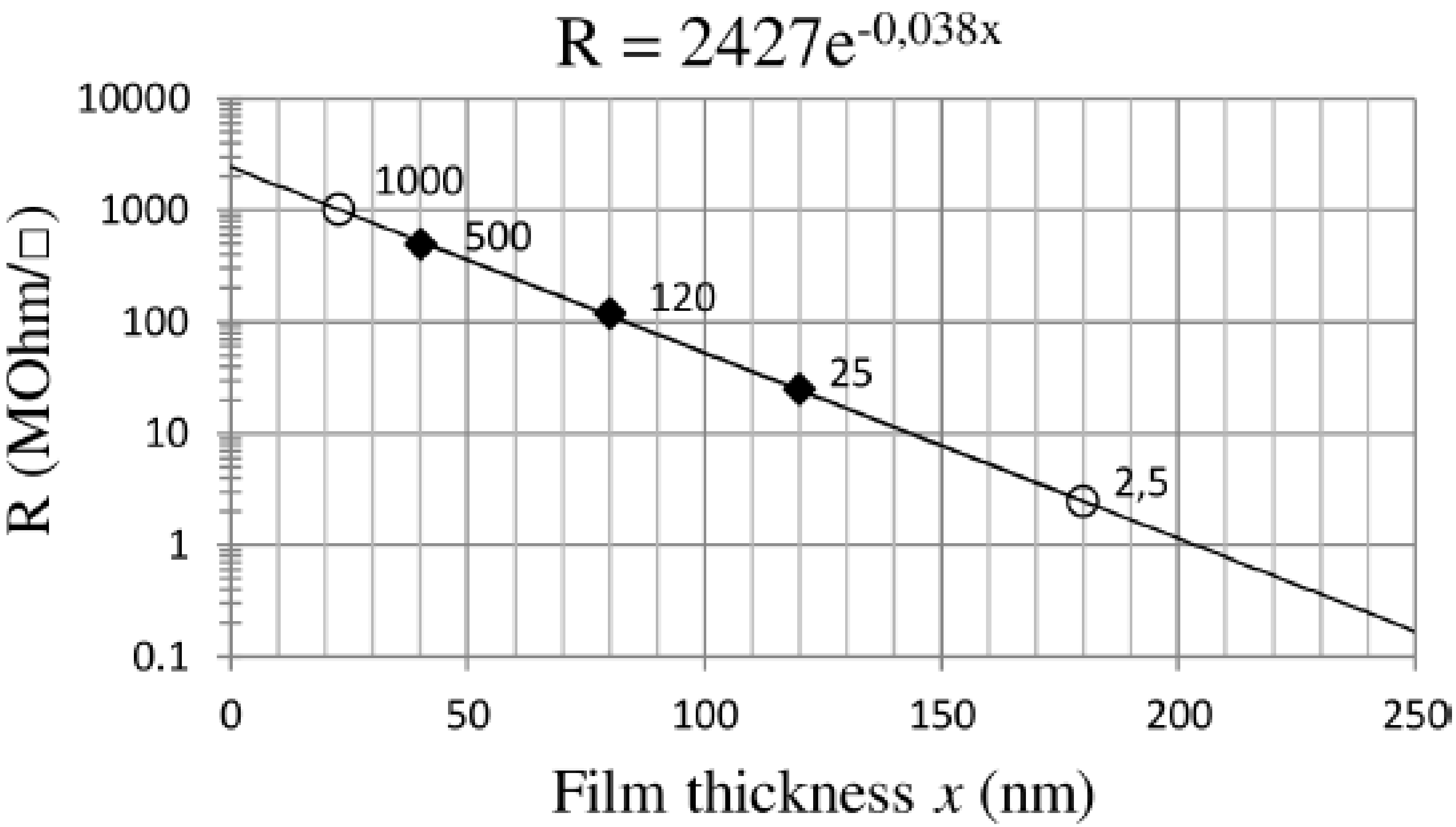


Modifications of the 2nd electrode



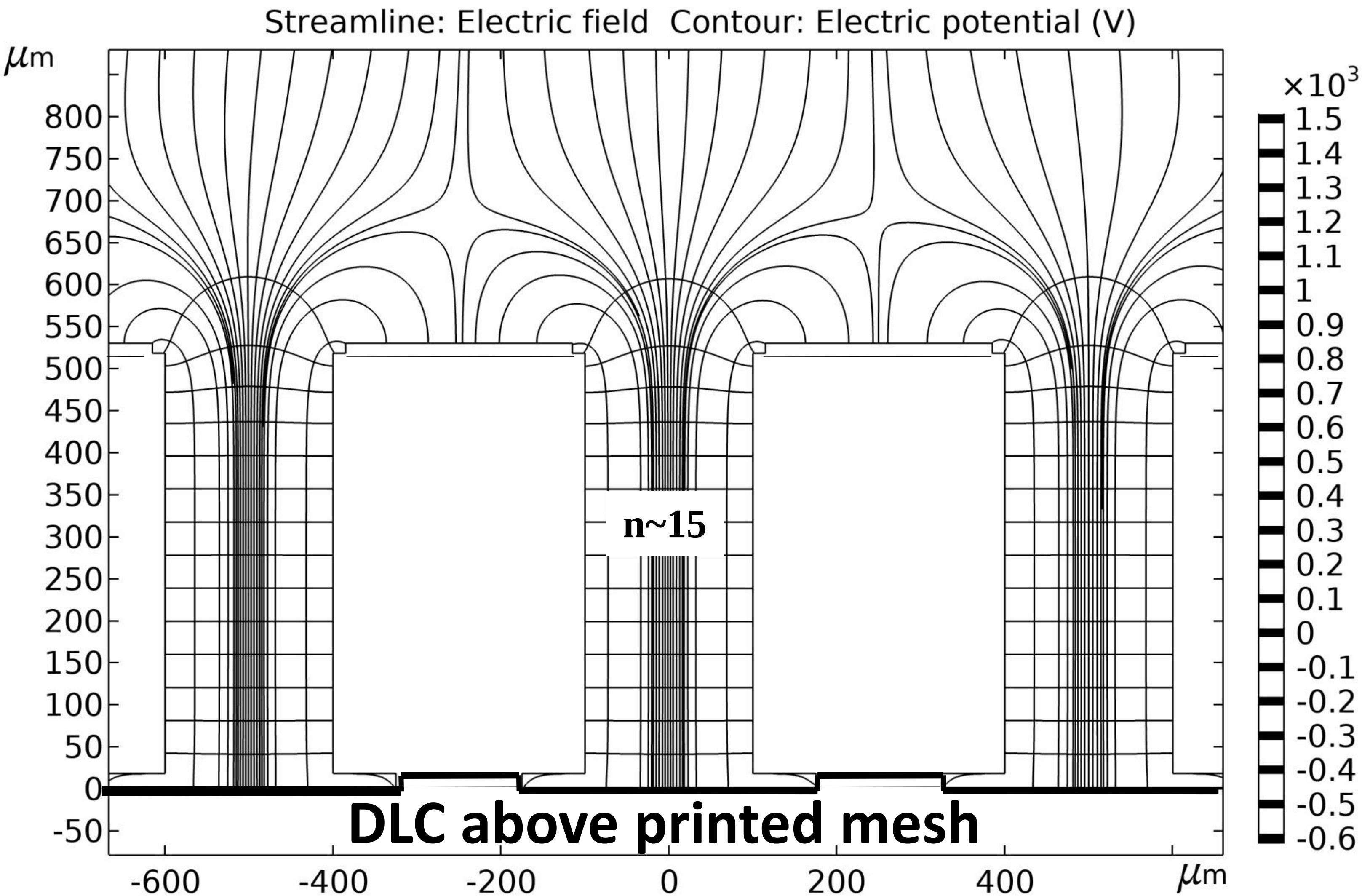
DLC is deposited on top of the mesh

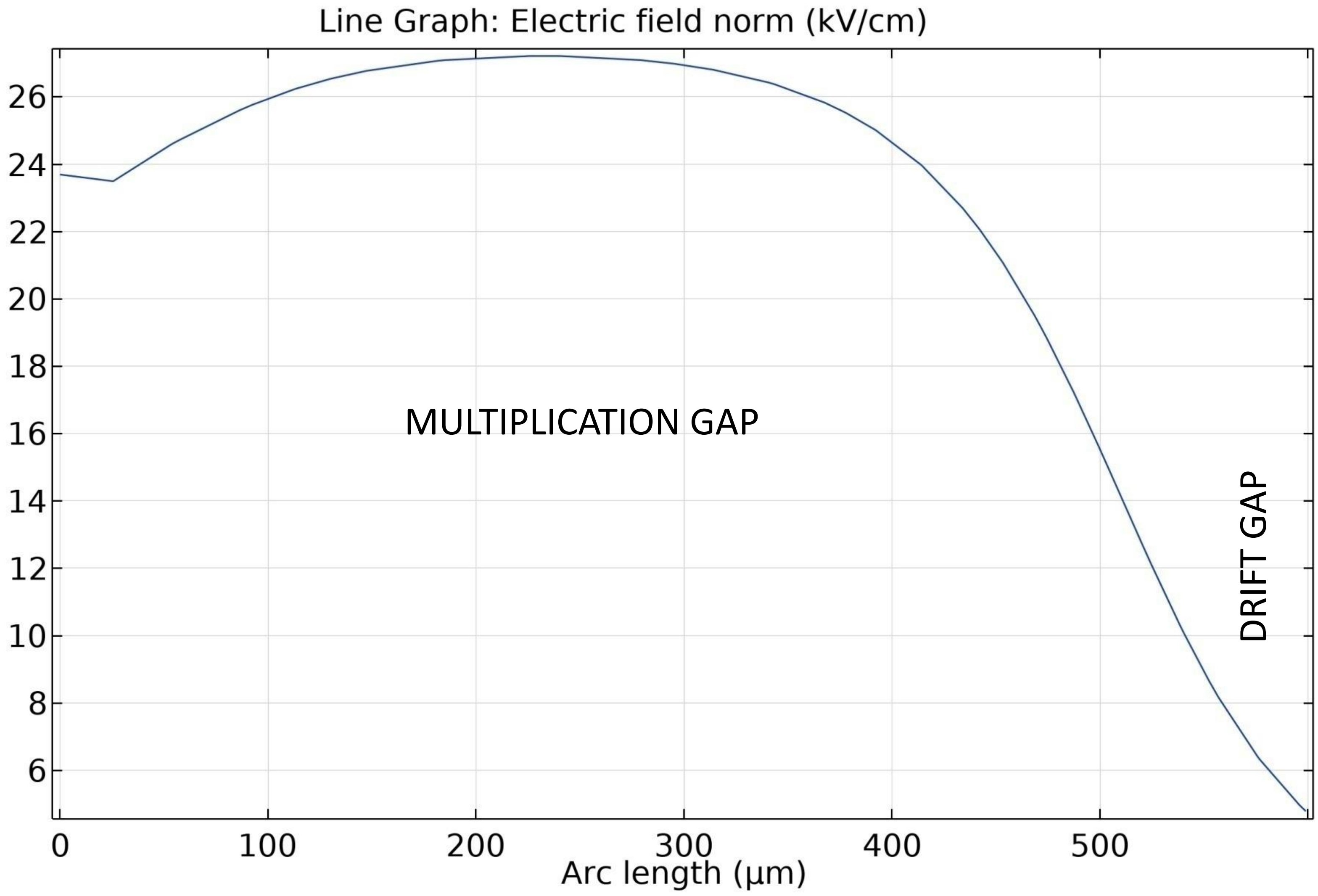
Resistivity vs. film thickness



RWELL (d200, s500, h500) at G~30k (n~15)

Uc=-600V_Utop=0V_Ubot=+1500V





Line Graph: Electric field norm (kV/cm)
26
24
22
20
18
16
14
12
10
8
6
0
100
200
300
400
500
Arc length (µm)
MULTIPLICATION GAP
DRIFT GAP

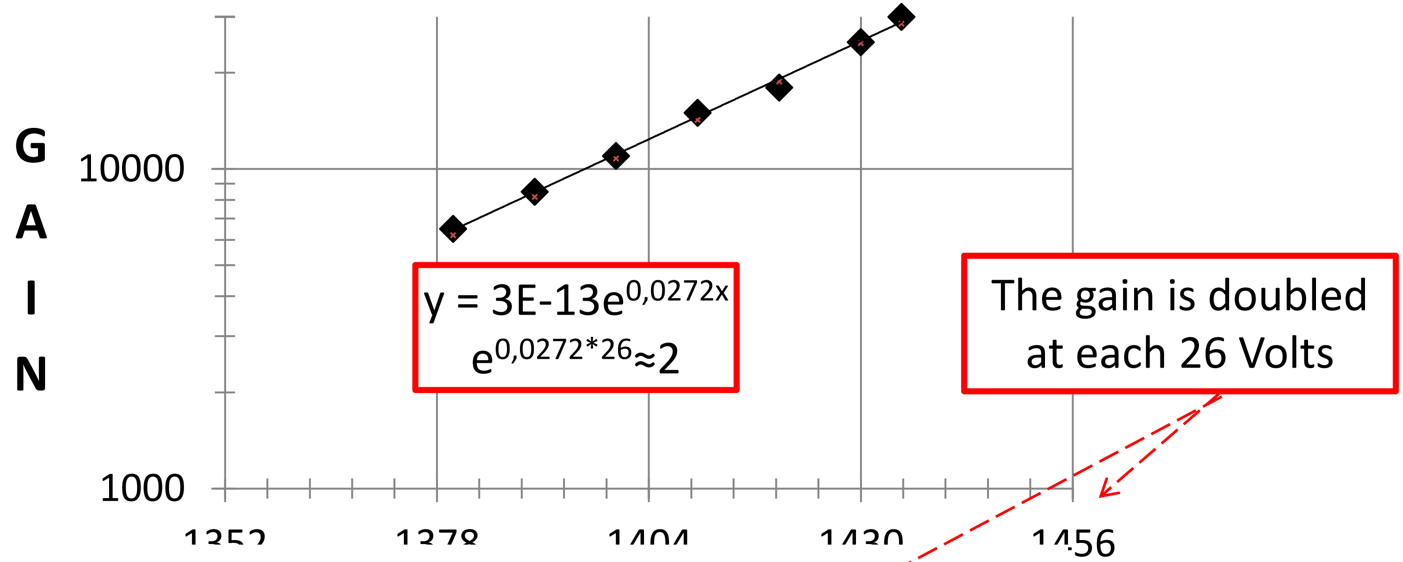
Gas Gain parameterization $G=2^{(V-V_{min})/\Delta V_i}=2^n$

2 parametrs: 1) Vmin – Voltage at which multiplication process starts

2) ΔVi=26 eV – average energy per pair electron-ion production

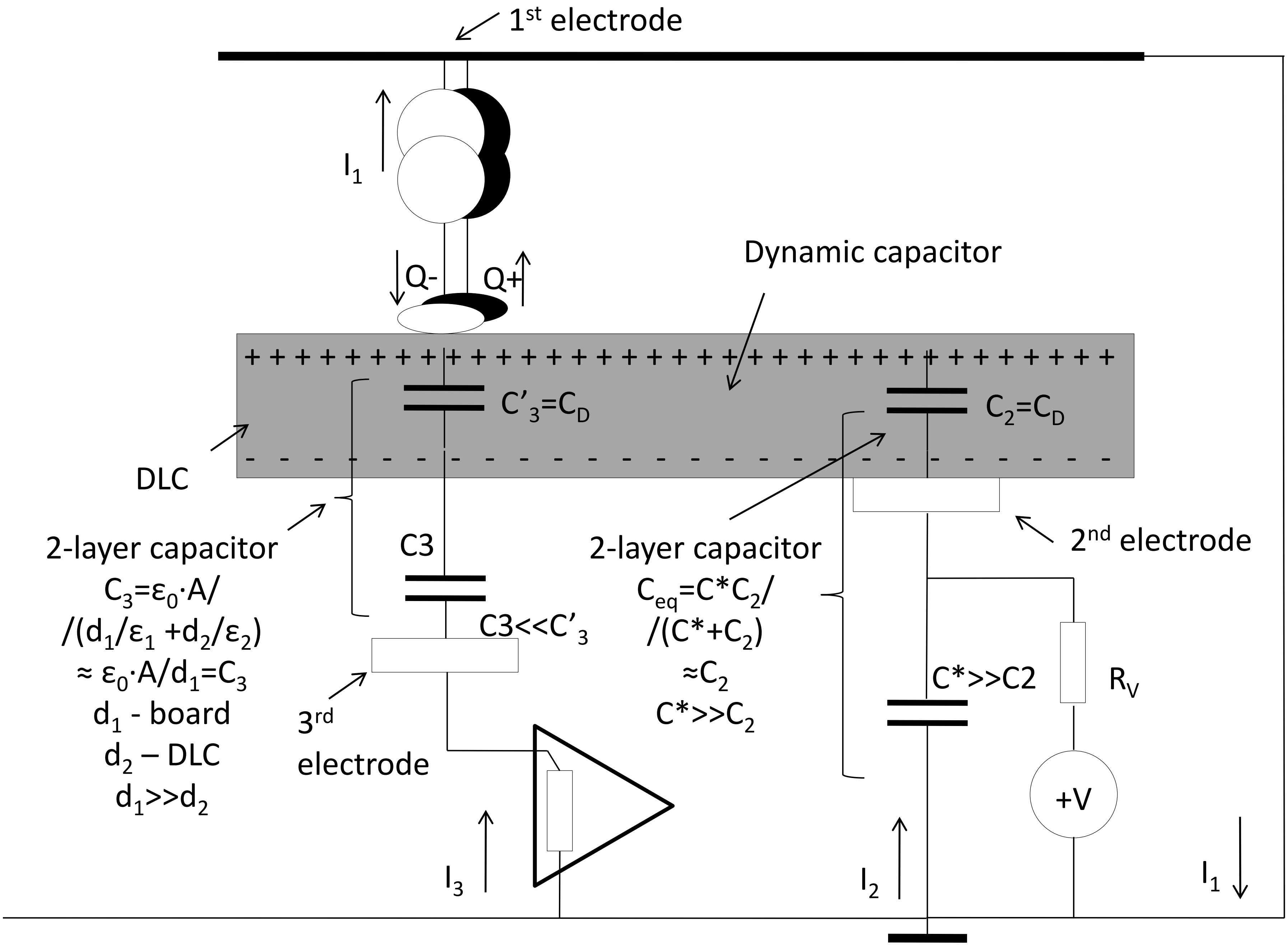
n – number of equipotentials in multiplication gap

For multiplication V>Vmin, otherwise – transport without multiplication



Gas	ρ [mg cm^{-3}]	E_X [eV]	E_I [eV]	W_I [eV]	$dE/dx\|_{min}$ [keV cm^{-1}]	N_P [cm^{-1}]	N_T [cm^{-1}]
He	0.18	19.8	24.6	41	0.32	3.5	7.7
Ne	0.84	16.7	21.6	37	1.45	13	40
Ar	1.66	11.6	15.7	26	2.53	25	97
Xe	5.50	8.4	12.1	22	6.87	41	312
CO_2	1.84	7.0	13.8	34	3.35	35	100
iC_4H_{10}	2.49	6.5	10.6	26	5.67	90	220

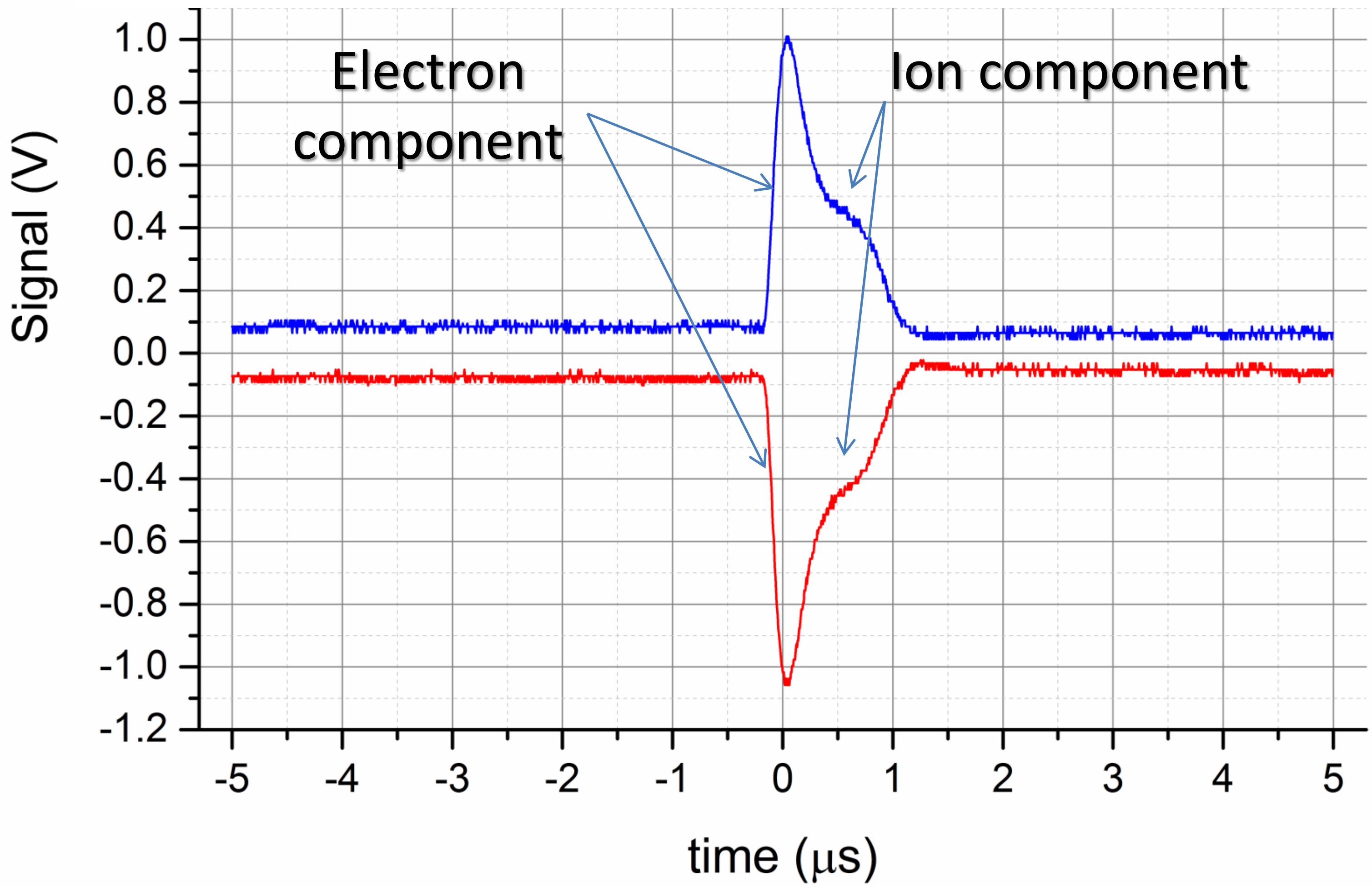
Table 2.1.: Properties of noble and molecular gases at normal temperature and pressure (NTP: 20°C, one atm). E_X, E_I: first excitation, ionization energy; W_I average energy per ion pair; $dE/dx|_{min}$, N_P, N_T: differential energy loss, primary and total number of electron-ion pairs per cm for a unit charge minimum ionizing particle [46].



1st electrode
I1
Q-
Q+
Dynamic capacitor
C'3=CD
C2=CD
DLC
2-layer capacitor
C3=ε0·A/
/(d1/ε1 +d2/ε2)
≈ ε0·A/d1=C3
d1 - board
d2 – DLC
d1>>d2
C3
C3<<C'3
3rd
electrode
2-layer capacitor
Ceq=C*C2/
/(C*+C2)
≈C2
C*>>C2
2nd electrode
C*>>C2
RV
+V
I3
I2
I1

SIGNALS

Signals on the 1st and 2nd electrodes are symmetric at missing 3rd electrode (закон Кирхгофа)



Amp. Tp=160 ns Mesh 1 мм (4 holes/cell)
Polarity inverted

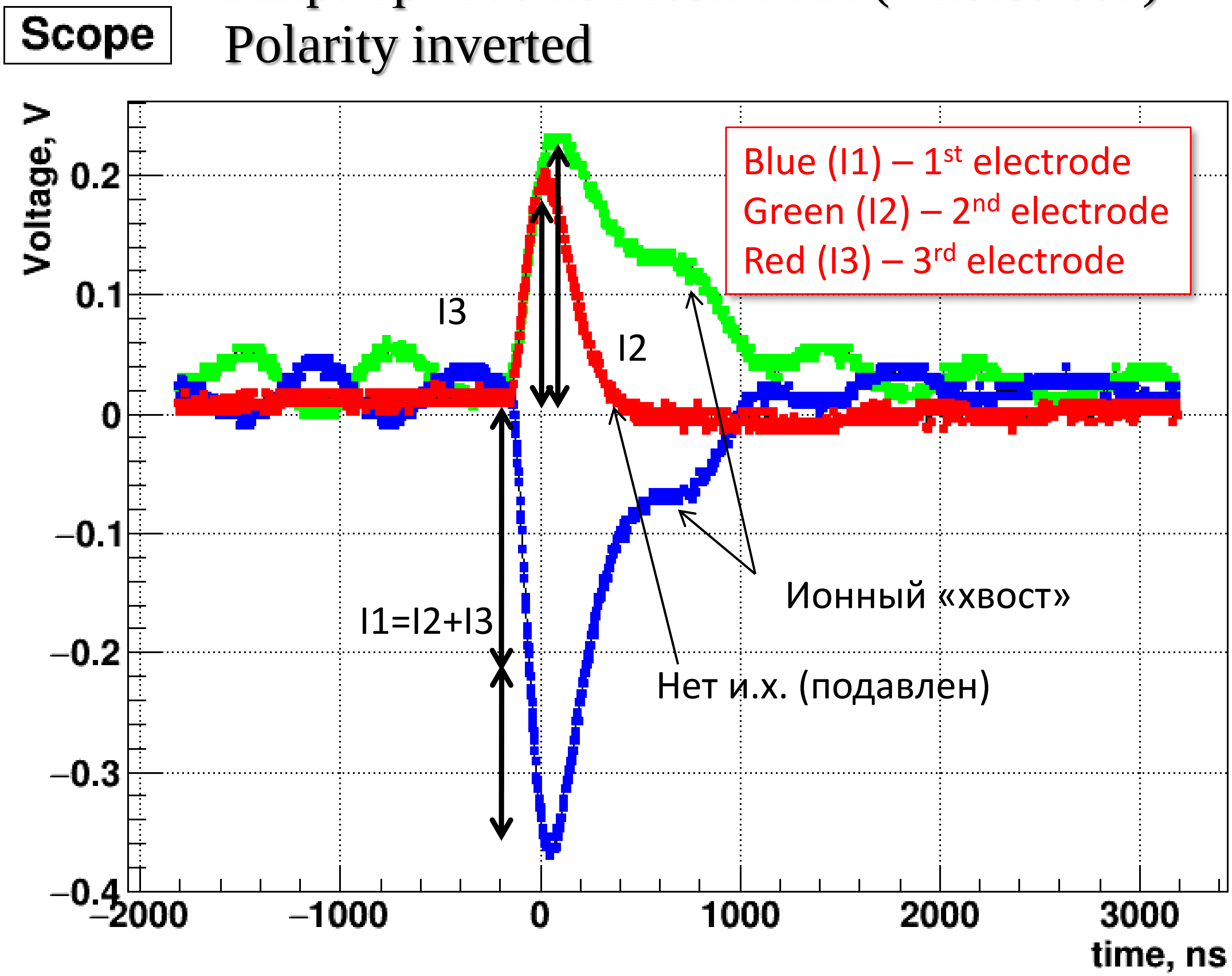
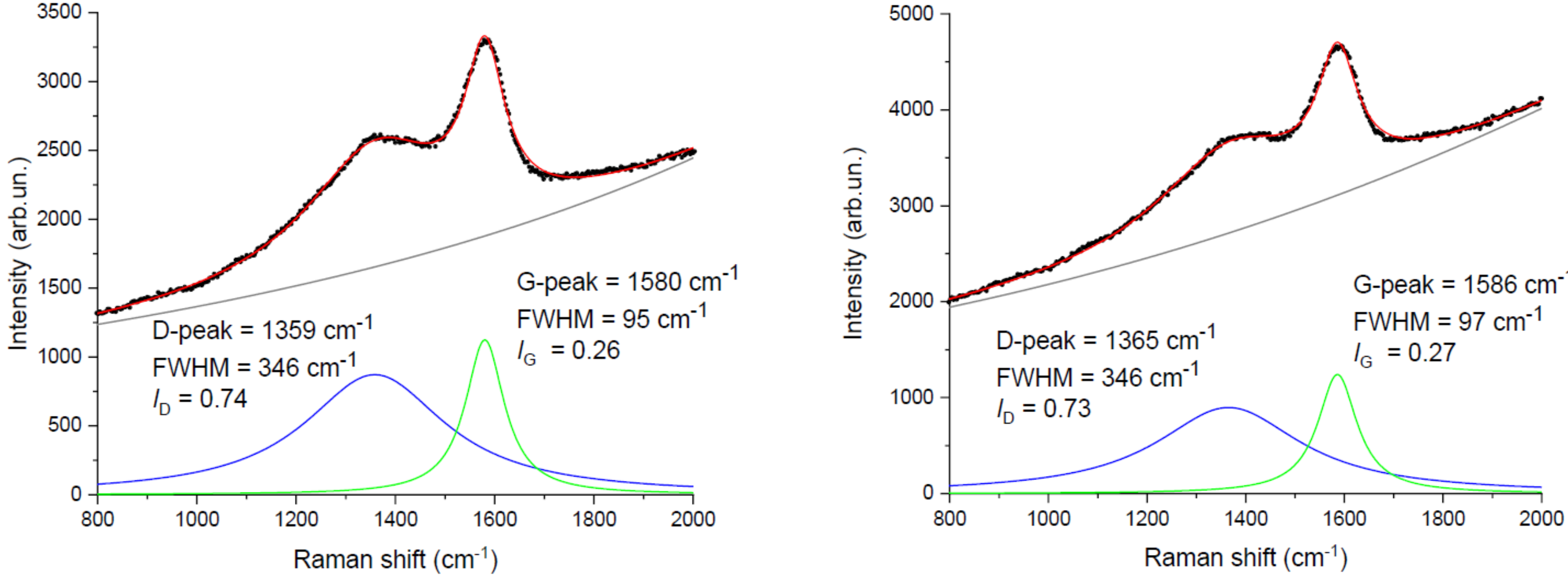


Figure 14. The ion tail suppression in the resistive Well MPGD (grid 2, figure 1) at scale 5 mV/div and 200 ns/div by changing capacitance C^* (figure 4): no capacitor (a), 100 pF (b), 1 nF (c), 2 nF (d).

Raman spectra before (left) and after (right) 1 million discharges with 5 MeV alpha-particles at op. gas gain 6000

NEW

No visible DLC damage, see parameters
sp3/sp2=(0.35+-0.02) before
sp3/sp2=(0.37+-0.02) after



Conclusion

- Fast electron evacuation with mesh 0.5-2 mm
- Ion tail suppression to 1% on the amp. input, the residuals will be suppressed by the Base Line Restorer
- High counting rates ~50 MHz, pulse width ~20 ns
- Robust detector:

  no visible DLC damage at one million discharges at operational gain 6000, as shown with Raman spectra
- Similar method can be used in conjunction with other MPGD, e.g. MM

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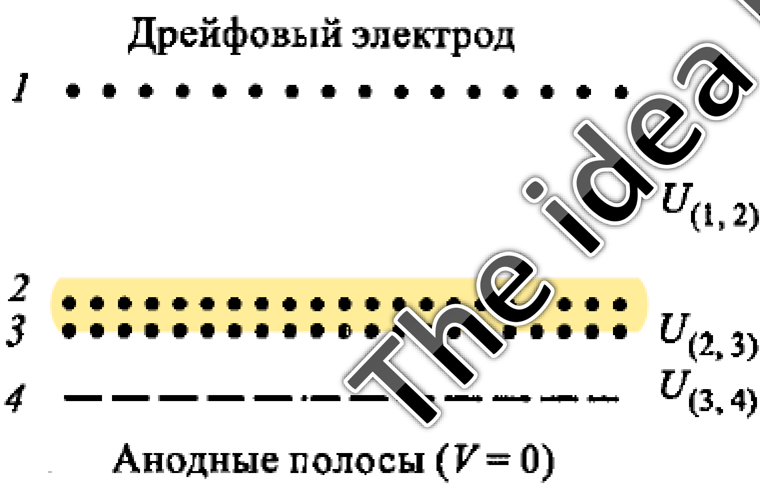
КООРДИНАТНЫЙ ДЕТЕКТОР ВЫСОКОГО ПРОСТРАНСТВЕННОГО РАЗРЕШЕНИЯ НА ОСНОВЕ МНОГОПРОВОЛОЧНОГО ГАЗОВОГО ЭЛЕКТРОННОГО УМНОЖИТЕЛЯ

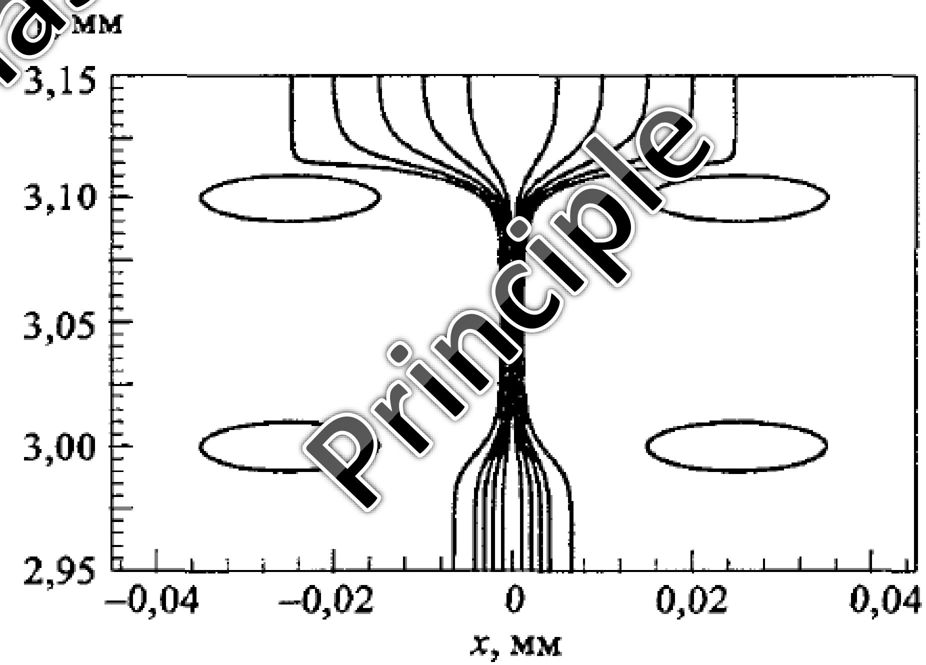
М.Д.Шафранов, Т.П.Топурия

Particles and Nuclei, Letters. 2001. №2[105]

The idea has 20 years

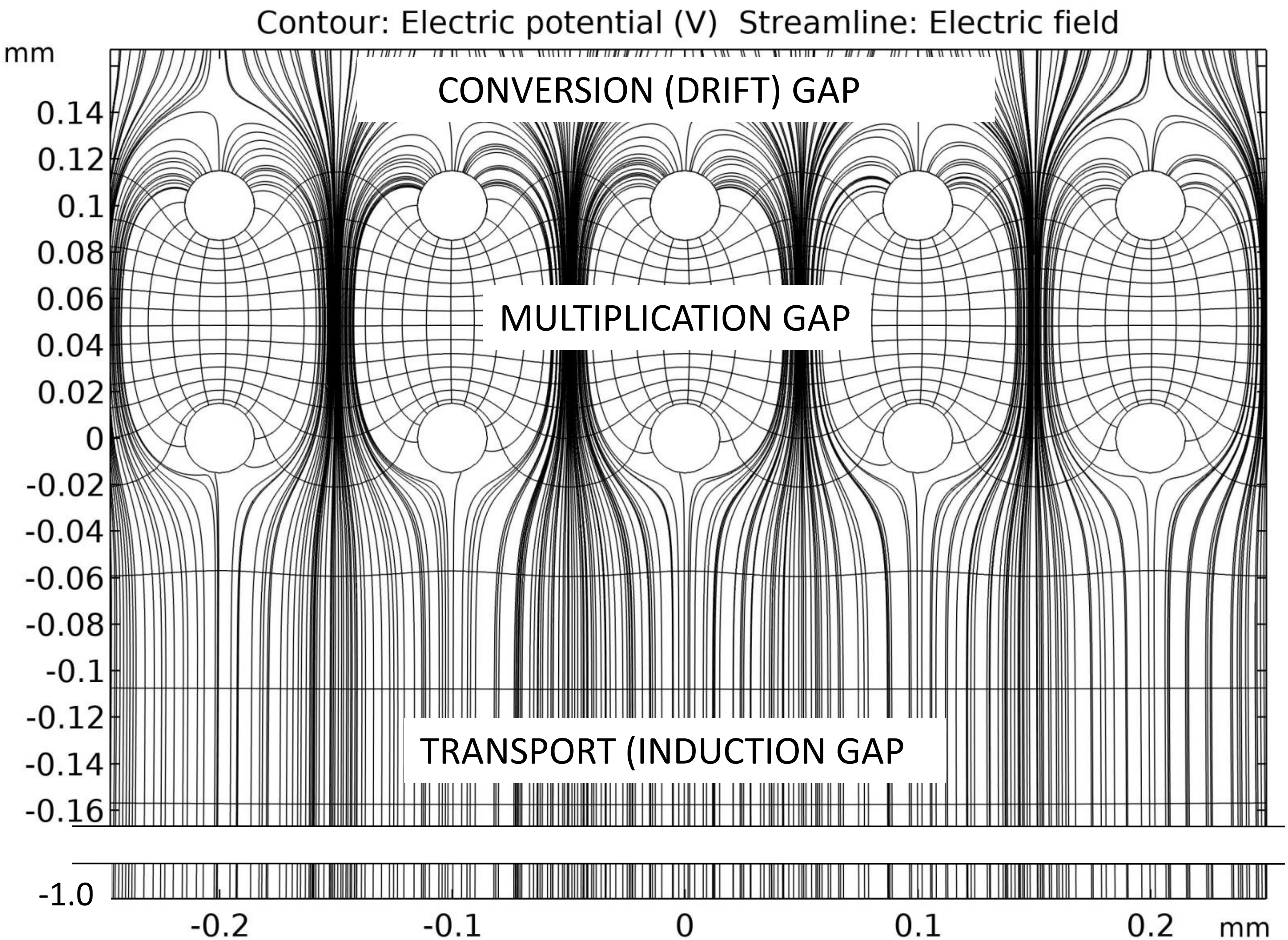
радиус проволочек r = 10 мкм, расстояние между центрами проволочек s, образующих каждую плоскость, составляет 50 мкм, расстояние между плоскостями проволочек d = 100 мкм.



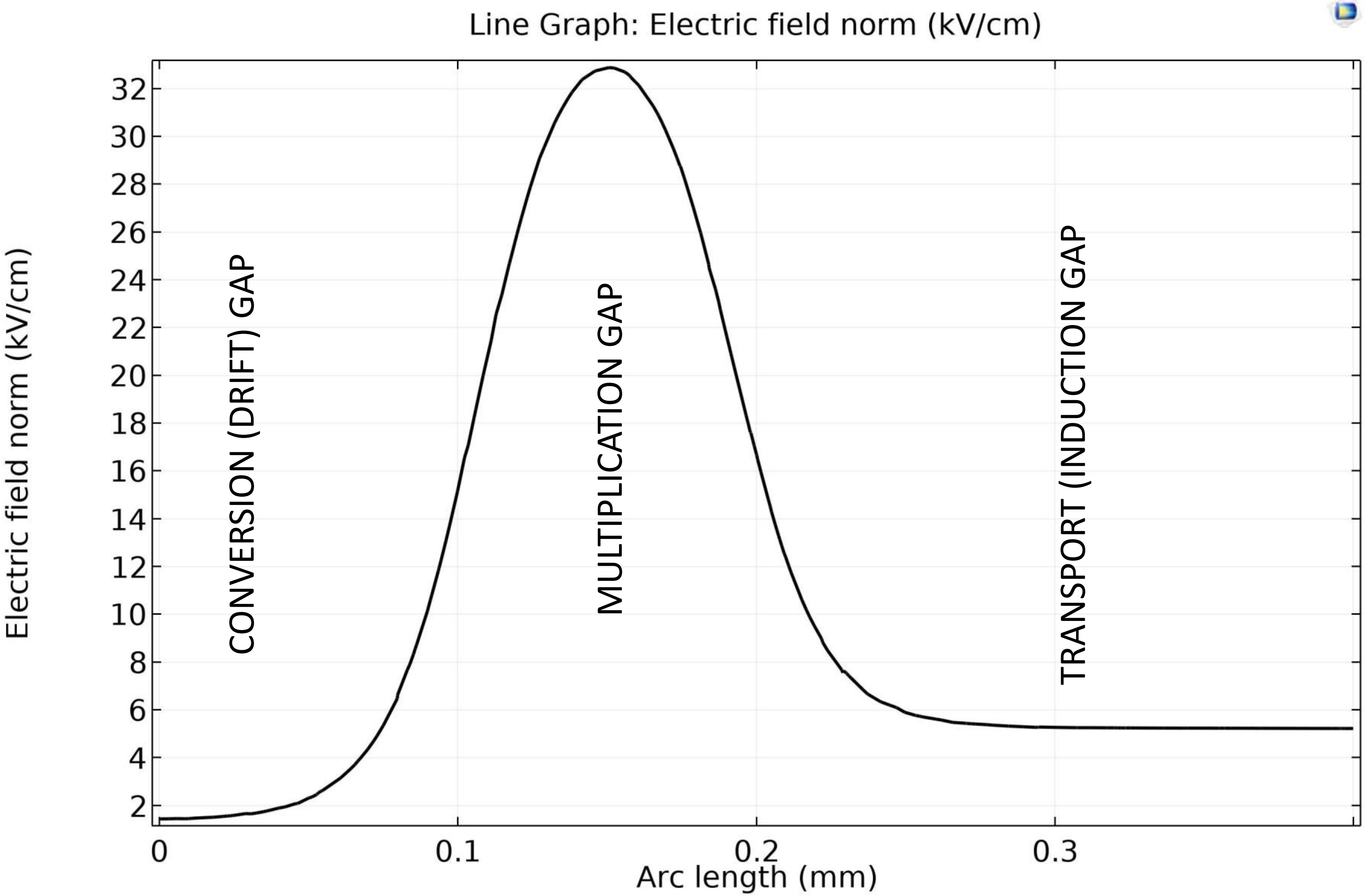


Principle

PWEM_d30s100h100g1000_-300/0/+350/+850V



E(z)_PWEM_d30s100h100g1000

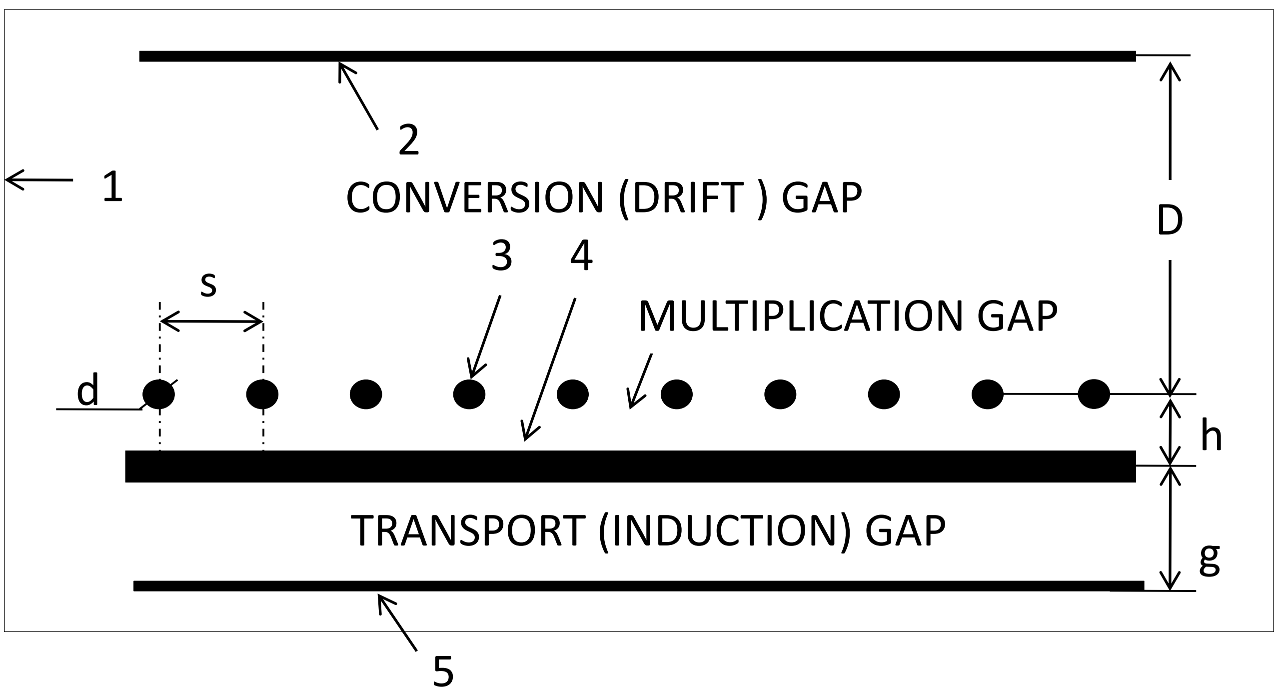


Crossing Wire gas-filled Electron Multiplier (CWEM)

gives both X и Y coordinates with X/X0~0.02% using AlMg(5%) wires

Typical wire diameter d=20-50 μm, pitch s≈πd, h>d

1 – Gas-filled volume
2 – Drift electrode
3 – 1st wire electrode
4 – 2nd wire electrode (with parallel or crossing wires)
5 – Readout (3rd electrode/option)



Inefficiency of grid shielding

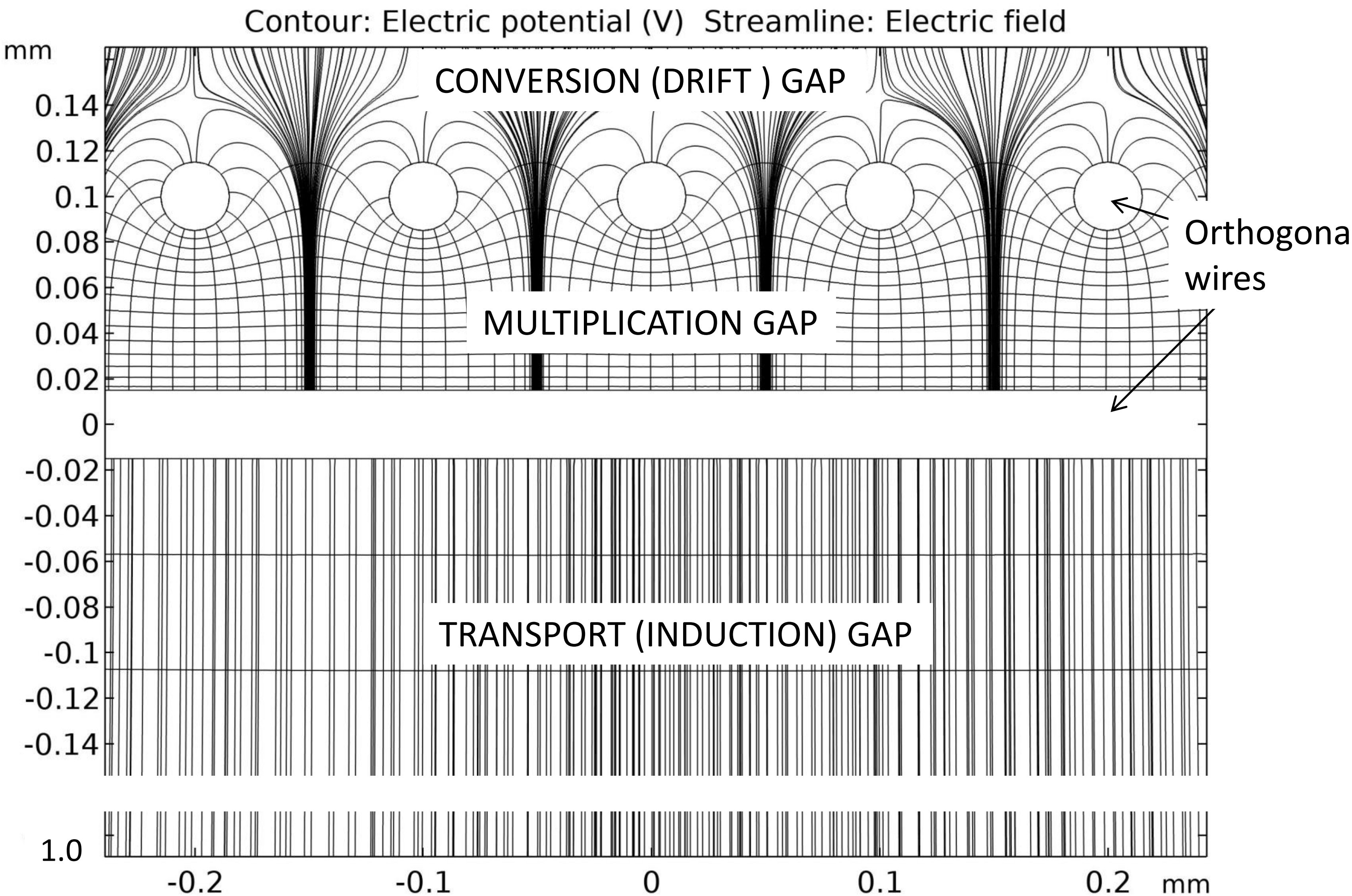
$$\sigma = \frac{s}{2\pi h} \cdot log\left(\frac{s}{\pi d}\right)$$

Buneman O., Granshjaw T.E., Harvey J.A. // Canad. J. Res. A. 1949. V.27. P.191

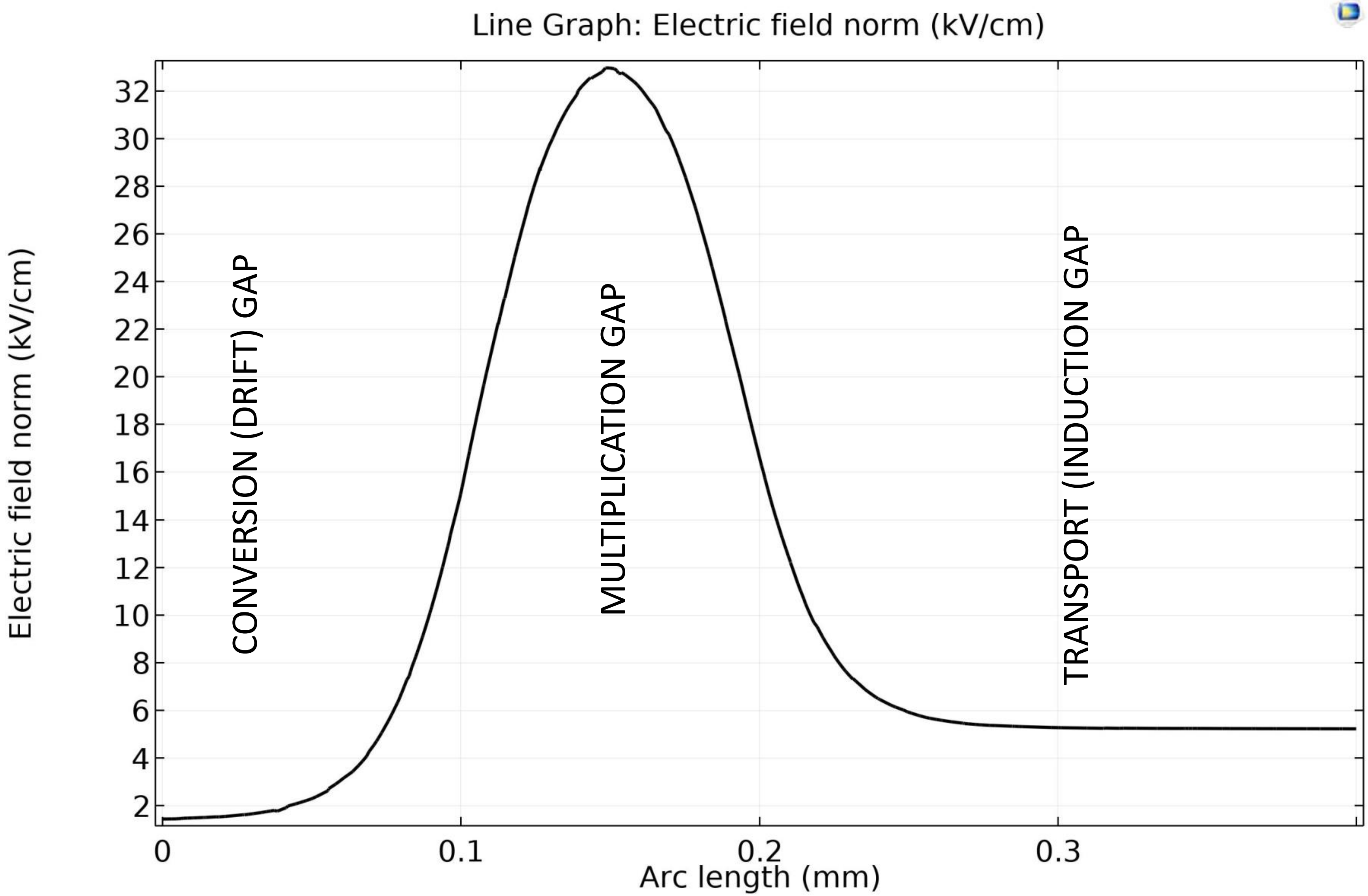
$\sigma=0$ at $s=\pi d$ for any h, h>d

Similar to GEM one can use h~2 mm to transport electrons to the readout board, minimizing the ion tail contribution to the output pulse width.
Similar to MM one can use h~100 µm (or even less) to minimize ion tail contribution to the output pulse width
Both PWEM and CWEM use h~2 mm similar to GEM and h~100 µm (or even less) similar to MM
To keep accurate planarity one can use technique developed for MM (pillars, etc.)

CWEM_d30s100h1000 with induction gap 1 mm



E(z)_CWEM_d30s100h100g1000



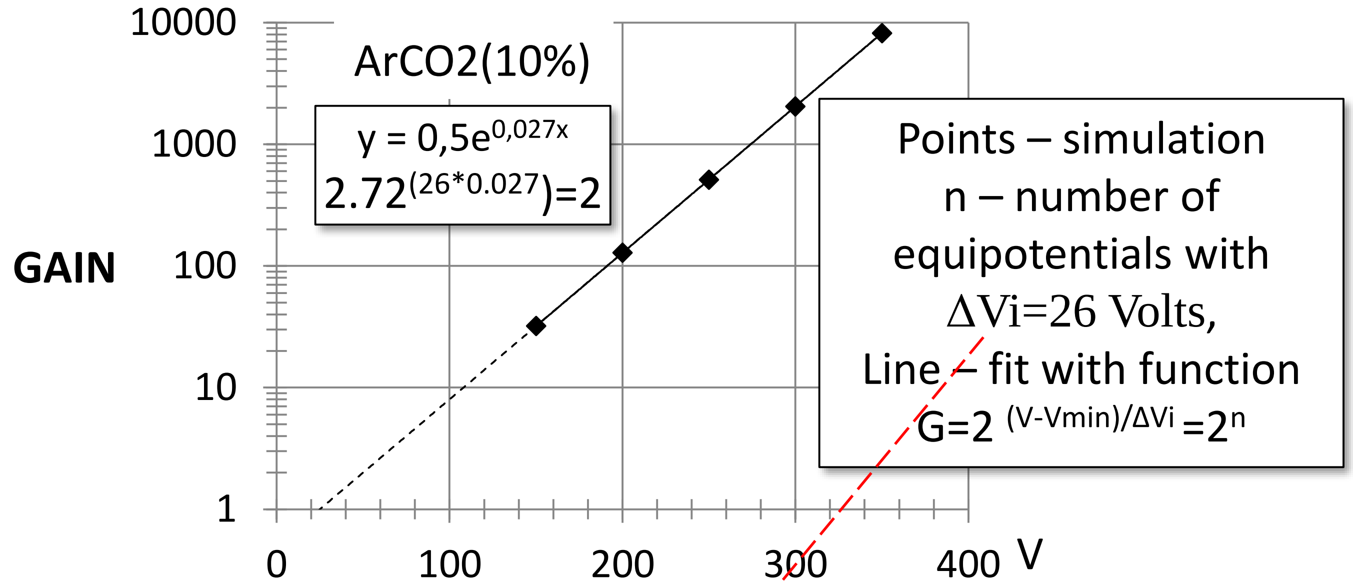
Gas Gain parameterization $G=2^{(V-V_{min})/\Delta V_i}=2^n$

2 parametrs: 1) Vmin – Voltage at which multiplication process starts

2) ΔVi=26 eV – average energy per pair electron-ion production

n – number of equipotentials in multiplication gap

For multiplication V>Vmin, otherwise – transport without multiplication



Gas	ρ [mg cm^{-3}]	E_X [eV]	E_I [eV]	W_I [eV]	$dE/dx\|_{min}$ [keV cm^{-1}]	N_P [cm^{-1}]	N_T [cm^{-1}]
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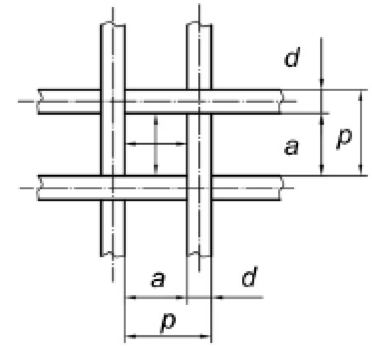
MM ATLAS

Woven wire mesh



“бугры” на поверхности каптона – резистивные стрипы
Под ними – металлические (считывающие) стрипы

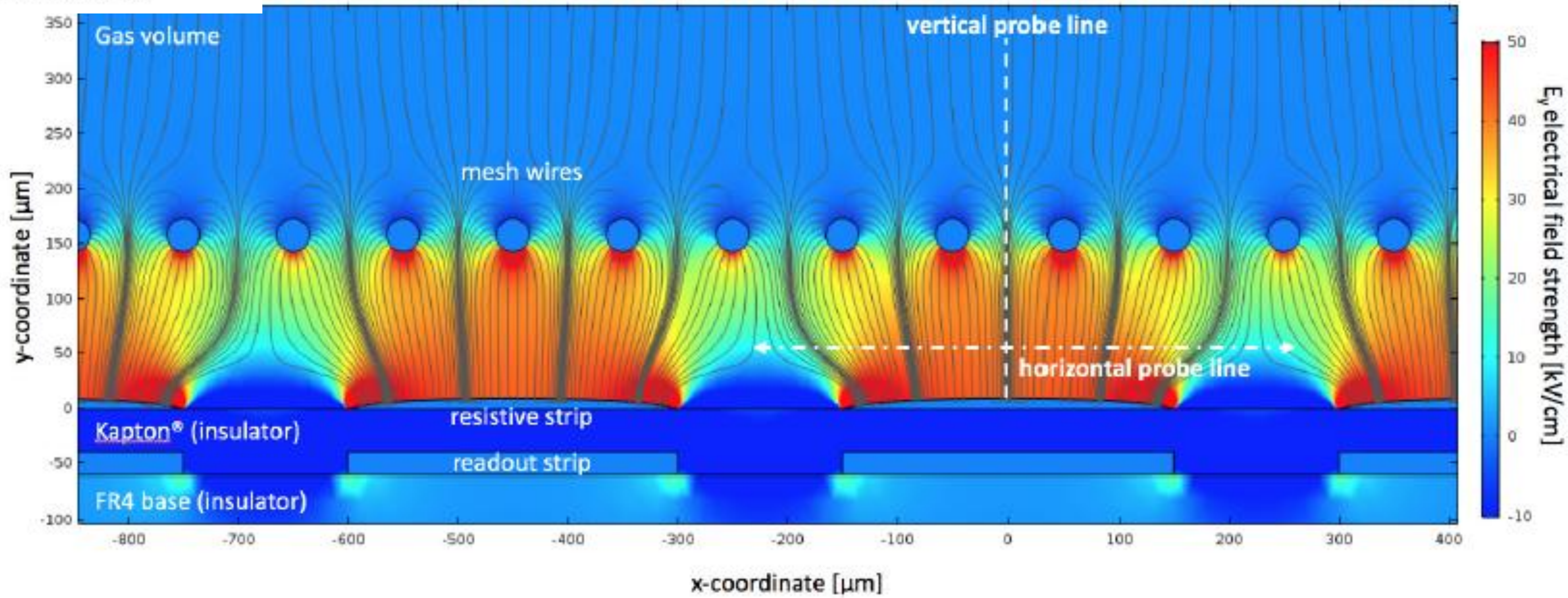


Figure 3. Electrical field strength in the vicinity of the mesh wires. The mesh has a periodicity of 100 μm (diameter = 30 μm, aperture = 70 μm), the strip pitch is 450 μm (strip width = 300 μm). The position and orientation of two probe lines are indicated (dashed). (COMSOL Multiphysics® [8] Simulation — the streamline (grey) density is not proportional to the field strength.)

F.Kuger

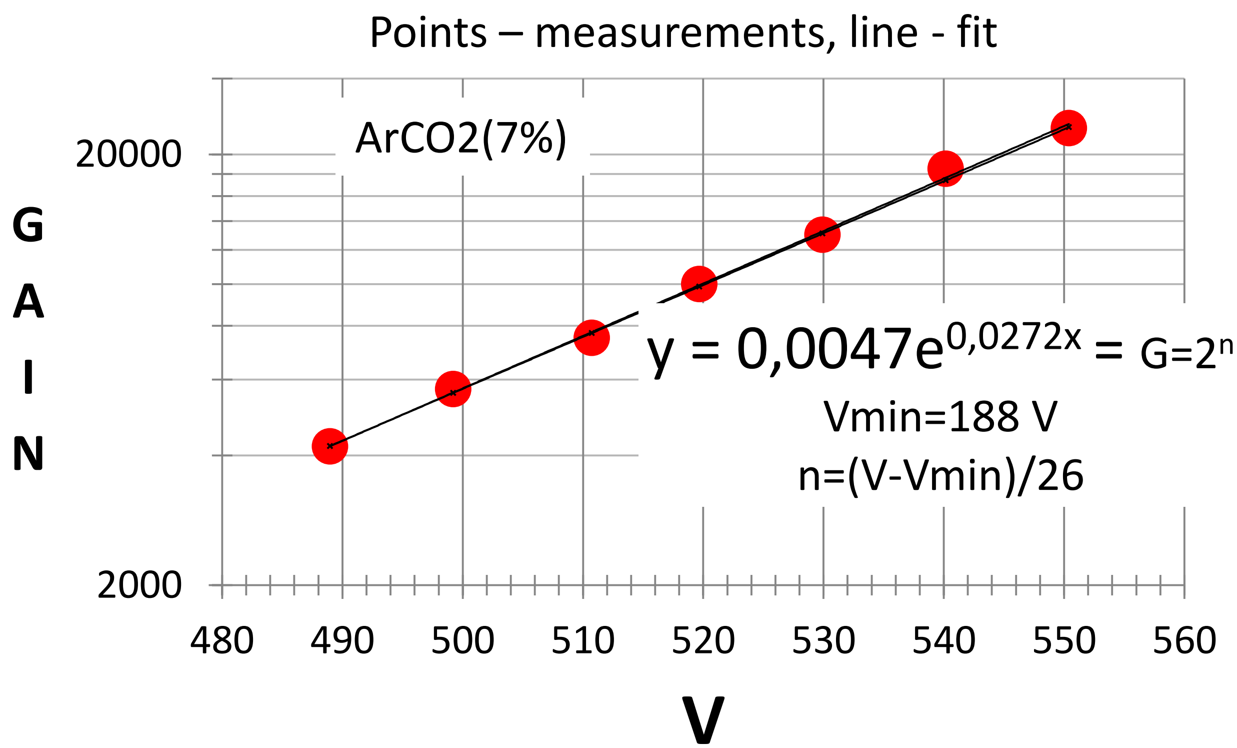
To find Vmin we compare to **MM-ATLAS**

Gas Gain parameterization $G=2^{(V-V_{min})/\Delta V_i}=2^n$

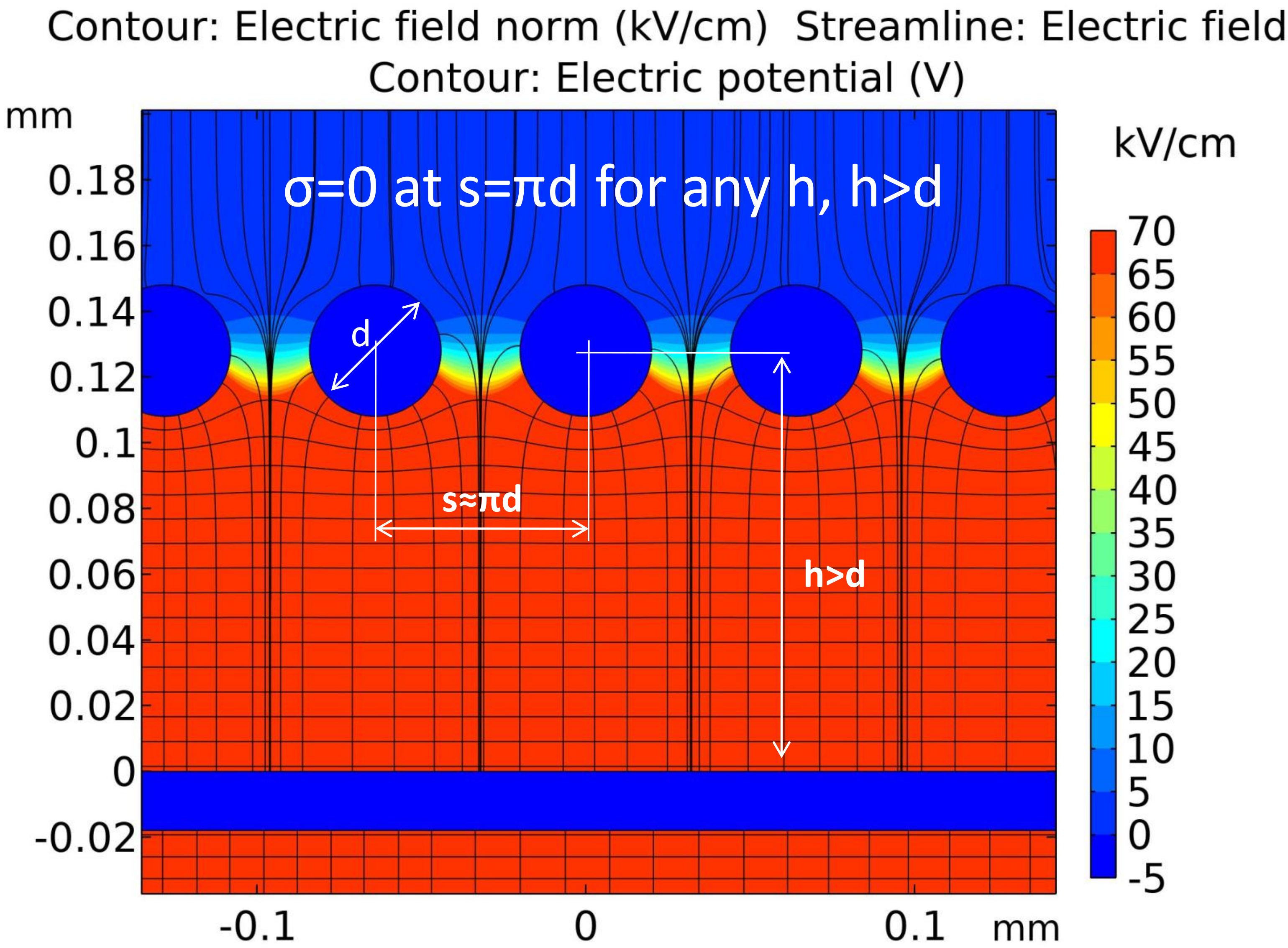
Vmin – Voltage at which multiplication process starts

ΔVi=26 eV – average energy/electron-ion pair production

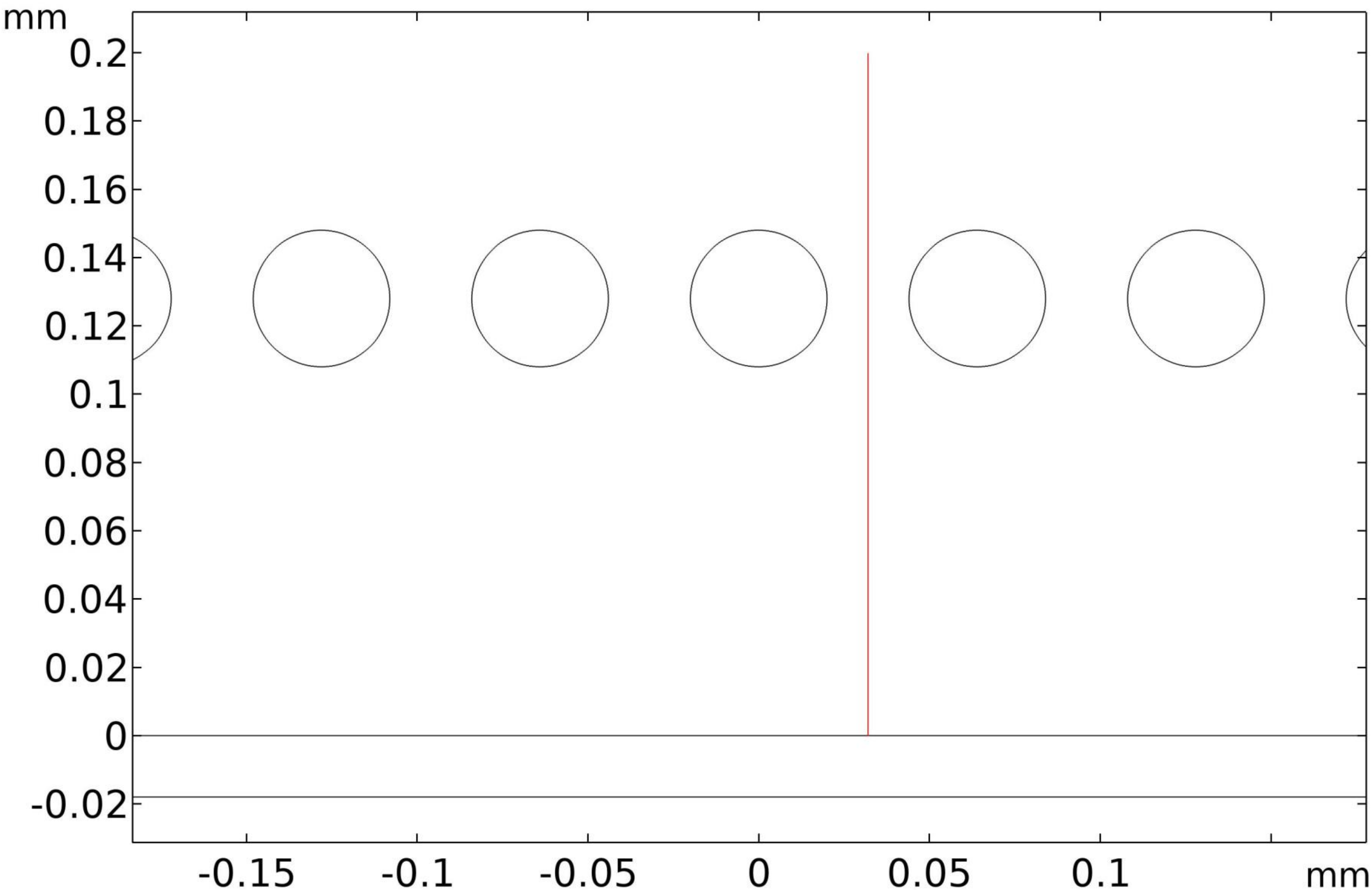
n – number of equipotentials in multiplication gap at V>Vmin



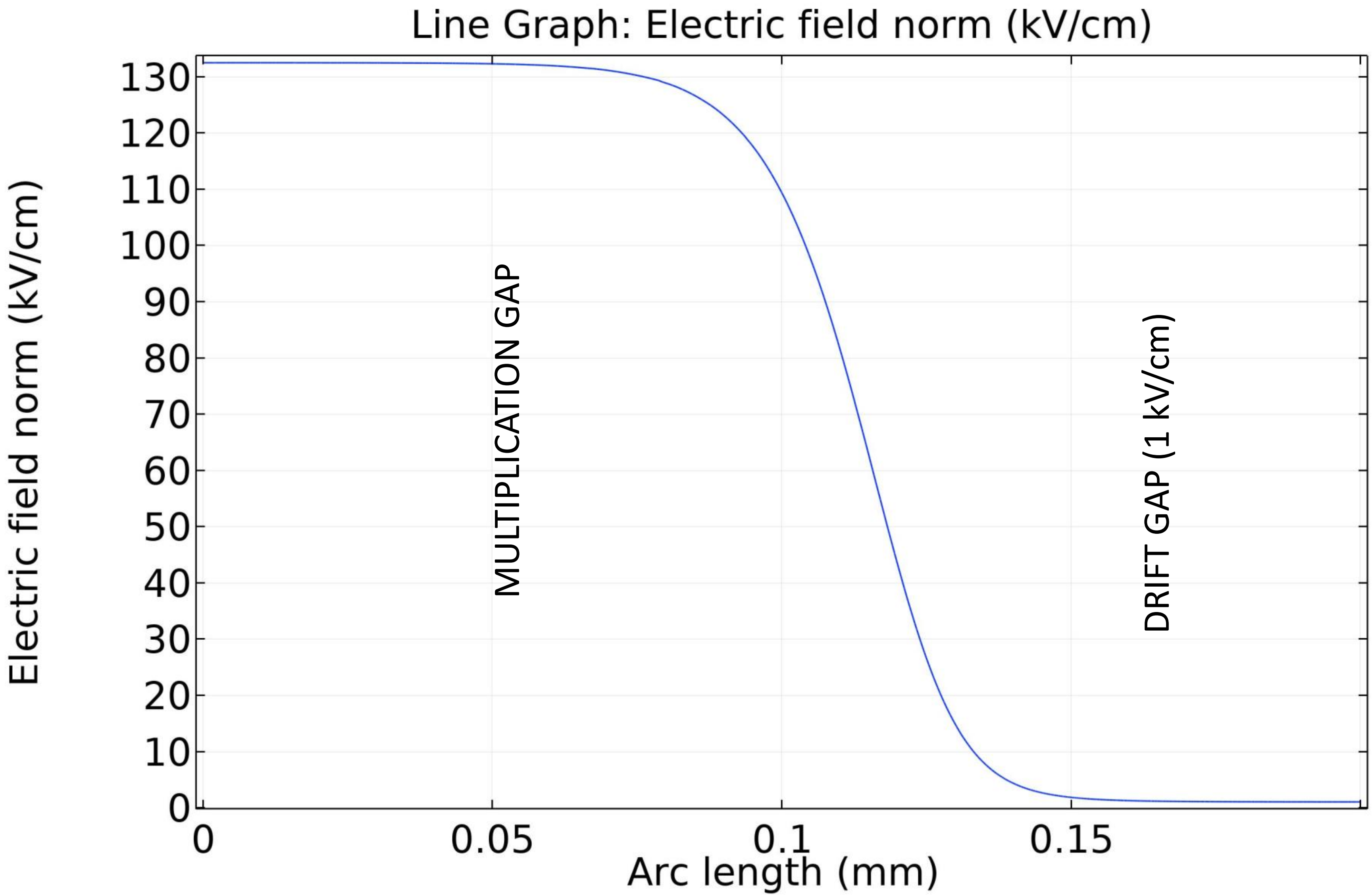
d40s63h128_Uc=+300V_Uw=0V_Ua=+1500V G~30000, n=15



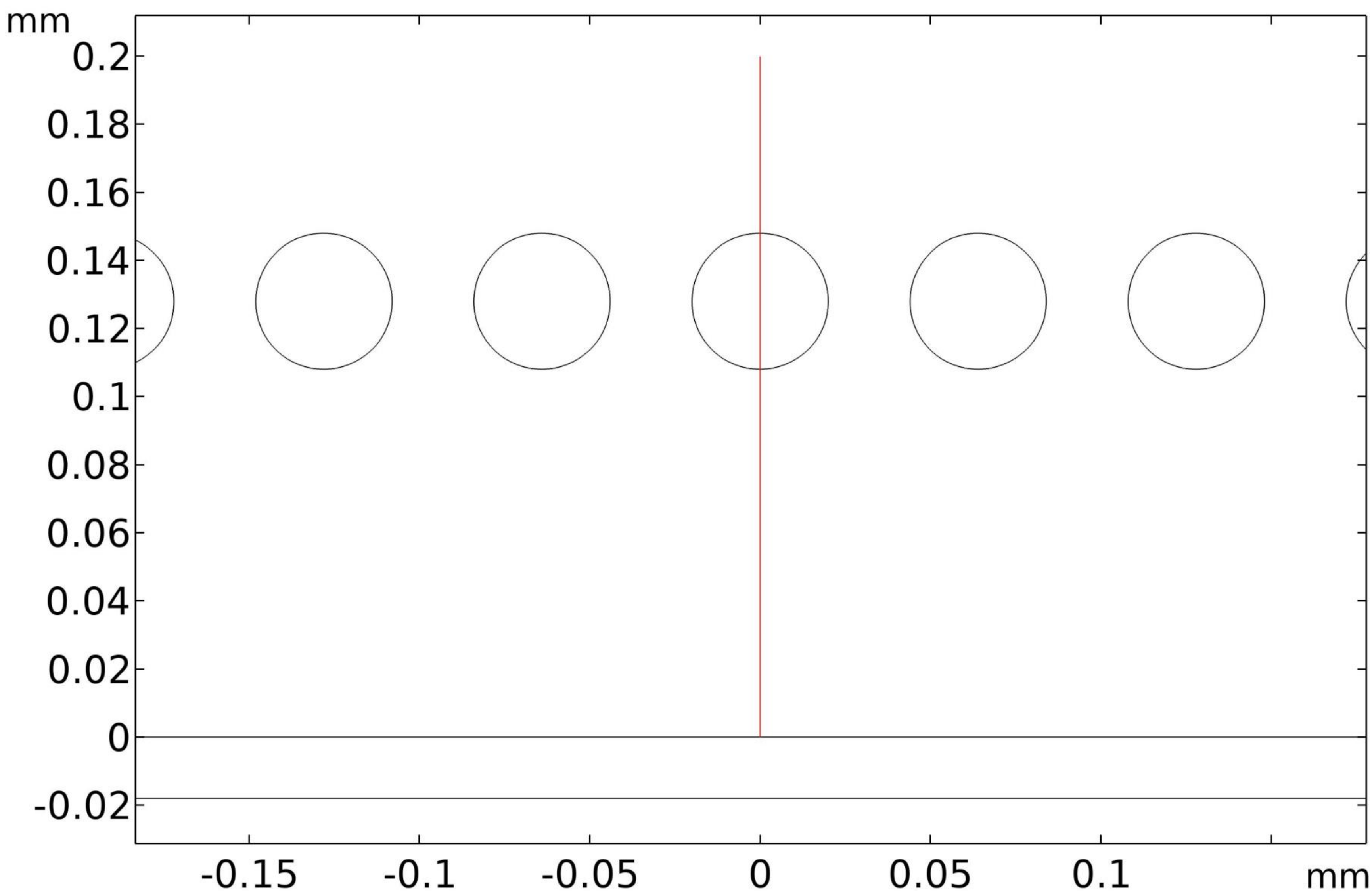
Field along red line between wires



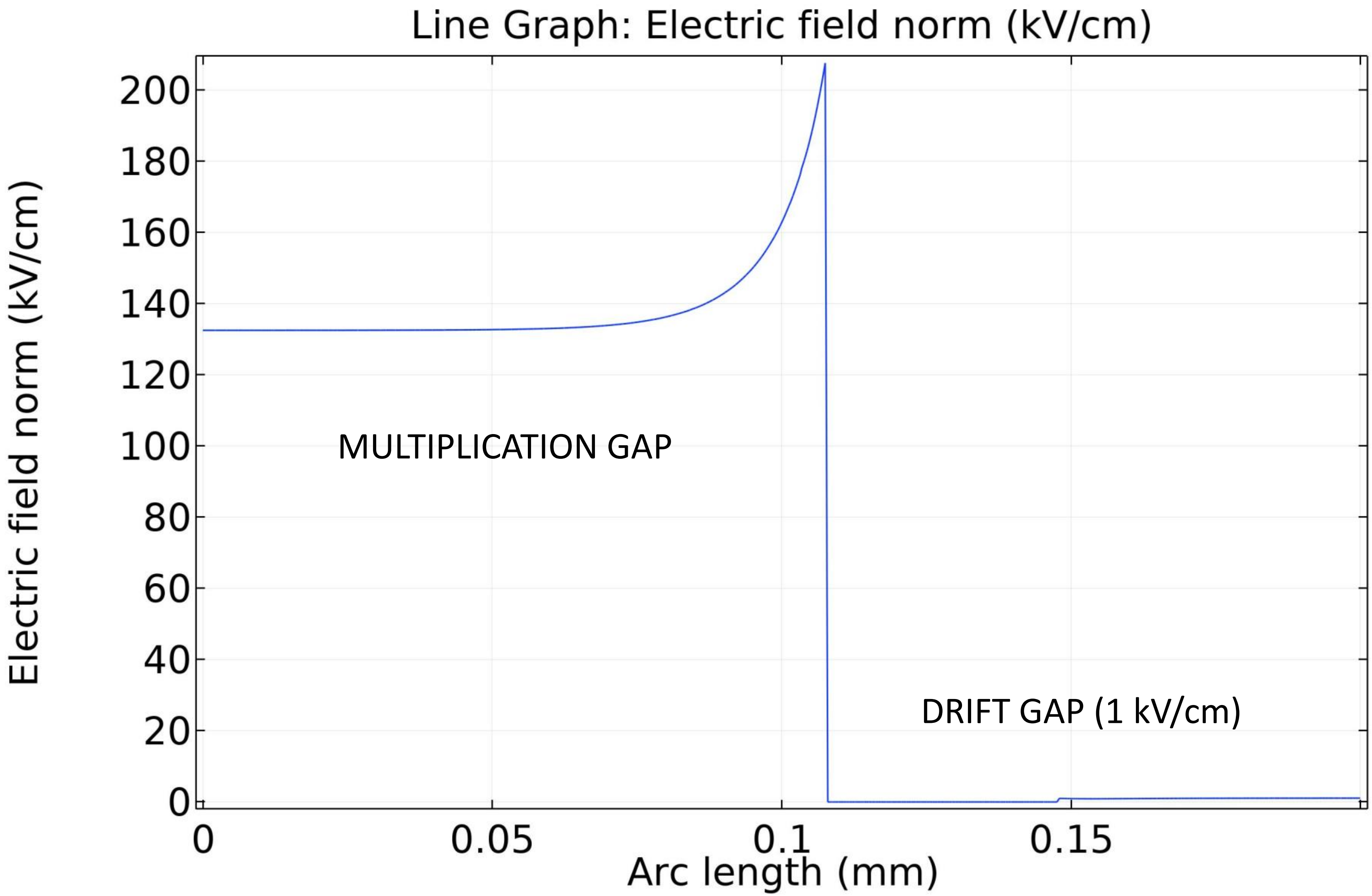
d40s63h128_Uc=+300V_Uw=0V_Ua=+1500V G~30000



Field along red line across wire

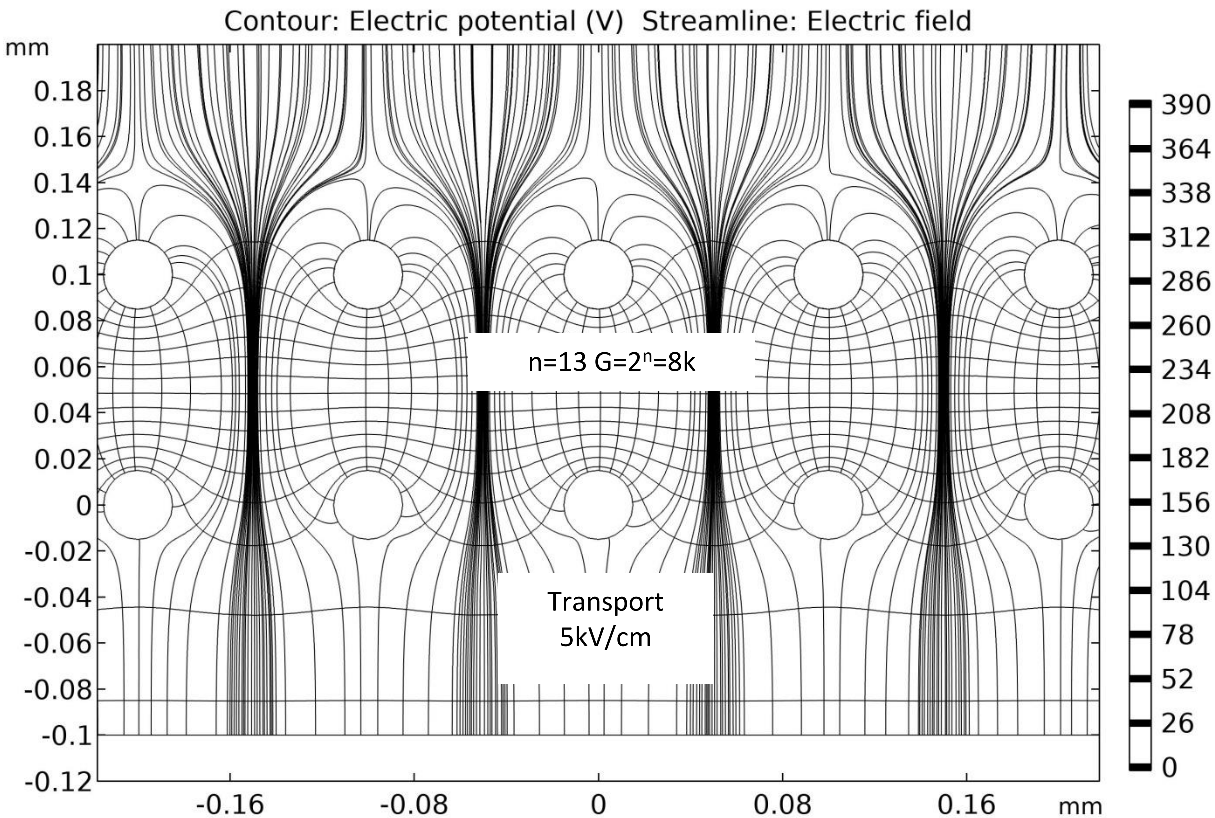


d40s63h128_Uc=+300V_Uw=0V_Ua=+1500V G~30000



Single multiplication gap and induction gap

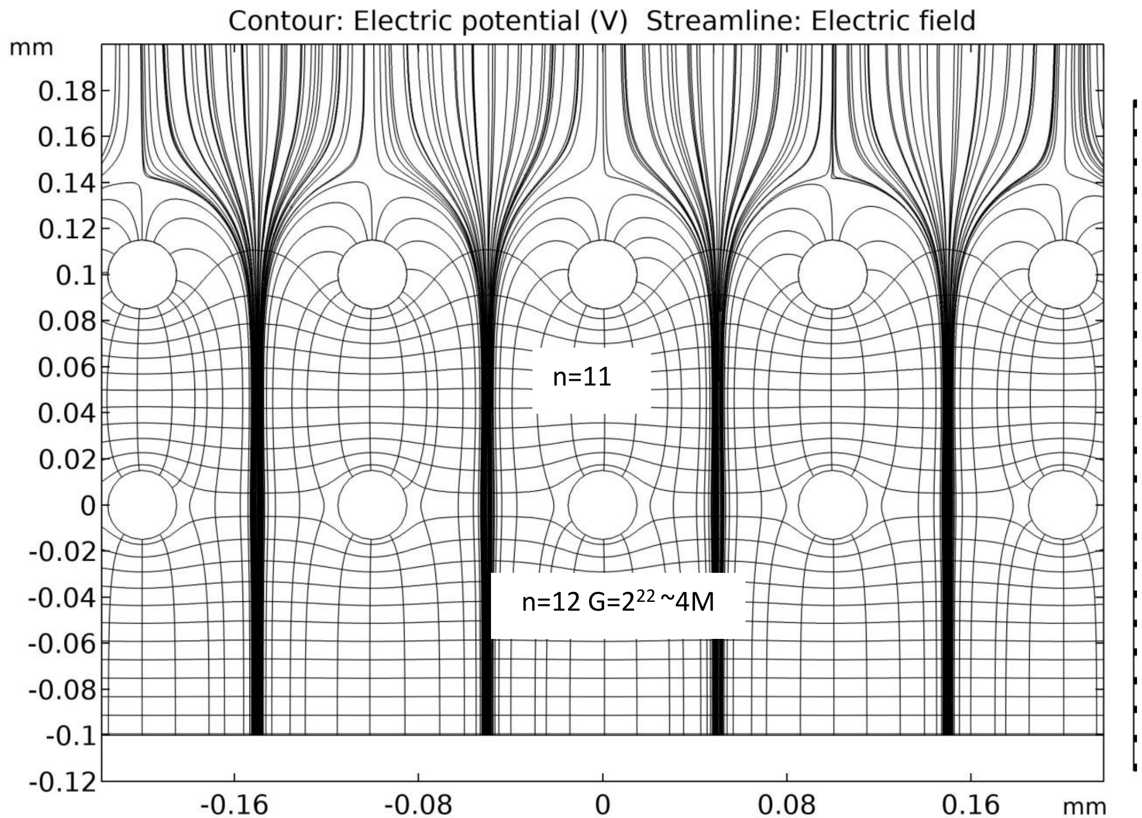
1Layer_PWEM_d30s100h100g100; -100/0/+350/+400 V



Double multiplication (cascade)

by changing voltage on induction gap at same geometry

2Layer_PWEM_d30s100h100g100; -100/0/+300/+600 V

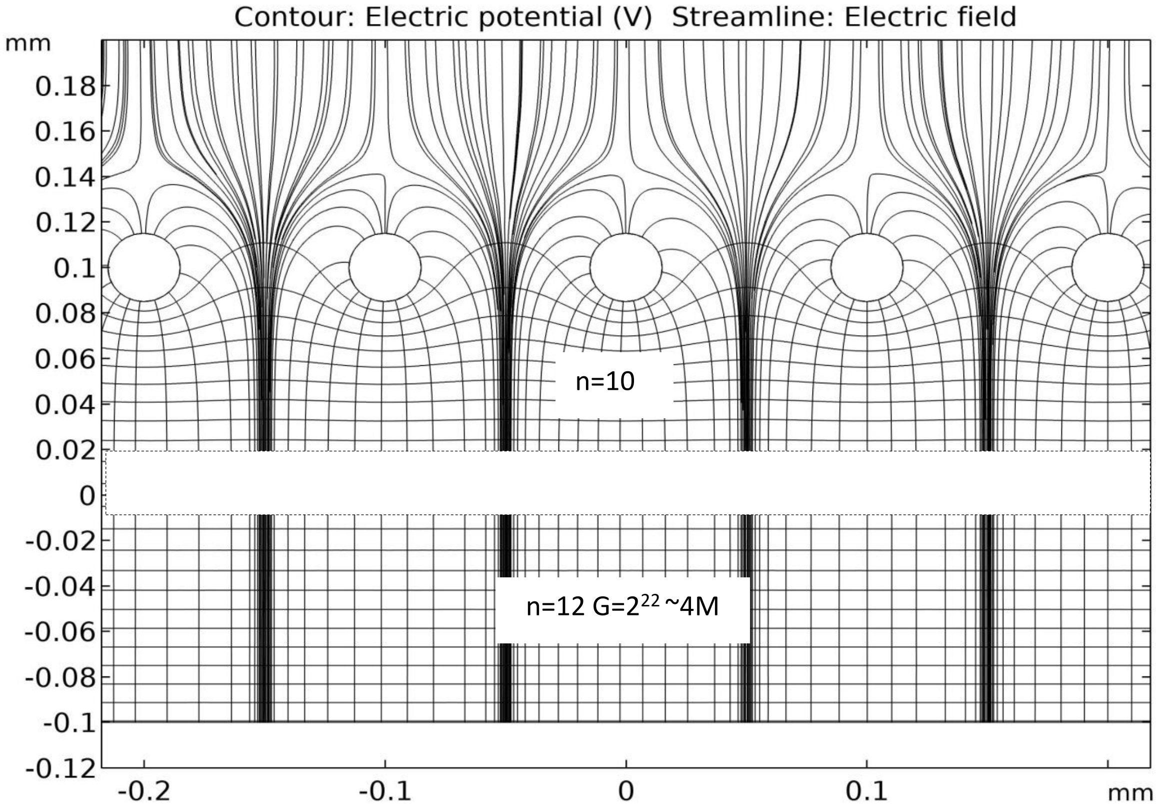


Less diffusion without transport gap between cascades, if compare to Double/Triple-GEM

Double multiplication (cascade)

by changing voltage on induction gap at same geometry

2Layer_CWEM_d30s100h100g100; -100/0/+300/+600 V



Less diffusion without transport gap between cascades, if compare to Double/Triple-GEM

CWEM: material budget

CW_GEM d20(30)s60(100)						
Material	X	Density (g/cm3)	X0 (g/cm2)	X0 (cm)	X/X0 (%)	
AlMg(5%)	0,0004 (0,0009)	2,7	24	8,9	0,0045 (0,0101)	
AlMg(5%)	0,0004 (0,0009)	2,7	24	8,9	0,0045 (0,101)	
					0,01 (0,02)	With 2D readout
MWPC						
BeCu d50s1000	0,00025	8,96	12,7	1,43	0,0174	
Tungsten d30s2000	0,000045	19,2	6,76	0,35	0,0128	
BeCu d50s1000	0,00025	8,96	12,7	1,43	0,0174	
					0,05	With 2D readout
MicroMegas (MM)						
Fe 18(30)/40 (70)µm	0,0009 0,0025	7,873	13,8	1,76	**0,05 (0,15)**	Without readout board
GEM						
Cu 5 µm	0,00025	8,96	12,7	1,43	0,0174	
PI 50 µm	0,0025	1,42	40,58	28,58	0,0087	
Cu 5 µm	0,00025	8,96	12,7	1,43	0,0174	
					0,05	Without readout board

The Multi-Wire gas-filled Electron Multiplier (MWEM)

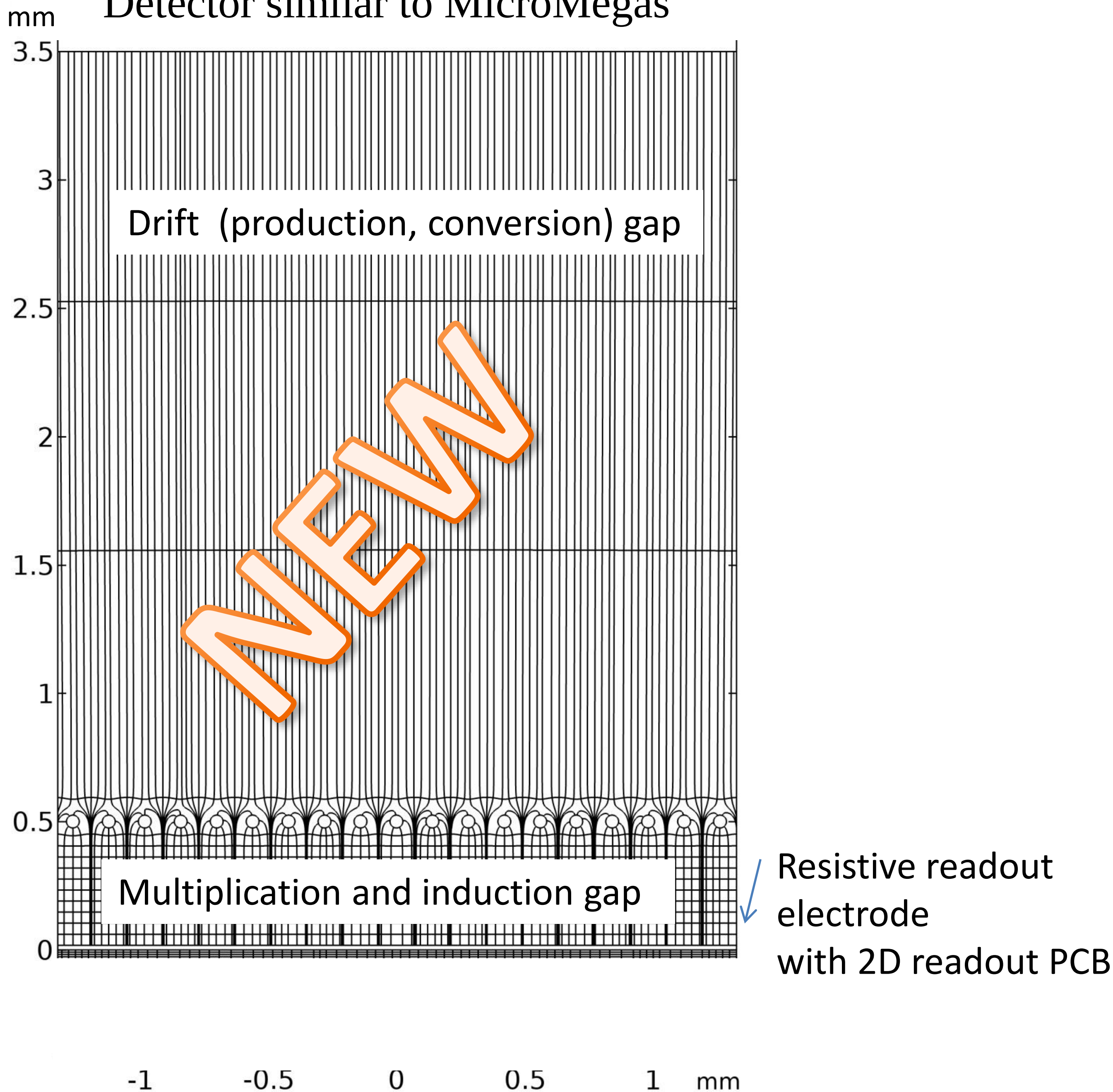
Detector similar to MicroMegas

d30s150h500
Uc=-300V_Uw=0V_Ua=+1100V

σ~0.6% at d30s150h500

σ~3.2% at d30s150h100

σ~0.4% at d30s100h100



Conclusion

PWEM/CWEM design configurations

- Single avalanche gap with parallel wires PWEM
- Single avalanche gap with crossing wires CWEM
- Double (cascade) gap with parallel wires 2L-PWEM (without transport gap)
- Triple gap, if necessary 3L-PWEM (without transport gaps)
- Double (cascade) gap with crossing wires 2L-CWEM (without transport gap)
- Triple gap, if necessary 3L-CWEM (without transport gaps)
- Similar to MicroGroove single raw of parallel wires located above the resistive readout electrode (μR-MWEM)
- To keep accurate planarity one can use the technique developed for MM (bulk, thermal bonding, etc.)

Thanks