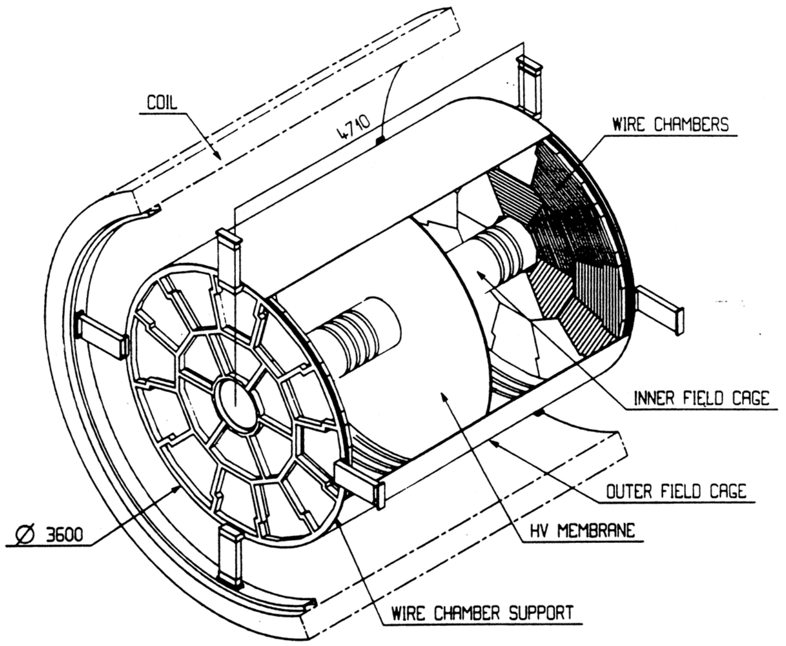
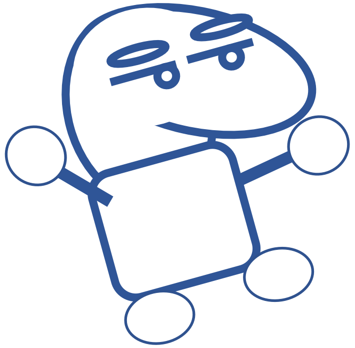
CERN-Korea summer student program

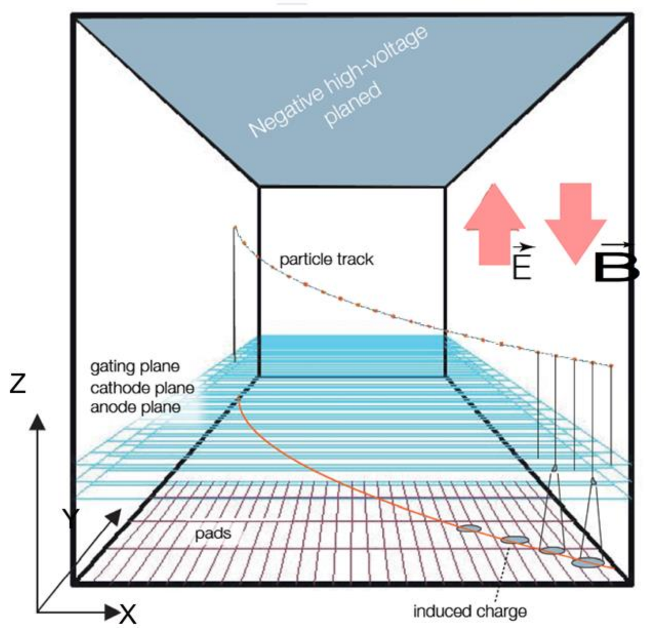
How to prevent ion backflow(IBF)? Gating grid and GEM



2024-07-12

Wonjun-Jeong



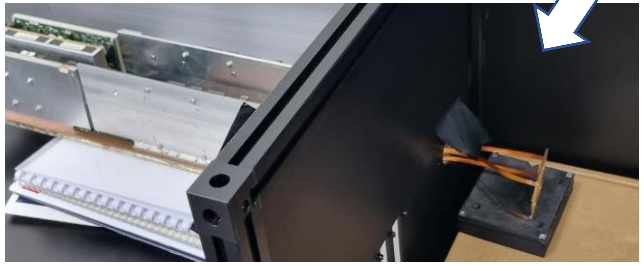


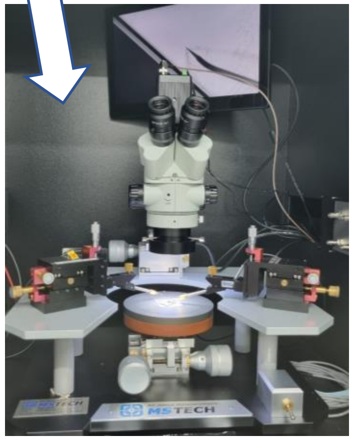
Introduce

이름 : 정원준
소속 : 인하대
MBTI : INFJ
취미 : 영화

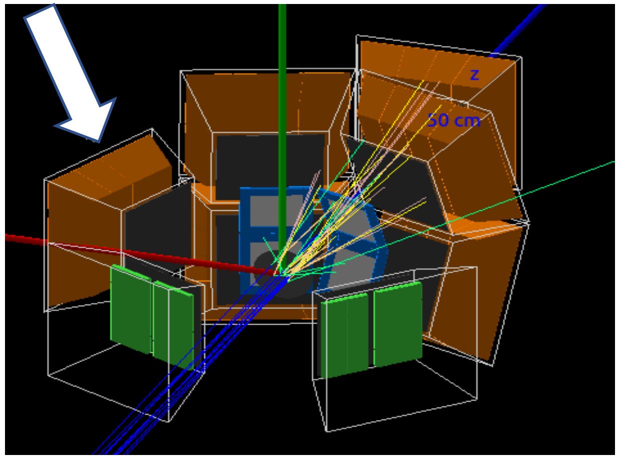
연구실에서 했던일들

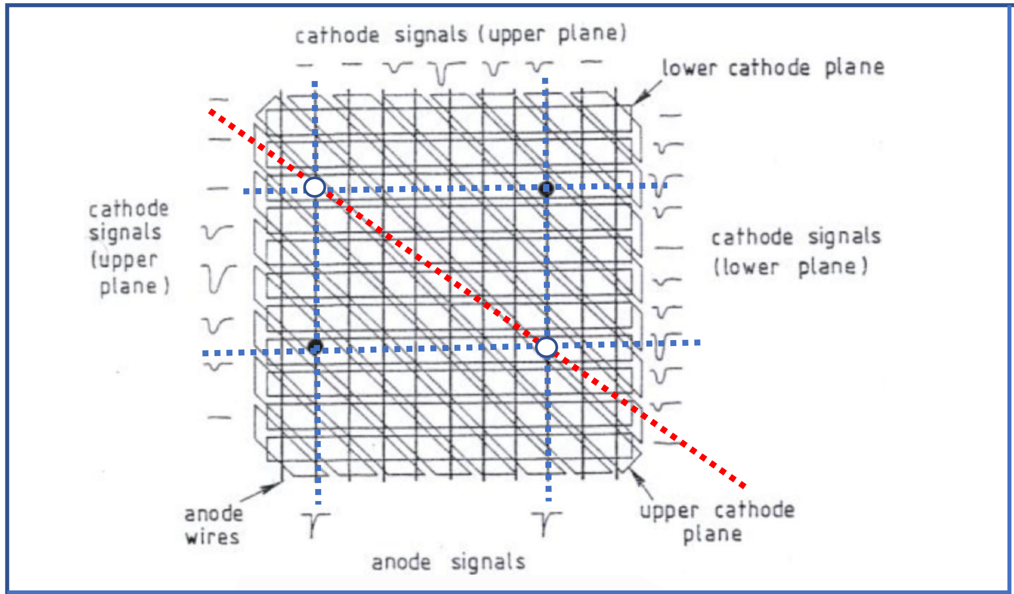
실리콘 칩 테스트

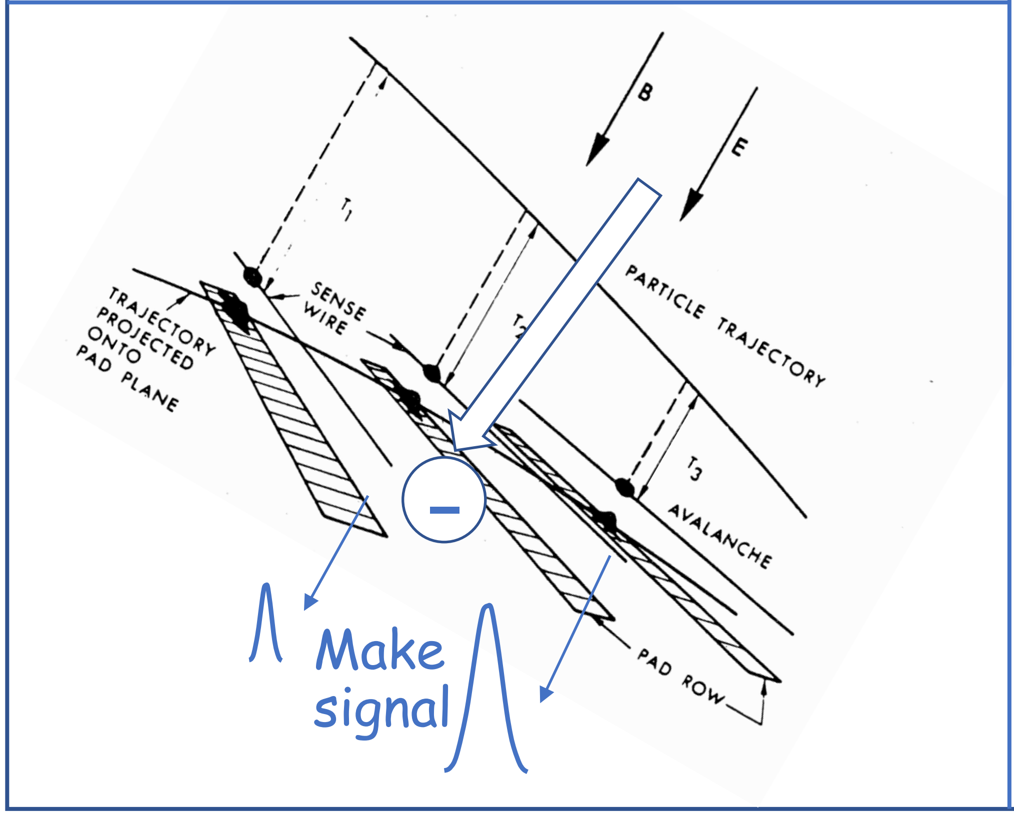


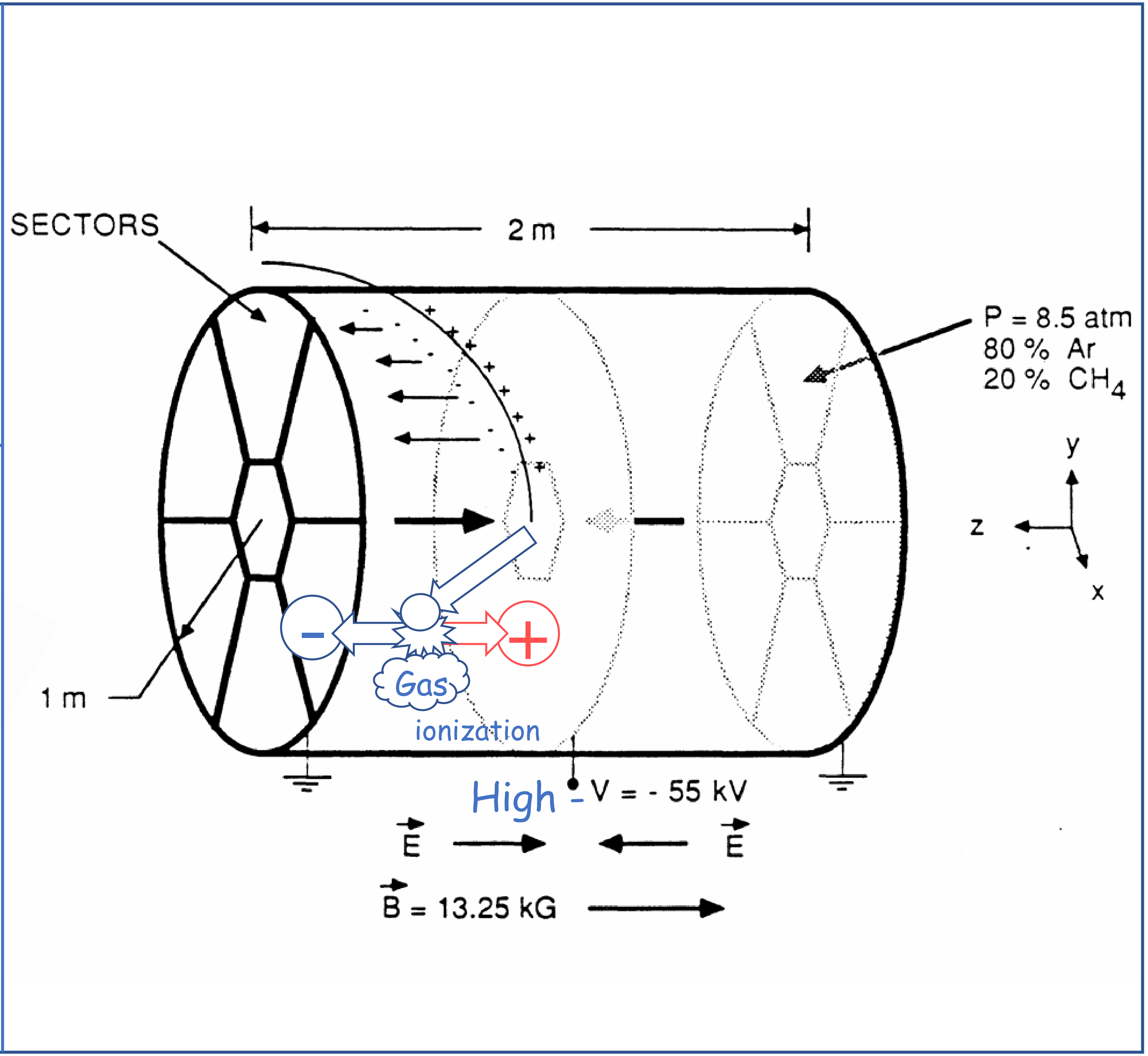


Nptool simulation

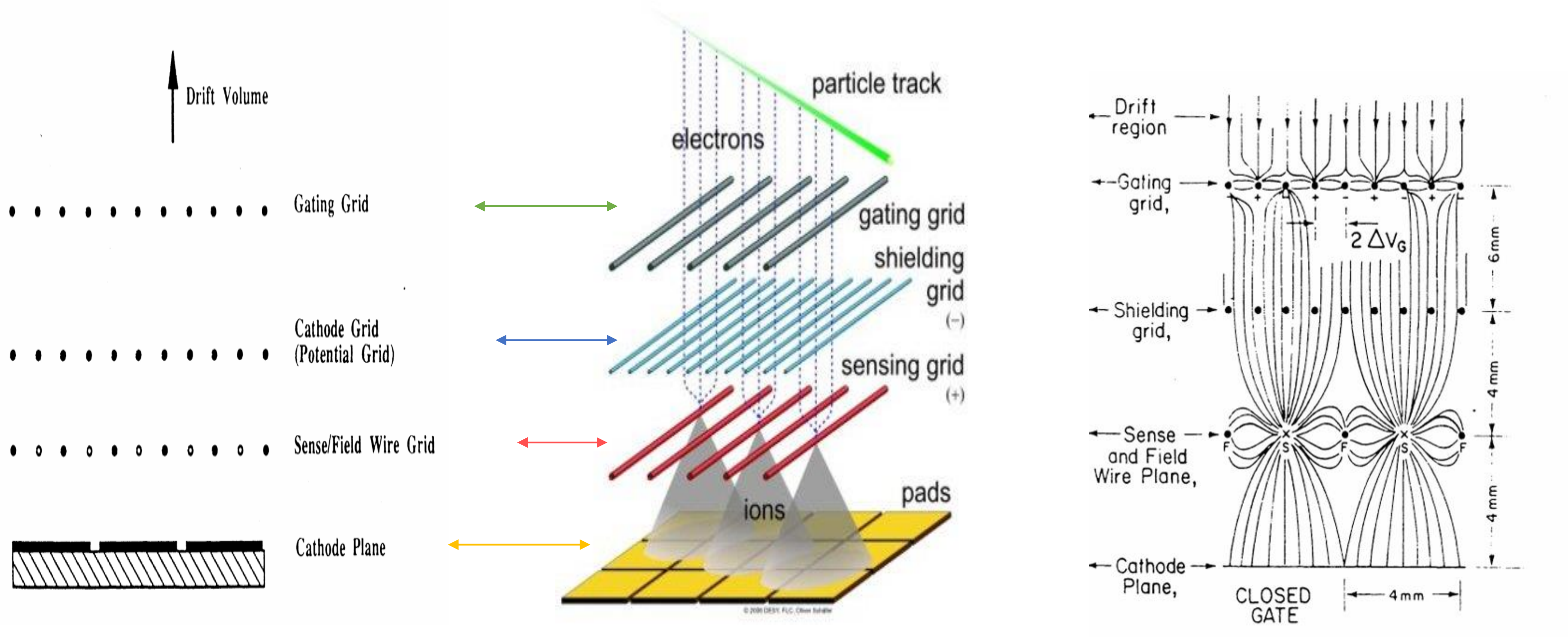



cathode signals (upper plane)
lower cathode plane
cathode signals (upper plane)
cathode signals (lower plane)
anode wires
upper cathode plane
anode signals


B
E
T_1
T_2
T_3
SENSE WIRE
TRAJECTORY PROJECTED ONTO PAD PLANE
PARTICLE TRAJECTORY
AVALANCHE
PAD ROW
Make signal

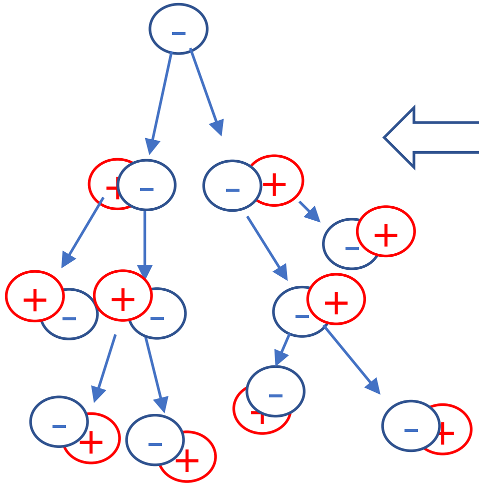

SECTORS
2 m
1 m
P = 8.5 atm
80 % Ar
20 % CH_4
y
z
x
Gas
ionization
High
V = - 55 kV
$\vec{E}$
$\vec{E}$
$\vec{B}$ = 13.25 kG

Wire Chamber

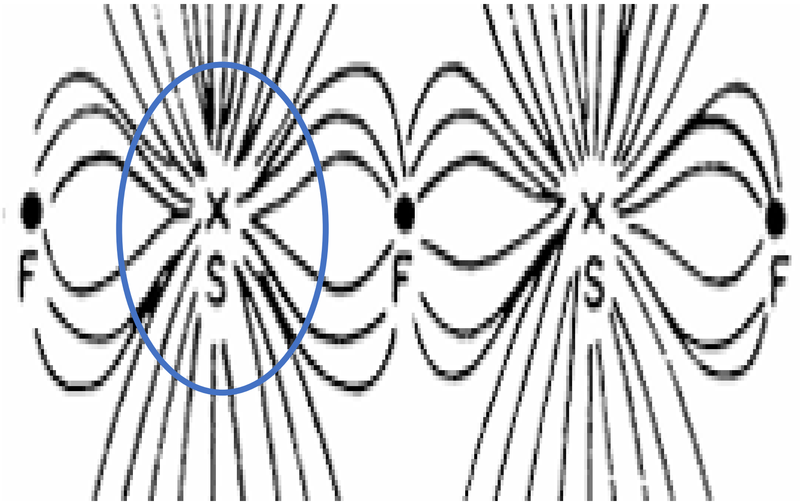


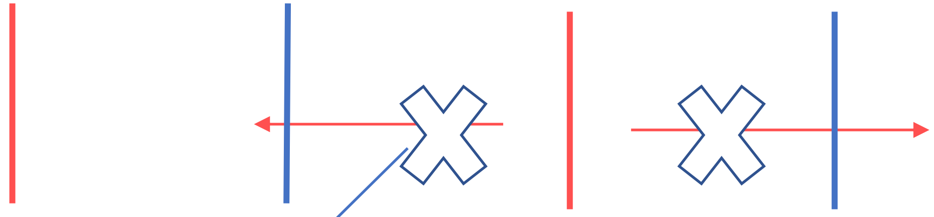
Wire Chamber

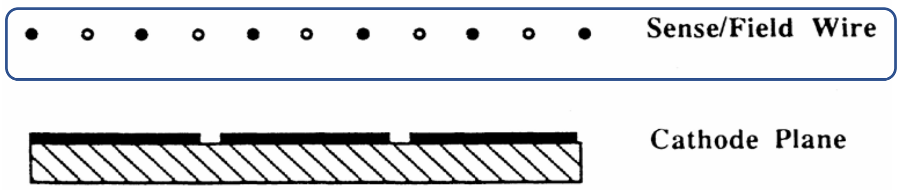
Avalanche effect



Strong $\vec{E}$ -> strong Kinetic E





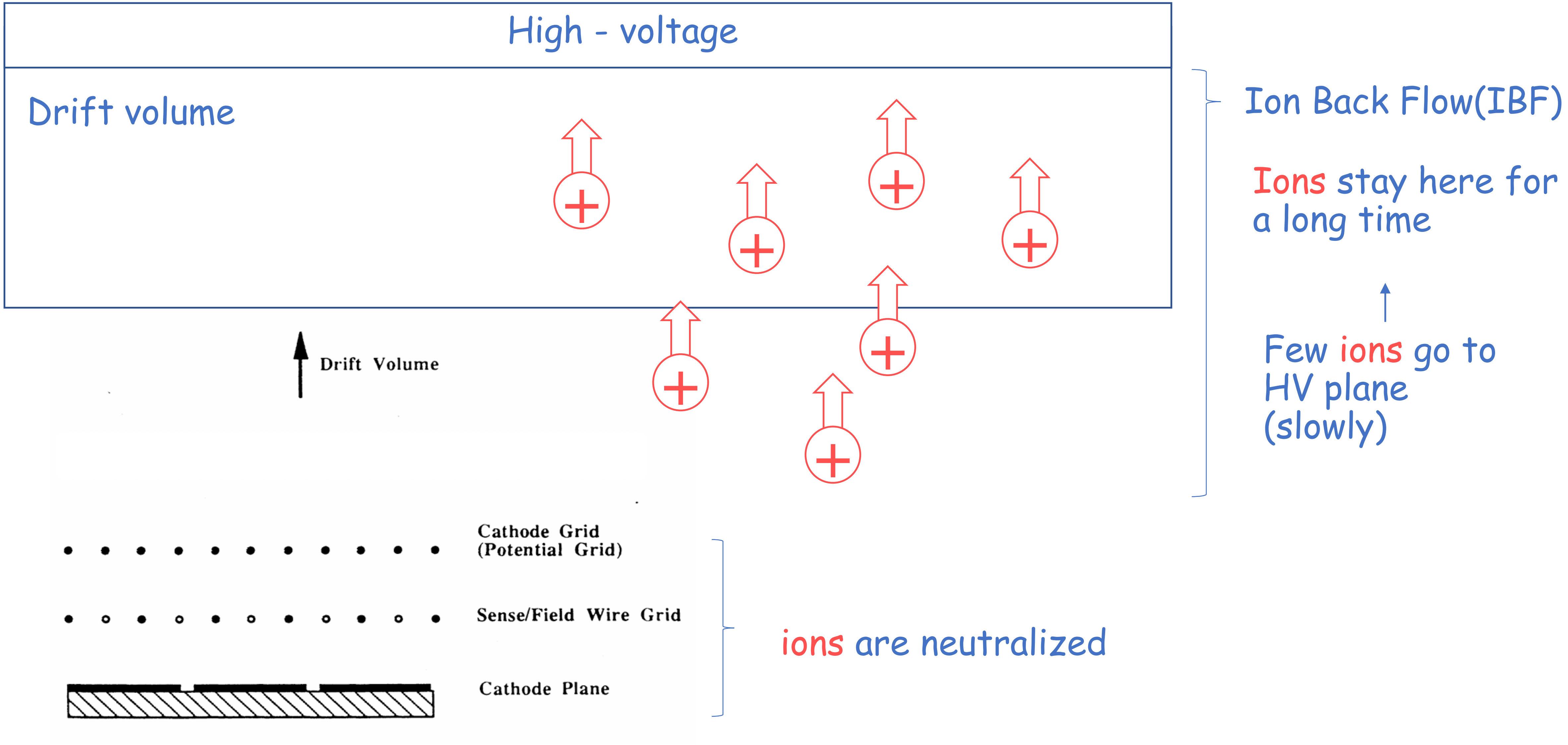


Using
conducting barrier

Field wire -> electrically decouple the sense wire

Sense wire : anode wire (+)

Before Gating Grid



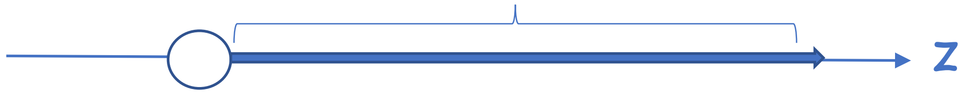
Before Gating Grid

Uniformity of the electric field -> very important

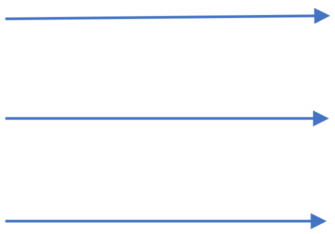
$\vec{v_d} \sim \vec{E}$ ⟹ Detect t_d ⟹

$t = l/v$

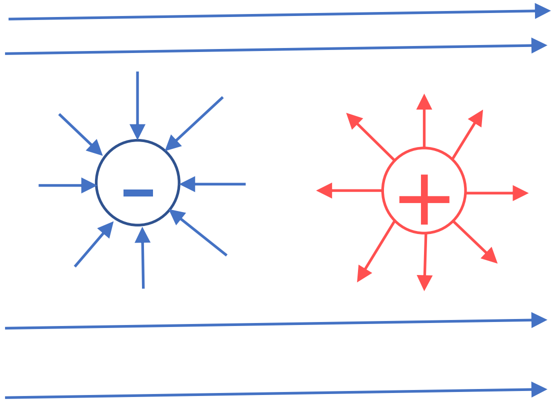
$position\ z = t_d v_d$



Homogenous Electric field



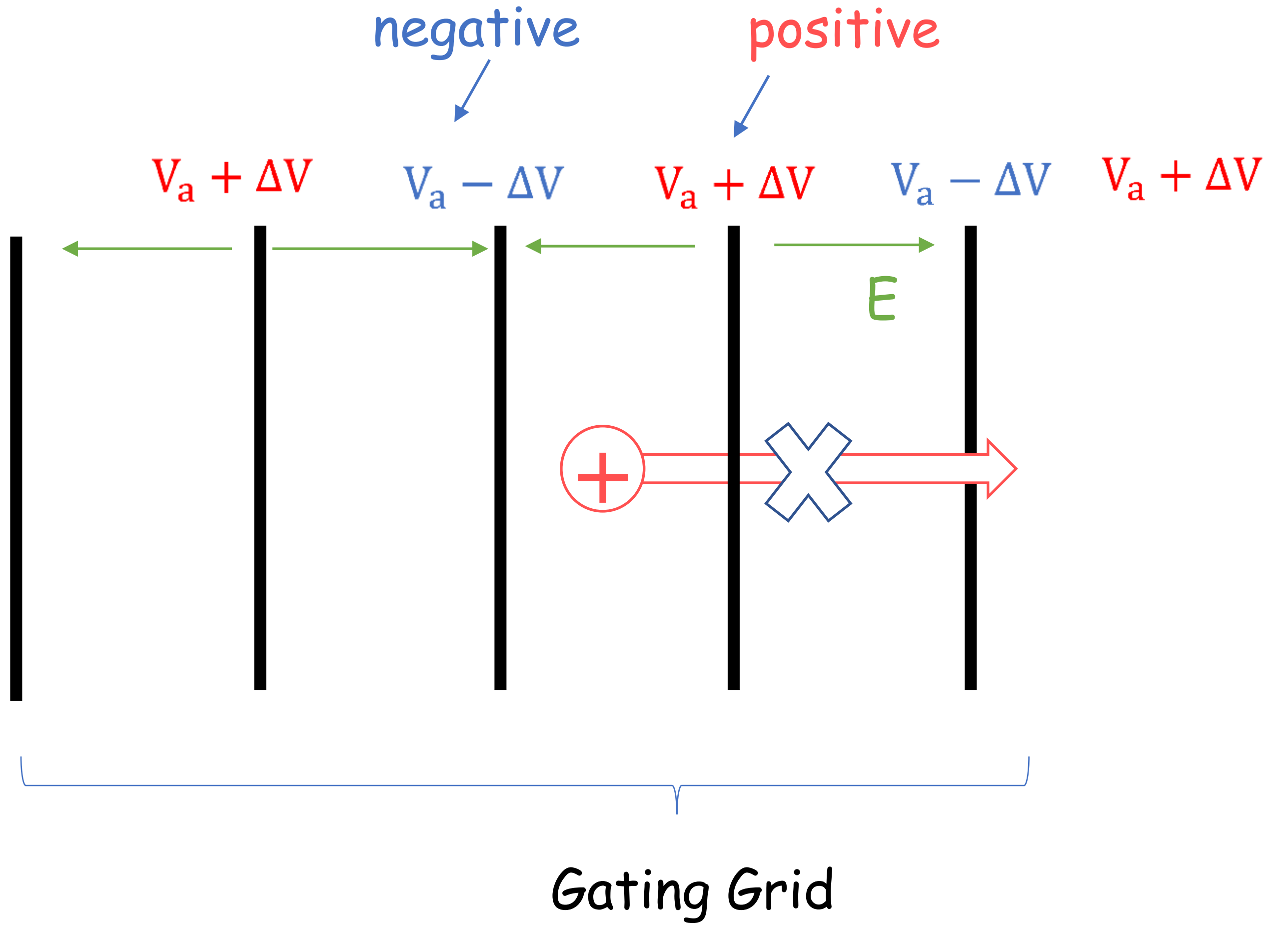
⟹ Ion Back Flow ⟹



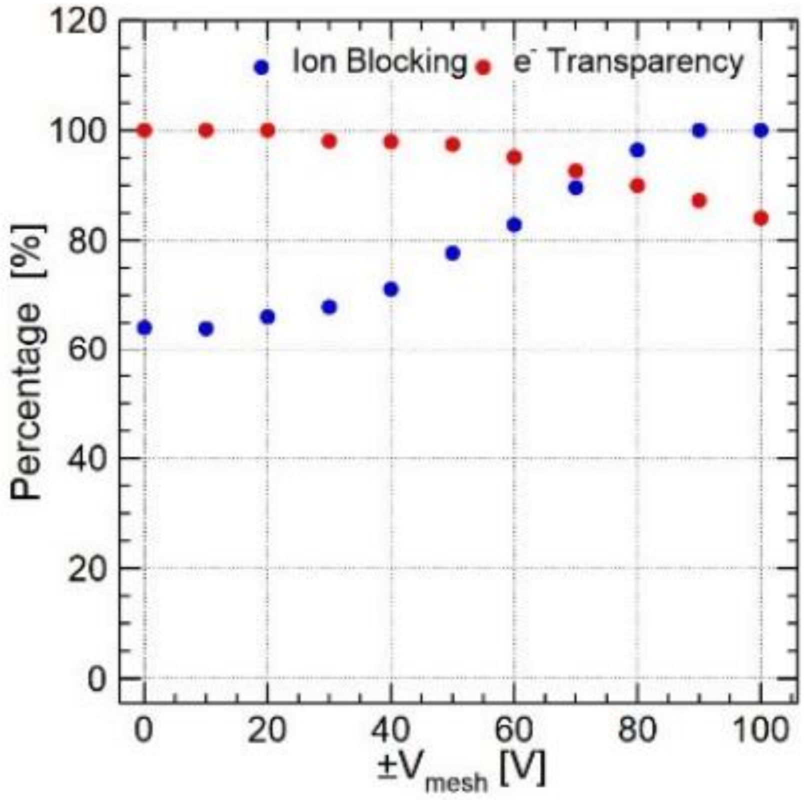
Still uniform?

(also near sense wire, Avalanche process make more positive ion)

Gating Grid



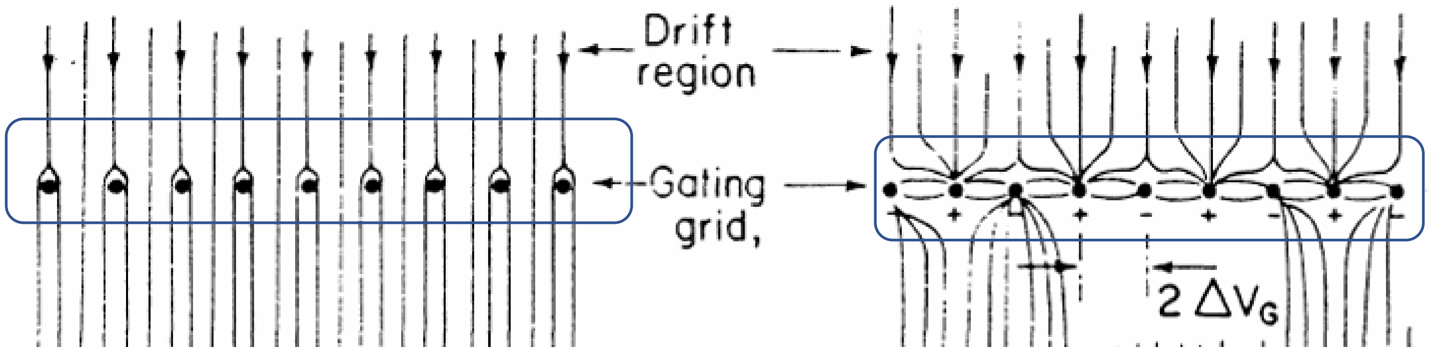
Big ΔV
transmittance ->0
ΔV ~ 50-100V

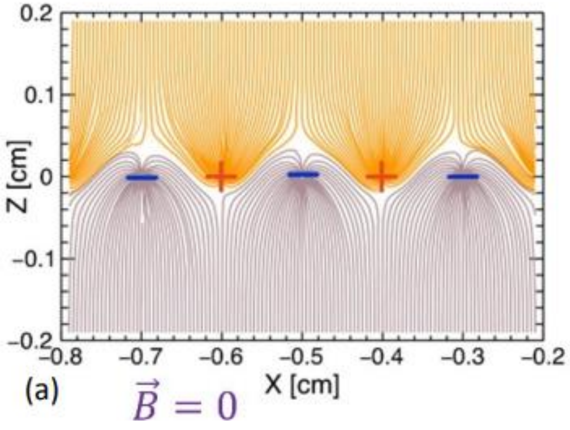


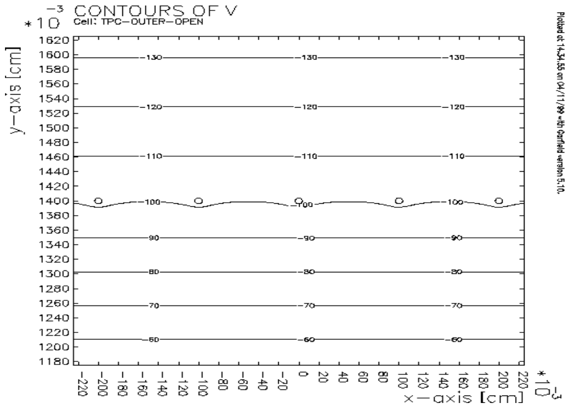
Gating Grid

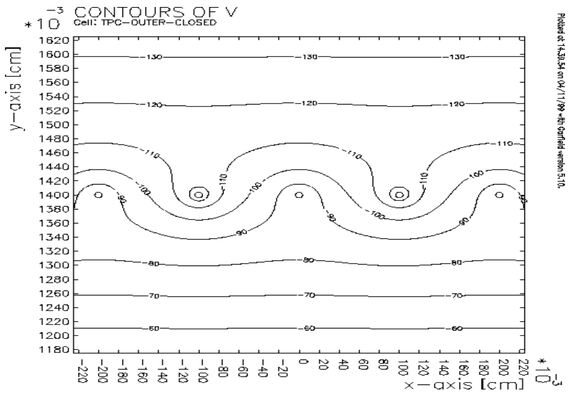
Open gate

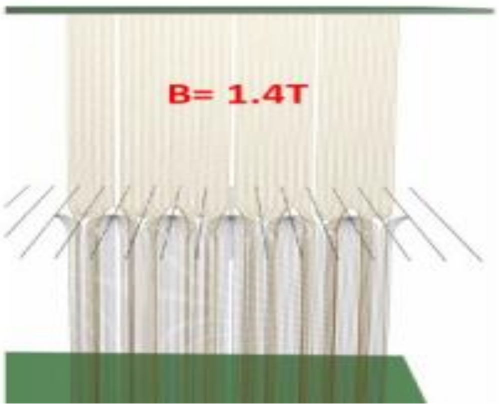
Closed gate





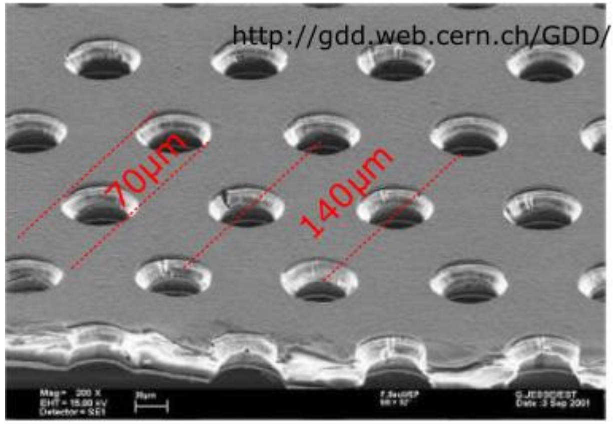


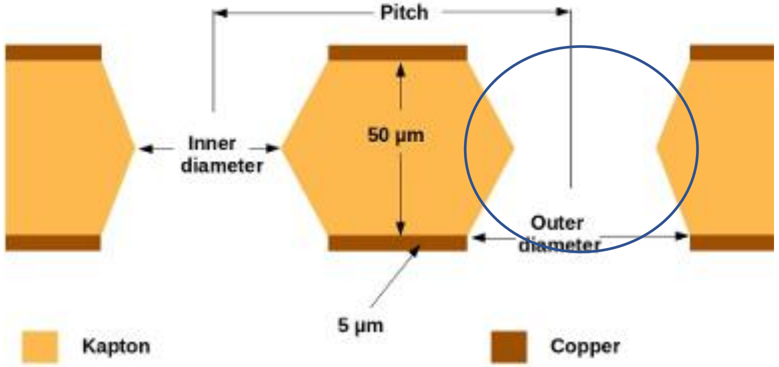


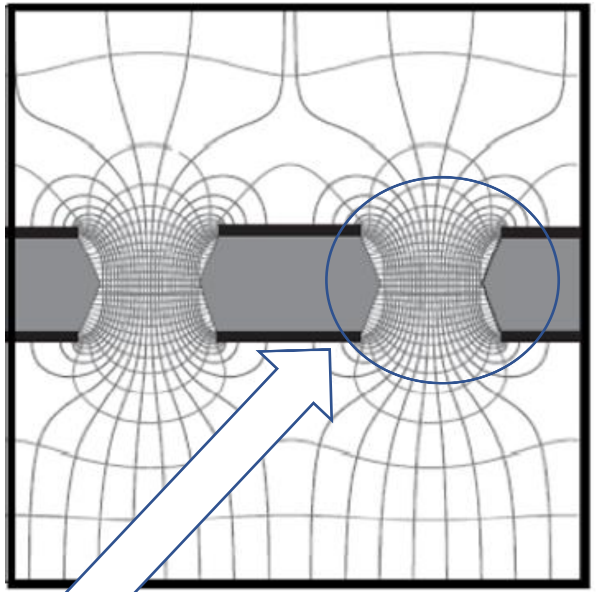


GEM(Gas Electron Multiplier)

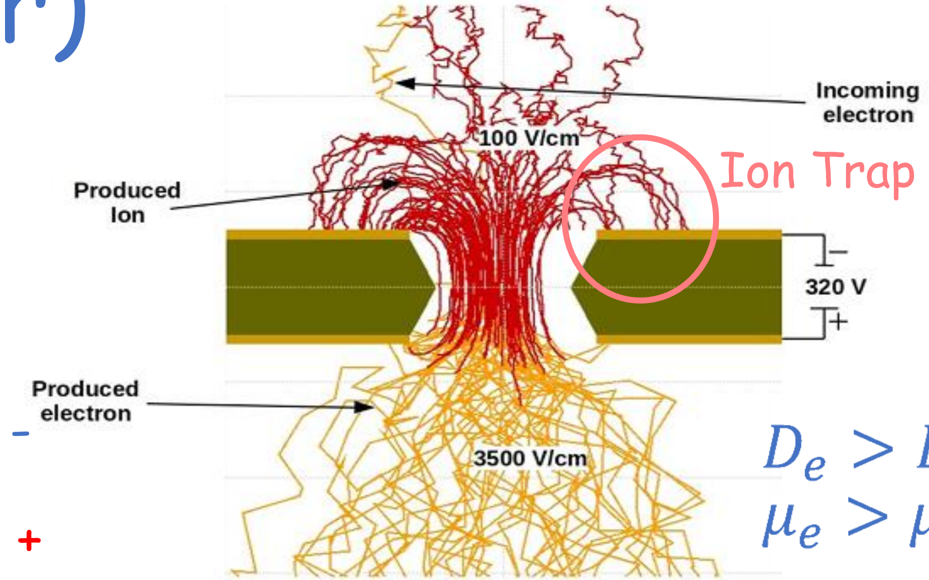
Copper coated Kapton foils





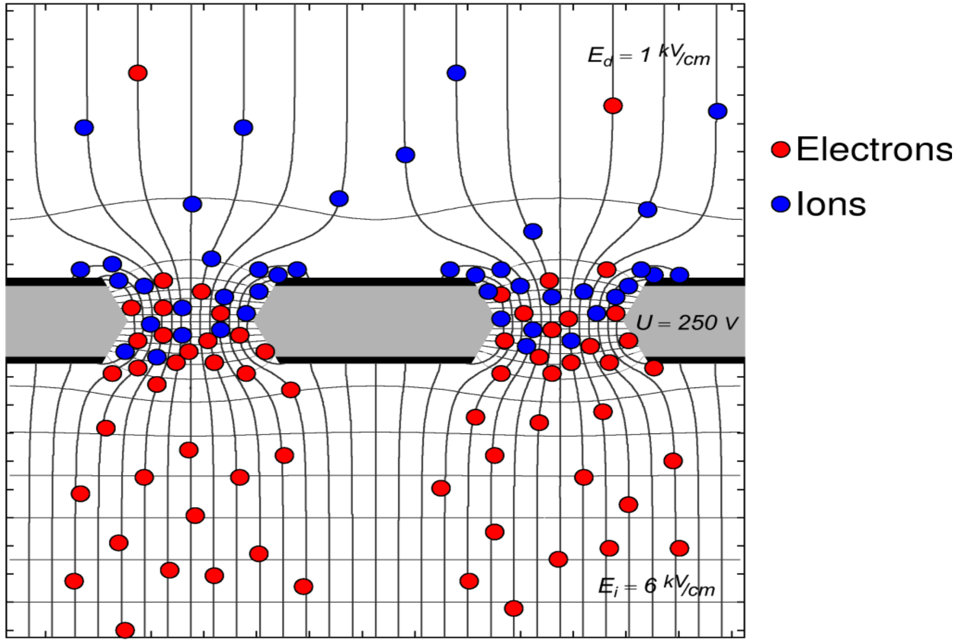


Field line focused in holes

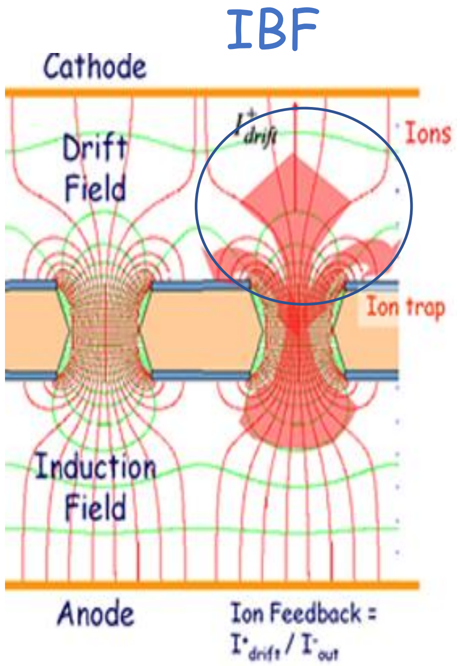


Ion Trap

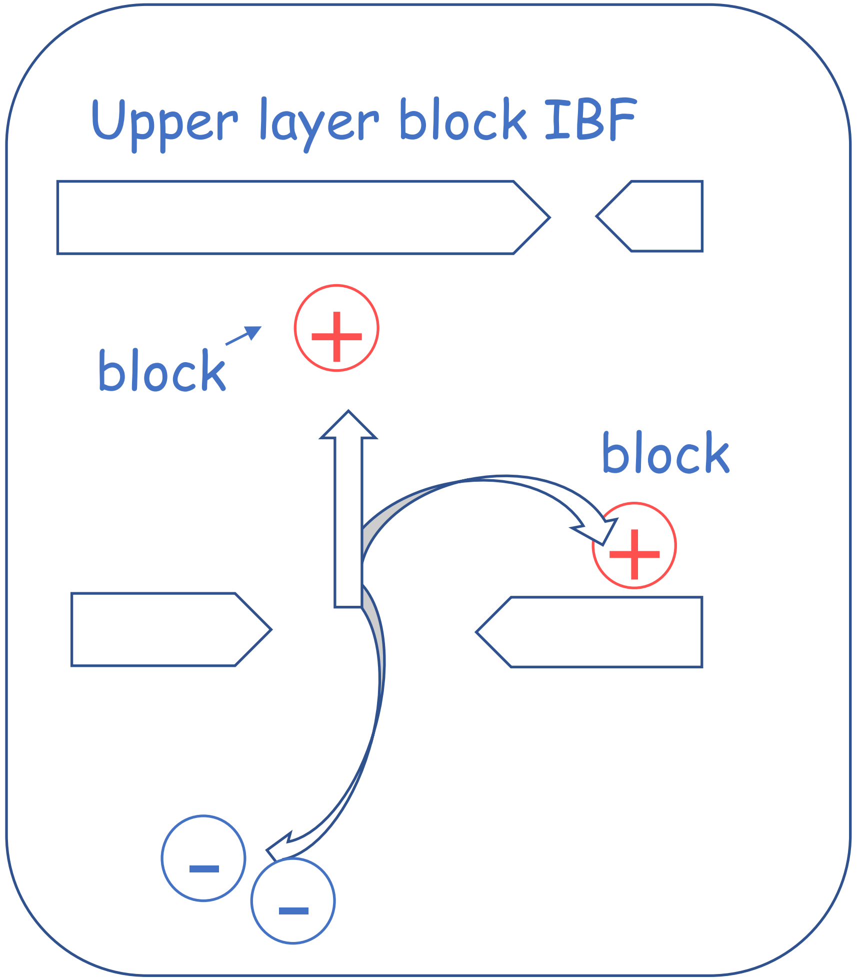
$D_e > D_{ion}$,
$\mu_e > \mu_{ion}$

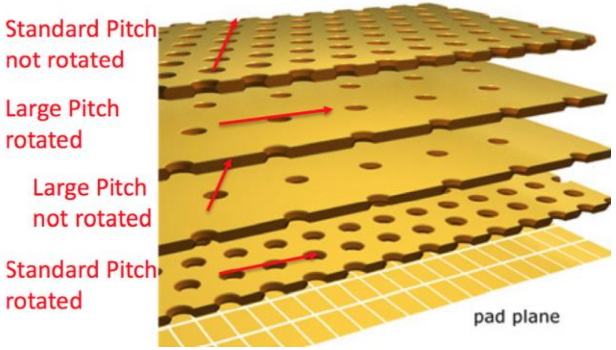


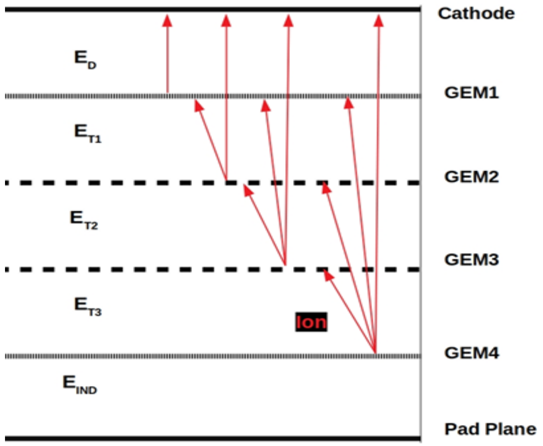
GEM

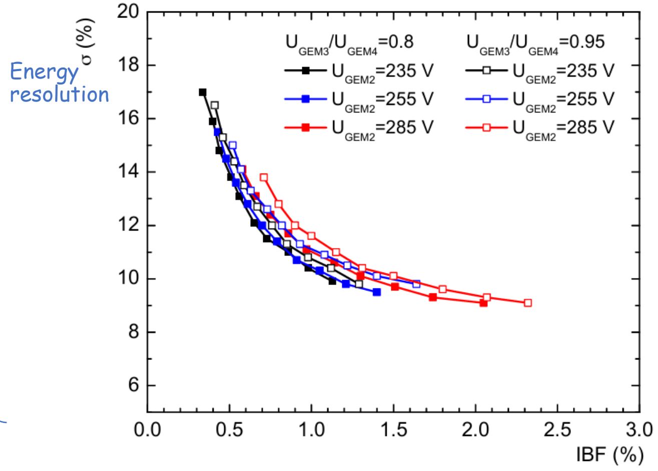


Using
multi Gem
layer









Reference

The Time Projection Chamber, Thomas Lohse and Werner Witzeling (1978)

William R.Leo, Techniques for Nuclear and Particle Physics Experiments

Development of a gating driver of TPC for exotic beam experiments, J Yuan (2023)

Simulation of the electron and ion movement through a 4-GEM stack

Study of Passive Gating Grid for Ion Back Flow Suppression

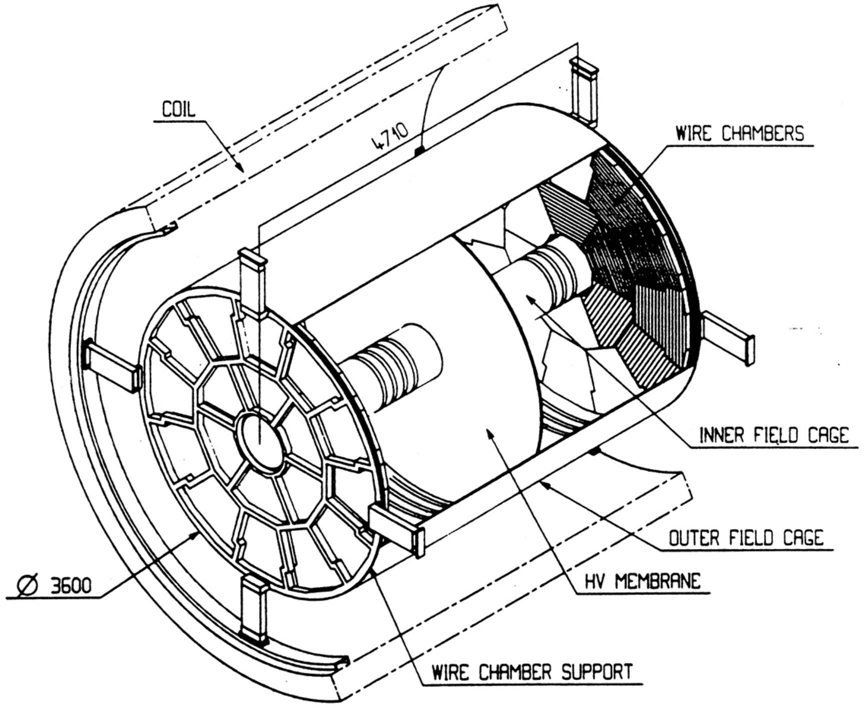
https://www.star.bnl.gov/public/tpc/hard/tpcrings/page11.html

https://flc.desy.de/tpc/basics/gem/index_eng.html

Thank you !

Back up

TPC = MWPC + Drift Chamber +TOF

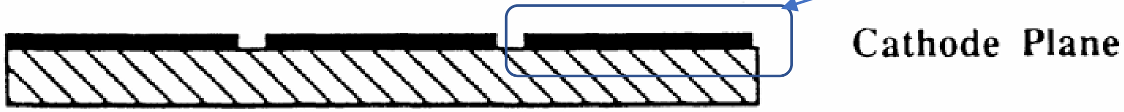


https://www.youtube.com/watch?v=vSbKxy7QF8I

https://www.youtube.com/watch?v=R5G1_hW0ZUA

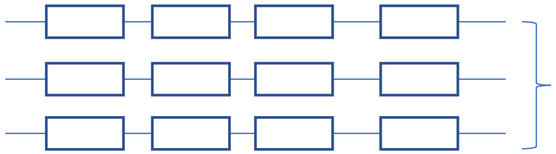
Wire Chamber

Small pad



Metallic surface
with photochemical etching process

Pad size : parameter



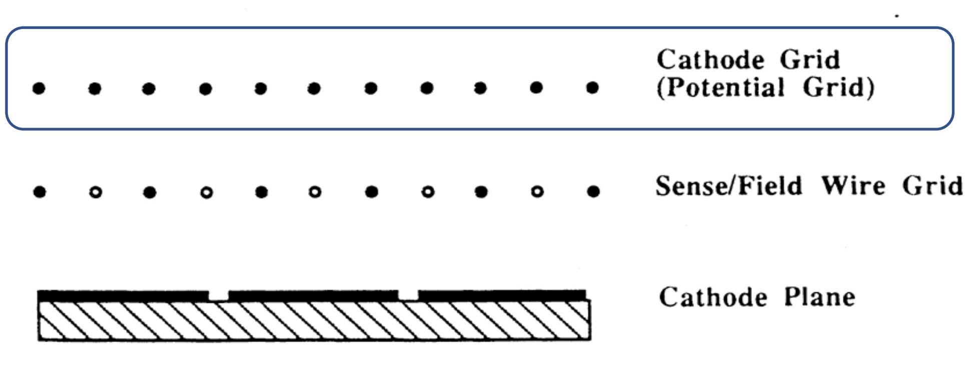
Straight pad rows
(PEP-4, Topaz, etc)

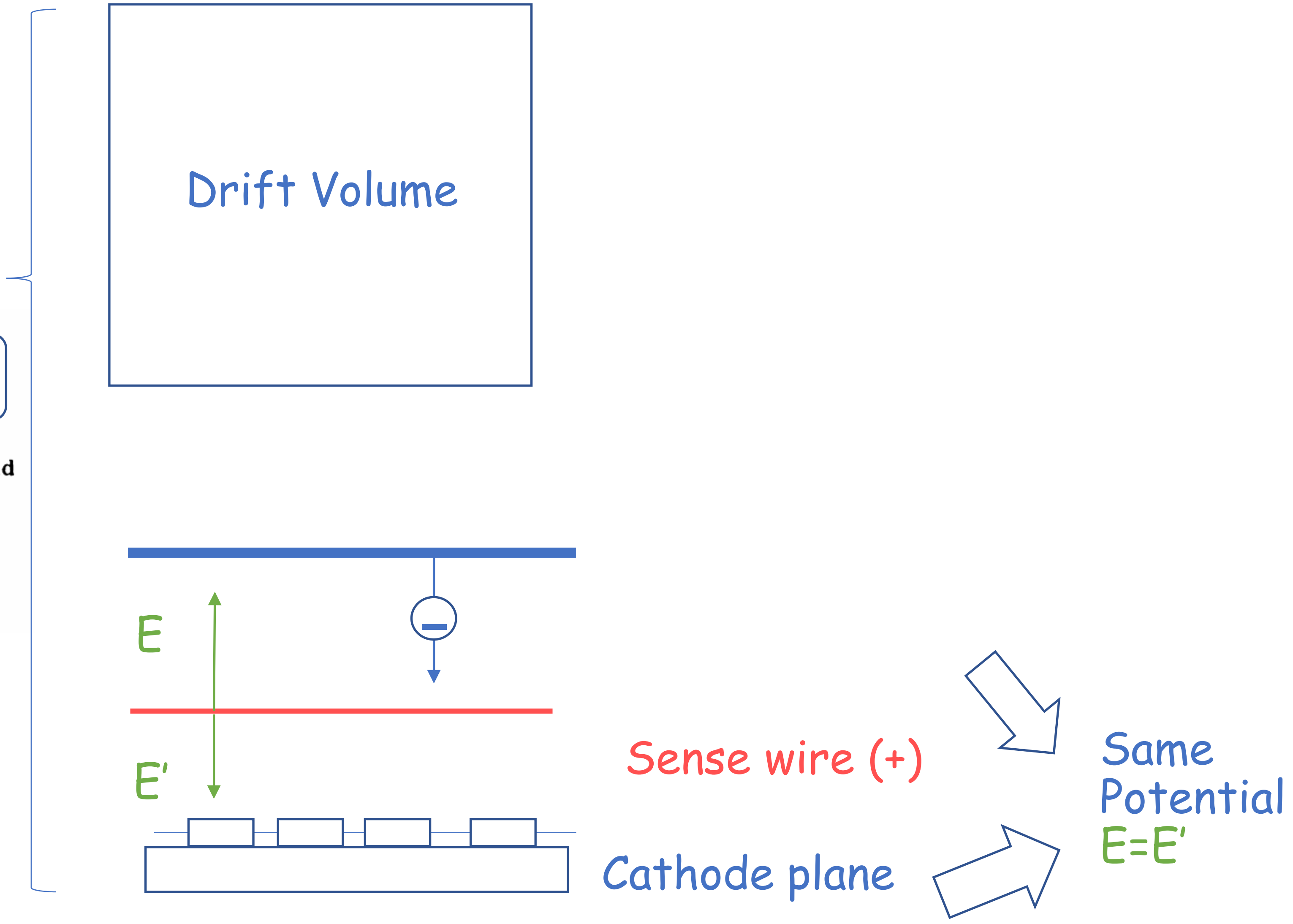
Pad covered plane
(NA35, HISS)

Pre amplifier -> electronic channel

Wire Chamber

Null potential or cathode (-)





GEM

Table 1. Parameters of the upgraded TPC.

Detector gas	Ne-CO_2-N_2 (90-10-5)
Gas volume	88 m^3
Drift voltage	100 kV
Drift field	400 V cm^{-1}
Maximal drift length	250 cm
Electron drift velocity	2.58 cm μs^{-1}
Maximum electron drift time	97 µs
$\omega\tau$ ($B = 0.5$ T)	0.32
Electron diffusion coefficients	$D_T = 209\ \mu m/\sqrt{cm}$, $D_L = 221\ \mu m/\sqrt{cm}$
Ion drift velocity	1.168 cm ms^{-1}
Maximum ion drift time	214 ms

GEM

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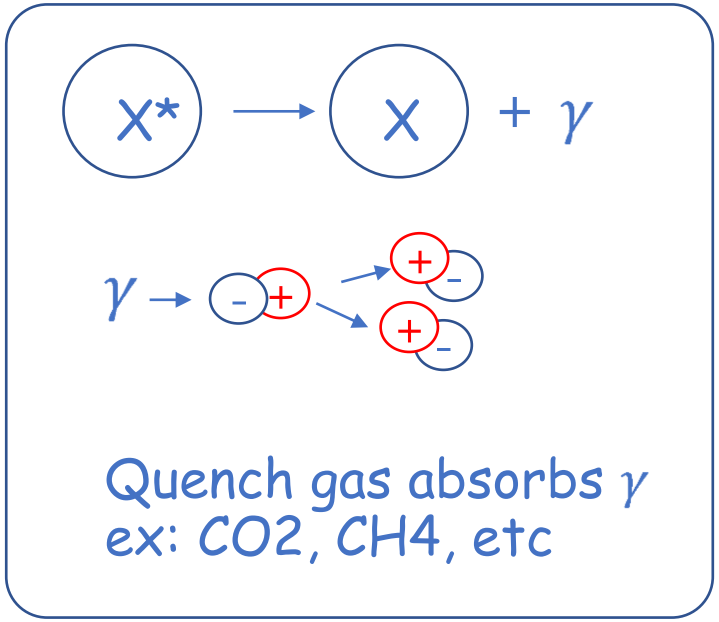
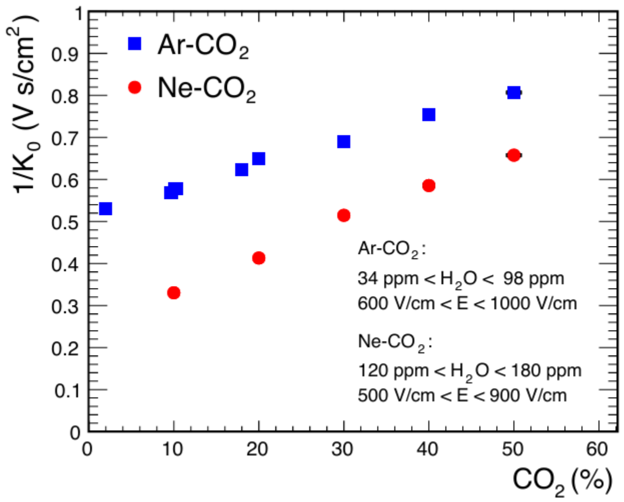


GEM

Table 2. Ionization and electron transport properties of a few gas mixtures used in modern TPCs, as calculated with the Magboltz [14] and Garfield [15] packages for an electric field of $400\ \mathrm{V\,cm^{-1}}$.

Gas	Eff. ionization energy W_i (eV)	Number of electrons per MIP N_p (primary) ($\mathrm{e\,cm^{-1}}$)	N_t (total) ($\mathrm{e\,cm^{-1}}$)	Drift velocity v_d ($\mathrm{cm\,\mu s^{-1}}$)	Diffusion coeff. D_L ($\mu\mathrm{m}/\sqrt{\mathrm{cm}}$)	D_T ($\mu\mathrm{m}/\sqrt{\mathrm{cm}}$)	$\omega\tau$
Ne-CO_2-N_2 (90-10-5)	37.3	14.0	36.1	2.58	221	209	0.32
Ne-CO_2 (90-10)	38.1	13.3	36.8	2.73	231	208	0.34
Ar-CO_2 (90-10)	28.8	26.4	74.8	3.31	262	221	0.43
Ne-CF_4 (80-20)	37.3	20.5	54.1	8.41	131	111	1.84



$$[\mu] = cm^2/(V \cdot s)$$

GEM

Readout chambers	
Total number	$2 \times 2 \times 18 = 72$
Readout technology	4-GEM stack, single mask, standard (S, 140 µm) and large (LP, 280 µm) hole pitch GEMs in S-LP-LP-S configuration
Effective gas gain	2000
Inner (IROC)	
Total number	$2 \times 18 = 36$
Active range	$848.5 < r < 1321$ mm
Pad rows	63
Total pads (IROC)	5280
S:N (MIP)	20:1
Outer (OROC)	
Total number	$2 \times 18 = 36$
Active range	$1347 < r < 2464$ mm
Total pads (OROC)	9280
S:N (MIP)	30:1
Pad rows	89
OROC 1	
Active range	$1347 < r < 1687$ mm
Pad rows	34
Number of pads	2880
OROC 2	
Active range	$1708 < r < 2068$ mm
Pad rows	30
Number of pads	3200
OROC 3	
Active range	$2089 < r < 2464$ mm
Pad rows	25
Number of pads	3200

Readout electronics	
Number of channels	524160
Signal polarity	negative
Average system noise (ENC)	670 e
Conversion gain	20 mV fC^{-1}
Dynamic range	100 fC
Peaking time	160 ns
ADC number of bits	10
ADC sampling rate	5 MHz
Power consumption (total)	56 mW per channel

GEM

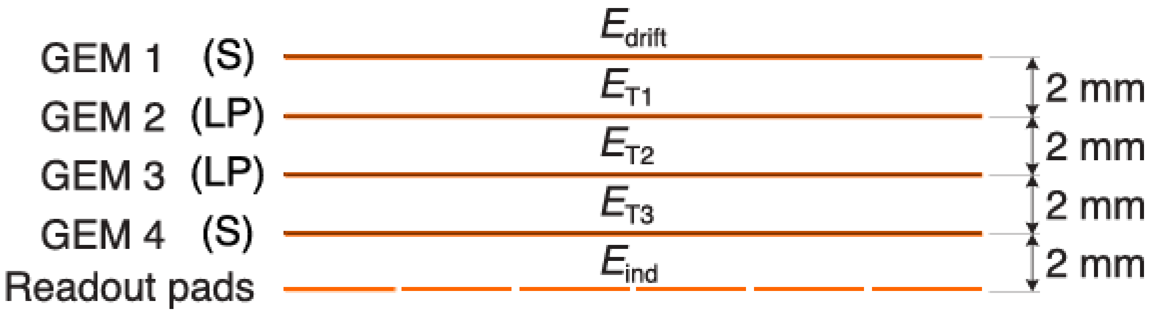
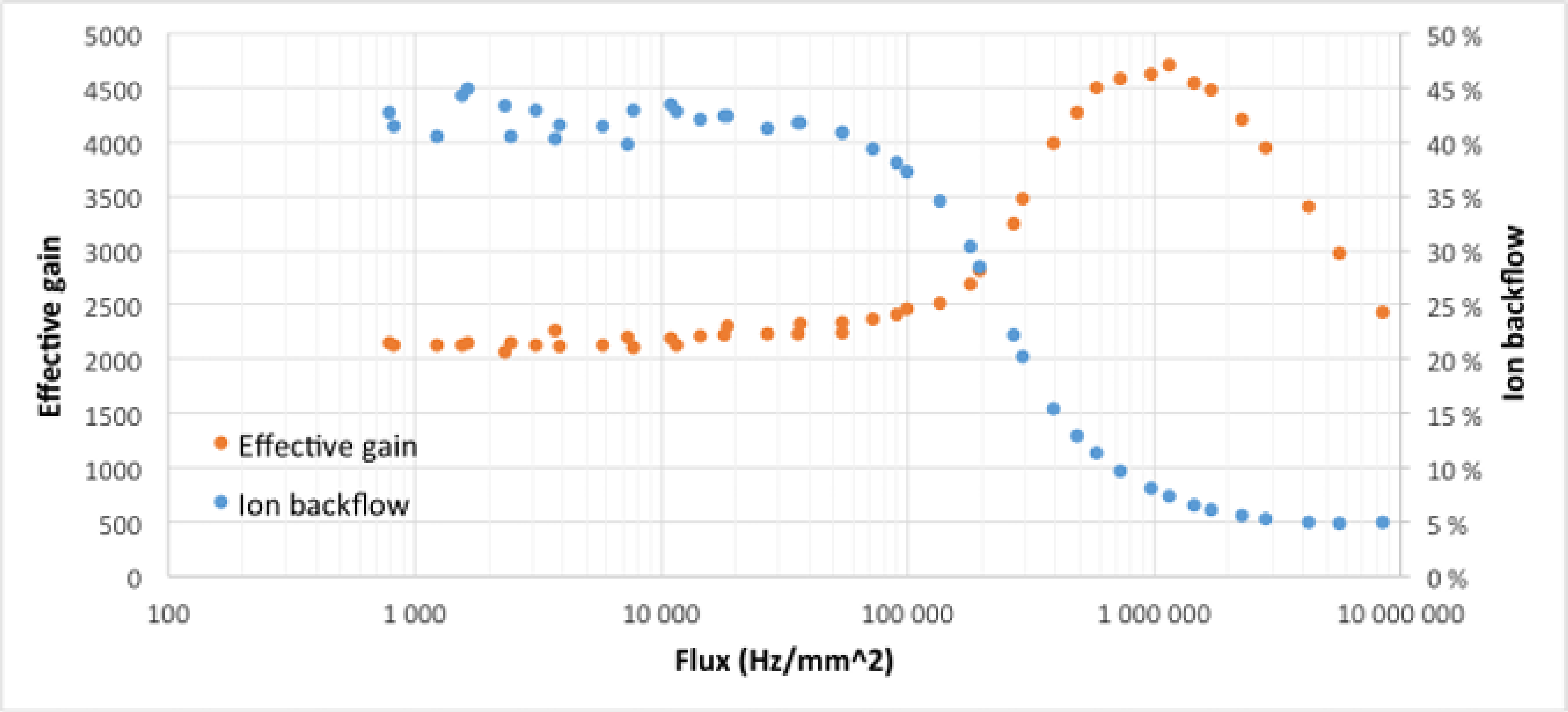


Figure 2. Schematic setup with four GEMs.

Table 8. HV test settings used for ROC quality assurance.

$\Delta V_{GEM\,1}$	=	270 V
$\Delta V_{GEM\,2}$	=	230 V
$\Delta V_{GEM\,3}$	=	288 V
$\Delta V_{GEM\,4}$	=	359 V
E_{drift}	=	$400\,V\,cm^{-1}$
E_{T1}	=	$4000\,V\,cm^{-1}$
E_{T2}	=	$4000\,V\,cm^{-1}$
E_{T3}	=	$100\,V\,cm^{-1}$
E_{ind}	=	$4000\,V\,cm^{-1}$

GEM



Effective gain
Ion backflow
Flux (Hz/mm^2)
Effective gain
Ion backflow
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
50 %
45 %
40 %
35 %
30 %
25 %
20 %
15 %
10 %
5 %
0 %
100
1 000
10 000
100 000
1 000 000
10 000 000