3層GEMチェンバー ゲイン特性測定

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内田智久　KEK **測定器開発室**

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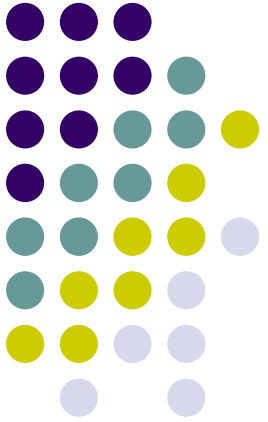
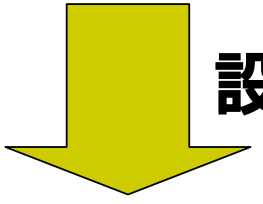
門松宏治、杉山晃、山本拓也 (**佐賀大**)
中野英一 (**大阪市大**)



Introduction

GEMを使用して
2次元読み出し検出器
中性子、X線検出器



設計

ゲイン特性の理解が必要
例えば、欲しいゲインで動作させる為のパラメータとは？

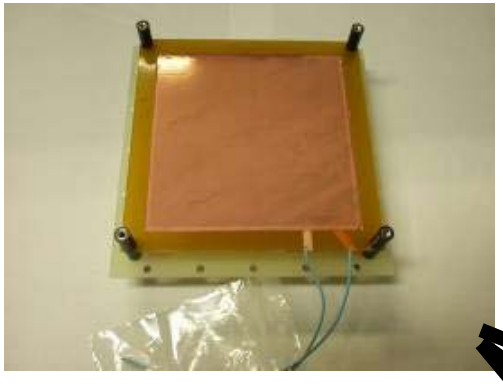
Outline

3層ＧＥＭチェンバーのゲイン特性測定

- テスト装置
- ゲイン特性
- 読み出しパッドとGEM foilからの信号
- 電子ドリフト時間と信号パルス幅
- まとめ

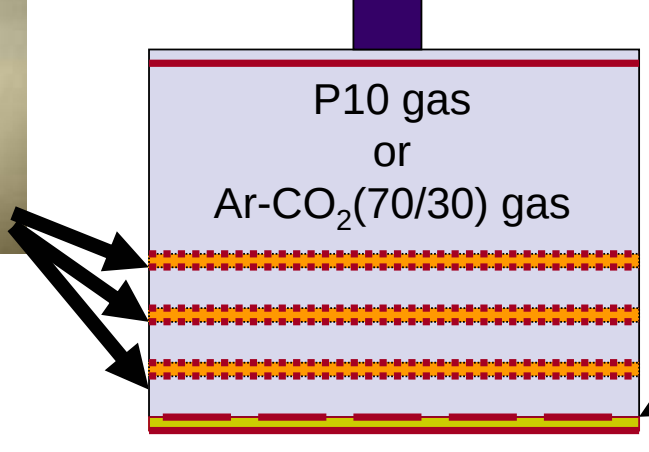
Test chamber

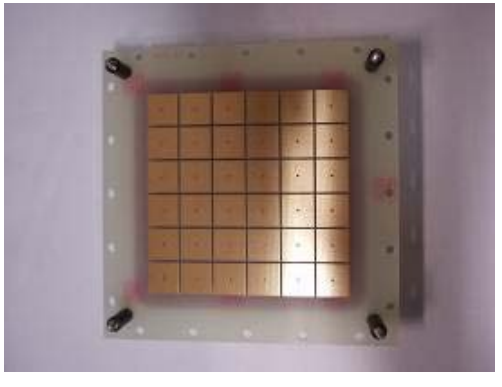
Triple GEM detector



GEM

10 cm×10 cm





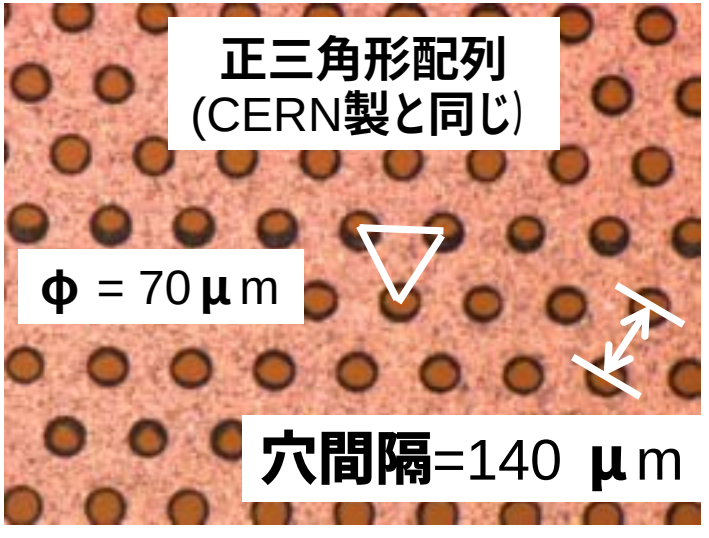
Readout pads

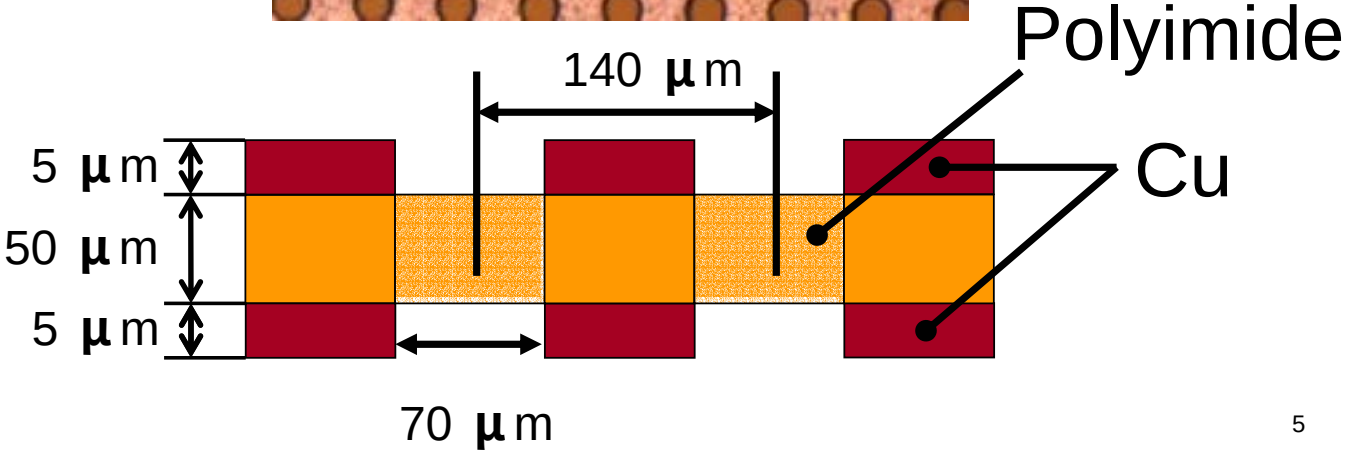
□15mm×15mm

36個＝6行×6列

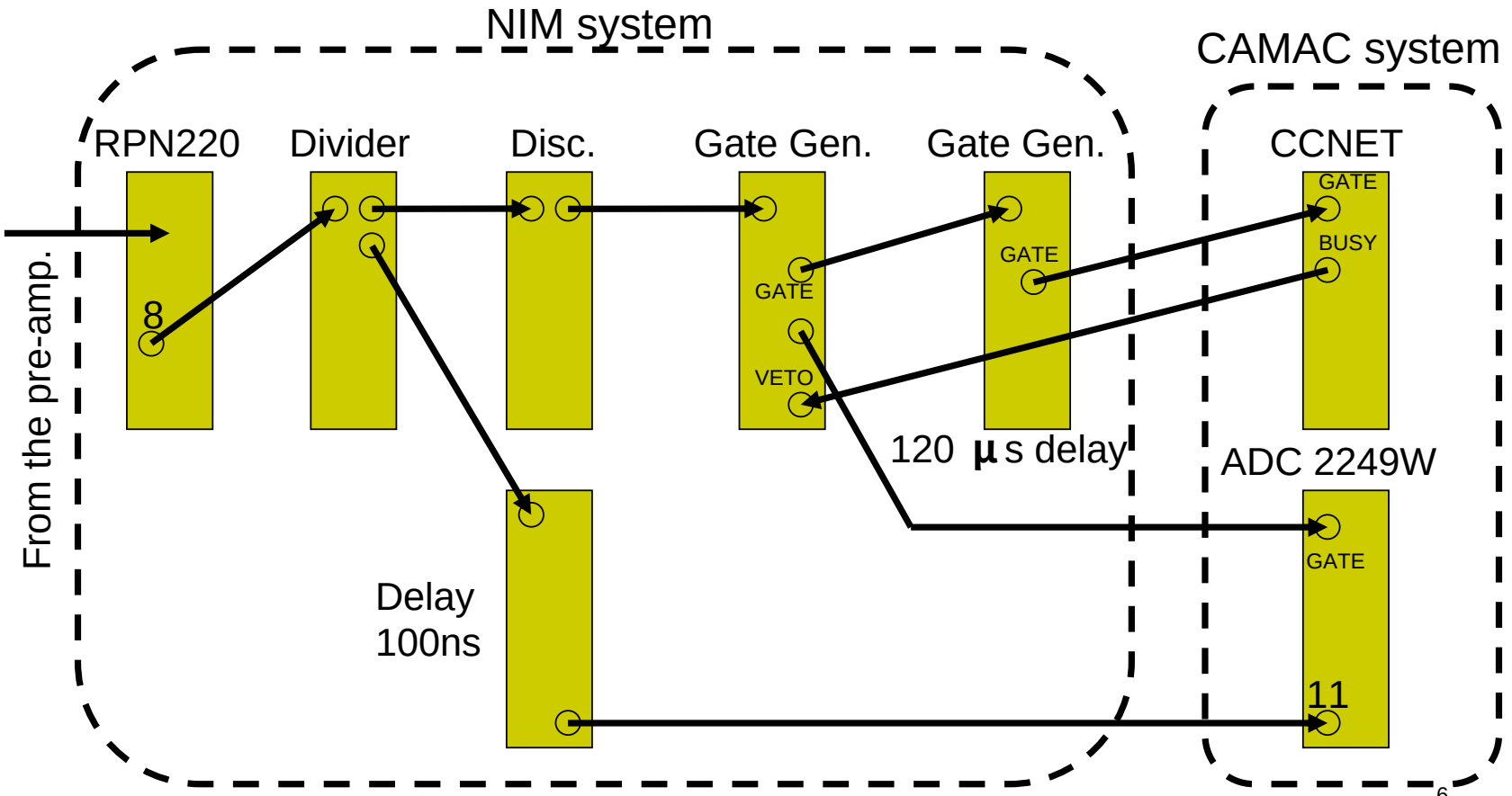
GEM foil

サイエナジー社製





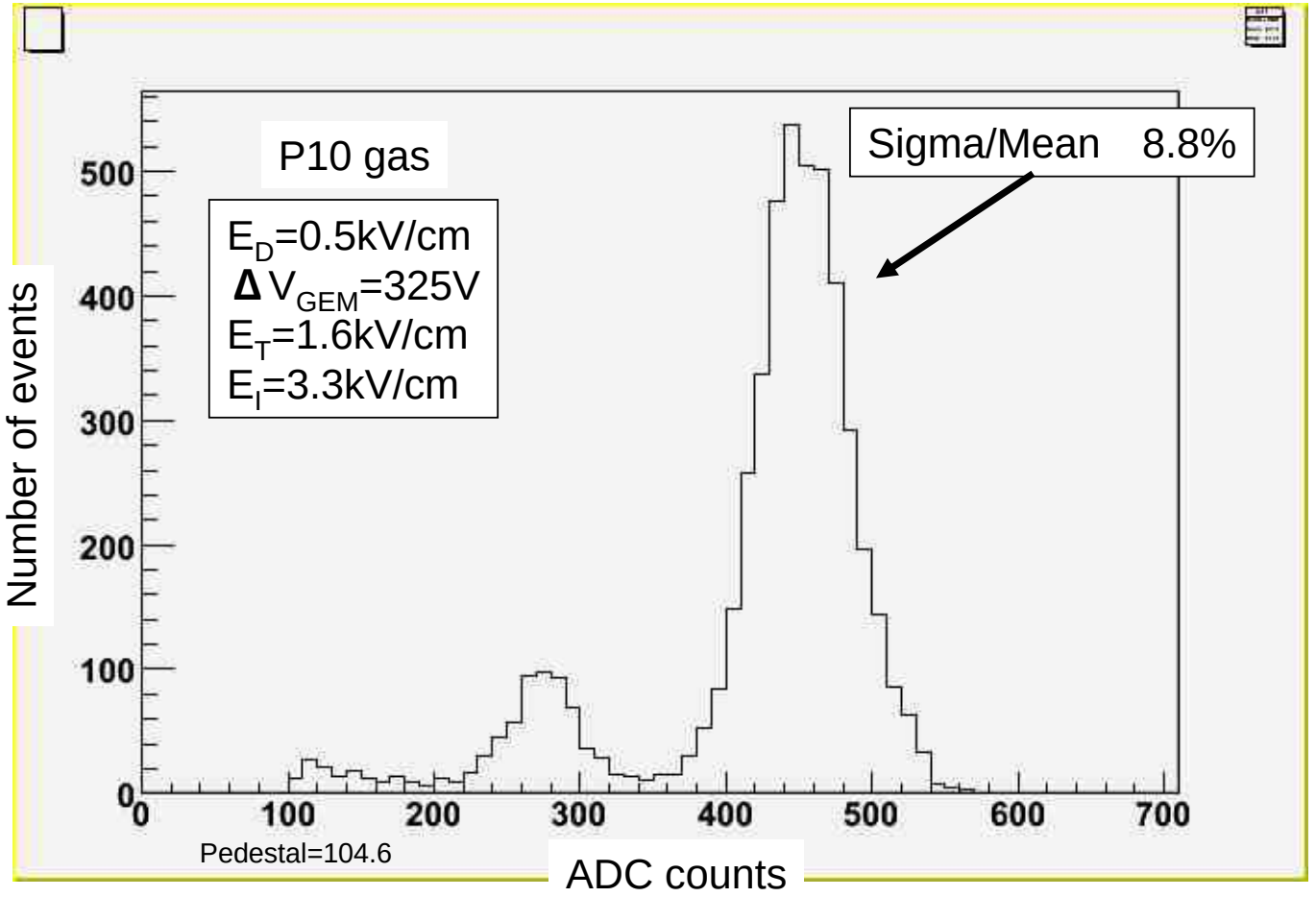
システム構成



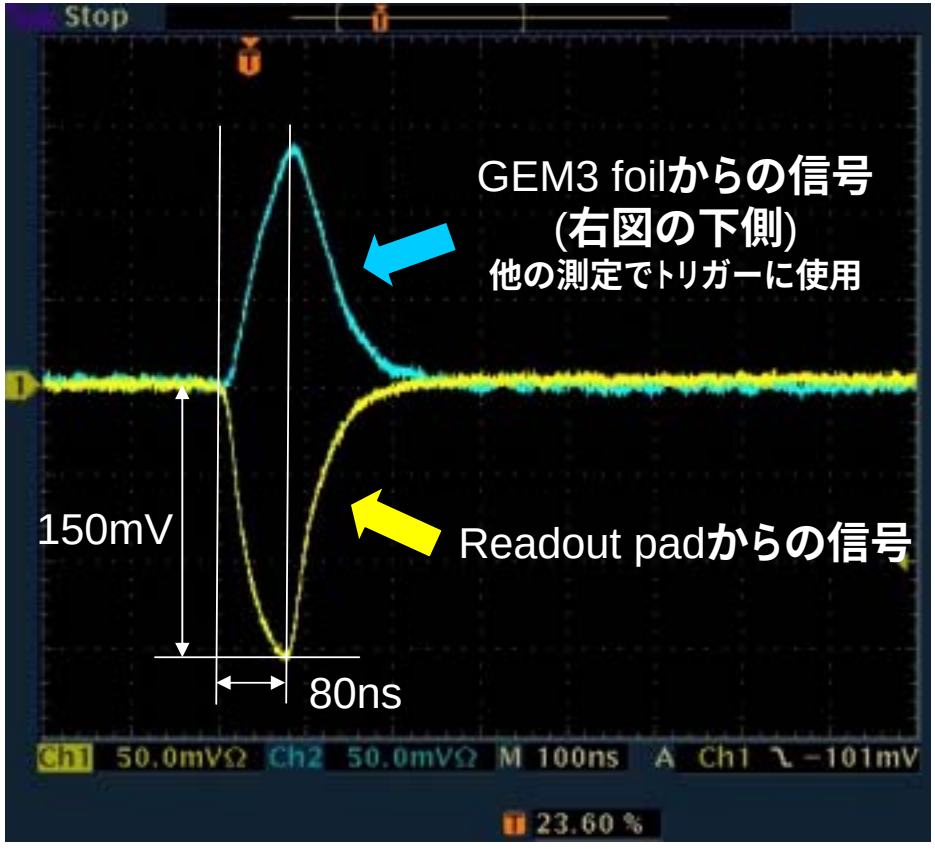
Pre-amp.はカレントアンプ

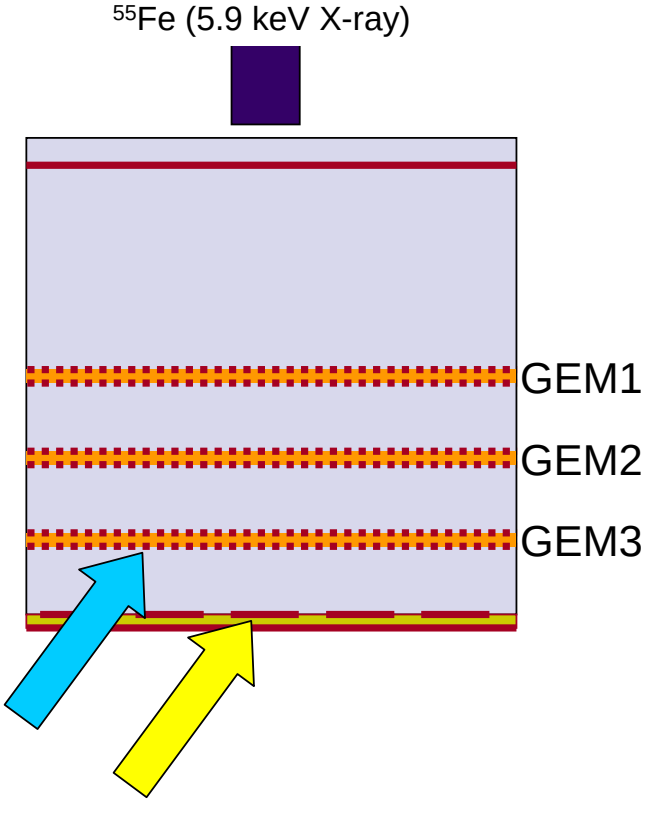
2249Wで波形を積分

A sample of spectrum



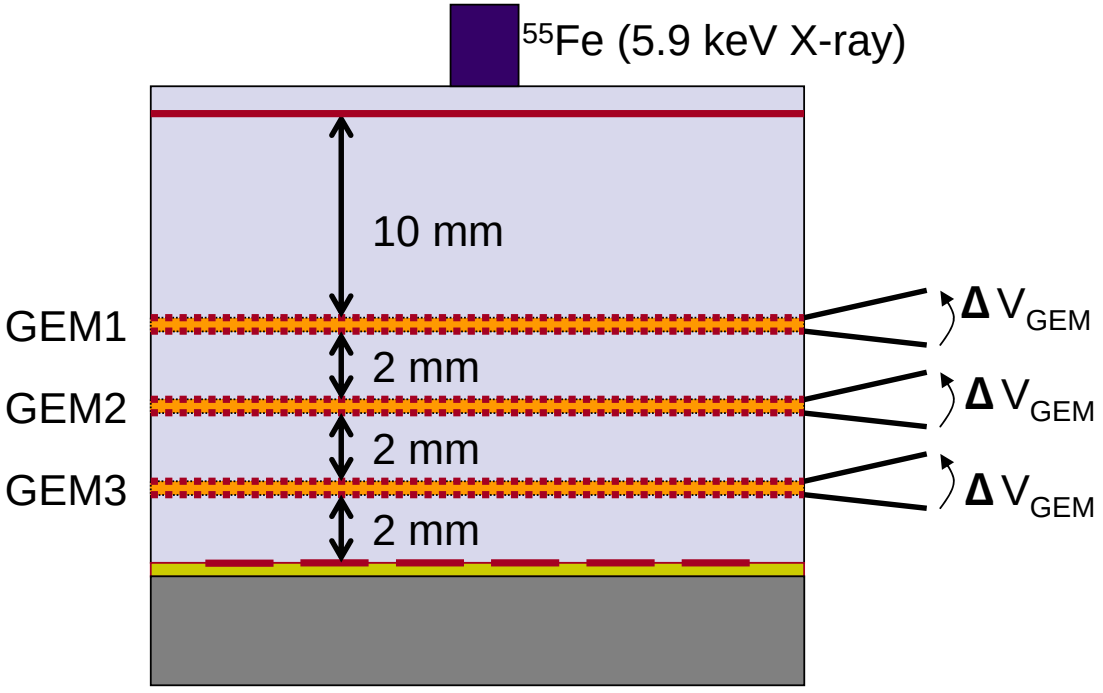
Pulse shape


Stop
GEM3 foilからの信号
(右図の下側)
他の測定でトリガーに使用
150mV
Readout padからの信号
80ns
Ch1 50.0mVΩ Ch2 50.0mVΩ M 100ns A Ch1 ∿ -101mV
23.60 %

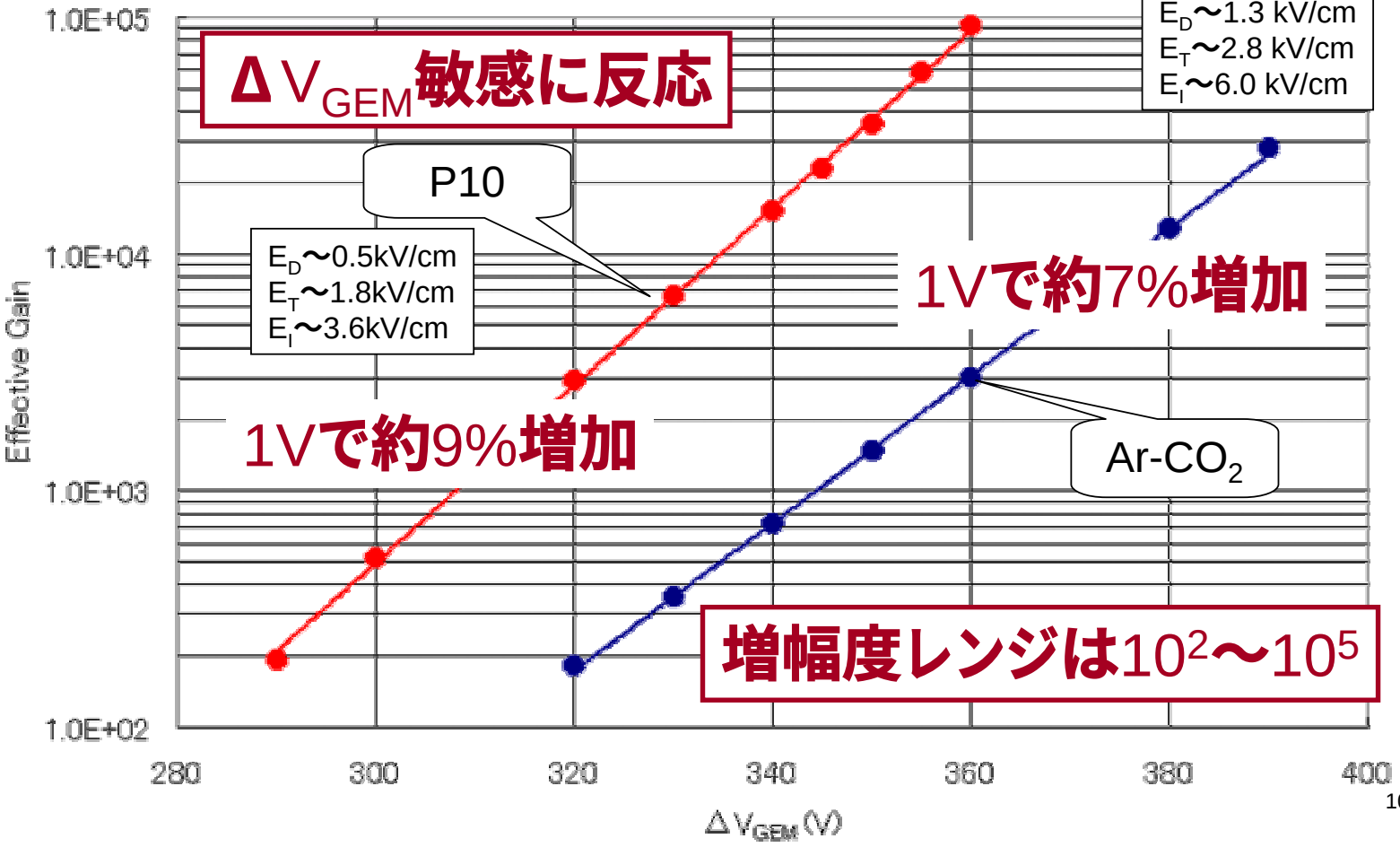

55Fe (5.9 keV X-ray)
GEM1
GEM2
GEM3

ゲイン特性
ΔV_{GEM} dependence

3枚のGEM両面間の電圧を変化させて測定

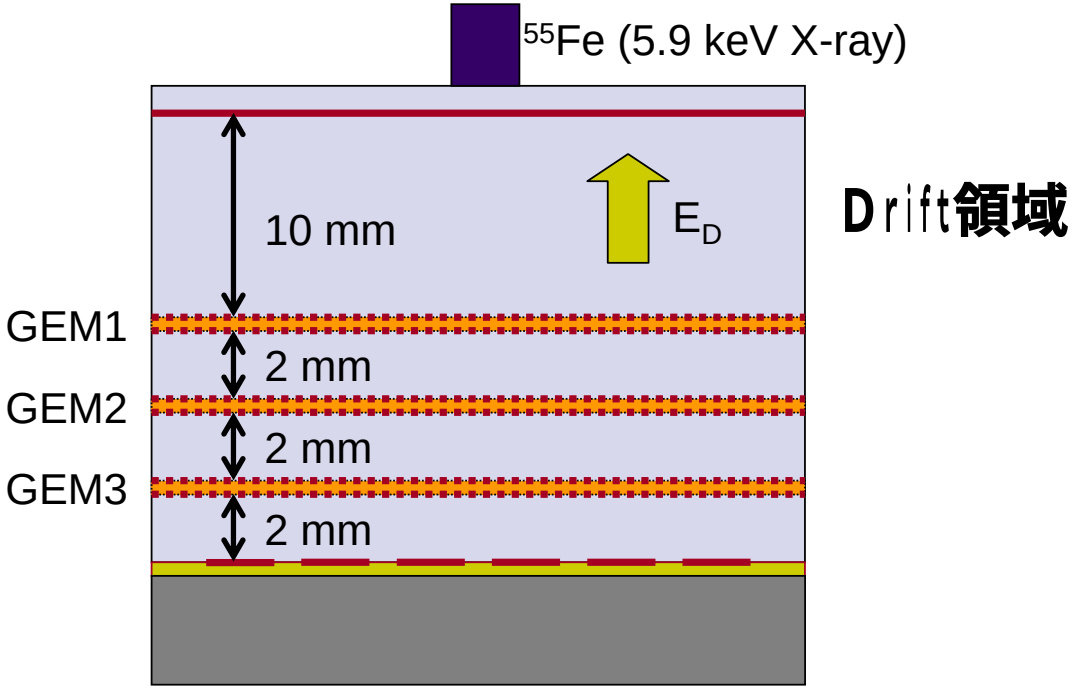


ΔV_{GEM} dependence

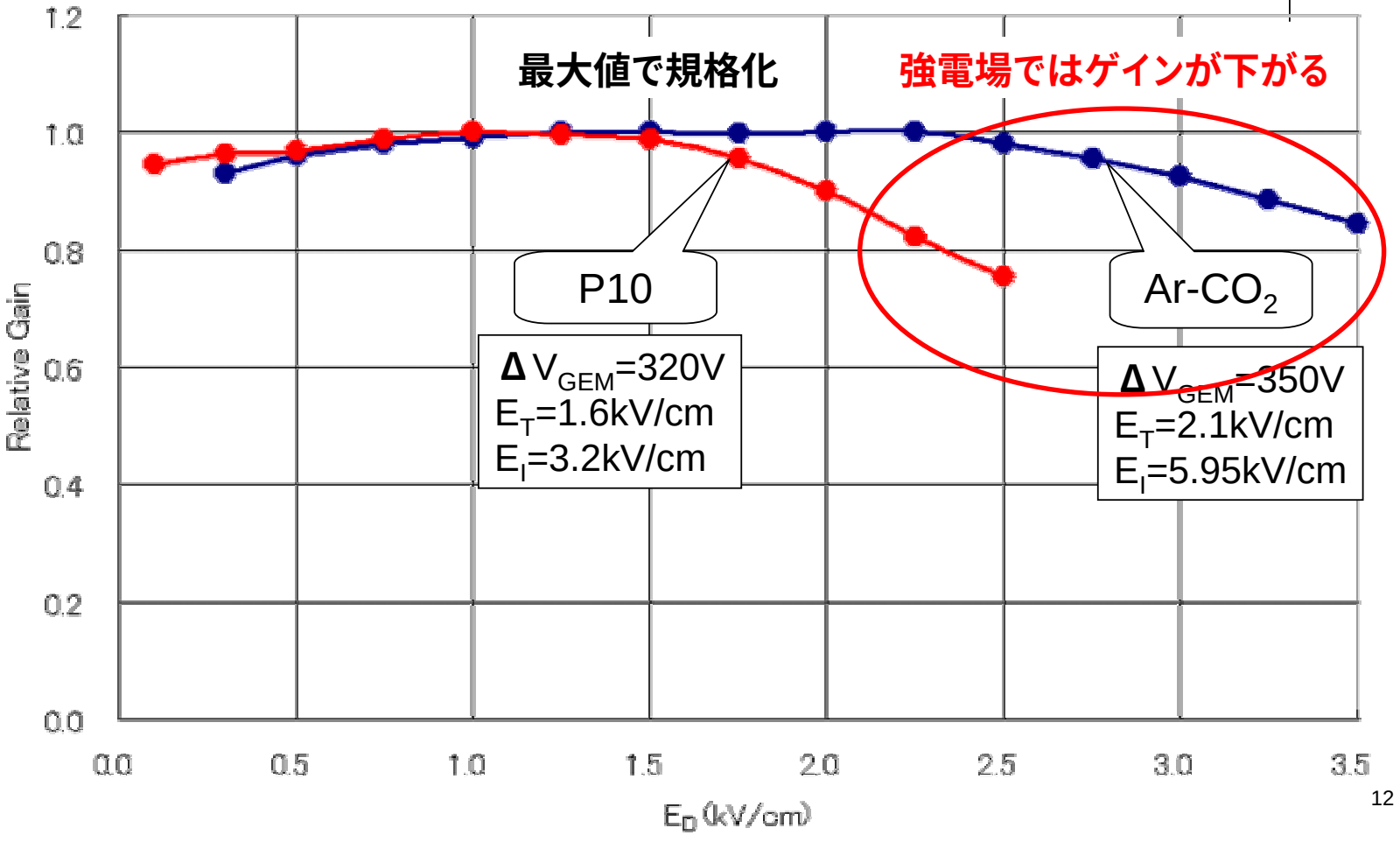


E_D dependence

Drift**領域**の電場を変化させてゲインを測定

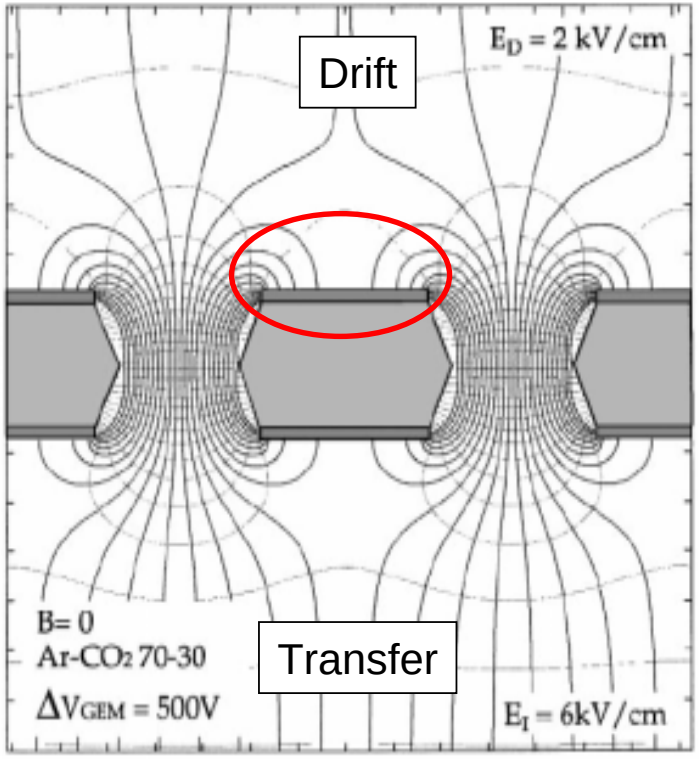


E_D dependence

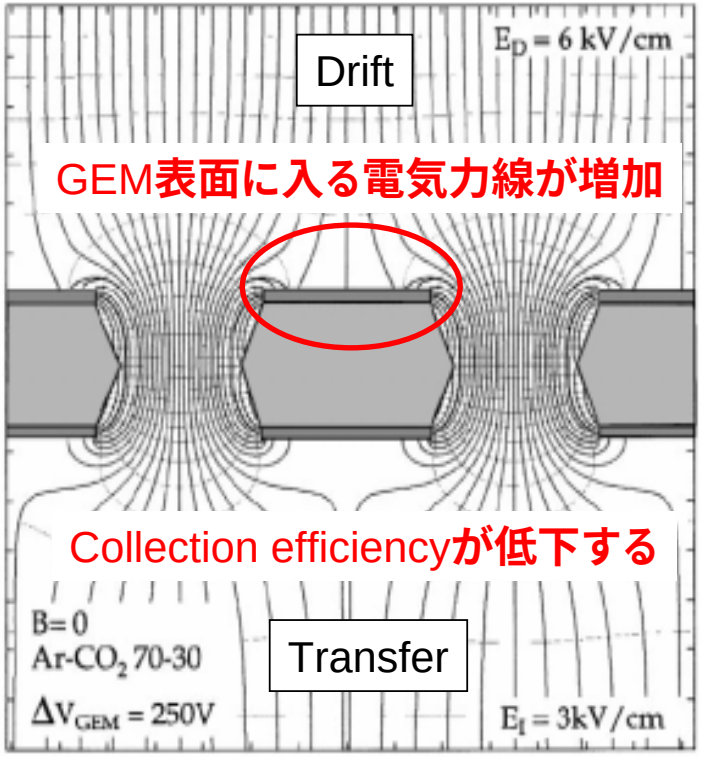


E_D dependence Electric field map

Drift電場が弱い場合

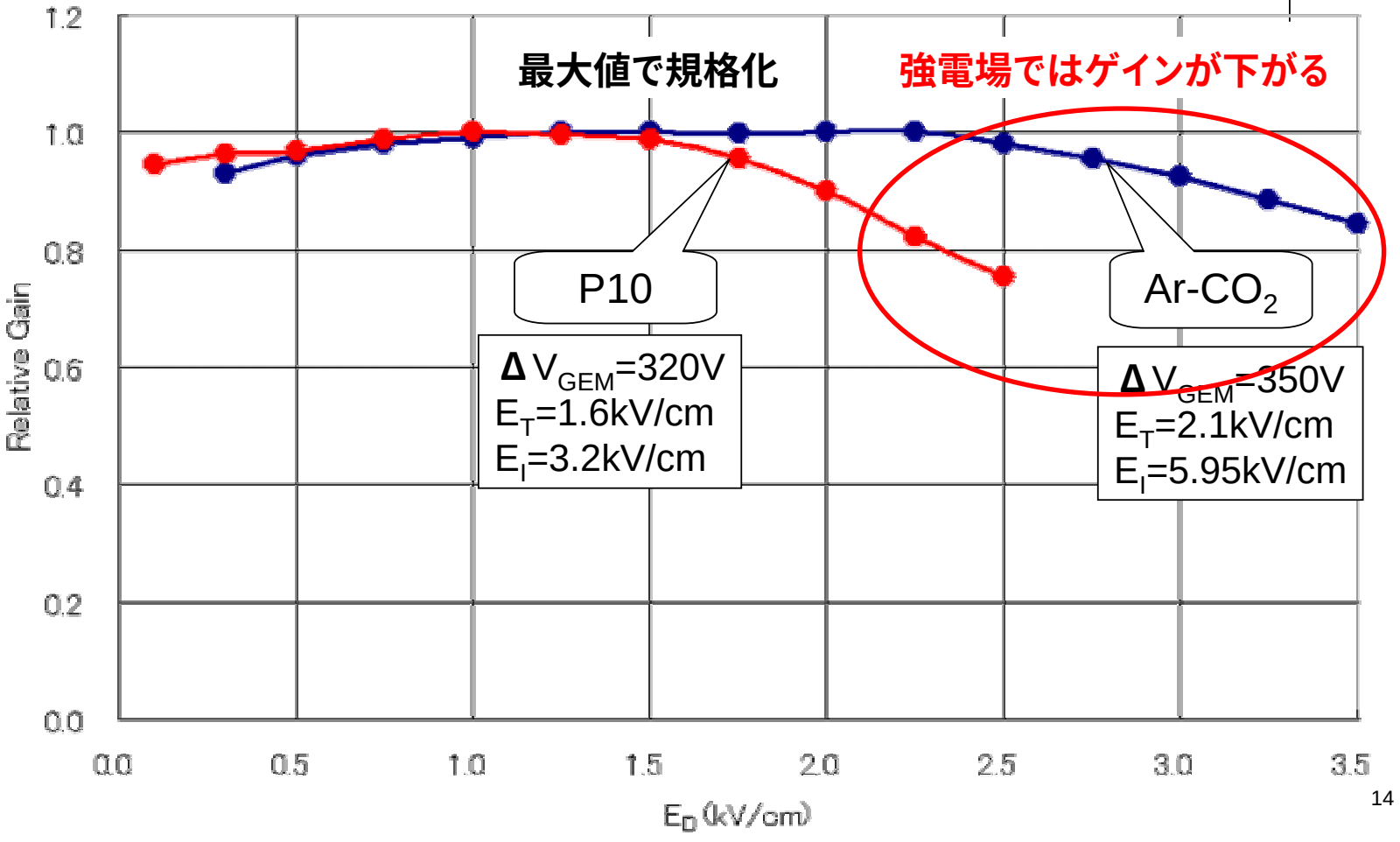


Drift電場が強い場合



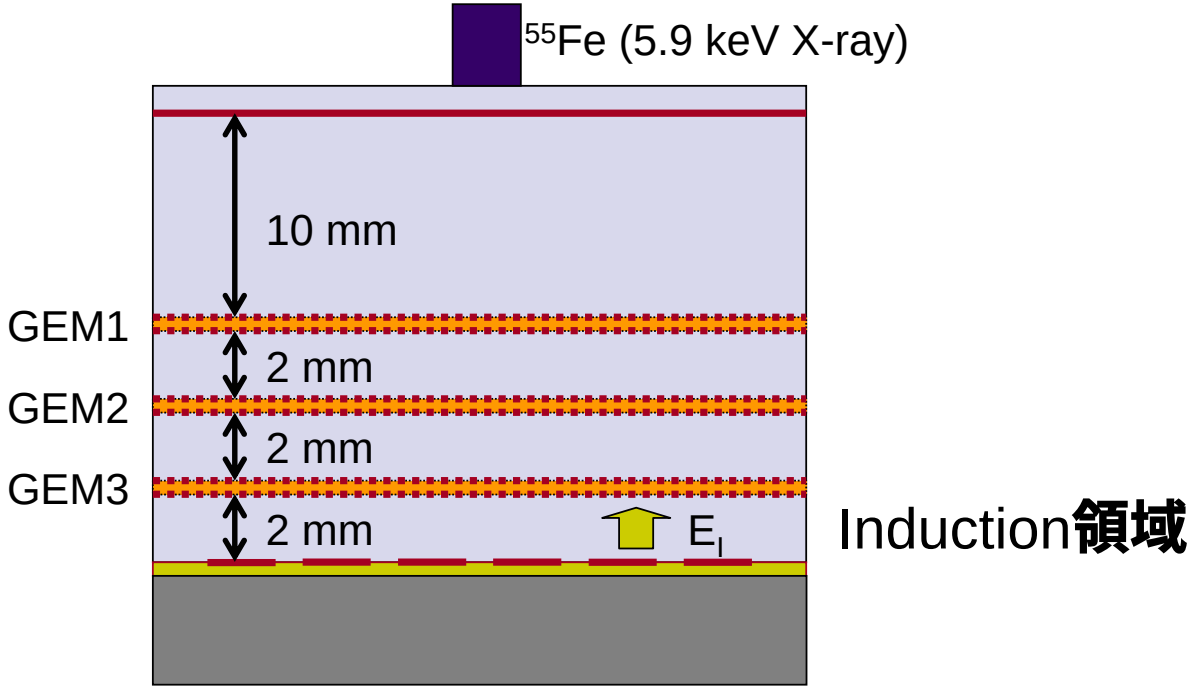
S.Bachmann, et. al., NIM A 438(1999) 376-408

E_D dependence

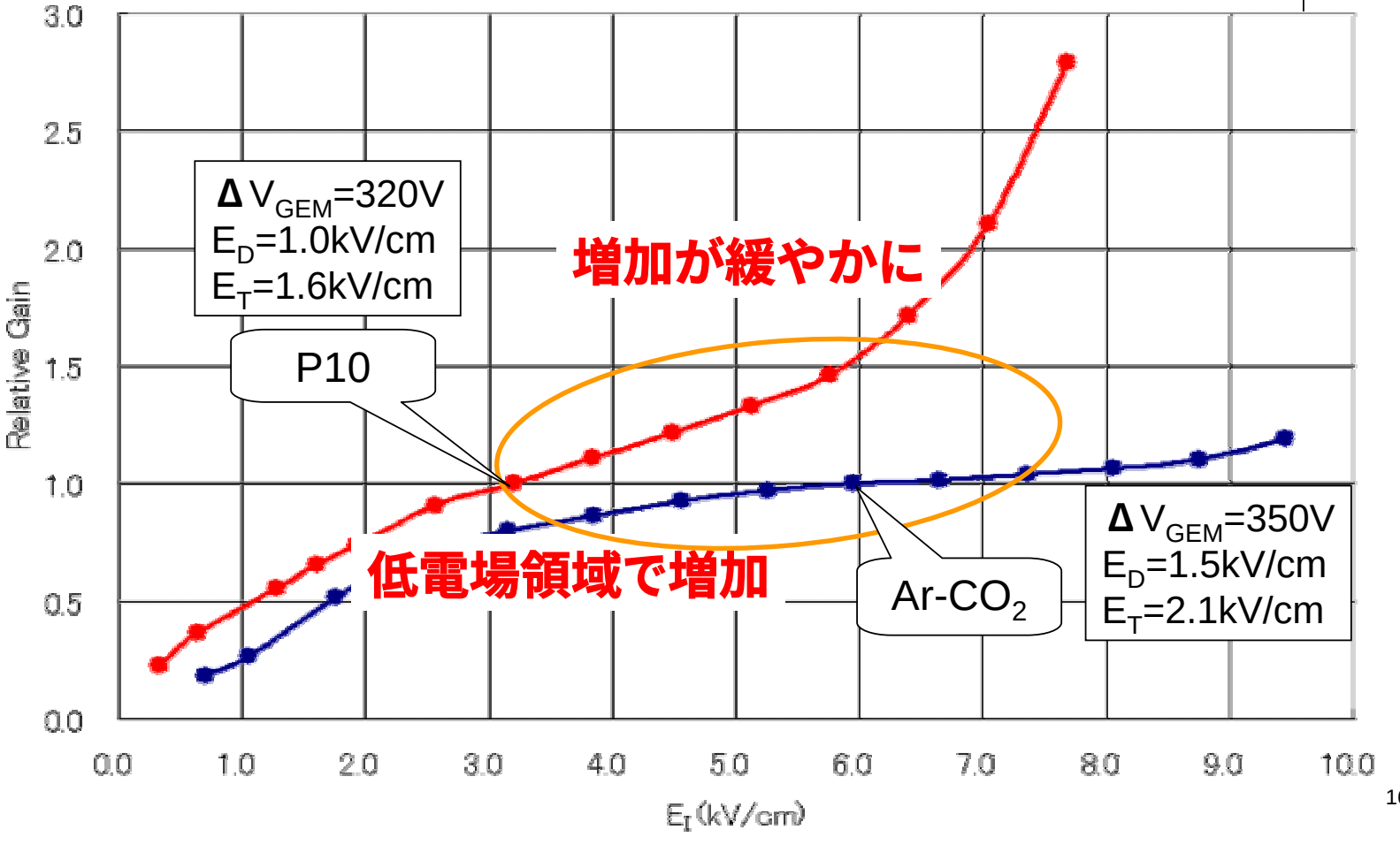


E_I dependence

Induction**領域**の電場を変化させてゲインを測定

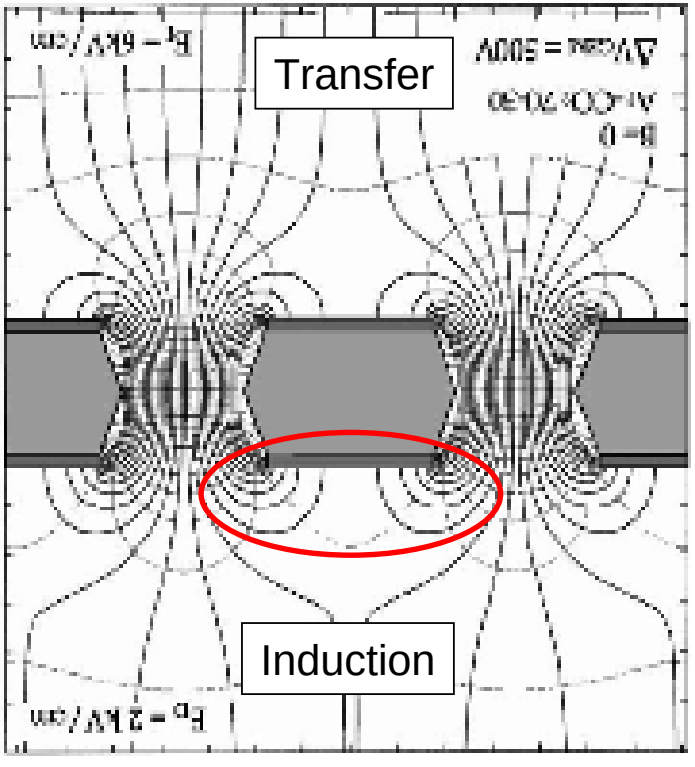


E_I dependence

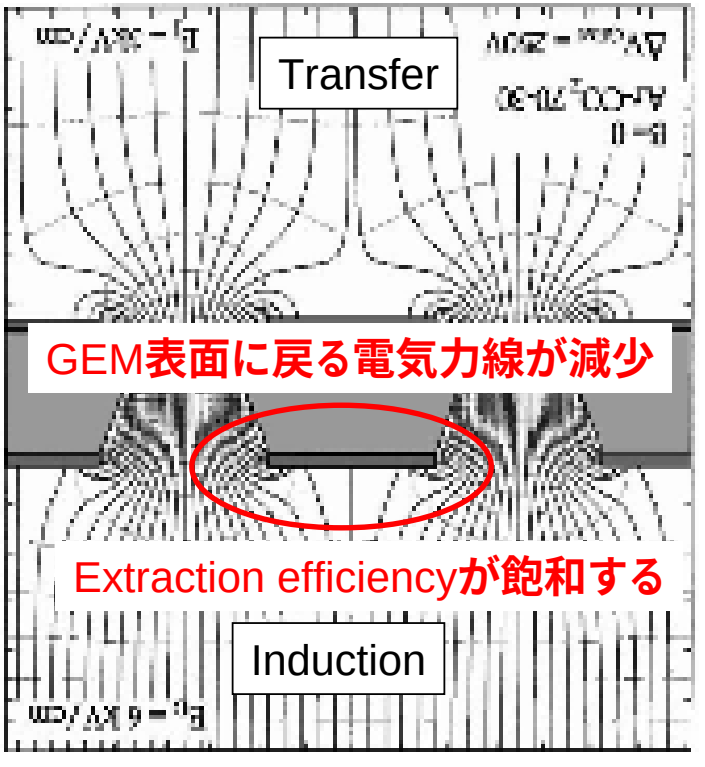


E_I dependence
Electric field map

Induction電場が弱い場合

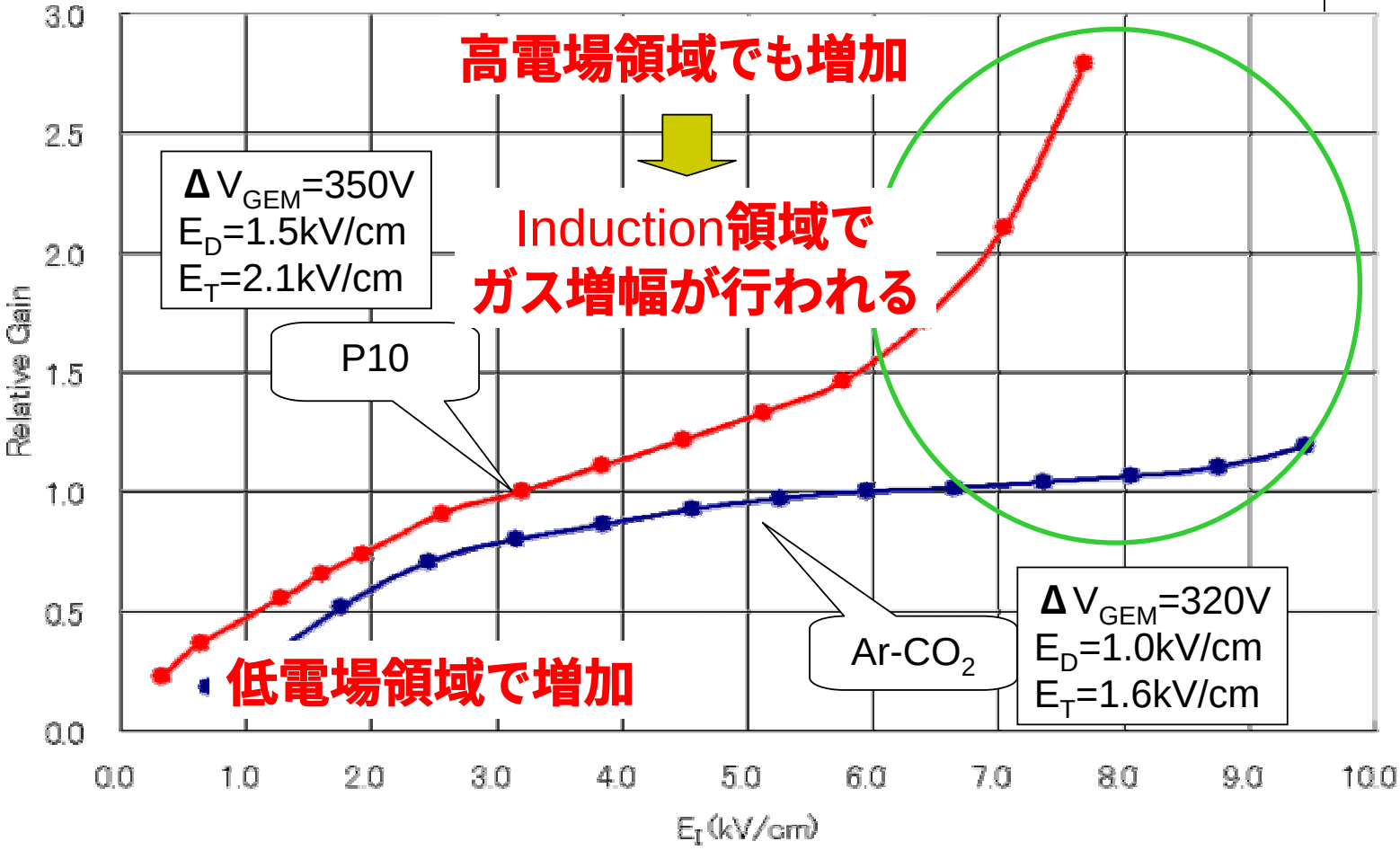


Induction電場が強い場合



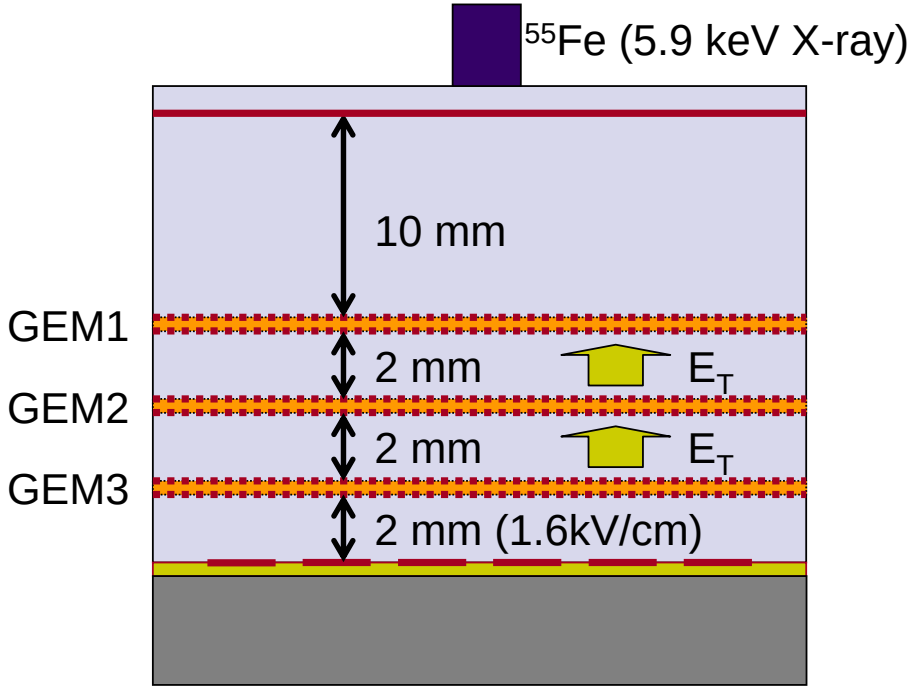
S.Bachmann, et. al., NIM A 438(1999) 376-408

E_I dependence

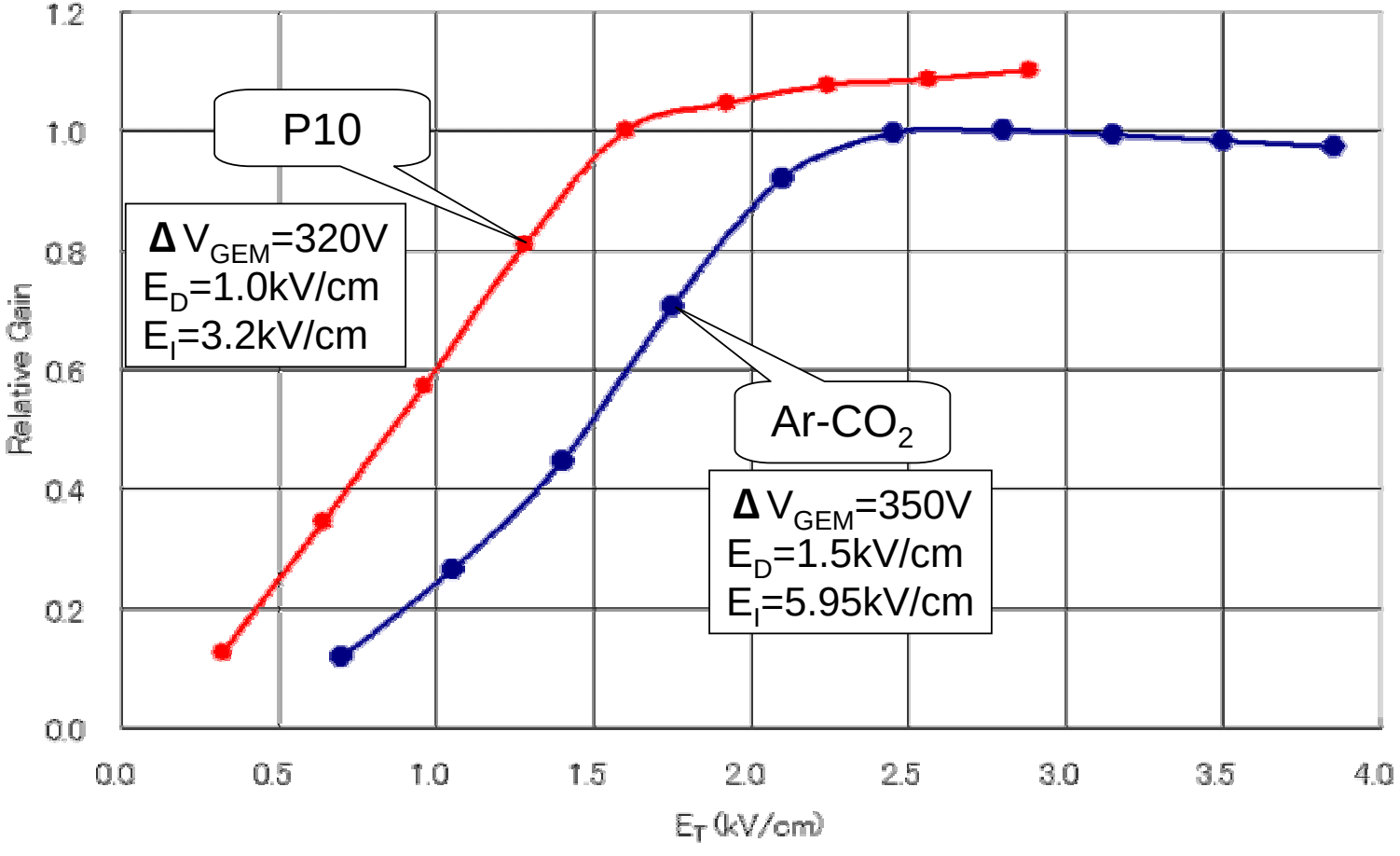


E_T dependence

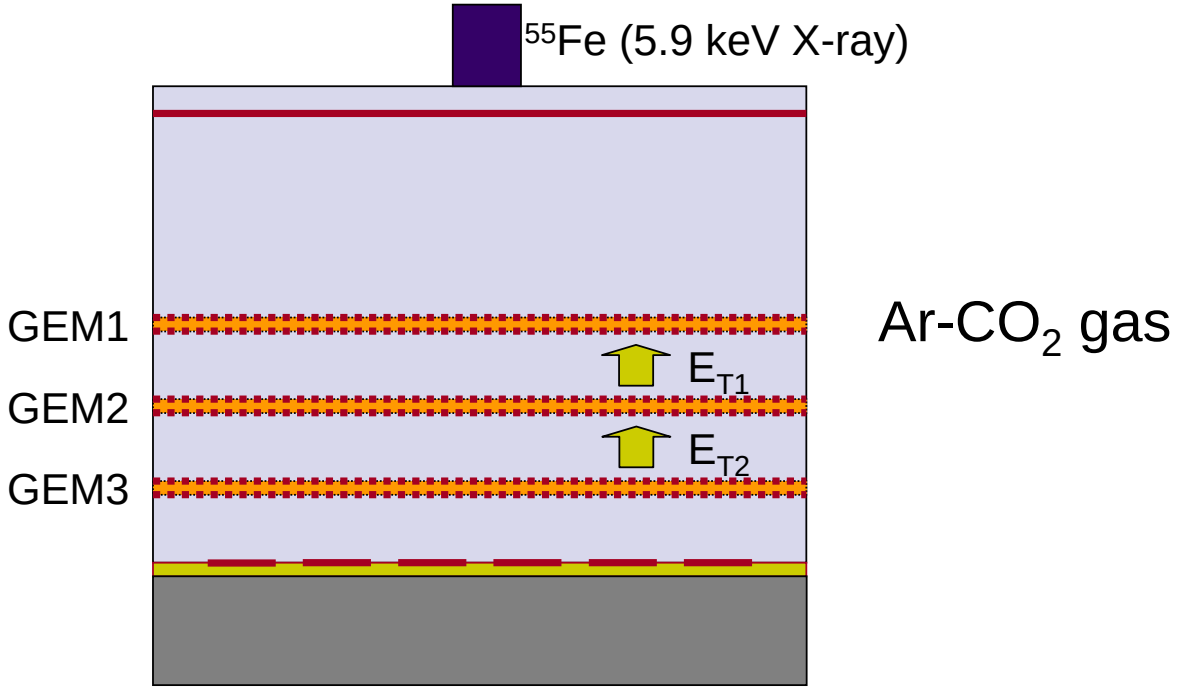
Transfer**領域**の電場を変化させてゲインを測定



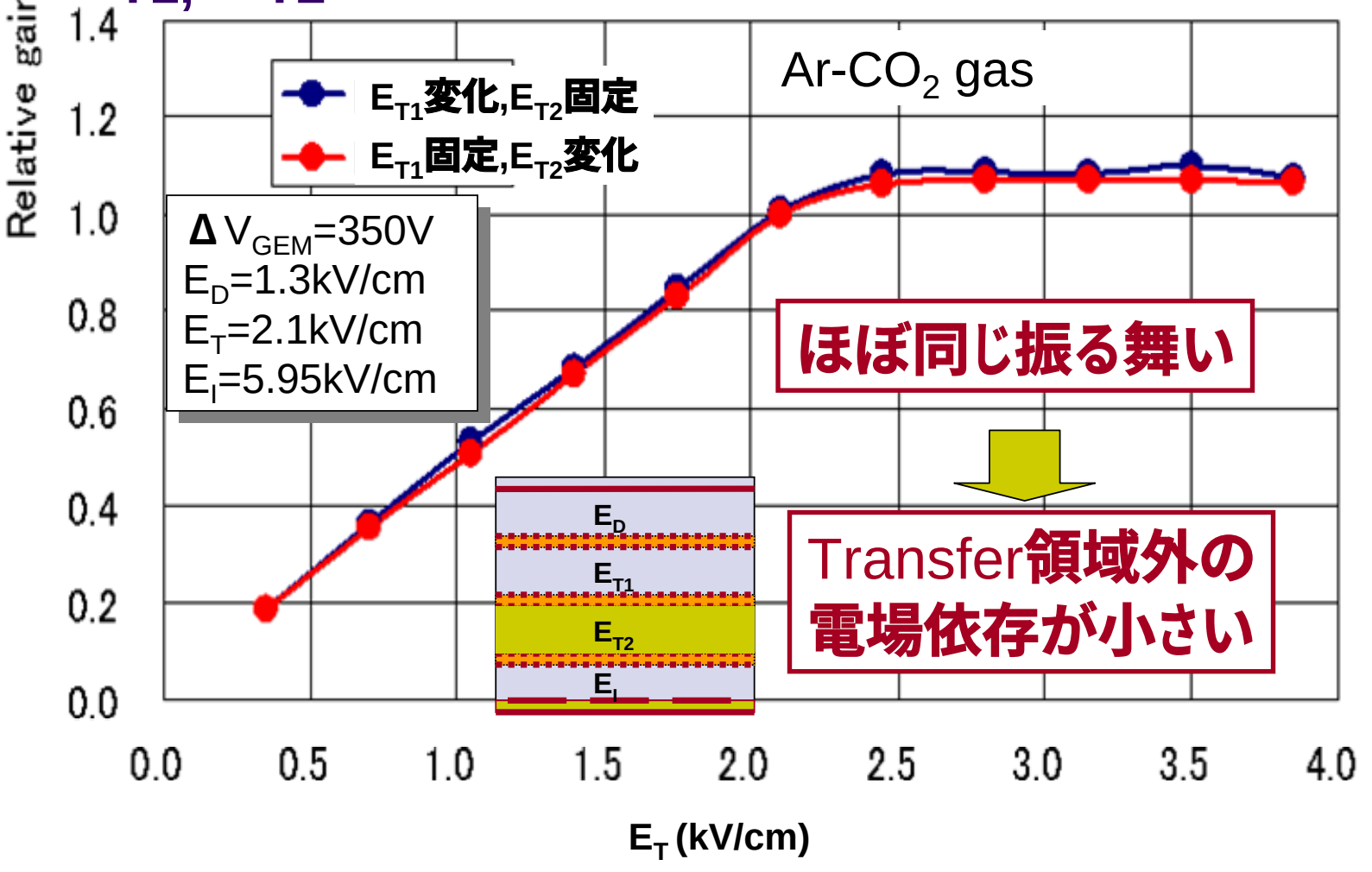
E_T dependence



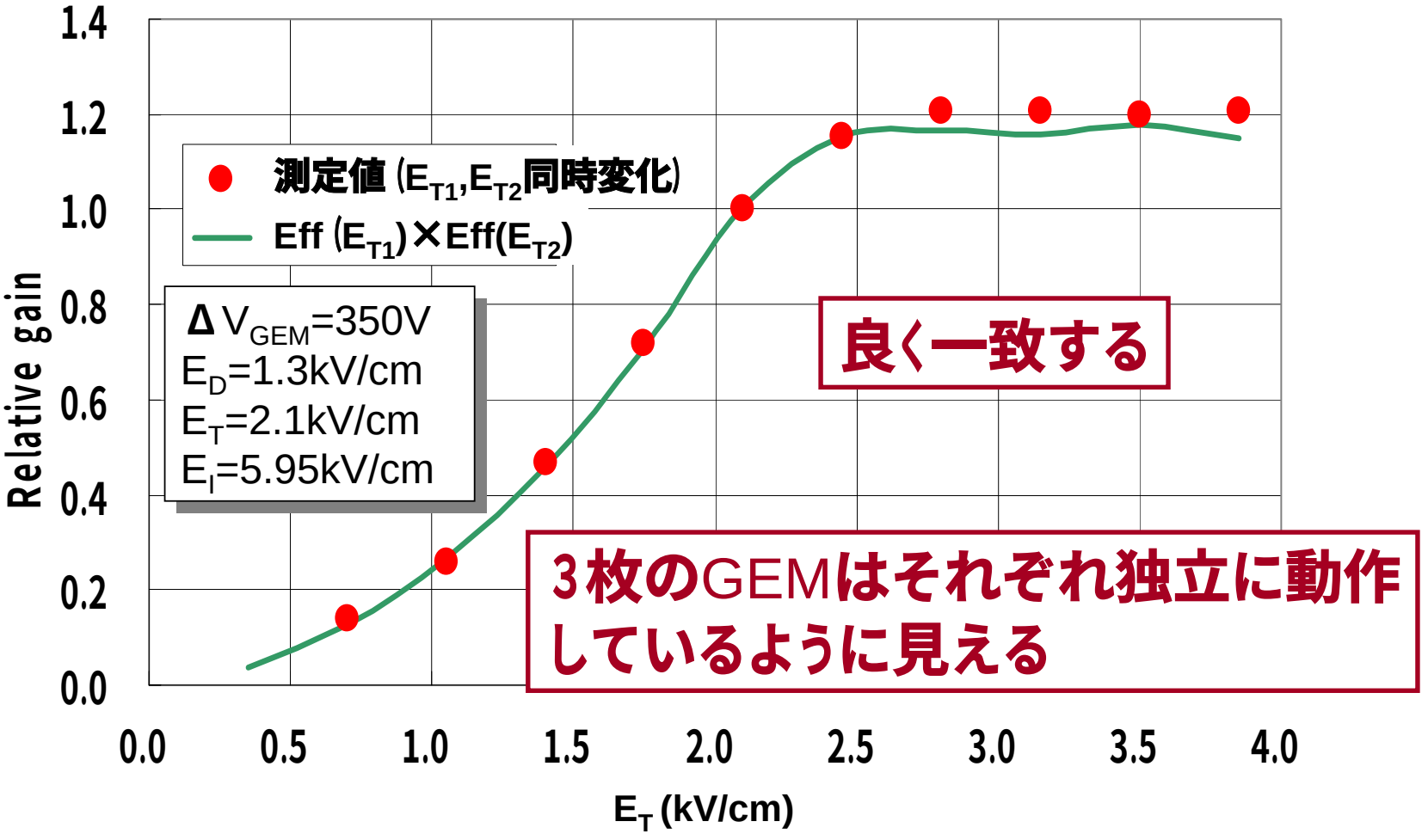
E_{T1},E_{T2}独立測定



E_{T1}, E_{T2} dependence

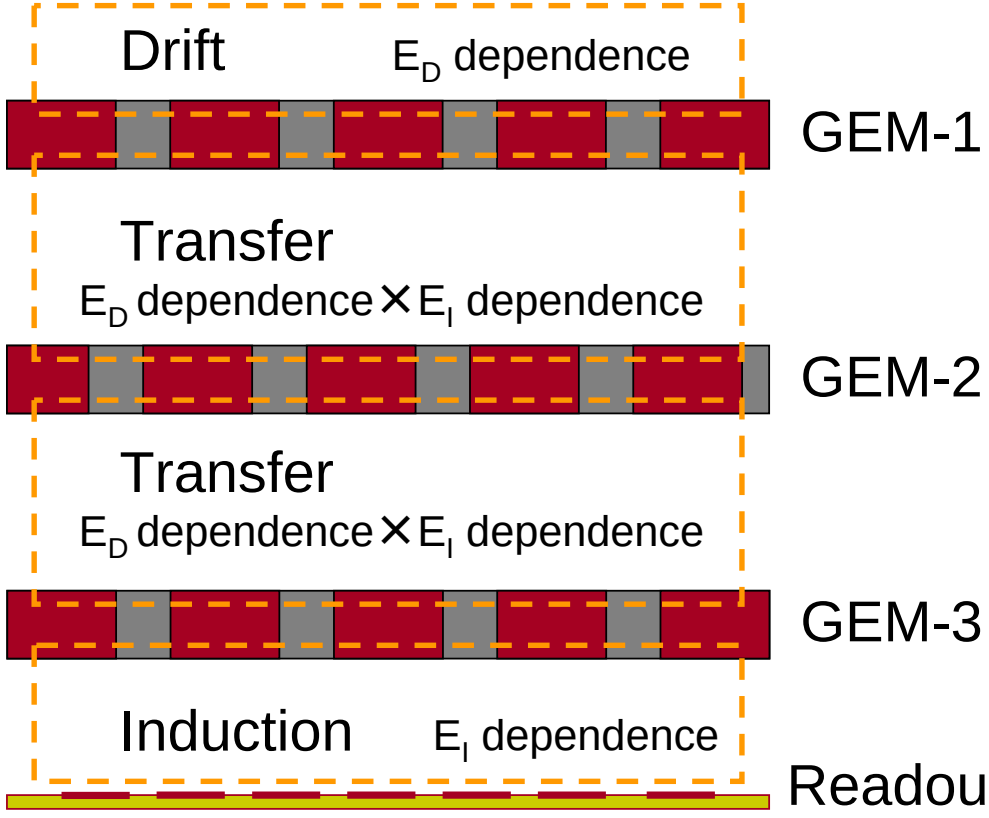


E_{T1}, E_{T2} dependence

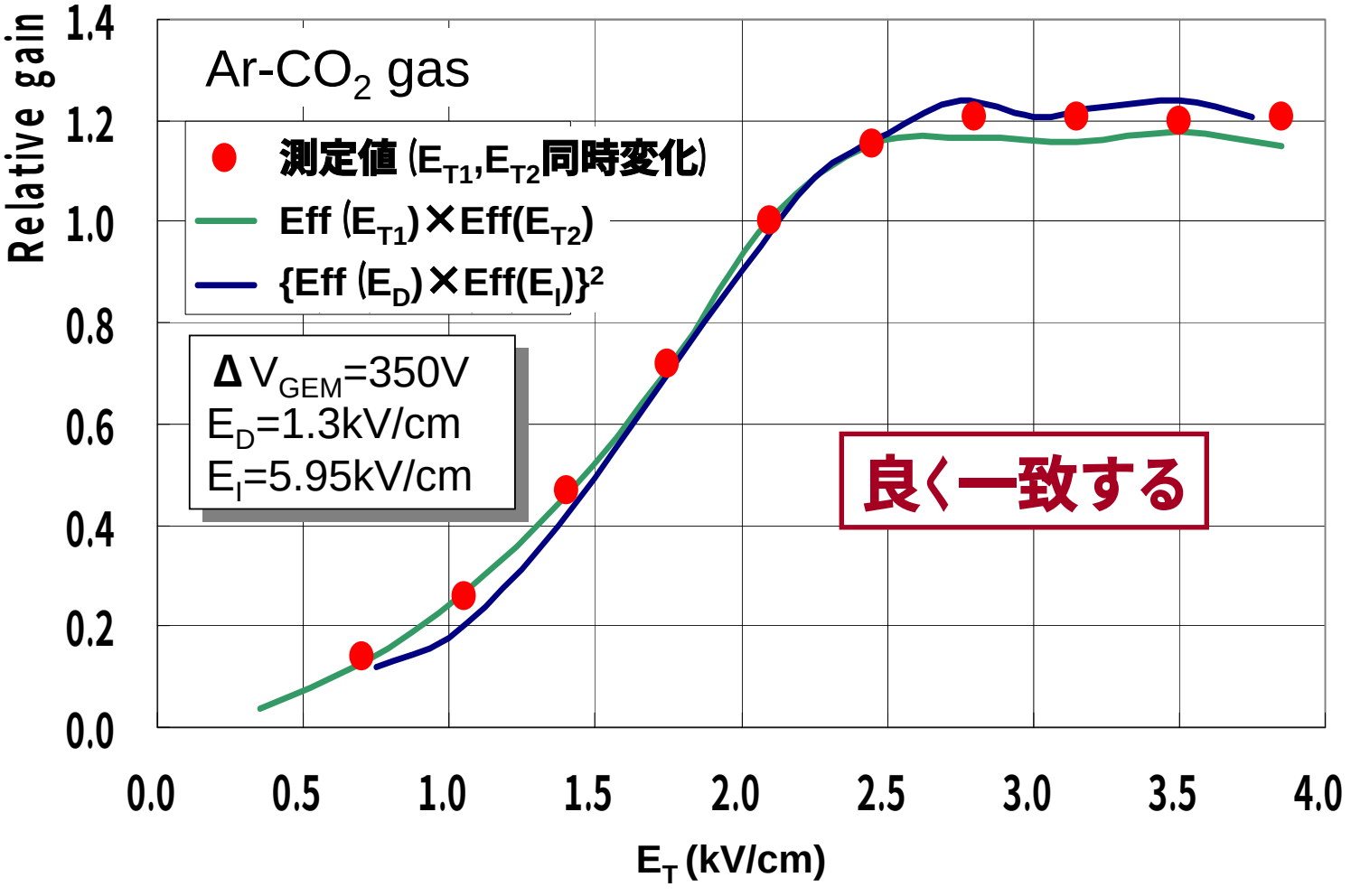


E_T dependence

Drift領域とInduction領域双方の特徴を持っているのではないか。



E_T dependence

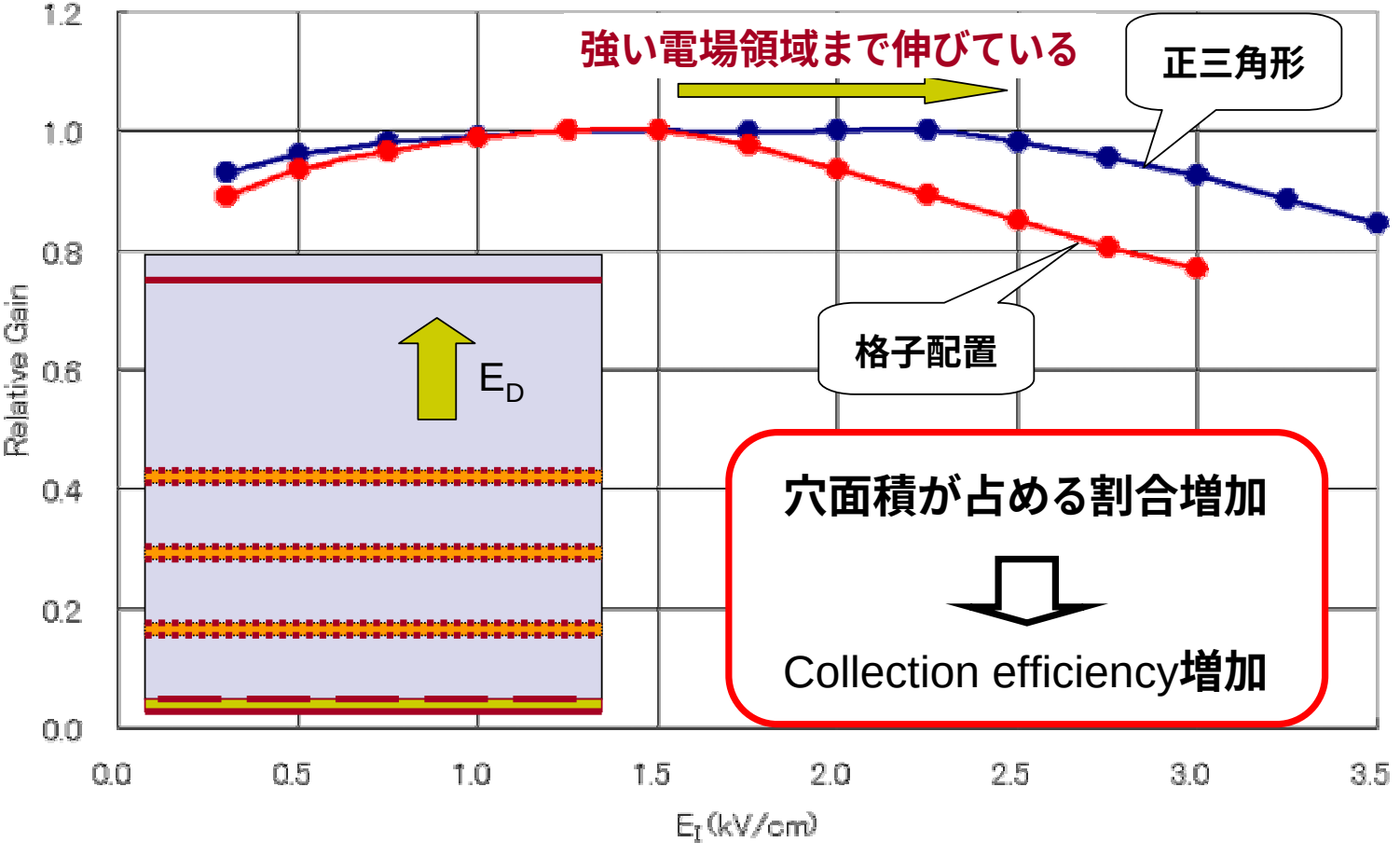


格子配列GEM

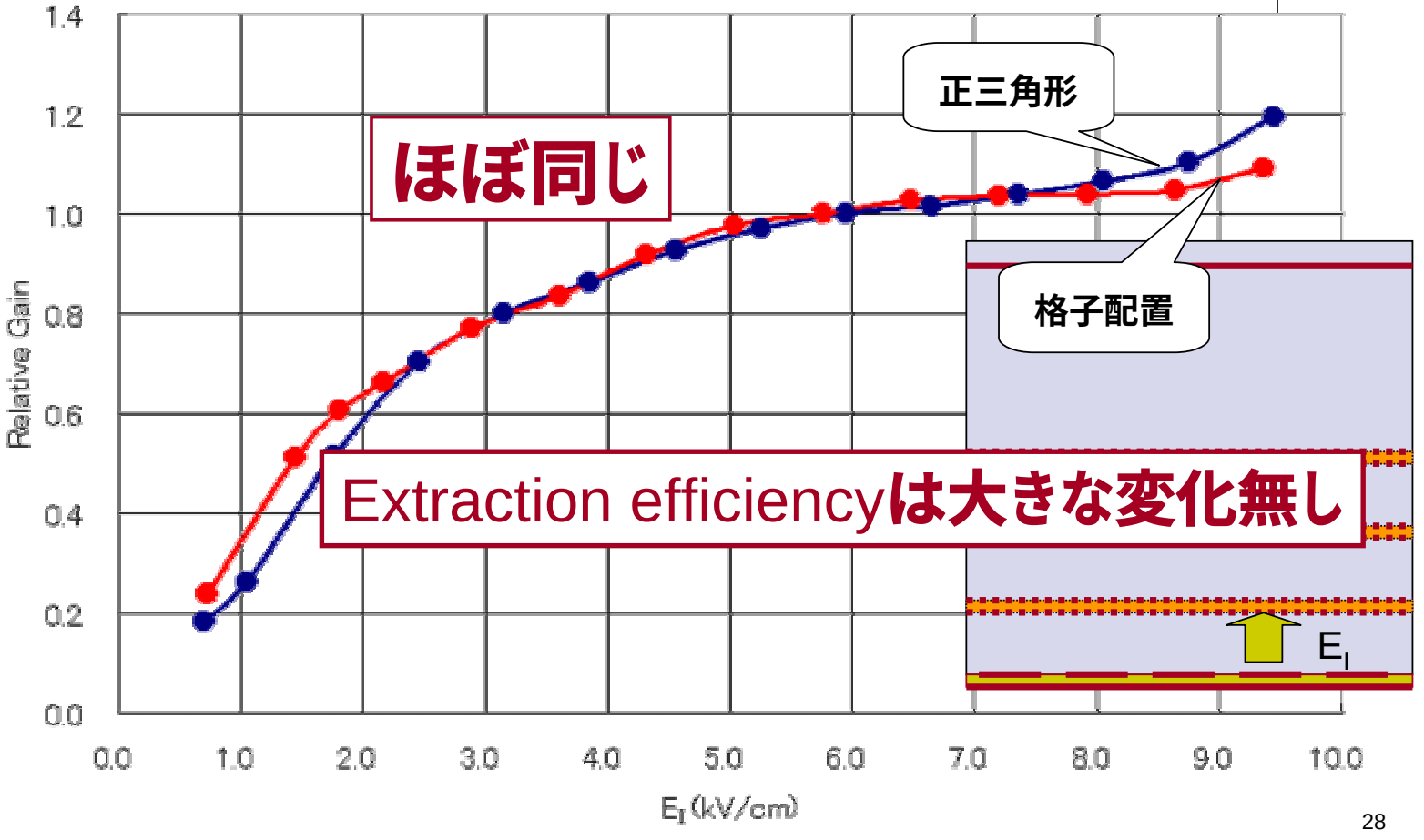
穴の占める面積が約13%減る

どの様な影響があるのか？

E_D dependence



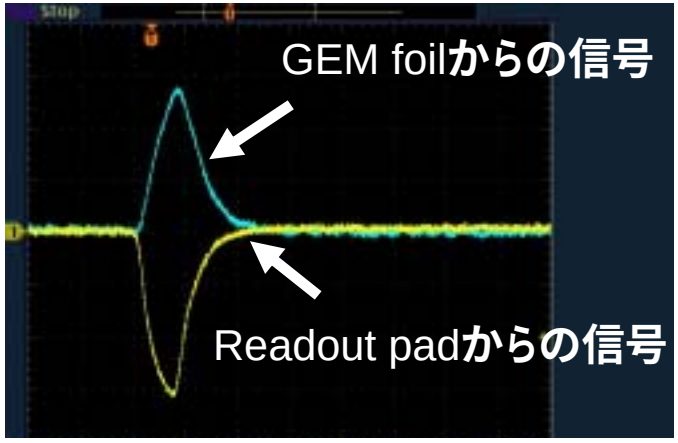
E_I dependence (Ar-CO_2)



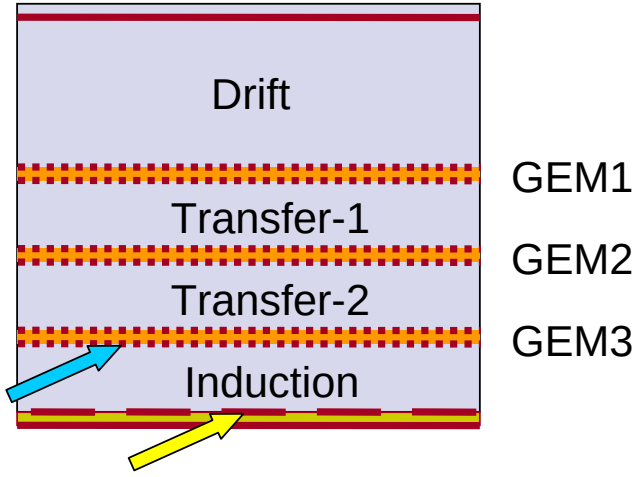
ここまでのまとめ
GEMのゲイン特性

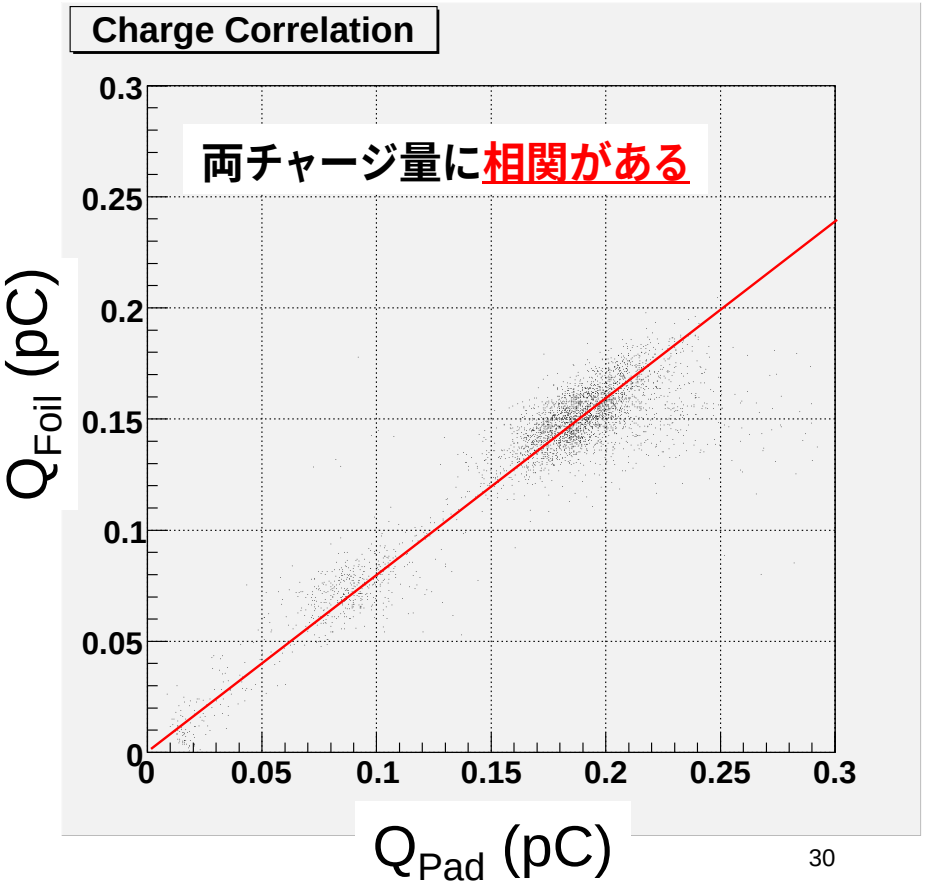
- GEM**両面電極間の電圧に**
  - **増幅率が敏感に変化する**
  - **増幅度レンジが**10^2**〜**10^5
- Drift**領域の電場が上昇すると**
  - Collection efficiency**が減少**
- Induction**領域の電場が上昇すると**
  - Extraction efficiency**が増加**
- Gain**は**ΔV_{GEM}**+各領域の電場強度でほぼ決まる**

パッドからの信号とフォイルからの信号



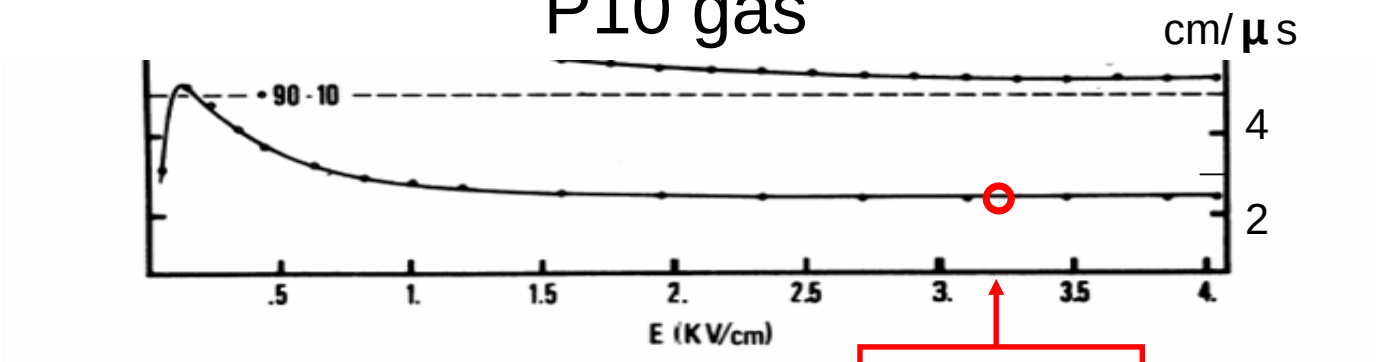
電荷量の相関はどうなっているのか



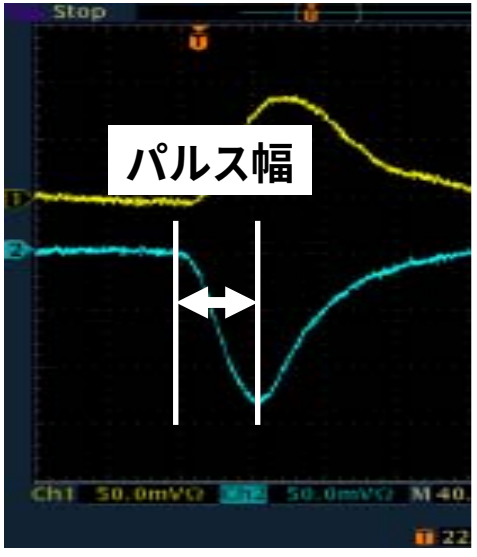


ドリフト時間と信号パルス幅

P10 gas



E_I=3.2kV/cm



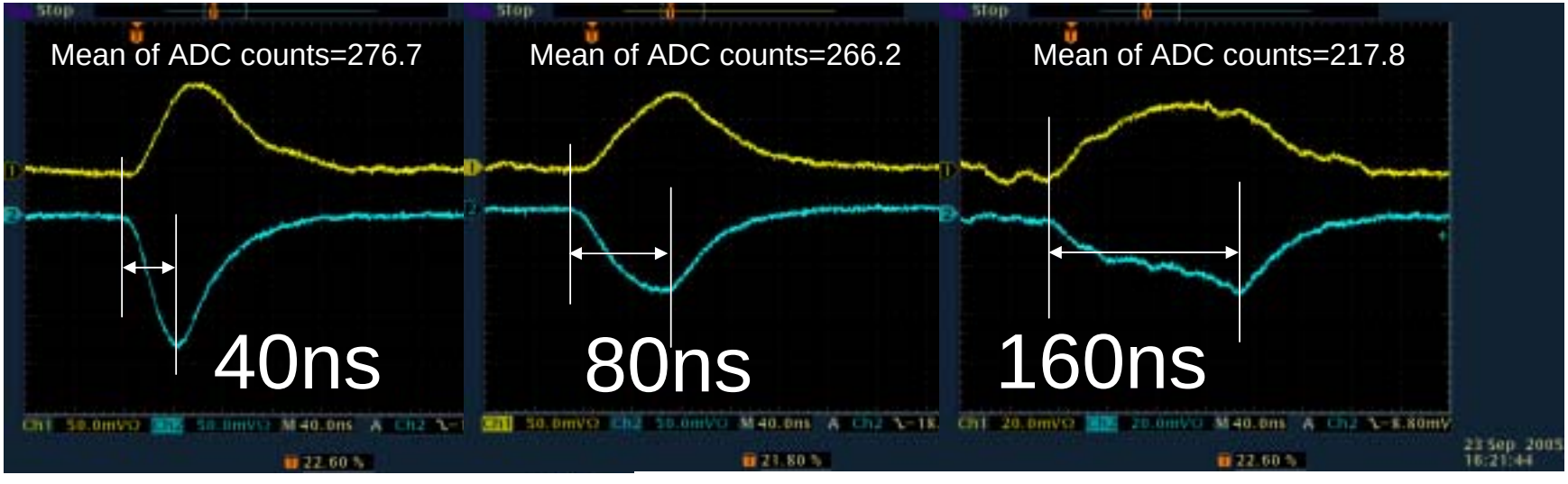
Drift velocity　2.5cm/μs (at 3.2kV/cm)

Induction gap = 1mmでPulse width = 40ns

1mmで40ns
2mmで80ns
4mmで160ns

Induction gap長と信号

1mm　　2mm　　4mm

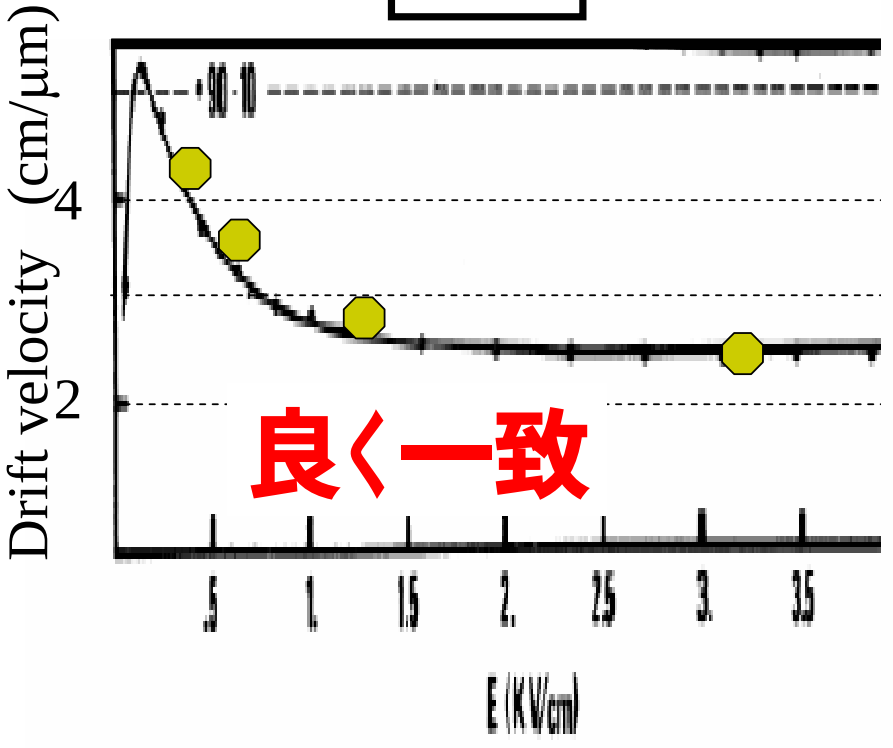


Drift velocity　　2.5cm/μs (at 3.2kV/cm)

計算値と良く一致する

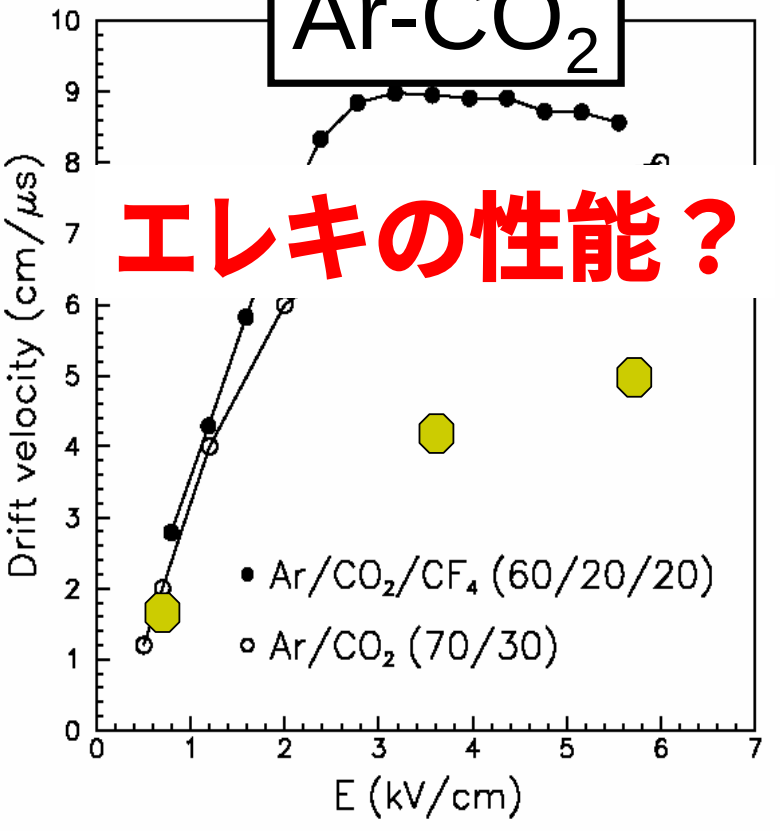
E_Iを変化させて測定

P10



良く一致

Ar-CO_2

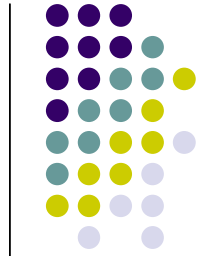


エレキの性能？

● 測定値

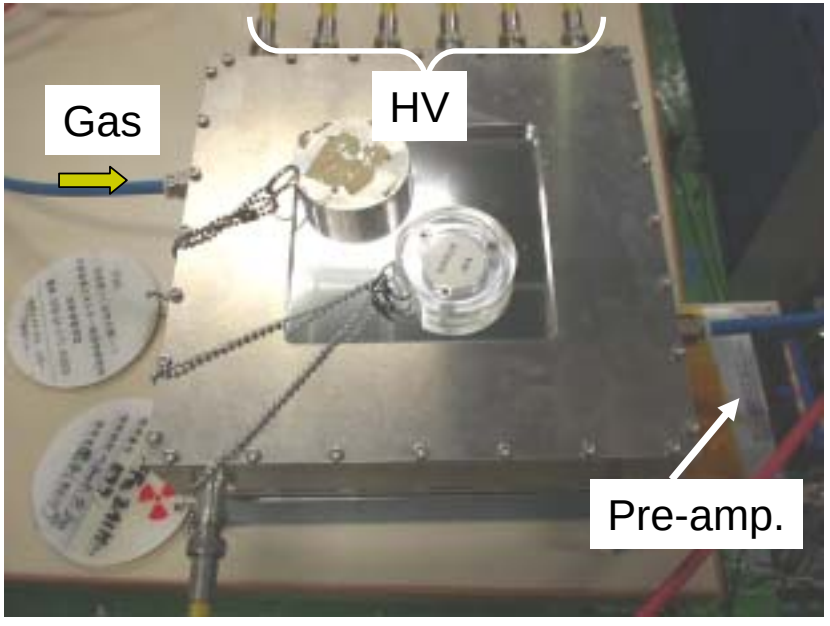
まとめ

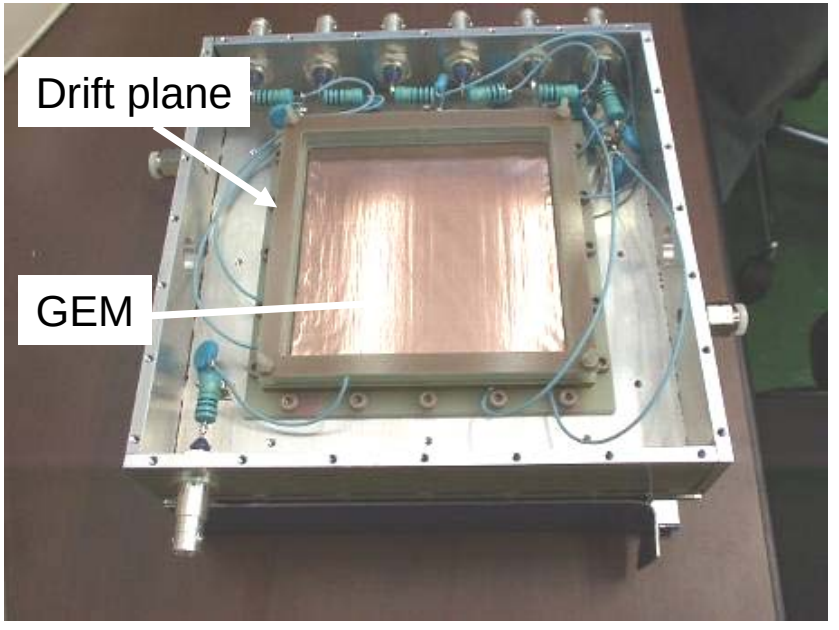
- GEMの基本特性を測定した。
- GEM foilからの信号読み出した。
- GEM foilと読み出しパッドからの信号は電荷相関があった
- ドリフト時間と信号パルス幅に関係があることを確認した。



ここから付録

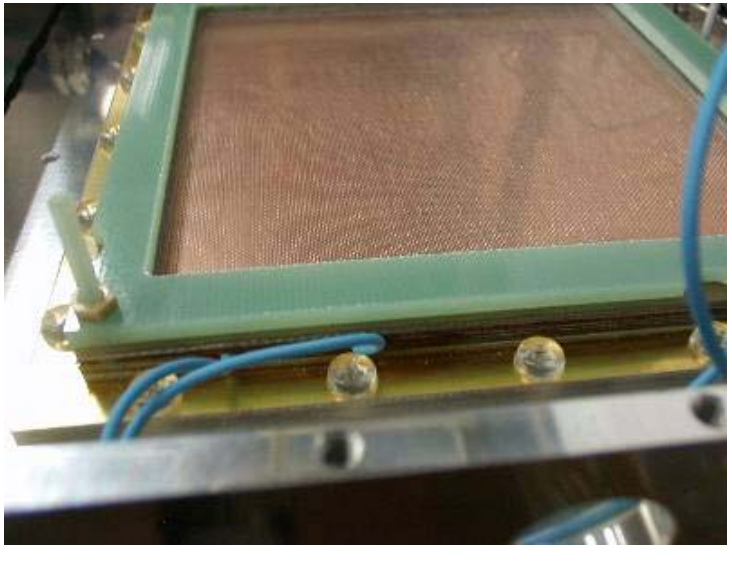
Test chamber

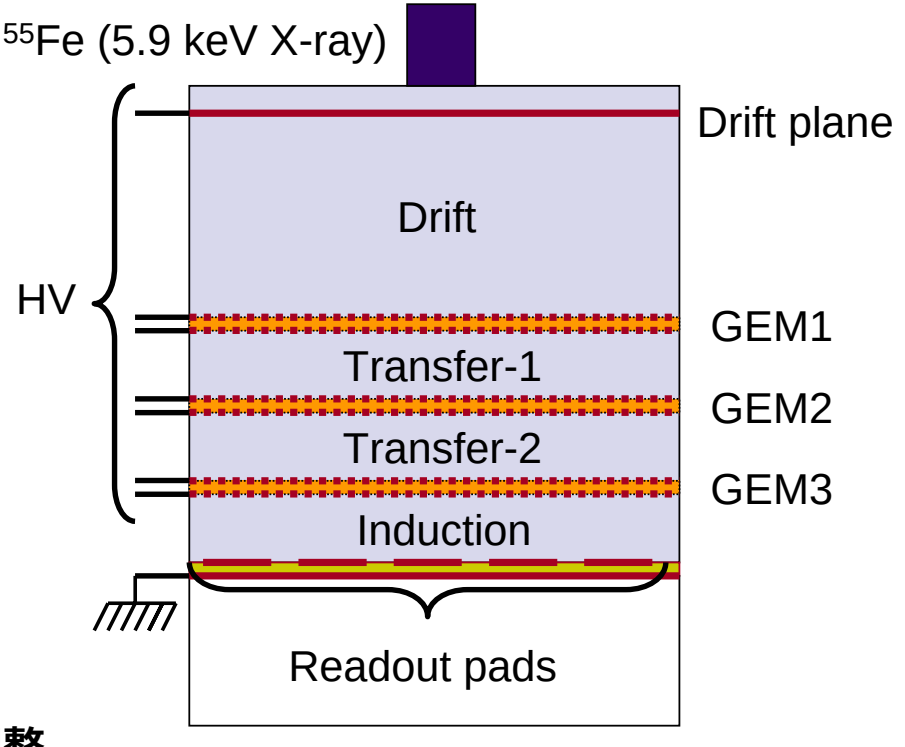




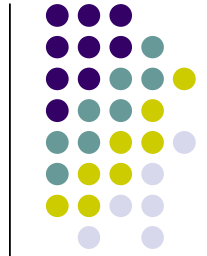
Test chamber

Triple GEM detector



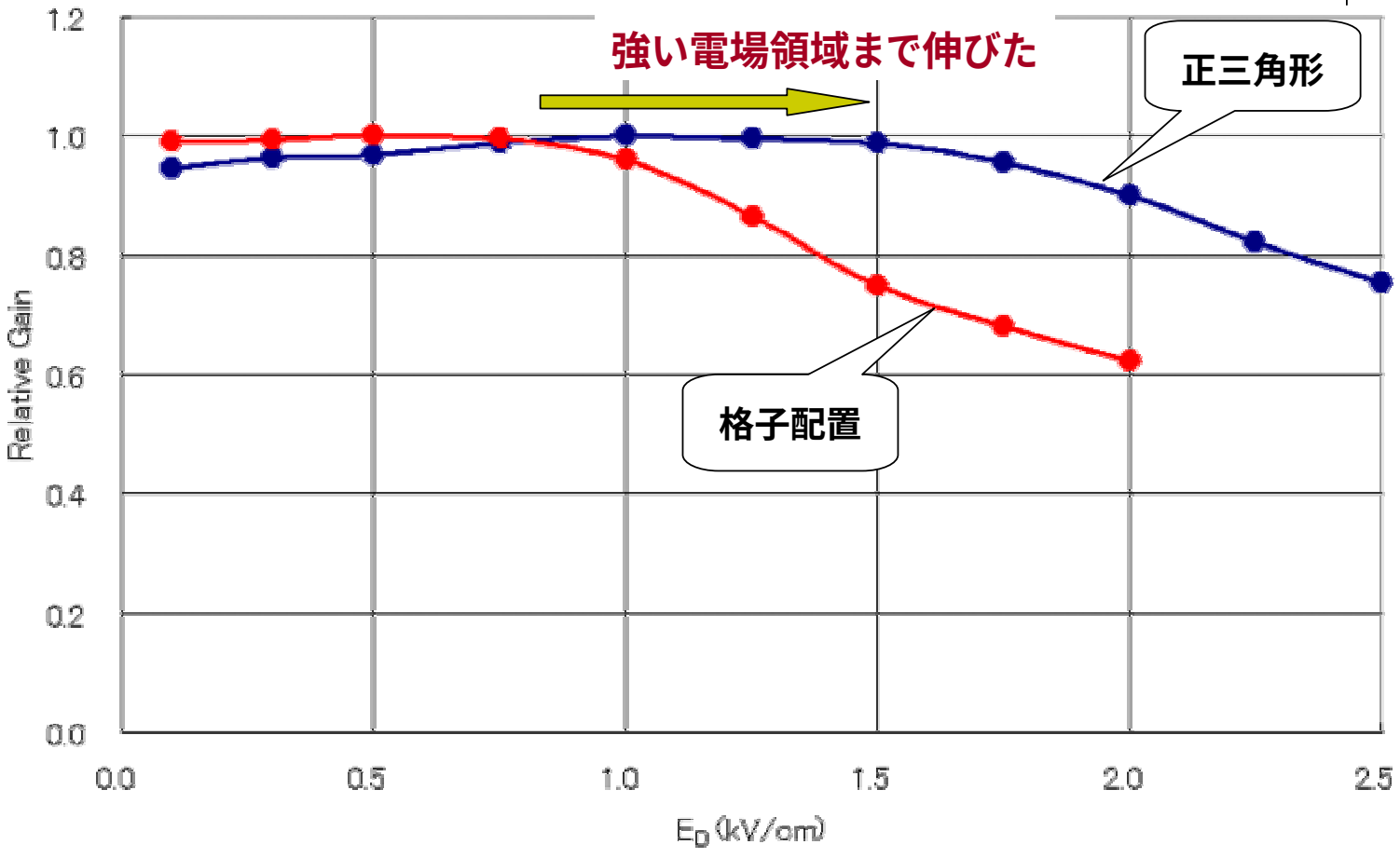


スペーサー(G10フレーム)により間隔を調整

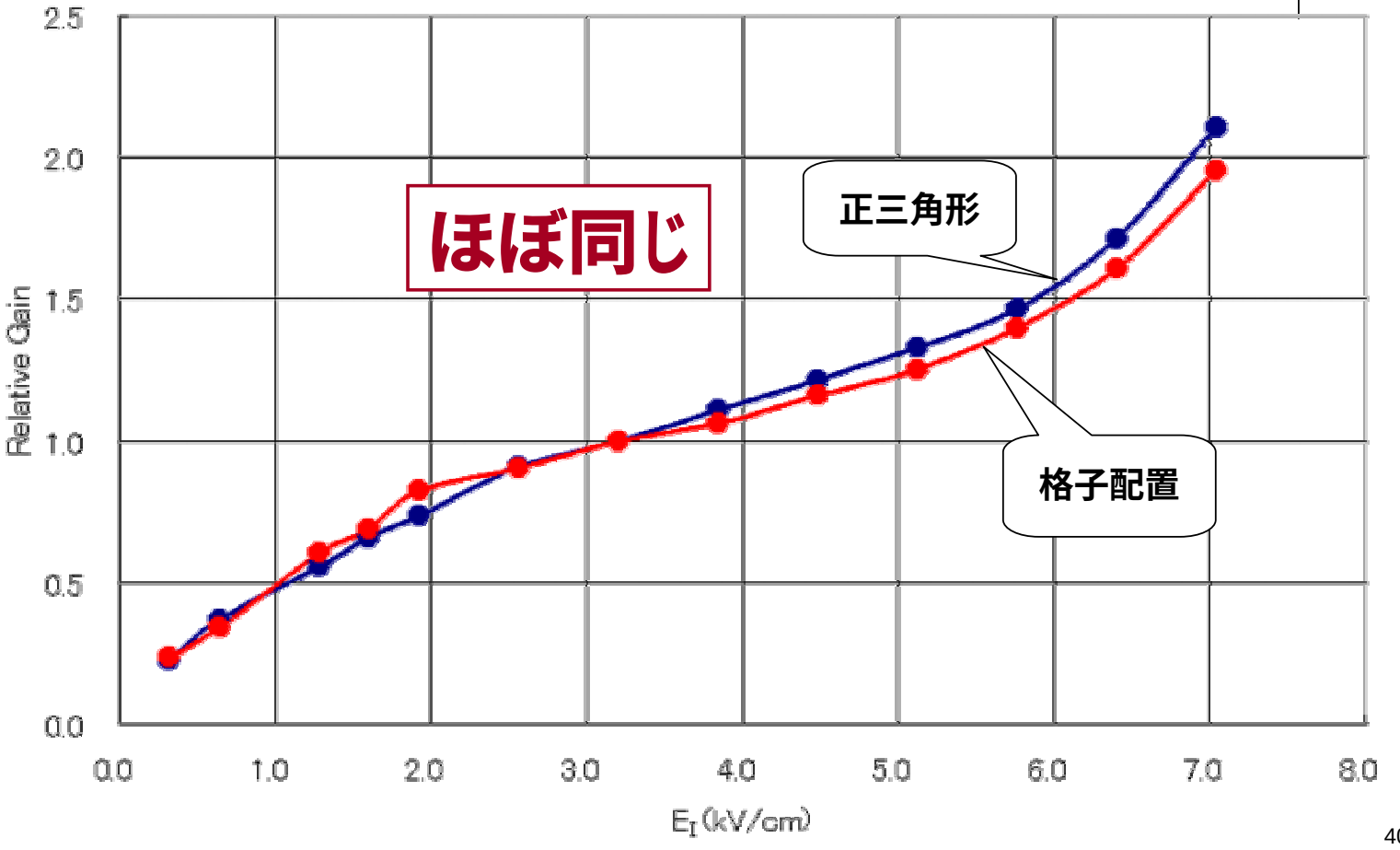


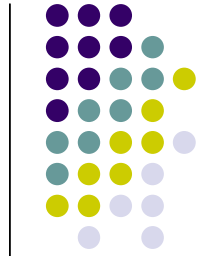
格子配置、正三角形配置

E_D dependence (P10)



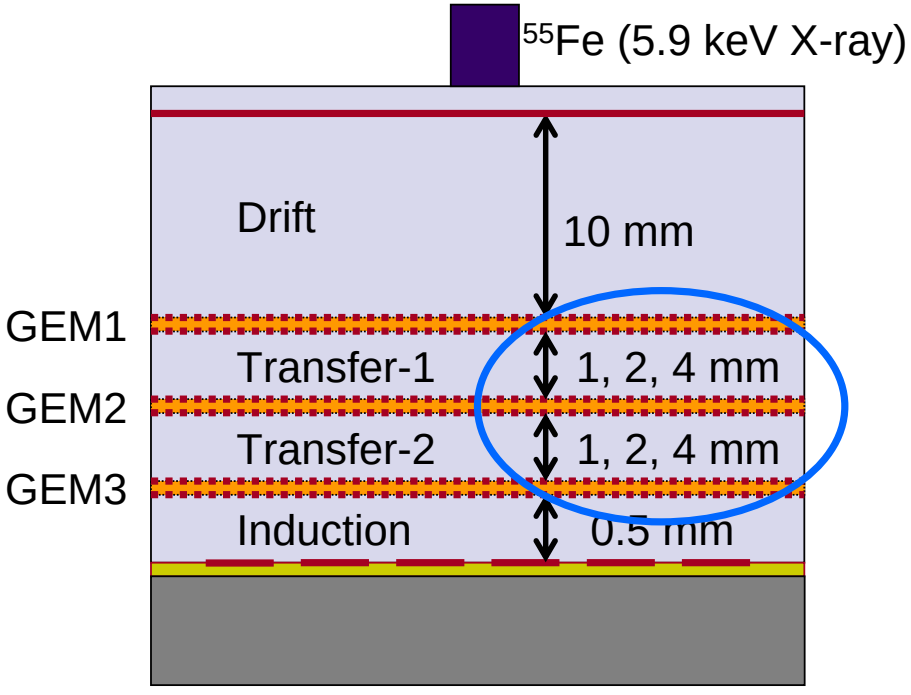
E_I dependence (P10)



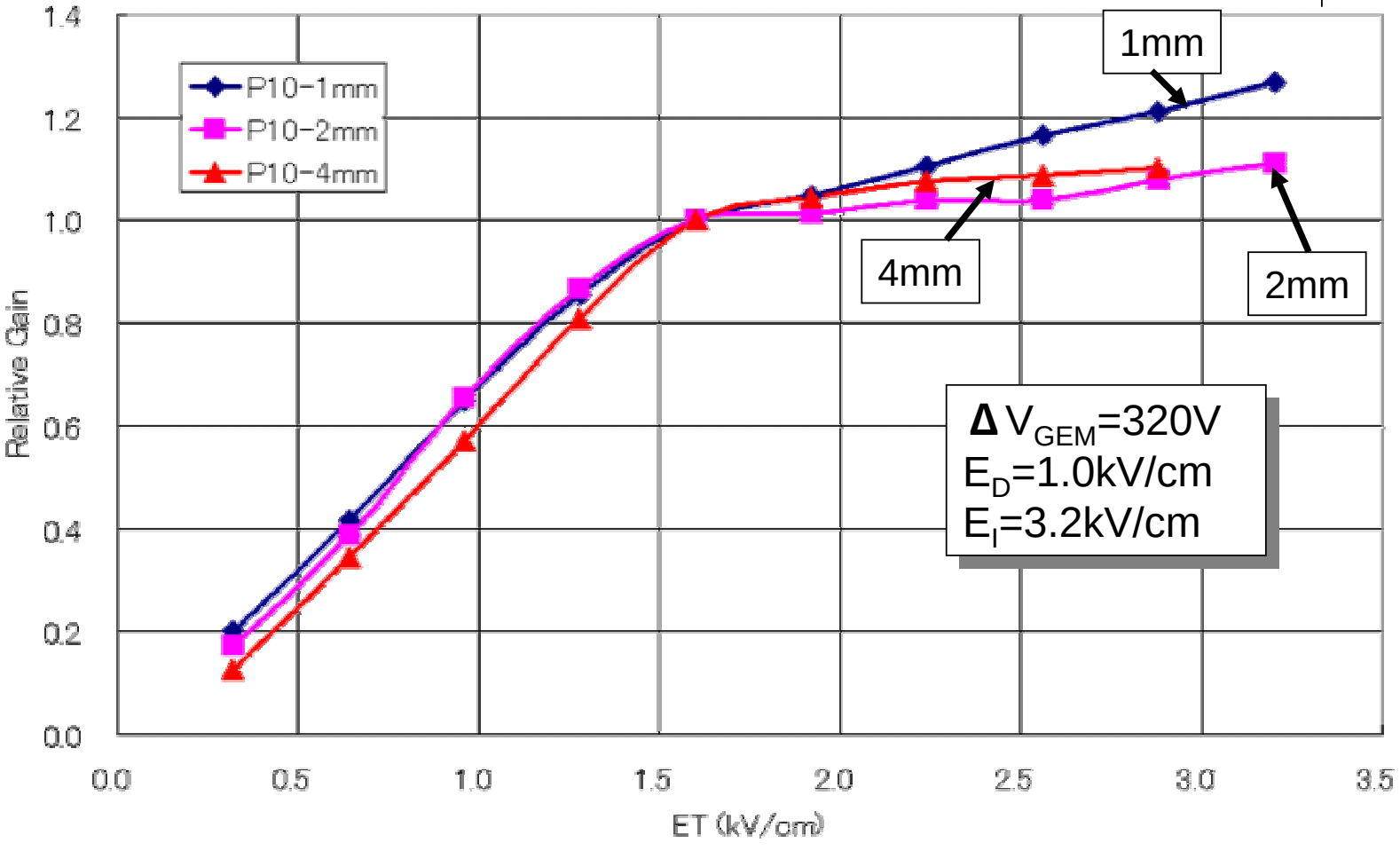


Transfer gap = 1, 2, 4 mm

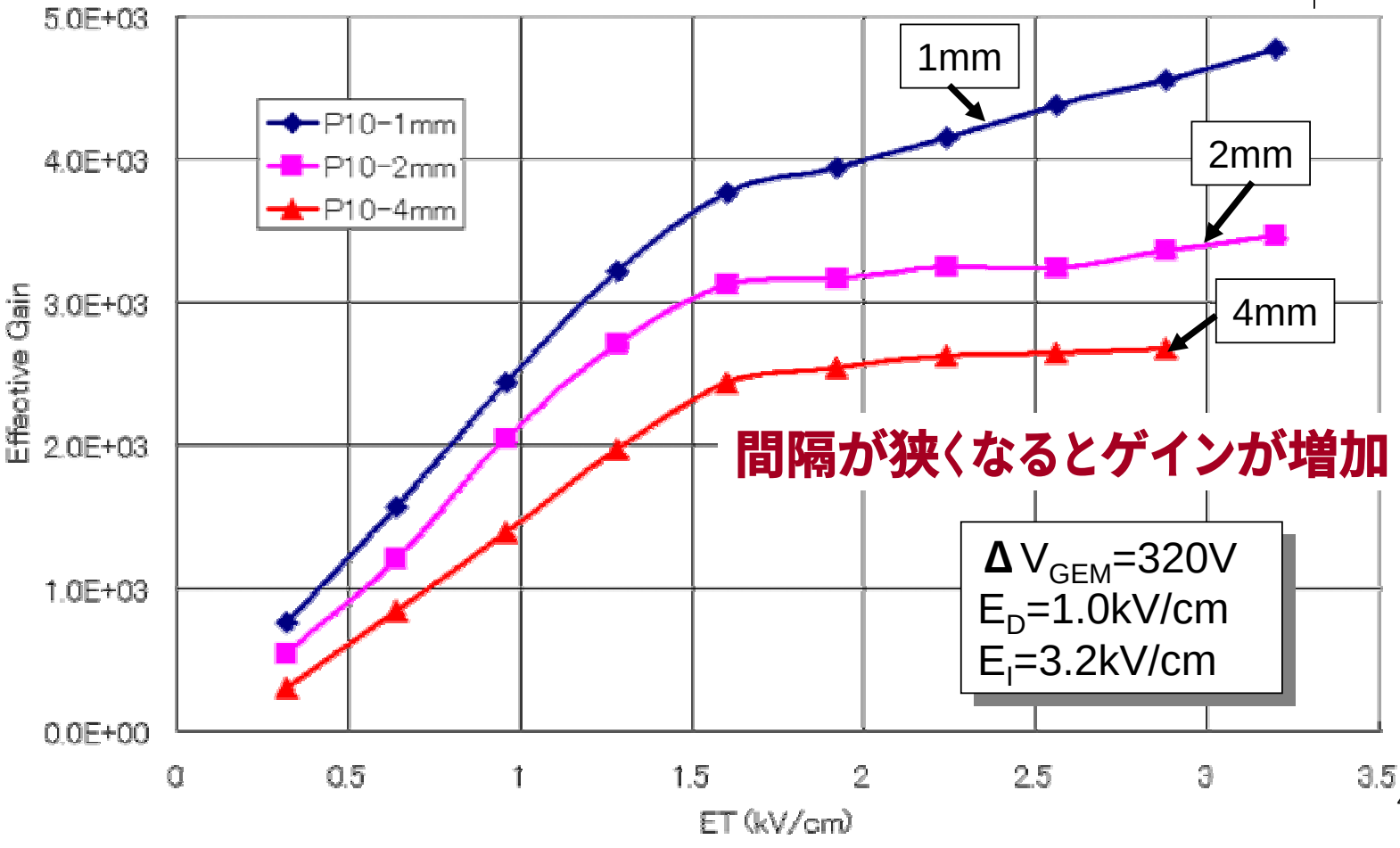
E_T dependence



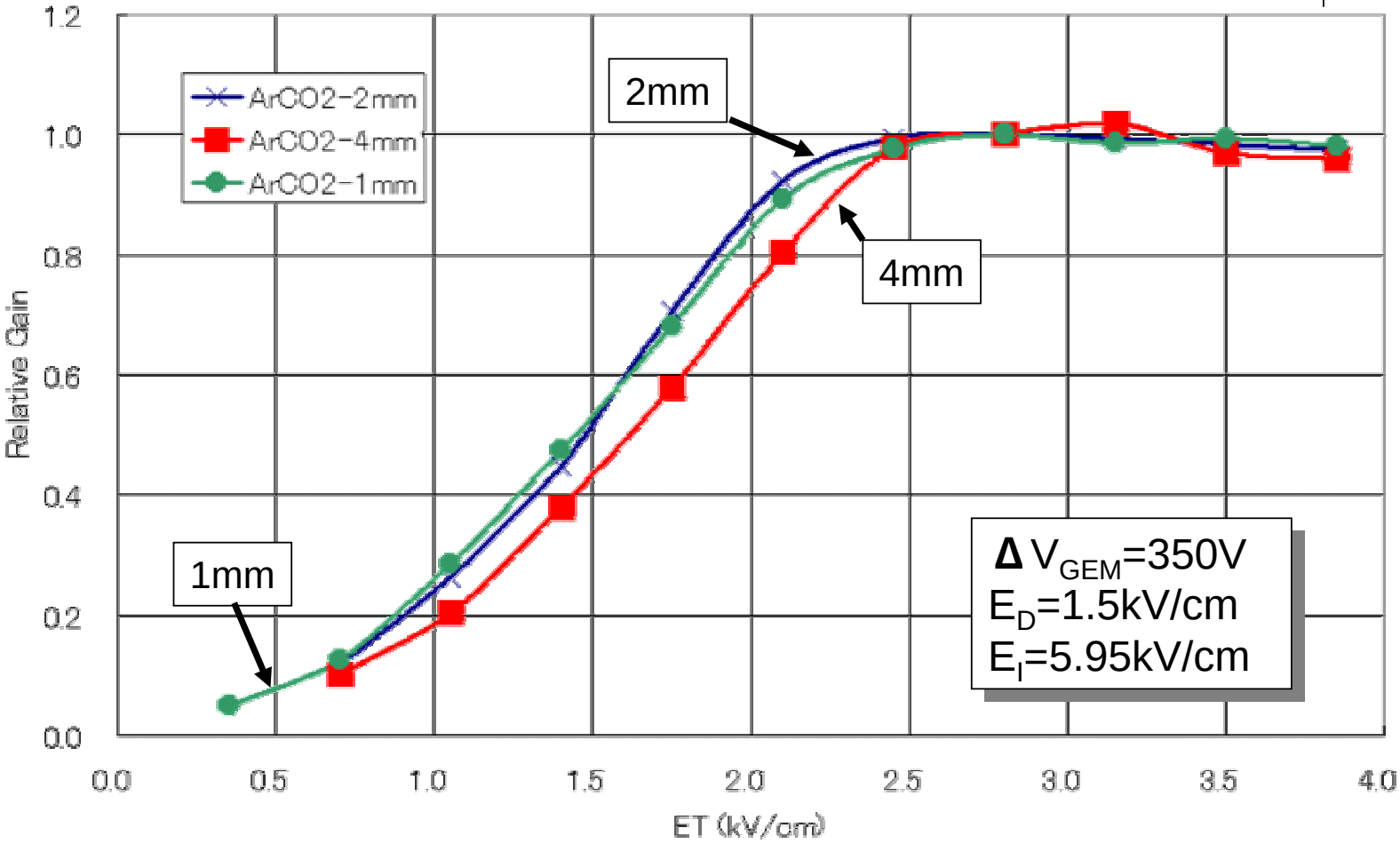
E_T dependence
P10 gas, Relative Gain



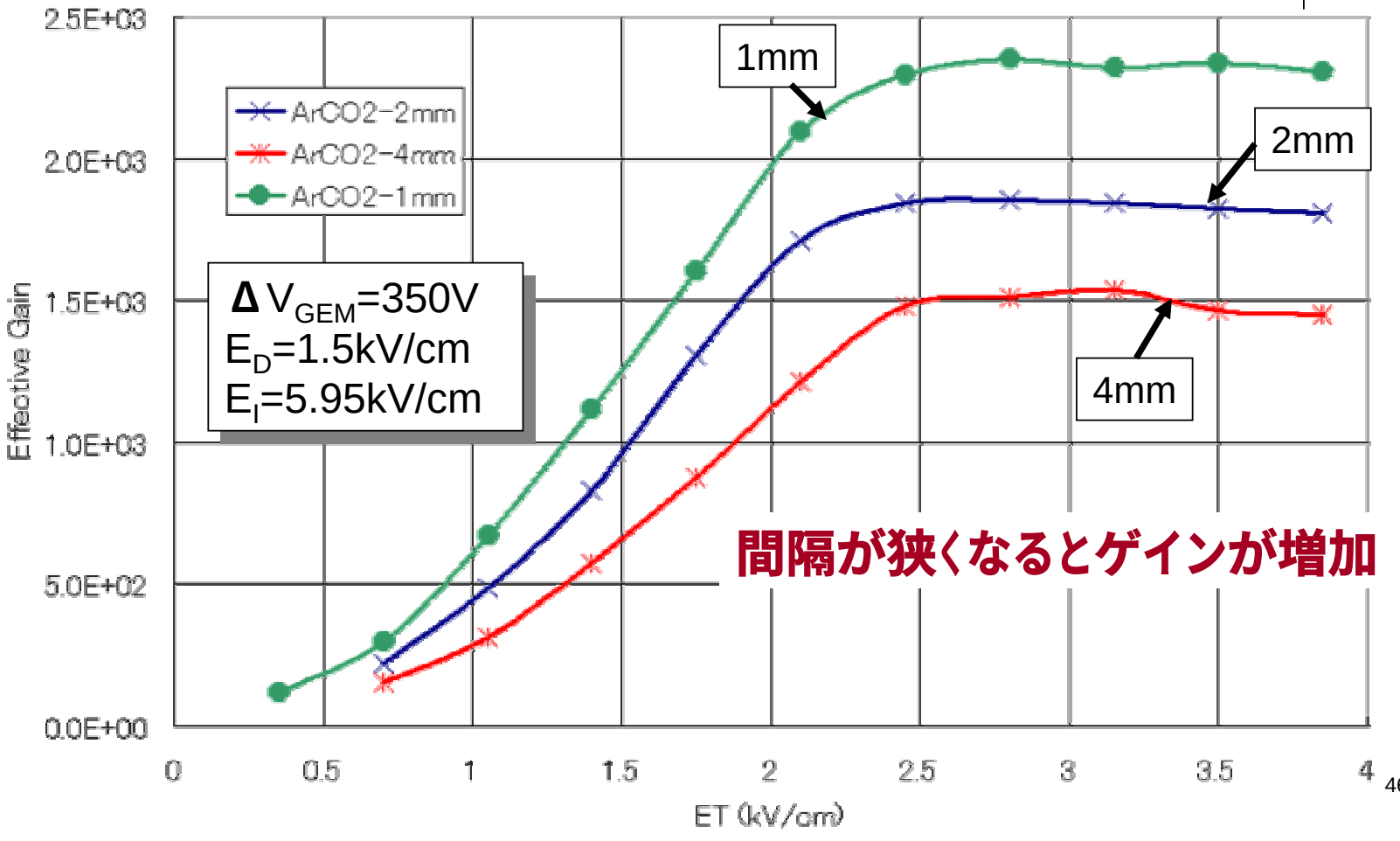
E_T dependence
P10 gas, Effective Gain



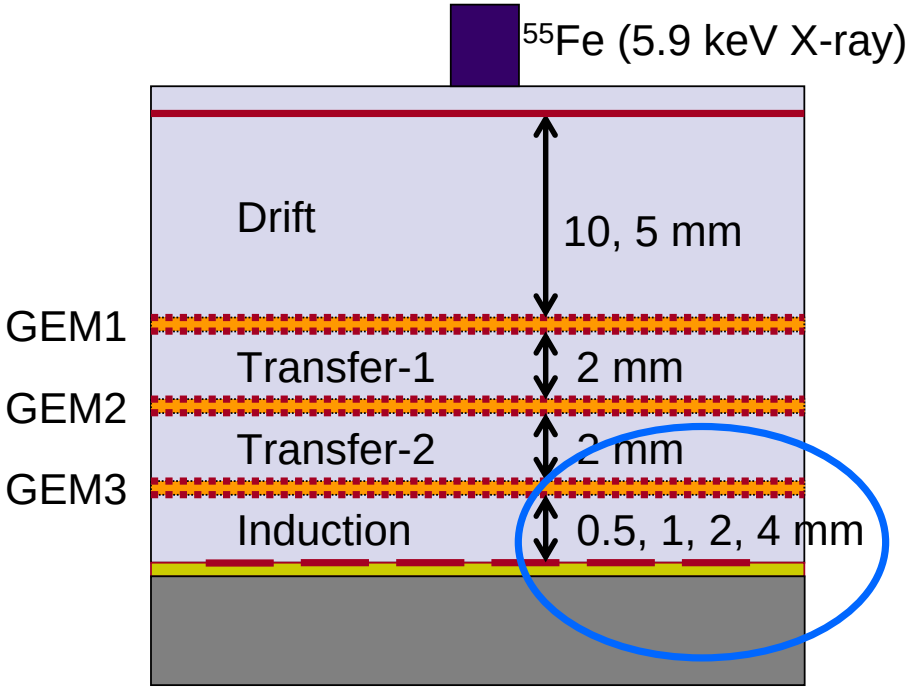
E_T dependence
Ar-CO_2 gas, Relative Gain



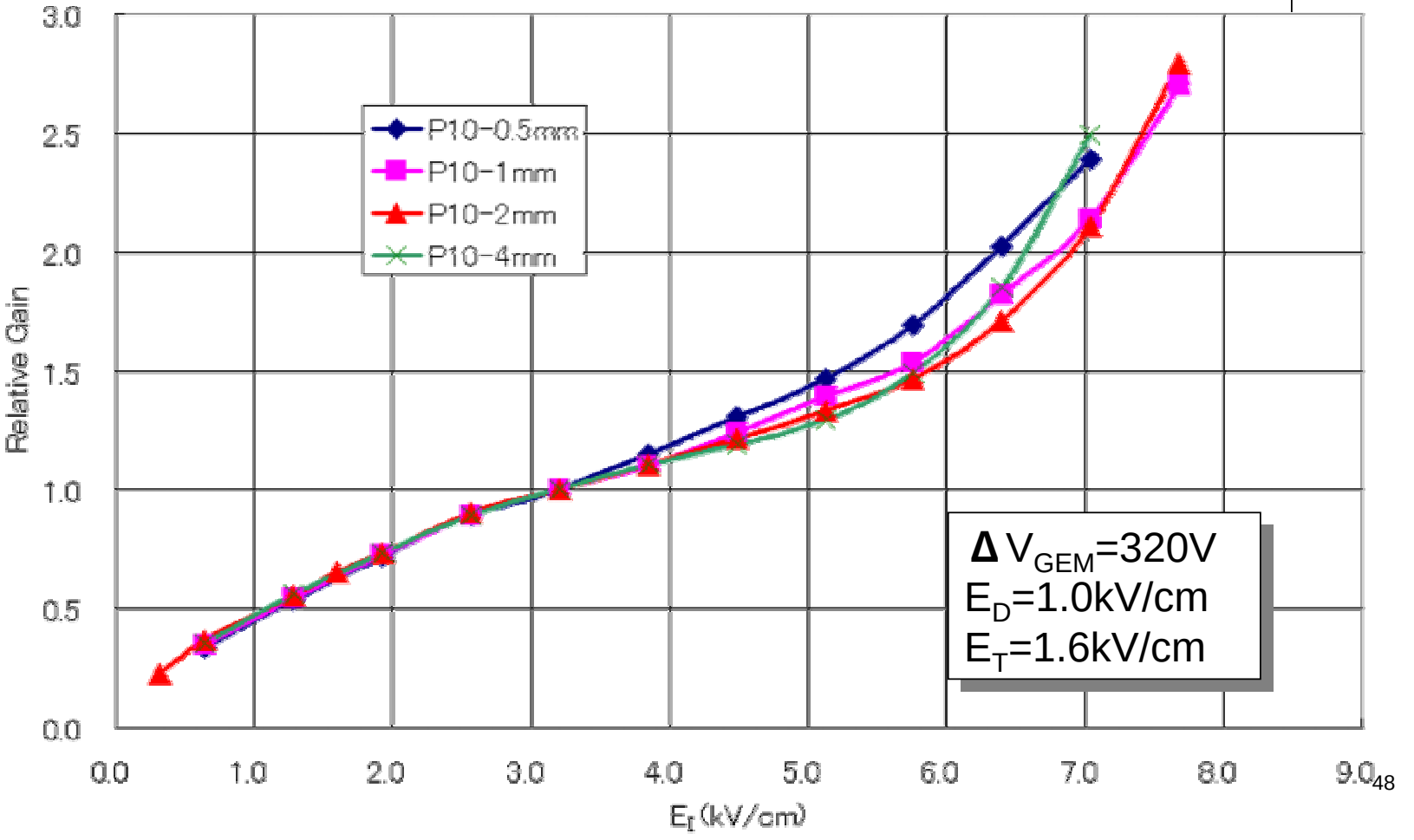
E_T dependence
Ar-CO_2 gas, Effective Gain



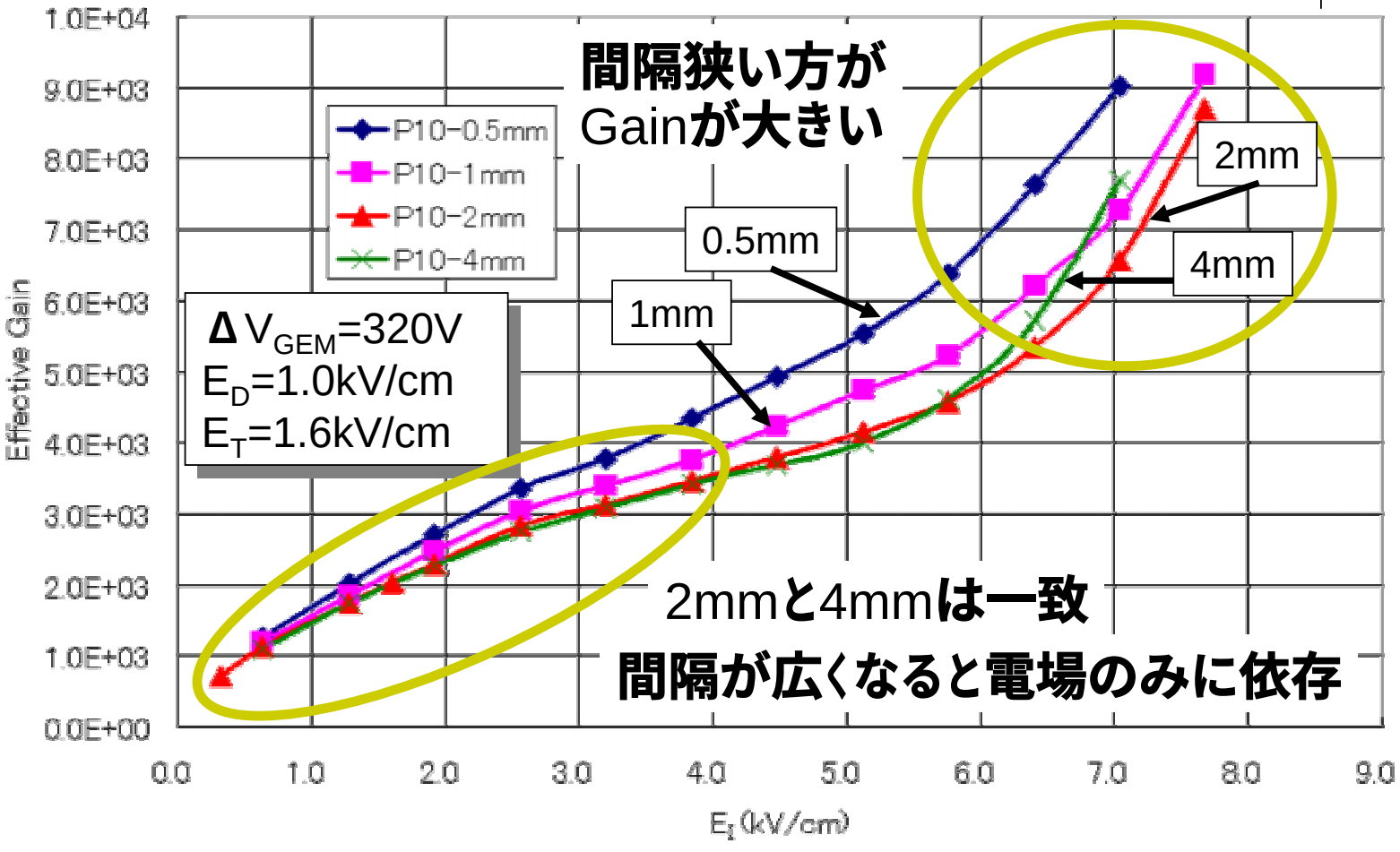
E_I dependence



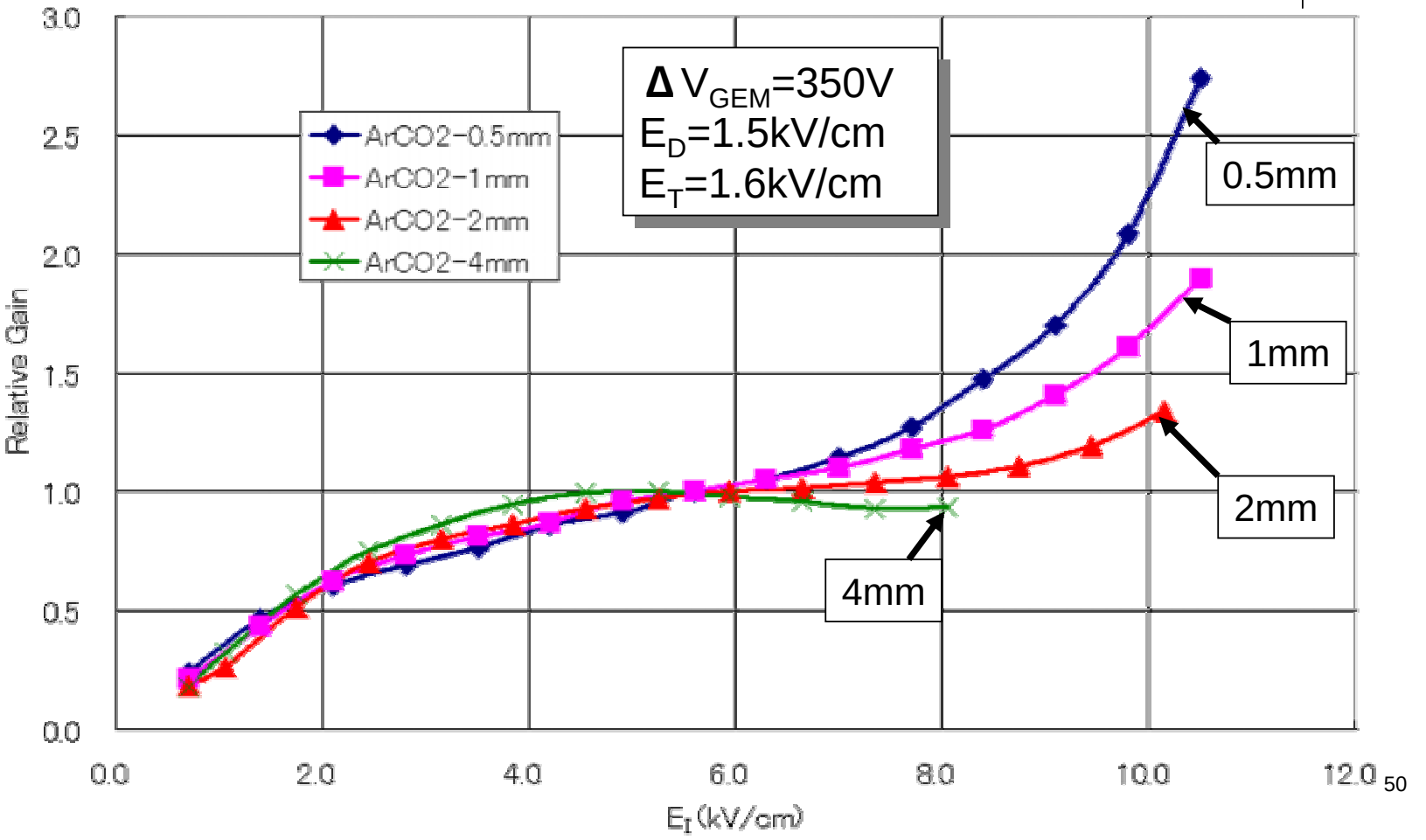
E_I dependence
P10 gas, Relative Gain



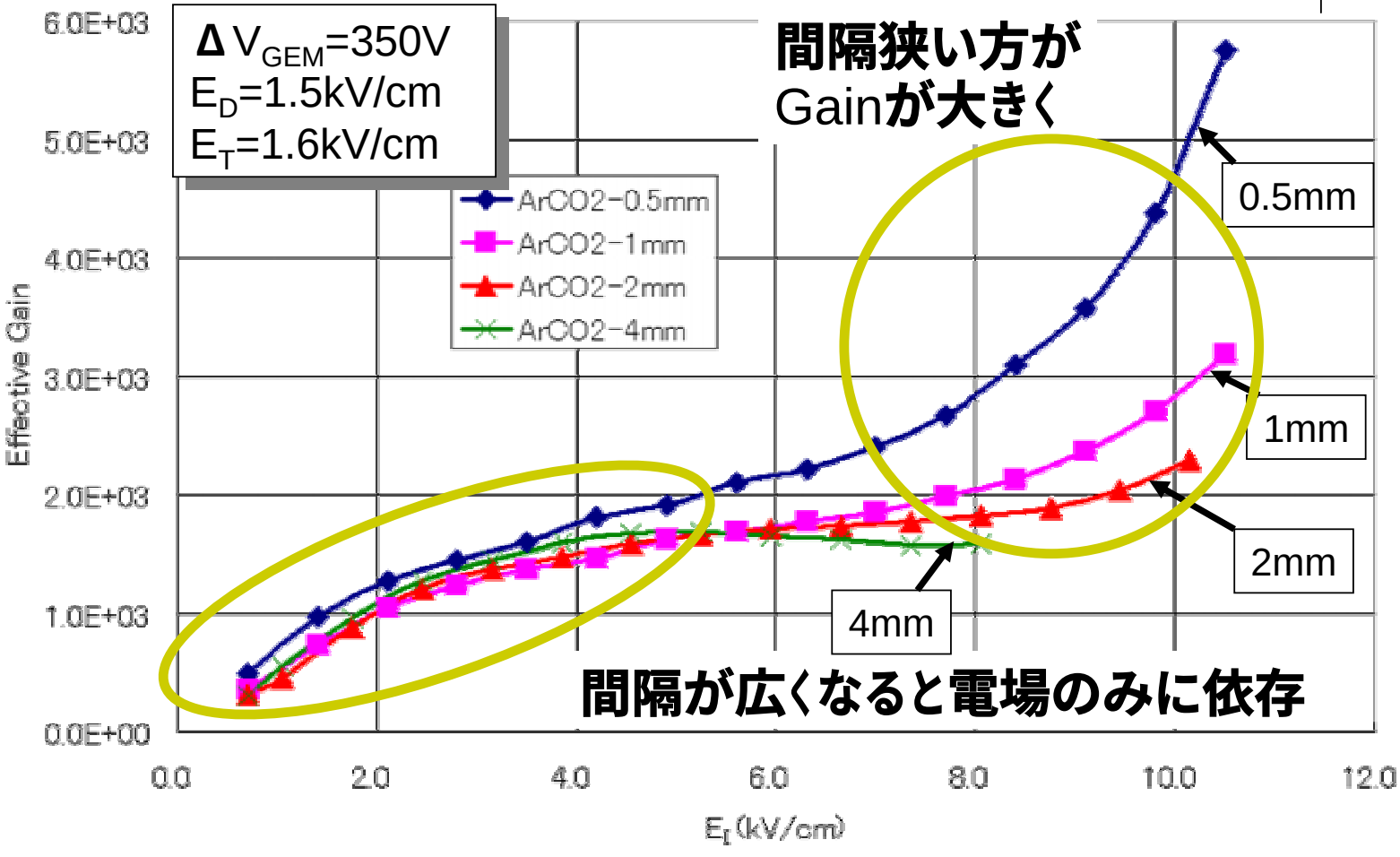
E_I dependence
P10 gas, Effective Gain



E_I dependence
Ar-CO_2 gas, Relative Gain

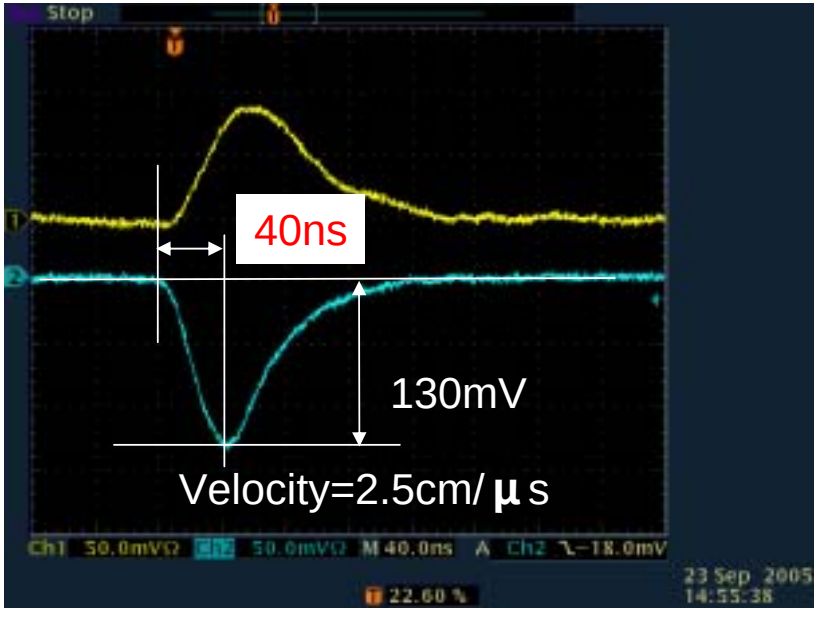


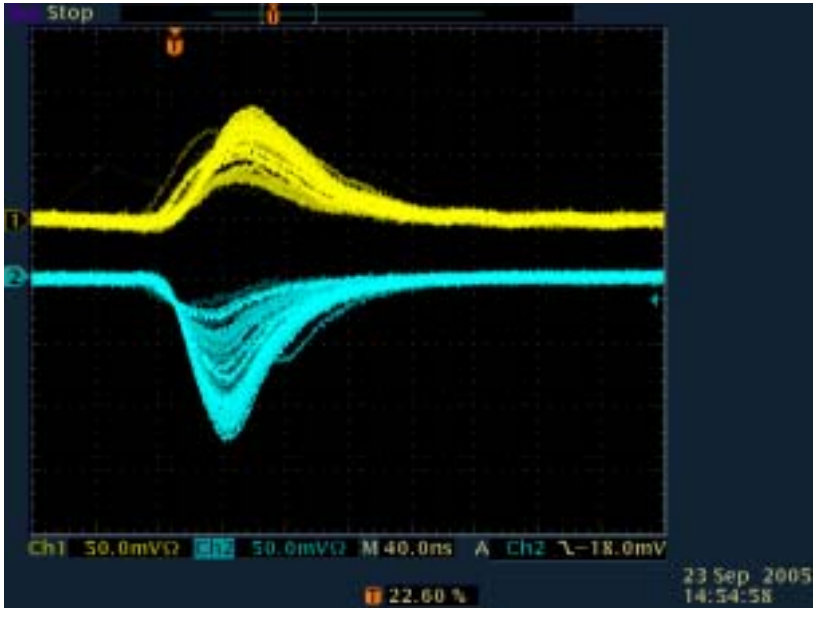
E_I dependence
Ar-CO_2 gas, Effective Gain



信号パルス幅と距離波形

Induction gapと信号



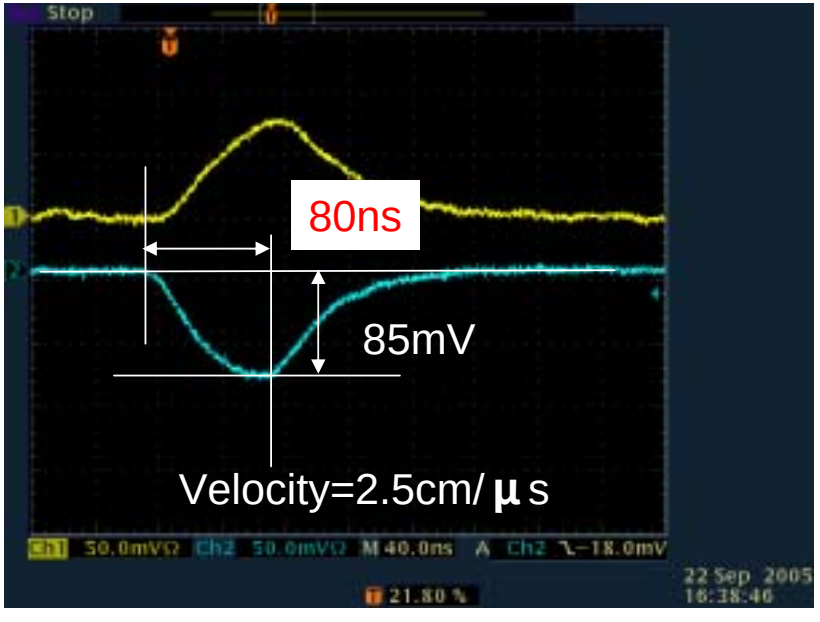


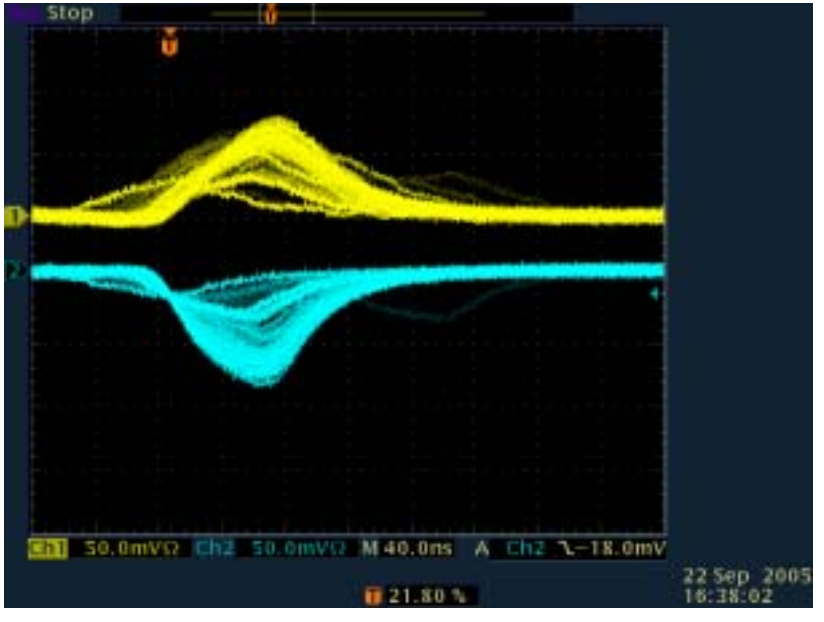
予想値＝40ns

Mean of ADC counts=276.7

E_I=3.2kV/cm
E_D=0.5kV/cm
ΔV_{GEM}=320V
E_T=1.6kV/cm

Induction gap = 2mm
E_I =3.2kV



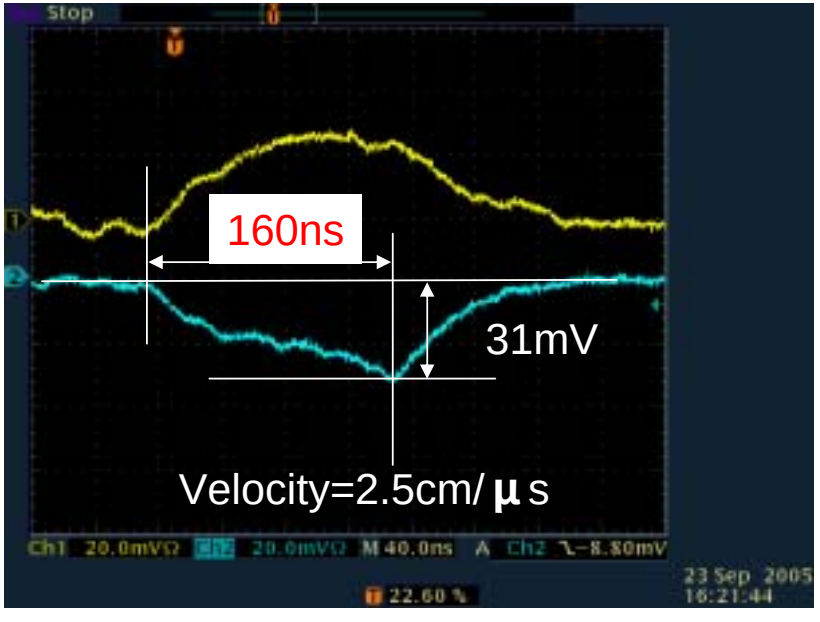


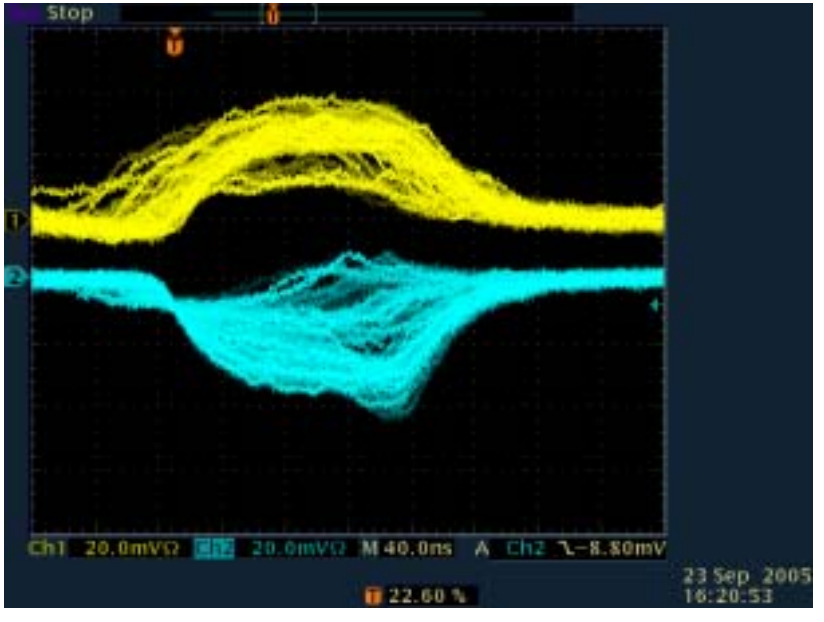
予想値＝80ns

Mean of ADC counts=266.2

E_I=3.2kV/cm
E_D=0.5kV/cm
ΔV_{GEM}=320V
E_T=1.6kV/cm

Induction gap = 4mm
E_I =3.2kV





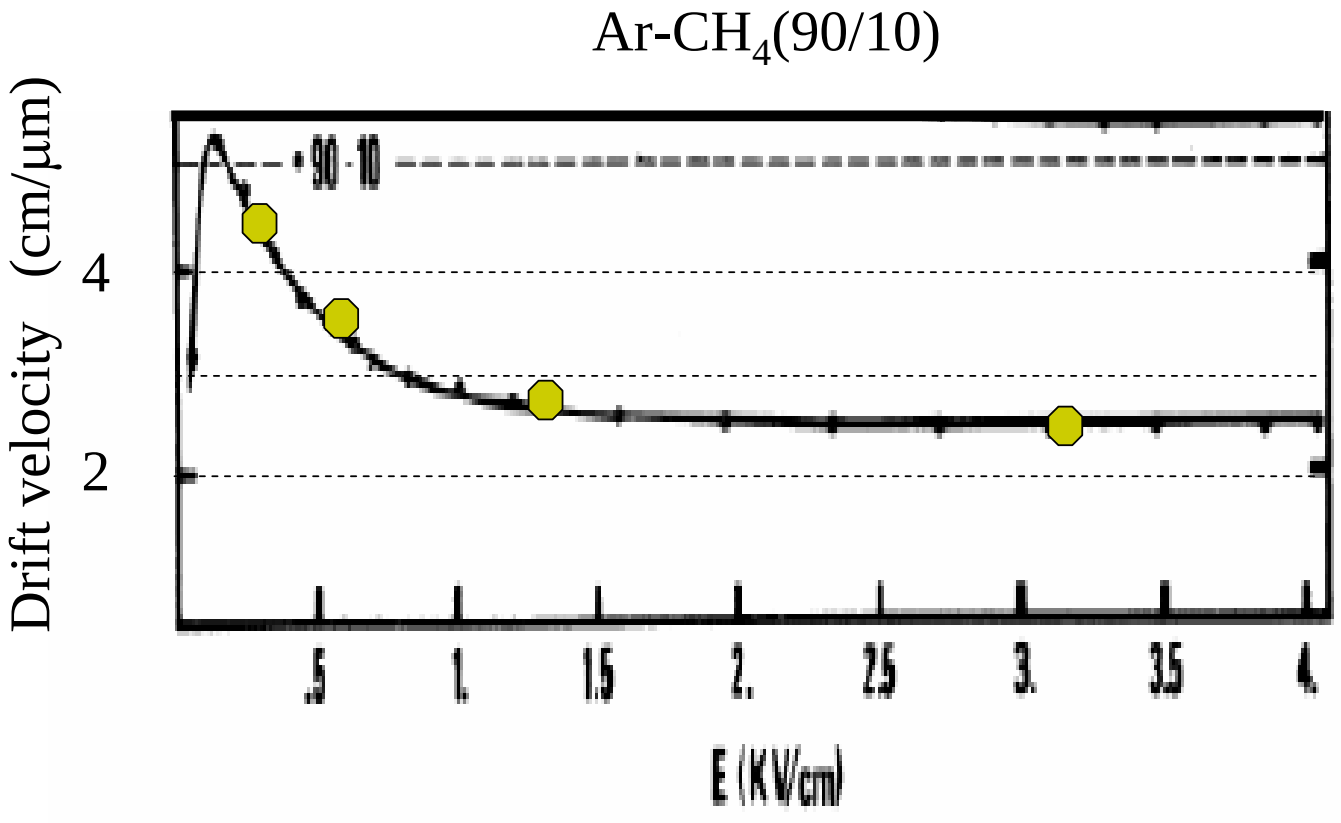
予想値＝160ns

Mean of ADC counts=217.8

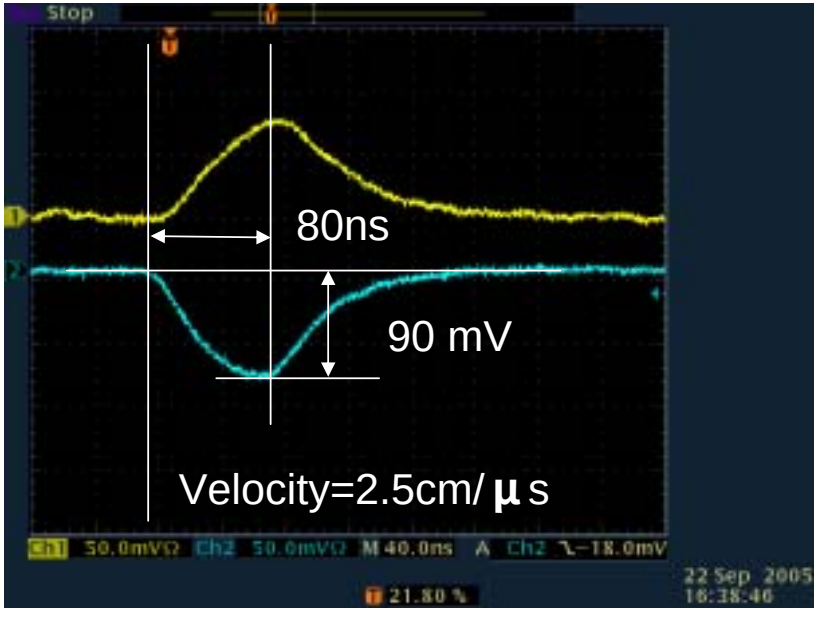
E_I=3.2kV/cm
E_D=0.5kV/cm
ΔV_{GEM}=320V
E_T=1.6kV/cm

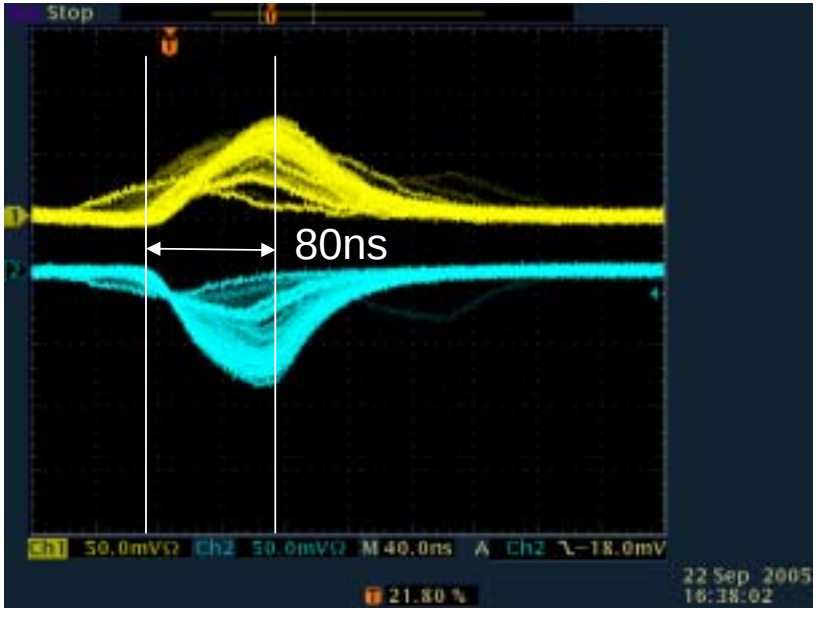
信号パルス幅と電場波形

E_lを変化させて測定 (P10 gas)



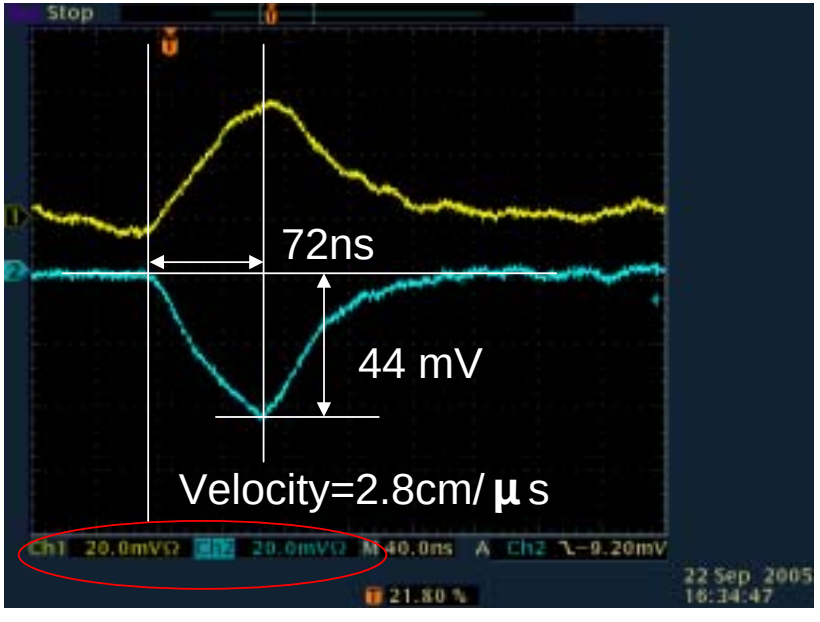
E_Iを変化させて波形測定:P10 gas
E_I =3.2kV, D_I=2mm

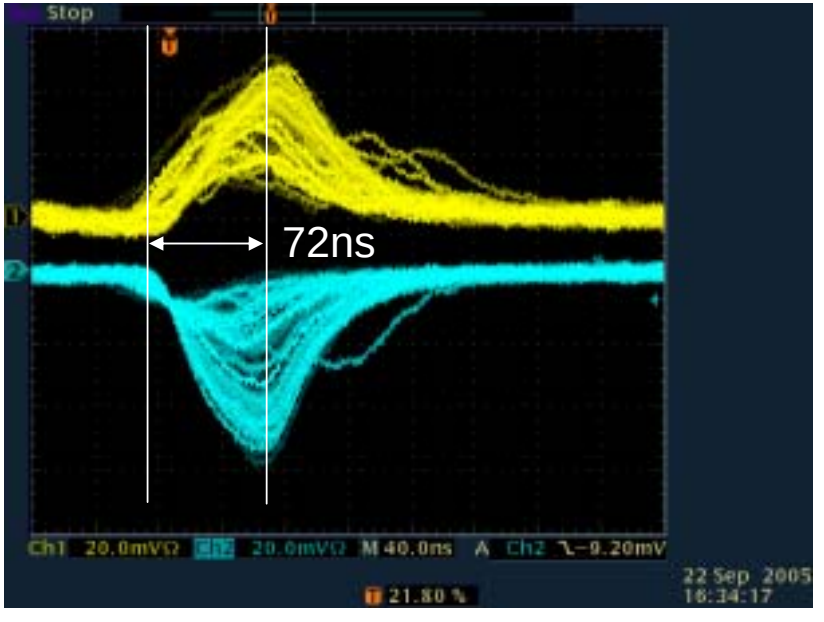




P10
ΔV_{GEM}=320V
E_D=0.5kV/cm
E_T=1.6kV/cm

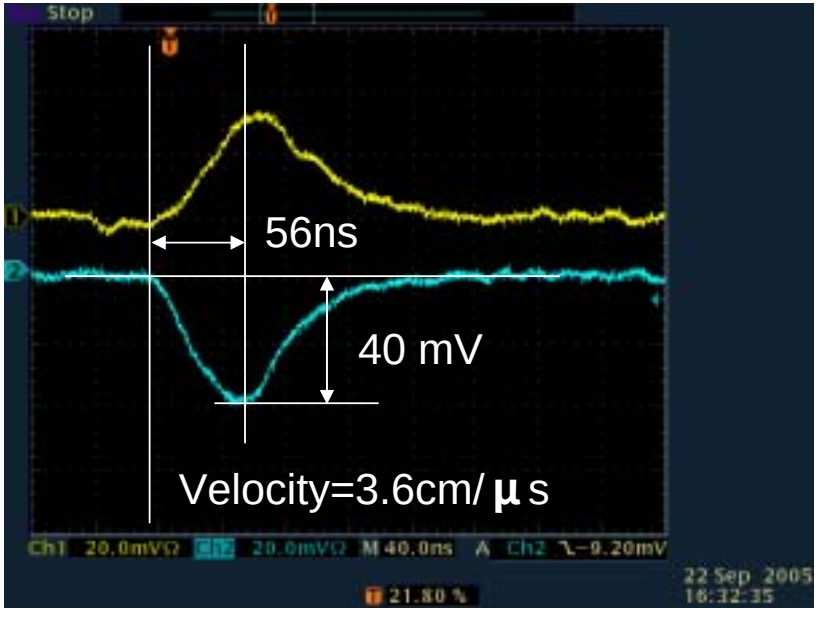
E_I =1.28kV, D_I=2mm

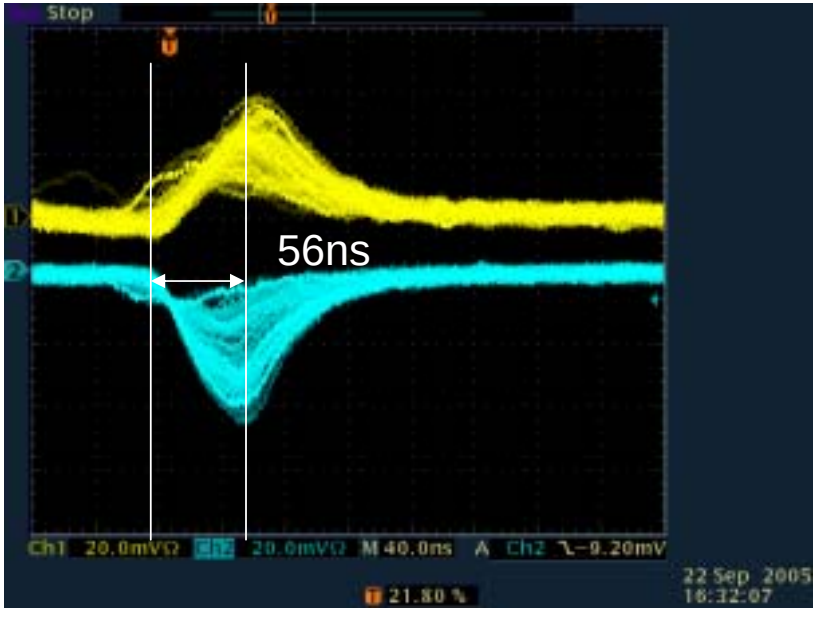




P10
ΔV_{GEM}=320V
E_D=0.5kV/cm
E_T=1.6kV/cm

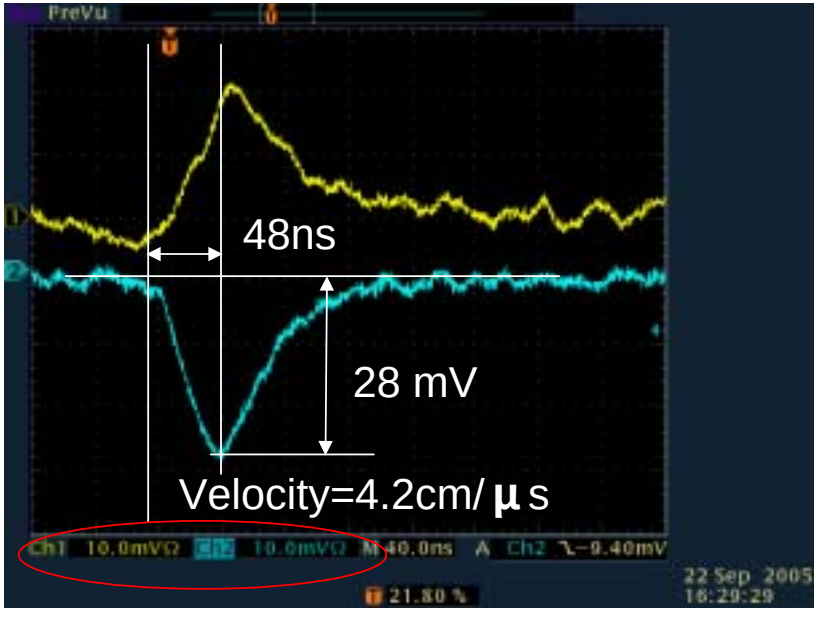
E_I =0.64kV, D_I=2mm

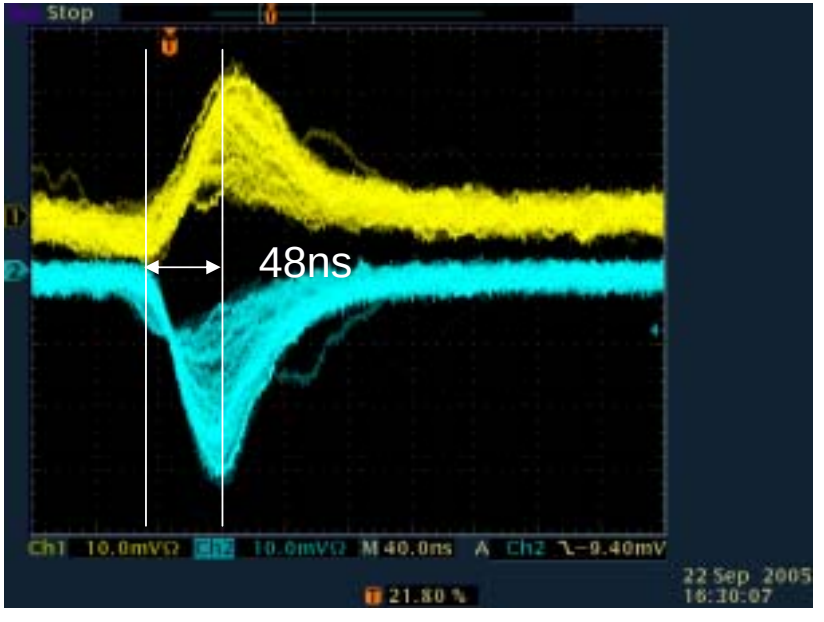




P10
ΔV_{GEM}=320V
E_D=0.5kV/cm
E_T=1.6kV/cm

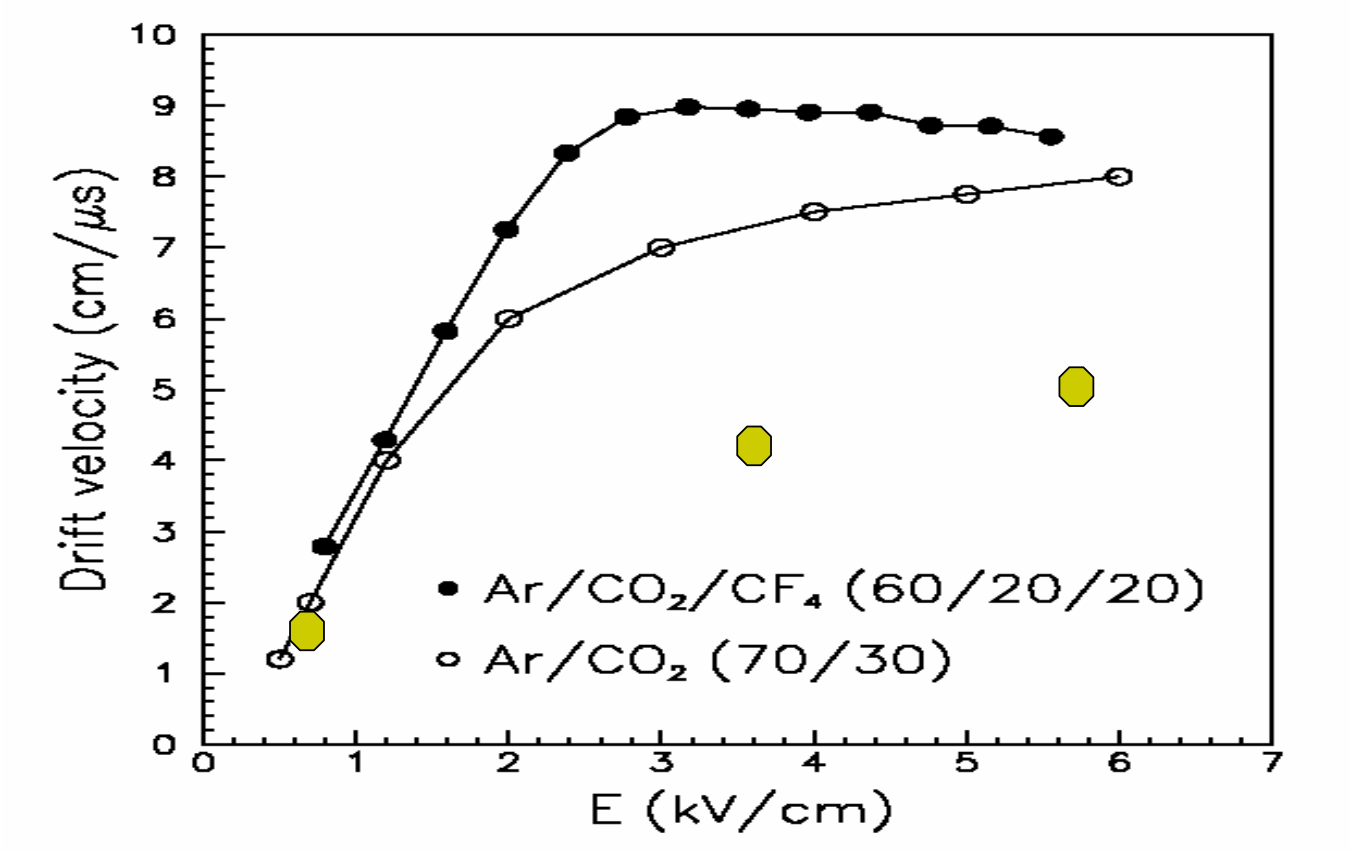
E_I =0.32kV, D_I=2mm



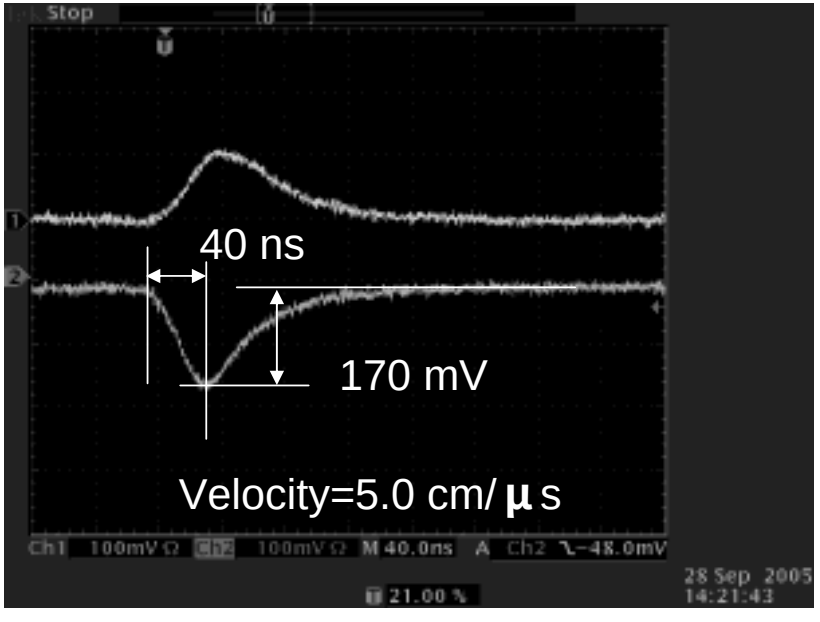


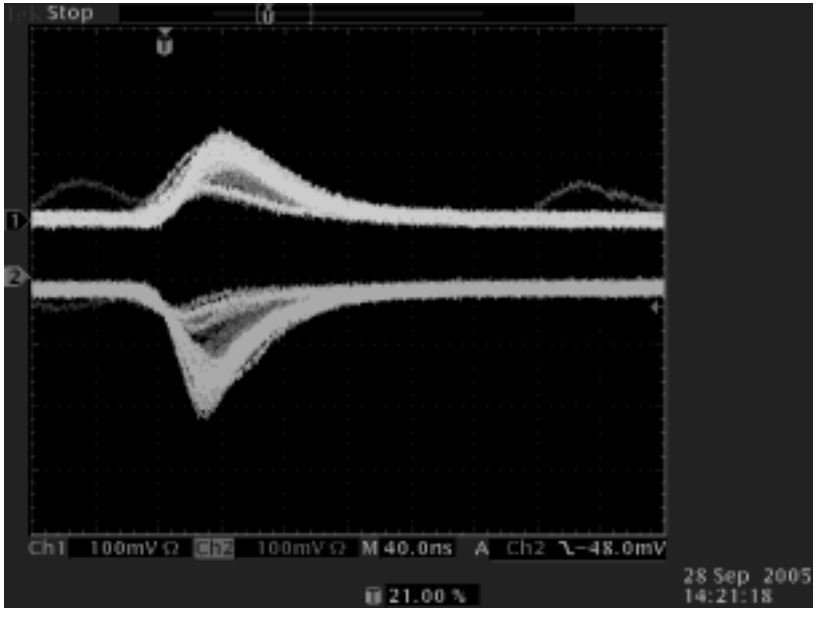
P10
ΔV_{GEM}=320V
E_D=0.5kV/cm
E_T=1.6kV/cm

E_Iを変化させて測定 (Ar-CO2 gas)



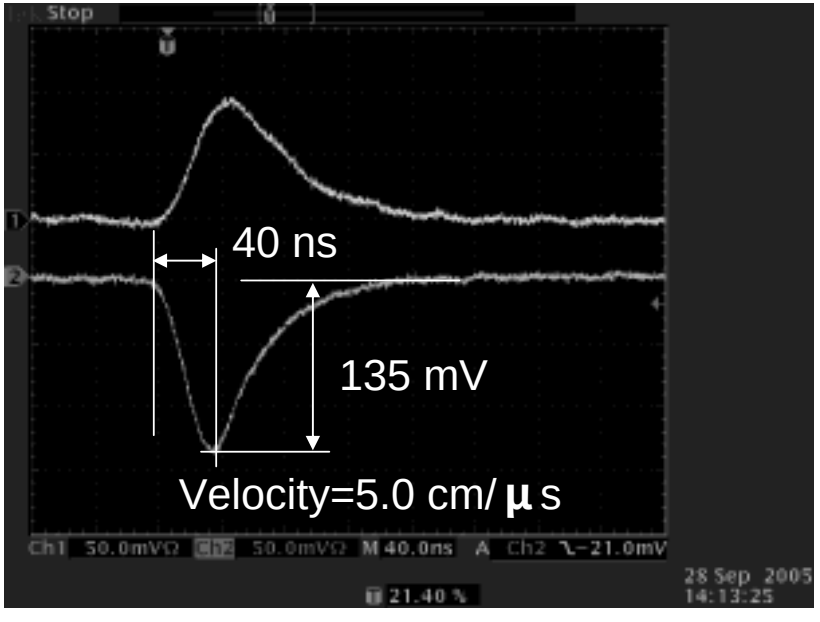
E_I=8.64kV/cm, D_I=2mm

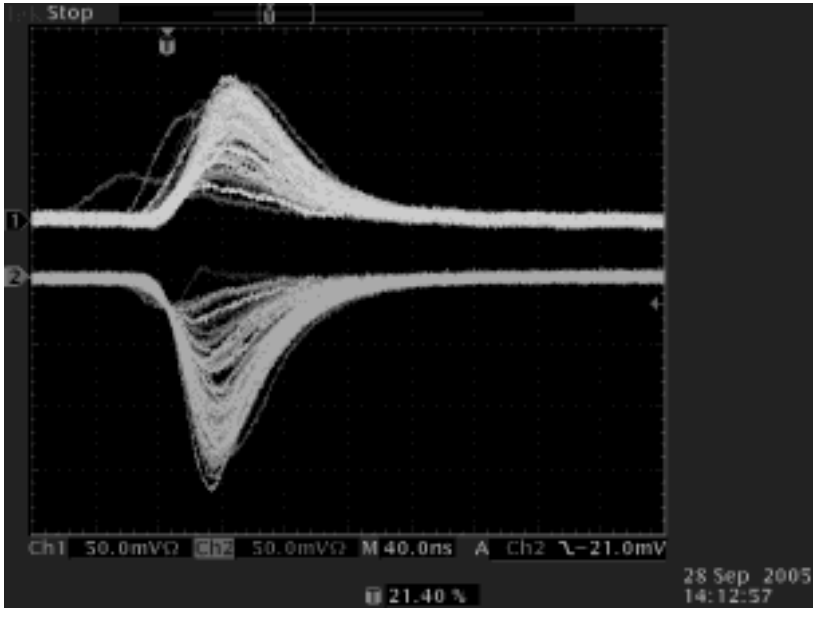




Ar-CO_2 (70/30)
ΔV_{GEM}=360V
E_D=0.5kV/cm
E_T=1.8kV/cm

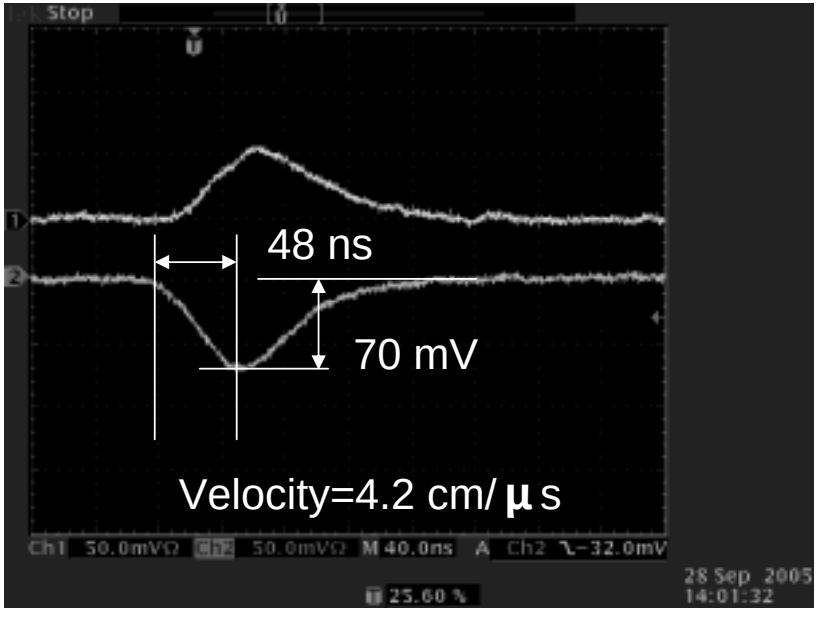
E_I=5.76kV/cm, D_I=2mm

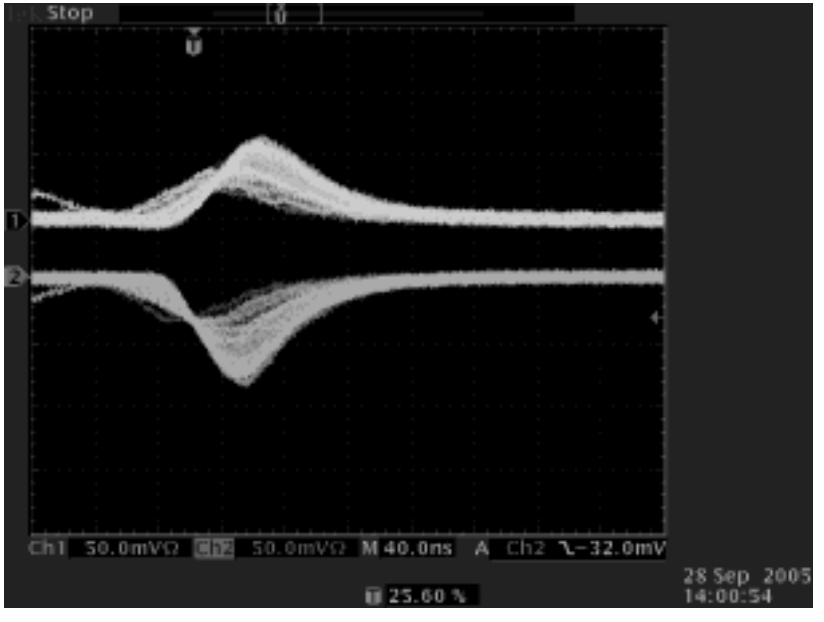




Ar-CO_2 (70/30)
ΔV_{GEM}=360V
E_D=0.5kV/cm
E_T=1.8kV/cm

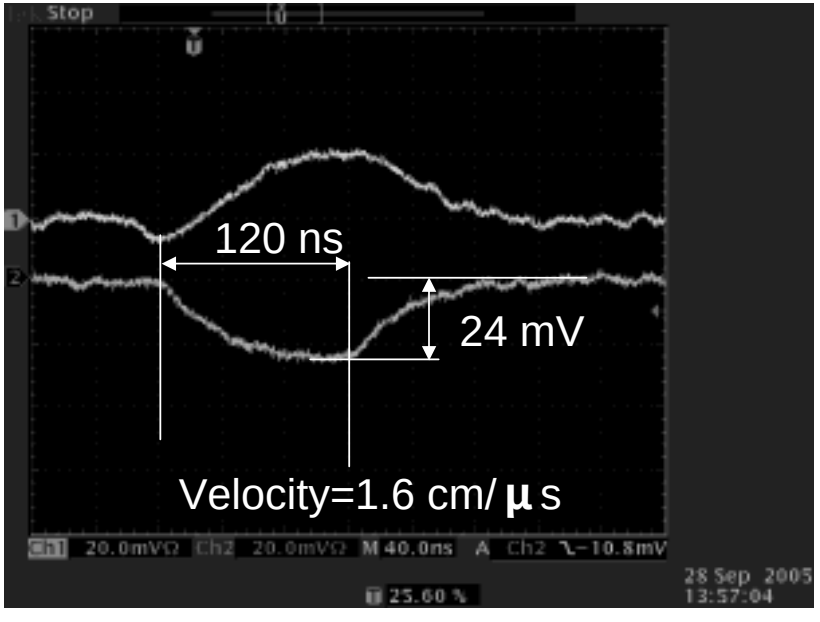
E_I=3.6kVcm, D_I=2mm

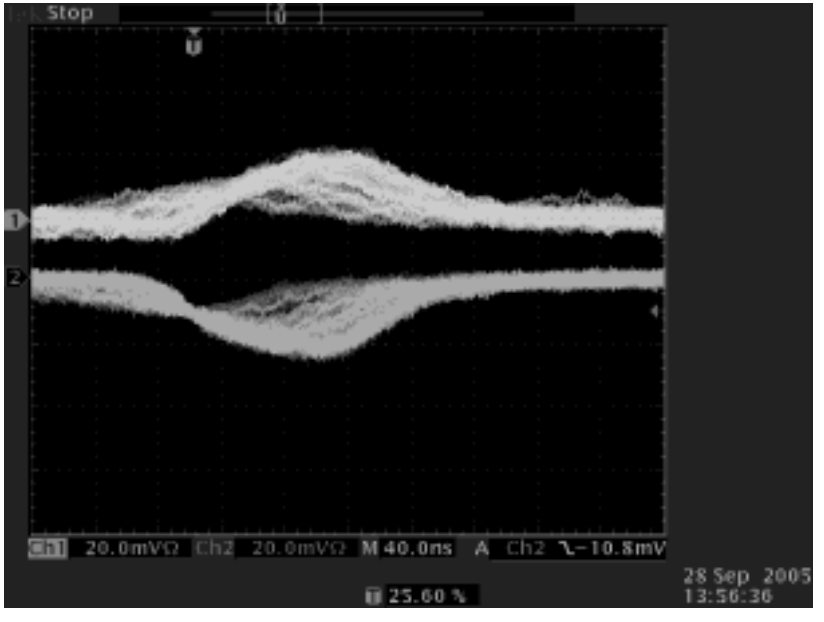




Ar-CO_2 (70/30)
ΔV_{GEM}=360V
E_D=0.5kV/cm
E_T=1.8kV/cm

E_I=0.72kVcm, D_I=2mm





Ar-CO_2 (70/30)
ΔV_{GEM}=360V
E_D=0.5kV/cm
E_T=1.8kV/cm