マイクロパターンガス検出器を用いたガスPMTの開発状況

門叶　冬樹

（山形大　理）

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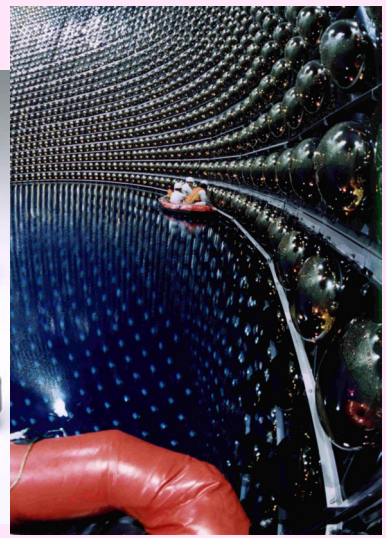
SLAC	J. Va'vra				
浜松ホトニクス	藤田良雄	遠藤哲朗	岡田晃行	渥美卓治	大石保生
山形大理	櫻井敬久	郡司修一	金子昌弘	菊地健太郎	外山幸太

従来の光センサー

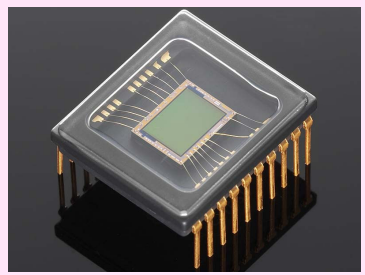
科学分野(生物、物理、化学):研究手段
放送、メディア、OA分野:情報取得手段

➡ ***多様な光センサーの開発・応用***

光電子増倍管 (PMT)



CCD、CMOS



キャノン社製

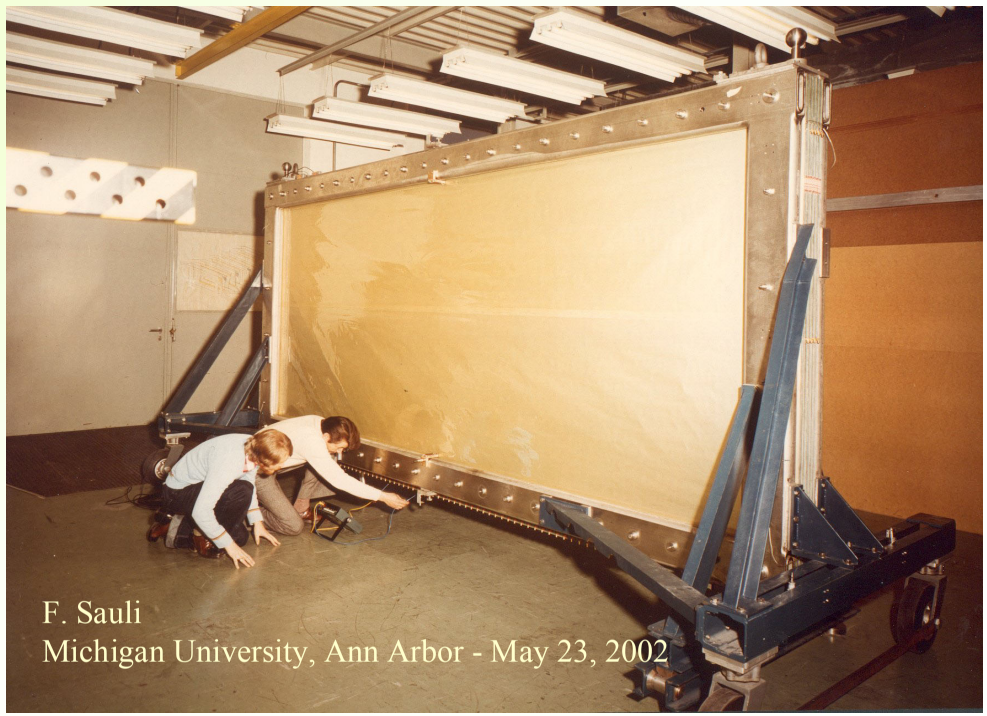
光センサー	感度	解像度	時間	面積	価格/ch	磁場	低温
光電子増倍管	◎	△	◎	△	△	×	×
CCD/CMOS	△	◎	×	×	◎	○	○

汎用型、低価格、大面積→ガスPMTの開発

ガスPMTの利点

ガス検出器の利点を全て使える。

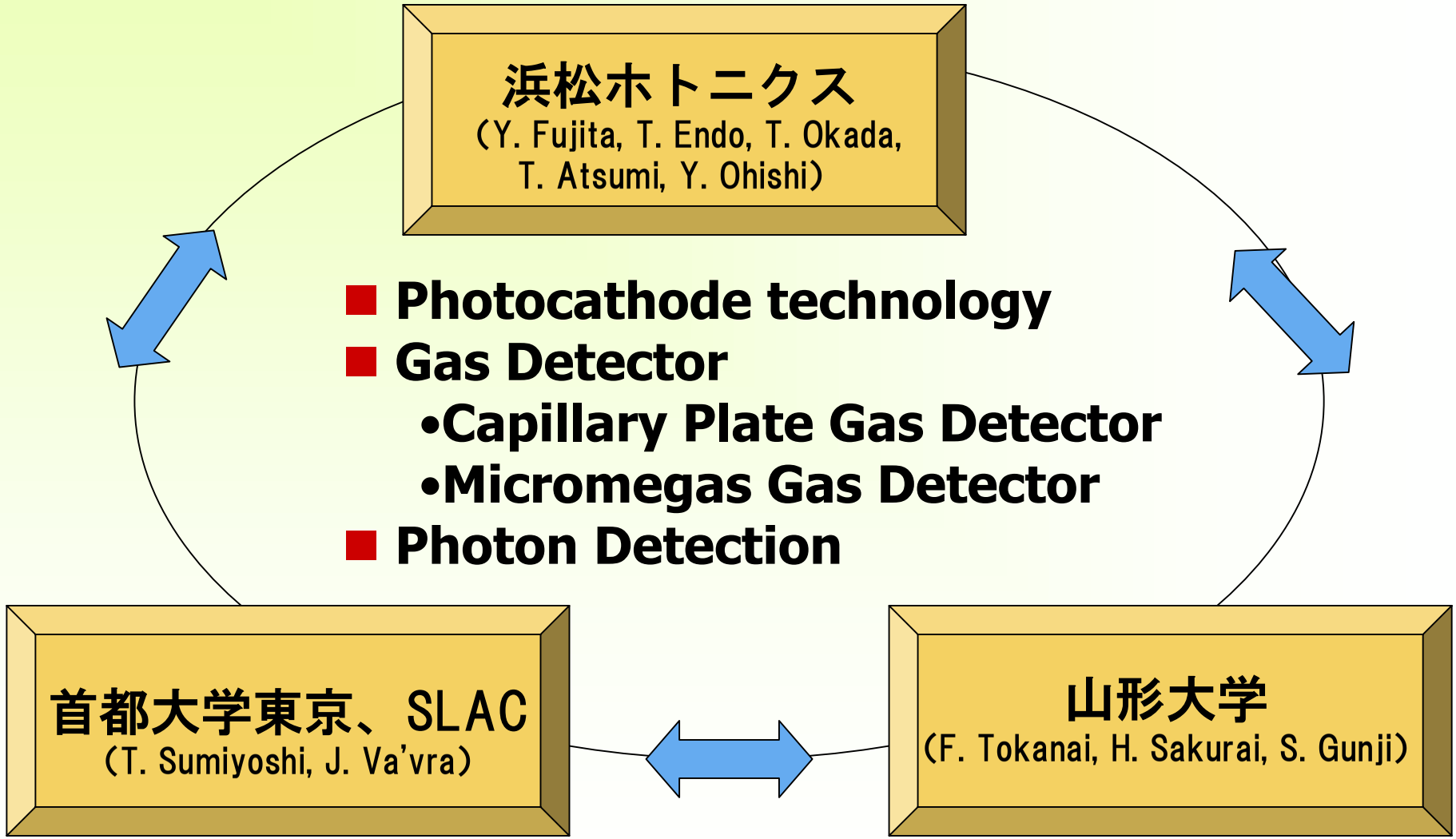
光センサー	感度	解像度	時間	面積	価格/ch	磁場	低温
光電子増倍管	◎	△	◎	△	△	×	×
CCD/CMOS	△	◎	×	×	◎	○	○
Gas PMT	◎	○	○	◎	○	◎	○



期待される応用

高エネルギー実験、プラズマ、天文学、
暗視カメラ、医療分野、ポストゲノム、、、

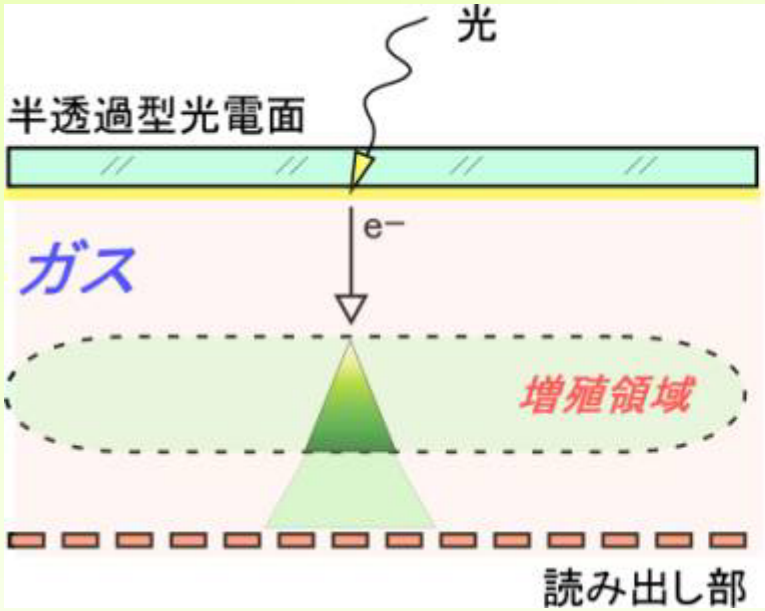
Hole-Type & Micromegasを使った マイクロパターンガスPMTの開発体制



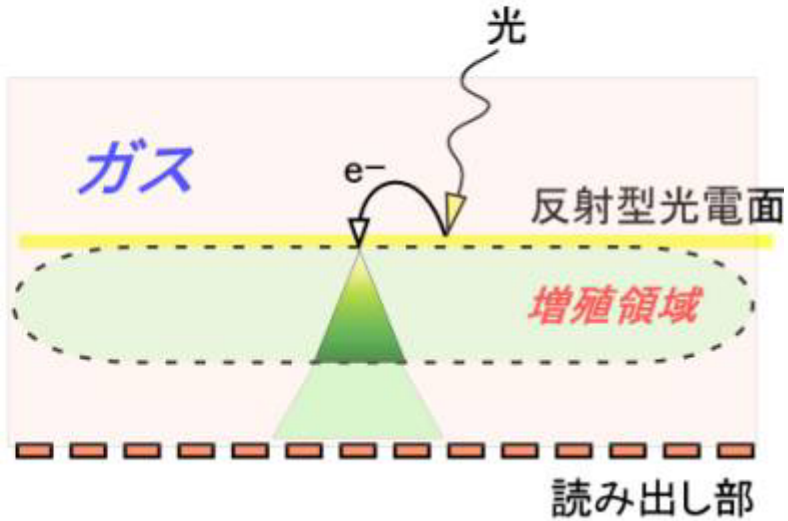
2005年3月より、スタート

Made in JAPAN

ガスPMTの動作原理



半透過型ガスPMT
（光電面と増幅領域が別）



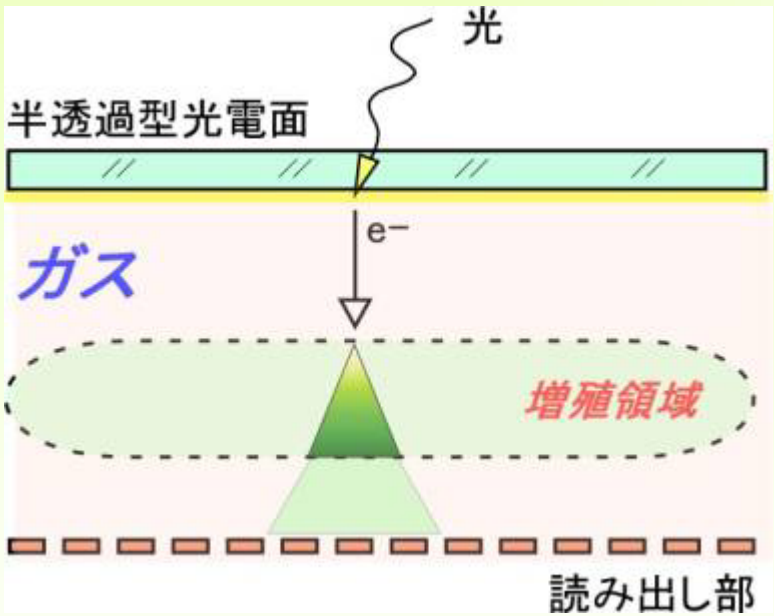
反射型ガスPMT
（光電面と増幅領域一体）

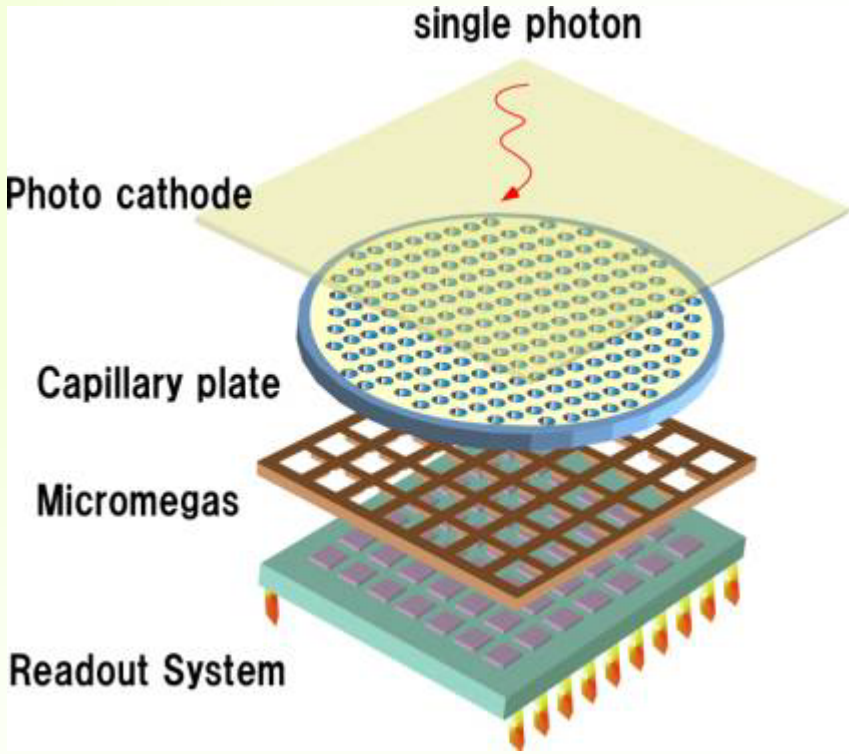
光→光電子→ガス増殖→読み出し

Very simple

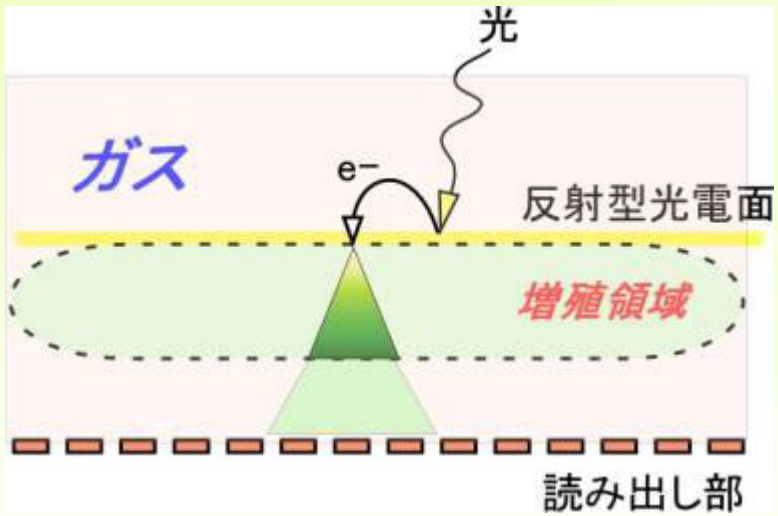
マイクロパターンガス検出器によるガスPMT開発へ

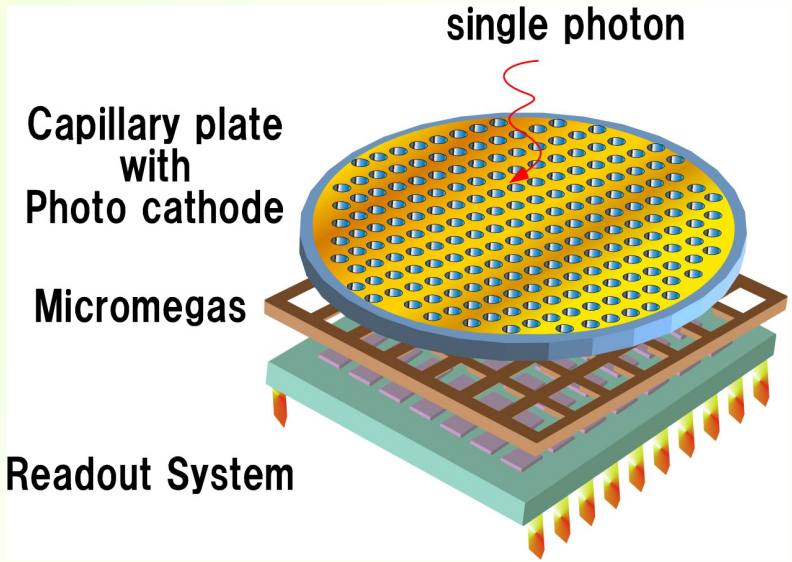
MPGDを用いた半透過型ガスPMT





MPGDを用いた反射型ガスPMT

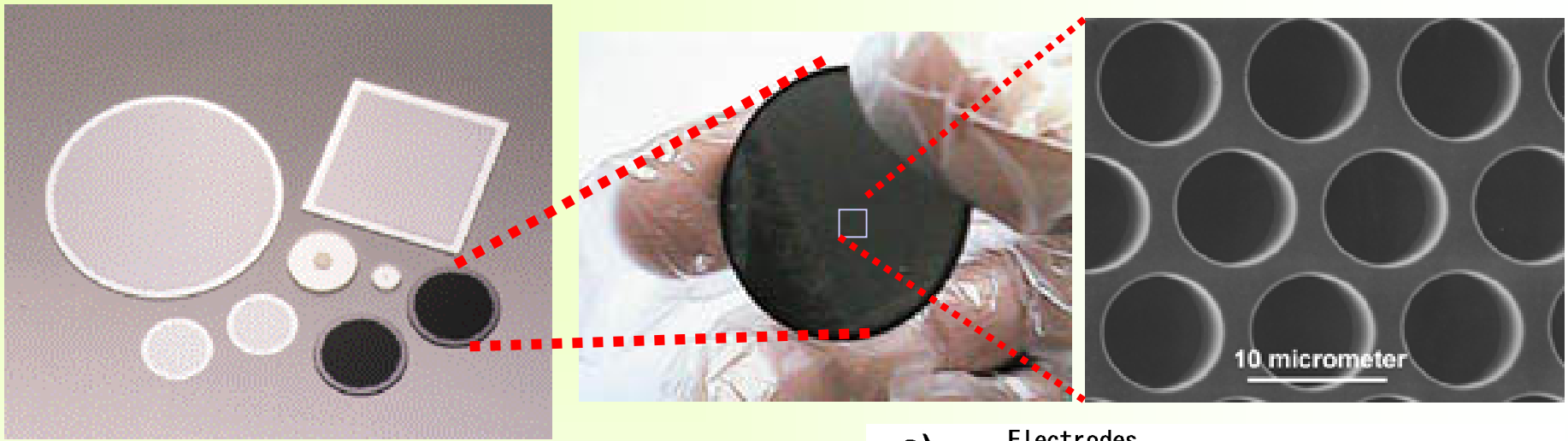




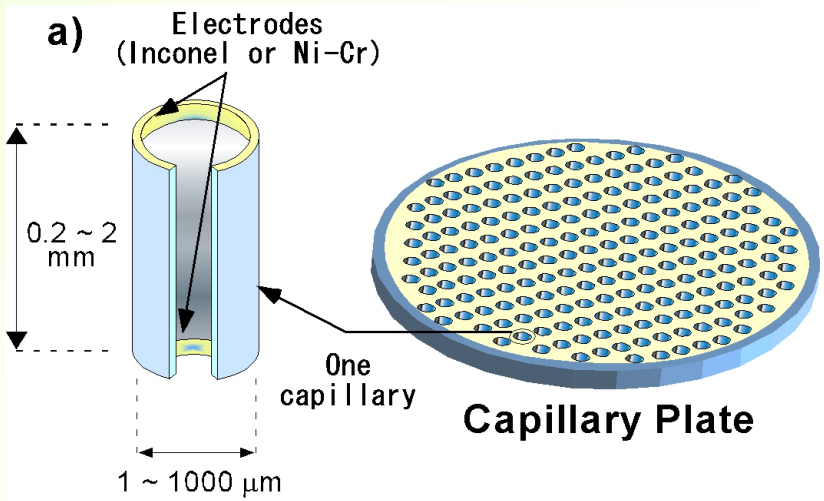
現在までの開発状況

- ✓ *CPガス検出器*
- ✓ Micromegas+CP
- ✓ 光電面開発

Glass Capillary Plate (CP)



Material	Glass capillary
Outer Diameter (mm)	10~100
Package Density (cm^{-2})	~10^6
Thickness (mm)	0.2~2
Channel Diameter (μm)	1~1000
Open area ratio(%)	60 (80)
Electrode Material	Inconel or Ni-Cr

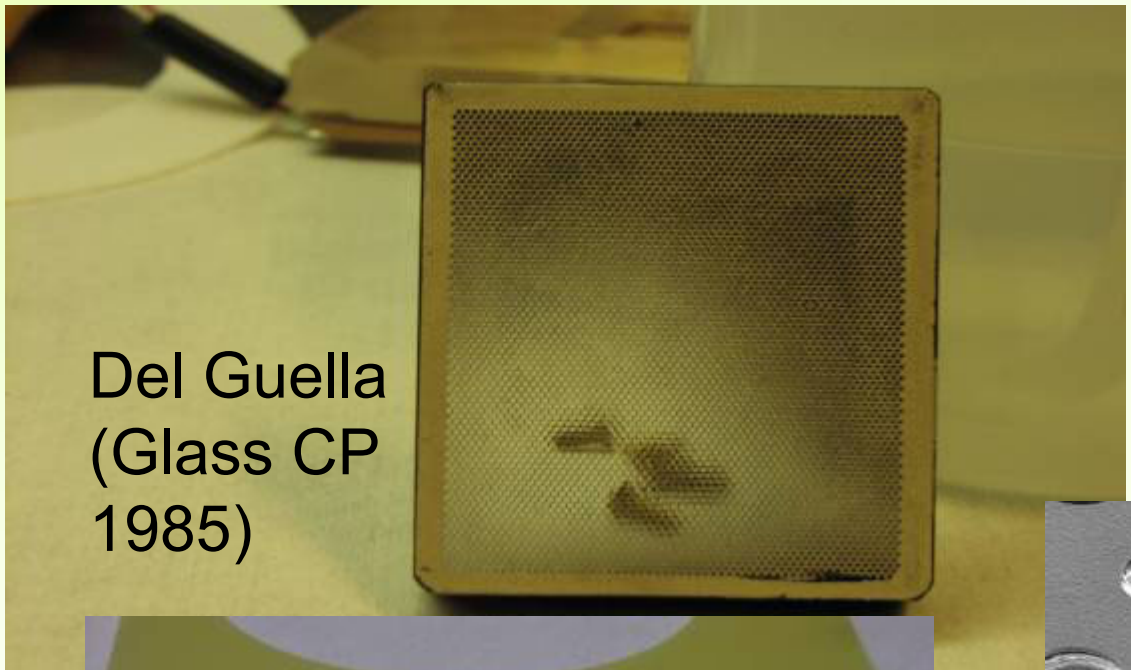


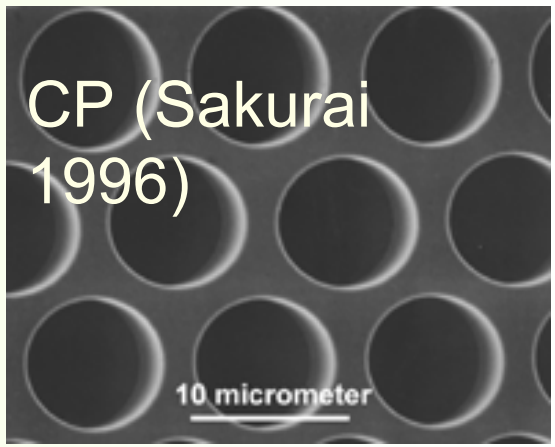
- **A flow controller for gas and liquid, a particle filter, as well as optical and X-ray collimeters.**

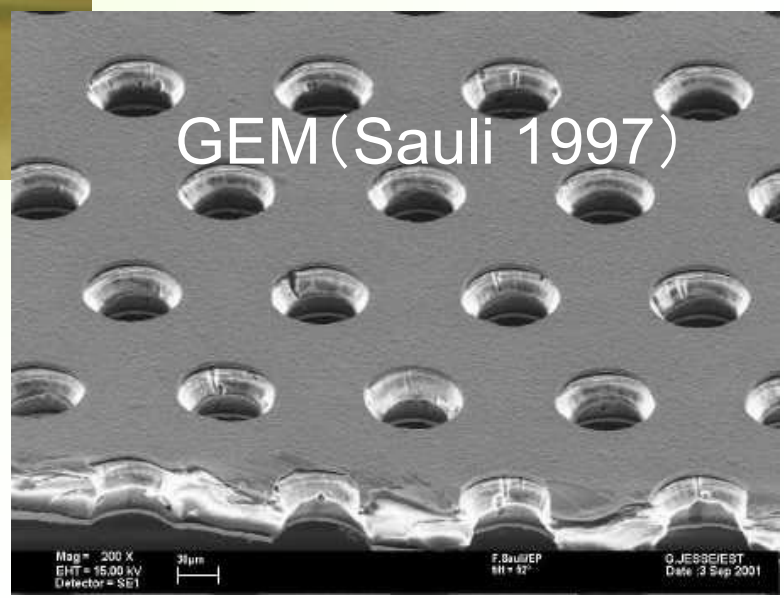
manufacturing process: see F. Tokanai et al. Vol. 52 No.5 (2005) pp. 1698- 1704

Glass Capillary Plate (CP)

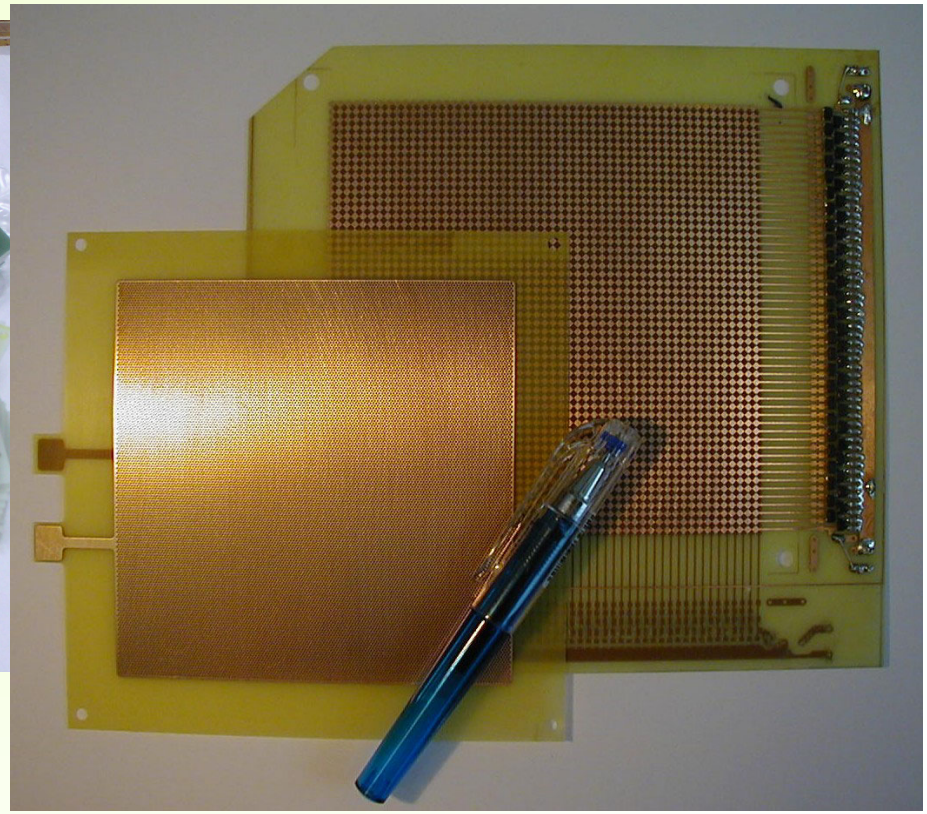
- One of the hole-type micropattern gas detectors (GEM like).







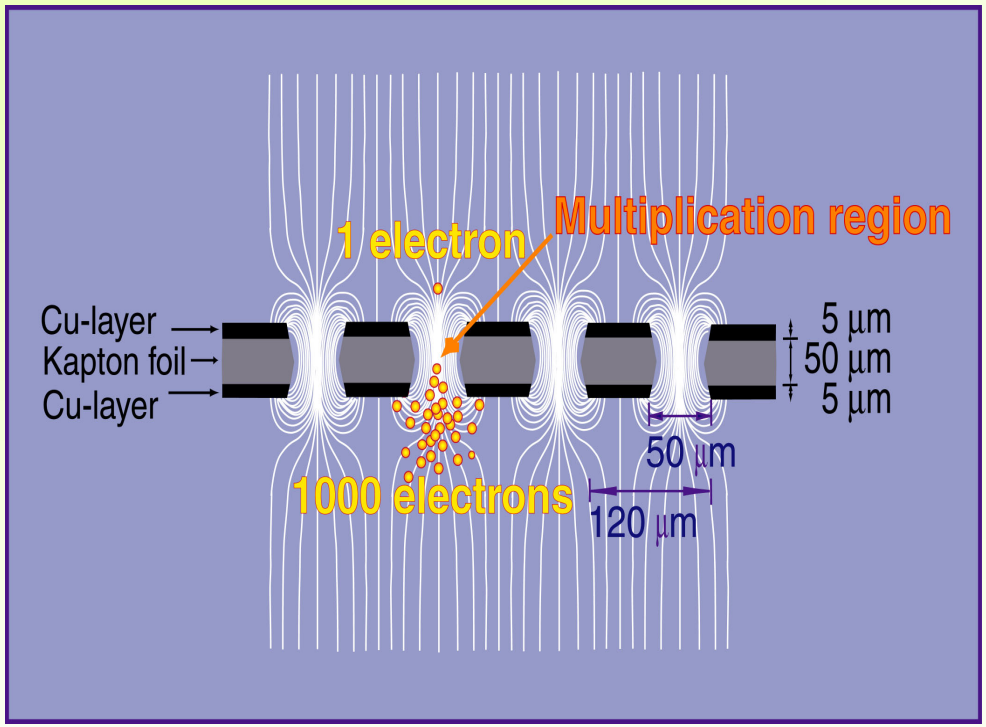
The THGEMs:

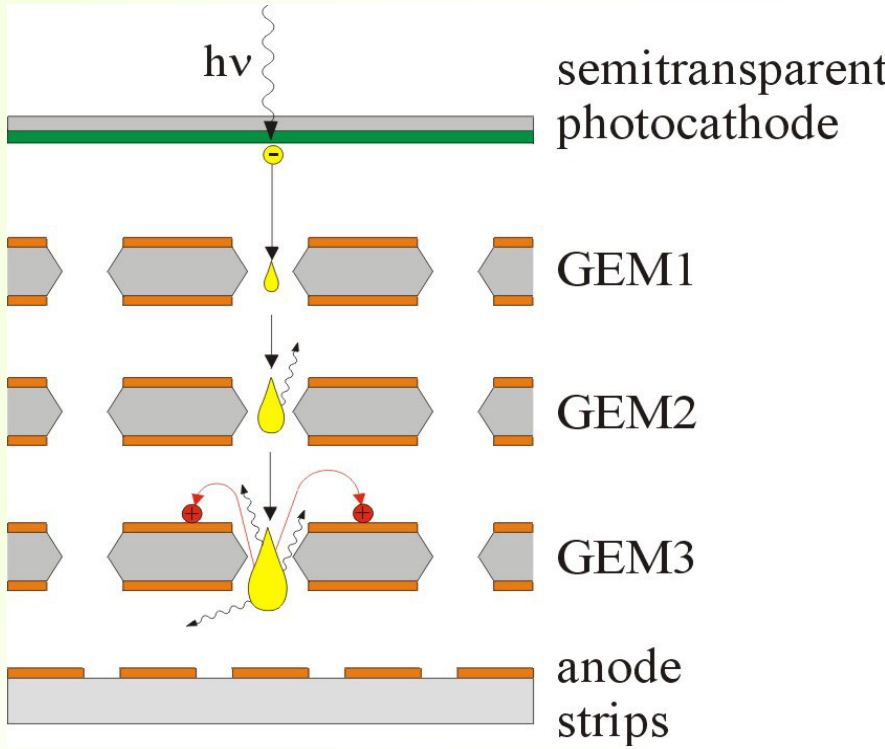


A small THGEM costs ~3$ /unit.
With minimum order of 400$ → ~120 THGEMs.
~10 times cheaper than standard GEM.

From. Prof. A. Breskin

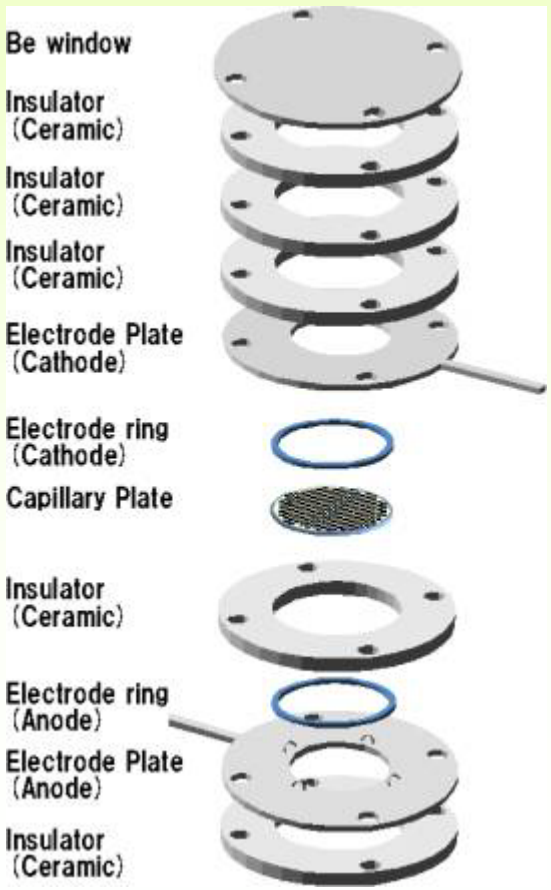
Advantages of hole-type MPGD

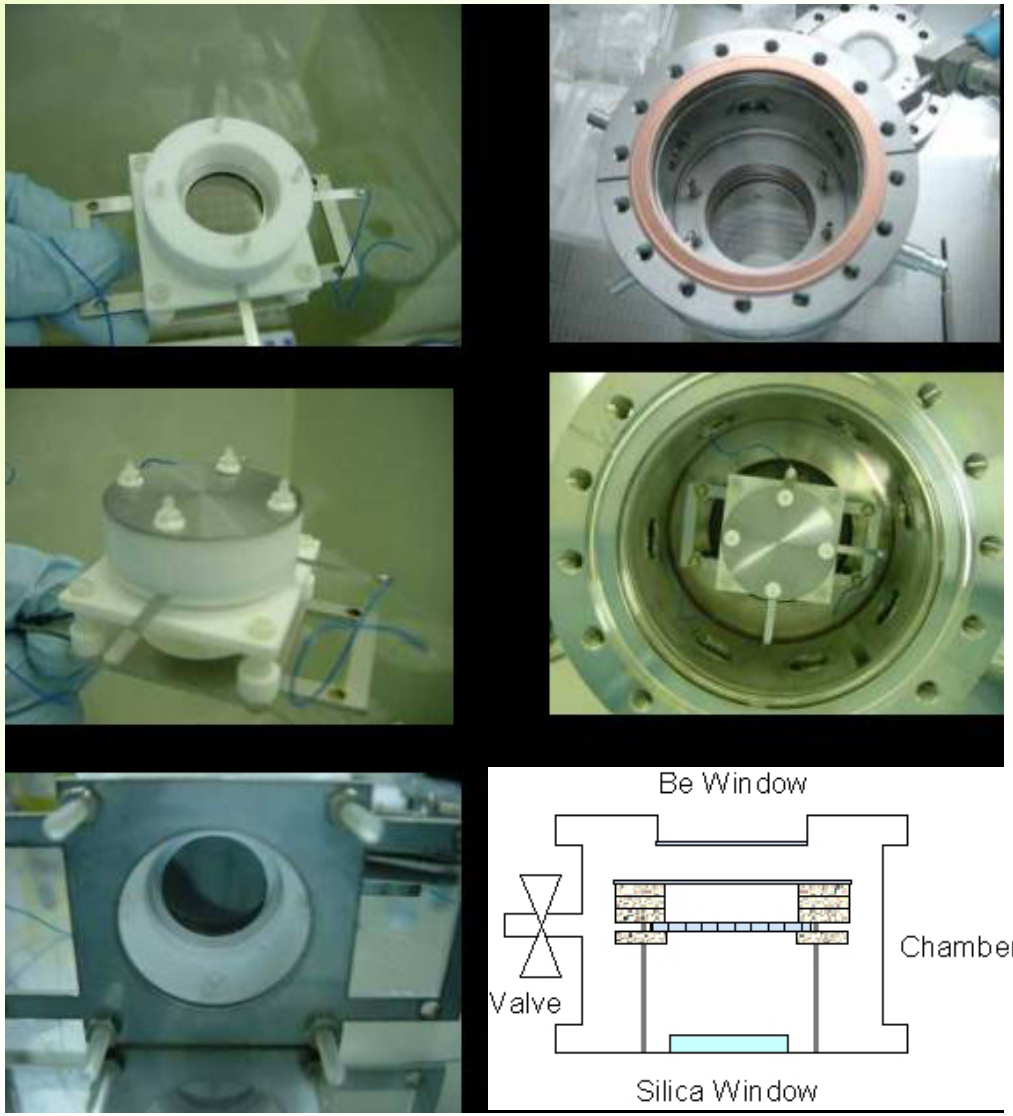




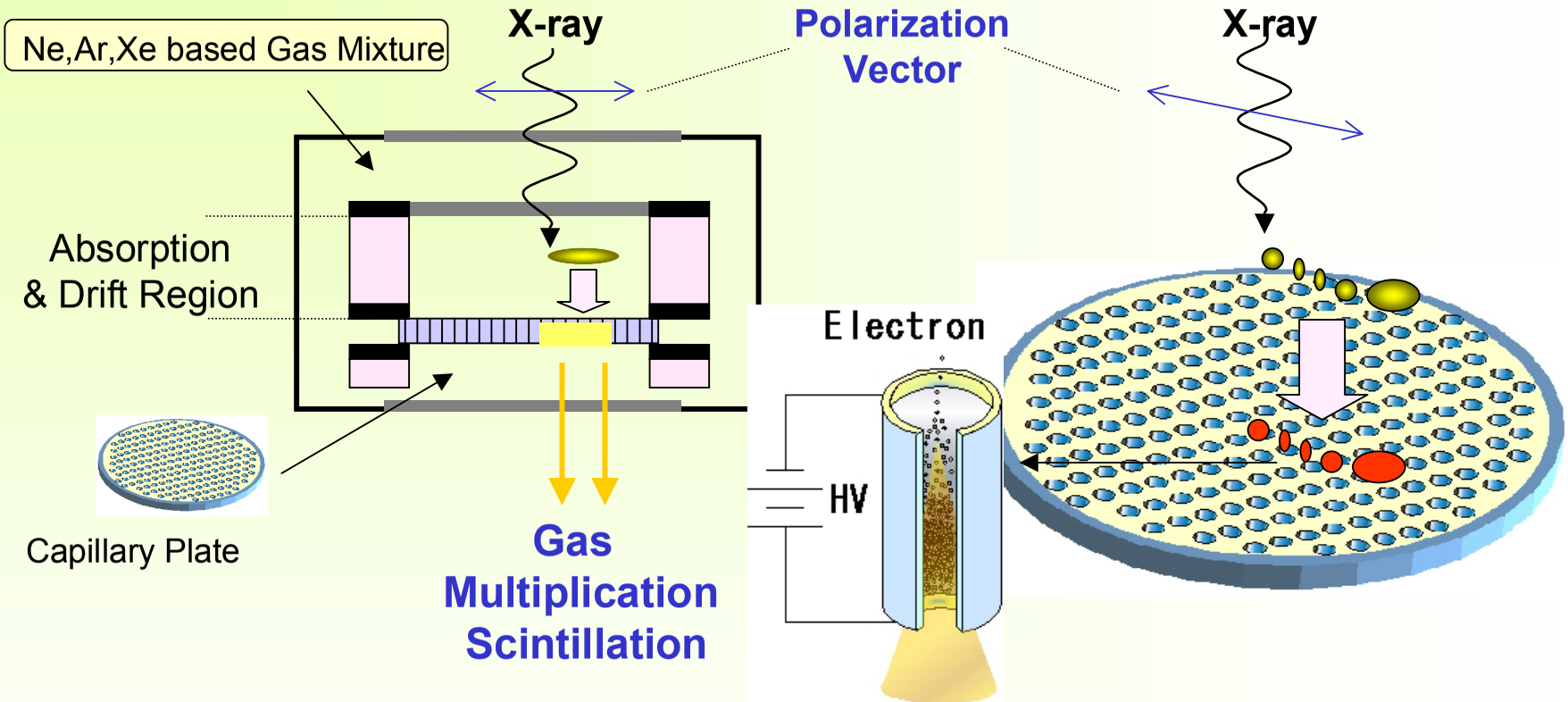
- **ガス増幅領域と読み出し領域が独立。**
読み出しシステムの選択が可能、CCDも使える。
- **タンデムオペレーション。**
放電に強く、高いガス増幅度が達成。PMTレベルの10^6のゲイン

Assembly of the Capillary Plate Gas Detector





Operation principle of CP gas detector



Ionization→Charge signal
- •X-ray energy, Timing
- •Trigger for CCD

Excitation → Light signal
- •X-ray Imaging
- •X-ray Polarimeter

Real Two-dimensional pixel detector

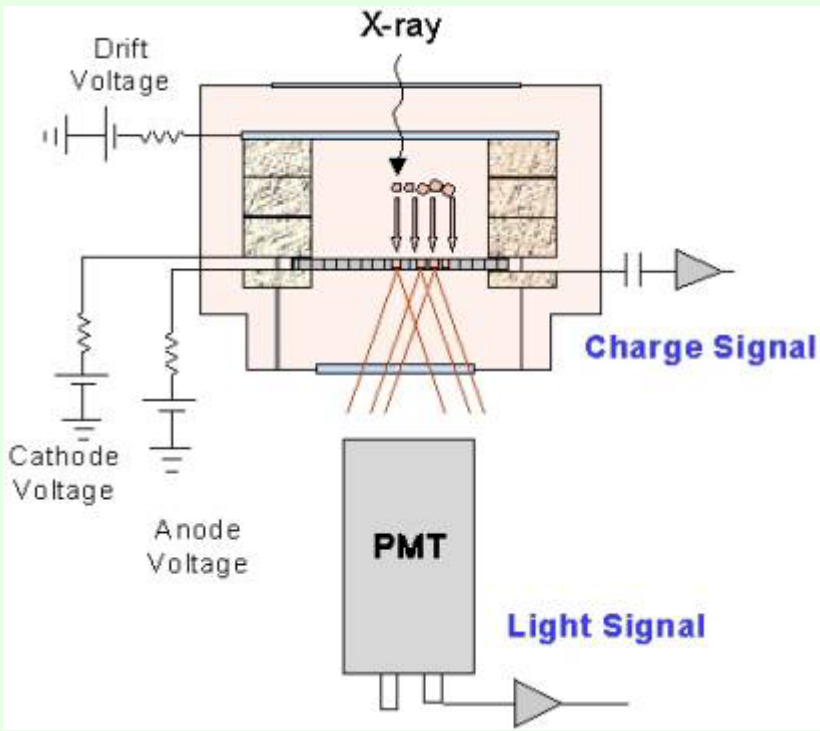
Basic characteristics of optical imaging CP

He（80nm), Ne(80nm), Ar (127nm) gas
Scintillation is EUV region. Detection is difficult.

Wavelength shifter

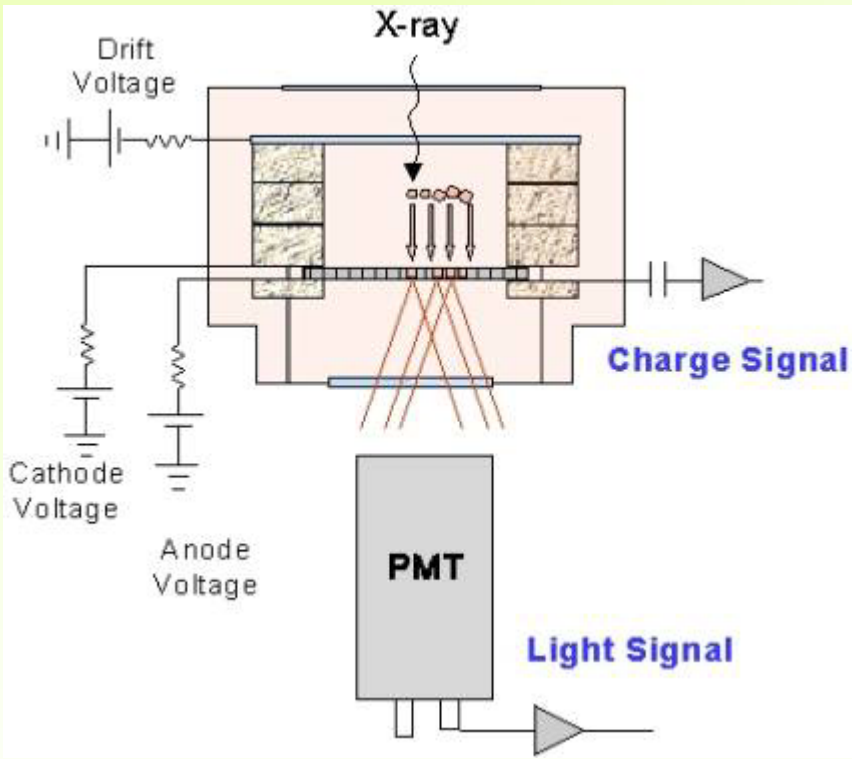
TMA → 290 nm Austin and Ramsey Opt. Eng. 1993

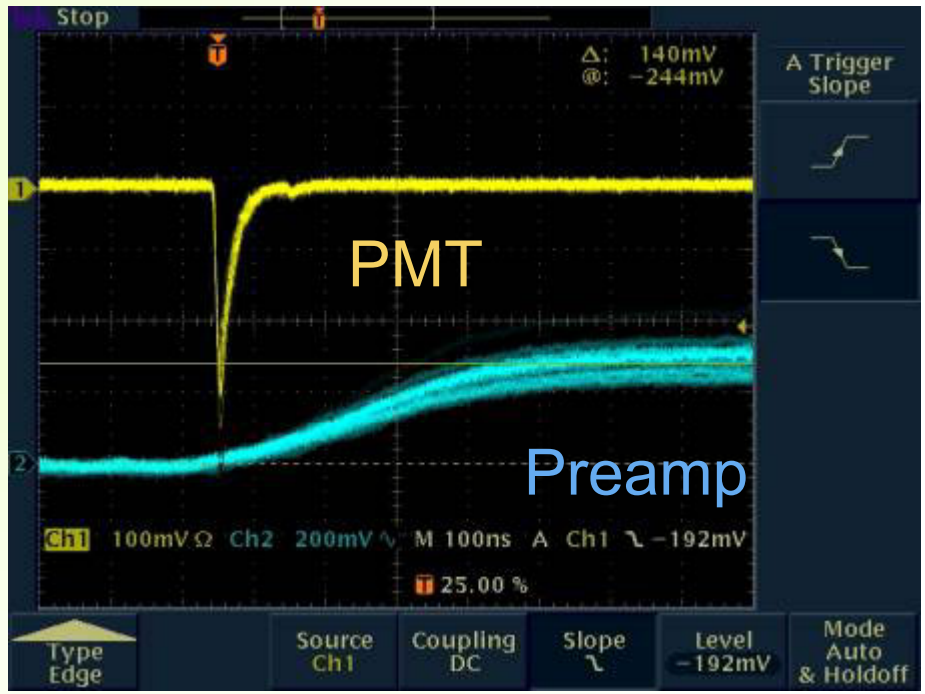
CF_4 → 620 nm Fraga et al. IEEE 2002



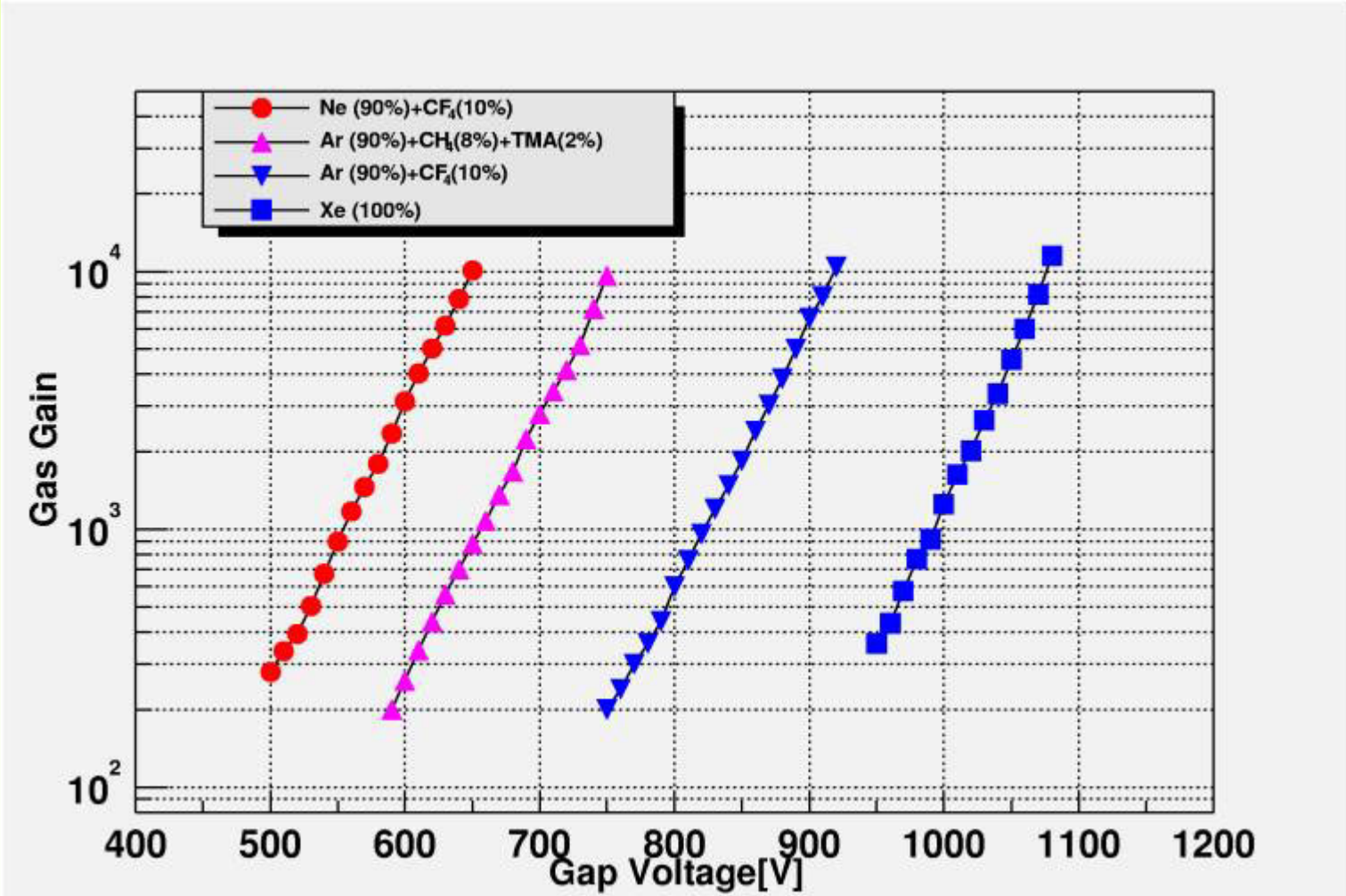
Experimental Setup

Gas Gain

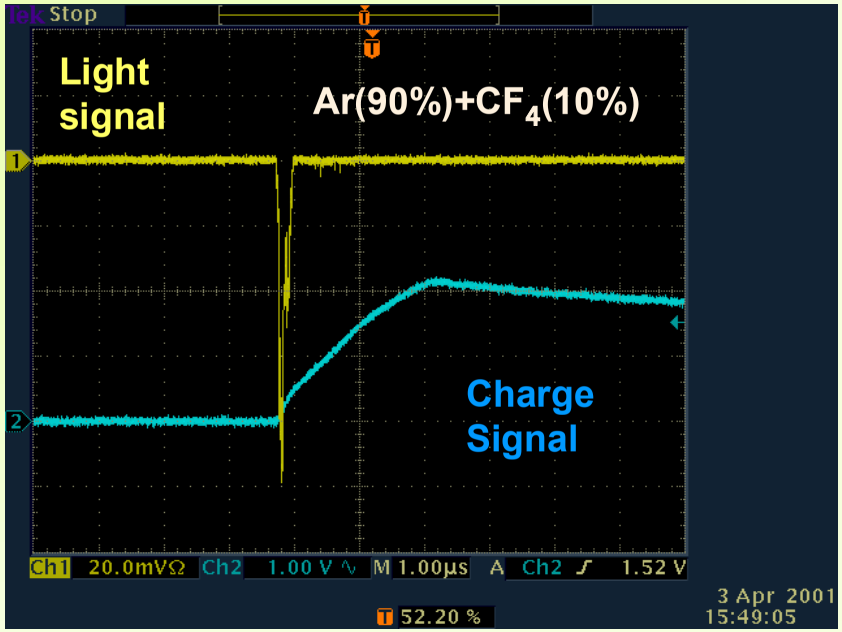

X-ray
Drift Voltage
Charge Signal
Cathode Voltage
Anode Voltage
PMT
Light Signal

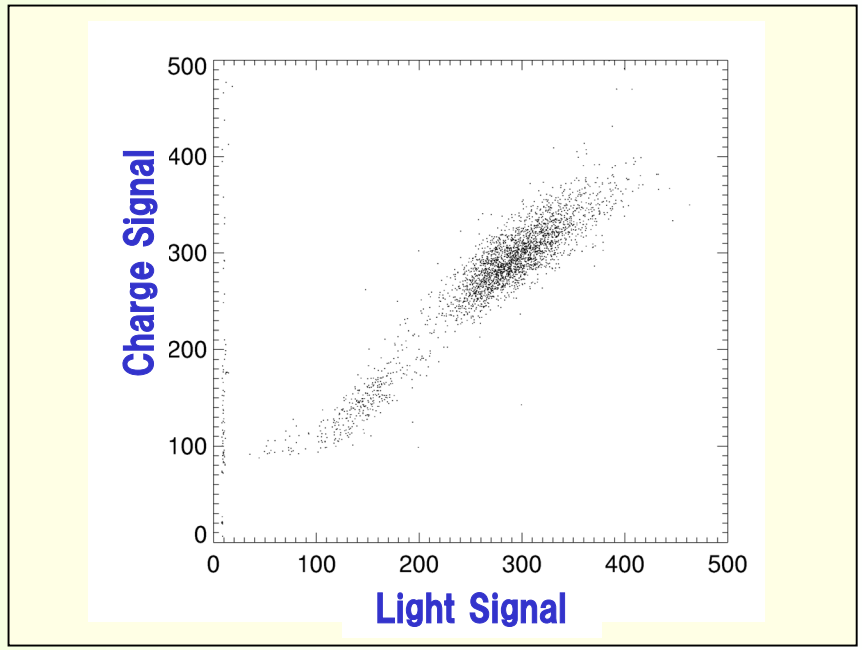

Stop
Δ: 140mV
@: −244mV
A Trigger Slope
PMT
Preamp
Ch1 100mV Ω Ch2 200mV M 100ns A Ch1 −192mV
25.00 %
Type Edge
Source Ch1
Coupling DC
Slope
Level −192mV
Mode Auto & Holdoff

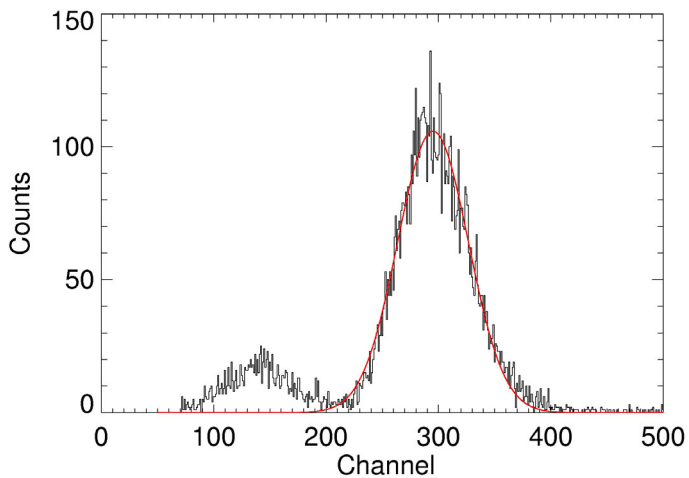
Gas Gain

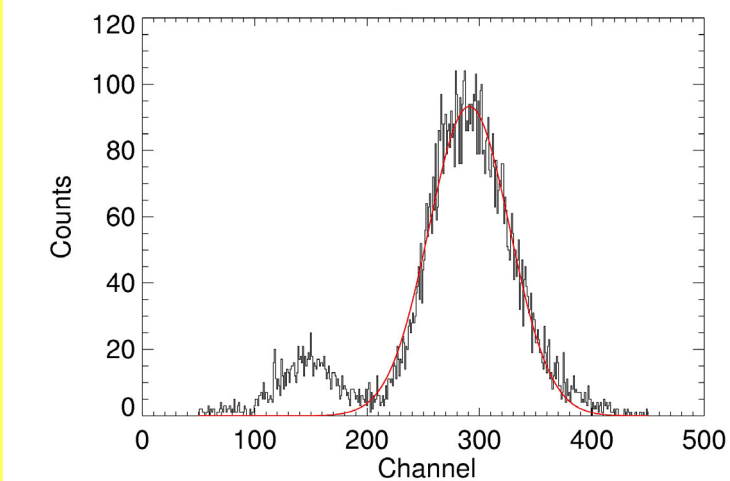

Ne (90%)+CF4(10%)
Ar (90%)+CH4(8%)+TMA(2%)
Ar (90%)+CF4(10%)
Xe (100%)
Gas Gain
10^4
10^3
10^2
400
500
600
700
800
900
1000
1100
1200
Gap Voltage[V]

Light emission from the CP detector

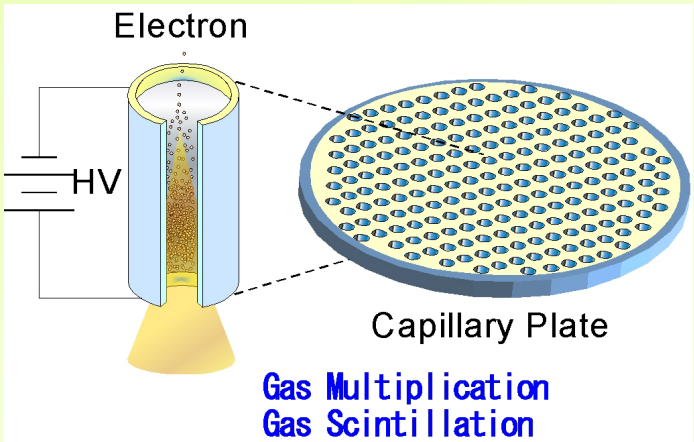


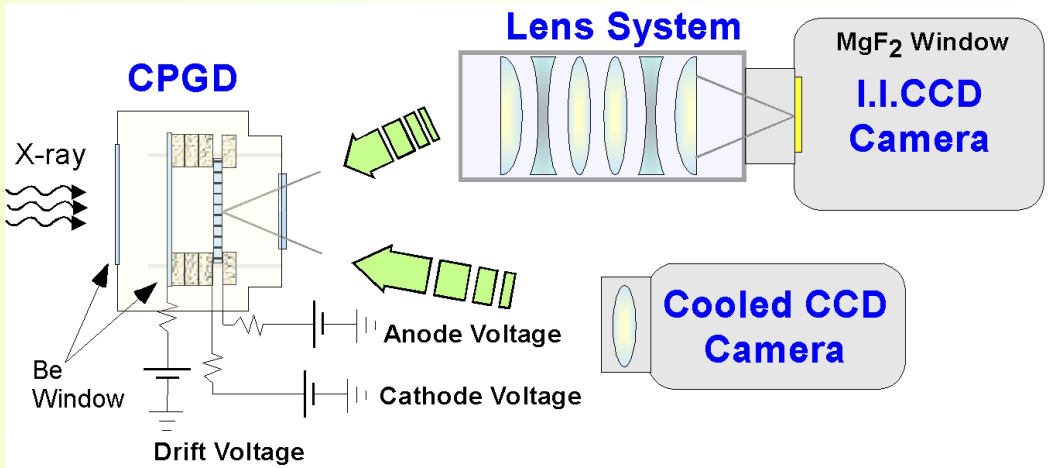


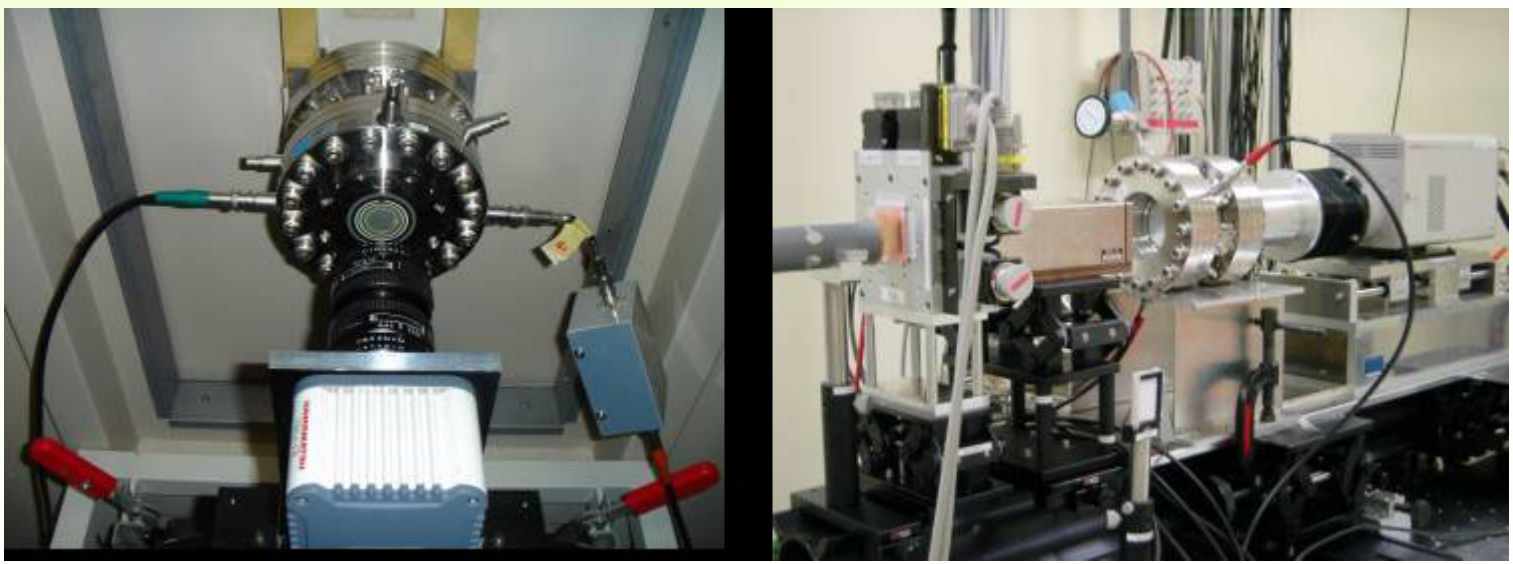




Optical Imaging CP Gas Detector



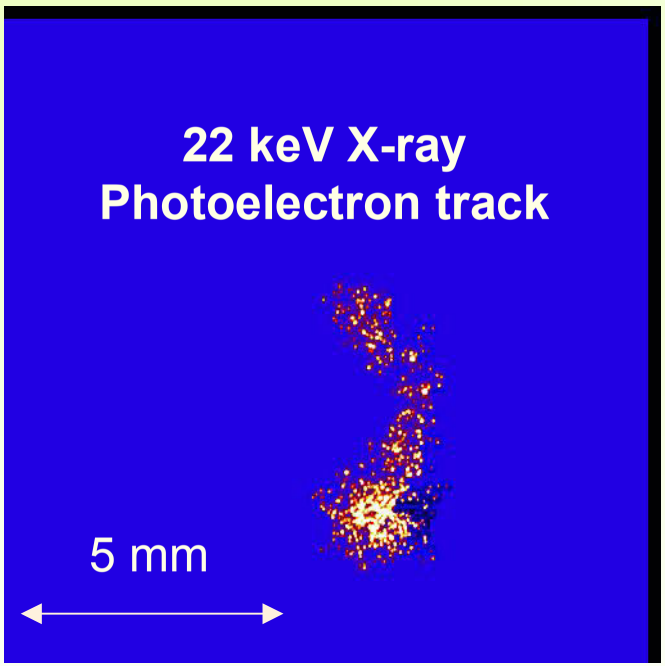


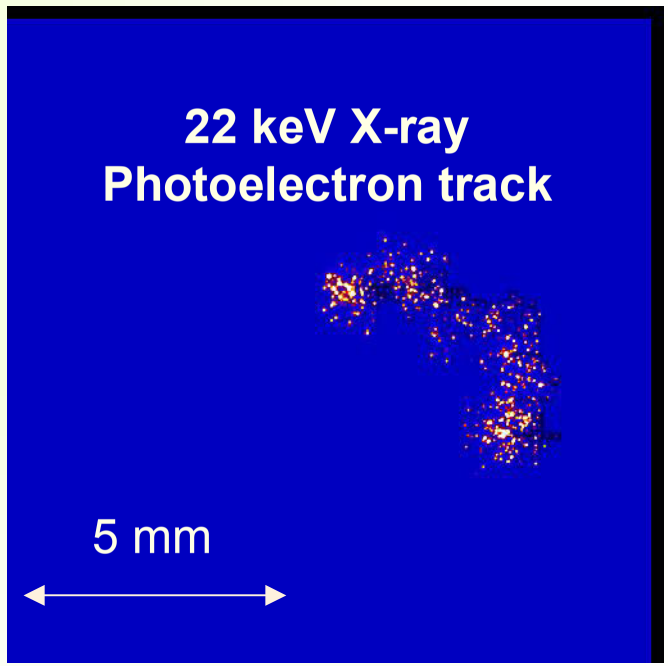


True 2 Dimensional Pixel Gas Detector

Single photoelectron track image

$Ar(90\%)+CH_4(8\%)+TMA(2\%)$



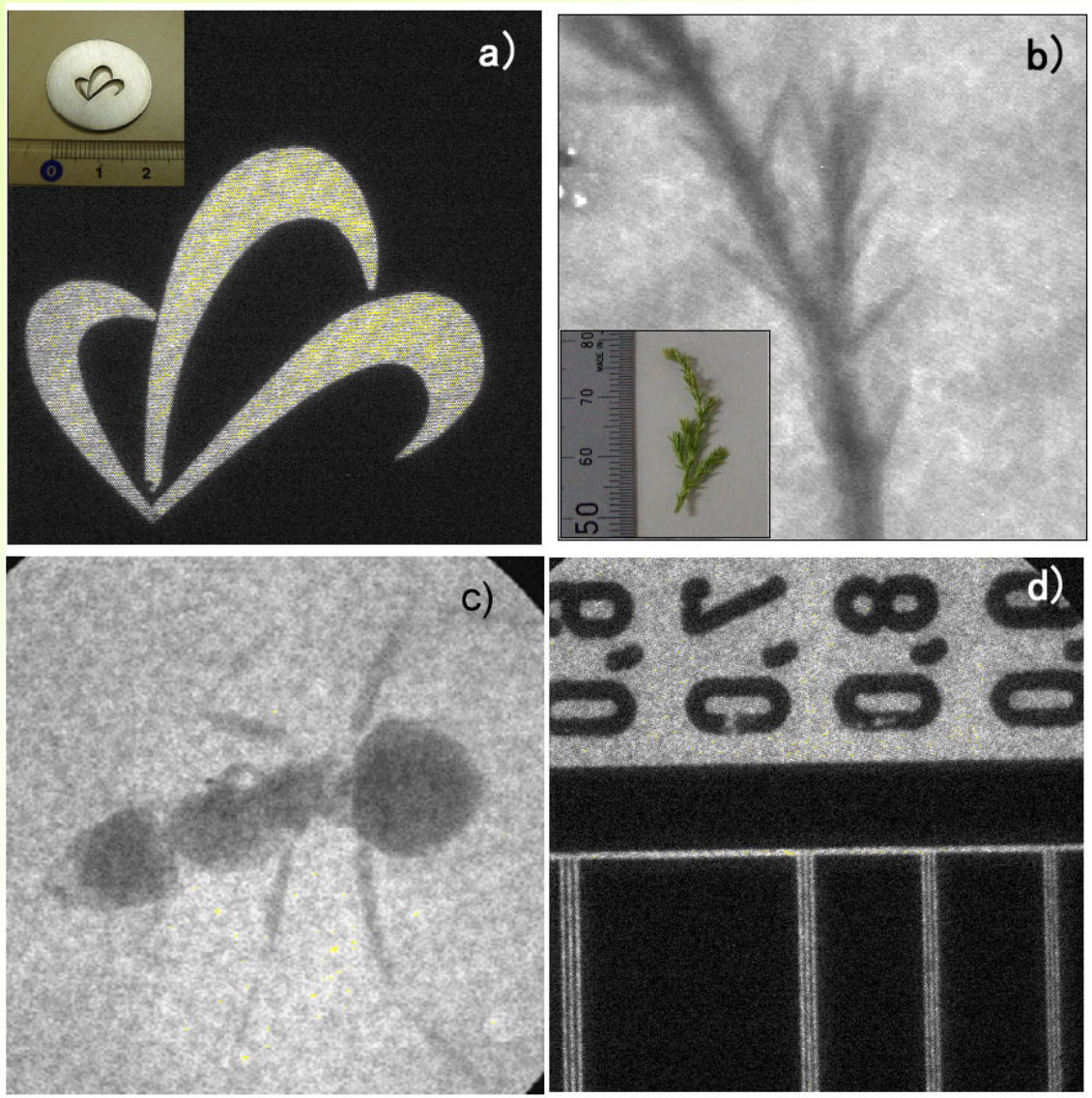


A powerful tool for the cosmic X-ray polarimetry.

***Nucl. Instr. and Meth. A* 513, p. 282, 2003**
***Nucl. Instr. and Meth. A* 525, p. 6, 2004**
F. Tokanai et al. IEEE NSS 2005

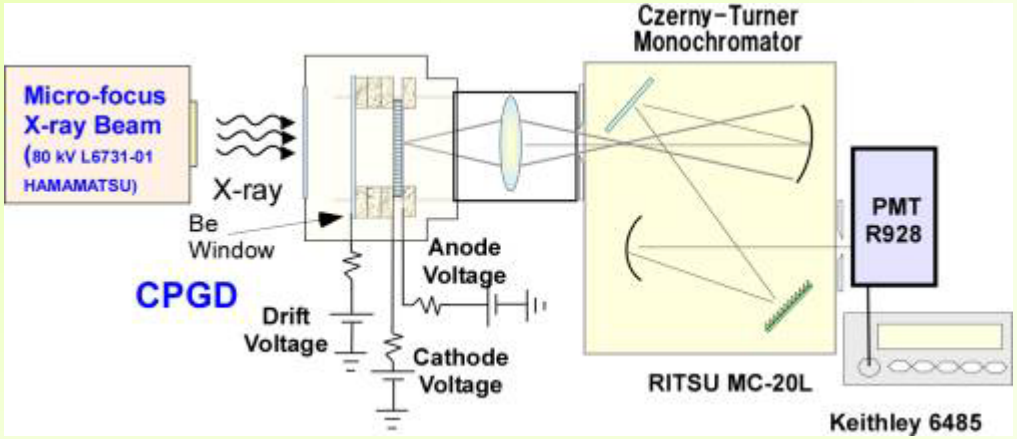
X線イメージ

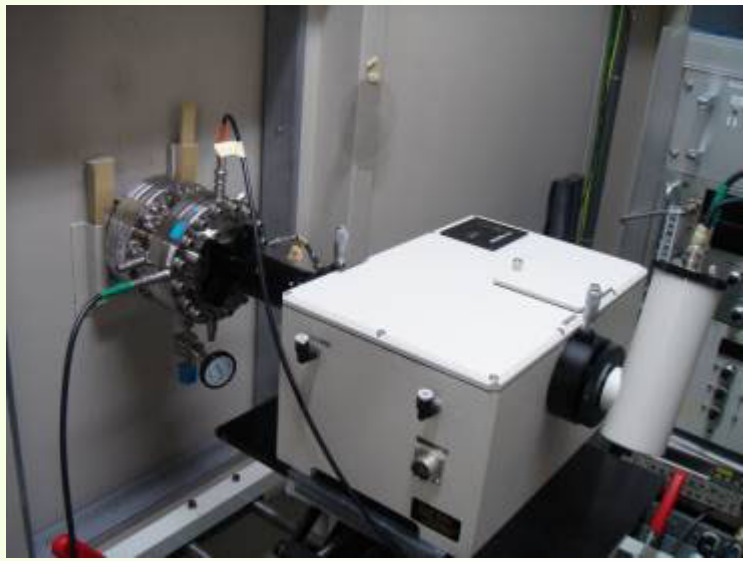
Ar(90%)+CF_4(10%)

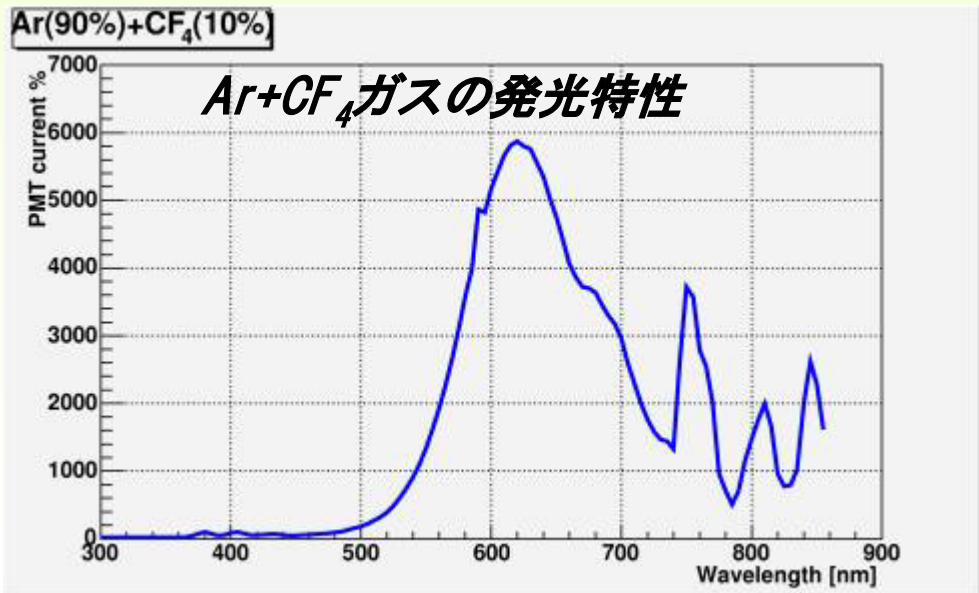


F. Tokanai et al. submitted to NIM A 2005
F. Tokanai et al. submitted to IEEE TNS 2006

CPガス検出器の発光特性



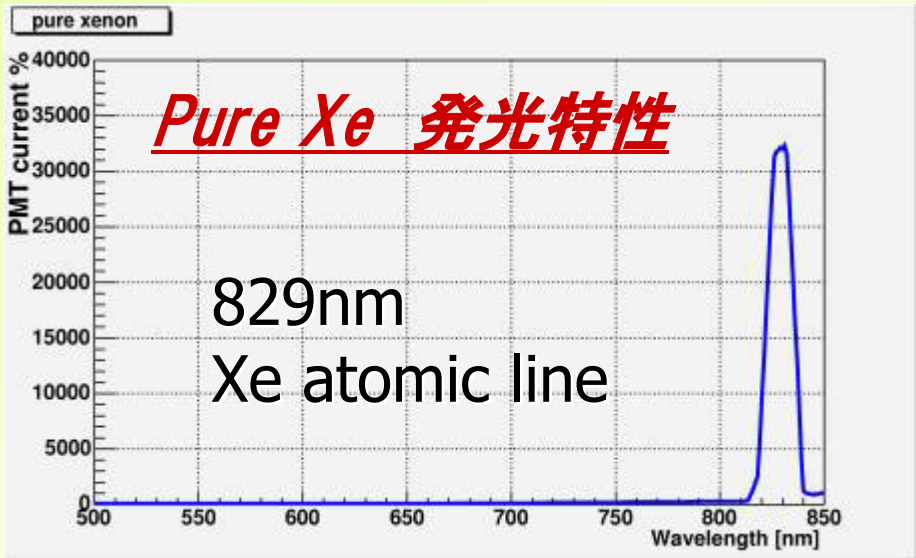


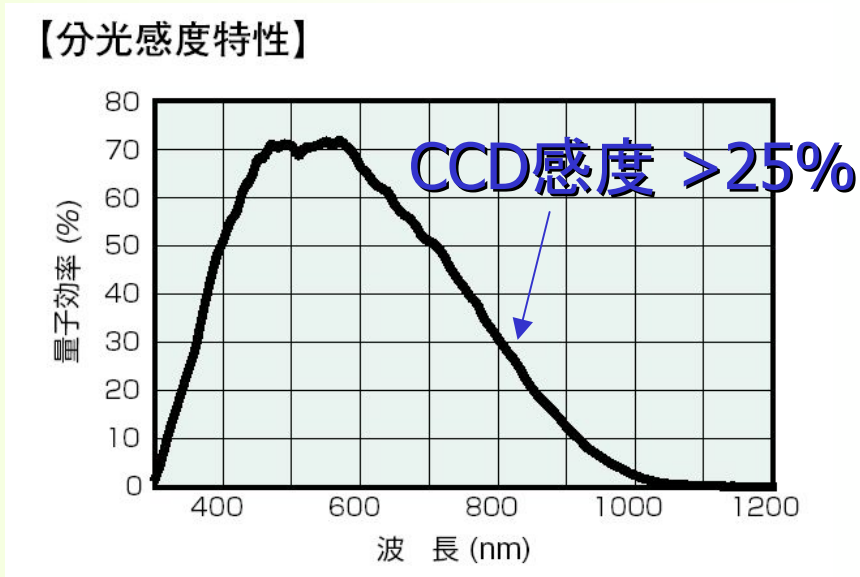


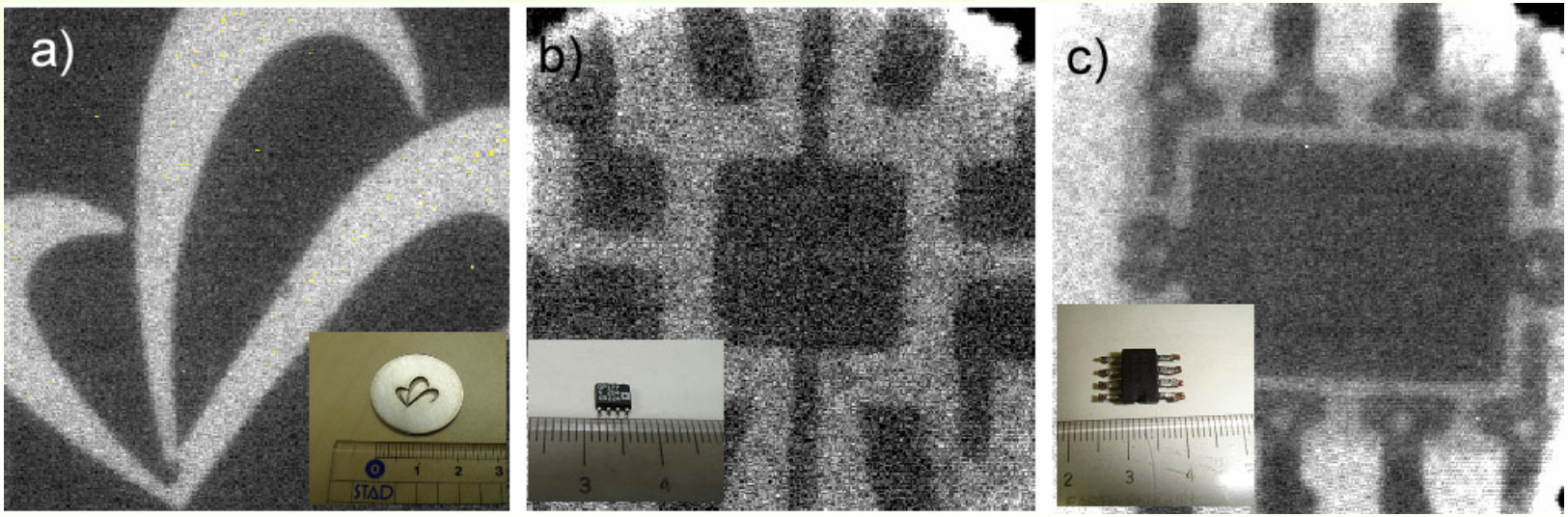
F. Tokanai et al.
submitted to IEEE TNS

ガスPMTの封入ガスの研究
（光電面との相性）

CPガス検出器の発光特性





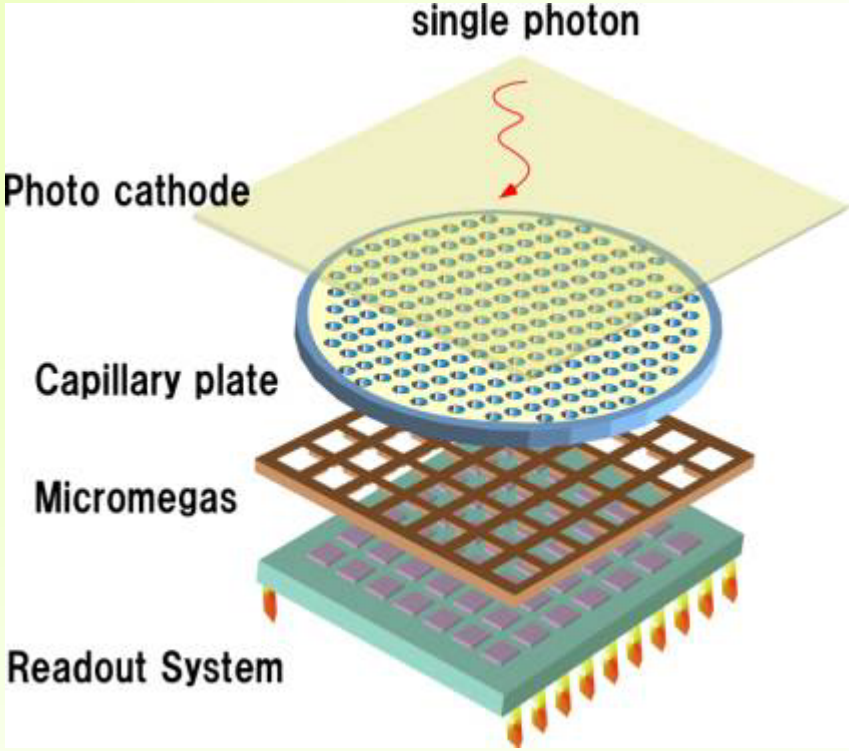


ガスPMTへの封入ガスの研究

現在までの開発状況

- ✓ CPガス検出器
- ✓ *Micromegas+CP*
- ✓ 光電面開発

CP+Michromegasを用いたガスPMT試験



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Nuclear Instruments and Methods in Physics Research A 535 (2004) 334–340
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Single electron amplification in a "single-MCP + Micromegas + pads" detector☆

J. Va'vra[a,*], T. Sumiyoshi[b]

[a]Stanford Linear Accelerator Centre, BIN 62, P.O. Box 4349, Stanford, CA 94309, USA
[b]Tokyo Metropolitan University, Tokyo, Japan

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Nuclear Instruments and Methods in Physics Research A 553 (2005) 76–84
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
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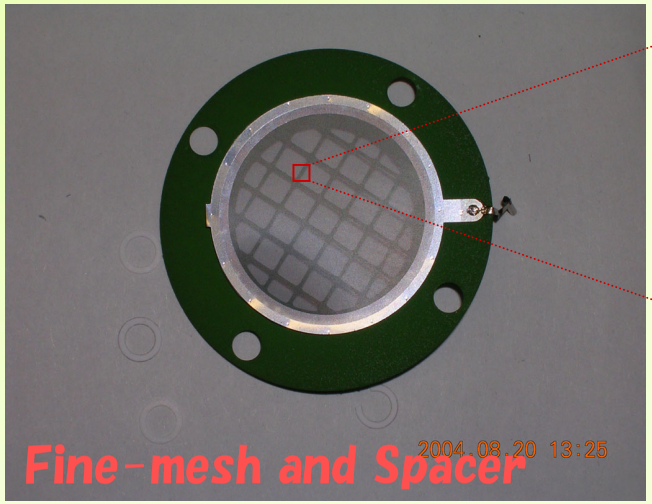
Ion feedback suppression using inclined MCP holes in a "single-MCP + micromegas + pads" detector

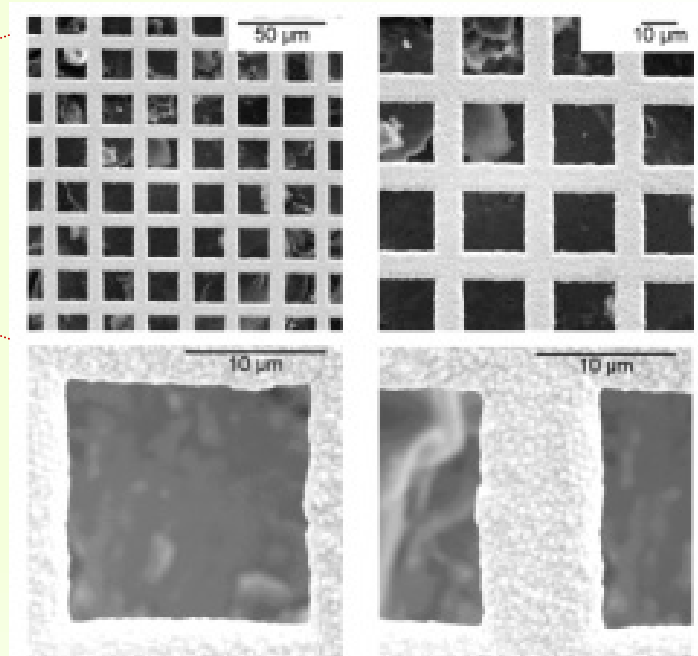
J. Va'vra[a,*], T. Sumiyoshi[b]

[a]SLAC, Stanford, CA 94305, USA[1]
[b]Tokyo Metropolitan University, Tokyo, Japan[2]

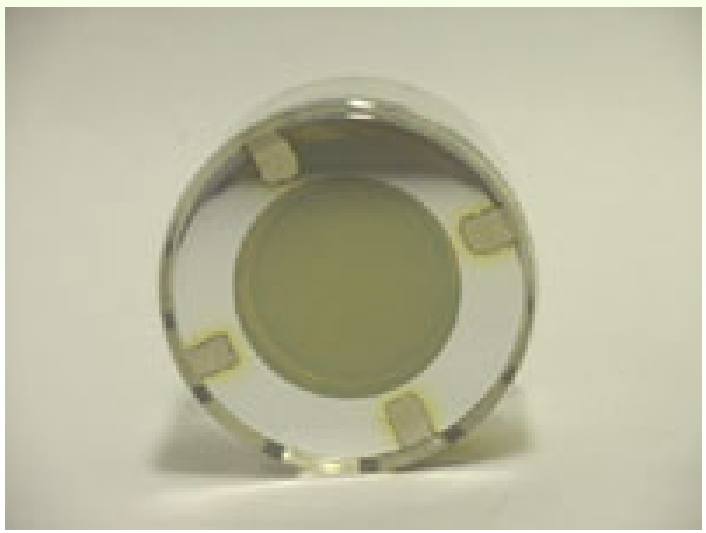
Available online 29 August 2005

Micromegas検出器の構造



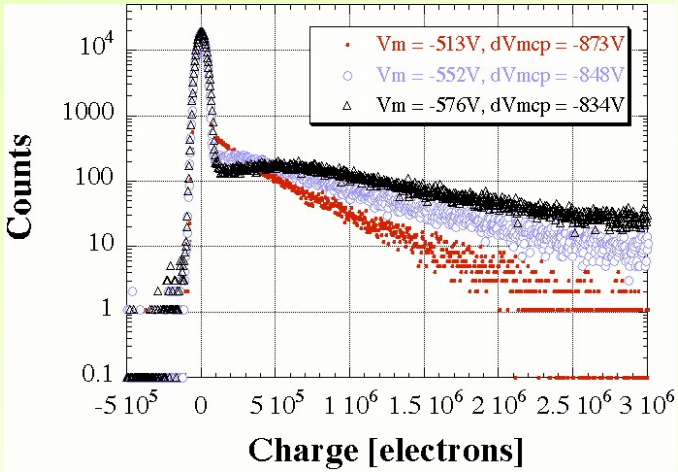


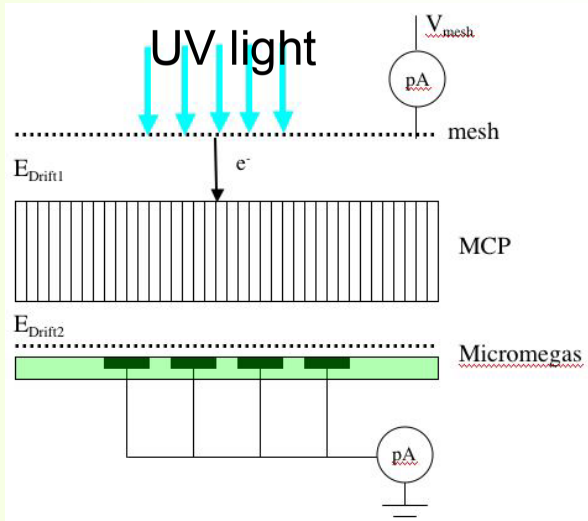
1000 lines per inch



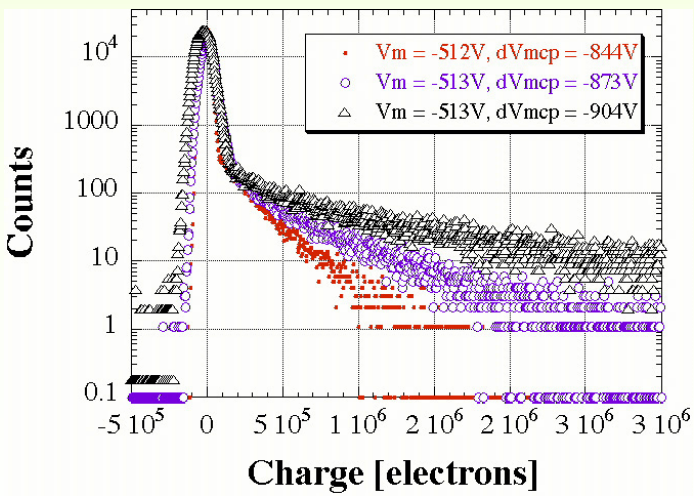
89.1%He+10.9%iC_4H_{10} gas at 1 bar

Vary Micromegas gain mainly:





Vary only the MCP gain:

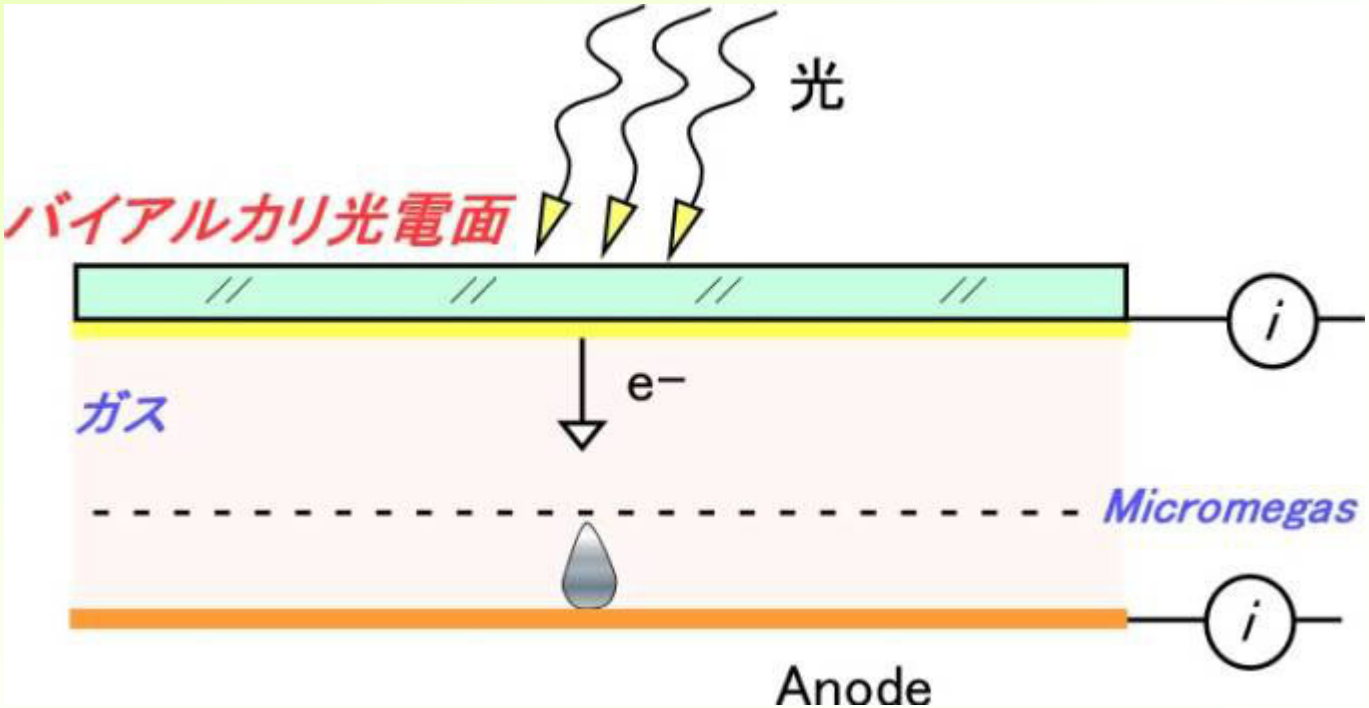


- **Very stable operation even at very high gain.**

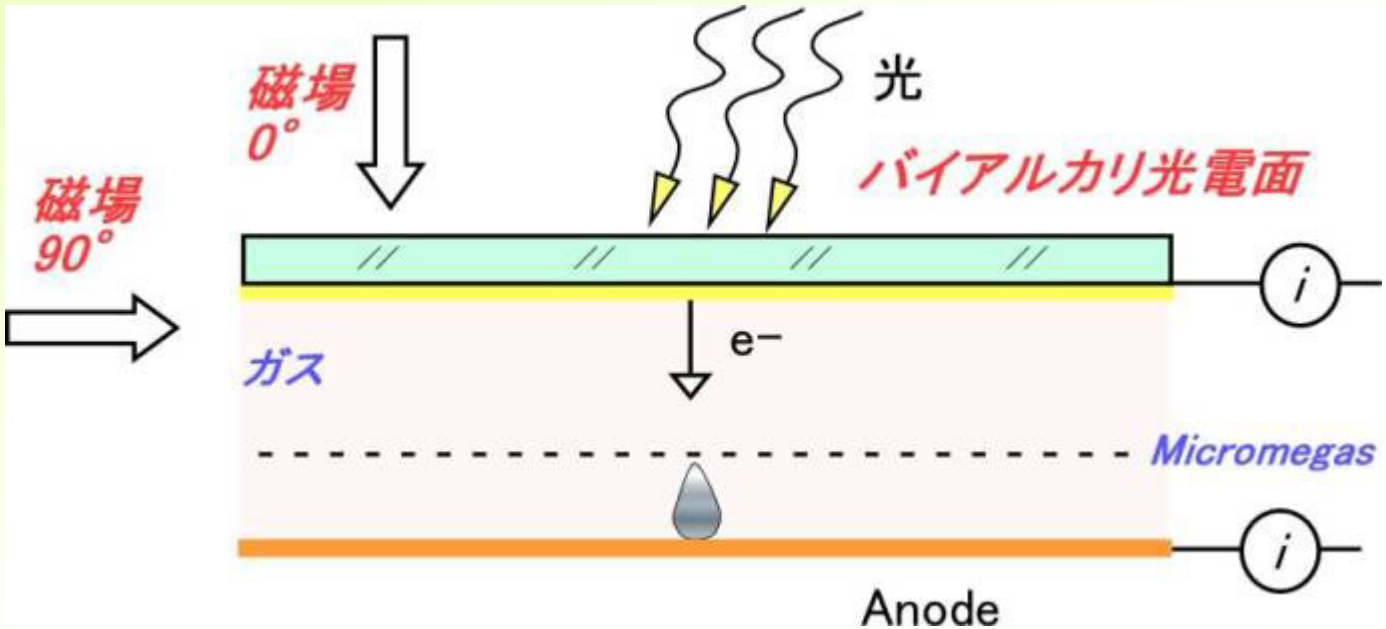
現在までの開発状況

- ✓ CPガス検出器
- ✓ Micromegas+CP
- ✓ ***光電面開発***

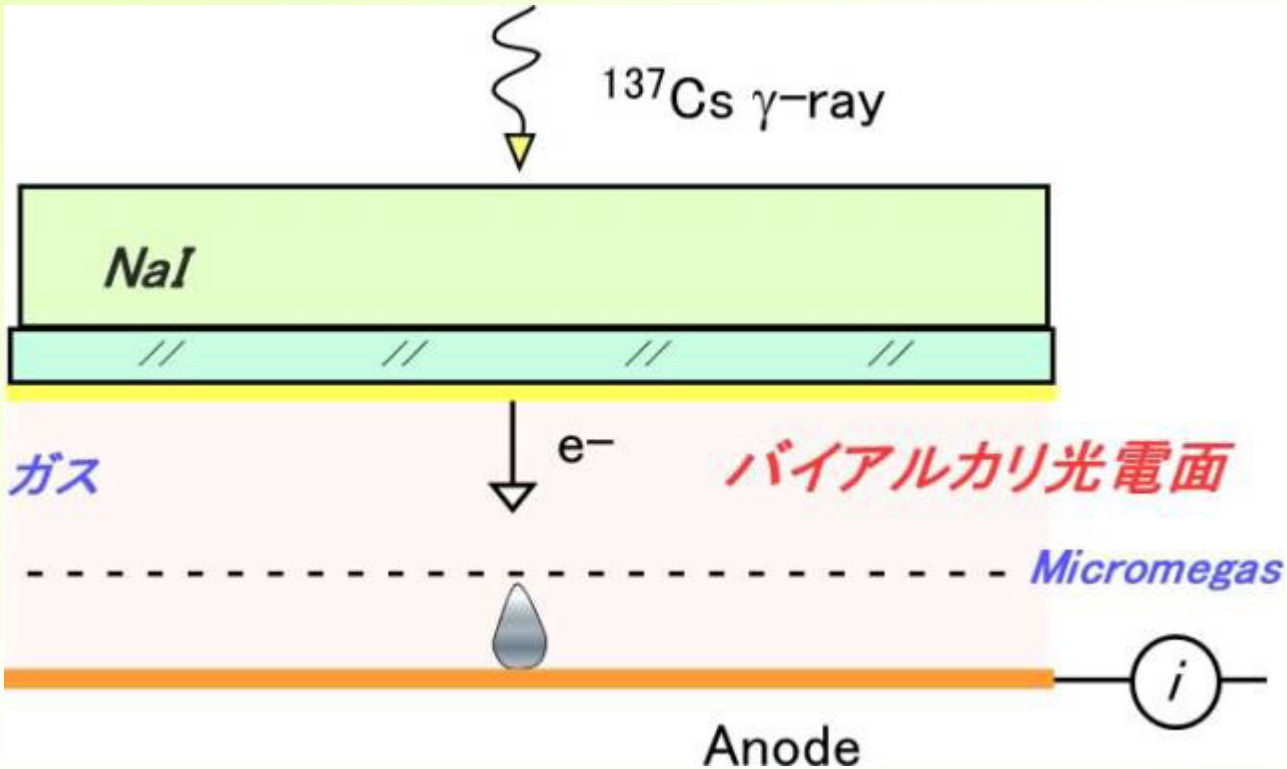
光電面特性 in GAS



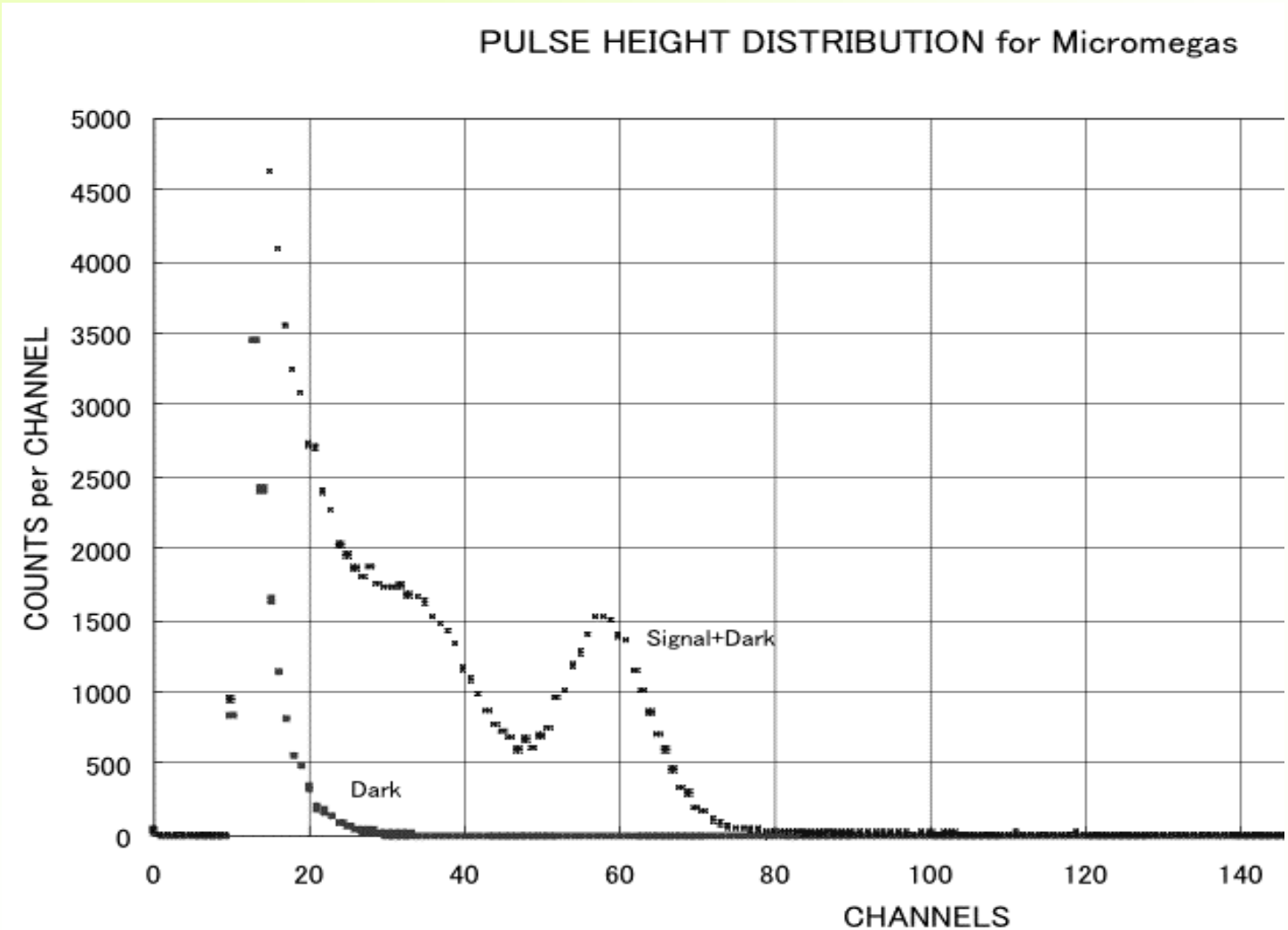
磁場中の光電面特性



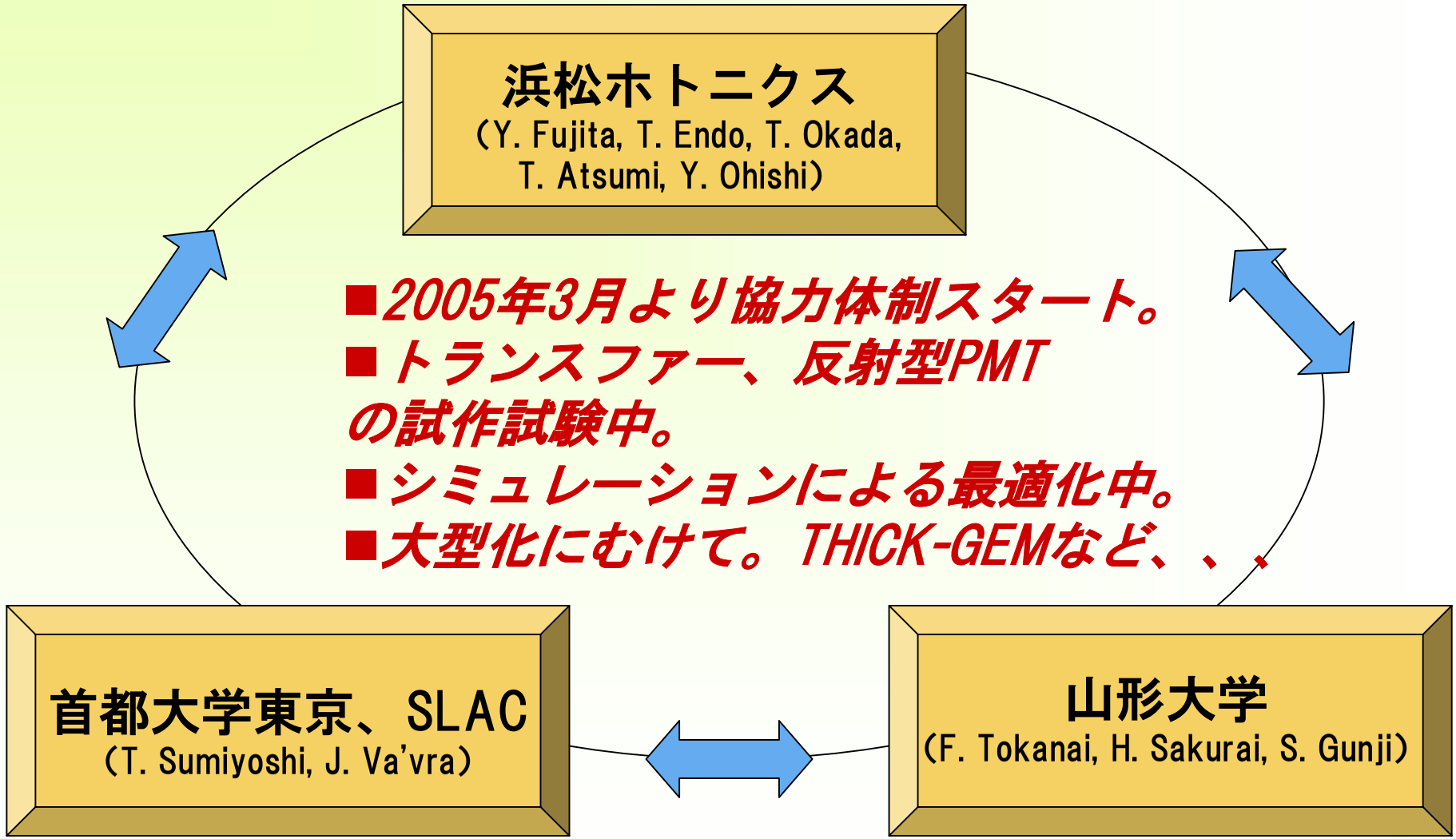
ガスPMTとしての試験



ガスPMTとしての試験

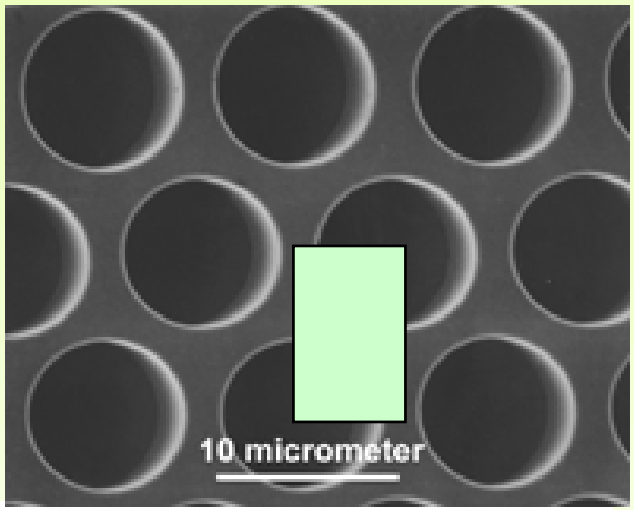


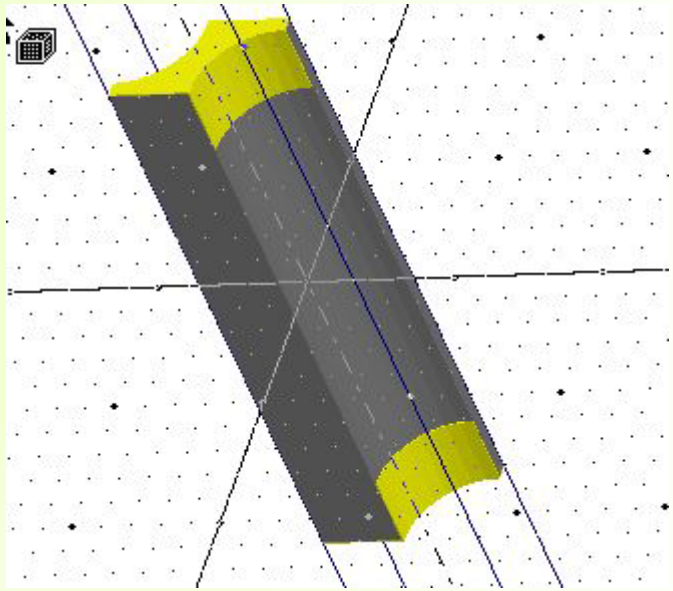
Hole-Type & Micromegasを使った マイクロパターンガスPMTのまとめ

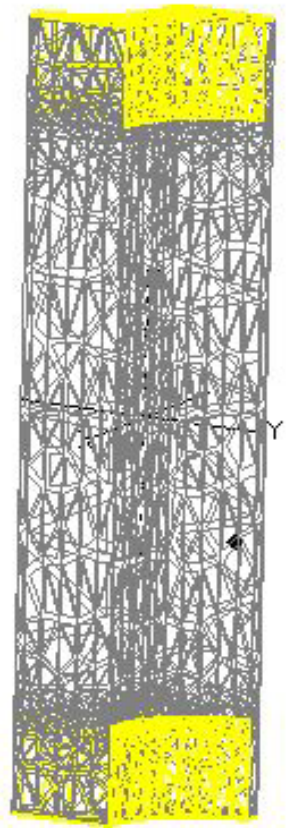


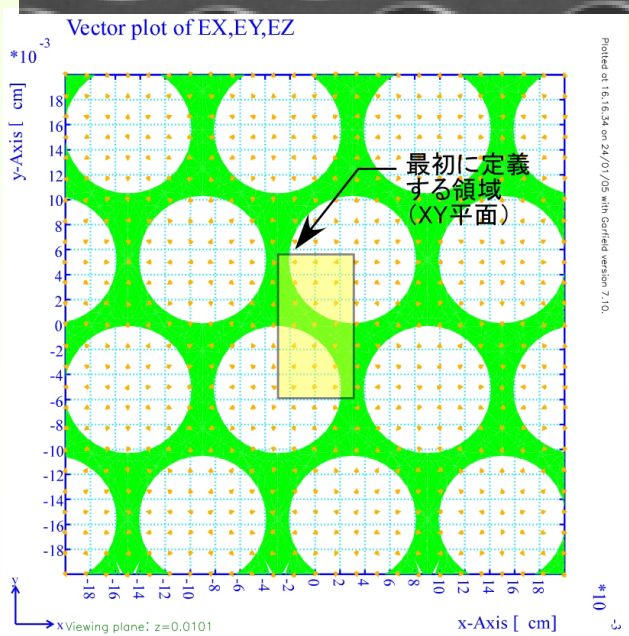
Maxwell&Garfieldを用いた最適化

Maxwell 3D









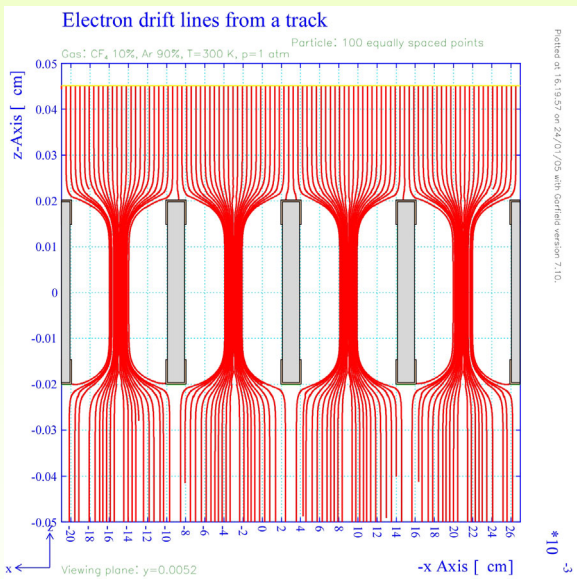
有限要素法（メッシュの分割）を用いた電磁場解析
山形大学に導入

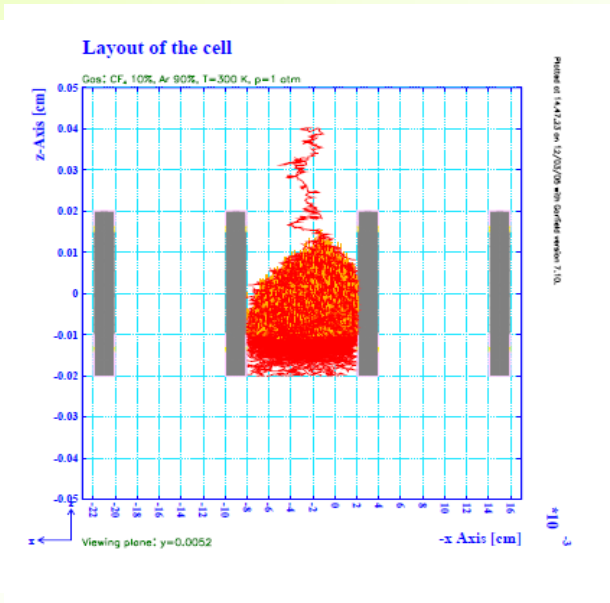
京都大学　谷森グループ

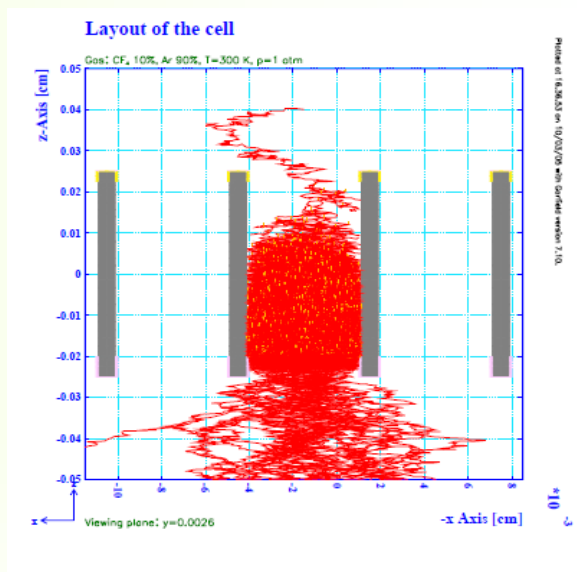
Maxwell&Garfieldを用いた最適化

Garfield

電子･イオンのガス中における運動解析

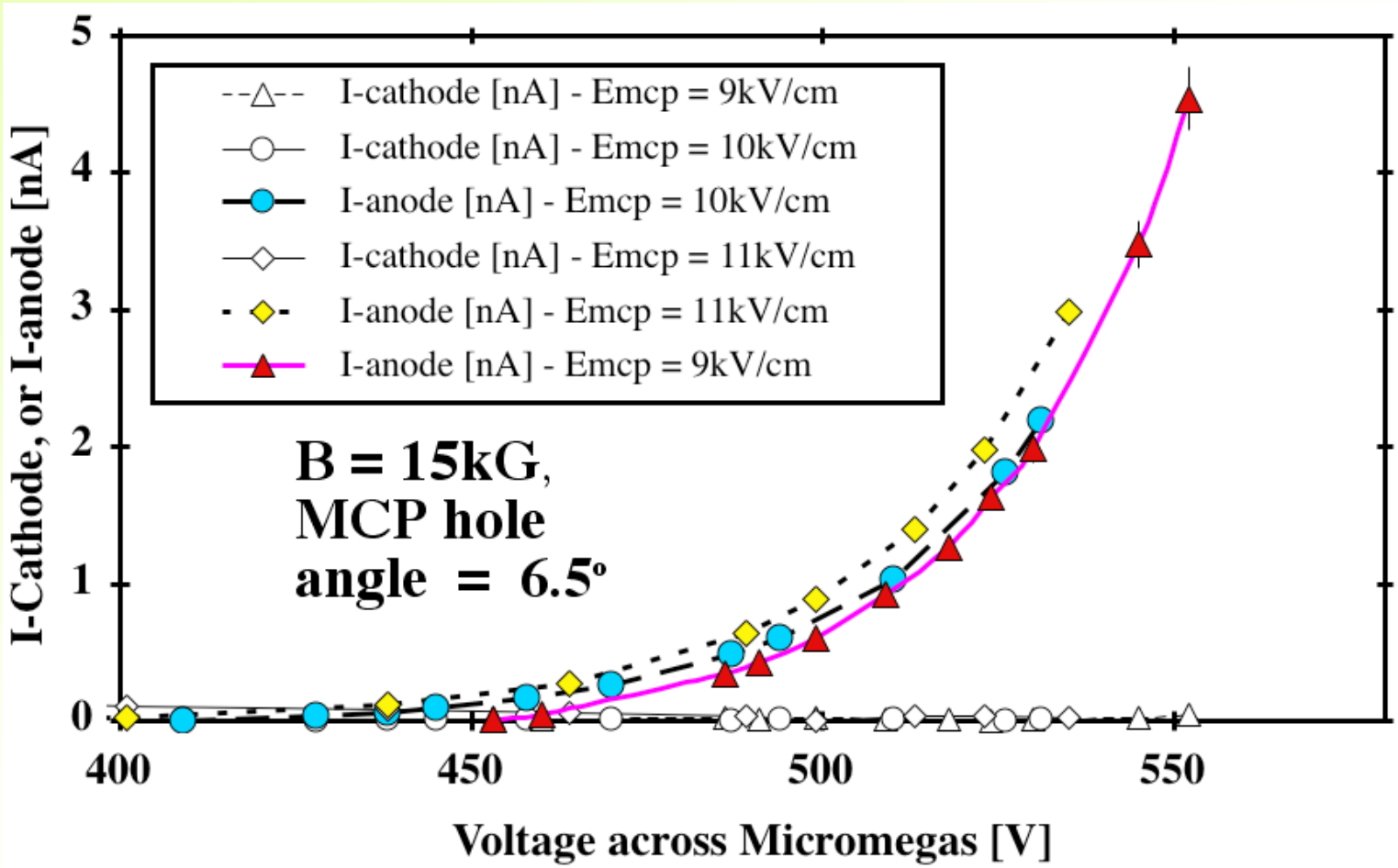






Maxwell & Garfieldを用いた3Dシミュレーションによる
システム全体設計と最適化

90%Ar + 10% CH_4 gas



- イオンフィードバックが見事に抑制される。