Focal-Plane Detectors for the SHARAQ Spectrometer

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Basic Ideas for Detectors' Design

Aim:

Dispersion-matching technique

against *energetically* and *angularly various* In-flight RI Beam

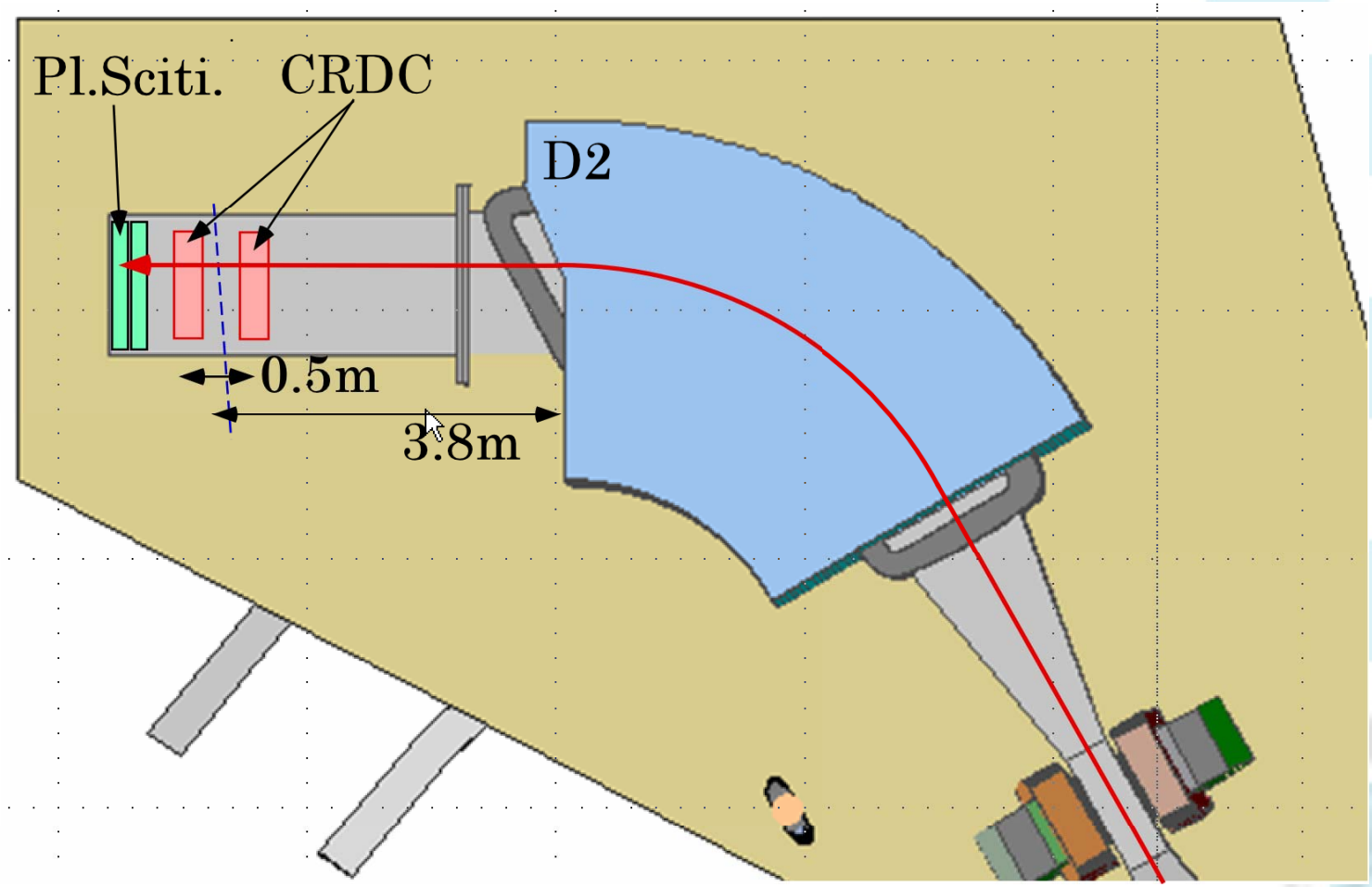
Detectors working for:

- Tuning for Dispersion-Matched Beam Transport
- Event-by-event measurement of beam trajectory
  to achieve the reaction Q value with a good resolution
  by canceling the x and θ dispersions
- PID of incident particles and Reaction products:
  Incident particles : BigRIPS
  Reaction Products: SHARAQ focal plane

Especially, Focal Plane Detector:

- Position on the last focal plane of SHARAQ with good resolution.
- PID for Reaction Products

Detector Setup at the Focal Plane



Requirements of Focal-Plane Detectors

for Good Position Resolution

- Little disturbing of the beam
  - Low Multiple Scattering: ~1 mrad (σ) ⇒Low gas pressure
- Precise measurement of momenta
  - High Position Resolution: ~300 μm (FWHM)
    - [30 cm*1 mrad ~ 300 μm]

for Measurement of RI-induced Reactions

- Overcoming of Low intensity
  - High Detection Efficiency → 100 % for light particles
- Count rate at the Focal Plane is not so high ... ~ 10^4 Hz

for PID of Reaction Products

- Light mass particle (Z~6) → ΔE-TOF-Bρ by CRDC+Plastic

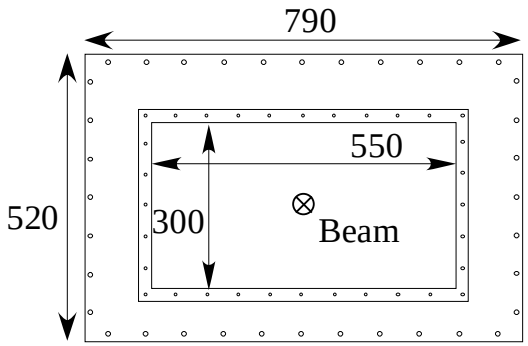
We have selected

Drift Chambers Operated with Low Pressure

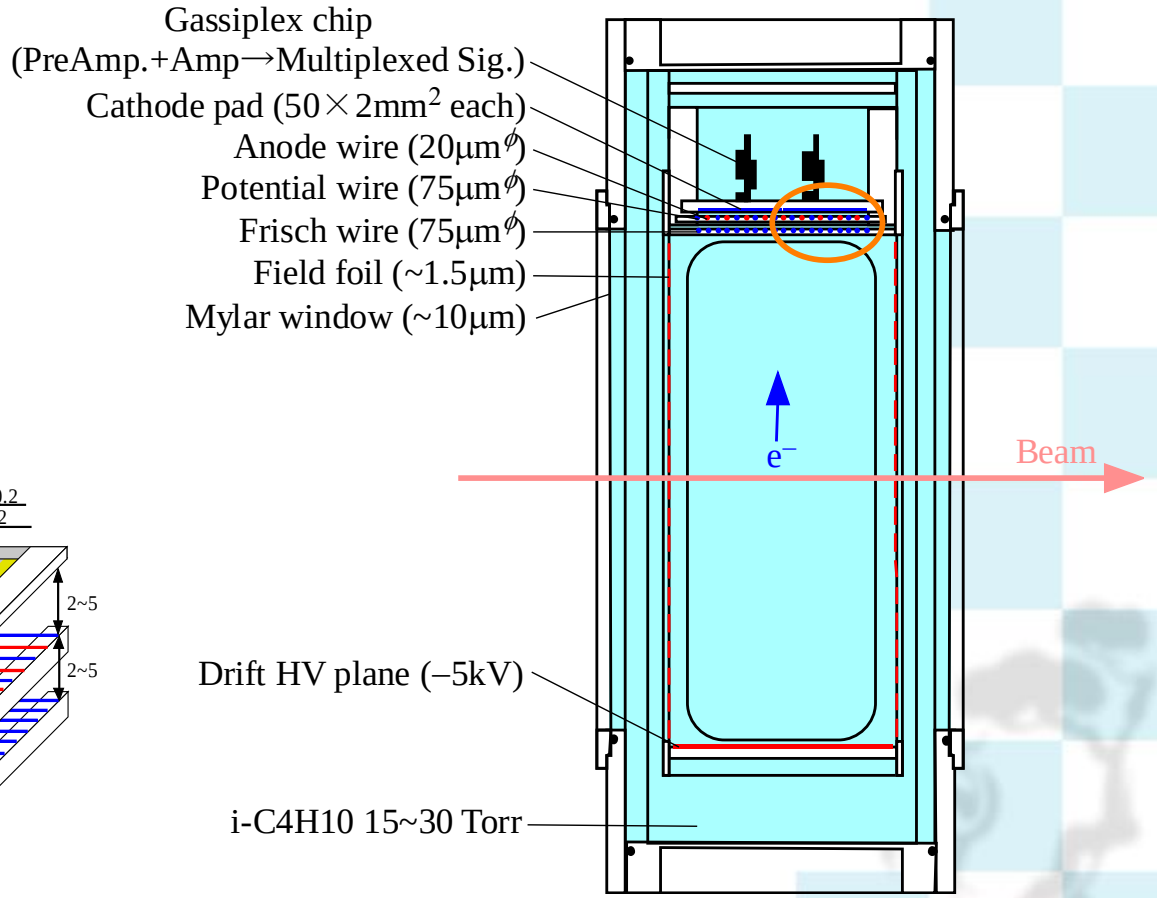
and **Plastic Scintillator Hodoscope**

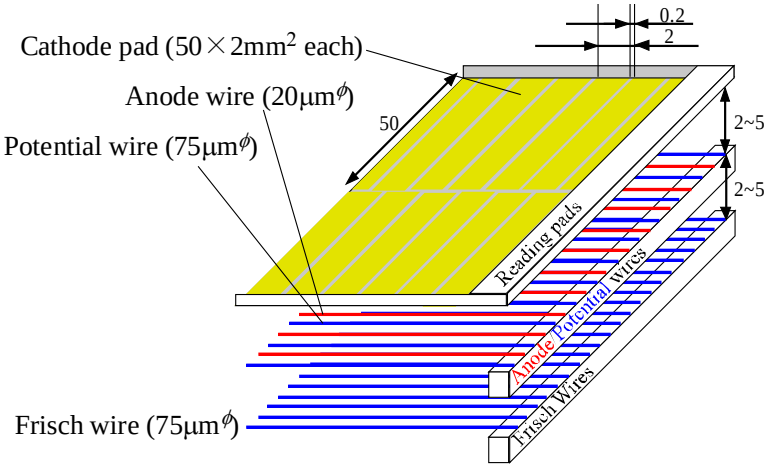
Design of Focal-Plane Detector

Size of CRDC



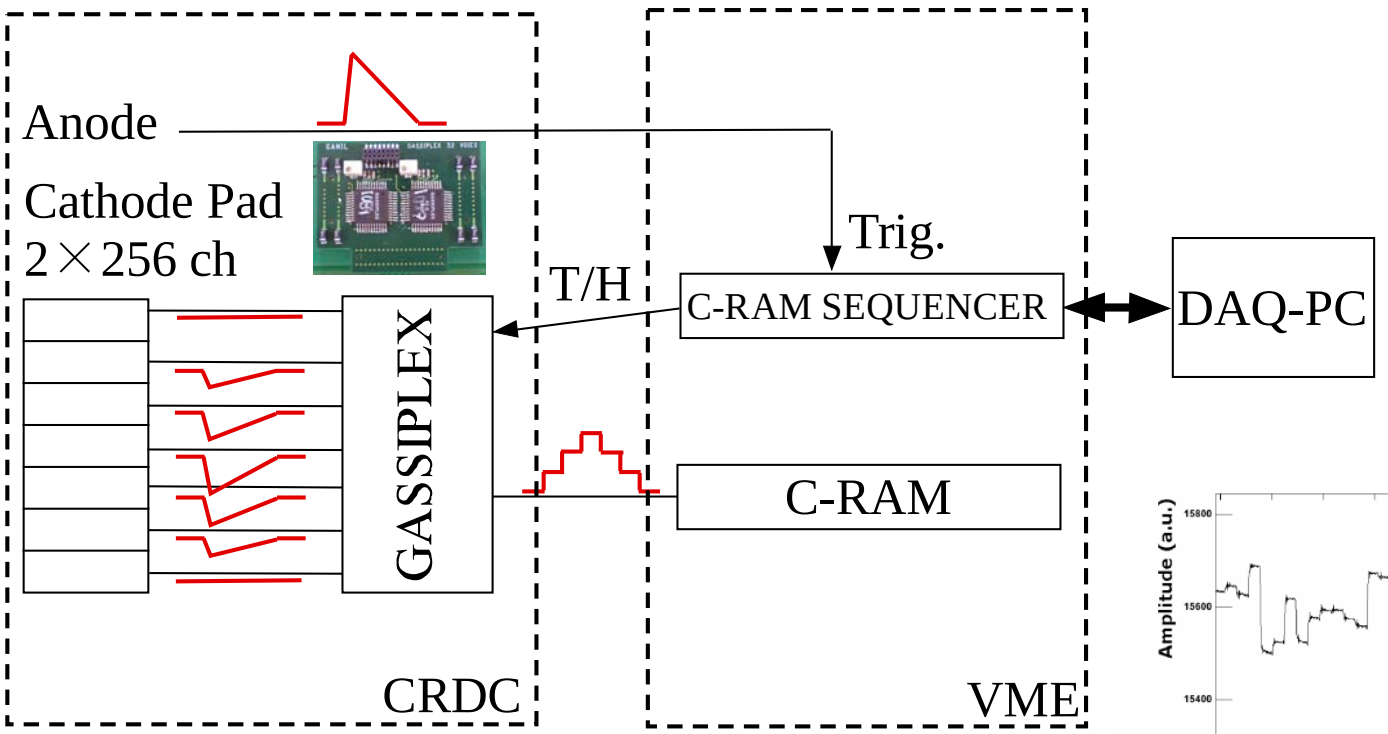
Cross-section view and specification of CRDC





Readout of the CRDC

Anode: PreAmp+Discri → Timing signal + Trigger of cathode readout
Cathode: Multiplexered readout using GASSIPLEX chips



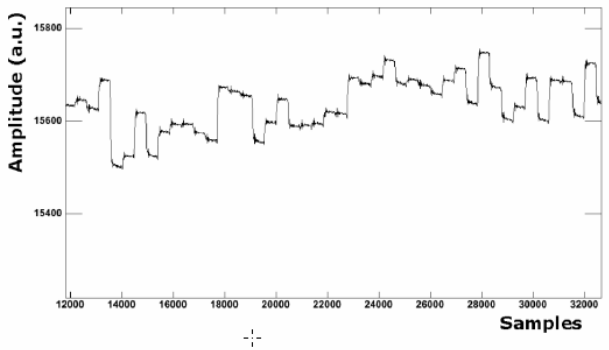


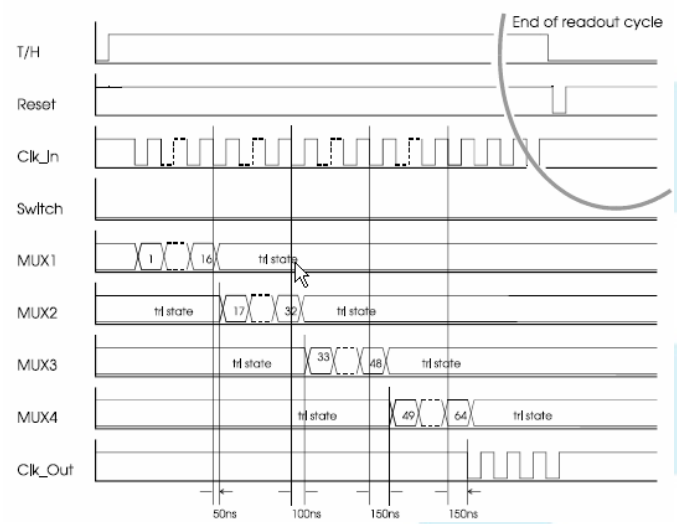
Fig. 2 - Typical baseline position histogram ("pedestals") from a GASSIPLEX, magnified from bin n. 12 up to bin n. 56.

Readout of the CRDC

Spec. of GASSIPLEX

Formatting Time	1.2 μsec
Regulating of Formatting Time	1.1 – 1.3 μsec
Noise at 0 pF	530 e^- rms
Slope of Noise Curve	11.2 e^- rms/Pf
Positive Dynamic Range (Output)	0 – 560 fC (0 – 2 V)
Negative Dynamic Range (Output)	0 – −300 fC (0 – −1.1 V)
Gain	2.2 mV/fC
Nonlinearity	± 2 fC
Return to Baseline	±5 % after 5 μsec
Maximum Reading Frequency	10 MHz
Power consumption at 10 MHz	8 mW/channel

Time Diagram of GASSIPLEX



Needed Time

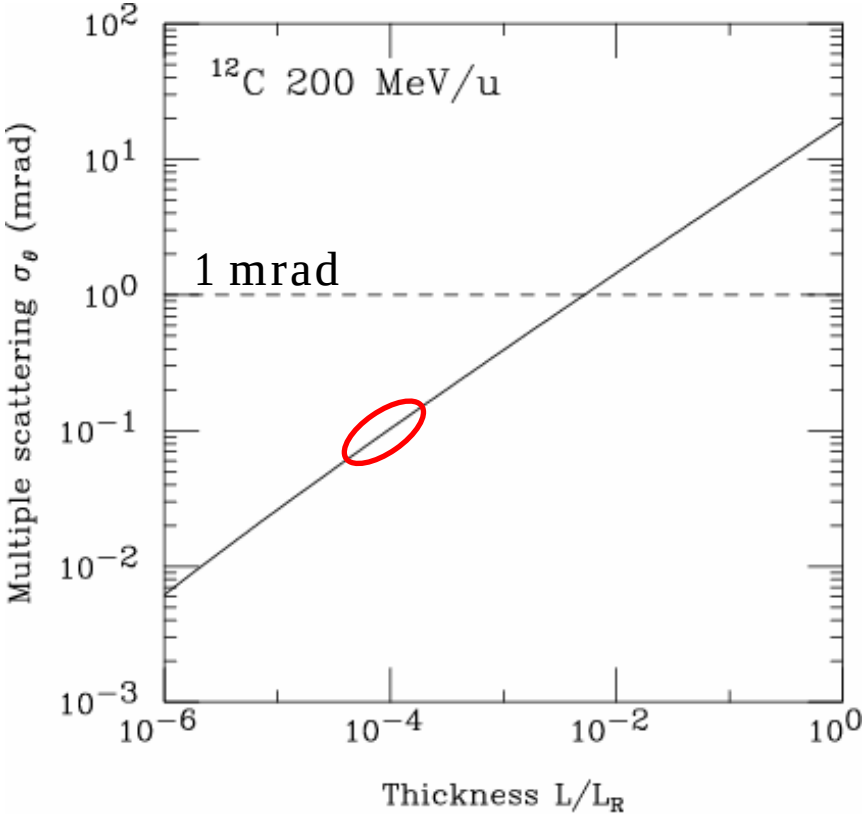
Buffer Format	1.2 µs
Readout per 16ch(1 chip)	(1600 + 50) ns
Total (256ch)	~30µs

→ up to 10^4 Hz

Disturbing of the Trajectory

Multiple Scattering

Molière Theory: $\sigma_\theta \propto (L/L_R)^{1/2} \cdot (1+1/9 \cdot \mathrm{Log}_{10}[L/L_R])$



$L/L_R \sim 10^{-4}$
$\rightarrow \sigma_\theta \sim 0.1$ mrad

Position Resolution

Focal-Plane Detector

$$R\ (\mathrm{FWHM}) \sim 2.35 \times \sigma_T \times (L/N)^{1/2}$$

σ_T : Transverse Diffraction per unit length

L : Drift Length = 30 cm

N : # of generated electron-ion pair

$\sim \Delta E/W_i = \Delta E/23$ eV

An example case:

^{4}He @ 200 MeV/u

p = 30 torr, Vdrift = 5kV → E = 167 V/cm

Transverse Diffraction: $\sigma_T \sim 600$ μm/cm

Energy Deposit

$\Delta E \propto Z^2 \times p \times t$,

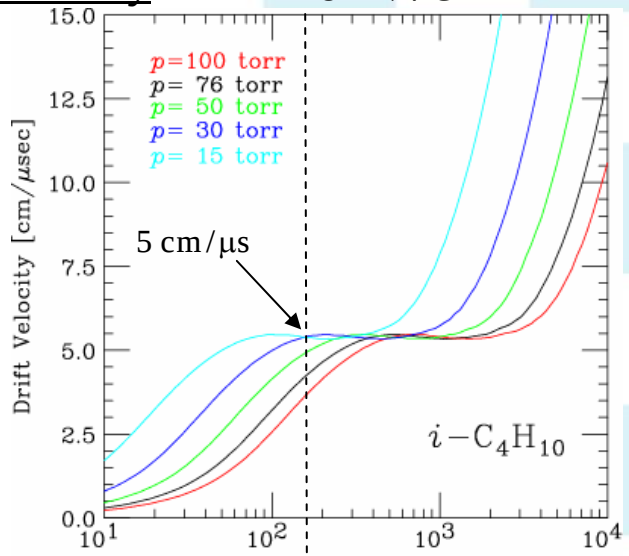
$\Delta E \sim 19$ keV → N ~ 830 pairs

[6 eV/torr/mm @ ^{4}He 200 MeV/u]

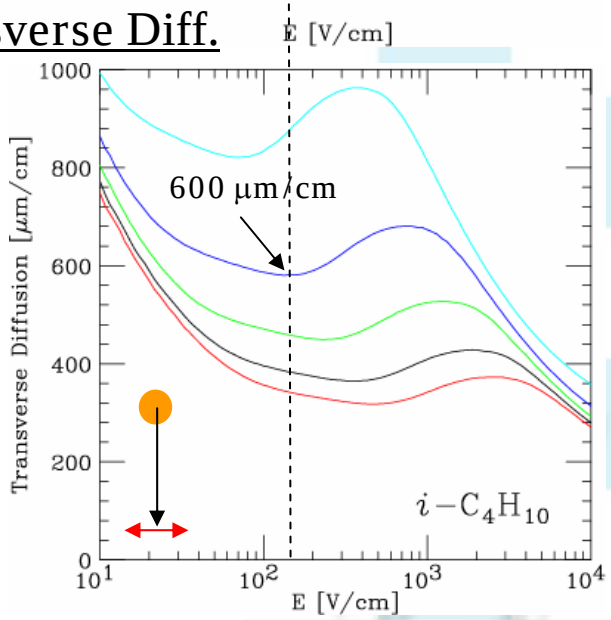
$R \sim 2.35 \times 600 \times (30/830)^{1/2}$ = **270 μm (FWHM)**

(^{12}C @200 MeV/u:
240 μm (FWHM) by 15-t0rr operation.)

Drift velocity 167 V/cm



Transverse Diff.



Required Gas Gain

Gas Gain Factor (G)

$Q = \varepsilon \times G \times (\Delta E / 23\ \text{eV})$

[ε : mirror charge efficiency]

Q for Gassiplex: ~ 150 fC ~ 10^6 e^-

[Range < 300 fC]

An example case:

(1) ^{4}He @ 200 MeV/u, p = 30 torr

$\Delta E/23$ eV ~ 830 e^-

ε ~ 0.1

$\Rightarrow$ $G \sim 1.1 \times 10^4$

(2) ^{12}C @200 MeV/u, p = 15 torr

$\Delta E/23$ eV ~ 3700 e^-

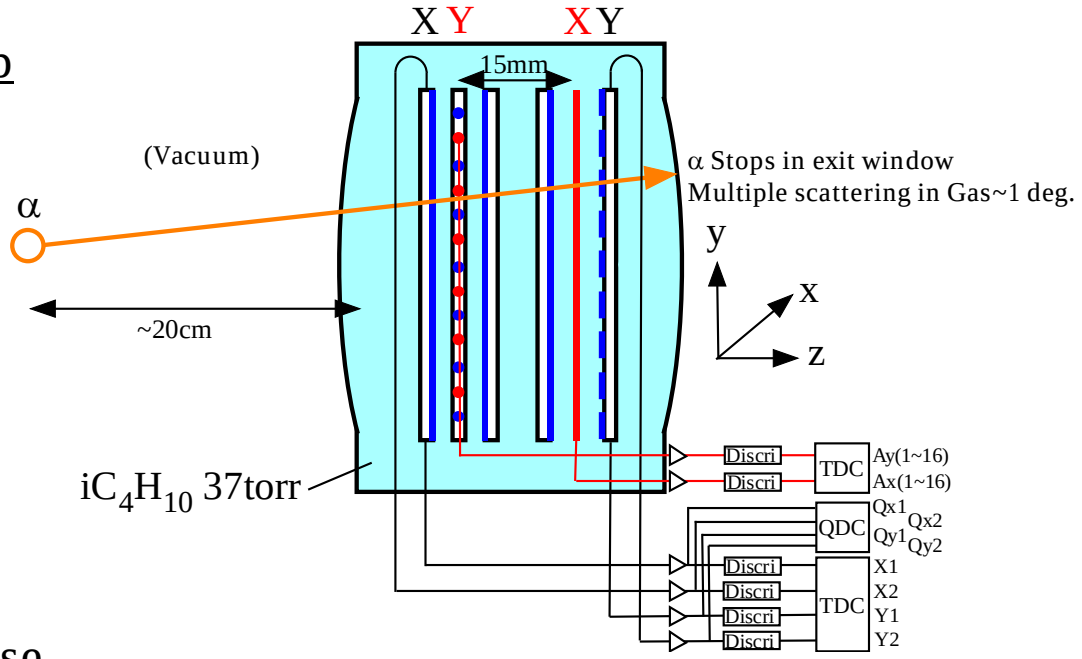
ε ~ 0.1

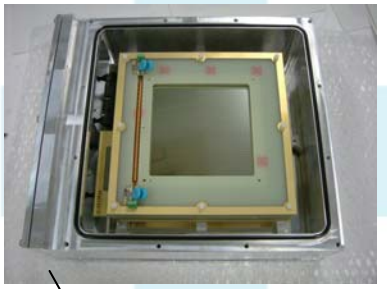
$\Rightarrow$ $G \sim 2.5 \times 10^2$

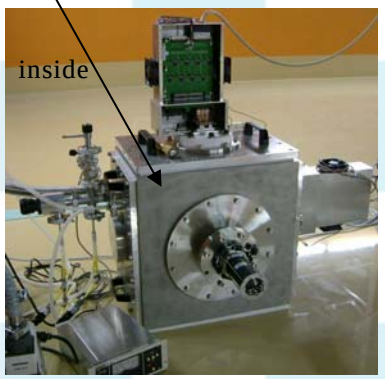
Required Gain is 100 ~ 10000 (need control)

MWDC Test using Alpha source

Setup







Purpose

- First operation of MWDC (proto type)
- Debug/Development of
  pulse-processing electronics and Data acquisition

Estimate:

- Position Resolution of Delay-line readout (Cathode)
- Avalanche gain as functions of Gas Pressure and HV

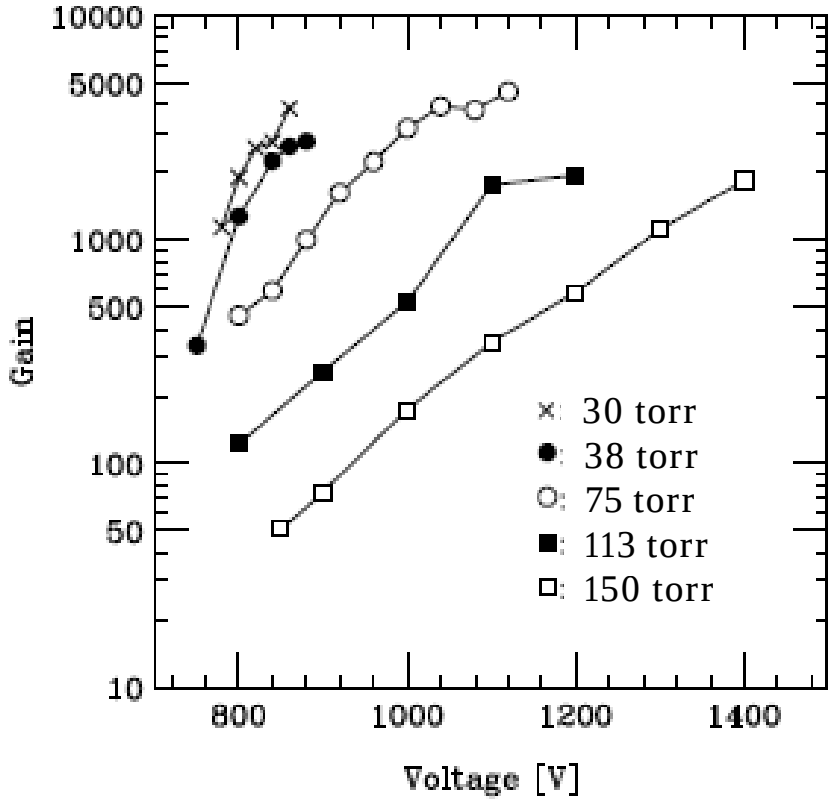
Avalanche Gain

$G \sim Q/(\Delta E/23\ eV)$

Q: Mirror Charge delivered from cathode readouts.

ΔE: believed the Zeegler estimation

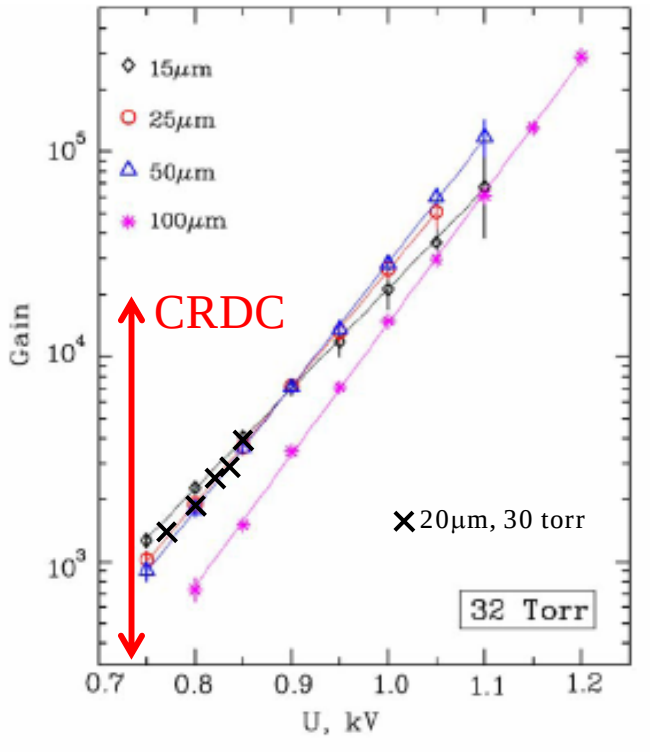
$\Delta E/23$ eV ~ electron-ion pair generated by alpha

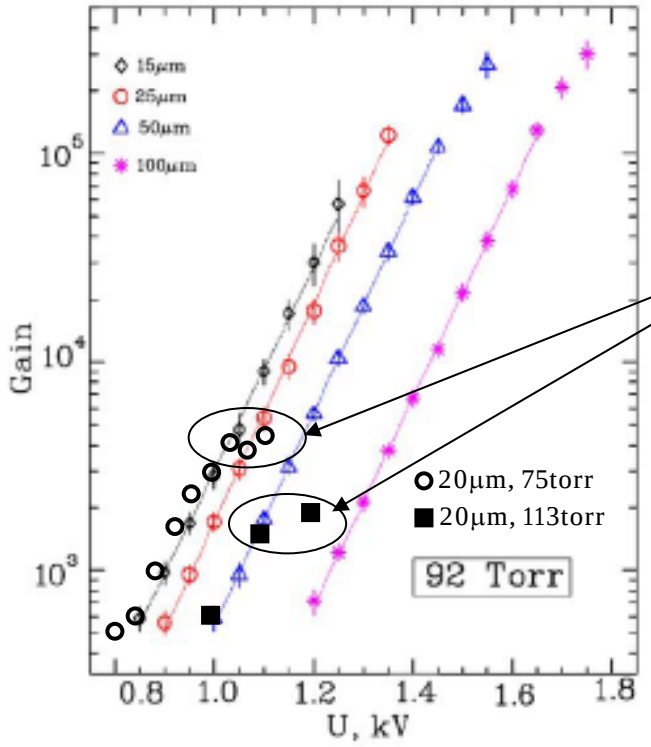


Avalanche Gain

Compare with Previous Data:

Yu.I.Davydov et al: NIM A 545 (2005) 194. (using 5.9-keV X-ray)





Saturation of Preamp?

- **Avalanche gain is consistent with Previous Data**
- **Required gain is achieved with HV < 1kV**
- **Need to test for 15-torr Operations**

Development Plan

Focal-plane CRDC

Designing CRDC is almost finished (GANIL, present)

Operation test of GASSIPLEX and Electronics (CNS, 2008/3~)

Manufacturing (GANIL, 2008/5-2008/8)

Operation test using α source (GANIL, 2008/9)

Delivery from GANIL to CNS (2008/10)

Operation test using a beam (position resolution, gain, position dep. etc...)

2009/3 SHRAQ operation will start

Summary

We have developed CRDC for focal-plane detectors to perform dispersion-matching experiments

- Low Multiple scattering
- Good position resolution
- High efficiency

CRDC were designed with

- Low gas pressure 15~30 torr operation
- Detectors with small density ($L/L_R \sim 10^{-4}$)
- Position Resolution (300 um FWHM)
- High counting rate (up to 10^4 Hz)

At low gas pressure (15~30 torr)

- Required gas gain is achieved.

Present Status: CRDC has designed, next manufacturing.

Collaborators

Focal-plane Detectors:

S. Michimasa, S. Shimoura, T. Uesaka, H. Sakai,
P. Roussel-Chomaz, R. Raabe, J. Gibelin