Beam-line and Focal-Plane Detectors for the SHARAQ Spectrometer

Shin'ichiro Michimasa
CNS, Univ. of Tokyo.

CNS

銀杏
ICHOR

GANIL
GRAND ACCELERATEUR NATIONAL D'IONS LOURDS
LABORATOIRE COMMUN DSM/CEA-IN2P3/CNRS

Basic Ideas for Detectors' Design

Aim:

Dispersion-matching technique

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

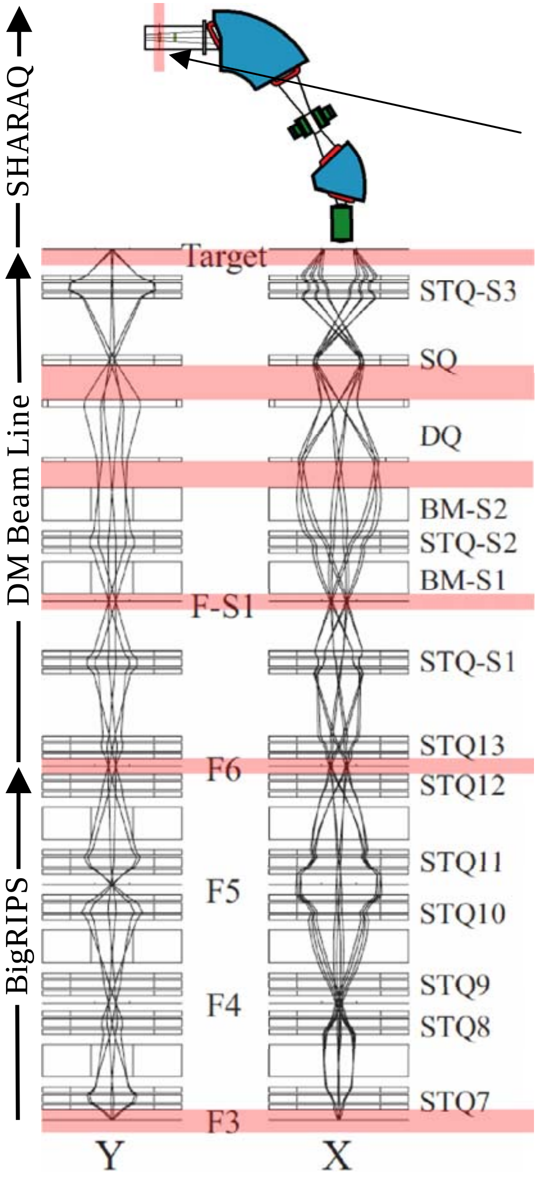
Detectors working for:

- 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

Arrangement of Detectors



	Beam Tuning	Exp.
S5	✓	✓ $\vec{p}_{out}$/PID
S4/FS3	✓	✓ $\vec{p}_{beam}$
S3/FS3	✓	
S2	✓	
S1/FS1	✓	
F6	✓	
F3	✓	✓ $\vec{p}_{F3}$ /Spot Size monitoring

Beam Tuning

- Confirmation of beam transport
- (x,y) and (x’,y’) at all points

Experiment

- $\vec{p}_{F3}$: essential for DM correction
- $\vec{p}_{out}$: Reaction Q value
- $\vec{p}_{out}$-$\vec{p}_{beam}$: Scattering Angle

Requirements of Tracking Detectors

for dispersion matching

- Little disturbing of the beam
  - Low Multiple Scattering: ~1 mrad (σ)
  - Low Energy Straggling: < 1/1650 (Energy Resolution of BigRIPS)
- Precise measurement of the beam trajectory
  - High Position Resolution: ~300 μm (FWHM)
    - [30 cm*1 mrad ~ 300 μm]

for using RI Beam

- Overcoming of Low intensity
  - High Detection Efficiency → 100 % for light particles

in Beam-line detectors, especially

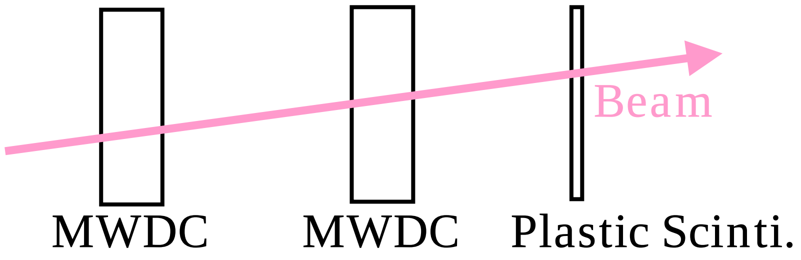
- Operate under High Counting Rates → ~1 MHz

We have selected

Drift Chambers Operated with Low Pressure

Design of Beam-line Detector

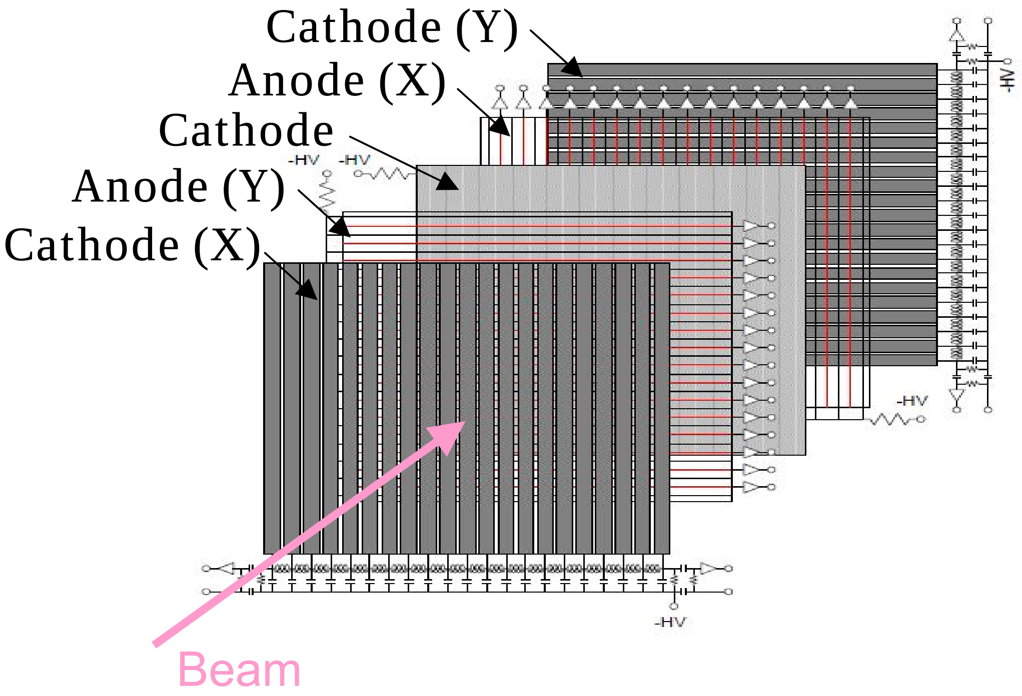
Detector setup at each focus of BL



Beam

MWDC MWDC Plastic Scinti.

MWDC with low gas pressure
(100*100 proto-type)



Cathode (Y)
Anode (X)
Cathode
Anode (Y)
Cathode (X)

Beam

Specifications:

Thickness
- Gas Window: 12μm
- Cathode: 2.2μm
- Anode wire: $20\mu m^{\phi}$
- Potential wire: $75\mu m^{\phi}$
- Gas: isobutane 75~150 Torr
- Total: $t/L_R \sim 10^{-4}$

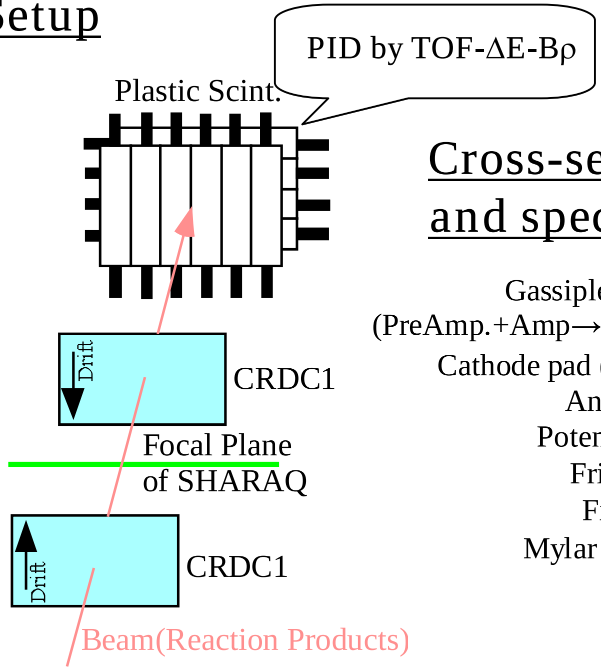
Effective area :
□□□100×100 (for achromatic focus)
□□□216×144 (for dispersive focus)

Readout (100×100/200×140)
- Anode: 32 ch / 88 ch
- Cathode: Delay Line 4 ch (X,Y)

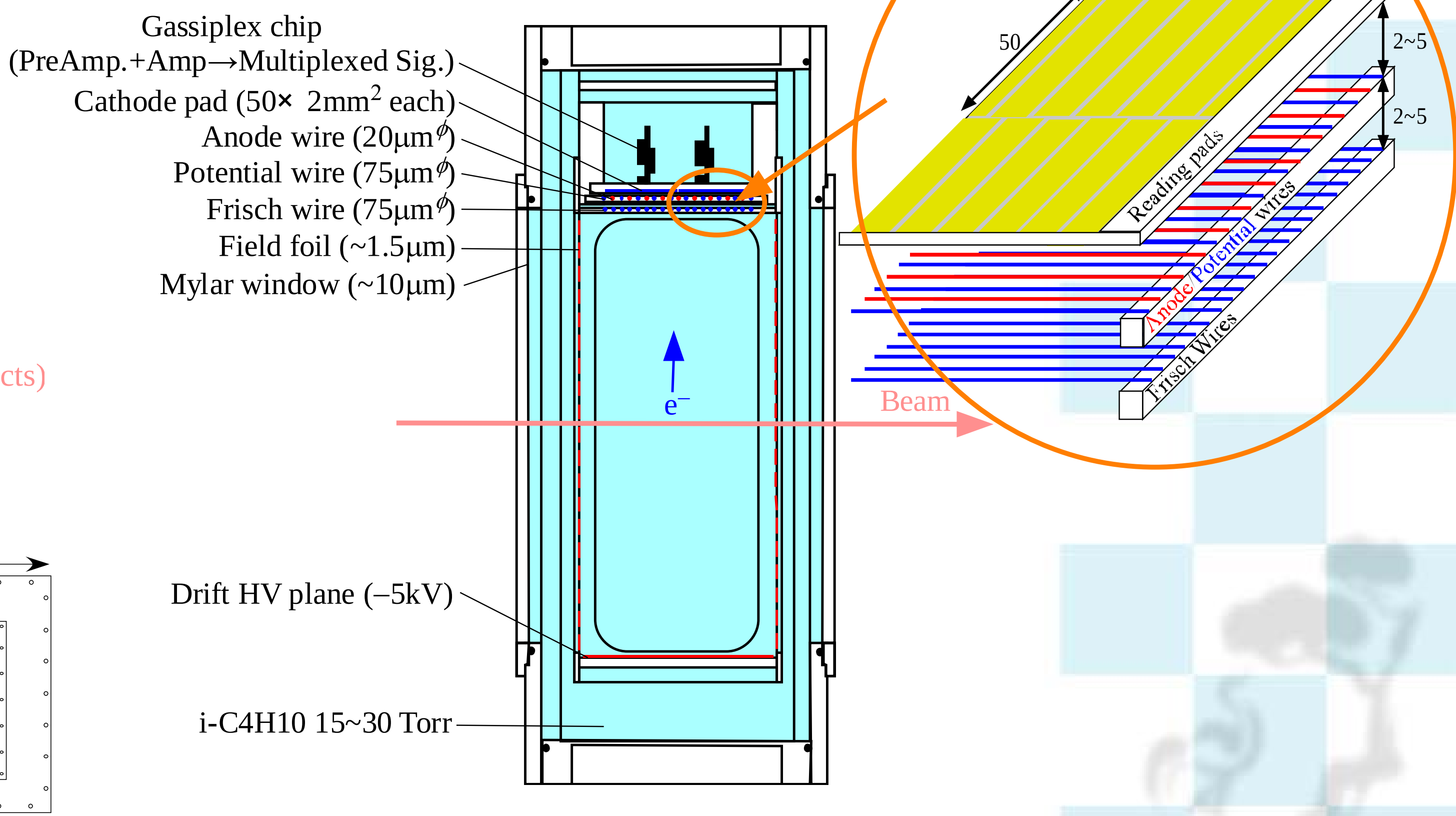
Position Info.
- Anode: Wire ID + Drift time
- Cathode: Delay-line

Design of Focal-Plane Detector

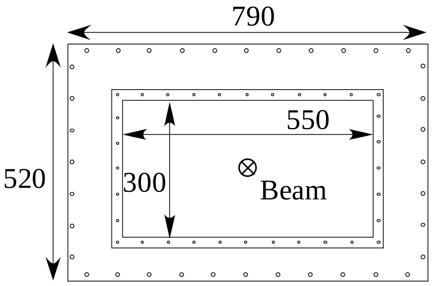
Setup



Cross-section view and specification of CRDC


Gassiplex chip
(PreAmp.+Amp→Multiplexed Sig.)
Cathode pad (50× 2mm^2 each)
Anode wire (20μm$^\phi$)
Potential wire (75μm$^\phi$)
Frisch wire (75μm$^\phi$)
Field foil (~1.5μm)
Mylar window (~10μm)
Drift HV plane (–5kV)
i-C4H10 15~30 Torr

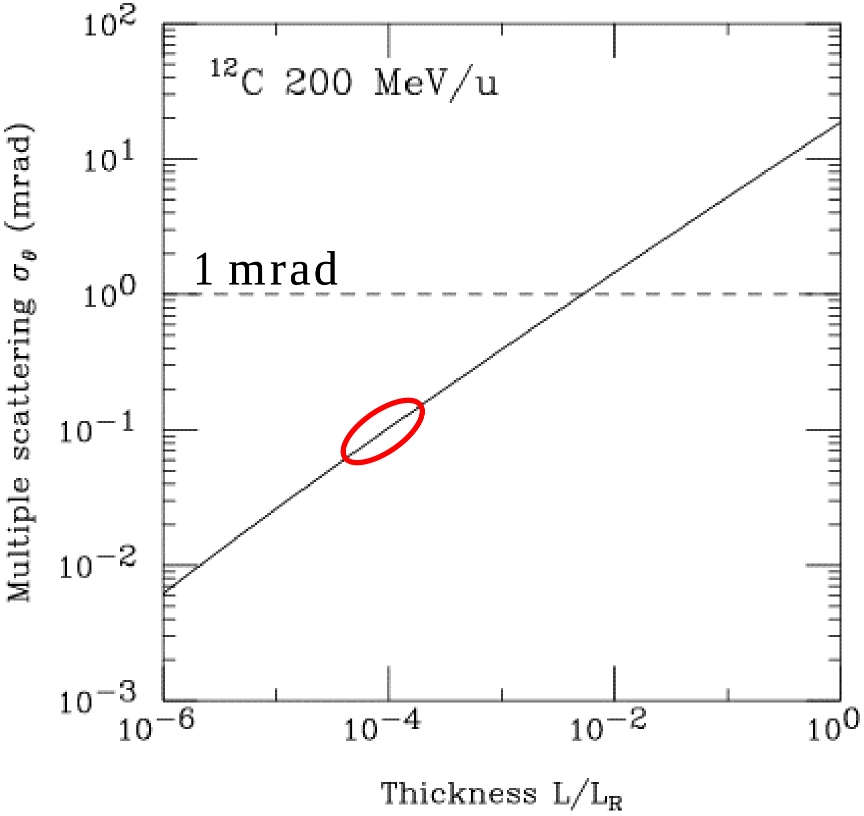
Size of CRDC



Disturbing of the beam

Multiple Scattering

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



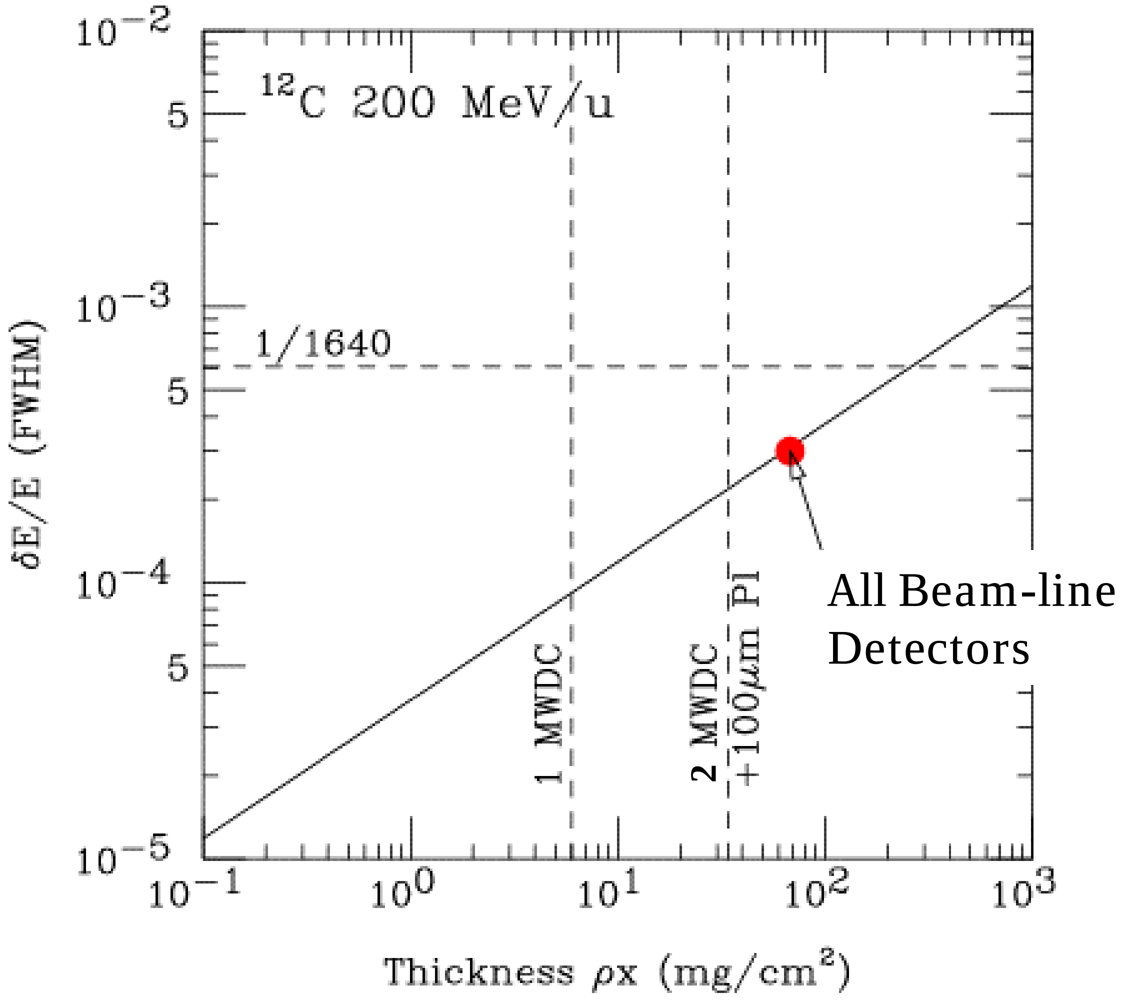
$L/L_R \sim 10^{-4}$

→ $\sigma_\theta \sim 0.1$ mrad

Disturbing of the beam

Energy Struggling

Vavilov Theory: $dE/E \square Z^2 \square (\rho x)^{1/2}$



All Beam-line Detectors

1 MWDC:
t ~ 6 mg/cm^2
→ δE/E~ 10^{-4}
All BL detectors:
t ~ 68 mg/cm^2
→ δE/E~ 3×10^{-4}

Position Resolution

Beam-line Detector

Resolution (Anode)

⬅ Diffraction of Electron Drift Time

An example case:

p = 100 torr

V_{wire} = 1 kV → E = 600 V/cm @ r = 3 mm

Drift Time

T ~ 0.3 (cm) / 5 (cm/us) = 60 ns

Longitudinal Diffraction

$dT \sim \sigma_L \times L^{1/2} / v_d$

$\sim 200\ (\mathrm{um/cm}) \times 0.3^{1/2}\ (\mathrm{cm}) / 5\ (\mathrm{cm/us})$

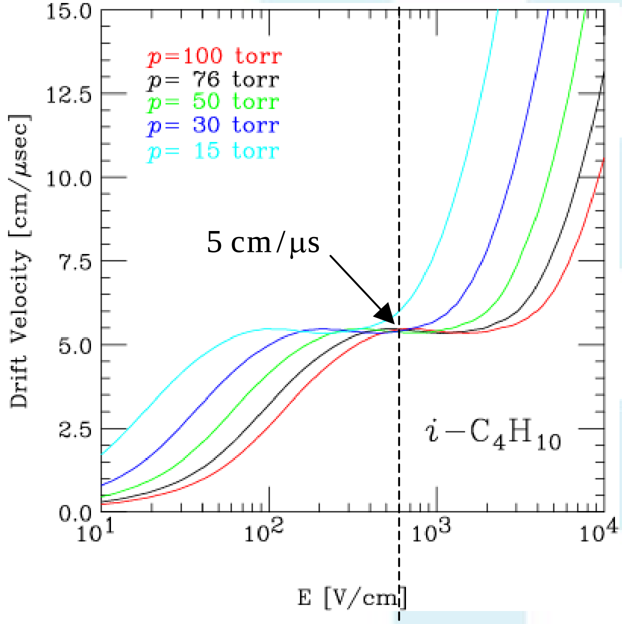
= 2.2 ns

R ~ 2.35 × 3 mm × dT/T ~ **260 μm (FWHM)**

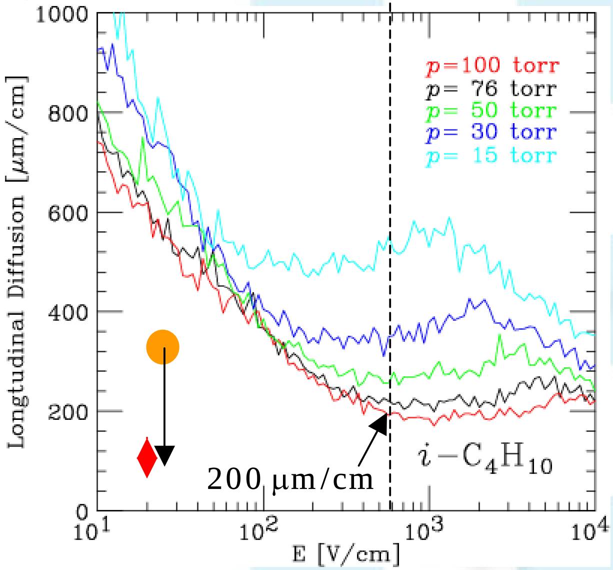
< 300 μm

Drift velocity

600V/cm



Longitudinal Diffraction



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

ΔE□$Z^2 \times p \times t$,

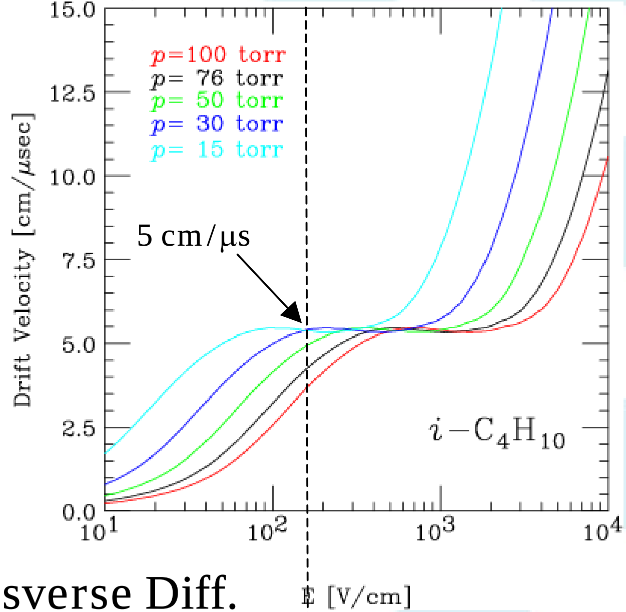
$\Delta E \sim 19$ keV → N ~ 830 pairs

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

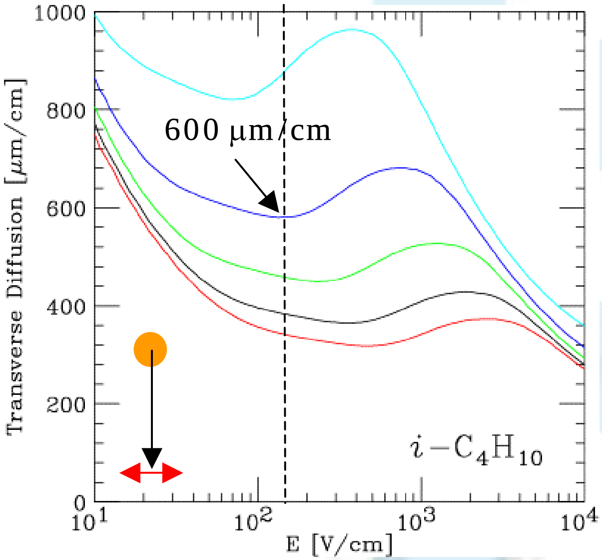
$R \sim 2.35 \times 600 \times (30/830)^{1/2}$ = **270 μm (FWHM)**

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

Drift velocity



Transverse Diff.



Capacity of counting rate

Beam-line Detector

Count rate per Cell:

spot size: 1 cm×1 cm

□□1MHz × $3^2/10^2$ ~ **100 kHz**

Drift time of electron

V_d ~ 5 cm/μs = 50 μm/ns

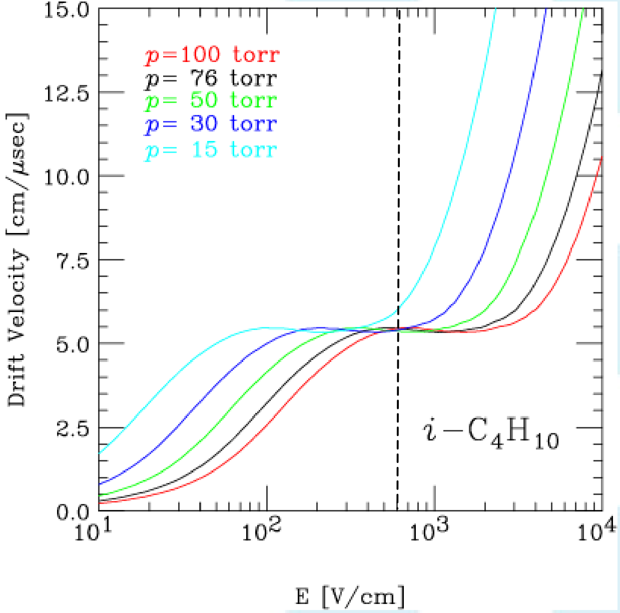
T1 ~ 3 mm/ V_d ~ 60 ns

Travel Time of Delay line

T2 ~ 200 ns (for 216-mm delay line)

T1+T2 ~ 260 ns□~ **1 MHz**

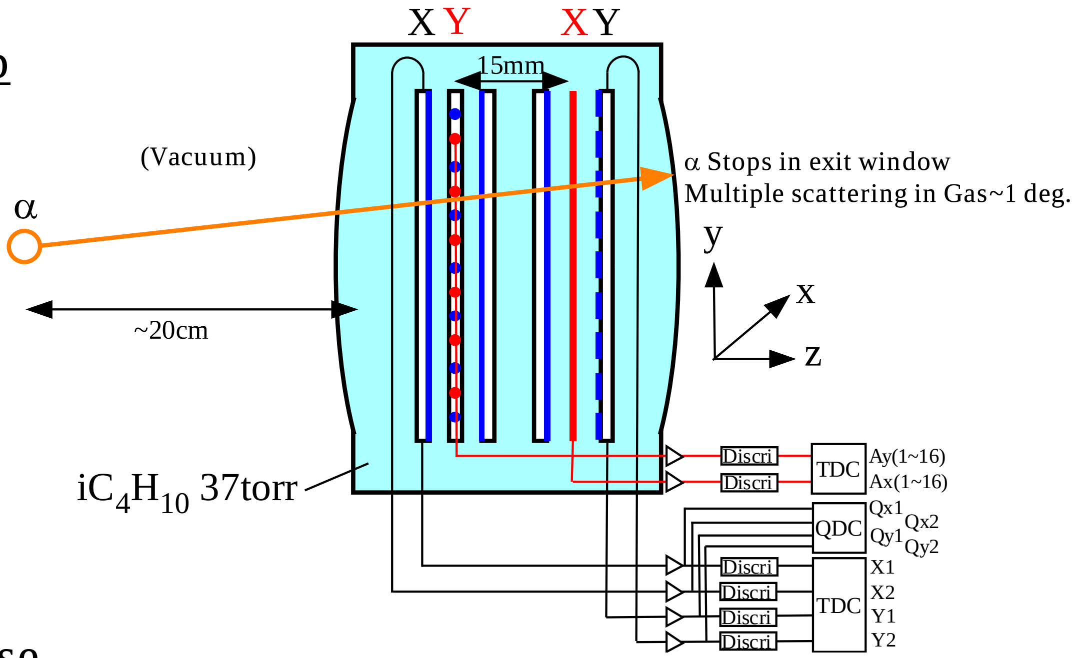
Drift velocity

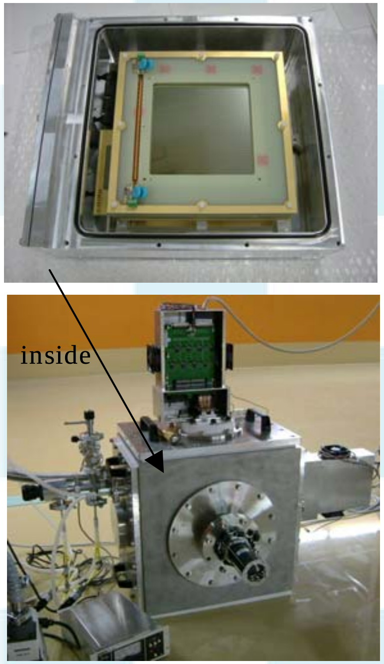

600 V/cm

➡ The beam-line detector may be enough capacity for beam intensity .

MWDC Test using Alpha source

Setup





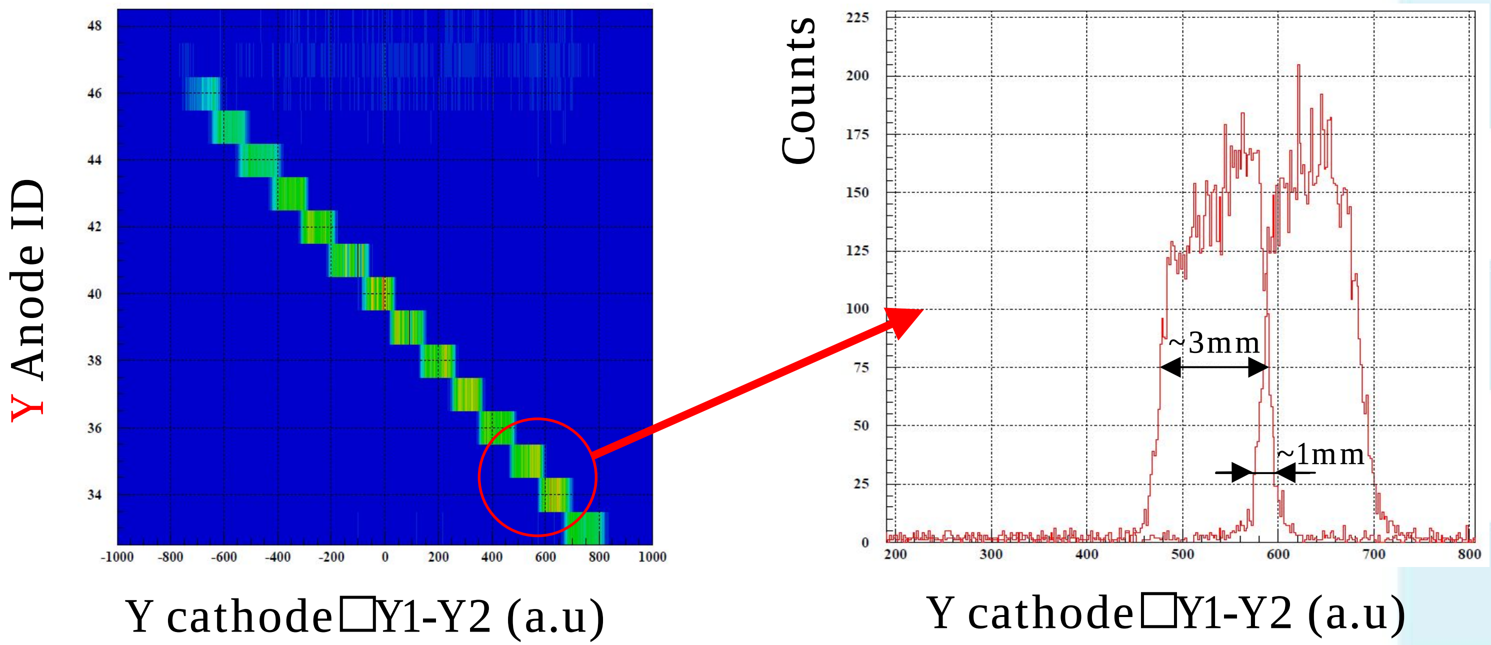
Purpose

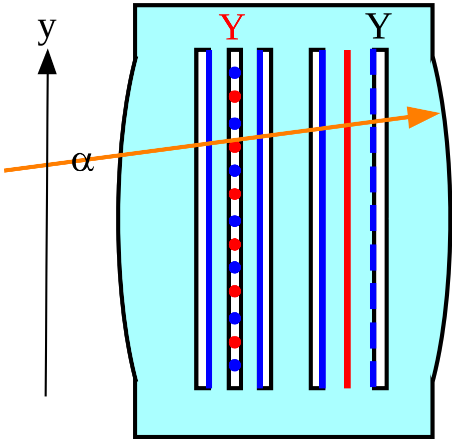
- First operation of MWDC (proto type)
- Debug/Development of
  pulse-processing electronics and Data acquisition

Estimate:

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

Position Resolution of Cathode





Though not taking into account …

- α incident angle
- multiple scattering
- and so on…

➡ Position deduced from Cathode is consistent.
Resolution may be less than ~1 mm

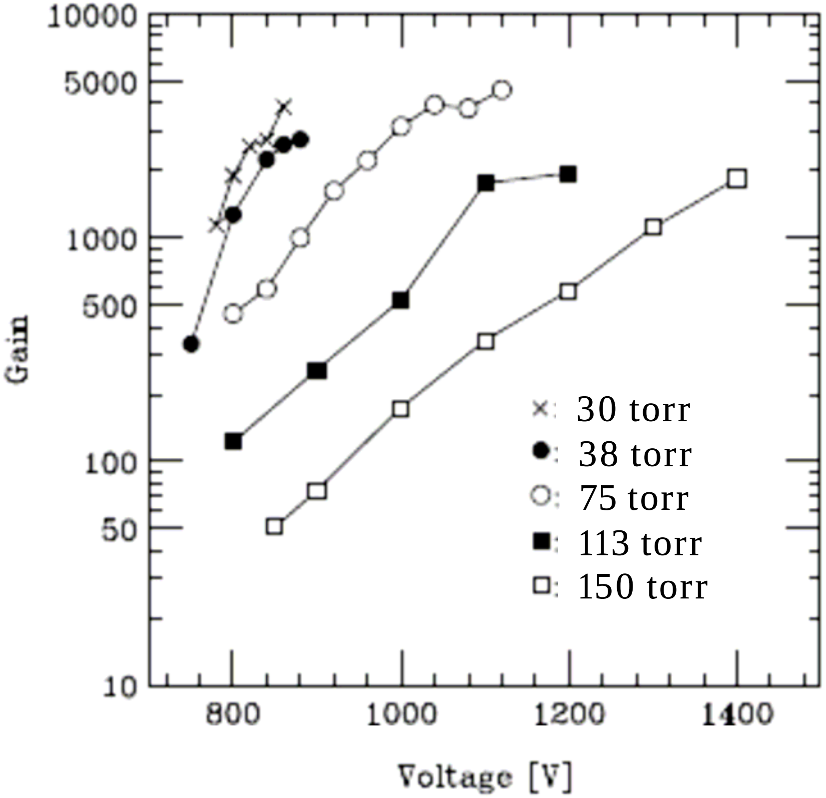
Avalanche Gain

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

Q: Mirror Charge delivered from cathode readouts.

ΔE: believed the Zeegler estimation

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

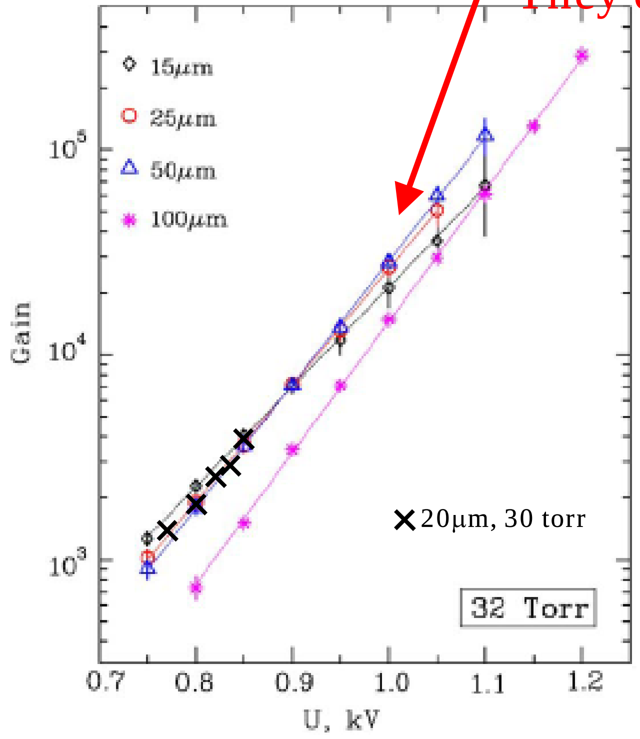


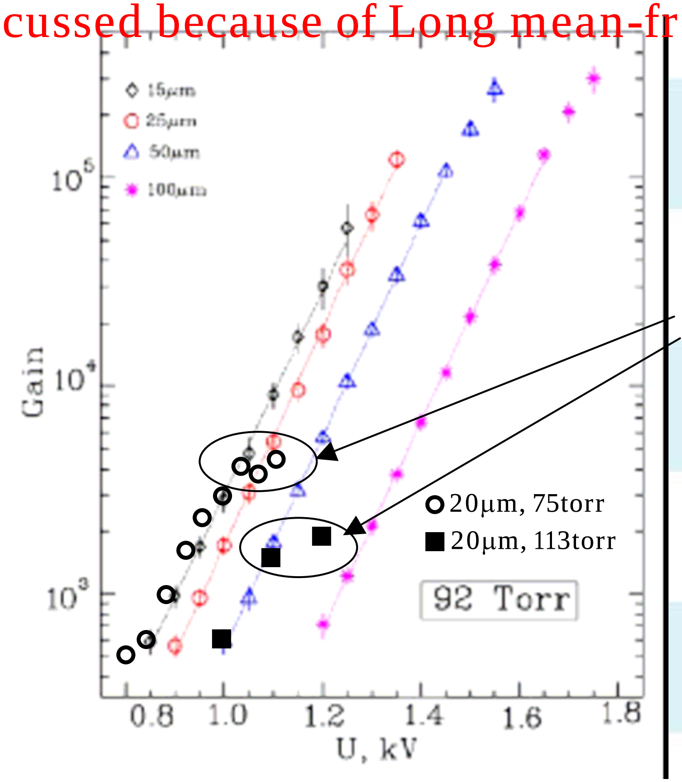
Avalanche Gain

Compare with Previous Data:

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

Notice! Lower gain using thinner wire at ~ 30 torr
They discussed because of Long mean-free path.

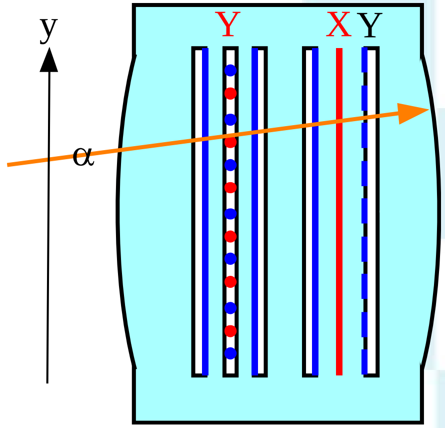




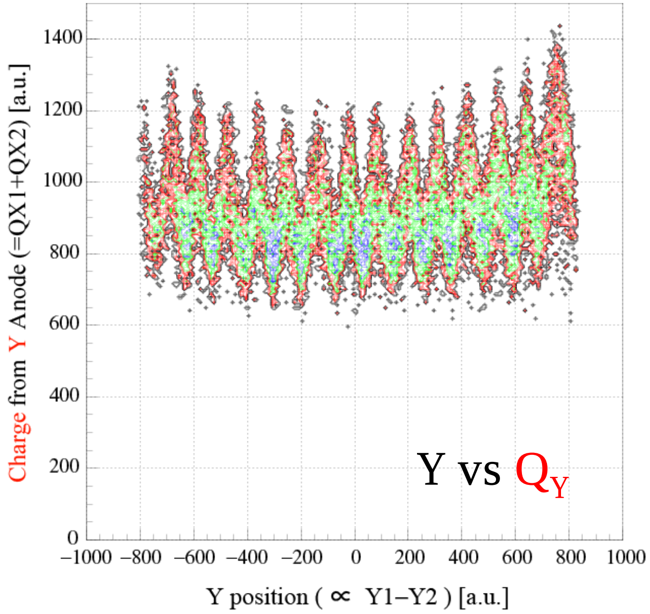
Saturation of Preamp?

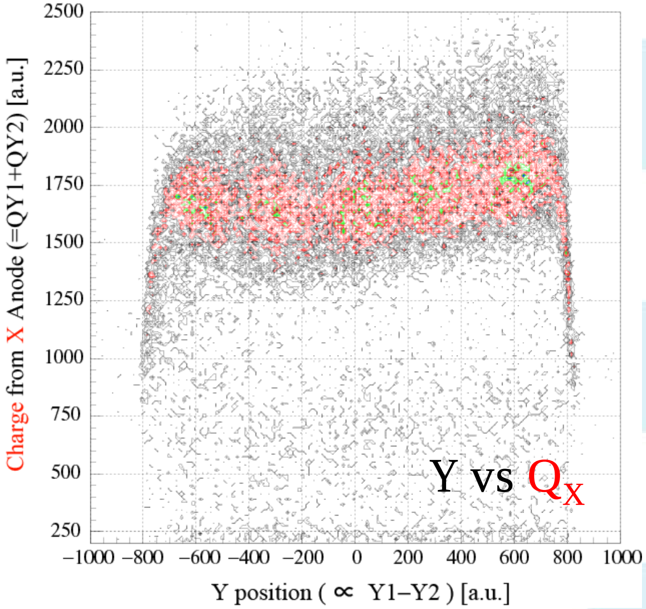
Avalanche gain is consistent with Previous Data

Avalanche Gain



Large mean free path (λ ~ 100 um)
☐small number of avalanche collisions,
when particles pass through vicinity of wires.
☐**Position dependence of gain?**





- At Low gas pressure, position dependence of gain might be seen?!
- In beam-line MWDC, Position dependence is considered to be weaker because of using **thicker** gas (75~150 torr).
- Gain of CRDC (operated at 15~30 torr) should be checked!

Further Development

Beam-line MWDC

Manufacturing MWDCs for the SHARAQ beam line (present)

Test using 8.8-MeV/u α beam (2008/3/17-19)

(Comparable energy deposit with 200-MeV/u ^{12}C beam)

- Detection efficiency
- Gain as functions of p and V at 75-150 torr
- Position deduced by drift time to Anode wires

Beam Test using many MWDCs

- Position resolution

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 beam-line and focal-plane detectors
to perform dispersion-matching experiments

- Tuning of the beam line and the SHARAQ spectrometer
- Event-by-event beam-tracking measurement

Tracking detectors were designed with

- Detectors with small density ($L/L_R \sim 10^{-4}$)
- Good position resolution
- High counting rate (up to 1 MHz, especially beam-line detectors)

At ~ 30 torr, HV>1000V,

- It is reported that gain is larger in thicker wires.
- The tendency may be reconfirmed by the Alpha-source test

Beam-line MWDC

- just operated, Next beam test.

Focal plane CRDC

- have been designed, Next manufacturing.

Collaborators

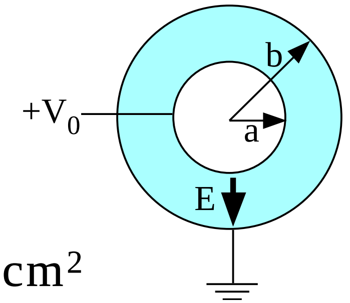
Beam-line Detectors:

A.Saito, S. Shimoura, T. Kawabata, S. Michimasa, H. Miya, Y. Sasamoto, T. Uesaka, H. Sakai

Focal-plane Detectors:

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

Avalanche Gain

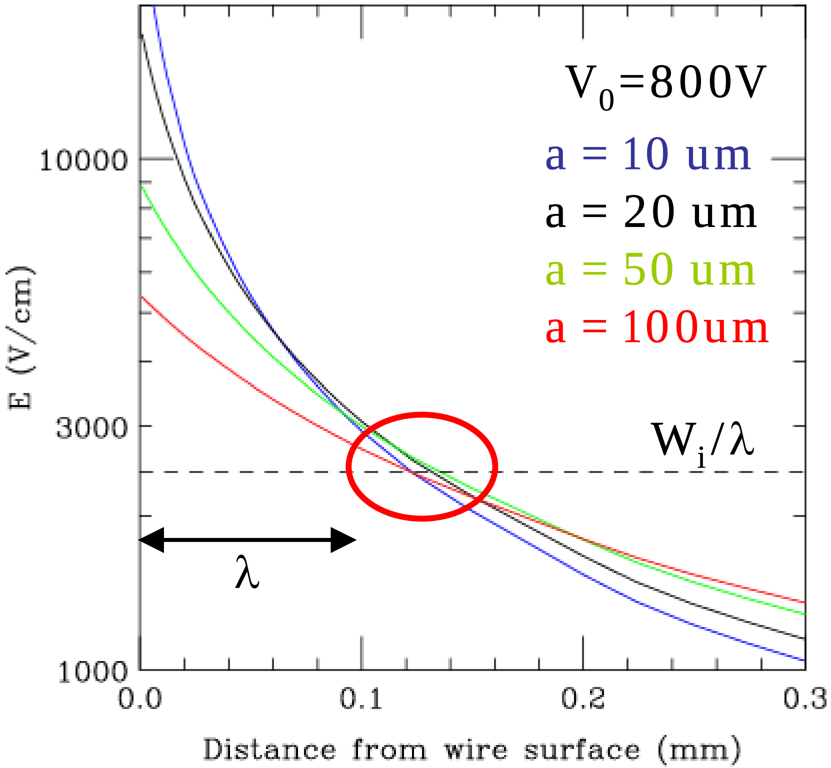


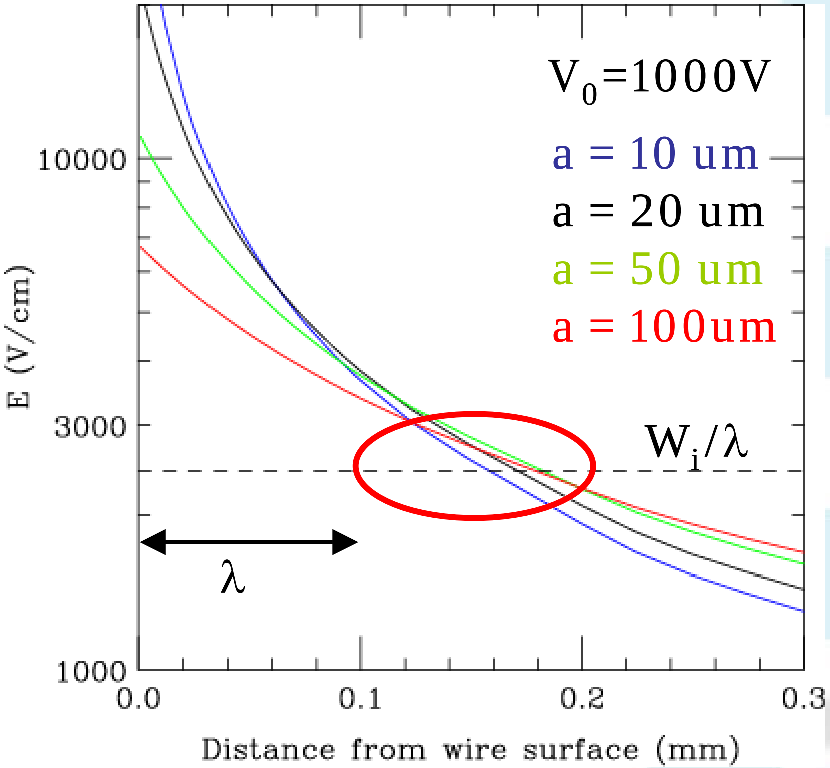
$E = V_0/\log_{10}(a/b)/r$

b = 3 mm

Electric field as function of distance

$\lambda = 1/(n\sigma) \sim 100\ \mu m$ @ 30 torr, $\sigma=10^{-16} cm^2$





Avalanche occurs around ○ area.

HV > 1000V□Avalanche area is wider in thicker wires.