Development of low-pressure MWPC

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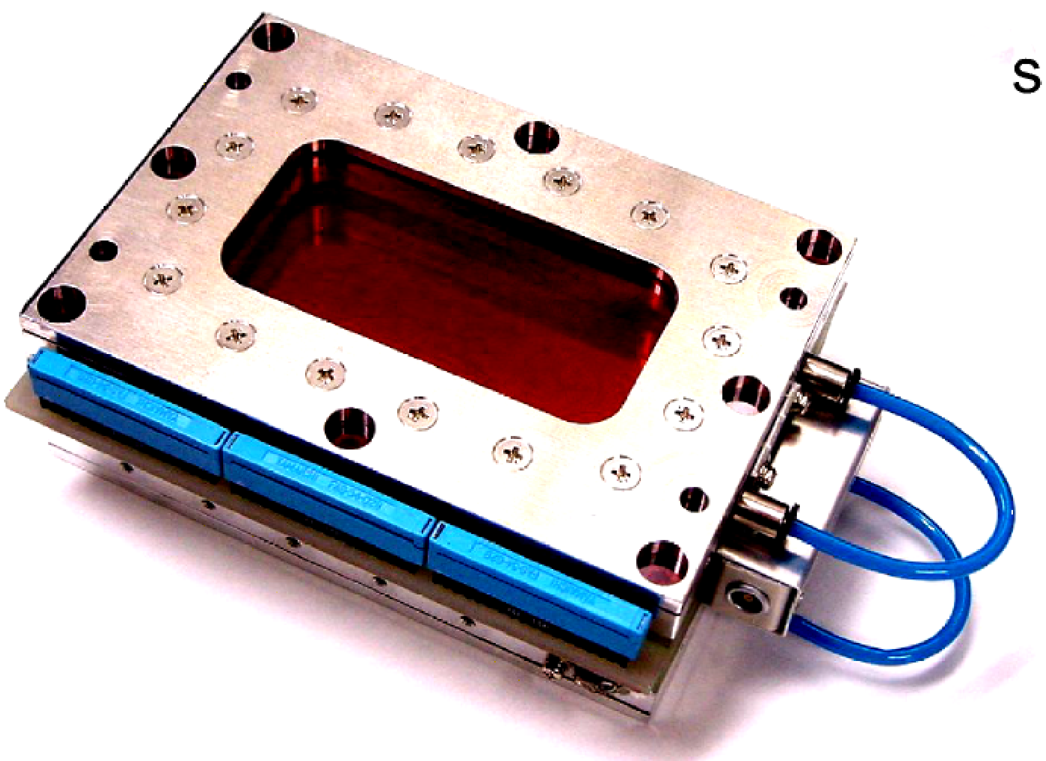


specification of MWPC for operation test

- effective area
  96×48 mm^2
- anode
  2 mm-spacing, 20 μmϕ Au-W,Re
- cathode
  12.5 μm thick
  Cu-Cr evaporated kapton
- half gap
  4 mm

motivation

secondary beam

$\frac{\Delta P}{P} \sim \pm 3\ \% \rightarrow$ determination of momentum for each particle

momentum determination method

time of flight $\frac{\sigma P}{P} \sim 0.5\ \%$

◎ position at momentum-dispersive focal plane $\frac{\sigma P}{P} \sim 0.1\ \%$

$$\left(\begin{array}{l} \sigma_x = D \frac{\sigma_P}{P} \\ D = 2 \sim 3\ \mathrm{cm}/\% \\ \sigma_x \approx 1\ \mathrm{mm} \end{array} \right.$$

requirements for position detector

- particle ~250A MeV $Z \geqq 1$
- positional accuracy $\sigma_x \approx 1$ mm
- counting rate 1M - 10M Hz/plane
- operation in beam line 10^{-6} Torr

MWPC operating at low pressure

definition of operating characteristics

- efficiency

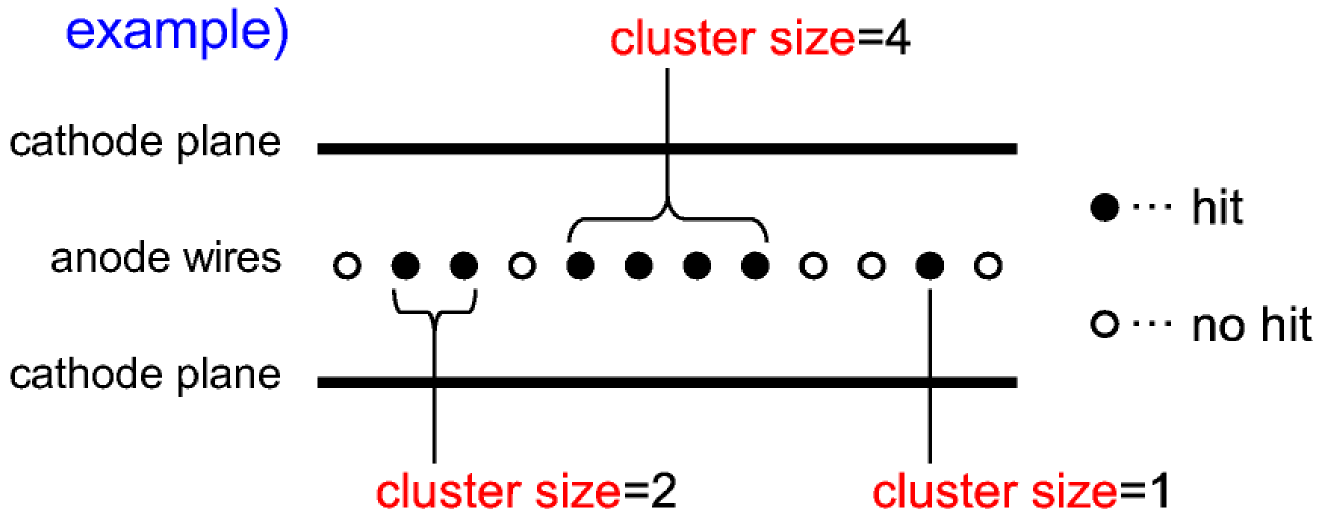
$$\frac{\text{(number of times MWPC detects particle)}}{\text{(number of triggers)}}$$

$$\rightarrow \text{imposed various conditions} \left(\begin{array}{l} \text{total} \\ \text{wire multiplicity=1, 2, } \cdots \\ \text{cluster multiplicity=1, 2, } \cdots \\ \quad \vdots \end{array} \right.$$

- wire/cluster multiplicity, and other terms

cluster : unit of neighboring wires which detect signal

example)

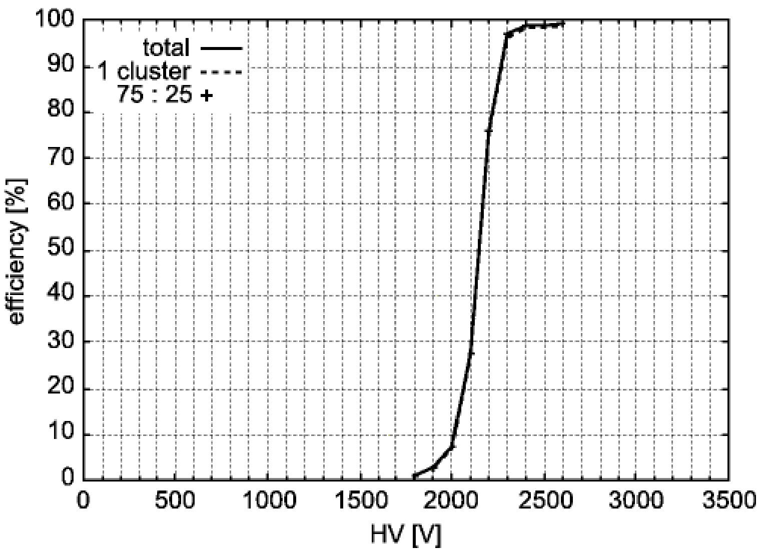


wire multiplicity=7
cluster multiplicity=3

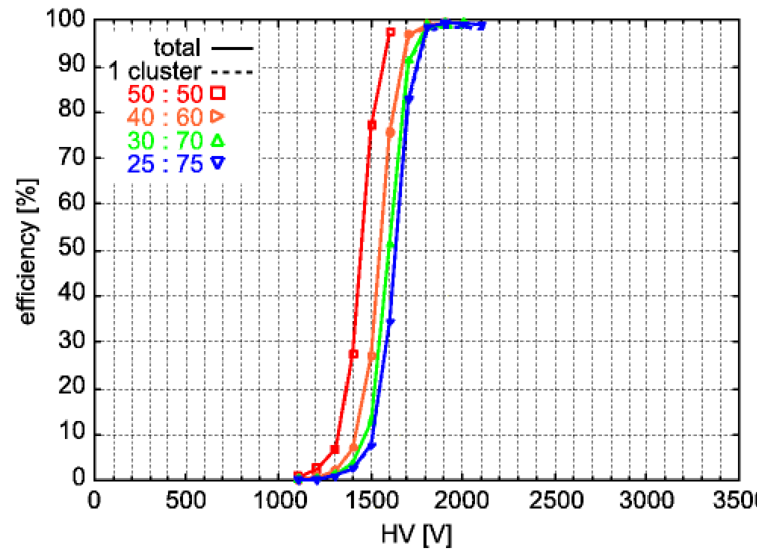
operating characteristics at low pressure

β -ray

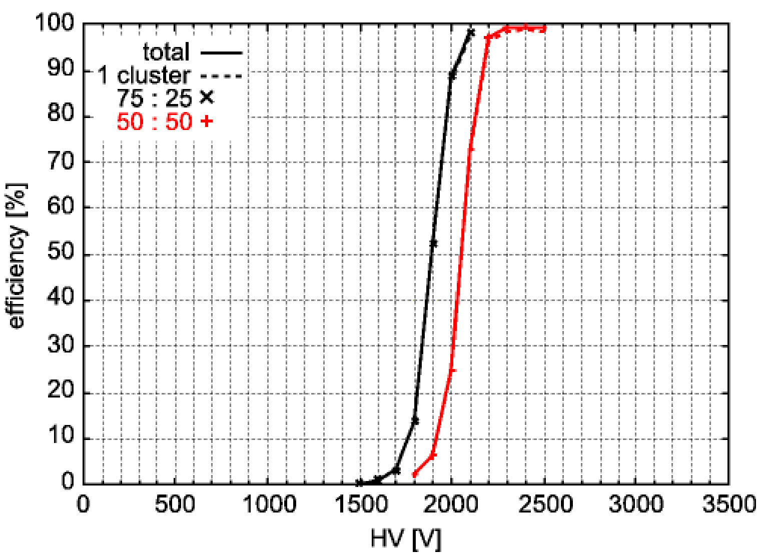
760 Torr



190 Torr



380 Torr



operation at each pressure

○ ··· stable
× ··· unstable

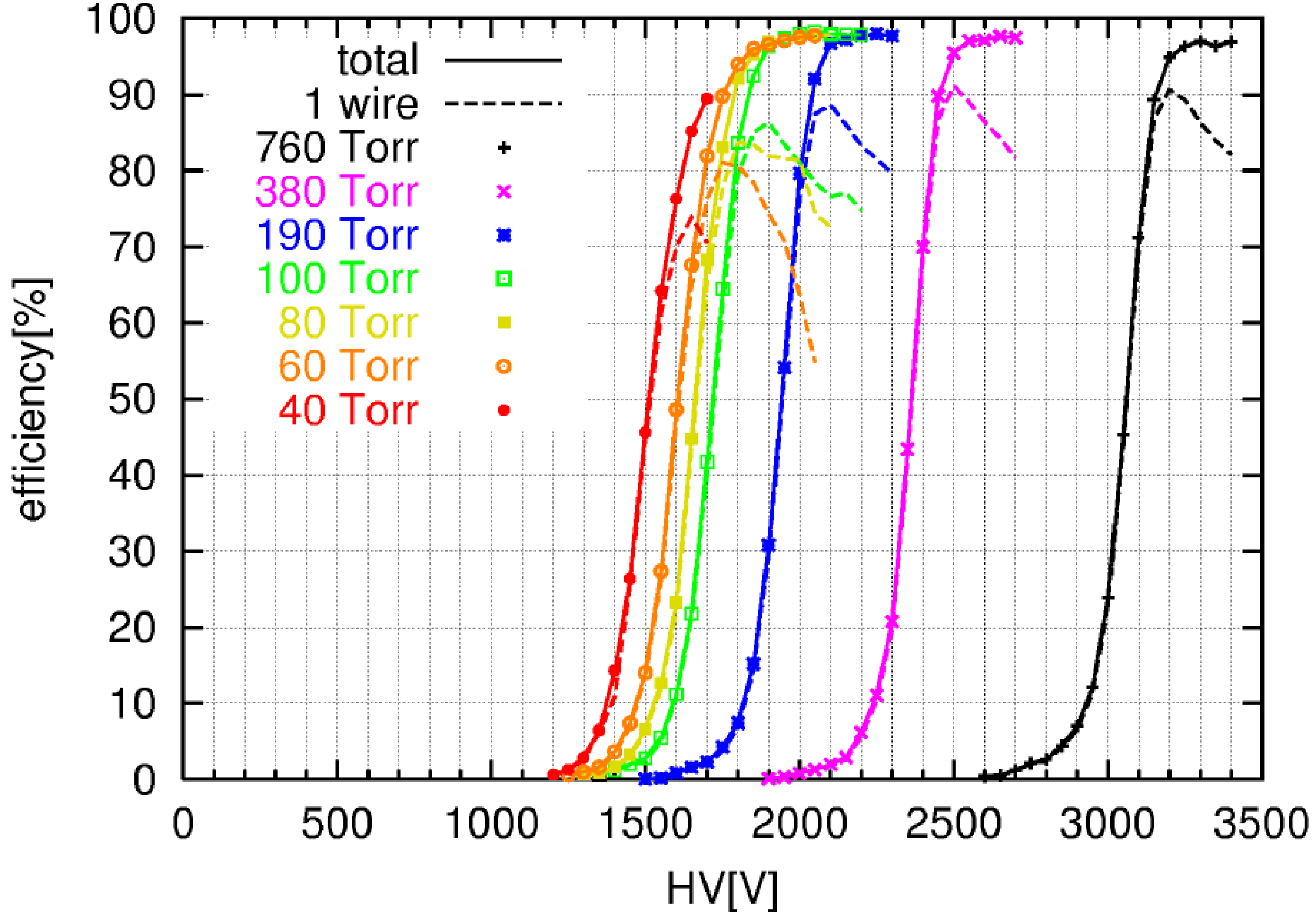
Ar : i-C_4H_{10}	75:25	50:50	40:60	30:70	25:75
760 Torr	○				
380 Torr	×	○			
190 Torr		×	○	○	○

lower pressure needs higher isobutane ratio for stable operation $\rightarrow$ importance of quenching effect

operation at isobutane 100 %

operating characteristics for β-ray

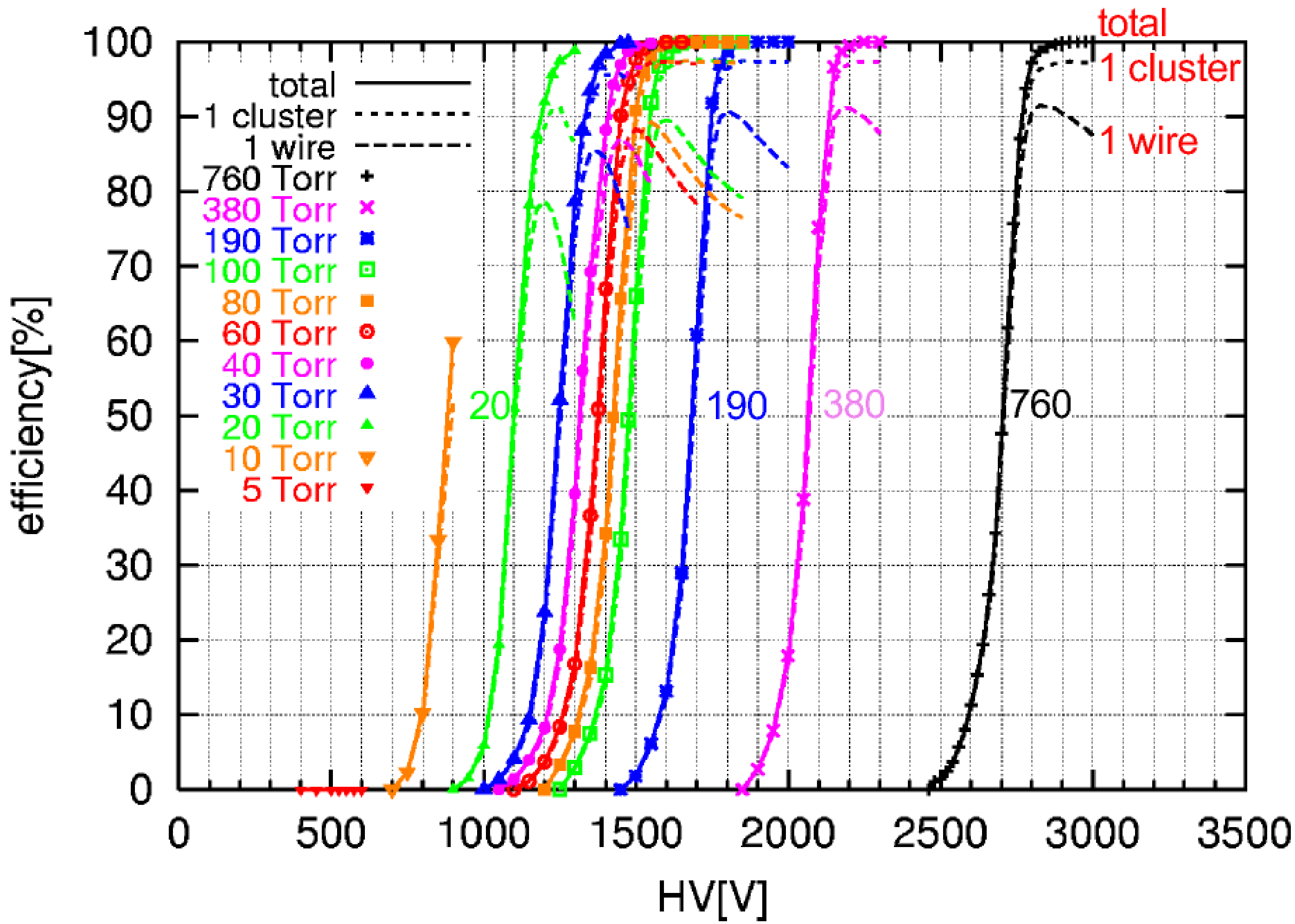
isobutane 100 %



operates stably as low as ~100 Torr

operating characteristics for proton (1)

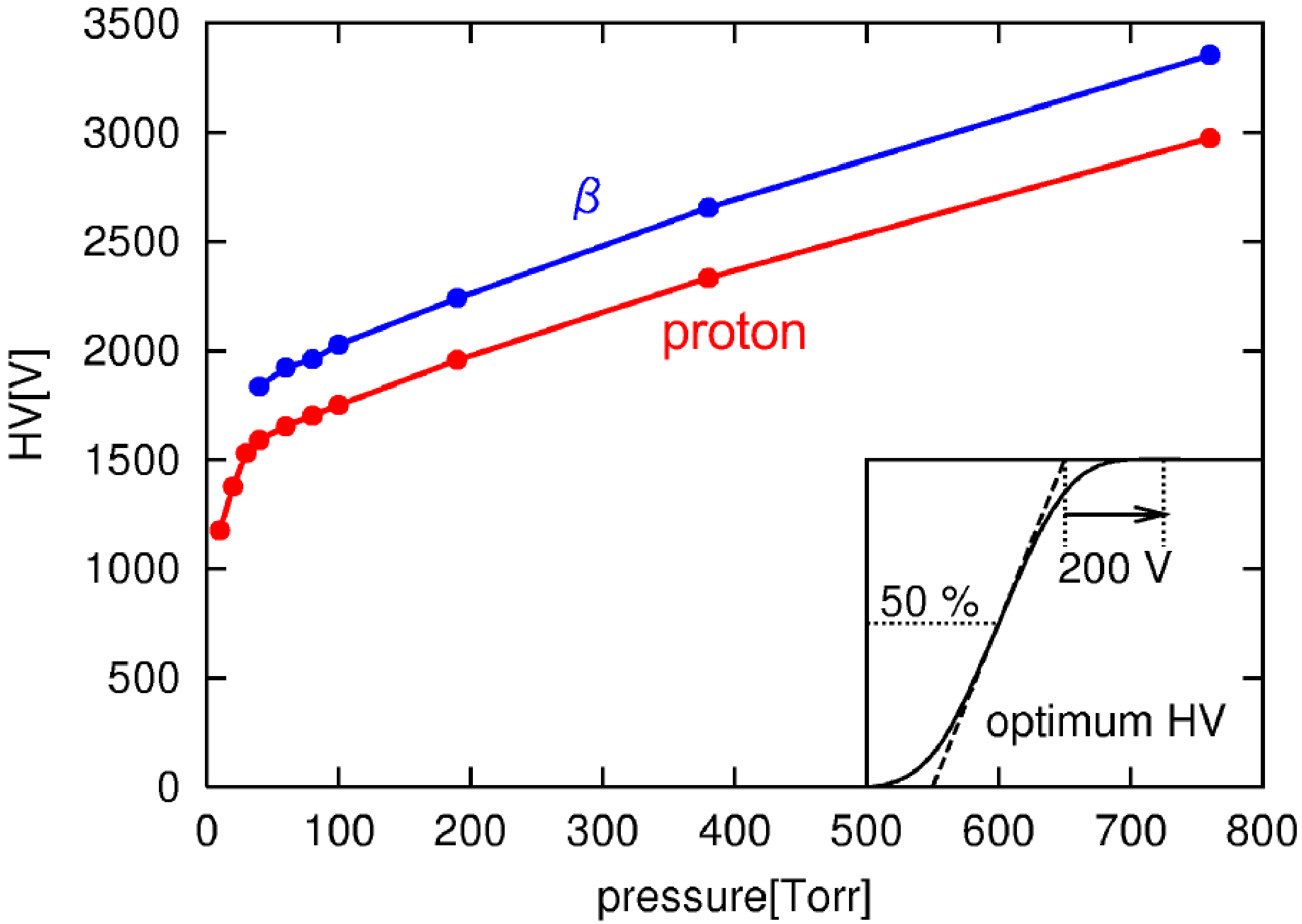
experiment @ CYRIC, Tohoku Univ. p ~64 MeV (energy loss ~5.7×M. I.)



operates stably as low as ~40 Torr

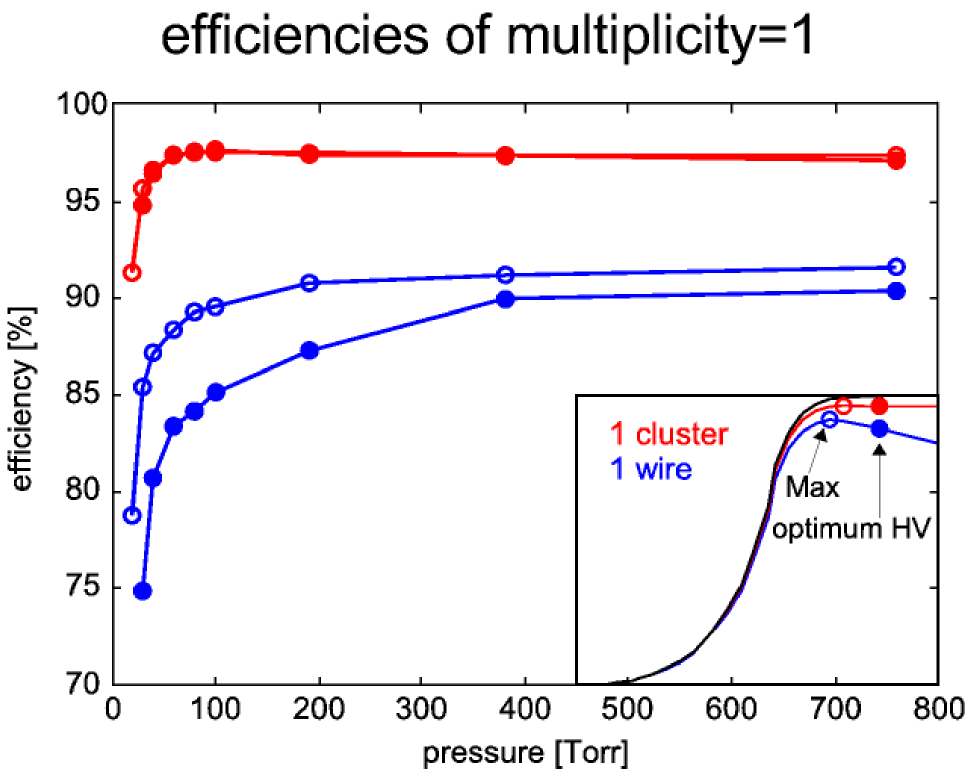
operating characteristics for proton (2)

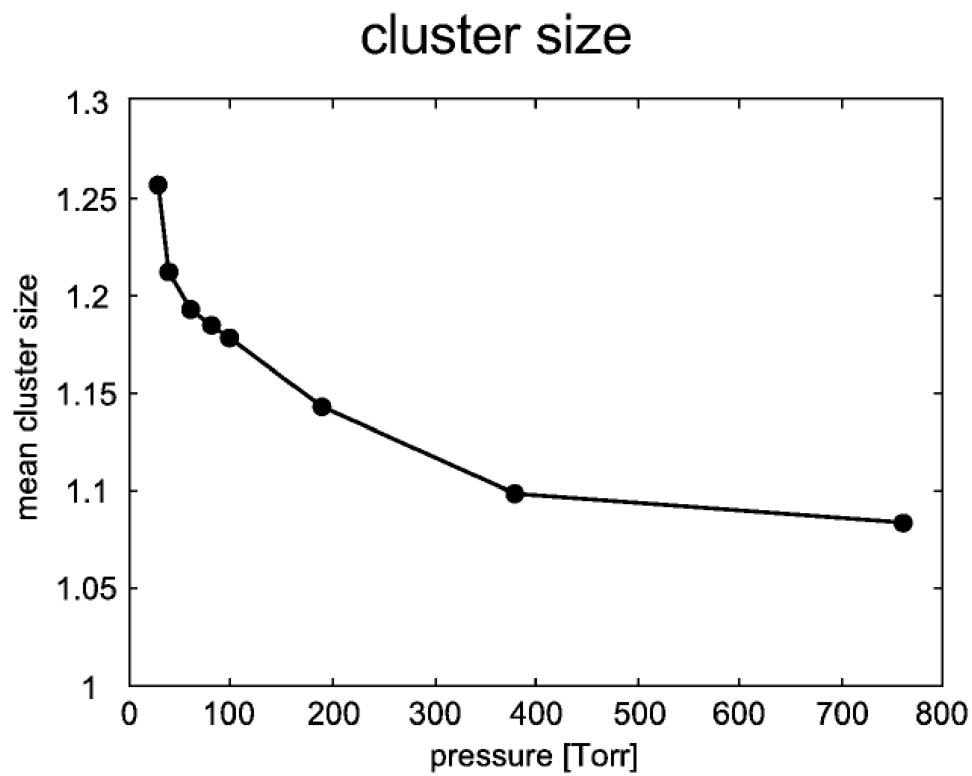
optimum HV



optimum HV decreases sharply below 40 Torr

operating characteristics for proton (3)

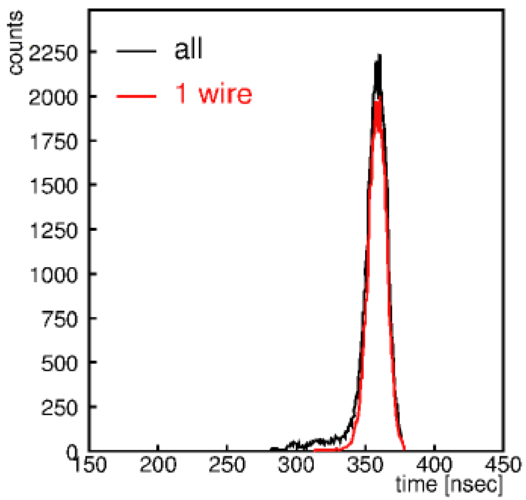


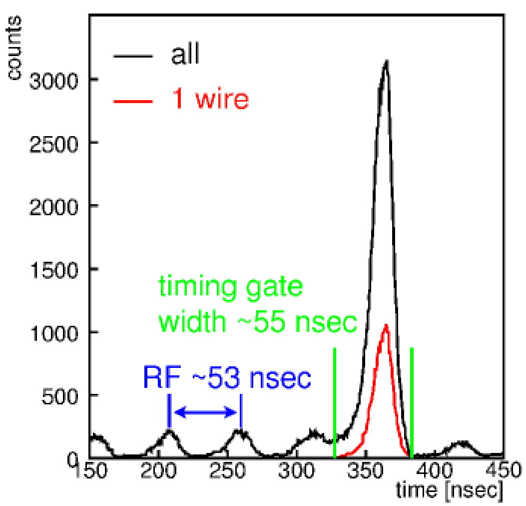


efficiencies of multiplicity=1 decrease
mean cluster size increases
} sharply below 60 Torr

operating characteristics for proton (4)

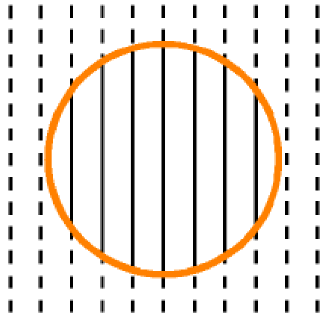
response at high counting rate

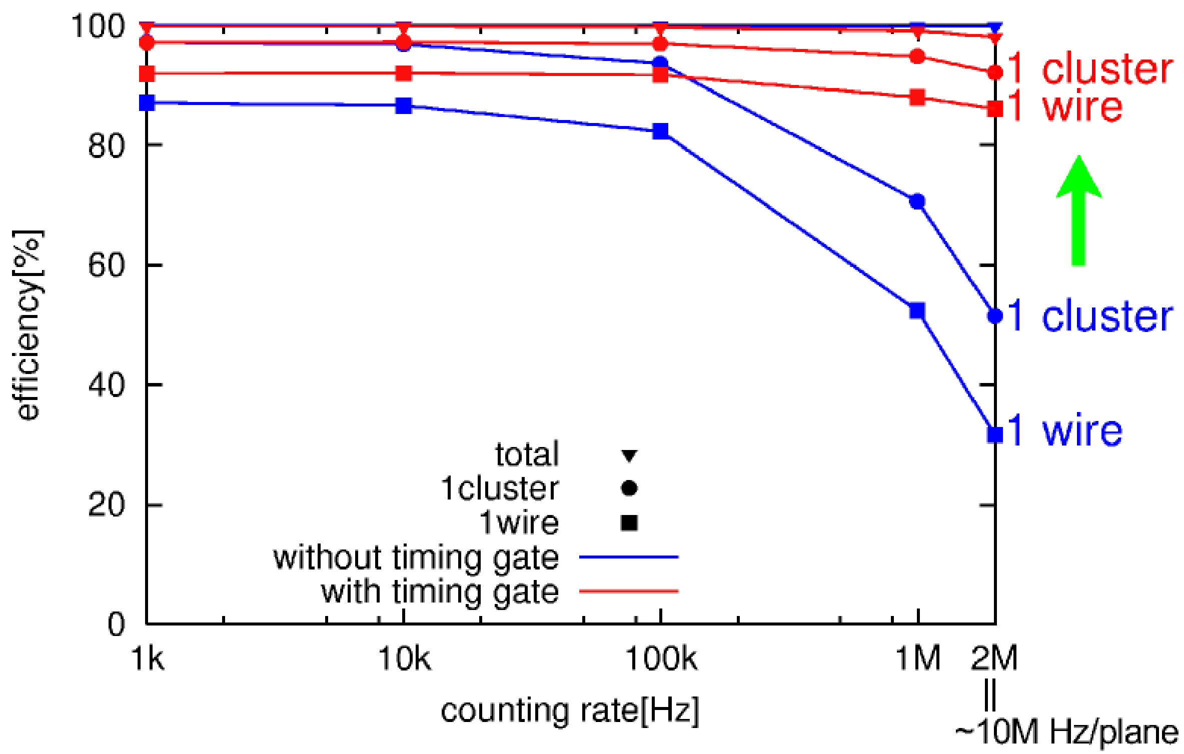




multi-hit TDC
190 Torr, 1900 V

irradiated to limited area
through collimator





applying timing gate → high "effective" efficiency

relation between pressure and optimum HV (1)

P-V model

- efficiency=100 %
  the number of electrons arrive at an anode for each event exceeds a constant number (N)
- the number of primary electrons
  proportional to pressure $P \rightarrow eP$
- first Townsend coefficient

$$\frac{\alpha}{P} = KS^m \exp(-LS^{m-1});\ S = \frac{E}{P} \quad \text{by T.Aoyama} \qquad cf.\ \frac{\alpha}{P} = A\exp(BS^{-1})$$

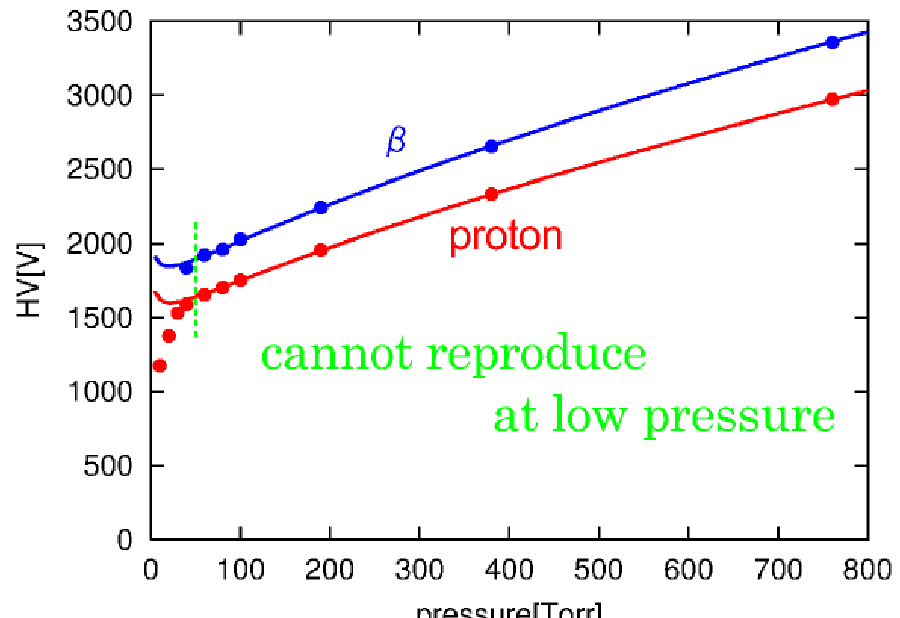
- electric field

cylindrical $\rightarrow \ E = d\frac{V}{r}$

$$\frac{KdV}{L(1-m)} \exp\left\{L\left(\frac{dV}{aP}\right)^{m-1}\right\} + dzV - \ln\frac{N}{eP} = 0$$

parameters : K, L, m, N, z

fitting result (60-760 Torr, proton and β)



relation between pressure and optimum HV (2)

extended *P-V* model

- electric field

$$E = d\frac{V}{r} \quad \text{where} \quad r \le \frac{s}{\pi} \quad \text{(cylindrical)}$$

$$E = d\frac{\pi V}{s} \quad \text{where} \quad r \ge \frac{s}{\pi} \quad \text{(parallel)}$$

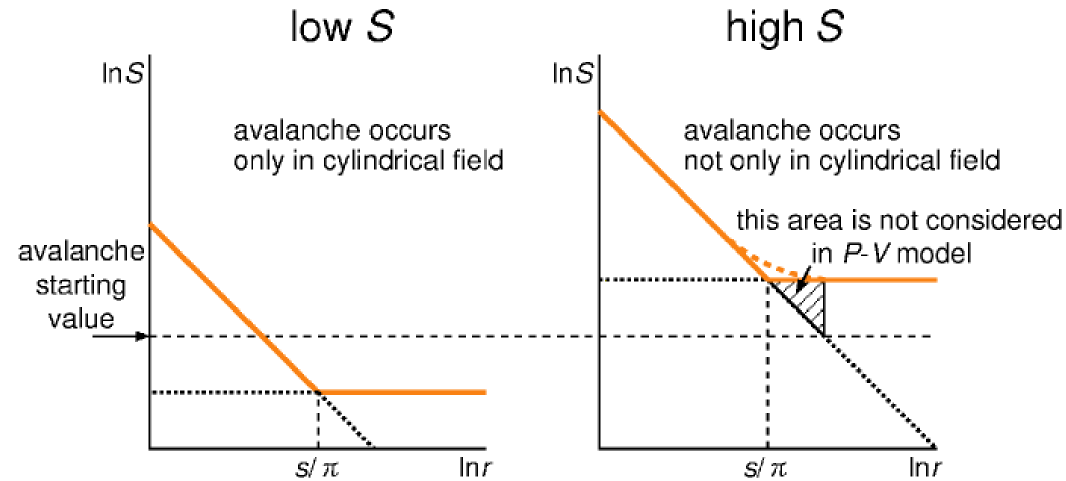
$$\frac{kdV}{L(1-m)} \exp\left\{-L\left(\frac{dV}{aP}\right)^{m-1}\right\} - \left\{\frac{KdV}{L(1-m)} - PK\left(\frac{d\pi V}{sP}\right)^{m}\left(b-\frac{s}{\pi}\right)\right\} \times \exp\left\{-L\left(\frac{d\pi V}{sP}\right)^{m-1}\right\} - \ln\frac{N}{eP} = 0$$

parameters : *K, L, m, N, b*

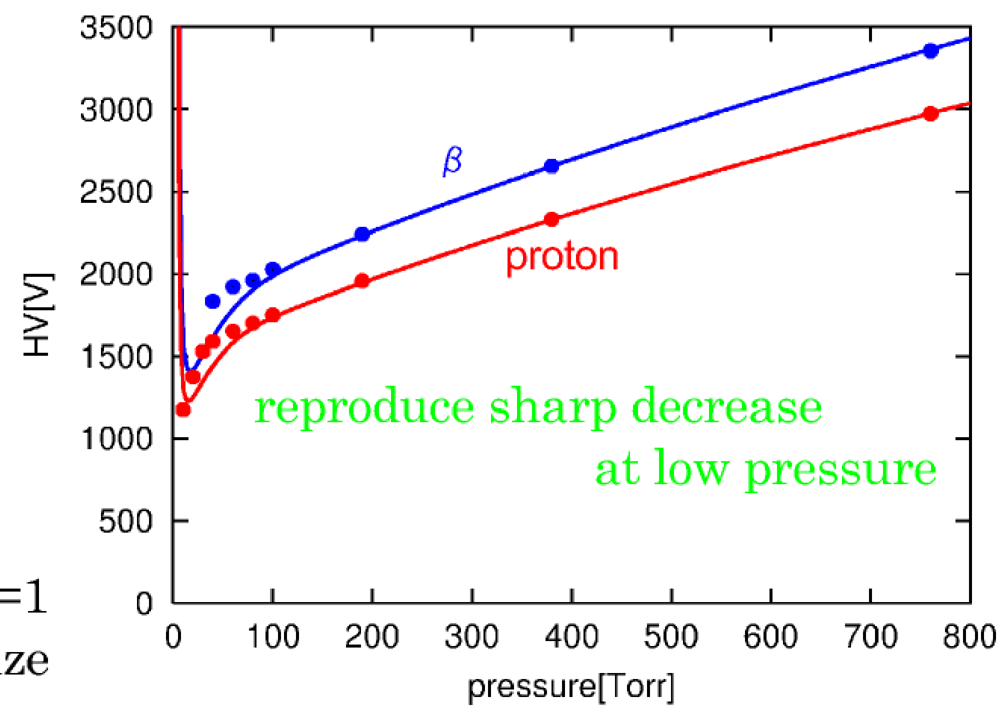
avalanche starts from
outside of cylindrical field
at low pressure

consistent ⇕

sharp decrease in efficiency of multiplicity=1
sharp increase in mean cluster size

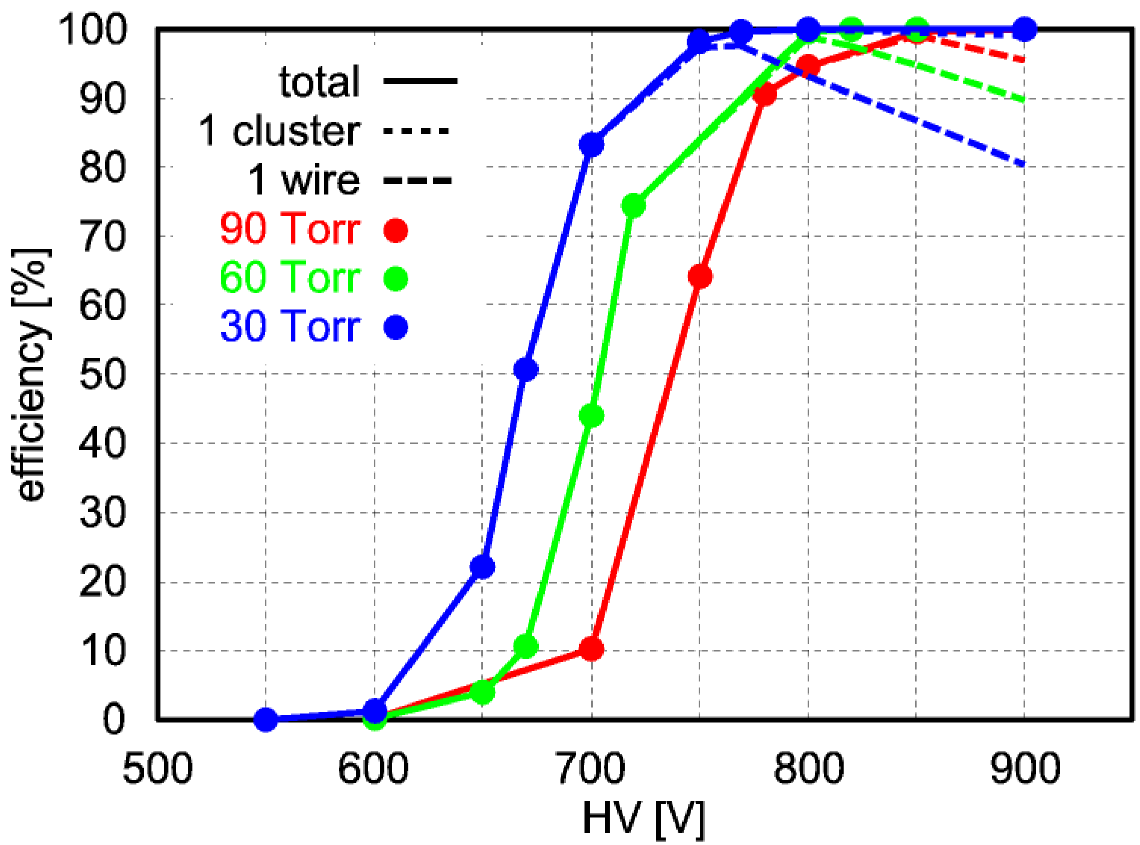


fitting result (10~760 Torr, proton only)



operation test for RI beam

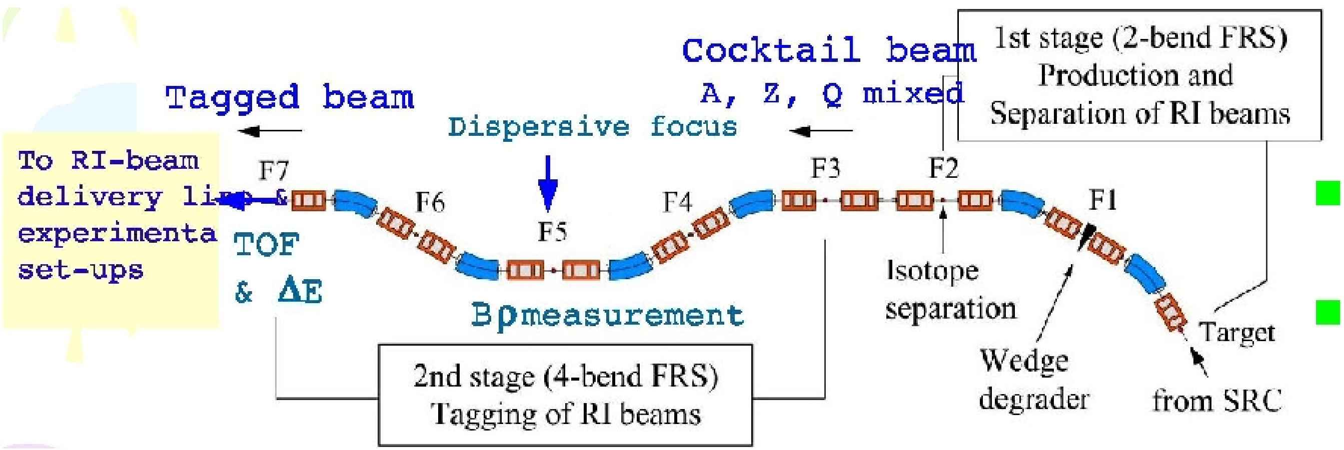
experiment @ HIMAC, NIRS $\quad {}^{40}$Ar ~270A MeV (energy loss ~650×M. I.)
counting rate ~300 Hz



larger energy loss
↓
larger number of primary electrons
↓
operation at lower pressure and HV

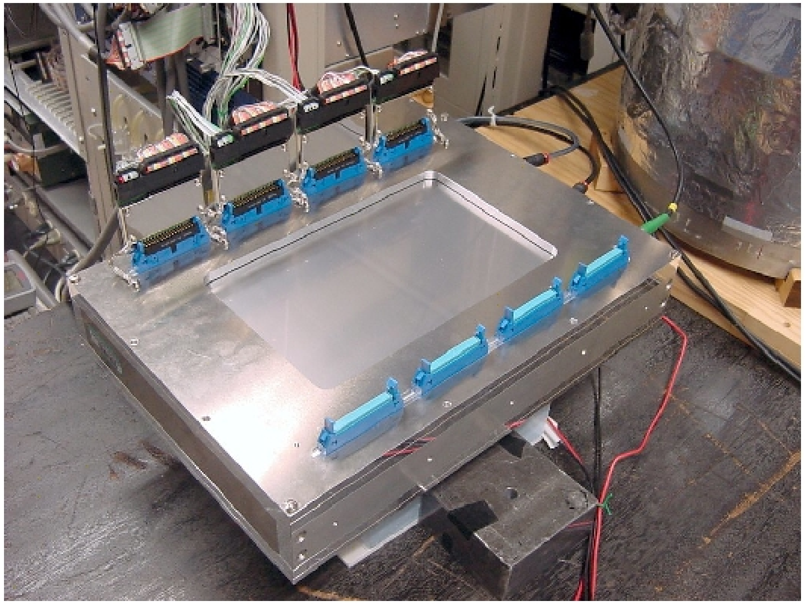
low-pressure MWPC for RIBF (1)

BigRIPS



- momentum dispersion
  33 mm/%
- momentum acceptance
  6 %

planned to install at F5 (F4)



(outer box containing MWPC)

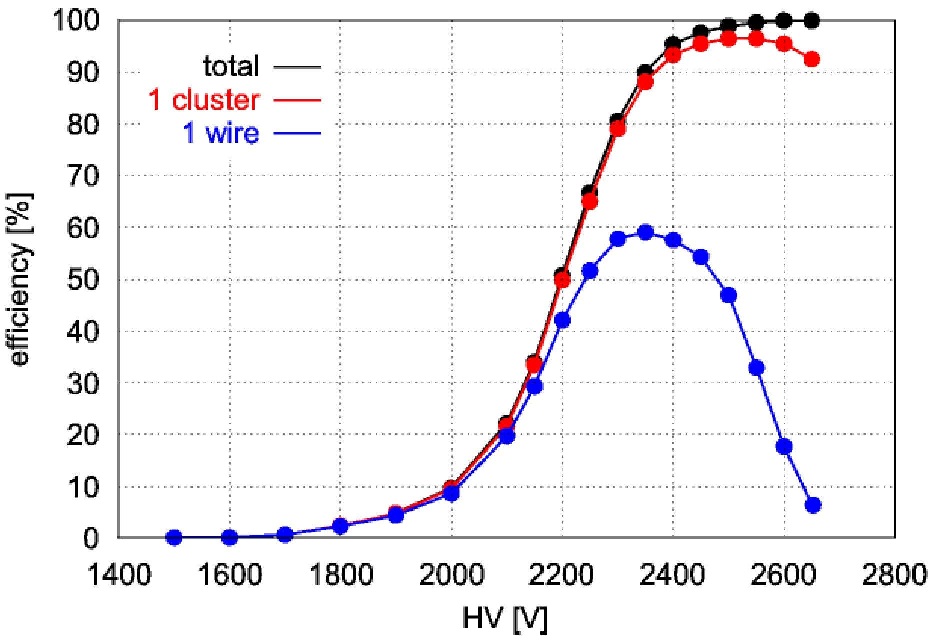
specification

- effective area
  240 mm (H) × 150 mm (V)
- number of planes
  2 (X-X)
- anode
  2 mm-spacing
  128 wires / plane
  neighboring 2 wires are bound into 1 channel
- half gap
  5 mm

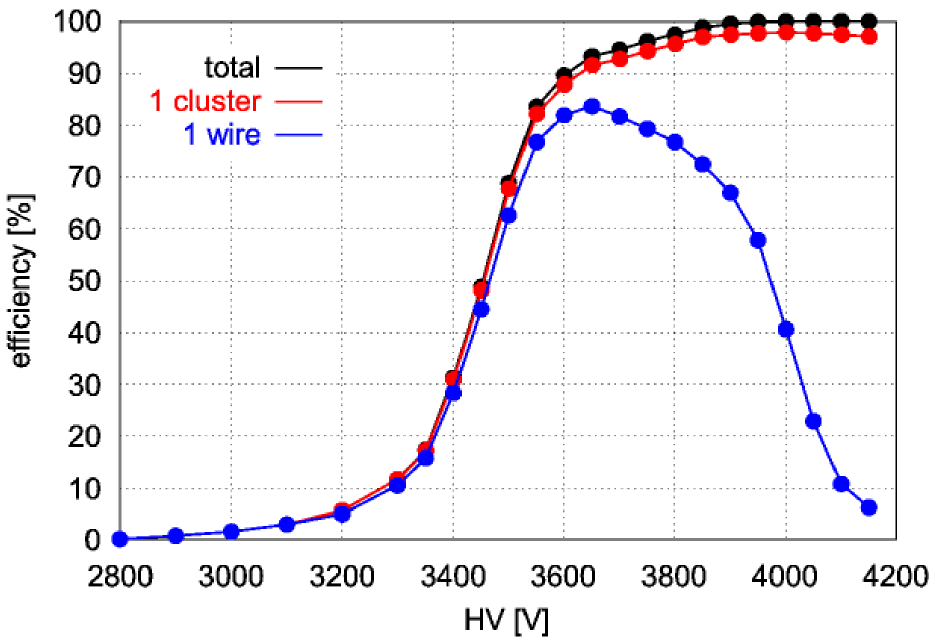
low-pressure MWPC for RIBF (2)

operation test… β -ray, 760 Torr

P10



isobutane



no trouble in operating at 760 Torr

Now under development

by under-graduate students in Tohoku Univ.

summary

- low-pressure MWPC as a position detector
  at momentum-dispersive focal plane

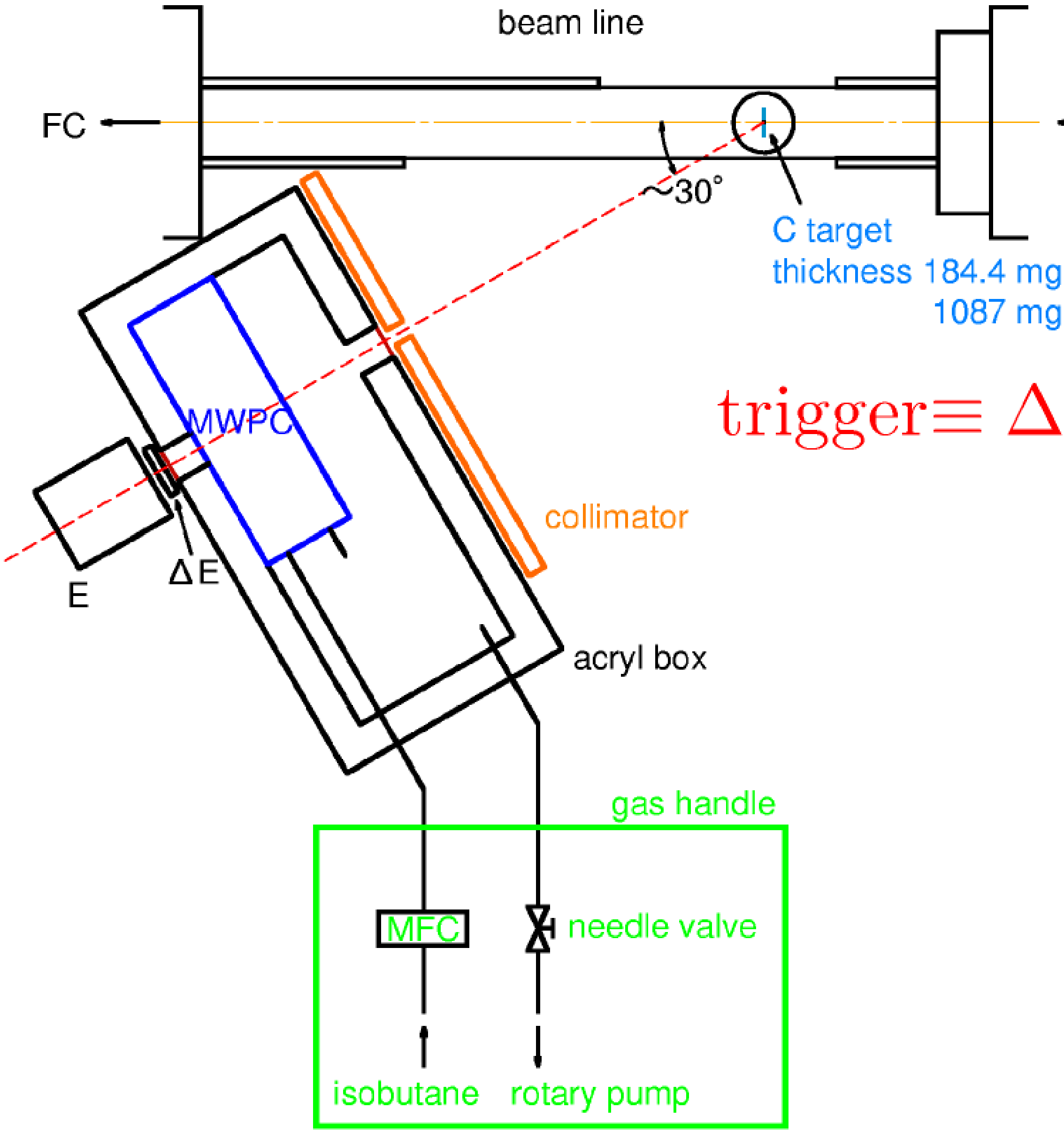
- operation test for MWPC at low pressure and high counting rate
  - isobutane 100 %
  - operating characteristics for M. I.×1/5.7/650
    operates stably at low pressure (≦ 100 Torr)
  - responce at high counting rate
    achieved high "effective" efficiency

- qualitative perception of operation of MWPC at low pressure
  - established a model concerning pressure and optimum HV

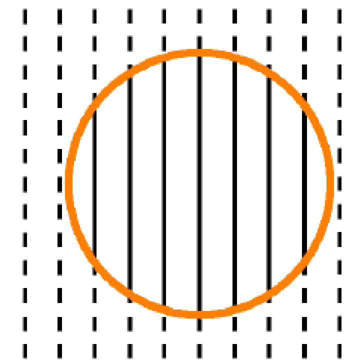
- low-pressure MWPC for RIBF is now under development

experiment at CYRIC

CYRIC, Tohoku Univ.

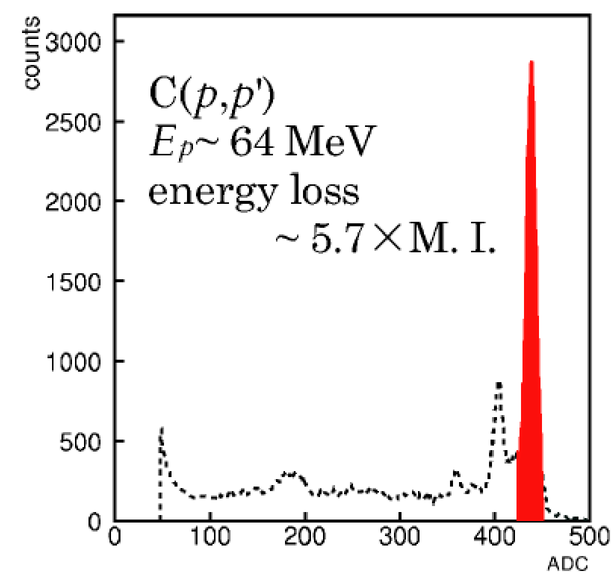


collimator
$15\ \mathrm{mm}\phi$



trigger $\equiv \Delta E \otimes E$

E ADC



electrical flux line of MWPC