Heavy Ion Detectors

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1-1. (General) Consideration

* Limitation : fully-stripped ions, A < 80~100

* PID (Particle IDentification) : Z(charge), A(mass)

← rigidity (R), charge (Z), velocity (β)

$$\frac{\sigma_A}{A} = \sqrt{\left(\frac{\sigma_R}{R}\right)^2 + \left(\frac{\sigma_Z}{Z}\right)^2 + \left(\gamma^2 \frac{\sigma_\beta}{\beta}\right)^2}$$

← rigidity (R), charge (Z), total energy (E)

$$\frac{\sigma_A}{A} = \sqrt{\left((\gamma+1)\frac{\sigma_R}{R}\right)^2 + \left((\gamma+1)\frac{\sigma_Z}{Z}\right)^2 + \left(\gamma \frac{\sigma_E}{E}\right)^2}$$

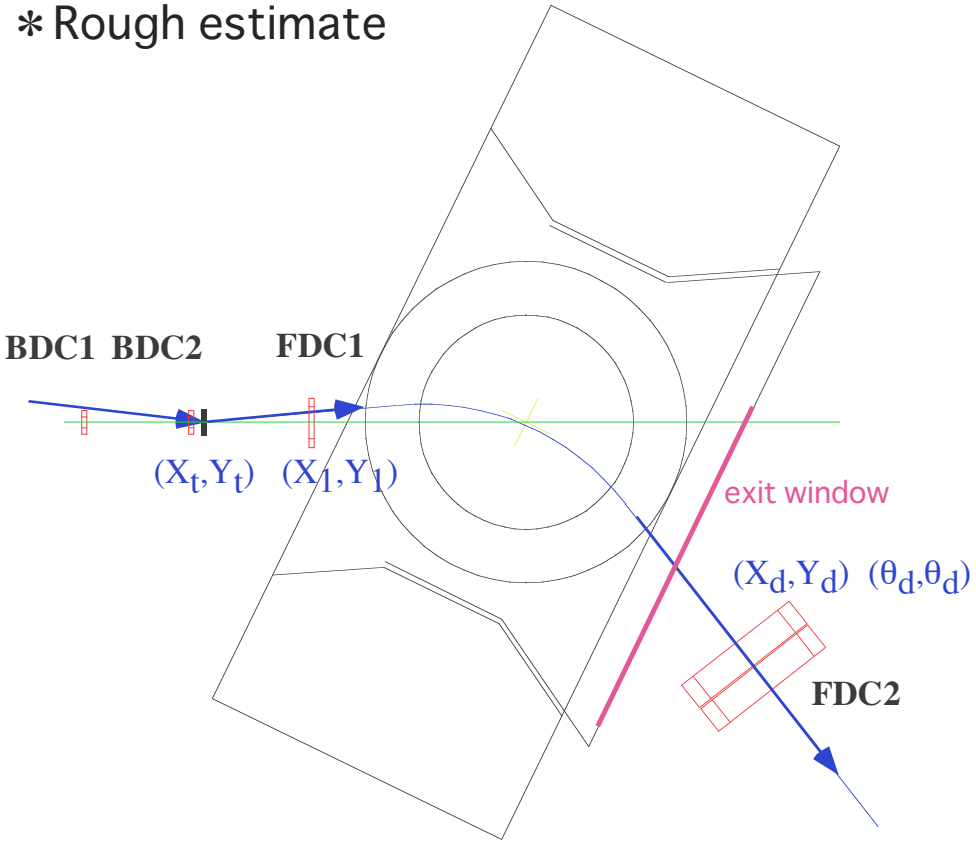
γ ~1.3

$$\frac{\sigma_A}{A} \approx \frac{0.2}{80} \leftrightarrow \frac{\sigma_R}{R} \approx \frac{\sigma_\beta}{\beta} \approx \frac{\sigma_E}{E} \approx 0.1\%$$

* required rigidity resolution for invariant-mass method ~ 1% > required rigidity resolution for PID ~ 0.1%

1-2. Rigidity measurement

* Rough estimate



A/Z=3, 250 MeV/A

$$D = 2.4cm/\%,\ D' = 8mrad/\%$$
$$(x|x) = 0,\ (x|\theta) = 0.3cm/mrad,$$
$$(\theta|\theta) = 0.01,\ (\theta|x) = 3.3mrad/cm$$
$$D_{eff} = (\theta|\theta)D - (x|\theta)D' \approx -240cm$$

Momentum Resolution:

$$\left(\frac{\sigma_p}{p}\right)^2 = \left(\frac{(\theta|\theta)}{D_{eff}}\sigma(x_D)\right)^2 + \left(\frac{(x|\theta)}{D_{eff}}\sigma(x'_D)\right)^2 + \left(\frac{\sigma(x_T)}{D_{eff}}\right)^2$$

$$\sigma(x_D) \approx 0.3mm,$$
$$\sigma(x'_D) \approx 1mrad,$$
$$\sigma(x_T) \approx 0.5mm$$

FDC2 : angular resolution < 1 mrad ~ L/Lr~10^{-3}

2.1. Heavy ion detectors

* Position measurement
  * Beam Proportional Chamber (BPC) : momentum tagging at F5
  * Beam Drift Chambers1,2 (BDC1,2) : beam phase space
  * Forward Drift Chamber1 (FDC1) : scattering angle
  * Forward Drift Chamber2 (FDC2) : rigidity analysis for fragments
  * Proton Drift Chamber1,2 (PDC1,2) : rigidity analysis for protons

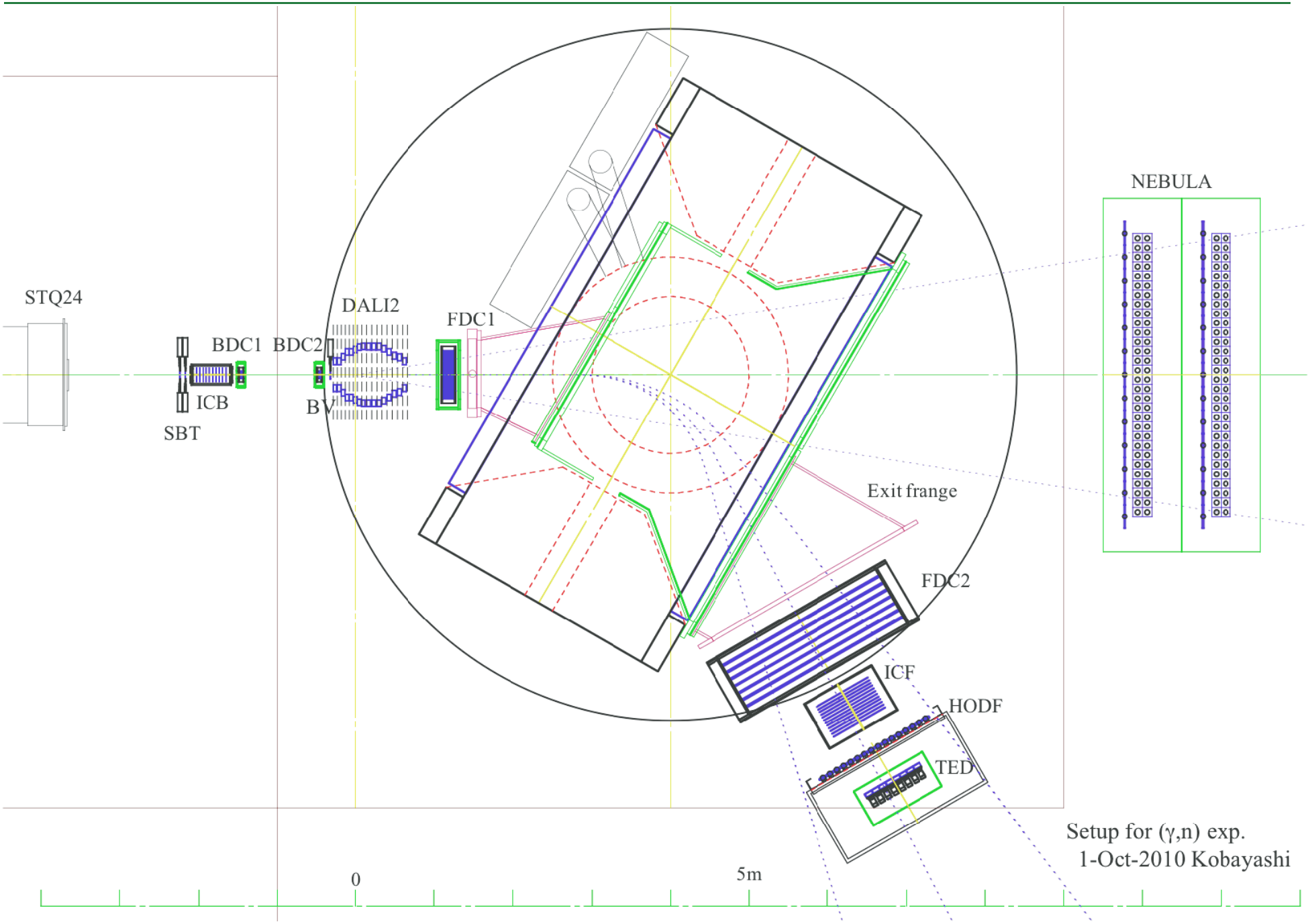
* Charge measurement
  * Ion Chamber for Beam (ICB) : charge of beam
  * Ion Chamber for Fragment (ICF) : charge of fragment

* TOF (charge) measurement
  * Hodoscope for Fragment (HODF) :
  * Hodoscope for protons (HODP) :

* Velocity measurement
  * Total Internal Reflection-type Cherenkov (TIRC) : high-precision velocity meas.

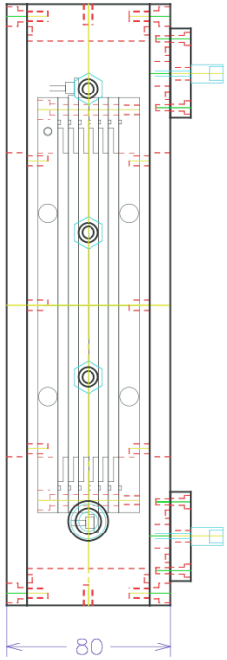
* Total-Energy measurement
  * Total Energy Detector (TED) : high-precision total-energy meas.

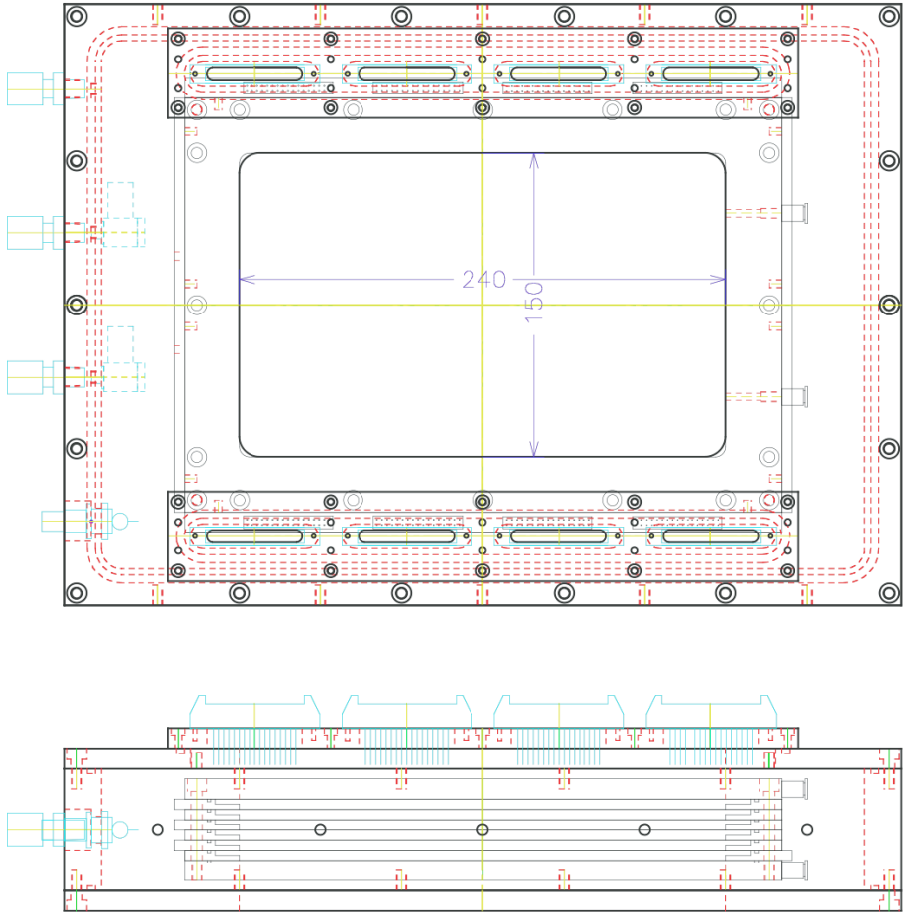
2.2 Planned Setup @spring 2012



3.1 : BPC (Beam Proportional Chamber)

Eff. Area:	240mm x 150mm
Config:	x1, x2
config:	4mm-spacing MWPC
#Anodes:	128
Gas:	iC_4H_{10}
	200 torr for p
	20 torr for Kr

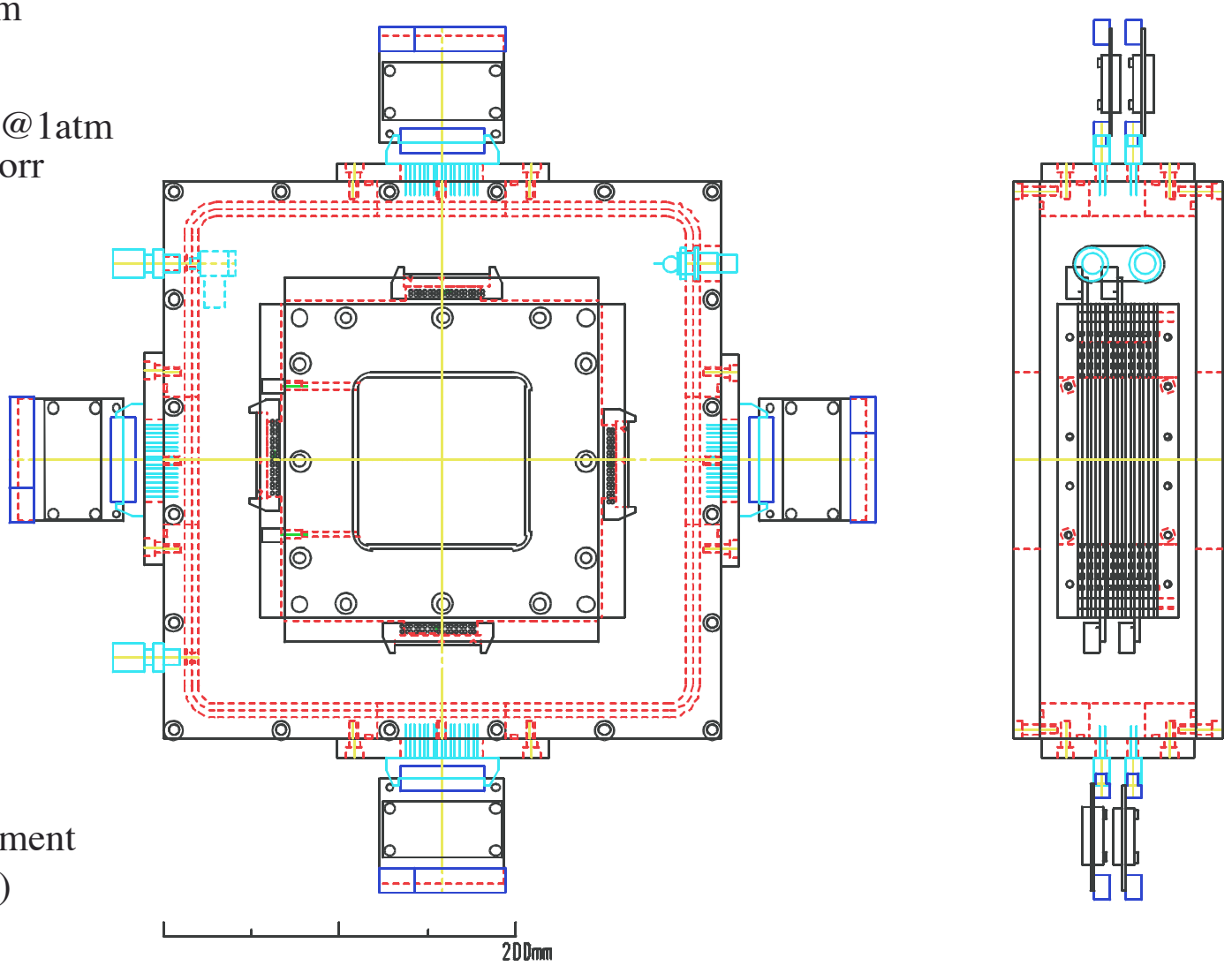




status : built, useded in the experiment

3.2 : BDC (Beam Drift Chamber)

Drift dist.: ±2.5mm for high rate
Half Gap: 2.5mm
Eff. Area: 80mm x 80mm
Config: xx'yy'xx'yy'
#Anodes: 256
Gas: He+60%CH_4 @1atm
iC_4H_{10} <200 torr
L/Lr: ~$0.3x10^{-3}$
Lr(He+60%CH_4) ~ 1000m

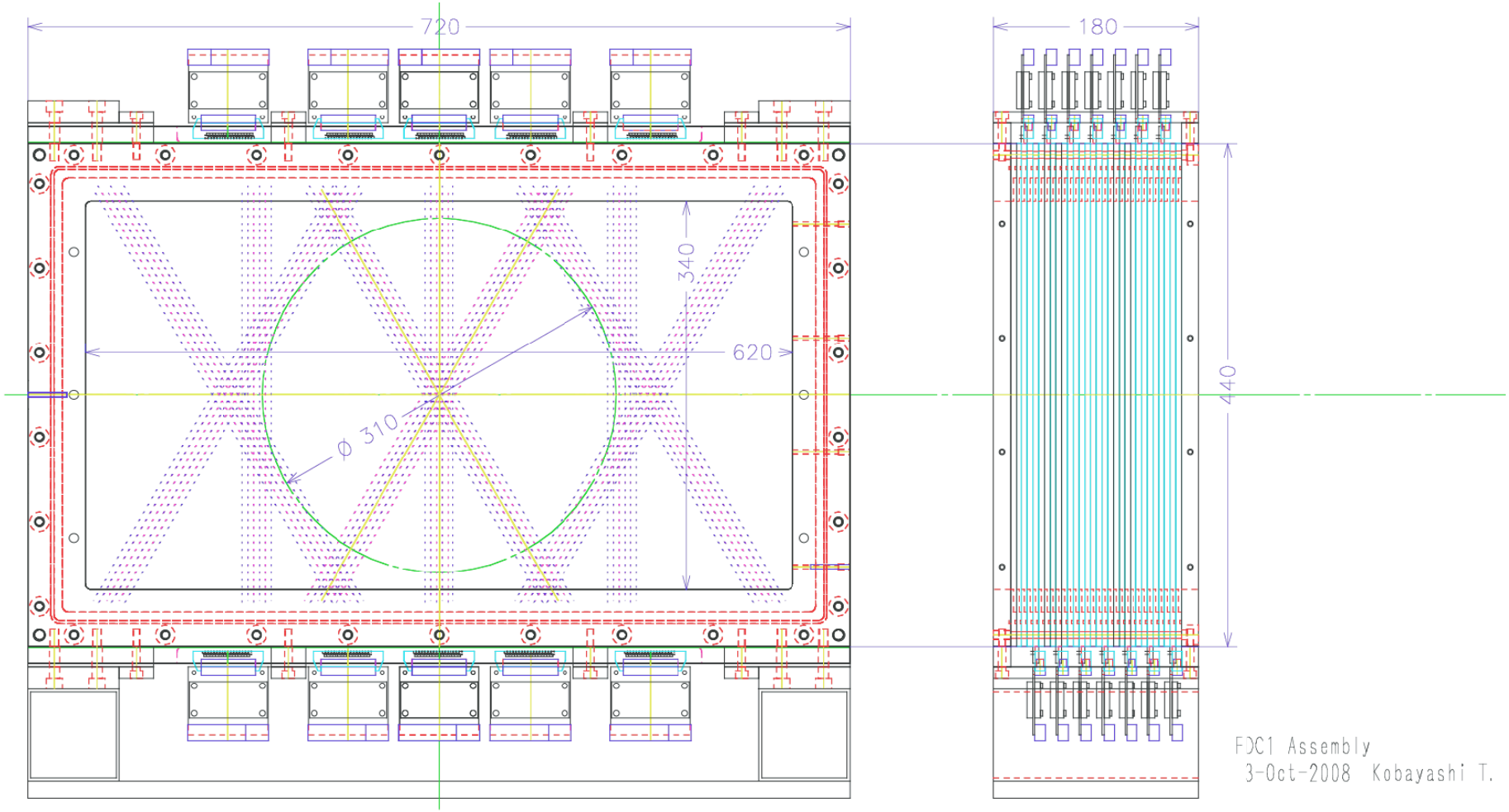


Status :
* built & used in the experiment
σ ~120 μm (p, He, Li)
* Outer box being made

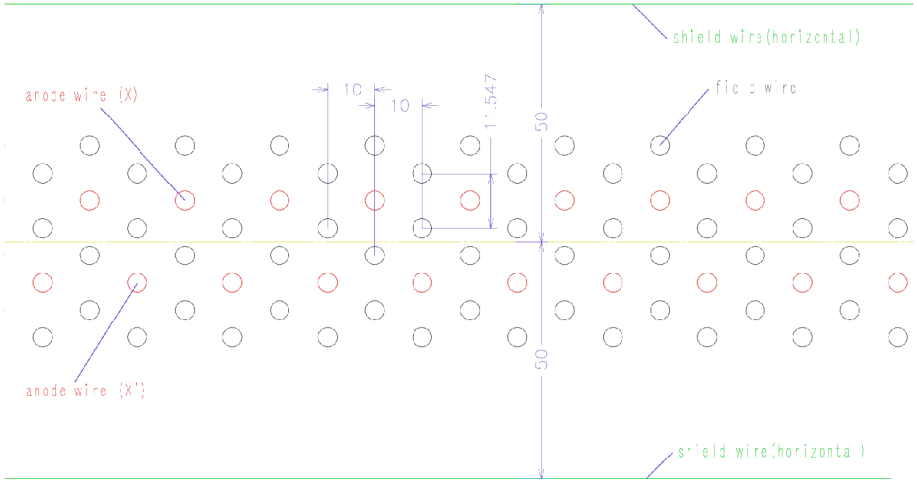
3.3 : FDC1 (Forward Drift Chamber 1)

Drift dist.:	±5mm
Half Gap:	5mm
Eff. Area:	ϕ 310mm (620 x 340)
#Anodes:	448
Config:	xx'uu'vv'xx'uu'vv'xx'
Gas:	He+60%CH_4 @1atm, iC_4H_{10} <200 torr
L/Lr :	0.5 x 10^{-3}

Status :
* built
* HV leakage problem fixed
* being tested
* Outer box being designed



3.4-1 : FDC2 (Forward Drift Chamber 2)

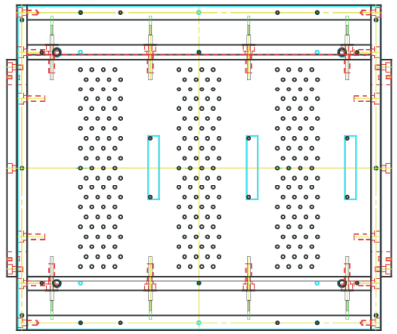


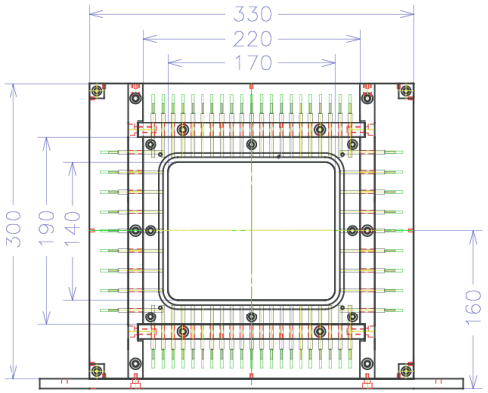
* cell : hexagonal cell (10mm drift length)

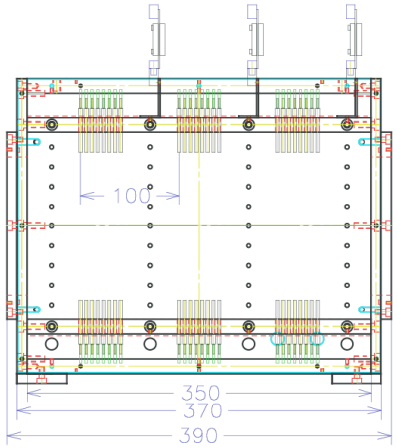
* anode wire : 40 μmϕ Au-W
* field wire : 80 μmϕ Au-Al

* xx', uu', vv' are grouped
  separated by shield wires

* Basic operation being studied
  using small test chamber
  with the identical cell/layer configuration



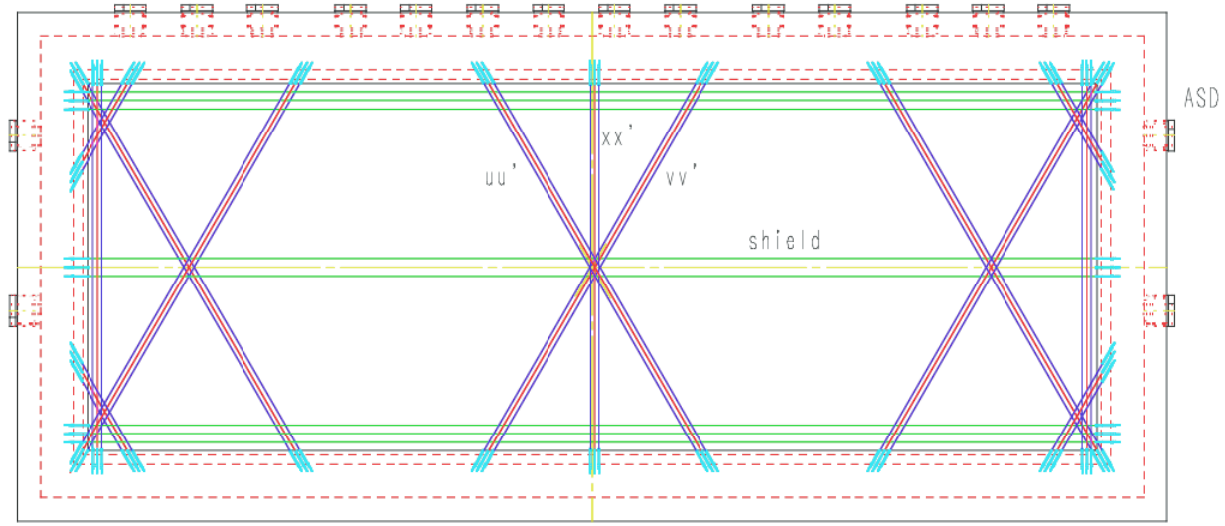


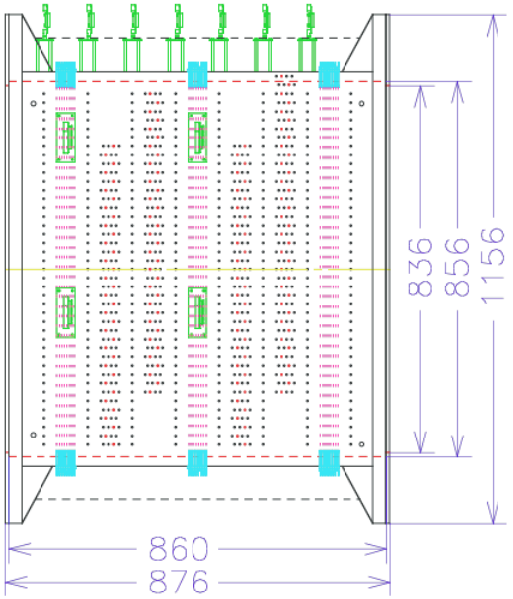


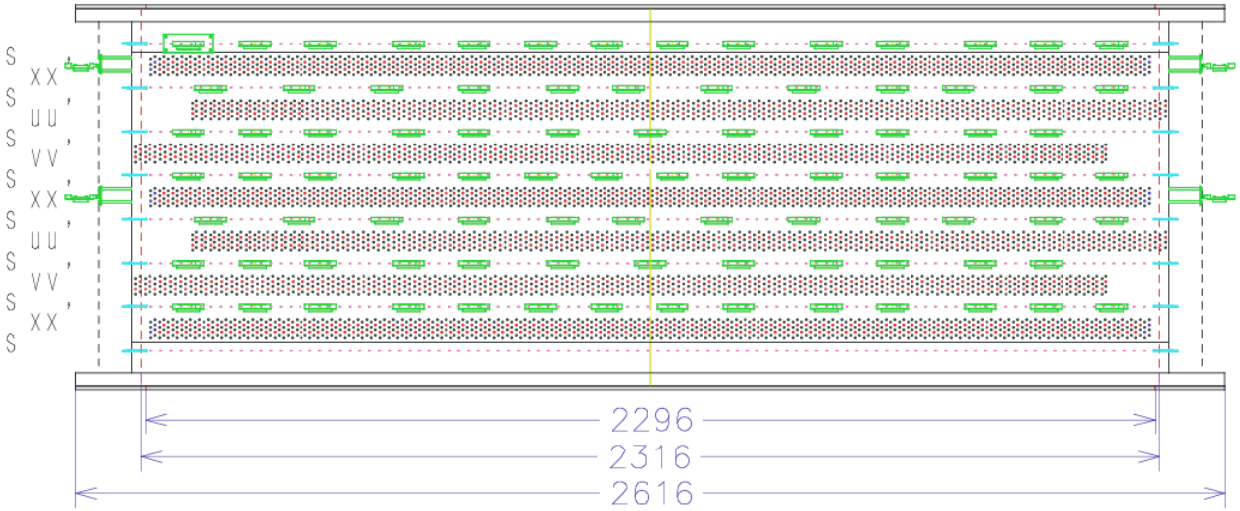
3.4-2 : FDC2

Eff. Area: 2.23m(H) x 0.81m(V) x 0.79m(D)
#Anodes: 1568
Config: xx'uu'vv'xx'uu'vv'xx'
Gas: He+60%CH_4 @1atm
L/Lr : 0.9×10^{-3}

Status :
* FDC2 wiring : ~3/4 finished
* Detector stand : being designed



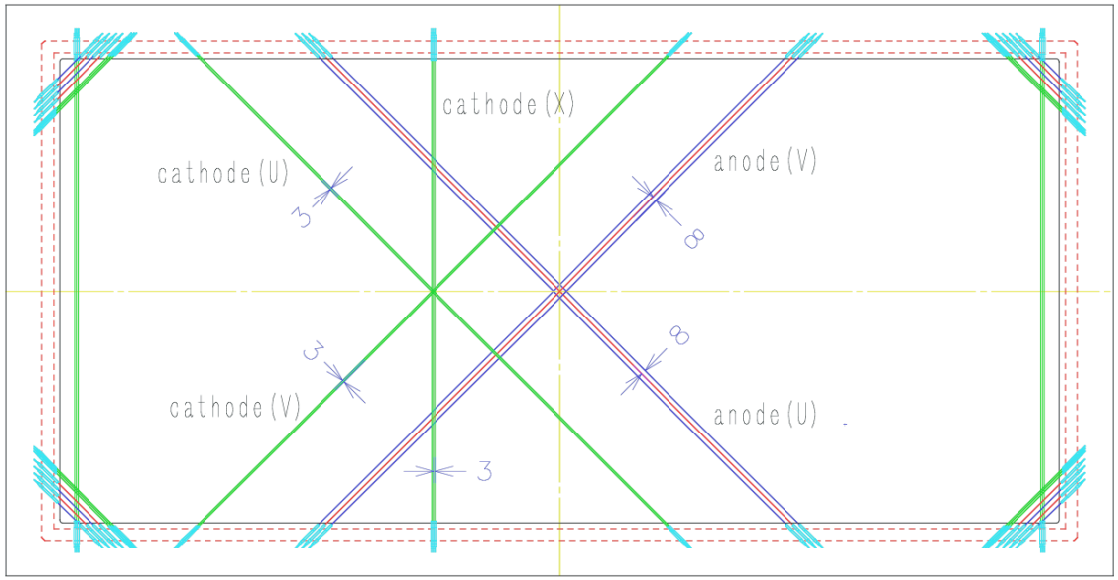


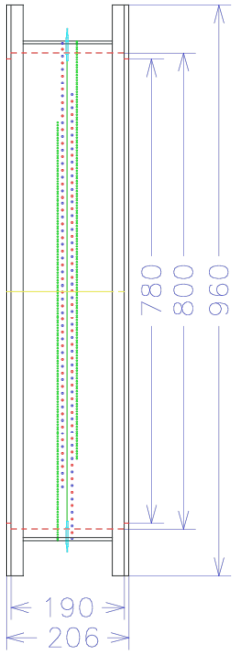


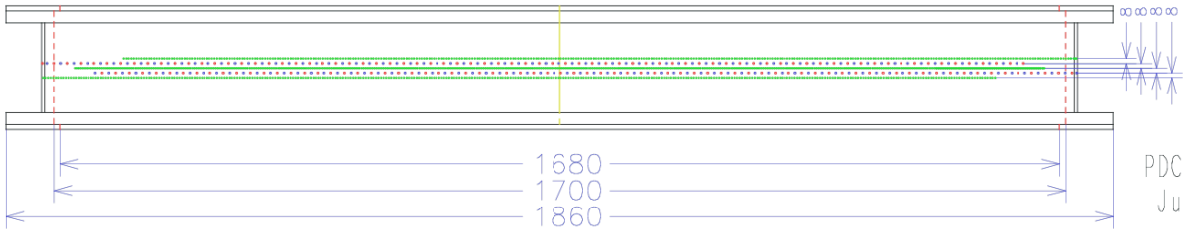
FDC2 assembly
3-Apr-2010 Kobayashi T.

3.5-1 : PDC1,2 (Proton Drift Chamber 1, 2)

Configuration:	Cathode_U(+45°), Anode_V(-45°), Cathode_X(0°), Anode_U, Cathode_V
Drift dist.:	±8mm
Half Gap:	8mm
Cathode pitch:	3mm
Cathode Strip:	12mm (4 cathode wires), #Readout: 136 strips/ plane x 3 planes x 2set~816ch
Anodes:	428 (no readout)
Effective area:	1700mm(H) x 800mm(V)



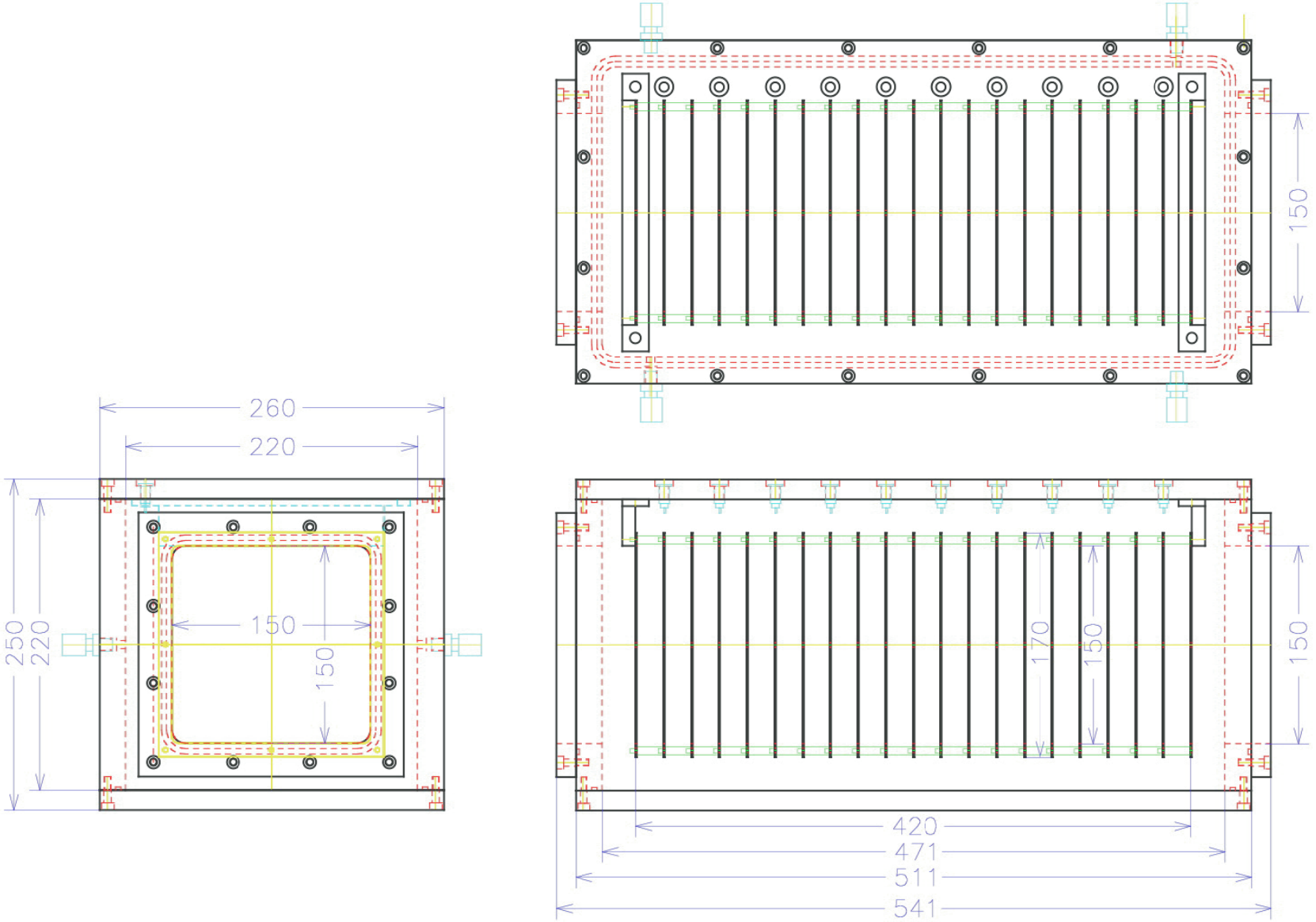




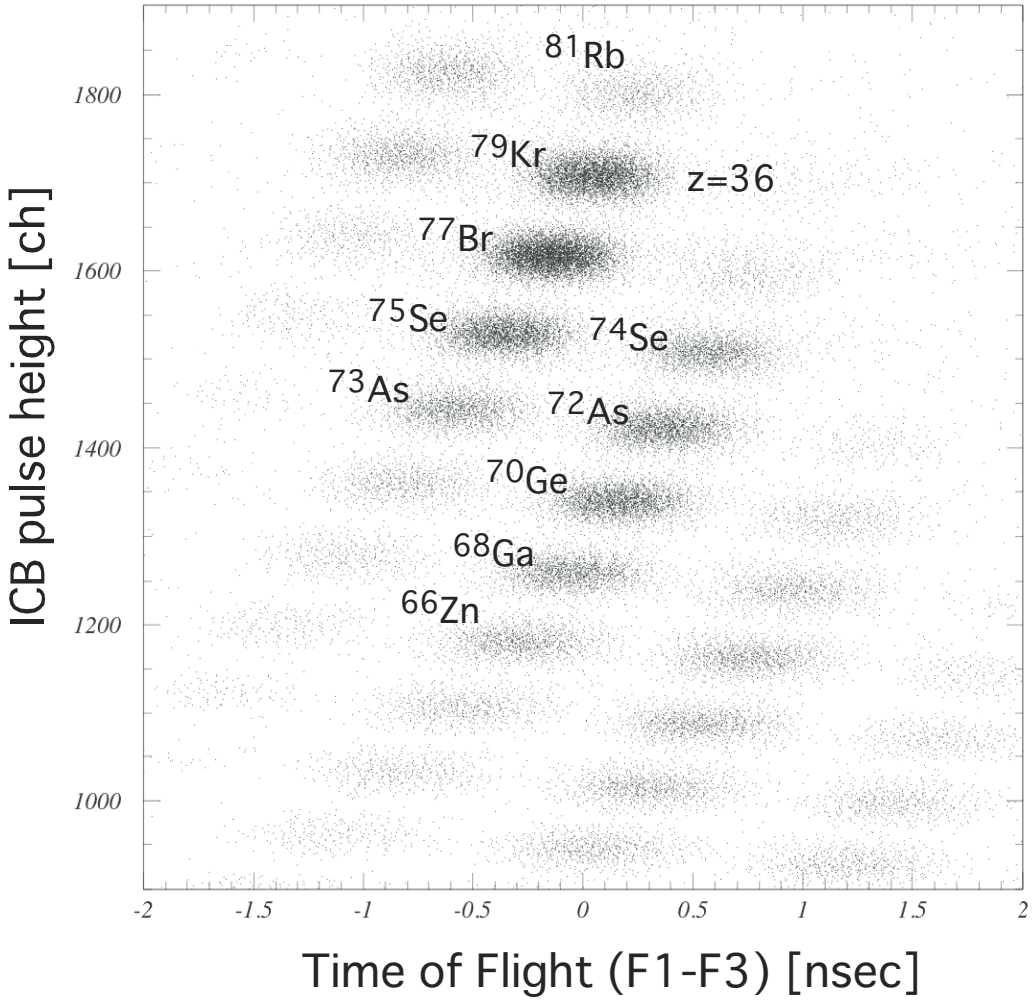
* Status
  final detector design
  in progress
* Readout
  *charge division
    for every 8 strips
    total 110 ch
  * individual readout
    total 816 ch
    being developed

3.6-1 : ICB (Ion Chamber for Beam)

Multi-Layer Ion Chamber: 10 anodes+11 cathodes (12umt Al-Mylar)
Effective area: 140mm(H) x 140mm(V) x 420mm(D)
Gas: P10 @1atm



PID of momentum-analyzed RI beams @HIMAC
270 MeV/A



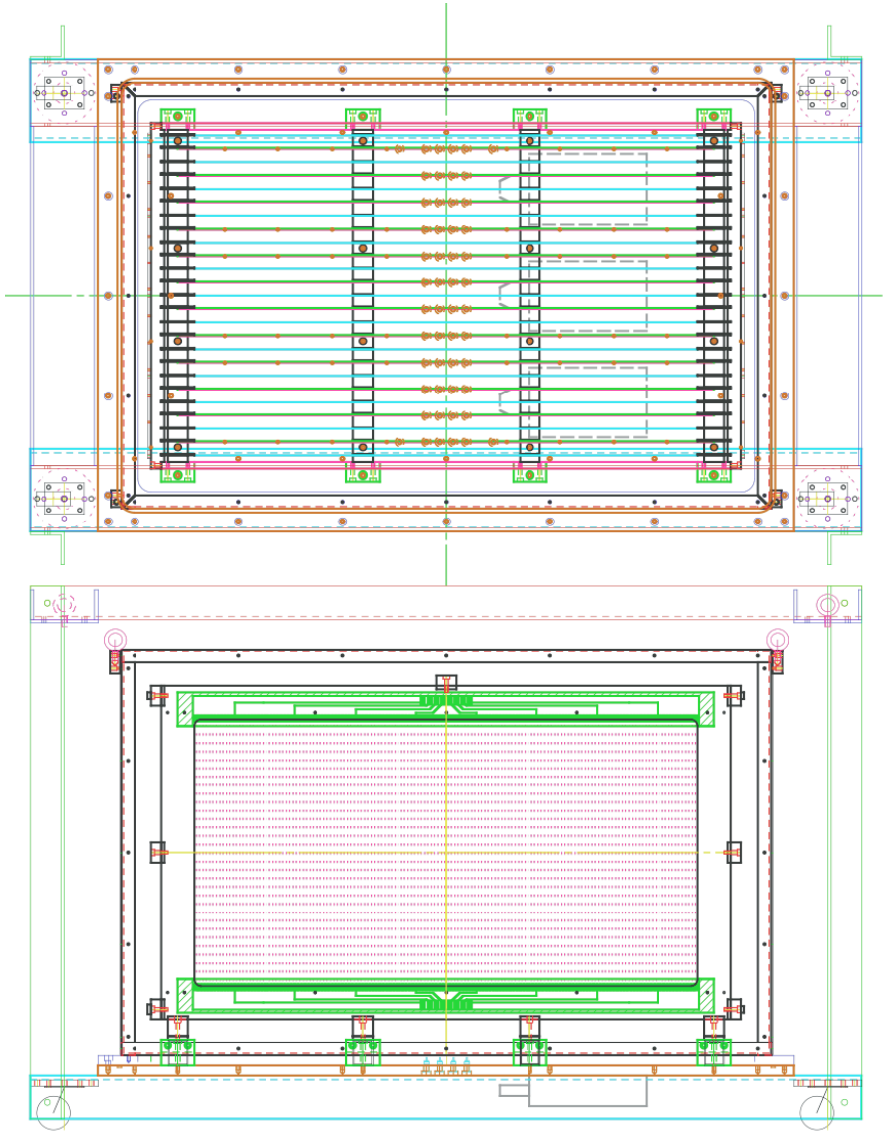
Status :
* built
* Preamp with 10 usec decay time
* Shaping amp. with 0.25usec time const.
  unipolar output with active baseline rest.
* tested

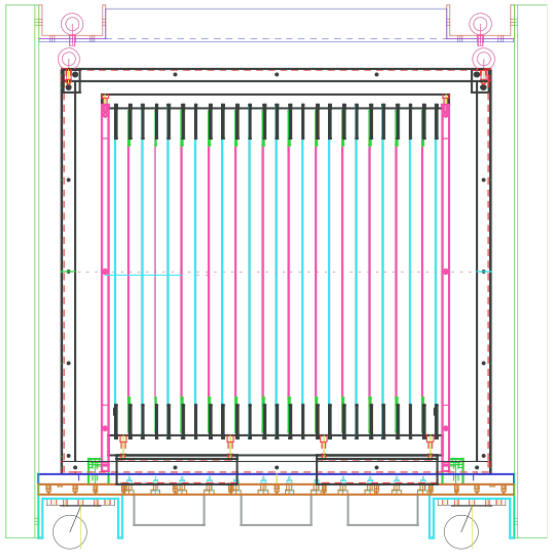
for z=36 @300MeV/A
pulse height resolution ~ 0.9%
Charge resolution: $\sigma_z \sim 0.17$

3.7 : ICF (Ion Chamber for Fragment)

Multi-Layer Ion Chamber: 12 anode planes (4-strips/plane) +13 cathodes, 48 readout channels
Effective area: 750mm(H) x 400mm(V) x 480mm(D)
Gas: P10 @1atm

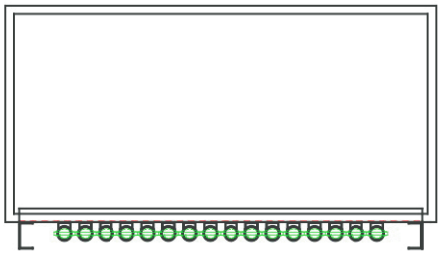
status :
being assembled

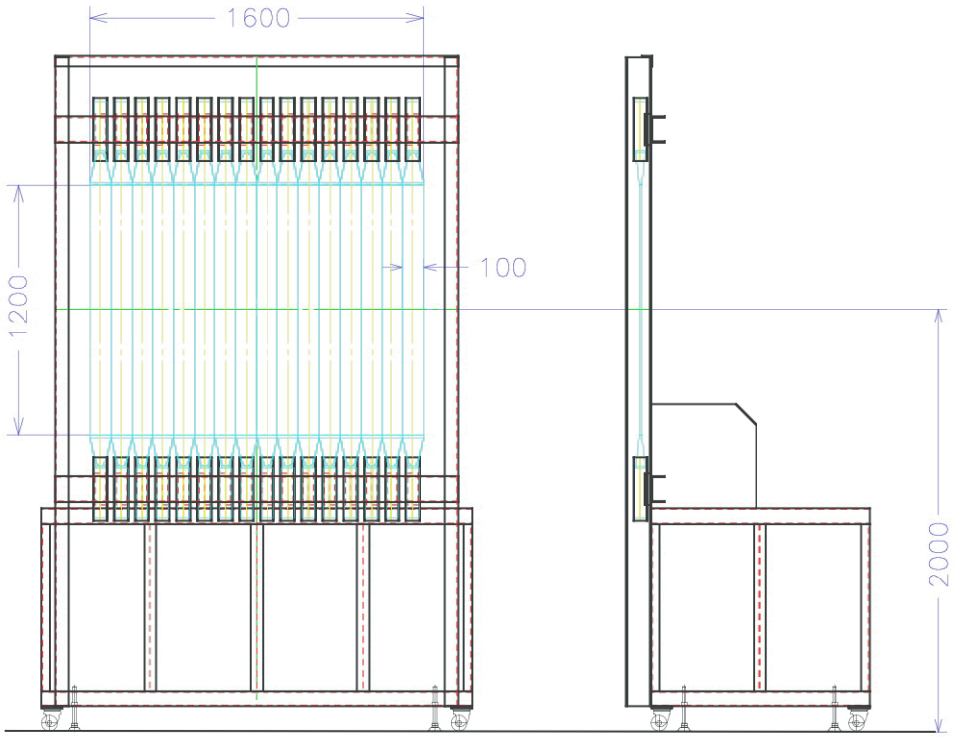




3.8 : HODF/HODP (Hodoscope for Fragment / Proton)

Slat:	1200mm(V) x 100mm(H) x 10mm(t), 16 slats/hodoscope
Plastic:	BC408/EJ200
effective area:	1600mm(H) x 1200mm(V)
PMT:	H7195 with Booster

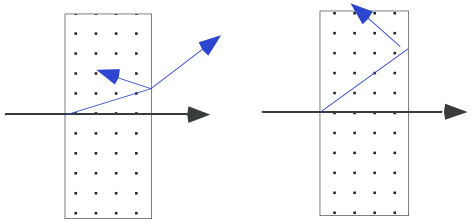




Status :
* 30 assemblies and 2 stands were built
* to be mounted on the stand

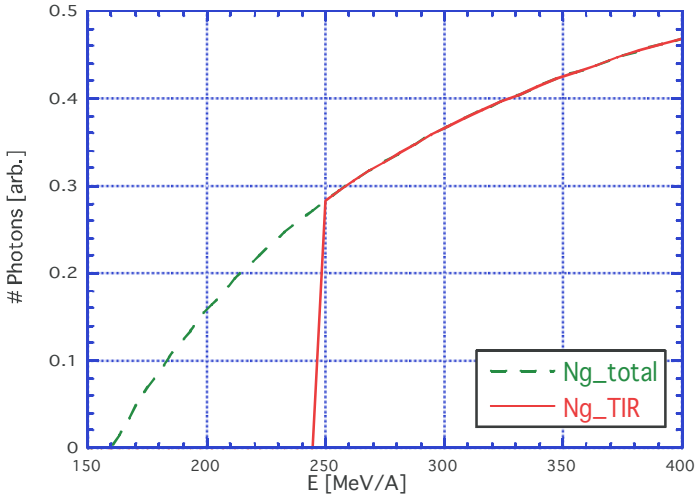
3.9-1 : TIRC (Total Internal Reflection Cherenkov)

＊Principle

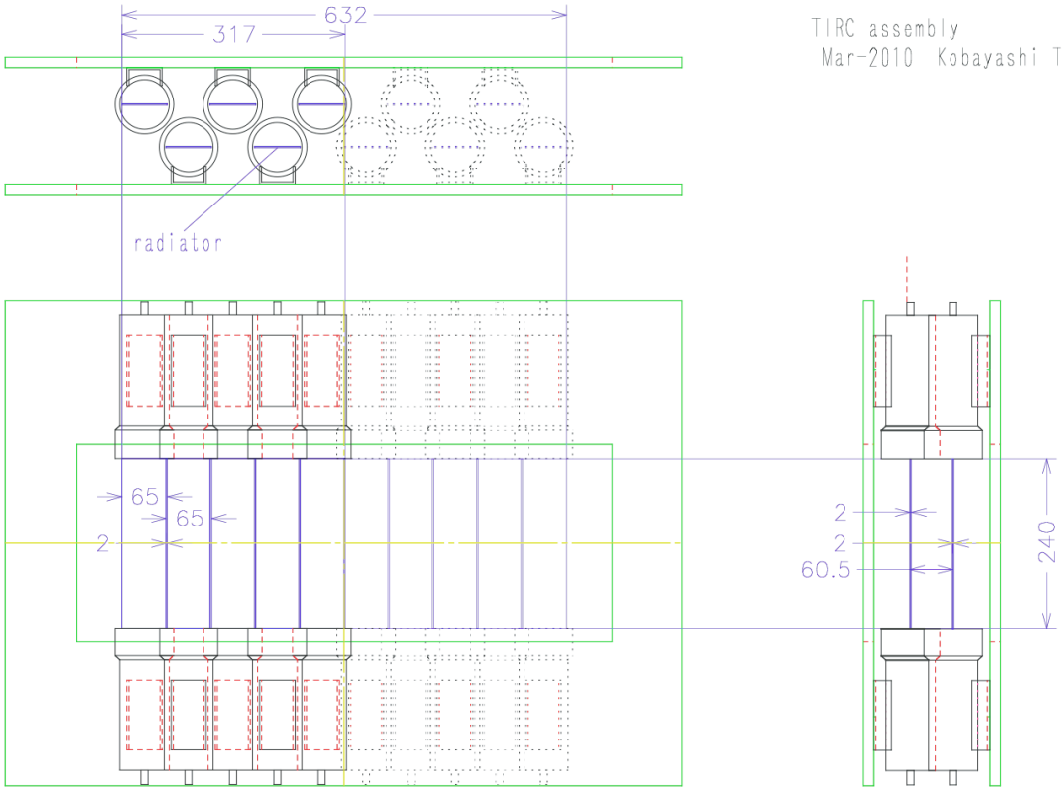


$$\beta \geq \frac{1}{n} \qquad \beta \geq \frac{1}{\sqrt{n^2-1}}$$

n=1.92
(TAFD30)



＊Design



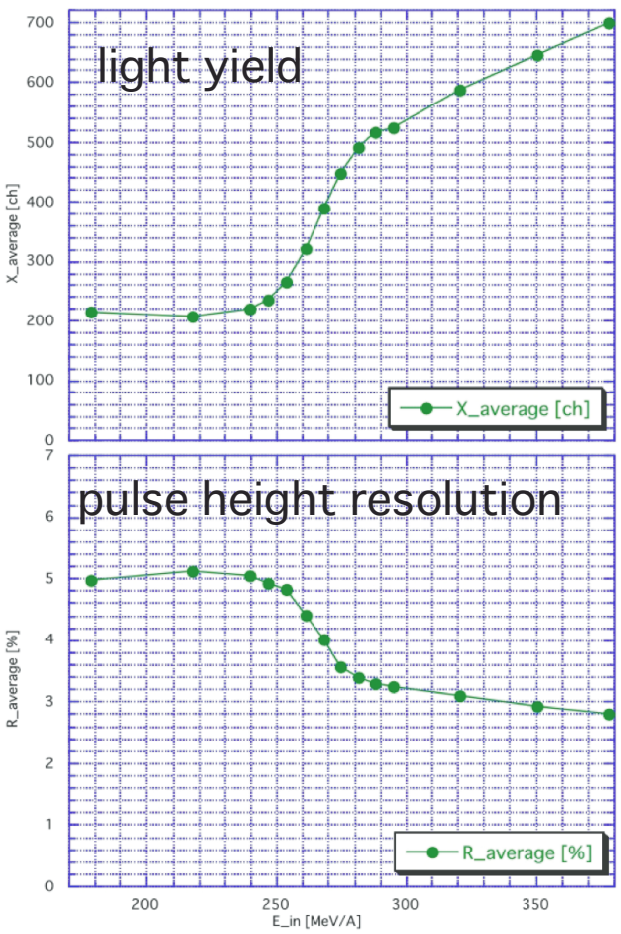
TIRC assembly
Mar-2010 Kobayashi T.

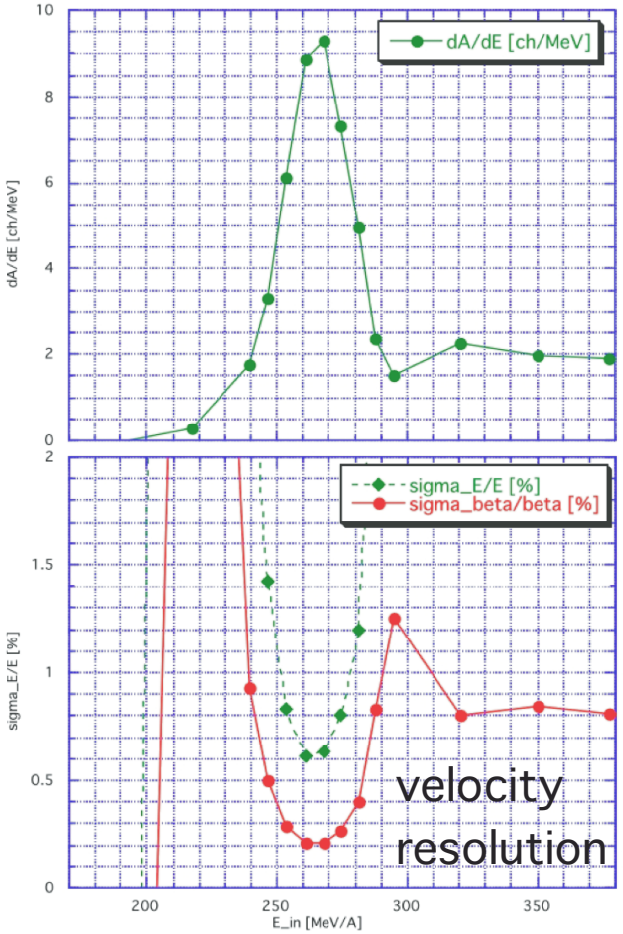
radiator : 65 x 240 x 2^t
PMT: H6559(3"ϕ)
effective area: 632 x 240

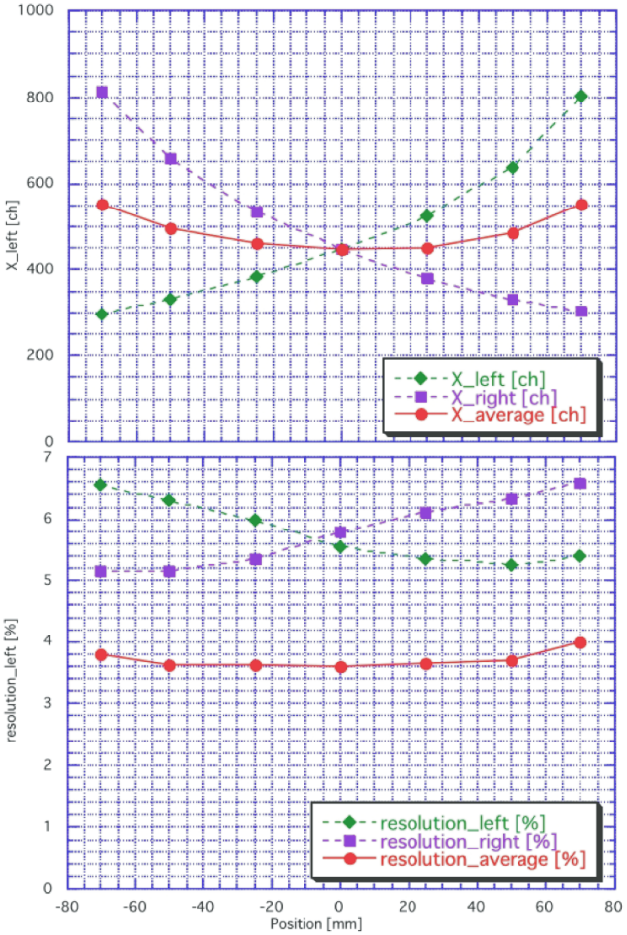
3.9-2 : TIRC (Beam tests)

Kr beam : 200-400MeV/A　　1mm^t, wide-gate

velocity dep.　　position dep.

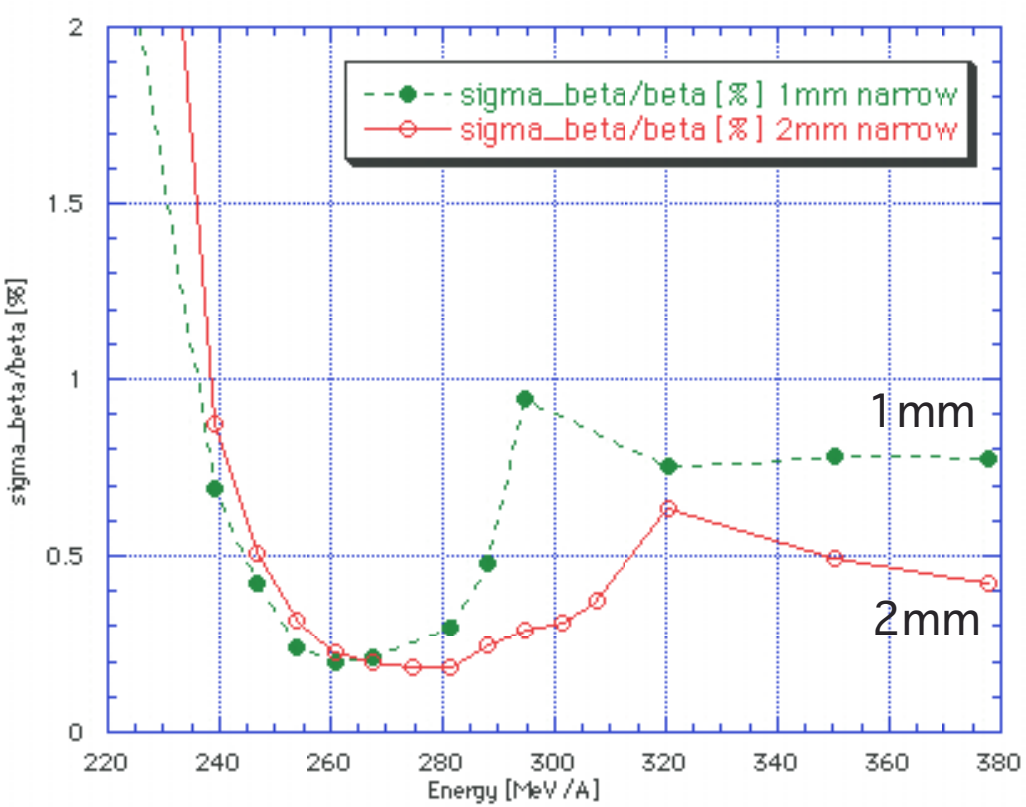






angle dep. : ~2.5%/deg

Estimated velocity resolution using energy-degraded Kr beam

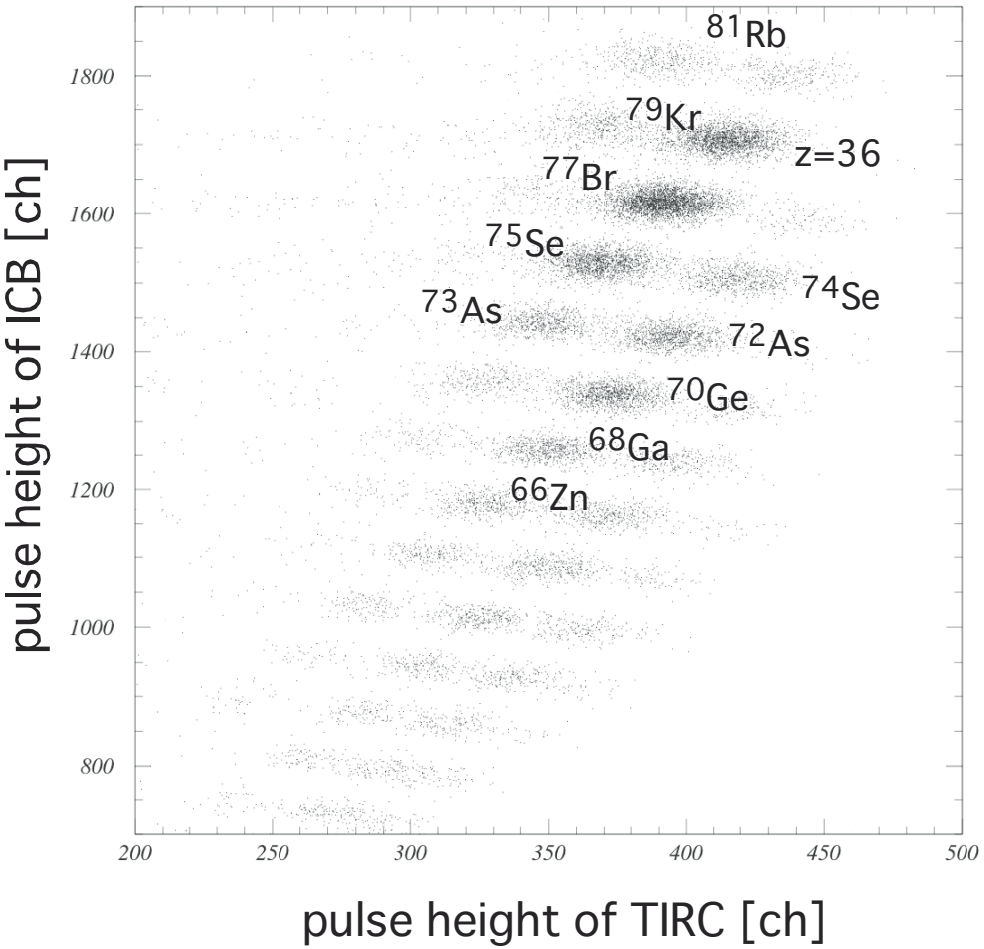


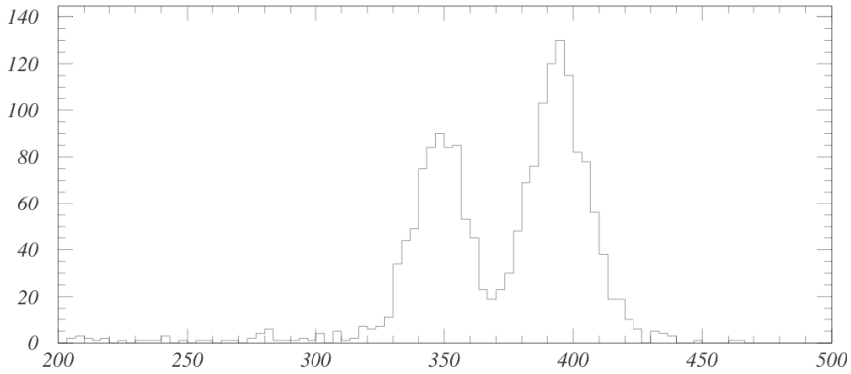
Thickness : 1, 2mm^{t}

∗pulse shape : cherenkov (short decay time) + scintillation? (long decay time)

3.9-4 : TIRC (PID test)

@270MeV/A (Δp/p~0.1%)





Δx/ σ ~4.2

thickness : ~1.2 g/cm^3

reaction loss : ~5%

＊large radiation damage observed

3.10-1 : TED (Total Energy Detector)

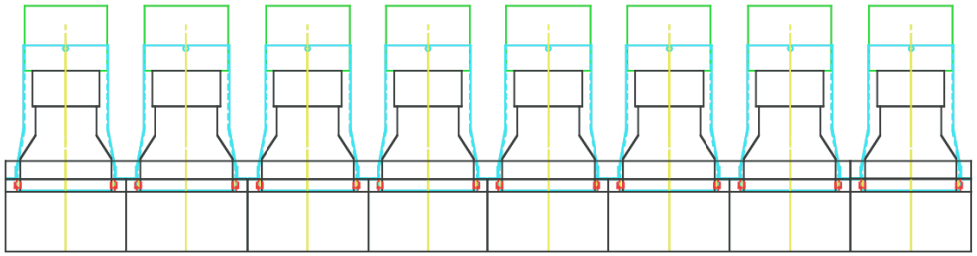
＊R&D

＊NaI(Tl)+PMT, HP-Ge, CsI(Tl)+PD : 0.3-0.4% (rms) for E=25-30GeV

＊CsI(pure) : - smaller light output, UV

+ fast decay time, strong against radiation damage

＊Design

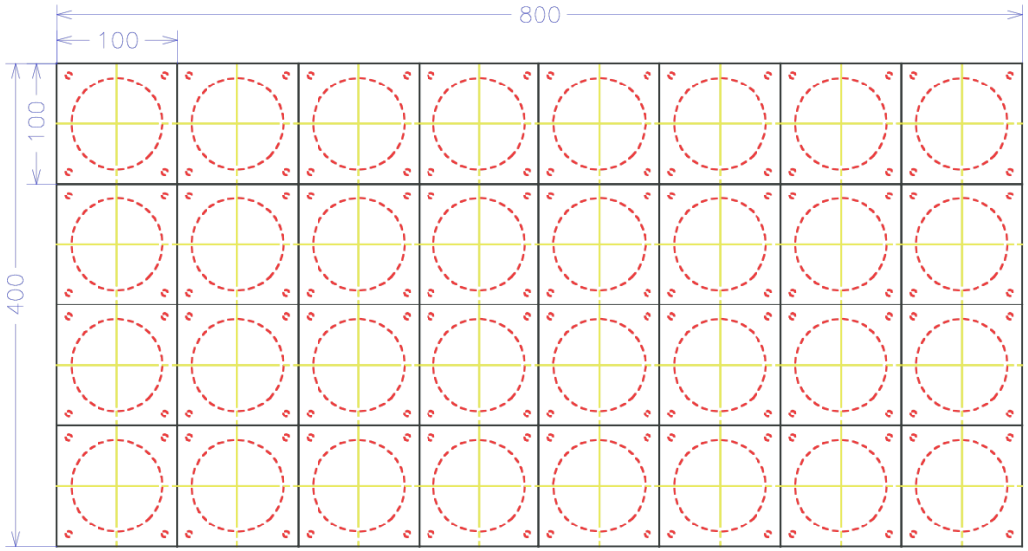


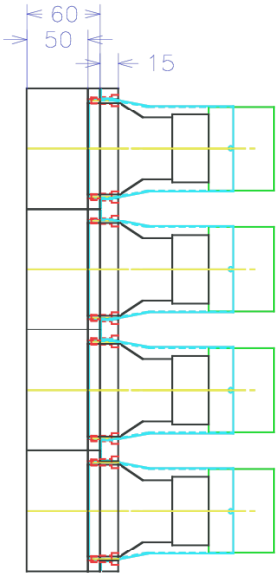
Crystal : pure CsI, 100x100x50(t)

32 elements

PMT : R6233HA (3"ϕ, non-UVW)

Effective area: 800 x 400

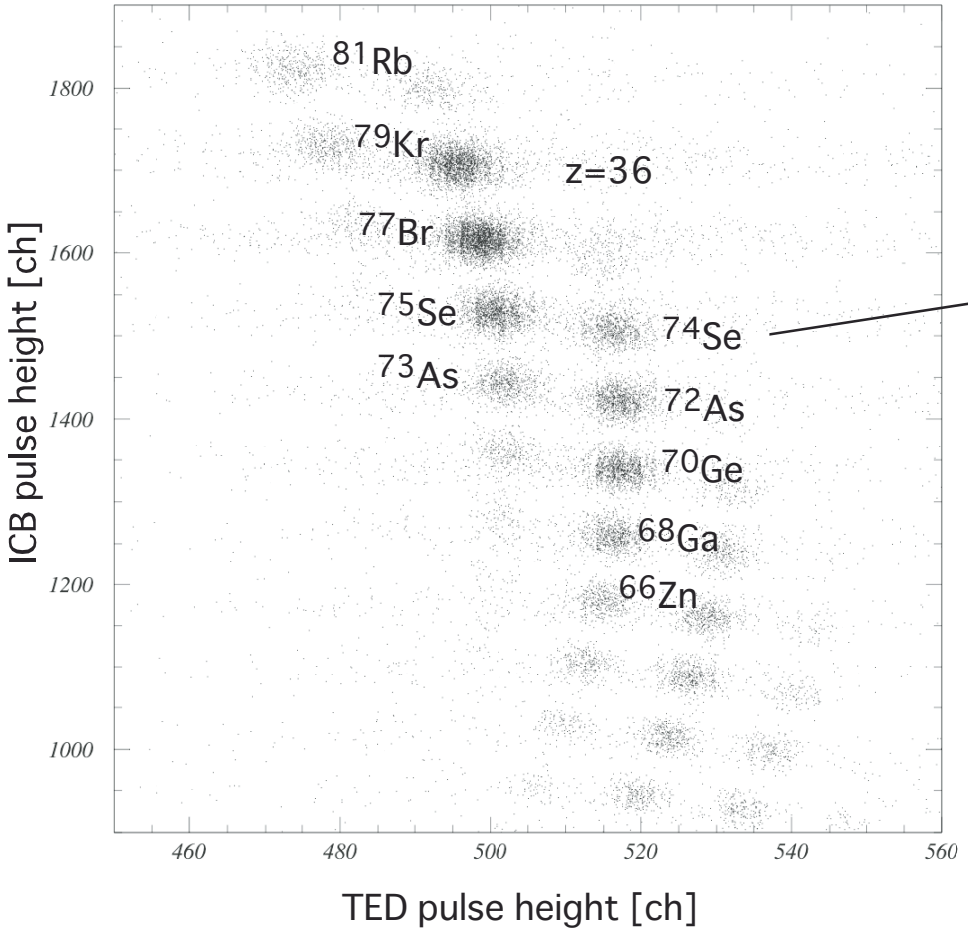


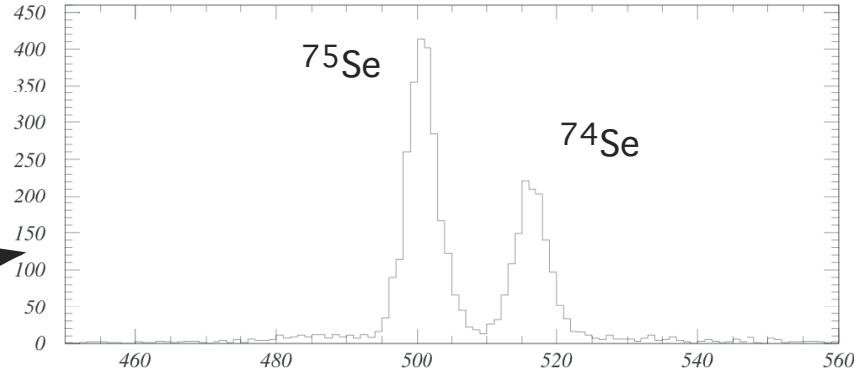


3.10-2 : TED (Beam test)

mass separation of RI beam

@270MeV/A ($\Delta p/p=0.1\%$) absorber : Al 9mm^t (~130MeV/A loss)





$\Delta x/\sigma \sim 6.5$

combined with the absorber,
>6 σ separation possible

reaction loss
absorber 0mm : ~12%
absorber 9mm : ~15%

radiation damage being studied

4. Summary ： Heavy Ion Detectors

- All detectors
  - more or less, conventional
  - mostly under construction w/o major problems
- Beam tests @HIMAC SB2
  - actual detectors, prototypes...
- to be constructed in FY2010
  - ICF
  - FDC2 + stand
  - TED elements
  - (FDC1 detector box)
- to be constructed in FY2011
  - PDC
  - and many other remaining items...