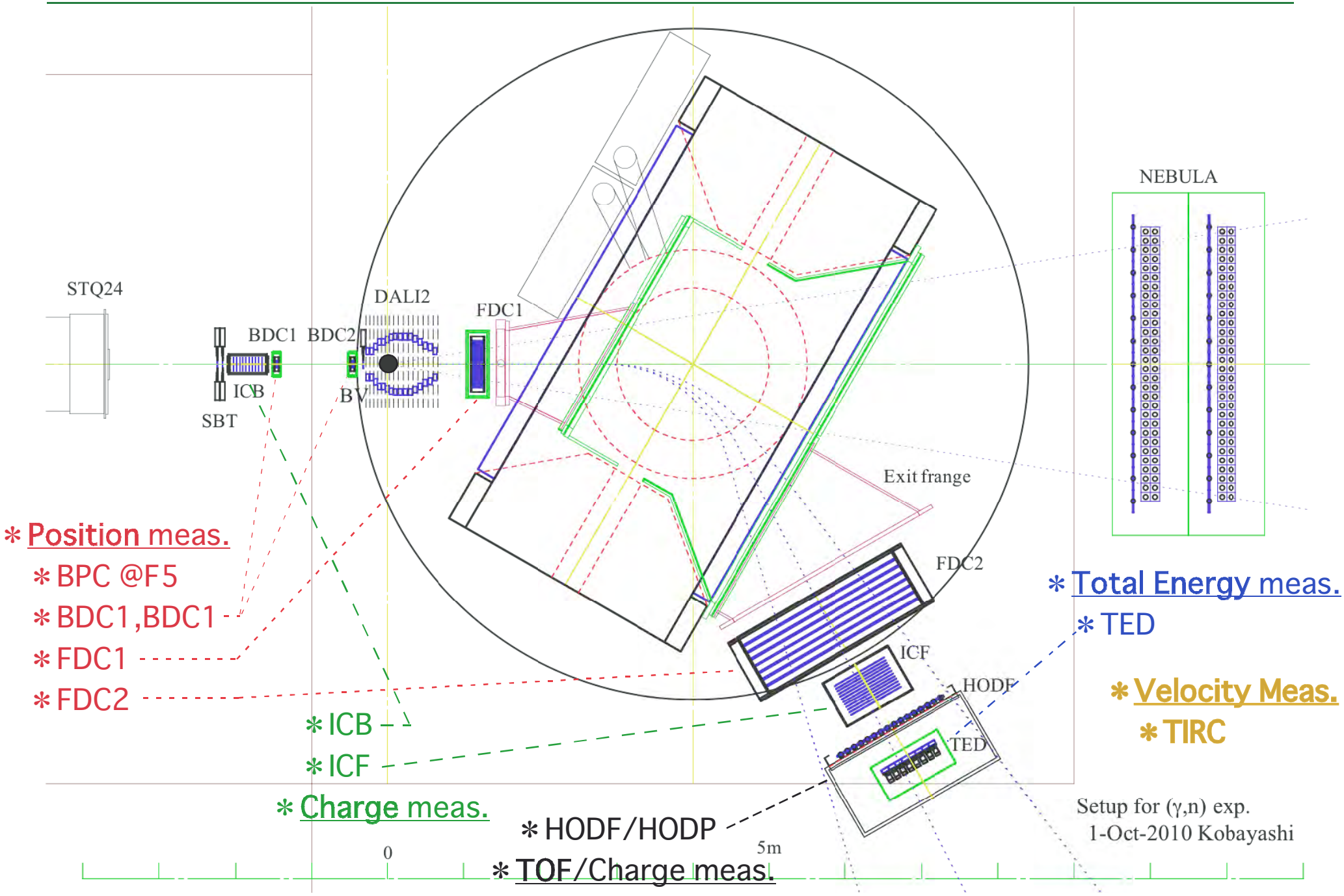
Heavy Ion Detectors

T. Kobayashi (Tohoku Univ.)

* Plan of Setup @spring-2012
* Status of Heavy-Ion Detectors
* Summary

1.1 Planned Setup @spring 2012



* Position meas.
  * BPC @F5
  * BDC1,BDC1
  * FDC1
  * FDC2
* ICB
* ICF
* Charge meas.
* HODF/HODP
* TOF/Charge meas.
* Total Energy meas.
  * TED
* Velocity Meas.
  * TIRC

1.2 Particle Identification (PID) & Resolution

* Limitation : fully-stripped ions, A < 80~100 @~250MeV/A (β ~0.62, γ ~1.3)

* 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*)

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

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

not "easy"

Magnet
BDC1,2
FDC1
FDC2
PDC

HODF
HODP
TIRC

TED

$\sigma_Z \sim 0.2$

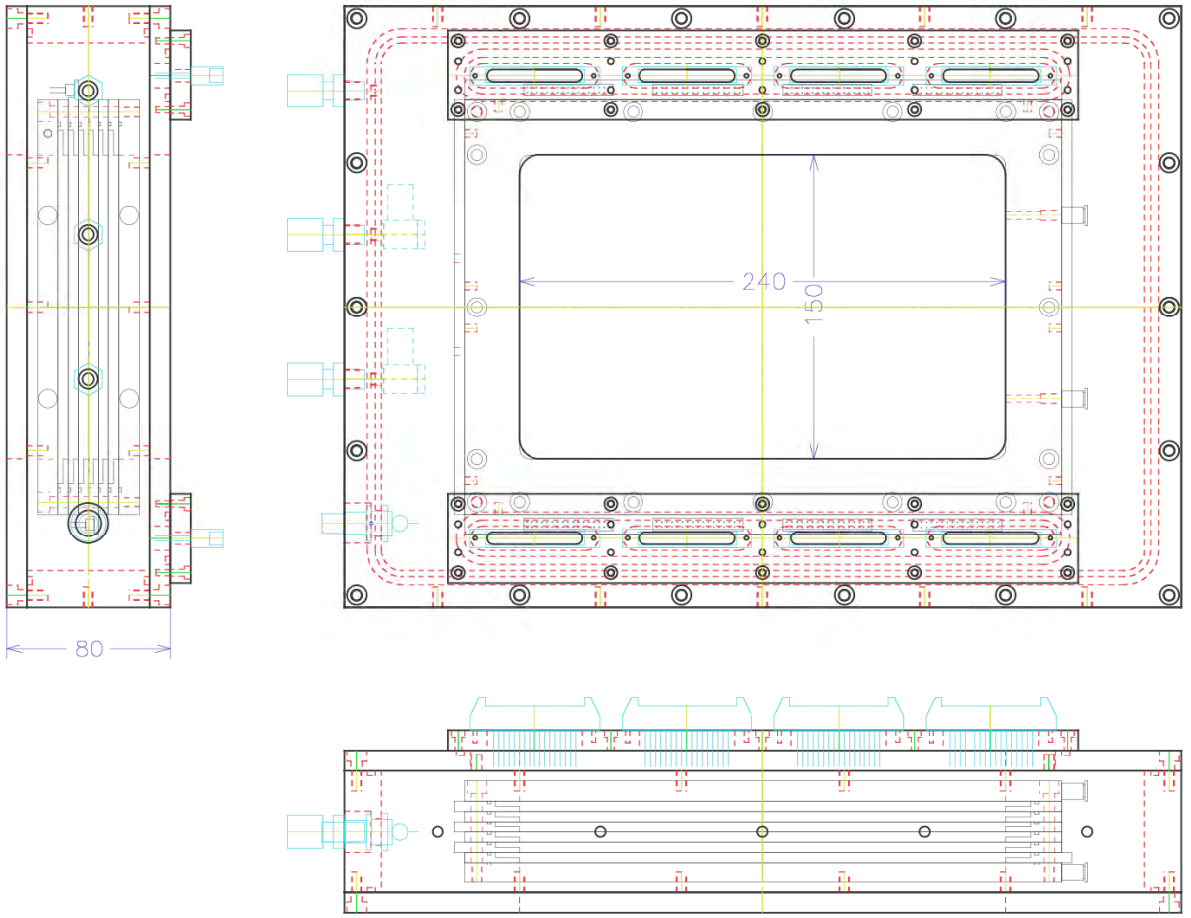
ICB
ICF

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

2.1 : BPC (Beam Proportional Chamber)

Placed at F5 (momentum-dispersive FP) for tagging beam rigidity

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

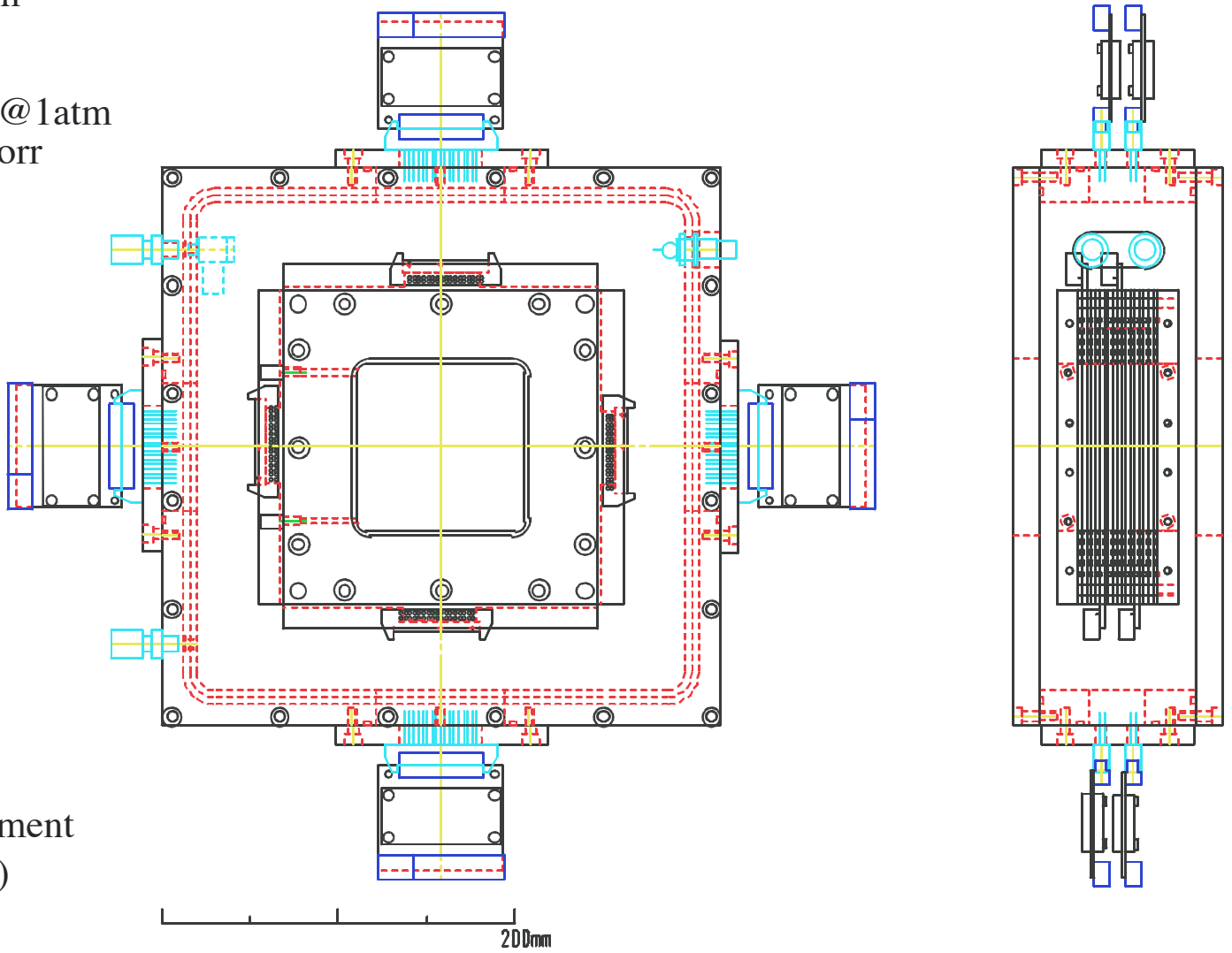


status : built, used in the experiment

2.2 : BDC1, BDC2 (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} <100 torr
L/Lr:	~0.3×10^{-3}

Lr(He+60%CH_4) ~ 1000m



Status :

* built & used in the experiment

  σ ~120 μm (p, He, Li)

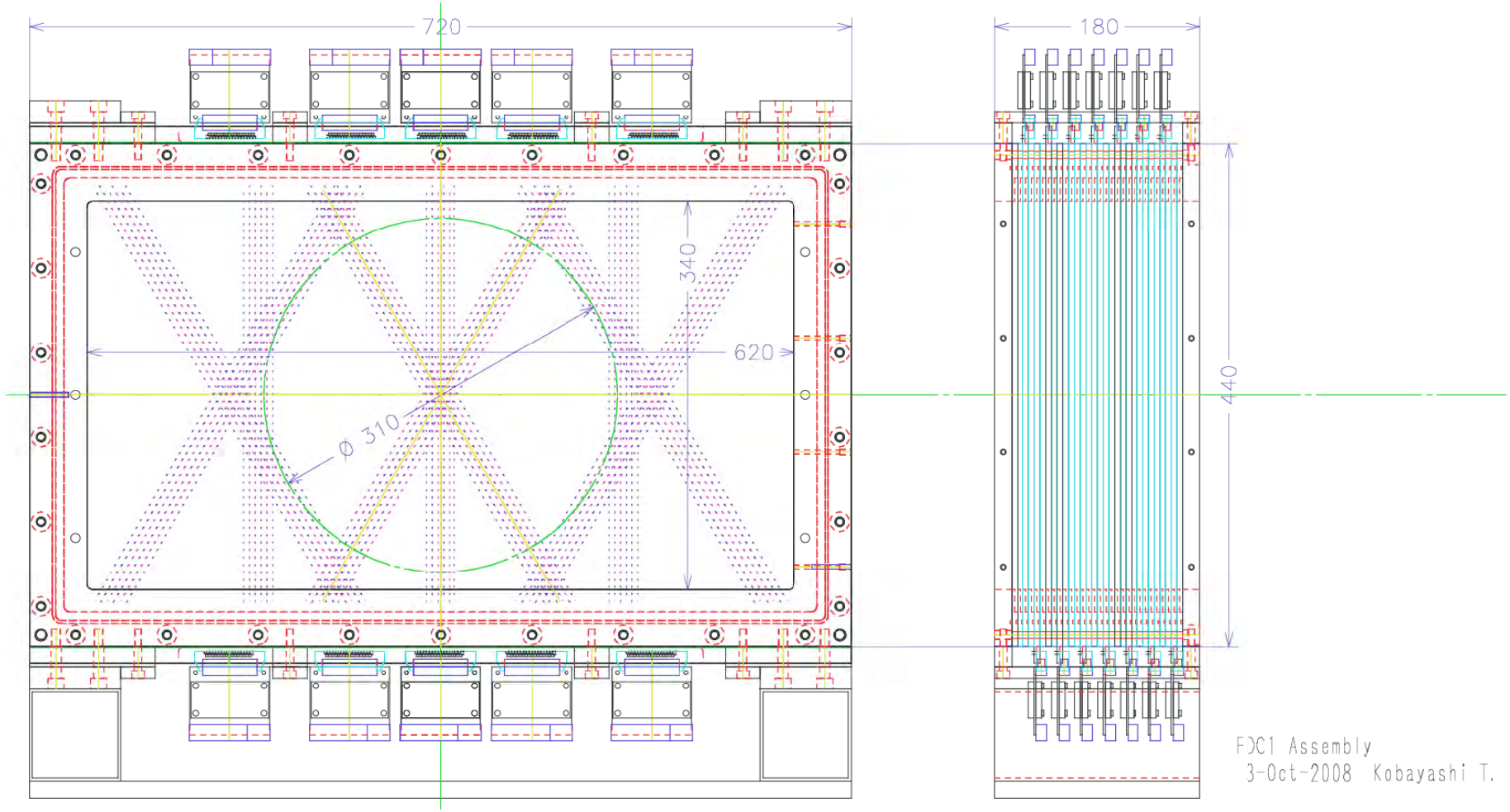
* BDC in low-pressure box being tested

* [stand]

2.3 : 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}

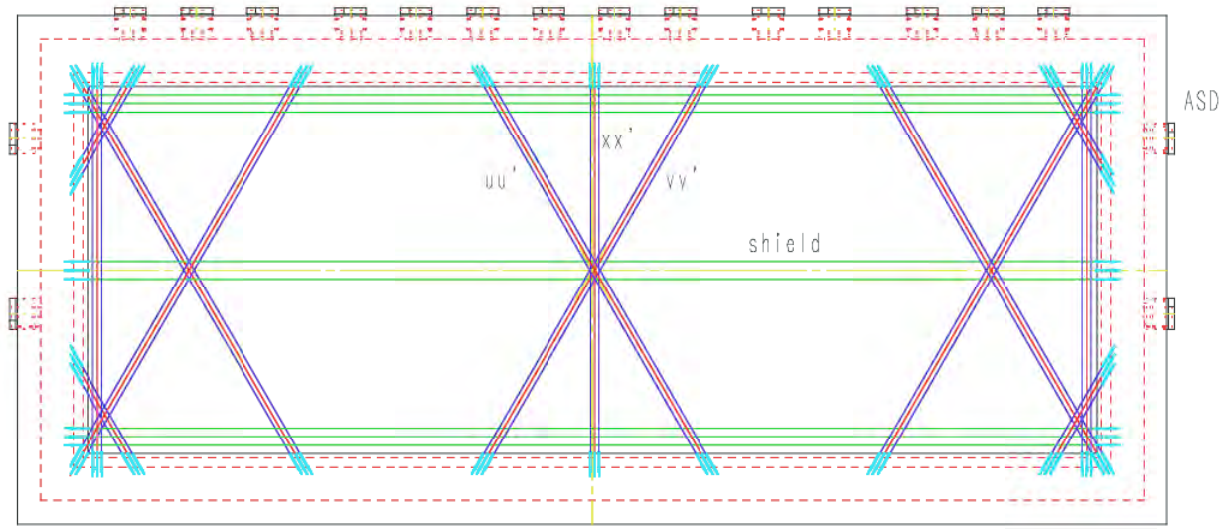
Status :
* built
* HV leakage problem fixed
* Outer box & Stand
  being made (<Mar-2011)

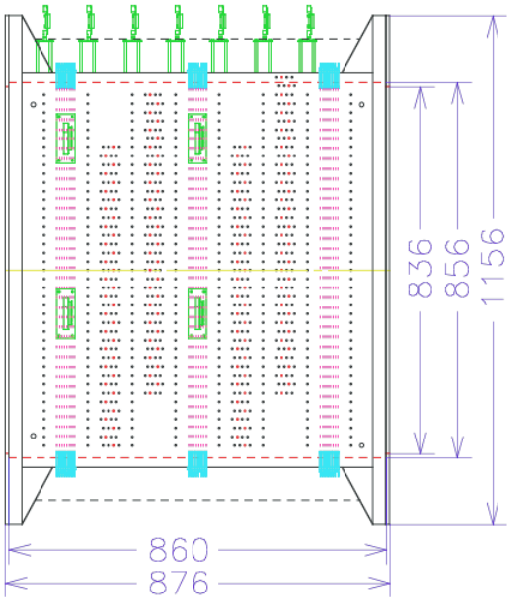


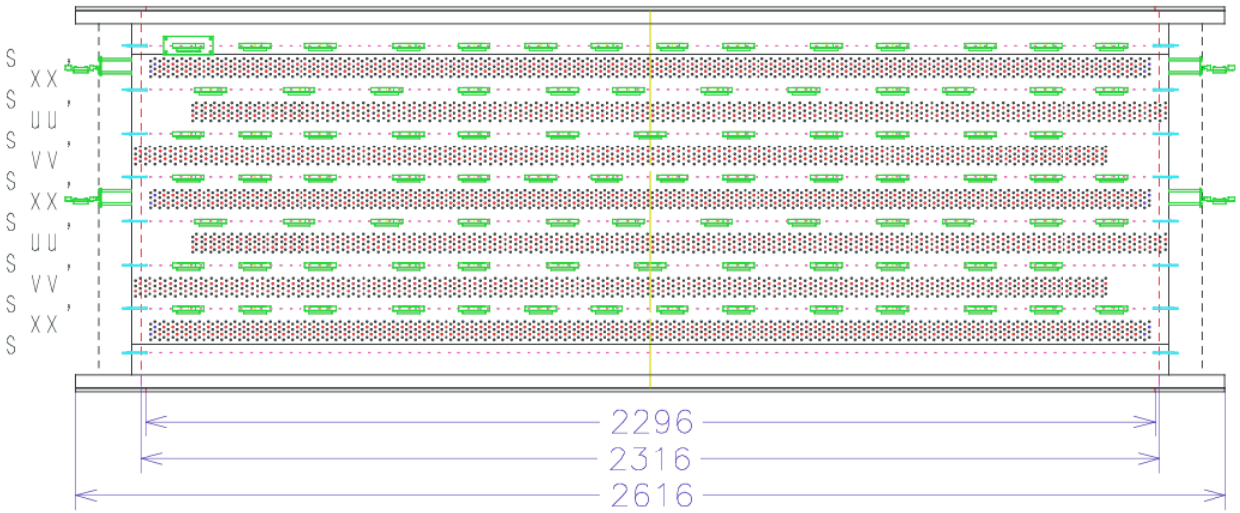
2.4 : FDC2 (Forward Drift Chamber 2)

Eff. Area:	2.23m(H) x 0.81m(V) x 0.79m(D)
#Anodes:	1568 (~100 ASD)
Config:	xx'uu'vv'xx'uu'vv'xx'
Gas:	He+60%CH_4 @1atm
L/Lr :	0.9×10^{-3}

Hexagonal cell, drift distance=10mm



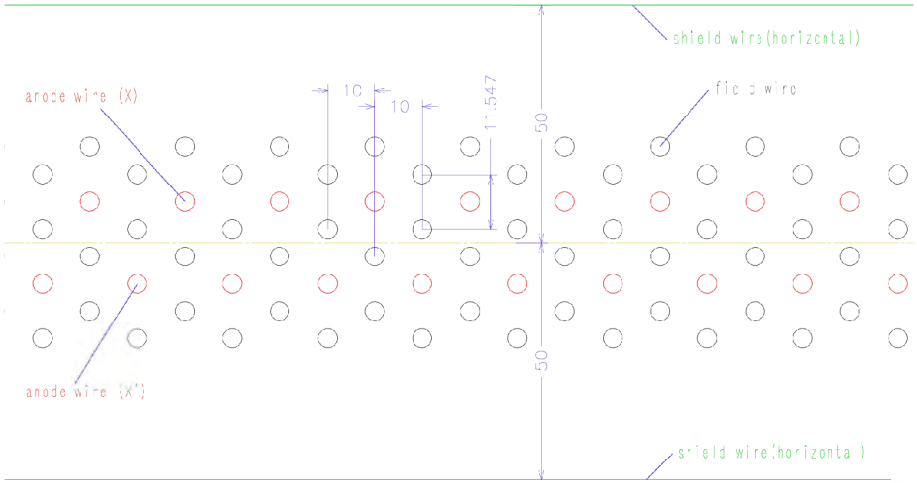




Status :
* wiring : ~1/2 finished
* Detector stand : being made
(< Mar 2011)

FDC2 assembly
3-Apr-2010 Kobayashi T.

FDC2 & FDC2P

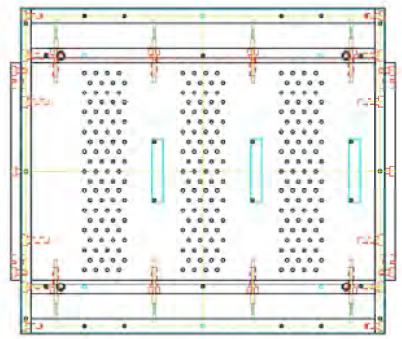


* cell : hexagonal cell (10mm drift length)

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

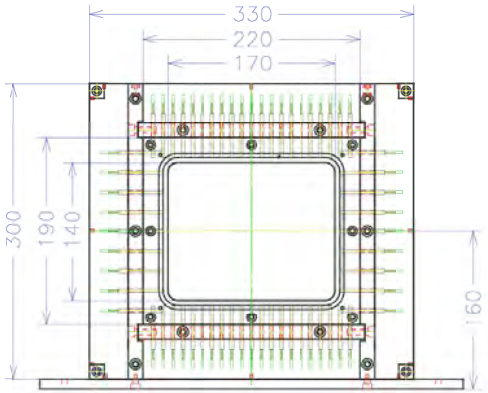
* xx', uu', vv' are grouped
  separated by shield wires

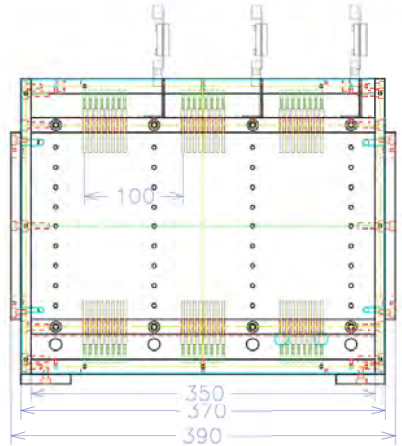
* Basic operation being studied
  using small test chamber (FDC2P)
  with the identical cell/layer configuration



FDC2P

* Tracking detector for MIP to Z=50 (ΔE range=1:5000)
  * control gas gain / keep sufficient drift field
    --> Prototype beam test

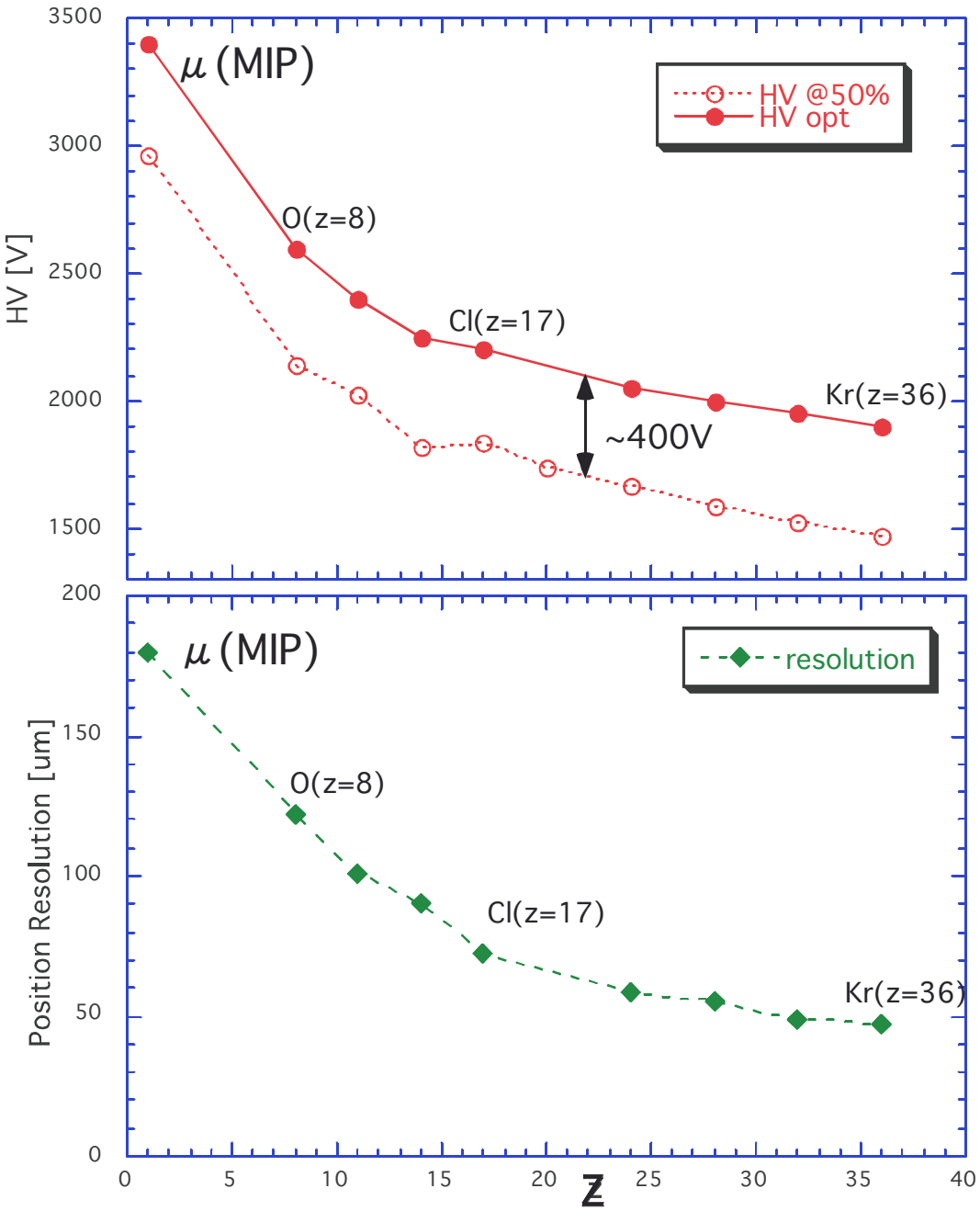




* parameters:
  * gas : He+60%CH_4/50%C_2H_6
  * ASD threshold : 0.3, 1.4, 2.5V
  * HV : gas gain / drift field

(Low-pressure operation abandoned)

Optimum HV & Resolution (for each Element)

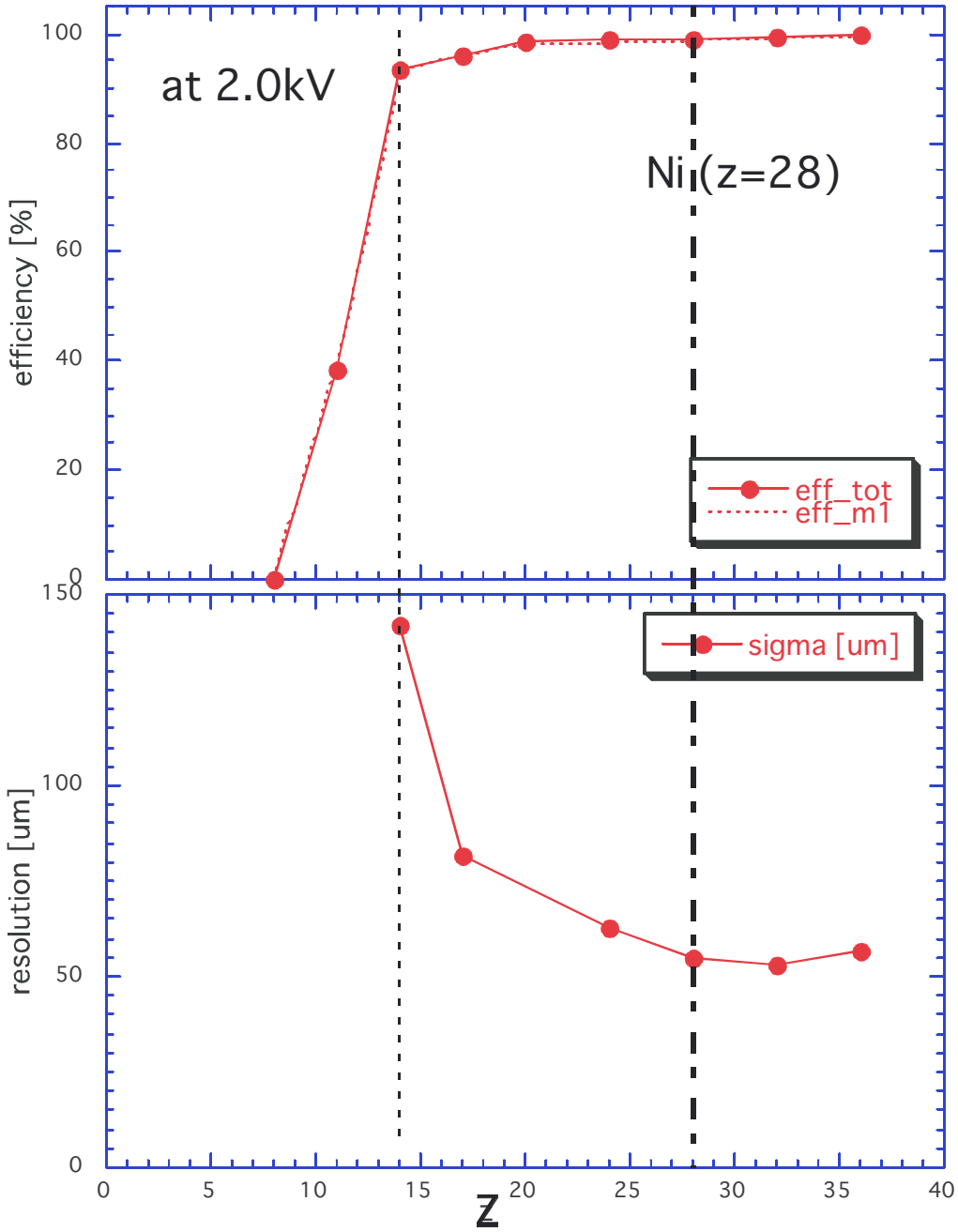


Optimum HV

@best pos. resolution

Position resolution @optimum HV

For fixed HV : dynamic range



* Optimum HV for Ni(z=28)
  = 2.0kV

* Efficiency (z-dep)

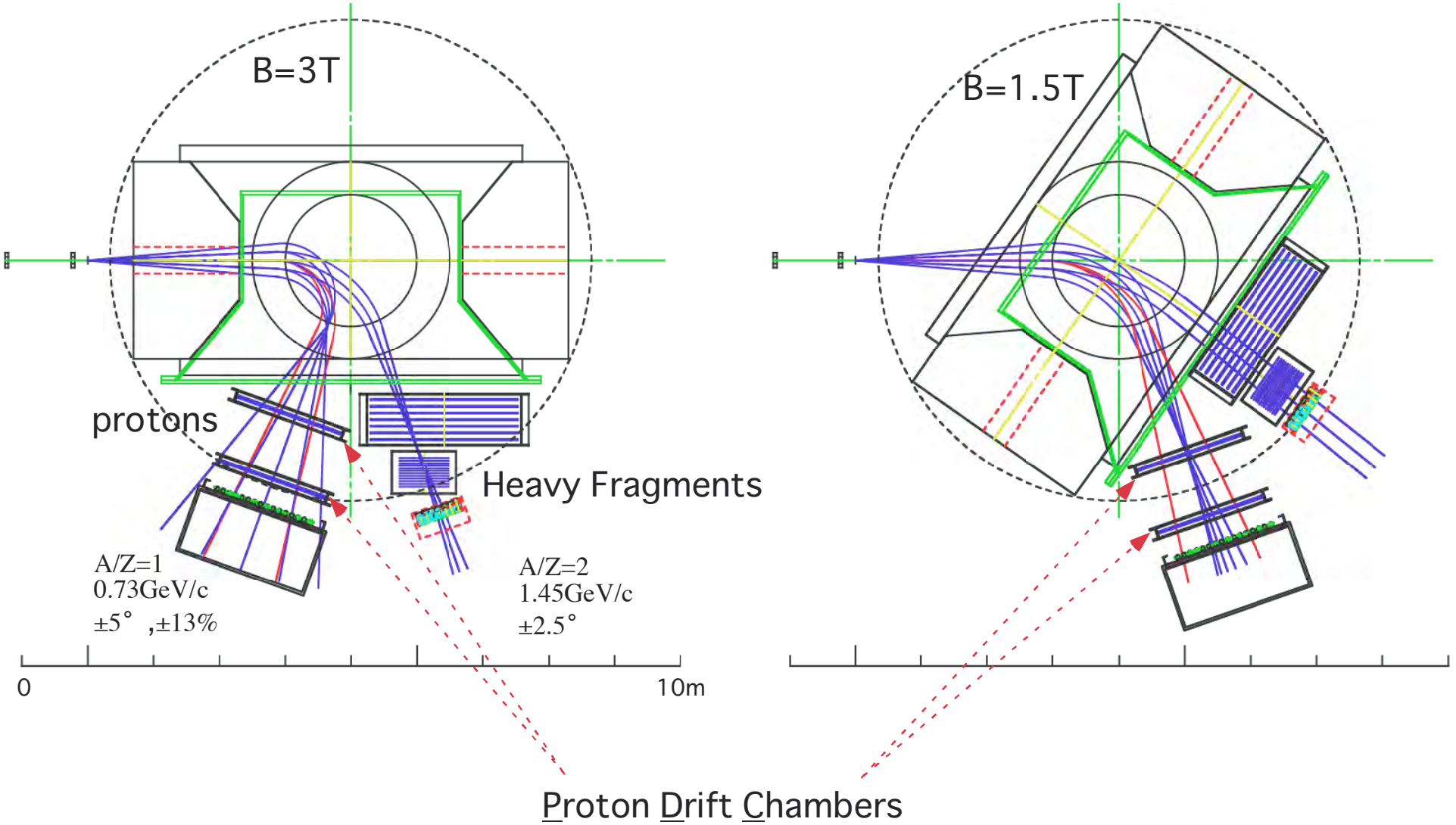
* Position resolution (z-dep)

* using time-distance calibration
  for each elements

* need to develop tracking routine
  to consider z of the track

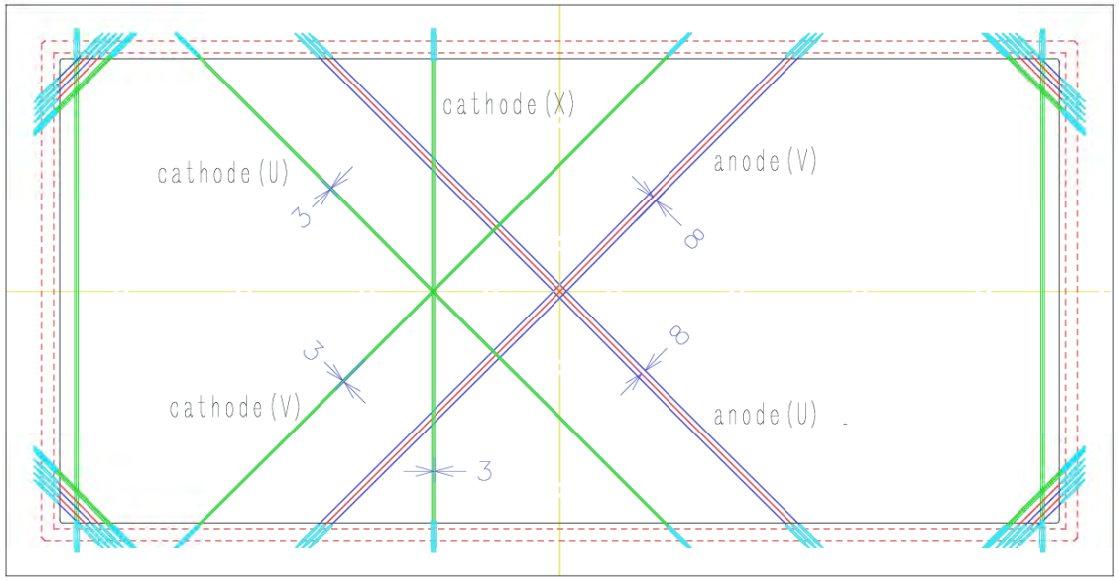
(γ,p)-type exp :

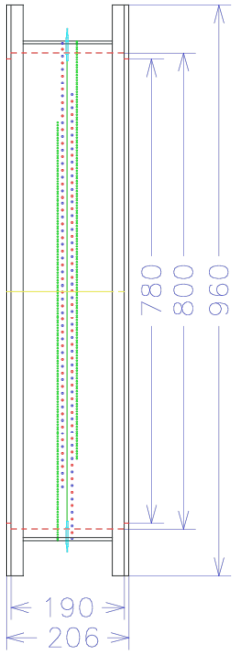
Two possible configurations : heavy fragment & proton(s) in coincidence

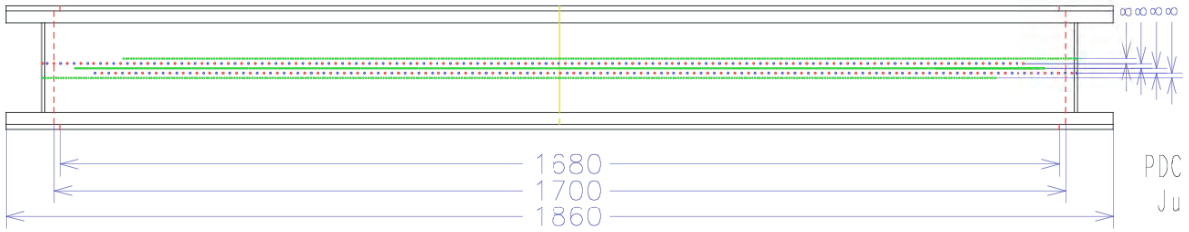


2.5 : PDC1,2 (Proton Drift Chamber 1, 2)

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)





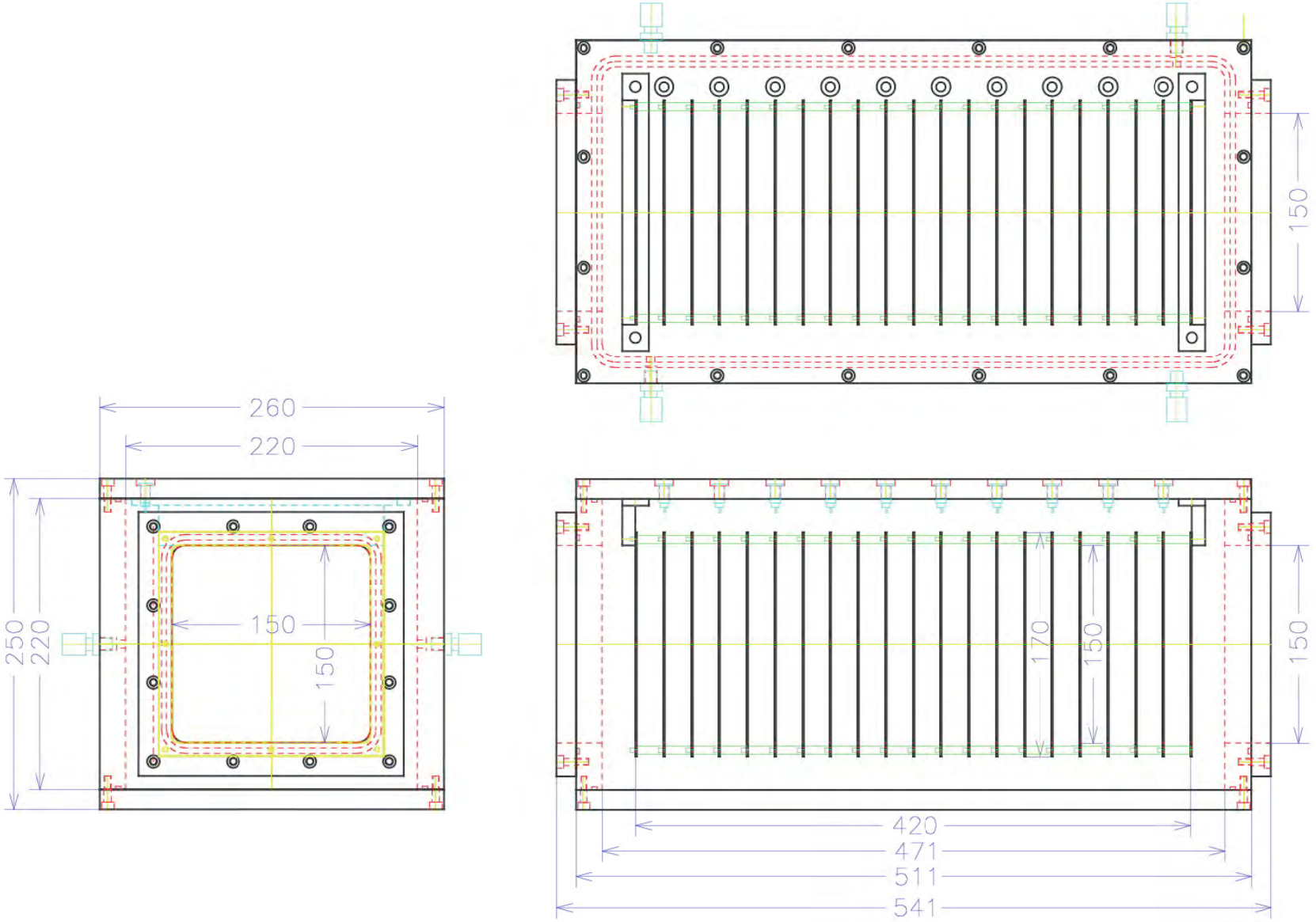


PDC assembly
Jul-2010 Kobayashi T.

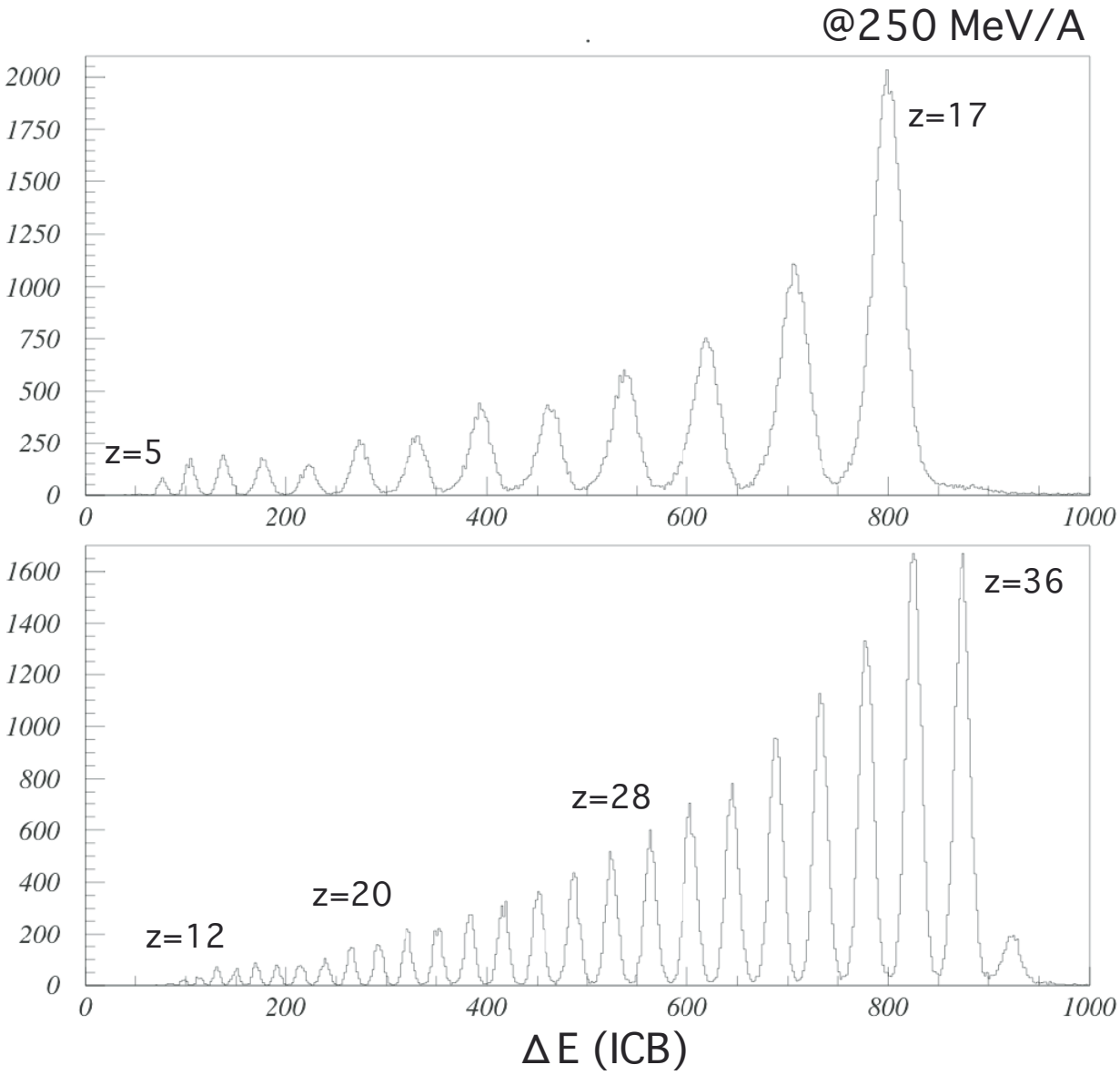
* Status
  final detector design
* Readout
  *<u>charge division</u>
    for every 8 strips
    total 110 ch
  * individual readout
    total 816 ch
    being developed

2.6 : ICB (Ion Chamber for Beam) : "z"

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



ICB : ΔE resolution



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

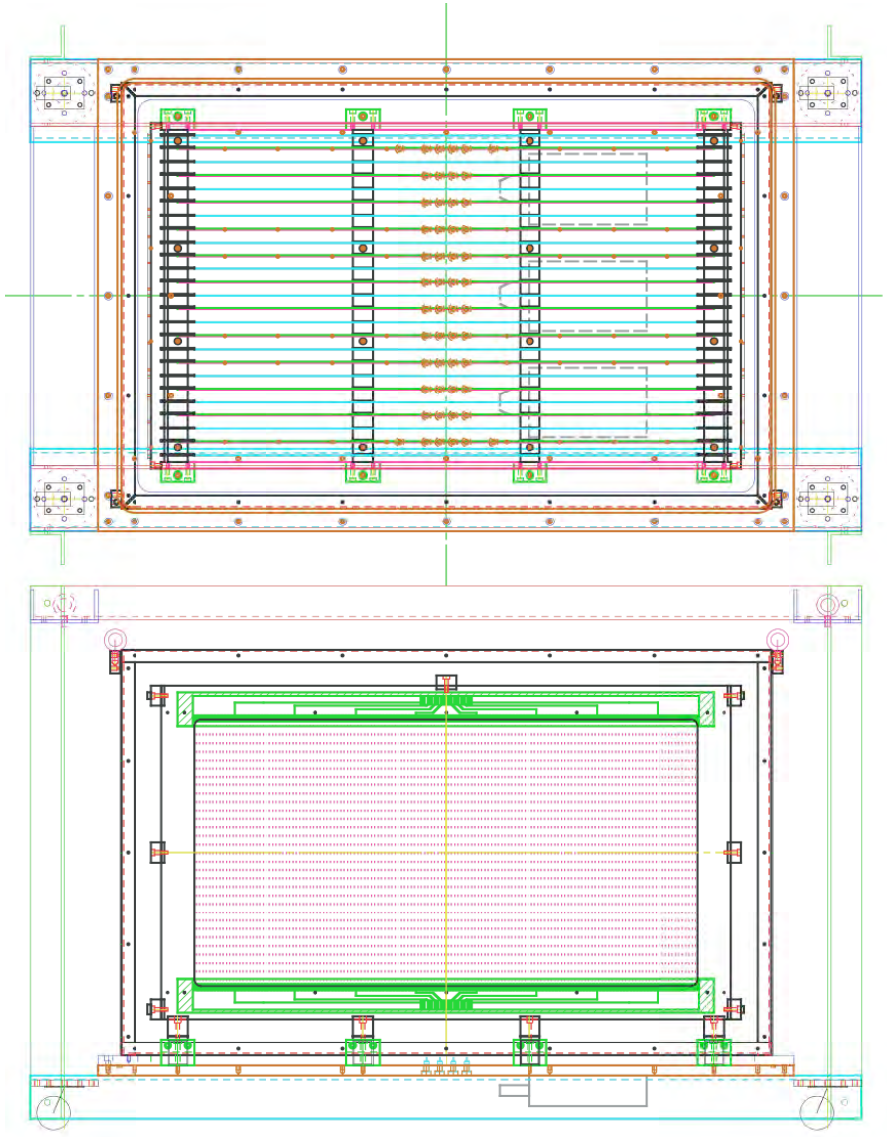
@z=36 @250MeV/A

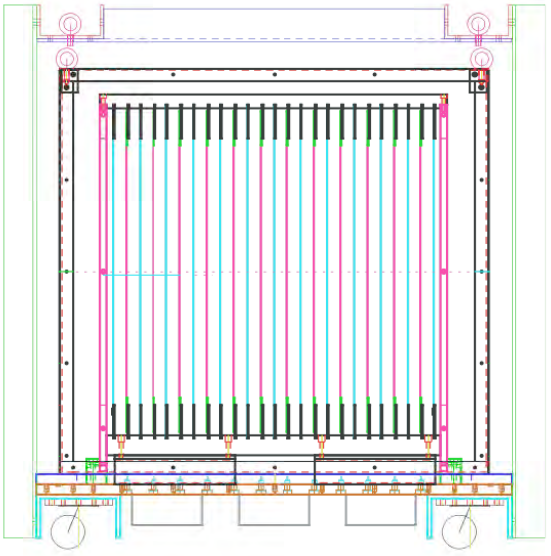
pulse height resolution ~ 0.90%

Charge resolution: $\sigma_Z \sim 0.17$

2.7 : ICF (Ion Chamber for Fragment) : "z"

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

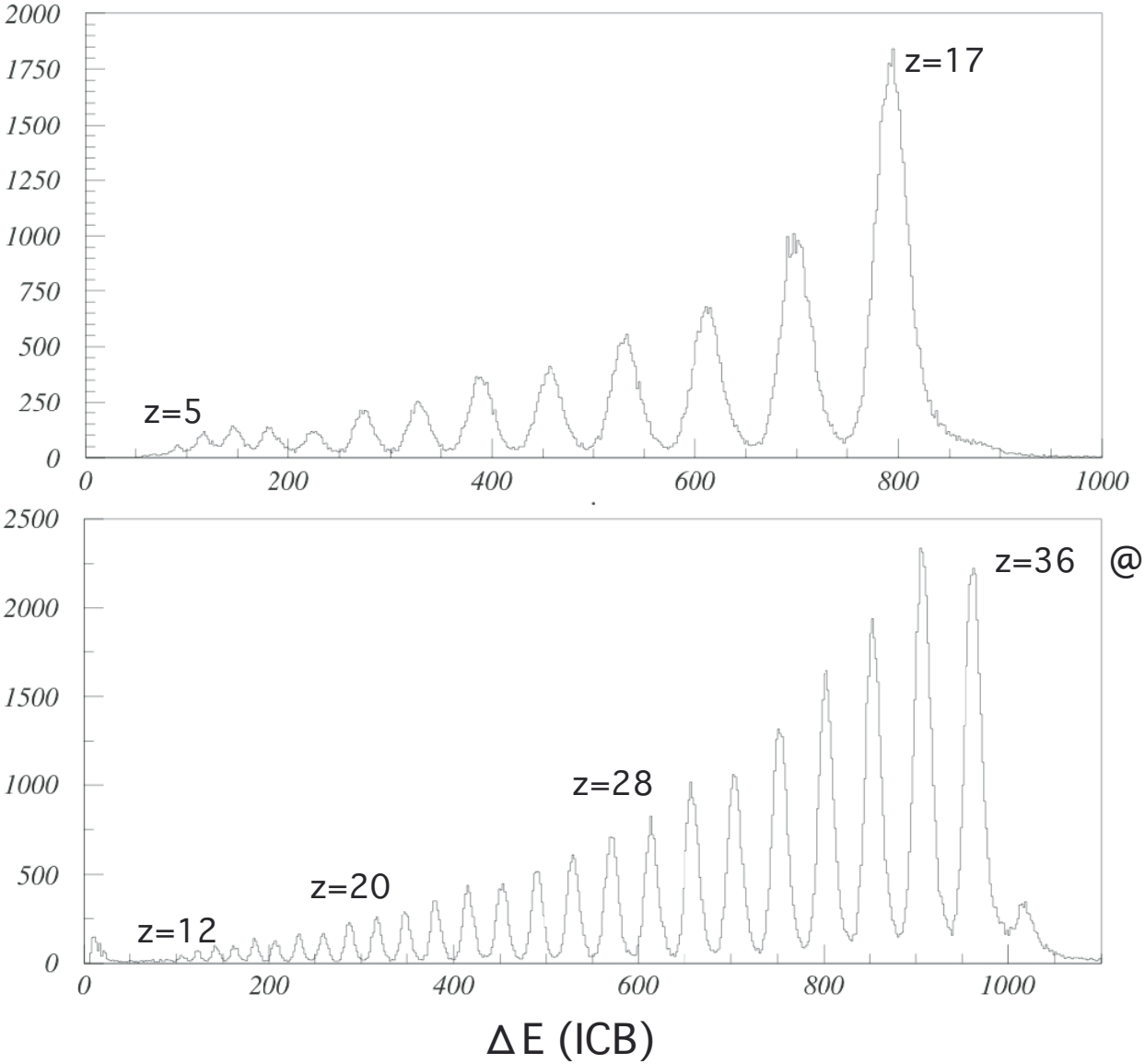




status :
* built & tested
* slight noise problem

ICF : ΔE resolution

@250MeV/A



＊noise problems

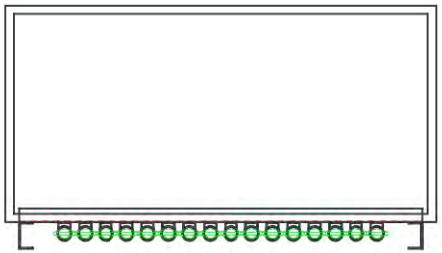
shaping time ≧ 0.5 μs

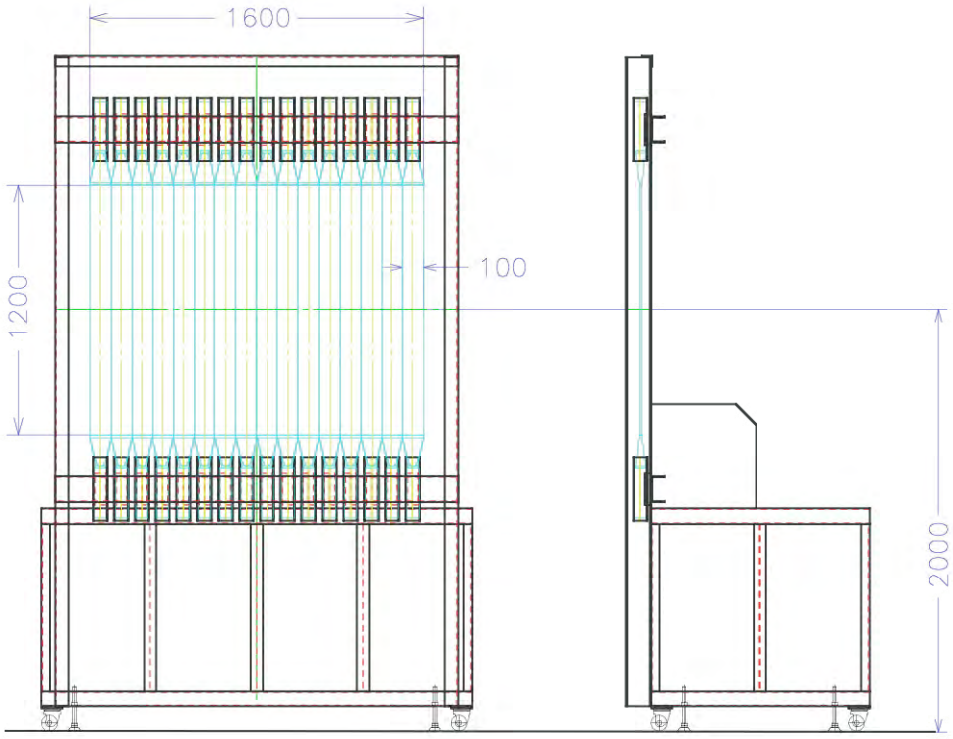
@z=36 @250MeV/A

pulse height resolution ~ 0.95%

2.8 : 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

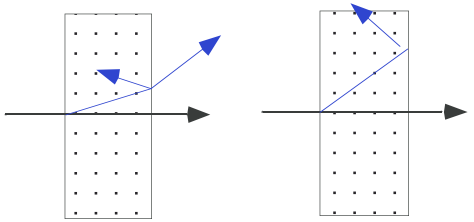




Status :
* 30 assemblies and 2 stands were built
* to be mounted on the stand

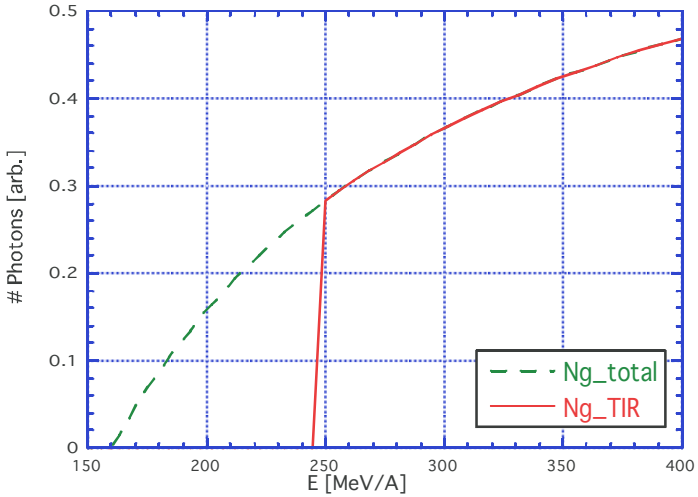
2.9 : TIRC (Total Internal Reflection Cherenkov) : "β"

＊Principle

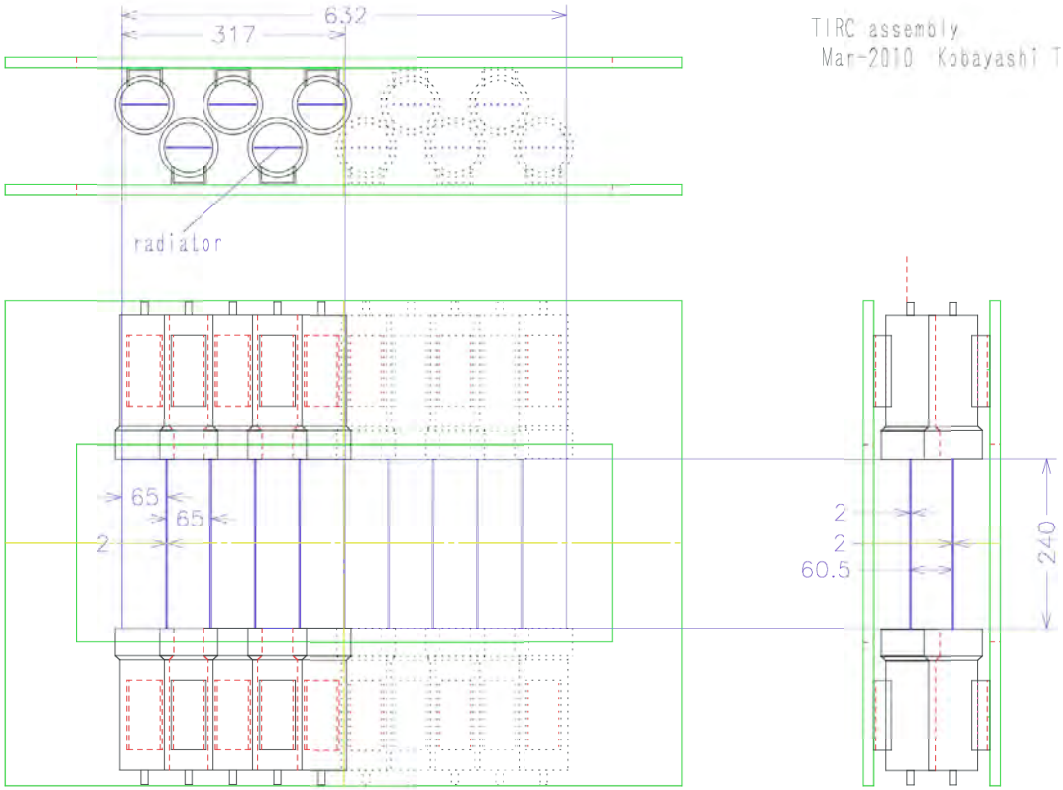


$$\beta \geq \frac{1}{n} \qquad \beta \geq \frac{1}{\sqrt{n^2-1}}$$

n=1.92
(TAFD30)



＊Design

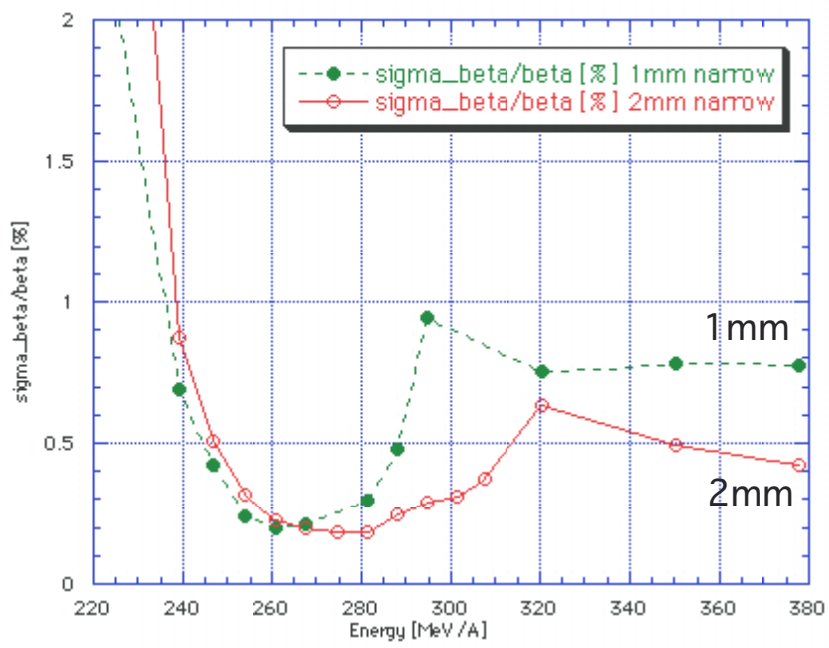


TIRC assembly
Mar-2010 Kobayashi T.

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

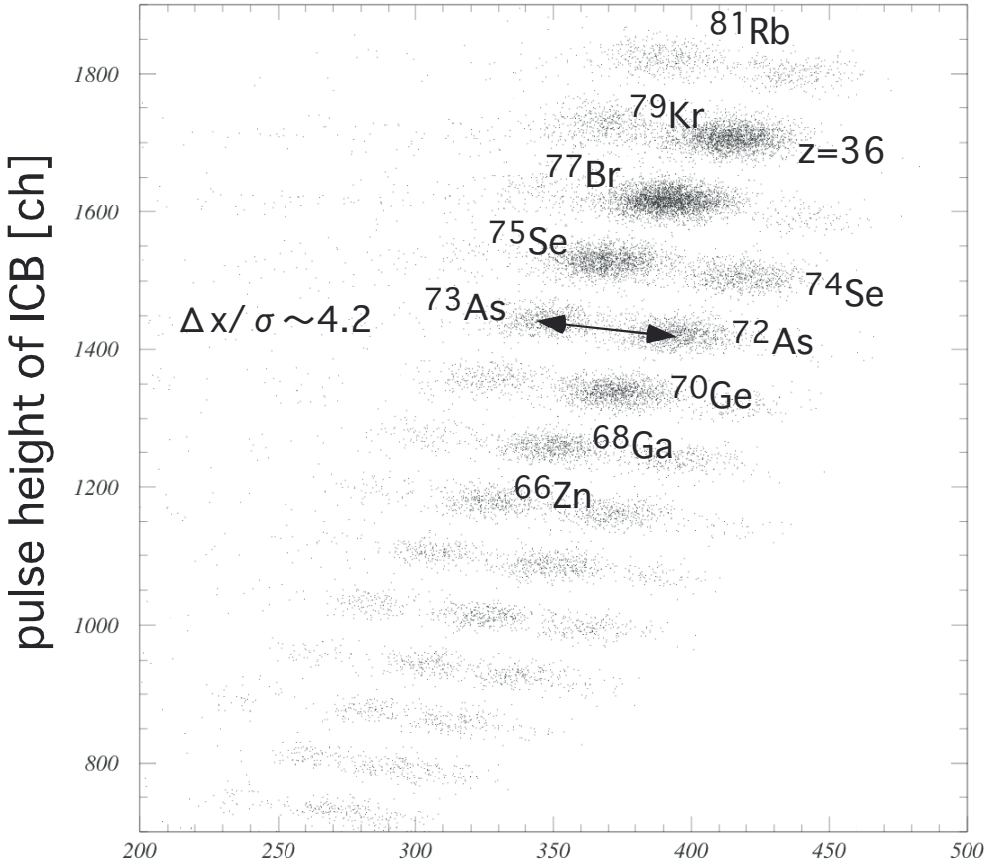
TIRC : Velocity Resolution & PID test

Estimated velocity resolution
using
energy-degraded Kr beam



＊radiation damage observed

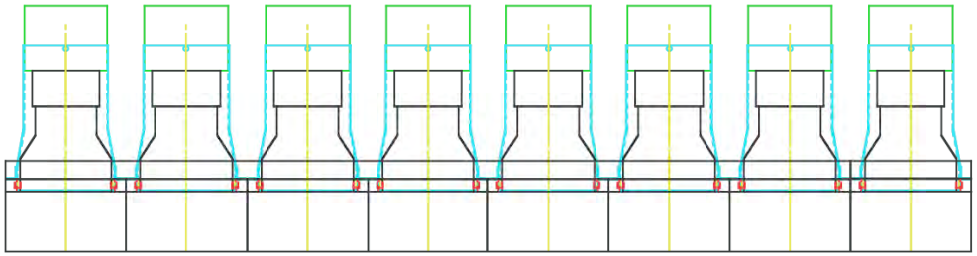
@270MeV/A (Δp/p~0.1%)



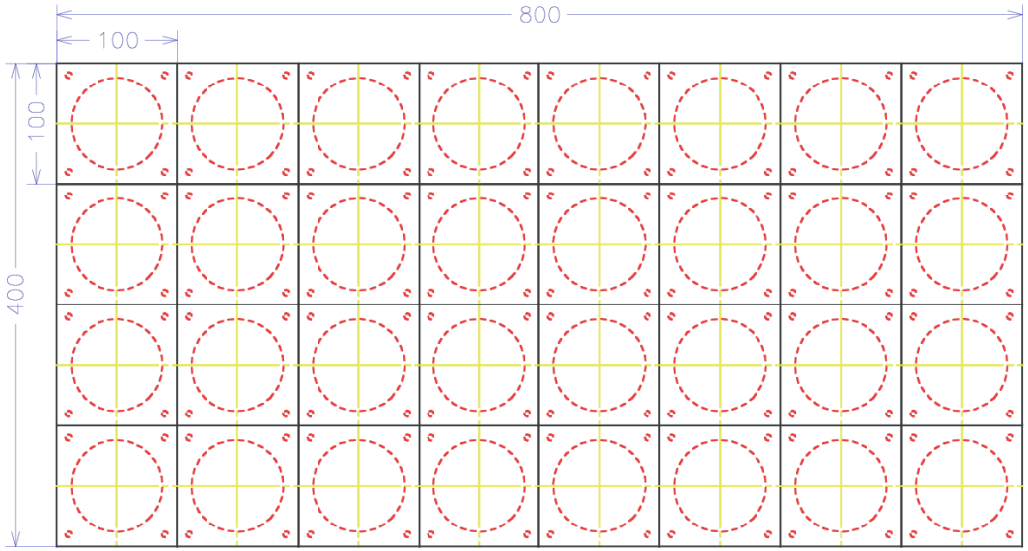
thickness : ~1.2 g/cm^3
reaction loss : ~5%

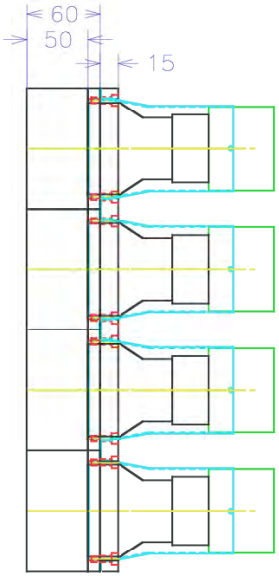
2.10 : TED (Total Energy Detector) : "E_{tot}"

* 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: 800mm x 400mm

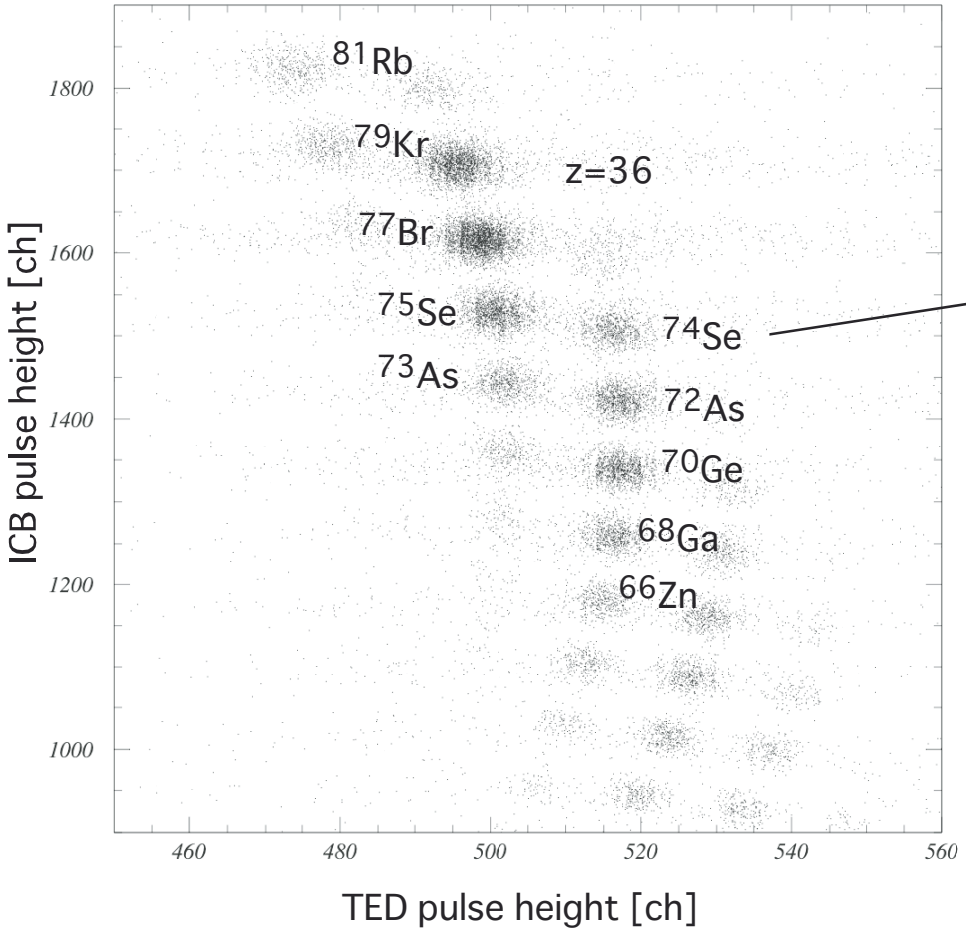


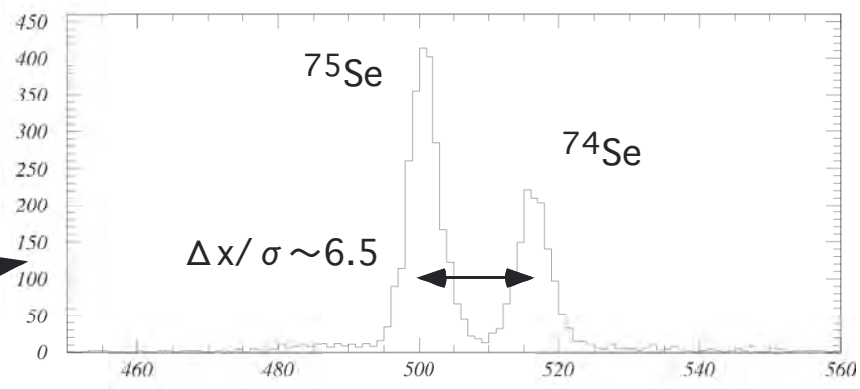


TED : PID

mass separation of RI beam

@270MeV/A ($\Delta p/p=0.1\%$) with degrader : 9mm^{t}-Al(~130MeV/A loss)





* combined with the degrader,
  >6 σ separation possible

* reaction loss : 12 ~ 15%

Summary

* Heavy ion detectors for exp. setups @spring 2012
  partly finished, the rest under construction w/o major problems

* Beam tests @HIMAC SB2
  z= 5 - 36 ~@250 MeV/A
  prototypes, actual detectors, ...

* PID detectors
  * ICB, ICF (z), TIRC (β), TED (Etot) : OK
  * what's left
    rigidity resolution of 1/700 ~ 1/1000 <--- magnet & FDC1/FDC2
    magnetic field measurement / calculated magnetic field (with normalization) ?

* what's left
  * BDC1, BDC2 stands
  * FDC1+LP-Box : low-pressure operation
  * FDC1 <-> large vac. chamber
  * TED *32, light/magnetic field shield box + stand
  * PDC + cathode readout
  * and many other remaining items...