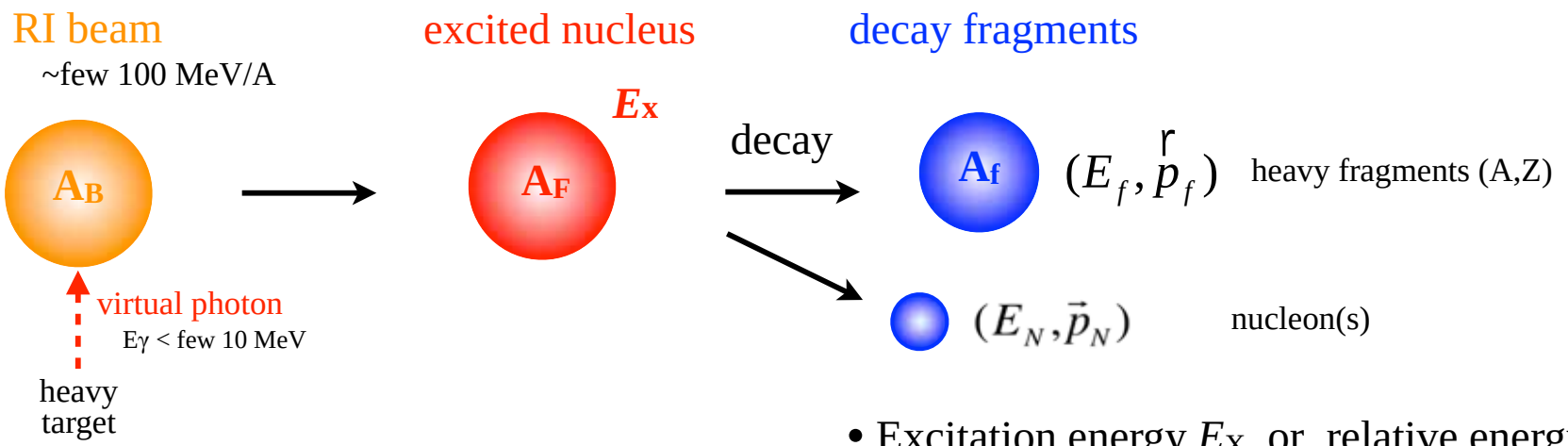
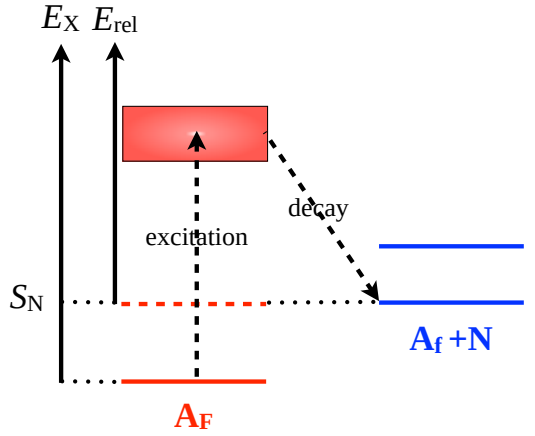
Total Energy Detector (TED) for RI-beam experiments

Invariant mass spectroscopy : one example of RI beam experiment



- Excitation energy E_X or relative energy E_{rel}

$$E_X = \sqrt{\left(E_f + E_N\right)^2 - \left(\vec{p}_f + \vec{p}_N\right)^2} - \left(M_f + M_N\right) + S_N$$



- Required resolution

  - Invariant mass : $\sigma(E_{rel}) \sim 0.2\sqrt{E_{rel}}$ [MeV]

rigidity(f)	velocity(N)	angle(N)
$\frac{\sigma_R}{R} \sim \frac{1}{200}$	$\frac{\sigma_\beta}{\beta} \sim \frac{5}{1000}$	$\sigma_\theta \sim \frac{1}{200}$
easy	σ_{TOF}~0.3nsec @L=10m	σ_X~5cm @L=10m

  - PID of heavy fragment : $\sigma_A/A \sim 0.2/100$

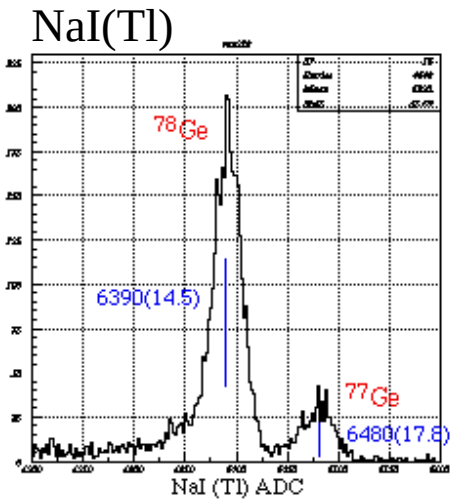
rigidity(f)	velocity(f)		rigidity(f)	total energy(f)
$\frac{\sigma_R}{R} \sim \frac{1}{700}$	$\frac{\sigma_\beta}{\beta} \sim \frac{1}{1100}$	or	$\frac{\sigma_R}{R} \sim \frac{1}{1600}$	$\frac{\sigma_T}{T} \sim \frac{1}{1000}$
@ R~2.2GeV/c	@ β ~ 0.6		@ R~2.2GeV/c	@ T~30GeV
standard	σ_{TOF}~50psec @L=10m		possible(realized)	**? ~Ge**

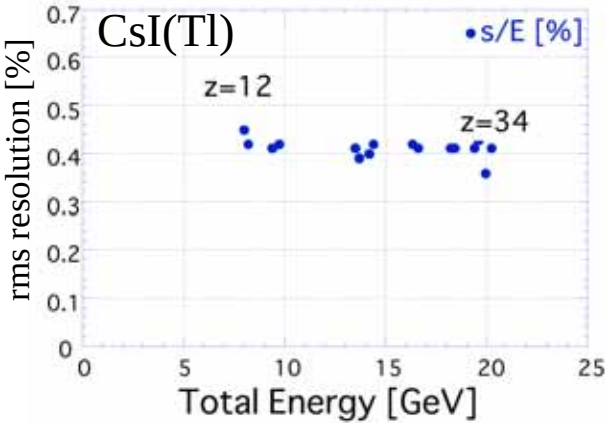
テキスト

Total energy detector (TED) : types of scintillators

- Goal / Purpose
  - σ_A/A~0.2/100 for PID ↔ σ_T/T-0.1~0.2% @T=20~30GeV

- Scintillators tested
  - **NaI(Tl)** : 3" cube + 3"φPMT
    - σ_T/T~0.15% @23GeV (290 MeV/A ^{78}Ge) OK
    - rate?(τ~200nsec), non-uniformity?, PMT at low HV?, hydroscopic: casing(MgO+Al), radiation damage?
  - **CsI(Tl)** : 5cm-cube + PD + charge-sensitive PA
    - PD : 1x1, 1.8x1.8, 2.8x2.8 cm^2
    - C_f of hybrid PA~100pF (low gain) , oscillation
    - σ_T/T ~ 0.4% for T= 7~20 GeV (@250MeV/A) X
    - rate?(τ~1usec), worse resolution, PD for larger crystals?
  - **HP Ge** : 60mmφx35mm (semi planar)
    - PreAmp (C_f=200-500pF), self made, oscillation
    - HV bias : large leak
    - σ_T/T ~ 0.35% @ 3GeV X



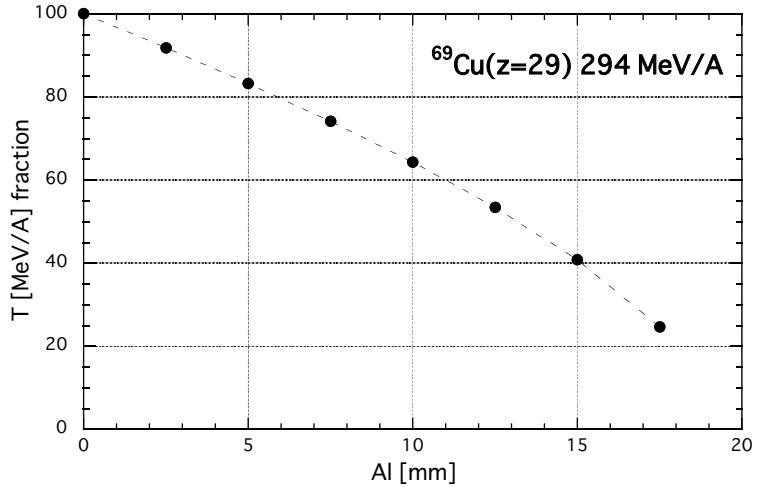


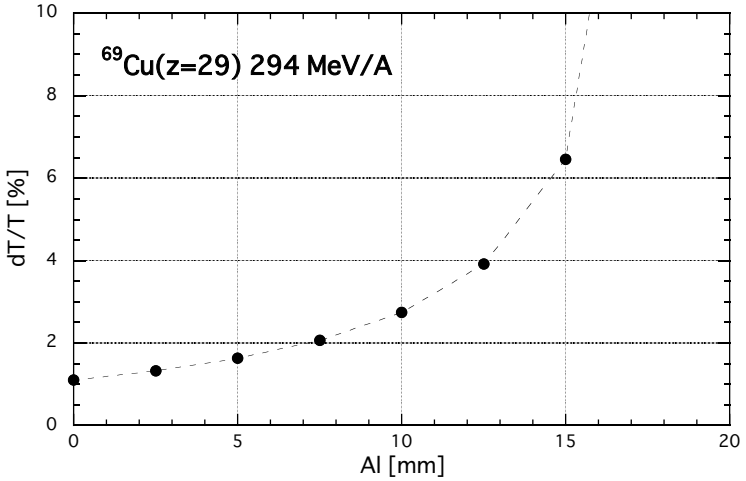
CsI(pure) ?

- **CsI(pure)** + PMT ?
  - less light, fast decay time
  - small radiation damage
  - UV light
  - large temperature dependence : ~% / deg

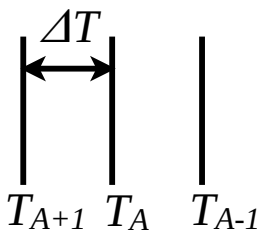
←
- NaI(Tl)+PMT, CsI(Tl)+PD, HP-Ge
  - may be OK
  - relatively slow, radiation damage?

- Beam test using CsI(pure) 100x100x50mm^3 + 3"φ-PMT (HPK-R6233)
  - large saturation effect observed
  - pulse shape of heavy ion is different from γ, e, & proton
  - UV / non-UV window tested : no difference in resolution → PMT w non-UV window
  - PMT breeder : taper-type w high breeder current
  - σ_T/T=0.1~0.2% was not achieved. THEN...
- enlarge total-energy difference using energy-loss for fragment with the same rigidity





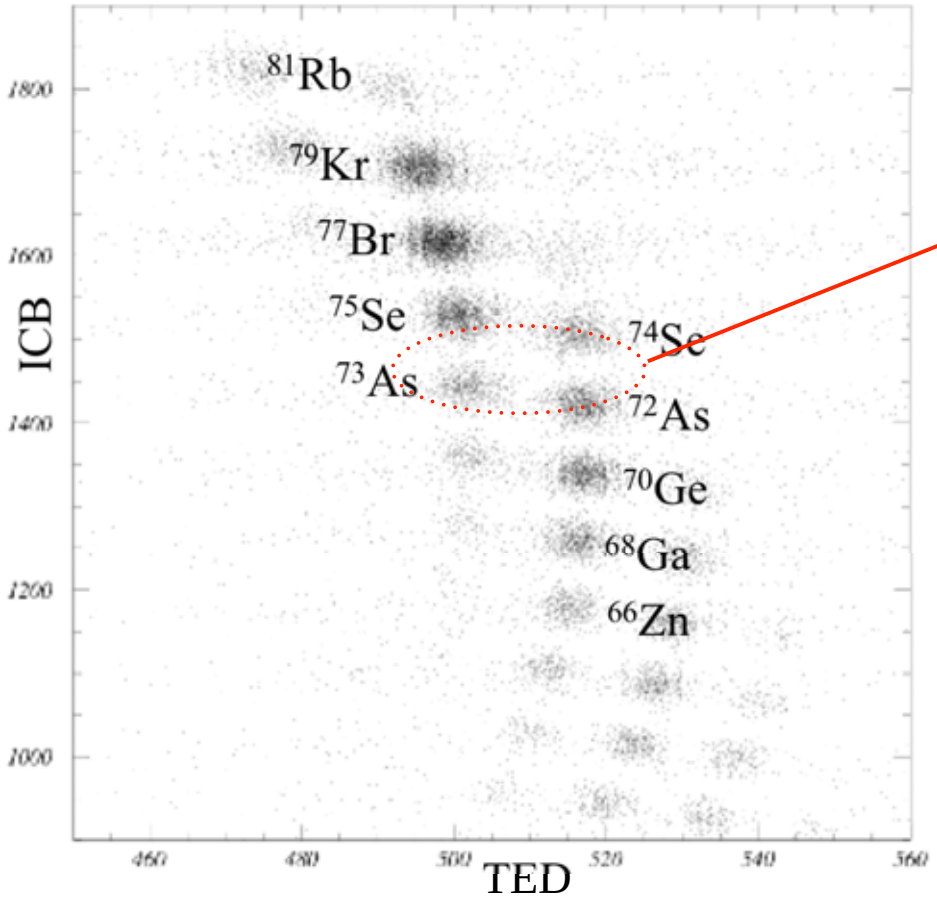
$^{69\pm1}$Cu (Z=29)
294 MeV/A

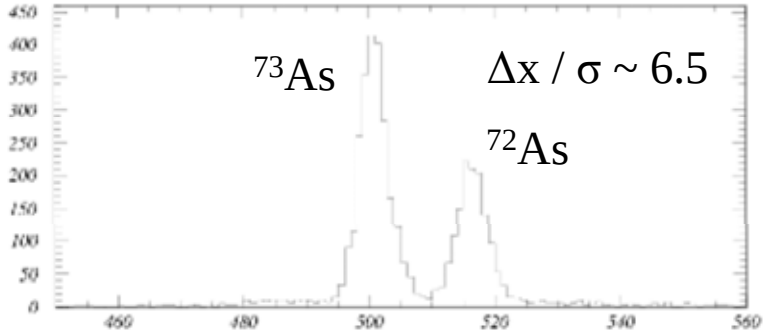


prototype test @HIMAC

CsI(pure, 100x100x50 mm²) + 3"ϕ PMT

270 MeV/A (Δp/p~0.1%) with Al absorber

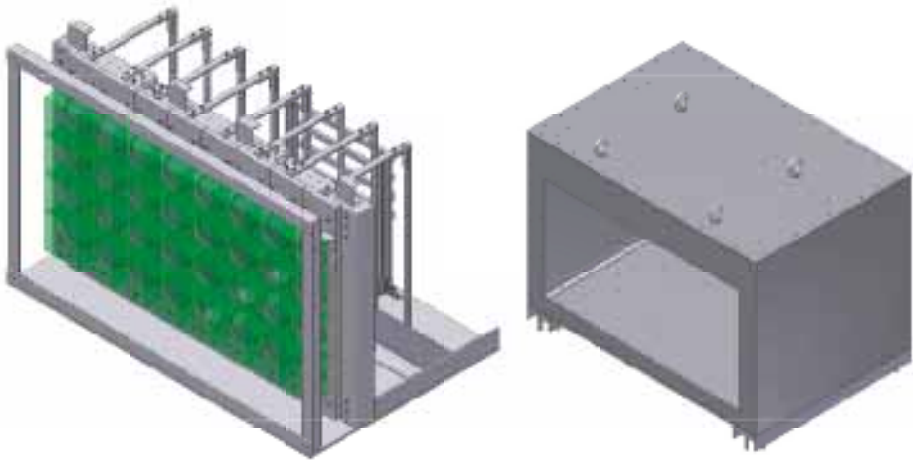


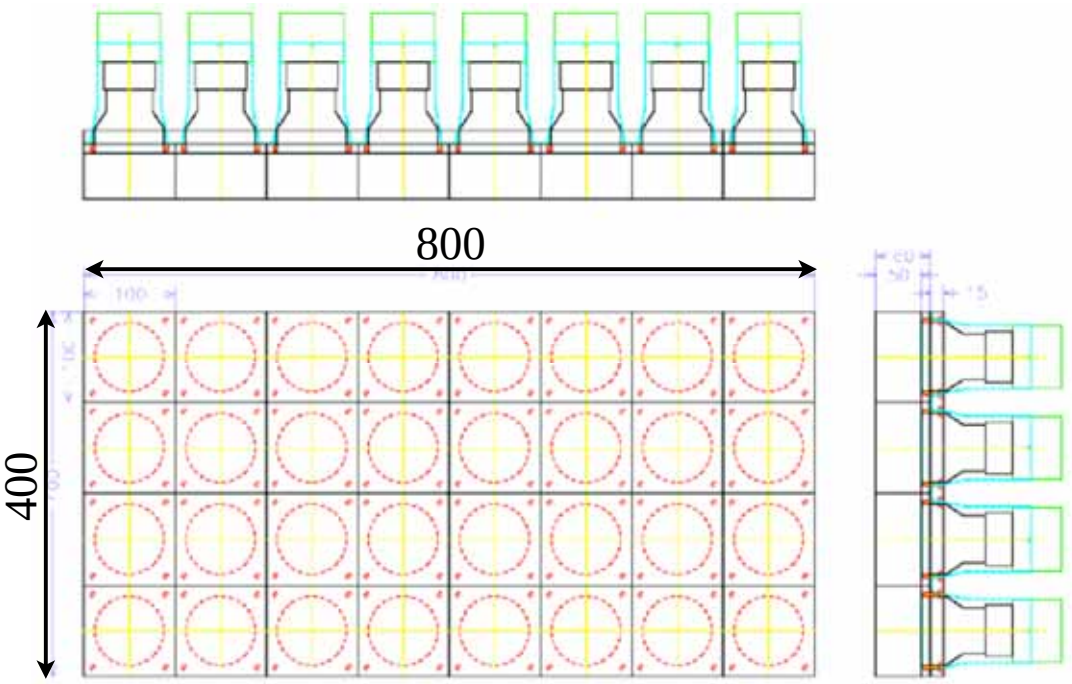


Total Energy Detector (TED)

* Purpose : σ_A~0.2 @A~100, E_{tot}=25~30GeV
* Configuration

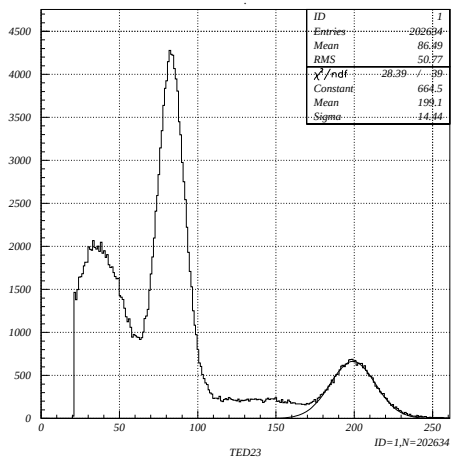
CsI(pure) : 100x100x50mm^3 x32
effective area : 800mm(H) x 400mm(V)
PMT : R6233HA (3”φ, non-UV)
in light / magnetic shield box



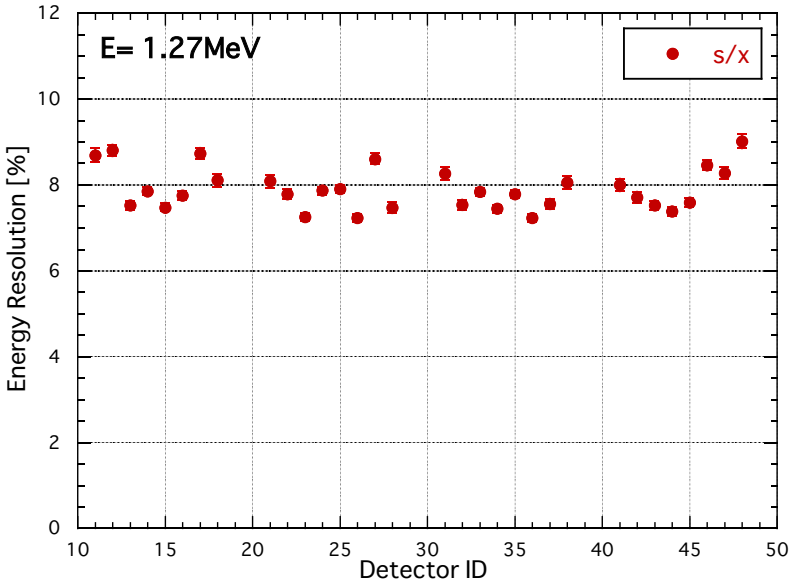


Resolution for γ-rays

- Pulse Height Distribution for ^{22}Na

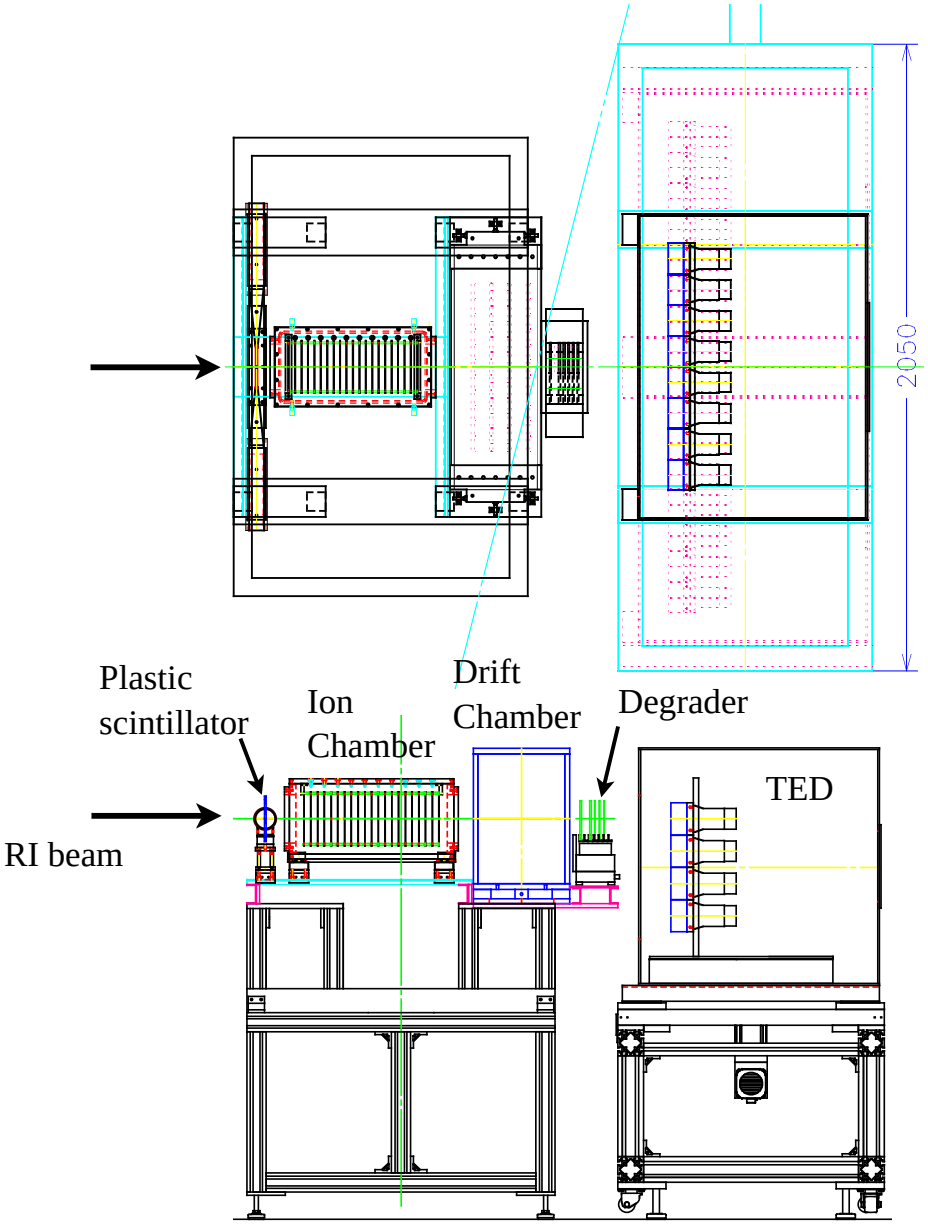


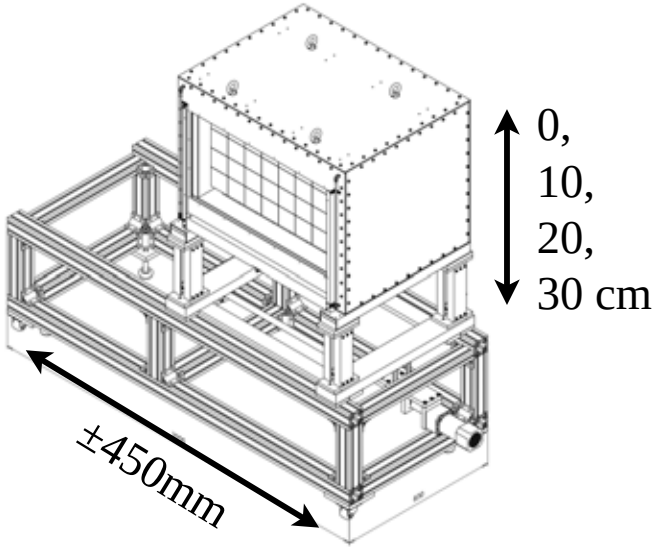
- Energy resolution (σ/<E>) at E_γ= 1.27 MeV



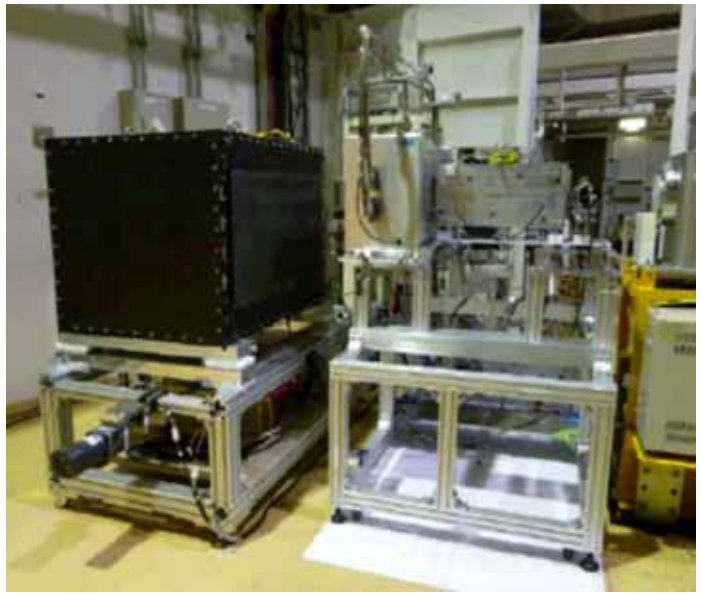
Calibration using secondary beam

- Setup @HIMAC SB2





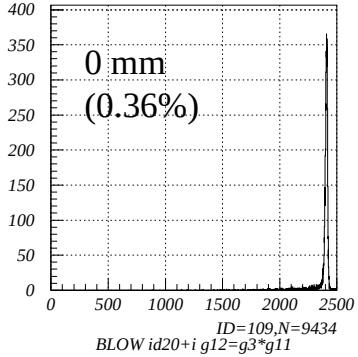
- Pulse height + position dependence
  for all 32 crystals
- RI beam： ~290 MeV/A, A~70

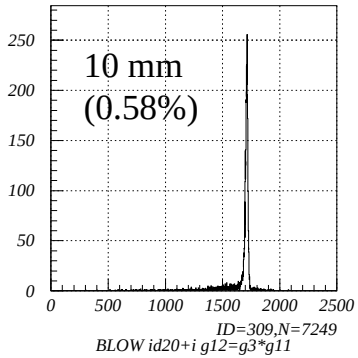


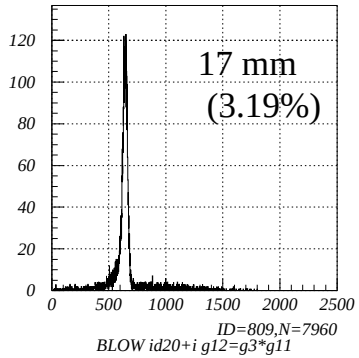
Pulse height： degrader thickness dependence @crystal center

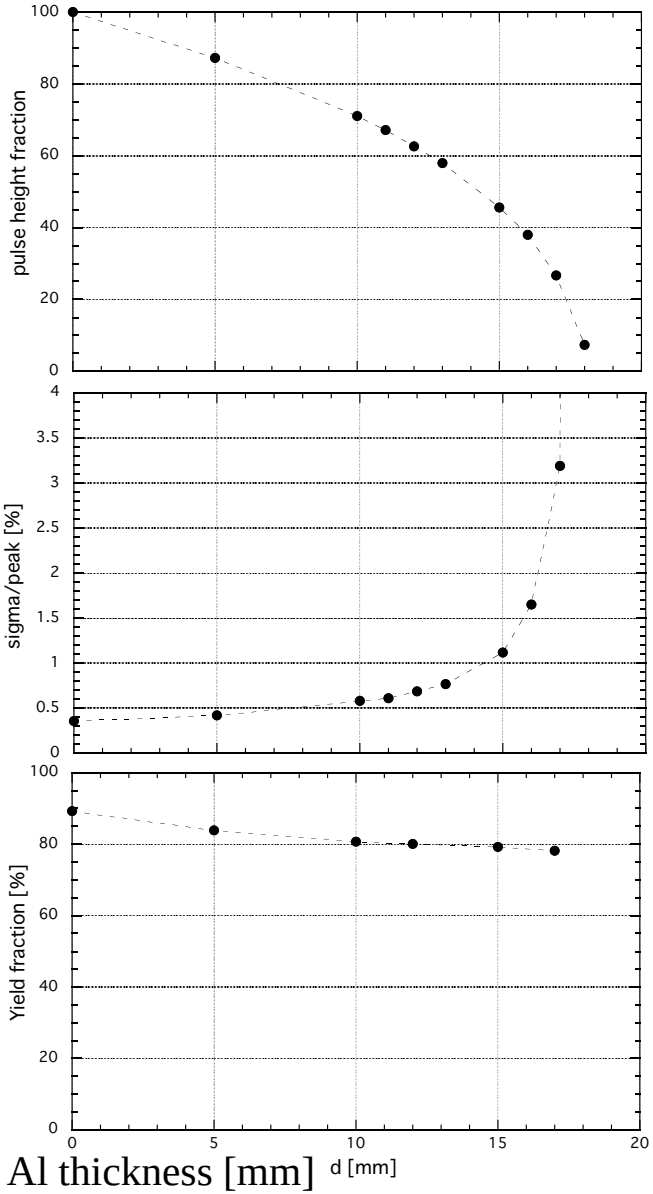
- ^{69}Cu(z=29) 294 MeV/A, Al thickness = 0~17mm

pulse height









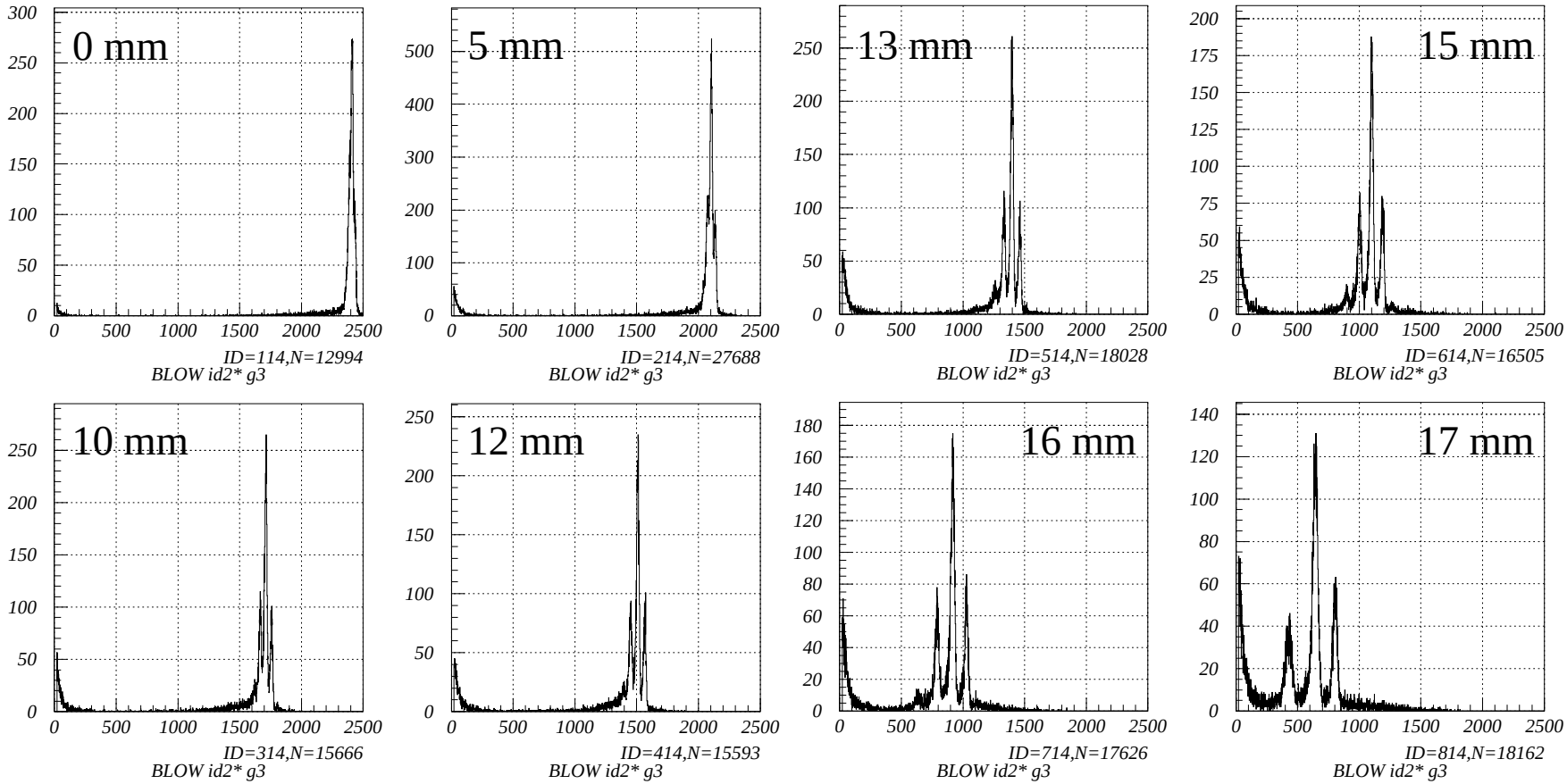
pulse height ratio [%]

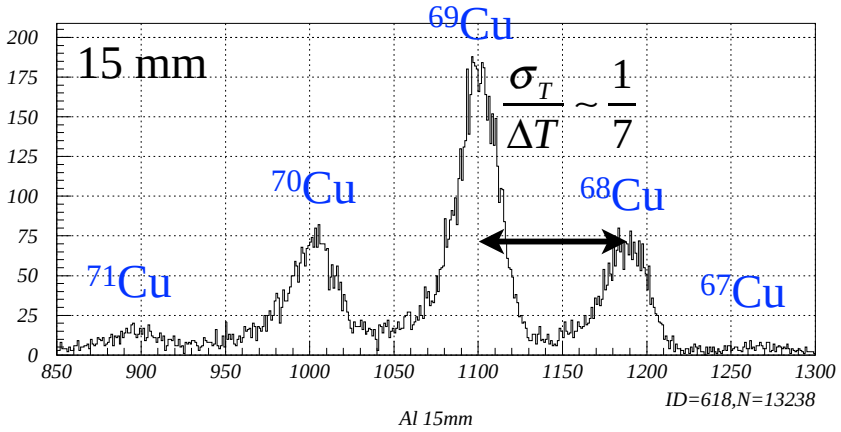
rms resolution [%]

yield (reaction loss) [%]

Mass separation： degrader-thickness dependence @crystal center

- ^{68,69,70}Cu(z=29) 294 MeV/A, Al= 0~17mm

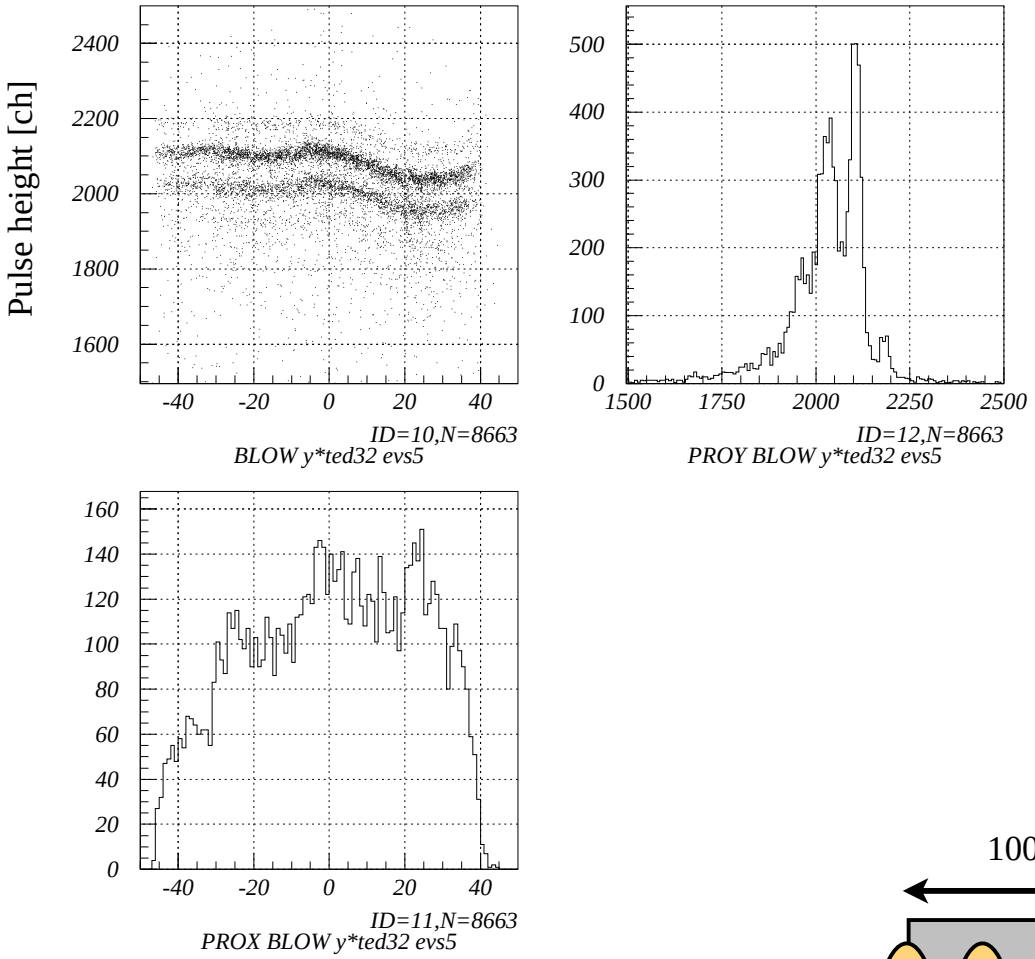




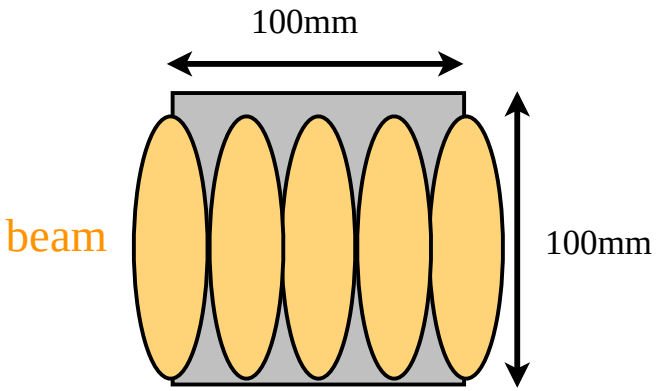
- mass separation ~7σ
  - but with low-energy tail
  - adjustable by changing absorber thickness
  - with energy resolution of σ_T/T~1%

Calibration : position dependence

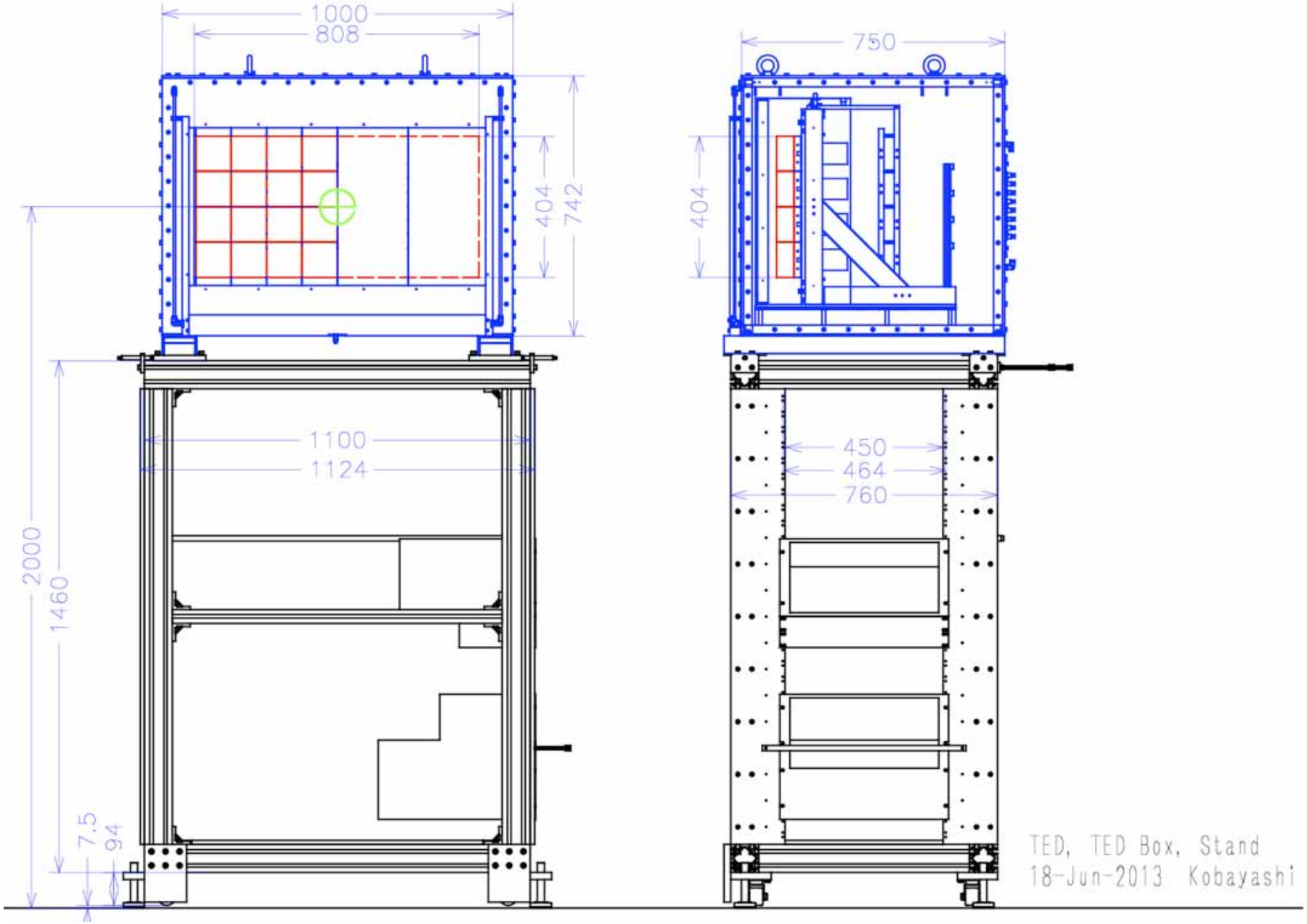
- position dependence by extrapolating drift chamber track



- strange position dependence
  - data taken for all crystals
  - calibration procedure ?



TED & detector stand



TED @SAMURAI

- p(^{132}Sn,n) exp. April-2014