report

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December 21, 2003

Contents

1 Doppler correction

1.1 introduction

In this experiment we detected γ-rays emitted from moving reaction products with a velocity v/c$\sim$0.32. Hence Doppler-shifted γ-ray energies were measured by the $\gamma - ray$ detectors. The transformation in the rest frame of the incident particle E_{γ}^{proj} and the γ -ray energy in the laboratory frame E_{γ}^{lab} is following.

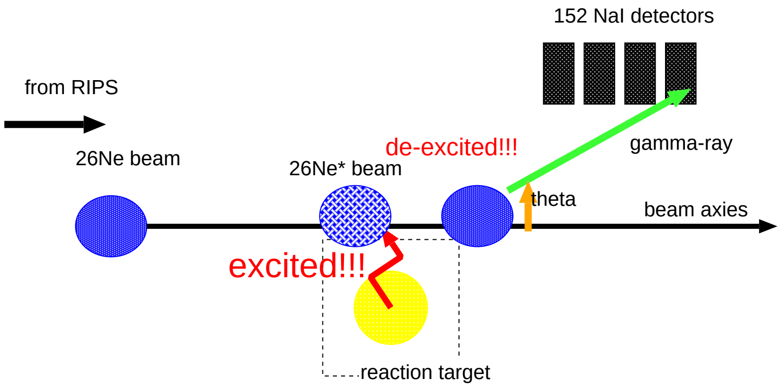


Figure 1: Schematic description of in-beam γ spectroscopy. The γ-ray detection angle with respect to the beam axis in the labratory frame θ.

$$\begin{pmatrix} E_{\gamma}^{\mathrm{proj}}/c \\ \mathbf{P}^{\mathrm{proj}} \end{pmatrix} = \begin{pmatrix} \gamma & -\beta\gamma \\ -\beta\gamma & \gamma \end{pmatrix} \begin{pmatrix} E_{\gamma}^{\mathrm{lab}}/c \\ \mathbf{P}^{\mathrm{lab}} \end{pmatrix}$$

- $E_{\gamma}^{\mathrm{proj}}$:$\gamma$ energy in the rest frame of the incident particle
- $\mathbf{P}^{\mathrm{proj}}$:$\gamma$ particle momentum in the rest frame of the incident particle
- $E_{\gamma}^{\mathrm{lab}}$:$\gamma$ energy in the laboratory frame
- $\mathbf{P}^{\mathrm{lab}}$:$\gamma$ particle momentum in the laboratory
- β:relativistic velocity
- γ:Loren factor $1/\sqrt{1-\beta^2}$

$$E_{\gamma}^{\mathrm{proj}}/c = \gamma E_{\gamma}^{\mathrm{lab}}/c - \gamma\beta\mathbf{P} \tag{1}$$

$$\beta = \beta\cos\theta \tag{2}$$

$$E_\gamma^{\mathrm{lab}} = h\nu \tag{3}$$

$$\mathbf{P} = \frac{h}{\lambda} = \frac{h\nu}{c} \tag{4}$$

$$\frac{P}{E_\gamma^{\mathrm{lab}}} = \frac{1}{c} \tag{5}$$

Therefore,

$$E_\gamma^{\mathrm{proj}} = E_\gamma^{\mathrm{lab}}\gamma(1 - \beta\cos\theta) \tag{6}$$

1.2 result

1.3 Energy resolution of the Doppler corrected γ-ray spectrum

Due to the finite accuracy of angular information and the velocity spread of the projectiles, the γ-ray energy peaks were broadened compared to the intrinsic energy resolution of the detectors. Based on equation, the resolution E_γ^{proj} is approximated,

$$(\frac{\Delta E_\gamma^{\mathrm{proj}}}{E_\gamma^{\mathrm{proj}}})^2 = (\frac{\beta\sin\theta_\gamma^{\mathrm{lab}}}{1-\beta\cos\theta_\gamma^{\mathrm{lab}}})^2(\Delta\theta_\gamma^{\mathrm{lab}})^2 + (\frac{\beta\gamma^2(\beta-\cos\theta_\gamma^{\mathrm{lab}})}{1-\beta\cos\theta_\gamma^{\mathrm{lab}}})^2(\frac{\Delta\beta}{\beta})^2 + (\frac{\Delta E_\gamma^{\mathrm{lab}}}{E_\gamma^{\mathrm{lab}}})^2 \tag{7}$$

From the correlation between energy and σ, the intrinsic energy resolution of the detectors is introduced in following.

$$\sigma = 1.9\sqrt{E} - 26.97 \tag{8}$$

The energy resolutions are evaluated using realistic condion, β of 0.32 and γ of 1.06 with $\Delta\theta_{\mathrm{max}}$ of 20 degrees in labratory frame of 90 degrees and $\Delta theta_{\mathrm{min}}$ of 0 degrees in labratory frame of 0 degrees respectively, $\Delta\beta/\beta$ of 11.5% including the energy loss in the secondary target.

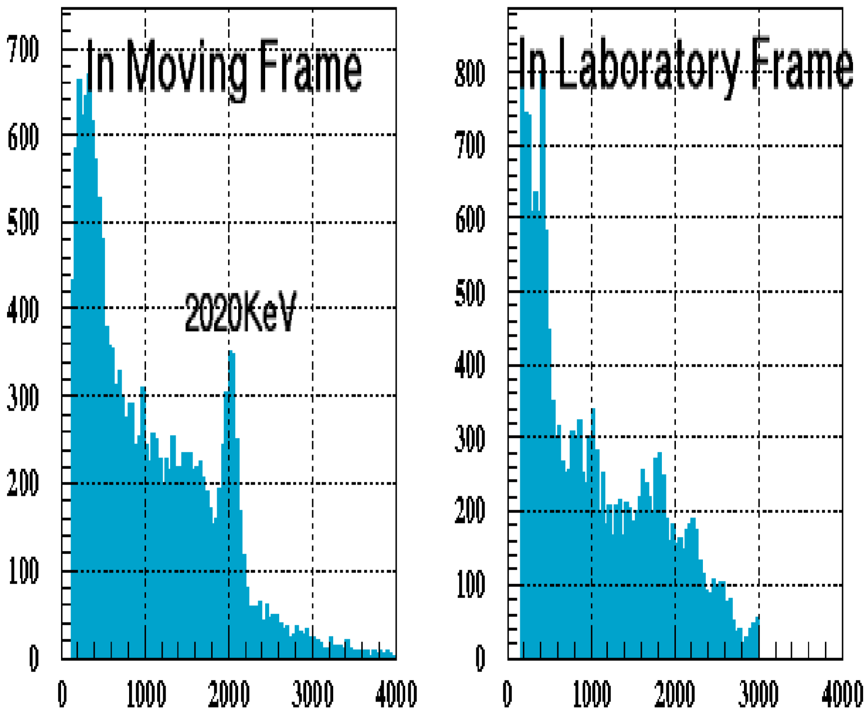
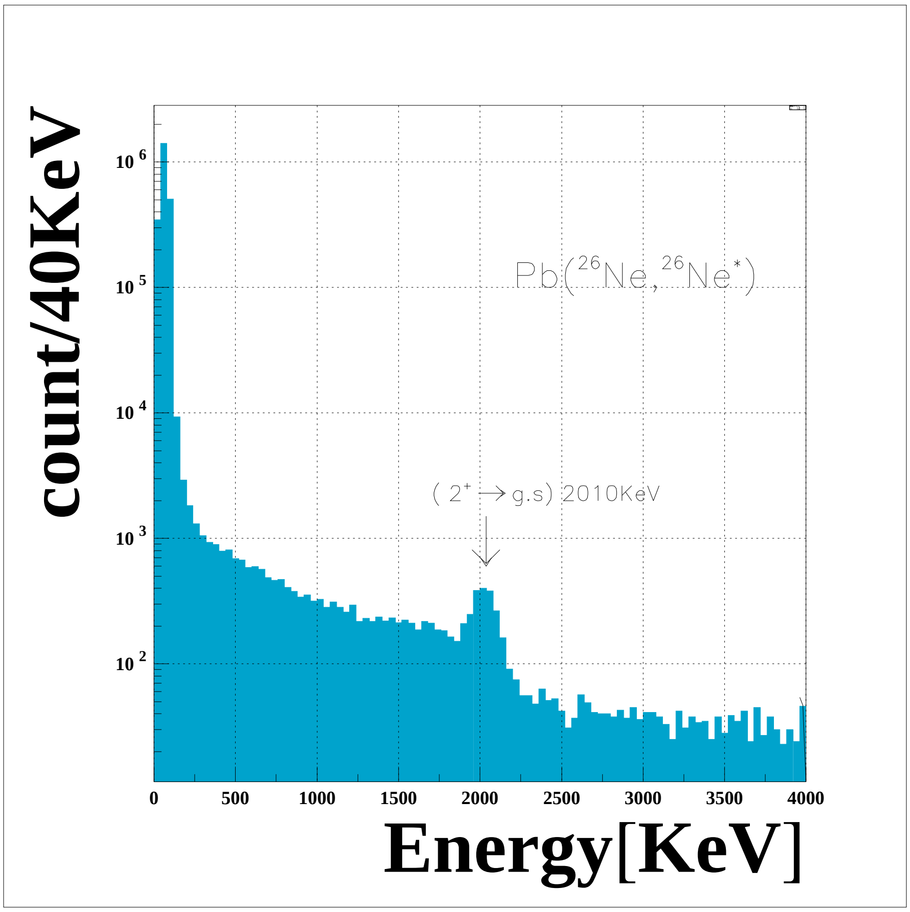


Figure 2: Energy spectrum of γ rays detected in coincidence with the ^{26}Ne reaction products.(right)Energy spectrum in laboratory frame.(left)Doppler-corrected γ rays energy spectrum with β=0.32. The peaks at 2020 keV is clearly seen while they are vague in right indicating a good quality of the Doppler correction.



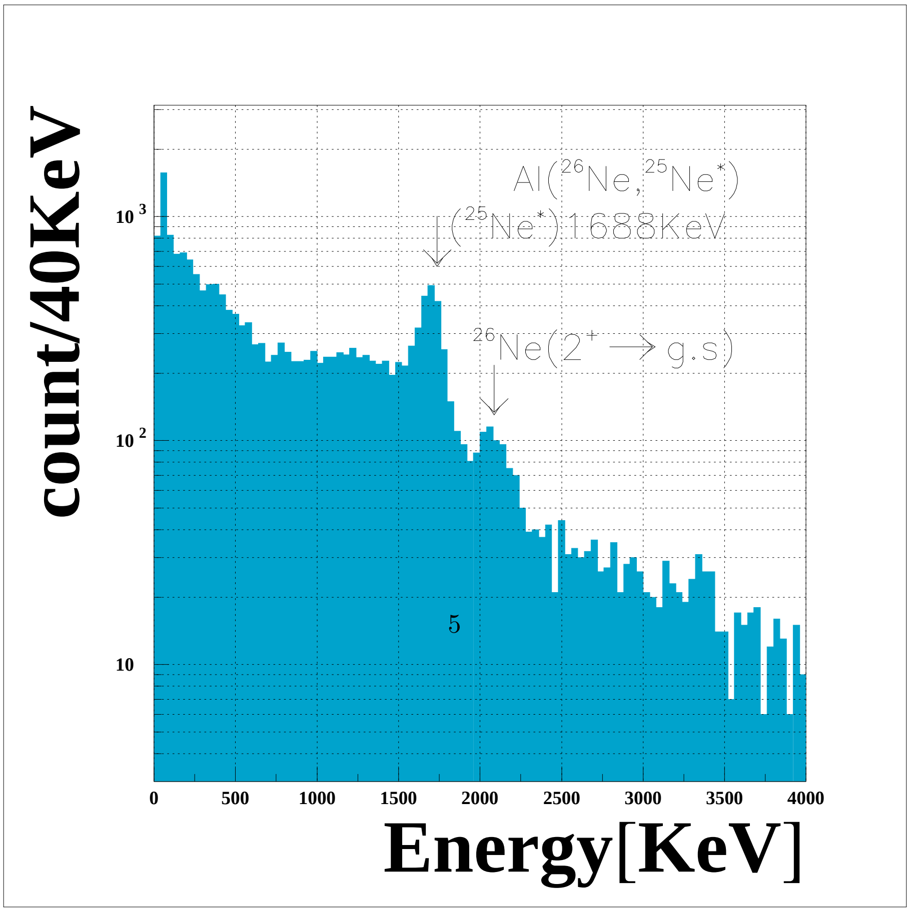


Figure 3: Gamma-ray energy spectra obtained in coincidence with the reaction products 26Ne,^{25}Ne.

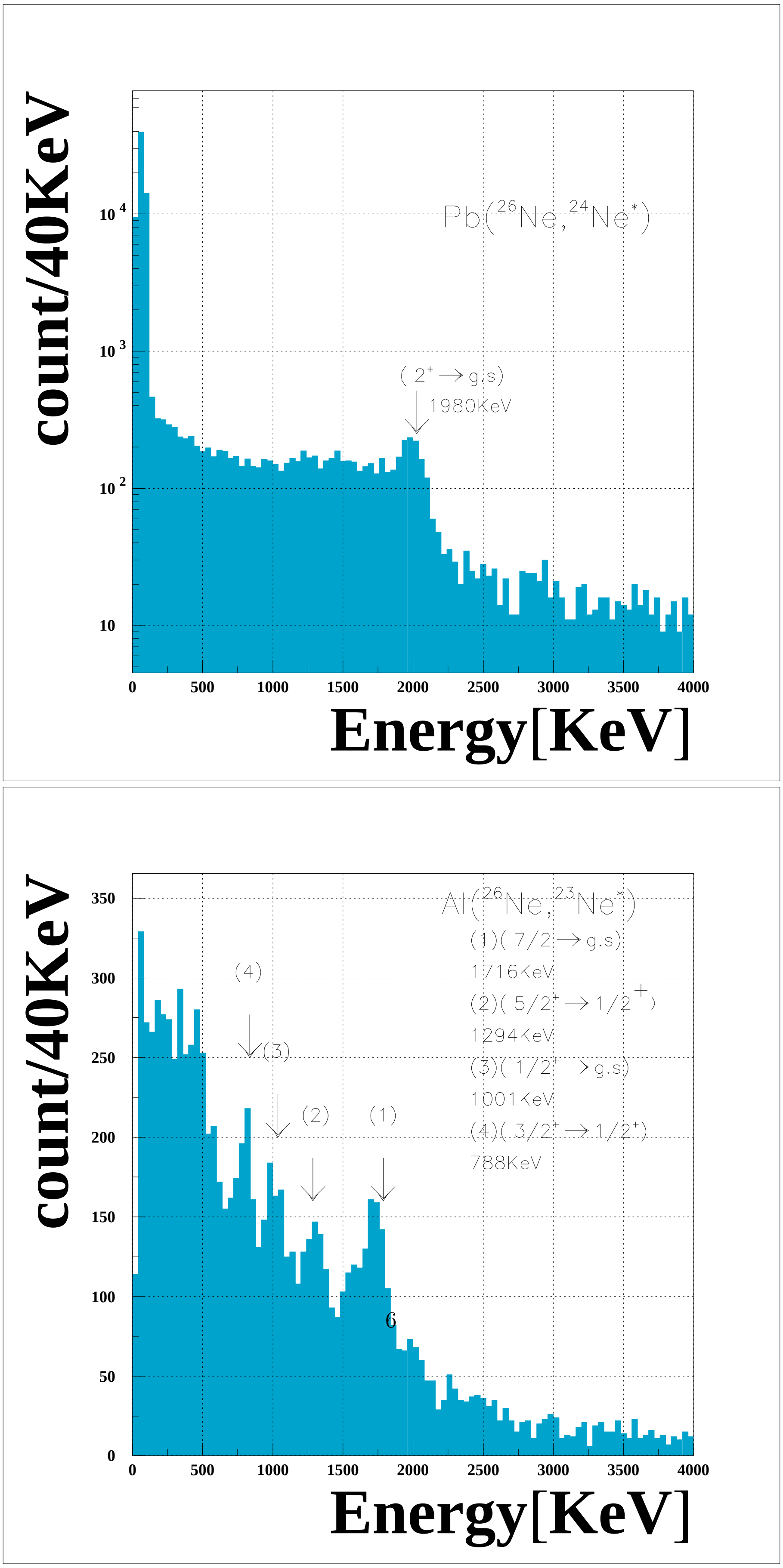


Figure 4: Gamma-ray energy spectra obtained in coincidence with the reaction products 24Ne,^{23}Ne.

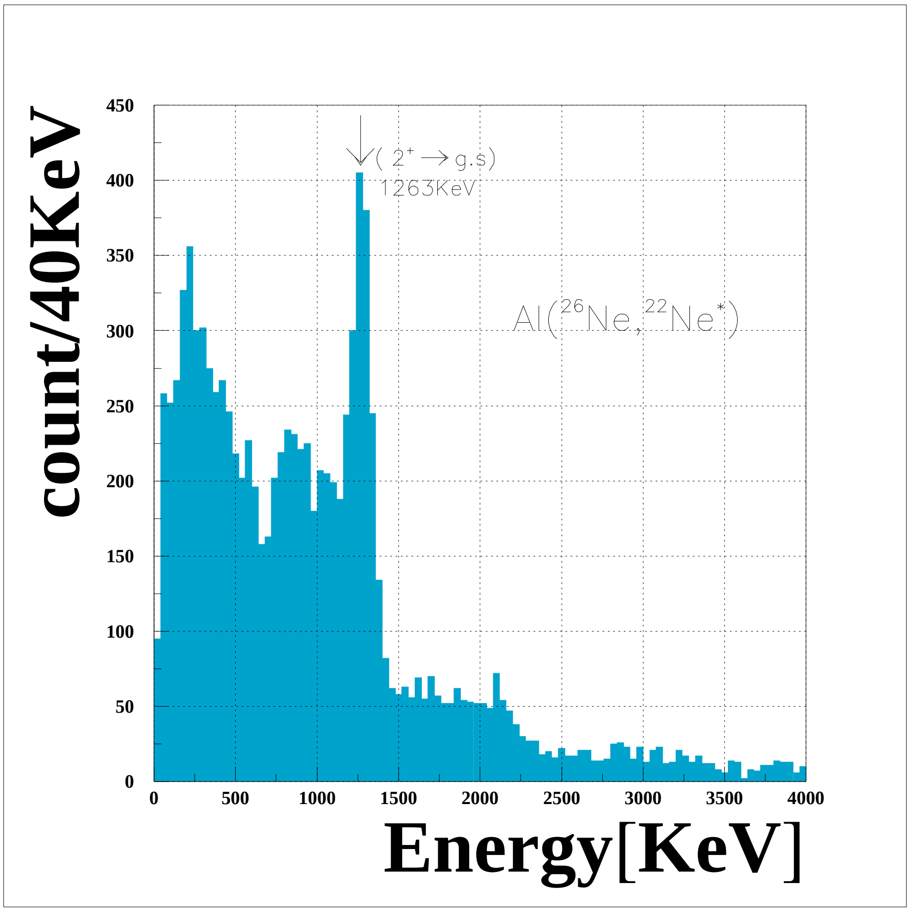


Figure 5: Ne fragments gamma ray spectrum

Figure 6: Gamma-ray energy spectra obtained in coincidence with the reaction products 22Ne.

fragment	E(exp)[keV]	σ	E(previous)[keV]	deviation[keV]	state
^{26}Ne	2020	109	2020	0	$(2^+ \rightarrow g.s)$
^{25}Ne	1688	89	1702	-14	unkown
^{24}Ne	1978	98	1981.6	3.6	$2^+ \rightarrow g.s$
^{23}Ne	1716	134	1701	15	$7/2 \rightarrow g.s$
	1294	170	1298	-4	$5/2^+ \rightarrow 1/2^+$
	1001	159	1017	-16	$1/2^+ \rightarrow g.s$
	785	120	805	-20	$3/2^+ \rightarrow 1/2^+$
^{22}Ne	1263	85	1274.5	-11	$2^+ \rightarrow g.s$
	848	171	-	-	-

Figure 7: Gamma-ray energies of Ne isotopes from A of 26 to A of 22. The energies deduced in the present work are compared with the literature values.

source	^{137}Cs	^{60}C		^{22}Na		Am-Be		
Energy[keV]	661	1173	1332	511	1274	3417	3928	4428
σ[keV]	26	32	36	25	36	84	105	95

Figure 8: The energy resolution of obtained value in standard gamma souce.

fragment	^{26}Ne	^{25}Ne	^{24}Ne	^{22}Ne
Energy[keV]	2020	1688	1978	1263
$\sigma[exp]$[keV]	109	89	98	85
$\sigma[calc]$[keV]	121	102	119	78

Figure 9: Energy resolution σ of obtained Doppler correted spectrum. The σ values in the present work are compared with the calcurated value.

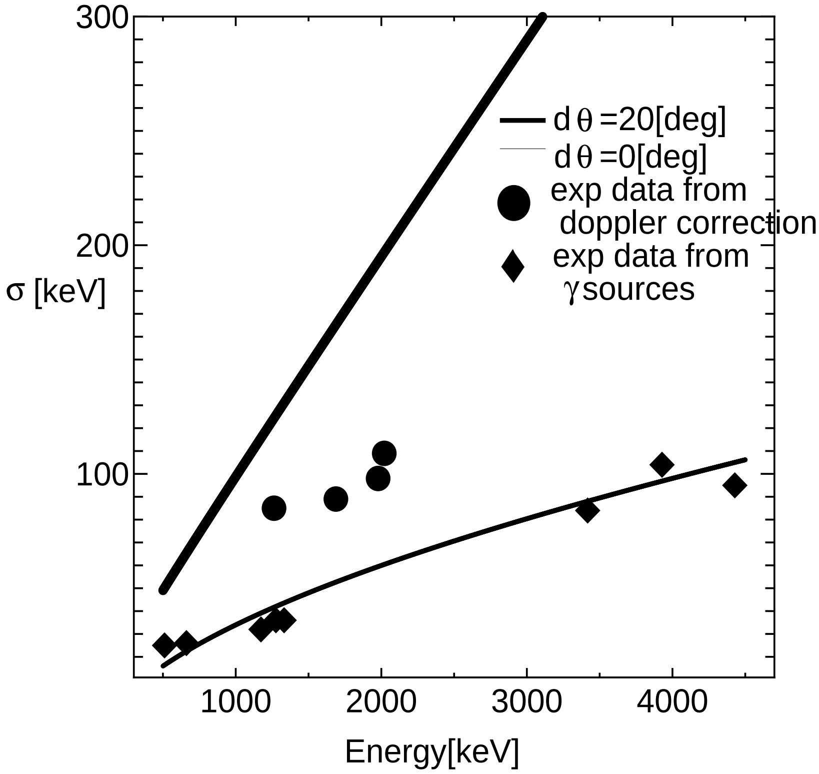


Figure 10: Energy resolutions for the function of energy of γ-ray emitted from moving souces .

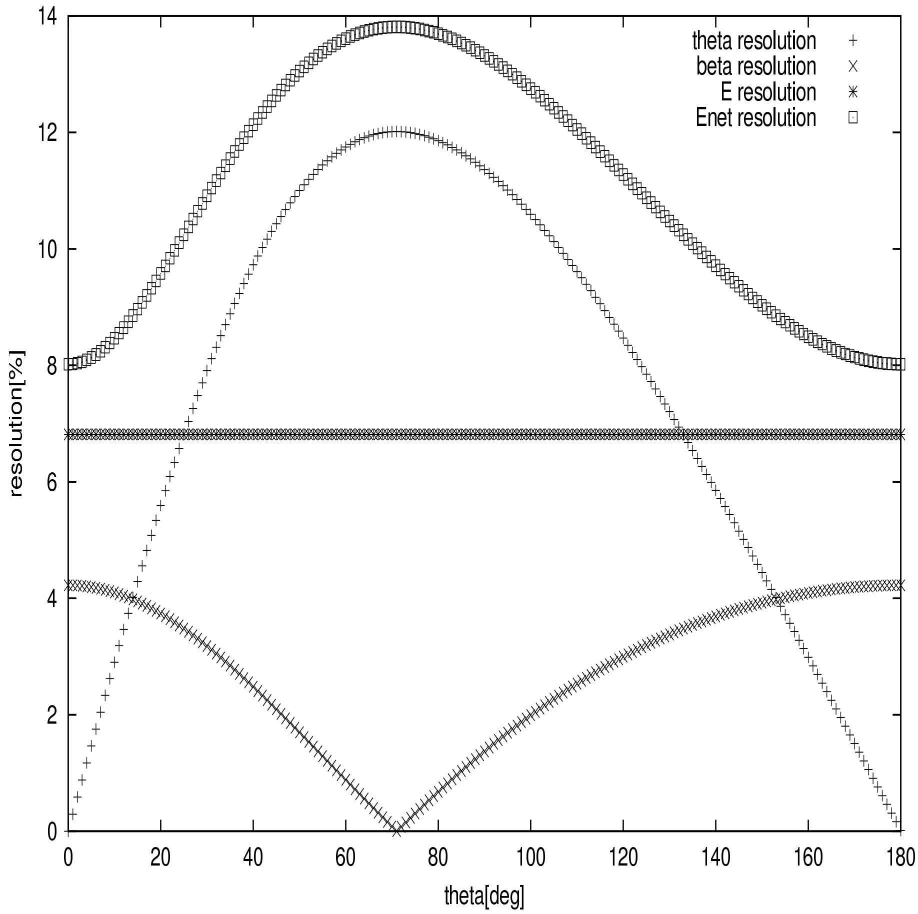


Figure 11: Energy resolutions for 2 MeV γ-ray emitted from moving souces with v/c$\approx$0.32