cross-section

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1 Cross section

1.1 formula

Cross section σ is given by

$$\sigma_{\mathrm{reaction}} = \frac{\mathrm{N_{reaction}}}{\mathrm{N_{beam}}} \frac{\mathrm{A}}{\mathrm{tN_A}} \tag{1}$$

- $\sigma_{\mathrm{reaction}}$:cross section of one events
- N_{reaction}:the number of one reaction events
- N_B:the number of the secondary beam,^{26}Ne
- A[g/mol]:the mass number
- t[g/cm^2:thickness of the target
- N_A[1/mol]:Avogadro‘s number

In this experiment,

- A:208[Pb]
- t:0.230[g/cm^2]

$$\frac{\mathrm{A}}{\mathrm{tN_A}} = 149.64 * 10^{-27} m^2 \tag{2}$$

- A:27[Al]
- t:0.130[g/cm^2]

$$\frac{\mathrm{A}}{\mathrm{tN_A}} = 34.48 * 10^{-27} m^2 \tag{3}$$

$$\sigma = \frac{\mathrm{N_{fragment}}}{\mathrm{N_{beam}}} \frac{\mathrm{A}}{\mathrm{tN_A}} \epsilon \tag{4}$$

$\mathrm{N_{beam}}$ is given by

$$\mathrm{N_{beam}} = (\mathrm{DS-factor}) * \mathrm{N_{^{26}Ne}} * (\mathrm{LiveTime})_{\mathrm{DS}} \tag{5}$$

- ϵ:the correction of the detectors
- DS-factor:down scale factor
- $(\mathrm{LiveTime})_{\mathrm{DS}}$:the live time of the down scale beam trigger

DS-factor and Live time is

$$(\mathrm{DS-factor}) = \frac{\mathrm{N_{beam}(scaler)}}{\mathrm{N_{DS}(scaler)}} \tag{6}$$

$$(\mathrm{LiveTime})_{\mathrm{DS}} = \frac{(\mathrm{DS-beam_{(raw-data)}})}{(\mathrm{DS-beam_{(scaler)}})} \tag{7}$$

$\mathrm{N_{fragment}}$ is given by
in the case of beam⊗ssd⊗neutron trigger

$$\mathrm{N_{fragment}} = \mathrm{N_{raw-data}} * (\mathrm{Livetime})_{\mathrm{b\otimes s\otimes n}} * \epsilon(\mathrm{acceptance}) \tag{8}$$

- $(\mathrm{Livetime})_{\mathrm{b\otimes s\otimes n}}$:the live time of the beam ⊗ ssd ⊗ neutron trigger

$$(\mathrm{LiveTime})_{\mathrm{b\otimes s\otimes n}} = \frac{\mathrm{N_{b\otimes s\otimes n}(raw-data)}}{\mathrm{N_{b\otimes s\otimes n}(scaler)}} \tag{9}$$

ϵ_γ(acceptance) is given by montecalro simulation.
in the case of beam⊗ssd⊗DALI trigger

$$\mathrm{N_{fragment}} = \mathrm{N_\gamma} * (\mathrm{Livetime})_{\mathrm{b\otimes s\otimes d}} * \epsilon(\mathrm{efficiency}) \tag{10}$$

$$(\mathrm{LiveTime})_{\mathrm{b\otimes s\otimes d}} = \frac{\mathrm{N_{b\otimes s\otimes d}(raw-data)}}{\mathrm{N_{b\otimes s\otimes d}(scaler)}} \tag{11}$$

- N_γ:the number of the photon peak
- $(\mathrm{Livetime})_{\mathrm{b\otimes s\otimes d}}$:the live time of the beam ⊗ ssd ⊗ dali
- $\epsilon_{\mathrm{efficiency}}$:efficiency of the DALI including acceptance of the geometry

ϵ is given by GEANT3 code.

1.2 the list of trigger event and livetime

RUN	^{26}Ne+Pb	^{26}Ne+Al	^{26}Ne+emp
Ungated Trigger(scaler)	14852201	4920463	1551938
Accepted Trigger(scaler)	13598070	4738277	152043
beam⊗SSD⊗DALI(scaler)	11084097	2136137	378380
beam⊗SSD⊗DALI(raw-data)	10038675	1952605	328419
beam⊗SSD⊗NEUT(scaler)	3306474	2166475	547899
beam⊗SSD⊗NEUT(raw-data)	2982517	1979953	472618
DS-Beam(scaler)	1578423	1755869	822505
DS-Beam(raw-data)	1443494	1630666	725995
Beam	789451741	878002704	411256850
Live Time(all)	0.92	0.96	0.98
Live Time(bsd)	0.91	0.91	0.87
Live Time(bsn)	0.90	0.91	0.86
Live Time(ds)	0.91	0.93	0.88
DS-factor	500	500	500
^{26}Ne(raw-data)*(livetime)	501886813	553961828	272365909

Figure 1: The table of each trigger event

beam⊗SSD⊗NEUT

RUN	^{26}Ne+Pb(live time)	^{26}Ne+emp(live time)	^{26}Ne+emp(live time)
^{25}Ne	11510(12789)	16010(17593)	2426(2821)
^{24}Ne	33470(37189)	32340(35538)	7963(9259)
^{23}Ne	31910(3546)	29650(32582)	8225(9564)
^{22}Ne	41010(45567)	31810(34956)	11090(12895)
^{21}Ne	17370(19300)	14260(15670)	5058(5881)
^{20}Ne	4373(4859)	3853(4234)	1406(1635)

Figure 2: The counts of Ne isotope from A of 26 to A of 20 at each target in coincidence with neutron.

After subtracting empty run

1.3 cross-section

Cross section table is following. The unit is mb.

The $E(2020;2^+)$ of the ^{26}Ne is following.

RUN	^{26}Ne+Pb(error)	^{26}Ne+Al(error)
^{25}Ne	7591(216)	11856(234)
^{24}Ne	20127(357)	16706(331)
^{23}Ne	17832(351)	13130(329)
^{22}Ne	21804(403)	8728(352)
^{21}Ne	8462(293)	3708(253)
^{20}Ne	1846(243)	909(162)

Figure 3: The counts of Ne isotope from A of 26 to A of 20 after subtracting empty target run at Pb and Al target in coincidence with neutron.

ds-beam(factor=500)

RUN	^{26}Ne+Pb(live time)	^{26}Ne+Al(live time)	^{26}Ne+emp(live time)
^{25}Ne	847(931)	827(889)	184(209)
^{24}Ne	449(493)	732(787)	154(175)
^{23}Ne	630(692)	414(445)	56(64)
^{22}Ne	353(388)	172(185)	73(83)
^{21}Ne	149(164)	380(409)	20(23)

Figure 4: The counts of Ne isotope from A of 26 to A of 20 at each target onbeam trigger.

RUN	^{26}Ne+Pb	^{26}Ne+Al
photo-peak$E$(2020keV; 2^+)	2495	2111
fitting error	55	55
statics error	50	46
ϵ efficiency	13.6%	13.6%
$\Delta\epsilon/\epsilon$	15%	15%
ϵ acceptance		
σ cross-section(mb)	60(9))	11(2)

1.4 appendix

How to estimate the value of the error.

$$\sigma_{\mathrm{reaction}} = \frac{\mathrm{N_{frag}}}{\mathrm{N_B}} \frac{\mathrm{A}}{\mathrm{tN_A}} \tag{12}$$

- $\sigma_j$reaction:cross section of one events
- N_{fragment}:the number of each fragments number
- N_B:the number of the secondary beam,^{26}Ne

RUN	^{26}Ne+Pb(error)	^{26}Ne+Al(error)
^{25}Ne	545(121)	464(127)
^{24}Ne	171(66)	431(90)
^{23}Ne	575(65)	316(63)
^{22}Ne	235(55)	16(53)
^{21}Ne	122(68)	362(322)

Figure 5: The counts of Ne isotope from A of 26 to A of 20 after subtracting empty target run at Pb and Al target on beam trigger.

RUN	^{26}Ne+Pb(error)	^{26}Ne+Al(error)
^{25}Ne	23(3.0)	7(1.3)
^{24}Ne	60(2.1)	10(0.7)
^{23}Ne	53(1.0)	8(0.3)
^{22}Ne	65(1.3)	5(0.1)
^{21}Ne	25(0.4)	2(0.1)
^{20}Ne	8(0.2)	1(0.01)

Figure 6: The cross section table at each target in coincidence with neuron.

- A[g/mol]:the mass number
- t[g/cm^2:thickness of the target
- N_A[1/mol]:Avogadro‘s number

$\Delta\sigma$ is introduced by following

$$\Delta\sigma = \sqrt{(\frac{\Delta N_{\rm frag}}{N_{\rm frag}})^2 + (\frac{\Delta\epsilon_{\rm frag}}{\epsilon_{\rm frag}})^2 + (\frac{\Delta N_B}{N_B})^2} \quad (13)$$

Subtracting empty target run from each target run produced the error of the each target run with error of the empty run.

In empty run

$$N_{\rm emp} = x \pm \Delta x \quad (14)$$

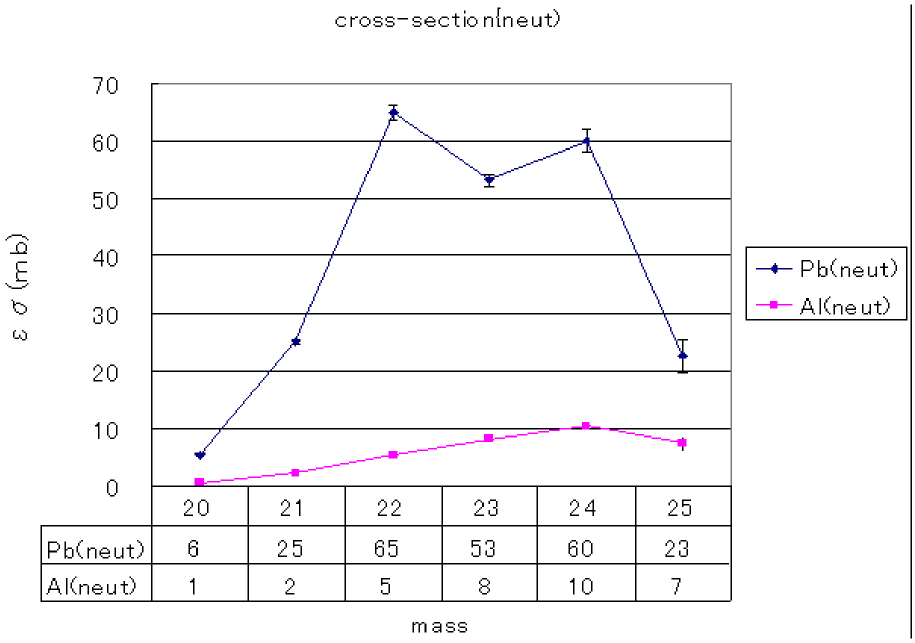
In target run

$$N_{\rm tgt} = y \pm \Delta y \quad (15)$$

Ds-beam cross-section is following. The unit is mb.

RUN	^{26}Ne+Pb(error)	^{26}Ne+Al(error)
^{25}Ne	813(452)	144(128)
^{24}Ne	255(60)	134(438)
^{23}Ne	857(97)	98(20)
^{22}Ne	350(135)	5(1)
^{21}Ne	182(40)	113(31)

Figure 7: The cross section table at each target on beam trigger.



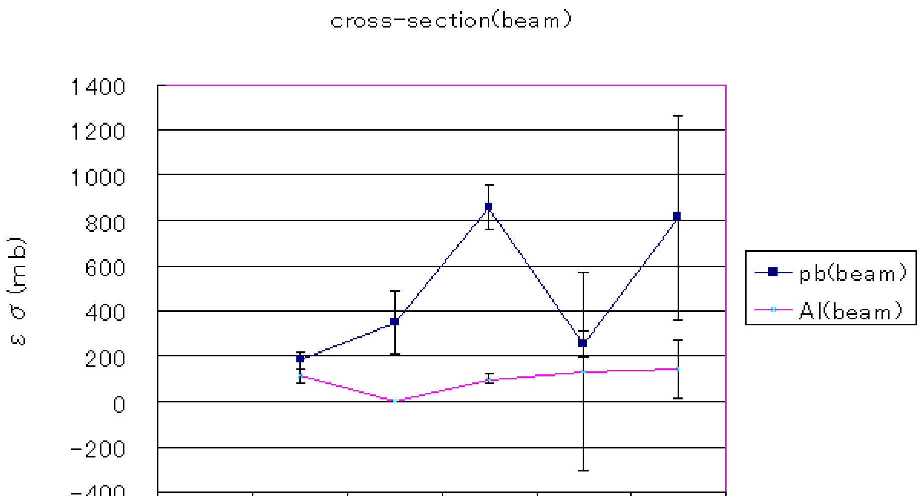
In empty subtraction,

$$F = N_{\rm tgt} - C1 * N_{\rm emp} \tag{16}$$

Therefore

$$\Delta N_{\rm frag} = \Delta F \tag{17}$$

- C1:the coefficient in normalizing target statics



	20	21	22	23	24	25
pb(beam)		182	350	857	255	813
Al(beam)		113	5	98	134	144

mass

$$\Delta F = \sqrt{(\frac{\delta F}{\delta x})^2(\Delta x)^2 + (\frac{\delta F}{\delta y})^2(\Delta y)^2} \tag{18}$$

$$\frac{\delta F}{\delta x} = 1 \tag{19}$$

$$\frac{\delta F}{\delta y} = C1 \tag{20}$$

Therefore

$$\Delta F = \sqrt{(\Delta x)^2 + (\Delta y * C1)^2} \tag{21}$$

- ϵ:acceptance of the ssd calculating doing now
- N_B:the number of the secondary beam,^{26}Ne
- N_B:the statics error of the photon peak number

- $\Delta N^{\mathrm{sta}}_{\mathrm{frag}}$:the statics error of the photon peak number
- $\Delta N^{\mathrm{fit}}_{\mathrm{frag}}$:the fitting error of the photon peak

In the γ-ray spectrum case, the estimate of the error is following.

$$\sigma = \frac{\mathrm{N}_\gamma}{\mathrm{N}_{\mathrm{beam}}} \frac{\mathrm{A}}{\mathrm{tN_A}} \tag{22}$$

Therefore,

$$\frac{\Delta\sigma}{\sigma} = \sqrt{(\frac{\Delta N_\gamma}{N_\gamma})^2 + (\frac{\Delta\epsilon_\gamma}{\epsilon_\gamma})^2 + (\frac{\Delta N_B}{N_B})^2} \tag{23}$$

$$\Delta N_\gamma = \sqrt{(\Delta N^{\mathrm{sta}}{}_\gamma)^2 + (\Delta N^{\mathrm{fit}}_\gamma)^2} \tag{24}$$

- σ:cross section
- N_γ:the number of the photon peak
- ϵ:efficiency of the DALI including acceptance of the geometry
- N_B:the statics error of the photon peak number
- $\Delta N^{\mathrm{sta}}_\gamma$:the statics error of the photon peak number
- $\Delta N^{\mathrm{fit}}_\gamma$:the fitting error of the photon peak