Study of $^{25}Al+p$ resonances using $^{27}Si(p,d)^{26}Si^*$ reactions

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Outline

- Introduction
  - Galactic ^{26}Al
  - $^{25}Al(p,\gamma)^{26}Si$ reaction
  - previous study of ^{26}Si
- Experiment details of $p(^{27}Si,^{26}Si^{*})d$ reaction
- Data analysis and preliminary results
- Ongoing and Future work

Galactic ^{26}Al

- Important probe for Inter-Stellar Medium

  ISM → birthplace of new stars

- Observed in
  - γ - emission study by satellite

    $$^{26}Al^{g.s.} \xrightarrow{\beta^+\nu} {}^{26}Mg^* \xrightarrow{\gamma\ decay} 1.8MeV\ \ \gamma\ ray$$

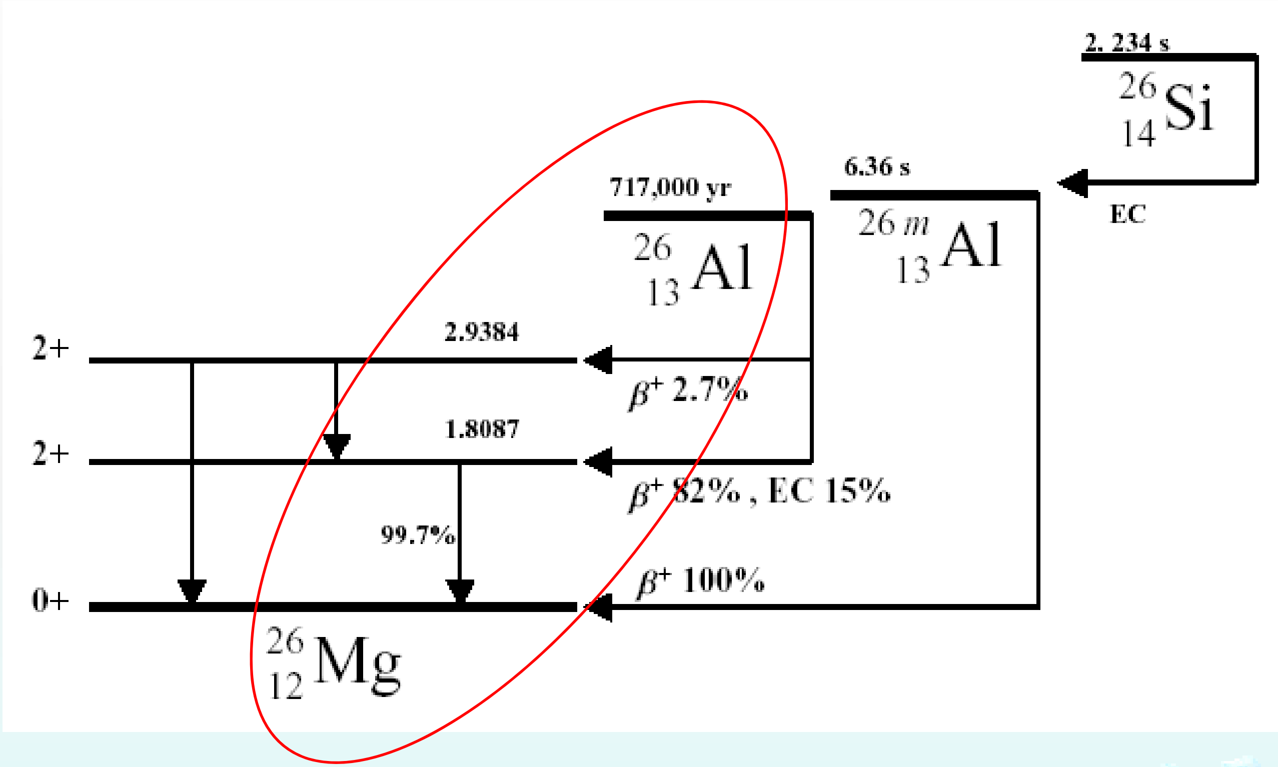
  - meteoritic abundance study

- Large uncertainty in the amount of ^{26}Al

  contribution from nova, supernova and other massive stars is uncertain

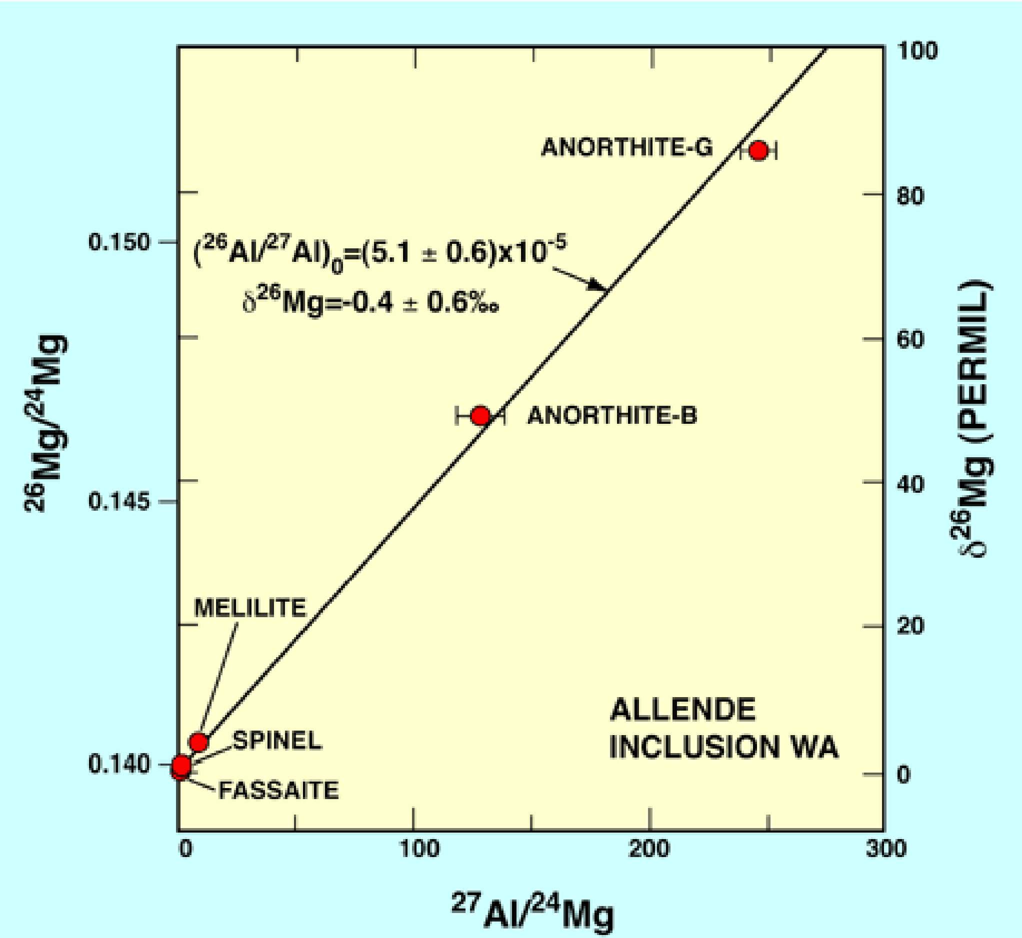
  production rates in these stars need to be accurately determined experimentally

Galactic ^{26}Al



- 1.809 MeV gamma-ray emitter
- T1/2 = 0.7 million years

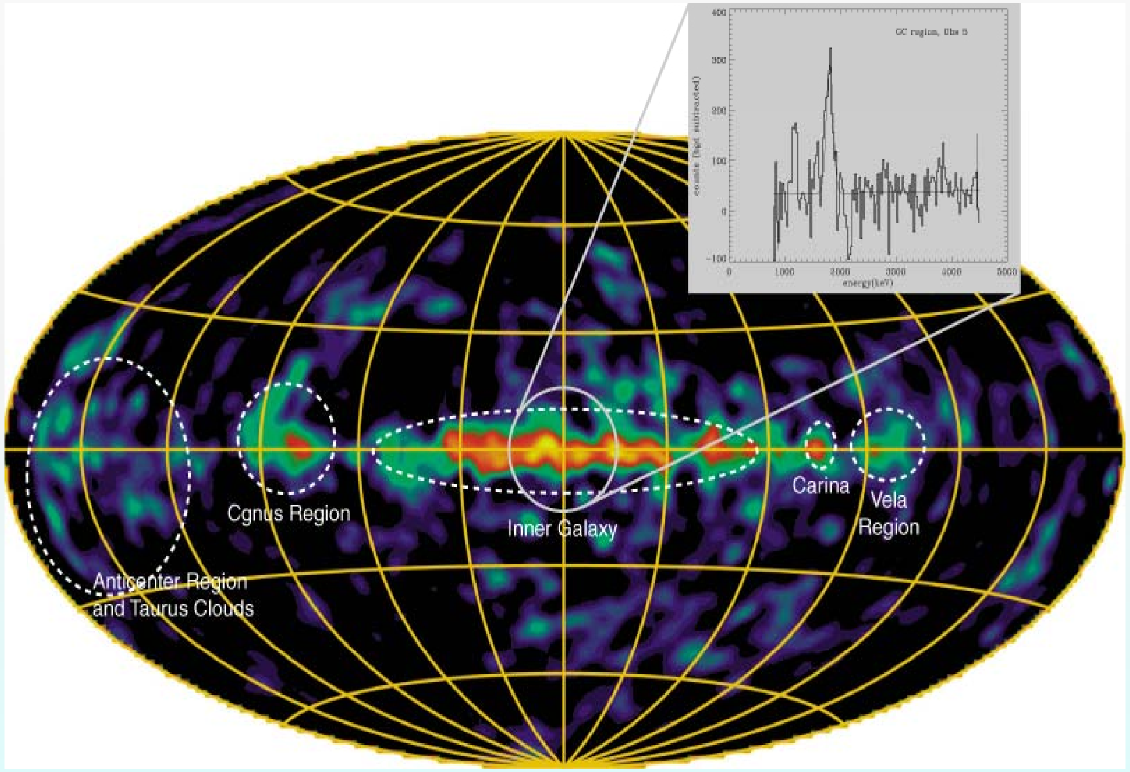
^{26}Al in Meteoritic Inclusions



(From Lee et.al., *Geophys. Res. Lett.*, 1976)

- Meteorites: abundances representative of early solar system
- From excess ^{26}Mg, infer $^{26}Al/^{27}Al$ ratio at that time

Galactic ^{26}Al: Gamma-rays and COMPTEL



- ^{26}Al decay: 1.809 MeV γ-ray
- M(^{26}Al) ~ 2.5 solar masses
- Evidence for recent nucleosynthesis in the Galaxy

Source of Galactic ^{26}Al

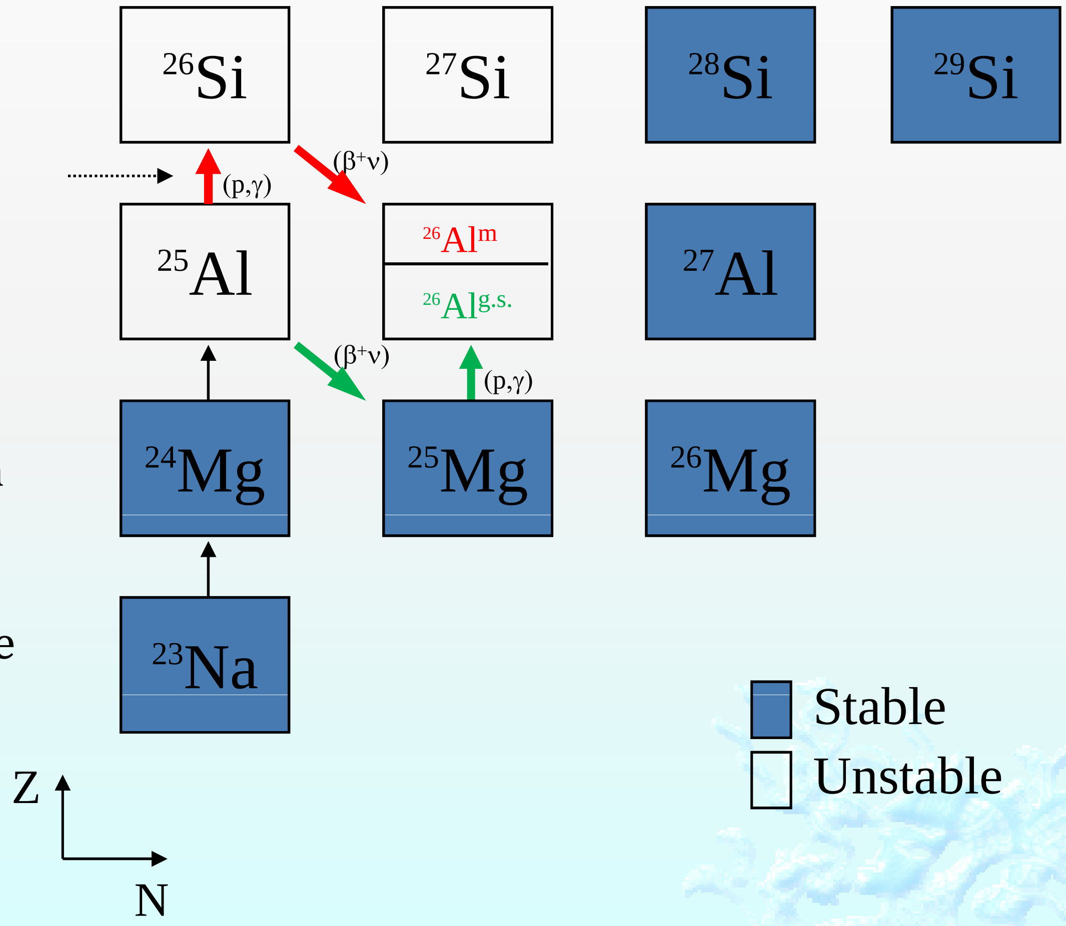
In nova explosion,

$^{25}Al(p,\gamma)^{26}Si$

competes with

$^{25}Al(\beta^{+}\nu)Mg$

But $^{25}Al(p,\gamma)^{26}Si$ is uncertain due to the existence of unknown states in nova temperature, resulting in the large uncertainty in ^{26}Al production.



$^{25}Al(p,\gamma)^{26}Si$ Reaction in Nova Explosion

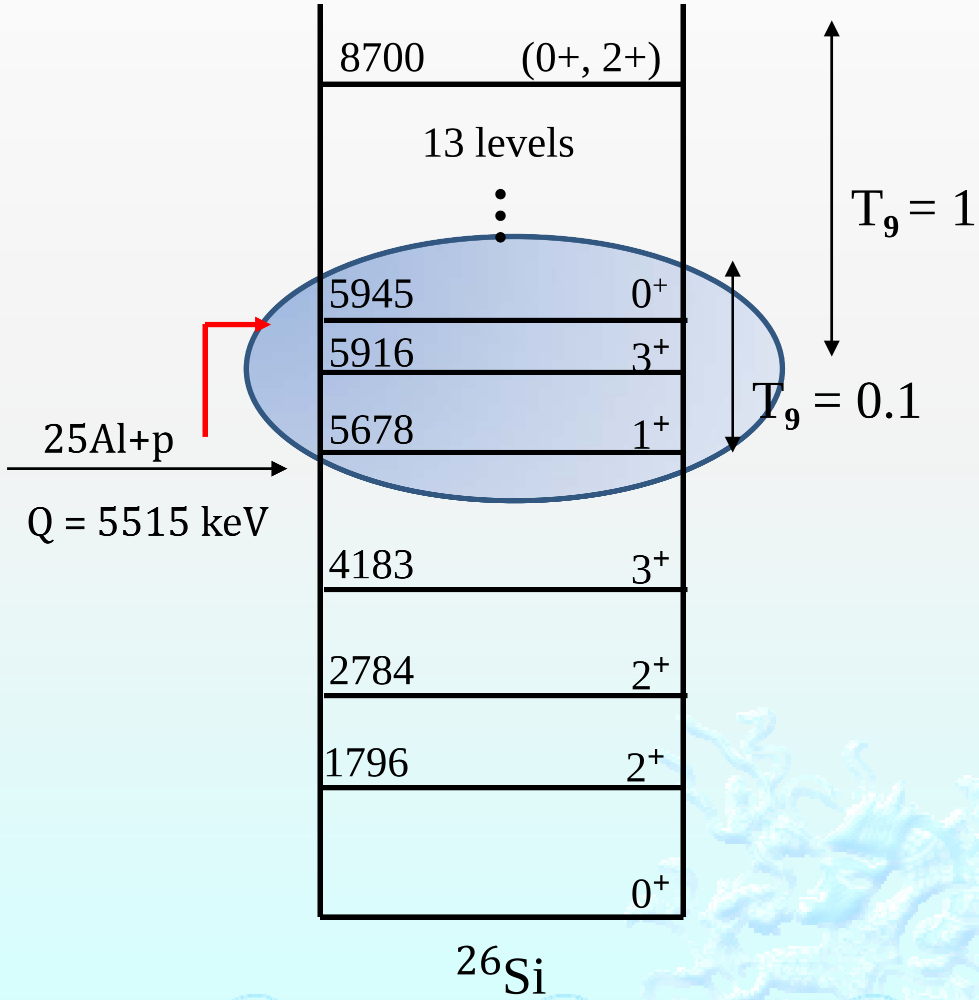
Uncertain and dominant states in this reaction at nova T.:

E_x=5.946 MeV, J^π =0^+(?)

E_x=5.916 MeV, J^π =3^+(?)

E_x=5.678 MeV, J^π =1^+(?)

These states and also the dominant states in the energy range at supernova temperature T_9=1 in ^{26}Si have to be well understood.



Previous Studies of Astrophysically Important States in ^{26}Si

- **$^{29}Si(^{3}He,^{6}He)^{26}Si$, Caggiano et al. 2002**

  $J^{\pi}=1^{+}$ to E_x = 5.678(8) MeV

  $J^{\pi}=3^{+}$ to E_x = 5.945(8) MeV

- **$^{28}Si(p,t)^{26}Si$, Bardayan et al.**

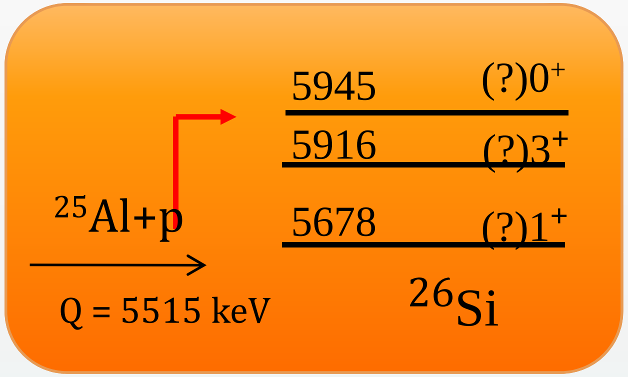
  $J^{\pi}=0^{+}$ to E_x =5.916(2) MeV 2002

  $J^{\pi}=3^{+}$ or 2^{+} to E_x =5.916(2) MeV 2006

- **$^{24}Mg(^{3}He,n)^{26}Si$, Parpottas et al. 2004**

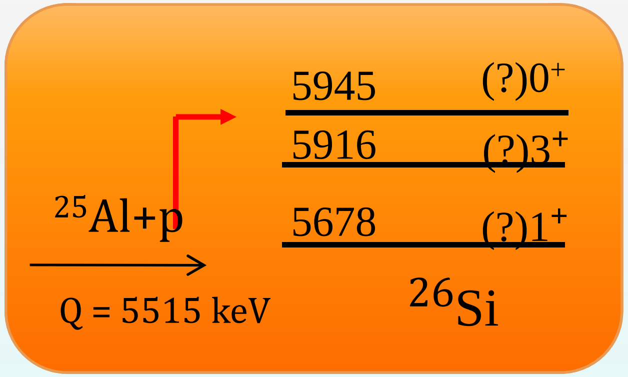
  $J^{\pi}=3^{+}$ to E_x = 5.912(4) MeV

  $J^{\pi}=0^{+}$ to E_x = 5.946(4) MeV



Our Proposed Experiments

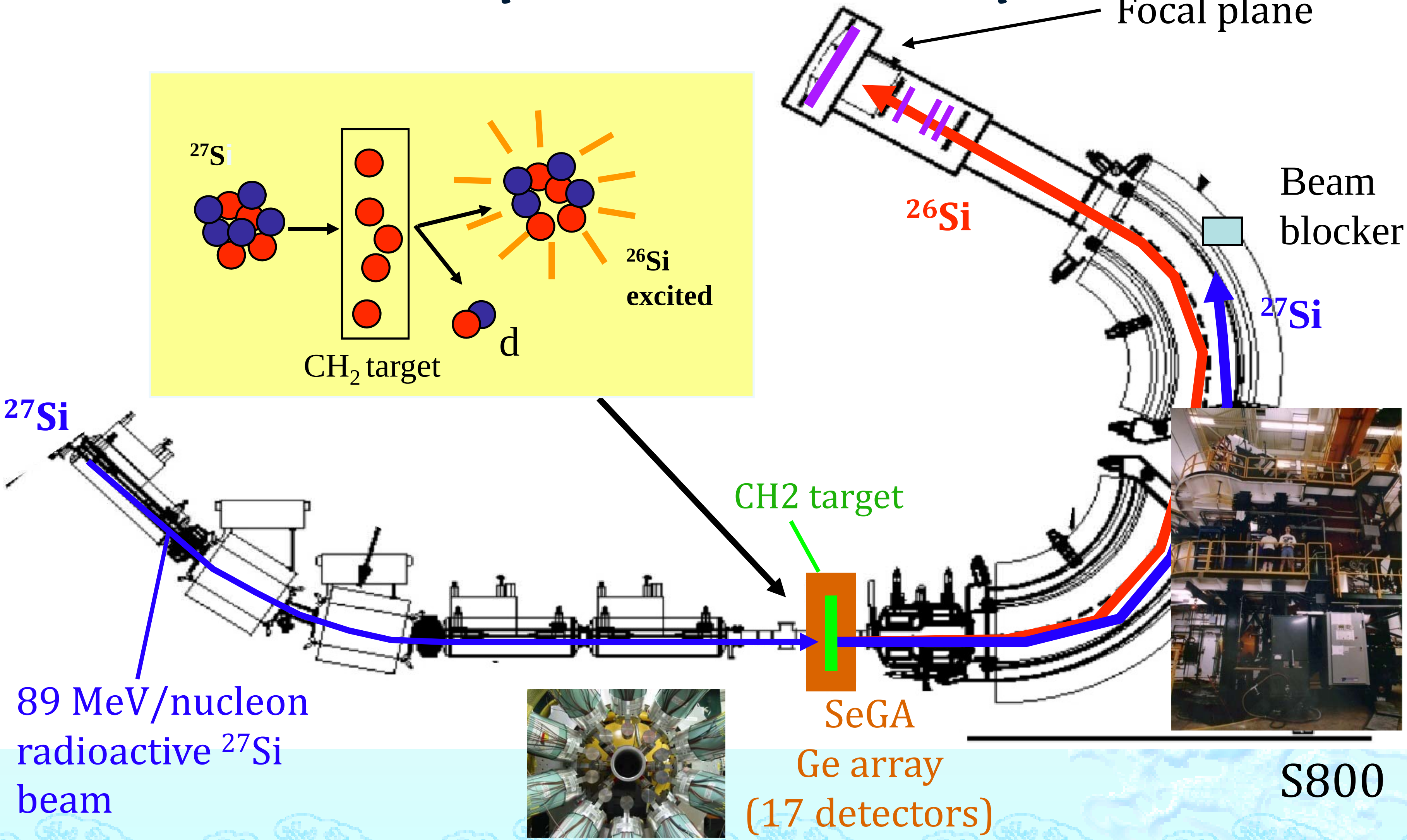
- Goal:
  - populate the $J^{\pi}=3^{+}$ and/or 0^{+} state in ^{26}Si and reduce the uncertainty of $^{25}Al(p,\gamma)^{26}Si$ reaction rate
  - find new states
- Two experiments:
  - $p(^{27}Si,^{26}Si^{*})d$ reaction at NSCL
  - $p(^{25}Al,^{25}Al)p$ elastic scattering at RIKEN

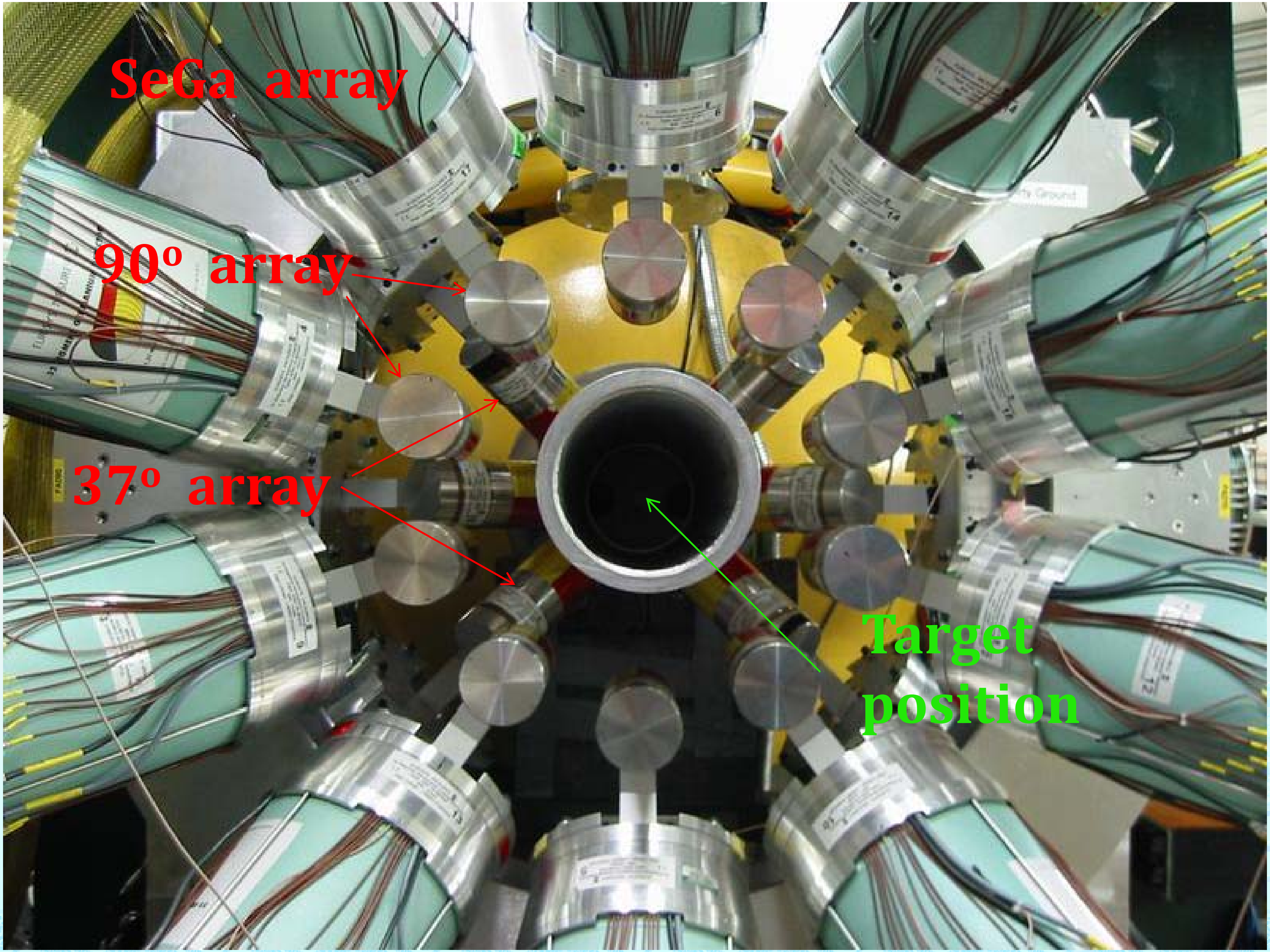


$p(^{27}Si, ^{26}Si^*)d$ reaction at NSCL Experiment Details

- Primary beam: 150 MeV/nucleon ^{36}Ar
- Secondary beam: 89 MeV/nucleon ^{27}Si
  - by fragmenting primary beam of ^{36}Ar on a 940 mg/cm^2 ^{9}Be target
  - intensity of 1×10^7 pps with purity of about 36%
- Target: 250 mg/cm^2 CH_2 foil
  - located at the target position of the S800 spectrograph
- Detectors:
  - segmented germanium detector array (SeGA) detecting the gamma decay from $^{26}Si^*$ in coincidence with the recoil detection in the focal plane.

$p(^{27}Si,^{26}Si^{*})d$ reaction at NSCL
Experiment Setup

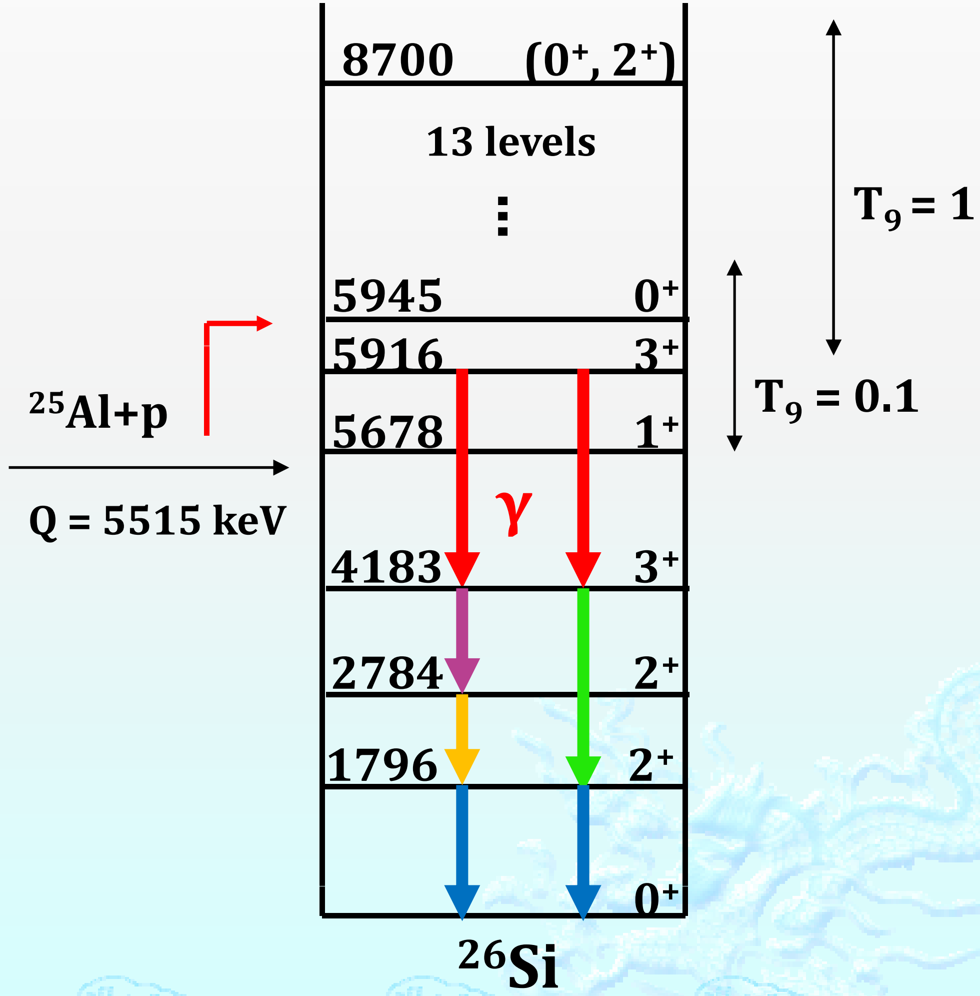



SeGa array
90° array
37° array
Target position

Expected transitions from $J^\pi = 3^+$ state at 5.912(4) MeV

Based on the known decay scheme of its mirror state at $E_x(^{26}Mg)$ = 6.125 MeV, this state in ^{26}Si is predicted to gamma decay through two possible cascades with equal probability:

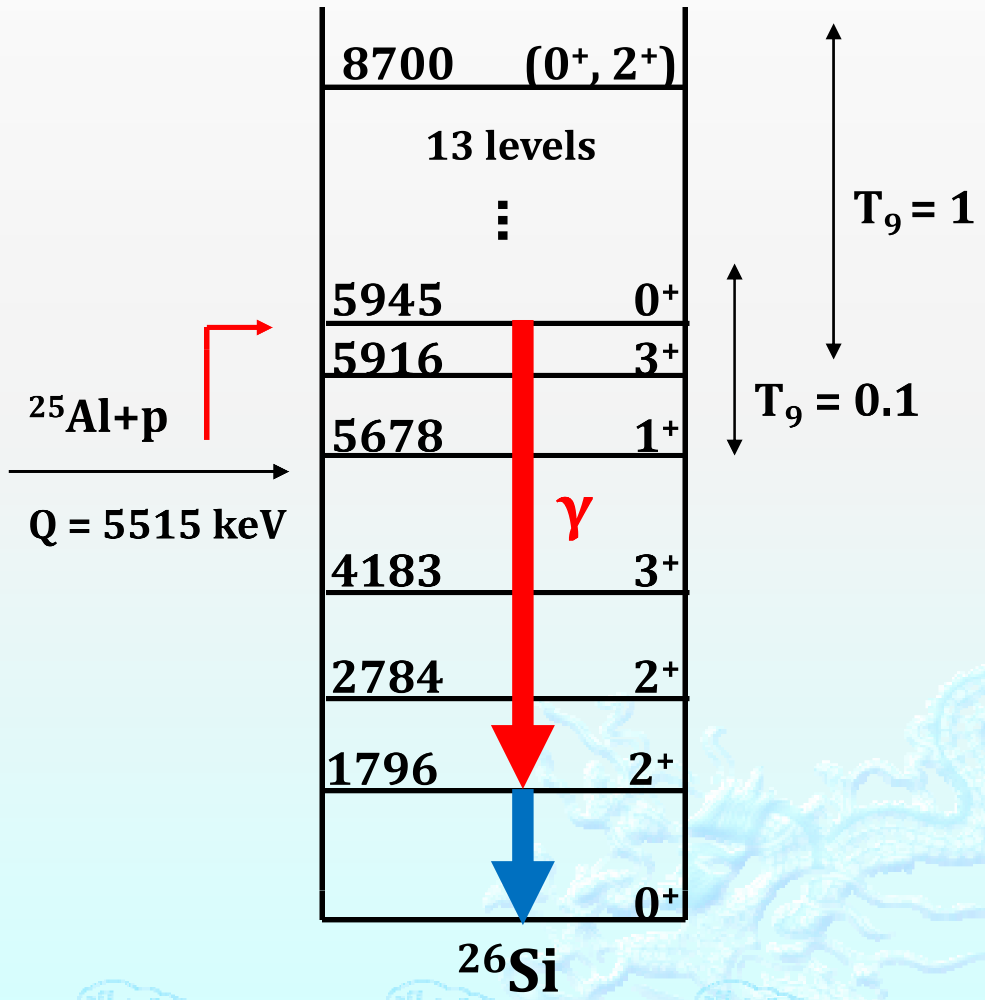
- E_γ= 1.729 MeV, 2.387 MeV, 1.796 MeV
- E_γ= 1.729 MeV, 1.399 MeV, 0.988 MeV and 1.796 MeV.



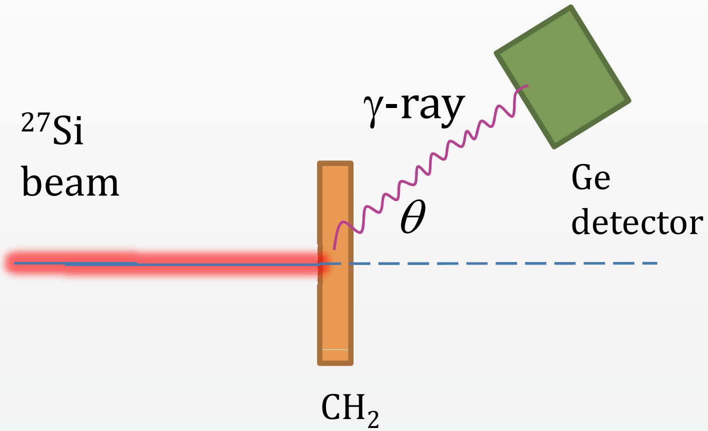
Expected transitions from $J^{\pi} = 0^+$ state at 5.946(4) MeV

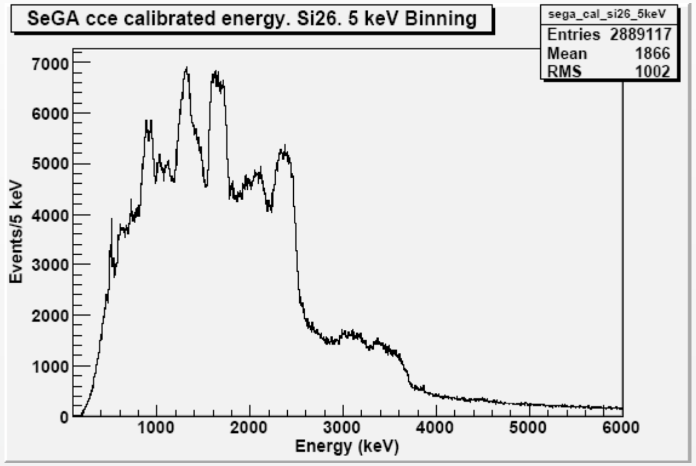
Based on the known decay scheme of its mirror state at $E_x(^{26}Mg)$ = 6.256 MeV, this state in ^{26}Si is predicted to gamma decay entirely through one gamma cascade

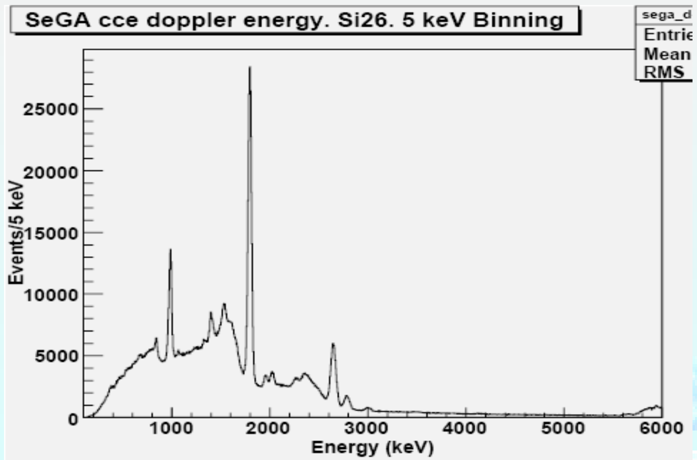
- E_{γ}= 4.150 MeV and 1.796 MeV.



Doppler Broadening Correction



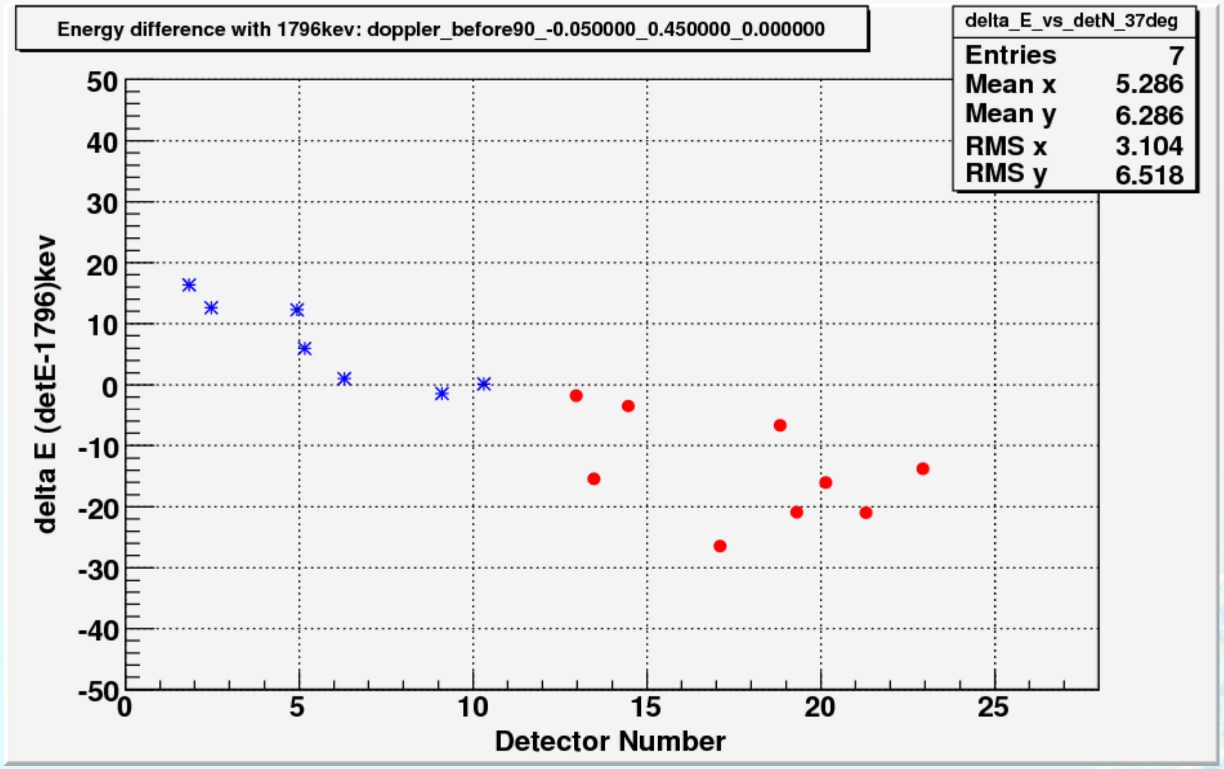




$$E_{dop} = \frac{1-\beta\cos\theta}{\sqrt{1-\beta^2}} E_{measured}$$

Minimizing deviation of Ge Segments

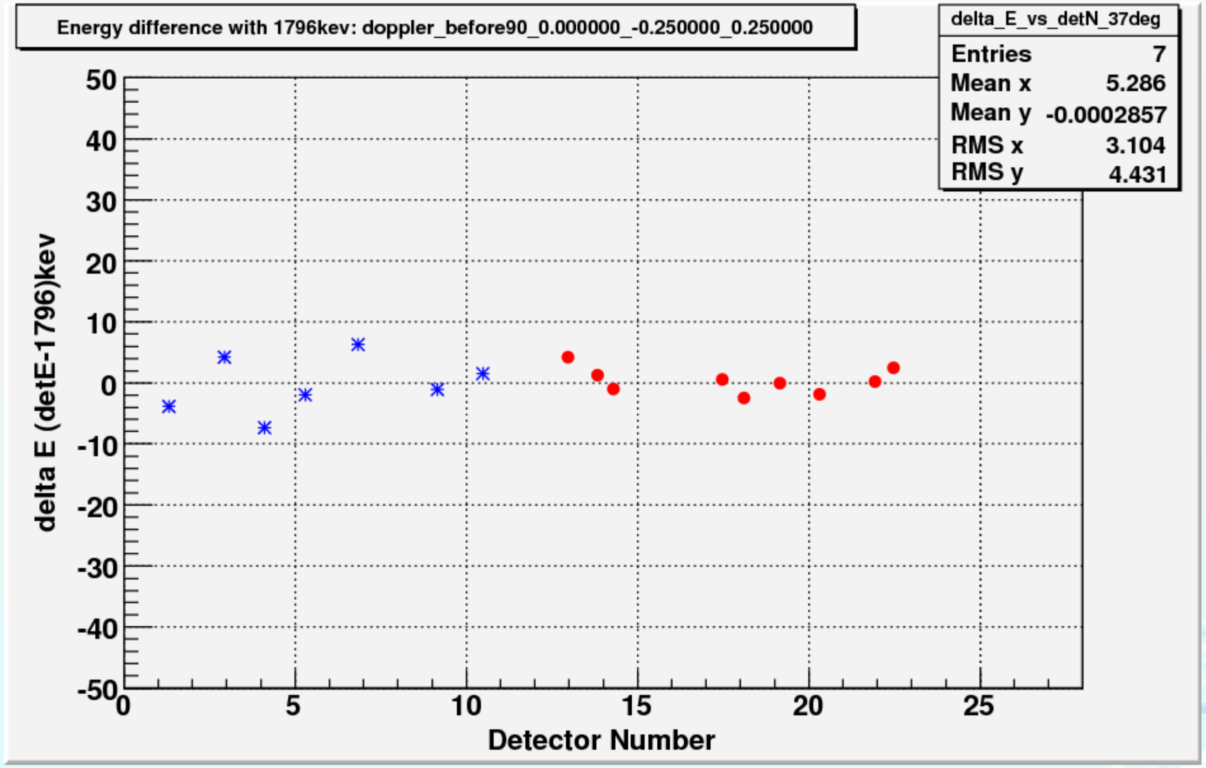
Find the difference between the measured energy of each segment and the real peak energy for peak 1796 keV



RMS= 6.518 keV

Minimizing deviation of Ge Segments

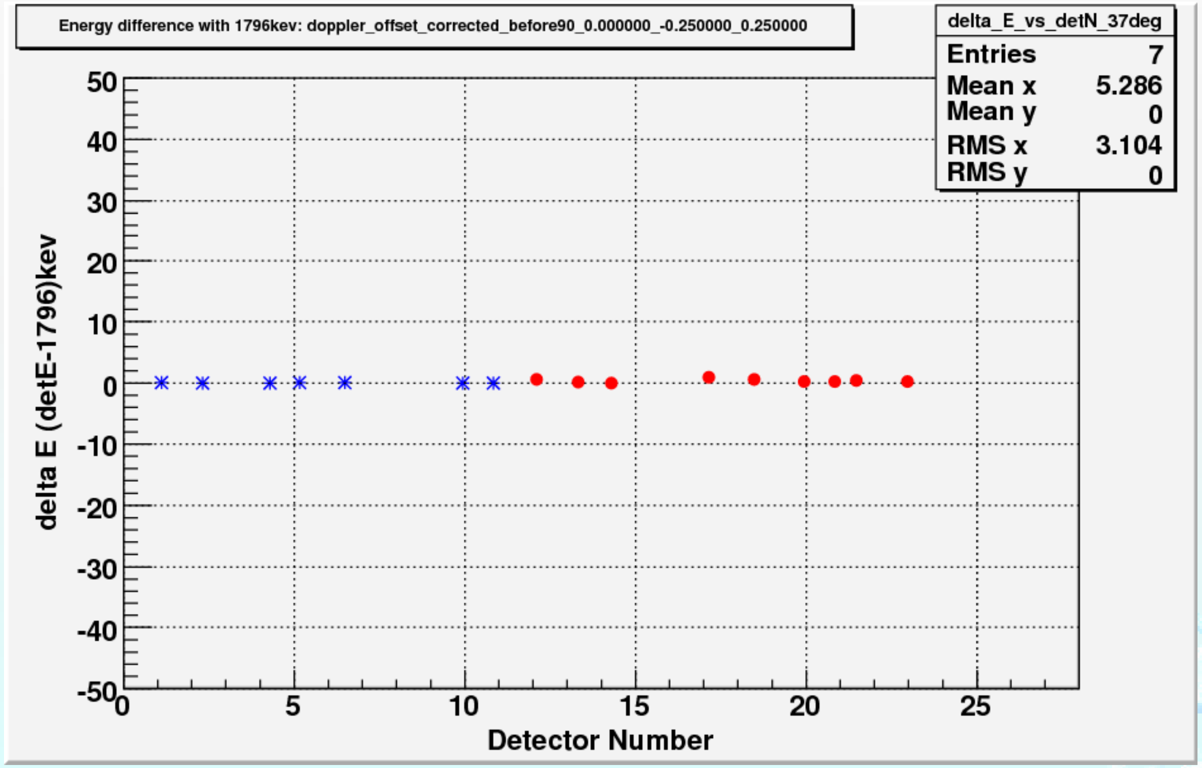
Step1: slightly change the target position to find the minimal RMS



RMS_{min}= 4.431 keV at target position (0,-0.25,0.25) mm

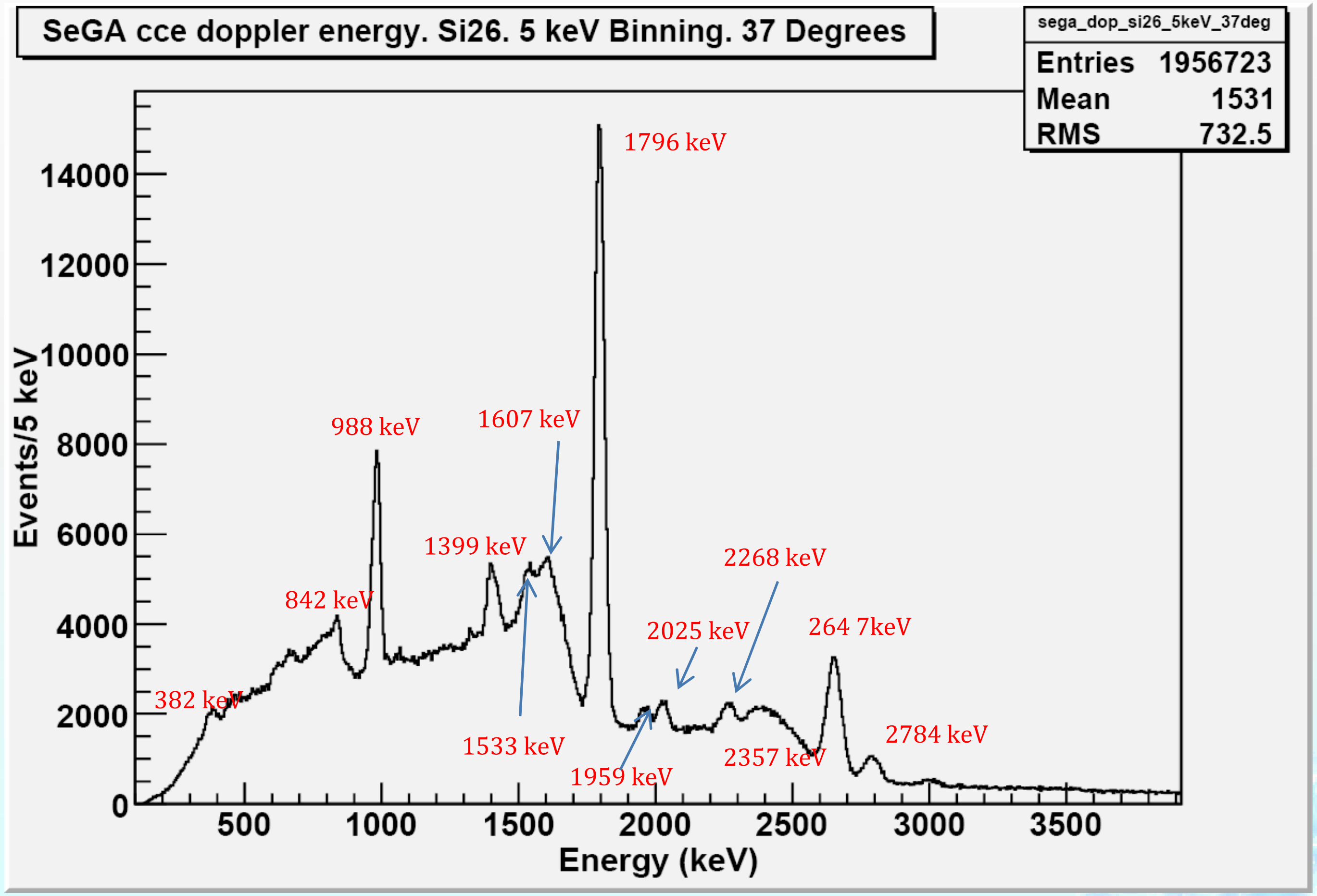
Minimizing deviation of Ge Segments

Step2: using the found position, add offset correction for each segment to make RMS equal to 0

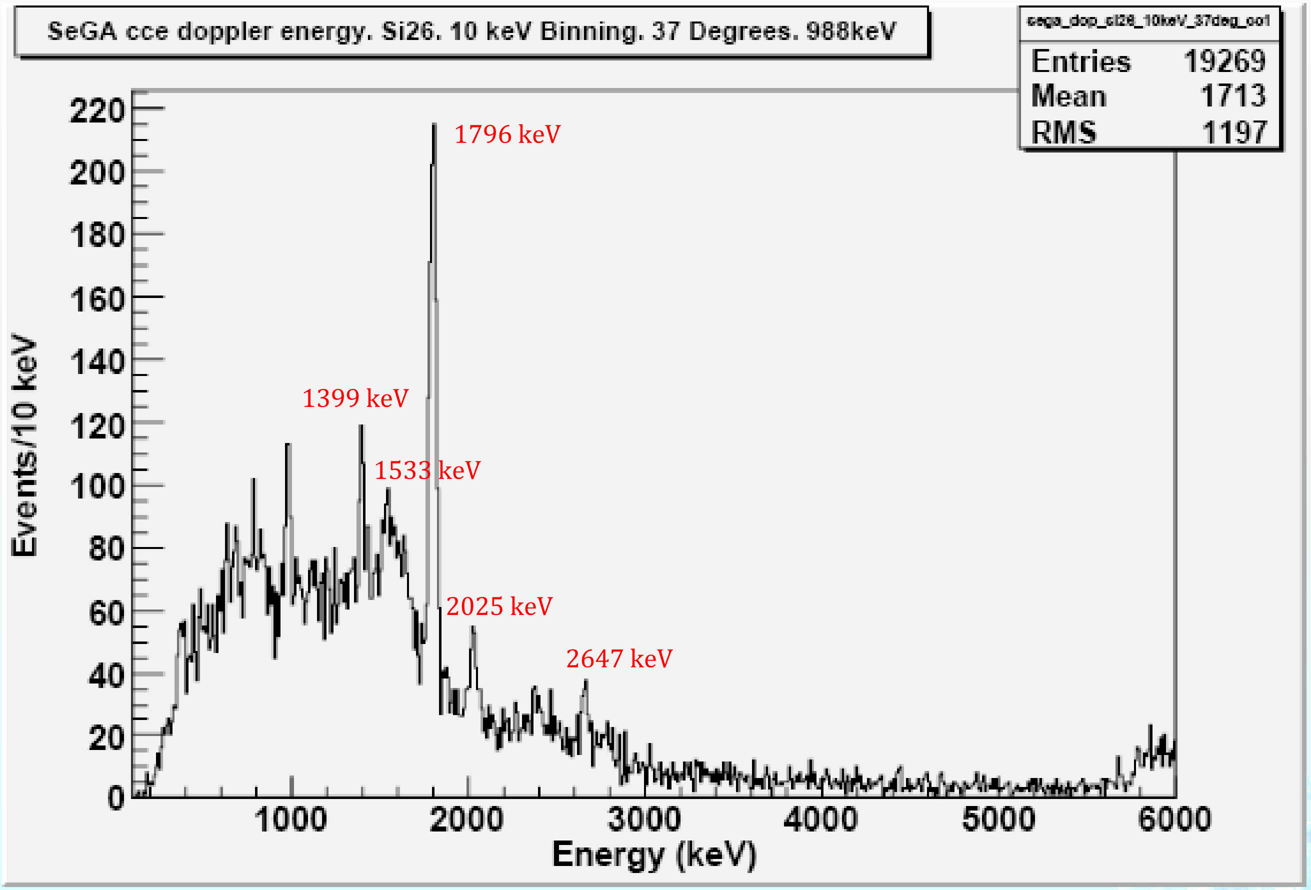


RMS_{min}= 0 keV after adding the offset for each segment

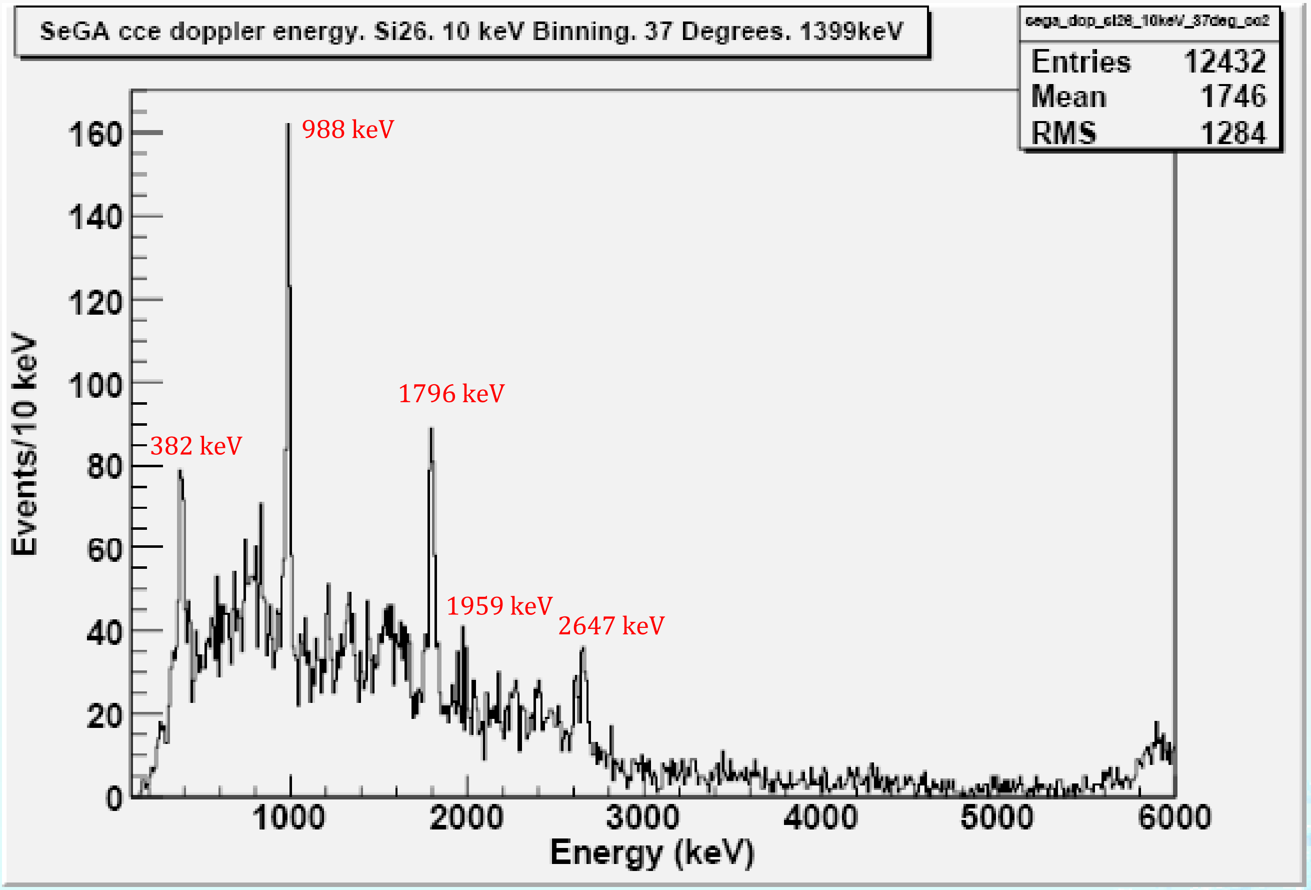
Corrected γ Spectrum



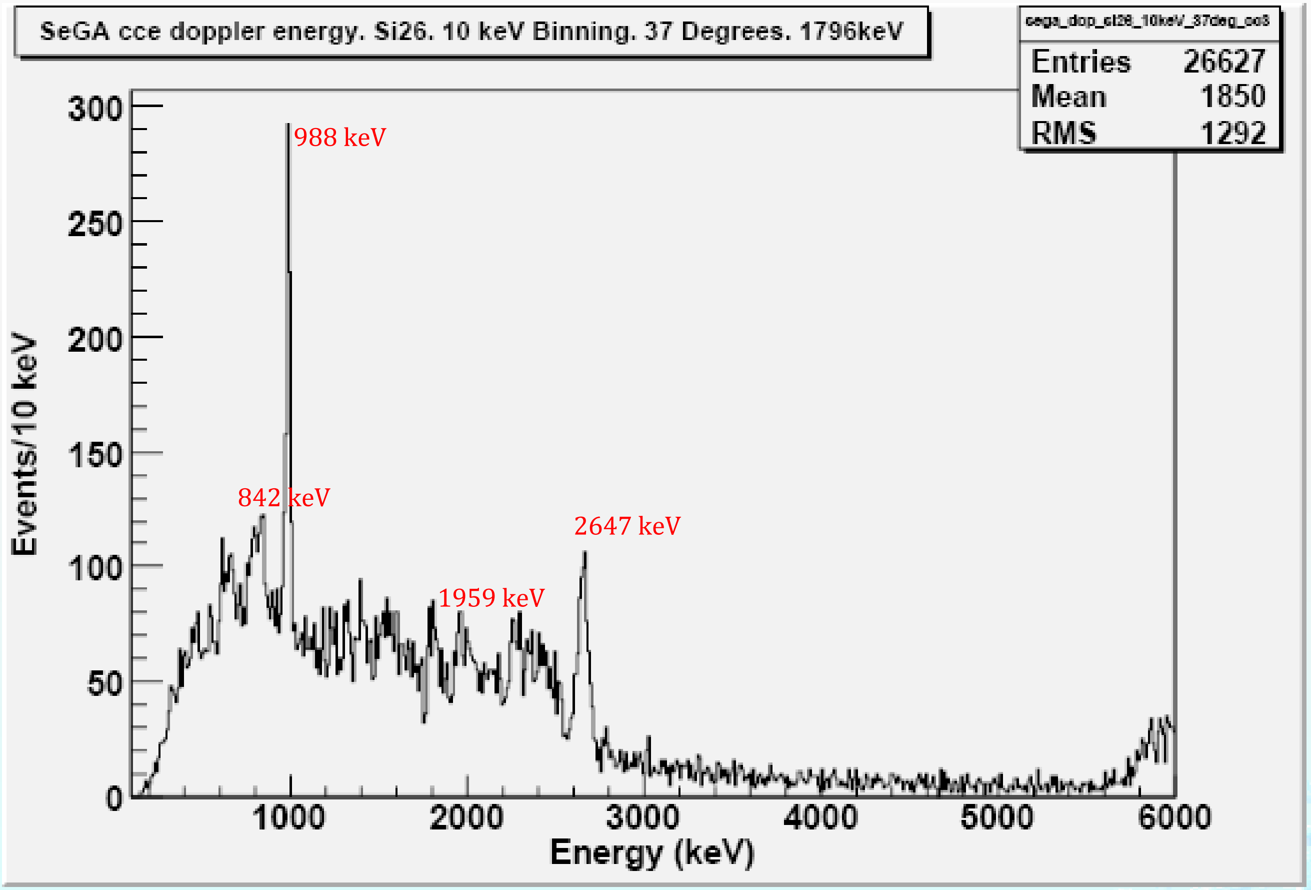
γ-γ coincidence spectrum 988keV



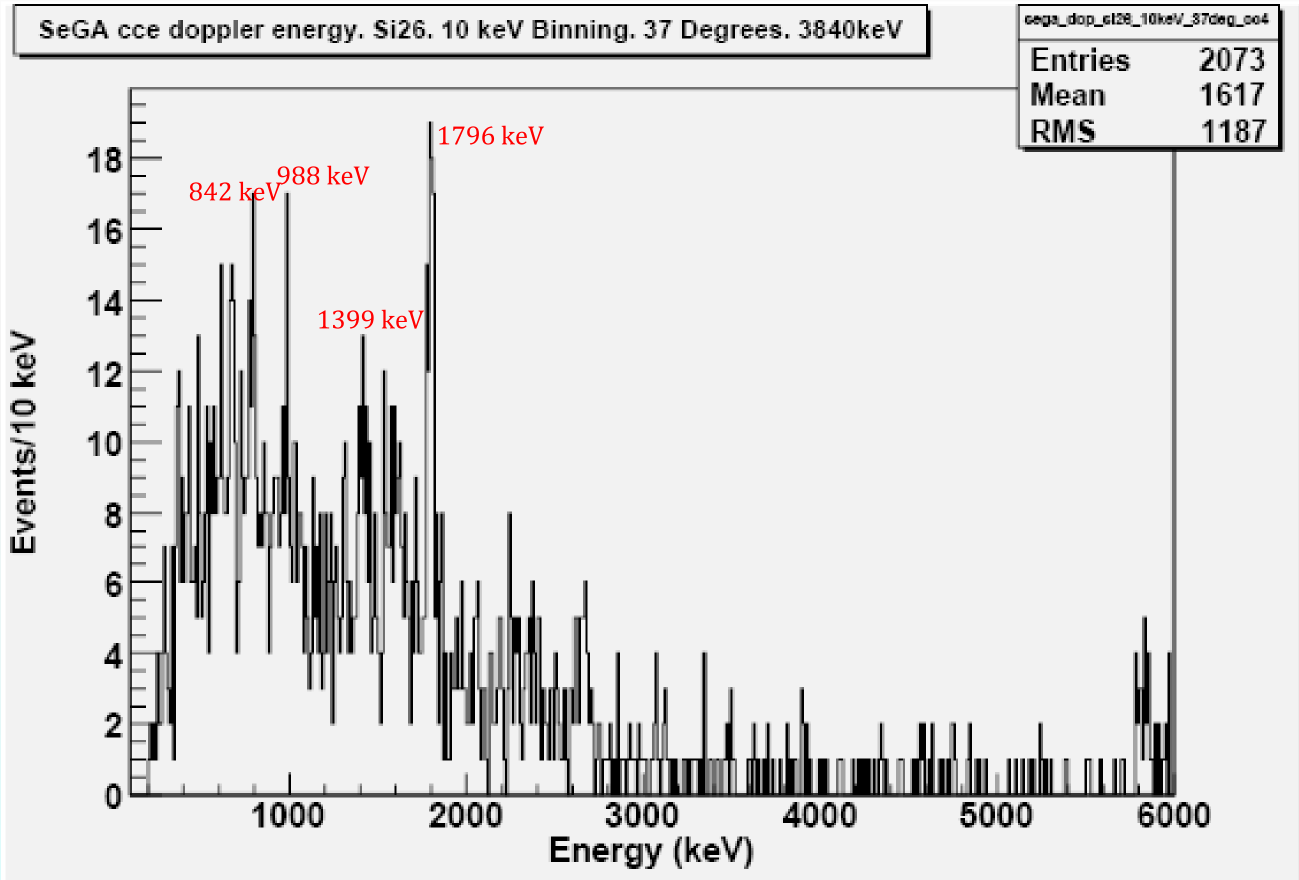
γ-γ coincidence spectrum 1399keV



γ-γ coincidence spectrum 1796keV



γ-γ coincidence spectrum 3840keV



Ongoing and Future work

- Extract physical parameters from analysis of the γ spectra
- Calculate the new $^{25}Al(p,\gamma)^{26}Si$ reaction rate
- Organize results and compare with previous work

Thank you!