

OSCAR calibration for an alpha beam and an oxidized ^{12}C target

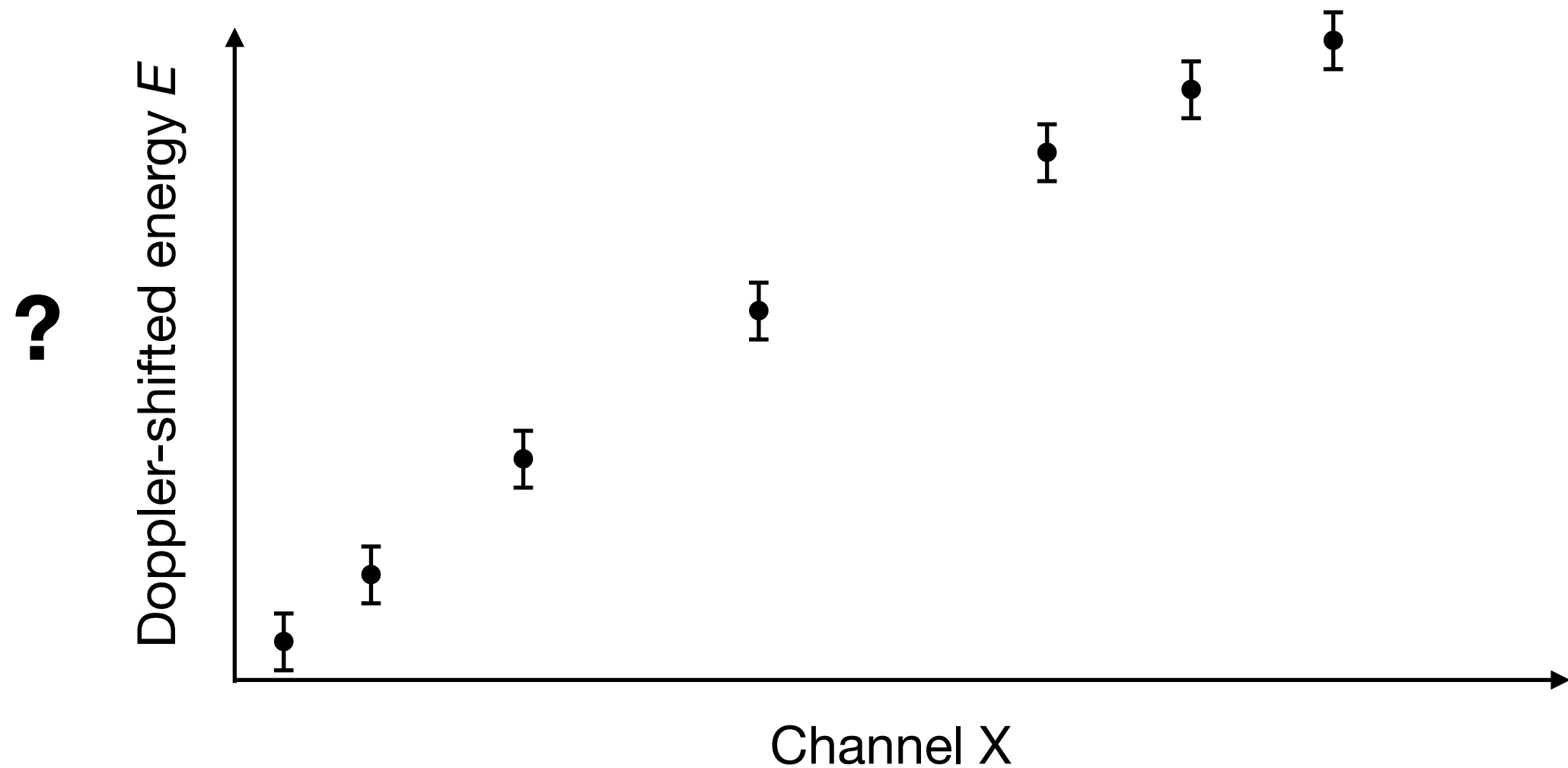
Introduction: In alpha beam experiments, a ^{12}C target contaminated with ^{16}O provides calibration lines from 110 keV to 7.3 MeV.

Problem: with an alpha beam of 24-26 MeV, and a light target (^{12}C or ^{16}O), the velocity of the recoil nucleus is in the order of 2-4%. For the high energy lines in ^{15}N (5-7 MeV), for example, the corresponding doppler shift is 150-200 keV.

Doppler-shifted energies:

$$E = E_0(1 + \beta \cos \theta)$$

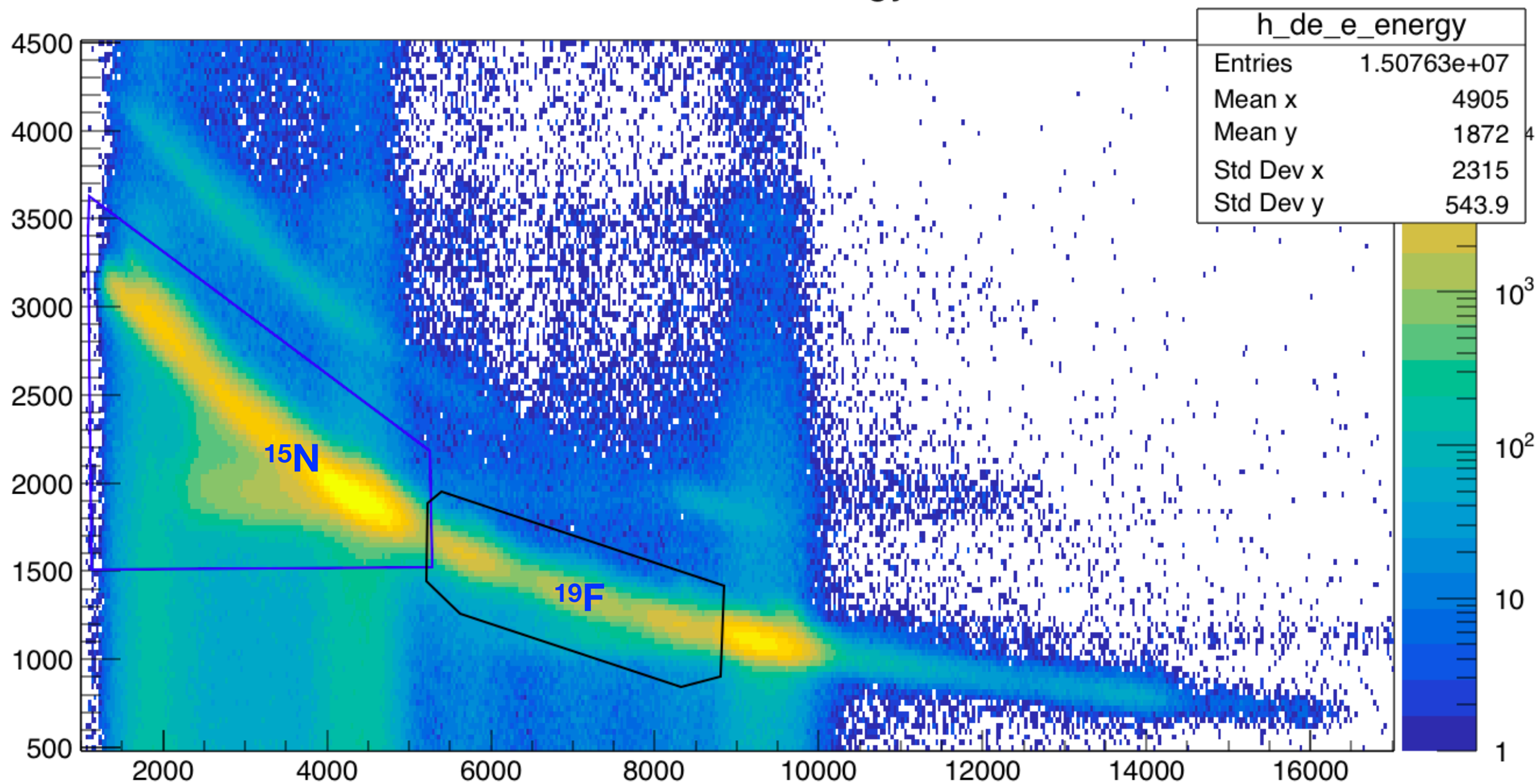
The doppler-shifted energies E must be found to perform the calibration.



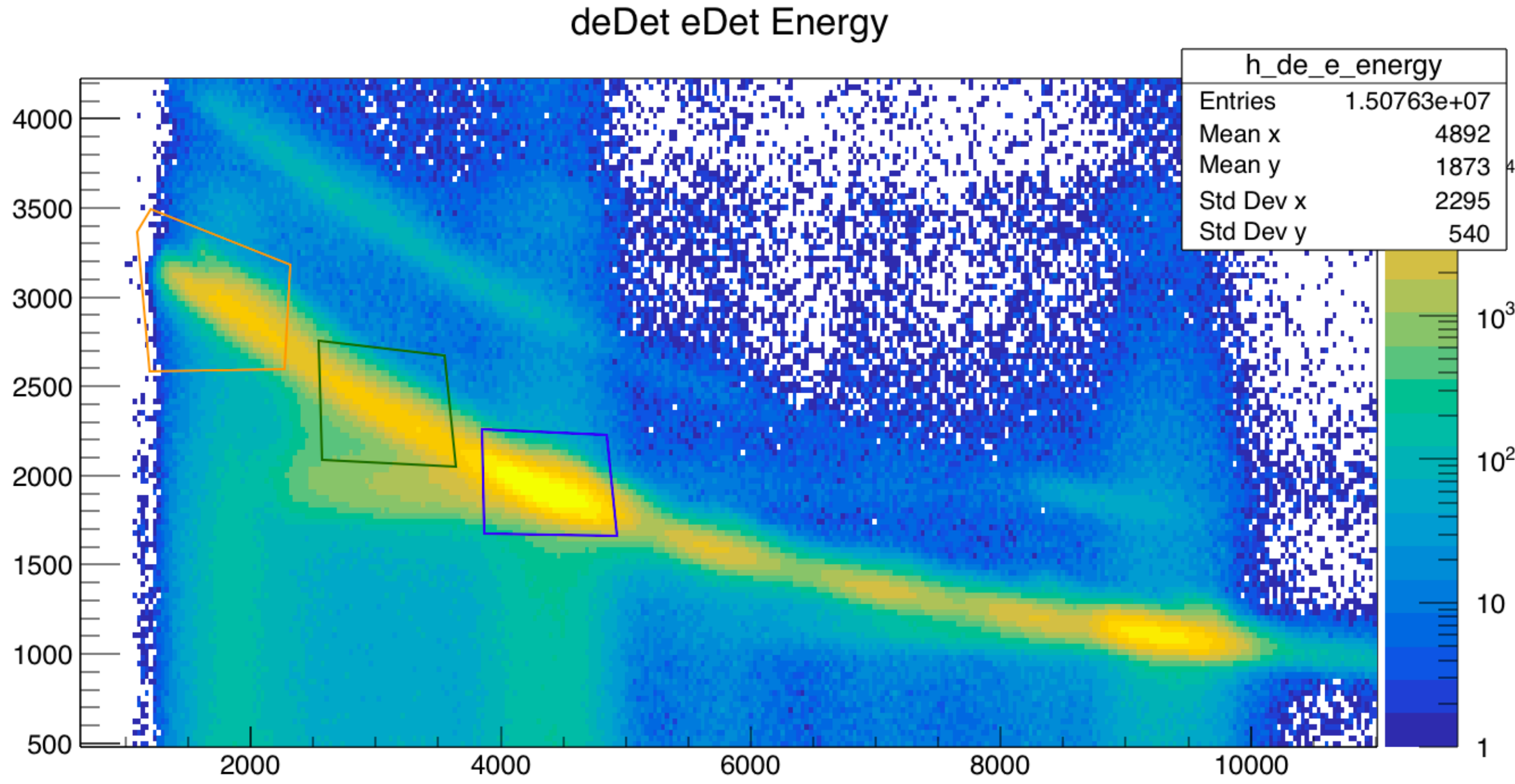
My recommendation of cuts and calibration lines:

Obs! This is for 26 MeV alphas in backwards. For other energies, other states can be populated (for example: for 30 MeV alphas, a 4.6 MeV $13/2^+$ state in ^{19}F seems to show up strongly in the ^{15}N cut shown below.)

deDet eDet Energy



Blue: (α ,p) gated (^{15}N 5.2 MeV (two states!))
Green: (α ,p) gated (^{15}N 6.3 MeV)
Orange: (α ,p) gated (^{15}N 7.3 MeV)



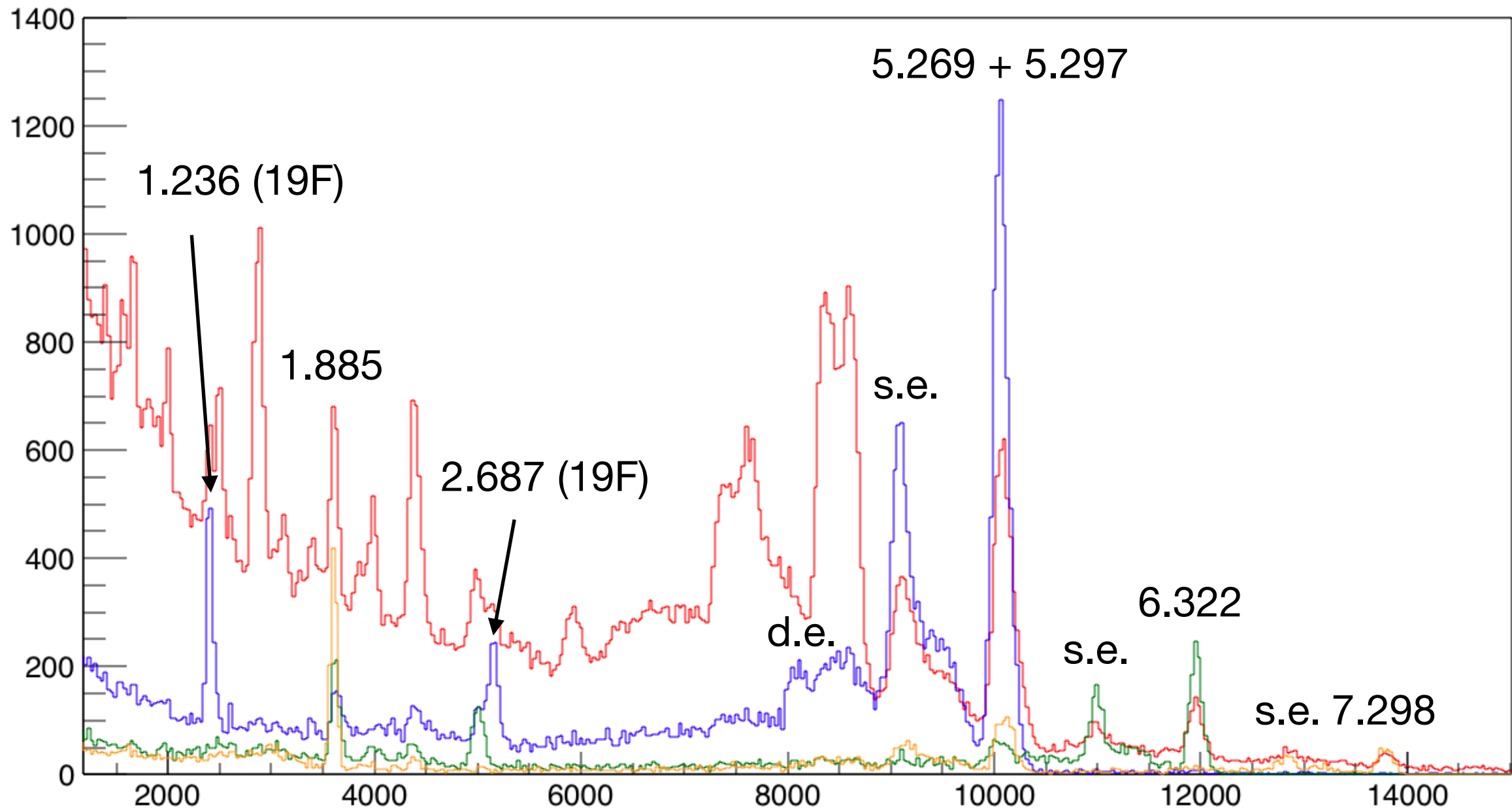
Red: Singles

Blue: (α ,p) gated (5.2 MeV)

Green: (α ,p) gated (6.3 MeV)

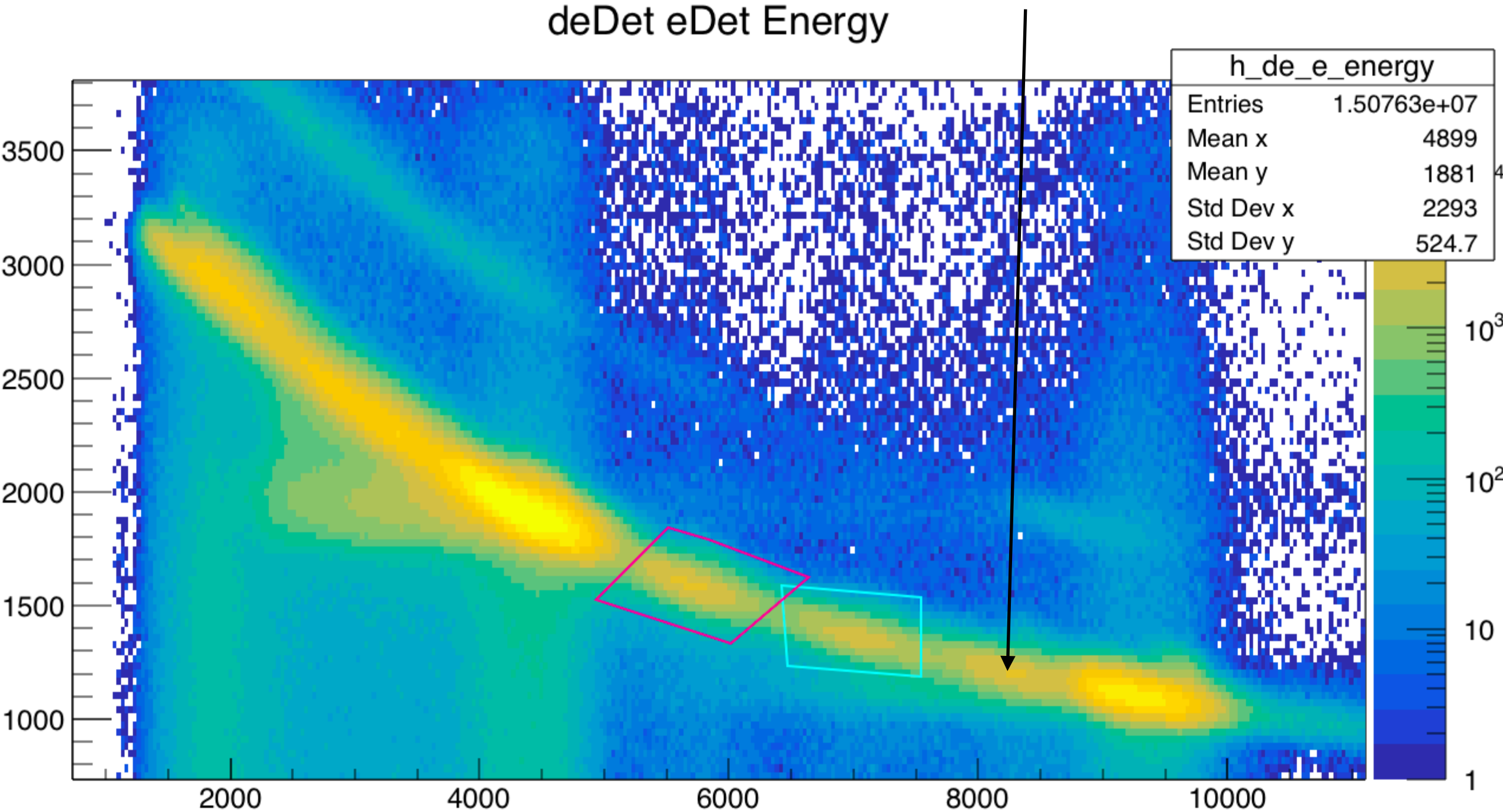
Orange: (α ,p) gated (7.3 MeV)

labr Energy



Pink: (α ,p) gated (^{19}F 2.7 MeV)
Cyan: (α ,p) gated (^{19}F 1.2 MeV)

^{19}F 110 keV + 197 keV + g.s.



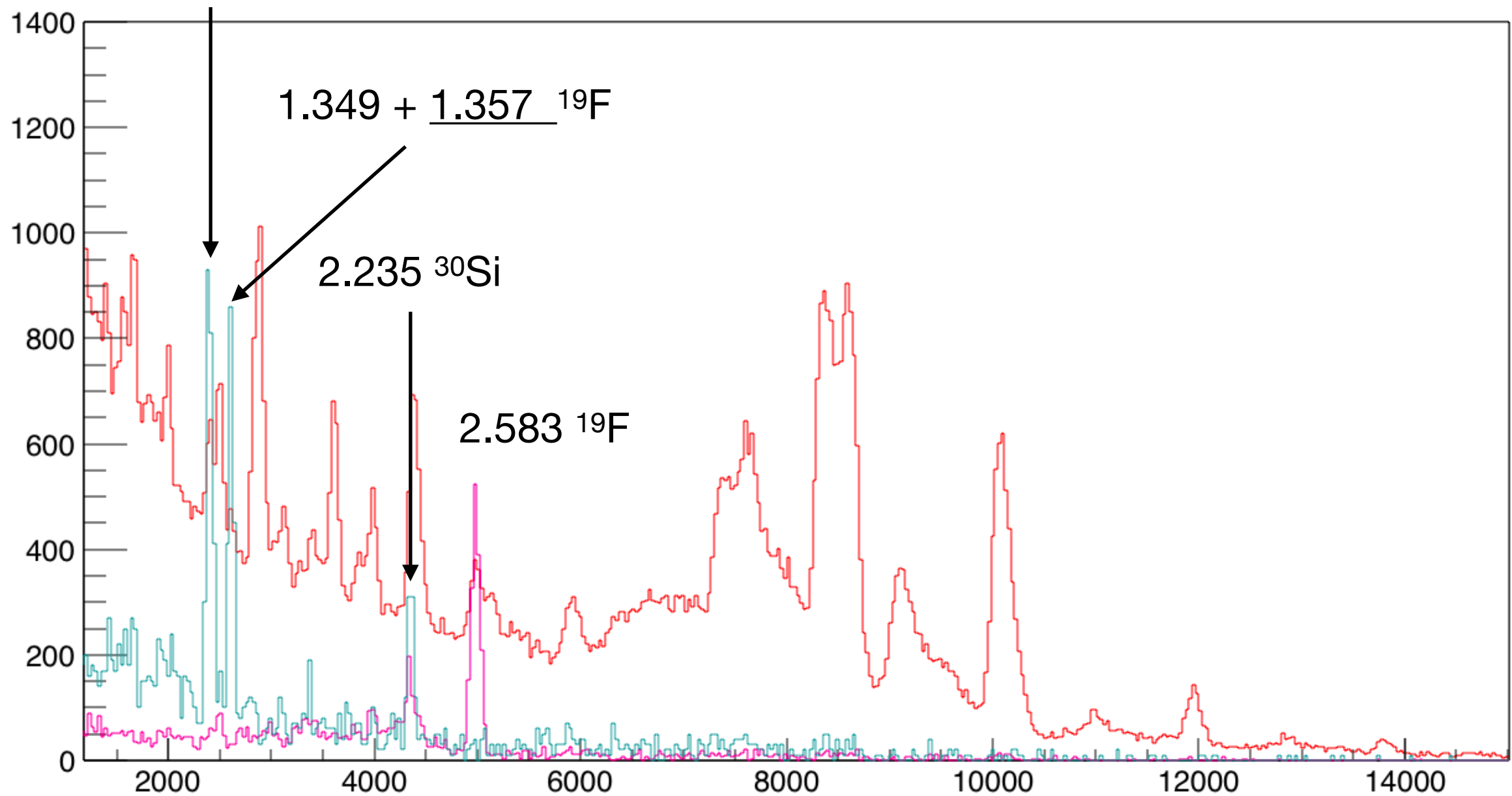
Red: Singles

Pink: (α ,p) gated (2.7 MeV)

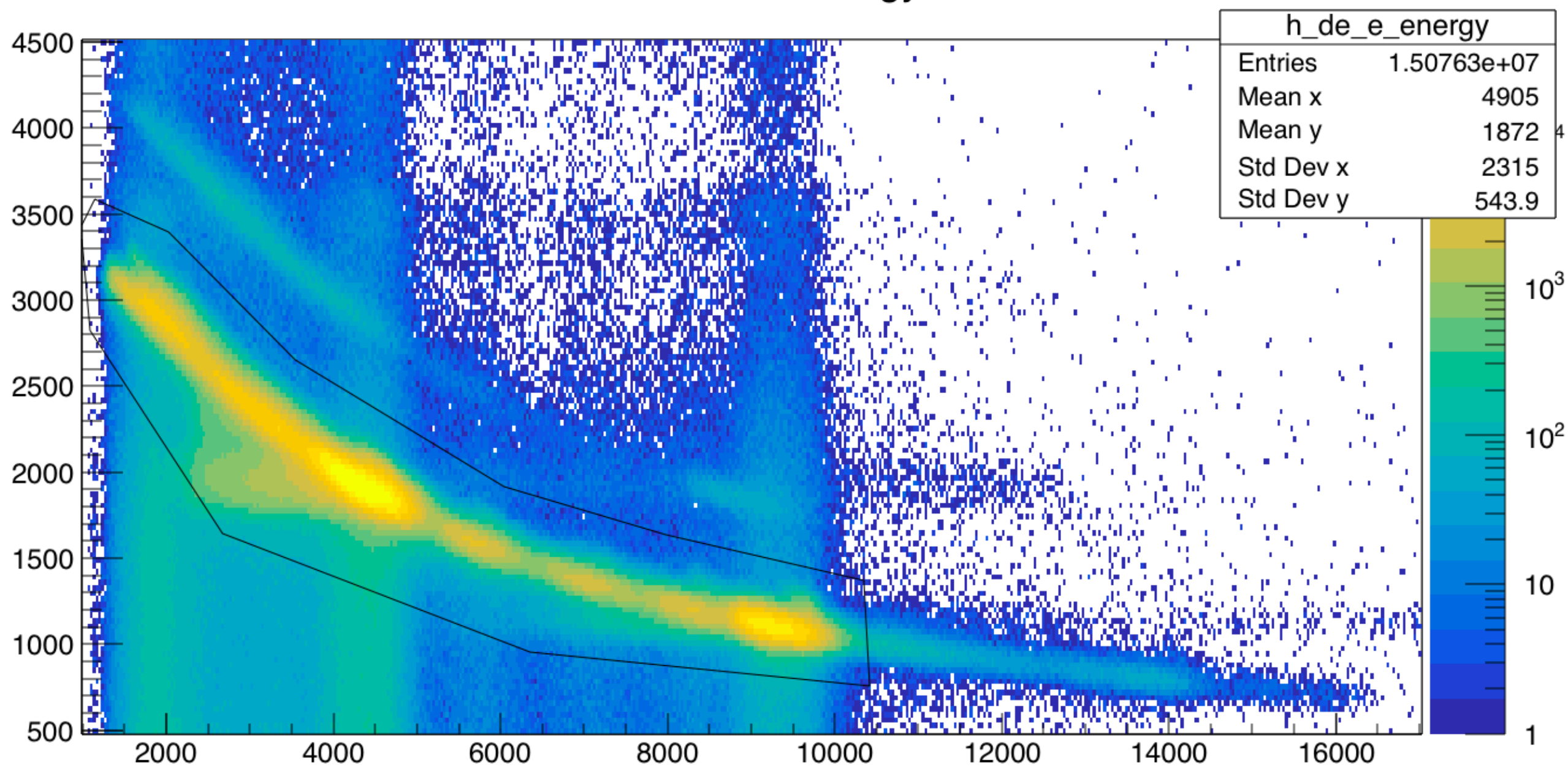
Cyan: (α ,p) gated (1.2 MeV)

1.236 ^{19}F + 1.263 ^{30}Si ?

labr Energy



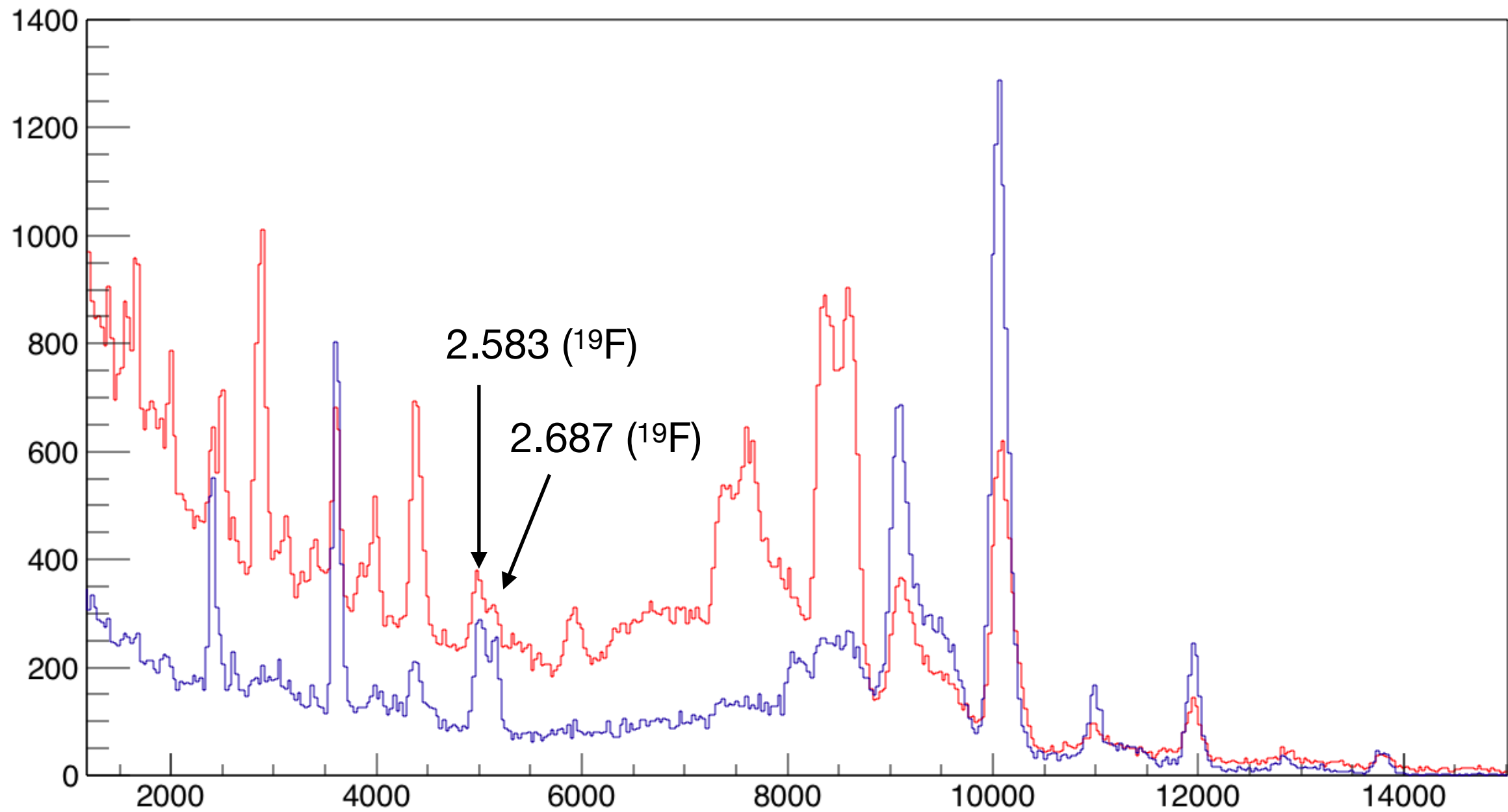
deDet eDet Energy



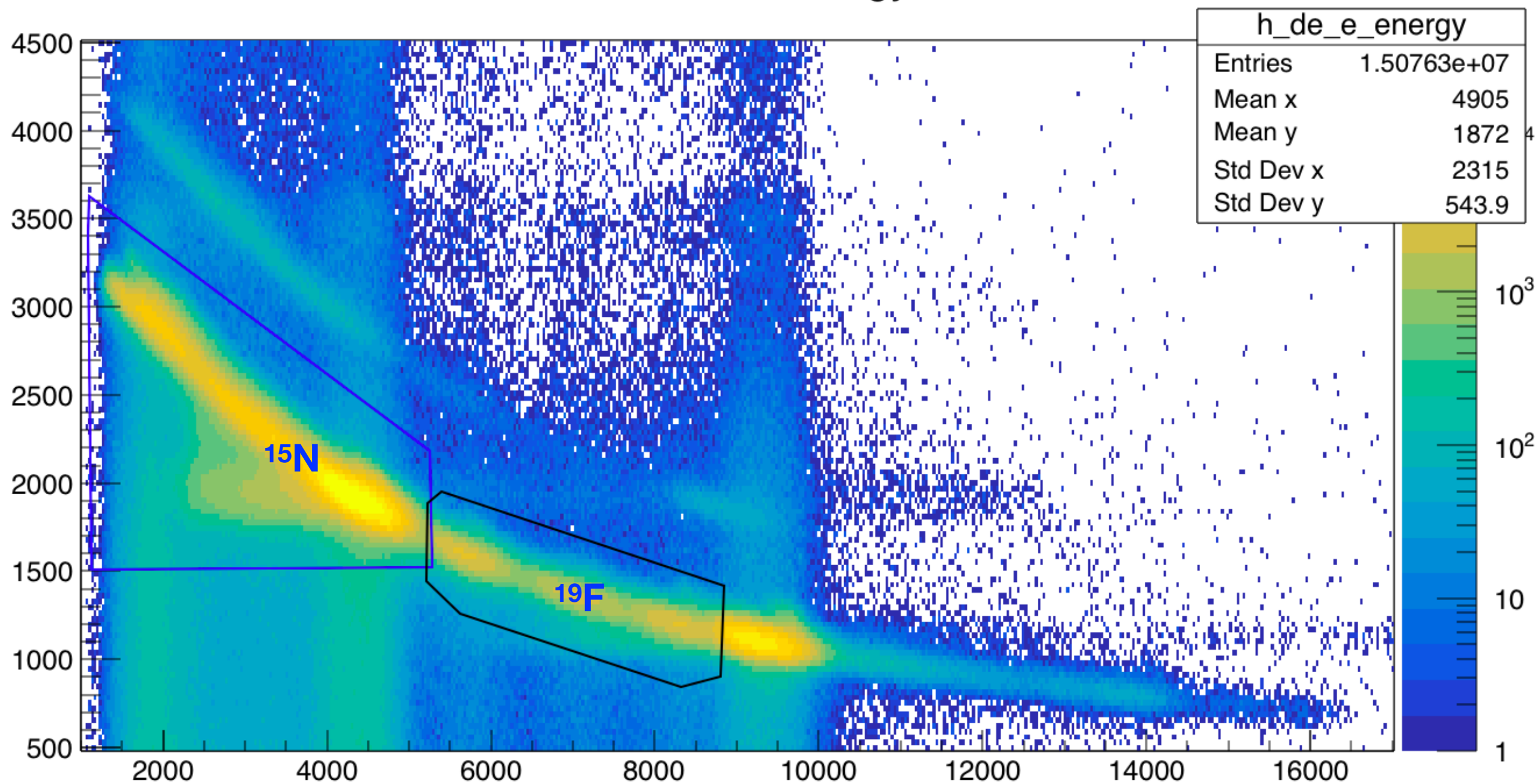
Red: Singles

Blue: (α ,p) gated (all)

labr Energy



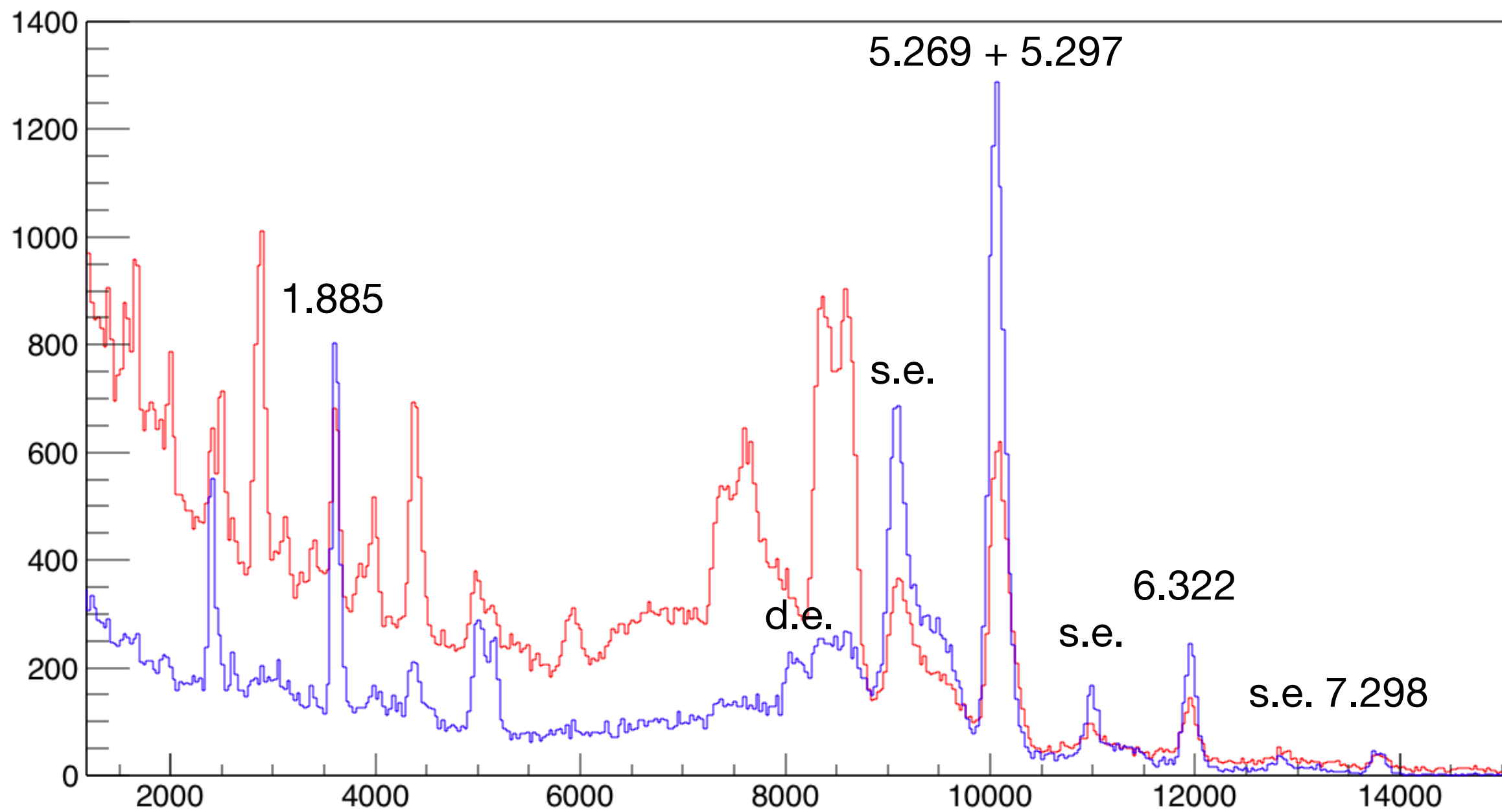
deDet eDet Energy



Red: Singles

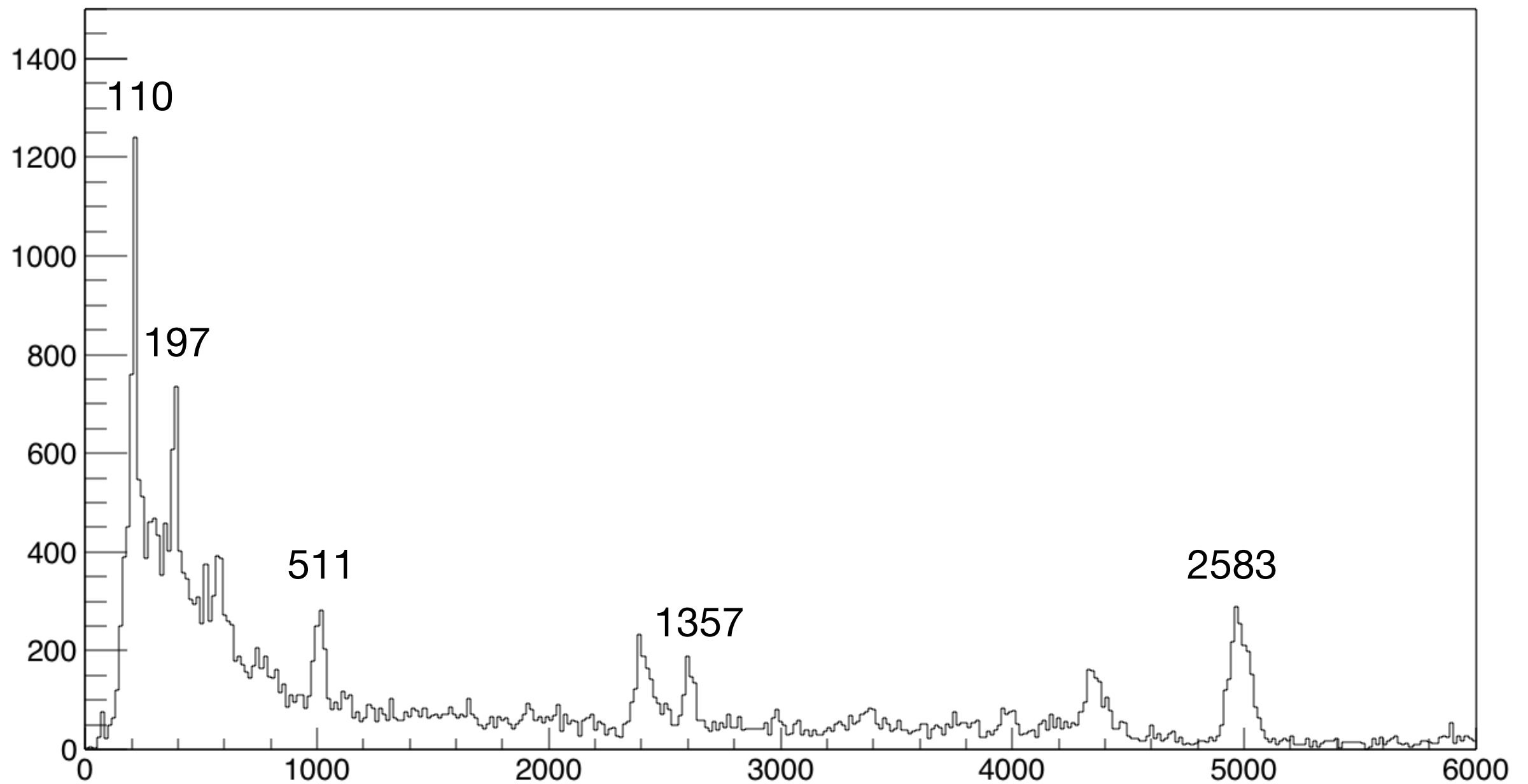
Blue: (α ,p) gated ^{15}N

labr Energy



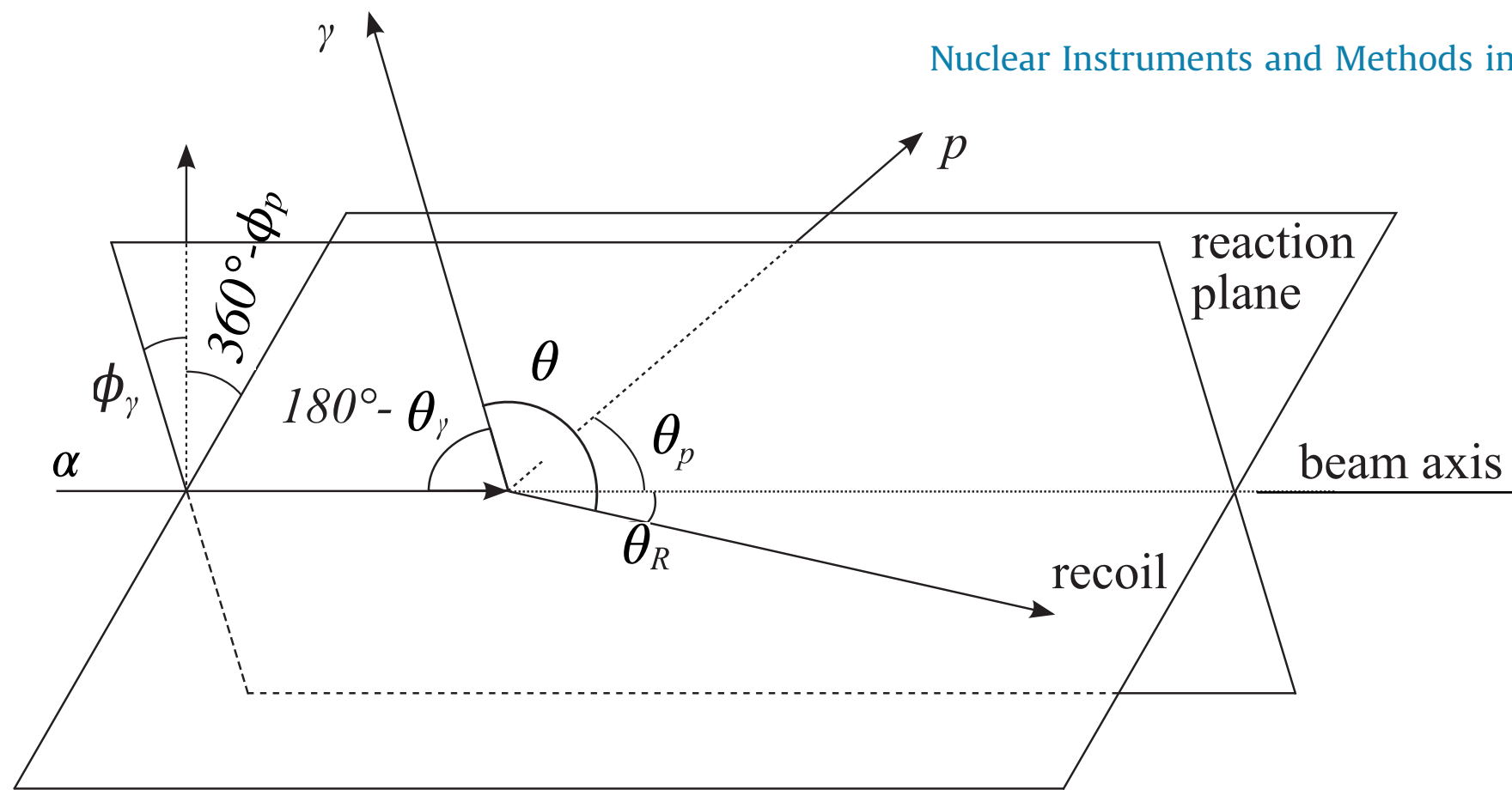
Black: (α ,p) gated ^{19}F

labr Energy



Kinematics:

Obs! I tried to obtain the doppler shifted energies directly from the spectrum without using the kinematic calculations to avoid possible systematics errors in the angles. That didn't work. The energy resolution is not good enough to get the doppler shifted energies from the peak positions.



Oscar angle

Siri angle

$$\cos \theta = \frac{1}{\sqrt{1+x^2}} \left[\cos \theta_\gamma - x \cdot \sin \theta_\gamma \cos (\phi_\gamma - \phi_p) \right]$$

$$x \equiv \tan \theta_R = \frac{\sin \theta_p}{\sqrt{\frac{E_\alpha}{E_p} - \cos \theta_p}}$$

Missing in the article!

Dependent on excitation energy and θ_p

Angle between the recoil direction and the emitted photon

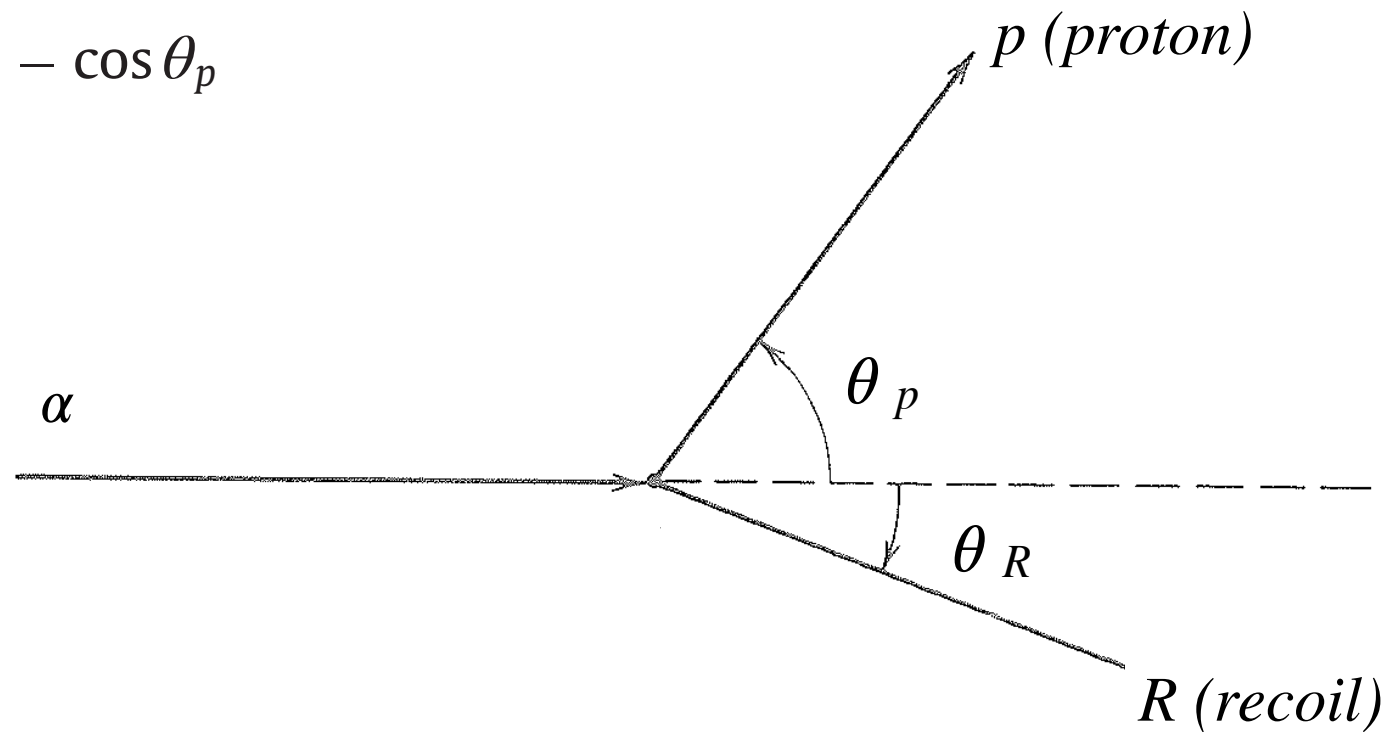
INTRODUCTORY NUCLEAR PHYSICS

$$P_{\alpha} = P_p \cos \theta_p + P_R \cos \theta_R$$

$$0 = P_p \sin \theta_p - P_R \sin \theta_R$$

$$x \equiv \tan \theta_R = \frac{\sin \theta_p}{\sqrt{\frac{E_{\alpha}}{E_p}} - \cos \theta_p}.$$

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Oregon State University



$$\sqrt{E_p} = \frac{(m_{\alpha} m_p E_{\alpha})^{1/2} \cos \theta_p + \{m_{\alpha} m_p E_{\alpha} \cos^2 \theta_p + (m_R + m_p)[m_R Q + (m_R - m_{\alpha}) E_{\alpha}]\}^{1/2}}{m_R + m_p}$$

$$\cos \theta = \frac{1}{\sqrt{1+x^2}} \left[\cos \theta_\gamma - x \cdot \sin \theta_\gamma \cos (\phi_\gamma - \phi_p) \right]$$

For gating on one SiRi ring:

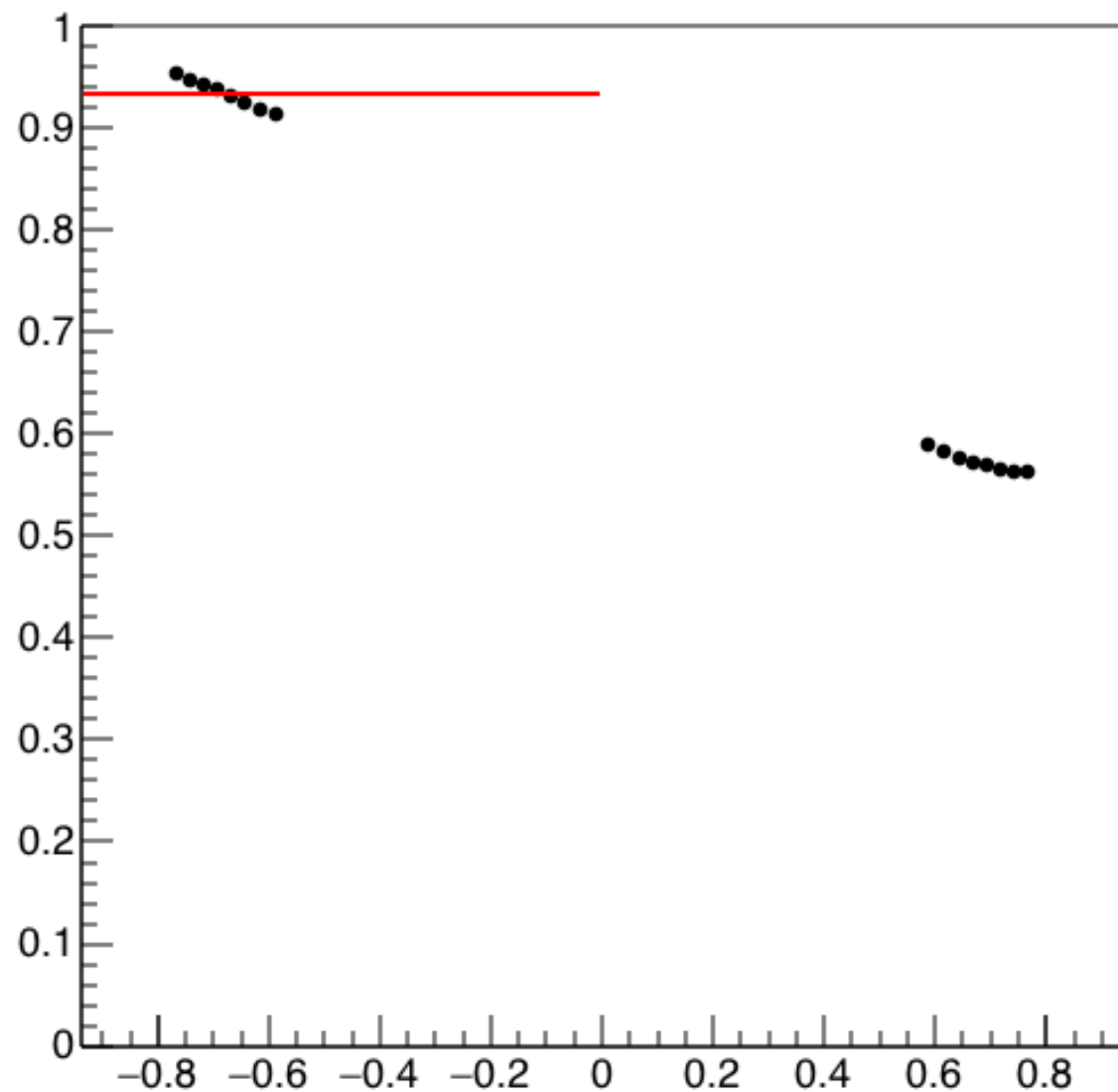
$$\overline{\cos \theta} = \frac{1}{2\pi} \int_0^{2\pi} \cos \theta \, d\phi_p = \frac{1}{\sqrt{1+x^2}} \cos \theta_\gamma$$

$$E = E_0(1 + \beta f \cos \theta_\gamma) \quad f = \frac{1}{\sqrt{1+x^2}} \quad x = \tan \theta_R = \frac{\sin \theta_p}{\sqrt{\frac{E_\alpha}{E_p} - \cos \theta_p}}$$

I did the kinematic calculations in kinematics.C

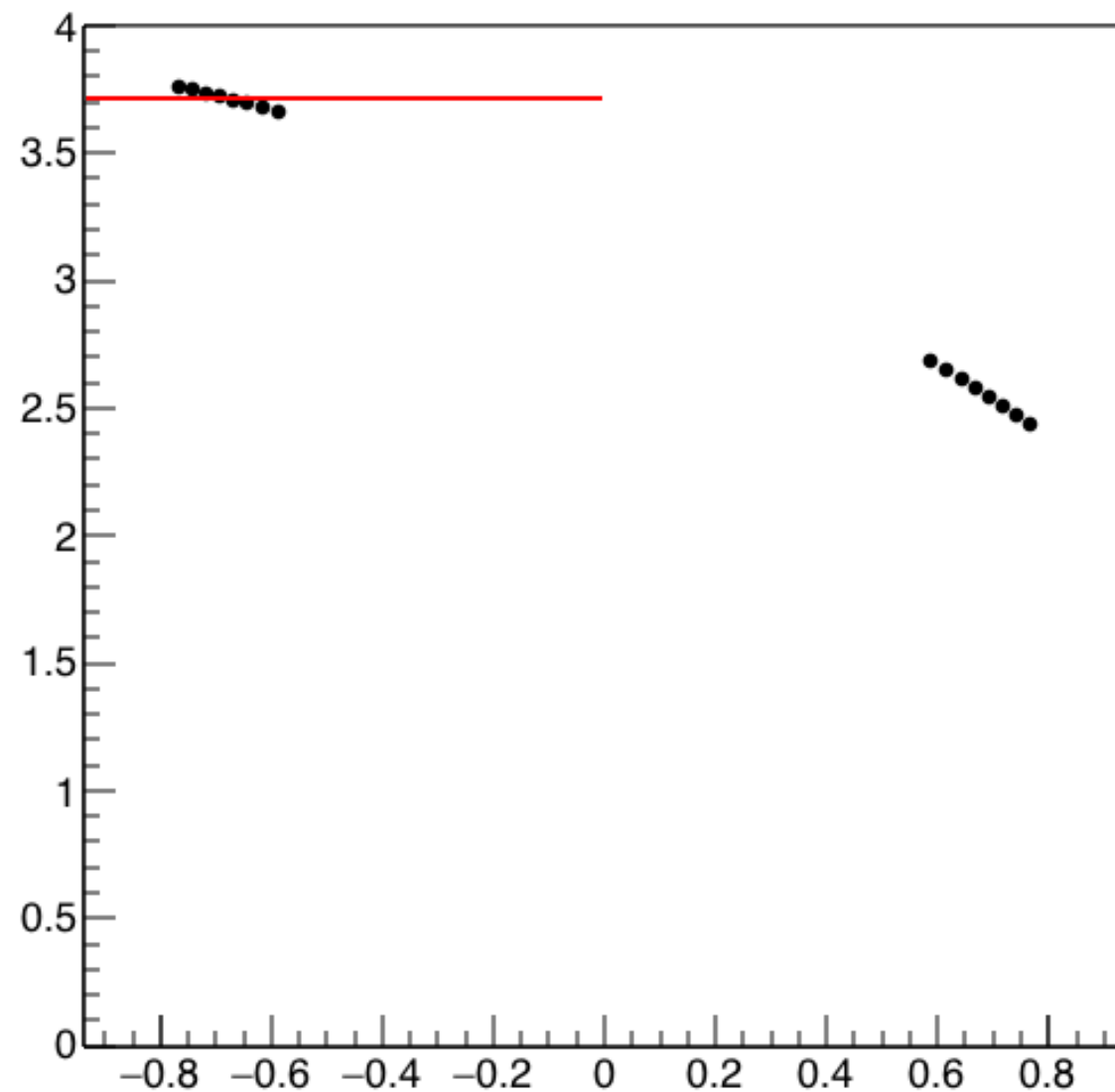
For 5.2 MeV:

Factor f



$f: 0.933 \pm 0.020$ (2.14%)

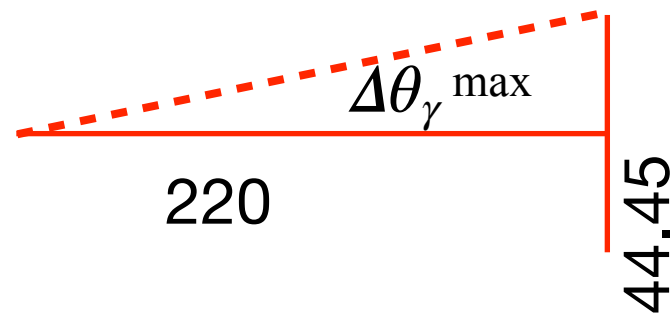
Velocity β [%]



beta: 3.713 ± 0.046 (1.25%)

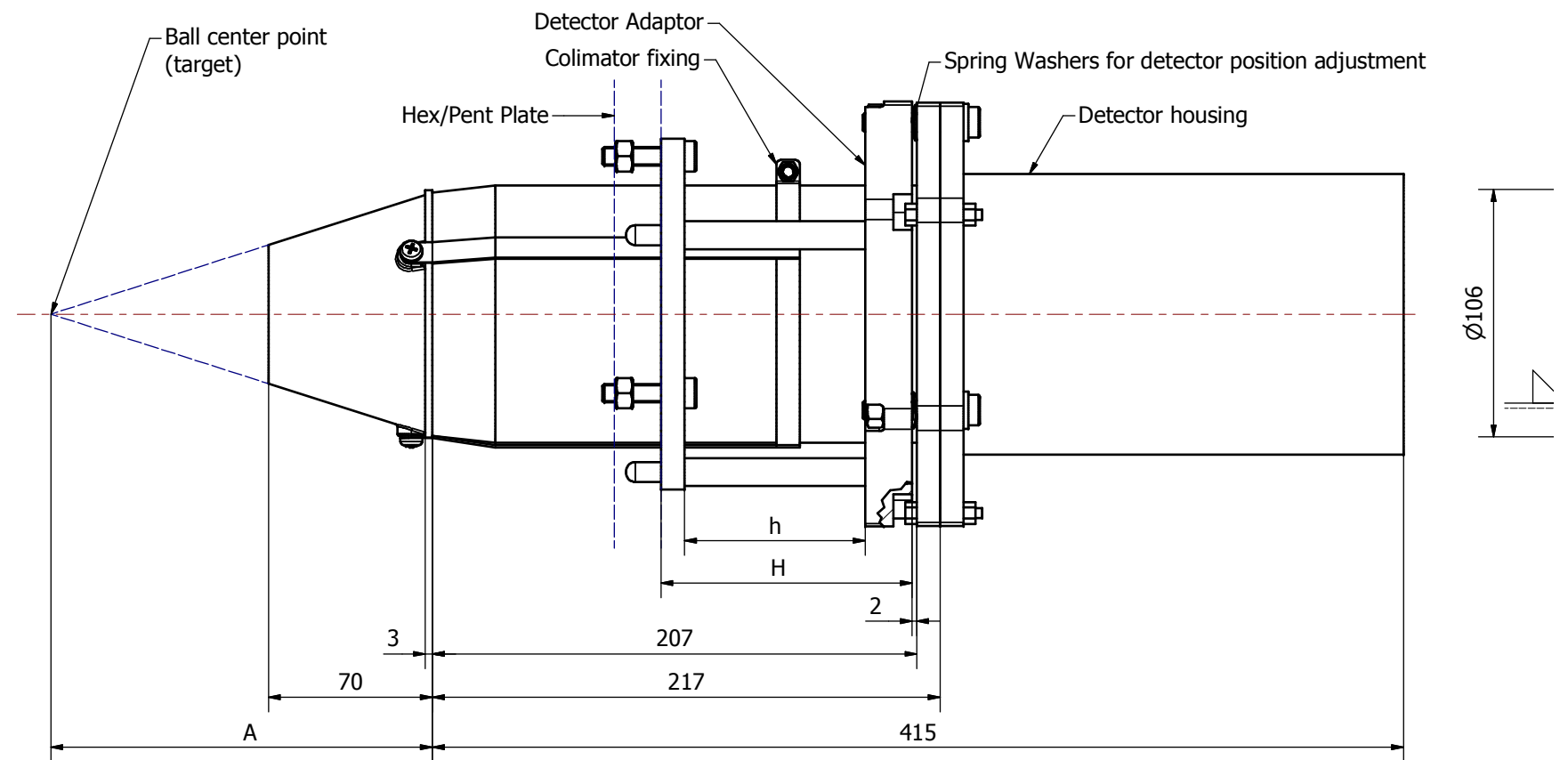
For the error I take the whole SiRi angular range.

For the error of OSCAR, I don't know what to take.
 The entire angular opening $\Delta\theta_{\gamma}^{\max}$ is 11.4°

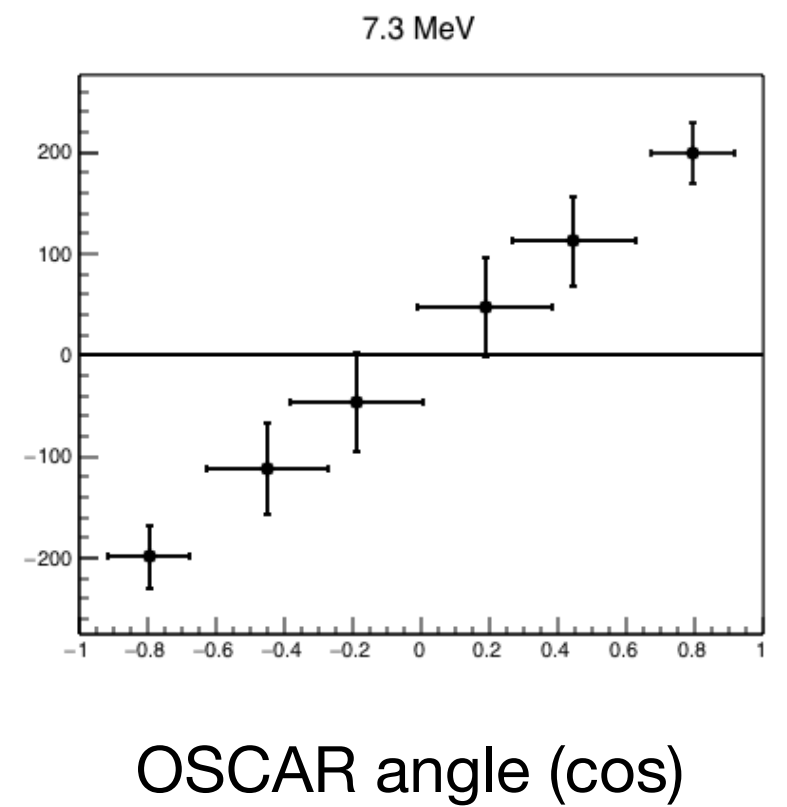
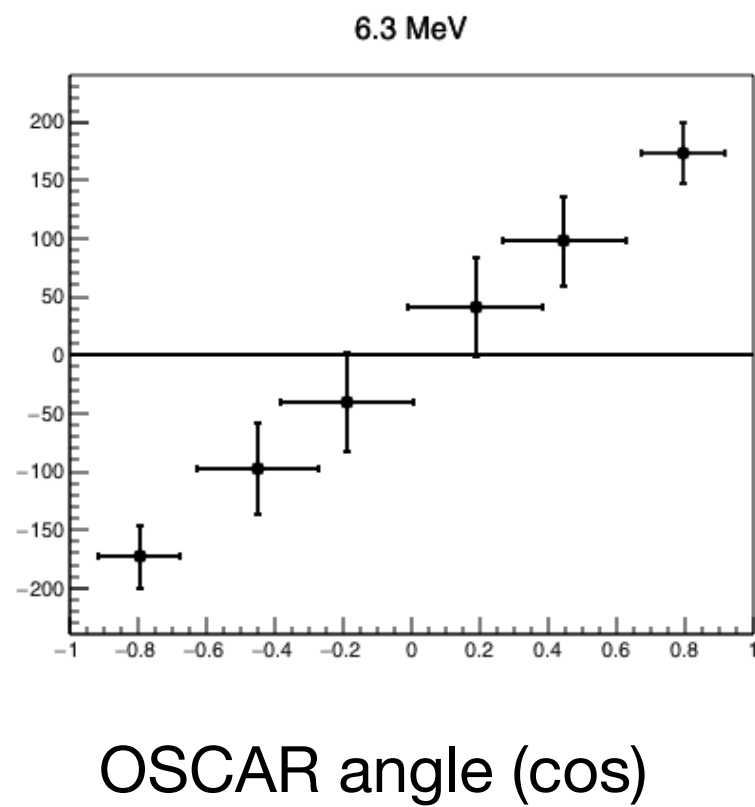
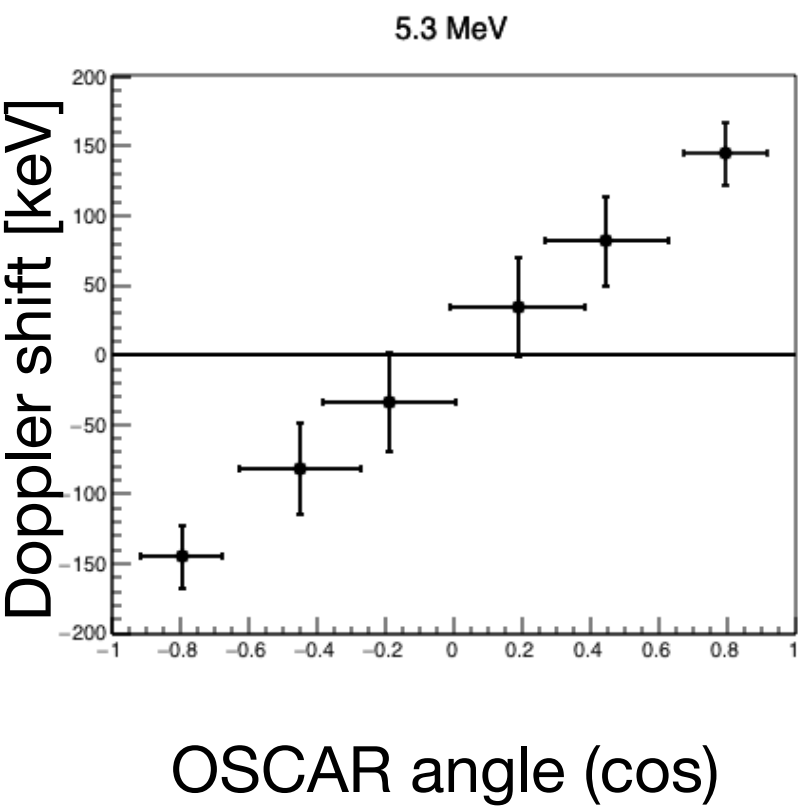


$$\tan \Delta\theta_{\gamma} = \frac{44.45}{220}$$

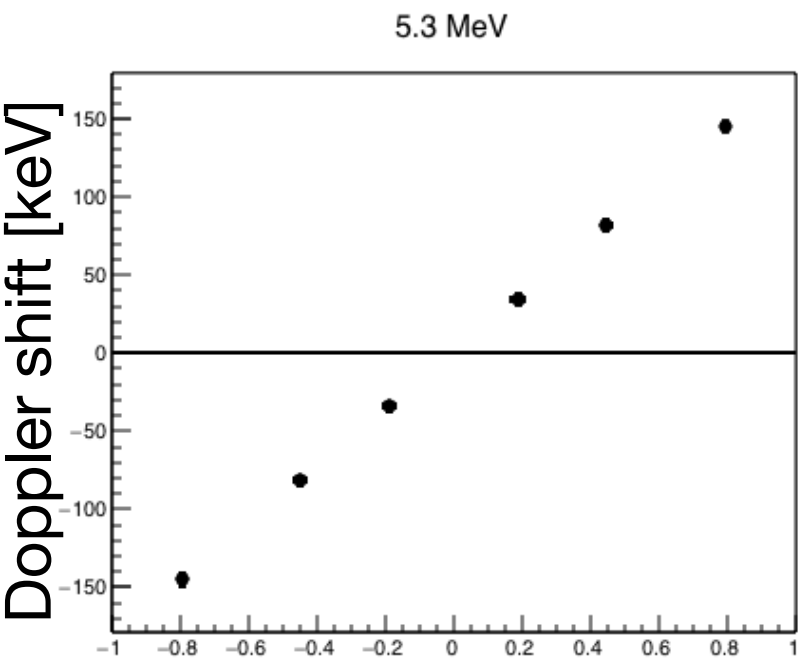
$$\Delta\theta_{\gamma} = 11.41$$



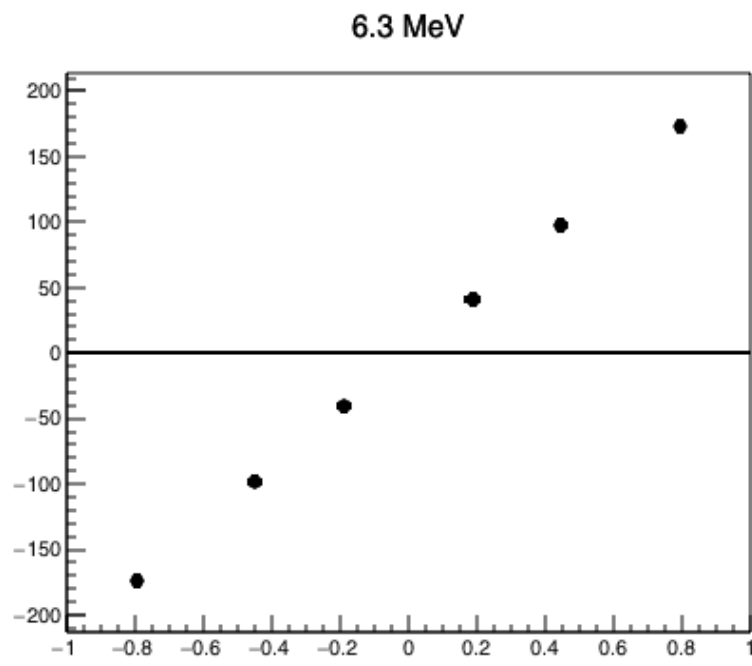
Doppler shift (^{15}N levels with $\Delta\theta_\gamma = 11.4^\circ$):



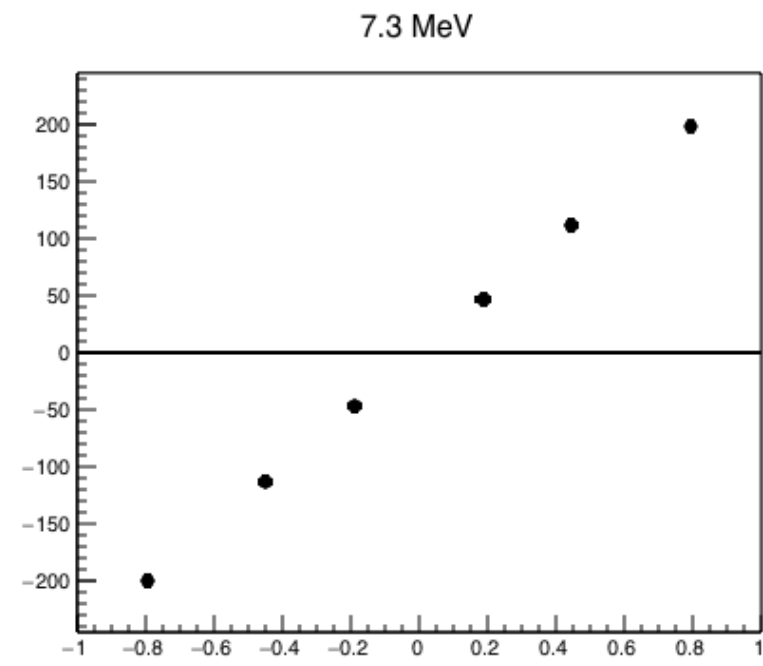
Doppler shift (^{15}N levels with $\Delta\theta_\gamma = 1^\circ$):



OSCAR angle (cos)

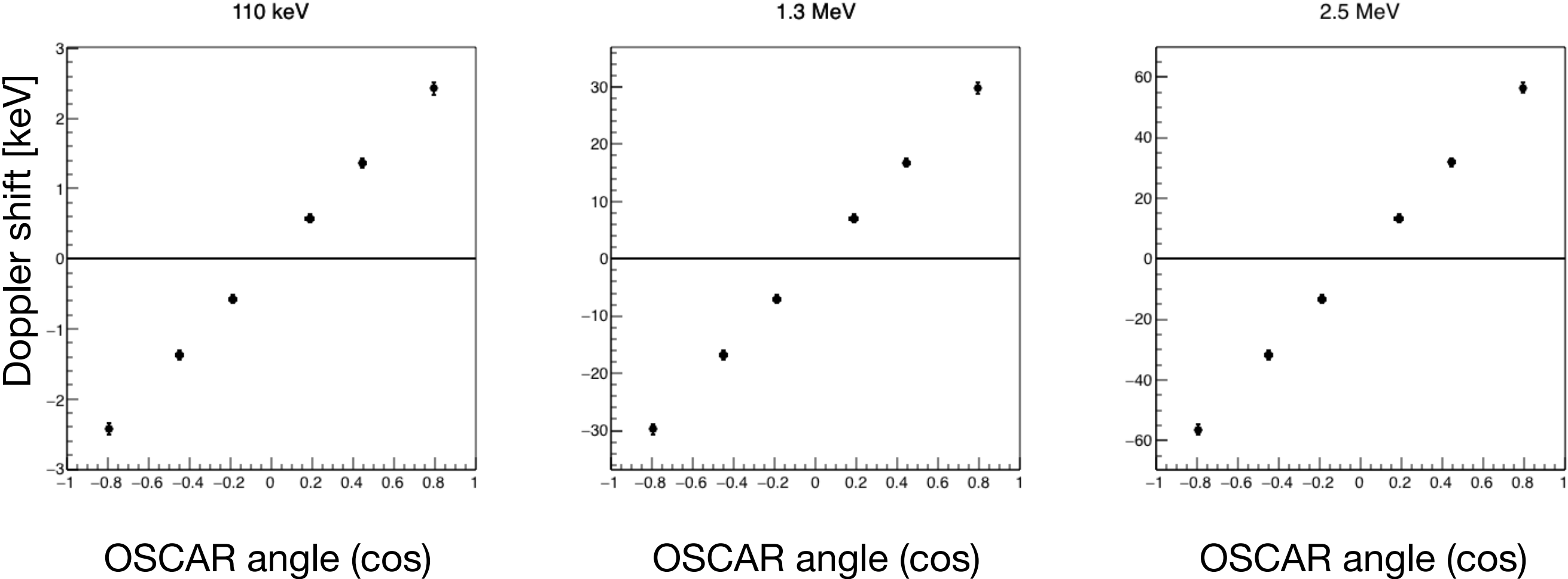


OSCAR angle (cos)

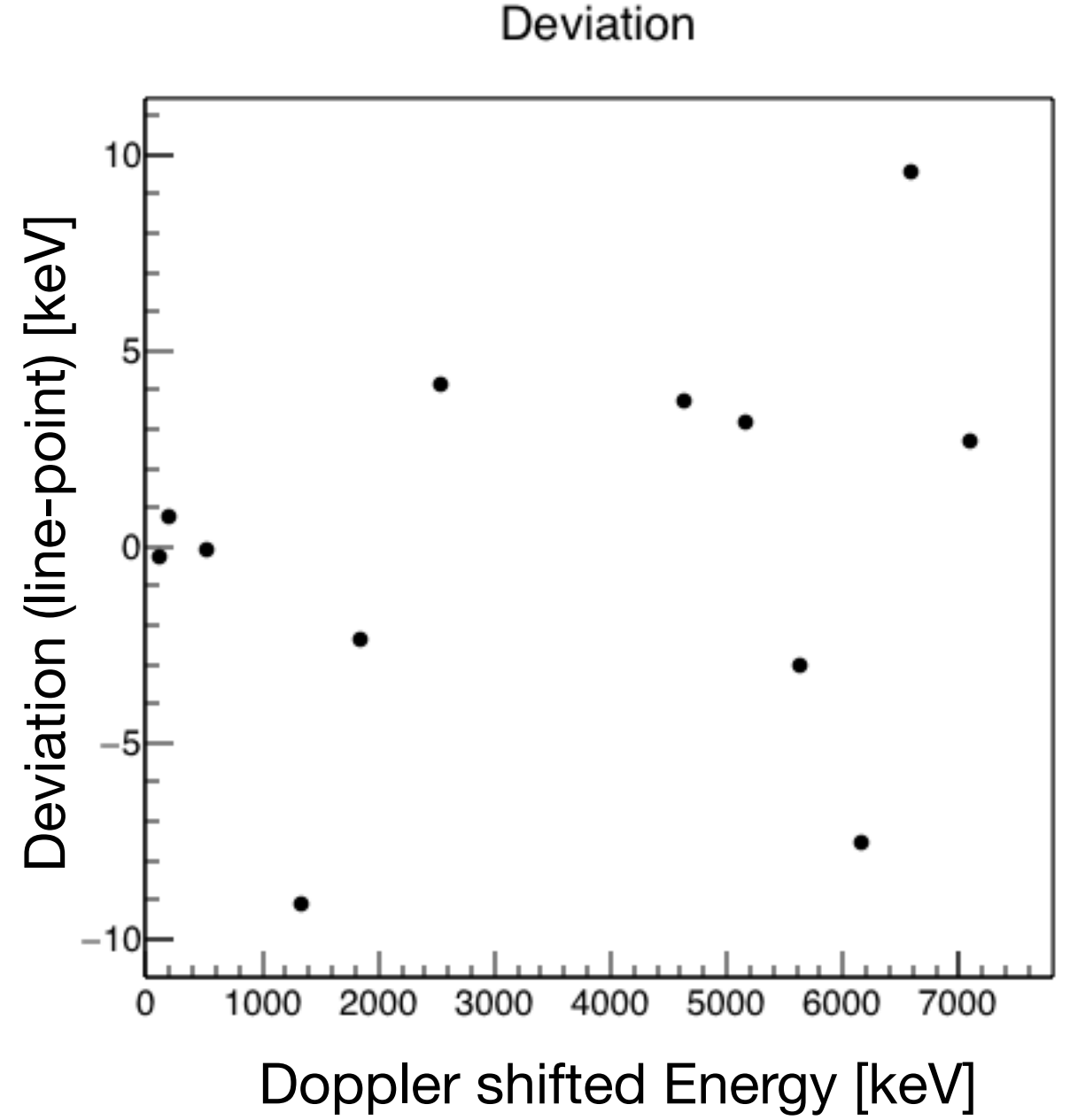
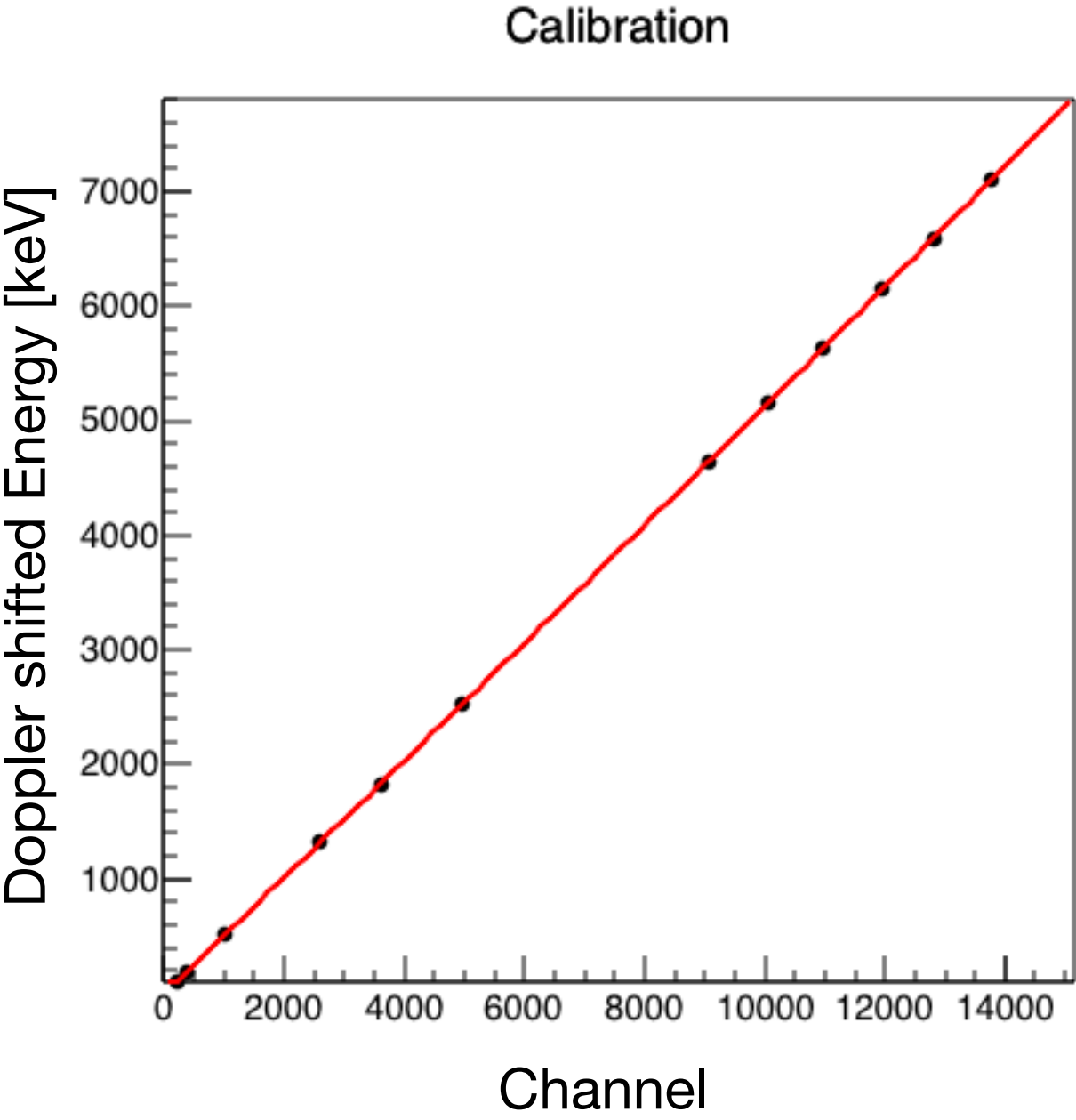


OSCAR angle (cos)

Doppler shift (^{19}F levels):



The calibration:

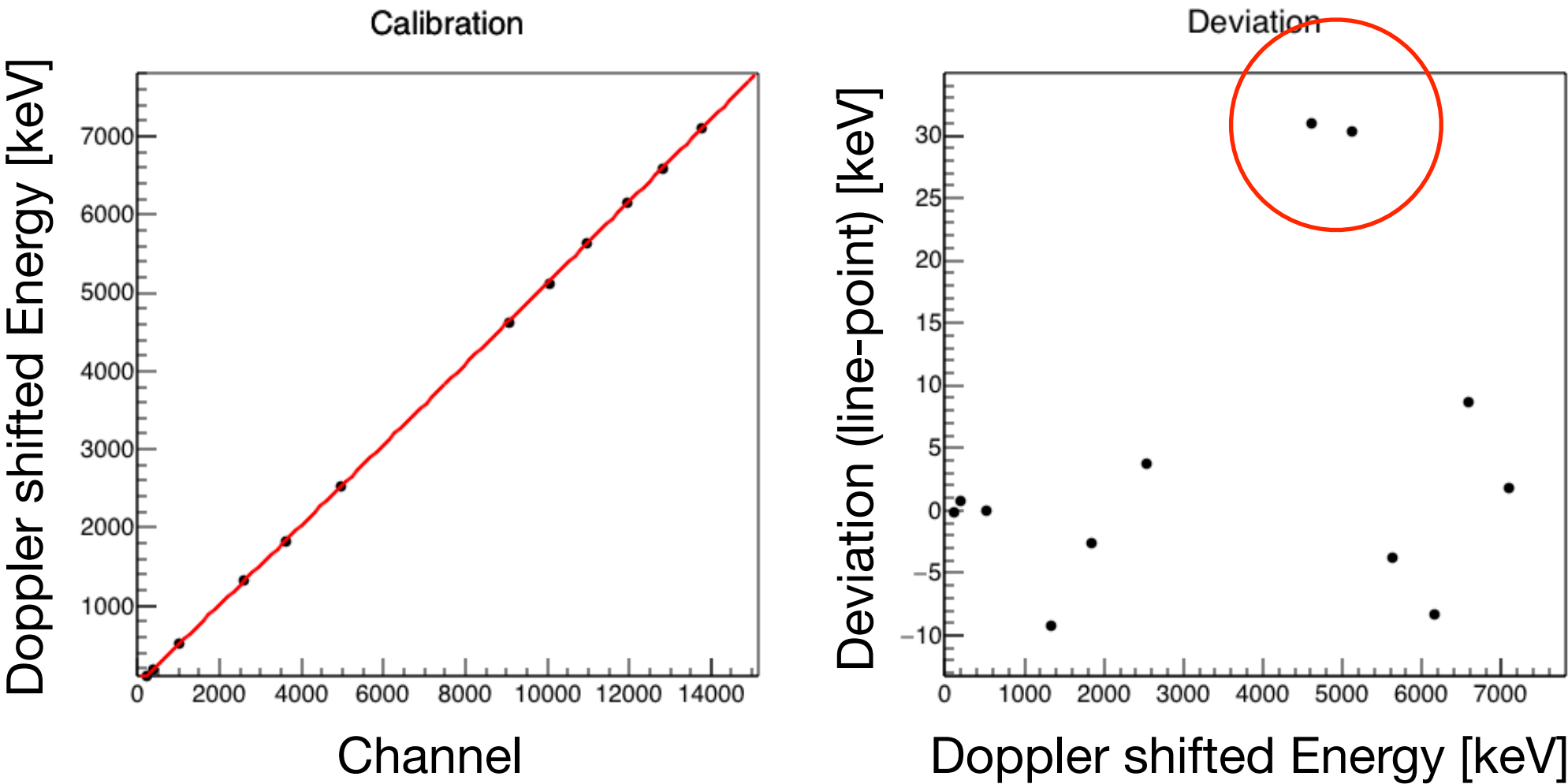


NAME	VALUE	ERROR
p0	8.02135e-01	6.87625e-01
p1	5.04581e-01	5.92953e-04
p2	7.93935e-07	5.09800e-08

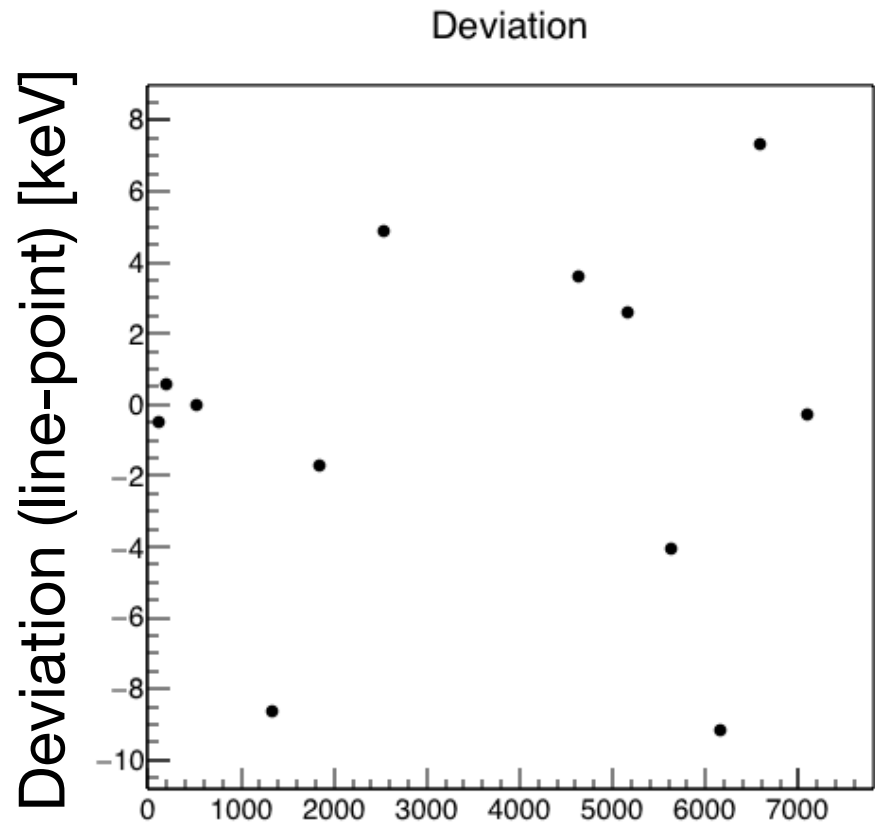
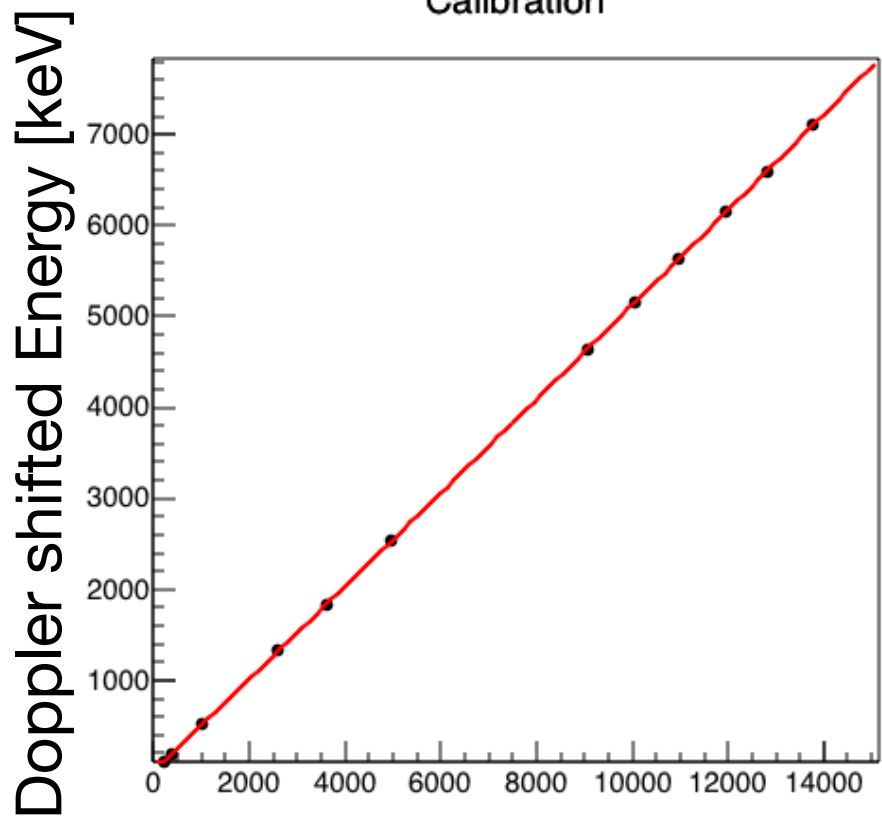
Notes: The 5.2 MeV state can be two states:

E (level) (keV)	XREF	J π (level)	T _{1/2} (level)	E (γ) (keV)
0.0	ABCDE JKLMN PQRS UVWX Zabcdefghijklmnopghijk	1/2-	STABLE	
5270.155 14	CD LM O QR U WX abcdef h jk	5/2+	1.79 ps 10	5269.161 14
5298.822 14	A CD GHI L N QRS U WX ab def h jk	1/2+	17 fs 5	5297.817 14

If I take 5270 keV that point lies below the calibration by 30 keV. If I take the 5299 KeV the point lies within 10 keV from the calibration line, as all the other points. This seems to indicate that the state is the 1/2+?

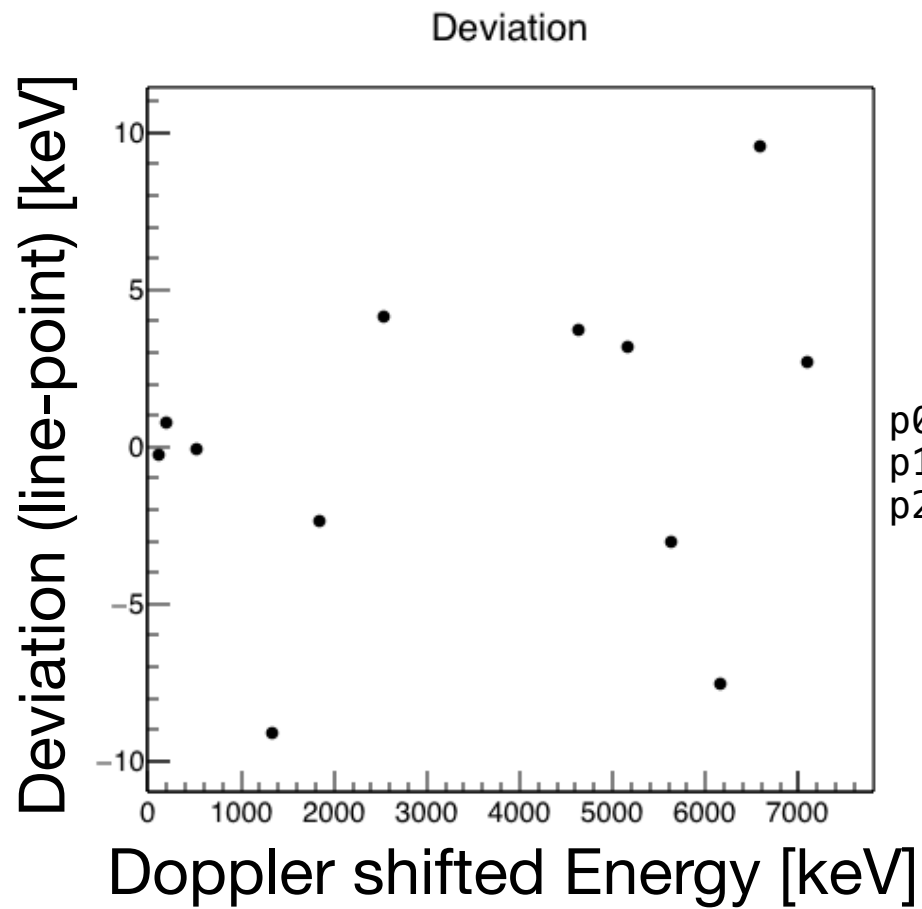
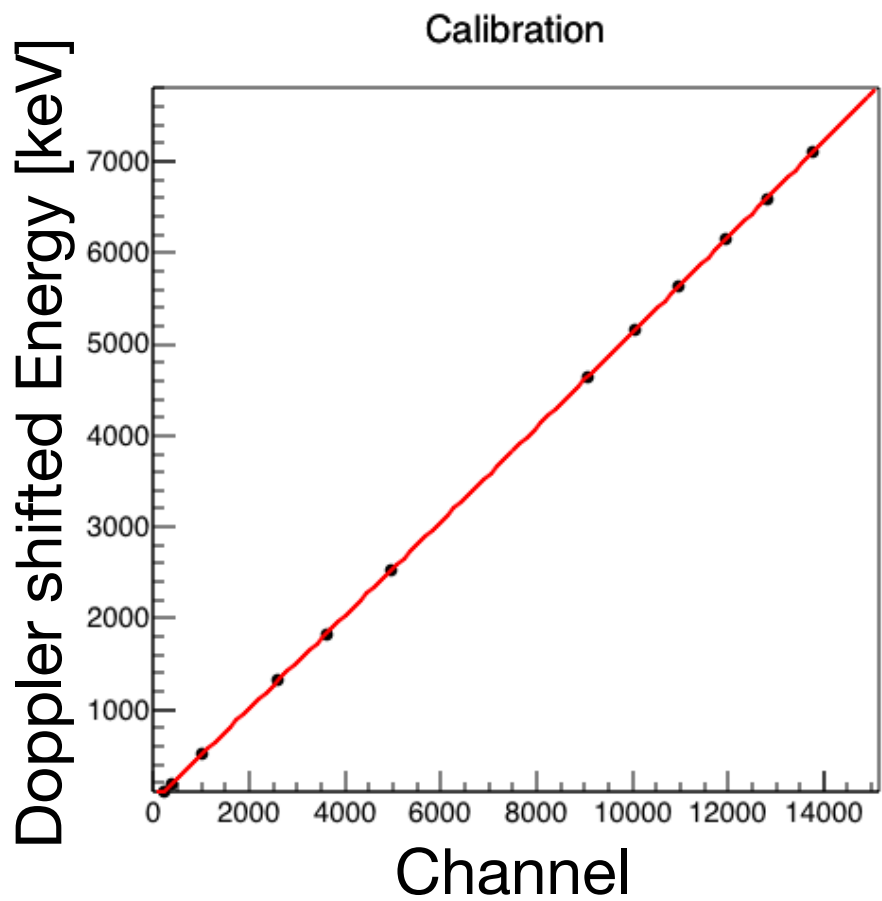


Notes: Using 1° or 11.4° for the angle error does not make a big difference in the calibration:



NAME	VALUE	ERROR
p0	4.75908e-01	1.10090e+00
p1	5.05015e-01	1.33309e-03
p2	7.48410e-07	1.45982e-07

11.4° error



NAME	VALUE	ERROR
p0	8.02135e-01	6.87625e-01
p1	5.04581e-01	5.92953e-04
p2	7.93935e-07	5.09800e-08

1° error

Notes: Without Doppler correction the calibration is less linear:

