

Fit with Compton tail of calibration peaks

~this is a revised analysis, especially for the low-energy tail~

(Please refer the reports on 20 and 22 May)

Tail-ratio estimation was changed

Previous : linear approximation



Present : average of TiKa and NiKa

no energy dependence !

FCN=810.144 FROM MINOS STATUS=SUCCESSFUL 5167 CALLS 5804 TOTAL
 EDM=5.38933e-08 STRATEGY= 1 ERROR MATRIX ACCURATE

EXT NO.	PARAMETER NAME	VALUE	PARABOLIC MINOS ERRORS		
			ERROR	NEGATIVE	POSITIVE
1	BGa	1.12592e+01	4.28197e+00	-6.45805e+00	6.51372e+00
2	BGb	1.59888e-03	1.33159e-03	-2.05328e-03	2.05187e-03
3	BGc	-1.32431e-07	9.91380e-08	-1.51945e-07	1.51465e-07
4	Noise [eV]	5.64882e+01	fixed		
5	Fano	1.45689e-01	fixed		
6	TiKa1 area	5.07534e+03	5.27554e+02	-5.19568e+02	5.38241e+02
7	NiKa1 area	3.20281e+03	4.64191e+02	-4.63187e+02	4.82746e+02
8	Ti Kb/Ka1 ratio	2.38255e-01	fixed		
9	Ni Kb/Ka1 ratio	2.77774e-01	fixed		
10	KHeXLa area	3.68648e+04	1.48270e+03	-1.49952e+03	1.53345e+03
11	LaLb ratio	4.23680e-01	3.07418e-02	-3.01072e-02	3.18352e-02
12	LaLg ratio	2.58802e-01	2.69770e-02	-2.74396e-02	2.91570e-02
13	LaLd ratio	5.92613e-02	2.05294e-02	-2.19598e-02	2.33688e-02
14	GammaLa [eV]	7.76913e+00	9.91402e+00	at limit	1.04997e+01
15	KHeXLa mean [eV]	6.46088e+03	4.06867e+00	-4.06664e+00	4.07434e+00
49	KHeXLa mean [eV]	8.72198e+03	7.10791e+00	-7.11296e+00	7.11602e+00
50	KHeXLg mean [eV]	9.75707e+03	1.19882e+01	-1.20330e+01	1.20031e+01
51	KHeXLd mean [eV]	1.02816e+04	5.98806e+01	-5.92067e+01	7.35991e+01
52	KHeXLa-d Gamma [eV]	7.27862e-10	1.12925e+01	at limit	9.91122e+00

WARNING - - ABOVE PARAMETER IS AT LIMIT.

---- Fit info ----
 # FitOption : RIEL0
 # Chisqr/NDF = 128.771/123 = 1.047

---- Tail ratio ----
 # TiKa1 0.052361 +- 0.00528872
 # NiKa1 0.039283 +- 0.00739603
 # KHeXLa 0.0479363 +- 0.004302
 # KHeXLa 0.0479363 +- 0.004302
 # KHeXLg 0.0479363 +- 0.004302
 # KHeXLd 0.0479363 +- 0.004302

Average of TiKa and NiKa
 No energy-dependent tail

---- Shift ----
 # KHeXLa : 6460.876 +- 4.070, Ref = 6464.000, shift = -3.124 +- 4.070
 # KHeXLa : 8721.980 +- 7.114, Ref = 8723.000, shift = -1.020 +- 7.114
 # KHeXLg : 9757.067 +- 12.018, Ref = 9768.000, shift = -10.933 +- 12.018
 # KHeXLd : 10281.605 +- 66.403, Ref = 10331.000, shift = -49.395 +- 66.403
 # Shift(weighted average) = -3.387 +- 3.385
 # Gamma KHeXLa = 7.769 +- 9.914
 # Gamma Lb-Ld = 0.000 +- 11.292

16	TiKa1 mean [eV]	4.51084e+03	fixed
17	NiKa1 mean [eV]	7.47815e+03	fixed
18	TiKb1 mean [eV]	4.93181e+03	fixed
19	NiKb1 mean [eV]	8.26466e+03	fixed
20	Pile area factor	1.07858e-01	fixed
21	Pile shift [eV]	2.00000e+02	fixed
22	Pile sigma factor	2.00000e+00	fixed
23	Tail TiKa area factor	5.23610e-02	fixed
24	Tail NiKa area factor	3.92830e-02	fixed
25	Tail slope Ka	3.00000e+00	fixed
26	Tail Kb/Ka area factor	1.00000e+00	fixed
27	Tail La area factor	4.79363e-02	fixed
28	Tail Lb area factor	4.79363e-02	fixed
29	Tail Lg area factor	4.79363e-02	fixed
30	Tail Ld area factor	4.79363e-02	fixed
31	Tail slope L	3.00000e+00	fixed
32	Comp La shift	5.04600e+01	fixed
33	Comp La sigma	8.79800e+01	fixed
34	Comp La area	1.38406e-01	fixed
35	Comp La slope	8.75800e-01	fixed
36	Comp Lb shift	8.18100e+01	fixed
37	Comp Lb sigma	1.08568e+02	fixed
38	Comp Lb area	1.74475e-01	fixed
39	Comp Lb slope	1.22324e+00	fixed
40	Comp Lg shift	9.88300e+01	fixed
41	Comp Lg sigma	1.21491e+02	fixed
42	Comp Lg area	1.86872e-01	fixed
43	Comp Lg slope	1.33329e+00	fixed
44	Comp Ld shift	1.08500e+02	fixed
45	Comp Ld sigma	1.27516e+02	fixed
46	Comp Ld area	1.91088e-01	fixed
47	Comp Ld slope	1.45616e+00	fixed
48	Voigt r	4.00000e+00	fixed

Cycle1 transition energy fit

Shift : -3.4 ± 3.4 eV

Gamma(La) : 7.8 +10.5 eV

c.f. common shift : -3.3 ± 3.4 eV

FCN=829.024 FROM MINOS STATUS=SUCCESSFUL 4862 CALLS 5491 TOTAL
 EDM=2.42334e-07 STRATEGY= 1 ERROR MATRIX ACCURATE

EXT NO.	PARAMETER NAME	VALUE	PARABOLIC ERROR	MINOS ERRORS	
				NEGATIVE	POSITIVE
1	BGa	4.67981e-01	3.86699e+00	-5.50487e+00	5.60669e+00
2	BGb	4.18351e-03	1.20360e-03	-1.76759e-03	1.74570e-03
3	BGc	-2.94412e-07	8.98157e-08	-1.29517e-07	1.30922e-07
4	Noise [eV]	5.44495e+01	fixed		
5	Fano	1.29799e-01	fixed		
6	TiKa1 area	5.16279e+03	5.05458e+02	-4.96793e+02	5.16024e+02
7	NiKa1 area	2.01546e+03	4.24361e+02	-4.20034e+02	4.40828e+02
8	Ti Kb/Ka1 ratio	2.42538e-01	fixed		
9	Ni Kb/Ka1 ratio	2.78295e-01	fixed		
10	KHeXLa area	4.23040e+04	1.44080e+03	-1.43528e+03	1.48654e+03
11	LaLb ratio	4.26822e-01	2.80828e-02	-2.74647e-02	2.88379e-02
12	LaLg ratio	2.33139e-01	2.26011e-02	-2.26612e-02	2.37768e-02
13	LaLd ratio	7.36312e-02	1.76720e-02	-1.85966e-02	1.94492e-02
14	GammaLa [eV]	7.53846e-08	1.49260e+01	at limit	6.45078e+00
WARNING - - ABOVE PARAMETER IS AT LIMIT.					
15	KHeXLa mean [eV]	6.46917e+03	3.35345e+00	-3.35226e+00	3.35516e+00
49	KHeXLb mean [eV]	8.72274e+03	6.26139e+00	-6.26061e+00	6.27013e+00
50	KHeXLg mean [eV]	9.76055e+03	1.00613e+01	-1.00955e+01	1.00681e+01
51	KHeXLd mean [eV]	1.03228e+04	3.01220e+01	-3.05084e+01	3.13458e+01
52	KHeXLb-d Gamma [eV]	1.13365e-06	1.19207e+01	at limit	9.07886e+00
WARNING - - ABOVE PARAMETER IS AT LIMIT.					

---- Fit info ----
 # FitOption : RIEL0
 # Chisqr/NDF = 165.378/123 = 1.345

---- Tail ratio ----
 # TiKa1 0.034624 +- 0.00415699
 # NiKa1 0.031852 +- 0.0052626
 # KHeXLa 0.0335589 +- 0.00326205
 # KHeXLb 0.0335589 +- 0.00326205
 # KHeXLg 0.0335589 +- 0.00326205
 # KHeXLd 0.0335589 +- 0.00326205

Average of TiKa and NiKa
 No energy-dependent tail

---- Shift ----
 # KHeXLa : 6469.170 +- 3.354, Ref = 6464.000, shift = 5.170 +- 3.354
 # KHeXLb : 8722.742 +- 6.265, Ref = 8723.000, shift = -0.258 +- 6.265
 # KHeXLg : 9760.555 +- 10.082, Ref = 9768.000, shift = -7.445 +- 10.082
 # KHeXLd : 10322.773 +- 30.927, Ref = 10331.000, shift = -8.227 +- 30.927
 # Shift(weighted average) = 2.963 +- 2.825
 # Gamma KHeXLa = 0.000 +- 14.926
 # Gamma Lb-Ld = 0.000 +- 11.921

16	TiKa1 mean [eV]	4.51084e+03	fixed
17	NiKa1 mean [eV]	7.47815e+03	fixed
18	TiKb1 mean [eV]	4.93181e+03	fixed
19	NiKb1 mean [eV]	8.26466e+03	fixed
20	Pile area factor	6.30420e-02	fixed
21	Pile shift [eV]	2.00000e+02	fixed
22	Pile sigma factor	2.00000e+00	fixed
23	Tail TiKa area factor	3.46240e-02	fixed
24	Tail NiKa area factor	3.18520e-02	fixed
25	Tail slope Ka	3.00000e+00	fixed
26	Tail Kb/Ka area factor	1.00000e+00	fixed
27	Tail La area factor	3.35589e-02	fixed
28	Tail Lb area factor	3.35589e-02	fixed
29	Tail Lg area factor	3.35589e-02	fixed
30	Tail Ld area factor	3.35589e-02	fixed
31	Tail slope L	3.00000e+00	fixed
32	Comp La shift	5.23100e+01	fixed
33	Comp La sigma	8.60284e+01	fixed
34	Comp La area	1.37001e-01	fixed
35	Comp La slope	8.83081e-01	fixed
36	Comp Lb shift	8.31000e+01	fixed
37	Comp Lb sigma	1.07792e+02	fixed
38	Comp Lb area	1.74774e-01	fixed
39	Comp Lb slope	1.20151e+00	fixed
40	Comp Lg shift	1.05740e+02	fixed
41	Comp Lg sigma	1.20631e+02	fixed
42	Comp Lg area	1.86762e-01	fixed
43	Comp Lg slope	1.29132e+00	fixed
44	Comp Ld shift	1.07100e+02	fixed
45	Comp Ld sigma	1.25054e+02	fixed
46	Comp Ld area	1.90864e-01	fixed
47	Comp Ld slope	1.47932e+00	fixed
48	Voigt r	4.00000e+00	fixed

Cycle2 transition energy fit

Shift : 3.0 ± 2.8 eV

Gamma(La) : $0.0 +6.5$ eV

c.f. common shift : 3.0 ± 2.8 eV

The two fit methods are consistent within their statistical errors

How are systematic errors ?

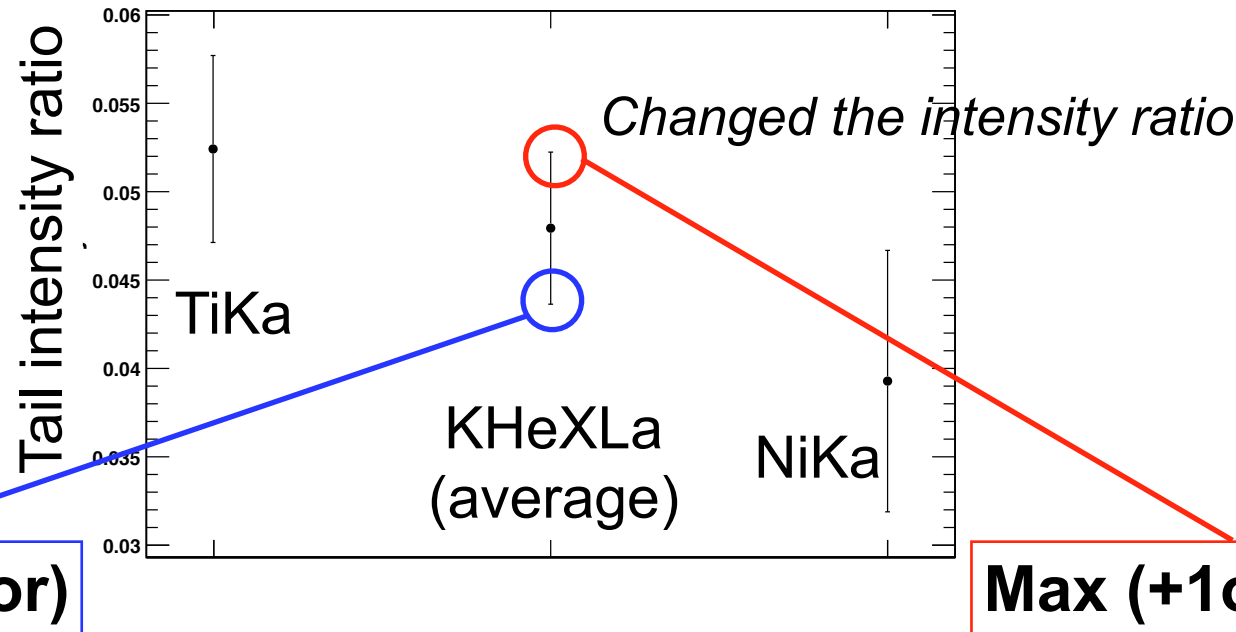
The systematic error associated with the low-energy tail is revised.

± 0.2 eV

for 1st and 2nd cycles.

How to estimate this number →

1st cycle systematic error estimation (low-energy tail)



```
# ---- Fit info ----
# FitOption : RIEL0
# Chisqr/NDF = 128.934/123 = 1.048
```

```
# ---- Tail ratio ----
# TiKa1 0.052361 +- 0.00528872
# NiKa1 0.039283 +- 0.00739603
# KHeXLa 0.0436343 +- 0.004302
# KHeXLb 0.0436343 +- 0.004302
# KHeXLg 0.0436343 +- 0.004302
# KHeXLd 0.0436343 +- 0.004302
```

```
# ---- Shift ----
# KHeXLa : 6460.672 +- 4.071, Ref = 6464.000,
shift = -3.328 +- 4.071
# KHeXLb : 8721.824 +- 7.113, Ref = 8723.000,
shift = -1.176 +- 7.113
# KHeXLg : 9756.866 +- 12.016, Ref = 9768.000,
shift = -11.134 +- 12.016
# KHeXLd : 10281.130 +- 66.370, Ref = 10331.000,
shift = -49.870 +- 66.370
# Shift(weighted average) = -3.581 +- 3.385
# Gamma KHeXLa = 8.113 +- 9.918
# Gamma Lb-Ld = 0.000 +- 11.503
```

$\Delta E = -0.2 \text{ eV}$

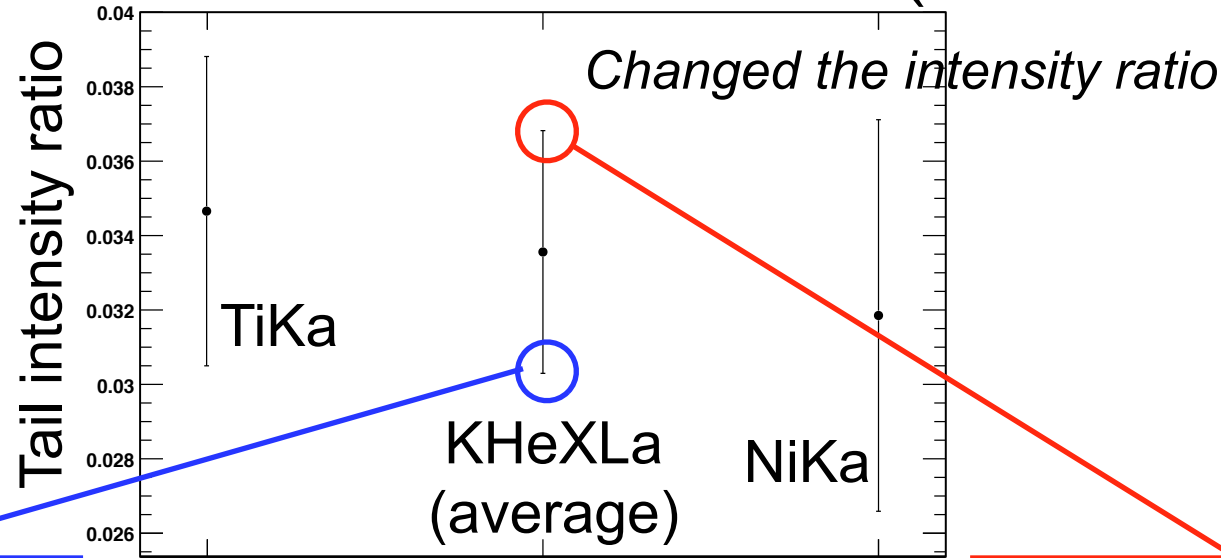
```
# ---- Fit info ----
# FitOption : RIEL0
# Chisqr/NDF = 128.621/123 = 1.046
```

```
# ---- Tail ratio ----
# TiKa1 0.052361 +- 0.00528872
# NiKa1 0.039283 +- 0.00739603
# KHeXLa 0.0522383 +- 0.004302
# KHeXLb 0.0522383 +- 0.004302
# KHeXLg 0.0522383 +- 0.004302
# KHeXLd 0.0522383 +- 0.004302
```

```
# ---- Shift ----
# KHeXLa : 6461.079 +- 4.070, Ref = 6464.000,
shift = -2.921 +- 4.070
# KHeXLb : 8722.136 +- 7.116, Ref = 8723.000,
shift = -0.864 +- 7.116
# KHeXLg : 9757.269 +- 12.020, Ref = 9768.000,
shift = -10.731 +- 12.020
# KHeXLd : 10282.085 +- 66.435, Ref = 10331.000,
shift = -48.915 +- 66.435
# Shift(weighted average) = -3.194 +- 3.385
# Gamma KHeXLa = 7.428 +- 9.910
# Gamma Lb-Ld = 0.000 +- 11.091
```

$\Delta E = +0.2 \text{ eV}$

2nd cycle systematic error estimation (low-energy tail)



Min. (-1 σ error)

```
# ---- Fit info ----
# FitOption : RIEL0
# Chisqr/NDF = 165.388/123 = 1.345
```

```
# ---- Tail ratio ----
# TiKa1 0.034624 +- 0.00415699
# NiKa1 0.031852 +- 0.0052626
# KHeXLa 0.0302969 +- 0.00326205
# KHeXLa 0.0302969 +- 0.00326205
# KHeXLa 0.0302969 +- 0.00326205
# KHeXLa 0.0302969 +- 0.00326205
```

```
# ---- Shift ----
# KHeXLa : 6469.030 +- 3.352, Ref = 6464.000,
shift = 5.030 +- 3.352
# KHeXLa : 8722.618 +- 6.264, Ref = 8723.000,
shift = -0.382 +- 6.264
# KHeXLa : 9760.438 +- 10.078, Ref = 9768.000,
shift = -7.562 +- 10.078
# KHeXLa : 10322.645 +- 30.930, Ref = 10331.000,
shift = -8.355 +- 30.930
# Shift(weighted average) = 2.830 +- 2.824
# Gamma KHeXLa = 0.000 +- 16.768
# Gamma Lb-Ld = 0.000 +- 12.175
```

$\Delta E = \sim -0.2 \text{ eV}$

Max (+1 σ error)

```
# ---- Fit info ----
# FitOption : RIEL0
# Chisqr/NDF = 165.380/123 = 1.345
```

```
# ---- Tail ratio ----
# TiKa1 0.034624 +- 0.00415699
# NiKa1 0.031852 +- 0.0052626
# KHeXLa 0.036821 +- 0.00326205
# KHeXLa 0.036821 +- 0.00326205
# KHeXLa 0.036821 +- 0.00326205
# KHeXLa 0.036821 +- 0.00326205
```

```
# ---- Shift ----
# KHeXLa : 6469.309 +- 3.356, Ref = 6464.000,
shift = 5.309 +- 3.356
# KHeXLa : 8722.865 +- 6.267, Ref = 8723.000,
shift = -0.135 +- 6.267
# KHeXLa : 9760.670 +- 10.085, Ref = 9768.000,
shift = -7.330 +- 10.085
# KHeXLa : 10322.903 +- 30.923, Ref = 10331.000,
shift = -8.097 +- 30.923
# Shift(weighted average) = 3.096 +- 2.827
# Gamma KHeXLa = 0.000 +- 13.464
# Gamma Lb-Ld = 0.000 +- 11.679
```

$\Delta E = \sim +0.2 \text{ eV}$

The systematic errors associated with the Compton tail and pileup events are same as the previous one.

$\pm 0.4 \text{ eV} \pm 0.4 \text{ eV}$ for 1st cycle

Compton tail *Pileup*

$\pm 0.4 \text{ eV} \pm 0.2 \text{ eV}$ for 2nd cycle

Most dominant error is the calculated
electromagnetic energy !

(We asked Koike-san to calculate the values)

Batty and Baird $\pm 2 \text{ eV}$  Koike $\pm X \text{ eV}$

Questions (for the draft of letter)

Is the weighted-average method correct ?

How to estimate the systematic error of the averaged-shift ?

(especially for the extrapolation of $L\beta$, $L\gamma$, $L\delta$)

I think we need to discuss about them...