DEAR Technical Note IR-19

Study of fluorescence excitation, optimal location of calibration foils and x-ray background rates

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1) Introduction

The importance of the presence of a fluorescence peak to be used for the long-term energy calibration of the x-ray energy spectra recorded in the DEAR experiment has been pointed out several times and corresponding measurements and simulations have been performed [1,2,3,4]. In the present note a comparison between the measurements of the Zr fluorescence line from foils attached inside the installed NTP target cell, excited by the background from circulating and colliding beams, is done. The main interest of the present investigation is to understand how efficiently foils in various locations inside the target cell have been excited and how large are the relevant x-ray rates in the case of collisions in the DEAR interaction point (I.P.).

2) X-ray measurements with CCD detectors

For the present measurements the following setups of the foils were considered:

a) Zr and Ti foils attached to the target cell walls, its roof and its bottom, but not covering the kaon entrance window, setup unshielded: **Location A**;
b) only Zr attached to the target cell walls, its roof and its bottom, but not covering the kaon entrance window, setup shielded: **Location B**;
c) Zr foils only covering the kaon entrance window, setup shielded: **Location C**.

d) Zr foils only covering the kaon entrance window, setup shielded, extra lead walls installed on both sides of the interaction region: **Location D**.

The backgrounds relevant for the fluorescence excitation came from different beam configurations:

i) Electron and positron beams circulating in DAΦNE, not colliding but kept separated in vertical in the DEAR interaction point (I.P.): **Beam A**;

ii) Electron and positron beams circulating in DAΦNE, colliding in the KLOE interaction point and not colliding but kept separated in vertical in the DEAR interaction point: **Beam B**;

iii) Electron and positron beams circulating in DAΦNE, colliding in the DEAR interaction point and not colliding in the KLOE one: **Beam C**;

In Fig.1 an example of a measured x-ray energy spectrum is reported.

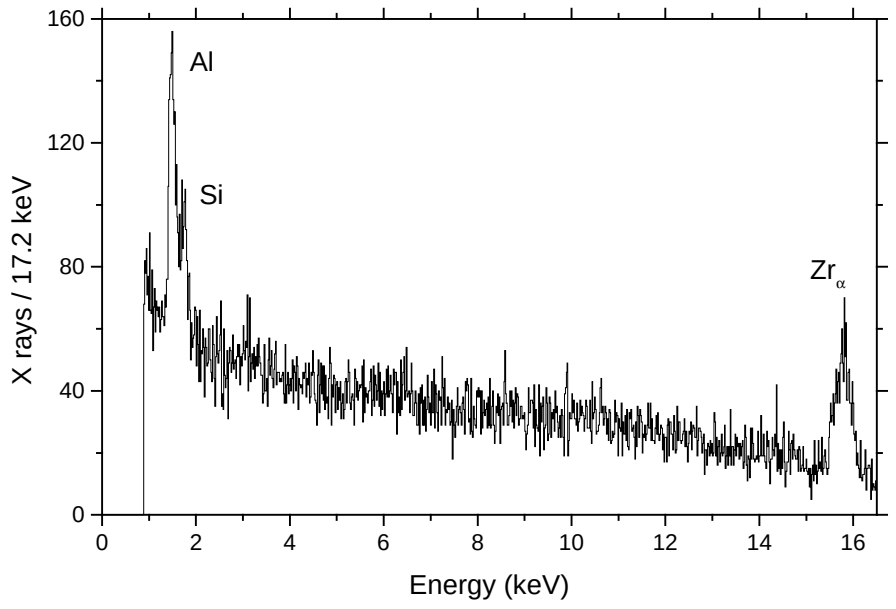

Fig.1: Example of measured x-ray energy spectrum with Zr foils in Location C and Beam C (15 h 50 min hours of exposure, integrated luminosity ~ 50 nb^{-1}). The aluminum fluorescence peak (detector housing, target cell) and silicon peak (CCD chip) can also be seen.

a) Peak-to-background ratios

To obtain a quantitative comparison between the different configurations the ratio zirconium K_α fluorescence peak to background under the peak – X^{Peak} / BG – was determined and normalized to one cm^2 of surface of the foil material. The surface of the attached Zr foil was measured to be for Location A: Zr = 600 cm^2; Location B: Zr = 900 cm^2; Location C, D: Zr = 225 cm^2. The results are collected in Table 1.

Measurement		X^{Peak} / BG $\times 10^{-6}$ / cm^2
Beam	Location	**Zr**
A	A	984 ± 80
A	B	969 ± 55
B	C	8100 ± 700
C	C	7500 ± 400
C	D	7000 ± 1300

Tab.1: The peak-to-background ratios per cm^2 of zirconium surface for the observed fluorescence peak of the given different measurements.

From Table 1 the following can be derived:

i) As far as the zirconium peak is concerned, the peak-to-background ratio turns out to be the same, independently if the setup is not shielded (Location A) or shielded (Location B), when the zirconium foils are on the walls. Obviously the particles creating the smooth x-ray background under the Zr peak are the same as the ones which are exciting fluorescence lines in the Zr foils. So the shielding affects both x-ray production mechanisms and the peak-to-background ratio remains the same.

ii) The peak-to-background ratio turns out to be a factor of 7 - 8 higher for the

measurement with the foil attached to the kaon entrance window (Location C, D) in comparison to the measurements with the foils attached to the walls (Location A, B). This was already suggested on the basis of Monte Carlo simulations in Ref.[2]. The higher excitation efficiency of the foil placed in the kaon entrance window is an indication of the direction of the background: its directionality through the target window points to a production mechanism occurring on the radial plane, such as the Touschek effect, which is forward oriented in a narrow cone. The relevant background contributions which are calculated in the DEAR Monte Carlo simulation confirm this hypothesis [1,3].

iii) No difference in the peak-to-background ratio was observed when beams were colliding in the DEAR interaction point or kept separated in vertical in the DEAR I.P., the lead walls placed on both sides of the beam pipe did not have an effect. This shows that increasing or decreasing the overall background does not, as expected, change the Zr peak-to-background ratio.

b) X-ray rates

The situation of collisions in the DEAR interaction point is, of course, of main interest for our analysis. The observed x-ray rates in the fluorescence-peak, which is used for the energy scale calibration, and in the fluorescence peak free region – both are determining the level of accuracy of the final DEAR result – were extracted from the respective x-ray energy spectra. The values are reported in Table 2 and refer to a setup without and with additional lead walls installed at the two sides of the DEAR interaction region. The rates of the background X rays can be used as input for the DEAR Monte Carlo simulation of the cryo setup.

One of the objectives of the cluster analysis of the period of collisions in the DEAR I.P., reported in Ref.[4], was the determination of the shielding factor due to two installed lead walls. A value of 2.4 ± 0.3 was derived by comparing the quantity number of cluster per added beam current difference, i.e. normalized to the current

losses (for a definition see [3]). Due to the high background rate of charged particles, this measurement has enough statistics to be done, in principle, already in a two minutes exposure period. However, the same measurement should be possible via the observation of background X rays, because the ratio X rays to clusters was found to be constant in [3], but one has to take into account the much lower x-ray rate of approximately one X ray per 1333 clusters [3].

X ray background rates	Xrays /CCD /cm^2 /nb^{-1} $\times 10^{-3}$	Xrays /CCD /keV /nb^{-1}	Xrays /CCD /cm^2 /hour $\times 10^{-3}$	Xrays /CCD /keV /hour
without lead walls				
Zr (@15.8 keV)	40 ± 4		128 ± 12	
BGX_{ROI} Region of interest		20 ± 3		64 ± 5
BGX 2.5 keV - 15 keV Fluorescence-free region		19 ± 3		59 ± 5
with lead walls				
Zr (@15.8 keV)	32 ± 6		55 ± 10	
BGX_{ROI} Region of interest		16 ± 3		27 ± 4
BGX 2.5 keV - 15 keV Fluorescence-free region		14 ± 3		23 ± 4

Tab.2: Rates of Zr fluorescence X rays per CCD per cm^2 of material surface and rates of background X rays (BGX) per CCD per keV for two energy regions: the region of interest for kaonic hydrogen from 5.55 keV to 6.75 keV and the fluorescence-free region from 2.5 keV to 15 keV. The rates are given per nb^{-1} and per hour, for beams colliding in the DEAR I.P., without and with lead walls installed at both sides of the interaction region.

If one considers the three given x-ray rates per nb^{-1}, the average shielding factor turns out to be 1.3 ± 0.2. This can be easily explained by considering the effective luminosity delivered per hour by the machine during the two series of measurements. The measurements without lead walls lasted an overall time of 15.8 hours,

corresponding to an integrated luminosity of 50.5 nb^{-1}, which means a rate of 3.2 nb^{-1}/hour. The measurements with lead walls lasted 3.3 hours, corresponding to an integrated luminosity of 5.6 nb^{-1}, which means a rate of 1.7 nb^{-1}/hour. Therefore the ratio between the luminosity rates turns out to be 1.9 and the effective value of about 2.4 ± 0.4 as shielding factor is again obtained.

The agreement with the value derived from the cluster analysis, despite the chosen unit of measurement, reflects the fact that the present beam lifetimes were stable and comparable before and after insertion of the lead walls - what implied comparable current losses -, so one can take the average x-ray rate per nb^{-1} or, equivalently, per hour and does not need the number of clusters per added beam current difference, a concept developed in [3] and used in order to be able to compare the background observed with beams at different conditions, i.e. with different lifetimes and beam currents.

Trivially, one can also calculate the X rays per hour rates from the given rates per nb^{-1} using the equation $\frac{X}{hour} = \frac{nb^{-1}}{hour} \cdot \frac{X}{nb^{-1}}$. The calculated values are also given in table 2.

Finally, from the x-ray rates in the region of interest and the fluorescence peak of Zr, one can calculate, depending on the estimated background, the expected height of the Zr peak which will be used for the long-term energy scale calibration in the cryogenic hydrogen target cell. The present cryogenic target cell for hydrogen has a kaon entrance window area of ~ 80 cm^2 and a ceiling of ~ 120 cm^2. As presently, at best, a peak-to-background ratio of 1:1 is expected for the kaonic hydrogen K_α peak, the corresponding ratio K_α (kaonic hydrogen) to K_α (zirconium) to be measured in the cryo target cell can be calculated:

$$\Rightarrow \quad \frac{K_\alpha(K^-H)}{K_\alpha(Zr)} = \frac{BGX_{ROI}}{K_\alpha(Zr)} = \frac{27}{(55 \cdot 10^{-3} \cdot 80)} \approx 6 \quad .$$

This ratio can only be improved by adding more zirconium to the target cell. However, only the cryo target cell ceiling (additional ~ 120 cm^2) is available for adding Zr with a relevant surface. This would finally result in a ratio of ~ 2:1 of $K_\alpha(K^-H)$: $K_\alpha(Zr)$, which would allow a reasonable long term calibration.

3) Conclusions

The comparison of x-ray rates and peak-to-background ratios allows us to draw the following conclusions:

1. It turns out that the dominant fraction of the background reaches the CCD detectors through the kaon entrance window.

2. It has now been clearly proven that, due to the dominant background from the beam plane, the location at the kaon entrance window is the favorable place for the zirconium foil, which is used for the long-term energy calibration: this is demonstrated by an observed higher excitation probability per cm^2 of foil for the Zr fluorescence peak.

3. According to the present estimations, a Zr foil in the kaon entrance window and on the roof of the cryo target cell would give a ratio of the kaonic hydrogen K_α line to the Zr K_α line not less than 2:1. This allows a reasonable accuracy for the long-term energy calibration of the DEAR kaonic hydrogen and deuterium measurements but underlines as well the importance of the daily calibration using a ^{55}Fe source to achieve the needed very high accuracy (a few eV) in the energy calibration.

4. The shielding factor given by the lead walls, installed on both sides of the DEAR interaction region, was measured for the first time with X rays, turning out to be 2.4 ± 0.4, in agreement with the previous evaluations using clusters. This shows that, with stable beam conditions, the measurement of X rays summed-up over several injection periods is equivalent to the measurement of the number of clusters divided by the added beam current difference which was used in all previous measurements to compare different beams and, in particular, to determine shielding factors and background levels.

References:

[1] S. Bianco et al., "The DEAR Case", LNF-98/039 (P) (1998); Rivista del Nuovo Cimento, 22, no.11, 1 (1999).

[2] T.M. Ito and R. King, "Summary of foil measurements, foil Monte Carlo, and recommendations for the long term calibration", DEAR Technical Note IR-2, Frascati, June 6, 1998.

[3] M. Augsburger et al., "First measurements at the DAΦNE ϕ-factory with the DEAR experimental setup", LNF-99/32(P) (1999), Accepted for publication by Nuclear Instruments and Methods in Physics Research A.

[4] M. Bragadireanu et al., "The background measurements with the NTP setup in the first period of collisions in the DEAR interaction region", DEAR Technical Note IR-17, Frascati, January 20, 2000.