(e^+e^-)-Production in Heavy Ion Collisions Near the Coulomb Barrier

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Two beamtimes were carried out in the year 1995 with the ORANGE-spectrometer at the UNILAC, using the new injector: In Feb. ^{238}U+^{181}Ta with beam energies of 6.0, 6.15 and 6.3 AMeV, in April ^{238}U+^{206}Pb at 5.9 AMeV. In the system ^{238}U+^{181}Ta a strong line had been found at ≈635 keV in the E_Σ-spectrum for events with non two-body HI kinematics in a previous beamtime (Oct. 1989, see Fig. 1a). The new data this year were obtained with much better statistics and an again upgraded experiment, solving problems in the central PPAC due to very high count rates. During the ^{238}U+^{181}Ta run 148000 (e^+e^-)-pairs, 40000 at 6.0 AMeV, 51000 at 6.15 AMeV and 57000 at 6.3 AMeV, respectively, and 87500 pairs in the ^{238}U+^{206}Pb run were accumulated. In comparison 11200 pairs were collected at 6.3 AMeV in Oct. 1989. In the new run in Feb. 1995 the identification of (e^+e^-)-pairs as well as the heavy-ion concidences were less affected by background and chance coincidences as in Oct. 1989 in spite of a ≈2.5 times higher beam intensity. A gain of more than a factor of two for the (e^+e^-)-coincidence efficiency at ≈635 keV was obtained in 1995 compared to the 1989 run.

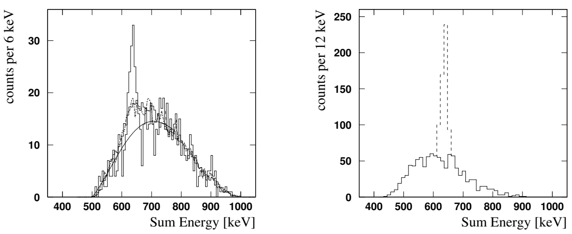

Fig. 1: ^{238}U+^{181}Ta 6.3 AMeV: left(1a): E_Σ-spectrum in coincidence with "fission" kinematics, -66≤E_Δ≤150 keV measured in Oct. 1989. Overlayed: event mixing curve, downscaled spectrum for peripheral collisions and the polynomial used in the first analysis [1] to describe the continuous part of the spectrum. right(1b): Same spectrum measured in Jan. 1995. Overlayed: Expected line from [1], scaled with integrated luminosity

The E_Σ-line in the 1989 data was strongly revealed by selecting (e^+e^-)- pairs in coincidence with two heavy ions, whose kinematics is consistent with "fission" of the ^{238}U after the collision [1,2]. In the original 1989 data analysis the significance of the line in Fig. 1a was deduced to be ≈6.5σ [1], assuming a polynomial fitted to the spectrum outside the line to describe the continuous part correctly. Reanalysis of the data including event-mixing and information based on the new data to determine the shape of the continuous part of the spectrum show that the formerly used polynomial might be incorrect. Applying a Kolmogorov-Smirnov test to the spectrum in Fig. 1a using the newly derived curves yield results equivalent to ≤3.4σ. In the 1993 and 1995 runs the 9 ns time structure of the ECR source was used instead of the 36 ns of the old injector. A significant reduction of chance coincidences was achieved due to the lower pulse intensity even though the average luminosity was 2-3 times higher. Analysis of the new data under the same conditions and cuts as in Fig. 1a led to no significant evidence of the 635 keV line in any of the new data taken at 6.3 AMeV 1995 (Fig. 1b). The dotted lines show the signal expected from the result of the 1989 experiment, taking the improved efficiency into account. Normalized to the peripheral quasi-elastic HI events in the range 18.6 fm≤R_{min}≤29.3 fm the line in 1989 had a production probablity of 4.2×10^{-7} compared to upper limits of $\leq 1.5\times10^{-8}$ (1σ) in the spectrum in Fig. 1b. The weak structures for other HI conditions found in the Nov. 1992 and Dec. 1993 data [3,4] could not be found in the 1995 data.

A second run took place in Apr. 1995 with the collision system ^{238}U+^{206}Pb with a bombarding energy of 5.9 AMeV. ^{206}Pb contains a E1-transition at 1844 keV, which deexcites via Internal Pair Conversion (IPC) and leads to a line at 822 keV in the corresponding E_Σ-spectrum. The cross section of the γ-line was measured to (12.1±1.1) mb/sr in the region R_{min}=25-32 fm. In the corresponding E_Σ-spectrum a line could be observed at 815 keV with a cross section of (6.3±0.6) μb/sr (Fig. 2) in good agreement with a Monte-Carlo estimation.

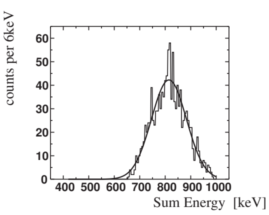

Fig. 2: ^{238}U+^{206}Pb at 5.9 AMeV: E_Σ spectrum in coincidence with two heavy ions, doppler corrected for ^{206}Pb recoil, R_{min}=25-32 fm, overlayed: fit of the continuous part of the spectrum

Experiments with radioactive sources were performed in 1995 and the results were compared to new theoretical calculations. With a ^{90}Sr source an IPC E_Σ-line at 739 keV was measured from a E0-transition in ^{90}Zr. The measured (e^+e^-)-angular anisotropy for various E_Δ [4] is slightly (≤14%) overestimated by the latest theoretical calculations [5]. Also a 1.77 MeV M1 transition in ^{207}Bi was investigated [4]. Older theoretical results predicted (e^+e^-)-opening angle distributions comparable to E2, ie. peaked at small opening angles. However, the measurement reveals a nearly isotropical distribution with a slight increase to large angles. Newest theoretical calculations confirm these results [6], which suggest a reinvestigation of IPC as the possible origin of some lines associated with large opening angles [1,2].

References

[1] I. Koenig et. al., Z. Phys. **A346** (1993) 153
[2] R. Bär et al., Nucl. Physics **A583** (1995) 237
[3] E. Berdermann et al., GSI Scientific Report **94-60** (1994)
[4] U. Leinberger, Ph.D. thesis, TU München, 1996
[5] C. Hofmann, e^+e^--Winkelkorrelation, ISBN 3-8171-1432-X
[6] C. Hofmann, priv. comm.