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им. Г.И. Будкера СО РАН

A.E. Blinov, V.E. Blinov, A.E. Bondar,
A.D. Bukin, V.R. Groshev, S.G. Klimenko,
A.P. Onuchin, V.S.Panin, I.Ya.Protopopov,
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MEASUREMENT OF INCLUSIVE Λ PRODUCTION IN ELECTRON-POSITRON INTERACTIONS AT THE UPSILON ENERGIES

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Measurement of Inclusive Λ Production in Electron-Positron Interactions at the Upsilon Energies

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Budker Institute of Nuclear Physics
630090 Novosibirsk, Russia

A B S T R A C T

Using the MD-1 detector at the VEPP-4 e^+e^- storage ring we have measured the inclusive production rate of the Λ and Ξ^- barions in direct $\Upsilon(1S)$ decays

$$< n_\Lambda (\Upsilon(1S)_{dir}) > = 0.194 \pm 0.018 \pm 0.017,$$

$$< n_{\Xi^-}(\Upsilon(1S)_{dir}) > = 0.038 \pm 0.015 \pm 0.009.$$

The Λ momentum spectrum in direct $\Upsilon(1S)$ decays was obtained.

We have measured also the inclusive production rate of the Λ barion in the continuum at center of mass energies 7.2-10.0 GeV

$$< n_\Lambda(cont.) > = 0.076 \pm 0.018 \pm 0.015.$$

In the range of cms energies between 7.2 and 9.4 GeV this measurement was performed for the first time.

INTRODUCTION

The inclusive production of barions in e^+e^- annihilation offers a unique opportunity for a study of the difference between the fragmentation of quarks and gluons. The previous measurements [1,2] discovered a large barion yield in direct $\Upsilon(1S)$-decays, that is enhanced by a factor of more than 2.5 in comparison with the continuum.

In this paper we present a new measurement of Λ-barion production in the direct $\Upsilon(1S)$ decays and in the continuum. In the range of cms energies between 7.2 and 9.4 GeV this measurement was performed for the first time. We have observed also the production of Ξ^- barion in the direct $\Upsilon(1S)$ decays through the $\Lambda\pi^-$ decay channel. The experiment was performed using the MD-1 detector at the VEPP-4 storage ring. The used event sample corresponds to an integrated luminosity of 5.6 pb^{-1} on the $\Upsilon(1S)$ resonance and 16.6 pb^{-1} in the continuum.

EXPERIMENTAL APPARATUS

The MD-1 detector was in operation at the VEPP-4 storage ring in 1980-1985. The detector and trigger requirements have been described elsewhere [3,4,5]. We will mention here only the features essential for the present analysis.

In MD-1 charged particles are detected and their momenta measured by 38 proportional chambers. In a solid angle of $0.4\cdot4\pi$ sr the momentum resolution of the tracking system is $\sigma_p/p=(5-7)\cdot p(GeV),\%$. The central part of the detector comprises also the shower-range system (sandwiches of proportional chambers and stainless steel plates), the 24 scintillation counters and the 8 gas Cherenkov counters. The magnetic field in the detector is transverse to the beam orbit plane and equal to 11.3 kG at the $\Upsilon(1S)$ resonance.

The trigger information comes from the scintillation counters, the shower-range and tracking systems. At least two particles (including photons) in an event are required. The detection efficiency of the trigger is 97.9% for the $\Upsilon(1S)$ hadronic decays.

EVENT SELECTION

The primary event sample contains a large contribution from Bhabha, two-photon, cosmic and beam-gas background. The procedure of its suppression was described elsewhere [5]. The criteria based on an information from the tracking system and shower-range chambers were used. The detection efficiency of 92% and 83% was achieved for the multihadronic $\Upsilon(1S)$ decays and the continuum events respectively.

Our Λ selection procedure uses the fact that about 85% of events of the decay $\Lambda \rightarrow p\pi^-$ *)(Λ from the $\Upsilon(1S)$ or continuum) contain proton and pion with the momenta greater and less than 400 MeV/c respectively. So in this analysis we simply identify charge particle as a proton if its momentum is greater than 400 MeV/c and as a pion otherwise.

The following cuts were used to reduce combinatorial background.

1. The distance from the secondary vertex of Λ to the beam axis in the plane transverse to the orbit is greater than 3 cm.

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*)References to specific states also imply charge conjugate state.

2. The minimum distance between tracks in the Λ candidate decay vertex is less than 0.6 cm.

3. The angle between the flight direction of the Λ and the vector connecting the primary and the secondary vertex is less than 8°.

The background from converted photons was suppressed by the requirement that the angle between p and π must be greater than 25°

DATA ANALYSIS

The detection efficiency was calculated using the Monte Carlo technique. The hadronic decays were generated with the LUND program [6,7]. The passage of particles through the detector was simulated using the UNIMOD code [8]. The interactions of hadrons were simulated with the NUCRIN code [9].

The detection efficiency was determined as a function of scaled momentum x_p ($x_p = p_\Lambda/p_{max}$, $p_{max} = \sqrt{E_b^2 - m_\Lambda^2}$). After above mentioned cuts it is equal to 2.5% for the x_p range 0.2-0.6. In the continuum the dependence of the detection efficiency on beam energy was taken into account.

The total number of events in our $\Upsilon(1S)$ sample is 98200. It decreases by 28% after the continuum subtraction. In this analysis the data with cms continuum energies in the region of 8.8-10.0 GeV were used. The corresponding integrated luminosities and cross-section dependence in the continuum 1/s were taken into account. Afterwards the number of Υ-mesons is decreased by (8.8 ± 0.5)% that is the part of observable $\Upsilon(1S)$ electromagnetic decays through $q\bar{q}$ pairs.

The integrated luminosities at different cms energies and corresponding number of produced multihadronic events in the continuum are shown in Table 1. The background from two-photon (1%), tau-tau (2%), beam-gas (1%), radiative Bhabha ($e^+e^-\gamma$) events (21%) was subtracted and detection efficiency was taken into account.

Table 1

The luminosity integrals and the number of produced multihadronic events in the continuum

cms energy (GeV)	luminosity (pb^{-1})	events number
7.2 - 8.0	1.02	6172
8.0 - 8.8	4.06	19022
8.8 - 9.42	4.42	19095
9.42 - 9.44	1.66	8237
9.47 - 10.0	4.89	22531

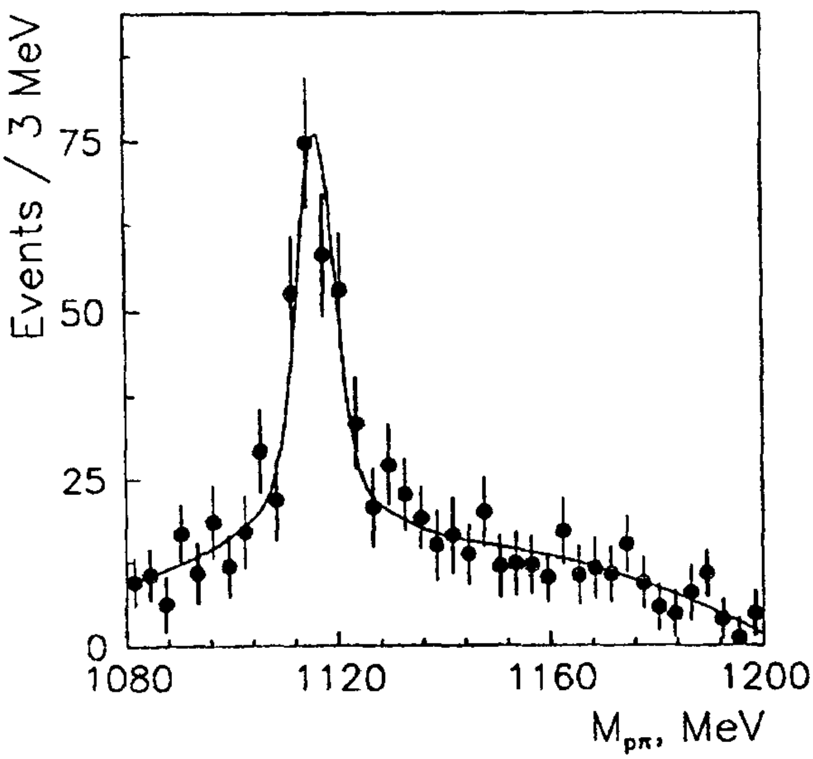

Fig. 1. $p\pi^-$ invariant mass distribution for the $\Upsilon(1S)$ data (the contribution of continuum is subtracted).

Figure 1 shows $p\pi^-$ mass spectrum for the $\Upsilon(1S)$ data after the above mentioned cuts. The contribution of the continuum was subtracted. For the data fit we used the resonance shape from Monte Carlo. The background was described by a second order polynomial with three free parameters. The results of the fit for the Υ(1S) data are following

$$M_\Lambda = 1116.2 \pm 0.4 \text{ MeV}, \; N_\Lambda = 228 \pm 21 .$$

Figure 2 shows $p\pi^-$ mass distribution for the continuum. In this case both the resonance and the background shapes were taken from Monte Carlo. The results of the fit for the data are following

$$M_\Lambda = 1116. \pm 2. \text{ MeV}, \; N_\Lambda = 77 \pm 18 .$$

Note that the fit with free background parameters gives almost the same values

$$M_\Lambda = 1116. \pm 2. \text{ MeV}, \; N_\Lambda = 67 \pm 22 .$$

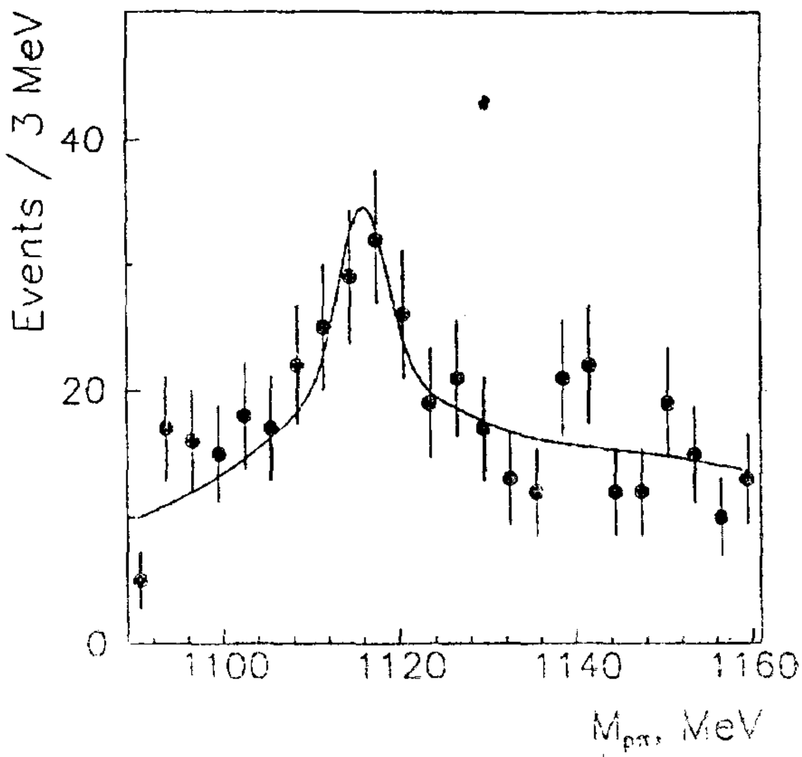

Fig. 2. $p\pi^-$ invariant mass distribution for the continuum data.

In Table 2 the Λ spectrum $(1/N)dn/dx_p$ in direct $\Upsilon(1s)$ decays is shown (N - total number of multihadronic events). It agrees with previous measurements [1,2].

Table 2

Λ spectrum in direct $\Upsilon(1S)$ decays

x_p interval	$(1/N)dn/dx_p$
0.1-0.2	0.82±0.14±0.09
0.2-0.3	0.57±0.09±0.06
0.3-0.4	0.29±0.07±0.04
0.4-0.6	0.053±0.016±0.011

The estimation of the different sources of systematic errors is given in Table 3. Our estimation of the error due to the uncertainty in Λ momentum distribution in the continuum is based on known experimental information on the Λ momentum spectrum [1,2]. The uncertainty in the Λ decay length distribution results from the fact that some lambdas are produced in the decays of Ξ^-, which has the decay length of the same order. The observable Λ decay length distribution is distorted and this fact must be taken into account in the efficiency calculation.

Taking into account systematic error we have obtained the following Λ yield per multihadronic event in the direct Υ decays and in the continuum

$$< n_\Lambda(\Upsilon(1S)_{dir}) > = 0.194 \pm 0.018 \pm 0.017,$$

$$< n_\Lambda(cont) > = 0.076 \pm 0.018 \pm 0.015.$$

We have obtained also the results for the production rate of the Λ in the continuum for different cms beam energy :

At W = 7.2 - 9.4 GeV $<n_\Lambda> = 0.070 \pm 0.027 \pm 0.020$,

At W = 9.4 - 10.0 GeV $< n_\Lambda> = 0.098 \pm 0.027 \pm 0.014$.

Table 3

The systematic errors (in %) in the measurement of inclusive production of the Λ

Source of systematic error	$\Upsilon(1S)$	Continuum
Detection efficiency of the tracking system	5	5
Uncertainty in the number of multi-hadronic events (background subtraction and efficiency calculation)	3	7
Uncertainty in the Λ momentum distribution	3	7
Uncertainty in the Λ decay length distribution	2	2
Monte Carlo statistics	5	5
Uncertainty in the resonance and the background shapes	3	16
Total systematic error	9	20

INCLUSIVE PRODUCTION OF THE Ξ^-

Λ barions are produced often in decay cascades of heavier barions. We studied the $\Lambda\pi^-$ combinations to extract the Ξ^- signal.

We didn't apply here the cut on the angle between Λ decay products. The following additional cuts were used

1. Λ-mass is restricted to be in the range of 1108-1124 MeV.

2. The angle between the flight direction of the Ξ^- and the vector connecting the main and Ξ^- vertex is less than 13°.

3. The distance from the secondary vertex of Ξ^- to the beam axis in the plane transverse to the orbit is greater than 0.5 cm.

Figure 3 shows $\Lambda\pi^-$ mass distribution for the $\Upsilon(1S)$ data after these cuts. The continuum was subtracted analogously to the Λ case. The clear Ξ^- signal is seen. For the fit we have used the resonance shape from Monte Carlo and linear background. The fit results are

$$M_{\Xi} = 1323 \pm 5 \text{ MeV}, \quad N_{\Xi} = 9.9 \pm 4.0 \ .$$

The sources of systematic errors are the same as in the Λ analysis. But the uncertainty in the Ξ^- momentum distribution gives larger error (16%). As a result we have obtained the Ξ^- yield per multihadronic event at $\Upsilon(1S)$ energy $\langle n_{\Xi^-} \rangle = 0.038 \pm 0.015 \pm 0.009$.

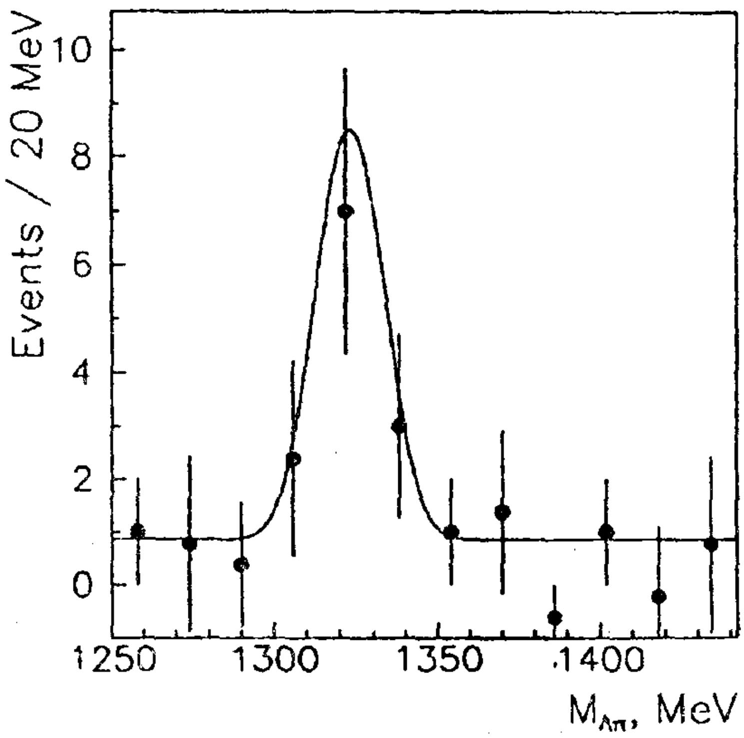

Fig. 3. $\Lambda\pi^-$ invariant mass distribution for the $\Upsilon(1S)$ data (the contribution of continuum is subtracted).

CONCLUSION

The production of the Λ and the Ξ^- barions in $\Upsilon(1S)$ decays and the Λ barions in $q\bar{q}$ continuum events have been studied. The results are in agreement with previous measurements (Tabl.4,5,6). The production of the Λ barion in the range of cms energies between 7.2 and 9.4 GeV was studied for the first time.

Table 4

The results on the inclusive production of the Λ in direct Υ(1s) decays

Experiment	$\langle n_\Lambda(Y_{dir})\rangle$
CLEO(85) [1]	0.19±0.02
ARGUS(88) [2]	0.228±0.003±0.021
this experiment	0.194±0.018±0.017

Table 5

The results on the inclusive production of the Λ in the continuum

Experiment	the cms range, GeV	$\langle n_\Lambda(\text{continuum})\rangle$
CLEO(85) [1]	10.4-10.6	0.066±0.010
ARGUS(88) [2]	9.4-10.6	0.092±0.003±0.008
this experiment	7.2-10.0	0.076±0.018±0.015
	7.2-9.4	0.070±0.027±0.020

Table 6

The results on the inclusive production of the Ξ^- in Υ(1S) direct decays

Experiment	$n_\Xi(Y_{dir})$
CLEO(85) [1]	0.016±0.004
ARGUS(88) [2]	0.0206±0.0017±0.0023
this experiment	0.038±0.015±0.009

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REFERENCES

1. *S.Behrends et al.* Phys.Rev. D31(1985)2161.
2. *H.Albrecht et al.* Z.Phys. C 39(1988)177.
3. *S.E.Baru et al.* Int.Conf.on Instrumentation for Colliding Beam Physics, SLAC, 1982.
4. *S.E.Baru et al.* Preprint INP 83-39, Novosibirsk, 1983.
5. *S.E.Baru et al.* Z.Phys. C 56(1992)547.
6. *T.Sjostrand.* Computer Phys.Comm. 27(1982)243, ibid 28 (1983)227.
7. *T.Sjostrand, M.Bengtsson.* Preprint LU TP 86-22.
8. *A.D.Bukin et al.* Preprint INP 84-33, Novosibirsk 1984.
9. *K.Hanssgen, J.Ranft.* Computer Phys.Comm. 39(1986)37, ibid 39(1986)53.

*A.E. Blinov, V.E. Blinov, A.E. Bondar,
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A.I.Vorobiov, V.N.Zhilich*

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*А.Е.Блинов, В.Е.Блинов, А.Е.Бондарь,
А.Д.Букин, А.И.Воробьев, В.Р.Грошев,
В.Н.Жилич, С.Г.Клименко, А.П.Онучин,
В.С.Панин, И.А.Протопопов, В.А.Сидоров,
Ю.И.Сковпень, А.Н.Скринский, В.А.Таюрский,
В.И.Тельнов, Ю.А.Тихонов, Г.М.Тумайкин,
А.Е.Ундрус, А.Г.Шамов*

Измерение инклюзивного рождения Λ в электрон-позитронных взаимодействиях при энергиях Ипсилон-мезона

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