CONFIRMATION OF A NEGATIVE RESULT FROM A SEARCH FOR BEAUTY AT THE ISR

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ABSTRACT

After evidence for beauty baryon ($A_b$) production at the ISR was reported in a publication by M. Basile et al. we have shown, by a consistency check, that $A_b$ production cannot be observed with the data available. This main argument was supported by a negative result from our own experiment. In a more recent publication by M. Basile et al. the significance of our negative result was questioned. The purpose of the present paper is to prove that the claims of the latter publication are partly wrong and partly incomplete, hence misleading. Thus we maintain our previous conclusion that the signal observed cannot be due to $A_b$ production.

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1. **INTRODUCTION**

The purpose of this paper is to maintain the claim put forward in [1] that one cannot observe $\Lambda_b$ production in association with an anti-beauty state $\bar{B}$ in the reaction

$$pp + \bar{B} \rightarrow \Lambda_b + X$$

$$| \rightarrow e^+ \ldots | \rightarrow D^0 p\pi^- | \rightarrow \geq 4 \text{ charged particles}$$

with the data presented in [2].

The basic argument of [1] was that it is not possible, by about 2 orders of magnitude, to obtain the reported number of $D^0 p\pi^-$ combinations from the number of events with identified positrons and reconstructed protons.

This was further substantiated by our negative result from a search for $\Lambda_b$ production [1]. Our experiment was performed with the Split Field Magnet (SFM) detector as well, has a much better sensitivity due to improvements for track reconstruction, but suffers from increased hadronic background in the "e trigger" compared to the experiment described in [2].

The claim for better sensitivity and our hadronic background were questioned in [3]. Here we show that the evaluation in [3] of our track reconstruction improvements is incomplete (sect. 3). Another estimation of the hadron contamination of our e trigger is given in sect. 2 and found to be in agreement with our previous values. Hence we confirm in sect. 4 the conclusion of [1] that the signal claimed in [2] is not due to a beauty particle.

In an appendix it is carefully checked that our data on charm production in events with a $K^-$ trigger [4] are not subject to internal inconsistencies in contrast to what is pointed out in [3].

With the present paper we hope to clarify the more important problems without commenting on each misleading statement occurring in [3].

(*) Particles are not identified.
2. THE ELECTRON TRIGGER

For a study of reaction (1) only those events were recorded in which a charged track was identified as an electron track by a trigger telescope in the SPM detector (fig. 1). Seen from the interaction region it consists of a wire chamber with analogue read-out (dE/dx chamber [5]) and a two-stage system of Cerenkov counters interspersed with multiwire chambers. A hadron trigger (called π trigger) is defined by a coincidence of groups of wires from different chambers fixing direction and curvature of the track. For an electron trigger a coincidence of 2 Cerenkov signals correlated with a charged track is further required.

The Cerenkov criterion can be fulfilled by:

(A) Electrons from semileptonic decays of charmed or beauty hadrons, from vector mesons or unknown sources (prompt electrons).

(B) Electrons from semileptonic strange particle decays or from Compton scattering (non-prompt electrons).

(C) Electrons from electron pairs due to internal or external conversion of γ from π⁰, η decays (non-prompt electrons).

(D) e pairs from γ conversion randomly associated with triggering hadrons.

(E) Knock on electrons.

In the off line analysis part of the electrons from pair production (C) were suppressed as mentioned in [1] and described in more detail in [6]. Here we concentrate on an estimation of the hadron contamination of the remaining e trigger data.

From the lepton spectra measured in e⁺e⁻ collisions above beauty threshold [7] one expects about 60% of the electrons produced in reaction (1) in the c.m.s. transverse momentum range between 0.6 and 1.6 GeV/c with a maximum at about 0.9 GeV/c. In the following the hadronic contamination is determined for this range. Fig. 2 shows the frequency of Cerenkov response
to \( \pi \) triggers as function of the track's laboratory momentum. Constant
to

values are expected from random coincidences of a Cerenkov signal (due to

processes like, e.g., (D) and (E)) and a triggering hadron. The momentum
dependent contribution to the Cerenkov response is shown in fig. 3 for the
counters C3 and C4 and is explained to be due to knock on electrons

produced by the triggering track: The curves shown are based upon formulae

of [8] and hold for knock on electrons of kinetic energy \( T \) above 20 MeV

(Cerenkov threshold) for the backward counters C3, C4 and for \( T \gtrsim 200 \) MeV

for C0. The latter counter is situated in the SFM field, therefore

electrons with \( T < 200 \) MeV are strongly bent such that they do not give a

signal.

The product, \( f' \), of the probabilities displayed in fig. 2 corresponds
to random coincidences of two uncorrelated Cerenkov signals and a charged

hadron trigger. The probability, \( f'' \), to produce two correlated Cerenkov

signals randomly associated with a \( \pi \) trigger due to process (D) was
determined from fully reconstructed events from \( \pi \) triggers:

\[
f'' = (1.7 \pm .3) \times 10^{-4}.
\]

With the values thus obtained for \( f = f' + f'' \)

\( (f \sim 2.5 \times 10^{-4}, \text{ whereas } (7.1 \pm 2.0) \times 10^{-4} \text{ was quoted in [3])}, \)

the

ratio of production cross sections for prompt electrons and hadrons

('e/\pi' ratio, [1]) in the relevant transverse momentum range, and a ratio

of 1:1 [1,3] for prompt and non-prompt electrons in the electron trigger,

one determines now the hadron contamination

\[
\frac{\sigma(\text{hadrons}) \times f}{\sigma(\text{e prompt}) + \sigma(\text{e non prompt}) + \sigma(\text{hadrons}) \times f}.
\]

The result is displayed in fig. 4 for the events selected [1] for heavy

flavour search.

It compares well with the two previous, independent estimates based

upon a study of energy deposited in electromagnetic shower detectors [2]
available for part of our data [1] and upon a \( dE/dx \) pulse height analysis

for triggering tracks [1,6]. As an example for the latter method fig. 5

shows the measured energy loss distributions for triggering tracks with

\( p_T \sim 0.8 \text{ GeV/c} \) with (fig. 5(a)) and without (fig. 5(c)) nearby track

candidates in the chambers behind C0. The fitted contributions of known

shape from pions, single electrons and \( e^+e^- \) pairs are displayed as

well. For comparison the measured spectrum from \( \pi \) triggers is shown in
fig. 5(b). Qualitatively one expects more hadron background for the event sample in fig. 5(a) due to process (D) and (E) in good agreement with experiment.

This section can be summarized by stating that three independent methods consistently yield a relative hadron contamination of about 35% in the relevant momentum region as reported previously [1]. Thus it still holds that, in addition to about 32% non prompt electrons, about 32% of our e triggers are prompt electrons, compared to 49% in the experiment described in [2].

Finally, fig. 6, in which Cerenkov pulse height distributions from the backward counters are displayed for π and e triggers, indicates that there are means to further decrease the hadron contamination by a minimal pulse height requirement. It also demonstrates that the hadron contamination is directly correlated with the Cerenkov pulse height cut applied at the stage of data taking and in the analysis.

3. TRACK RECONSTRUCTION

In the following we derive that the efficiency of the present experiment to detect D^+_s K^- systems(*) in reaction (1) is much larger than that of experiment R415 [2].

The relative sensitivity of the present experiment, labelled R416, and of experiment R415 is deduced from table 1. It shows the numbers of events and numbers of effective mass combinations for the two experiments [2,9] for all selection criteria devised in [2] and detailed in [1]; in column 4 we give the relative efficiency of the two experiments, i.e. the ratio ('R416/R415') of the fraction of events surviving the selection criteria.

First, one notices that the relative integrated luminosity is 3.6/4.4 = 0.82, whereas experiment R416 collects a factor of

(*) In this section "D^0" denotes a K^-π^+ system with |m(K^-π^+) - m(D^0)| ≤ 0.075 GeV [2].
18136/14155 = 1.28 more e triggers. However, the relative prompt electron yield is 1.28x0.32/0.49 = 0.84 due to a larger hadron contamination in R416 (see sect. 2).

The relative efficiency to obtain events with a positive particle with \( x > 0.32 \) (labelled "proton") from e triggers is 2.39, which is due to our effort to do better track reconstruction in the forward SFM detector telescopes. This factor has to be compared to the factor 1.55x1.53 = 2.37 quoted in [3]. The relative sensitivity for events with 7 particles in addition to the trigger track and the proton turns out to be 1.36, whereas a value of 1.33x1.1 = 1.46 was found in [3]. At this stage R416 obtains a factor of 2.39x1.36x3.25 more events than R415. The corresponding factor determined in [3] is 2.37x1.46 = 3.46 and was defined to be the relative sensitivity of the two experiments to final states with 7 charged particles, a proton and a positron. However, this is not a complete treatment: A further cut selects only those events where at least one \( D^+\pi^-p \) system is produced with rapidity larger than 1.4 and one additional track is emitted into the azimuthal hemisphere opposite to the trigger track (|\( \Delta \phi \)| > \( \pi/2 \)). The relative efficiency of this selection is 1.47. Finally, the relative yield of \( D^+\pi^-p \) mass combinations per selected event is 1.49 due to the higher reconstructed event multiplicity of R416. The two latter factors 1.47x1.49 = 2.19 were ignored in [3].

The total relative yield of \( D^+\pi^-p \) systems of the two experiments is then 1.28x3.25x1.47x1.49 = 9.1, whereas a factor of 9.1x0.32/0.49 = 5.94 is found for \( D^+\pi^-p \) systems associated with prompt electrons. These numbers were already mentioned in [1] and are obviously much bigger than the factor 3.46 stated in [3].

We conclude with the following remark: the relative efficiency to find 7 particles in addition to an e\(^+\) and a proton turned out to be 1.36. It is partly due to a more favourable chamber configuration in our experiment and partly due to an improvement of the single track efficiency by about 10% for the bulk of particles at \( x < 0.3 \). Since our present average single track efficiency is ~ 90%, the corresponding number for the previous track reconstruction procedure [10] used for [2,3] was better than 80%, already a good achievement indeed.
4. CONCLUSIONS

We maintain that the strongest argument against the \( \Lambda_b \) signal reported in [2] is due to a check for internal inconsistencies of these data [1]. From the number of events with a triggering \( e^+ \) and reconstructed proton one expects less than 0.3 \( D^0 p\pi^- \) systems in the \( \Lambda_b \) mass range where about 30 have been claimed [2]. This upper limit can, fortunately, be established in a rather simple way being based upon only 5 straight forward parameters and the average detector efficiency for charged particles not including the more complicated electron and time-of-flight [11] acceptances. It should be mentioned that in the calculation of the upper limit [1] about a 40% loss of \( D^0 p\pi^- \) systems due to the \( D^0 \) mass cut was generously neglected.

The above severe inconsistencies were not resolved in [3], even by using rather ad hoc values for the parameters involved.

It should be added that the width of the \( \Lambda_b \) signal presented in [2] is smaller by a factor of nearly 2 than the width of \( \approx 260 \) MeV calculated from the detector resolution.

The above arguments are supported by a negative search for \( \Lambda_b \) production in the present experiment [1] which is confirmed here: in sect. 2 the hadron contribution, determined by 3 independent methods, is shown to be consistently less than or in the order of 35% as stated previously [1]. Thus we are in a good position to do a reasonable search for \( \Lambda_b \) produced in association with \( e \) triggers. In sect. 3 it is explained in detail why our efficiency for \( D^0 p\pi^- \) systems in events with prompt electrons is a factor of about 6 better than the one of [2] in perfect agreement with our previous estimation [1]. Hence, from the 30 \( D^0 p\pi^- \) combinations in the \( \Lambda_b \) range observed in [2], one expects about 180 combinations in our experiment in contrast to what is actually found [1]. On the other hand the absence of a signal in our experiment is in agreement with the upper limit of 2.2 beauty baryons derived in [1].

We are thus led once more to the conclusion that one cannot observe \( \Lambda_b \) production with the type of experiment described in [1,3].
In the appendix we prove that there are no inconsistencies in our data on charm production in events with $K^-$ triggers. This is in disagreement with a calculation in [3] which is, however, oversimplified and makes use of our sample size in a misleading way.

Additional comments

The arguments presented here and in ref. [1] were made known, in particular to the authors, before publication of refs [2,3].

Since we have developed both the basic and the improved versions of the reconstruction program and are the only group that has used both of them, we feel qualified to express an opinion on their relative merits.

Because of the wrong or misleading statements made in ref. [3], but especially since a new experiment is planned, which is based upon the results of ref. [2], we felt compelled to comment again. We anticipate that this should be our last publication on this controversy.
APPENDIX

ON THE CONSISTENCY OF THE ACCEPHW DATA ON FORWARD PRODUCTION OF CHARM

This section refers to the production of $D^+$ and $\Lambda^+_c$ observed in pp collisions at $\sqrt{s} = 53$ GeV [4] by triggering on forward $K^-$ at the SFM.

The type of consistency check outlined below was applied in [1] to the data on beauty production of [2](*) and in [3] to the data on charm production of [4]. First the following quantities are defined (see also [3]) and their numerical values given:

\[
\begin{align*}
N &= \text{number of events with } x(K^-) > 0.3: & 49707 [4] \\
N' &= \text{number of events with } x(K^-) > 0.3 \text{ after} \\
&\hspace{1cm} \text{the selection criteria described in [4]:} & 12124 \\
S_{D} &= \text{number of } D^+ \text{ observed:} & 92 \pm 18 [4] \\
S_{\Lambda} &= \text{number of } \Lambda^+_c \text{ observed:} & 29 \pm 7 [4] \\
\epsilon &= \frac{\text{(number of genuine } K^-)}{\text{(number of } K^- \text{ triggers):}} & 0.80 \pm 0.05 [4] \\
\rho' &= \frac{\text{(number of } K^- \text{ from charm)}}{\text{(number of genuine } K^-):} & \text{unknown} \\
B'_{3,D} &= \text{relative branching ratio} \\
&\quad \left[ B(D^+ \to K^- \pi^+ \pi^+)/B(D^+ \to K^- X) \right]_{x(K^-) > 0.3} & \text{unknown} \\
B'_{3,D} > B_{3,D} = B(D^+ \to K^- \pi^+ \pi^+)/B(D^+ \to K^- X) \text{ since} \\
&\quad \text{the decay } D^+ \to K^- \pi^+ \pi^+ \text{ produces more often} \\
&\quad \text{K}^- \text{ with } x > 0.3 \text{ than the decay } D^+ \to K^- X \text{ due} \\
&\quad \text{to the larger average } Q \text{ value.} \\
B_{3,D} \text{ (weighted average from [12]):} & 0.29 \pm 0.08 \\
B'_{3,A} > B_{3,A} &= \text{relative branching ratio:} \\
&\quad B(A^+_c \to K^- p)/B(A^+_c \to K^- X) \text{ (see above). With} \\
&\quad B(A^+_c \to K^- p) = 0.022 \pm 0.01 [12] \text{ and} \\
&\quad B(A^+_c \to K^- X) = 0.53 \pm 0.25 \text{ (not measured,} \\
&\quad \text{taken from [3]) one obtains:}
\end{align*}
\]

(*) Note that the parameters used in [1] are incorrectly quoted in [3].
\[ B_{3,A} = \text{relative branching ratio} \]
\[ B(D^+ \to (K^\pi)_{\ell}^{\mp} K^\pi\bar{\pi})/B(D^+ \to K^\pi\pi) : \]
\[ 0.042 \pm 0.028 \]

\[ B_{2,D} = \text{relative branching ratio} \]
\[ B(A_0^+ \to (K^\pi)_{\ell}^{\mp} p)/B(A_0^+ \to K\pi^+\pi^-) : \]
\[ 0.3 \pm 0.2 \]

\[ B_{2,A} = \text{average SFM acceptance for } \pi^+ \pi^- \text{ from } D^+ \text{ decays:} \]
\[ 0.5 \pm 0.05 \]

\[ \varepsilon_{\text{SFM, D}} = \text{average SFM acceptance for } \pi^+ p \text{ from } \Lambda_c^+ \text{ decays:} \]
\[ 0.5 \pm 0.05 \]

With these definitions one should observe
\[ N_D(A) = S_D(A)/(B_{2,D}(A) \times B_{3,D}(A) \times \varepsilon_{\text{SFM, D}}(A)) \]
\[ \leq S_D(A)/(B_{2,D}(A) \times B_{3,D}(A) \times \varepsilon_{\text{SFM, D}}(A)) = 2115 \pm 1588 \text{ (D^+) } \]
\[ 3452 \pm 3005 \text{ (}\Lambda_c^+) \]

events from \( D^+(\Lambda_c^+) + K^-X \) decays with \( x(K^-) > 0.3 \). The total number of events with \( x(K^-) > 0.3 \) can then be calculated from
\[ N = (N_D + N_A)/(\varepsilon_{\rho''} \times \varepsilon'') \]

Here \( \rho'' = \)
\[ \frac{\text{number of events with } x(K^-) > 0.3 \text{ from } D^+ \text{ and } \Lambda_c^+ \text{ decays}}{\text{number of events with } x(K^-) > 0.3 \text{ from } D^+, D^0, \Lambda_c^+ \text{ decays}} \]

\[ \frac{\Delta \sigma(D^+)B(D^+ + K^-X) + \Delta \sigma(\Lambda_c^+)B(\Lambda_c^+ + K^-X)}{\Delta \sigma(D^+)B(D^+ + K^-X) + \Delta \sigma(\Lambda_c^+)B(\Lambda_c^+ + K^-X) + \Delta \sigma(D^0)B(D^0 + K^-X)} \]

where \( \Delta \sigma(h) \) is the inclusive cross section at \( \sqrt{s} = 53 \text{ GeV} \) for charmed particles \( h(h = D^+, D^0, \Lambda_c^+) \) such that \( h + K^-X \) yields \( K^- \) with \( x(K^-) > 0.3^{(*)} \)

\[ \Delta \sigma(D^+) : (50 \pm 30) \mu b [4] \]
\[ \Delta \sigma(\Lambda_c^+) : (80 \pm 40) \mu b [4] \]
\[ \Delta \sigma(D^0) \text{ unknown, assume: } \Delta \sigma(D^+) \pm \Delta \sigma(D^0). \]

\[ (*) \text{ Using [3] the integrated non-inclusive cross sections measured at } \sqrt{s} = 63 \text{ GeV is of course misleading.} \]
From these numbers one derives

\[ \rho'' = 0.52 \pm 0.22. \]

Finally, one has

\[ N < \frac{1}{\rho''}(13725 \pm 6780), \]

whereas the observed number is 49707\(^*(\ast)\). Therefore one gets perfect agreement with \( \rho' \approx 0.28 \pm 0.14 \), the value suggested in [3]. The same relation holds for the number \( N' \) of events with \( x(K^-) > 0.3 \) retained after the charm selection criteria

\[ N' < \frac{1}{\rho'}(13725 \pm 6780). \]

Since \( N' = 12124 \) this inequality holds for \( \rho' > 0.5 \). This is larger than the previous value of \( 0.28 \pm 0.14 \) and indicates that the selection criteria [4] really help to suppress background. Hence, we conclude that there is no hint of inconsistencies in the data of [4]. Actually, such a cross check was already performed before publication as can be concluded from fig. 15 of [14], where the \( D^+ \) cross section at \( x \approx 0.6 \) is compared to the inclusive \( K^- \) yield. Keeping in mind that \( B(D^+ + K^-X) = (16 \pm 4.1)\% \) [12] and \( <x(K^-)> \approx 0.35 \) for decays of \( D^+ \) produced at \( x \approx 0.6 \), one cannot deduce any inconsistency.

Finally, we wish to point out that there is no basic disagreement between our charm cross sections [4] and \( e/\pi \) ratios published so far [14]. The rather imprecise value of \( e/\pi \) calculated from present data on charm production at \( \sqrt{s} = 63 \) GeV holds for the transverse momentum range of about 0.3 to 0.6 GeV/c only, where no measurements of \( e/\pi \) have been published so far (see, however, [6]).

\(^*(\ast)\) \( N = 49707 \) was replaced by \( N' = 12124 \) in [3].
Summarizing the appendix we state that there is no evidence for inconsistencies of our charm data nor for intrinsic problems of this type of cross checks. In [3] one arrived at different conclusions due to an oversimplified treatment and by making use of our sample size in a misleading way.

It should be pointed out, however, that the method generally works much more reliably in the case of beauty baryon production since:

(a) the relevant inequality contains only 6 parameters (15 parameters in the charm case) and

(b) the upper limit calculated is about 2 orders of magnitude above observation whereas upper limit and observation are of the same order of magnitude in the case of charm production.
REFERENCES
H. Frehse et al., Nucl. Instr. and Meth. 156 (1978) 97.
D. Drijard, SFM Internal note 1976.
### TABLE 1

Integrated luminosities:
- R416: $3.6 \times 10^{36}$ cm$^{-2}$
- R415: $4.4 \times 10^{36}$ cm$^{-2}$

<table>
<thead>
<tr>
<th>Selection criteria</th>
<th>number of events or mass combinations</th>
<th>ratio ($\frac{R416}{R415}$) of fractions of events surviving the selection criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e^+$ protons, $x &gt; 0.32$</td>
<td>18136 ev. 14155 ev.</td>
<td>2.39 ($=\frac{4771}{18136}$, $\frac{14155}{1600}$)</td>
</tr>
<tr>
<td>$n_{ch} &gt; 9$</td>
<td>4771 ev. 1600 ev.</td>
<td>1.36</td>
</tr>
<tr>
<td>$</td>
<td>y(D^0 p\pi^-)</td>
<td>&gt; 1.4$, $</td>
</tr>
<tr>
<td></td>
<td>983 ev. 165 ev.</td>
<td>1.49</td>
</tr>
<tr>
<td></td>
<td>4640 comb. 523 comb.</td>
<td></td>
</tr>
</tbody>
</table>

Relative yield of $D^0 p\pi^-$ combinations: $\frac{18136}{14155} \times 2.39 \times 1.36 \times 1.47 \times 1.49 = 9.1$

Relative yield of $D^+ p\pi^-$ combinations associated with prompt positrons:

$9.1 \times 0.32 = 5.94$. 
FIGURE CAPTIONS

Fig. 1   Top view of the split field magnet detector.

Fig. 2   Frequency of Cerenkov response to \( \pi \) triggers as function of laboratory momentum for counter C0 (fig. 2(a)) and counters C3, C4 (fig. 2(b)).

Fig. 3   Excess of measured Cerenkov response to \( \pi \) triggers in fig. 2(b) above expectations from random trigger/\( \gamma \) conversion coincidences (see text) for counters C3, C4. The curves indicate the theoretical expectations for knock on electrons for counters C3, C4 (curve (1)) and counter C0 (curve (2)).

Fig. 4   Percentage of hadron contamination versus c.m.s. transverse momentum of the trigger particle determined from shower counters (○), from d\( E/dx \) chamber (●) and from Cerenkov response to \( \pi \) triggers (x).

Fig. 5   Measured d\( E/dx \) spectra for triggering tracks with \( p_T = 0.7 - 0.9 \) GeV/c:

(a) triggering electrons with close by track candidate,

(b) reference spectrum from \( \pi \) triggers.

(c) triggering electrons without close by track candidate. The fitted contributions of known shape from single electrons, hadrons and \( e^+e^- \) pairs are displayed as well.

Fig. 6   Cerenkov pulse height spectra for electron and pion triggers.
Fig. 4

- □ from shower counter
- ● from the "dE/dx" chamber
- × from Č response to π-triggers

Hadron contamination (%) vs. Trigger transverse momentum (GeV/c)
Fig. 5
Cerenkov ADC spectra

31 GeV DATA

Fig. 6