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A Study of the Claim to Observe Beauty Production at the ISR Using Two Čerenkov Counters in Series to Identify e±.

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Summary. — The purpose of this work was to study the claim of the *R*416 group to be able to observe the production of « beauty » at the Split-Field Magnet (SFM) facility of the CERN Intersecting Storage rings (ISR). The two basic points of these authors were: i) by using an improved « new » version of the reconstruction programs, a factor ~ 9 in efficiency can be achieved with respect to the « old » SFM reconstruction programs; ii) with two Čerenkov counters, each 1 m long, and each with a large area of coverage as in the SFM structure, a rejection power of $1.5 \cdot 10^{-4}$ against charged hadrons can be achieved. Point i) would mean that the previous programs, used for five years at the SFM, were incredibly inefficient despite the efforts, by all people concerned, to produce a reasonable program for the SFM users. The proof that the old programs produce a correct figure for the track detection efficiency is given by our measurements of the average charge multiplicity $\langle n_{ch} \rangle$ at three total c.m. (pp) energies: $\sqrt{s} = 30, 44, 62$ GeV. These values of $\langle n_{ch} \rangle$ are in excellent agreement with previous measurements and corroborate our confidence in the « old » SFM reconstruction programs. Our estimate of the efficiency for the « new » programs gives at least a factor of ~ 3 less than the claimed factor of 9. Concerning point ii), it is well known that the correct figure cannot be better than $\sim 10^{-3}$. Any experimental physicist can check this point if he has not done so already. Our measurement $(7.1 \pm 2.0) \cdot 10^{-4}$ for incident-particle momenta between 0.8 GeV/c and 3.0 GeV/c, performed at the SFM facility of the CERN ISR, is perfectly consistent with the universally accepted figure for the above-mentioned rejection power. The conclusion of our study is that the *R*416 group has not the necessary rejection power against charged hadrons. Therefore, their claim to be able to observe « beauty » production at the ISR is unfounded.

1. – Introduction.

The purpose of this paper is to report on a measurement of the rejection power against charged hadrons, which can be obtained with two gas threshold Čerenkov counters, filled with nitrogen at atmospheric pressure, one of which is in a magnetic field, as shown in fig. 1.

The reason for this study is the claim (1) by another SFM group (*R*416)

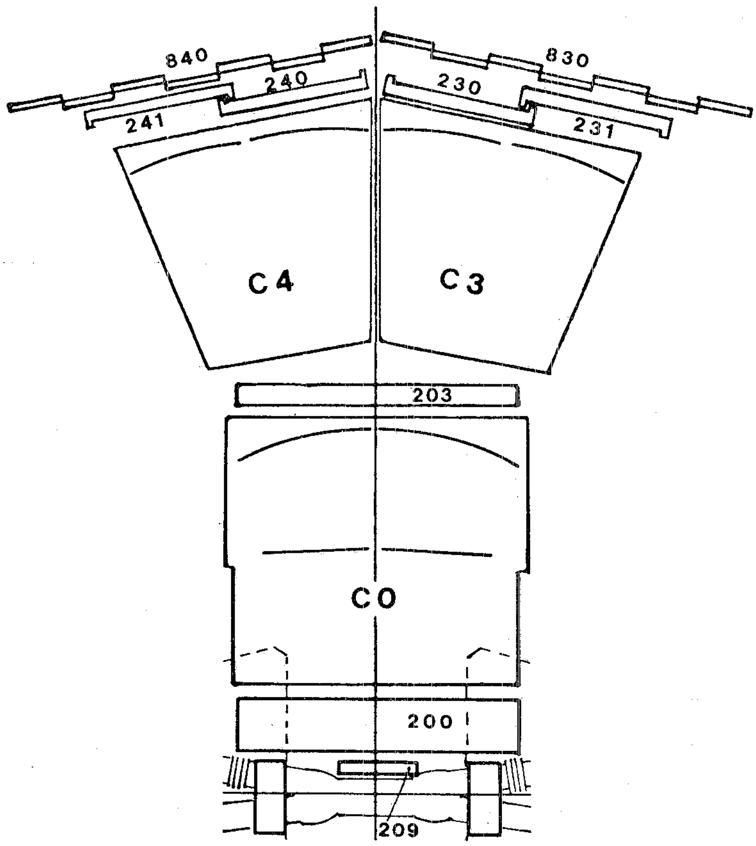

Fig. 1. – Top view of the *R*416 detector, showing the MWPCs, the dE/dx chamber (209), the gas threshold Čerenkov counters (C), and the time-of-flight system (TOF).

(1) D. DRIJARD, H. G. FISCHER, H. FREHSE, W. GEIST, P. G. INNOCENTI, D. W. LAMSA, W. T. MEYER, A. NORTON, O. ULLALAND, H. D. WAHL, G. FONTAINE,

that this rejection power is comparable to the one achieved by the same pair of Čerenkov counters with the addition of an electromagnetic-shower detector (EMSD), as shown in fig. 2.

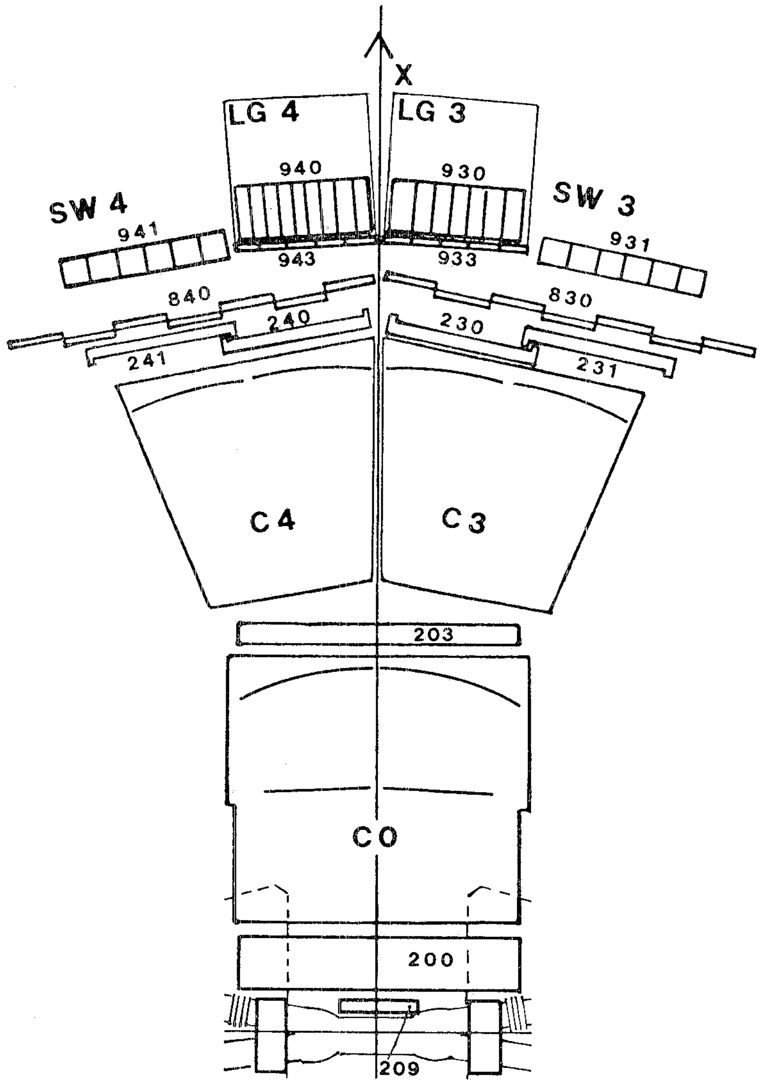

Fig. 2. – Top view of the $R415$ detector, showing also the electromagnetic-shower detectors (SW, LG).

G. Ghesquière, G. Sajot, W. Hofmann, M. Panter, K. Rauschnabel, J. Spengler, D. Wegener, P. Hanke, M. Heiden, E. E. Kluge, T. Nakada, A. Putzer, M. Della Negra, D. Linglin, R. Gokieli and R. Sosnowski: *Further investigation of beauty baryon production at the* ISR, preprint CERN-EP/81-96, August 1981, submitted to *Phys. Lett. B*.

The relevance of this study is related to the observation of « heavy flavour » production in high-energy (pp) collisions at the ISR [2-13]. The key point of this search was, in fact, a powerful prompt ($e^{\pm}$) detector. The absence of the EMSD from the experimental set-up spoils the ($e^{\pm}$) detection, thus destroying the possibility of observing charm or beauty signals.

In the following the effect of removing the EMSD, thus limiting the ($e^{\pm}$) identification simply to the gas Čerenkov counters in series, is shown. We also try to evaluate the efficiency of track reconstruction of the « new » program, which is claimed [1] to be ~ 9 times higher than that of the « old » program used throughout all our work on charm and hadronic production studies at

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[2] For a review see M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Charm production at the* CERN *Intersecting Storage Rings*, Internal report CERN-EP/81-02 (June 1981).

[3] M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Nuovo Cimento A*, **63**, 230 (1981).

[4] M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Nuovo Cimento A*, **62**, 14 (1981).

[5] M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Lett. Nuovo Cimento*, **30**, 487 (1981).

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[8] M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Nuovo Cimento A*, **67**, 40 (1982).

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[11] M. BASILE, G. BONVICINI, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Lett. Nuovo Cimento*, **31**, 97 (1981).

[12] M. BASILE, G. BONVICINI, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Nuovo Cimento A*, **65**, 408 (1981).

[13] M. BASILE, G. BONVICINI, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Nuovo Cimento A*, **65**, 391 (1981).

the ISR. Finally in the appendix we discuss their « numerological » argument and apply it to the scarce data of the ACCDHW group on charm production.

The conclusion is that the claim of some authors (1) to be able to observe the production of heavy flavours at the ISR, without the necessary rejection power against charged hadrons, is unfounded.

2. – Experimental apparatus and triggering conditions.

The measurements have been performed at the Split-Field Magnet (SFM) facility of the CERN Intersecting Storage Rings (ISR), looking at particles produced in an angular range $\Delta\theta = (35 \div 90)°$, and in a transverse-momentum interval between 0.8 and 3 GeV/c.

Figure 2 shows the $e^\pm$ detector of the *R*415 experiment (CERN-Bologna-Frascati Collaboration). Outside the interaction region, there are: a multiwire proportional chamber with analog read-out « dE/dx » (209), a multiwire proportional chamber (MWPC) (200), a Čerenkov counter (C_0), another MWPC (203), two Čerenkov counters (C_3 and C_4), other MWPCs (230/1, 240/1), some TOF counters and, finally, the electromagnetic-shower detectors, or EMSDs (lead-glass LG3, LG4, and lead/scintillator sandwiches SW3, SW4).

The *R*416 apparatus, used by the Annecy-CERN-Collège de France-Dortmund-Heidelberg-Warsaw (ACCDHW) Collaboration (1) and shown in fig. 1, *lacks the* EMSDs *as outer elements.*

The hardware trigger, for both experiments, required

(H.1): hits in all MWPCs;

(H.2): coincidences of hits on two Čerenkov counters (C_0C_3 or C_0C_4).

The *R*415 *experiment further required*

(H.3): an energy release above a fixed threshold in the EMSDs

$$[E_{min}(e) \geqslant 500 \text{ MeV}] .$$

The software analysis for the two experiments was essentially the same except for the requirement of the match of the trigger track with an energy cluster on the EMSDs, which *R*415 could apply to the data.

The dE/dx chamber was used at the software level to reject (e^+e^-) pairs due to external plus internal γ conversions from π^0 and η Dalitz decay. This type of background was reduced to 50 % of the *R*415 final sample of events (14).

(14) M. Basile, G. Cara Romeo, L. Cifarelli, A. Contin, G. D'Alí, P. Di Cesare, B. Esposito, P. Giusti, T. Massam, F. Palmonari, G. Sartorelli, G. Valenti and A. Zichichi: *Nuovo Cimento A*, **65**, 421 (1981).

Most of the charged hadrons simulating $e^{\pm}$ were rejected (down to 2 % of the final sample of events ([14])) by the $R415$ experiment using, in addition to the Čerenkov counters, the EMSDs.

3. – Charged-hadron contamination with two Čerenkovs in series.

By using the $R415$ experiment data sample, to compute the charged-hadron contamination on the $R416$ single-electron trigger, a sample of $R415$ charged track triggered events has been used in which conditions (H.2) and (H.3) were not applied at the hardware level. Those conditions may, however, be applied at the software level.

The charged-hadron contamination obviously depends on the particle momenta. In the following, only tracks with $p_T \geqslant 800$ MeV/c and $\Delta p/p \leqslant 15\,\%$, which is the region of interest for beauty search, are retained.

Two methods can be used:

Method A. Follow the complete software analysis chain of experiment $R415$, which gives a nearly pure electron sample: the difference between the number of events left before and after the requirement of an energy release in the EMSDs gives the fraction (h_c/t) of charged hadrons expected in the final sample of events for $R416$, *i.e.* when the electromagnetic-shower detectors are turned off. The result is

$$\frac{h_c}{t} = (63 \pm 15)\,\% \,. \tag{1}$$

Method B. Select tracks which give an energy release in the electromagnetic-shower detectors corresponding to a minimum ionizing particle, thus obtaining a clean sample of charged hadrons, determine the Čerenkov efficiency for these tracks, and then apply this efficiency to the expected rate of charged hadrons in the trigger region. The result will be the expected charged-hadron rate in the $R416$ final sample of events.

The Čerenkov efficiency for charged hadrons is measured to be

$$\varepsilon_C = (7.1 \pm 2.0)\cdot 10^{-4} \,.$$

The measured e_{prompt}/π ratio for $p_T \geqslant 800$ MeV/c in the 90° region is $\simeq 1.6\cdot 10^{-4}$ (ref. ([14])). This means that the rate π/e_{prompt} is $\simeq 6250$. By taking into account kaons and protons $[(p+\bar{p}+K^+ + K^-) \simeq 0.2\times(\pi^+ + \pi^-)]$, the rate of charged hadrons to electrons (h/e_{prompt}) is $\simeq 7500$. The rate (h_c/e_{prompt}) of charged hadrons seen by the Čerenkov counters, thus simulating electrons in the $R416$ apparatus, is

$$\frac{h_c}{e_{\text{prompt}}} = \frac{h}{e_{\text{prompt}}}\,\varepsilon_C \simeq 5.3 \pm 1.5 \,.$$

Taking into account the background from neutral hadrons and γ conversion, whose rate is equal to that of the prompt electrons, as pointed out in sect. **2**, the *R*416 experiment gets, for each genuine prompt electron in the final events sample, (h_c/e_{prompt}) charged hadrons and one background electron coming from neutral hadrons; then, the percentage of charged hadrons in the *R*416 final sample of events is

$$\frac{h_c}{t} = \frac{h_c/e_{\text{prompt}}}{(h_c + e_{\text{background}} + e_{\text{prompt}})/e_{\text{prompt}}} \simeq (73 \pm 6)\,\% \,. \tag{2}$$

Method *A* has the advantage of not relying on the measured e/π ratio, while method *B* is more independent of differences in the apparatus acceptances and analysis details between the two experiments.

The results (1) and (2) from methods *A* and *B* can be expressed as the percentage of good electrons in the final sample of events. One obtains

method *A*: good electrons/event $\simeq (18.5 \pm 7.5)\,\%$;

method *B*: good electrons/event $\simeq (13.5 \pm 3.0)\,\%$.

If one combinines the two results,

good electrons/event $\simeq (16 \pm 4)\,\%$.

4. – Consequences for the beauty search.

By studying the rejection power against charged hadrons of the two set-ups shown in fig. 1 and 2, it has been measured that, *for each genuine prompt electron event*,

i) the set-up of *experiment R*415 (two Čerenkov counters in series plus an EMSD (fig. 2)) collects

1 fake event from neutral-hadron background, plus

0.04 ± 0.02 fake events from charged-hadron background ([14]), *i.e.*

1.04 ± 0.02 *fake events*: *total*;

ii) the set-up of *experiment R*416 (only two Čerenkov counters in series (fig. 1)) collects

1 fake event from neutral-hadron background, plus

4.3 ± 1.6 fake events from charged-hadron background, *i.e.*

5.3 ± 1.6 *fake events*: *total*.

It is worth noting that the ratio (events/good electron) does not vary linearly, and varies very rapidly, with the percentage of charged hadrons in the final sample of events. This is illustrated in fig. 3, in which the *R*416 charged-hadron contamination is also reported.

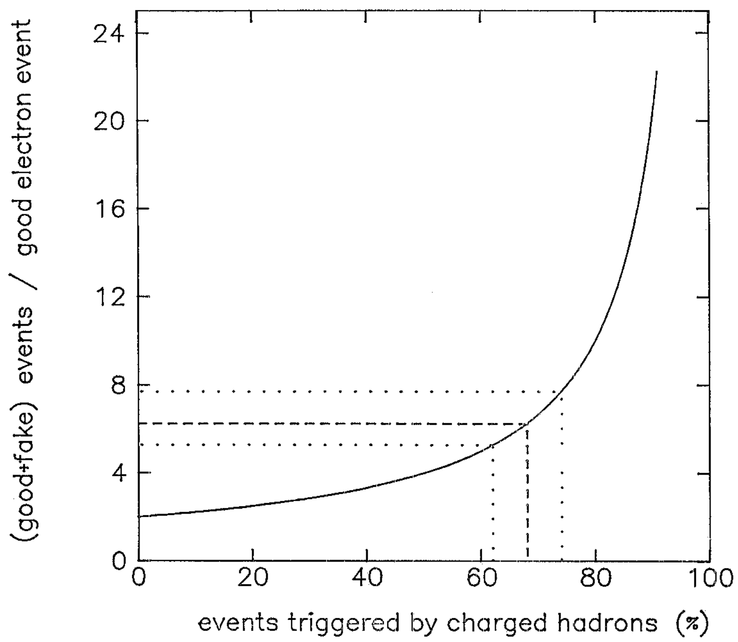

Fig. 3. – Events in the final sample per good electron as a function of the fraction of events triggered by a charged hadron. A fixed neutral-hadron contamination of 50% of the pure electron fraction of the final event sample is assumed.

As the prompt electron signal is used by both experiments to select events in which heavy flavours are produced, the *R*415 experiment has a signal/background ratio of 1/1.04 at the trigger level, while the *R*416 experiment has the most unfavourable ratio of 1/5.3.

The effect of such a background can be evaluated on the Λ_b^0 beauty baryon signal, observed by experiment *R*415 ([11]) in the reaction

(3) $$pp \to \Lambda_b^0 + M_{\bar{b}}^- + \text{anything}$$

$$M_{\bar{b}}^- \to e^+$$

$$\Lambda_b^0 \to pD^0\pi^-$$

$$D^0 \to K^-\pi^+ .$$

The ratio signal/background in the *R*415 experiment was perfectly consistent with the expected value, *i.e.* one to one. In fact, in the Λ_b^0 mass range there were 30 combinations (the signal) and 26 background combinations.

The other experiment (R416) studied reaction (3) in a sample of $1.8 \cdot 10^4$ triggered events [1]. Given the contamination on the trigger stated above, only $(2.9 \pm 0.7) \cdot 10^3$ events were genuine prompt electron events. The R416 experiment should, therefore, expect

$$12 \pm 3.6 \ \Lambda_b^0 \text{ combinations}, \tag{4a}$$

and

$$54 \pm 17 \text{ background combinations}, \tag{4b}$$

if the efficiency for the detection of the final state of reaction (3) were the same for the two experiments.

The R416 experiment had

i) a better efficiency for « leading » protons $\left(|x_L| = 2|p_L|/\sqrt{s} \geqslant 0.3\right)$, due to improvements in the forward part of the SFM spectrometer (compensator magnet chambers) only partially available during the R415 run;

ii) a better single-track efficiency due to improvements in the reconstruction programs with respect to the R415 ones.

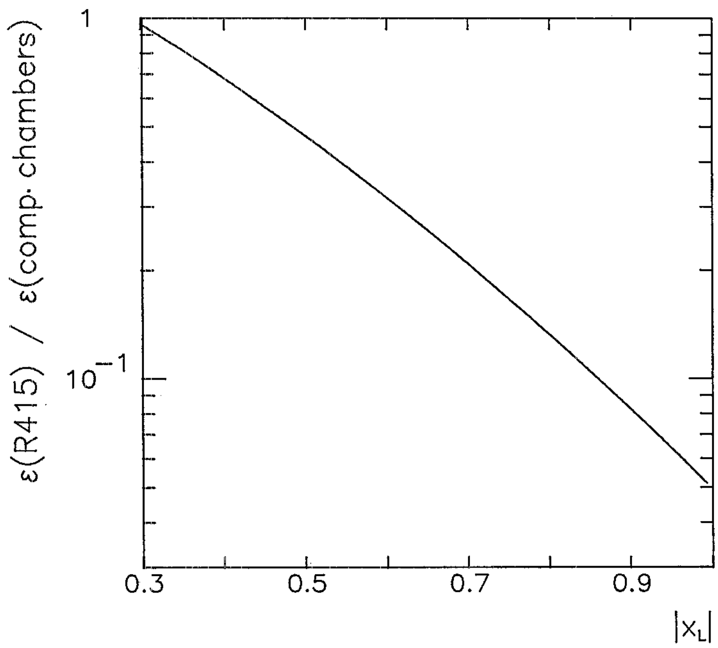

Fig. 4. – Ratio between the efficiency for detecting positive particles as it is in the R415 data and the same efficiency with the compensator chambers, as a function of $|x_L|$.

Figure 4 shows the ratio between the efficiency for positive particles as it is in the R415 data and the efficiency for positive particles with the compensator chambers, plotted as a function of $|x_L|$. By folding the observed $|x_L|$ distribution of protons in the R415 data, shown in fig. 5, with the efficiency shown in fig. 4,

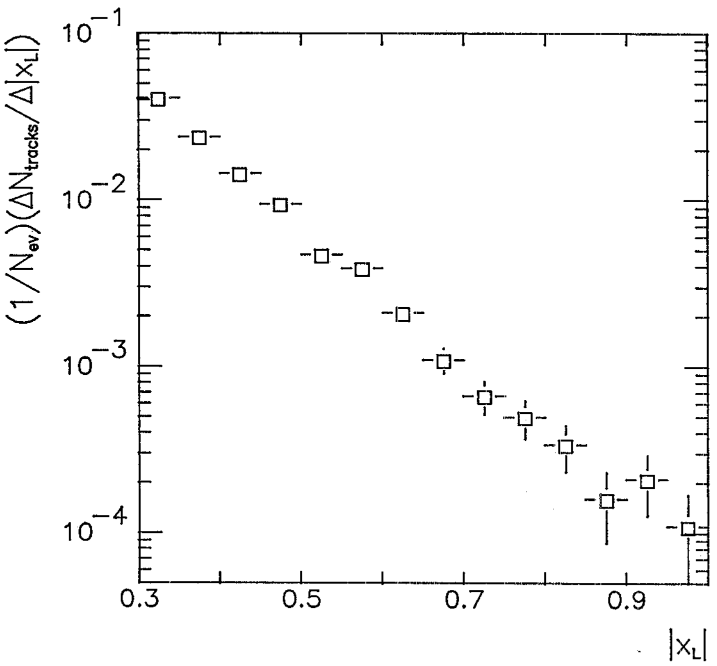

Fig. 5. – Measured $|x_L|$ distribution of positive particles in R415 data.

the increase in efficiency for detecting the «leading» protons of the R416 experiment is

$$(5a)\qquad \frac{\varepsilon(R416\text{: protons, } |x_L|\geqslant 0.3)}{\varepsilon(R415\text{: protons, } |x_L|\geqslant 0.3)} = 1.55\,.$$

However, the increase in efficiency for detecting protons coming from reaction (3) must be computed from the expected $|x_L|$ distribution, shown in fig. 6, of the protons coming from Λ_b^0, when this is produced according to the measured $|x_L|$ distribution ([12]). From fig. 4 and 6, one obtains

$$(5b)\qquad \frac{\varepsilon(R416\text{: protons from } \Lambda_b^0,\ |x_L|\geqslant 0.3)}{\varepsilon(R415\text{: protons from } \Lambda_b^0,\ |x_L|\geqslant 0.3)} = 1.26\,.$$

About 20 % of the events selected by the R416 experiment, containing a proton with a very high $|x_L|$, are, therefore, useless for Λ_b^0 search, and contribute only to the background.

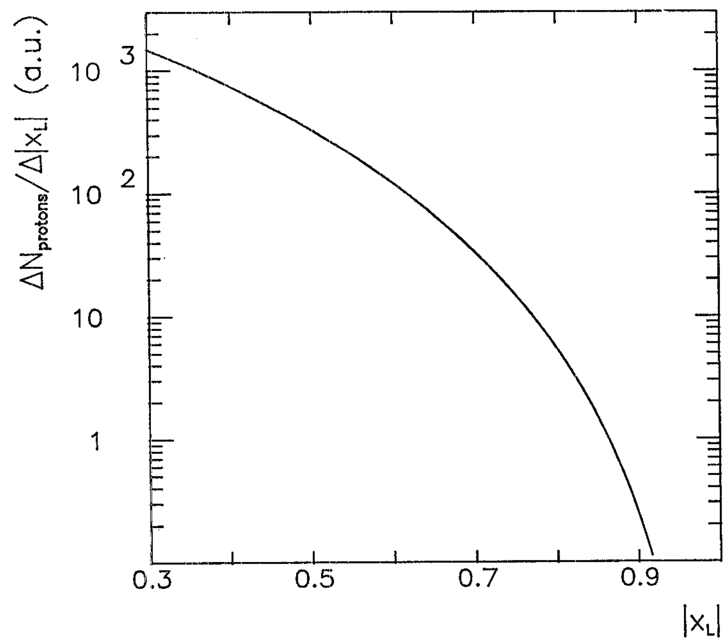

Fig. 6. – Expected $|x_L|$ distribution of protons coming from the decay $\Lambda_b^0 \to pD^0\pi^-$, when the Λ_b^0 is produced following the measured $|x_L|$ distribution: $(d\sigma/d|x_L|) \propto \propto (1-|x_L|)^{0.9}$.

The improvements in the reconstruction programs lead to an increase in efficiency, for the $R416$ experiment, of

$$\frac{\varepsilon(R416:\ \text{protons})}{\varepsilon(R415:\ \text{protons})} = 1.53\ (^*)\,, \tag{6}$$

$$\frac{\varepsilon(R416:\ K^-\pi^+\pi^-)}{\varepsilon(R415:\ K^-\pi^+\pi^-)} = 1.33 \tag{7}$$

and

$$\frac{\varepsilon(R416:\ \text{« anything » in reaction } (3) \geqslant 4)}{\varepsilon(R415:\ \text{« anything » in reaction } (3) \geqslant 4)} = 1.10\,. \tag{8}$$

Results (7) and (8) are based on the declared $R416$ efficiencies [1] and on the efficiency tables, computed via Monte Carlo simulation, for the $R415$ experiment. These have been proved to be correctly computed by measuring the

(*) Note that this number does not take into account the different background contaminations of the $R415$ and the $R416$ event samples, and assumes that all the difference in the number of « leading » protons found is due only to the efficiency of the reconstruction programs.

correct total charged multiplicities produced in (pp) collisions at three different values of the c.m. energy ([15]).

Combining the results (5*b*)-(8), the total increase in efficiency for the detection of the final state of reaction (3), obtained by the *R*416 experiment, is

$$\frac{\varepsilon(R416)}{\varepsilon(R415)} = 2.82\,, \tag{9}$$

while results (5*a*), (6)-(8) indicate an increase by a factor of 3.47 in the efficiency for detecting background events.

If we apply these increases in efficiencies to the *R*416 expectations (4*a*) and (4*b*), the result is

(10*a*) expected Λ_b^0 signal: 34 ± 10 combinations;

(10*b*) expected background: 187 ± 59 combinations.

The $p(K^+\pi^-)_{D^0}\pi^-$ invariant-mass spectrum obtained by the *R*416 experiment ([1]) and shown in fig. 7 contains, in the Λ_b^0 mass range $(5.35 <$

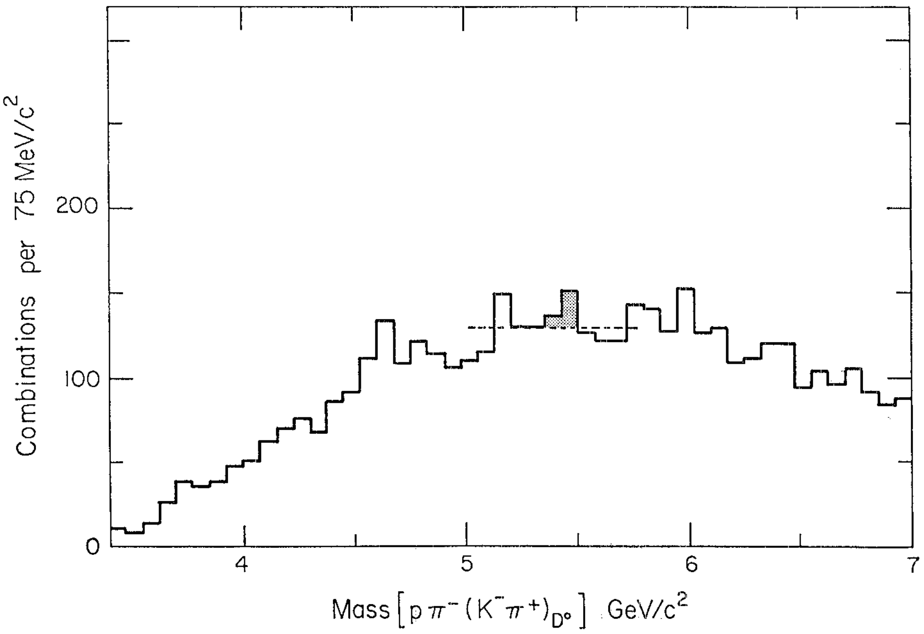

Fig. 7. – $p(K^-\pi^+)_{D^0}\pi^-$ invariant-mass distribution of experiment *R*416, obtained as illustrated in ref. ([1]).

([15]) M. Basile, G. Cara Romeo, L. Cifarelli, A. Contin, G. D'Alí, P. Di Cesare, B. Esposito, P. Giusti, T. Massam, R. Nania, F. Palmonari, V. Rossi, G. Sartorelli, M. Spinetti, G. Susinno, G. Valenti, L. Votano and A. Zichichi: *Nuovo Cimento A*, **65**, 400 (1981).

$< m(\mathrm{pK^-\pi^+\pi^-}) < 5.50\ \mathrm{GeV}/c^2$), about 280 combinations, 30 of which can indeed be considered as a Λ_b^0 « signal ». The background level, 250 ± 16 combinations, is within one standard deviation of the value expected by our calculation (10*b*).

The *R*416 experiment could not see 30 combinations in such a high background level.

The claim of the *R*416 group (1) to be able to see the signal, if the Λ_b^0 was really produced in (pp) interactions at $\sqrt{s} = 62$ GeV, is, therefore, deprived of any experimental basis. The work reported by our group (11-13) on the observation of Λ_b^0 in (pp) interactions at $\sqrt{s} = 62$ GeV remains, therefore, the only experimental study of this process and it is fully valid, as it was before the *R*416 claimed « check » (1).

APPENDIX

The numerology applied to the ACCDHW data on charm production.

An argument, referred to in the following as « numerology », has been used by the ACCDHW Collaboration (1) to support their alleged « experimental evidence » against the presence of Λ_b^0 signal in their data. It states the following.

Let us define the quantities

N = number of events with an e^+ trigger and with a proton with $|x_L| > 0.32$;

S = number of observed events with a $\Lambda^0 \to p(K^-\pi^+)_{D^0}\pi^-$, associated with a $M_{\bar{b}} \to e^+ +$anything; the proton has $|x_L| > 0.32$;

ε = number of prompt e^+/number of e^+ triggers in events with a « leading » proton ($|x_L| > 0.32$);

ϱ = number of e^+ from antibeauty/number of prompt e^+ in events with a « leading » proton;

B_1 = number of Λ_b^0's/number of beauty hadrons produced in events with a « leading » proton;

B_2 = branching ratio $(\Lambda_b^0 \to pD^0\pi^-)/(\Lambda_b^0 \to p+\text{anything})$, when the protons have $|x_L| > 0.32$;

B_3 = branching ratio $(D^0 \to K^-\pi^+)/(D^0 \to \text{all})$;

ε_{SFM} = probability of detecting in the SFM two pions and a kaon from a Λ_b^0 decay.

From the above definitions, the *R*415 experiment should have observed

$$N = S/(\varepsilon \cdot \varrho \cdot B_1 \cdot B_2 \cdot B_3 \cdot \varepsilon_{SFM}) \tag{A.1}$$

events with an e^+ trigger associated with a « leading » proton.

In eq. (A.1) ϱ, B_1, and B_2 are unknown, ε is known only for the inclusive

e^+ spectrum (*i.e.* when no request for fast protons is made), ε_{SFM} depends on the production and decay mechanisms of Λ_b^0, and B_3 has been measured ([16]) to be $(3.0 \pm 0.6)\%$.

The ACCDHW Collaboration uses the following values for the above quantities, in our experimental conditions:

$$\text{(A.2)} \qquad \begin{cases} \varepsilon &= 0.45\,, \\ \varrho &= 0.1\,, \\ B_1 &= 0.5\,, \\ B_2 &= 0.1\,, \\ B_3 &= 0.03\,, \\ \varepsilon_{SFM} &= 0.5\,, \\ S &= 30\,. \end{cases}$$

Thus, from eq. (A.1),

$$\text{(A.3)} \qquad N = 30/3.375\cdot 10^{-5} = 8.9\cdot 10^5\,.$$

This number has to be compared with the observed $N = 1.6\cdot 10^3$ events.

From the above calculations, we conclude that this kind of extrapolation to 4 orders of magnitude cannot be applied when dealing with an instrument of such complexity as the SFM in which acceptances for tracks can be as high as 90 % and drop to 10% for time-of-flight studies and to 10^{-3} for the electron detection. This is even more true, if we consider that:

i) By reasonably changing the values (A.2), assuming $\varepsilon = 0.5$, $\varrho = 0.5$, $B_1 = 0.8$, $B_2 = 0.2$, $B_3 = 0.03$, $\varepsilon_{SFM} = 0.5$, eq. (A.1) gives the result

$$N = 30/6\cdot 10^{-4} = 5\cdot 10^4\,,$$

which is more than one order of magnitude lower than estimate (A.3). This indicates how unreliable are such calculations.

ii) The same numerological arguments can be applied to the charm signals, observed in (pp) collisions at $\sqrt{s} = 53$ GeV by the ACCDHW Collabora-

([16]) R. H. Schindler, M. S. Alam, A. M. Boyarski, M. Breidenbach, D. L. Burke, J. Dorenbosch, J. M. Dorfan, G. J. Feldman, M. E. B. Franklin, G. Hanson, K. G. Hayes, T. Himel, D. G. Hitlin, R. J. Hollebeek, W. R. Innes, J. A. Jaros, P. Jenni, R. R. Larsen, V. Lüth, M. L. Perl, B. Richter, A. Roussarie, D. L. Scharre, R. F. Schwitters, J. L. Siegrist, H. Taureg, M. Tonutti, R. A. Vidal, J. M. Weiss, H. Zaccone, G. Abrams, C. A. Blocker, A. Blondel, W. C. Carithers, W. Chinowsky, M. W. Coles, S. Cooper, W. E. Dieterle, J. B. Dillon, M. W. Eaton, G. Gidal, G. Goldhaber, A. D. Johnson, J. A. Kadyk, A. J. Lankford, R. E. Millikan, M. E. Nelson, C. Y. Pang, J. F. Patrick, J. Strait, G. H. Trilling, E. N. Vella and I. Videau: SLAC-PUB-2507; LBL-10905, May 1980 (*T/E*), submitted to *Phys. Rev. D.*

tion ([17,18]) in experiments *R*407 and *R*408 at the SFM detector, using a forward $(|x_L| > 0.3)$ K^- trigger:

$$D^+ \to (K^-\pi^+)_{\overline{K}^{*0}}\pi^+ \ ([17]),$$
$$\Lambda_c^+ \to (K^-\pi^+)_{\overline{K}^{*0}}p \ ([18]).$$

Let us define

N = number of events with a K^- with $|x_L| > 0.3$;

S_D = number of observed events with a $D^+ \to (K^-\pi^+)_{\overline{K}^{*0}}\pi^+$, with the K^- having $|x_L| > 0.3$;

S_Λ = number of observed events with a $\Lambda_c^+ \to (K^-\pi^+)_{\overline{K}^{*0}}p$, with the K^- having $|x_L| > 0.3$;

ε = (number of genuine K^-)/(number of K^- triggers);

ϱ' = (number of K^- from charm)/(number of genuine K^-);

ϱ'' = (number of K^- from D^+ and Λ_c^+)/(number of K^- from charm (D^+, Λ_c^+ and D^0));

$B_{2,D}$ = branching ratio $(D^+ \to K^-\pi^+\pi^+)/(D^+ \to K^- + \text{anything})$;

$B_{2,\Lambda}$ = branching ratio $(\Lambda_c^+ \to K^-\pi^+p)/(\Lambda_c^+ \to K^- + \text{anything})$;

$B_{3,D}$ = branching ratio $(D^+ \to (K^-\pi^+)_{\overline{K}^{*0}}\pi^+)/(D^+ \to K^-\pi^+\pi^+)$;

$B_{3,\Lambda}$ = branching ratio $(\Lambda_c^+ \to (K^-\pi^+)_{\overline{K}^{*0}}p)/(\Lambda_c^+ \to K^-\pi^+p)$;

$\varepsilon_{SFM,D}$ = probability of detecting in the SFM the two π's from the D^+ decay;

$\varepsilon_{SFM,\Lambda}$ = probability of detecting in the SFM the π^+p pair from the Λ_c^+ decay.

From the above definitions, the *R*407/408 experiments should observe

$$N_D = S_D/(B_{2,D} \cdot B_{3,D} \cdot \varepsilon_{SFM,D}) \tag{A.4a}$$

events, with a K^- with $|x_L| > 0.3$, coming from $D^+ \to K^- + \text{anything}$ decays, and

$$N_\Lambda = S_\Lambda/(B_{2,\Lambda} \cdot B_{3,\Lambda} \cdot \varepsilon_{SFM,\Lambda}) \tag{A.4b}$$

([17]) D. Drijard, H. G. Fischer, W. Geist, R. Gokieli, P. G. Innocenti, V. Korbel, A. Minten, A. Norton, R. Sosnowski, S. Stein, O. Ullaland, H. D. Wahl, P. Burland, M. Della Negra, G. Fontaine, P. Frenkiel, C. Ghesquière, D. Linglin, G. Sajot, H. Frehse, E. E. Kluge, M. Heiden, A. Putzer, J. Stiewe, P. Hanke, W. Hofmann, M. Panter, K. Rauschnabel, J. Spengler and D. Wegener: *Phys. Lett. B*, **81**, 250 (1979).

([18]) D. Drijard, H. G. Fischer, W. Geist, P. G. Innocenti, V. Korbel, A. Minten, A. Norton, S. Stein, O. Ullaland, H. D. Wahl, P. Burland, G. Fontaine, P. Frenkiel, C. Ghesquière, G. Sajot, P. Hanke, W. Hofmann, M. Panter, K. Rauschnabel, J. Spengler, D. Wegener, H. Frehse, E. E. Kluge, M. Heiden, W. Herr, A. Putzer, M. Della Negra, D. Linglin, R. Gokieli, R. Sosnowski and M. Szeptycka: *Phys. Lett. B*, **85**, 452 (1979).

events, with a K^- with $|x_L| > 0.3$, coming from $\Lambda_c^+ \to K^- + \text{anything}$ decays. The total number of events with a K^- with $|x_L| > 0.3$ is then given by

$$N = (N_D + N_\Lambda)/(\varepsilon \cdot \varrho' \cdot \varrho'') . \tag{A.4c}$$

The following values for the above quantities are taken:

$$\left\{ \begin{array}{l} D^+ : \; S_D \;\;\; = 92 \; (^{17}) , \\ \qquad B_{2,D} \; = 0.33 \; (^{19}) , \\ \qquad B_{3,D} \; = 0.3 \; (^{19}) , \\ \qquad \varepsilon_{SFM,D} = 0.5 \; (^{*}) ; \\ \Lambda_c^+ : \; S_\Lambda \;\;\; = 29 \; (^{18}) , \\ \qquad B_{2,\Lambda} \; = 0.042 , \\ \qquad B_{3,\Lambda} \; = 0.3 \; (^{19}) , \\ \qquad \varepsilon_{SFM,\Lambda} = 0.5 \; (^{*}) ; \\ \varepsilon \;\; = 0.78 \; (^{20}) , \\ \varrho' \; = 0.25 , \\ \varrho'' = 0.45 . \end{array} \right. \tag{A.5}$$

The values of ϱ'' and $B_{2,\Lambda}$ can be obtained from the data of ref. [19]. As an example, if we denote by σ_{D^+}, $\sigma_{\Lambda_c^+}$, σ_{D^0} and $\sigma_{\text{charm}} = \sigma_{D^+} + \sigma_{D^+} + \sigma_{\Lambda_c^+}$ the total cross-sections for producing D^+, Λ_c^+, D^0, or all charm in (pp) interactions at $\sqrt{s} = 53$ GeV, the quantity ϱ'' is defined as

$$\varrho'' = \frac{\left(\dfrac{\sigma_{D^+}}{\sigma_{\text{charm}}} \dfrac{D^+ \to K^- X}{D^+ \to \text{all}}\right) + \left(\dfrac{\sigma_{\Lambda_c^+}}{\sigma_{\text{charm}}} \dfrac{\Lambda_c^+ \to K^- X}{\Lambda_c^+ \to \text{all}}\right)}{\left(\dfrac{\sigma_{D^+}}{\sigma_{\text{charm}}} \dfrac{D^+ \to K^- X}{D^+ \to \text{all}}\right) + \left(\dfrac{\sigma_{\Lambda_c^+}}{\sigma_{\text{charm}}} \dfrac{\Lambda_c^+ \to K^- X}{\Lambda_c^+ \to \text{all}}\right) + \left(\dfrac{\sigma_{D^0}}{\sigma_{\text{charm}}} \dfrac{D^0 \to K^- X}{D^0 \to \text{all}}\right)} . \tag{A.6}$$

The following quantities are measured:

$$\sigma_{D^+} = \sigma_{D^0} = 2\sigma_{\Lambda_c^+} \; (^{3,7,8}) , \tag{A.7a}$$

$$\frac{D^+ \to K^- X}{D^+ \to \text{all}} = 0.19 \; (^{19}) , \tag{A.7b}$$

$$\frac{D^0 \to K^- X}{D^0 \to \text{all}} = 0.55 \; (^{19}) . \tag{A.7c}$$

([19]) G. H. TRILLING: *The properties of charmed particles*, preprint LBL-12283 (February 1981).

(*) We assume a single-track efficiency of $\sim 70\%$ in all the detector.

([20]) D. DRIJARD, H. G. FISCHER, W. GEIST, P. G. INNOCENTI, V. KORBEL, A. MINTEN, A. NORTON, S. STEIN, O. ULLALAND, H. D. WAHL, G. FONTAINE, P. FRENKIEL, C. GHESQUIÈRE, G. SAJOT, P. HANKE, W. HOFMANN, M. PANTER, K. RAUSCHNABEL, J. SPENGLER, D. WEGENER, H. FREHSE, E. E. KLUGE, M. HEIDEN, A. PUTZER, M. DELLA NEGRA, D. LINGLIN, R. GOKIELI and R. SOSNOWSKI: preprint CERN-EP/81-12 (1981), submitted to *Z. Phys. C*.

The quantity $(\Lambda_c^+ \to K^-X)/(\Lambda_c^+ \to \text{all})$ has not been directly measured, but can be derived via the relation

$$(A.8)\quad \frac{\Lambda_c^+ \to K^-X}{\Lambda_c^+ \to \text{all}} = \frac{\Lambda_c^+ \to \mathcal{N}X}{(\Lambda_c^+ \to \mathcal{N}X) + (\Lambda_c^+ \to \Lambda^0 X)} \, \frac{\Lambda_c^+ \to \mathcal{N}K^-X}{(\Lambda_c^+ \to \mathcal{N}K^0X) + (\Lambda_c^+ \to \mathcal{N}K^-X)}$$

since only the decay of the Λ_c^+ into a nucleon (proton or neutron) can produce a kaon in the final state.

The following quantities have been measured:

$$(A.9a)\quad \frac{\Lambda_c^+ \to \mathcal{N}X}{(\Lambda_c^+ \to \mathcal{N}X) + (\Lambda_c^+ \to \Lambda^0 X)} = 0.8\ (^{19}),$$

$$(A.9b)\quad \frac{\Lambda_c^+ \to pK^-\pi^+}{\Lambda_c^+ \to pK^0} = 2\ (^{19}).$$

By assuming

$$\frac{\Lambda_c^+ \to \mathcal{N}K^-X}{\Lambda_c^+ \to \mathcal{N}K^0X} = \frac{\Lambda_c^+ \to pK^-\pi^+}{\Lambda_c^+ \to pK^0},$$

relation (A.8) gives

$$(A.10)\quad \frac{\Lambda_c^+ \to K^-X}{\Lambda_c^+ \to \text{all}} = 0.8 \times 0.66 = 0.53\,.$$

Substituting the values (A.7*a*), (A.7*b*), (A.7*c*) and (A.10) into eq. (A.6), one obtains

$$\varrho'' = 0.45\,.$$

With the same reasoning the value of $B_{2,\Lambda}$ can be derived. The assumption $\varrho' = 0.25$ (one fourth of the K^- with $|x_L| > 0.3$ coming from charm) seems to be reasonably optimistic.

From eqs. (A.4*a*)-(A.4*c*), substituting the values (A.5) for the various parameters, one obtains

$$N = 7.4 \cdot 10^4\,,$$

to be compared with the number $1.2 \cdot 10^4$ of K^- with $|x_L| > 0.3$ observed by the *R*407/408 experiments [17,18].

The same «inconsistencies» existing in our data can thus be found also in the ACCDHW published results.

We believe that these «inconsistencies» are determined, firstly, by the errors intrinsic to the numerological arguments, and, secondly, by the scarce knowledge we have of the production of heavy flavours in high-energy (pp) interactions.

The same kind of inconsistencies are, in fact, found if one tries to determine the e/π ratio expected from the measured cross-sections of charm and beauty[21]

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[21] F. MULLER: *Charmed particles: properties and production characteristics*, lectures given at the *International School of Subnuclear Physics, Erice, 1980* (see preprint CERN-EP/80-195 (1980)).

and from the known semi-leptonic branching ratio of these heavy flavours. This expected e/π ratio turns out to be of the order of 10^{-3}, while the measurements centre at $\sim 1.5 \cdot 10^{-4}$ (see, for example, ref. [14]). Contrary to the ACCDHW Collaboration, we have measured the e/π ratio [14].

Our knowledge of heavy-flavour production in high-energy (pp) collisions can only be increased by further studies, and certainly not by criticizing the results already obtained by using arguments whose captious nature is demonstrated by the fact that the same authors do not apply the same arguments to their own results.

● RIASSUNTO

Scopo di questo lavoro è lo studio della presunta possibilità da parte dell'esperimento $R416$, effettuato dalla collaborazione ACCDHW, di osservare la produzione di « beauty » allo Split-Field Magnet degli ISR del CERN di Ginevra. Tale possibilità sarebbe basata su due caratteristiche essenziali: i) l'uso di una « nuova » versione dei programmi di ricostruzione consentirebbe un guadagno di un fattore 9 in efficienza di rivelazione rispetto ai « vecchi » programmi di ricostruzione; ii) la capacità di ottenere un fattore di reiezione di $1.5 \cdot 10^{-4}$ contro la contaminazione di adroni carichi usando due contatori Čerenkov di 1 m di lunghezza in serie. Il punto i) significherebbe, se confermato, che la « vecchia » versione dei programmi, usata per cinque anni nell'analisi dei dati dell'SFM, era incredibilmente inefficiente nonostante gli sforzi, da parte del gruppo che li ha approntati, di produrre un programma valido per gli utenti dell'SFM. La prova che i vecchi programmi danno dei risultati validi per quanto riguarda l'efficienza di ricostruzione è data dalle misure di molteplicità media $\langle n_{ch} \rangle$ in interazioni (pp) a tre diverse energie nel centro di massa, $\sqrt{s} = 30, 44, 62$ GeV, da noi ottenute. I valori di $\langle n_{ch} \rangle$ sono in ottimo accordo con le misure precedenti e corroborano la nostra confidenza nei « vecchi » programmi di ricostruzione. La nostra stima del guadagno dei nuovi programmi è un fattore ~ 3 inferiore al fattore 9 che si sostiene. Il fattore di reiezione contro adroni carichi da parte dei due Čerenkov in serie è stimato essere $7.1 \cdot 10^{-4}$, in buon accordo con il valore $\sim 10^{-3}$ universalmente accettato per tale tipo di rivelatore. La nostra conclusione è che l'esperimento $R416$ non ha il necessario potere di reiezione contro adroni carichi. Se ne conclude l'impossibilità da parte di tale esperimento di osservare la produzione di « beauty » agli ISR.

Исследование условий для наблюдения рождения « красоты » на встречных накопительных кольцах, используя два черенковских счетчика, расположенных последовательно, для идентификации $e^{\pm}$.

Резюме (*). — Цель этой работы — исследовать условия группы $R416$ для наблюдения рождения « красоты » в устройстве для расщепления магнитного поля на встречных накопительных кольцах в ЦЕРНе. Авторы отмечают два основных момента: 1) Используя « новый » улучшенный вариант программ восстановления,

(*) *Переведено редакцией.*

можно получить фактор ~ 9 для эффективности по сравнению со « старыми » программами восстановления; 2) с помощью двух черенковских счетчиков, каждый 1 м длиной и каждый с большой областью применимости, можно получить степень фильтрации заряженных адронов $1.5 \cdot 10^{-4}$. Пункт 1) означает, что « старые » программы, использованные в течемие пяти лет для анализа данных, являлись неэффективными, несмотря на все попытки получения разумной программы. Наши измерения средней множественности заряженных частиц $\langle n_{ch} \rangle$ при трех полных (pp) энергиях в системе центра масс: $\sqrt{s}=30$, 44, 62 ГэВ представляют доказательство, что « старые » программы правильно воспроизводят эффективность восстановления. Эти величины $\langle n_{ch} \rangle$ хорошо согласуются с предыдущими измерениями и подтверждают наше доверие к « старым » программам восстановления. Наша оценка эффективности для « новых » программ дает, по крайней мере, фактор ~ 3, т.е. меньше чем требуемый фактор 9. Что касается пункта 2), то хорошо известно, что правильная фигура не может быть лучше, чем $\sim 10^{-3}$. Любой экспериментатор может проверить этот пункт, если но это уже не сделал. Наше измерение дает $(7.1 \pm 2.0) \cdot 10^{-4}$ для импульса падающих частиц в интервале от 0.8 ГэВ/с до 3.0 ГэВ/с. Наш вывод из этого исследования состоит в том, что эксперимент $R416$ не обладает необходимой степенью фильтрации заряженных адронов. Следовательно, условия для наблюдения рождения « красоты » на встречных накопительных кольцах не найдены.