Strangelet Search in S-W Collisions at 200*A* GeV/*c*

K. Borer, F. Dittus, D. Frei, E. Hugentobler, R. Klingenberg, U. Moser, K. Pretzl, J. Schacher, F. Stoffel, and W. Volken
Laboratory for High Energy Physics, University of Bern, CH-3012 Bern, Switzerland

K. Elsener and K.D. Lohmann
CERN, CH-1211 Geneva, Switzerland

C. Baglin, A. Bussière, and J.P. Guillaud
Laboratoire de Physique des Particules, CNRS-Institut National de Physique Nucléaire et de Physique des Particules, F-74019 Annecy-le-Vieux, France

G. Appelquist, C. Bohm, B. Hovander, B. Selldèn, and Q.P. Zhang
Fysikum, Stockholm University, Box 6730, S-113 85 Stockholm, Sweden
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A search for new massive particles with a low charge to mass ratio in S-W collisions at a beam momentum of 200 GeV/c per nucleon is presented. Upper limits for the production of strangelets with a mass to charge ratio of up to 60 GeV/c^2 at rigidities of ±150 GV are reported.

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There are long-standing predictions that at high energy densities matter should undergo a phase transition to a deconfined, hot quark-gluon plasma (QGP). The cooling process of the QGP might result in droplets of strange matter [1], so-called strangelets. If so, strangelets will serve as a strong signature for the formation of a QGP. The existence of strange matter is of interest not only to particle physics but also to astrophysics [2,3]. As first pointed out by Witten [3], strange matter might be absolutely stable, and thus be the true ground state of matter. Strangelets can exist in charged or neutral form. Because of their s-quark content, strangelets are supposed to have a high mass ($M > 5\,\mathrm{GeV}/c^2$) and a low charge to baryon ratio ($|Z/A| < 0.3$).

Experimental searches for strange matter were recently carried out in heavy ion collisions at the Alternating Gradient Synchrotron at Brookhaven (experiments E814 [4], E858 [5], E878 [6], E886 [7]), and in a cosmic-ray experiment [8].

The data we present here were obtained during the sulphur beam period in 1992 at CERN. The experimental setup is shown schematically in Fig. 1. Particles were identified by the measurement of their rigidity R in the spectrometer [H6 beam line in the North Area at the CERN Super Proton Synchrotron (SPS)], their velocity, and their charge. The velocity was determined by time of flight (TOF) and the charge Z was measured using the dE/dx information of the TOF counters. In the relativistic limit, the mass of the particle in terms of the measured variables is

$$M = \sqrt{\frac{2\Delta t}{t_0}} RZ. \tag{1}$$

Here, $t_0 = d/c$ is the TOF of ultrarelativistic particles over the distance d. The measured time delay of heavier particles with respect to t_0 is Δt. The quantity $\Delta t/t_0$ is obtained from a linear fit to the arrival time measurements at the four TOF counter positions along the spectrometer. The TOF counters covered a total flight path of 262 m. The χ^2 of the fit was used as a consistency check and allowed us to reject background events efficiently. The charge was determined by fitting for each event a Landau distribution to the dE/dx values obtained from the TOF counters.

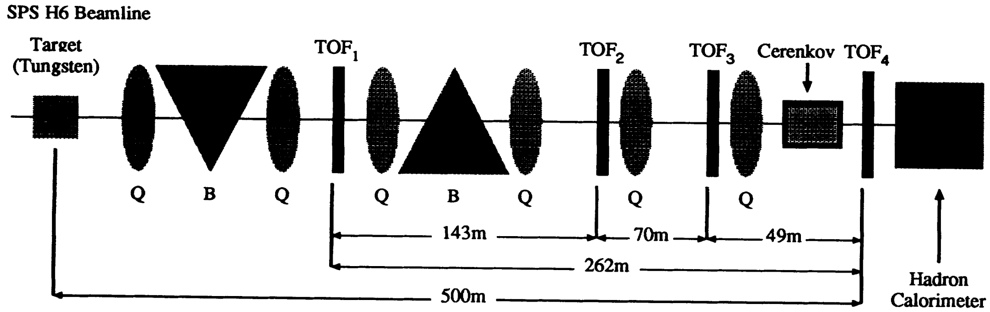

FIG. 1. Sketch of the experimental setup in the H6 beam line of the North Area of the SPS at CERN.

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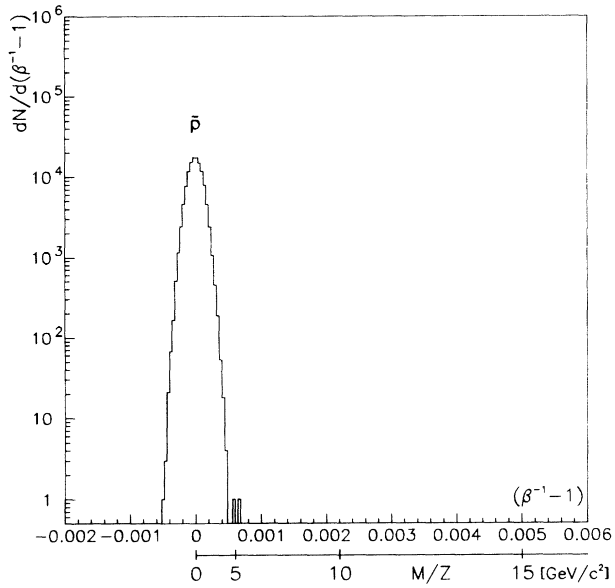

FIG. 2. Time of flight distribution of negatively charged particles not vetoed by the Čerenkov counter.

A TOF counter consisted of one vertical and one horizontal array of three scintillator strips (Bicron 404) each, with dimensions $75 \times 3 \times 1$ cm^3 and $10 \times 3 \times 0.5$ cm^3, respectively. Each scintillator strip was read out via a light guide and a phototube at both ends. These TOF counters were already used in another experiment [9]. The resolution σ_t of a TOF counter was about 100 ps resulting in a relative TOF resolution σ_t/t_0 of 10^{-4}.

The H6 beam line was operated at 0° production angle with a momentum acceptance $\Delta p/p$ of 3% and a solid angle acceptance of 2.3 μsr. The total distance from the production target to the last TOF plane was 500 m, requiring a particle lifetime $\gamma\tau \gtrsim 1.7\,\mu$s for detection.

The trigger was derived from a coincidence of three beam defining counters in anticoincidence with a threshold Čerenkov counter. The Čerenkov counter was used to avoid a too high trigger rate due to light particles. The Čerenkov signal was prescaled to record an appropriate fraction of light particles needed for the calibration of the TOF system. A segmented uranium/scintillator hadron calorimeter was used for the energy measurement.

The data were taken with spectrometer rigidities of +150 GV and −150 GV. The Čerenkov counter threshold for +150 GV was set between protons and deuterons, and

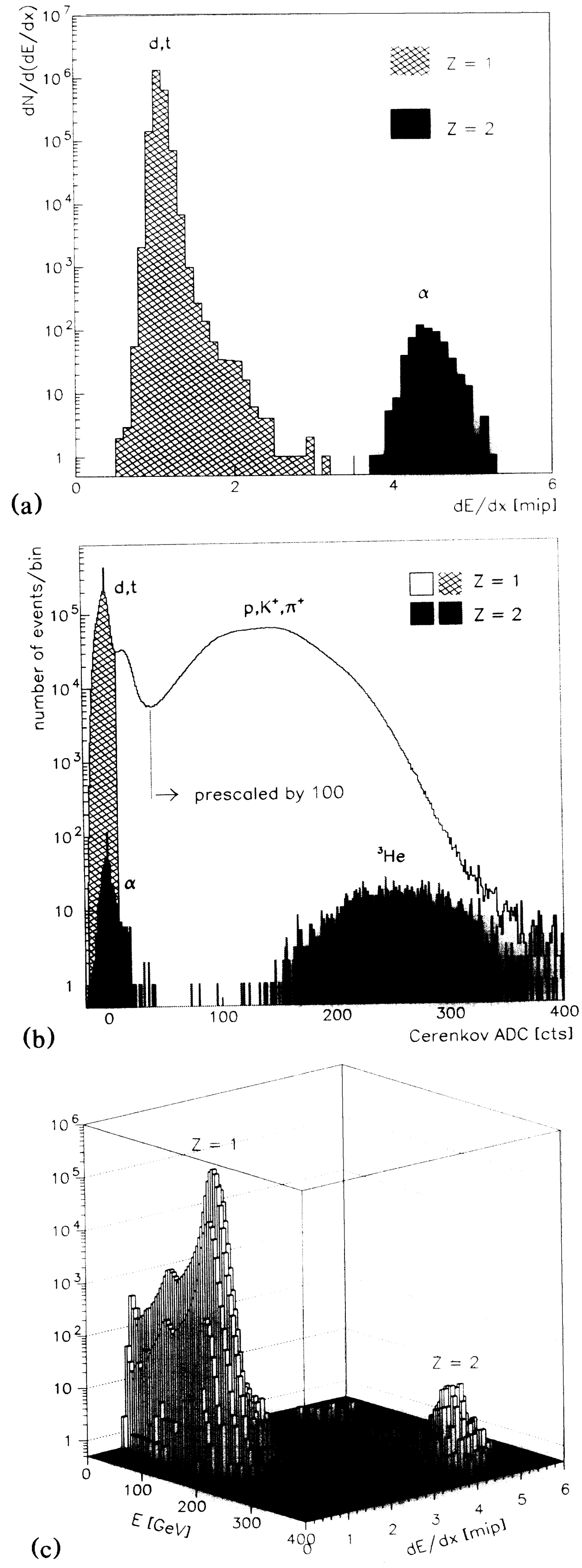

FIG. 3. Results for +150 GV: (a) dE/dx distribution of particles below the Čerenkov threshold. (b) Čerenkov pulse-height distributions of the particles with $Z = 1$ and 2. (c) Cross-check of the charge measurement: particles with $Z = 2$ have twice the energy of $Z = 1$ particles in the calorimeter. The enhancement at 75 GeV/c is due to deuterons, which broke up at the end of the beam spectrometer, and of which one of the nucleons was not detected.

a prescaling factor 100 was used. The tungsten target was 0.1λ thick. For data taking at -150 GV the Čerenkov counter threshold was set between K^- and $\bar{p}$, and the prescaling factor was 10. In this case, the thickness of the tungsten target was 1λ. The results reported below correspond to 2.3×10^{11} interactions at each polarity. Figure 2 shows the TOF distribution measured at -150 GV. Only particles not seen by the Čerenkov counter are shown here. No particles with charge $|Z| > 1$ were detected. Therefore the peak is mostly due to $\bar{p}$'s, possibly with some unresolved contributions from $\bar{d}$'s and $\bar{t}$'s. As shown in Fig. 2, no heavy object with mass $M > 5\,\mathrm{GeV}/c^2$ was observed.

In Figs. 3(a)–3(c) and Fig. 4 the results for $+150$ GV are shown. The charge separation of slow particles is demonstrated in Fig. 3(a). Events with $Z = 1$ contain d's and t's, which cannot be distinguished from each other. The events with $Z = 2$ are most probably due to α particles. Fast ^{3}He particles can clearly be identified from their pulse-height distribution in the Čerenkov counter as shown in Fig. 3(b). For a given rigidity particles with $Z = 2$ have twice the energy of particles with $Z = 1$. Therefore the energy measurement with the calorimeter can be used as a cross check of the charge of the particles as demonstrated in Fig. 3(c). In Fig. 4 the TOF distribution at $+150$ GV is shown. The observed tail for the $Z = 1$ events up to a mass of $10\,\mathrm{GeV}/c^2$ is due to a pileup effect in the electronics of the TOF system. No heavy object with a mass larger than $10\,\mathrm{GeV}/c^2$ was observed. The particle yields and ratios are summarized in Table I. The numbers are corrected for prescaling, efficiencies, and absorption in materials.

The sensitivity S for strangelets is defined as

TABLE I. Particle yields per 2.3×10^{11} interactions at 0° production angle. The particle ratios are normalized to the number of protons. The errors are mainly systematic.

	Yield	Ratio
p	$1.3 \times 10^9 \pm 5\%$	1
d	$5.7 \times 10^6 \pm 6\%$	$4.5 \times 10^{-3} \pm 8\%$
^{3}He	$4.9 \times 10^5 \pm 6\%$	$3.9 \times 10^{-4} \pm 8\%$
α	$1.6 \times 10^3 \pm 6\%$	$1.3 \times 10^{-6} \pm 8\%$
$\bar{p}$	$3.0 \times 10^5 \pm 13\%$	$2.4 \times 10^{-4} \pm 14\%$

$$S = \frac{1}{N_{\mathrm{int}} f \epsilon}, \qquad (2)$$

where N_{int} is the number of interactions, f is the fraction of strangelets which are accepted by the spectrometer, and ϵ is the detection efficiency. In order to calculate f, a strangelet production model with a factorized phase space distribution [10] was used:

$$\frac{d^2N}{dy\,dp_T} = \frac{4p_T}{\langle p_T\rangle^2} \exp\left(-\frac{2p_T}{\langle p_T\rangle}\right) \times \frac{1}{\sqrt{2\pi}\,\sigma_y} \exp\left(-\frac{(y-\bar{y})^2}{2\sigma_y^2}\right). \qquad (3)$$

Here, y is the rapidity of the strangelet, $\bar{y}$ is the rapidity of the c.m.s. of the nucleons participating in the interaction, and σ_y is the width of the rapidity distribution which was taken to be $\sigma_y = 0.5$. Since the transverse momentum of the strangelets is unknown, a value of $\langle p_T\rangle = 0.5\sqrt{M}\,\mathrm{GeV}/c$ was assumed [10], where M is the mass of the strangelet in GeV/c^2. The fraction f can

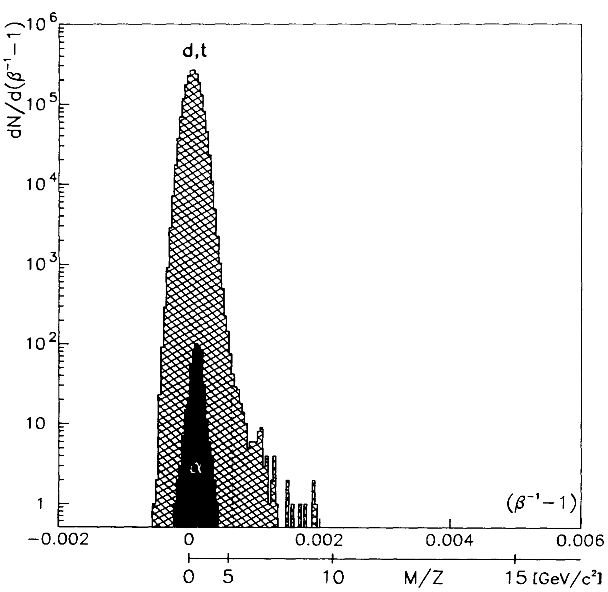

FIG. 4. Time of flight distribution of positively charged particles not vetoed by the Čerenkov counter.

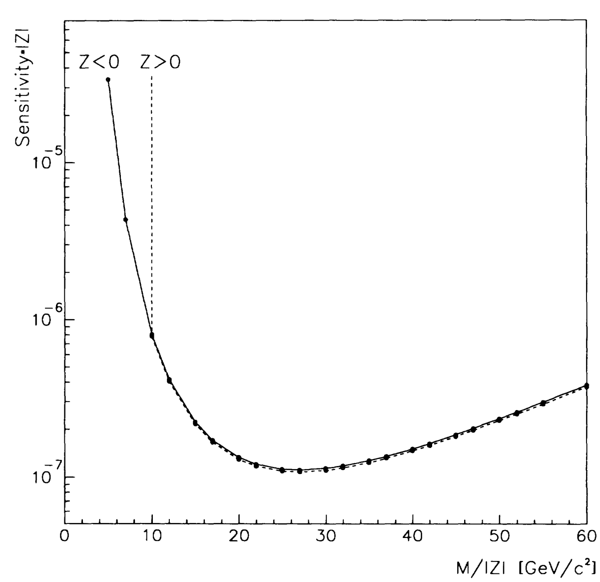

FIG. 5. Sensitivity$\times|Z|$ for strangelets of charge Z and mass M.

then be calculated by integrating $d^2N/dy\,dp_T$ over the acceptance in y and p_T of the spectrometer. The resulting sensitivity is shown in Fig. 5. However, it must be emphasized that the results strongly depend on the model parameters. For example, with $\langle p_T \rangle = 0.1\sqrt{M}\,\text{GeV}/c$ one obtains a 25 times better sensitivity.

In 2.3×10^{11} S-W interactions at $200\,\text{GeV}/c$ per nucleon no negatively charged object with a mass above $5\,\text{GeV}/c^2$ and no positively charged object above $10\,\text{GeV}/c^2$ was found. Encouraged by the success of this experiment, we are now preparing a new experiment, NA52 [11], to search for charged strangelets in Pb-Pb interactions at $160\,\text{GeV}/c$ per nucleon.

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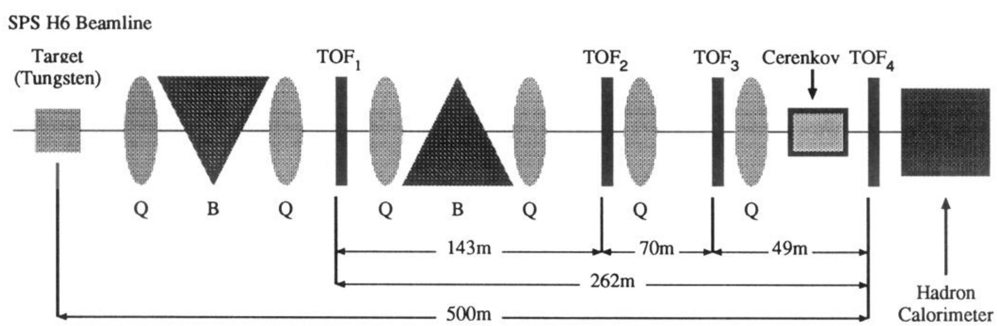

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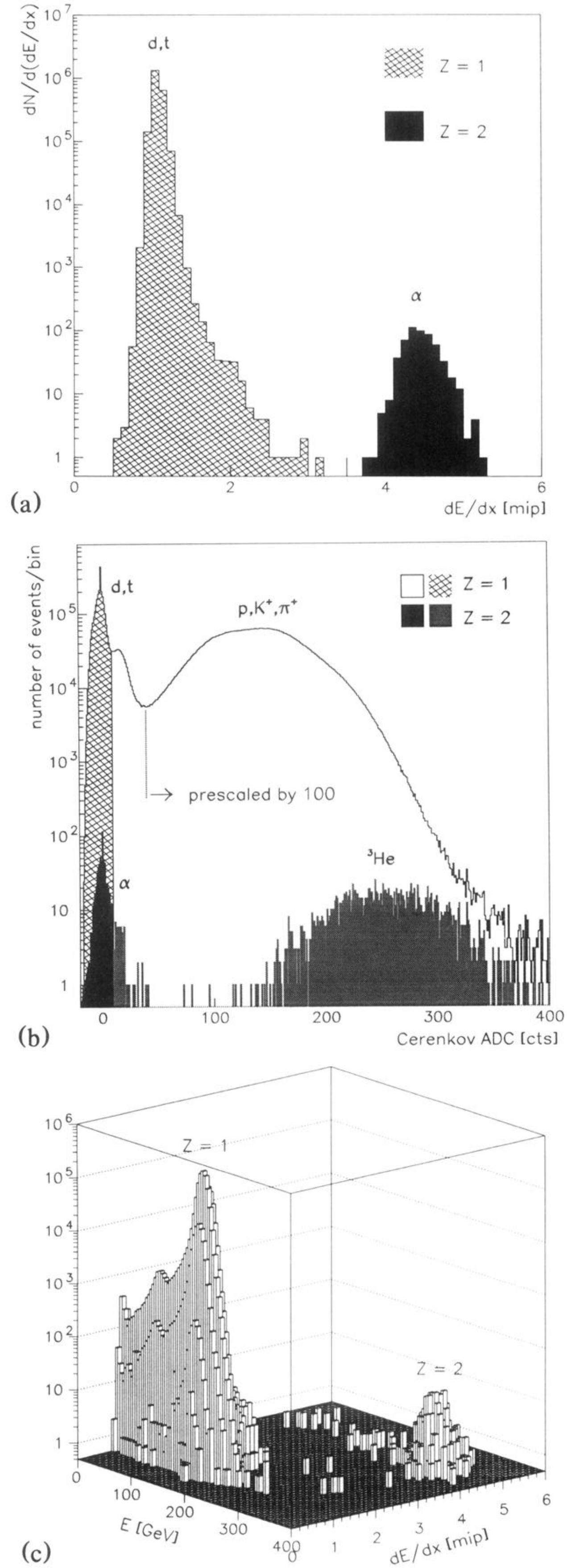

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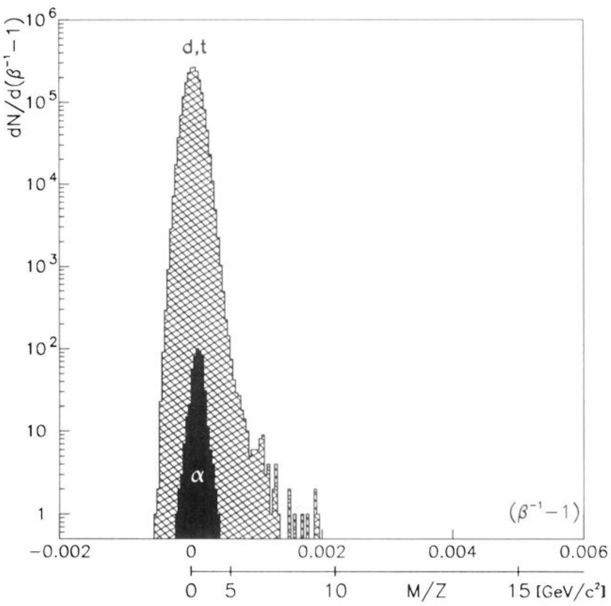

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