Towards a Determination of the Σ^--Charge-Radius in the WA89 Hyperon-Experiment at CERN

The WA89 Collaboration*

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Abstract

WA89 is a fixed target experiment using the 330 GeV hyperonbeam (33% Σ^- and 66% π^-) at the CERN–SPS. We report on our approach to determine the Σ^-–charge–radius by measuring the differential cross section $d\sigma/dQ^2$ of elastic Σ^-–e^-–scattering at low Q^2.

1 Introduction

The electromagnetic size of hadrons [1] [2] [3] is, similar to their magnetic moments an interesting quantity to probe the internal structure of hadronic matter. Electromagnetic radii $< r_h^2 >_0$ calculated within the nonrelativistic quark model turn out to be systematically too small (table 1) compared to the experimental values. To improve the calculations, a finit extension of the constituent quarks $< r_q^2 > \sim 1/m_q^2$ has to be taken into account. Weighting these squared radii with the charge of the respective quark gives a contribution

$$\Delta = \sum_q e_q \cdot < r_q^2 > \tag{1}$$

to the electromagnetic size of the hadron:

$$< r_h^2 > = < r_h^2 >_0 + \Delta. \tag{2}$$

The sum (1) is taken over all quarks, e_q beeing their charges. Using the known proton charge radius to tune the parameter, one can predict the charge radii $< r_h^2 > = < r_h^2 >_0 + \Delta$ of other hadrons (also table 1).

Experimentally, the electromagnetic radii of the Σ^- can be extracted from the differential cross section [4] of Σ^--e^- scattering given by

$$\frac{d\sigma}{dQ^2} = \left(\frac{d\sigma}{dQ^2}\right)_{mott} F^2(Q^2) \tag{3}$$

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with the four momentum transfer Q^2 and the electromagnetic formfactor squared:

$$F^2(Q^2) = \frac{G_e^2 + \frac{Q^2}{4M^2} G_m^2}{1 + \frac{Q^2}{4M^2}} + \frac{\frac{1}{2} Q^4}{4m^2 E_\Sigma^2 + Q^2 (M^2 + 2mE_\Sigma)} G_m^2. \quad (4)$$

M and E_Σ are the mass and energy of the beam-Σ^-, respectively, and m ist the electron mass. The electric and magnetic formfactor G_e and G_m both have a dipole form:

$$G_e(Q^2) = \frac{-1}{(1 + \frac{1}{12} < r_e^2 > Q^2)^2}, \qquad G_m(Q^2) = \frac{1 + \mu}{(1 + \frac{1}{12} < r_m^2 > Q^2)^2} \quad (5)$$

and depend on the electric and magnetic radius of the Σ^-, respectively.
Analog to the measurement of $< r^2 >_\pi$ and $< r^2 >_K$ we have to use inverse kinematics to measure the Σ^-–e^- scattering cross section. The existing hyperonbeam allows the investigation of the scattering of Σ^- off electrons from solid target materials. The low mass particle initially beeing at rest in the lab system (inverse kinematics) sets a very low upper limit on the maximum allowed Q^2. At our beam momentum of 330GeV, Q^2_{max}=0.06. An expansion of equation 4 therefore leads to

$$F^2(Q^2) = 1 - \frac{1}{3} < r_e^2 > Q^2 + \circ(Q^4), \quad (6)$$

where the $\circ(Q^4)$-term constitutes a correction of about 1% only. The slope of a linear fit to $F^2(Q^2)$ will therefore provide the charge radius whereas a measurement of the magnetic radius may not be possible.

2 Apparatus

WA89 is an experiment at the CERN SPS. It's main aim is the investigation of production and decay mechanisms of charmed baryons [5]. The detector is dedicated to serve this purpose.
The beam is produced from 450 GeV protons in a production target made of BeO [6] . A subsequent magnetic channel consisting of 3 magnets with an integrated field of 8.4 Tm each selects negative particles with a momentum of 330 GeV/c and a momentum spread of $\Delta p/p \approx 7\%$. The momentum is chosen to optimize the Σ^--flux ($2\cdot10^5$ Σ^-/Spill) and content (33% purity) of the beam. Pions contaminating the beam (66%) are rejected at the trigger level by a beam transition radiation detector (TRD). 12 planes of silicon detectors are used for beam finding, 28 planes placed downstream the target allow the reconstruction of production and decay vertices in the target region. The target itself consists of copper and carbon slices and the 12 most upstream silicon planes adding up to about 3.7% of an interaction length. A TRD based on microstrip gas chambers is placed downstream the silicon detectors serving electron identification. The particle momenta are measured by the Ω-spectrometer [7] consisting of a super-conducting magnet with a field integral of 7.2 Tm. Positioning of the target at about 13 m upstream of the Ω-spectrometer provides a 10 m long decay area for detection of strange particles. Tracks in the decay area are detected by 36 planes of drift chambers and 20 planes of multiwire proportional chambers. Downstream of the Ω magnet is a Ring Imaging Cerenkov Detector (RICH) [8] for identification of protons, kaons, pions and electrons. A lead glass calorimeter for photon and electron measurement [9] and a hadron calorimeter for neutron identification (SPACAL) [10] [11] form the end of the detector.

3 The Event Kinematics

Requiring 4–momentum conservation in the scattering process of a Σ^- off an electron at rest, the ranges of the scattering angles and the momenta of the scattered particles can be determined. The electron gets only little momentum ($p_e \leq 70 GeV/c$) and is scattered under a big angle ($\Theta_e \leq 10 mrad$). The Σ^- keeps most of its momentum ($p_\Sigma \leq 250 GeV/c$) and is scattered under a very small angle ($\Theta_\Sigma \leq 500 \mu rad$). The relevant detector resolutions were determined in MC simulations. They are: $\Delta\Theta_\Sigma$=23μrad, $\Delta\Theta_e$=110μrad, $\Delta p_\Sigma/p_\Sigma^2 = 9 \cdot 10^{-4}$/(GeV/c)). The error $\Delta p_e/p_e$ is dominated by Bremsstrahlungslosses of the electrons in target and detector material. $\Delta p_e/p_e$ is therefore not gaussian but described by a Bethe-Heitler-distribution the mean value of which is defined by the radiation length of target (35% for interactions in Cu and 9% in C) and the upstream part of the detector (5 %).

4 The Analysis Method

In the 1994 beamtime, 310 M events were recorded triggering on both charmed baryons and sigma electron scattering events. A first filter, requiring two negative and no positive particle seen in the spectrometer reduces the data to 1.2 M events.
Due to the large Bremsstrahlungslosses the measurement of the electron momentum is disturbed. The Q^2 of an event is therefore calculated by means of a constrained fit determining the maximum Likelihood

$$L_{max} = \max_{Q^2} P_1(\Theta_e) \cdot P_2(\Theta_\Sigma) \cdot P_3(p_e) \cdot P_4(p_\Sigma). \quad (7)$$

Here $P_i(X_i)$ is the probability to measure the respective quantity at the given value of Q^2 to be X_i. The functions P_i reflect the detector resolution. $P_3(p_e)$ therefore is given by a Bethe-Heitler spectrum whereas the other functions are gaussian with widths given above. L_{max} being large for scattering events and aquiring very small values for the largest part of backgroud events was used for a further filter stage keeping 60 K events. For further background reduction, electron identification will be used. There exist three detectors serving this purpose: The RICH detector is able to identify electrons in the momentum range below 25 GeV/c with a geometrical cut off of about $p_{min} \approx$15 GeV/c. The geometrical acceptance of the leadglass calorimeter starts at 35 GeV/c. The electron TRD in principle covers the whole momentum range but consisted in the 1994 run only of two of the eight planes foreseen. Its identification efficiency is therefore low. But the combination of these three detectors will provide a clean sample of scattering events.

5 Conclusions

The 1994 run of WA89 was used to record $\Sigma^- - e^-$-scattering data which are currently beeing analysed. Making use of the low multiplicity and the kinematics of these events, the data could be reduced to a sample of 60 K events. For further background reduction, e^--identification will be used. First results on $< r^2 >_{\Sigma^-}$ can be expected in the first half of 1996.

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particle	$< r^2 >_{exp}$	$< r_h^2 >_0$	Δ	$< r_h^2 >$
p	0.67 ± 0.02	0.27	0.40	0.67
Σ^-	?	0.24	0.31	0.55
π^+	0.44 ± 0.01	0.14	0.40	0.54
K^+	0.34 ± 0.05	0.13	0.27	0.40

Table 1: Experimental and calculated values of charge radii (in fm^2) of some hadrons

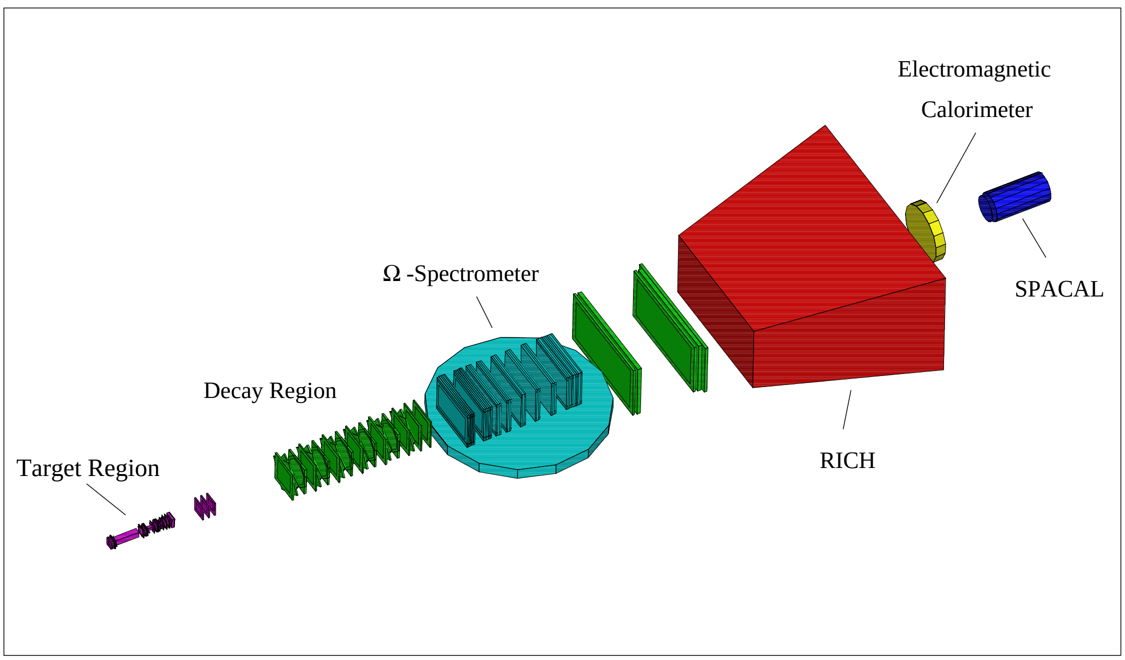

Figure 1: WA89–Setup in the beamtime 1994