Hyperon physics - the future?

V.J.Smith
Univ. of Bristol

- what I would like to do next...

$\Sigma^{\pm}$ semileptonic decays

* Why are they interesting?

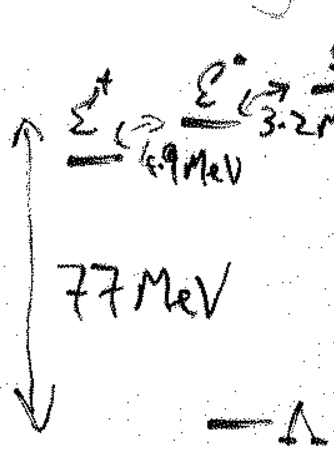
→ to measure purity of Λ
(is there a small mixing with Σ^0?)

u-d quark mass difference breaks isospin symmetry of strong interaction.
So the mass eigenstates are

$$\Lambda = \Lambda_8 \cos\phi + \Sigma_8^0 \sin\phi$$

$$\Sigma^0 = -\Lambda_8 \sin\phi + \Sigma_8^0 \cos\phi$$

How big is the mixing angle ϕ?



Σ^0 lies about 0.9 MeV above the mid point

$M_{\Sigma^0} - M_{\Lambda} = 77$ MeV

Notice $\frac{0.9}{77} = 1.2\%$

Karl (Phys Lett B328, 149 1994)
& Henley & Miller (HEP-PH-9408227)
estimate $\phi \approx 1.3\% - 1.5\%$

[2] * How to observe this?

perhaps by $\Sigma^0 \to \Lambda\gamma$ transition? (E-M)

$\mu(\Sigma\Lambda)$ measured by Primakoff effect $= -1.61 \pm 0.08$ nm

Theory (simple quark model):

$\mu(\Sigma\Lambda) = \frac{1}{\sqrt{3}}(\mu_d - \mu_u) = -1.63$ nm

so this measurement is inconclusive.

Related transitions: $\Sigma^\pm \to \Lambda e^\pm \nu$

now with a small piece of $\Sigma^\pm \to \Sigma^0_8 e^\pm \nu$ added, which will change the situation.

$\Sigma^+ \quad \Sigma^- \quad = \quad suu \quad sdd \qquad uu, dd = \text{spin } 1$

$\Sigma^0_8 \quad : \quad s\,ud \qquad ud = \text{spin } 1$

$\Lambda_8 \quad = \quad s\,\underline{ud} \qquad \underline{ud} = \text{spin } 0$

in these decays, s quark is a <u>spectator</u>

$\Sigma^- \to \Sigma^0_8$ (spin 1-spin 1) can be a Fermi transition f_1 or Gamow-Teller g_1

Cabibbo theory: $f_1 = \sqrt{2} \quad g_1 = \sqrt{2}\,F$

$\Sigma^- \to \Lambda_8$ (spin 1 - spin 0) can only be G-T

Cabibbo theory: $f_1 = 0 \quad g_1 = \sqrt{\frac{2}{3}}\,D$

(Cabibbo theory has 3 parameters, F, D, $\sin\theta_c$)

3) Now if $\Lambda = \Lambda_8 \cos\phi + \Sigma_8^0 \sin\phi$

$$f_1 : \quad 0 \longrightarrow \sqrt{2}\sin\phi$$

$$g_1 : \quad \sqrt{\tfrac{2}{3}}\, D \longrightarrow \sqrt{\tfrac{2}{3}}\, D\cos\phi + \sqrt{2}\, F \sin\phi$$

<u>Observables</u> Decay rate $\propto (f_1^2 + 3 g_1^2)$

$$\tfrac{2}{3} D^2 \longrightarrow \tfrac{2}{3} D^2 + \tfrac{4}{\sqrt{3}} DF\,\phi$$

ie $\Gamma(\Sigma^- \to \Lambda e^- \nu) = \Gamma_0\left(1 + \frac{2\sqrt{3}\,F}{D}\phi\right)$

since $\frac{F}{D}$ is experimentally $\simeq 0.63$, the correction becomes $\simeq +3\%$

and for $\Sigma^+ \to \Lambda e^+ \nu$ it is -3%

ie a difference of $\sim 6\%$ due to the mixing.

<u>NB</u> A larger, but easily calculable difference is the ratio of phase space in the two decays, because of the difference of $\Sigma^\pm$ mass:

$$R = \frac{\Gamma'_+}{\Gamma'_-} = \left(\frac{M_{\Sigma^+} - M_\Lambda}{M_{\Sigma^-} - M_\Lambda}\right)^5 \left(1 + 3\,\frac{M_{\Sigma^-} - M_{\Sigma^+}}{M_\Sigma - M_\Lambda}\right)$$

~~0.59~~ 0.61

One might also hope to measure f_1/g_1 in each decay: This $= 0$ without mixing and $\to \mp \frac{\sqrt{2}}{D}\phi$ with mixing

$= \mp\, 0.03$

Measure Λ spin direction (by $\Lambda \to p\pi^-$) asymmetry to e, ν direction

④

* What has been done already?

$\tau_{\Sigma^-} = 1.48 \times 10^{-10}\,s$ $\quad BR(\Sigma^- \to \Lambda e^- \nu)$
$= (5.73 \pm 0.25)\,10^{-5}$
(1843 events world total: 1620 events WA2)

$$\to \Gamma_- = \frac{5.7 \times 10^{-5}}{1.48 \times 10^{-10}} = 3.87 \times 10^5\ s^{-1} \quad (\pm 5\%)$$

$\tau_{\Sigma^+} = 0.8 \times 10^{-10}\,s$ $\quad BR(\Sigma^+ \to \Lambda e^+ \nu)$
$= (2.0 \pm 0.5)\,10^{-5}$
(21 events world total)

$$\to \Gamma_+ = \frac{2 \times 10^{-5}}{0.8 \times 10^{-10}} = 2.5 \times 10^5\ s^{-1} \quad (\pm 25\%)$$

So $\dfrac{\Gamma_+}{\Gamma_-} = \dfrac{2.5}{3.87} = 0.65 \pm 0.17$ (cf 0.61)

<u>inconclusive!</u>

Can we improve on this?

$\to$ Measure $\dfrac{\Gamma_+}{\Gamma_-}$ to better than 1% ?

So need to measure $\gg$ 10,000

of each decay $\Sigma^+ \to \Lambda e^+ \nu$
$\Sigma^- \to \Lambda e^- \nu$

5

10,000 s.l. decays means $\frac{10^4}{5.7\times10^{-5}} = \frac{1.75\times10^8}{(2\times10^8)}$ Σ^-

and $\frac{10^4}{2\times10^{-5}} = 5\times10^8$ Σ^+

Typical beam fractions at 330 GeV/c: $\Sigma^- \sim 30\%$ (foreground π^-)
$\Sigma^+ \sim 1\%$ (foreground p/π^+)

If beam rate $= 10^7\ s^{-1}$

$$\left.\begin{array}{l} \text{trigger live time} = 10\% \ (??) \\ \text{SPS duty cycle} = \frac{2.2}{14.5} = 15\% \\ \text{SPS efficiency} = 70\% \end{array}\right\} 1\%$$

We will have $3\times10^4\ s^{-1}$ of Σ^-
or $10^3\ s^{-1}$ of Σ^+ } in real time

Of these, perhaps 30% of Σ^- decay in fiducial volume of length 5m
$\lambda_{\Sigma^-} = 12.2$m at 330 GeV/c
and 50% of Σ^+ decay $\lambda_{\Sigma^+} =$ 665m

If experiment acceptance $\simeq 50\%$ (??) see later...

Then running time $\Sigma^- = \frac{2\times10^8}{0.5\times0.3\times3\times10^4} = 4\times10^4$ s
$\boxed{= 12\text{ hr}}$

& running time $\Sigma^+ = \frac{5\times10^8}{0.5\times0.5\times10^3} = 2\times10^6$ s
$\boxed{= 3-4 \text{ weeks}}$

*** Trigger** $e^{\pm}$ – TRD / Lead glass

Λ – multiplicity

(e threshold ?)

($\Lambda \to p\pi^-$ BR : 64%)

*** Backgrounds** $\Xi^- \to \Lambda\pi^-$ for –ve beam

1% of Σ^- ?

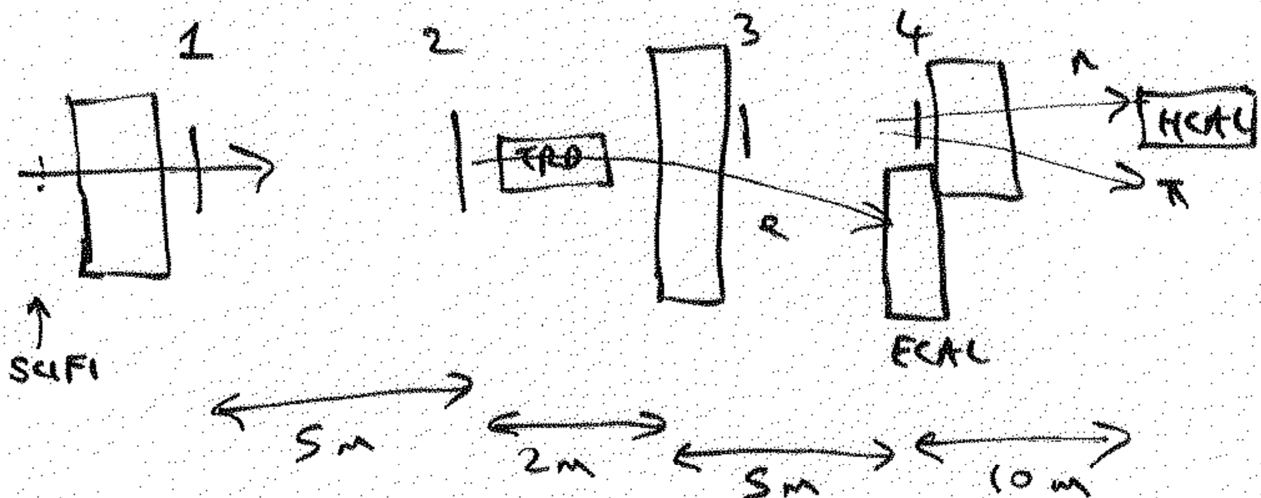
Inelastic collisions producing Λ and π^0 ($\to$ em showers) for both +ve and –ve beam $\Rightarrow$ helium bags

*** Normalisation** $\Sigma^- \to n\pi^-$ [NB $\bar{\Sigma}^+ \to \bar{n}\pi^+$]

$\Sigma^+ \to p\pi^0$, $n\pi^+$

(need hadron calorimeter)

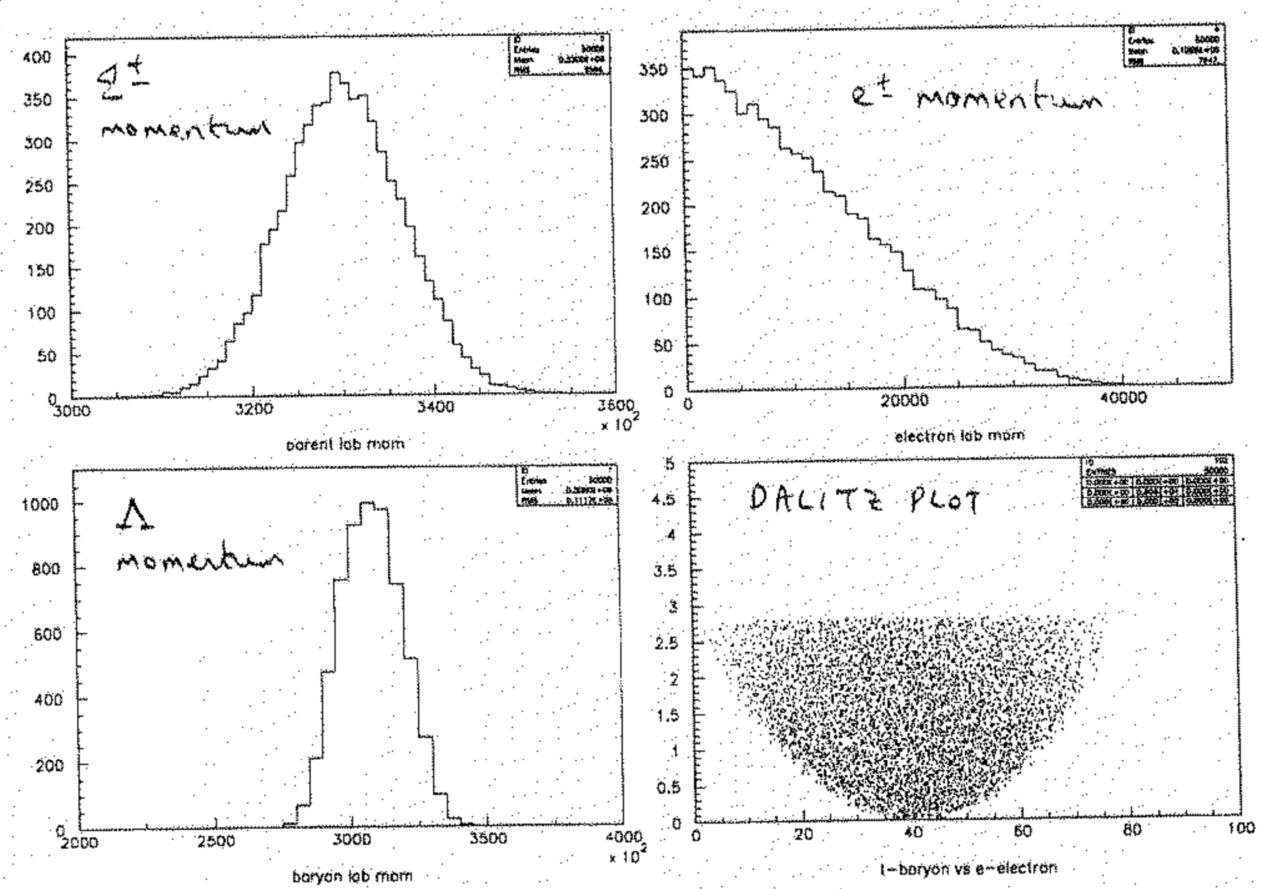
Need good momentum resolution for incident hyperon $\to$ scifi hodoscope ?



***

$\Sigma^{\pm} \to \Lambda e^{\pm} \nu \quad f_1 = 0 \quad g_1 = 1$

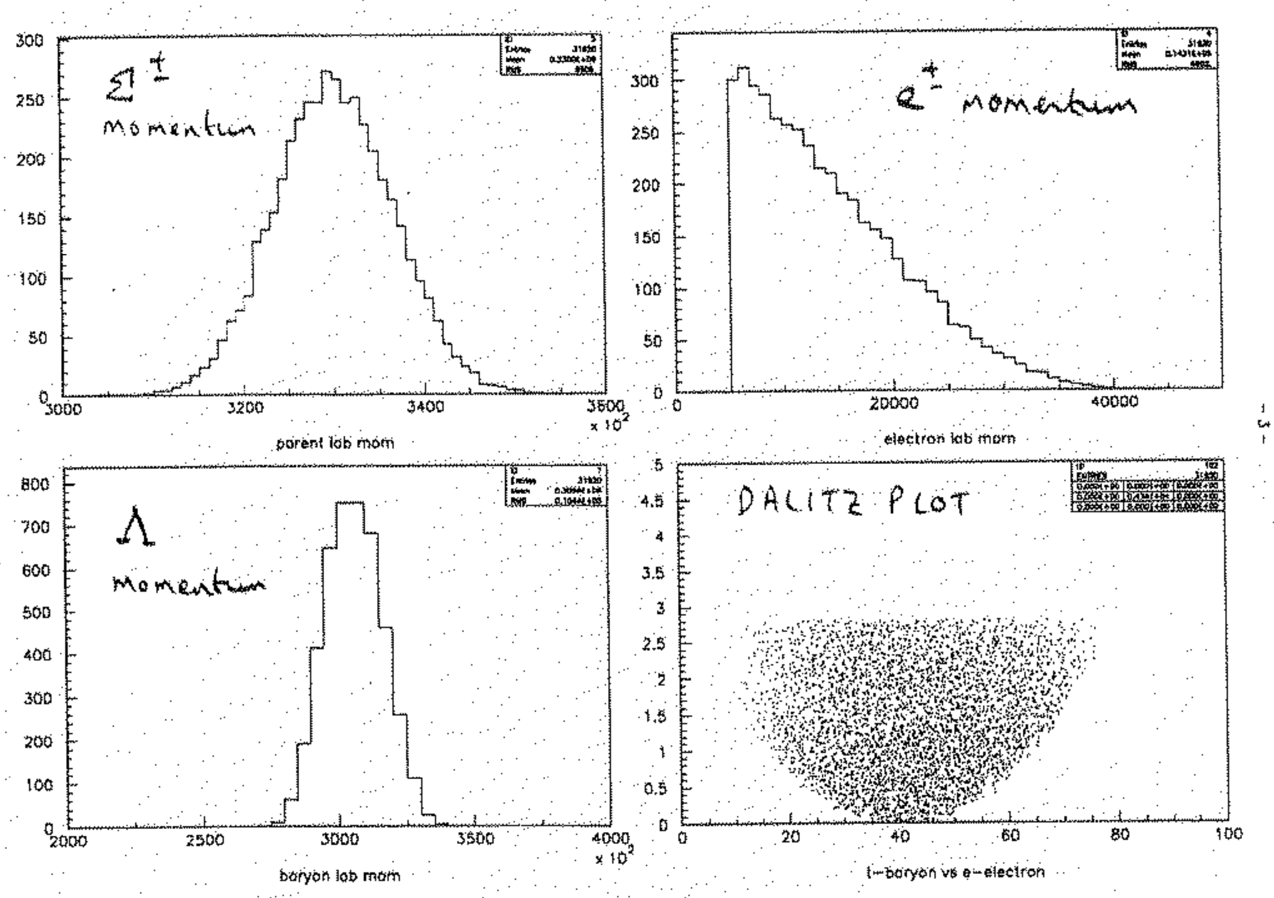
94/11/23 22.41



8)

$\Sigma^{\pm} \to \Lambda e^{\pm} \nu \quad f_1 = 0 \quad g_1 = 1$

94/11/23 22.39



[5 GeV cut on electron]