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An outlook for hyperon physics in the next millennium

It seems to me that the future of hyperon physics can be tightly connected with possible realization of VLHC project in Fermilab which includes the construction of the proton 3 TeV Booster

The fixed target program on this machine is capable to give a new life for hyperon studies.

Thus, to give you some qualitative and even quantitative estimations for the future in the next millennium, let me return back on 1.5 decade, in the middle of 80-ties.

1984-85. UNK program with fixed-target experiments at $E_p = 3$ TeV (IHEP, Protvino). Our great enthusiasm.

Is it possible to obtain a new quality in the experiments from the increase of energy

$$E_p = 0.9 \text{ TeV (now 1 TeV)} \longrightarrow E_p = 3 \text{ TeV} \ ?$$

a) charm physics?
   No, the gain is not very significant (special beams?)

b) Beauty physics?
   The increase in cross sections and fluxes is more important here.
   But pp colliders? Future B-factories (now they exist)? (spec. beams?)

c) lepton-hadron deep-inelastic processes, structure functions?
   Not very significant gain;
   future e-p colliders (now HERA exists)

d) neutrino physics?
   But it seems that for the most interesting problems (neutrino oscillations) we need low energy and high intensity (NUMI in Fermilab).

But there is one way for such qualitative progress – the experiments with hyperon beams!

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EXPERIMENTS ON HYPERON BEAM OF UNK

Collaboration IHEP-ITEP-LINP-INPS MSU*)

See also
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Protvino 1990

Hyperon beam of UNK 3 TeV proton accelerator (project)

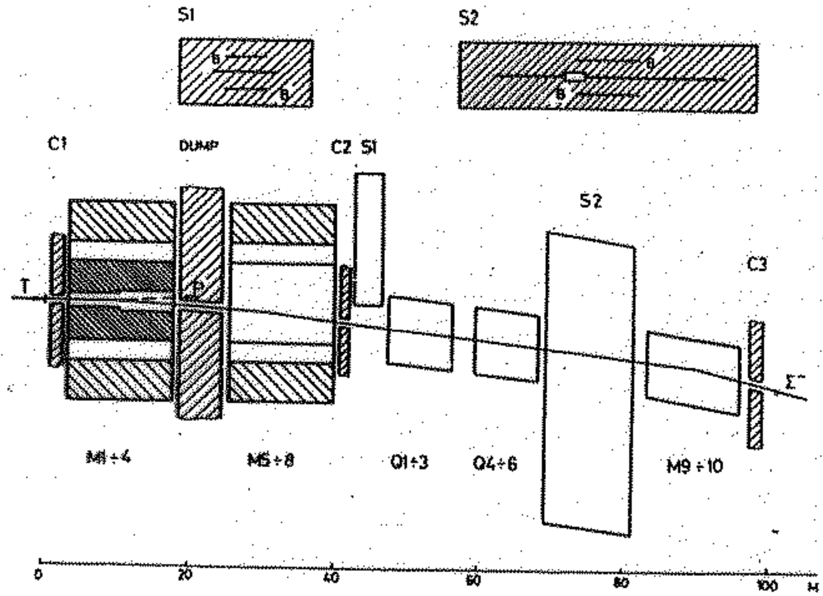

Fig. 1. Hyperon beam layout: T - target; M1-M4 - radiation resistant magnets; M5-M8 - magnets; M9, M10 - superconducting magnets; Q1-Q6 - SC quadrupole lenses; C1-C3 - collimators; DUMP - absorber to dump protons not interacting in the target; S1, S2 - magnet spoilers.

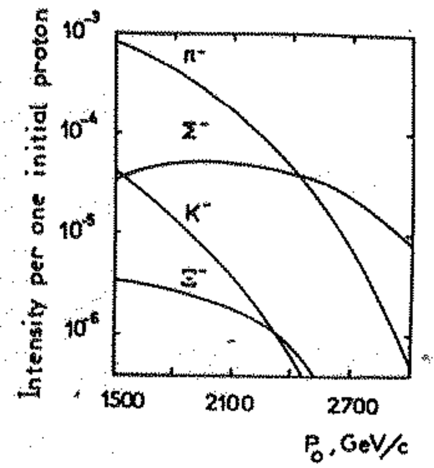

Fig. 2. Secondary particle flux at the end of the hyperon beam (for Be target 500 mm thick).

Table I. The Main Parameters of the Hyperon Beam.

Beam line length	100m
Total deflection angle	9.6 mrad
for M1-M8 set including	4.8 mrad
Maximum momentum	3000 GeV/c
Horizontal angular acceptance	0.3 mrad
Vertical angular acceptance	0.7 mrad
Selected momentum bite (FWHM)	20 %

Secondary particle fluxes at the end of the hyperon beam channel were calculated with the data borrowed from ref.[3]. They are presented in fig.2 and Tables II and III.

Table II. Σ^--hyperon beam characteristics.

p_o, GeV/c	$\langle p_\Sigma \rangle$, GeV/c	$\sigma_{\delta p}$, %	σ_x, mm	σ_y, mm	Σ^- hyperon intensity per incident proton	π^-/Σ^- intensity ratios
2100	2062	6.7	4.1	2.5	$5.0 \cdot 10^{-5}$	3.3
2400	2347	6.4	3.9	2.4	$4.1 \cdot 10^{-5}$	1.2
2700	2608	5.9	3.3	2.4	$2.5 \cdot 10^{-5}$	0.32
2850	2706	4.9	2.2	2.6	$1.6 \cdot 10^{-5}$	0.14
3000	2789	3.9	1.4	2.7	$8.0 \cdot 10^{-6}$	0.056

Note: Here p_o-momentum, corresponding to the optical beam axis, $\langle p_\Sigma \rangle$ average momentum of Σ^- beam at the end of the beam line.

$I_p = 10^{12}\ p/s$

$X_F \gtrsim 0.85 - 0.9$

$I(\Sigma^-) \simeq 10^7\ \Sigma^-/s$

$\%\ \Sigma^- \simeq (85 \div 90)\%$

muon halo ($\sim 1\ m^2$)

without magnetic shielding $\sim 2 \cdot 10^7\ \mu/s \cdot m^2$

with magnetic shielding $\sim (2 \div 3) \cdot 10^5\ \mu/s \cdot m$

$X_F \sim 0.75$

$I_{\pi^-} \sim 5 \cdot 10^6\ \pi^-/s$

$I(\Sigma^-) \sim 4 \cdot 10^6\ \Sigma^-/s$

$I(\Xi^-) \sim 10^5\ \Xi^-/s$

$I(\Omega^-) \sim 1.5 \cdot 10^2\ \Omega^-/s$

Fermilab hyperon } $I_p \sim 0.7 \div 1 \cdot 10^{11}\ p/s^{-1}$ } $I(\Sigma^-) \simeq 3 \cdot 10^5\ \Sigma^-/s$ || muon halo $\sim 1.5 \cdot 10^6\ \mu/s \cdot m^2$

1. Search for strange-charmed and strange-beauty exotic hadrons

$P^0 = (s\bar{c}uud)$; $\tilde{F}_s = sc\bar{u}\bar{d}$ (H. Lipkin); P_b ; $\tilde{F}_b$ (quasistable)

Search for other exotic hadrons in hyperon diffractive and Coulomb production processes, etc.

TABLE 2
Search and study of the production of exotic hadronic states.

Process	Experimental sensitivity	Notes
$\Sigma^- + N \to \underbrace{(ddsc\bar{c})^-}_{\hookrightarrow \Psi\Sigma^-} + N$ $\Sigma^- + N \to \underbrace{(ddsb\bar{b})^-}_{\hookrightarrow \Upsilon\Sigma^-} + N$	600 events/nb (for $\sigma_{dif.} \cdot BR[(ddsc\bar{c}) \to \Psi\Sigma^-]$). 200 events/nb (for $\sigma_{dif.} \cdot BR[(ddsb\bar{b}) \to \Upsilon\Sigma^-]$).	Diffractional production of cryptoexotic baryons with heavy quarks. Be target, 15 $g \cdot cm^{-2}$.
$\Sigma^-(p) + N \to \underbrace{(s\bar{s}c\bar{c})^0}_{\hookrightarrow \phi\psi;\ K^+K^-\psi} + X$ $\Sigma^-(p) + N \to \underbrace{(q\bar{q}b\bar{b})^0}_{\hookrightarrow \Upsilon\pi;\ \Upsilon\rho} + X$	300 - 600 events/nb; 200 events/nb } for $\sigma\|_{x>0.5\div0.9} \times BR$	Production of cryptoexotic mesons and baryons with heavy quarks in the reactions (8) and (9). Be target, 15 $g \cdot cm^{-2}$
$\Sigma^-(p) + N \to \underbrace{(\bar{c}uuds)^0}_{\hookrightarrow p(\phi,\eta)\pi^-;\ \Lambda K^+\pi^-}\|_{x_F>0.5} + X$ $\Sigma^-(p) + N \to \underbrace{(cs\bar{u}\bar{d})^0}_{\hookrightarrow \pi^+\pi^+K^-K^-}\|_{x_F>0.5} + X$	It is assumed, that the production cross sections of these open exotic states are $\sim 10^{-2}\ \sigma(\Xi_c)$ (see Table 1). The best possibilities for the identification of these states are for the hadrons which can decay only weakly (exposure with vertex detector). $10^3 \div 10^4$ events of this type for each process may be detected.	
$\Sigma^- + Pb \to \Sigma(3170)^-_\phi + Pb$ $\hookrightarrow \Sigma^- K\bar{K} + k\pi;\ \phi\Sigma^-$ $\Sigma^- + Pb \to \underbrace{(c\bar{c}dds)^-}_{\hookrightarrow \Psi\Sigma^-} + Pb$ $\hookrightarrow e^+e^-;\ \mu^+\mu^-$	This studies allow one to solve the problem on the existence of a narrow $\Sigma(3170)^-_\phi \equiv (ddss\bar{s})^-$ baryon, if $BR[\Sigma^-_\phi \to \phi\Sigma^-] > 0.04 \div 0.07$, or $\Sigma(5000)^-_\psi \equiv (c\bar{c}dds)^-$ if $BR[\Sigma(5000)^-_\psi \to \psi\Sigma^-] > 0.07$.	Experiments on exotic hadron production in the nuclear Coulomb field: $h + Pb \to$ (Exotic) + Pb. Pb target, 1.4 $g \cdot cm^{-2}$.

Notes:

1. The measurements are assumed to be carried out during 10 days ($3 \cdot 10^5$ s with an account of the accelerator duty factor) at the intensity of 10^7 particles/s.
2. In estimating the sensitivity the setup efficiency and secondary particles decay branchings (ϕ, ψ, Υ etc.) were taken into account.

2. Physics of strange-charmed and strange-beauty baryons of „ordinary" type

3. The elastic and inelastic hyperon scattering on the atomic electron target and the study of the Σ^-, Ξ^-, Ω^- hyperon formfactors and transition $\Sigma - \Sigma^*$ formfactors.

4. The Coulomb production of the excited hyperon states $\Sigma(1385)^{*-}$, $\overline{\Sigma(1385)^{*+}}$, $\Xi(1530)^*$, $\Lambda(1520)^*$, etc. and the measurements of their radiative decay widths. Some of these radiative processes are $SU(3)$ and $SU(6)$ suppressed. Polarizability of hyperons, mesons, protons.

5. The measurement of the Σ^- hyperon structure function and its comparison with the proton structure function in the reaction $\Sigma^- N \to (\mu^+\mu^-) + X$ and $pN \to (\mu^+\mu^-) + X$ at 3 TeV ($4 < m_{\mu^+\mu^-} < 25$ GeV).

6. Weak decays of Σ^-, Λ^0, Ξ^-, Ω^- hyperons (high precision studies of weak hyperon decays and search for rare processes of this type). The sensitivity of the relevant experiments may be 10^{-13} for Σ^- decays, 10^{-11} for the Ξ^- and Λ^0 decays, and 10^{-8} for Ω decays (the decay $\Xi^- \to \Lambda^0\pi^-$ is the source of the tagged polarized Λ^0 hyperons). Example: $\Sigma^- \to \Lambda e^- \bar{\nu}$ ($BR = 5.7 \cdot 10^{-5}$) $\sim 10^7$ decays/day; $\Sigma^+ \to \Lambda e^+ \nu$ ($\bar{\Sigma}^+ \to \bar{\Lambda} e^- \nu$) $\sim 10^3 - 10^4$ decays/day

7. A standard program for study of the hyperon strong interactions in a new energy region (total cross sections, elastic scattering, exclusive and inclusive processes, polarization experiments).

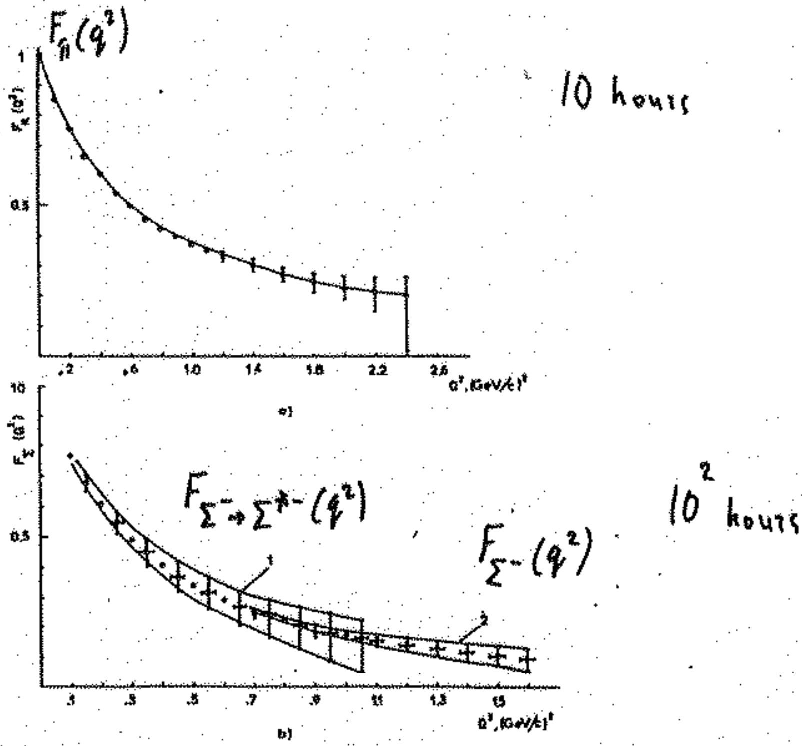

Fig. 13. Expected accuracies for form factor measurements a) F_π (q^2) (10^7 π/s; 10 hours); b) $F_{\Sigma^-}(q^2)$ and $F_{\Sigma^-\to\Sigma^{*-}}(q^2)$ (10^7 Σ^-/s; 100 hours)

Conclusion

1° It is a pity that we have finished the experiments on Fermilab hyperon beam – the best one in the world.

Many problems are not resolved
Many new interesting results would not be obtained

2°. If there would be in the future proton accelerator with $E_p \sim 3$ TeV – injector for a very big proton collider – it would be important to use it also for production of a high quality „pure" hyperon beam

$I(\Sigma^-) \sim 10^7 \Sigma^-/s$; $\% \Sigma^- \simeq (85-90)\%$

low background

3° A wide program of hyperon studies can be realized on this beam.