# NEW UPPER LIMIT FOR THE BRANCHING RATIO OF THE $\Omega^- \to \Xi^-\gamma$ RADIATIVE DECAY (E761 experiment, FNAL)

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Among the weak hyperon radiative decays, the $\Omega^- \to \Xi^-\gamma$ presents a special challenge to both experimentalists and theorists. This is because of the low flux of $\Omega^-$ when compared to other hyperons and the theoretical expectation of having the smallest branching ratio of all the hyperon radiative decays [1]. To the theorist the challenge is that this is the only such decay involving a transition from an SU(3) decuplet to an octet with the inherent complications of a spin 3/2 system. It has been conjectured [2,3] that this decay is a good testing ground for penguin diagrams whose magnitude remains uncertain.

The unitarity lower bound for the branching ratio [1] of the $\Omega^- \to \Xi^-\gamma$ is $0.8 \times 10^{-5}$. An estimate [1] of the real part of the amplitude leads to a branching ratio of $(1.0\text{–}1.5)\times 10^{-5}$. The only previous experimental information [4] for this decay is an upper limit of $2.2 \times 10^{-3}$.

The E761 experiment was performed at the Fermilab Proton Center beam line during the 1990 fixed target run. The main goals of the experiment were to determine the asymmetry parameter and the branching ratio for the weak hyperon radiative decays $\Sigma^+ \to p\gamma$ [5] and $\Xi^- \to \Sigma^-\gamma$ [6]. The 800 GeV/c proton beam from the Tevatron impinged on a 1 interaction length Cu target to produce a 375 GeV/c charged hyperon beam. This target was placed at the beginning of the channel inside the Hyperon Magnet (Fig.1).

The spectrometer was divided into three main systems in order to measure the trajectory and momentum of the hyperon, the baryon and the photon energy. The hyperon spectrometer consisted of 3 stations of silicon strip detectors (SSD's) with 50 $\mu$m pitch and one dipole magnet with a field integral of 4.3 T·m. The resolutions ($\sigma$) obtained for this part of the spectrometer were $\delta p/p = 0.7\%$, 12 $\mu$rad and 5 $\mu$rad for momentum, horizontal and vertical angles respectively.

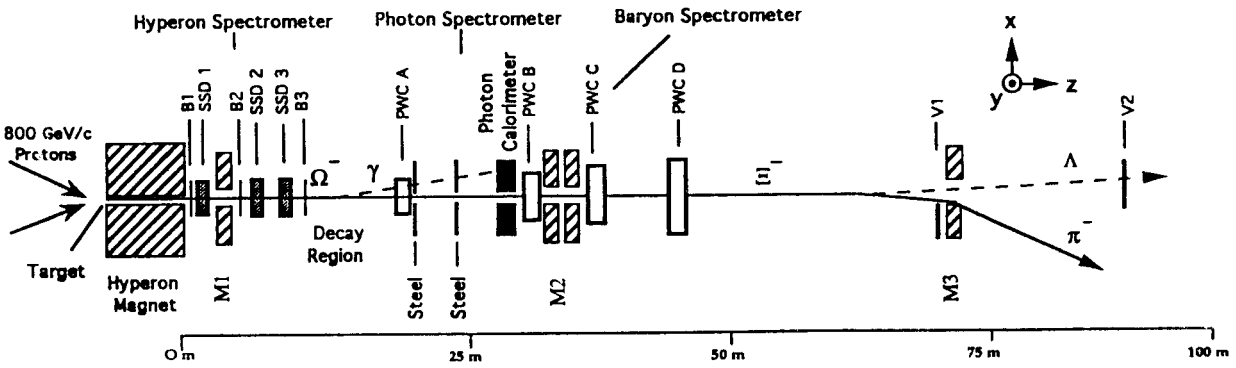


**Fig.1.** Plan view of the E761 apparatus in the Fermilab Proton Center charged hyperon beamline

The 12 m-long decay region (Fig.1) starting at 14 m from the target was filled with helium gas. The baryon spectrometer consisted of 4 stations of multiwire proportional chambers (MWPC's) and 2 dipole magnets (a total of 5.3 T·m). A third magnet (2.6 T·m) was situated downstream of the last MWPC in order to deflect low momentum baryons which were part of the background to another decay analyzed by E761, the $\Xi^- \to \Sigma^- \gamma$ [6]. The resolutions of the baryon spectrometer were $\delta p/p = 0.6\%$, 21 $\mu$rad and 12 $\mu$rad for momentum, horizontal and vertical angles respectively.

The photon spectrometer had two steel plates and a photon calorimeter which consisted of lead glass and bismuth germanate (BGO) blocks. The steel plates and the photon calorimeter had a hole in their center to allow the baryon through. A more detailed description of the E761 apparatus can be found in [5,6,7].

The trigger required a beam particle through a coincidence of the scintillation counters, a photon conversion in one of the steel plates and a high momentum baryon. The latter was defined by scintillation counters. Undecayed beam particles were rejected by counter V1 and low momentum baryons by V2 (see Fig.1). We collected 2.8 $\times 10^8$ events with this trigger.

The data analysed here were selected after requiring good quality hyperon and baryon tracks reconstruction, as well as a decay vertex in the decay region. We measured the missing neutral mass squared ($M^2_{x^0}$) under the hypothesis that the hyperon was an $\Omega^-$ and the baryon a $\Xi^-$.

The backgrounds consisted of the decays $\overline{\Sigma}^- \to \overline{p}\,\pi^0$, $K^- \to \pi^-\,\pi^0$ and $\Omega^- \to \Xi^-\,\pi^0$. These occur at a much higher rate than the $\Omega^- \to \Xi^-\,\gamma$ decay and have a $\pi^0$ in the final state which could satisfy the trigger. The first two can be separated using as kinematical variables the ratio between the baryon and hyperon momentum and the angle between their trajectories. The other source of background, $\Omega^- \to \Xi^-\,\pi^0$, is harder to separate due to

the small mass difference of $\pi^0$ and $\gamma$ compared to the momentum of the $\Omega^-$. In order to separate this source of background the information from the photon calorimeter was used. A further source of background is beam particle interactions. To decrease their number we required that the decay vertex occurred between 1 to 8 meters from the start of the decay region where the material in the beam is minimized.

Figure 2 plots $M^2_{x^0}$, under the hypothesis $\Omega^- \to \Xi^- X$, with all the data that survived the cuts described above. Note a clear signal for the $\Omega^- \to \Xi^- \pi^0$ and that there is no signal for the $\Omega^- \to \Xi^- \gamma$. The solid line corresponds to the fitted exponential background plus a Gaussian at the $\pi^0$ peak.

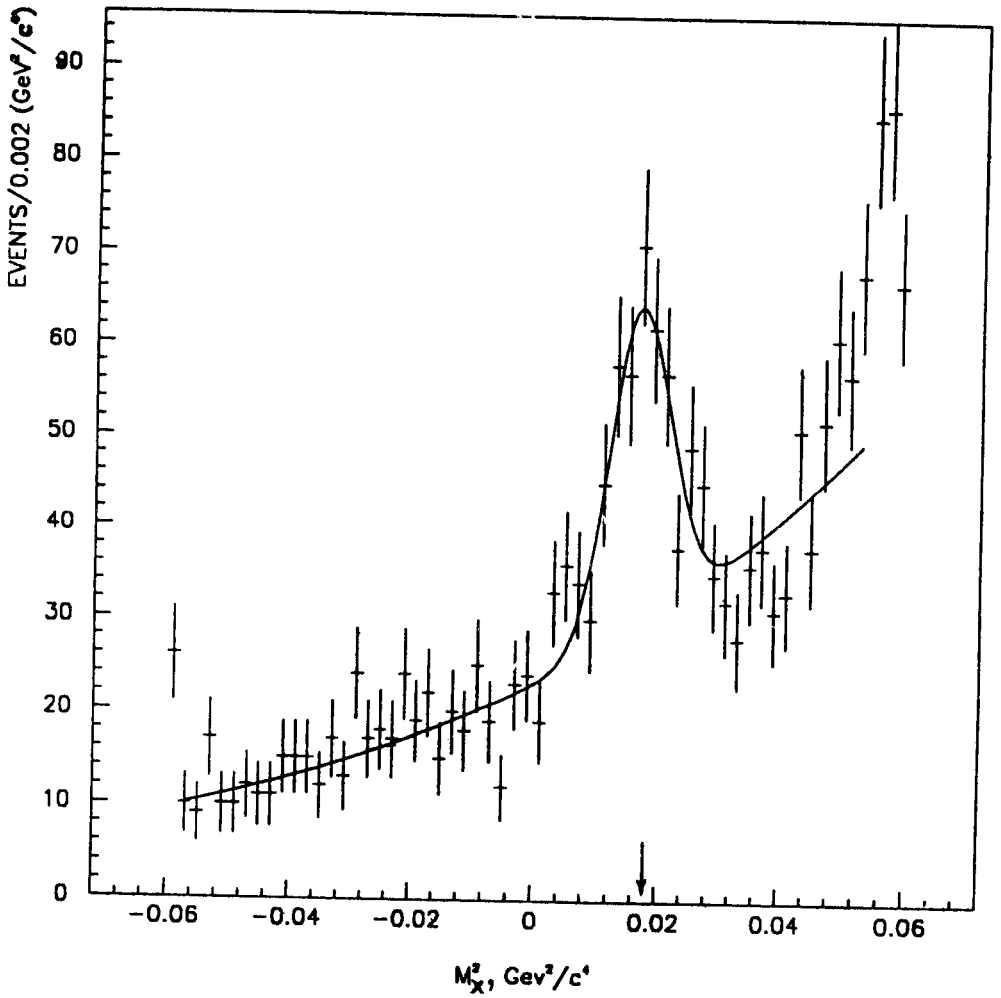


**Fig.2.** Distribution of $M^2_{x^0}$ for the hypothesis $\Omega^- \to \Xi^- X$. The arrow indicates the $\pi^0$ squared mass. No signal appears on the $\gamma$ squared mass

Two steps are then taken, one to confirm that there is no signal for the $\Omega^- \to \Xi^- \gamma$ and the other to obtain an upper limit with 90% C.L. The first consists of adjusting a Gaussian centered to the left of the $\pi^0$ peak (see Fig.2), by an amount equal to the $\pi^0$ mass squared and with the same width as the $\Omega^- \to \Xi^- \pi^0$ peak. The amplitude of such a fit is negative, which assures us that there is no signal around the $\gamma$ mass squared. The second step, in order to obtain the number of events that gives us 90% C.L., is to force the amplitude of the Gaussian to change in such a way that the $\chi^2$ of the fit will increase by 1.64 units. The

result of this procedure is a total of 9 events.

The normalization needed for extracting an upper limit for the branching ratio is provided by the $\Omega^-$ fraction in our secondary beam. This was determined by the analysis of the decays $\Omega^- \to \Lambda^0 K^-$ and $\Omega^- \to \Xi^- \pi^0$. Both analyses agree and the results are dominated by statistical errors. Their average gives an $\Omega^-$ fraction of $(4.8 \pm 0.4) \times 10^{-5}$ in the E761 hyperon beam, at 13.6 meters from the target. The average transverse momentum of production is 0.66 GeV/c while the average $X_F$ is 0.47.

The upper limit for the branching ratio is given by:

$$B < \frac{N_\gamma}{\varepsilon_\gamma \cdot f_{\Omega^-} \cdot N_{bp}} \tag{1}$$

where $N_\gamma$ is the number of $\Omega^- \to \Xi^- \gamma$ at 90% C.L., $\varepsilon_\gamma$ is the efficiency for this decay, $f_{\Omega^-}$ is the fraction of $\Omega$'s in the hyperon beam and $N_{bp}$ is the number of particles in the hyperon beam. $\varepsilon_\gamma$ includes geometrical acceptance, trigger and cuts efficiencies. It was determined by Monte Carlo studies that used the same experimental apparatus and the same trigger and cuts (except those related to the photon calorimeter) as the data analysed. The efficiency of the cuts related to the photon calorimeter was determined through studies using samples of single photons obtained from the $\Sigma^+ \to p\gamma$ analysis.

We obtain as a final result the following upper limit with 90% C.L.:

$$B(\Omega^- \to \Xi^- \gamma) < 4.6 \times 10^{-4} \tag{2}$$

This result is smaller than the previous upper limit [4] by a factor of 4.8. It confirms the indication [6] that radiative decays of hyperons which do not contain a valence $u$ quark have low branching ratious. We note that this new measurement is still more than an order of magnitude above the unitarity lower bound [1].

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