Hyperon Physics Symposium
HYPERON 99

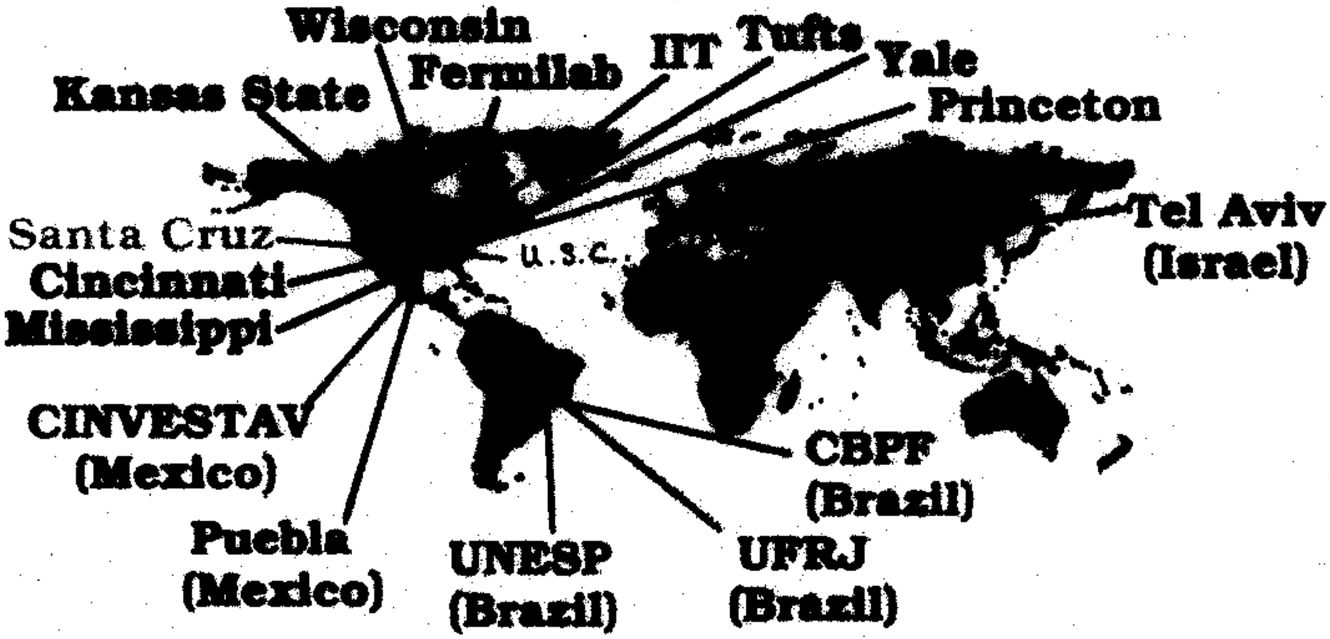
Fermilab, September 27-29, 1999

Particle/Antiparticle Asymmetries in the Producion of Hyperons in 500 GeV/c π^- – Nucleon Interactions

João C. Anjos

representing
E791 Collaboration

The E-791 Collaboration



Centro Brasileiro de Pesquisas Fisicas (CBPF)
University of California - Santa Cruz
University of Cincinnati
Fermilab
Illinois Institute of Technology (IIT)
Kansas State University
CINVESTAV (Mexico)
University of Mississippi
Princeton University
Universidad Autonoma de Puebla
Universidade Federal do Rio de Janeiro (UFRJ)
UNESP - Sao Jose do Rio Preto
University of South Carolina
Tel Aviv University
Tufts University
University of Wisconsin - Madison
Yale University

Motivation

- What we call particle antiparticle asymmetry is an excess in the production rate of a particle over its antiparticle (or vice-versa). It can be quantified by means of an asymmetry parameter as:

$$A_Y = \frac{N_Y - N_{\bar{Y}}}{N_Y + N_{\bar{Y}}} \quad (1)$$

where: N_Y ($N_{\bar{Y}}$) = number of baryons (antibaryons)

- The measurement of this parameter in the production of a given particle can be used to study non-perturbative QCD effects in quark production and hadronization.

- As an example this parameter can be used to put in evidence leading particle effects, which are manifest as an enhancement in the production rate of particles which have one or more valence quarks in common with an initial state hadron compared to that of their antiparticles which have fewer valence quarks in common.

- Other effect like associated production of baryons and mesons can also contribute to a non-zero value of the asymmetry parameter.

- Leading particle effects have been extensively studied in recent years in charm production from both experimental (WA89, ACCMOR, E769, E791) and theoretical point of view (Bengtsson and Sjostrand, Vogt and Brodsky, Hwa, etc.).
- Leading order QCD does not predict any asymmetry in this case. Next-to-leading order QCD predicts very small asymmetry. All proposed models incorporate some type of non-perturbative mechanism of recombination, responsable for the leading particle effect.
- The same type of leading particle effects are expected in light hadron production.
- Measurements of global asymmetries in Λ, Ξ and Ω have been reported (ACCMOR, E580, E415, E002, E281, E597 and E234) but in general light hadron production asymmetries in pion – nucleon interactions have not been studied systematicallly.
- In E791 we collected a large sample of hyperons Λ, Ξ and Ω, which we have used to measure the asymmetry parameter. The large statistics allowed for the first time to study the asymmetry as a joint function of xf and pt.

RECOMBINATION MODELS

A priori, given E791's π^- beam and nucleon target, recombination effects should produce strong differences in the asymmetries observed in the ($x_F > 0$) and ($x_F < 0$) regions since the content of valence quarks in the beam and target hadrons are different.

π^- – Nucleon Interactions

Beam: $\pi^-(\bar{u}d)$

Target: $p(uud)$ and/or $n(udd)$

- For Lambda: $\Lambda \rightarrow p\pi$

  $\Lambda^\circ\ (uds)$; $\bar{\Lambda}^\circ\ (\bar{u}\bar{d}\bar{s})$

  A growing asymmetry is expected in $\Lambda^\circ/\bar{\Lambda}^\circ$ production as $|x_F|$ increases in the negative direction towards the target fragmentation region. A smaller asymmetry or none at all is expected for $x_F > 0$ increasing towards the beam fragmentation region, because $\Lambda^\circ(uds)$ and $\bar{\Lambda}^\circ(\bar{u}\bar{d}\bar{s})$ each share one valence quark with the incident $\pi^-(\bar{u}d)$.

- For Cascade: $\Xi \rightarrow \Lambda\pi$ **with** $\Lambda \rightarrow p\pi$

  $\Xi^-(dss)$; $\bar{\Xi}^+(\bar{d}\bar{s}\bar{s})$

  For $\Xi^-/\bar{\Xi}^+$ production, a growing asymmetry with $|x_F|$ is expected in both regions since the $\Xi^-(dss)$ shares one valence quark with the π^- as well as with the target $p(n)$ whereas the $\bar{\Xi}^+(\bar{d}\bar{s}\bar{s})$ none.

- For Omega: $\Omega^- \rightarrow \Lambda K$ **with** $\Lambda \rightarrow p\pi$

  $\Omega^-\ (sss)$; $\bar{\Omega}^+\ (\bar{s}\bar{s}\bar{s})$

  No leading particle effects are expected for $\Omega^-(\bar{\Omega}^+)$ which shares no quarks with either the target or the beam.

The E791 Experiment

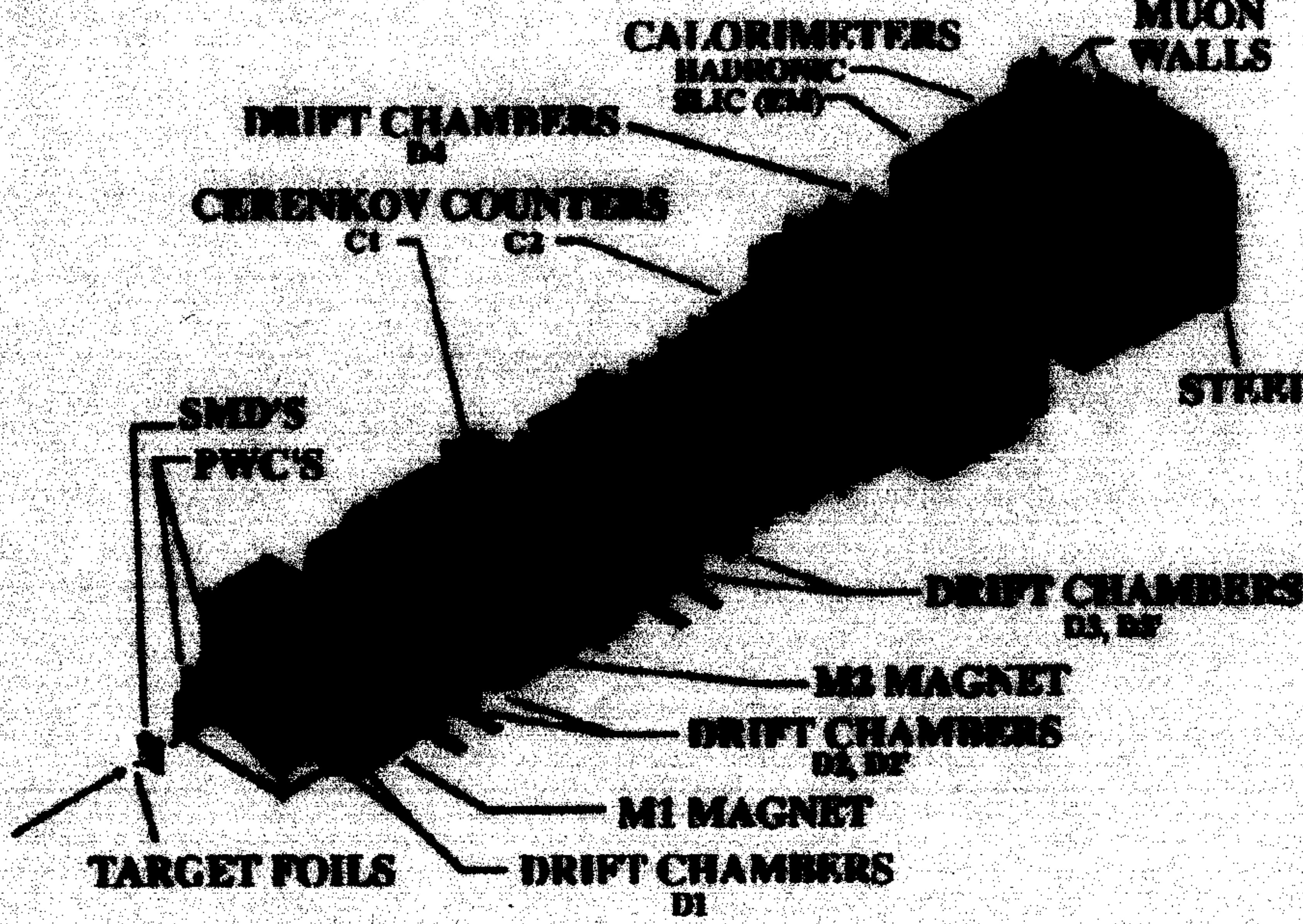
The Spectrometer

- Upgrade of photoproduction experiments E516 and E691 and hadroproduction experiment E769, located at the Tagged Photon Laboratory
- Beam of 500 GeV/c π^-; Platinum and Diamond targets
- Beam tracking: 8 planes of MWPC's and 6 planes of SMD's
- 17 planes of SMD's (Silicon Microstrip Detectors) for track and vertex reconstruction
- 2 MWPC's and 35 drift chamber planes in 4 stations
- 2 threshold Čerenkov counters
- 2 analysing magnets (same polarity)
- Electromagnetic and hadronic calorimeters
- Muon detector system (scintillators behind steel)

Data Sample

- Collected 20 billion events on 24,000 8mm tapes during 6 months in 1991
- Hadronic interaction and loose transverse energy requirement in trigger
- Fully reconstructed more than 200,000 charm mesons and many millions of strange baryons

E-791 Spectrometer



Event Selection Criteria

Event Selection

- **We used only interactions in the isoscalar carbon targets, that have same number of protons and neutrons.**
- **We select the hyperons wich decayed with decay point before the first magnet and downstream of the SMD planes.**

Λ Event Selection

- **Λ°'s were reconstructed using the $p\pi^-$ decay mode only.**
- **Selection criteria (cuts):**
  - Proton and π^- tracks had a distance of closest approach less than 0.7 cm at the decay vertex
  - Invariant mass between 1.101 and 1.127 GeV/c^2
  - The ratio of the momentum of the proton to that of the pion was required to be larger than 2.5
  - The reconstructed Λ° decay vertex formed by the two tracks was required to be downstream of the last target
  - Impact parameter with respect to the primary vertex less than 0.3 cm if decaying within the first 20 cm and 0.4 cm if decaying more than 20 cm downstream of the target region (to avoid lambdas from cascade decays)

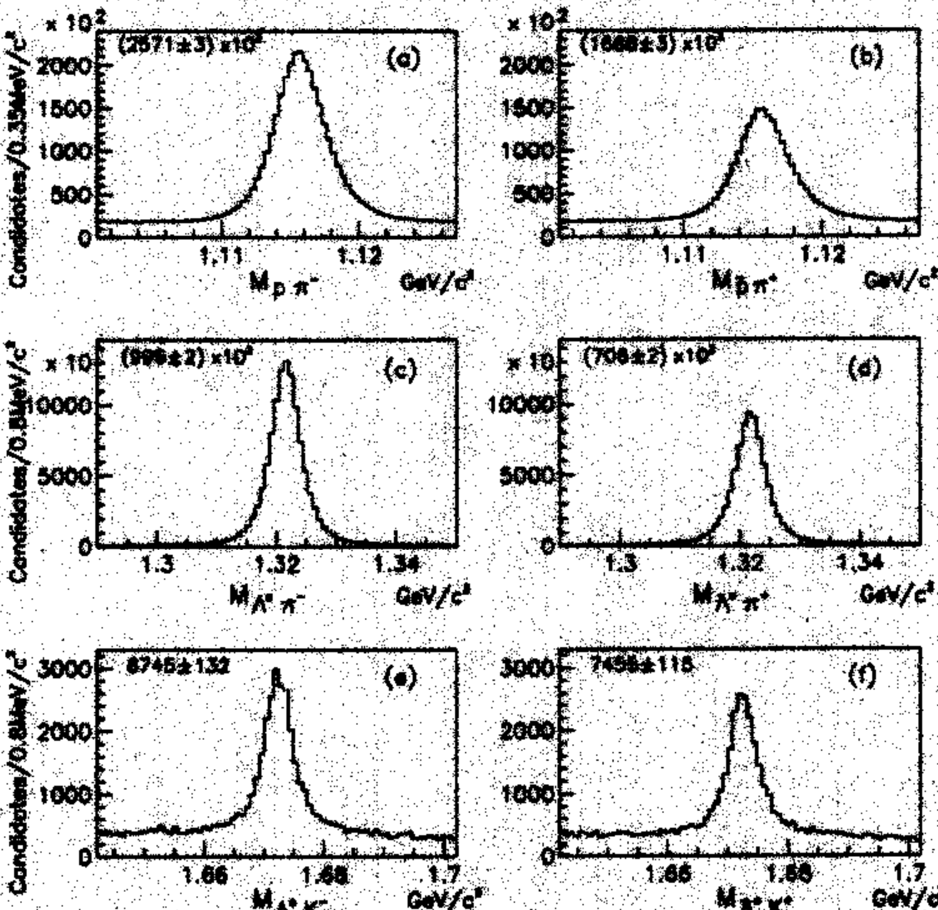
Ξ/Ω Event Selection

- Ξ^-'s were selected via the decay mode $\Xi^- \to \Lambda^\circ \pi^-$.
- Ω^-'s from the $\Omega^- \to \Lambda^\circ K^-$ channel.
- Selection criteria (cuts):
  - Starting with Λ° candidates we added a third, distinct track as a possible pion/kaon daughter.
  - All three tracks were required to be only in the drift chamber region
  - The cuts for Λ° were the same as those above except for that on the impact parameter
  - Invariant mass for Ξ^- between 1.290 and 1.350 GeV/c^2
  - Invariant mass for Ω^- between 1.642 and 1.702 GeV/c^2
  - The charged hyperon track, entirely in the SMD region, also had to be identified:
    * Its direction had to match that determined by its daughter tracks in the drift chamber region to within 1 mrad
    * Distance of closest approach to the primary vertex less than 100 μm
  - The Ξ^- (Ω^-) decay vertices were required to lie in the region upstream of the Λ° decay and downstream of the SMD region
  - For the Ω^- sample, the third track had to have a kaon signature in the Čerenkov counters. The kaon identification efficiency was about 85% in the momentum range 6-40 GeV/c. The probability for misidentifying a pion as a kaon was about 5%

Final Data Sample

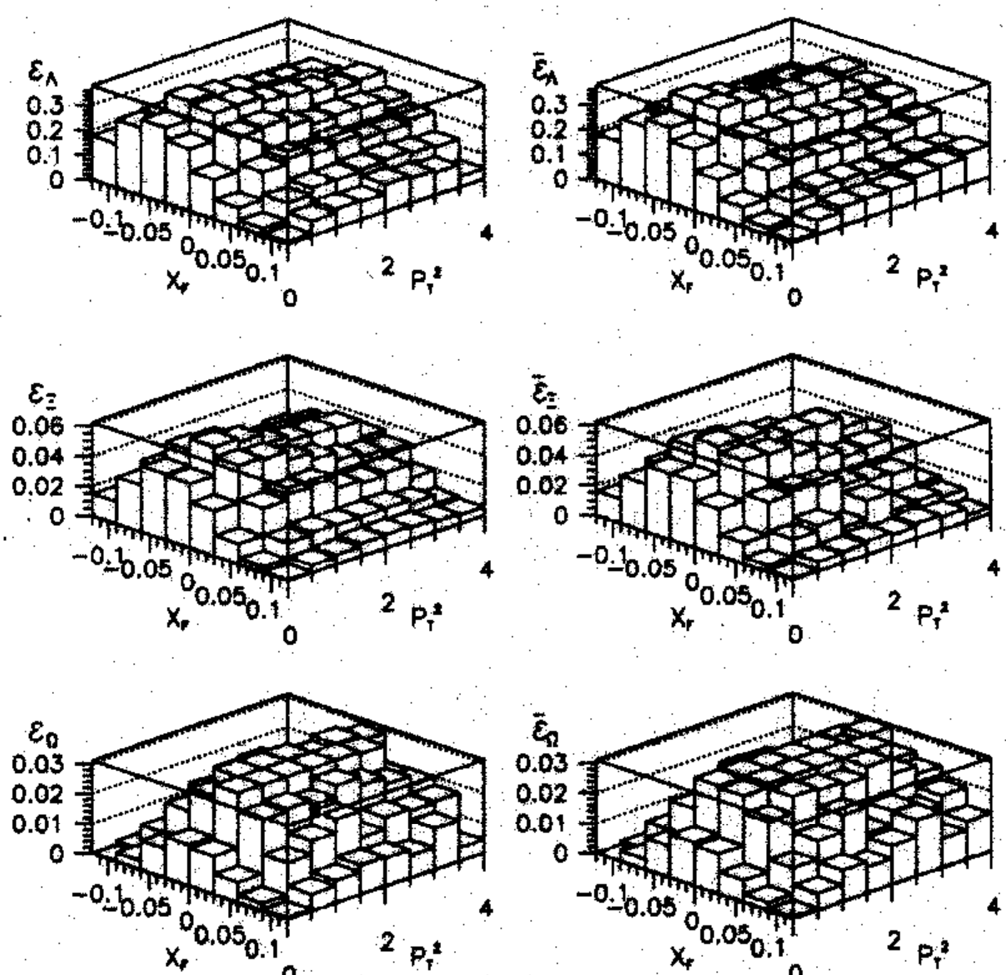
Signal Measurement

- Fit with Gaussian signal and linear background function for each interval of x_F and p_T^2.
- $2\,571\,700 \pm 3\,100$ Λ^0's and $1\,669\,000 \pm 2\,600$ $\bar{\Lambda}^0$'s,after background subtraction, taken from approximately 6.5% of the total E791 data sample
- $996\,200 \pm 1\,900$ Ξ^-, $706\,600 \pm 1\,700$ $\bar{\Xi}^+$, $8\,750 \pm 130$ Ω^-, and $7\,460 \pm 120$ $\bar{\Omega}^+$, with the 100% of E791 data



Efficiency Studies

- MC Generation: **5 million Λ's, 16,4 million Ξ's and 4,8 million Ω's**
- Correction for Efficiency: **The acceptance correction, for each hyperon, was made for each 2-dim interval x_F–p_T^2**



Systematic Effects

We looked for systematic effects from the following sources:

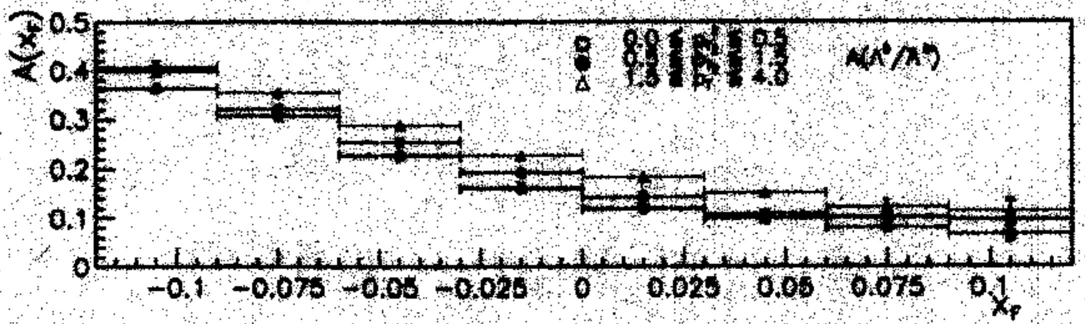
- Event selection criteria;
- The minimum transverse energy in the calorimeters required in the event trigger;
- Uncertainties in calculating relative efficiencies for particle and anti-particle;
- Effect of the 2.5% K^- contamination in the beam.

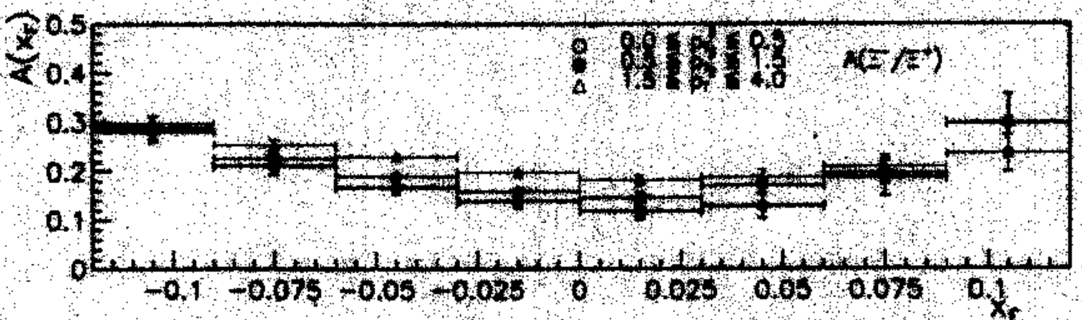
The first two effects were found to be negligible. The kaon contamination is hard to estimate but the extrapolation of data on hyperon asymmetries in K^- production in our x_F range would change our final results by about 1.5%. The only significant effect came from the spectrometer efficiency, and this uncertainty is included as a systematic error.

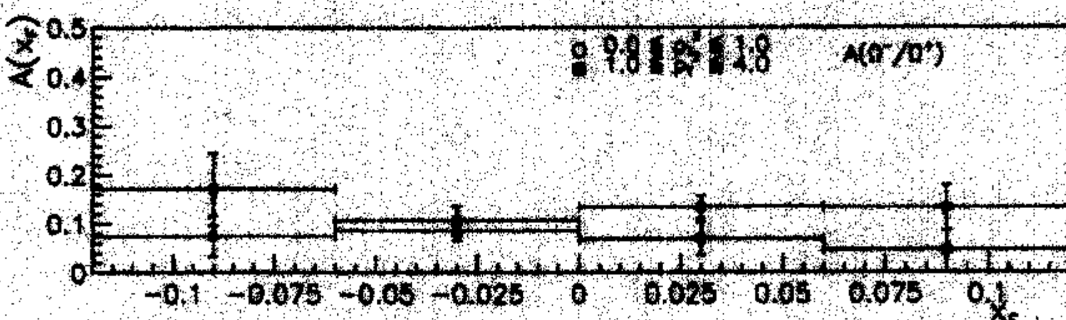
We also study:

- Effects of K_s^o contamination in the Λ sample.
- Stability of the analysis considering different fidutial volumes.
- Binning effects

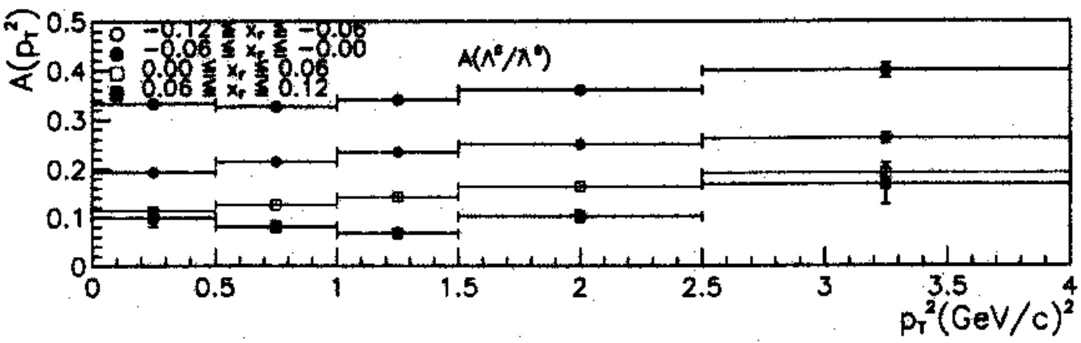
Final Results – A(x_F)

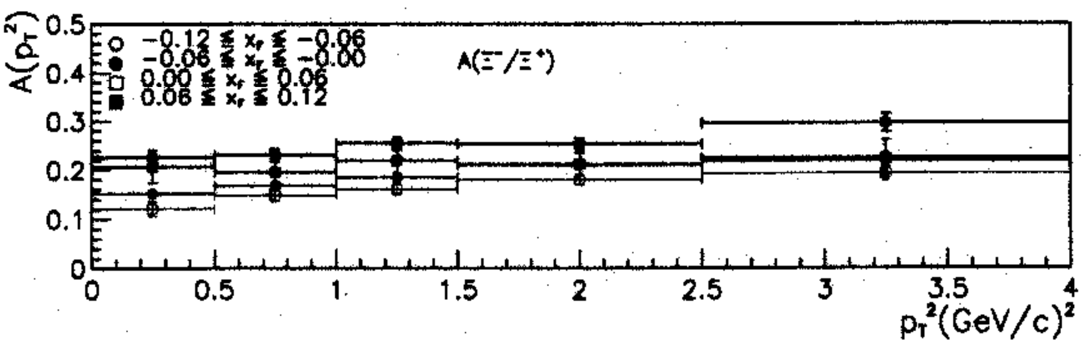


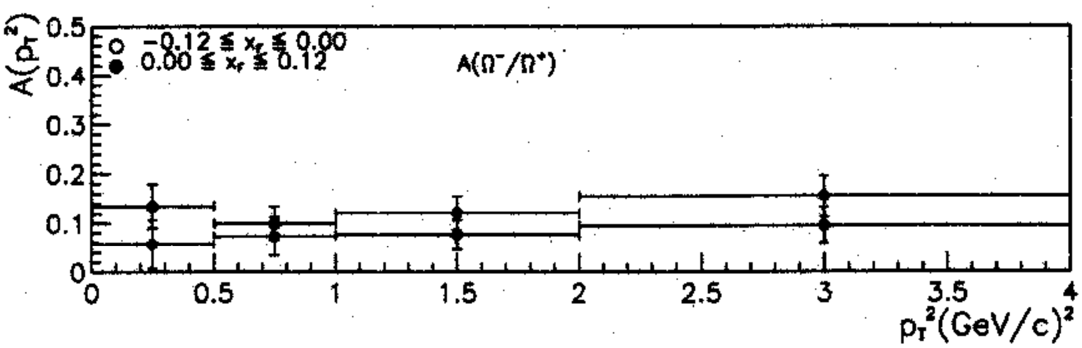




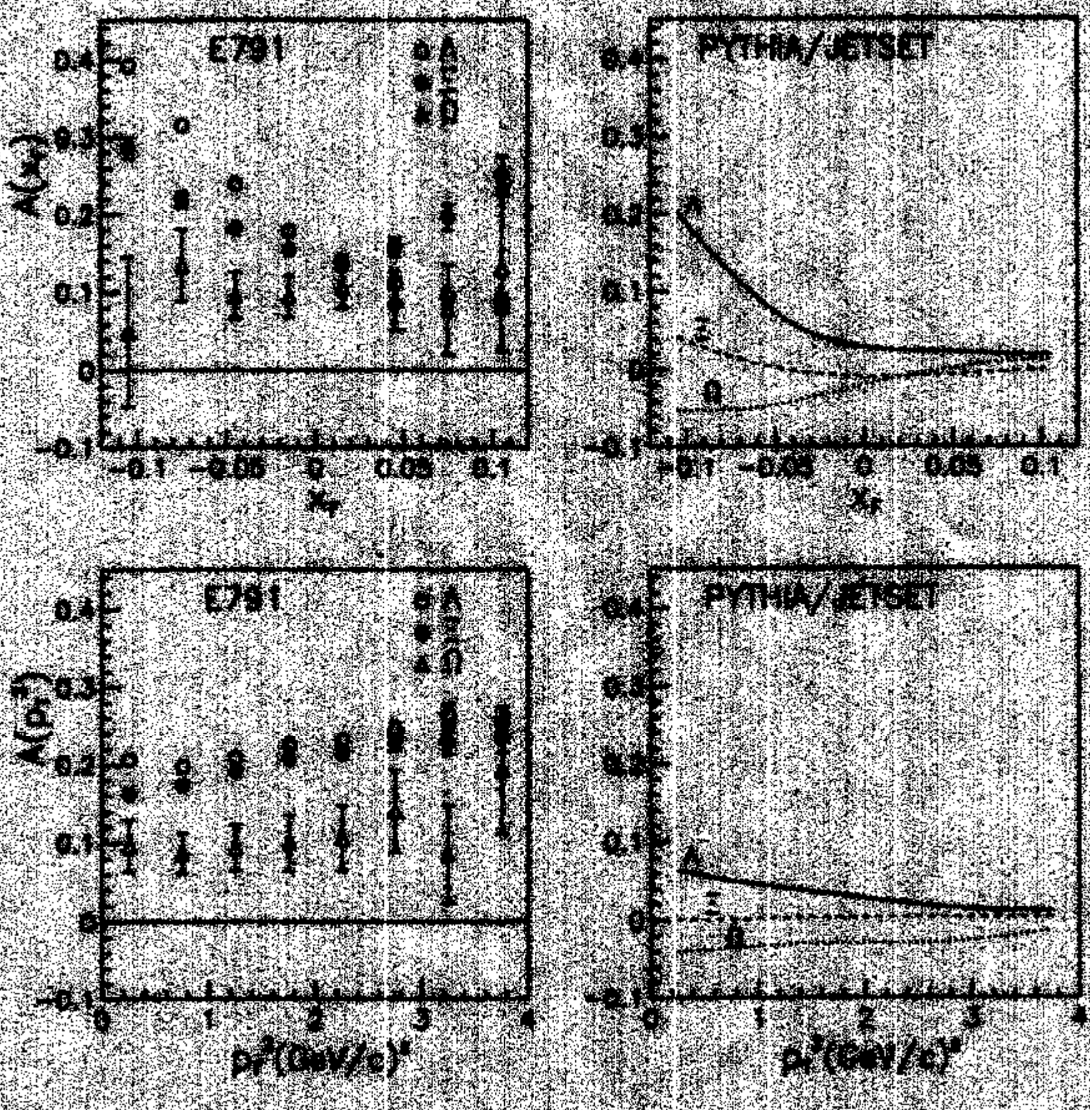
Final Results – A(p_T^2)







Final Results – Λ, Ξ and Ω



Conclusions

- The Pythia/Jetset model describes only qualitatively our results.
- Our data show that, even in the central region, the asymmetries are not zero, and suggest that leading particle effects play an increasingly important role as $|x_F|$ increases
- We have reported the most precise, systematic study to date of the production asymmetry for Λ, Ξ and Ω hyperons in a single experiment
- The range of x_F covered, $-0.12 \leq x_F \leq 0.12$, allowed the study of asymmetries in regions close to $x_F = 0$ for the first time in a fixed target experiment.
- Our results can be described qualitatively in terms of recombination models and the energy thresholds for the production of hyperons and anti-hyperons together with their associated particles.

- The observed positive asymmetry for Ω could arise from the associated production of kaons. This could also be the origin of the observed positive asymmetry near $x_F = 0$ for Ξ's and Λ's.

- The associated production enhancement of baryons as opposed to antibaryons may come from the higher energy thresholds for the production of antibaryons.

- Some evidence on possible correlations between x_F and p_T has been observed

- Our results for particle/antiparticle asymmetries are consistent with the experimental results obtained by previous experiments.

Final asymmetries of Λ, Ξ, and Ω showing the statistical plus systematical errors. Results of ACCMOR integrated over the range $0 \le x_F \le 0.35$ are shown for comparison.

	E791 $-0.12 \le x_F \le 0.12$	E791 $-0.12 \le x_F \le 0$	E791 $0 \le x_F \le 0.12$	ACCMOR $0 \le x_F \le 0.35$
$A(\Lambda^0/\bar{\Lambda}^0)$	0.207 ± 0.001	0.242 ± 0.002	0.124 ± 0.002	0.119 ± 0.009
$A(\Xi^-/\bar{\Xi}^+)$	0.176 ± 0.004	0.186 ± 0.004	0.150 ± 0.007	0.130 ± 0.050
$A(\Omega^-/\bar{\Omega}^+)$	$0.0[illegible] \pm 0.013$	$0.0[illegible] \pm 0.018$	0.101 ± 0.020	0.107 ± 0.070

Hyperon Physics Symposium
HYPERON 99

Fermilab, September 27-29, 1999

Particle/Antiparticle Asymmetries in the Producion of $\Lambda_c^+/\bar{\Lambda}_c$ in 500 GeV/c π^- – Nucleon Interactions

João C. Anjos

representing

E791 Collaboration

$\Lambda_c^+/\bar{\Lambda}_c$ asymetries in E791.

Λ_c's were selected in the $pK\pi$ decay mode.

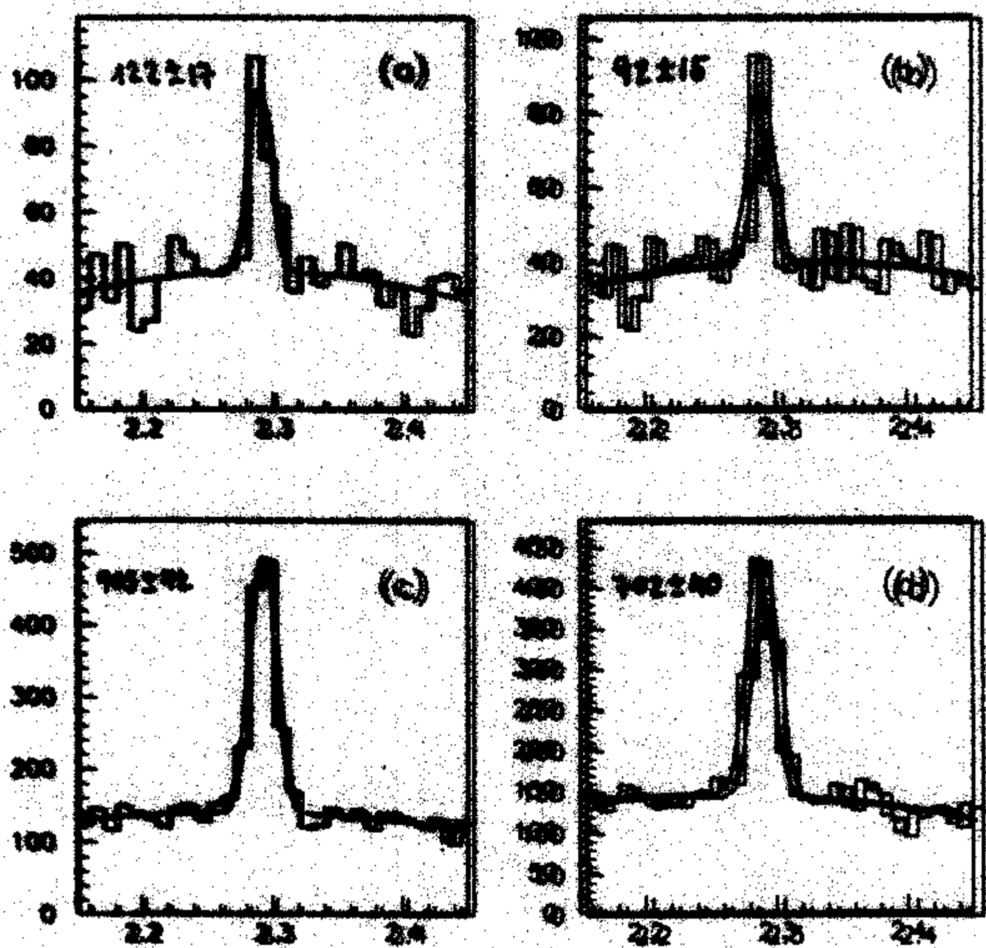
Event Selection:

- The five targets (four Carbon and one Platinum) were used.
- In most cases, Λ_c's decayed in air between the target foils, and before entering the silicon vertex detectors.
- All combinations of three tracks consistent with an *a priori* Cherenkov probability of being identified as a $pK\pi$ combination were selected for further analysis if:
  - The distance between the calculated candidate Λ_c decay to primary vertex was at least five standard deviations.
  - The invariant mass was between 2.15 and 2.45 GeV/c^2.
- To further enrich the sample, we required the Λ_c to decay at least five standard deviations downstream from the nearest target foil and between one and four lifetimes.
- The Λ_c momentum vector, reconstructed from its decay products, was required to pass within 3σ of the primary vertex and primary and secondary vertices had to have acceptable χ^2 per degree of freedom.
- We also require that at least two of the Λ_c-candidate decay tracks be inconsistent with coming from the primary interaction point.
- After applying all cuts, we obtain a sample of $1,819 \pm 62$ fully reconstructed $Lambda_c$'s.

Λ_c's: Final data sample

Λ_c's:

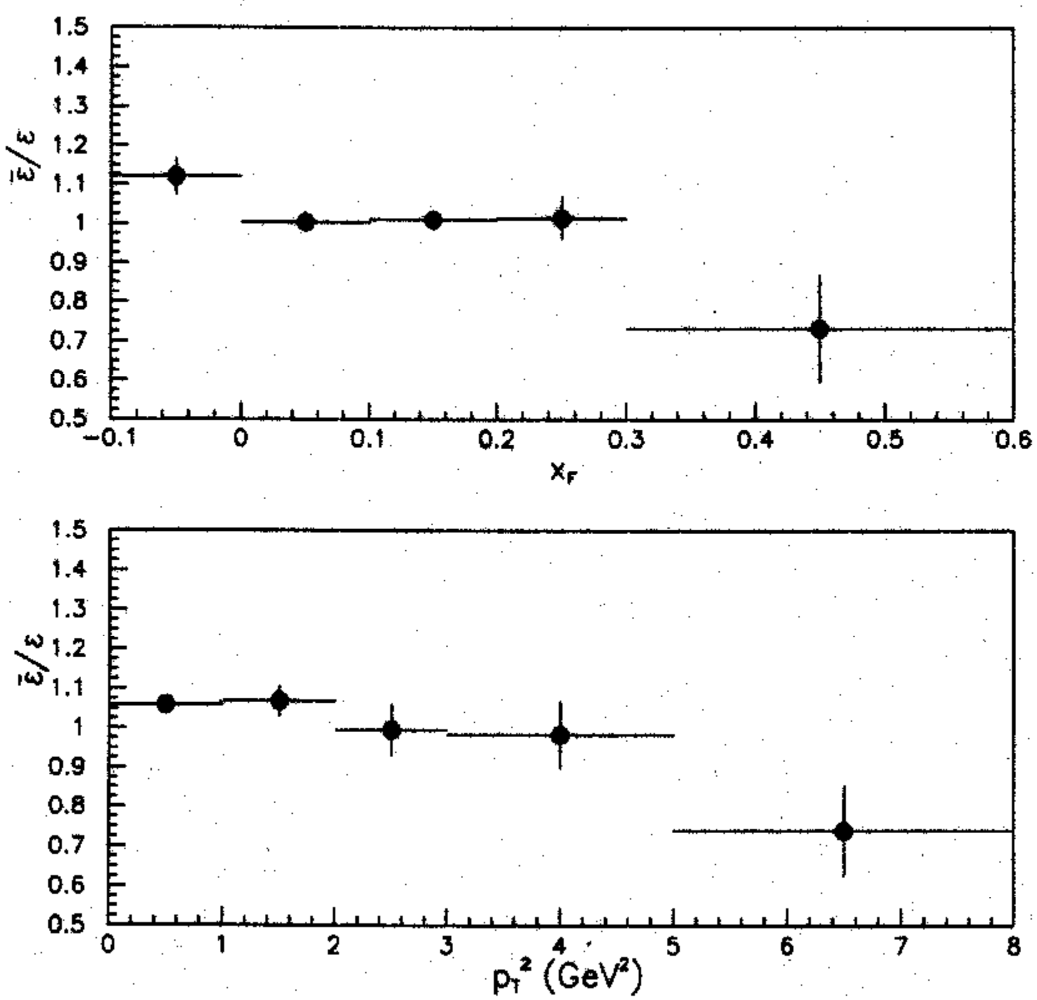
- Fits to a Gaussian on a parabolic background indicate samples in the whole x_F and p_T^2 range of $1,035 \pm 45$ Λ_c and 794 ± 42 $\bar{\Lambda}_c$.



(a) Λ_c^+ and (b) $\bar{\Lambda}_c^-$ signals in the $-0.1 \leq x_F \leq 0$ region. (c) Λ_c^+ and (d) $\bar{\Lambda}_c^-$ signals in the $0 \leq x_F \leq 0.6$ region.

Λ_c's: Acceptance corrections as a function of x_F and p_T^2

- <u>MC Generation:</u>
  - 7 million of Λ_c's events.



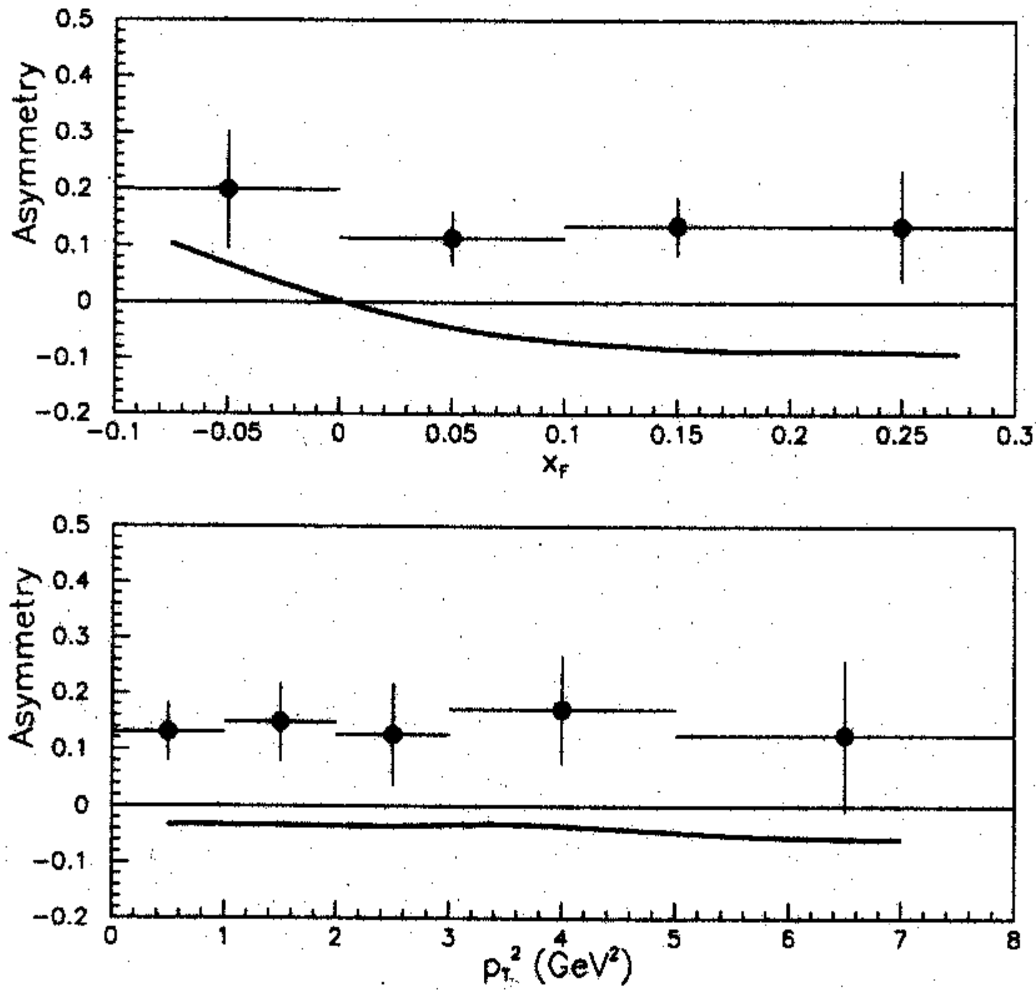
Systematic Effects

We looked for systematic effects from the following sources:

- Event selection criteria.
- Uncertainties in calculating relative efficiencies for particle and anti-particle.
- Effect of the 2.5% K^- contamination in the beam: expected to produce a negative asymmetry in the forward region were antilambdac's are leading and lambdac's are not, but effect is negigleable in comparison with statistical errors.
- Contamination of the sample with D's and Ds's decaying into $K\pi\pi$ and $KK\pi$ modes. This was negligeable when selected the $Lambda_c$'s were required to decay between one and four lifetimes.
- Parametrization of the background shape.

The only significant effect came from the parametrization of the background shape and even this was small relative to the statistical errors.

Λ_c's: Asymmetries as a function of x_F and p_T^2.



Full line: Pythia/Jetset predictions.

Conclusions

- We have presented, for the first time in a fixed target experiment, data on *Lambda*$_c$ production asymmetries in both the forward and backward regions.
- Our results, after acceptance corrections, show a positive asymmetry of 12.7 ± 3.4 % over the full kinematical range studied.
- The Pythia/Jetset model which predicts a negative asymmetry over this range does not provide a good description of our data.
- Non zero asymmetries were measured in regions close to $x_F = 0$, suggesting that energy thresholds for the associated production of baryons and mesons play a role in particle / anti-particle production.
- Our results for particle/antiparticle asymmetries are consistent with the experimental results obtained by previous experiments.

Λ_c^+/Λ_c^- asymmetry as a function of x_F and p_T^2. Only statistical errors are shown.

x_F bin	Asymmetry	p_T^2 bin	Asymmetry
−0.1–0.0	0.20 ± 0.10	0.0–1.0	0.13 ± 0.05
0.0–0.1	0.11 ± 0.05	1.0–2.0	0.15 ± 0.07
0.1–0.2	0.14 ± 0.05	2.0–3.0	0.13 ± 0.09
0.2–0.3	0.14 ± 0.10	3.0–5.0	0.17 ± 0.10
–	–	5.0–8.0	0.13 ± 0.14

COMPAIRISON OF Λ_c AND Λ^0
ASYMMETRIES