TEST OF CPT INVARIANCE USING $\overline{\Xi}^{+}$ and Ξ^{-} HYPERONS

Antonio Wong Chan

Institute of Physics, Academia Sinica

(representing the E871 Collaboration at Fermilab)

- Introduction - The E871 Spectrometer
- Summary of E871 1997 Run
- Some of the Physics Goals in E871
- CPT test with Ξ hyperon
- The E871 Monte Carlo
- Analysis Procedure
- Status of E871 Physics Analysis

The HyperCP Collaboration

A. Chan, Y.C. Chen, C. Ho and P.K. Teng
Academia Sinica, Nankang, Taipei 11529, Taiwan, Republic of China

W.S. Choong, G. Gidal, K.B. Luk[1)] and P. Zyla
Lawrence Berkeley Laboratory and University of California, Berkeley, CA 94720, USA

C. James and J. Volk
Fermilab, Batavia, IL 60510, USA

J. Felix and G. Lopez
Universidad de Guanajuato, León, Mexico

R.A. Burnstein, A. Chakravorty, D.M. Kaplan, L.M. Lederman, W. Luebke, D. Rajaram, H.A. Rubin, C.G. White, and S.L. White
Illinois Institute of Technology, Chicago, IL 60616, USA

N. Leros and J.-P. Perroud
Université de Lausanne, Lausanne, Switzerland

H.R. Gustafson, M.J. Longo, and F. Lopez
University of Michigan, Ann Arbor, MI 48109, USA

V. Papavassiliou
New Mexico State University, Las Cruces, NM 88003, USA

M. Jenkins and K. Clark
University of South Alabama, Mobile, AL 36688, USA

E.C. Dukes[2)], C. Durandet, M. Huang and K.S. Nelson
University of Virginia, Charlottesville, VA 22901, USA

[1)] Spokesperson: LUK@CSA.LBL.GOV, (510)486-7054
[2)] Spokesperson: DUKES@UVAHEP.PHYS.VIRGINIA.EDU, (804)982-5364

The E871 spectrometer

- An 800 GeV/c proton beam incident on a Cu target creates a secondary beam with a mean momentum ~ 172 GeV/c. Secondary beam is composed of a mixture of π^-, K^-, $\overline{p}$, Σ^-, Ξ^- and Ω^-. Secondary beam of opposite charge can be obtained by reversing magnetic field of hyperon magnet.

- Secondary beam goes through a vacuum pipe (~ 13 m long) where unstable particles can decay.

- Spectrometer composed of 4 multi-wire proportional chambers (MWPC) before the analyzing magnet, and 4 MPWC after the analyzing magnet.

- Analyzing magnet provides a $p_t \sim 1.5$ GeV/c kick to separate negative and positive tracks.

- Spectrometer is equipped with hadronic calorimeter to separate proton and muons. Also, it has a muon station for muon identification.

- Two hodoscopes and calorimeter form a fast and simple trigger, which requires a charged particle to pass through the "opposite-sign" hodoscope and hit the hadronic calorimeter and at least one charged particle in the "same-sign" hodoscope.

- Strict requirements for spectrometer include high-rate ($\sim$ 0.5 MHz/wire), high-resolution MWPC's (1-2mm wire pitch), along with high-rate DAQ (up to $\sim$ 17 Mb/sec).

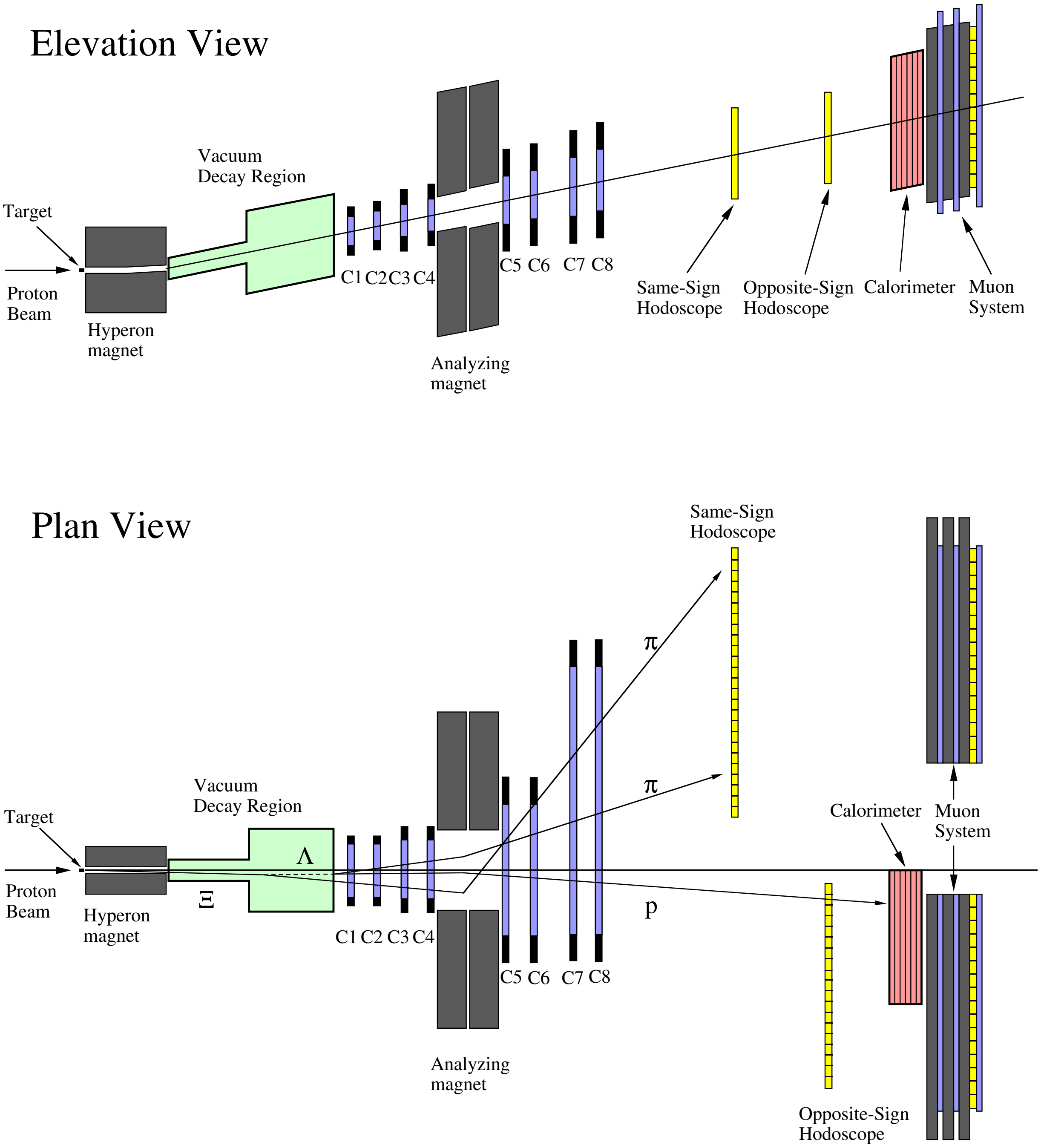

Figure 1: Elevation view (top) and plan view (bottom) of the E871 spectrometer.

Summary of E871 1997 run

- The data taking period lasted from 04/97 to 09/97.
- Average trigger rate during the run was ~ 75 KHz.
- We have written $\sim 75 \times 10^9$ events on $\sim 11,000$ exabyte tapes.
- We expect to reconstruct $\sim 1.6 \times 10^9$ $\Xi \to \Lambda\pi$ events, $\sim 2.8 \times 10^8$ $K \to \pi\pi\pi$ events and $\sim 3 \times 10^7$ $\Omega \to \Lambda K$ events.

Some of the physics goals in E871

- Detector designed to measure direct CP violation in the decay $\Xi \rightarrow \Lambda\pi \rightarrow p\pi\pi$, through the asymmetry variable, $A = (\alpha_\Lambda \alpha_\Xi - \alpha_\Lambda \alpha_\Xi)/(\alpha_\Lambda \alpha_\Xi + \alpha_\Lambda \alpha_\Xi)$. With the data collected in the 1997 run, we expect to obtain a statistical sensitivity of $\delta A \sim 2 \times 10^{-4}$.

- E871 also can measure CP violation from $K \rightarrow \pi\pi\pi$ decays. With the data collected in the 1997 run, we expect to obtain a statistical sensitivity of $\sim 6 \times 10^{-4}$, an order of magnitude better than the current limit.

- Test of CPT invariance of the K^-, Λ°, Ξ^-, Ω^- and their associated antiparticles.

- Production cross-sections for π^-, K^-, Ξ^-, Ω^- and their associated antiparticles.

- Measurement of the polarization and magnetic moments of Ξ^-, Ω^- and their associated antiparticles.

- Leptonic flavor violation in weak decays, such as the following $\Delta L = 2$ decay: $\Xi^- \to p\mu^-\mu^-$. We can improve the current limits by about 4 orders of magnitude to about 10^{-8}.

CPT Test with Ξ hyperon

- E871 has the largest sample of Ξ hyperons in the world, so we should use the sheer size of our data sample to obtain precision measurements.
- The CPT theorem is a fundamental principle of quantum field theory, and it is based on very general assumptions, such as causality and spin statistics. The CPT theorem states that all particle interactions are invariant under the succession of the 3 operations C, P and T taken in any order.
- CPT invariance requires among other things that particles and antiparticles (such as the Ξ^- and $\overline{\Xi}^+$) have the same lifetime and mass.
- Previous results from FNAL and CERN indicate no CPT-violating effects in other channels, such as K° and $\overline{K}^\circ$.

The E871 Monte Carlo

- It has 35+ preset decay modes which cover the physics decay channels accessible to E871.
- The Monte Carlo simulation include various effects such as multiple scattering, MWPC efficiency, MWPC hit multiplicity, magnet fringe field corrections, etc.
- Events are generated at the target and required to pass through the hyperon magnet. In the fiducial region, the particles are allowed to decay, and the charged particles in the decay are traced through the spectrometer. If the event satisfied the software trigger requirements, the spatial positions of the charged particles were digitized into wire hits, and the event was reconstructed.

Analysis Procedure (PRELIMINARY)

- First generate MC events with different input Ξ lifetimes. Then, collect all candidate events into z-bins (the z-decay vertex). Finally, fit the MC to data to extract the lifetime, after applying acceptance correction (correlated to momentum).

- More sophisticated approach would involve a momentum bin-by-momentum bin analysis of the Ξ lifetime.

- A mass measurement would involve a very precise knowledge of the mass scale. This implies a precise knowledge of the detector alignment, geometric parameters and operating parameters of the magnets.

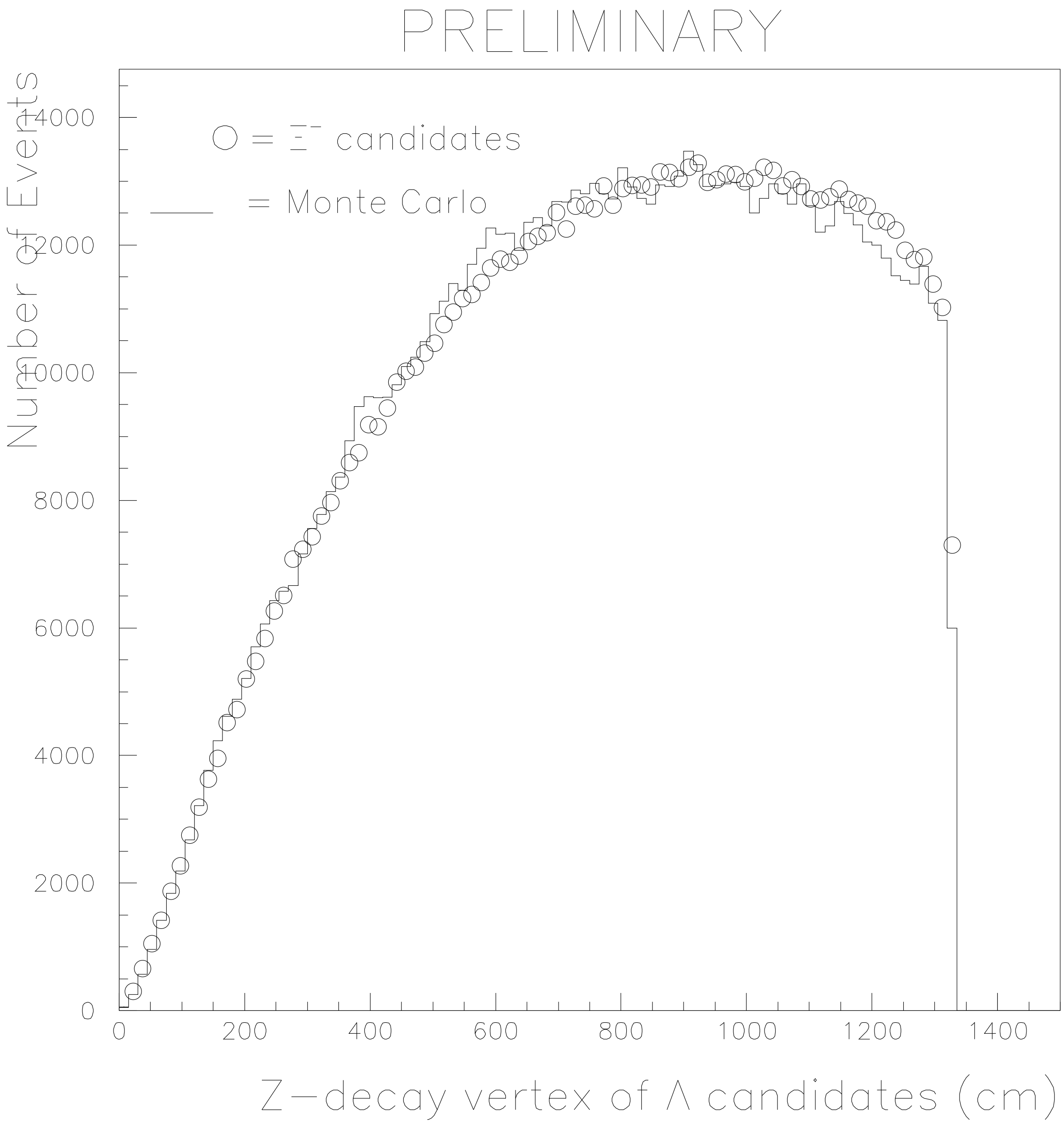

Figure 2: Comparison between data and Monte Carlo Λ° z-decay vertex distribution for Ξ^- candidates. The Monte Carlo was normalized to data.

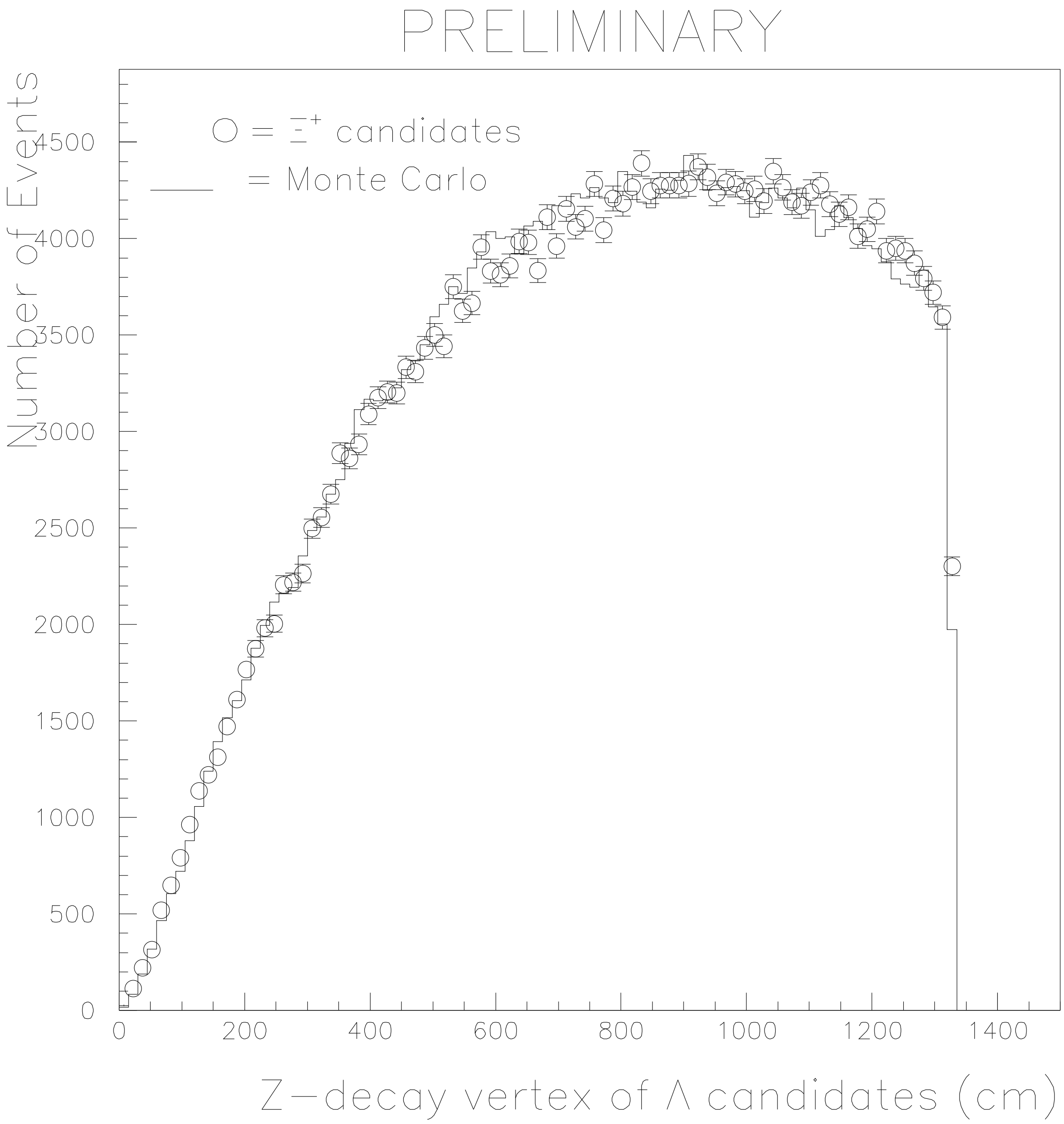

Figure 3: Comparison between data and Monte Carlo $\overline{\Lambda}^{\circ}$ z-decay vertex distribution for $\overline{\Xi}^{+}$ candidates. The Monte Carlo was normalized to data.

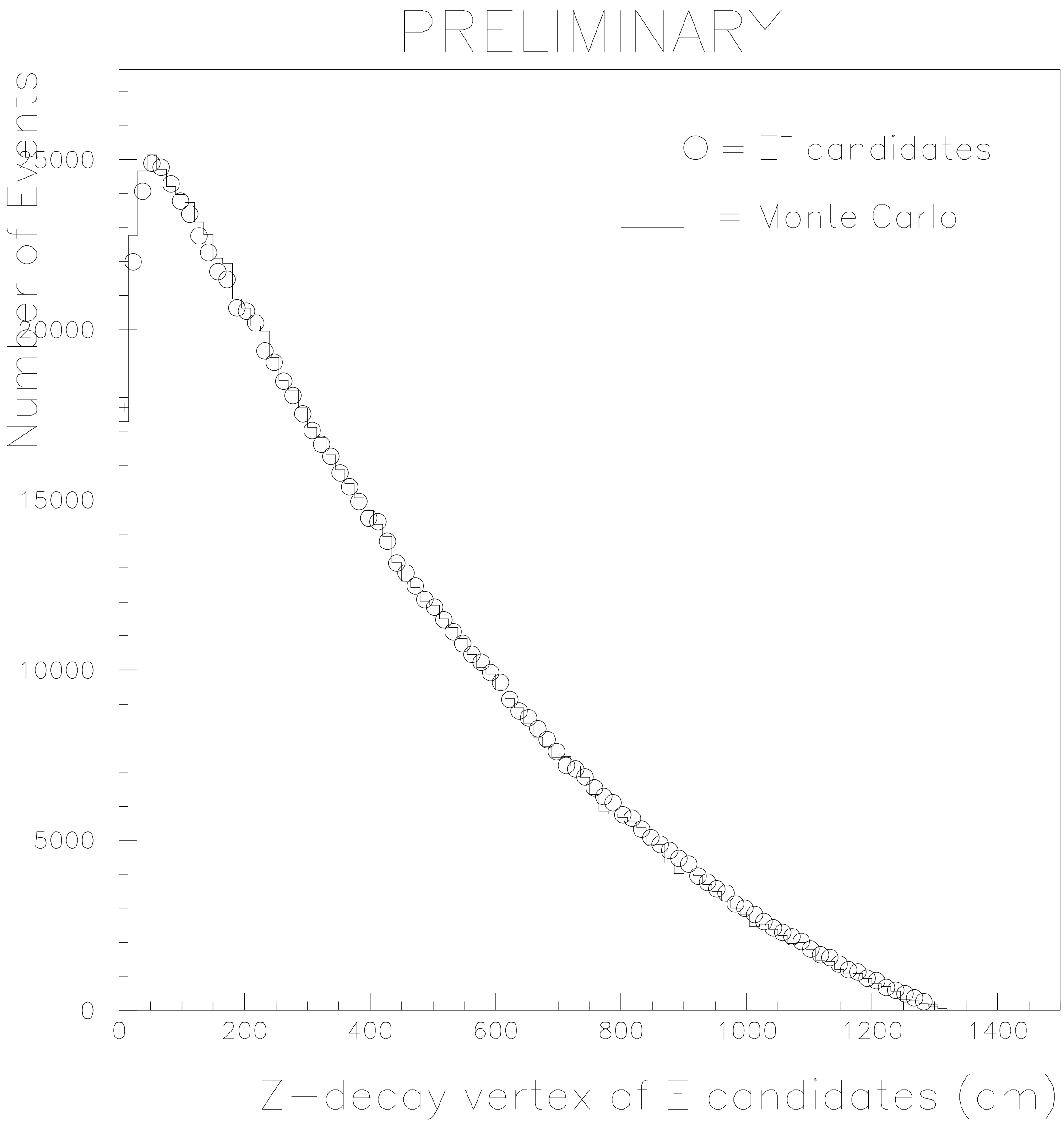

Figure 4: Comparison between data and Monte Carlo Ξ z-decay vertex distribution for Ξ^- candidates. The Monte Carlo was normalized to data.

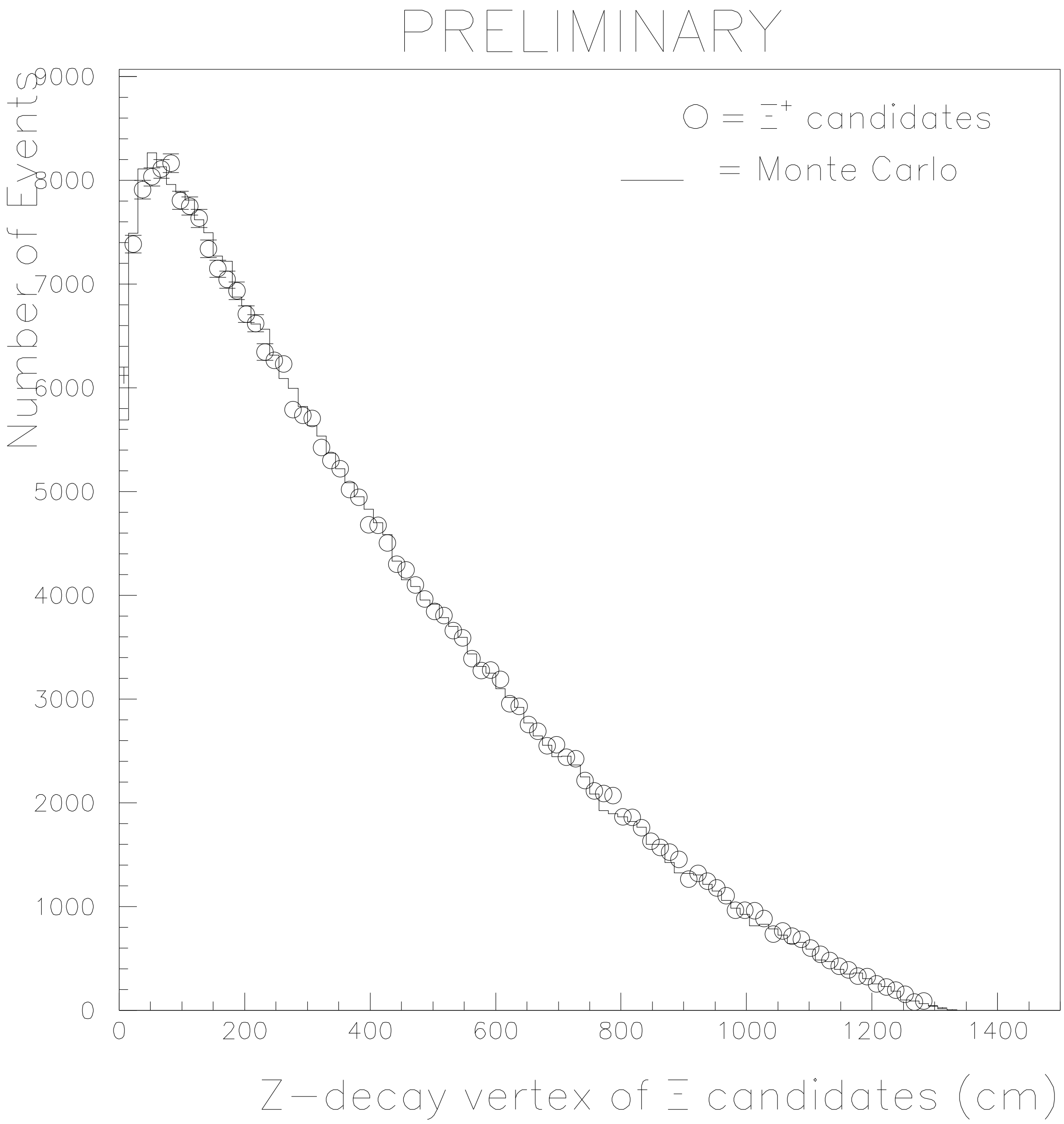

Figure 5: Comparison between data and Monte Carlo Ξ z-decay vertex distribution for $\overline{\Xi}^+$. The Monte Carlo was normalized to data.

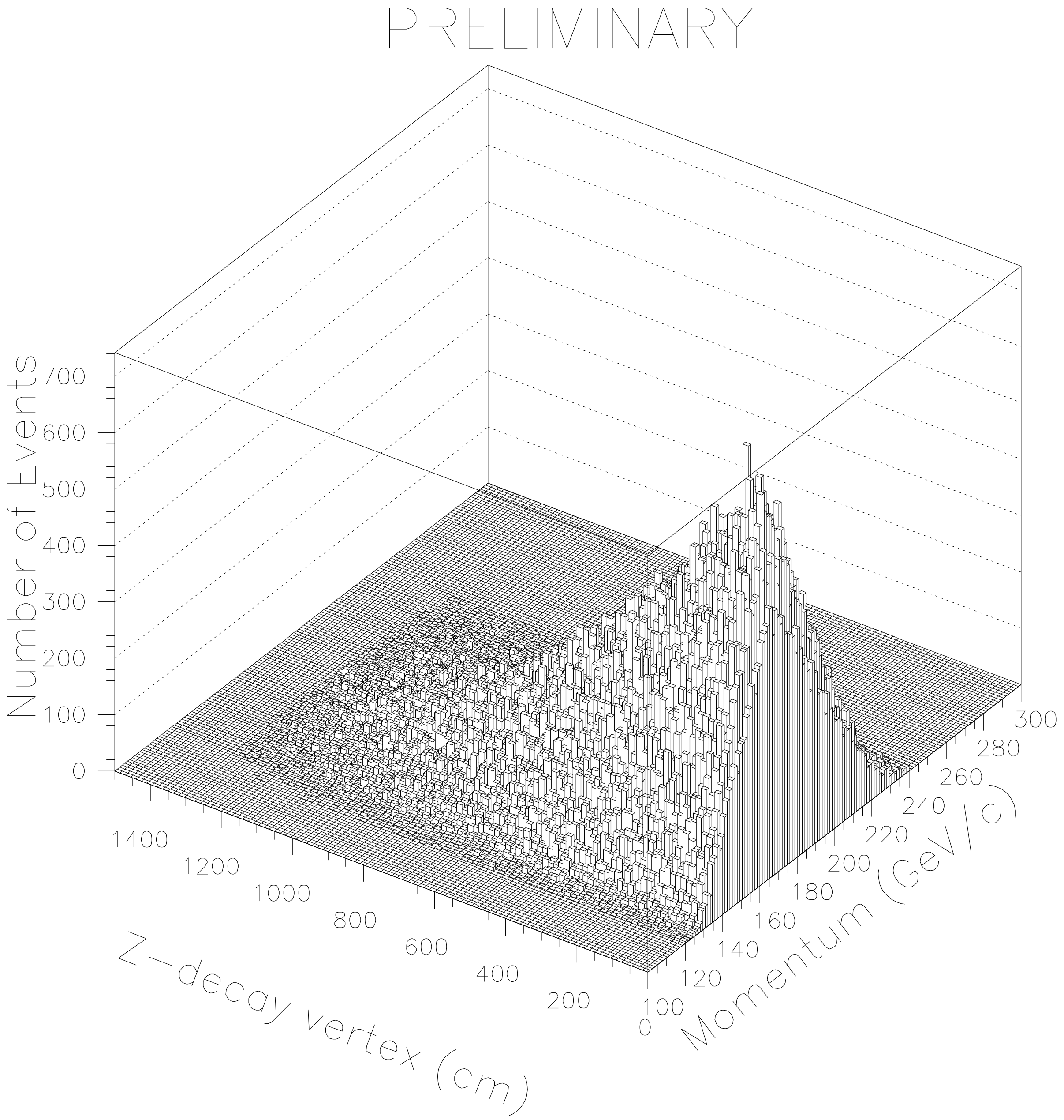

Figure 6: The "lego" plot of momentum vs. z-decay vertex distributions for Ξ^- candidates.

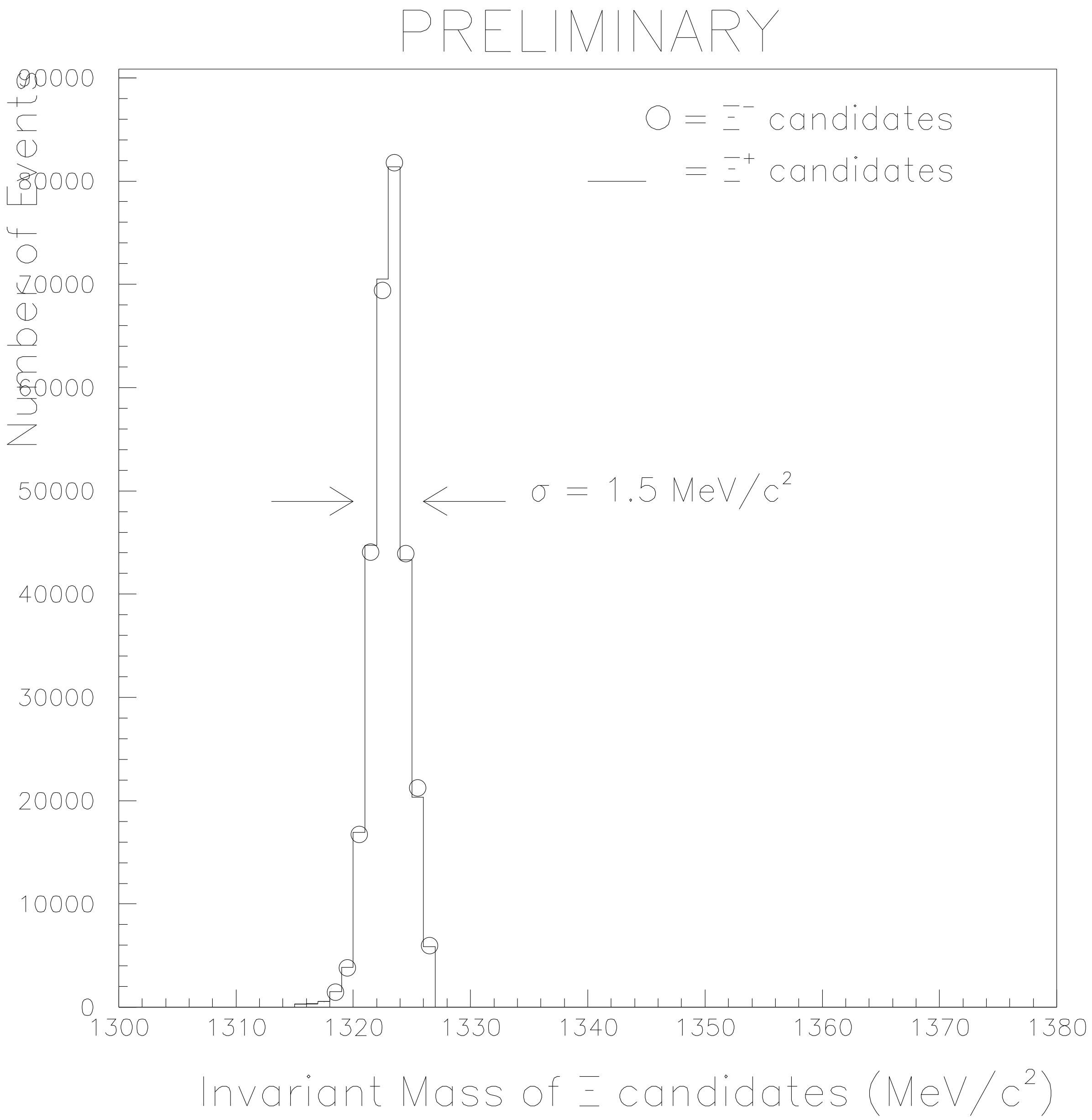

Figure 7: Invariant Mass distribution for Ξ^- and $\overline{\Xi}^+$ candidates. The Ξ^- distribution was normalized to the $\overline{\Xi}^+$ distribution.

Status of E871 Physics Analysis

- Data being processed at the Fermilab Computer Farms.
- Work on physics analysis, Monte Carlo simulation and systematic studies is in progress.
- Initial studies of the Ξ lifetime from a small fraction of the data already yielded a statistical uncertainty a factor of 3 better than present PDG values. We expect further improvements as we analyze a larger fraction of the data.

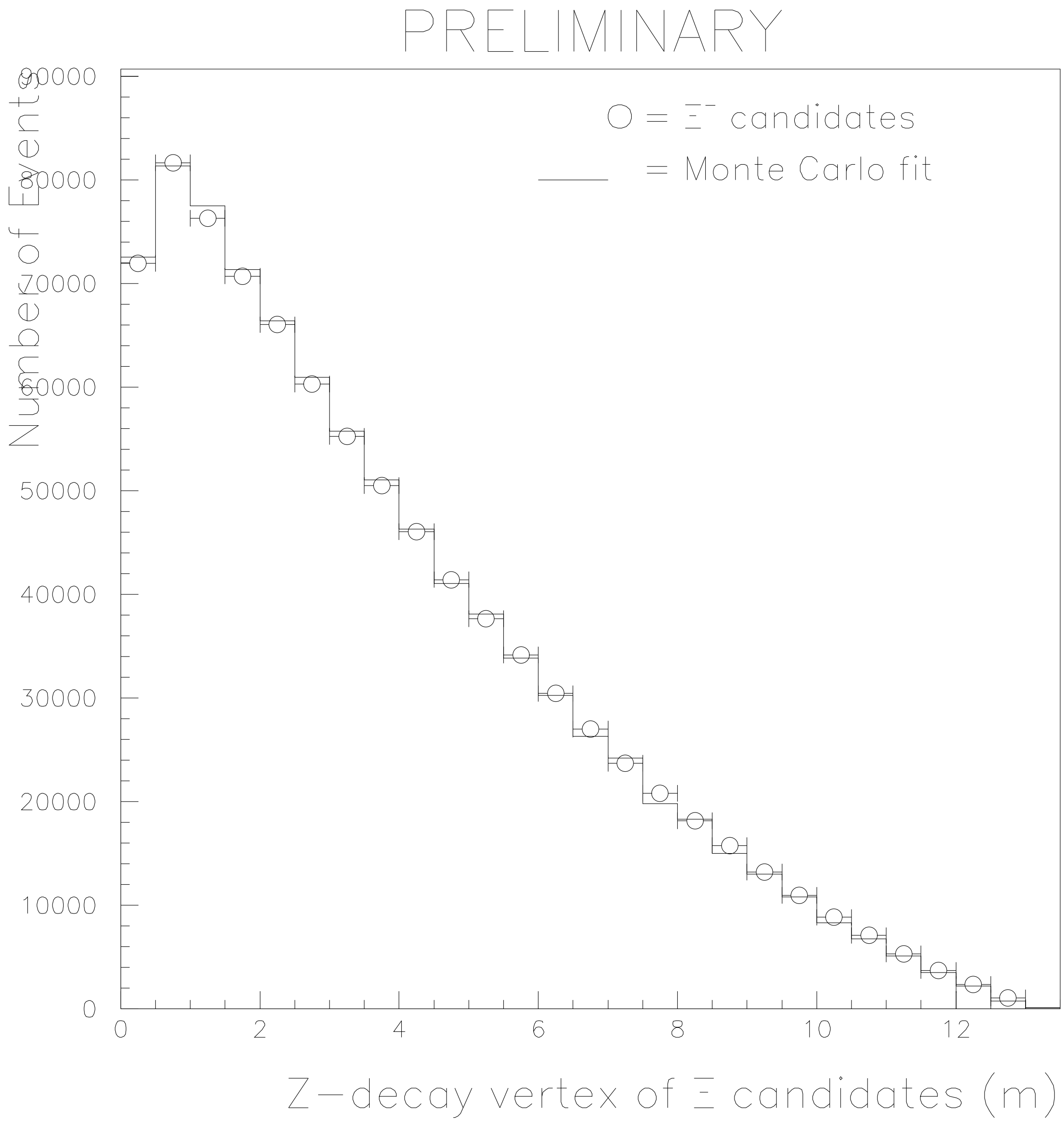

Figure 8: Monte Carlo fit to z-decay vertex distribution for Ξ^- candidate events in data.