

Study of the Decay

$$\Omega^- \rightarrow \Xi^- \pi^+ \pi^-$$

in the HyperCP Experiment

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for the HyperCP Collaboration

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Previous Observations and Theoretical Estimates



The final state of the 3-body rare hyperon nonleptonic decay

$$\Omega^- \rightarrow \Xi^- \pi^+ \pi^-$$

can be reached through the resonance decay channel

$$\Omega^- \rightarrow \Xi_{1530}^{*0} \pi^- \rightarrow \Xi^- \pi^+ \pi^-$$

where Ξ_{1530}^{*0} is a short-lived resonance, which decays via

$$\Xi_{1530}^{*0} \rightarrow \Xi^- \pi^+$$

The current PDG branching ratios are:

$$\text{BR}(\Omega^- \rightarrow \Xi^- \pi^+ \pi^-) = (4.3^{+3.4}_{-1.3}) \times 10^{-4}$$

$$\text{BR}(\Omega^- \rightarrow \Xi_{1530}^{*0} \pi^-) = (6.4^{+5.1}_{-2.0}) \times 10^{-4}$$

Both measurements were done by M. Bourquin *et al.*, Nucl. Phys. B 241, 1 (1984) and are **based on the same four observed events.**

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"The $\Omega^- \rightarrow \Xi^*(1530)\pi^-$ decays are expected to dominate the $\Xi^- \pi^+ \pi^-$ decay modes.

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Assuming that the 4 events are $\Omega^- \rightarrow \Xi_{1530}^{*0} \pi^-$ events, we deduce using a branching ratio of

2/3 for $\Xi_{1530}^{*0} \rightarrow \Xi^- \pi^+$:

$$\Gamma(\Omega^- \rightarrow \Xi_{1530}^{*0} \pi^-) / \Gamma(\Omega^- \rightarrow \text{all}) = (6.4^{+5.1}_{-2.0}) \times 10^{-4} "$$

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The HyperCP Spectrometer

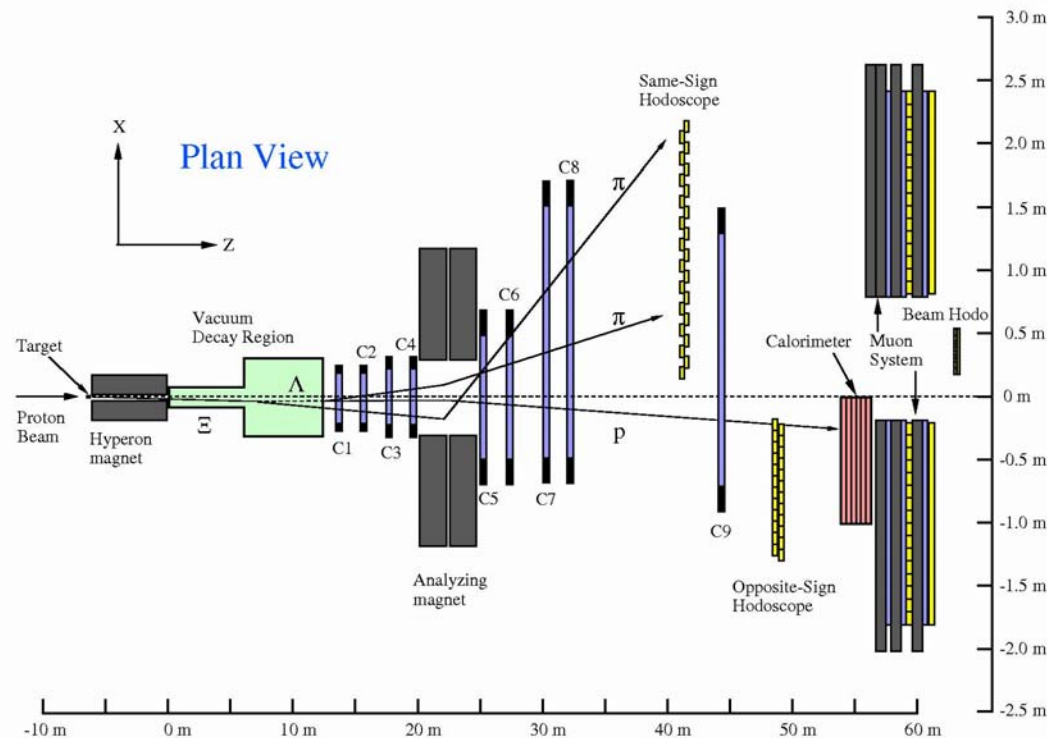
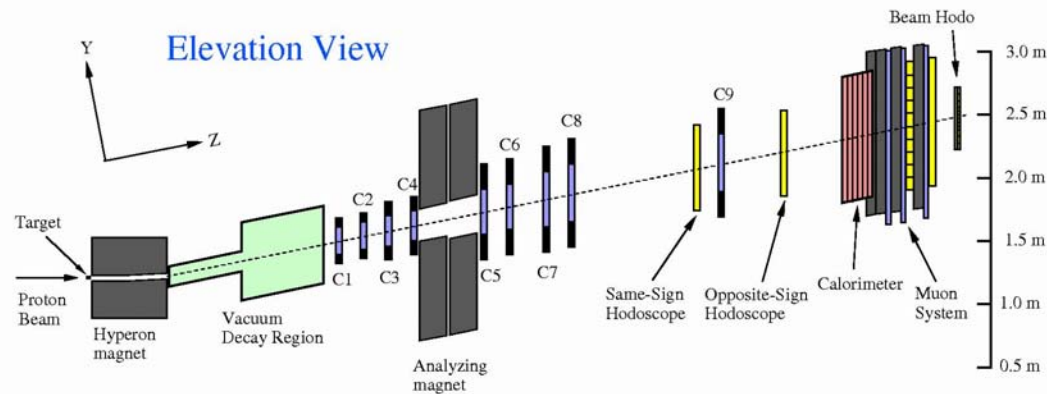


Primary Goal:

Search for exotic sources of CP violation in hyperon decays.

Spectrometer features:

- High-rate detectors & DAQ (100k evts/s)
- Alternating “+” & “-” running (with reversed B fields) to minimize systematics
- Simple, low-bias triggers based on hodoscope coincidences



The HyperCP Spectrometer

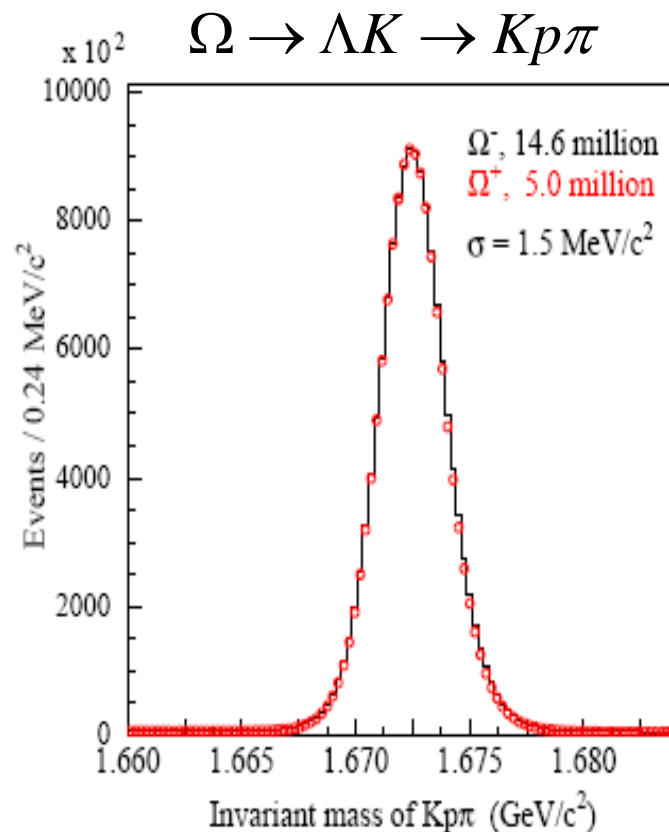


In 12 months of data taking in 1997–99, HyperCP recorded one the largest data samples ever by a particle-physics experiment:

231 billion events, 29,401 tapes, and 119.5 TB of data

Reconstructed event samples.

Reconstructed Events (10^6)			
Polarity:	-	+	Total
$\Xi \rightarrow \Lambda p \rightarrow p\pi\pi$	2032	458	2490
$\Omega \rightarrow \Lambda K \rightarrow pK\pi$	14	5	19
$K \rightarrow \pi\pi\pi$	164	391	555
$K_S \rightarrow \pi^+\pi^-$	693	2025	2718



The HyperCP Spectrometer



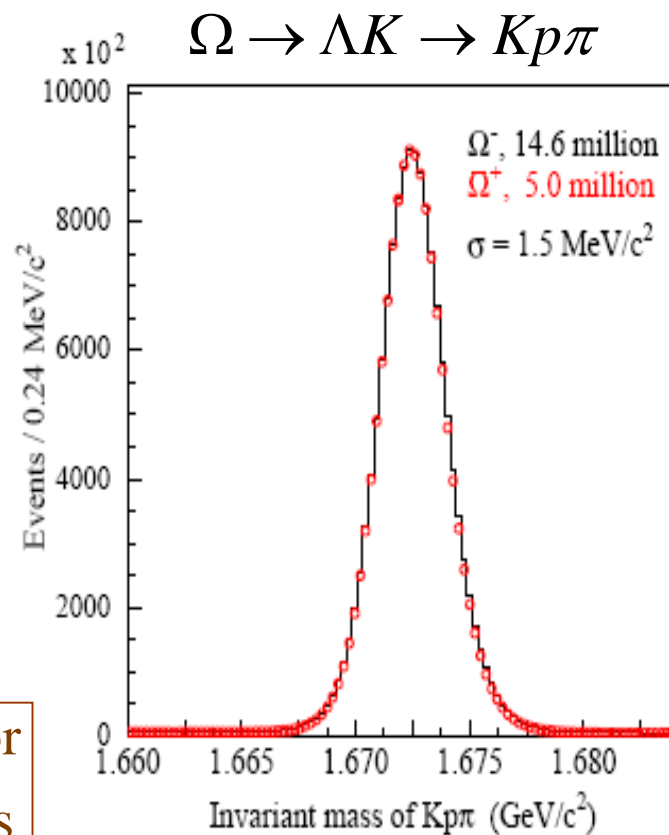
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Large Ω sample \Rightarrow Searches for rare hyperon decays



Decay Modes



- $\Omega^- \rightarrow \Xi^- \pi^+ \pi^-$ 5-tracks, including subsequent decays $\Xi^- \rightarrow \Lambda \pi^-$, $\Lambda \rightarrow p \pi^-$

137 events are observed (≈ 35 times higher statistics than the previous experiment),
preliminary

$$\text{BR}(\Omega^- \rightarrow \Xi^- \pi^+ \pi^-) = (3.6 \pm 0.3(\text{stat}) \pm 0.45(\text{syst})) \times 10^{-4}$$

(N. Solomey, Nuclear Physics B (Proc. Suppl.) 115 (2003) 54-57)

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Does this resonance mode contribute?

Monte Carlo

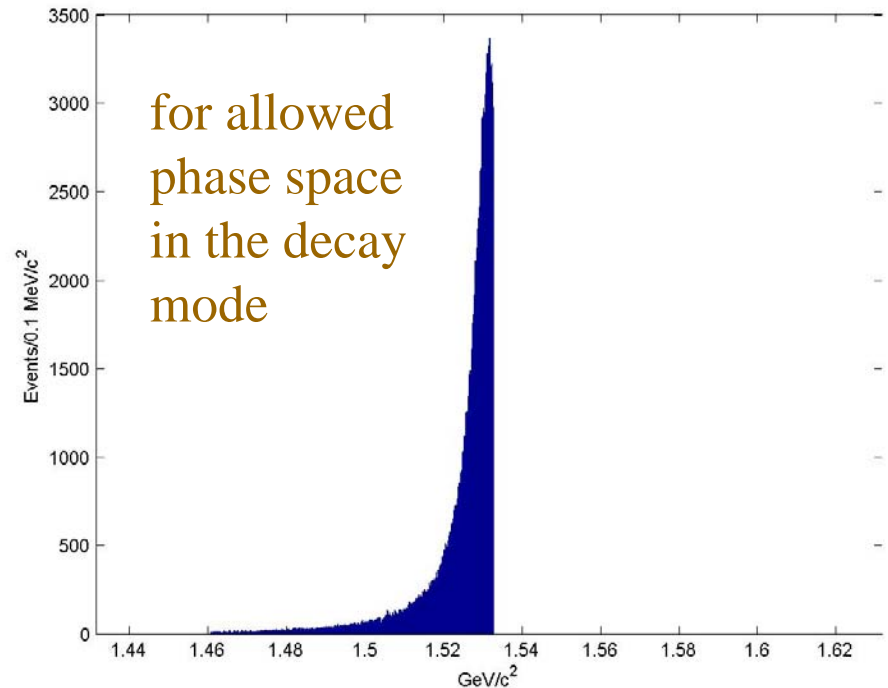
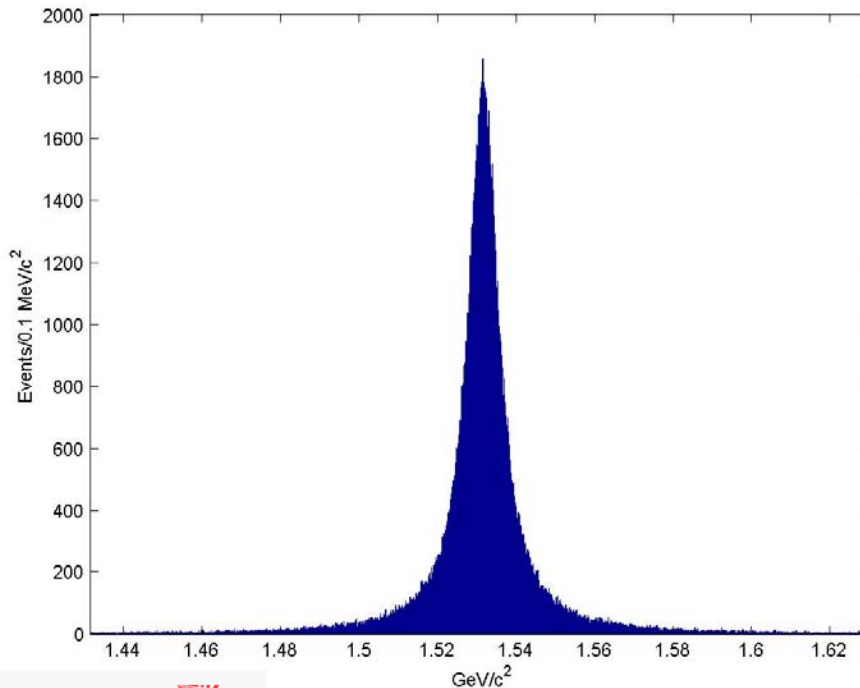


- All Ω^- decays were generated with uniform phase space

- Ξ_{1530}^{*0} mass was generated with Breit-Wigner distribution
$$p(m) = A \frac{\Gamma/2}{(m - m_0)^2 + (\Gamma/2)^2},$$

where $m_0 = 1.5318$ GeV, $\Gamma = 9.1$ MeV (PDG values)

MC generated Ξ_{1530}^{*0} mass



Event Selection Criteria

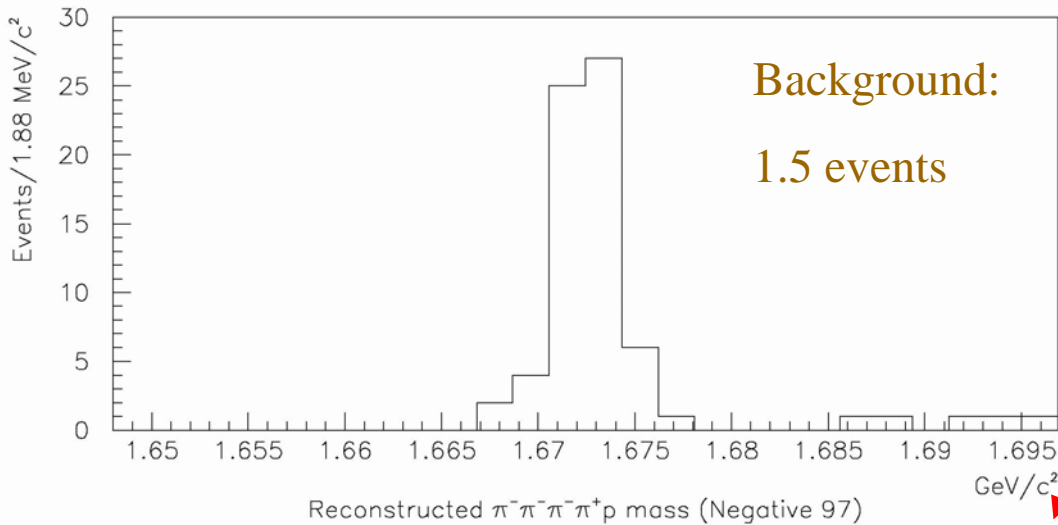


$\Omega^- \rightarrow \Xi^- \pi^+ \pi^-$ and $\Omega^- \rightarrow \Xi_{1530}^{*0} \pi^-$ Selection Criteria

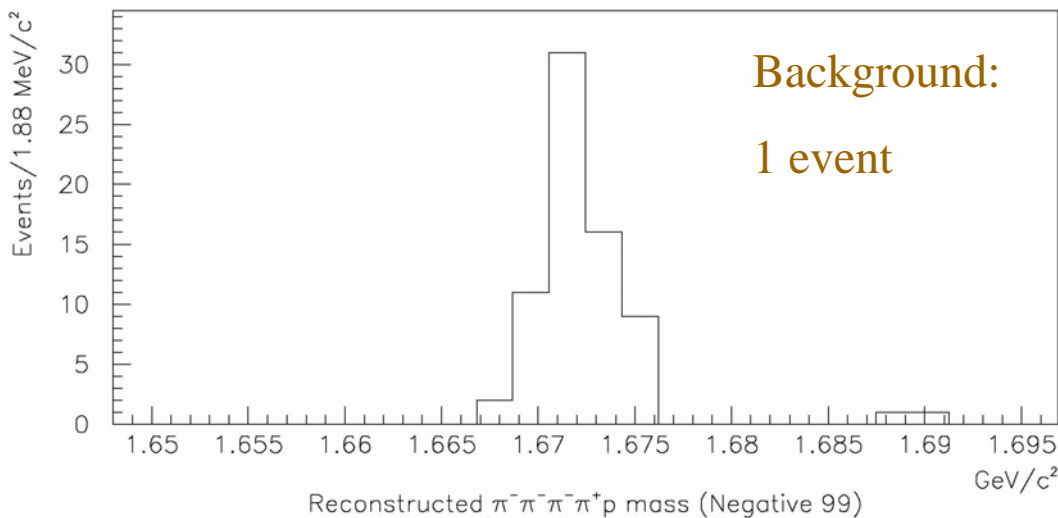
- 3 negative and 2 positive tracks
- All decay vertices inside the decay volume
- Vertex topology consistent with the decay
- Total momentum between 120 and 220 GeV/c
- $p\pi^-$ invariant mass within 3σ of Λ mass
- $\Lambda\pi^-$ invariant mass within 3σ of Ξ^- mass
- $\Xi^- \pi^+ \pi^-$ invariant mass within 3σ of Ω^- mass
- Reconstructed Omega track within the aperture of the collimator
- No muon hodoscope hits

Resonance mode acceptance is ≈ 2.3 times higher than the acceptance for the 3-body decay mode.

Reconstructed Events



Reconstructed $\pi^- \pi^- \pi^- \pi^+ p$ mass with all cuts applied except Ω mass cut, for the 1997 (top plot) and the 1999 (bottom plot) data runs.



To estimate the background in each of these plots, the number of events between 5σ and 11σ was counted and used to estimate the average number of background events per bin. This was then used to estimate the background in the 3σ range of the Ω mass.

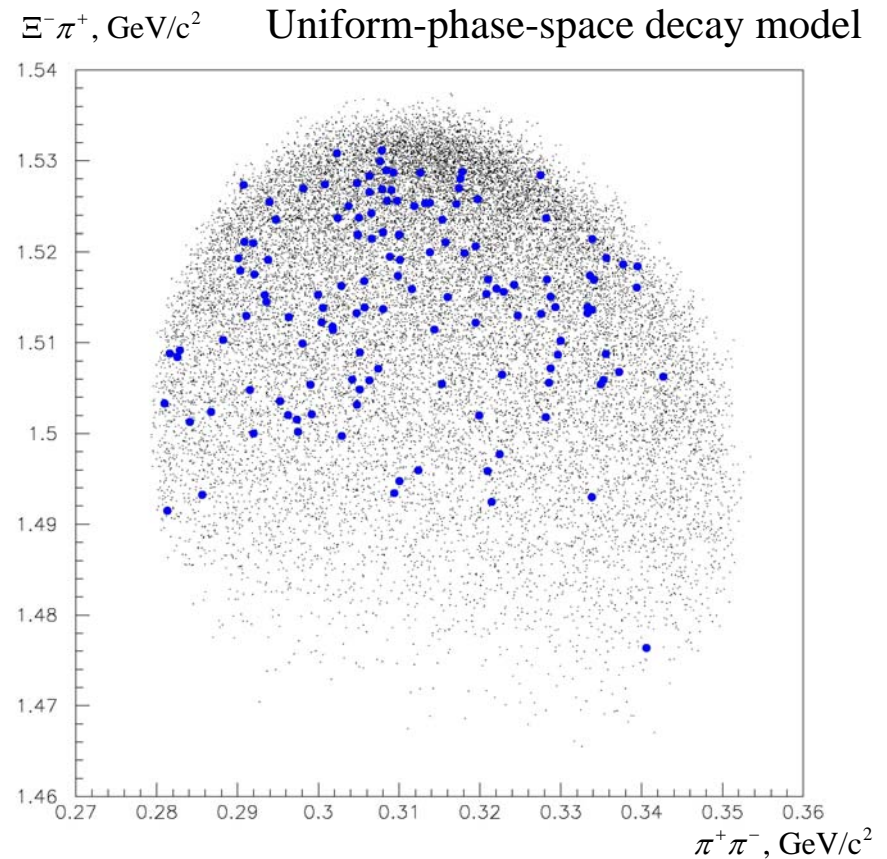
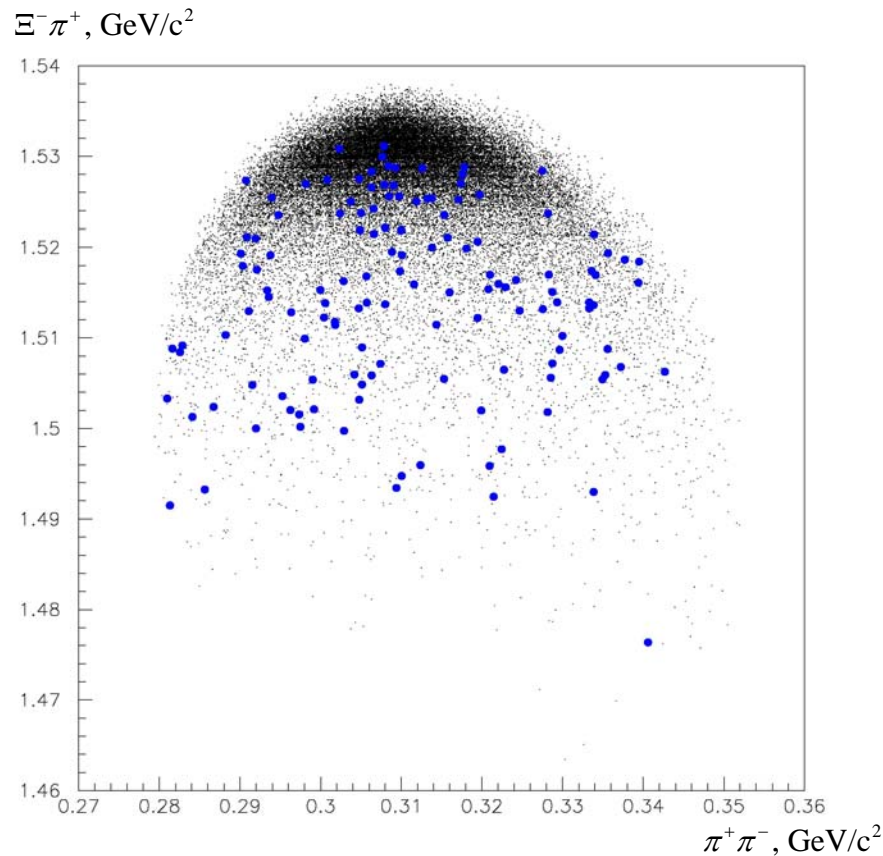
Dalitz plot



Big blue dots – data; Small black dots – Monte Carlo

Monte Carlo for $\Omega^- \rightarrow \Xi_{1530}^{*0} \pi^-$

Monte Carlo for $\Omega^- \rightarrow \Xi^- \pi^+ \pi^-$



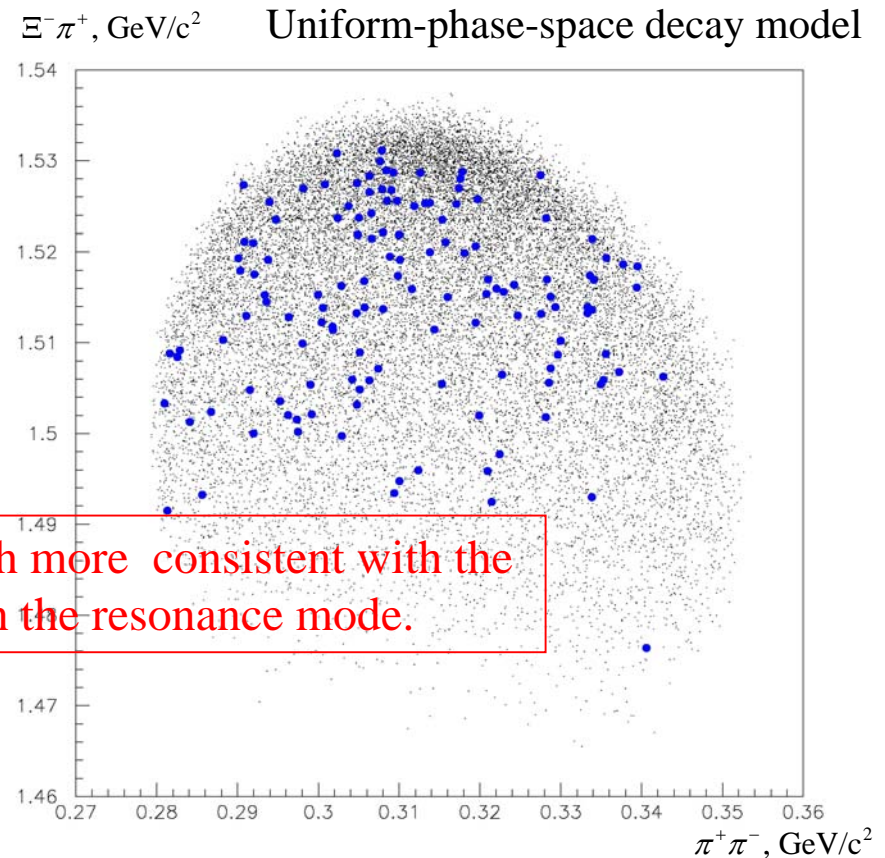
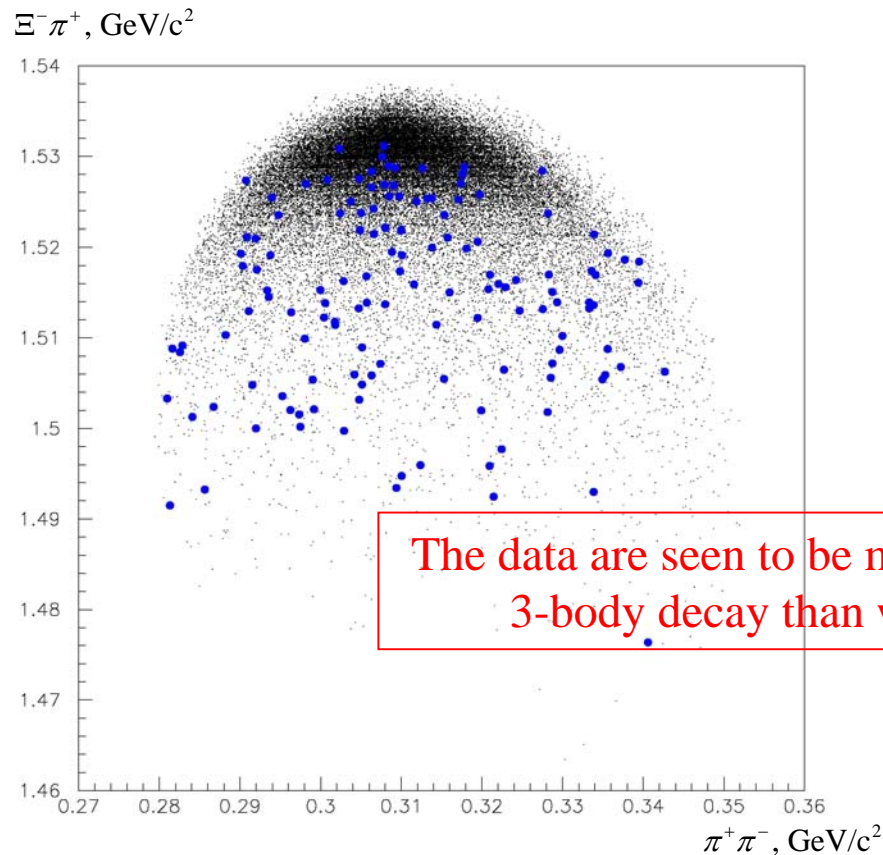
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The data are seen to be much more consistent with the 3-body decay than with the resonance mode.

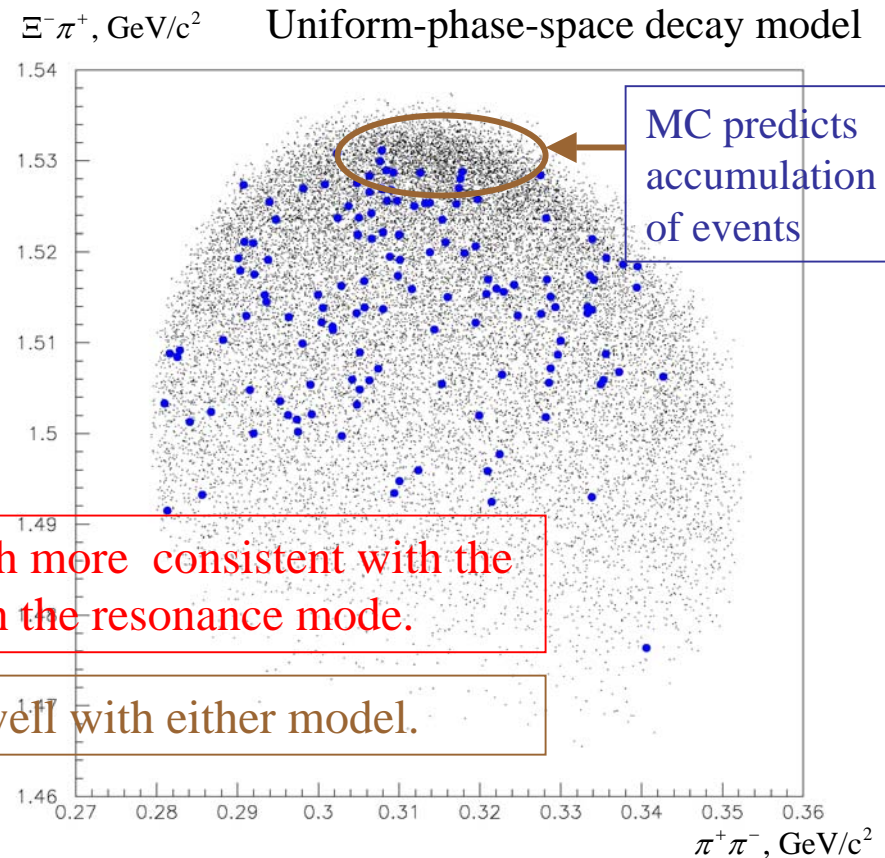
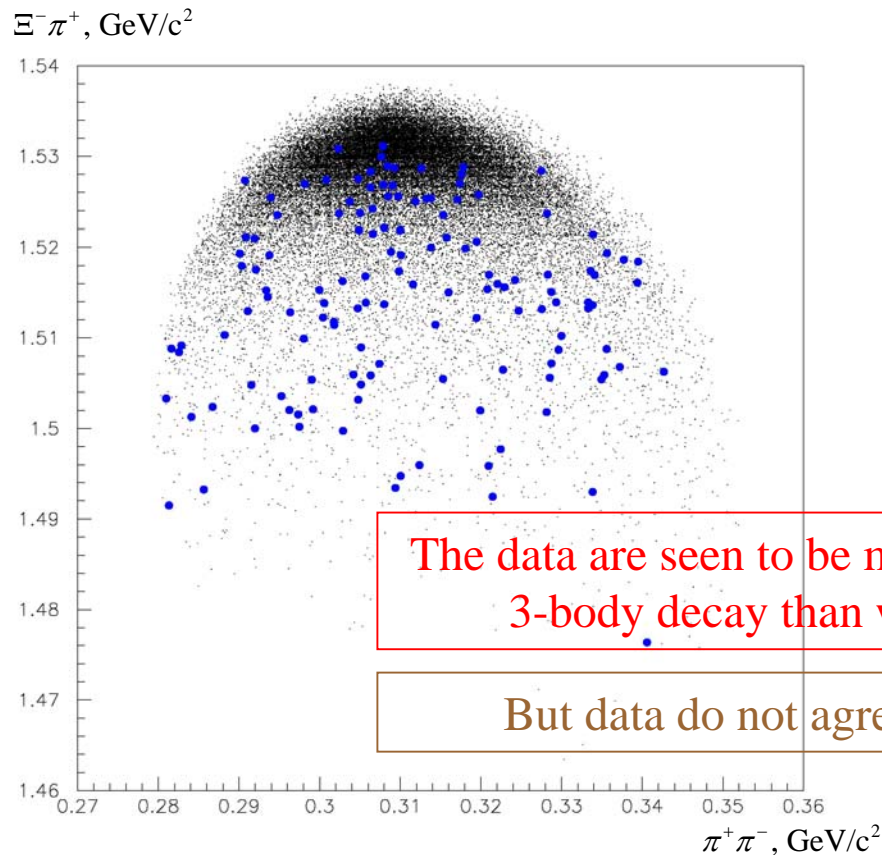
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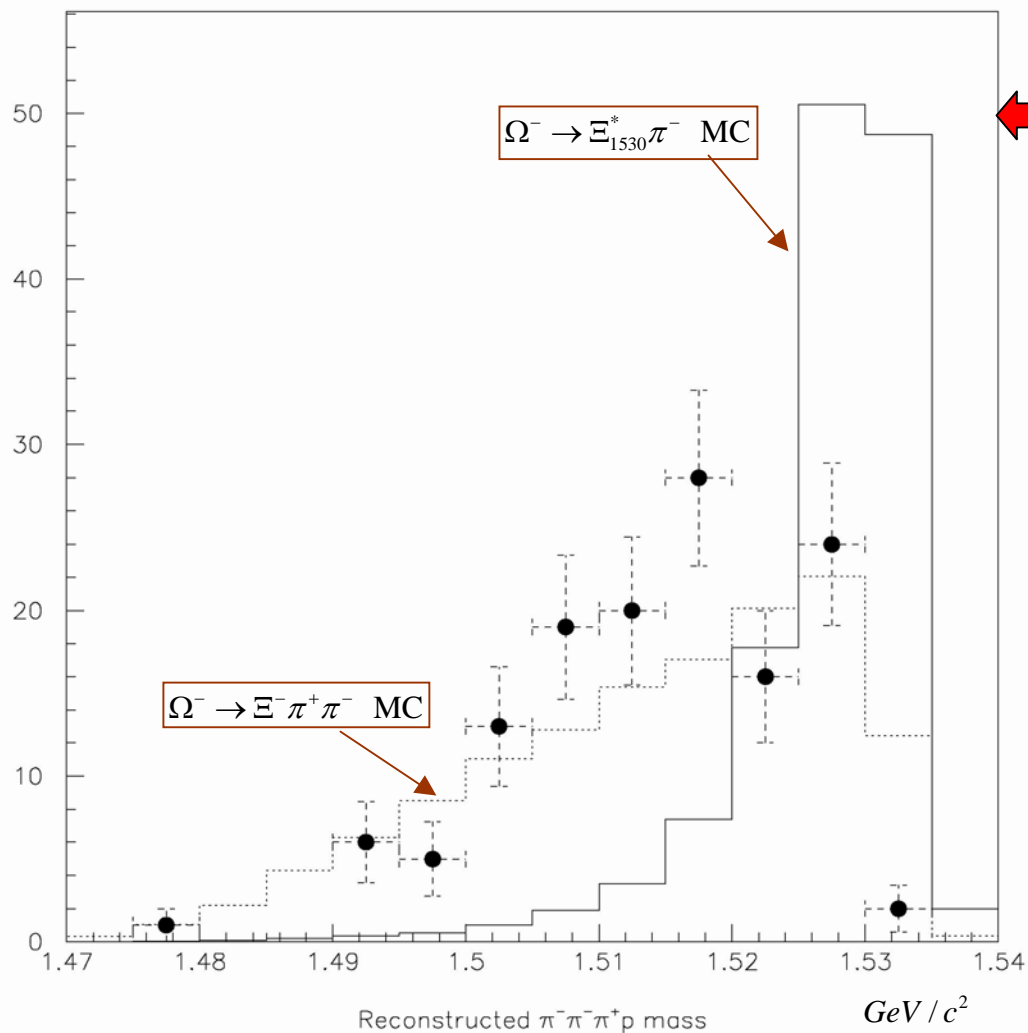
Monte Carlo for $\Omega^- \rightarrow \Xi^- \pi^+ \pi^-$



The data are seen to be much more consistent with the 3-body decay than with the resonance mode.

But data do not agree well with either model.

Reconstructed Invariant Mass of the Resonance



Dalitz plot projection on " $\Xi^- \pi^+$ mass" axis
(dots with error bars - data;
solid line - resonance channel MC;
dotted line - 3 body MC)

Preliminary:

Data appear inconsistent with
both resonant and 3-body
uniform-phase-space models!

Conclusion



- With ≈ 35 times the number of previously observed $\Omega^- \rightarrow \Xi^- \pi^+ \pi^-$ events, we can measure the contribution from the resonance decay channel $\Omega^- \rightarrow \Xi_{1530}^{*0} \pi^-$.
- **Preliminary** conclusion:
Contrary to previous assumption, decay is dominantly continuum $\Omega^- \rightarrow \Xi^- \pi^+ \pi^-$ decay, not $\Omega^- \rightarrow \Xi_{1530}^{*0} \pi^-$.
- Further work is needed to study how the result depends on decay models and asymmetry parameters as well as other systematics.