Measurement of α_Ω in $\Omega^- \to \Lambda K^-$ Decays

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Motivation for Measuring α_Ω in $\Omega \to \Lambda K$ Decays

- Angular-momentum conservation allows the ΛK system to be P-wave and D-wave, corresponding to parity-conserving and parity-violating decays respectively.

- Parity violation is characterized by the decay parameter α_Ω defined as:

$$\alpha_\Omega = \frac{2Re(P^* D)}{|P|^2 + |D|^2}.$$

  Non-zero α_Ω indicates parity violation in this decay.

- All non-leptonic two-body decays of strange baryons have non-zero α decay parameters. But previous experimental results for α_Ω are **consistent with zero at the** 2% **level**. **Is it really zero?**

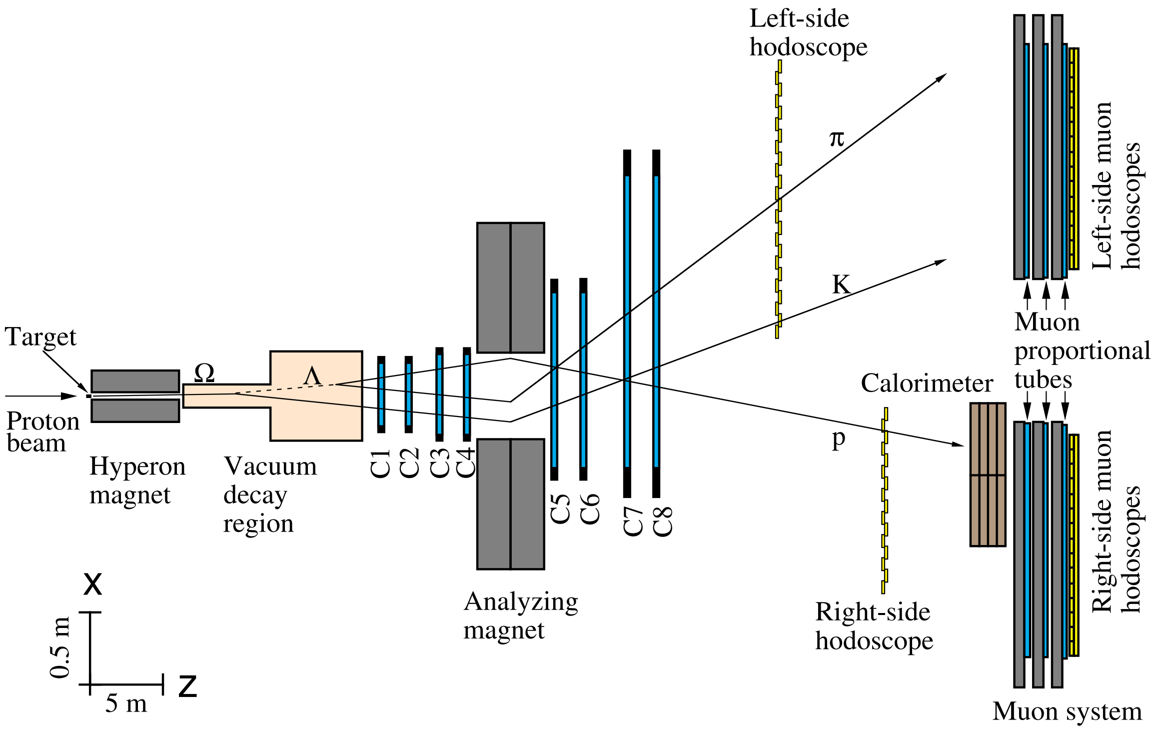
- *HyperCP* has collected about 14 million Ω^- and 5 million $\bar{\Omega}^+$ in RUN-I (1997) and RUN-II (1999), which allows us to measure α_Ω for both Ω^- and $\bar{\Omega}^+$ at the 10^{-3} level.

Number of Reconstructed Events (10^6)					
Type	Channeled beam polarity +		Channeled beam polarity −		Total
$\Xi \longrightarrow \Lambda\pi$	460		2000		2460
$K \longrightarrow \pi\pi\pi$	390		160		550
$\Omega \longrightarrow \Lambda K$	RUN–I	RUN–II	RUN–I	RUN–II	
	1.54	3.32	5.71	8.41	
	4.86		14.12		18.98

- A difference between $|\alpha_\Omega|$ and $|\alpha_{\bar{\Omega}}|$ would be evidence of *CP* violation.

The *HyperCP* (E871) Spectrometer

- Protons on target = $(7 \sim 8)$ GHz
- Secondary beam intensity = $(10 \sim 15)$ MHz
- Trigger rate = $(50 \sim 80)$ KHz
- Charge of Sec. beam selected by the sign of Hyperon magnet



Analysis Method

The angular distribution of the proton from unpolarized Ω decays

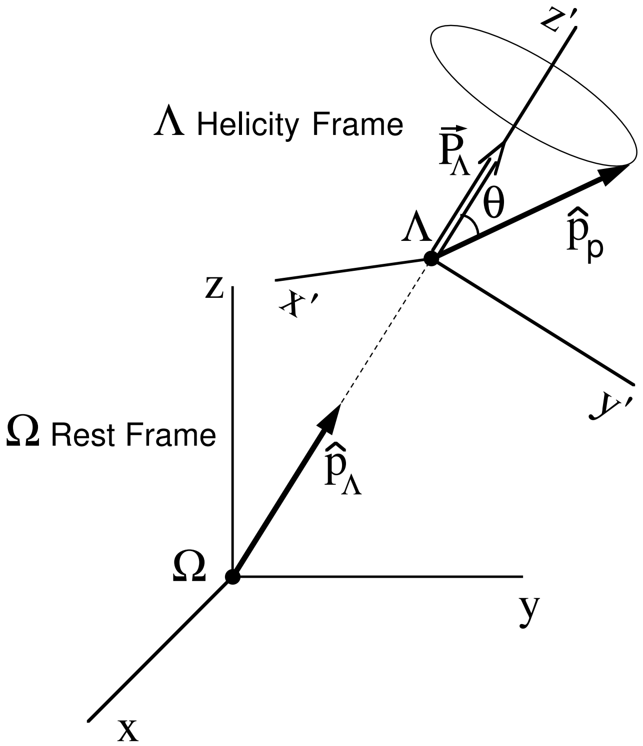
$$\Omega \to \Lambda K, \Lambda \to p\pi$$

is expressed as

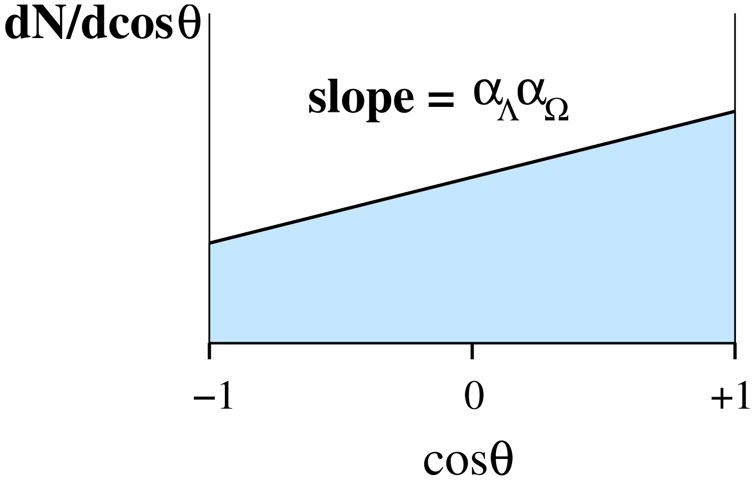
$$\frac{dN}{d\cos\theta} = \frac{N_0}{2}(1 + \alpha_\Lambda \alpha_\Omega \cdot \cos\theta), \tag{1}$$

where:

θ is the polar angle of the proton in the Λ helicity frame.



- Slope of the proton $\cos\theta$ distribution in the Λ helicity frame given by $\alpha_\Lambda \alpha_\Omega$



- The parameter α_Λ of the $\Lambda \to p\pi$ decay defined as

$$\alpha_\Lambda = \frac{2Re(S^*P)}{|S|^2 + |P|^2} \quad \Longrightarrow \text{well measured !!!}$$

$$\Downarrow$$

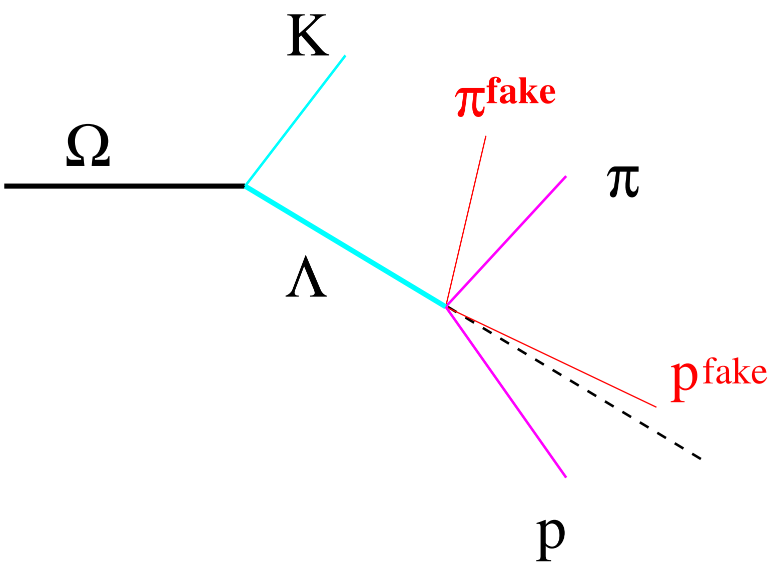
$$\alpha_\Lambda = 0.642 \pm 0.013$$

$$\Downarrow$$

allowing α_Ω to be extracted

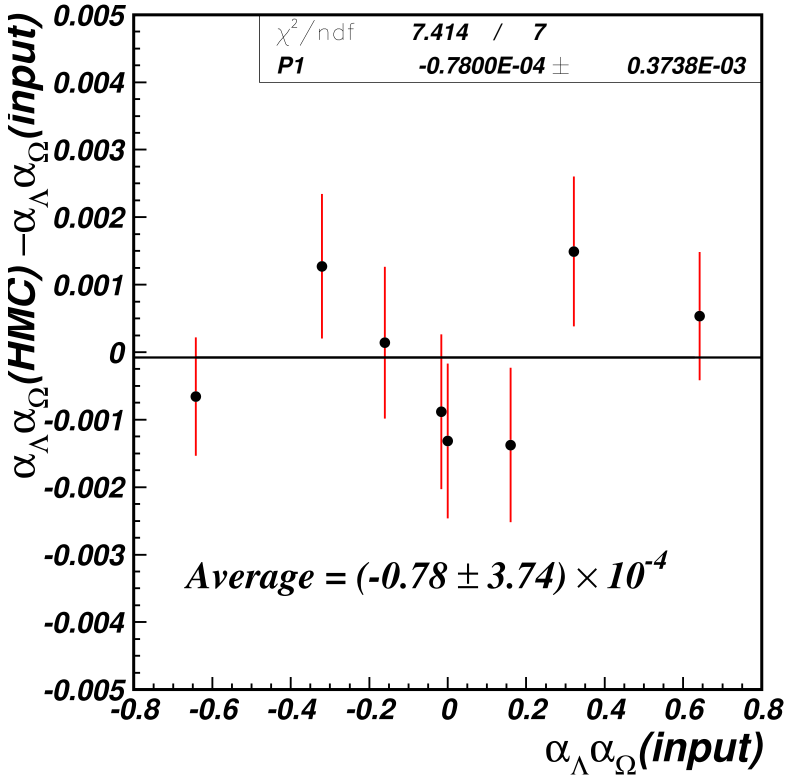
- In reality, the proton $\cos\theta$ distribution is distorted by the spectrometer acceptance

- Use Hybrid Monte-Carlo Method (HMC) to handle the acceptance
  - Take all variables from each real event except $\cos\theta$
  - Generate HMC events (**fake events**) with uniform $\cos\theta_f$
  - Let all the **fake events** go through the software spectrometer, triggers, etc. to simulate the behavior of real events in the experiment; hence determine the acceptance
  - Weight **fake events** by a function $W(\alpha_\Lambda\alpha_\Omega)$ so as to match $\cos\theta$ distributions of real and fake events to obtain $\alpha_\Lambda\alpha_\Omega$



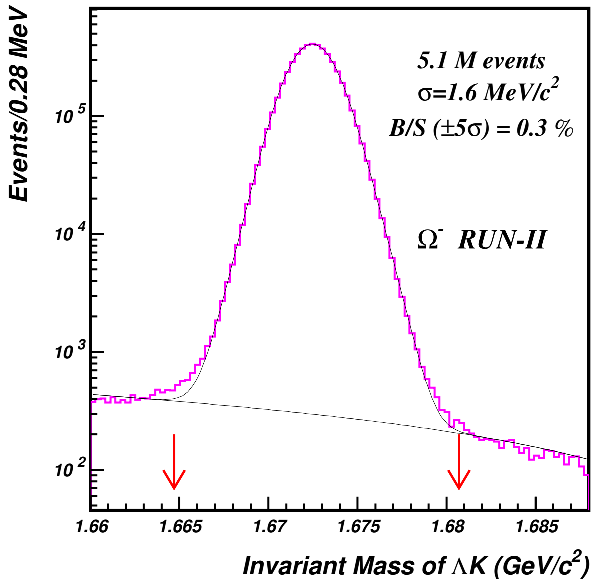
Validation of HMC

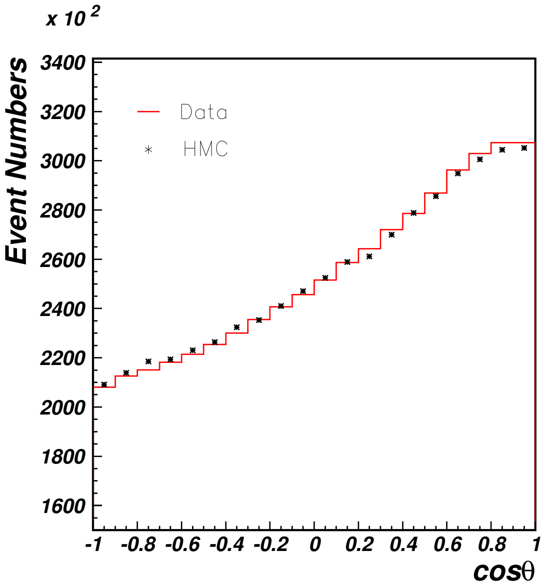
- Generate Monte-Carlo data samples with different input $\alpha_\Lambda\alpha_\Omega$
- Analyze these Monte-Carlo data samples with HMC



Data Analysis

- **ΛK Invariant Mass and Proton Angular Distribution in Λ Helicity Frame ($\cos\theta$)**





- Background: 0.3% $\Rightarrow$ small effect on $\alpha_\Lambda \alpha_\Omega$ measurement

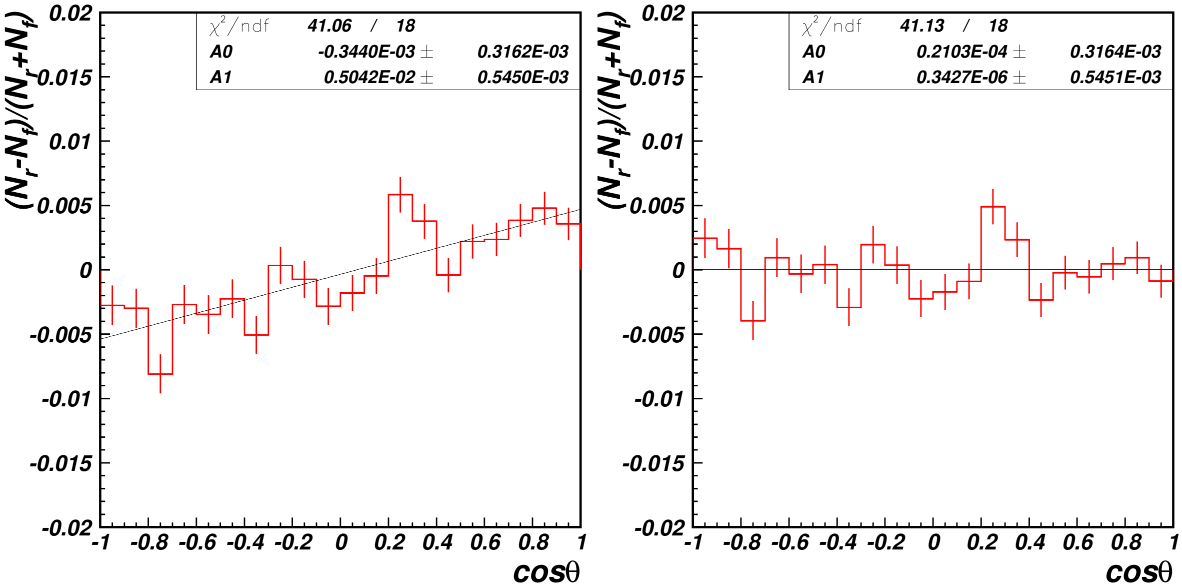
- Measure $\cos\theta$ slope: $\dfrac{dN}{d\cos\theta} = \dfrac{N_0}{2}(1+S_m \cdot \cos\theta)$, where

  $S_m = f(\alpha_\Lambda \alpha_\Omega, S_b)$

  S_b is the slope of background angular distribution.

- Estimate background slope S_b from side bands.

- **Difference of $\cos\theta$ Distributions Between Real and Fake Events**

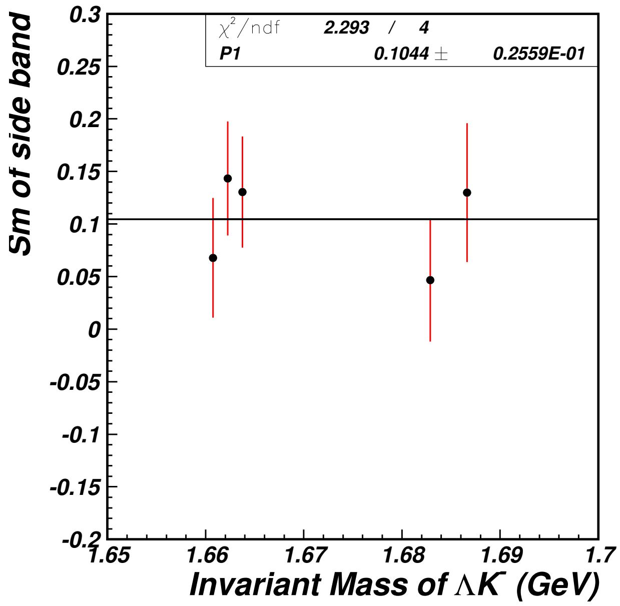


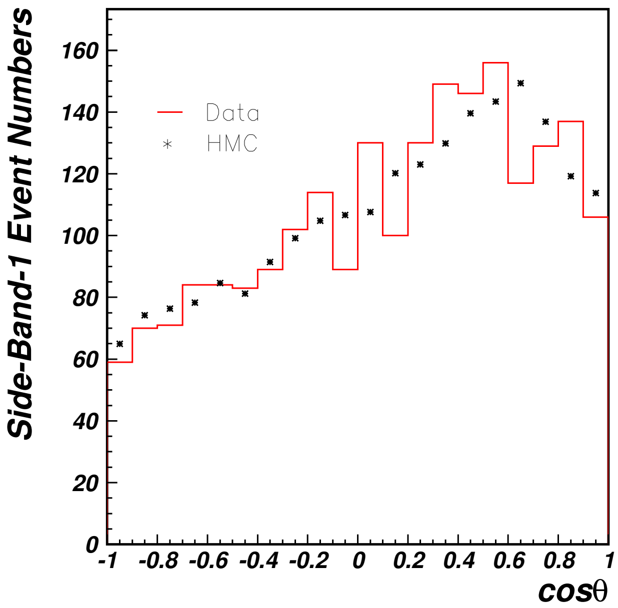
$\Uparrow$ **before weighting** $\Uparrow$ **after weighting**

The measured slope:

$$S_m = (1.32 \pm 0.11) \times 10^{-2}$$

- **Slope and $\cos\theta$ Distribution of Side Bands**



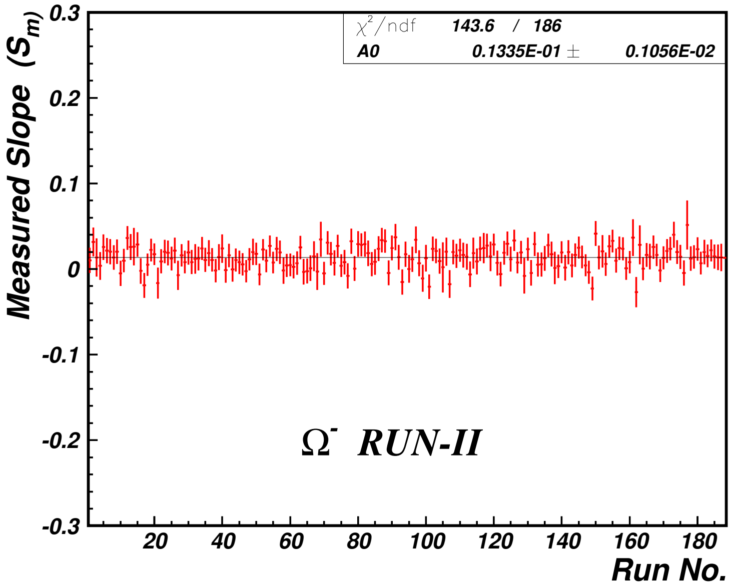


$$S_b = (10.44 \pm 2.56) \times 10^{-2}$$

- **After background correction, we get**

$$\boxed{\alpha_\Lambda \alpha_\Omega = [1.29 \pm 0.11\ (\mathrm{stat})] \times 10^{-2}}$$

- **Stability of Measured Slope S_m**



- **Systematic Uncertainties**

Type	Fraction of $\sigma_{\text{stat.}}$
π_Λ-momentum cut	≤ 3.5
Calorimeter efficiency	≤ 0.5
SS Hodoscope efficiency	0.1
OS Hodoscope efficiency	0.2
Wire Chambers efficiency	0.3

- **Further systematic error study is underway.**

Our Preliminary Results

- $\alpha_\Lambda \alpha_\Omega = [1.29 \pm 0.11\ (\text{stat})] \times 10^{-2}$ (5 million RUN-II data), and

  $\alpha_\Lambda \alpha_\Omega = [1.18 \pm 0.29\ (\text{stat})] \times 10^{-2}$ (1 million RUN-I data).

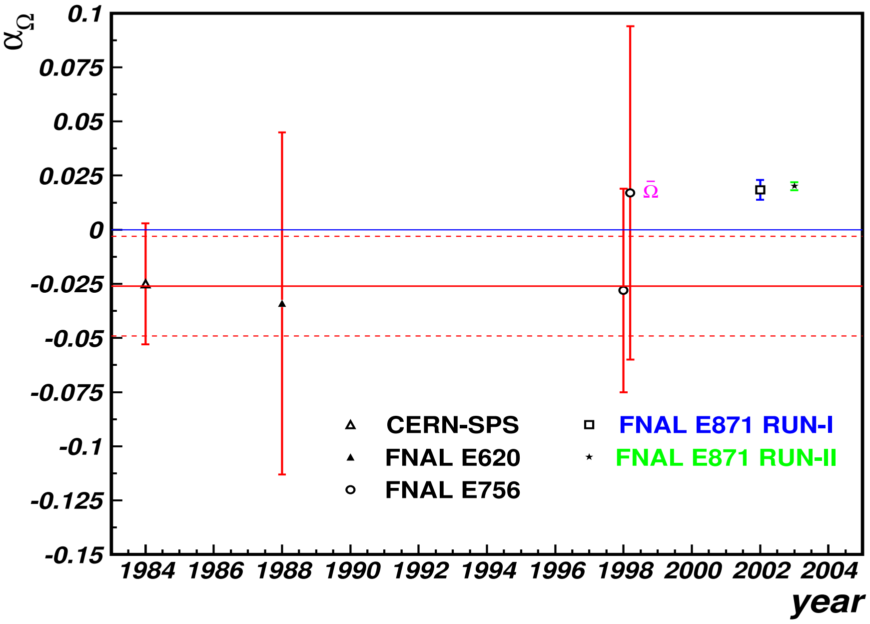
- Using PDG value $\alpha_\Lambda = 0.642 \pm 0.013$,

  $\alpha_\Omega = [2.01 \pm 0.17\ (\text{stat}) \pm 0.04\ (\text{syst PDG})] \times 10^{-2}$ (RUN-II), and

  $\alpha_\Omega = [1.84 \pm 0.46\ (\text{stat}) \pm 0.04\ (\text{syst PDG})] \times 10^{-2}$ (RUN-I).

Conclusions

- With about five million events from RUN-II and one million events from RUN-I of $\Omega^- \to \Lambda K^-$ decay, our preliminary measurement of α_Ω is a significant improvement over previous results.



- Our preliminary result indicates that α_Ω is non-zero and hence that parity violation exists in $\Omega \to \Lambda K$ decays.

- After finishing the Ω^- analysis and freezing all cuts, we will run through the $\bar{\Omega}^+$ data sample to obtain $\alpha_{\bar{\Omega}}$. We expect the precision of the measurement of $\Delta(\alpha_\Lambda \alpha_\Omega) \equiv \alpha_\Lambda \alpha_\Omega - \alpha_{\bar{\Lambda}} \alpha_{\bar{\Omega}}$ in $\Omega \to \Lambda K$ decays to be $\sim 2 \times 10^{-3}$ (stat), which allows us to test CP conservation in these decays.