* Natural asymmetry in decay rates of the neutral charmed meson D^0 in its final states of $K_{long}\pi^0$ and $K_{short}\pi^0$

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Graduate Seminar, Virginia Tech

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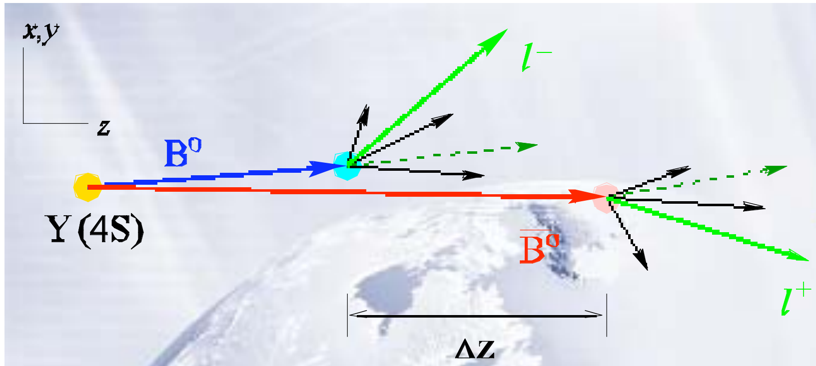
*Measurement carried out at
B Meson factory, KEK Lab, Japan



The Belle Detector

Vertex by SVD

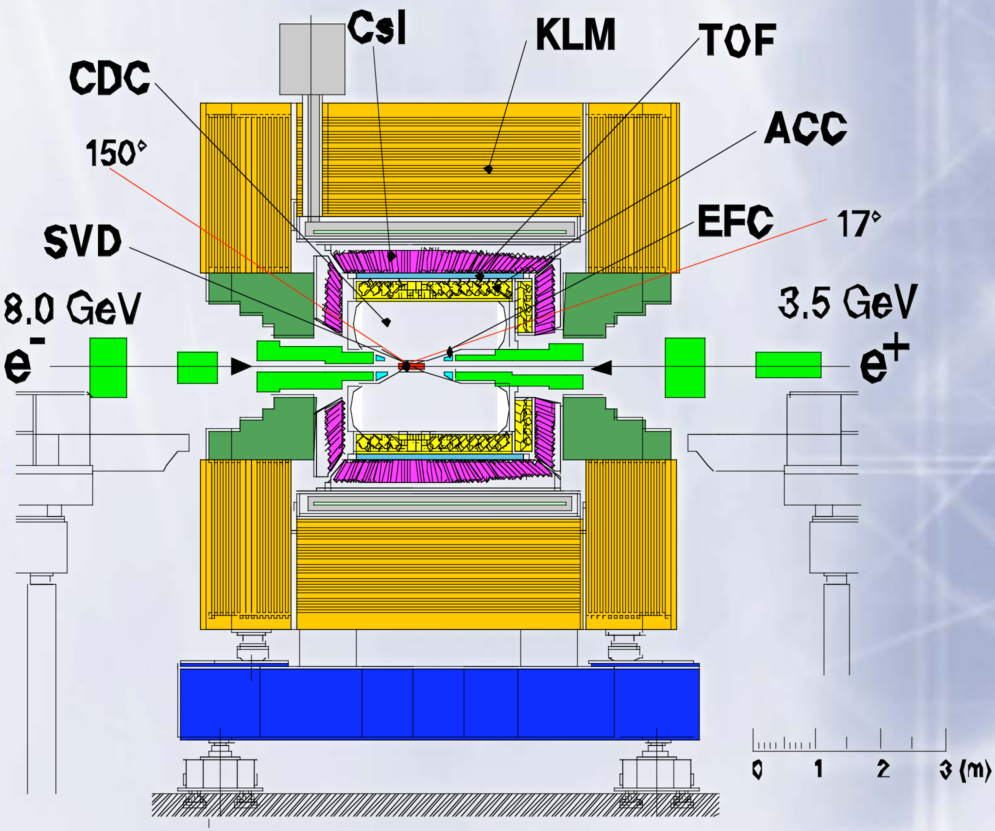
Charged particle by CDC

Particle identification by dE/dX in CDC, ACC and TOF

Electromagnetic showers by ECL and EFC

Muons and K_L^0 detection by KLM

1.5 T super conducting solenoid



Asymmetry in decays of D^0 meson

D^0 decays occur through $\bar{K}^0\pi^0$ (CF mode) and $K^0\pi^0$ (DCS mode)

The interference in Cabibbo favored and doubly suppressed modes point towards an asymmetry present in the following decay modes of D^0 represented by their decay widths

$$\Gamma_{D^0\to K_S\pi^0} = \frac{1}{2}\Gamma_{CF} - (\sqrt{\Gamma_{CF}}\sqrt{\Gamma_{DCS}})\cos(\delta_{CF} - \delta_{DCS}) + \frac{1}{2}\Gamma_{DCS}$$

$$\Gamma_{D^0\to K_L\pi^0} = \frac{1}{2}\Gamma_{CF} + (\sqrt{\Gamma_{CF}}\sqrt{\Gamma DCS})\cos(\delta_{CF} - \delta_{DCS}) + \frac{1}{2}\Gamma_{DCS}$$

$$A = \frac{(\Gamma_{D^0\to K_S\pi^0}) - (\Gamma_{D^0\to K_L\pi^0})}{(\Gamma_{D^0\to K_S\pi^0}) + (\Gamma_{D^0\to K_L\pi^0})} \simeq -2\sqrt{\frac{\Gamma_{DCS}}{\Gamma_{CF}}} cos(\delta_{CF} - \delta_{DCS}) \simeq tan^2\theta_c \simeq 5\%$$

Measurement of the asymmetry

Collision

$$e^+e^- \rightarrow c\bar{c} \rightarrow DD$$

Asymmetry

$$D^0 \rightarrow \bar{K}^0[K_S^0]\pi^0$$

$$D^0 \rightarrow \bar{K}^0[K_L^0]\pi^0$$

Detector

Effect

$$D^0 \rightarrow K^{*-}[K_S^0\pi^-]\pi^+$$

$$D^0 \rightarrow K^{*-}[K_L^0\pi^-]\pi^+$$

Signal

Tagging

$$D^{*+} \rightarrow D^0\pi^+$$

This asymmetry can be measured at the Belle Detector although it poses several difficult issues as we will discuss later. The decay modes mentioned here and their charge conjugate counterparts are both included in the measurement.

Any asymmetry as a result of bias coming from Detector is calibrated from decay modes where $K_{L/S}$ comes from the K^* so that these are produced at equal rates, as any asymmetry in these modes are a result of reconstruction. CP asymmetry is negligible.

The signal is recognized in terms of "D^* mass" or "D^* and D^0 mass difference"

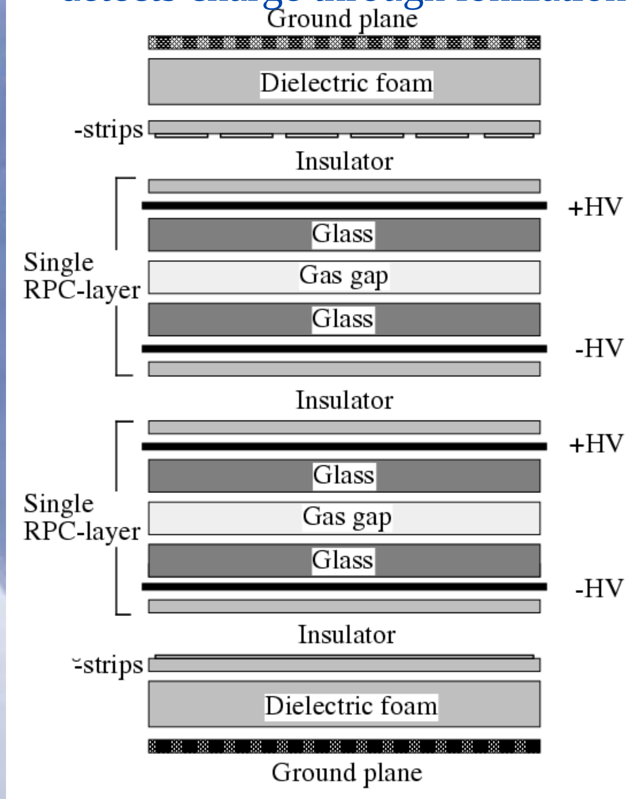
Issues with measurement.

1. Measurement unique, never performed. Important Physics.
2. K_L is not identified completely, only its direction is.
3. K_S Vs K_L, daunting problem. K_S cleaner and more precise.
4. K_L less efficiently reconstructed, efficiency low at low momentum
5. 3-body modes have different kinematics from 2-body modes

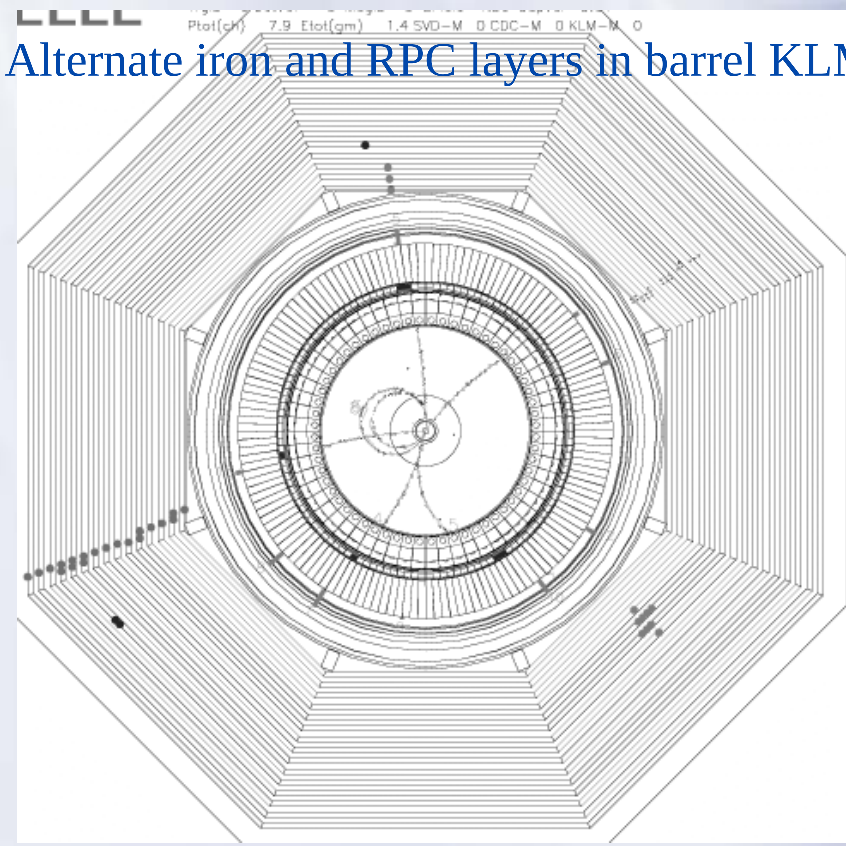
K_L and μ [muon] detector

RPC super layer in KLM

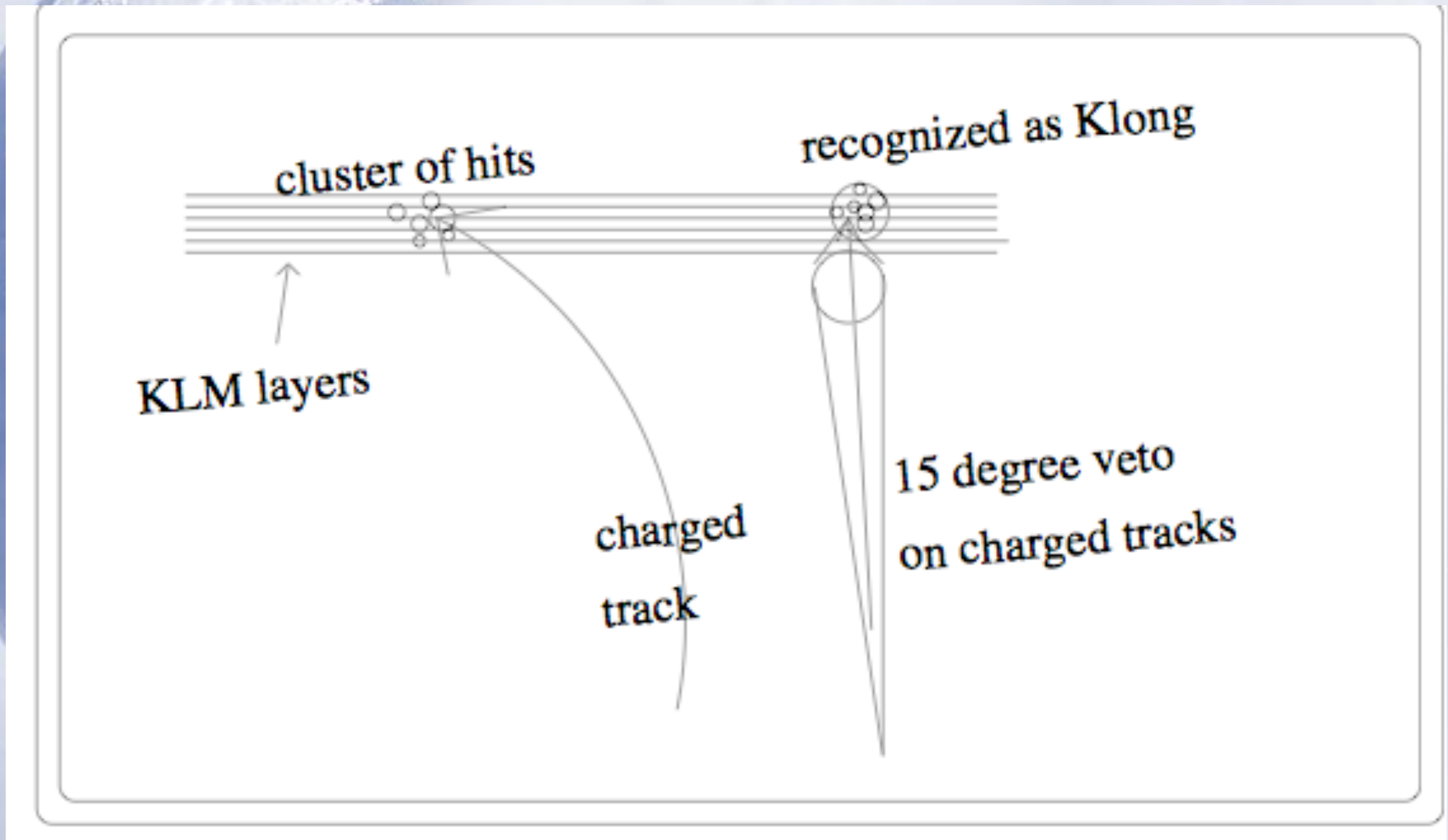
detects charge through ionization



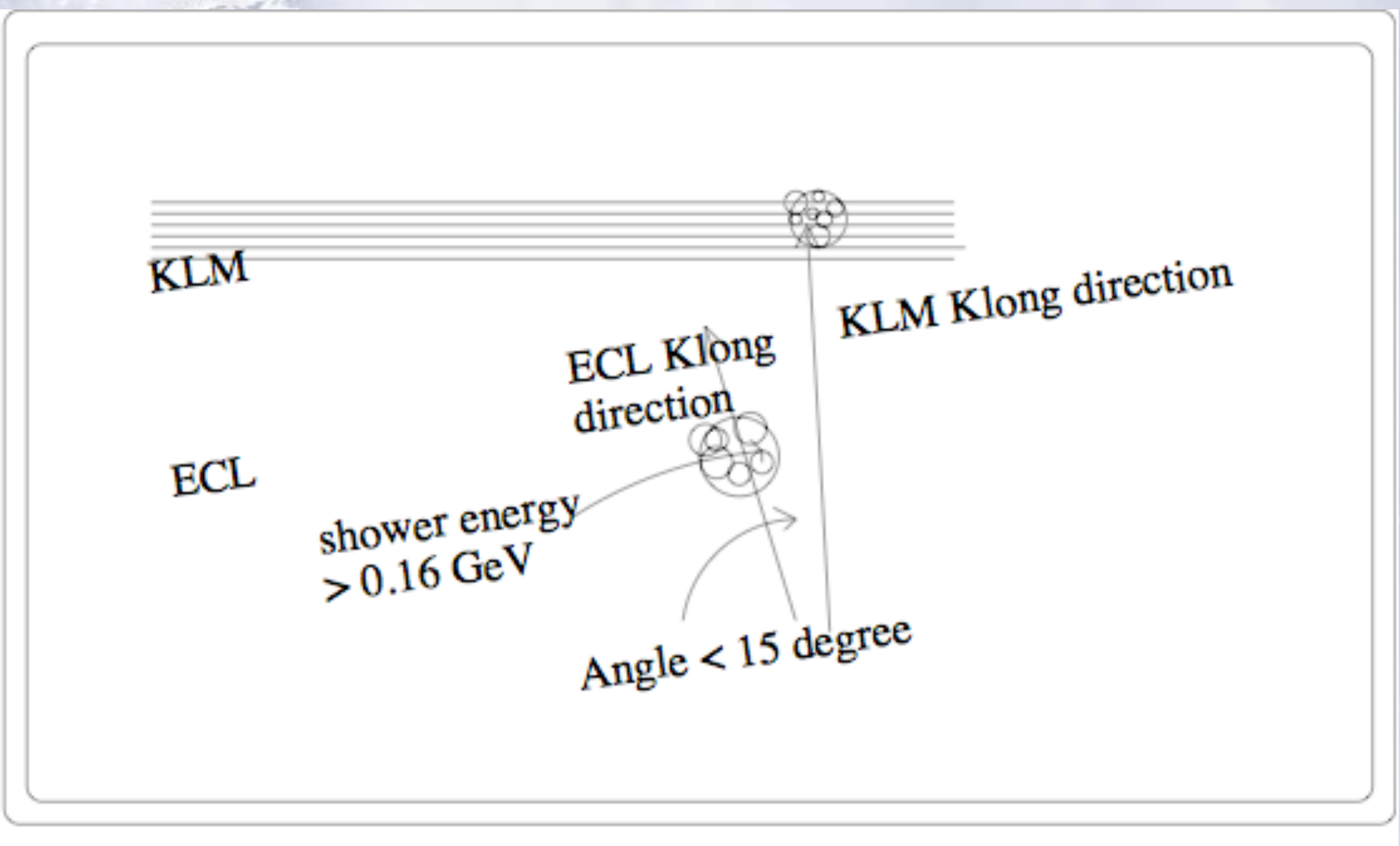
Alternate iron and RPC layers in barrel KLM



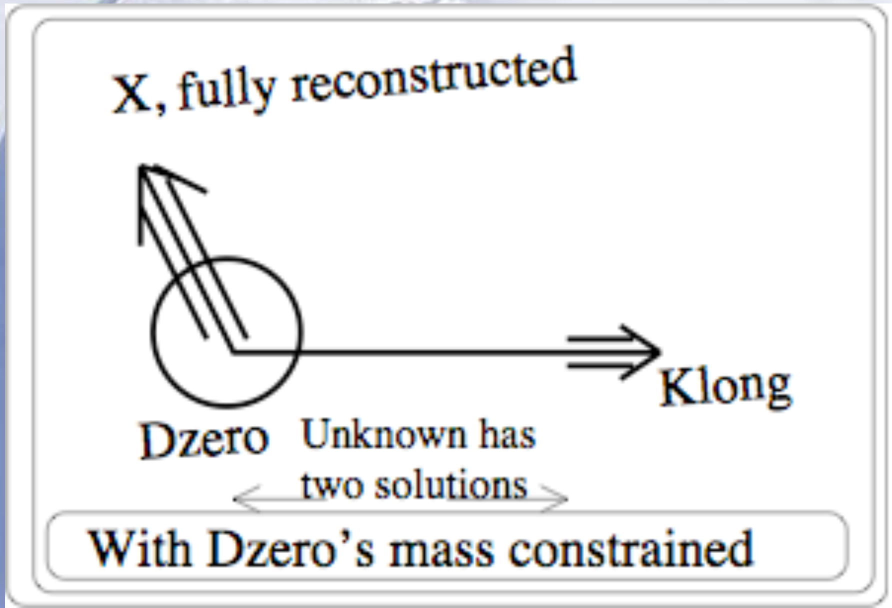
K_L Detection

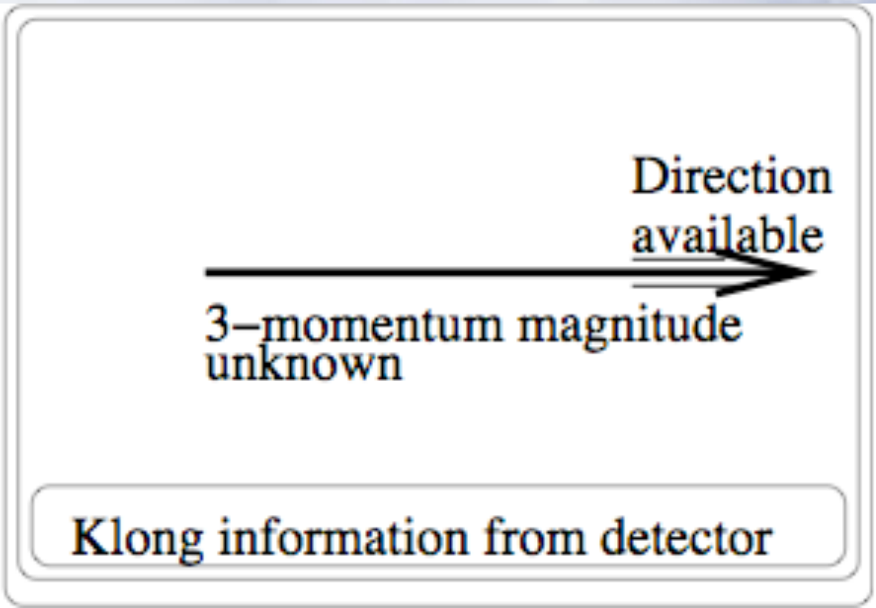


Improved K_L Detection



K_L Reconstruction





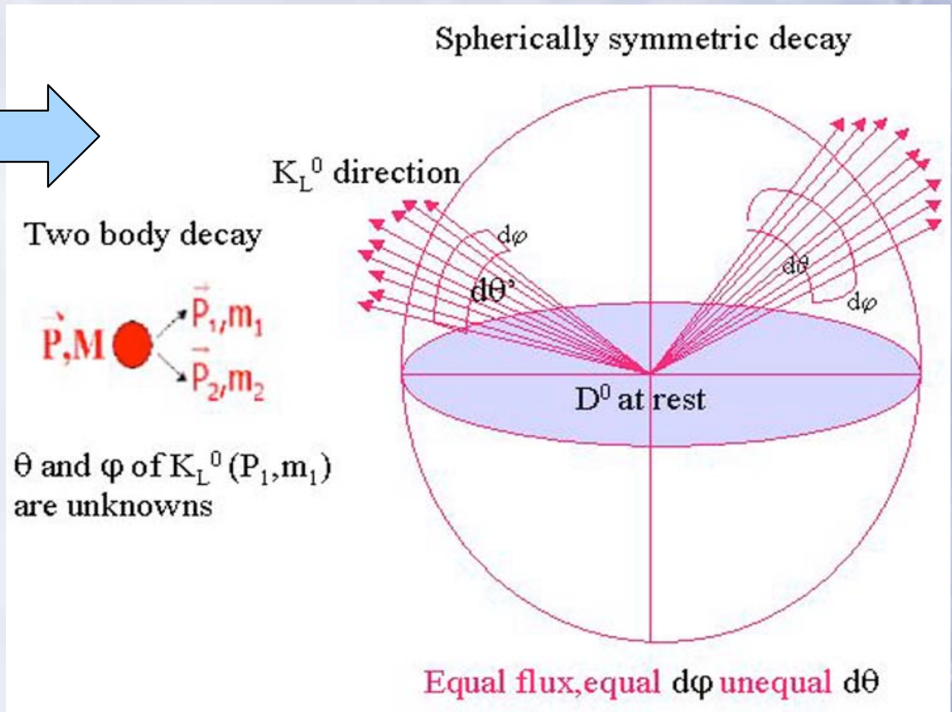
$$A \to BC$$
$$P_A^4 = P_B^4 + P_C^4$$

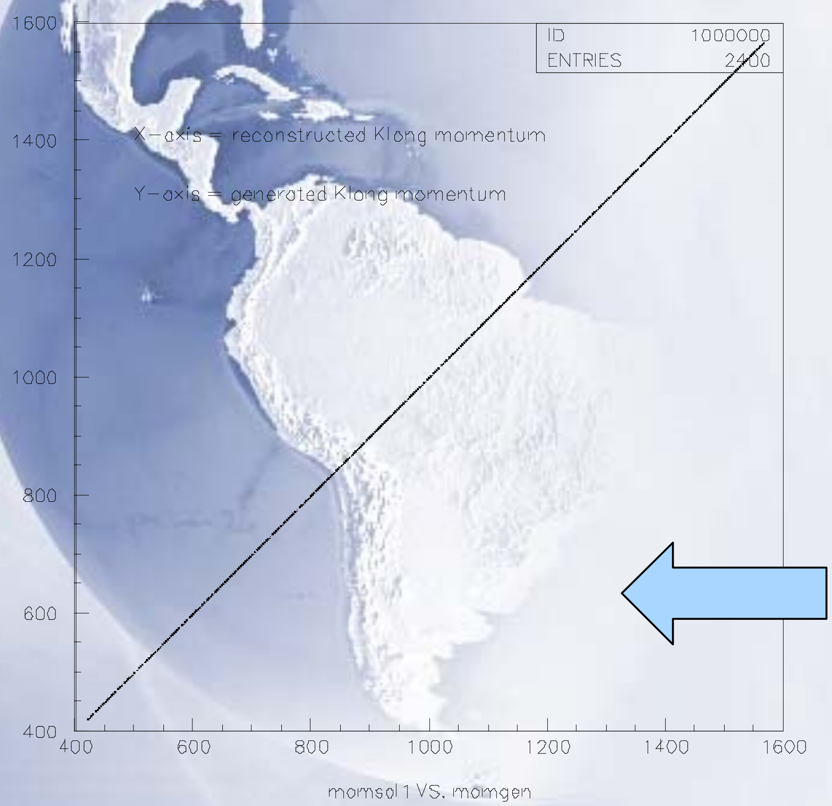
&

$$E^2 = \vec{p}^2 c^2 + \left(mc^2\right)^2$$

A simple toy Monte Carlo study of $D^0 \rightarrow K_L{}^0 \pi^0$ is done to see how well D^0 mass constraint works

A signal is generated for the decay by simulating θ and φ with random numbers





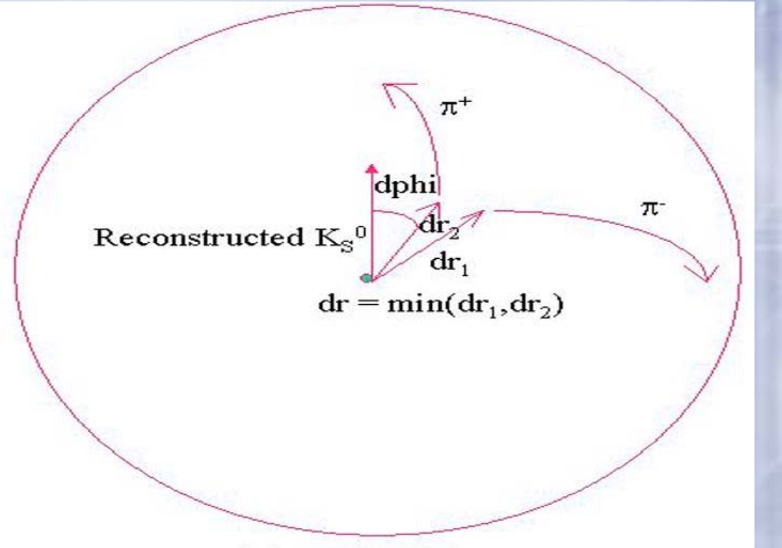
Reconstructed momentum for $K_L{}^0$ match exactly with what was generated

Reconstruction of K_S^0, shown in Monte Carlo

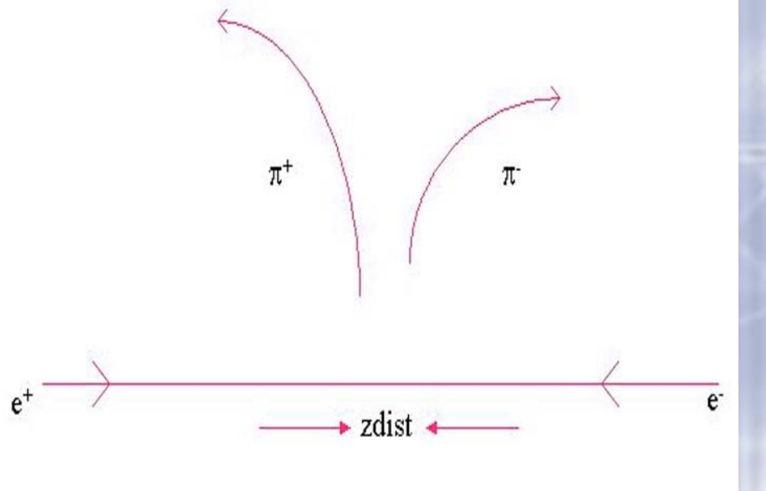
Track cuts shown in picture have been applied zdist < 1, dr > 0.25, dphi < 0.1

Following invariant mass cuts have been applied 20 MeV on K_S^0, 150 MeV on K^{*-}, 60 MeV on D^0 and D^{*+}

A K_S^0 reconstructed by D^0 mass constraint and whose direction distribution is smeared to match K_L^0 resolution is called a pseudo K_L^0



End view of K_S^0 decay

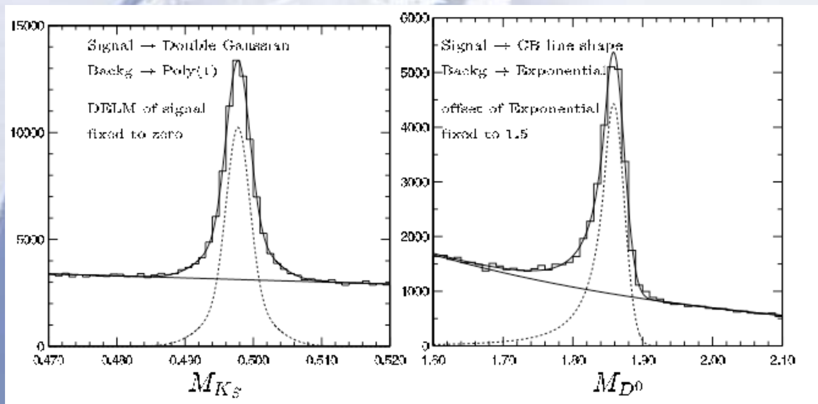


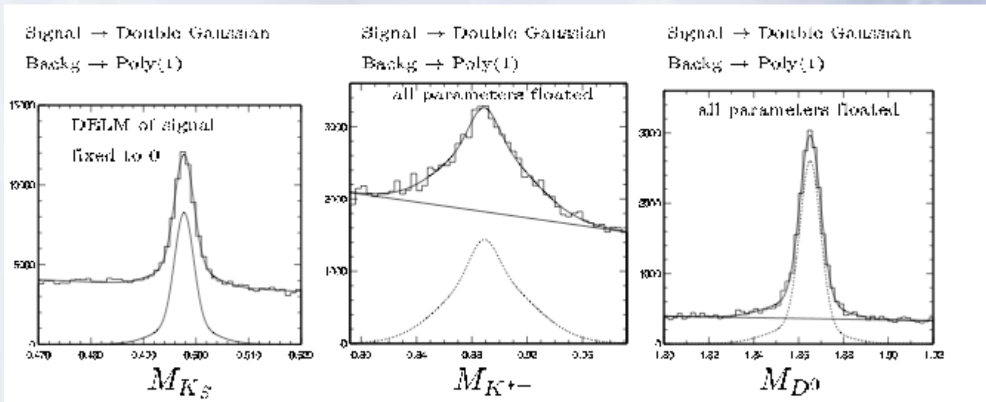
Side view of K_S^0 decay

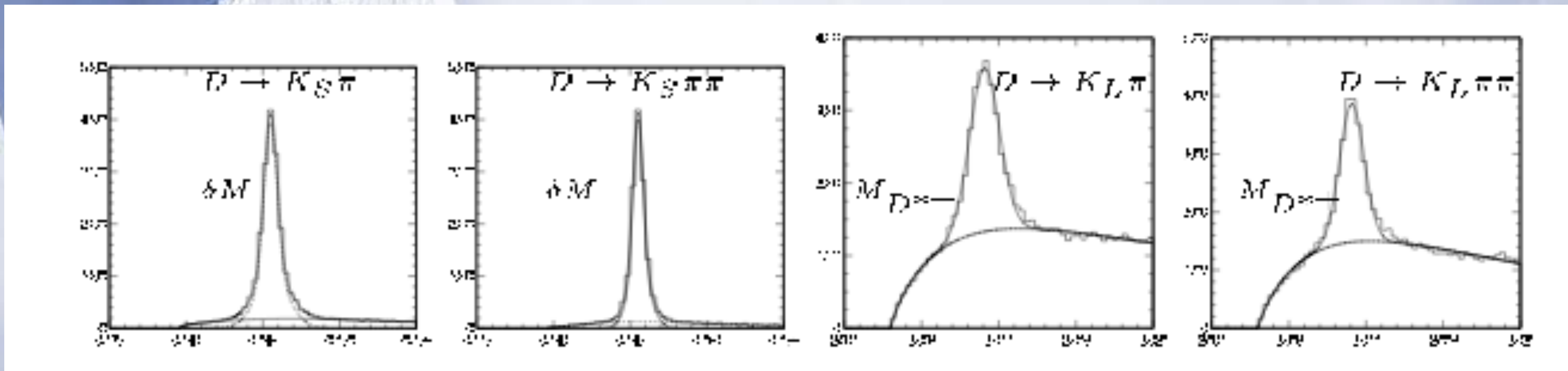
Direction resolution for K_L^0 and K_S^0 was studied in Monte Carlo where only signal was present

	σ_θ	σ_φ	REMARK
K_S^0	0.002	0.002	
K_L^0	0.016	0.018	K_S^0 resolution is ~10 times better than K_L^0 resolution
KLM K_L^0	0.022	0.028	
ECL K_L^0	0.012	0.014	ECL K_L^0 resolution is better than KLM K_L^0 resolution

Monte Carlo simulation







The state of the Science situation

Physics Letters B 505(2001)94-106

- comes from interference in CF and DCS modes of D0 decay, expected up to 5%.
- constrains the strong phase in $K^+\pi^-$, $K^-\pi^+$

hep-ex/0107078, July 2001

- can be calibrated against $D0 \rightarrow (\overline{K}^0\ \pi^-)_{K^{*}\ -}\ \pi+$
- measured at belle, 0.06 ± 0.05 ± 0.05

hep-ex/0607068, July 2006

- measurement at cleo 0.122 ± 0.024 ± 0.030

Reconstruction and Event selection

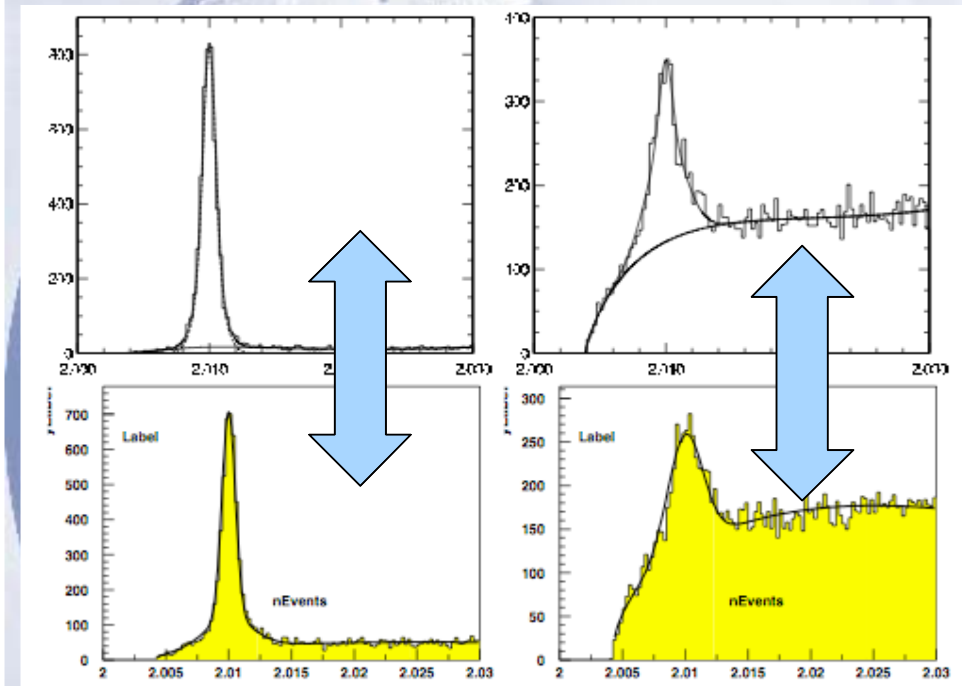
- π^0 from mdst_pi0, $E_\gamma \geq 0.05$ GeV/c^2
- $\pi^\pm$, good charged
- K_S , good Kshort
- K_L , mdst_klong, $D^0 \to K_L \pi^0$ and $D^0 \to (K_L \pi^-)_{K^{*-}} \pi^+$ assumed
- $K^{*\pm}$ within 50 MeV of nominal mass
- D^0 within 100 MeV of nominal mass (for K_S modes only)
- $D^{*\pm}$ tags the signal, $M_{D^{*\pm}} \leq 2.03$ GeV
- $\delta M = D^{*\pm}$ and D^0 mass difference
  $\delta M + 1.8645 \leq 2.03$ GeV
  (for K_S modes only)

- A K_L with ECL cluster energy in 0.15 to 0.3 GeV range (corresponding to minimum ionization energy) rejected
- K^0 flight angle wrt D^0 boost (θ_{DK}), $-0.95 \leq \cos(\theta_{DK}) \leq 0.2$ for all modes
- Invariant mass of $(\pi^+\pi^-) \leq 0.7$ GeV
- Reconstructed scaled momentum of D^*, $0.6 \leq x_p \leq 1.0$

Some differences in procedure

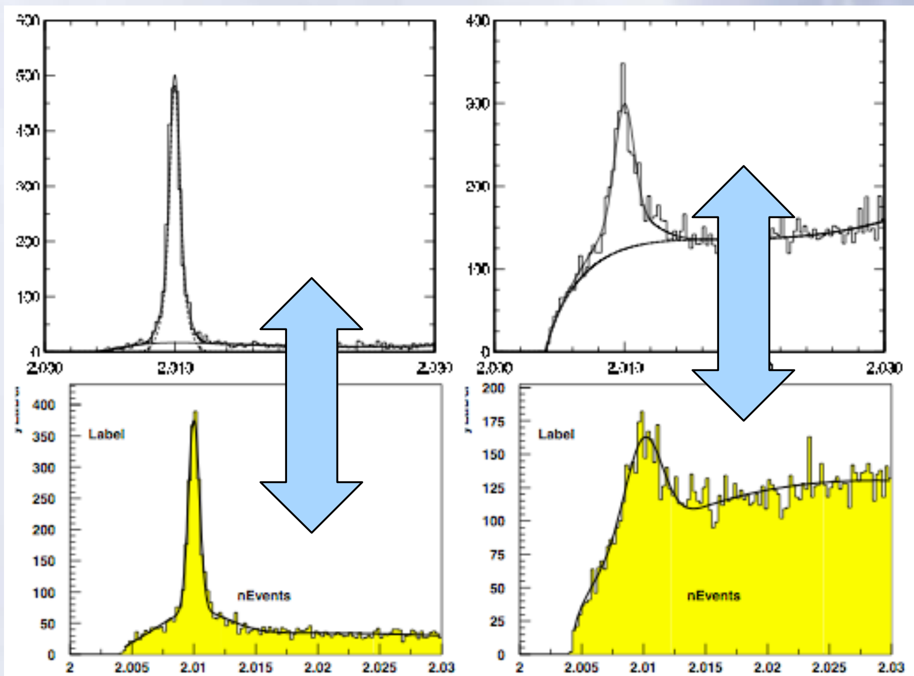
		This analysis	previous measurement at Belle, 2001
selection	K_S selection	"Good" kshort	Tighter vertex
	π^0 / $\pi^\pm$ selection	π^0 from mdst_pi0, $E_\gamma \geq 0.05$ GeV/c^2 $\pi^\pm$, good charged	Standard (?) procedure, 2001
fitting	Signal	Double Gaussian Mean of Gaussian fixed to D* nominal mass	Double Gaussian (KS modes), Single Gaussian (KL modes), means fixed
	Background	Threshold function	1st Poly x sqrt threshold

Qualitative comparison with previous study, same amount of data

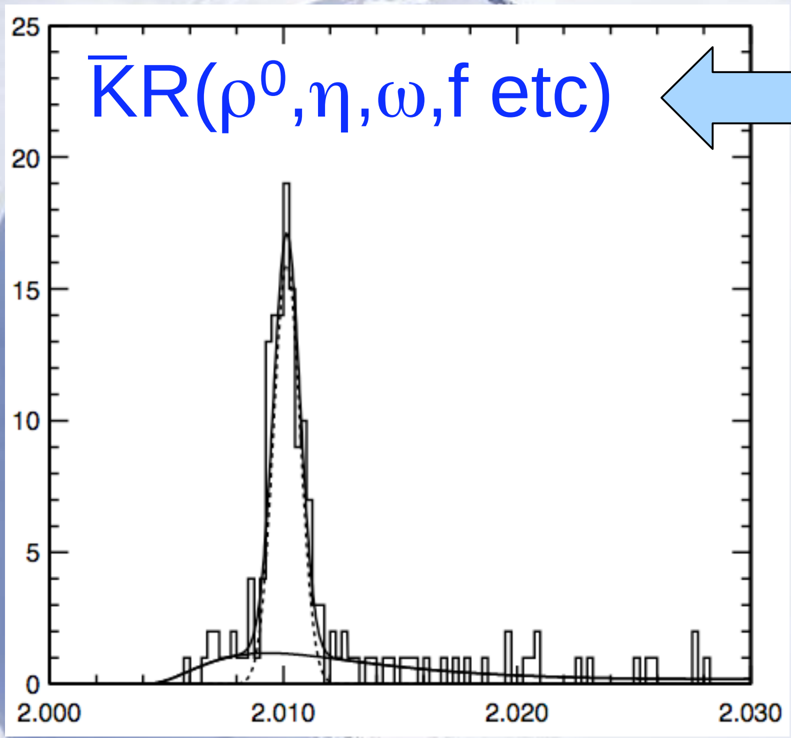


Mode 1 and 2

Mode 3 and 4

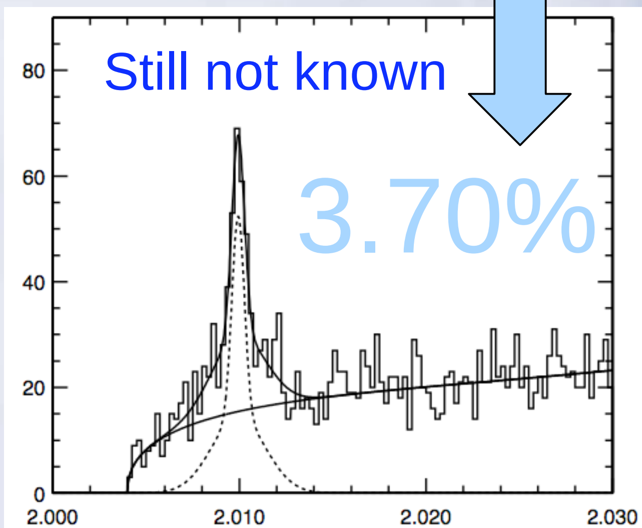


Detailed, extensive study in Monte Carlo



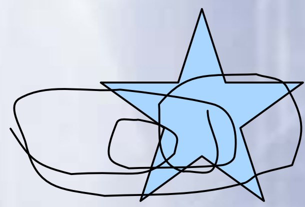
The only peaking background that affect the modes where asymmetry is measured. Yield is so small it doesn't affect much.

The calibration modes suffer from various issues in peaking backgrounds, one shown here.



Future efforts

1. Upgrade of data size, consistent calculations, writing of technical notes and completion of thesis, thesis defense.
2. “Acceptance of God”
3. Buying a car, house
4. Find a job (oops !!)



Hardworking people are happy people