My presentation today is based on the following topics

1 Introduction to CP violation

2 Details of Belle detector

3 Physics goals

4 K_L^0 detection at Belle

5 Toy Monte Carlo study of $D^0 \to K_L^0 \pi^0$

6 Calibration and resolution study

7 Conclusion

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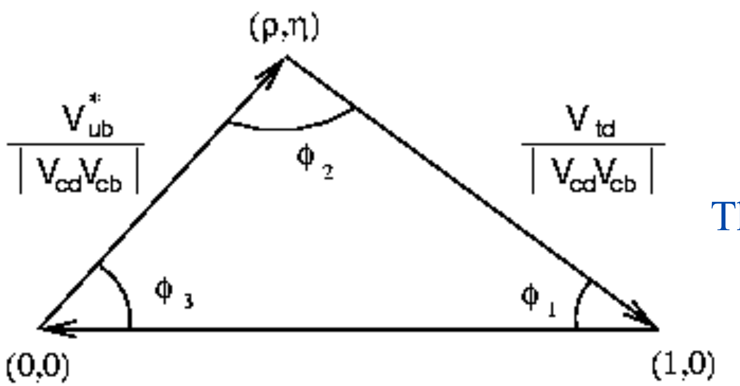
The Belle experiment intends to investigate Kobayashi-Maskawa mechanism for CP violation

The Cabibbo Kobayashi Maskawa(CKM) matrix

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \cdot \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$



The Cabibbo Kobayashi Maskawa unitarity triangle

The Belle detector shown in side view consists of the following subdetectors with the stated functions

Vertex measurement by SVD

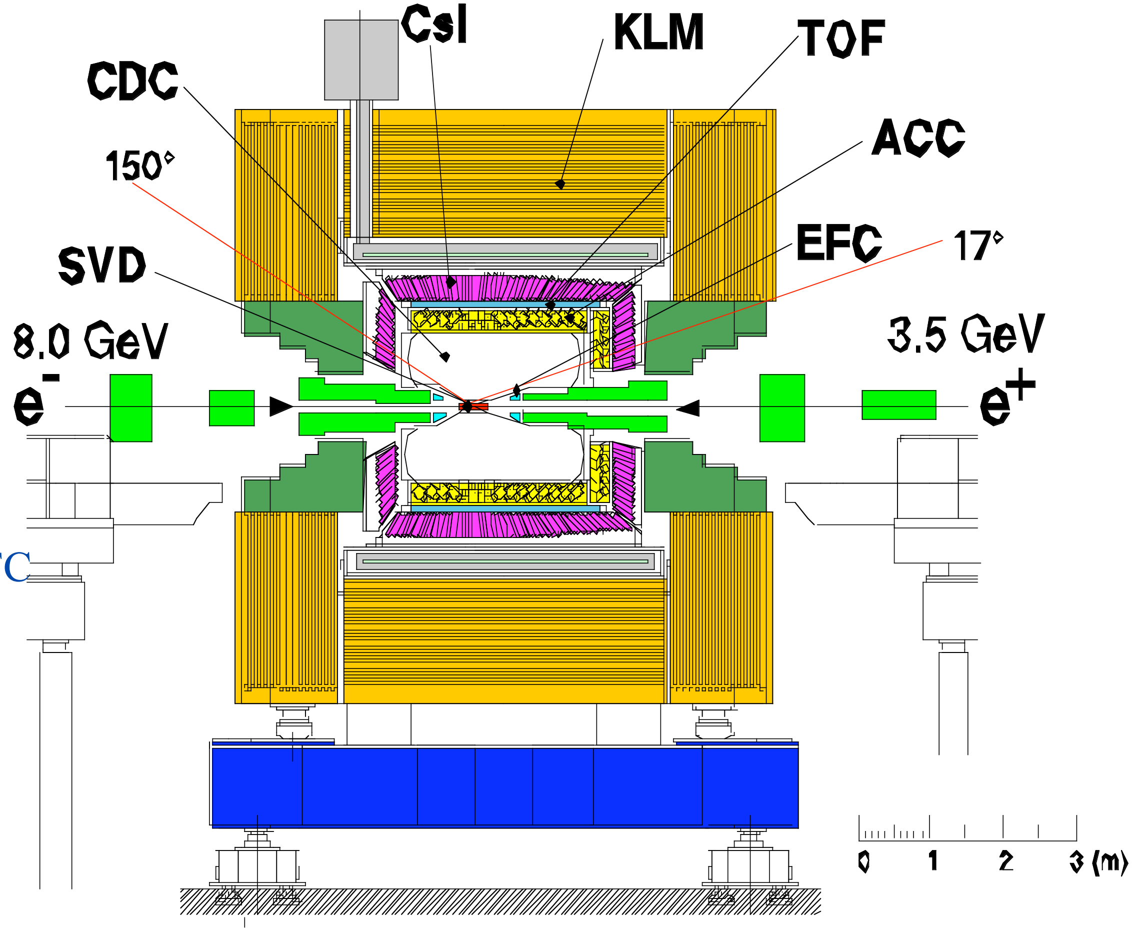
Charged particle tracking by CDC

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

Electromagnetic showers by ECL and EFC

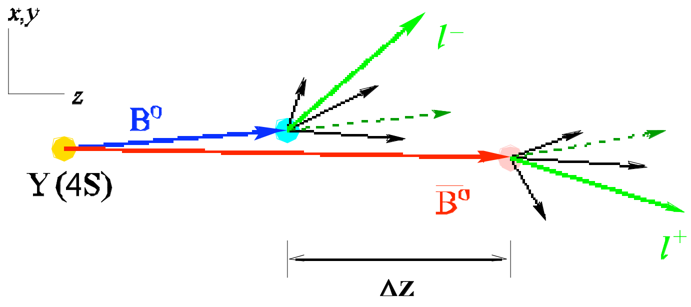
Muons and K_L^0 detection by KLM

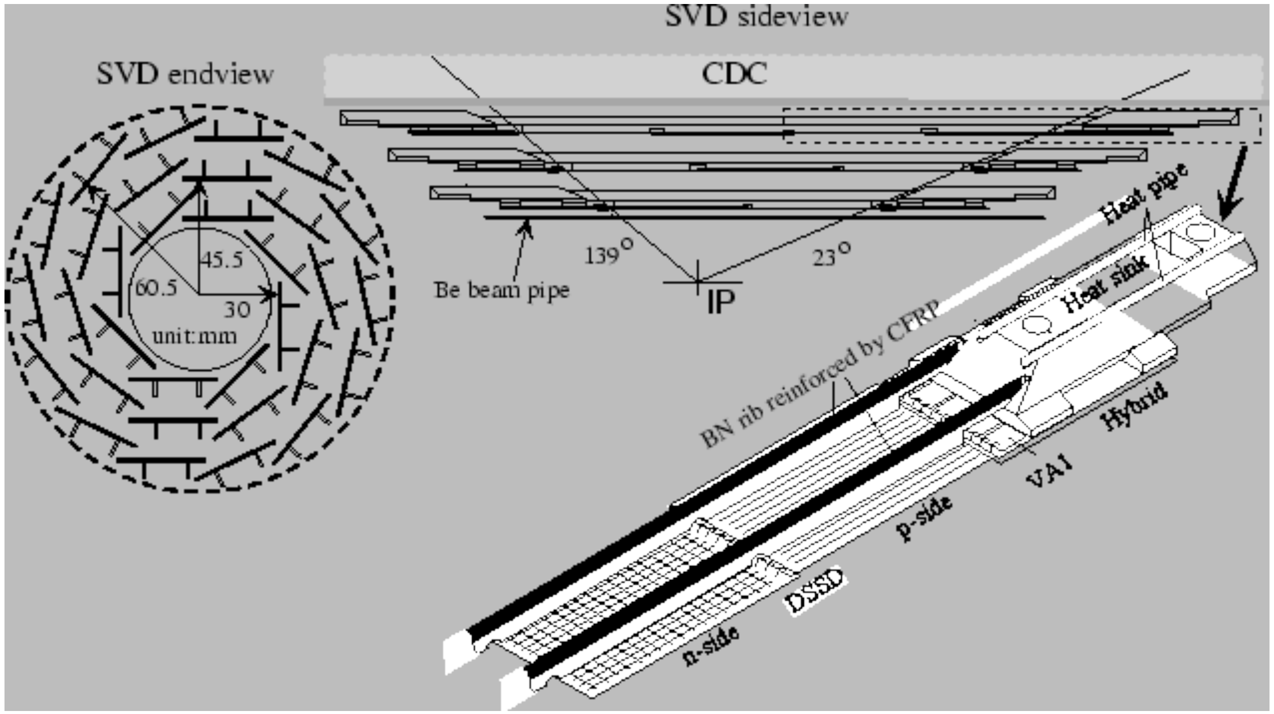
1.5 T super conducting solenoid



Version 1.x of silicon vertex detector or SVD consists of 3 layers, measures Z-vertices of B and D-mesons and τ's

z-vertex of B/Bbar pair important for time dependent CP violation

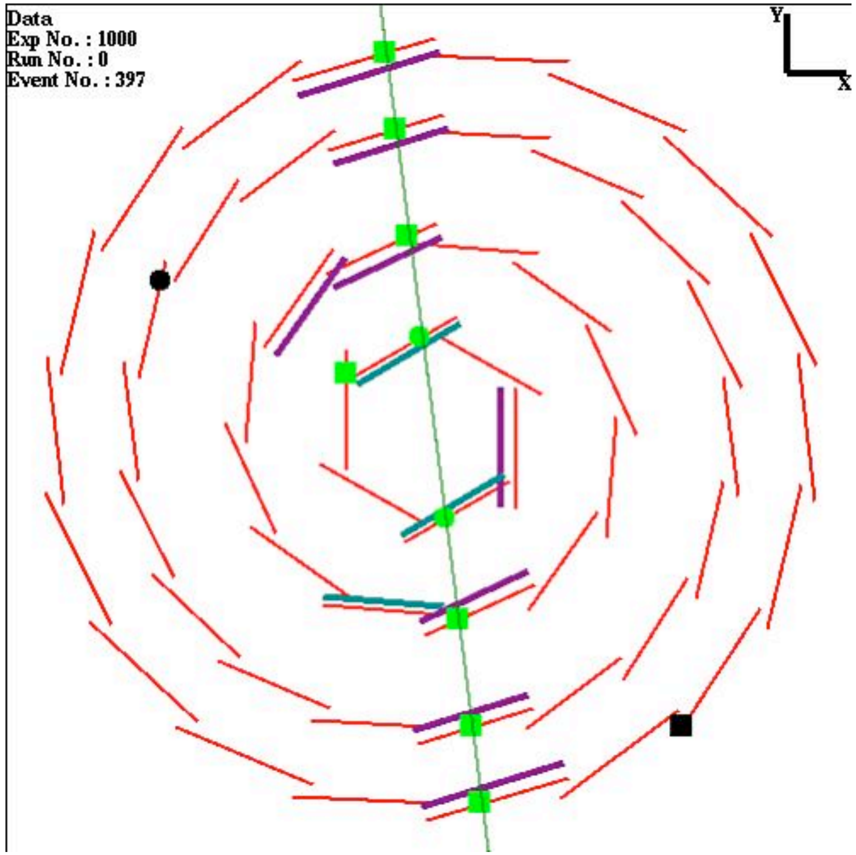




Innermost layer very close to beam pipe wall

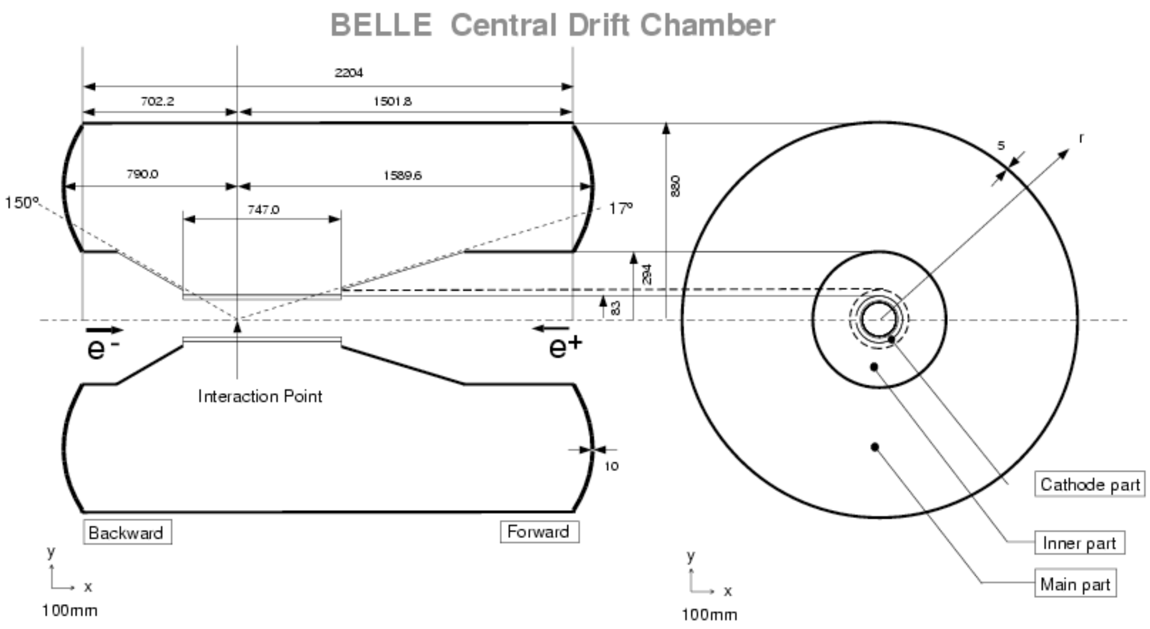
Version 2.0 of SVD consisting of 4 layers has better resolution and was installed in summer 2003

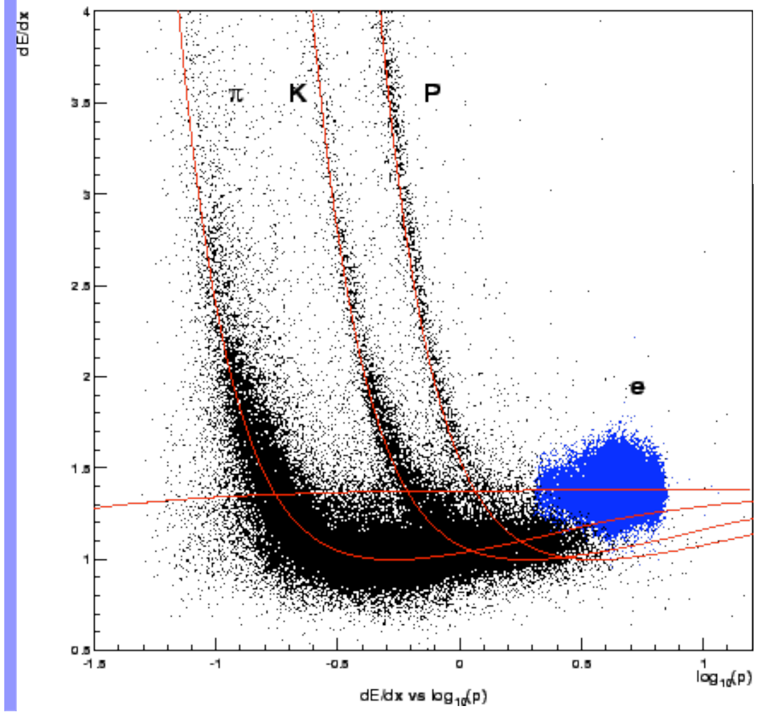
The innermost layer is closer to Interaction Point(IP)



The central drift chamber or CDC reconstructs charge tracks and 3-momentum with precision

z asymmetry to cover $17^0<\theta<150^0$

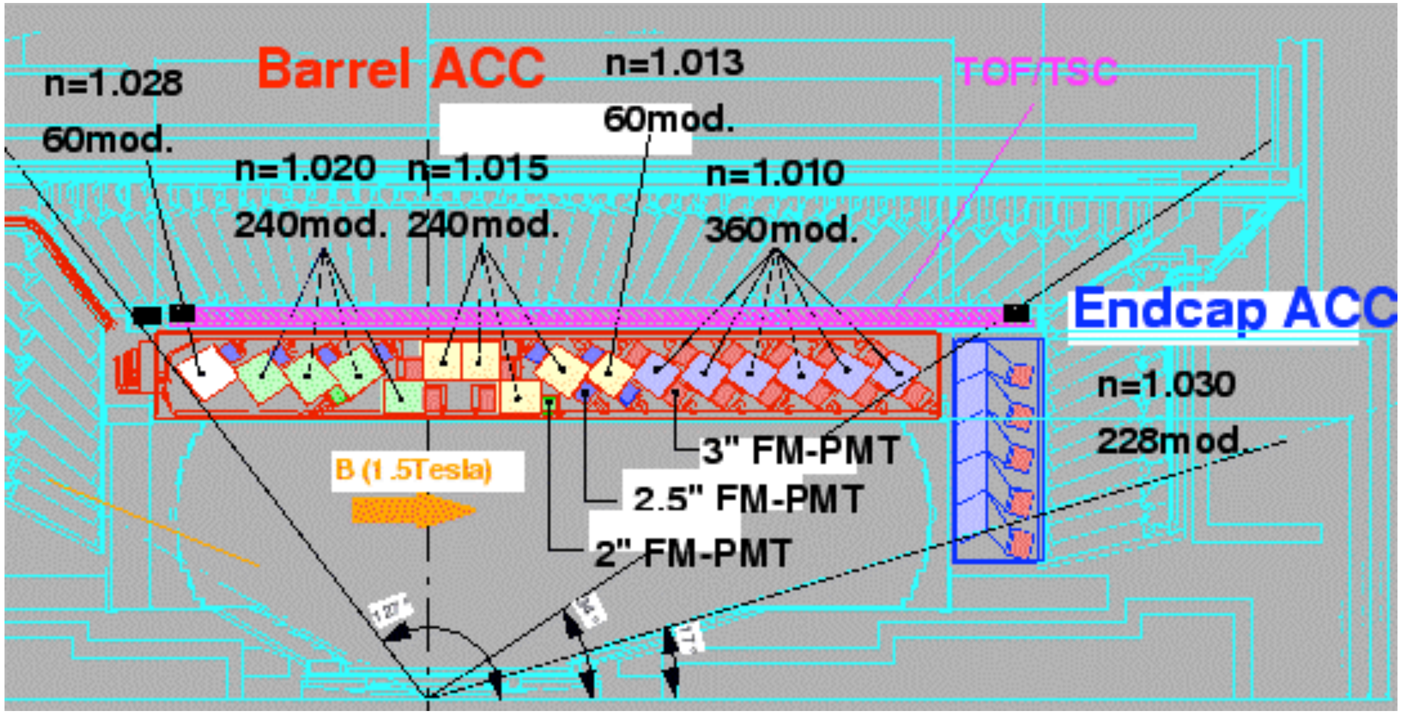




Precise dE/dX measurement for particle identification

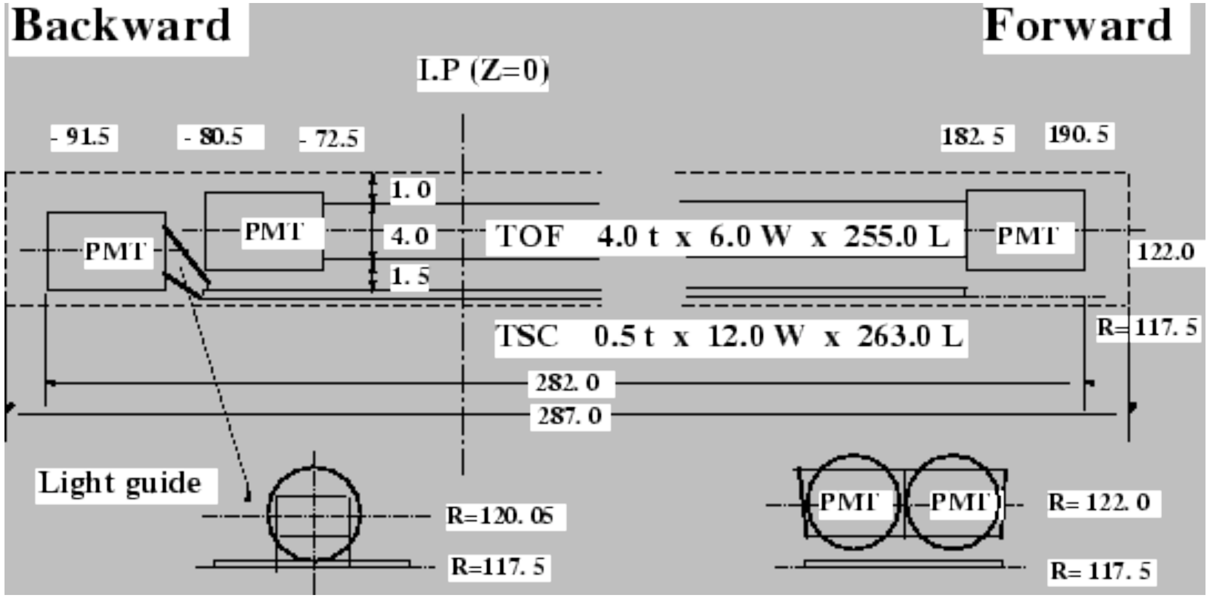
The aerogel cherenkov counter or ACC helps in particle identification especially $\pi^{\pm}$ from $K^{\pm}$

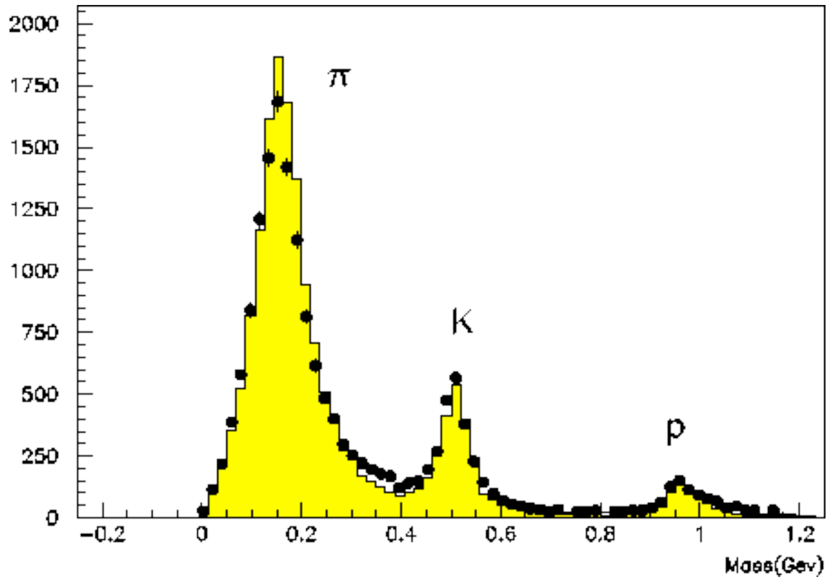
Array of silica aerogel cherenkov counters



Time of flight or TOF consists of TOF & TSC(trigger scintillator counters)and helps in particle identification

TOF and TSC counters in the time of flight detector



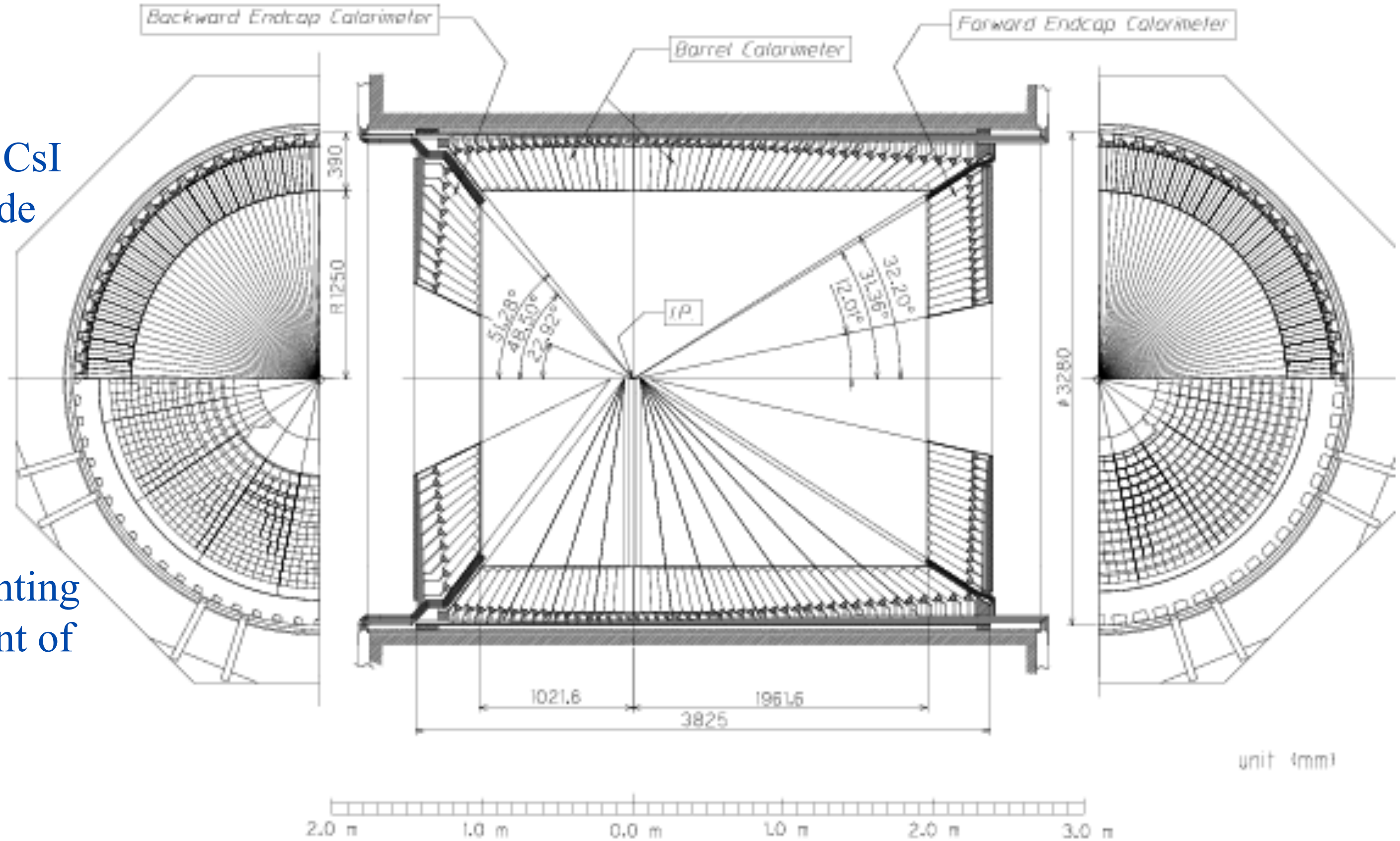


Particle identification by TOF

The electromagnetic calorimeter or ECL detects photons and electrons with high efficiency and resolution

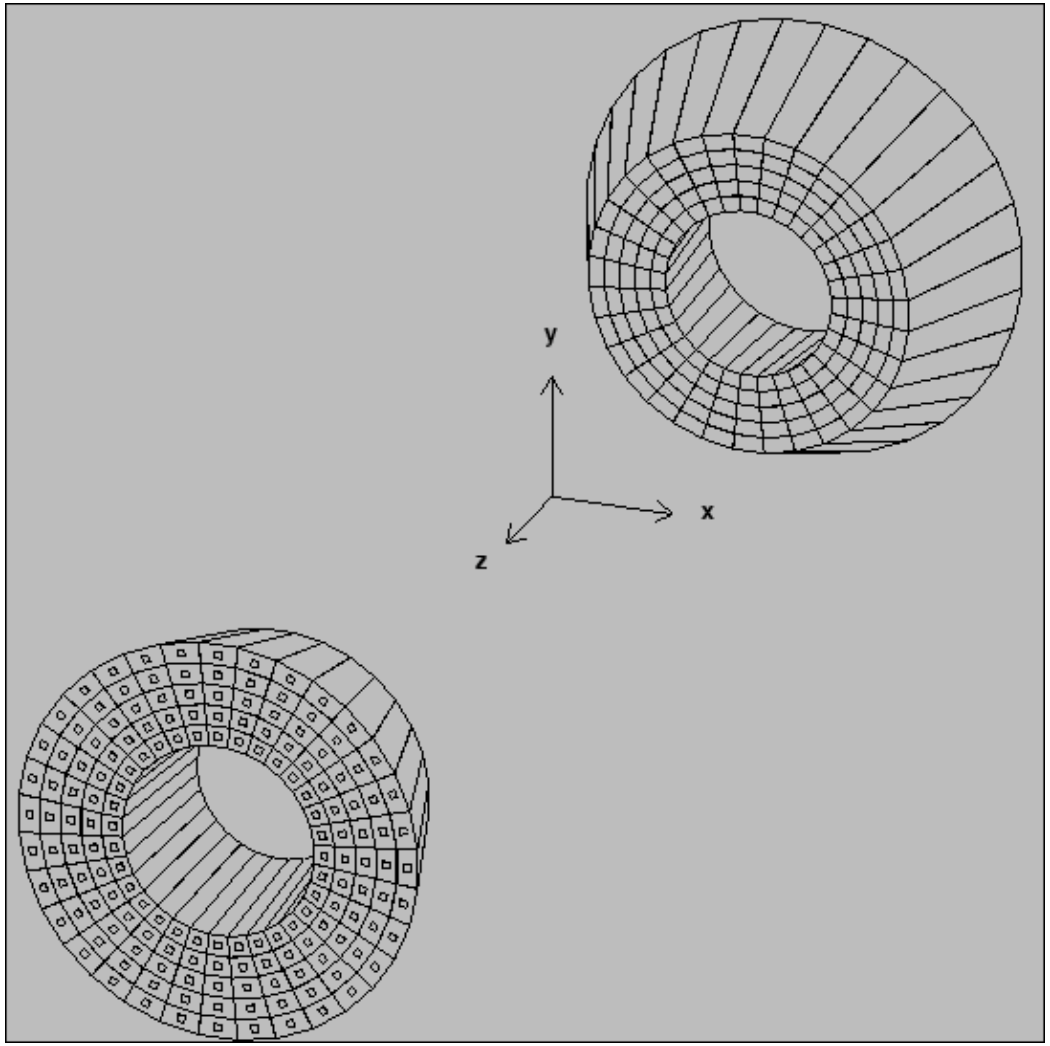
Fine grained segmented CsI crystal, silicon photodiode readout

Tower like crystals pointing towards interaction point of e^+e^-



The extreme forward calorimeter or EFC increases polar angle coverage and hence experimental sensitivity

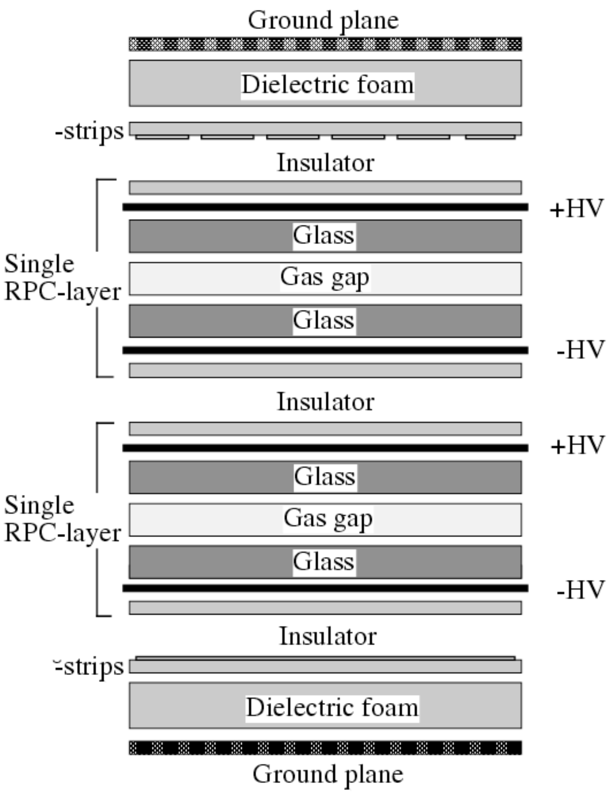
Covers polar angle region ($6.4^0<\theta<11.5^0$) and ($163.3^0<\theta<171.2^0$)

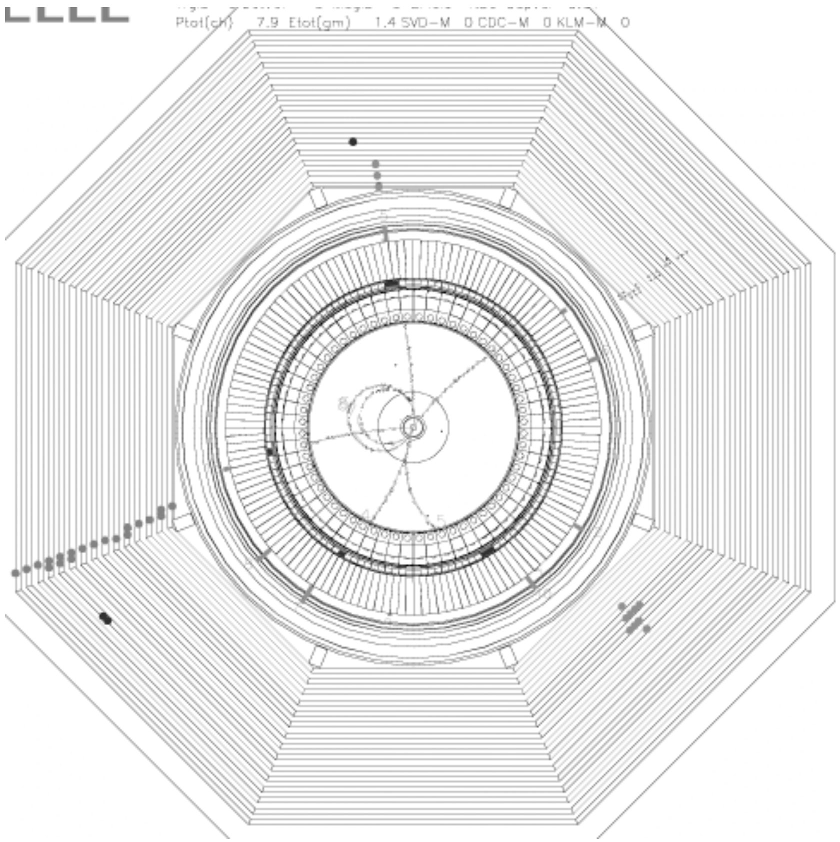


Consists of BGO(bismuth germanate)

The K_L^0 and muon detector or KLM identifies K_L^0 and muons and consists of alternate iron and RPC layers

Alternate iron and RPC layers in barrel KLM (octagon shaped region)

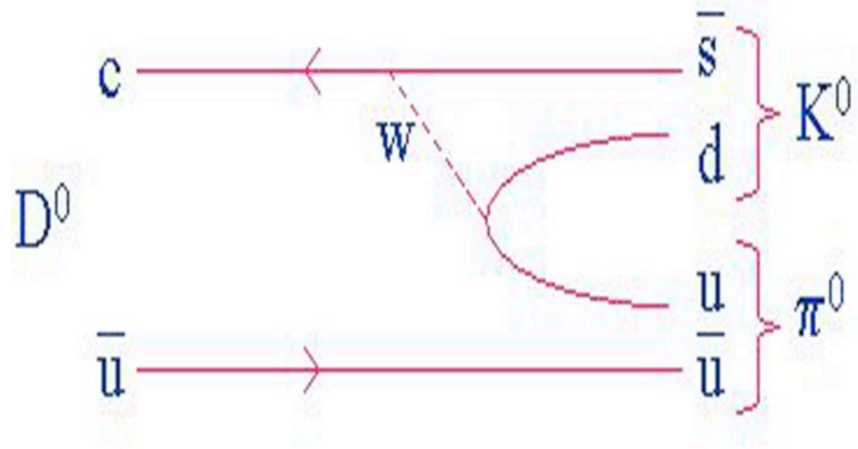




RPC super layer in KLM detects charge through ionization

The Physics goals of this analysis is to measure the decay asymmetry in $D^0 \to K_L^0 \pi^0$ and $D^0 \to K_S^0 \pi^0$

$D^0 \to K_L^0 \pi^0$ and $D^0 \to K_S^0 \pi^0$ decay



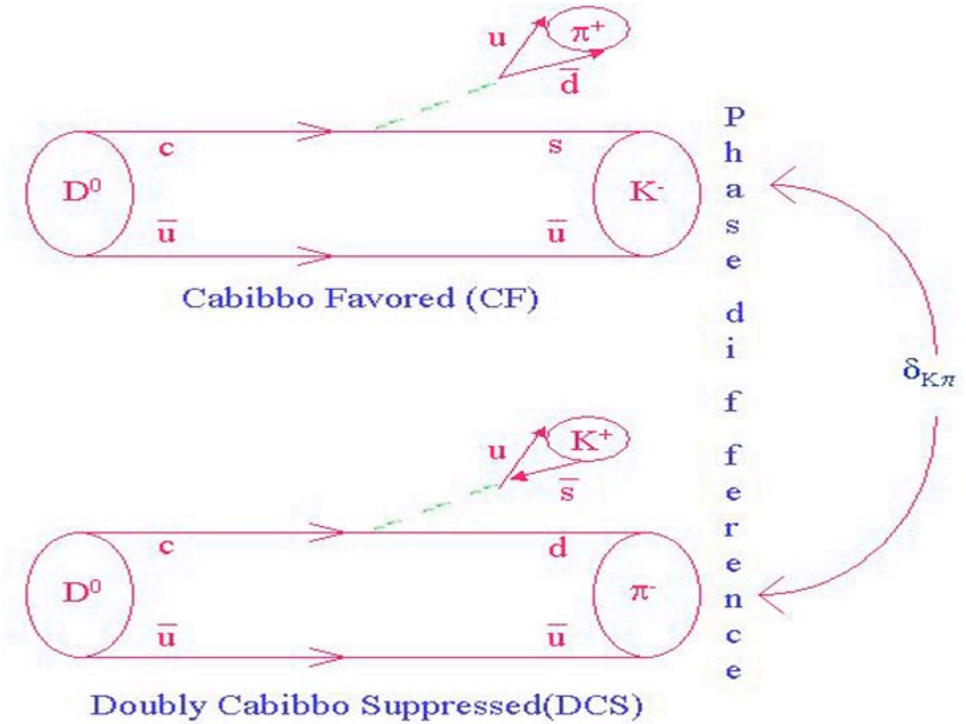
Doubly Cabibbo Suppressed decay

$$\frac{\mathcal{B}(D^0 \to K_L^0 \pi^0)}{\mathcal{B}(D^0 \to K_S^0 \pi^0)} = \frac{N(K_L^0 \pi^0)/N(K_S^0 \pi^0)}{N((K_L^0 \pi)\pi)/N((K_S^0 \pi)\pi)}$$

K_L^0 / K_S^0 reconstruction efficiency from $D^{*+} \to D^0 \pi^+$, $D^0 \to K^{*-} \pi^+$, $K^{*-} \to (K_L^0 / K_S^0) \pi^-$ reduces systematics

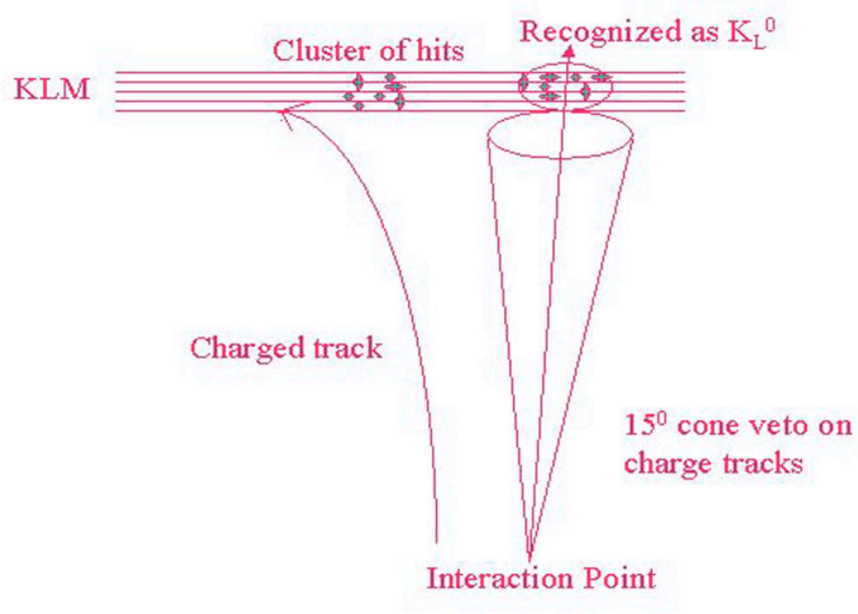
The decay asymmetry in $D^0 \rightarrow K_L{}^0\pi^0$ and $D^0 \rightarrow K_S{}^0\pi^0$ is very important for study of D^0-D^0 bar mixing

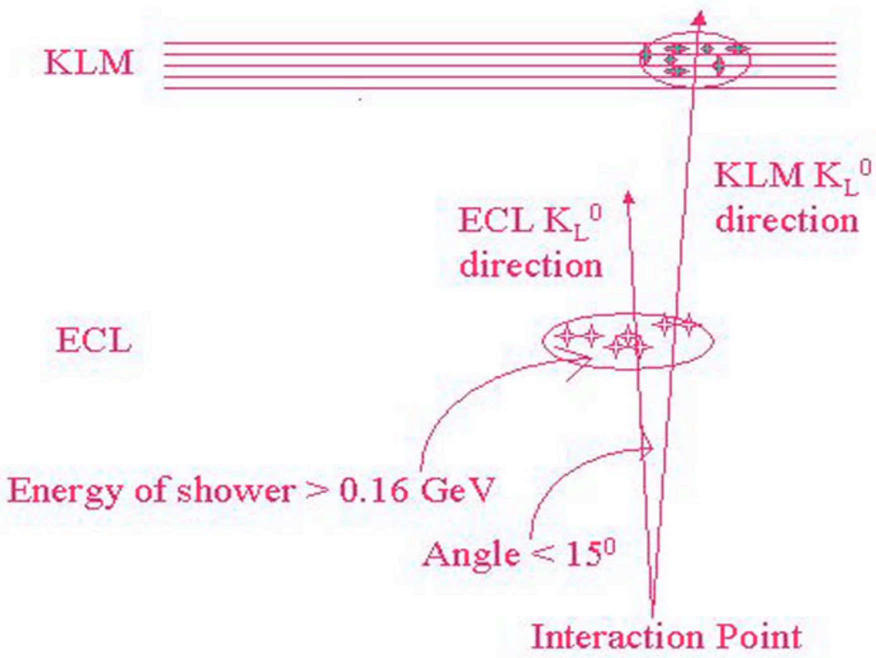
The decay asymmetry constrains $\delta_{K\pi}$ which is important for D^0-D^0 bar mixing



A K_L^0 is reconstructed by information from 2 detectors: ECL and KLM

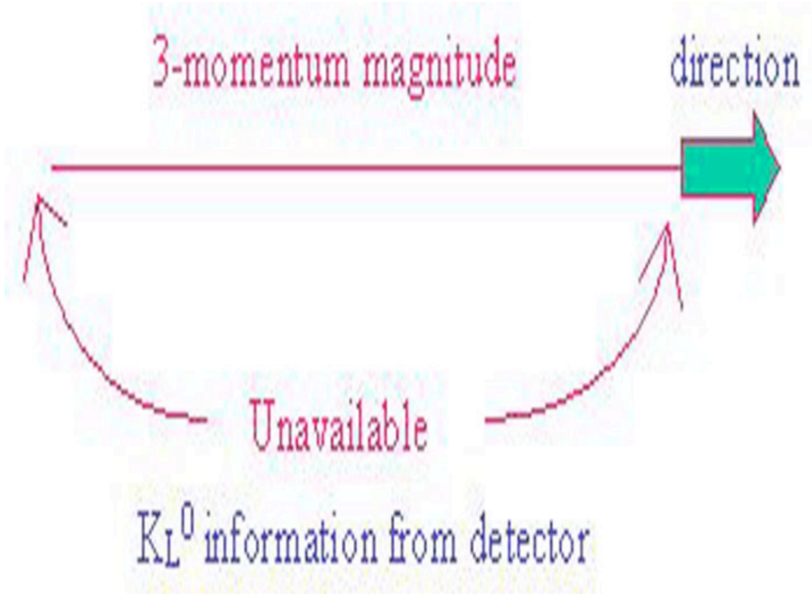
K_L^0 is reconstructed by rejecting charged tracks in a 15^0 cone of K_L^0 cluster direction



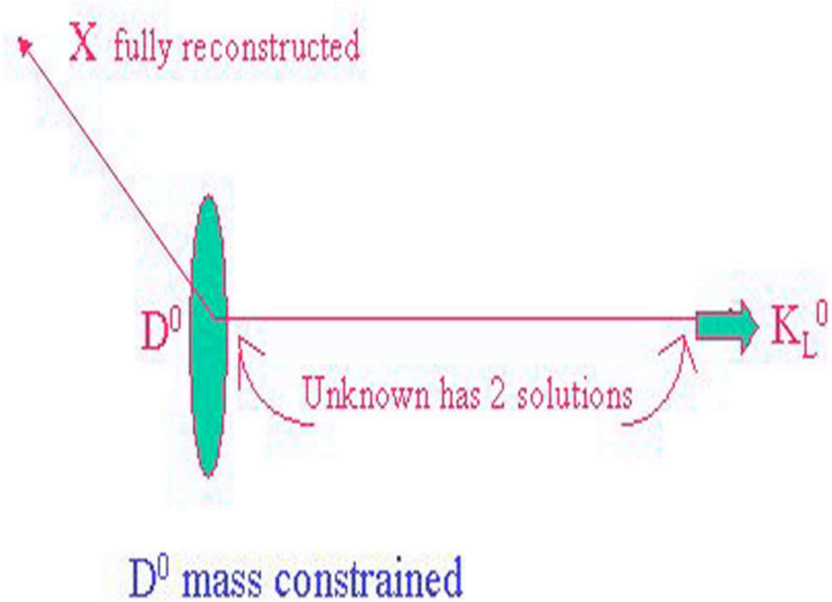


ECL has better directional resolution for those K_L^0 s that interact in the ECL

While K_L^0 direction is reconstructed from detector momentum magnitude is obtained from kinematic constraints



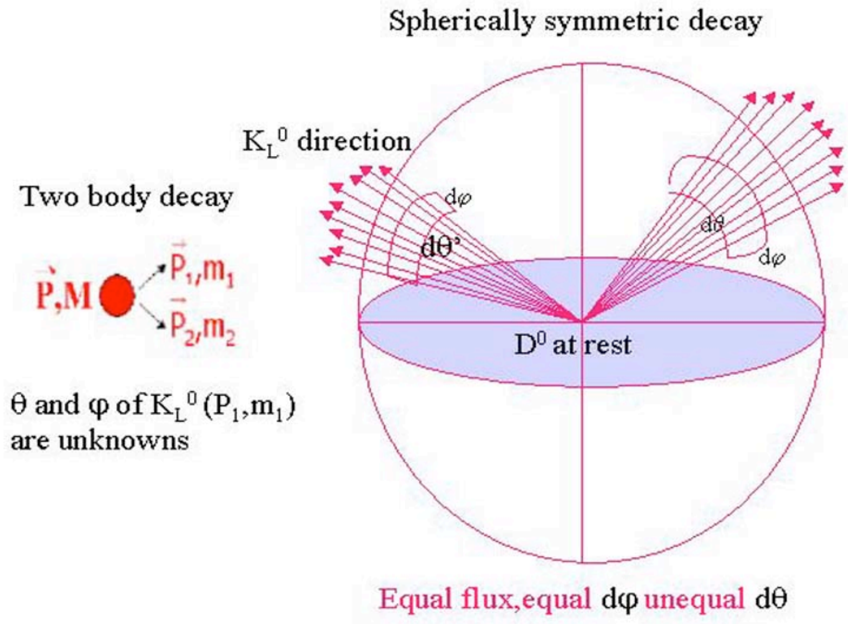
Only direction information for K_L^0

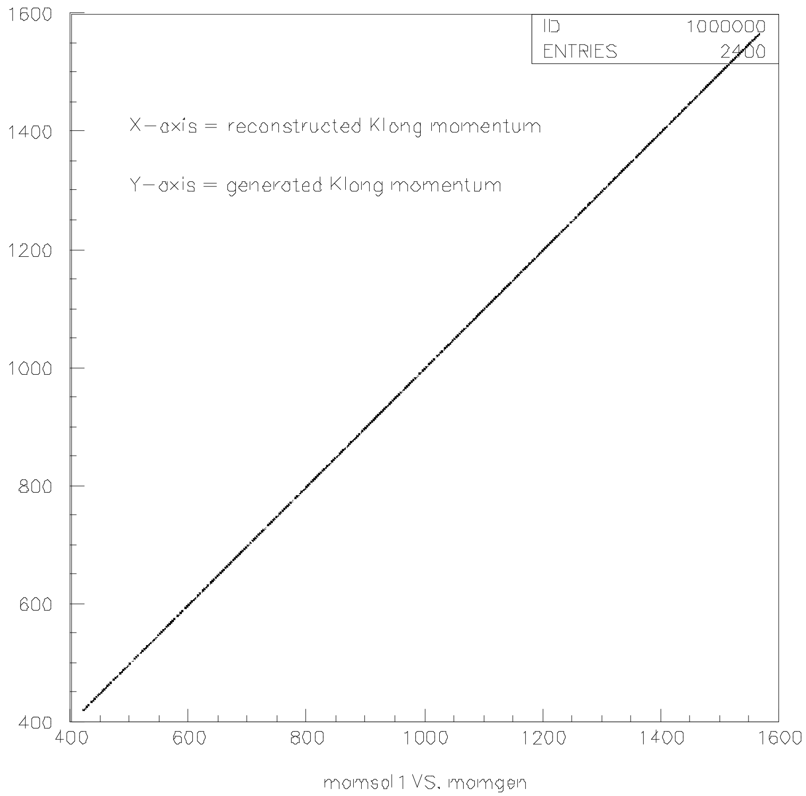


D^0 mass constraint for assumed two-body decay

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





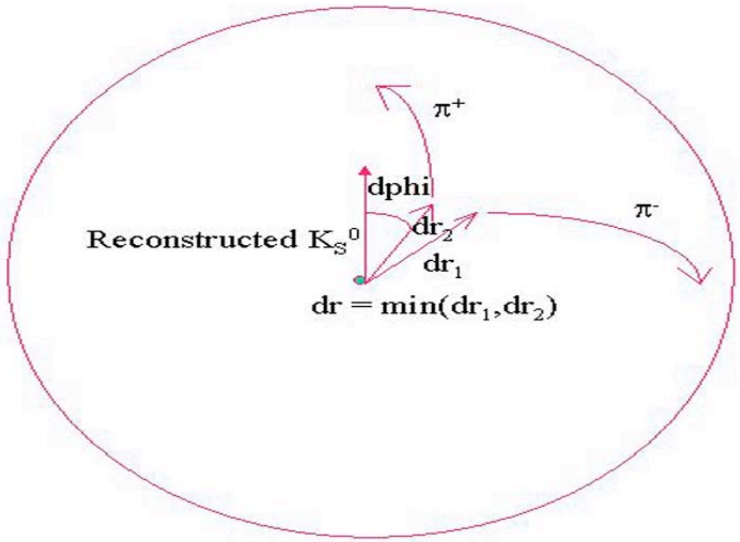
Generated and reconstructed momentum for $K_L{}^0$ match exactly

Reconstruction of $D^{*+} \rightarrow D^0\pi^+$, $D^0 \rightarrow K^{*-}\pi^+$, $K^{*-} \rightarrow K_S^0\pi^-$ from signal Monte Carlo

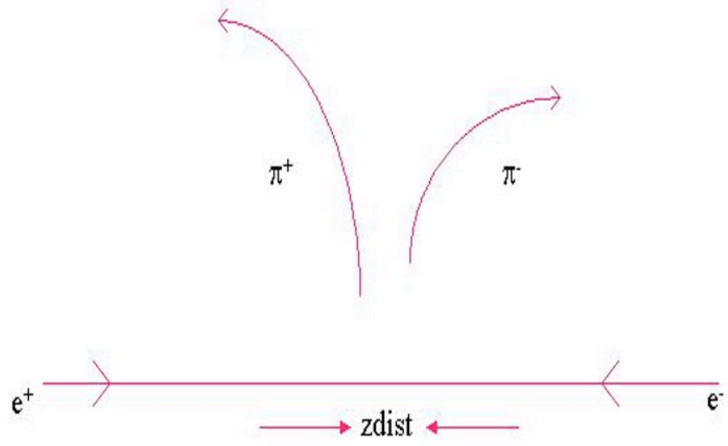
Track cuts shown in picture(quality cuts) have been applied zdist < 1, dr > 0.25, dphi < 0.1

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



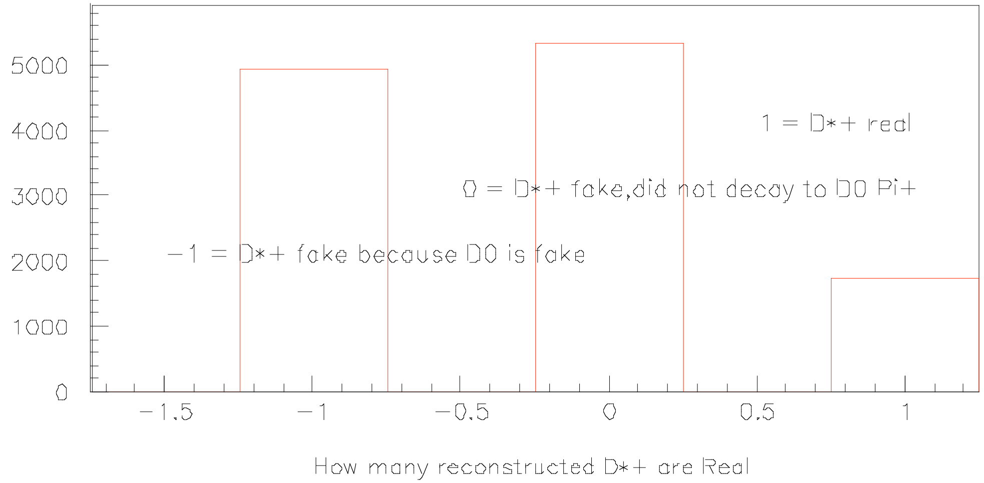
Side view of K_S^0 decay

Direction resolution for K_L^0 and K_S^0 has been studied in signal Monte Carlo

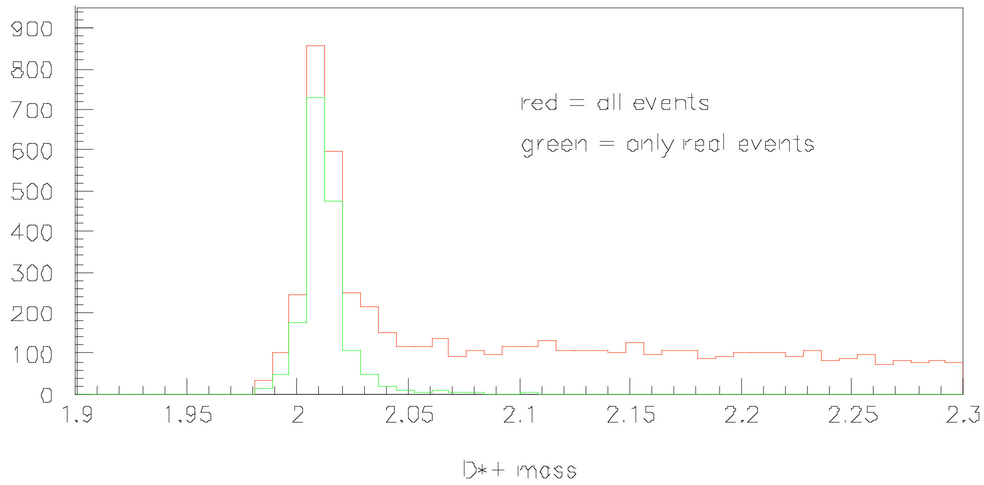
	σ_θ	σ_φ	REMARK
K_S^0	0.002	0.002	
K_L^0	0.016	0.018	K_S^0 resolution is ~10 times better than K_L^0 resolution
KLM K_L^0	0.022	0.028	
ECL K_L^0	0.012	0.014	ECL K_L^0 resolution is better than KLM K_L^0 resolution

How many reconstructed $D^{*+} \to D^0\pi^+$, $D^0 \to K^{*-}\pi^+$, $K^{*-} \to K_S^0\pi^-$ in signal Monte Carlo are real?

The decay is compared to generator level information to check if it has been reconstructed correctly

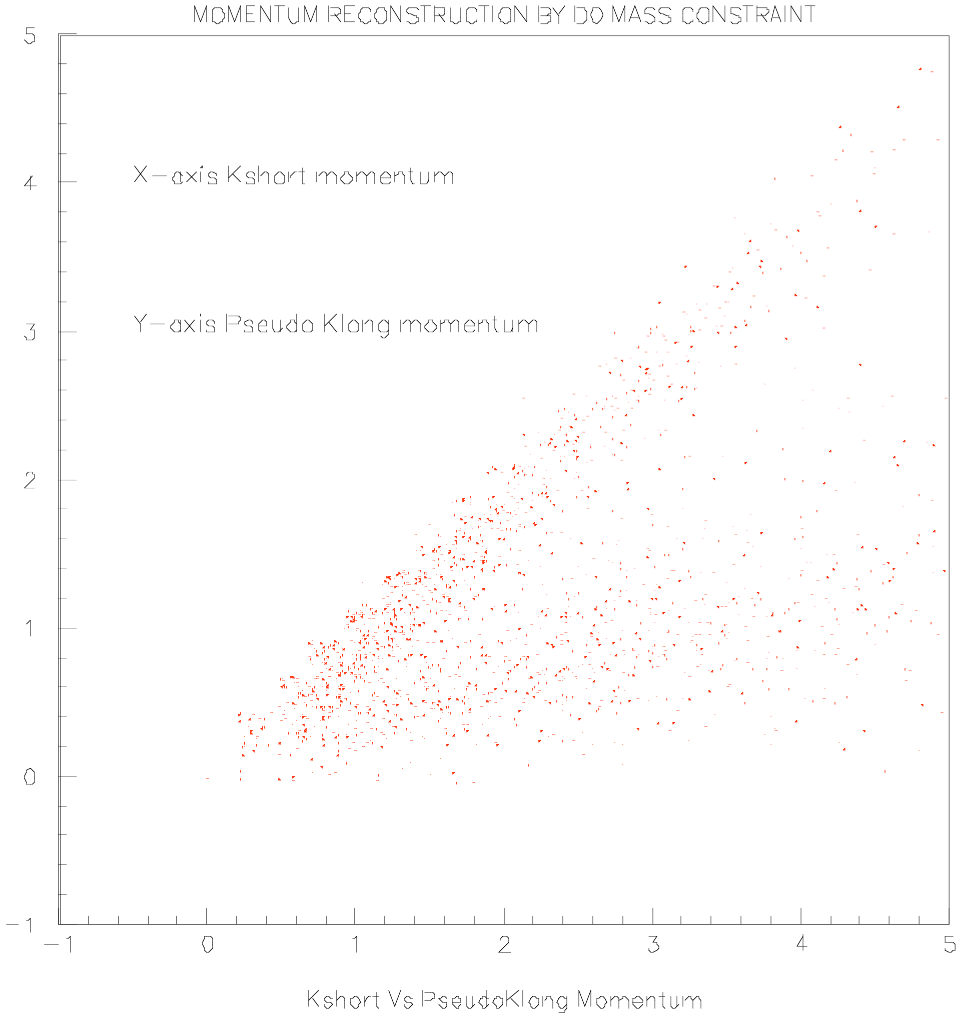


D^{*+} Mass for correctly reconstructed events in green



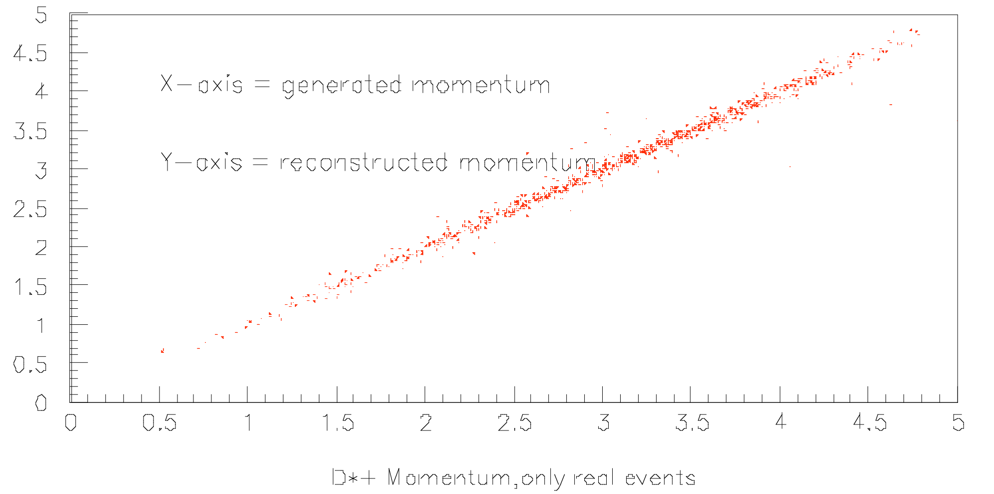
How good is D0 mass constraint in $D^{*+} \rightarrow D^0\pi^+$, $D^0 \rightarrow K^{*-}\pi^+$, $K^{*-} \rightarrow K_S^0\pi^-$ signal Monte Carlo?

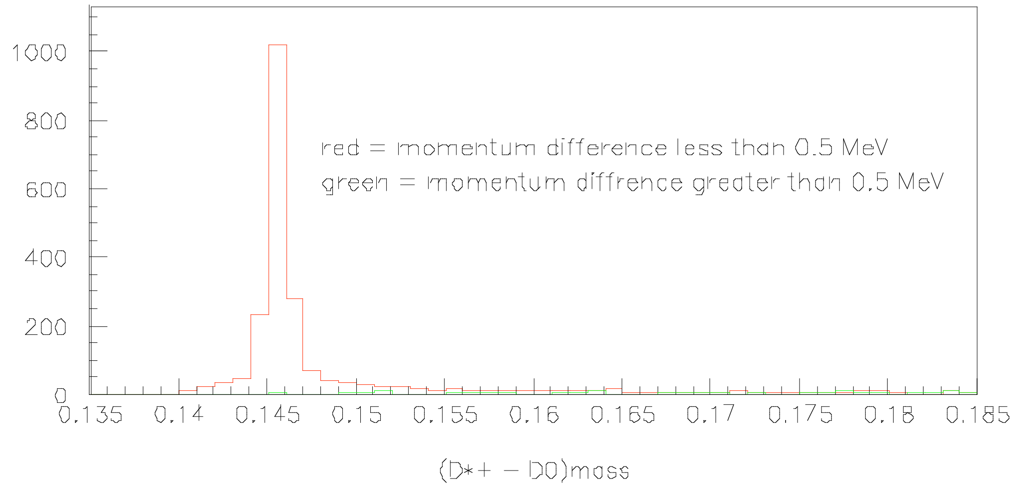
Mass constraint technique works well is seen by the correlation in momentum reconstructed in two ways



$\Delta M = (D^{*+} - D^0)$ mass is a good cut in reducing fake reconstruction and useful in analyzing experimental data

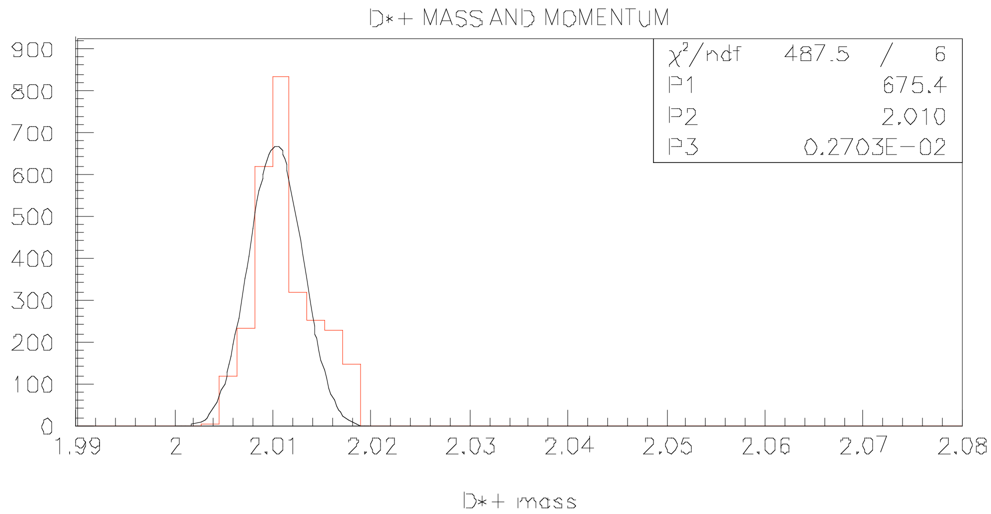
Correctly reconstructed events from Monte Carlo peak at $\Delta M = 0.145$ MeV which corresponds to the slow pion from D^{*+}



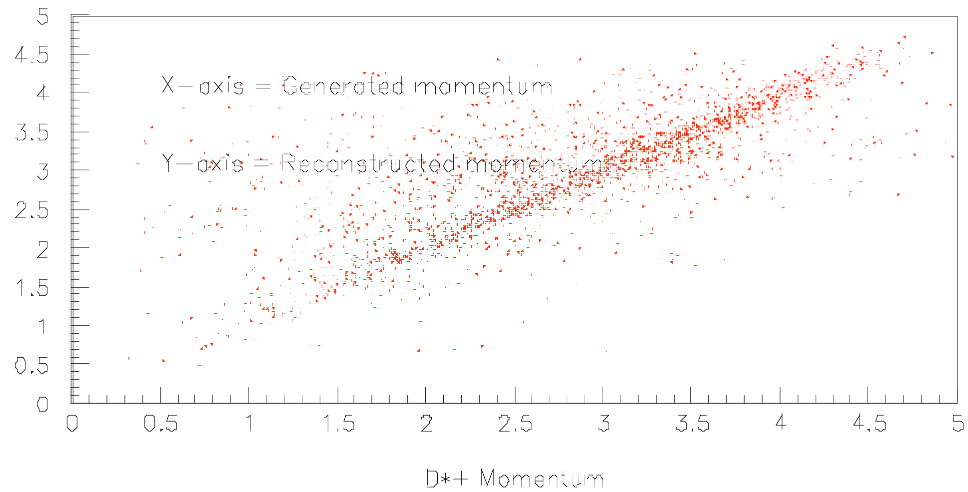


Reconstruction of $D^{*+} \to D^0\pi^+$, $D^0 \to K^{*-}\pi^+$, $K^{*-} \to K_L^0\pi$ from signal Monte Carlo

The decay was reconstructed by applying 3σ mass cuts on K^{*-} and D^{*+} candidates

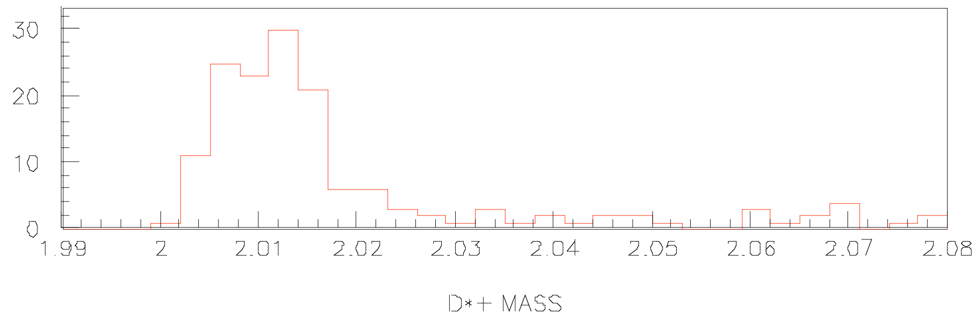


Good correlation in generated and reconstructed D^{*+} momentum, reconstruction efficiency = 28%

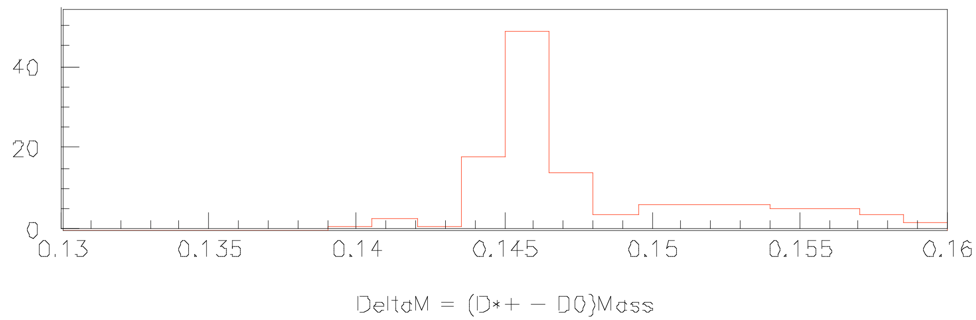


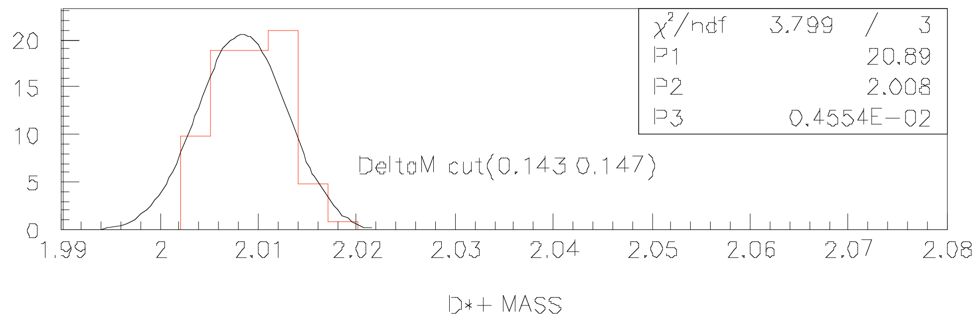
$D^{*+} \rightarrow D^0\pi^+$, $D^0 \rightarrow K^{*-}\pi^+$, $K^{*-} \rightarrow K_S^0\pi^-$ was reconstructed from skimmed experimental data

Experiment 7(~6.5 million B/Bar events) was skimmed by applying 3σ mass cuts on the candidates



Reconstruction done from skimmed data using quality cuts, 2σ mass cuts on candidates and a ΔM window (0.143,0.147)on D^{*+}





The analysis $D^0 \rightarrow K_L^0 \pi^0$ of is ongoing and I will conclude the same with the following roadmap in mind

We have ~175 fb^{-1} of experimental data at Belle at the end of 2003

The previous analysis at Belle was based on a data sample of ~23 fb^{-1}, decay rate asymmetry = 0.88 ± 0.09

We expect to see 33005/12,873 # of $D^0 \rightarrow K_L^0 \pi^0$/ $D^0 \rightarrow K_S^0 \pi^0$ events in the larger data sample

I expect to finish the calibration analysis by next 2 months

Once K_S^0/K_L^0 relative reconstructive efficiency is calculated in the calibration study I'll start decay asymmetry analysis in $D^0 \rightarrow K^0 \pi^0$