LHCb – the RICH and Potential in Charm Physics

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Contents

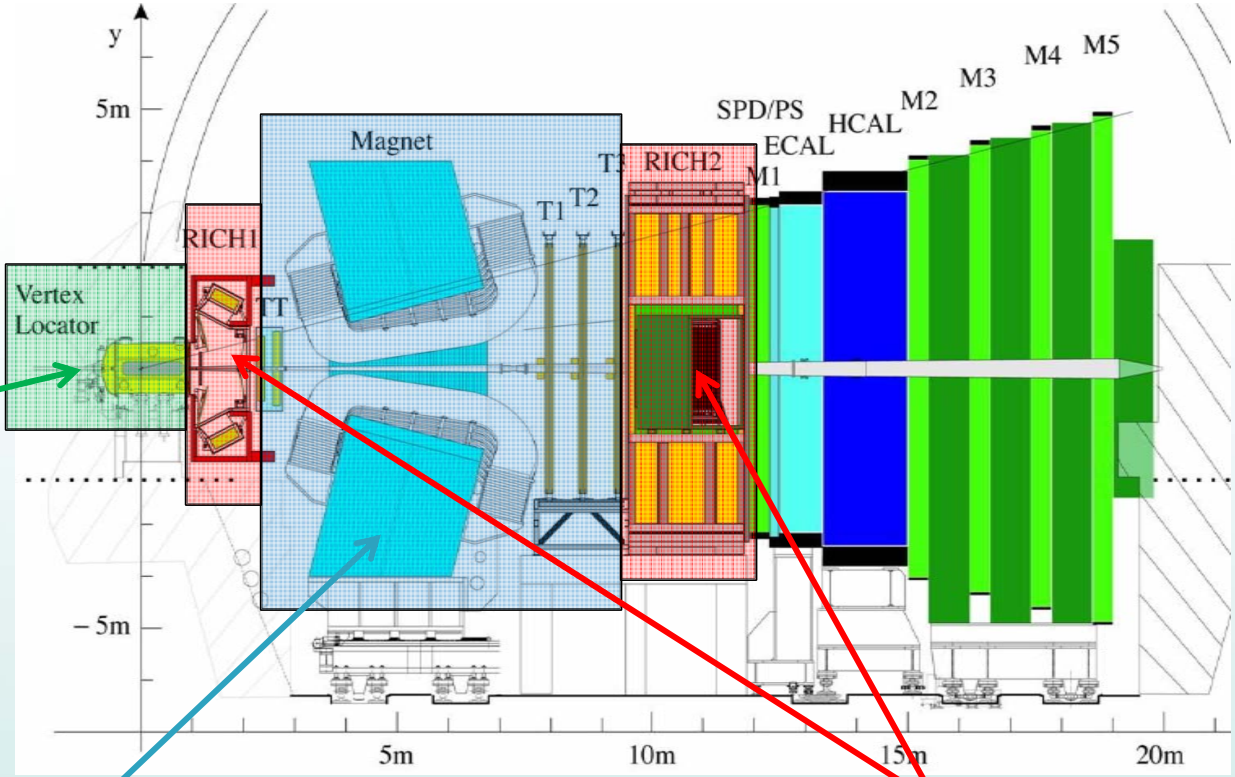
- **LHCb Detector**
  1) Ring Imaging Cherenkov Detector (RICH);
  2) HPD and Its Magnetic Distortion Calibration.
- **Charm Physics Programme in LHCb**
  1) Mixing and CPV Formalism;
  2) Sensitivity Studies.

1. LHCb Detector

1.1 LHCb

- The features that make LHCb excellent for *B* physics also make it a good charm physics experiment

High event rate



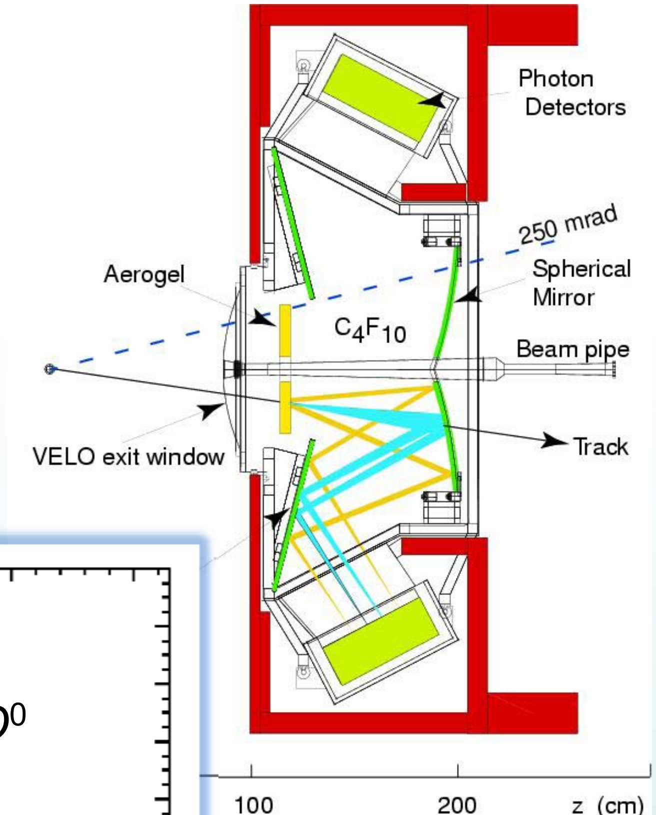
Excellent vertexing
Δt ~ 45 fs for D^0 from B decays

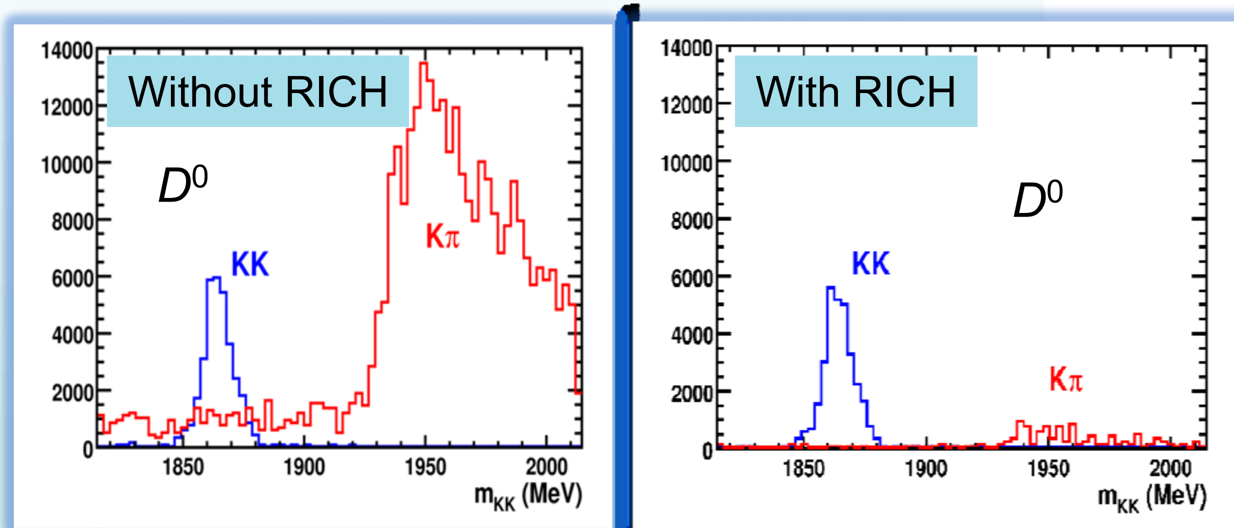
Good tracking and momentum resolution:
Δt ~ 6 MeV for D^0 *mass*

Excellent *K- π discrimination*

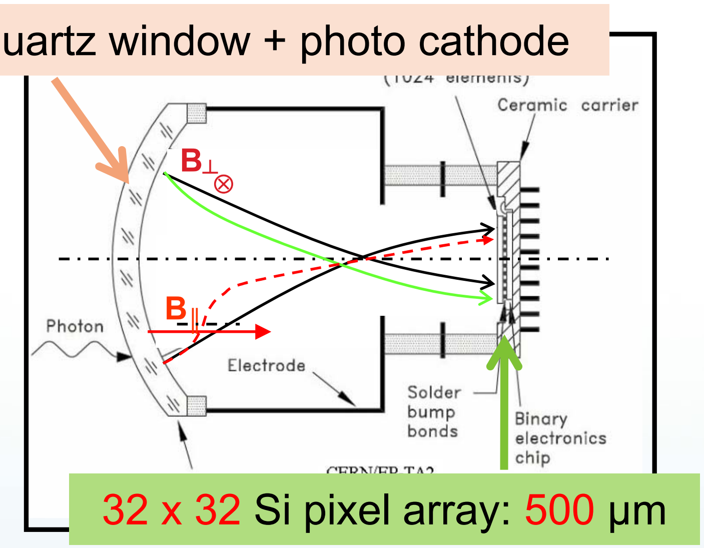
1.2 RICH and HPD

- RICH1 & RICH2;
- 3 different radiators covering momentum range 2–100 GeV;
- Hybrid Photo Diodes (HPDs):
  - 196+288 HPDs

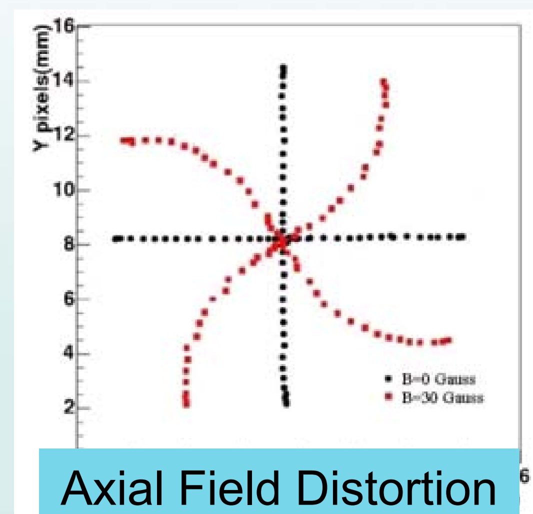




1.3 HPD Magnetic Distortion Calibration

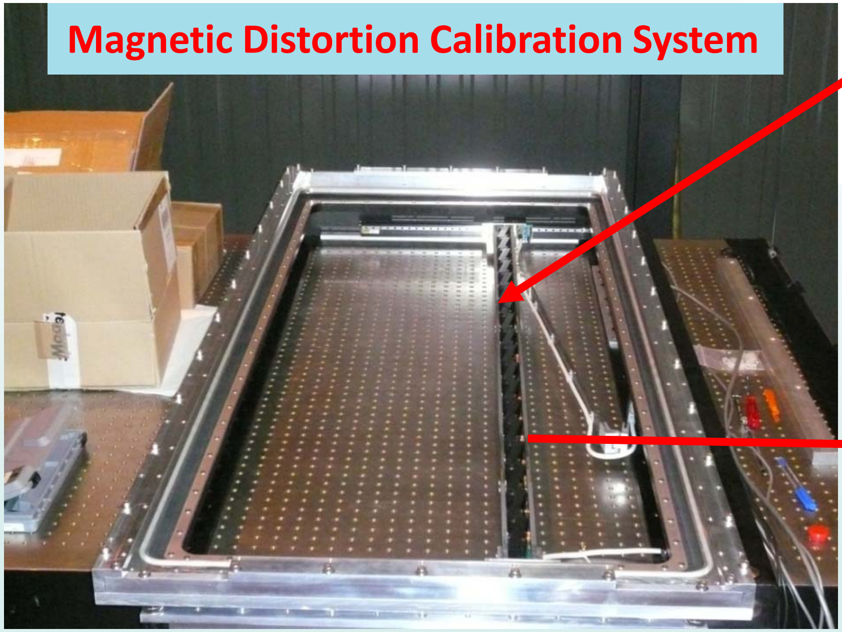


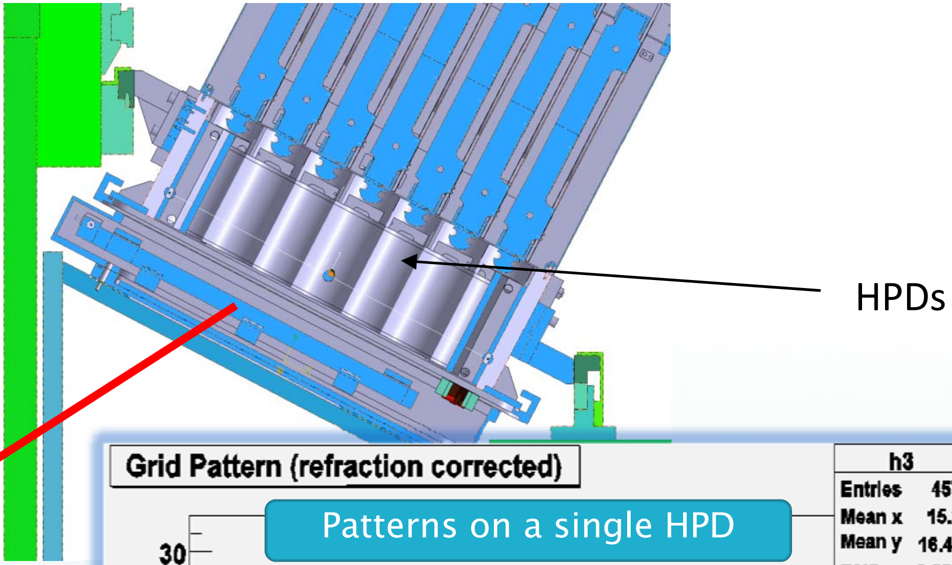
- B distorts the photo-electron trajectories;
- Effect significant in the RICH1 (up to 25G);
- Tubes are individually shielded;
- Distortions tolerable but need corrections.

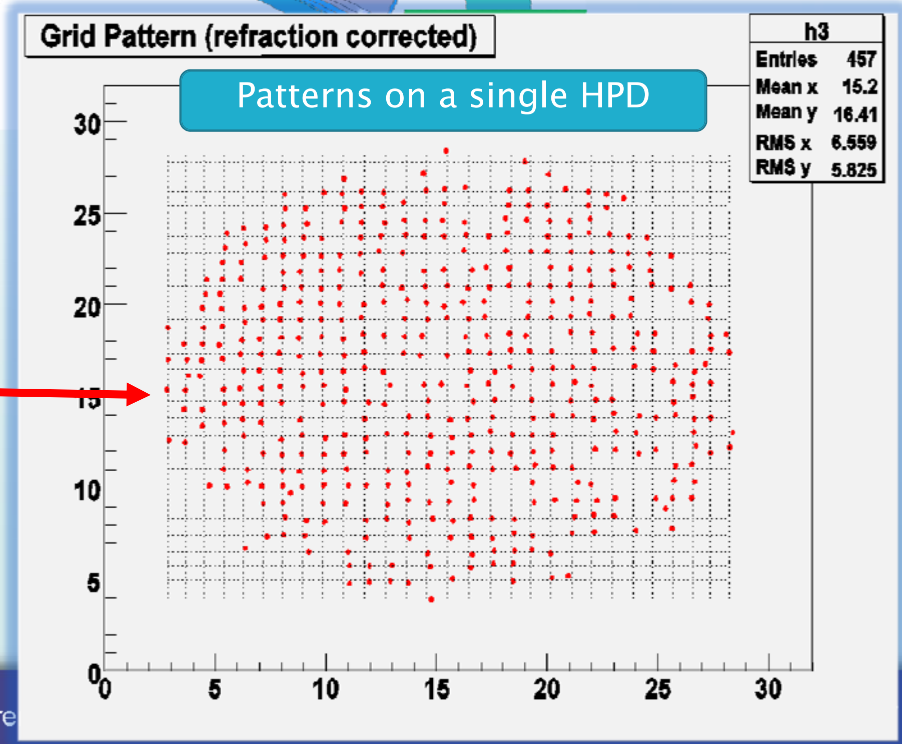


1.3 HPD Magnetic Distortion Calibration

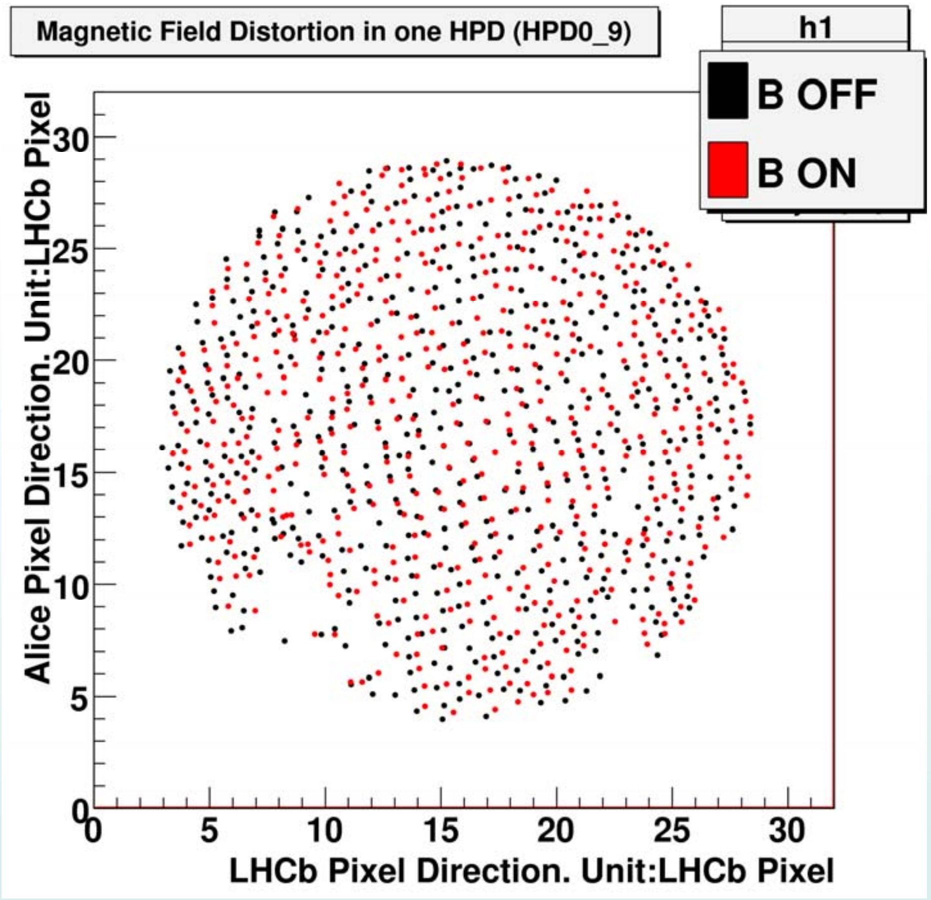
- 1 LED light bar
- 19 LED boards
- 5x28 LEDs per board





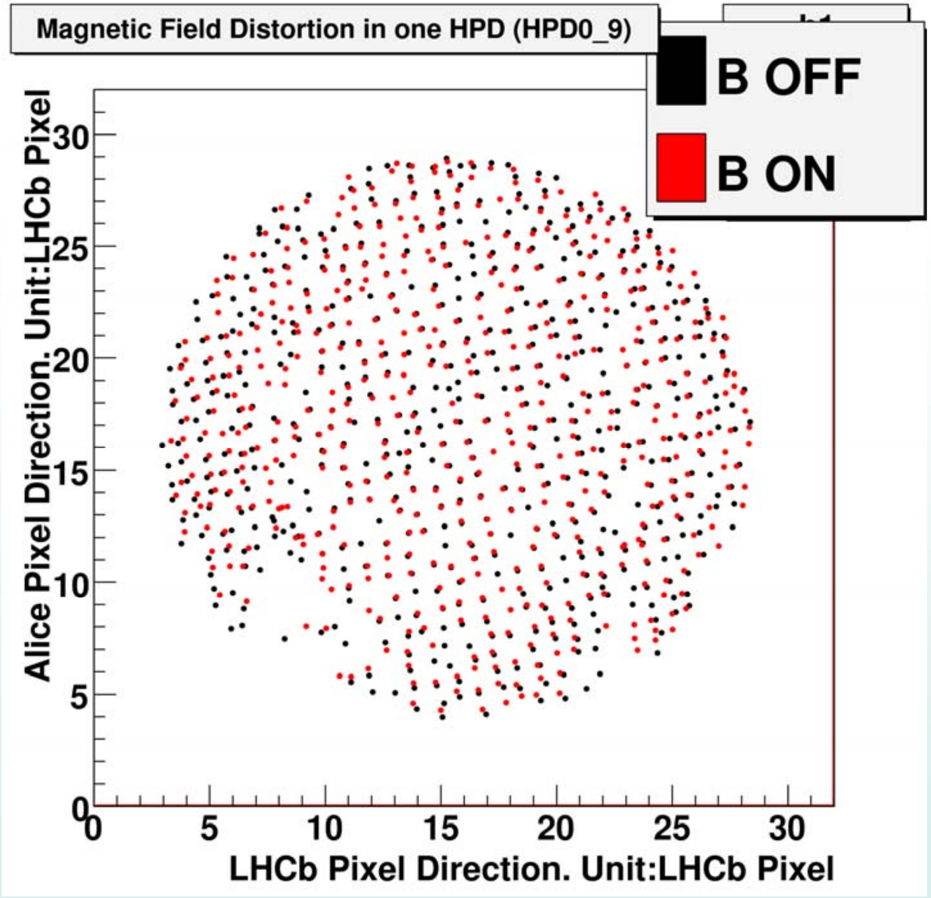


1.3 HPD Magnetic Distortion Calibration



- Real data taken during magnet test (2008 June)
- Black: Magnet OFF
- Red: Magnet at nominal field
- Before applying corrections

1.3 HPD Magnetic Distortion Calibration



- Corrections Applied
- Transverse Field: x-y translational shifts;
- Axial Field: 3rd order polynomial

1.4 Summary on B Calibration

- Global pattern resolution after calibrations:
  0.19*pixel;

- This is smaller than the pixel resolution:
  ~0.29*pixel

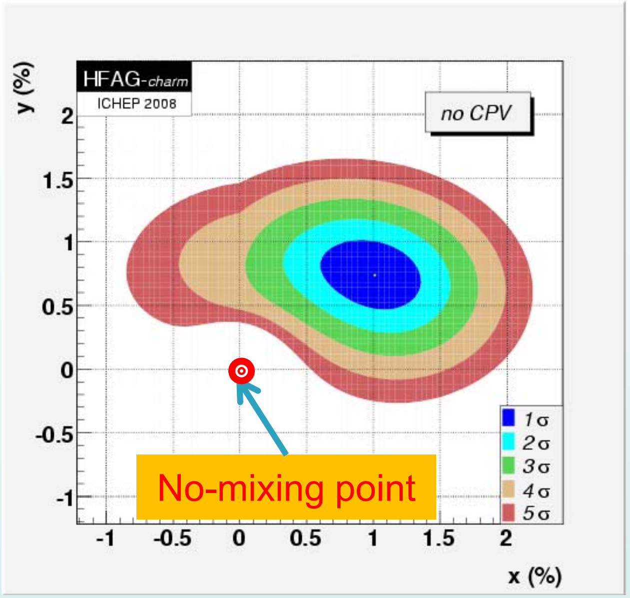
Preliminary

⇒ B field after calibration will only have small effect on Cherenkov angle resolution.

2. Charm Physics Programme in LHCb

2. LHCb Charm Physics Programme

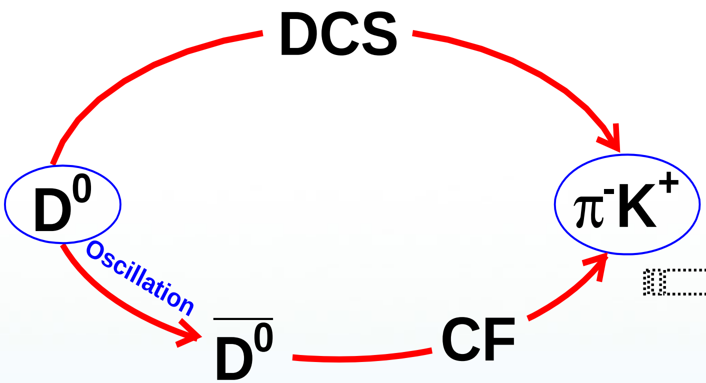
- Looking for unambiguous signs of New Physics in as many channels as possible;
- Both time integrated and time dependent CPV searches;
- This talk will focus on the 2-body decays:
  - Wrong-Sign $D^0 \to K\pi$ *mixing analysis*
    - Sensitive to x'^2 *and* y'
  - Two body lifetime ratio measurement
    - SCS $D^0 \to \pi\pi / KK$, to CF $K\pi$;
    - *Sensitive to* y_{CP} *and* A_Γ



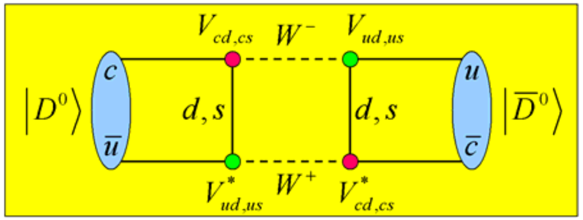
- SM predicts negligible CPV → window for New Physics

2.1 Mixing and CP Violation Formalism in 2-Body D^0 Decays

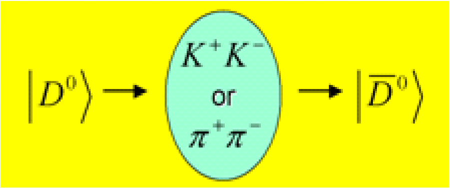
2.1.1 Mixing in “Wrong-Sign” Kπ Decays



- $x \equiv \Delta m / \Gamma$



- $y \equiv \Delta\Gamma / 2\Gamma$



$$\frac{dN}{dt} \propto e^{-\Gamma t}\left[R_D + \sqrt{R_D}\, y'(\Gamma t) + \frac{x'^2 + y'^2}{4}(\Gamma t)^2\right]$$

DCS Interference Pure-mixing

- R_D : Ratio of DCS to CF decays.
- x’ : x cosδ + y sinδ
- y’ : y cosδ – x sinδ
- δ: DCS-CF strong phase amplitudes difference

2.1.2 CP Violation in KK/Kπ Lifetime Ratio

- Get also a mixing parameter for free;
- Two parameters measured: y_{cp} (mixing) and A_Γ (CPV).

$$y_{cp} = \frac{\tau(D^0 \to K^-\pi^+)}{\tau(D^0 \to K^+K^-)} - 1 \qquad A_\Gamma = \frac{\tau(\overline{D^0} \to K^+K^-) - \tau(D^0 \to K^+K^-)}{\tau(\overline{D^0} \to K^+K^-) + \tau(D^0 \to K^+K^-)}$$

- Expressed in CP violation parameters:

$$y_{cp} = y\cos\phi - \frac{1}{2}A_M x \sin\phi \qquad A_\Gamma = \frac{1}{2}A_M y\cos\phi - x\sin\phi$$

- If CP is conserved $A_M = \varphi = 0$
  => $y_{cp} = y$ and $A_\Gamma = 0$

2.2 Mixing and CP Violation Sensitivity Studies using Monte-Carlo Data

2.2.1 Signal and Background Yields

- Decay Chain used:

$$B \to D^{*} X, \quad D^{*} \to D^{0}\pi, \quad D^{0} \to KK / \pi\pi / K\pi$$

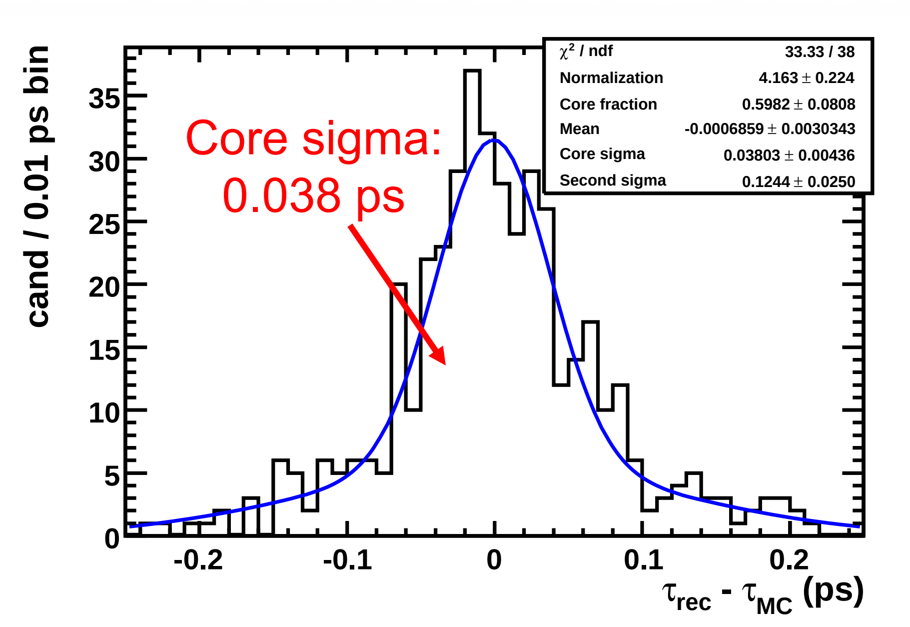
- Selections developed by P. Spradlin;
- Intend also to use prompt D^{*} productions, study in progress;
- Secondary D^{*} yields from full MC study:

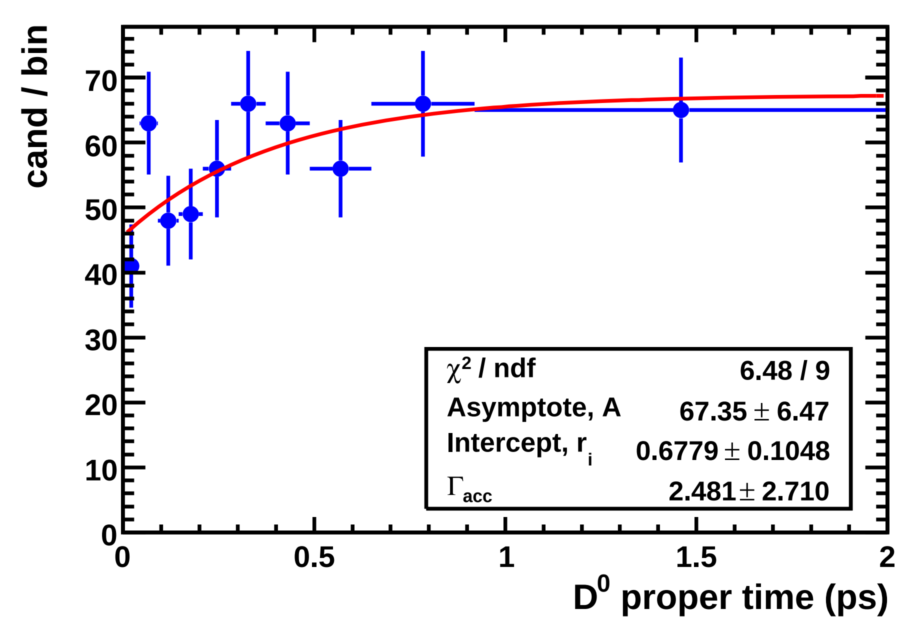
	Yield / 2 fb^{-1}	S/B
$\pi^{+}K^{-}$ (RS)	12.4 x 10^{6}	4.73
$\pi^{-}K^{+}$ (WS)	4.56 x 10^{4}	0.39
$K^{+}K^{-}$	1.3 x 10^{6}	4.8

2.3.2 Proper Time Resolution & Proper Time Acceptance

$$R_{es} = f_{core} G_{core} + (1 - f_{core}) G_{tail}$$

$$f_{acc}(t) = A(1 - (1 - r) e^{-\Gamma_{acc} t})$$





(Δt similar to that using prompt *D**)

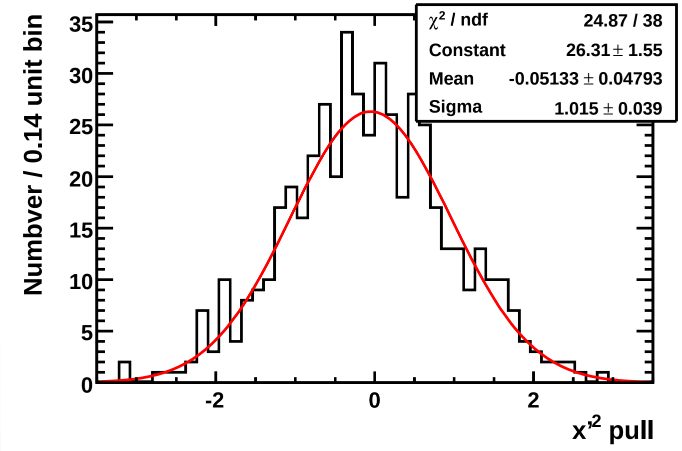
2.3.3 Toy MC Studies

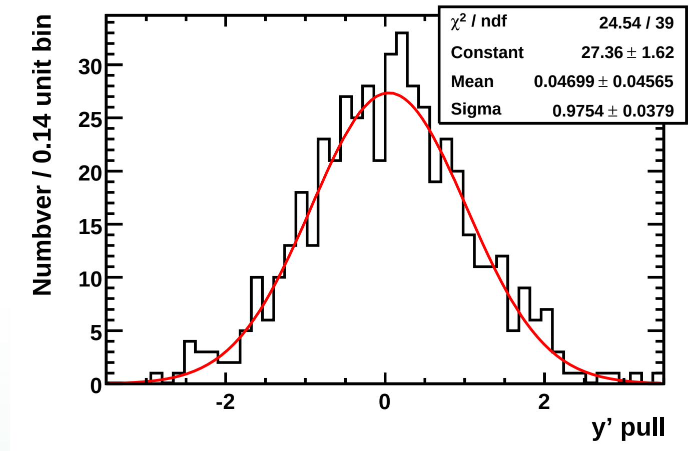
- Signal PDF;
- Background PDF – same Γ as in signal;
- Multiply with acceptance function;
- Convolve with proper time resolution;

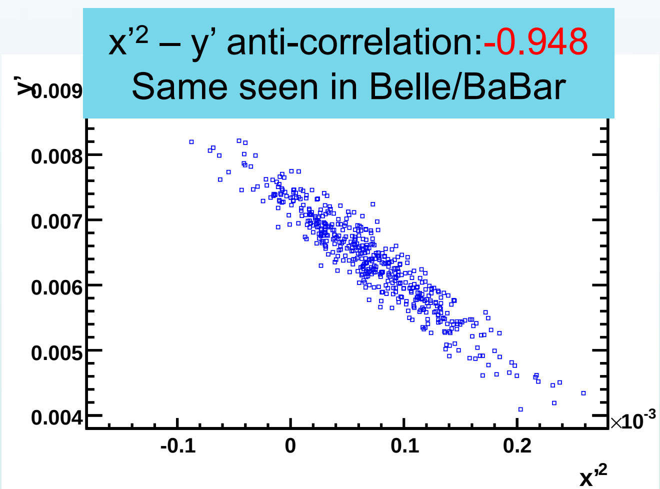
$$F = f_{s/b} \times [\, f_{acc} \times PDF_{sig}\,] \otimes R_{es} + [\, f_{acc} \times PDF_{bkg}\,] \otimes R_{es}$$

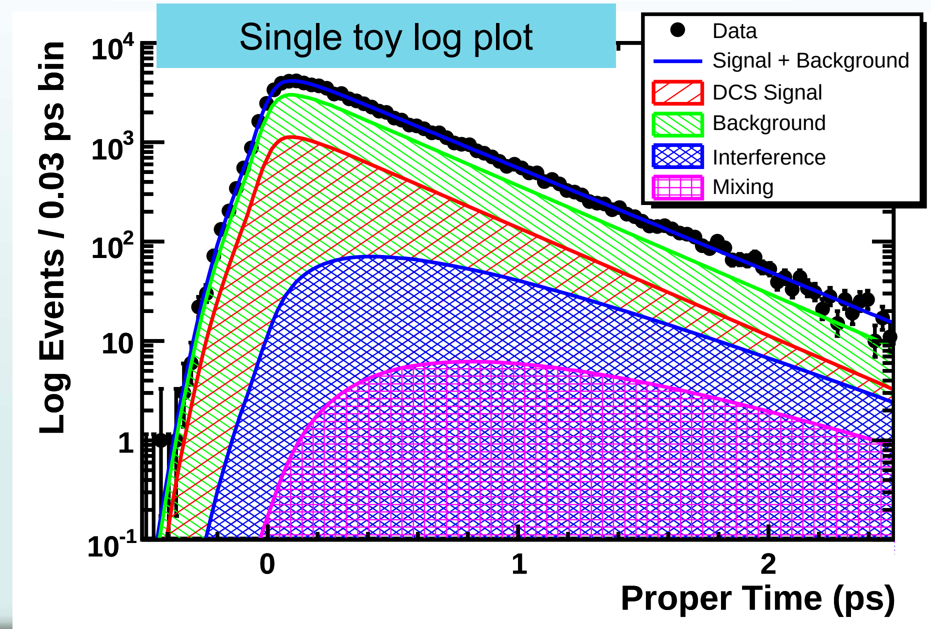
- Generate Toy Monte Carlo samples;
- Perform Log Likelihood fits.

2.3.4 Results – Wrong Sign Mixing

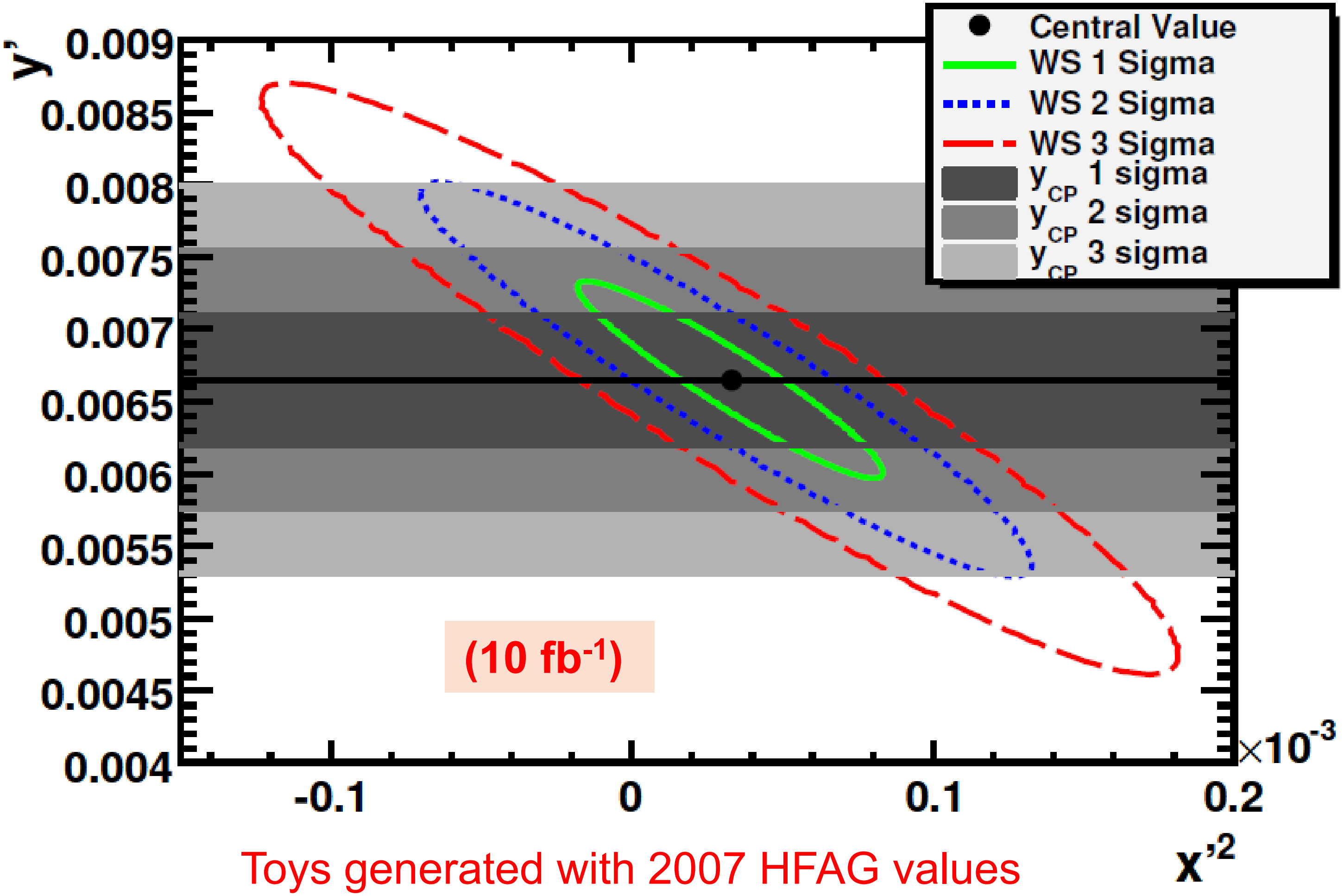








2.3.5 Results – Combined Mixing



Toys generated with 2007 HFAG values

2.3.6 Summary on D^0 Mixing/CPV

Statistical uncertainties comparison to recent measurements:

	$\sigma x'^2$ (10^{-4})	$\sigma y'$ (10^{-3})	σy_{cp} (10^{-3})	σA_Γ (10^{-3})
LHCb ($10\ fb^{-1}$)	0.64	0.87	0.49	0.48
Belle	2.1	4.0	3.2	3.0
BaBar	3.0	4.4	3.9	3.6
CDF	3.5	7.6		

Prompt *D* not yet included

- LHCb has excellent sensitivity to D^0 mixing and CP violation searches;
- Precise measurement on mixing parameters;
- Power to detect CP violation → New physics;
- Systematic biases to be investigated;
- Will also utilise prompt D^* productions.