$B^{\pm} \rightarrow D^0(K_s \pi^+\pi^-)K^{\pm}$ Dalitz analysis at LHCb

Susan Haines
University of Cambridge

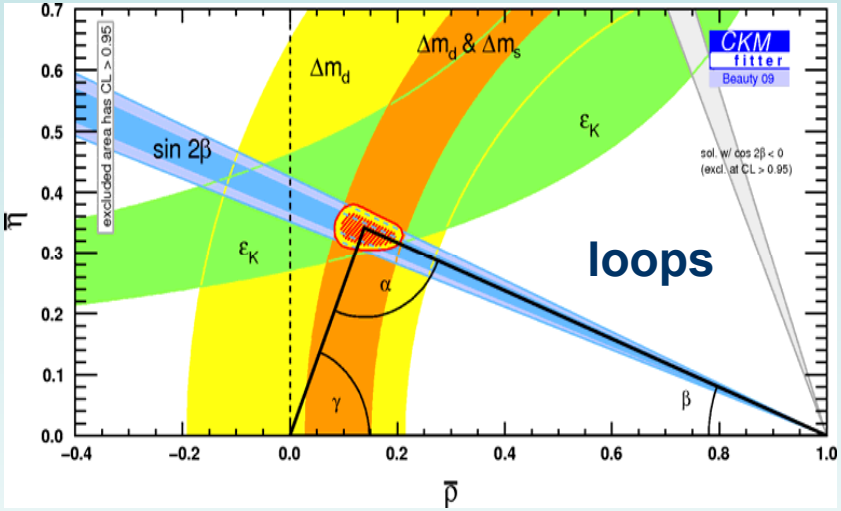
IoP HEPP/APP 2010, March 30th 2010

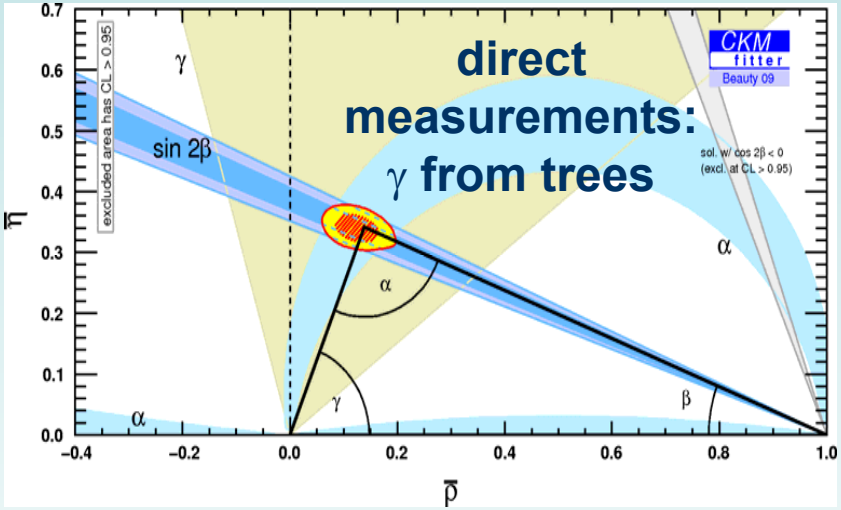
Overview

- CKM angle γ
- $B^- \rightarrow DK^-$ measurements
- Dalitz analysis of $B^- \rightarrow D(K_s \pi\pi)K^-$
- MC studies
- First look at 2009 collision data
- 2010/2011 – what can we expect?

CKM angle γ "from trees"

- Tightest experimental constraints on γ from loop processes, which are sensitive to new physics





- Current value of γ from direct measurement

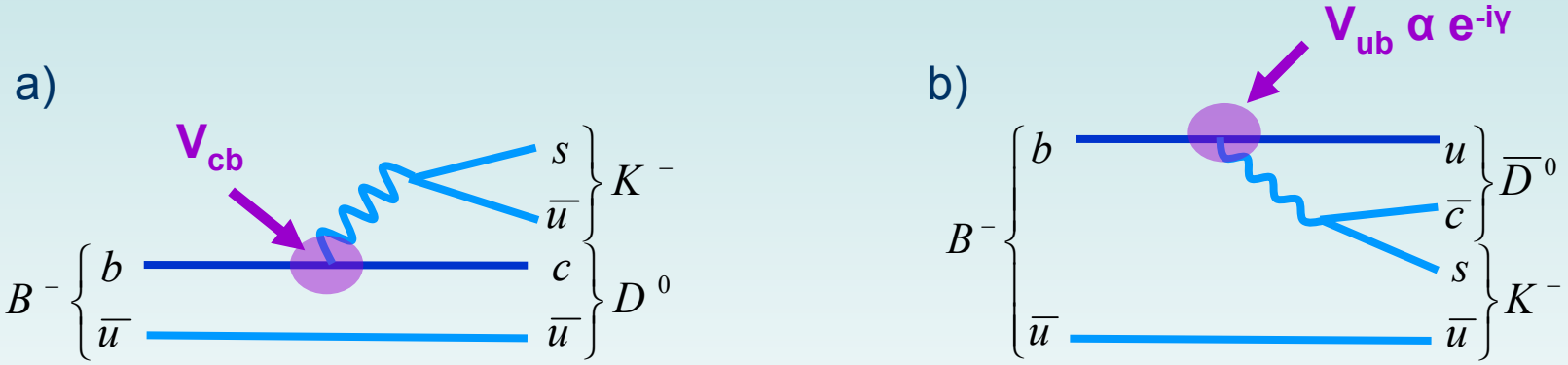
$$\gamma = (73^{+22}_{-25})^{\circ}$$ *(CKMfitter)*

- Tree-level processes are expected to be dominated by Standard Model
- Differences between tree-level and loop Unitarity Triangles $\Rightarrow$ new physics
- Also test SM unitarity and 3 generation model by overconstraining tree Unitarity Triangle
- Aim to measure γ from trees to much higher precision: sensitivity from expected total LHCb data set (10 fb^{-1}) 1.9-2.7°, including systematics(1)

(1) K. Akiba et al. , LHCb-2008-031 (2008)

Time integrated $B^- \to DK^-$ measurements

- Sensitive to γ at tree level when D^0 or $\overline{D}^0$ decays to same final state, due to interference effects



- Diagram b) CKM and colour suppressed
- No penguin loop contributions – largest correction is from D^0-$\overline{D}^0$ mixing, giving bias <<1° on γ[2]

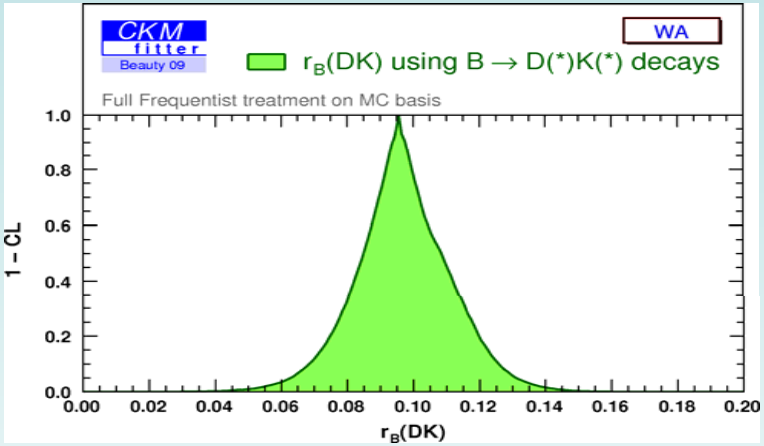
(2) Yu. Grossman, A. Soffer and J. Zupan, Phys. Rev. D 72, 031501 (2005)

- Ratio of amplitudes allows extraction of parameters:

$$\frac{A(B^- \to \overline{D}^0 K^-)}{A(B^- \to D^0 K^-)} = r_B e^{i\delta} e^{-i\gamma}$$

δ strong phase difference

γ unitarity triangle angle



$r_B = (V_{ub}V^*_{cs}/V_{cb}V^*_{us})f_c \sim 0.1$

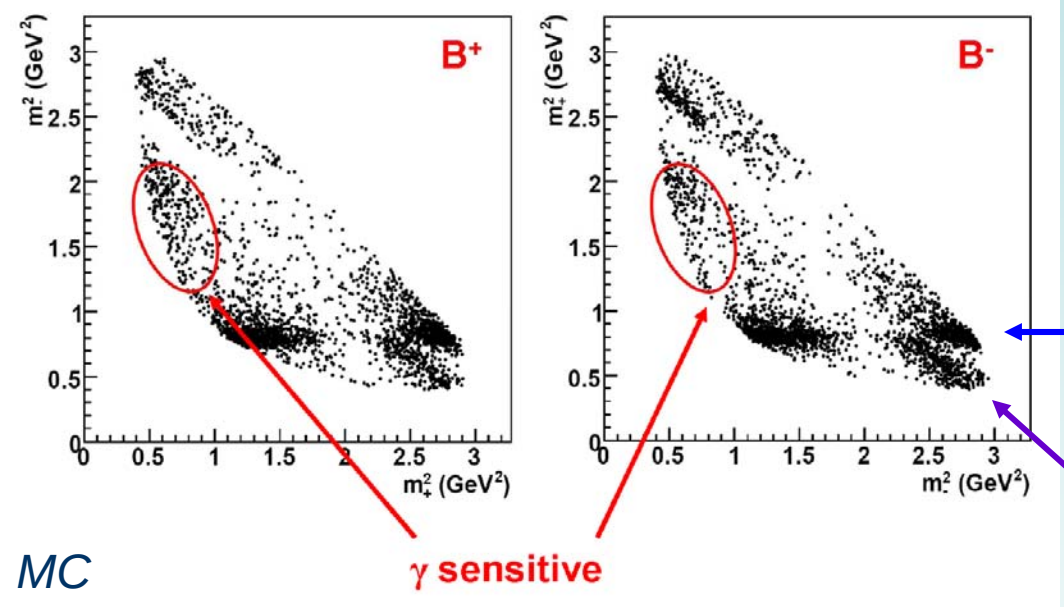
- Possible D decay modes include(3)
  - $\pi\pi$, KK, $K\pi$ (GLW(4)/ADS(5) analysis combined)
  - $K\pi\pi\pi$ (ADS-type analysis with resonances)
  - $K_s\pi\pi$ (Dalitz analysis)

(3) LHCb collaboration, LHCb-PUB-2009-029 (2009)
(4) M. Gronau and D. London, Phys. Lett. B 253, 483 (1991); M. Gronau and D. Wyler, Phys. Lett. B 265, 172 (1991)
(5) D. Atwood, I. Dunietz and A. Soni, Phys. Rev. Lett. 78, 3257 (1997); D. Atwood, I. Dunietz and A. Soni, Phys. Rev. D 63, 036005 (2001)

Dalitz analysis: $B^- \to D(K_s \pi\pi)K^-$

- Analysis of 3 body self-conjugate D decay[6,7] with rich resonance structure

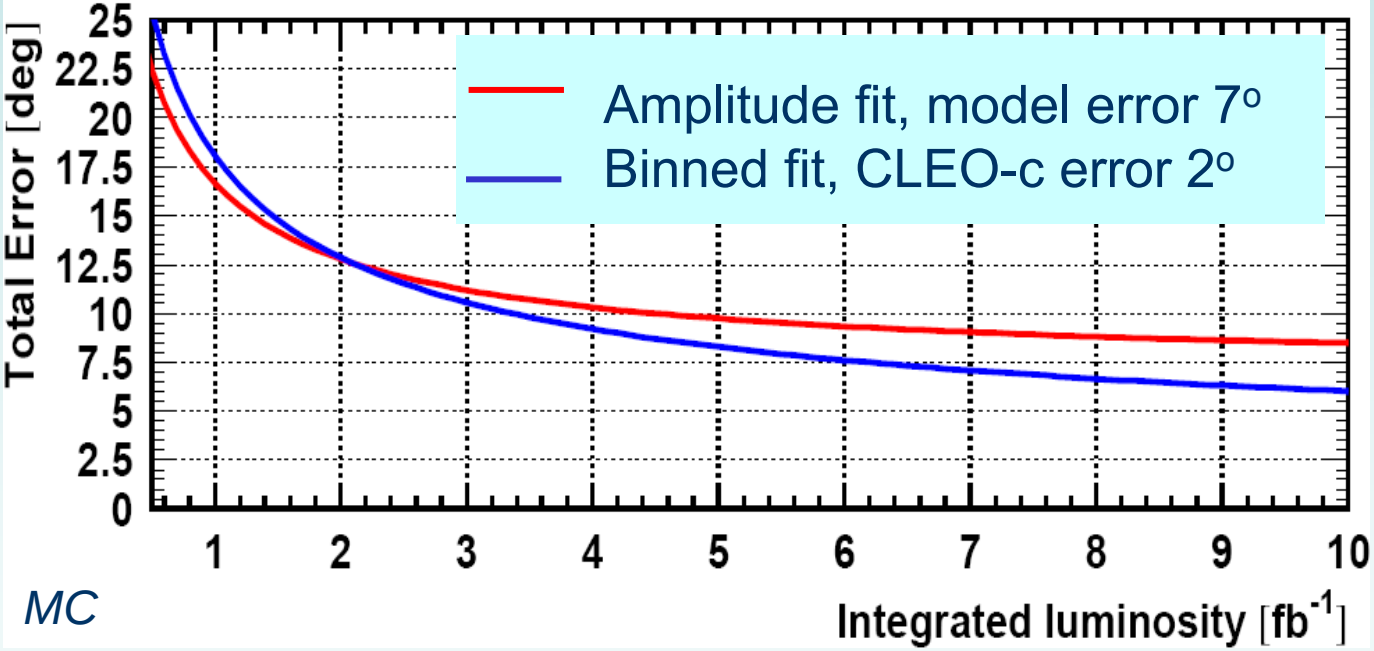
Bands centred on invariant mass of 2-body intermediate states



- Sensitivity to γ from differences in Dalitz plot of D decay from $B^- \to DK^-$ and $B^+ \to DK^+$

(6) A. Giri, Yu. Grossman, A. Soffer and J. Zupan, Phys. Rev. D 68, 054018 (2003)
(7) A. Bondar, Proceedings of BINP Special Analysis Meeting on Dalitz Analysis, 24-26 Sep. 2002, unpublished

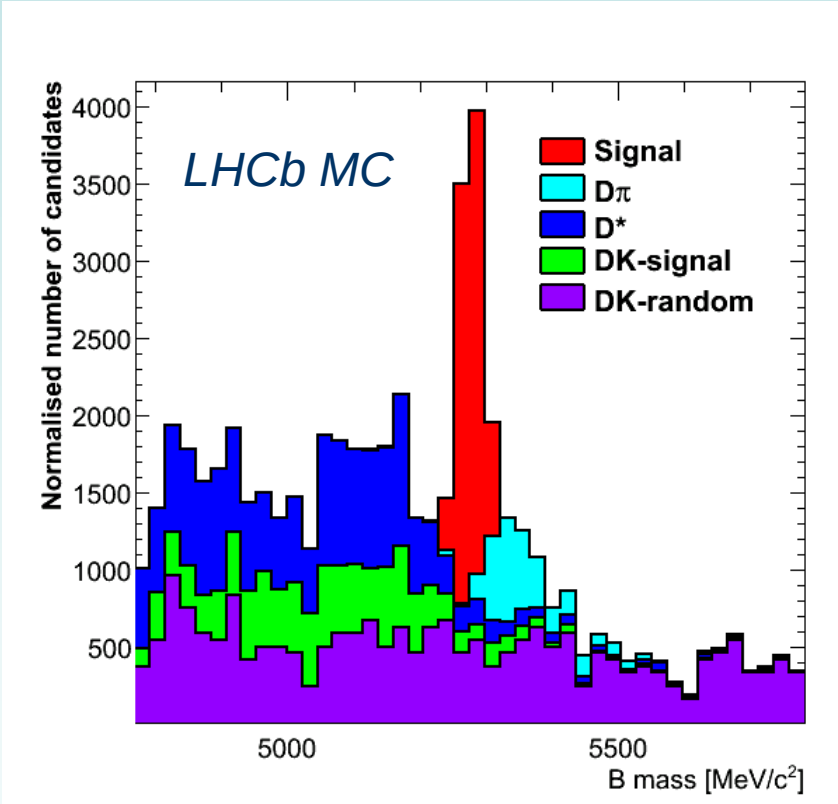
- Two methods to determine γ :
  - Model-dependent likelihood fit; model assumptions give systematic error (8,9)
  - Model-independent binned method; uses strong phase difference from CLEO-c, has lower statistical precision



(8) B. Aubert et al. (BaBar collaboration), Phys. Rev. D 78(3), 034023 (2008)
(9) A. Poluektov on behalf of the Belle collaboration, 'CPV measurements in B decays at Belle', presented at The 2009 Europhysics Conference on High Energy Physics, July 16th–22nd 2009, Krakow

Study on 14 TeV MC

- Cut-based event selection on MC simulation at CoM energy 14 TeV
- 2 fb^{-1} yield of **14376±397** events(10) (no trigger)
- Study identified several categories of background, including combinatoric and specific $B \rightarrow DK$/$B \rightarrow D\pi$ decays(10)
- Largest background real D plus random K



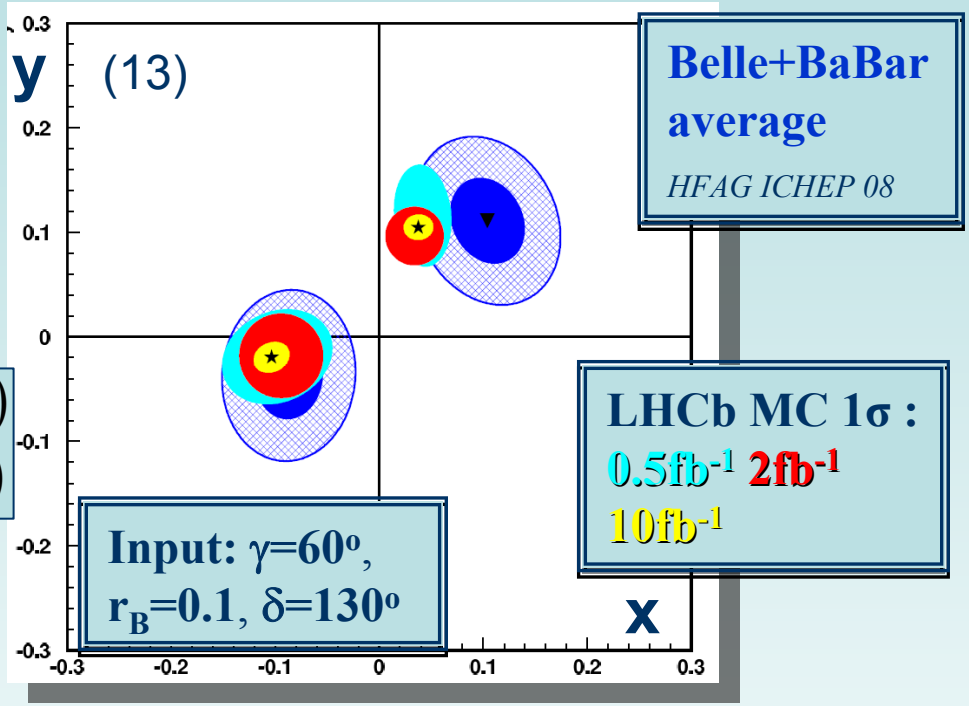
(10) V. Gibson, C. Lazzeroni, Y. Y. Li, LHCb-2008-028 (2008)

- Sensitivity to γ found using toy MC with Belle and BaBar resonance models(11,8)
- With 2 fb^{-1} data at 14 TeV, expect

  $\sigma(\gamma) = 12°$ (12)

$$x_{\pm} = r_{B\pm}\cos(\pm\gamma + \delta)$$
$$y_{\pm} = r_{B\pm}\sin(\pm\gamma + \delta)$$

Belle, BaBar contours: -2Δ(lnL)=χ^2=1, corresponding to 60.7% CL for 2 DOF



- Latest Belle result(14) (605 fb^{-1}):

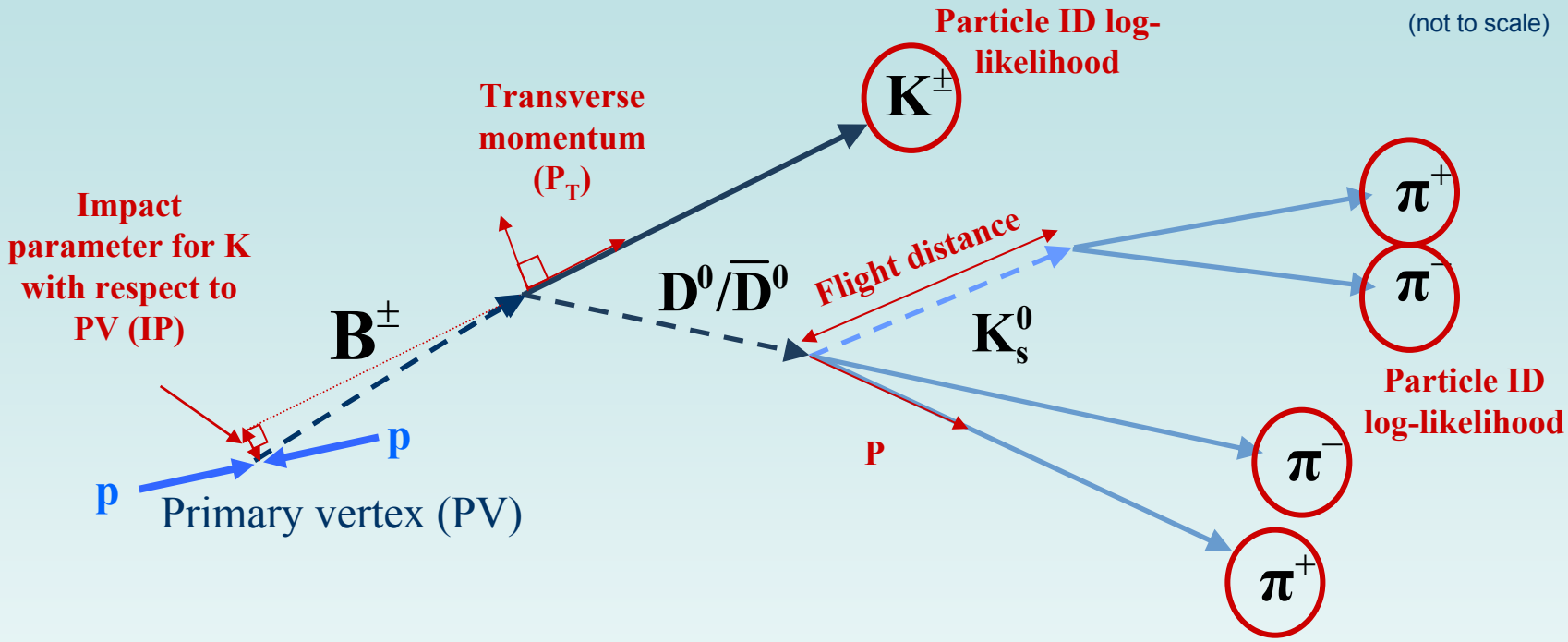
$\gamma = 78.4°^{+10.8°}_{-11.6°} \pm 3.6°$ (syst) $\pm 8.9°$ (model)

(11) K. Abe et al. (Belle collaboration), arXiv:0803.3375v1 (2008)
(8) B. Aubert et al. (BaBar collaboration), Phys. Rev. D, 78(3):034023 (2008)
(12) Y. Y. Li, Thesis, (2009)
(13) Y. Y. Li, B+/- ->D(Kspipi) K+/- at LHCb, presented at LHCb-UK Dalitz plot workshop, Warwick, 2nd October 2009
(14) A. Poluektov et al. (Belle collaboration), arXiv: 1003.3360v1 (2010)

Study on 10 TeV MC – preparation for first data

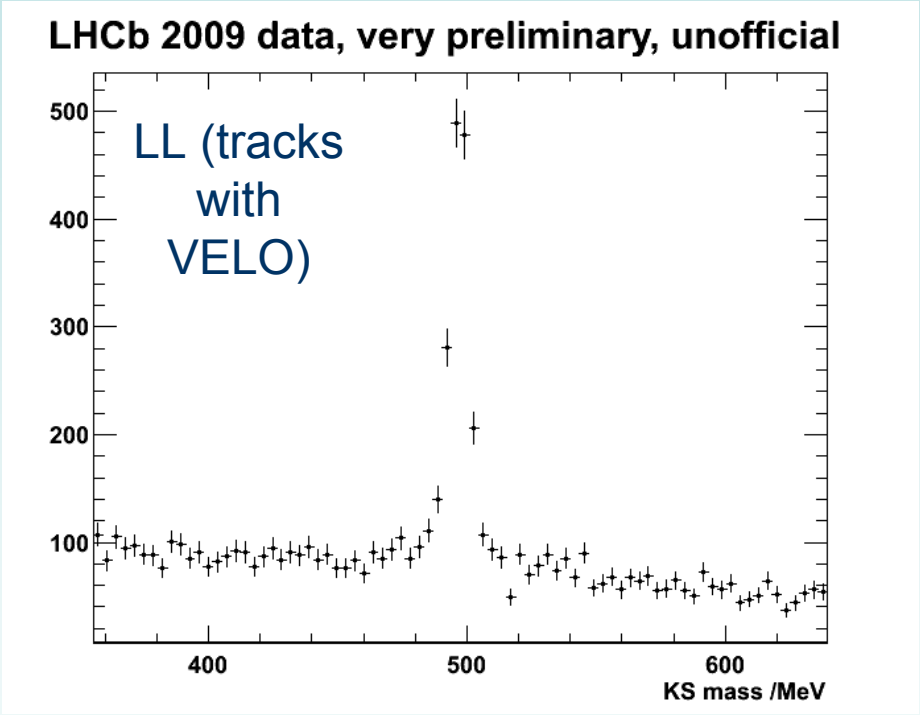
- Simulation at 10 TeV CoM energy
- New cut-based event selection optimising # Signal/√(# Signal + # Background) and associated preselection
- 2 fb^{-1} yield of **12655±310** signal events (no trigger)
- Non-peaking background < 6262 events at 90% conf.

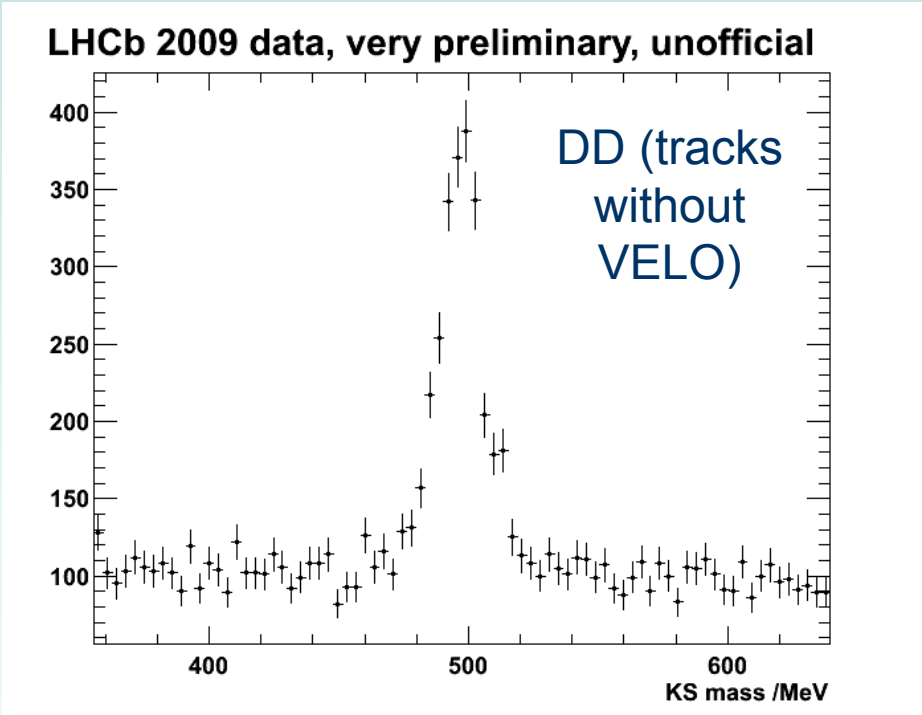
- Example cuts:



- Selection efficiency $(2.838 \pm 0.049) \times 10^{-3}$

K_s mass peaks from $B^- \rightarrow D(K_s\pi\pi)K^-$ optimised selection (2009 collisions)





Promising results!

See backup for peaks from dedicated 2009 LHCb Ks selection

What is expected in 2010/2011?

- MC at 7 TeV CoM energy currently in production…
- 1 fb^{-1} of data, assume $\sigma_{b\bar{b}}$ = 454 μb (Pythia); efficiency from 10 TeV MC with optimised selection:

Yield ~ 8000 events (no trigger)

Trigger eff ~50% depending on running conditions

- Sensitivity estimate ~ same as 2 fb^{-1} at 14 TeV, i.e. $\sigma(\gamma) = 12°$
- Close to latest Belle result errors (slide 10)

Conclusions

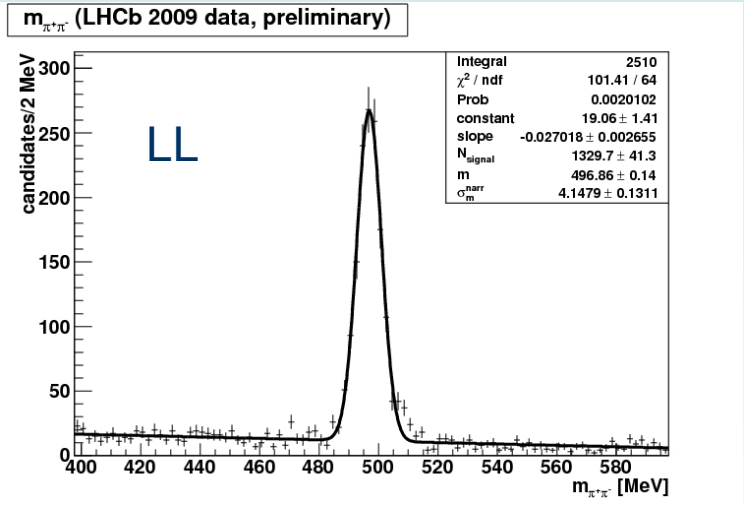
- γ from trees is a key measurement at LHCb
- Differences between tree-level and loop Unitarity Triangles would point to new physics
- $B^- \to D(K_s\pi\pi)K^-$ analysis ready for 2010/2011 data – could provide competitive measurement

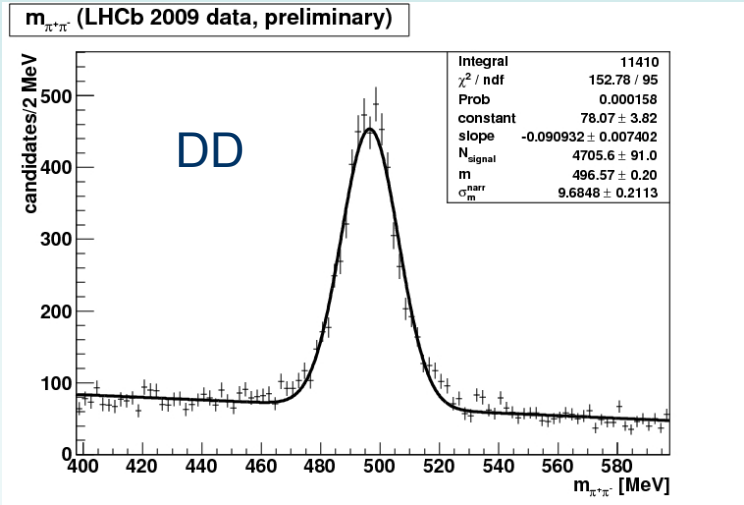
Backup – yield calculations

- $N_{year} = L_{year} \times \sigma_{b\bar{b}} \times 2 \times Br(b \rightarrow B^{\pm}) \times Br(B^{\pm} \rightarrow DK^{\pm}) \times Br(D \rightarrow K_s \pi\pi) \times Br(K_s \rightarrow \pi\pi) \times \varepsilon_{selection}$
- For 14 TeV CoM energy MC study, assume 2 fb^{-1} integrated luminosity, $\sigma_{b\bar{b}}$ taken as 500μb
- For 10 TeV CoM energy MC study, assume 2 fb^{-1} integrated luminosity, $\sigma_{b\bar{b}}$ taken as 336μb

Backup – K_s mass peaks

- K_s mass peaks from LHCb 2009 collision data, using dedicated K_s selection optimised for this data – official results





M. Schiller