Studies of charmed hadronic B-decays with the early LHCb data and prospects for γ

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On behalf of the LHCb collaboration

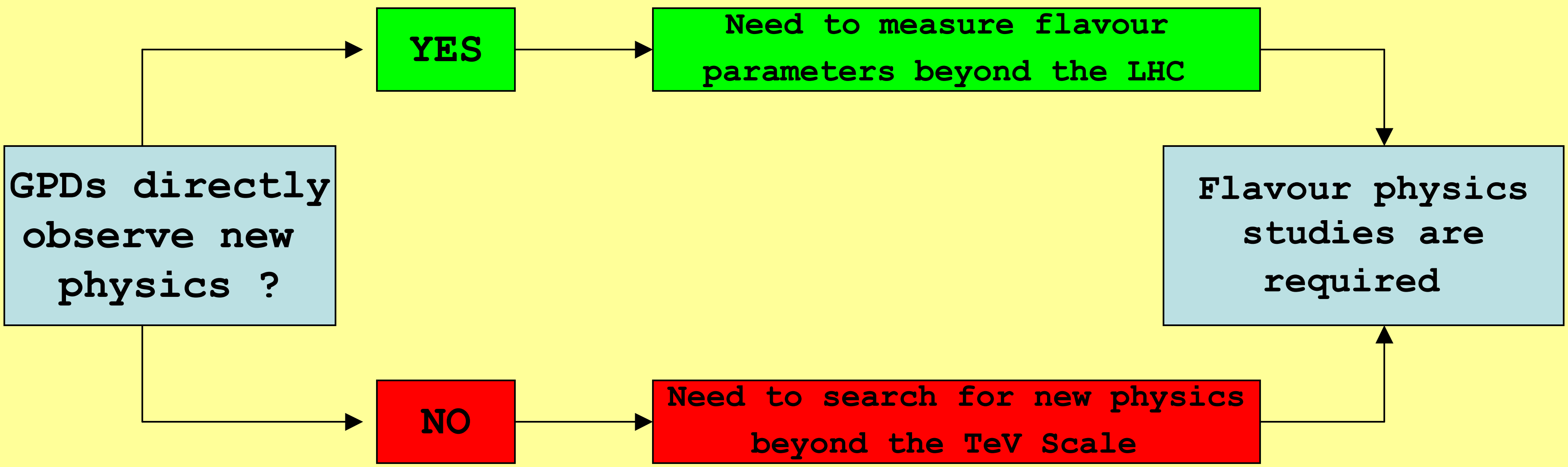
Science and Technology Facility Council
Rutherford Appleton Laboratory

QCD@Work 2010

Why B (Flavour) physics ?

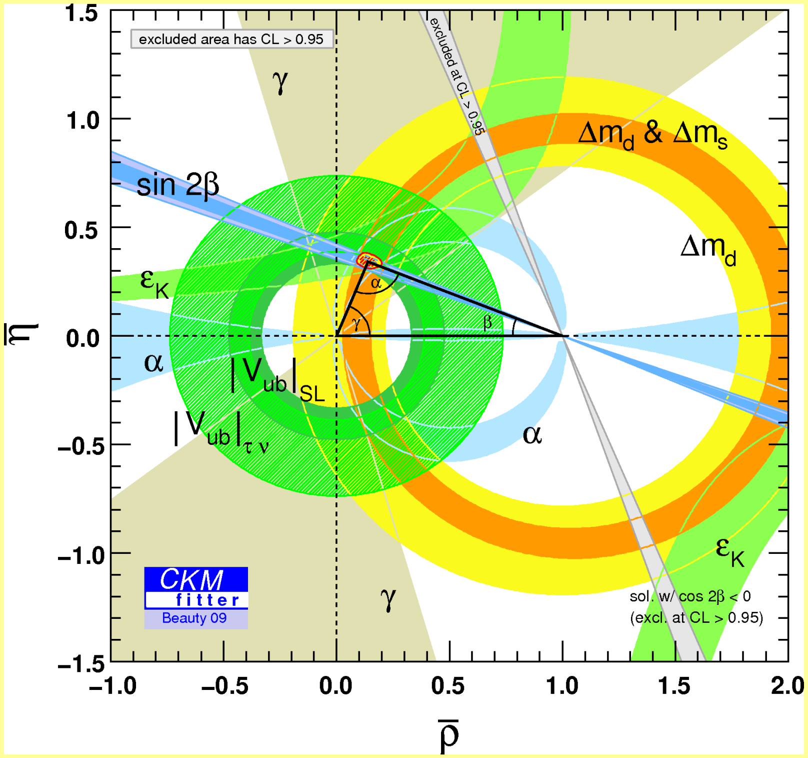
Search for new physics by looking at processes dominated by loop-diagrams

→ These involve "virtual" particles
Sensitivity to particles order or magnitude above the center of mass energy



B-physics in 2010

→ The CKM picture of CP violation is well established, but there are still possibilities for new physics in precision measurements of the Unitarity Triangle



Angles precision limited by experiments:

→ $\sigma(\alpha)$ ~ 5°

→ $\sigma(\beta)$ ~ 1°

→ $\sigma(\gamma)$ ~ 20°

(B_s system less tested)

→ $\sigma(\varphi_s)$ poorly determined

LHCb GOALS

b-hadron decays offer sensitivity to a wide range of NP

Rare decays	Observations or BR limits	$B_s \rightarrow \mu^+\mu^-$
	Angular analysis	$B_d \rightarrow K^*\mu^+\mu^-$
	Radiative penguins in $b \rightarrow s\gamma$ transitions	$B_d \rightarrow K^*\gamma$ $B_s \rightarrow \phi\gamma$

See LHCb roadmap document: arXiv:0912.4179v2

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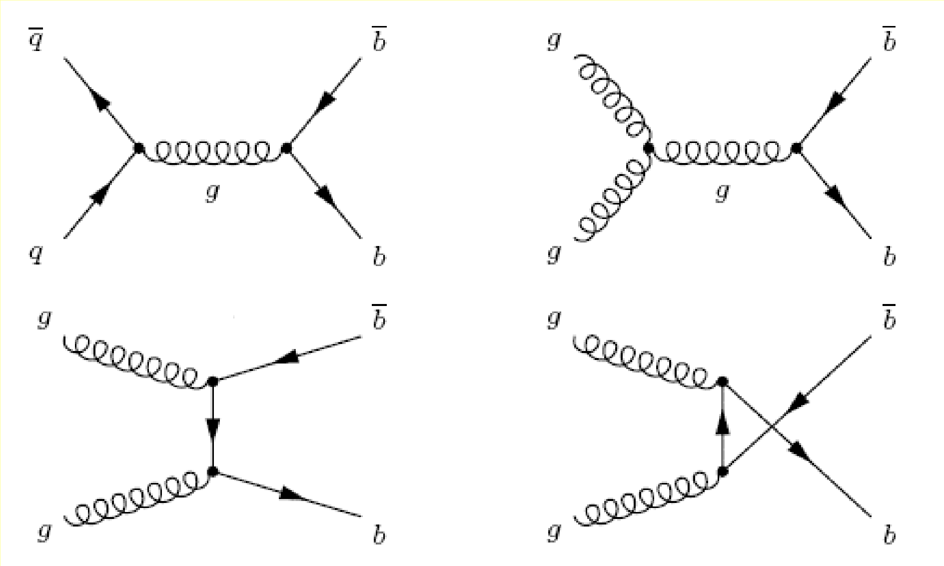
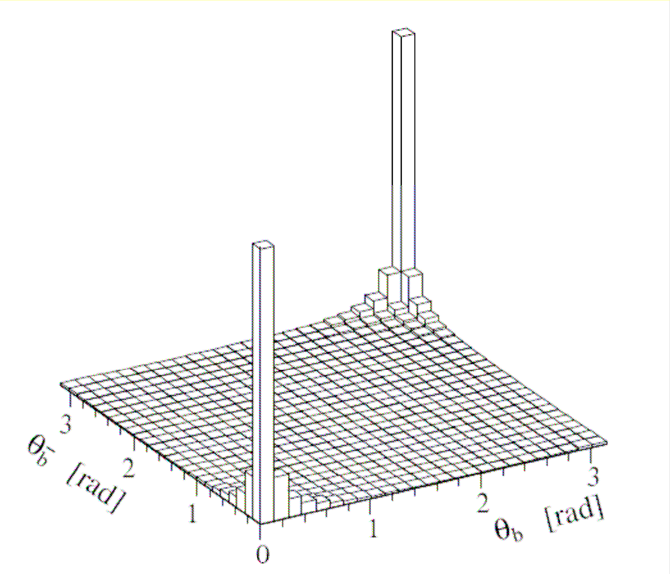
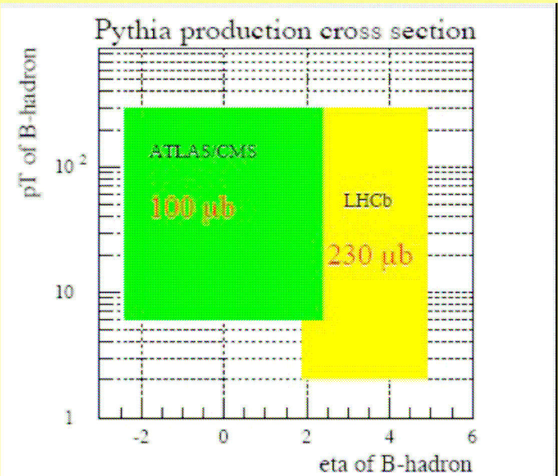
	Radiative penguins in $b \to s\gamma$ transitions	$B_d \to K^*\gamma$ $B_s \to \varphi\gamma$
CP Violation	Mixing phase β_s	$B_s \to J/\Psi\varphi$
	CKM angle γ from loop decays	$B_d \to \pi^+\pi^-$ $B_s \to K^+K^-$
	CKM angle γ from tree decays	$B_s \to D_sK$ $B_d \to D^0K^{*0}$; $B^+ \to D^0K^+$

See LHCb roadmap document: arXiv:0912.4179v2

B-physics at the LHC







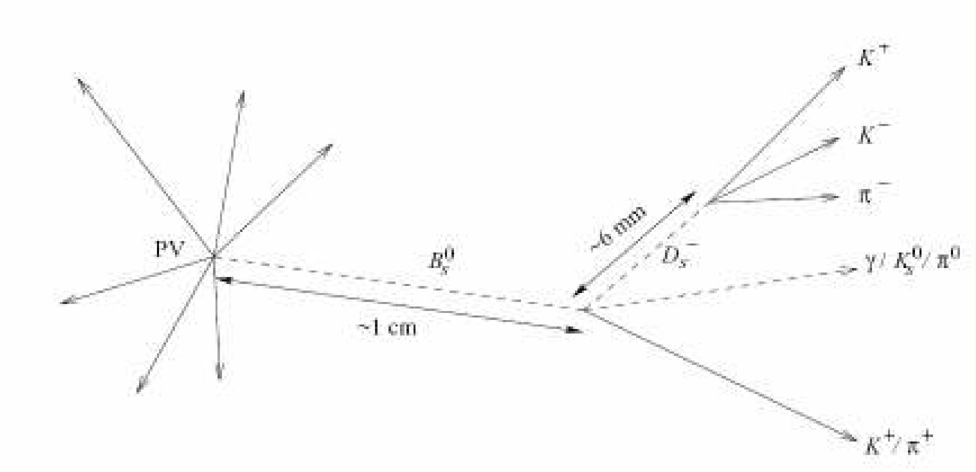
- b-hadrons are mostly produced in the forward (or backward) direction
- $b\bar{b}$ cross section at 7 TeV: 0.46 mb

Different flavour production:
B_d : 40% ; B_u : 40%; B_s : 10%; B_c : ~0.1%
B-Baryons : 10%

B-physics requirements

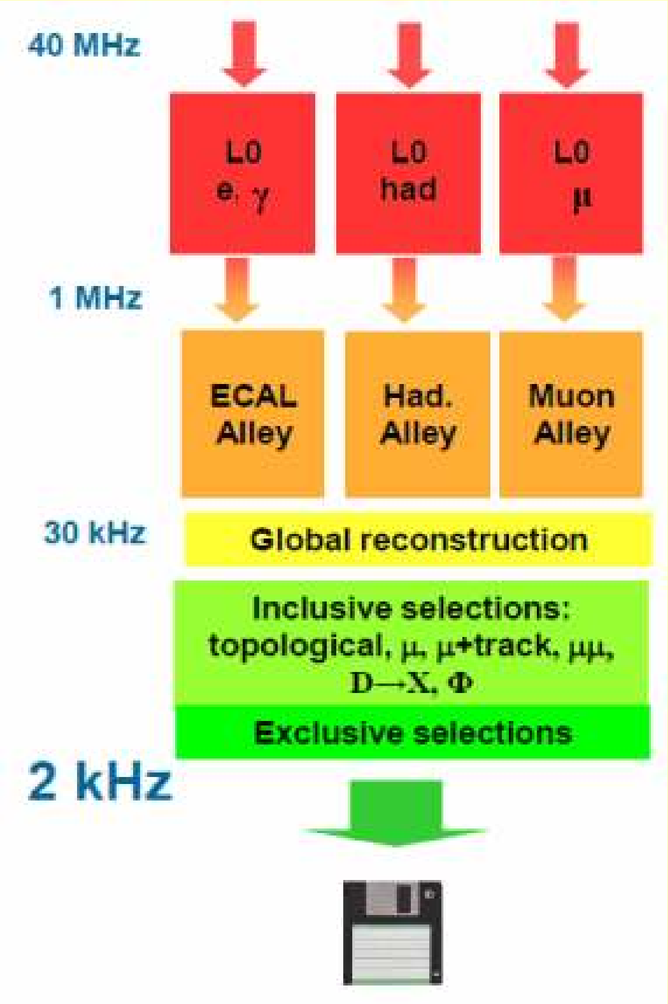
- **Precise vertexing for lifetime measurements**
  → Separate B decay vertex from primary vertex

- **Particle ID for final states**
  → Distinguish π/K and identify leptons over large momentum range



- **Efficient triggering**
  → Trigger for leptons and hadrons
  → Many different channels have low branching ratios
  → Reduction factor up to 1/5000

LHCb trigger

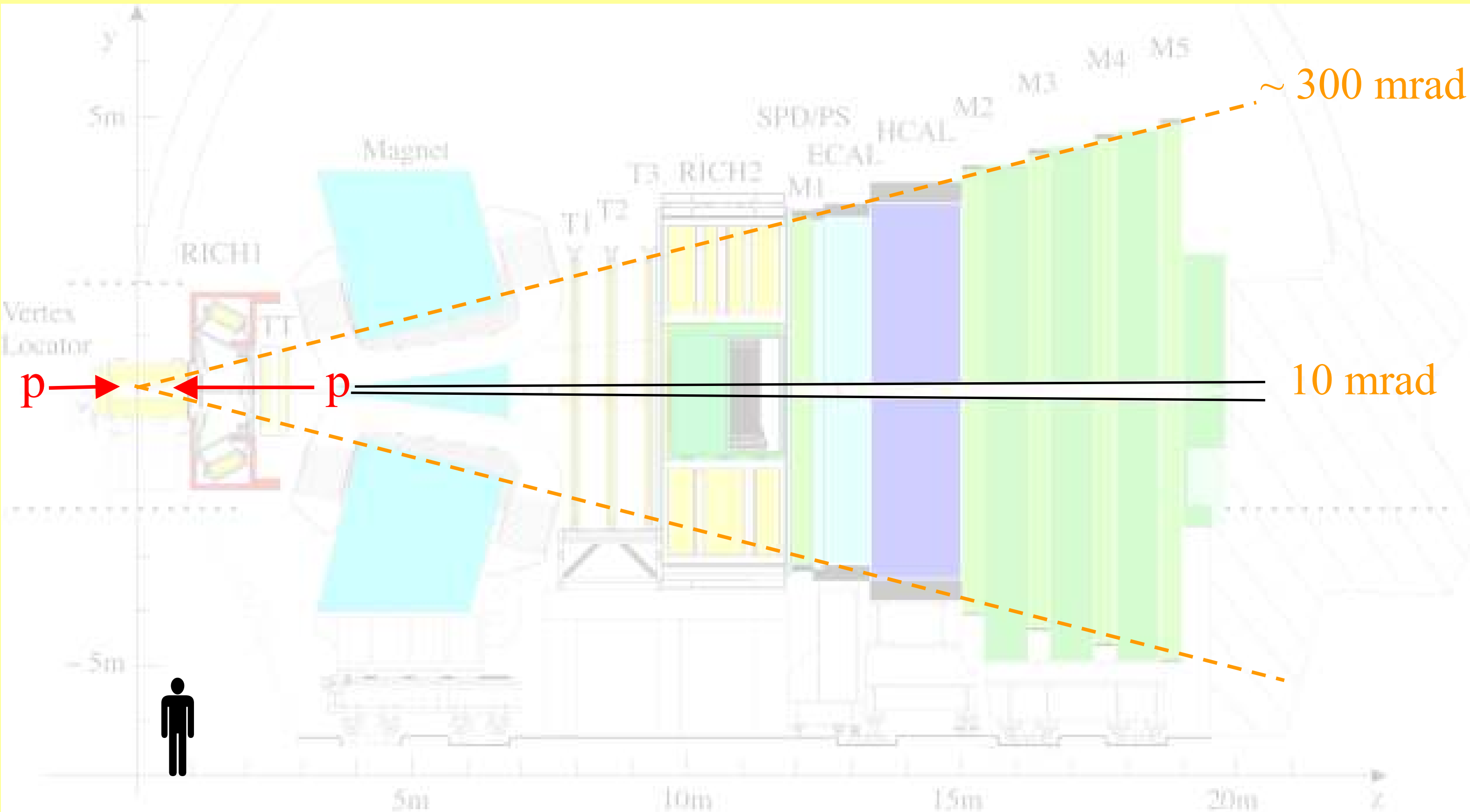


Level 0 – High P_T, high E_T, in the muon system and in the calorimeters

HLT1 – Confirms L0 decision by matching L0-object to tracks

HLT2 – Does full reconstruction and loose selections

LHCb



- Forward spectrometer: pp collisions at the LHC at 14 TeV
- Design luminosity $2*10^{32}cm^{-2}s^{-1}$
- Annual integrated luminosity $2fb^{-1}$

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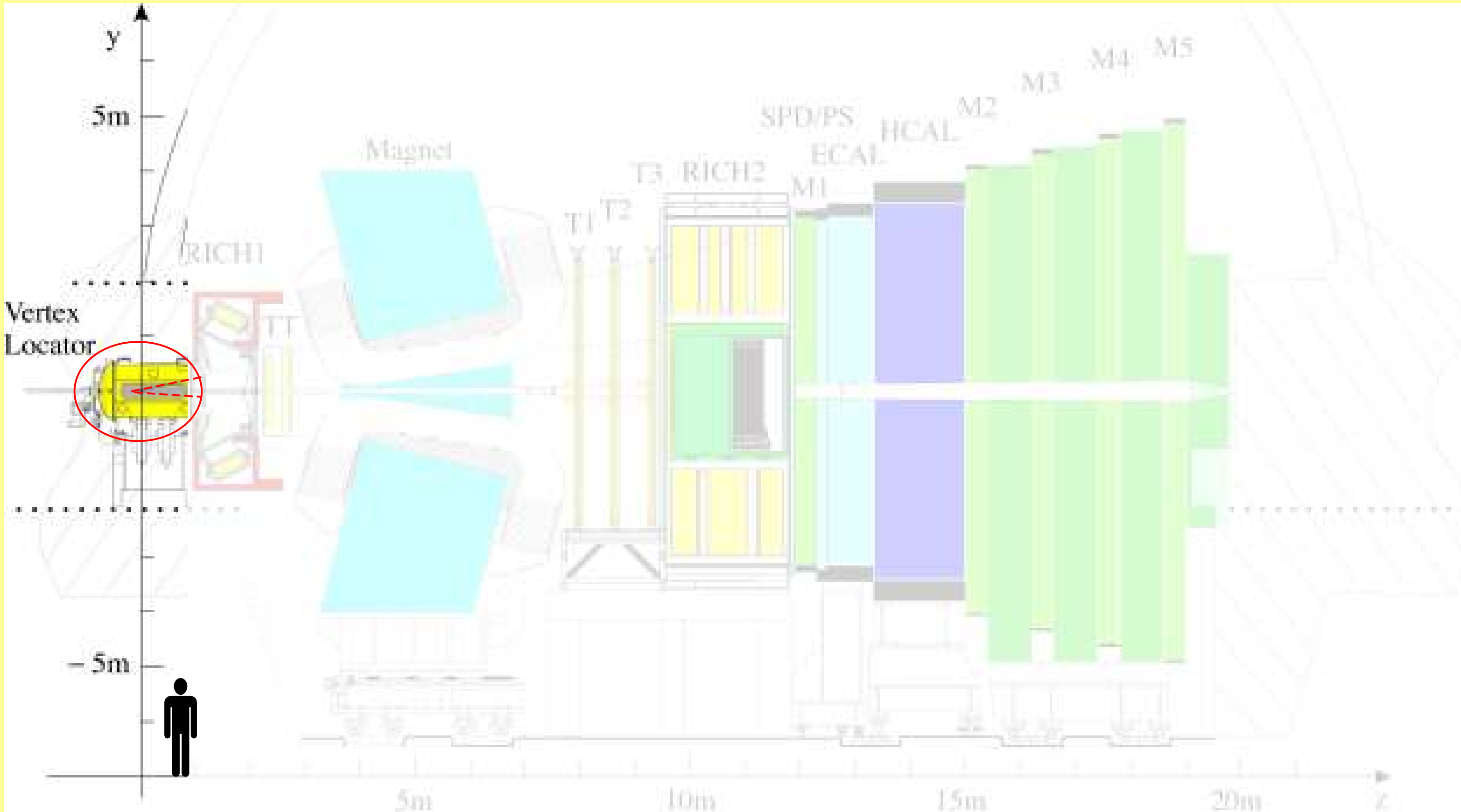
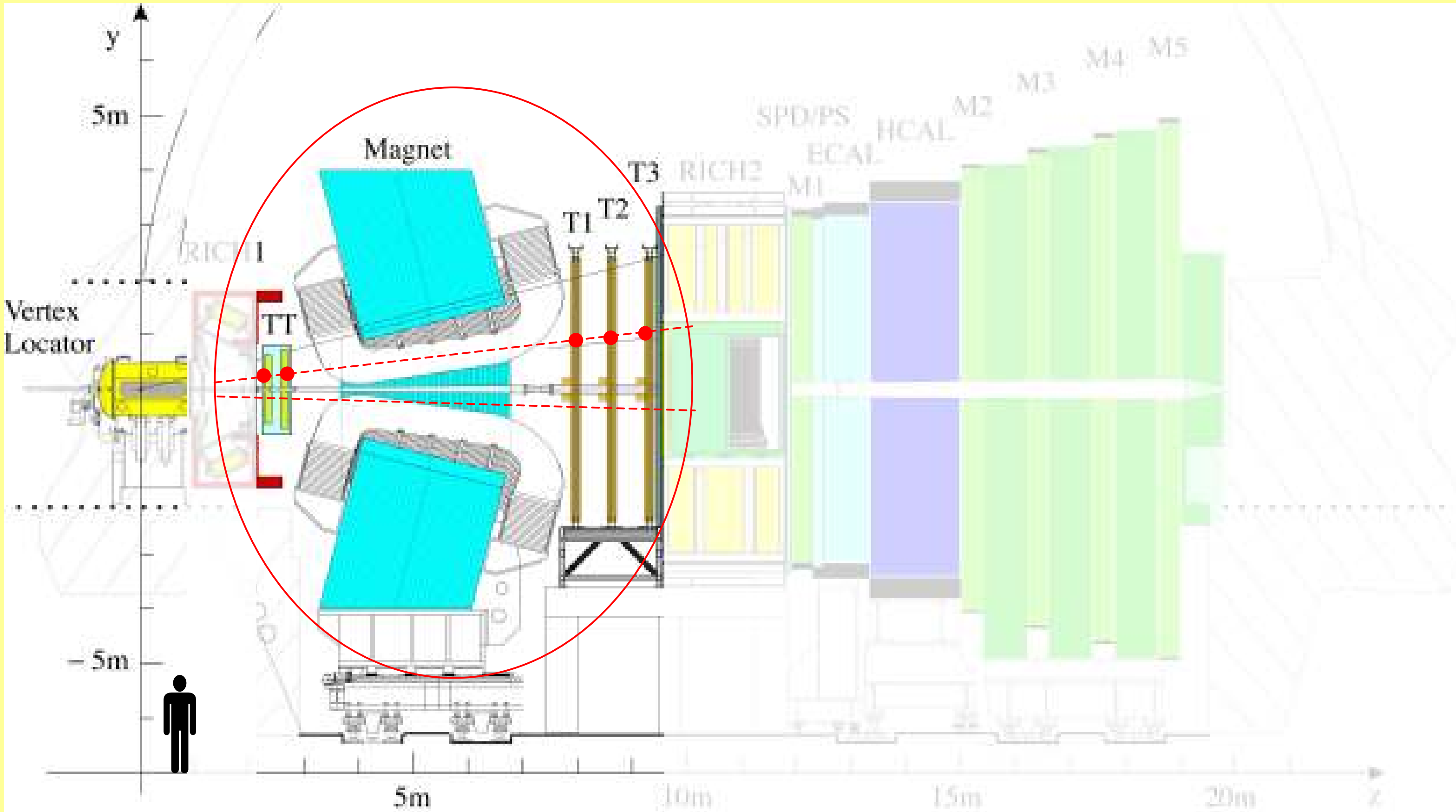
LHCb



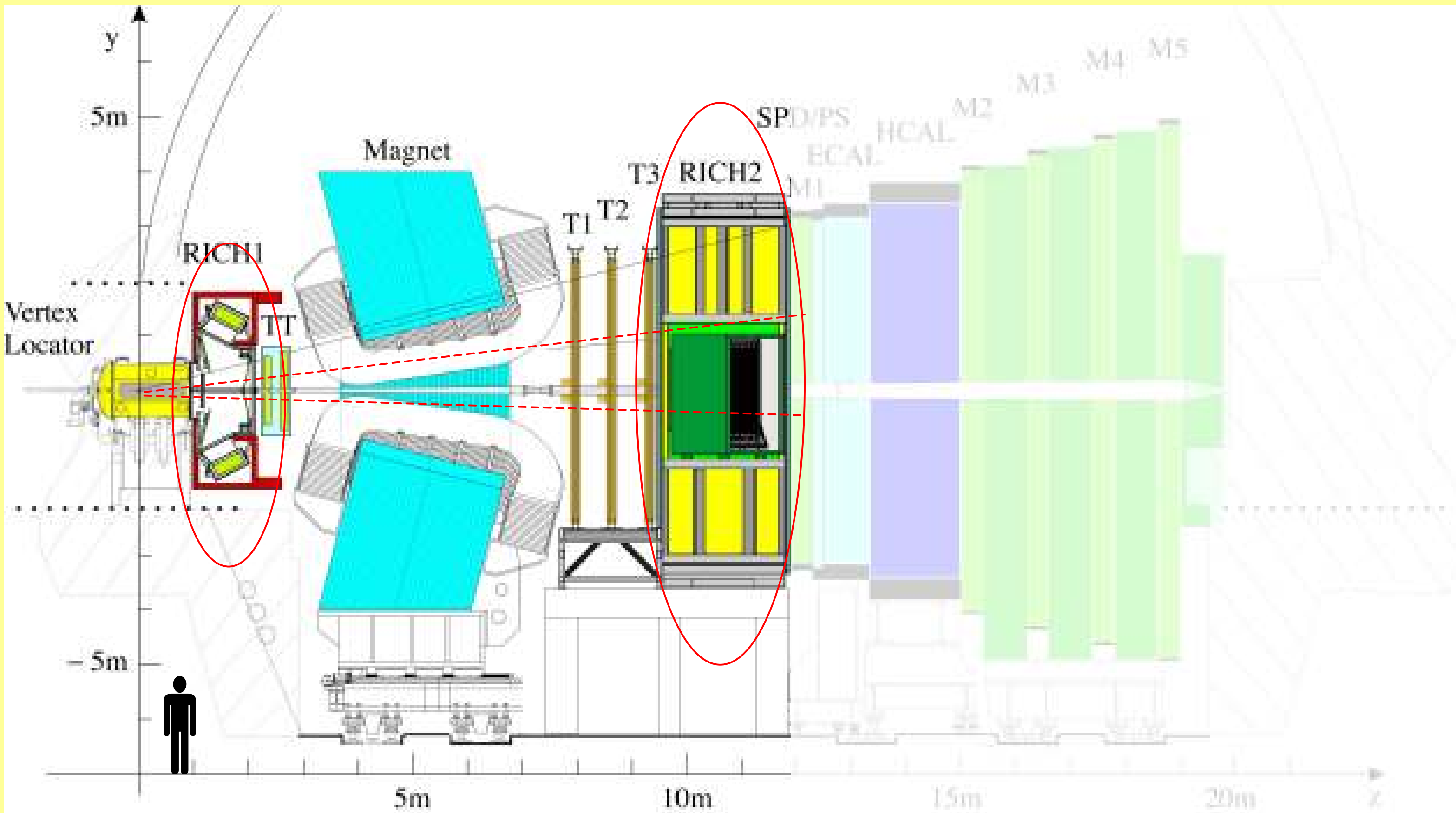
- Vertex locator around the interaction region
  → B-proper time resolution ~ 40fs

LHCb



• Tracking system and dipole magnet to measure angles and momenta → $\delta p/p$ ~0.4% and B-mass resolution 16 - 20 MeV/c^2

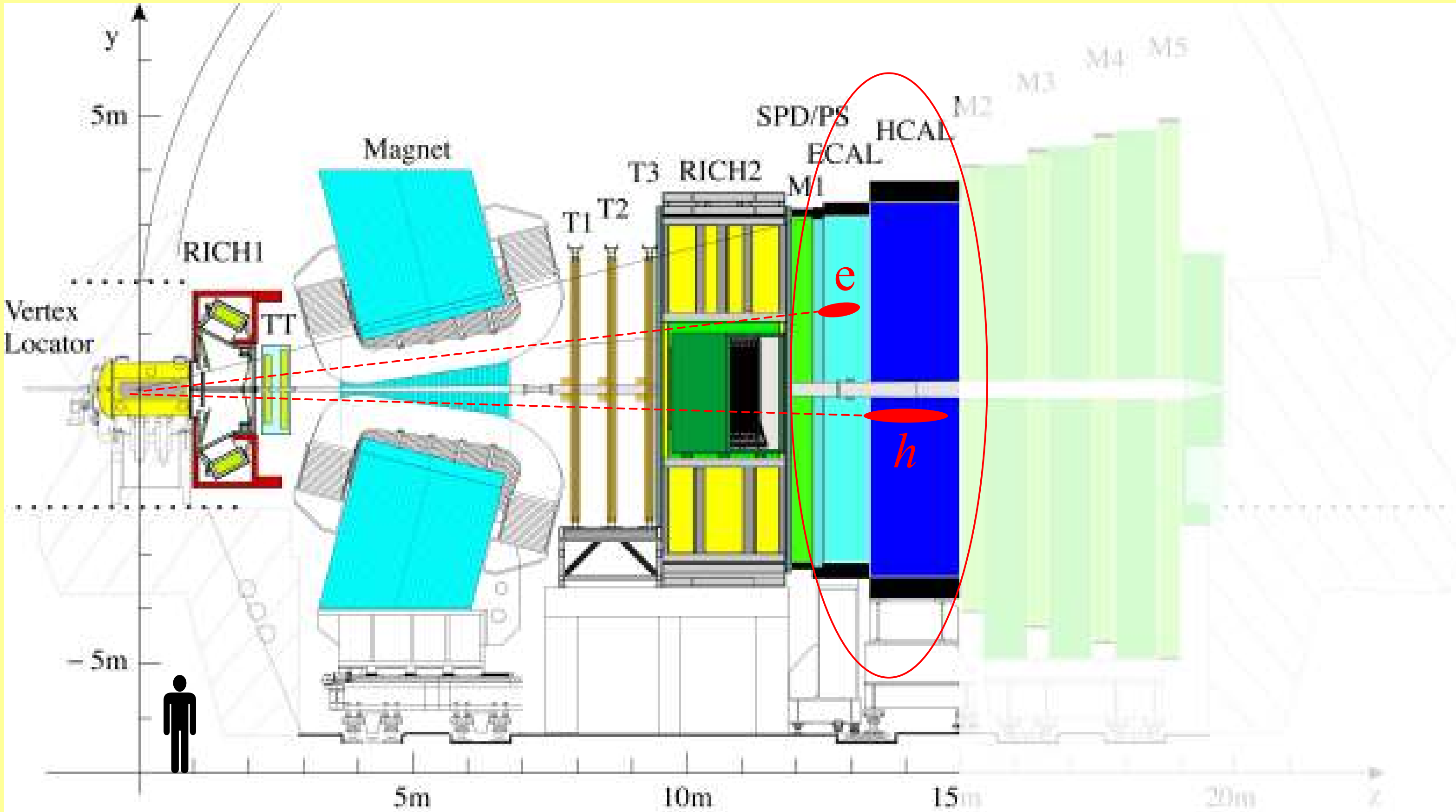
LHCb



- **Two RICH detectors for charged hadron identification**

→ Provide > 3σ π\K separation for 3 < *p* < 100 GeV

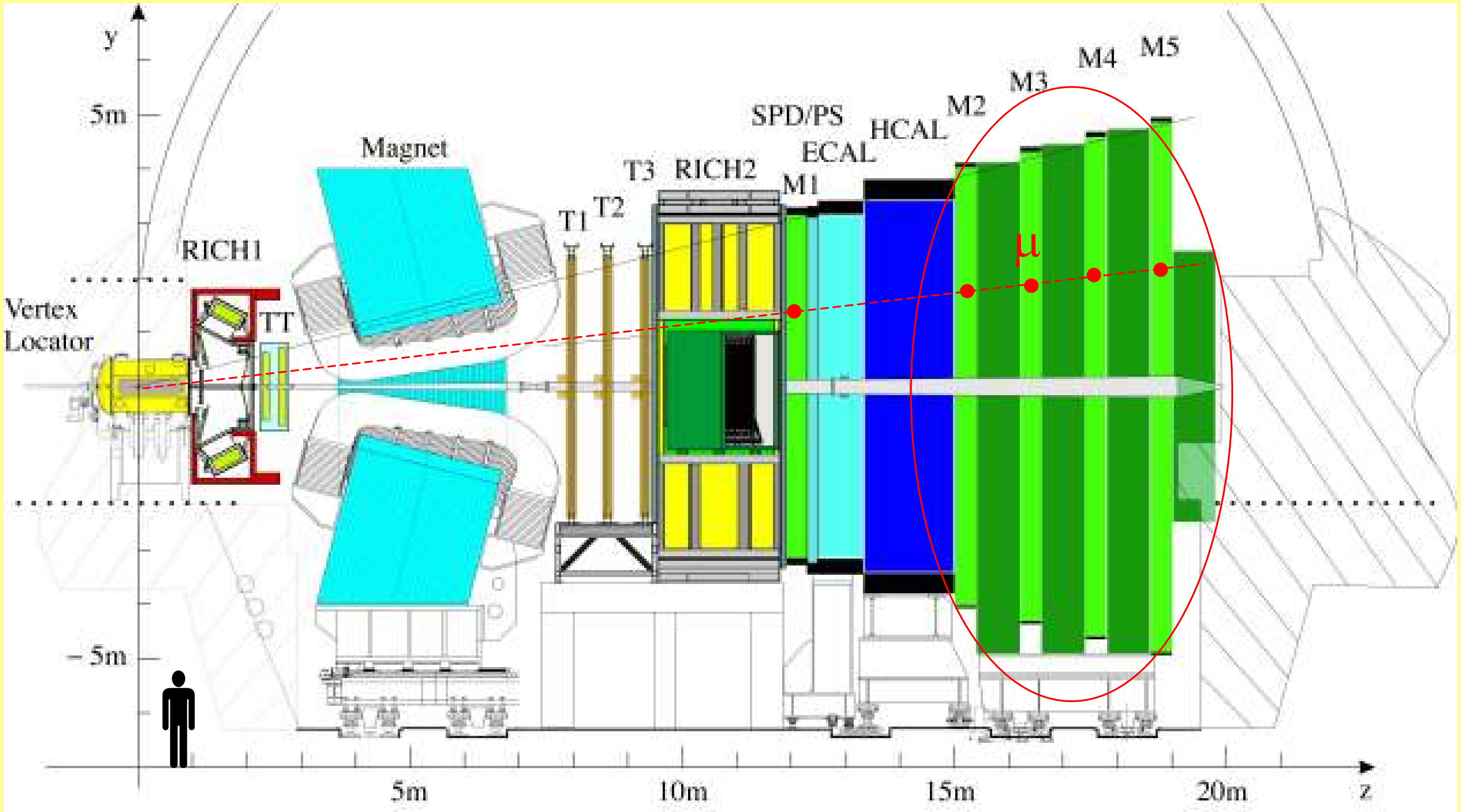
LHCb



- Calorimeter system to identify electrons, hadrons and photons

→ Important for the Level-0

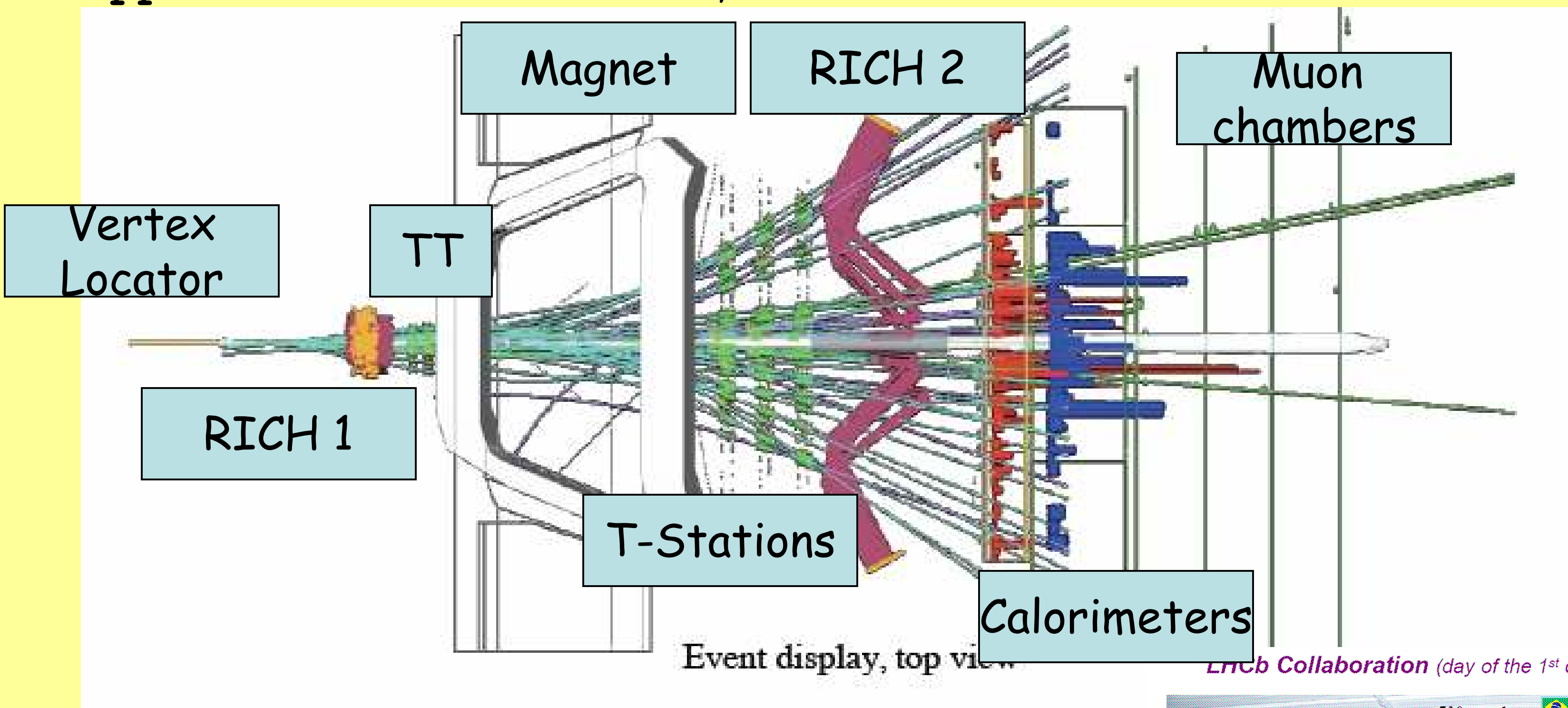
LHCb



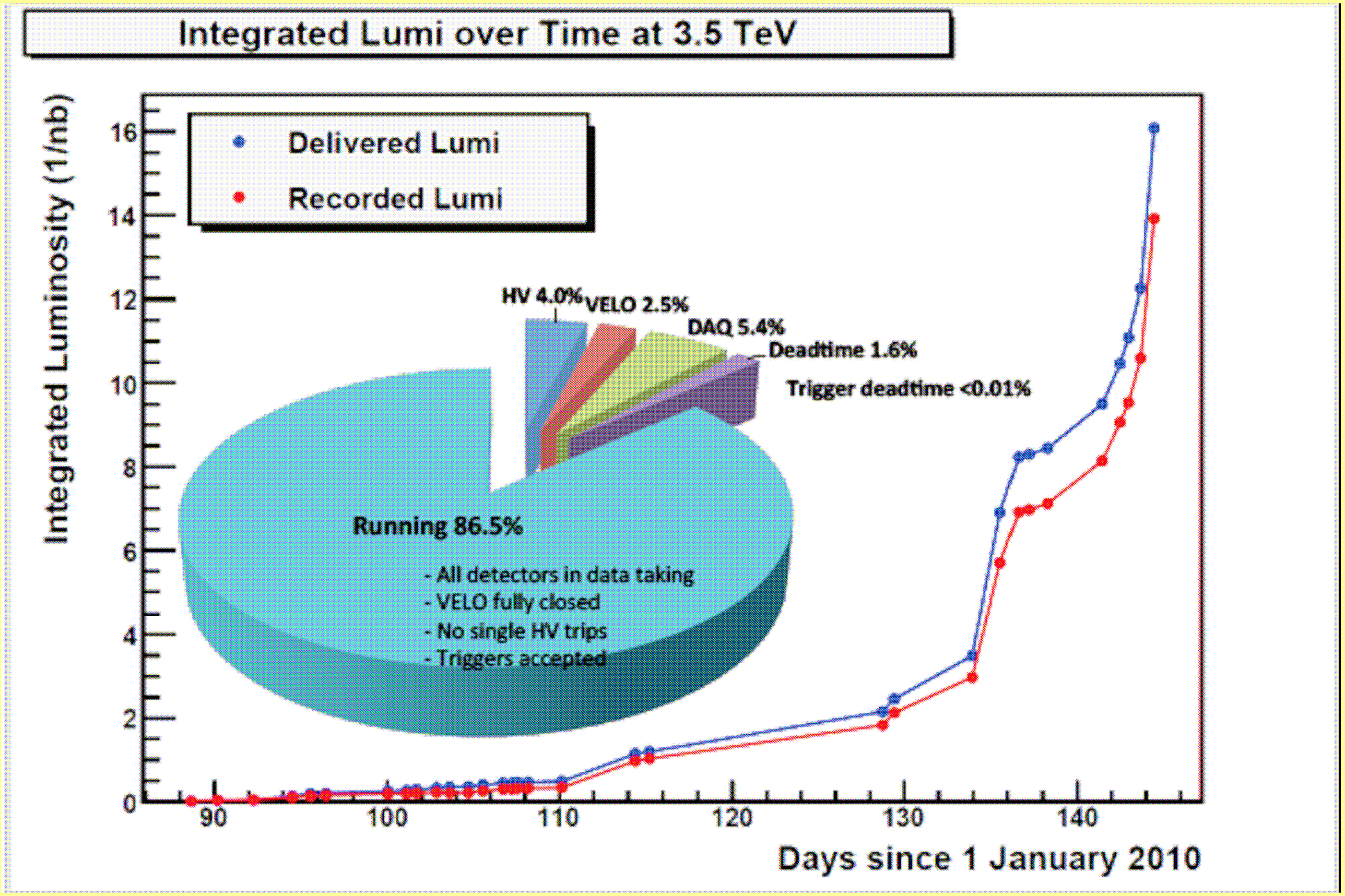
- Muon system to identify muons, also used in the Level-0

Day 1 at 7 TeV

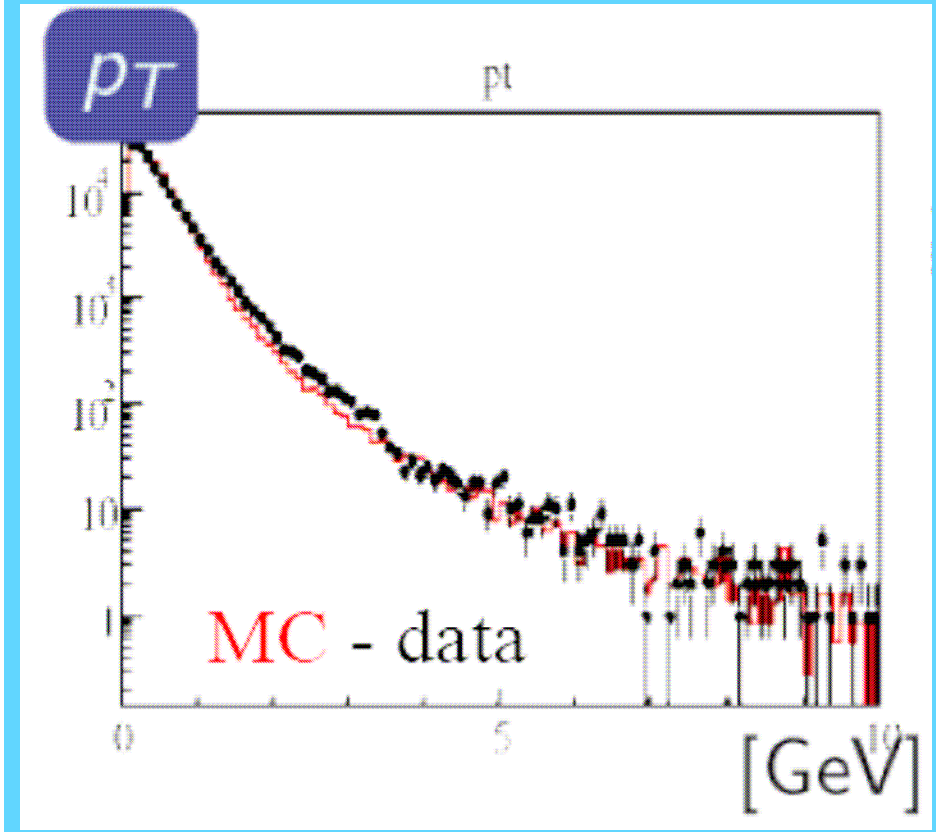
First pp collisions at 7 TeV, March 30th 2010

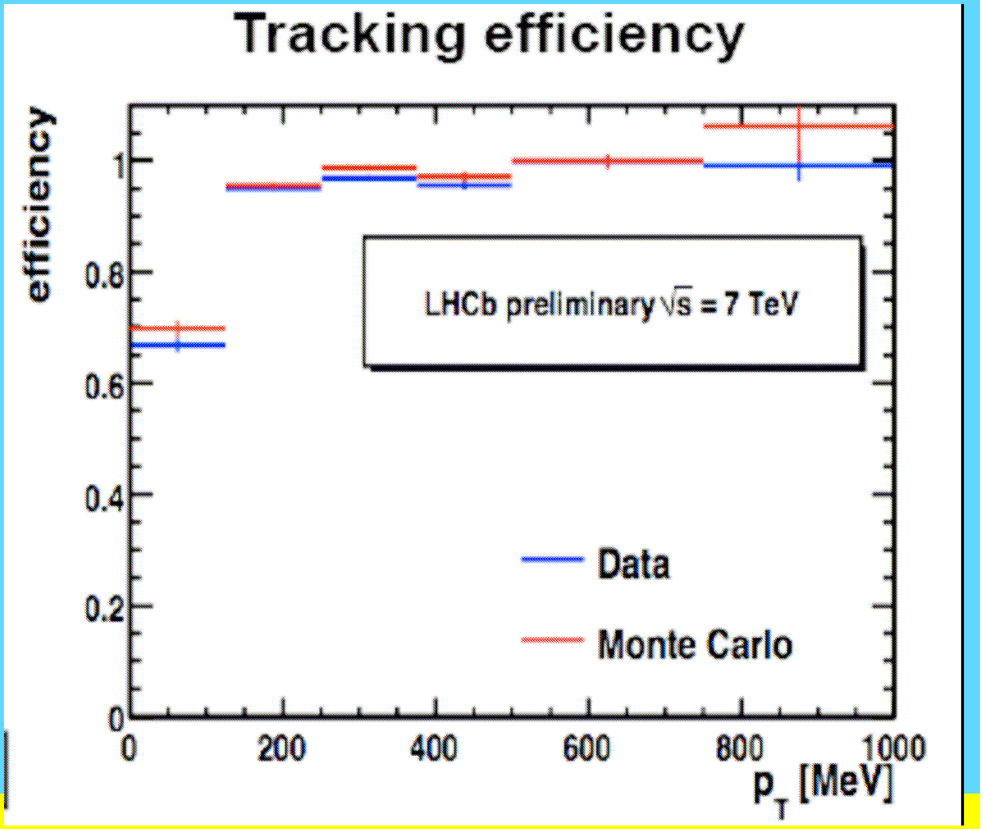


Accumulated luminosity



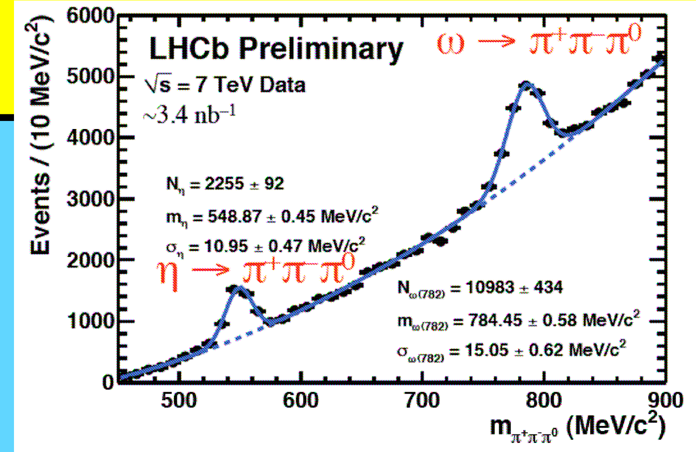
Good agreement between data and MC

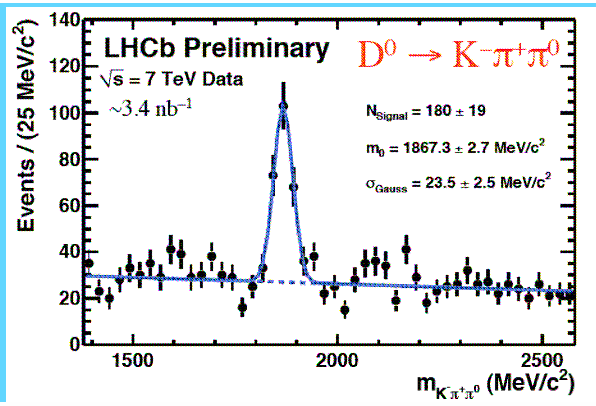


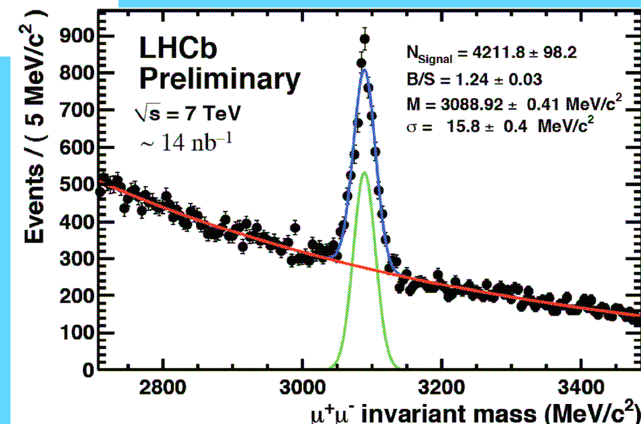


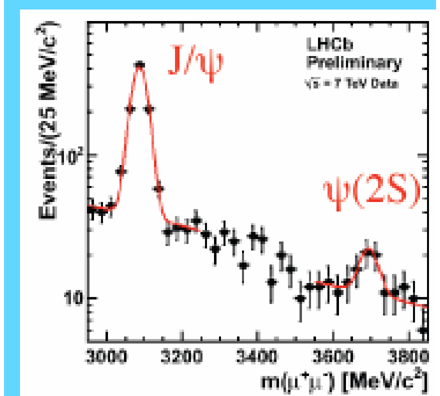
Fully reconstructed particles

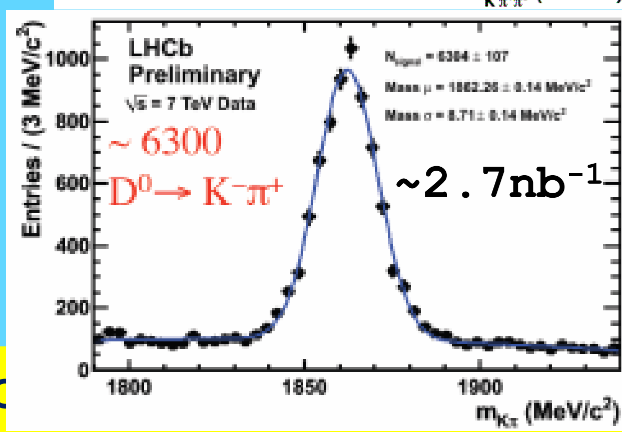
- $\pi^0 \to \gamma\gamma$
- $\eta \to \gamma\gamma, \pi^+\pi^-\pi^0$
- $\omega \to \pi^+\pi^-\pi^0$
- $\eta' \to \pi^+\pi^-\gamma$
- $K_S \to \pi^+\pi^-$
- $K^{*0} \to K^-\pi^+$
- $\Lambda \to p\pi^-$
- $\Xi^- \to \Lambda\pi^-$
- $\Omega^- \to \Lambda K^-$
- $\phi \to K^+K^-$
- $D^0 \to K^-\pi^+, K^-K^+, \pi^-\pi^+$
- $D^0 \to K^-\pi^+\pi^0, K^-\rho^+$
- $D^0 \to K^-\pi^+\pi^+\pi^-$
- $D^+ \to K^-\pi^+\pi^+, K^-K^+\pi^+$
- $D^{*+} \to D^0\pi^+$
- $D_s \to K^-K^+\pi^+$
- $\Lambda_c \to pK^-\pi^+$
- $J/\psi \to \mu^+\mu^-, e^+e^-$
- $\psi(2S) \to \mu^+\mu^-$
- $B^{0/+} \to D^{+/0}\pi^{-/+}$

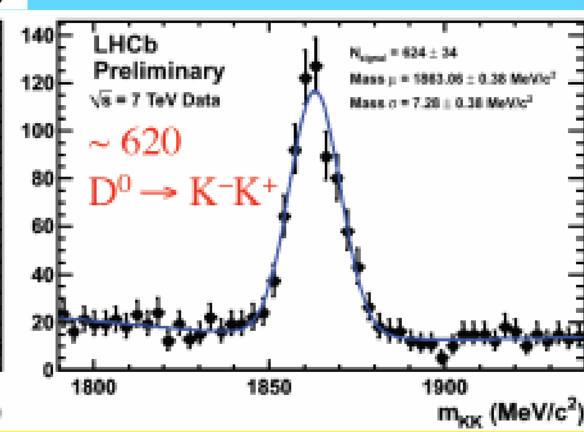


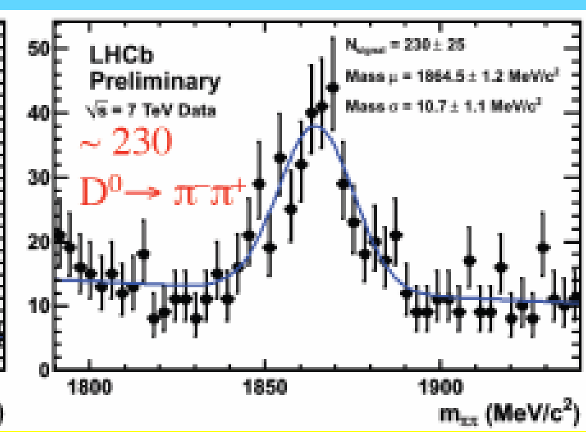




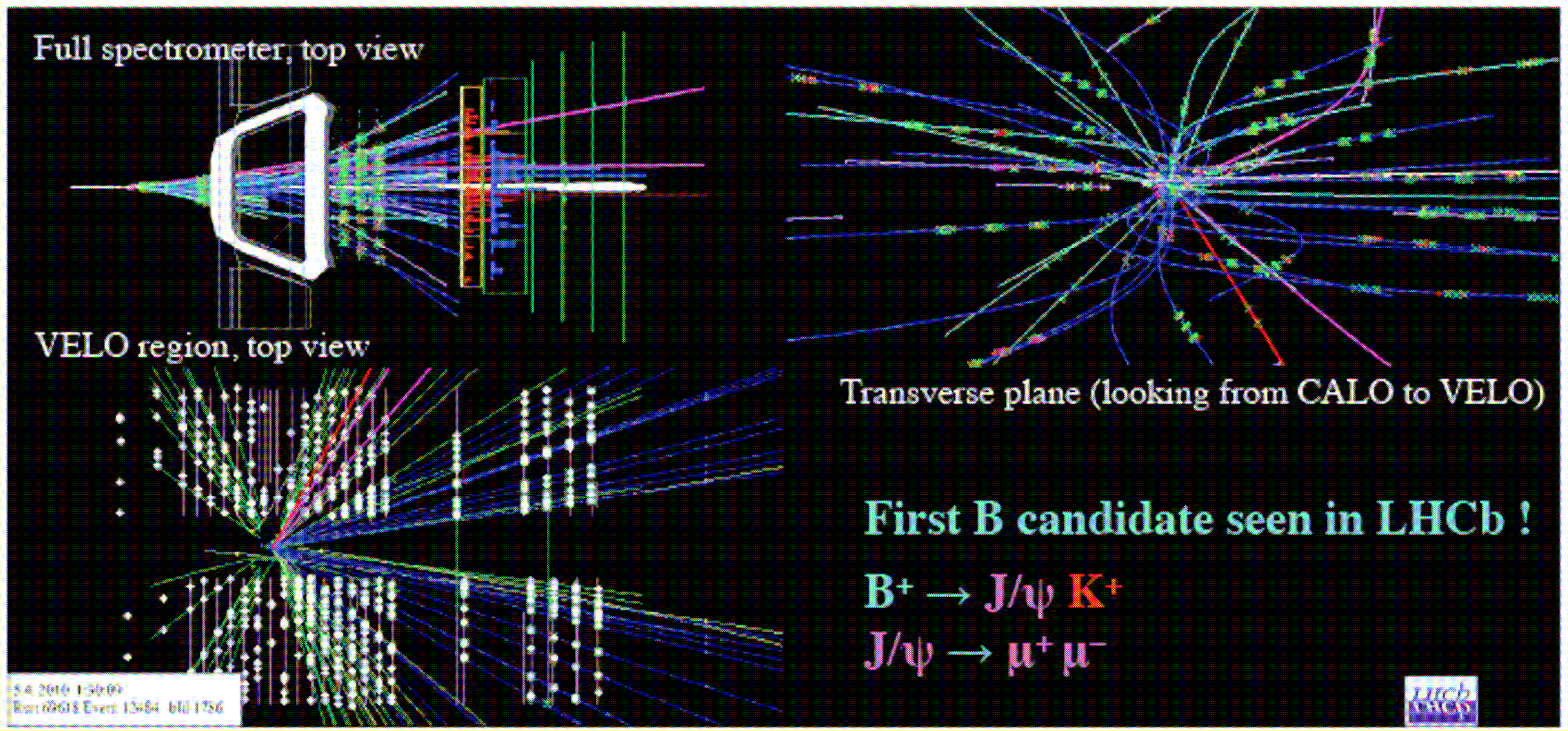




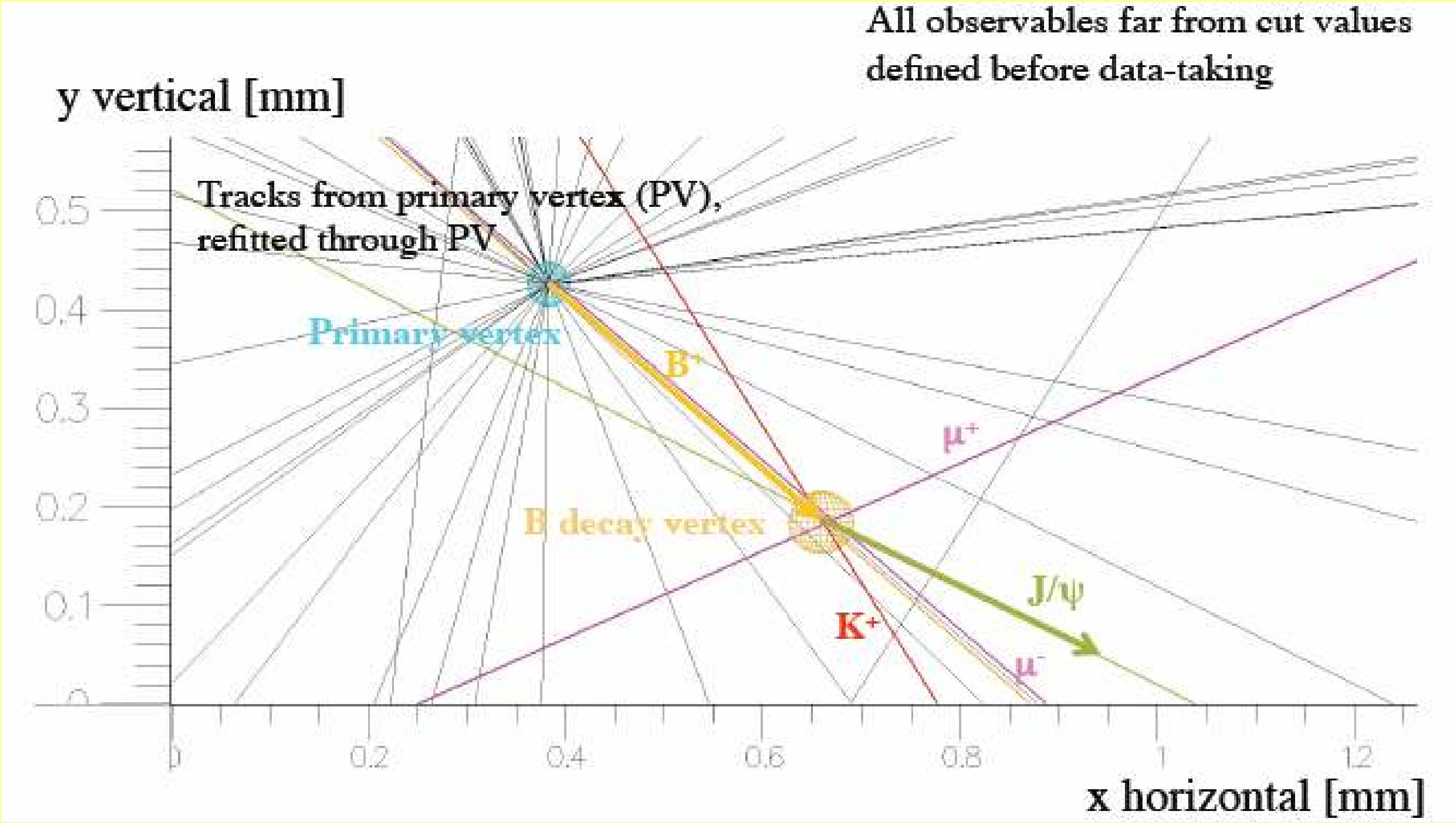




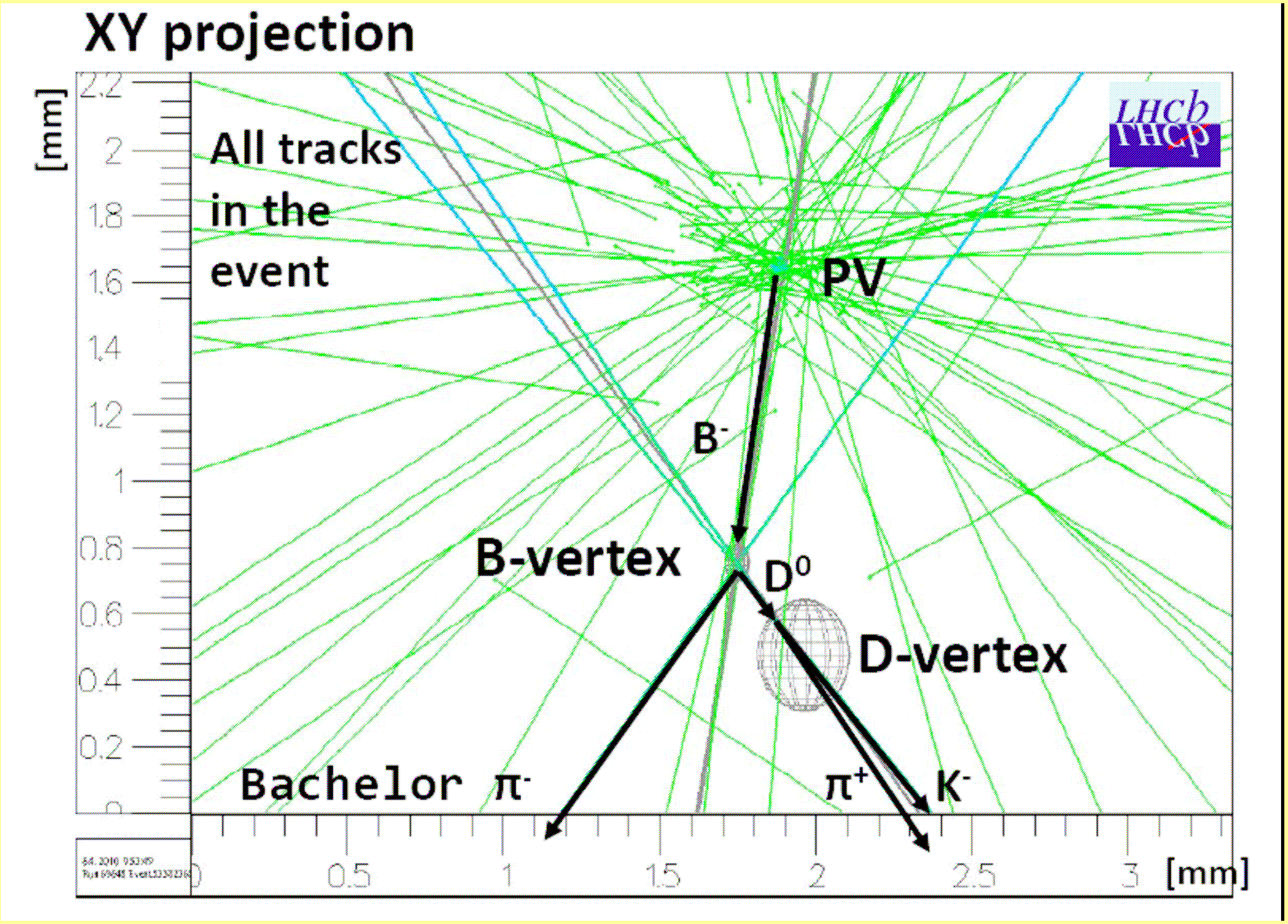
Fully reconstructed B → J/ψ K+



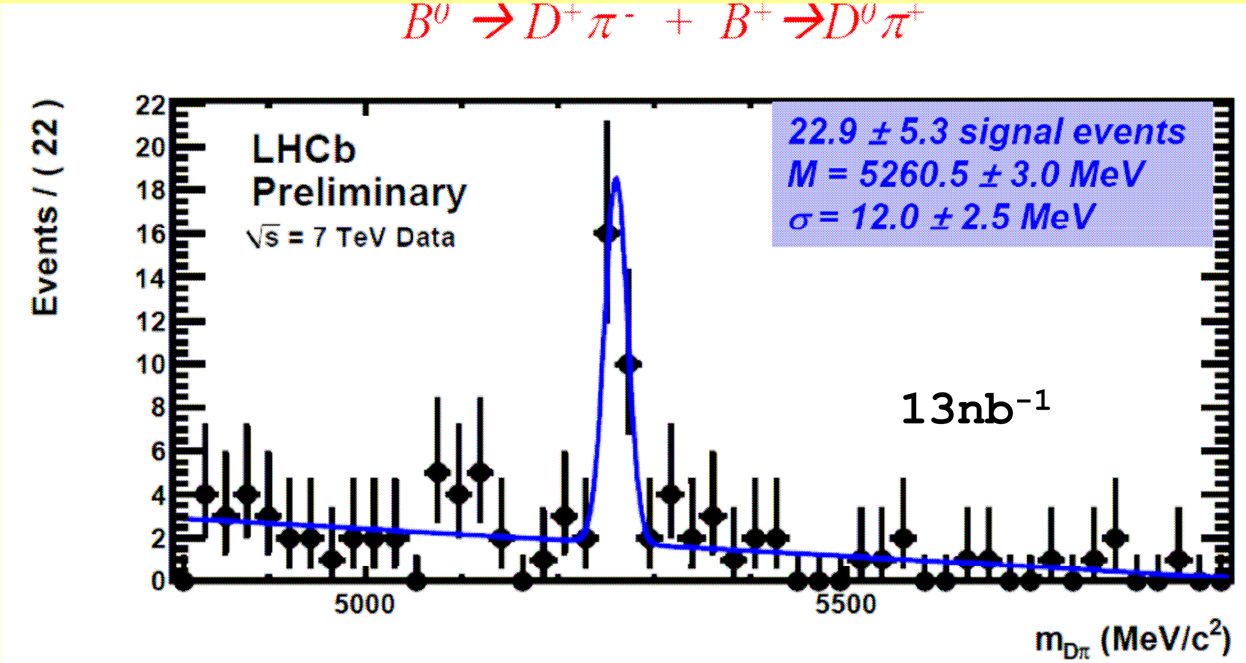
Fully reconstructed B → J/ψ K⁺



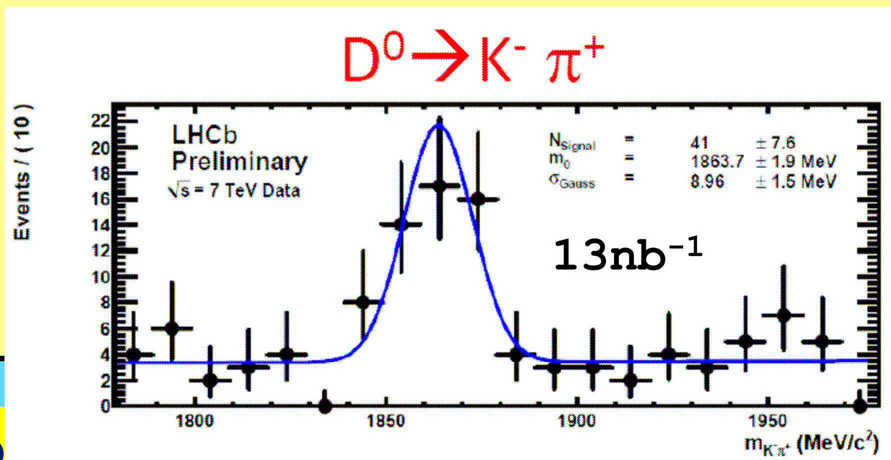
First hadronic B decay
$B^- \rightarrow D^0(\pi^+K^-)\pi^-$

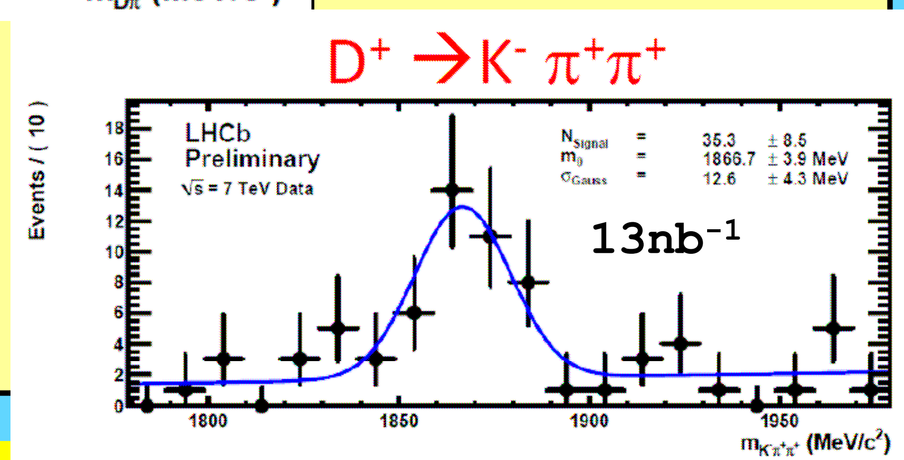


First fully reconstructed B-mesons



Calibration of mass scale and B-field is ongoing



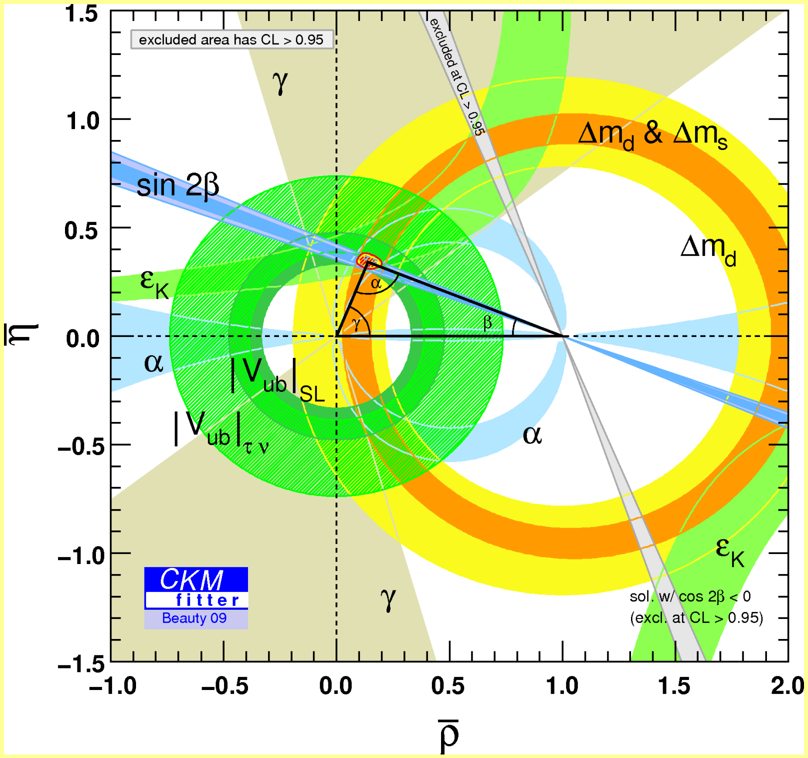


The ckm angle γ

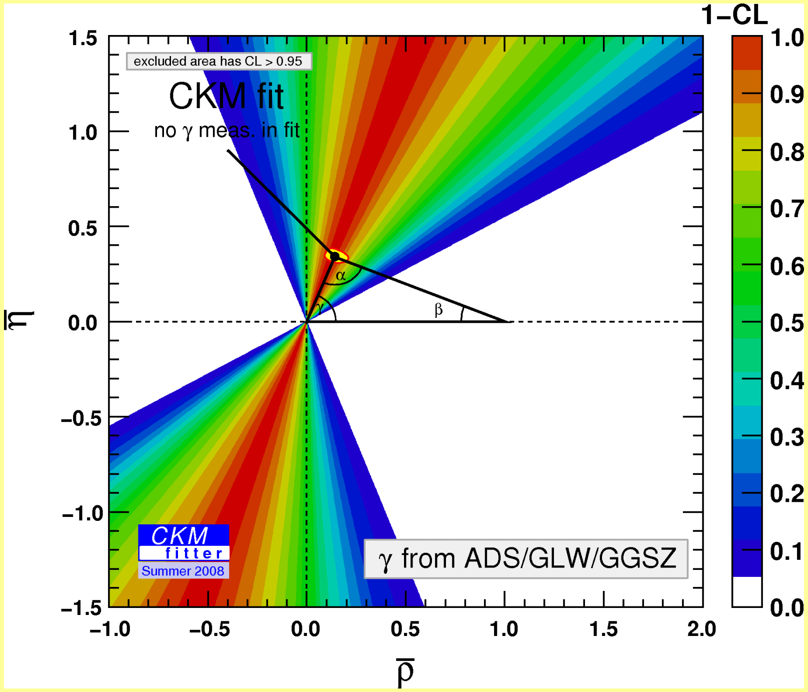
Crucial to constrain the Unitarity Triangle !

Measurements from Babar and Belle

CKM Fitter $\gamma = 73^{+22}_{-25}$



Constraints from γ compared to the prediction from the global CKM fit



The ckm angle γ

Measurement following several different approaches

Tree level decays

→ Direct CP violation

B → DK with ADS/GLW method

M. Gronau and D. London, Phys Lett B253, 483 (1991); M. Gronau and D Wyler Phys. Lett. B 265, 172 (1991).
D. Atwood, I. Dunietz and A. Soni, Phys Rev. Lett. 78, 3257 (1997)

B → DK with GGSZ method
(Dalitz analysis with $D \rightarrow K_s\pi\pi$)

A.Giri, Y. Grossman, A. Soffer and J. Zupan, Phys. REv. D 68, 054018 (2003).

→ Time dependent measurement

$B_s \rightarrow D_sK$ (using $B_s \rightarrow D_s\pi$)

$B_s \rightarrow D_sK$ with $B \rightarrow D\pi$ using U-spin symmetry

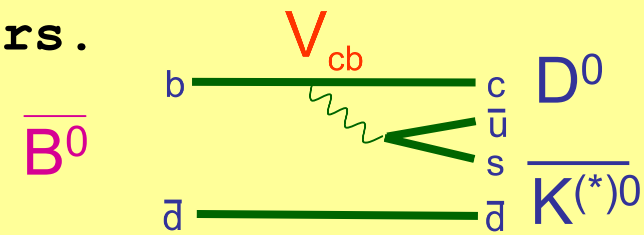
Loop decays

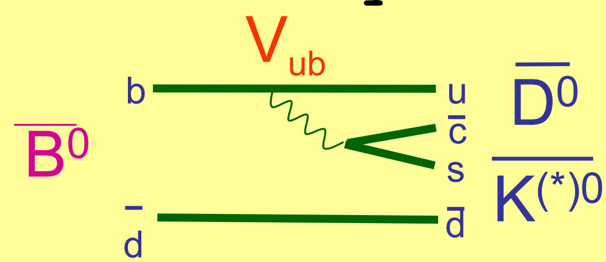
B →hh decays using U-spin symmetry

R. Fleischer, PLB 459 (1999) 306

γ from trees – ADS/GLW

• Combination of color suppressed B decays with Cabibbo favoured D decays increases the sensitivity to CP parameters.





Pro-1.Both diagrams colour-suppressed ⇒ similar magnitude large interference

$$r_B = \frac{A(B \longrightarrow DK^*)}{A(B \longrightarrow \overline{D}K^*)} \approx \frac{1}{\lambda}\frac{|V_{ub}|}{|V_{cb}|} \approx 0.4$$

Pro-2.Modes with $K^{*0} \rightarrow K^+\pi^-$ are self-tagging: sign of kaon charge distinguishes B^0 from anti-B^0

Con: Branching fractions involved all rather small

γ from trees – ADS/GLW

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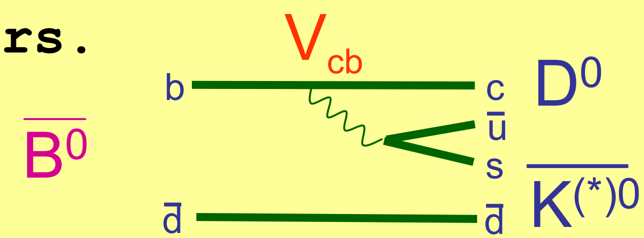
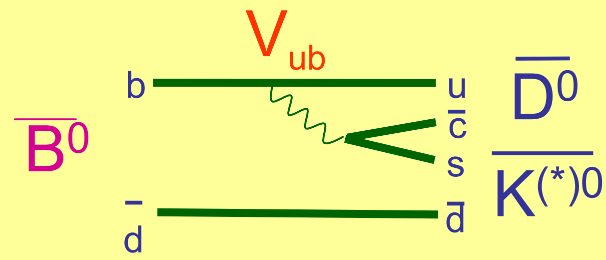




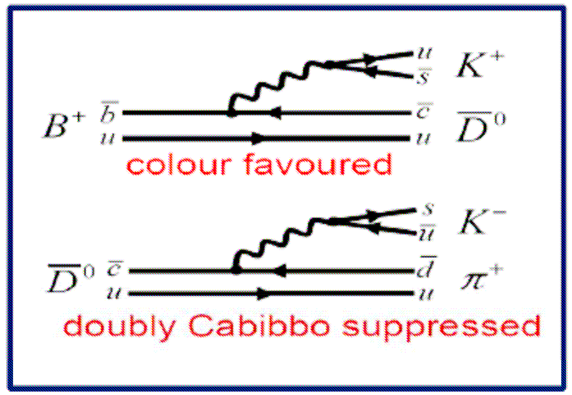
$$
\begin{aligned}
N(B^0 \to D(K^+\pi^-)K^{*0}) &= N_{K\pi}[1 + r_{B^0}^2 r_D^2 + 2r_{B^0} r_D \cos(\delta_{B^0} + \delta_D + \gamma)], \\
N(B^0 \to D(K^-\pi^+)K^{*0}) &= N_{K\pi}[r_{B^0}^2 + r_D^2 + 2r_{B^0} r_D \cos(\delta_{B^0} - \delta_D + \gamma)], \\
N(\overline{B^0} \to D(K^-\pi^+)\overline{K^{*0}}) &= N_{K\pi}[1 + r_{B^0}^2 r_D^2 + 2r_{B^0} r_D \cos(\delta_{B^0} + \delta_D - \gamma)], \\
N(\overline{B^0} \to D(K^+\pi^-)\overline{K^{*0}}) &= N_{K\pi}[r_{B^0}^2 + r_D^2 + 2r_{B^0} r_D \cos(\delta_{B^0} - \delta_D - \gamma)], \\
N(B^0 \to D_{CP}K^{*0}) &= N_{CP}[1 + r_{B^0}^2 + 2r_{B^0} \cos(\delta_{B^0} + \gamma)], \text{ and} \\
N(\overline{B^0} \to D_{CP}\overline{K^{*0}}) &= N_{CP}[1 + r_{B^0}^2 + 2r_{B^0} \cos(\delta_{B^0} - \gamma)],
\end{aligned}
$$

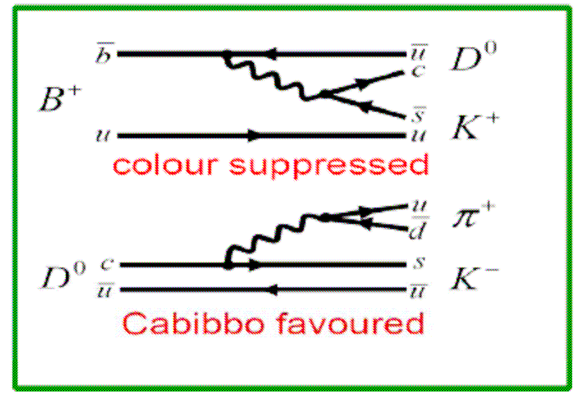
— What we measure

— Unknown

γ from trees – ADS/GLW

- Combination of color suppressed B decays with Cabibbo favoured D decays increases the sensitivity to CP parameters.





Mode	MC Yield: 14TeV, $2fb^{-1}$	MC B/S
$B^{\pm} \rightarrow D(K\pi)K^{\pm}$	84k	0.6
$B^{\pm} \rightarrow D_{sup}(K\pi)K^{\pm}$	1.6k	0.6
$B^{\pm} \rightarrow D(K\pi\pi\pi)K^{\pm}$	53k	0.2
$B^{\pm} \rightarrow D_{sup}(K\pi\pi\pi)K^{\pm}$	0.55k	3.1
$B^{\pm} \rightarrow D(hh)K^{\pm}$	11.4k	1.4
$B^{0} \rightarrow D(K\pi)K^{*}$	3.2k	0.25
$B^{0} \rightarrow D_{sup}(K\pi)K^{*}$	0.3k	< 10
$B^{0} \rightarrow D(hh)K^{*}$	0.4k	< 8

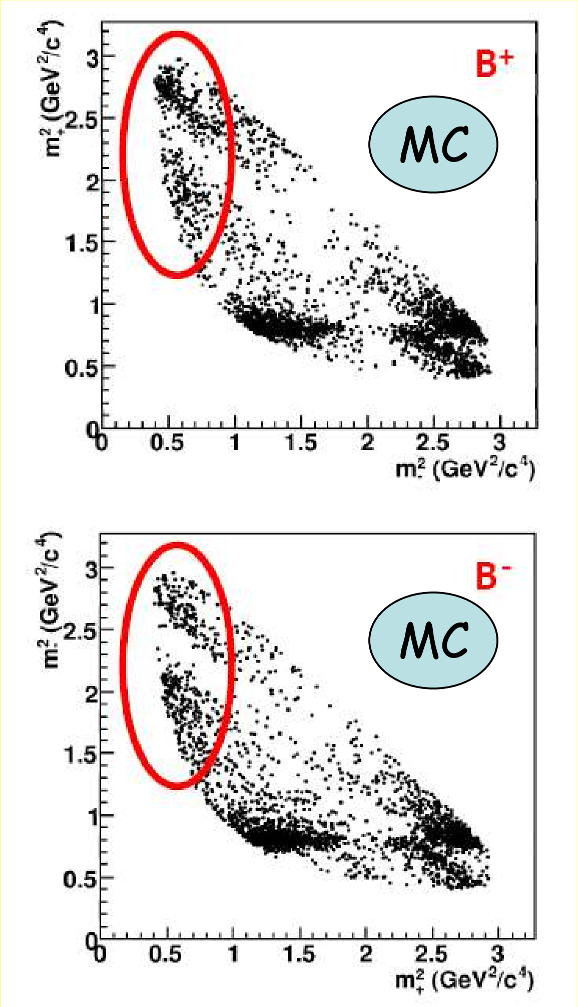
γ from trees – GGSZ

Sensitivity to γ from differences in Dalitz plot for B^+ and B^- decays

- Two approaches to the Dalitz analysis

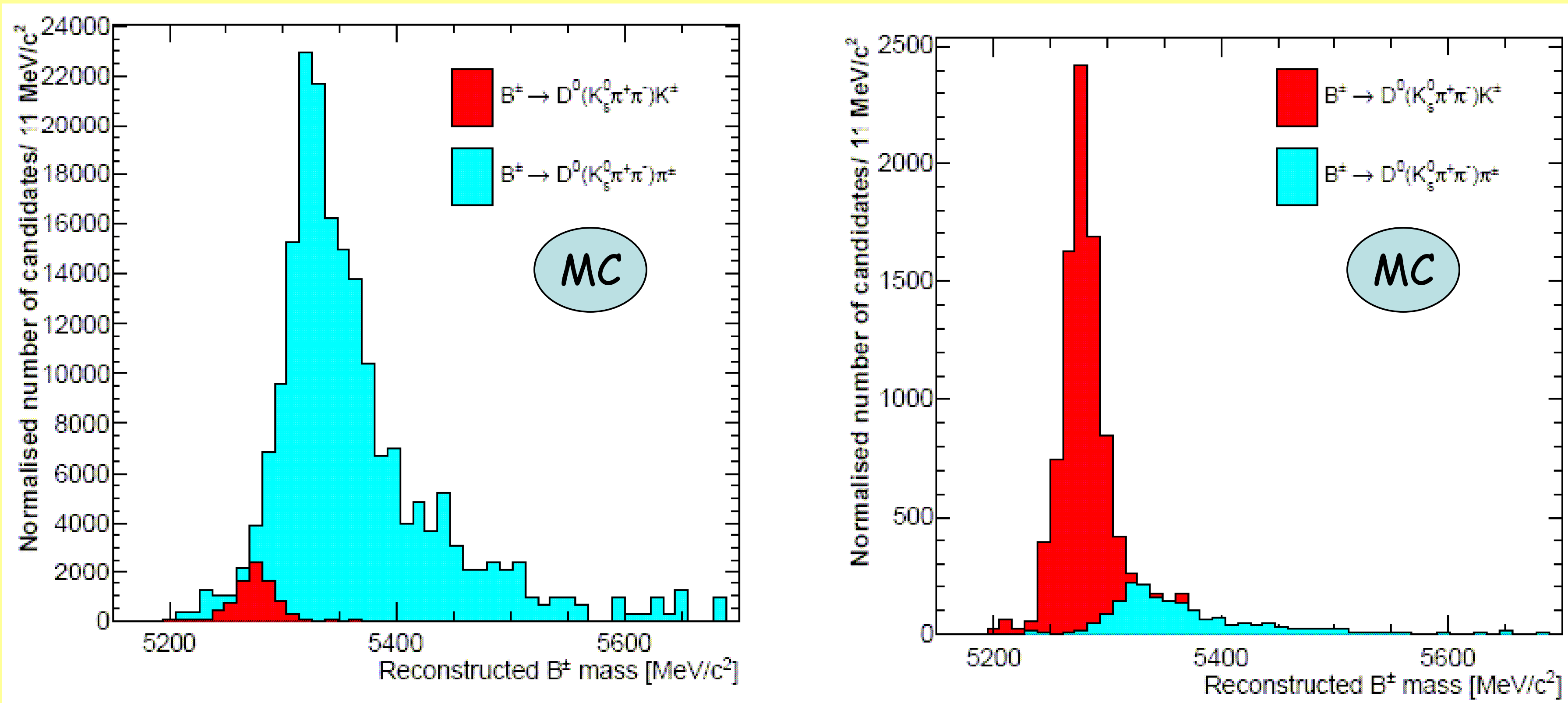
  → Unbinned fit using a model for the Dalitz plane. This approach makes full use of the statistics but incurs a systematic uncertainty of between 6° and 15° due to the model assumptions

  → A binned model-independent fit which relies on input from CLEO-c data. Model error replaced by uncertainty on strong phase parameters: 2°. Not full use of the statistics available



γ from trees – GGSZ

Crucial role of PID in this analysis

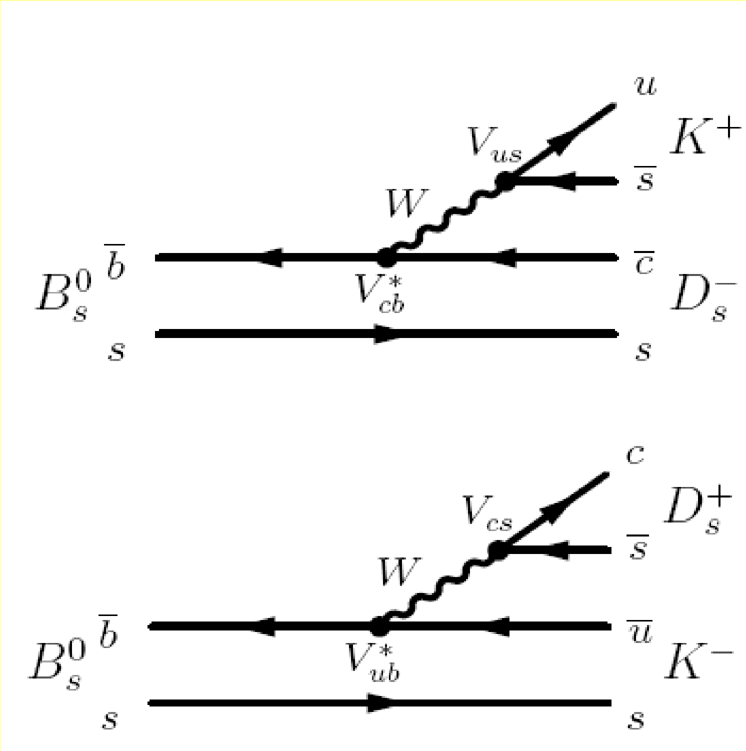


$B^{\pm} \to D(K_s\pi\pi)K^{\pm}$: MC Yield: 6800 at 14TeV in $2fb^{-1}$

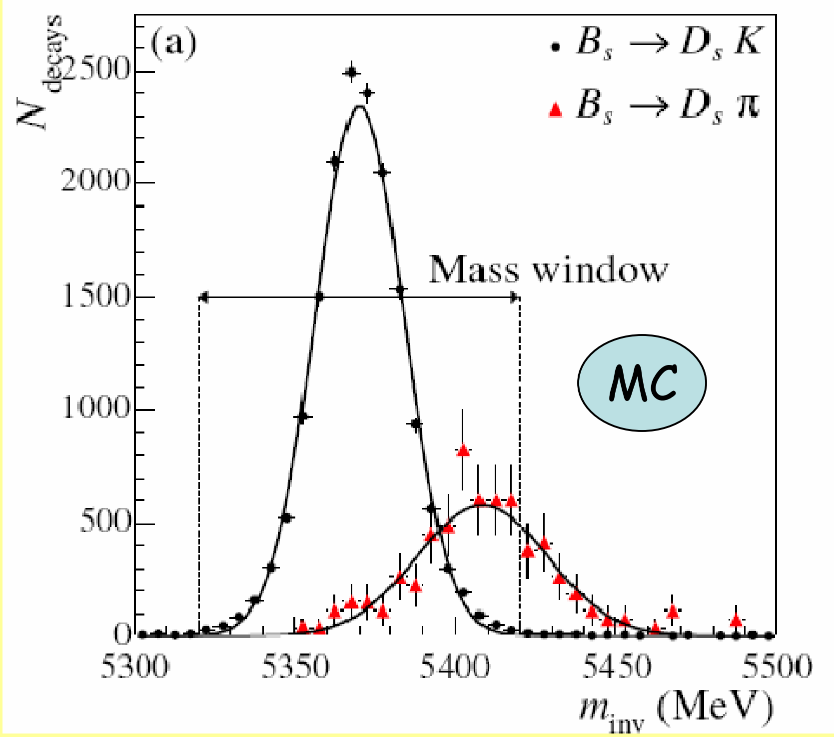
B/S < 1.1 @90% C.L.

γ from trees
Time dependent CPV

- Extraction of γ from interference in mixing and decay of $B_s \to D_s K$



Crucial role of PID



Simultaneous fit to $B_s \to D_s \pi$ allows extraction of Δm_s and $\Delta\Gamma_s$

Signal yield 14k
B/S < 0.45 @ 90% C.L.

γ from trees – Summary

- Fit to obtain the best sensitivity to γ including all previous methods

Statistical sensitivity to γ

→ 4-5° with 2 fb^{-1}

→ 8-10° with 0.5 fb^{-1}

Conclusions

- LHCb is performing in an excellent way
- Fantastic agreement between MC and Real data so far
- First B-peak is observed
- Looking forward collecting more data
- Hopefully on the 2010/2011 run we'll have $1\ fb^{-1}$ of data
- Most of the LHCb physics program can be done with that statistics
- A "New-physics free" and theoretically clean measurement of γ can be done with a statistical precision of 5-7°

Thank you

- I would like to thank the organizers for having dedicated this workshop to the memory of my father

backup

γ from trees – ADS/GLW

Mode	Yield	B/S
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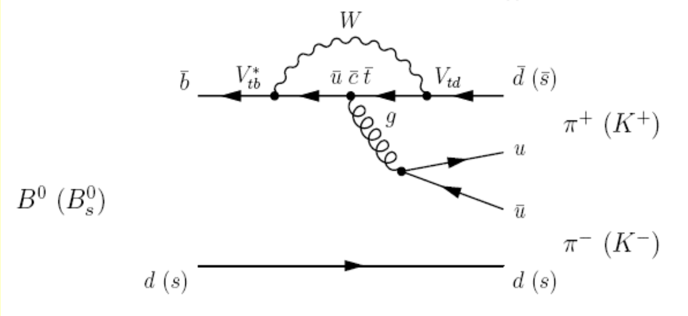
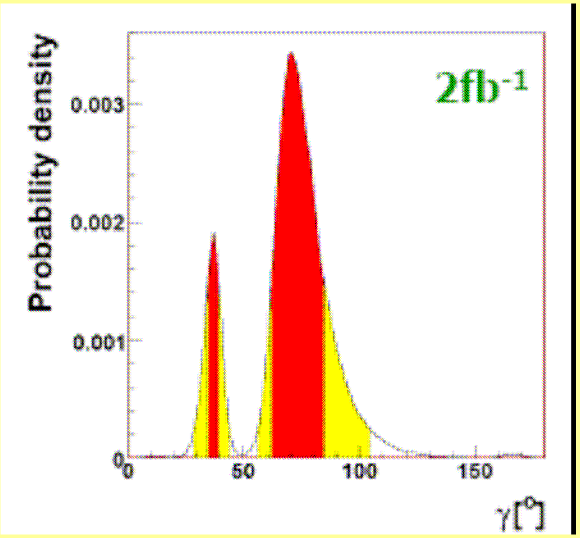
γ from loops

- Sensitivity to γ from time dependent CP asymmetries in B→hh

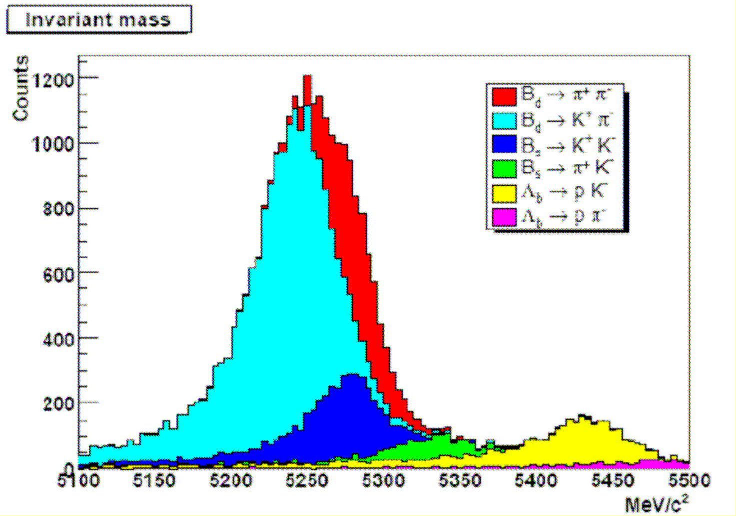


Loop diagrams sensitive to NP

Measurement of γ in loops could differ from γ in tree diagrams



PID and mass resolution crucial for the analysis



Use U-spin symmetry to constrain the problem and extract γ