LHCb Detector & performance

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ON BEHALF OF THE LHCb COLLABORATION

Beauty 2011 Conference

4-8th April 2011

Amsterdam

LHCb

Outline

- Introductory remarks
- The LHCb detector and running conditions
- The detector operating performance
- A taste of the physics
  (focussing somewhat on non-B physics)
- 2011 running
- Summary

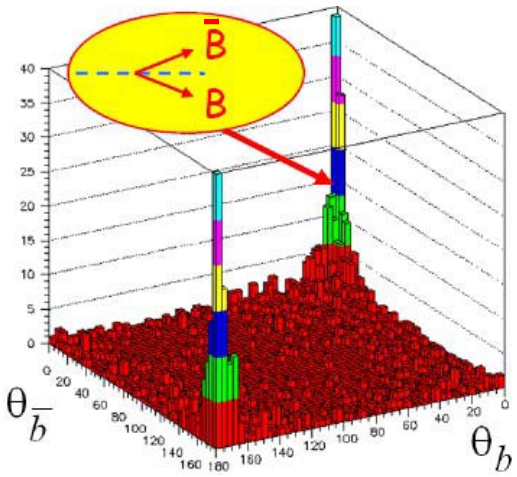
Note – I will only skim the surface – the detailed physics will be left to the many individual talks at this conference

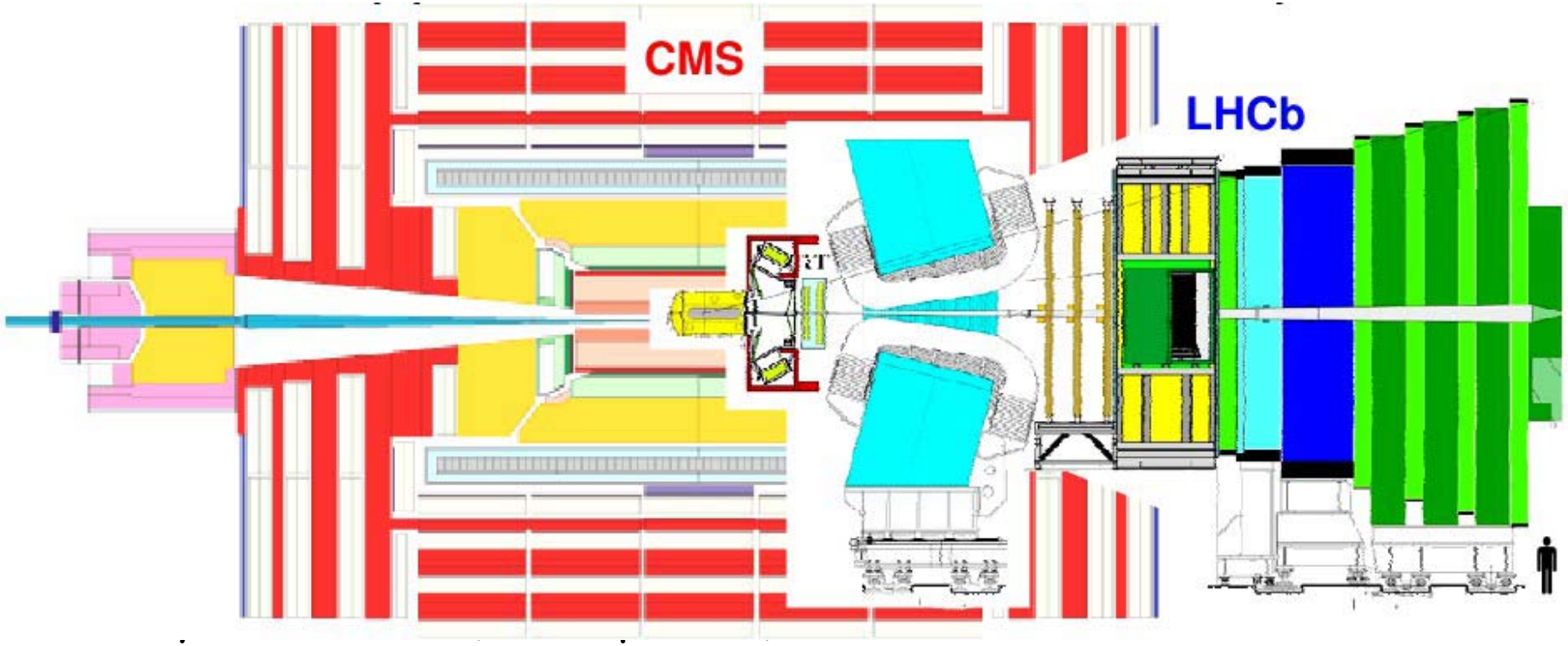
14 LHCb talks at Beauty 2011

- **MONDAY**
  - 10:10 LHCb detector performance: Neville HARNEW (University of Oxford)
  - 15:05 Flavour tagging and mixing at LHCb : Stefania VECCHI (INFN, Universita di Ferrara)
  - 15:55 Bs -> J/psi phi : Uli UWER (Physikalisches Institut Heidelberg)
- **TUESDAY**
  - 09:00 Bs -> mumu, B -> K*mumu & B -> s gamma : Matteo PALUTAN (Frascati (LNF)
  - 12:10 Charm mixing/CP violation and plans : Marco GERSABECK (CERN)
  - 16:55 b production cross section and fragmentation fractions at LHCb : Niels TUNING (NIKHEF)
  - 17:20 Charm production at LHCb : Alexandr KOZLINSKIY (NIKHEF)
- **WEDNESDAY**
  - 09:30 Upsilon production, Psi(2S), X states, chi-c at LHCb : Julien COGAN (CPPM)
  - 10:00 J/Psi cross section (incl. B->J/Psi X), J/Psi polarization : Jibo HE (LAL - Universite de Paris)
- **THURSDAY**
  - 09:25 Semileptonic decays (beauty/charm) & plans : Rob LAMBERT (CERN)
  - 12:00 First measurement of sin2beta at LHCb with B0-> J/psi Ks, Marc GRABALOSA GANDARA (Barcelona)
  - 12:15 Bs -> DsK and D K states : Steven BLUSK. (Department of Physics - Syracuse University)
  - 14:20 B -> hh (hadronic final states) : Vincenzo VAGNONI (INFN Bologna)
- **FRIDAY**
  - 12:05 LHCb Upgrade : Marcel MERK (NIKHEF)

LHCb – a forward physics experiment

- LHCb covers forward region: $1.9 < \eta < 4.9$: a unique rapidity range
- LHCb is optimized for the strongly forward peaked heavy quark production at the LHC
- It covers only ~4% of solid angle but captures ~40% of heavy-quark production cross section





A chequered history …

- Forward physics experiments at hadron colliders has historically been challenging
  - ISR first paved the way
  - SPS and Tevatron focussed on the "central" region
  - H1/ZEUS – found the forward region "difficult"
  - HERA-B was beset with problems
- So would LHCb actually be able to deliver physics ?
  - Trigger is a monumental challenge
  - Occupancies
  - Secondary interactions
  - Radiation damage ... etc etc ...
- We at LHCb (+ the CERN LHCC + our funding agencies) thankfully had confidence, but it was always going to be difficult …

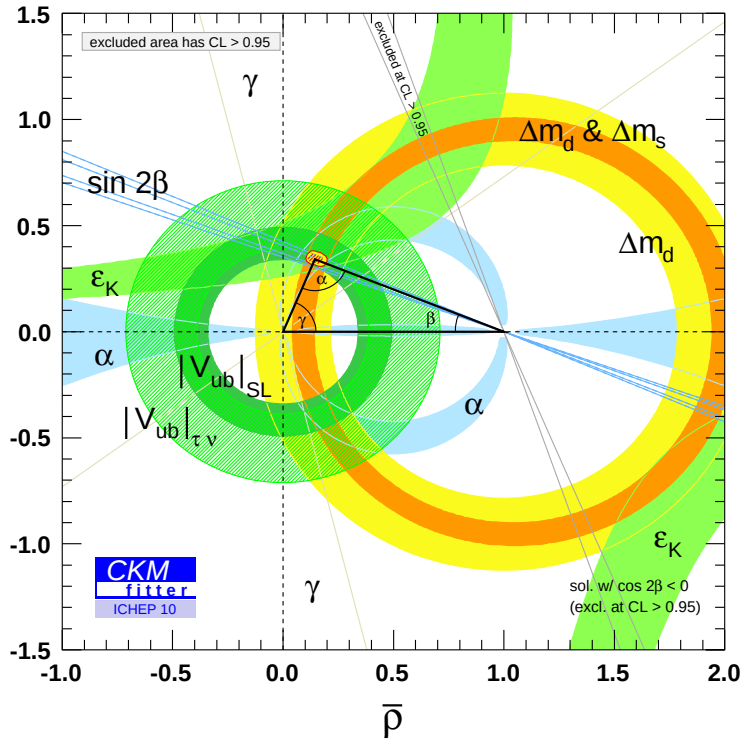
LHCb major physics aims – the "big six"

LHCb roadmap document: [arXiv:0912.4179v2 [hep-ex]]

- Tree and penguin-level determinations of CKM angle γ
- Charmless charged two-body B decays
- B_s mixing phase φ_s from $B_s \rightarrow J/\psi\phi$
- Branching fraction of $B_s \rightarrow \mu^+\mu^-$
- Angular distributions in $B^0 \rightarrow K^*\mu^+\mu^-$
- $B_s \rightarrow \phi\gamma$ and other radiative decays

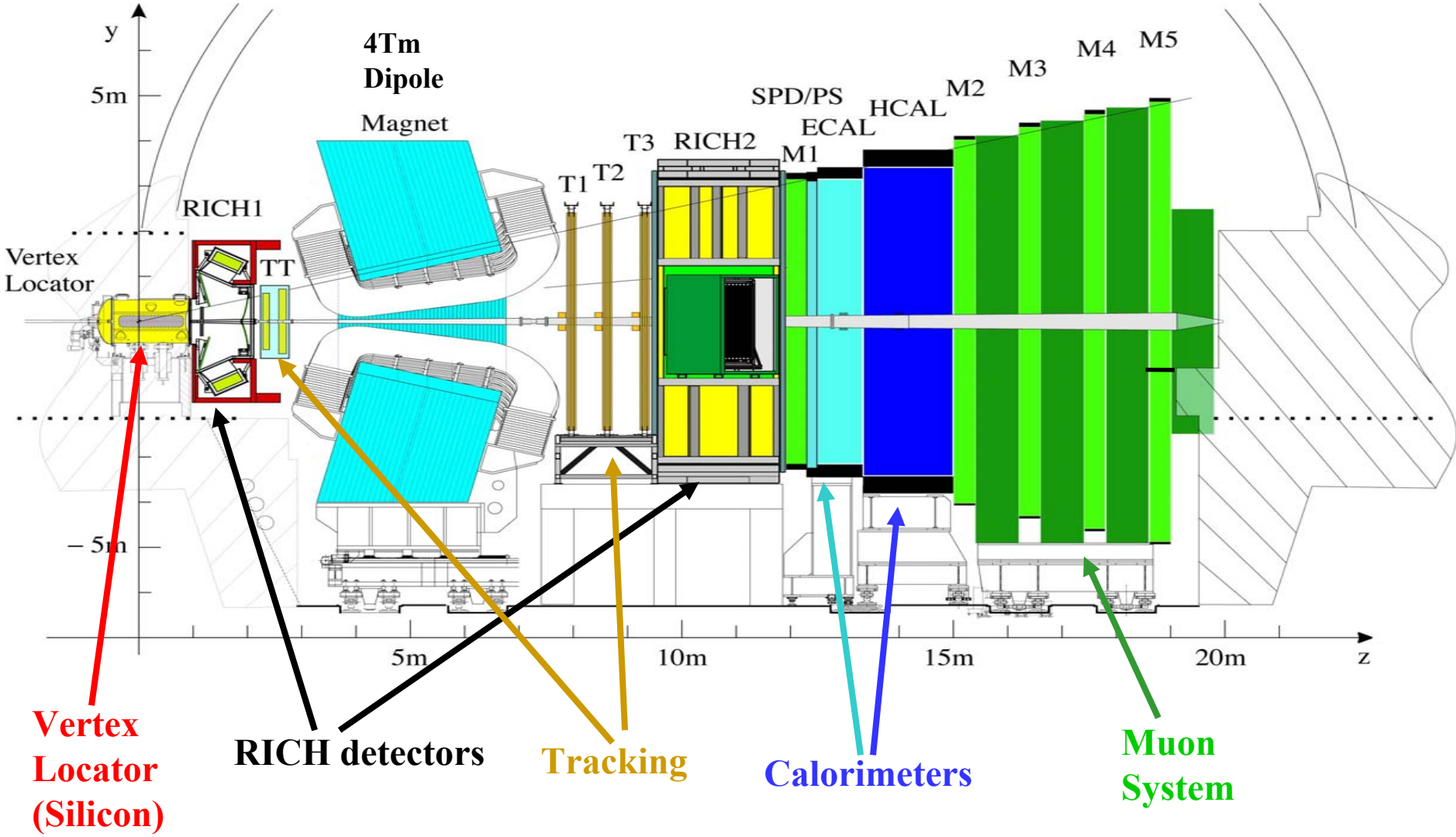
AND A WHOLE LOT MORE !!!

- LHCb IS A PRECISION EXPERIMENT DESIGNED TO MEASURE CKM PARAMETERS - BUT *PRIMARILY* TO DISCOVER PHYSICS BEYOND THE STANDARD MODEL

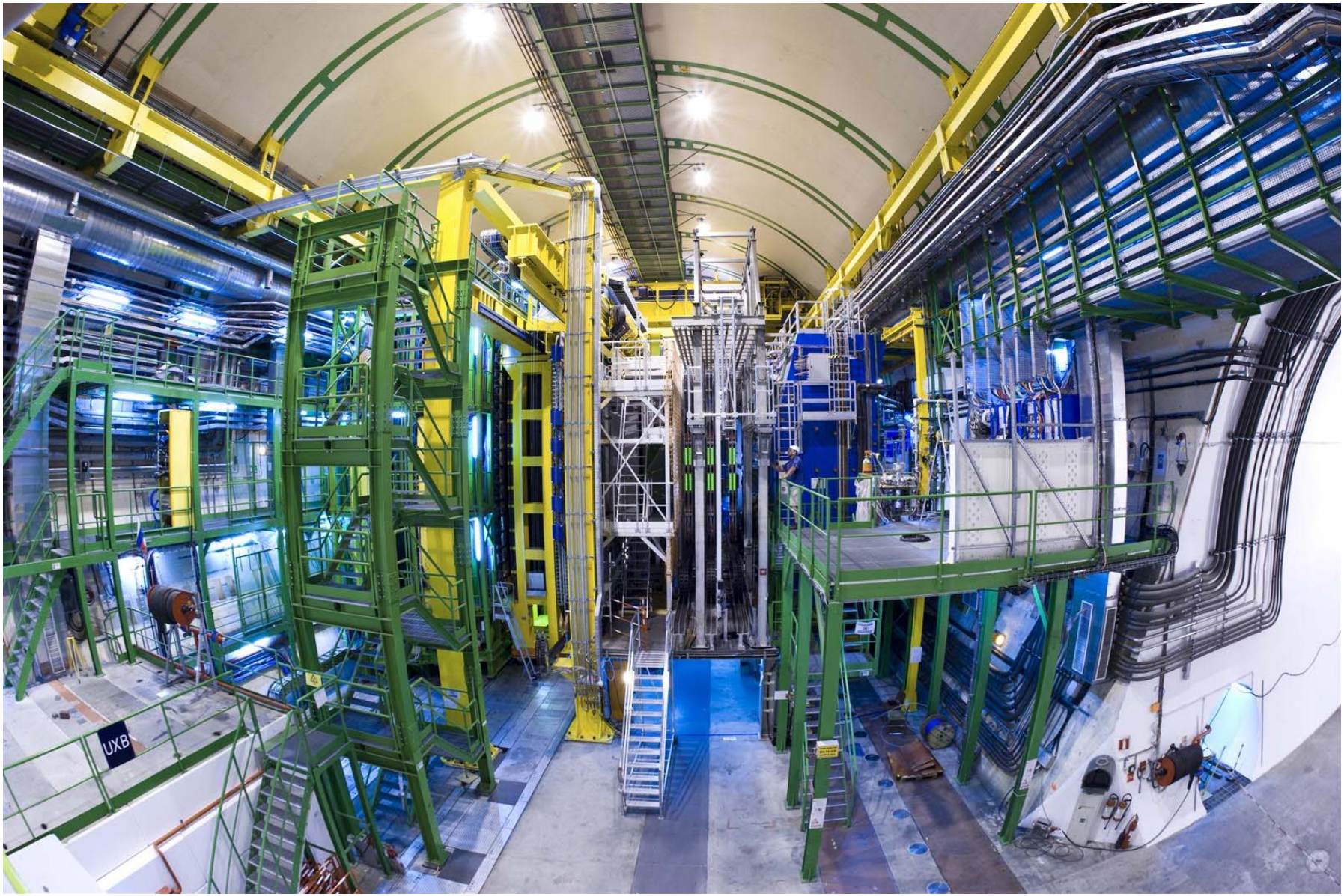


The LHCb detector and 2010 running conditions

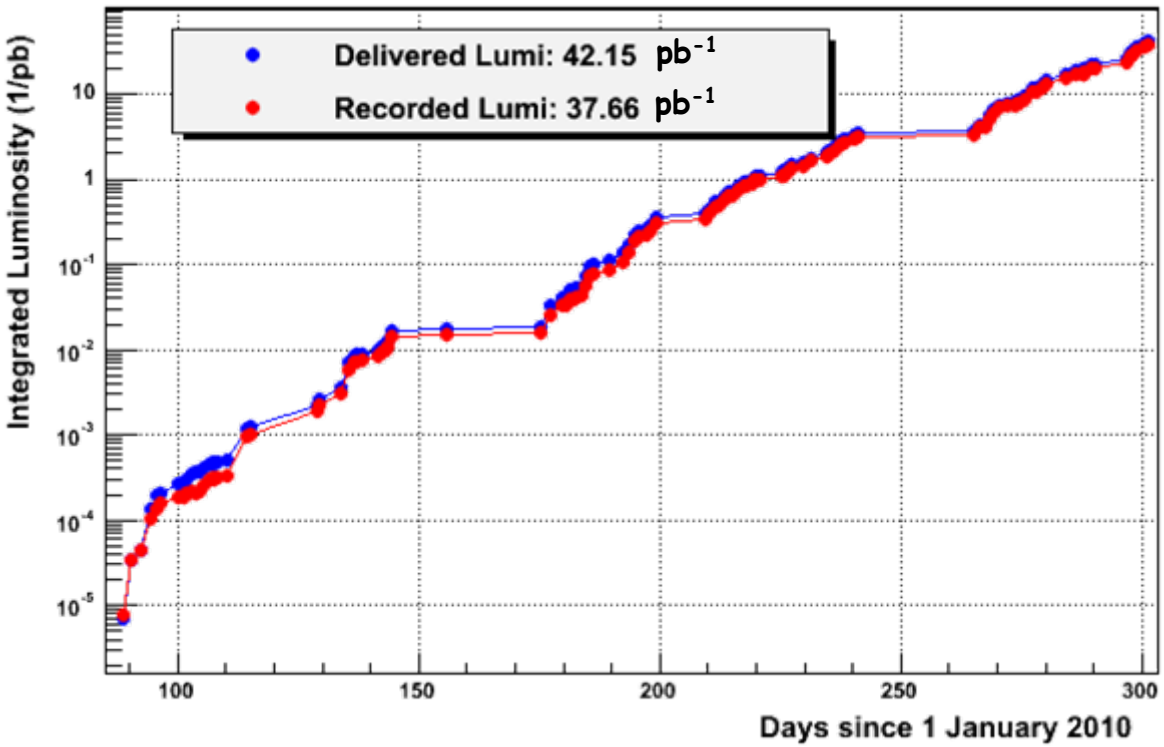
The LHCb spectrometer



A fish-eye view



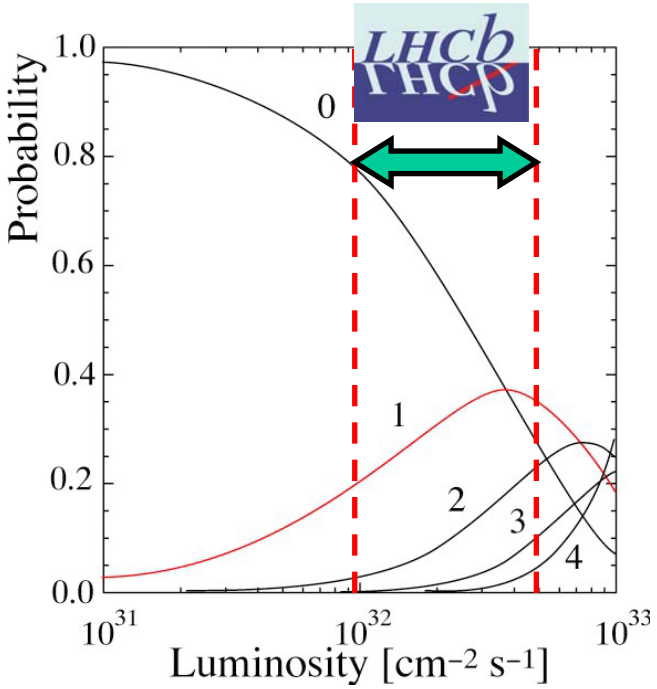
2010 Integrated Luminosity @ 2x3.5 TeV



… Note that it's a logarithmic scale …

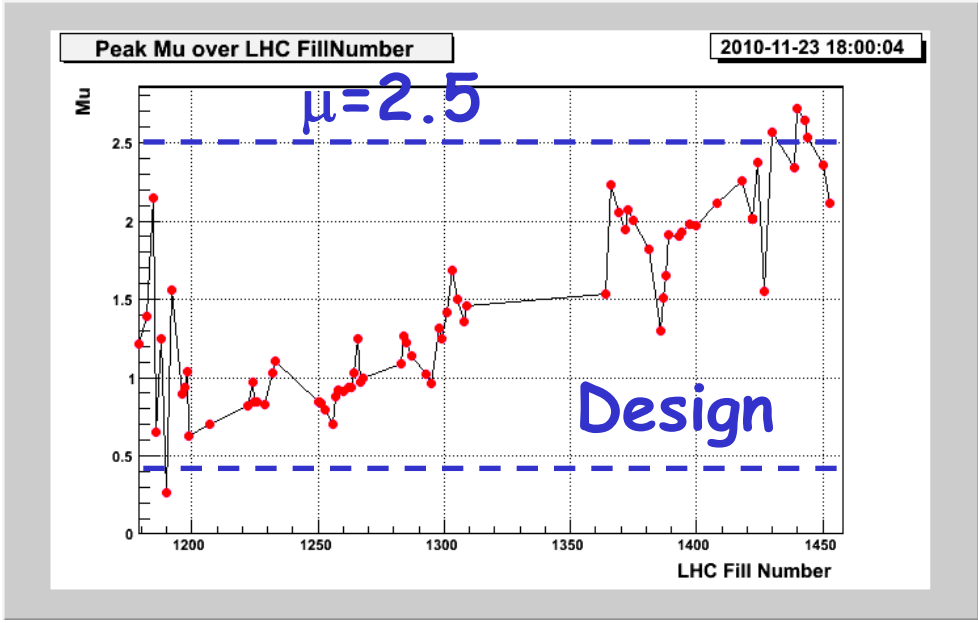
- Recorded 37.7 pb^{-1} at $\sqrt{s}$ = 7 TeV
- Data taking efficiency > 90%

It has not always been easy ...



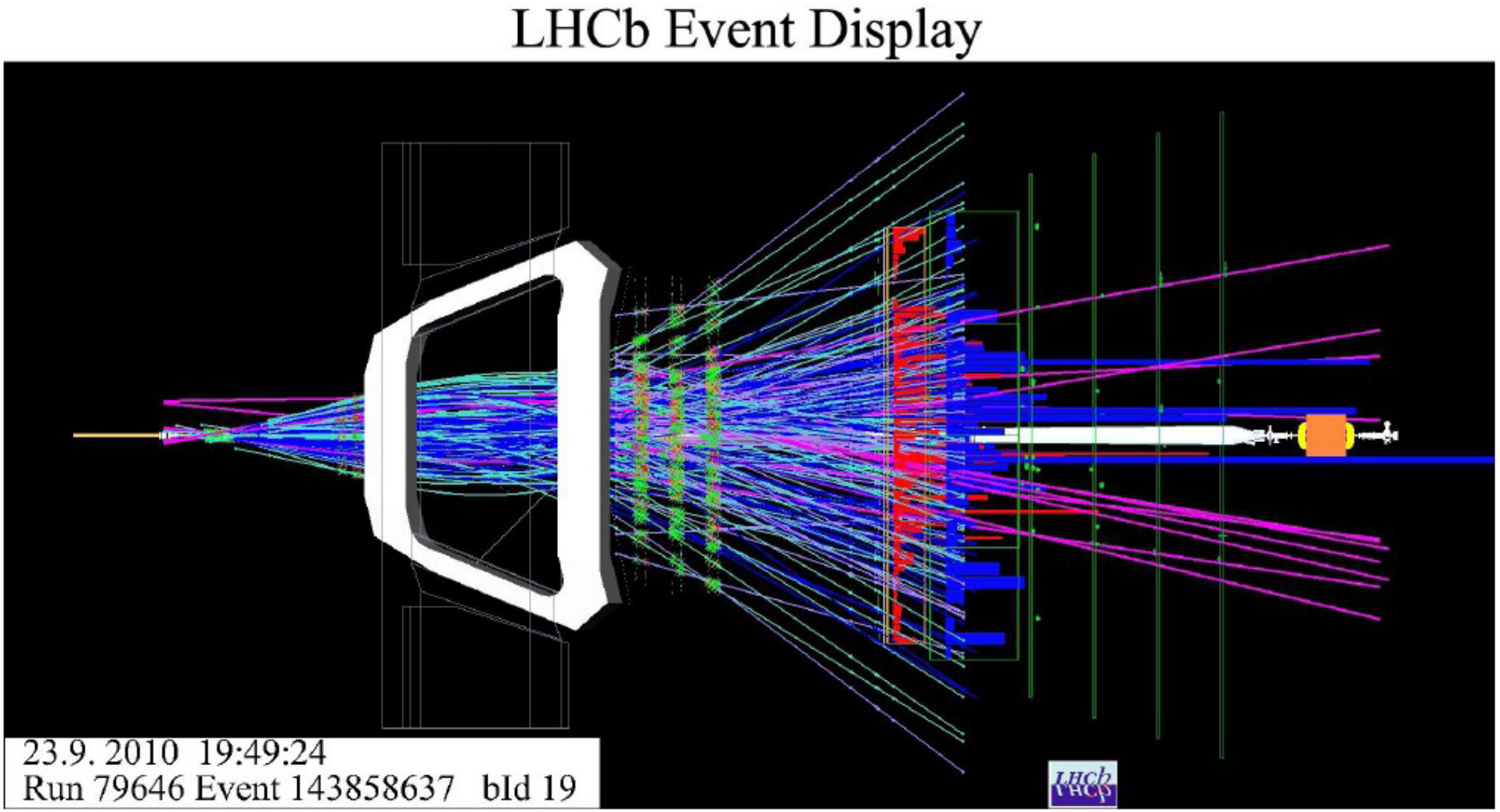
- LHCb designed for a single interaction per bunch crossing at luminosity of 2×10^{32} cm^{-2} s^{-1}
- Design: $\langle\mu\rangle$=0.4 interactions per crossing

What we had to learn to cope with …

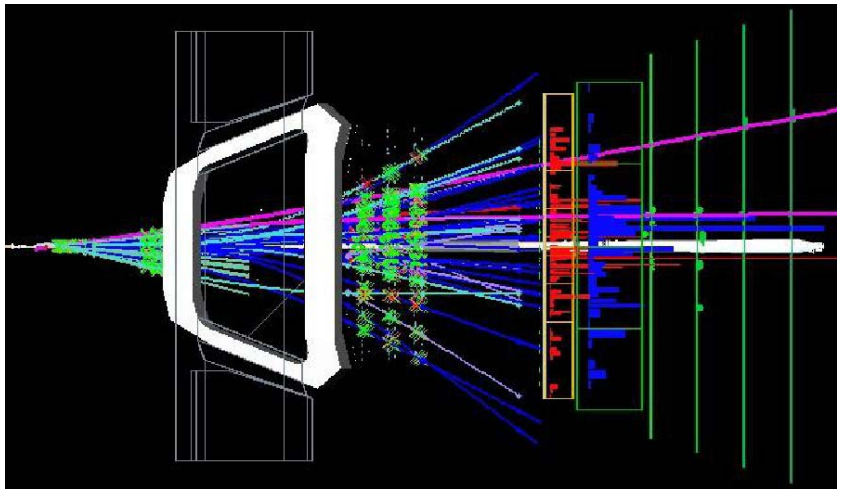


- Peak instantaneous luminosity almost 2×10^{32} cm^{-2}s^{-1} at end of run
- But: with only 344 colliding bunches (factor ~8 unfilled)
- But with all sub-detectors still working at > 99% efficiency.

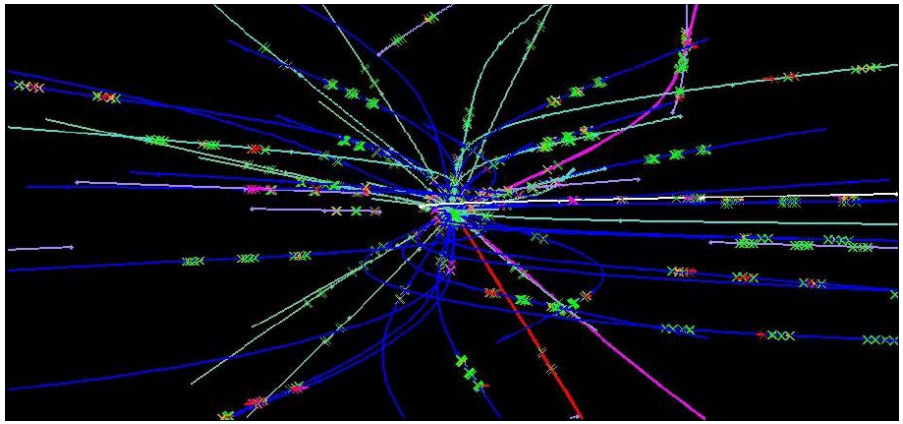
Typical event at <μ> = 2.5 -the challenge

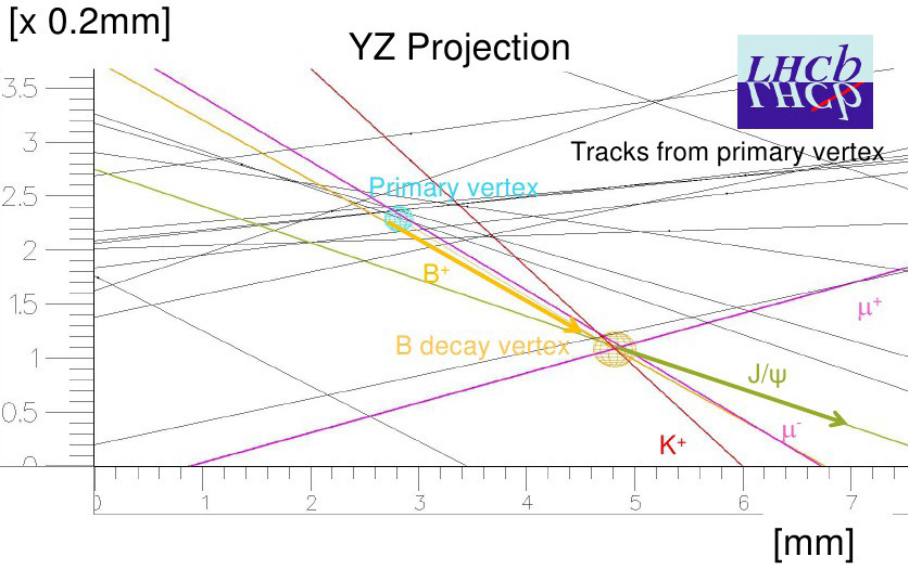


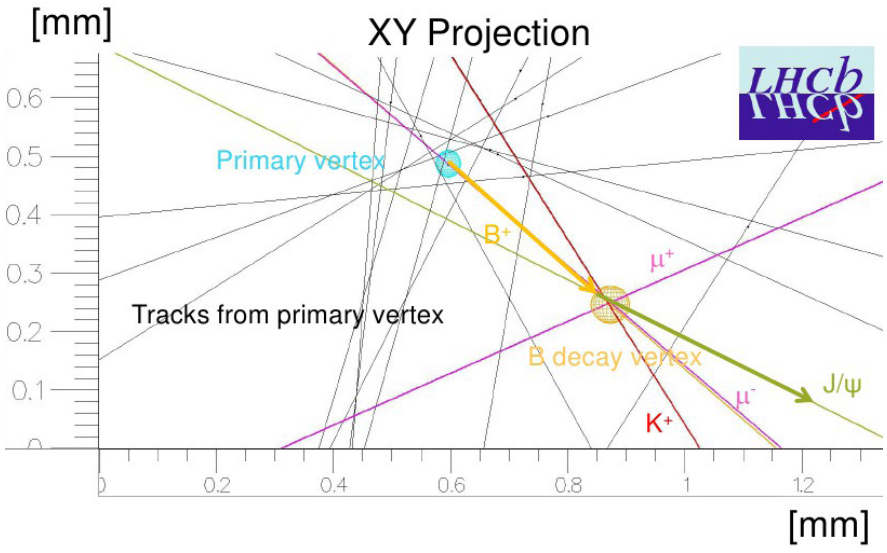
The reality... first $B^+ \rightarrow J/\psi K^+$ candidate



5 April 2010, 01:30:09

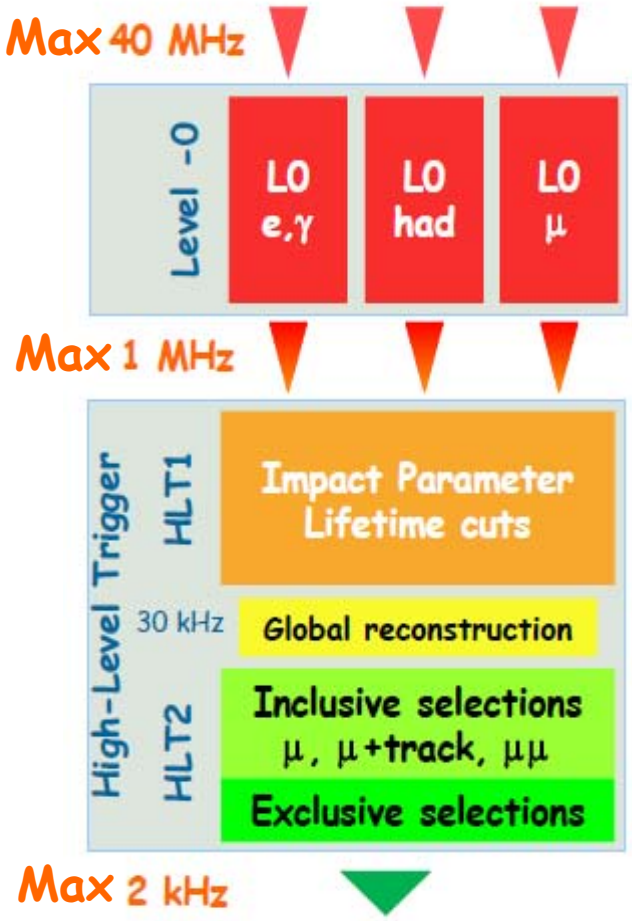






LHCb detector performance

The LHCb trigger



L0: High-pt E & HCAL & muon

Trigger efficiencies L0xHLT1 determined on data using the tag-and-probe methods:		
	Muon trigger (J/ψ)	**Hadron trigger (D^0)**
Data	94.9±0.2%	60±4%
MC	93.3±0.2%	66%

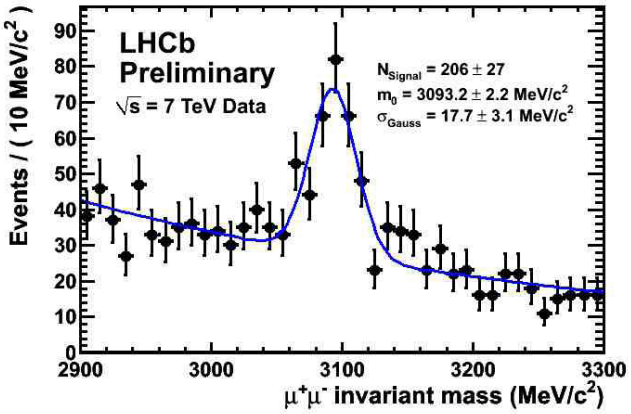
HLT1: Associate L0 signals with tracks, especially those in VELO displaced from PV

HLT2: Full detector information available. Inclusive signatures, exclusive selections in certain key channels.

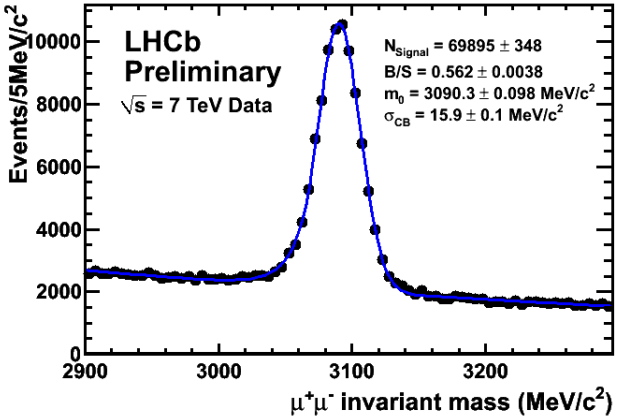
- **To cope with the increased <μ>, the trigger strategy evolved over the course of the run – giving excellent efficiency**

Tracking: Evolution of $J/\psi \rightarrow \mu^+\mu^-$ mass calibration

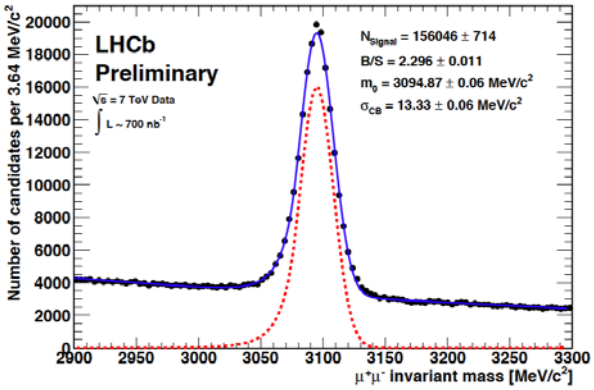
May 2010: 17.1 MeV



July 2010: 15.9 MeV

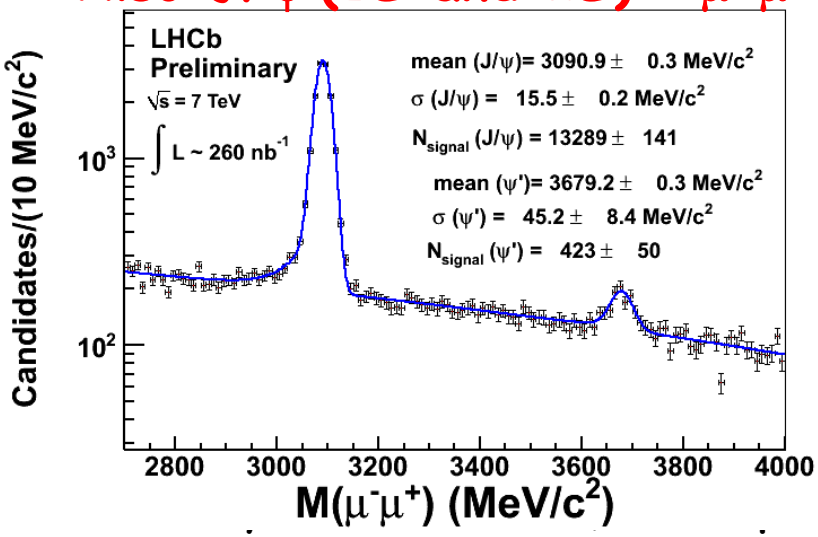


Dec 2010: 13.3 MeV

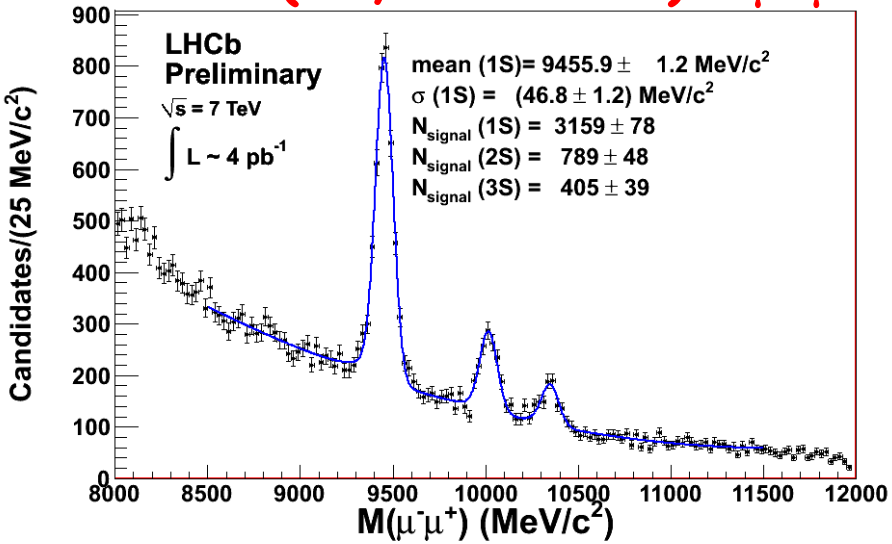


(Detector alignment steadily improves: Monte-Carlo: 12.1 MeV)

Also J/ψ (1S and 2S) $\rightarrow \mu^+\mu^-$

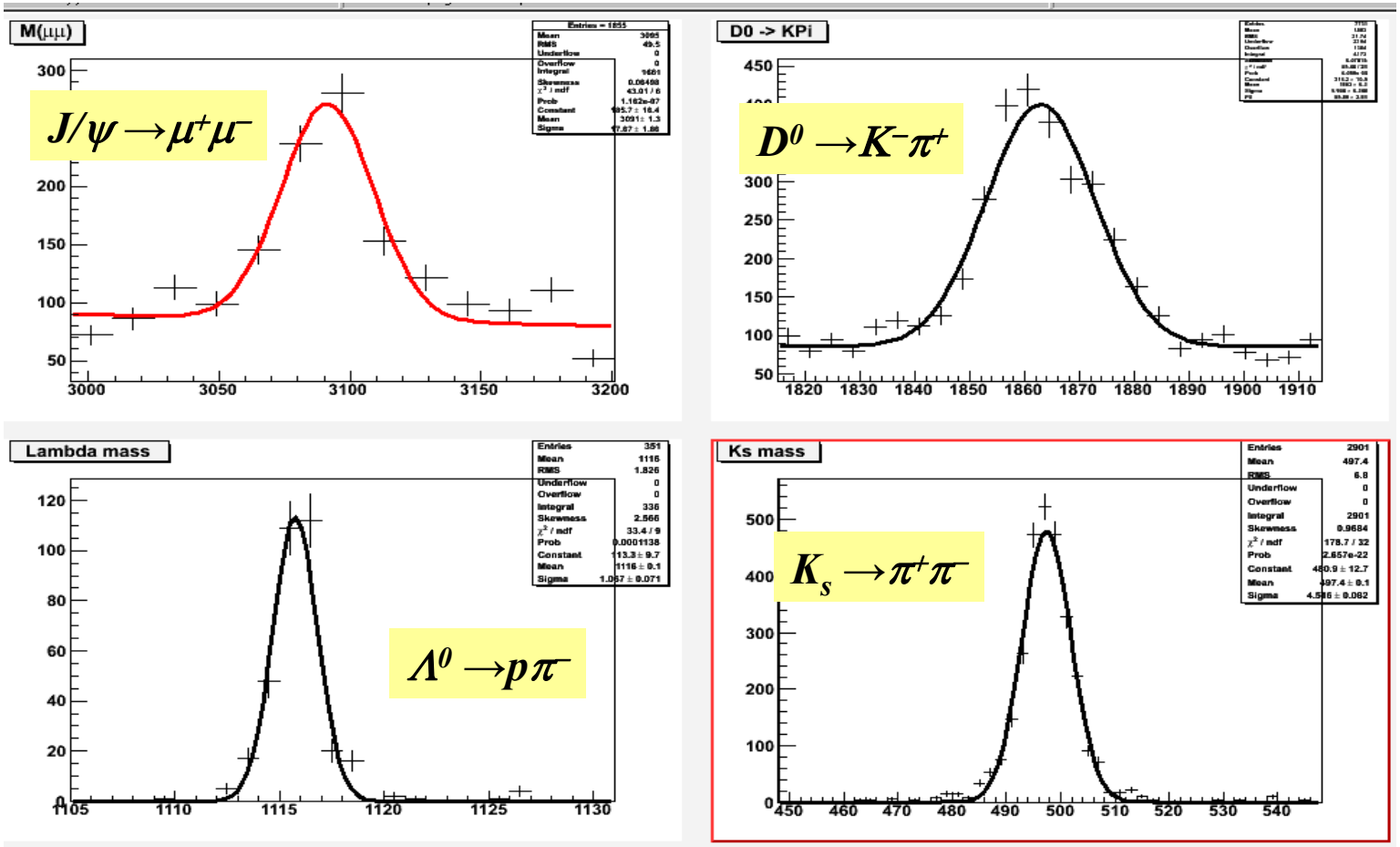


And Υ (1S,2S and 3S) $\rightarrow \mu^+\mu^-$



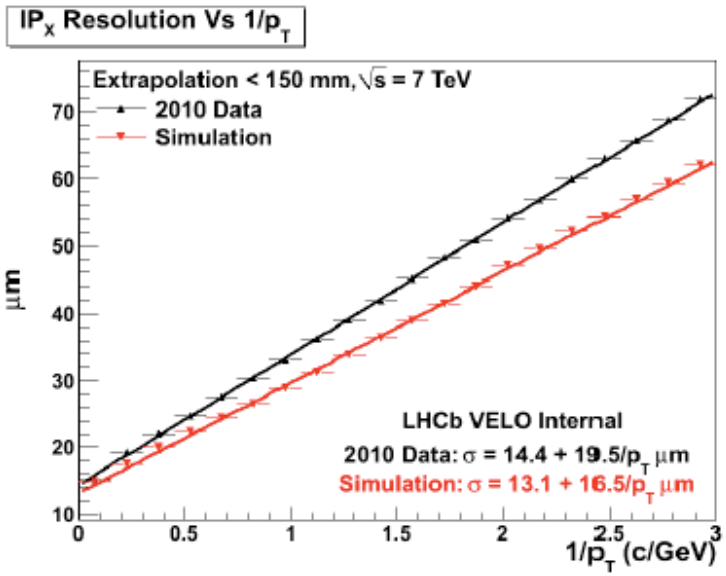
On-shift online real-time plots ….

- 1 hour of data at 7 TeV. A fill of 300nb^{-1}. The HLT2 uses a fast version of reconstruction to make on-line plots.



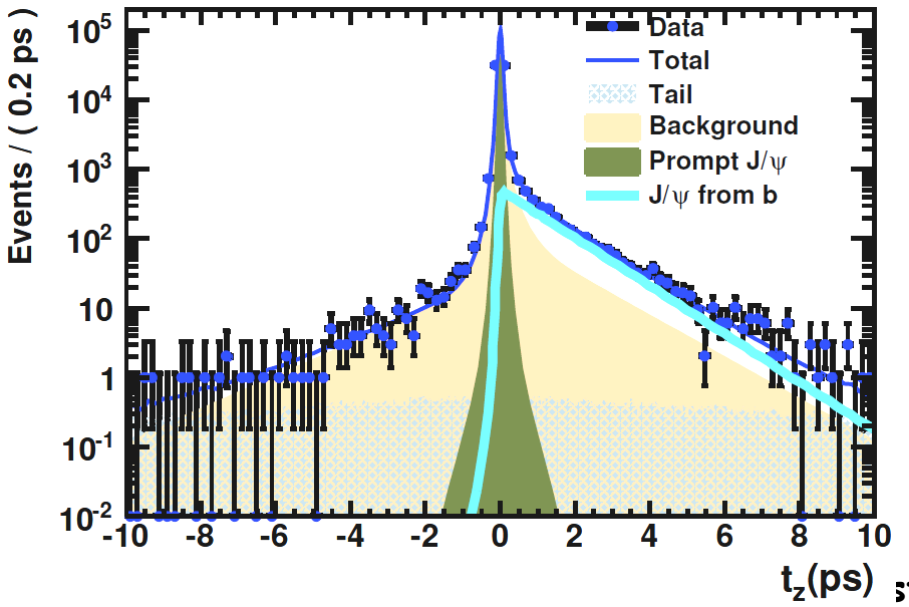
Vertexing (& lifetime) performance

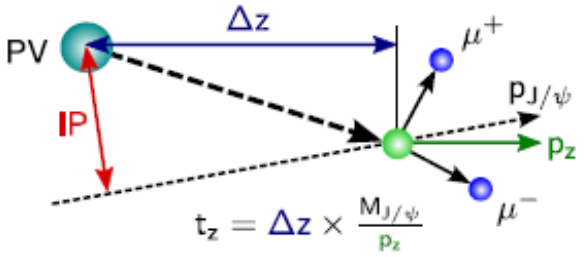
- IP resolution ~15 mm for the highest p_t bins :
  - slope determined by multiple scattering, not an alignment effect
  - understanding is ongoing
  - Proper time resolution ~ 50 fs



LHCb preliminary
L=5 pb^{-1}

$B \to J/\psi X$





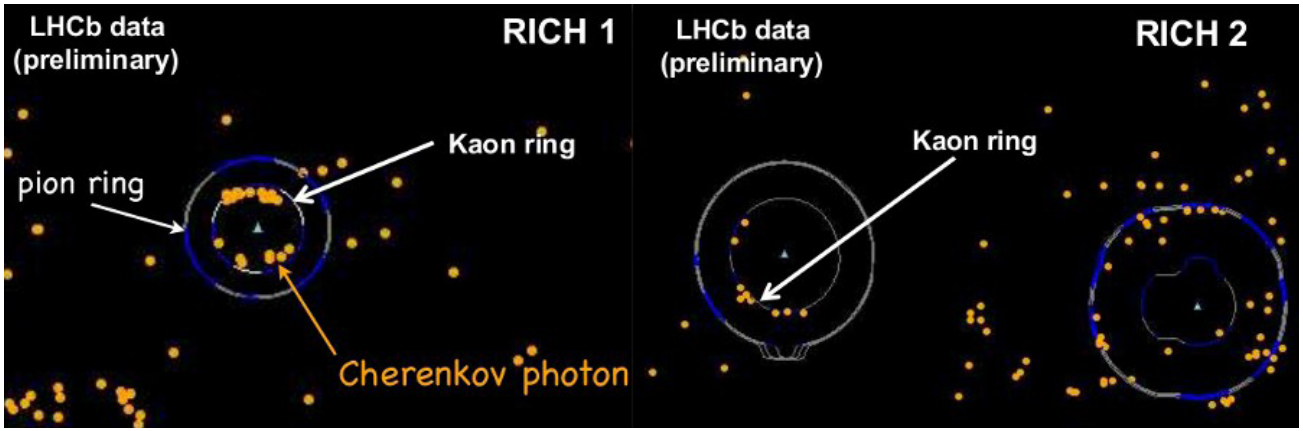
- *Take J/ψ produced in B decays:*
- *Pseudo-time t_z J/ψ from b:*

Particle ID

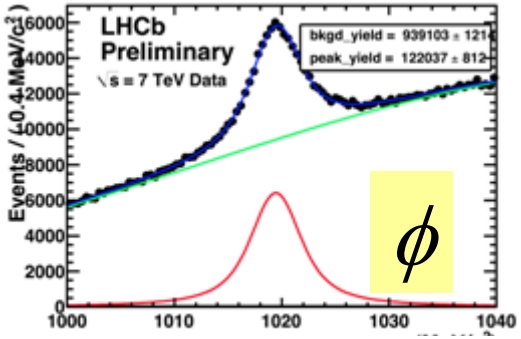
- Crucial for particle ID of B decays with identical topology, e.g. $B^0 \to \pi^+\pi^-$ and $B^0 \to K^+\pi^-$ and for flavour tagging

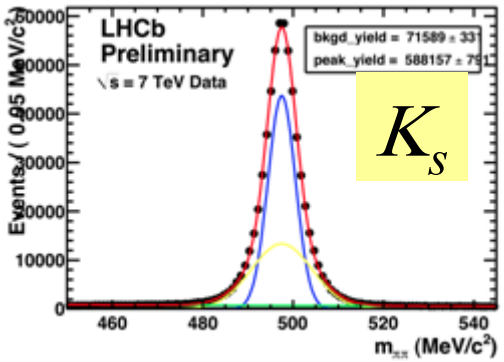
- Two RICH detectors with three radiators

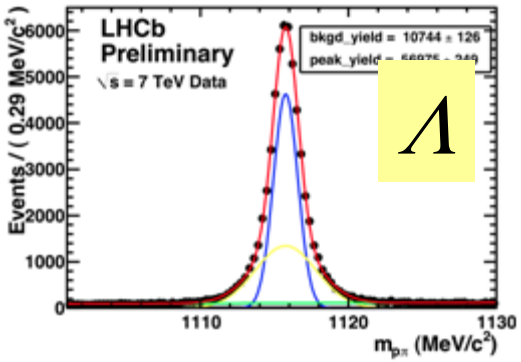
- Efficiencies and mis-ID determined from data using calibration samples on $K_S \to \pi^+\pi^-$, $\Lambda \to p\pi^-$, $D \to K\pi$, $\phi \to K^+K^-$

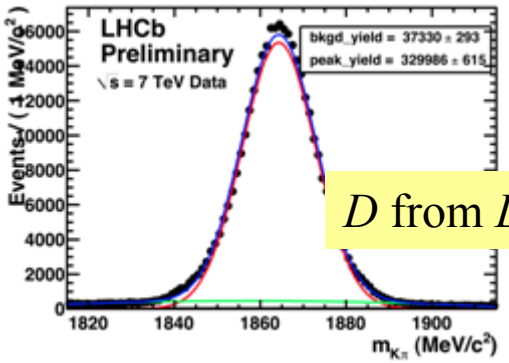


PID calibration samples



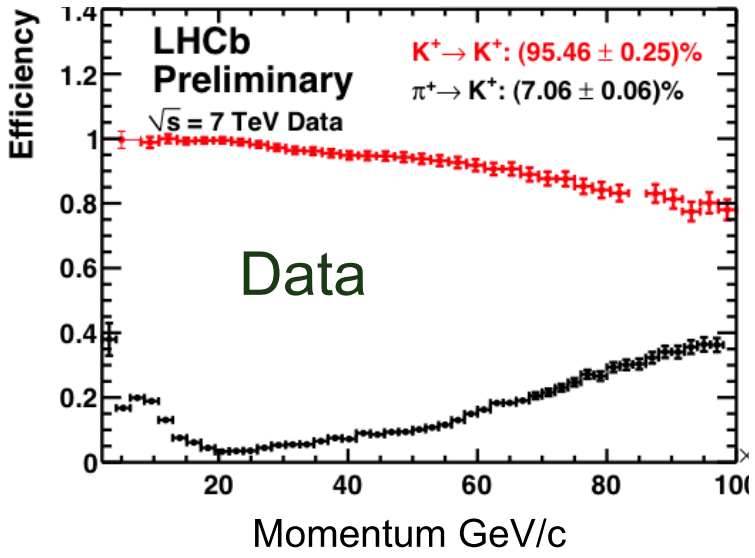


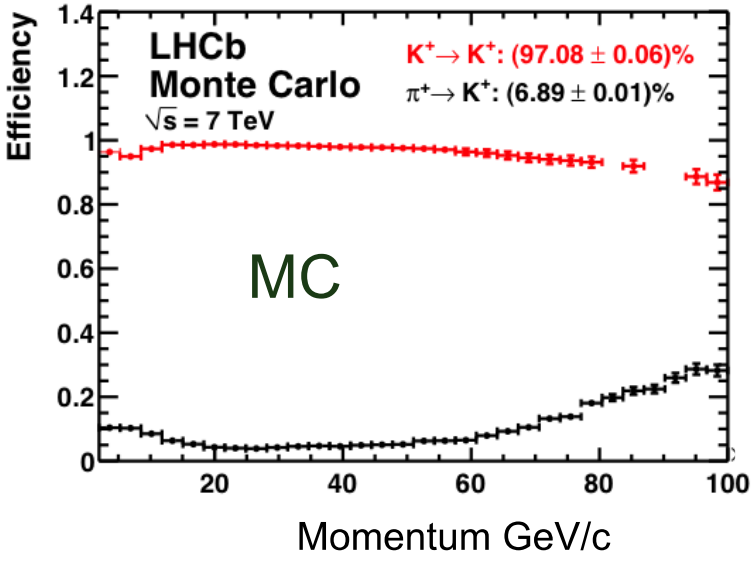




D from D^*

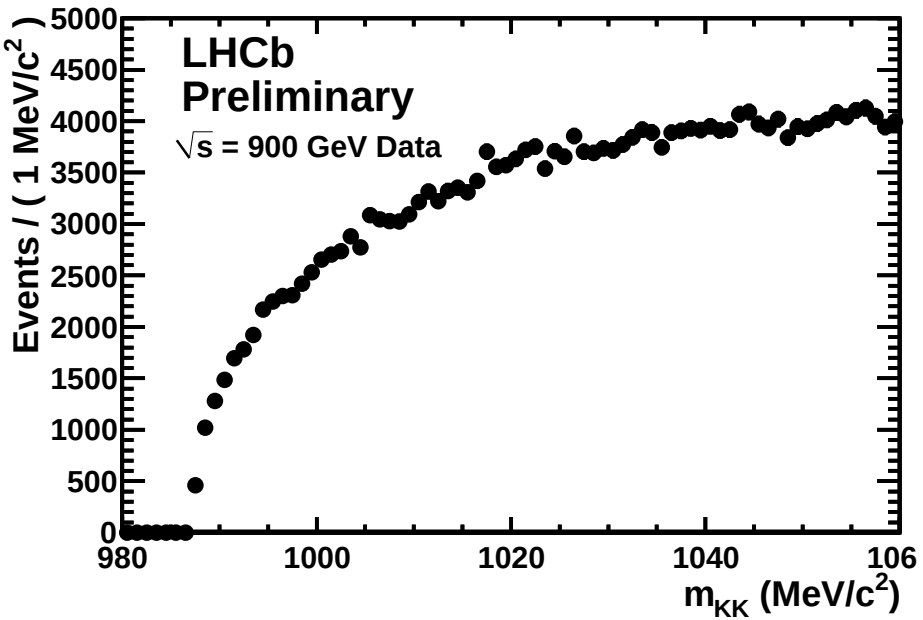
- **Impressive calibration purity → samples allow PID calibrations in efficiency and purity to be evaluated with data**

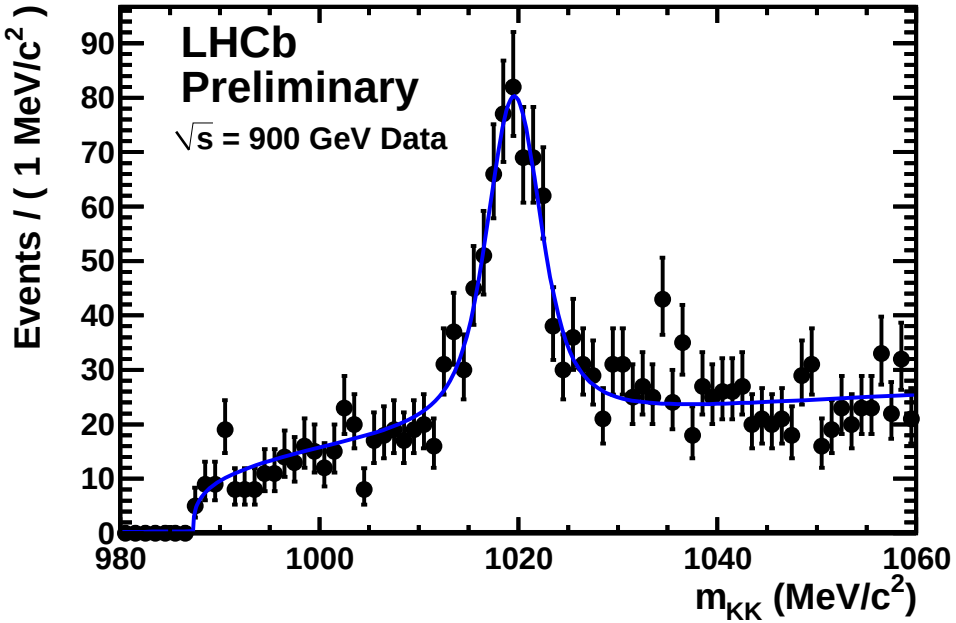




Effect of PID on $\phi \to K+ K-$

- Early 900 GeV data
- Hard-ish RICH cut on each kaon track DLL(K-pi)>15

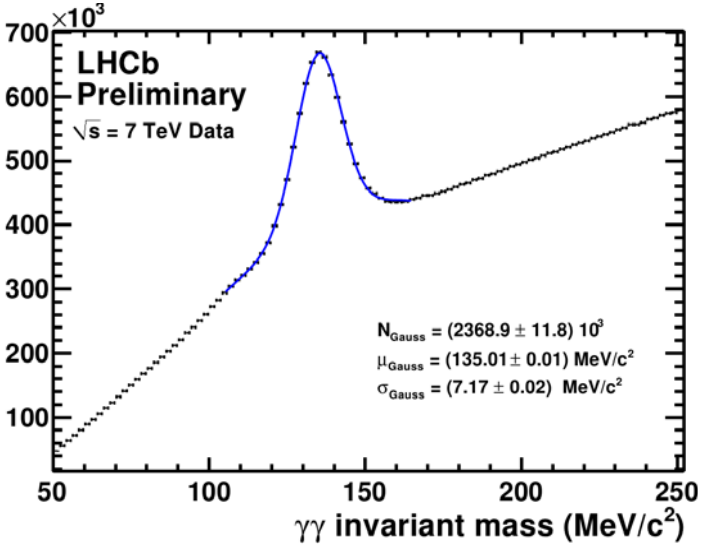




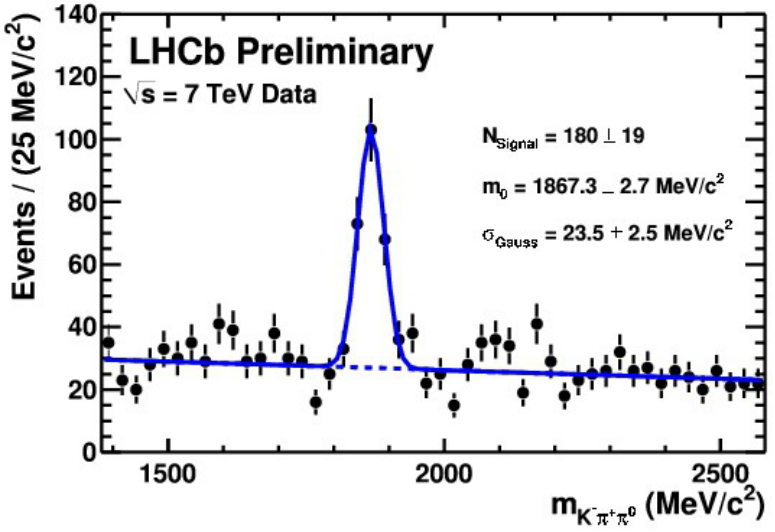
Calorimeters – photon and electron ID

- EM/Had calorimeters provide trigger, electron ID and neutral reconstruction $\rightarrow$ e, γ, π^0 etc
- π^0 resolution found in data actually exceeds expectations

$\pi^0 \rightarrow \gamma\gamma$ σ = 7.2 MeV



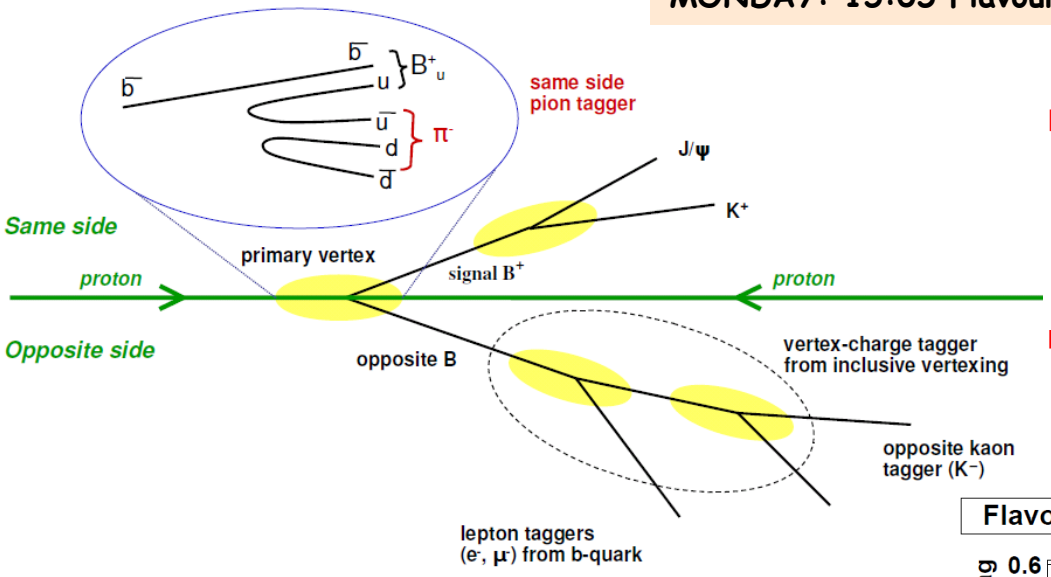
Charm multi-body $D^0 \rightarrow K^-\pi^+\pi^0$




www.erwinvoogt.com
A taste of the physics ...

Tagging performance – where are we?

MONDAY: 15:05 Flavour tagging and mixing at LHCb : Stefania VECCHI



- At present, opposite side kaon, lepton,vertex charge and same-side pion studied
- $\varepsilon_{eff} = \varepsilon_{tag} (1- 2\omega)^2$

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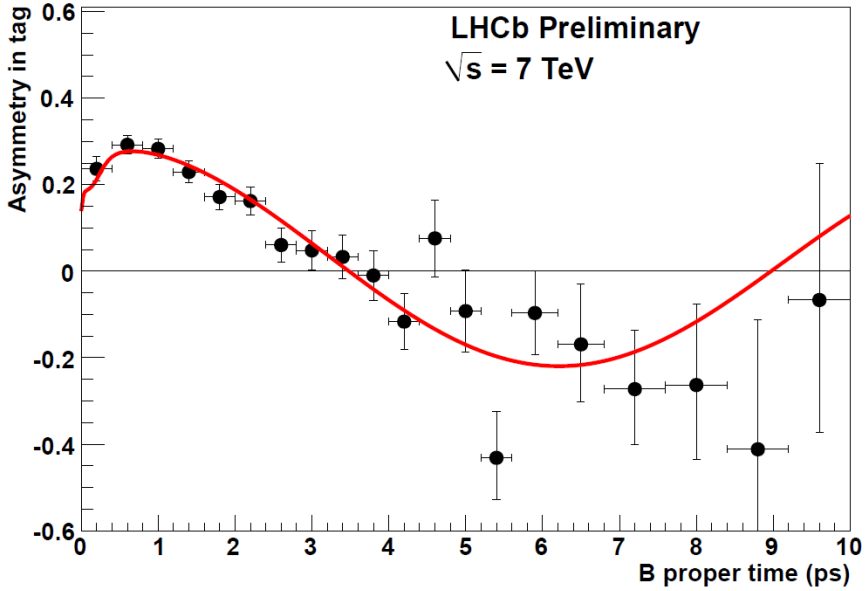
LHCb-CONF-2011-10

Flavour Oscillation signal region

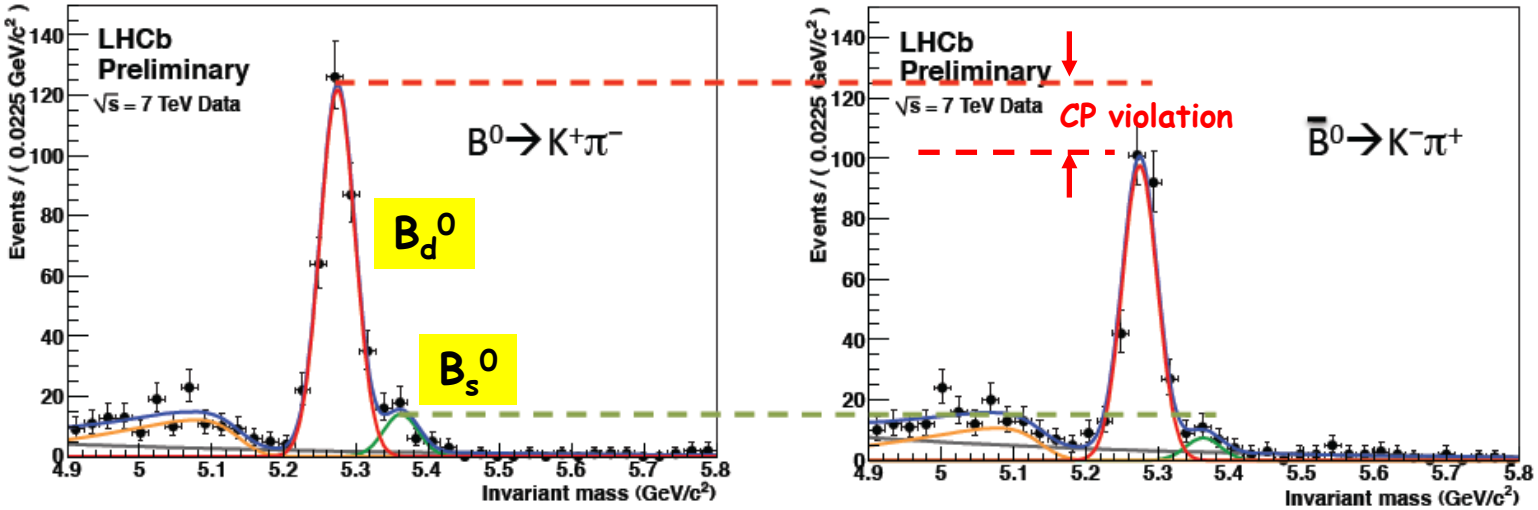


- Oscillation studied in $B^0 \to D^{*-} \mu^+ \nu$ "flavour specific" calibration channel
- Measured tagging power (1.97±0.18)% using OS tagging only
- Good agreement with PDG oscillation frequency
- This work is in progress

Example of CP violation measurement

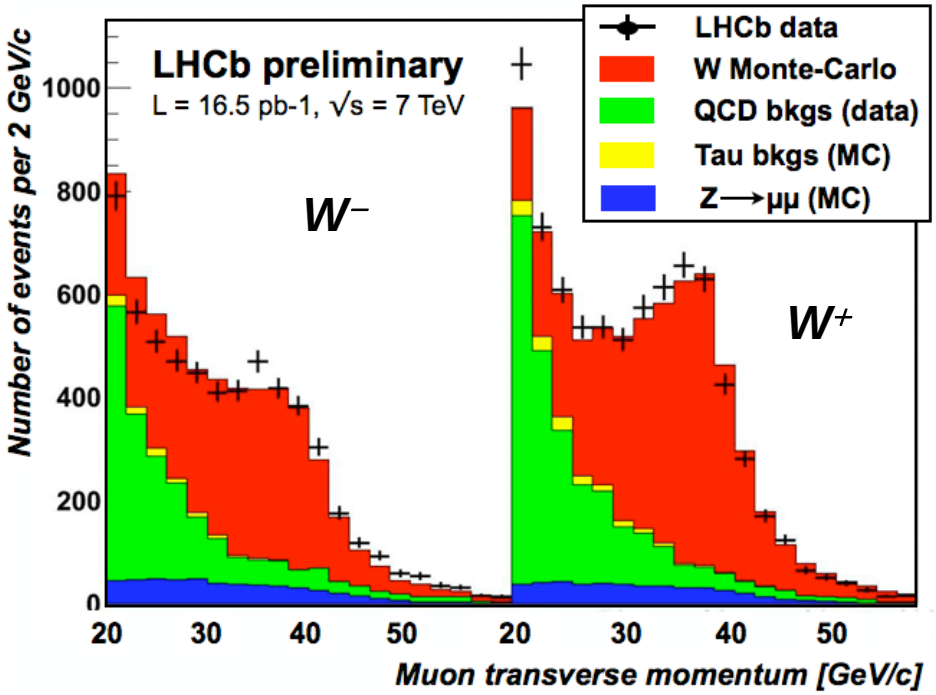
THURSDAY 14:20 B -> hh (hadronic final states) : Vincenzo VAGNONI (INFN Bologna)

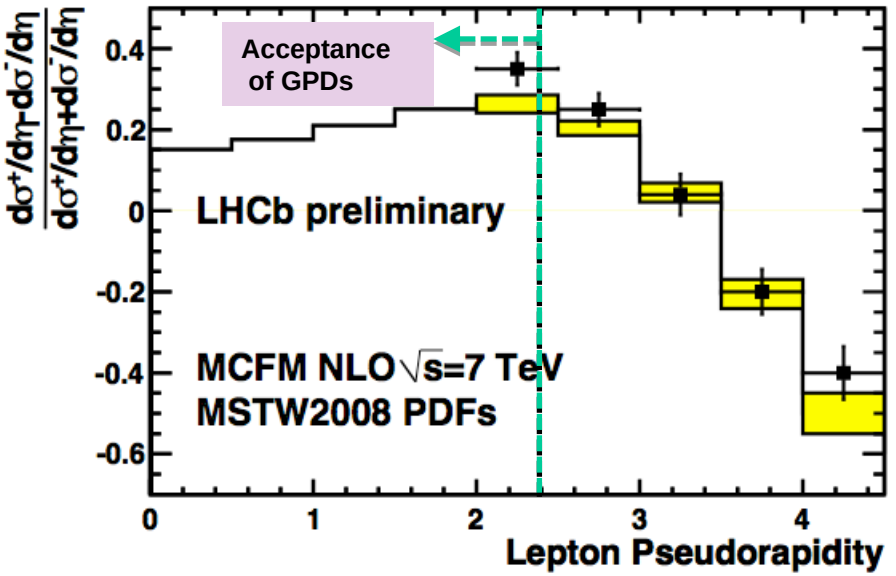
- Separate samples into $\bar{B}^0$ and B^0 using particle ID
- Raw asymmetries clearly visible in data: direct CP Violation > 3σ
- Central values consistent with expectations and previous measurements
- NB: corrections from production and detector asymmetry not yet corrected for

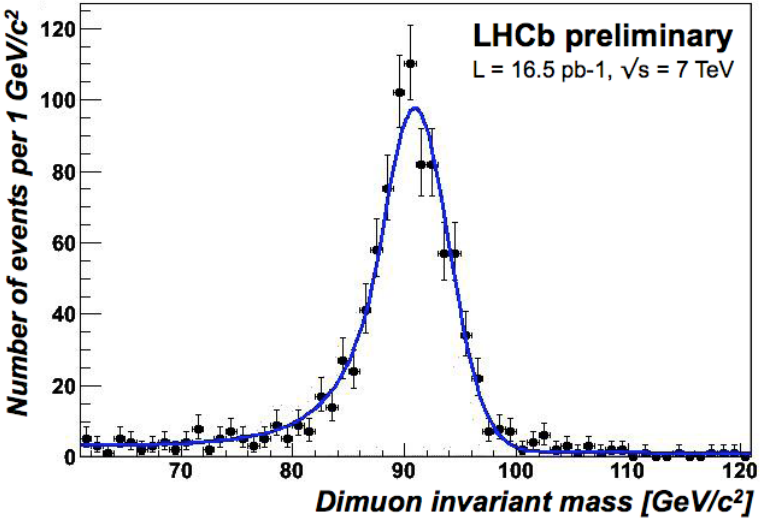


Physics not in our initial planning …

- W: single isolated μ with P_t > 20 GeV/c & small P_t opposite
- W^+/W^- asymmetry measurement: $W \to \mu\nu$



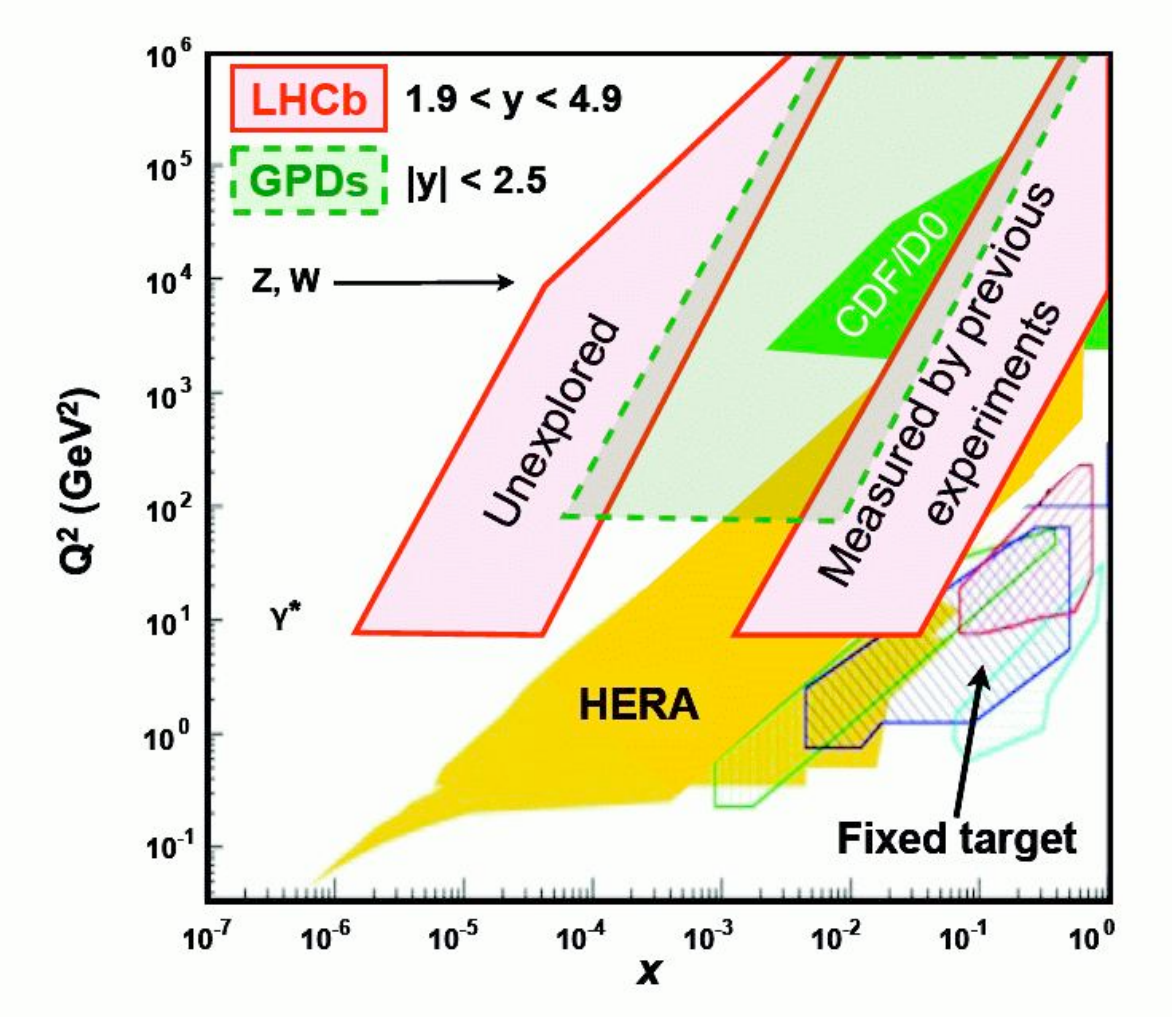




- And $Z \to \mu^+\mu^-$

Very sensitive to PDFs

- New regions of proton structure measurement



B_s : a number of first observations

- $B_s \to D_{s2}(2573)^+ \mu^- \nu$
- $B_s \to J/\psi f_0(980)$
- $\bar{B}_s \to K^{*0} K^{*0}$

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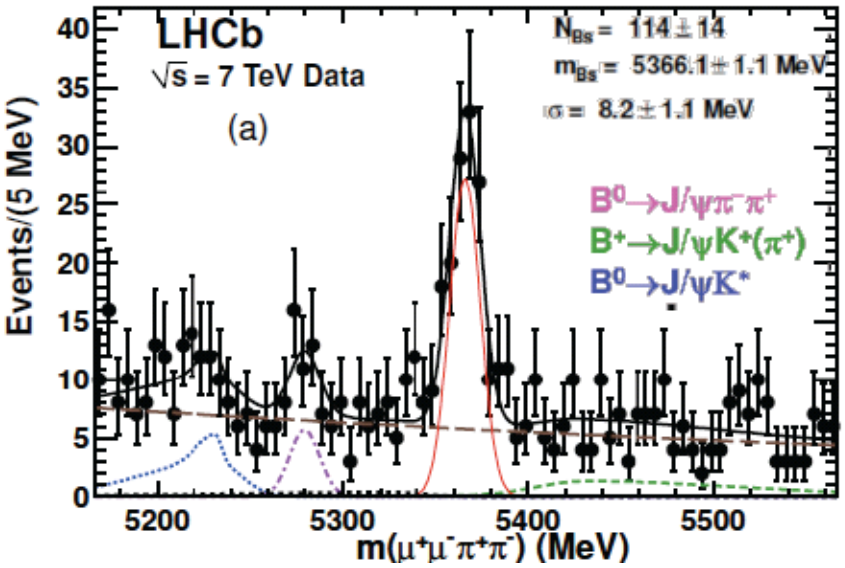
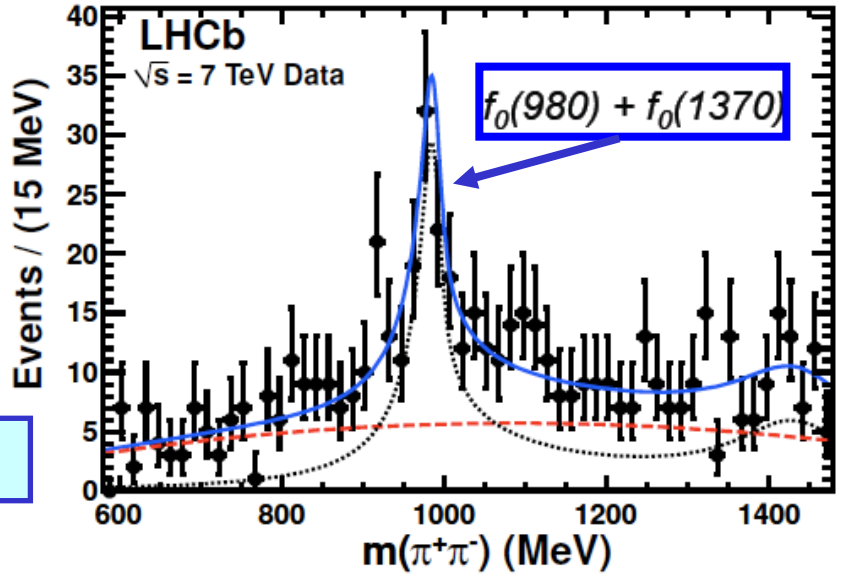
- $B_s \to D^0 K^{*0}$

LHCb-CONF-2011-08





PLB 698 (2011) 115.


The next steps

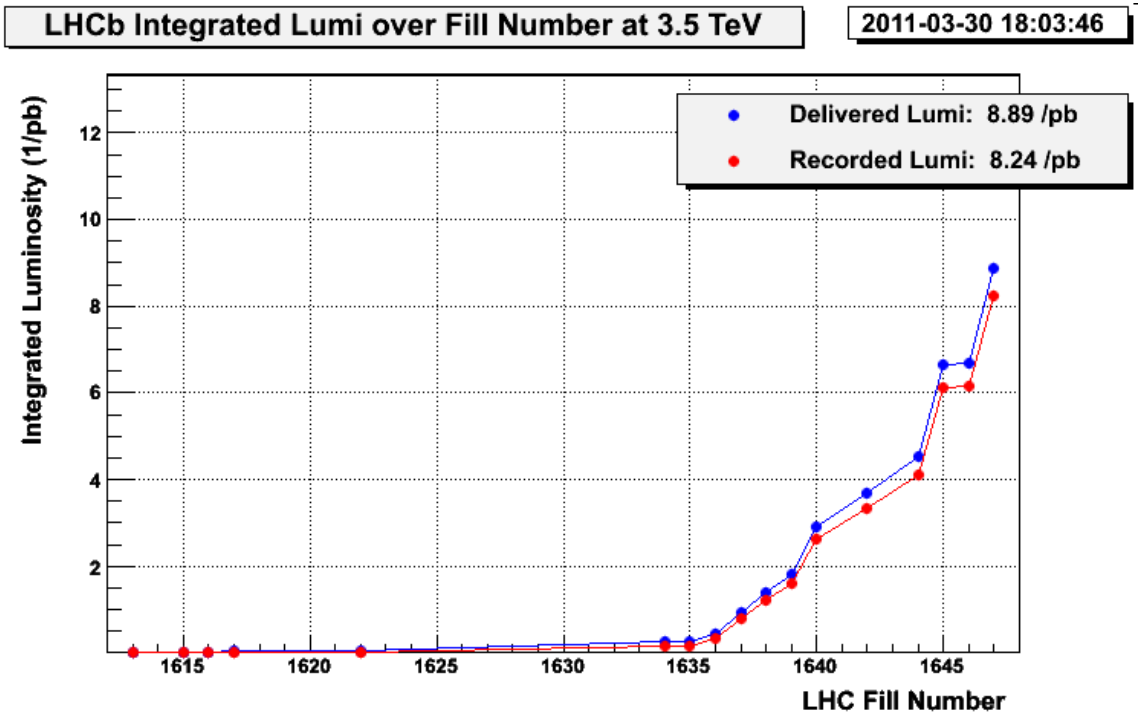
LHCb 2011 running

- LHCb plan to run in 2011 with a visible pp-collisions/bunch crossing up to $\langle\mu\rangle=2$ (2.5 at start-up). We prefer to maximize the number of LHC bunches to minimize $\langle\mu\rangle$.

- Luminosity levelling will be crucial for running with almost flat luminosity (to ~3×10^{32} cm^{-2} s^{-1}) throughout the year.

- We hope to get ≥200 pb^{-1} by end of June and ~1 fb^{-1} by the end of 2011.

And the 2011 startup …



- 2011 data-taking has just started:
- Fills with 32/64/136/200 bunches being taken with >90% efficiency.
- Soon necessary for luminosity levelling
- It's all kicking off again ... ☺ !

Summary

- LHCb running in 2010 has been splendid, recording 37 pb^{-1} of excellent data.

- LHCb has proven extremely versatile, both in its ability to trigger (<μ>) and in its physics. And it *works* !

- LHCb is already competing with Tevatron in some areas of B_s physics. Next year we will surpass the B factories.

- Long programme over several years to explore the full potential of physics beyond the Standard Model

2011 WILL BE A VERY EXCITING TIME !

ACKNOWLEDGEMENTS

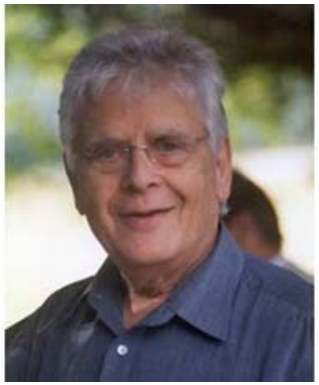
... to the representatives of LHCb experiment who helped me to prepare this talk

Marco Adinolfi, Patrick Koppenburg, Andrew Powell, Marie-Noelle Minard, Olaf Steinkamp, Andrei Goloutvin, Frederic Teubert, Guy Wilkinson, Stefania Vecchi, Matthew Charles, Gaia Lanfranchi, Victor Egorychev, Hamish Gordon ...

And the many detector experts and analysists who I don't mention but we all rely on

Many thanks

AND IN MEMORY OF ...



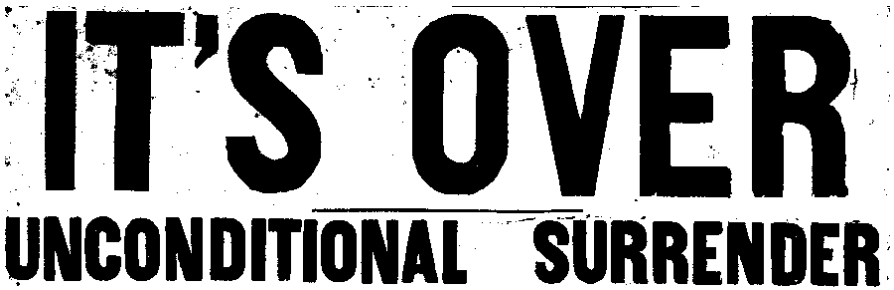
Peter Schlein

Werner Ruckstuhl

Tom Ypsilantis

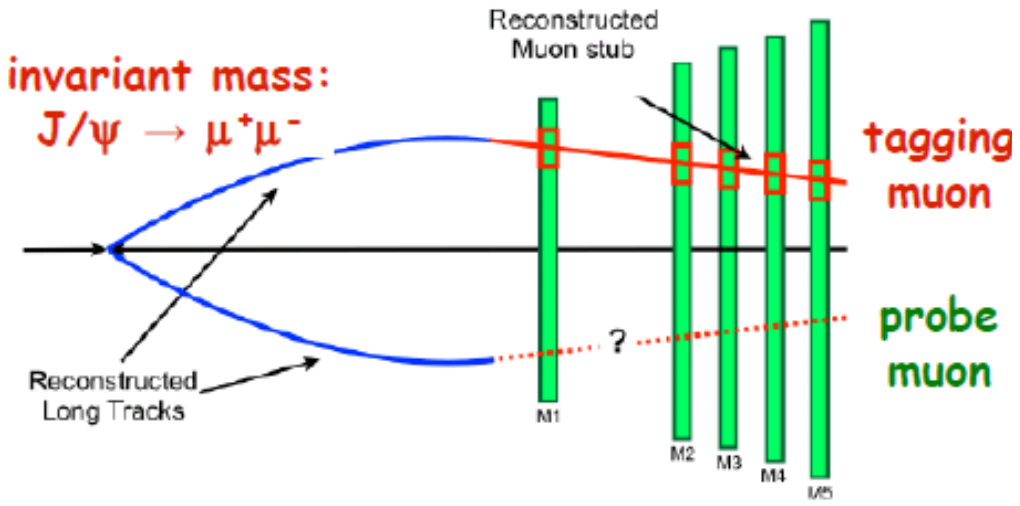
Who sadly never got to see the results from this pioneering experiment

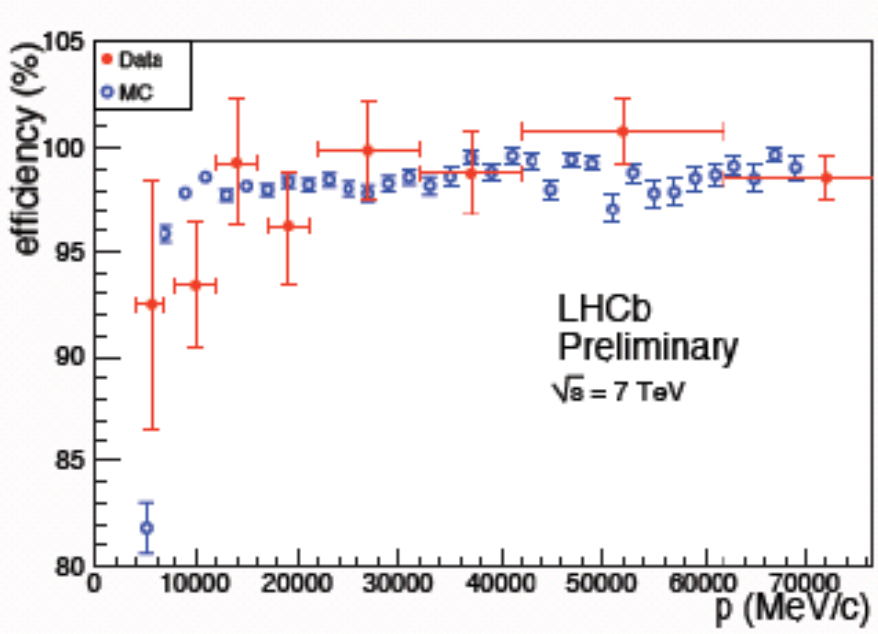
That's all folks ! Spare slides from here on



Muon Identification Performance

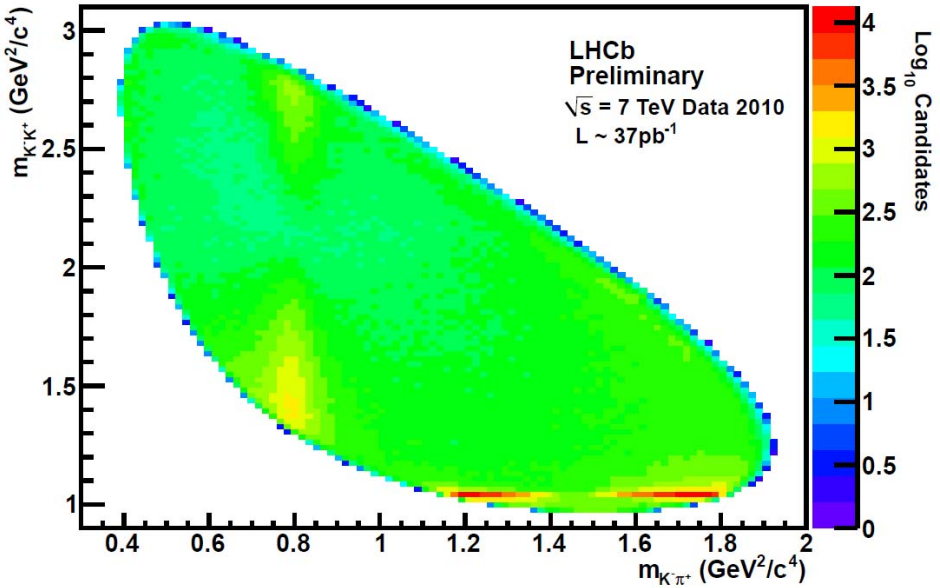
- Efficiency determined from data using tag-and-probe method on $J/\psi \rightarrow \mu^+\mu^-$
- Found to be > 90 % for p > 10 GeV
- Mis-ID probabilities $K \rightarrow \mu$, $\pi \rightarrow \mu$, $p \rightarrow \mu$ determined from data using tag-and-probe method on $\phi \rightarrow K^+K^-$, $K_S \rightarrow \pi^+\pi^-$, $\Lambda \rightarrow p\pi$
- All found to be < 2 % for p > 10 GeV
- Good agreement between data and simulation

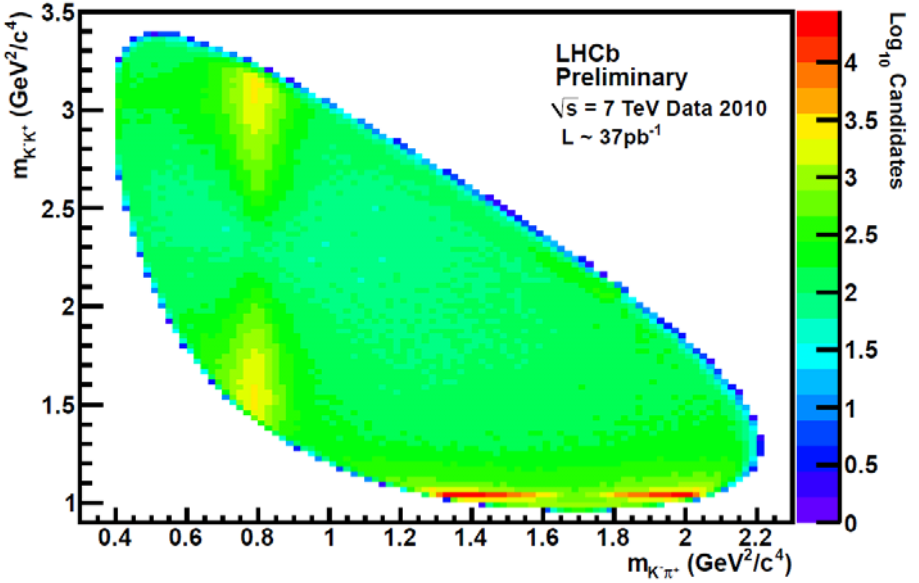




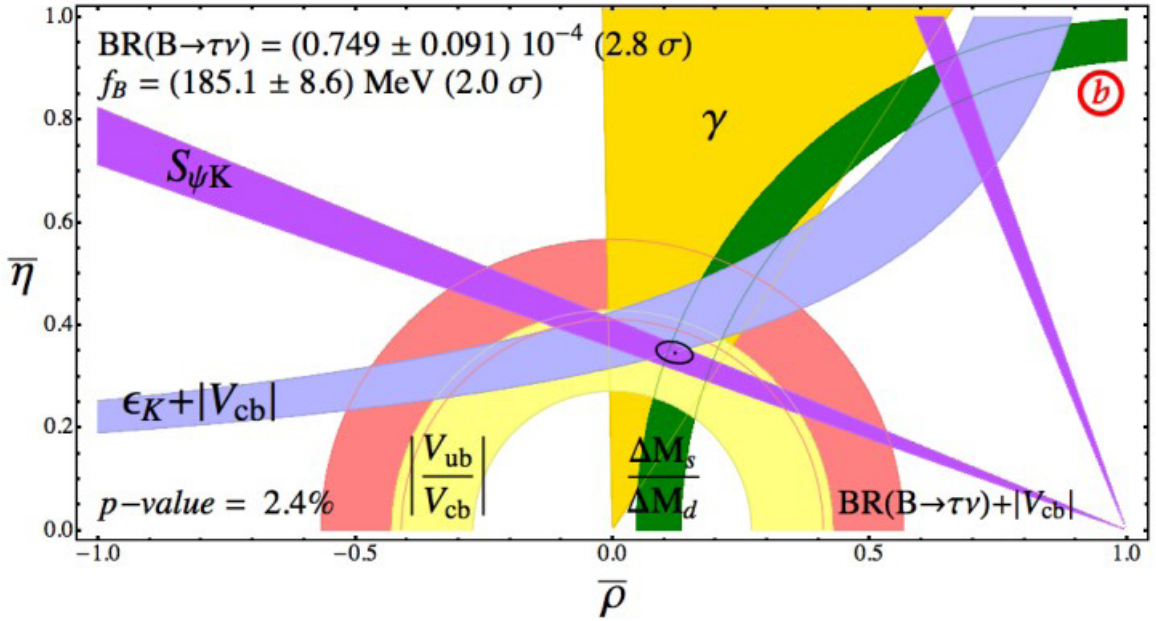
Vibrant programme of Charm physics ...

- Dalitz structure in
  - $D^+ \rightarrow K^- K^+ \pi^+$
  - $D_s^+ \rightarrow K^- K^+ \pi^+$
- Signal and control for CP violation search





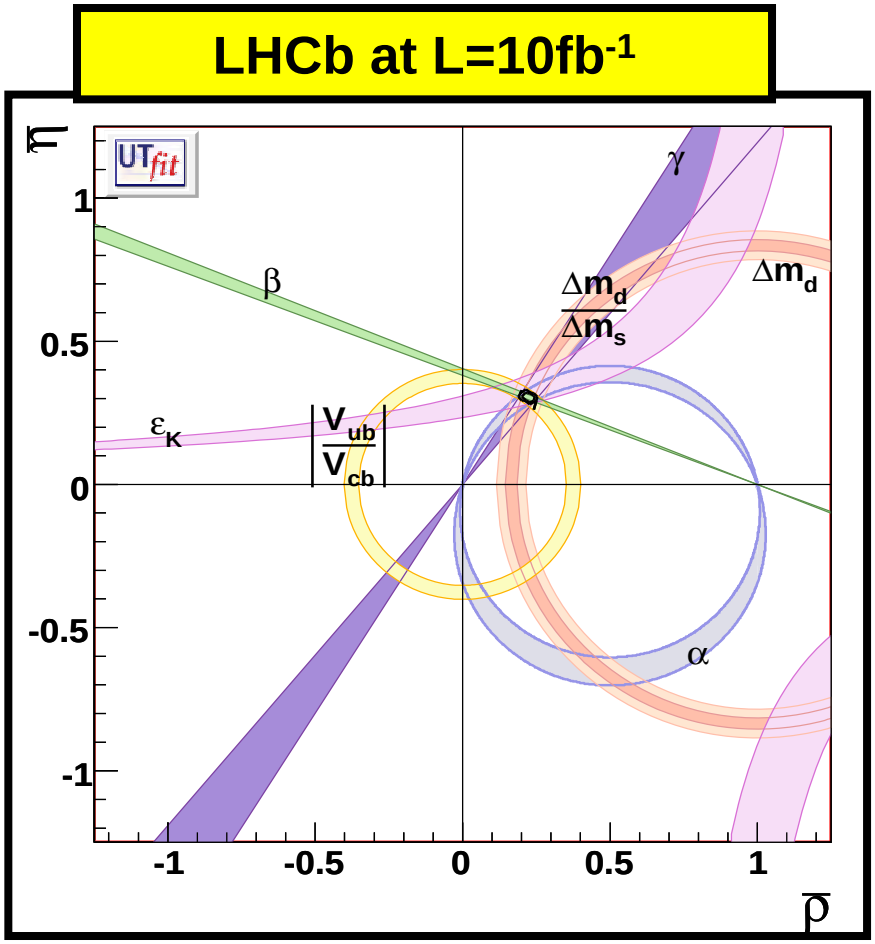
Tension in the CKM fit



From Lunghi and Soni, arXiv:1010.6069 (see also CKMfitter, UTfit, etc., etc.)

n.b. $\gamma = (74 \pm 11)^\circ$ used as input but CKMfitter gives $(71^{+21}_{-25})^\circ$

Contribution of LHCb to UT



Lattice QCD assumed: $\sigma(\xi)/\xi = 1.5\%$

$\sigma(\sin(2\beta)) = 0.01$; $\sigma(\gamma) = 2.4^{o}$; $\sigma(\alpha) = 4.5^{o}$