Recent Progress on the LHCb Experiment

On behalf of the LHCb Collaboration

Tatsuya Nakada
CERN
and
Swiss Federal Institute of Technology
Lausanne (EPFL)
1) Introduction

LHCb is a dedicated experiment at LHC to study CP violation and other rare phenomena in B-meson decays.

Impressive progress by LEP experiments

\[ |V_{cb}| \ (b \to c + W), \ |V_{ub}| \ (b \to u + W), \]
\[ |V_{td}| \ (\Delta m_d), \ |V_{ts}| \ (b \to s \text{ penguin}) \]

Experiments at Y(4S)

\[ |V_{cb}|, \ |V_{ub}|, \]
\[ |V_{td}| \ (\Delta m_d), \ |V_{ts}| \ (b \to s \text{ penguin}), \]
\[ \arg V_{td} \ (\text{CP in } b \to c + W), \]
\[ \arg V_{ts} \ (\text{CP in } b \to s \text{ penguin}) \]
\[ \arg V_{ub} \ (\text{CP in } b \to c + W \otimes b \to u + W \text{ via } D-\bar{D} \text{ mixing}) \]
\[ \arg V_{ub} \ (\text{CP in } b \to c + W \otimes b \to u + W) \]

Tevatron experiments

\[ |V_{td}|, \ |V_{ts}|, \ \arg V_{td} \]
Standard Model

Tree
\[ \Gamma(b \to c) \]
\[ \Gamma(b \to u) \]
\[ b \quad W \quad c, u \]
\[ |V_{cb}| \quad |V_{ub}| \]

Penguin
\[ \Gamma(b \to s) \]
\[ \Gamma(b \to d) \]
\[ b \quad W \quad d, s \]
\[ |V_{td}| \quad |V_{ts}| \]

Box
\[ \omega(B_d - B_d) \]
\[ \omega(B_s - B_s) \]
\[ b \quad t \quad d, s \]
\[ W \quad W \]
\[ |V_{td}| \quad |V_{ts}| \]

\[ \text{CR(Tree} \otimes \text{Box)} \]
\[ 2 \text{ arg } V_{td} (V_{ts}) + \text{ arg } V_{cb} (V_{ub}) \]

\[ \text{CP(Pengu} \otimes \text{Box)} \]
\[ 2 \text{ arg } V_{td} (V_{ts}) + \text{ arg } V_{td} \]
\[ 2 \text{ arg } V_{td} (V_{ts}) + \text{ arg } V_{ts} \]

\[ \Gamma(B \to \mu \mu) \]
\[ d, s \quad W \quad \nu \quad \mu \quad \mu \]
\[ |V_{td}| \quad |V_{ts}| \]
The LHCb Experiment will
determine the CKM parameters in a model independent manner and
look for new physics-
e.g.
  ● extracting $B_d$ and $B_s$ oscillation frequencies and phases: B. Carron
    (in the Standard Model $V_{td}$ and $V_{ts}$)
    -$B_d \rightarrow J/\psi K_S$, $B_s \rightarrow J/\psi \phi$, $B_s \rightarrow J/\psi \eta$,
  ● extracting arg $V_{ub}$ from CP asymmetries in
    -$B_s \rightarrow D_s K (+ B_s$ oscillation phase): E. Rodrigues
      no hadronic uncertainties
      no effect from new physics
      large asymmetries
    -$B_d \rightarrow \pi^+ \pi^- \Theta B_s \rightarrow K^+ K^- (+ B_d$ and $B_s$ oscillation phase) L. Fabbri
      hadronic uncertainties (U-spin)
      affected by new physics in penguin
    -$B_d \rightarrow DK^*$ S. Amato
      affected by new physics in $D\overline{D}$
-and look for surprises-
e.g. rare decays I. Belyaev
2) Status of the detector construction

Good mass and eigentime resolution: VELO + tracking system
Hadron identification: RICH system
L0 Lepton and Hadron $p_T$ trigger: Calorimeter and muon system
Magnet

\[ \int B \, dl = 4 \, \text{Tm} \]
Normal conductor (Al)
Power = 4.2 MW
Fe Yoke = 1600 t

commissioning in Autumn 2004
VErtext LOcator

Si sensor hybrid with readout chip

Si sensor as close as 8mm from the beam

collision point

~ 1m

beam axis

10°-20° stereo angle

4x45° sectors

84 mm
Silicon Tracker

Magnet

RICH1

TT

T1 T2 T3

beam pipe

Inner Tracker

320 µm Si
410 µm Si

Trigger Tracker

~130×45 cm²

500 µm Si

~1.4×1.2 m²
TT layout with the CMS sensors

IT box mechanical design

electronics hybrid

sensors

Kapton cables

electronics hybrid

sensors
Outer Tracker

One station = X-U-V-X module planes

Straw drift chambers

40µm Kapton XC-160 + Laminated Kapton-Al
Serial production is starting in four production sites

- Wire tension measurement
- RMS of wire deviation <100 µm
Two RICH with three radiators
Aerogel
\( \text{C}_4\text{F}_{10} \)  RICH1 (25-300 mrad)
\( \text{CF}_4 \)  RICH2 (15-120 mrad)
RICH2 construction advancing

Space frame

mirror support

Photon detector for both: HPD

RICH1 design advancing

Photo Detectors

250 mrad

Spherical Mirror

Beam pipe

Aerogel

C_{4}F_{10}

VELO exit window

Plane Mirror

Track
Production well advanced
100% of E-cal
70% of H-cal
modules delivered to CERN.
30% of SPD/PS modules produced

SPD/PS superstructure mechanical test

Preproduction of CW PM base for E- and H-cal
Muon

MWPC production has started in various sites.

Projective pad readout based on MWPC’s.

A total of 1368 chambers with various types

Muon filter chariot being delivered.

(filter: a total of 2000 t Fe)
Level-0 Trigger
Level-0: Muon, Calorimeter (e, h, γ, π⁰), Pile-up veto, Decision Unit prototype work advancing.
Level-1/High Level Trigger and DAQ

Level-0: 40 MHz → 1 MHz

Level-1 data (VELO, TT, L0-info)
with a possibility to include Tracker, Muon, L0-Calo

1 MHz @ ~5 kB/event

Network Switches

commercial components

sub-farm sub-farm sub-farm

sub-farm sub-farm sub-farm ...

network

storage device

nominal 200 Hz @ ~100 kB/event

Real Time Trigger Challenge: a vertical slice planned in 2005
Testing both hardware and software
Software and computing

2003: Production version of software
  framework based on C++
  most of the event reconstruction and analyses in C++
PYTHIA and GEANT3: FORTRAN
MC Production tool for distributed computing
  DIRAC job scheduling and submission, data transfer
  data catalogue, etc.
A total of > 40M events generated for physics/trigger studies

2004: Production version of software
  all C++ (transition to GEANT4) except
  PYTHIA
Incorporating LCG middle-ware in the production tool
Goal to produce ~5 times more data than 2003
Do analysis with distributed computing
Summary

LHCb is designed to study CP violation and rare decays using a large sample of different b hadrons ($B^\pm, B_d, B_s, B_c, \Lambda_b, \text{etc.}$) in order to look for a sign of New Physics:

- A complementary approach to ATLAS/CMS

Expected performance in the afternoon talks!

Detector construction is advancing.

Physics potential can be fully exploited with the initially expected LHC luminosity

i.e. LHCb needs $\sim 2 \times 10^{32}$,
LHC will start with $\sim 10^{33}$