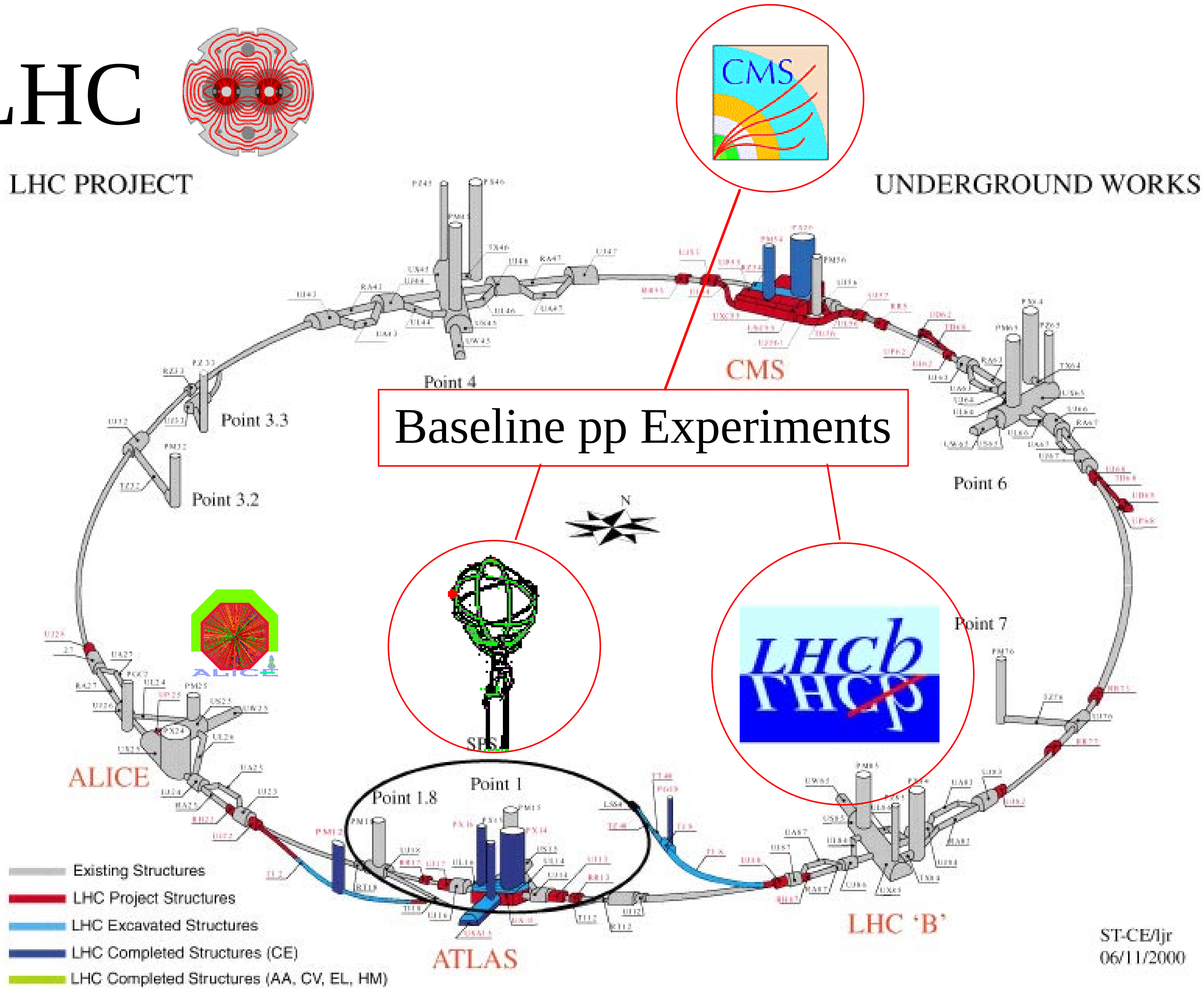
What do we expect from LHC(b)?

Tatsuya Nakada

CERN and University of Lausanne

19-23.2.2001, Ise, Japan

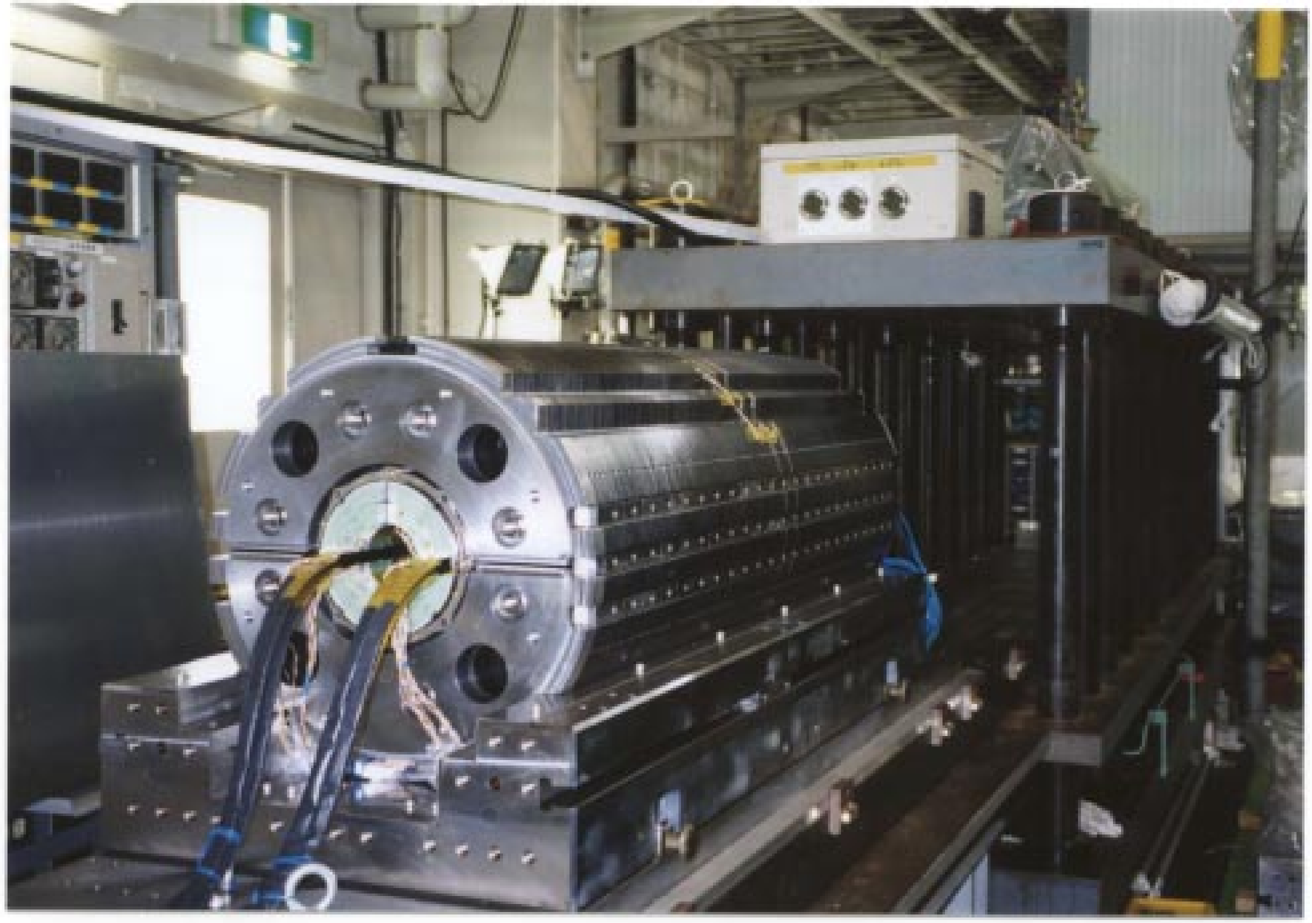
LHC



LHC PROJECT
UNDERGROUND WORKS
Baseline pp Experiments
CMS
ATLAS
ALICE
LHC 'B'
LHCb
Point 1
Point 1.8
Point 3.2
Point 3.3
Point 4
Point 6
Point 7
SPS
N
Existing Structures
LHC Project Structures
LHC Excavated Structures
LHC Completed Structures (CE)
LHC Completed Structures (AA, CV, EL, HM)
ST-CE/ljr
06/11/2000

LHC magnet string

http://www.kek.jp/
文部科学省 高エネルギー加速器研究機構
HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION
KEK



LHC prototype low-β quadrupole at KEK

LHC Plan

Beam injection and a sector test in 2005

Detector installation completed: January 2006

LHC beam commissioning: February-March 2006

First collisions and pilot run: April 2006

$L = \sim 5\times 10^{32}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$,for 4 weeks

Start of physics run: August 2006

$L = \sim 2\times 10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$, for 7 months

Experimental Conditions

Cross sections (PYTHIA)

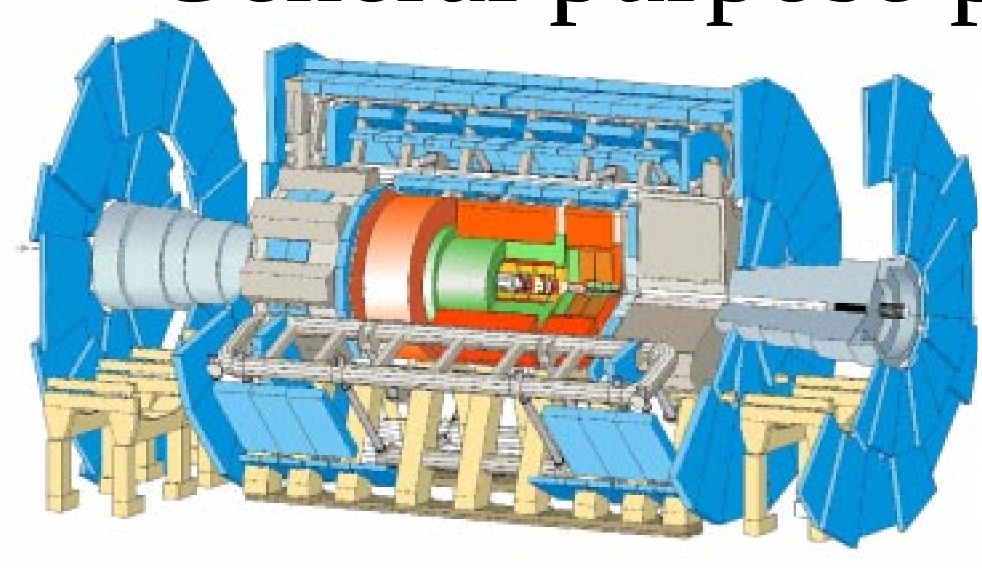
σ_{total}	100 mb
$\sigma_{inelastic}$	80 mb
$\sigma_{inelastic} - \sigma_{diffractive}$	55 mb
σ_{bb}	500 μb
σ_{cc}	1.5 mb

Machine parameters

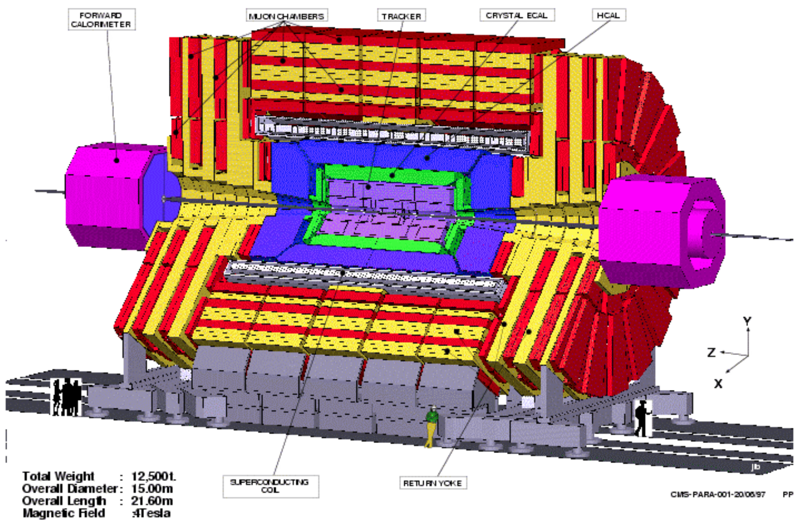
$f_{\text{bunch crossing}}$	40 MHz
L(B physics ATLAS, CMS)	10^{33} cm^{-2}s^{-1}
L(LHCb)	2×10^{32} cm^{-2}s^{-1}

(design luminosity 10^{34} cm^{-2}s^{-1})

General purpose pp experiments



ATLAS



CMS

Central detector: $|\eta| \lesssim 2.5$

Pixel vertex detector

Si strip tracker

High resolution E cal

H cal

High resolution muon system

High P_T lepton triggers

ATLAS

SC coil for
toroidal magnet

Cryostat for
Liquid Argon E-cal

CMS

$PbWO_4$ E-Cal

Fe yoke

Dedicated B detector

Forward detector: $2.1 < \eta < 5.3$

Si mini-strip vertex detector

Inner and Outer Tracker

RICH detectors

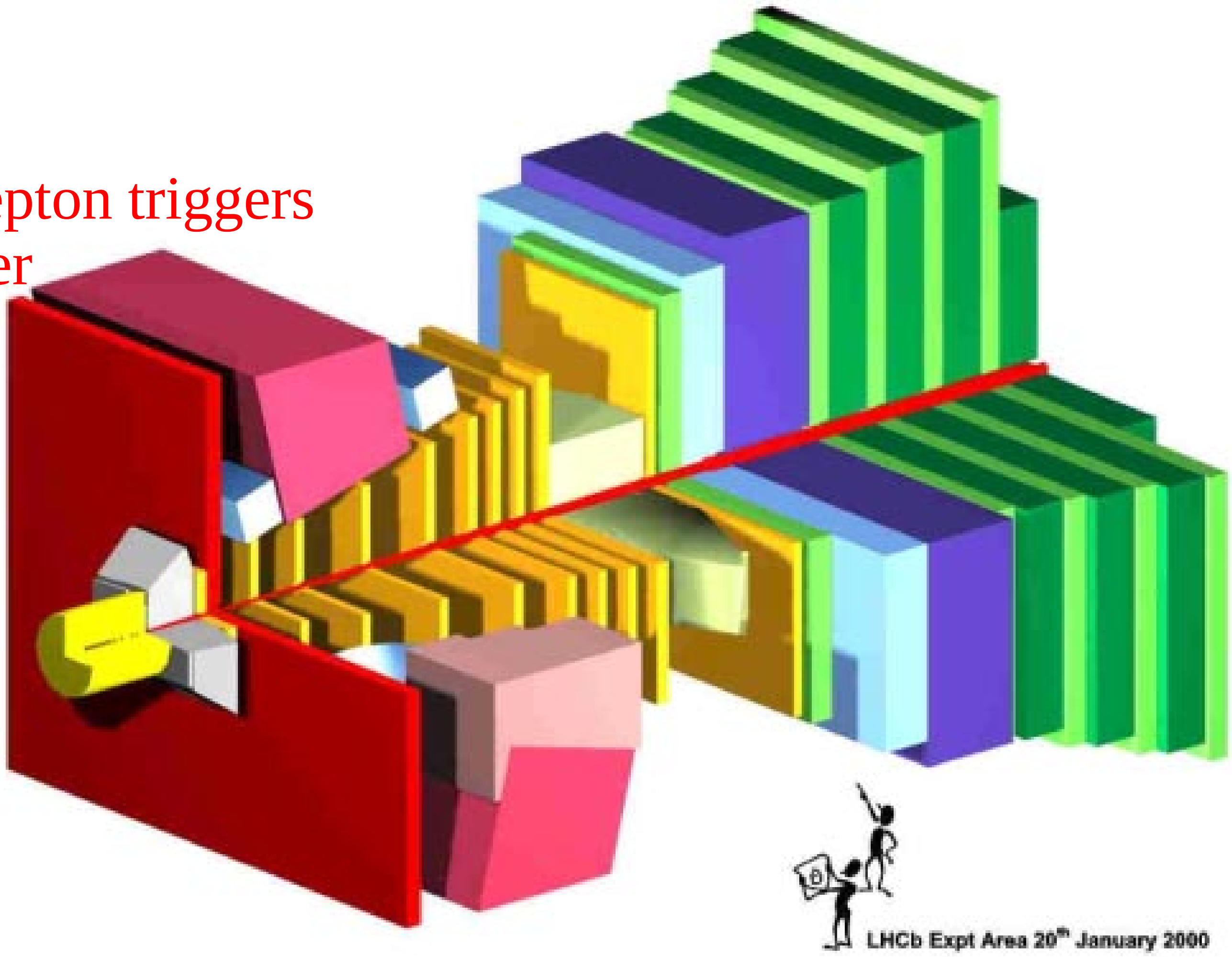
E-cal, H-cal

Muon system

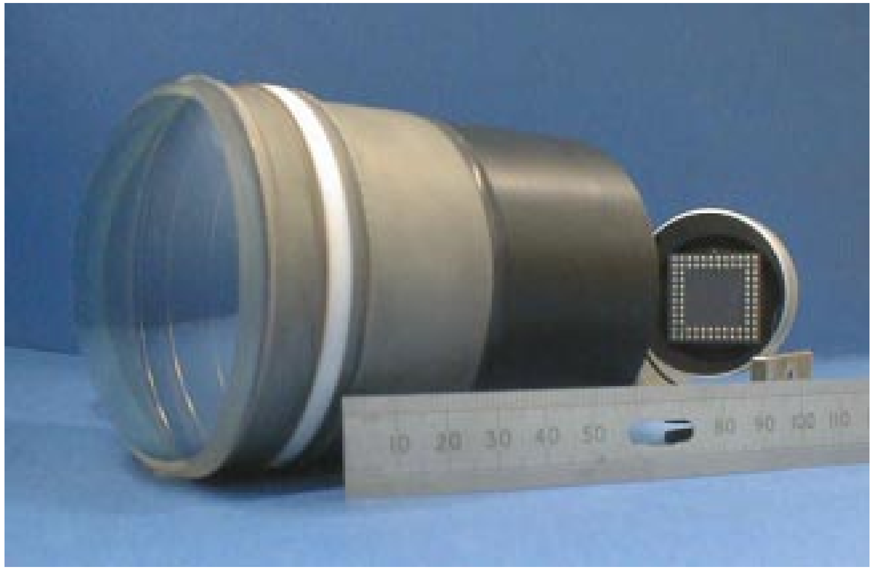
High P_T hadron and lepton triggers

Detached vertex trigger

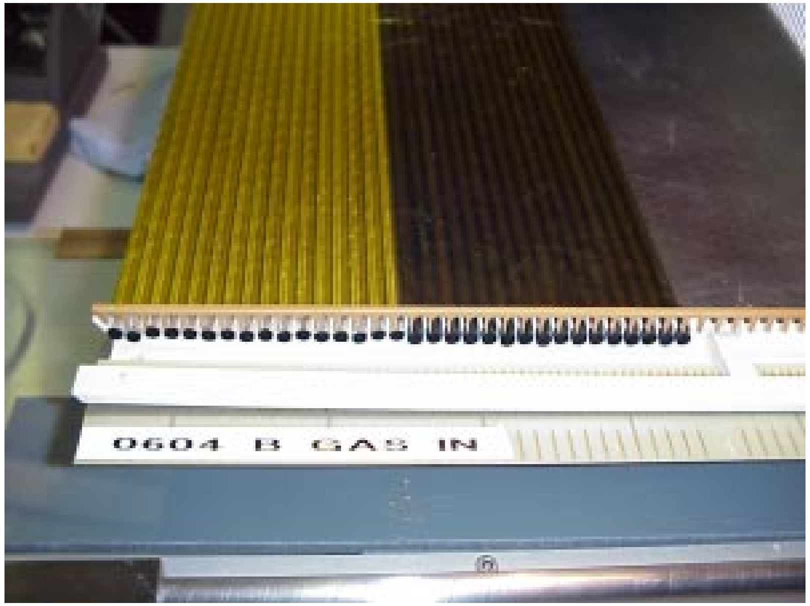
Dipole magnet



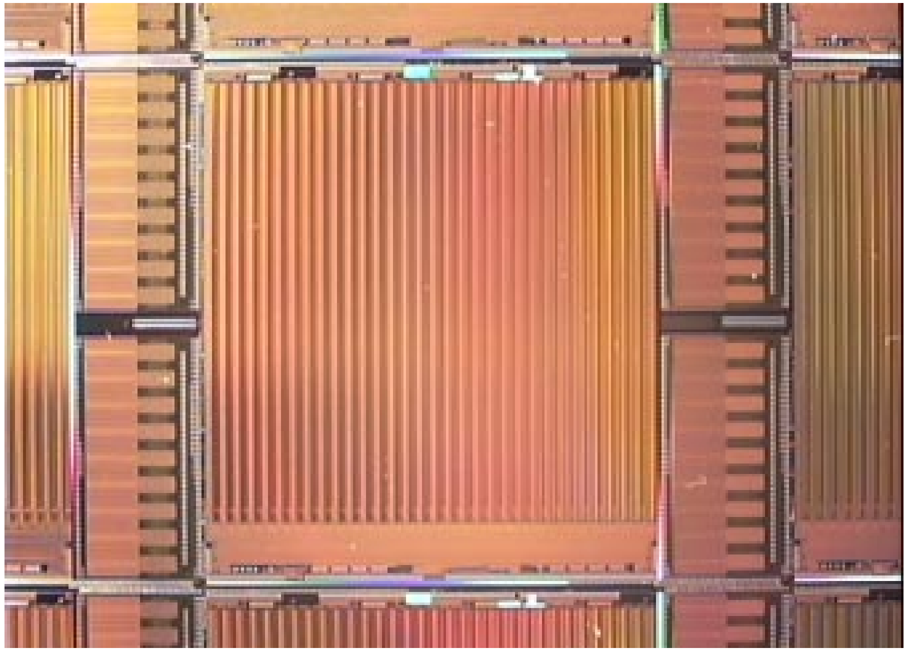
LHCb



Hybrid Photo-Deitector



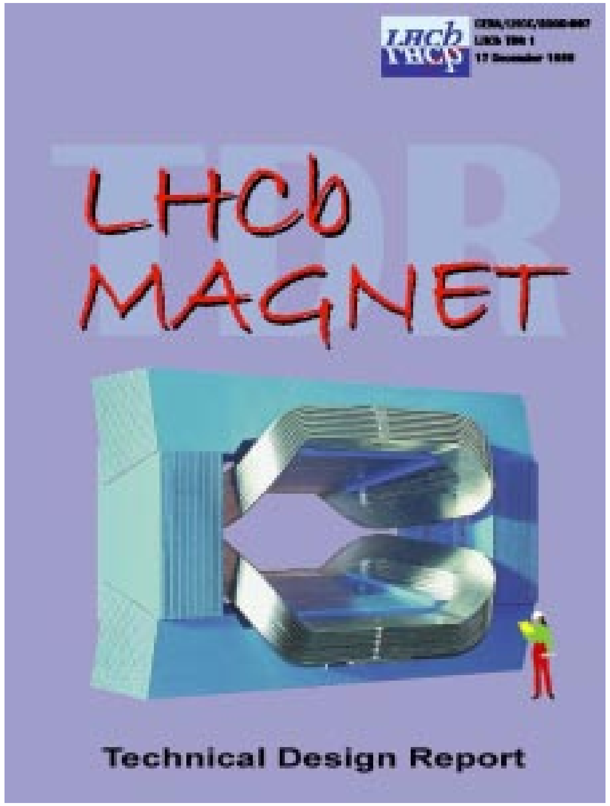
straw driftchamber



HPD pixel readout chip

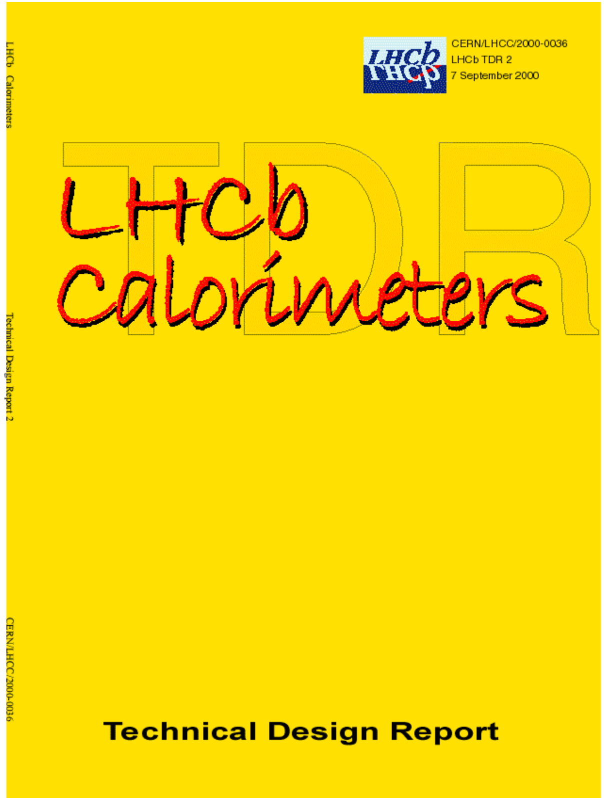
LHCb Technical Designed Reports

January 2000, submission
April 2000, approved



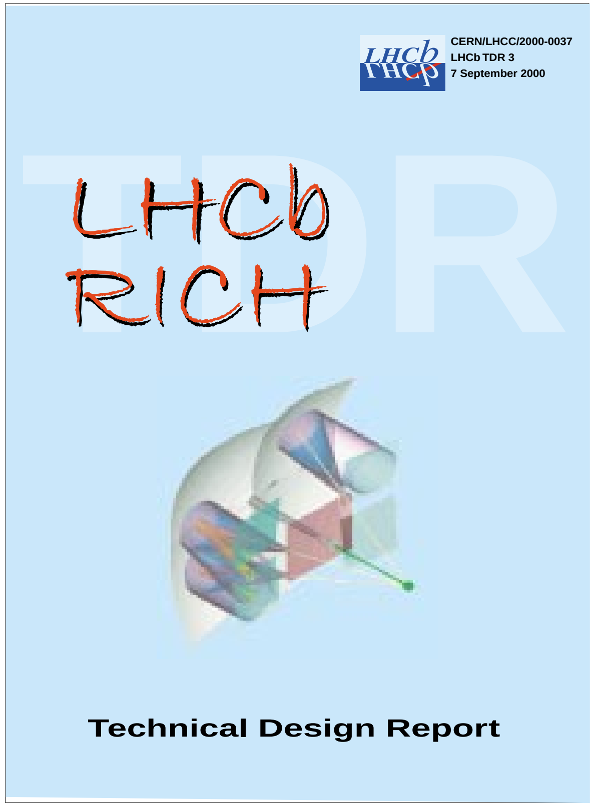
yoke, coil
being orders

September 2000, submission
February 2001, approved



construction will
start in 2001

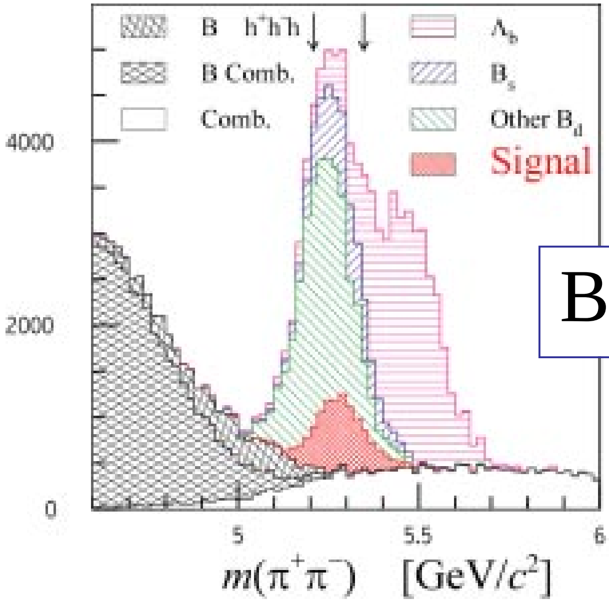
September 2000, submission
February 2000, approved



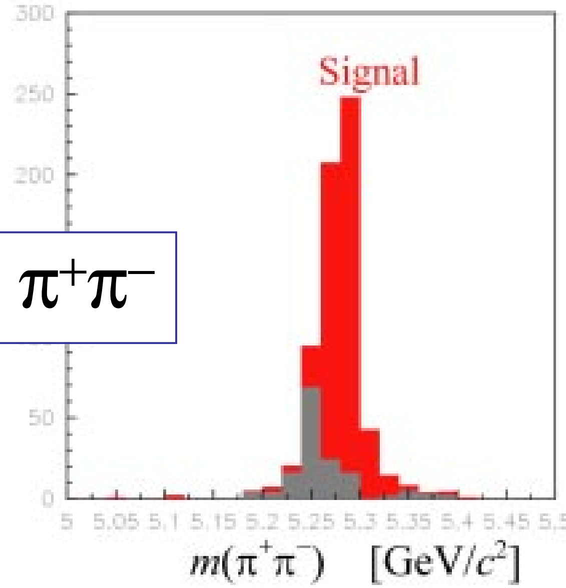
construction will
start ~end 2001

Important Issue I: Hadron ID

Without hardon PID (ATLAS)



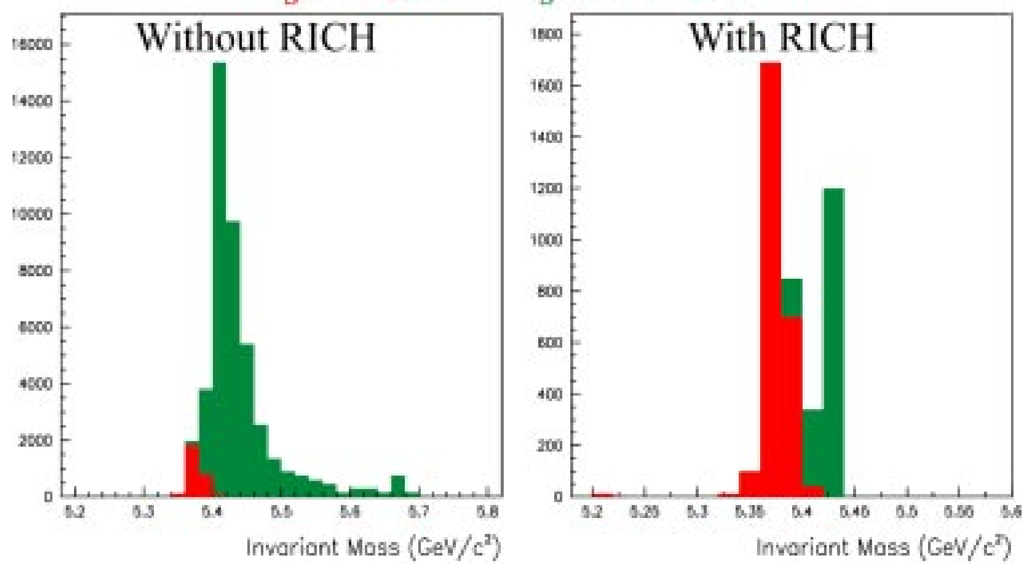
$B \to \pi^+\pi^-$



With hardon PID (LHCb)

LHCb

D_sK signal $D_s\pi$ background



Important Issue II: Trigger

Lepton trigger (and no hadron ID)

-ATLAS, CMS-

trigger and tag

$b\bar{B} \to \underline{\ell^-} + X$, $b\bar{B} \to \ell^+\ell^- + X$

$b\bar{B} \to \underline{\text{b}}\text{-jet} + X$, $b\bar{B} \to \ell^+\ell^- + X$

$b\bar{b} \to B + \underline{h}^+$, $B \to \ell^+\ell^- + X$

$b\bar{B} \to \underline{\ell^-} + X$, $b\bar{B} \to \pi^+\pi^-,\ \rho^+\pi^-,\ D^*\pi,\ \vdots$

(not very clean tag: $\dfrac{\text{wrong}}{\text{all}} \gtrsim 0.4$)

Hadronic final states are not efficiently triggered.

Lepton+hadron trigger with hadron ID
-LHCb-

trigger and tag

$b\bar{B}$: → ℓ^- + X (tag); → $\ell^+\ell^-$ +X (trigger)

$b\bar{B}$: → b-jet + X (tag); → $\ell^+\ell^-$ +X (trigger)

$b\bar{B}$: → ℓ^- + X (tag); → $\pi^+\pi^-$, $\rho^+\pi^-$, $D^*\pi$, :

$b\bar{B}$: → K^- + X (tag); → $\pi^+\pi^-$, $\rho^\pm\pi^\mp$, $D^*\pi^\pm$, : (trigger)

$b\bar{B}$: → K^- + X (tag); → $\ell^+\ell^-$ +X (trigger)

$\bar{b}b$: → B + h^+ (tag), B → $\ell^+\ell^-$ + X (trigger)

(not very clean tag)

Trigger efficiencies for the hadronic final states are very much enhanced.

High tagging efficiency with good quality.

ATLAS and CMS

Central geometry and no vertex trigger

$\rightarrow$ high threshold values for the P_T trigger (~6 GeV)

=

Low b efficiency

LHCb

Forward geometry and with vertex trigger

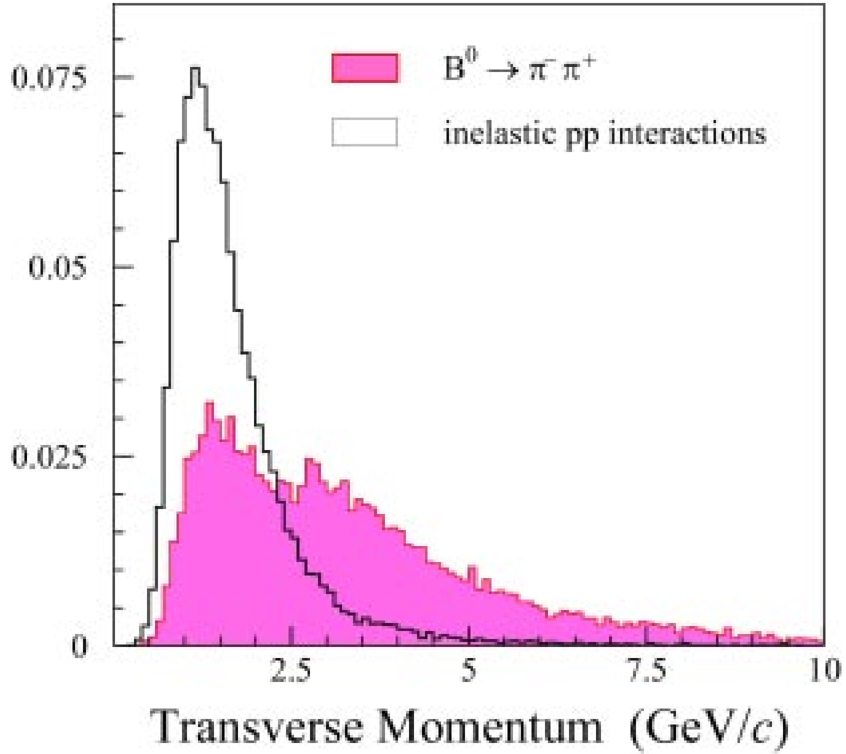
$\rightarrow$ moderate threshold values for the P_T trigger (1~2 GeV)

=

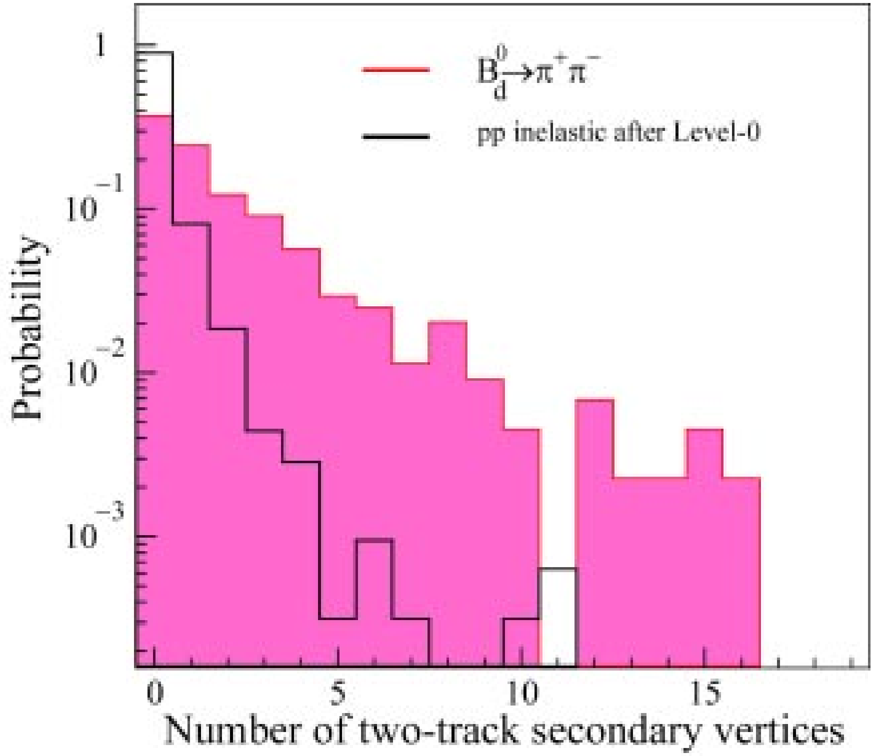
Higher b efficiency

LHCb Trigger

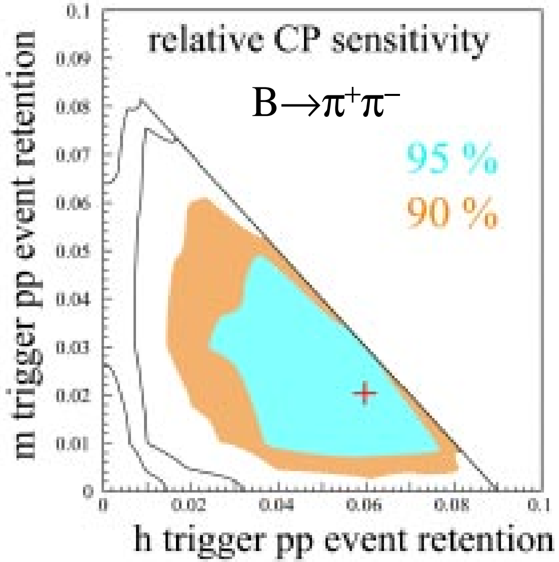
Level-0 Hadron



Level-1



Working point stability



Difference can be seen by…

$B_d \to \pi^+\pi^-$ + tag			
	ATLAS	CMS	LHCb
σ_m [MeV/c^2]	70	27	17
Annual yield	2.3k	0.9k	4.9k

$B_s \to J/\psi\ \phi$			
	ATLAS	CMS	LHCb
σ_τ [fs]	63	63	31

LHC contributions to CP violation

Improvement in statistics

useful B sample @ LHC in one year $\gtrsim$

Σ all previous B experiments by then

$B_d \rightarrow J/\psi\, K_S$ (ATLAS, CMS, LHCb) $\sigma(\sin 2\beta) < 0.01$

$B_d \rightarrow K^{*} \mu^{+}\mu^{-}$ (ATLAS, CMS, LHCb) 45k events/year LHCb

$B_d \rightarrow \pi^{+}\pi^{-}$ (LHCb, ATLAS???) ~5k flavour tagged/year

$B_d \rightarrow \rho\pi$ (LHCb) 100 flavour tagged $\rho^{0}\pi^{0}$/year ($Br = 10^{-6}$)

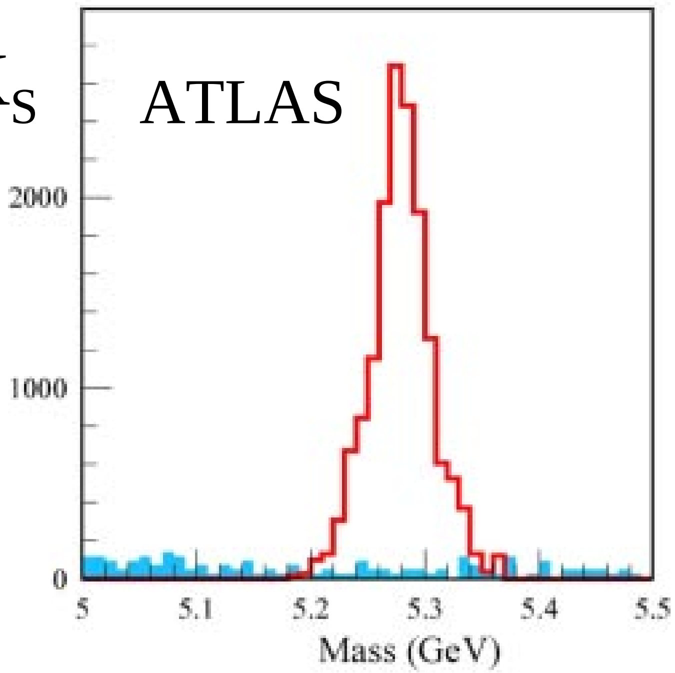
$B_d \rightarrow D^{*}\pi$ (LHCb) 340k flavour tagged $D^{*}\pi$/year

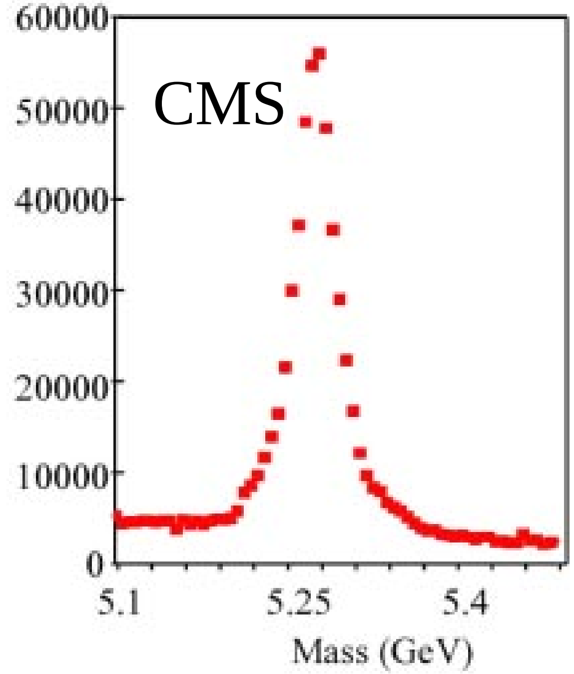
$B_d \rightarrow K^{\pm}\pi^{\mp}$ (LHCb)

$B_d \rightarrow \phi\, K_S$ (LHCb)

Up to one π^{0} in the final state.

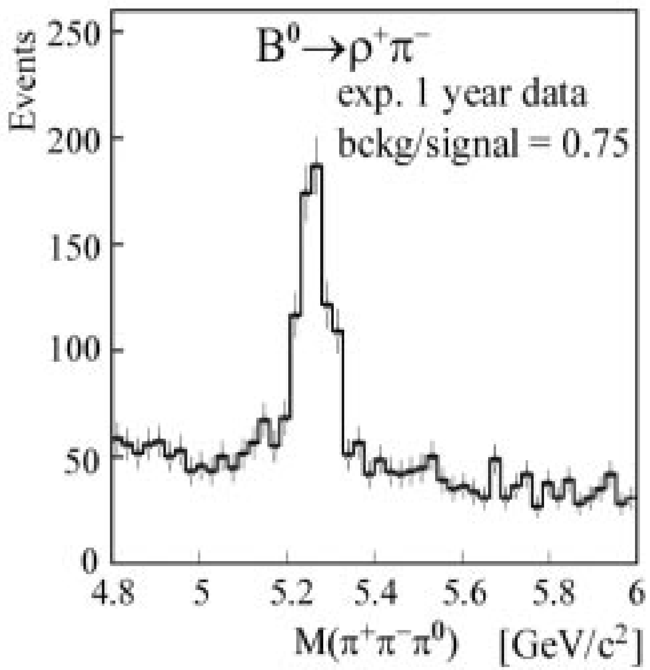
$B_d \rightarrow J/\psi K_S$





$B_d \rightarrow \rho^+\pi^-$

LHCb



New decay modes

$B_s \to J/\psi\,\phi$ (ATLAS, CMS, LHCb)

$B_s \to D_s^{\pm} K^{\mp}$ (LHCb)

$B_s \to K^{+} K^{-}$ (LHCb)

$B_s \to K^{\pm} \pi^{\mp}$ (LHCb)

$B_s \to \phi\,\phi$(LHCb)

Combination gives a model independent value of arg V_{ub} even with presence of new physics.

$\sigma_{\phi_3} < 10°$ in one year.

$|V_{ub}|$ will be well known from the B factory experiments by then.

(ρ, η)

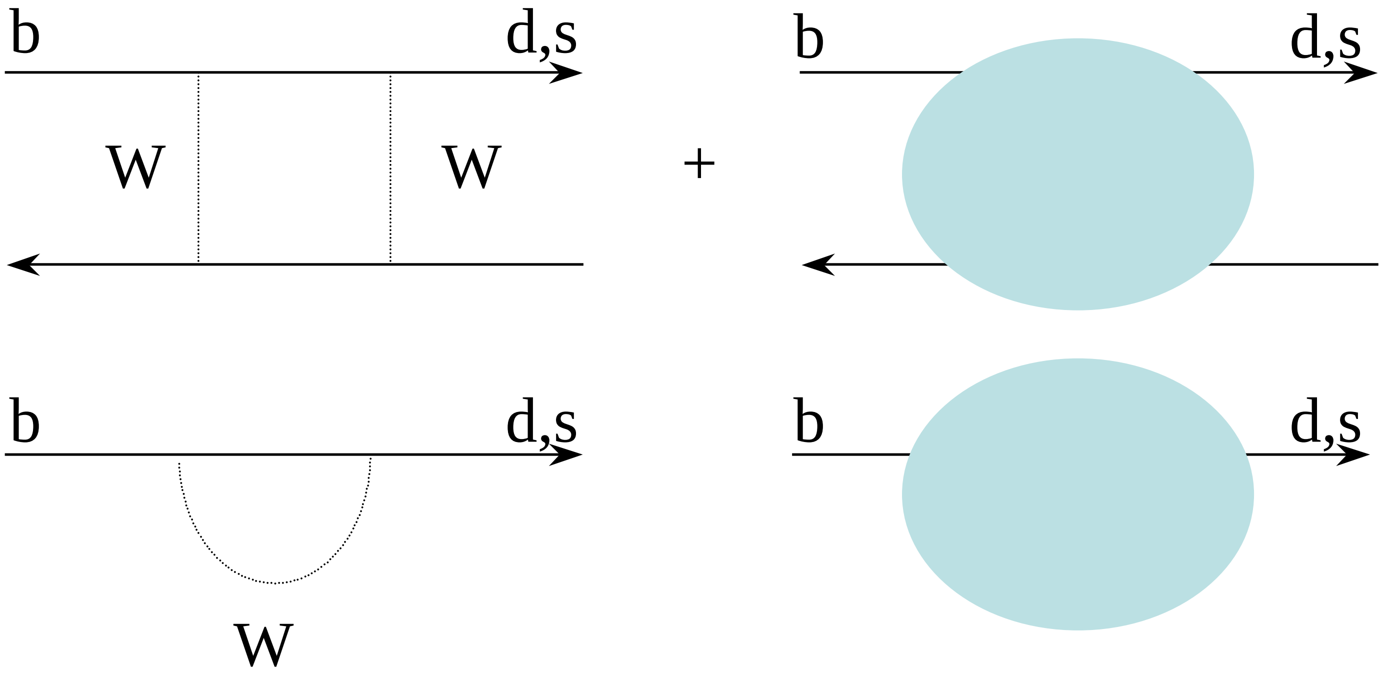
With LHCb in operation, **a model independent determination** of the CKM parameters is possible **even in a presence of New Physics**.

Effect due to **new physics can be isolated unambiguously**!!

Standard Model FCNC | New Physics FCNC

$B_{d,s}$-$\bar{B}_{d,s}$ oscillations

$b \to s,d$ penguin decays



No New Physics contribution to the Standard Model tree induced decay modes.

In addition...

very rare decays $Br < 10^{-8}$

$B_s \to \mu^+\mu^-$,	ATLAS	CMS	LHCb
Signal	9	7	11
Background	31	1	3.3

In one year with
$Br = 3.5\times10^{-9}$
$L =$
10^{33} (ATLAS,CMS)
2×10^{32} (LHCb)

forbidden in the Standard Model

$B_s \to e^\pm\mu^\mp$, $B_d \to e^\pm\mu^\mp$,
$\tau^\pm \to \mu^\pm\mu^\pm\mu^\mp$

LHCb (very preliminary): $\tau^\pm \to \mu^\pm\mu^\pm\mu^\mp$
upper limit of $< 1.8\times10^{-7}$ @ 90% CL
in one year @ $L = 2\times10^{32}$

Possible improvements for LHCb

Running with higher luminosity: 5×10^{32}
Dedicated trigger combinations:
Two or three high P_T muons with a relaxed requirement on the detached vertex.