# *LHCb status report*

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On behalf of the LHCb Collaboration

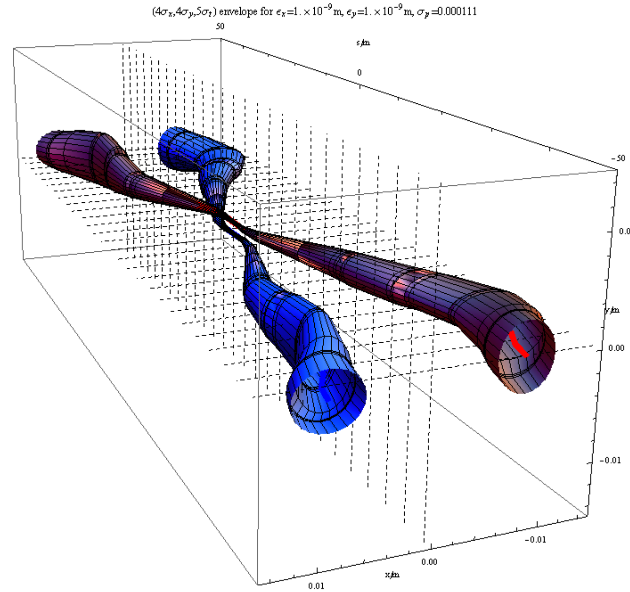
# Introduction

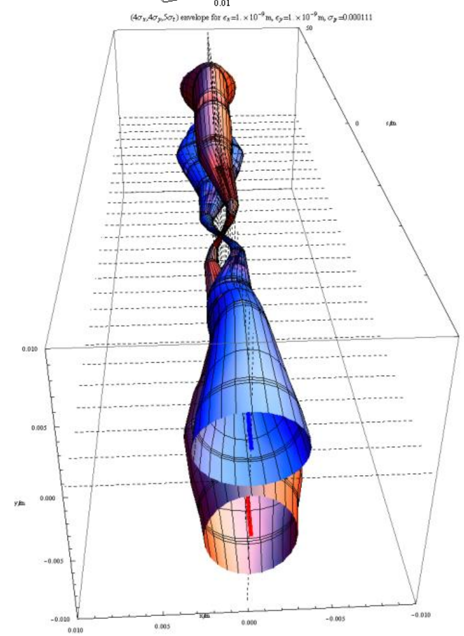
- Running conditions in 2012
  - Tilted beam planes
  - HLT improvements
- New results since last LHCC
- LHCb upgrade Framework TDR.

# *Data taking 2012*

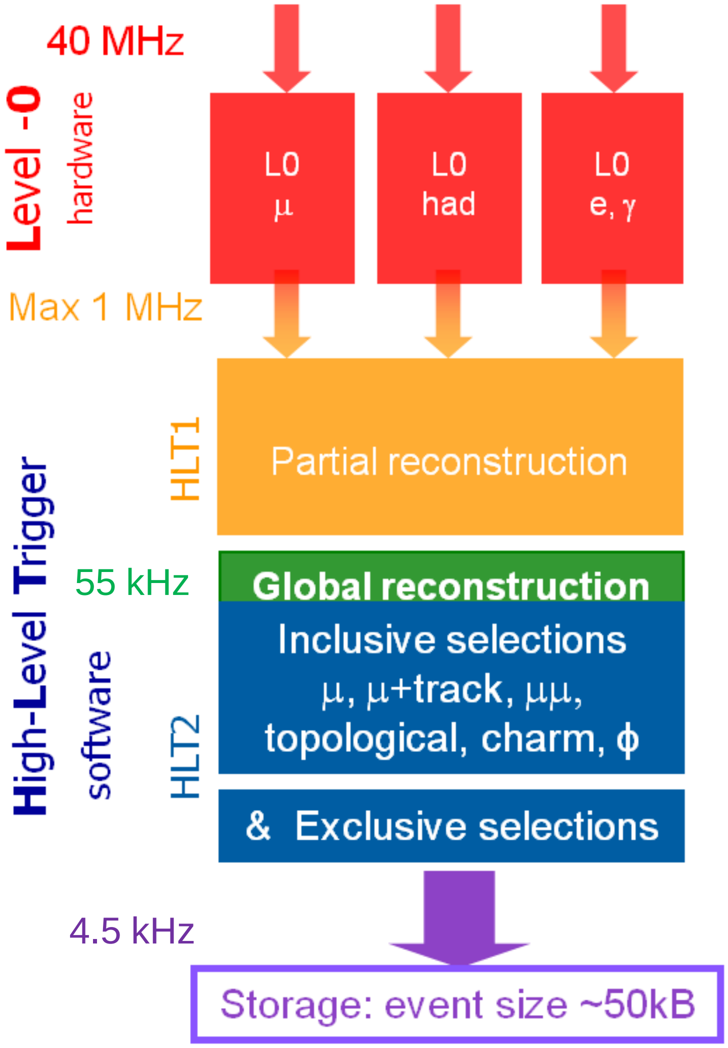
Several new aspects of operation in 2012:

- Running conditions $4 \times 10^{32}$ and
  1 MHz L0 rate (saturating the bandwidth)
- Deferred HLT trigger
- Tilted beam crossing-plane
  - Have exactly the same beam crossing angle with the two polarities, which improves the situation in terms of systematic uncertainties
  - Running smoothly, including magnet polarity changes
  - Thanks to the machine for setting  this up and commissioning it.





# Trigger 2012



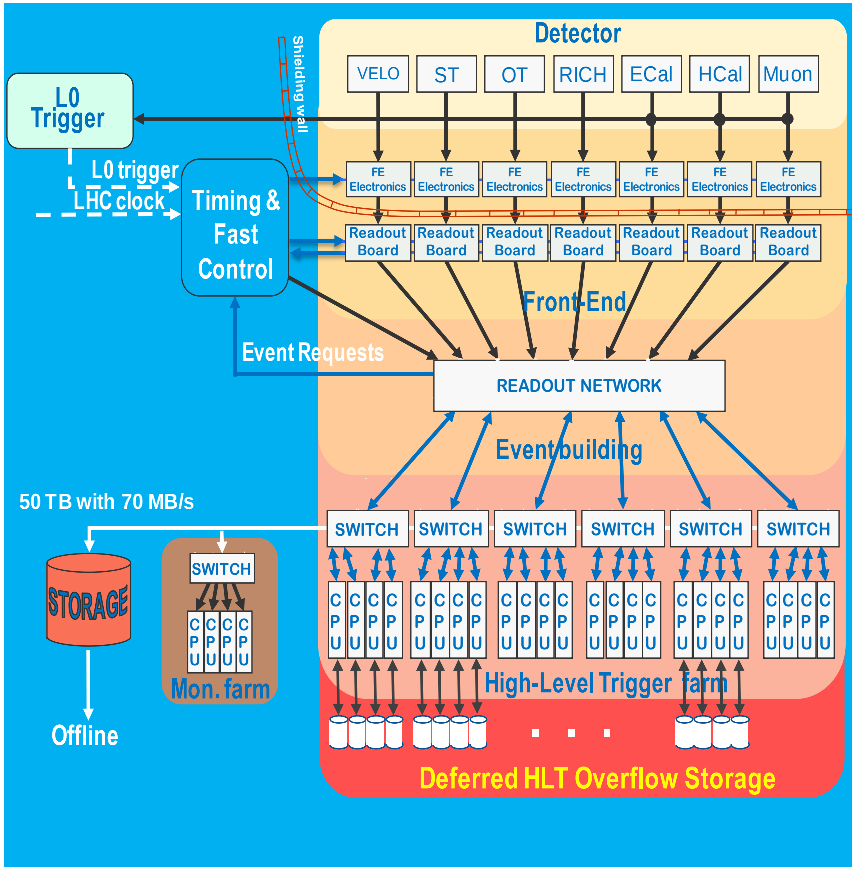

- Running conditions different than 2011
  - L = $4x10^{32}$ (vs $3.5x10^{32}$ last year)
  - 8 TeV vs 7 TeV (→ ~14% bigger bb xsection)

- HLT1 input rate closer to 1 MHZ (maximum bandwidth) than before (850KHz→950KHz)

- 10% more CPU power, algorithm improvements

- Deferred HLT…

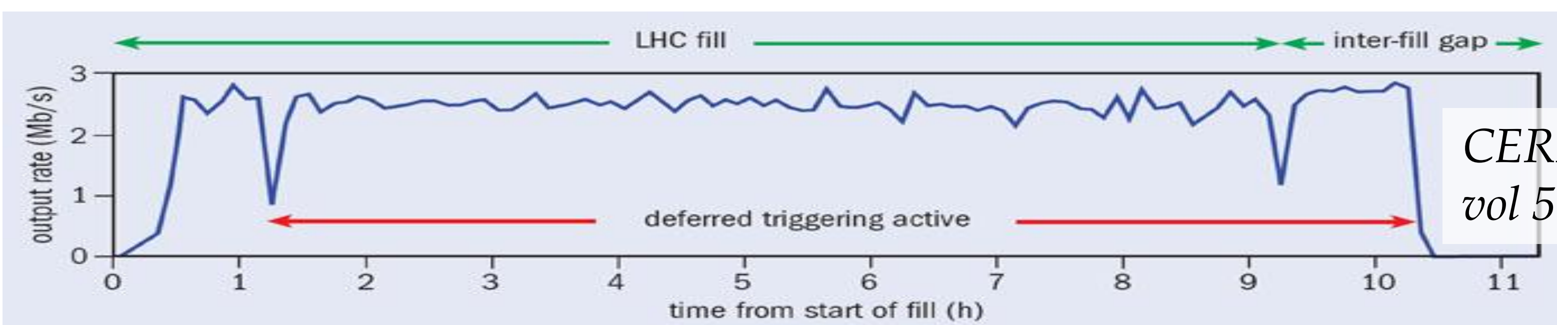
# *Deferred triggering*




- Delay the HLT triggering for ~5% (will be ~20% with new disks recently installed) of the L0 rate into the EFF.

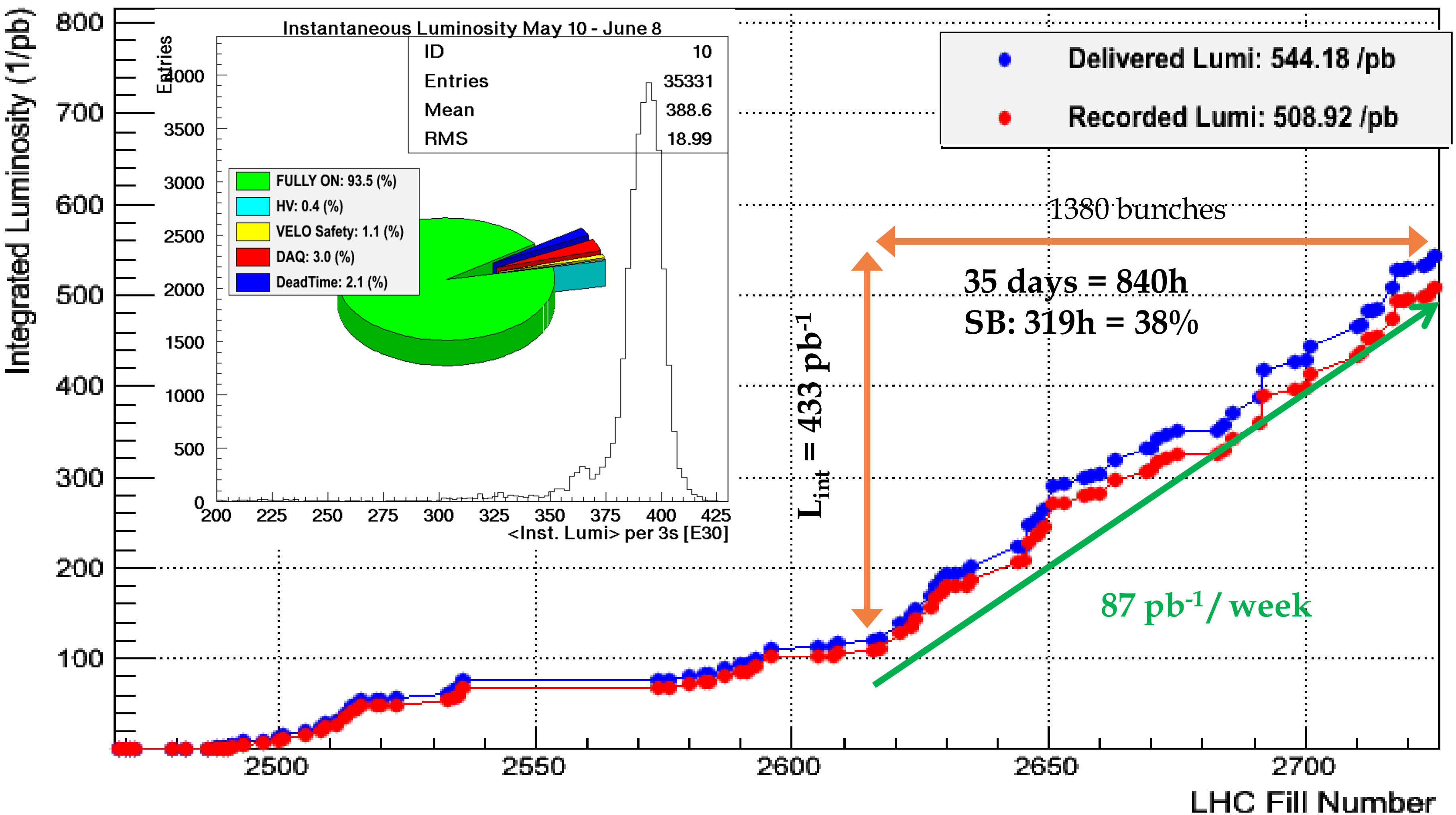
- When the eventbuilder detects that the HLT cannot process all the incoming events, they are written to the hard disk of the nodes in the EFF. Between fills, these events will be processed.

- Equivalent ~20% gain in CPU (but cheaper than buying 20% more CPU's)



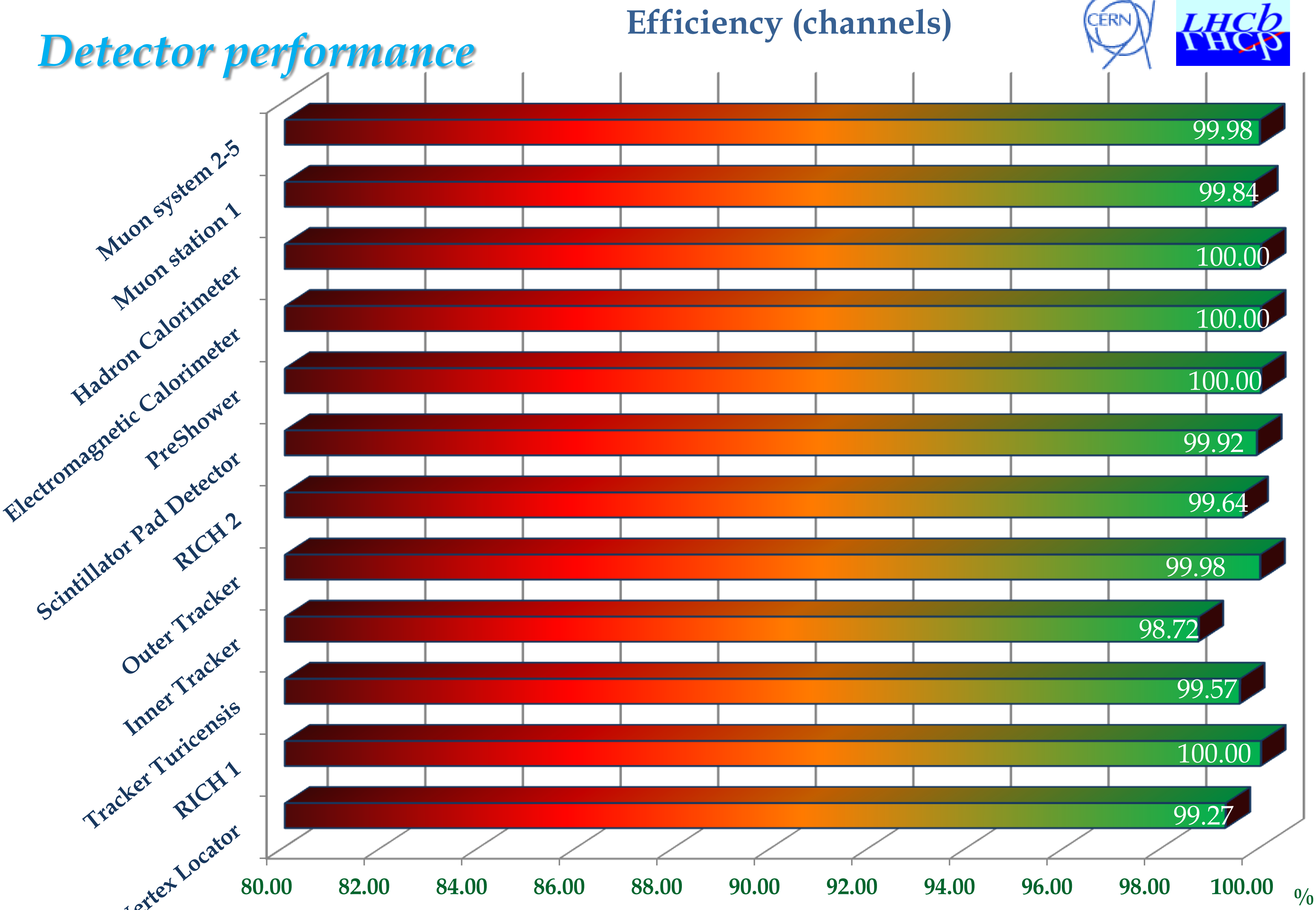

*CERN courier, vol 52, no. 5*

# *Integrated Luminosity – Status & Prospect*




2012 expectation: 1.0 $fb^{-1}$ + 0.5 $fb^{-1}$ (now) ~ 1.5$fb^{-1}$ delivered

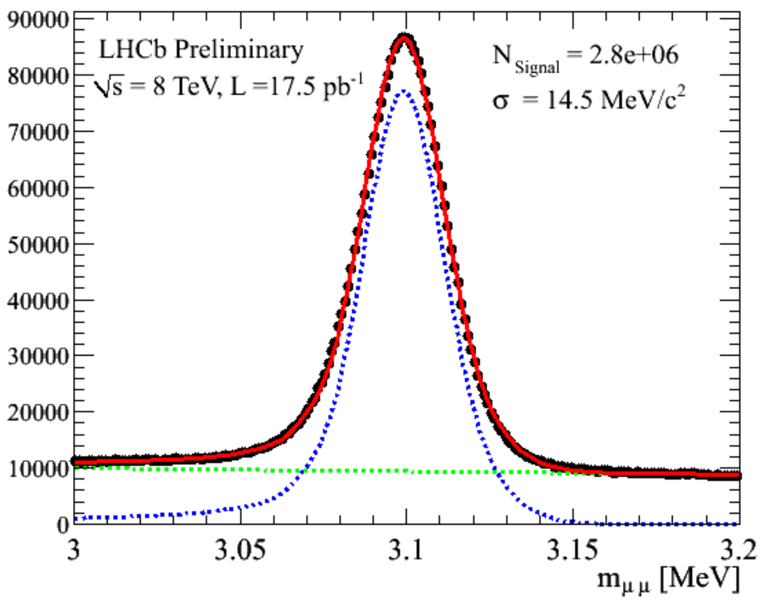
# *Detector performance*

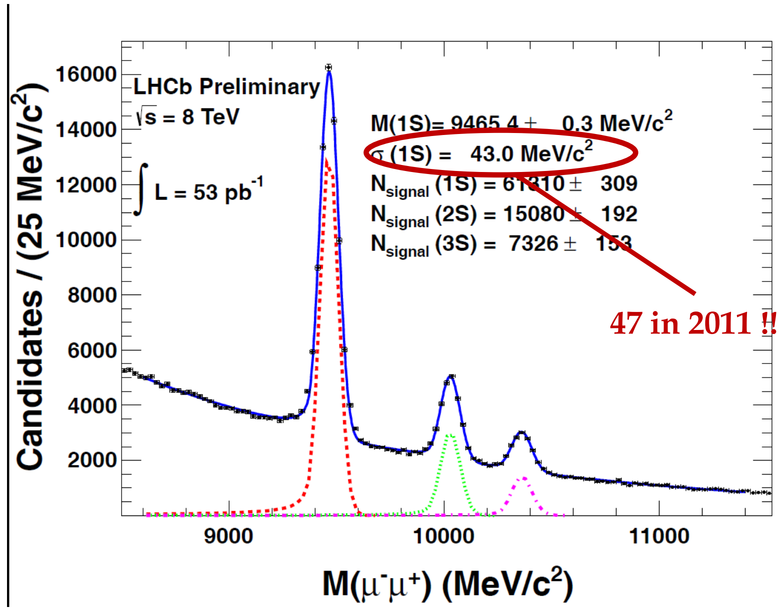


# *Detector performance*

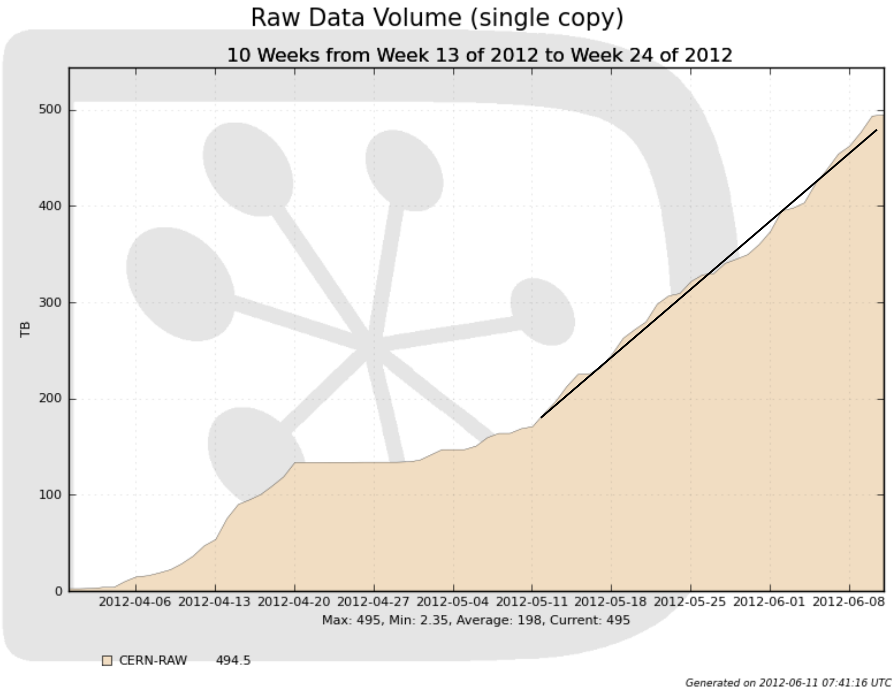
- LHCb performing well

- Preliminary studies in the show a possible improvement in the mass resolution in the Υ (43 MeV in 2012 vs 47 in 2011). The mass resolution found in the J/$\psi$ is the same.



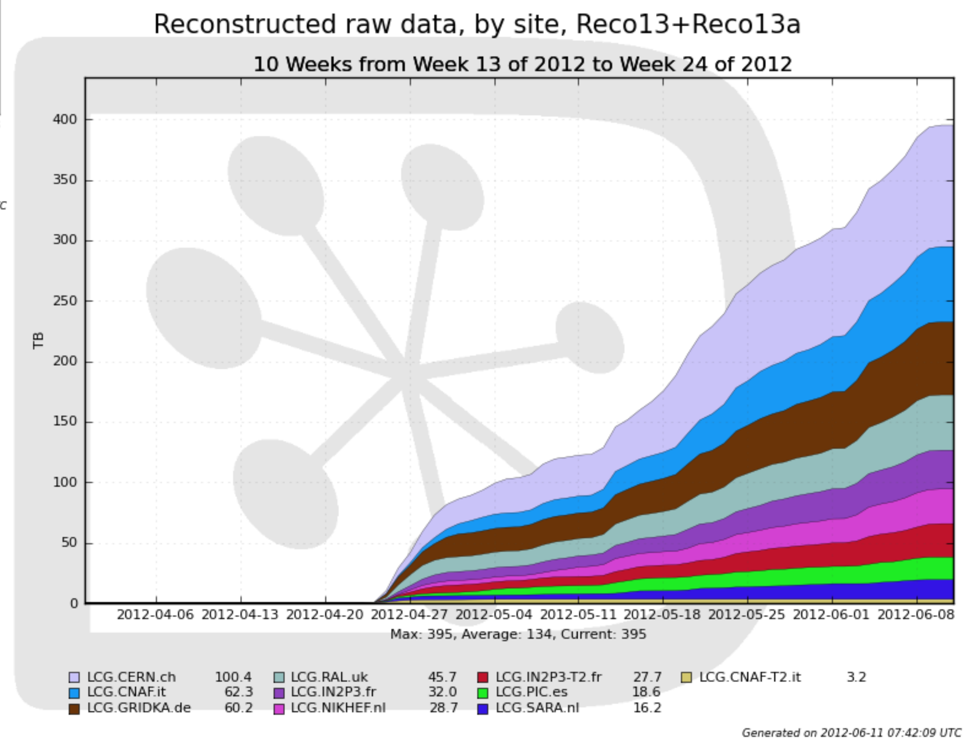



# *Data processing*




Raw data recording:
long term average rate : ~120 MB/s
during stable beam : ~300 MB/s

~1 TB per $pb^{-1}$




Reconstruction:
- Data reconstructed within ~5 days delay w.r.t data taking

# Physics results (papers)

- New results since the Winter Conferences, using 2011 / 2010 data

•*Measurement of the isospin asymmetry in $B \to K^{(*)}\mu^+\mu^-$ decays* (PAPER-2012-011)

•*Measurement of the branching fractions of charmless charged two-body decays of bottom hadrons* (PAPER-2012-002 )

•*Observation of excited $\Lambda_b$ baryons* (PAPER-2012-012 )

•*Measurement of relative branching fractions of B decays to $\psi(2S)$ and $J/\psi$ mesons* (PAPER-2012-010 )

•*Inclusive W and Z production in the forward region at $\sqrt{s}$ = 7 TeV* (PAPER-2012-008)

•*Study of $D_{sJ}$ decays to $D^+K_S$ and $D^0K^+$ final states in pp collisions at $\sqrt{s}$=7 TeV* (PAPER-2012-016 )

•*Measurement of the $D^+_s$-$D^-_s$ production asymmetry in 7 TeV pp collisions* (PAPER-2012-009)

# Physics results (conference reports)

- New results since the Winter Conferences, using 2011 / 2010 data

•*Search for the rare decays* $B_{s(d)} \to \mu\mu$ *at the LHC with the ATLAS, CMS, and LHCb experiments* (CONF-2012-017)

•*Search for the lepton flavour violating decay* $\tau^- \to \mu^+\mu^-\mu^-$ (CONF-2012-015 )

•*Search for Higgs-like bosons decaying into long-lived exotic particles* (CONF-2012-014)

•*Low mass Drell-Yan production in the forward region at* $\sqrt{s} = 7$ *TeV* (CONF-2012-013 )

•*Measurement of jet production in* $Z^0/\gamma^* \to \mu^+\mu^-$ *events at LHCb in s√=7 TeV pp collisions* (CONF-2012-016 )

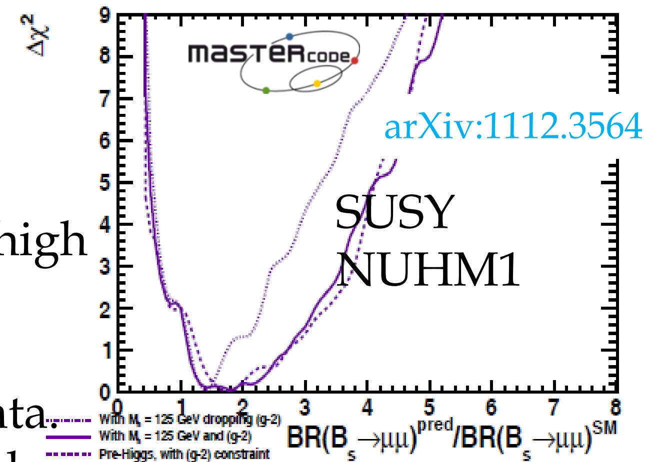
•*Measurement of the cross-section for* $Z^0 \to e^+e^-$ *production in pp collisions at* $\sqrt{s} = 7$ *TeV* (CONF-2012-011)

•*Measurement of the forward energy flow in pp collisions at* $\sqrt{s} = 7$ *TeV with the LHCb experiment* (CONF-2012-012 )

# $B_{s,d}\to\mu\mu$ LHC combination

- BR(Bs→μμ) very small in the SM
  - BR(Bs→μμ) = $(3.2\pm0.2)\times10^{-9}$, defined at t=0
  - time integrated is (in the SM) ~10% higher (see arXiv:1204.1737)

- Departures of SM are possible, specially in SUSY at high tanβ, regardless of other experimental constraints




- Current world best limit $4.5\times10^{-9}$ from LHCb 2011 data. Also, LHCb observes a small excess (~1 sigma) w.r.t bkg only

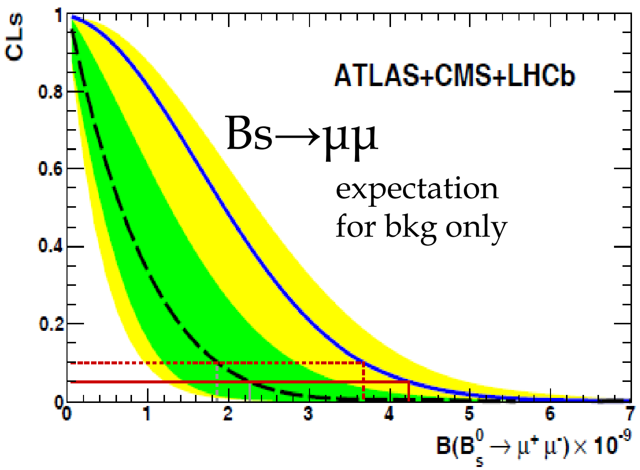
- CMS has similar sensitivity, slightly bigger excess (p-value of ~11%)

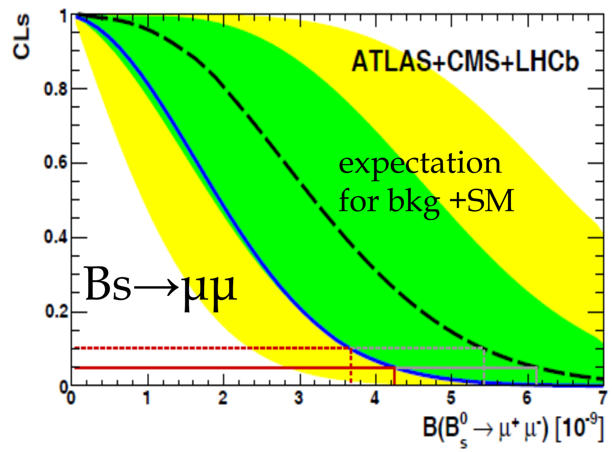
| Limit 95% C.L. $(10^{-9})$ | ATLAS | CMS | LHCb 2010 | LHCb 2011 |
|---|---|---|---|---|
| Bkg Only | 23 | (3.6) | 65 | 3.4 |
| Bkg+SM | | 8.4 | | 7.2 |
| Obs | 22 | 7.7 (7.2) | 56 | 4.5 |

Combine all these results into a single measurement

# $B_{s,d}\to\mu\mu$ LHC combination

LHCb-CONF-2012-017
CMS-PAS-BPH-12-009
ATLAS-COM-CONF-2012-090




- LHC combination sets world best limits on BR(Bs→μμ), strongly constraining SUSY

- Expected limit improves by 32% with respect to LHCb alone (gain in sensitivity, even if the gain in the observed limit seems smaller)
- Low p-value (1-CLb~5%) for bkg-only, improves over CMS alone (11%) but still not enough to claim observation
- Combination for BR($B_d\to\mu\mu$) yields $8.1\times10^{-10}$

| Limit 95% C.L. ($10^{-9}$) | ATLAS | CMS | LHCb 2010 | LHCb 2011 | Comb. | Improv. vs LHCb |
|---|---|---|---|---|---|---|
| Bkg Only | 23 | (3.6) | 65 | 3.4 | 2.3 | 32% |
| Bkg+SM | | 8.4 | | 7.2 | 6.1 | 15% |
| Obs | 22 | 7.7 (7.2) | 56 | 4.5 | 4.2 | 7% |

# *Isospin asymmetries in B→K(*)μμ*

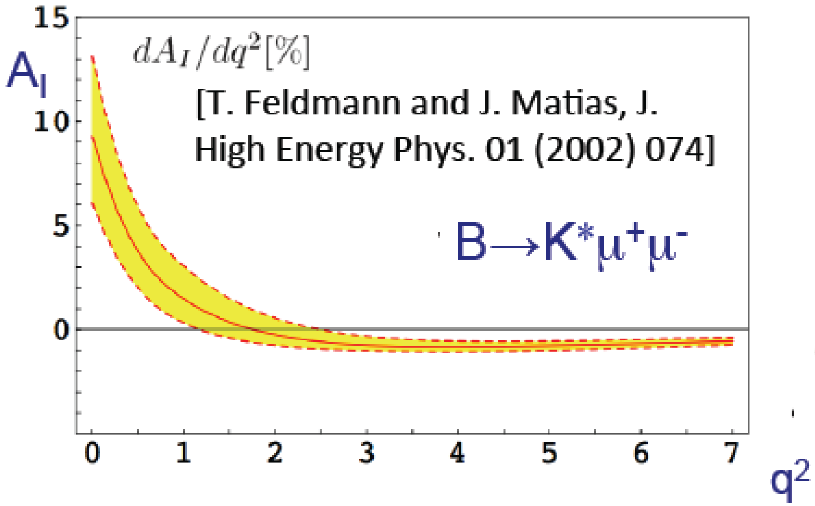
PAPER-2012-011

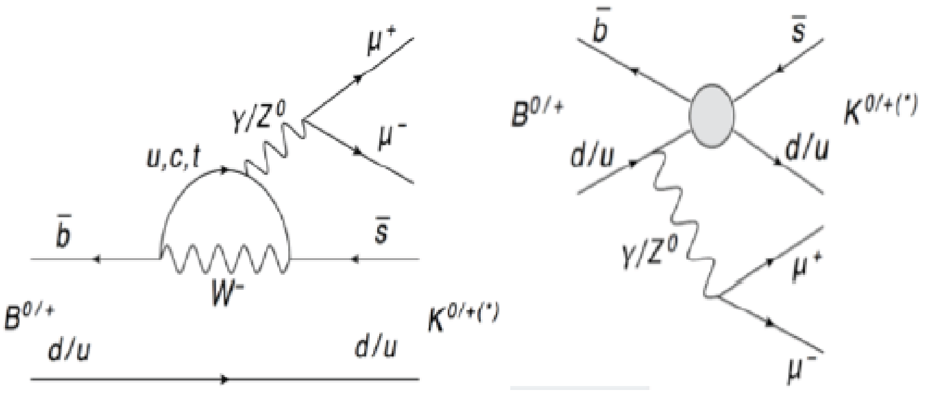
- Measurement of the Isospin asymmetry of $B \to K^{(*)}\mu\mu$ in bins of the dimuon mass squared ($q^2$).

$$A_I = \frac{\mathcal{B}(B^0 \to K^{(*)0}\mu^+\mu^-) - \frac{\tau_0}{\tau_+}\mathcal{B}(B^\pm \to K^{(*)\pm}\mu^+\mu^-)}{\mathcal{B}(B^0 \to K^{(*)0}\mu^+\mu^-) + \frac{\tau_0}{\tau_+}\mathcal{B}(B^\pm \to K^{(*)\pm}\mu^+\mu^-)}$$

- In SM expected to be close to zero

- Analyzed 1.0 $fb^{-1}$ of data

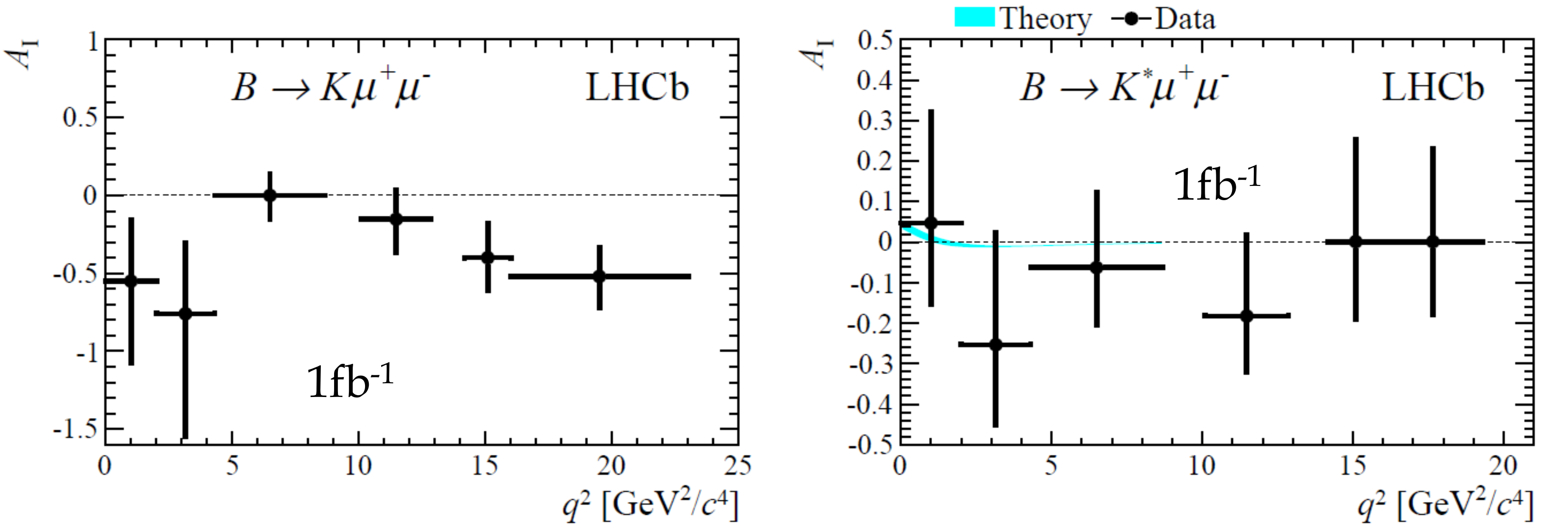


# *Isospin asymmetries in B→K(*)μμ*

PAPER-2012-011

- B→K*μμ
  - •Consistent with previous measurements (BELLE, BaBar, CDF)
  - •Consistent with zero
- B→Kμμ
  - •Consistent with previous measurements (BELLE, BaBar, CDF)
  - •**Inconsistent with zero at ~4.4 sigma.** No clear explanation yet.



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PAPER-2012-011

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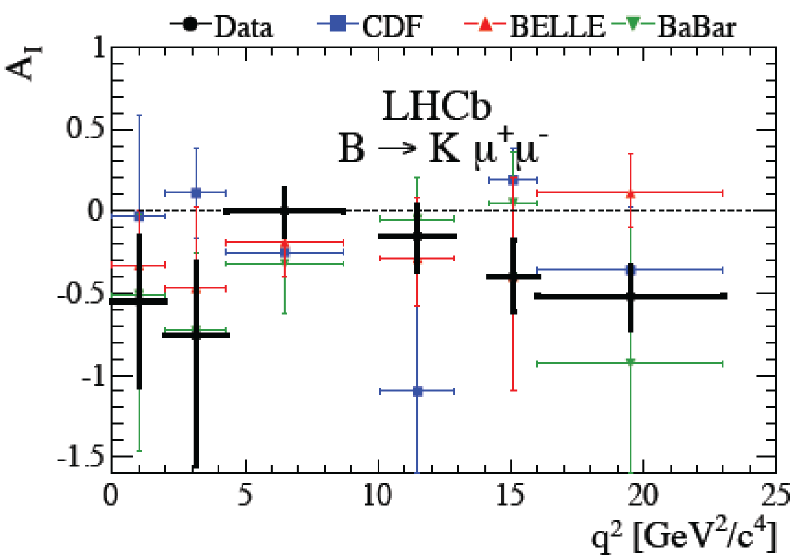
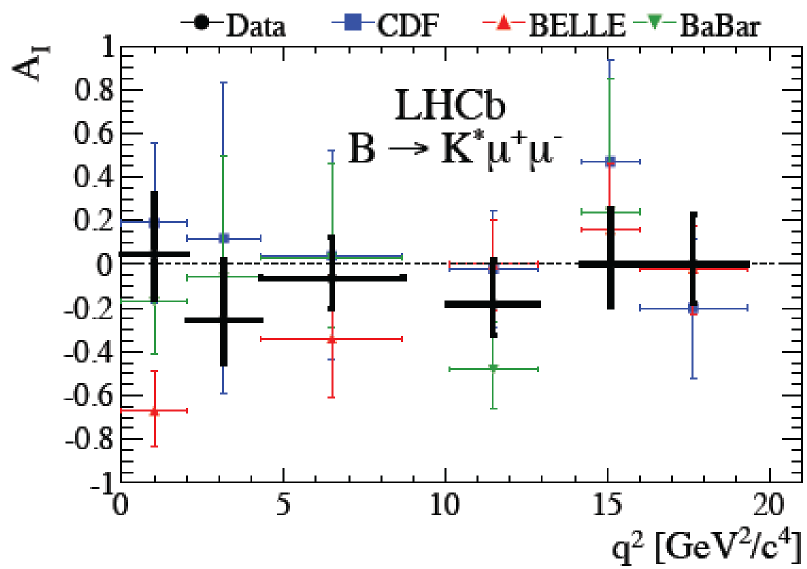


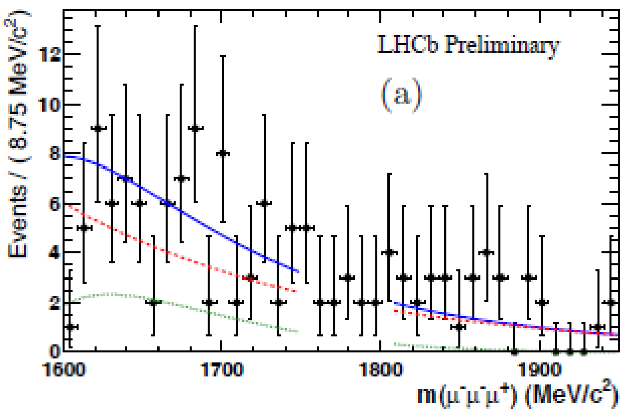
# $\tau \to \mu\mu\mu$

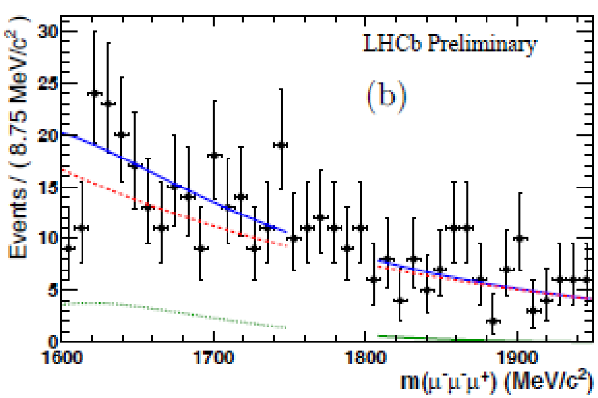
LHCb-CONF-2012-015

- Lepton Flavour Violating decay

  •BR O($10^{-54}$) in SM + neutrino oscillations.

- Sensitive to NP scenarios (SUSY, LHT…), enhancements up to $10^{-8}$ are possible.




- Current limits

  •BR($\tau \to \mu\mu\mu$) < $3.3 \times 10^{-8}$ @ 90% CL (BaBar)
  •BR($\tau \to \mu\mu\mu$) < $2.1 \times 10^{-8}$ @ 90% CL (Belle)

- LHCb set an upper limit at the same order, with first $fb^{-1}$:

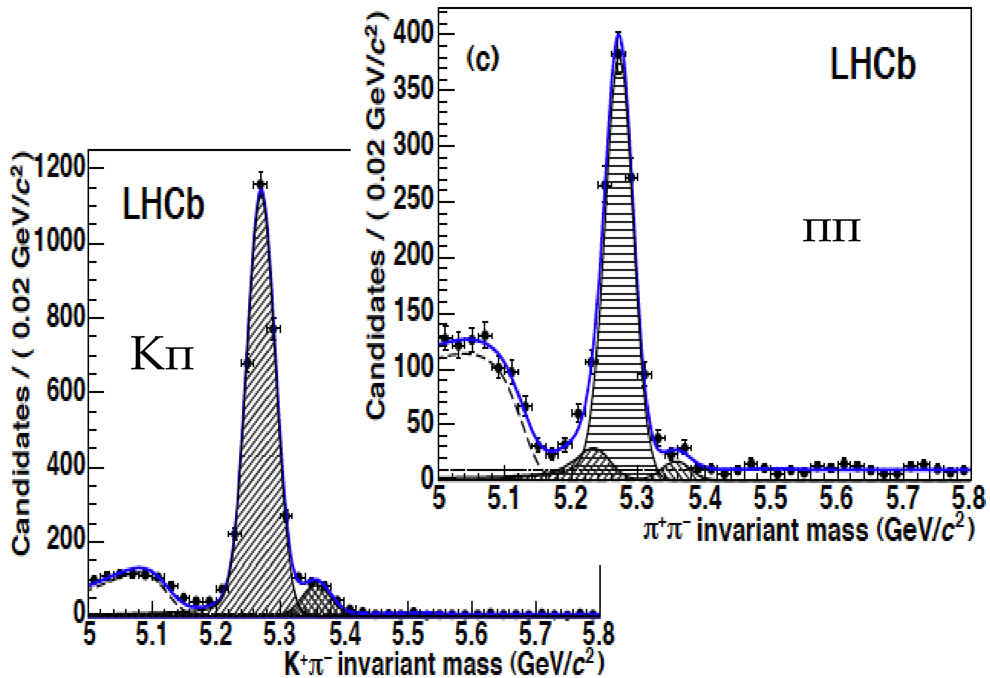
  **•BR($\tau \to \mu\mu\mu$) < $6.3(7.8) \times 10^{-8}$ @ 90(95)% CL (LHCb)**

- Excellent prospects for next years (+upgrade)

# $H_b \to hh'$ Branching Fractions

LHCb-PAPER-2012-002

- Analysis using 370pb$^{-1}$
- Fit to the mass lineshape in different daughters' mass hypotheses and for different PID cuts, taking into account simultaneously all the $H_b \to hh$ modes.
- World first observation of the decay Bs $\to \pi^+\pi^-$ at a branching fraction of $10^{-6}$.




$$\begin{aligned}
\mathcal{B}\left(B^0 \to \pi^+\pi^-\right) &= (5.08 \pm 0.17 \pm 0.37) \times 10^{-6}, \\
\mathcal{B}\left(B_s^0 \to K^+K^-\right) &= (23.0 \pm 0.7 \pm 2.3) \times 10^{-6}, \\
\mathcal{B}\left(B_s^0 \to \pi^+K^-\right) &= (5.38 \pm 0.44 \pm 0.62) \times 10^{-6}, \\
\mathcal{B}(B^0 \to K^+K^-) &= (0.11\,^{+0.05}_{-0.04} \pm 0.06) \times 10^{-6}, \\
\mathcal{B}(B_s^0 \to \pi^+\pi^-) &= (0.95\,^{+0.21}_{-0.17} \pm 0.13) \times 10^{-6},
\end{aligned}$$

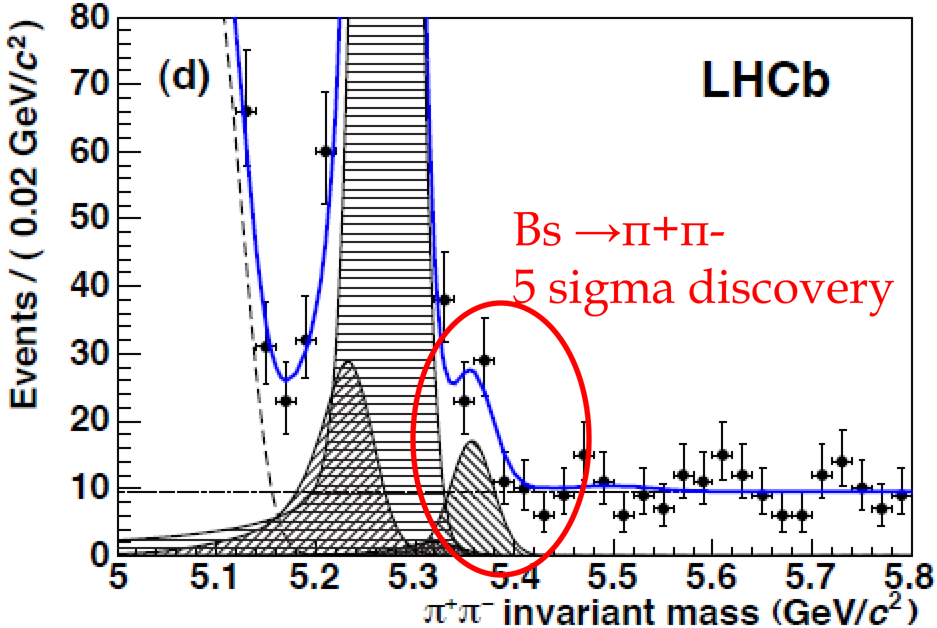
# $H_b \rightarrow hh'$ Branching Fractions

LHCb-PAPER-2012-002

- Analysis using 370$pb^{-1}$

- Fit to the mass lineshape in different daughters' mass hypotheses and for different PID cuts, taking into account simultaneously all the $H_b \rightarrow hh$ modes.

- World first observation of the decay Bs $\rightarrow \pi^+\pi^-$ at a branching fraction of $10^{-6}$.

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$$\mathcal{B}(B^0 \rightarrow K^+K^-) = (0.11\,^{+0.05}_{-0.04} \pm 0.06) \times 10^{-6},$$
$$\mathcal{B}(B_s^0 \rightarrow \pi^+\pi^-) = (0.95\,^{+0.21}_{-0.17} \pm 0.13) \times 10^{-6},$$

# *Observation of excited b baryons*

- **First observation** of two narrow states in the $\Lambda_b\pi\pi$ mass spectrum,

$\Lambda_b^{*0}(5912)$ (16.4 ± 4.7 events , **4.9σ**) and $\Lambda_b^{*0}(5920)$ (49.5 ± 7.9 events , **10σ**).

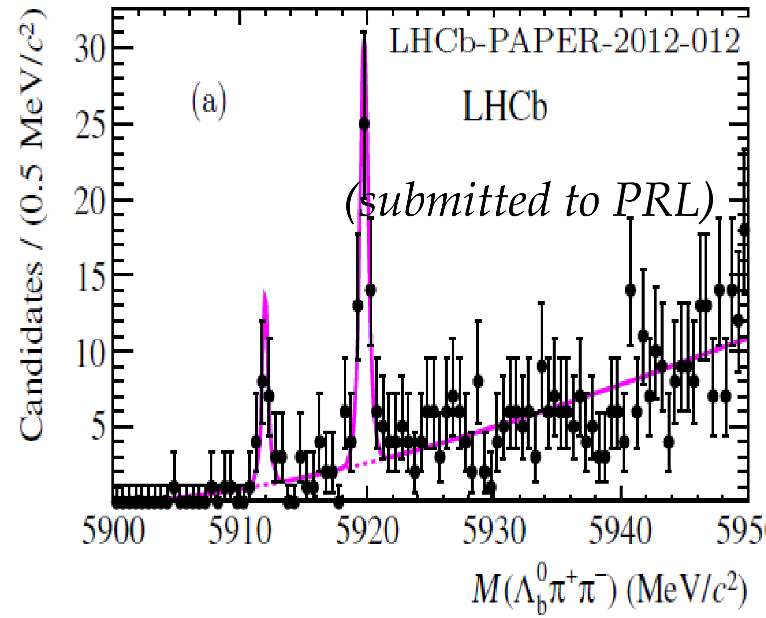
- With masses:

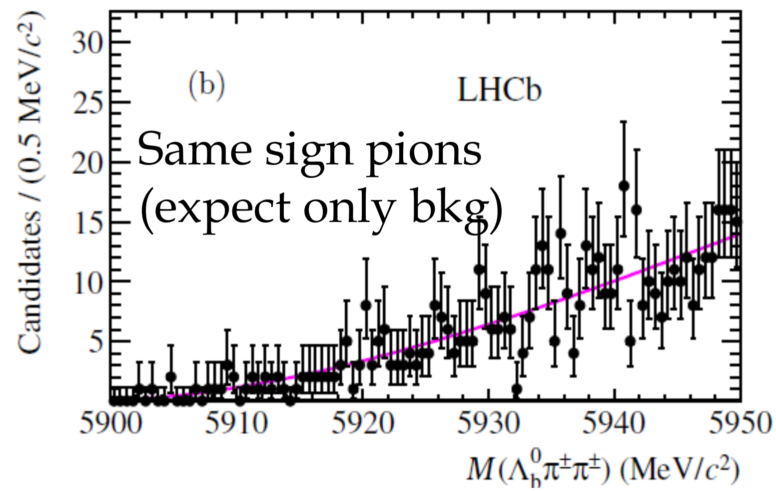
$$M_{\Lambda_b^{*0}(5912)} = 5911.95 \pm 0.12 \pm 0.03 \pm 0.66\,\mathrm{MeV}/c^2,$$
$$M_{\Lambda_b^{*0}(5920)} = 5919.76 \pm 0.07 \pm 0.02 \pm 0.66\,\mathrm{MeV}/c^2,$$

- Last error (dominant) comes from knowledge of $\Lambda_b$ mass

- We also provide limits for the widths. @95% CL:

$$\Gamma_{\Lambda_b^{*0}(5912)} < 0.82\ \mathrm{MeV}$$
$$\Gamma_{\Lambda_b^{*0}(5920)} < 0.71\ \mathrm{MeV}$$



# *Hadronic production of $D^*_{sJ}$*

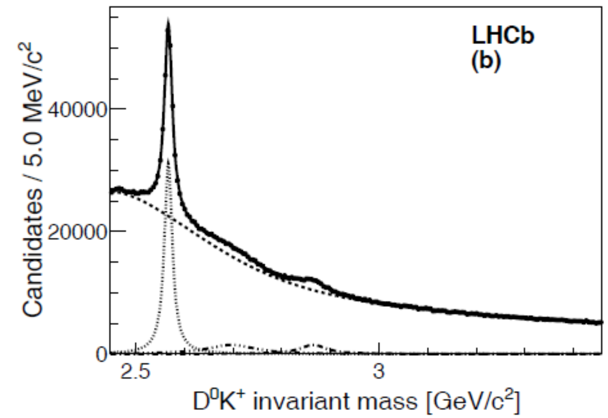
LHCb-PAPER-2012-016

- LHCb also performed first observation of $D^*_{s1}(2710)^+$ and $D^*_{sJ}(2860)^+$ hadronic production

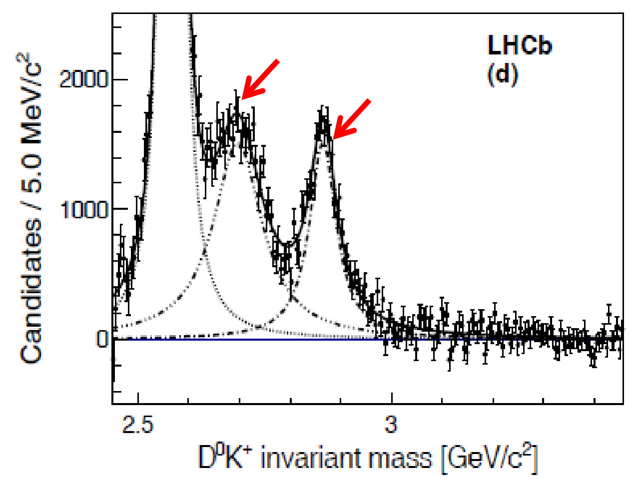
- Provide also masses and widths:

$$m(D^*_{s1}(2710)^+) = (2709.4 \pm 1.9_{\rm stat} \pm 4.5_{\rm syst})\ {\rm MeV}/c^2,$$
$$\Gamma(D^*_{s1}(2710)^+) = (121.7 \pm 7.3_{\rm stat} \pm 12.1_{\rm syst})\ {\rm MeV},$$

$$m(D^*_{sJ}(2860)^+) = (2866.7 \pm 1.0_{\rm stat} \pm 6.3_{\rm syst})\ {\rm MeV}/c^2,$$
$$\Gamma(D^*_{sJ}(2860)^+) = (64.5 \pm 3.2_{\rm stat} \pm 6.6_{\rm syst})\ {\rm MeV}.$$



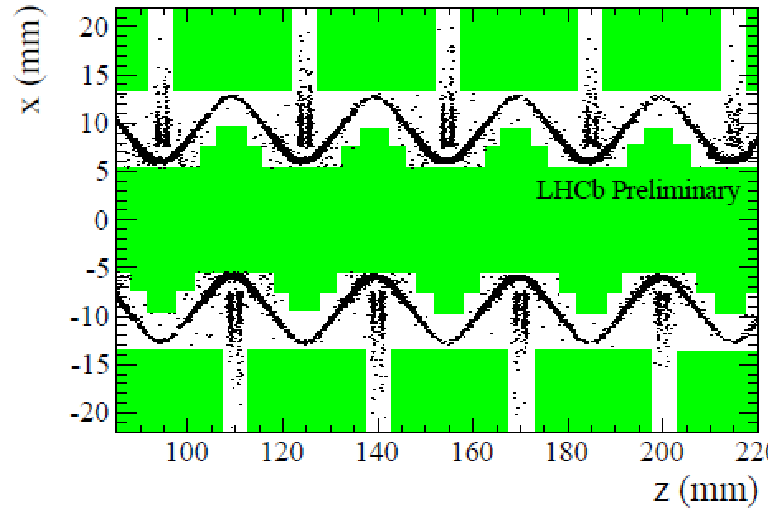

**Bkg subtraction**

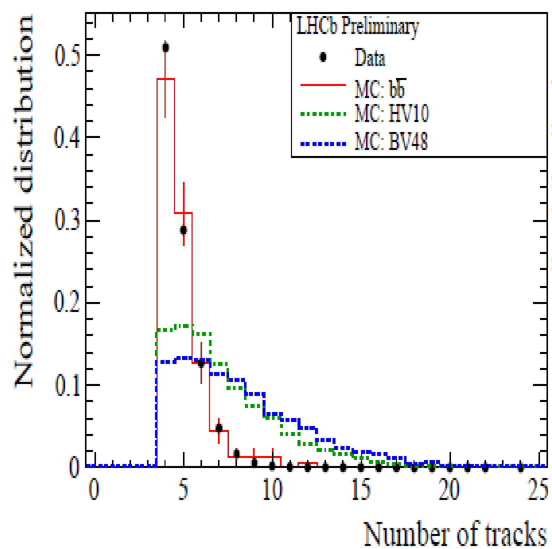


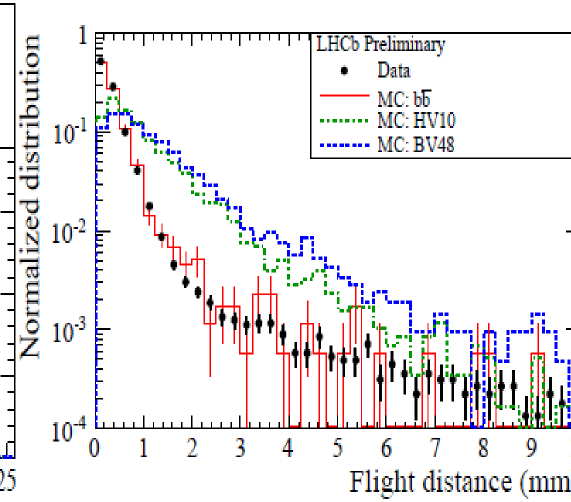
# *Higgs boson like objects to long lived particles*

LHCb-CONF-2012-014

- Used 36 $pb^{-1}$ of 2010 data
- The search covers lifetimes from 3 to 25 ps and Higgs masses of 100 to 125 GeV
- Considers Baryon number violation (BV) and Hidden Valley (HV) models
- Selection designed to remove bkg from material interactions and bb events



# *Higgs boson like objects to long lived particles*

LHCb-CONF-2012-014

- 0 observed events. Report upper limits on cross section depending on the masses and lifetimes of the involved particles.

- Used Feldman-Cousins unified approach

- Will update with more statistics

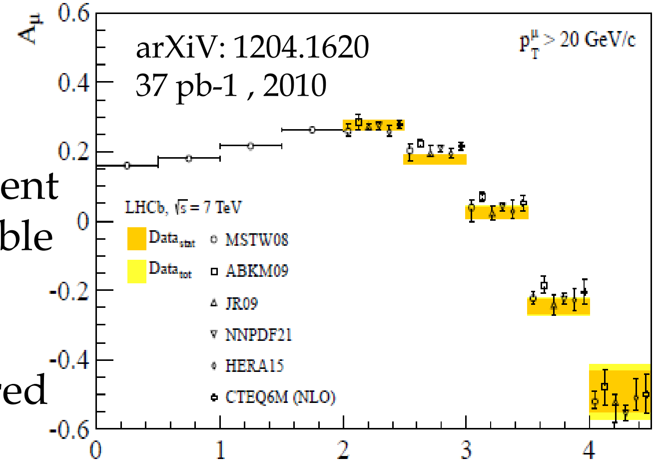
| $m_{LLP}$ | 30 | 35 | 40 | 48 | 55 |
|---|---|---|---|---|---|
| $m_{h^0}$ | | | | | |
| 100 | 101 | 58 | 44 | 58 | |
| 105 | 100 | 75 | 44 | 39 | |
| 110 | 132 | 75 | 56 | 34 | |
| 114 | 128 | 91 | 47 | 32 | 46 |
| 120 | 148 | 93 | 58 | 34 | 31 |
| 125 | 179 | 90 | 61 | 41 | 29 |

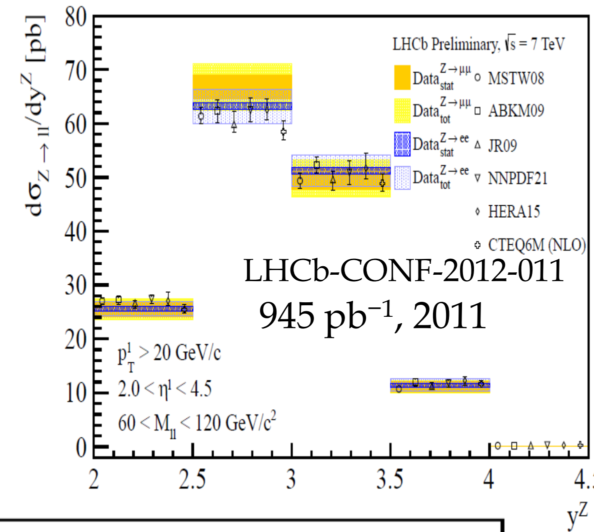
| $m_{LLP}$ | 30 | 35 | 40 | 48 | 55 |
|---|---|---|---|---|---|
| $\tau_{LLP}$ | | | | | |
| 3 | 210 | 156 | 136 | 168 | 410 |
| 5 | 145 | 101 | 68 | 58 | 137 |
| 10 | 129 | 91 | 47 | 32 | 46 |
| 15 | 155 | 90 | 49 | 31 | 33 |
| 20 | 131 | 93 | 63 | 32 | 31 |
| 25 | 142 | 100 | 61 | 34 | 25 |

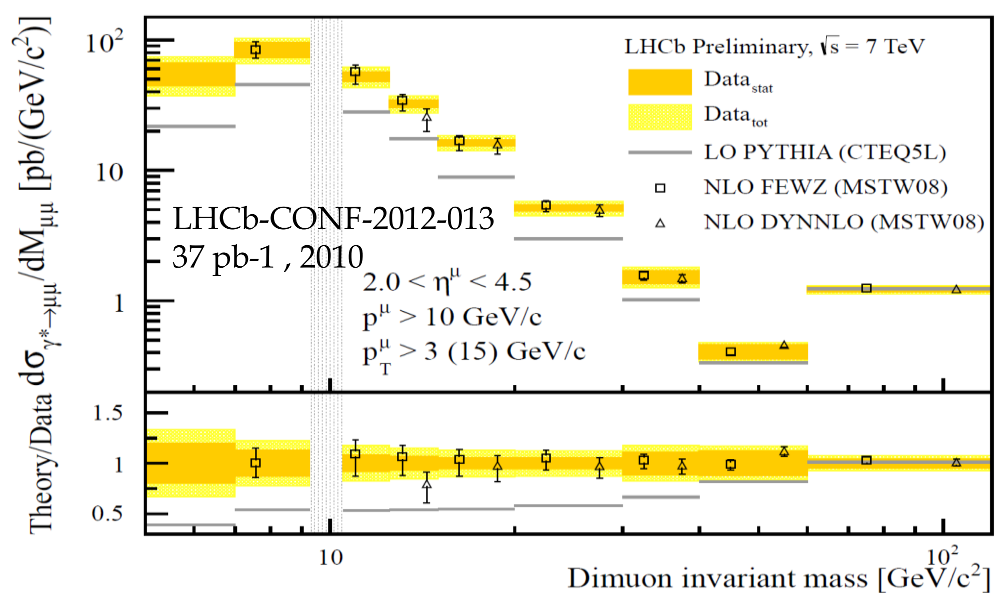
Table 5: 95 % CL upper limits on the cross-section for the production of a Higgs boson in the BV model, as a function of the LLP and Higgs masses for a LLP lifetime of 10 ps (left), and as a function of the LLP mass and lifetime for a Higgs mass of 114 GeV/$c^2$ (right). Cross-sections, masses and lifetimes are given in pb, GeV/$c^2$ and ps, respectively.

# *Electroweak measurements*

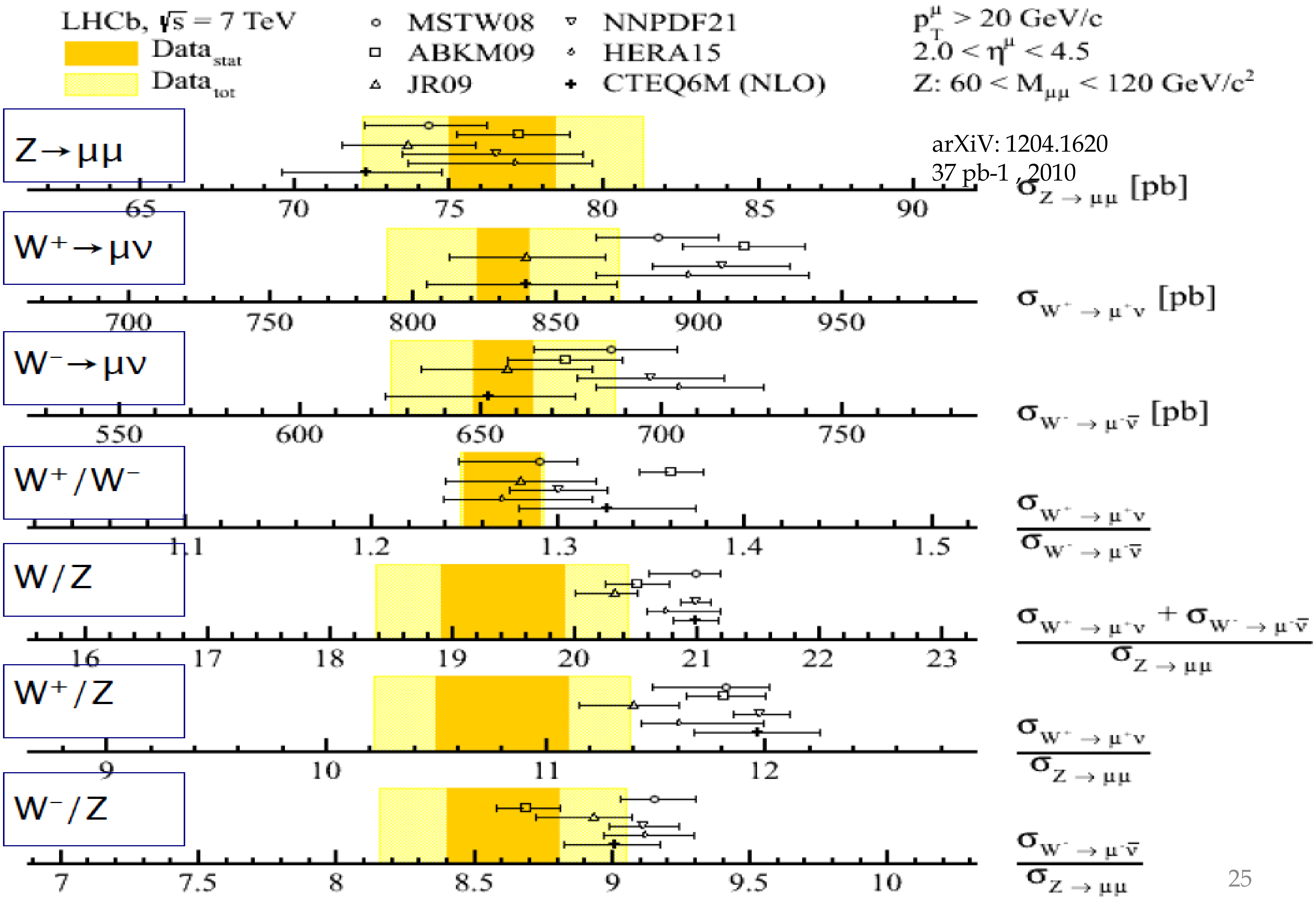
- LHCb has an unique kinematic range down to $x=8\times10^{-6}$
- First measurements of W/Z productions at LHCb in agreement with NNLO. Precision comparable to theory uncertainties
- Ratio W+/W- xsection measured 1.7% accuracy
- First measurements of low mass D-Y production at M>5 GeV
- First measurement of Z+jet production
- Will update with more statistics
- Measurement of Z→ee (~1fb$^{-1}$)



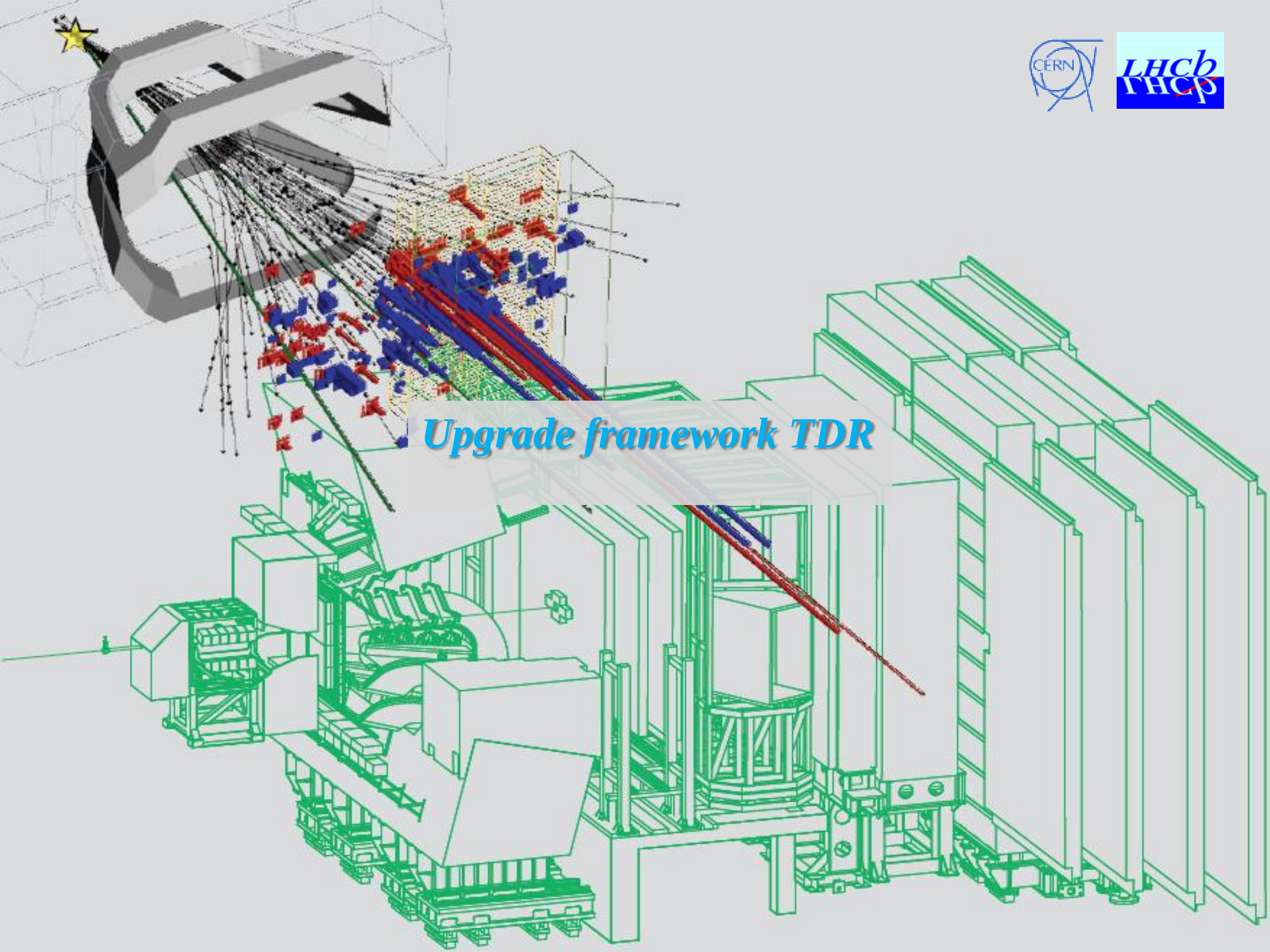



# *Electroweak measurements*




arXiV: 1204.1620
37 pb-1 , 2010

# *Upgrade framework TDR*



# *Introduction*

CERN/LHCC 2012-007
(LHCb TDR 12)

- LHCb planning to upgrade the detector to 40 MHz readout with a very flexible software trigger, improving signal annual yields by factor 10(muons)-20(hadrons) compared to 2011.

- Will operate at leveled luminosity of up to $2x10^{33}$, requiring therefore a peaking luminosity of up to $\sim10^{34}$ from the LHC

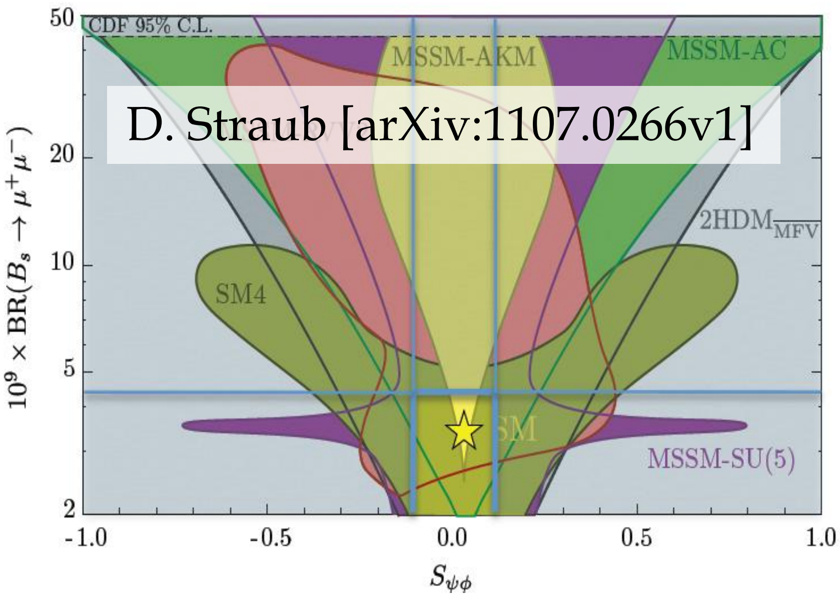
- Before proceeding to subsystem TDR's, we produced a Framework TDR, providing schedules, costs and participating institutes.

- Subsystems are progressing well towards TDR, for some subsystems investigating best possible technologies

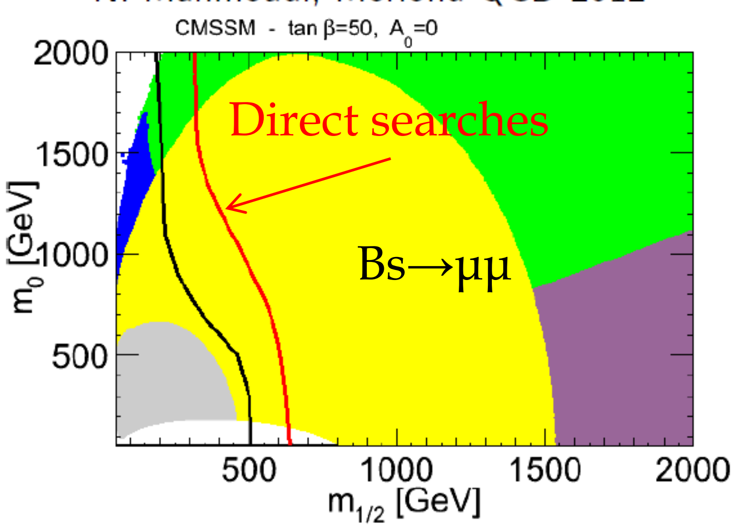
- LHCb Upgrade scheduled for starting installation in 2018.

# *Physics motivation*

CERN/LHCC 2012-007
(LHCb TDR 12)




N. Mahmoudi, Moriond QCD 2012




- LHCb has provided excellent results up to now, which impose severe constraints in physics beyond the SM
- LHCb upgrade will allow us to improve our precision as well as to enrich the physics program with new observables.
- LOI for LHCb Upgrade presented to LHCC in March 2011. Physics case endorsed and recommendation to proceed to Upgrade TDR
- The expected sensitivities were based on MC or 40 pb-1 of data, have been now confirmed using bigger samples

# Physics motivation

CERN/LHCC 2012-007
(LHCb TDR 12)

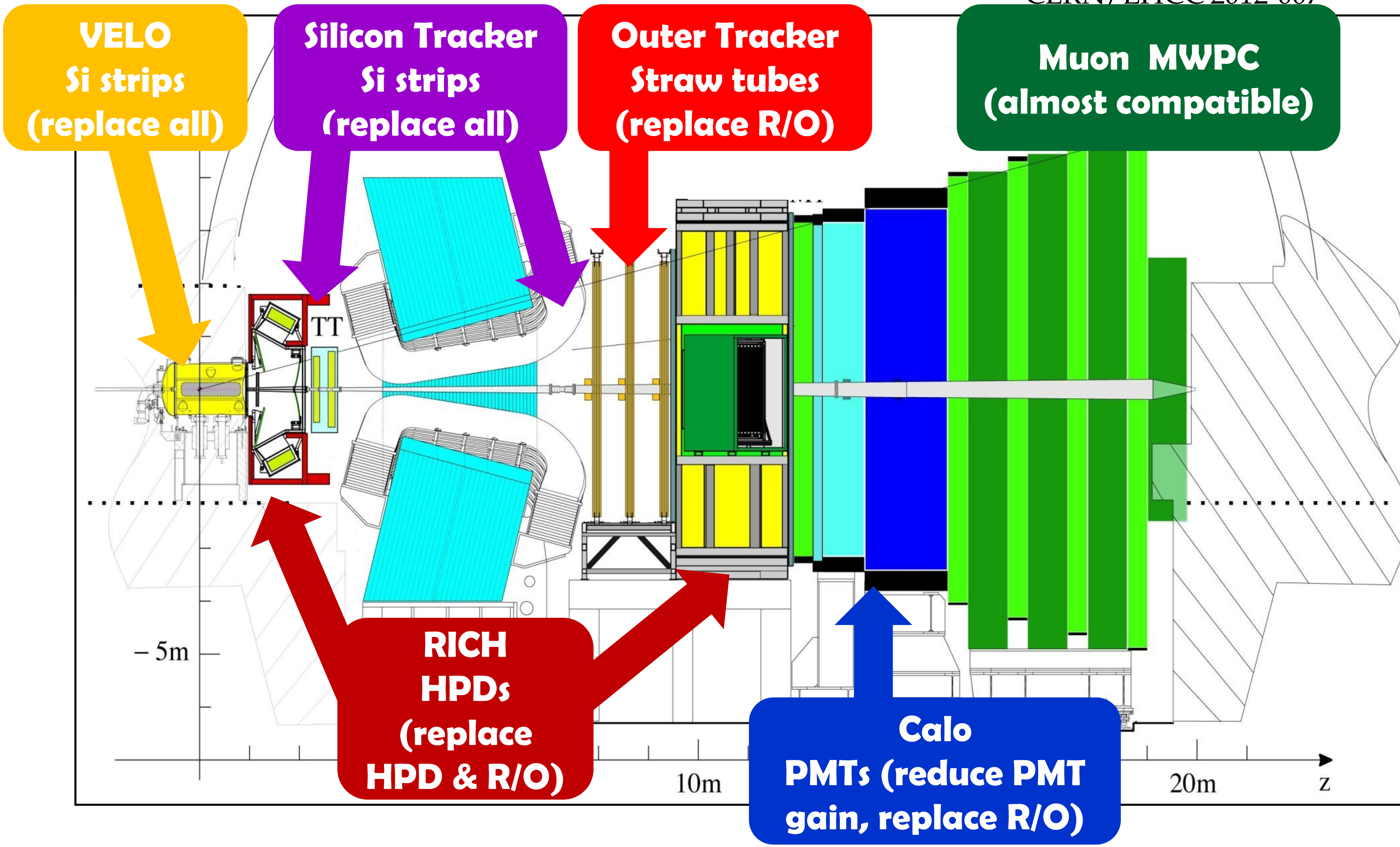
| Type | Observable | Current precision | LHCb 2018 | Upgrade ($50\,\text{fb}^{-1}$) | Theory uncertainty |
|---|---|---|---|---|---|
| $B_s^0$ mixing | $2\beta_s\ (B_s^0 \to J/\psi\ \phi)$ | 0.10 [9] | 0.025 | 0.008 | $\sim 0.003$ |
| | $2\beta_s\ (B_s^0 \to J/\psi\ f_0(980))$ | 0.17 [10] | 0.045 | 0.014 | $\sim 0.01$ |
| | $A_{\text{fs}}(B_s^0)$ | $6.4 \times 10^{-3}$ [18] | $0.6 \times 10^{-3}$ | $0.2 \times 10^{-3}$ | $0.03 \times 10^{-3}$ |
| Gluonic | $2\beta_s^{\text{eff}}(B_s^0 \to \phi\phi)$ | – | 0.17 | 0.03 | 0.02 |
| penguin | $2\beta_s^{\text{eff}}(B_s^0 \to K^{*0}\bar{K}^{*0})$ | – | 0.13 | 0.02 | $< 0.02$ |
| | $2\beta^{\text{eff}}(B^0 \to \phi K_S^0)$ | 0.17 [18] | 0.30 | 0.05 | 0.02 |
| Right-handed | $2\beta_s^{\text{eff}}(B_s^0 \to \phi\gamma)$ | – | 0.09 | 0.02 | $< 0.01$ |
| currents | $\tau^{\text{eff}}(B_s^0 \to \phi\gamma)/\tau_{B_s^0}$ | – | 5 % | 1 % | 0.2 % |
| Electroweak | $S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\,\text{GeV}^2/c^4)$ | 0.08 [14] | 0.025 | 0.008 | 0.02 |
| penguin | $s_0\ A_{\text{FB}}(B^0 \to K^{*0}\mu^+\mu^-)$ | 25 % [14] | 6 % | 2 % | 7 % |
| | $A_{\text{I}}(K\mu^+\mu^-; 1 < q^2 < 6\,\text{GeV}^2/c^4)$ | 0.25 [15] | 0.08 | 0.025 | $\sim 0.02$ |
| | $\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$ | 25 % [16] | 8 % | 2.5 % | $\sim 10$ % |
| Higgs | $\mathcal{B}(B_s^0 \to \mu^+\mu^-)$ | $1.5 \times 10^{-9}$ [2] | $0.5 \times 10^{-9}$ | $0.15 \times 10^{-9}$ | $0.3 \times 10^{-9}$ |
| penguin | $\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$ | – | $\sim 100$ % | $\sim 35$ % | $\sim 5$ % |
| Unitarity | $\gamma\ (B \to D^{(*)}K^{(*)})$ | $\sim 10$–$12°$ [19, 20] | $4°$ | $0.9°$ | negligible |
| triangle | $\gamma\ (B_s^0 \to D_s K)$ | – | $11°$ | $2.0°$ | negligible |
| angles | $\beta\ (B^0 \to J/\psi\ K_S^0)$ | $0.8°$ [18] | $0.6°$ | $0.2°$ | negligible |
| Charm | $A_\Gamma$ | $2.3 \times 10^{-3}$ [18] | $0.40 \times 10^{-3}$ | $0.07 \times 10^{-3}$ | – |
| $CP$ violation | $\Delta A_{CP}$ | $2.1 \times 10^{-3}$ [5] | $0.65 \times 10^{-3}$ | $0.12 \times 10^{-3}$ | – |

Table 1: Statistical sensitivities of the LHCb upgrade to key observables. For each observable the current sensitivity is compared to that which will be achieved by LHCb before the upgrade, and that which will be achieved with $50\,\text{fb}^{-1}$ by the upgraded experiment. Systematic uncertainties are expected to be non-negligible for the most precisely measured quantities.

+ (Many other not included here…)

# *LHCb upgrade*

CERN/LHCC 2012-007



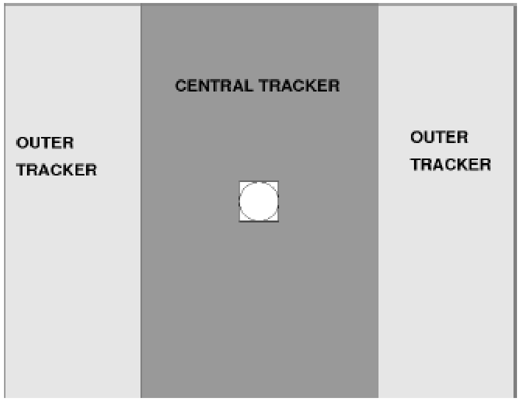

•Designed a common R/O Board: TELL40.

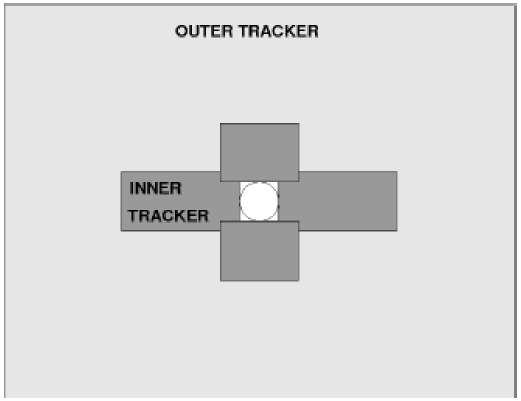
# *Technology options for tracking*

CERN/LHCC 2012-007
(LHCb TDR 12)

- **VELO (Vertex Locator).**
    - Two possible technologies under investigation: **Pixels** and **microstrips**.
    - Try improving IP resolution by reducing foil inner radius from 5.5 mm to 4-3 mm.

- **Tracking stations**. At high luminosity → keep OT occupancies at an acceptable level → Investigating two different geometries/technologies



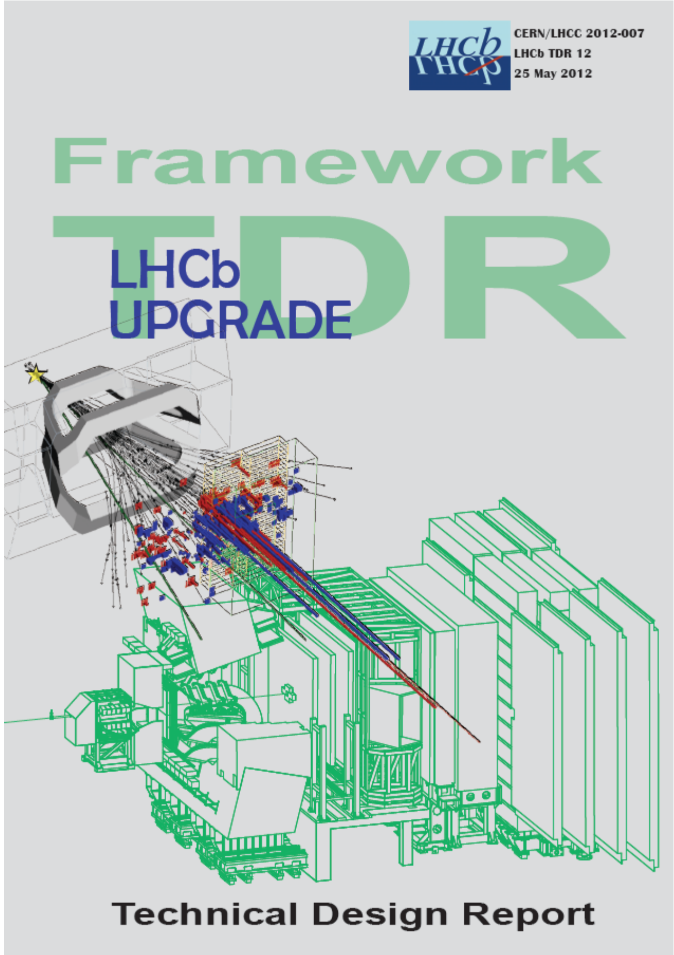

**a)** CT (Central Tracker): Central part of the OT (straw tubes) is replaced by scintillating fibers

**b)** A larger IT (silicon) would cover the region of the current IT + the inner region of the current OT.

# *LHCb upgrade (schedule)*

CERN/LHCC 2012-007
(LHCb TDR 12)

- June 2011: LoI fully endorsed
- June 2012: "Framework TDR" submitted
- 2012: continue R&D towards technical choices
- 2013: technical review & choice of technology. TDRs & prototype validation
- 2014-16: tendering & serial production
- 2016-17: quality control & acceptance tests
- 2018/19: installation (18 months according to planning!)



# Conclusions

- LHCb efficiently taking and processing data
  - Already recorded 0.5 $fb^{-1}$ in 2012, expected 1.5 $fb^{-1}$ by the end of the year.
  - Thanks to the help of LHC team LHCb is running smoothly with vertical collisions and magnet polarity swaps
  - Deferred HLT working, expect to reach a gain equivalent to 20% more CPU

- Several new results presented

- Framework TDR: CERN/LHCC 2012-007

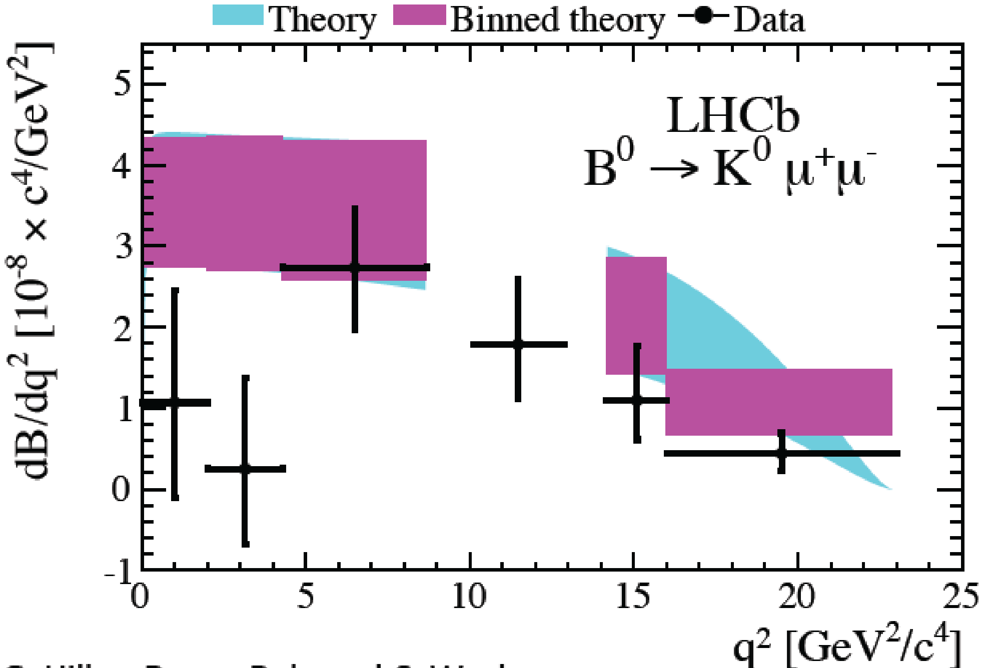
  - LHCb upgrade will allow us to improve our current precision by one order of magnitude in our main channels
  - Starting of installation scheduled for 2018
  - More details in the upgrade session of Tuesday

Thanks for your attention

# $dBF/q^2(B^0 \to K^0 \mu^+ \mu^-)$

- There is a deficit of $B^0 \to K^0 \mu^+ \mu^-$ signal in the $q^2$ regions which are not adjacent to the charmonium resonances

[LHCb-PAPER-2012-011]




C. Bobeth, G. Hiller, D. van Dyk, and C. Wacker,

$$\mathrm{BR}(B_s \to \mu^+\mu^-) = \left[\frac{1 - y_s^2}{1 + \mathcal{A}_{\Delta\Gamma}\, y_s}\right] \mathrm{BR}(B_s \to \mu^+\mu^-)_{\mathrm{exp}},$$

+1 in the SM

$$y_s \equiv \tau_{B_s} \Delta\Gamma_s/2 = 0.088 \pm 0.014,$$

# *Other Physics results*

LHCb-PAPER-2011-037

- Measurement of prompt charged hadron production ratios at 0.9 TeV and 7 TeV (First measurement at this last energy )

- Comparisons with several generator tunes (LHCb MC, Perugia 0, Perugia NOCR), none of them describes well all the observables

- Fitting $\bar{p}/p$ ratio vs Δy with Regge theory function (and including mid-rapidity data from ALICE) indicates no significant contribution from Odderon exchange