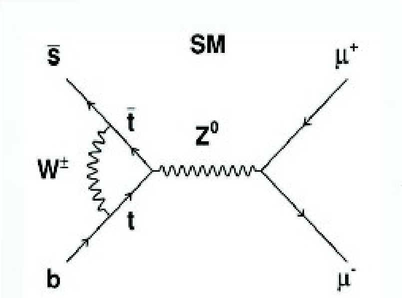
LHCb Physics and Upgrade Introduction

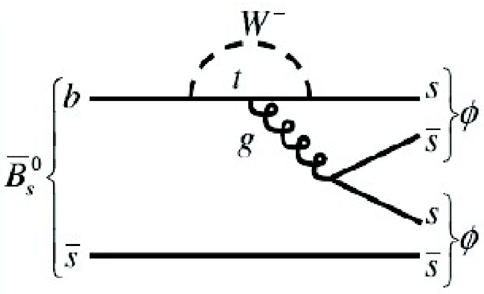
Physics Results & upgrade introduction	DL
RICH upgrade	Gabriele Simi
DAQ & trigger upgrade	Gianmaria Collazuol

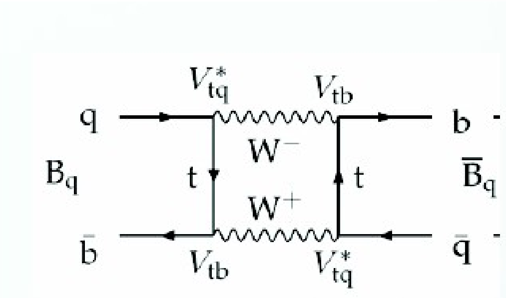
Why b Physics

- Direct search for New Physics is becoming difficult, the mass scale could be not in LHC reaches
- Any extension of SM found in direct search must comply with a non-trivial flavor structure → flavor key element of any BSM
- Searches via quantum loops already have reached quite large mass scales given certain assumptions.
- Examples :

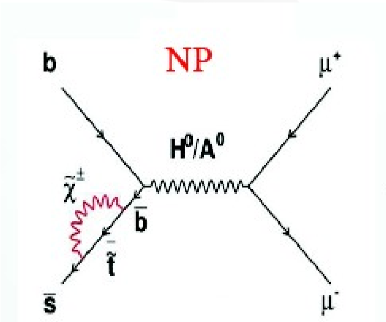
SM

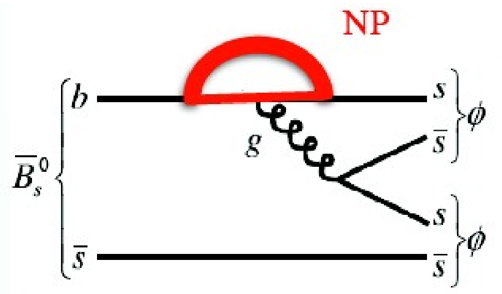


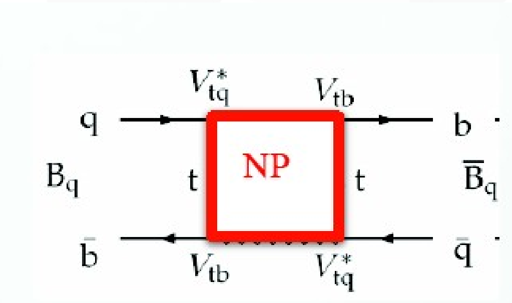




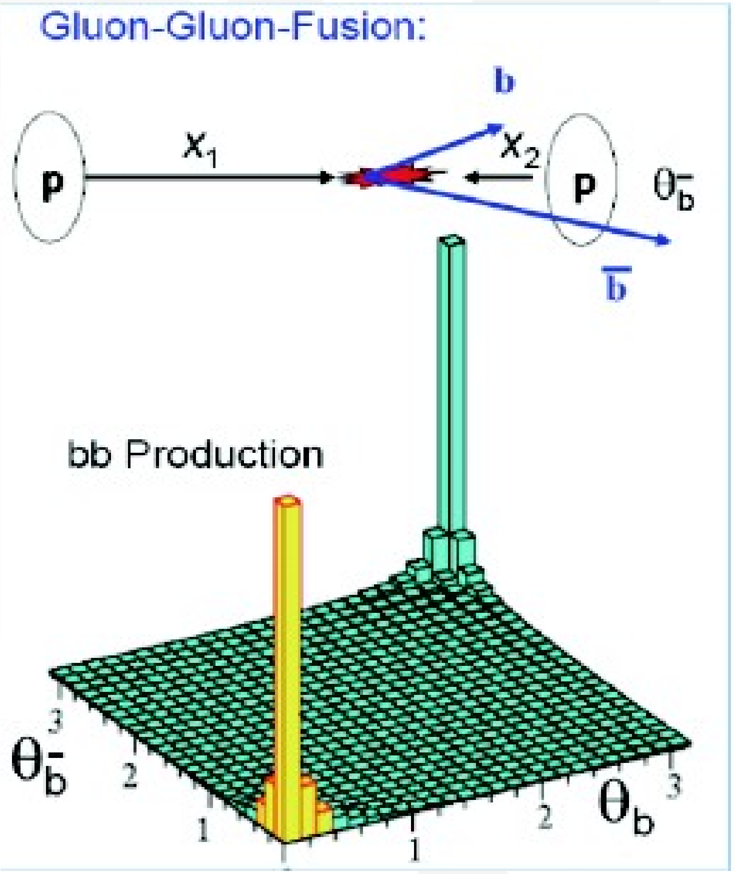
NP







b Production at LHCb

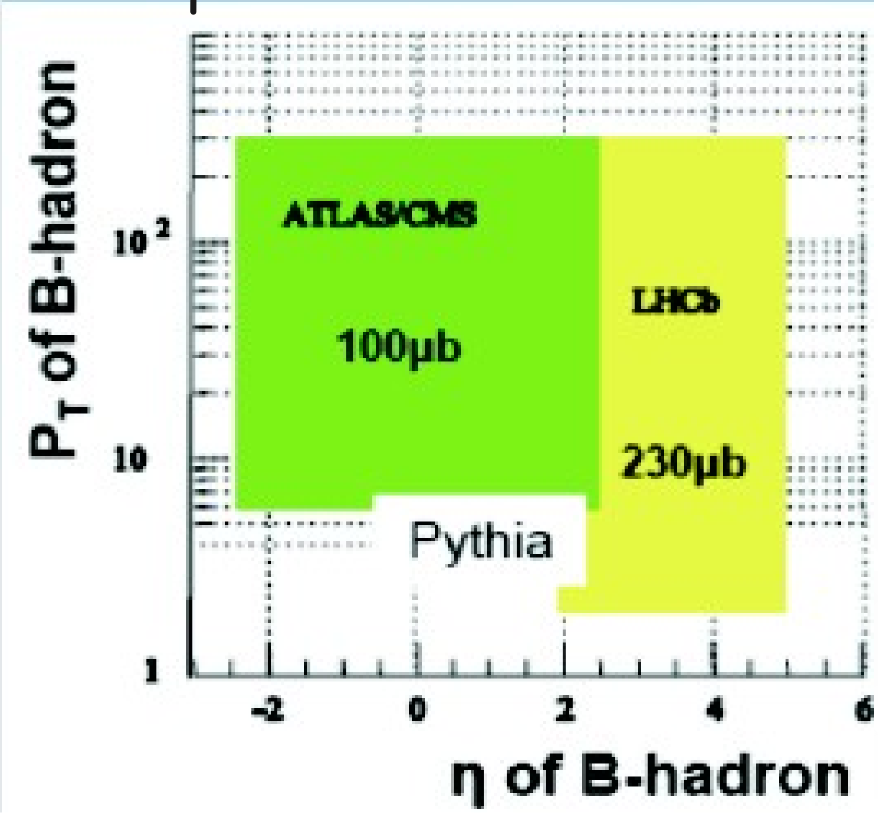


All b-hadron species produced :

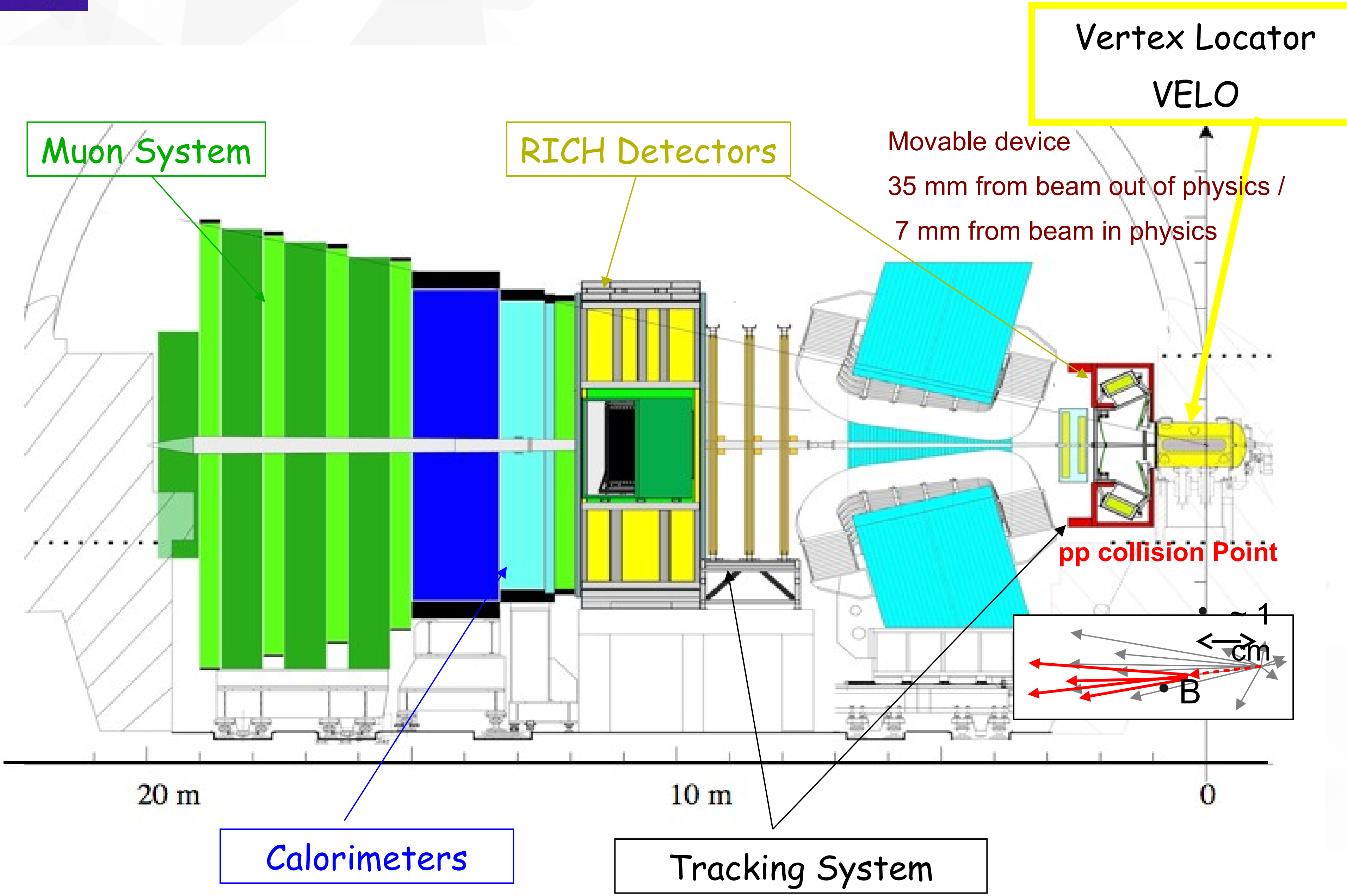
B_u, B_d, B_s, B_c, Λ_b, Ξ_b,...

and c-hadrons as well

Acceptance



LHCb Detector



Tracking Detector

VELO (Vertex Locator)

21 modules of *r*-φ silicon sensor disks

Retracted for safety during beam injection

Impact parameter resolution ~ 20μm

Proper-time resolution: $\sigma t = 45$ fs

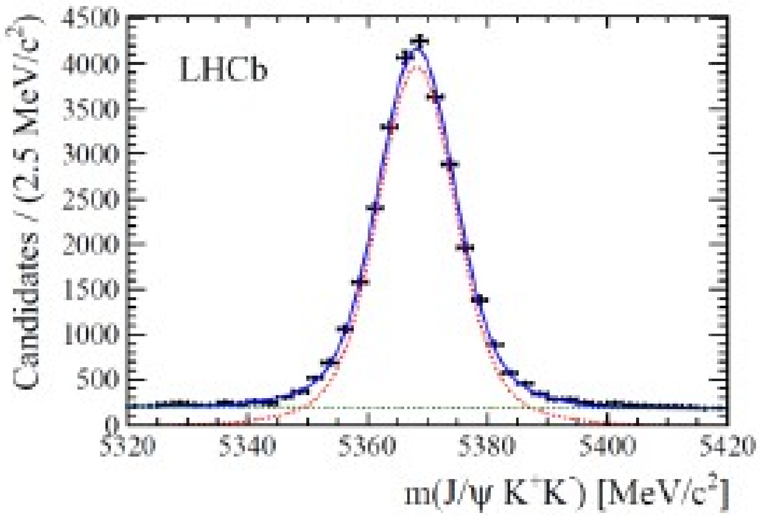
cf CDF: $\sigma t = 87$ fs

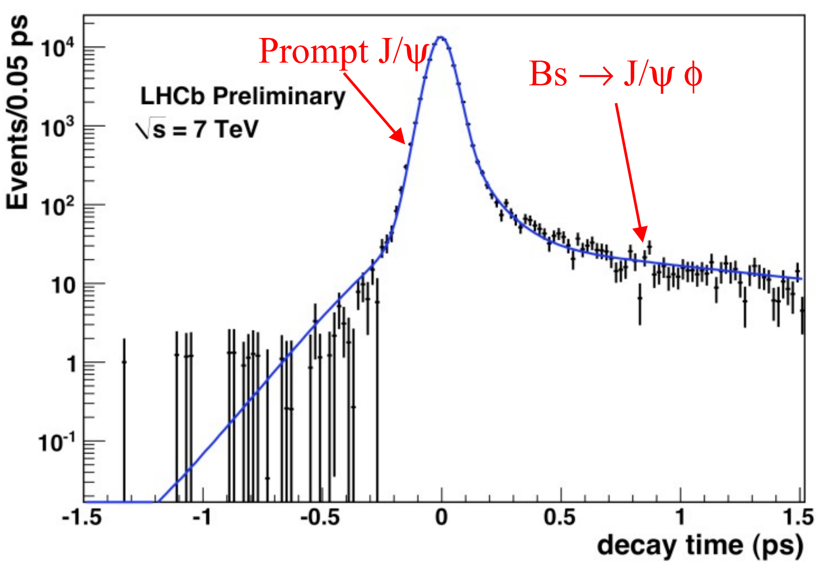
Tracking stations upstream (Si)

downstream(drift) magnet

Magnet field reversed time by time

Mass Resolution 6 MeV/c^2



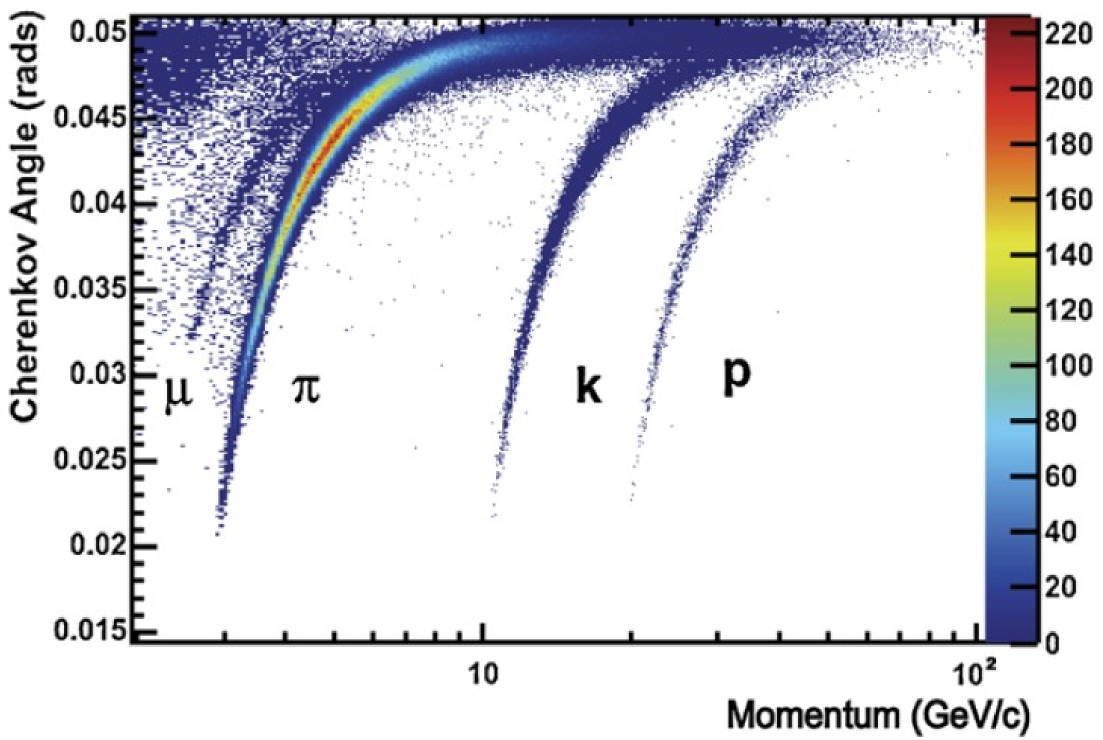


Particle Identification: RICH

Charged hadrons identified with two Ring-Imaging Cherenkov :

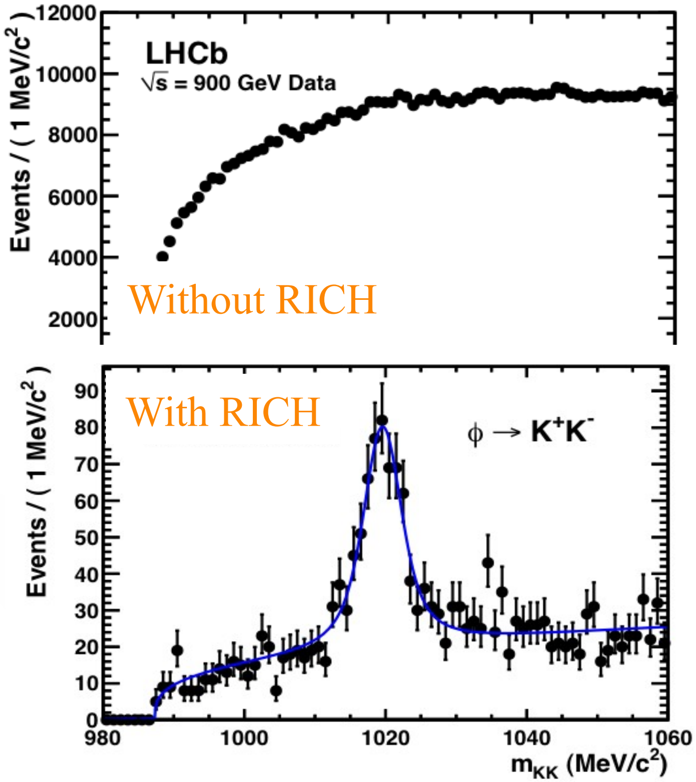
RICH1 aereogel +C_4F_{10}, cover 1<p<60 GeV/c, upstream magnet

RICH2 CF_4, cover 15<p<100 GeV/c, downstream tracking station



Cover picture of EPJ C, May 5, 2013

Strong suppression of combinatorial background in hadronic decays *e.g.* $\phi \to K^+K^-$



Particle Identification: e,γ and μ

ECAL: Shashlik Pb-scintillator

$\sigma(E)/E = 10\% / \sqrt{E} \oplus 1\%$

HCAL: Tile Fe-scintillator

allows triggering on hadronic final states

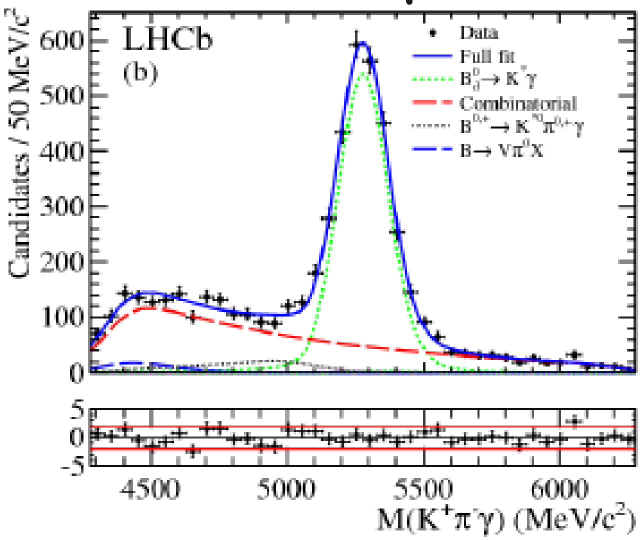
$\sigma(E)/E = 80\% / \sqrt{E} \oplus 10\%$

Muon system: 5 stations MWPCs/Fe

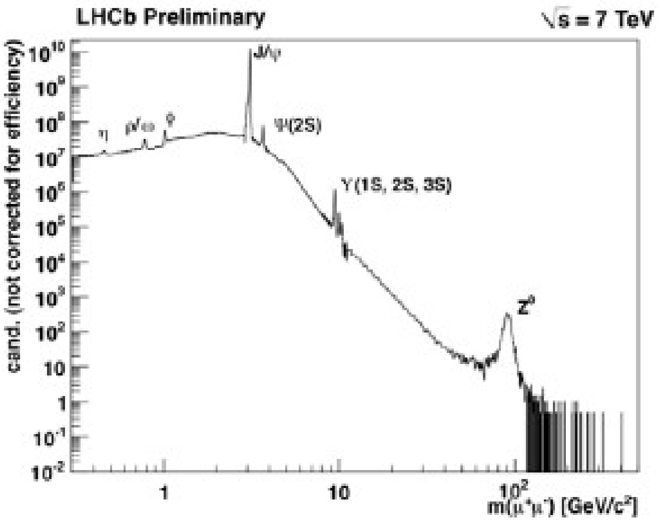
eccelent μ/π separation

single hadron mis-id rate ~0.7 %

B → K*γ



Raw di-muon mass

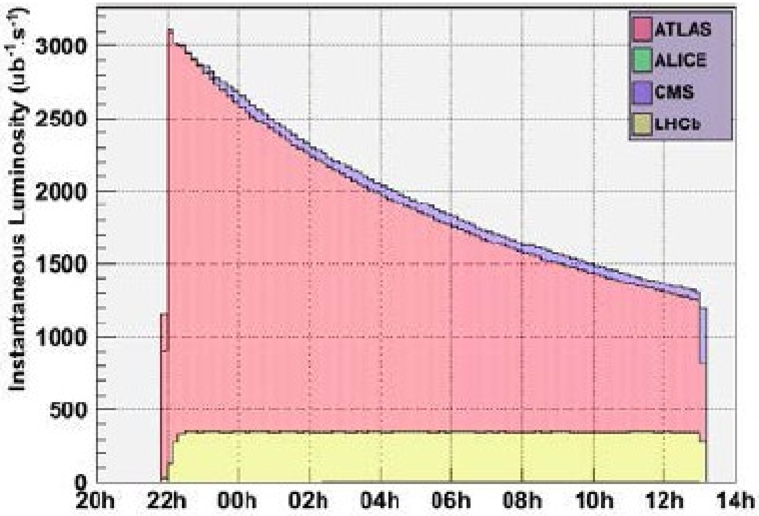


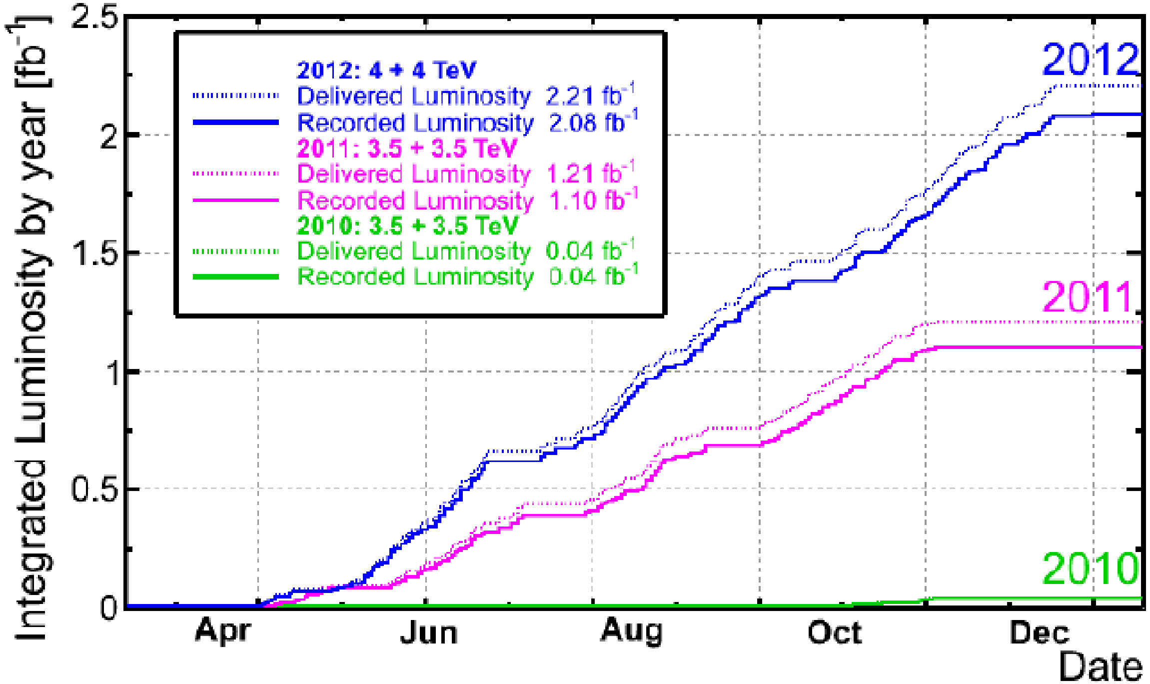
Data Taking LHCb

Automatic luminosity leveling throught vertical beam displacement

Design 2×10^{32} $cm^{-2}s^{-1}$

Actual 4×10^{32} $cm^{-2}s^{-1}$

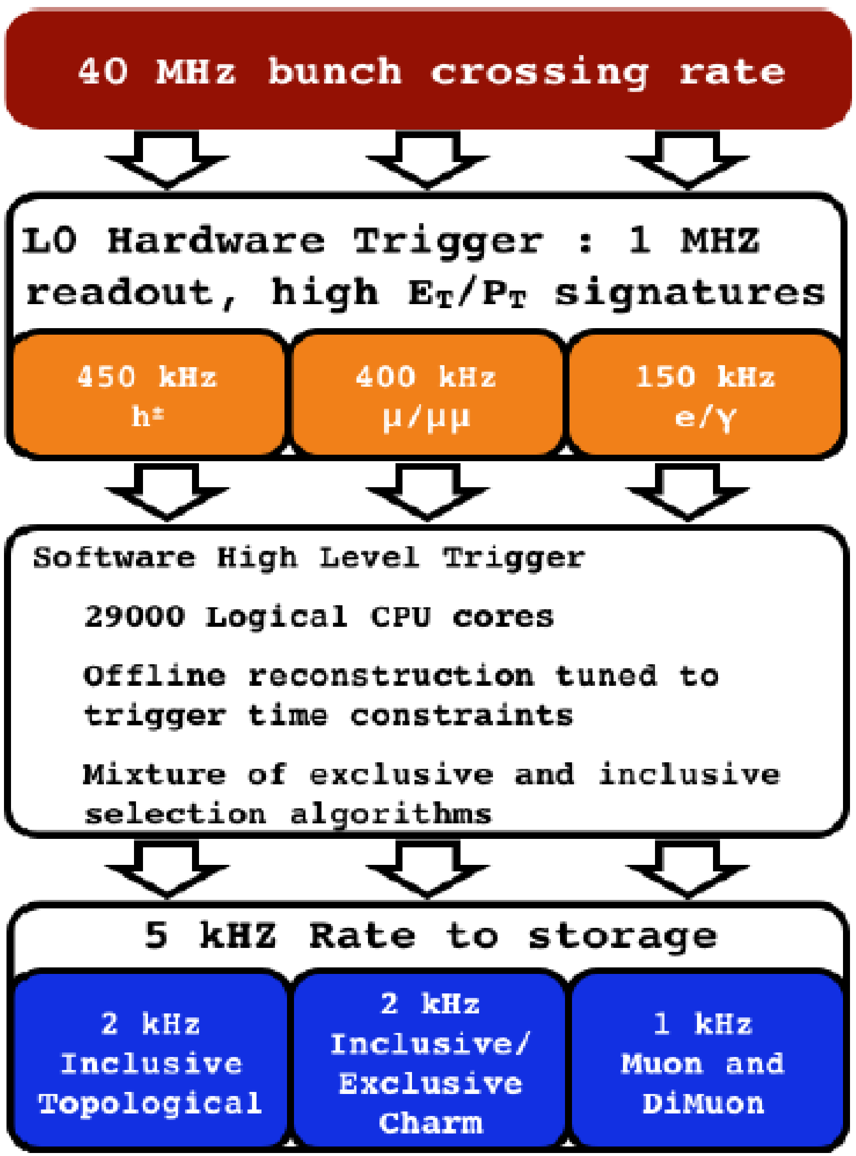




Very good efficiency : ε~ 94 %

$$\int L = 0.035 + 1.1 + 2.0\ fb^{-1}$$

Trigger Strategy



Level-0 :

- use custom electronic to get 1 MHz rate
- select the highest pT(ET) hadron/e/γ/μ

HLT :

- two software levels :
  - HLT1 partial event reconstruction (pT, IP)
  - HLT2 full event reconstruction (invariant mass, etc)

Data Preservation

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Silvia Amerio, Mauro Morandin

- Interest in long term data preservation by HEP community.
- LHC experiments devote efforts to data preservation issues
- LHCb : long term data preservation task force started Spring 2013

Areas of work:

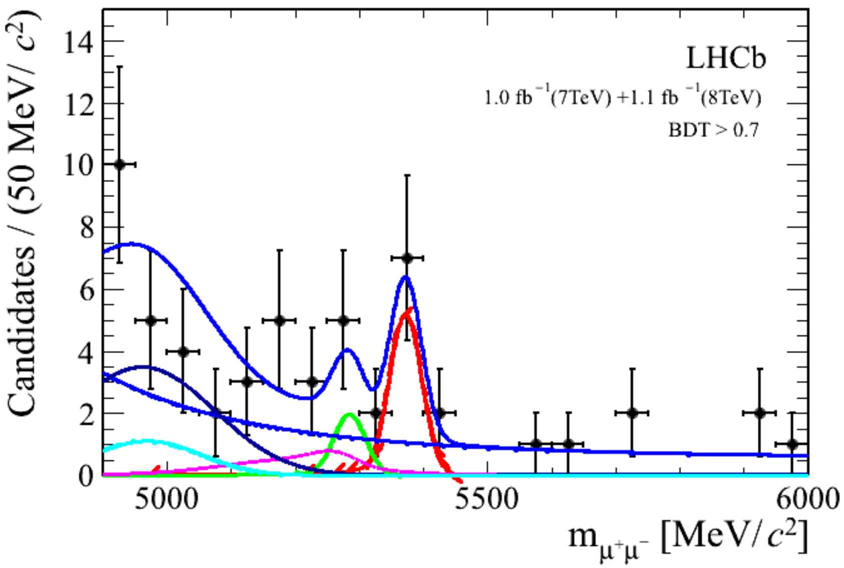
- *open access :* open access policy since February 2013; small data samples available for educational purposes
- *preservation of the full analysis chain*: requirements definition; construction of long term future analysis framework

Padova is contributing in the development of the analysis and validation framework.

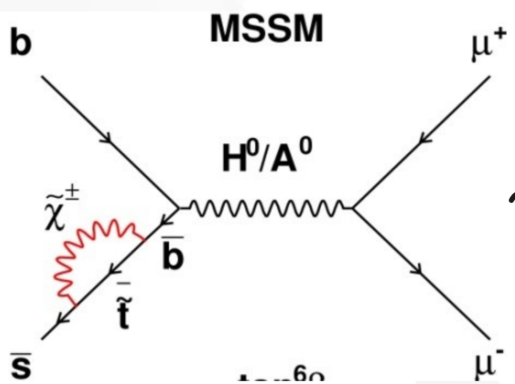
Physics Highlights

Rare Decays: $B_s \to \mu^+\mu^-$

First observation of $B_s \to \mu^+\mu^-$

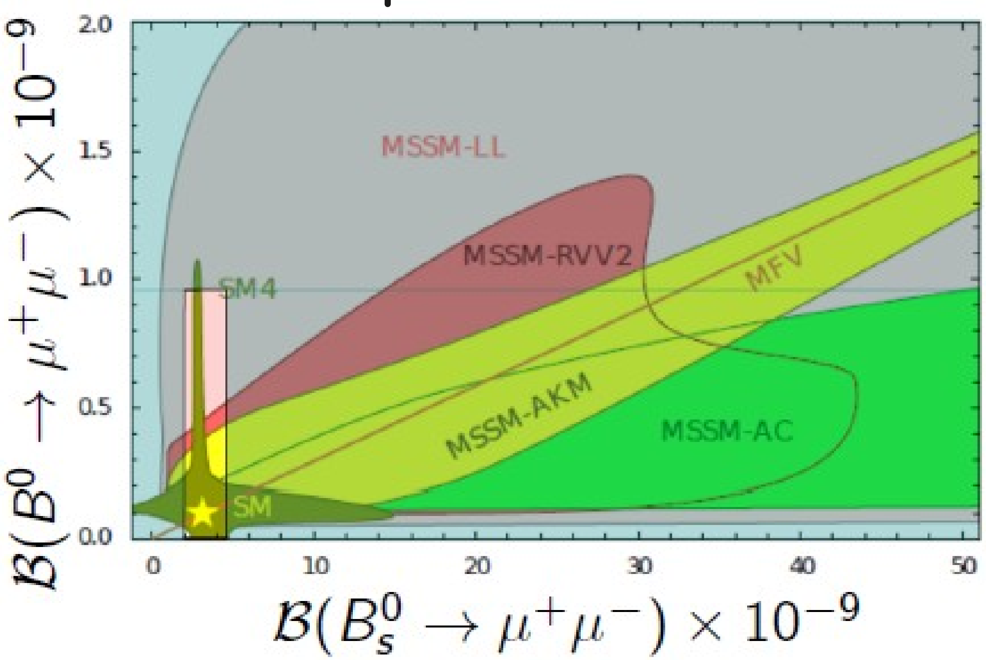


Strongly suppressed in SM, BR=$(3.5 \pm 0.3)\times10^{-9}$ it could be strongly enhanced in SUSY



$\sim \tan^6\beta / M_{H/A}^4$

Straub plot



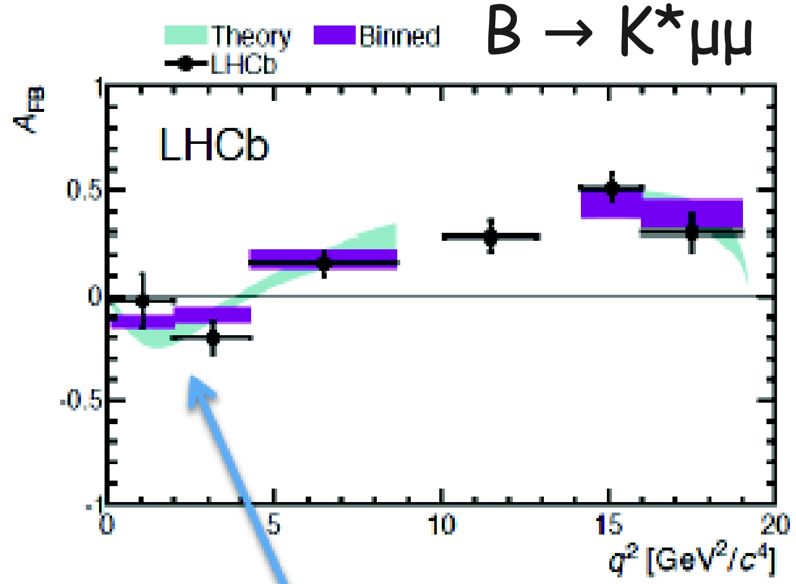
Limit on BR($B_d \to \mu^+\mu^-$)= $(9.4 \pm 0.3)\times10^{-10}$ @95% CL

Rare Decays: b → s transitions

B →φμμ and B → K*μμ Flavor Changing Neutral Current decay proceeding via penguings. NP can contribute at any level : rate, asymmetry, angular distributions.

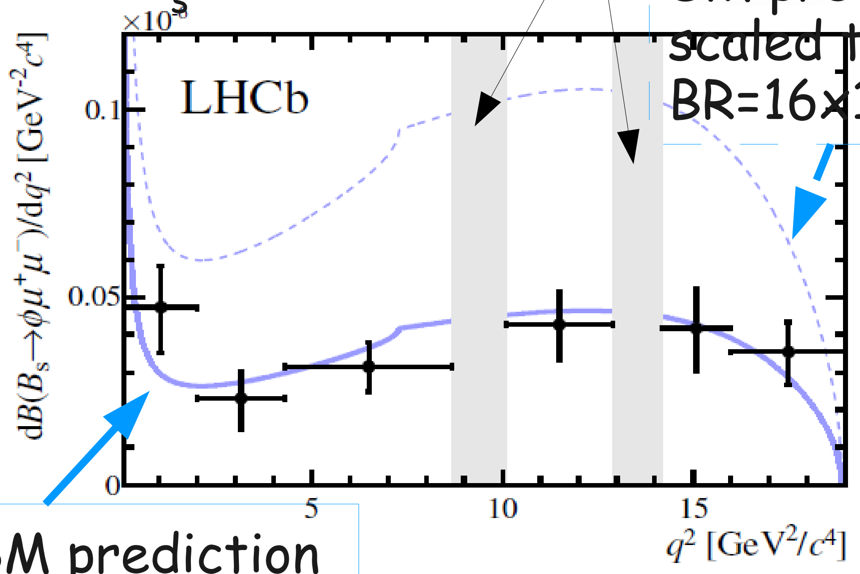
A_{FB} changes sign at well defined q^2

J/ψ and ψ veto



$q_0^2 = 4.9 \pm 0.9$ GeV^2

q^2_{SM} :4.36 ± 0.33 GeV^2

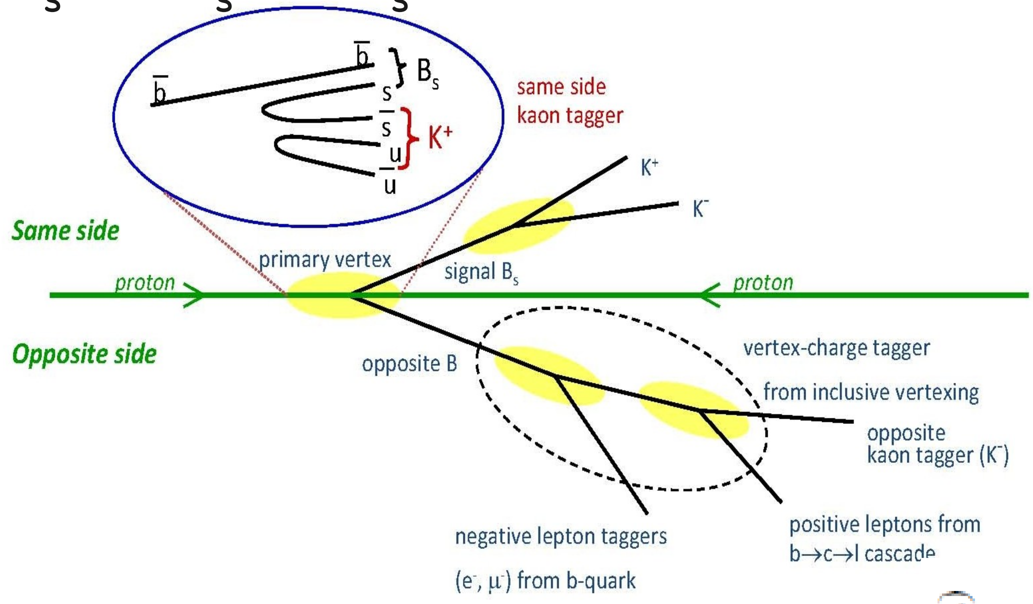


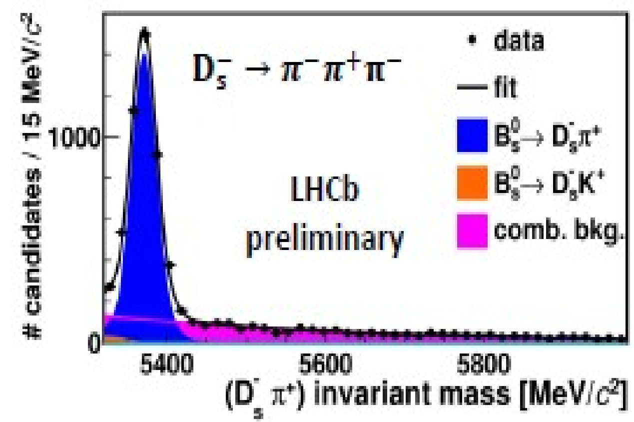
SM prediction scaled to total BR=16x10^{-7}

SM prediction scaled to the fitted total BR

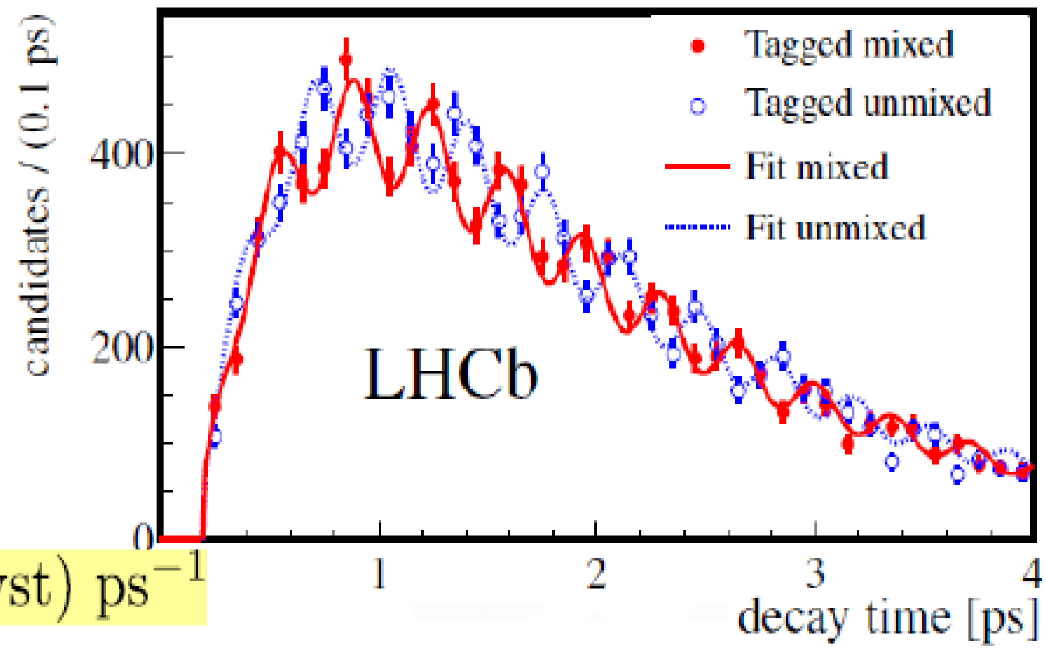
Bs Mixing measurement

$B^0_s \rightarrow D^-_s \pi^+$ $D^-_s \rightarrow \phi\pi^-$ K^*K, $KK\pi$, $K\pi\pi$, $\pi\pi\pi$ decay channels combined





Time dependent mixed and unmixed asymmetry are fitted to extract:



$$\Delta m_s = 17.768 \pm 0.023(\text{stat}) \pm 0.006(\text{syst})\ \text{ps}^{-1}$$

Mixing phase, ϕ_s

CP violation in the interference between mixing and decay:

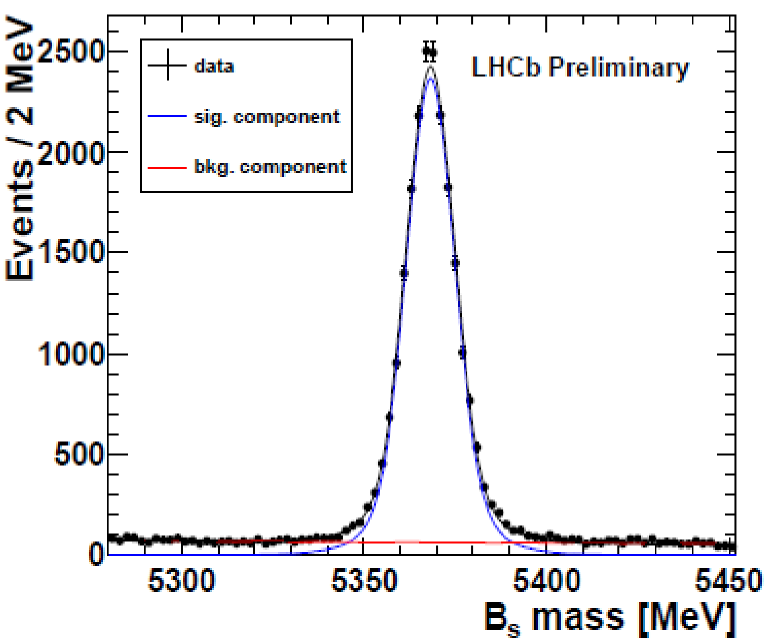
B → J/ψKs favored → sin(2β)

Bs → J/ψV suppressed → sin(2Φs) Φs ~ -2βs

Contribution from physics beyond SM can effect measured Φs

Bs → J/ψΦ: very complex measurement, needs:

- flavor tagged time dependent angular analysis to disantangle CP-even from CP-odd components

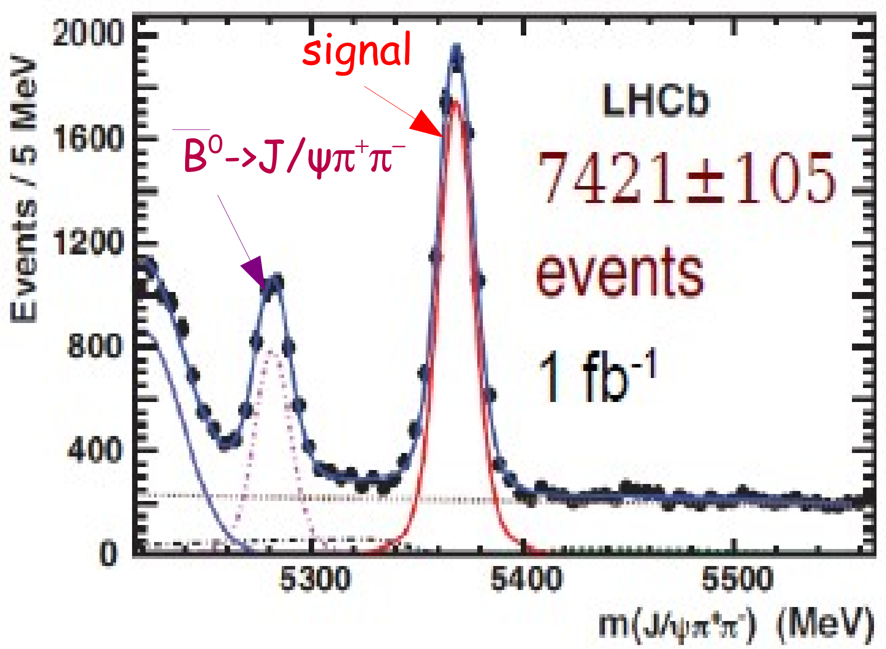


Most precise measurement

$$\phi_s = 0.07 \pm 0.09 \pm 0.01 \text{ rad}$$
$$\Gamma_s = 0.663 \pm 0.005 \pm 0.006 \text{ ps}^{-1}$$
$$\Delta\Gamma_s = 0.100 \pm 0.016 \pm 0.003 \text{ ps}^{-1}$$

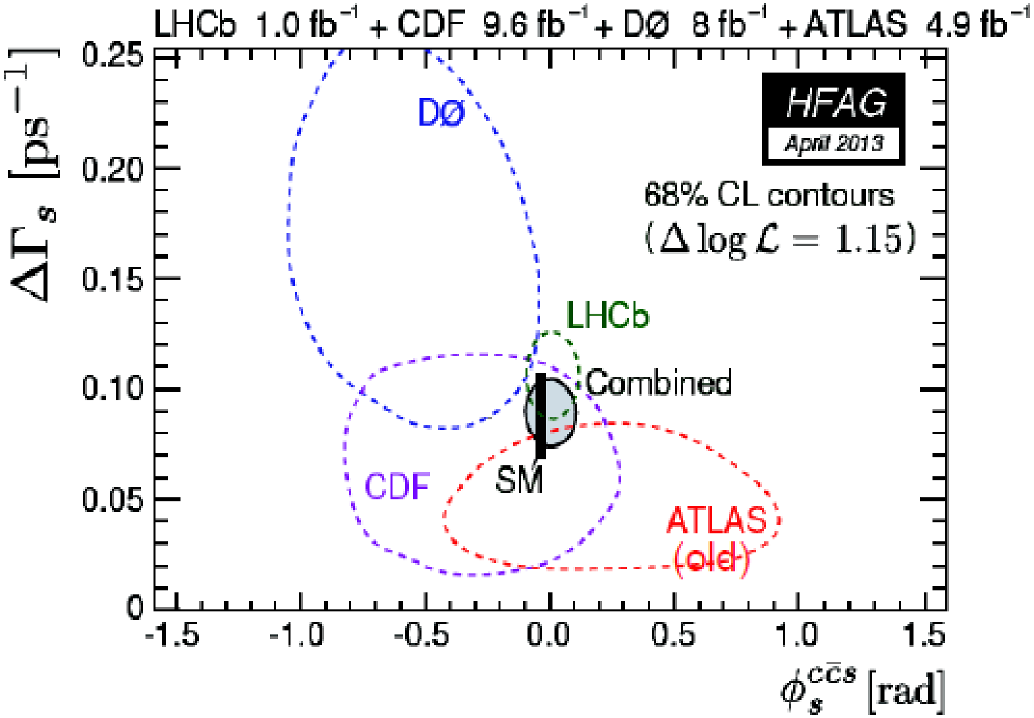
Mixing phase, ϕ_s combination

Bs →J/ψππ: dominated by CP-odd via f(980) amplitude, angular analysis not needed



$$\phi_s = -0.14^{+0.17}_{-0.16} \pm 0.01 \text{ rad}$$

LHCb Combination



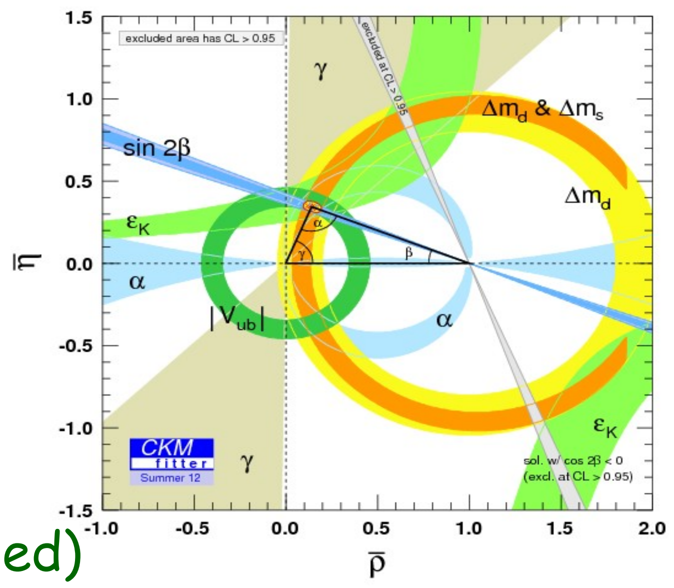
$$\phi_s = 0.01 \pm 0.07 \pm 0.01 \text{ rad}$$
$$\Gamma_s = 0.661 \pm 0.004 \pm 0.006 \text{ ps}^{-1}$$
$$\Delta\Gamma_s = 0.106 \pm 0.011 \pm 0.007 \text{ ps}^{-1}$$

CP Violation: γ, B^0 decays

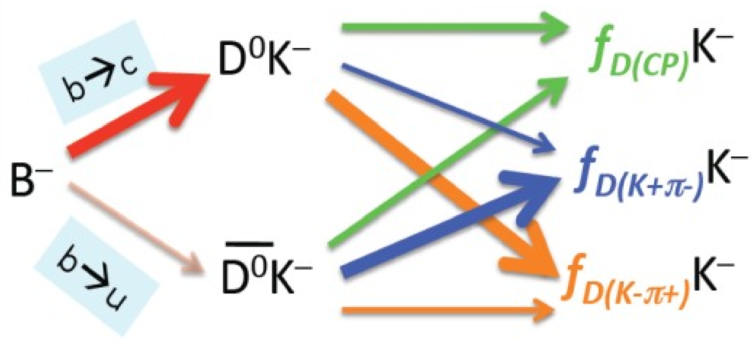
The least well-determined CKM angle

$$\gamma = \arg\left(\frac{-V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right)$$

SM fit: $\gamma = (67.7^{+4.1}_{-4.6})^o$



Tree-level decays:



b→c (dominant) and b→u (color suppressed) amplitudes interfere in decays to a common D^0 and $\bar{D}^0$ modes.

B → DK combination : $\gamma = (67 \pm 12)^\circ$ world's most precise

Bs → Ds K: Interference between 2 tree diagrams via B_s mixing

CP Violation: γ Time dependent

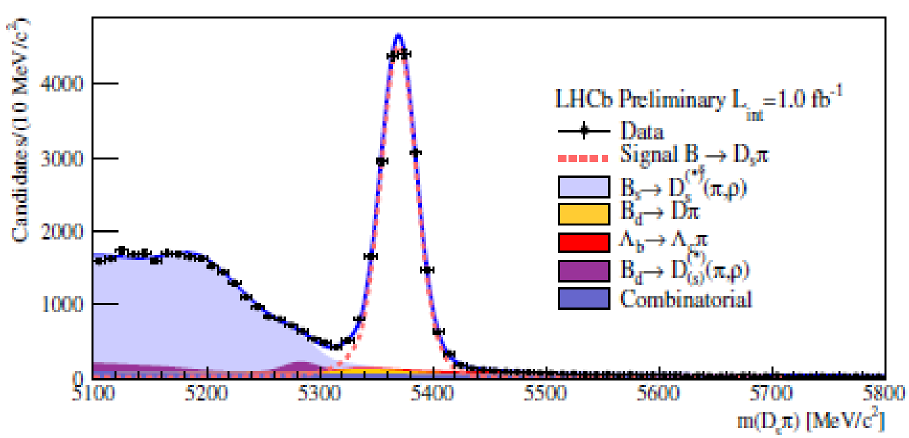
Interference between mixing and decay amplitude generate CP violation:

- weak phases γ, ϕ_m and strong phases δ
- measure 4 decay amplitudes as function of proper time:

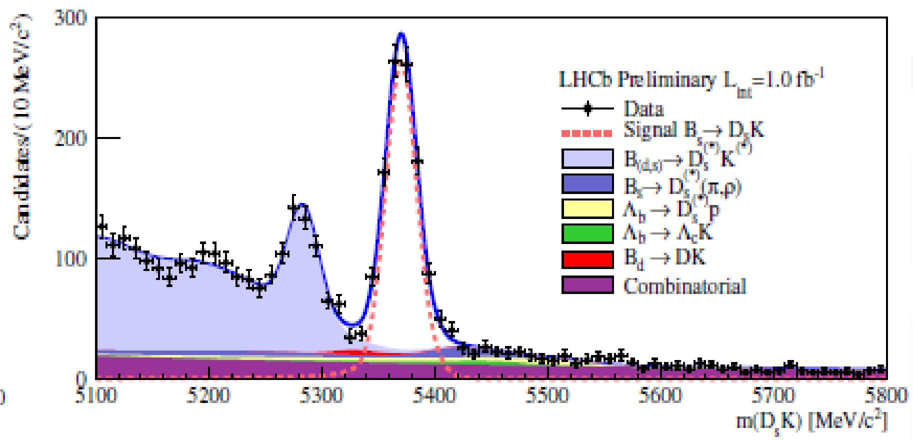
$$\Gamma_{B_s^0 \to D_s^- K^+}(t),\ \Gamma_{B_s^0 \to D_s^+ K^-}(t),\ \Gamma_{\overline{B_s^0} \to D_s^- K^+}(t),\ \Gamma_{\overline{B_s^0} \to D_s^+ K^-}(t)$$

- select Bs->DsK and Bs->Dsπ, analysis optimized for DsK

Dsπ



DsK



Need flavor tagging

Flavor Tagging

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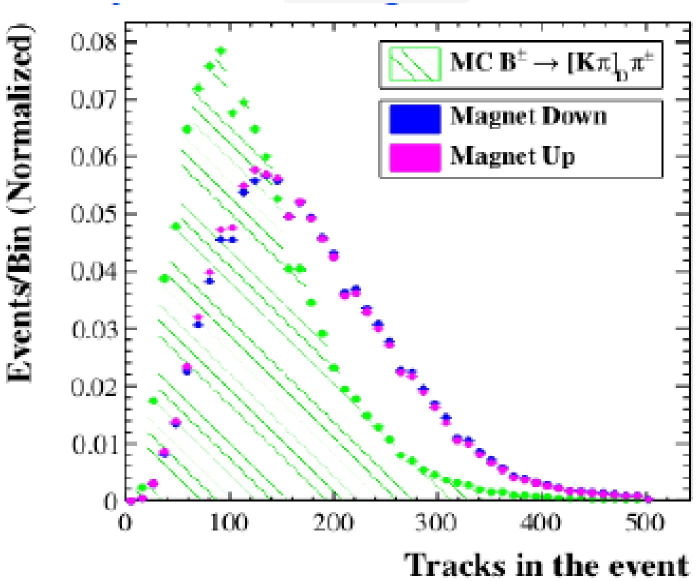
ε = efficiency
D = dilution
D = 1-2ω
ω = mistag prob.

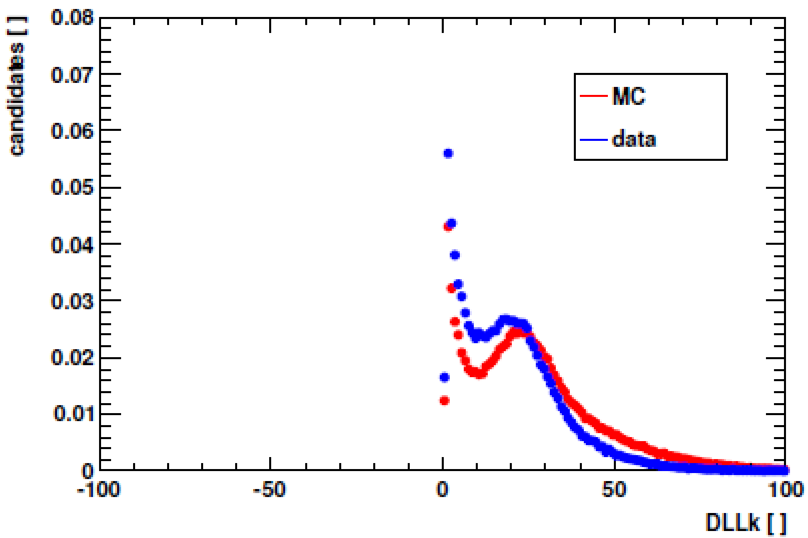
tagger	$\varepsilon_{tag}(\%)$	$\omega(\%)$	$\varepsilon_{tag} D^2(\%)$
OSμ	5.20 ± 0.04	30.8 ± 0.4	0.77 ± 0.04
OSe	2.46 ± 0.03	30.9 ± 0.6	0.36 ± 0.03
OSK	17.67 ± 0.08	39.33 ± 0.24	0.81 ± 0.04
Q_{vtx}	18.46 ± 0.08	40.31 ± 0.24	0.70 ± 0.04
SSK	16.3 ± 0.4	35.3 ± 2.1	1.4 ± 0.4

Efficiency and dilution measured on data: $B^+ \rightarrow J/\psi K^+$ $B_s^0 \rightarrow D_s^- \pi^+$

To to improve the algorithm need a better MC tuning: particularly true for the next run at 14 TeV.

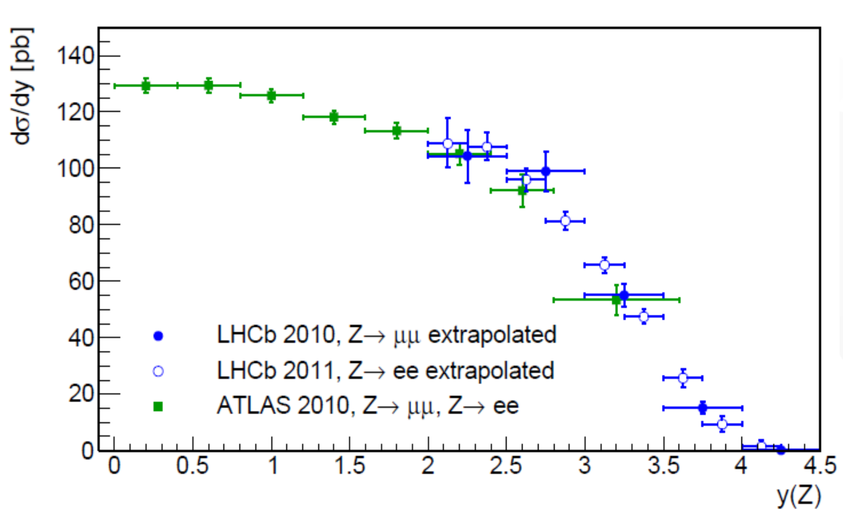


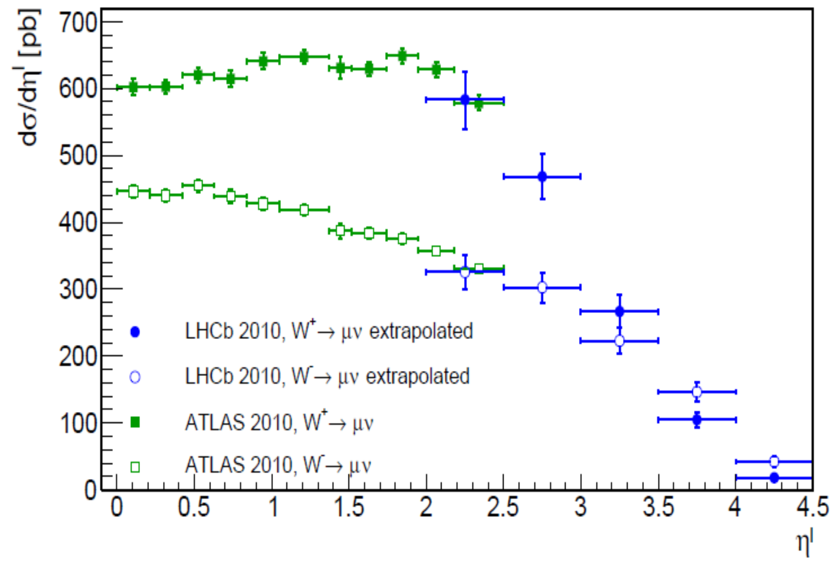
DLLk



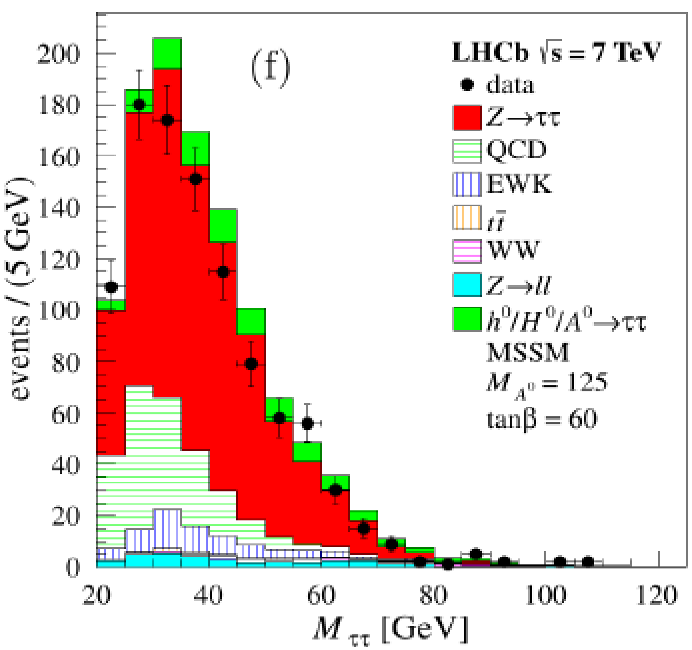
Not only b-physics...

LHCb can test SM in regions complementary to Atlas/CMS





Search for Higgs



In progress, search for :

- W/ZH → l bb
- A/Φ → bbbb

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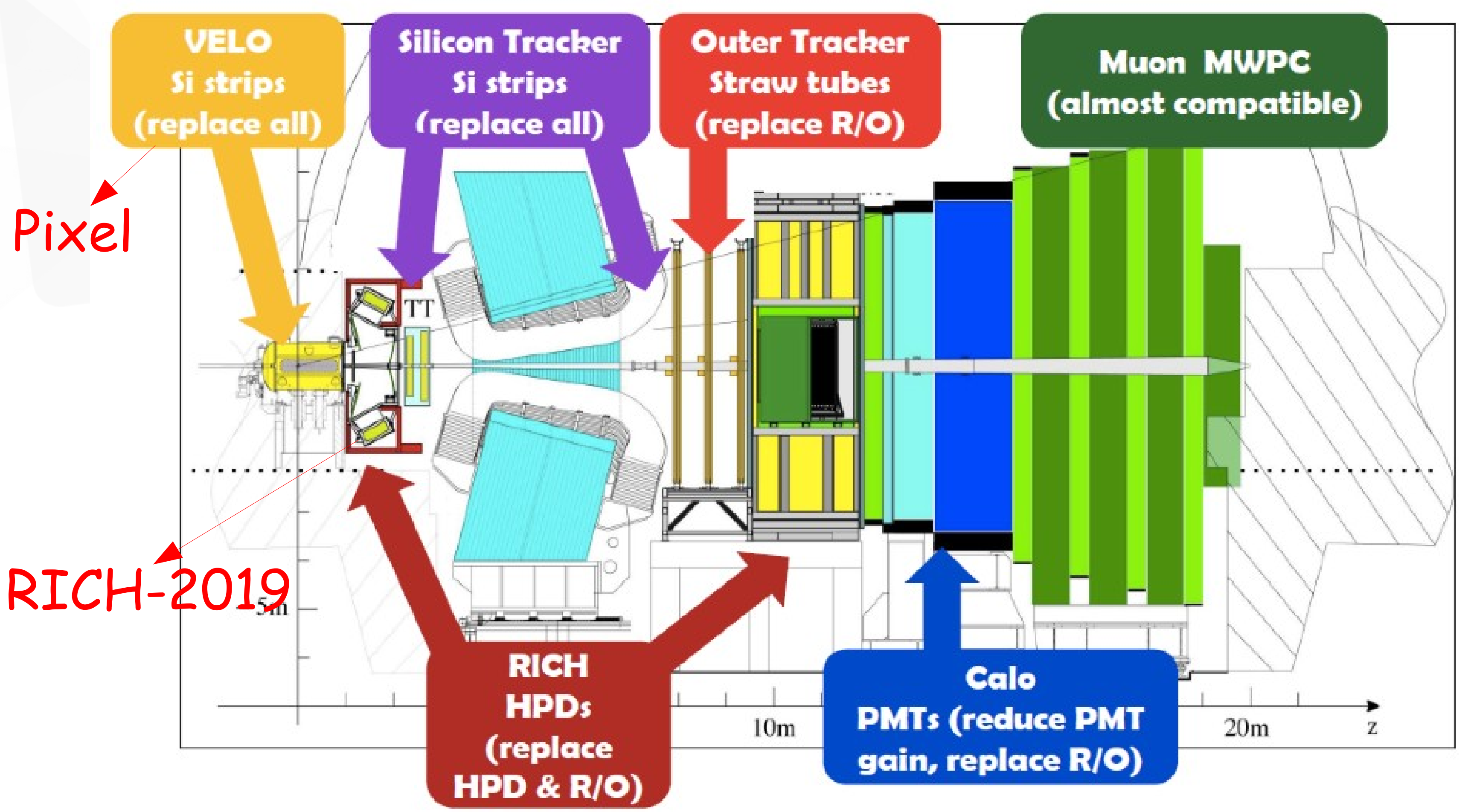
Measured :

- $\sigma(b\bar{b})$
- Central/Forward asymmetry $A^{b\bar{b}}_{FC}$

LHCb Upgrade

Baseline detector modifications to allow 40 MHz readout
Several decisons taken recently.



LHCb upgrade in Italy

detector	sub-system	countries involved
VELO	modules & infrastructure	BR, CERN, ES, IE, NL, RU, UK, US
	electronics & readout	BR, ES, CERN, CN, NL, PL, UK, US
Tracker	modules & infrastructure	CERN, CH, DE, NL, RU, UK, US
	electronics & readout	BR, CERN, CH, CN, DE, ES, FR, NL, PL, US
RICH	mechanics & infrastructure	CERN, IT, UK
	electronics & readout	CERN, IT, RO, UK
Calo	electronics & readout	ES, FR, RU
Muon	chambers	IT, RU
	electronics & readout	IT
Trigger	electronics & readout	BR, CN, FR, IT

Table 15: Expressions of interest to the detector construction, subject to funding.

Sunday submitted the upgrade project to CTS
First audit July 12th

LHCb upgrade in Italy

CTS Document

WP1 *Muon upggrade* (Ca, Fe, Fi, Frascati, Rm1, Rm2)

WP2 *Upgrade of the RICH* (Fe, Ge, Mi-B, Pd)

WP3 *Construction of PCIe Gen3 readout boards for the LHCb DAQ system* (Bo)

WP4 *Track Trigger in the LLT* (Mi, Pi)

WP5 *High Level Trigger Farm based on many-core architectures* (Pd)

Padova People and Requests

Ricercatori	FTE
Amerio Silvia	0.7
Busetto Giovanni	0.7
Collazuol Gianmaria	0.3
Lucchesi Donatella	0.8
Morandin Mauro	0.7
Simi Gabriele	0.7
Stroili Roberto	0.7
Rotondo Marcello	0.7
Total	5.3
Tecnologi	
Bellato Marco	0.3
Benettoni Massimo	0.4
Corvo Marco	1
Gianelle Alessio	1
Montecassiano Fabio	0.3
Total	3
Total	8.3

Request :

MI : 1 k€/FTE

ME : 2 m.u./FTE +

1 m.u/FTE service task

1 m.u. = 3.8 k€

Consumo : 1.5 k€/FTE

Apparati e inventariabile :

Simi e Collazuol