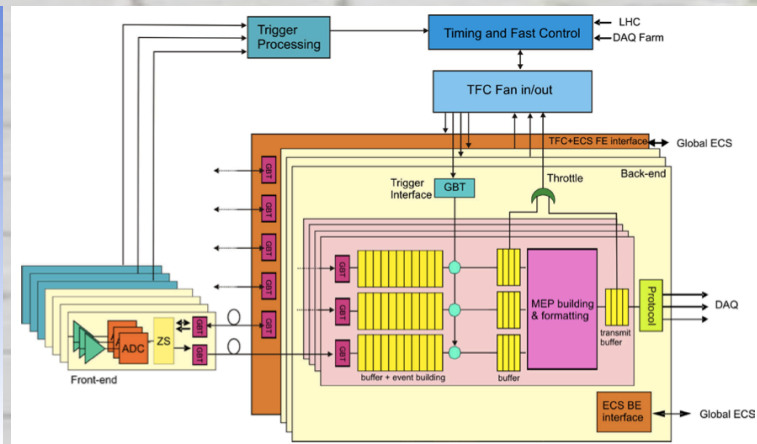
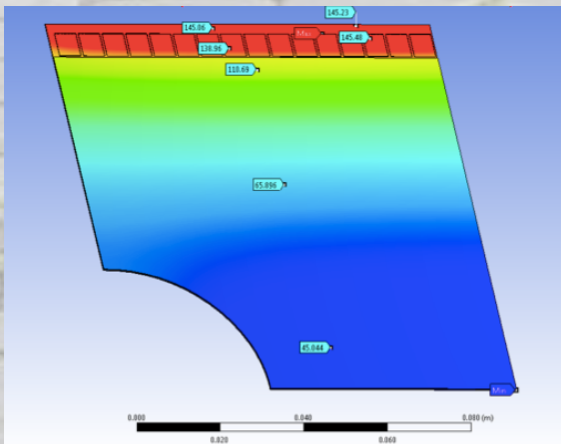


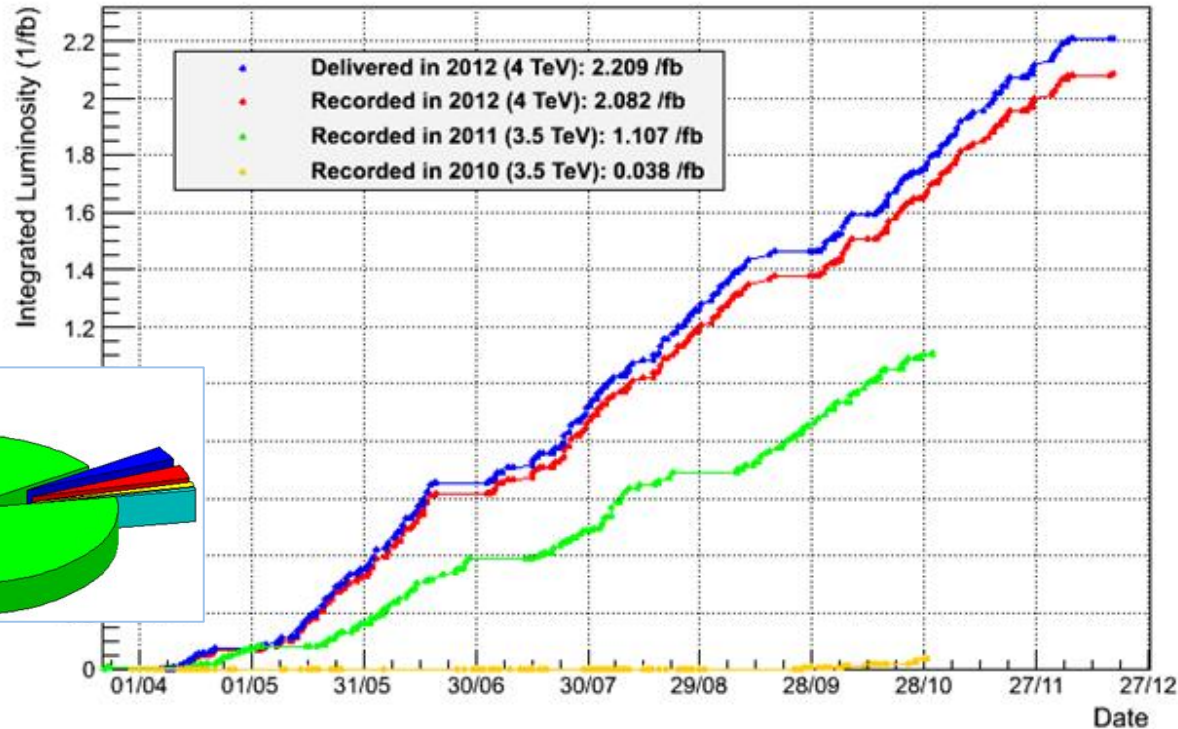
# Status report on LHCb

P. Campana (CERN/Frascati)  
RRB meeting, 17.04.2013



# pp RUN #1

LHCb Integrated Luminosity pp collisions 2010-2012



2012

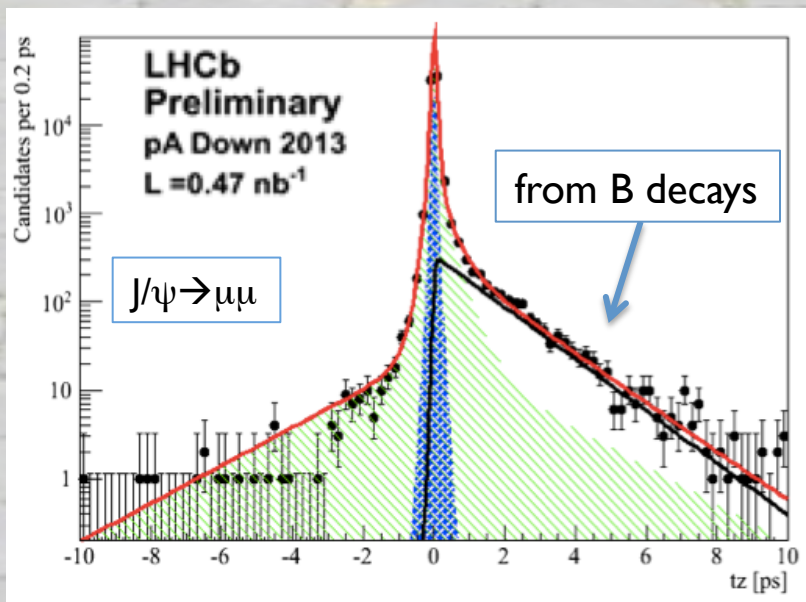
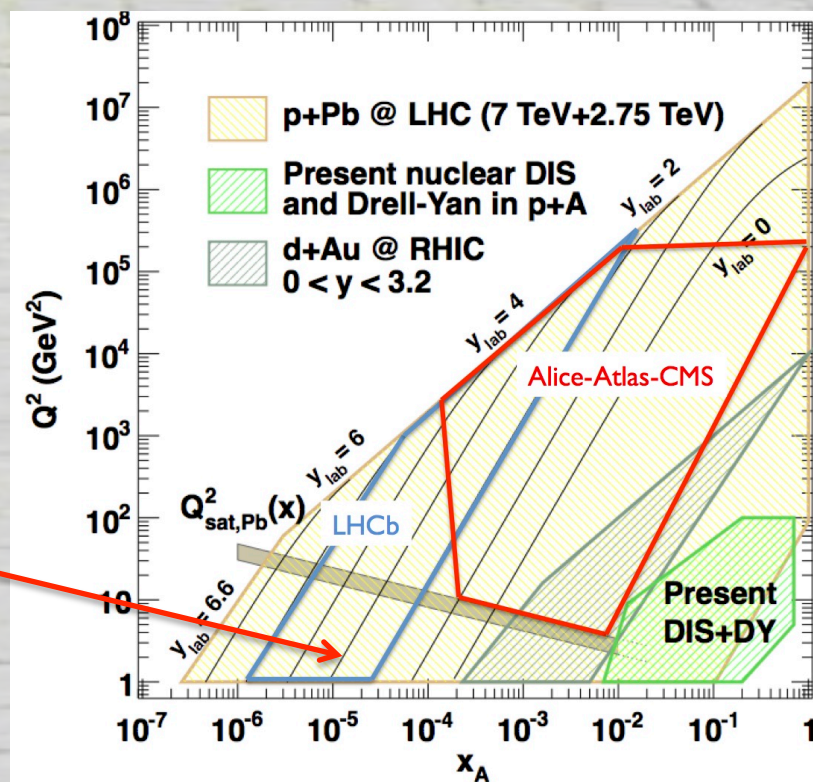
FULLY ON: 93.05 (%)  
HV: 0.54 (%)  
VELO Safety: 0.85 (%)  
DAQ: 2.85 (%)  
DeadTime: 2.88 (%)

- Smooth and highly efficient running throughout the year
- Average luminosity  $3.2 \cdot 10^{32} \text{ cm}^{-2}\text{s}^{-1}$  (max  $L=4 \cdot 10^{32} \text{ cm}^{-2}\text{s}^{-1}$ )
- Special runs: up to  $6 \cdot 10^{32}$  (full detector) –  $10^{33}$  (Velo-ST-Calo-Muon) and 25 ns  
→ VERY useful to prepare 2015 run & upgrade
- 3/fb fully available for analyses (50/50 with Magn. Up/Magn. Down)

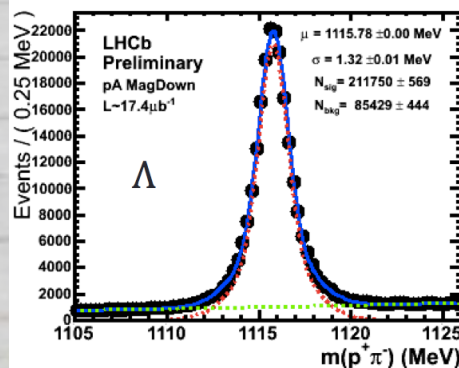


# pA/Ap RUN

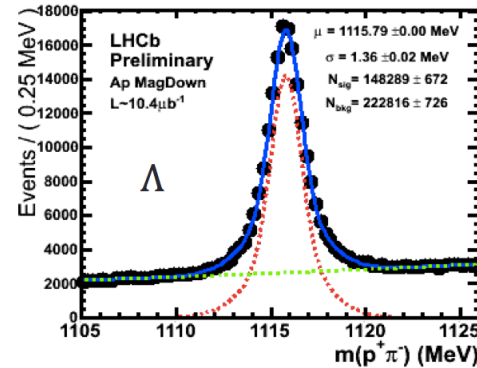
- Very good pA/Ap run (data on both directions, and with magnet UP & DOWN) 2/nb collected
- Analyses started: particle multiplicities, resonances (D,  $J/\psi$ , Y) as probes of Drell Yan processes in a low ( $x$ ,  $Q^2$ ) area specific of LHCb only



pA MagDown ( $\sim 17.4 \mu\text{b}^{-1}$ )



Ap MagDown ( $\sim 10.4 \mu\text{b}^{-1}$ )



## Tasks scheduled for the LSI

The **LHCb** experiment is in operation since 2008 without any major intervention over the last five years: extensive consolidation and maintenance work has been scheduled for the shut down period of more than 20 months

This comprises all general and detector related services, equipment and safety systems

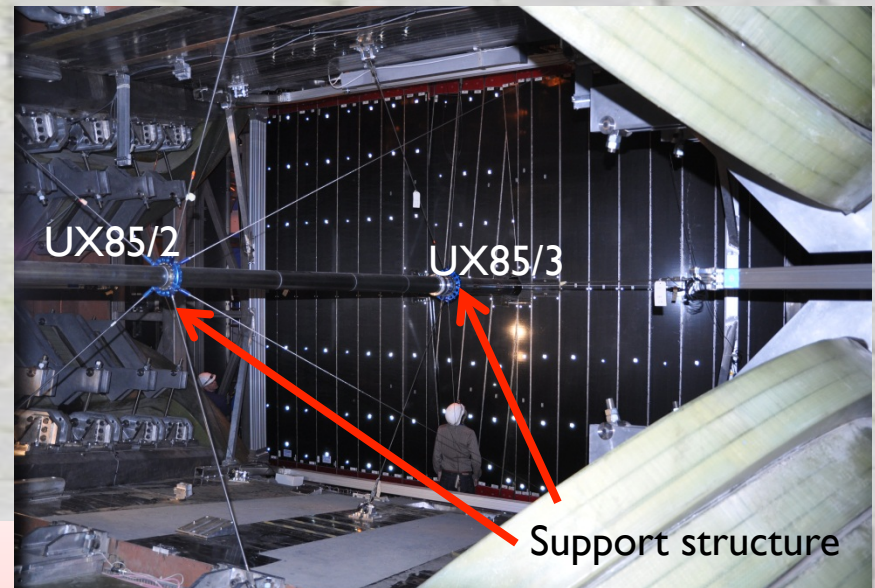
### Beam pipe

- Exchange of the LHCb beam pipe section UX85/3
  - New and much lighter support structure of the beam pipe section UX85/2 and /3
- Requires the dismounting of section 2, 3 and 4 (16.5 m)*

### Upgrade

*(LHCb upgrade installation planned for 2018/19)*

- First preparation of infrastructure, cable trays for optical fibers and their support structure from the underground to the surface
- Installation of detector prototypes for test purpose

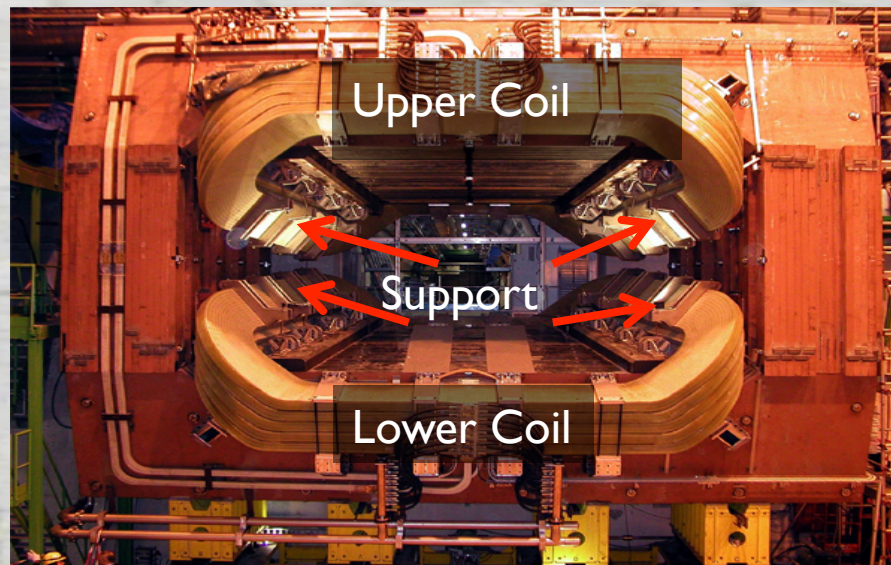
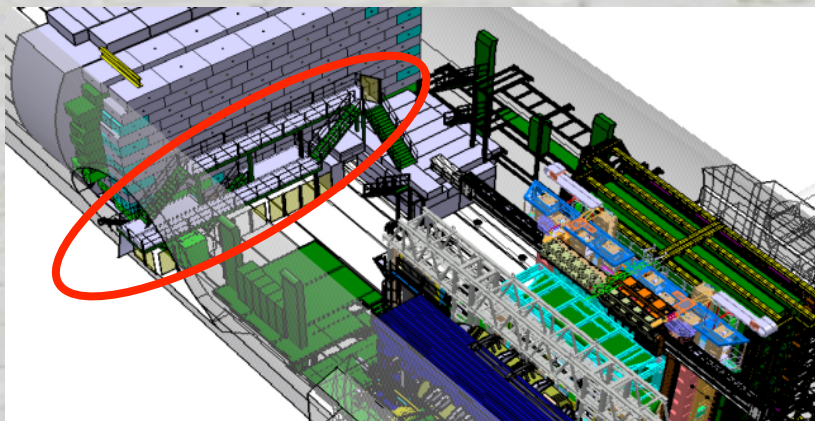




## LHCb Dipole

Replacing of mechanical protection  
between magnet coils and support  
structure

*Requires displacing of both coils, each 25tons*



## Visitor Platform

New gangway for increased number of  
visitors and improved safety with easy  
access

## Detector (only a small excerpt)

- Change of the optical fibers of the ECAL LED monitoring
- MUON PNPI HV channel doubling to improve the system granularity
- HPD replacement according to expectations from ion feedback measurements
- Further aging tests on the OT are scheduled using  $^{90}\text{Sr}$  sources in situ

## **Infrastructure maintenance**

- Metallic structure/access: improve access to RICHI, RP labs, new structure for UPS
- Additional shielding behind Muon system
- HVAC: Replacement of units inherited from Delphi.
- Maintenance and upgrade, monitoring system for IT and beam pipe movements.
- New Control Room building.
- Maintenance, test and consolidation of all safety systems.

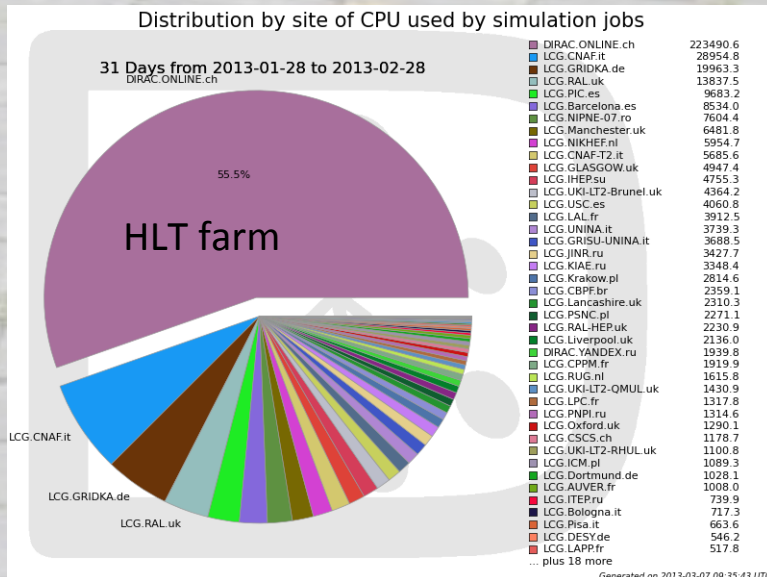
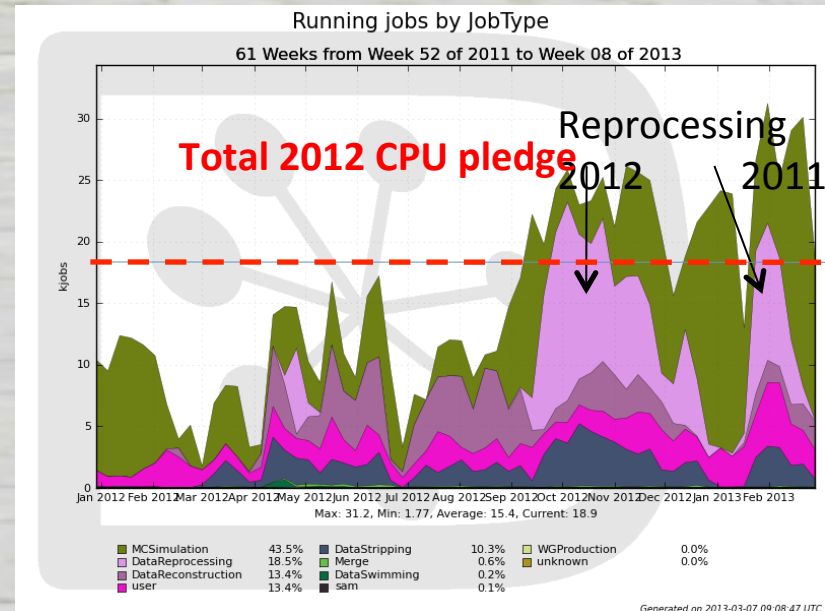
## **Detector service maintenance**

- Cooling: Consolidation IT/TT primary cooling circuits – new chiller
- Consolidation of power distribution for Online monitoring and storage. New UPS
- Replacement of turbines in all electronic racks (end of life cycle)
- Replacement of all mixed water connections in all racks (detector & barracks)
- Maintenance of all cooling plants and circuits
- Maintenance of power converters, transformers and switchboards



# Computing: recent production activities

- Reprocessing of 2011+2012 data (Reco14) completed to be used for all new analyses during LSI
- To be replaced by “last” reprocessing before end of LSI
- Successful heavy ion run. Data will be reprocessed with improved calibrations and selections for the analysis



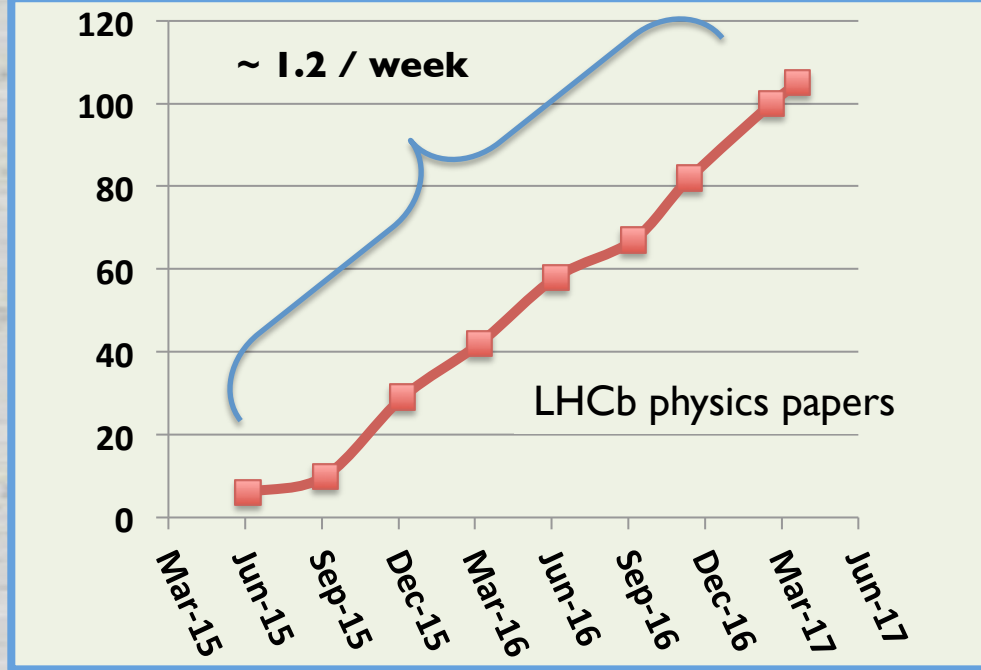
- HLT farm fully commissioned for offline use
- It accounts for 55% of simulation CPU in February, in parallel with pA data taking

## Computing: resource status

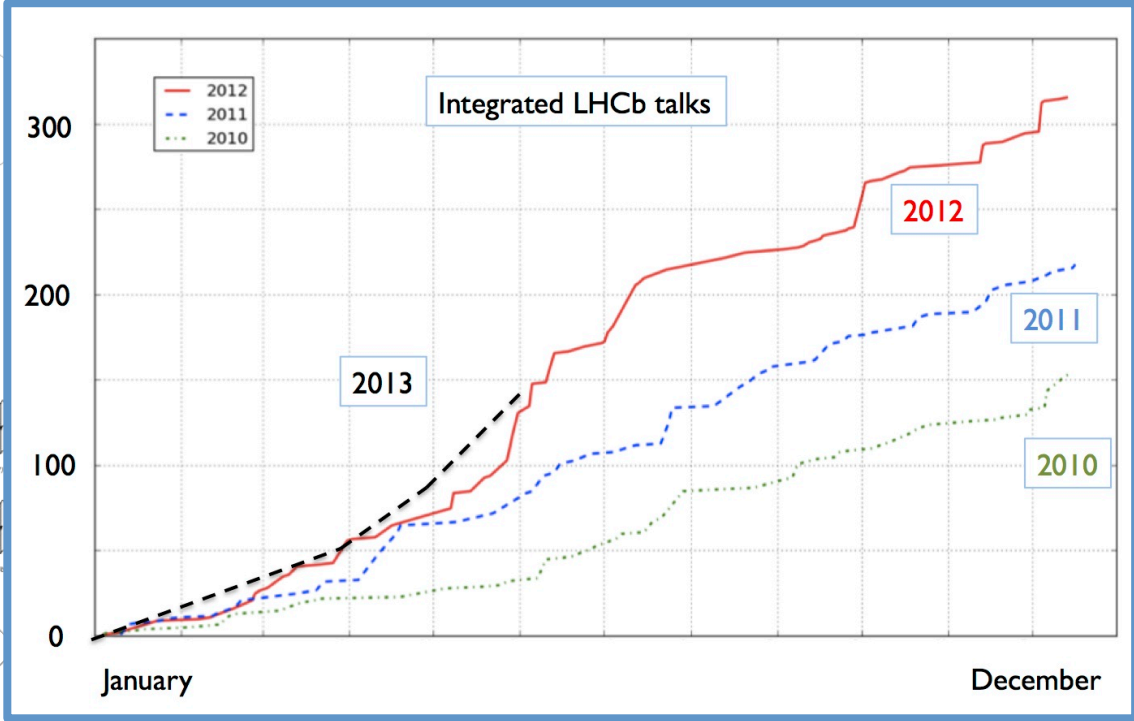
- Scrutinized requests have **not** been fully met by the Tier I
  - Structural problem, pledges are sized according to national algorithms in Tier I countries, cannot add up to 100% (C-RSG requests to address this urgently)
- Extension of 2012 run has increased pressure on storage
  - 3 PB **shortfall** of Tape at Tier I, finally mitigated by some generous Tier I providing their 2013 pledges ahead of schedule
  - Disk space situation has continued to be fraught, not helped by late implementation of pledges by some Tier I and share reduction by others
- Resources requests for 2014+2015 submitted to C-RSG (based on x2 physics output due to  $8 \rightarrow 13$  TeV)
  - CPU: 14% increase (all in 2014)
  - Disk: 110% increase (of which 85% in 2014)
  - Tape: 104% increase (of which 11% in 2014)

If large disk increase not pledged in 2014, cannot use all available CPU resources for simulation
- Ongoing: review and optimization of LHCb computing model





## Selected highlights of recent LHCb results



# LHCb results in fall 2012

## The search for $B_{s(d)} \rightarrow \mu \mu$

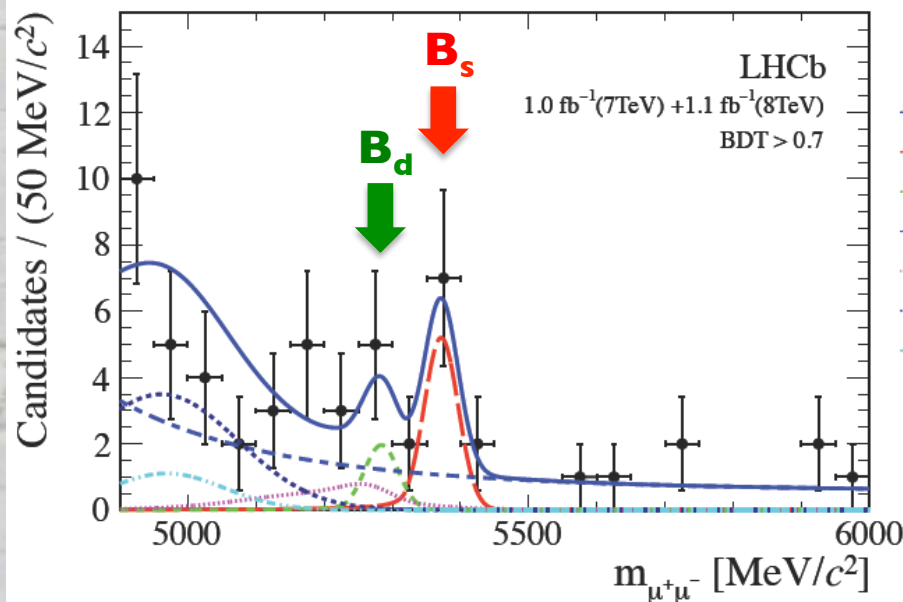
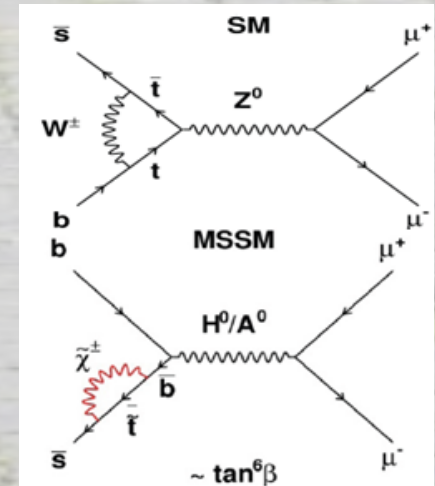
Predicted to be very rare in SM

Precise predictions in SM:

- $\text{BR}(B_s \rightarrow \mu \mu) = 3.5 \pm 0.2 \cdot 10^{-9}$
- $\text{BR}(B_d \rightarrow \mu \mu) = 1.1 \pm 0.2 \cdot 10^{-10}$

“Golden channel” for New Physics effects

$$\text{Br}_{\text{MSSM}}(B_q \rightarrow \ell^+ \ell^-) \propto \frac{M_b^2 M_\ell^2 \tan^6 \beta}{M_A^4}$$



Phys. Rev. Lett. 110, 021801 (2013)

With 2011 + part of 2012 data (2.1/fb)  
LHCb has got the first evidence of  
 $B_s \rightarrow \mu \mu$  decay at  $\sim 3.5\sigma$

$$\mathcal{B}(B^0_s \rightarrow \mu^+ \mu^-) = (3.2^{+1.5}_{-1.2}) \times 10^{-9}$$

in agreement with SM

“background only” p value  $\sim 5 \cdot 10^{-4}$

Also best limit on  $B_d \rightarrow \mu \mu$

$$\mathcal{B}(B^0 \rightarrow \mu^+ \mu^-) < 9.4 \times 10^{-10} \text{ at 95\% CL}$$



## CPV in $B_d$ system

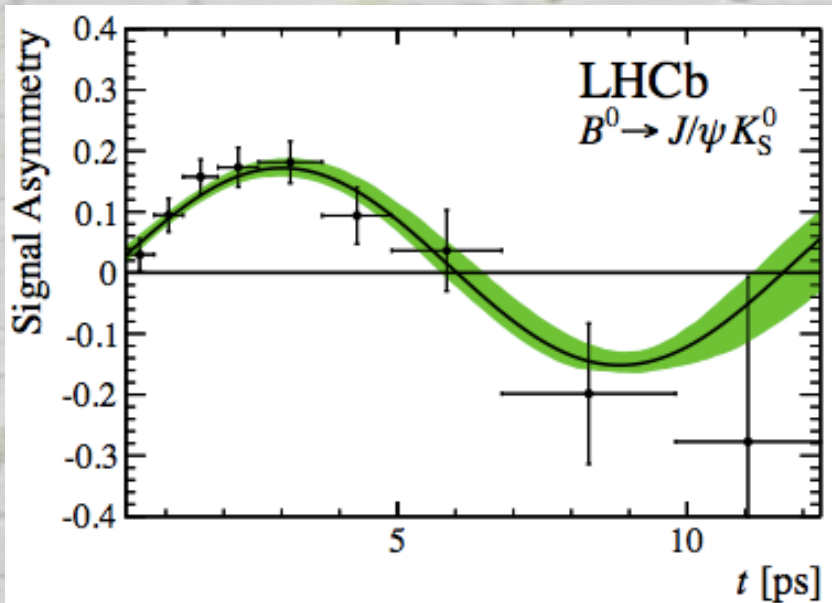
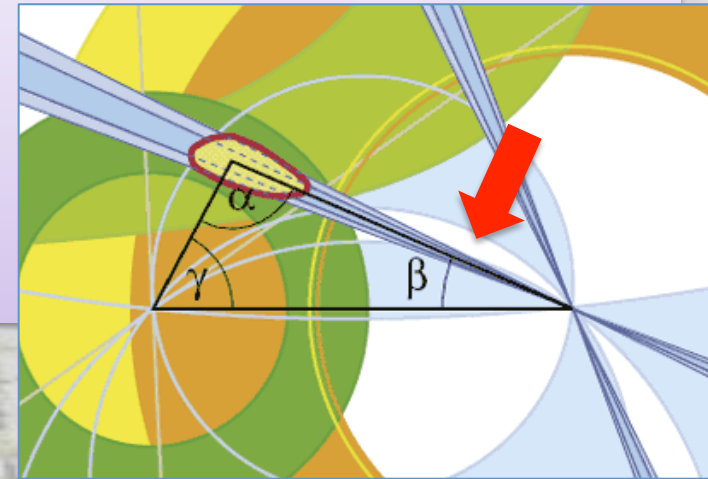
Measuring CPV variables in  $B_d$  decays (1/fb data):

- $\Delta m_d$  oscillation frequency in  $B_d \rightarrow D\pi$  and  $B_d \rightarrow J/\psi K^*$  decays
- $\sin 2\beta$  from  $B_d \rightarrow J/\psi K_S$  decays

Both measured precisely at B factories

Test bench for future capabilities of LHCb at upgrade in  $B_d$  sector

Time-dependent measurement: flavor tagging needed



LHCb results:

$$\sin 2\beta = 0.73 \pm 0.07 \text{ (stat)} \pm 0.04 \text{ (syst)}$$

Still less precise than B factories ( $\sigma_{\text{STAT}} \times 3$ )

$$\Delta m_d = 0.5156 \pm 0.0051 \text{ (stat.)} \pm 0.0033 \text{ (syst.) ps}^{-1}$$

World's best measurement

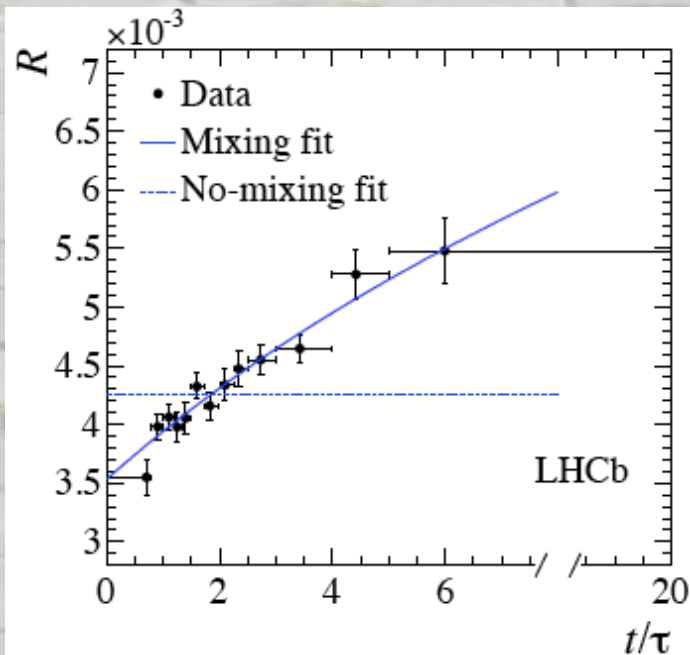
# $D^0 - \bar{D}^0$ oscillations

LHC is also a charm factory and charm is the only “up type” quark where we can search for NP

LHCb has the world’s largest sample of c-hadron decays in charged modes (x10 current B factories)

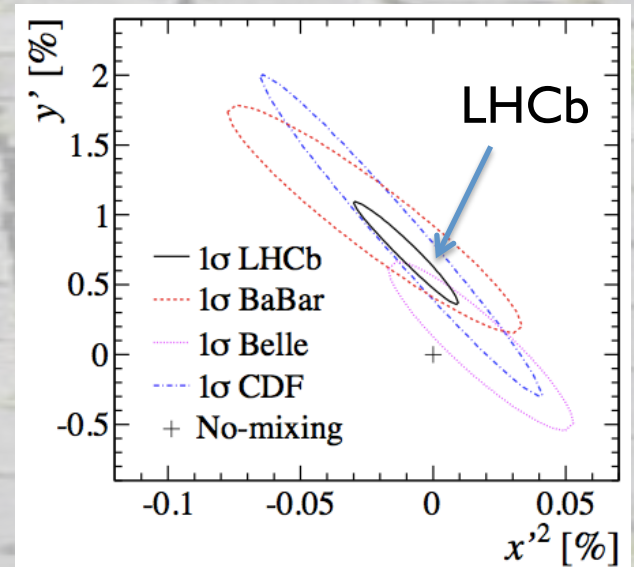
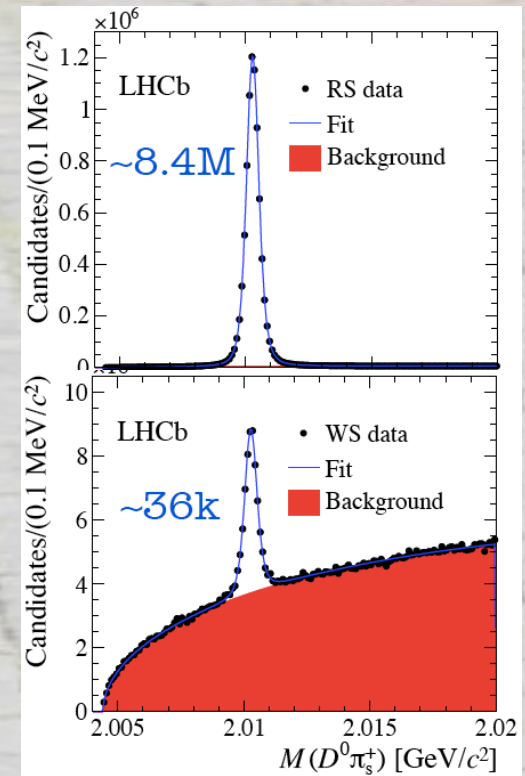
First observation of **charm mixing** in time dependent  $D^0 \rightarrow K\pi$  RS & WS decays by a single measurement ( $9\sigma$ )

$$R(t) = \frac{N_{WS}(t)}{N_{RS}(t)} = R_D + \sqrt{R_D} y' t + \frac{x'^2 + y'^2}{4} t^2$$



Parameter	Fit result ( $10^{-3}$ )
$R_D$	$3.52 \pm 0.15$
$y'$	$7.2 \pm 2.4$
$x'^2$	$-0.09 \pm 0.13$

PRL 110, 101802 (2013)





# LHCb results at 2013 Winter Conferences

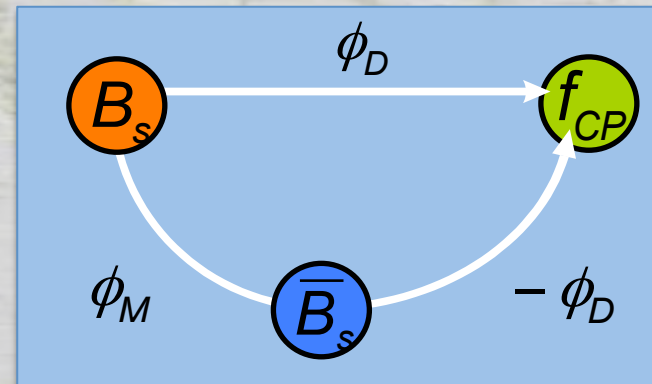
## CP violation phase in $B_s$ tree decays

Update of LHCb measurement (1/fb)

- $\phi_s$  in  $B_s \rightarrow J/\psi$  KK and  $B_s \rightarrow J/\psi \pi\pi$  decays

New in this analysis :

- use of SSKT (more sensitivity)
- better study of systematics
- KK in [990, 1050] MeV and full  $\pi\pi$  spectrum



Opposite Side Tagger  $\varepsilon D^2 = (2.29 \pm 0.06)\%$

Same Side K Tagger  $\varepsilon D^2 = (0.89 \pm 0.17)\%$

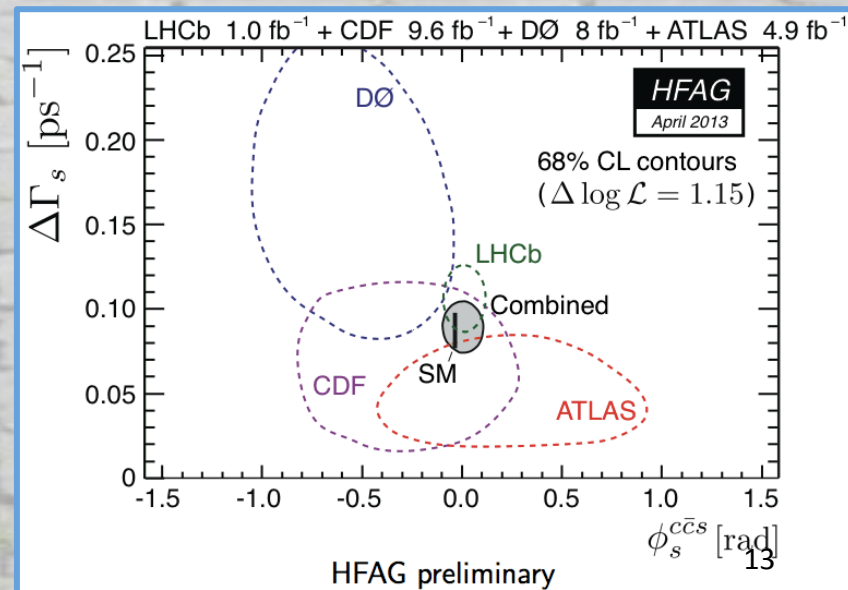
Combined tagging  $\varepsilon D^2 = (3.13 \pm 0.23)\%$

Sizeable reduction of syst. error on  $\phi_s$

$$\begin{aligned}\phi_s &= 0.01 \pm 0.07 \text{ (stat)} \pm 0.01 \text{ (syst) rad,} \\ \Gamma_s &= 0.661 \pm 0.004 \text{ (stat)} \pm 0.006 \text{ (syst) ps}^{-1} \\ \Delta\Gamma_s &= 0.106 \pm 0.011 \text{ (stat)} \pm 0.007 \text{ (syst) ps}^{-1}\end{aligned}$$

Previous result:  $\phi_s = -0.002 \pm 0.083 \pm 0.027$  rad

Interference of mixing&decay: CPV phase  
Penguin diagrams could give NP effects



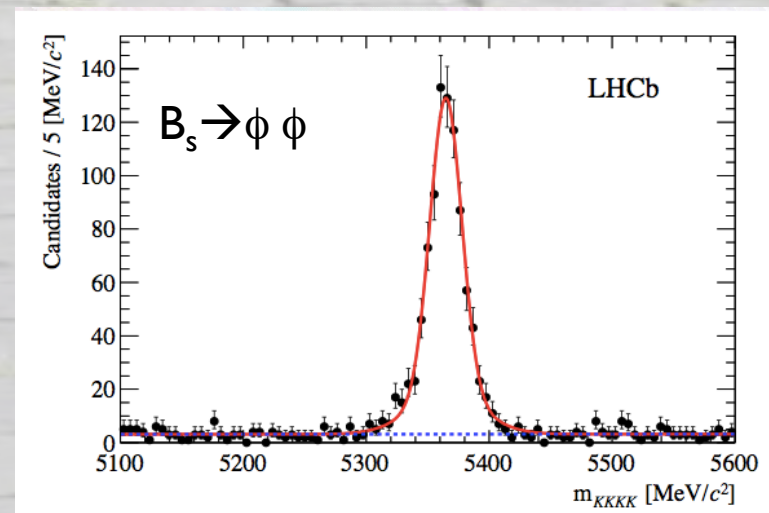
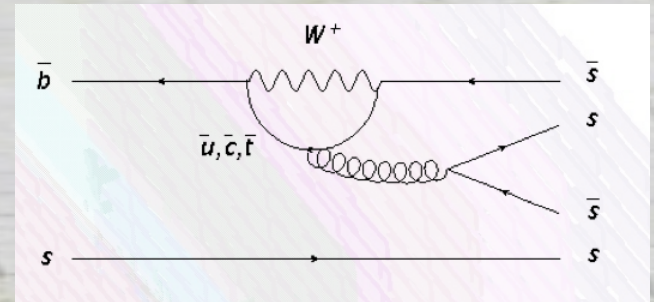
## CP violation phase in a $B_s$ penguin decay

- $B_s \rightarrow \phi \phi$  is mediated by the pure penguin transition  $b \rightarrow sss$  and  $\phi_s$  can be measured
- SM predicts  $\phi_s \sim 0$  due to cancellation of weak and decay phases. NP could induce bigger values of  $\phi_s$
- VV final state, same angular analysis as  $B_s \rightarrow J/\psi \phi$  : much lower statistics ( 880 events in 1/fb )
- OS and SSK tagging used
- $\Gamma_s$  ,  $\Delta\Gamma_s$  and  $\Delta m_s$  taken from other LHCb measurements

$$\phi_s = (-2.46, -0.76) \text{ 68\%CL (stat) } \pm 0.22 \text{ (syst)}$$

One of the key channels for the upgrade  
(yield x 200 w.r.t. now)

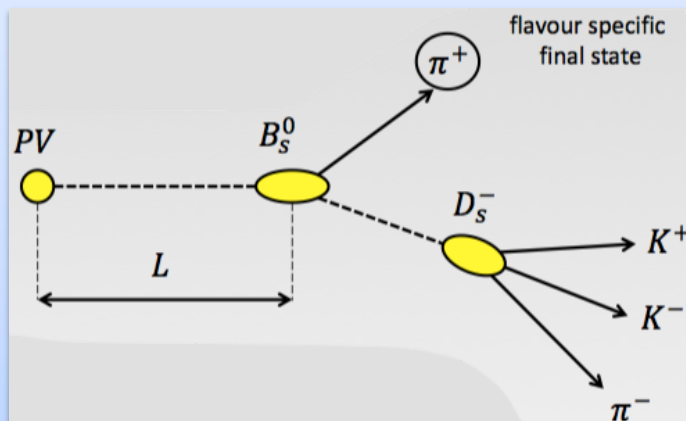
arXiv:1303.7125





# Measuring $\Delta m_s$ in $B_s$ oscillations

- Data sample (1/fb) : 34,000 signal candidates from  $B_s \rightarrow D_s \pi$  with  $D_s$  decaying in 5 different final states:  
( $D_s \rightarrow \phi\pi$ ,  $KK$ ,  $KK\pi$ ,  $K\pi\pi$ ,  $\pi\pi\pi$ )
- Time dependent, flavor tagged analysis



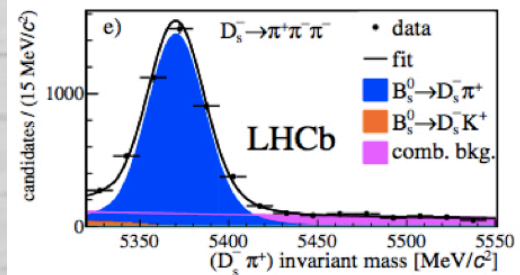
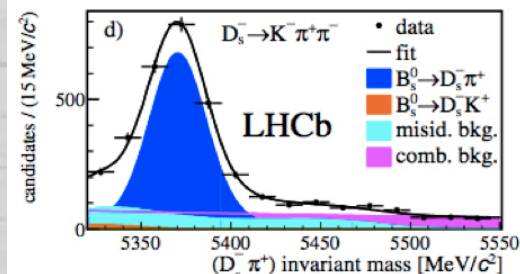
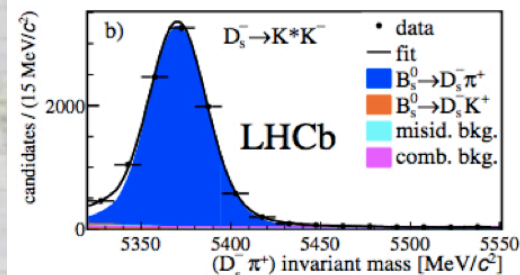
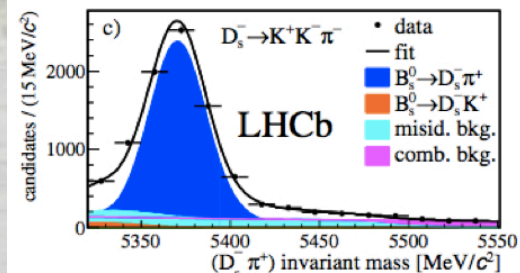
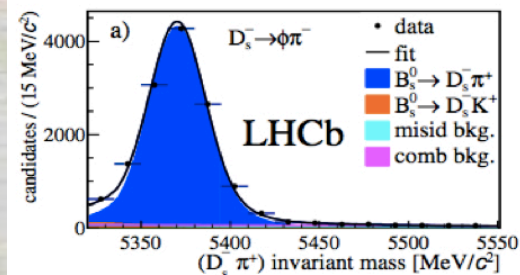
- Time resolution:  $\sigma_t \sim 44$  fs (as expected)
- Main systematics: decay length and momentum scales

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

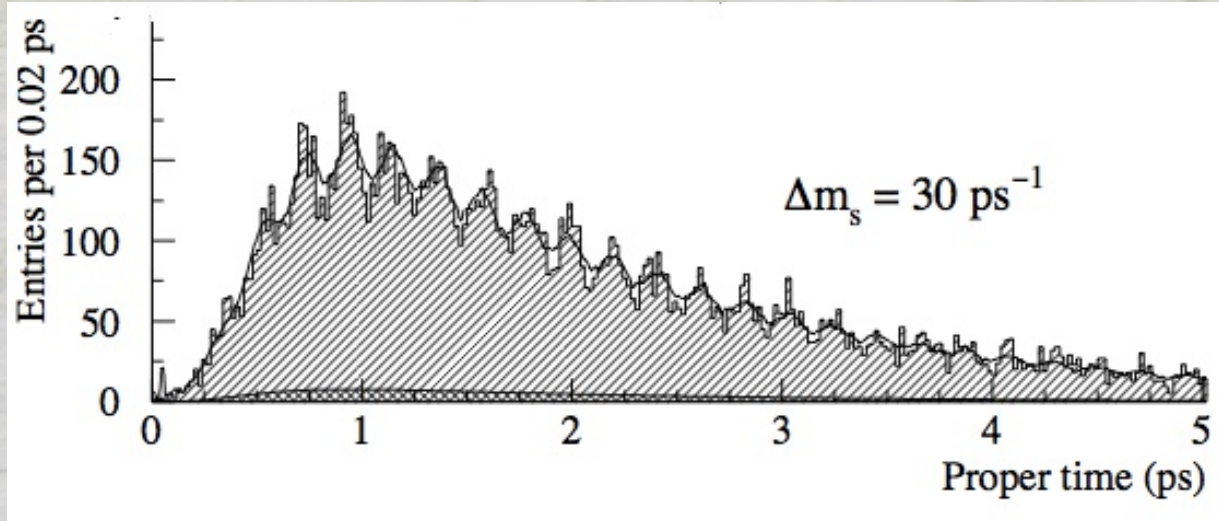
(previous result with 0.36/fb =  $17.725 \pm 0.041 \pm 0.026 ps^{-1}$ )

LHCb-PAPER-2013-006

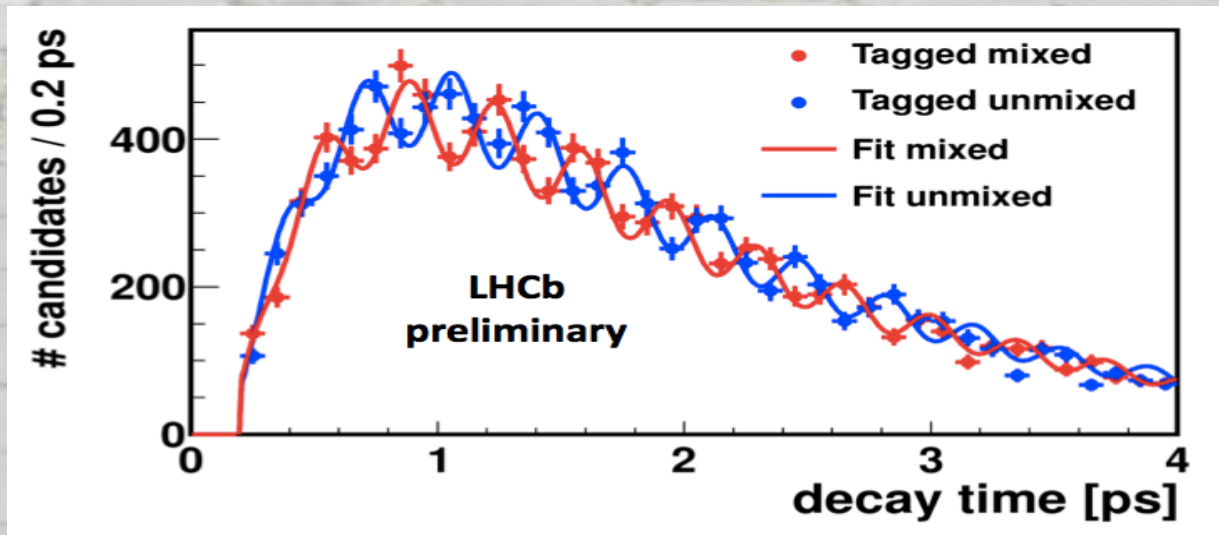
(sizeable reduction of systematics)



## LHCb Technical proposal (1998)



## LHCb data analysis (2013)



15 years (!)



# X(3872)

X(3872) resonance found 10 years ago by BELLE and confirmed later.

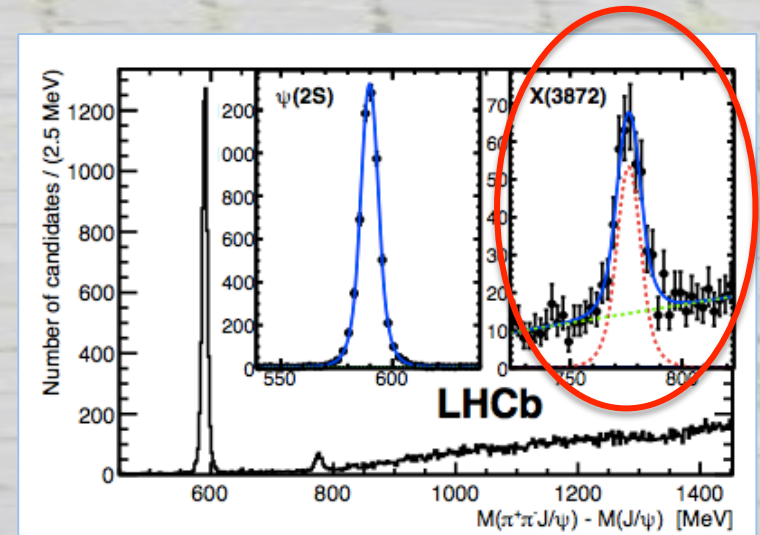
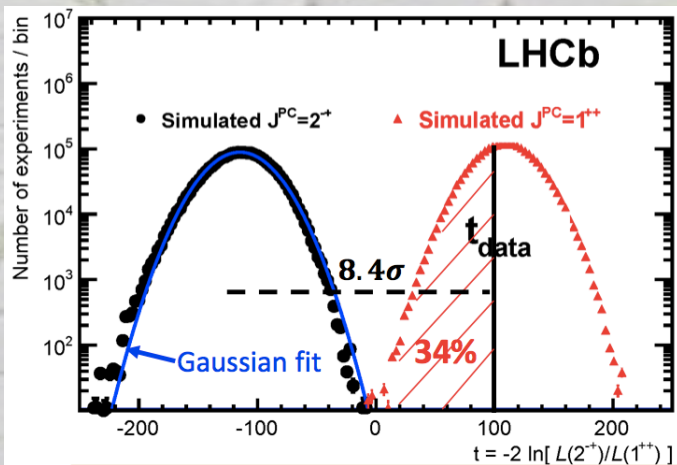
Since then, a puzzle for the determination of its nature as it is difficult to host in the charmonium spectrum.

A conventional  $\eta_{c2}$ , a tetra-quarks system, a  $D^*D$  molecule, or some mixture ?

Determination of quantum numbers is **vital** :  $J^{PC}$  could be  $1^{++}$  or  $2^{-+}$

LHCb observes X(3872) in  $B^+ \rightarrow XK^+$  decays with  $X(3872) \rightarrow J/\psi \pi \pi$  (1/fb data sample **313** ev.)

5D fit to angular variables to test against  $J^{PC}$  hypotheses  $\rightarrow J^{PC} = 2^{-+}$  **rejected at  $8\sigma$**



$J^{PC} = 1^{++}$  favors unconventional explanations (such as  $D^*D$  molecule, tetra-quarks) and provides further food for theorists' thoughts ...

arXiv:1302.6269

## CP violation in charm decays

Charm is the only “up type” quark where we can search for NP  
CP violation in SCS decays is a preferred place for studies (CPV  $\sim 0$  expected in SM)

At the end of 2011 LHCb presented  $3.5\sigma$  evidence for direct CPV in 0.6/fb sample

$\Delta A_{CP} = A_{CP}(KK) - A_{CP}(\pi\pi)$   
based on  $D^*$  prompt (with  $\pi$  soft tag)

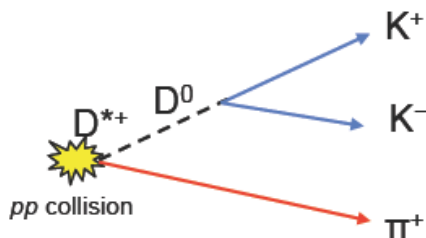
$$\Delta A_{CP} = [-0.82 \pm 0.21(\text{stat.}) \pm 0.11(\text{sys.})] \%$$

In Moriond QCD2013 two new analyses were presented:

- $D^*$  prompt sample, updated with full 2011 reprocessed data (1/fb)
  - $D^0$  from a sample of  $B \rightarrow D \mu^\pm X$  (1/fb), with  $D^0$  flavor tagged by the sign of the  $\mu$
- Independent samples, totally different systematics

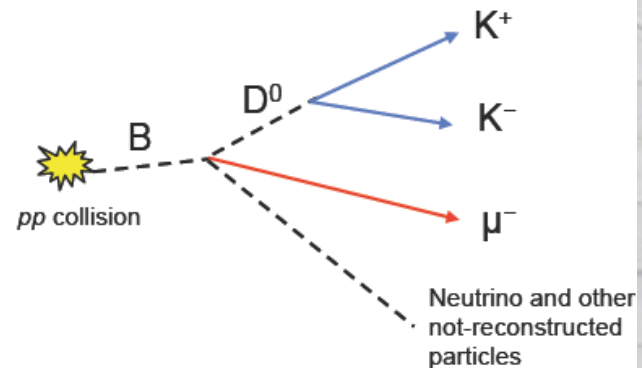
### Pion-tagged analysis

(prompt  $D^{*\pm}$  decays)



### Muon-tagged analysis

(semileptonic B decays)



- $\Delta A_{CP}$  with prompt  $D^*$

$$\Delta A_{CP} = [-0.34 \pm 0.15 \text{ (stat)} \pm 0.10 \text{ (syst)}]\%$$

The result is closer to zero than the result in 2011, but the shift is consistent with originating from the larger statistics

LHCb-CONF-2013-003

- $\Delta A_{CP}$  with semileptonic tag

$$\Delta A_{CP} = [+0.49 \pm 0.30 \text{ (stat)} \pm 0.14 \text{ (syst)}]\%$$

arXiv:1303.2614

The results are statistically compatible ( $2.2 \sigma$ )

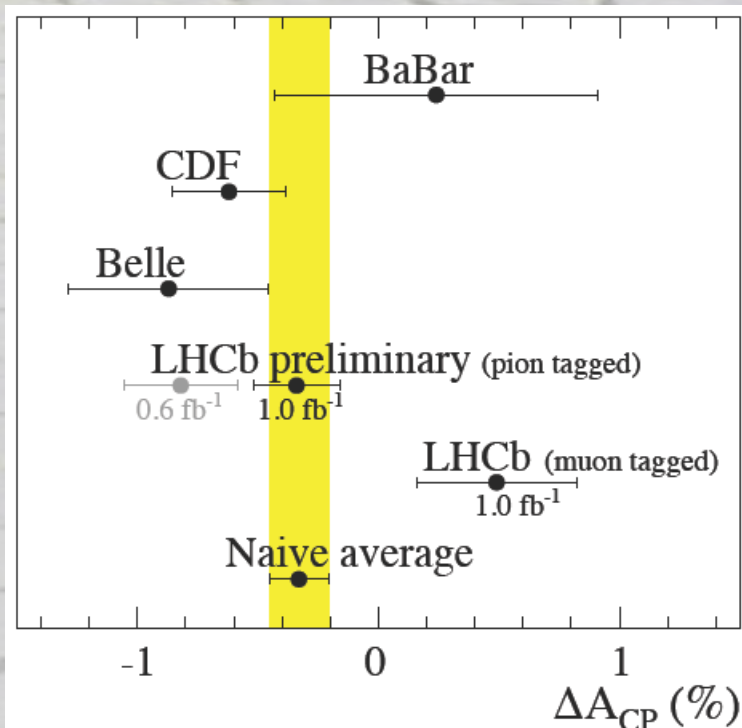
- LHCb results combined

$$\Delta A_{CP} = (-0.15 \pm 0.16)\%$$

- New preliminary world average

$$\Delta A_{CP} = (-0.33 \pm 0.12)\%$$

→ Previous evidence for CPV in charm not confirmed



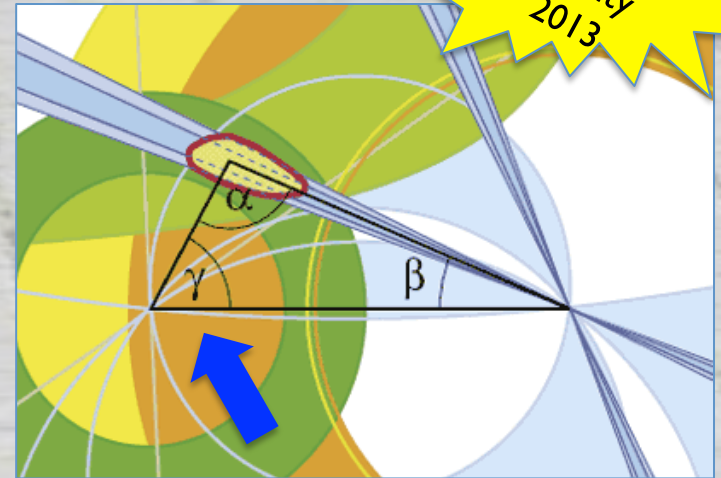


## A new measurement of CKM $\gamma$ angle

So far, CKM  $\gamma$  is known to  $\pm 16^\circ$  from LHCb and B factories

Last LHCb result released at CKM2012 from combination of  $B^+ \rightarrow DK^+$  modes (1/fb):

- GLW ( $D \rightarrow KK$ ,  $D \rightarrow \pi\pi$ )
- ADS ( $D \rightarrow K\pi$ ,  $D \rightarrow K\pi\pi\pi$ )
- GGSZ ( $D \rightarrow K_S KK$ ,  $D \rightarrow K_S \pi\pi$ )



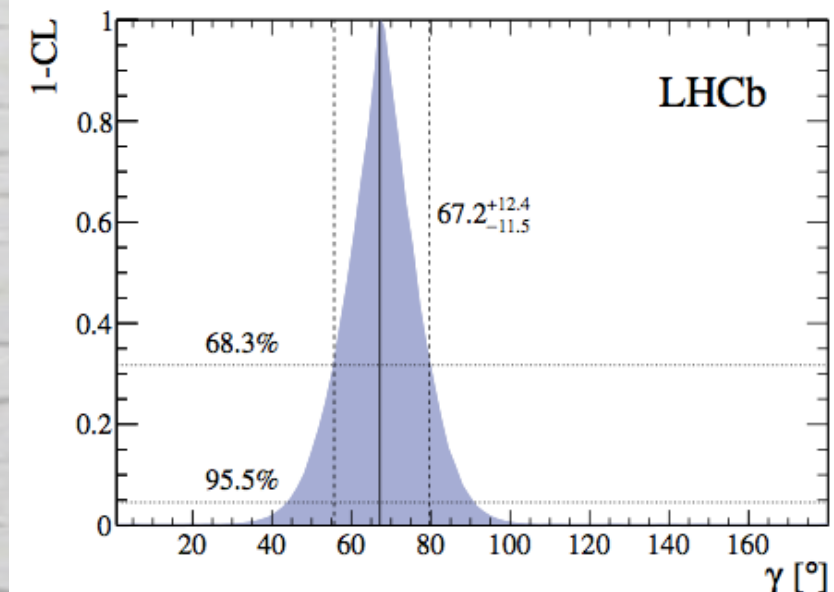
### Update of GGSZ analysis with 3/fb

New combination brings a significant decrease of the error

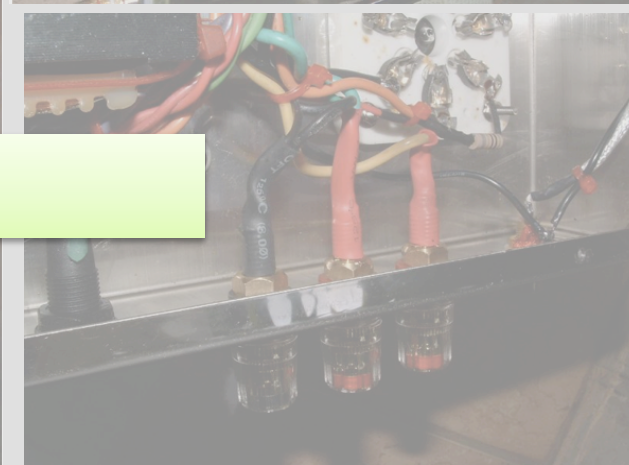
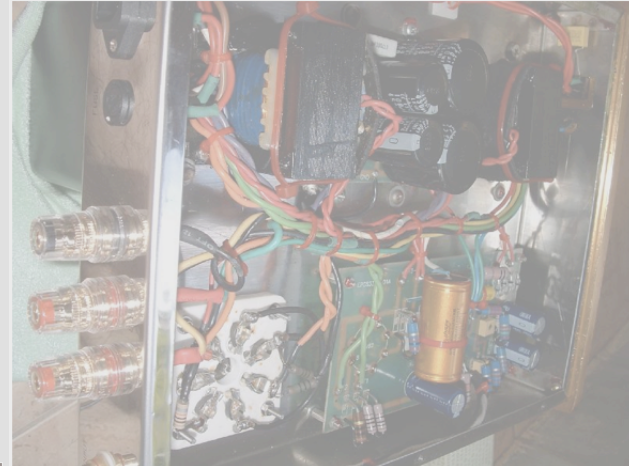
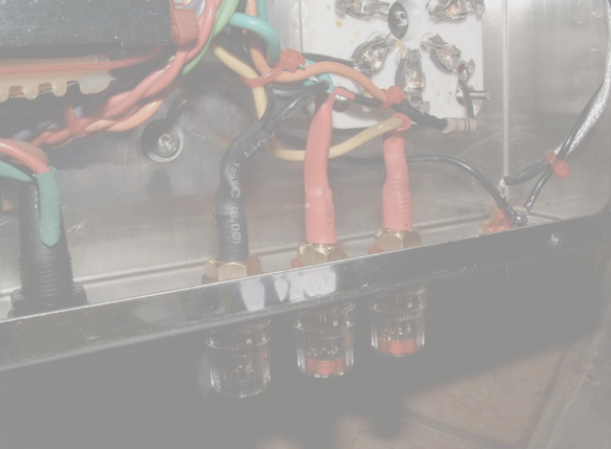
$$\gamma = (67 \pm 12)^\circ$$

Now LHCb has world's best result

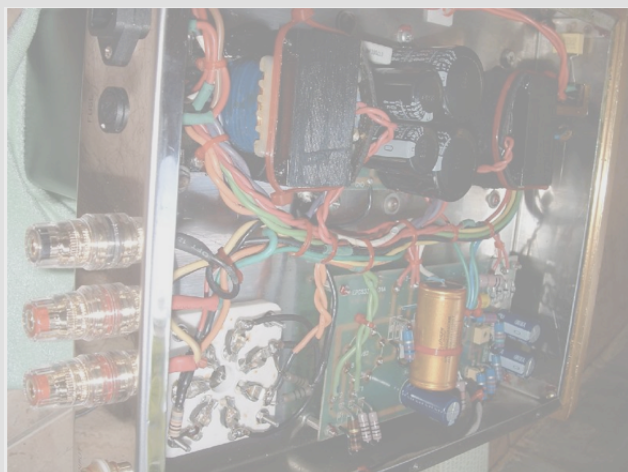
Brilliant perspectives for the near future as more statistics and more channels will be available for a global LHCb combination



LHCb-CONF-2013-004  
LHCb-CONF-2013-006



# The LHCb upgrade





## Status of LHCb upgrade

Since last RRB:

- The LHCb upgrade has been approved by the CERN Research Board
- ESPP document: Flavor physics is part of full exploitation of LHC (including HL-LHC)

At this RRB:

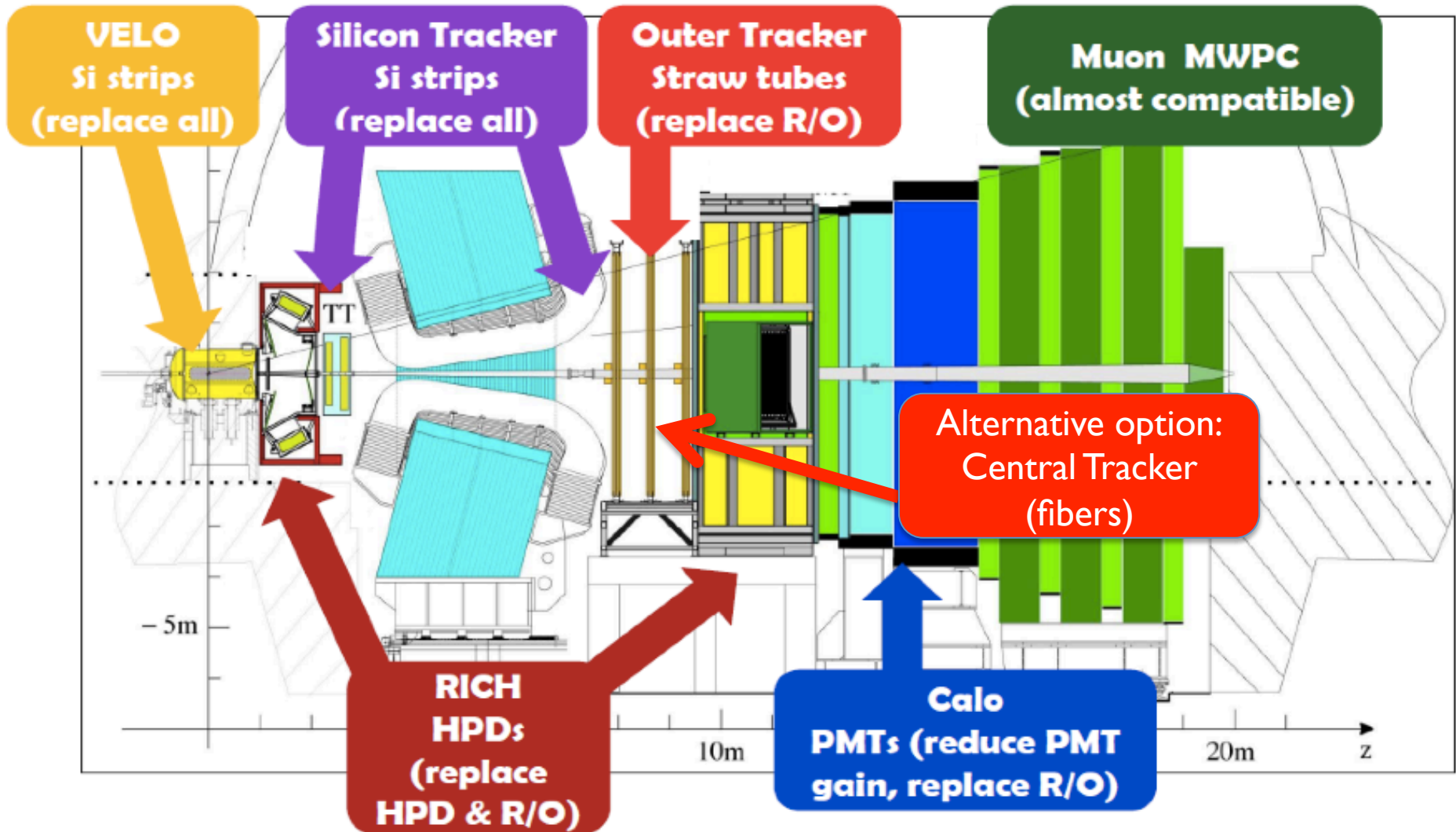
- First [Upgrade Money Column](#) presented ([Matrix](#) will be released soon after technological choices will be finalized)
- Expecting first feedbacks from Funding Agencies also on [MoU on Common Items](#) (which is now in final form, as also approved by CERN legal service)

Proceeding towards TDRs in fall 2013. Major next milestones :

- choice of detector technology for [Vertex Locator](#) (pixel vs strips)
- choice of technology for [Tracking System](#) (fibers vs silicon)
- choice of layout for [RICH](#) (new RICH1 or RICH1/2 integrated)



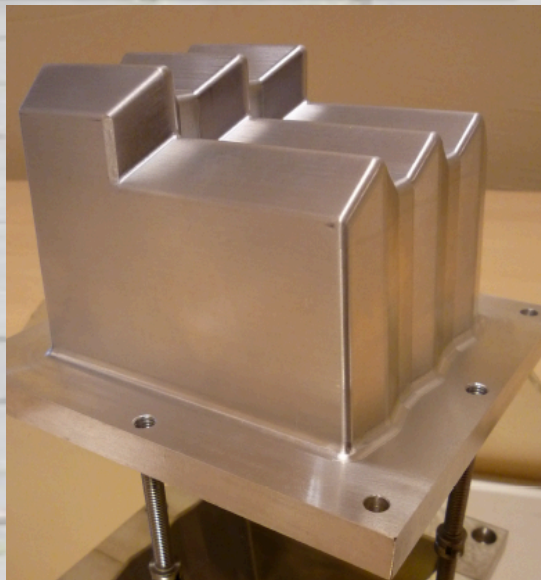
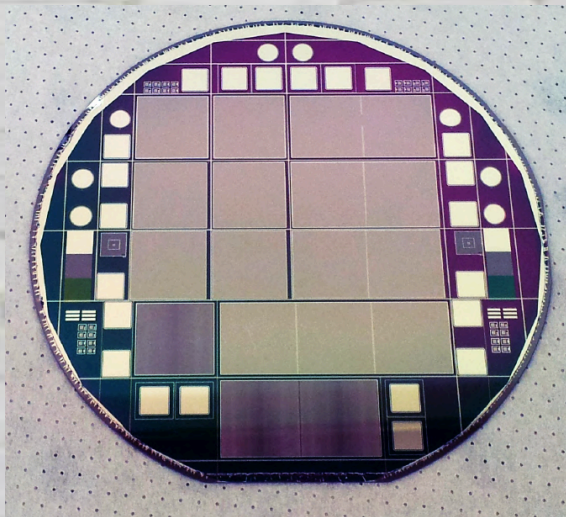
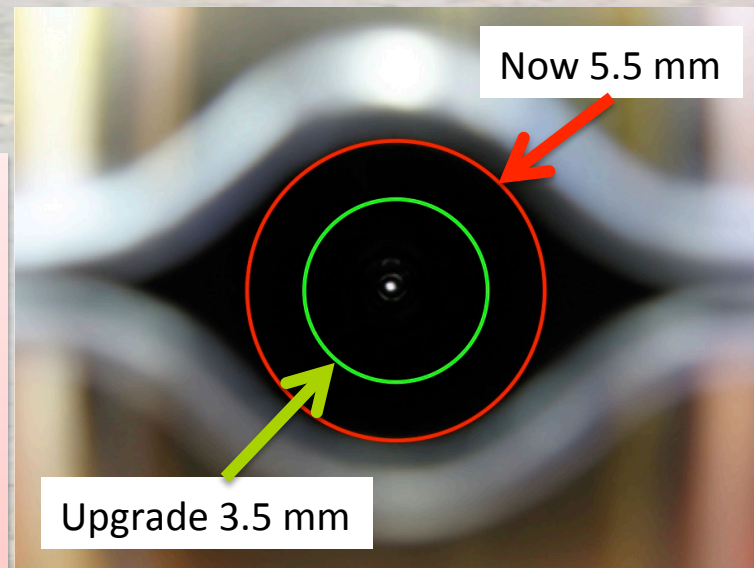
## LHCb detector modifications for the upgrade



## VELO upgrade

Important progresses on several items:

- New apertures studies → smaller beam pipe (approved by LMC) will allow better IP resolution
- R&D on micro-channel cooling well advanced (critical item for both solutions), but studies continuing also on more standard option
- RF foil samples machined in Nikhef with new technology (goal: 0.15 mm thickness)
- Sensor studies and tests (Pixel and Strips)
- Modules 0 prototyping and simulations ongoing



## Road map toward a decision on VELO technology

### ON detector side

Review: 5 referees appointed (3 external)

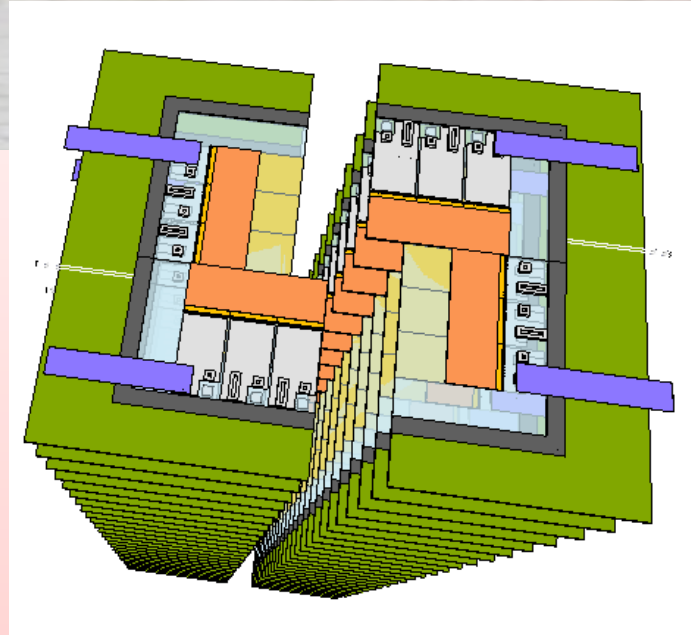
May 22-23 – Review VELO meeting in Nikhef

June 20 – LHCb Technical Board to ratify the baseline solution

VELO TDR should be ready by end of 2013

### ON simulation side

- Implications of technology choice on physics: 4 benchmark channels ( $B_s \rightarrow \phi\phi$ ,  $B \rightarrow K^*\mu\mu$ ,  $B \rightarrow \phi\gamma$ ,  $D^* \rightarrow D^0\pi$ ) under study to evaluate performances
- Results are reported in an “Upgrade Physics and Trigger” (UPT) document to support technical reports under preparation (will be available for review meetings) with several options simulated





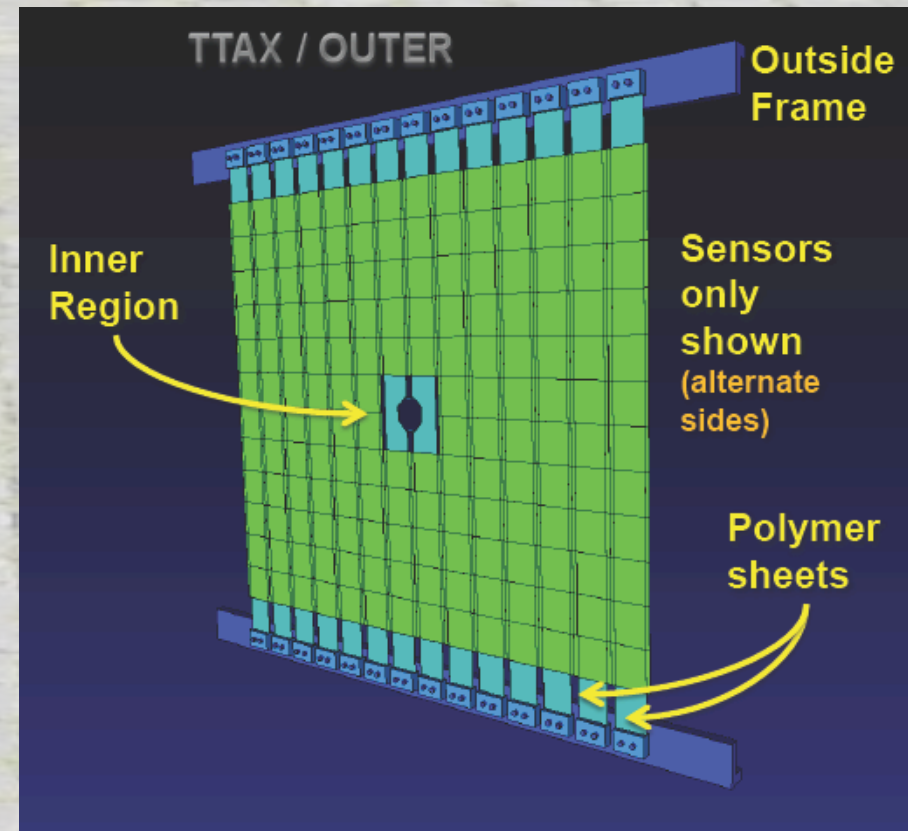
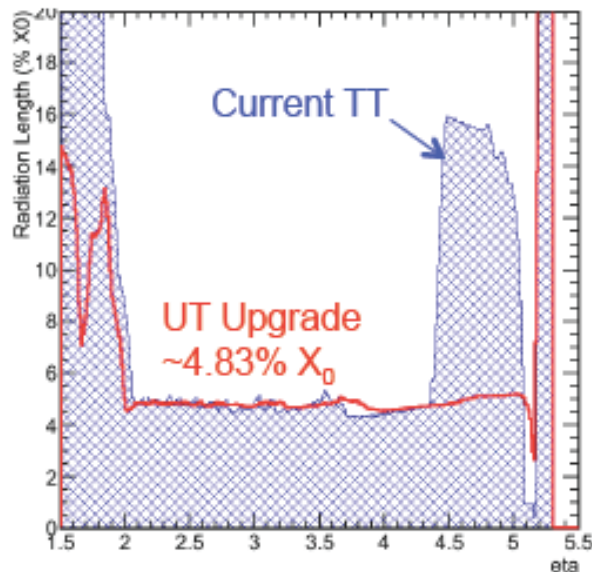
## Trigger Tracker upgrade

Trigger Tracker (silicon detector) of vital importance to:

- give first measurement of  $p$  in HLT
- $K_s$  and  $\Lambda$  reconstruction
- remove track ghosts

Technological challenges:

- long ladders (cooling, mechanics)
- coverage at low  $\eta$
- low material budget



Optimizing the current layout to profit from magnetic field, to measure momentum of tracks

Custom chip (SALT) under preparation: 2 foundry submissions already completed, 3<sup>rd</sup> (with FE and ADC blocks) ready by mid 2013

# Fiber tracker viability assessment

Question: can fibers and SiPM sustain the occupancy and radiation ( $\sim 1 \text{ Mrad}$ ) ?

Review of viability assessment (3 referees)

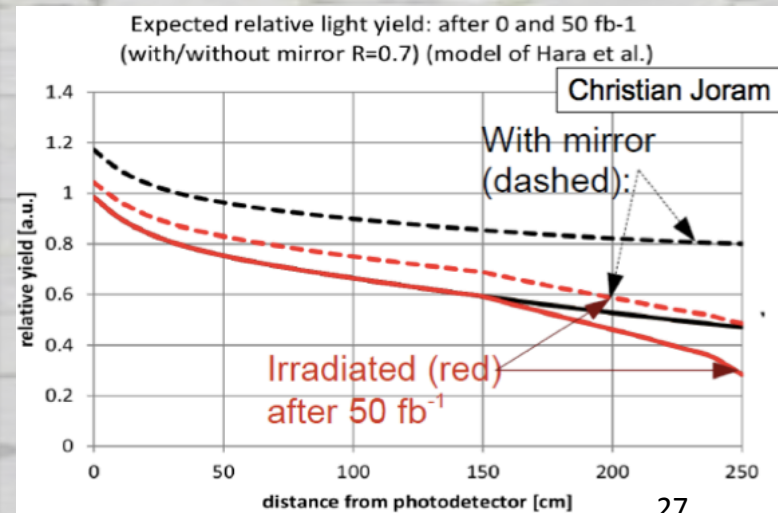
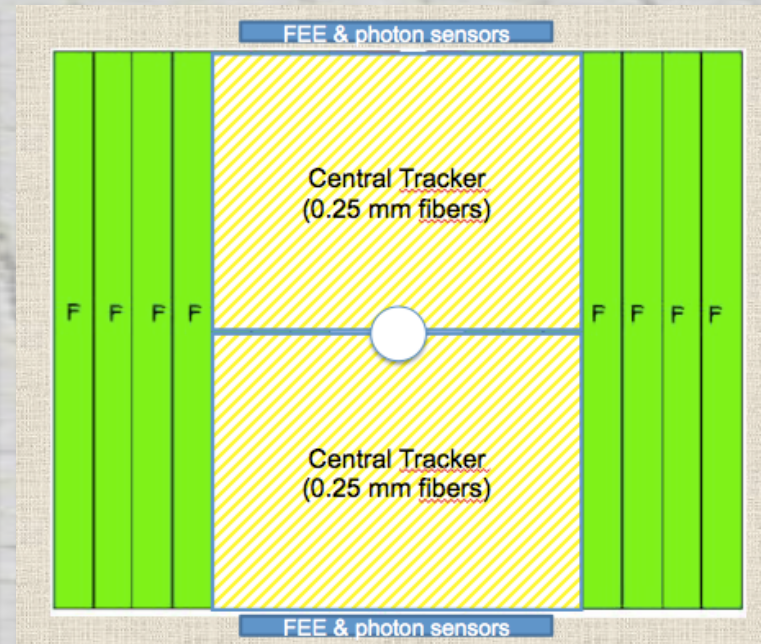
“Our (reviewer) view is that **we do not see any showstopper** due to radiation effects in both SciFi and SiPM technologies as applied to the tracking system of LHCb, provided the operation conditions for the detector, as shown in the review, can be satisfied.

These conditions resume to:

- An integrated luminosity of  $50 \text{ fb}^{-1}$  over 10 years;
- A number of detected photoelectrons of 15 or higher;
- A temperature of  $-40^\circ\text{C}$  or lower for the SiPM;
- A neutron shield, capable of lowering x2 the flux.”

Therefore we will continue to study F.Track. option to explore its construction feasibility and physics performance (also evaluating a full fiber option)

We expect the other option (Silicon T.) will work, although the replacement of shorter straw tubes may pose a problem of resources



## RICH upgrade

Currently two options under evaluation:

- Modification of the current RICH 1 optics to cope with high occupancy : sizeable increase in the amount of PM
- Integration of RICH 1&2 in a single vessel (TRIDENT, which could host in LS3 the TORCH for the low momentum PID) : more photon yield, less PM but a new mechanical structure

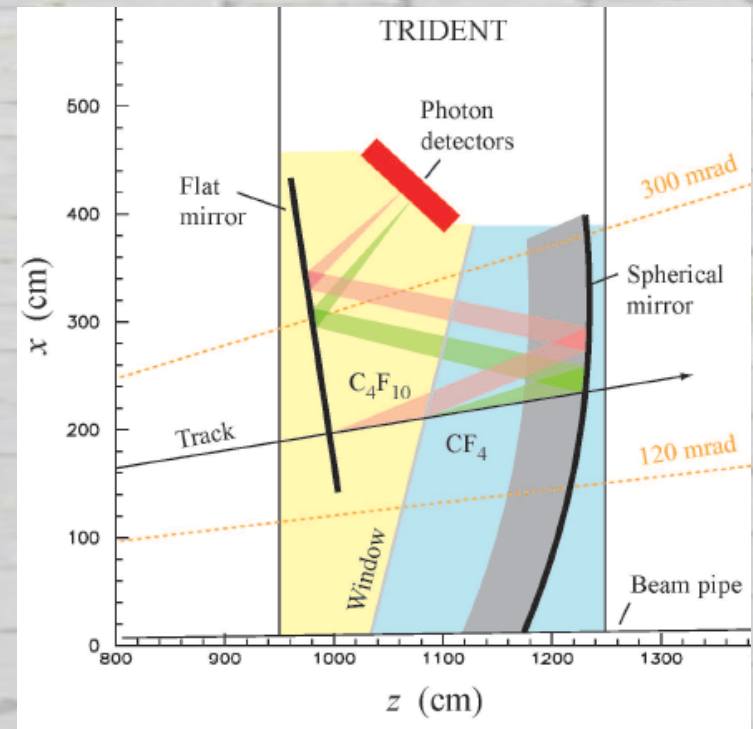
Detailed studies on performances, costing and feasibility undergoing

Roadmap toward a decision on RICH layout :

- April 4<sup>th</sup>, first review of options
- 4 reviewers appointed (2 external)
- June 2<sup>nd</sup>, RICH review meeting
- June 20<sup>th</sup>, proposal for ratification to the LHCb TB

Several other activities ongoing on :

- optoelectronics chain
- FEE chip developments and tests
- PM characterization
- mechanics





## **CALO**

- SPD&PS removed (less material in front of ECAL)
- Adaptation of ECAL and HCAL FEE electronics for 40 MHz operation is well advanced (in particular FE ASIC design to reduce PM gain)
- Study of radiation hardness of inner ECAL modules for operation at  $2 \cdot 10^{33} \text{cm}^{-2}\text{s}^{-1}$  : possibility of their replacement (test undergone during 2012-13 data taking)

## **MUON**

- Removal of MI (due to occupancy)
- Adaptation of off-detector electronics for 40 MHz operation – decision taken to remove all legacy-based elements
- Extensive tests made with special runs: high occupancy rates in inner regions do not affect severely the muon id and some benchmark channels
- Smaller size logical pads could be necessary at high luminosity (not in baseline solution)

## **Electronics & Data Processing**

- External review of “Readout Architecture” successfully passed in December 2012
- Readout board projects (TELL40 & TFC) very well advanced
- Intense work on trigger (LLT+HLT) and on farm online architecture. Several new ideas under test/evaluation (HLT splitting, low level track triggers, use of GPU, use of PCIe)
- Studies on computing framework for the upgrade

## **Machine interface**

- LMC gave ok on reducing VELO radius. Operation of LHCb at upgrade compatible without installation of TAS.

## Cost estimate from FTDR (CORE)

	Sub-Detector	Options	Cost (kCHF)
Tracking systems			
	VELO	Pixel Option	5430
		Strip Option	4530
	Trigger Tracker		6215
	T-stations with CT + OT option		
		CT	7860
		OT	2000
	T-stations with IT + OT option		
		IT	5350
		OT	5915
Particle Identification			
	RICH		9435
	Calorimeters		1905
	Muon System		1805
Trigger and Readout			1840
Common Projects			
	General Infrastructure		2500
	Common Electronics		2500
	Online System		10670

RICH-CALO-MUON ( $2 \cdot 10^{33}$ ) reserve

3500

**TOTAL COST (depending on options) 55÷57 MSF (15% contingency included)**

## Economic requests to Funding Agencies

Country	CORE request [MCHF]
Brasil	1.56
CERN	8.00
China*	
France IN2P3	6.20
Germany BMBF	2.88
Germany MPG*	
Great Britain	11.40
Ireland	0.50
Italy INFN	7.80
Netherlands	3.60
Poland	1.25
Romania	0.90
Russia	5.00
Spain	1.64
Switzerland	5.00
Ukraine*	
United States	4.95
Total	60.67

\*request to be finalized

First contacts with funding agencies provided encouraging feedback concerning at least 70% of the requested funds - including participation to Common Items

Detailed cost sharing among institutes will be defined when submitting the individual sub-system TDRs at the end of 2013, together with the relevant Addenda to the Constr. MoU



## Collaboration matters

- **Cincinnati University (US)** group from associateship to full membership
- **MIT (US)** group: interests in HLT and in tracking for the upgrade (full member)
- **Groeningen University (NL)** group: interests in HLT and in feasibility studies for GPU to be used in the farm (associated to Nikhef)
- **Celal Bayar University (Manisa, TK)** group: interests in luminosity studies and in Trigger Tracker upgrade (associated to CERN)

From ex-SuperB project, several physicists from Ferrara, Padova, and other individuals, have joined existing LHCb groups

New institutes are queing up for membership or associateship (to be discussed at next Collaboration Board)

Ukraine institutes (Kharkiv and Kiev) have separately signed the MoU for M&O  
Payments for 2012 M&O-A have been received (Kharkiv) or are expected soon (Kiev)

## Conclusions

Thanks to LHC performances and an efficient running, **LHCb** has collected  $\sim 3/\text{fb}$  in (pp) and  $\sim 2/\text{nb}$  (pA) in LHC Run I

**LHCb** accounts (already with 1/fb) for several world's best on a variety of measurements :

$\phi_s$ ,  $\Delta m_s$  &  $\Delta m_d$ ,  $B_s \rightarrow \mu\mu$ ,  $\gamma$ , D-D mixing, CPV in charm, ...

pA physics is dawning at the horizon of **LHCb** with very interesting perspectives

We are preparing 2015 with a lot of activities in the pit and outside, to improve our physics reach already in Run II

The **LHCb** upgrade will contribute significantly to a full exploitation of LHC and to increase the opportunities of New Physics discovery in the next decades

Entering the hot and challenging period of technological reviews and choices


Hoping (and expecting) full support on upgrade from all **LHCb** Funding Agencies

From: “Implications of LHCb measurements and future prospects”  
document submitted to ESPP – arXiv 1208.3355


Type	Observable	Current precision	LHCb 2018	Upgrade (50 fb <sup>-1</sup> )	Theory uncertainty
$B_s^0$ mixing	$2\beta_s (B_s^0 \rightarrow J/\psi \phi)$	0.10 [137]	0.025	0.008	$\sim 0.003$
	$2\beta_s (B_s^0 \rightarrow J/\psi f_0(980))$	0.17 [213]	0.045	0.014	$\sim 0.01$
	$a_{sl}^s$	$6.4 \times 10^{-3}$ [43]	$0.6 \times 10^{-3}$	$0.2 \times 10^{-3}$	$0.03 \times 10^{-3}$
Gluonic penguins	$2\beta_s^{\text{eff}}(B_s^0 \rightarrow \phi\phi)$	–	0.17	0.03	0.02
	$2\beta_s^{\text{eff}}(B_s^0 \rightarrow K^{*0}\bar{K}^{*0})$	–	0.13	0.02	$< 0.02$
	$2\beta_s^{\text{eff}}(B^0 \rightarrow \phi K_S^0)$	0.17 [43]	0.30	0.05	0.02
Right-handed currents	$2\beta_s^{\text{eff}}(B_s^0 \rightarrow \phi\gamma)$	–	0.09	0.02	$< 0.01$
	$\tau^{\text{eff}}(B_s^0 \rightarrow \phi\gamma)/\tau_{B_s^0}$	–	5 %	1 %	0.2 %
Electroweak penguins	$S_3(B^0 \rightarrow K^{*0}\mu^+\mu^-; 1 < q^2 < 6 \text{ GeV}^2/c^4)$	0.08 [67]	0.025	0.008	0.02
	$s_0 A_{\text{FB}}(B^0 \rightarrow K^{*0}\mu^+\mu^-)$	25 % [67]	6 %	2 %	7 %
	$A_I(K\mu^+\mu^-; 1 < q^2 < 6 \text{ GeV}^2/c^4)$	0.25 [76]	0.08	0.025	$\sim 0.02$
	$\mathcal{B}(B^+ \rightarrow \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \rightarrow K^+\mu^+\mu^-)$	25 % [85]	8 %	2.5 %	$\sim 10 \%$
Higgs penguins	$\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-)$	$1.5 \times 10^{-9}$ [13]	$0.5 \times 10^{-9}$	$0.15 \times 10^{-9}$	$0.3 \times 10^{-9}$
	$\mathcal{B}(B^0 \rightarrow \mu^+\mu^-)/\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-)$	–	$\sim 100 \%$	$\sim 35 \%$	$\sim 5 \%$
Unitarity triangle angles	$\gamma (B \rightarrow D^{(*)}K^{(*)})$	$\sim 10\text{--}12^\circ$ [243, 257]	$4^\circ$	$0.9^\circ$	negligible
	$\gamma (B_s^0 \rightarrow D_s K)$	–	$11^\circ$	$2.0^\circ$	negligible
	$\beta (B^0 \rightarrow J/\psi K_S^0)$	$0.8^\circ$ [43]	$0.6^\circ$	$0.2^\circ$	negligible
Charm	$A_\Gamma$	$2.3 \times 10^{-3}$ [43]	$0.40 \times 10^{-3}$	$0.07 \times 10^{-3}$	–
$CP$ violation	$\Delta\mathcal{A}_{CP}$	$2.1 \times 10^{-3}$ [18]	$0.65 \times 10^{-3}$	$0.12 \times 10^{-3}$	–




	2011-12	2015	2016	2017	2018 ?
Collected Luminosity per year	3/fb	1/fb	1.5/fb	1.5/fb	1.5/fb
Luminosity (scaled to 14 TeV)	1.5/fb				
Integrated Luminosity (14 TeV)	1.5/fb	2.5/fb	4/fb	5.5/fb	7/fb
Statistics w.r.t. 2011-12		X 1.7	X 2.7	X 3.7	X 4.7



LS1.5 ?



LS2 ?



LS2 ?