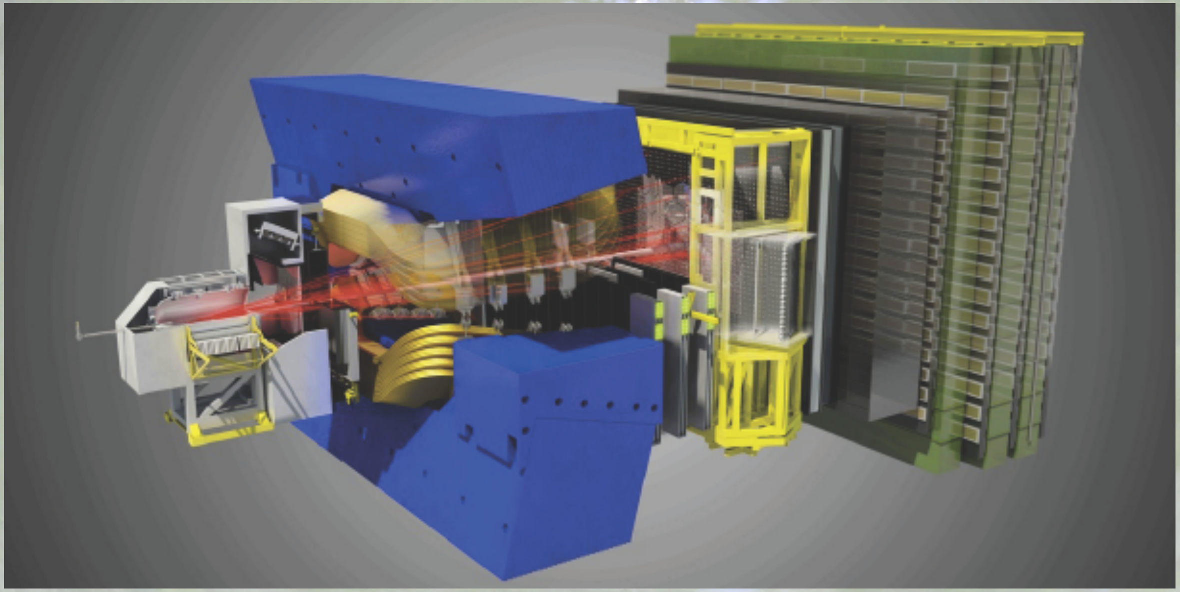
Status report on LHCb

P. Campana (CERN/Frascati)
RRB meeting, 30.04.2014



Preparing LHCb for Run 2

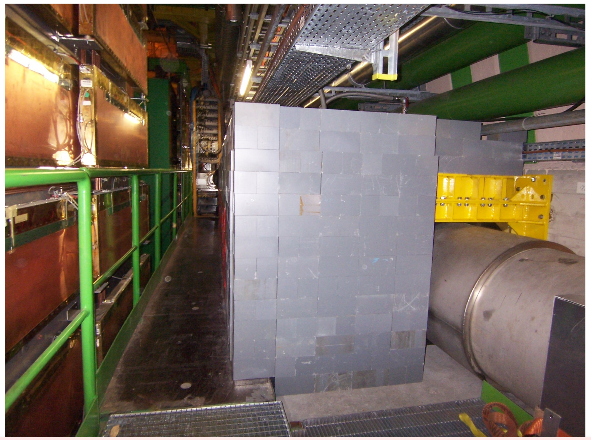
Maintenance on infrastructures (magnet, power, cooling, etc…) and replacement of a part of the beam pipe. New field map

Refurbishment/consolidation of detectors and online system (HLT farm will double the CPU available in Run 2)

Optimization of code/processing procedures: calibrations and analyses-quality data quasi online (saves CPU and disk space)

Ready to write on tape at a rate of 12.5 kHz (was 5 kHz in 2012 - *b* and *c* cross sections nearly double w.r.t. to 8 TeV - smarter HLT selections)

New cooling plants

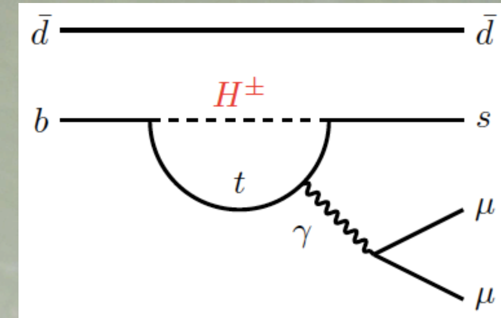


Shielding behind the Muon stations

Dipole Magnet special maintenance

Highlights of recent LHCb results

Studies of B→K$^{(*)}$μμ decays

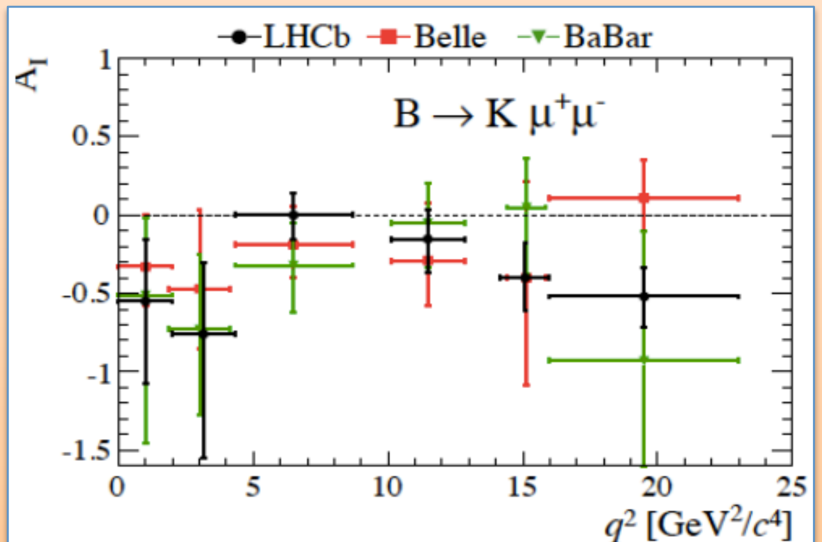


B→K$^{(*)}$μμ are dominated by loop diagrams and are very sensitive to New Physics: many variables to be studied

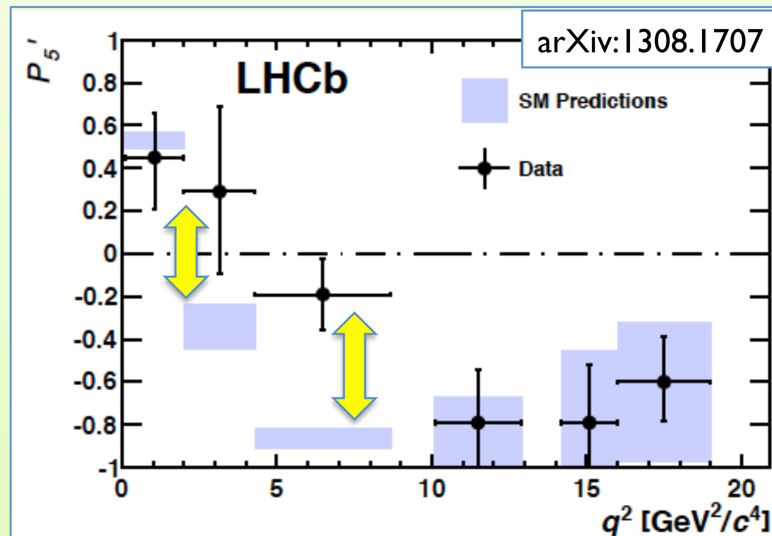
Isospin asymmetry (A_I) is a clean variable
In SM the expected value is small (1%)

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

LHCb(1/fb), Belle and BaBar had some evidence for $A_I \neq 0$ in B→Kμμ



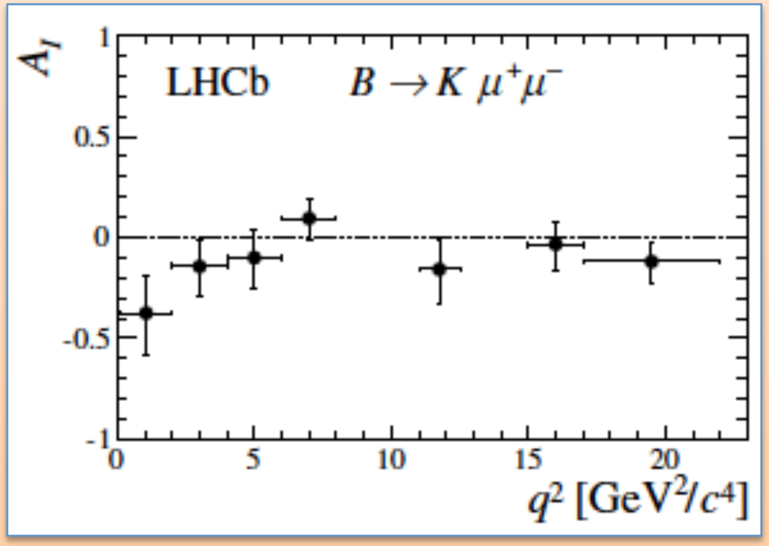
LHCb analysis of an angular variable (P_5') in B→K*μμ shows discrepancy w.r.t. the SM predictions :
3.7 σ local effect on the 1/fb data sample



Strong interest from theorists on the anomaly for possible NP effects

New LHCb analysis on 3/fb does not confirm the isospin anomaly in B→Kμμ . Result consistent with statistical fluctuation

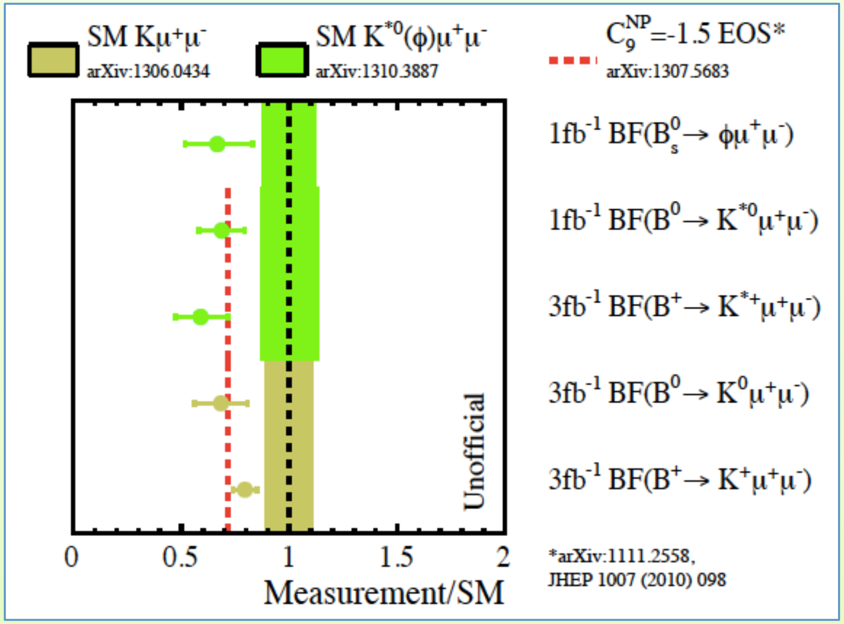
Still a trend for non zero A_I at low q^2



The angular analyses (F_H, A_{FB}) of $B^+ \to K^+\mu\mu$ and $B^0 \to K_S\,\mu\mu$ are also in agreement with SM expectations

arXiv: 1403.8044

The trend of a smaller $d\mathcal{B}r/dq^2$ at high q^2 w.r.t. SM predictions in all b→s μμ decays is confirmed



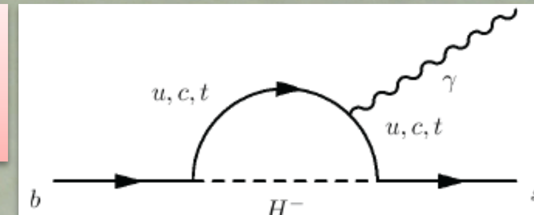
… however better explained by presence of NP in the form suggested by the angular analysis …

Update with 3/fb is under preparation

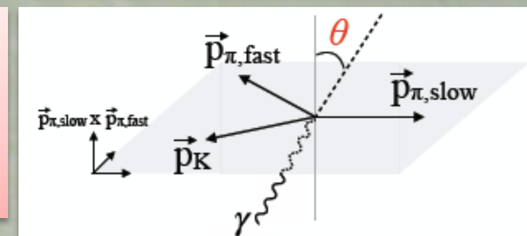
arXiv: 1403.8045

Photon polarisation in b→sγ decays

SM predicts the photon in b→sγ decays to be LH
New Physics could add a RH component



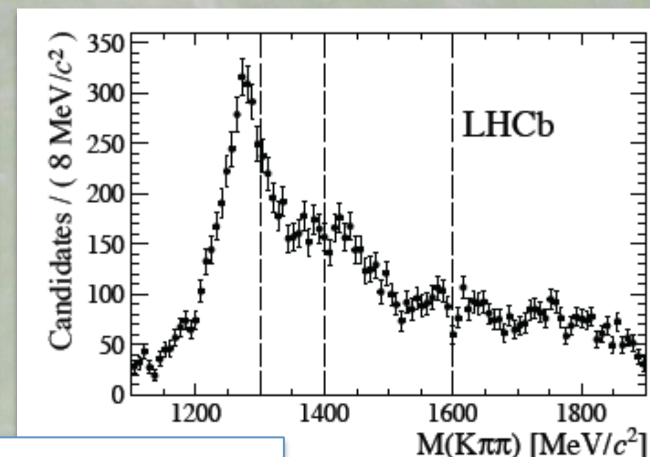
Up-down asymmetry (A_{ud}) is proportional to photon polarization λ_γ (±1 in SM)
Fit the angular distribution in $B^+ \to K^+\pi\pi\gamma$ decays



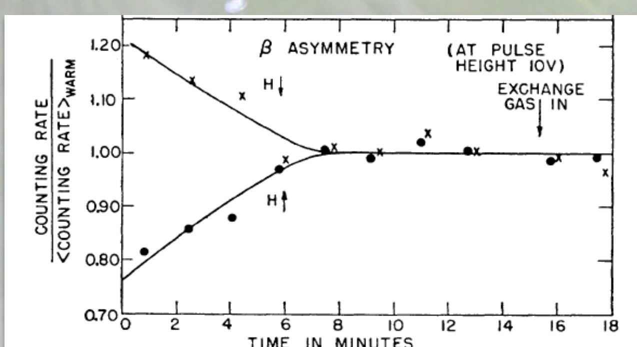
Complexity due to many ($K^+\pi\pi$) resonances involved
5.2 σ first observation of polarization in 4 $m_{K\pi\pi}$ bins

$$6.9 \pm 1.7,\ 4.9 \pm 2.0,\ 5.6 \pm 1.8,\ -4.5 \pm 1.9\%$$

However theoretical input is needed to determine λ_γ and to constrain the effects of New Physics in b→sγ



arXiv:1402.6852



Counting Up/Down experiment very similar to the one performed for the discovery of P violation
C.S.Wu et al., Phys. Rev. 105 (1957) 1413

Observation of exotic state $Z^+(4430)$

arXiv:1404.1903

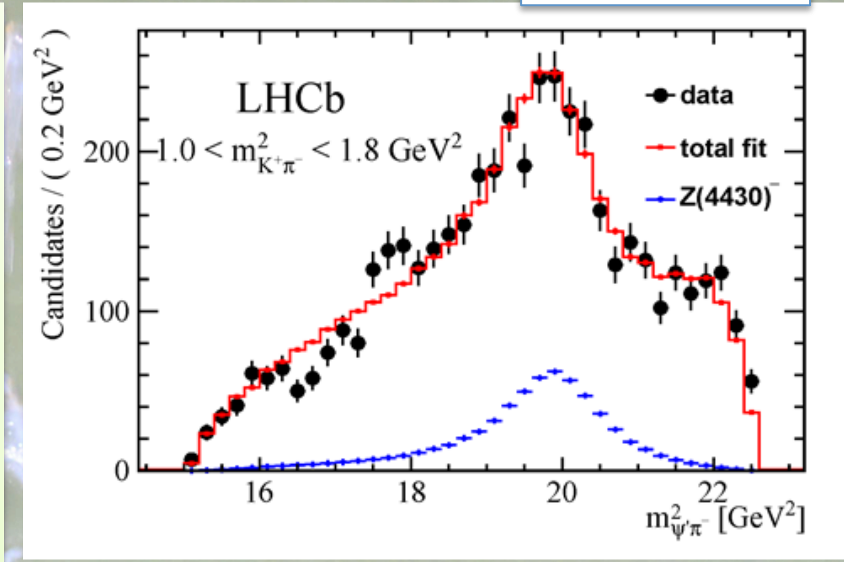
Belle has observed this state for the first time in 2007. Not seen by BaBar. Confirmation needed (very complex final state)

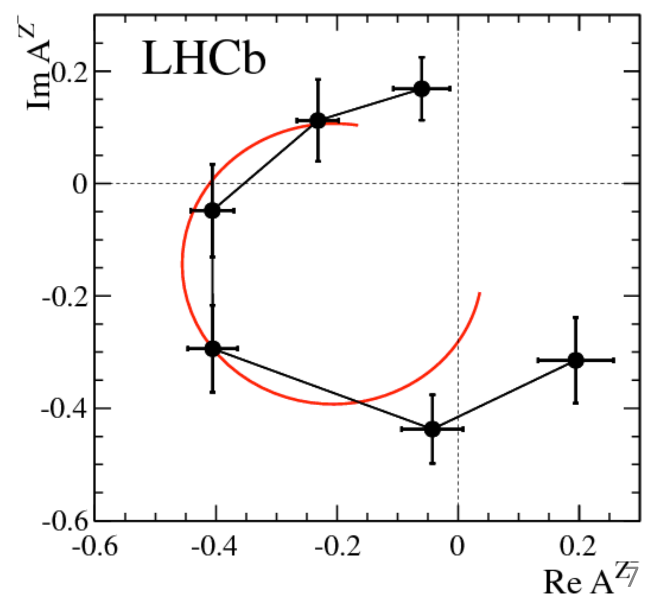
State unexplained in naïve quark model
Must contain *c-c bar quarks* ($Z^+ \rightarrow \psi(2S)\ \pi^+$)
but also *u* and *d quarks* needed (it is charged).
Is it a **tetra-quark** state ?

LHCb observed it in $B^0 \rightarrow \psi(2S)\pi^+ K^-$ decays (10 times more statistics than Belle)

Very detailed analysis (2 independent methods). For the first time, LHCb able to see also the "footprint" of the resonant nature of this particle ("Argand plot") : unambiguous confirmation

Spin and parity also determined ($J^P=1^+$)
Evidence of a second exotic $Z^+(4240)$ state (to be confirmed)

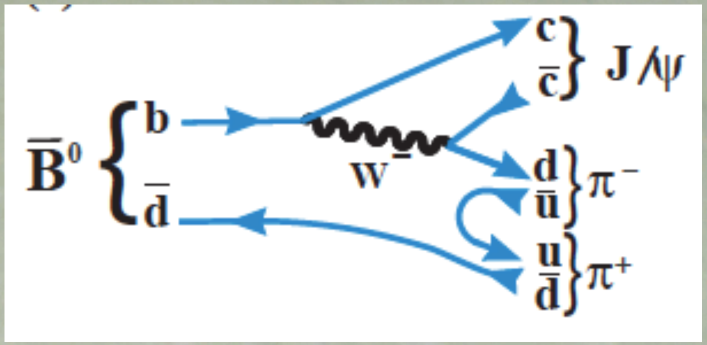




A study on the nature of $f_0(500)$ and $f_0(980)$ mesons

Since many years, the nature of $f_0(500)$ and $f_0(980)$ mesons has been debated at length

These states are difficult to explain with naïve qq model, therefore tetra-quark, or KK molecule hypotheses have been made



$B^0 \rightarrow J/\psi\ \pi\pi$ decays are an ideal laboratory to study such mesons

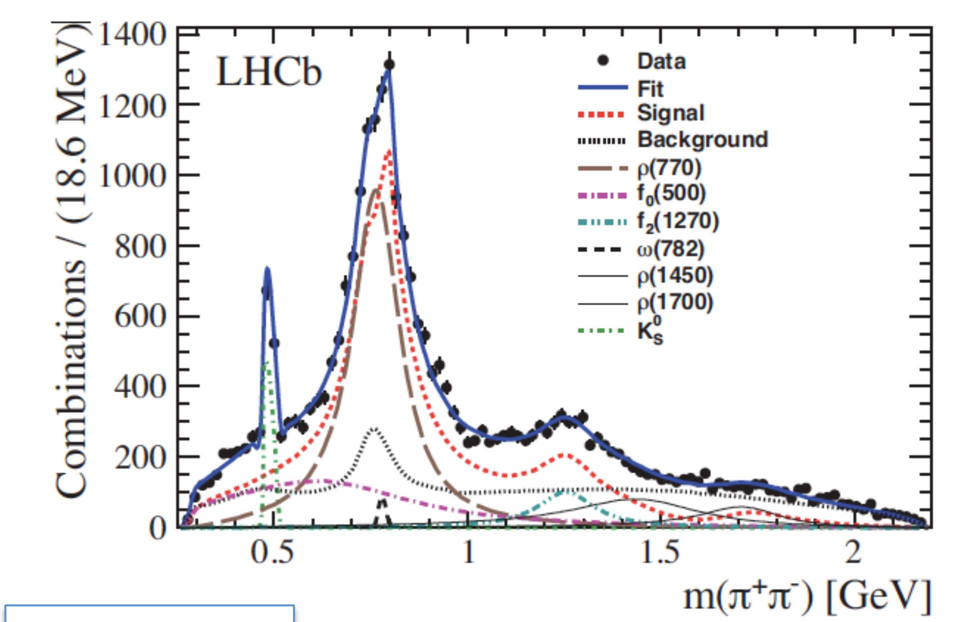
If $f_0(500)$ and $f_0(980)$ are tetra-quark states, the ratio

$$r_\sigma^f = \frac{\mathcal{B}\left(\overline{B}^0 \to J/\psi\, f_0(980)\right)}{\mathcal{B}\left(\overline{B}^0 \to J/\psi\, f_0(500)\right)} \sim 0.6$$

No evidence of $f_0(980)$ production seen in these B^0 decays

Setting a limit on **$r < 0.1$** at 90% CL

Tetra-quark hypothesis rejected at 8 σ



arXiv:1404.5673

LHCb has a strong potential in studying low energy spectroscopy and exotica

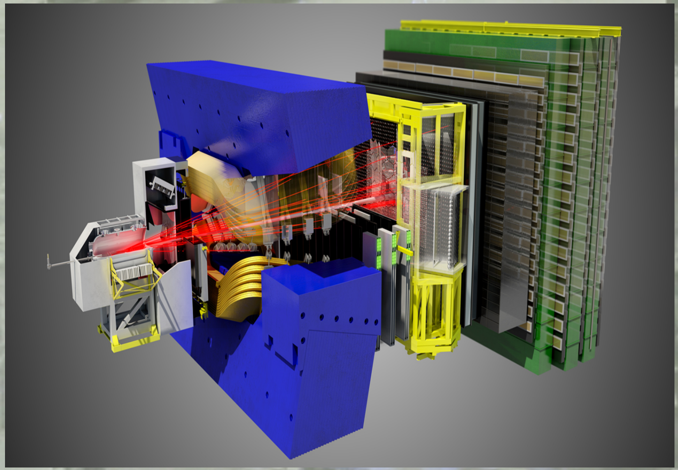
Analyses (with 3/fb) to be completed for spring/summer conferences :

- CPV in charm (ΔA_{CP} in prompt and semi-leptonic tagged $D^0 \to \pi\pi$, $D^0 \to KK$)
- $B^0 \to K^*\mu\mu$ angular analysis (to clarify P'_5 possible anomaly)
- Lepton Universality in $R_K = \mathcal{B}r(B^+ \to K^+\mu\mu)/\mathcal{B}r(B^+ \to K^+ee)$
- a_{SL} in B_s semi-leptonic decays (to study di-muon anomaly from D0)
- ϕ_s CPV phase (in $B_s \to J/\psi\ \phi$ and $B_s \to J/\psi\ \pi\pi$ decays)
- $\mathcal{B}r(B_{(s)} \to \mu\mu)$ combination with CMS
- update of CKM γ angle
- Lepton Flavor Violation decay $\tau \to \mu\mu\mu$

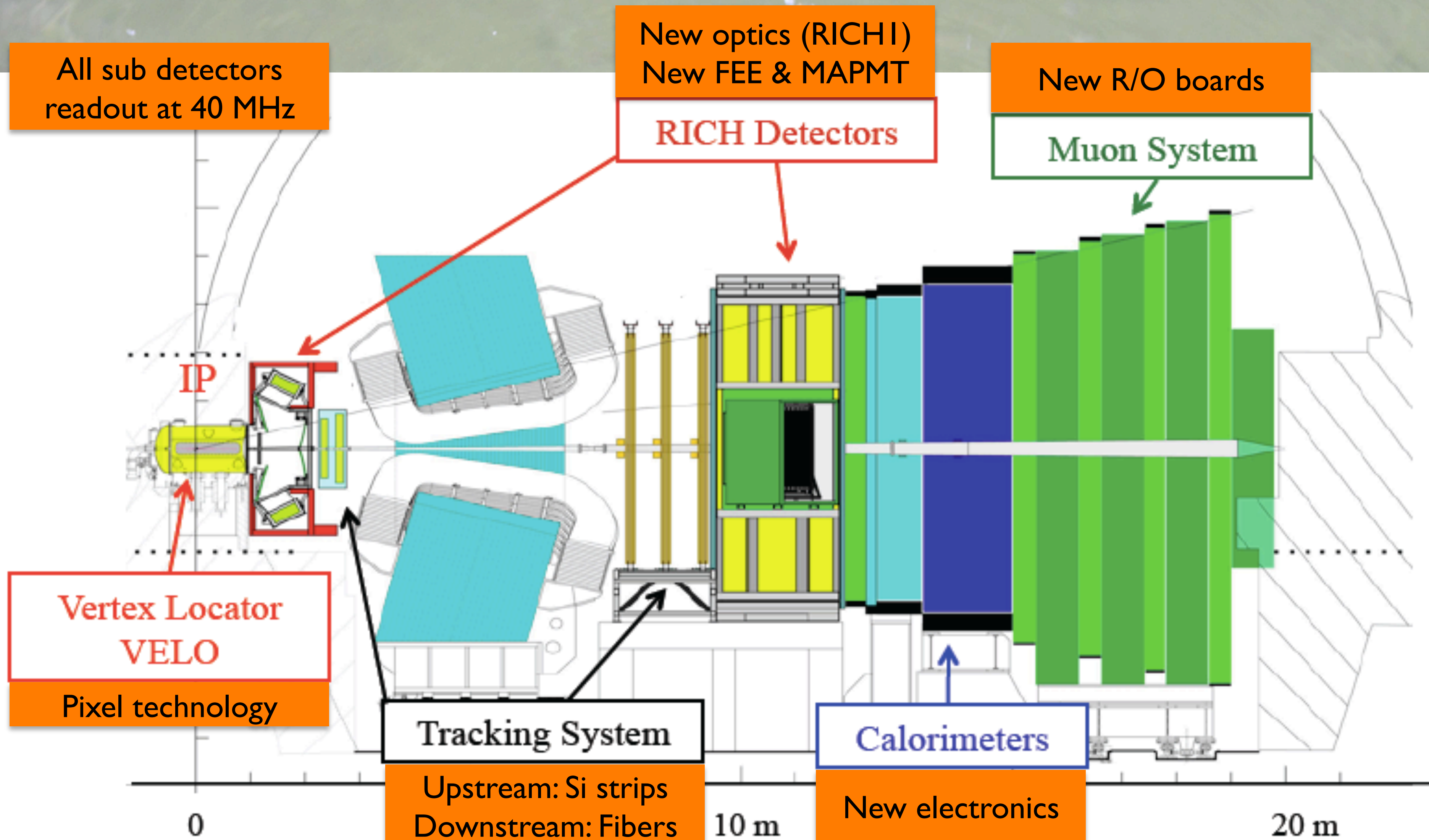
182 papers published by LHCb so far (+75 since April 2013 RRB)

~ 100 more analyses in the pipeline of physics working groups to be completed, before the Run 2 data sample will start to be available

The LHCb upgrade



LHCb detector modifications for the upgrade



Wrap-up on the LHCb upgrade

Goals of Framework TDR (April 2012):

- running LHCb at 40 MHz, in trigger-less R/O mode and at 1÷ 2 10^{33} $cm^{-2}s^{-1}$
- x5 gain in muon channels, x10 gain in hadronic channels (w.r.t. Run 2)
- Collect at least 50/fb in ~ 10y of data taking
- The LHCb upgrade has been approved by the CERN Research Board [RB] as part of long term exploitation of LHC

In 2013 and early 2014 several major milestones achieved:

- choice of technology for Vertex Locator (pixels)
- choice of solutions for the upgrade of PID systems (RICH, CALO & MUON)
- choice of technology for the upgrade of Tracking (UT & Sci.Fi.)
- choice of technology for the upgrade of Online and DAQ
- choice of baseline option for Trigger deployment (fully in software)

Based on above solutions, we are confident
LHCb will be capable to stand a luminosity of 2 10^{33} $cm^{-2}s^{-1}$
with a network and a HLT farm able of sustaining 40 MHz data rate at the startup,
without the need of a 1st level HW trigger (today called "L0")

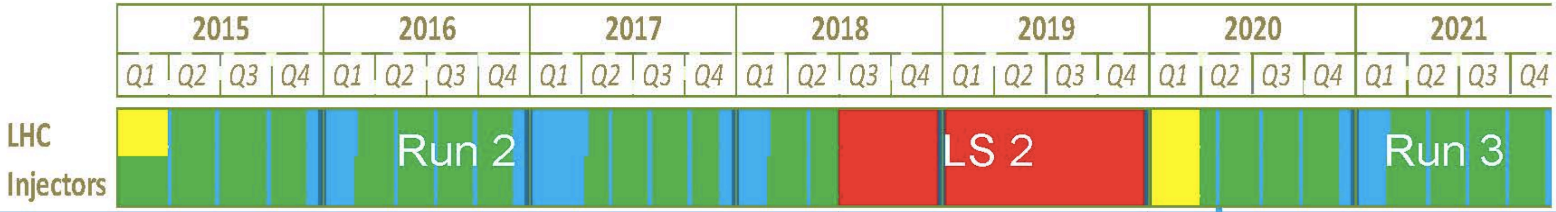
LHCb and the new LHC schedule

Winter 2016-17: EYETS (no Linac4 connection during Run2)

LS2 starting in 2018 (July) 18 months + 3months BC (Beam Commissioning)

LS3 LHC: starting in 2023 => 30 months + 3 BC

injectors: in 2024 => 13 months + 3 BC



LHCb upgrade installation starts

LHCb upgrade completed

This schedule is very beneficial for LHCb:

- longer Run 2 data taking (3 full years - until July 2018)
- 18 months installation in LS2 (beam-to-beam)
- LS2 startup delayed (~7 months): more contingency for construction
- smoother spending profile
- 3 full years of data taking in Run 3 (enough time for ramp up of luminosity)

A few LHCb Upgrade physics goals

	Run 1	Run 2	Run 3	Run 4	Theory uncertainty
Integrated lumi	$3\ fb^{-1}$	$8\ fb^{-1}$	$23\ fb^{-1}$	$46\ fb^{-1}$	
$\frac{Br(B_d \to \mu\mu)}{Br(B_s \to \mu\mu)}$	-	110 %	60%	40%	5%
$q_0^2 A_{FB}(B_d \to K^{*0}\mu\mu)$	10%	5%	2.8%	1.9%	7%
$\phi_s(B_s \to J/\psi\phi, B_s \to J/\psi\pi\pi)$	0.05	0.025	0.013	0.009	0.003
$\phi_s(B_s \to \phi\phi)$	0.18	0.12	0.04	0.026	0.02
γ	7°	4°	1.7°	1.1°	negl.
$A_\Gamma(D^0 \to KK)$	$3.4\ 10^{-4}$	$2.2\ 10^{-4}$	$0.9\ 10^{-4}$	$0.5\ 10^{-4}$	-

From "Heavy Flavor Physics in the HL-LHC era"
Document prepared for the Aix-les-Bains ECFA Workshop – Oct 2013

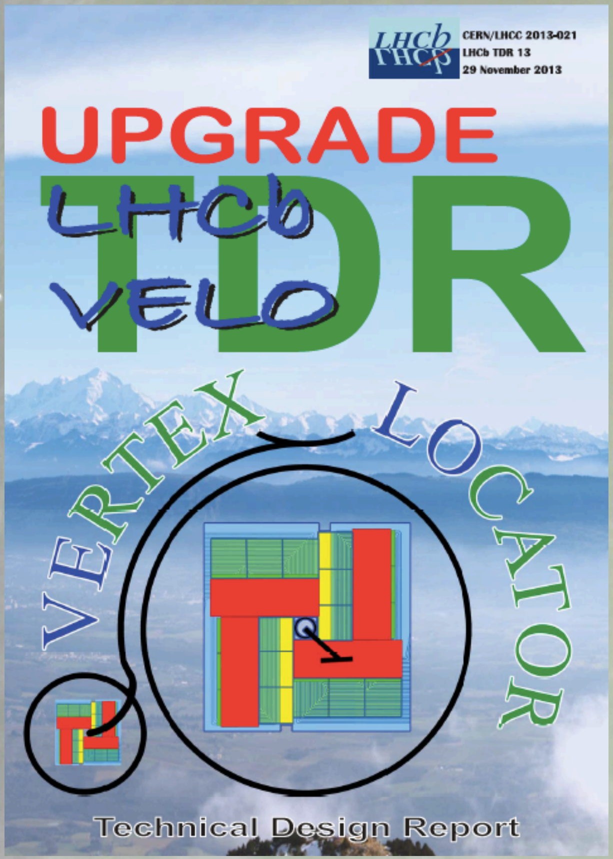
The roadmap to precision physics in LHCb

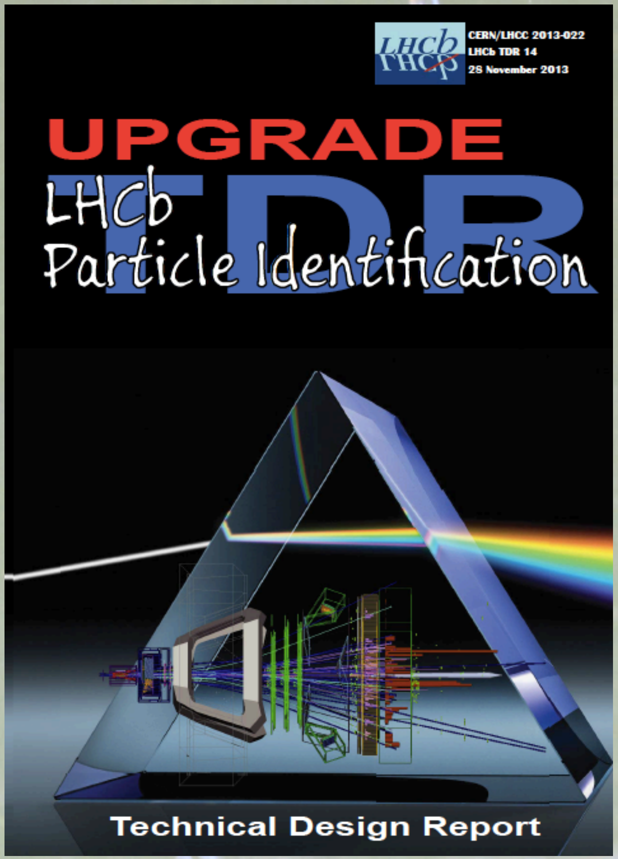
	RUN 1 7-8 TeV L=3÷4 10^{32}	**RUN 2** 13-14 TeV L=4 10^{32} (2015-18)	**RUN 3** 14 TeV L=1÷2 10^{33} (2020-22)	**RUN 4** 14 TeV L=2 10^{33} (2026-28)
Luminosity (per Run)	3/fb	5/fb	15/fb	23/fb
Integrated Luminosity	3/fb	8/fb	23/fb	46/fb
bb yield (Run 1=1 a.u.)	*1*	*2.8*	*9.1*	*13.9*
Integrated *bb yield* (Run 1=1 a.u.)	*1*	*3.8*	*12.9*	*26.8*
Decrease in stat. error (*bb yield*)		*1.9*	*3.6*	*5.2*
Integrated *bb yield* in hadronic decays (Run 1=1 a.u.)	*1*	*3.8*	*22**	*50**

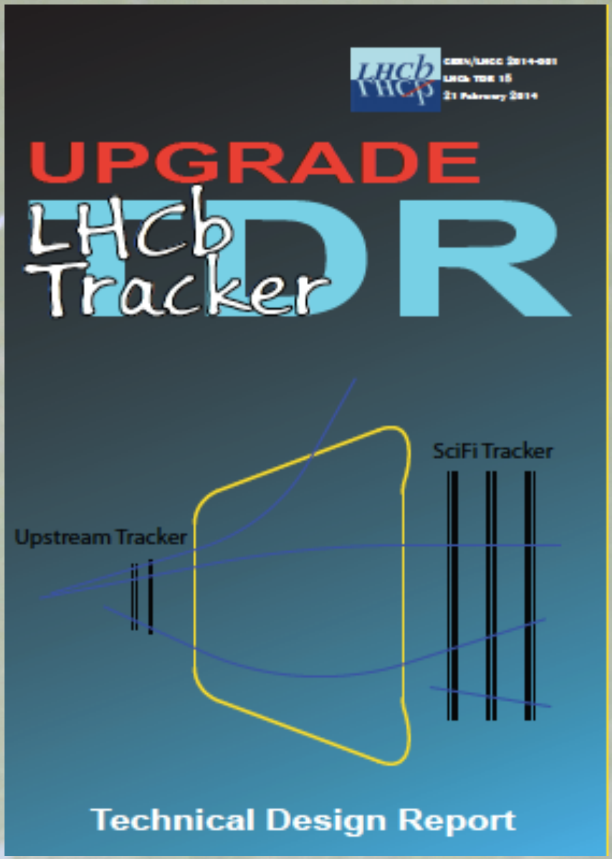
Integrated luminosities based on experience from Run 1 data taking

* At upgrade, trigger efficiency increases x2 for hadronic final states (e.g. $B^0 \to K\pi$, $B^0 \to DD$, $B_s \to \phi\phi$)

Status of TDRs







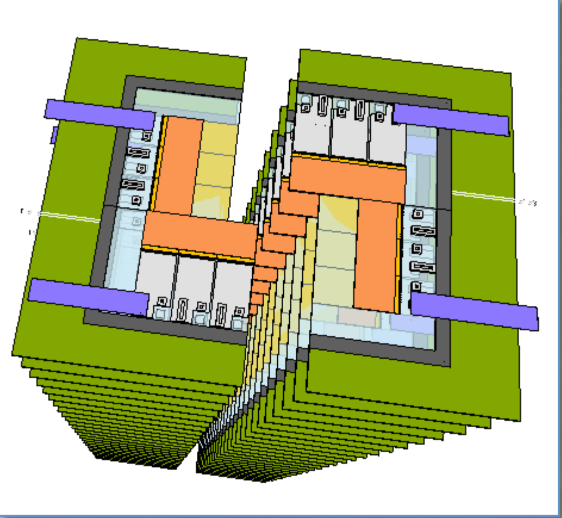
Submitted to LHCC in Nov 13
Reviewed by LHCC and UCG
Approved by RB

Submitted to LHCC in Feb14
Under LHCC & UCG scrutiny

VELO (vertex detector)

Technological choice: pixels (50x50 μm^2)

- superior patter recognition (3D)
- excellent spatial resolution/improved acceptance
- minimal amount of material (micro-channel cooling)
- radiation resistance
- "state of the art technology"
- closer to beam line (5 mm vs 8 mm)



PID → Goal: keep performance at 2 10^{33} $cm^{-2}s^{-1}$ close to that now at 4 10^{32} $cm^{-2}s^{-1}$

RICH

- New optics, new FEE, new photo sensors (MAPMT)
- Reduced impact on LHCb mechanics / Fits in LHCb tight installation schedule

CALO

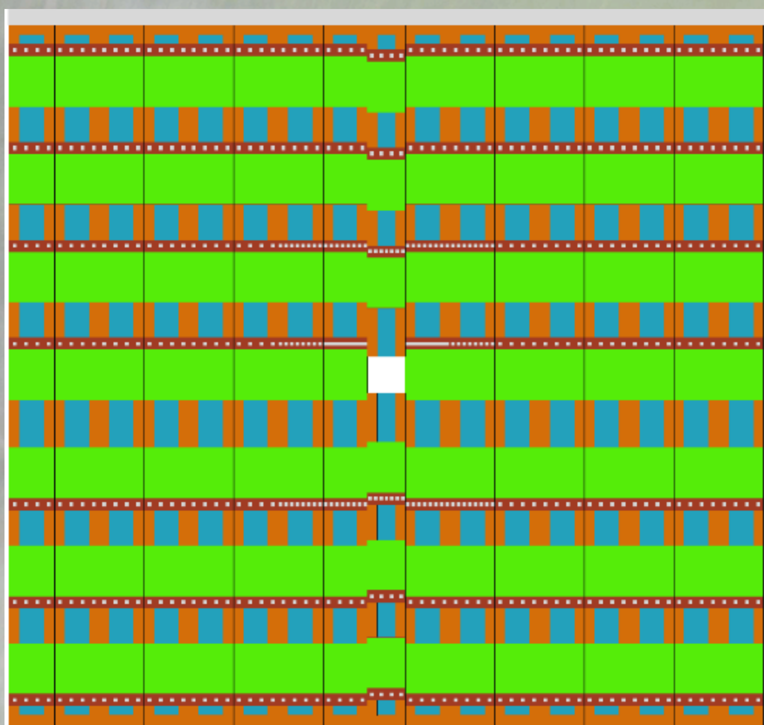
- SPD&PS removed (high occupancy)
- Radiation tests show ECAL ok up to ~20/fb (but inner modules can be replaced)
- HCAL ok up to ~50/fb
- Upgrade to 40 MHz FEE electronics

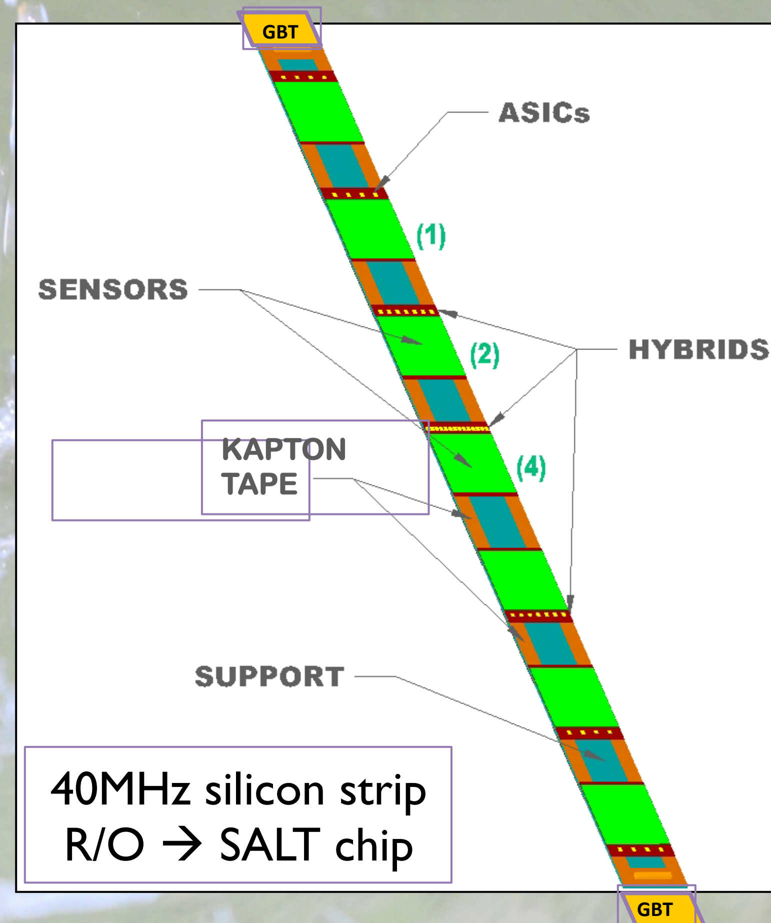
MUON

- Removal of M1 (due to occupancy) and more shielding in front of M2
- New off-detector electronics for an efficient readout in the 40 MHz scheme

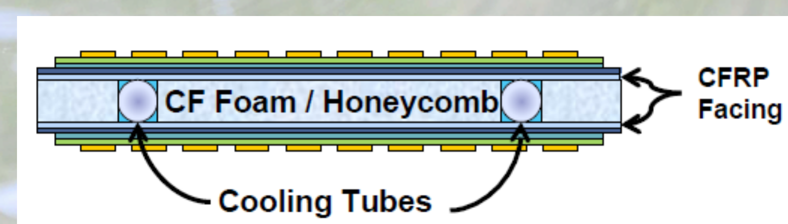
The Upstream Tracker (UT)

Silicon strip detector
- tune granularity to varying occupancy
- technology from ATLAS IBL staves
- full active in acceptance
- lower radiation length (w.r.t. to present TT)





40MHz silicon strip R/O → SALT chip



TDR submitted for February 2014 LHCC

The Scintillating Fibre tracker (Sci.Fi.)

Layout

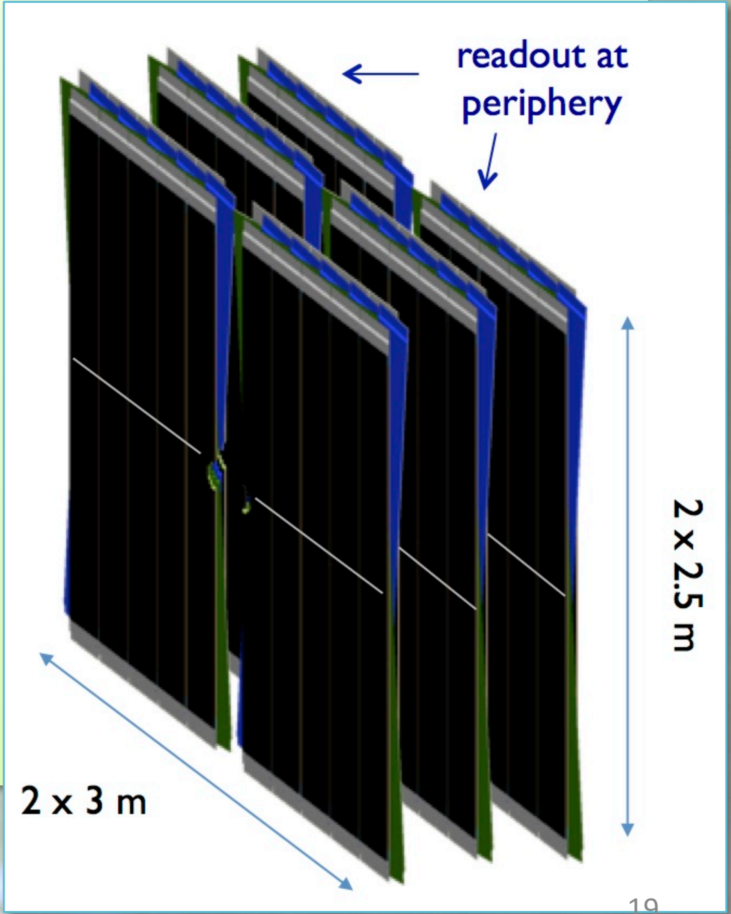
- 3 stations of X-U-V-X (±5° stereo angle) scintillating fibre planes
- every plane made of 5-6 layers of Ø=250 μm fibres, 2.5 m long
- 40 MHz readout and Silicon PMs at periphery

Challenges

- Radiation damage to fibres → tested ok
- Neutron damage to SiPM → operate at -40°C

Benefits of the Sci.Fi. concept:

- a single technology to operate
- uniform material budget
- SiPMs + infrastructure outside acceptance
- x-position resolution of 50 – 75 μm
- high hit detection efficiency (≥ 99%)
- fast pattern recognition



TDR submitted for February 2014 LHCC

ONLINE & DAQ

All signals will be brought outside the pit
(all R/O boards near PC farm)

Smart solution for network based on PC & PCI-express commodities (40 MHz capacity since startup within planned budget)

TRACKING

Improved VELO+UT pattern recognition

Use the magnetic field between the VELO and UT to get a Δp/p~15%

Drastic reduction in tracking reconstruction time (a factor 3 decrease)

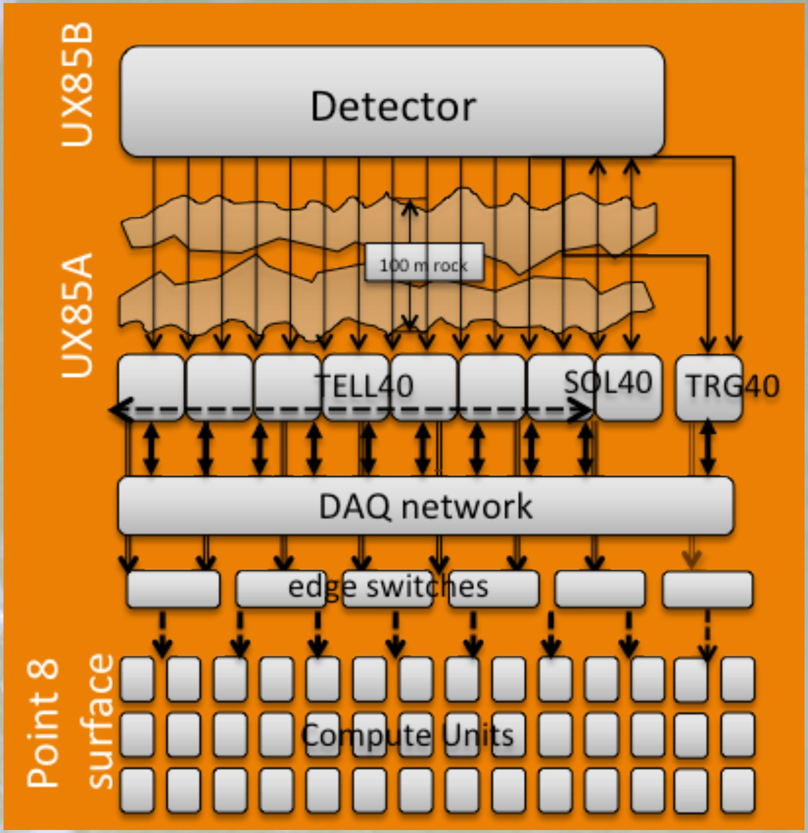
TRIGGER

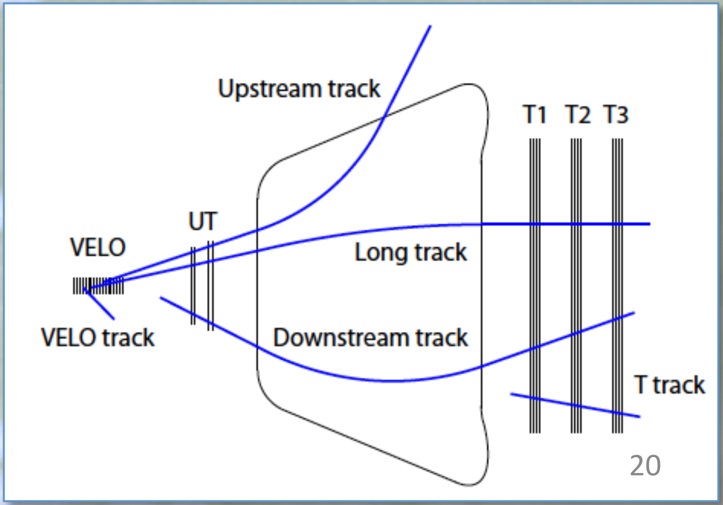
A full software HLT processing is doable within the planned CPU budget of the 2020 farm thanks to a faster tracking

No L0 hardware "knob" needed to limit the rate at < 40 MHz (keep it as "safety belt")

A full 40 MHz data taking in trigger-less R/O mode today seems feasible

TDR to be submitted for June 2014 LHCC





Responsibilities and costs (from TDRs)

Subsystem	Cost (MSF)	Contributing countries
VELO	**5.8**	Brasil, CERN, Netherlands, Spain, UK
Upstream Tracker	**6.5**	CERN, Italy, Poland, Switzerland, US
Sci. Fi. Tracker	**15.2**	Brasil, CERN, China, France, Germany, Netherlands, Russia, Spain
RICH (with 1,500 PMs in RICH2)	**10.1**	CERN, Italy, Romania, UK
Calorimeters (incl. LLT)	**2.2**	France, Russia, Spain
Muon system	**1.7**	Italy, Russia
Common Projects	**15.7**	Shared among all countries
TOTAL	**57.2**	

Costs include margins for risk mitigation (where needed) and a variable no. of spares.
Estimate is **tight**, but realistic
FTDR cost : 51.3÷53.4 MSF (+3.5 MSF reserve for PID at 2 10^{33}) ~ 57 MSF

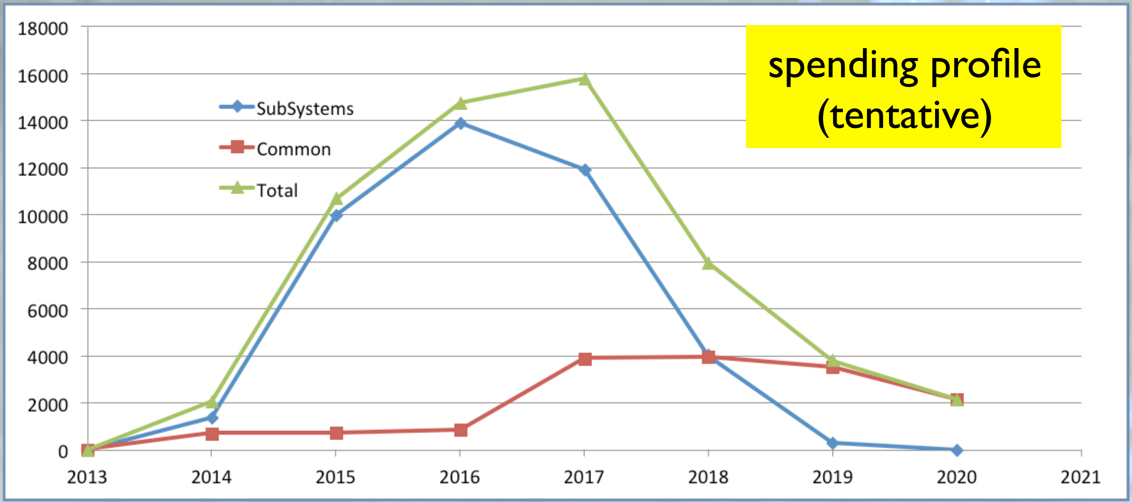
Status of funding coverage (CORE+CF)

News since last meeting

(*) Resources (for 2014-18) approved (CERN, IT) or envelope defined (FR)
UT/US proposal under review at NSF
LHCb rated at top level in STFC-UK programmatic review
Positive advancement of reviews in CH, D, NL, RU

Start of negotiations with Brasil to provide in-kind contribution on network fibers (CF)
Spain grant review process restarted

Goal: get >80% of resources for a working detector by 2018, the rest can be provided in 2019-20
final decisions expected before summer



	Requests (MSF)
Brasil	1.56
China	0.3
France *	5.0
Germany BMBF	4.1
Germany MPG	0.2
Ireland	
Italy *	6.7
Netherlands	4.8
Poland	1.2
Romania	0.9
Russia	5.0
Spain	2.4
Switzerland	5.0
Turkey	
UK	10.2
Ukraine	
US NSF	5.0
CERN *	8.1
TOTAL	**60.5**

Addenda for the upgrade

Addendum no. 1 to MoU for Construction: Common Projects

Already circulated at October 2012 RRB
Common Fund fixed to 15,710 kSF (unchanged)
New revision since then:
- sharing updated at April 2014
- spending profile according to new LHC schedule
- mechanisms of admission of new FA

Signatures requested for MoU Addendum on Common Projects in coming months

Addendum no. 2 to MoU for Construction: Upgrade TDRs

Under preparation
Defines responsibilities and resources for TDRs
Composed of one annex per sub system
It will define the LHCb Money Matrix

To be presented at October RRB

CERN/RRB 2012-119A - Rev. 10 April 2014

Addendum No. 1

to the

Memorandum of Understanding
for Collaboration in the Construction of the
LHCb Detector

The Upgrade of the LHCb Detector:
Common Project Items

Annexes

Annex 1:	Upgrade of the LHCb VERTEX LOCATOR
Annex 2:	Upgrade of the LHCb UPSTREAM TRACKER
Annex 3:	Upgrade of the LHCb SCINTILLATING FIBRE TRACKER
Annex 4:	Upgrade of the LHCb RICH SYSTEM
Annex 5:	Upgrade of the LHCb CALORIMETERS
Annex 6:	Upgrade of the LHCb MUON SYSTEM
Annex 7:	Upgrade of the LHCb TRIGGER SYSTEM

Actions on LHCb computing

- Preparing the Addendum to the MoU for M&O – LHCb Core Computing

Motivation

LHCb Core Computing is becoming increasingly important for the efficient Operation of the experiment AND for the preparation of the Upgrade .

Core Computing shared (*mainly*) among interested institutes (volunteer basis scheme) and integrated by the rest of the Collaboration.

In particular, Computing Upgrade needs important dedicated efforts.

Note: LHCb is the only LHC experiment NOT having a Computing MoU

- A more flexible model for LHCb computing resources

Motivation

Current LHCb Computing is based mainly on Tier1 (D, F, I, NL, SP, UK) resources

This creates uneven share and a systematic lack of resources

Need for a more flexible scenario: include Tier2 (fully, not only for MC productions) in computing model and obtain a better share

Discussions ongoing with BR, CH, PL, RU, US

Documents for both items are under preparation, to be submitted to the RRB

Collaboration matters

- Aachen RWTH (Germany) group: strong expertise in the area of tracking with fibres and willing to take part to the construction of the Sci.Fi. Tracker for the upgrade (accepted as full member)

- Wuhan CCNU (China) group: interests in the area of CP violation in B hadronic decays (associated to Tsinghua Univ.)

LHCb collaboration today:

- 66 institutes from 17 countries (54 institutes at beginning of 2011 +22%)
- 700 authors (545 at beginning of 2011 +28%)

The Collaboration Board has elected
G. Wilkinson (Oxford) as the new spokesperson, term starting on July 1st, 2014

Conclusions

- LHCb is actively preparing the 2015 data taking to profit of the nearly doubled cross section for charm and beauty
- Several important physics results obtained (on 1/fb and on 3/fb samples) and many more to come on benchmark flavor physics observables (and not only)
- Important upgrade milestones achieved on time : 2 TDRs approved, one under LHCC review, another in preparation. The shape and the cost of the upgrade is now defined
- The upgraded detector will be able to sustain a luminosity of 2 10^{33} $cm^{-2}s^{-1}$, reading out events at 40 MHz, and process them in the farm, with superior tracking capabilities and PID performance similar to the one available today
- To achieve this target, the support in resources at a level close to that requested by your LHCb groups is mandatory. With the new LHC schedule, the resources can be spread up to 2020. We hope this can help in positive answers from FAs
- Signatures requested for MoU on Common projects in coming months

My work with you (as SP) has nearly come to its end, after 3 very dense years. It has been a pleasure and I thank YOU all for the support and the help !