Framework TDR for the LHCb upgrade and next steps

(on behalf of the LHCb upgrade steering group)

- Roadmap for the LHCb upgrade
- Status for submission of the "Framework TDR"
- Evolution of requirements and main technical options
- Next steps: tracker optimisation and open questions related to PID
- Long-term schedule
- Cost and expression of interests
- Conclusion

Roadmap for the LHCb upgrade

- ✓ submitted "Upgrade LOI" to LHCC beginning of March 2011 [CERN-LHCC-2011-001]
  - ➢ physics case fully *endorsed*, 40 MHz architecture reviewed
  - ➢ *recommendation* in June 2011 to proceed to "Framework TDR" and detector TDRs

- ✓ 25 May submitting "Framework TDR" for discussion at the June 2012 LHCC session
  - ➢ seeking for *approval* of LHCb upgrade by autumn 2012
  - ➢ start preparation of "Framework MoU" at October RRB for funding request

- ✓ have now to proceed to sub-system TDRs according to schedules given in FTDR
  - ➢ decide on technical options (VELO, Tracker, etc.) by mid 2013 at latest
  - ➢ all detector TDRs in Q3 & Q4 of 2013, online TDR early 2016

Planning towards submission of the "Framework TDR for the LHCb Upgrade"

timeline

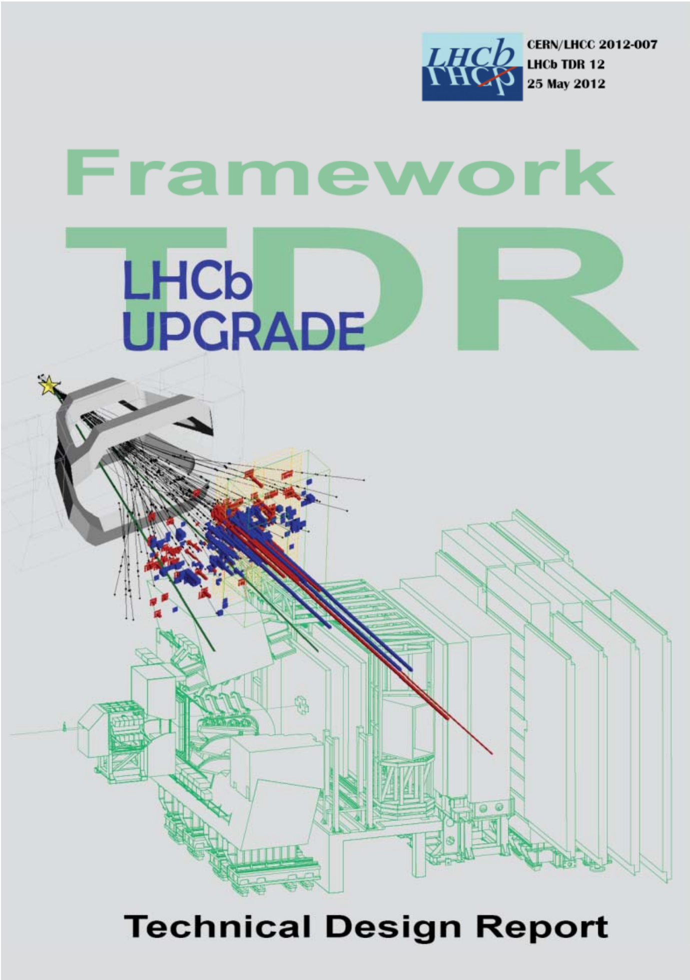
Date	Event	Sub-system schedule	Sub-system cost	Institute commitments	Document status
June 12	LHCC session				
May 25	LHCC submission	final version V2	final version V2	final version V2	final version V2 & final version physics reference
May 11	final version to Collaboration				
April 23	RRB	manpower profile	cost profile	prepare delegates	
April 16-20	URB approval	draft of full version V1	draft of full version V1	firm commitments to WP (V1)	first complete version V1 & draft physics reference
	TB approval				
April 13	deadline				
March 20	LHCC discussion of content	milestones & skeleton version V0	skeleton version V0	status of declarations of interests (V0)	layout and table of content (V0)
March 12-16	URB discussion	milestones & skeleton version V0	Skeleton version V0	declarations of interest to WP	review status of R&D options and content of Addendum
	TB on upgrade				
March 9	deadline				
February (early)	preparation	MPP template to projects	XLS template to projects	define project work-packages (WP)	

note: URB = LHCb Upgrade Resources Board ; WP = Work Packages ; MPP = Microsoft Office Project ; XLS = Excel

Contents of “Framework TDR”

Many thanks to all of you having contributed!

(editors: steering group & Rolf & Tim)



CERN/LHCC 2012-007, LHCb TDR 12, 25 May 2012

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FTDR: Updated table on physics reach

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

FTDR: Evolution of requirements & main technical options

LHCb declared its interest to upgrade the LHCb detector to run

- ✓ at a nominal luminosity of $\mathcal{L}=1\cdot10^{33}\ cm^{-2}\ s^{-1}$
- ✓ with a fully flexible software trigger at 40 MHz
- ✓ to increase its annual signal yields *as compared to 2011*
  - ➢ for muonic B-decays by a factor 10
  - ➢ for hadronic heavy-flavour physics by a factor 20 or more
- ✓ in order to accumulate 50 fb^{-1} over 10 years

→ For reasons of flexibility and to allow for possible evolutions of the trigger, LHCb decided to design those detectors that need replacement for the 40 MHz upgrade such that they can sustain a minimal luminosity of $\mathcal{L}=2\cdot10^{33}\ cm^{-2}\ s^{-1}$

- ➢ Particular consequence for area that needs to be covered by IT to keep occupancies in OT at a reasonable level
- ➢ In FTDR we concentrated on two main tracker options for central region:
  - ✓ large silicon-strip IT complemented by OT
  - ✓ scintillating fibre CT

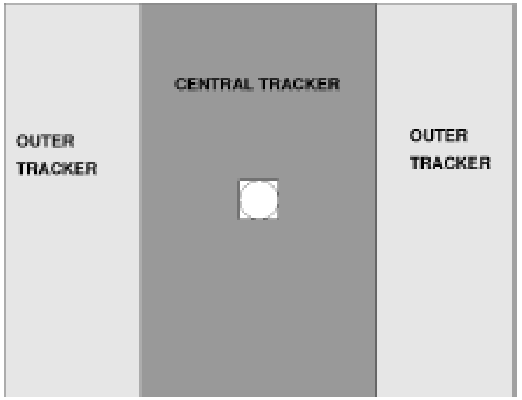
→ Other sub-detector with alternative technology options:

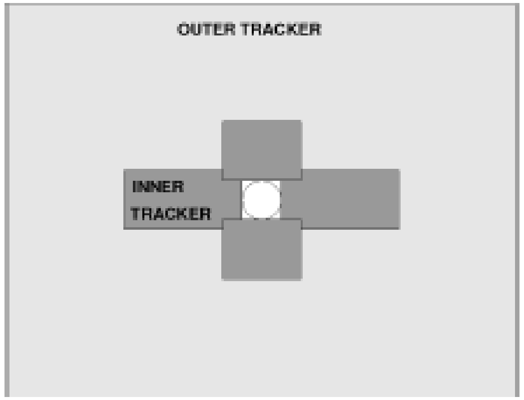
- ➢ VELO pixel vs. VELO strip
- ➢ studying possible improvement of impact parameter resolution by moving sensors closer to beam

Next steps: Tracking System & Tracking

Baseline options of FTDR

Subsystem	Technology options
VELO	microstrip silicon sensors pixel sensors
TT	microstrip silicon sensors
Tracker stations	OT straw tubes + CT scintillating fibers OT straw tubes + large area IT microstrip silicon sensors





In order to be able to converge on realistic options

- ➢ need to continue R&D on technologies ***AND in parallel***
- ➢ need to optimise overall tracking system ***AND***
- ➢ need to evaluate physics performance of these options!

→ realistic simulation & pattern recognition & reconstruction & …

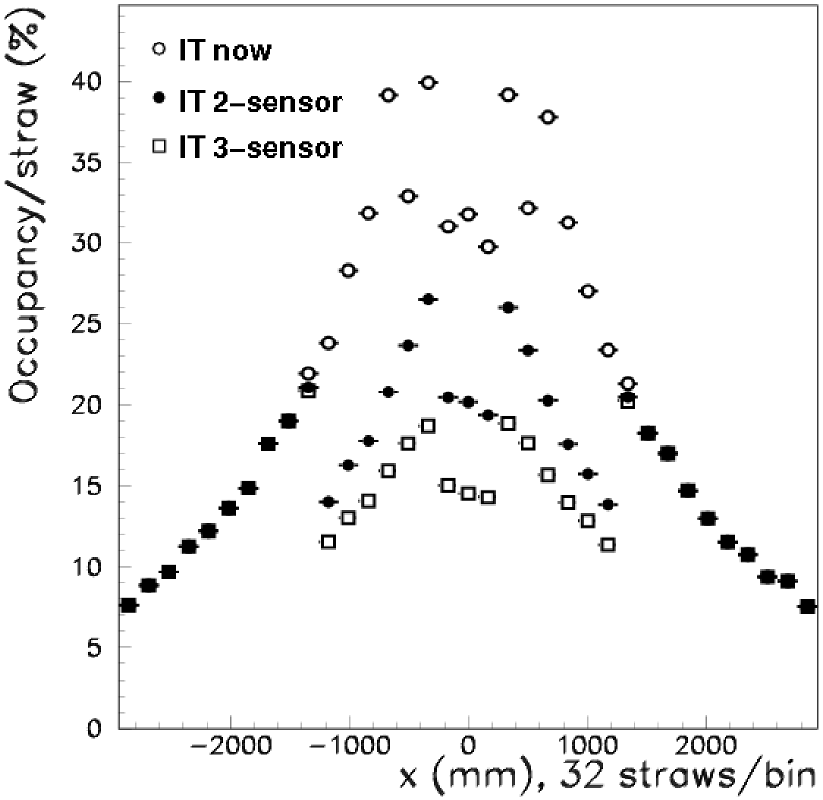
Next steps: Examples of Tracker optimisation studies

Compare occupancies in OT for different IT options:

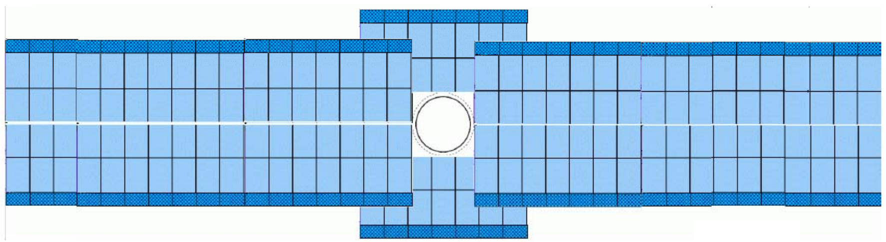
a) current LHCb IT detector:126 x 22 (41) cm^2

b) larger IT coverage with 2-sensor ladders, 255 x 42 (63) cm^2

c) even larger IT coverage with 3-sensor ladders, 255 x 63 (84) cm^2



Example of IT 2-sensor option



To be studied and confirmed with FULL simulation !

Next steps: Examples of Tracker optimisation studies

VELO

- impact parameter resolution as function of distance of sensors to beam
- realistic description of RF foil

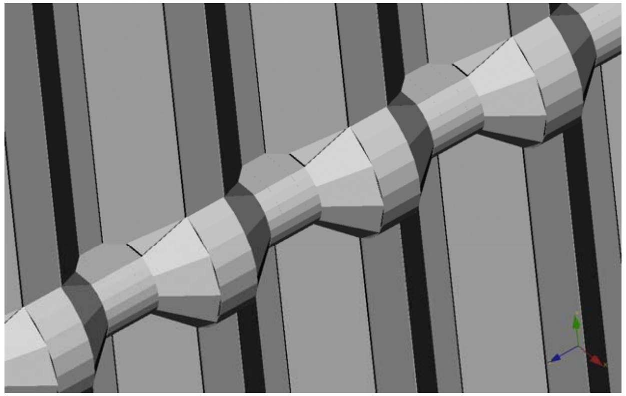
TT

- importance of acceptance coverage
- ideal segmentation
- number of layers
- material budget
- effect of B-field

Tracker stations

- pattern recognition performance as function of position of Tracker layers (X,U,V) along Z for OT & IT
- pattern recognition performance for CT & OT option

RF foil description



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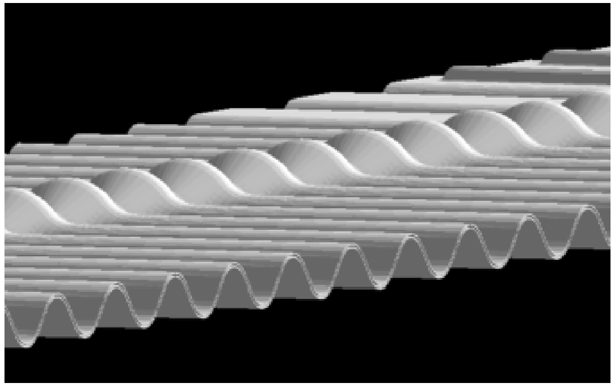

GDML description
importing CAD drawing

Next steps: Particle Identification (RICH, Calo, Muon)

RICH

- effect of removing aerogel (TORCH not baseline)?
- consequence of RICH1 occupancies with increasing luminosity?
- benefit from optimised RICH1 optics (if needed)?

Calo

- consequence of not having any SPD & PS (low p_T identification)?
- effect of ECAL performance with increasing luminosity for low/high energy gamma & pizero identification?

Muons

- effect of rate increase in inner chambers when increasing luminosity?

→ Need to get better understanding of all this by beginning of 2013!

Global upgrade schedule towards installation in 2018

Overall generic milestones as defined in 2011:

➢	in 2018:	installation (18 months according to planning!)
➢	2016-17:	quality control & acceptance tests
➢	2014-16:	tendering & serial production
➢	2013:	TDRs & prototype validation
➢	**2012/13:**	**technical review & choice of technology**
✓	2012:	continue R&D towards technical choices
✓	June 2012:	"Framework TDR"
❖	2011:	LoI (fully endorsed in June)

↑ timeline

→ Now have to meet **major milestones** given in FTDR: TDRs, EDRs , PRRs, …

Cost and declaration of interests

Cost:

- ✓ depending on technological choice total upgrade cost is between 51.3 and 53.4 MCHF with a common fund of ~30%
- ✓ add a reserve of 3.5 MCHF for possible additional modifications to make RICH, Calo and muons compatible with $\mathcal{L} = 2\cdot10^{33}\ cm^{-2}\ s^{-1}$
- ➢ total cost including reserve is 57 MCHF

Declaration of interests:

- ✓ *ALL institutes* of the LHCb Collaboration have signed the FTDR!
- ✓ expression of interest by countries to detector construction
- ✓ HLT & Computing is part of common project, but sharing of responsibilities has to be defined soon!

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.

→ Need to finalise and archive the LHCb internal documents (that have been the basis for the FTDR) on schedule, cost and institute responsibilities!

Conclusion

In 2012:

- Framework TDR ready to be submitted to the LHCC!
- Finalise and archive very soon the LHCb internal documents on schedule, cost and institute responsibilities!
- Seek for FTDR approval in autumn and discuss with funding agencies in October
- Continue R&D on detector technologies
- Optimise tracker and PID performance in parallel
- Intensify activities around trigger and computing (also in view of $\mathcal{L} = 2 \cdot 10^{33}\ cm^{-2}\ s^{-1}$)

In 2013:

- Review technical options
- Review detector performance with different viable options
- Produce detector TDRs

→ Challenging times ahead of us!