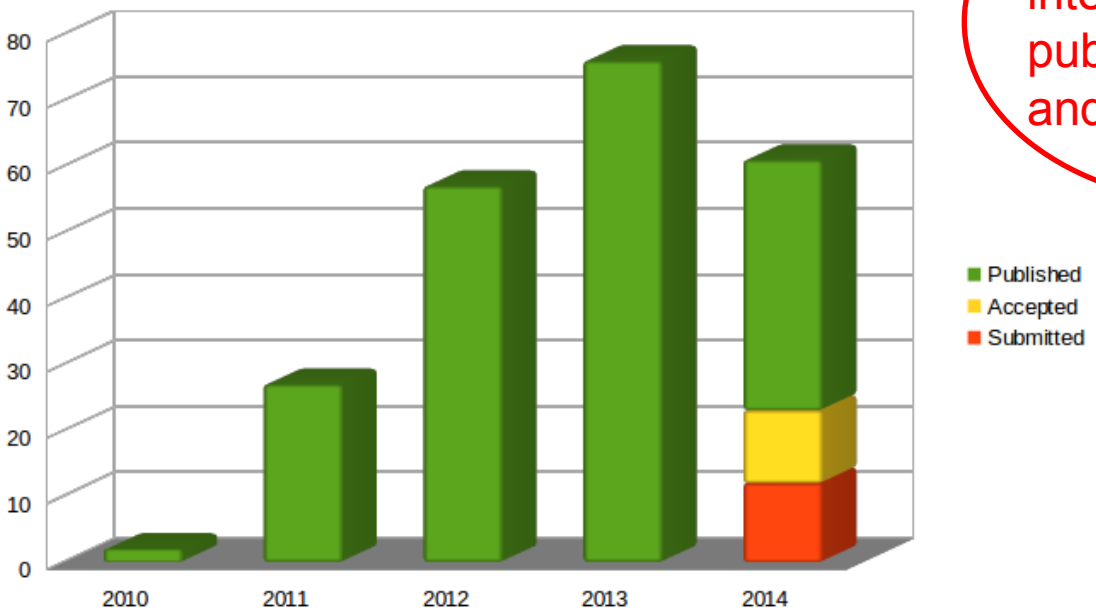
LHCb status and plans

- Recent physics achievements
- Preparations for Run II
- Upgrade progress
- Addendum II to the MoU
- Conclusions

Guy Wilkinson
(University of Oxford and CERN)
on behalf of the LHCb collaboration
15/10/2014

Run-I physics output

Status, as of Monday 13/10/2014

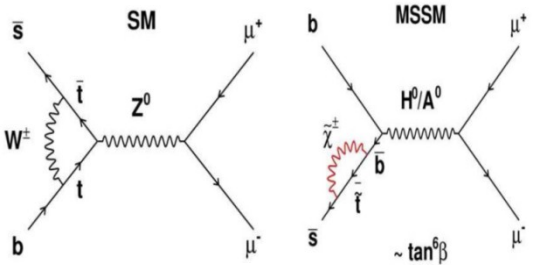


224 papers in total, integrating over published, accepted and submitted

We are still exploiting run-I data at same rate as last year – maybe even higher.

Very important results are still appearing – a very limited selection will follow.
We are finalising some of our 'flagship' analyses – aim to publish before Run II

$B_{d,s} \to \mu\mu$: run-I legacy paper & CMS-LHCb combination

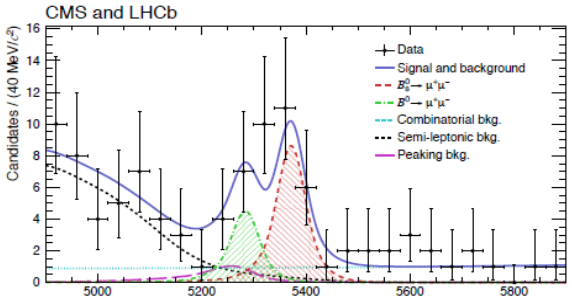


$$Br^{MSSM}(Bq \to l^+l^-) \propto \frac{m_b^2 m_l^2 \tan^6\beta}{M_{A0}^4}$$

$B_s \to \mu\mu$ very rare (~10^{-9}) and very sensitive to contributions from beyond the Standard Model.

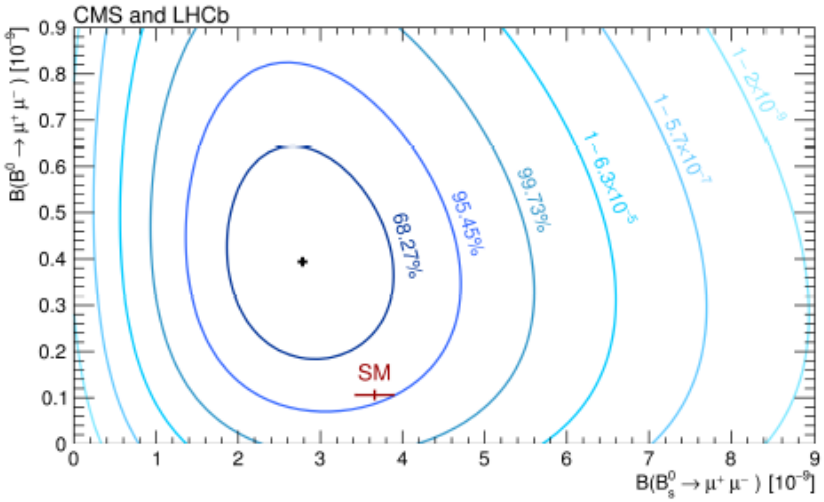
Observing this mode was a top priority in run I, and LHCb already published first evidence of the decay [PRL 110 (2013) 02180; PRL 111 (2013) 101805] , later confirmed by CMS.

LHCb and CMS physicists have now performed a combined fit to their datasets, making use of common assumptions. The first combination of results from the LHC !



LHCb-PAPER-2014-049;
CMS-BPH-13-007

to be submitted to Nature

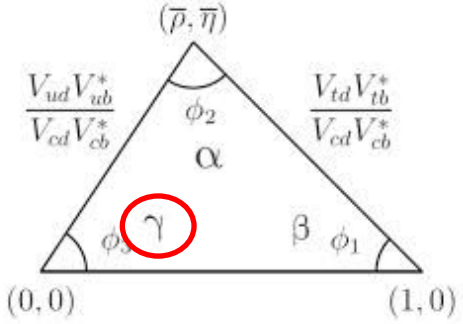


$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = \left(2.8\,^{+0.7}_{-0.6}\right) \times 10^{-9} \quad (6.2\sigma)$$

$$\mathcal{B}(B^0 \to \mu^+\mu^-) = \left(3.9\,^{+1.6}_{-1.4}\right) \times 10^{-10} \quad (3.0\sigma)$$

Included also are results for the even rarer $B_d \to \mu\mu$, where a signal may be emerging too. The picture is intriguing and provides encouragement for run II !

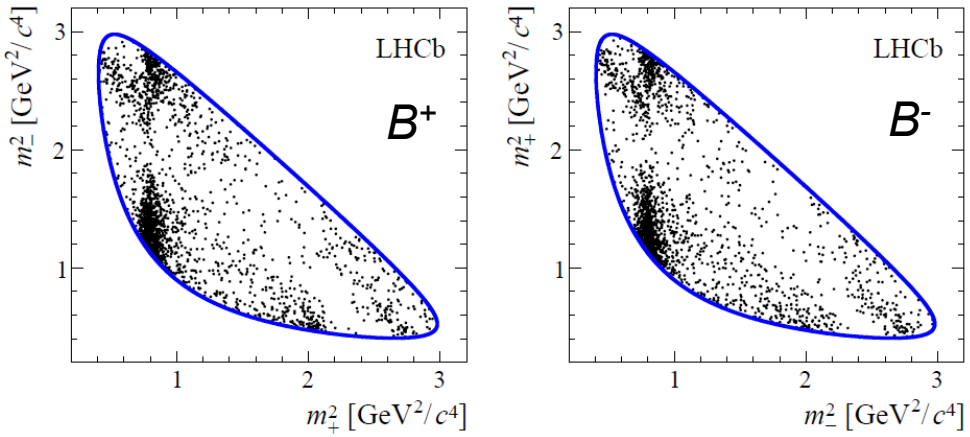
Mapping the unitarity triangle: world's best measurement of the angle γ



Standard Model description of CP-violation encoded in the unitarity triangle.

One of most important goals of LHCb is a precise measurement of the angle γ, which prior to LHC turn-on was known with a precision of ~30°

Run-1 $B\to D(K_S\pi\pi)K$ sample, D Dalitz plots

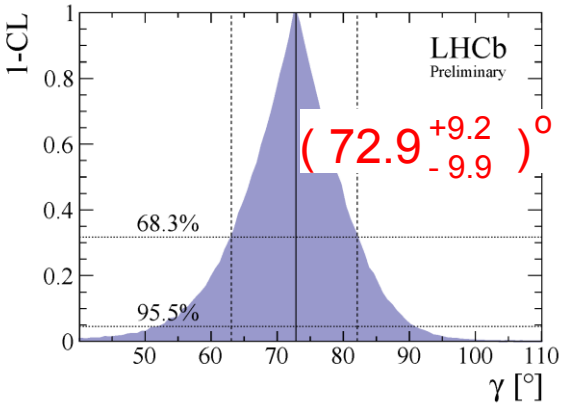


arXiv:1408.2748; accepted by JHEP

Differences between these distributions related to γ

Still very important run-I results to come.
The goal is to reach 3-4° with run-II data.

Combination of all LHCb analyses…



LHCb-CONF-2014-004

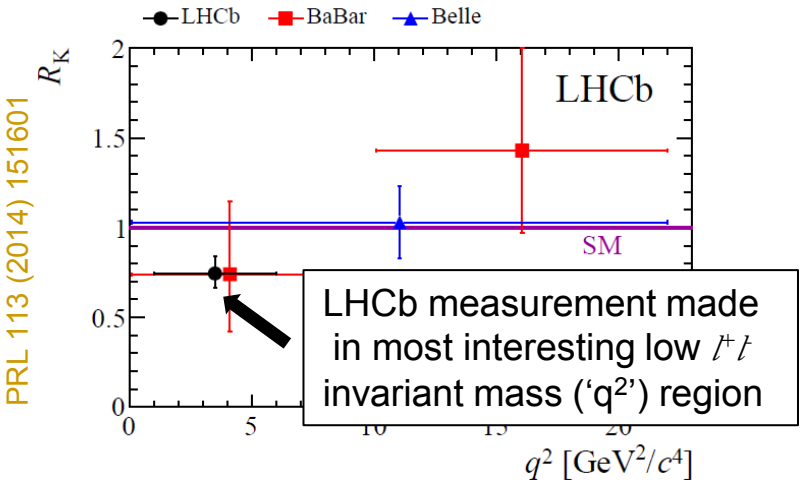
…a precision better than the B-factories combined

Who ordered that ?

Run-I analyses are still yielding surprises, some potentially very significant

Lepton universality tests in $B \to K l^+ l^-$

Determine R_K, the low-q^2 ratio of $B \to K \mu^+ \mu^-$ to $B \to K e^+ e^-$ which is expected to be 1 in SM



PRL 113 (2014) 151601

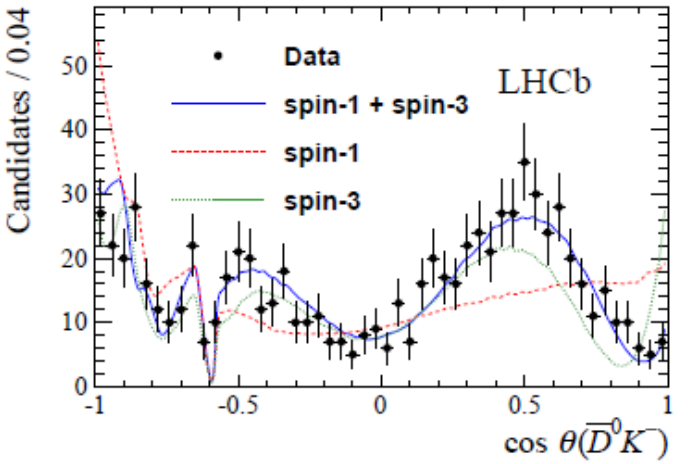
$$R_K = 0.745 \,^{+0.090}_{-0.074} \pm 0.036$$

2.6σ from unity, 3.1σ if BaBar included.

Follow up studies underway, *e.g.* $B \to K^* l^+ l^-$

Findings in spectroscopy

Study of the $B_s \to D^0 K^- \pi^+$ Dalitz plot performed to understand nature of previously observed D^*_{sJ} resonances



arXiv:1407.7574, sub. to PRL;
arXiv:1407.7712, sub. to PRD

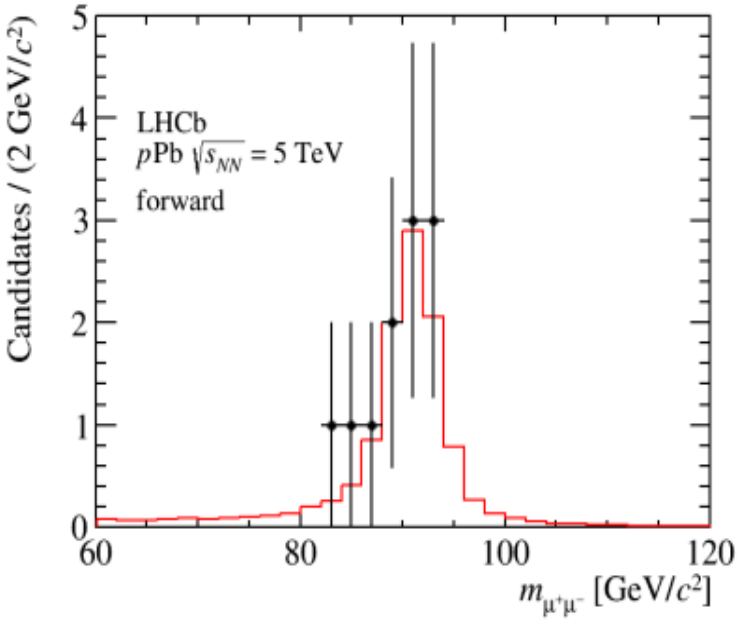
Find that the $D^*_{sJ}(2860)^-$ is actually a superposition of spin-1 & spin-3 states

This is the first observation of a heavy-flavour spin 3 particle.

Beyond flavour

LHCb continues to contribute strongly in other fields outside flavour physics, taking advantage of its unique geometry and instrumentation.

Lead-proton physics



arXiv:1406.2885 ; sub. To JHEP

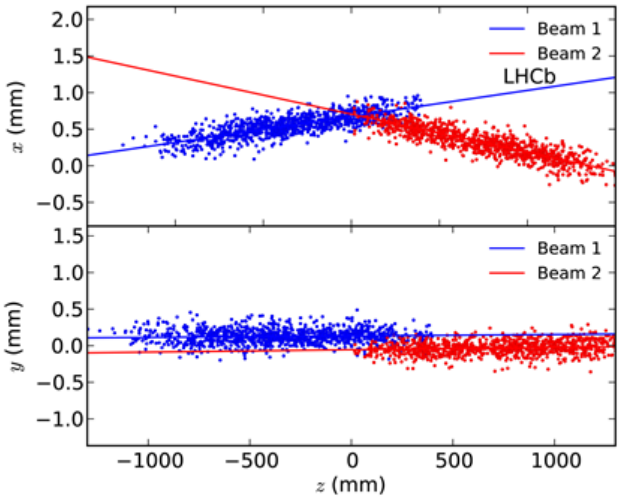
First observation of *Z* boson production in *Pb-p* collisions

Luminosity measurement for production studies

LHCb has unique ability to reconstruct beam-profile with beam-gas interactions

Lumi measured to 1.12 %

Best precision ever achieved at a (bunched) hadron collider

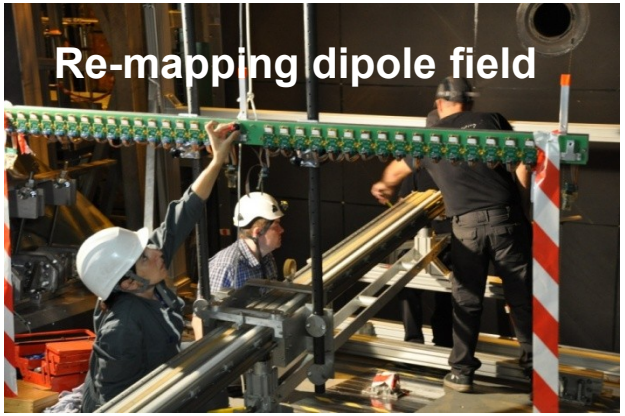


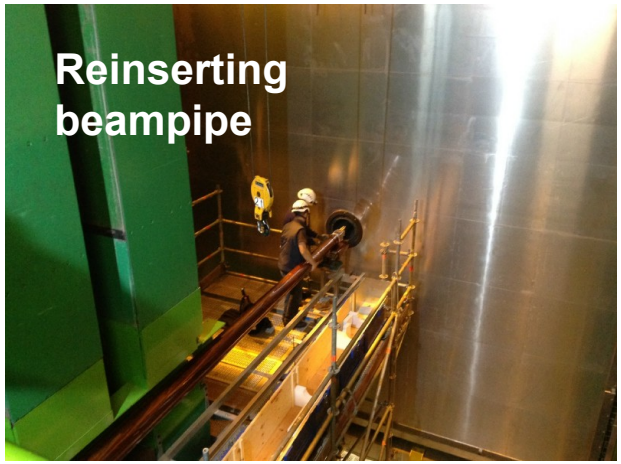
arXiv:1410.0149 , sub. to JINST

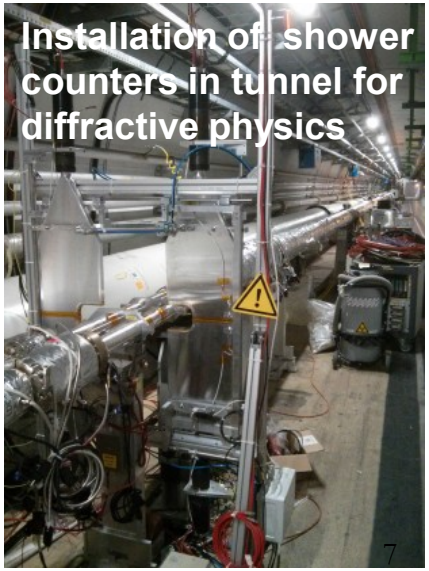
This, together with conventional method (van der Meer scan) means LHCb has most precise lumi measurement at the LHC

LS1 activities – preparing for run II

A very busy time – all work being completed on schedule. Detector will be fully closed next month.



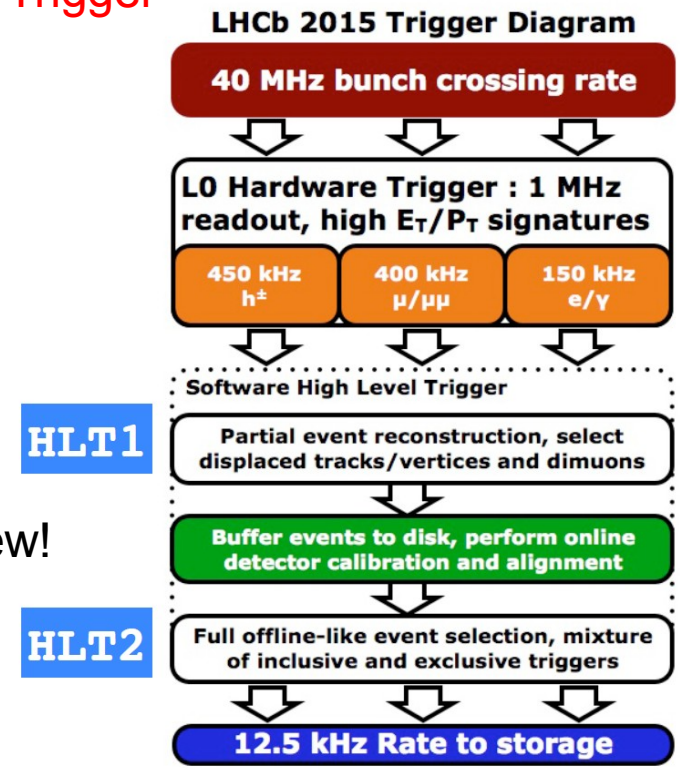




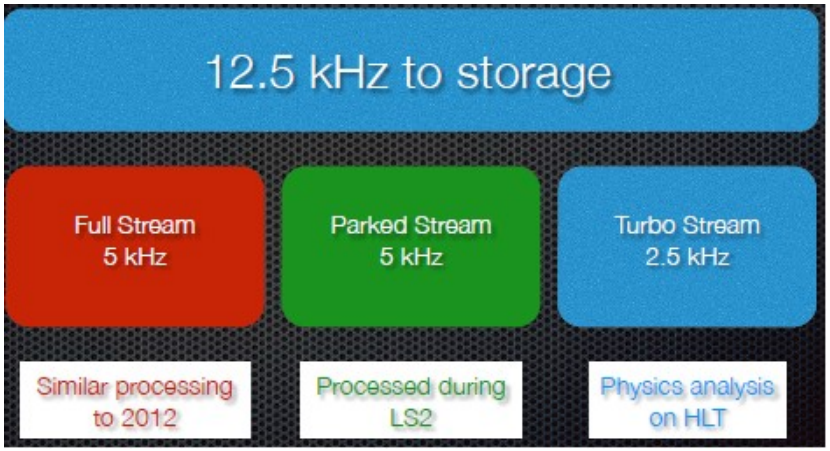
Run II operation

Several ambitious changes planned for operation during run II aimed at increasing physics output and making optimal use of resources

Trigger



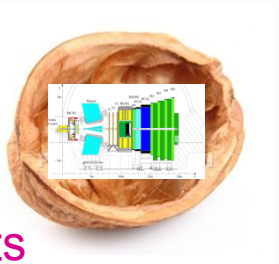
Output streams



Turbo-stream will need no offline processing. If this works well then it has important implications for Upgrade.

This splitting of HLT into two steps enables more info to be used in HLT2 (*e.g.* RICH) → improved signal-to-background separation (and helps test ideas we wish to use in Upgrade trigger)

The Upgrade in a nutshell



Indirect search strategies for New Physics, *e.g.* precise measurements & the study of suppressed processes in the flavour sector become ever-more attractive following the experience of LHC 1 run that direct signals are elusive

Our knowledge of flavour physics has advanced spectacularly thanks to LHCb. Maintaining this rate of progress beyond run II requires significant changes.

The LHCb Upgrade

1) Full software trigger
- Allows effective operation at higher luminosity
- Improved efficiency in hadronic modes

2) Raise operational luminosity to 2×10^{33} cm^{-2} s^{-1}

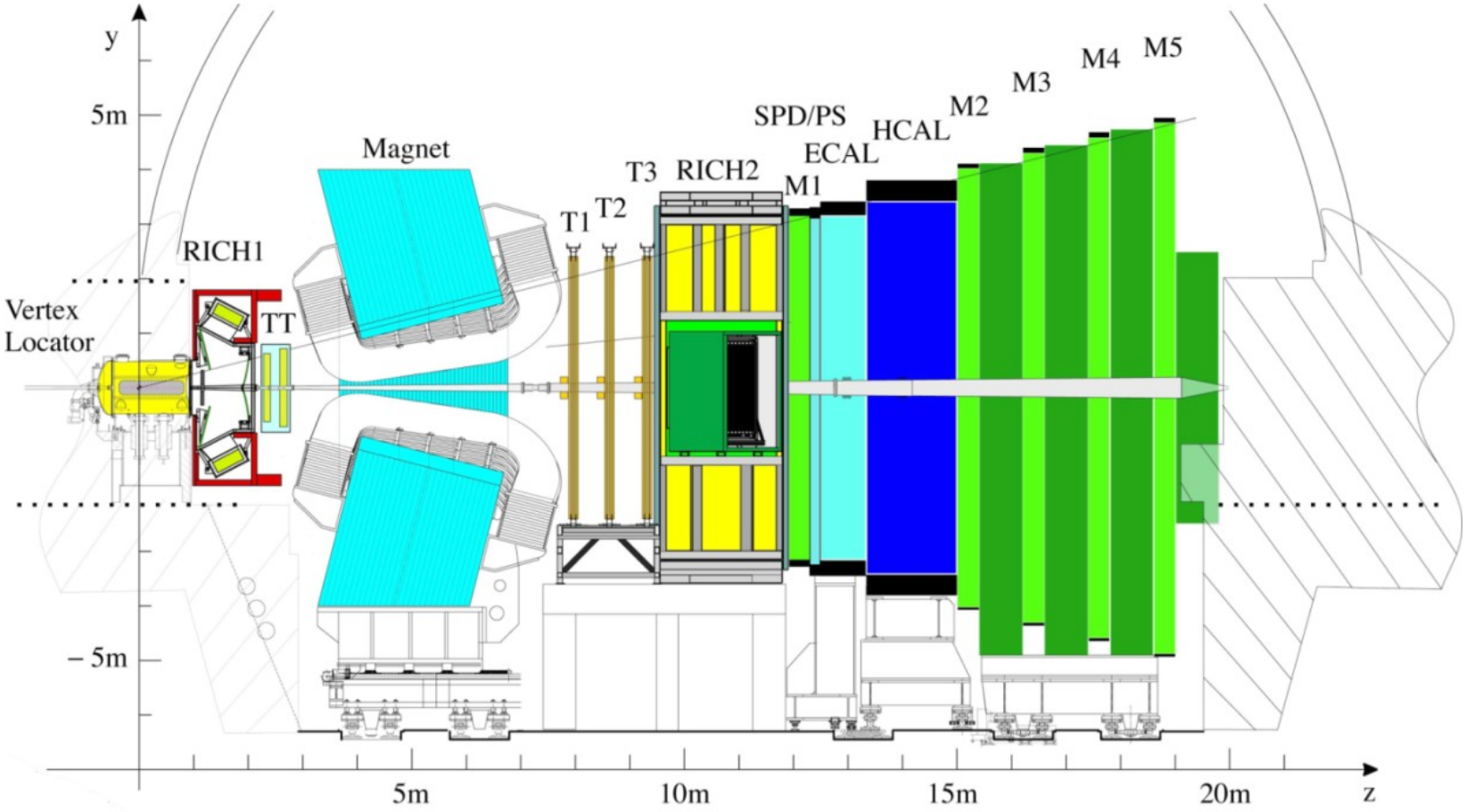
Necessitates redesign of several sub-detectors & overhaul of readout

Huge increase in precision, in many cases to the theoretical limit, and the ability to perform studies beyond the reach of the current detector.

Flexible trigger and unique acceptance also opens up opportunities in other topics apart from flavour (‘a general purpose detector in the forward region’)

Upgrade overview

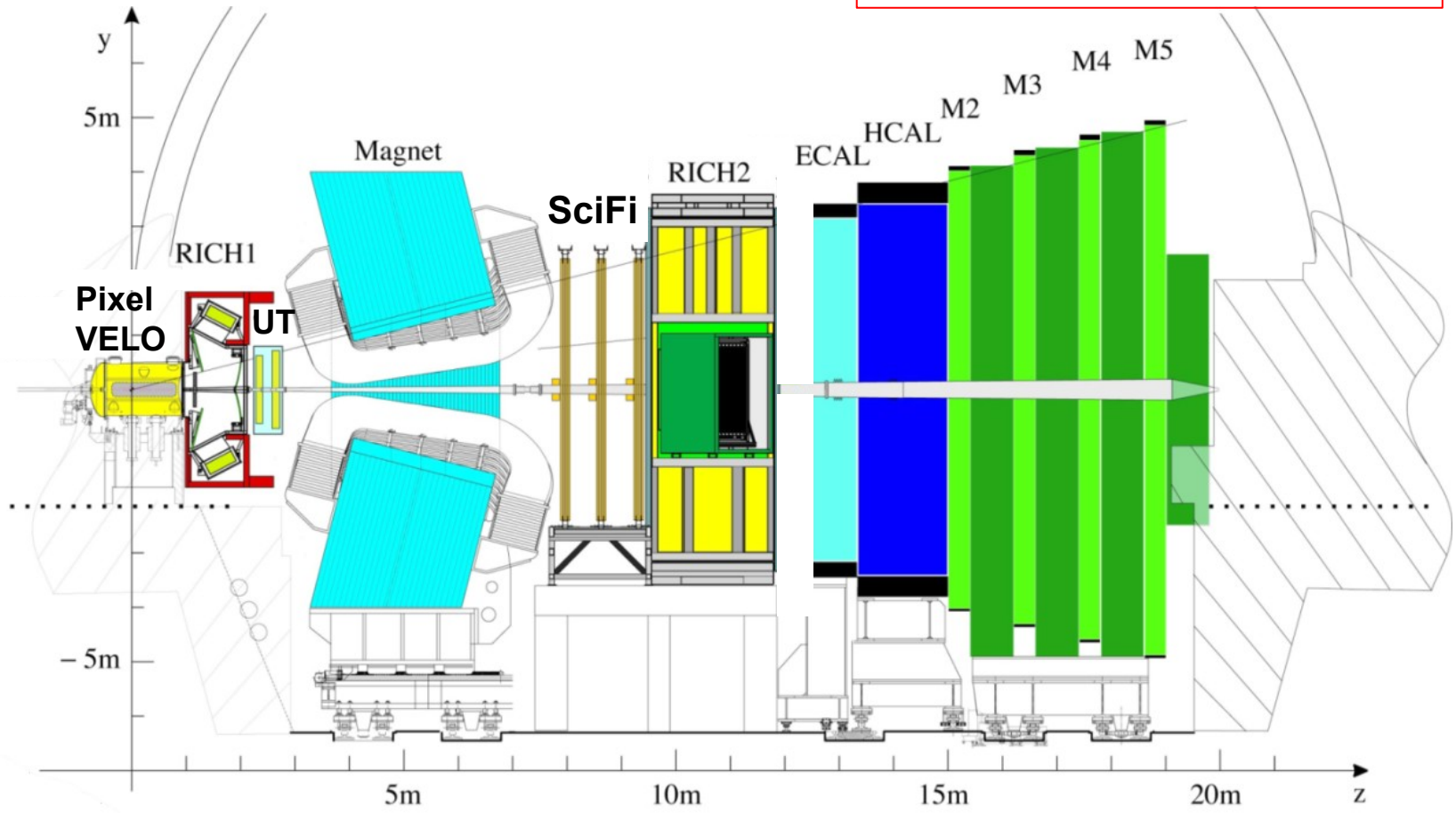
Current detector



Upgrade overview

Current detector → upgraded detector

All sub-detectors read out at 40 MHz for software trigger



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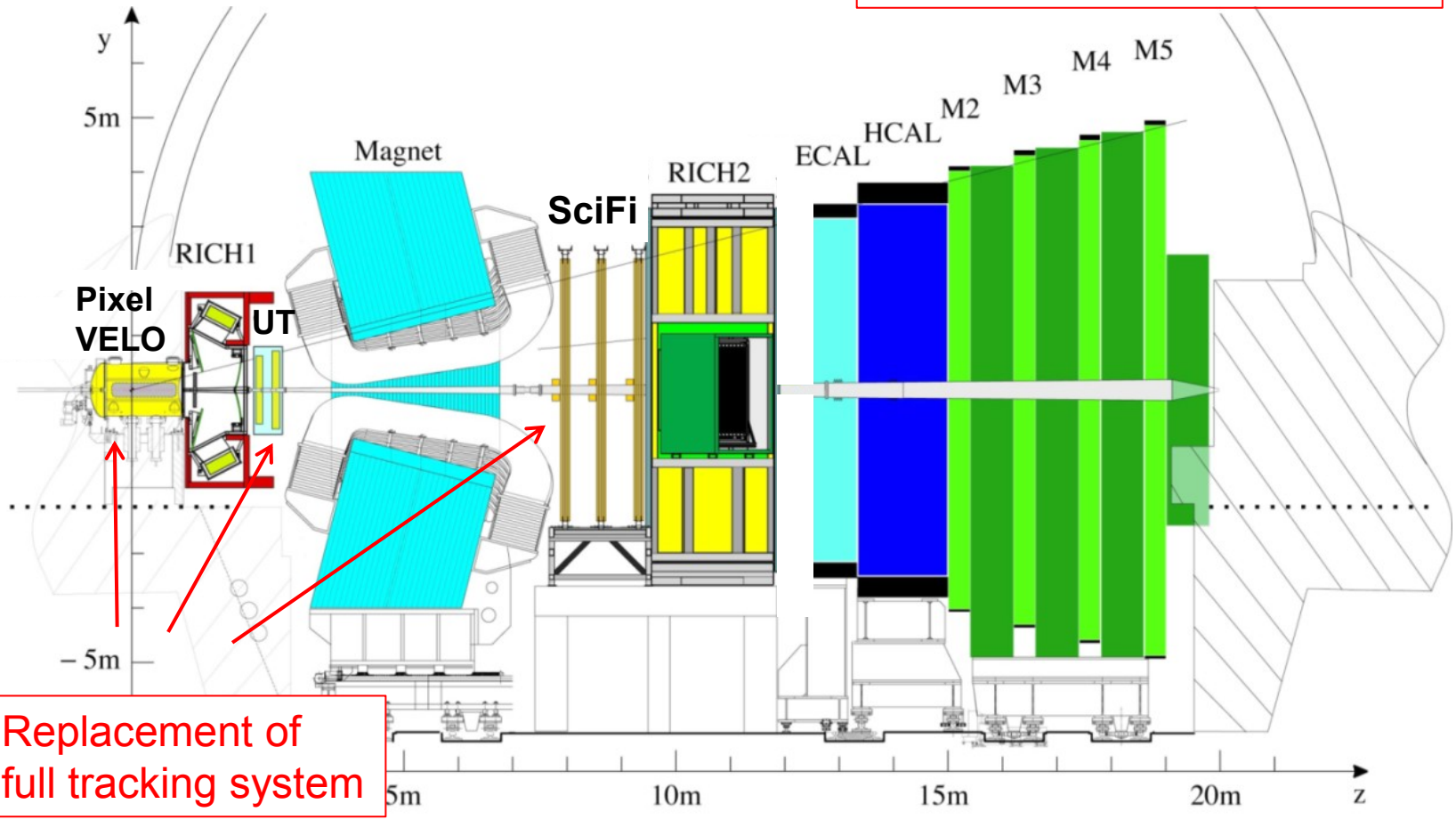


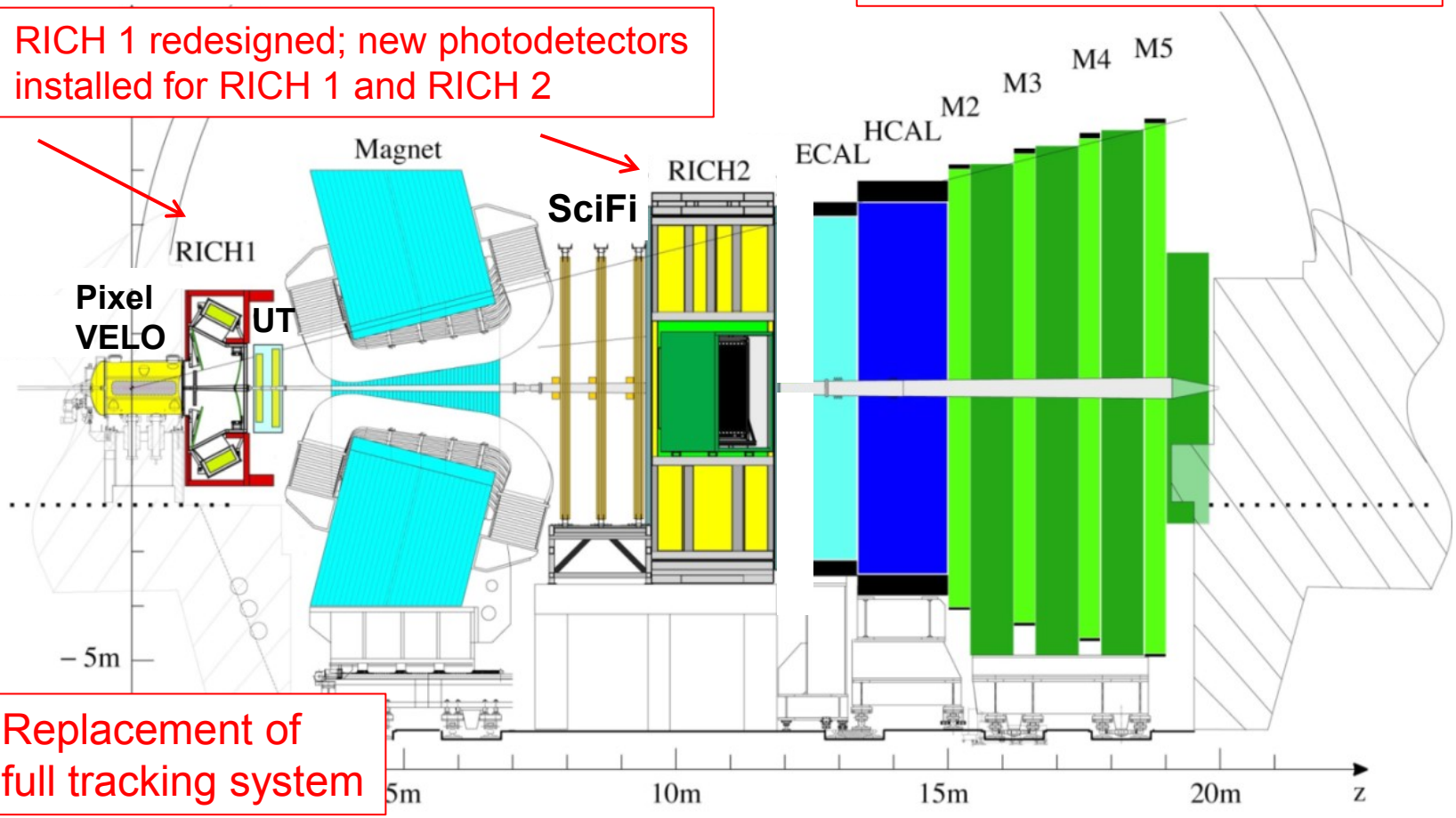
Replacement of full tracking system

Upgrade overview

Current detector → upgraded detector

All sub-detectors read out at 40 MHz for software trigger

RICH 1 redesigned; new photodetectors installed for RICH 1 and RICH 2



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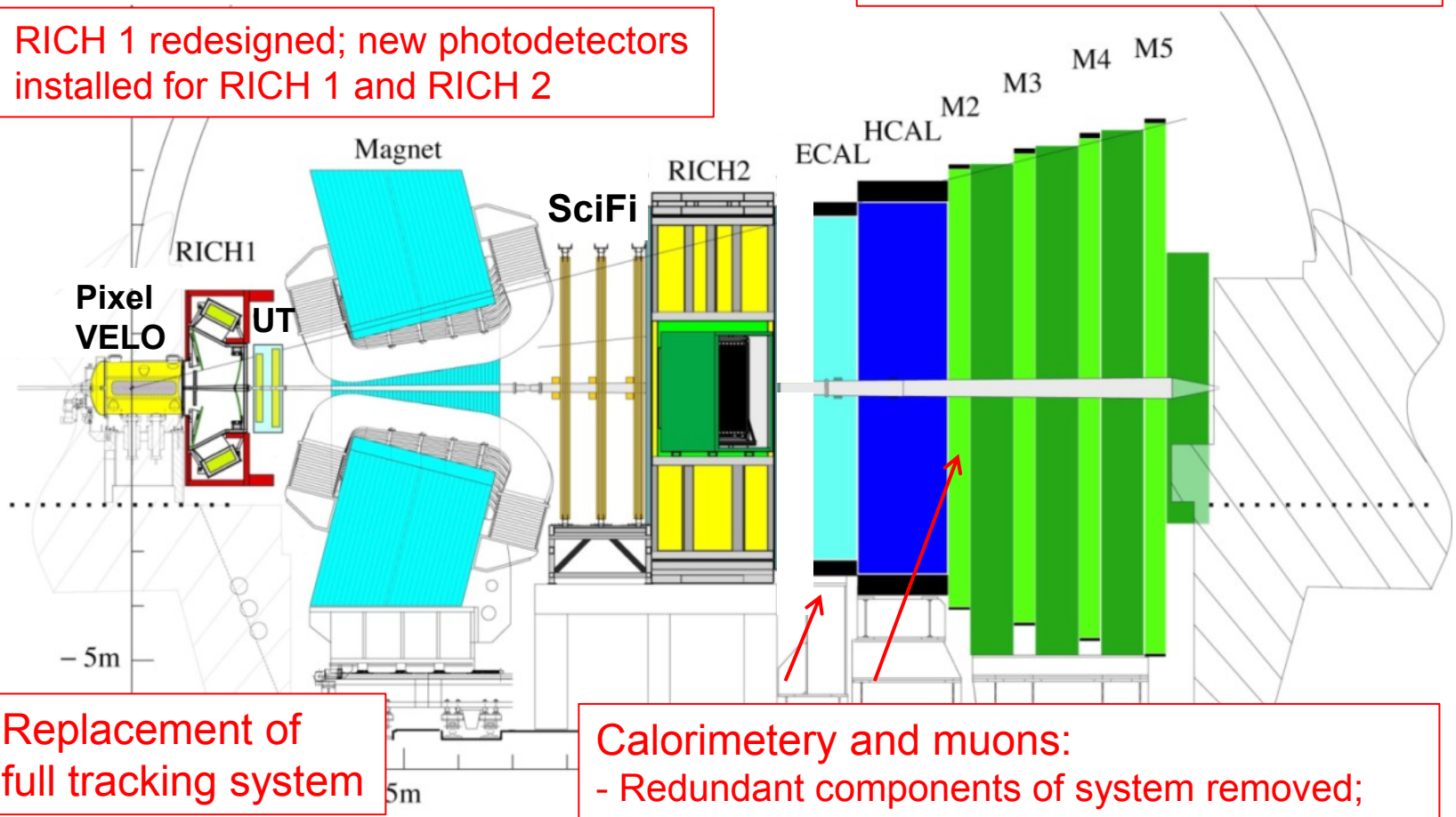
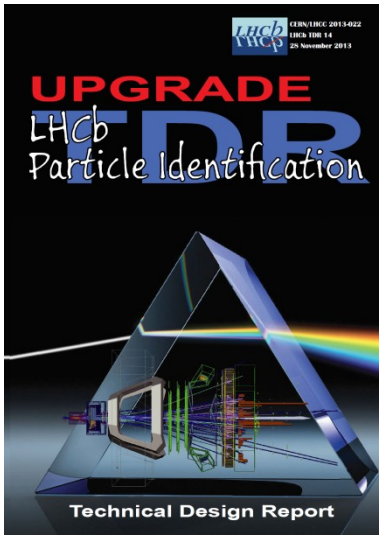


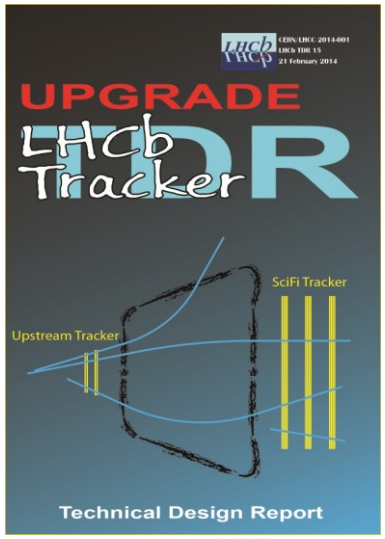
Replacement of full tracking system

Calorimetery and muons:
- Redundant components of system removed; new electronics added; more shielding included

Completion of upgrade TDRs

All* upgrade TDRs have now been approved by the Research Board (the last two since the April RRB). We have final & achievable technology choices for all systems.





We have now organised ourselves for the next phase of the programme, *i.e.* final stages of R&D, engineering and production readiness reviews, and production

* Caveat: a computing TDR is foreseen for Q1 2017

Organisation of Upgrade Activities

New body, Upgrade Planning Group, established to oversee Upgrade Activities

- Spokesperson (chair)
- Deputy Spokesperson
- Technical Coordinator
- Physics Coordinator (or representative)
- Upgrade Detector Coordinator
- Upgrade Performance Coordinator
- Upgrade Resources Coordinator
- Upgrade Data Processing Coordinator

New positions created for this body

Upgrade activities for each sub-system are pursued within existing 'Projects' (*i.e.* VELO Project deals with current detector and Upgrade) – this optimises use of expertise and resources, and keeps lines of communication clear.

Exceptions are the new detectors: the Upstream Tracker and the Scintillating Fibre Tracker, where new Projects have been created.

Milestones

High-level milestones have been defined for each sub-system, in order to track progress.

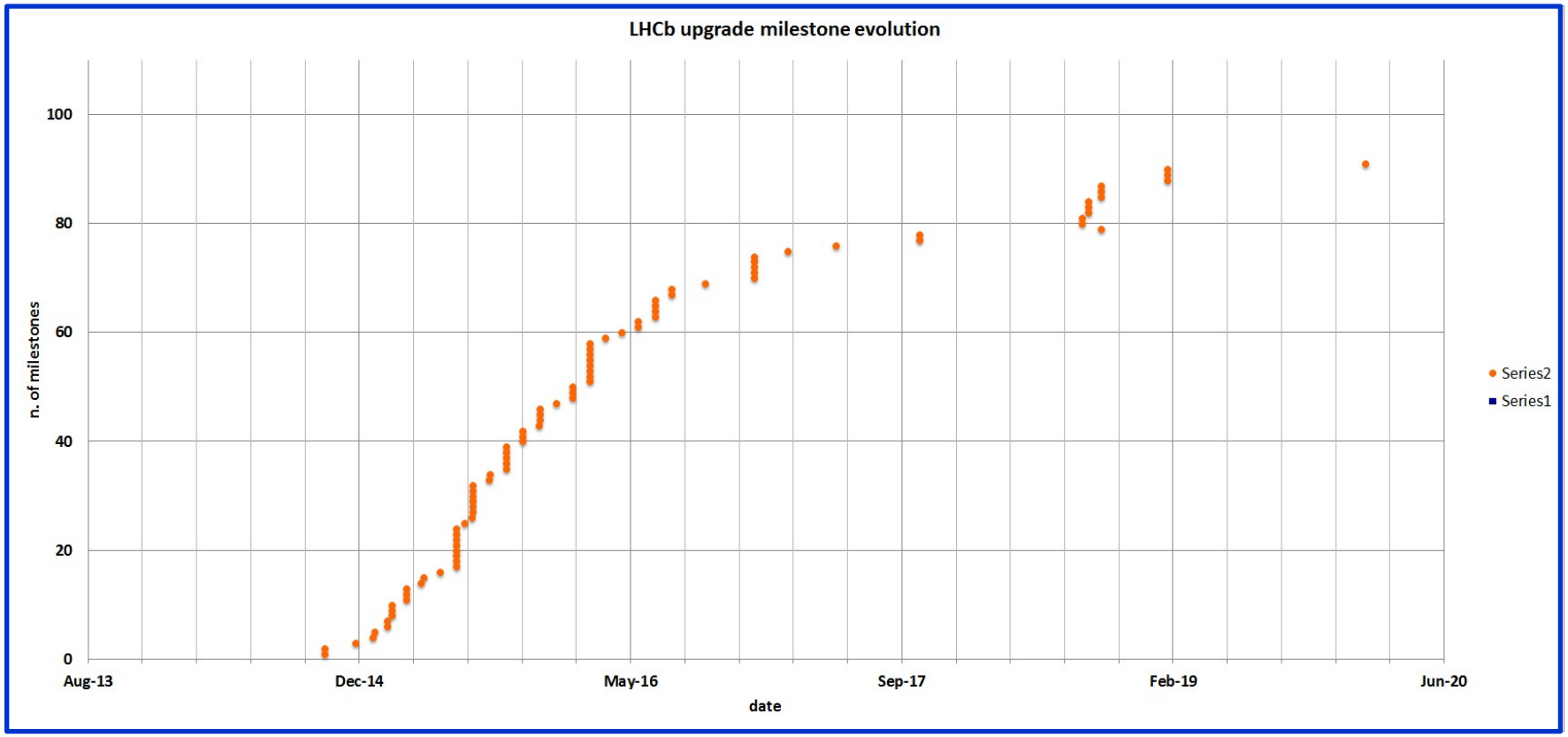
These will be monitored, both internally and in conjunction with the LHCC

Example: RICH milestones

Item	Milestone	Date
CLARO + front-end board	Engineering Design Review (EDR)	Nov 14
CLARO + front-end board	Production Readiness Review (PRR)	Mar 15
Elementary cell	EDR	Nov 14
Elementary cell	PRR	Mar 15
Photon detector module	EDR, optoelectronic chain module and assembly	Apr 15
MaPMT	Place order and start production	Apr 15
Digital board	EDR, DB hardware with basic firmware + ECS	Feb 15
Digital board	PRR	Sep 15
RICH1 mirrors + supports	EDR, spherical and flat mirrors with their supports	Jun 15
RICH1 mirrors + supports	PRR	Nov 15
RICH mechanics	EDR, including gas envelope, PMT boxes, photon funnel	Dec 15
RICH mechanics	PRR	Jul 16
Installation	Installation	Sep 18

Milestones

Milestones of all systems, plotted against time



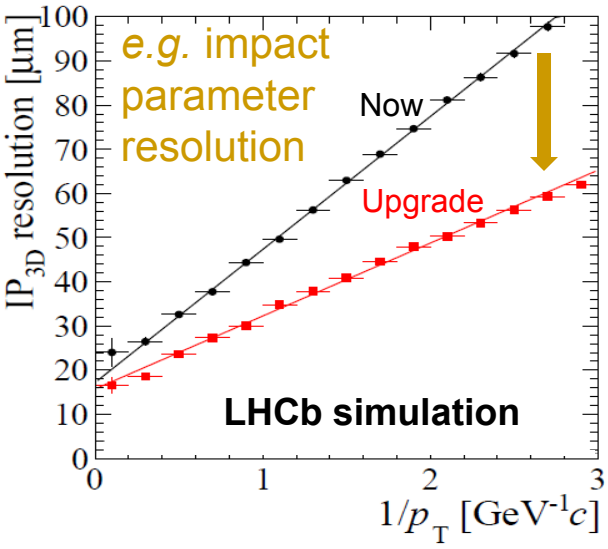
Vertex Locator (VELO)

(copied from 'money matrix') → Brazil, CERN, NL, Poland, Spain, UK

New, pixel (50 x 50 μm^2) based VELO

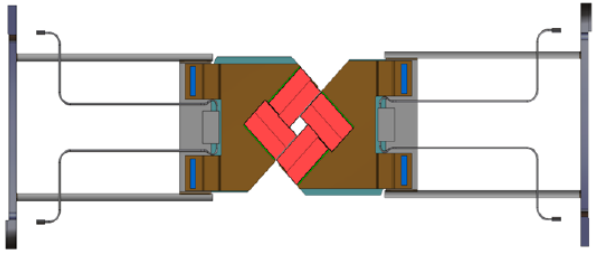
- Good 3D pattern recognition
- Excellent resolution
- Micro-channel cooling → minimises material
- Radiation resistance
- Closer to beam line (5 mm, *cf.* 8 mm currently)

Improved performance



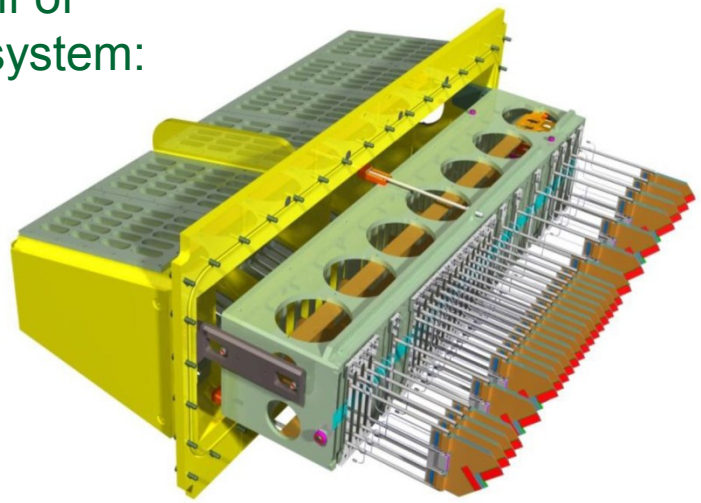
Exciting progress since TDR, *e.g.* :

- optimised, rotated module design



- cooling prototype
- prototype sensors
- front-end chip (VeloPix)

One half of VELO system:

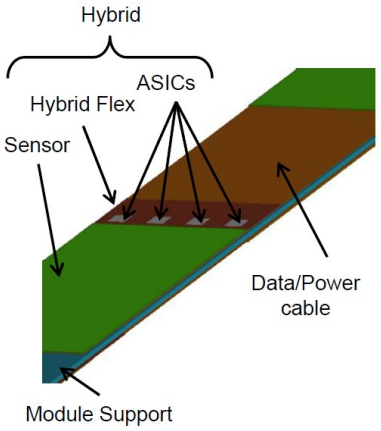


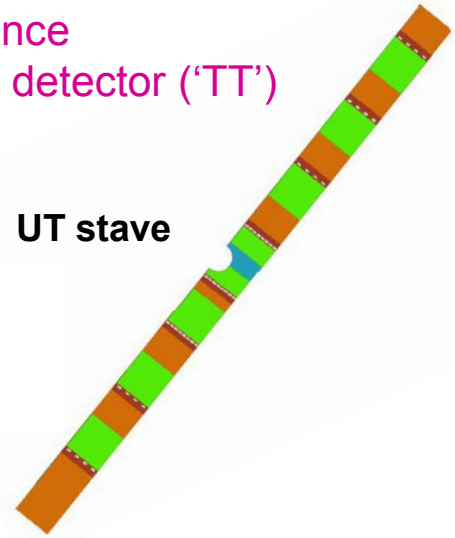
Upstream Tracker (UT)

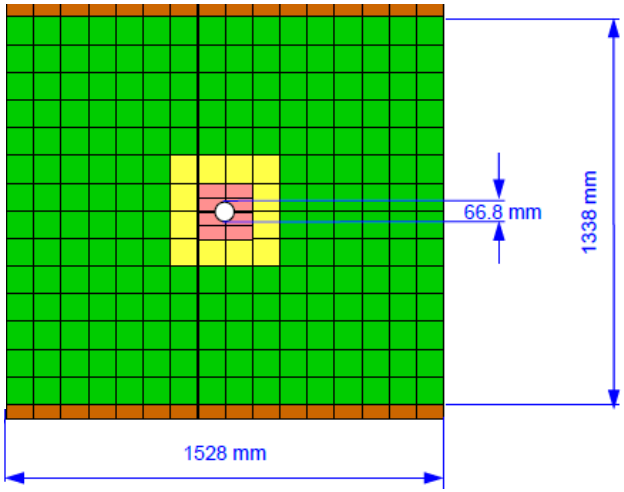
CERN, Italy, Poland, Switzerland, USA

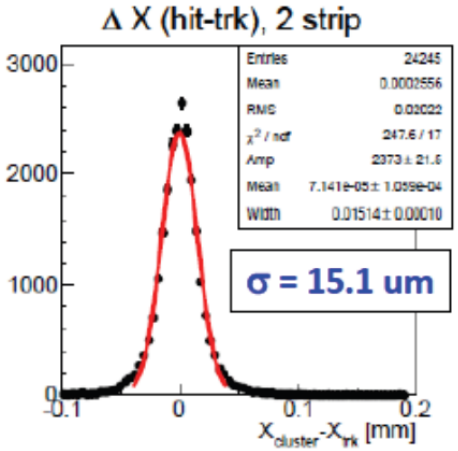
Critical silicon strip tracking plane just before magnet.

- Variable granularity to match occupancies
- Stave system inspired by ATLAS IBL
- Fully active within acceptance
- Less material than current detector ('TT')









Recent progress on *e.g.* data/power flex, on mechanics, and on evaluating sensor performance in test-beam.

New test-beam this month will evaluate irradiated sensors.
Imminent design review is expected to lead to submission of ASIC prototype

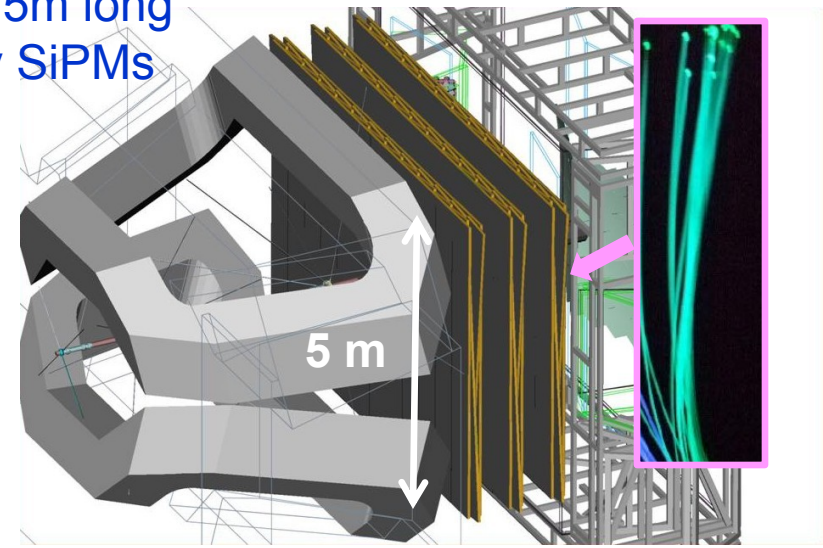
UT now assigned 'project' status with Marina Artuso (Syracuse) as Project Leader

Scintillating Fibre Tracker (SciFi)

Brazil, CERN, China, France, Germany, NL, Russia, Spain, Switzerland

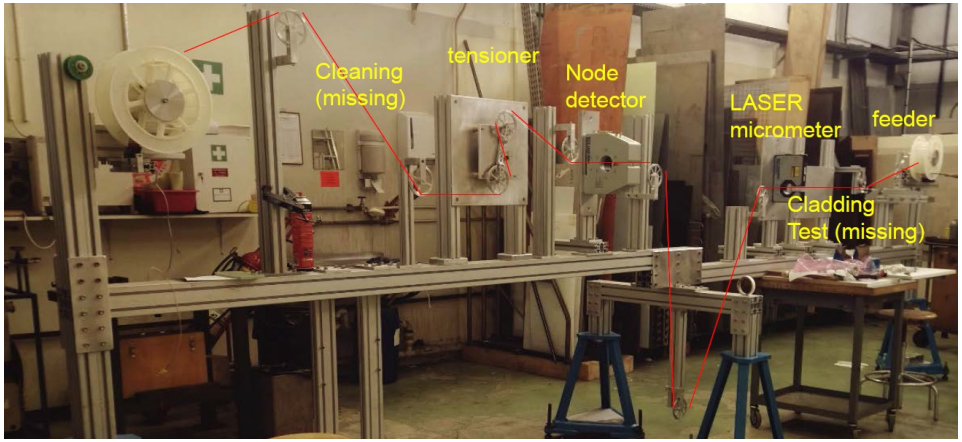
Large scale tracking system based on mats of 2.5m long scintillating fibres of 250μm diameter, readout by SiPMs

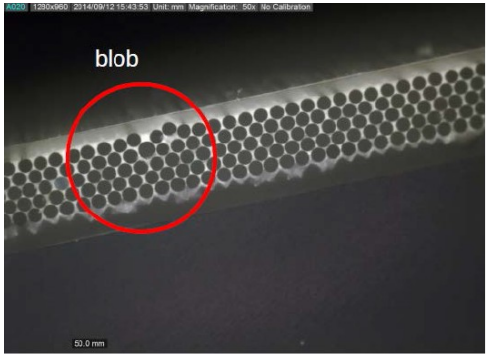
- 3 stations of X-U-V-X (+/- 5° stereo)
- each plane made of 5 layers



Benefits include single detector technology, fast pattern recognition, good resolution…

Test benches available to study fibre quality; close collaboration with industrial partner to solve problems



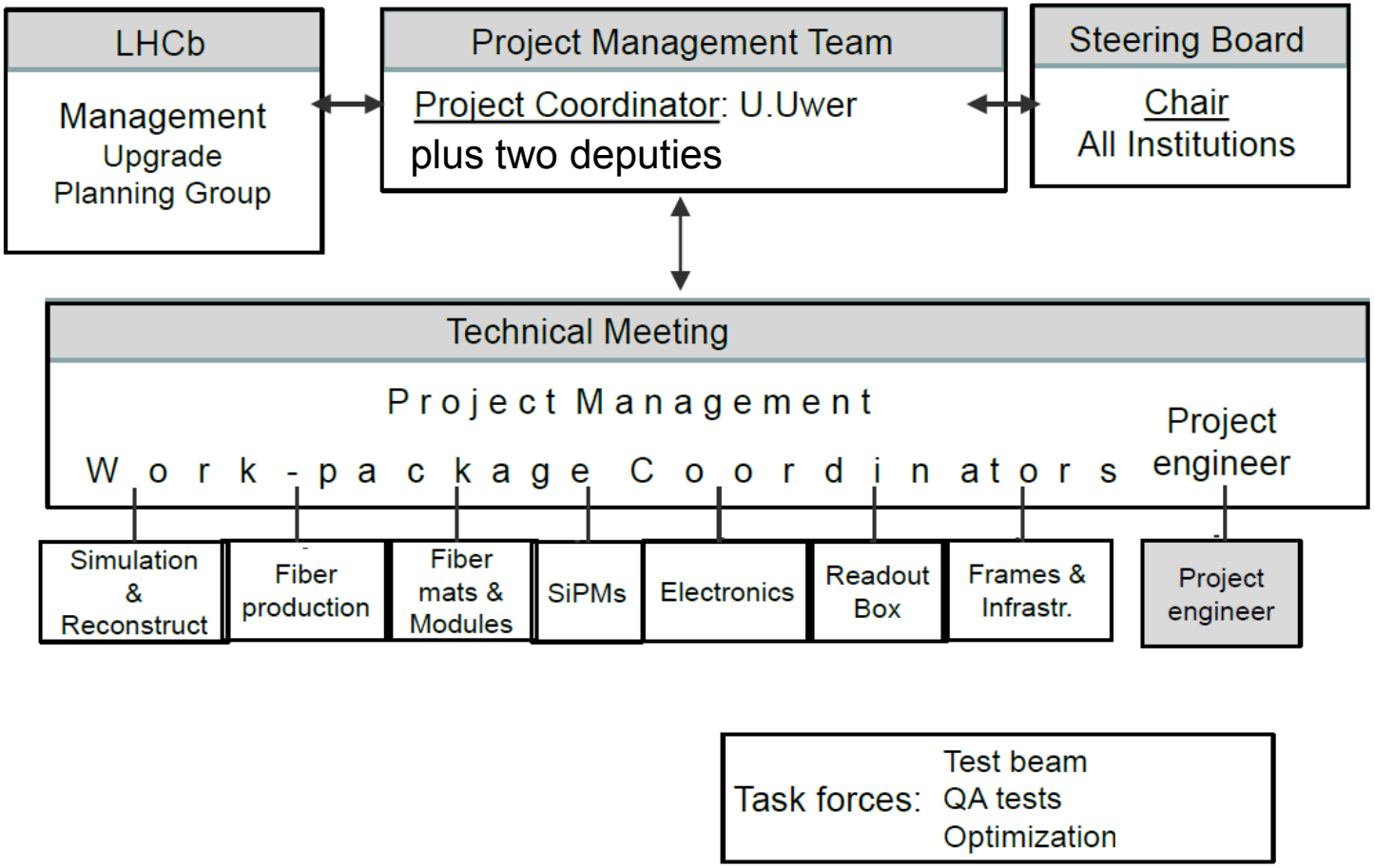


Large scale production will occur in several centres: equipment being prepared

Scintillating Fibre Tracker (SciFi)

Brazil, CERN, China, France, Germany, NL, Russia, Spain, Switzerland

New Project created under Ulrich Uwer (Heidelberg) with an organisational structure appropriate for a task of this magnitude

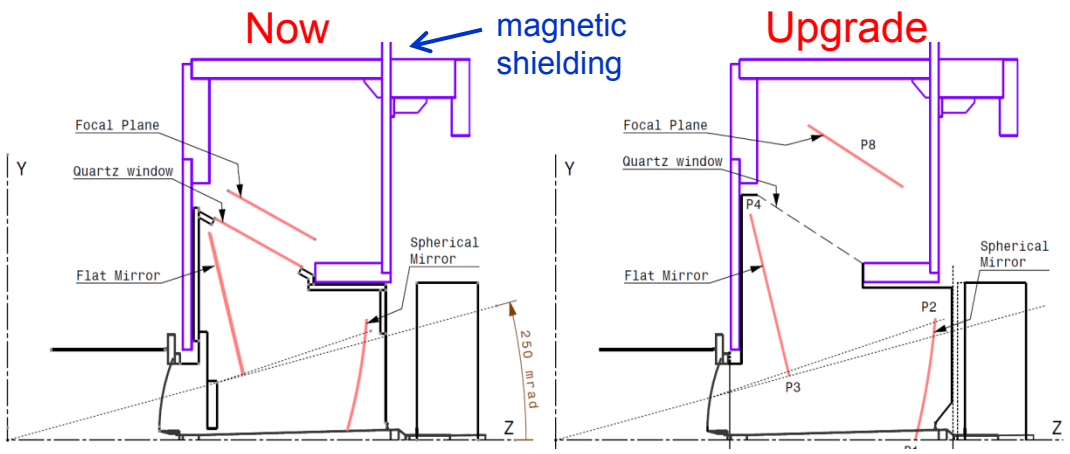


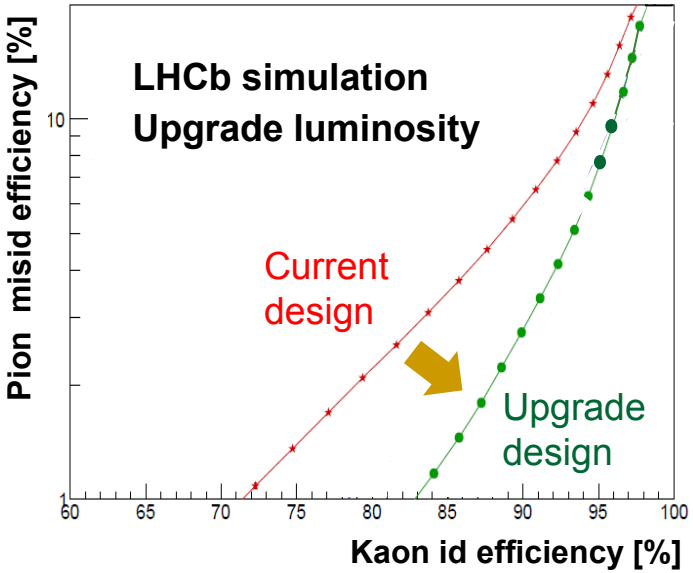
RICH system

CERN, Italy, Poland, Romania, UK

Two very significant changes are required:

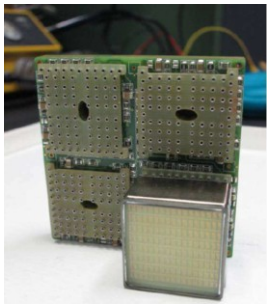
- High luminosity means higher occupancy in RICH 1. To recover performance optics must be changed → new mechanics



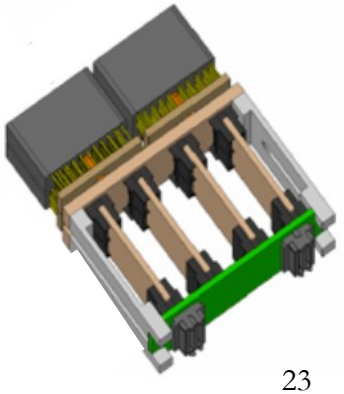


- 40 MHz readout requires new photodetectors

A candidate upgrade photodetector in an 'elementary cell'



EDRs already occurring for front-end chip and for design of elementary cell



Photodetector tendering underway now. Order must be placed next year !

Calorimeter system

France, Russia, Spain

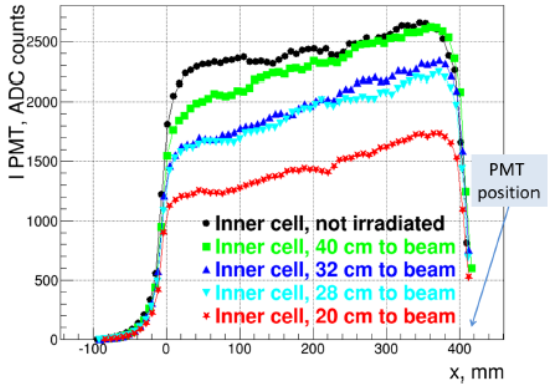
- Removal of SPD/PS system (not needed in trigger anymore)
- Reduce the photodetector gain by factor 5, and compensate for this modification in FE electronics

Two options for analogue part FE under evaluation:

i) dedicated ASIC
ii) based on discrete commercial elements

Decision imminent! Meanwhile prototype of FE board exists

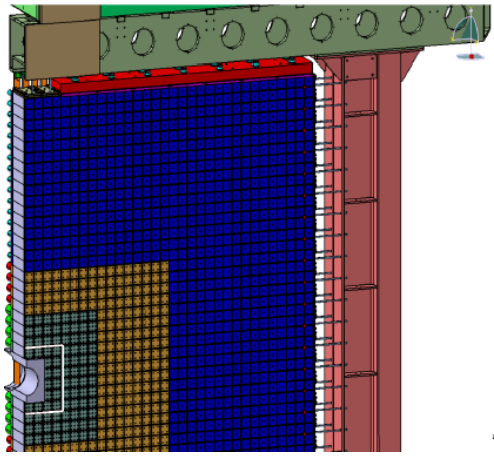
- Radiation damage in the hottest, inner part of the ECAL, assessed by measurement & simulation, No need for any intervention during LS2



Measurements of response for module irradiated in tunnel

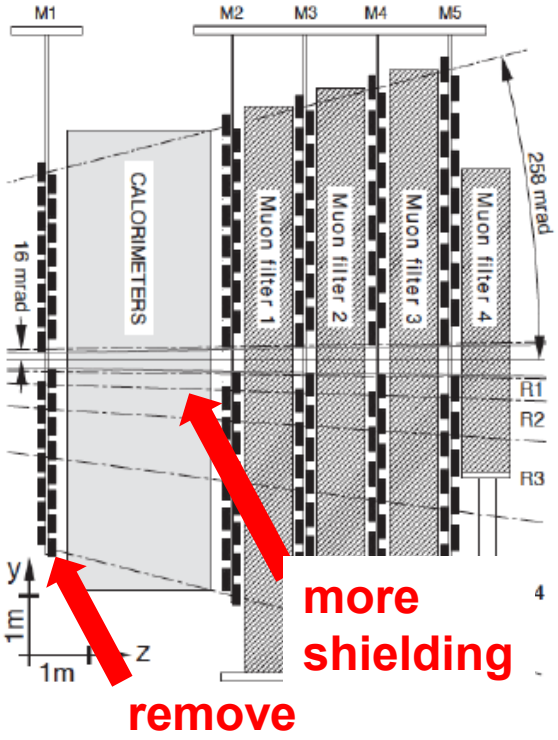
Rather, replacement campaign will occur during LS3 – sufficient modules already exist

Region for replacement



Muon system

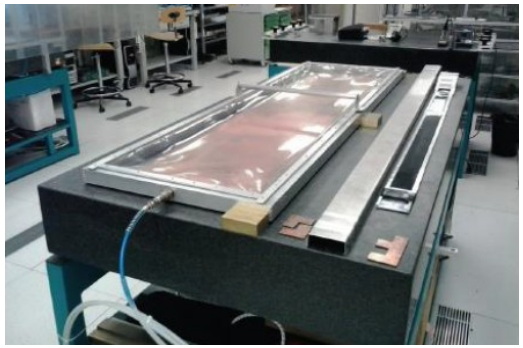
CERN, Italy, Russia



Muon system modifications required for Upgrade:

- Removal of M1 (not needed in new trigger)
- Design of new off-detector readout electronics compliant with 40 MHz readout
- Additional shielding in front of M2

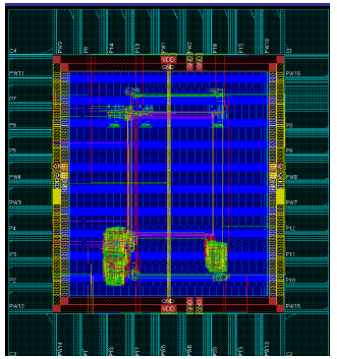
Other essential and important work needed
e.g. production of spare chambers – underway!



Cathode panel production

Refurbished wiring machine

Building blocks of new SYNC ASIC are already designed



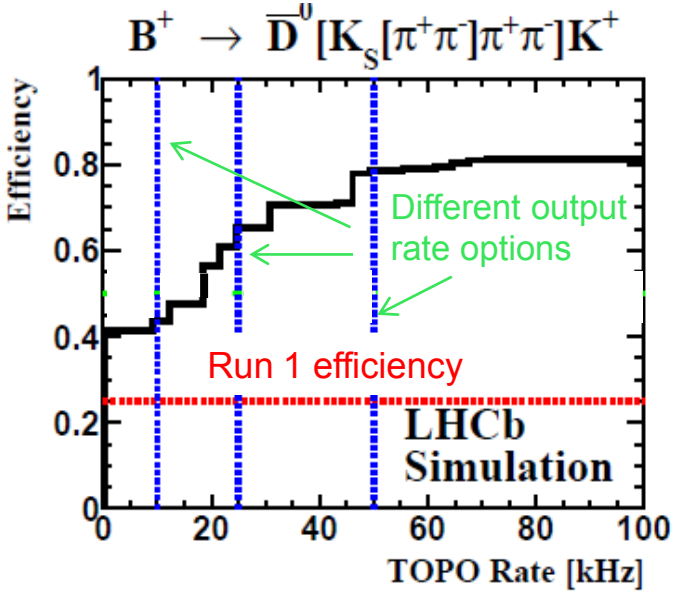
Trigger & online

All, plus France (for readout board project)

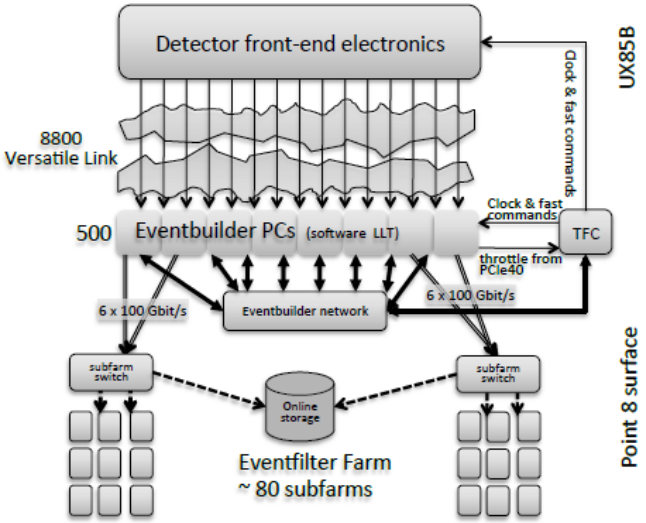
Upgraded detector will be readout at 40 MHz, and events processed by full software trigger running on event-filter farm (a low level trigger, LLT, based on Calo and Muon information will be available to throttle rate into farm, if needed)

TDR demonstrated tracking and algorithms can be performed within CPU budget

Big increases in efficiency !



Architecture of readout system

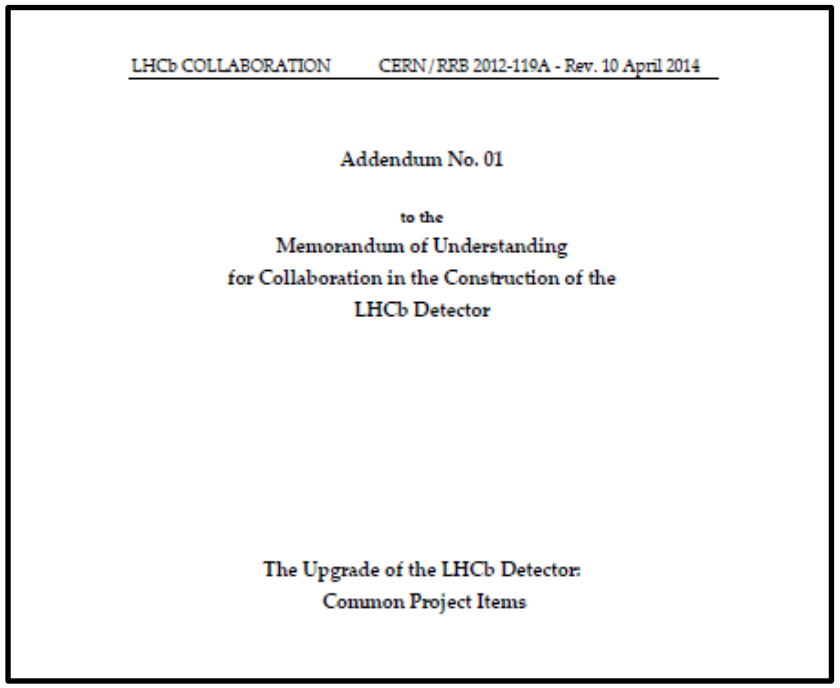


Successful tests to blow optical cables from cavern to surface

Design of PCIe40 readout board progressing well and prototype expected soon

Addenda 1 & 2 to MoU

Addendum presented today complements Common Project addendum of April

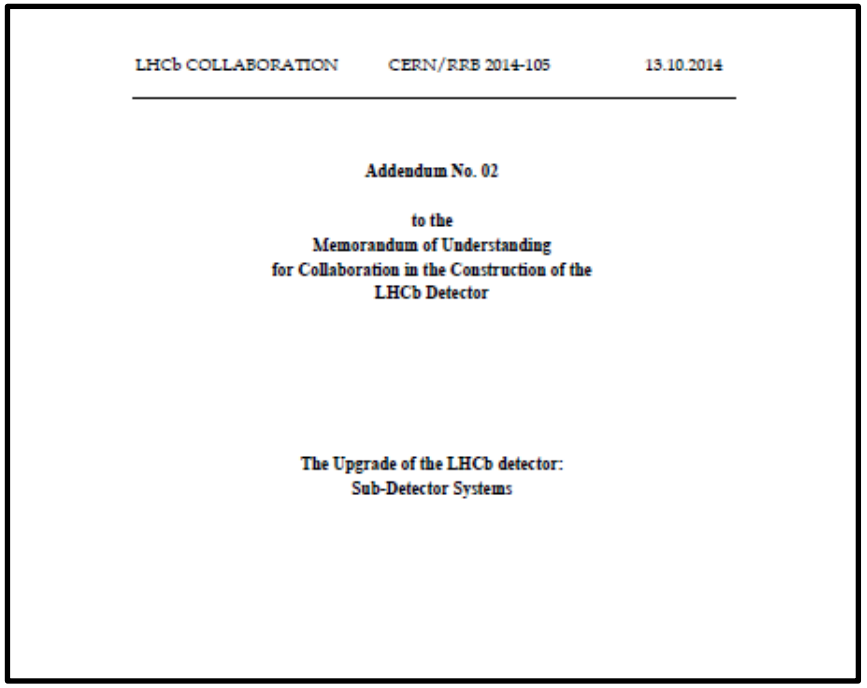


LHCb COLLABORATION CERN/RRB 2012-119A - Rev. 10 April 2014

Addendum No. 01

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

The Upgrade of the LHCb Detector:
Common Project Items



LHCb COLLABORATION CERN/RRB 2014-105 13.10.2014

Addendum No. 02

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

The Upgrade of the LHCb detector:
Sub-Detector Systems

Requested funds total is identical to that in Frame Work TDR (LHCC/2012-007)

Timely provision of resources is *essential* to enable orders to be placed and milestones to be met, so that installation can be completed during LS2 !

Detector 'money matrix' (kCHF)

Funding Agency	VELO	UT	SciFi	RICH	CALO	MUON	Readout Boards	Total Detectors
BRASIL	60		150					210
CHINA			150					150
FRANCE			2310		1085		380	3775
GERMANY			3840					3840
GERMANY MPG								
IRELAND								
ITALY		480		2000		1554		4034
NETHERLANDS	1320		1920					3240
POLAND	75	650		48				773
ROMANIA				450				450
RUSSIA			2600		362	45		3007
SPAIN	375		150		455			980
SWITZERLAND		810	2500					3310
TURKEY								
UK	2919			3705				6624
UKRAINE								
UN. STATES		4310						4310
CERN	1044	250	1550	2982		100		5926
Total	***5793***	***6500***	***15170***	***9185***	***1902***	***1699***	***380***	**40629**
TDR cost	*5793*	*6500*	*15170*	*10089*	*1902*	*1699*	*380*	*41533*
Underfunding				*904*				*904*

Conclusions

LHCb continues to harvest rich results from Run I,
with many more important papers still foreseen

LHCb will be ready and fully operational for Run II. Ambitious,
but realisable, changes to operation planned to increase
physics output and optimise resources.

Upgrade preparations are entering a new, exciting phase
- all system TDRs approved: we have all technologies defined
- final R&D, procurement, and construction underway/about to start
- resources now needed to be on track for installation in LS2 !

Backups

Money Matrix including Common Fund (kCHF)

Funding Agency	VELO	UT	SciFi	RICH	CALO	MUON	Readout Boards	Total Detectors	Common Fund	CF & detectors
BRASIL	60		150					210	666	876
CHINA			150					150	175	325
FRANCE			2310		1085		380	3775	1508	5283
GERMANY			3840					3840	912	4752
GERMANY MPG									210	210
IRELAND									35	35
ITALY		480		2000		1554		4034	2735	6769
NETHERLANDS	1320		1920					3240	596	3836
POLAND	75	650		48				773	456	1229
ROMANIA				450				450	175	625
RUSSIA			2600		362	45		3007	1157	4164
SPAIN	375		150		455			980	596	1576
SWITZERLAND		810	2500					3310	877	4187
TURKEY									35	35
UK	2919			3705				6624	2735	9359
UKRAINE									105	105
UN. STATES		4310						4310	561	4871
CERN	1044	250	1550	2982		100		5926	2174	8100
Total	***5793***	***6500***	***15170***	***9185***	***1902***	***1699***	***380***	**40629**	***15710***	***56339***
TDR cost	*5793*	*6500*	*15170*	*10089*	*1902*	*1699*	*380*	*41533*	*15710*	*57243*
Underfunding				*904*				*904*		*904*