LHCb status and plans

- Physics output
- Run 2 status and 2016 restart
- Upgrade progress
- Conclusions

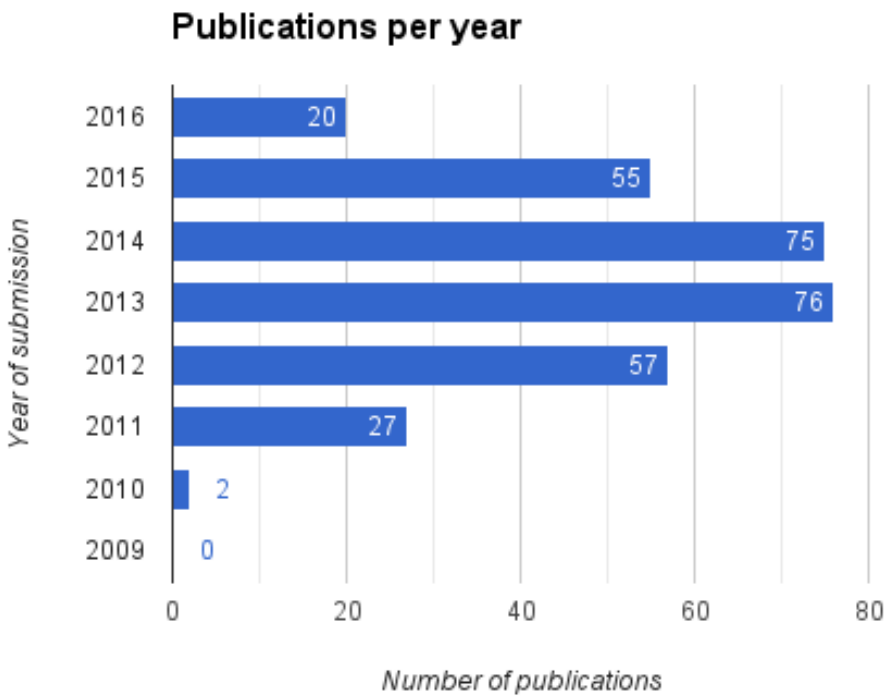
Guy Wilkinson
(University of Oxford and CERN)
on behalf of the LHCb collaboration
27/04/2016

Physics output: overview & selected highlights

LHCb publications

Status, as of Wednesday 20/5/2016

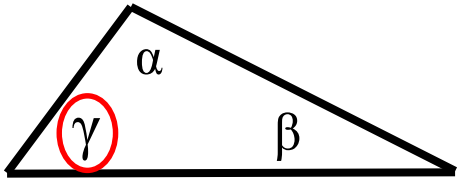
312 papers in total, integrating over published, accepted and submitted
(25 since Oct '15 RRB)



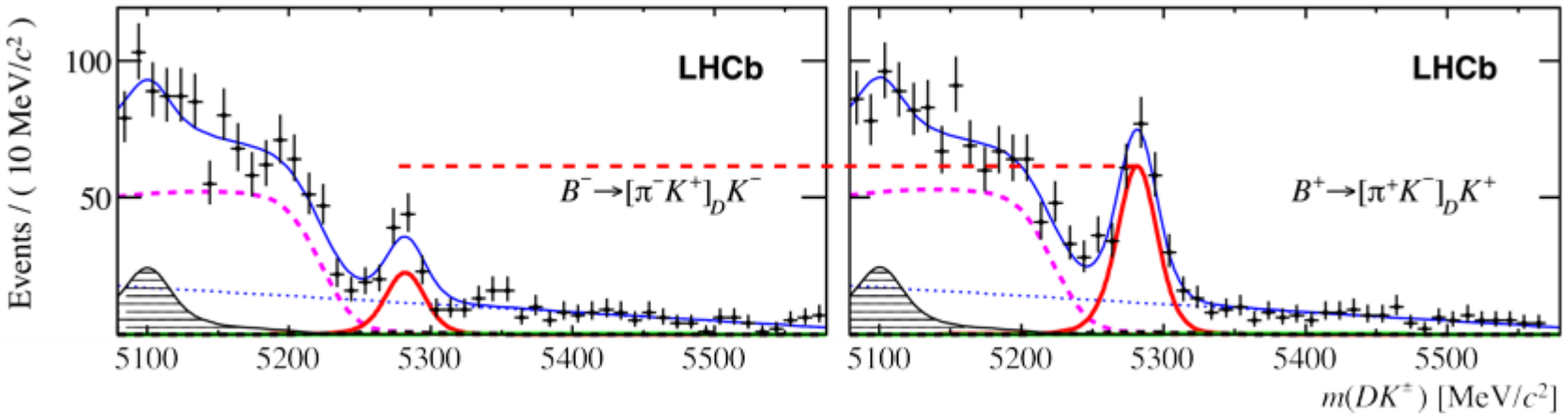
~40 other analyses under review, so already looks almost certain that we will surpass 2015 total !

Most analyses are still mining the Run-1 sample, but are now adding Run-2 data. Others, sensitive to collision energy, are based on the Run-2 data set alone.

Precise results in CP-violation



New precise *CP*-violation measurements in very rare (~10^{-7}) channels.

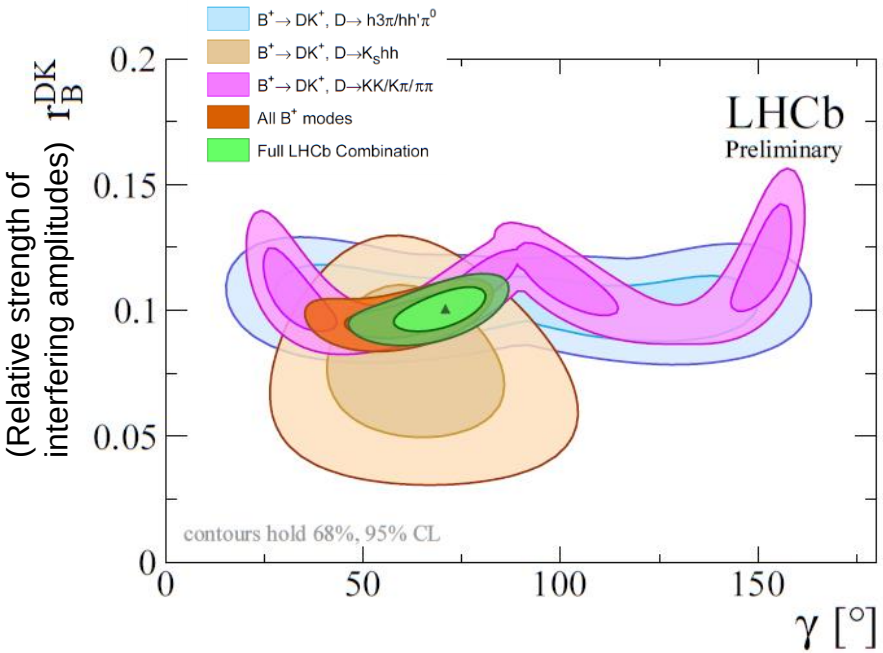


[arXiv:1603.08993]

When combined with LHCb results from similar studies allows for the world's most precise measurement of the unitarity-triangle angle γ

$$\gamma = (71^{+7}_{-8})^\circ$$

Excellent progress on the road to ~1° precision with the LHCb upgrade.



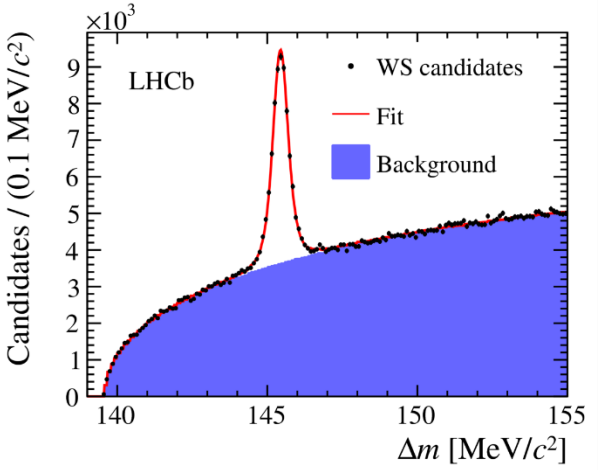
[LHCb-CONF-2016-001]

Precise results in the charm sector

Mixing & CP-violating effects in the charm system much reduced to those that occur in b-sector, so ability of LHCb to exploit high production rate at LHC is crucial.

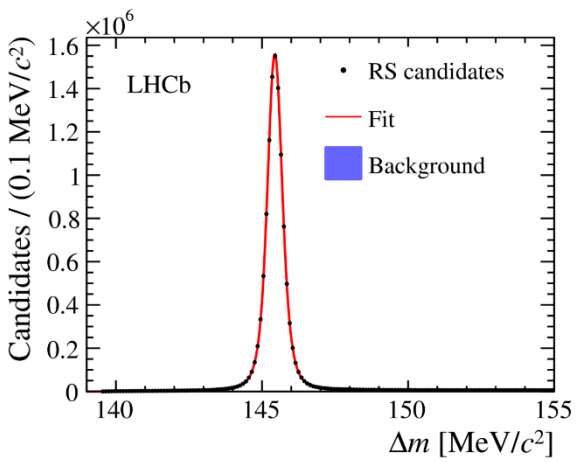
LHCb already made first single-experiment observation of charm mixing using D→Kπ decays [PRL 110 (2013) 101802]. Now complemented by observation with D→Kπππ:

Suppressed ('wrong sign') mode



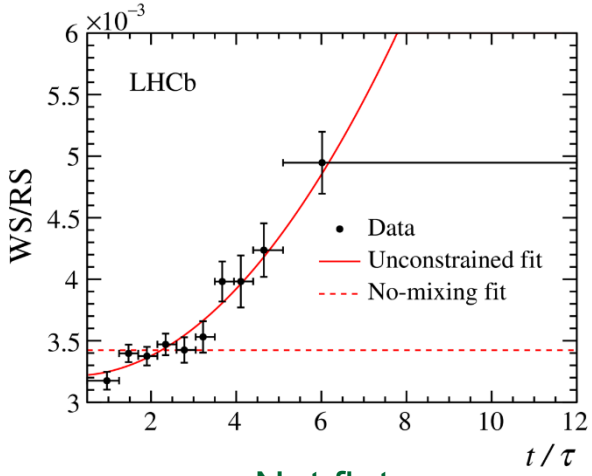
High statistics in rare channel

Favoured ('right sign') mode



High purity

Ratio studied vs. decay time



[arXiv:1602.7224]

Not flat → vivid signature of mixing !

In parallel, searches for CP violation are now reaching ***< 0.1% sensitivity !***

$$\Delta A_{CP} \equiv A_{CP}(K^-K^+) - A_{CP}(\pi^-\pi^+) = (-0.10 \pm 0.08\ (\text{stat}) \pm 0.03\ (\text{syst}))\,\%$$

[arXiv:1602.03160]

Puzzles in spectroscopy

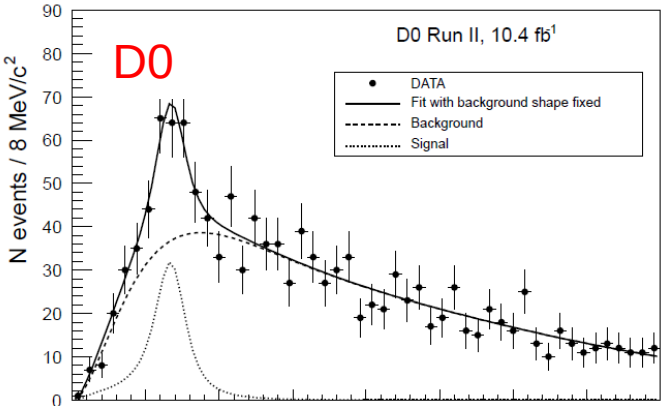
LHCb has many recent achievements in hadron spectroscopy, including observation of first pentaquark states, and first unambiguous observation of a four-quark state.

[PRL 115 (2015) 072001] [PRL 112 (2014) 222002]

But we are not the only player in this game. In February the D0 collaboration announced the observation of a $B_s\pi$ resonance which would be interpreted as a tetraquark.

LHCb responded very quickly, exploiting our fast analysis chain, >20x larger data set, PID, more precise vertexing *etc*.

[arXiv:1602.07588]



Production rate w.r.t. B_s mesons $\rho_X^{\mathrm{D0}} = (8.6 \pm 1.9 \pm 1.4)\,\%$

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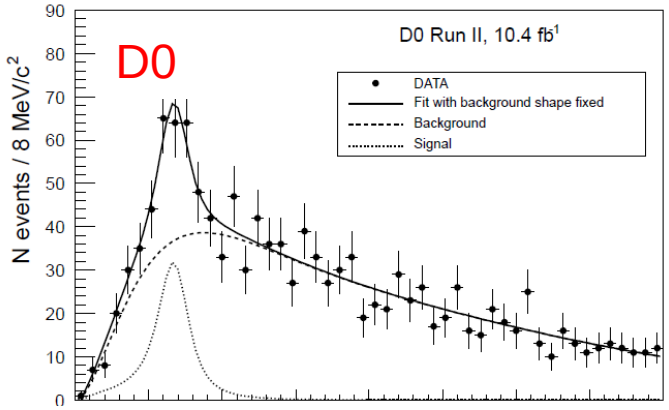

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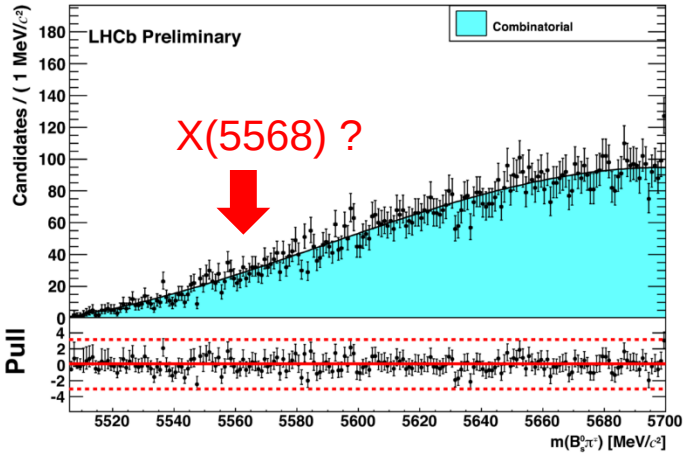

[LHCb-CONF-2016-004]

$\rho_X^{\mathrm{LHCb}}(B_s^0\ p_{\mathrm{T}} > 5\,\mathrm{GeV}/c) < 0.009\,(0.010)\ @\ 90\,(95)\,\%\ \mathrm{CL}$

Puzzles in spectroscopy

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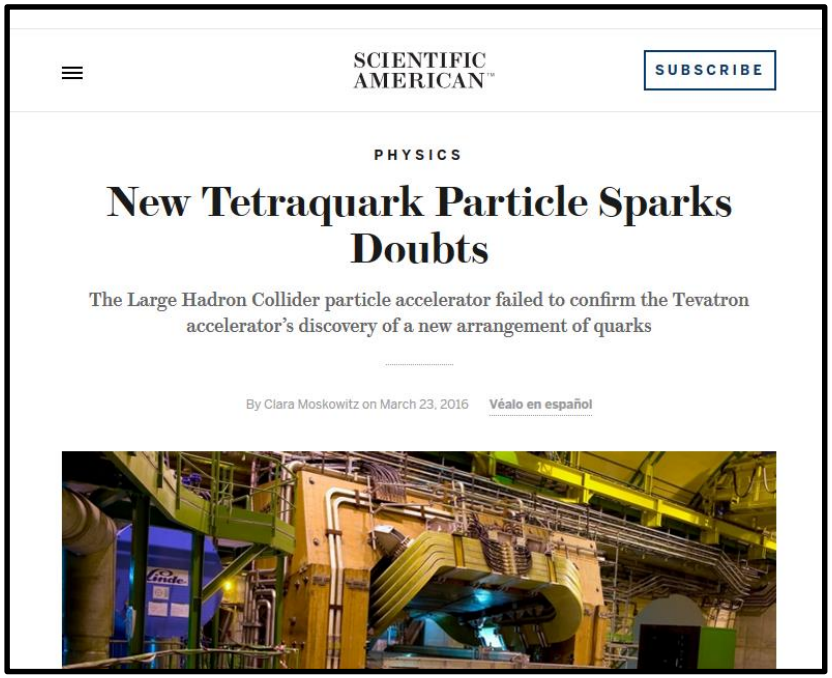
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PHYSICS

New Tetraquark Particle Sparks Doubts

The Large Hadron Collider particle accelerator failed to confirm the Tevatron accelerator's discovery of a new arrangement of quarks

By Clara Moskowitz on March 23, 2016 Véalo en español

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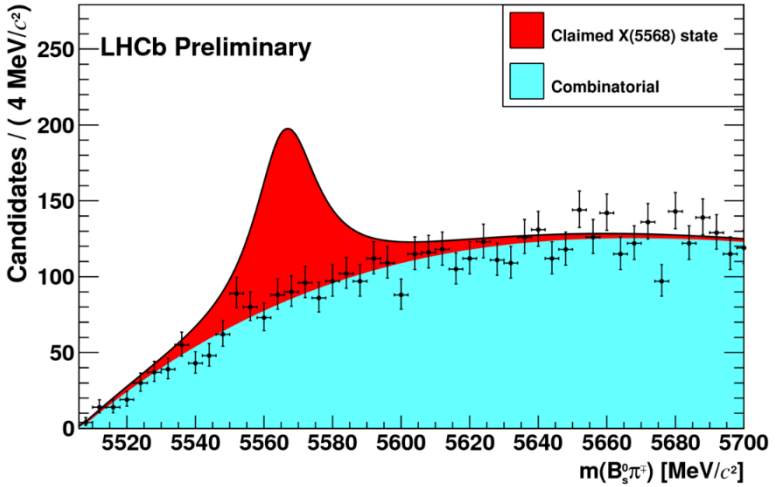


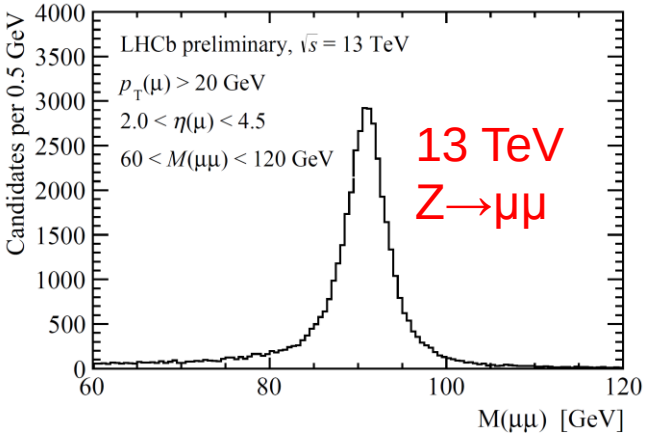
[LHCb-CONF-2016-004]

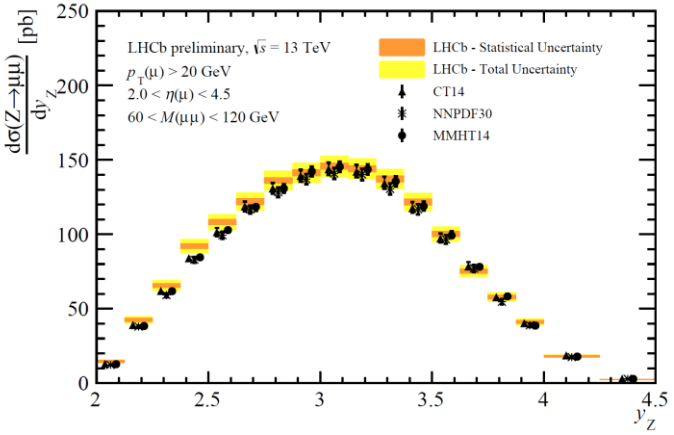
Overall situation puzzling. Take home message: LHCb can respond quickly and unambiguously !

What we would have seen…

Precise results in electroweak physics

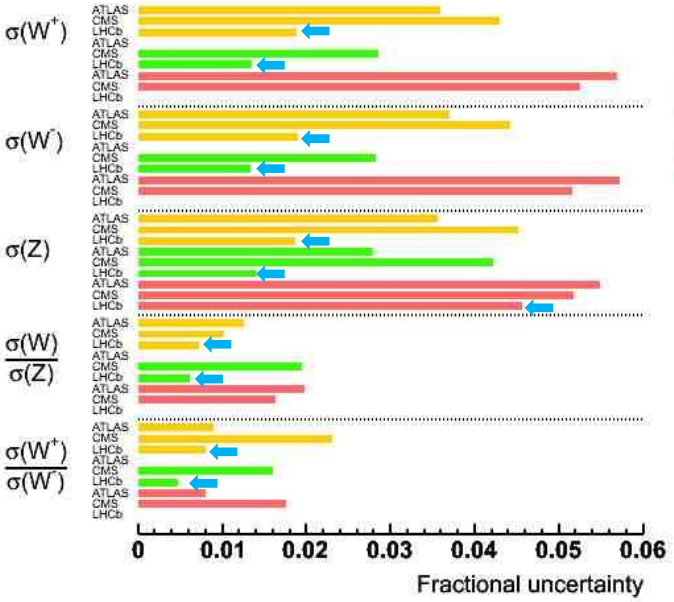
First studies of electroweak boson production in run 2 are now emerging.





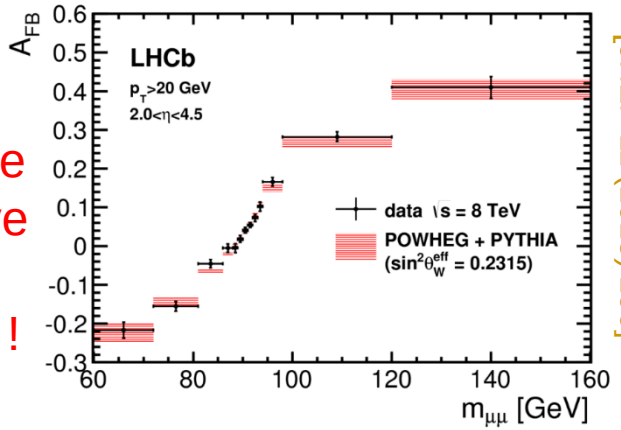
[LHCb-CONF-2016-002]

Will complement the suite of run-1 measurements, which are now largely complete



LHCb also has the most precise LHC measurement of $\sin^2\theta_W$

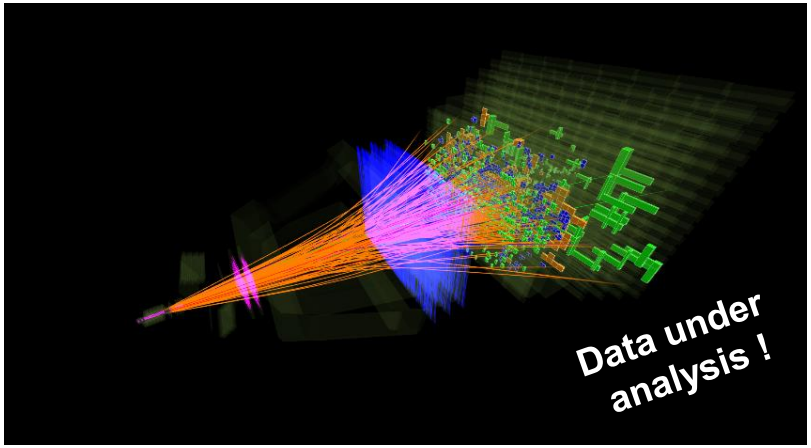
LHCb (⬅) has consistently attained the best (*i.e.* lowest) relative uncertainty on fiducial cross-sections & ratios !



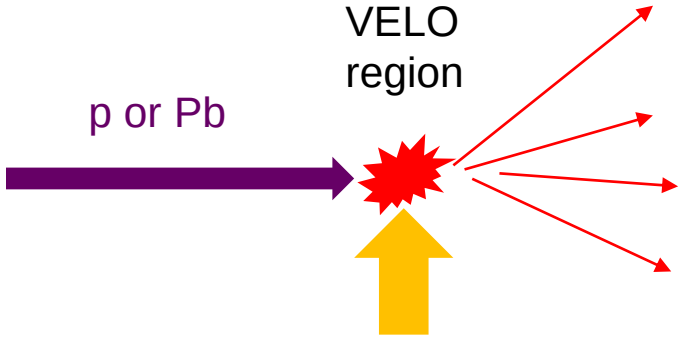
[JHEP 11 (2015) 190]

A growing presence in heavy-ion physics

At the end of 2015 LHCb participated (for the first time) in the Pb-Pb run.



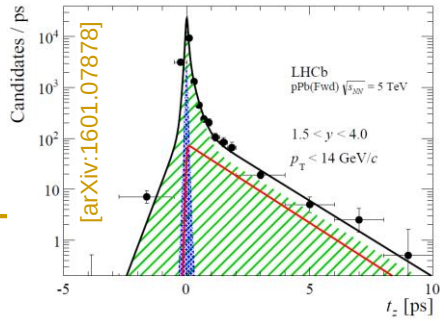
We exploit, ever more strongly, our SMOG system, which gives us unique opportunities in fixed-target mode.



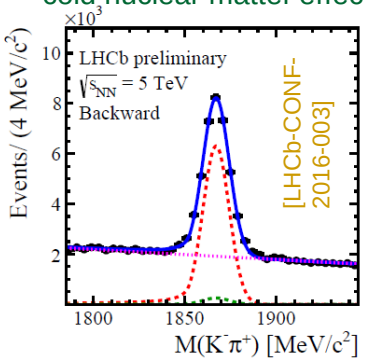
This year we will collect p-Pb data & are looking to collect 10x sample of run 1.

Meanwhile important results continue to emerge from run 1 p-Pb data set.

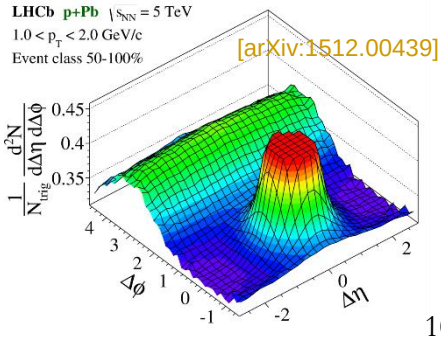
Ψ(2S) (and b production) & cold nuclear matter effects



D-meson production) & cold nuclear matter effects

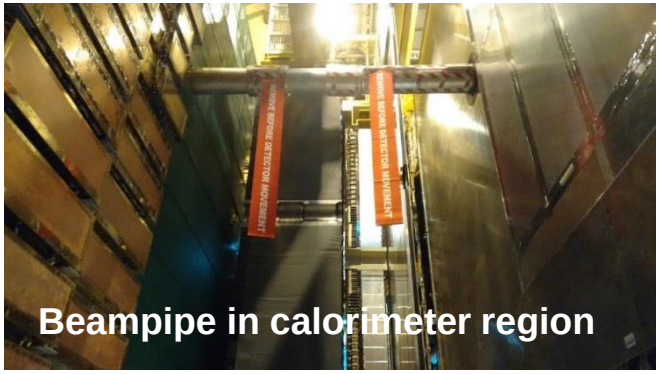


Studies of long-range near-side correlations

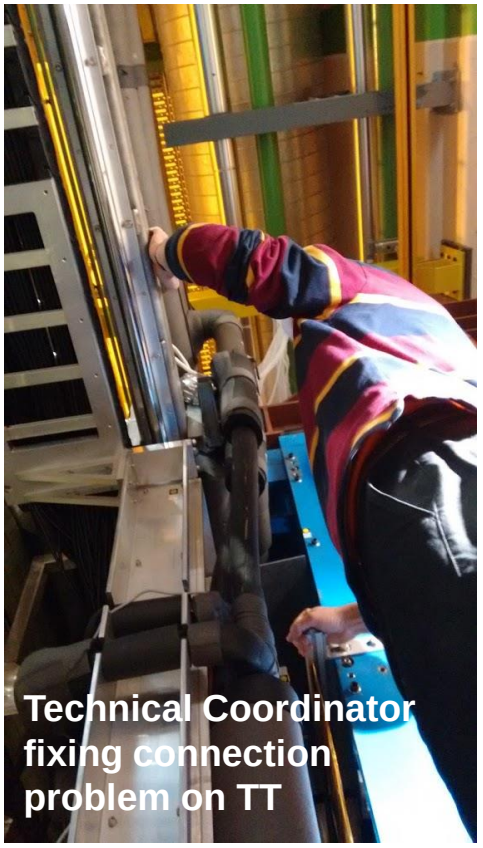


Run 2 status

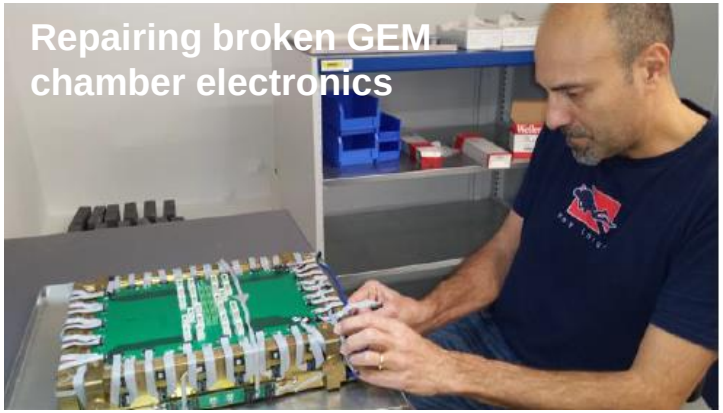
Year-end technical stop: all scheduled work successfully completed – no major interventions


Beampipe in calorimeter region

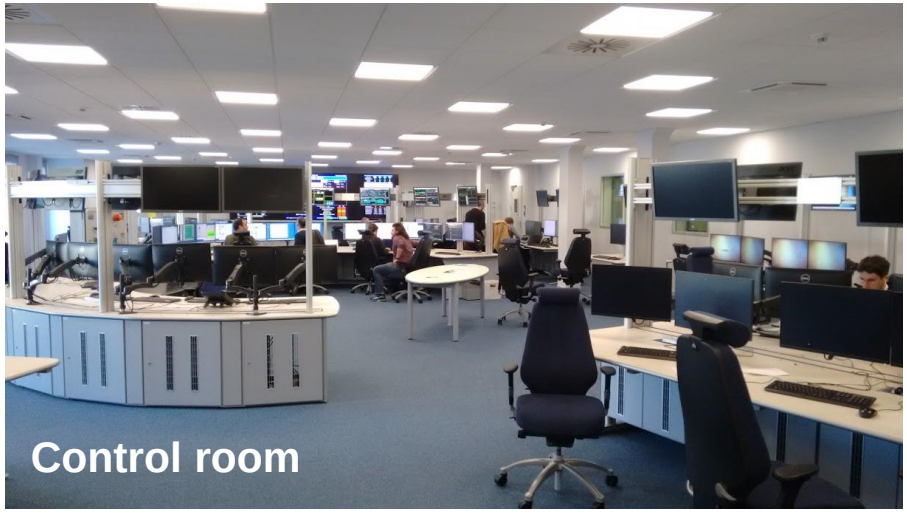

Conditioning muon chambers


Technical Coordinator fixing connection problem on TT


Realigning IT

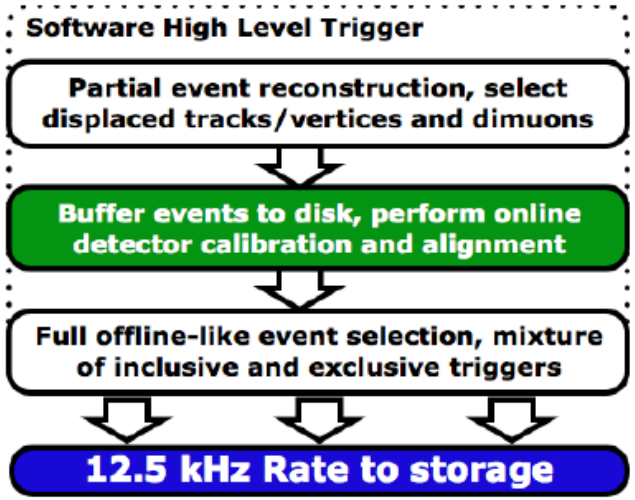

Repairing broken GEM chamber electronics

New control room and conference room



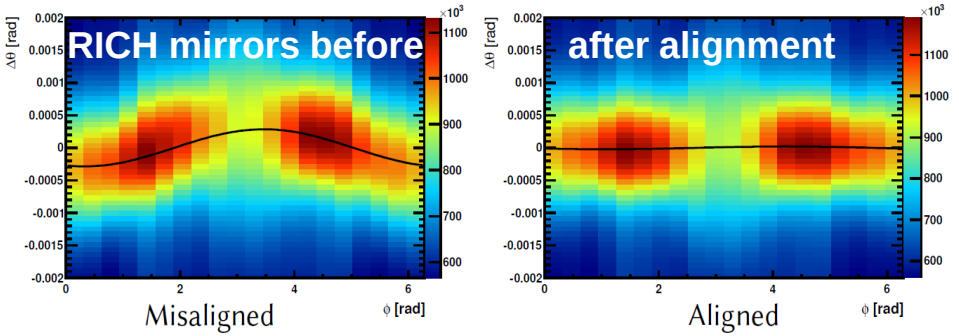
Gearing up for 2016 – the trigger

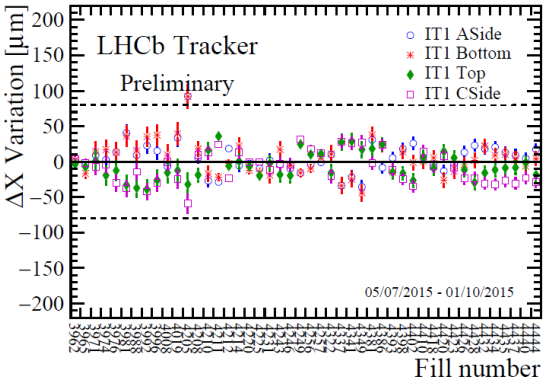
'split HLT'

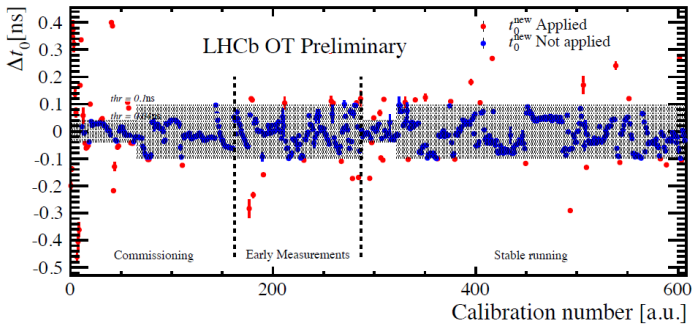


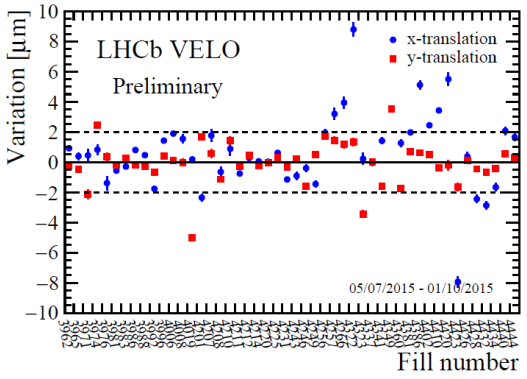
Recall the Big Idea of 2015 data taking:

- Calibrate and align detector (if needed) as soon as data are collected;









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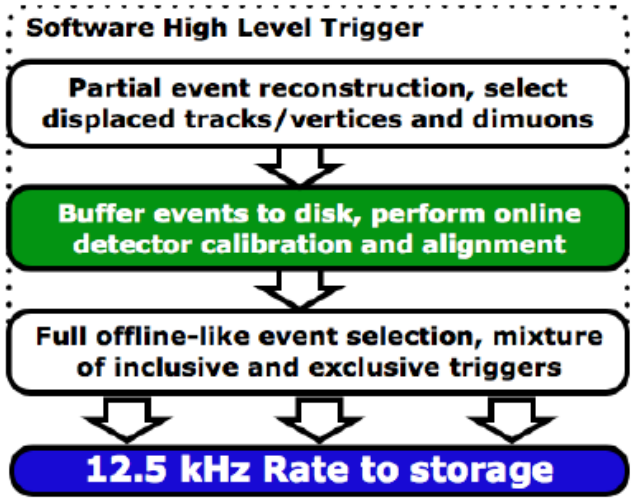

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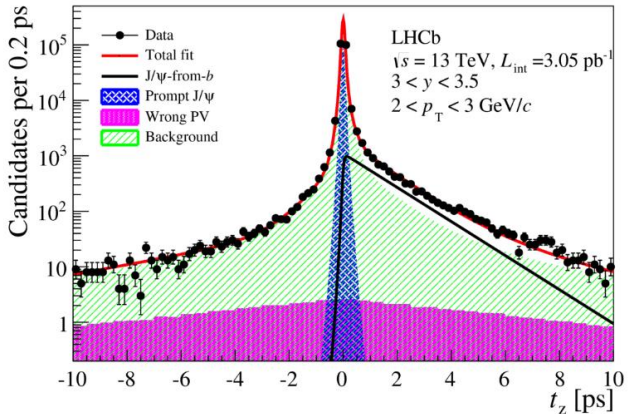
- Calibrate and align detector (if needed) as soon as data are collected;
- Only run 2nd stage of software trigger when calibration / alignment OK;
- Consequences: most critical trigger step has access to offline-like data quality.

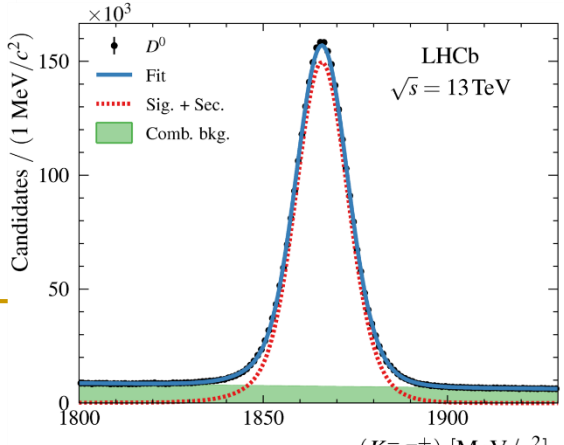
→ more discriminant trigger;

→ no time-consuming offline reprocessing;

→ immediate analysis with trigger information ('the TURBO' stream) !

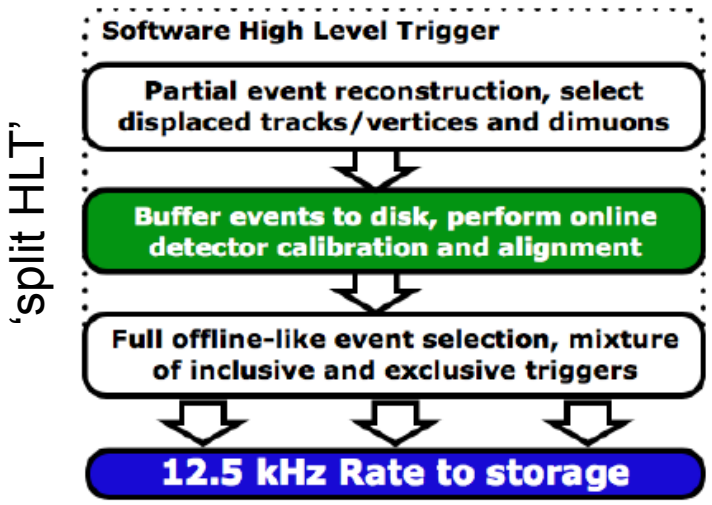


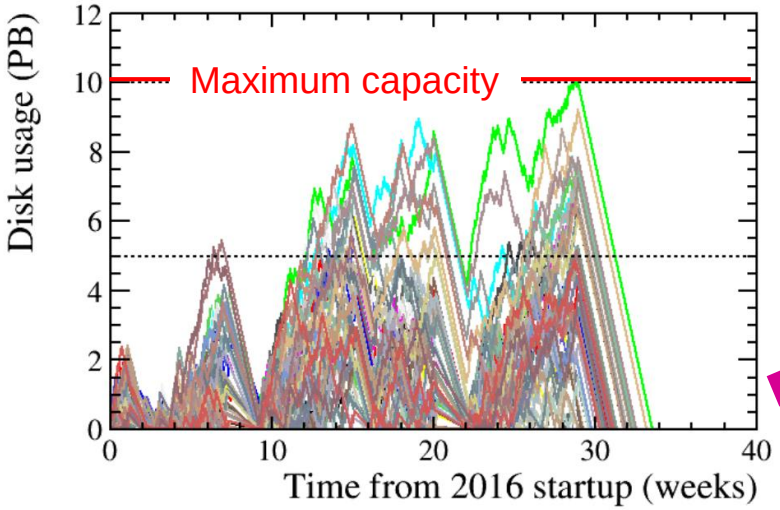
e.g. forward J/ψ production at 13 TeV [JHEP 10 (2015) 172]



e.g. open charm production at 13 TeV [JHEP 03 (2016) 159]

Gearing up for 2016 – the trigger





Simulation of 2016 disk usage assuming a plausible LHC fill-turnaround time.

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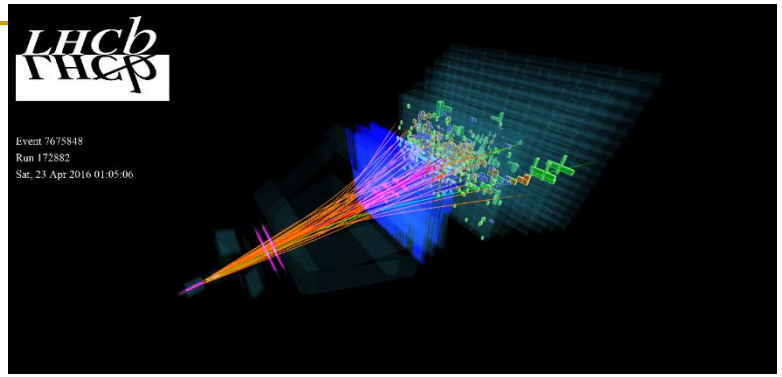
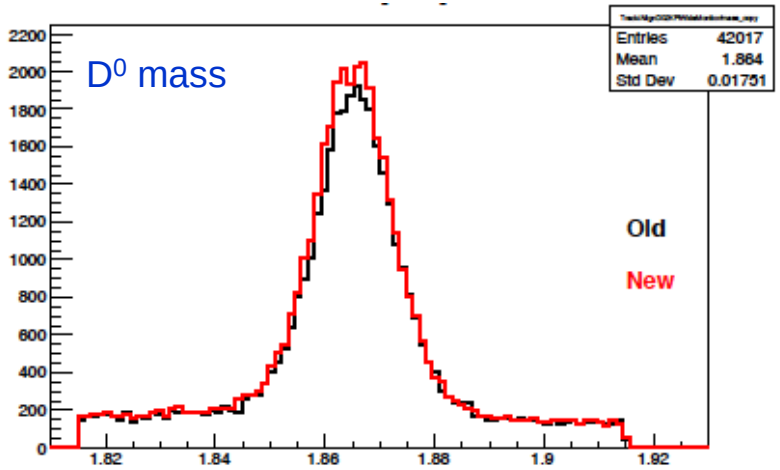
  - → immediate analysis with trigger information ('the TURBO' stream) !

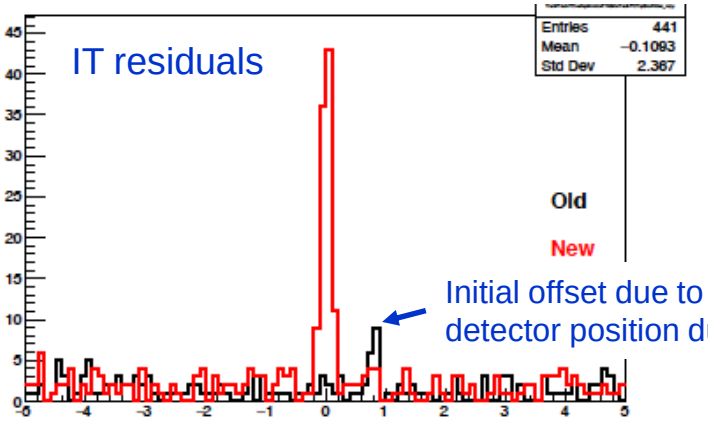
- For 2016 run, the code has been sped up, and made even more 'offline-like'. HLT rates have been tuned so that disk buffer will not overflow. Plan to extend TURBO approach for analyses of higher complexity.

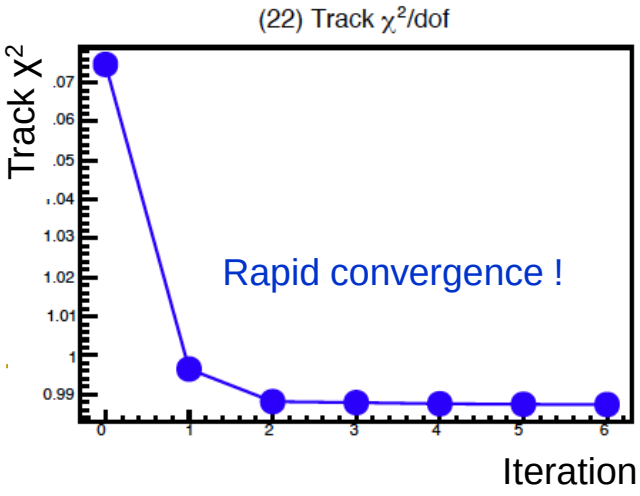
And so it begins

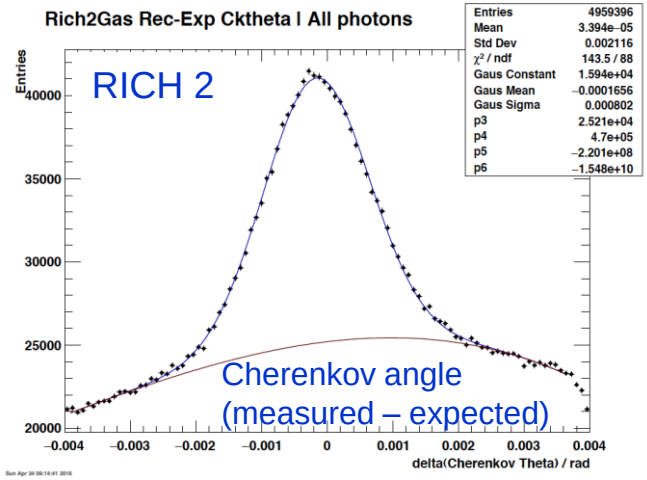
Stable beams returned this past weekend, and LHCb was fully ready. Initial alignment and calibration procedures successfully run.

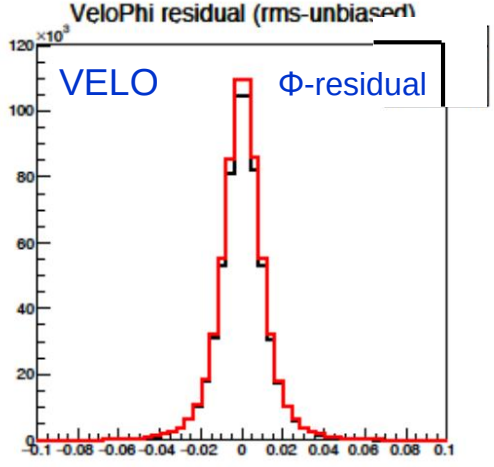






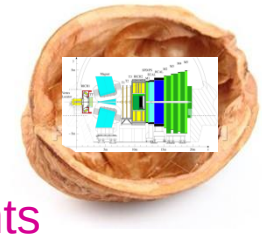






Progress to LS2 Upgrade

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 run-1 LHC that direct signals are elusive

Our knowledge of flavour physics has advanced spectacularly thanks to LHCb. Maintaining this rate of progress beyond run 2 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}

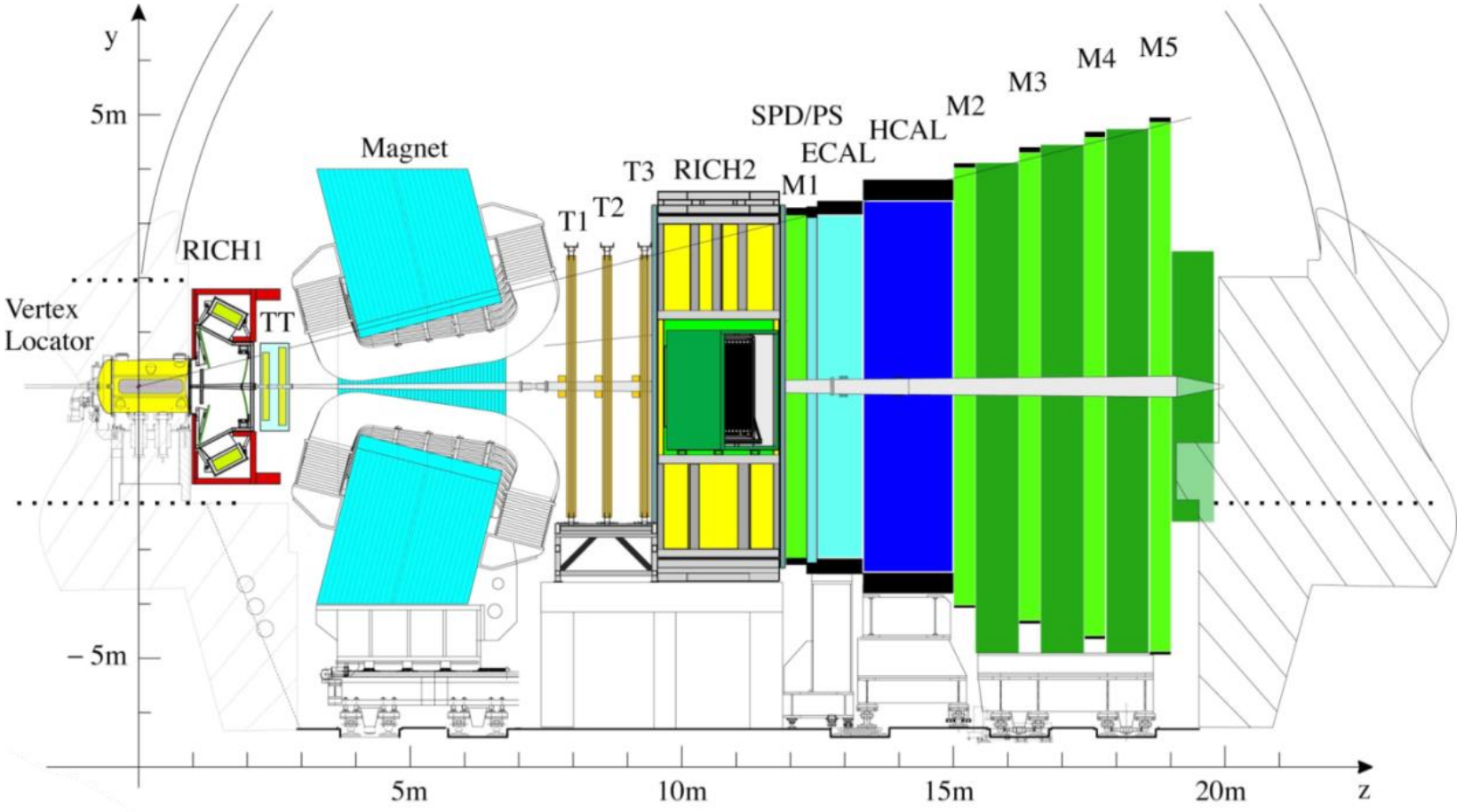
Necessitates redesign of several sub-detectors & overhaul of readout

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

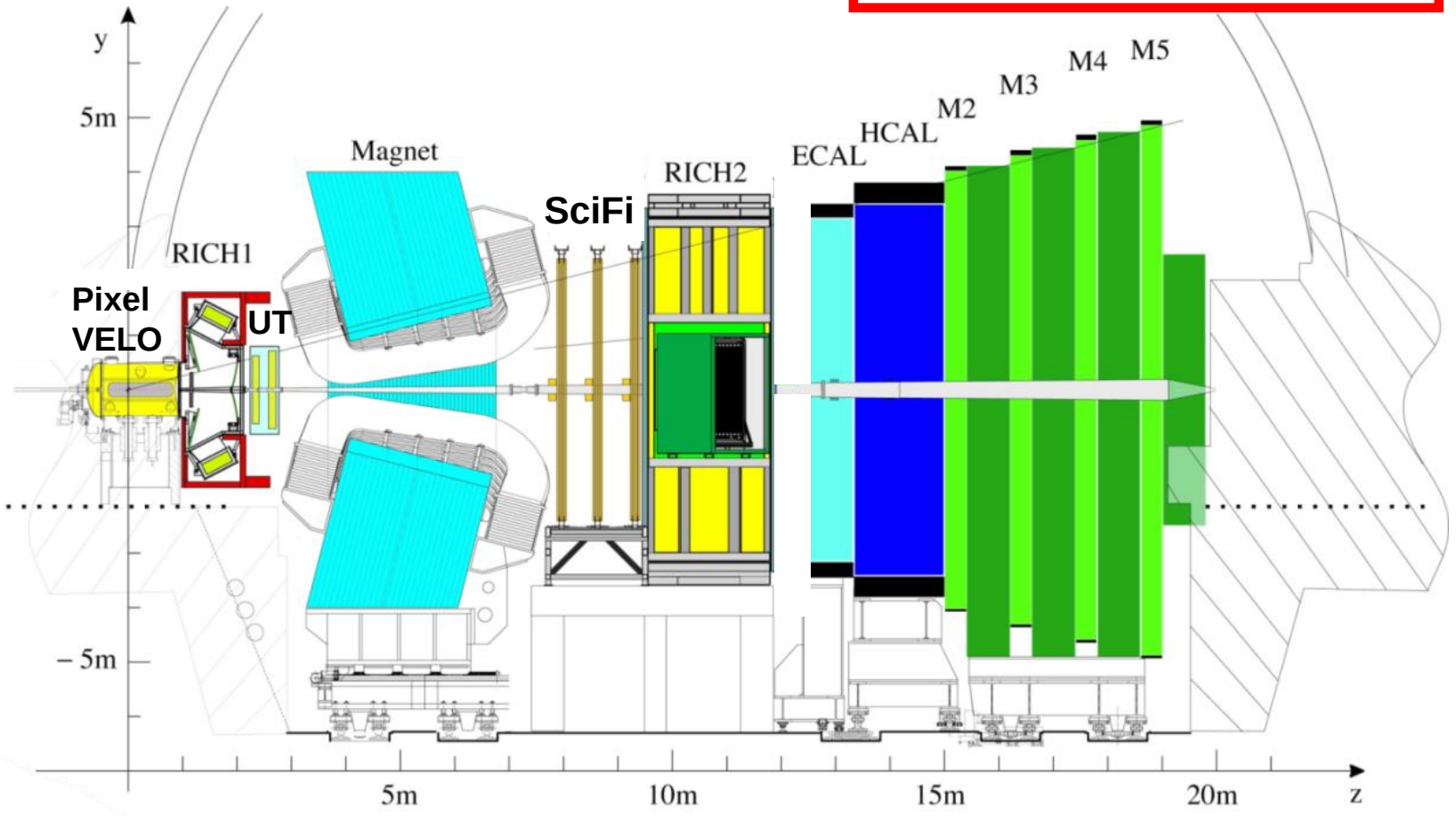
Current detector



Upgrade overview

Current detector → upgraded detector

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



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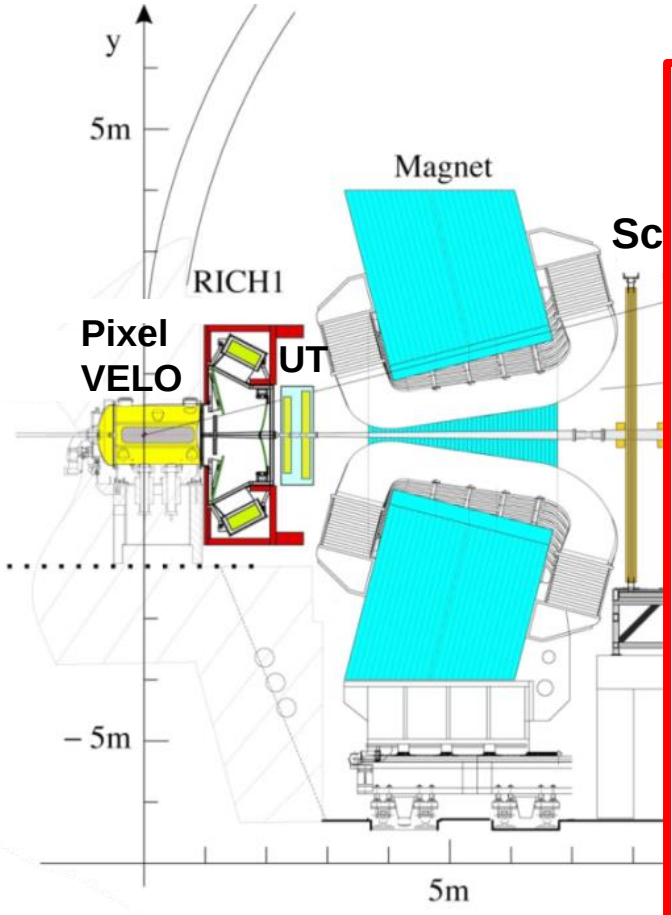
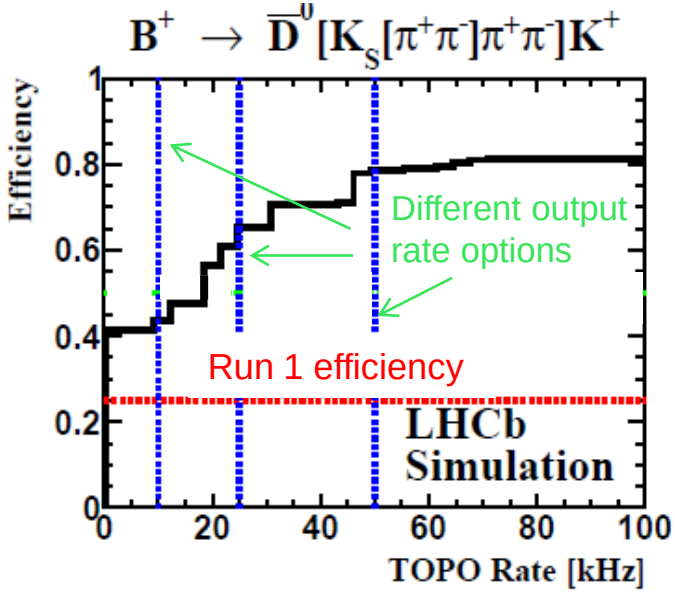


Upgrade software trigger

Full event information → much improved efficiency

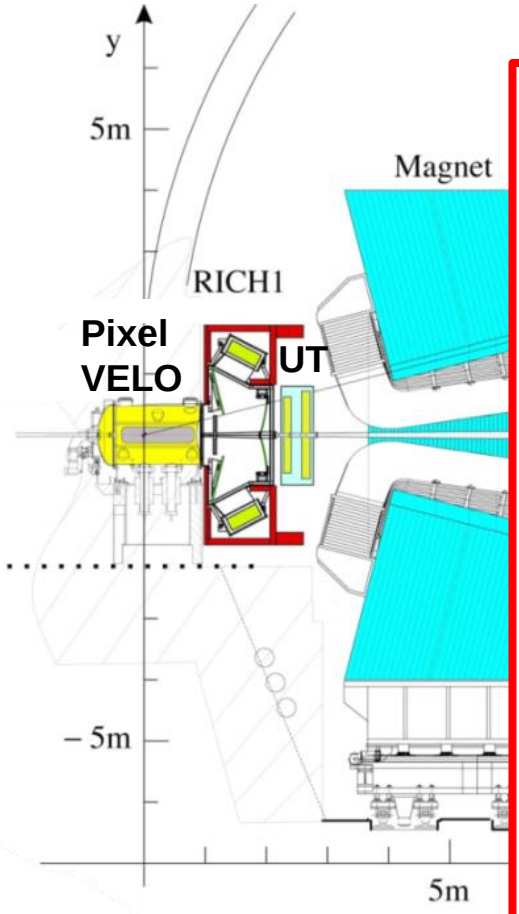


NB: many of run-2 innovations can also be considered as R&D for the Upgrade trigger !

Upgrade overview

Current detector → upgraded detector

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



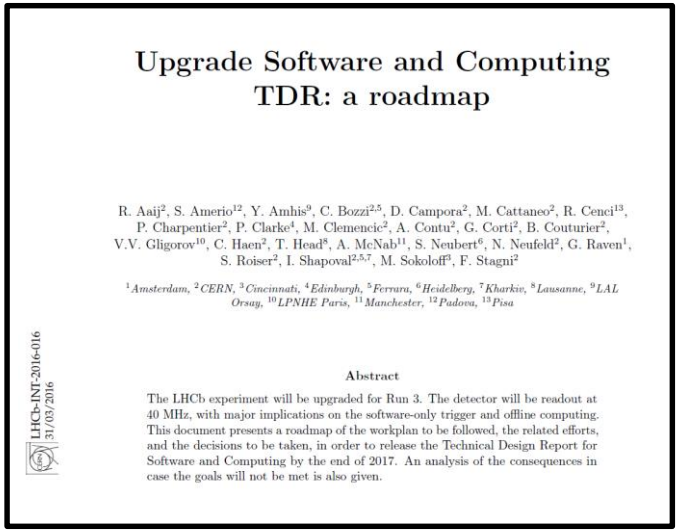
Upgrade computing

Redesign of LHCb event model, and optimal exploitation of modern computing technologies essential for Upgrade trigger (& offline computing).

We will present a ‘s/w and computing TDR’ at end of 2017.

The process has begun with the definition of the ‘roadmap’ leading up to this TDR.

Work underway !



Upgrade Software and Computing TDR: a roadmap

R. Aaij[2], S. Amerio[12], Y. Amhis[9], C. Bozzi[2,5], D. Campora[2], M. Cattaneo[2], R. Cenci[13], P. Charpentier[2], P. Clarke[4], M. Clemencic[2], A. Contu[2], G. Corti[2], B. Couturier[2], V.V. Gligorov[10], C. Haen[2], T. Head[8], A. McNab[11], S. Neubert[6], N. Neufeld[2], G. Raven[1], S. Roiser[2], I. Shapoval[2,5,7], M. Sokoloff[3], F. Stagni[2]

[1]*Amsterdam,* [2]*CERN,* [3]*Cincinnati,* [4]*Edinburgh,* [5]*Ferrara,* [6]*Heidelberg,* [7]*Kharkiv,* [8]*Lausanne,* [9]*LAL Orsay,* [10]*LPNHE Paris,* [11]*Manchester,* [12]*Padova,* [13]*Pisa*

LHCb-INT-2016-016
31/03/2016

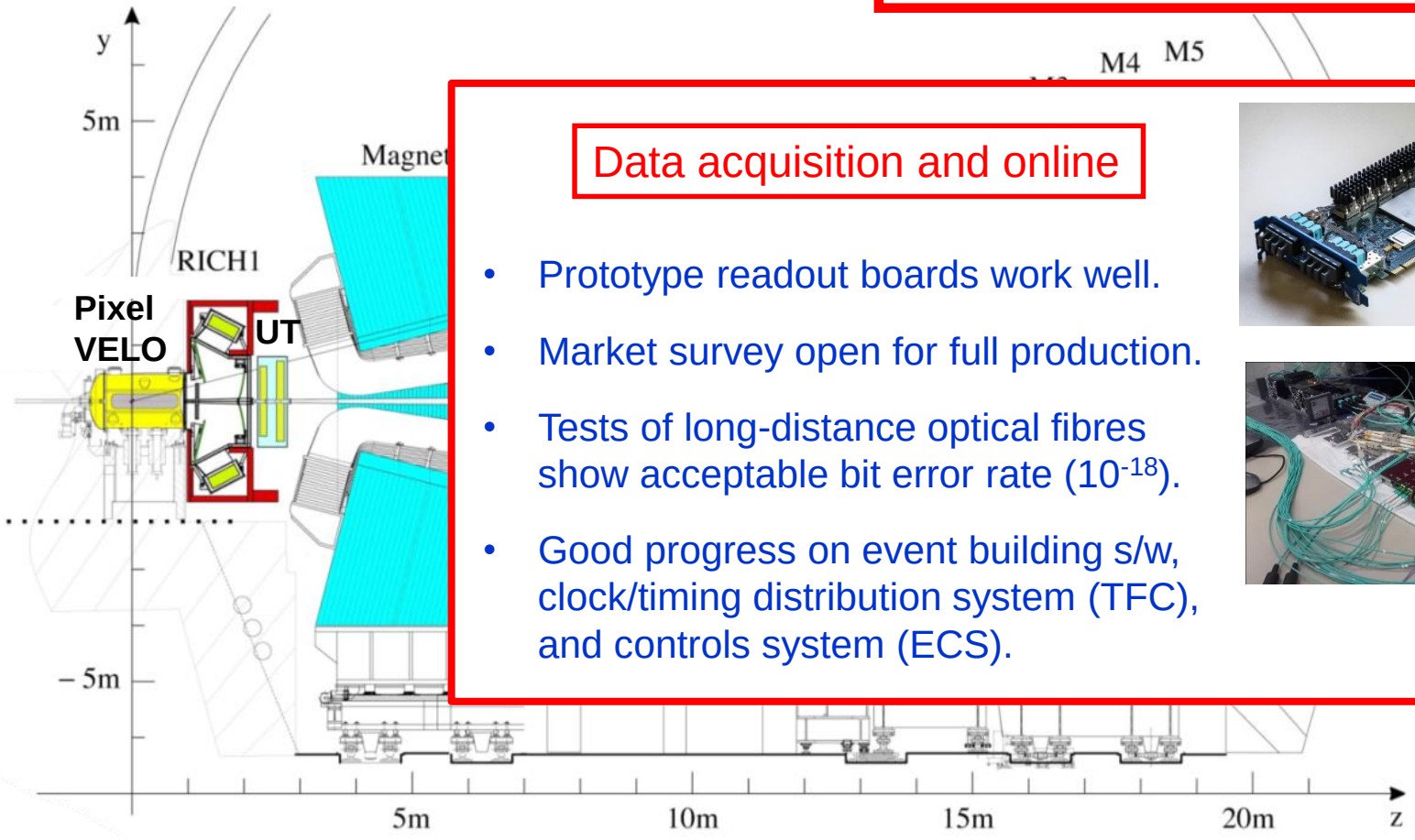
Abstract

The LHCb experiment will be upgraded for Run 3. The detector will be readout at 40 MHz, with major implications on the software-only trigger and offline computing. This document presents a roadmap of the workplan to be followed, the related efforts, and the decisions to be taken, in order to release the Technical Design Report for Software and Computing by the end of 2017. An analysis of the consequences in case the goals will not be met is also given.

Upgrade overview

Current detector → upgraded detector

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



Data acquisition and online

- Prototype readout boards work well.
- Market survey open for full production.
- Tests of long-distance optical fibres show acceptable bit error rate (10^{-18}).
- Good progress on event building s/w, clock/timing distribution system (TFC), and controls system (ECS).

Upgrade overview

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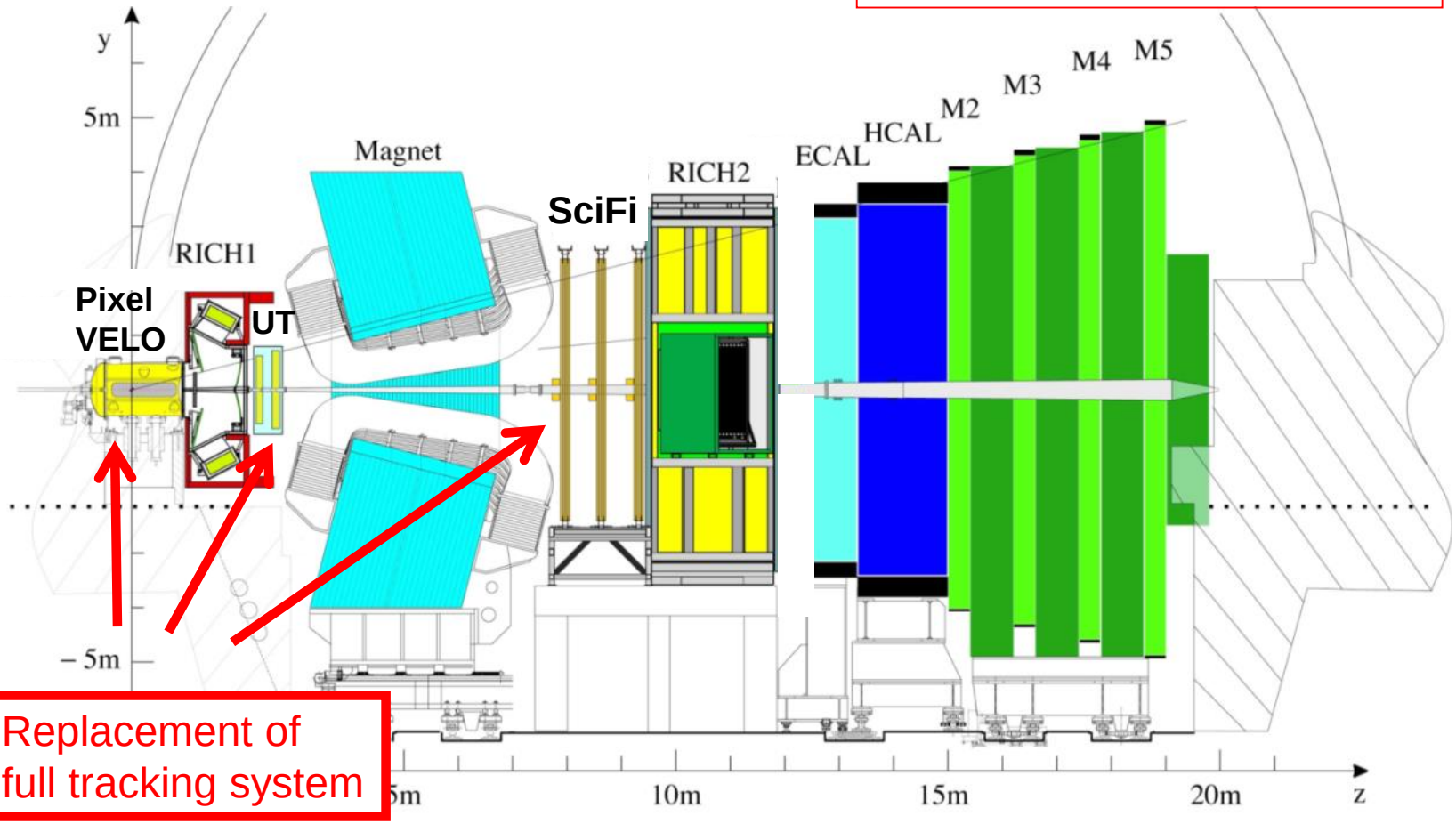
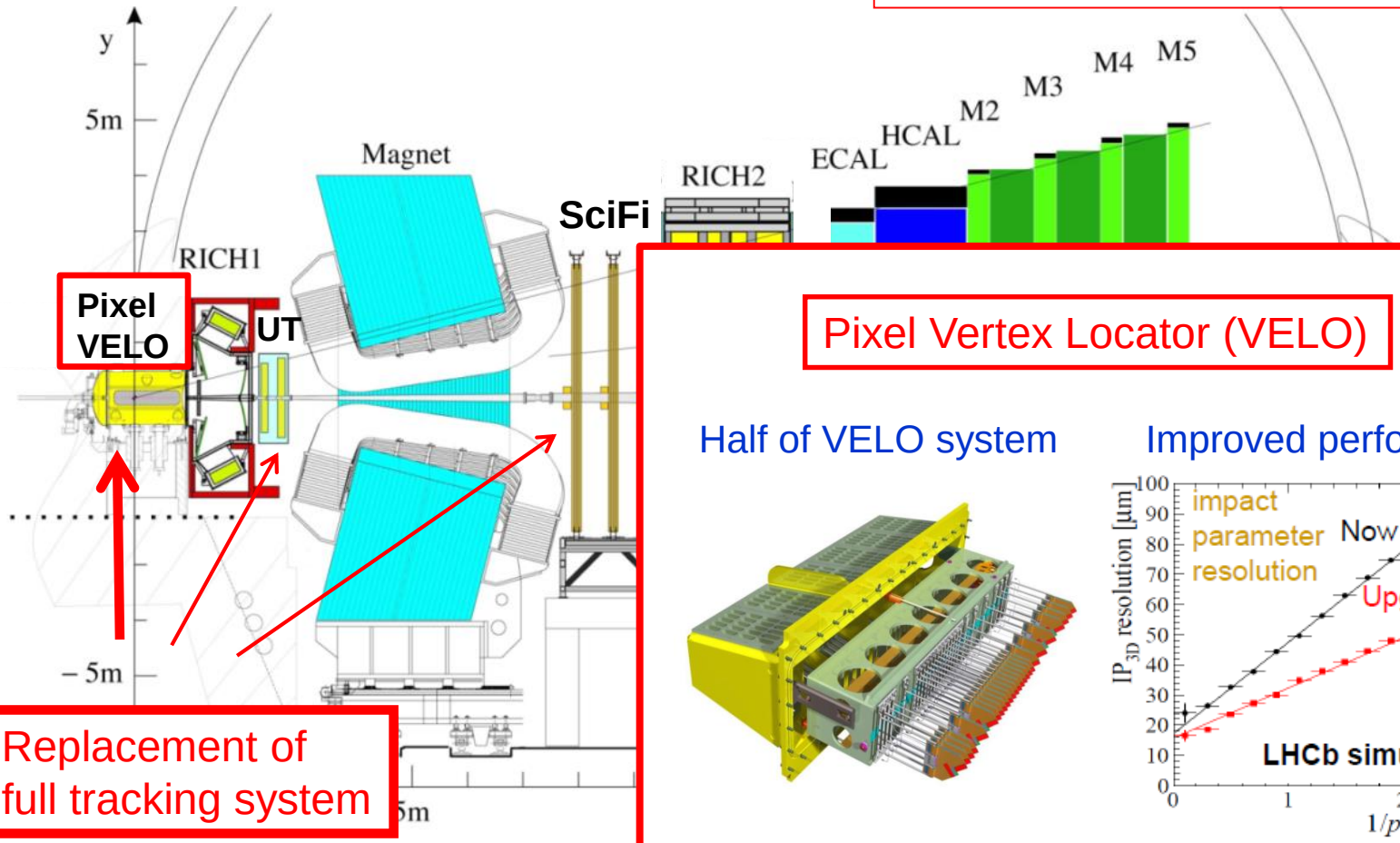


Replacement of full tracking system

Upgrade overview

Current detector → upgraded detector

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



Pixel Vertex Locator (VELO)

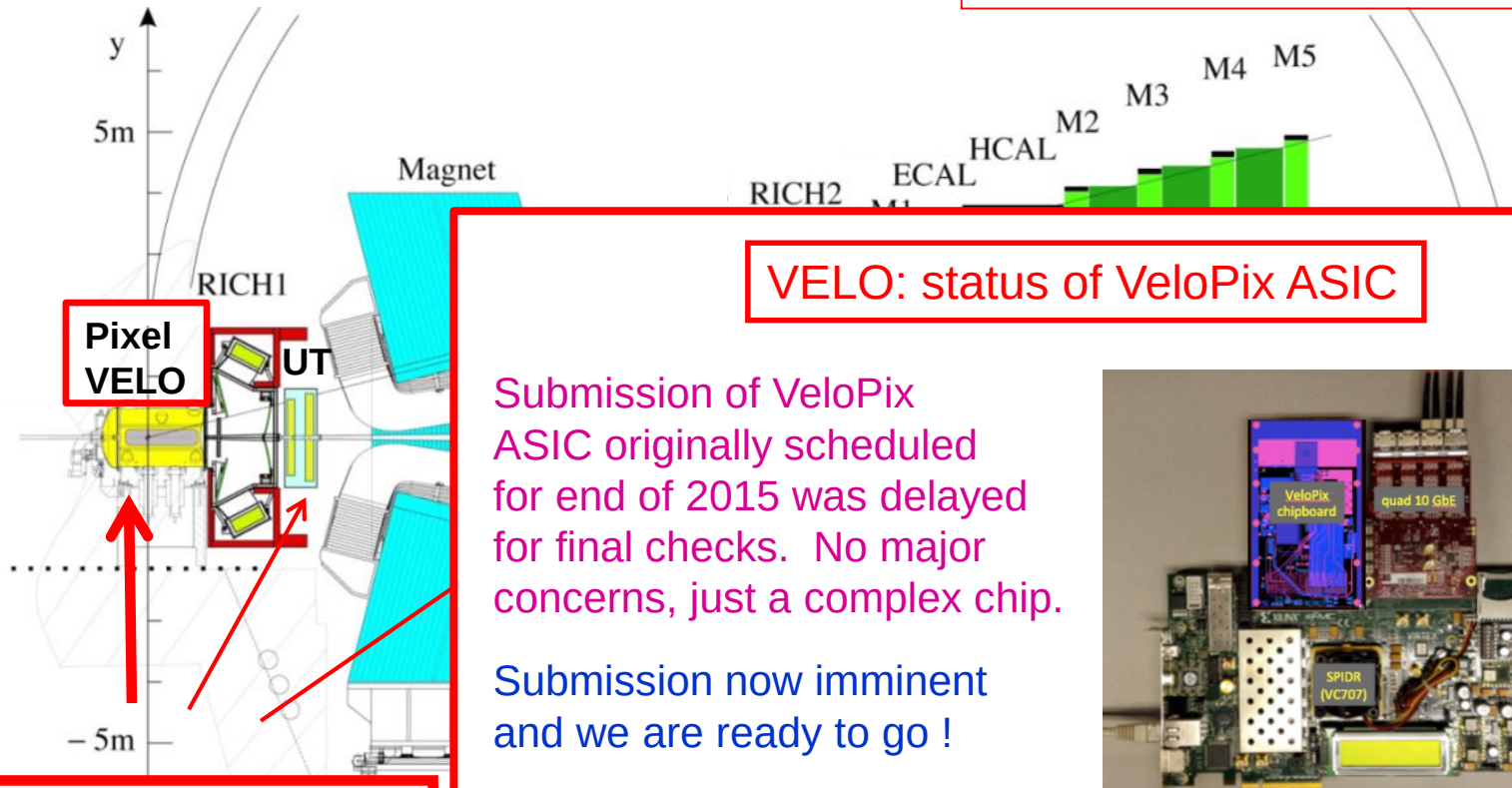
Half of VELO system

Improved performance

Upgrade overview

Current detector → upgraded detector

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



Replacement of full tracking system

VELO: status of VeloPix ASIC

Submission of VeloPix ASIC originally scheduled for end of 2015 was delayed for final checks. No major concerns, just a complex chip.

Submission now imminent and we are ready to go !

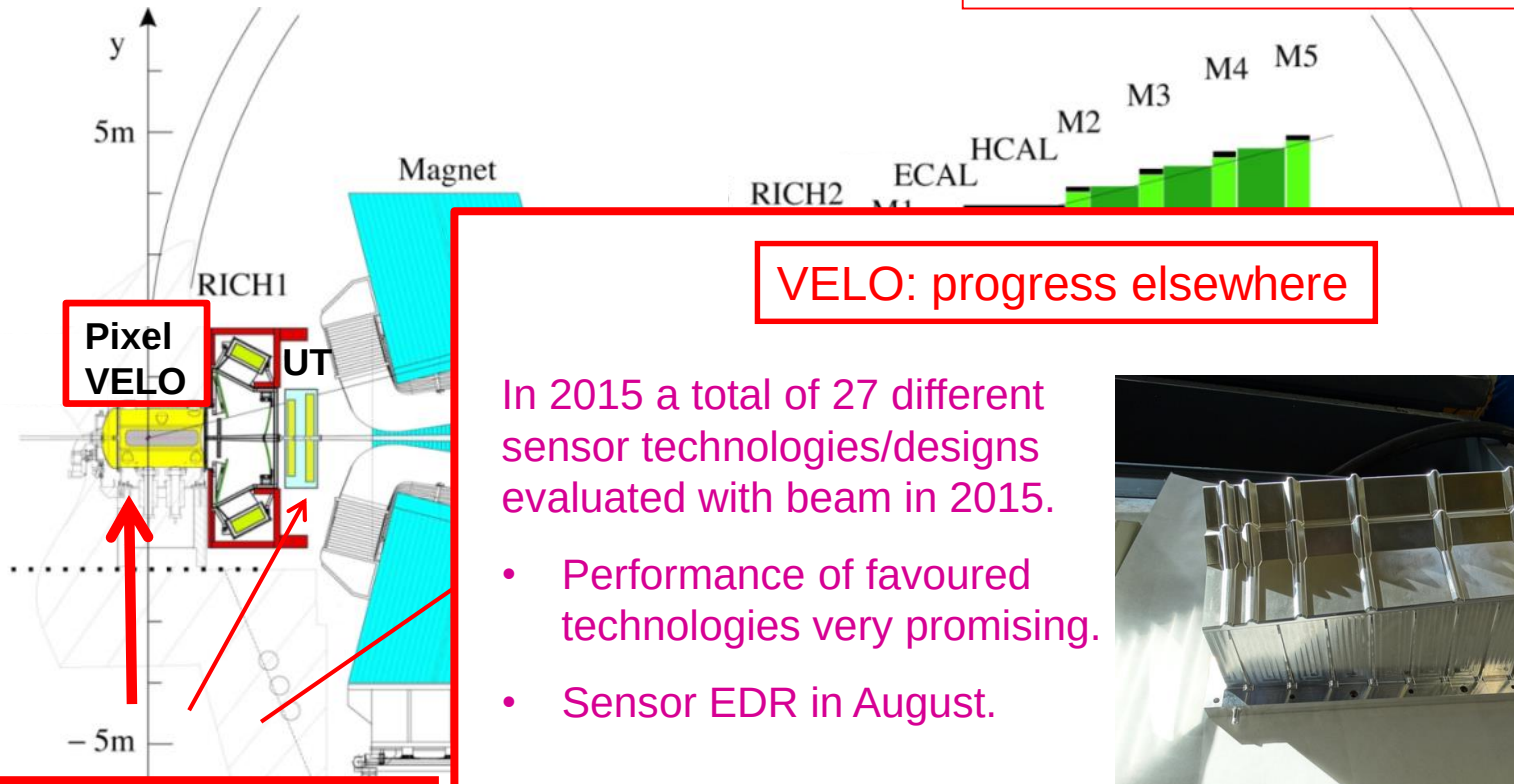
Delay has been absorbed, with no serious consequences for rest of project.

SPIDR testing system will be ready when chip arrives in June.

Upgrade overview

Current detector → upgraded detector

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



Replacement of full tracking system

VELO: progress elsewhere

In 2015 a total of 27 different sensor technologies/designs evaluated with beam in 2015.

- Performance of favoured technologies very promising.
- Sensor EDR in August.

In addition, much activity in: cooling, mechanics, module design and RF-foil box.

Latest half-size 500 μm thick prototype of RF-foil box.

Upgrade overview

Current detector → upgraded detector

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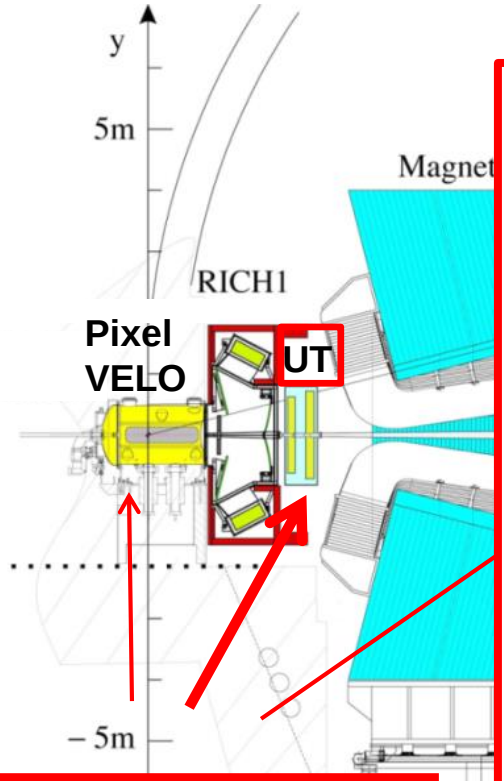


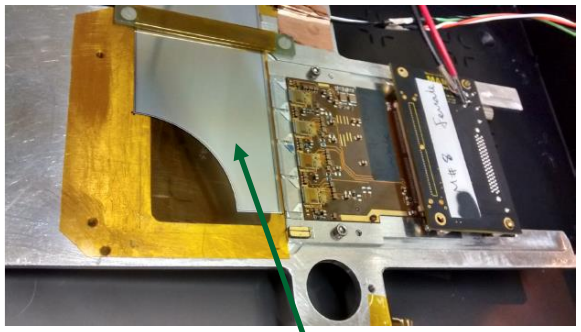
Replacement of full tracking system

Upstream Tracker (UT)

Si-strip detector in front of magnet

Much learned about sensors in 2015 testbeams. (No show-stoppers identified.)

Excellent results on tests of 2nd version of eight-channel ASIC ('SALT'). 128-channel SALT to be submitted in May.



Sensor for beampipe region

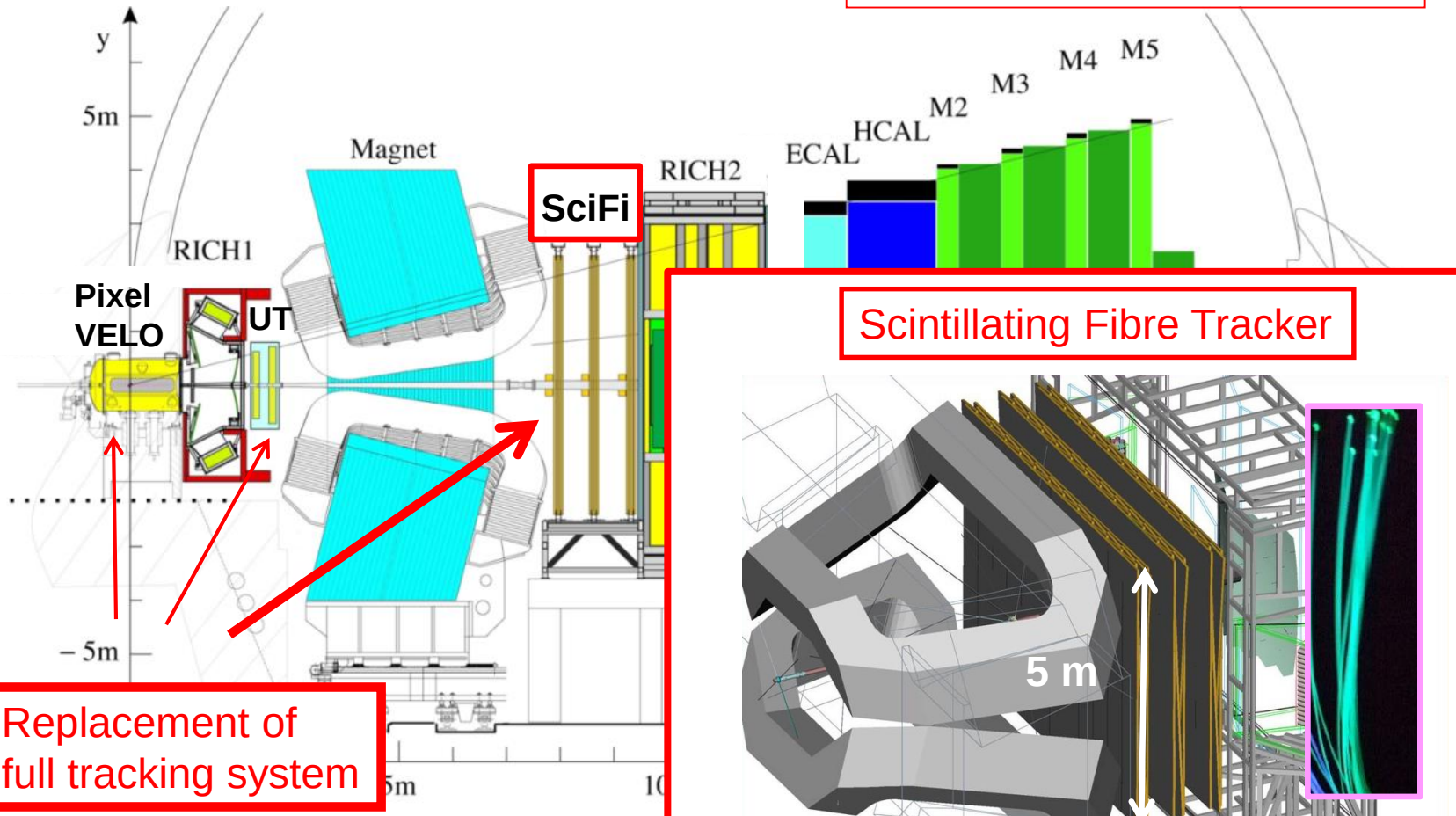
Eight-channel SALT prototype

Good progress on hybrid design, flex cables, cooling & mechanics.

Upgrade overview

Current detector → upgraded detector

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



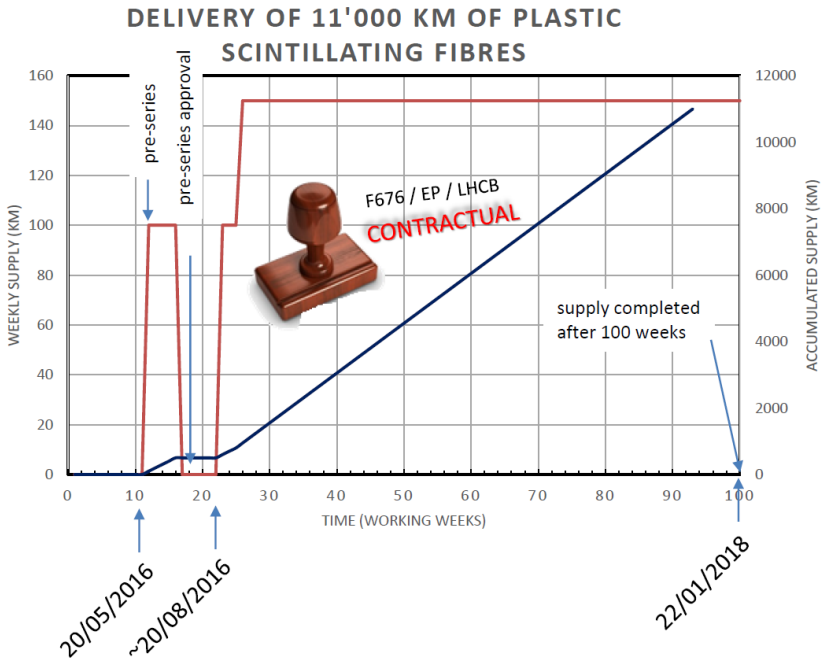
Scintillating Fibre Tracker

Large scale system (~12,000 km of fibres)

SciFi – entering the production phase

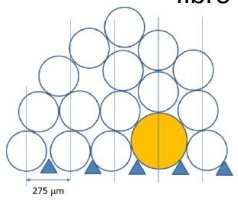
Much progress in mechanics, SiPMs, ASIC development, cooling & reconstruction. Here focus on fibres & mat production.

Order now placed with supplier, with pre-series to arrive in May.



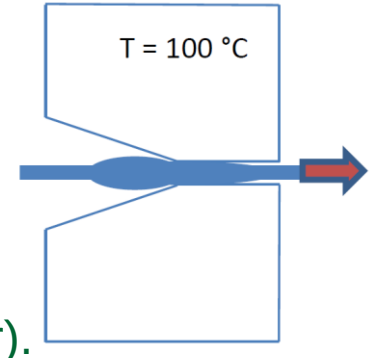
When in production we will receive 300 km / 2 weeks, on 12.5 km spools.

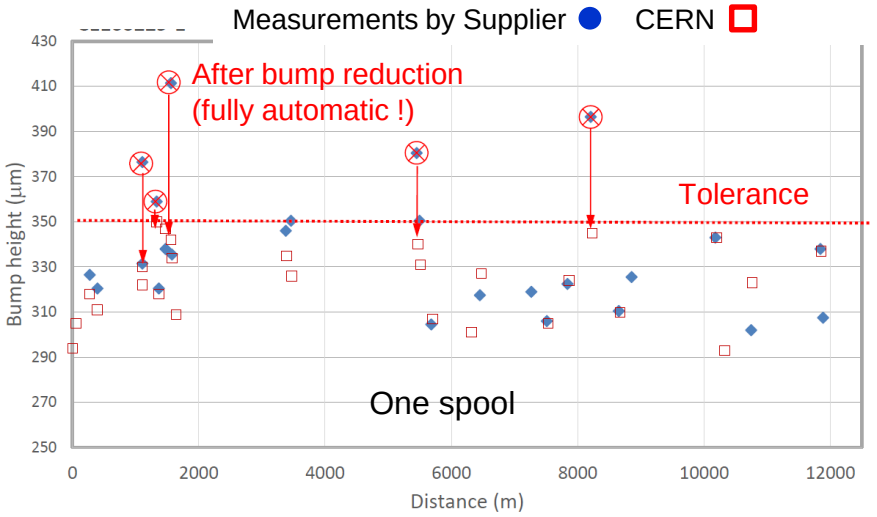
'bump' disturbs fibre lattice



Elegant and automatic heating solution found for shrinking occasional 'bumps' in fibre spools

(rate already minimised through intensive collaboration with supplier).



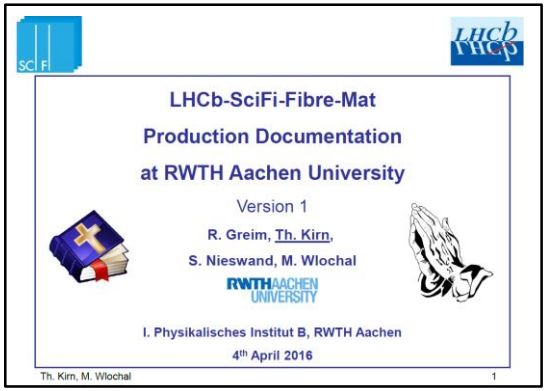


SciFi – entering the production phase

Much progress in mechanics, SiPMs, ASIC development, cooling &

Order nov
with pre-s

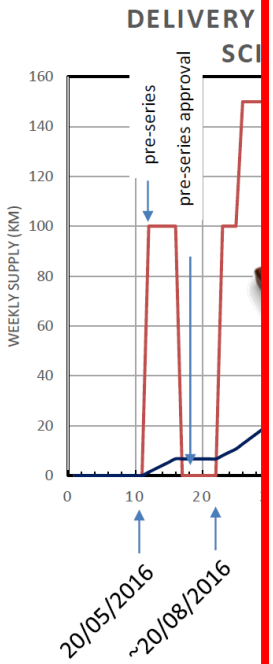
We are ready to go !



Complete 250 page documentation ('Bible') on how to make a mat.

Two weeks ago: production readiness review of first mat assembly centre (of which there are four).

When in production we will receive 300 km / 2 weeks, on 12.5 km spools.



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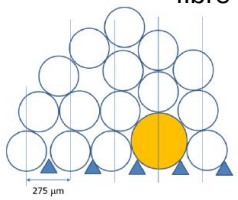

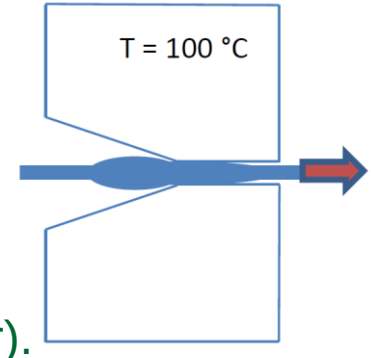

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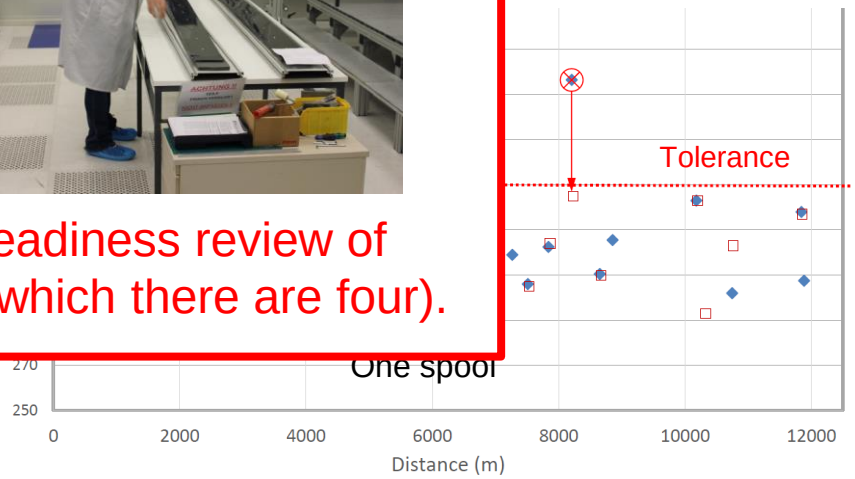
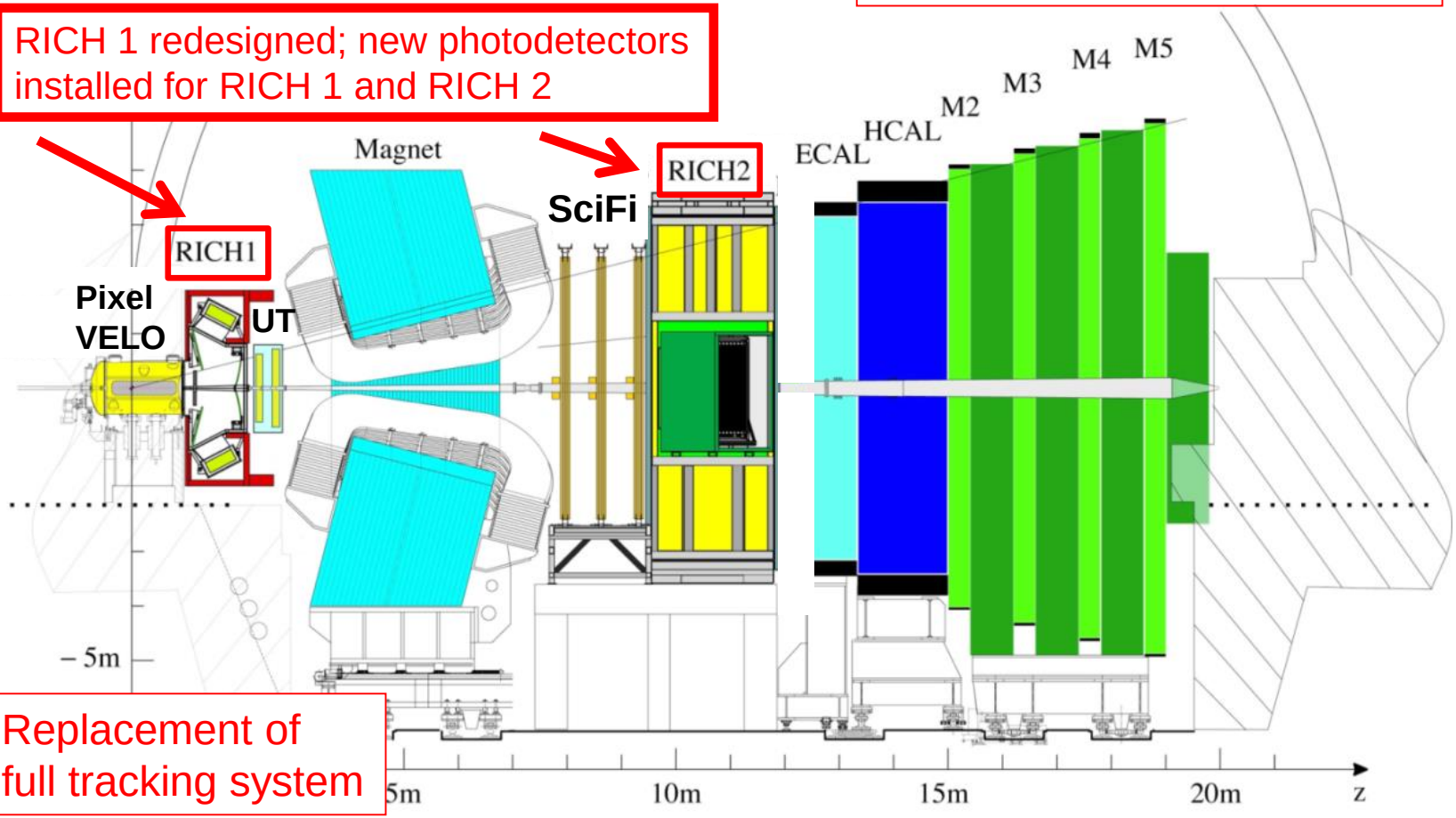


Upgrade overview

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



Replacement of full tracking system

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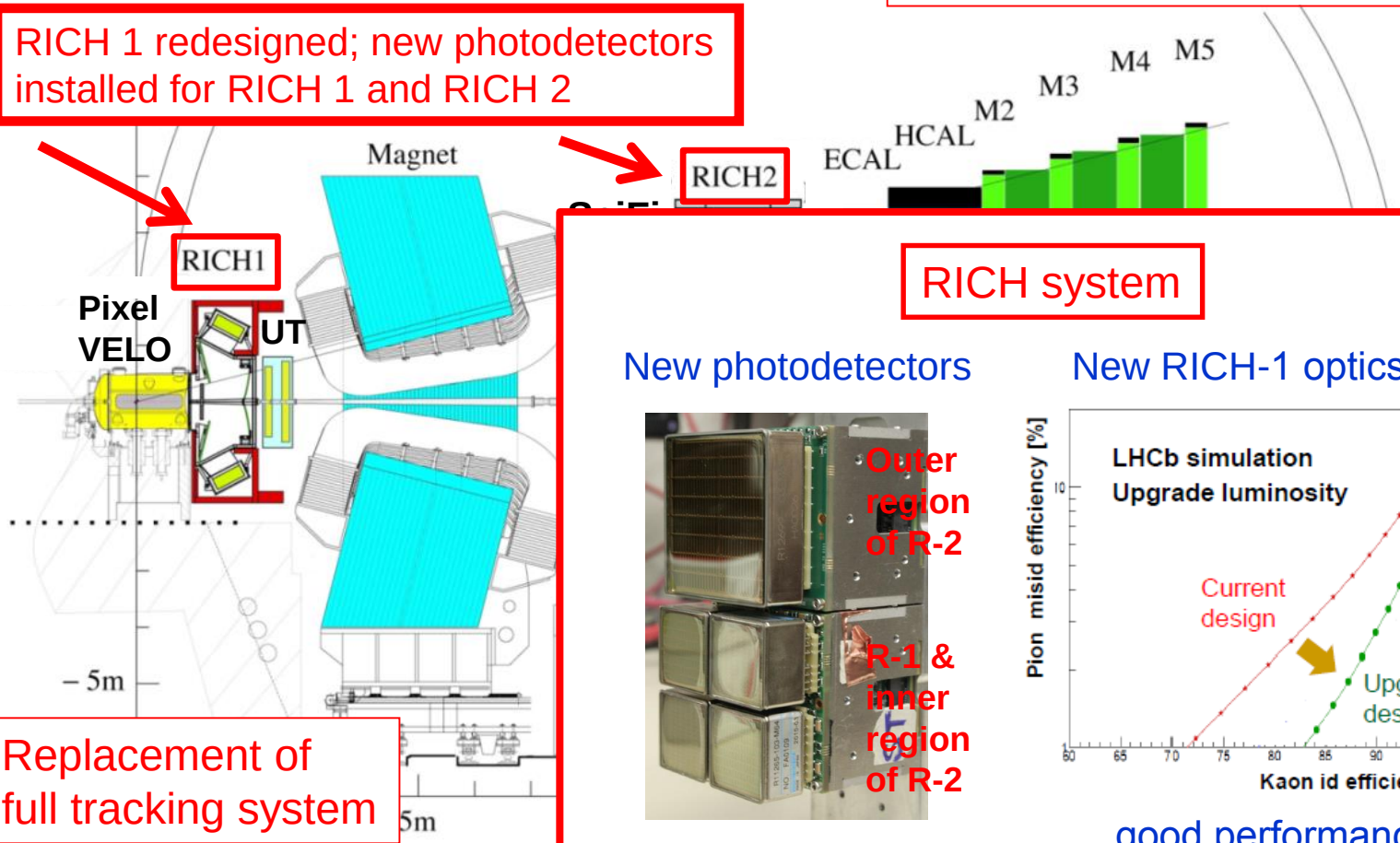


Replacement of full tracking system

RICH system

New photodetectors

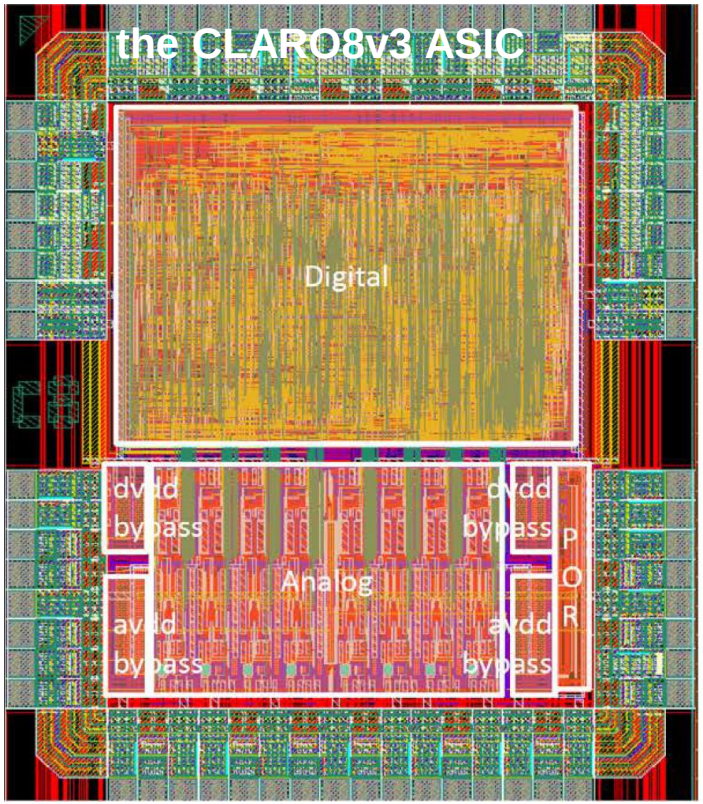
Contract awarded & first tubes have arrived.

New RICH-1 optics….

…good performance at high luminosity.

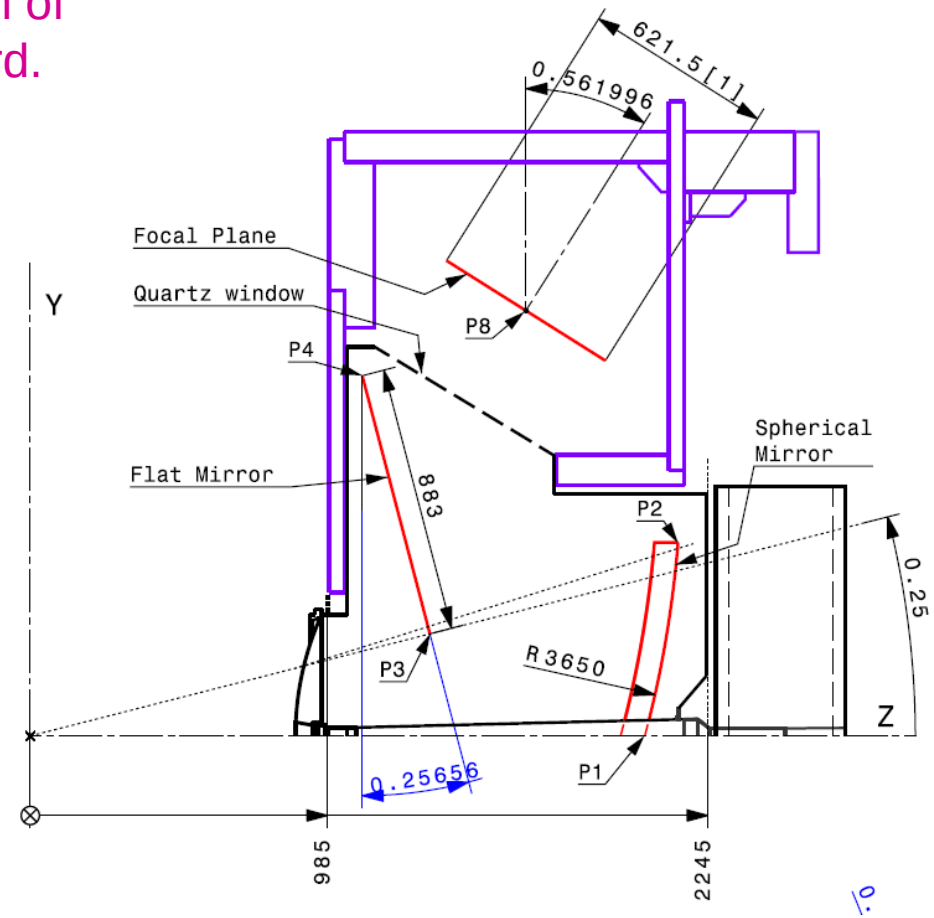
RICH progress – challenges overcome

Some delays w.r.t. LHCC milestones after deciding to include improved robustness against radiation in design of the ‘CLARO’ ASIC and front-end board.



First chips have been delivered for testing.

Design of RICH1 mechanics proved challenging, due to very limited space.



Problems solved, with EDR in May.

RICH progress – challenges overcome

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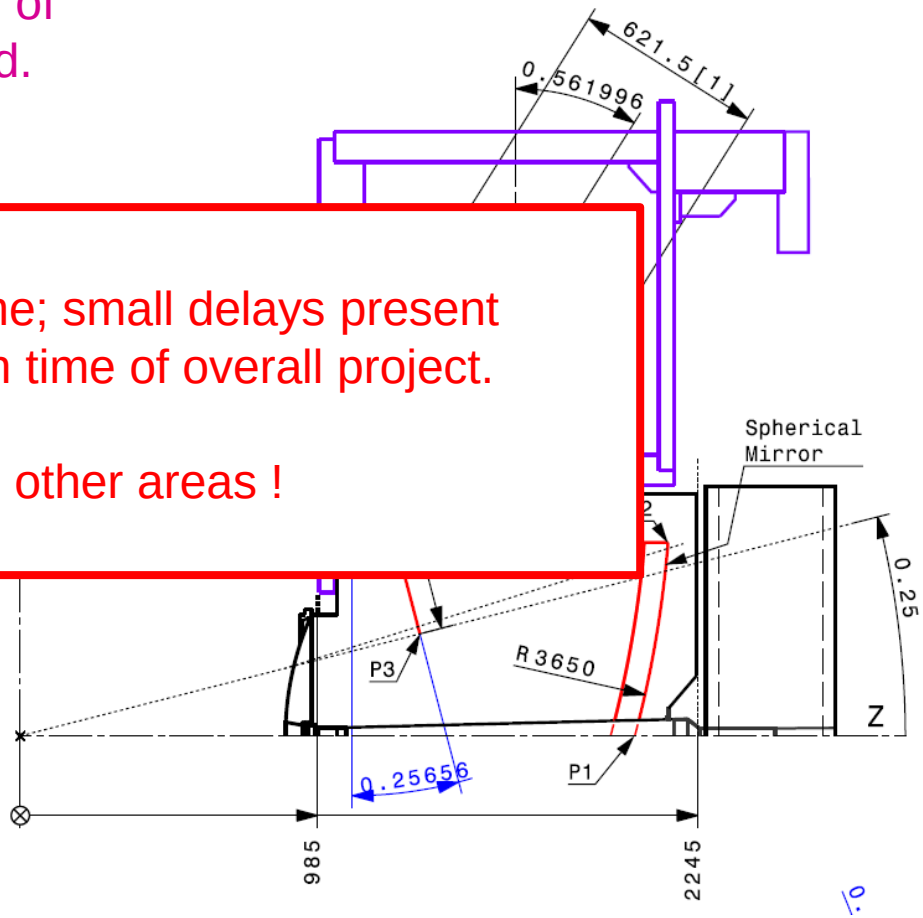
Design of RICH1 mechanics proved challenging, due to very limited space.

Challenges overcome; small delays present no risk to completion time of overall project.

Good progress in all other areas !



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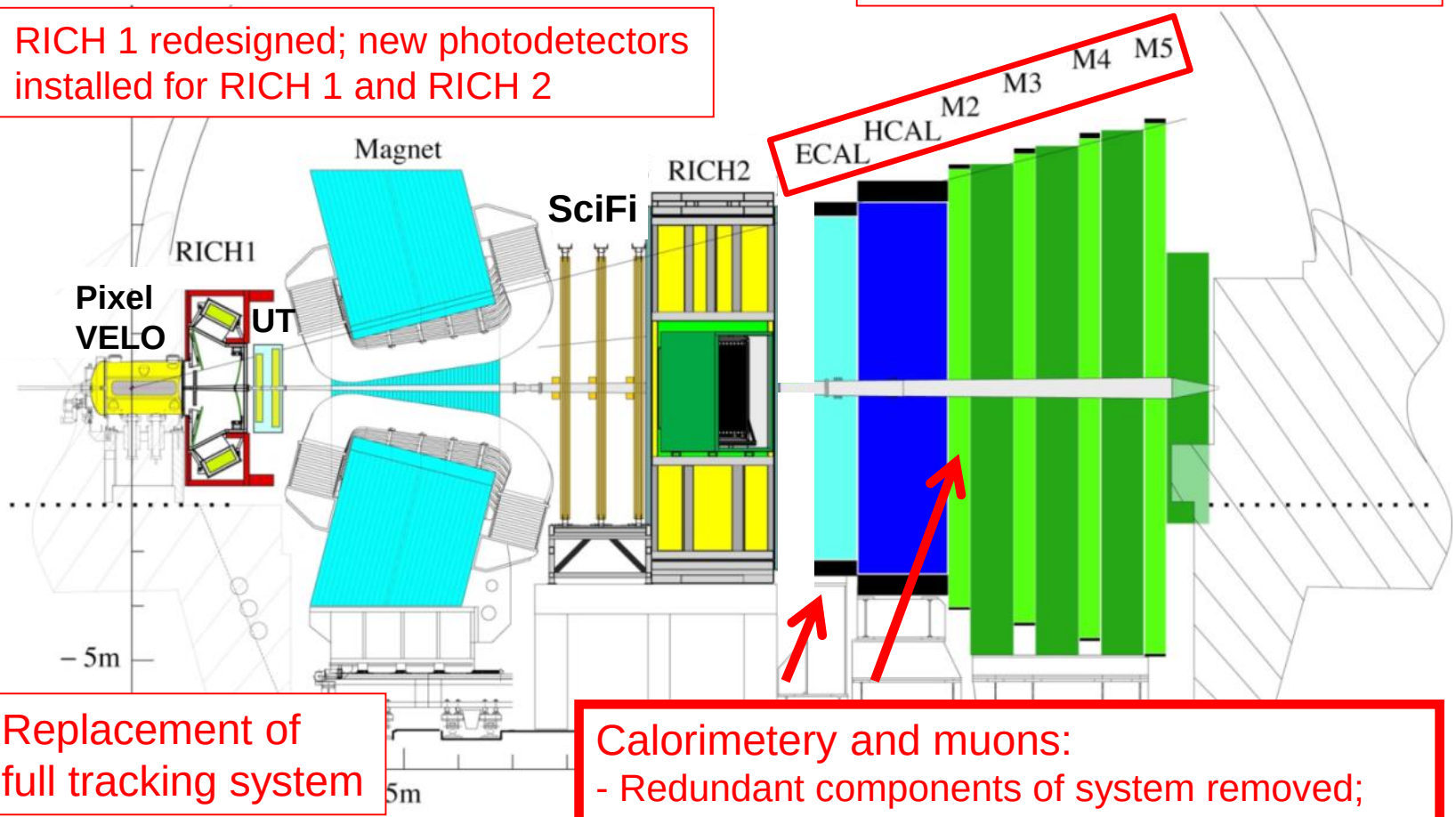
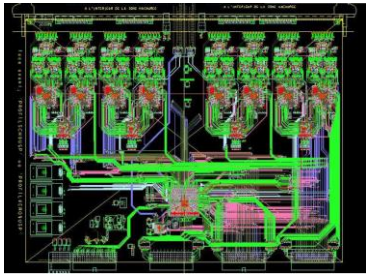


Replacement of full tracking system

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

Calo system

Good progress with all electronics, *e.g.* design of new front-end board now complete.



Infrastructure & tooling being prepared.

Muon system

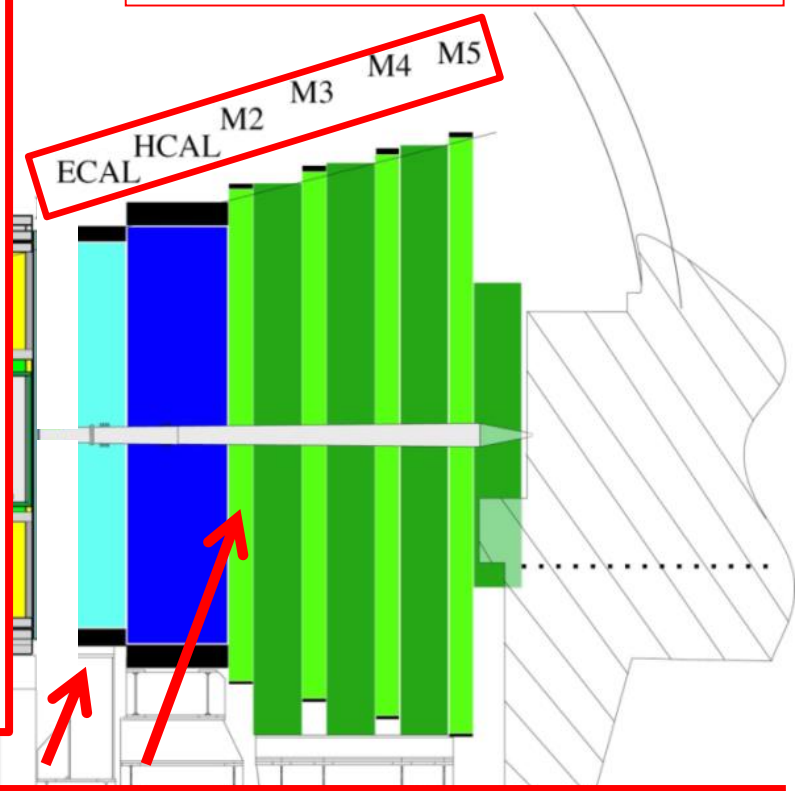
Many of required spare MWPCs now available.

Excellent progress on new electronics.

Preparations advanced for additional shielding.

Good progress in reconstruction s/w.

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



Replacement of full tracking system

Calorimetery and muons:
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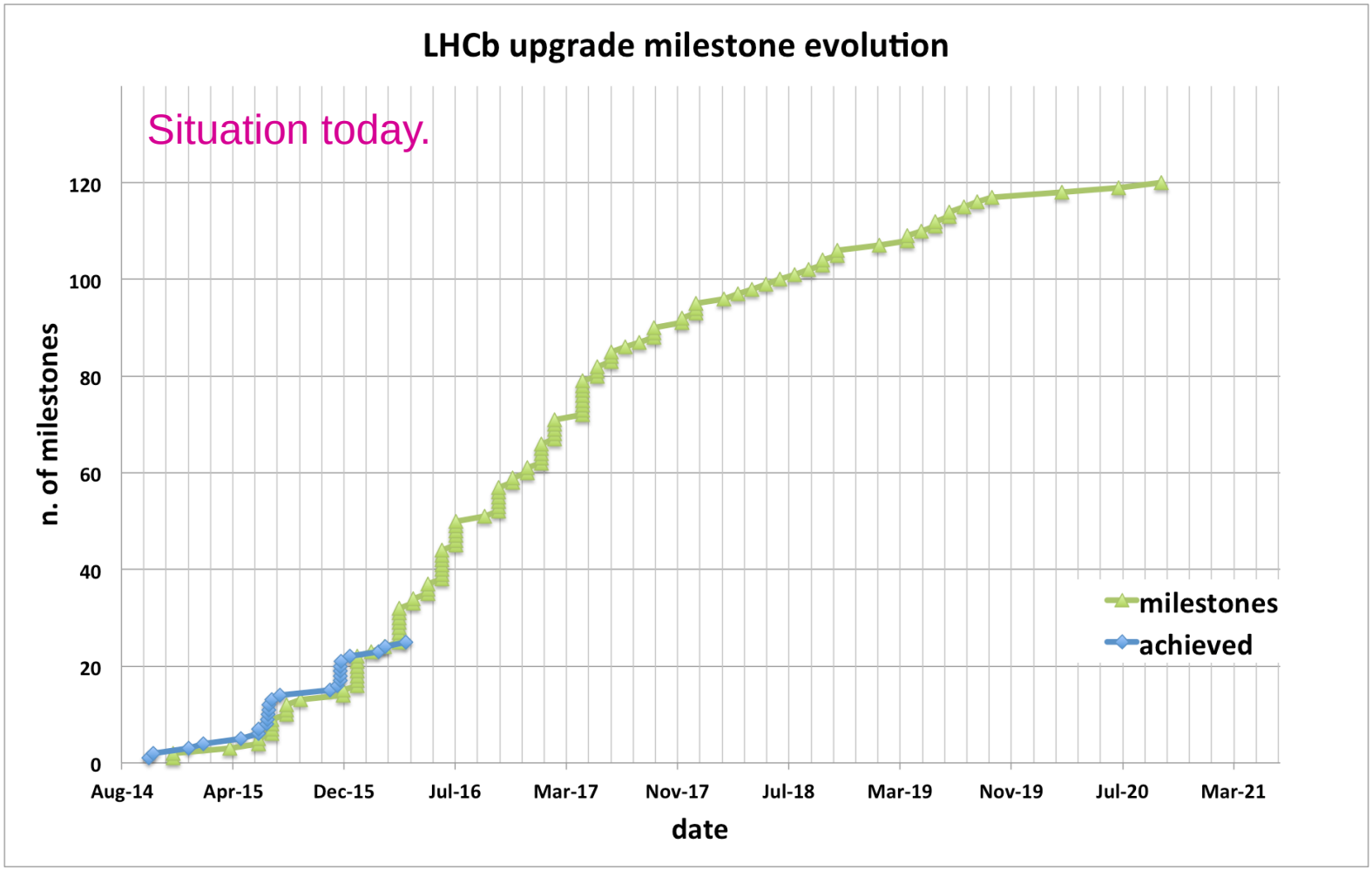
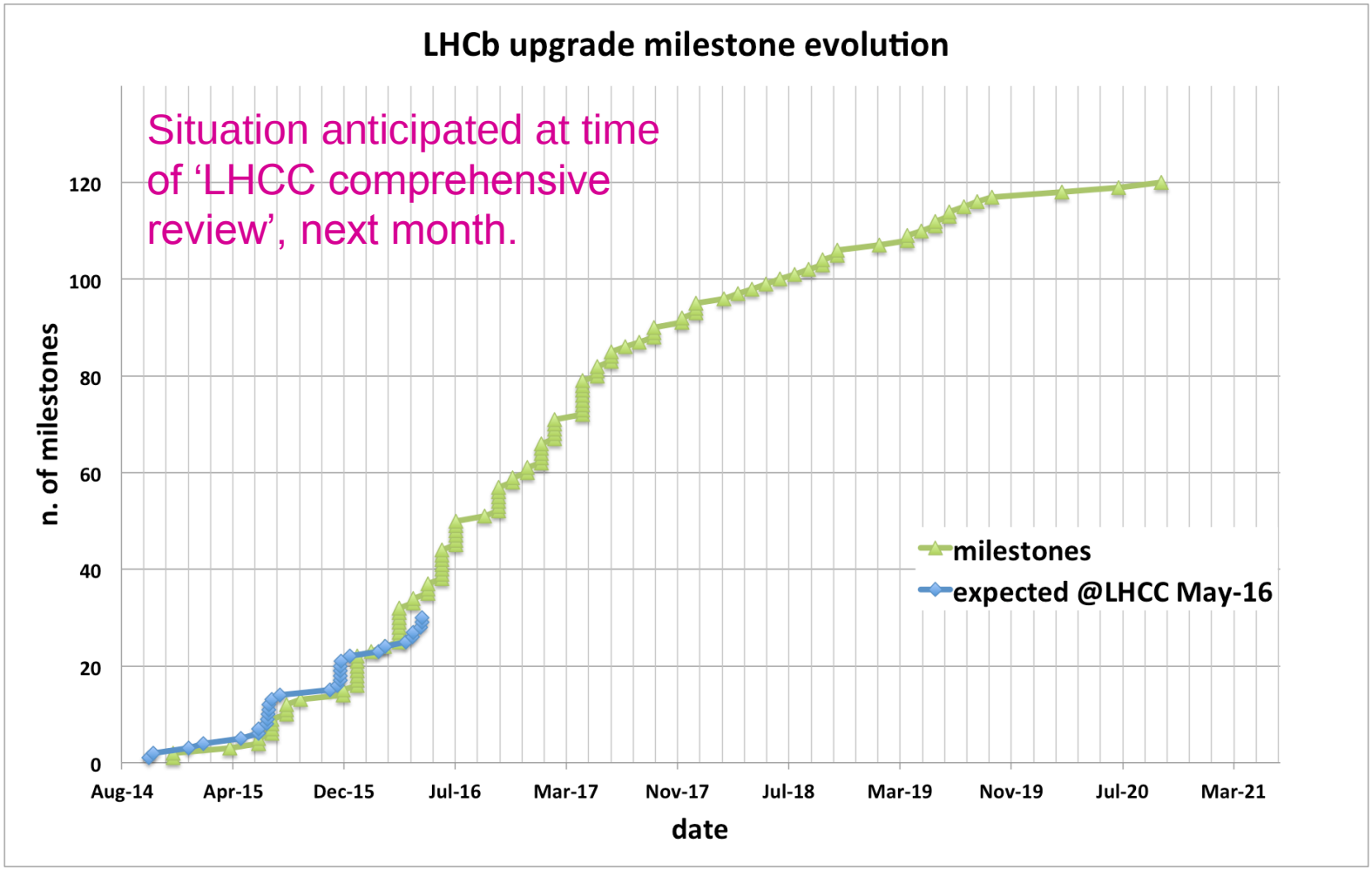
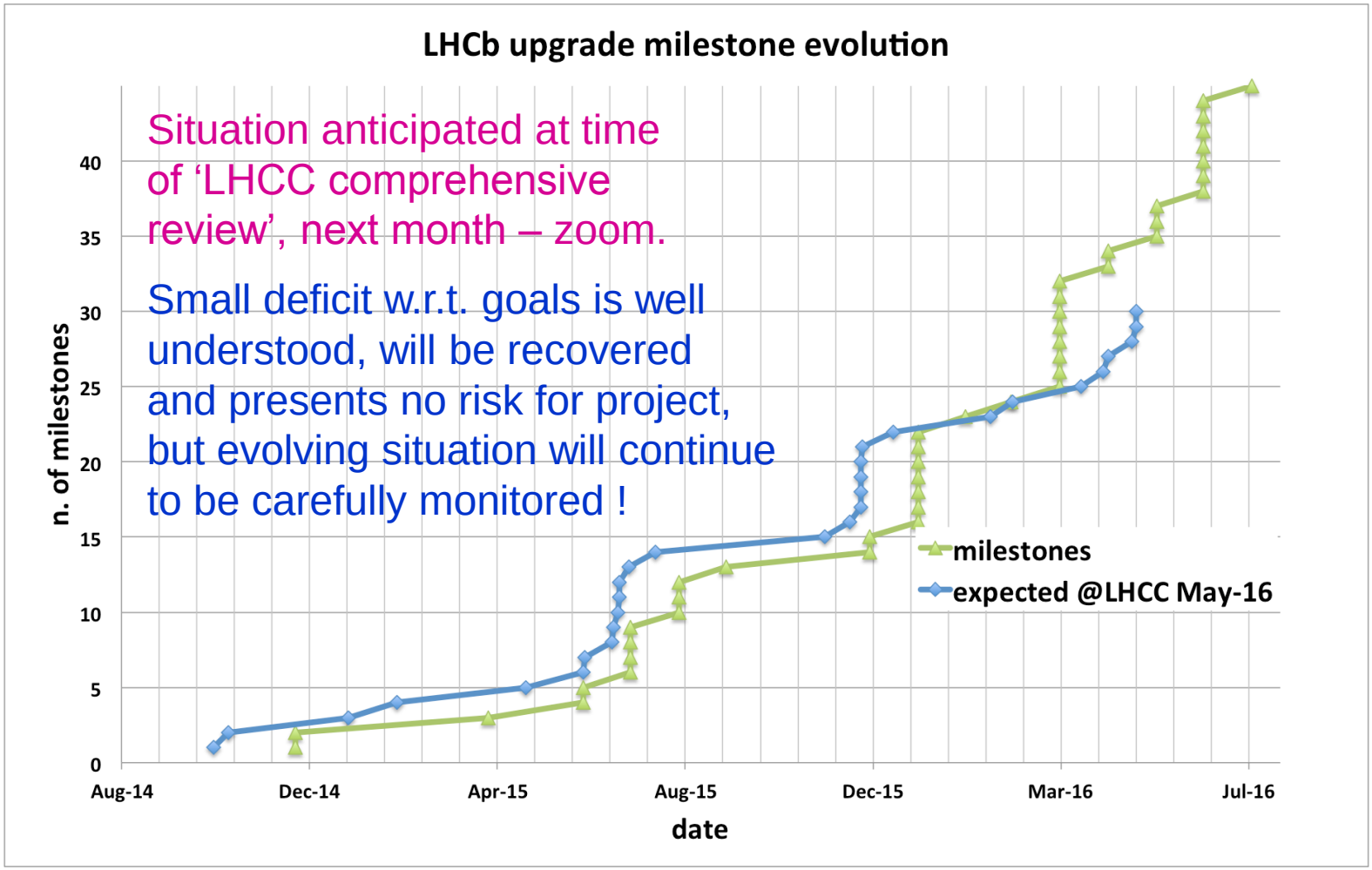
Upgrade milestones



Upgrade milestones



Upgrade milestones



Conclusions

LHCb continues to harvest rich results from run 1
- delivering strongly in core areas: great prospects for run 2 !
- increasing presence in electroweak physics, and p-A, A-A physics.

Year-end technical stop activities all successfully completed on time.
Further improvements have been made to split-HLT/TURBO stream.
Data from first collisions have been collected – detector working very well !

LS2 Upgrade will deliver huge increase in physics:
- good progress on all subsystems;
- entering production phase for many projects; several contracts signed for major items, and more to follow soon;
- progress being carefully monitored through milestones.

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			3405				6324	2735	9059
UKRAINE									105	105
UN. STATES		4310						4310	561	4871
CERN	1044	250	1550	2982		100		5926	2174	8100
Total	***5793***	***6500***	***15170***	***8885***	***1902***	***1699***	***380***	**40329**	***15710***	***56039***
TDR cost	*5793*	*6500*	*15170*	*10089*	*1902*	*1699*	*380*	*41533*	*15710*	*57243*
Underfunding				*1204*				*1204*		*1204*

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.