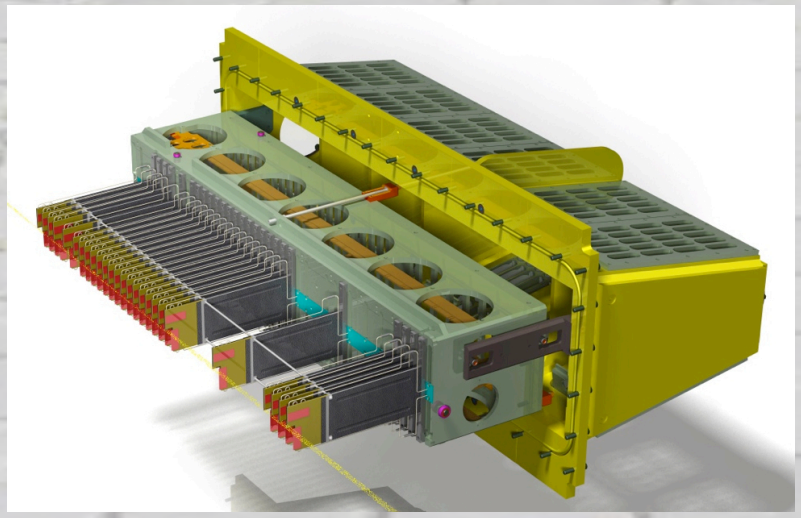
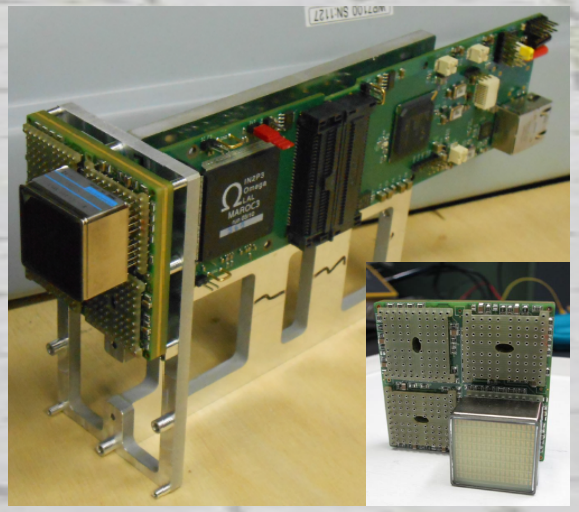
Status report on LHCb

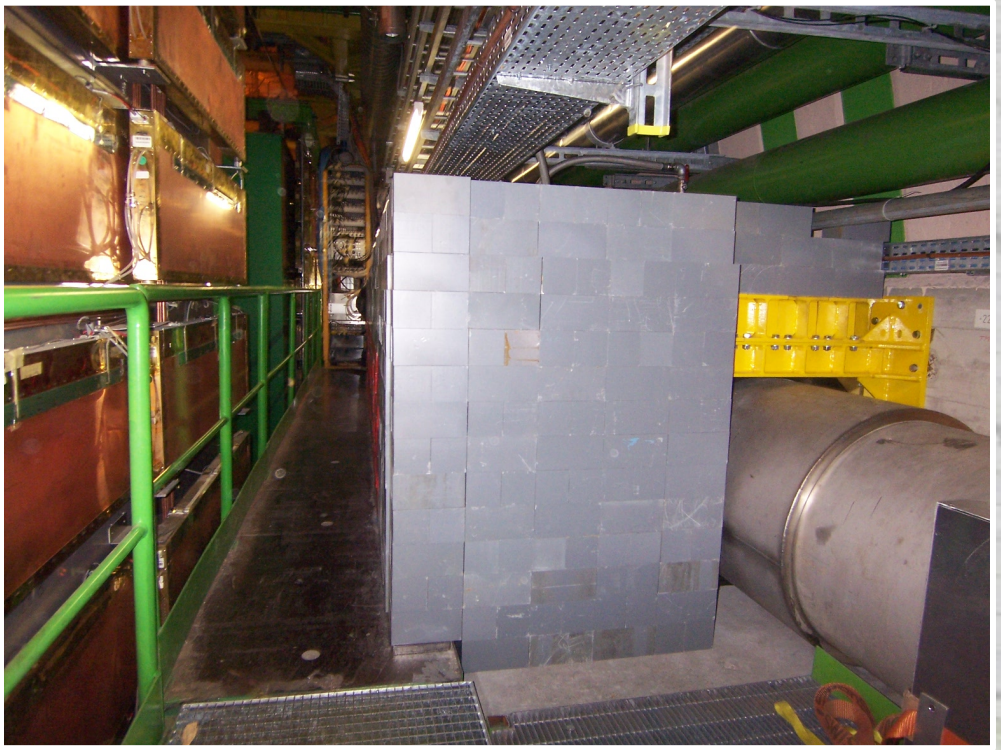
P. Campana (CERN/Frascati)
RRB meeting, 30.10.2013





Activities during LS1

Consolidation of IT/TT cooling station: new plant installed



Additional shielding behind the Muon stations to reduce background in M5

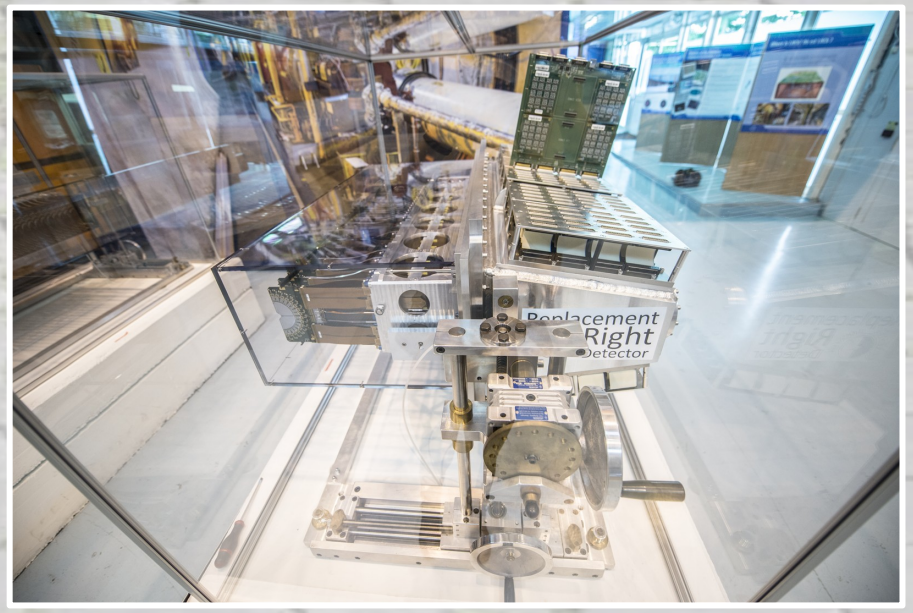
Completion of the various consolidation activities
Preparation for the long cooling shutdown (mobile unit to cool farm, VELO and IT/TT)

Consolidation of Magnet Dipole:
replacement of protection between coils and support

Activities on detectors:
MUON - better grounding and duplication of HV channels,
OT – module repair and source scan for aging studies
CALO – LED calibr. system repair, etc…

Regular commissioning weeks – all detectors ON one week/every two months

Prepare infrastructures for upgrade (long fibre samples in test)



Very successful Open Day:
more than 2400 people visited LHCb

Replacement VELO module on display

Computing

Changes to computing model for the 2015-17 data taking

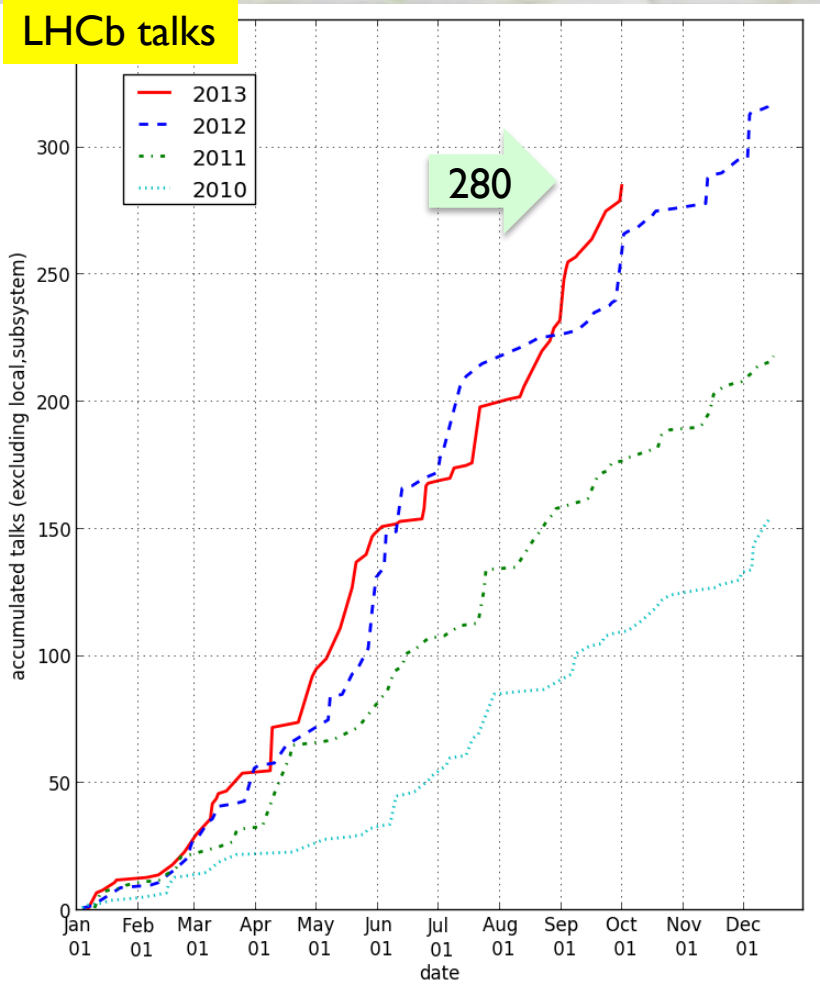
- 12.5 kHz HLT rate (up to 5 kHz parked, 2.5 kHz "turbo")
  (note: ~50 kHz of b events, ~300 kHz of c events in LHCb acceptance at 14 TeV)
- Only prompt reconstruction, no reprocessing
- Gradual reduction in CPU time for MC (major developments required - already a reduction of factor 2 in space achieved)
- Moore's law still applies (effort to adapt software for more efficient vectorisation and use of multicore CPUs)
- Adjust parking rate and MC production to fit in (~constant budget) envelope
  CPU +20%/year – disk +15%/year – tapes +25%/year (not possible)
- Mitigation measures for CPU and disk, new resources needed for tapes (uncompressible RAW data)

A plan is on going to extend to non-Tier1 sites the full computing LHCb capabilities (through Tier2 sites with large disk storage)

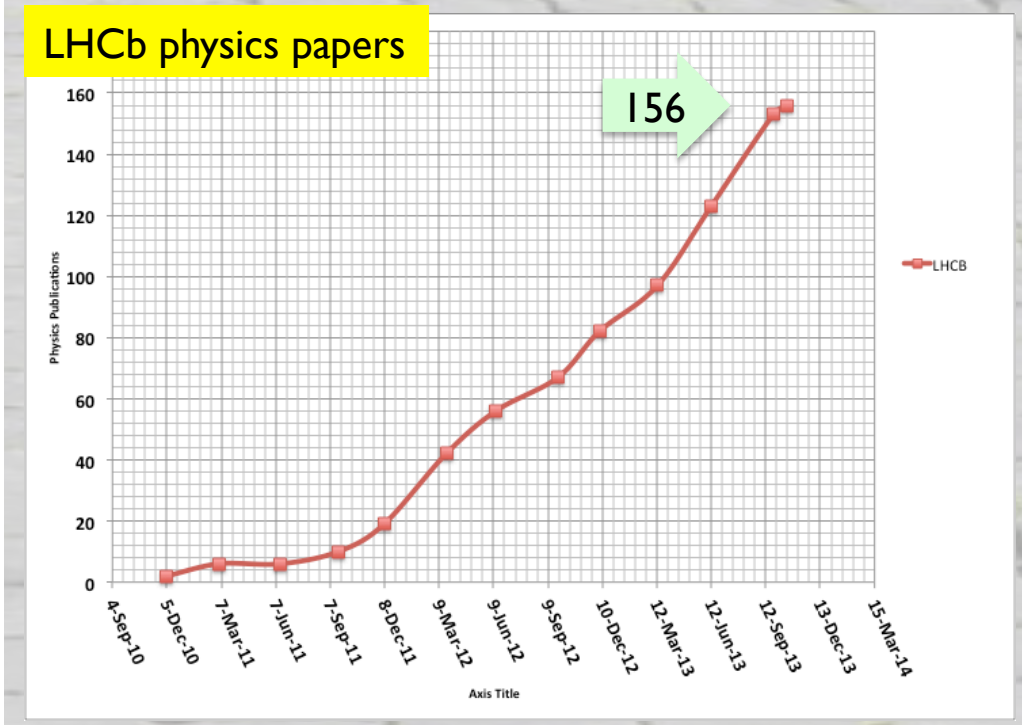
Selected highlights of recent LHCb results

The "luminosity" plots

LHCb talks



LHCb physics papers

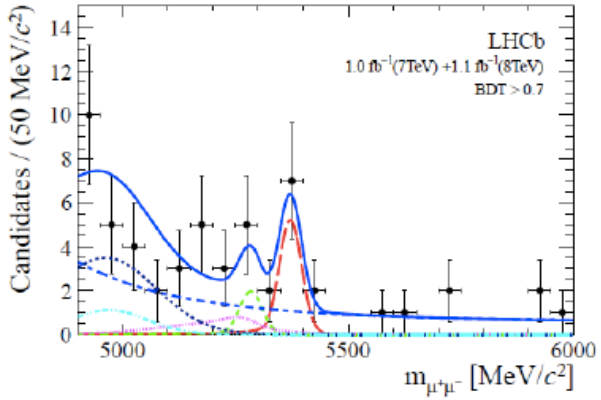


LHCb update on $B_{(s)} \to \mu\mu$

EPS 2013

- November 2012: LHCb find the first evidence with 1 (7 TeV) + 1 (8 TeV) fb^{-1}

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



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

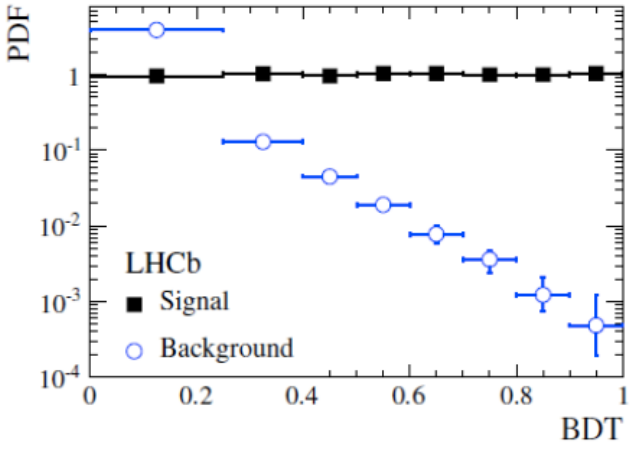
$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (3.2^{+1.5}_{-1.2}) \times 10^{-9}$$

Significance of 3.5 σ !

Update with the full data set: 1/fb (2011) 2/fb (2012)

Strategy similar to previous analysis
Main improvements:

- new detector alignment and reconstruction
- Improved BDT classifier
- Refined exclusive background estimate



Data driven approach: BDT output based on B→hh events (signal), on sidebands (background)

LHCb results on $B_{(s)} \to \mu\mu$

- Simultaneous un-binned maximum likelihood fit to the mass spectra
- Free parameters: BR($B^0 \to \mu^+\mu^-$), BR($B_s \to \mu^+\mu^-$) and combinatorial bckg.
- B_s branching fraction corrected for finite width ($\Delta\Gamma_s \neq 0$)

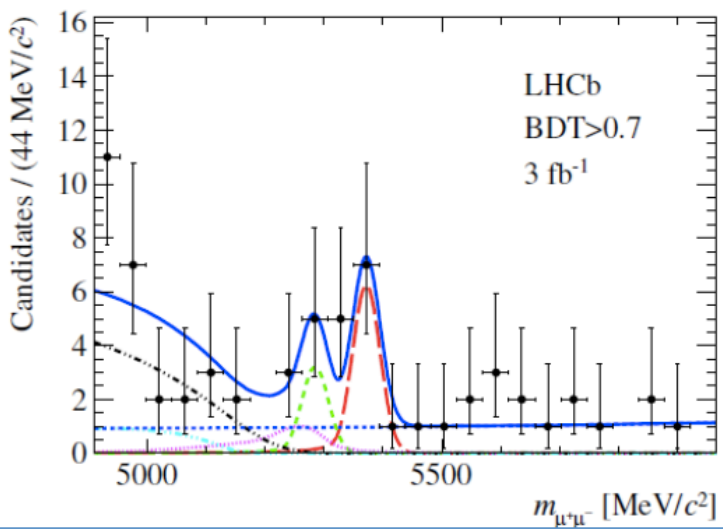
$$BR(B_s^0 \to \mu^+\mu^-) = (2.9^{+1.1}_{-1.0}(stat)^{+0.3}_{-0.1}(syst)) \times 10^{-9}$$

Significance: 4.0 σ
expected 5.0 σ(median)

$$BR(B^0 \to \mu^+\mu^-) = (3.7^{+2.4}_{-2.1}(stat)^{+0.6}_{-0.4}(syst)) \times 10^{-10}$$

Significance: 2.0 σ

PRL 111(2013)101815



Preliminary combination of LHCb and CMS results

LHCb-CONF-2013-012
CMS PAS BPH-13-007

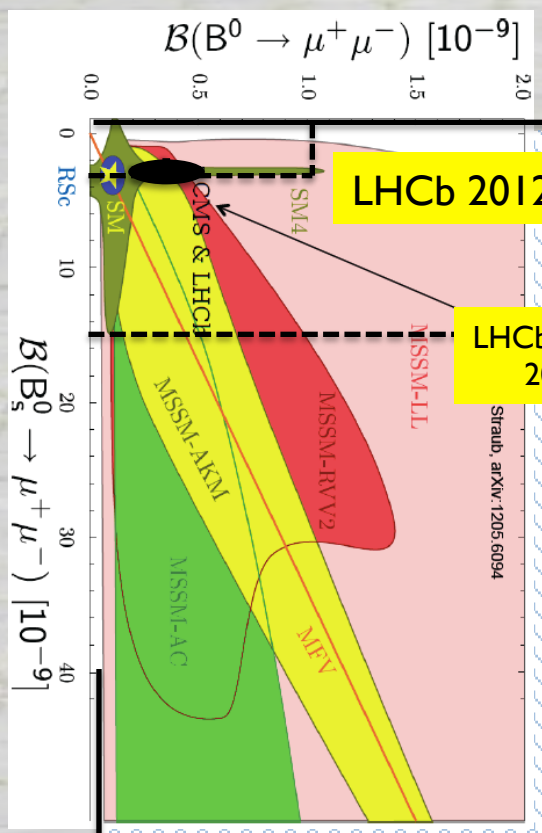
$$BR(B_s^0 \to \mu^+\mu^-) = (2.9 \pm 0.7) \times 10^{-9}$$

Observation!!

$$BR(B^0 \to \mu^+\mu^-) = (3.6^{+1.6}_{-1.4}) \times 10^{-10}$$

Not statistically significant

Impact of $B_{(s)} \to \mu\mu$ on NP models



LHCb 2012

LHCb+CMS 2013

LHCb 2011

LHC(b) era

Before LHC(b) era

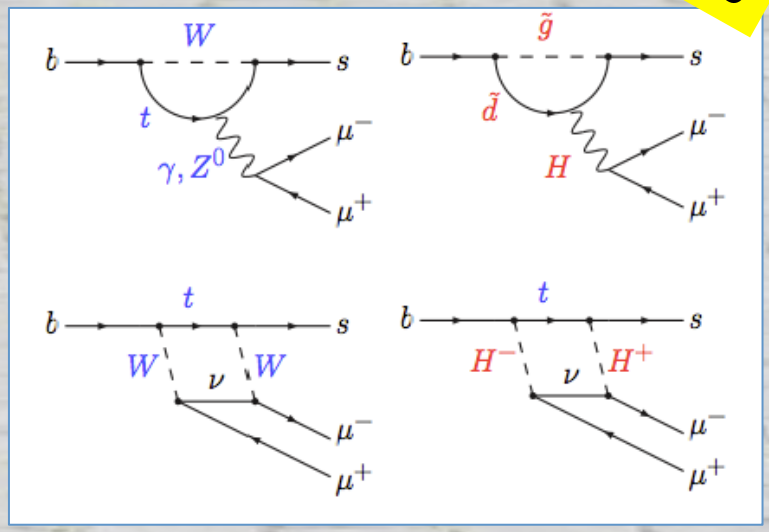
Electroweak penguin transitions in b→sμμ

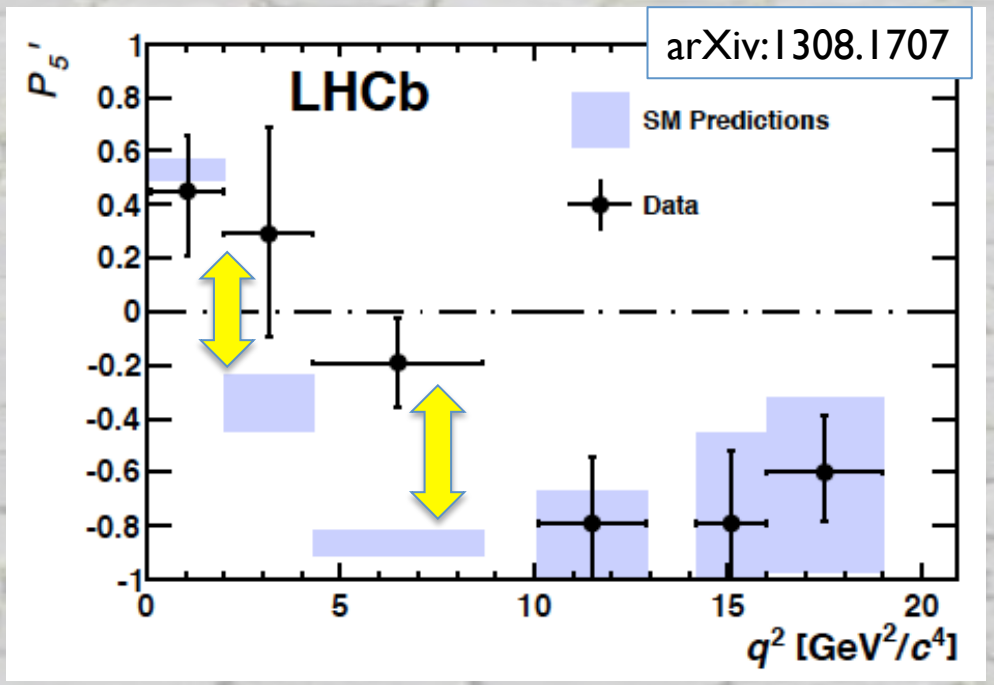
EPS 2013

Measuring angular variables in $B^0 \to K^* \mu\mu$ decays (penguin dominated)

Sensitive to New Physics in Wilson coefficients

New analysis with variables less dependent on form factors uncertainties





One of these variable (P_5') shows discrepancy wrt SM (3.7 σ local effect) affecting C_7', C_9'

Interest from theorists on the anomaly for possible NP effects

13 theory papers since the appearance on arXiv of this result

More data available (+2/fb) – A deeper theoretical understanding is needed

Search for CPV in $D^0 \to KK$ and $D^0 \to \pi\pi$ time dep. decays

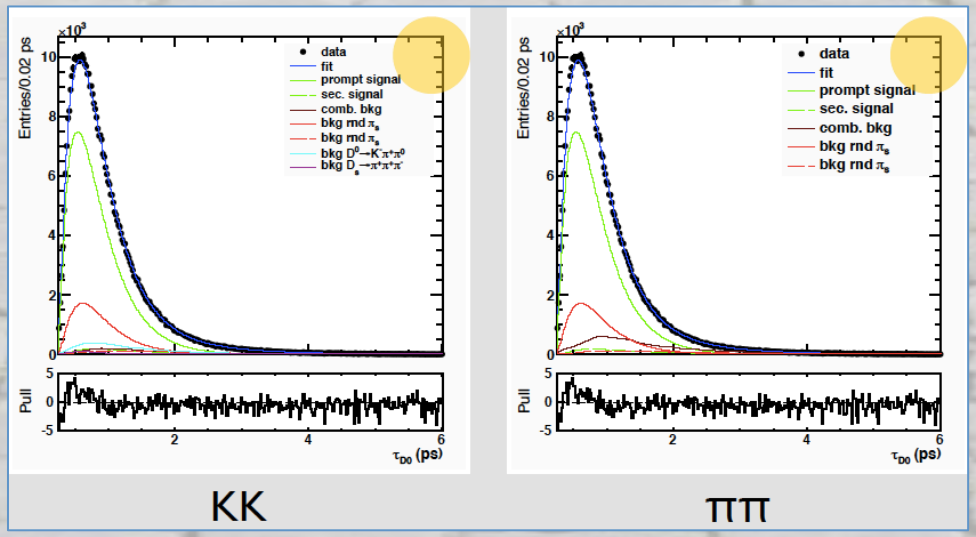
Charm 2013

- Measure lifetime asymmetries in $D \to hh'$ decays
- Decays to CP eigenstates: $f = K^-K^+, \pi^-\pi^+$

$$A_\Gamma \equiv \frac{\hat{\Gamma}(D^0 \to K^+K^-) - \hat{\Gamma}(\overline{D}^0 \to K^+K^-)}{\hat{\Gamma}(D^0 \to K^+K^-) + \hat{\Gamma}(\overline{D}^0 \to K^+K^-)}$$

a nearly pure measurement of indirect CPV in charm

- Expect $<10^{-4}$ in SM and $<10^{-3}$ in BSM
- Previous world average precision 1.6 10^{-3} (averaging KK and $\pi\pi$ results)



KK ππ

Results :

$A_\Gamma(KK) = -0.35 \pm 0.62 \pm 0.12\ 10^{-3}$

$A_\Gamma(\pi\pi) = 0.33 \pm 1.06 \pm 0.14\ 10^{-3}$

No evidence for indirect CPV

$\mathbf{A_{CP}^{ind} \sim 0}$

LHCb-PAPER-2013-054

Mixing and search for CPV in $D^0 \to K^+\pi^-$

Charm 2013

Measuring charm mixing with right-sign/wrong-sign $D^0 \to K\pi$ tagged decays and time dependent analysis

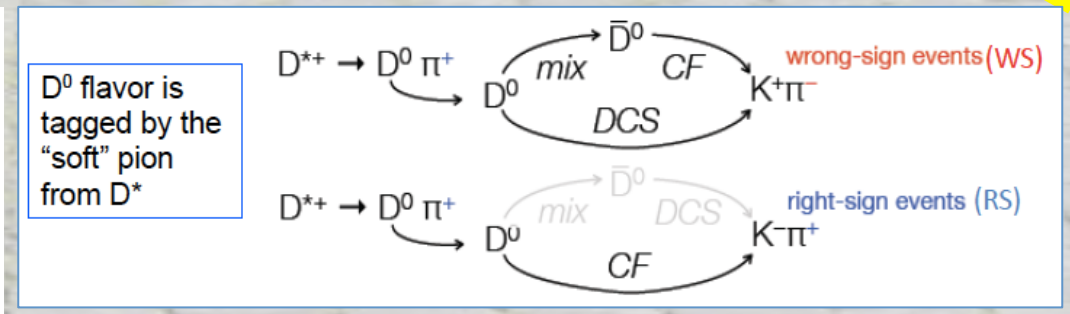
LHCb update of mixing parameters with 3/fb

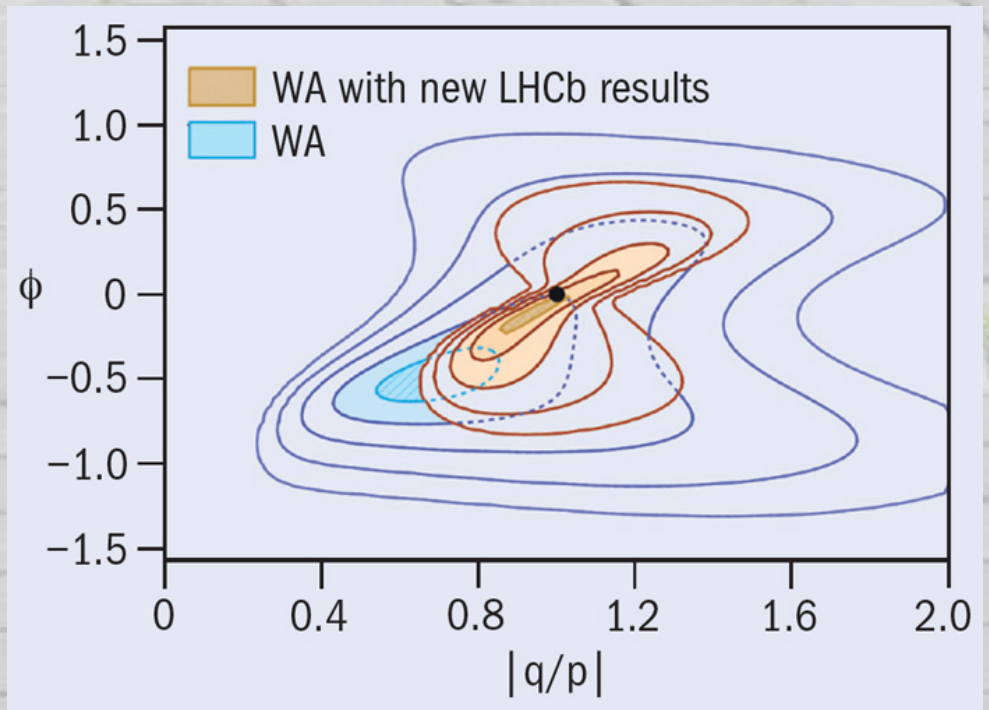
R_D $[10^{-3}]$	$3.568 \pm 0.058 \pm 0.033$
y' $[10^{-3}]$	$4.81 \pm 0.85 \pm 0.53$
x'^2 $[10^{-5}]$	$5.5 \pm 4.2 \pm 2.6$

and a measurement of direct CP violation looking to asymmetries in the (y', x'^2) parameters

$A_D = (-1.3 \pm 1.9)\ 10^{-3}$
$0.75 < |q/p| < 1.24$ (68% CL)

arXiv:1309.6534





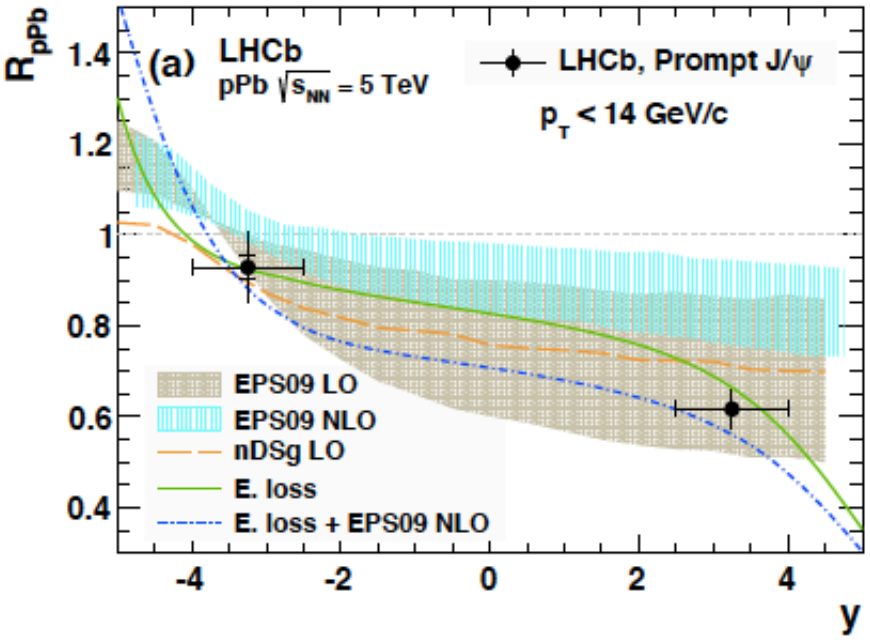
Suppression of J/ψ in pA collisions

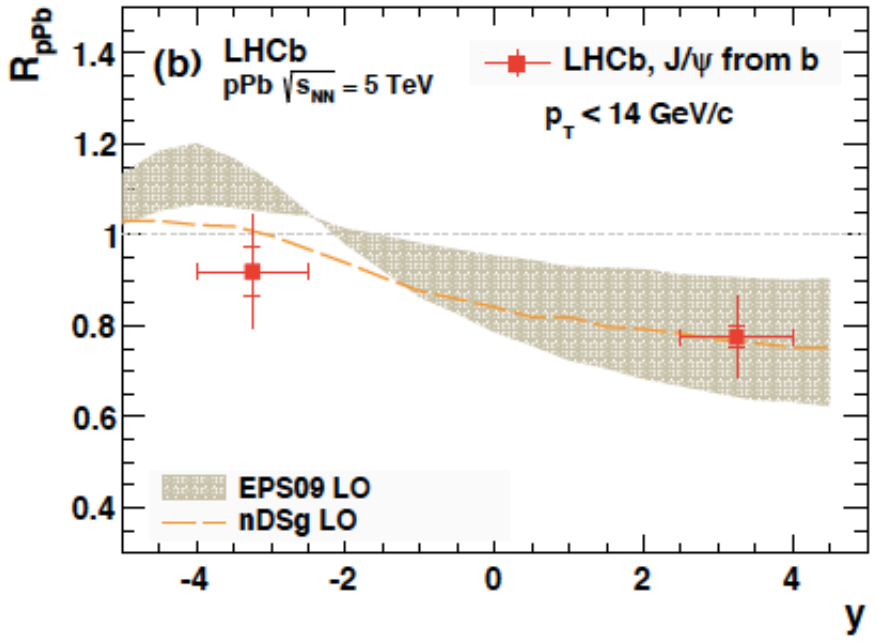
First LHCb paper on pA collisions. Co-ordinated submission to JHEP with similar paper from ALICE

Prompt J/ψ suppression confirmed also in pA environment in the forward direction
Also observed in J/ψ originating from b decays (only LHCb can do it)

Other analysis ongoing (Υ states, multiplicities, ridge effect, etc…)

arXiv:1308.6729



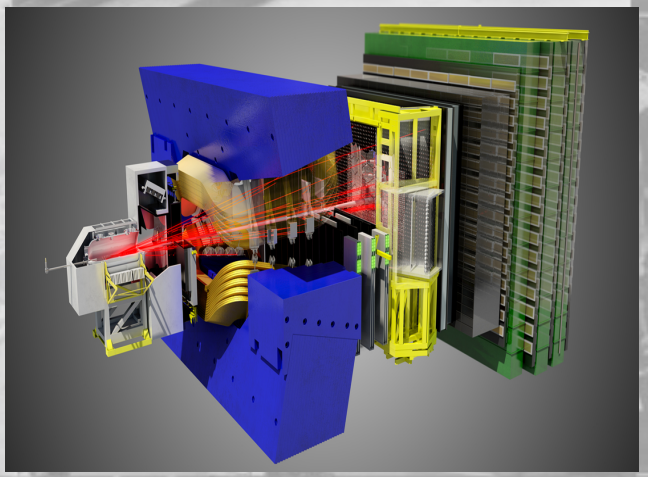


… and many more results …

- *Measurement of CPV in $B^{\pm} \rightarrow hhh$ decays*
- *Observations of several B_c decay channels*
- *Measurement of CPV in $D \rightarrow KK\pi\pi$ and $D \rightarrow \pi\pi\pi\pi$*
- *Measurement of time dependent CPV in $B_s \rightarrow KK$ decays*
- *Measurement of CP asymmetry in $B^{\pm} \rightarrow K^{\pm} \mu\mu$ decays*
- *First observation of $B^0 \rightarrow pp$*
- *Observation of a resonance structure in $B^{\pm} \rightarrow K^{\pm} \mu\mu$ decays*
- *Measurement of J/ψ polarization*
- *Search for LFV decays $B_{(s)} \rightarrow \mu e$*
- *Precise measurement of Λ_b lifetime*
- *Measurement of B meson production cross sections*
- *Search for rare decay $D \rightarrow \mu\mu$ decay*
- *Measurement of J/ψ and Υ production cross sections*
- *Measurement of BF of $B^0 \rightarrow K^* ee$*
- *Precise measurement of D meson mass differences*
- ….

~ 50 papers published since last RRB

The LHCb upgrade



Status of LHCb upgrade

Since last RRB:

- Progress in technological choices
- Road map for presentation of TDRs at future LHCCs
- ECFA workshop on physics and detectors at HL-LHC

At this RRB:

- Update of detector cost (preliminary, final evaluation available with TDRs)

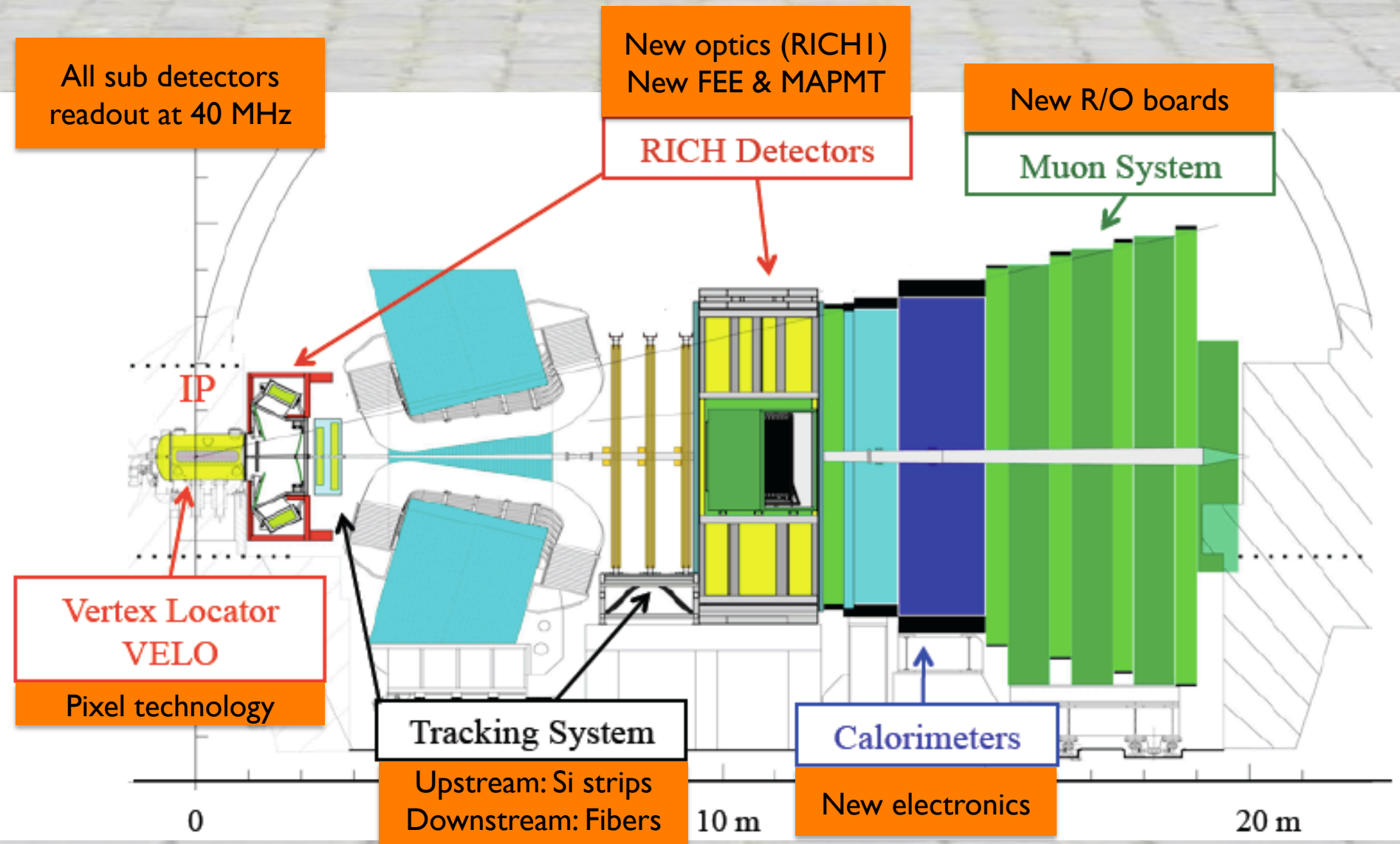
At next RRB

- TDRs will be available (being submitted to LHCC). Expecting to put in operation the Addendum to Construction MoU "*LHCb common projects*"
  MoU addenda to TDR will follow soon after

Major milestones :

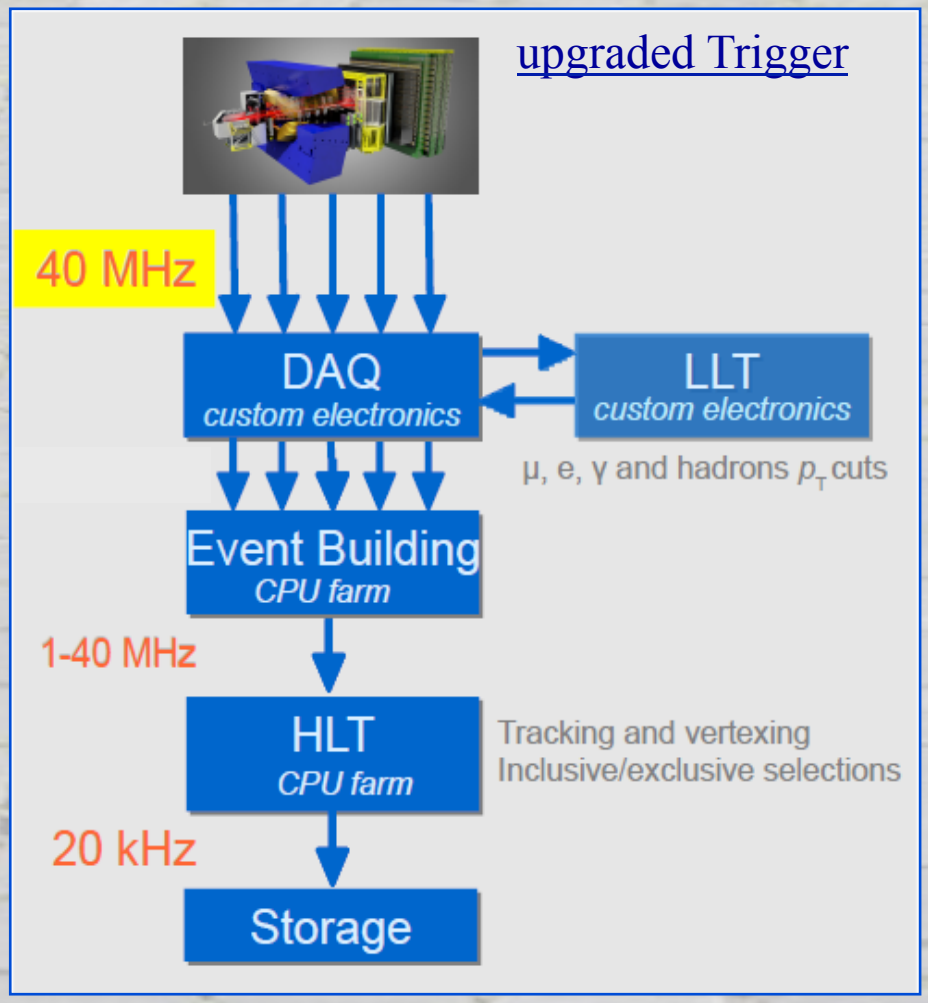
- choice of detector technology for Vertex Locator: pixel ✔
- choice of layout for RICH: keep RICH 1 & 2 ✔
- choice of technology for Tracking System (do be done by end of November)

LHCb detector modifications for the upgrade

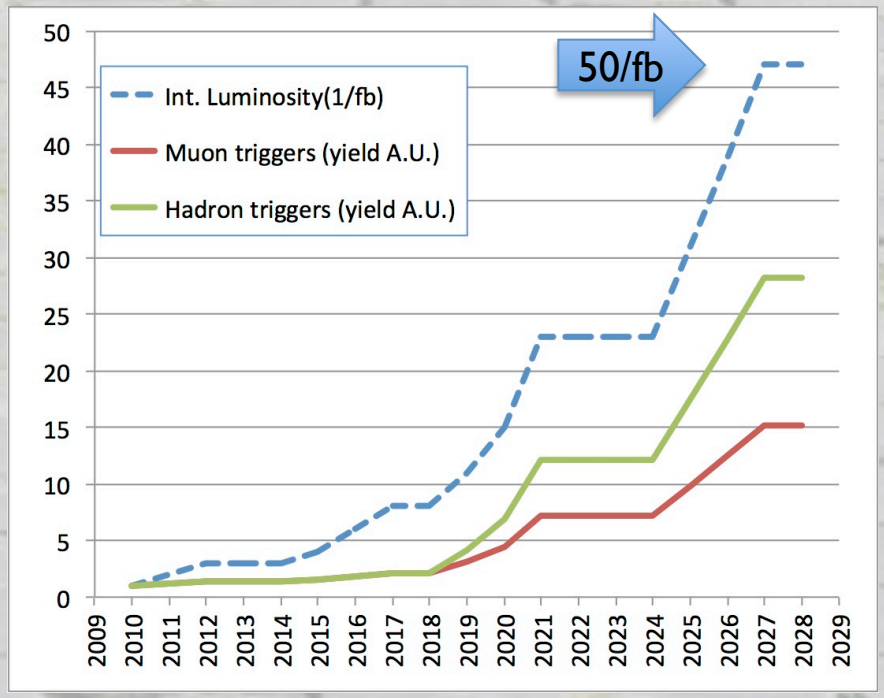


The LHCb upgrade trigger concept

Run an efficient and selective software trigger with access to the full detector information at every 25 ns bunch crossing



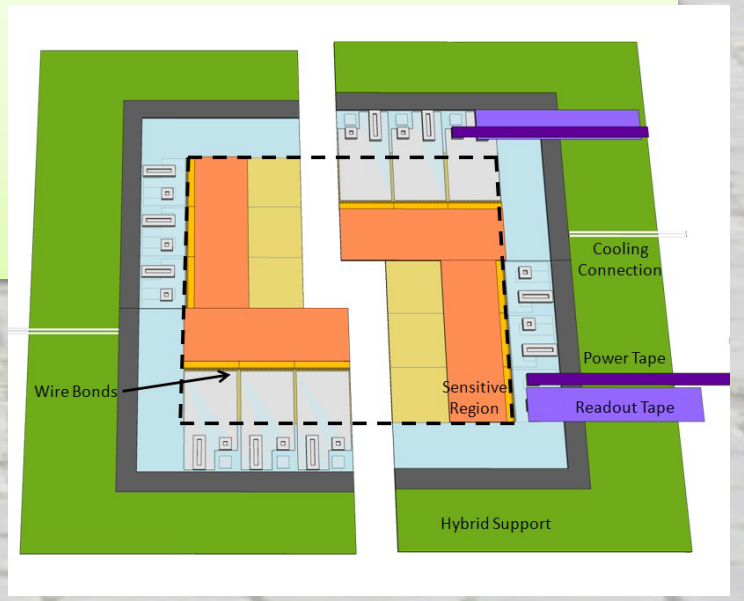
- Increase luminosity up to a levelled $2 \cdot 10^{33}$ $cm^{-2}s^{-1}$, pile-up ~5
- increase efficiencies in hadronic channels by a factor ~2
- record on tape ≥20 kHz
- collect up to 50/fb

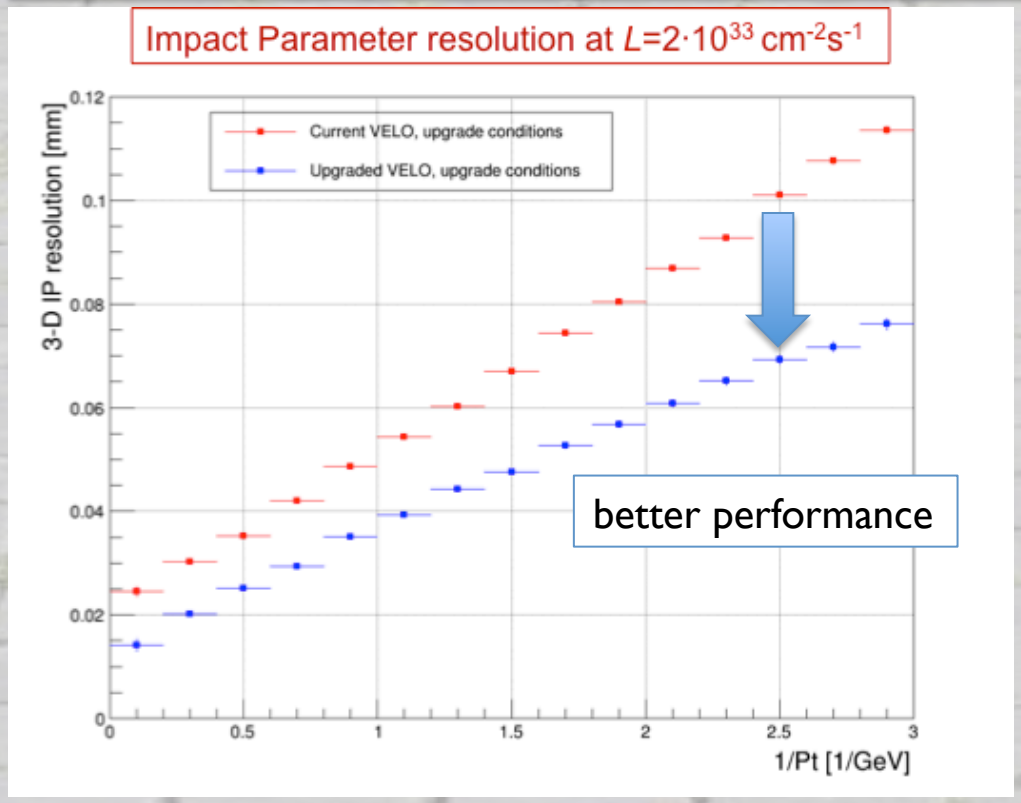


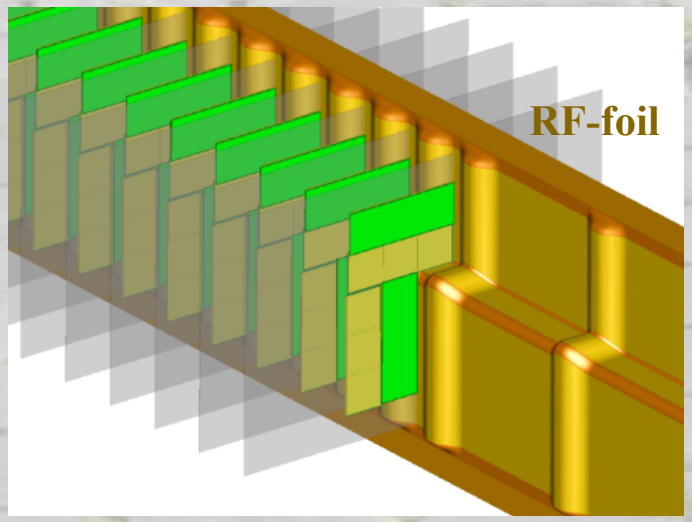
VELO upgrade

Technological choice: pixels (50x50 μm^2) with micro-channel cooling

- Superior patter recognition
- Excellent spatial resolution/improved acceptance
- Minimal amount of material
- Radiation resistance
- "State of the art technology"

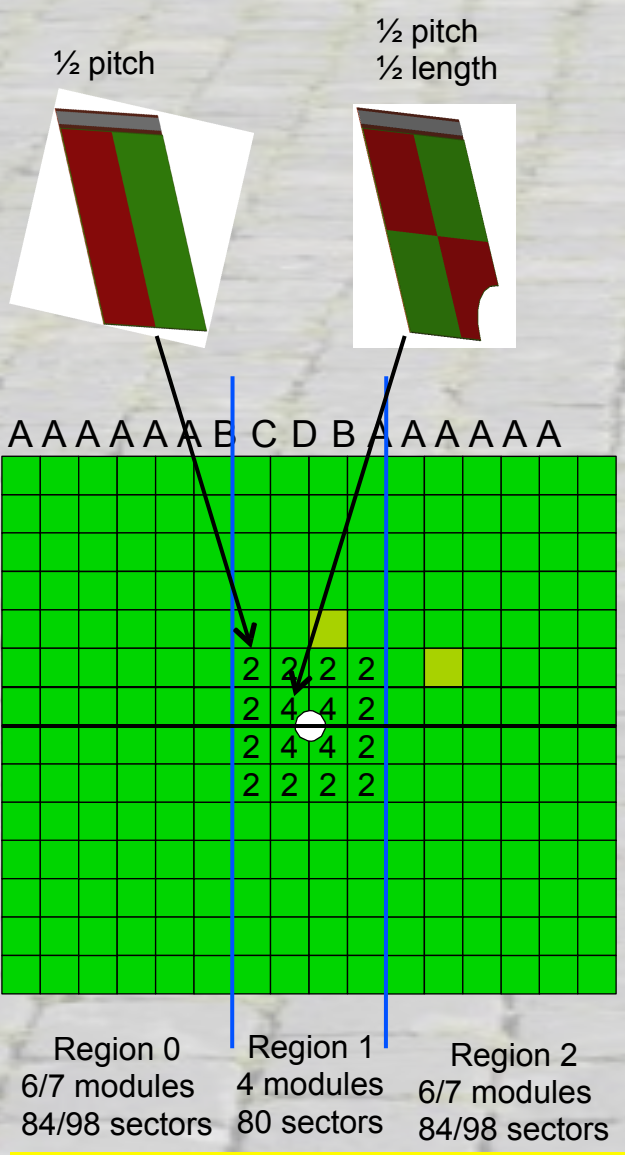






→ TDR ready by Nov. 2013

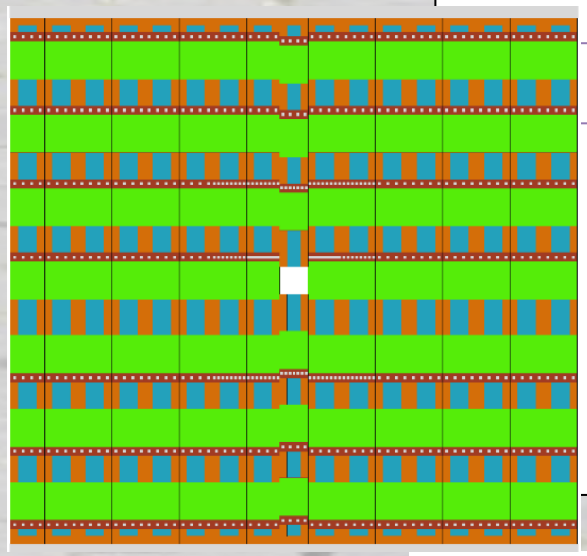
Upstream Tracker



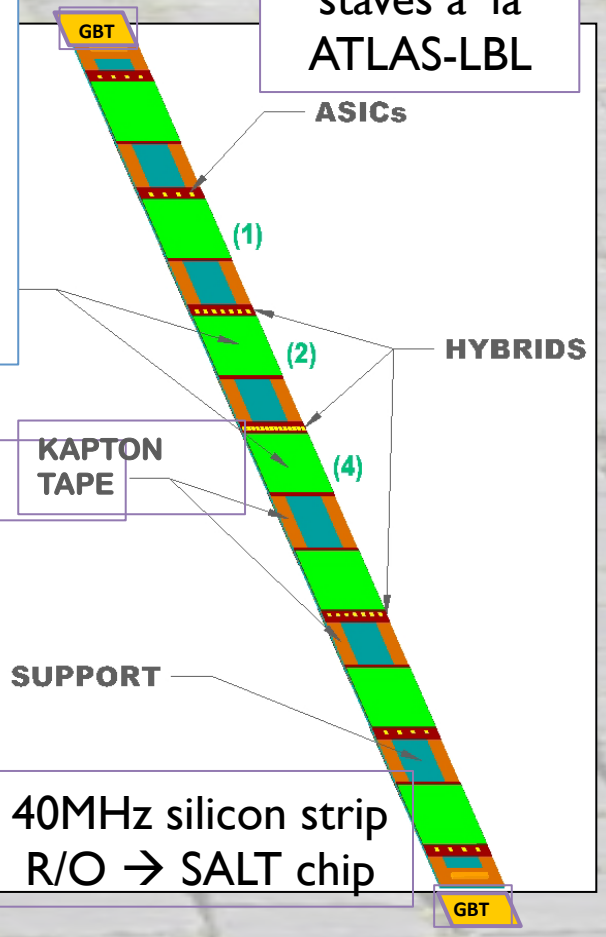
Silicon strip detector

adapt segmentation to varying occupancies (out → in-side):

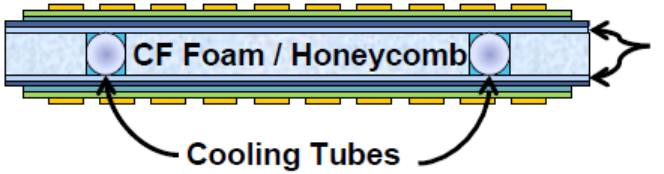
- 10→5 cm long silicon strips
- 180 → 90 µm pitch
- *p-in-n* → *n-in-p*



staves a' la ATLAS-LBL

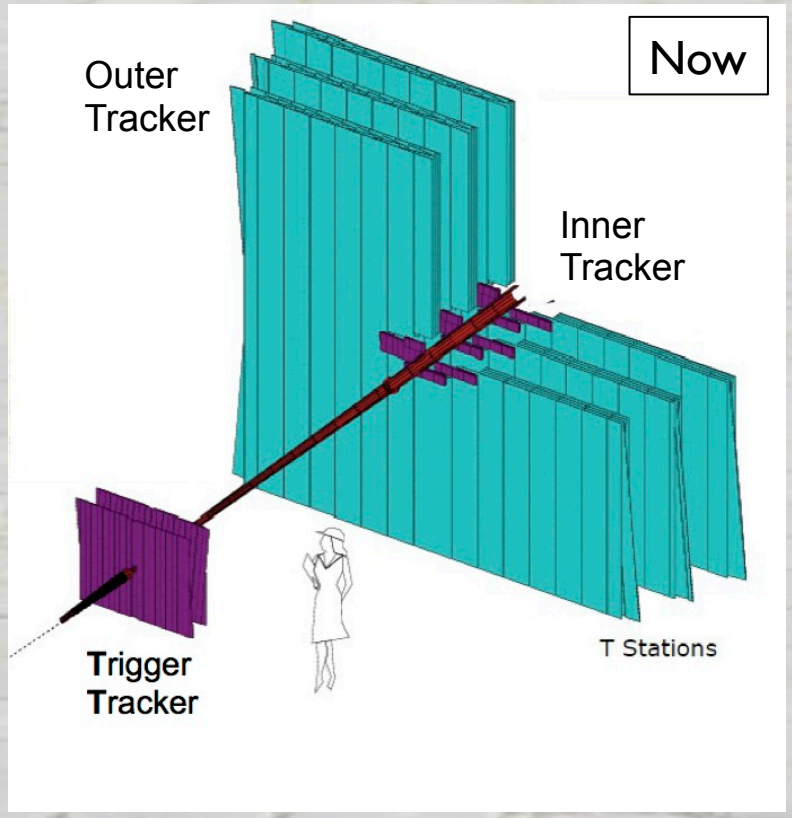


40MHz silicon strip R/O → SALT chip

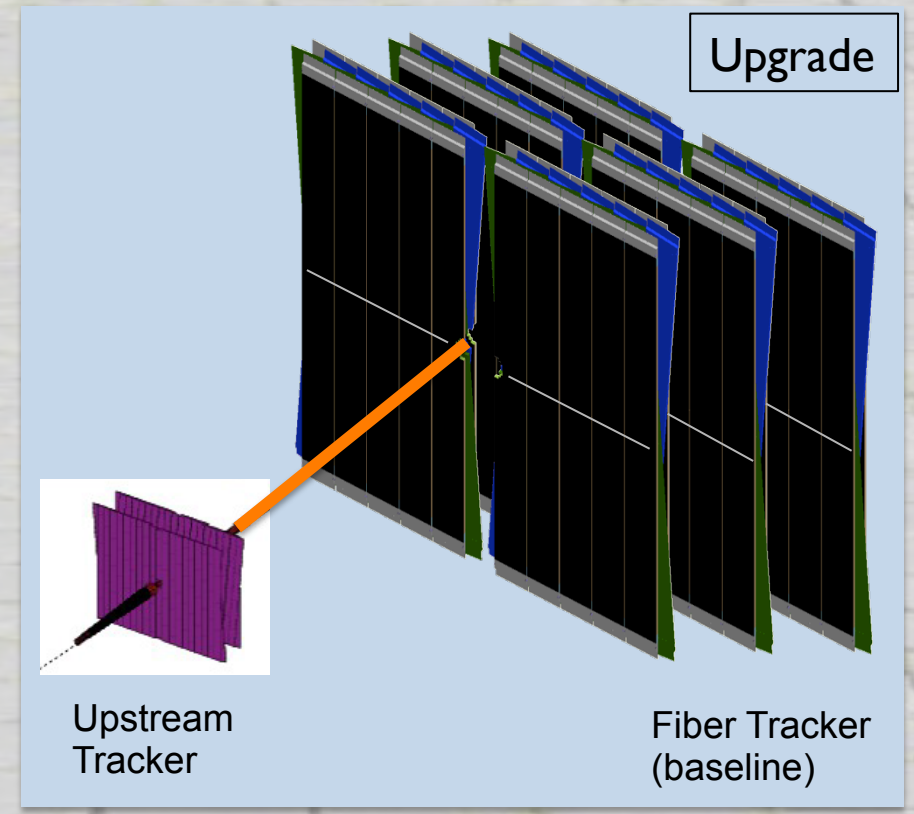


Technical Review in November
→ TDR ready by March 2014

Tracking



HLT 1 MHz – 40 ms/ev



Target: HLT 40 MHz – 16 ms/ev

How to achieve the upgrade target ? Note: events at the upgrade are more complex

- More powerful farm (x10)
- Faster tracking (combination of VELO pixel+UT+FT information)

Preliminary results show this target is reachable with very low rate of fake tracks (comparable to the amount we have now)

Downstream Tracking: Sci.Fi. Tracker

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

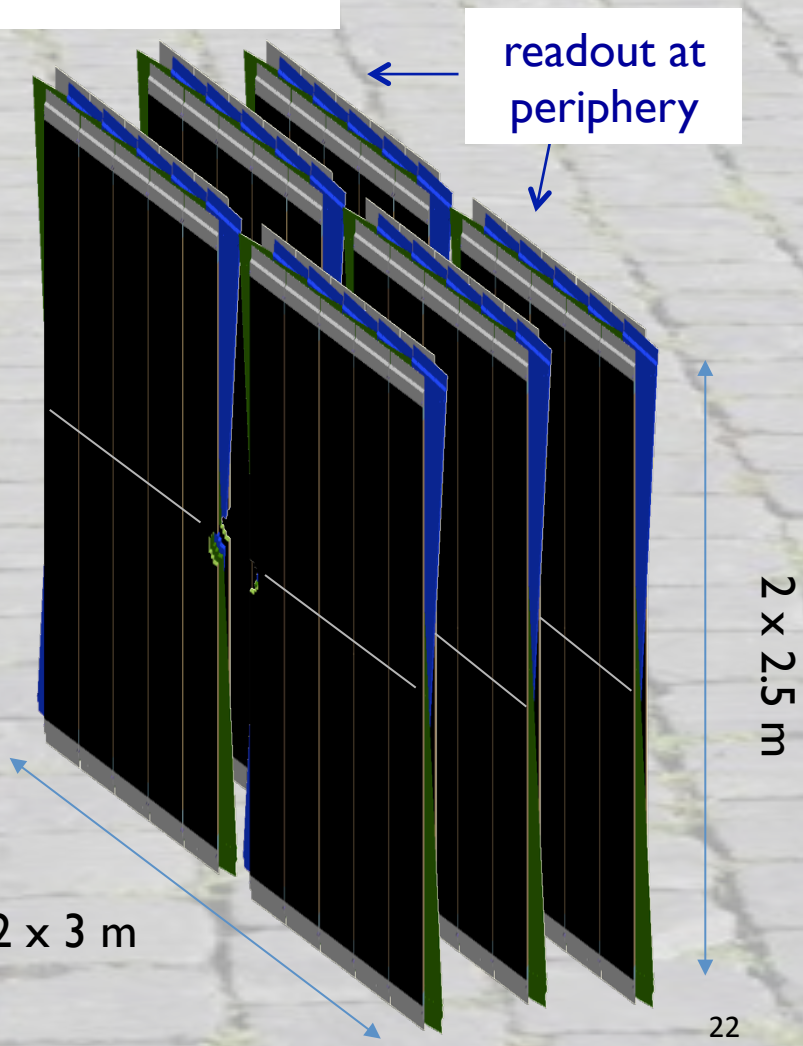
Challenges → radiation environment
ionization damage to fibres → tested ok
neutron damage to SiPM → operate at -40°C

Benefits of the SciFi concept:

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

Technical Review in November
→ TDR ready by March 2014

Straw tubes + enlarged Silicon Inner Tracker kept as a backup solution

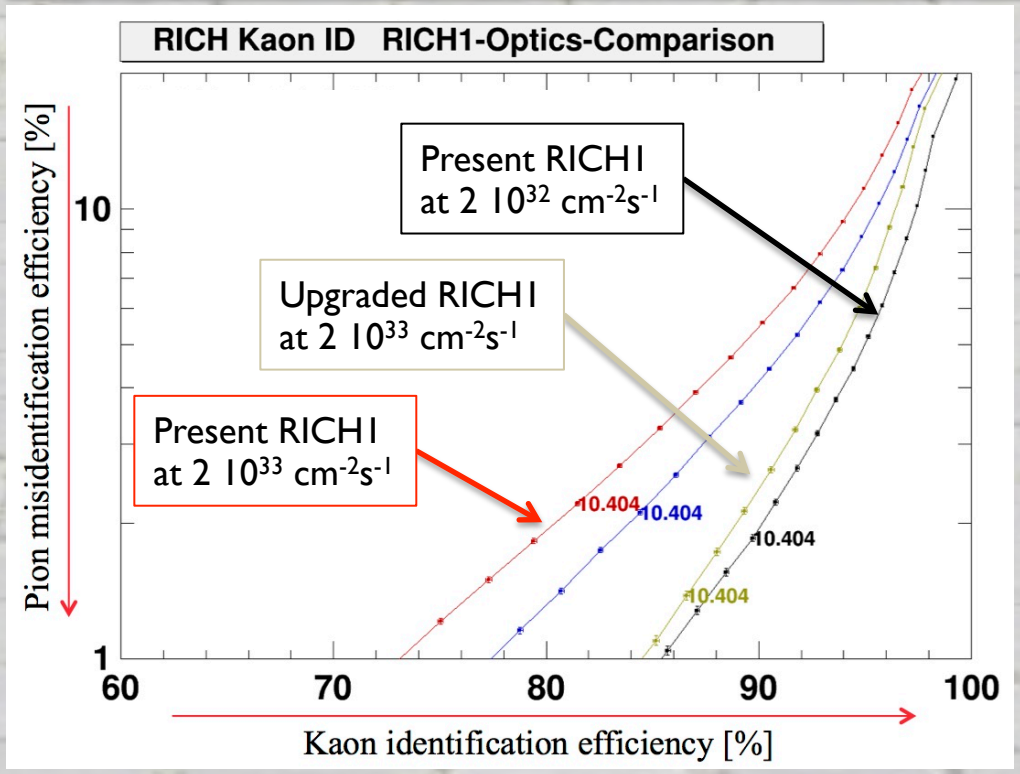


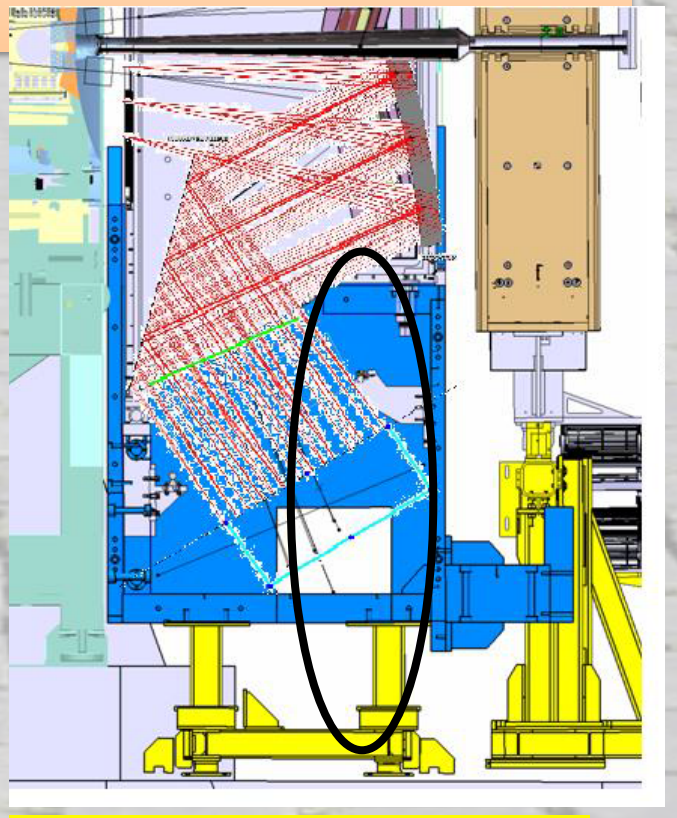
RICH upgrade

Technological choice: RICH1 with new optics - RICH1&2 with new FEE, new MAPMT

- Performance at 2 10^{33} $cm^{-2}s^{-1}$ is close to that now at 2 10^{32} $cm^{-2}s^{-1}$
- Reduced impact on LHCb mechanics
- Fits in LHCb tight installation schedule
- Minimize risk (TRIDENT was a completely new layout)

Optimization of the optical path (RICH1)
Optimization in no. of PMs (use of lenses in RICH2)



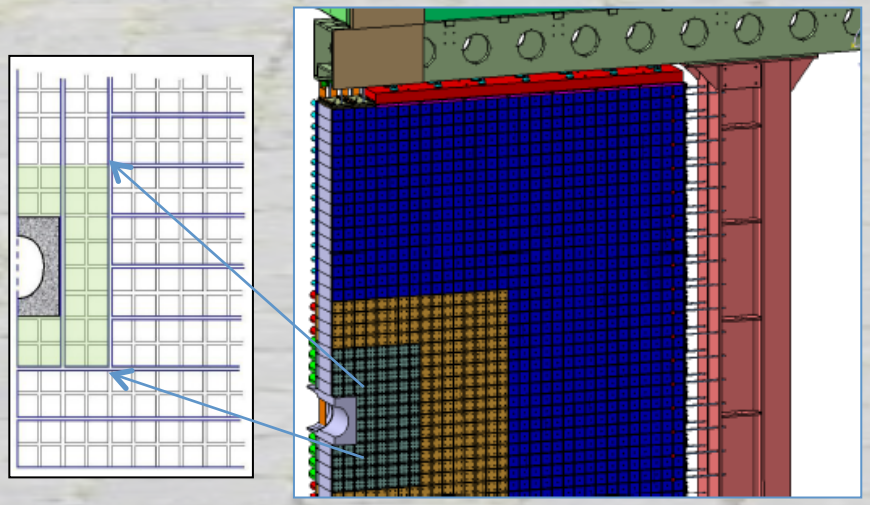


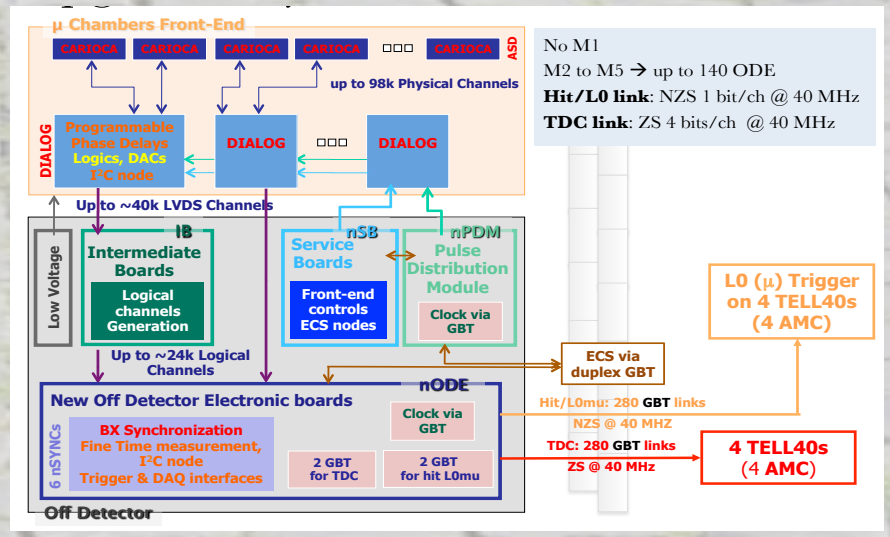
→ TDR ready by Nov. 2013

CALO

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

→ TDR ready by Nov. 2013





MUON

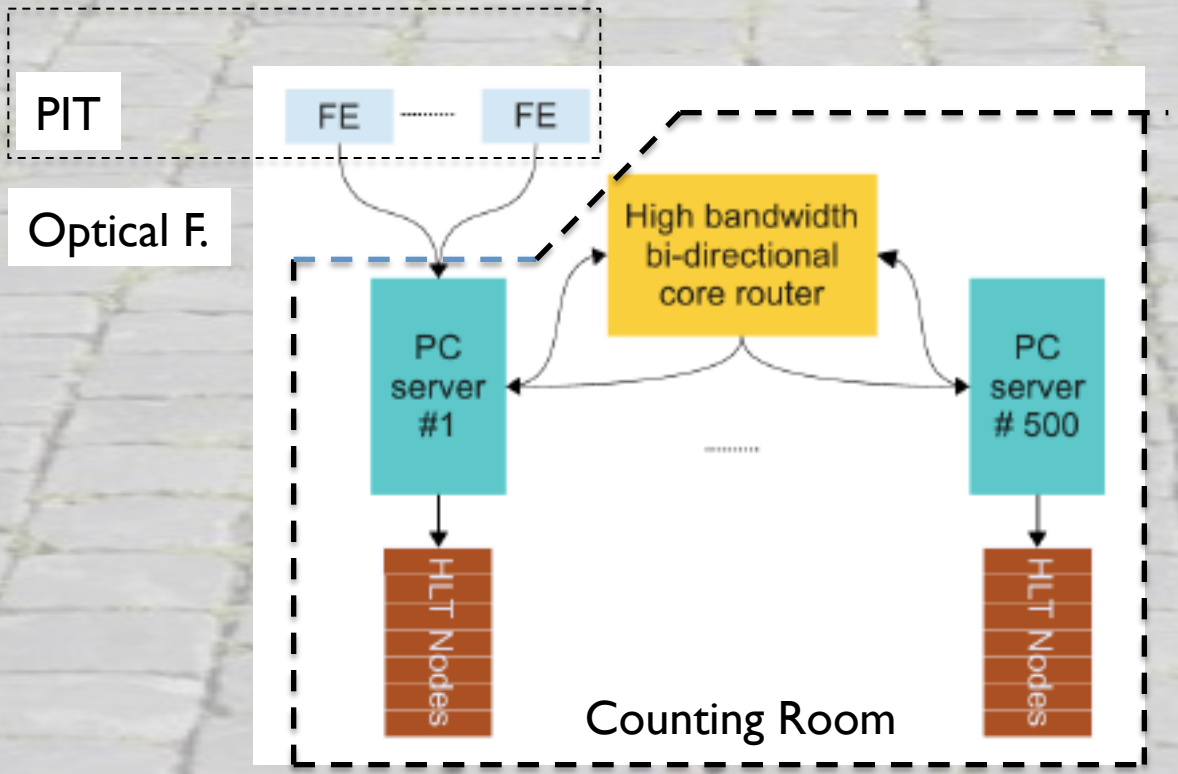
- Removal of M1 (due to occupancy) and more shielding
- New off-detector electronics for an efficient readout via TELL40
- Production of spare detectors for installation in hottest regions
- Smaller size logical pads could be necessary at high luminosity (not in baseline solution) but foreseen as extension of present layout (+R&D on GEM and MPWC)

→ TDR ready by Nov. 2013

Electronics & Data Processing

Intense R&D since last RRB

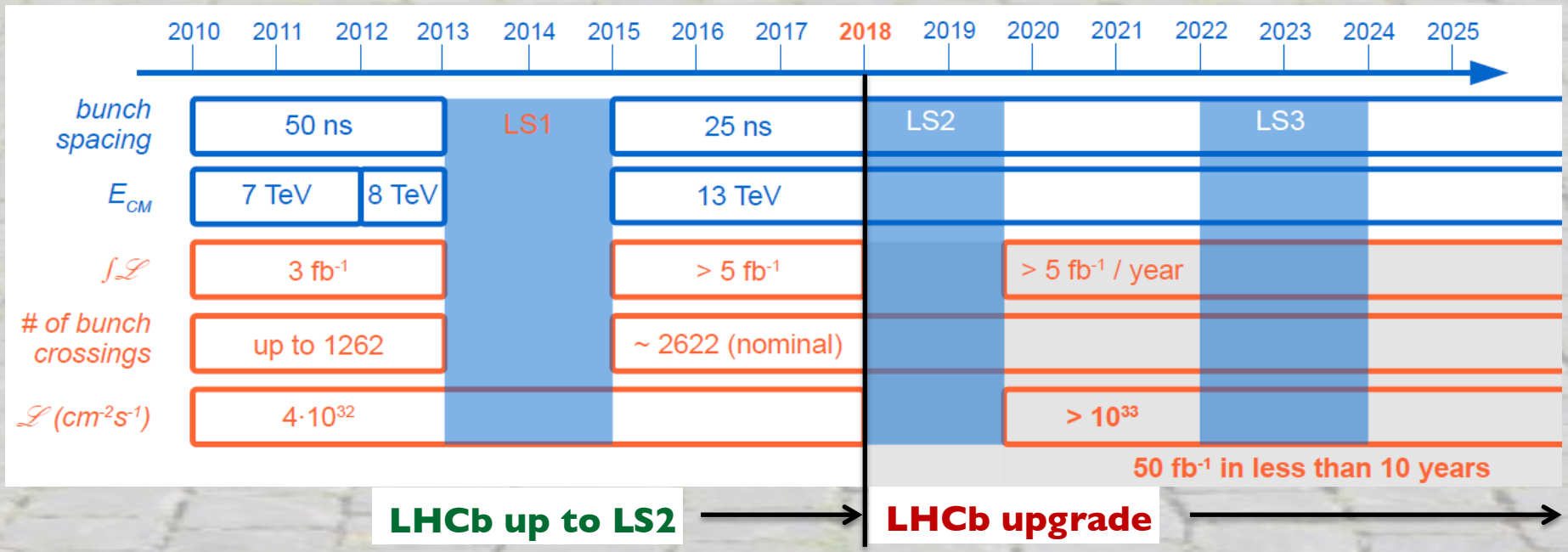
- Readout board projects very well advanced
- Proposal to have an event builder based on commercial components (PCIe + PC = "uniform event builder") and on cheaper network
- Intense work on trigger, on tracking and on simulation of upgraded LHCb



The new architecture allows a full bandwidth for data (40 MHz from "downstairs" to "upstairs"), and an efficient and lower cost event builder

Event fragments are "assembled" on PC servers and sent directly to HLT farm nodes

Expected evolution of luminosity in LHCb



LHCb up to 2018 → ~ 8 fb^{-1}:

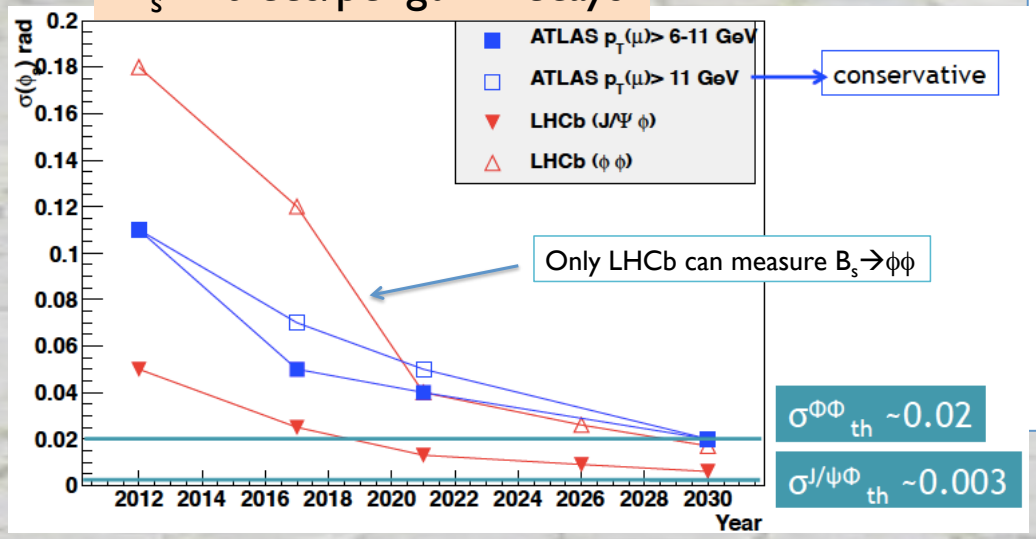
- find or rule-out large sources of flavour symmetry breaking at the TeV scale
- after LS2, increase in precision will be limited (and slow)

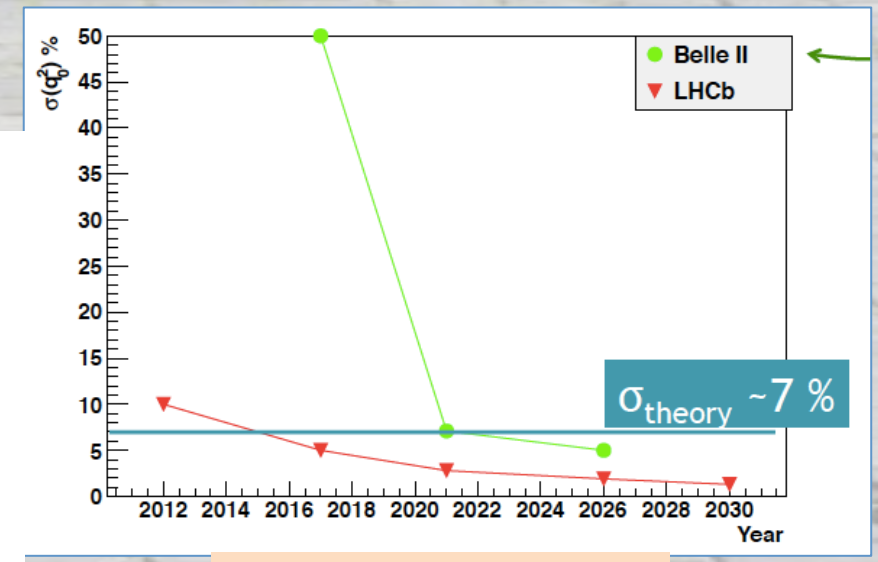
LHCb upgrade → ≥ 50 fb^{-1}:

- increase precision on quark flavour physics observables
- aim at experimental sensitivities comparable to theoretical uncertainties
- reinforce LHCb as a general purpose forward detector

Four physics cases (from Aix-les-Bains ECFA workshop)
(or the importance of doing flavor physics at LHC soon)

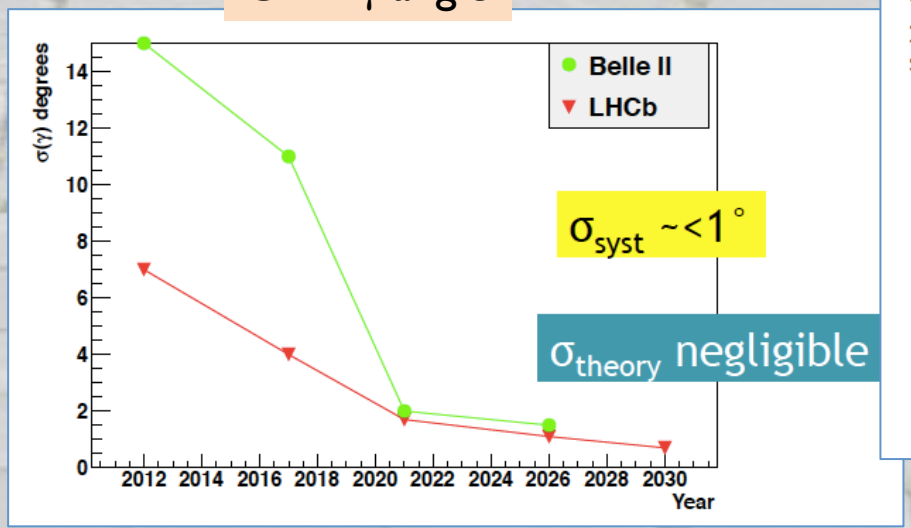
Φ_s in trees/penguin decays

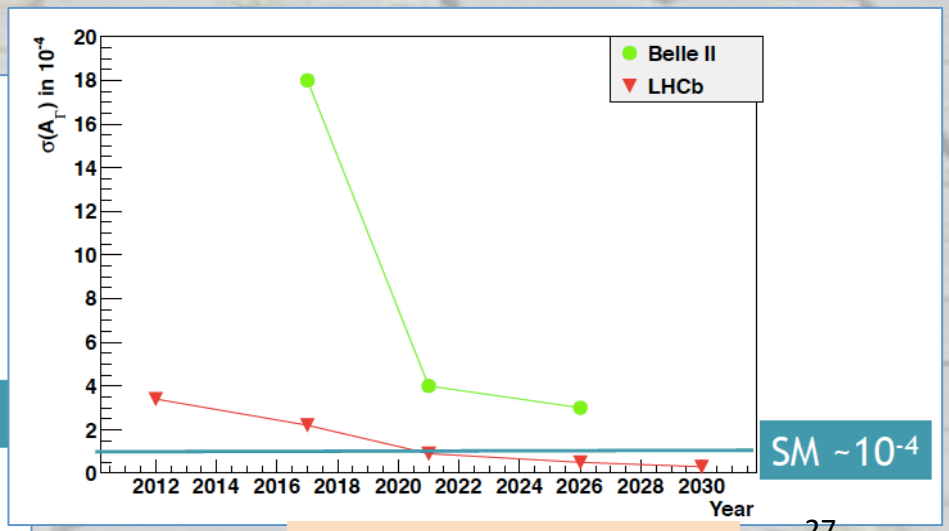




A_{FB} in B→K*ll decays

CKM γ angle





CPV in charm decays

LHC schedule

- Present schedule (baseline)

2015-16-17	RUN2
~JAN 2018	LS2 (14 months)
2019-20-21	RUN3
2022-23	LS3 (30 months)
2024-25-26	RUN4

- "Delayed baseline"

2015-16-17-18	RUN2 (including a longer stop in winter 16/17)
~SEP 2018	LS2 (18 months)
2020-21-22	RUN3
2023-24	LS3 (>30 months)
2025-26-27	RUN4

From the schedule it is evident we cannot wait LS3 for the upgrade (delay of 5 years in the start of 40MHz data taking)

- 18 months installation time during LS2 is mandatory
- a later start of LS2 would be advantageous for LHCb (for contingency in construction and for funding availability)
- a further delay of the start of LS2 beyond 2019 would be disfavoured

LHCb timeline

2011 - LoI submitted: encouraged by the LHCC to proceed to TDRs

2012 - "Framework TDR" with costing (~57 MSF envelope) and technical options submitted. Endorsed (LHCC) & approved (RB: *"LHCb upgrade approved to be part of the long-term exploitation of the LHC"*)
Submission of Addendum to MoU for Common Projects

2012/13 - R&D towards technical choices

2013/14 - Technical Design Reports & MoUs of sub-systems (updated costs still within the envelope of the FTDR)

2014 - Prototype validation & Engineering Design Reviews

2014/16 - Tendering & serial production

2016/17 - Quality control & acceptance tests

2018/19 -18 months installation during LS2

CERN-LHCC-2011-001

We are here

CERN-LHCC-2012-007

Cost estimate from FTDR (CORE)

	Sub-detector	Option	Cost (kSF)
Tracking Systems	VELO	Pixel	5400
	Upstream Tracker	Strips	6200
	T-stations with fibers + OT		9860
	T-stations with IT + OT		11200
Particle Identification	RICH		9400
	Calorimeters		1900
	Muon System		1800
Trigger & Readout			1800
Common Projects	Infrastructure		2500
	Common Electronics		2500
	Online Systems		10670
Reserve for 2 10^33 cm-2 s-1			3500
TOTAL COST (depending on options-15% contingency included)			**55000-57000**

Updates since FTDR

New estimates (preparing the TDR) show costs within original FTDR envelope (VELO, UT, RICH, CALO, MUON, Trigger, Common Funds)

Particle identification systems (at current costs) optimized to stand up to 2 10^{33} $cm^{-2}s^{-1}$

The choice of a full Fiber Tracker will cost MORE than the current option – but will perform much better, reducing the time needed for tracking (effect on farm size)

The reorganization of readout boards and of related network will allow savings on the detectors, and the construction of an online system capable of reading out at 40 MHz on day one

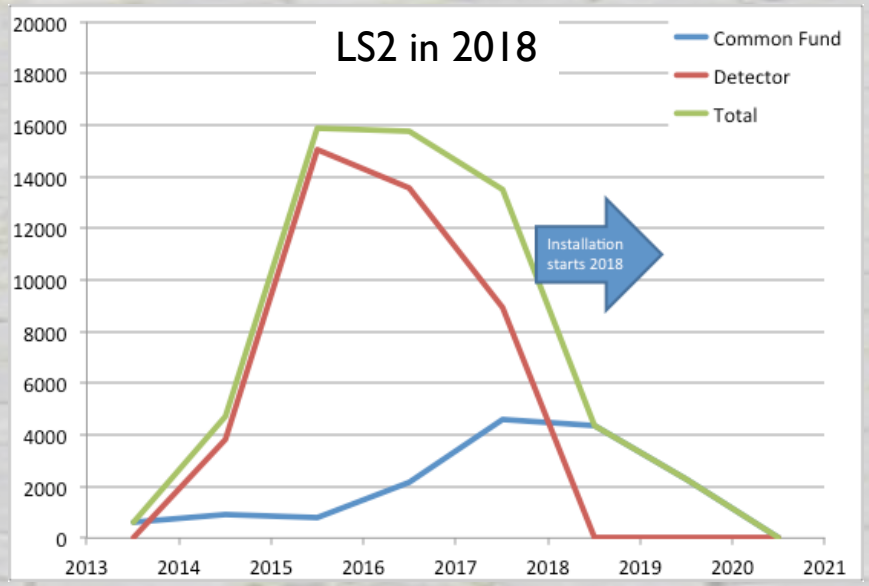
We are still working on optimization, especially the for funding profile (easier if LS2 is delayed by ~one year)

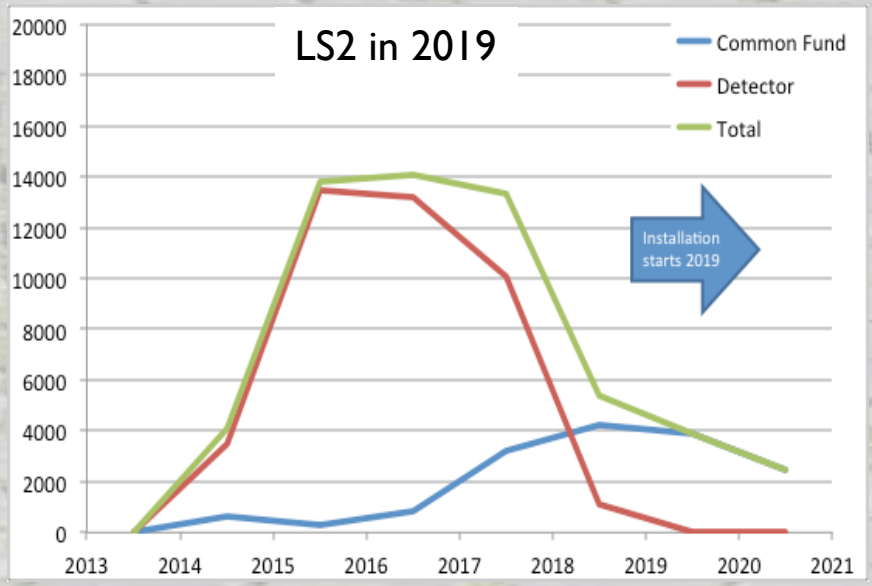
Main message:
We should be able to build a better LHCb upgraded detector , at *basically* the FTDR envelope cost of 57 MSF

This is a preliminary estimate – to be finalized with TDR submissions

Funding requests & spending profile

- Requests to FAs sum to ~60 MSF (in line with the cost of the upgrade)
- Positive informal feedbacks from several FAs
- Expected to get at least 80% by the time of installation (some CF expenditures can be delayed beyond detector installation)





For the spending profile, two scenarios considered:

- LS2 starting in 2018 or LS2 starting in 2019

These estimates are related to a fully financed or pledged detector (~57 MSF) in the period 2014-2020

Our road map to the effective start of LHCb upgrade

(LEGENDA : Addendum MoU for CF – TDRs – Addendum MoU for TDRs)

- TDRs will define the cost of single subsystems and the sharing of responsibilities >> ready by March 2014
- Add. MoU for TDRs will define the cost sharing among institutes >> drafts ready by April 2014 RRB
- Add. MoU for CF must be signed to allow the real start of the LHCb upgrade (sharing of common funds based on # of PhD authors) >> ready since last RRB, signing procedures to be initiated in the next RRB

This complicated path has to be finalized by ~ April 2014

We cannot wait any longer ! We must soon enter into investment phase to avoid the risk of not meeting the LS2 deadline

Collaboration matters

- Milano (INFN and University "Statale") group: interested in charm physics, tracking and in the upgrade of the UT detector (full member)
- Kurchatov Institute (Russia) group: interests in core software and in technical work for Sci.Fi. Tracking option (associated to ITEP Moscow)
- Valencia group: interests in B radiative decays, calorimetry (present and upgraded) (associated to Barcelona)

Still few individuals from ex-SuperB project are joining existing LHCb groups

LHCb now:

- 65 institutes from 17 countries (54 institutes at beginning of 2011 +20%)
- 669 authors (were 545 at beginning of 2011 +23%)

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

P. Koppenburg (NIKHEF) is the new physics coordinator starting Jan 1st , 2014

Conclusions

LHCb is full steam analyzing the ~ 3/fb in (pp) and ~ 2/nb (pA) in LHC Run 1

LHCb paper production greatly enhanced in 2013. Hope to continue like this

LHCb has several world best results on a variety of measurements : ϕ_s , Δm_s , $B_{(s)} \rightarrow \mu\mu$ and rare decays , γ , penguin decays, D-D mixing , CPV in charm, …
and it is contributing in New Physics searches (together with ATLAS/CMS)

LHCb is preparing 2015 with a lot of activities in the pit and outside to improve our physics reach already in Run2 with very interesting perspectives

In the "Post Higgs Depression" era (PHD syndrome*), the ***LHCb*** upgrade will contribute significantly to a full exploitation of the LHC and to increase the opportunities of New Physics discovery

Several upgrade milestones achieved: entering TDR time – and let's start the upgrade !

Above points not achievable without the support from ***LHCb*** Funding Agencies (thanks!)

*Quote from S. Dimopoulos