The upgrade of the LHCb detector

LHC France - Annecy

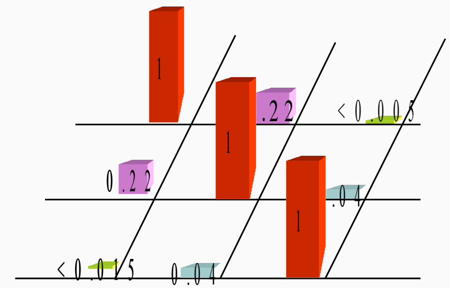
Frédéric Machefert
On behalf of the LHCb collaboration

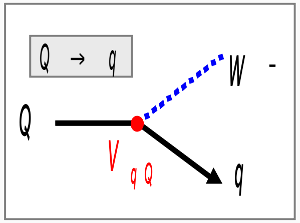
Laboratoire de l'Accélérateur Linéaire, Orsay

Flavour physics

- Flavour physics is the study of the interactions between the quark or lepton families
  - In the Standard Model, the transitions are mediated by the weak interaction
  - The CKM matrix contains the couplings between quarks

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \hat{V}_{CKM} \cdot \begin{pmatrix} d \\ s \\ b \end{pmatrix} \qquad \hat{V}_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$





- Ideal field to look for new physics :
  - Drastic constraints from SM on CP violation (originates in SM from a phase)
  - Many processus are suppressed in the SM
    - The NP contributions could potentially be relatively large wrt SM
      - Example of a FCNC-ΔB=2 transition

NP couplings

Relative NP effect $\left| \frac{Q^{NP}_{\Delta B=2}}{Q^{SM}_{\Delta B=2}} \right| \leqslant r \quad \rightarrow \quad \frac{|\delta_{bq}|}{\Lambda_{eff}} \leqslant \sqrt{r} \frac{|V^*_{tb} V_{tq}|}{M_W}$

NP mass scale

If the couplings are not too defavorable, can look for heavy particles

Direct and indirect searches

- No sign of any new physics
  - A boson looking like a Higgs Boson has been observed at m ~ 125GeV/c^2
- If the collision energy is sufficient
  - Possibility to produce directly new particles
    - What is done on ATLAS and CMS at LHC
- If the precision is good enough
  - Possibility to see new physics by its indirect effects
    - New virtual particles in loops
  - LHCb is built for this type of search
  - Precision measurement can reveal NP far beyond the TeV scale
  - Natural domain for those precision measurements
    - CP violation
      - Strong constrains from SM
      - Many observables that depend from a few parameters
    - Rare decays
- High complementarity between direct searches and indirect searches

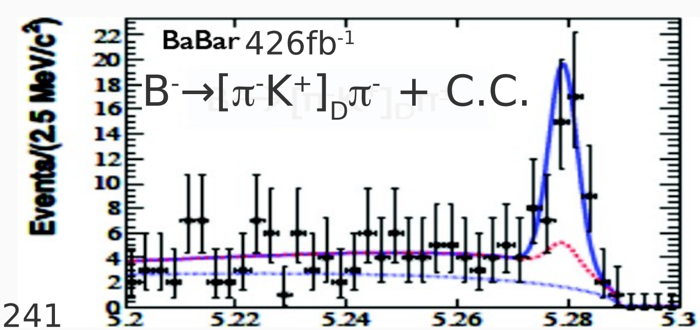
B physics on a hadronic collider

- Common prejudice :

Lepton collider	↔	Precision measurement
Hadronic collider	↔	New particle discovery

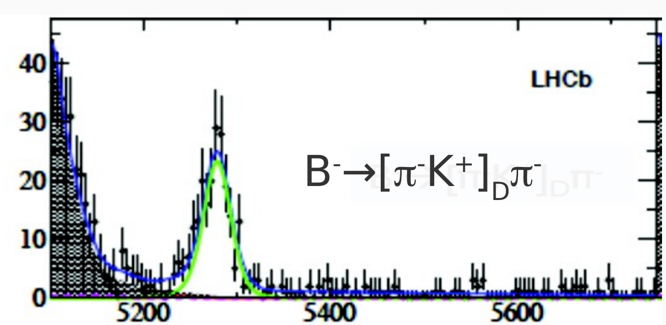
?

- This was reviewed by Tevatron and now by LHC
  - CDF/D0 : W boson mass measurement, flavour physics, Δms
- Leptonic collider (B factory)
  - Collision energy constraint
  - Potentially very high luminosity ($10^{34} - 10^{36}$ $cm^{-2}.s^{-1}$)
  - Better tagging of the flavour of the B (x10)
  - But only $B_{d,u}$ are produced at the $\Upsilon(4s)$
- Hadronic collider
  - Very large cross-section $\sigma_{bb}(LHCb - 7\text{TeV}) \approx 3\times10^5 \sigma_{bb}(\Upsilon(4S))$



ArXiv:1006.4241

Energy-substituted mass (GeV/



1.0fb-1

ArXiv:1206.3662

Invariant mass (GeV/

The upgrade of the detector

- The Standard Model is already precisely tested
  - We have to look for tiny effects
  - If NP is seen before 2019
    - Flavour physics and rare decays will give precise indications on its nature and its properties
  - If not
    - Reduce the uncertainties on CKM angles to the theoretical level (1°)
    - Look for rare decays that cannot be tested yet
      - Example : $B_d \rightarrow \mu\mu$
        - Valuable informations on Minimal Flavour Violation

- Both situations require more statistics → upgrade of LHCb
  - Increase the instantaneous luminosity up to 2×10^{33} $cm^{-2}.s^{-1}$
  - Increase the trigger efficiency
    - Overall increase by a factor 5 for muon channels
    - Overall increase by a factor 10 for hadronic channels
      - This is mainly allowed by a new trigger
        - Remove L0 (hardware), new fully software trigger
  - Reach $L_{integrated}$=$50 fb^{-1}$

Important channels for the upgrade – status in 2018

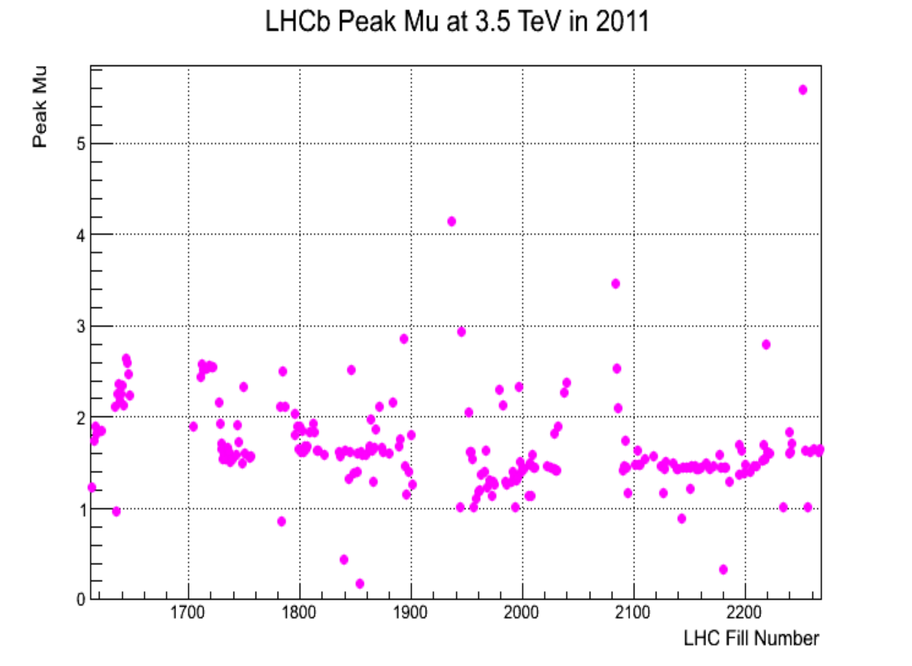
- $B_{(s)}^0 \rightarrow \mu\mu$ (see talk by Mathieu on April 5th)
  - $B_s \rightarrow \mu\mu$: precision Br~1.5×10^{-9} → 2018 : 0.5×10^{-9} (theory 0.3×10^{-9})
  - $Br(B_d \rightarrow \mu\mu)/Br(B_s \rightarrow \mu\mu)$ not measured in 2018 (theory ~5%)
- $B^0 \rightarrow K^{*0}\mu\mu$ (see talk by Marie-Hélène on April 5th)
  - Precision on q^2_0 : 25 % → in 2018 : 6 % (theory 7%)
- CP violation in the mixing B_s^0 : $B_s^0 \rightarrow J/\psi\ \phi$ (see talk by Olivier on April 3rd)
  - Precision on ϕ_s : 0.1 → 0.025 in 2018 (theory ~0.003)
- CKM angle γ (tree decay) : $B \rightarrow DK^{(*)}$
  - Precision γ : 12° → 4° (theory < 1°)

(see talk by Alexandra on April 3rd and poster from Alexis – panel 31)

- CP Violation in the D sector
  - Precision ΔA_{CP} : $2.1\times10^{-3} \rightarrow 0.65\times10^{-3}$

Expected running conditions

- Instantaneous luminosity expected to reach $10^{33}cm^{-2}.s^{-1}$
  - Sub-detectors are expected to sustain up to $2x10^{33}cm^{-2}.s^{-1}$
- Collision rate should be 25ns
  - Same rate as after LS1 (>2015)
- The main consequence is the average pile-up increase up to μ=2.5
  - Higher multiplicity
  - Faster aging of the detectors
  - Higher data bandwidth
  - Event reconstruction time consumption
- Running conditions in 2011-2012
  - High pile-up tests have been performed both in 2011 and 2012
  - No important effect on the data quality, the flavour tagging, etc...



- Nevertheless, upgrade of the sub-detectors is requested to work routinely in those conditions. The upgrade of the trigger will also contribute to the statistics increase.

(see talk by S. T'Jampens on April 2nd)

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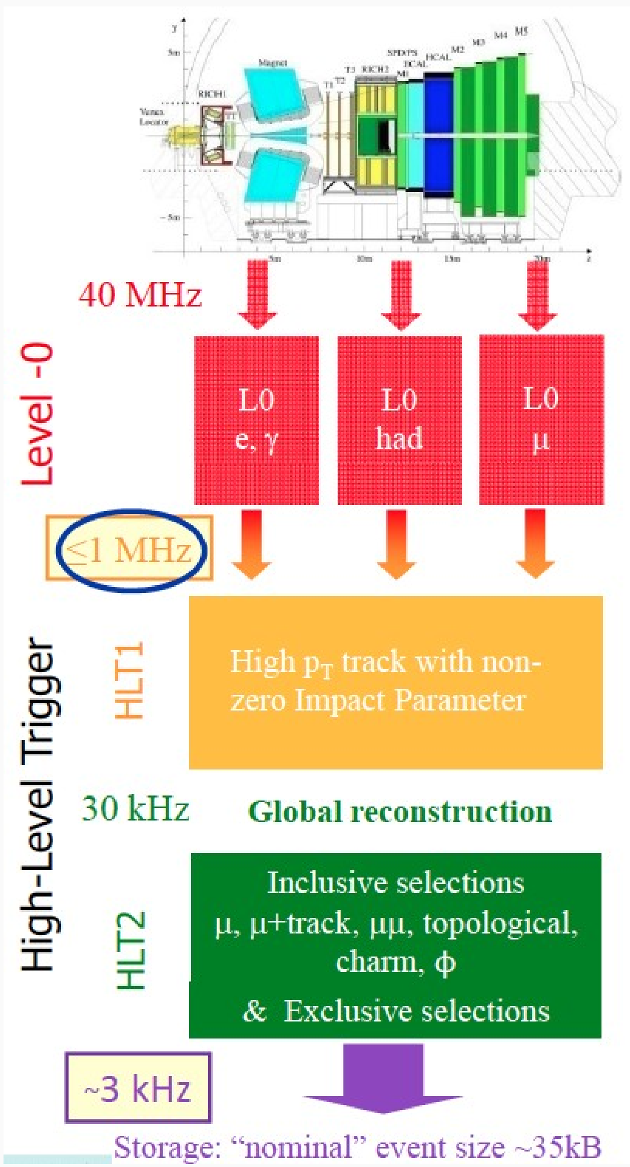
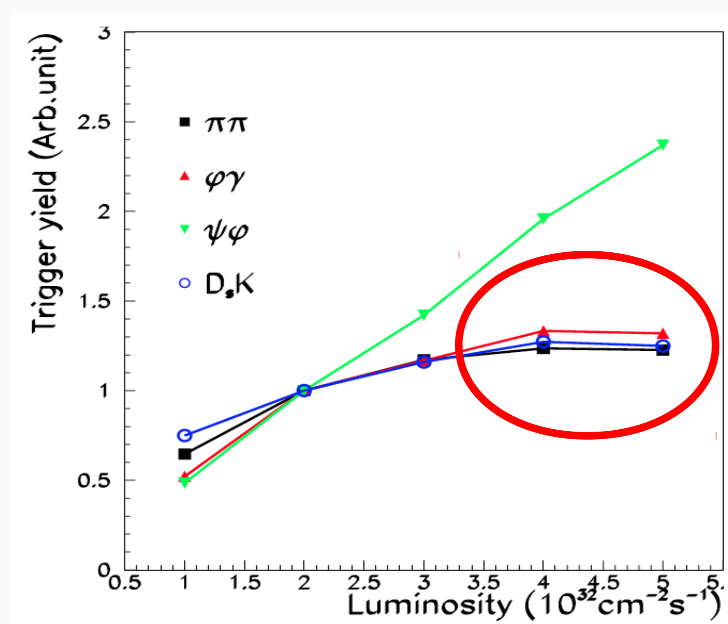
The current trigger

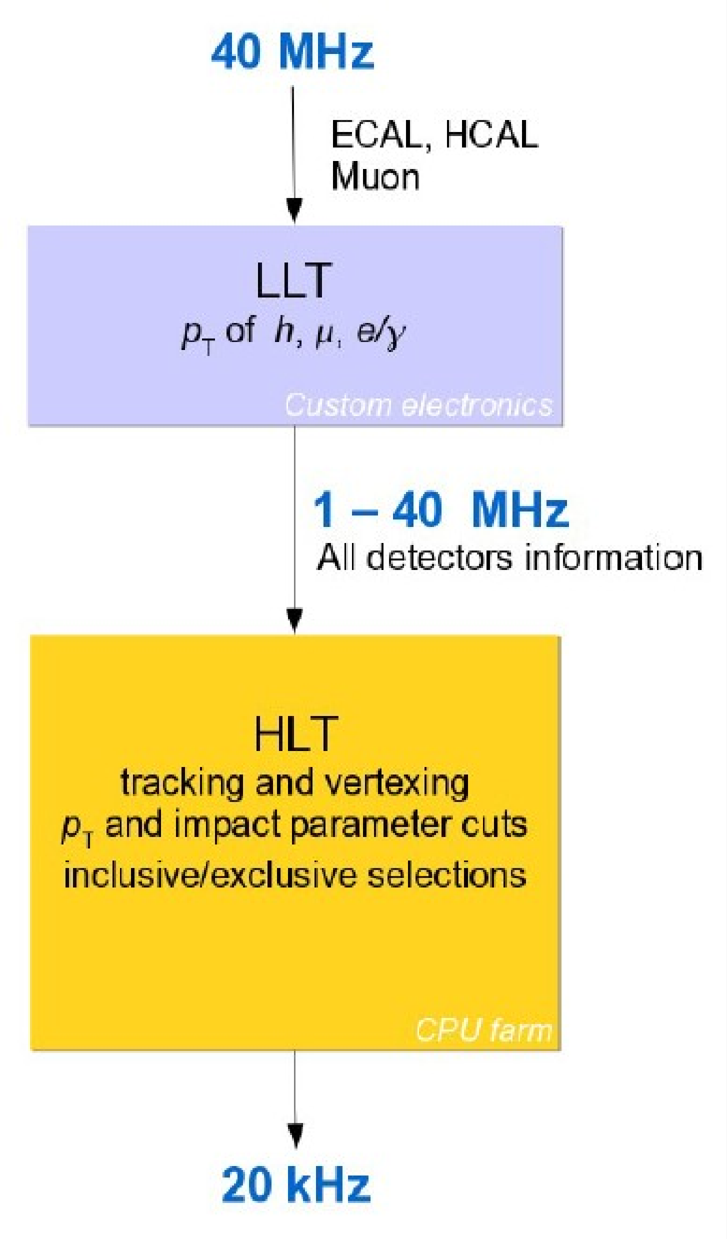
HLT « Trigger software » : 29000 CPU running the same code as the offline reconstruction



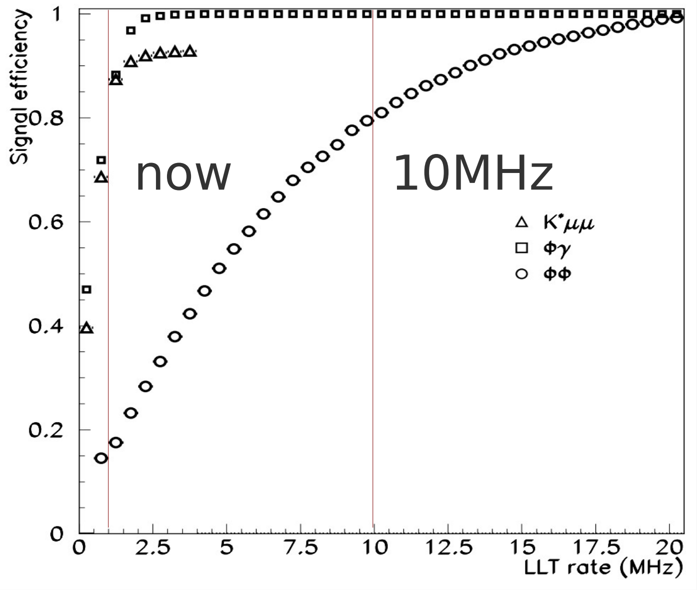
- The acquisition rate is limited to 1MHz
  - Interaction rate (~12MHz) is reduced to 1MHz by a hardware trigger (L0)
    - L0 decision based on
      - High Pt particles (Calo and Muon)
        - Electrons, photons, hadrons
        - Muons
- The 1MHz « bottleneck » is an efficiency limitation for the detector if we want to run at a high instantaneous luminosity
  - Especially for hadronic channels



The upgraded trigger



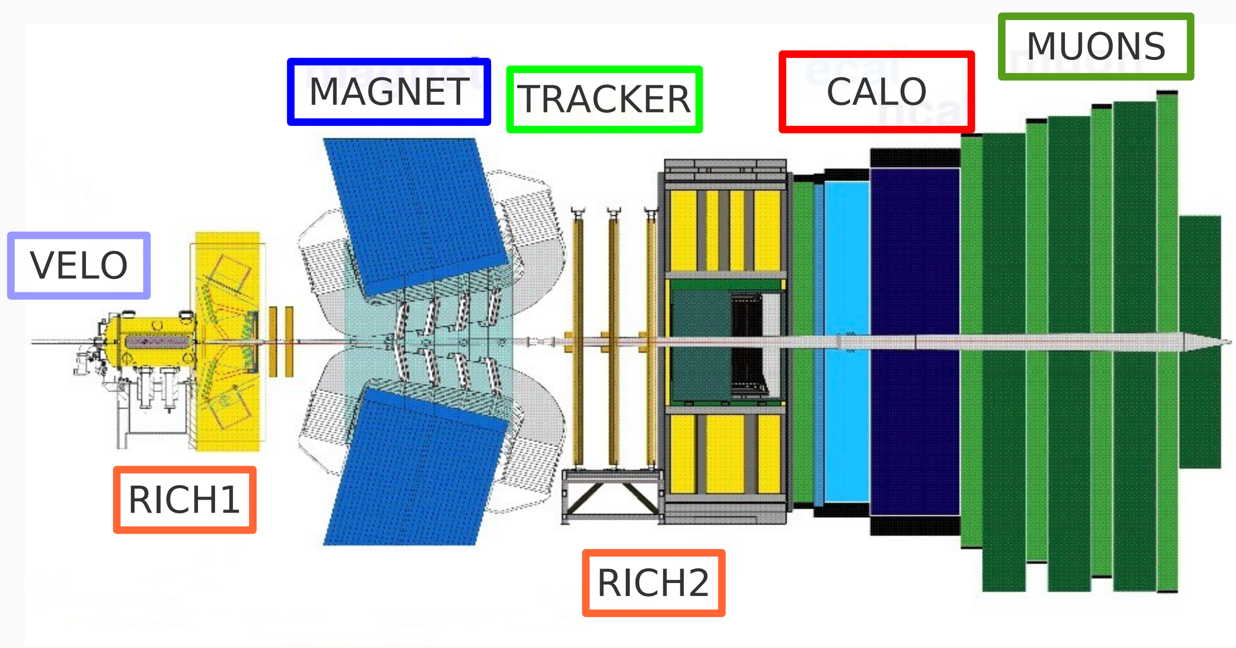
- Remove the L0
  - Fully software trigger
    - efficient : full detector information
    - Flexibility : Can be easily adapted
- Still keep a low level trigger (LLT)
  - Adjust the bandwidth between 1 and 40MHz
  - LLT is similar to L0 with tunable thresholds
    - Progressive increase of the PC farm size
    - Throttling mechanism in case of trouble



Replacement of the front-end electronics and implementation of a 40MHz readout

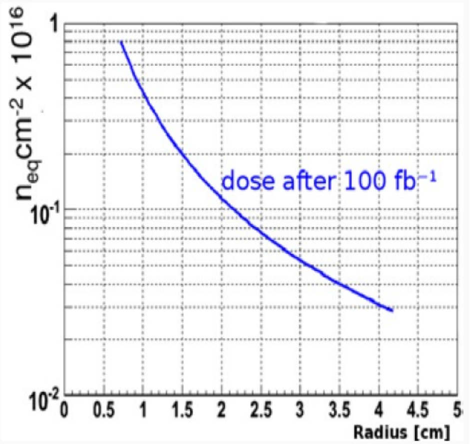
The LHCb detector

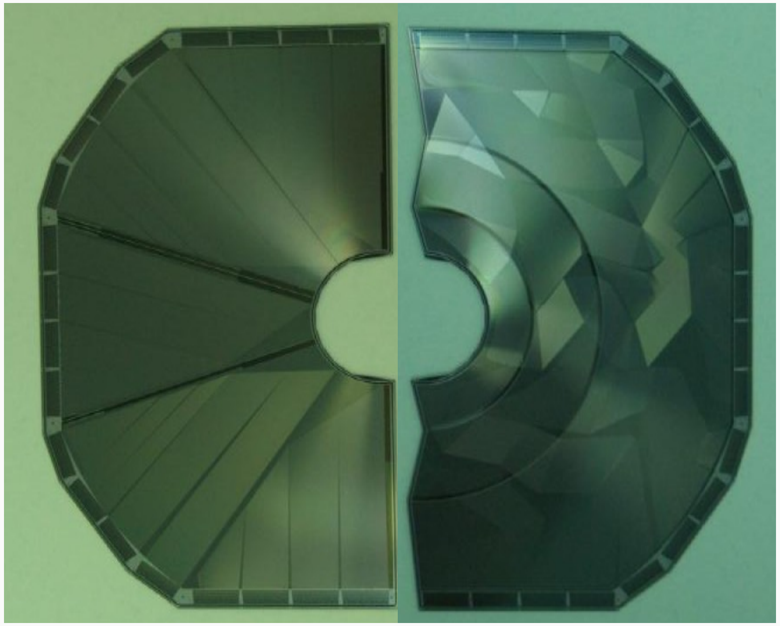
- Vertexing :
  - VELO, 21 (R+ϕ) Si stations
    - Movable at LHC injection, proper time resolution ~ 40 fs
- Track reconstruction :
  - Si TRAKER (close to the beam), straw tubes in the outer, 4Tm B FIELD
    - Resolution ~ $\delta p/p$ of 0.3 – 0.6 %
- Particle identification :
  - RICH1 : Cherenkov detector, C4F10 + aerogel
    - π/K separation in range 2<p<60 GeV/c
  - RICH2 : CF4
    - Range 20<p<100 GeV/c
    - e(K)>95 %, MisId<5 %
  - Calorimeters
    - SPD/PS : scintillators
    - ECAL : shashlik
    - HCAL : tiles
  - Muons
    - MWPC+GEM



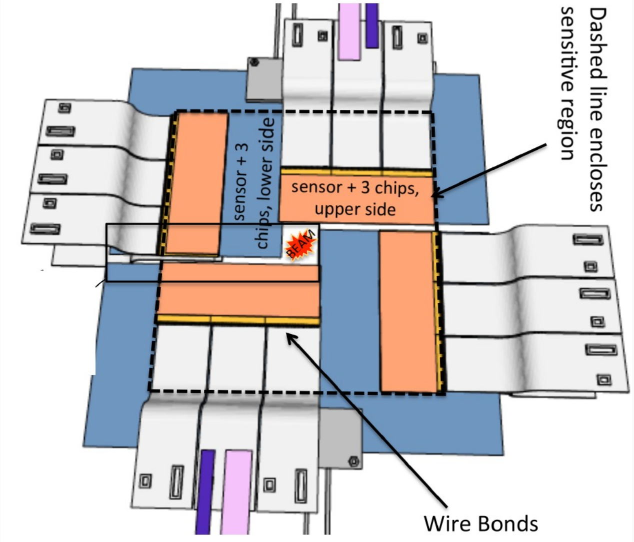
Vertex Locator

- Main concerns with the upgraded design:
  - Withstand the increased radiation level (up to 0.3x1016 $n^{eq}.cm^{-2}$)
  - Reduce material budget
  - Improve the already excellent performances
- 2 options for the upgraded LHCb vertex locator:
  - Upgraded micro-strip detector
    - Geometry very similar to the present one
    - 20% more channels
    - Smaller pitch and thickness



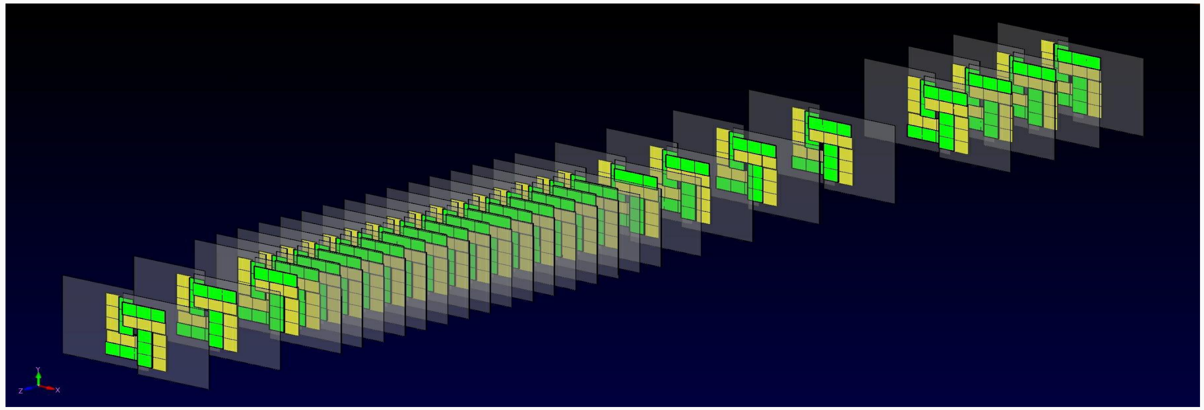


- Pixel detector
  - $55x55\mu m^2$ cells
  - ~780k channels per module
  - 50 modules
    - 40 million pixels...

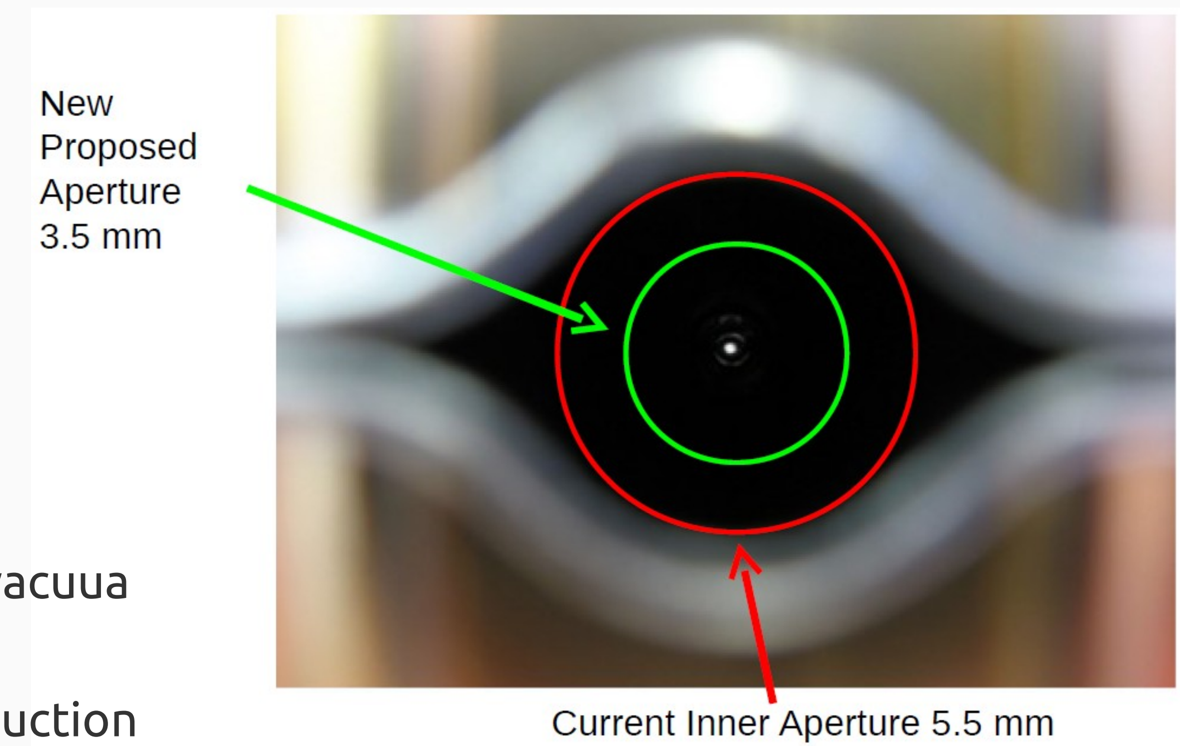


Vertex locator

- Proposed layout of the pixel detector

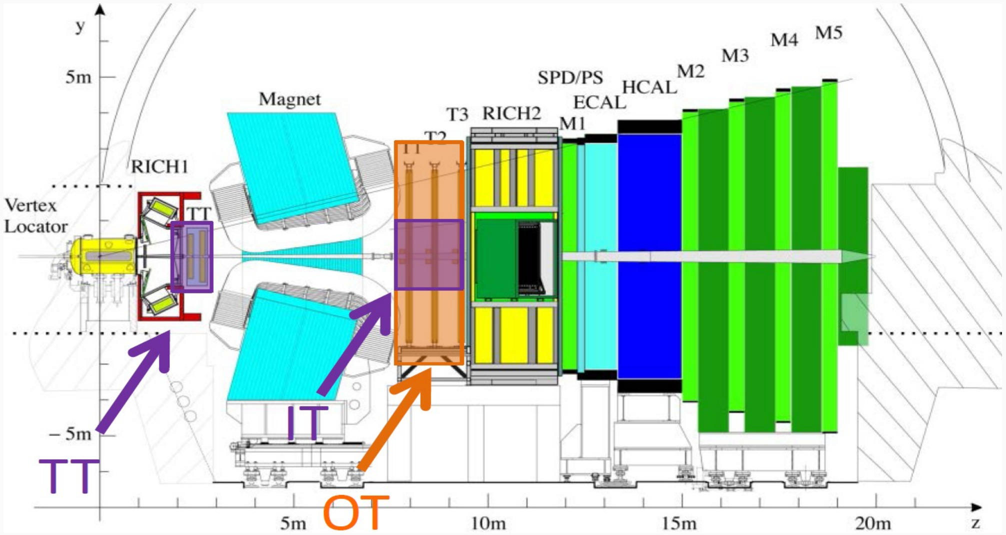


- Improving the impact parameter measurement
  - $\sigma^2_{IP} \sim r^2$
  - The aim is to reduce the inner aperture from 5.5 to 3.5 mm

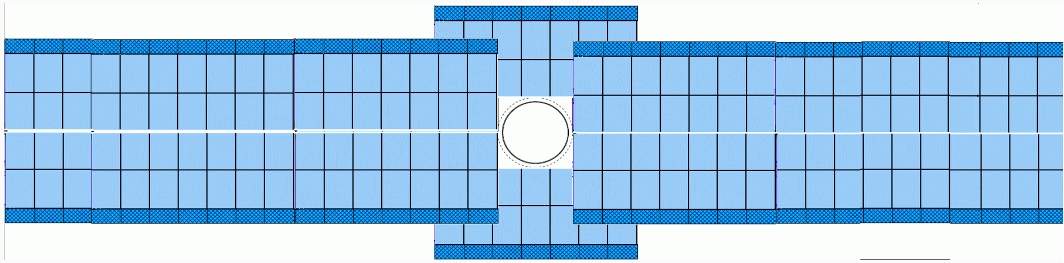


- RF-foil
  - Separates primary-secondary vacuua
  - Guides weakfields
  - Contributes to secondary production
  - New design under study

- Current tracking based on
  - TT tracking stations (Silicon strip)
  - Inner Tracker (Silicon strip)
  - Outer Tracker (straw tubes)

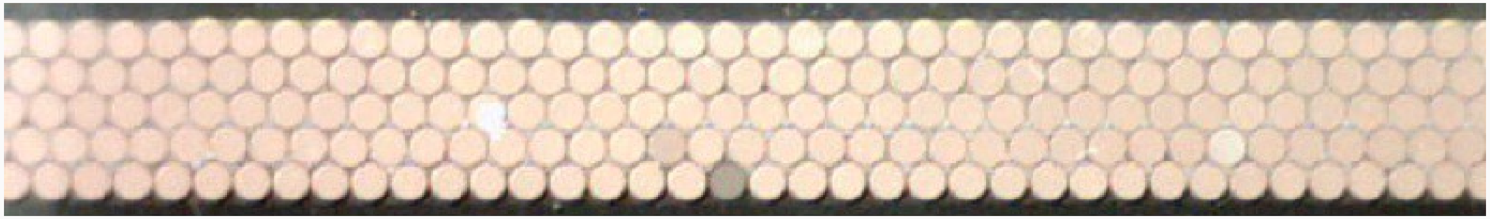


- Upgrade baseline:
- TT stations replaced by similar but slightly improved Si-strip detector
  - Better coverage (overlapping sensors)
  - Getting closer to the beam pipe
  - Less material with thinner sensors
- 2 options for the IT+OT
  - Similar to the current detector, with an increased size Inner Tracker
    - Outer Tracker straw tube is sensitive to spill-over from previous crossing and next crossings (drift time ~40ns)
      - Occupancy driven by cumulative effects of pile-up and spill-over
    - Increase surface of IT by a factor 4 → OT occupancy similar to the present one
    - 4 x more channels, detector thiner and lighter

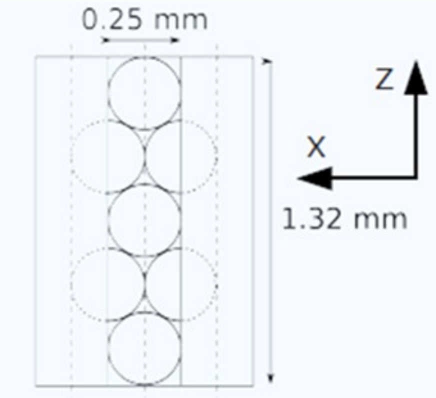


Scintillating Fibers

- Second solution : scintillating fibers



  - 2.5 m long fibers (5 layers per station, diameter of 0.25mm)
    - Readout with SiPM
      - Cells of 0.25x1.32mm^2
  - 3 stations, 4 layers each
  - But less material in the acceptance

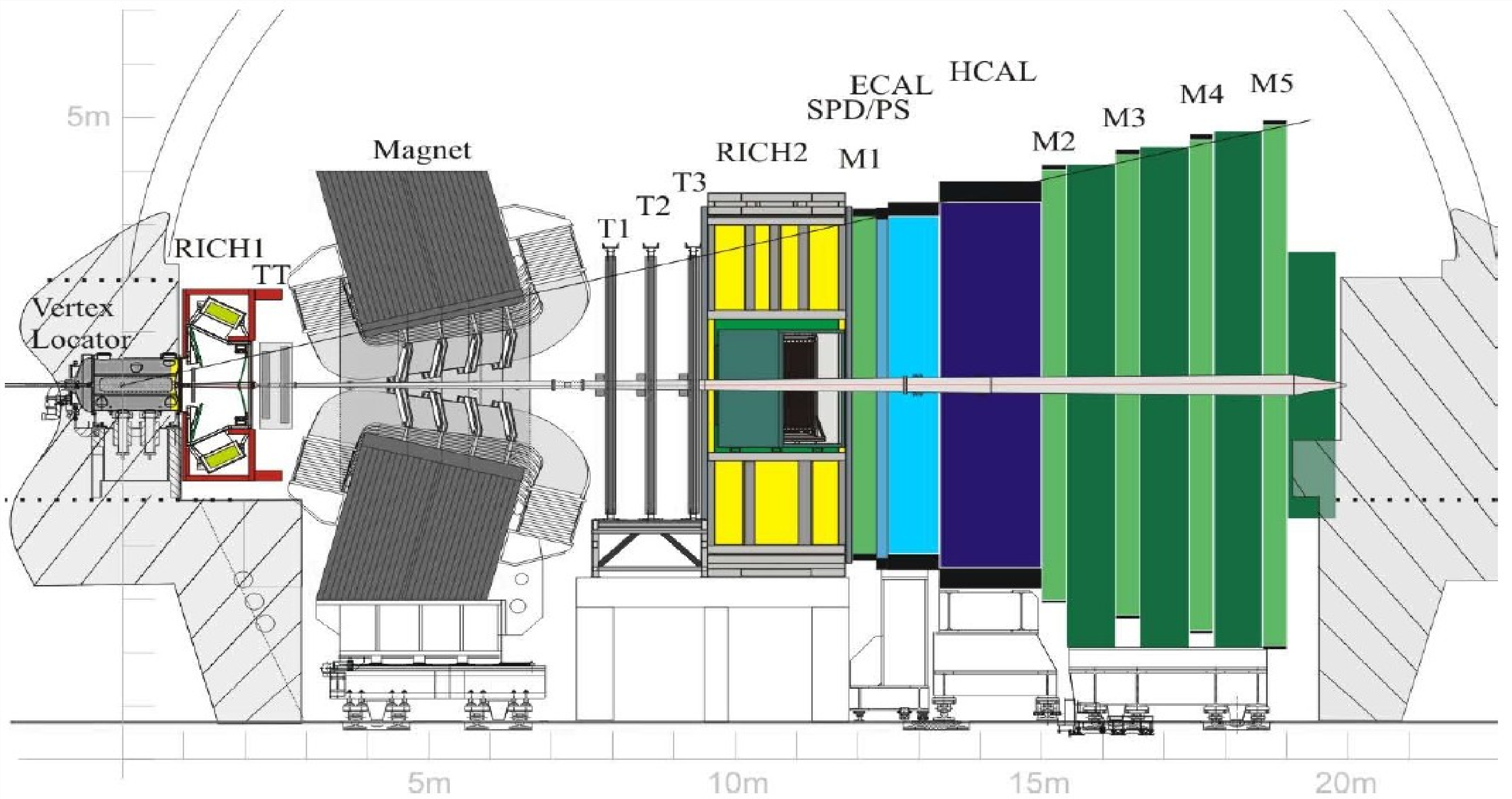


- R&D ongoing to validate this option
  - Radiation hardness of SiPM
    - Need dedicated shielding, low temperature
    - Cluster analysis in the front-end → noise reduction
  - Radiation hardness of the fibres (baseline: multi-clad blue emitting fibres)
  - Accuracy of the mechanics:
    - Fibres have to be kept straight at 50µm and flat at 250µm over 2.5m long

Particle Identification

- The scintillating pad detector, the preshower and the first muon station will be removed due to their reduced role in the upgrade trigger scheme

- The aerogel radiator of the RICH1 will be removed due to the larger occupancy at higher luminosity (keep CF_4 for RICH1 and C_4F_{10} for RICH2)



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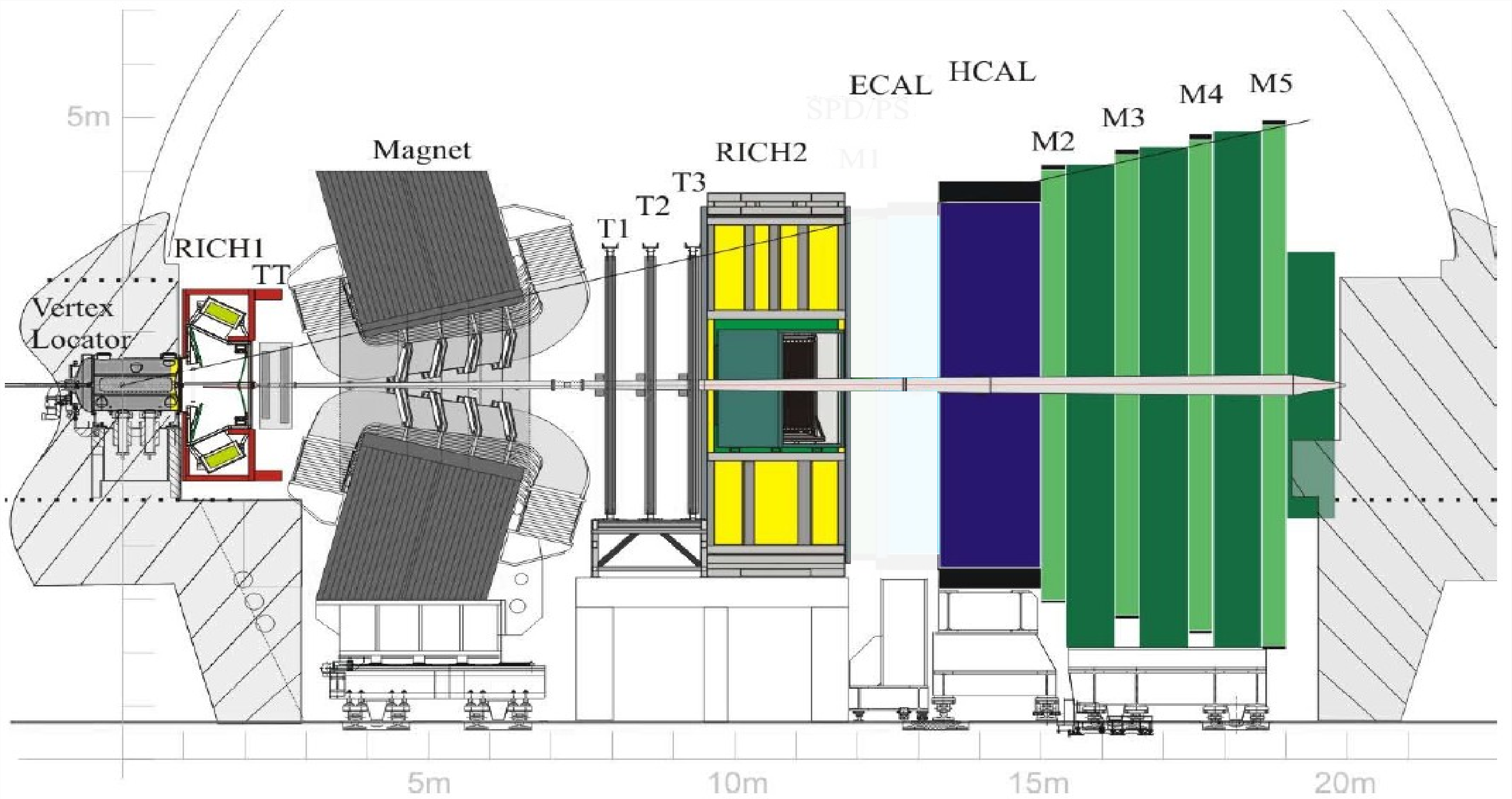
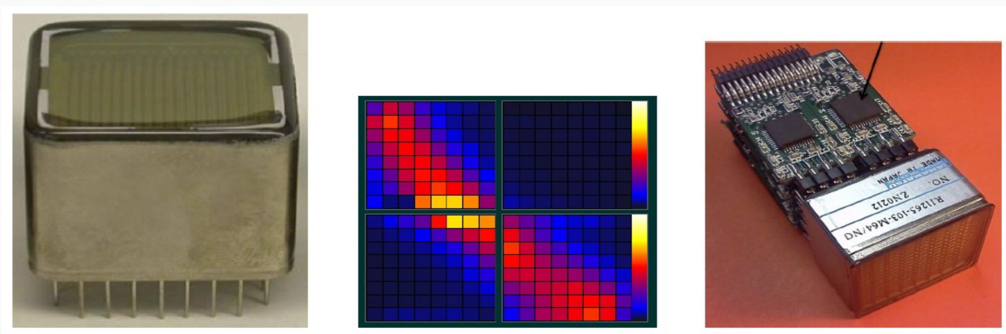
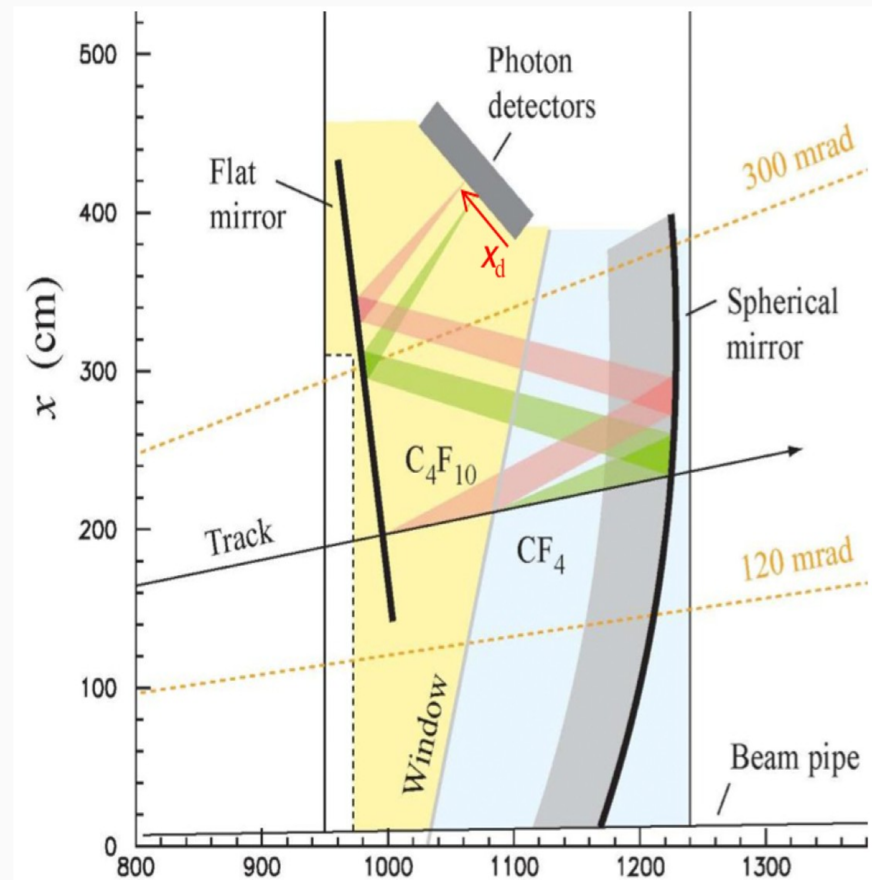


Cherenkov detectors

- Cherenkov photo-detectors have to be replaced
  - Plan is to use Multi-Anode PMT
  - Custom ASIC (Claro or Maroc chip)

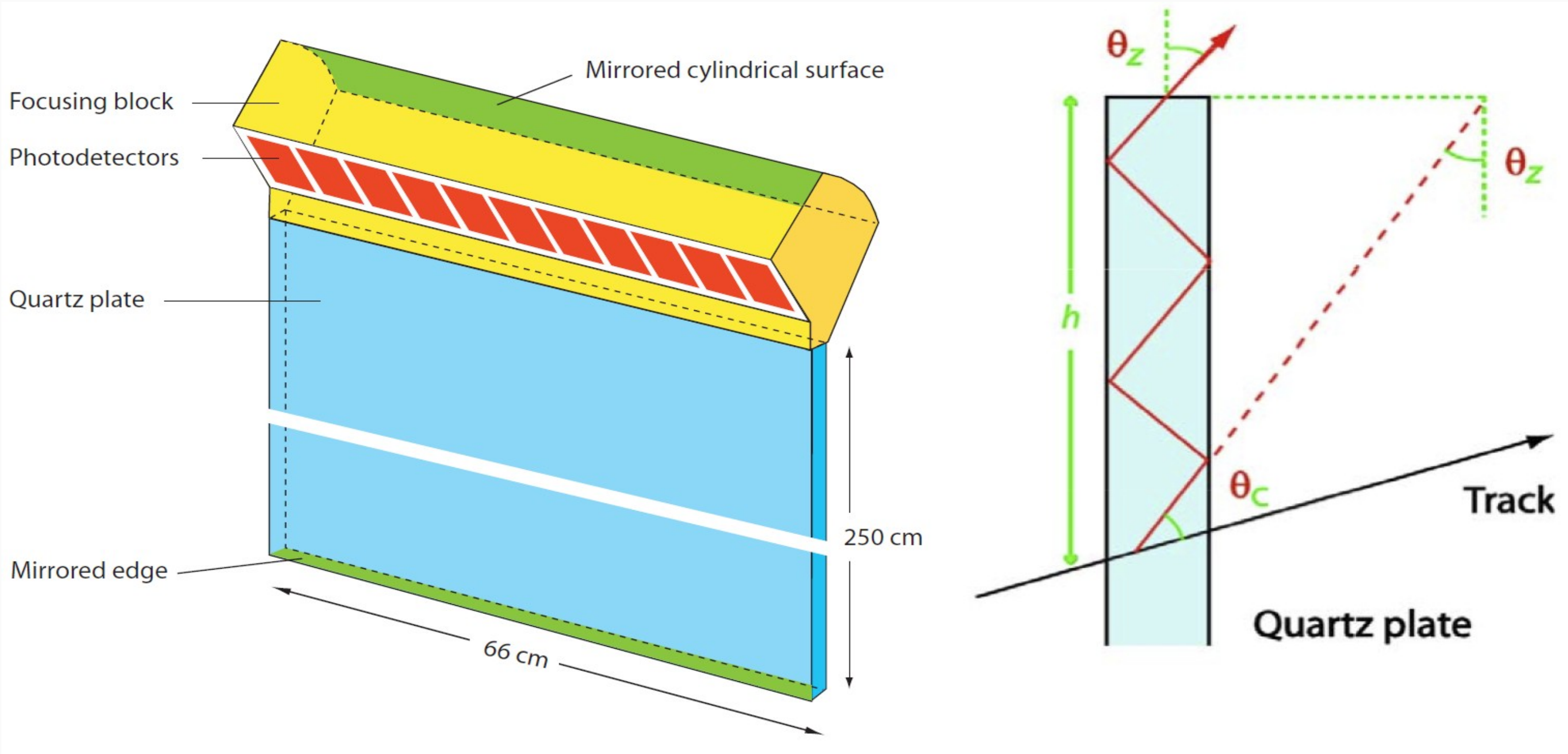


- Occupancy is large in RICH1
  - May reach up to 30% at $L=2x10^{33}cm^{-2}.s^{-1}$
  - Several ideas being looked at
    - New optics to spread out the rings
    - Remove RICH1 and adapt RICH2 to include 2 radiators
      - PID in the expected momentum range



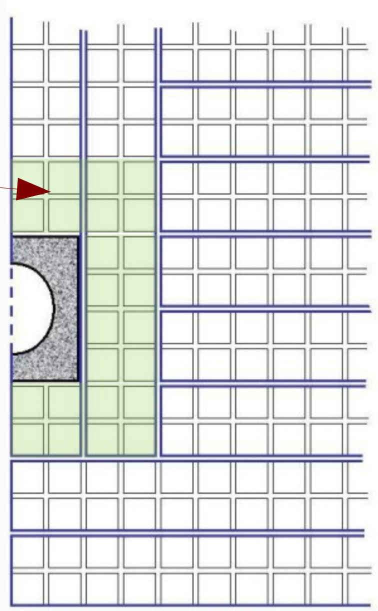
TORCH project

- Time Of Flight measurement using Cherenkov photons from a 1cm thick quartz plate
  - PID for momenta lower than 10 GeV/c
  - Required time resolution ~ 15ps
  - Not part of the baseline, but still subject of R&D



Calorimeter - Muon upgrade

- Scope of the calorimeter upgrade – what is (un)changed ?
  - most of the detector cells are kept
    - some modules in the inner region (probably) replaced
    - Radiation tolerance R&D: can we recuperate the performance in situ ?
  - PMT → a reduction factor is applied on the gain to keep them alive
  - The front-end electronics has to be fully re-designed
    - Compensate for the gain reduction factor of the PMT
    - Send data at 40MHz to the counting room
  - Hardware L0 calo should be modified to be part of the LLT



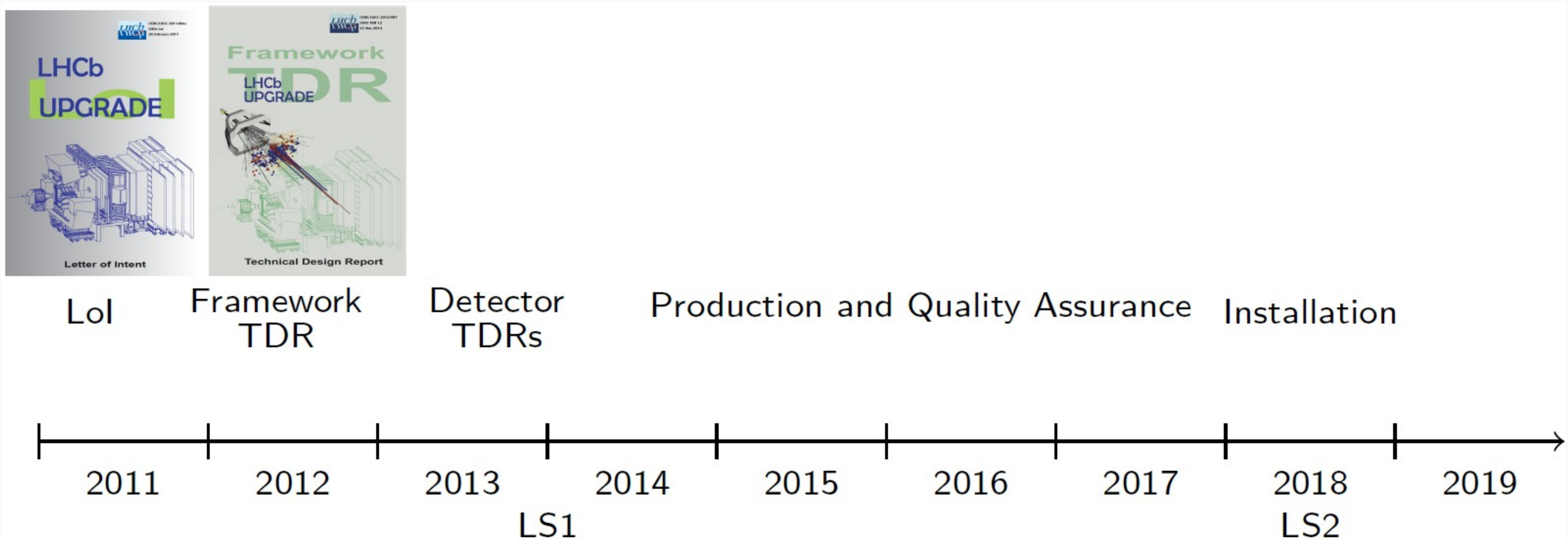
- Muon electronics should be almost compatible with the upgrade
  - Tolerable ageing effects
  - Regions close to the beam pipe could suffer from a too large occupancy
    - Alternative technology → from MWPC to 3-GEM ?
    - Additional shielding

Physics reach after 50fb^{-1}

- Extract from the paper « implications of LHCb measurements and future prospects », arXiv:1208.3355

Type	Observable	Current precision	LHCb 2018	Upgrade (50 fb^{-1})	Theory uncertainty
B_s^0 mixing	$2\beta_s\ (B_s^0 \to J/\psi\ \phi)$	0.10 [137]	0.025	0.008	~ 0.003
	$2\beta_s\ (B_s^0 \to J/\psi\ f_0(980))$	0.17 [213]	0.045	0.014	~ 0.01
	$a_{\rm sl}^s$	6.4×10^{-3} [43]	0.6×10^{-3}	0.2×10^{-3}	0.03×10^{-3}
Gluonic penguins	$2\beta_s^{\rm eff}(B_s^0 \to \phi\phi)$	–	0.17	0.03	0.02
	$2\beta_s^{\rm eff}(B_s^0 \to K^{*0}\bar{K}^{*0})$	–	0.13	0.02	< 0.02
	$2\beta^{\rm eff}(B^0 \to \phi K_S^0)$	0.17 [43]	0.30	0.05	0.02
Right-handed currents	$2\beta_s^{\rm eff}(B_s^0 \to \phi\gamma)$	–	0.09	0.02	< 0.01
	$\tau^{\rm eff}(B_s^0 \to \phi\gamma)/\tau_{B_s^0}$	–	5 %	1 %	0.2 %
Electroweak penguins	$S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\,{\rm GeV}^2/c^4)$	0.08 [67]	0.025	0.008	0.02
	$s_0\, A_{\rm FB}(B^0 \to K^{*0}\mu^+\mu^-)$	25 % [67]	6 %	2 %	7 %
	$A_{\rm I}(K\mu^+\mu^-; 1 < q^2 < 6\,{\rm GeV}^2/c^4)$	0.25 [76]	0.08	0.025	~ 0.02
	$\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$	25 % [85]	8 %	2.5 %	~ 10 %
Higgs penguins	$\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	1.5×10^{-9} [13]	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	$\gamma\ (B \to D^{(*)}K^{(*)})$	~ 10–12° [243, 257]	4°	0.9°	negligible
	$\gamma\ (B_s^0 \to D_s K)$	–	11°	2.0°	negligible
	$\beta\ (B^0 \to J/\psi\ K_S^0)$	0.8° [43]	0.6°	0.2°	negligible
Charm CP violation	A_Γ	2.3×10^{-3} [43]	0.40×10^{-3}	0.07×10^{-3}	–
	ΔA_{CP}	2.1×10^{-3} [18]	0.65×10^{-3}	0.12×10^{-3}	–

Roadmap - Summary



- Letter of intent and Framework TDR endrosed by LHCC in 2011 and 2012
- Sub-detectors TDR expected this year

- Upgrade in 2018 to exploit higher luminosity with better efficiency
  - Achieved by a 40MHz readout and a fully software trigger
- Detector R&D program ongoing, the challenges being
  - 40MHz
  - Radiation tolerance
  - Robust and fast reconstruction
  - Material budget

Backup

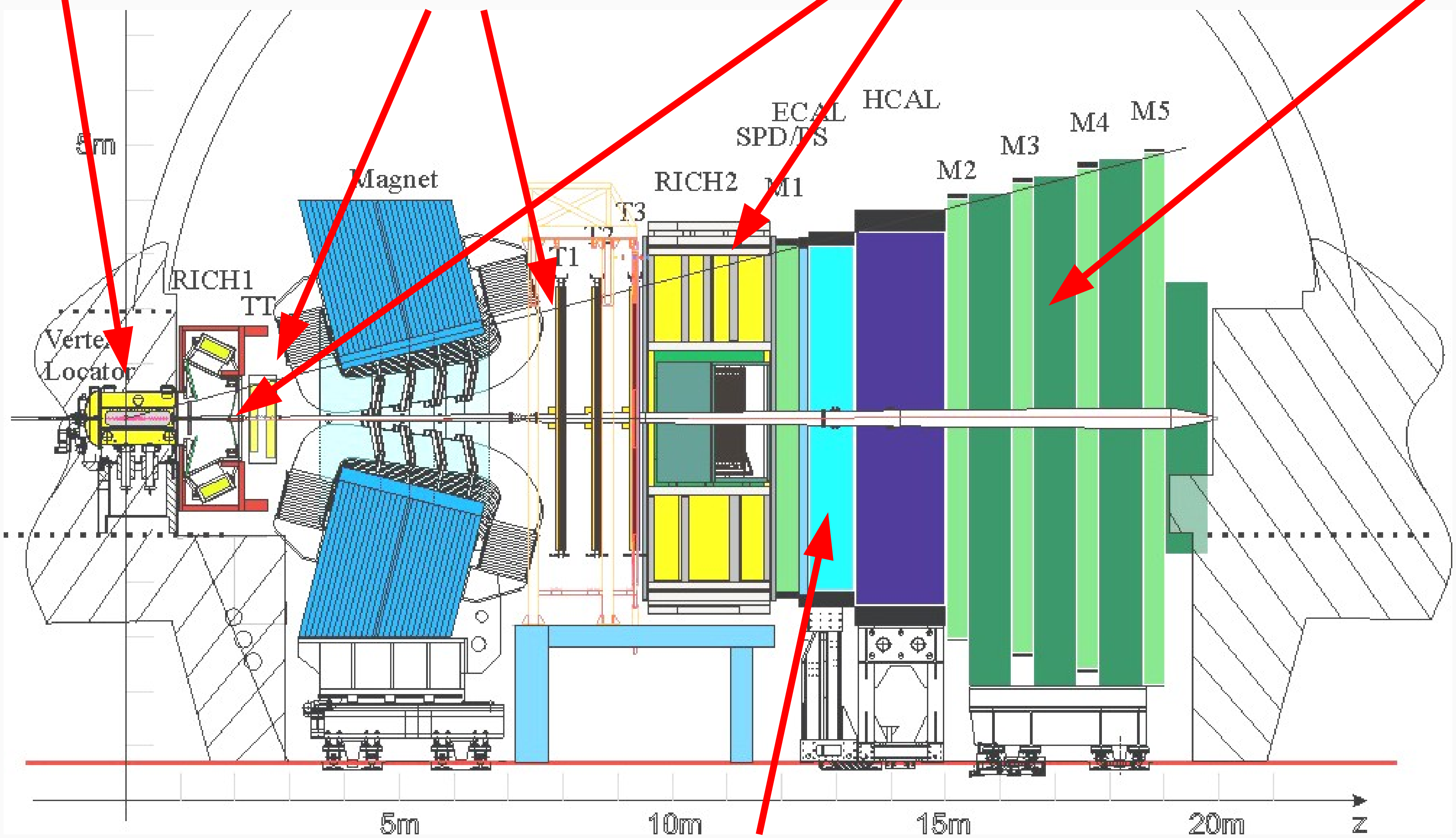
Detector modifications

VELO
Si strips / pixels

Trackers
Use of Si strips
and
Fiber tracker

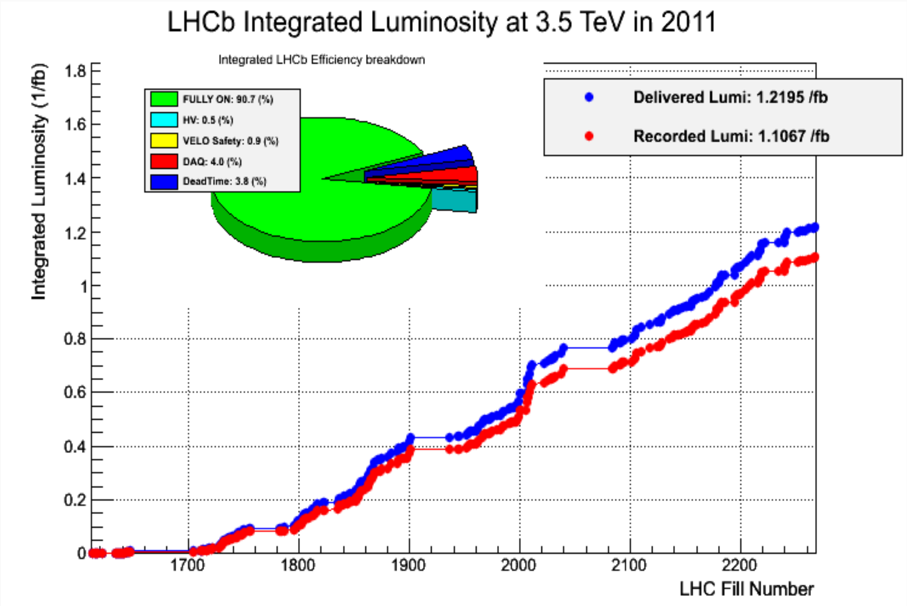
RICH
Remove RICH1
New RICH2

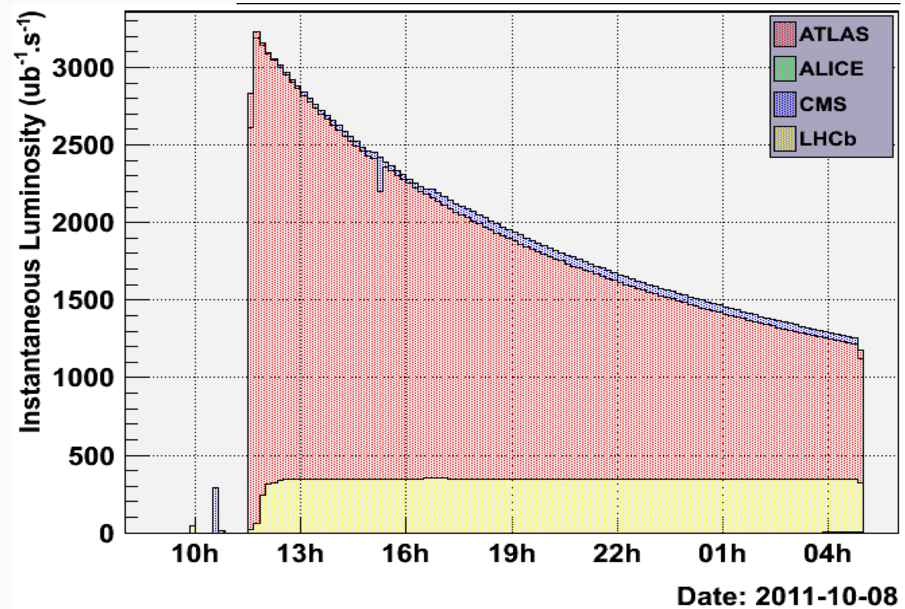
Muons
Mostly kept unchanged
M1 removed



Calorimeter
Remove SPD-PRS
Replace the electronics

Data taking conditions in 2011

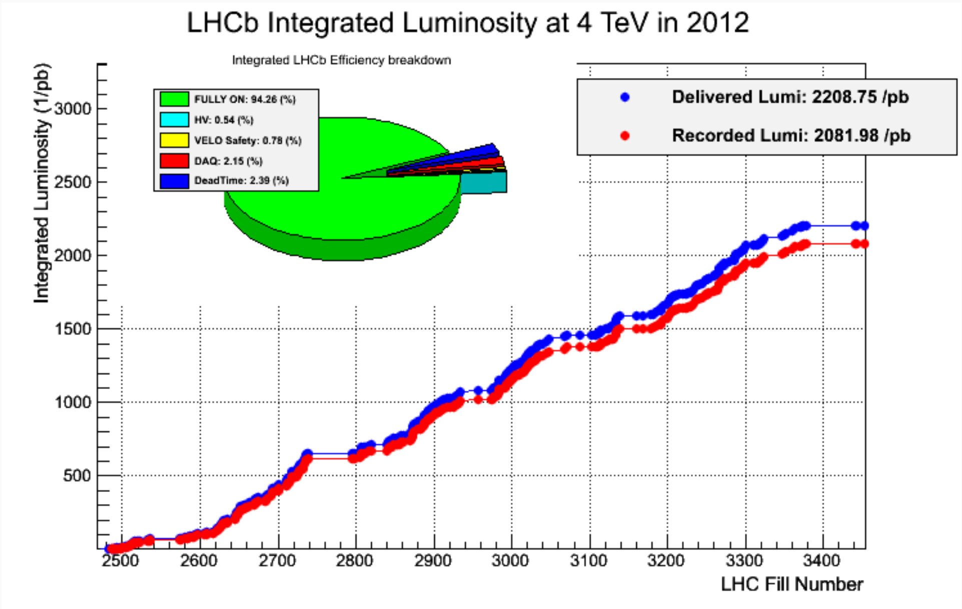


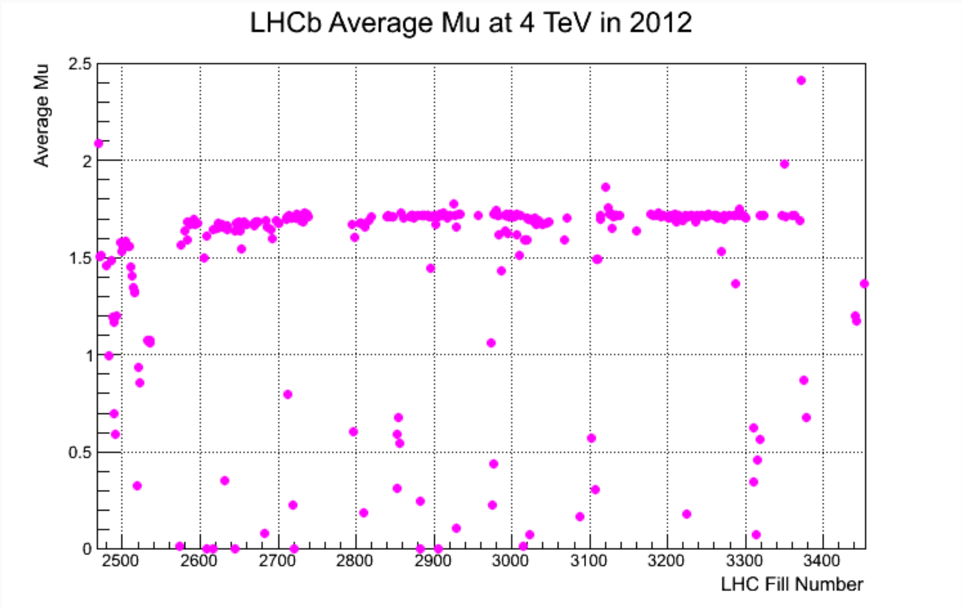


- Instantaneous Luminosity L ~ 3.5×10^{32}cm^{-2}.s^{-1}
  - Design was 2×10^{32}cm^{-2}.s^{-1}
  - Luminosity constant over the fill → luminosity levelling method
  - Trigger and pile-up stable at μ=1.5 (design of 0.4)
  - Hardware trigger rate ~ 0.85MHz
  - Data bandwith 3kHz → stored on disc

- L_{2011} = 1.1fb^{-1}

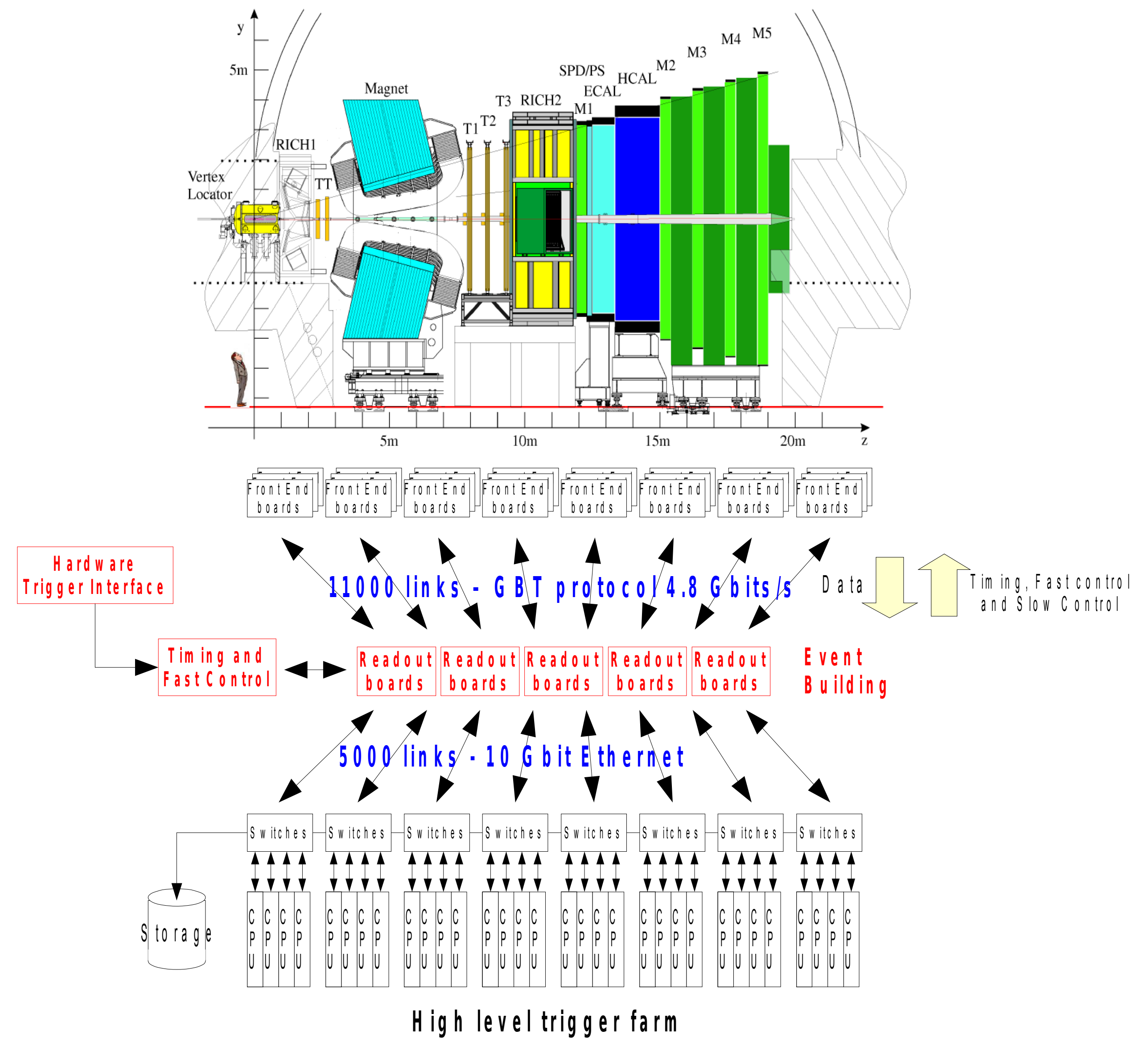
Data taking conditions in 2012





- Energy increased from 3.5TeV → 4 TeV
- Instantaneous Luminosity L ~ $4 \times 10^{32} cm^{-2}.s^{-1}$
  - Trigger and pile-up maintained at μ=1.7
  - Data taking efficiency ~ 95 %
  - Hardware trigger rate ~0.95 MHz
  - 4.5kHz of events on disc
- L_{2012} ~ 2.1 fb^{-1}

- Readout of the full detector at 40MHz
- New design of the interface between the front-end of the sub-detectors and the PC Farm (software trigger)



Electronics : Introduction

- The electronics is facing the following problems :
  - Need to save our PMT at high luminosity
  - Need to be able to run our DAQ at 40MHz
  - Provides calorimeter information to the LLT
- PMT :
  - The gain of the PMT should be reduced by a factor ~ 5 in order to keep them alive
  - This should be compensated in the analog electronics
    - Design of a new analog part
      - responsability of Barcelona group (UB)
      - LAL helped in the design of the ASIC (slow control, clock phase adjust.)
    - By adding this factor 5, we should **NOT** increase the noise by a factor 5 !
- DAQ
  - Need to design a new digital part
  - Based on the GBT (component developed by CERN)
    - Several optical links per FEB are needed
      - University of Bologna must provide optical mezzanine boards
  - Would like to re-use what can be re-used
    - Crates, PS, some hardware (LED, HV, Integrators, etc...)
      - Has consequences on the ECS (→ GBT)

Detector modifications

- The front-end electronics must be adapted to cope with the 40MHz readout

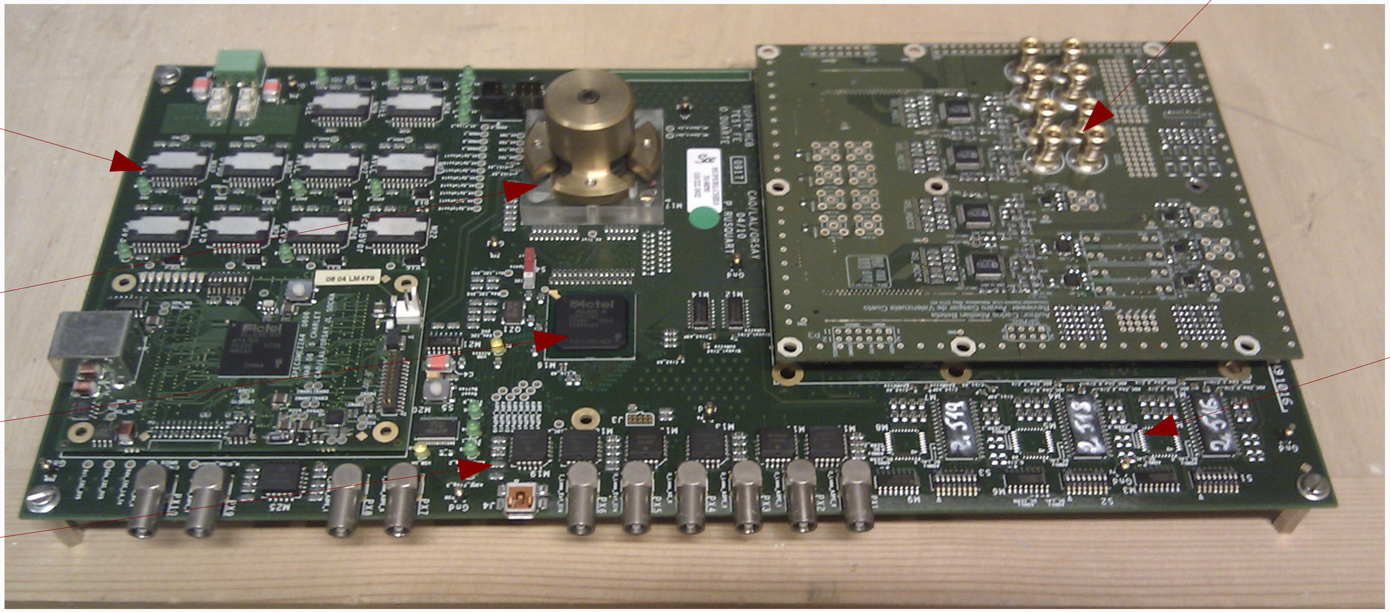
- The higher luminosity imposes constraints on the trackers (VELO, UT, IT, OT)
  - Radiation tolerance
  - Efficiency and momentum resolution
  - Low ghost track rate
  - Cope with the larger multiplicity
  - Not be affected by spill-over effects
  - Track reconstruction at 40MHz (time budget per event < 25ms)
  - Baseline for the tracker :
    - VELO → pixel, strips
    - UT → Si strips
    - IT, OT → scint. fiber tracker, ...

- Rich photo-detectors must be replaced
  - Baseline is remove RICH1 and replace RICH2 for a more performant RICH

- Muon and Calo : mostly adapt the electronics

Digital prototype motherboard

- The digital part is a mother board on which the analog part can be mounted
- Purposes :
  - Perform acquisition of the analog with solutions foreseen for the digital part
    - FPGA, clock phase adjustment, power supplies (DCDC converter), etc...
  - FPGA A3PE from Actel (flash based – SEE tolerance)
    - ProASIC (Actel) known to have problems at high IO rate
    - Want to test IO → FPGA AX is used to perform high rate data transferts
  - Radiation tolerance of the components
  - Test signal type chosen by GBT (SLVS)

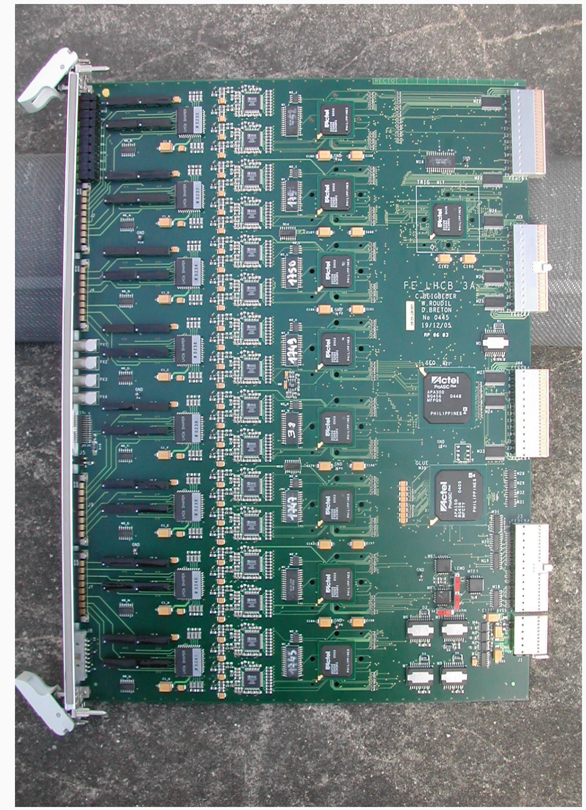


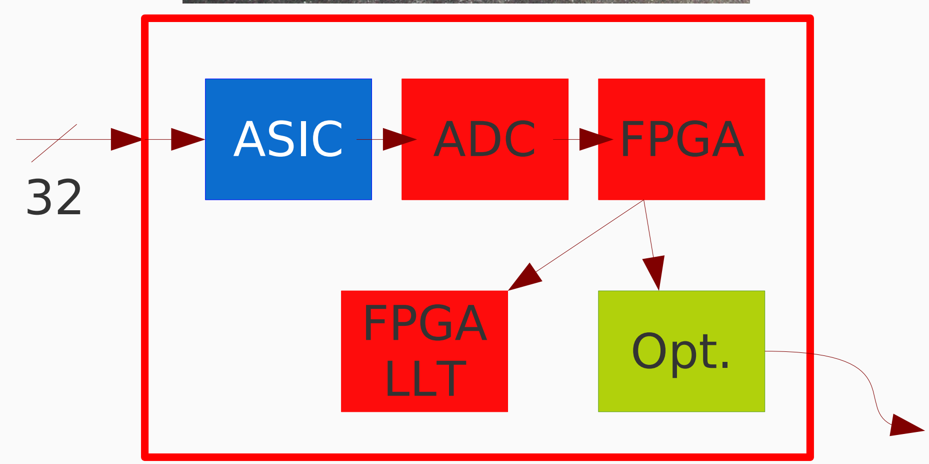
Digital motherboard

Objective

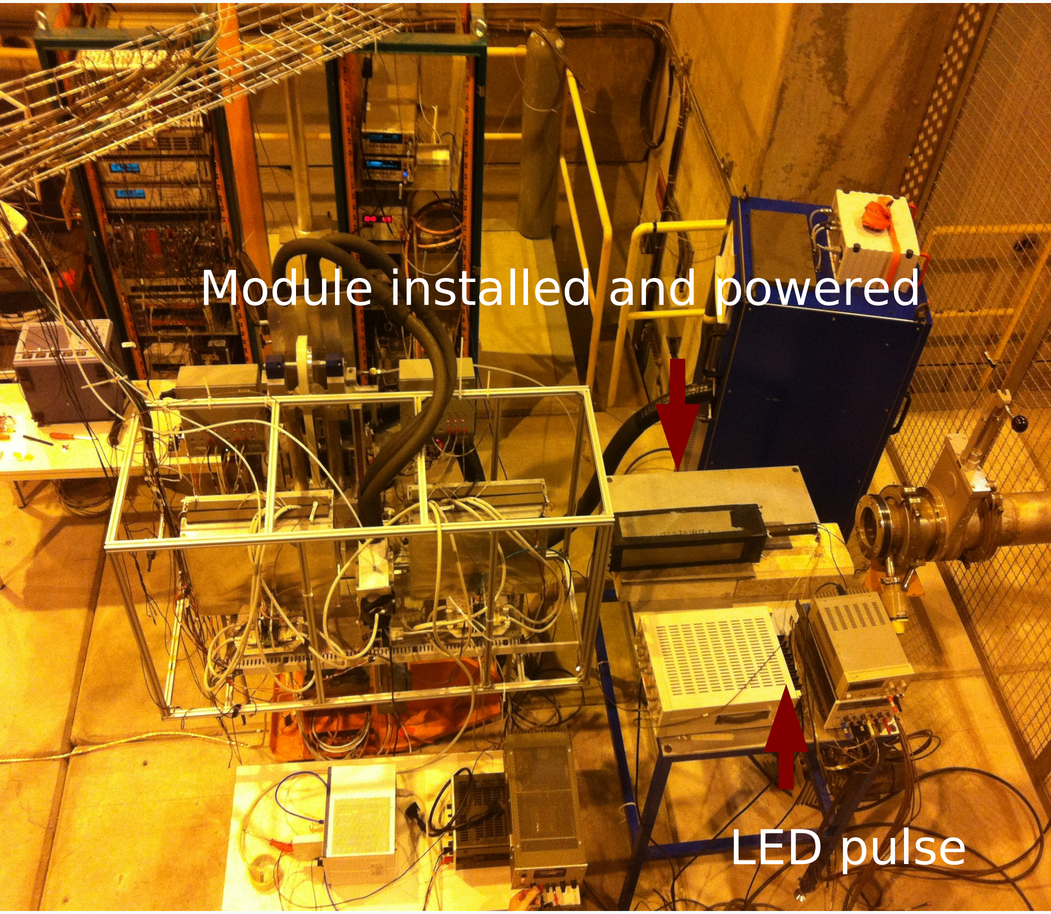
- The objective is to produce a 32 channel FEB incorporating
  - the analog ASIC from UB,
  - the opt. Mezzanine from Bologna
- The FEB performs
  - Digital treatments
    - Pedetal subtraction
    - Calibrations
    - Numerical corrections
    - Event formatting
    - Trigger calculations
  - The 40MHz readout
- We need to equip ~ 8000 channels
  - ~ 280 boards (including spares)
- Same boards for ECAL and HCAL as for the current electronics

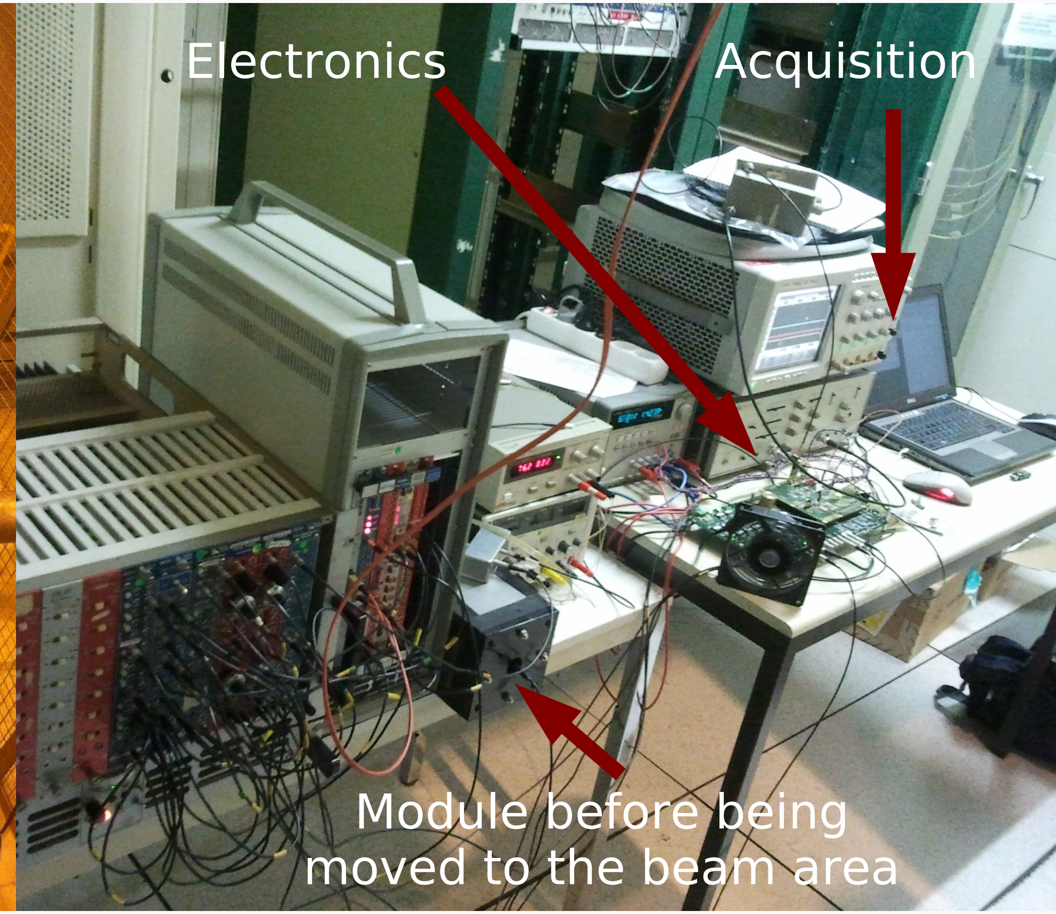
The present FEB





Test beam at CERN on November

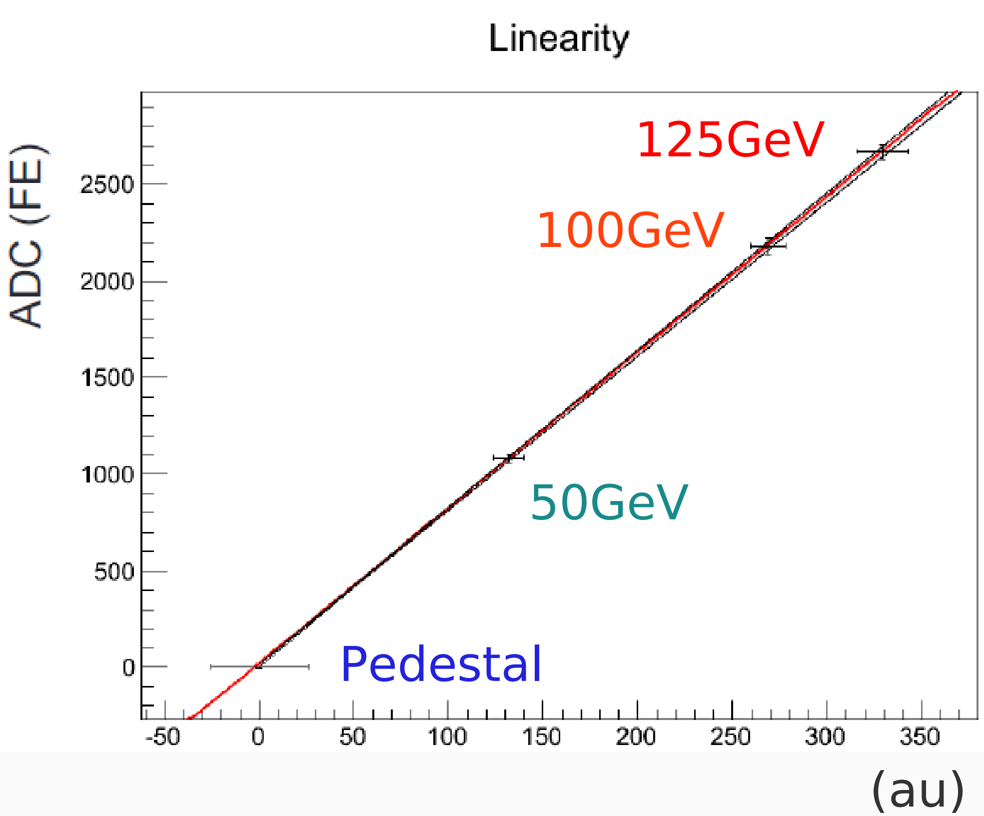




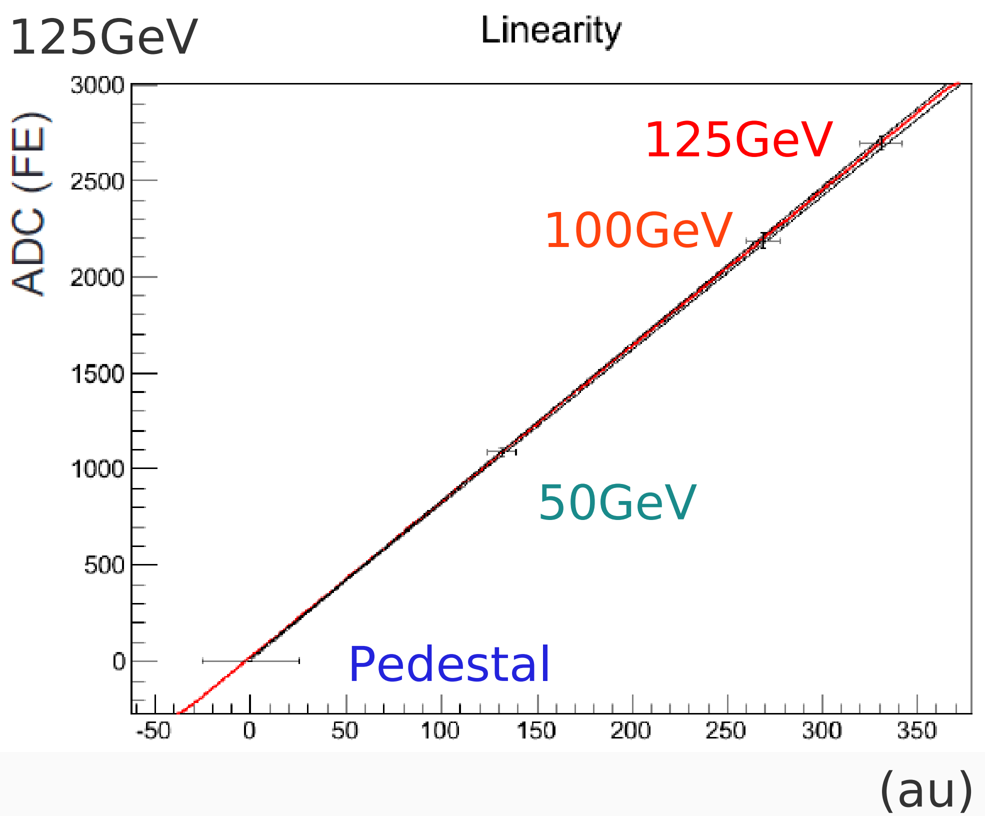
- 6 members of the group participated to the test beam
- LAL developped the test bench software (used at Barcelona, CERN)

- Example : linearity measurement performed with the test beam data

Channel 2



Channel 3

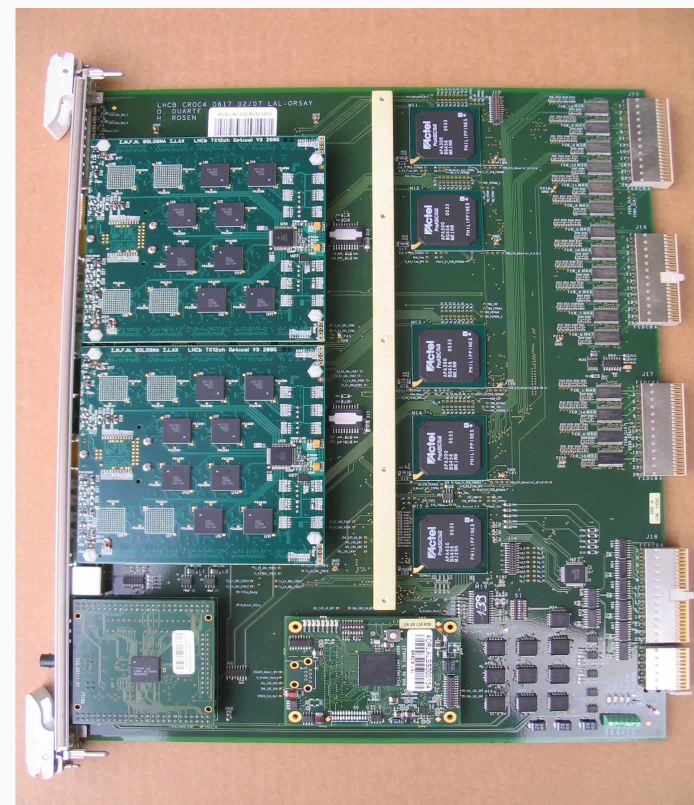


Interest for the Control board

- The group started to work on a first prototype of FEB
- We need to build a new control board
  - 1 board per crate
  - Distributes slow control, clocks, synchronous commands, etc... to the boards

- We were engaged in the design of the FEB and the control board of the electronics of « the first LHCb »
  - We have been able to conduct the two projects smoothly
  - This was well appreciated at CERN
  - The front-end electronics (FEB+Control board have proven to work nicely

- We would like to keep the same responsabilities
  - Control and FEB have exchange a lot of signals
  - Design of the FEB and the Control board at LAL



The present control board of the LHCb calo

Calorimeter upgrade electronics - Ressources

- The calorimeter front-end electronics projects is a collaboration among
  - UB (Barcelona), La Salle University (Barcelona) : Analog, test 50 % of the prod.
  - University of Bologna : optical mezzanines

- We would like LAL to be involved in the
  - Design of the Front-end electronics
  - We would like also to design the control board

- Ressources :
  - 2FTE (electronics) should be sufficient for 3 years
  - Support needed during CAO and installation at CERN
- All physicists of the group wanted to be involved at some level(s)
  - Development, test of the production, debugging, installation, control software

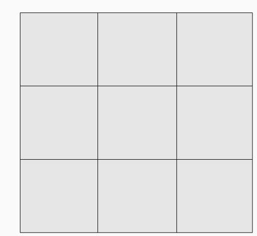
- LAL (1 physicist) coordinates the project of upgrade of the calorimeter

- Extract of the IN2P3 « conseil scientifique » report :

Le groupe du LAL a pour projet de prendre en charge la refonte de l'électronique de « Front-End » du calorimètre. Ayant développé toute l'électronique actuelle à 1MHz, l'équipe a à la fois les compétences techniques et une très bonne connaissance du système actuel. La collaboration existante avec Barcelone est solide avec un bon découpage des responsabilités, les travaux sont bien avancés et le planning est réaliste.

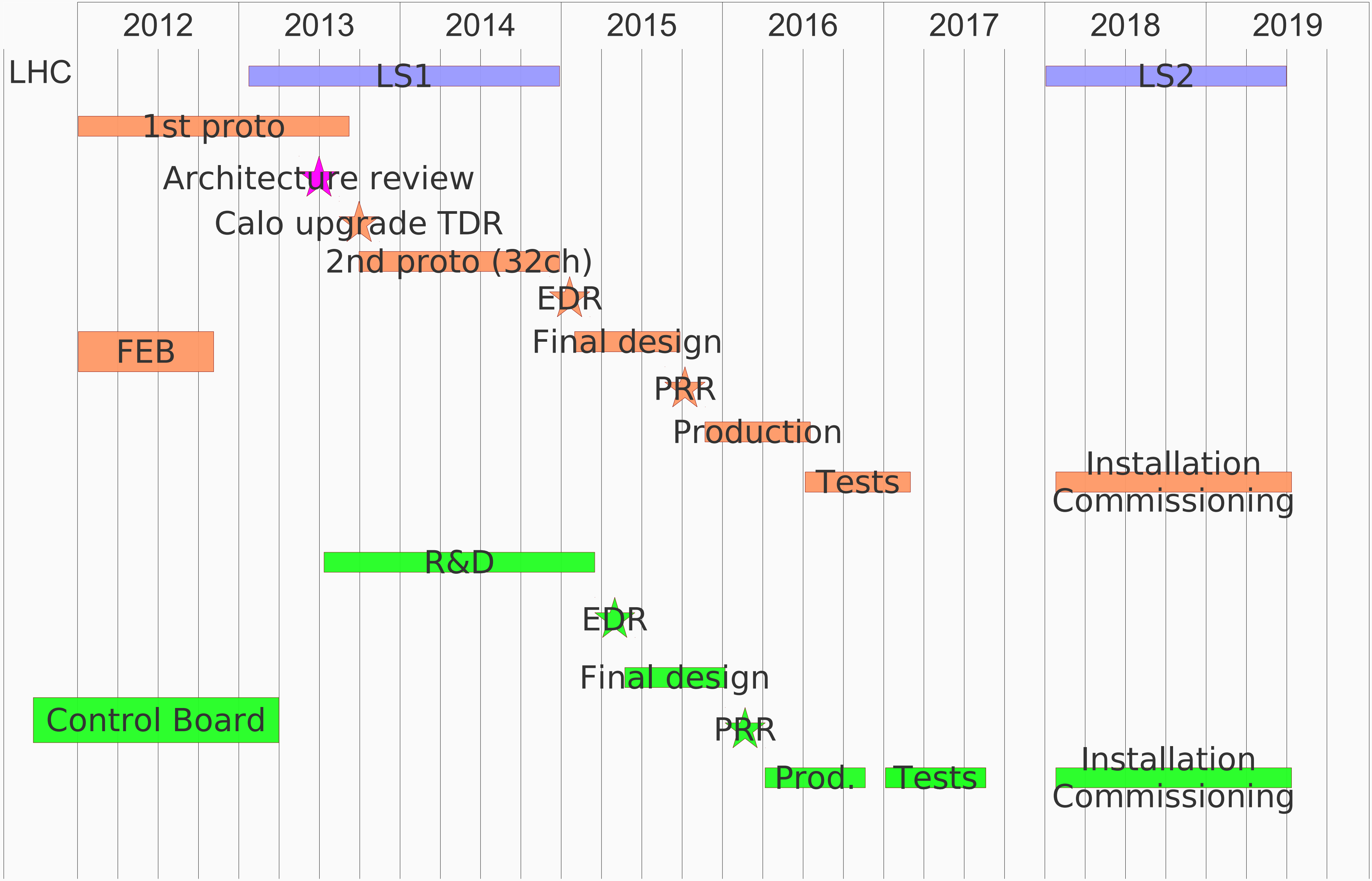
Calorimeter performance studies - reconstruction

- The group worked on the estimation of the effect of the pile-up on the performances of the calorimeter for the upgrade
- New MC samples should be produced soon
  - Latest upgrade calorimeter geometry and upgrade beam conditions
- Performances of the upgraded calorimeter should be re-evaluated
- It is possible to modify the reconstruction in the ECAL in order to reduce the effect of the pile-up
- Clusters are presently made from groups of 3x3 cells
  - Could easily make clusters from 2x2 cells
  - Energy and position reconstruction
    - Should be fine in Outer and Middle regions
    - Probably not so easy in the inner part



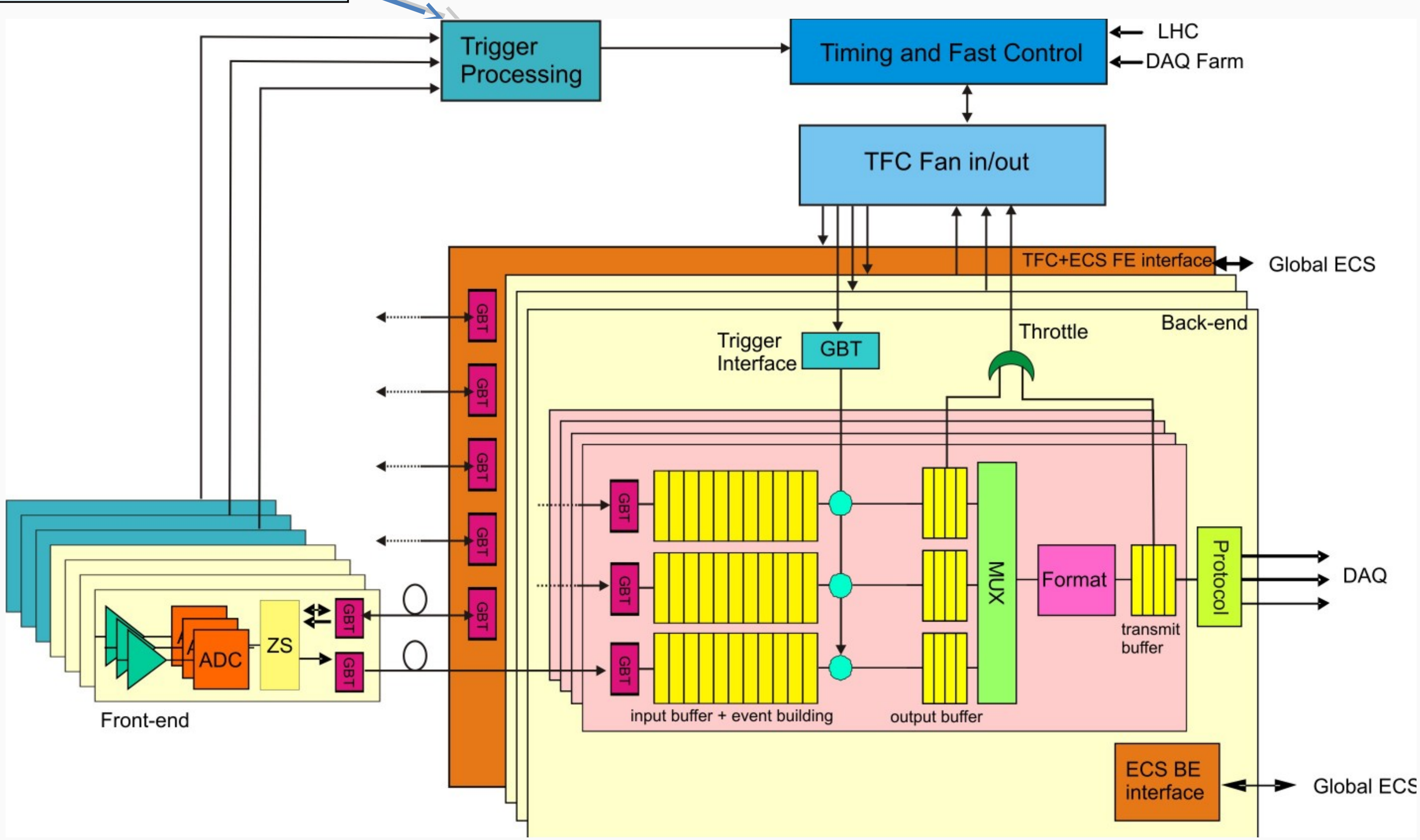
- The pile-up will be larger after the LS1
  - Changing the reconstruction already at the end of LS1 may be a good idea
  - A PhD student of the group works on this subject.

Schedule


2012
2013
2014
2015
2016
2017
2018
2019
LHC
LS1
LS2
1st proto
Architecture review
Calo upgrade TDR
2nd proto (32ch)
EDR
FEB
Final design
PRR
Production
Tests
Installation
Commissioning
R&D
EDR
Final design
Control Board
PRR
Prod.
Tests
Installation
Commissioning

Low Level Trigger

Low Level Trigger



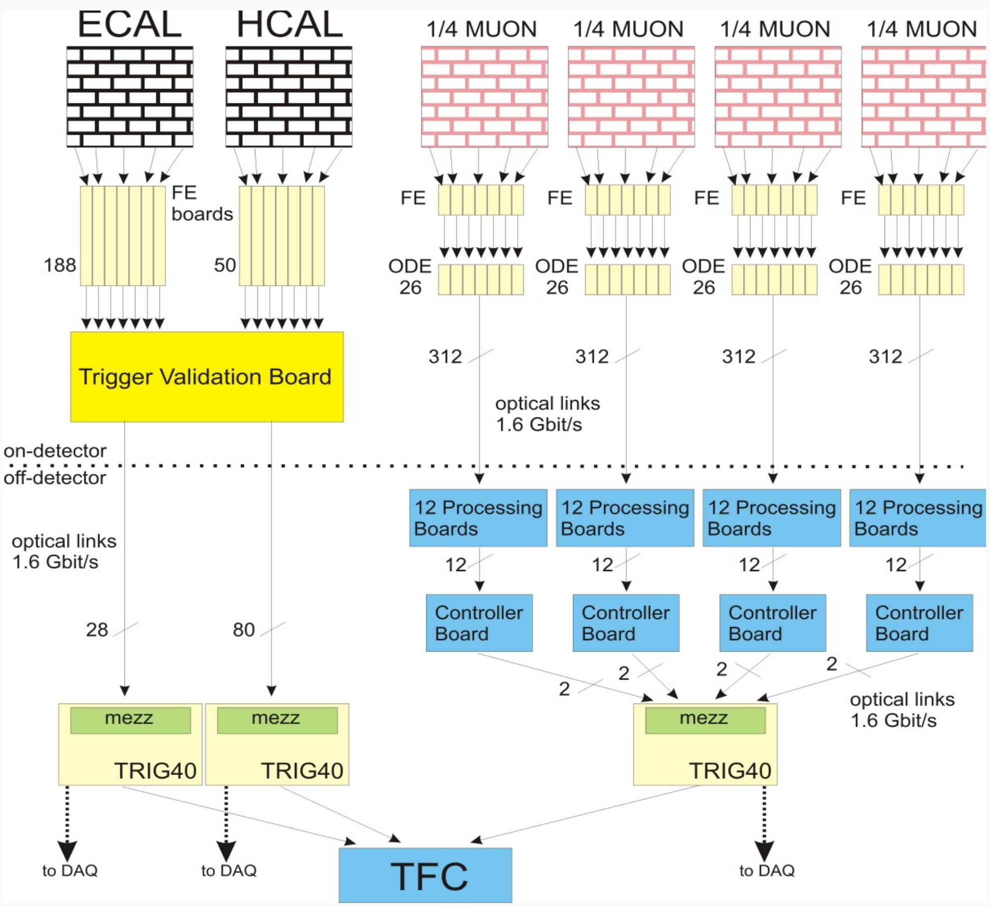
The Low Level Trigger (LLT) – Migration of current L0

- Upgraded LHCb detector will have a software trigger (HLT) designed to work at an input rate of 40 MHz, using full detector information, but:
  - It may be useful to still have a simple Low Level Trigger in order to:
    - Select only « non empty » interactions (30 MHz).
    - Have a throttling system based on simple physics quantities (p_T of μ, *h*, « electron ») in case readout buffers are full, instead of a random throttling.
    - Have a way to reduce the input rate of HLT in case the installation is not complete at the beginning.

- LLT will be a synchronous trigger with a fixed latency, based on Calorimeter and Muon informations.
- The current L0 electronics (CALO and MUON) already runs @ 40 MHz (except its DAQ part) and will be the starting point of LLT:
  - Reuse long distance optical cabling between FE (cavern) and barracks, which is already installed.
  - Already existing hardware and algorithms can be re-used rather easily in a new framework.

Baseline of the LLT

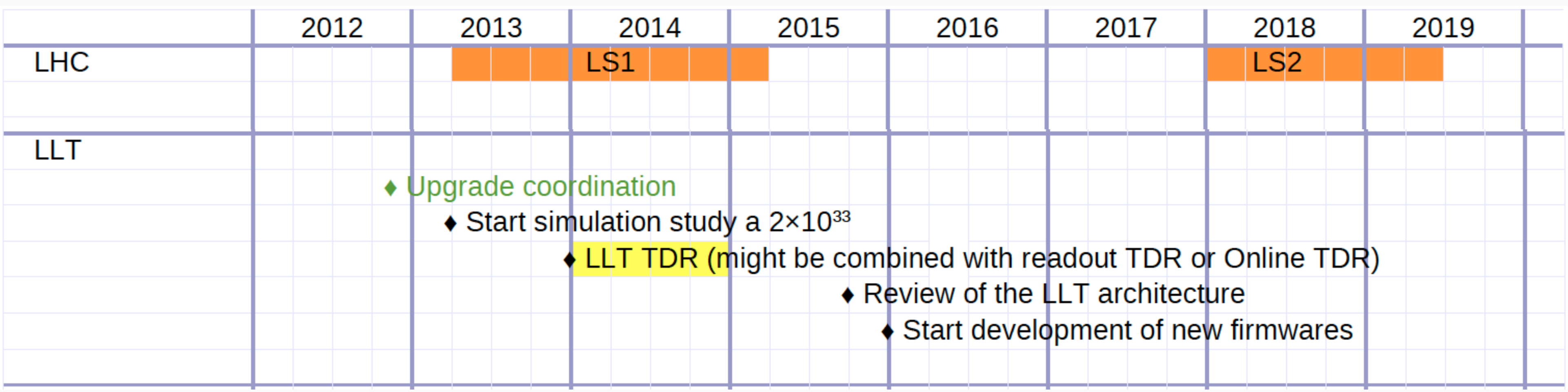
- Given that M1, PS and SPD will be removed, LLT will provide:
  - p_T of muons
  - E_T and Sum E_T of hadrons
  - E_T of « electrons » (objects identified in the Electromagnetic calorimeters)
- But the designed architecture will also allow other subdetectors to take part to LLT decision, if needed.



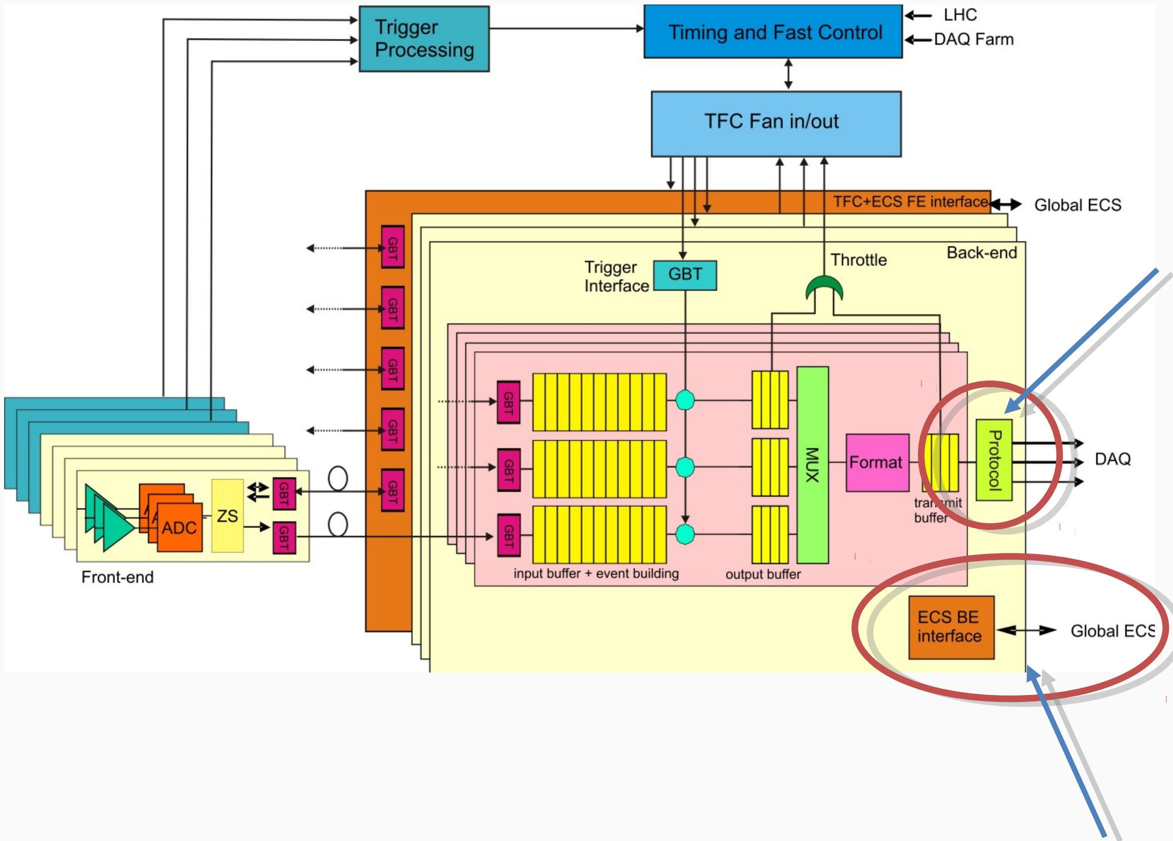
Interface of LLT to the Time and Fast Control system will be done in TRIG40 boards which are a variation of the Marseille boards used for the 40MHz readout.

Schedule

- The next important step of the design of the LLT is to have Monte Carlo samples:
  - Check the impact of removing M1, SPD and PS on the rejecting power of the LLT
  - Determine the algorithms that will be implemented in the different boards' firmwares
  - Determine the latency of the LLT and the sizes of the readout buffers.



LAL: responsability of LLT (1 physicist) for the coordination, installation, Commissioning and software studies.

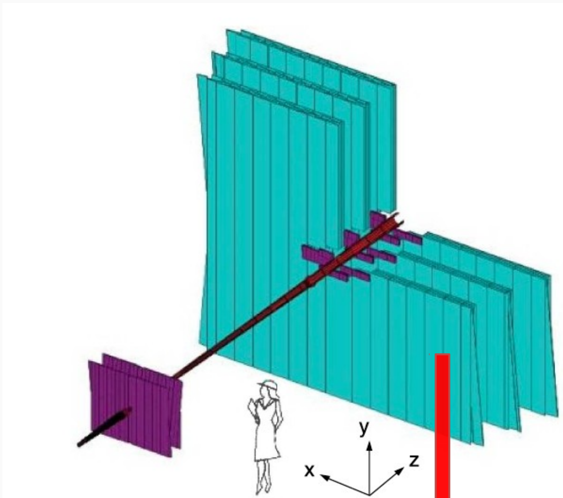


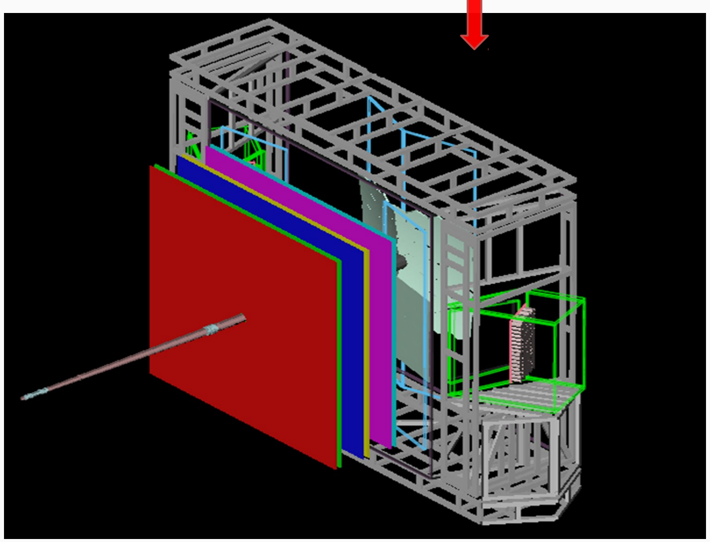
Participation to reflection about technological choices for the network interface (infiniband, PCI express computer interconnections) [0.25 FTE]

Participation to slow control software development with other groups [0.25 FTE]

Central tracking – Scintillating fibers

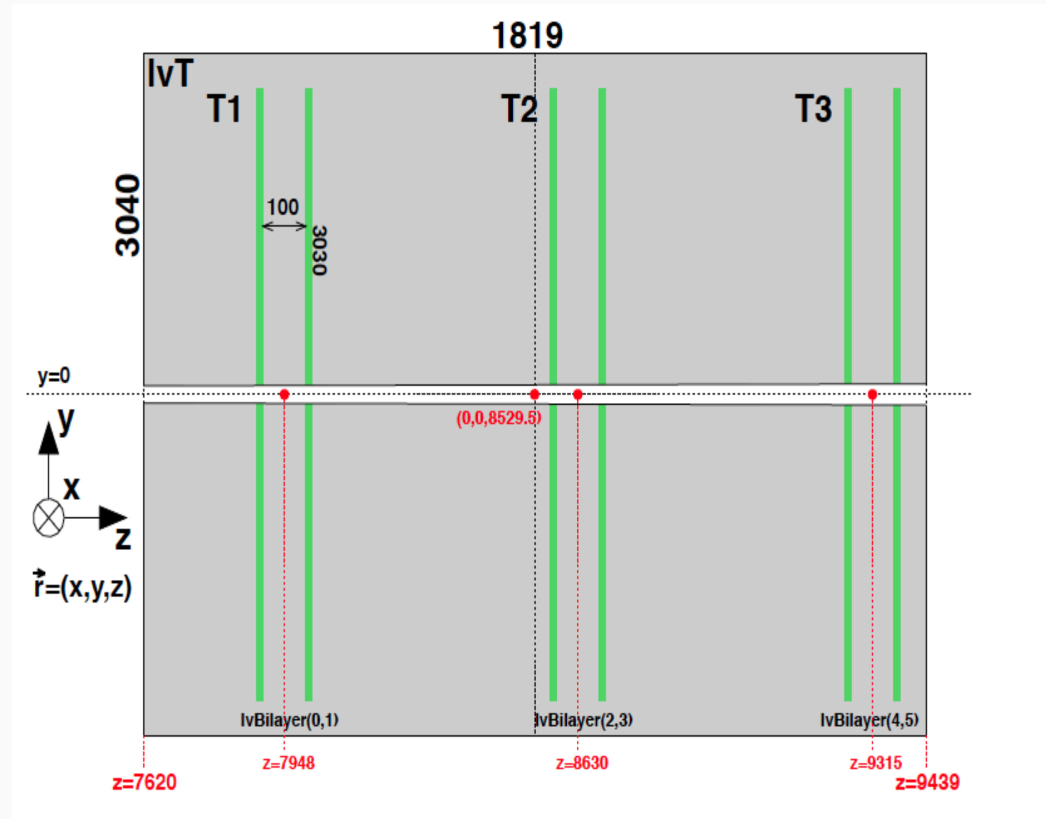
Main trackers - Today





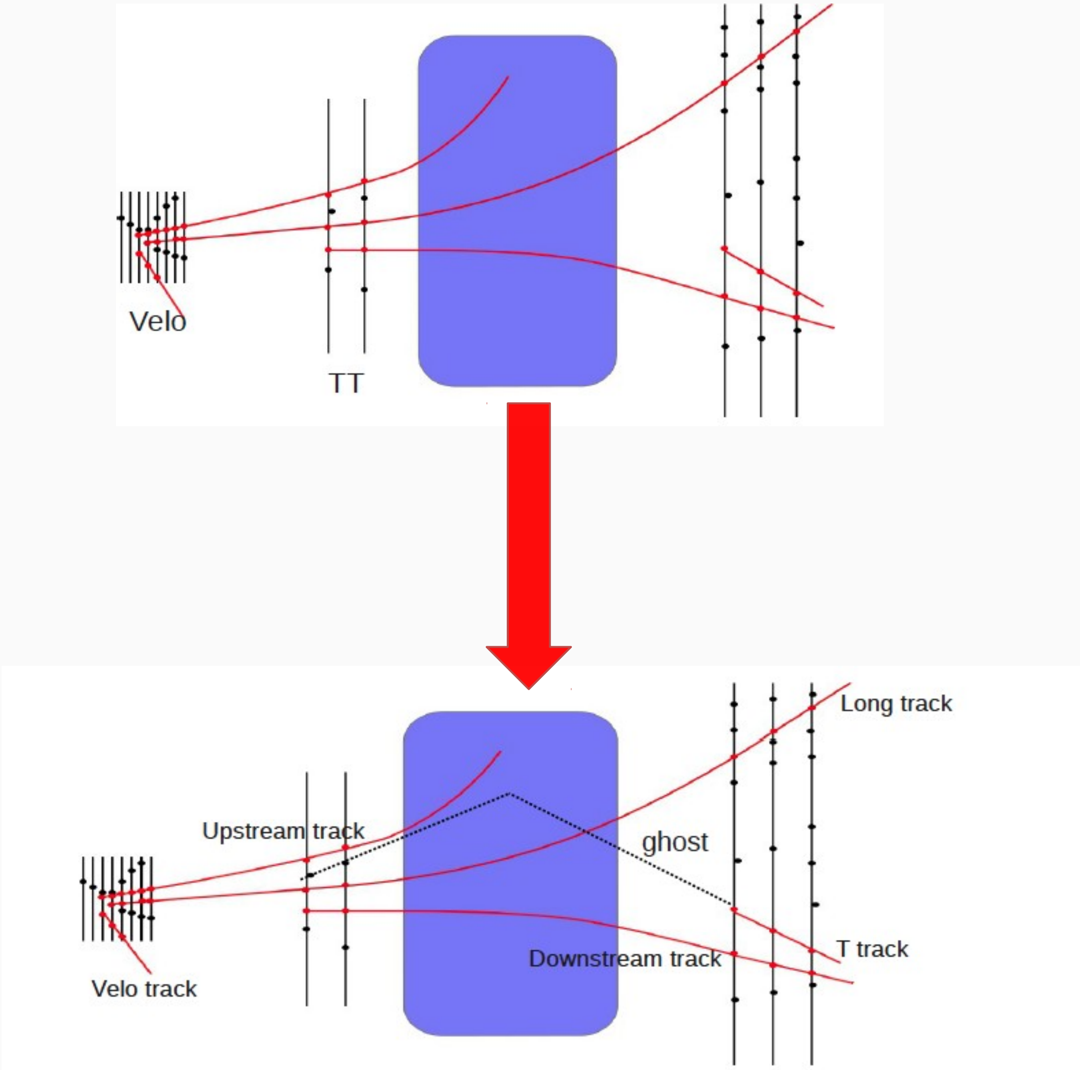
Panoramix view of the tracker

SiPM readout



Geometry x-u-v-x

Tracking in LHCb

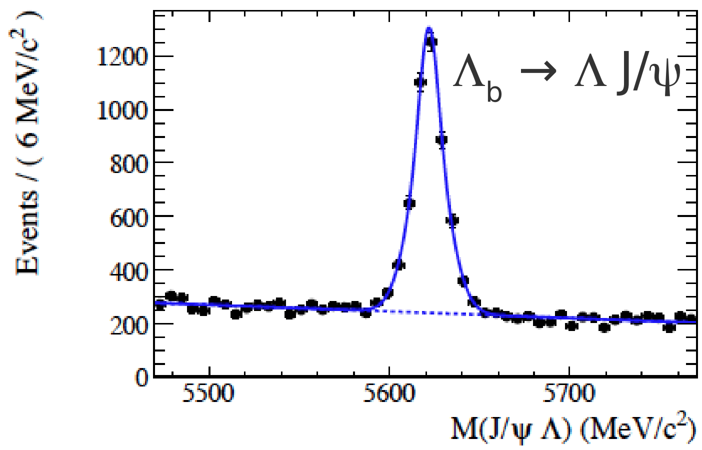


Several categories of tracks are reconstructed in LHCb

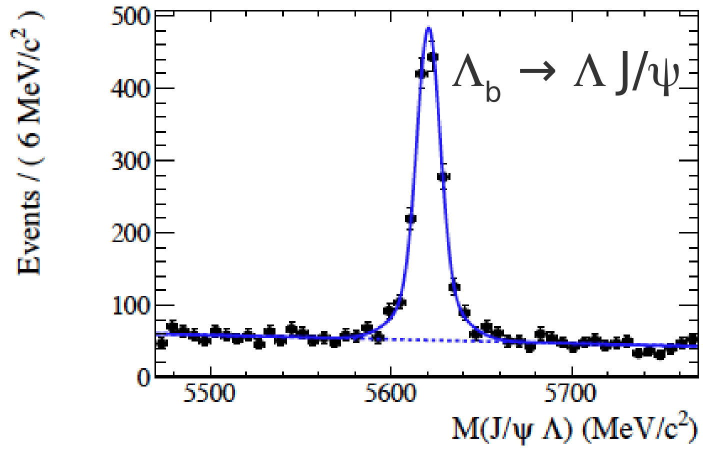
- Method
  - Charged particles create hits in the tracking chambers
  - Pattern recognition
    - Associate hits belonging to a particle along its trajectory
  - Track fits permit to extract parameters of the particles
    - Momenta,
    - Errors,
    - Quality
  - Last step is the identification of « ghosts »

- 2 main algorithms to be developped
  - Forward tracking : mainly for the « Long Tracks »
    - Upgrade prototype exists (Olivier Callot)
    - Track reconstruction efficiency ~ 95 % (p>5GeV/c) with Sci-Fi tracker

« DD » tracks



« LL » tracks



  - Seeding : mainly for « Downstream » tracks (starts from external regions)
    - To be developped
- The two algorithms should have 2 possible configurations
  - HLT trigger and offline reconstruction
- Olivier in charge until end of February (collaboration with Heidelberg)
  - Wish of the group to continue → 1 physicists at LAL in charge from March

Conclusions

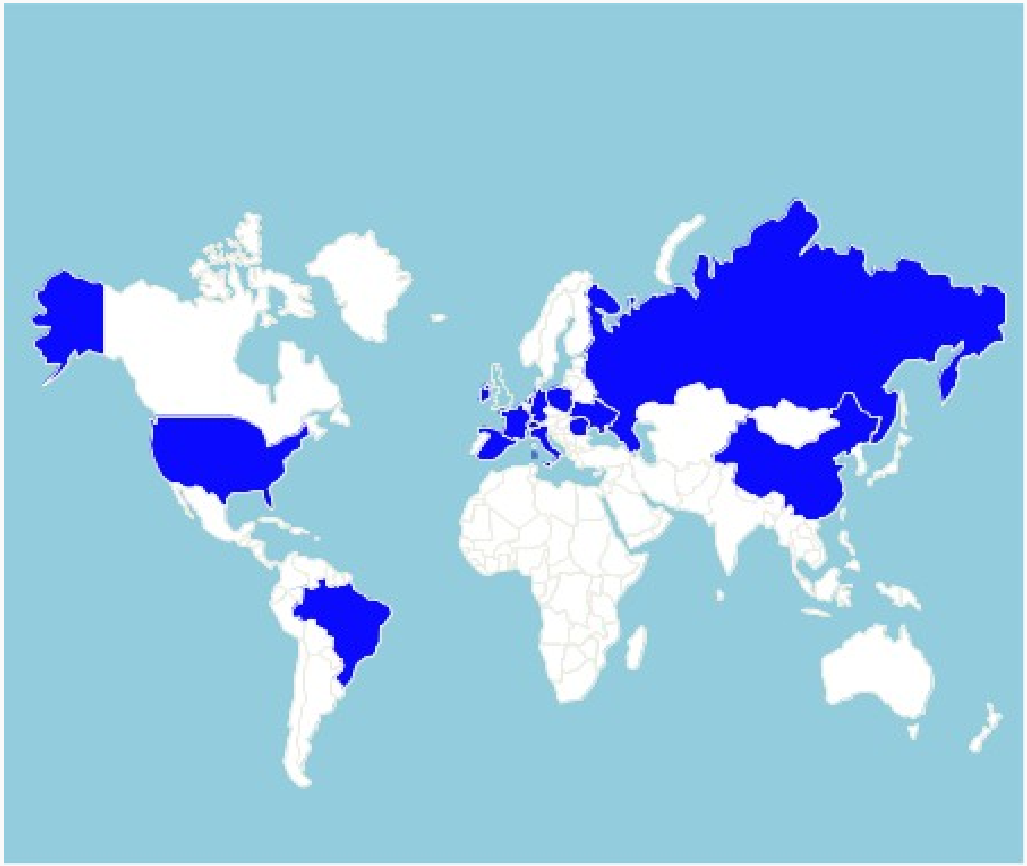
- The upgrade of the LHCb detector is planned for 2018
  - Short time scale (R&D, prod.) and time slot for the upgrade (installation, commissionning) are very short
- There is no « second step » in the upgrade
- Deep interest of the French groups
- LAL wish to be involved in
  - Calorimeter
  - Low level trigger
  - Tracking reconstruction

- The present results of LHCb make us confident in the future of the upgraded experiment.

- Man-power needed from LAL:
  - Calo (1 physicist + contributions from the rest of the group)
    - 2FTE for calo electronics upgrade until mid-2016
    - Ponctual needs for CAO and during installation (2018)
  - LLT (1 physicist + contribution from another physicist)
    - Electronics, 0.25FTE (reflection on Infiniband) until 2015
    - Computing, 0.25FTE (slow control, collaboration with CERN) from 2016 to 2018
  - Tracking (1 physicist)

The LHCb collaboration

- The LHCb collaboration
  - 700 members
  - From 15 countries
  - ~ 60 institutes



- In France, LHCb represented at
  - LAPP (Annecy)
  - LPC (Clermont-Ferrand)
  - CPPM (Marseille)
  - LAL (Orsay)
  - LPNHE (Paris)
- Publications, conferences
  - 103 papers
  - More than 800 talks since 20
    - ~500 conference proceedings