Status and progress for LHCb Upgrade-II detector

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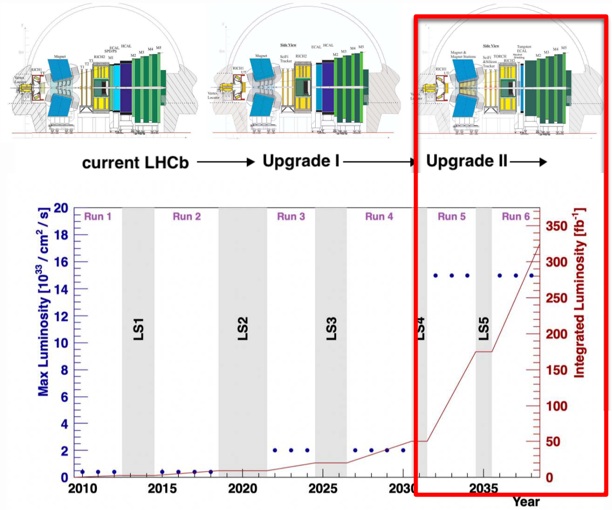
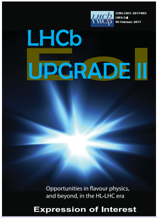
on behalf of the LHCb collaboration

The Ninth Annual Conference on Large Hadron Collider Physics

The LHCb Upgrade II: overview

- LHCb experiment: 2010-2018, 9 fb^{-1} (see Chris Parkes' talk on Monday)
- LHCb upgrade: currently being installed, expect to collect 50 fb^{-1} (see Tomasz Szumlak's talk on Friday)
- LHCb upgrade II: the flavour physics experiment for the Hi-Lumi era, aim to collect over 300 fb^{-1} (see Francesca Dordei's talk on Monday)



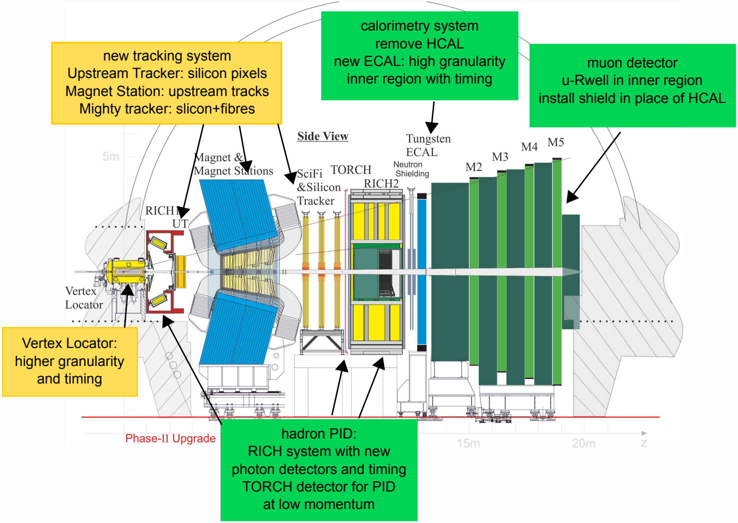


expression of interest submitted in 2017: CERN-LHCC-2017-003
physics case submitted in 2018: CERN-LHCC-2018-027

The LHCb Upgrade II: detectors

aim to retain physics performance of Run1&2 and Upgrade in much harsher environment

improve physics reach whenever possible



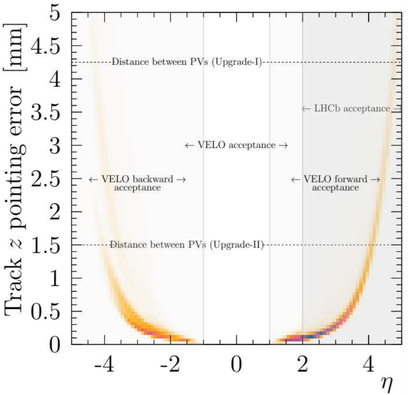
ambitious plan, preparatory work / consolidation in LS3 when possible

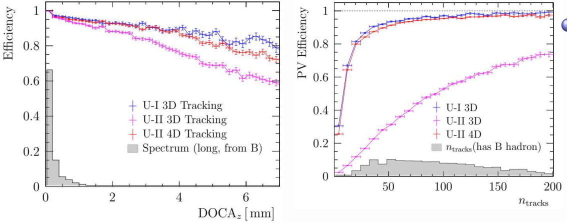
⇒ intense R&D campaign ongoing!

Vertex Locator: challenge and requirements

Upgrade II conditions applied to current VELO geometry would result into:

- 7.5 x peak hit rate
- 6 x radiation damage
- distance between vertices in Upgrade II becomes comparable to detector resolution
- improvement of spatial resolution is not enough to cope ⇒ timing is needed to resolve interactions (timestamp required ~50 ps per hit)
- alternative geometries under study



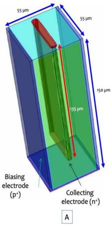


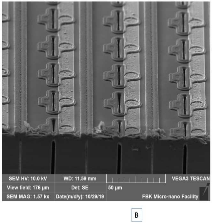
- timing implementation allows to almost fully recover Upgrade I performance in tracks and vertices reconstruction

VELO R&D and studies

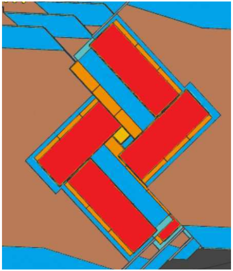
hybrid silicon pixels are the baseline, ASIC most likely to use 28nm CMOS, replacements of sensor needed due to radiation damage. options under study

Requirement	scenario A
Pixel pitch [μm]	$\leq$55
Matrix size	256×256
Time resolution RMS [ps]	$\leq$ 30
Loss of hits [%]	$\leq$ 1
TID lifetime [MGy]	> 24
ToT resolution/range [bits]	6
Max latency, BXID range [bits]	9
Power budget [W/cm^2]	1.5
Power per pixel [μW]	23
Threshold level [e$^-$]	$\leq$ 500
Pixel rate hottest pixel [kHz]	> 350
Max discharge time [ns]	< 29
Bandwidth per ASIC of 2 cm^2 [Gb/s]	> 250

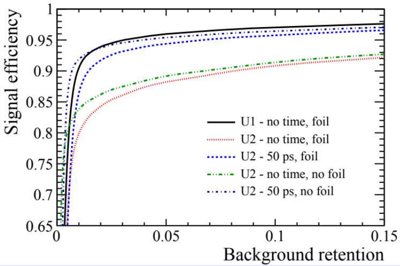


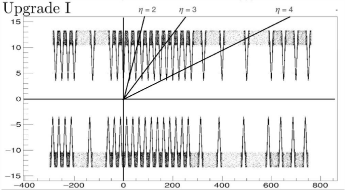


- 3D
- thin planar
- LGAD



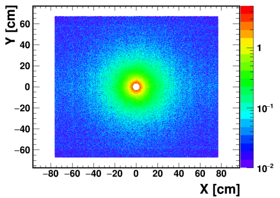
studies on the design of the RF foil: critical to reduce material before the first measured point (studies on foil removal in the past), intense R&D campaign to make foil as thin as possible

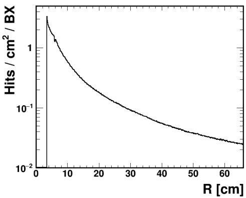


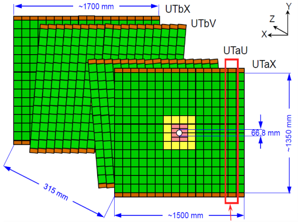


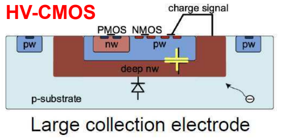
Upstream Tracker

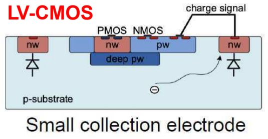
expected hit density at the first UT plane in Upgrade II conditions: highest values can reach ≈5 hits/cm^2/BX ⇒ need for a new UT to handle both the high occupancy and the radiation levels







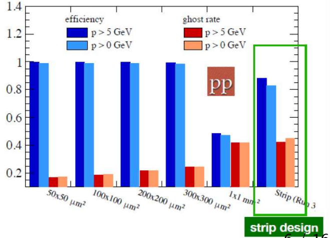




- Large collection electrode
- typical size $50 \times 150 \mu m^2$
- higher noise, power consumption and possible cross-talk

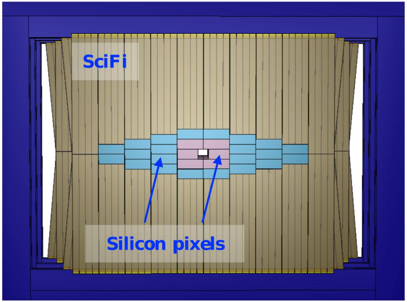
- Small collection electrode
- typical size $30 \times 30 \mu m^2$
- lower noise, power consumption and cross-talk

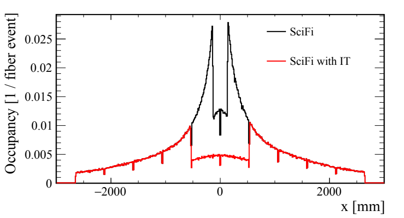
different geometries considered, standalone UT reconstruction studies comparing efficiency and ghost rate for various pixel sizes (Run 5) and strip design (Run 3)

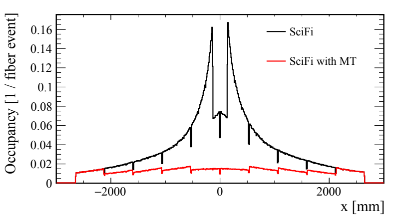


Mighty Tracker

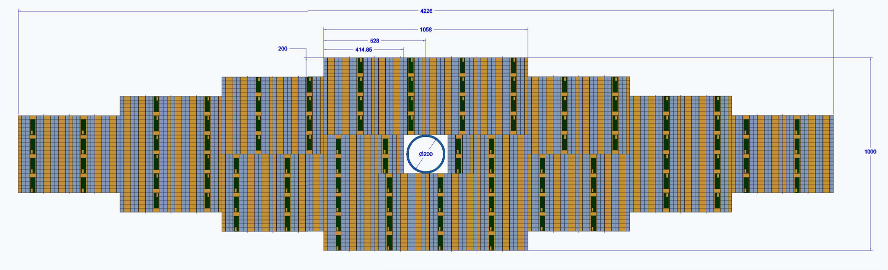
- occupancy in the inner part of SciFi will reach up to 20% in Upgrade II conditions
- harsh radiation environment already challenging for SciFi by the end of Run3
- hybrid downstream tracker: Mighty Tracker = silicon in central region + Scintillating Fibres in the outer region
- large area to be covered by silicon
- enhancements needed for the Scifi area to cope with Upgrade II radiation levels

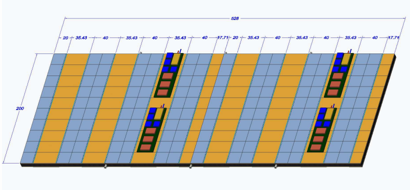


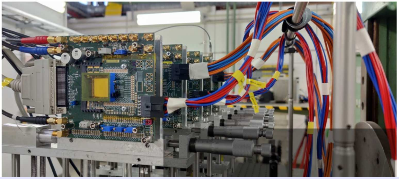




Mighty Tracker: inner







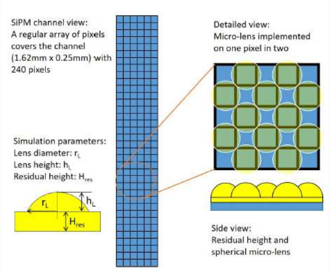
- HV-CMOS are most promising technology: first sample produced last year on MuPix back-end and tested on beam
- test-beam planned this summer on irradiated sensors
- different geometries considered for module design
- strategies for integration within the SciFi detector under study: interaction with SciFi services (especially cryo cooling), routing of Mighty Tracker services while minimising material budget

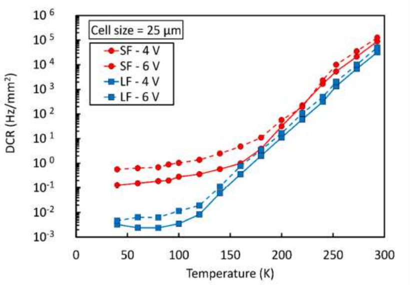
Mighty Tracker: outer

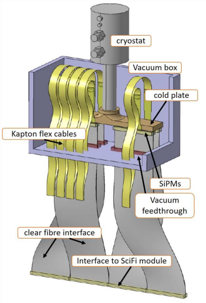
radiation damage in Fibers and to SiPMs is a major challenge for the upgrade

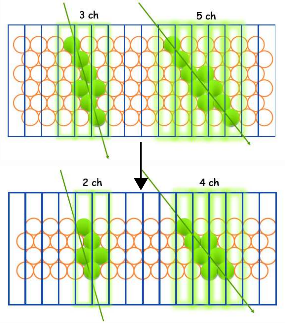
need to maintain high clustering efficiency for manageable noise rate

- decrease operating temperature for SiPM to limit DCR
  → move towards cryo cooling
- increase SiPM light collection with micro-lenses
- investigate reduction of fibre layers per mat to reduce occupancy



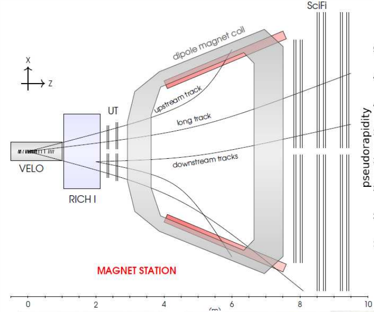


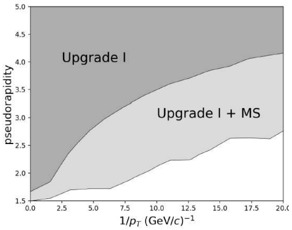


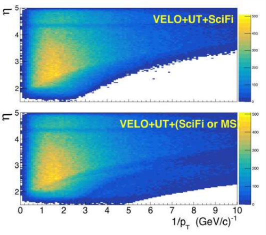


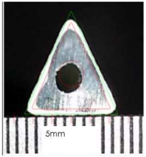
Magnet Stations

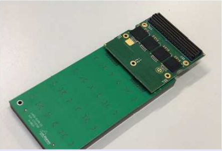
new detector proposed to enhance LHCb tracking capabilities, enlarging the pseudorapidity range and improving the track reconstruction in outer edges of SciFi
acceptance is extended for low momentum tracks





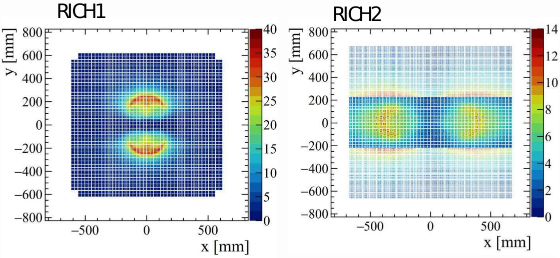




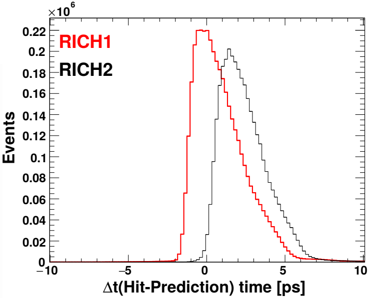


- panels composed by extruded triangular scintillating bars
- light guided through fibres to SiPM located outside the magnet
- timing option with TDC under study to reject tracks coming from very slow particles

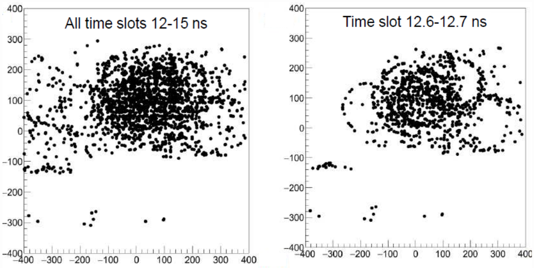
Ring Imaging CHerenkov detectors



- peak occupancy in Run3 conditions reaches ∼35% in RICH1
- occupancy in Run5 keeping same photon detectors and geometry would reach 100%



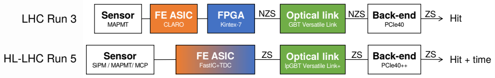
- prompt nature of Cherenkov radiation: time of arrival of Cherenkov photons for a given track can be predicted to better than 10 ps

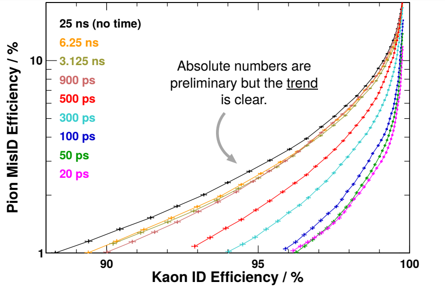


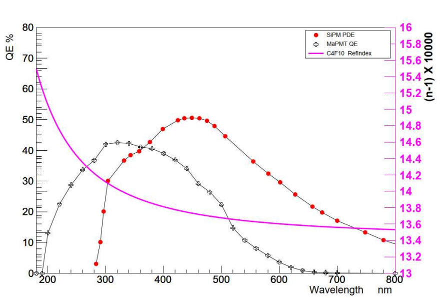
- timing implementation on RICH detectors helps in reducing the peak occupancy and recover PID performance

RICH studies

- timing allows to recover loss of PID performance
- studies on possible photon detectors ongoing
- baseline candidate: SiPM
  - smaller pixel size allows to further reduce peak occupancy
  - high QE shifted towards green wavelengths reduces chromatic error
  - radiation hardness poses bigger challenge: R&D for cryo cooling
- studies ongoing on next generation MaPMTs and MCPs
- R&D on new time sensitive FE electronics
  - FastIC chip to be tested on beam in Autumn
  - plan to implement time gating already in Run4



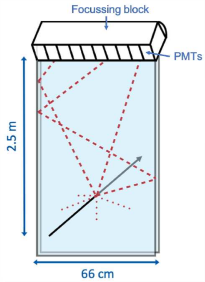


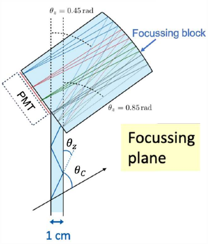


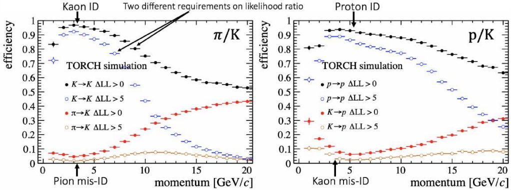
Time Of internally Reflected CHerenkov light

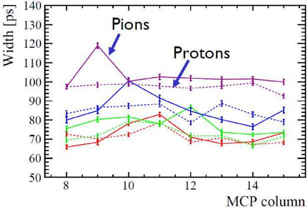
TORCH is a brand new detector for the enhancement of the LHCb PID capabilities at low momentum

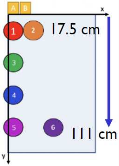
- Cherenkov photons produced by charged particle traversing quartz plane, then transported by total internal reflection to focusing block and detected with MCP-PMTs
- measurement of Cherenkov angle, path length and time of arrival
- the time resolution required is 70 ps per photon
- studies of expected PIDs carried out within the LHCb framework









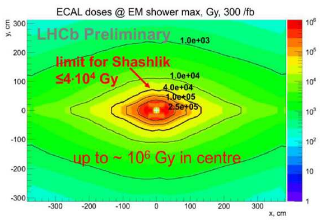


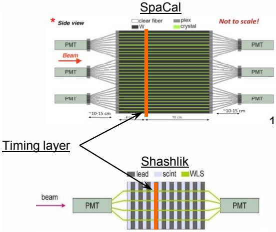
half-size module, partially populated with MCPs, tested on beam
time resolution achieved already approximates closely the benchmark of 70 ps

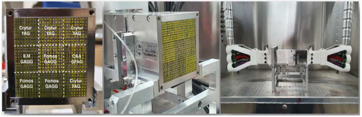
Electromagnetic CALorimeter

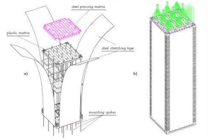
ECAL designed for maximum radiation dose of 2.5 kGy/year, expected dose in Upgrade II up to 1 MGy, inner region will already reach maximum dose by the end of Run3

- need to replace inner region during LS3
- need to upgrade ECAL for Run5
- timing needed to cope with high occupancy!
- intense R&D campaign ongoing
- SpaCal (W/GAGG, Pb/Polystyrene) / Shashlik baseline option: test beam campaign ongoing
- possibility to add timing layer ⇒ LAPPDs under test

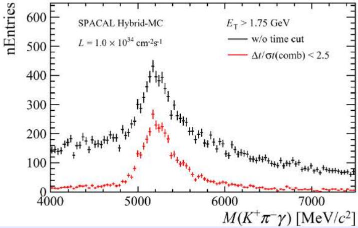


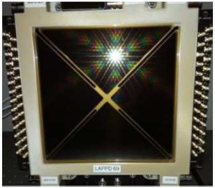




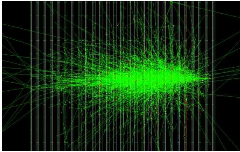


Impact of timing on $B^0 \to K^{*0}\gamma$, full simulation SpaCal/Shashlik





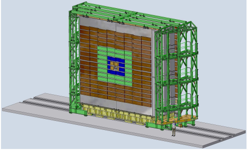
W/Si sampling calorimeter

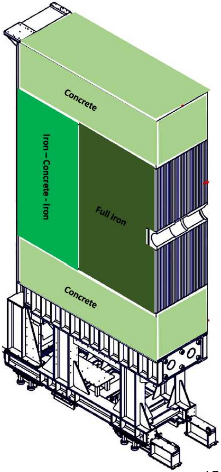


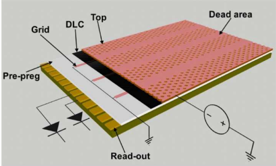
Muon system

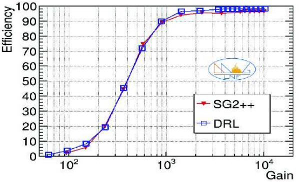
by the end of Run4 the inner regions (R1 and 2) of the muon system will have reached their maximum integrated charge
⇒ need to replace them

- equip R1-2 (144 chambers = 23 m^2) with uRWell, new generation MPGD detectors, optimised to cope with rates up to few MHz/cm^{-2}
- keep original MWPC in outer region, R3-4 (960 chambers = 364 m^2)
- equip with new front-end electronics
- uRWell R&D well advanced, test beam campaign already started
- keep original MWPC provided good ageing behaviour is confirmed by further studies
- other possibilities for outer region under study (RPCs and SCI-Tiles)
- proposal to add shielding wall in place of HCAL to reduce the number of muons hitting the stations









Conclusions

LHCb Upgrade II: unique opportunity for an ultimate precision flavour physics and general purpose experiment in the forward region. It will be able to reach SM precision on several observables

EOI & Physics Case approved by LHCC/RB

Strong support received in European strategy

very challenging project ⇒ lots of R&D ongoing on all sub-systems

Green light to proceed to Framework TDR from LHCC and CERN research board:
"The recommendation to prepare a framework TDR for the LHCb Upgrade-II was endorsed, noting that LHCb is expected to run throughout the HL-LHC era"

FTDR in preparation: coming later this year!