

Micro-channels activities at CPPM

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Meeting with CPPM direction

Timeline and origin of the project

- Since 1994, CPPM has great expertise in pixels/vertex detectors, both in electronics and mechanics (DELPHI, ALEPH, ATLAS)
- In Feb 2017, LHCb presented an expression of interest to upgrade the detector for Run 5 (2030)
Expression of Interest for Upgrade II "U2", (2030)

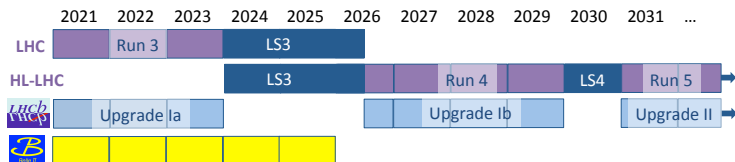
⇒ July, 7th 2018, we organized at CPPM a *Workshop on Vertex Detector for LHCb Upgrade II*

⇒ Well received and a synergy emerged between several actors: LHCb, CPPM mechanic service, NA62/P2O, LP3 lab with laser expertise, ATLAS expertise on gas.

- On Sep. 2018. *Excellent LHCC feedback to LHCb U2*: the LHCC "supports the effort of LHCb to start preparing for HL-LHC running. LHCb should prepare the framework TDR by mid-2021."
- 2019: started an R&D with CPPM/LP3 on micro-channels, with laser-etched silicon wafers.
(→ next talks)
- Jan 24th, 2020: *S. Beurthey, contribution au GT08 des prospectives nationales de l'IN2P3*. Three IN2P3 Labs interested by micro-cooling: CPPM, LAPP, LPNHE (10 persons).

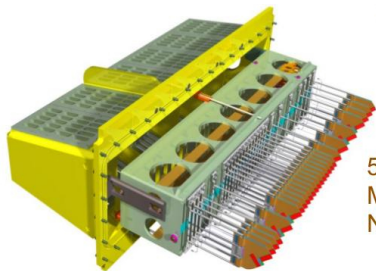
Timeline and vocabulary in LHCb

	Date	Runs	Instantaneous \mathcal{L} [$\text{cm}^{-2}\text{s}^{-1}$]	Integrated \mathcal{L} [fb^{-1}]	Status
LHCb	2010 – 2018	Run 1 & 2	4×10^{32}	9	Done
LHCb Upgrade I	2021 – 2029	Run 3 & 4	2×10^{33}	50	Approved
LHCb Upgrade II	2031 –	Run 5 & beyond	1.5×10^{34}	300	FTDR 2021

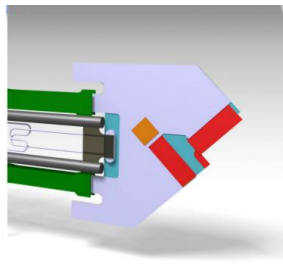


Upgrade I = U1. Upgrade II = U2.

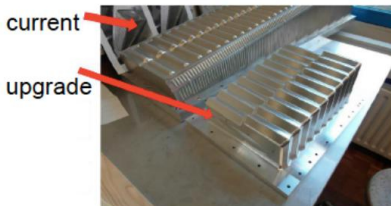
VELO Upgrade I (Run 3–4: 2020–2029)



52 modules
Module pitch
N*25 mm



enclosed in
an "L" shape foil

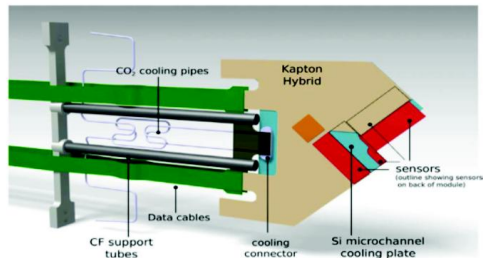
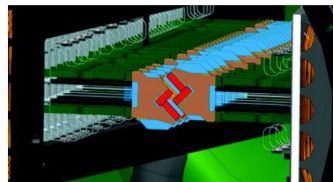
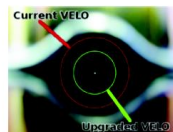
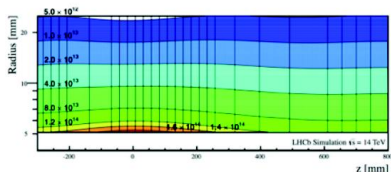


featuring pixel
sensors 5 mm
from the beam line

VELO Upgrade I (Run 3–4: 2020–2029)

VELO challenges in Run 3:

- Retain high vertex and track reco. efficiency with $\sim 5x$ increase in interactions per bunch crossing
- Increased radiation (order of magnitude higher than current doses), highly non-uniform
- Use silicon hybrid pixels
- 52 modules, two retractable halves
 - Innermost sections ~ 5.1 mm from beam pipe
 - 4 silicon sensors per module, $55 \mu\text{m} \times 55 \mu\text{m}$



Challenges for Upgrade II

- First CO₂ micro-cooling solution in HEP was used by NA62 GigaTracker (4D tracking).
- LHCb VELO-U1 pioneered micro-cooling with bi-phasic CO₂ in HEP
- Efficient and elegant cooling solution, but **expensive** (complicated processes).
One cooling substrate cost $\sim 10 - 20$ k€.
- Main limitations of LHCb-U1: bonding of large surface (8 inches wafers) to close the micro-channels (a small defect imply throwing away the wafer).

Challenges for LHCb U2:

- **Radiation** hardness: expected Fluence $5 - 8 \times 10^{16} \text{ 1 MeV n}_{\text{eq}} \text{ cm}^{-2}$ at 5.1 mm of the beam during the life of the detector ($> \times 5$ ATLAS ITK !) \Rightarrow modules will have to be regularly **replaced** (~ 1 year?)
- Multiplicity of vertex $\times 10 \Rightarrow$ add timing information: “4D tracking” \Rightarrow **more power to dissipate**
- To limit the leak current of the sensors, probably need to **go below -40°C** \Rightarrow study alternative gas to CO₂, like Krypton
- **Reduce the cost by at least a factor 10**
- **Improve the yield of production** \Rightarrow **reduce substrate size**: several “small substrate” instead of the large 8 inches used in U1 \Rightarrow Many connectors
- Think to a “**global solution**”: ASIC - mechanical support - cooling substrate - connectors - “high voltage pist”. Two solutions considered: **Titanium 3D printing** (NIKHEF) and **improved etched micro-channels** (CPPM).

Status of VELO LHCb Upgrade II Framework TDR

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

CERN-EP-2020-020
18th April 2020, 12:17
March 30, 2020

VELO upgrade II FTDR

LHCb-substructure/

Abstract

LHCb VELO TDR Revision by Appendix 2

draft

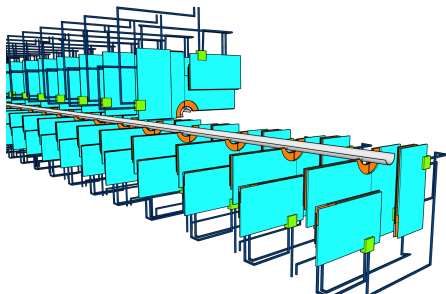
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Version for internal use and for the project

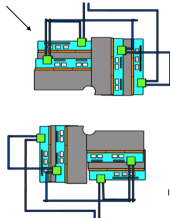
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→ to be submitted early 2021

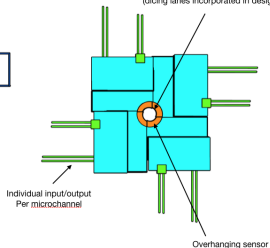
VELO U2: example of cooling solutions



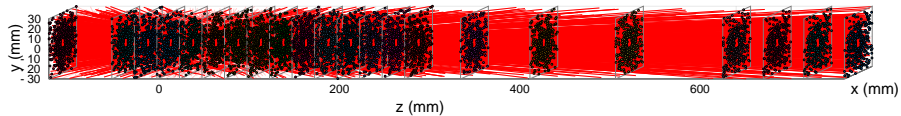
Cooling flowing serially between micro channels



Bespoke dicing on ASIC (dicing lanes incorporated in design)



A challenging environment:



Conclusions and prospects

- Current microchannels used by LHCb for U1 are **too expensive for U2**: we need to reduce the costs.
- The LHCb collaboration consider: **3D Titanium printing** and/or **low-cost micro-cooling** ⇒ CPPM investigation on micro-cooling → next talks;
- As a reminder: **we need a room** to continue our pressure tests and future connector developpements.
Ideally, close to existing CO₂ facility (i.e. in current building).
- A **publication** is planned with the outcome of the laser-etched wafer, in a laser journal, with LP3.
- We also plan a section in the **VELO Framework TDR** (by the end of this year).
- Now, we work with existing resources (LHCb, mechanics, NA62) and a “stagiaire en mécanique”. In case first steps are successful, **we anticipate the need for money and manpower**.

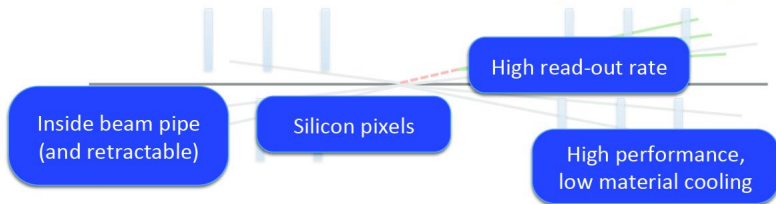
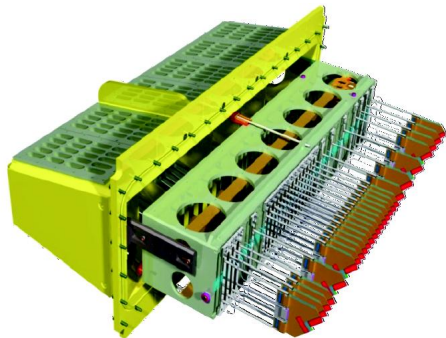
Backups

VELO Upgrade II (Run 5–6: 2030–)

We want to achieve same or better physics performance as Upgrade-I VELO, at 10x luminosity...

- 10x higher particle multiplicity
- 10x denser vertex environment
- 10x higher radiation damage

Can it be done? How?



- Multiplicité des particules $10\times \rightarrow$ petits pixels ($27.5\times 27.5\ \mu\text{m}$)
- Multiplicité des vertex $10\times \rightarrow$ info en temps (4D, 200 ps)
- Taux de radiation $10\times$, fluence attendue $5 - 8 \times 10^{16}\ 1\ \text{MeV}\ n_{\text{eq}}\text{cm}^{-2}$ à 5.1 mm des faisceaux pendant la durée de vie du détecteur ($> \times 5$ ATLAS ITK !) \Rightarrow 2 technologies pour les parties internes et externe? Capteurs remplac cables?
- Sensor thickness = $100\ \mu\text{m}$.
- Il se peut qu'une telle technologie ne voit pas le jour si nous ne la poussons pas!
- Enlever la feuille RF: capteurs directement dans le vide primaire du LHC? Refroidissement?

Challenge A: 10x particle multiplicity

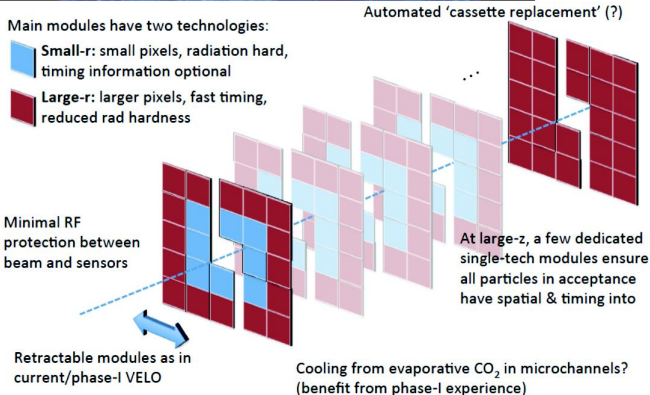
Challenge B: 10x vertex multiplicity

Challenge C: 10x radiation damage

Small Pixels

Timing

Replacement



Micro-cooling

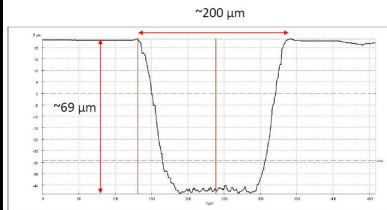
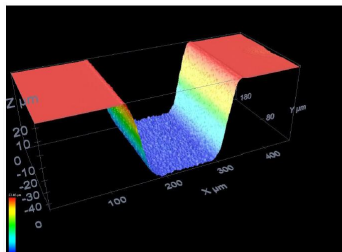
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Stéphan Beurthey (CPPM-mécanique), Julien Cogan et Olivier Leroy (CPPM-LHCb), Mathieu Perrin-Terrin (CPPM-P2O), Greg Hallewell (CPPM-ATLAS) et

Alexandros Mouskeftaras (LP3)

- VELO-Upgrade-I pioneered micro-cooling with bi-phasic CO₂ in HEP.
- Efficient and elegant cooling solution, but expensive (complicated processes)
- For VELO-Upgrade-II, with replacable modules, need to improve the cooling
- We are investigating the micro-cooling with laser etching (instead of the traditional photolithography).

Collaboration cross-experiments and cross-laboratories



REFROIDISSEMENT: ÉTAT DE L'ART

