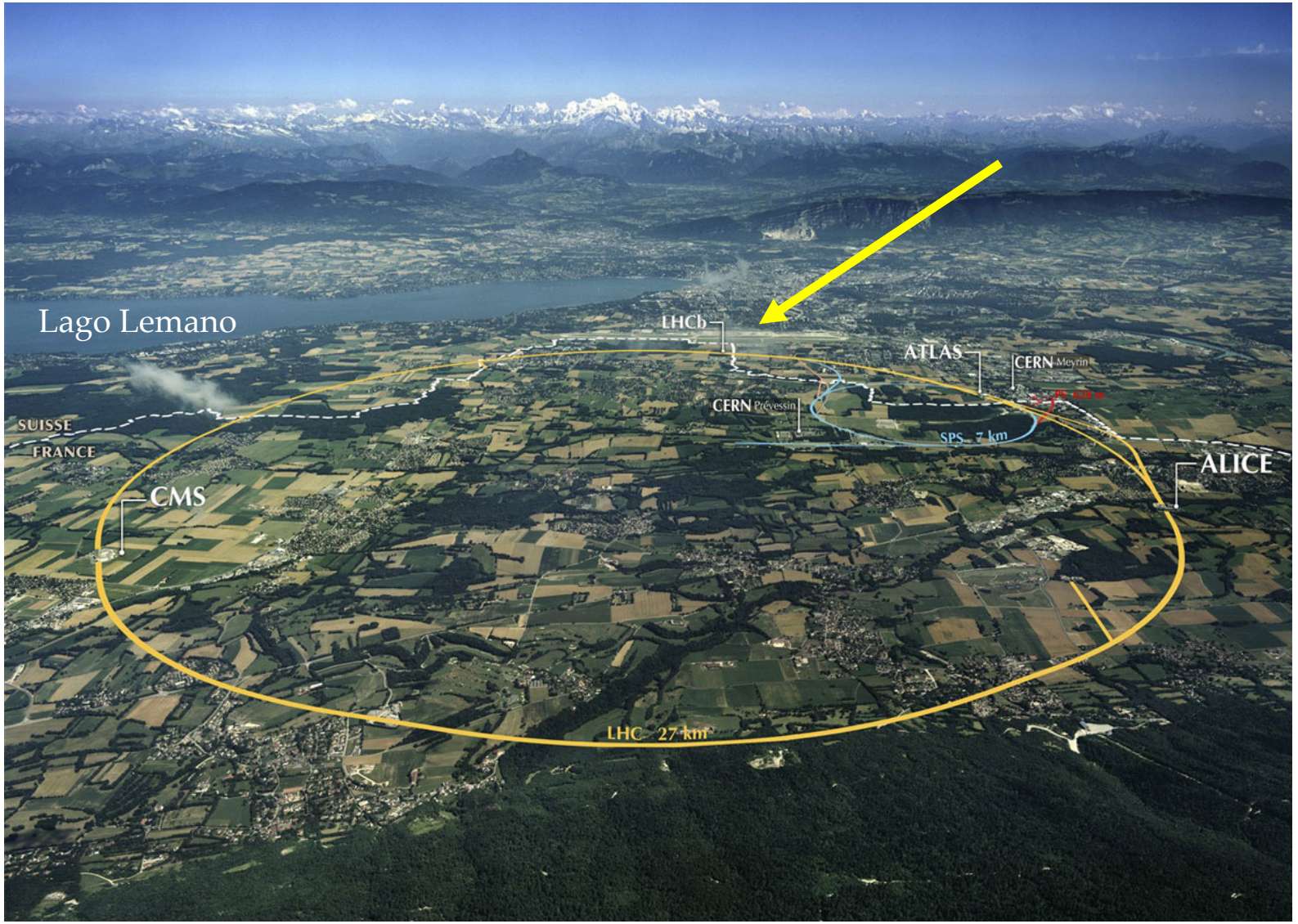
# LHCb
# Preventivi 2023

Massimiliano Fiorini

Consiglio di Sezione INFN

Ferrara, 1 Luglio 2022

# Esperimento LHCb



# Preventivi LHCb 2023

Ricercatori

| | Nome | Contratto | Qualifica | Percentuale | Note: percentuali su sigle sinergiche | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | Baldini Wander | Dipendente | Ricercatore | 70 | | | | |
| 2 | Bolzonella Riccardo | Associato | Dottorando | 20 | 50 | 50% su ERC 4DPHOTON | | |
| 3 | Bozzi Concezio | Dipendente | Dirigente di Ricerca | 70 | 25 | 25% su spoke 10 di ICSC (PNRR) | | |
| 4 | Calabrese Roberto | Associato | Prof. Ordinario | 60 | 10 | 10% su ERC 4DPHOTON | | |
| 5 | Cavallini Viola | Associato | Borsista | 50 | | | | |
| 6 | Couturier Ben | Associato | Dottorando | 100 | | | | |
| 7 | Fiorini Massimiliano | Associato | Prof. Ordinario | 10 | 60 | 60% su ERC 4DPHOTON | | |
| 8 | Franzoso Edoardo | Associato | Dottorando | 70 | | | | |
| 9 | Giugliano Carmen | Associato | Assegnista | 70 | | | | |
| 10 | Guarise Marco | Associato | Assegnista | 50 | 20 | 20% su ERC 4DPHOTON | | |
| 11 | Kotriakhova Sofia | Associato | Dottorando | 100 | | | | |
| 12 | Luppi Eleonora | Associato | Prof. Ordinario | 70 | | | | |
| 13 | Okamura Shinichi | Associato | Dottorando | 70 | | | | |
| 14 | Pappalardo Luciano Libero | Associato | Prof. Associato | 70 | | | | |
| 15 | Passalacqua Barbara | Associato | Dottorando | 100 | | | TOTALE FTE RIC+TECNOL | |
| 16 | Tomassetti Luca | Associato | Prof. Associato | 70 | | | 13.50 | |
| 17 | Vecchi Stefania | Dipendente | Ricercatore | 70 | | | TOTALE FTE RIC+TECNOL (incl. sigle sinergiche) | |
| Numero Totale Ricercatori | 17 | | FTE | 11.2 | | | 16.35 | |
| | | | | | 1.65 | 12.9 | | |

Tecnologi

| | Nome | Contratto | Qualifica | Percentuale | | |
|---|---|---|---|---|---|---|
| 1 | Andreotti Mirco | Dipendente | Tecnologo | 70 | | |
| 2 | Biesuz Nicolò | Dipendente | Tecnologo | 0 | 90 | 90% su ERC 4DPHOTON |
| 3 | Carassiti Vittore | Associato | Dirigente Tecnologo Pensione | 50 | | |
| 4 | Cotta Ramusino Angelo | Dipendente | Dirigente Tecnologo | 15 | 20 | 20% su ERC 4DPHOTON |
| 5 | Donati Andrea | Dipendente | Tecnologo | 65 | | |
| 6 | Saputi Alessandro | Dipendente | Tecnologo | 30 | 10 | 10% su ERC 4DPHOTON |
| Numero Totale Tecnologi | 6 | | FTE | 2.30 | | |
| | | | | | 1.2 | 3.5 |

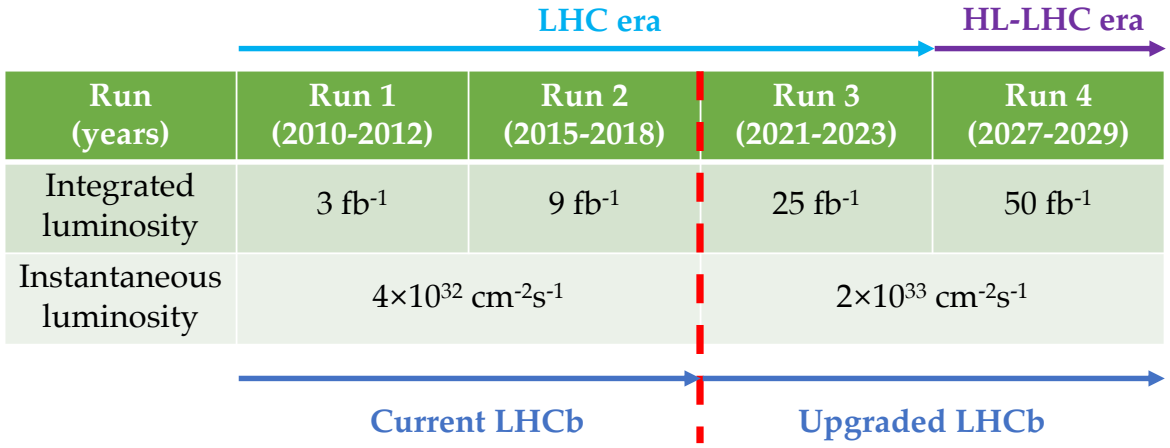
Tecnici

| | Nome | Contratto | Qualifica | Percentuale | | |
|---|---|---|---|---|---|---|
| 1 | Cavallina Michele | Dipendente | Collaboratore Tecnico E.R. | 10 | | |
| 2 | Chiozzi Stefano | Dipendente | Collaboratore Tecnico E.R. | 20 | 20 | 20% su ERC 4DPHOTON |
| 3 | Gambetti Michele | Associato | Tecnico Categoria C | 35 | | |
| 4 | Magnani Andrea | Associato | Tecnico Categoria C | 20 | | |
| 5 | Malaguti Roberto | Dipendente | Collaboratore Tecnico E.R. | 20 | | |
| 6 | Neri Ilaria | Associato | Tecnico Categoria C | 20 | | |
| Numero Totale Tecnici | 6 | | FTE | 1.3 | | |
| | | | | | 0.2 | |

- 16.4 FTE totali (ricercatori + tecnologi)
- Responsabilità:
  - C. Bozzi: Project Leader Computing, Computing Resource Manager
  - L. Pappalardo: LHCb representative for the PBC QCD group
- Stima richieste finanziarie:
  - Missioni
    - Interne 15 k€
    - Estere 160 k€
  - Consumi 40 k€

# LHCb Upgrade Program

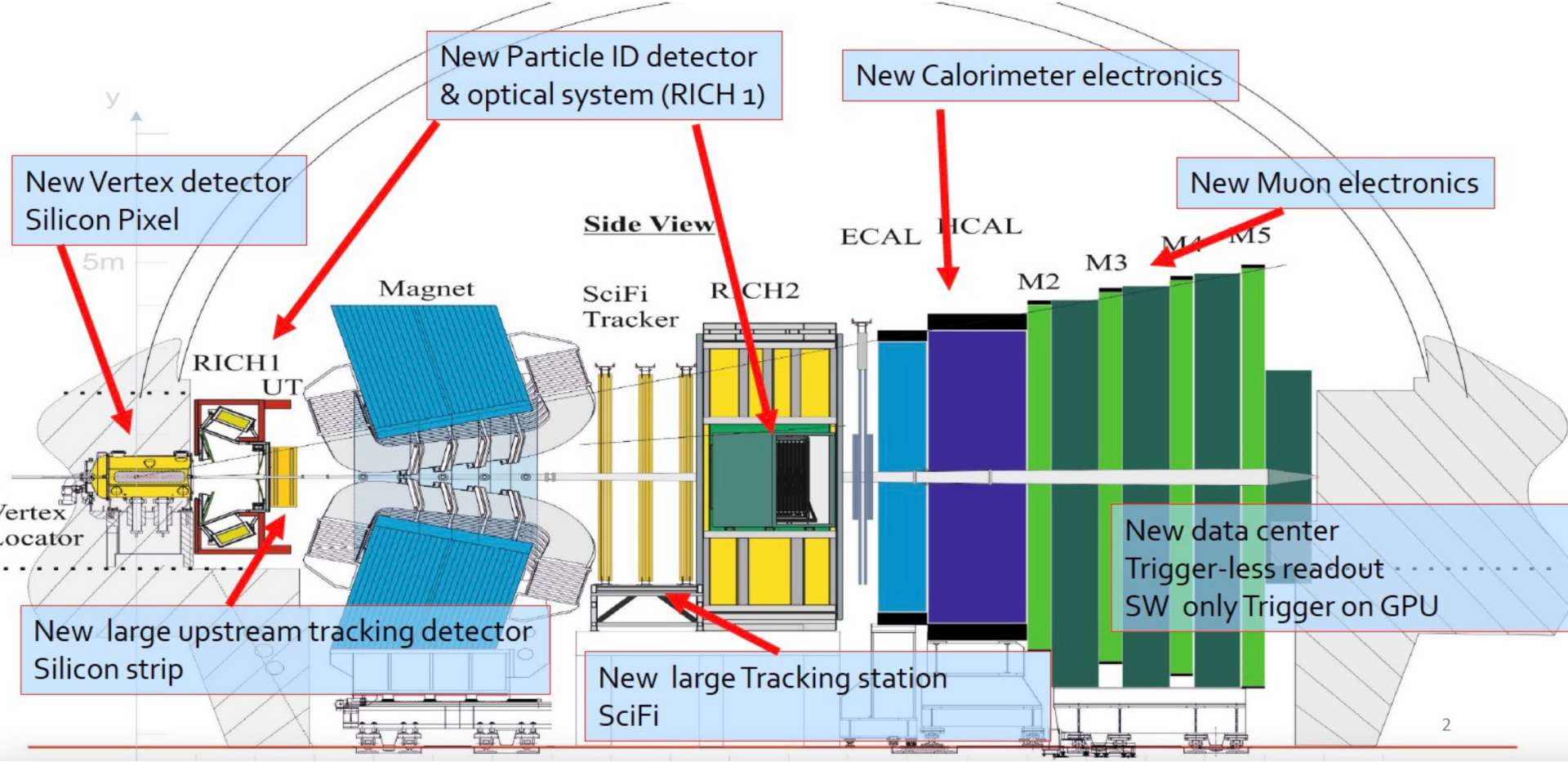
- During Run 1 LHCb operated at leveled luminosities up to $4 \times 10^{32}$ cm$^{-2}$s$^{-1}$, 2× higher than design value
- In Run 2 we collected ~6 fb$^{-1}$ more
  - Main limitation: 1 MHz L0 trigger rate




- LHCb Phase 1 Upgrade
  - Operate detector at $2 \times 10^{33}$ cm$^{-2}$s$^{-1}$ instantaneous luminosity
  - Read out the full detector at 40 MHz
  - Install upgraded LHCb during long shutdown 2 (2019-21)

# LHCb Upgrade I

## Reminder: rivelatore LHCb Upgrade I



# LHCb Upgrade I

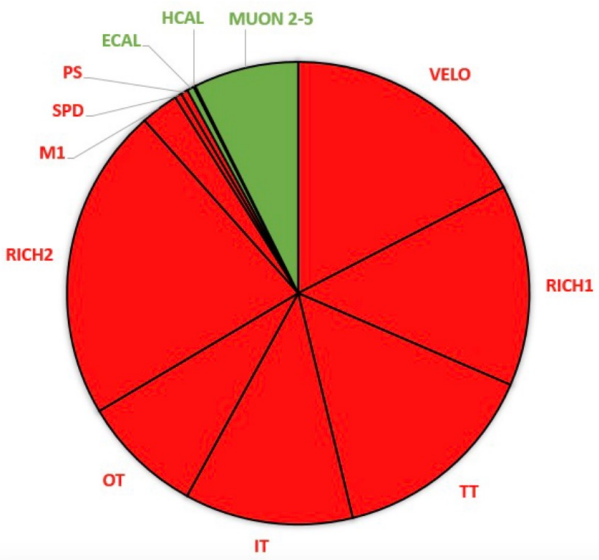
## Reminder: rivelatore LHCb Upgrade I

To be removed/replaced

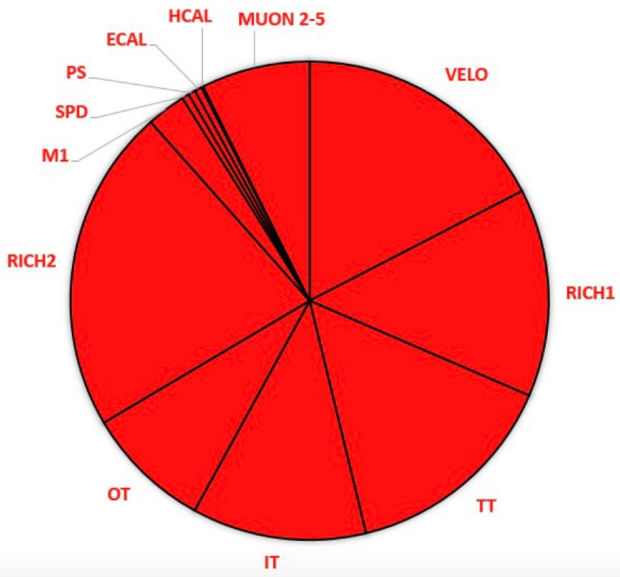
To be kept

- Mantenuto meno del 10% dei canali del vecchio rivelatore
- 100% dell'elettronica di R/O rimpiazzata
- Nuovo Sistema di DAQ e nuovo data center

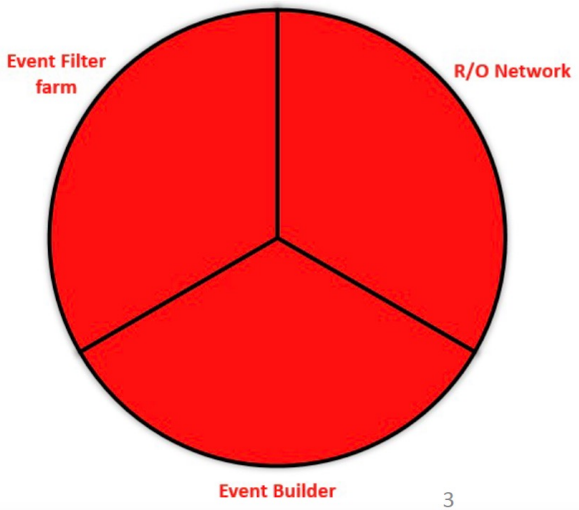
Detector Channels




R/O Electronics




DAQ

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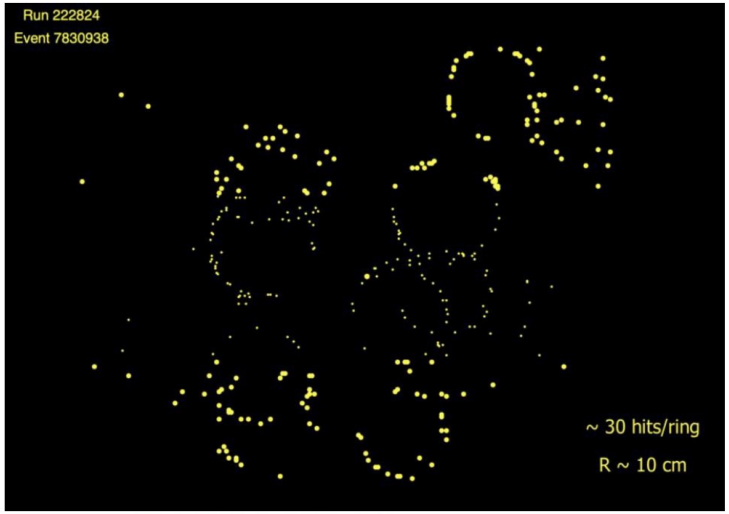
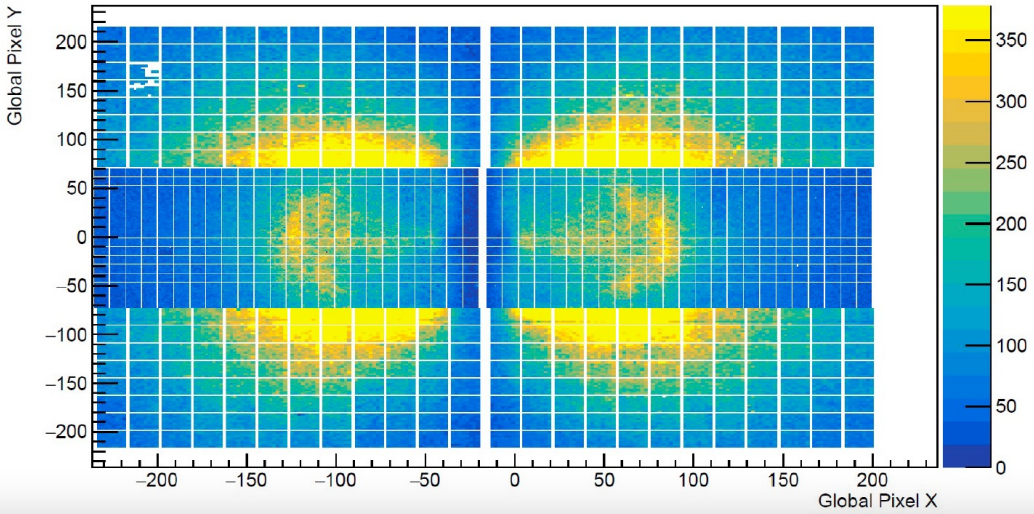
# LHCb Upgrade I

## Stato dei RICH

- RICH 2
  - Installazione completata nell'estate 2021
  - Commissioning molto avanzato
  - Dati già acquisiti nel Pilot Run di ottobre
  - Primi anelli nell'immagine a destra



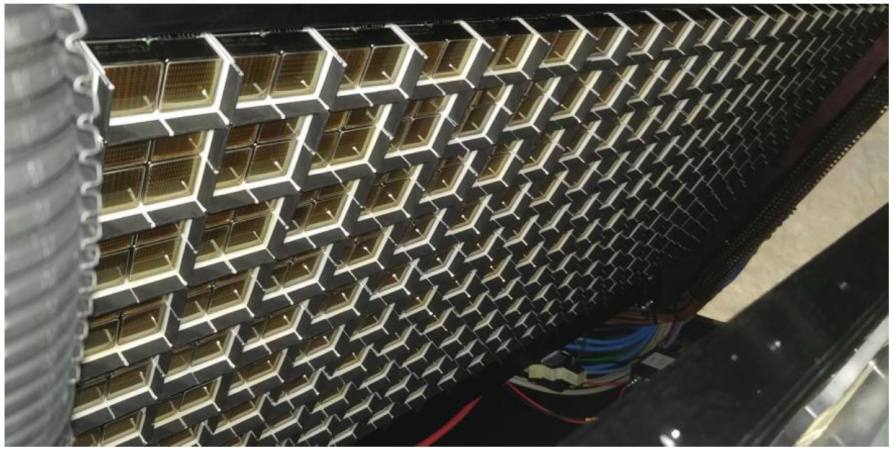

Rich2 Global Pixel Map



# LHCb Upgrade I

## Stato dei RICH

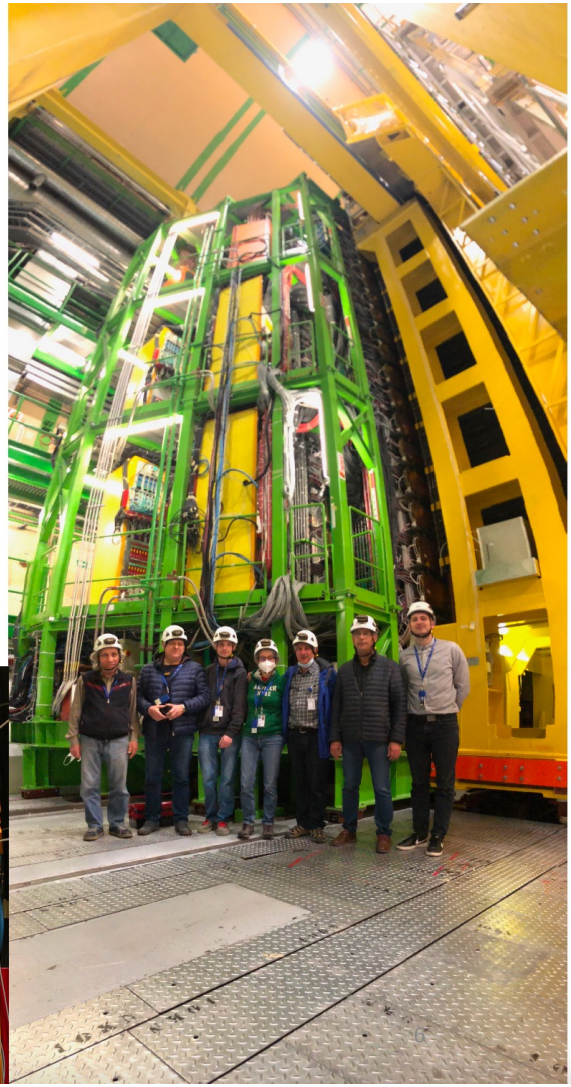
- RICH 1
  - Nuovo gas enclosure ✓
  - Nuovi specchi sferici e piani ✓
  - Nuova finestra d'uscita ✓
  - Nuove finestre al quarzo ✓
  - Sigillatura con il VELO ✓
  - Gas enclosure testato e a tenuta ✓
  - Ultima colonna di MaPMT installata e connessa in gennaio 2022 ✓

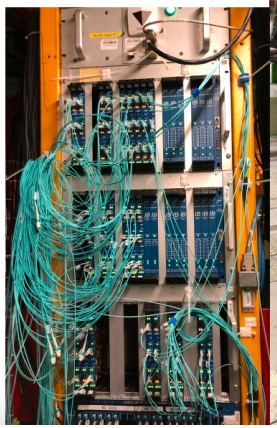


# LHCb Upgrade I

## Sistema camere a muoni

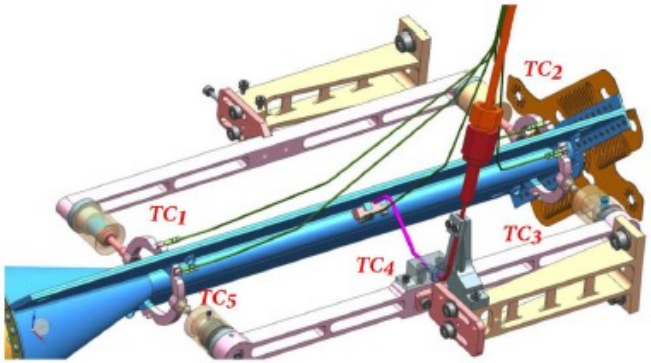
- Pronto alla presa dati
  - Nessun canale problematico
  - Tutte le connessioni (dati e controllo) OK
  - Spare sufficienti per il 2022
  - Flussaggio del gas OK
  - High Voltage in STANDBY, pronto per READY
- Sistema vista da HLT/RTA
  - Codifica/decodifica pronta e testata sulla versione del software CPU, e il progetto Real Time Analysis sta ora lavorando per la parte GPU (HLT1)
  - Ricostruzione e Muon ID pronte in HLT1 e HLT2
- Commissioning in via di completamento
  - Run in partizione DAQ locale: OK
  - Run in partizione DAQ globale: OK
  - HV/LV in partizione globale: OK
  - Monitoring: quasi completato

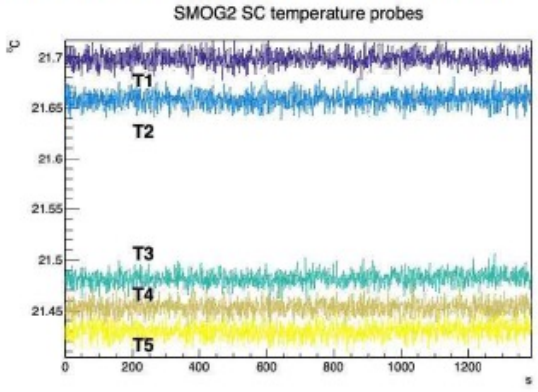


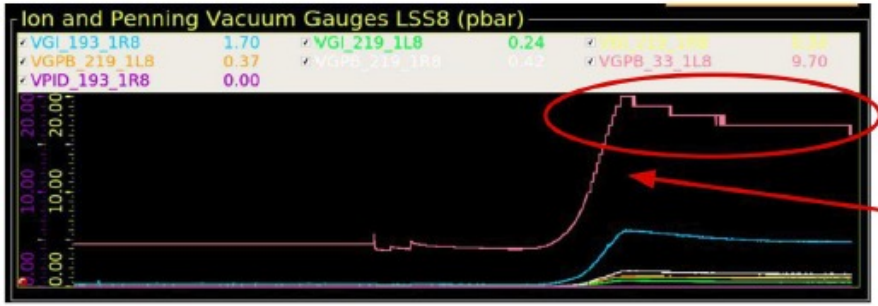


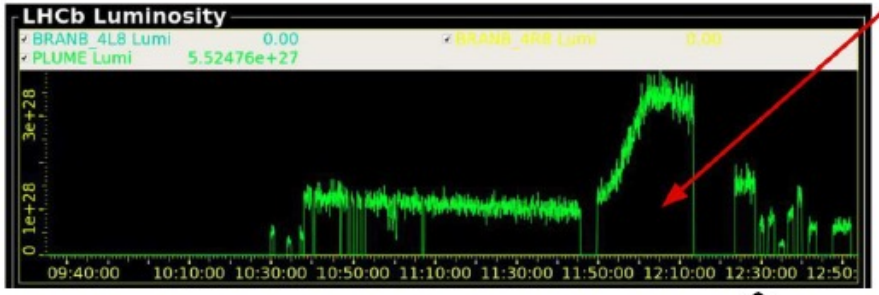
# SMOG2 (V. Carassiti, G. Ciullo, P. Lenisa, L. Pappalardo)


**5 sonde di temperatura, lettura implementata in LHCb Online** (S. Kotriakhova)




**Instantaneous pressure** as read from different gauges around IP8

**SMOG injection**

**slide by S. Mariani**

**Instantaneous luminosity** as read from the local PLUME monitoring system in bb configurations

- ✓ **Gas Feed System completato, installato (3/22) e funzionante**
- ✓ **4 linee di gas (3 per gas nobili, 1 per H/D)**
- ✓ **primi test di iniezioni**

# Attività completate, in corso e previste per 2022/2023

## SMOG2

- ✓ Calibrazione 5 sonde di temperatura sulla storage cell (G. Ciullo)
- ✓ Monitoring delle temperature implementato in LHCb Online framework (S. Kotriakhova)
- ✓ Completamento, montaggio e calibrazione del Gas Feed System nel PIT
- ✓ Primi test di iniezione di gas con e senza fascio
- • Commissioning (2022) e data taking

## R&D per LHCspin

- • Studio e progettazione di diverse configurazioni dell'apparato (V. Carassiti, P. Lenisa, in collab. con LNF)
- • Studio delle performance di fisica attese (L. Pappalardo in collab. con LNF)
- • Studio del coating per la cella di accumulazione in collab. con CERN e Juelich
- • ERC con massimo dei voti, progetto 'fundable' (ma non finanziato)

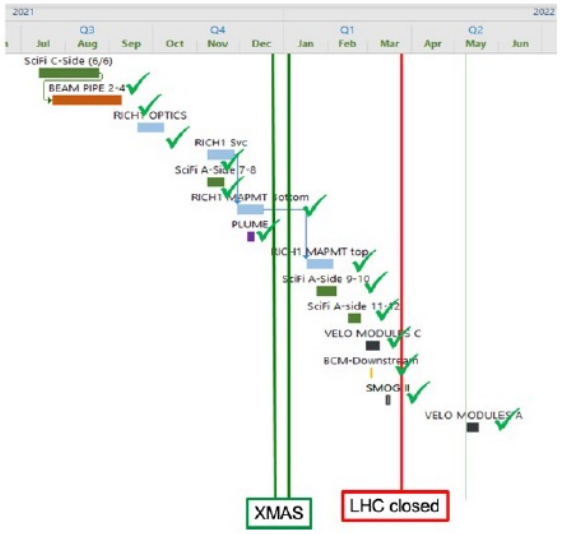
## Analisi dati con SMOG

- • Studio di cold nuclear matter effects in produzione di adroni leggeri su campioni pHe, pNe e pAr a $\sqrt{s_{NN}} = 110\ GeV$ (E. Franzoso)
- • Studio di cold nuclear matter effects in produzione di adroni leggeri su campioni pNe e PbNe a $\sqrt{s_{NN}} = 69\ GeV$ (S. Okamura)
- • Studio di incremento di stranezza in produzione di adroni leggeri in campioni pNe e PbNe a $\sqrt{s_{NN}} = 69\ GeV$ (B. Passalacqua)

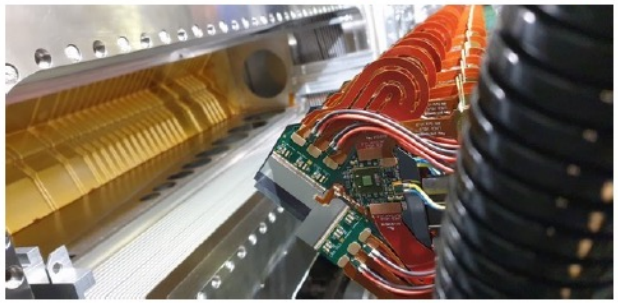
# LHCb Upgrade I

## Upgrade I Status – Installation – Congratulations !

- The last period was tense, but we made it !
  - Thanks to everyone for the enormous efforts
- One week intervention was given for VELO A-side installation
  - Minimal effect on machine schedule given delays in LHC




- SciFi completion
- VELO completion
- SMOG II gas injection system



- Look forward to completion of UT, still good performance in absence

# LHCb Upgrade I

## Take Away Messages

- **We made it !**
- Installed largest cern detector project since completion of LHC
  - On-budget and near-schedule
- Commissioning underway
  - Strong progress, will take time
- UT has made progress
  - Multi-stave mounting next stage, schedule followed closely

# Collisioni

## High-energy collisions: 5th July 2022

**Thanks to Bolek Pietrzyk, Violaine Belee & Mark Williams for the outreach WG**

- 4th July – Higgs @ 10 symposium

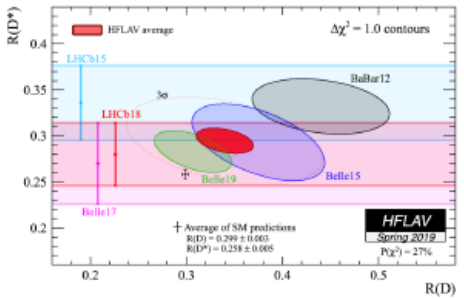
- Run 3 Live event
- In collab. with EBU
- **2 hour live running commentary** of the procedure to get stable beams and first collisions for Physics at the LHC
- In live connection with the **4 LHC experiments control rooms** + the Computing Centre
- **5 language channels** (English, French, German, Italian and Spanish)

# Attività di analisi

## Test of Lepton Flavor Universality in $\bar{B}_s^0 \to D_s^+ \tau^- \bar{\nu}_\tau$ decays using 3-prong $\tau^-$ decays

C. Bozzi, B. Couturier, C. Giugliano, B. Siddi and S.Vecchi

- Combination of measurements by several experiments show interesting anomalies wrt SM predictions in semileptonic $b-$hadron decays (violation LFU)
  - Crucial to improve precision and perform new measurements
  - several LHCb measurements ongoing/foreseen involving different $b-$hadron decay modes and lepton decays




- We aim to measure $\mathcal{R}(D_s) = \frac{\mathcal{B}(\bar{B}_s^0 \to D_s^+ \tau^- \bar{\nu}_\tau)}{\mathcal{B}(\bar{B}_s^0 \to D_s^+ \mu^- \bar{\nu}_\mu)}$
  - Use $\tau^- \to \pi^+\pi^-\pi^-\nu_\tau$ decays (similarly to $\mathcal{R}(D^*)$ measurement done by our group)
  - Use normalization channel with a topology similar to the signal to achieve the best precision
    - ✓ comparison among different channels. The best is $B_d \to D^- 3\pi^+$
- ✓ common selection of signal and normalization channels
- ✓ MVA analysis to discriminate between $\bar{B}_s^0 \to D_s^{*+} \tau^- \bar{\nu}_\tau$ and $\bar{B}_s^0 \to D_s^+ \tau^- \bar{\nu}_\tau$, validated using a control sample
- ✓ MVA selection to suppress partially reconstructed background with extra charged tracks
- × ongoing: refine the signal selection to suppress main backgrounds ($H_b \to D_s^{(*)} H_c X$) [need to produce some MC]
- ✓ develop the fit code and performed some preliminary studies on TOY data samples
- × ongoing: evaluate efficiencies, yield of normalization, systematic uncertainties

# Sviluppo software

## Software alignment of the Muon detector

S.Vecchi

- LHCb detector alignment exploits track reconstruction to align different detector elements. Runs online since Run2 → guarantees best performance at trigger level. Will be crucial for the Upgrade.
- We are responsible for alignment of the Muon detector since Run1 → continue for the upgrade.
  - ✓ Change geometry.
  - ✓ Update software to new framework.
  - ✓ Update the scripts to run online (Moore).
  - ✓ Continous validation tests with simulated data.
  - × ongoing: keep the code updated as the rest of the software changes
  - × ongoing: migrate to new detector geometry description (DD4Hep)

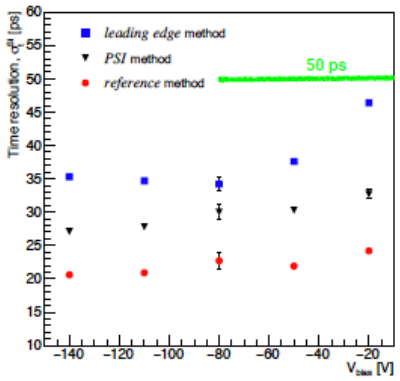
# Attività sinergica (CSN5)

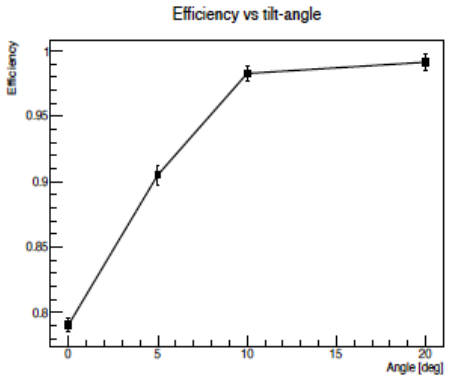
## Attività sinergica: progetto TimeSpot - Call CSN5-2018

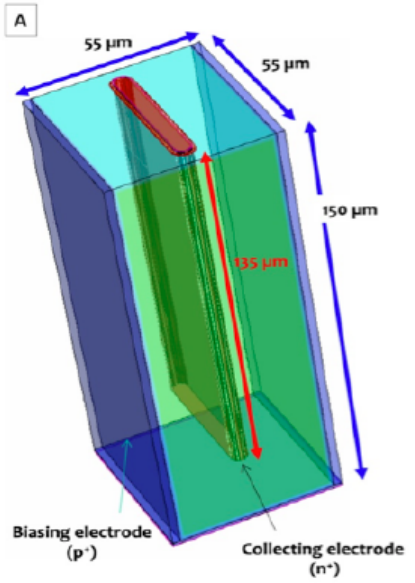
C. Bozzi, B. Siddi, S.Vecchi

Design, production and test of a silicon-pixel detector with good timing performances ($< 50ps$) and radiation resistence (up to $5\times10^{16}$ 1MeV neq as possible solution for the LHCb-Updade2 vertex detector.
We are involved inWP2 (simulation) & WP6 (Test, measurements)

- ✓ Beam Test PSI and data analysis [JINST 15 P09029 (2020)]
- ✓ Full simulation of the sensor (TCad), physics (GEANT4) and electronics (TFBoost) to compare with PSI results [JINST 16 P09028 (2021)].
- ✓ Beam Test SPS (2021 and 2022) and data analysis [paper in preparation] of new and irradiated sensors with custom FEE




Excellent timing performances with high efficiency

# Computing

## Coordination of LHCb computing Activities in 2023

- **Development and maintainance of the core software infrastructure:**
  - Gaudi framework for data taking, physics selections & analysis, simulation
  - Detector description & conditions DB
  - Validation of SW stack on non-x86 architectures
  - continuous integration, nightly builds, software performance & regression tests

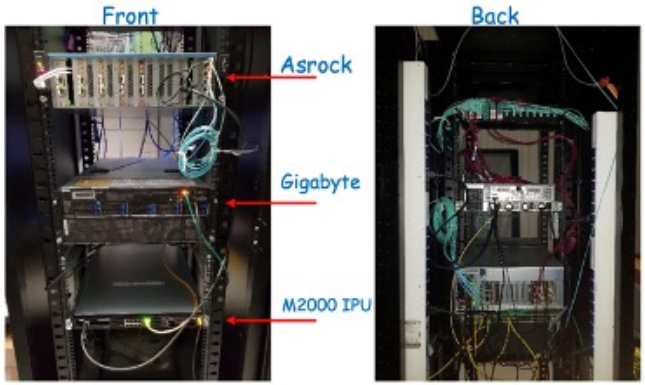
- **Development and maintainance of the distributed computing system:**
  - Continuous operations on Grids and Clouds
  - Exploitation of opportunistic resources such as HPC centers
  - Modernization of the DIRAC middleware for data and workload management

- **Resource management**
  - Estimate CPU, disk and tape needs
  - Negotiate with funding agencies and the CERN Resource Review Board to ensure resource needs are properly supported
  - Design the computing model and associated computing requests for Phase-II Upgrade (Run5)

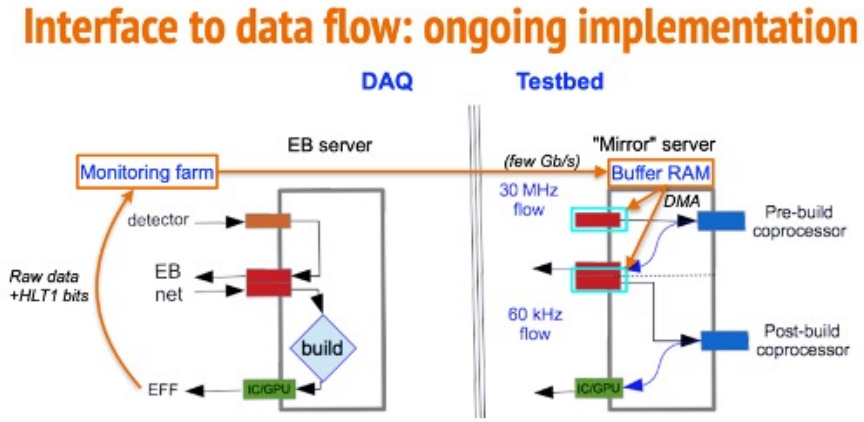
# RTA

## RTA/WP6 – Preprocessing dati via FPGA

- L'idea: pre-processamento veloce dei dati tramite FPGA, prima dell'Event Builder (EB) per ridurre il carico sulla farm
- Applicabile a tutti i rivelatori, al momento studi per Velo (1 quadrante) e Muon
- Con i fondi ricevuti finora (~80kE, 13kE a Ferrara) e' stato realizzato un "testbed" con 3 servers e 5 schede (altre 3 in arrivo)
- Ferrara si occupa:
  - del sistema di comunicazione ottico tra le schede
  - sistema di gestione e configurazione integrato tra schede
  - pre-processamento dei dati Muon
- Per il 2023 si prevede di effettuare i primi processamenti in "parassitaggio" tramite la monitoring farm, a rate limitato (~1kHz) ma con le informazioni sull'intero rivelatore
- Persone coinvolte: W.Baldini, C.Bozzi, S.Kotriakhova

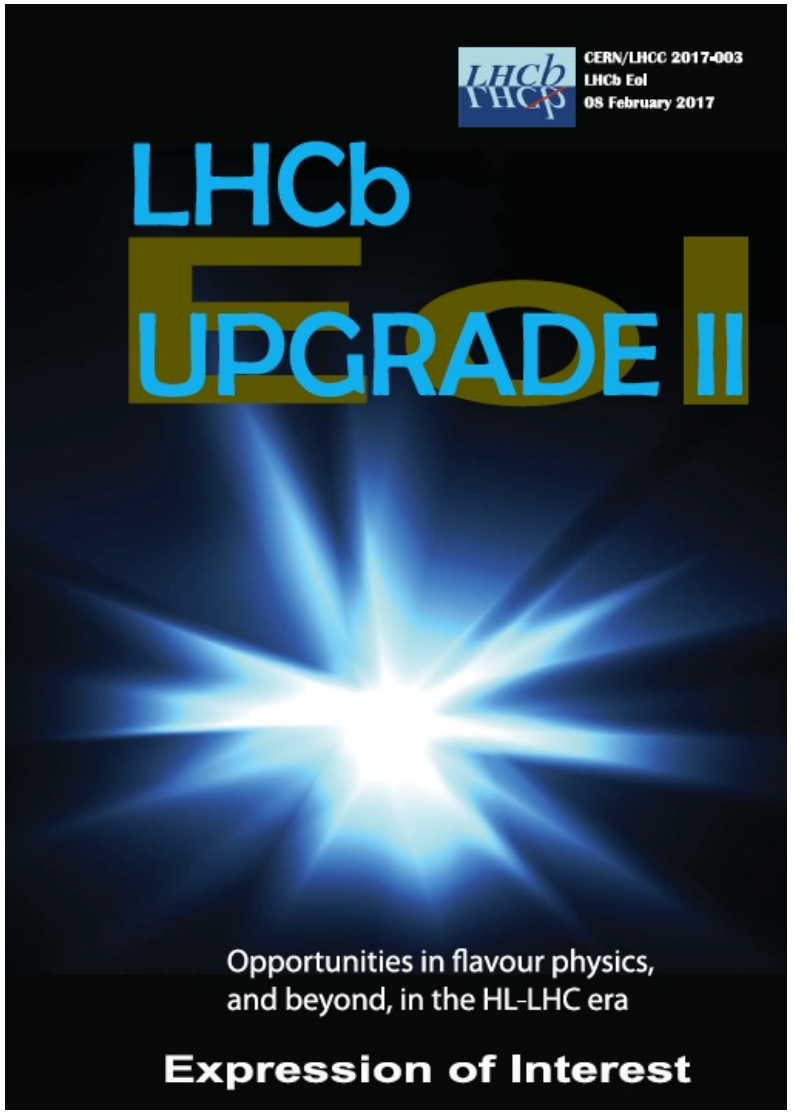



**Testbed al CERN: rack con 2 servers per 5 schede FPGA + un server per IPUs (UK)**



# LHCb Phase II Upgrade

- LHCb is proposing a Phase II Upgrade to take full advantage of the flavour physics opportunities at the HL-LHC
  - Ten-fold increase in luminosity compared to the Phase 1 upgrade ($1\text{-}2 \times 10^{34}$ $cm^{-2}s^{-1}$)
  - Operation from 2030 on
- The design of a very challenging RICH detector is being evaluated by the Collaboration



# Muon

## Attivita' Muon 2023

### Upgrade Fase II:

- Il Framework TDR e' stato pubblicato: Febbraio 2022
- Per Il Muon detector si prevede di **sostituire le MWPC delle regioni interne con µRWell**, nuova tecnologia adatta a rates fino a 10 MHz/cm$^2$
- grosso lavoro in corso per **stimare con precisione i rate attesi, e individuare le tecnologie adatte**
- Per le regioni esterne si riutilizzeranno molte MWPC (~50%), **oltre 200 nuove camere da produrre**
- La attuale situazione politica causa un importante cambiamento nella strategia: non potranno essere prodotte nuove MWPC in Russia
  → tecnologia da individuare (e nuovi gruppi!)
- Studi di "ageing" e organizzazione run speciali durante il Run3 (inizio ufficiale: 5 Luglio)
- **Ferrara ha attualmente la coordinazione del progetto** (design rivelatore, elettronica, simulazioni...): Wander

### Commissioning e presa dati con l'attuale rivelatore:

- Messa in opera della nuova elettronica di lettura
- Gestione dell'Experimental Control System (ECS): Sofia Kotriakhova
- Gestione rivelatore e presa dati
- Allineamento spaziale rivelatore: Stefania Vecchi


BI-GAP PAD Rate in Q2 M2C @ 1.5 x 10^34 + shielding + iron wall

| | | | | | | |
|---|---|---|---|---|---|---|
| 1175326 | 1475623 | 693531 | 2231054 | 4601730 | | 16 |
| 961879 | 1269898 | 578857 | 1628807 | 2501656 | 4406823 | 15 |
| 1005071 | 1154987 | 502426 | 1080551 | 2510948 | | 14 |
| 729314 | 901337 | 333953 | 687592 | 1264223 | | 13 |
| 735807 | 776426 | 262468 | 838630 | | | 12 |
| 538877 | 582858 | 180300 | 539778 | | | 11 |
| 542835 | 499617 | 143093 | 361713 | | | 10 |
| 401511 | 371001 | 92624 | 230638 | | | 9 |
| 397514 | 332479 | 732344 | 1511816 | | | 8 |
| 302379 | 243399 | 473199 | 1015470 | | | 7 |
| 292209 | 219852 | 411168 | 758637 | | | 6 |
| 223099 | 159274 | 286032 | 505145 | | | 5 |
| 221442 | 150893 | 247450 | 401111 | | | 4 |
| 168890 | 125281 | 189127 | 293904 | | | 3 |
| 159487 | 143063 | 203707 | 275506 | | | 2 |
| 147341 | 156022 | 218588 | 274975 | | | 1 |
| D | C | B | A | | | |

**Stima rates a 1.5x10$^{34}$cm$^{-2}$s$^{-1}$ con dati presi nel 2018: in rosso le camere da sostituire (per singolo quadrante)**

# RICH Upgrade phase II

- Intense R&D program for photodetector development
  - Single photon sensitivity, with large (green-shifted) QE
  - Able to sustain very high photon rates
    - In the current (i.e. Upgrade I) RICH detector we expect a maximum channel occupancy of ~25% with ~9 $mm^2$ pixel area (~1 $MHz/mm^2$ photon hit density)
    - For the Upgrade II we expect a photon hit density of ~10 $MHz/mm^2$
  - High granularity (hence electronics channel density) to keep maximum channel occupancy below ~25%
    - Translates in a pixel size of ~$1 \times 1$ $mm^2$
  - Excellent time resolution within a 25 ns bunch (<100 ps r.m.s.)
  - Radiation hard
    - Extrapolating from Upgrade I (using a factor $\times 10$): ~2 Mrad TID, ~$3 \times 10^{13}$ 1 MeV $n_{eq}/cm^2$, ~$1 \times 10^{13}$ HEH/$cm^2$
- Ferrara activities
  - SiPM and microchannel plate characterization (including irradiation)

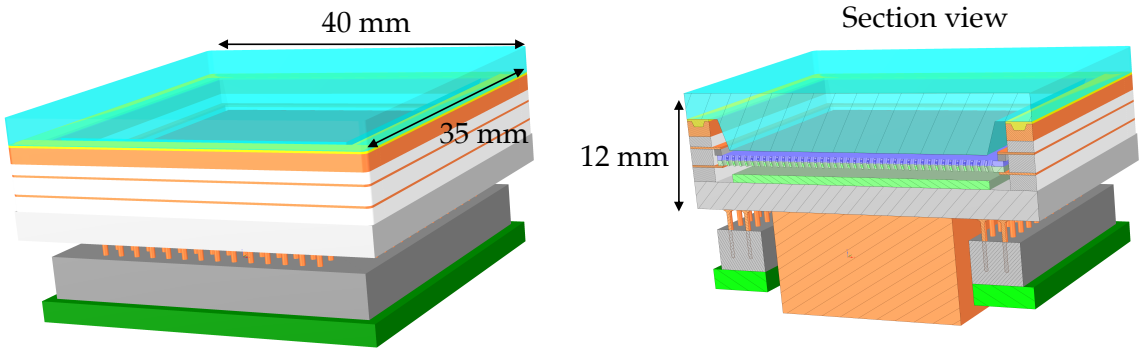
# Attività sinergica: Progetto ERC 4DPHOTON

# Progetto 4DPHOTON

- ERC Consolidator Grant, 5 years project (2019 – 2024)
  - Host Institution: INFN (beneficiaries: CERN and UNIFE)

European Research Council

- Development and construction of single-photon imaging detector with unprecedented performance
  - Detector, electronics and data acquisition system




- Main activities in 2023:
  - Construction of prototype vacuum tube, mechanics and cooling
  - Detector test with complete DAQ chain

# Anagrafica 4DPHOTON 2023

| Ricercatori | | | | |
|---|---|---|---|---|
| | **Nome** | **Contratto** | **Qualifica** | **Percentuale** |
| 1 | Bolzonella Riccardo | Associato | Dottorando | **50** |
| 2 | Calabrese Roberto | Associato | Prof. Ordinario | **10** |
| 3 | Fiorini Massimiliano | Associato | Prof. Ordinario | **60** |
| 4 | Guarise Marco | Associato | Assegnista | **20** |
| **Numero Totale Ricercatori** | 4 | | **FTE** | **1.40** |
| | | | | |
| **Tecnologi** | | | | |
| | **Nome** | **Contratto** | **Qualifica** | **Percentuale** |
| 1 | Biesuz Nicolò | Dipendente | Tecnologo | **90** |
| 2 | Cotta Ramusino Angelo | Dipendente | Dirigente Tecnologo | **20** |
| 3 | Gianoli Alberto | Dipendente | Dirigente Tecnologo | **10** |
| 4 | Saputi Alessandro | Dipendente | Tecnologo | **10** |
| **Numero Totale Tecnologi** | 4 | | **FTE** | **1.30** |
| | | | | |
| **Tecnici** | | | | |
| | **Nome** | **Contratto** | **Qualifica** | **Percentuale** |
| **1** | Cavallina Michele | Dipendente | Collaboratore Tecnico E.R. | **10** |
| 2 | Chiozzi Stefano | Dipendente | Collaboratore Tecnico E.R. | **20** |
| 3 | Squerzanti Stefano | Dipendente | Collaboratore Tecnico E.R. | **15** |
| **Numero Totale Tecnici** | 3 | | **FTE** | **0.5** |