European Strategy for Particle Physics: input from LHCb

European Strategy for Particle Physics: LHCb

The full exploitation of LHC potential for flavour physics received strong support in the Update of the European Strategy for Particle Physics in 2020

Flavor physics all around the world

BSM Physics can be discovered in complementary approaches

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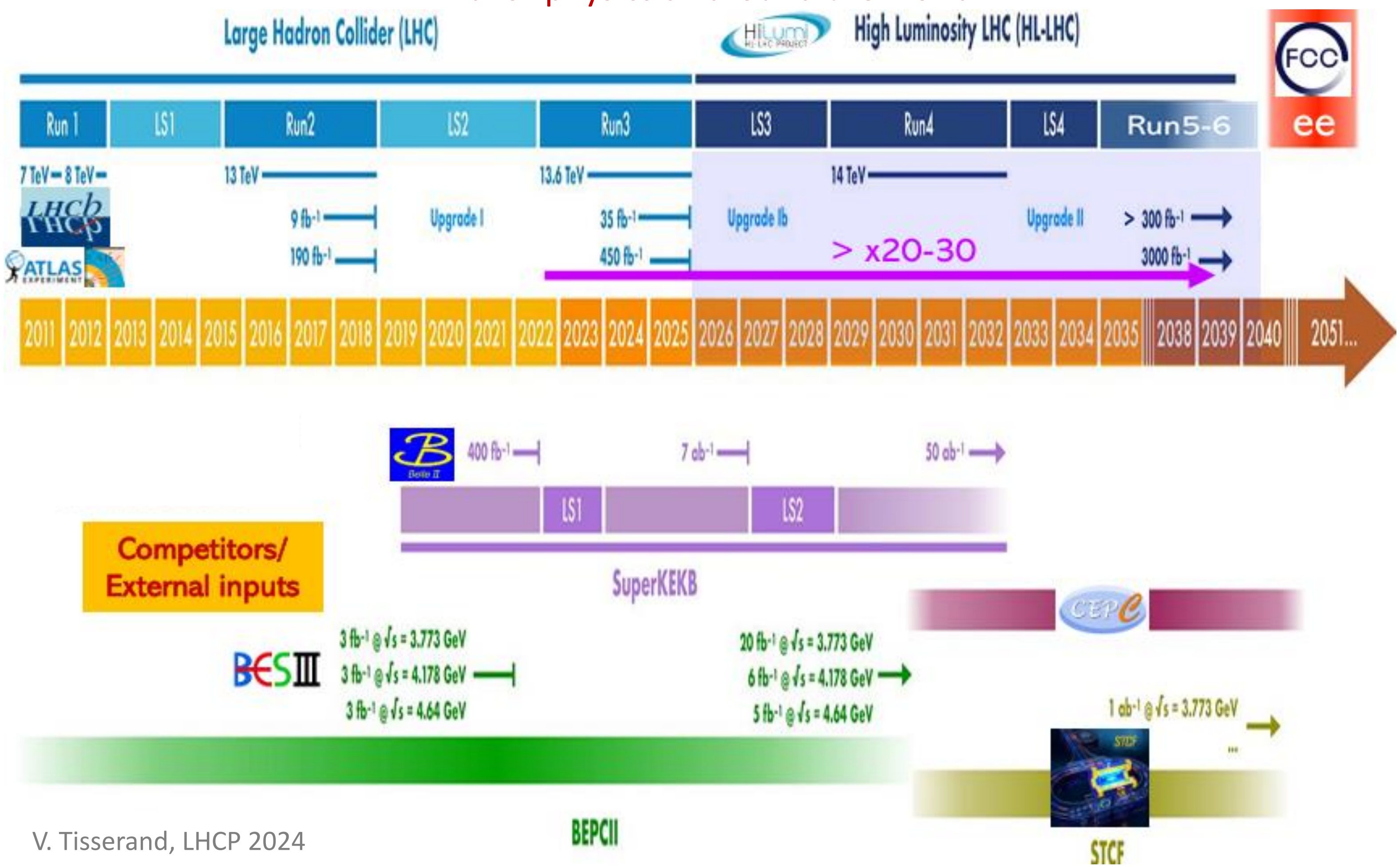
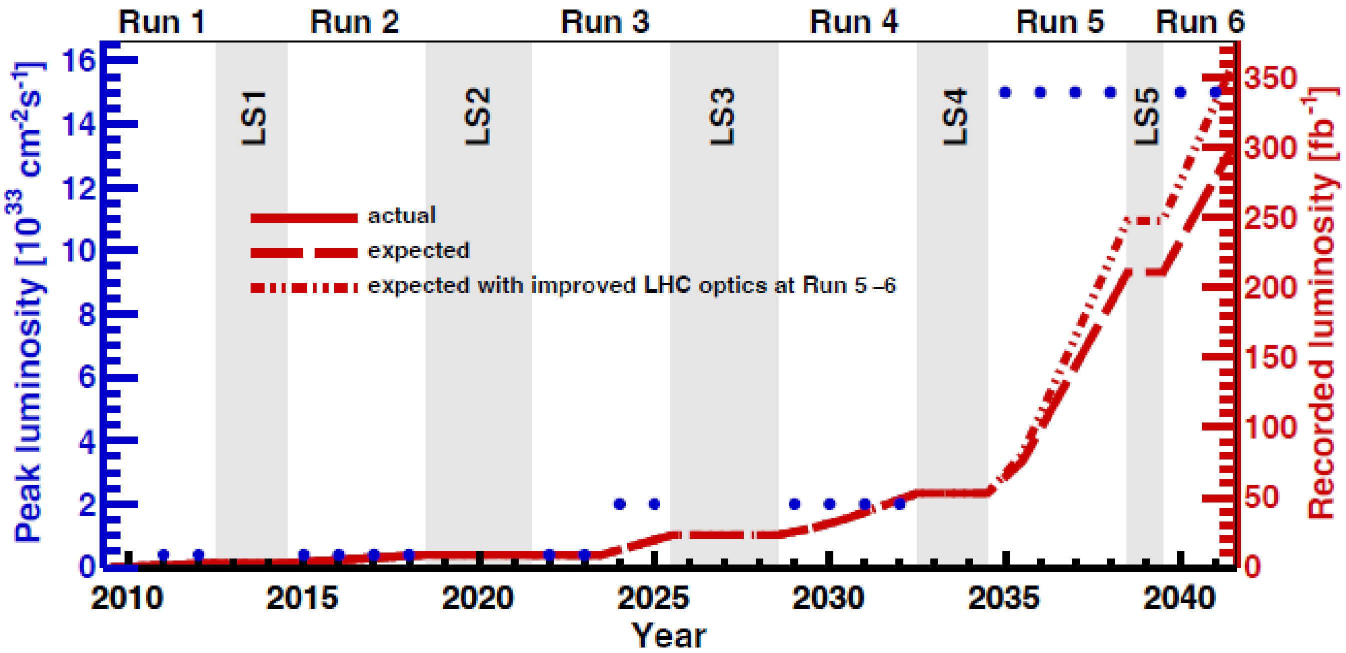
Flavor physics all around the world



European Strategy for Particle Physics: LHCb



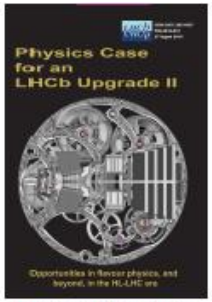
LHCb towards Upgrade II:

Run 1-2	*9 fb^{-1}*
Run 3-4	*50 fb^{-1}*
Run 5-6	*≥300 fb^{-1}*

Expression of Interest

LHCC-2017-003

Physics Case



LHCC-2018-027

Upgrade II FTDR

LHCC-2021-012

Scoping document currently under LHCC review, aiming at approval in 2025

The Upgrade II LHCb Physics case

Observable	Current LHCb	LHCb 2025	Belle II	Upgrade II
EW Penguins				
R_K $(1 < q^2 < 6\,\mathrm{GeV}^2c^4)$	0.1 [274]	0.025	0.036	0.007
R_{K^*} $(1 < q^2 < 6\,\mathrm{GeV}^2c^4)$	0.1 [275]	0.031	0.032	0.008
R_ϕ, R_{pK}, R_π	–	0.08, 0.06, 0.18	–	0.02, 0.02, 0.05
CKM tests				
γ, with $B_s^0 \to D_s^+ K^-$	$(^{+17}_{-22})^\circ$ [136]	4°	–	1°
γ, all modes	5° [167]	1.5°	1.5°	0.35°
$\sin 2\beta$, with $B^0 \to J/\psi K_S^0$	0.013 [609]	0.011	0.005	0.003
ϕ_s, with $B_s^0 \to J/\psi\phi$	20 mrad [44]	14 mrad	–	4 mrad
ϕ_s, with $B_s^0 \to D_s^+ D_s^-$	170 mrad [49]	35 mrad	–	9 mrad
$\phi_s^{s\bar{s}s}$, with $B_s^0 \to \phi\phi$	154 mrad [94]	39 mrad	–	11 mrad
a_{sl}^s	33×10^{-4} [211]	10×10^{-4}	–	3×10^{-4}
$\lvert V_{ub}\rvert/\lvert V_{cb}\rvert$	6% [201]	3%	1%	1%
$B_s^0, B^0 \to \mu^+\mu^-$				
$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	90% [264]	34%	–	10%
$\tau_{B_s^0 \to \mu^+\mu^-}$	22% [264]	8%	–	2%
$S_{\mu\mu}$	–	–	–	0.2
$b \to c\ell^-\bar{\nu}_l$ LUV studies				
$R(D^*)$	0.026 [215, 217]	0.0072	0.005	0.002
$R(J/\psi)$	0.24 [220]	0.071	–	0.02
Charm				
$\Delta A_{CP}(KK - \pi\pi)$	2.9×10^{-4} [613]	1.7×10^{-4}	5.4×10^{-4}	3.0×10^{-5}
A_Γ $(\approx x\sin\phi)$	2.8×10^{-4} [240]	4.3×10^{-5}	3.5×10^{-4}	1.0×10^{-5}
$x\sin\phi$ from $D^0 \to K^+\pi^-$	13×10^{-4} [228]	3.2×10^{-4}	4.6×10^{-4}	8.0×10^{-5}
$x\sin\phi$ from multibody decays	–	$(K3\pi)$ 4.0×10^{-5}	$(K_S^0\pi\pi)$ 1.2×10^{-4}	$(K3\pi)$ 8.0×10^{-6}

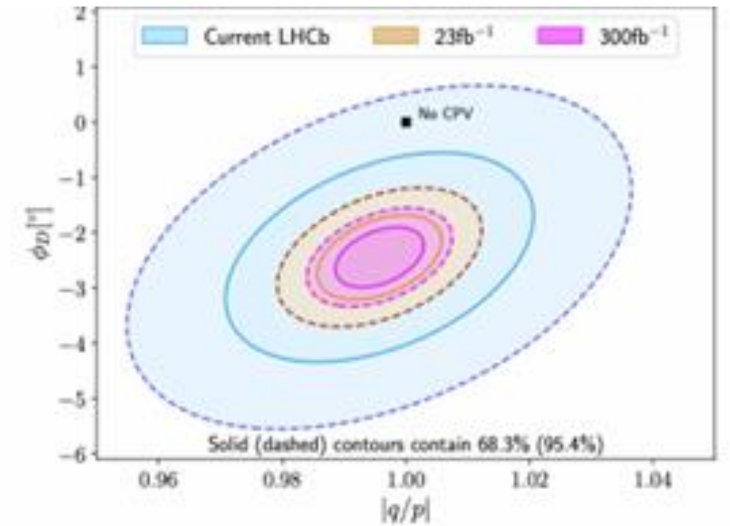
From CERN-LHCC-2018-027
With some edits for current LHCb

Increased precision in flavour physics

$\Rightarrow$ indirect probe for NP at high energy scales

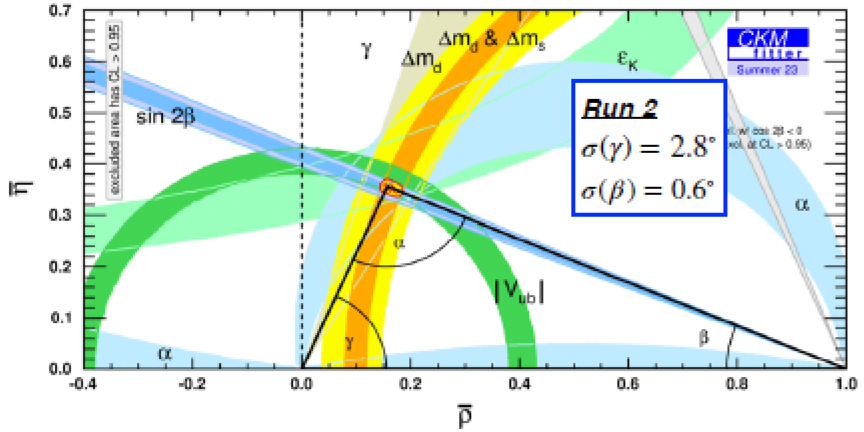
European Strategy for Particle Physics: LHCb

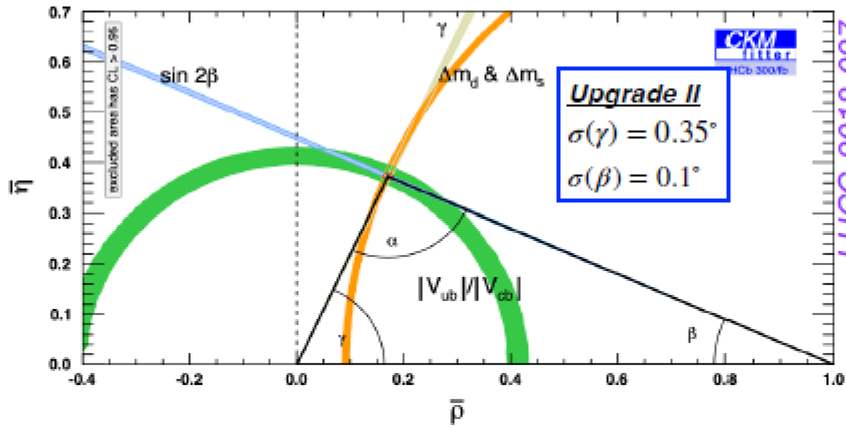
The Upgrade II LHCb
Physics case:
some examples



LHCC-2021-012

Unique capability to reach required 10^{-5} precision
for the understanding of CP violation in charm sector





LHCC-2018-027

Most precise measurements of all CP violation parameters in the B sector

European Strategy for Particle Physics: LHCb

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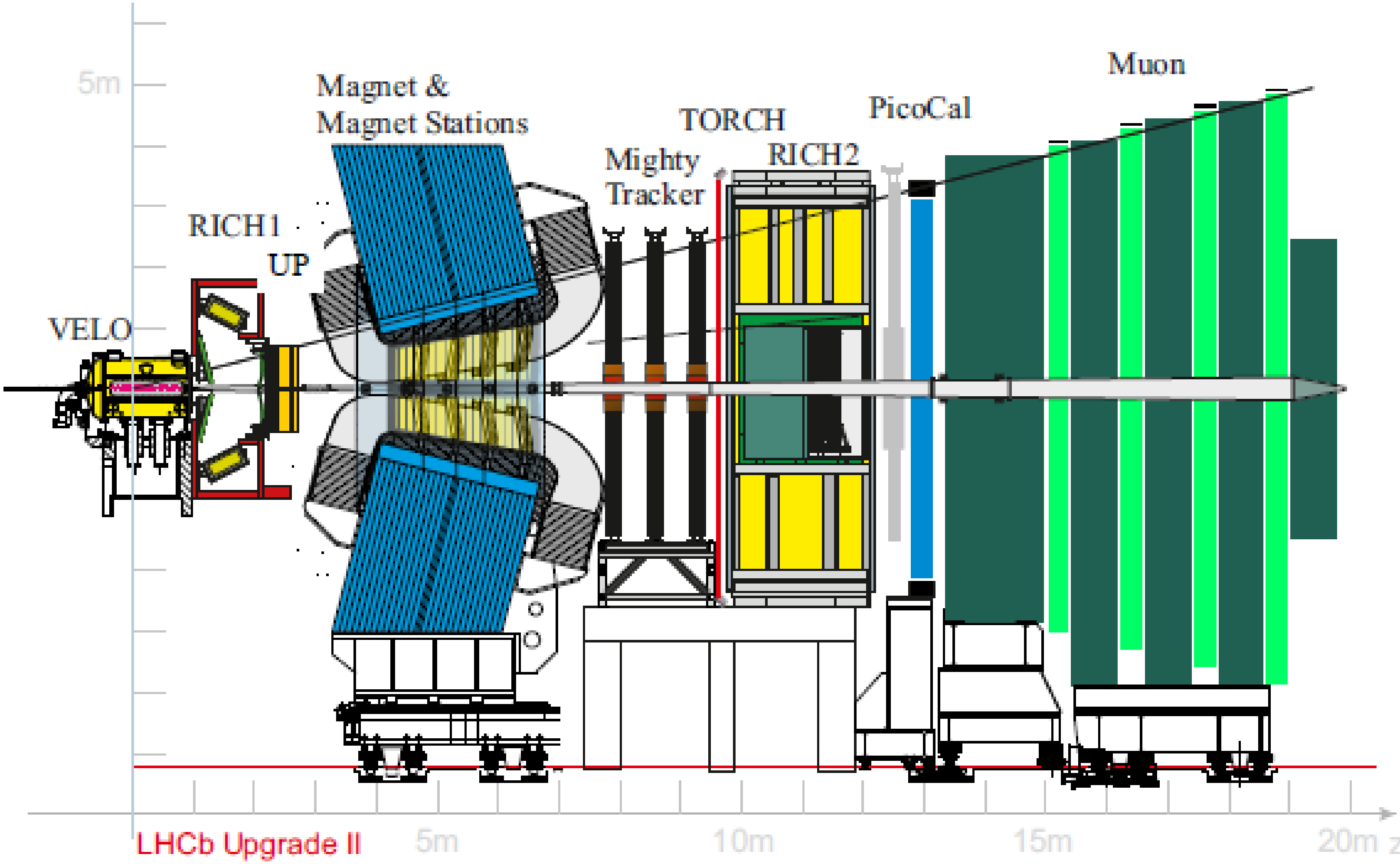
From CERN-LHCC-2018-027
With some edits for current LHCb

Need efficiency tracking, robust reconstruction of decay vertices, excellent charged hadrons, leptons ID

European Strategy for Particle Physics: LHCb

The Upgrade II detector



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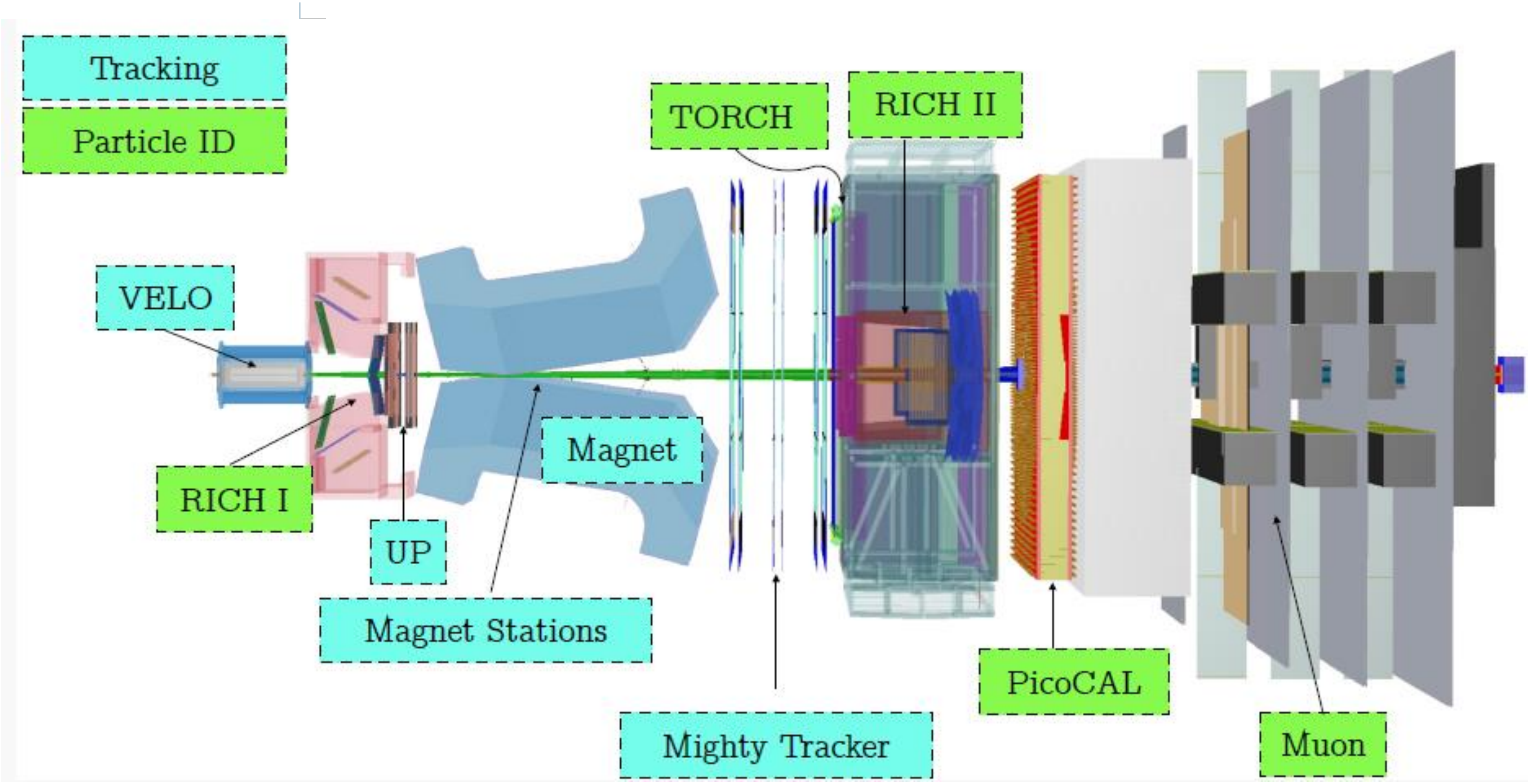

European Strategy for Particle Physics: LHCb

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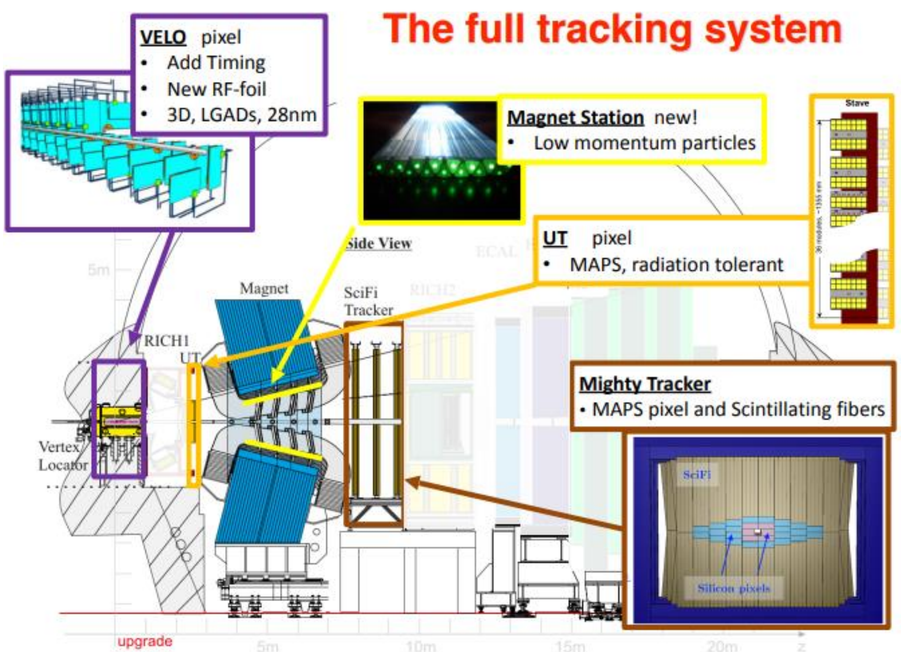
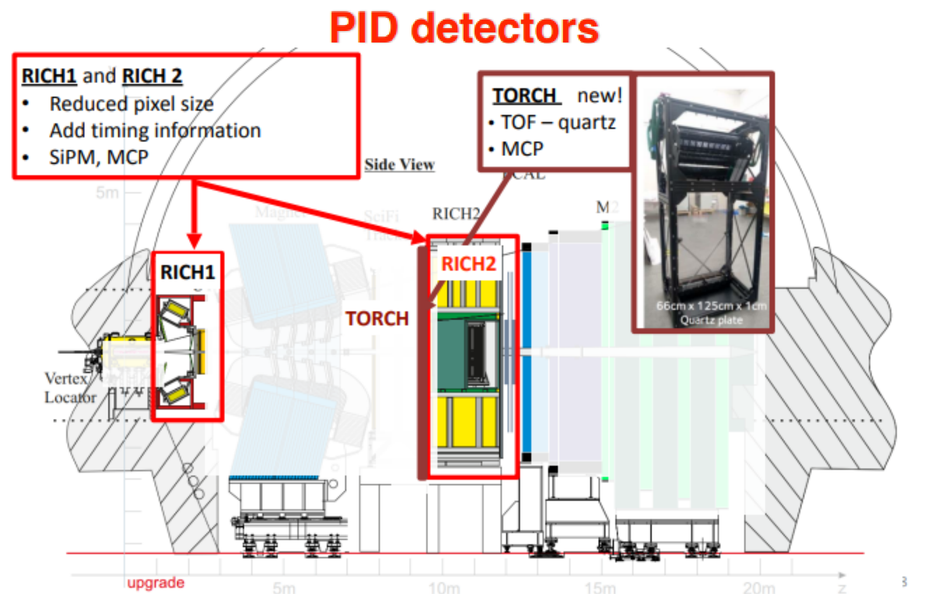
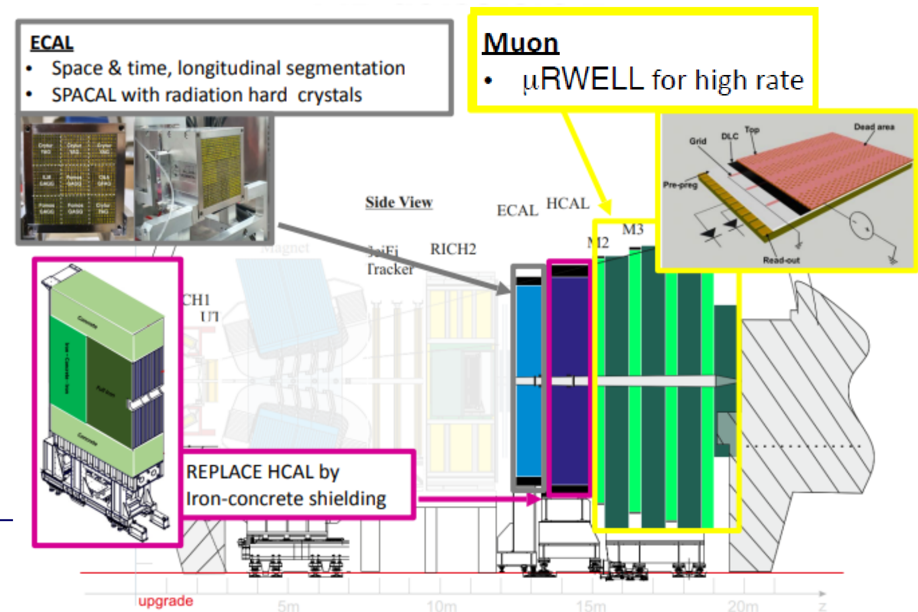




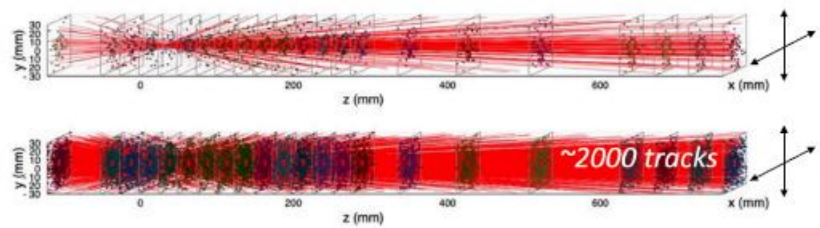


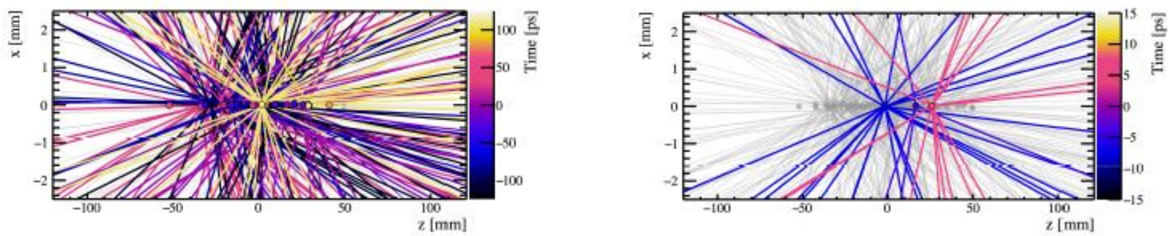
Key ingredients:

- **Higher rate capability**
- **Increased granularity**
- **Improved time resolution**
- **Better radiation hardness**

European Strategy for Particle Physics: LHCb

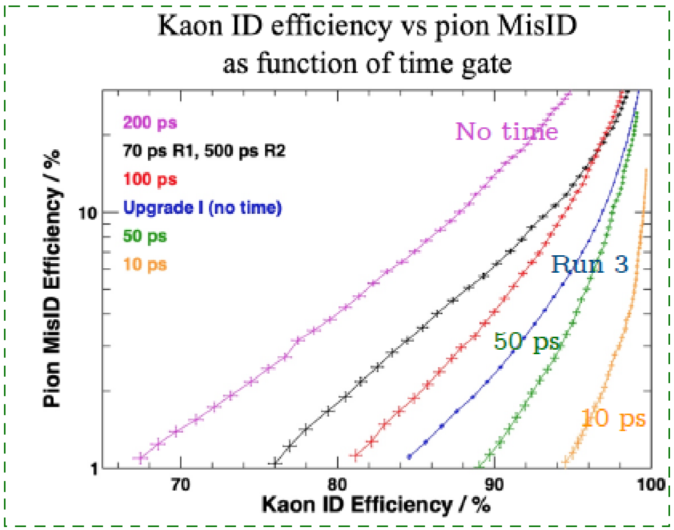
- Run 3 (Upgrade I):
  - pile-up ~ 5
- Upgrade II:
  - pile-up ~ 40





"Problem" complexity with no timing per track

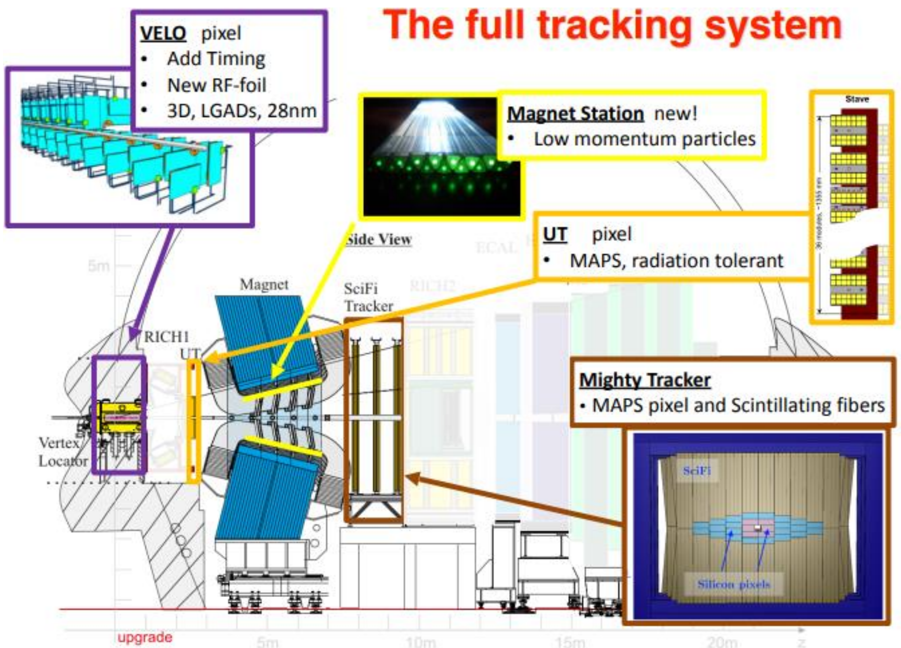
"Problem" complexity with 20ps/track resolution



Time resolution ~ tens of ps

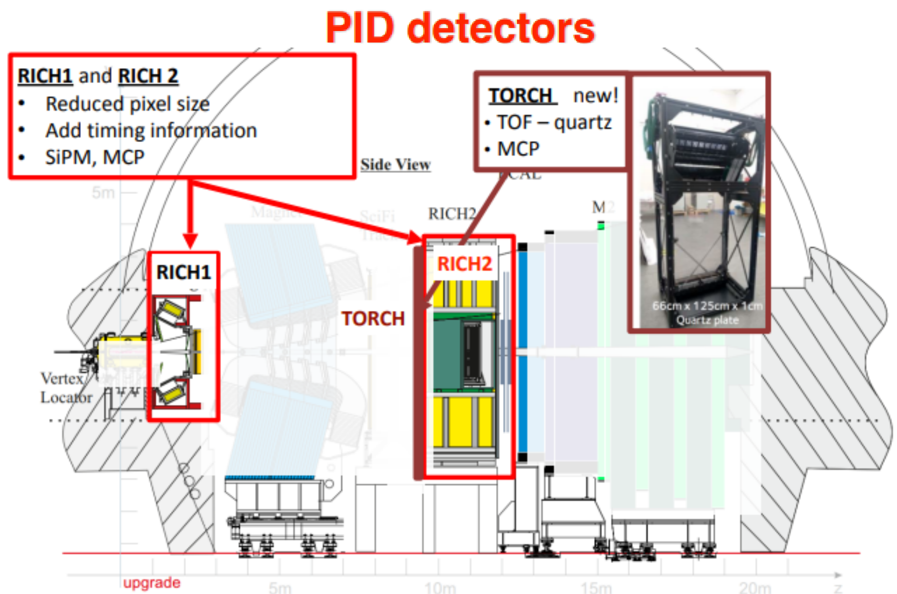
European Strategy for Particle Physics: LHCb

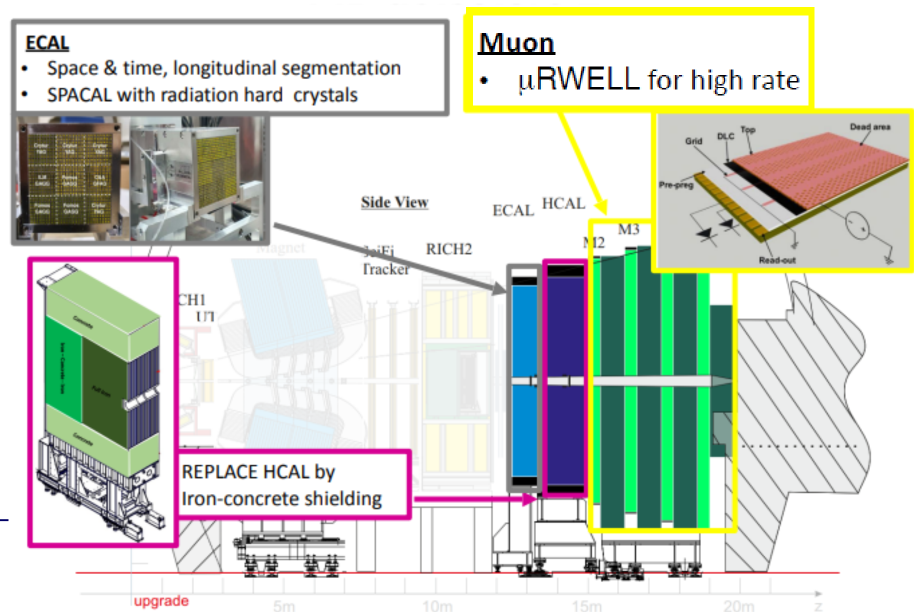
The Upgrade II detector



Technologies under R&D – INFN

- PicoCal
- RICH
- MUON detector
- VELO with timing
- RETINA





European Strategy for Particle Physics: LHCb

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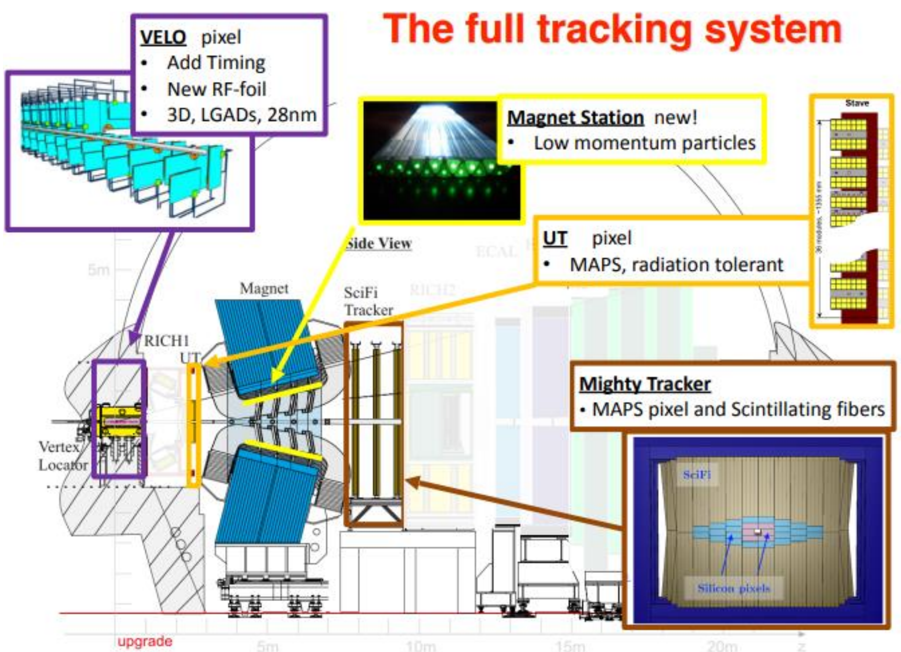

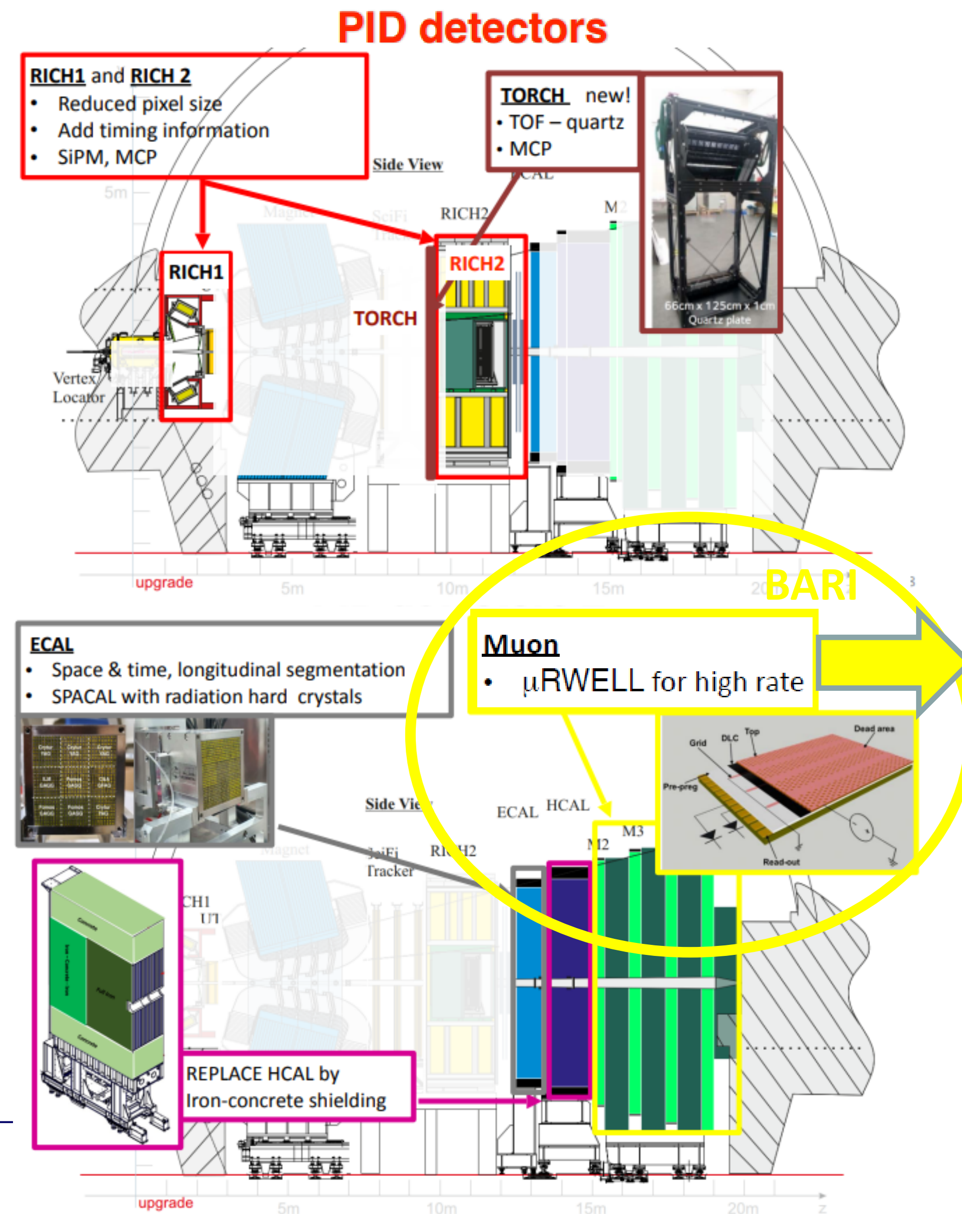

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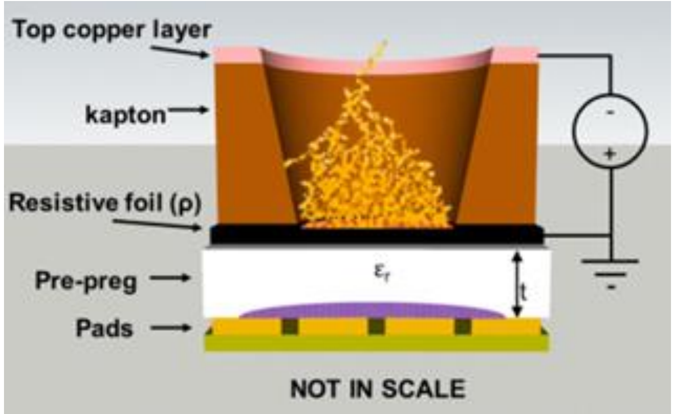
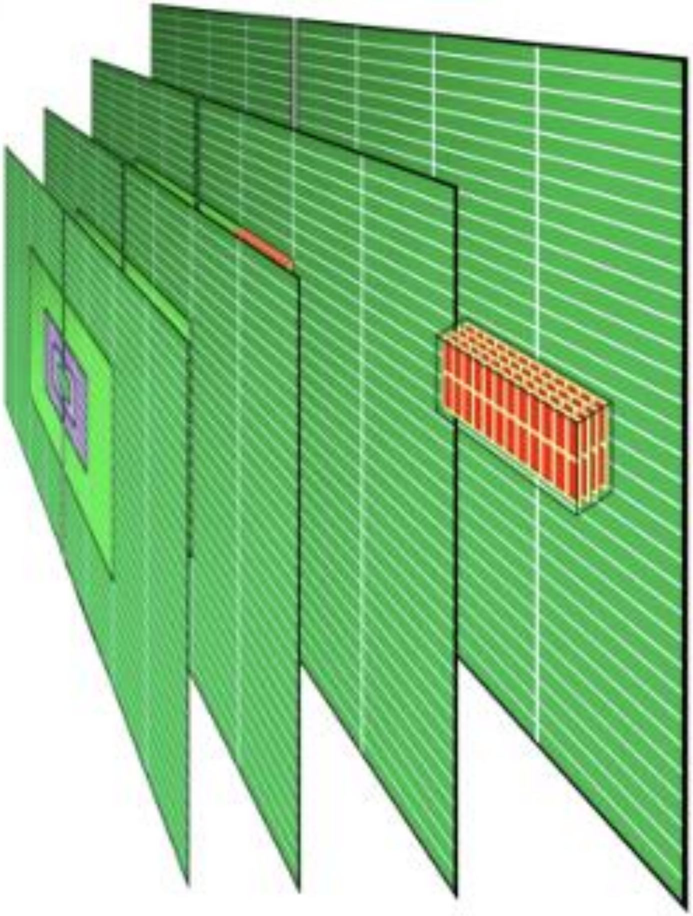
μRWELL technology for HL-LHC



The micro-Resistive WELL detector: a compact spark-protected single amplification-stage MPGD
Bencivenni *et al* 2015 *JINST* **10** P02008



90 m² detector surface (regions R1-R2)

μ-RWELL detector requirements

- Rate up to **1 MHz/cm²** on detector single gap
- Rate up to **700 kHz** per electronic channel
- Efficiency (4 gaps) > 98% in the single bunch-crossing (25 ns)
- Stability up to **1C/cm²** accumulated charge in 10y in M2R1, G=4000

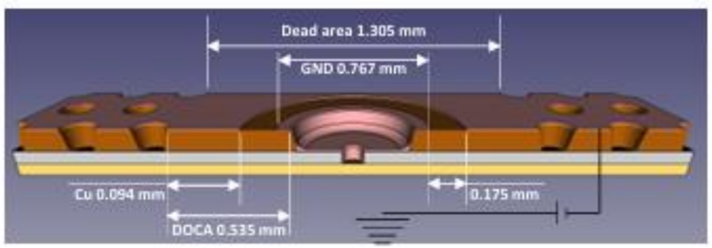
European Strategy for Particle Physics: LHCb

μRWELL technology for HL-LHC

2023 – DOT

DLC grounding by
conductive DOT
Pad R/O = 9×9 mm^2
Grounding: - pitch = 9mm
- rim = 1.3mm

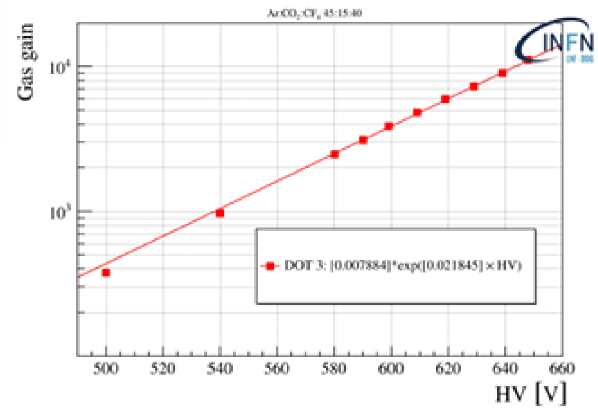
→ **97% geometric** acceptance

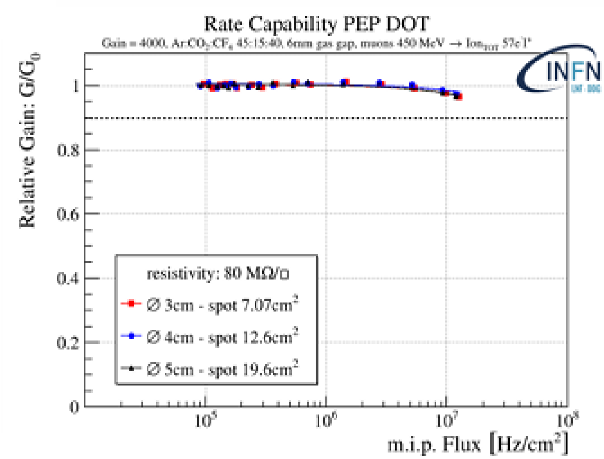


Performance:

- gas gain up to 10^4
- rate capability(@ 90% drop) > 10 MHz/cm^2

Calibration with X-ray





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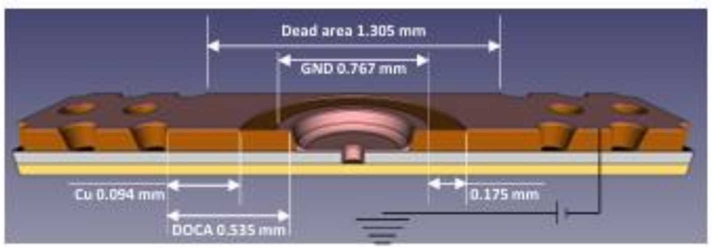

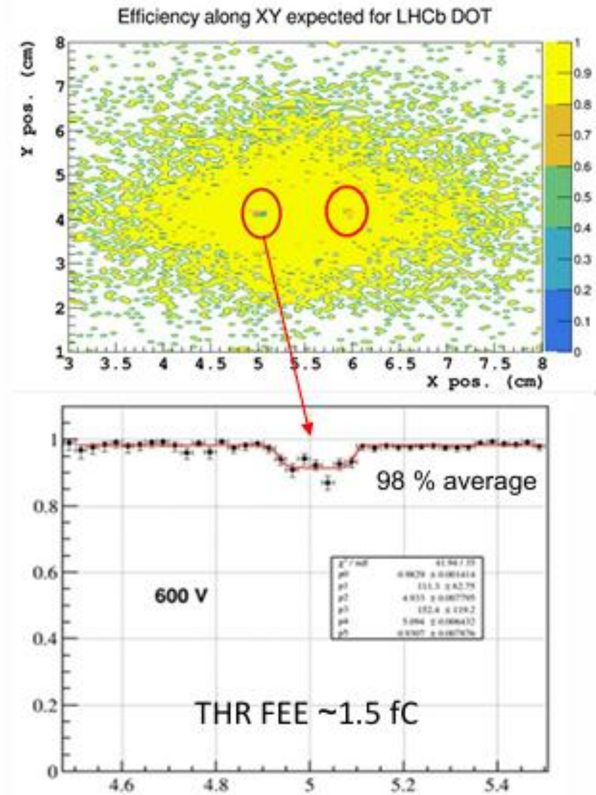

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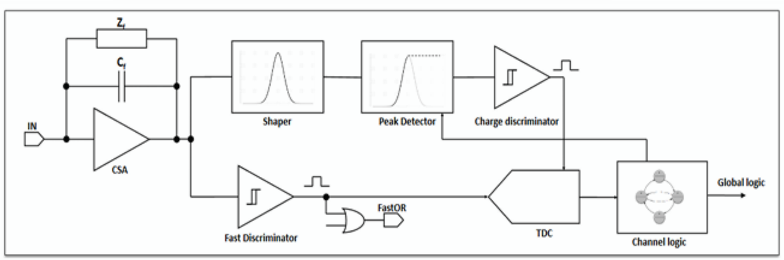
μRWELL technology for HL-LHC

- Need for new fast sensitive electronics



FATIC (Fast Timing Integrated Circuit):
FE Electronics under dev in Bari

- Need for eco-gas studies

μRWELL detectors currenly operated with $Ar/CO_2/\mathbf{CF_4}$ (45/15/**40**)

Up to now, CF_4 crucial for the time performance of the detector: possible replacements?

See Alessandra's talk

European Strategy for Particle Physics: LHCb

- LHCb Upgrade II currently under discussion
- Excellent performance expected in many channels relevant for BSM physics
- Several R&D activities in progress within LHCb-INFN community:
  - possible future interest beyond HL-LHC
  - R&D @ Bari

    - development of fast sensitive electronics
    - studies of eco-friendly gas mixtures