Testing Micro Channel Plate Detectors for the Particle Identification Upgrade of LHCb

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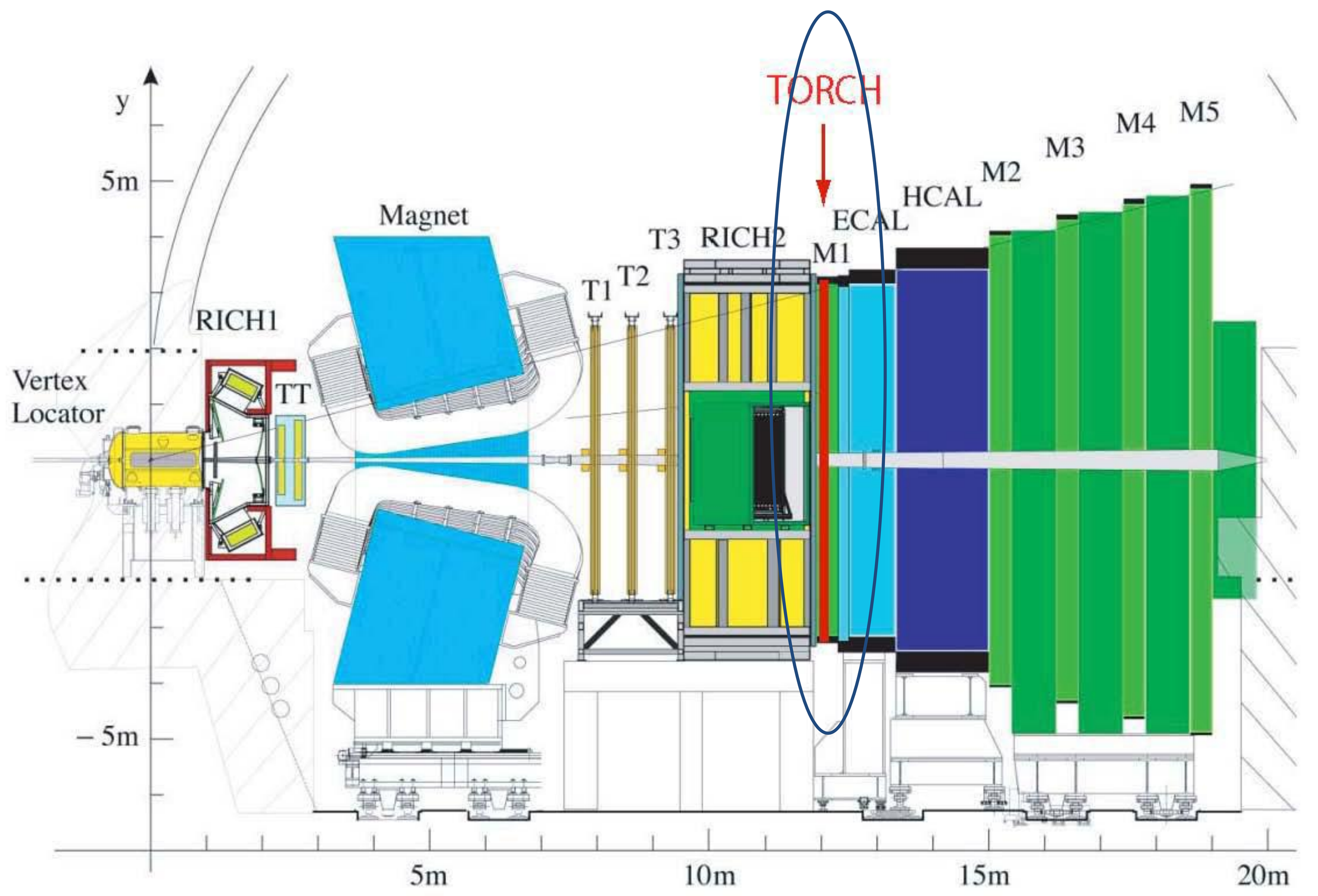
The **TORCH**, Time Of internally Reflected Cherenkov light, is proposed for the **high luminosity upgrade** of the LHCb experiment. The detector combines Time-of-Flight and Cherenkov techniques to achieve **positive π/K/p separation** on a **≥3σ level** in the momentum range below 10 GeV/*c*. The required time resolution is ≤50 ps for single photon signal.
We have shown that already commercially available micro-channel plate tubes with 8×8 channels fulfil the requirements. Timing properties of the tubes have been investigated with a pulsed laser diode **in single photon regime**. **An excellent timing resolution of <40 ps is achieved with an efficiency of ~90 %.**

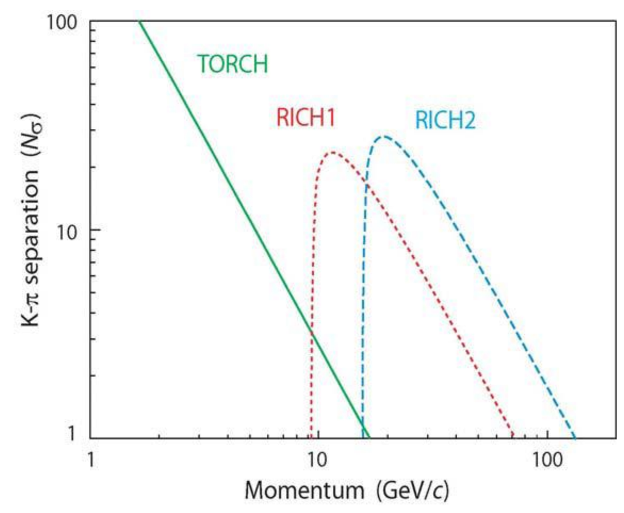
LHCb experiment upgrade



50 detected Cherenkov photons per track ➕ total resolution per detected p.e. ~ 70 ps ➡ **15 ps resolution per track**

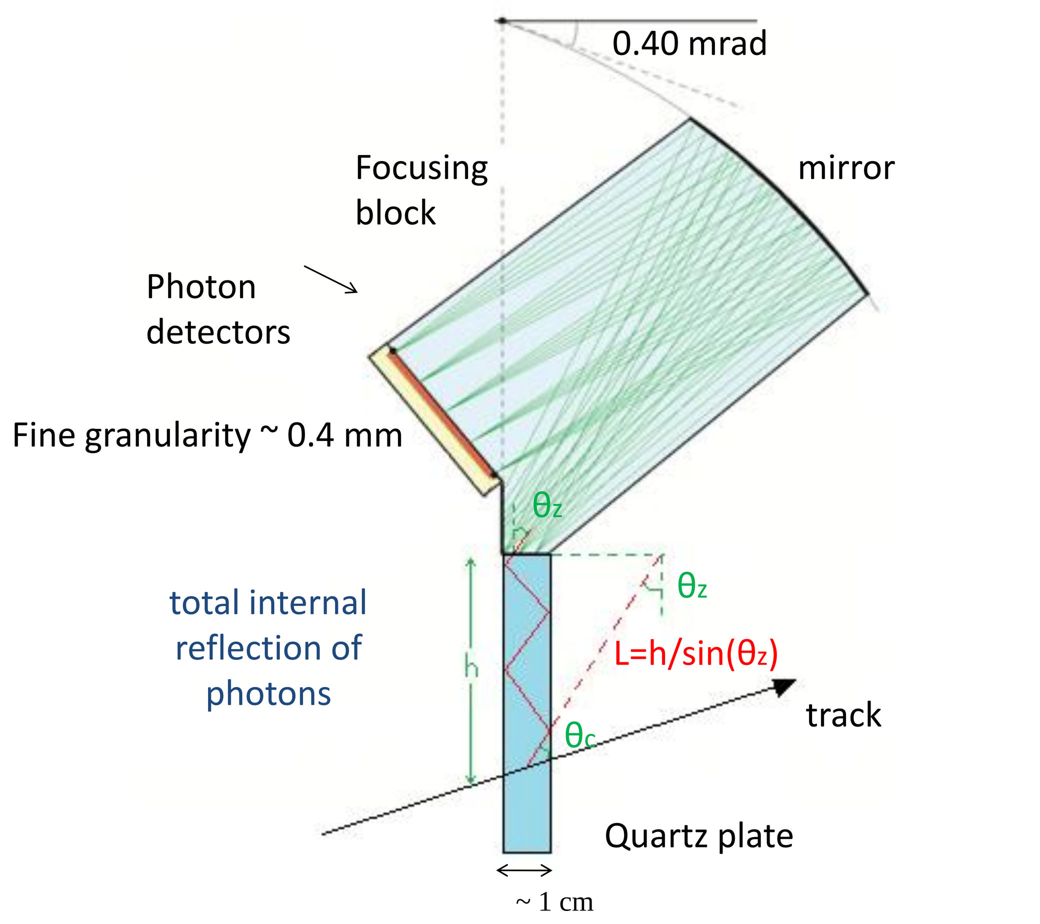
ΔTOF (π-K) = 35 ps at 10 GeV over a distance of ~ 10 m

Simulated PID



Calculated performance (in sigma separation) of the different components of the PID system versus momentum, for isolated tracks.

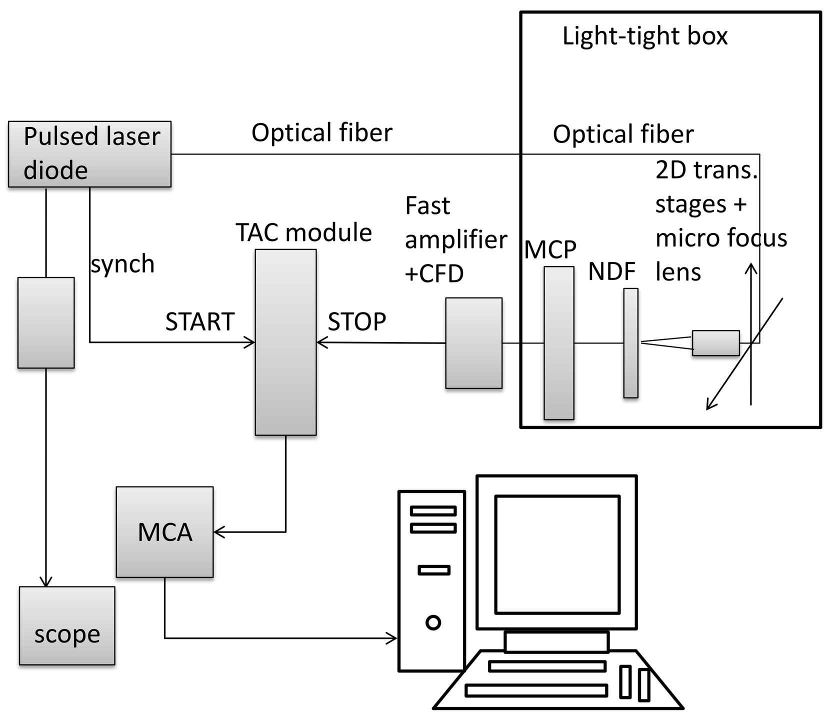
TORCH layout



Cross-section through focusing element, attached to the edge of the quartz plate. The focusing of photons is indicated for five illustrative angles between 450 and 850 mrad, emerging at different points across the edge of the plate.

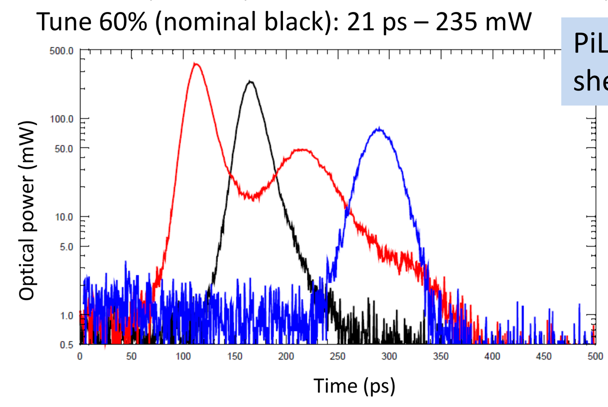
MCP-PMT's performance for single photons

Set-up

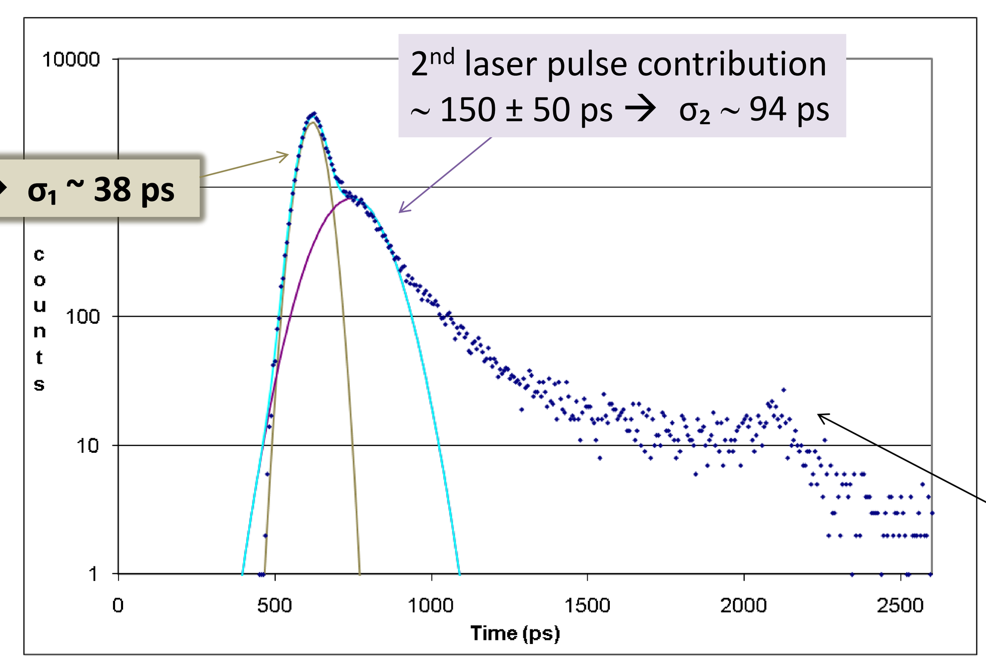


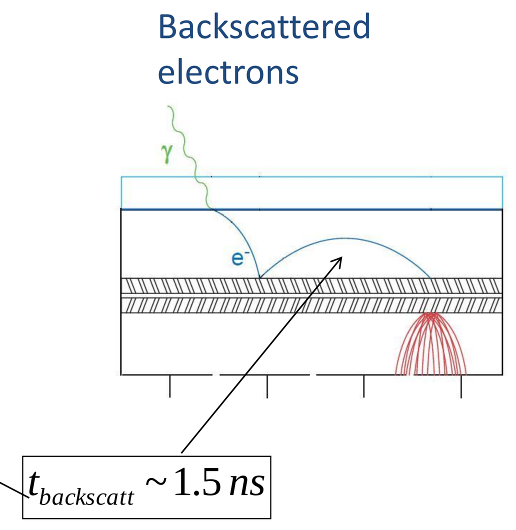
Laboratory set-up used for the systematic studies of the timing performance of the MCP-PMT's.

Timing jitter distribution



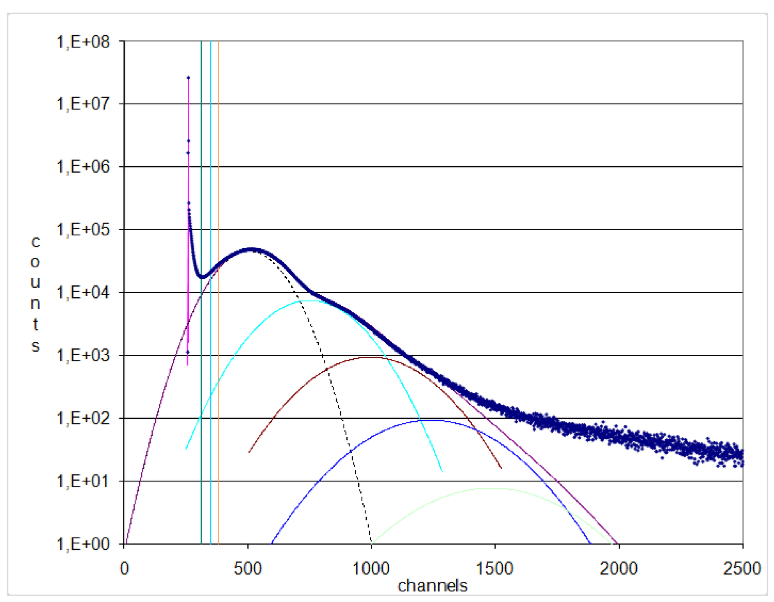
- **2nd relaxation oscillation** clearly seen ~ 150 ± 50 ps
  → **shoulder** in distribution
- Achieved an **excellent timing resolution O(< 40ps)**





Single photoelectron timing distribution (vertical logarithmic scale). Prompt signal with a time resolution of ~38ps, shoulder due to the second laser pulse and tail due to backscattered photoelectrons.

Pulse height spectra and photoelectron efficiency

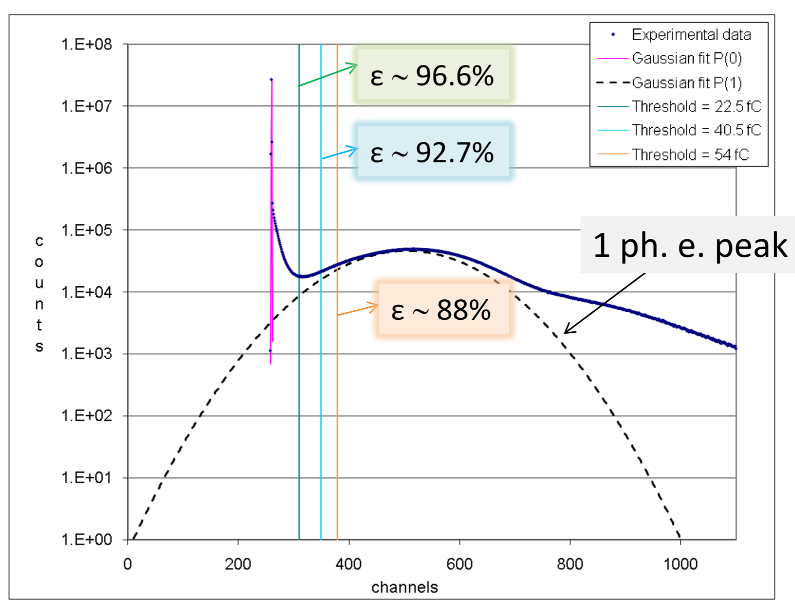


MCP charge spectrum fitted with a Poisson distribution model.

- Operating at rather **moderate MCP gain ~ 7 10^5**
- **Single photoelectron regime** with avg. number of photoelectrons: **μ ~ 0.5**
- **~ 90% efficiency** estimated **single photoelectrons**

Light source fluctuation: $P_\mu(N) = \frac{\mu^N}{N!} e^{-\mu}$

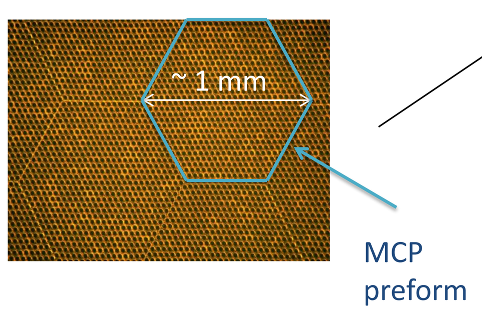
MCP gain fluctuation: $\sigma_N = \sqrt{N}\sigma_1$

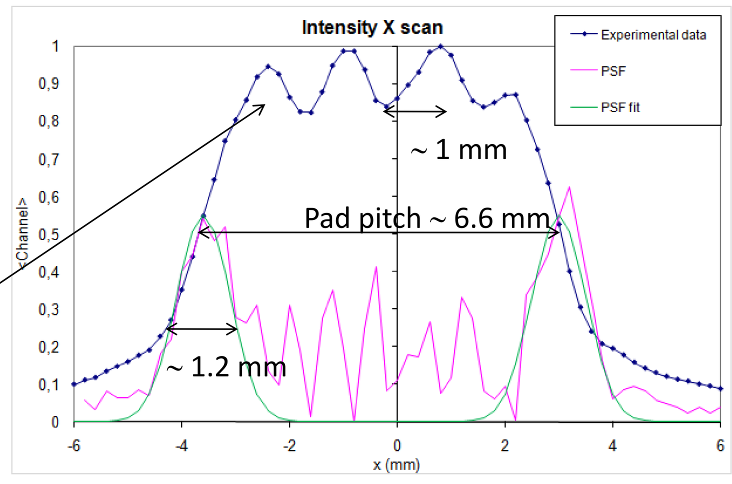


MCP charge spectrum and efficiency estimate for three thresholds applied at the CFD level.

Spatial scans

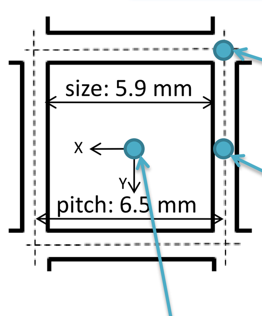
- very fine segmentation is required (8x128 pixels)
- Achieved **Point Spread Function of ~ 1.2 mm**
- **Spatial beating effect between 2 MCPs** (pitch compatible with MCP preform pitch)



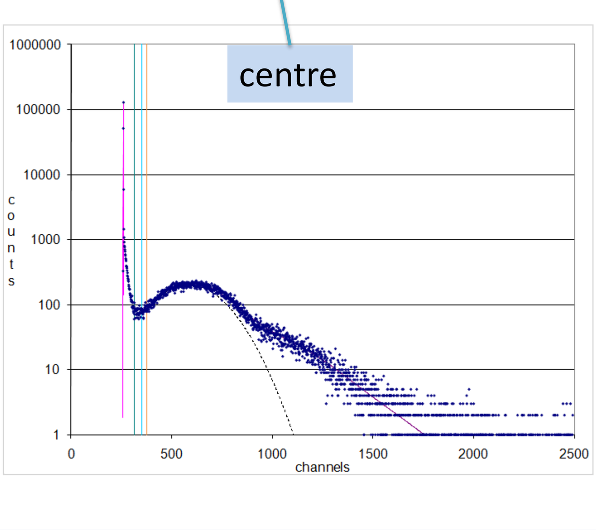


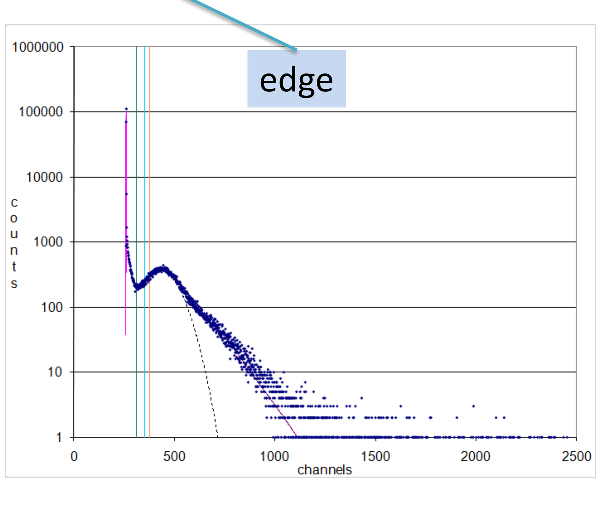
Average signal amplitude corresponding to a laser scan along a pad axial line. Point spread function inferred from the derivative of the experimental data fitted with a Gaussian model.

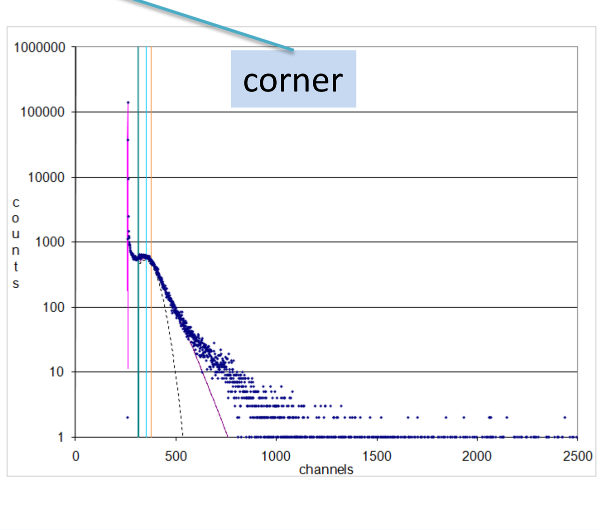
Scans at pixels boundaries



- Importance on anode read-out segmentation and timing performance
- **Charge sharing effect** is observed
  - edge: half of charge
  - corner: a quarter of charge
- **Timing performance is similar** at pixel boundaries with expected **efficiency drop**







References

[1] LHCb Collaboration, Letter of Intent publication, CERN-LHCC-2011-001

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