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V^0 production in Run 3 at LHCb

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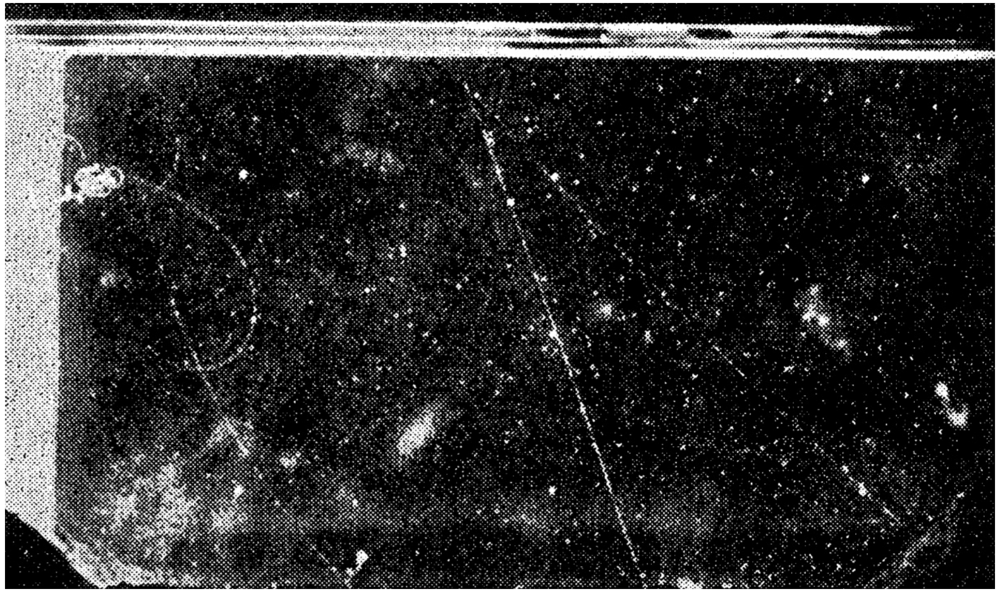
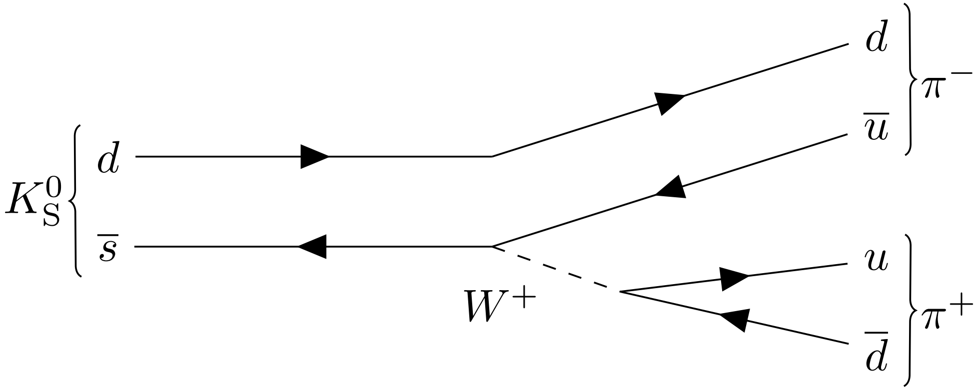
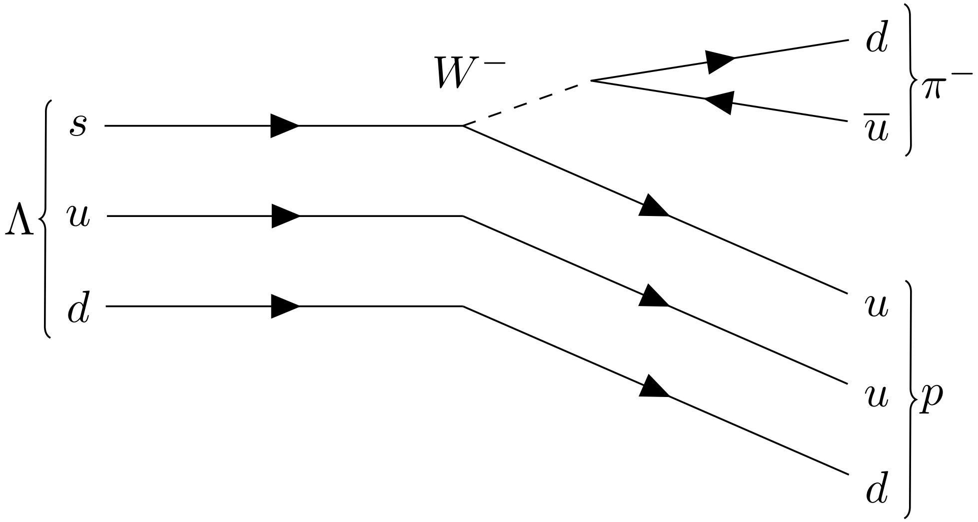
V^0 particles

- Long-lived neutral particles weakly decaying into two charged hadrons
- Displaced decay topology
  - → $\tau(V^0) \approx \mathcal{O}(10^{-11} - 10^{-10}\ \mathrm{s})$ vs. $\tau(B^0) \approx \mathcal{O}(10^{-12}\ \mathrm{s})$
- Huge cross-sections ($\mathcal{O}(1\mathrm{b})$ vs. $\sigma(b) \approx \mathcal{O}(100\ \mu\mathrm{b})$)
  - $\mathrm{K}_S^0 \to \pi^+\pi^-$ ($^{\Gamma_i}/_{\Gamma} \approx 69.2\ \%$)
  - $\Lambda^0 \to p\pi^- + c.c.$ ($^{\Gamma_i}/_{\Gamma} \approx 63.9\ \%$)



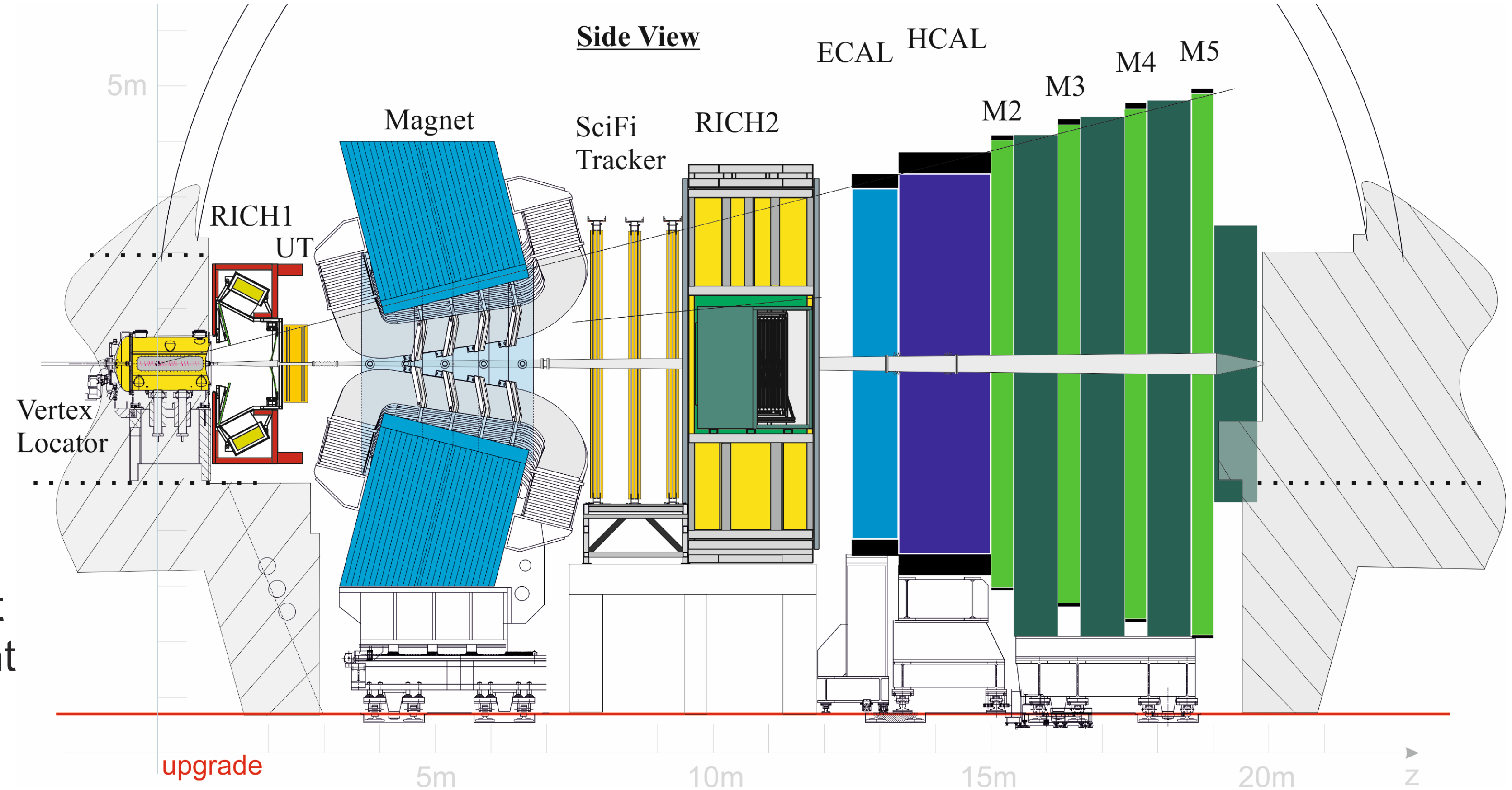
R. B. Leighton, S. D. Wanlass, and C. D. Anderson, The decay of V^0 particles, Phys. Rev. **89**, 148 (1953).





The LHCb detector

- LHCb has undergone major upgrades for Run 3 data taking
  - New tracking detectors
  - Upgraded RICH detectors
  - Upgraded electronics
  - Software-only trigger
  - → Detector performance needs to be evaluated step by step
- V^0 measurement can be done without particle identification
- Measure cross-section ratios to not depend on luminosity measurement



Alessio Piucci, The LHCb upgrade, IOP Conf. Series: Journal of Physics: Conf. Series **878** 012012 (2017).

$$R(\bar{\Lambda}^0, K_S^0) = \frac{\sigma(\bar{\Lambda}^0 \to \bar{p}\pi^+)}{\sigma(K_S^0 \to \pi^+\pi^-)} = \frac{N(\bar{\Lambda}^0 \to \bar{p}\pi^+)\epsilon_{K_S^0 \to \pi^+\pi^-}\mathcal{B}(K_S^0 \to \pi^+\pi^-)}{N(K_S^0 \to \pi^+\pi^-)\epsilon_{\bar{\Lambda}^0 \to \bar{p}\pi^+}\mathcal{B}(\bar{\Lambda}^0 \to \bar{p}\pi^+)}$$

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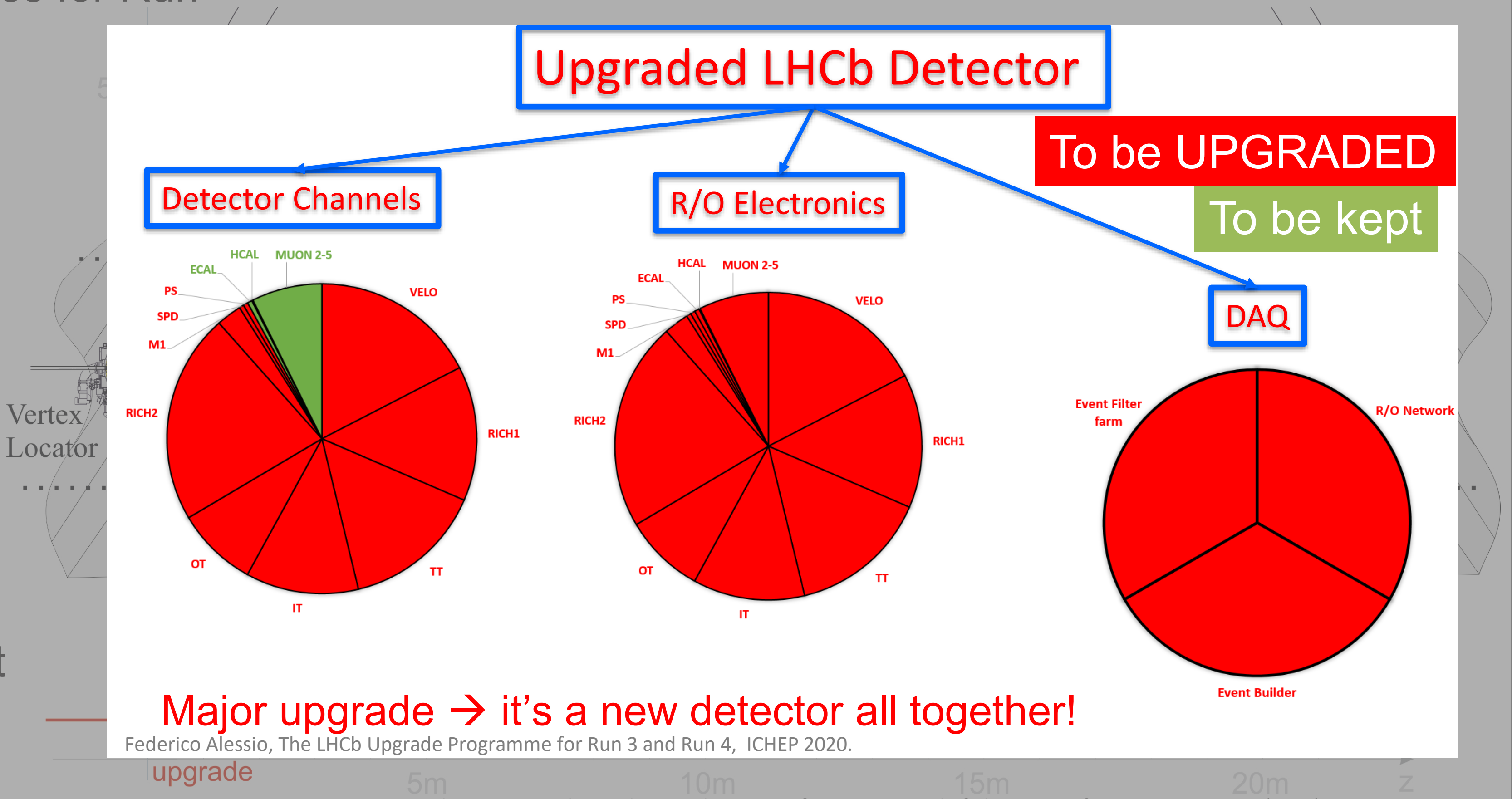

Federico Alessio, The LHCb Upgrade Programme for Run 3 and Run 4, ICHEP 2020.

Alessio Piucci, The LHCb upgrade, IOP Conf. Series: Journal of Physics: Conf. Series 878 012012 (2017).

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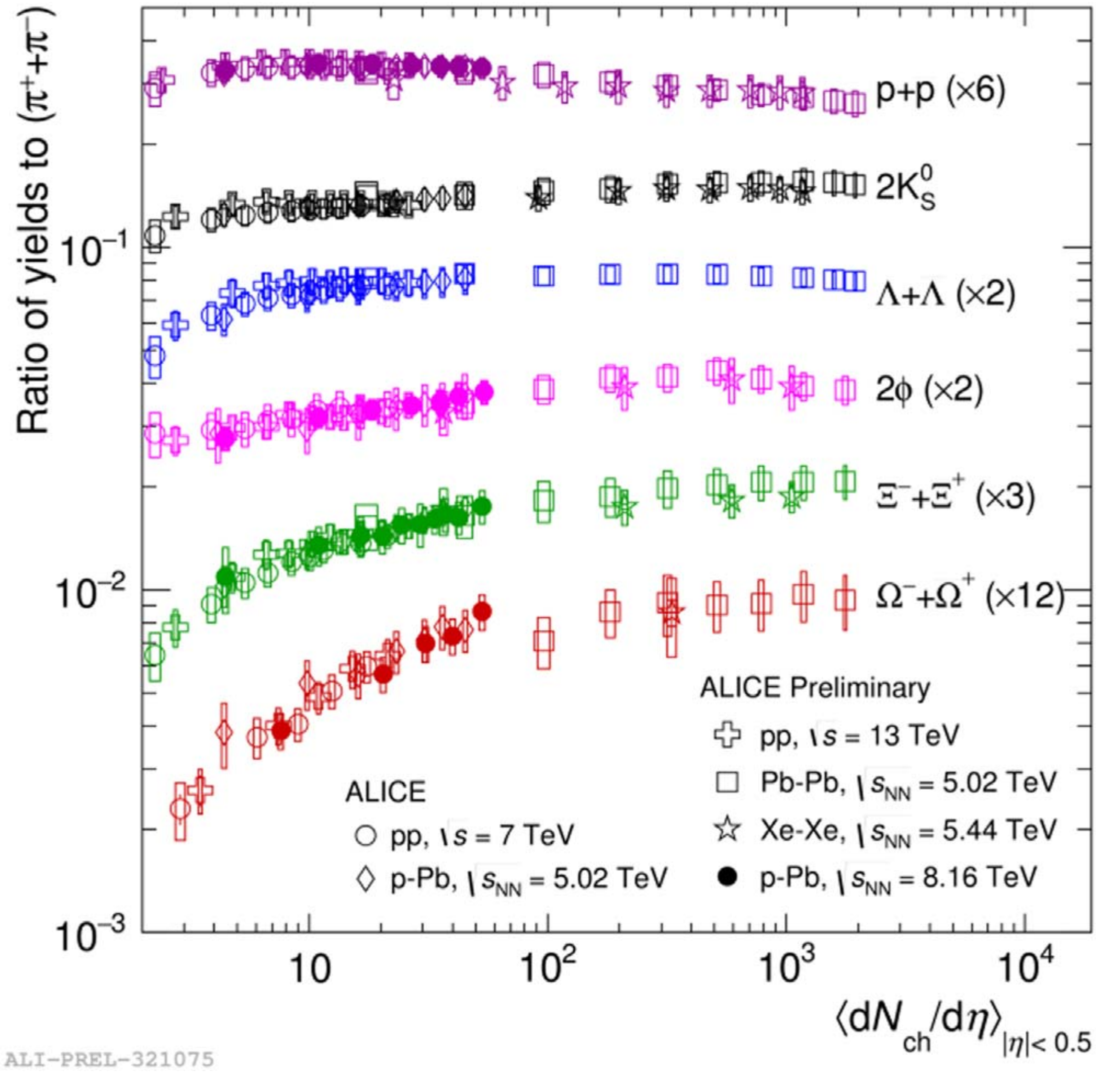
Strangeness enhancement

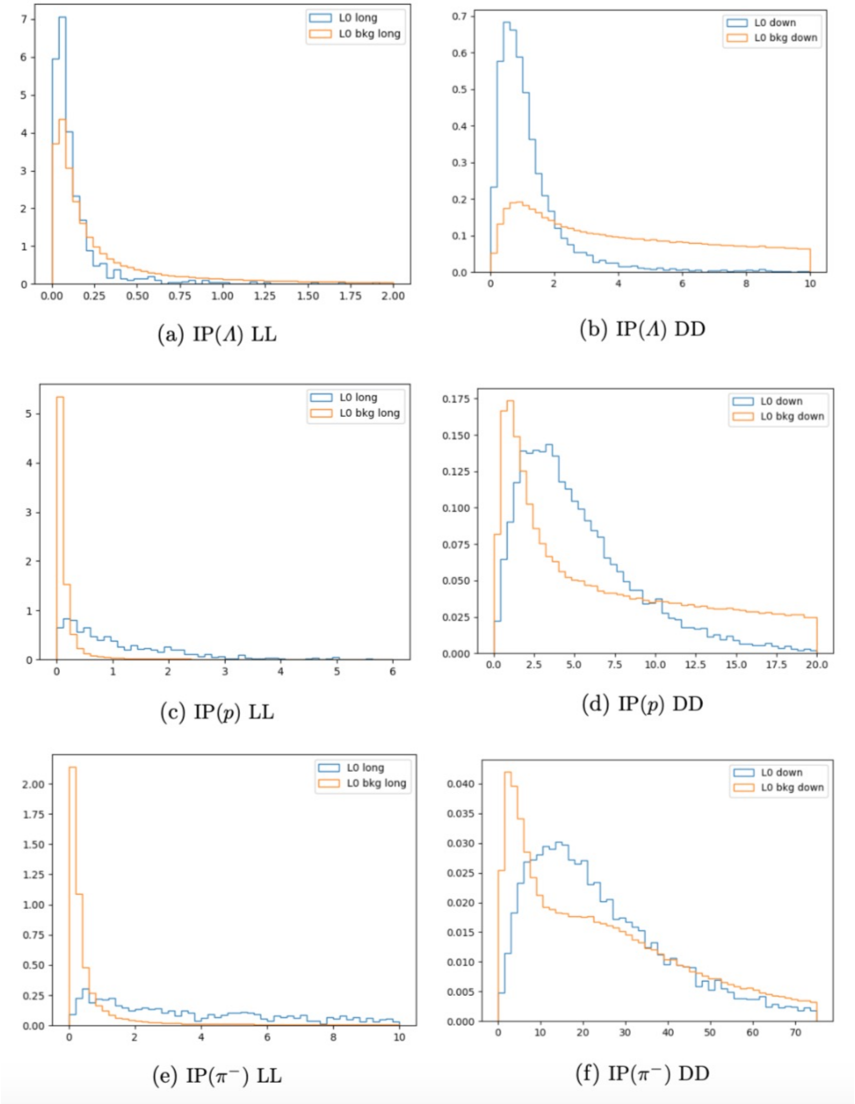
- Muon excess observed in cosmic-ray-induced atmospheric showers
  - → Promising solution to this muon puzzle could be enhancement of strangeness production
- Enhancement of strangeness production in high multiplicity events by ALICE experiment Nature Phys. 13 (2017) 535-539
- Consistent for different centre-of-mass energies and collision systems
  - → Well known in quark-gluon-plasma, but not in $pp/p\text{−ion}$
- Dependence seems to be only on density of charged tracks
- Measurement performed at mid-rapidity $|\eta| < 0.5$
  - → LHCb unique environment to study strangeness enhancement in very-forward region



Maria Vasileiou and On behalf of the ALICE Collaboration, Phys. Scr. **95** 064007 (2020).

V^0s in the detector

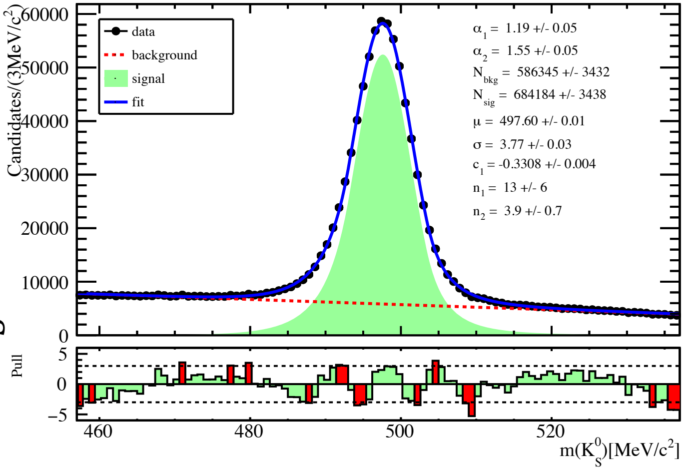
- Build pairs of all tracks that originate in the VELO and leave hits in all tracking detectors
- Add π/p mass hypothesis to tracks and require invariant mass to be within 50 MeV/c^2 of K_S^0/Λ^0 mass
- Suppress combinatorial background by applying a cut on the Fisher discriminant
  $\mathcal{F}_{\mathrm{IP}} = \log_{10}(\mathrm{IP}(h^+)) + \log_{10}(\mathrm{IP}(h^{(\prime)-})) - \log_{10}(\mathrm{IP}(V^0))$
- Optimial $\mathcal{F}_{\mathrm{IP}}$ cuts determined in Run 2 analysis
  $\mathcal{F}_{\mathrm{IP}}\left(K_S^0/\Lambda^0\right) > 2.6/1.5$
- Additional cut $\mathrm{IP}(\Lambda^0) < 0.13$ to suppress contribution from hyperon decays (e.g. $\Xi^- \rightarrow \Lambda^0\pi^-$)



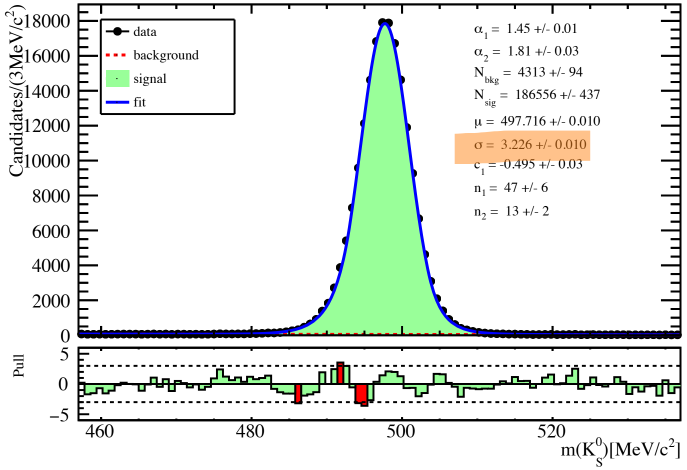
First V^0 plots – Run 256145

$K_S^0 \to \pi^+\pi^-$

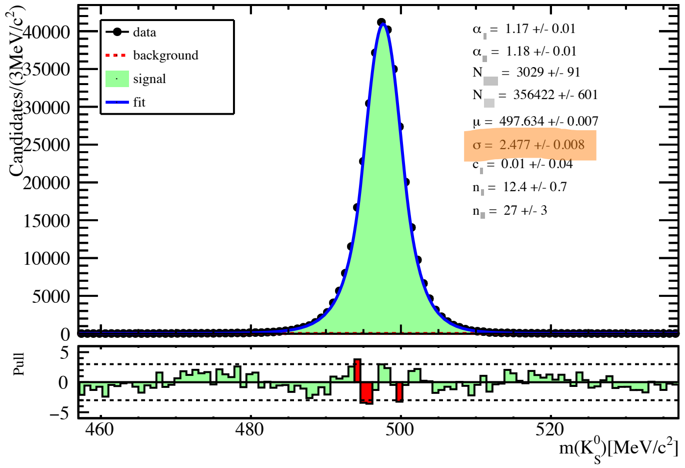
$\mathcal{F}_{\mathrm{IP}}(K_S^0 \to \pi^+\pi^-) > 1$



$\mathcal{F}_{\mathrm{IP}}(K_S^0 \to \pi^+\pi^-) > 2.6$



2018 MagDown, $\mathcal{F}_{\mathrm{IP}}(K_S^0 \to \pi^+\pi^-) > 2.6$



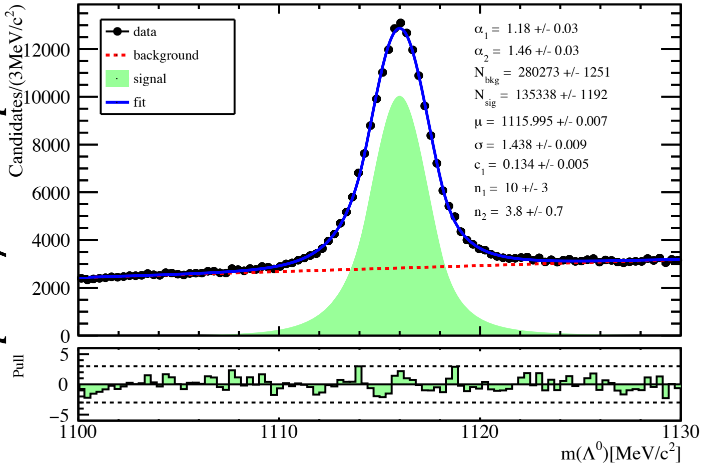
Worse resolution compared to Run 2

Spatial resolution of tracking detectors not yet finalised

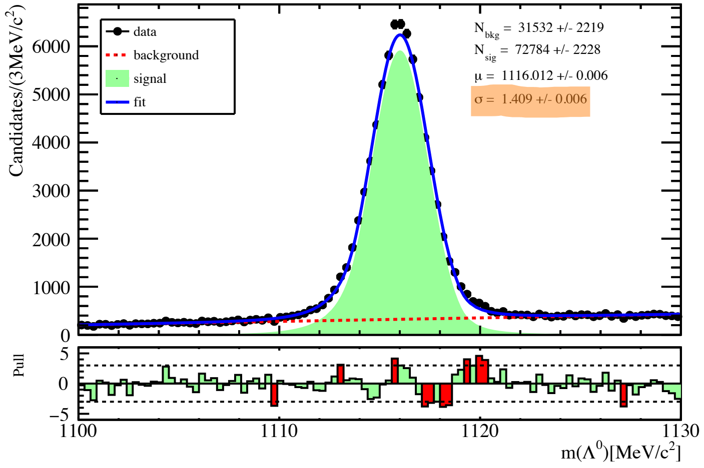
Data taken without UT

$\Lambda^0 \to p\pi^- / \overline{\Lambda^0} \to \bar{p}\pi^+$

$\mathcal{F}_{\mathrm{IP}}(\Lambda^0 \to p\pi^-) > 1$



$\mathcal{F}_{\mathrm{IP}}(\Lambda^0 \to p\pi^-) > 1.5$ & $\mathrm{IP}_{\mathrm{BPV}}(\Lambda^0) < 0.13$



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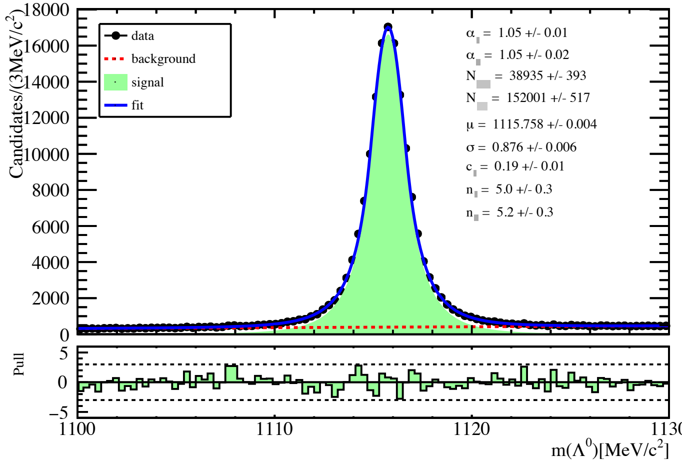

Summary and outlook

- Study of V^0 production offers a simple way to study LHCb detector performance in Run 3
- Analysis pipeline is adjustable to measure absolute cross-sections once precise luminosity measurements are available
- Binning in multiplicity allows to validate observation of strangeness enhancement in high charged-track-density events first observed by the ALICE experiment
  - → Possible explanation for muon puzzle in astroparticle physics