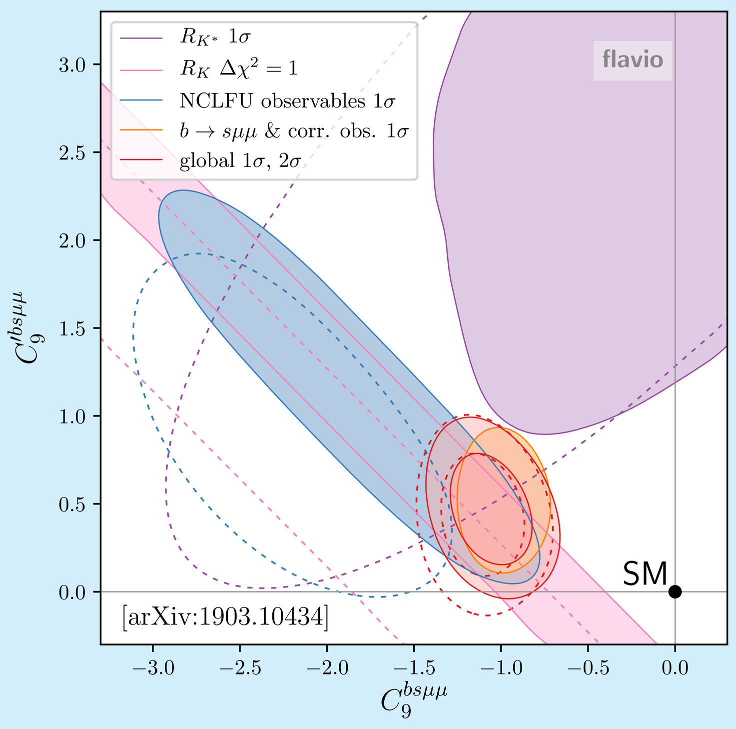
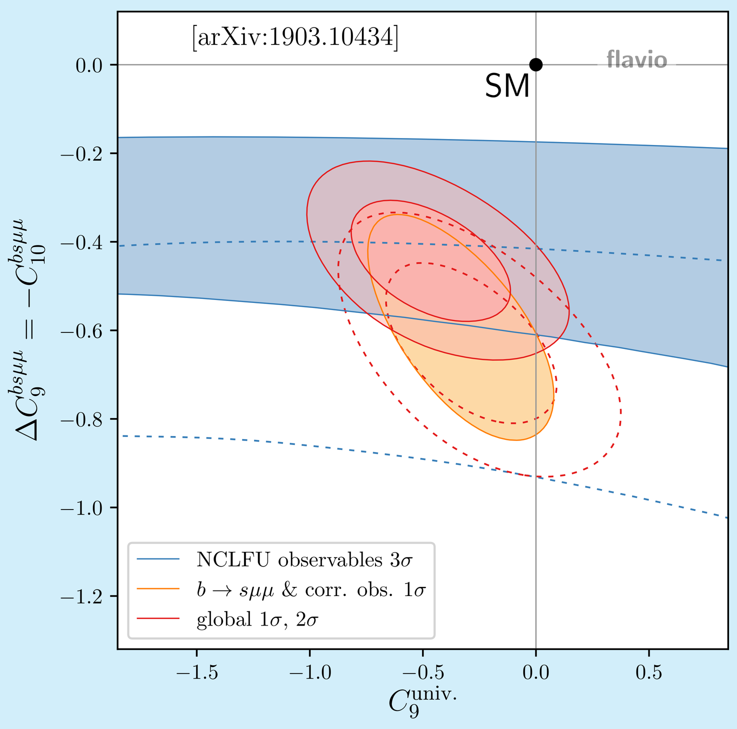
Lepton universality tests with rare decays at LHCb

Dan Moise[1], on behalf of the LHCb collaboration

[1]*Imperial College London, United Kingdom*

Flavour anomalies: measurements of b-hadron decays, with leptons in the final state, in tension with the Standard Model (SM)
e.g.: the rare processes $b \to s\ell^+\ell^-$, $\ell \in \{e, \mu\}$
Lepton universality: SM couplings of leptons to gauge bosons are flavour-independent



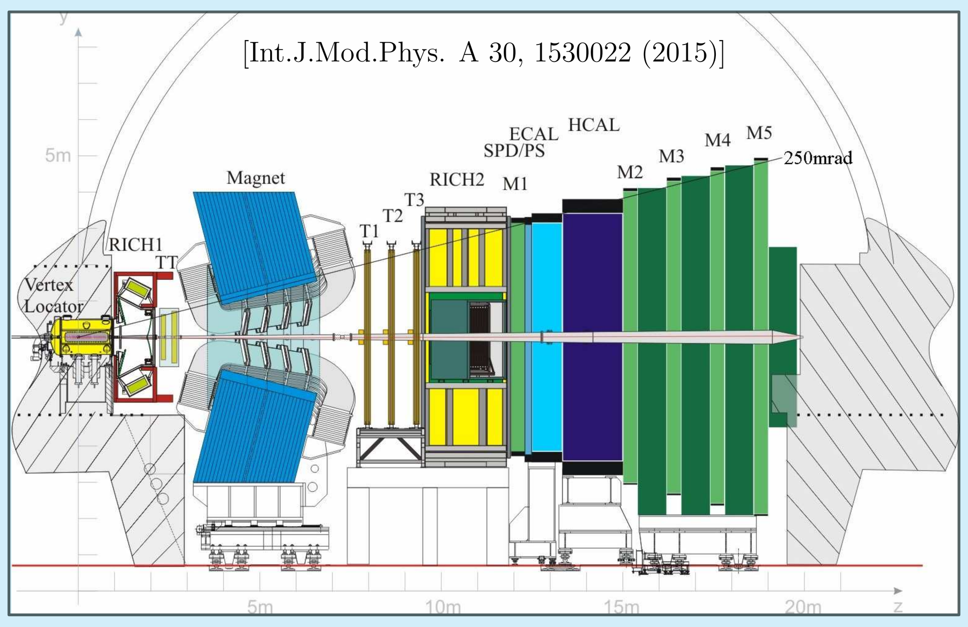


The flavour anomalies seem connected.

Ratios of branching fractions:
✓ very clean SM prediction
✓ **flavour anomalies**
✓ sensitive to New Physics that breaks **lepton universality**

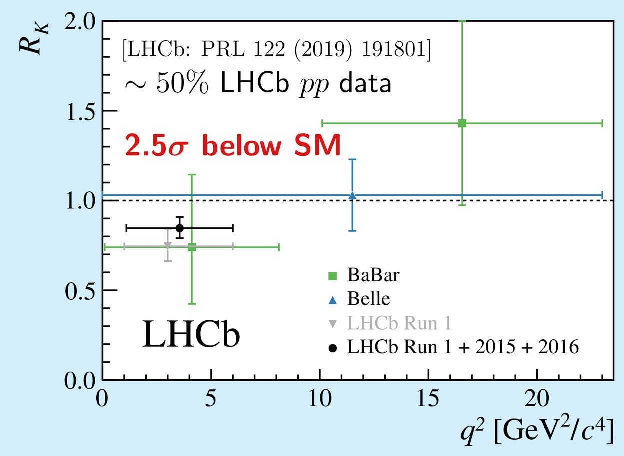
$$R_H = \frac{\mathcal{B}(X_b \to H\mu^+\mu^-)}{\mathcal{B}(X_b \to He^+e^-)}$$

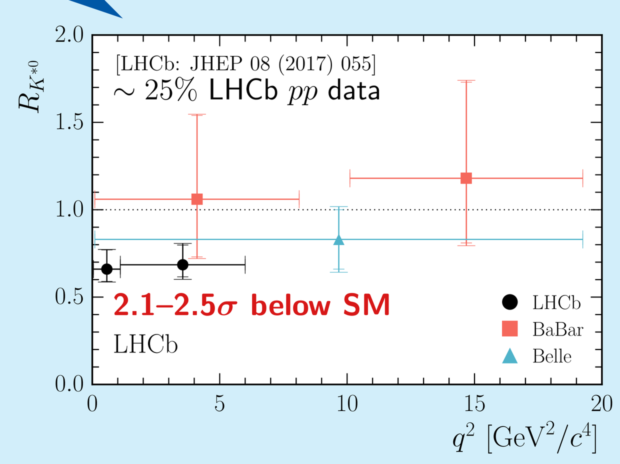
The detector

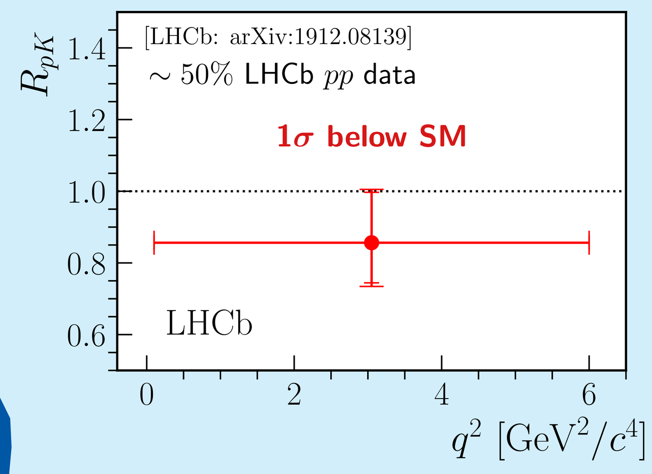


✓ Designed to study charmed and beauty hadrons
✓ Excellent particle identification (PID)
✓ Good momentum resolution
✓ High-precision vertexing

The results







The technique

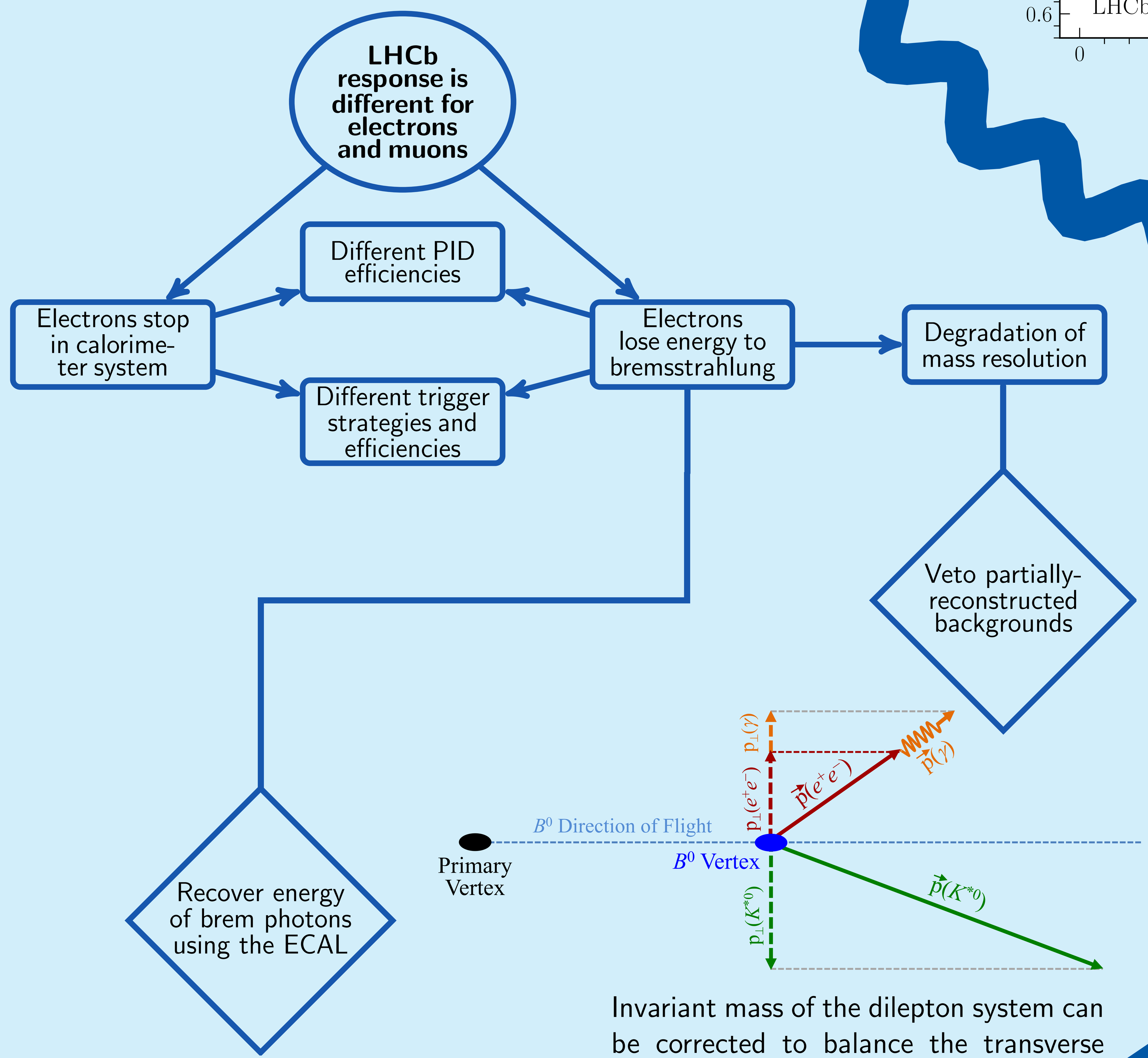
Rare processes are measured with respect to control channels $B \to HJ/\psi(\ell^+\ell^-)$.

- ✓ much higher branching fractions
- ✓ $\mathcal{B}(J/\psi \to \mu^+\mu^-)/\mathcal{B}(J/\psi \to e^+e^-)$ known with sub-percent precision
- ✓ dominate in certain regions of $q^2 \equiv m^2_{\ell\ell}$
- ✓ good overlap between rare and resonant modes in variables relevant to detector response
- ✓ suppress systematics due to different electron-muon behaviours

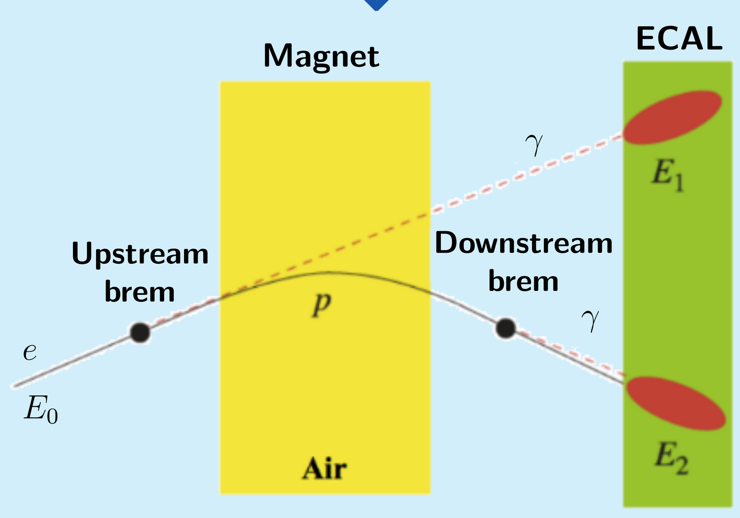
yields obtained from fits to data

$$R_H = \left(\frac{N^{\mu\mu}_{\text{rare}}}{\epsilon^{\mu\mu}_{\text{rare}}} \Big/ \frac{N^{ee}_{\text{rare}}}{\epsilon^{ee}_{\text{rare}}}\right) \Big/ \underbrace{\left(\frac{N^{\mu\mu}_{\text{control}}}{\epsilon^{\mu\mu}_{\text{control}}} \Big/ \frac{N^{ee}_{\text{control}}}{\epsilon^{ee}_{\text{control}}}\right)}_{r_{J/\psi}}$$

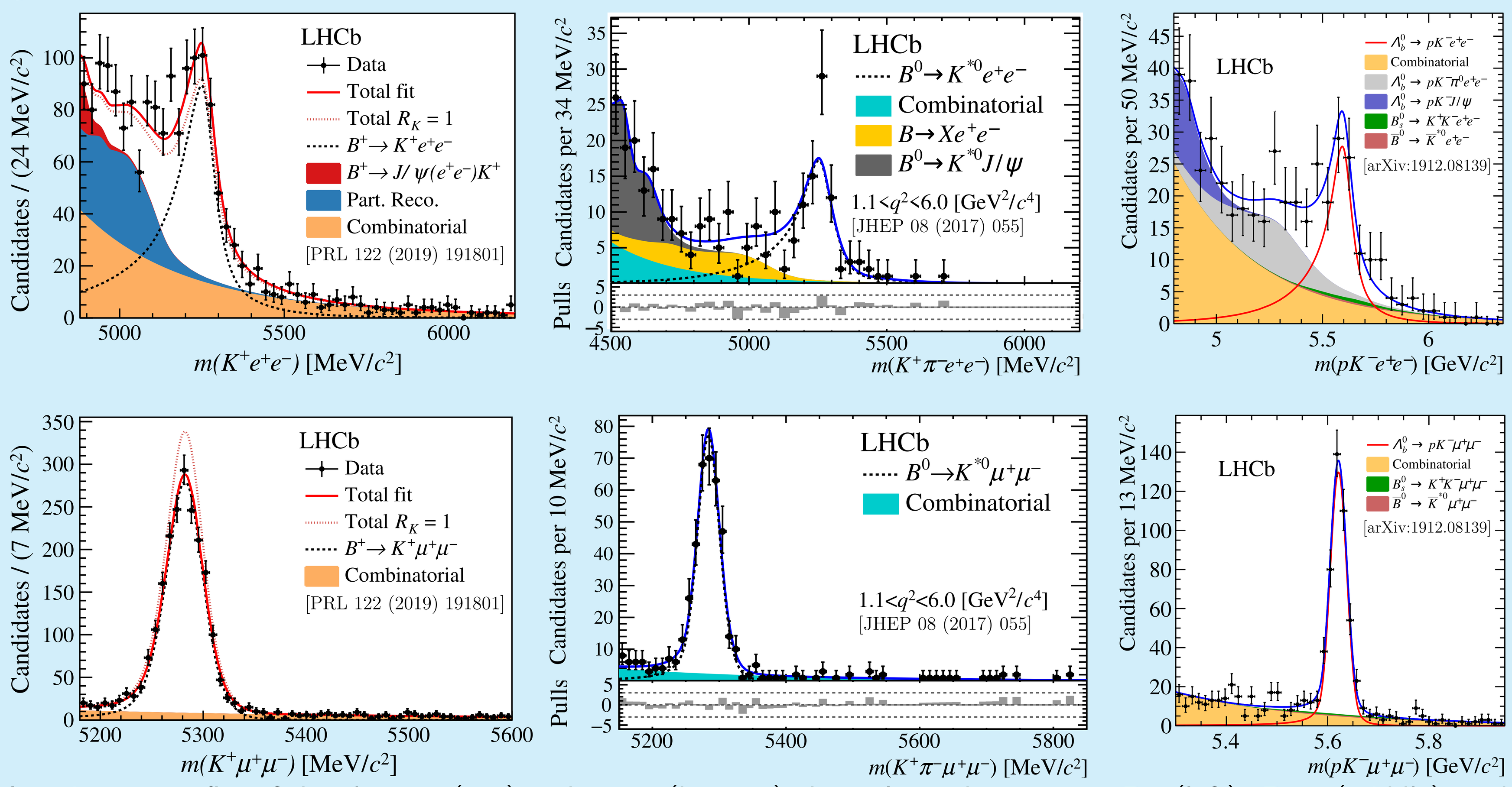
efficiencies estimated from simulation



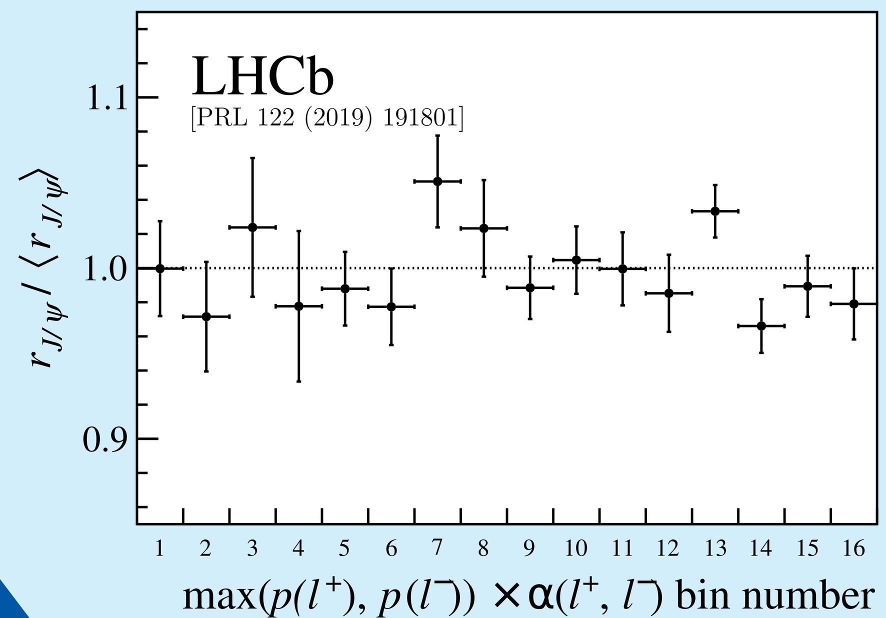
Invariant mass of the dilepton system can be corrected to balance the transverse momentum of the hadronic system.



Search for energy deposits in the ECAL that are compatible with the trajectory of an electron, but do not have an associated charged track. Add the deposits' energy to the measured electron momentum.

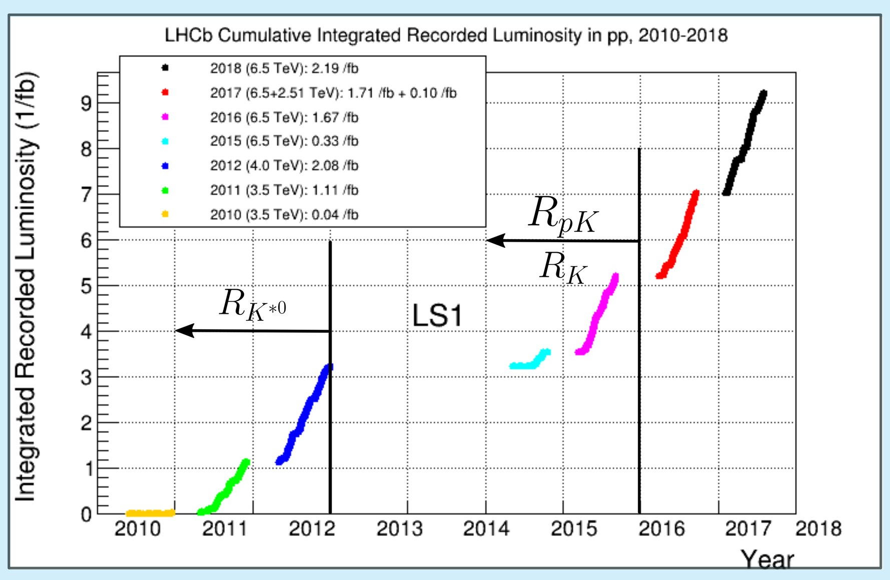


Invariant-mass fits of the electron (top) and muon (bottom) channels used to extract R_K (left), $R_{K^{*0}}$ (middle), and R_{pK} (right). Notice how the better energy resolution in the muon modes significantly reduces contamination from partially-reconstructed backgrounds.



$r_{J/\psi}$ used as a cross-check (flat in kinematic variables)

The future



Lepton universality tests using the full Run1 + Run2 LHCb dataset are well underway.
Significantly improved precision is expected thanks to larger datasets and improved analysis techniques.