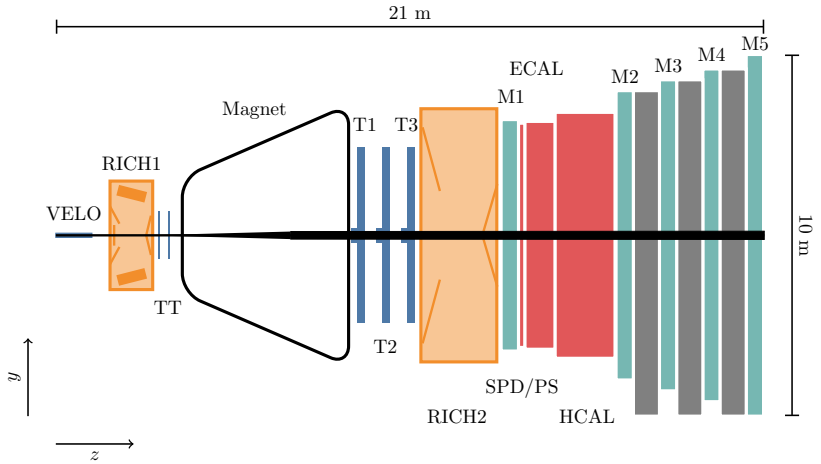
Ultra-peripheral collisions at LHCb

Tom Boettcher

APS GHP Meeting
March 15, 2025

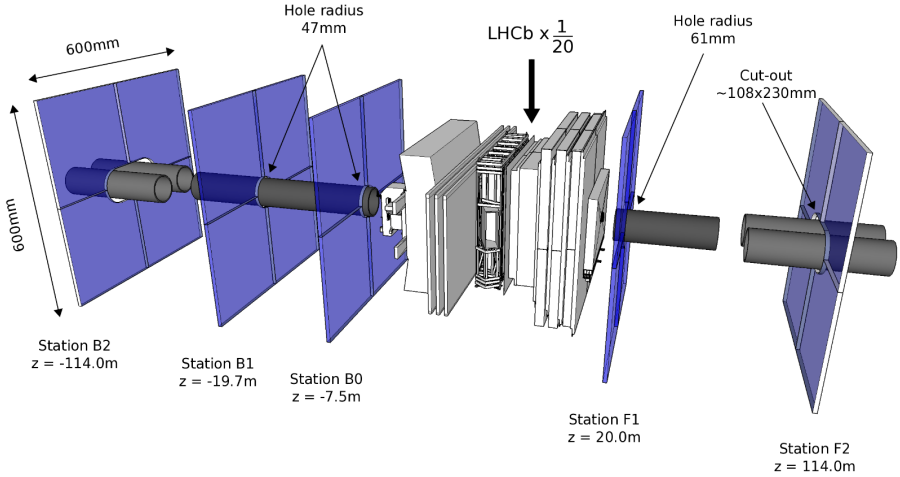
The LHCb detector (Int. J. Mod. Phys. A 30, 1530022 (2015))



Tracking/vertexing, **calorimetry**, **RICH**, μ **ID**, $2 < \eta < 5$

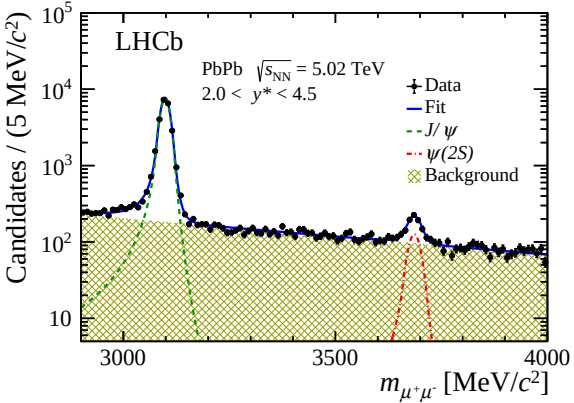
Can reconstruct and identify: γ, $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, $K^{\pm}$, p, d, ^{3}He

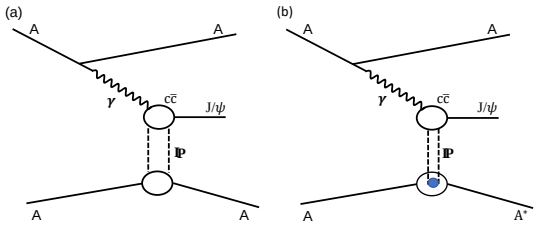
The HeRSCheL detector (JINST 13 (2018) no.04, P04017)



Scintillator planes covering $5 < |\eta| < 10$.
HeRSCheL activity can help identify photonuclear interactions.

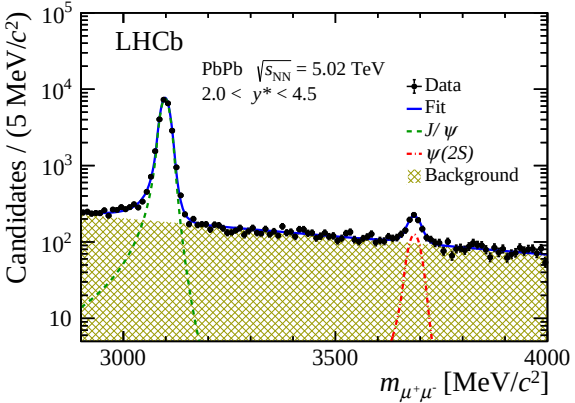
Charmonium production (JHEP 2023, 146 (2023))

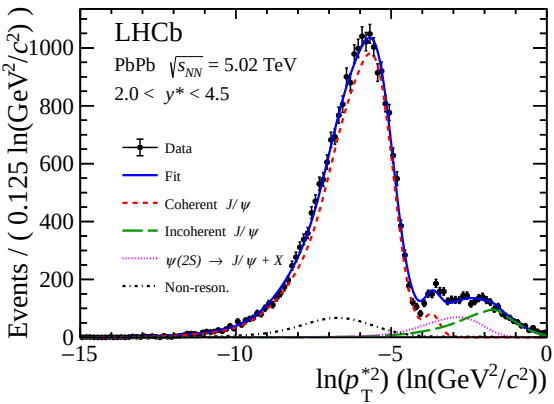




Sensitive to the spatial gluon distribution in the nucleus.
States of different masses provides sensitivty to different Q^2.

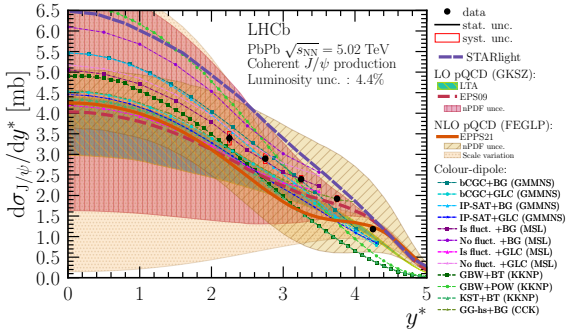
Charmonium production (JHEP 2023, 146 (2023))

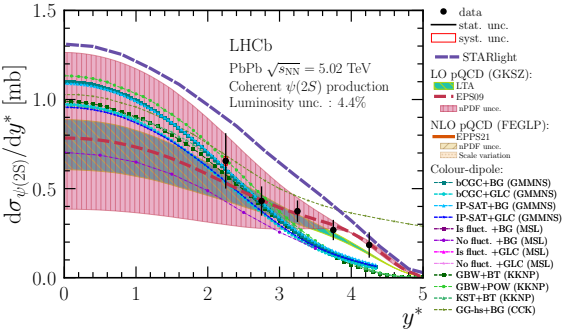




Sensitive to the spatial gluon distribution in the nucleus.
States of different masses provides sensitivty to different Q^2.

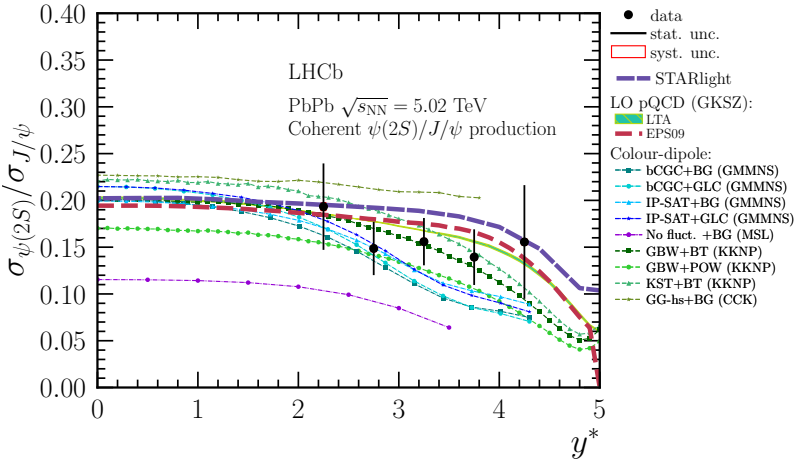
Charmonium production (JHEP 2023, 146 (2023))





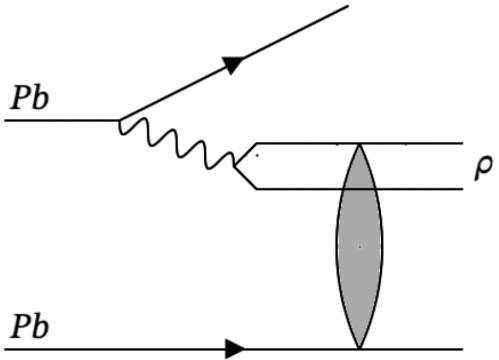
Charmonium cross sections provide sensitivity to the low-x structure of the nucleus, but predictions suffer from large scale uncertainties.

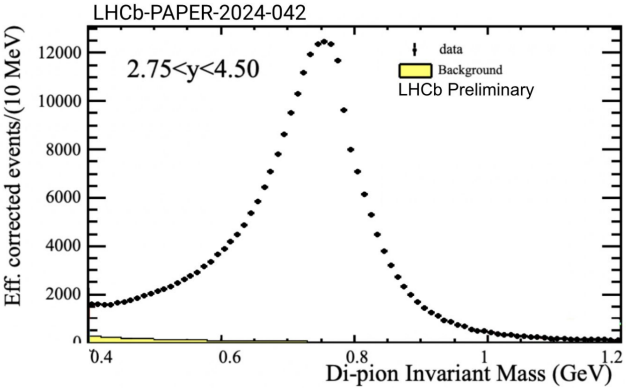
Charmonium production (JHEP 2023, 146 (2023))



Some theoretical uncertainties cancel in cross section ratios, allowing for better discrimination between models.

ρ production (**NEW!** LHCb-PAPER-2024-042, in preparation)

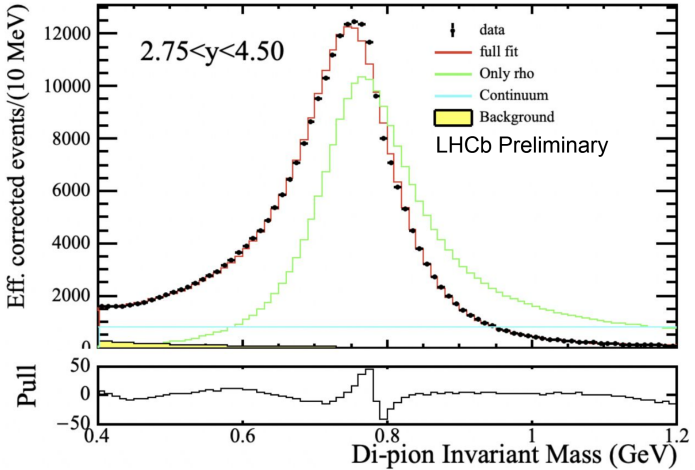




The low mass of the ρ means that its production is sensitive to non-perturbative effects and is described by phenomenological models.

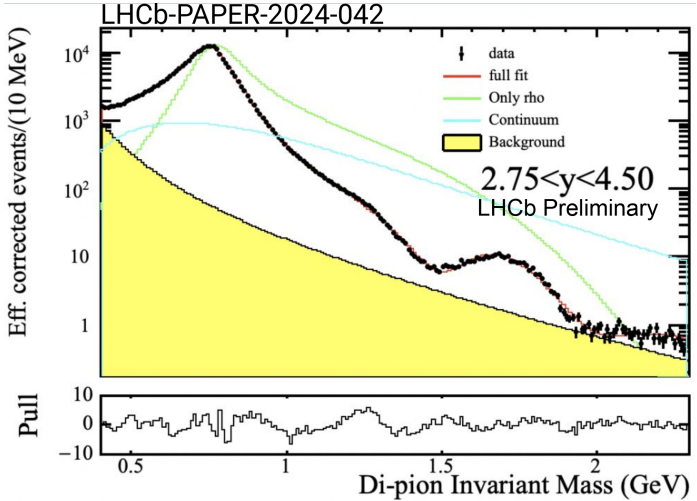
LHCb's forward acceptance allows for efficient reconstruction of a high-purity dipion sample in UPCs.

ρ production (**NEW!** LHCb-PAPER-2024-042, in preparation)



The high-quality LHCb data requires a more detailed model than the simple Söding model (ρ BW amplitude interfering with a flat continuum).

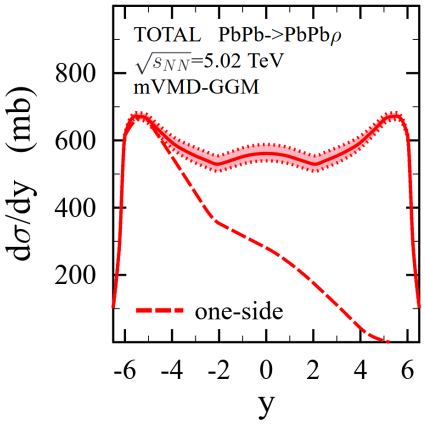
ρ production (**NEW!** LHCb-PAPER-2024-042, in preparation)



Data better described by including ω and an additional $\rho' \sim \rho(1700)$.

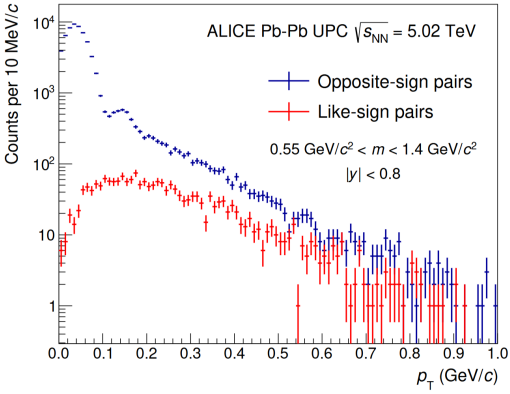
ρ production: next steps

PRC 93, 055206 (2016)



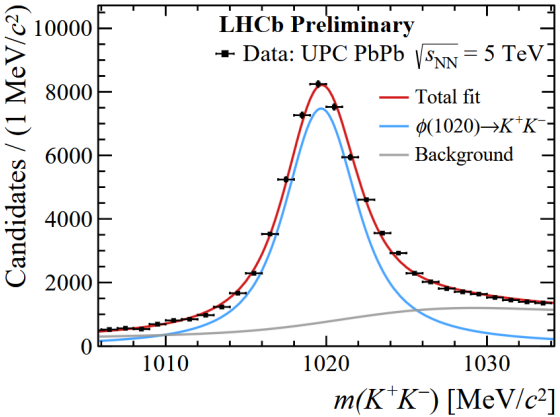
Use rapidity dependence to disentangle contributions from low-x and high-x gluons.

JHEP06 (2020) 35



p_{T} distribution is sensitive to the size and shape of the nucleus.

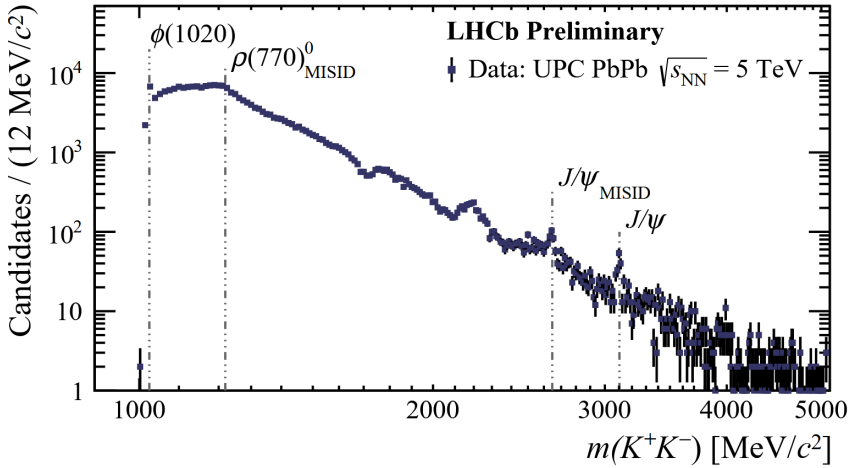
K^+K^- production (**NEW!** LHCb-CONF-2024-006, in preparation)



- Coherent ϕ production sits at the border of perturbative and non-perturbative. Seen as a golden channel for studying saturation effects.
- Analysis is challenging as the final-state K^+K^- have very little p_T
- LHCb's forward acceptance allows for efficient, high-quality reconstruction of $\phi \to K^+K^-$ in UPCs!

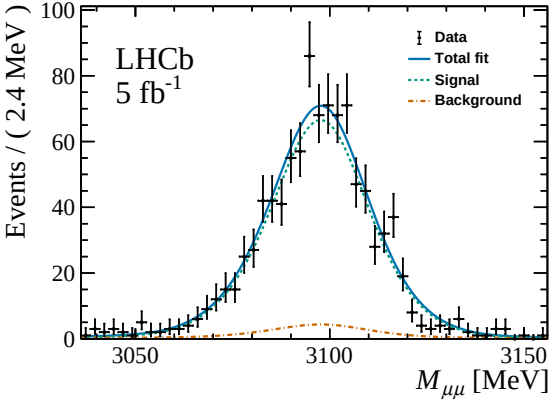
Cross section measurement is in progress.

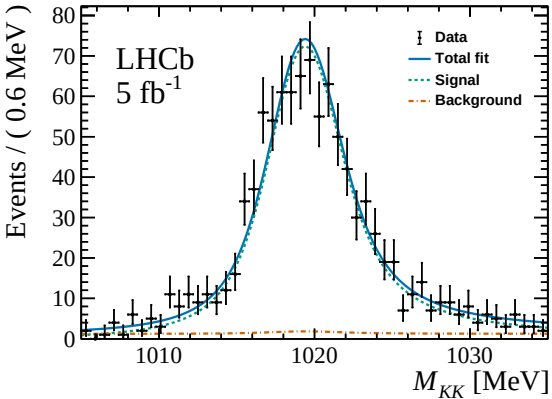
K^+K^- production (**NEW!** LHCb-CONF-2024-006, in preparation)



The gluon-rich interactions probed by UPCs provide opportunities to study a wide variety of states.

Diffractive $J/\psi\phi$ production in pp (PRL 134 (2025) 031902)

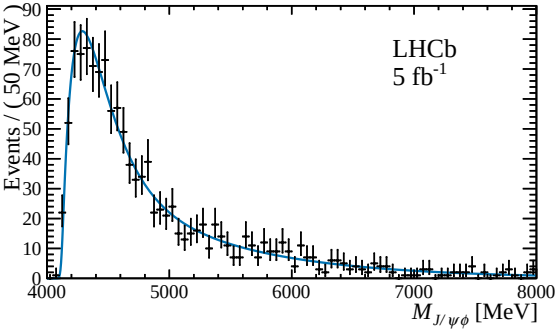




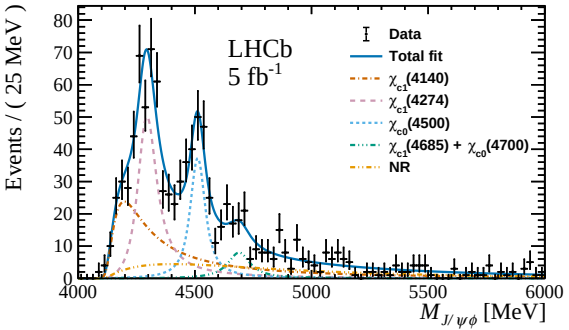
Exclusive production in pp collisions is dominated by pomeron-pomeron processes, providing a gluon-rich environment for creating exotic states.

Diffractive $J/\psi\phi$ production in pp (PRL 134 (2025) 031902)

Non-diffractive enhanced

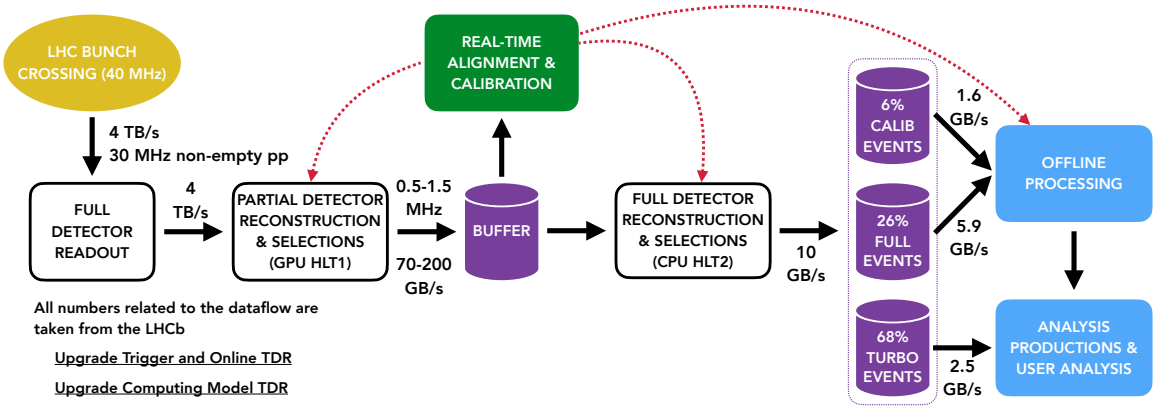


Diffractive



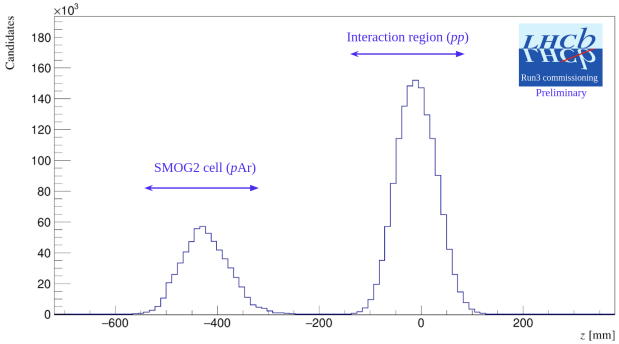
Diffractive data are described by a model containing five exotic hadron candidates previously observed in $B^+ \to J/\psi\phi K+$ decays (PRL 127, 082001 (2021)).
$\chi_{c0}(4500)$ observed with 5.5σ significance.

LHCb in Run 3

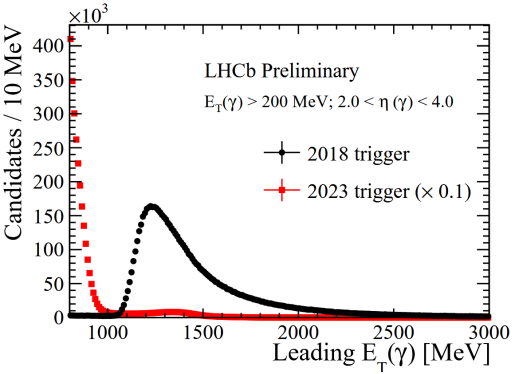


Since the start of Run 3 in 2022, LHCb has collected data with a GPU-based software-only trigger.

LHCb in Run 3



LHCb-FIGURE-2023-001



LHCb-FIGURE-2024-012

LHCb's flexible trigger allows for simultaneous collection of fixed-target and collider data, as well as studying new probes, such as low-p_{T} photons in UPCs.

Final thoughts

- The LHCb experiment is uniquely equipped to study UPCs at the LHC.
- Studies of UPCs at LHCb are expanding, taking advantage of the detector's forward acceptance and particle ID capabilities
- The upgraded LHCb detector and trigger will allow for new studies of UPCs in both collider and fixed-target modes.
- In 2024, LHCb collected its largest PbPb dataset ever, along with a large PbAr fixed-target sample that we've just started to explore.

Thank you!