



Low-mass Drell-Yan measurement in Run 3 with the LHCb detector

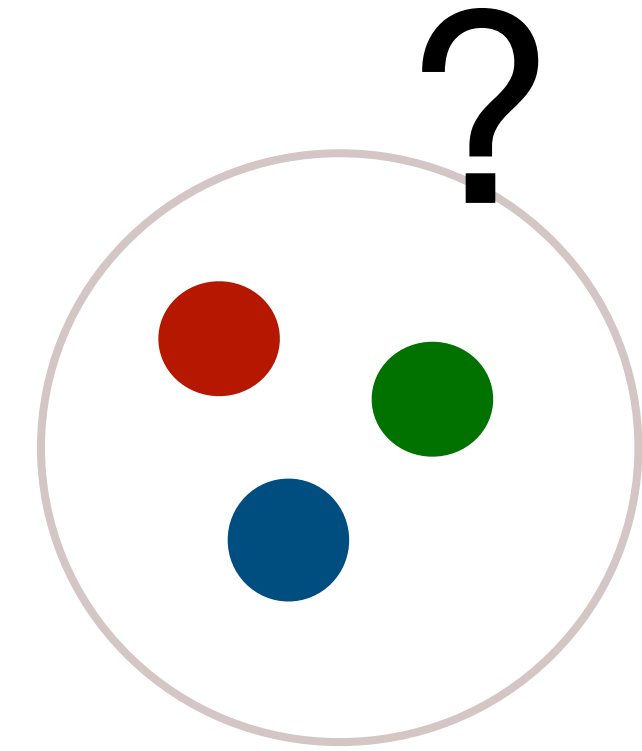
Alisha LIGHTBODY, 08/06/2026

CEA / IRFU

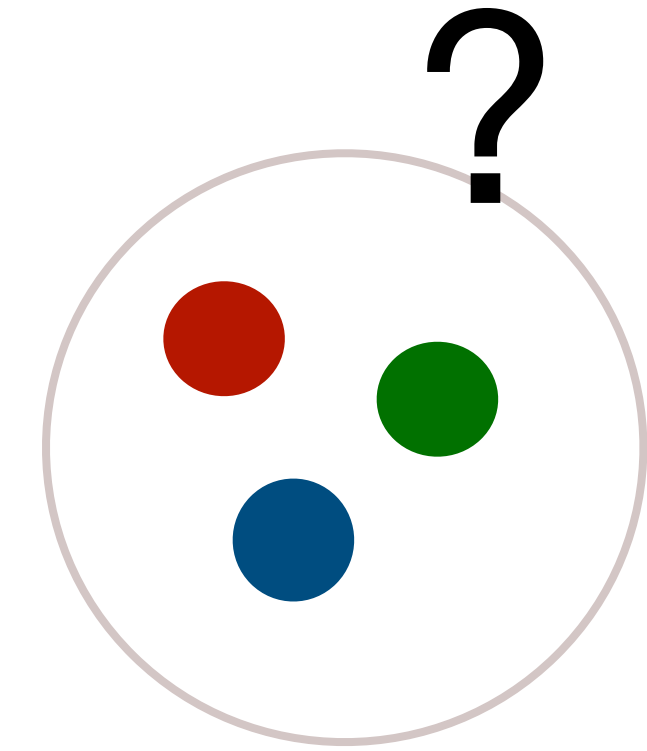


The parton model

- How can one access the **inner structure of the proton**?

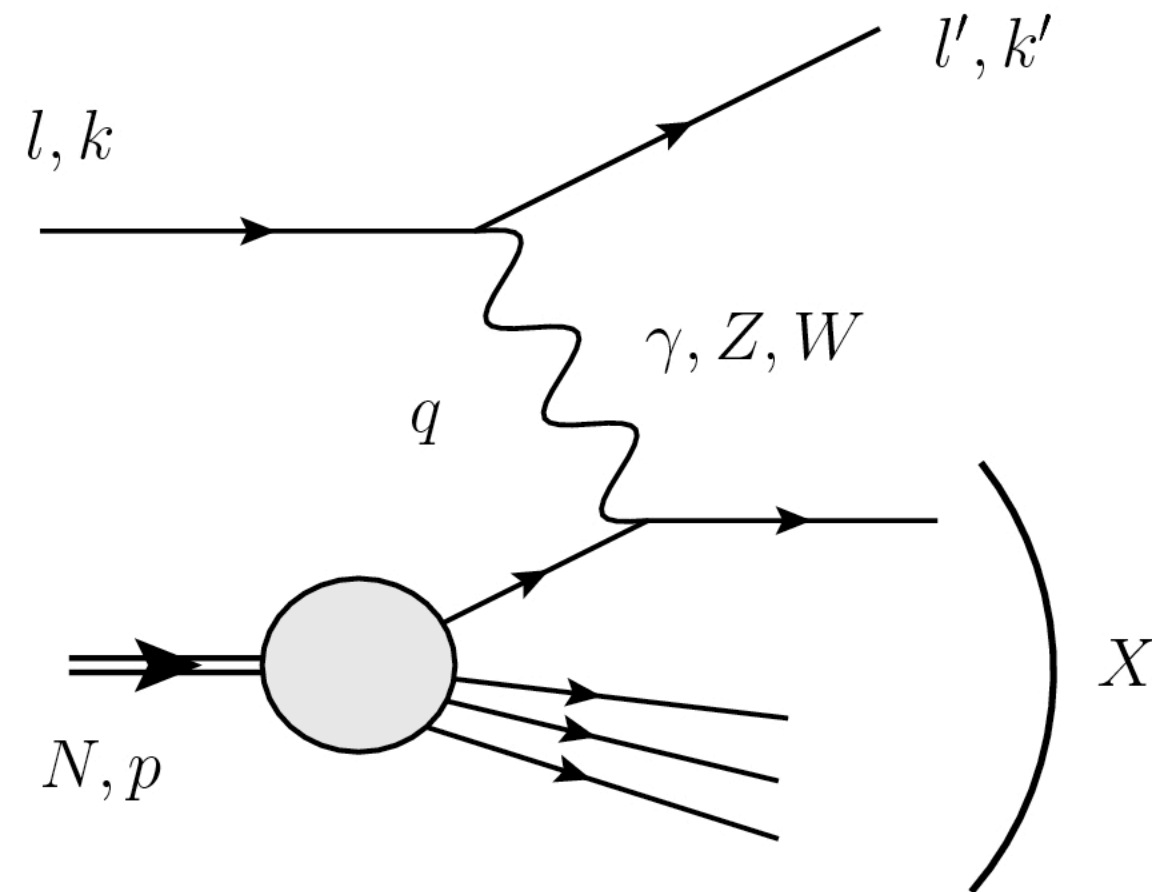


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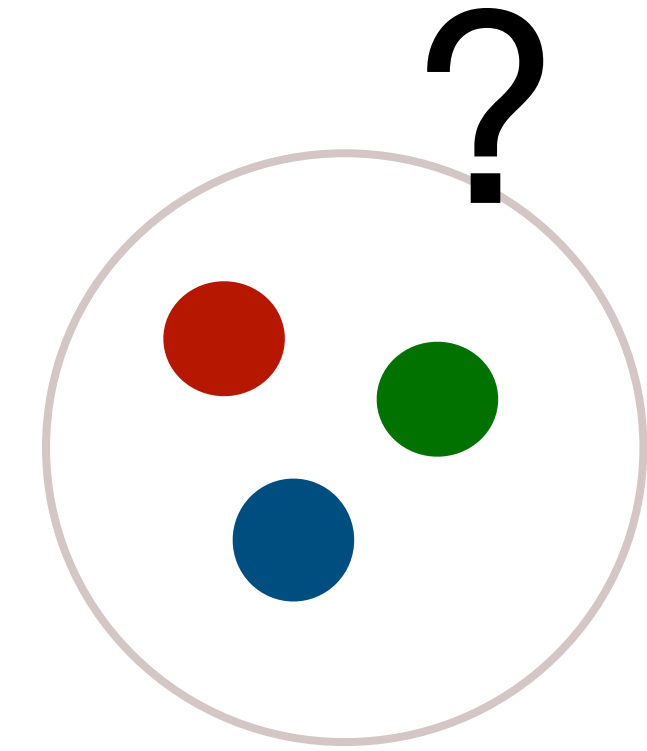


- How can one access the **inner structure of the proton**?

1. **Small projectile on proton** : Deep Inelastic Scattering (DIS)

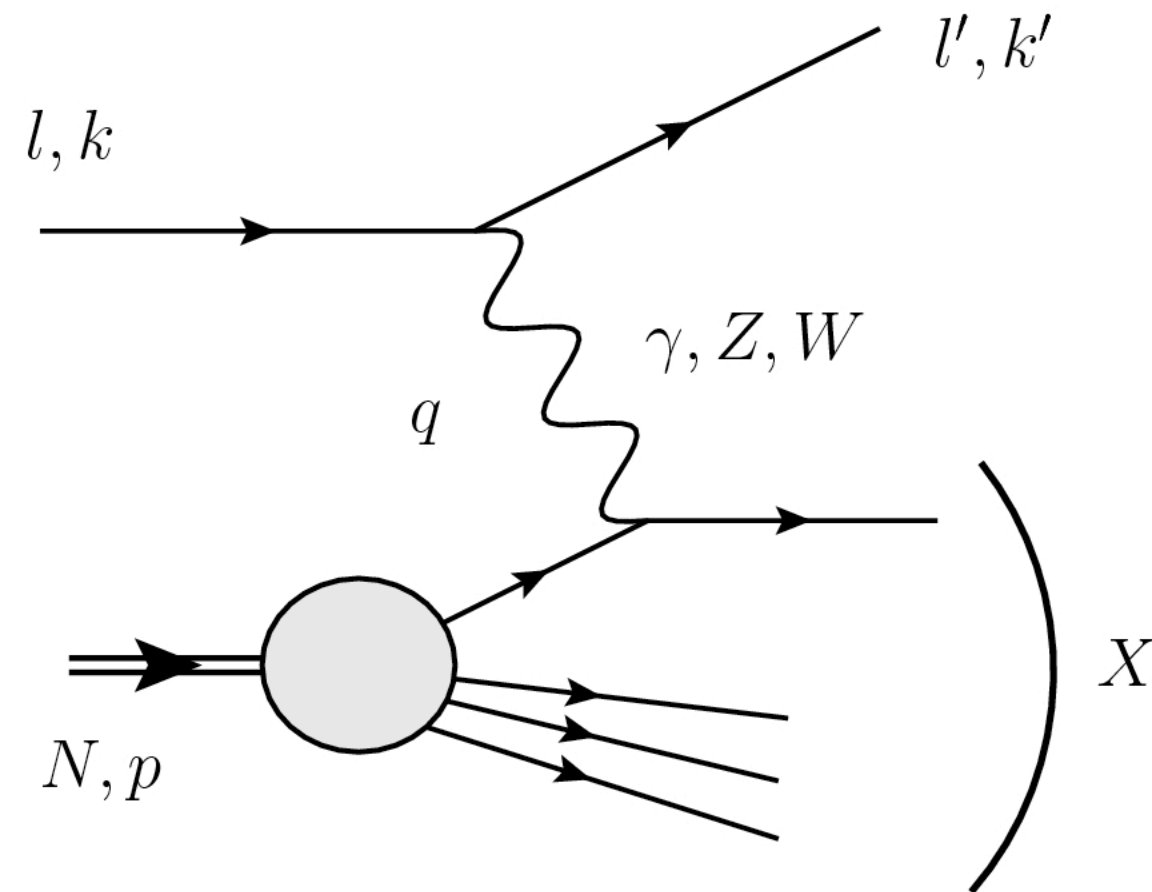


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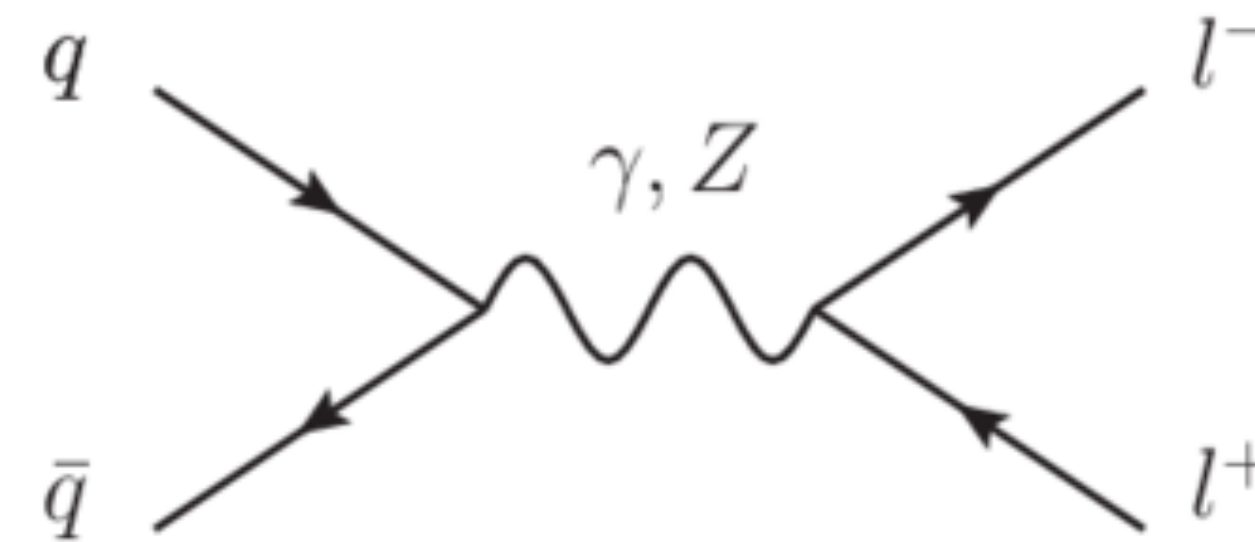


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1. **Small projectile on proton** : Deep Inelastic Scattering (DIS)



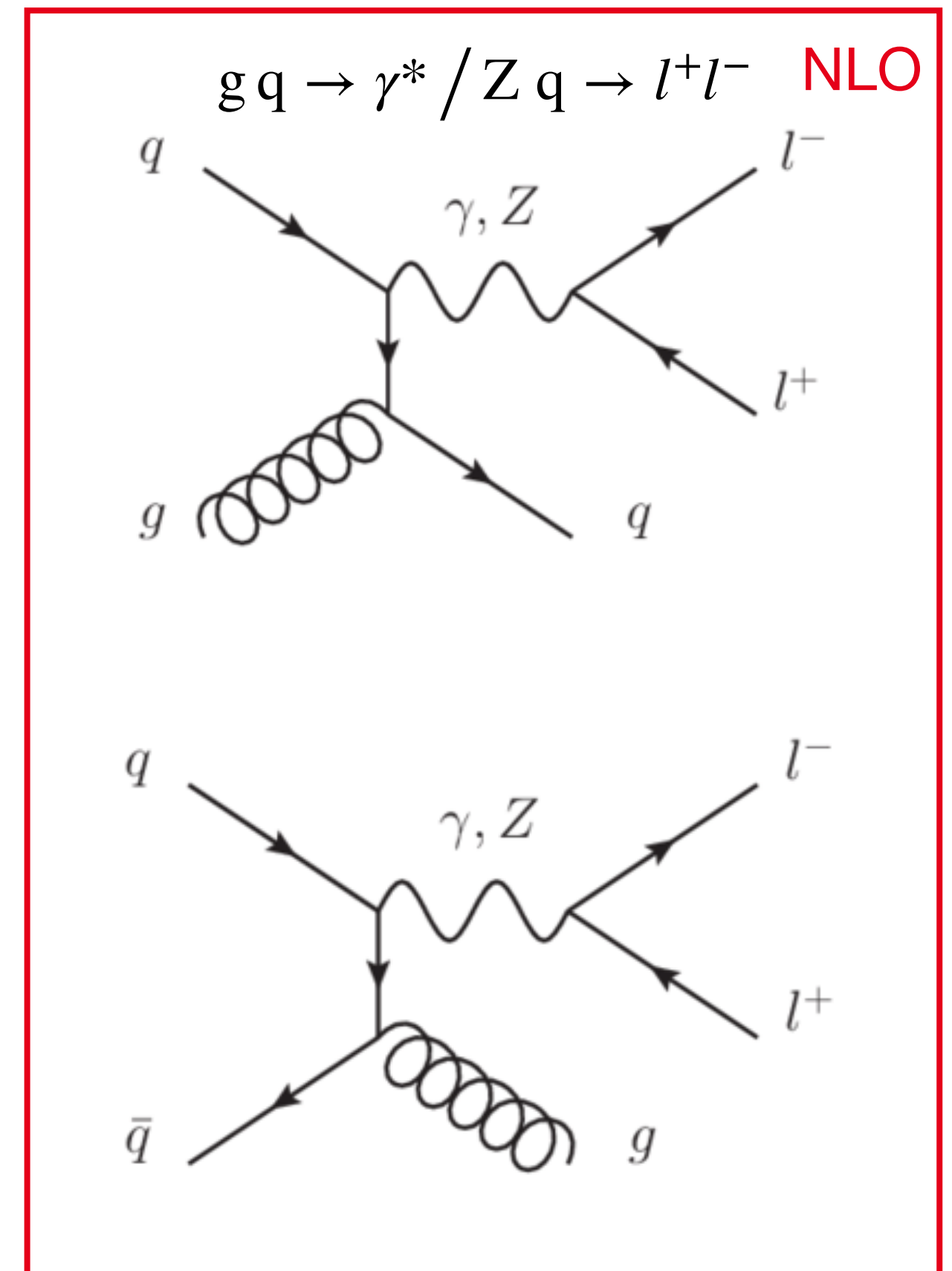
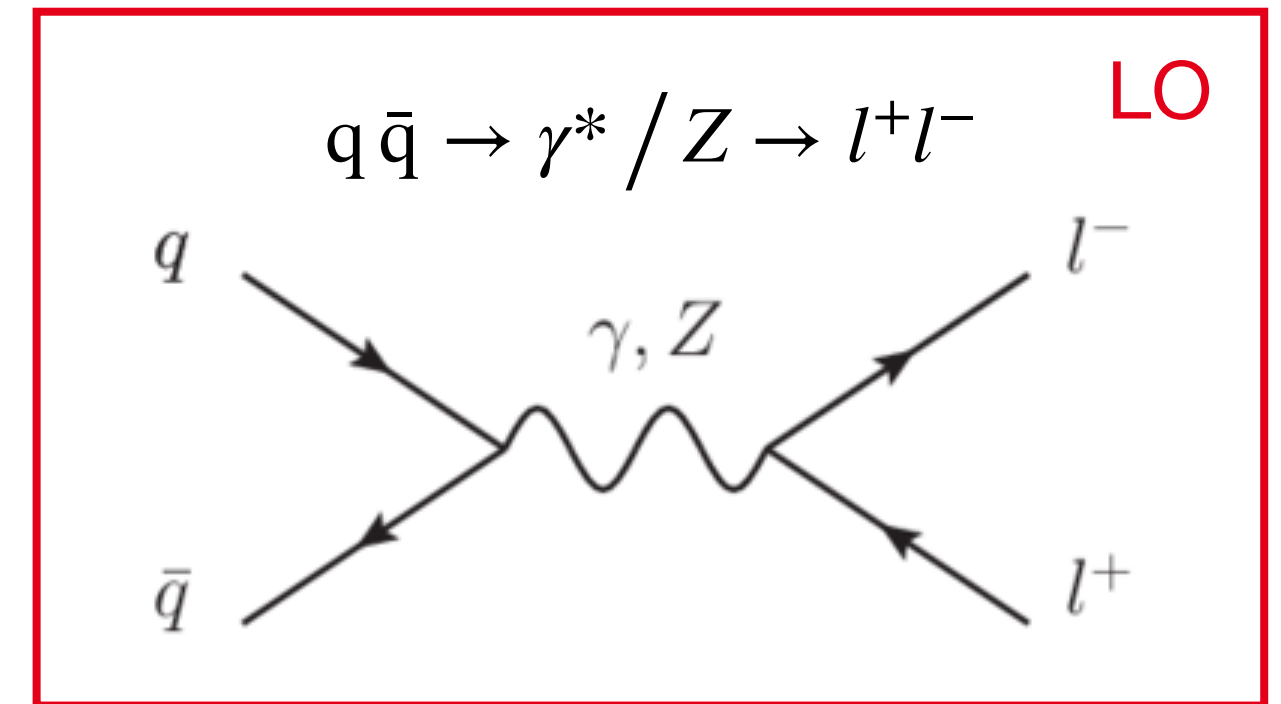
1. **Smash protons together** (e.g. Drell-Yan)



The Drell-Yan process

- **Production of a lepton pair** (e^+e^- , $\mu^+\mu^-$) in initial hadron-hadron collision: $\bar{q}q \longrightarrow Z, \gamma^* \longrightarrow l^+l^-$ at leading order (LO)
- Cross-section computation **available up to NNLO** for theoretical comparison with data
- **High sensitivity to parton distribution** of the colliding hadrons

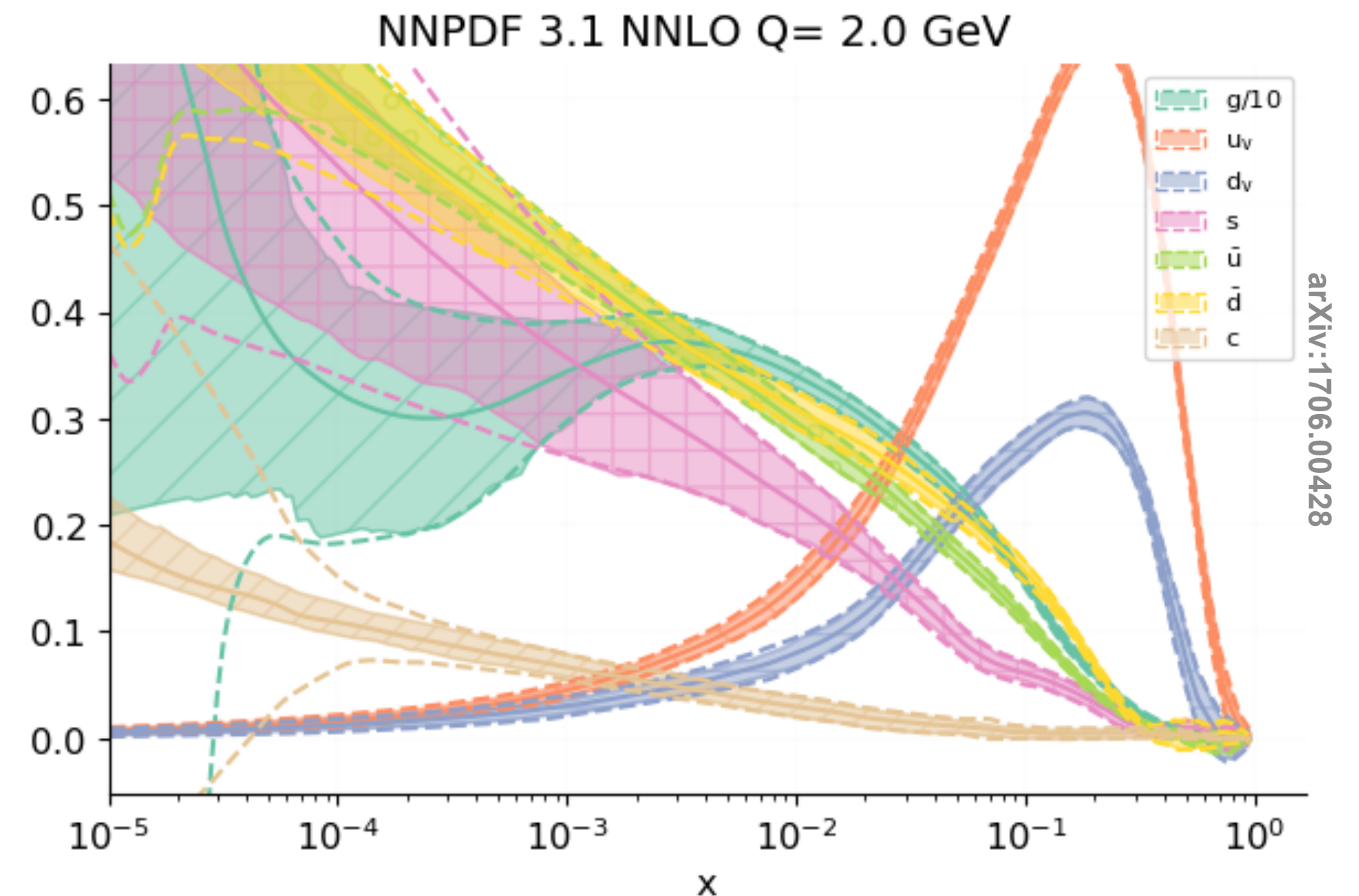
$$\sigma_{AB \rightarrow X} = \int dx_a dx_b \underbrace{f_{a/A}(x_a, Q^2) f_{b/B}(x_b, Q^2)}_{\text{PDFs}} \underbrace{\sigma_{ab \rightarrow X}(x_a, x_b, Q^2)}_{\text{pQCD}}$$



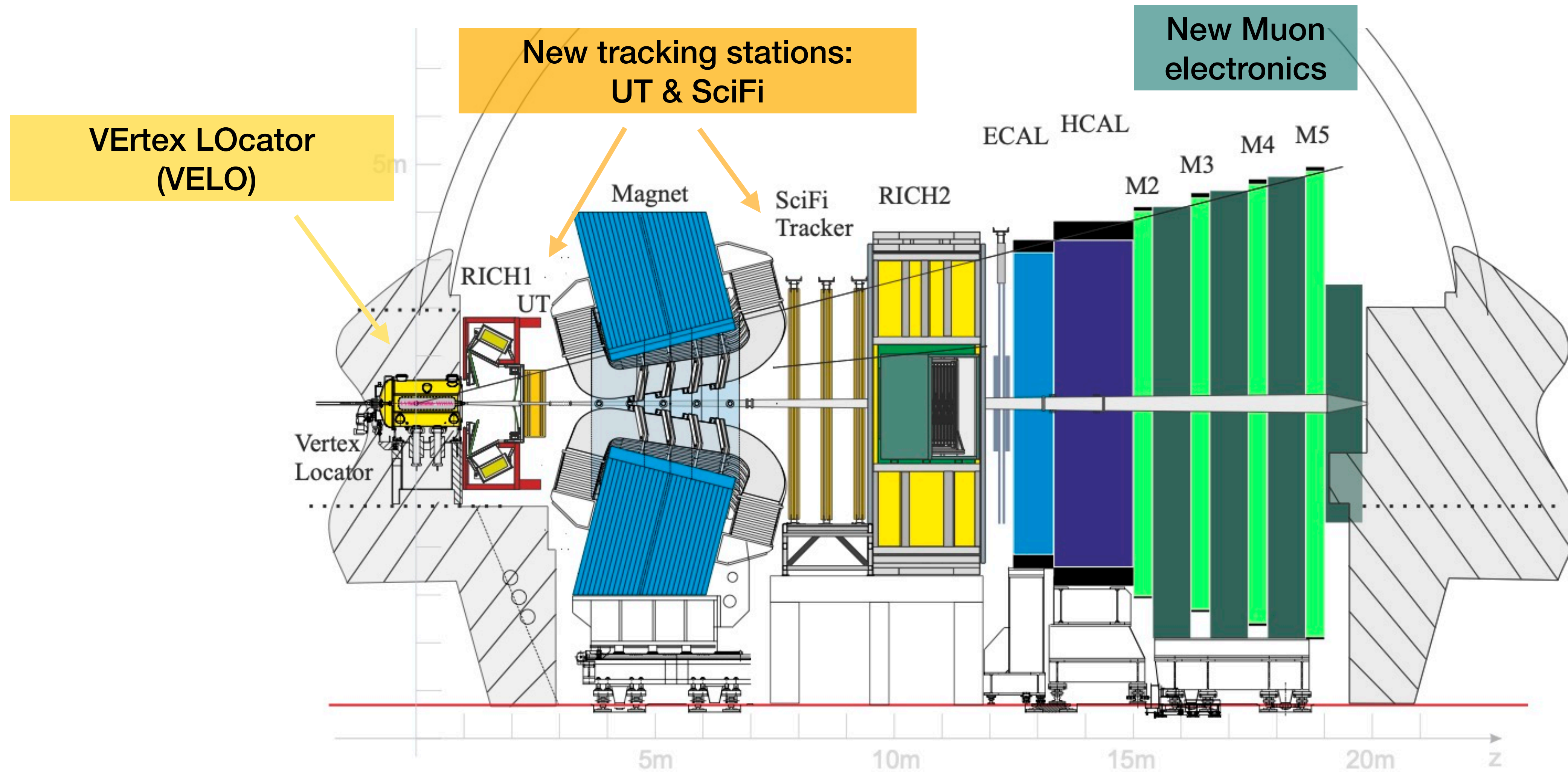
Parton Distribution Functions (PDFs)

- Describe **momentum distribution of partons** inside hadron as function of Bjorken-x
- With LHCb, Possibility of reaching very low-x with **forward geometry**:
 - Sensitivity to **sea-quark** and **gluon PDFs**
- At LO in collinear factorisation:

$$x_{1,2} = \frac{m_{ll}}{\sqrt{s}} \cdot e^{\pm y}, \quad m_{ll}^2 = Q^2$$

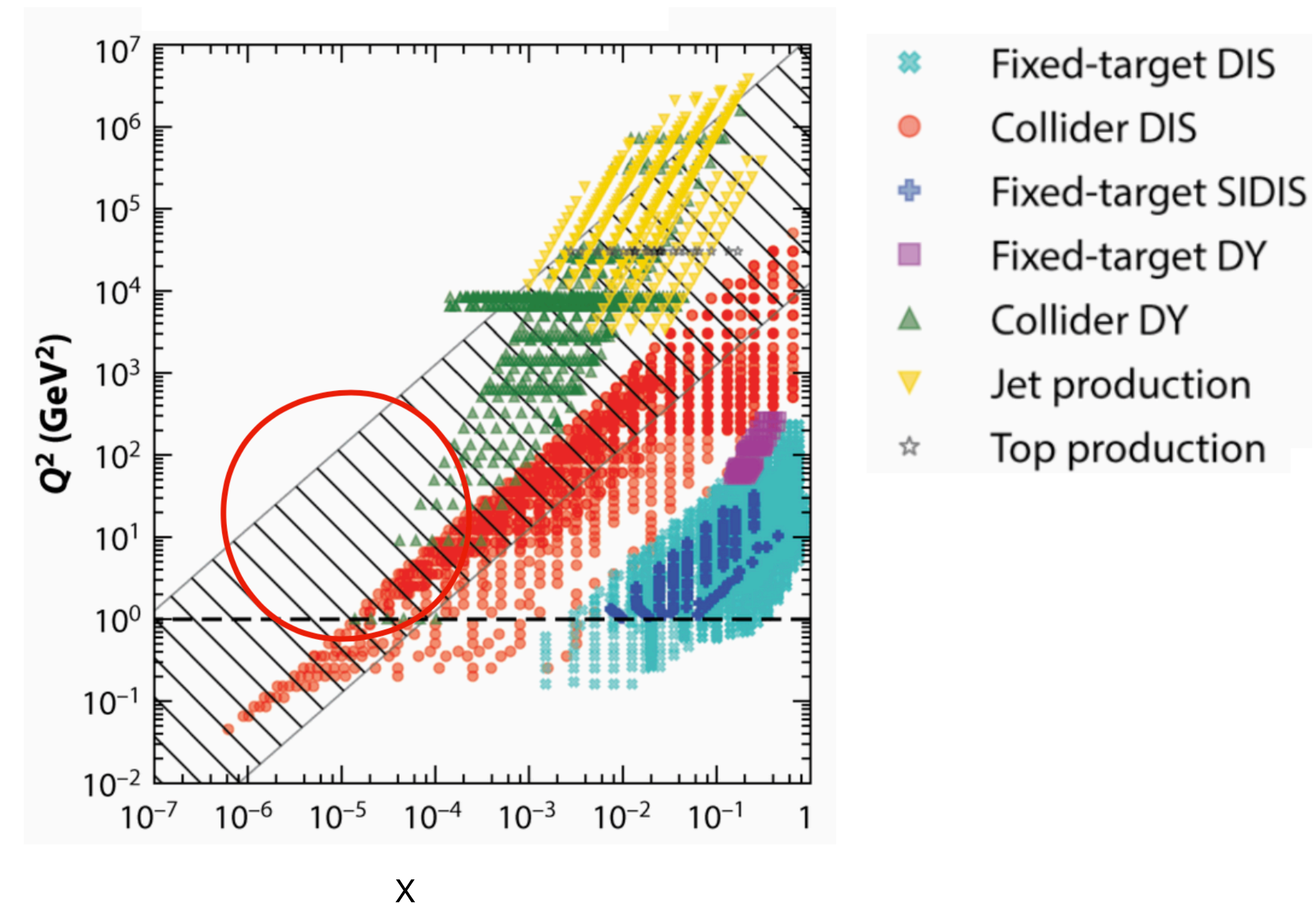


The LHCb experiment in Run 3



Low Mass Drell-Yan studies at LHCb

- Drell-Yan production in the mass range $3 < m_{\mu\mu} < 60 \text{ GeV}/c^2$ Run3 data at LHCb
- Access unexplored kinematic region in the x, Q^2 plane down to $x \approx 10^{-6}$
- Constrain **PDFs** and **TMDs** at low- x in p-p
- Feasibility of **preequilibrium dilepton** measurements in Pb-Pb:
 - ▶ **direct experimental access** to the pre-equilibrium stage
 - ▶ p-p would act as a reference to estimate DY background

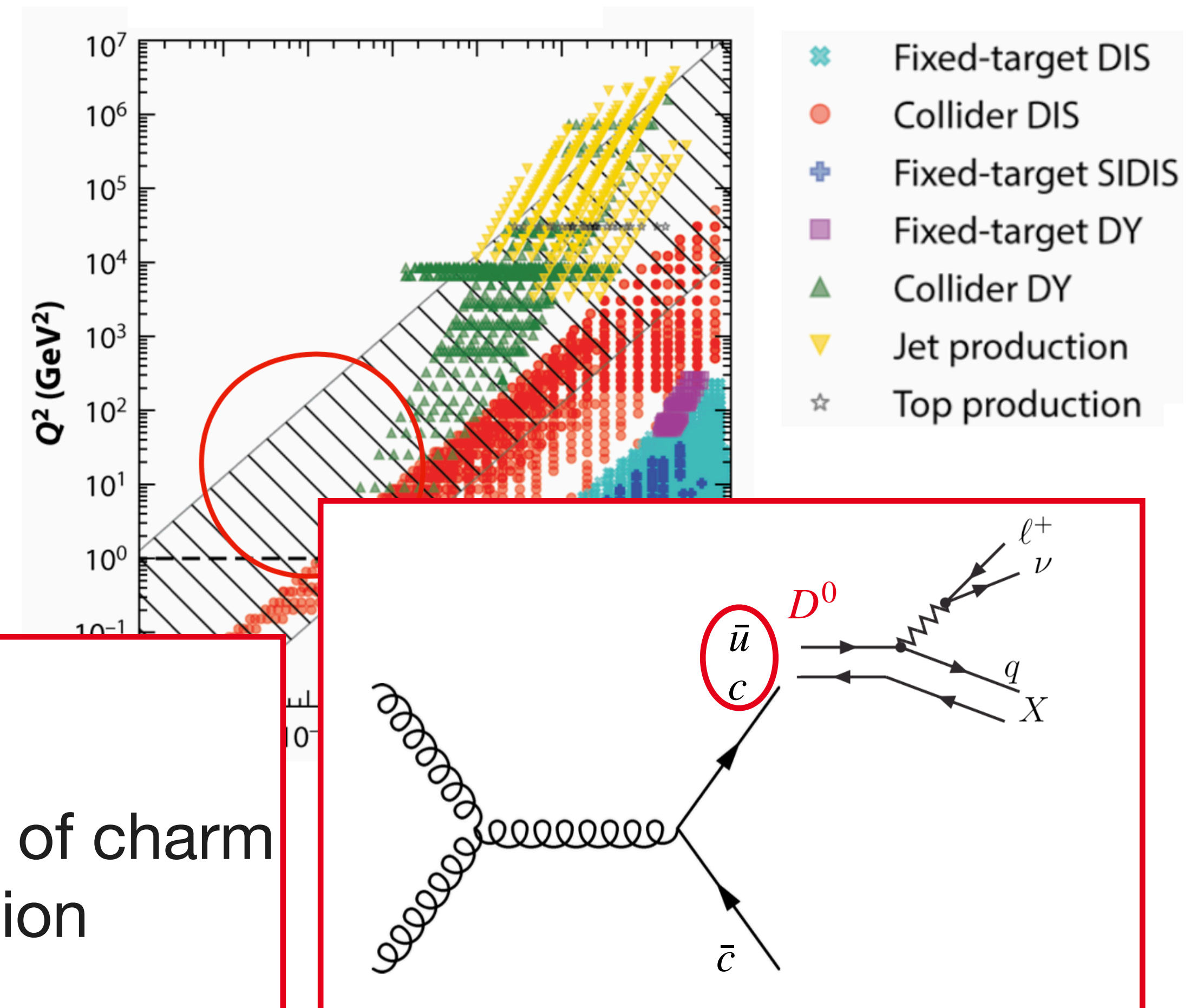


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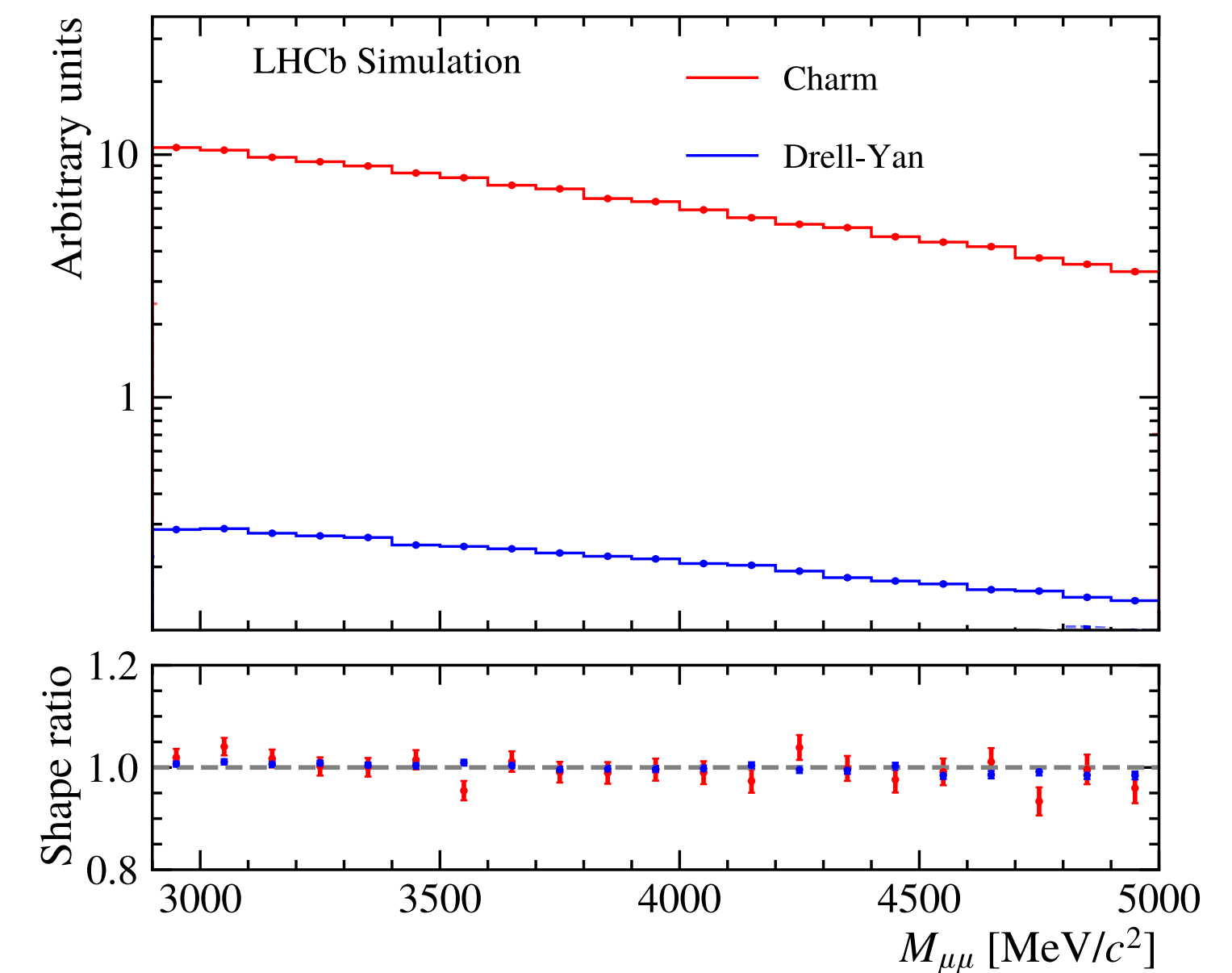
- ▶ **direct experimental**
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Challenging
Weak semi-leptonic decays of charm and beauty in this mass region



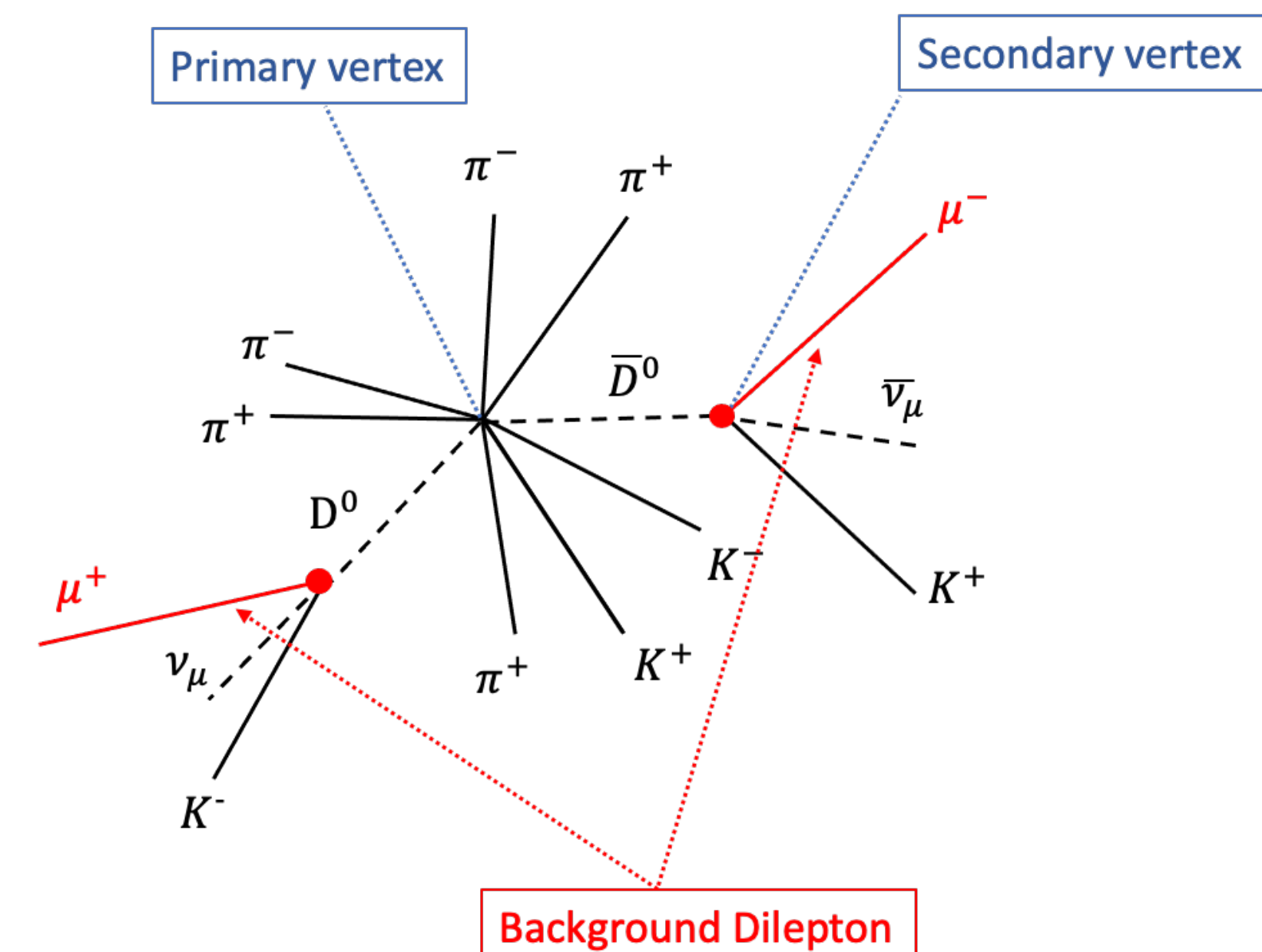
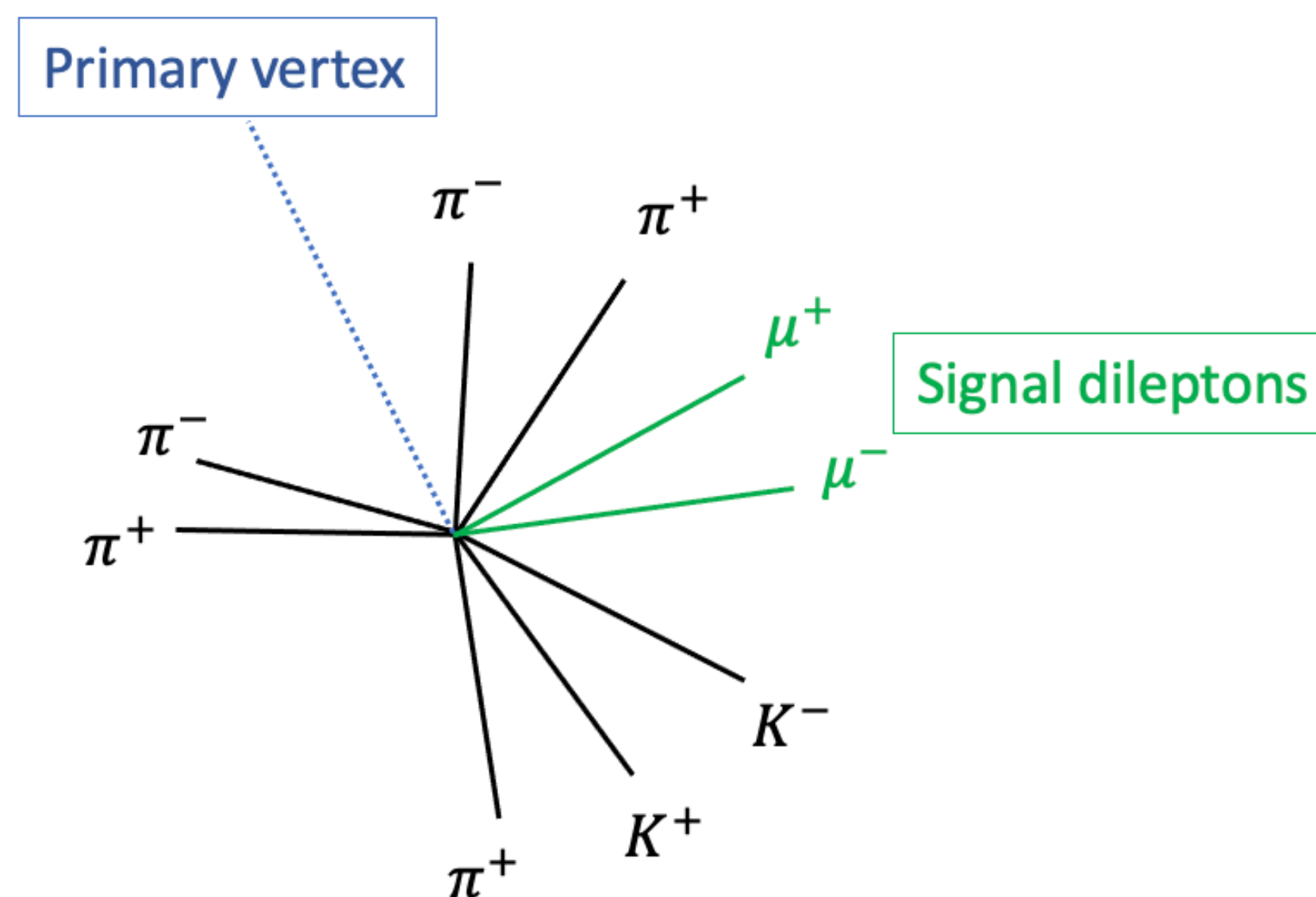
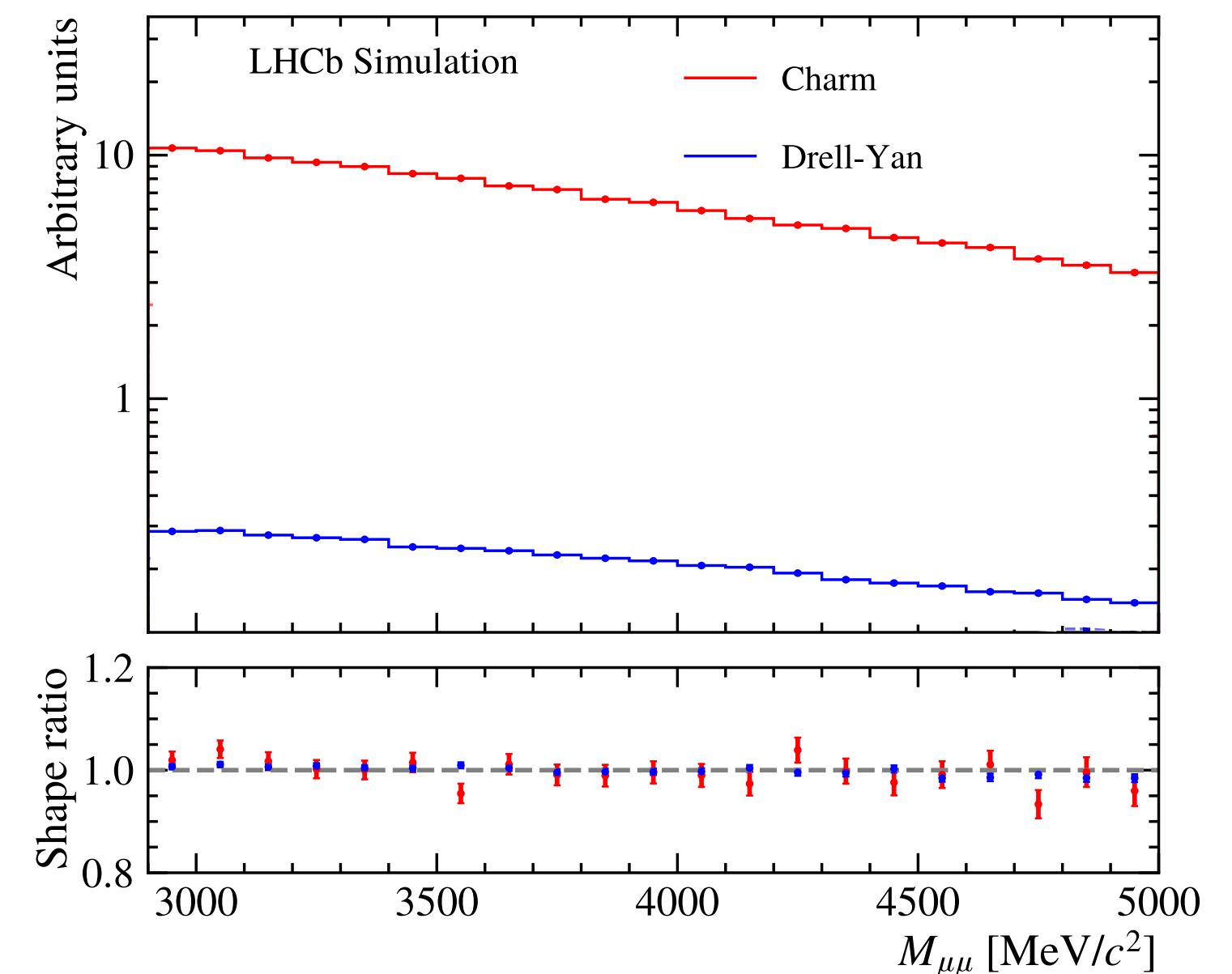
Heavy-Flavour background

- At $M < 5 \text{ GeV}/c^2$: **Weak semileptonic decays** of charm and beauty **dominate by 2 orders of magnitude** the Drell-Yan production



Heavy-Flavour background

- At $M < 5 \text{ GeV}/c^2$: **Weak semileptonic decays** of charm and beauty **dominate by 2 orders of magnitude** the Drell-Yan production
- **Presence of another track at vertex can help reject these decays**

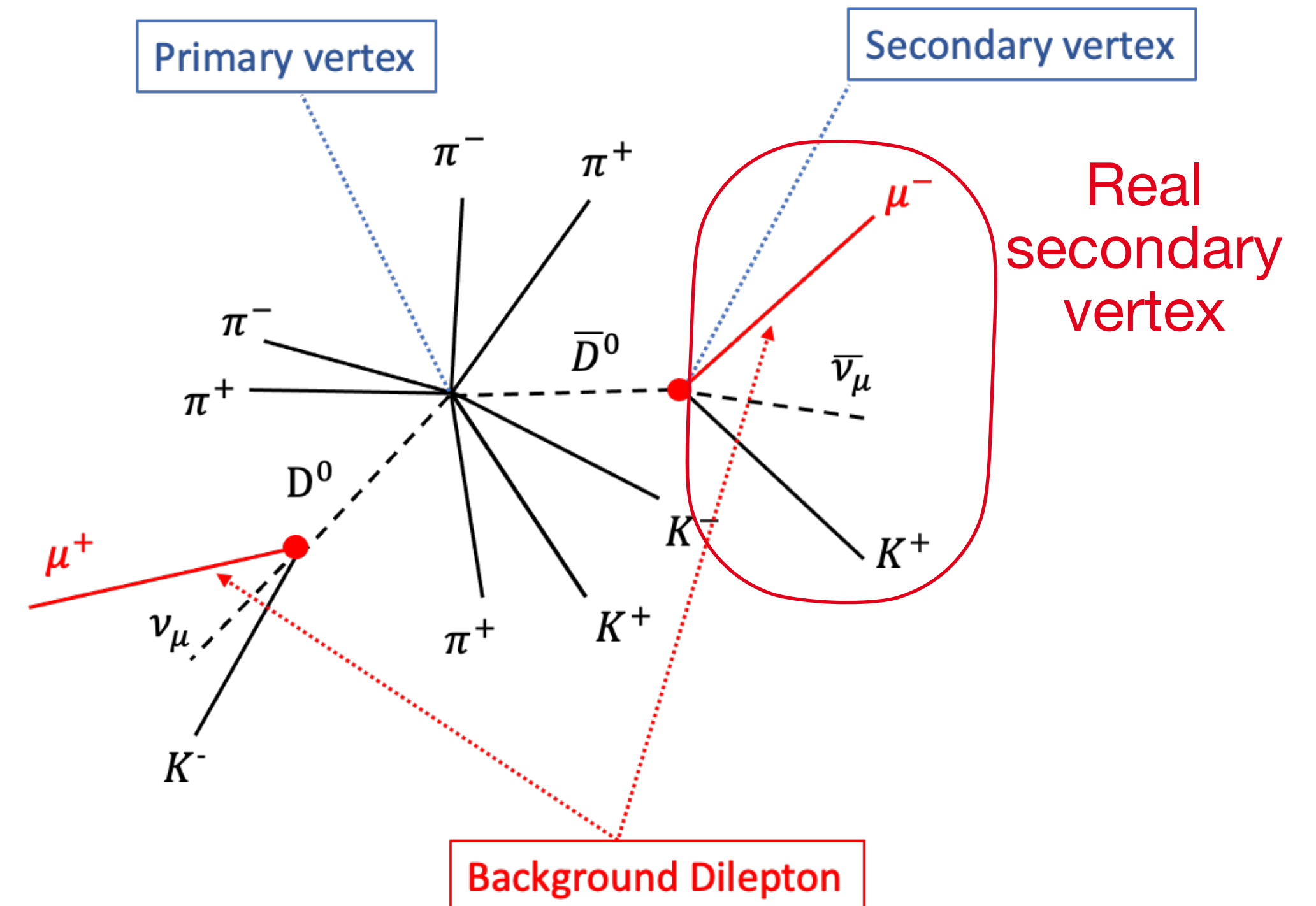
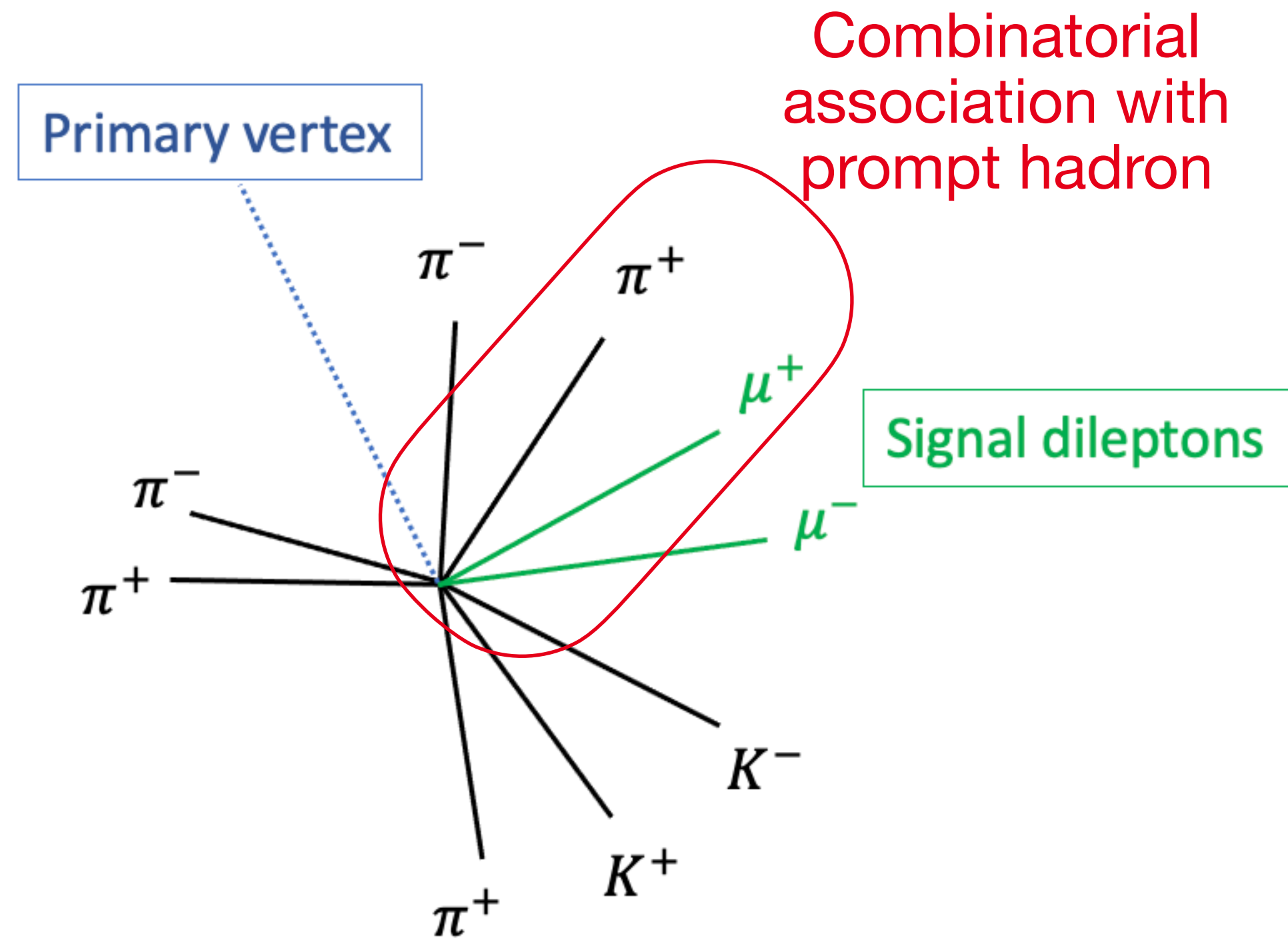


Heavy-Flavour tagging

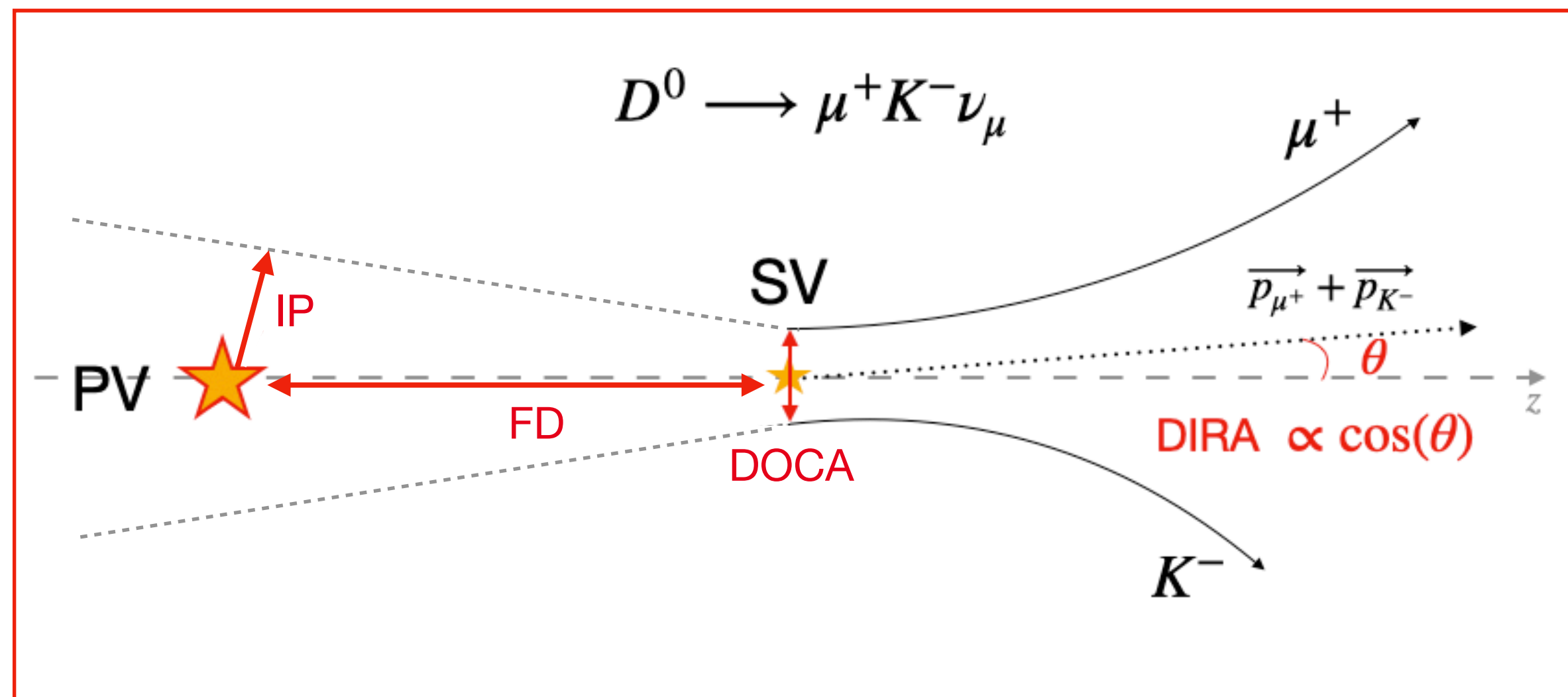
[arXiv:2604.11574](https://arxiv.org/abs/2604.11574)

• New tool SemiCharmTag:

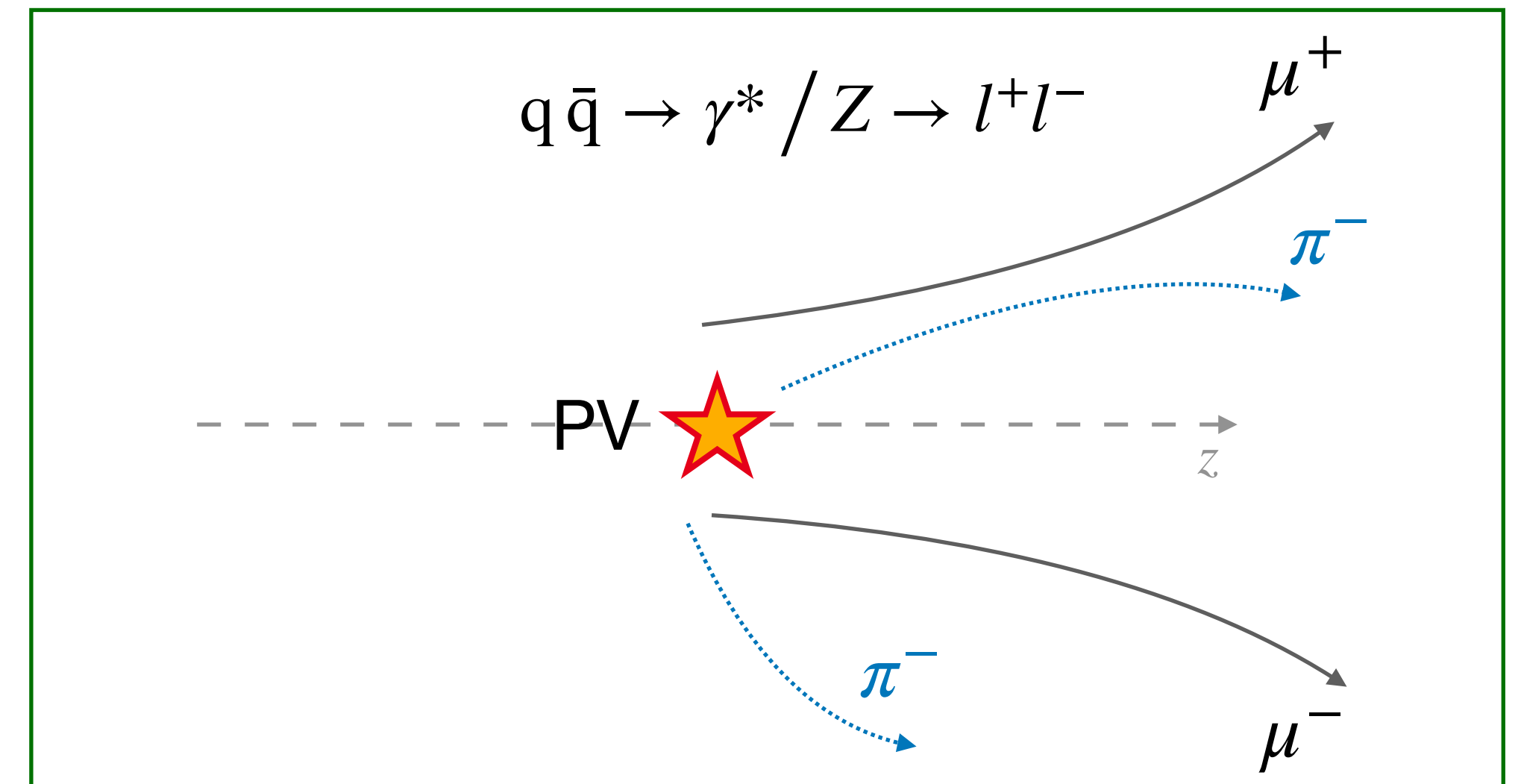
- Semileptonic tagging based on properties of the $(\mu + \text{hadron})$ at decay vertex
- Separation based on a BDT



Anatomy of the background

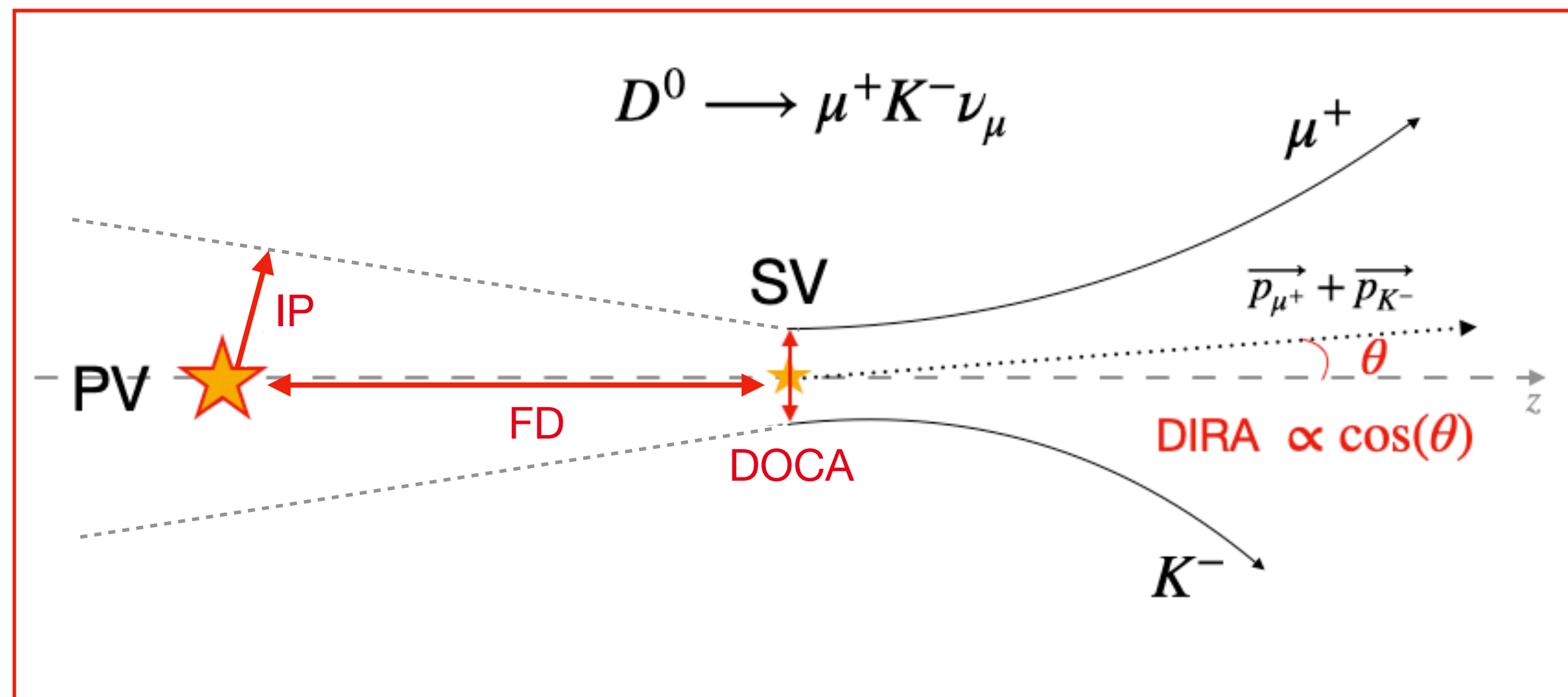


Background



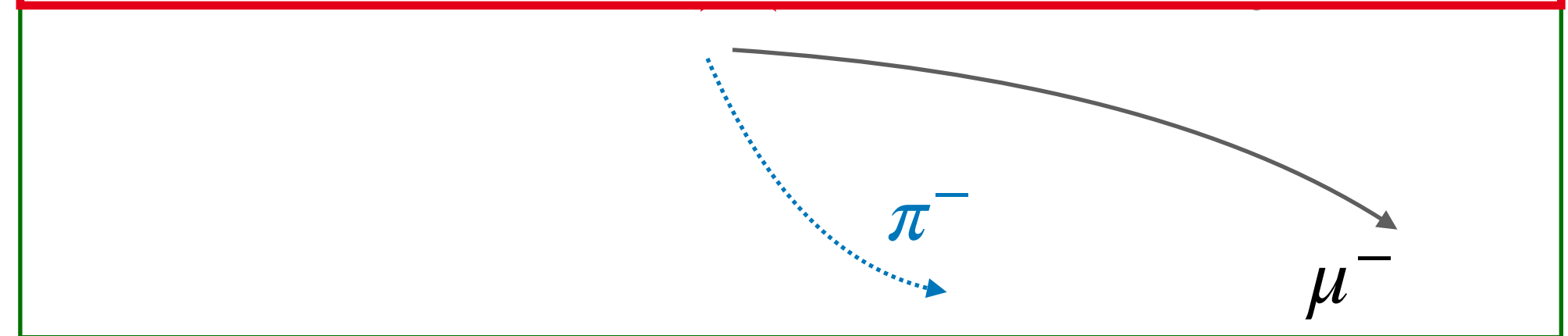
Signal

Anatomy of the background



Background

- Use hadron track to tag the background muon
 - Benefit from displacement of the secondary vertex (SV)
 - Boost at decay vertex
 - Harder process



Signal

Discriminant variables

Impact Parameter (IP)

Displacement of track wrt to PV in background events

Distance of Closest Approach (DOCA)

Benefit from longitudinal boost

$$IP \chi^2$$

Displacement of track wrt to PV in background events

Direction of Flight Angle (DIRA)

Benefit from longitudinal boost at secondary vertex

PID K

Primary tracks: kaons suppressed compared to pions

Flight Distance / Lifetime

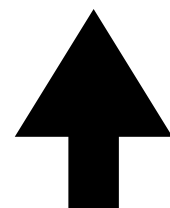
Benefits from displacement of secondary vertex

$$P_T$$

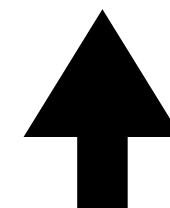
Tracks from Signal events come from underlying event of p-p collision

Invariant mass

Invariant mass at decay vertex limited by mass of B / D

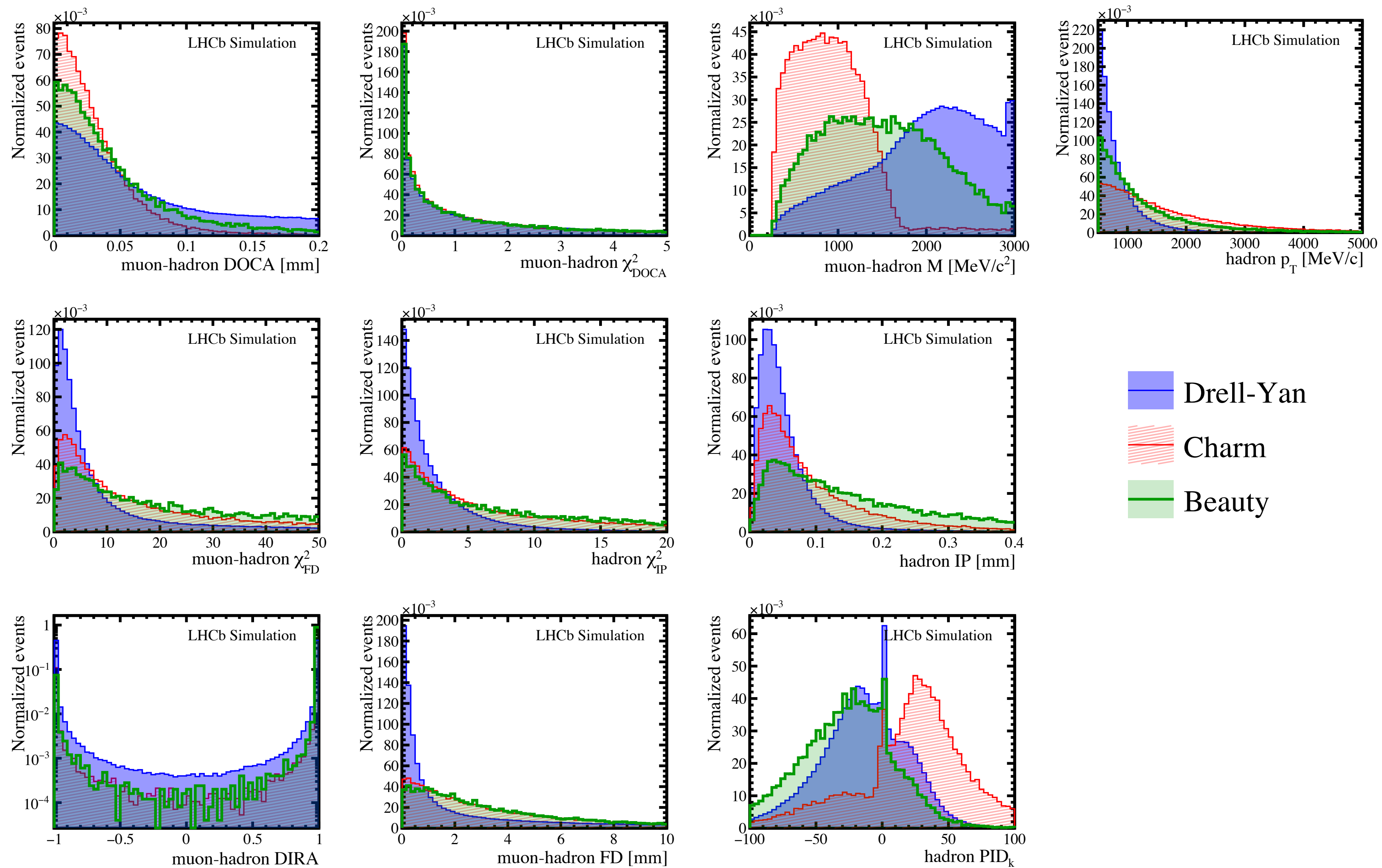


Tagged track information

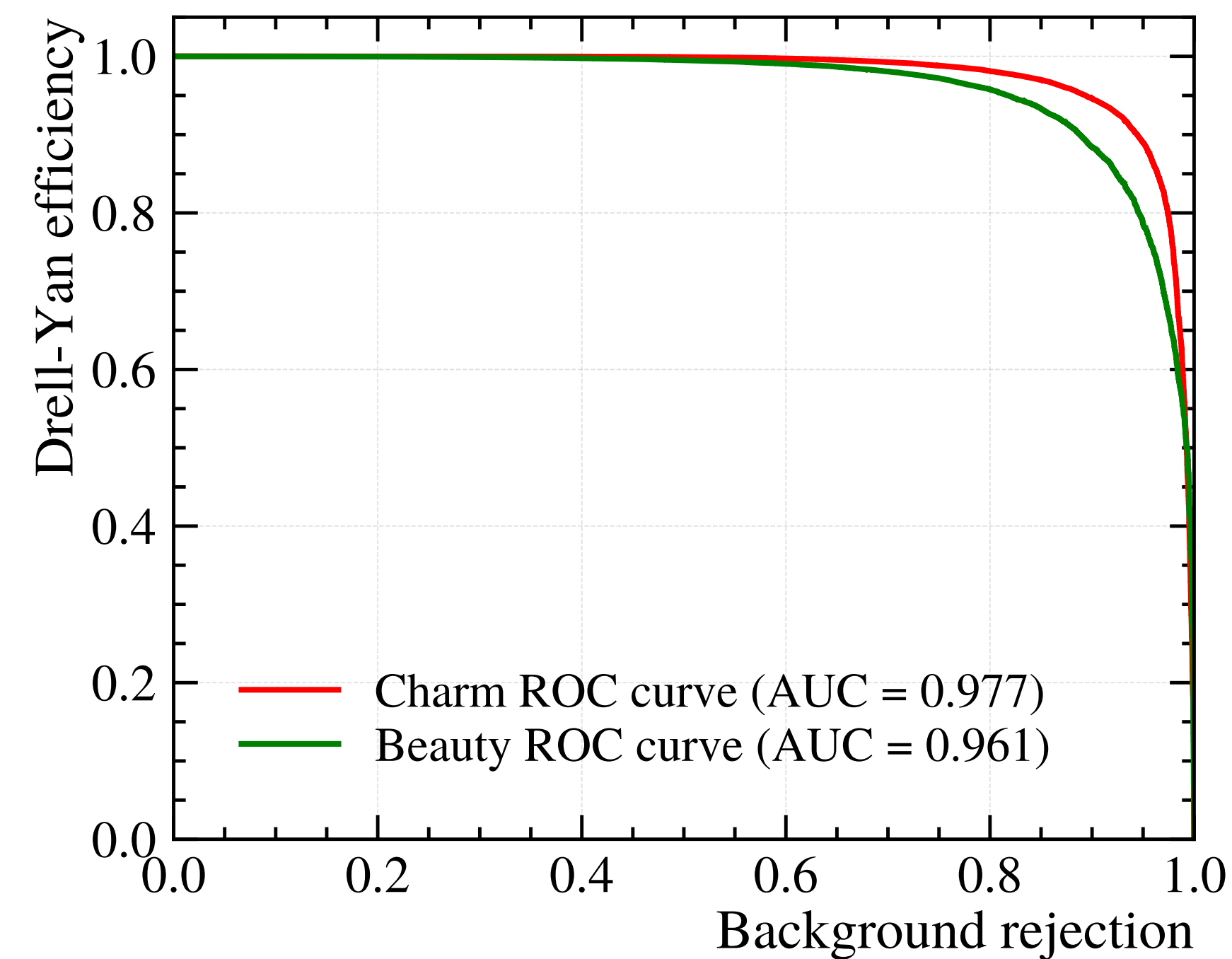
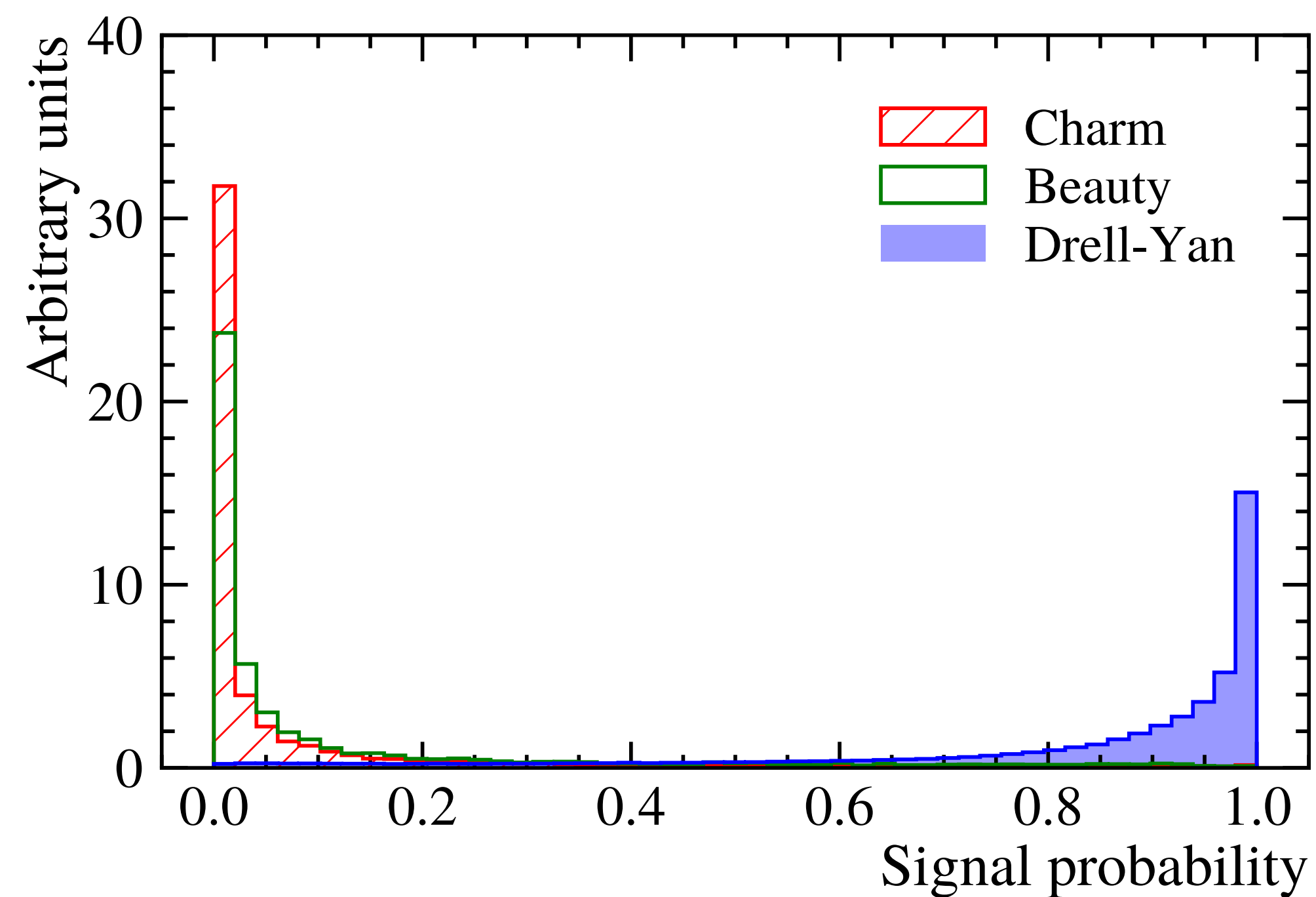


Secondary vertex information
(muon + tagged track)

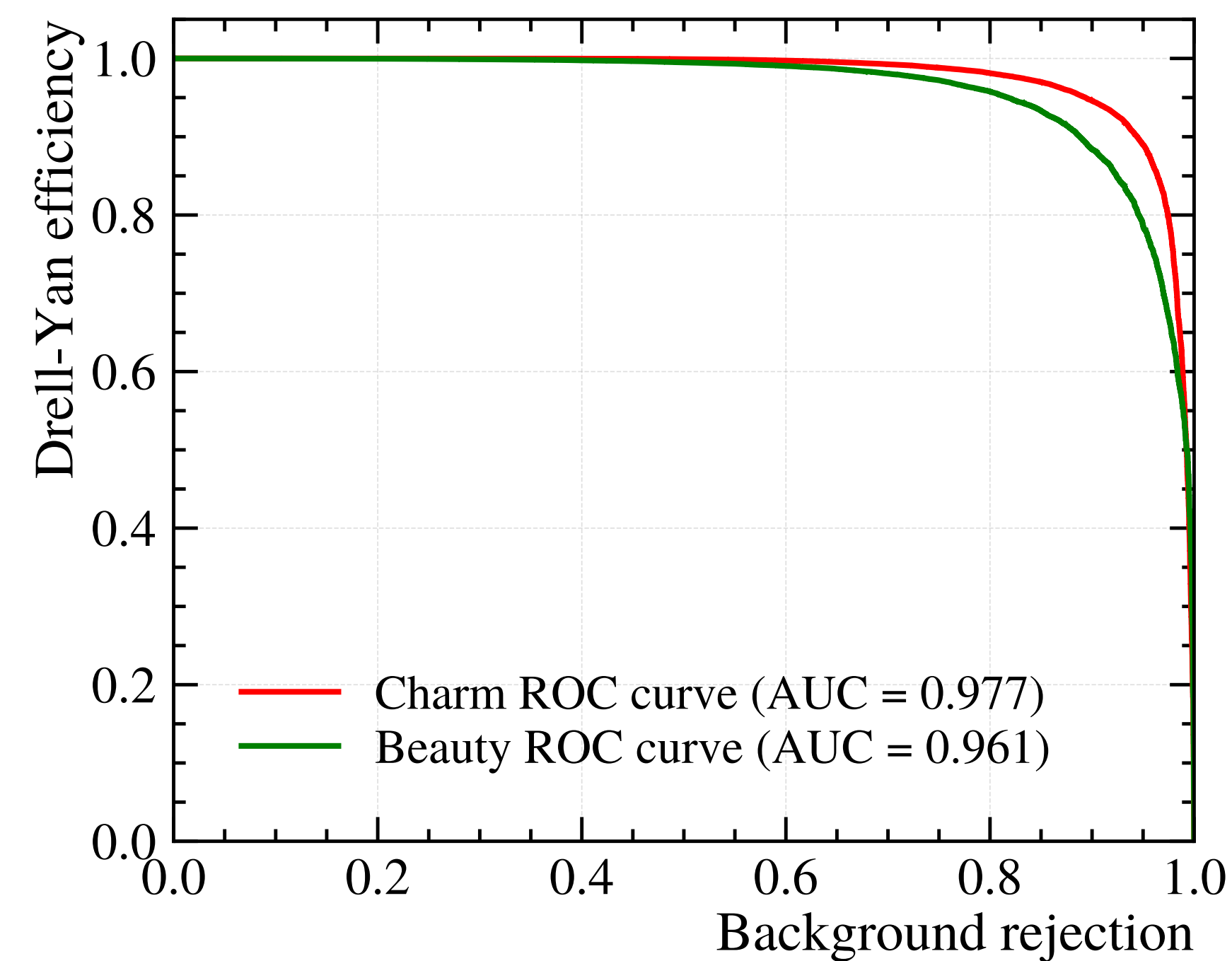
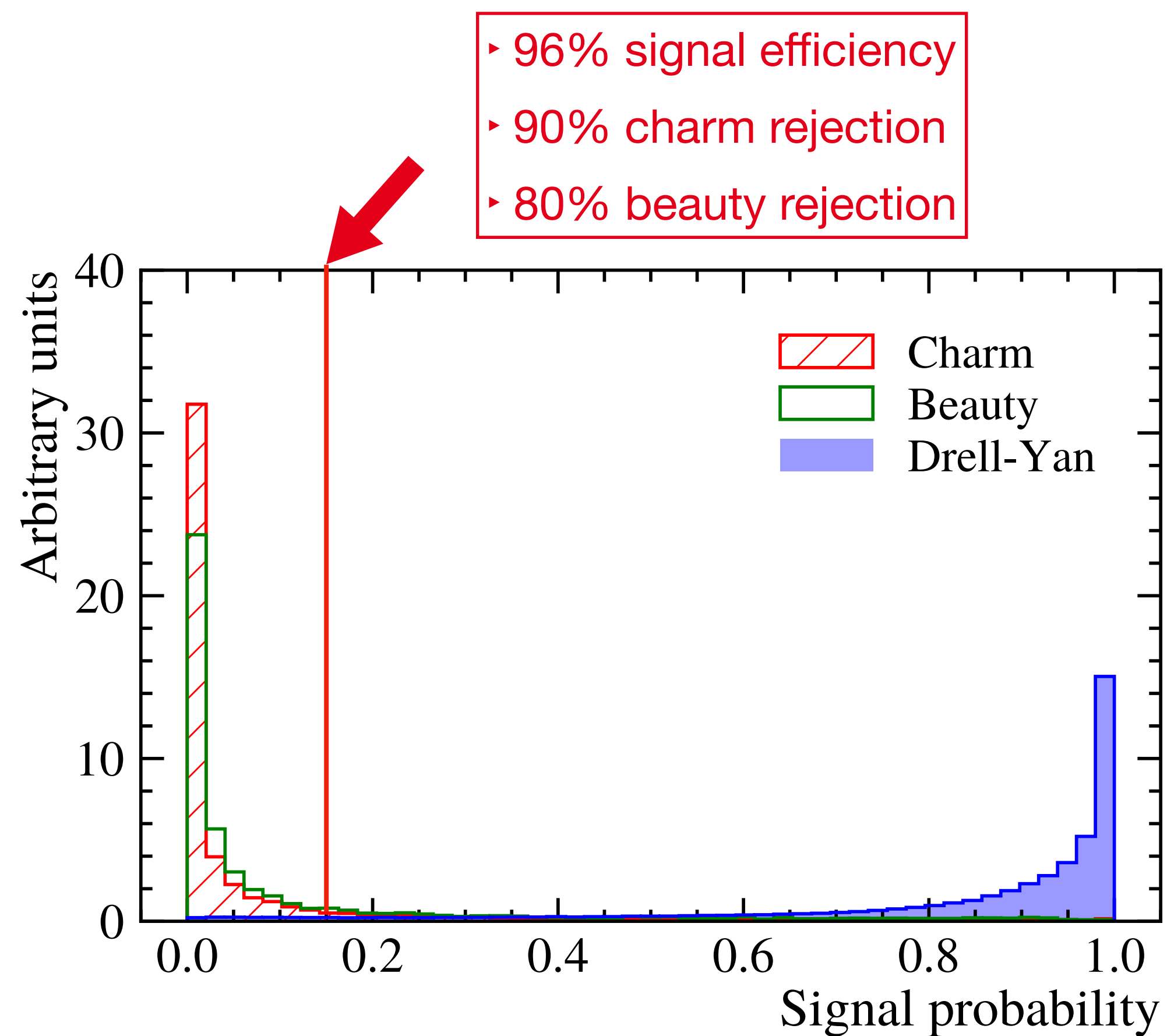
Discriminant variables



Performance

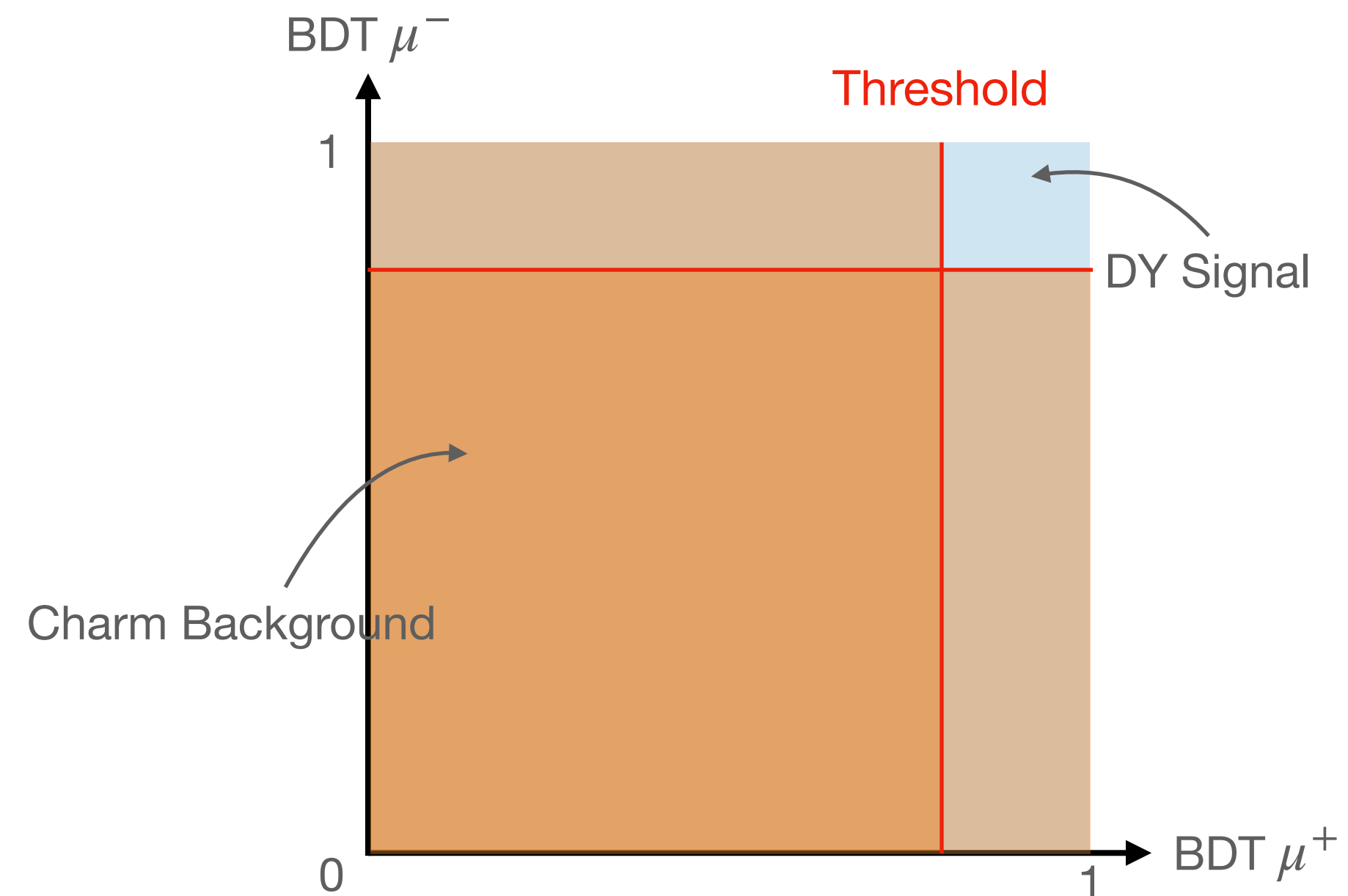
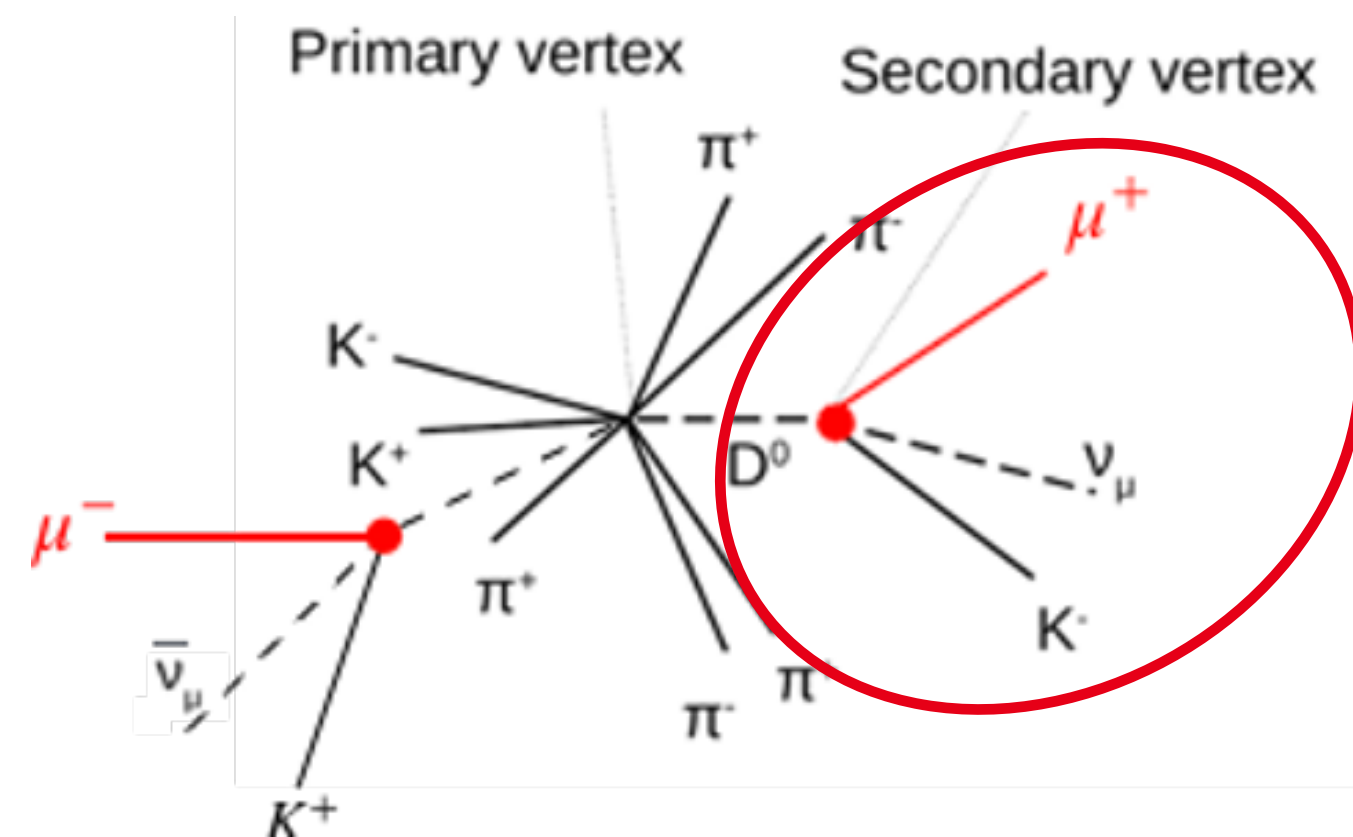


Performance



Double-tagging strategy

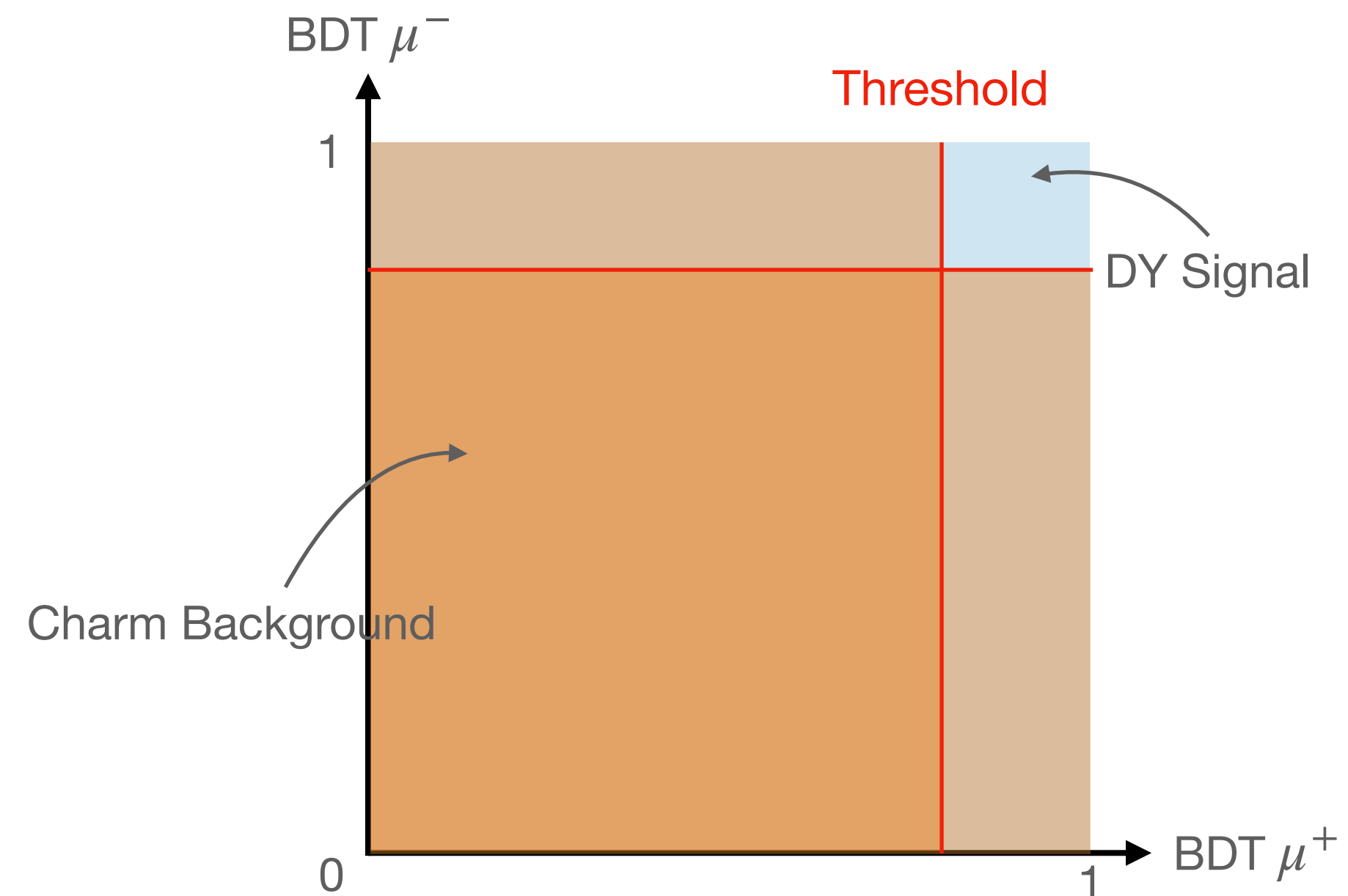
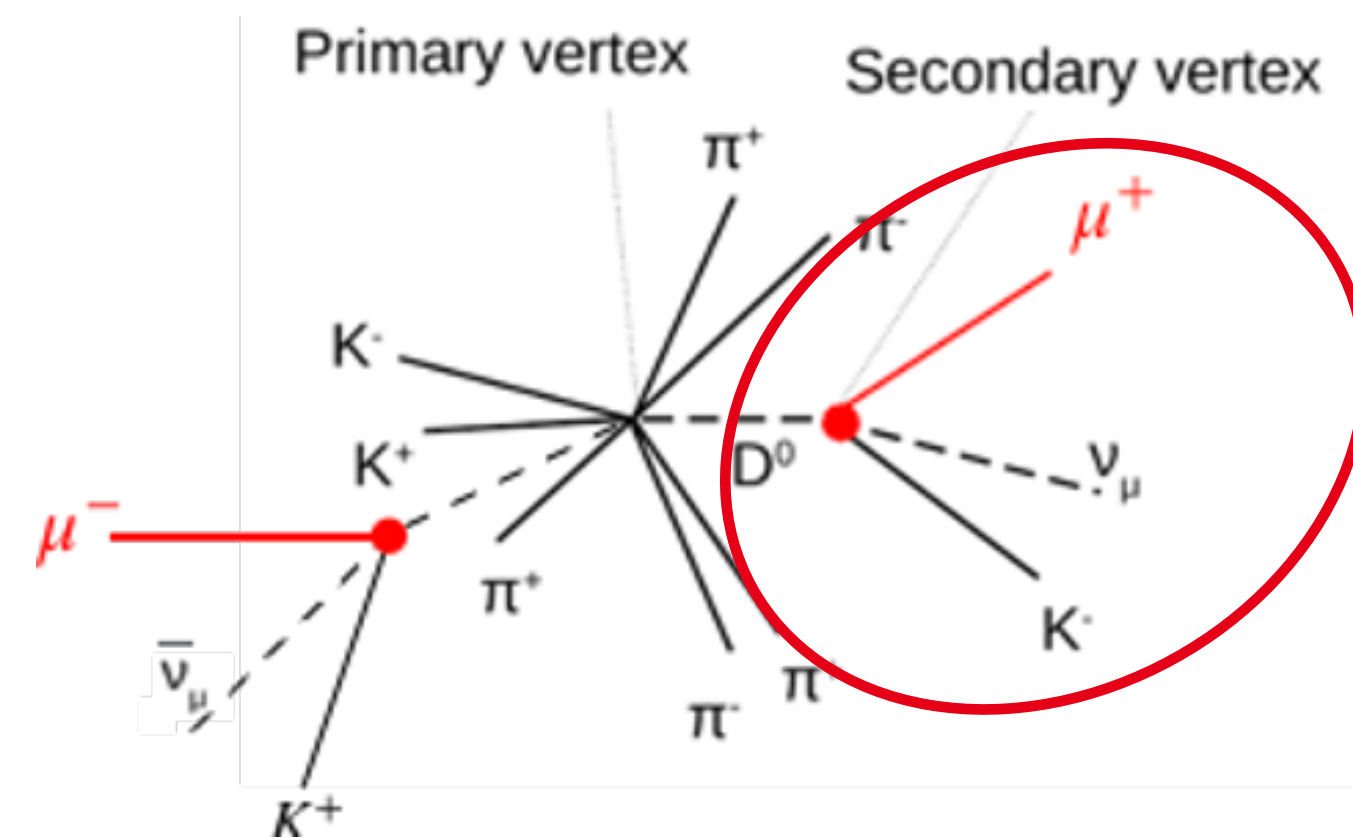
- Reject dimuon candidate if at least one of the two muons is tagged as being from a semileptonic decay \rightarrow below chosen threshold
- Benefit from **independent performance** on both muons



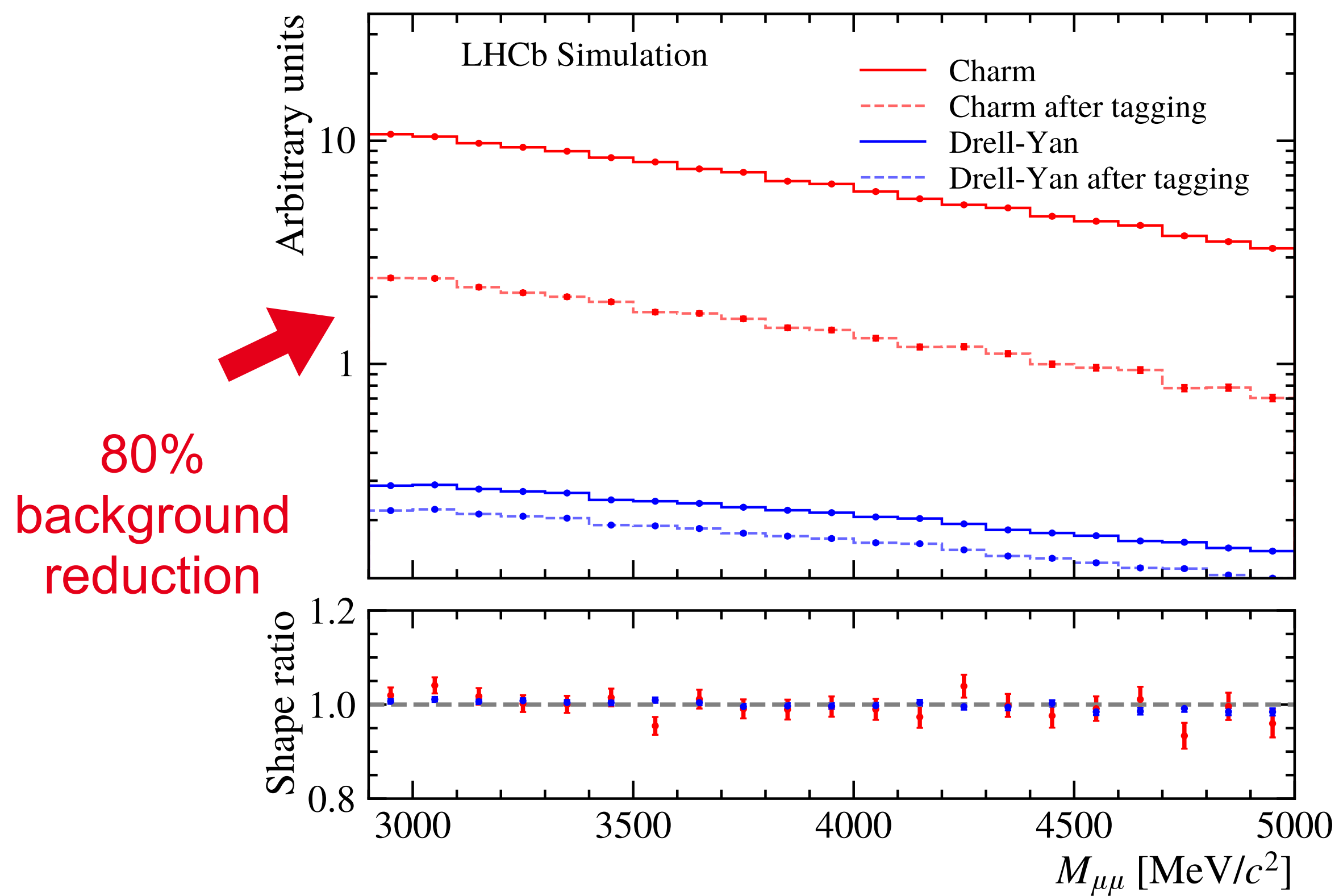
Double-tagging strategy

- Reject dimuon candidate if at least one of the two muons is tagged as being from a semileptonic decay \rightarrow below chosen threshold
- Benefit from **independent performance** on both muons

\rightarrow Natural limitations: branching fraction, reconstruction efficiency, acceptance...

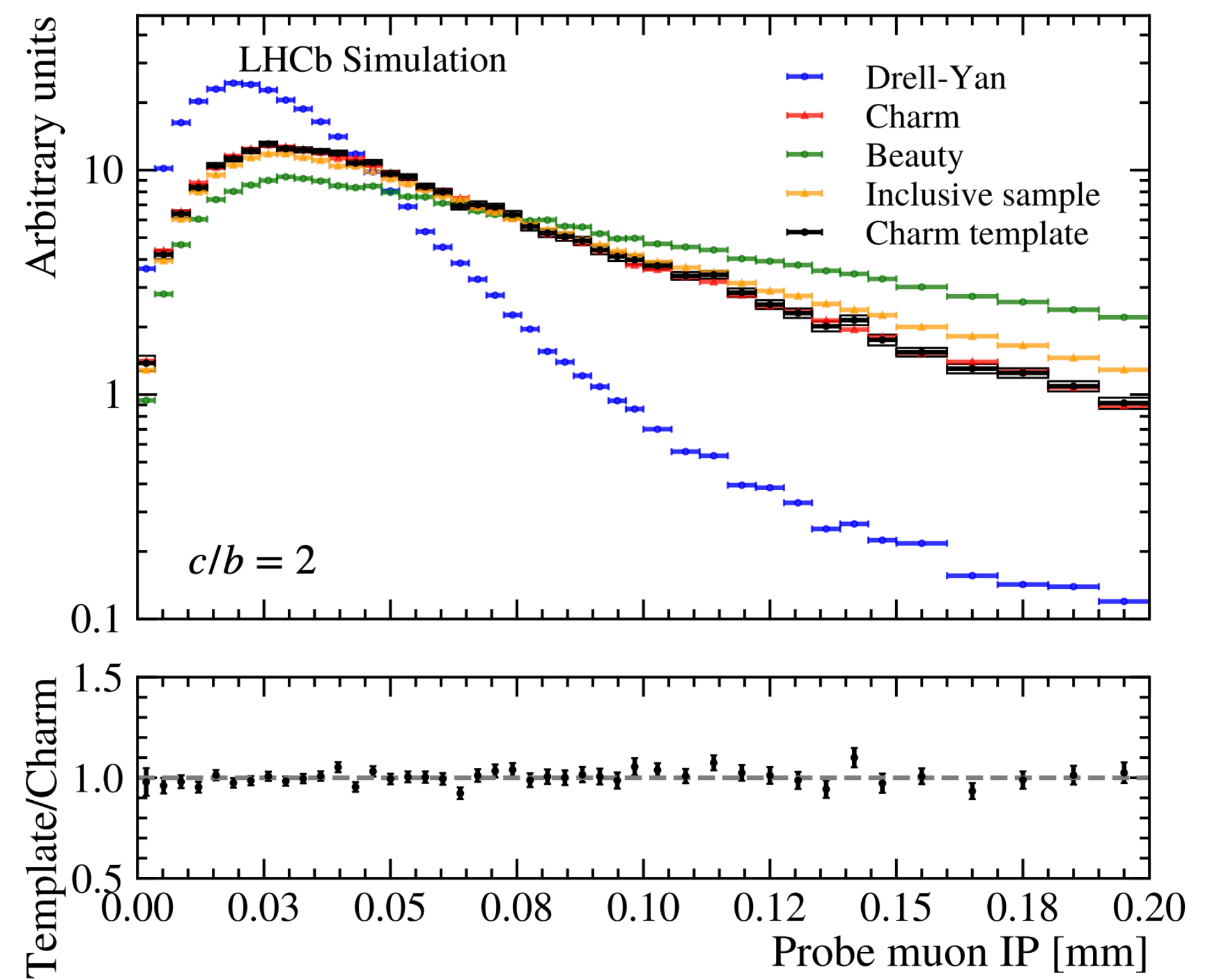
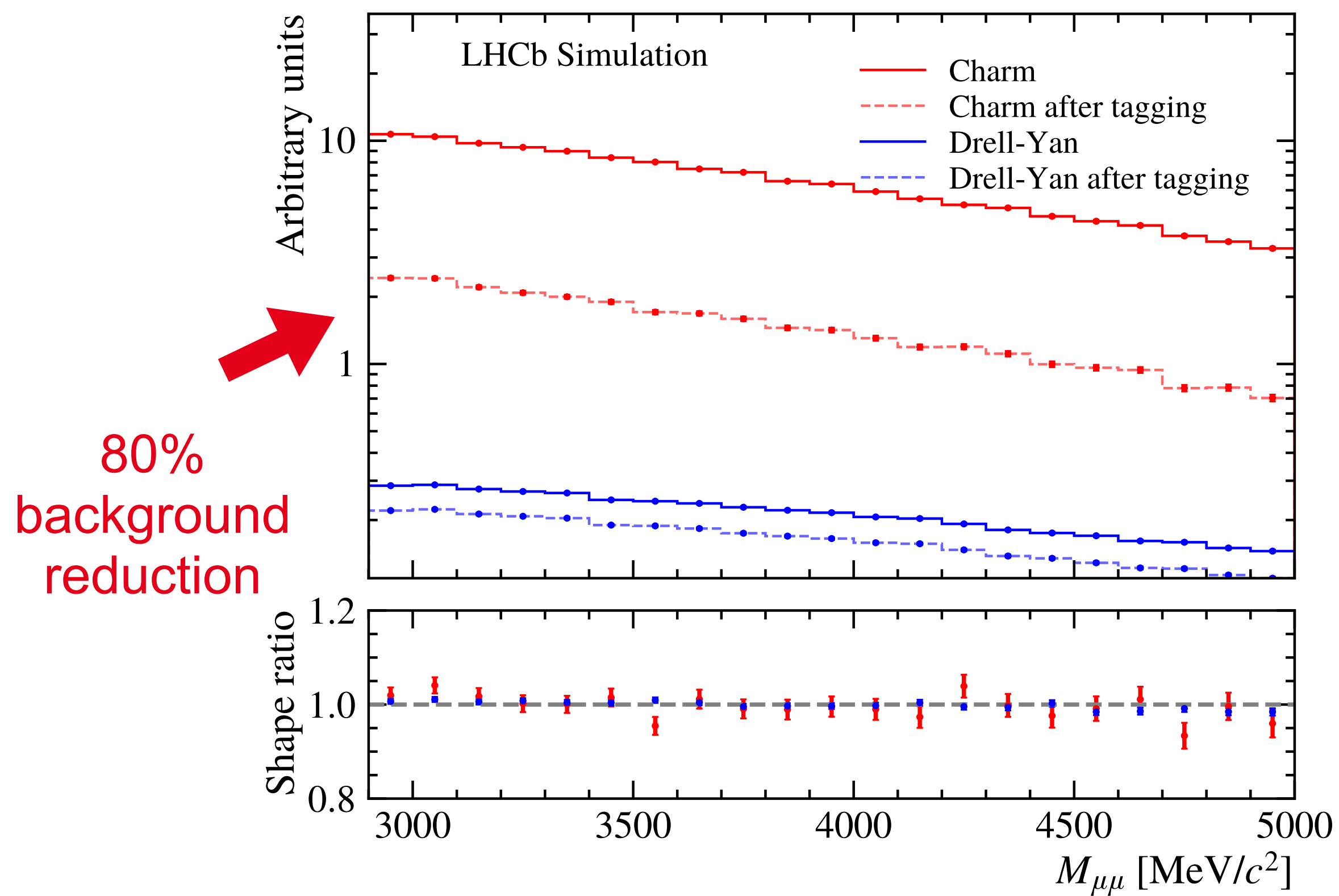


Background rejection & templates



Background rejection & templates

Still requires in a second step final signal extraction using template fit method



Conclusion

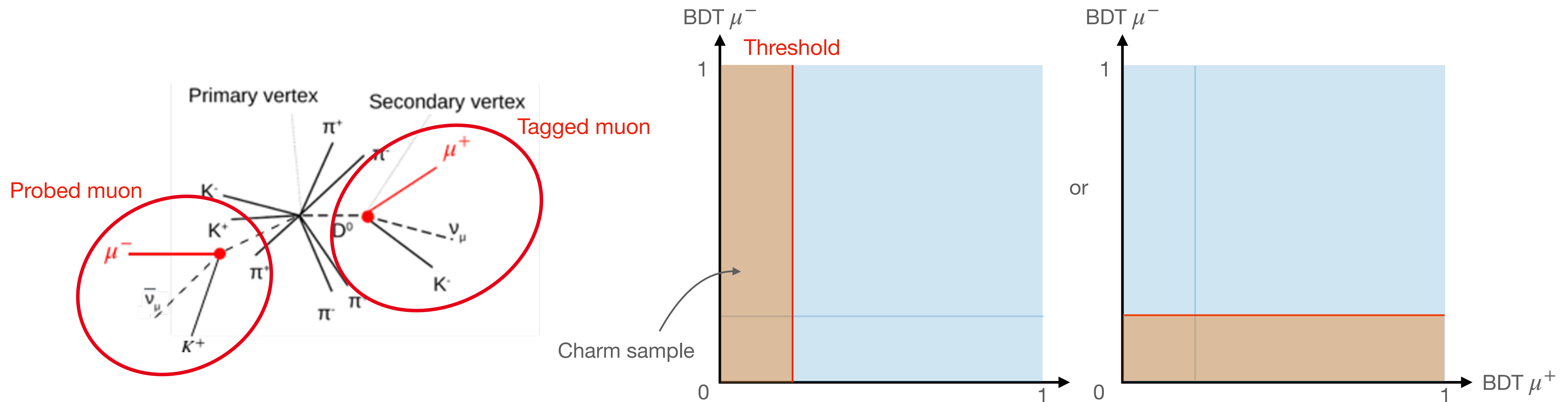
- **Low-mass Drell-Yan is a challenging measurement** that requires excellent detector performance and proper signal extraction
 - Benefit from upgraded detector and full software trigger in Run 3
 - New tool will play an **important role in the extraction of the signal** and will significantly reduce systematics in final fit
 - Only one piece of the puzzle: template fits required, tagging can help provide data-driven charm template

Thanks for listening!

Backup

Single tagging

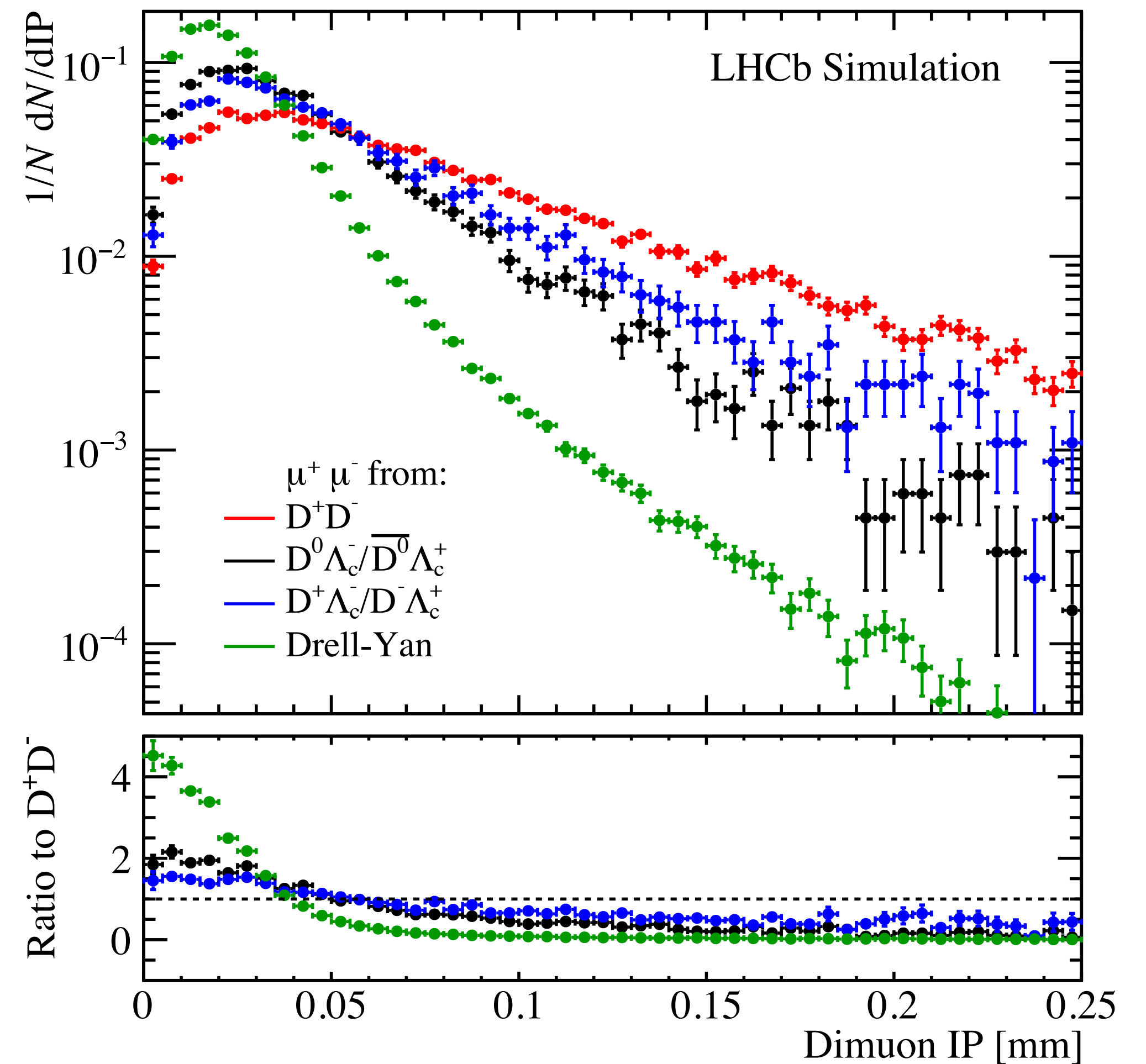
- Require strict selection on **one of the two** muons' side (tagged muon)
- Extract muon properties on the probe-muon side
- Enables **unbiased** single-muon observable extraction while suppressing prompt muons
- Reconstruction of dimuon information based on the single muon information



Charm templates

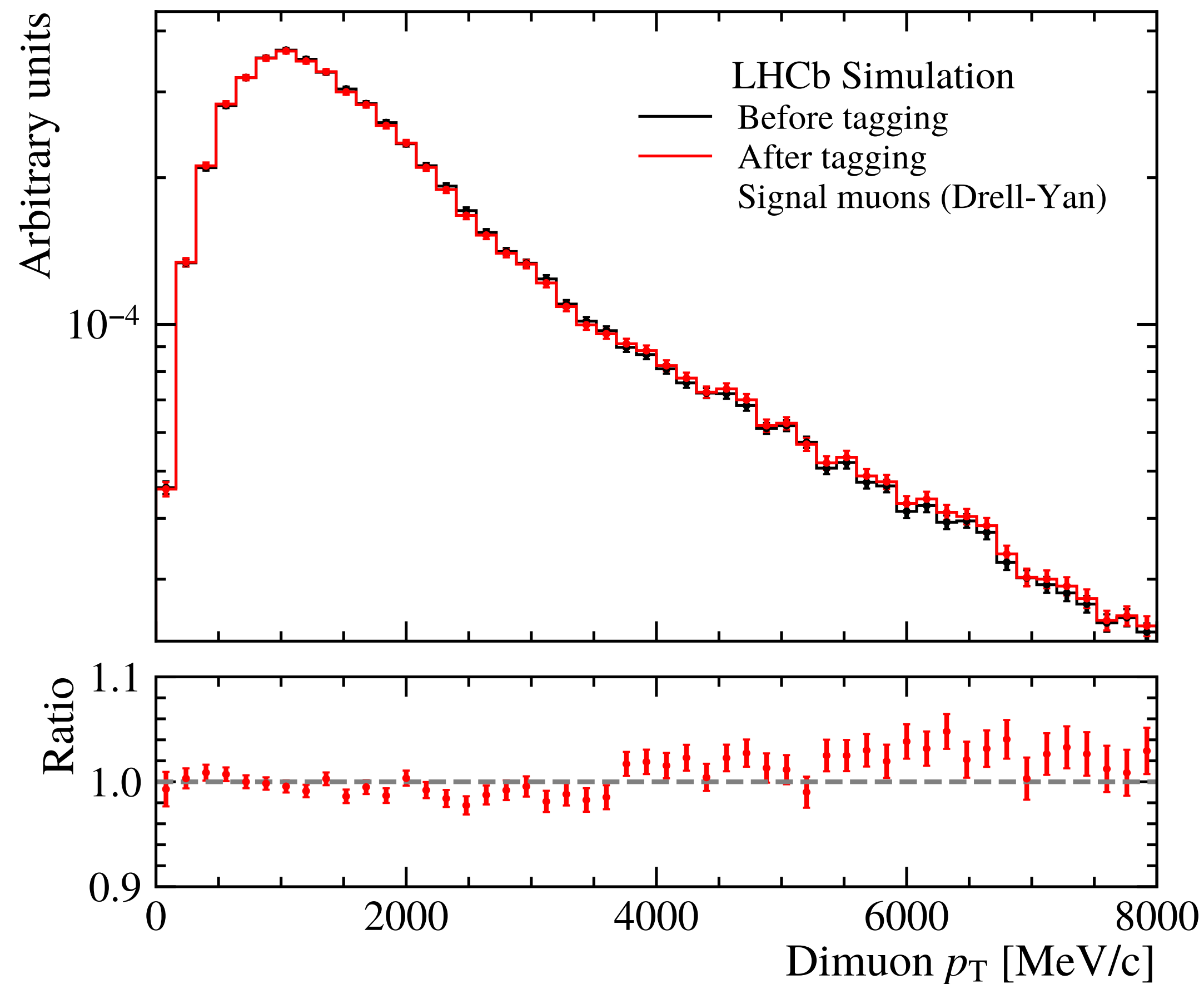
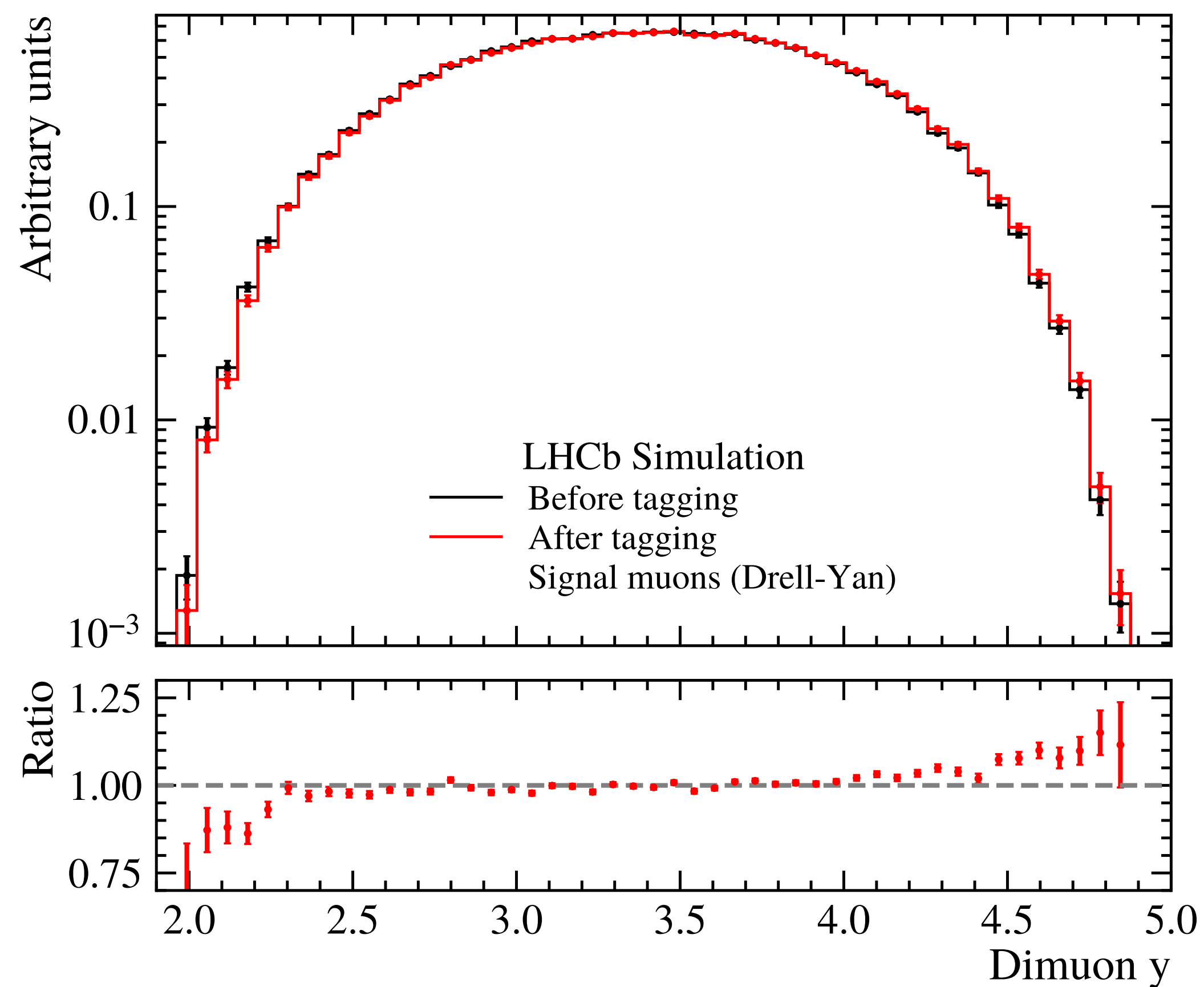
- **Can't rely only on simulation**
 - ▶ Charm production fractions not measured precisely in LHCb acceptance, but known to differ between LEP and ALICE
 - ▶ Missing knowledge on semileptonic branching fractions of baryons
- Final signal extraction using displacement: significant difference between charm species

➔ **important to have data driven method to make realistic charm template**



Double-tagging strategy

Bias



Tag & probe

- After selection:
 - ▶ **Tag muon:** biased due to different lifetime composition of tagged hadron decays compared to the inclusive charm sample
 - ▶ **Probed muon:** compatible with no bias within 2σ

