Exotica Searches at LHCb

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• fully instrumented between \(2 < \eta < 5\)
• momentum resolution between 0.5% at 5 GeV to 1% at 200 GeV
• impact parameter resolution of 13 – 20 \(\mu \text{m}\) for tracks
• secondary vertex precision of 0.01 – 0.05(0.1 – 0.3) mm in \(xy(\bar{z})\)
• real-time calibration and full event reconstruction in Run 2
• inclusive dimuon from threshold and jet triggers in Run 2
• full detector readout in Run 3
Long Lived Particles
search for heavy, charged, very long lived particles, e.g. $\tilde{\tau}$
utilize absence of light in RICH in addition to minimal energy loss
assume Drell-Yan production and compare to SPS7 benchmark scenario
Single Displaced Particle

- search for single long lived particle decaying into jet pair, e.g. $\pi \nu$
- production from SM-like Higgs decay

![Graph showing dijet mass distribution with $3.0 < R_{xy} < 5.0$ mm and $\sqrt{s} = 8$ TeV]

$$\frac{(\sigma/\sigma_{SM}) \cdot B(H_0 \rightarrow \pi \nu \pi \nu)}{LHCb}$$

$\mu_{\pi \nu} = 25$ GeV/c$^2$

$\mu_{\pi \nu} = 35$ GeV/c$^2$

$\mu_{\pi \nu} = 43$ GeV/c$^2$

$\mu_{\pi \nu} = 50$ GeV/c$^2$, $\pi \rightarrow c \bar{c}$

$\mu_{\pi \nu} = 35$ GeV/c$^2$, $\pi \rightarrow s \bar{s}$

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$\mu_{\pi \nu} = 35$ GeV/c$^2$, $\pi \nu \rightarrow s \bar{s}$

- $LHCb$, arXiv:1705.07332
Two Displaced Particles

- search for two long lived particles, \( \chi^0_1 \)
- production from SM-like Higgs decay with baryon number violation
- masses from 20 – 60 GeV and lifetimes from 5 – 100 ps

![Diagram of LLP radial distance and normalised distribution]
Associated Leptons
Displaced with Muon

- search for long lived particle decaying into di-quark and muon
- consider full PYTHIA model and four simplified models
- utilizes excellent secondary vertex reconstruction

![Diagram showing decay processes](image-url)

$LHCb$, EPJC 77 (2017)

- $m_{\tilde{q}} = 200 \text{ GeV}/c^2$
- $\tau_{LLP} = 10 \text{ ps}$

- $\sqrt{s} = 8 \text{ TeV}$

- $LHCb$ parameters:
  - $\tilde{h}^0$
  - $\tilde{\chi}$
  - $\tilde{q}$
  - $\tilde{\bar{q}}$
Higgs Decay into $Q \bar{Q}$

- search in association with $W/Z$
- utilize excellent heavy flavor tagging and $b/c$ separation
- limits not competitive with SM, but important proof-of-concept
Light Dark Sector
Resonances in $B$ Decays

- $B^0 \to K^{*0} \mu\mu$ and $B^+ \to K^+ \mu\mu$
- perform both prompt and displaced search simultaneously
- model independent limits provided for re-casting

LHCb, PRD 95 (2017)
Dark Photons

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**Graphical Content**

- **Axes:** 
  - $s^3$ on the y-axis
  - $m_{A'}$ [GeV] on the x-axis

- **Data Points and Curves:**
  - Various experimental data points and curves from experiments such as DarkLight, SHiP, SeaQuest, HPS, APEX, Mu3e, Mesa, and LHCb.
  - Experiments imply constraints or regions of interest for $s^3$ and $m_{A'}$. For example, PRL 116 (2016) and PRD 92 (2015) are marked.

- **Textual Annotations:**
  - $D^0 \rightarrow D^0 \gamma (\rightarrow ee)$
  - $X \rightarrow Y \gamma (\rightarrow \mu \mu)$

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**Additional Information:**

- The graph illustrates the sensitivity of various experiments towards dark photons and their mass values.
- The region $X \rightarrow Y \gamma$ is particularly highlighted, indicating a specific focus area for these experiments.
- The ultimate LHCb reach is also indicated, signifying the theoretical or experimental limit set by the Large Hadron Collider's B-experiment on dark sector phenomena.
Dimuon Spectrum

LHCb preliminary

prompt trigger output

\[ p_T(\mu) > 1 \text{ GeV}, \chi^2_{ip}(\mu) < 6, \chi^2_{v}(\mu\mu) < 9 \]

\[ \mu\text{-ID neural network} > 0.95 \]

\[ \eta \rightarrow \mu\mu(\gamma) \]

\[ \omega/\rho \phi \]

\[ \psi(2S) \]

\[ \psi(2S) \]

\[ \psi(2S) \]

\[ \psi(2S) \]

\[ \mu^+\mu^- \]

\[ \mu^\pm\mu^\pm \]

\[ m_{\mu\mu} \text{ [GeV]} \]

\[ 10^0 \quad 10^1 \quad 10^2 \]
Outlook
Outlook

• exotica search program reaching maturity at LHCb

• important to utilize strengths of detector, provide complementarity
  • flexible trigger with very low $p_T$ and mass requirements
  • full particle identification including RICH
  • excellent secondary vertex and lifetime resolution

• variety of searches using new inclusive dimuon dataset underway

Thank you!