LHCb: precision measurement

**Trigger**
High efficiency esp. muon triggers

**VELO**
IP resolution $15+29/\sqrt{\text{GeV}} \, \mu\text{m}$

**Tracking**
$\Delta p/p$
$0.4\%$ @ $5 \, \text{GeV}/c$ – $1.0\%$ @ $200 \, \text{GeV}/c$

**RICH**
PID $\varepsilon(K) \sim 95\%$ for MisID($\pi\rightarrow K$) $\sim 5\%$

**Muon ID**
Identification $\varepsilon \sim 97\%$ misID $\sim 2\%$

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Direct searches

ATLAS/CMS advantages
High luminosity (8x)
Large acceptance

Advantages of LHCb
Mass resolution
Vertex resolution
Particle ID
Soft triggers
Complementary acceptance

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Outline

Latest LHCb results + ideas for future

- Charged Massive Stable Particles
  - Idea: light NMSSM Higgs

- Low Mass Dark Boson
  - Idea: dark photon searches

- Long Lived Particles to di-jet
  - Idea: emerging jets

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Charged Massive Stable Particles

Stable = can pass through μ– stations

Models considered
- SUSY stau can be NLSP in mGMSB
- Long-lived with m > 100 GeV/c²

CMSP signature
- smaller dE/dx
- longer time-of-flight
- absence of Cherenkov signal

Other searches
- LEP, Tevatron, HERA, ATLAS/CMS

see refs in [EPJ C75(2015)595]

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CMSP in LHCb

Selection
pair of muon-\textit{like} tracks
mass 120 - 300 GeV/c^2

Neural network
train to combine RICH
with dE/dx in VELO + Calos

Reach
Not competitive with D0 (low mass)
or ATLAS (high mass)

Proof of concept for future searches

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**Idea: light NMSSM Higgs**

- **Spin-0 particle**
  coupling mainly to 3\(^{rd}\) generation, may have escaped detection in 10 – 50 GeV/c\(^2\) range

- **Portal**
  Well motivated in NMSSM and as portal to dark sector

- **Unique LHCb potential**
  Best di-muon mass resolution
  Forward acceptance
  Very soft di-muon trigger

From Υ(n) @ LHCb (~3% of 2012 data)

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Haisch & Kamenik [1601.05110]
Low Mass Dark Boson

- “hidden sector” predict TeV-scale DM interacts via GeV-scale boson $\chi$
- LHCb searched for $B^0 \rightarrow K^* \chi(\mu\mu)$
- FCNC $b \rightarrow s$ sensitive to $\chi$-t coupling
- Constrain axial-vector + scalar portals (not photon portal)

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N Arkani-Hamed et al [PRD 79 015014(2009)]
M Pospelov and A Ritz [PLB 671 391(2009)]
C Cheung et al [PRD 80 035008(2009)]
LMDB Results

- Full Run-I data set
- Search narrow $m_\chi$ windows interpolate background from sidebands
  M. Williams [JINST 10 P06002(2015)]
- BR limit normalized to $K^*\mu\mu$ ($q^2 = 1.1 - 6 \text{ GeV}^2$)
  LHCb [JHEP 08 (2013)131]
- Also set direct limit on inflaton & axion models
  Freytsis, Ligeti and Thaler, [arXiv:0911.5355]
  Bezrukov and Gorbunov, [arXiv:0912.0390]

214 \leq m_\chi \leq 4350 \text{ MeV/c}^2

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Idea: dark photon search

- Dark sector with photon portal
- Dark photon A' mixes kinetically with SM photon
- LHCb potential in 2+ ways:
  - Mixing $\gamma^*/A'(\mu\mu)$
    $m = 210–520$ MeV & 10–40 GeV
    Ilten et al [arXiv:1603.08926]
  - Dalitz D* decays $D^* \rightarrow D'(ee)$
    $m < 100$ MeV
    Ilten et al [arXiv:1509.06765]

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LLP → 2jet
Long Lived Particle $\rightarrow$ jet jet

Several NP models:

- LSP in SUSY with BNV
- Next-to-LSP in gravity mediated SUSY
- Neutral $\pi_V$ particle in Hidden Valley models with $H\rightarrow\pi_V\pi_V$ and $\pi_V\rightarrow bb$

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An incomplete schematic overview
suppl. mat. of cds/record/1975714
Limit Extraction $H \rightarrow \pi_{\nu} \pi_{\nu}$

- Mass fit in five bins in $R_{xy}$ (proxy of $\pi_{\nu}$ lifetime)
- Smooth exponential background fitted
- Limit extracted with CLs method
- Main systematics from modeling of HLT2 and vertex reconstruction

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LLP Results

\[ \sigma(H) \times \mathcal{B}(H \to \pi^+\nu) \text{[pb]} \]

- \( m_{\pi^+} = 25 \text{ GeV}/c^2 \)
- \( m_{\pi^+} = 35 \text{ GeV}/c^2 \)
- \( m_{\pi^+} = 43 \text{ GeV}/c^2 \)
- \( m_{\pi^+} = 50 \text{ GeV}/c^2 \)

\( m_{\nu} = 35 \text{ GeV}/c^2 \):
- \( \nu \to c\bar{c} \)
- \( \nu \to s\bar{s} \)

\( \sigma(H) @ 7 \text{ TeV} = 17 \text{ pb} \)

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Idea : emerging jets

- “Emerging jets”

Jets with many displaced vertices are smoking gun for dark parton ‘shower’ (models with composite dark sector)

- LHCb has potential

precise jet vertexing sensitive to low mediator mass
Future for LHCb

**LHCb upgrade** vertex detector, tracking, RICH, move to **purely software trigger**

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<tr>
<td>Integrated luminosity</td>
<td>3 fb⁻¹</td>
<td>8 fb⁻¹</td>
<td>25 fb⁻¹</td>
<td>50 fb⁻¹</td>
</tr>
<tr>
<td>Instantaneous luminosity</td>
<td>$4 \times 10^{32}$ cm⁻²s⁻¹</td>
<td>$2 \times 10^{33}$ cm⁻²s⁻¹</td>
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**Expect 8 fb⁻¹ by 2018**

**Run at 5x luminosity: collect 50 fb⁻¹ by 2030**

High Luminosity LHCb? Phase-2 upgrade?
Conclusion
Take away message

- LHCb is a wonderful detector
  - can go beyond its main goal of b/c physics
  - can achieve world-best sensitivity in some NP direct searches
- Presented some results and some ideas
- Run 2 has already started, taking data right now
- For LHCb higher energy does not open new realm, but
  - increases most production x-sections (b$\bar{b}$, c$\bar{c}$, most NP),
  - higher boost enlarges the fraction at high $\eta$
- New purely-software trigger will be key
  - larger efficiency for low-mass and highly-displaced tracks
    as well as high multiplicity events

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Thank you for your attention!