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# Exotica @ LHCb

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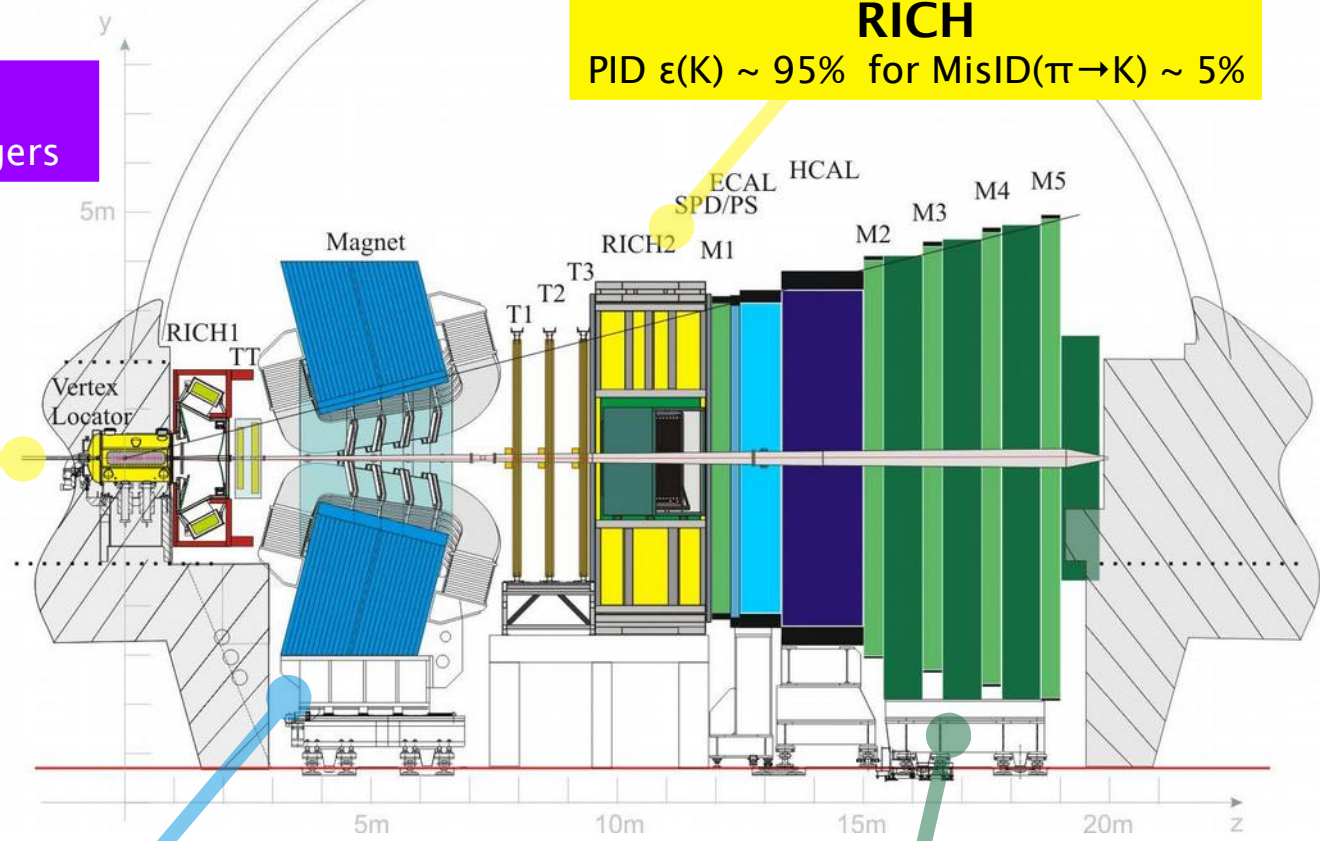
*on behalf of the LHCb collaboration*

SUSY2016, Melbourne, AUS, 3-8 July 2016

# LHCb : precision measurement

**Trigger**
high efficiency *esp.* muon triggers

**RICH**
PID ε(K) ~ 95% for MisID(π→K) ~ 5%




**VELO**
IP resolution 15+29/$p_T$[GeV] μm

**Tracking Δp/p**
0.4% @ 5 GeV/*c* – 1.0% @ 200 GeV/*c*

**Muon ID**
identification ε ~ 97% misID ~ 2%



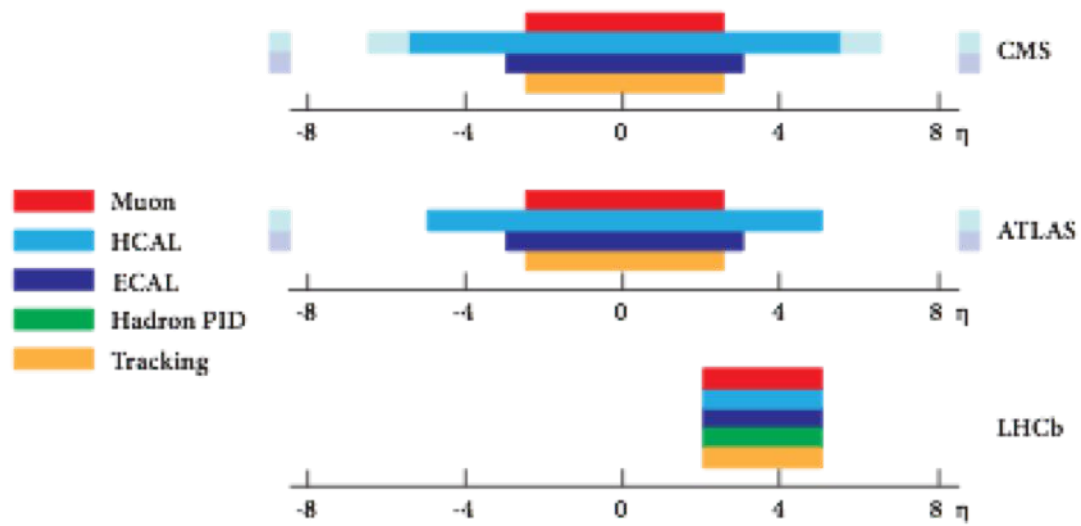
Int. J. Mod. Phys. A 30, 1530022 (2015)

# Direct searches

## ATLAS/CMS advantages

High luminosity (8x)

Large acceptance




## Advantages of LHCb

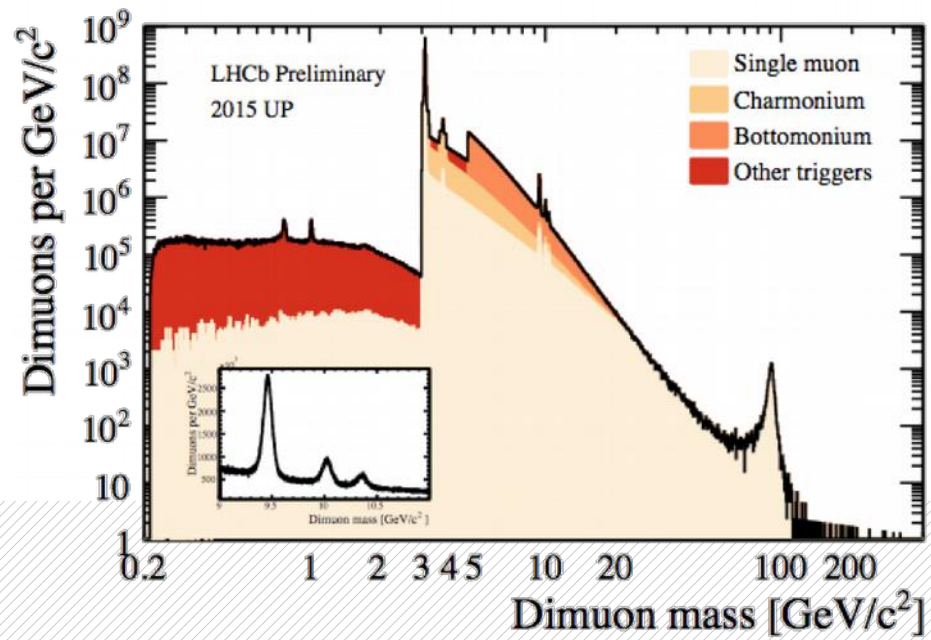
Mass resolution

Vertex resolution

Particle ID

Soft triggers

**Complementary acceptance**



# 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*

# CMSP

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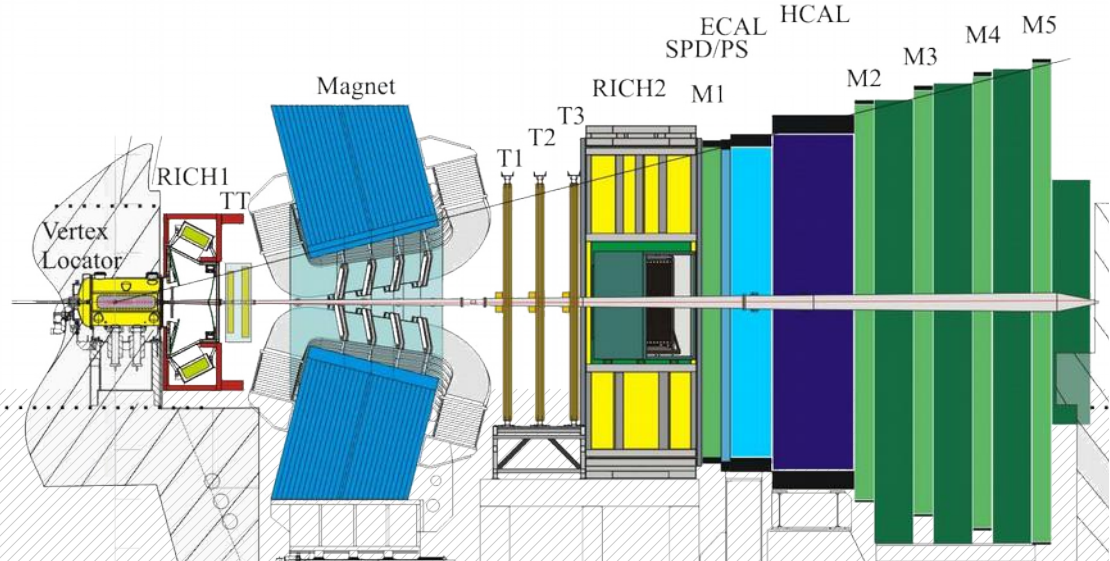
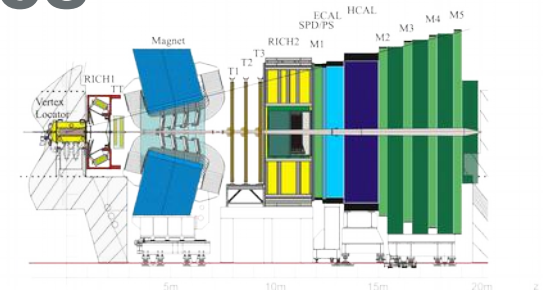


# Charged Massive Stable Particles




## Stable = can pass through μ−stations

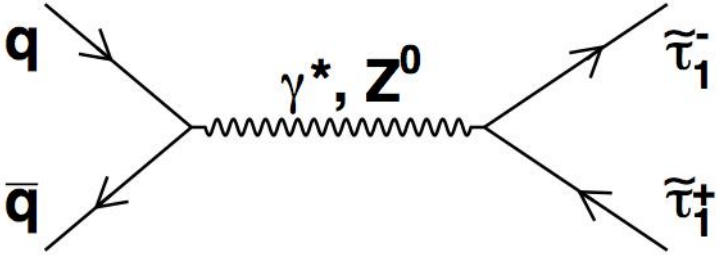
## Models considered

- SUSY stau can be NLSP in mGMSB
- Long-lived with m >100 GeV/$c^2$

Dimopoulos *et al* [NPB488(1997)39]
Giudice & Rattazzi [Phys.Rep. 332(2011)419]

## 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]

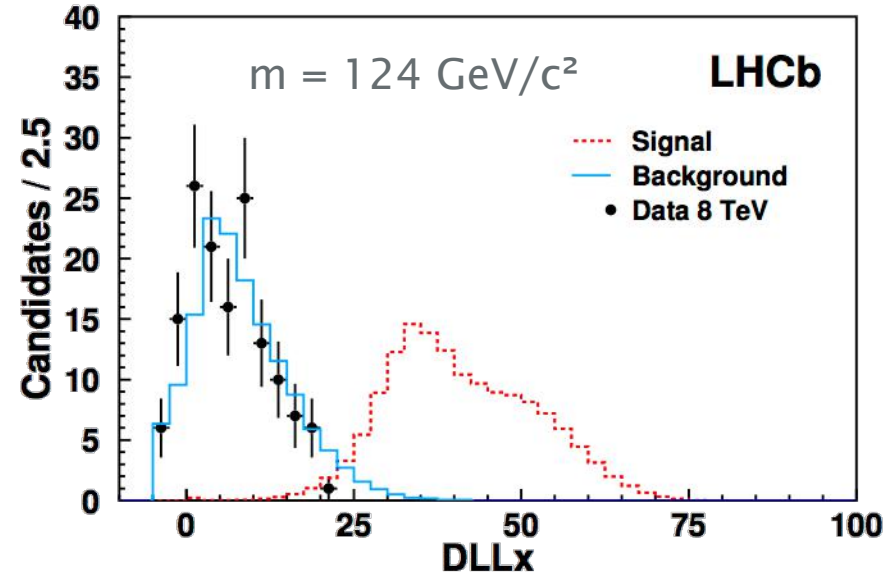
# CMSP in LHCb

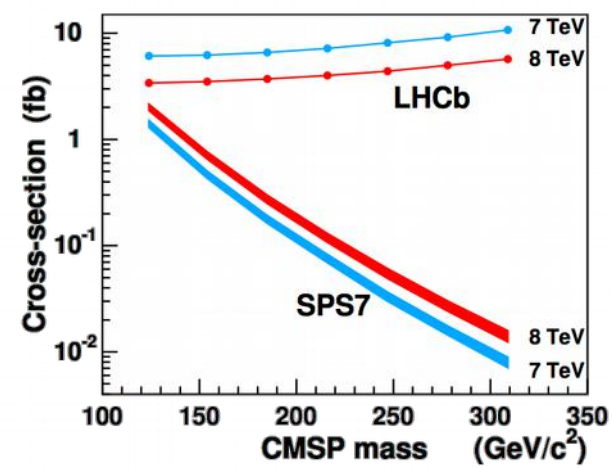
- **Selection**
  pair of muon-*like* tracks
  mass 120 – 300 GeV/c²

- **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**

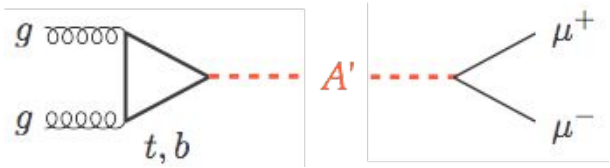





[EPJ C75(2015)595]

# *Idea : light NMSSM Higgs*




- **Spin-0 particle**

coupling mainly to 3rd generation, may have escaped detection in 10 – 50 GeV/c² range

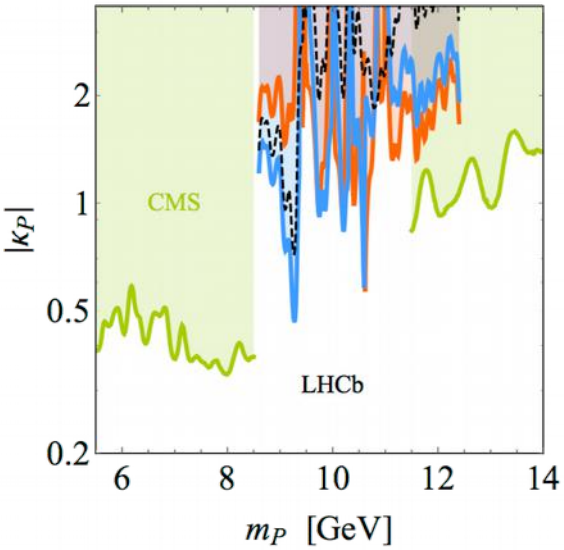
- **Portal**

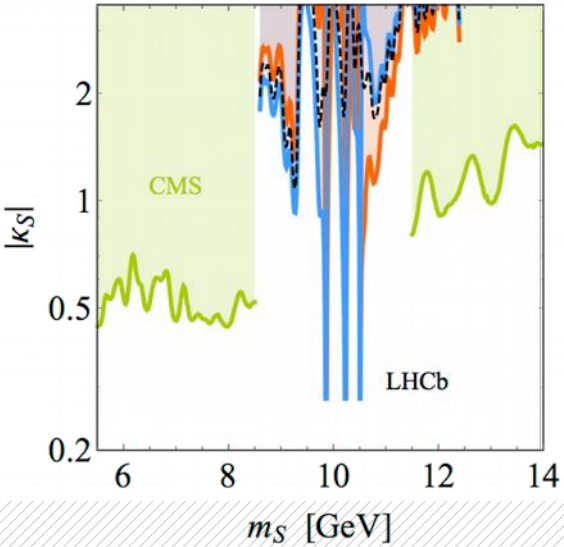
Well motivated in NMSSM and as portal to dark sector

- **Unique LHCb potential**

Best di-muon mass resolution
Forward acceptance
Very soft di-muon trigger

From Υ(n) @ LHCb (~3% of 2012 data)




Haisch & Kamenik [1601.05110]

# LMDB

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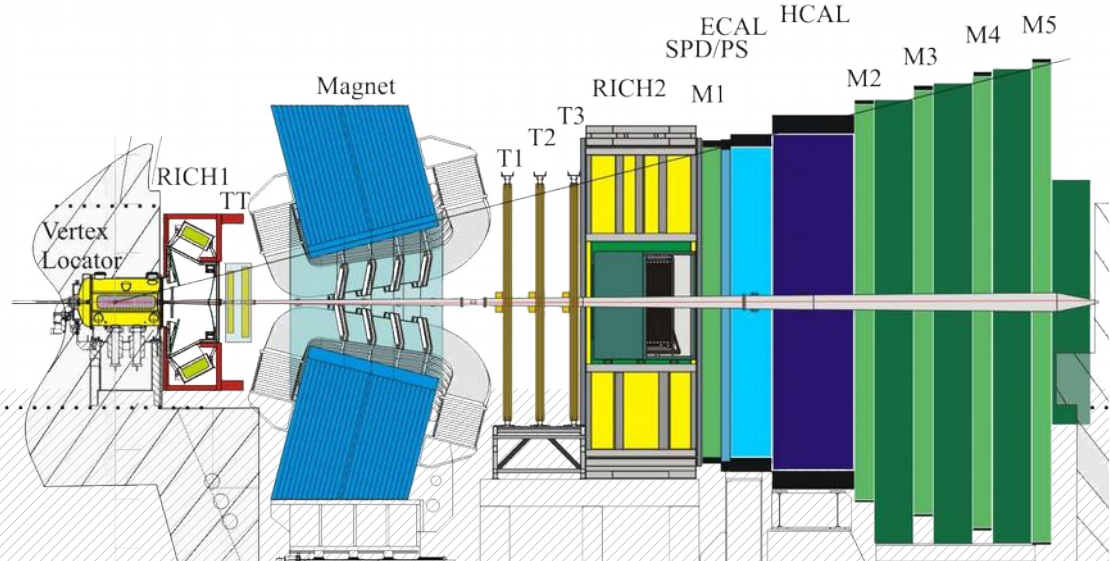
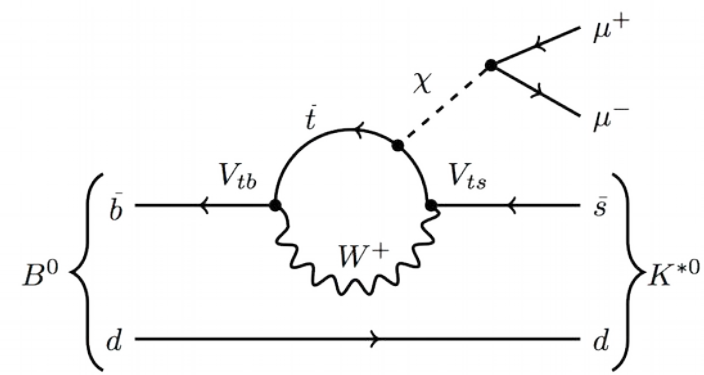
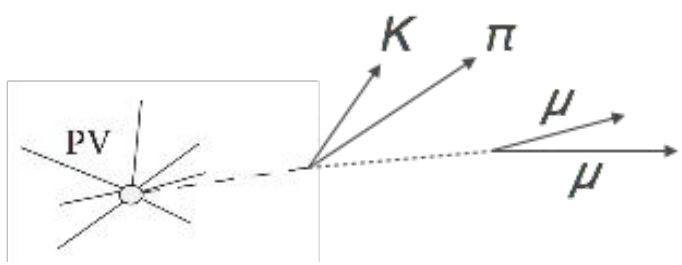


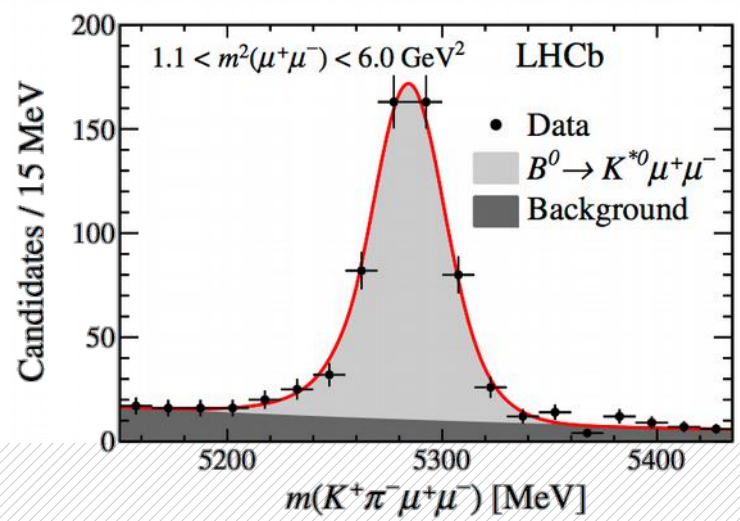
# Low Mass Dark Boson

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)]

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



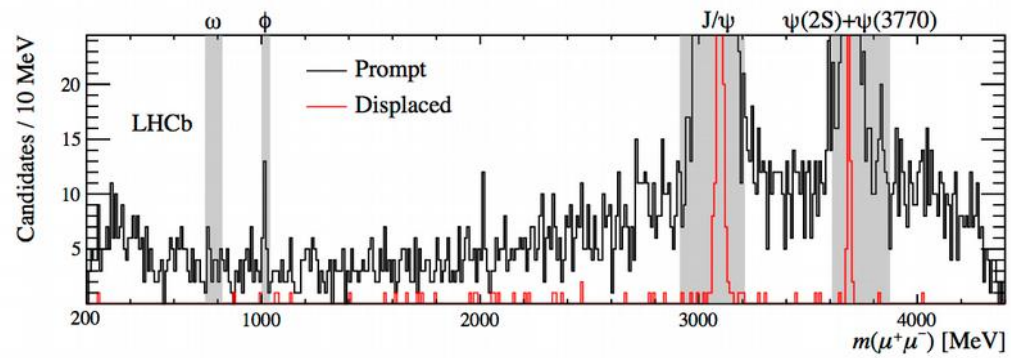


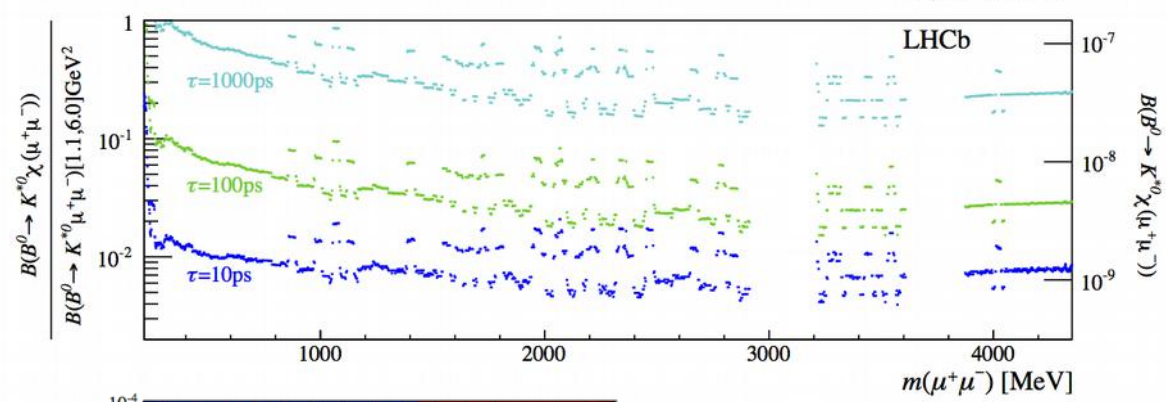

PRL 115, 161802 (2015)

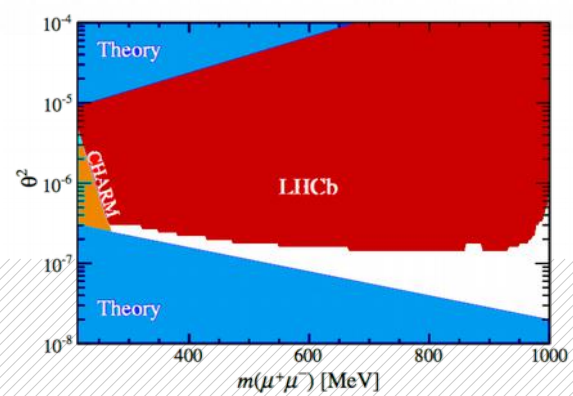
# LMDB Results

- 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 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]

**$214 \leq m_\chi \leq 4350$ MeV/c²**



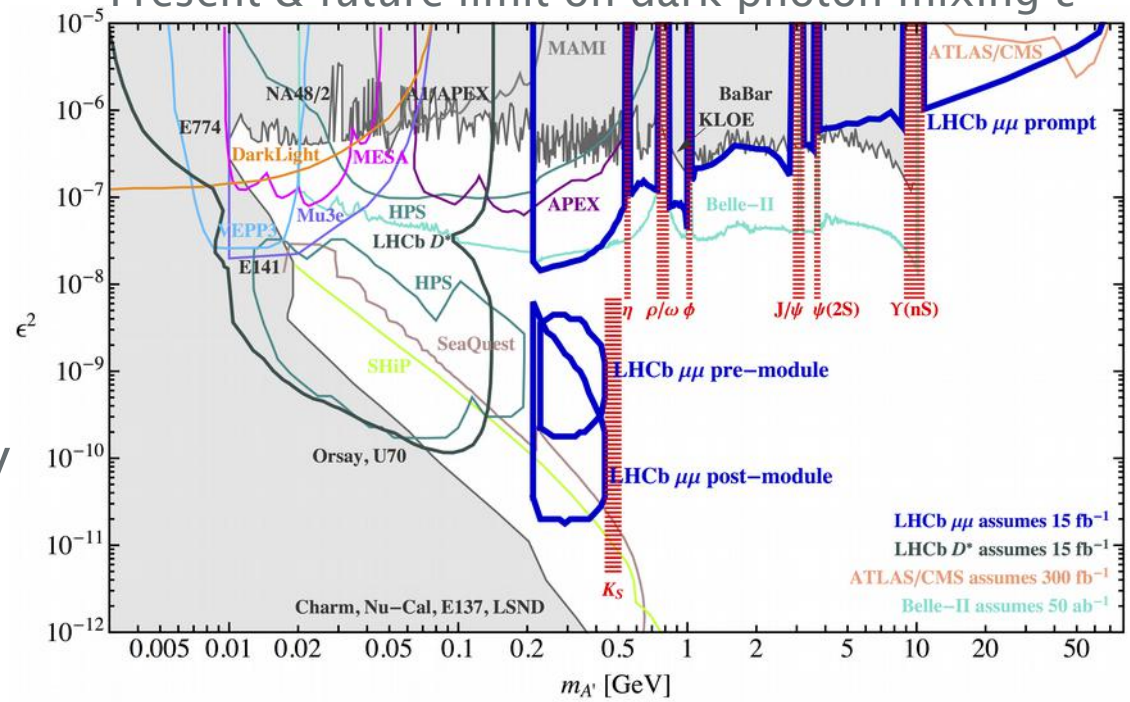




LHCb [PRL 115(2015)161802]

# Idea : dark photon search

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

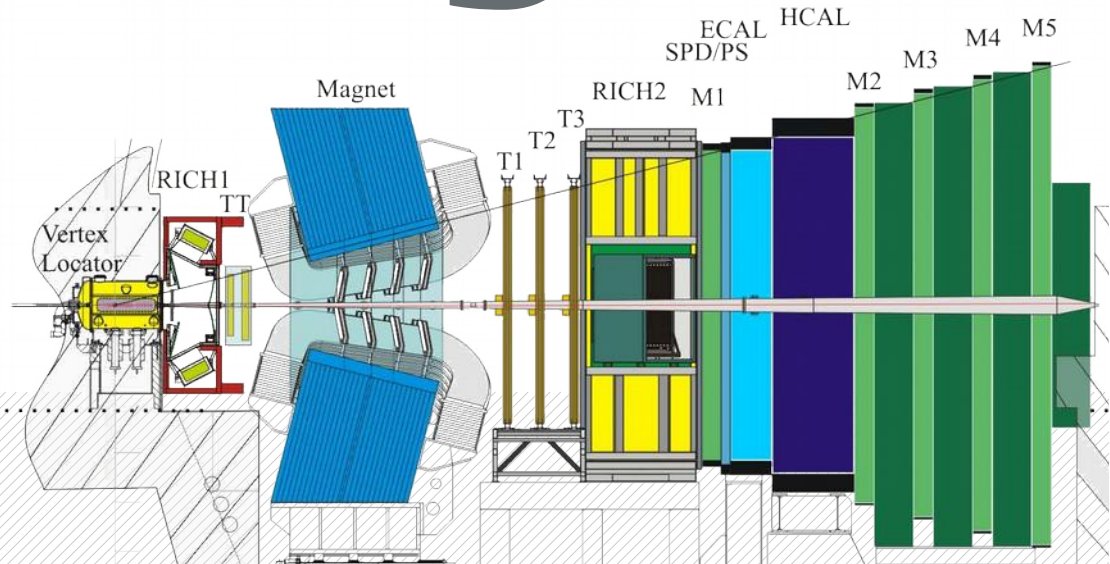
Present & future limit on dark photon mixing ε



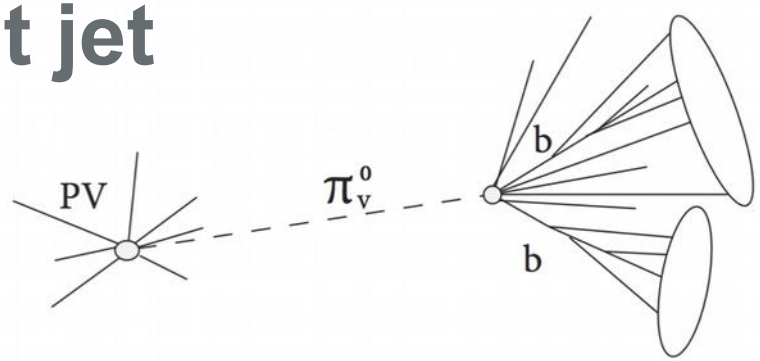

Ilten *et al* [arXiv:1603.08926]

# LLP → 2jet

ong ived article



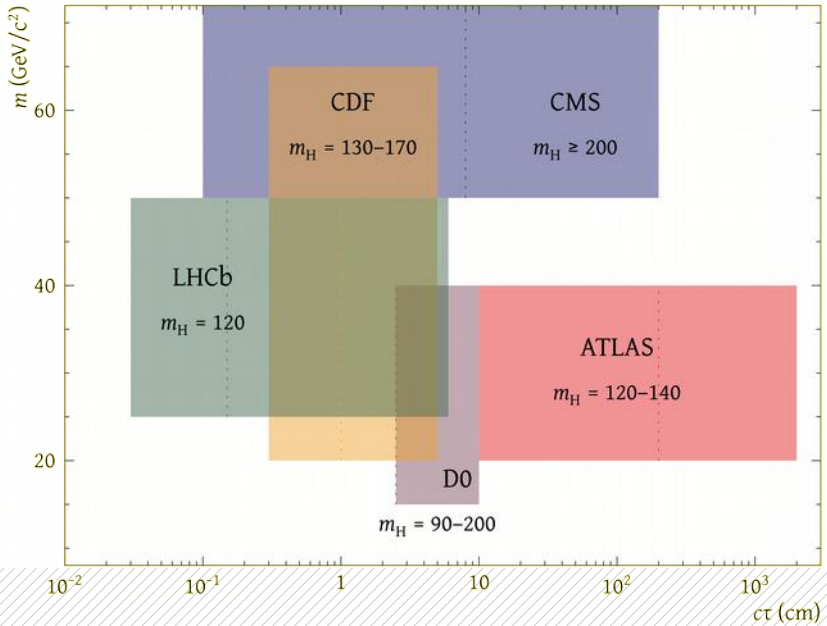
# Long Lived Particle → jet jet




**Several NP models:**

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

An incomplete schematic overview
suppl. mat. of cds/record/1975714

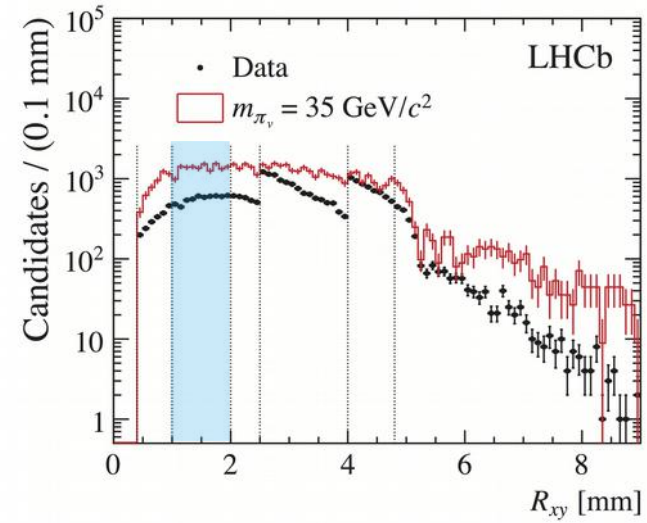


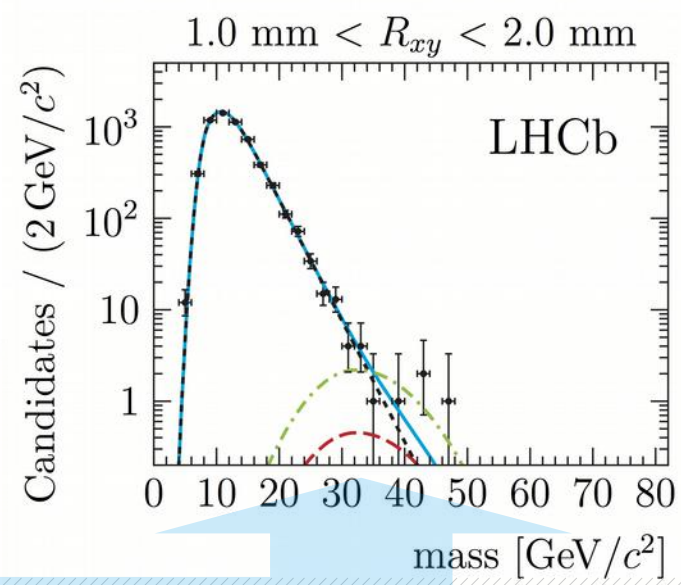


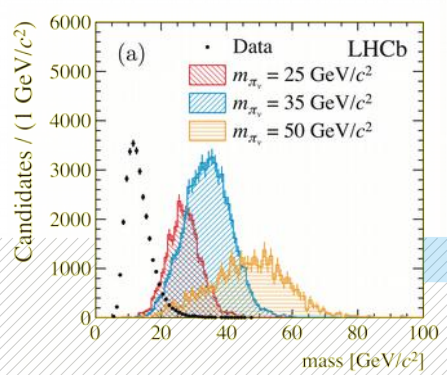

LHCb [EPJ C75(2015)152]

# Limit Extraction $H \rightarrow \pi_V \pi_V$

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



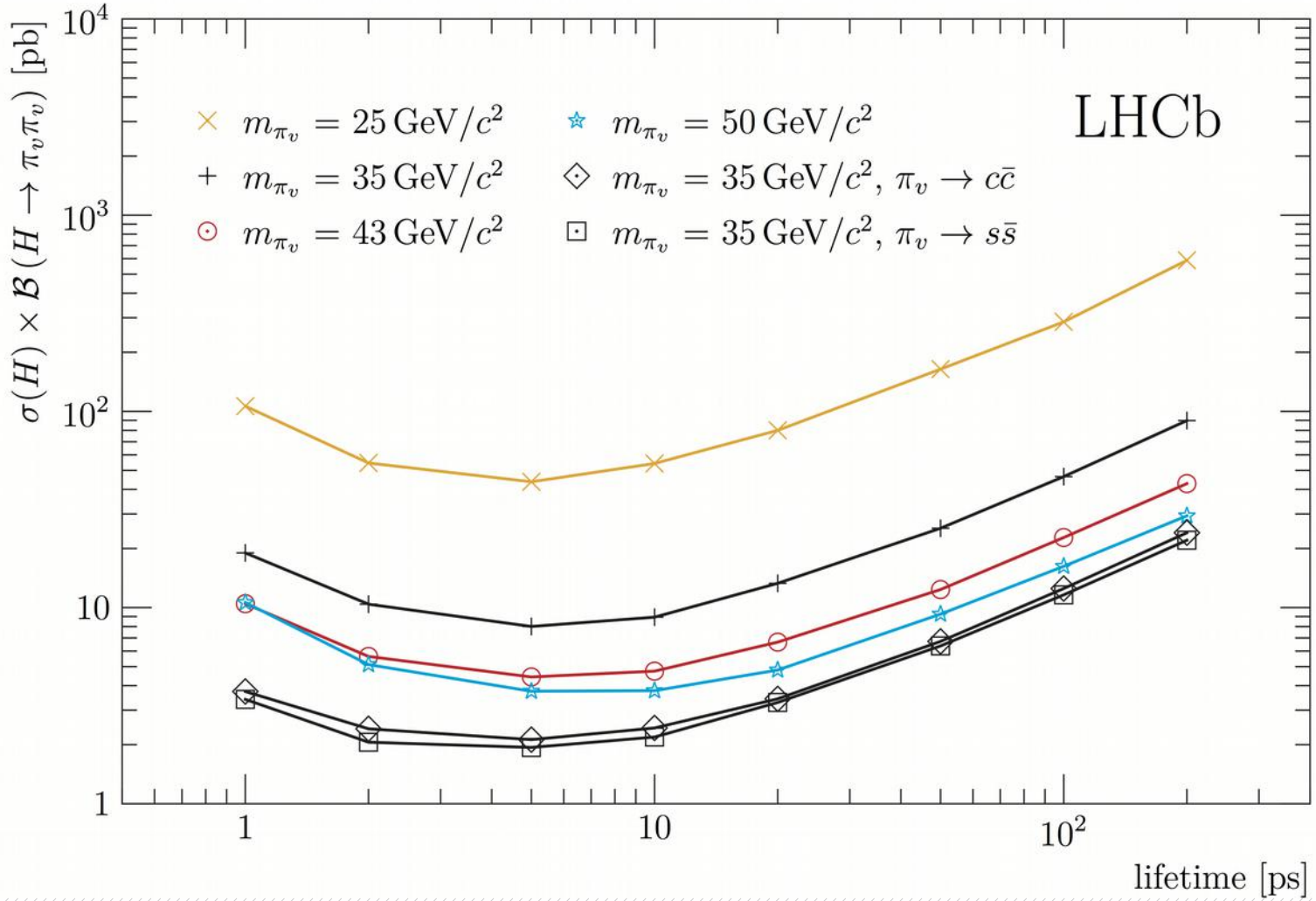






LHCb [EPJ C75(2015)152]

# LLP Results




σ(H) @ 7 TeV
= 17 pb



LHCb [EPJ C75(2015)152]

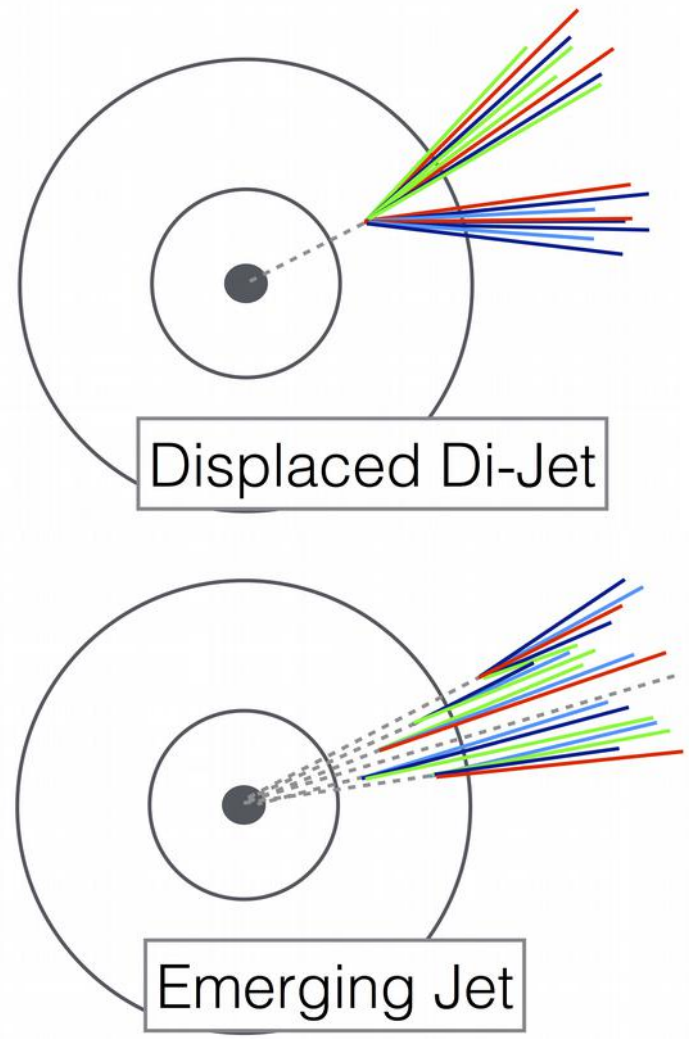
# Idea : emerging jets

- **"Emerging jets"**

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

- **LHCb has potential**

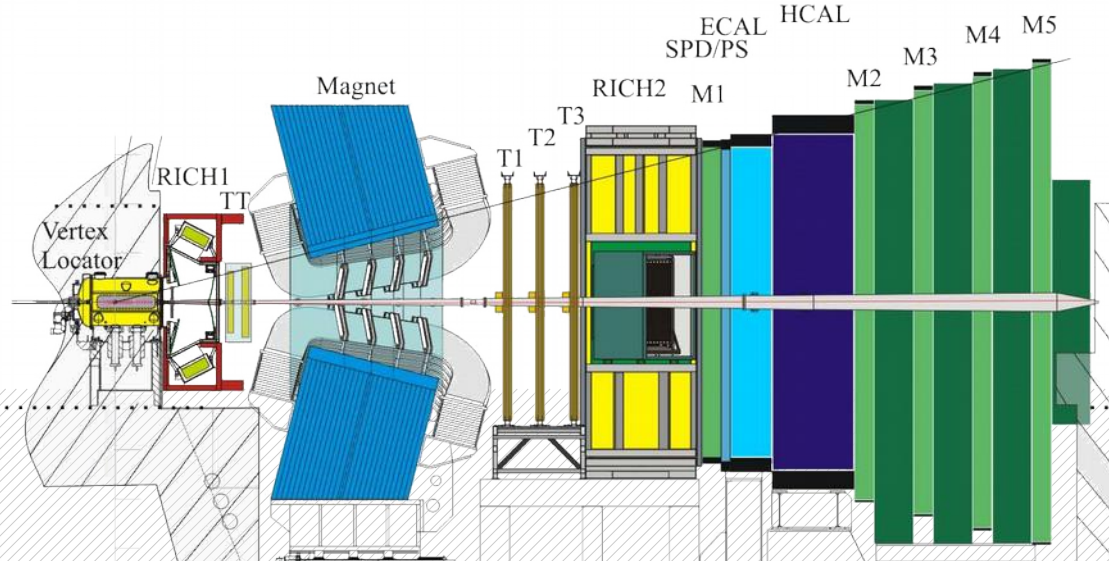
precise jet vertexing
sensitive to low mediator mass






Schwaller, Stolarski, Weiler, [arXiv:1502.05409]

# Future


Vertex Locator
RICH1
TT
Magnet
T1
T2
T3
RICH2
M1
SPD/PS
ECAL
HCAL
M2
M3
M4
M5

# Future for LHCb

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

High Luminosity LHCb? Phase-2 upgrade?

LHC era → HL-LHC era

| Run (years) | Run 1 (2010-2012) | Run 2 (2015-2018) | Run 3 (2021-2023) | Run 4 (2027-2029) |
|---|---|---|---|---|
| Integrated luminosity | 3 $fb^{-1}$ | 8 $fb^{-1}$ | 25 $fb^{-1}$ | 50 $fb^{-1}$ |
| Instantaneous luminosity | $4 \times 10^{32}$ $cm^{-2}s^{-1}$ | | $2 \times 10^{33}$ $cm^{-2}s^{-1}$ | |

Current LHCb → Upgraded LHCb

Expect 8 $fb^{-1}$ by 2018

Run at 5x luminosity: collect 50 $fb^{-1}$ by 2030

# 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*

# Thank you for your attention!