

The background of the slide is a deep space image showing a vast field of galaxies. The galaxies are of various shapes and sizes, some appearing as bright, diffuse clouds and others as more compact, point-like sources. The color palette is rich, with many galaxies appearing in shades of orange, yellow, and red, interspersed with some blue and green ones. A prominent feature is a large, bright, pinkish-purple glow that emanates from the center of the image, creating a radial gradient of light. The overall effect is that of a dense, multi-colored galaxy cluster or a similar astronomical phenomenon.

# search for dark matter @LHC

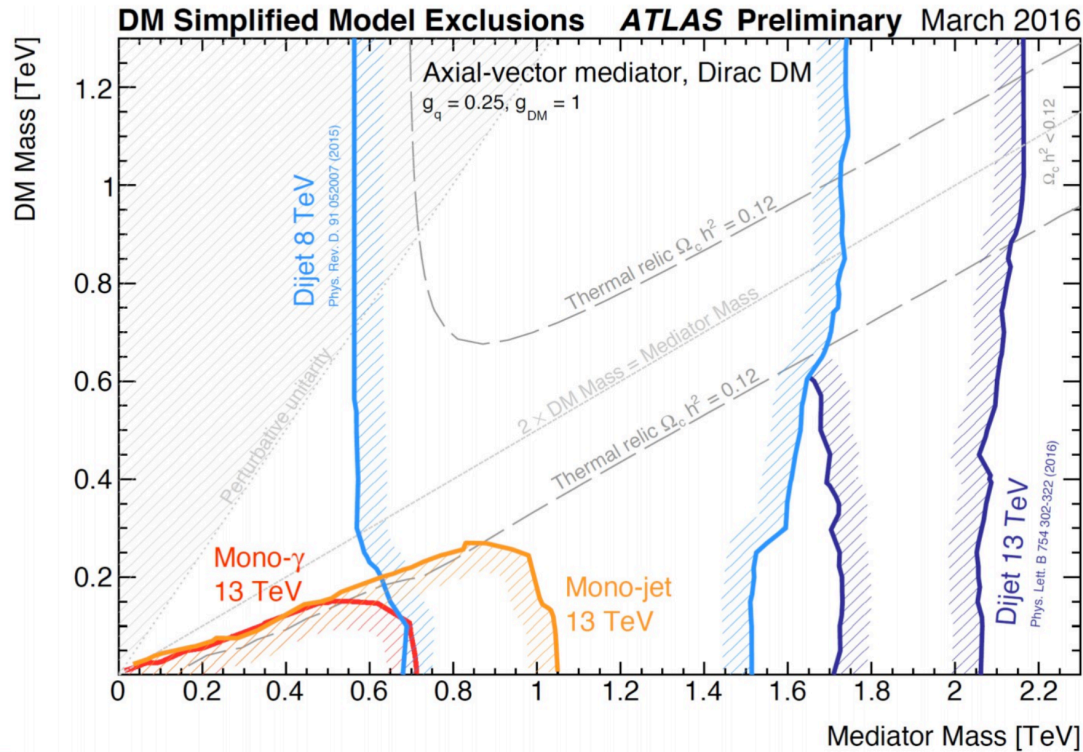
andrea de simone  
valerio ippolito  
mia tosi

-- pp@LHC 2016 --  
Pisa, Apr 16<sup>th</sup>-18<sup>th</sup>, 2016






1.5'

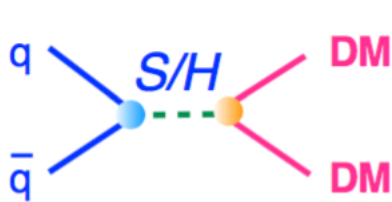
1

# complementarity



## GOAL

-  combine DM searches
-  add di-jet searches
-  add  $X \rightarrow YY$  searches
-  add higgs  $\rightarrow$  invisible
-  add 2HDM searches



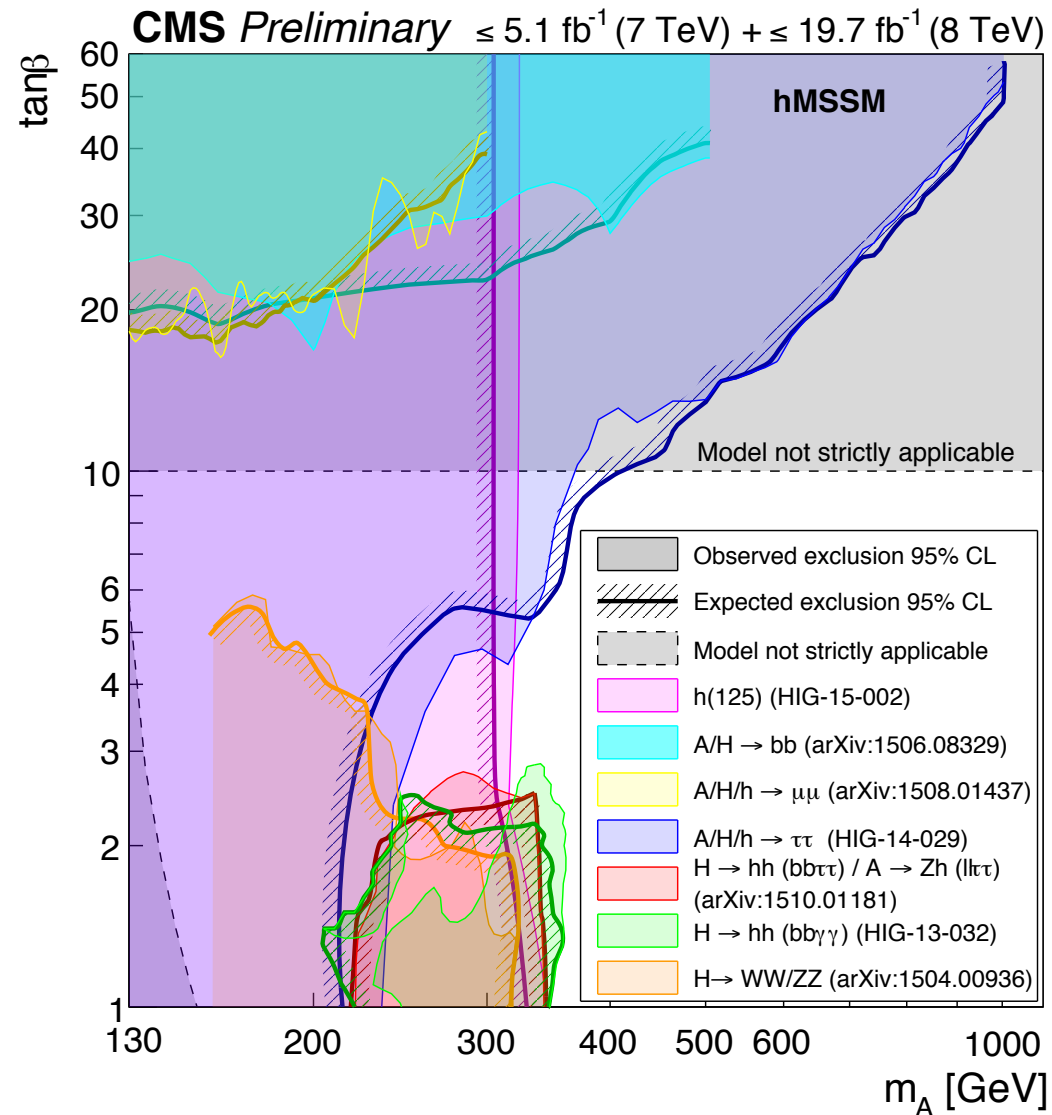
.. as seen,

## SCALAR-HIGGS PORTAL

is a nice framework for practicing

# complementarity

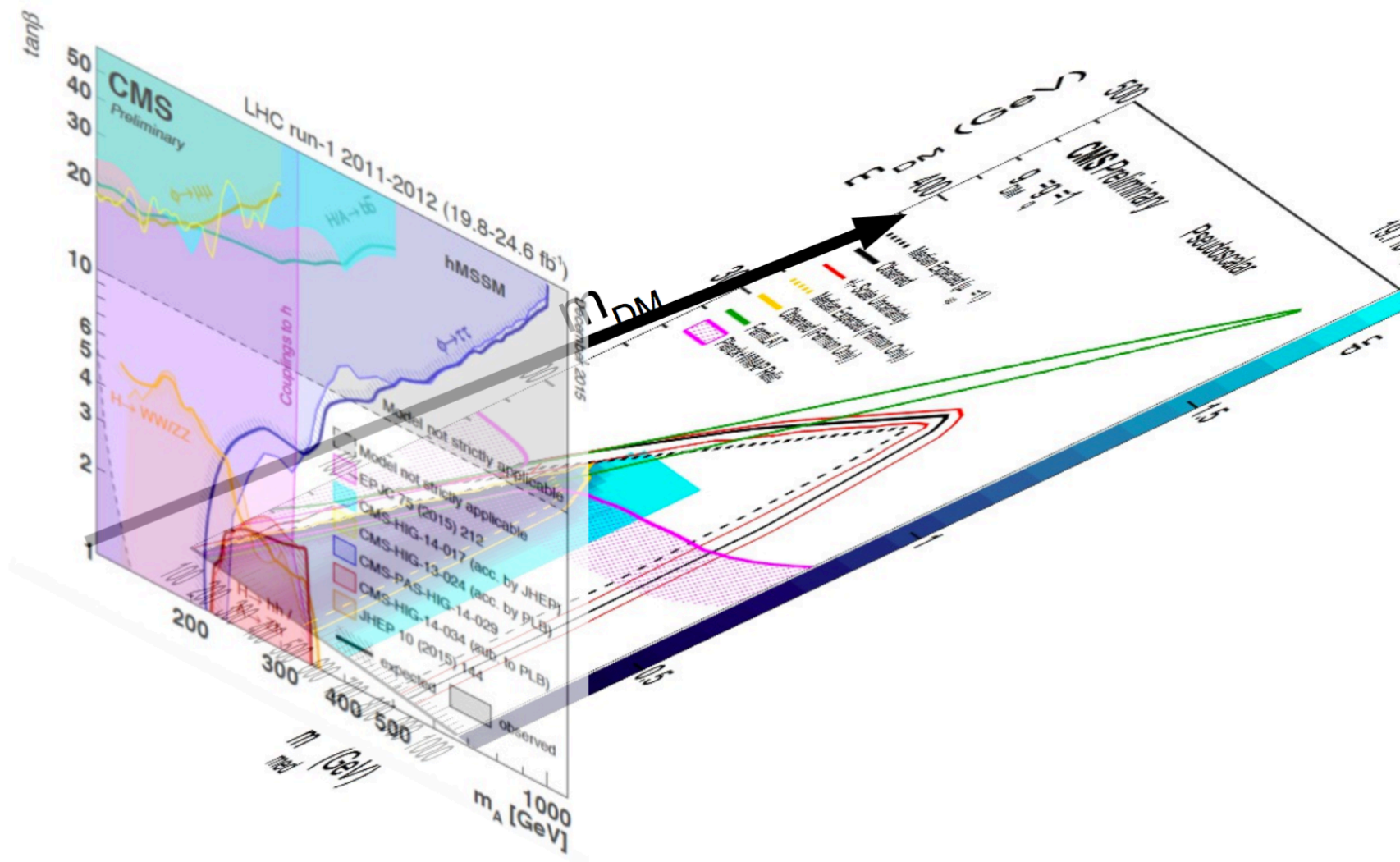
every search is some how related to dark matter



# complementarity

every search is some how related to dark matter

**almost every search can extend it to search for dark matter**



# challenges

if you want to see nothing,  
you have to reconstruct everything !

- main variable: **MET**
  - reconstruction: high resolution and low uncertainty
- main additional ingredients: **H, V, top, b tagging**
  - algorithms (sub structure, ..), reconstruction, vertexing
  - as now,  
ATLAS: trimming  
CMS: pruning
- **new approaches/strategies ?**
  - differential distributions, kinematics, alphaT, razor
    - need well modelled background
    - as now,  
ATLAS: razor on going in SUSY  
CMS: alphaT and razor on going
- statistics, maintaining sensitivity @low MET [DM is soft]
  - **trigger !!** [low thresholds, highest resolution as possible, keep rate w/in bandwidth, ..]
    - MET resolution
    - offline variables (alphaT, razor)
    - scouting
    - .....
    - tracking@L1 (HL-LHC)
    - how to increase acceptance ?
  - both ATLAS and CMS make use of scouting for di-jet analysis

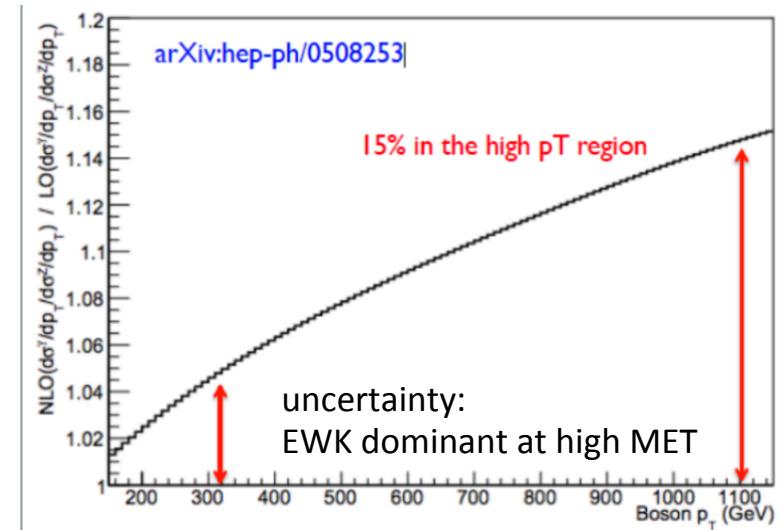
# challenges

if you want to see nothing,  
you have to reconstruct everything !

- background modeling
  - **theory corrections**
    - Z+jets QCD NLO corrections included in aMC@NLO
    - EWK NLO correction
      - use Z+jet /  $\gamma$ +jet
  - **control statistics** :
    - ✓  $Z\mu\mu : Z\nu\nu = 1:6 \rightarrow V$ +jets
    - 🔧 di-boson, top

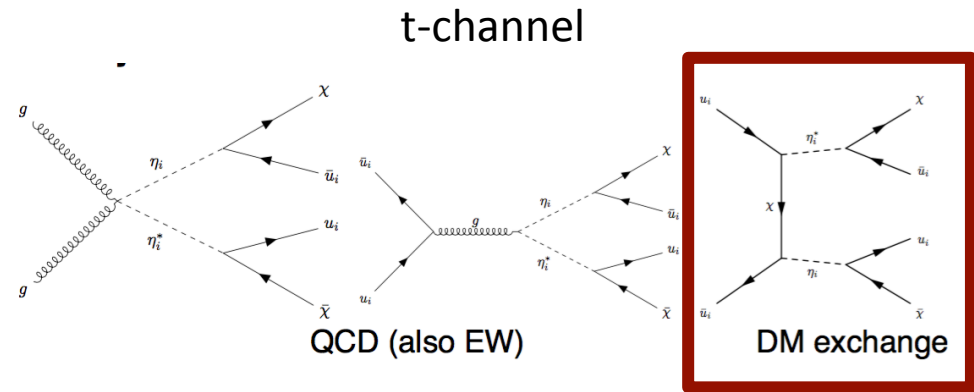
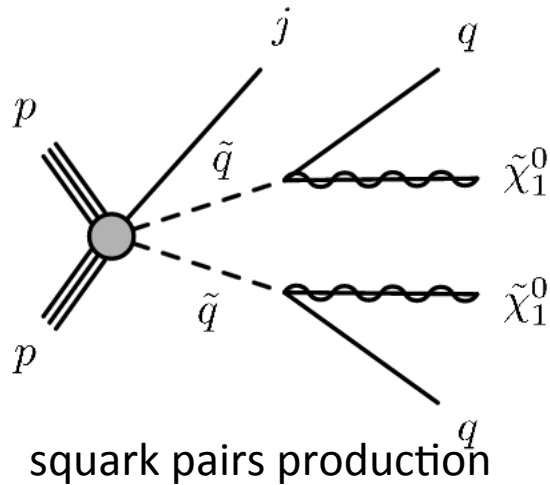
as now,  
☐ ATLAS  
✓ CMS

- combinations
  - **categorization**
  - overlaps + correlation between uncertainties
- interpretation
  - **parameters scan** → MC productions



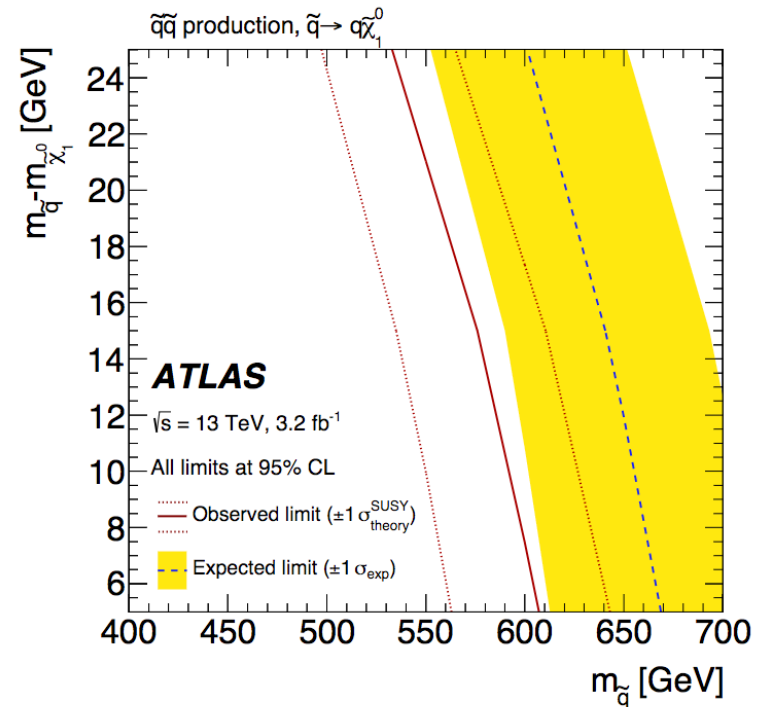
as now,  
☐ ATLAS  
🔧 CMS

# DM-SUSY searches interplay: t-channel



ATLAS already started to work on it [1604.07773]

- ✓ interpretation in terms of the search for squark pair production in a compressed supersymmetric scenario



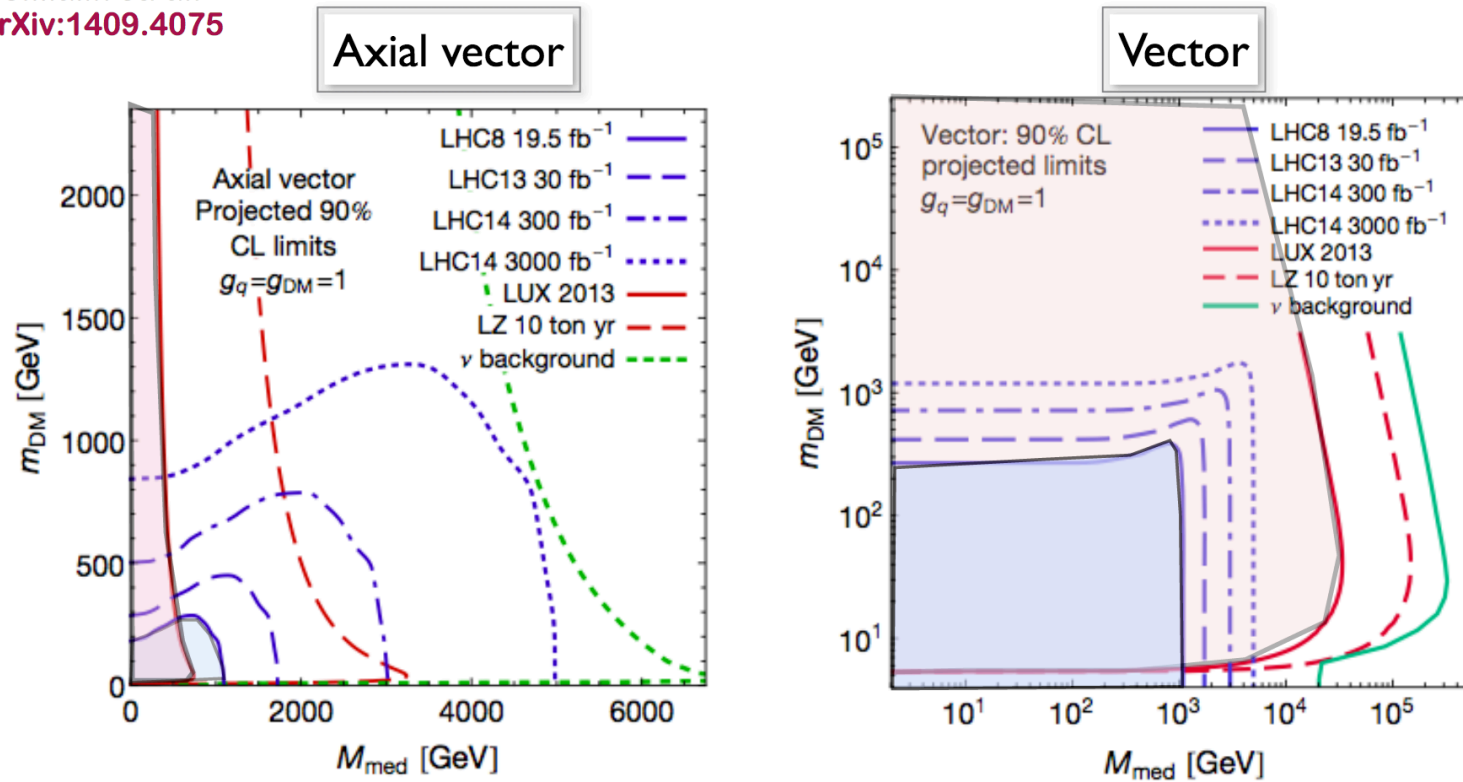
BACKUP





# LHC - Run I

S.Malik et. al.  
arXiv:1409.4075

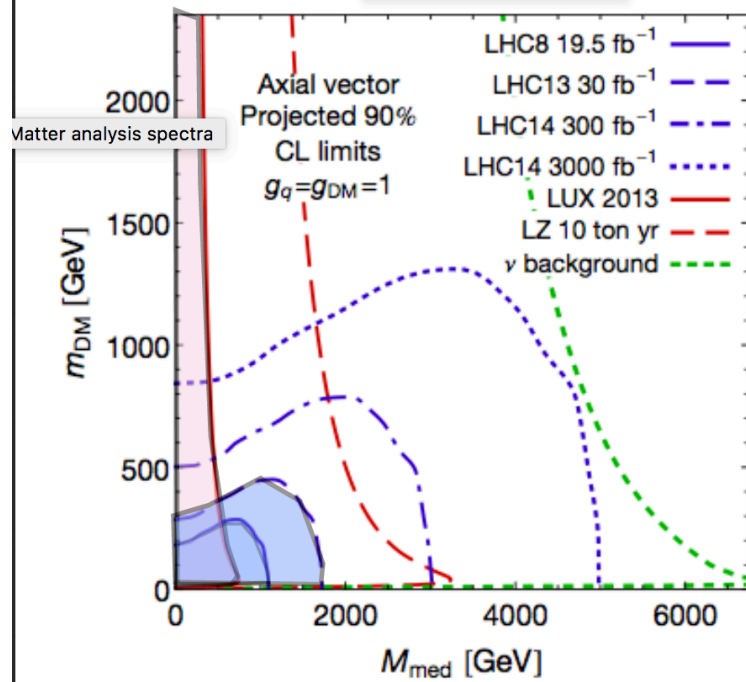


	2012	2015-2016	~2020	HL-LHC
Energy	8 TeV	13 TeV	13 TeV	13/14 TeV
Luminosity	20 fb <sup>-1</sup>	30 fb <sup>-1</sup> ?	300 fb <sup>-1</sup>	3000 fb <sup>-1</sup>

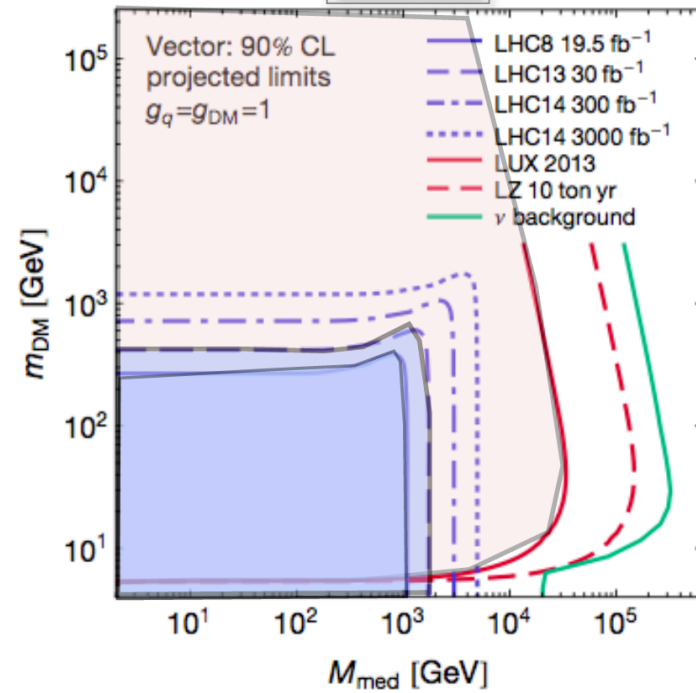
# LHC - Run 2

S.Malik et. al.  
arXiv:1409.4075

Axial vector



Vector

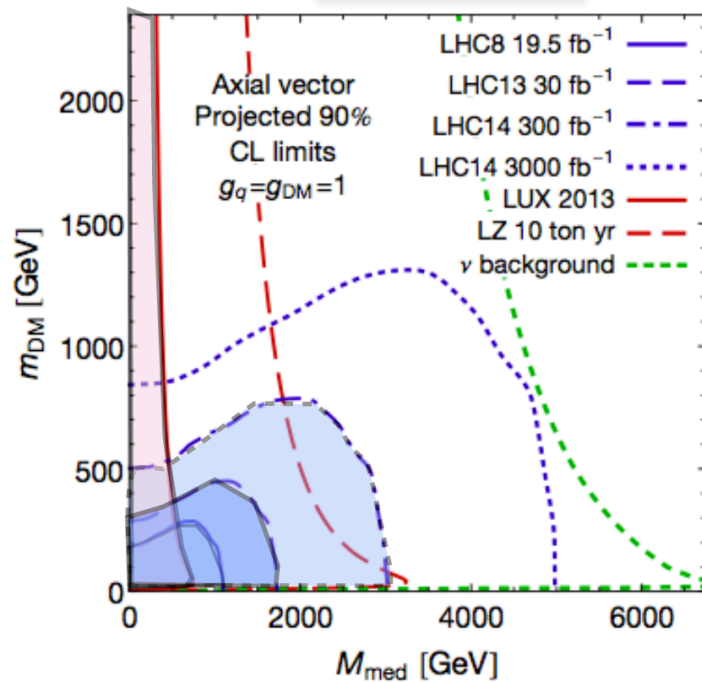


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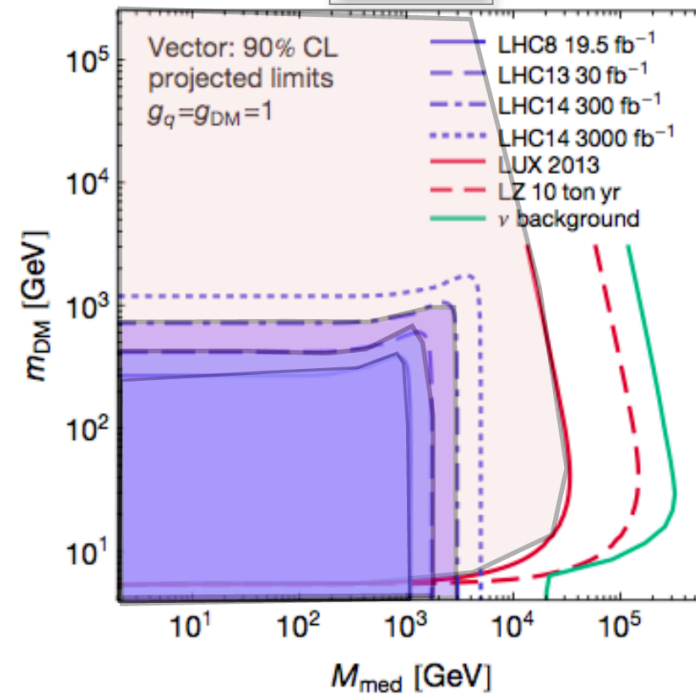
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Axial vector



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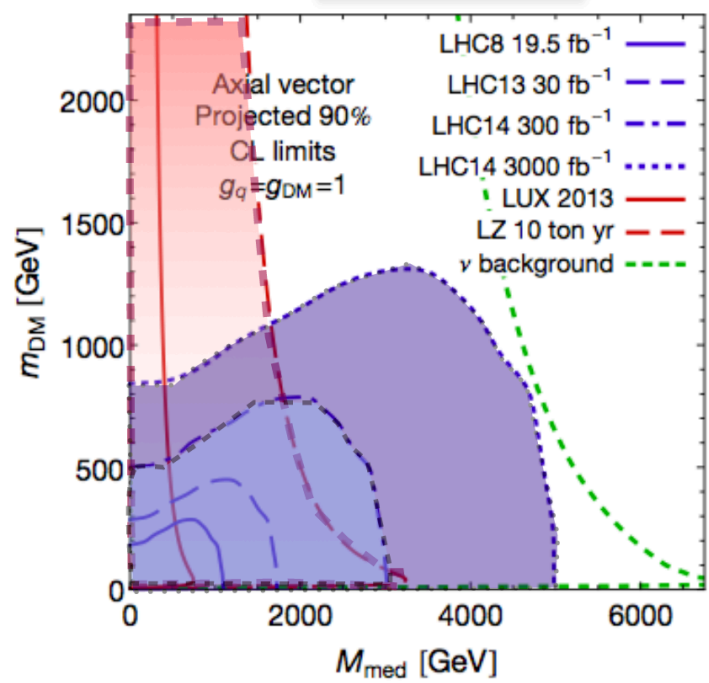


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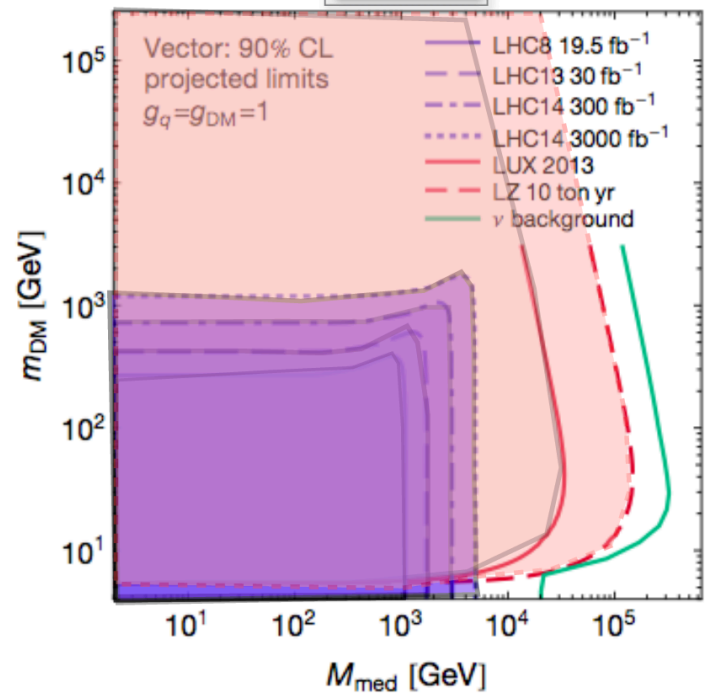
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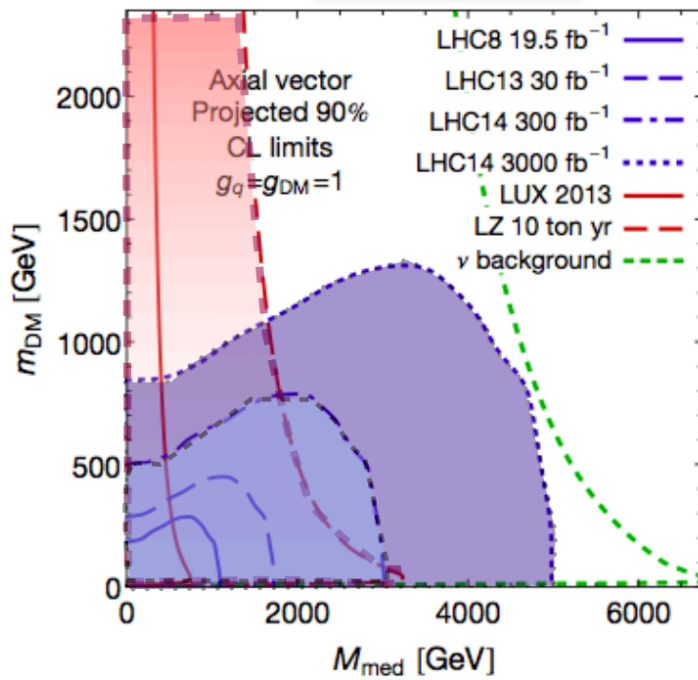


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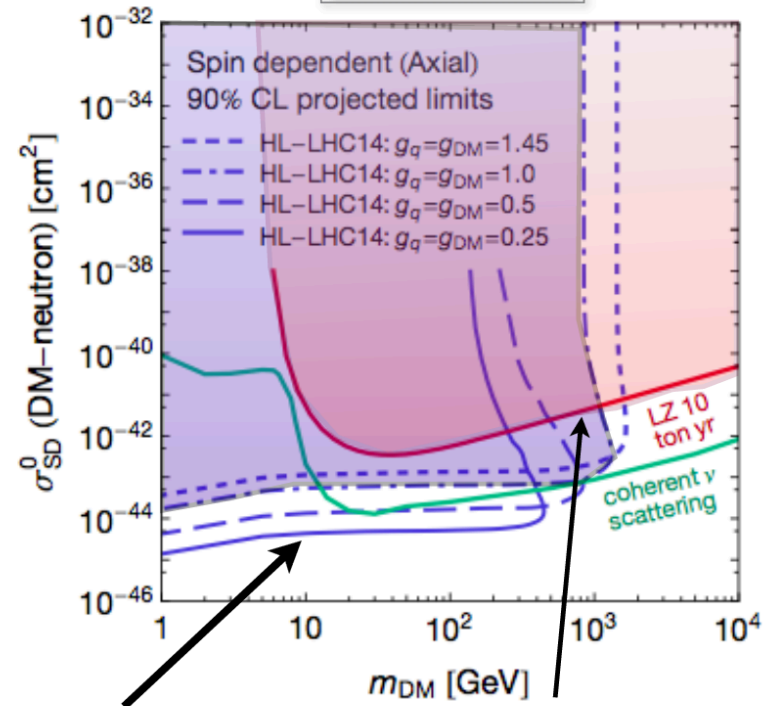
# HL-LHC

S.Malik et. al.  
arXiv:1409.4075

Axial vector



Axial vector



Colliders able to probe all the way up to and beyond neutrino barrier with HL-LHC

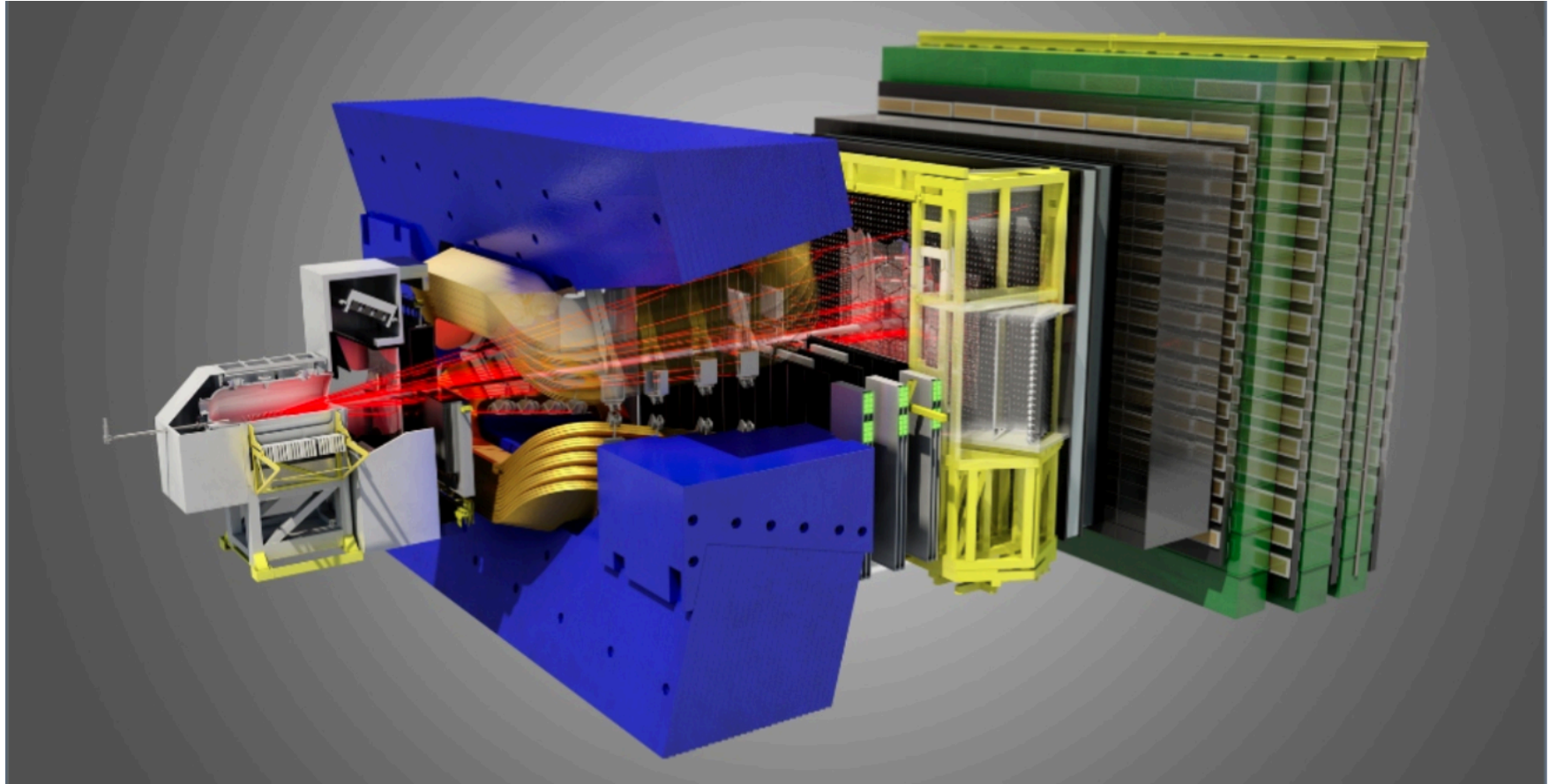
reach of next generation of DD expt

# Dark Matter analysis spectra (CMS)

Jets	Inclusive	V tag	Top	b tag	Higgs
1	EXO-16-013	EXO-16-013	EXO-16-005	B2G-15-007	EXO-16-012
2	SUS-15-005	EXO-16-013	EXO-16-005	B2G-15-007	EXO-16-012
3	SUS-15-005		EXO-16-005	SUS-15-005	
n					
leptons		EXO-16-010			
$\Upsilon$	EXO-16-014				EXO-16-011
Indirect					HIG-16-016

# LHCb

the LHC's forward detector



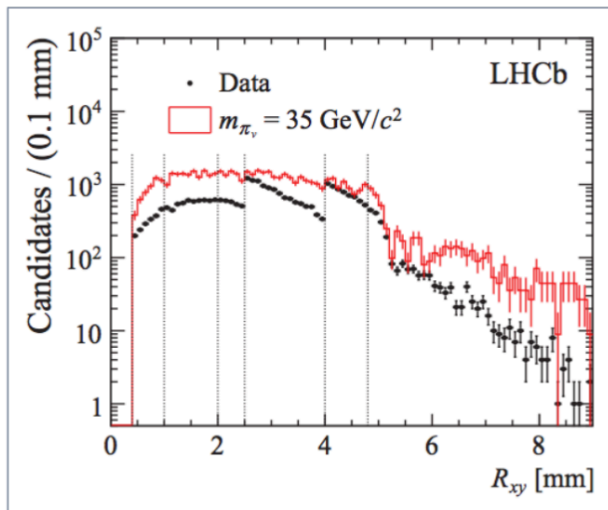
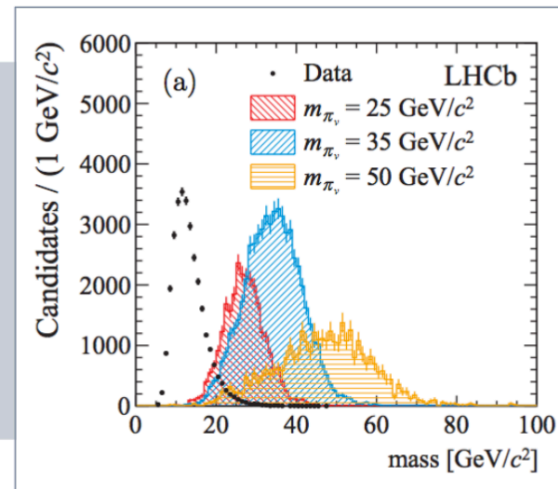
- ➡ no MET !
- ➡ forward reconstruction !

# LHCb: displaced jets

Eur.Phys.J.C75(2015)152

## Displaced jets

- $H \rightarrow \pi_{\nu}(bb)\pi_{\nu}(bb)$ 
  - Hidden valley - long-lived particles
- **Low mass**
  - 25 GeV – 50 GeV
- **Displaced bb**
  - 0.4 mm – 4.8 mm



### LHCb advantages

- **Triggers:** low-mass &  $p_T$ 
  - Upgrade: full software trigger
- **Vertex resolution**
  - Critical for displaced searches

DM@LHC: see Swagata Mukherjee for Atlas+CMS long lived



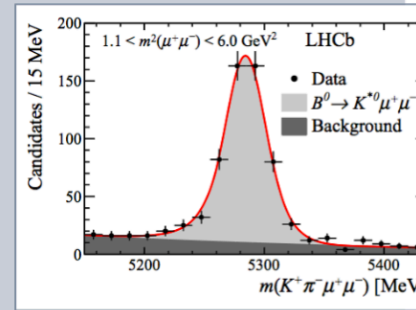
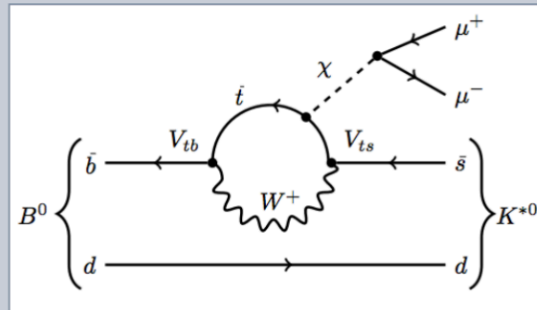
# LHCb: $K^* \mu \mu$

## $K^* \mu \mu$

PRL115(2015)161802

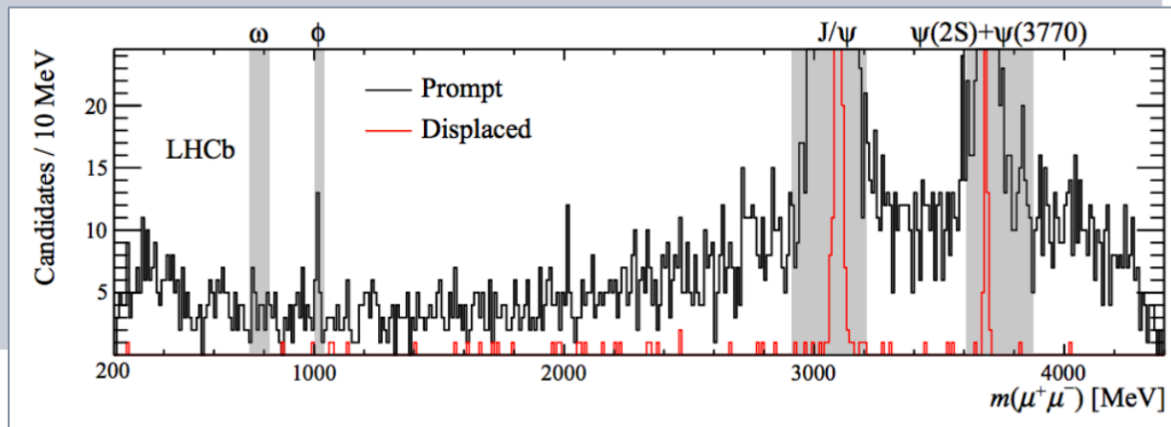
$B_d \rightarrow K^* \mu^+ \mu^-$

- 'Rare'  $b \rightarrow s \gamma$  decay
  - Penguin suppressed
- Dark sector search
  - $X \rightarrow \mu \mu$



Search for displaced dimuons:  $t > 3\sigma$

- $\sigma \sim [0.2 - 1] \text{ ps}$
- Low-mass bosons

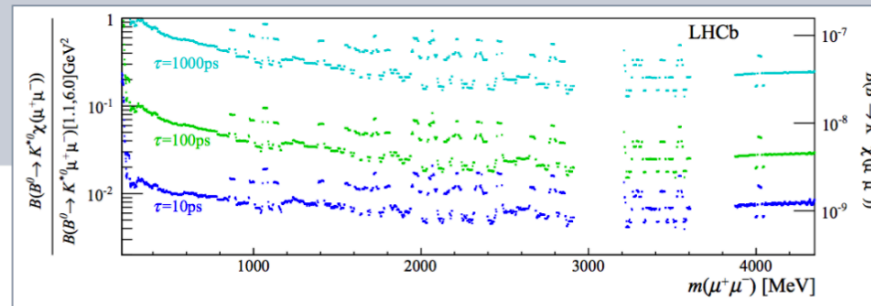


# LHCb: $K^* \mu \mu$

## $K^* \mu \mu$ limits

PRL115(2015)161802

- Model-independent



- Axion / inflaton

