

# Search for lepton jets using 8TeV data with the ATLAS detector

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# Outline

- Motivation
- Lepton jet definition
- Event selection
- Signal prediction and background estimation
- Results

# Motivation for lepton jet search

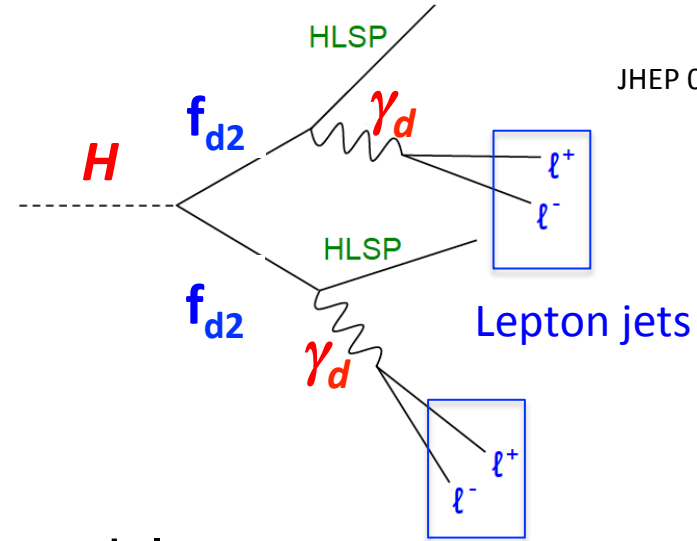
## Astrophysical observations – Positron excess

AMS PRL 113, 121101 (2014), PAMELA, Nature 458 (2009) 607

### Production at LHC

- **Higgs portal**

- 10% BR to hidden dark sector
- $f_{d2}$  – dark fermion
- HLSP – Hidden lightest stable particle
- $\gamma_d$  – dark photon



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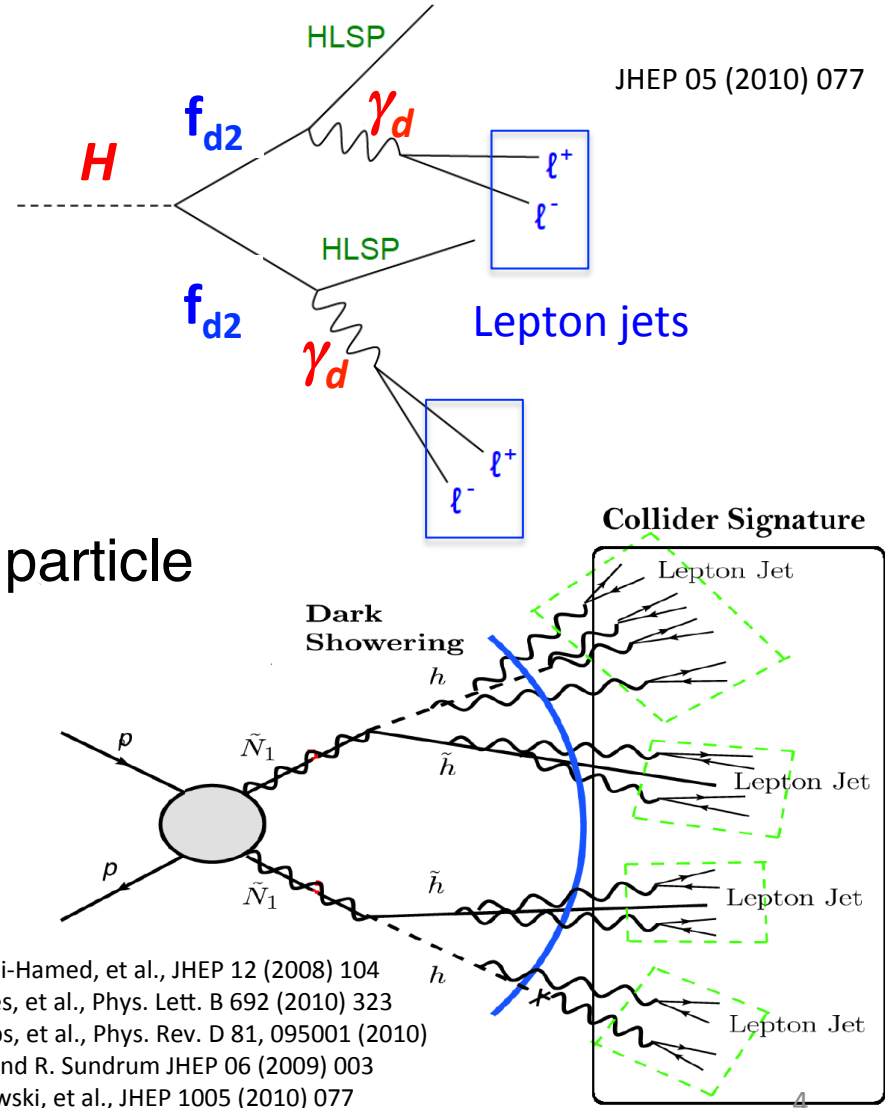
### Production at LHC

- **Higgs portal**

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- **SUSY portal**

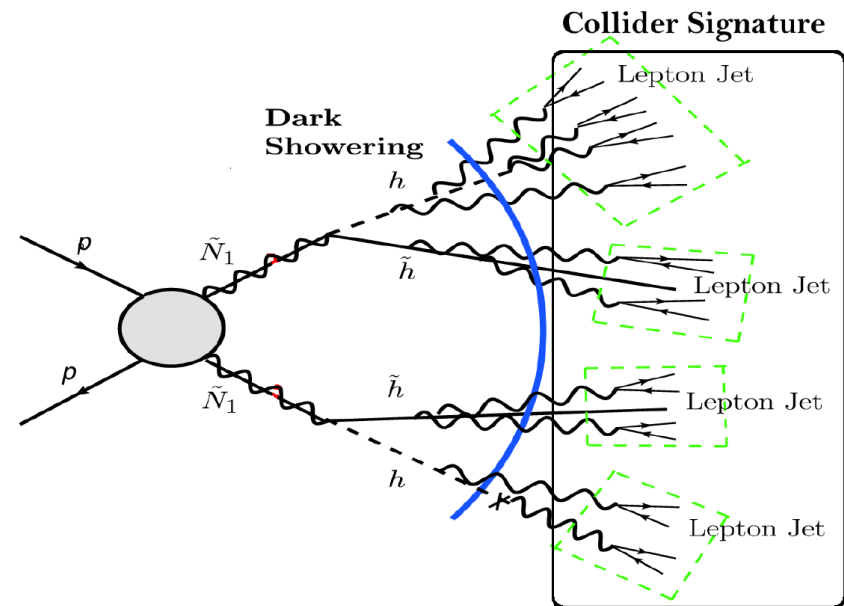
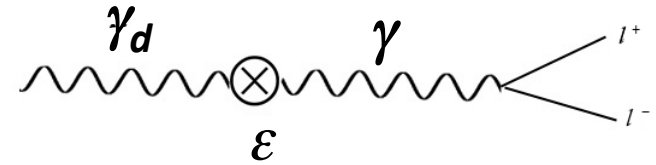
- $N_1$  – Neutralino
- $\gamma_d$  – dark photon



N. Arkani-Hamed, et al., JHEP 12 (2008) 104  
 D.S. Alves, et al., Phys. Lett. B 692 (2010) 323  
 G.D. Kribs, et al., Phys. Rev. D 81, 095001 (2010)  
 A. Katz and R. Sundrum JHEP 06 (2009) 003  
 A. Falkowski, et al., JHEP 1005 (2010) 077

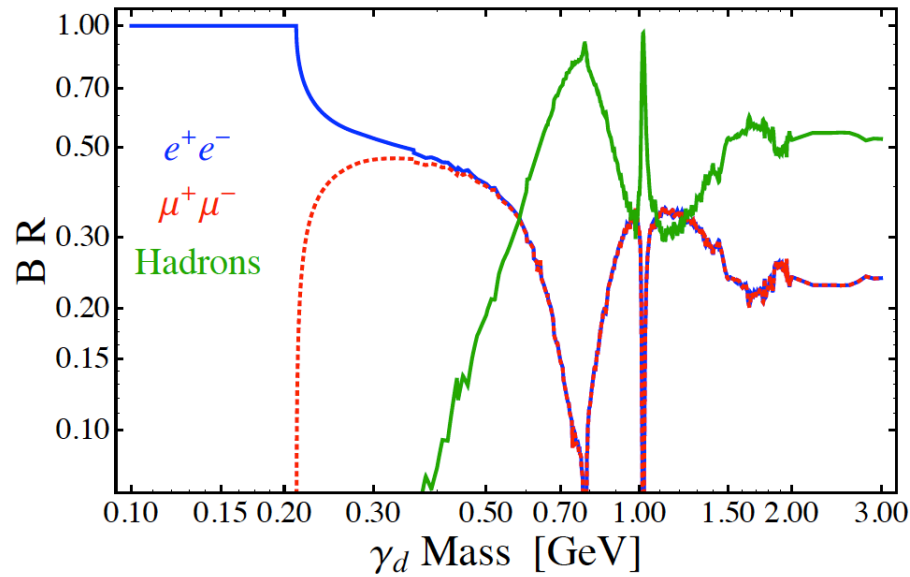
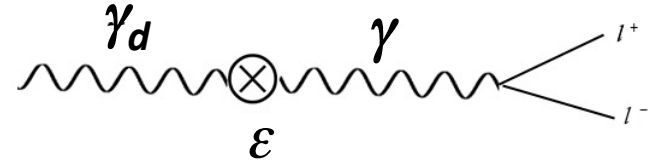
# Motivation for lepton jet search

- Dark photon ( $\gamma_d$ ) kinetically mixes ( $\epsilon$ ) with the Standard Model (SM) photon.
- Signature – collimated pairs of leptons – lepton jets.



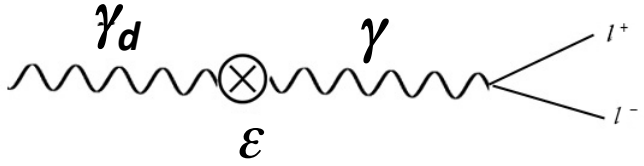
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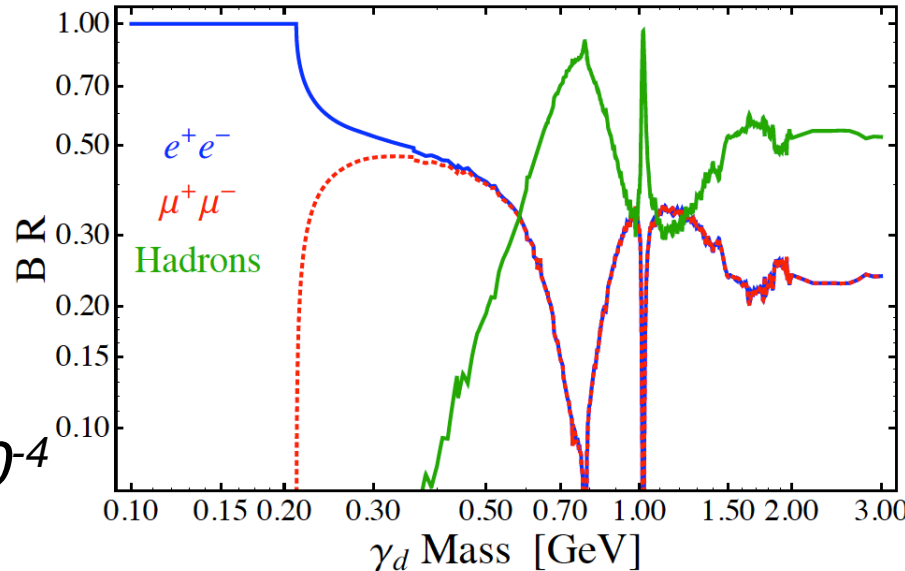
- Mass of the dark photon:  
 $m_{\gamma_d}: 100 - 2000 \text{ MeV}$

- Prompt lepton jets:  $\epsilon \sim 10^{-3} - 10^{-4}$

- In progress (ATL-COM-PHYS-2014-454)

- Non-prompt lepton jets:  $\epsilon \sim 10^{-5} - 10^{-7}$

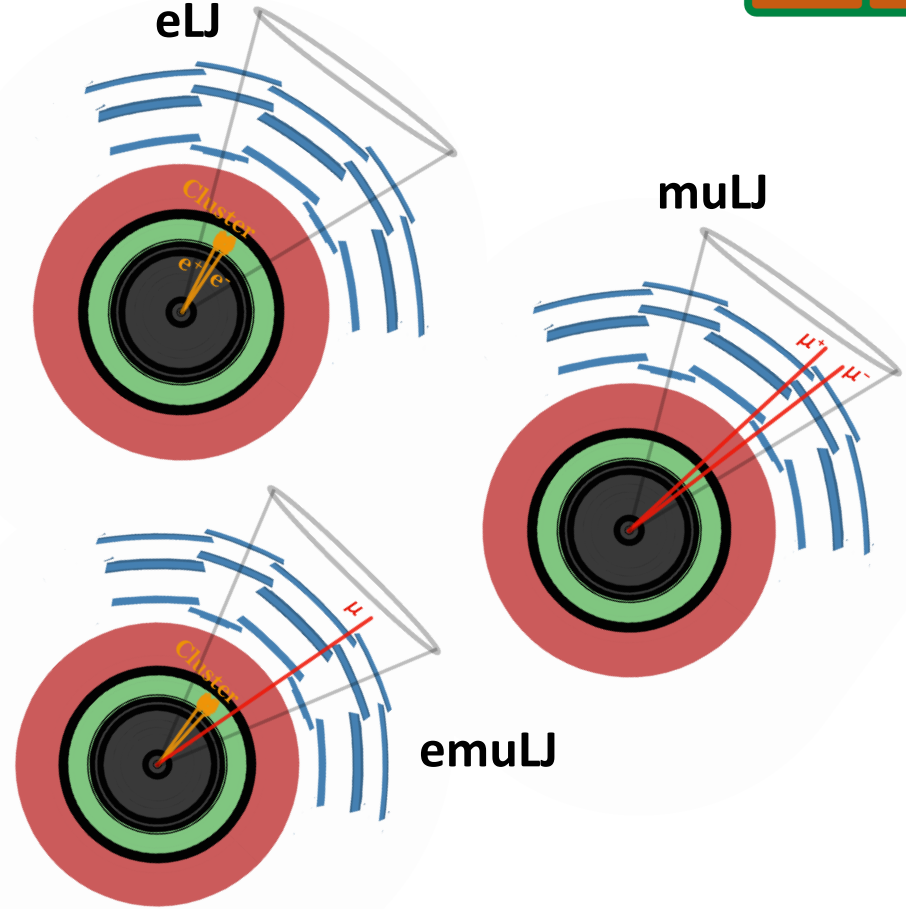
- Submitted to JHEP (arXiv:1409.0746v2)



Parameters of Interest
$\epsilon$
Mass of $\gamma_d$

# Lepton Jet definition

- Electron LJ (eLJ)
  - Two inner detector (ID) tracks matched to one or two EM clusters.
  - Tracks within  $\Delta R (=0.5)$  cone.
- Muon LJ (muLJ)
  - $\geq$  two muons with matched inner detector tracks within  $\Delta R (=0.5)$  cone.
- Mixed LJ (emuLJ)
  - $\geq$  one EM cluster with  $\geq$  one ID track
  - $\geq$  one muons with  $\geq$  one ID track.



EM - Electromagnetic

No inner detector track requirement for the non-prompt lepton jets.  
arXiv:1409.0746v2

- Data: 20.3 fb<sup>-1</sup> 8 TeV data.
- Backgrounds: QCD,  $\gamma$ +jets, dibosons(WW, WZ, ZZ,  $\gamma\gamma$ ), tt, Z+jets, W+jets, Drell-Yan



# Signal selection

- Triggers
  - Prompt lepton jets: Single electron OR two EM cluster, single OR multi-muon with lower threshold.
  - Non-prompt lepton jets: Calorimeter and MS only trigger.

MS- Muon Spectrometer

- Preselection

- Quality events.
- Primary vertex with  $\geq 2$  lepton jets.
- Di-lepton mass  $< 2$  GeV.
- Electron and muon,  $p_T > 10$  GeV,  $|d_0| < 1$  mm (prompt only).
- MS Muons  $|d_0| < 200$  mm,  $|z_0| < 270$  mm (non-prompt only)

Electron channel	eLJ – eLJ
Muon channel	muLJ – muLJ
Mixed channel	eLJ – muLJ
	eLJ – emuLJ
	muLJ – emuLJ
	emuLJ - emuLJ

- Background rejection

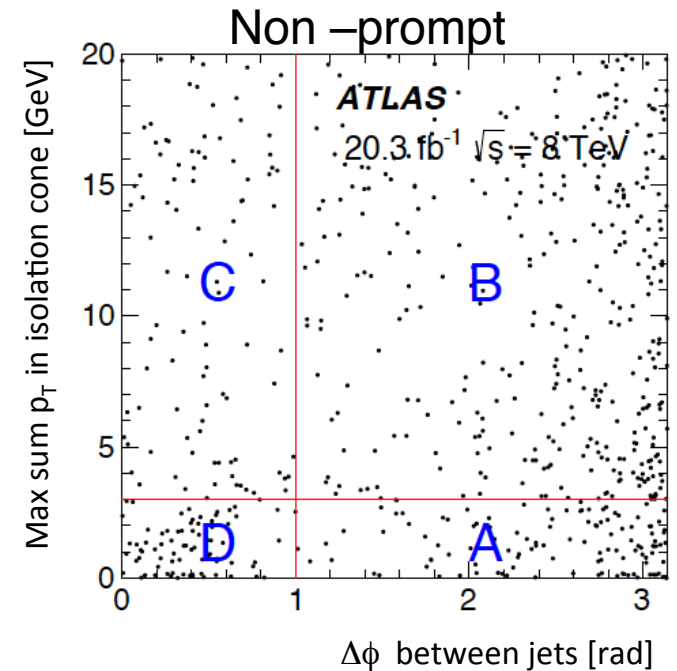
- Optimized discriminating variables.

# Background estimation

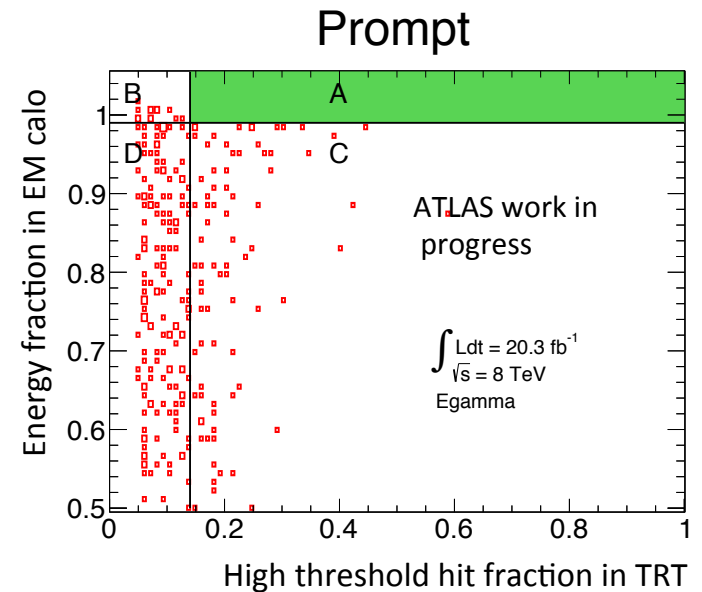
## Data-driven method

- Two relatively uncorrelated variables.
- A – signal region.
- B, C, D – control regions.
- B, C and D content used to estimate the background in A.

Prompt lepton jet analysis is still blinded



arXiv:1409.0746v2



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# Analysis sensitivity and background estimation

## Non-prompt analysis

### Background estimation

	Event
Background estimated	$41 \pm 12 \pm 29$
Data (observed)	29

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### Higgs portal – MC prediction 10% BR to dark sector

$m_{\gamma d} = 400 \text{ MeV}$	Events
$n_{\gamma d} = 2$	$60 \pm 4$
$n_{\gamma d} = 4$	$104 \pm 5$

arXiv:1409.0746v2

## Prompt analysis

### Background estimation

Channel	Background estimate in region A
eLJ-eLJ	$3.1 \pm 0.8$

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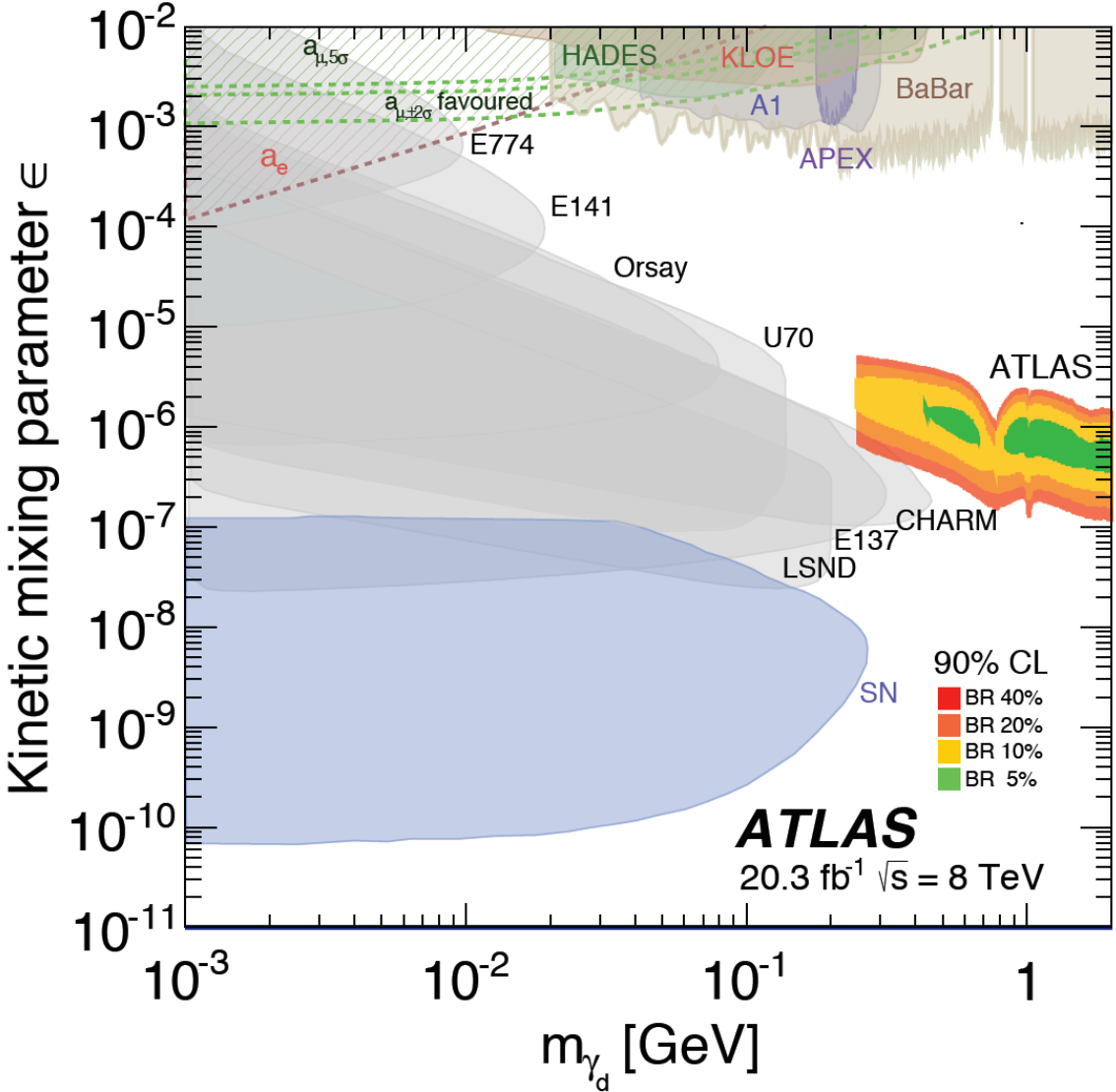
### SUSY signal portal – MC prediction 700 GeV squarks – 64fb at 8TeV

Signal sample	Events
$m_{\gamma d} = 100 \text{ MeV}$	$35.8 \pm 0.9$
$m_{\gamma d} = 300 \text{ MeV}$	$15.0 \pm 0.6$
$m_{\gamma d} = 1200 \text{ MeV}$	$6.0 \pm 0.2$

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# Results

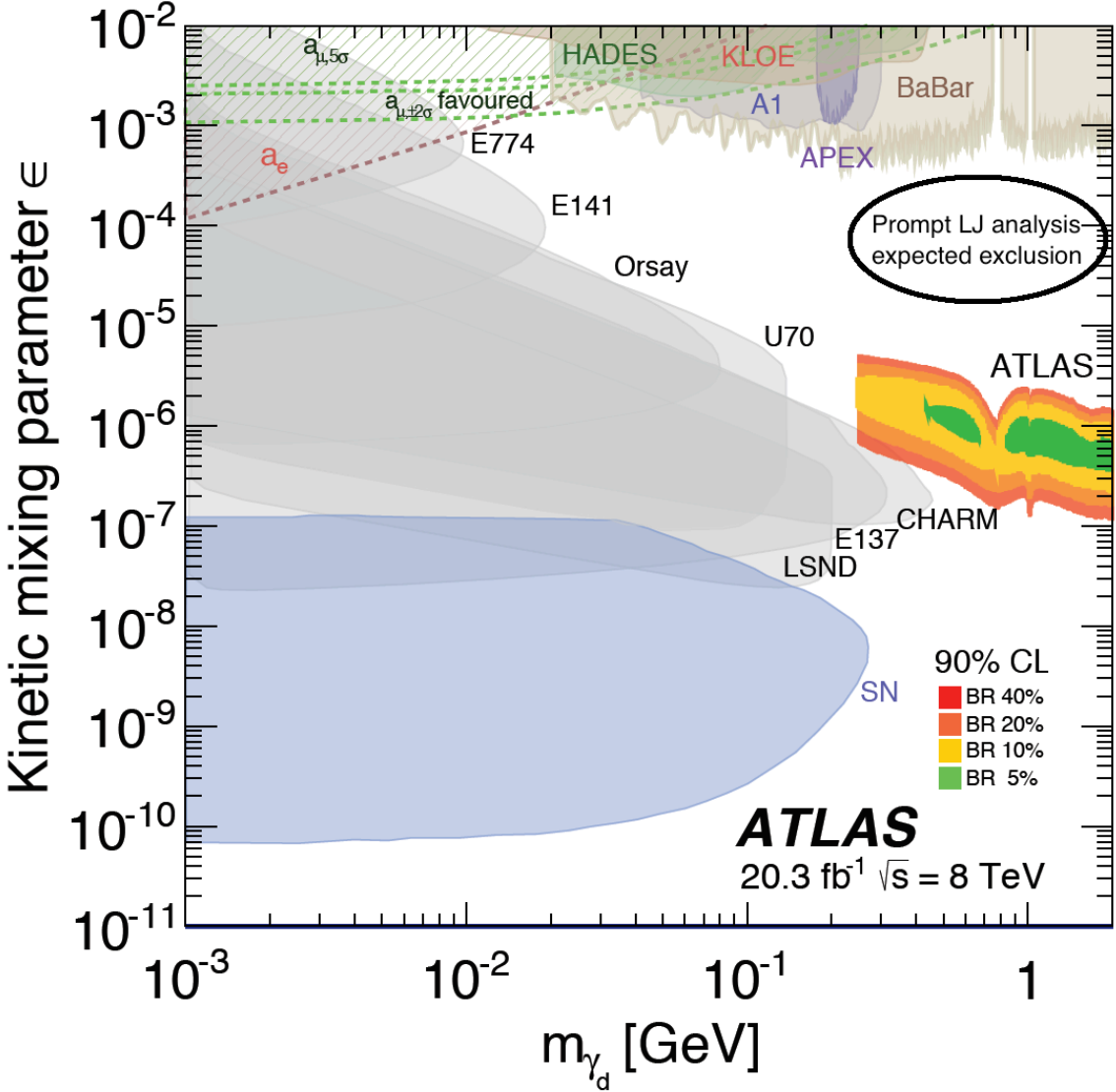
- Result is interpreted in the 2D plane of  $\epsilon$  and the mass of the dark photon.
- ATLAS result is shown for the non-prompt lepton-jet analysis.
- Prompt lepton-jet analysis is still blinded.



arXiv:1409.0746v2

# Results

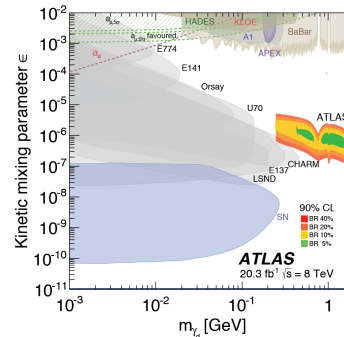
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# Conclusion

- Searches are performed for prompt and non-prompt lepton jets.
- Complementary in covering dark parameter space.
- Non-prompt search – submitted to JHEP (arXiv:1409.0746v2)
  - 8 TeV ATLAS data
  - $\epsilon \sim 10^{-5} - 10^{-7}$
  - $m_{\gamma d} = 150 - 1500$  MeV
- Prompt lepton jet search
  - 7 TeV ATLAS data (published - PLB 719 (2013) 299-317),  $\epsilon \sim 10^{-3} - 10^{-4}$
  - 8 TeV ATLAS data – waiting to unblind - stay tuned!
- No lepton-jet excess observed.



# Backup

## Objects - preselection

- ID Tracks
  - $p_T > 5 \text{ GeV}$ ,  $|\eta| < 2.5$
  - Blayer hits  $\geq 1$
  - Pix hits  $\geq 2$
  - Pix + SCT hits  $\geq 7$
- MUID muons  
(following MCP group recommendation )
  - $p_T > 5 \text{ GeV}$ ,  $|\eta| < 2.5$
  - isSegmentTagged or isCombined
- EM Cluster
  - $p_T > 10 \text{ GeV}$
  - $|\eta| < 2.47$ , excluding fiducial region ( $1.37 < |\eta| < 1.52$ )
  - Author 1 or 3



## Data

- 20.3 fb<sup>-1</sup> of 8 TeV data
- Egamma stream
- Muon stream
- JetTauEtmis (for evaluating QCD background)

## Signal MC– SUSY

- Mass of  $\gamma_d$ ,  $m_{\gamma_d} = 100, 300, 500, 700, 900, 1200, 1500, 2000$  MeV.
- Number of  $\gamma_d$  in the final state,  $n_{\gamma_d} = 2, 4$ .

## Signal MC- Higgs

- $m_H = 125$  GeV,  $m_{\gamma_d} = 400$  MeV,  $n_{\gamma_d} = 2, 4$ .

## Background MC

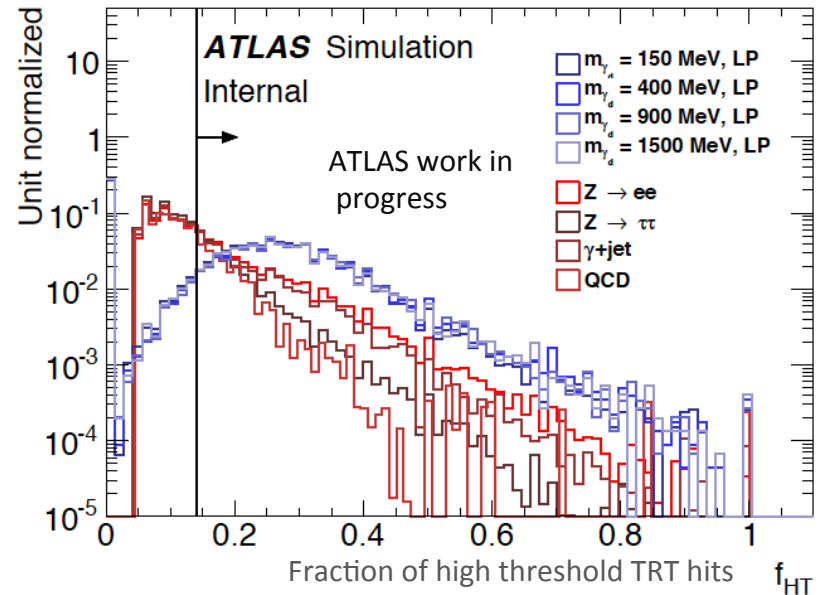
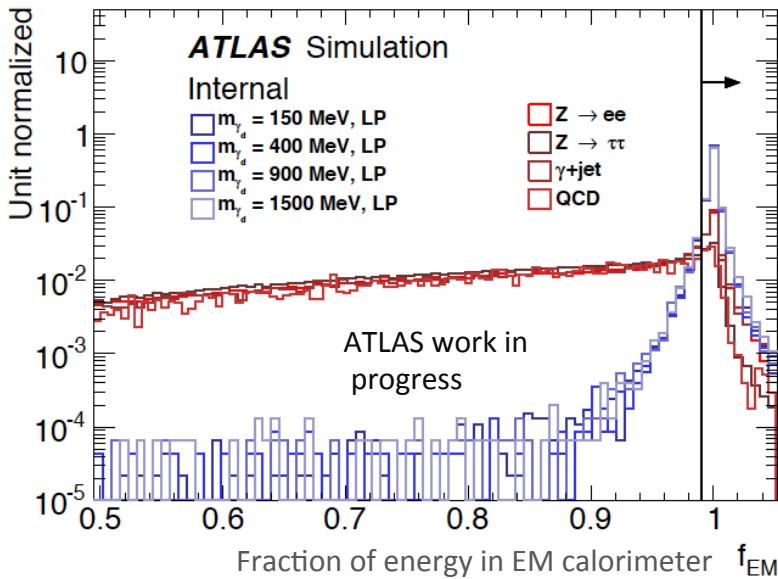
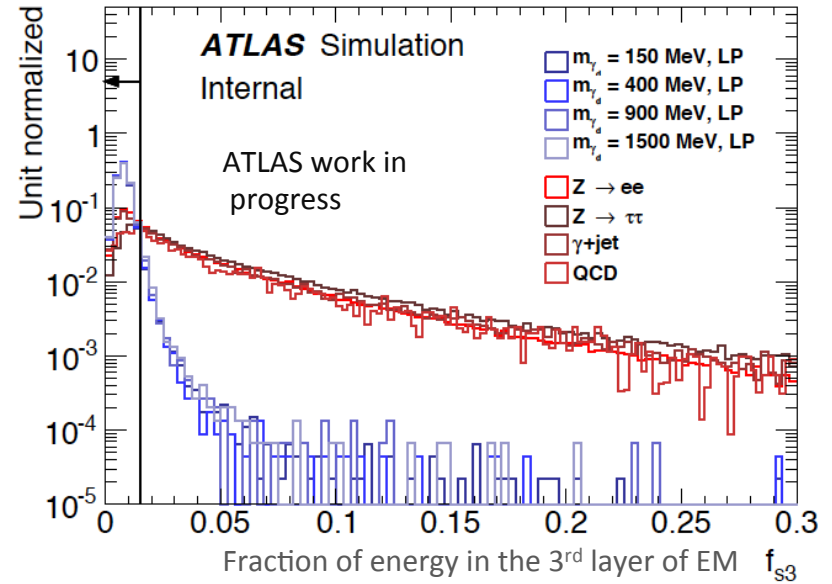
- QCD,  $\gamma$ +jets, dibosons(WW, WZ, ZZ,  $\gamma\gamma$ ), tt, Z+jets, W+jets, Drell-Yan

# Prompt eJ discriminating variables

- Blue shade – signal MC
- Red shades – background MC

Used part of QCD di-jet data for cut optimization

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# Background estimation

## Data-driven method

- Region A – signal region.
- Regions B, C, D – control regions.
- Two relatively uncorrelated variables.
- Data driven background estimation
  - Use number of events in regions B, C and D to estimate the amount of background in region A.

