

# SEARCH FOR DISPLACED LEPTON-JETS IN ATLAS

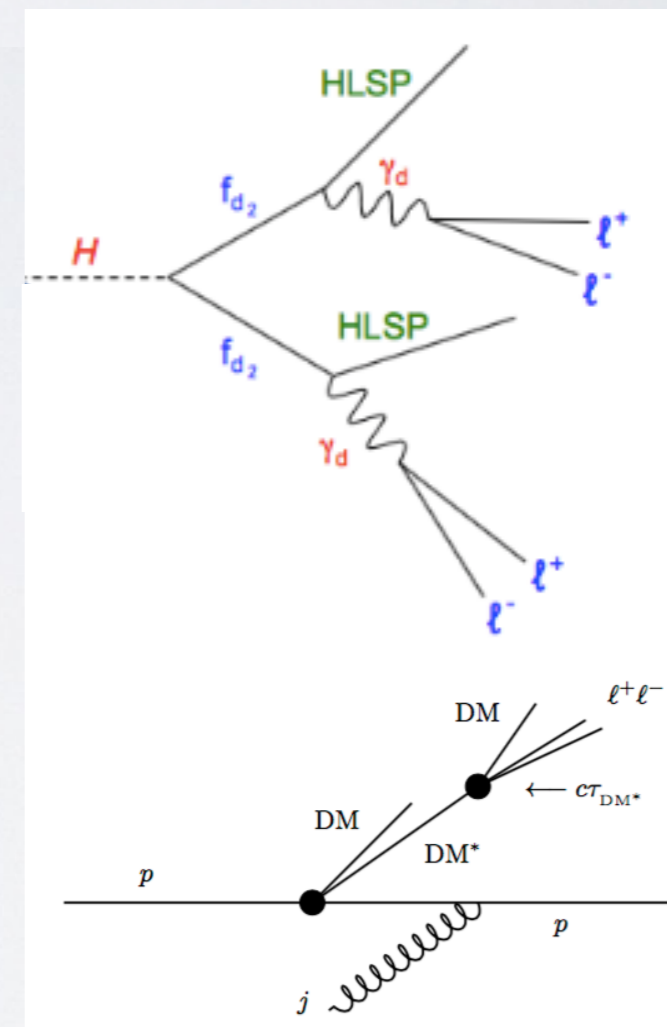
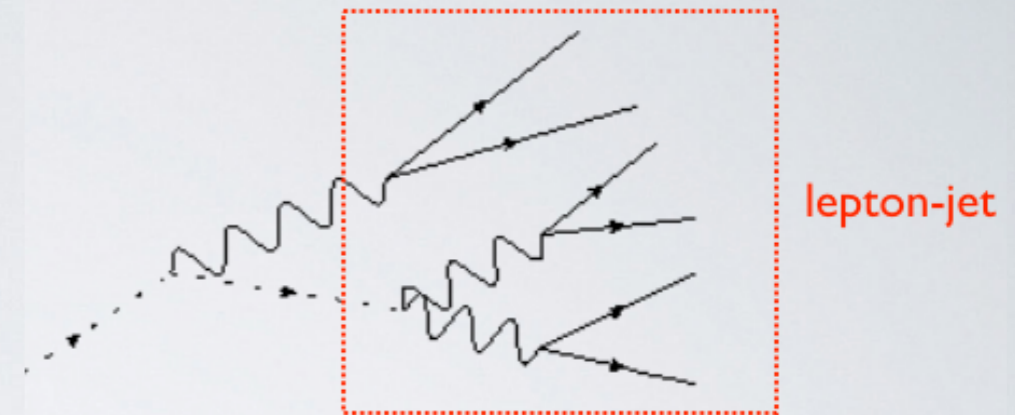


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# DISPLACED LEPTON-JETS

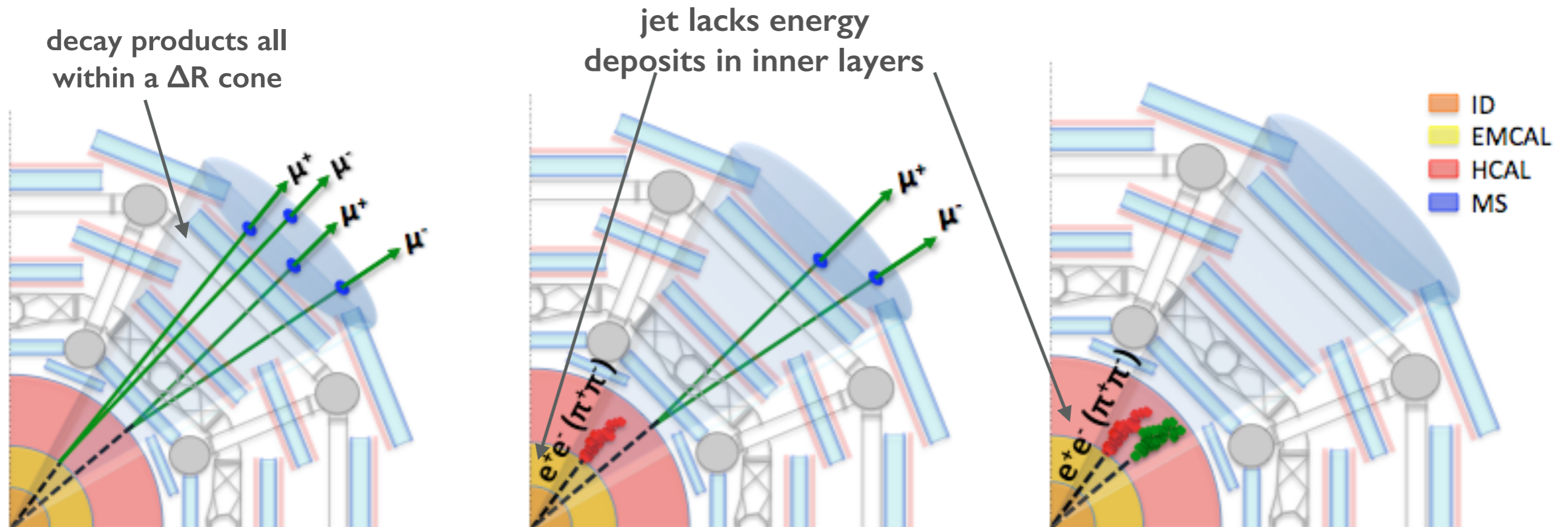
- Lepton-jet: boosted, light dark photon(s) decaying to pairs of electrons/muons/light hadrons in a narrow cone
- Long-lived dark photon  $\Rightarrow$  displaced lepton-jets (dLJ)
- Dark photons appear in a variety of New Physics models and can gain their long lifetimes via a variety of mechanisms (nearly conserved quantities, small couplings, phase-space suppression)
  - Hidden-sector scenarios (FRVZ models, SUSY mediated hidden sector model, Hidden Abelian Higgs model)
    - Higgs-like decays to dLJs (Higgs boson as a discovery tool!)
      - Inelastic thermal relic dark matter
      - ...
- Many dark-photon producing models include DM candidates
  - produced in association with the LLP, mediate interactions, ...
- Final states with displaced, collimated, relatively low  $p_T$  objects  $\rightarrow$  require innovative and dedicated trigger and analysis techniques
- Instrumental background has a significant role  $\rightarrow$  Searches require full understanding of:
  - material effects
  - timing
  - non-collision background



Monte Carlo generation of benchmark processes in MadGraph using UFO produced by theoreticians

# DISPLACED LEPTON-JET RECONSTRUCTION

**Aim:** model independent search  $\Rightarrow$  try to use as much as possible an experimental definition that reproduces a set of signatures



Simple clustering algorithm

- **Muonic dLJs:**  $\geq 2$  Muons in a  $\Delta R$  cone + veto on jets
- **Mixed dLJs:**  $\geq 2$  Muons + jets in a  $\Delta R$  cone
- **Hadronic dLJs:** jet with low em fraction to reduce the QCD background (select decays in HCAL) + veto on muons in a  $\Delta R$  cone

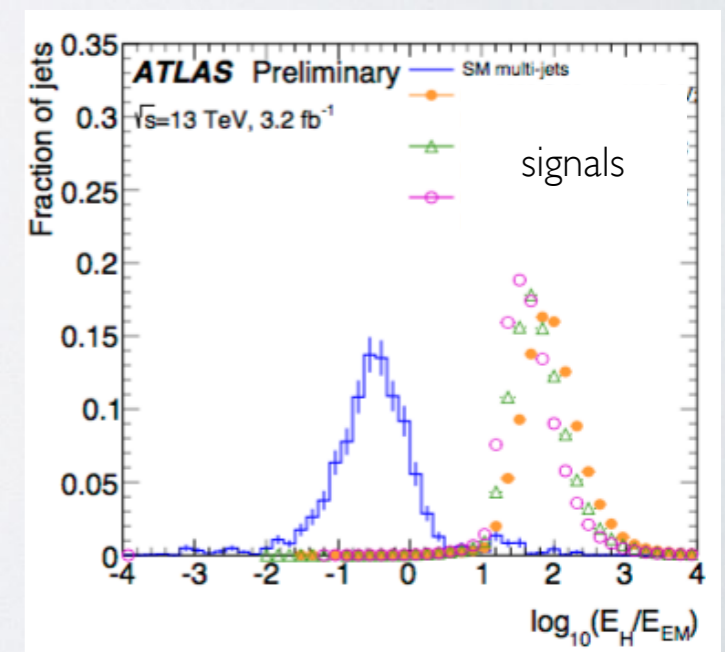
**Muon constituents:**

- tracks reconstructed in Muon Spectrometer without connecting track in Inner Detector

**Jet constituents:**

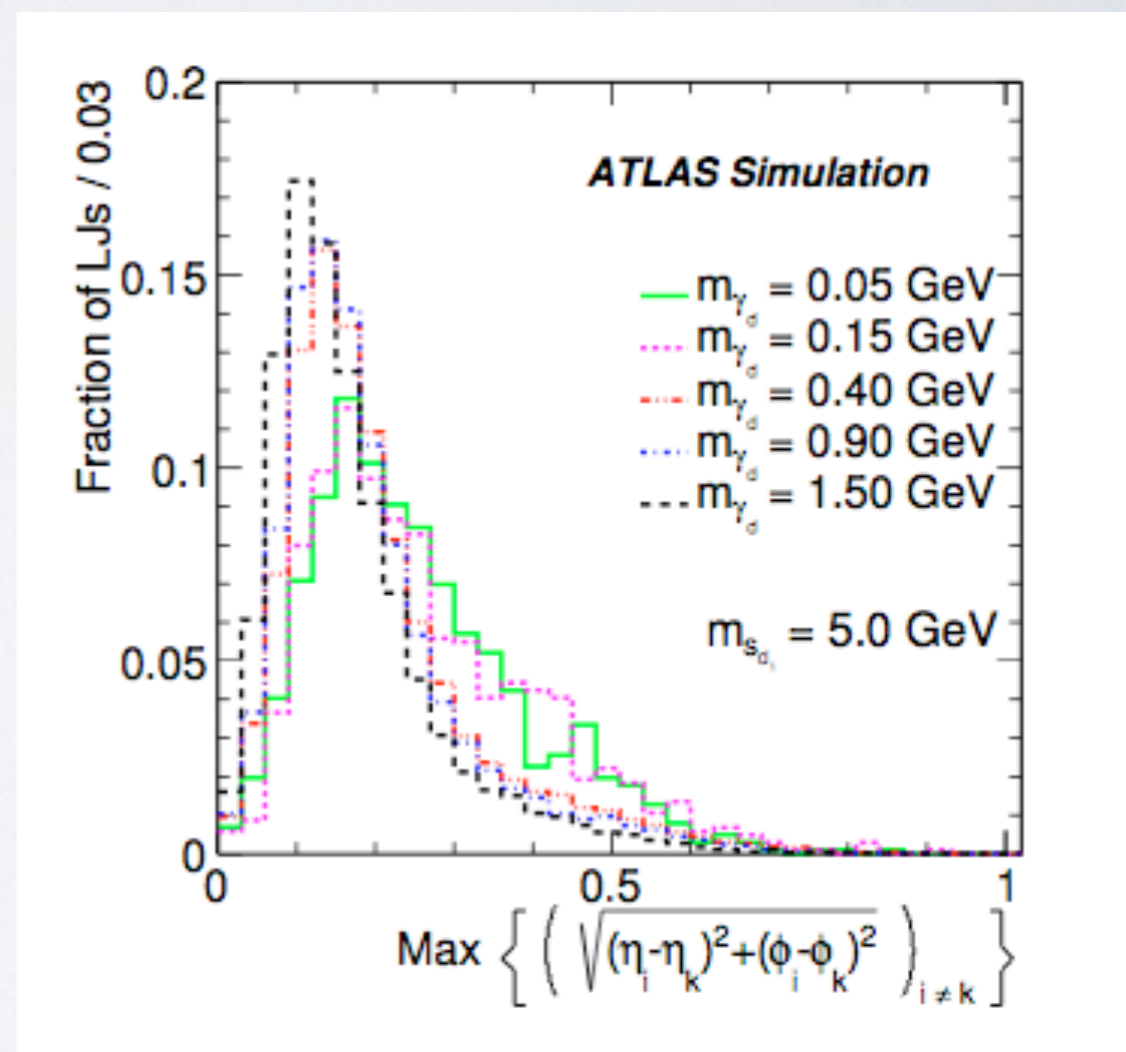
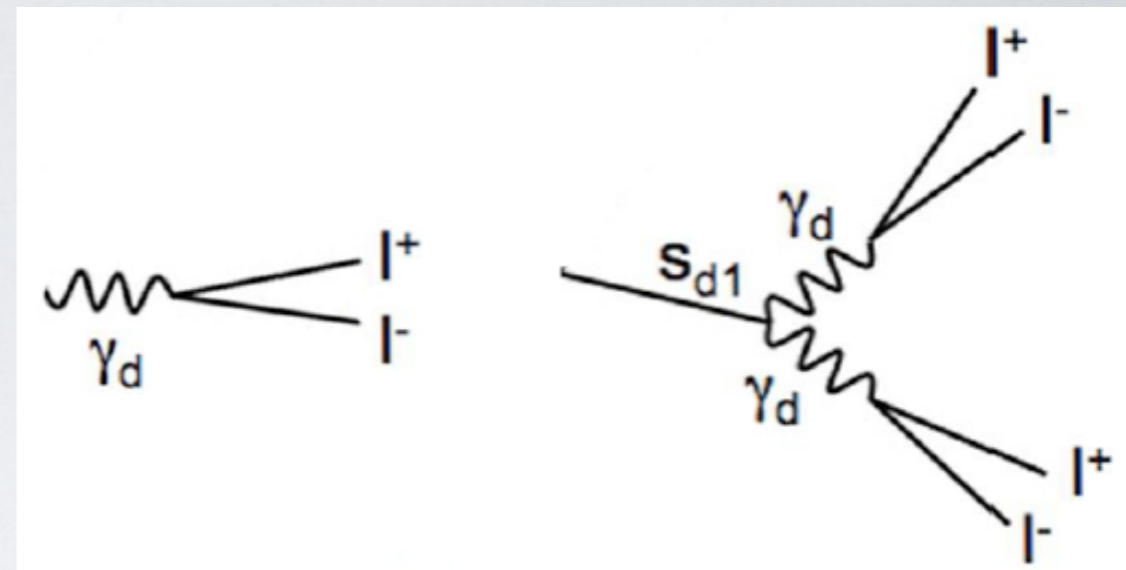
- standard antiKt04 jets

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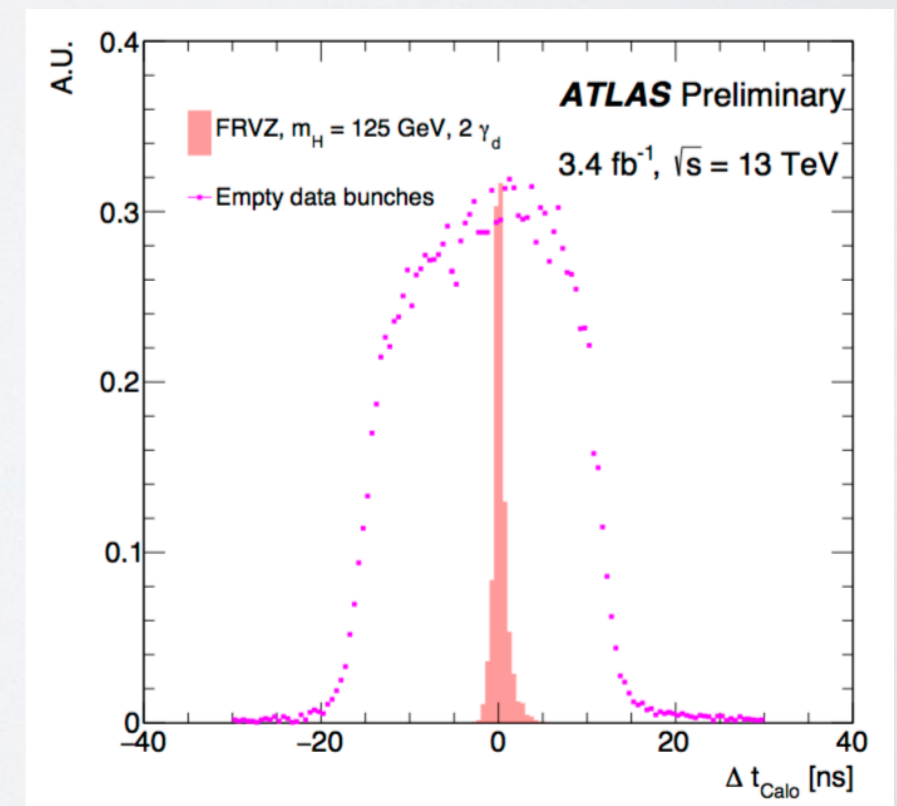
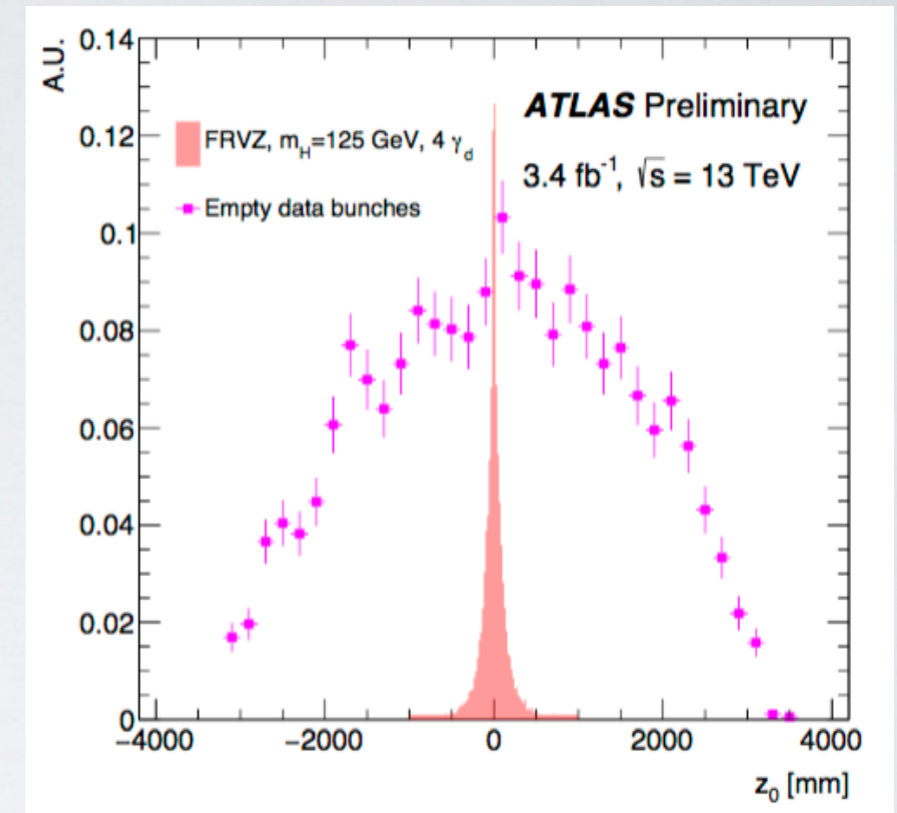
# LJ GUN MONTE CARLO TOOL

- Simulates dLJs with one or two dark photons varying the mass, the transverse momentum and the lifetime in the parameter space allowed by theory prediction
- Very useful tool to study the dLJ signatures in the detector
- Allows to determine detector response
  - As a function of various dLJ observables (composition, lifetime, opening angle,  $p_T$ )
  - For different models that produce dLJs
- LJ gun MC samples valuable for finding suitable set of dLJ selection cuts, estimating the corresponding detection efficiency, and defining the parameter space we can access
  - Used for production of efficiency tables as a function of decay distance and transverse momentum
  - Constrain theory models predicting dLJs



# BACKGROUNDS

- Backgrounds to dLJ signature
  - QCD multi-jets
  - Cosmics
- Discriminant variables:
  - QCD multi-jets  $\Rightarrow$  jet em fraction, width and jet vertex tagging, track isolation
  - Cosmics  $\Rightarrow$  jet timing, muon impact parameter
- Define cuts on discriminant variables using
  - Signal samples from dLJ Monte Carlo gun
  - QCD data control sample
  - Events in EMPTY bunches
- All sources of residual background estimated using data-driven methods

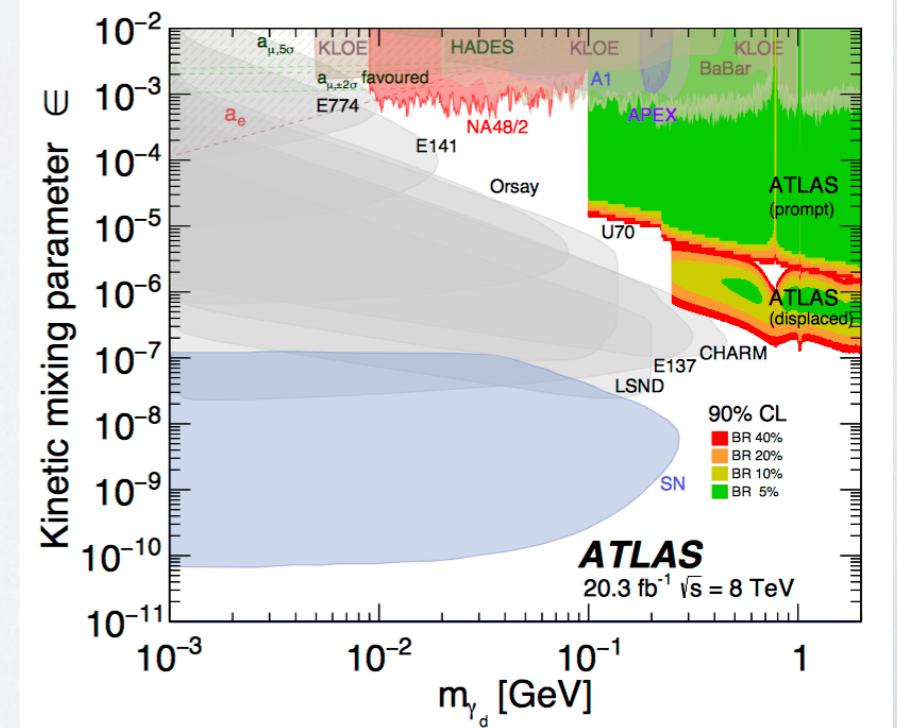
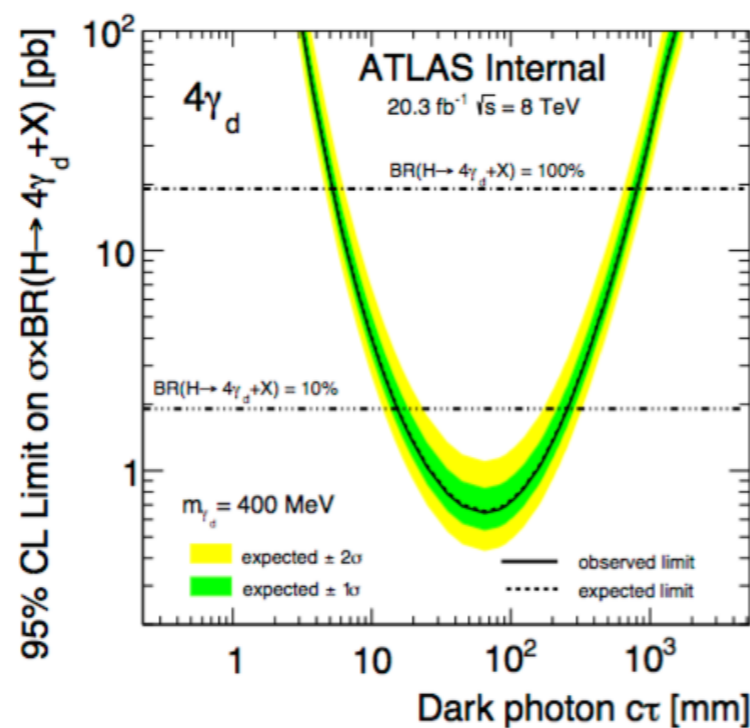
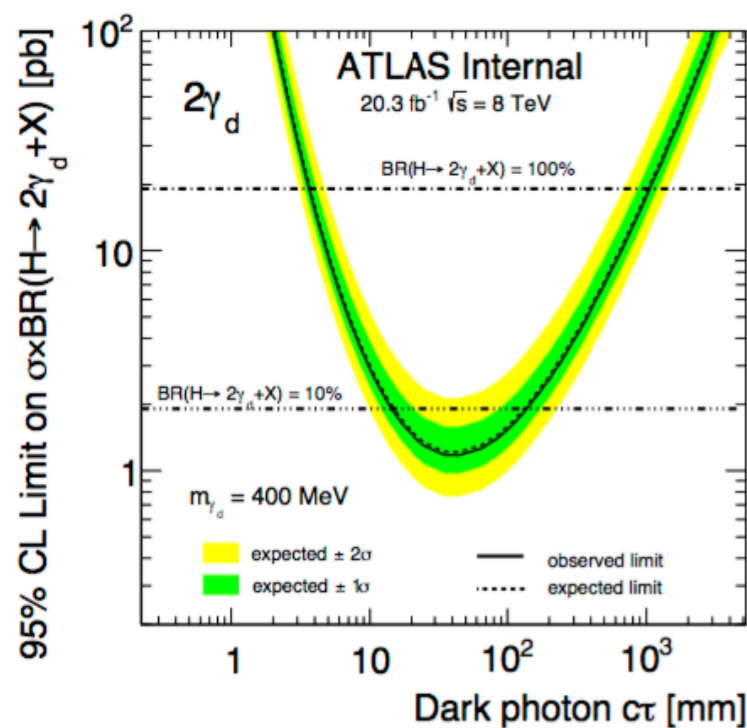


# RUN I: RESULTS

JHEP 11 (2014) 088  
PLB 721 (2013) 32

- Search for two back to back dLJs from heavy particle decay in 20.7/fb 8 TeV data
- Triggers:
  - Multi-muon Muon Spectrometer MS-only trigger: 3mu6\_MSonly
    - selects dLJs with muon content (not a single dLJ trigger due to low granularity of LI muon trigger)
  - calorimeter ratio trigger - jet with no em fraction of energy
    - selects dLJs with electrons/pions produced in HCAL
- Final results from search
  - interpretation in the Hidden-Sector FRVZ model: 125 GeV Higgs decays to long-lived neutral dark photons forming the dLJs
    - limits are set on  $\sigma \times BR$  of the signal as a function of the proper lifetime of the dark photons
  - Exclusion limits in the dark matter plot in the hypothesis of the Higgs portal model
  - Detection efficiency tables obtained with the dLJ gun Monte Carlo (<https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2013-22/>)
    - Useful for “recasting” analysis using somewhat different model assumptions

← single dLJ trigger!



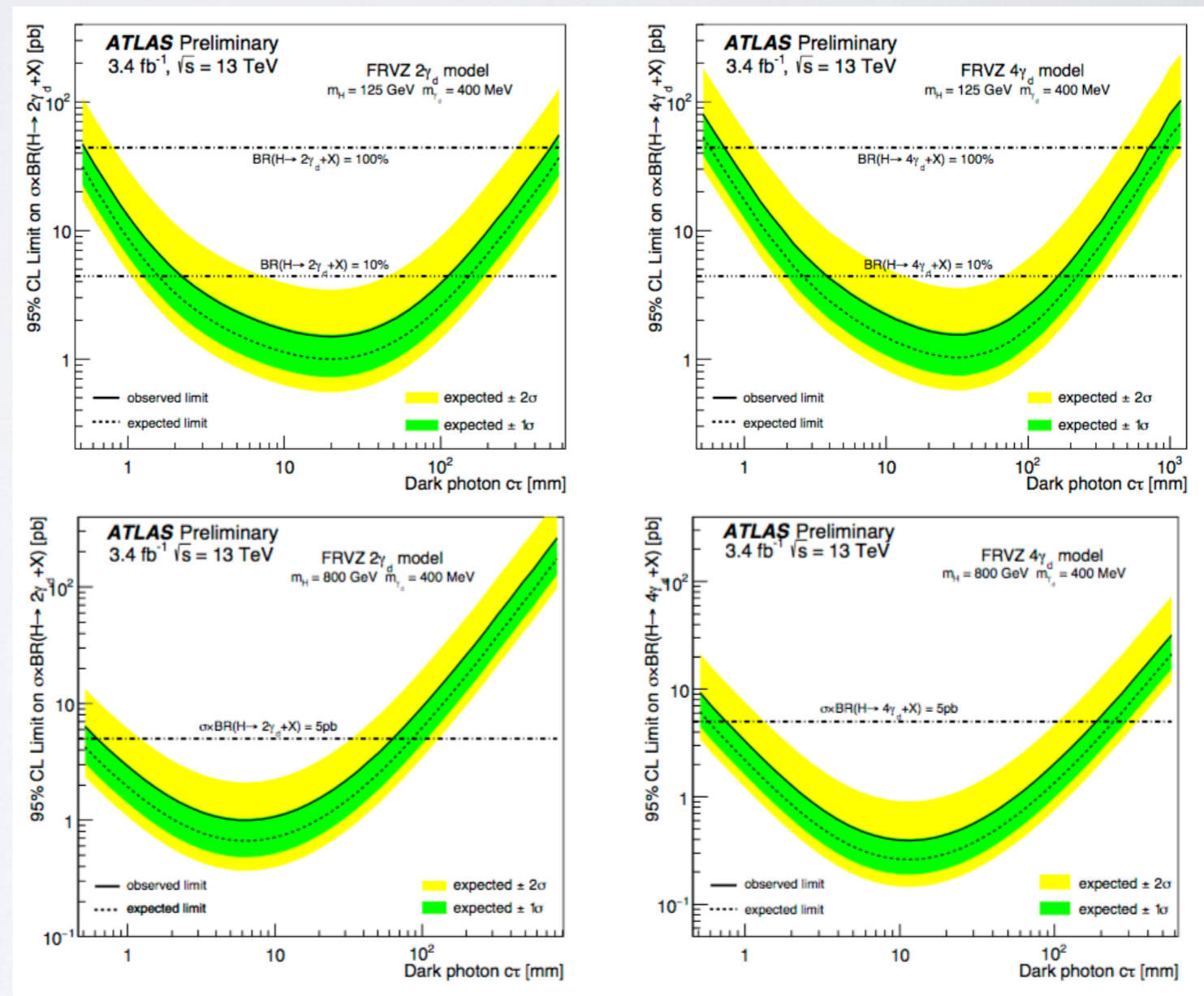
# RUN 2: PRELIMINARY RESULTS

ATLAS-CONF-2016-042

- Improved close-by muon track reconstruction
  - tracks sharing hits were rejected!
- Improved trigger efficiency by adding a specialised trigger for close-by muons
  - Muon narrow scan trigger: 20 GeV LI muon confirmed at HLT as a MS-only muon + a HLT MS-only second-leg 6-11 GeV muon in a 0.5 cone around the first muon ← single dLJ trigger!

- Search for two back to back dLJs from heavy particle decay in 2015 data (3.4/fb) with results interpreted in the FRVZ model

- limits set on  $\sigma \times BR$  of the signal as a function of the proper lifetime of the dark photons are comparable or even better of the RUN 1 results but with a factor  $\sim 6$  less statistics
- limits also set on a 800 GeV heavy scalar boson decaying to dLJs



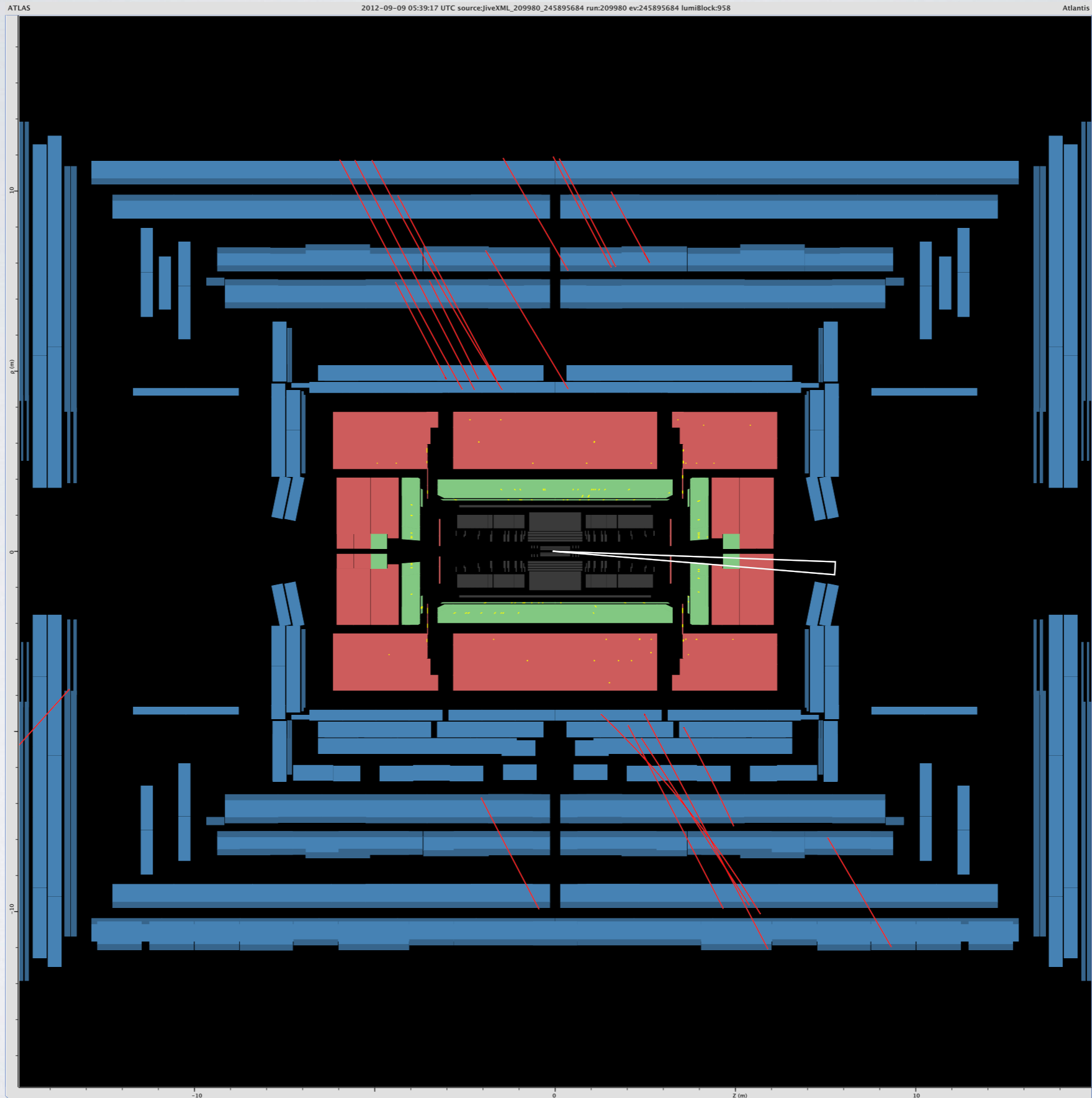
# CONCLUSIONS

- ATLAS is carrying out a very interesting analysis program in searching for dLJs with already two published papers and 1 CONF-NOTE
  - such searches require active engagement of the authors with analysis for a long time (development of peculiar trigger and reconstruction techniques, background rejection and estimation, systematics errors)
- The Run 2 ongoing analysis aims to improve improve global sensitivity of the search and extend its coverage to more final states
  - Results expected this Summer
- Trigger is the major issue for the future of such analysis



EXTRA

# COSMICS EVENT



# BIB EVENT

ATLAS

2010-10-03 15:30:22 CEST source:JiveXML\_166142\_33488938 run:166142 ev:33488938 lumiBlock:204

Atlantis

