Search for dark photons decaying to lepton jets with the CMS experiment

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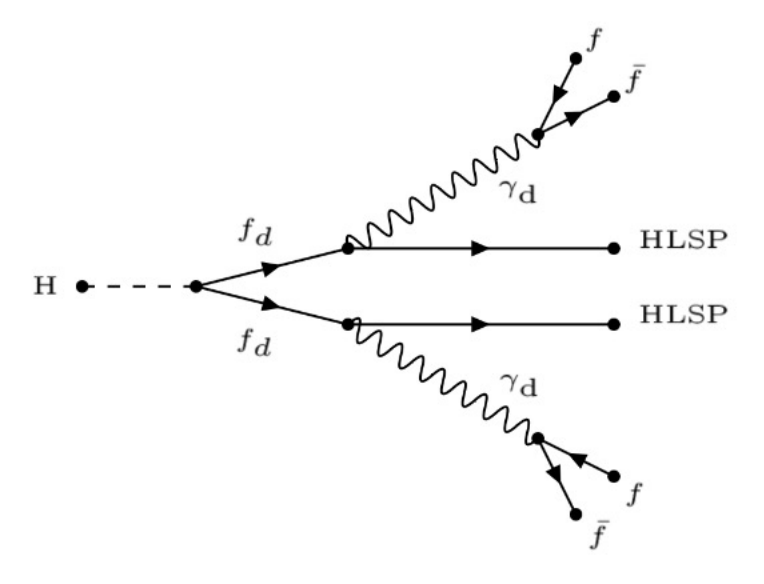
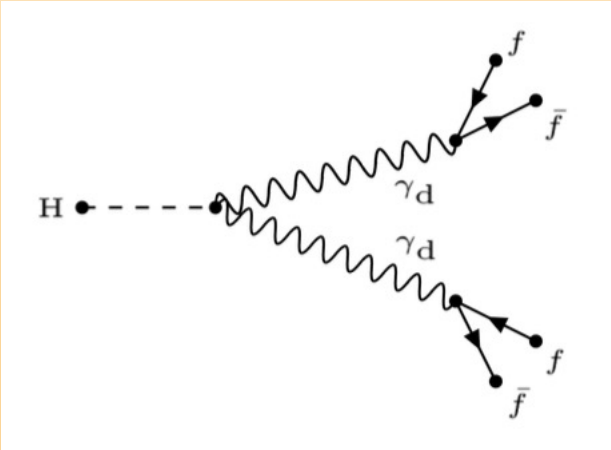
Models of dark photon production from BSM higgs



Falkowski-Ruderman-Volansky-Zupan
(FRVZ) model JHEP 1005:077,2010

f_d dark fermion
γ_d dark photon
HLSP hidden lightest stable particle (fermion)
f standard model fermion

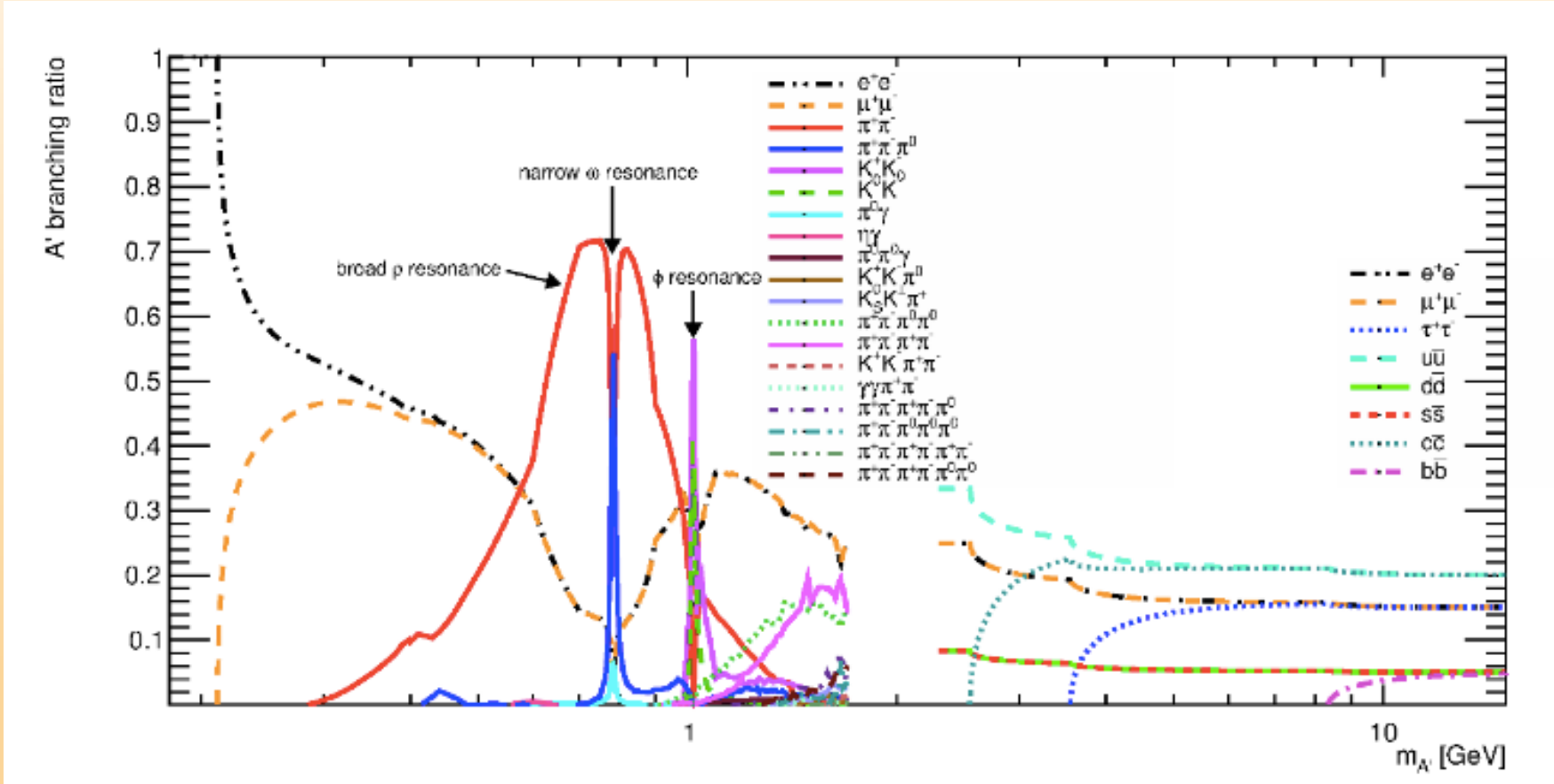


Hidden Abelian Higgs Model (HAHM)
D. Curtin, R. Essig, S. Gori and J. Shelton, JHEP 02 (2015) 157

Figures from ATLAS Collab., JHEP 06 (2023) 153

Dark photon branching fractions to SM particles

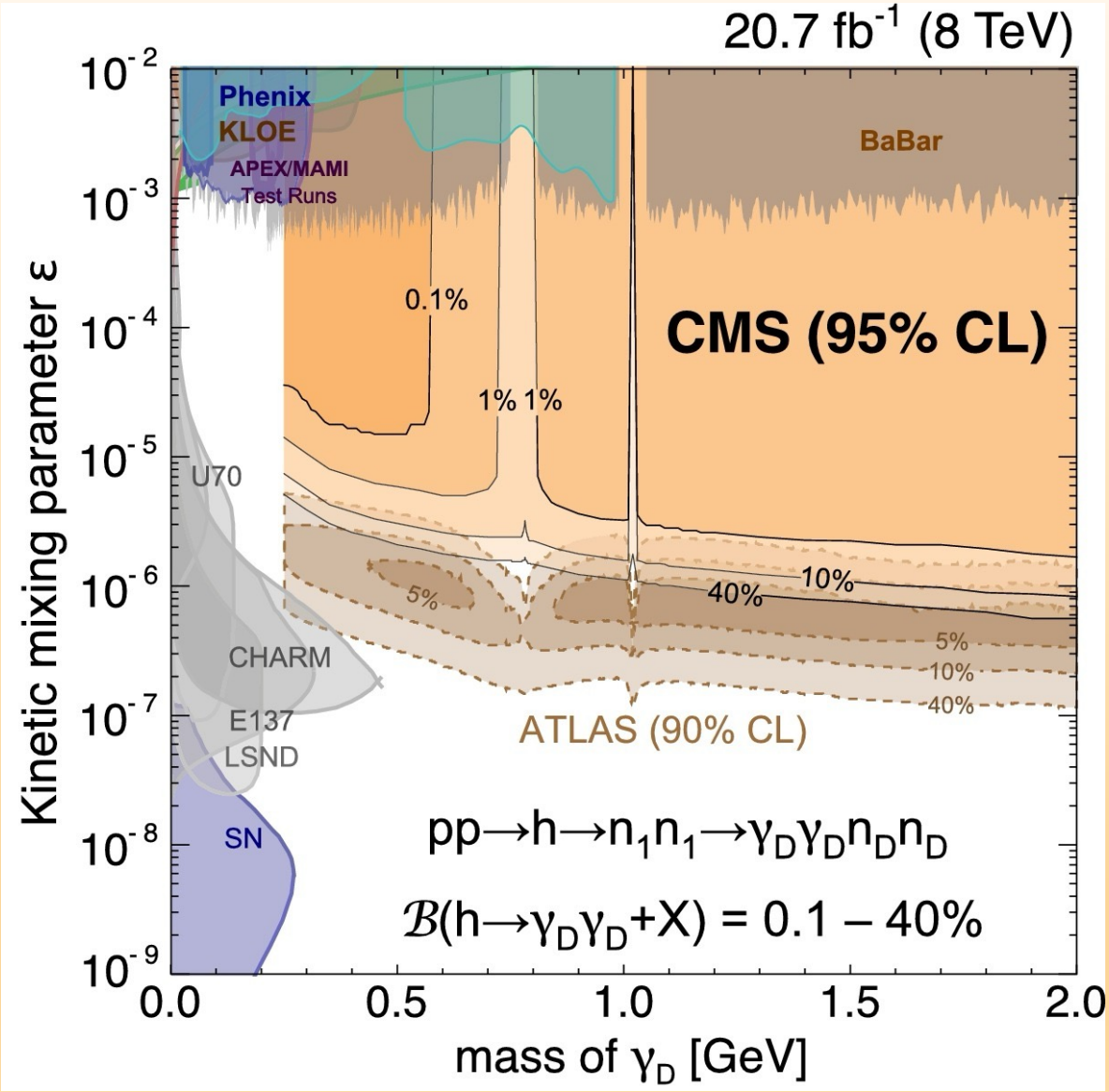
Malte Buschmann, Joachim Kopp, Jia Liu, Pedro A. N. Machado, "Lepton Jets from Radiating Dark Matter," JHEP 07 (2015) 045



Existing searches for prompt dark photons

CMS Collab .
Physics Letters B 752 (2016) 146–168

ATLAS Collab.
JHEP 02 (2016) 062.



Full Simulation Trigger Study for CMS HL-LHC detector

CERN-LHCC-2021-007, CMS-TDR-022.

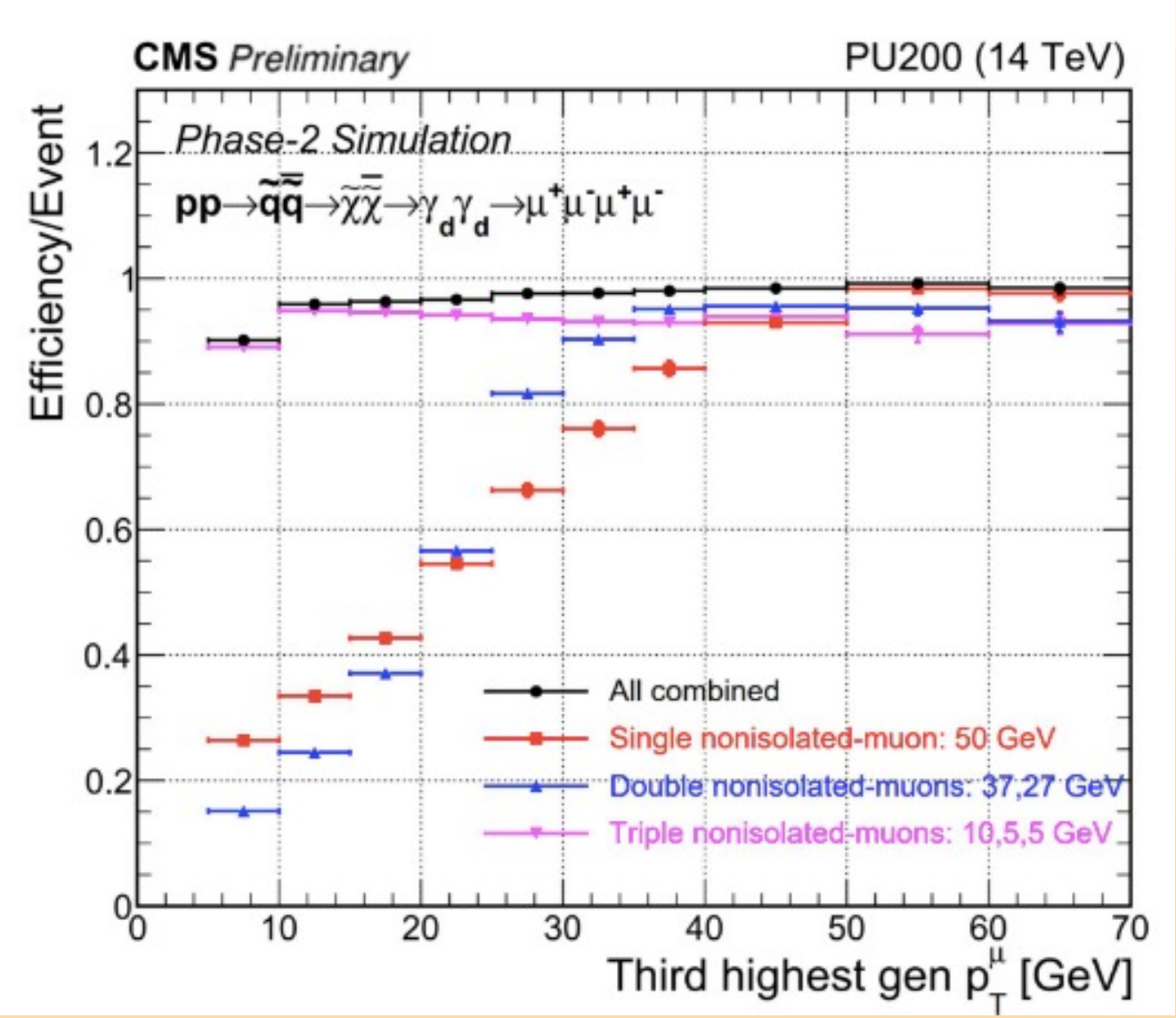
SUSY model, Cheung, Ruderman, Wang, and Yavin JHEP 04 (2010) 116

γ_d -> μ+μ-

γ_d mass 1 GeV

muon |η|<2.1

80k events



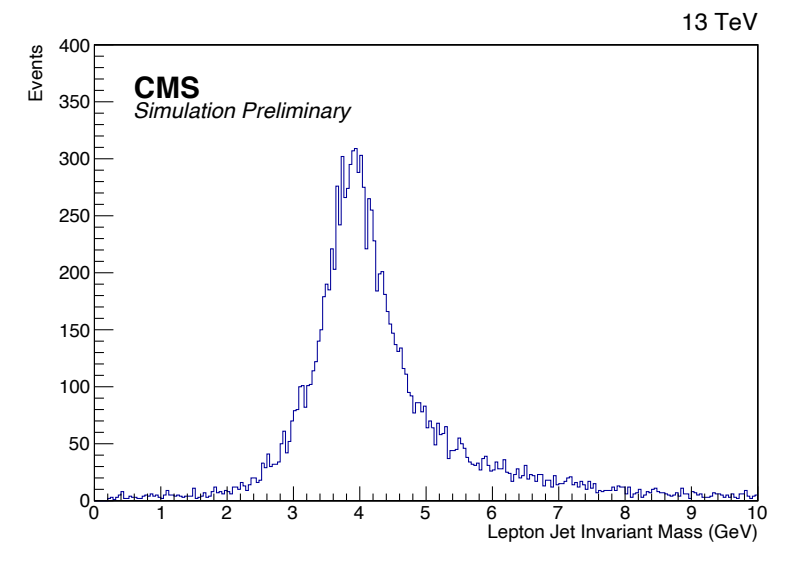
CMS Run 2 Full Simulation: Reconstructed Mass of Dark Photon

FRVZ model
- BSM higgs mass 1000 GeV
- pair of dark photons

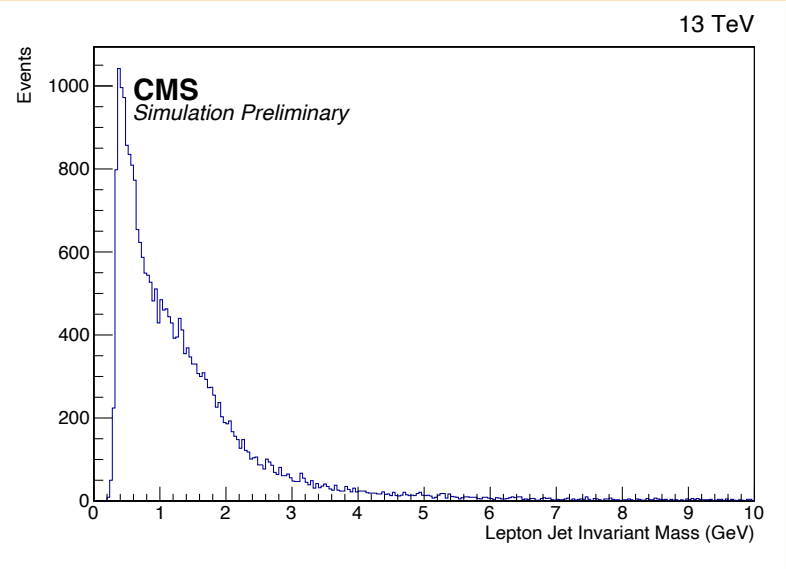
Lepton jet reconstruction
- reconstructed muons with pT > 5 GeV
- jet cone size ΔR < 0.01

Triggers
- Single muon: One isolated muon with pT > 24 GeV
- Double muon: One muon pT > 27 GeV, one muon pT > 37 GeV

Dark Photon Mass = 4 GeV



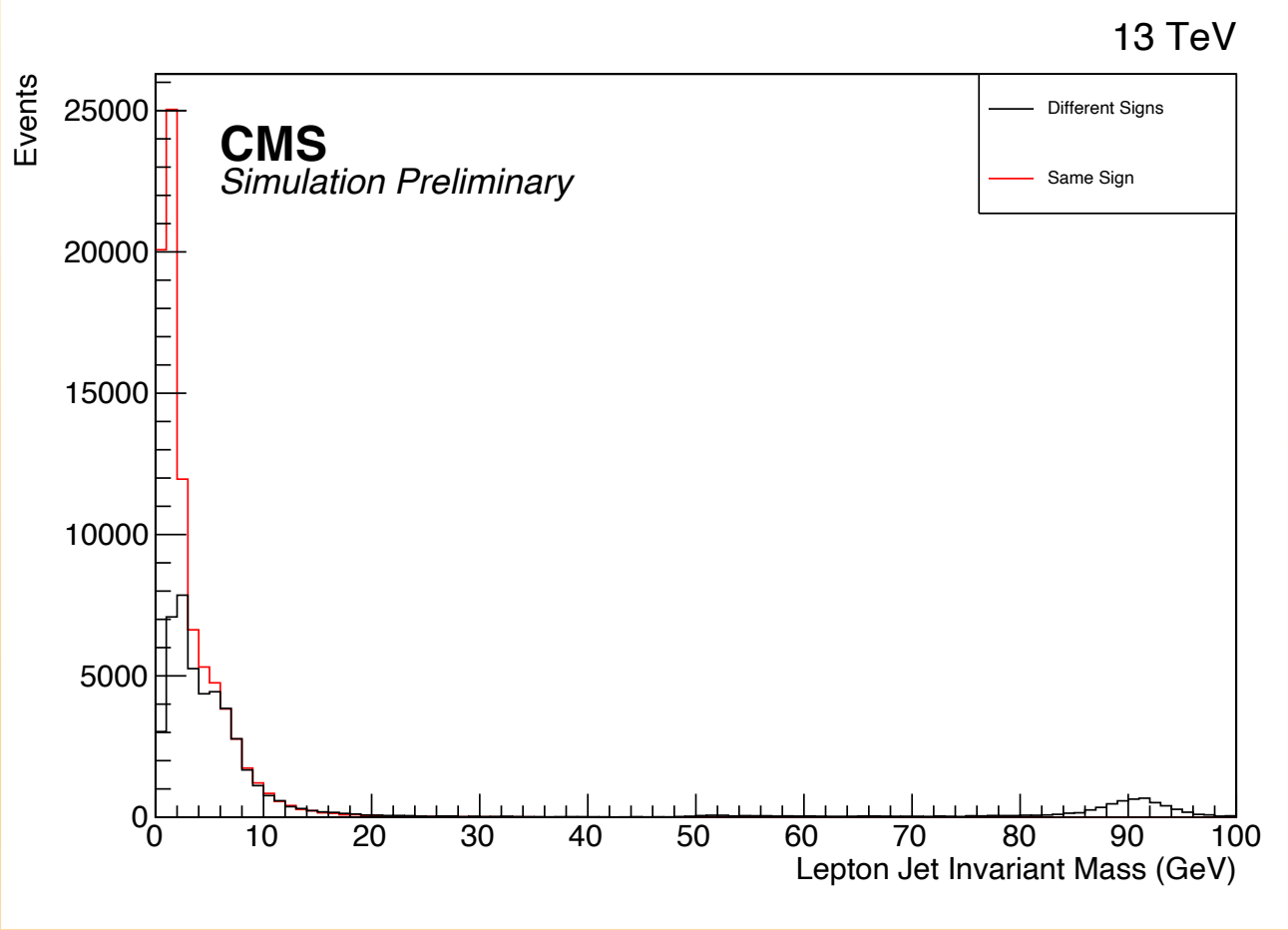
Dark Photon Mass = 0.3 GeV



CMS Run 2 Full Simulation: Drell-Yan Production

Simulation sample corresponds to Run 2 integrated luminosity of 137 fb^{-1}

- no trigger requirement
- each muon: $p_T > 5$ GeV
- reconstructed jet requires two muons with $\Delta R < 0.50$



Multivariate Selection for Dark Photon Signal with Drell-Yan Background

Run 2 MC, full simulation

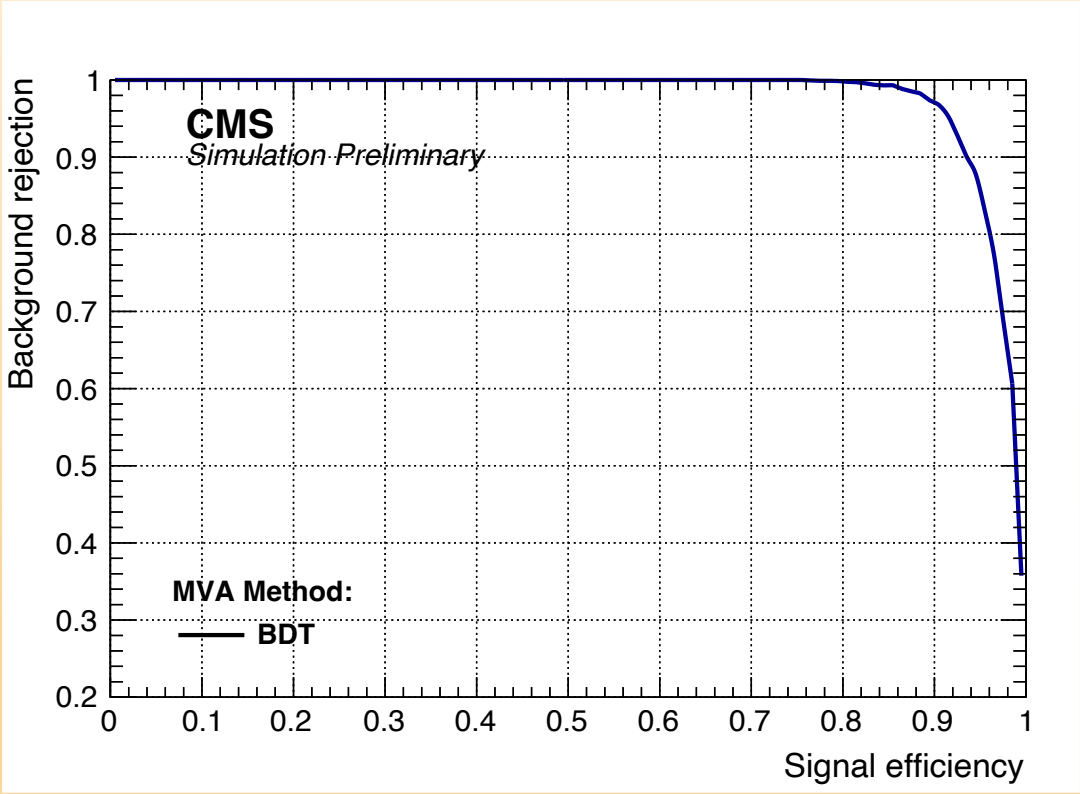
FRVZ model,
γ_d mass 0.5 GeV,
higgs mass 1000 GeV

signal efficiency = efficiency per jet

BDT = boosted decision tree

MVA variables:
- # of particles in jet
- maximum single particle isolation of jet particles
- η of jet
- ΔR
- ΔpT (between leading pT muons in jet)

no trigger selection
each muon pT > 5 GeV, no charge selection
ΔR < 0.50 for muon pairs in jet
most events have one reconstructed jet



Summary of Results

- The shape of the reconstructed dark photon mass distribution is studied over the range from 0.1 GeV to 4.0 GeV.
  - At low mass the distribution has a tail-like structure, while at high mass, a peak shape is evident.

- The normalized mass distribution of standard model Drell-Yan events is compared between opposite sign and like sign muon pairs, suggesting a possible control sample for a blind analysis.

- A multivariate event selection using the boosted decision tree method provides suppression of Drell-Yan background by better than a factor of 100 while retaining good signal efficiency.