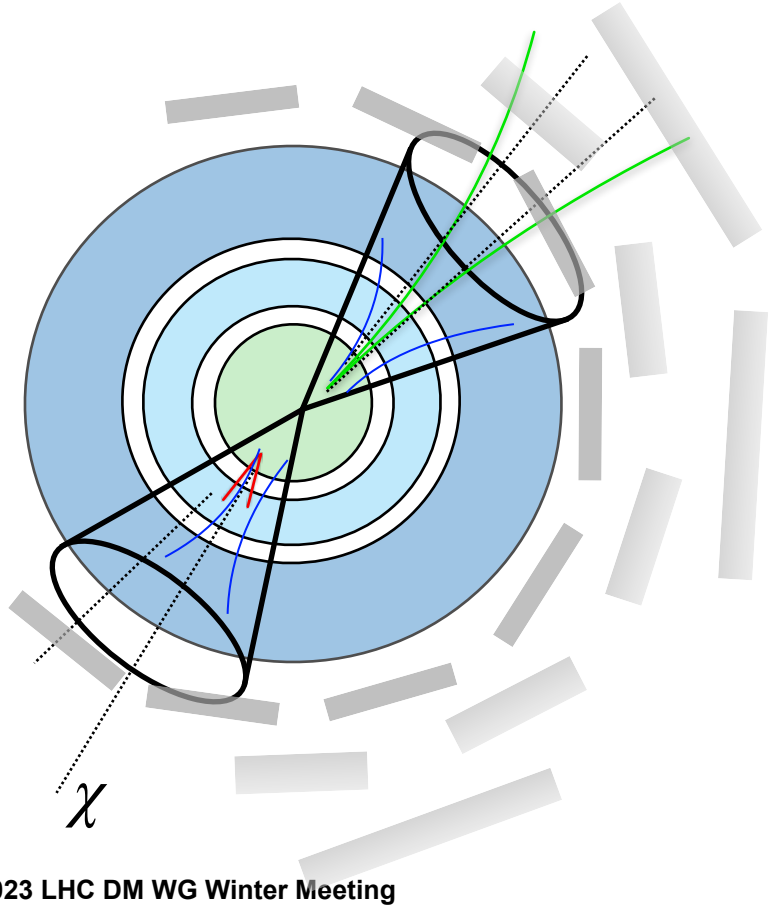


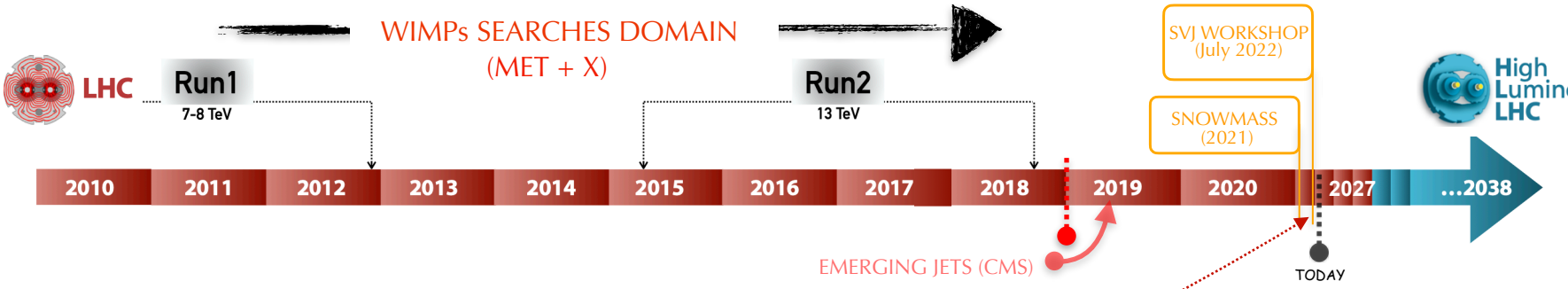
LEPTONS-ENRICHED SIGNATURES FOR SEMI-VISIBLE JETS

CESARE CAZZANIGA (ETH Zurich)

On behalf of the working group including:

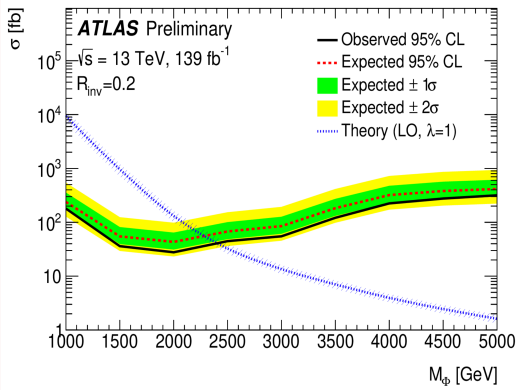
H. Beauchesne, A. de Cosa, C. Doglioni, T. Fitschen, G. Grilli di Cortona, Z. Zhou

QCD-LIKE DS SEARCHES @ THE LHC



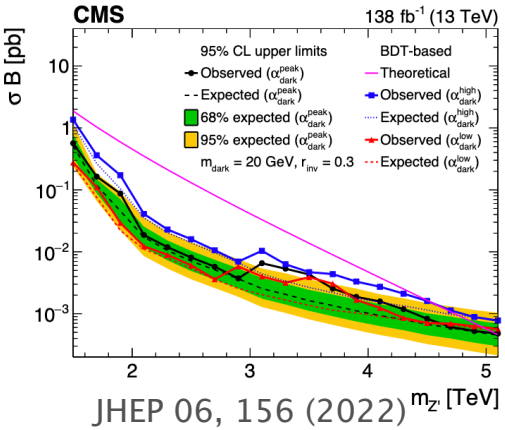
SEMI-VISIBLE JETS (SVJ)

t-channel



ATLAS-CONF-2022-038

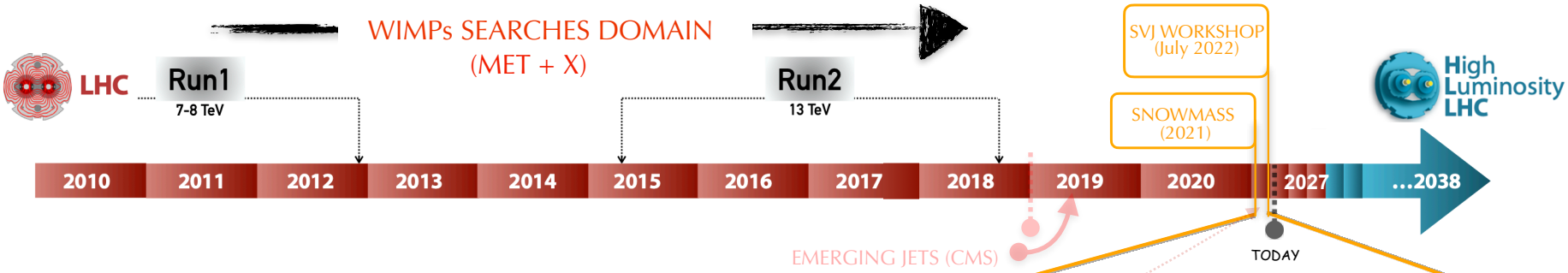
s-channel



JHEP 06, 156 (2022)

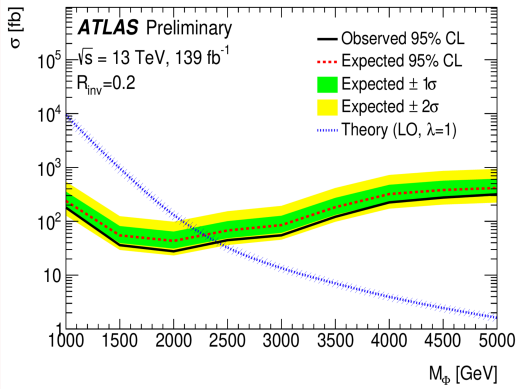
~~STATUS~~ → PERSPECTIVE

QCD-LIKE DS SEARCHES @ THE LHC



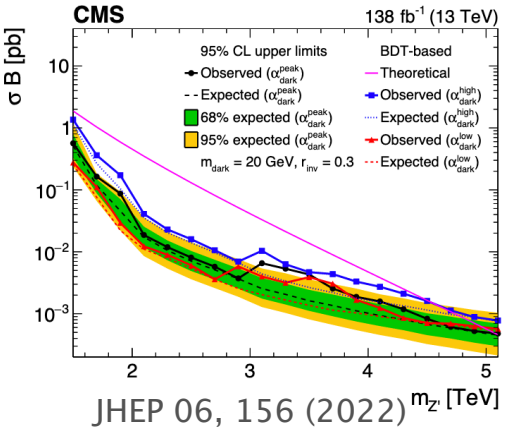
SEMI-VISIBLE JETS (SVJ)

t-channel



ATLAS-CONF-2022-038

s-channel



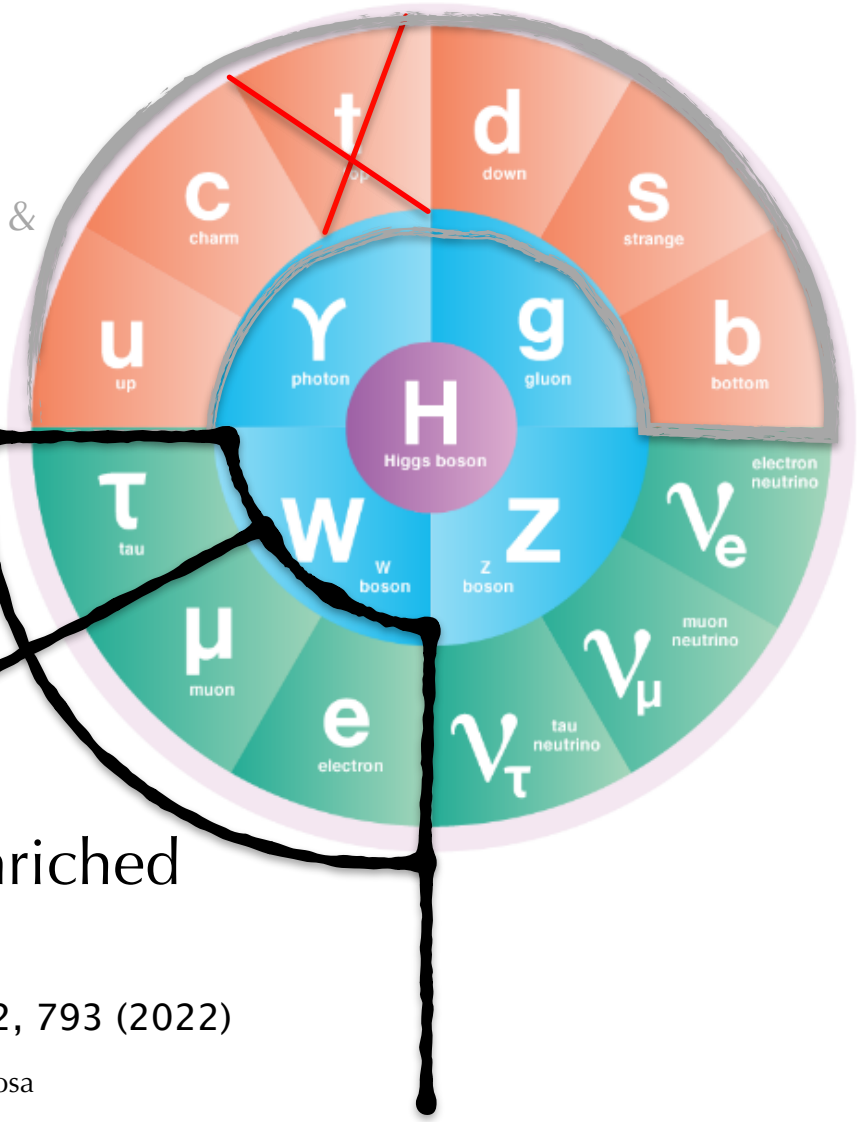
JHEP 06, 156 (2022)

PERSPECTIVE

Vast landscape of models being investigated,
many others waiting in the drawer,
and lots of others still not being thought of …

OUTLINE

FULLY HADRONIC SVJ:
EXPLORED THEORETICALLY &
EXPERIMENTALLY



OUR FOCUS

τ leptons-enriched signatures

arXiv:2212.11523v1
(to be submitted to EPJ C)

H. Beauchesne, C. Cazzaniga,
A. de Cosa, C. Doglioni,
T. Fitschen, G. Grilli di Cortona,
Z. Zhou

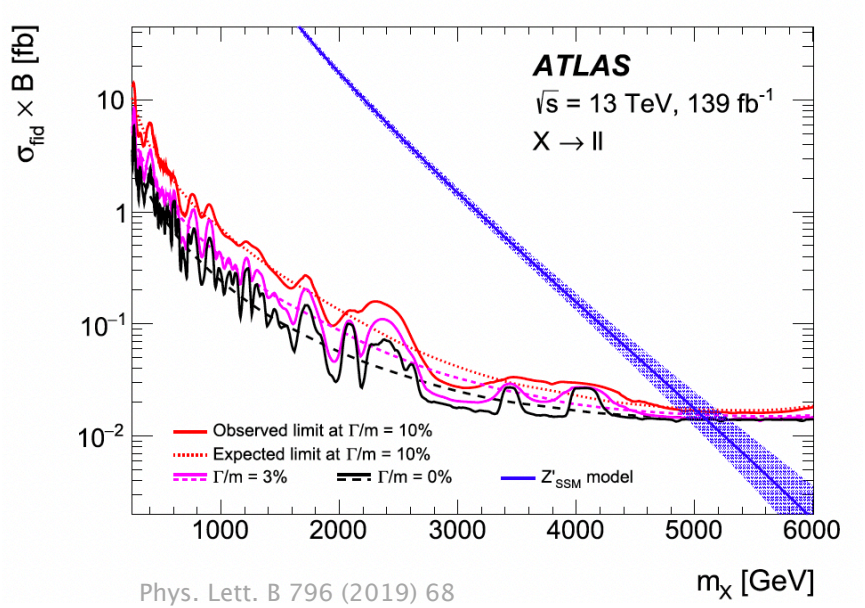
Leptons-enriched signatures

Eur. Phys. J. C 82, 793 (2022)

C. Cazzaniga, A. de Cosa

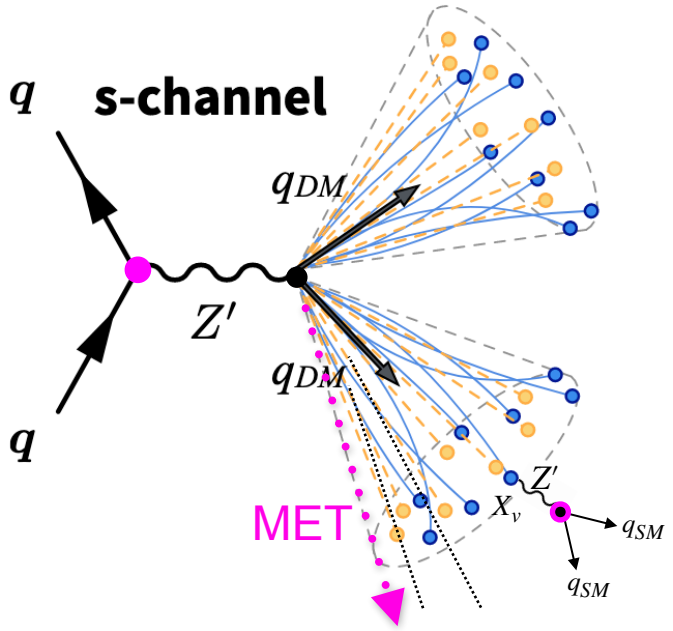
LIMITATIONS OF THE CURRENT SVJ MODEL

HIGH MASS DI-LEPTON SEARCH



Phys. Lett. B 796 (2019) 68

SIMPLIFIED MODEL



FULLY HADRONIC SVJ (MULTI-JET + $\not{E}_T$)

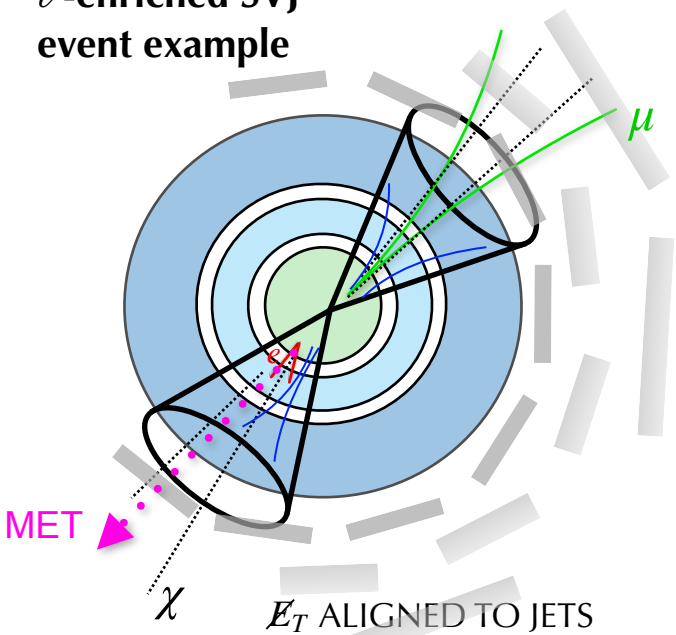
LEPTOPHOBIC (*) Z′ AS MEDIATOR TO EVADE HIGH MASS DI-LEPTON SEARCHES
CONSTRAINTS: FULLY HADRONIC DARK BOUND STATES DECAYS (OFF-SHELL Z′)

(*) constraints on Z′ coupling to leptons (backup)

SIGNATURE-DRIVEN MODEL BUILDING

EXPLOITING THE EXPERIMENTAL HANDLE OF LEPTONS IN SVJ-LIKE SIGNATURE

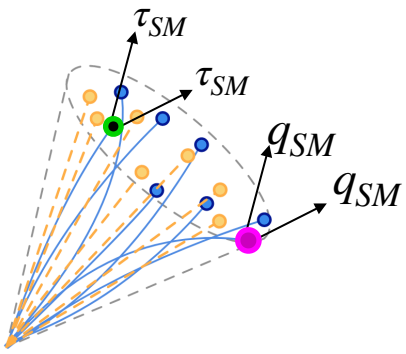
ℓ-enriched SVJ event example



$\not{E}_T$ ALIGNED TO JETS

+ PROMPT LEPTON PAIRS PRODUCED INSIDE HADRONIC JETS

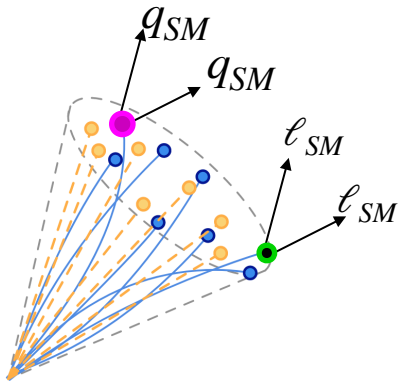
"non-resonant" (Model 1)



SVJ τ-ENRICHED

arXiv:2212.11523v1

resonant e/μ (Model 2)



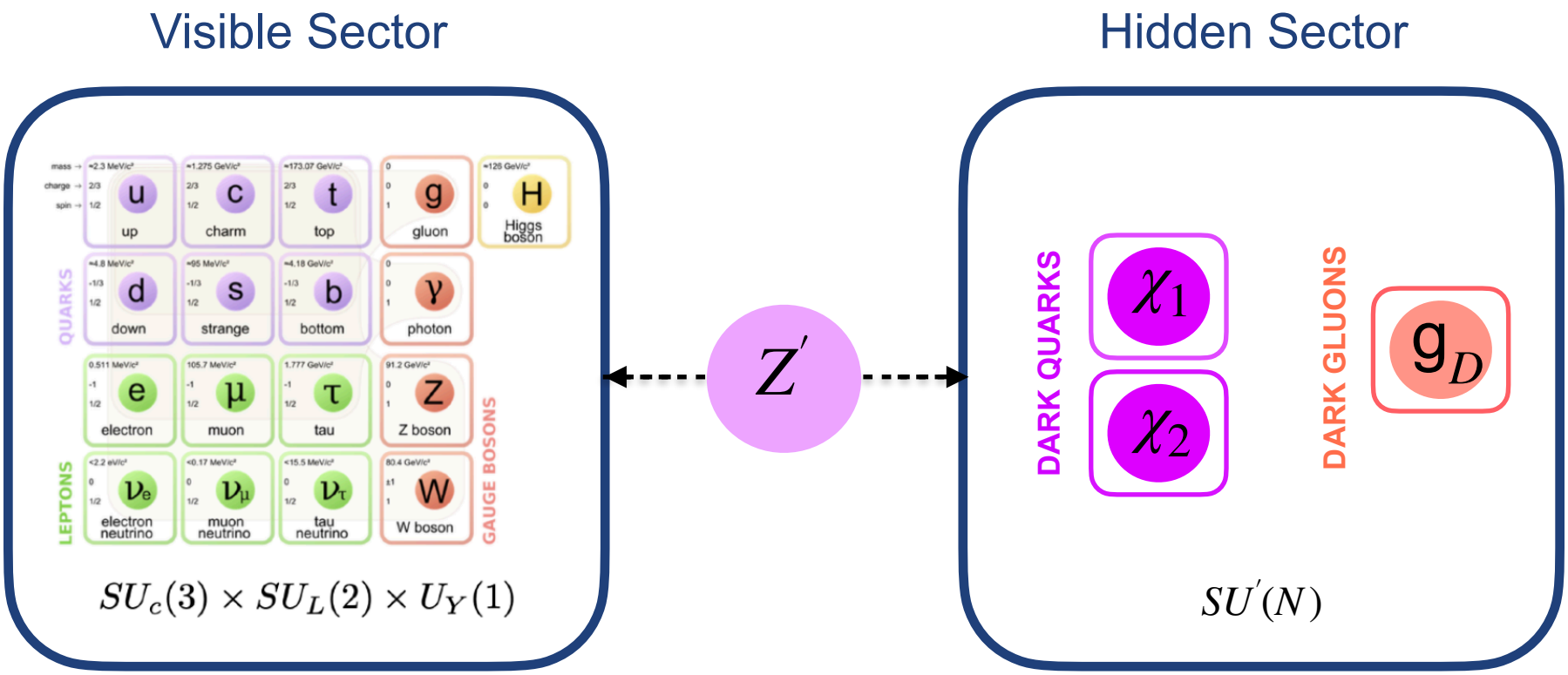
SVJ ℓ-ENRICHED

Eur. Phys. J. C 82, 793 (2022)

SIMPLIFIED MODEL(S) ?

arXiv:2212.11523v1

MODEL 1: SINGLE MESSENGER FIELD



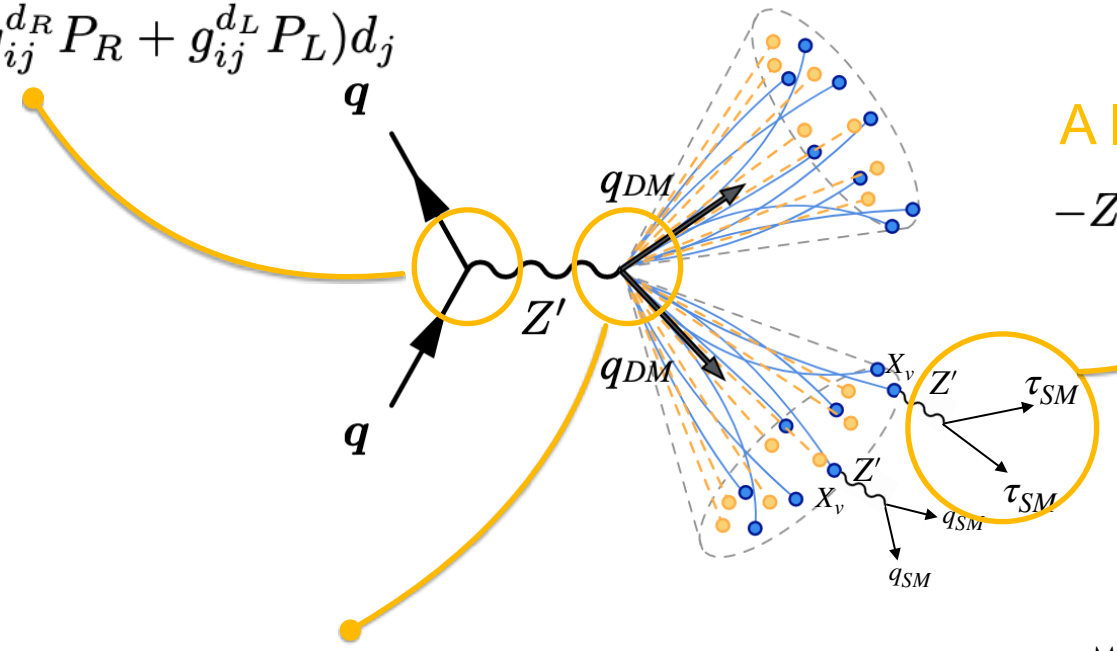
arXiv:2212.11523v1

MODEL 1: SINGLE MESSENGER FIELD

A portal for pp colliders

$$-Z'_\mu \bar{u}_i \gamma^\mu (g_{ij}^{u_R} P_R + g_{ij}^{u_L} P_L) u_j$$

$$-Z'_\mu \bar{d}_i \gamma^\mu (g_{ij}^{d_R} P_R + g_{ij}^{d_L} P_L) d_j$$



A leptonic decay mode

$$-Z'_\mu \bar{e}_i \gamma^\mu (g_{ij}^{e_R} P_R + g_{ij}^{e_L} P_L) e_j$$

A coupling to the dark sector

$$-Z'_\mu \bar{q}_{vi} \gamma^\mu (g_{ij}^{q_{vR}} P_R + g_{ij}^{q_{vL}} P_L) q_{vj}$$

MODEL BASED ON:

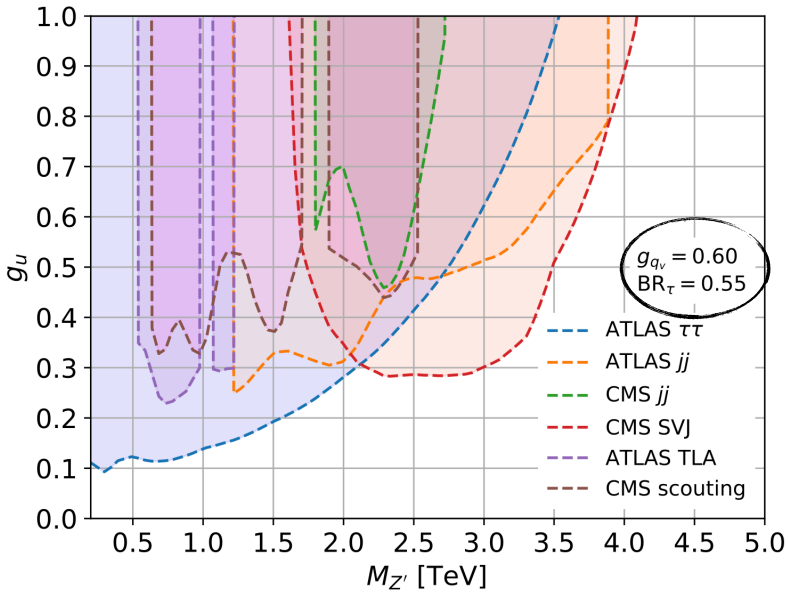
Phys. Rev. D 84, 115006 (2011)

Phys. Rev. D 89, 095033 (2014)

arXiv:2212.11523v1

MODEL 1: PARAMETERS & CONSTRAINTS

Parameter		Description	Benchmark
$M_{Z'}$		Z' pole mass	0.5-5 TeV
r_{inv}	(*)	invisible fraction	0.3
Λ_v		dark confinement scale	10 GeV
m_{π_v}/Λ_v	(**)	pseudo-scalar mass ratio	0.8
BR_τ	(***)	branching to τ leptons	0.15, 0.3 0.55, 0.7



* Neutrinos can be included adding a term $\propto \text{BR}_\tau \times (1 - r_{inv})$

** dark hadron masses set using Lattice QCD fits (Nf = 2, Nc = 3):

$m_{\pi_v} = 8$ GeV $\quad m_{\rho_v} \simeq 25$ GeV $\quad \rho \to \pi\pi$ open

see Eur. Phys. J. C (2022) , and backup

*** effective parameter controlled by the ratio: g_u/g_τ

Constrained by high mass di-lepton searches

COUPLINGS SETTINGS

$$g_{ij}^{d_R} = g_{ij}^{d_L} = g_{ij}^{u_L} = g_{ij}^{e_L} = 0, \quad g_{ij}^{u_R} = g_u \delta_{ij},$$
$$g_{ij}^{e_R} = g_\tau \delta_{i3}\delta_{j3}, \quad g_{ij}^{q_v R} = g_{ij}^{q_v L} = g_{q_v}\delta_{ij}.$$

respect NWA

Allow coupling to third generation leptons

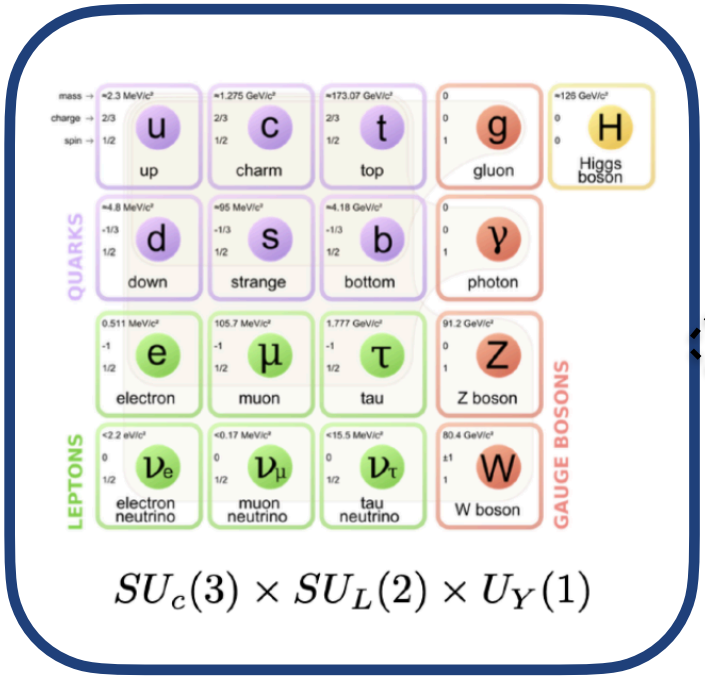
[Phys. Dark Univ. 27, 100365 (2020) JHEP 06, 156 (2022)]

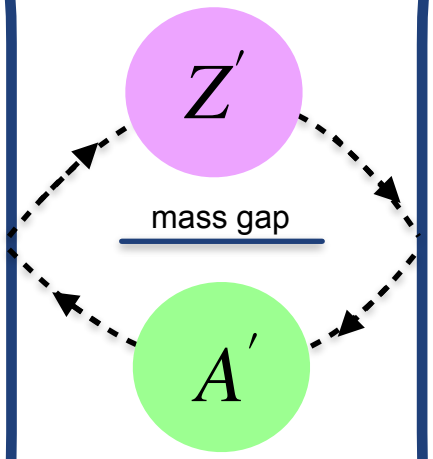
(*) samples generation flow (backup)

Eur. Phys. J. C 82, 793 (2022)

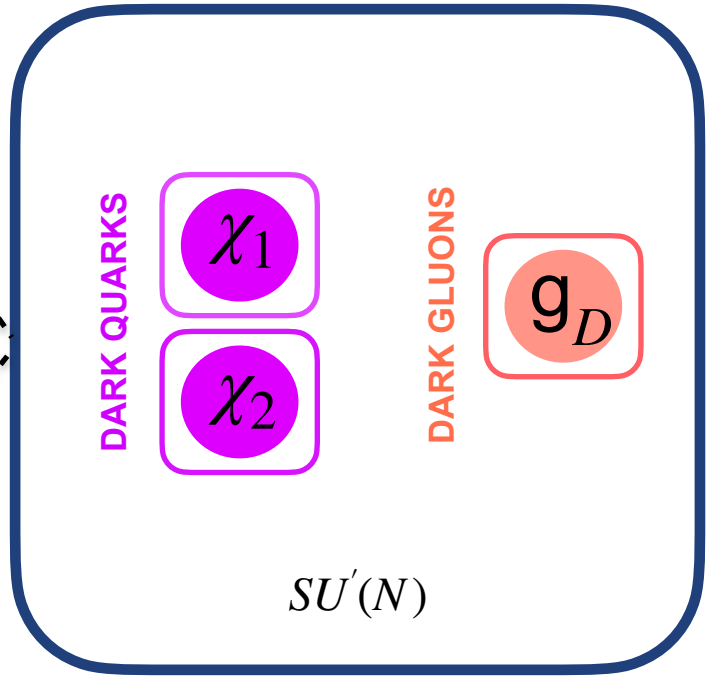
MODEL 2: TWO MESSENGER FIELDS

Visible Sector





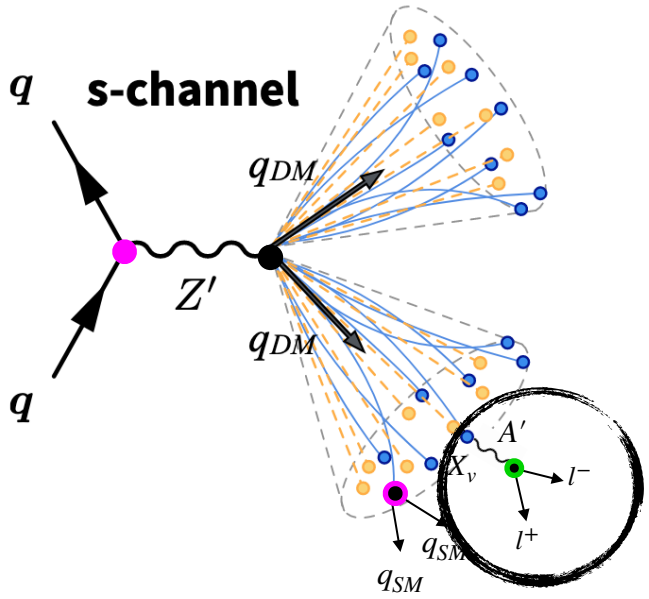
Hidden Sector



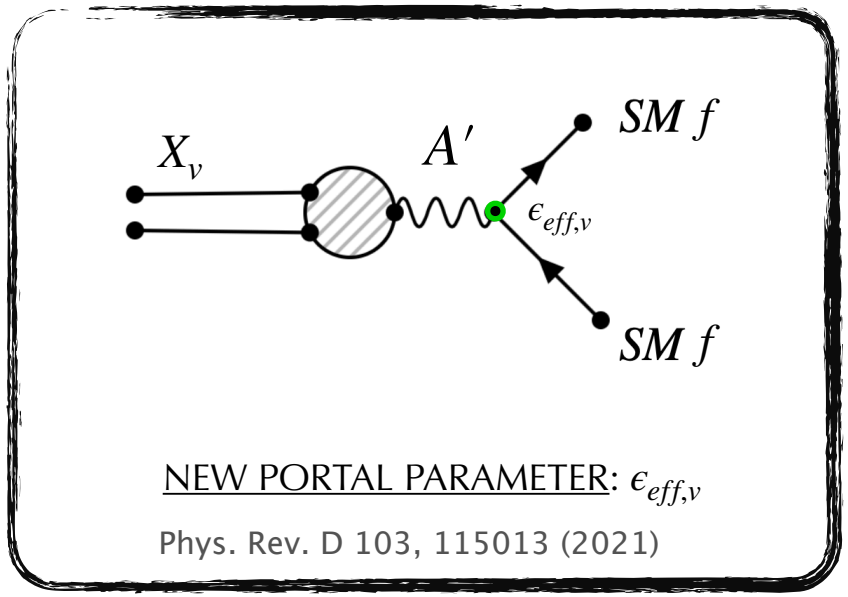
Eur. Phys. J. C 82, 793 (2022)

MODEL 2: LEPTONIC DECAYS IN SVJ VIA A′

PROMPT LEPTONIC DECAYS OF DARK BOUND STATES ALLOWED BY LOWER MASS MEDIATOR A′



HADRONS + LEPTONS SVJ

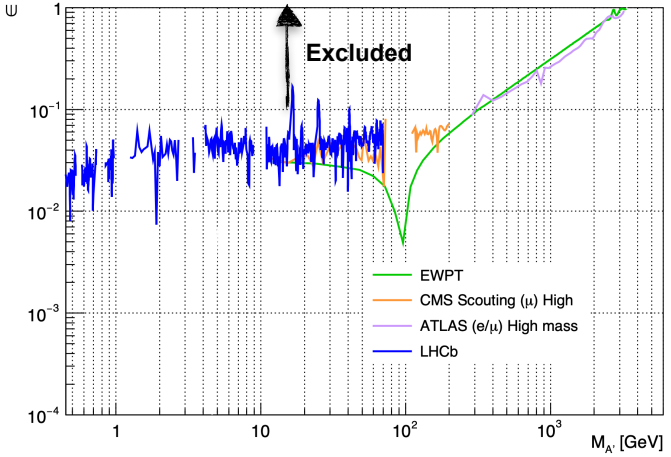


LOWER MASS MEDIATOR: OFF-SHELL Z′ SUPPRESSED IN DARK BOUND STATES DECAYS ~ $1/M_{Z'}^4$

Eur. Phys. J. C 82, 793 (2022)

MODEL 2: PARAMETERS & CONSTRAINTS

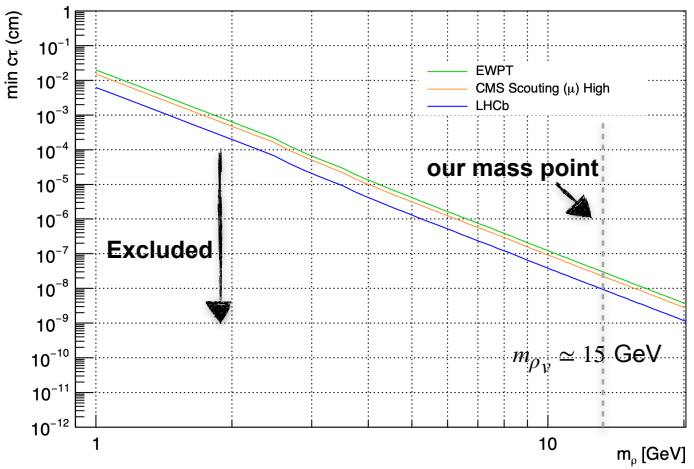
Parameter	Description	Benchmark
$M_{Z'}$	Z' pole mass	1.5–5 TeV
$\epsilon_{\text{eff,v}}$	Effective mixing	0.03
r_{inv}	Invisible fraction	0.3, 0.5, 0.7
Λ_v	Dark confinement scale	5 GeV
m_{π_v}/Λ_v (*)	Pseudo-scalar mass ratio	1.6



constraints $A' \to \ell^+\ell^-$

- **~ 15% democratic decay** of unstable ρ to <u>all lepton flavours</u>
- **Z′ COUPLINGS SETTINGS**: $g^v_{Z'} = 0.4$, $g^q_{Z'} = 0.25$

[Phys. Dark Univ. 27, 100365 (2020)
JHEP 06, 156 (2022)]



* effective mixing fixed saturating $A' \to \ell^+\ell^-$ bounds

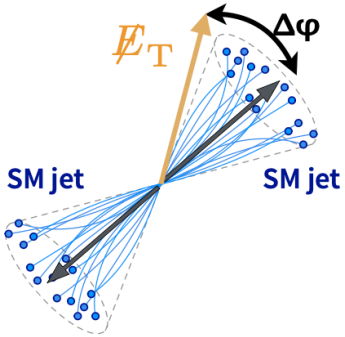
** dark hadron masses set using Lattice QCD fits (Nf = 2, Nc = 3):

$m_{\pi_v} = 8$ GeV $m_{\rho_v} \simeq 15$ GeV $\rho \to \pi\pi$ closed

(*) samples generation flow (backup)

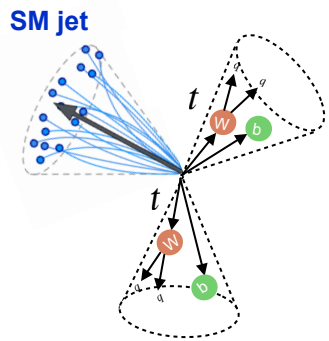
BACKGROUNDS PROCESSES

QCD - DIJET



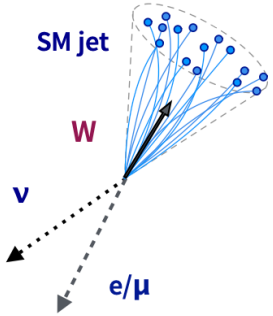
- Jet mis-measurement induces $\not{E}_T$ aligned with jet
- Large cross-section

$t\bar{t}$ + jets



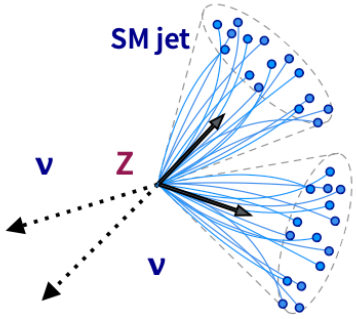
- Wide, high-pT jets: boosted tops
- Overlapping lepton from W boson decay
- Neutrino aligned with jet

W + JETS



- Lost lepton or hadronic τ
- Real $\not{E}_T$ from neutrino (less likely to be aligned with jet)

Z + JETS



- Real $\not{E}_T$ from neutrino but less likely to be aligned with jet

(*) more information on samples (backup)

RESONANT HADRONIC SVJ INCLUSIVE ANALYSIS

GOOD OBJECTS

- ≥ 2 AK8 Jets with $p_T > 200$ GeV & $|\eta| < 2.4$
- $p_T(e,\mu) > 10$ GeV & $|\eta(e,\mu)| < 2.4$

SELECTIONS

- $R_T > 0.15$: $\not{E}_T$-like cut, no M_T sculpting
- $\Delta\eta(j_1, j_2) < 1.5$: removes t-channel QCD
- $M_T > 1500$ GeV : trigger requirement
- $\Delta\phi_{min}(j_{1,2}, \not{E}_T) < 0.8$: W/Z + jets suppression
- Veto mini-isolated leptons

VARIABLES LEGEND

M_T : di-jet transverse mass

R_T : $\not{E}_T/M_T$

IS IT EFFICIENT FOR OUR SIGNATURES ?

SELECTIONS BASED ON: JHEP 06, 156 (2022)

BUMP HUNT ON A FALLING BACKGROUND IN M_T SPECTRUM : 1.5 - 5 TeV (HIGH MASS SEARCH)

RESONANT HADRONIC SVJ INCLUSIVE ANALYSIS

GOOD OBJECTS

- ≥ 2 AK8 Jets with $p_T > 200$ GeV & $|\eta| < 2.4$
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- $\Delta\phi_{min}(j_{1,2}, \not{E}_T) < 0.8$: W/Z + jets suppression
- Veto mini-isolated leptons **LIMITATION !**

VARIABLES LEGEND

M_T : di-jet transverse mass

R_T : $\not{E}_T/M_T$

IS IT EFFICIENT FOR OUR SIGNATURES ?

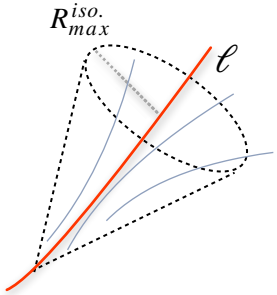
SELECTIONS BASED ON: JHEP 06, 156 (2022)

BUMP HUNT ON A FALLING BACKGROUND IN M_T SPECTRUM : 1.5 - 5 TeV (HIGH MASS SEARCH)

LIMITATIONS: CLASSICAL LEPTONS ISOLATIONS

RELATIVE STANDARD ISOLATION (FIXED R)

$$I(\ell) = \frac{1}{p_{T,l}} \sum_{i \neq \ell}^{\Delta R < R_{max}^{iso.}} p_t(i)$$

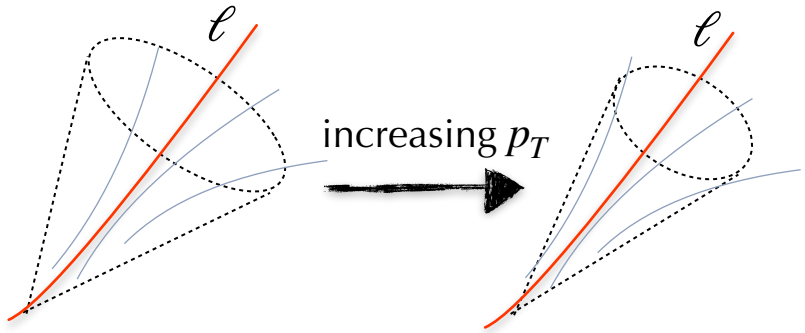


ISOLATION VETO: LIMITATION FOR ELECTRONS AND MUONS PRODUCED INSIDE JETS

RELATIVE MINI-ISOLATION (VARIABLE R) JHEP 1103:059,2011

$$I_{mini} = \frac{1}{p_{T,l}} \sum_{i \neq l}^{\Delta R < R_{max}^{mini\ iso.}} p_t(i)$$

$$R_{\text{max}}^{\text{mini iso.}} = \begin{cases} 0.2, & p_{\text{T}}^{\ell} \leq 50\,\text{GeV} \\ \frac{10\,\text{GeV}}{p_{\text{T}}^{\ell}}, & 50\,\text{GeV} < p_{\text{T}}^{\ell} < 200\,\text{GeV} \\ 0.05, & p_{\text{T}}^{\ell} \geq 200\,\text{GeV} \end{cases}$$



USED IN CMS SVJ TO VETO LEPTONS from top/V decays

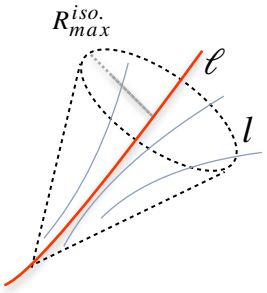
MINI-ISOLATION VETO: LIMITATION FOR e/μ FROM DIRECT DARK BOUND STATES DECAYS (RESONANT SIGNATURE)

BEYOND CLASSICAL ISOLATION: INTER-ISOLATION

RELATIVE INTER-ISOLATION (FIXED R)

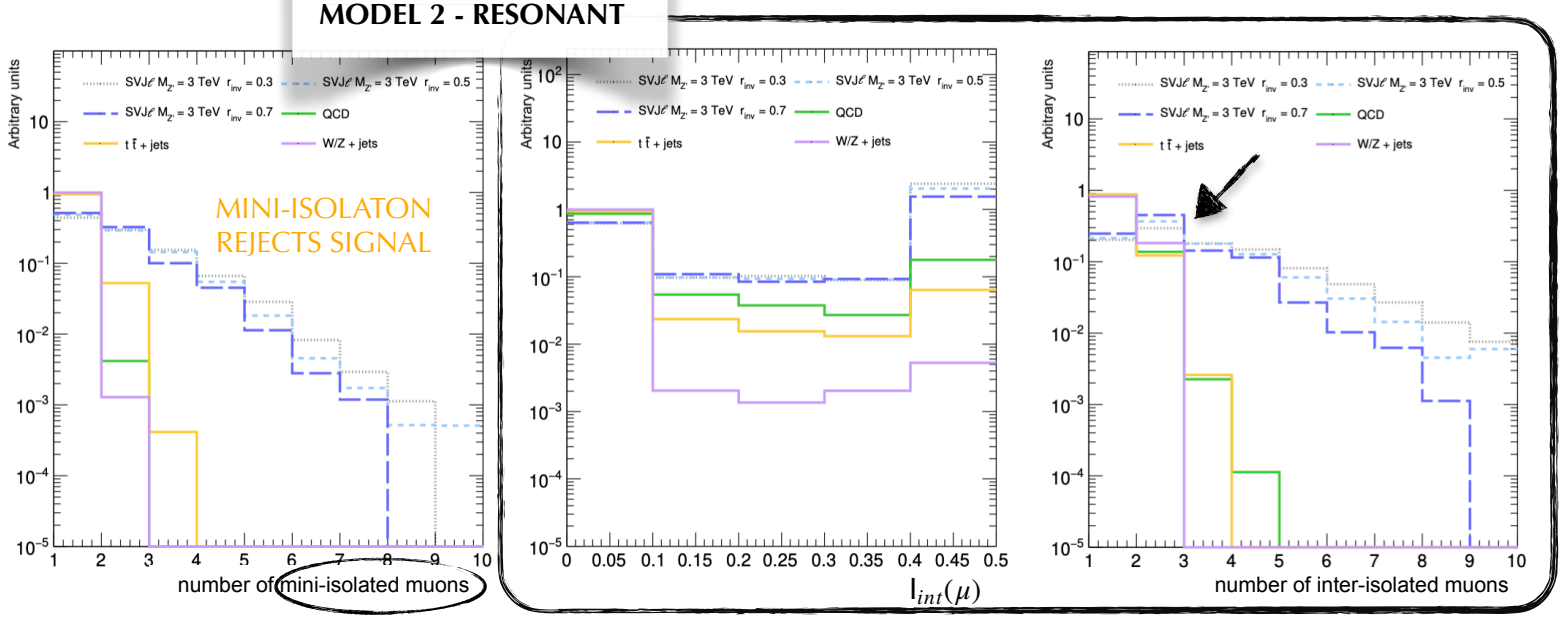
Eur. Phys. J. C 82, 793 (2022)

$$I_{int}(\ell) = \frac{1}{p_{T,\ell}} \sum_{l \neq \ell}^{\Delta R < R_{max}^{iso.}} p_t(l)$$



- CAPTURES NEARBY NON-ISOLATED LEPTONS INSIDE JETS (LEPTONIC ACTIVITY)
- BACKGROUNDS ARE EXPECTED TO BE MORE INTER-ISOLATED

MODEL 2 - RESONANT



Eur. Phys. J. C 82, 793 (2022)

SVJℓ TARGETED INCLUSIVE APPROACH

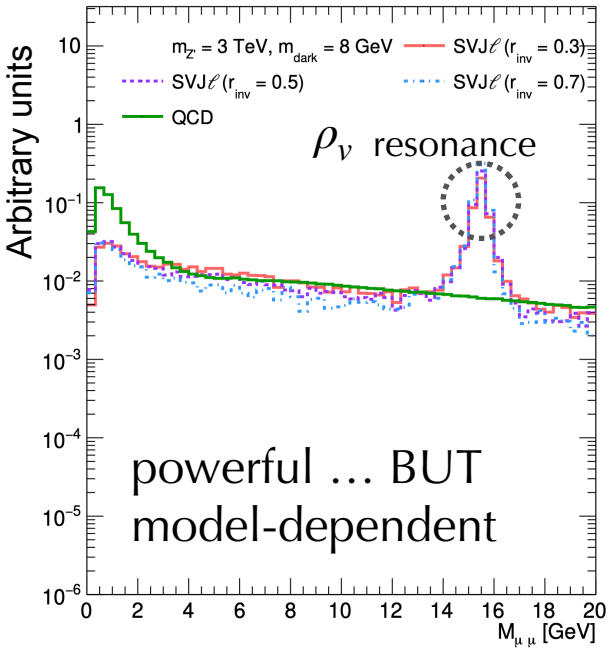
GOOD OBJECTS

- ≥ 2 AK8 Jets with $p_T > 200$ GeV & $|\eta| < 2.4$
- $p_T(e,\mu) > 10$ GeV & $|\eta(e,\mu)| < 2.4$
- ✦ $d_0(\mu, e) < 100\ \mu m$: prompt dark hadrons leptonic decays

SELECTIONS

- $R_T > 0.15$: $\not{E}_T$-like cut, no M_T sculpting
- $\Delta\eta(j_1, j_2) < 1.5$: removes t-channel QCD
- $M_T > 1500$ GeV : trigger requirement
- $\Delta\phi_{min}(j_{1,2}, \not{E}_T) < 0.8$: W/Z + jets suppression
- ✦ Veto events with at least 2 isolated leptons
- ✦ Opposite sign non inter-isolated ($I_{int} > 0.1$) leptons pairs

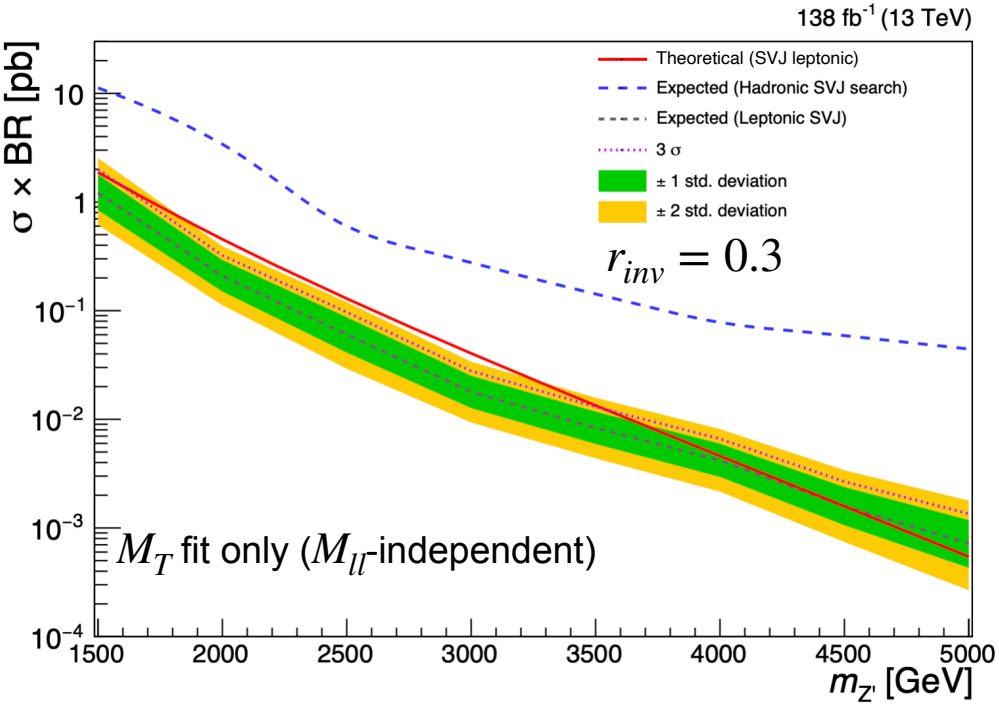
DI-LEPTON RESONANCE

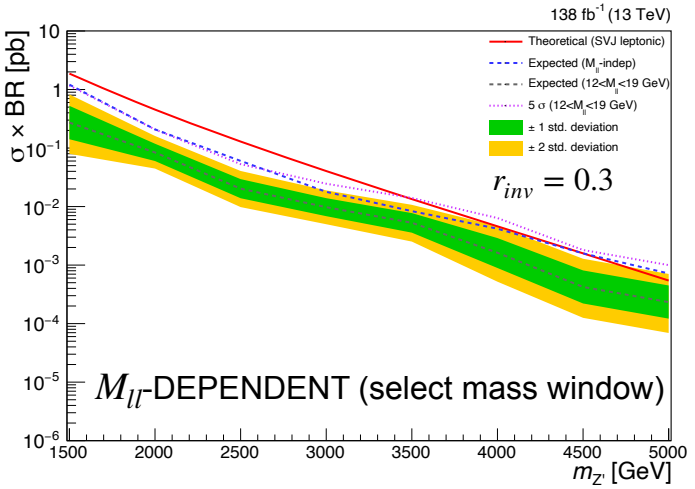


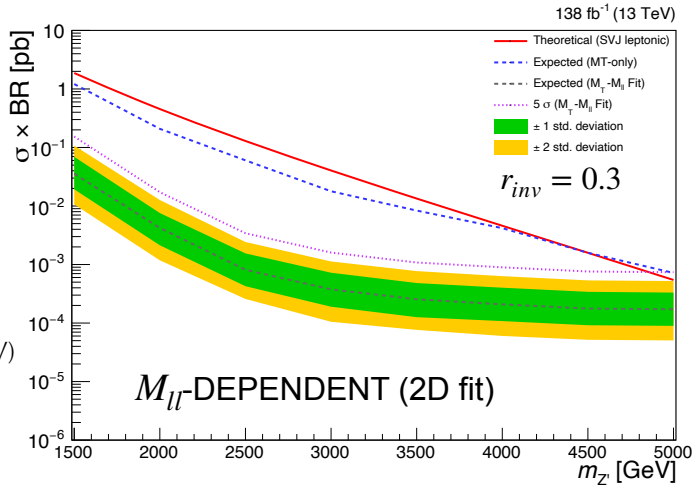
• = SVJ-tag ✦ = additional requirements

Eur. Phys. J. C 82, 793 (2022)

SVJℓ-TARGETED INCLUSIVE ANALYSIS SENSITIVITY







- ✦ CMS INCLUSIVE HADRONIC STRATEGY: NO SENSITIVITY
- ✦ SVJℓ-INCLUSIVE STRATEGY : EXCLUSION REACH (EVIDENCE) UP TO ~ 4.5 TeV (~ 3.5 TeV)
- ✦ IMPROVEMENT EXPLOITING DI-LEPTON RESONANCE - METHOD-DEPENDENT (MODEL-DEPENDENT)

(*) more on limits varying r_{inv} in backup

RESONANT HADRONIC SVJ INCLUSIVE ANALYSIS

GOOD OBJECTS

- ≥ 2 AK8 Jets with $p_T > 200$ GeV & $|\eta| < 2.4$
- $p_T(e,\mu) > 10$ GeV & $|\eta(e,\mu)| < 2.4$

SELECTIONS

- $R_T > 0.15$: $\not{E}_T$-like cut, no M_T sculpting
- $\Delta\eta(j_1, j_2) < 1.5$: removes t-channel QCD
- $M_T > 1500$ GeV : trigger requirement — **LIMITATION !**
- $\Delta\phi_{min}(j_{1,2}, \not{E}_T) < 0.8$: W/Z + jets suppression
- Veto mini-isolated leptons — **LIMITATION !**

VARIABLES LEGEND

M_T : di-jet transverse mass

R_T : $\not{E}_T/M_T$

IS IT EFFICIENT FOR OUR SIGNATURES ?

SELECTIONS BASED ON: JHEP 06, 156 (2022)

BUMP HUNT ON A FALLING BACKGROUND IN M_T SPECTRUM : 1.5 - 5 TeV (HIGH MASS SEARCH)

arXiv:2212.11523v1

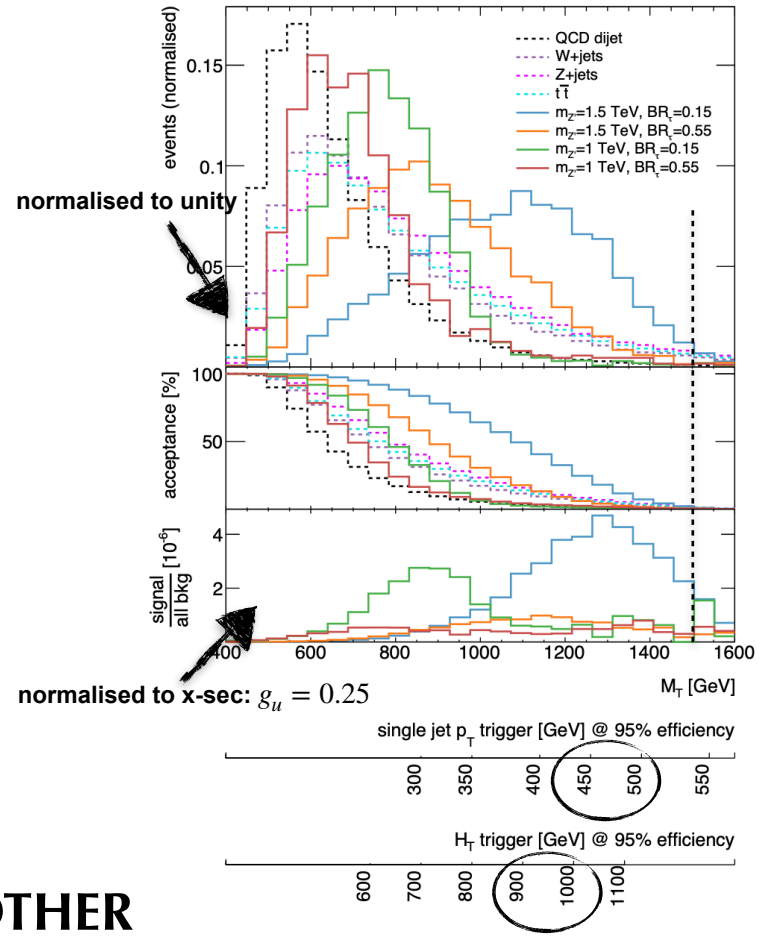
LIMITATIONS: CLASSICAL TRIGGERS

CMS SVJ SEARCH SELECTIONS

Selection	BR_τ :	Signal efficiency (%) 0.7	0.55	0.15
$N(AK8jets) \geq 2$		71.8	76.5	85.7
$\Delta\eta(j_1, j_2) < 1.5$		51.5	53.5	56.6
$M_T > 1500$ GeV		16.2	25.5	42.7
$R_T > 0.15$		10	14.3	20.2
$\Delta\phi_{min}(\not{E}_T, j) < 0.8$		9.3	13.6	19.5
$N_{\mu,e} = 0$		5.7	9.2	17.3

Benchmark mass point: $M_{Z'} = 3\ TeV$

- Jet HT || pT triggers used by CMS: inherited from high mass di-jet search JHEP 06, 156 (2022)
- CMS fully efficient trigger requirement $M_T > 1.5$ TeV limits sensitivity for $SVJ\tau$ (effect of neutrinos from τ)
- MET and Tau triggers low signal acceptance: too high thresholds and strict τ isolation requirements (see backup)



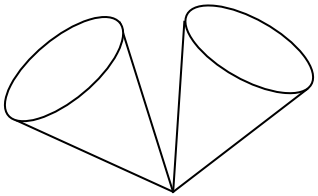
ARE THERE OTHER POSSIBILITIES ?

arXiv:2212.11523v1

TOPOLOGICAL TRIGGERS AND BEYOND

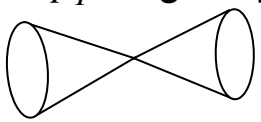
TOPOLOGICAL TRIGGERS

- Exploit the s-channel topology at L1:
  ≥ 2 AK4 $p_T > 100$ GeV & $\Delta\eta(j_1, j_2) < 2$
  reduce hadronic rates prior to HLT
- Promising for lowering HT threshold
- Hypothetical target: HT > 600 GeV
  (MT > 800 GeV) [need full sim]

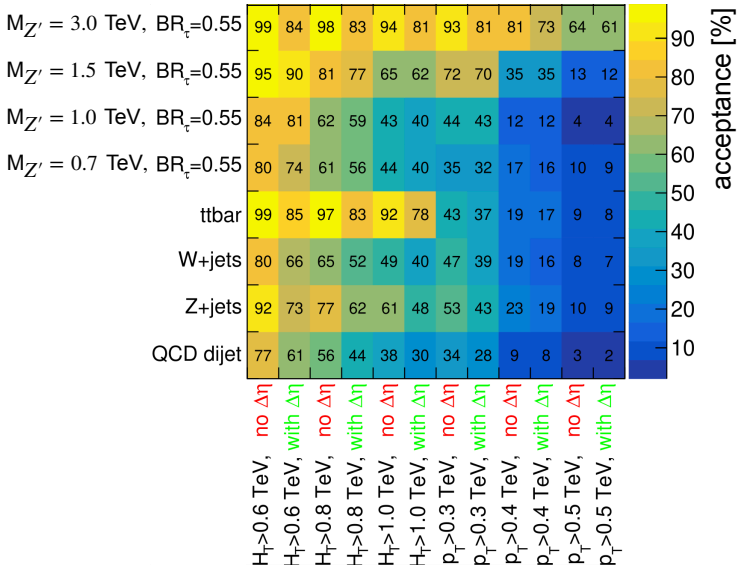


Passes:
high p_T , low $\Delta\eta$

Fails:
low p_T , high $\Delta\eta$



TOPOLOGICAL TRIGGERS



… AND BEYOND ?

- Alternative data-taking: Data Parking and Scouting
- + Partial event building to exploit jet substructure

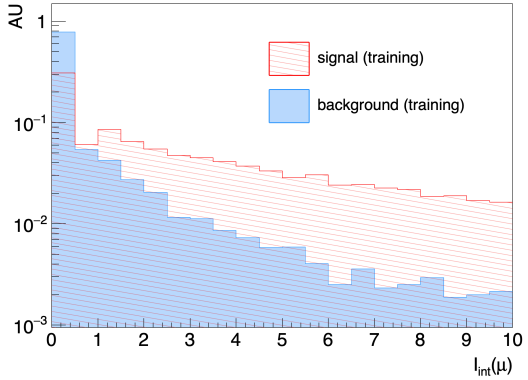
arXiv:2212.11523v1

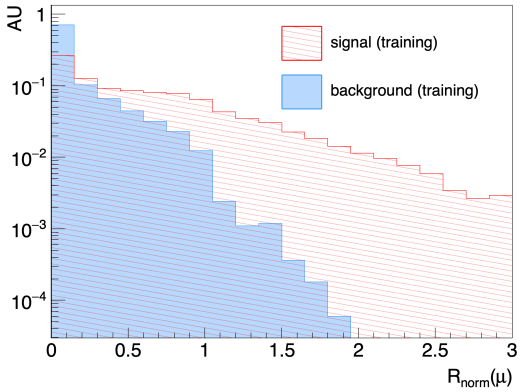
LEPTON FLAVOUR-BASED JET TAGGER FEATURES

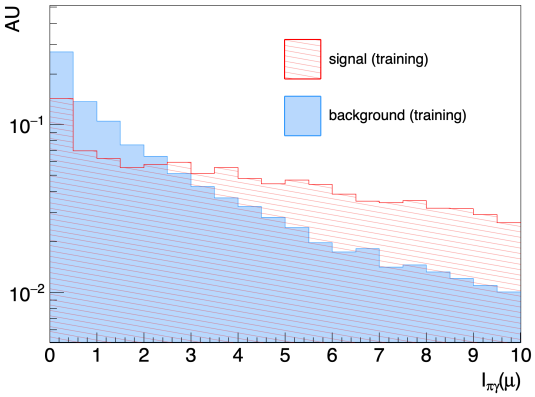
- Set of variables to exploit e/μ enriched jet content from leptonic τ decays (~ 35 %)
- 3 main classes of features (per e/μ):
  1. Energy/momentum flow,
  2. Spatial distributions,
  3. Specific isolations (capture leptonic and hadronic boosted di-τ decays)
- Adaptive BDT (TMVA) trained on a mixture of signal jets hypo (scan over Z′ mass and BR_τ)

JET-TAGGER INPUT FEATURES

Rank	Variable	Separation
1	$I_{inter}(\mu)$	2.703×10^{-1}
2	$R_{Norm}(\mu)$	2.601×10^{-1}
3	$I_{\gamma\pi}(\mu)$	2.164×10^{-1}
4	$R_{Norm}(e)$	1.786×10^{-1}
5	$I_{inter}(e)$	1.632×10^{-1}
6	$Energyfraction(e)$	7.500×10^{-2}
7	$I_{\gamma\pi}(e)$	7.175×10^{-2}
8	$p_{T,Norm}(\mu)$	6.272×10^{-2}
9	$Energyfraction(\mu)$	6.220×10^{-2}



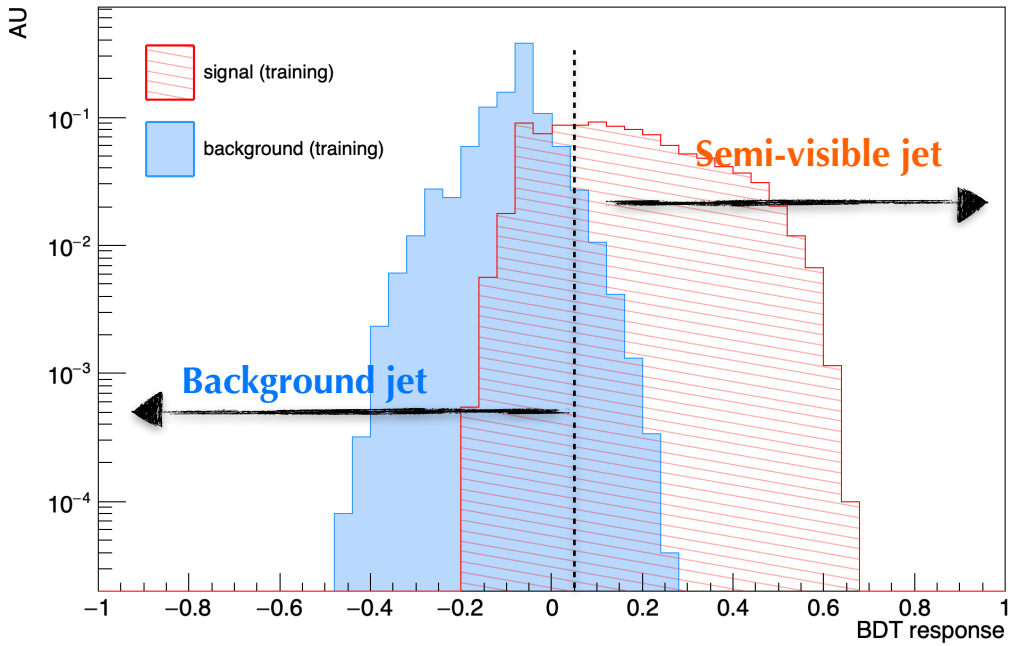


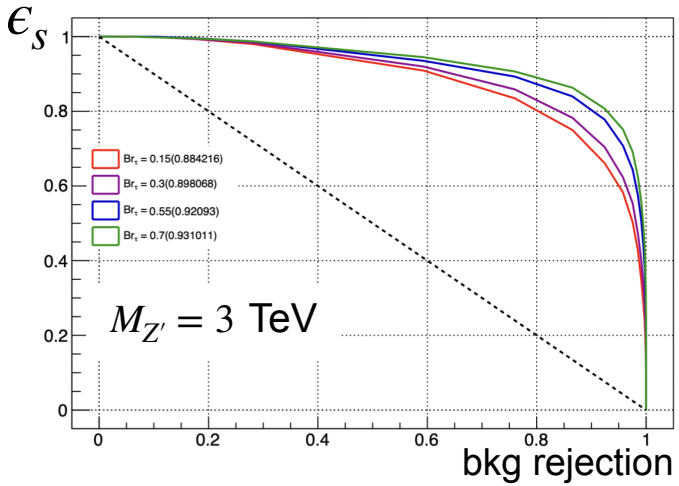


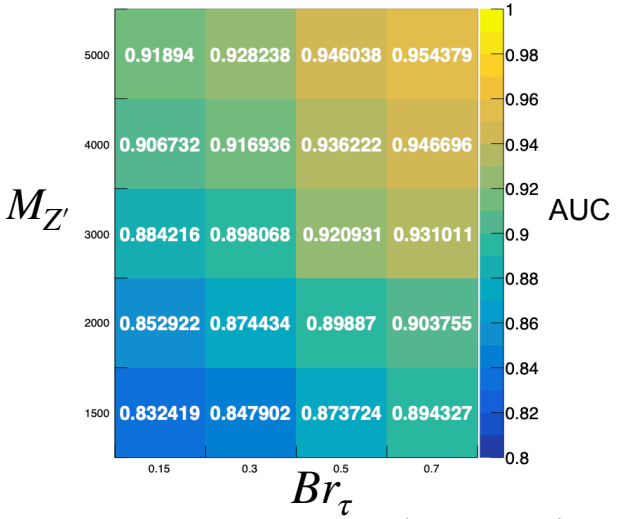
(*) all distributions shown are for training datasets

arXiv:2212.11523v1

LEPTON FLAVOUR-BASED JET TAGGER PERFORMANCE



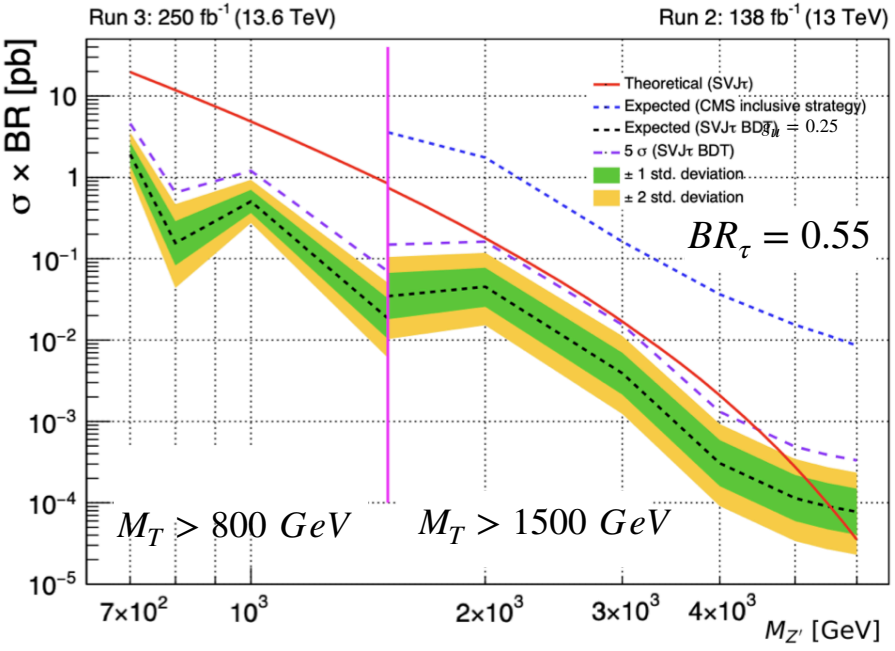


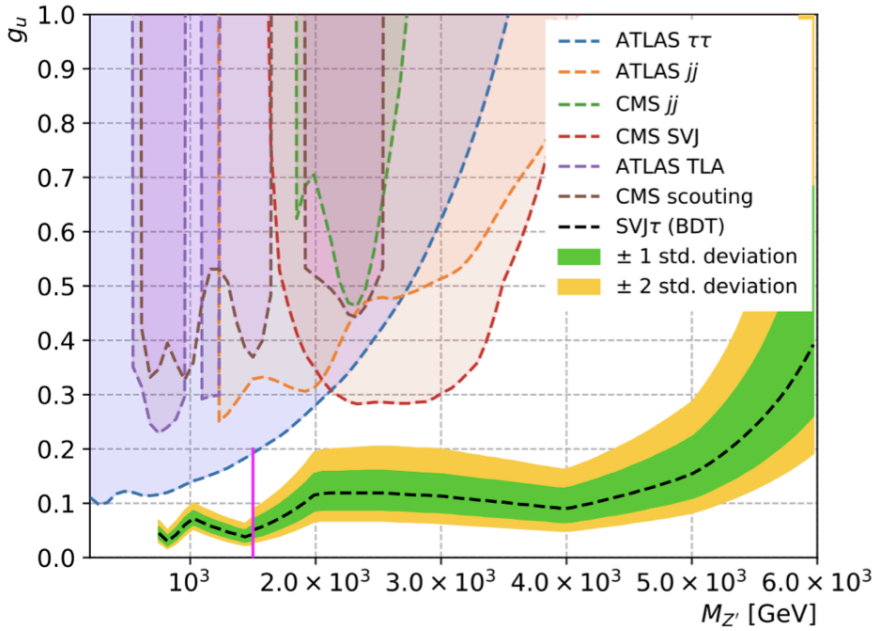


- BDT working point: maximise $s/\sqrt{s+b}$
- Rejects ~97% of background jets, tags: 88%, 89%, 92%, 93% signal jets ($BR_\tau = 0.15, 0.3, 0.55, 0.7$, $M_{Z'} = 3$ TeV)

arXiv:2212.11523v1

SVJτ-TARGETED ANALYSIS SENSITIVITY





- NO SENSITIVITY FOR CMS INCLUSIVE HADRONIC STRATEGY: NEED TO EXPLOIT TAU CONTENT FEATURES
- EXPLOITING BDT JET-CLASSIFICATION : EXCLUSION REACH (DISCOVERY) UP TO ~ 5.5 TeV (~ 4.5 TeV)
- RESULT OUTPERFORMS ANY EXISTING SEARCH: PROBE UNEXPLORED g_u COUPLING VALUES

(*) more on limits varying BR_τ in backup

CONCLUSIONS

LEPTONS-ENRICHED SIGNATURES: NEW PROMISING SEARCHES FOR CONFINING DARK SECTORS

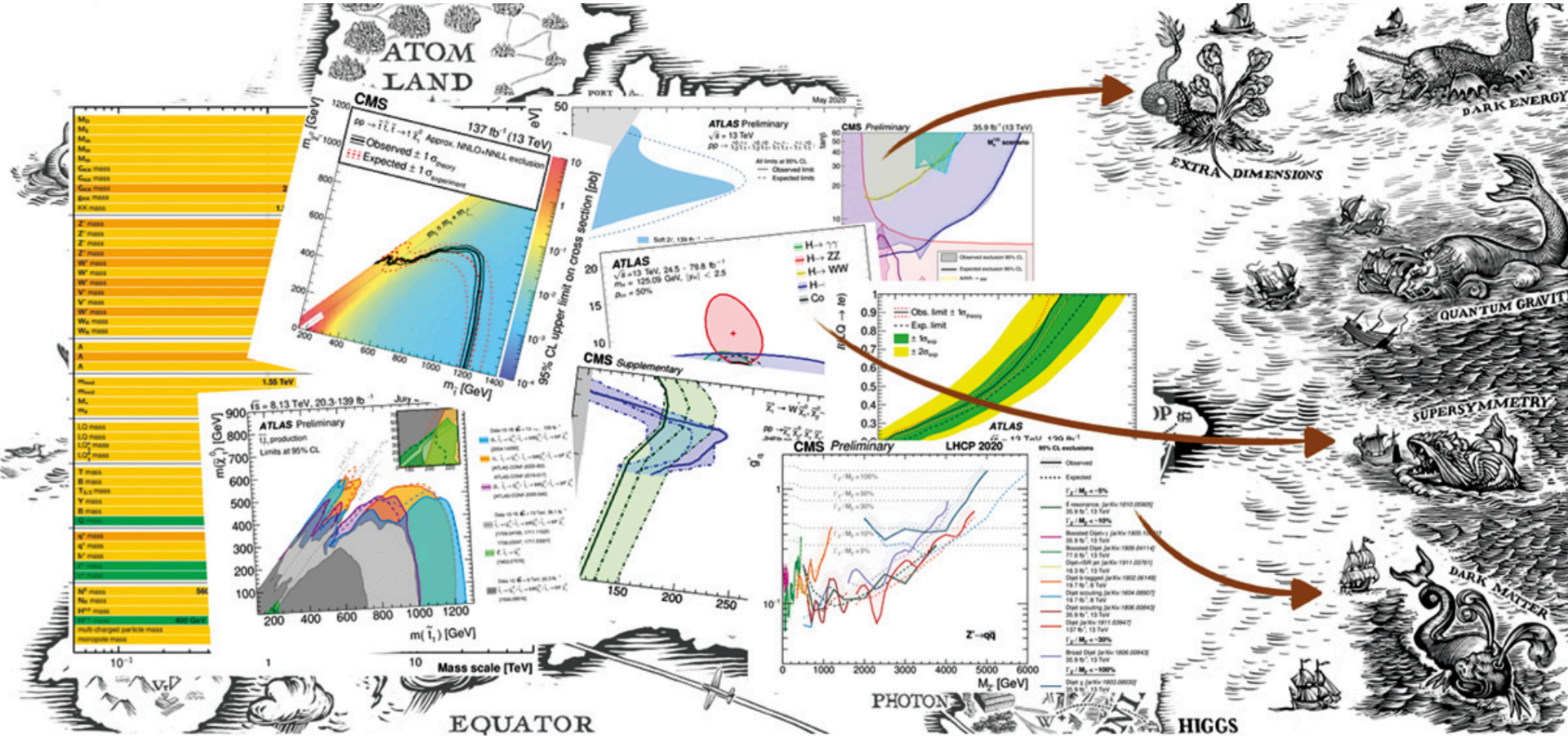
→ Investigated models for resonant and non-resonant leptonic decays

→ Provided possible search strategies based on: new lepton-based variables (possible inputs for jet taggers)

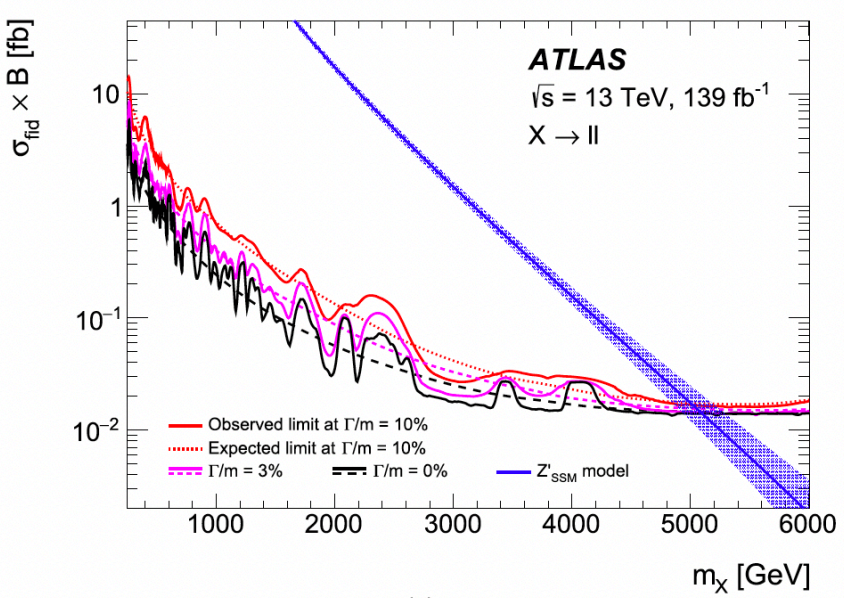
→ Examined triggers limitations and explored new possibilities

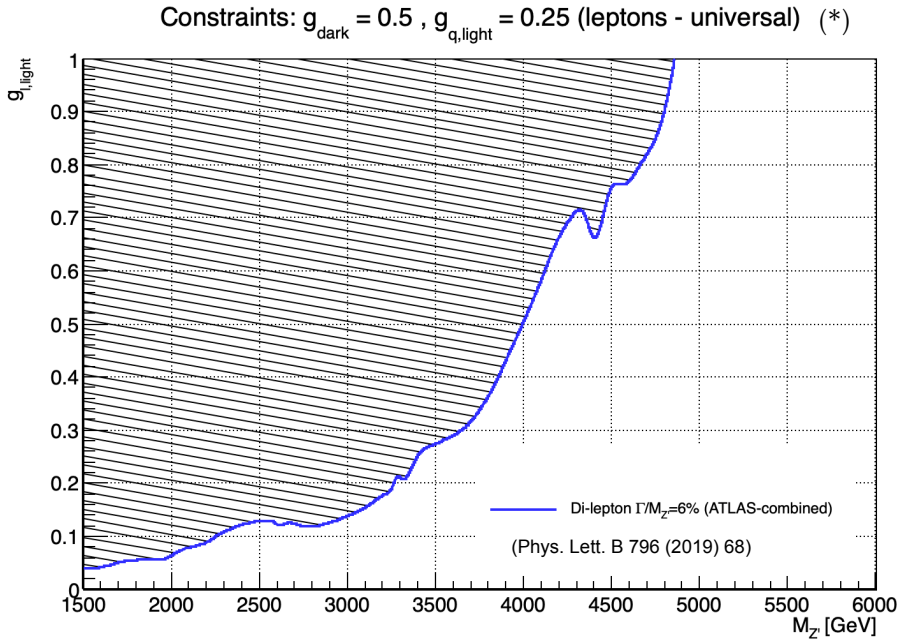
→ These signatures are currently mildly constrained and offer Hidden Valleys discovery opportunities

BACKUP


ATOM LAND
EXTRA DIMENSIONS
DARK ENERGY
QUANTUM GRAVITY
SUPERSYMMETRY
DARK MATTER
HIGGS
PHOTON
EQUATOR
CMS
ATLAS Preliminary
CMS Preliminary
ATLAS
CMS Supplementary
LHCP 2020
Mass scale [TeV]

CONSTRAINTS ON Z′ COUPLING TO LEPTONS

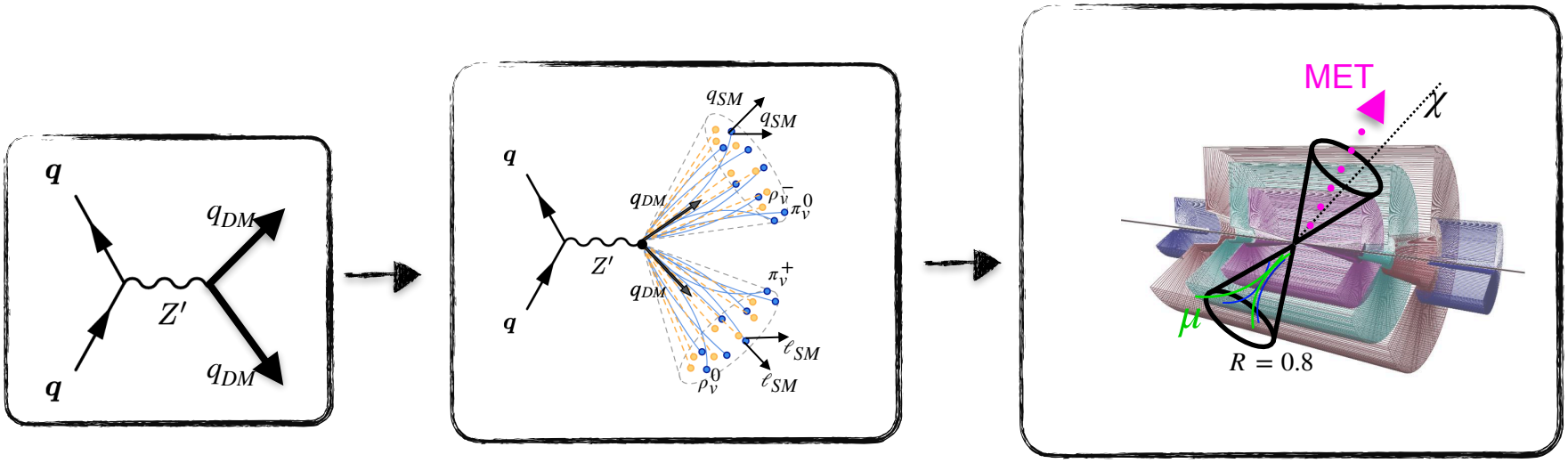




ALLOWING IN THE CURRENT SVJ MODEL FOR Z′ COUPLING TO LEPTONS WOULD INTRODUCE IMPORTANT CONSTRAINTS FROM HIGH MASS DI-LEPTON SEARCHES

(*) parameters are set consistently with CMS Z′ model

SIGNAL MODELS GENERATION



Madgraph5

- ✦ Generation of matrix element
- ✦ Cross-section computation
- ✦ Inputs: couplings, $M_{Z'}$ mass

PYTHIA8

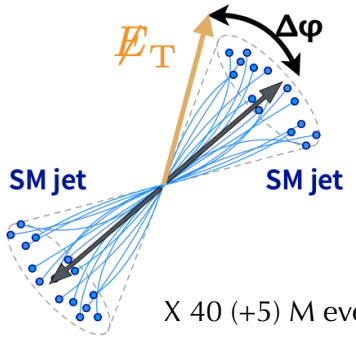
- ✦ HV MODULE : dark sector parton shower, hadronization, dark hadrons decays to SM
- ✦ Inputs: dark sector parameters and dark hadrons decay modes

FASTJET/DELPHES3

- ✦ Clustering AK8 jets with $p_T > 200$ GeV
- ✦ Filter out from AK8 invisible final states (DM, neutrinos)
- ✦ Fast detector simulation: parametric response

BACKGROUNDS SAMPLES

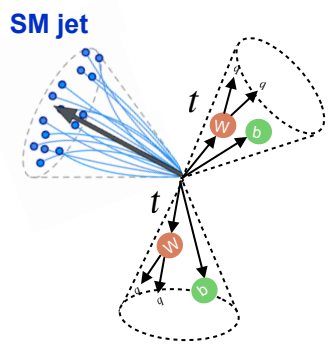
QCD - DIJET



- 2 HARD PARTONS IN ME
- GEN PT CUT: 500 GeV (200 GeV - trigger study)

X 40 (+5) M events

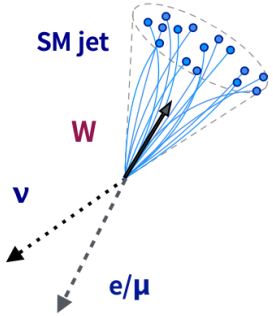
$t\bar{t}$ + jets



- MAXIMUM 2 ADDITIONAL PARTONS IN ME

X 50 M events

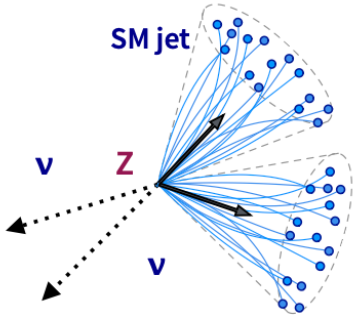
W + JETS



- MAXIMUM 3 ADDITIONAL PARTONS IN ME
- GEN HT CUT: 100 GEV

X 25 M events

Z + JETS

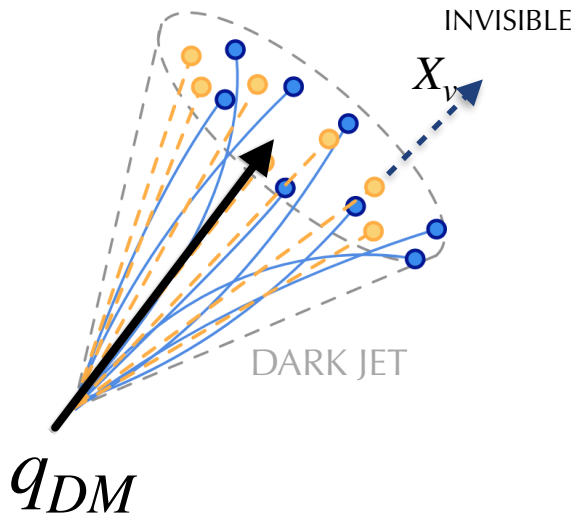


- MAXIMUM 3 ADDITIONAL PARTONS IN ME
- GEN HT CUT: 100 GEV

X 25 M events

INVISIBLE FRACTION

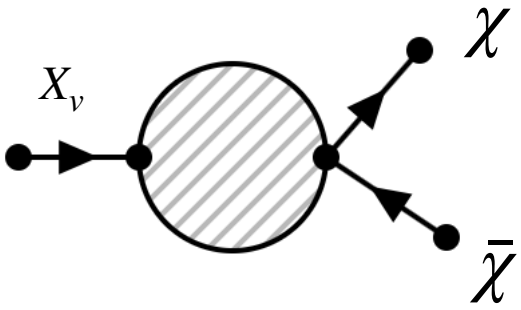
NUMBER OF INVISIBLE DM STATES IMPLEMENTED AS A BRANCHING RATIO



EFFECTIVE INVISIBLE FRACTION

$$r_{\text{inv}} \equiv \left\langle \frac{\#\text{ of stable hadrons}}{\#\text{ of hadrons}} \right\rangle$$

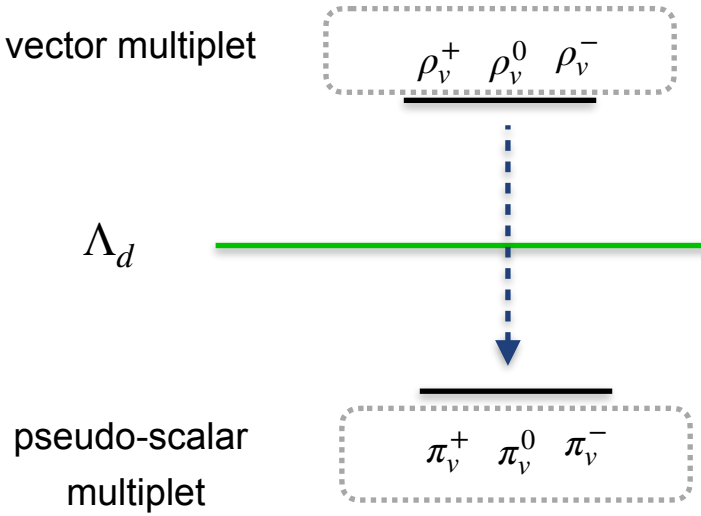
BR_{inv} :



CAPTURES VARIATION IN NUMBER OF DARK FLAVOURS (N_f), NUMBER OF DARK COLORS (N_c) & DARK QUARKS MASS SPLITTING (LUND STRING)

SIMPLIFIED HIDDEN VALLEY SPECTRUM

SIMPLE Nf = 2 HV SPECTRUM
(mass degenerate dark quarks)



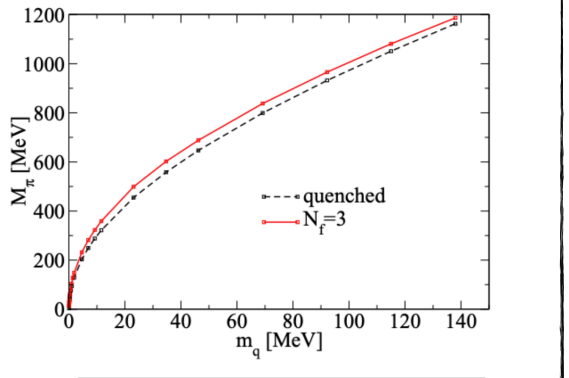
HOW TO FIX THE MASSES ?

FULL HADRONIC SEARCH ASSUMES ONE DARK HADRON MASS SCALE

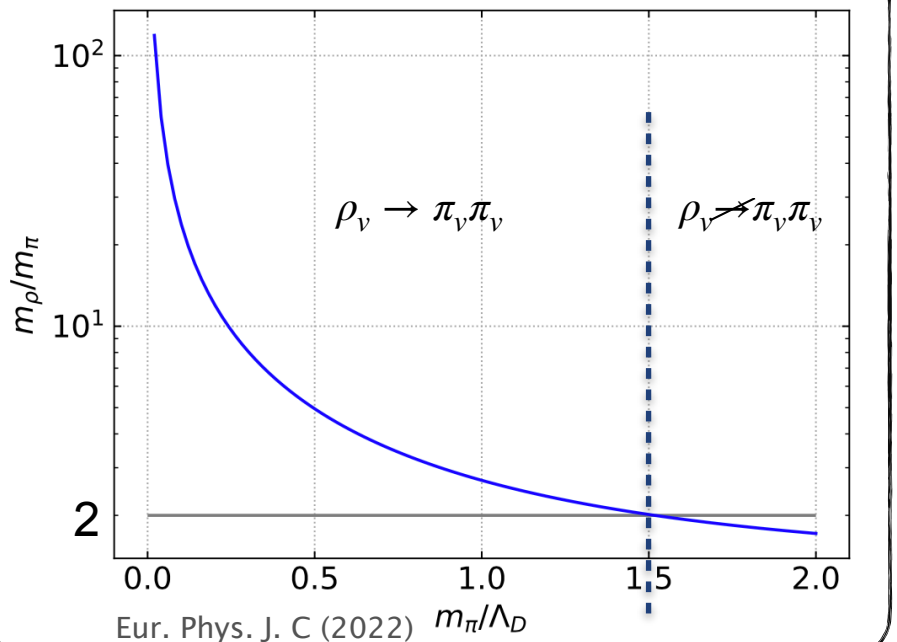
DEVELOPMENTS IN SNOWMASS 2021-2022 Eur. Phys. J. C (2022)

DARK SECTOR HADRON MASSES

LATTICE CALC



DM SPECTRUM PREDICTION

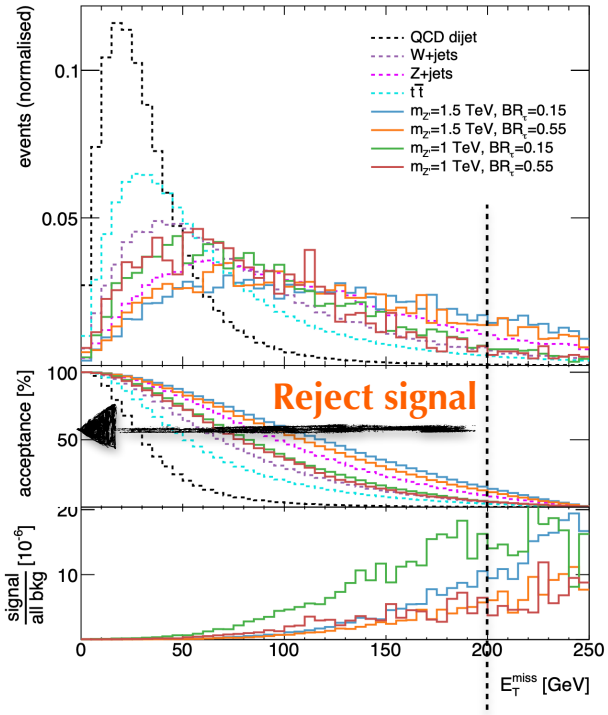


LATTICE CALCULATION: INPUT DARK CURRENT QUARK MASS AND GET DARK HADRON MASSES (BOTH DIVIDED BY OVERALL SCALE Λ_d)

(*) Predictions DM spectrum independent from Nc and Nf (Backup)

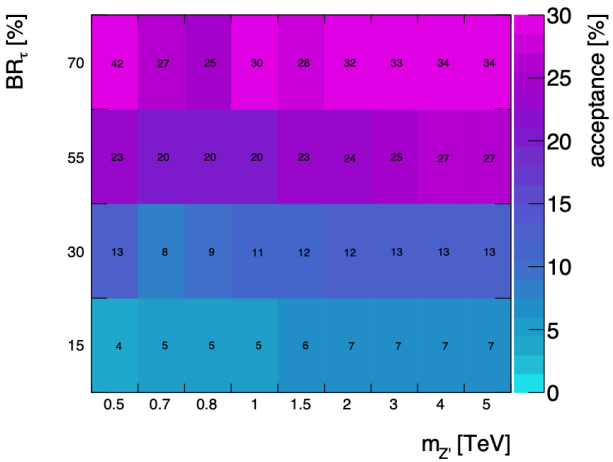
CLASSICAL MET AND TAU TRIGGERS

MET TRIGGERS

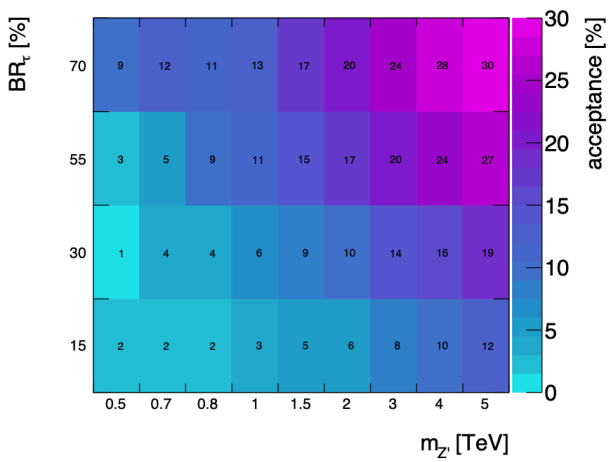


lowest unprescaled threshold $\mathcal{O}(200\ GeV)$

SINGLE TAU TRIGGER

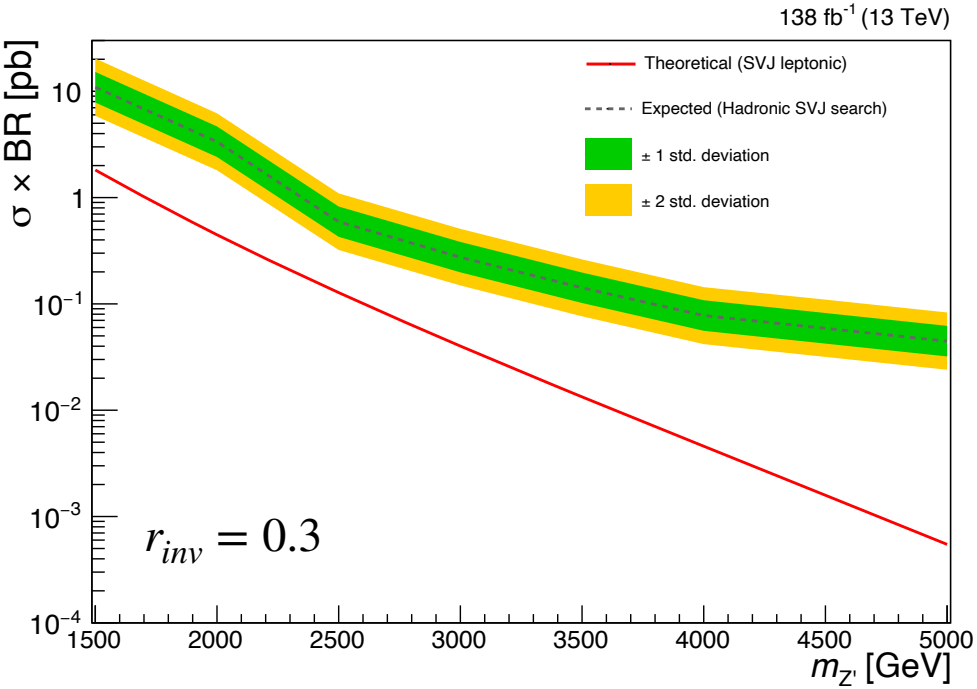


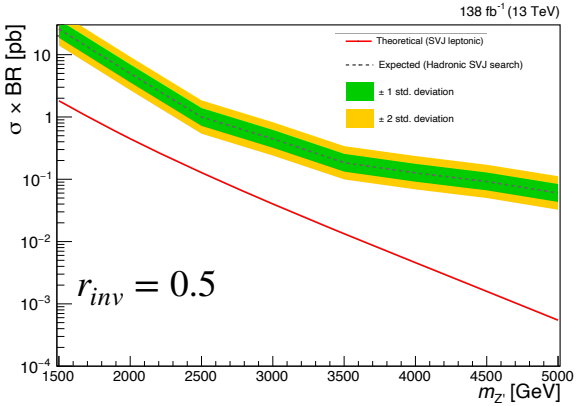
DI-TAU TRIGGER

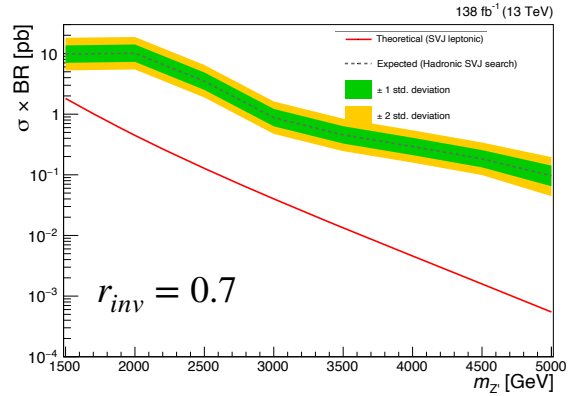


- MET triggers: too high threshold for lowest unprescaled
- Single tau triggers: limited by isolation criteria
- Di-tau triggers: isolation applied to τ candidates $p_T < 25$ GeV
  no significant improvement (relatively soft τ leptons in signal)

HADRONIC SVJ ANALYSIS SENSITIVITY ON SVJℓ-RESONANT

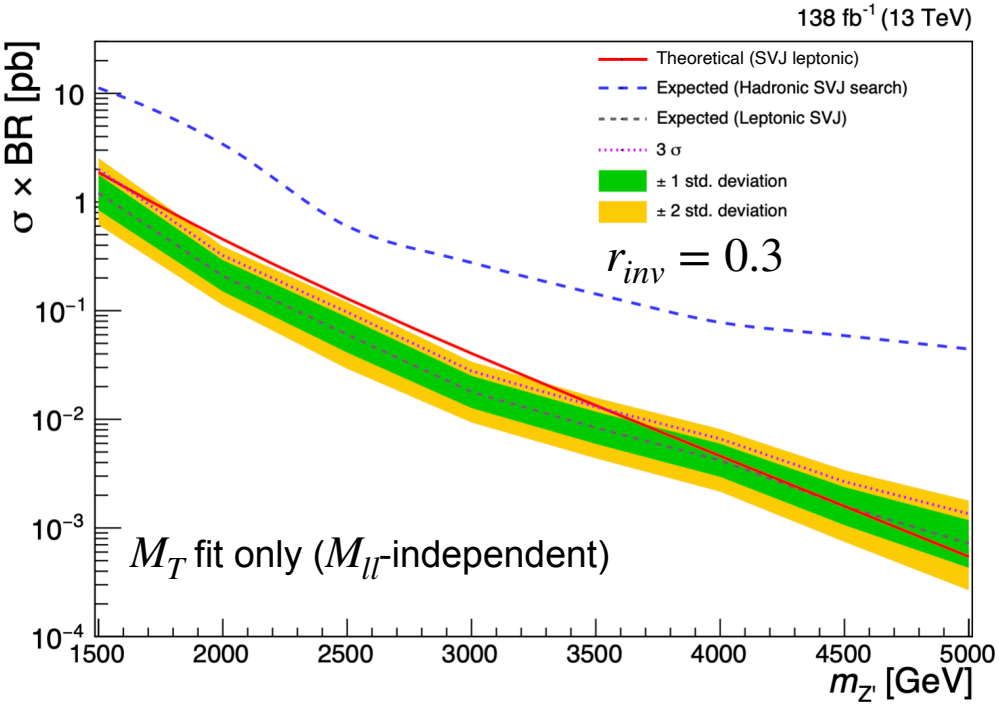


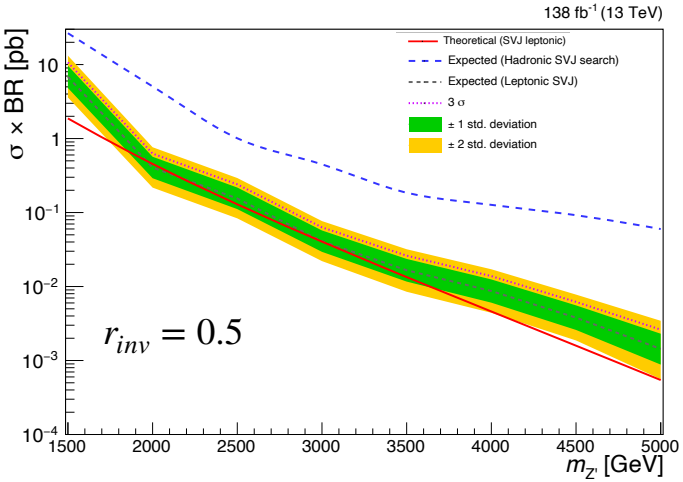


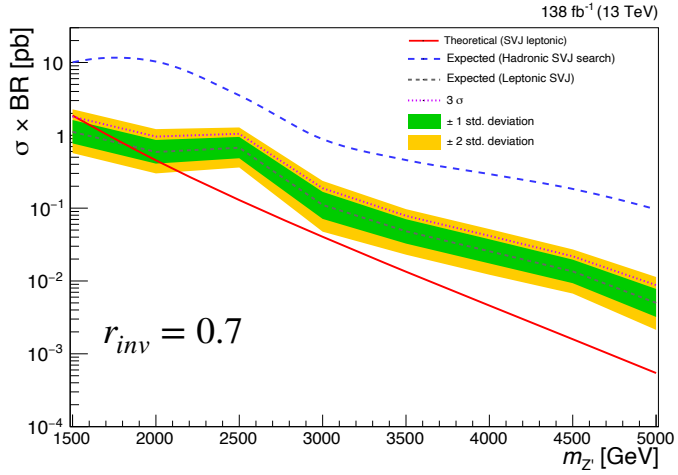


NO EXCLUSION REACH FROM FULL HADRONIC ON SVJℓ (NOR DISCOVERY) IN THE FULL MASS RANGE AND ALL TESTED VALUES OF INVISIBLE FRACTION

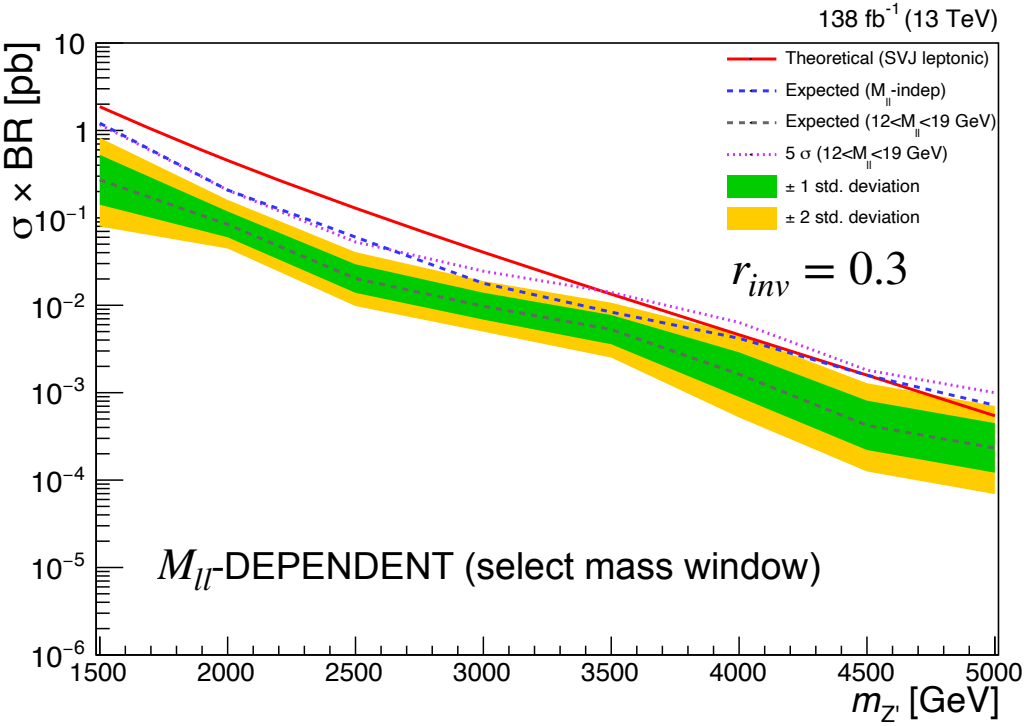
SVJℓ-TARGETED ANALYSIS SENSITIVITY (M_{ll}-INDEPENDENT)

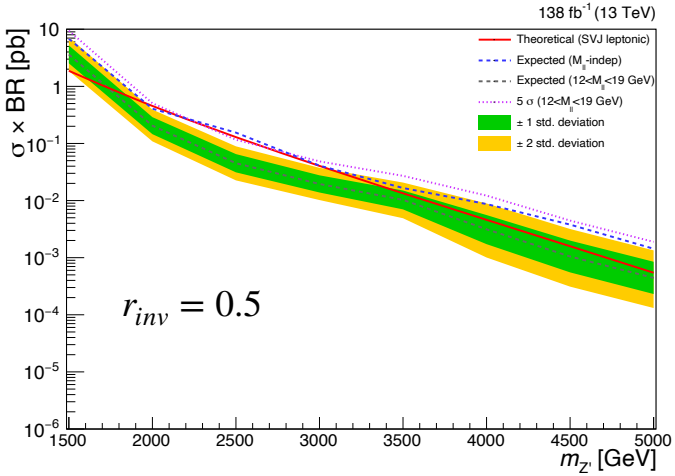


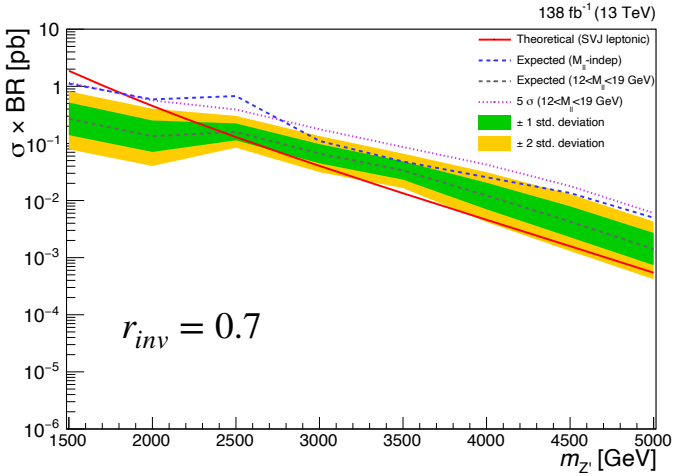




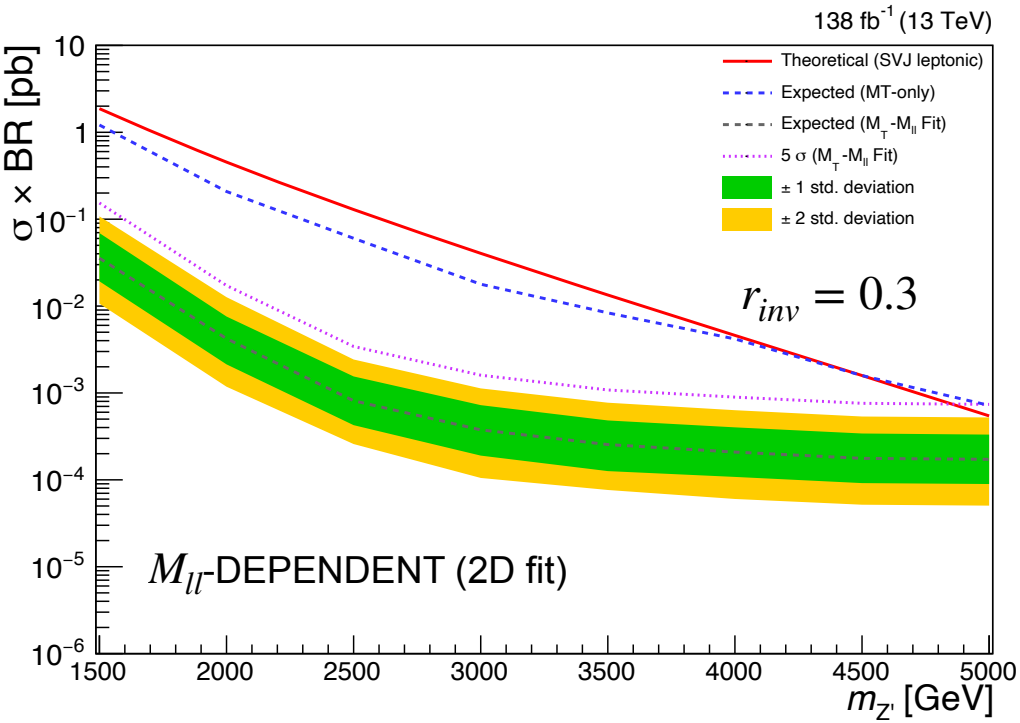
SVJℓ-TARGETED ANALYSIS SENSITIVITY (M_{ll}-CUT)

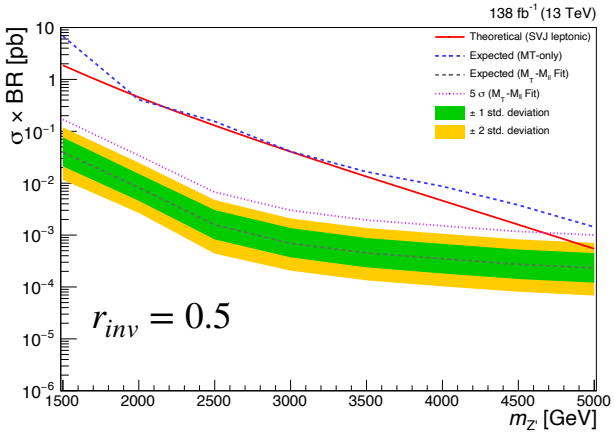


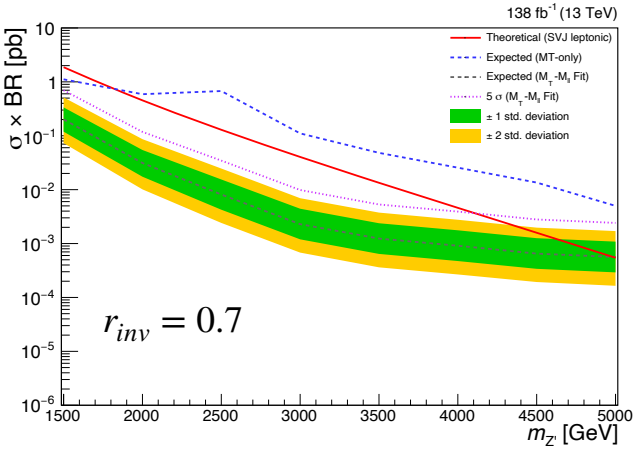




SVJℓ-TARGETED ANALYSIS SENSITIVITY (2D FIT)







SVJτ-TARGETED ANALYSIS SENSITIVITY