



Experimental status on BSM searches

LFC24 - Fundamental Interactions at Future Colliders

16-20 September 2024

Livia Soffi

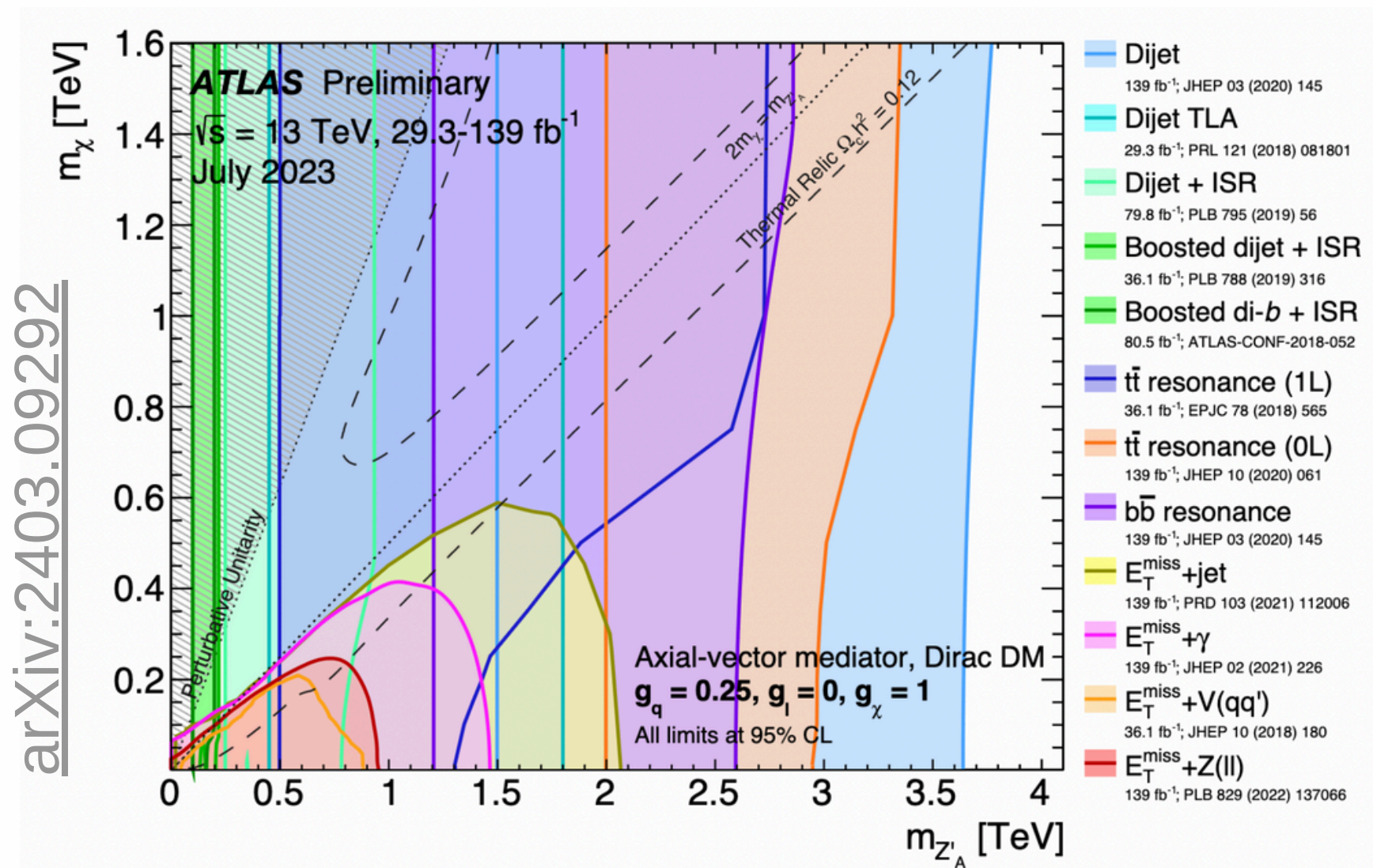
on behalf of ATLAS and CMS collaborations



A Comprehensive review of BSM searches at LHC

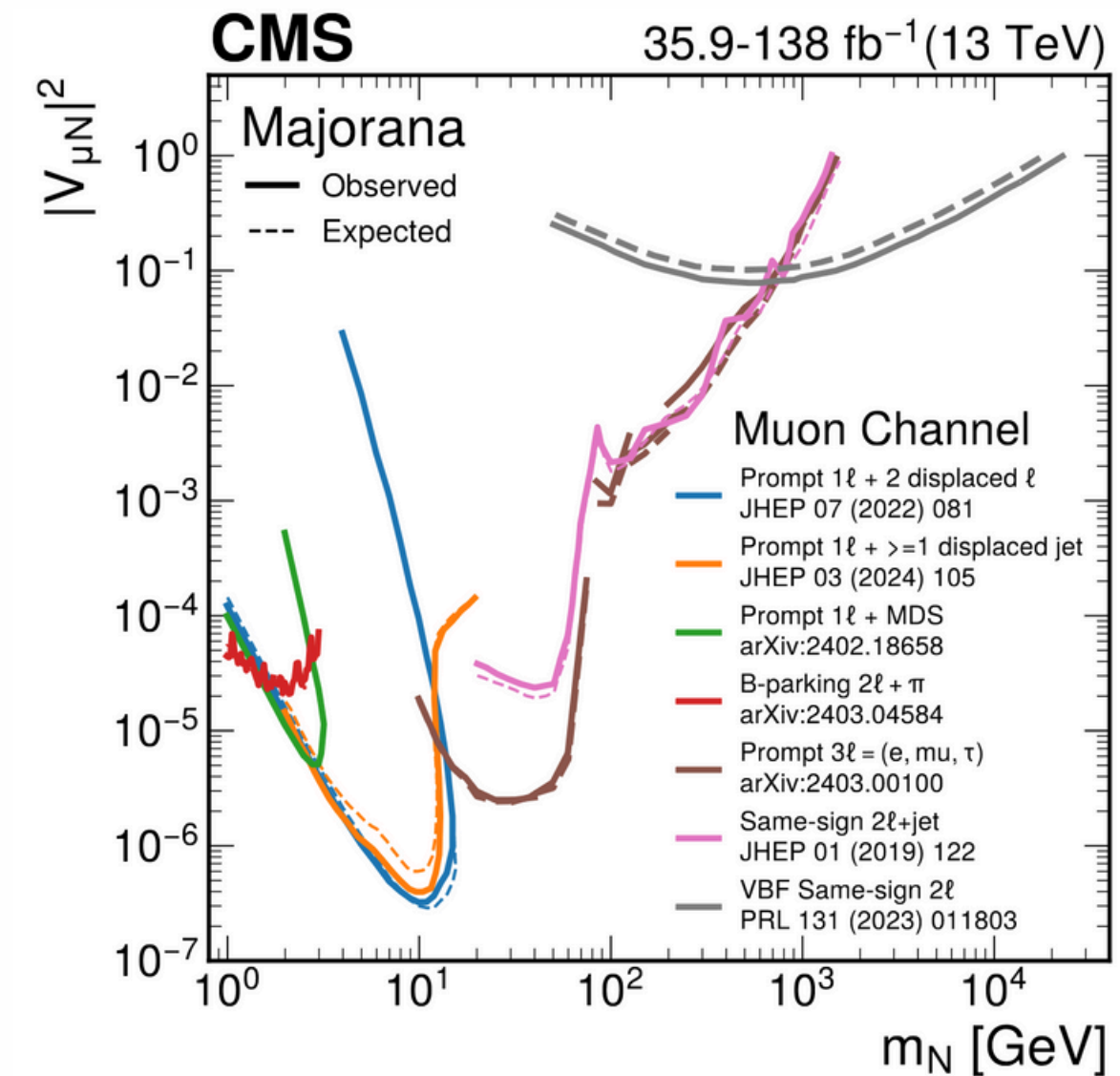
Many **Physics Reports about BSM Run 2 physics @LHC** submitted: state-of-the-art of a broad set of physics results and techniques in many areas of LHC BSM physics. Two examples:

All 2024 Physics Reports from ATLAS



arXiv:2403.09292

All 2024 Physics Reports from CMS



Heavy Neutral Leptons: different analyses techniques optimized in dedicated mass ranges

arXiv:2405.17605

New BSM searches in Summer 2024

Reference	Topic	Experiment	Model	Explored energy range	
				0	300 600 900 1200 1500 1800 2100 2400 2700 3000 [GeV]
HDBS-2021-07	$H \rightarrow aa \rightarrow bb\tau\tau$	ATLAS	Extended Higgs Sector		
HDBS-2020-11	$H^\pm \rightarrow cs$	ATLAS			
HDBS-2023-19	Combination of charged Higgs	ATLAS			
EXOT-2022-13	$A \rightarrow t\bar{t}$	ATLAS			
HIG-24-002	$H \rightarrow ZZ \rightarrow 4l$	CMS			
HIG-22-004	$A \rightarrow Zh(\tau\tau)$	CMS			
SUS-24-001	$\phi \rightarrow b\bar{b}$	CMS			
EXOT-2018-55	Prompt Lepton-Jets	ATLAS	Dark Sector		
EXOT-2022-04	Long Lived Particles in the hadronic calorim.	ATLAS			- displaced
SUS-23-004	mono- t	CMS			dark matter
SUS-23-012	mono- $h(\tau\tau)$	CMS			dark matter
SUS-23-018	$H \rightarrow Za \rightarrow ll\chi\chi$	CMS			
SUS-24-004	pMSSM	CMS	Supersymmetry		
SUS-23-003	Compressed Supersymmetry	CMS			Δm
ATLAS-CONF-2024-011	Run3 displaced leptons	ATLAS			- displaced
SUS-23-002	Supersymmetry w/ charged leptons and missing energy	CMS			
ATLAS-CONF-2024-008	Vector Like Leptons (VLL) 4321 model (tau hadronic)	ATLAS	Heavy Fermions		
EXOT-2021-02	Combination of VLQ	ATLAS			
EXO-23-015	$VLL \rightarrow \tau a(\gamma\gamma)$	CMS			- displaced
B2G-22-005	$t^* \rightarrow tg$	CMS			
EXO-23-010	$ll + b - \text{jets, non - resonant}$	CMS	EFT		
EXOT-2022-33	Low mass dijet + ISR gamma	ATLAS	New Mediators		
EXOT-2020-26	Dark Higgs via Z'	ATLAS			
EXO-24-007	Low mass dijet+ISR	CMS			
EXO-22-006	$Z' \rightarrow \mu\mu + b - \text{jets, resonant}$	CMS			
EXO-22-013	t-channel scalar and vector	CMS		Leptoquarks	



Beyond Standard

Model

Strategies

Signatures

Tools

Beyond Standard

Model

- *Extended Higgs Sector (2HDM)*
- *Supersymmetry (SUSY)*
- *Heavy fermions*

Signatures

Tools

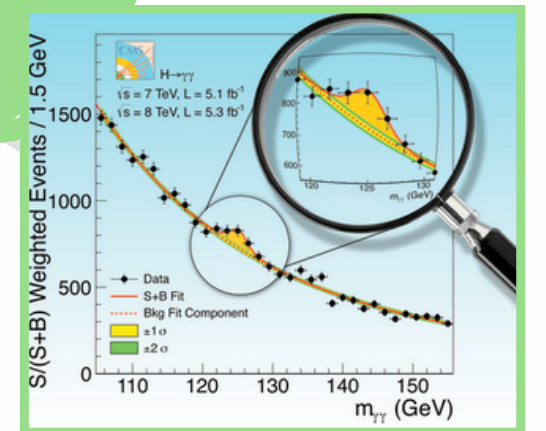
Extended Higgs Sector: Two Higgs doublet model (2HDM).

H^\pm

A

H

h



[link]

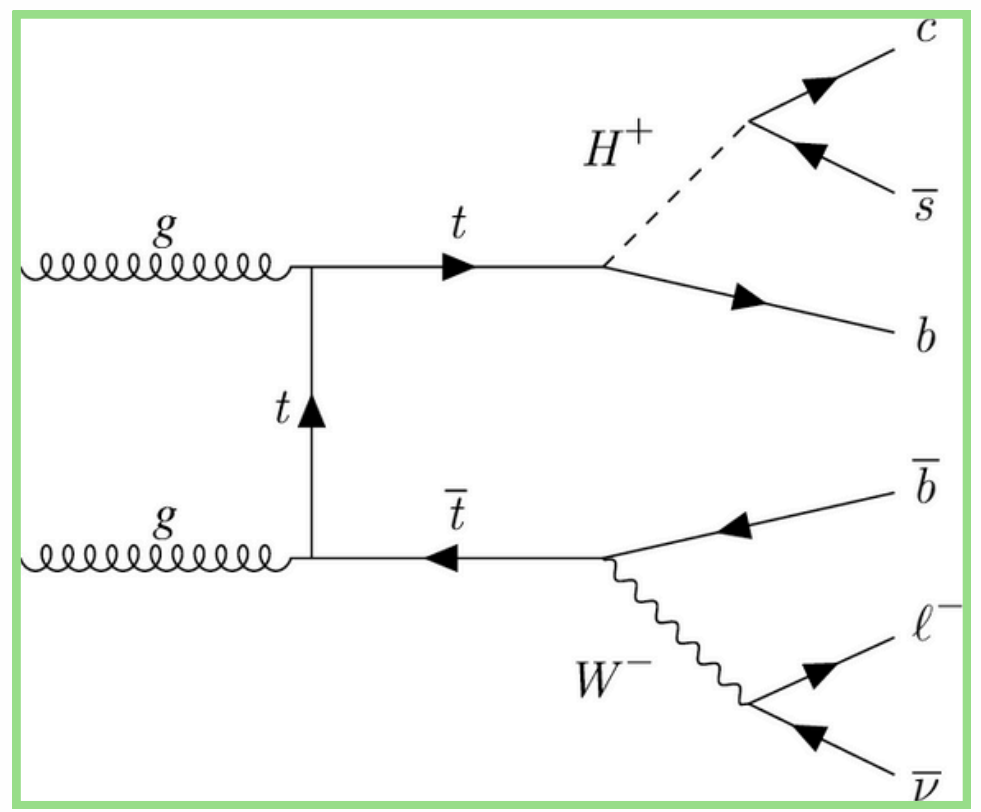
Already observed
Higgs Boson

Two Higgs doublet model (2HDM): H^\pm, A, H, h

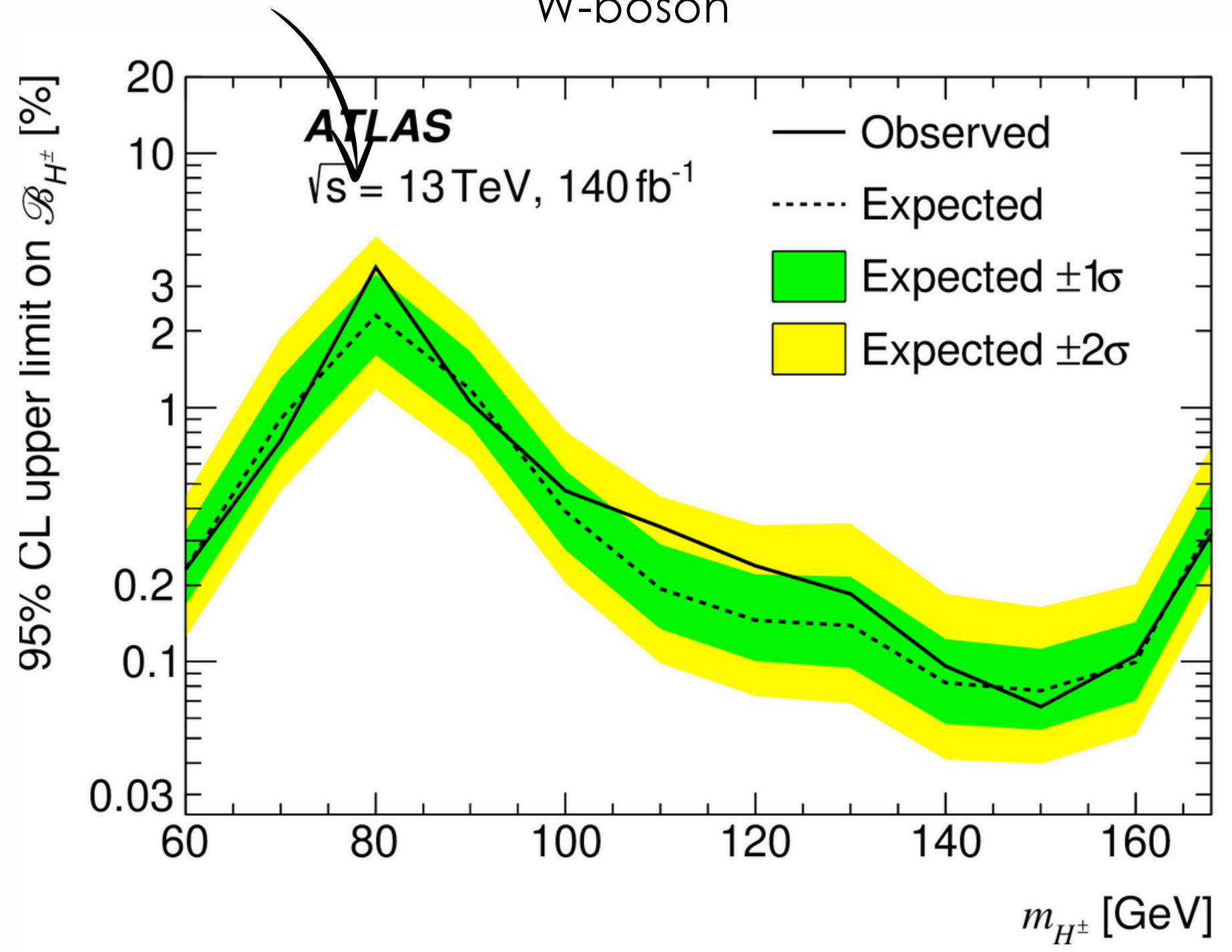
Search for $t \rightarrow H^\pm b$ with $H^\pm \rightarrow cs$

Least stringent at ~ 80 GeV about 2.3%, as signal mass closest to W-boson

$H^\pm \rightarrow cb$ moderate **excess around 130 GeV from ATLAS**, with global significance of 2.5σ [\[link\]](#)



Dedicated flavour-tagging scheme: **simultaneous tagging of b - and c -jets.**

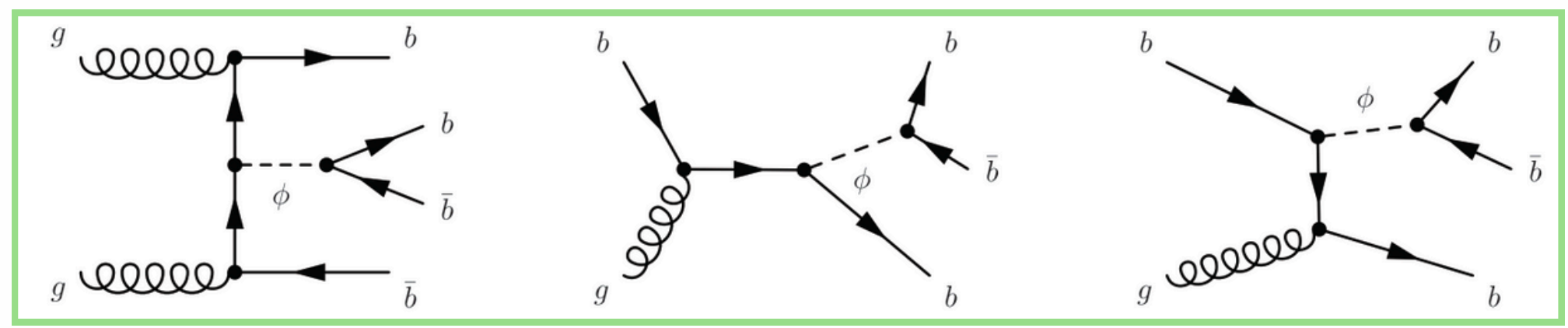


Limits worsen as the acceptance decreases

Two Higgs doublet model (2HDM): H^\pm, A, H, h

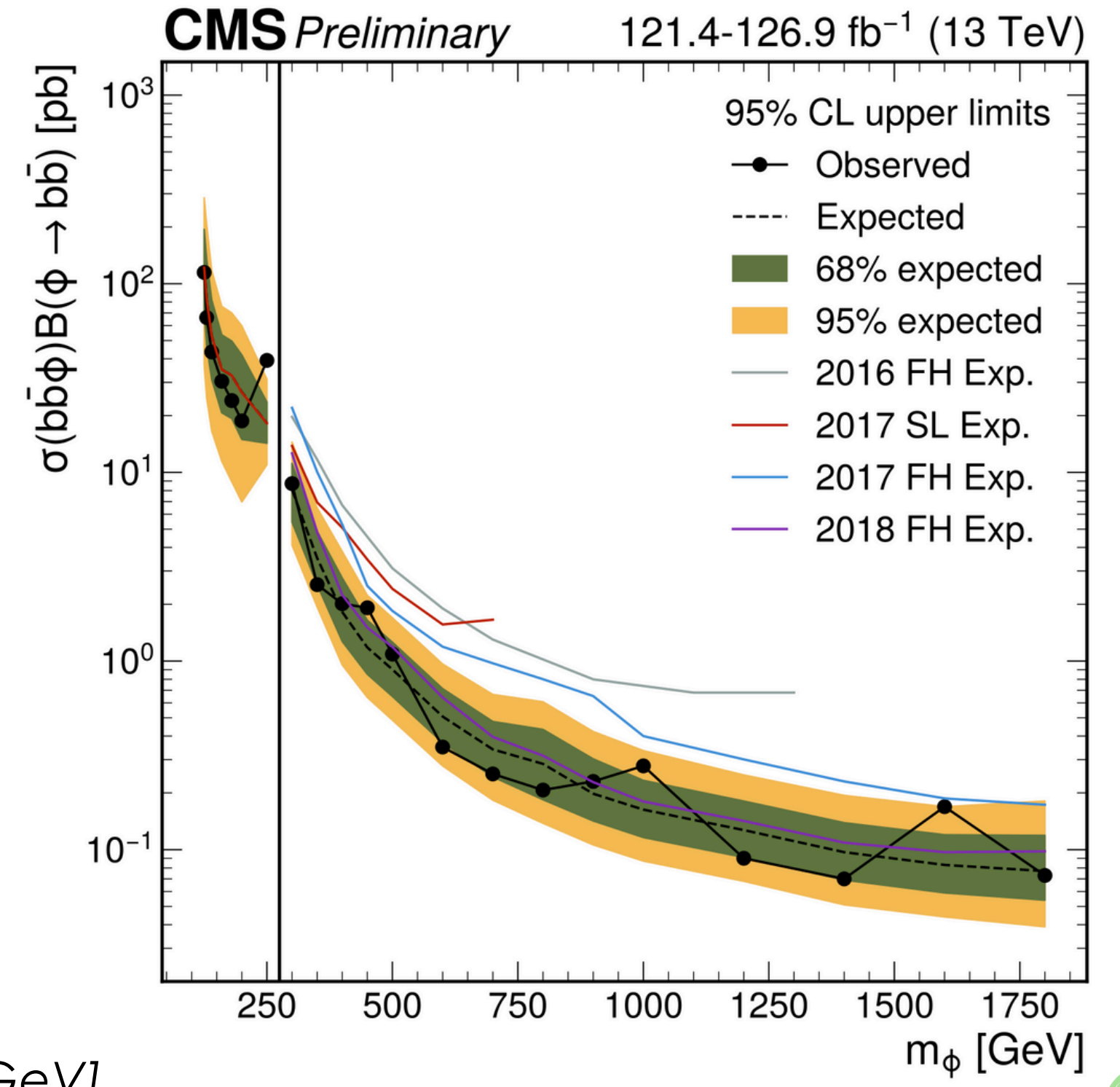
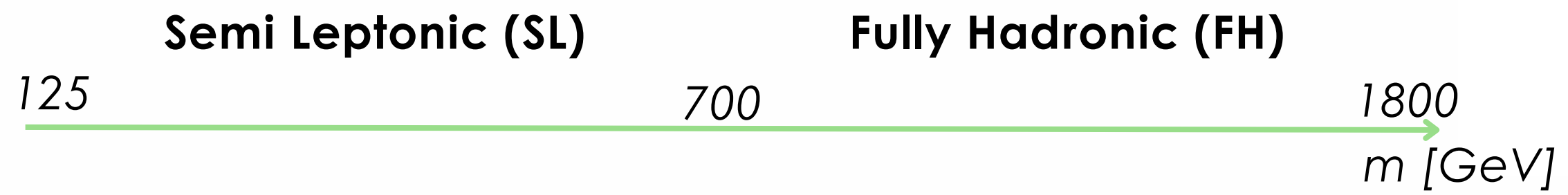


Search for bosons of an extended Higgs sector in b quark final states



Searching for a **peak in the invariant mass distribution**, of the two b jets with the highest p_T values

Two different signatures explored to maximize sensitivity over a wide mass range

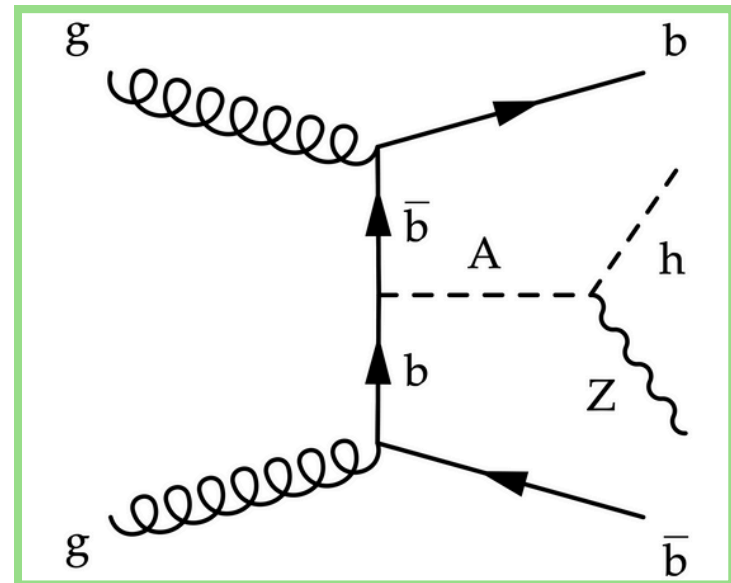
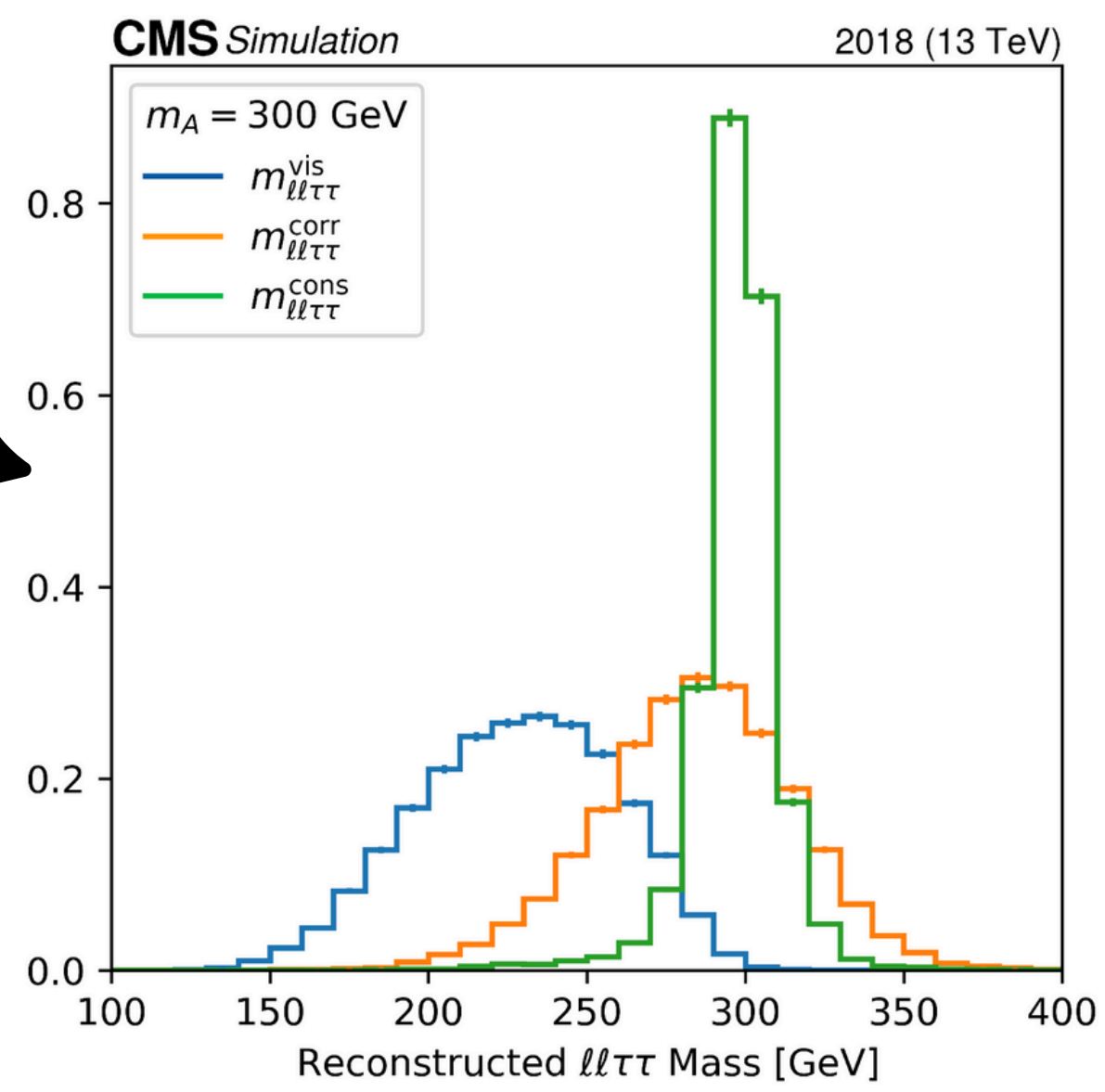
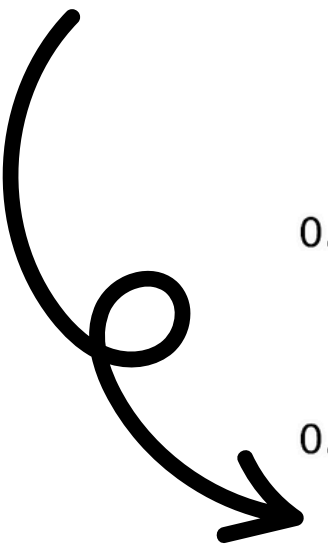


Two Higgs doublet model (2HDM): H^\pm, A, H, h

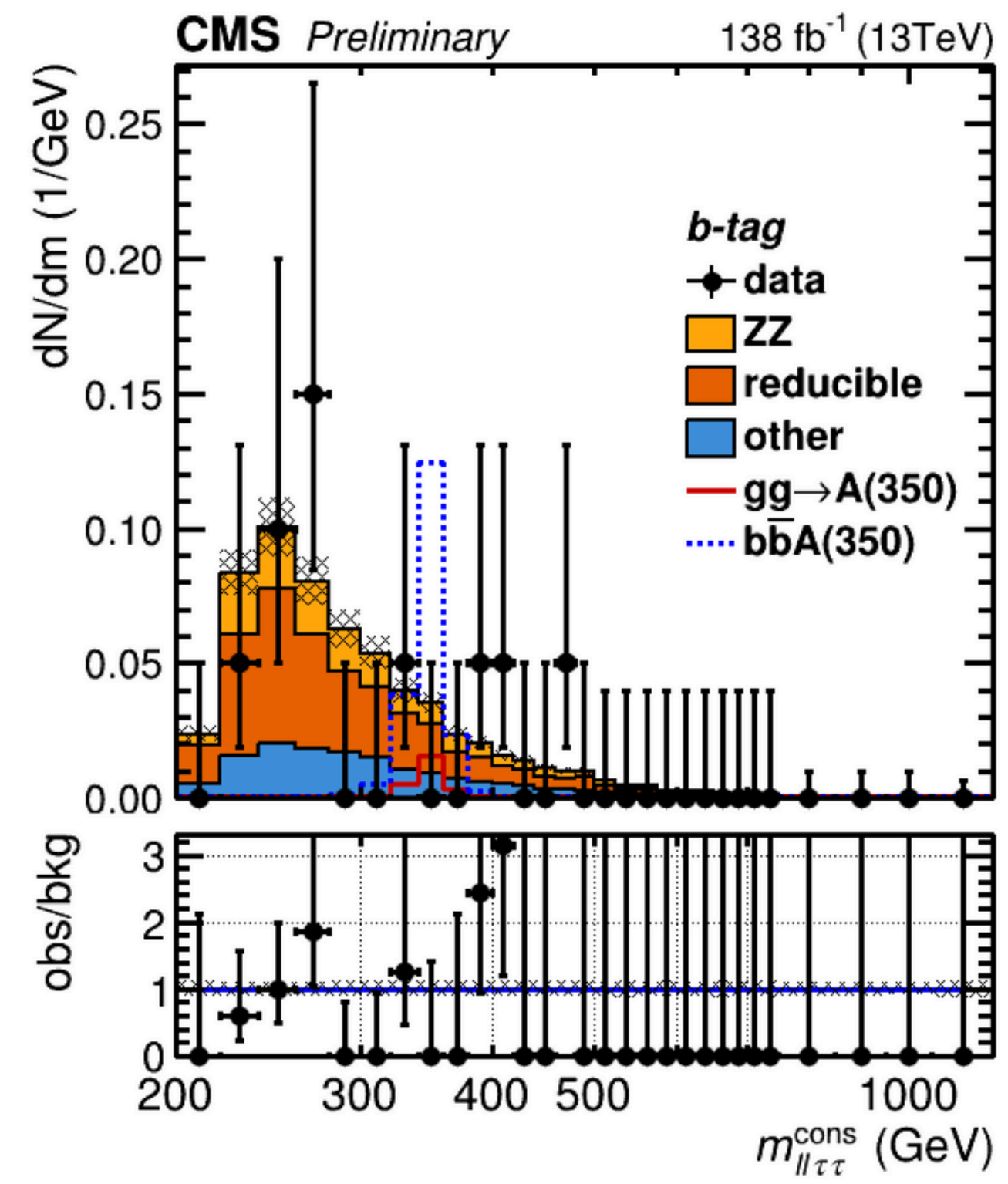


Search for $A \rightarrow Zh (h \rightarrow \tau\tau)$

Dedicated mass estimator corrects for missing momentum from neutrinos while constraining h mass to 125 GeV: **best mass resolution of 5-7%**



Category w/ b-jets designed to bbF production mode



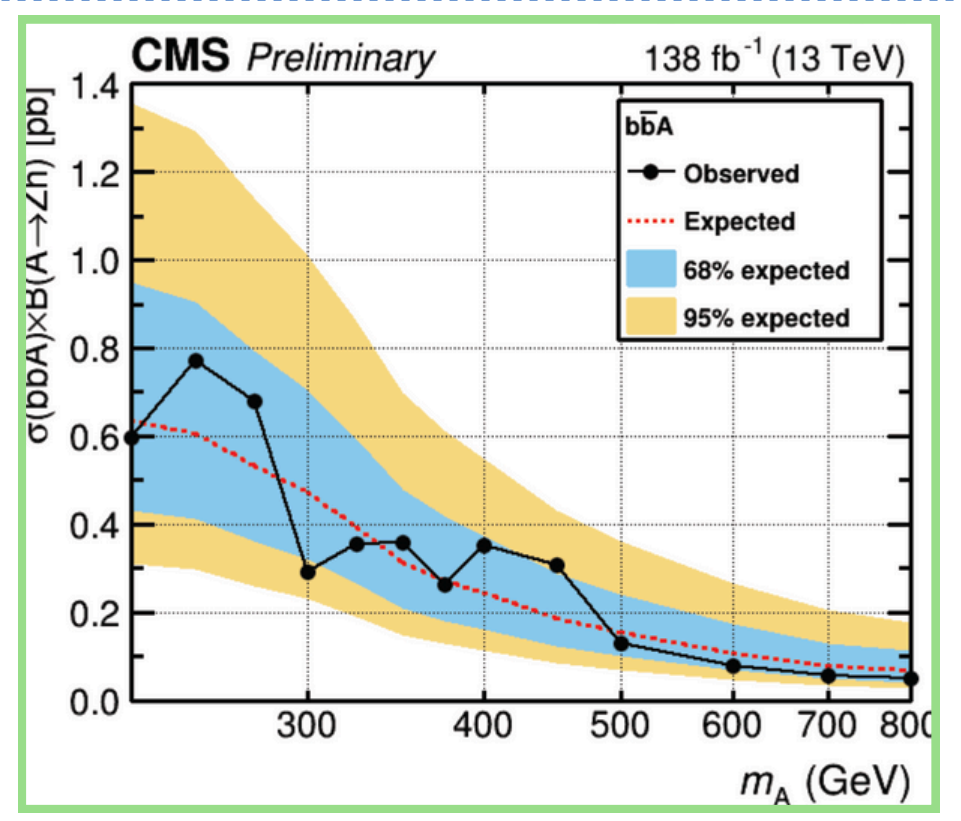
CMS-PAS-HIG-22-004

Backup

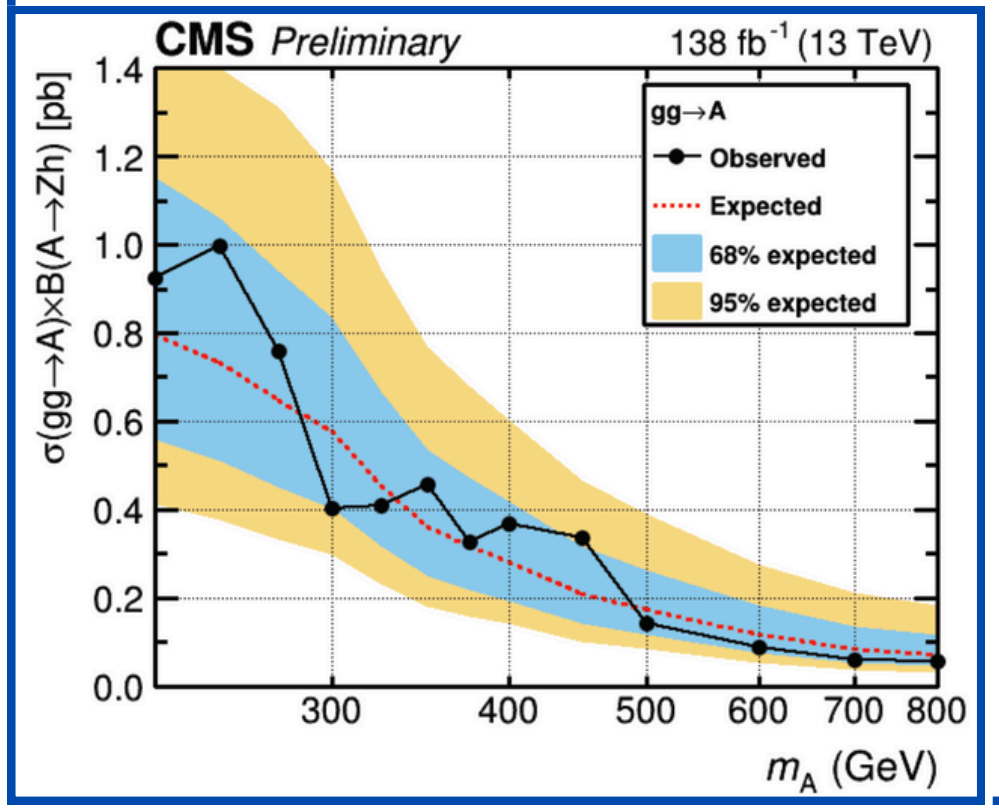
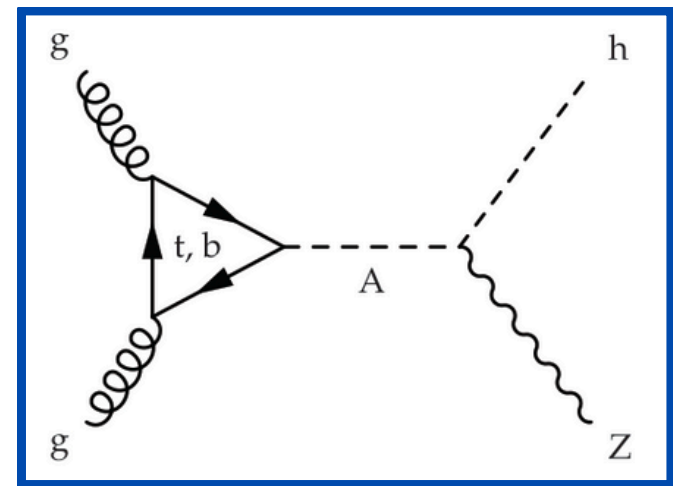
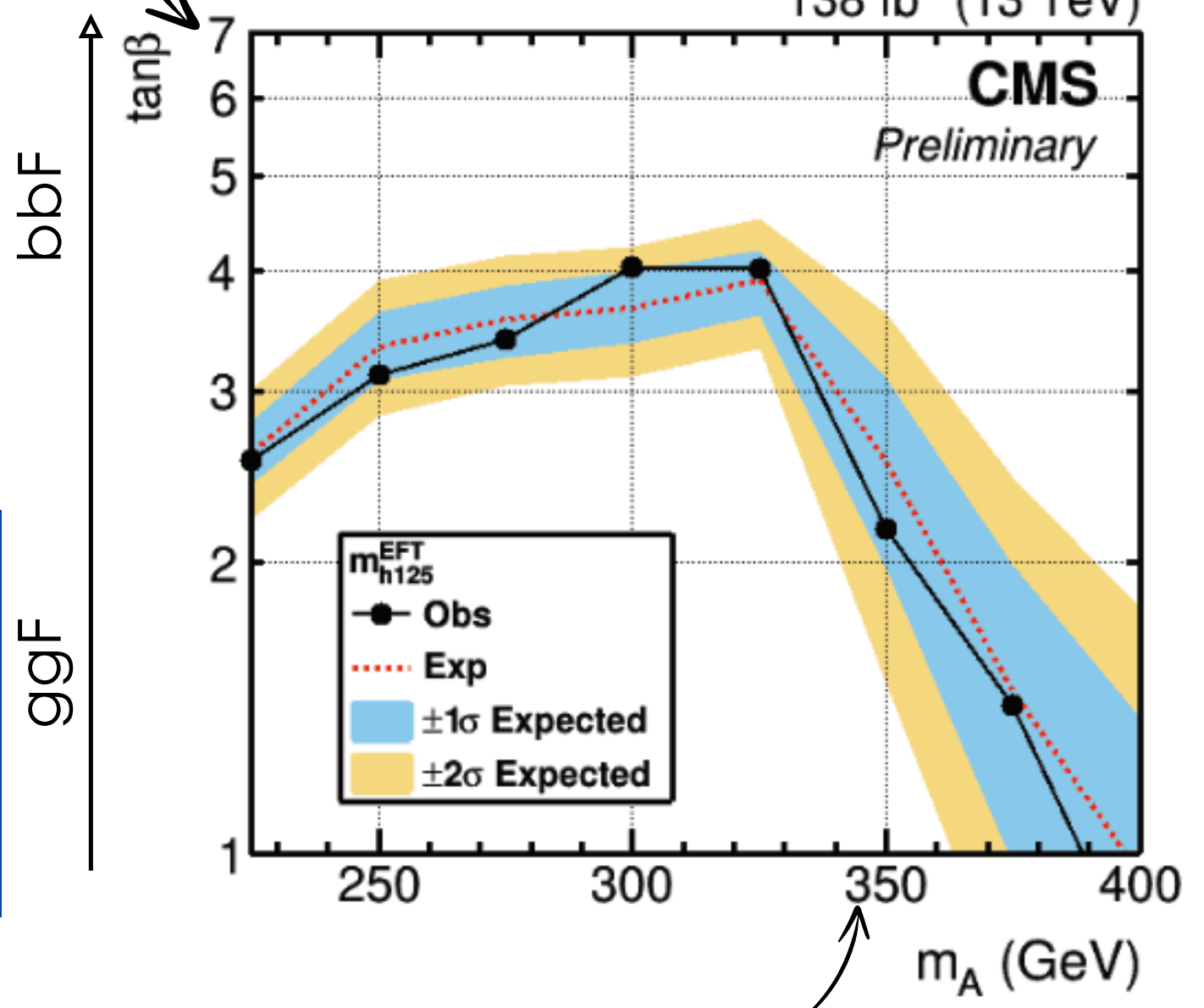
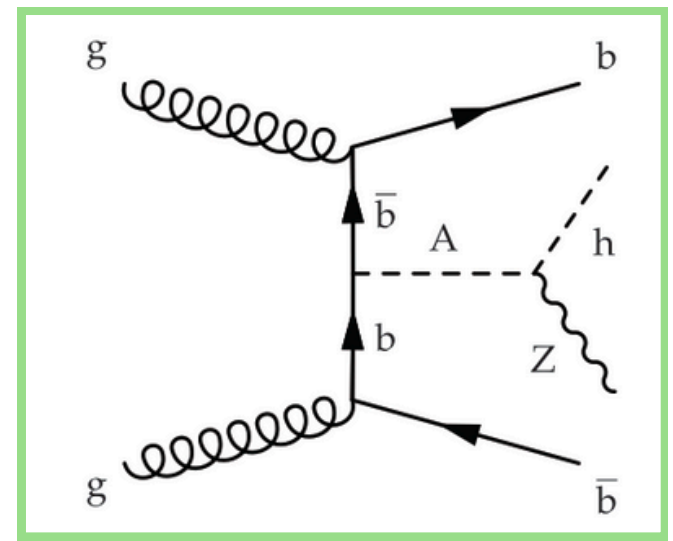
Two Higgs doublet model (2HDM): H^\pm, A, H, h



Search for $A \rightarrow Zh (h \rightarrow \tau\tau)$



At high $\tan \beta$ values associated production w/ b-quarks takes over



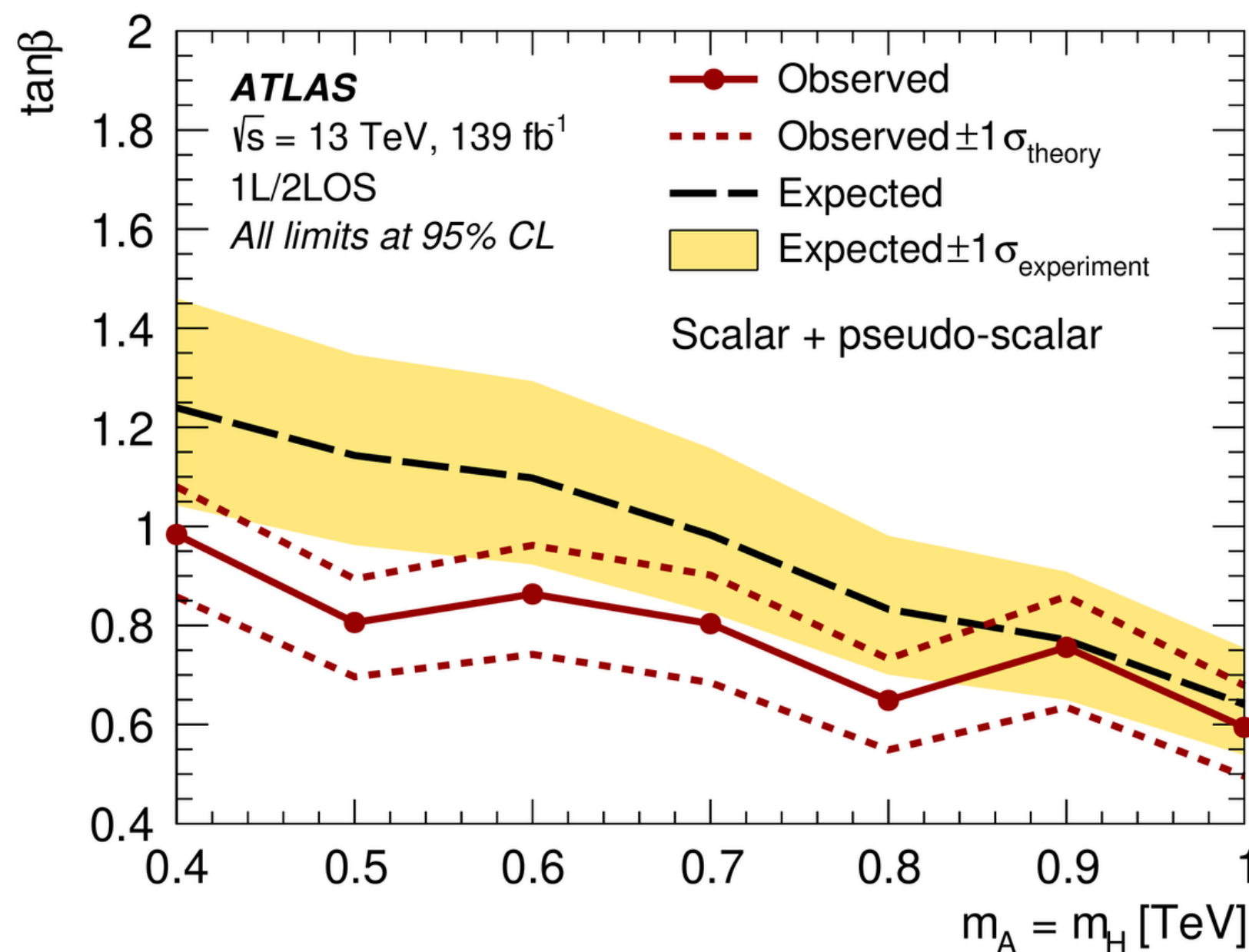
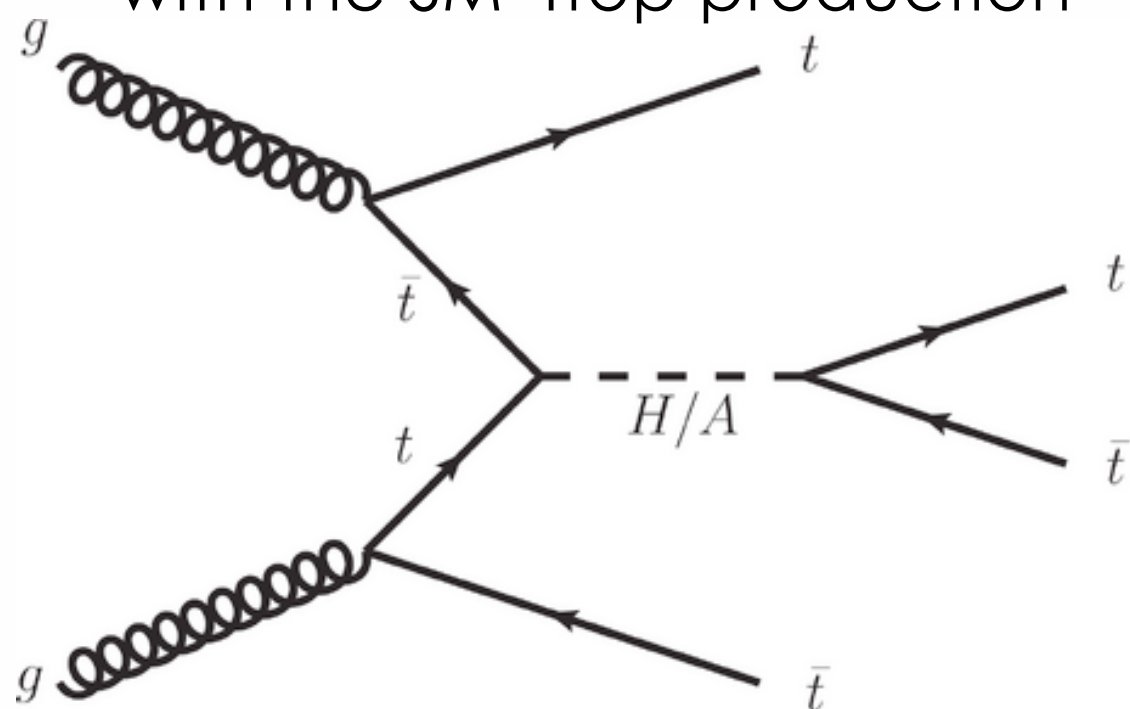
Two Higgs doublet model (2HDM): H^\pm, A, H, h

Search for $t\bar{t}A/H \rightarrow t\bar{t}t\bar{t}$

Data-driven technique applied to improve modelling of the **$t\bar{t}$ +jets bkg in regime with high (b-)jet multiplicities**

Exactly one lepton (electron or muon) or two leptons with opposite electric charge (1L/2LOS)

H/A production in **association with a $t\bar{t}$ pair**, much less susceptible to interference effects with the SM 4top production



The search in the 1L/2LOS final states **combined with that in the multilepton final states**

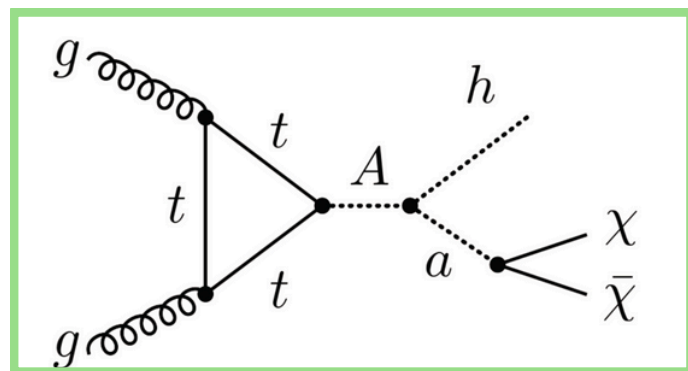
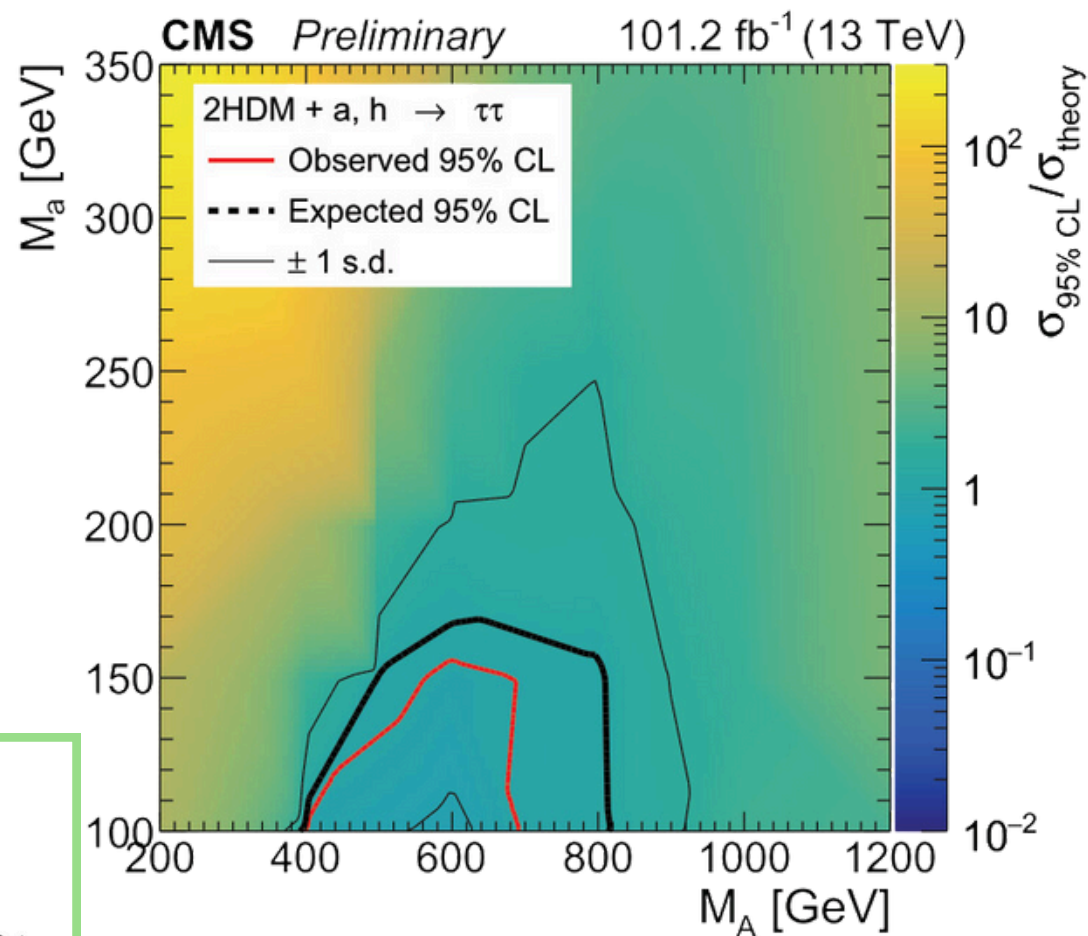
Two Higgs doublet model (2HDM+a): H^\pm, A, H, h, a



2HDM+a: extension of the Standard Model that includes two Higgs doublets and **an additional pseudoscalar particle (a)**

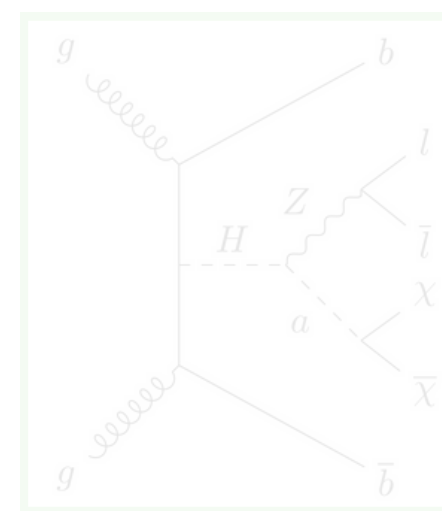
Search for **dark matter produced with a Higgs boson decaying to $\tau\tau$**

CMS-PAS-SUS-23-012

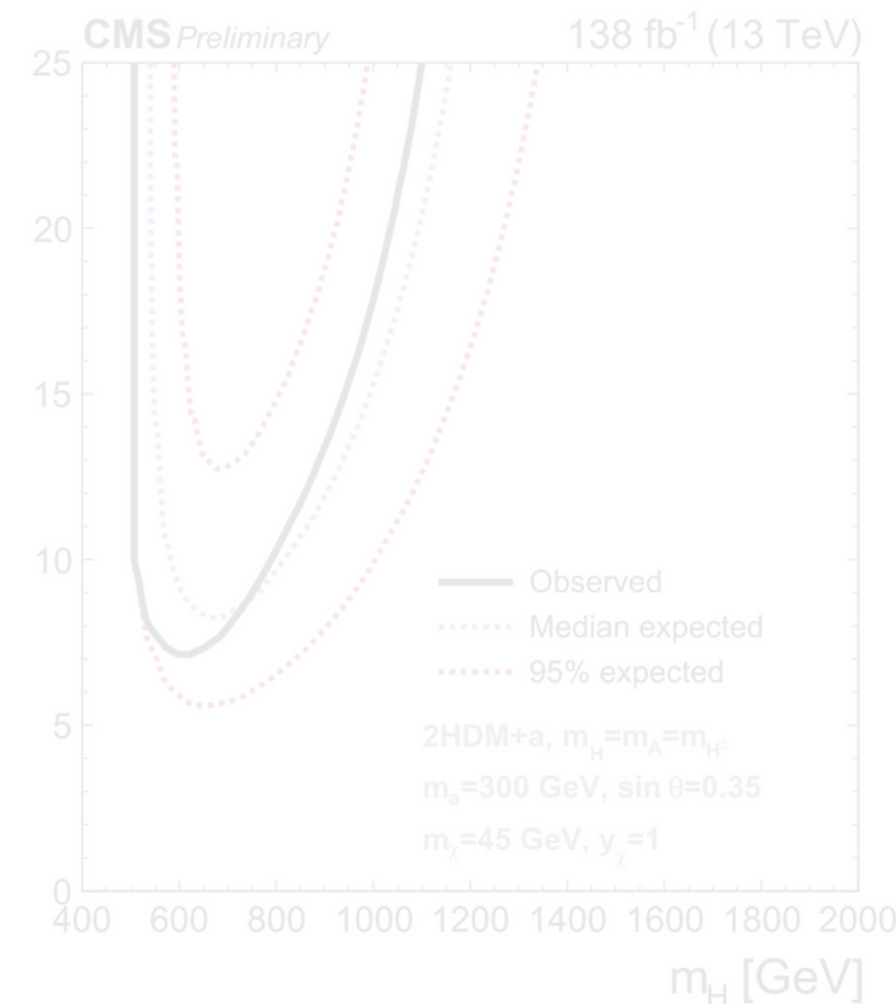


Search for **dark matter with b-quarks and lepton pairs**

Impacts the masses and couplings of the Higgs bosons



tan β



CMS-PAS-SUS-23-018

first time at the LHC

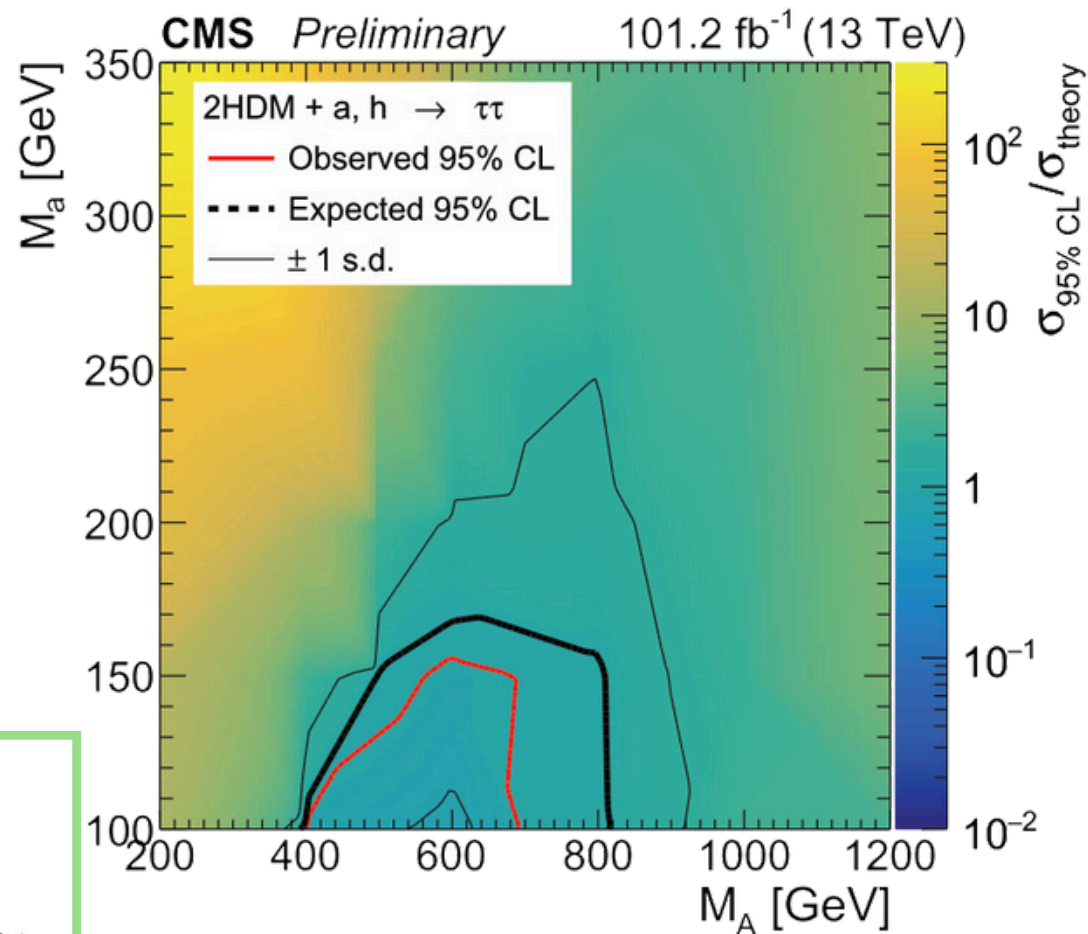
Backup

Two Higgs doublet model (2HDM+a): H^\pm, A, H, h, a

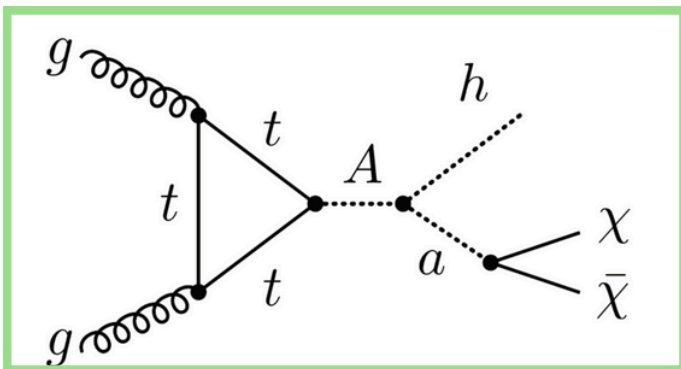


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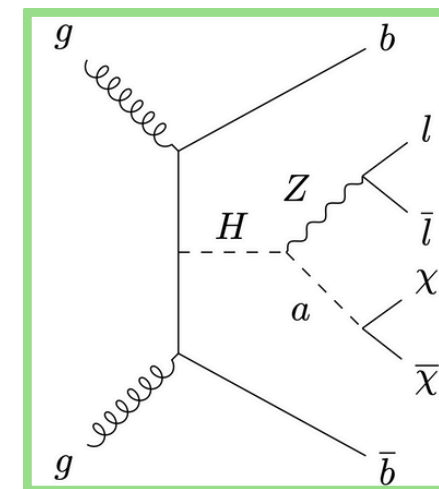


CMS-PAS-SUS-23-012



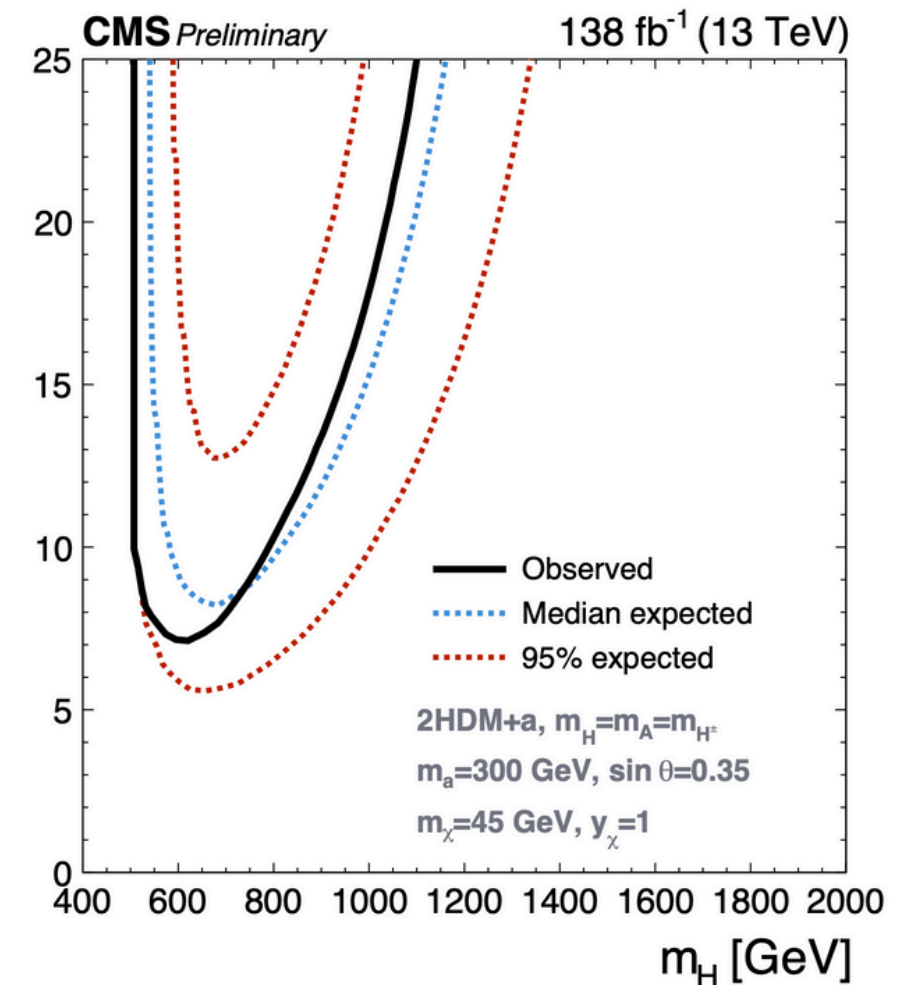
Search for **dark matter with b-quarks and lepton pairs**

Impacts the masses and couplings of the Higgs bosons



b-quark fusion

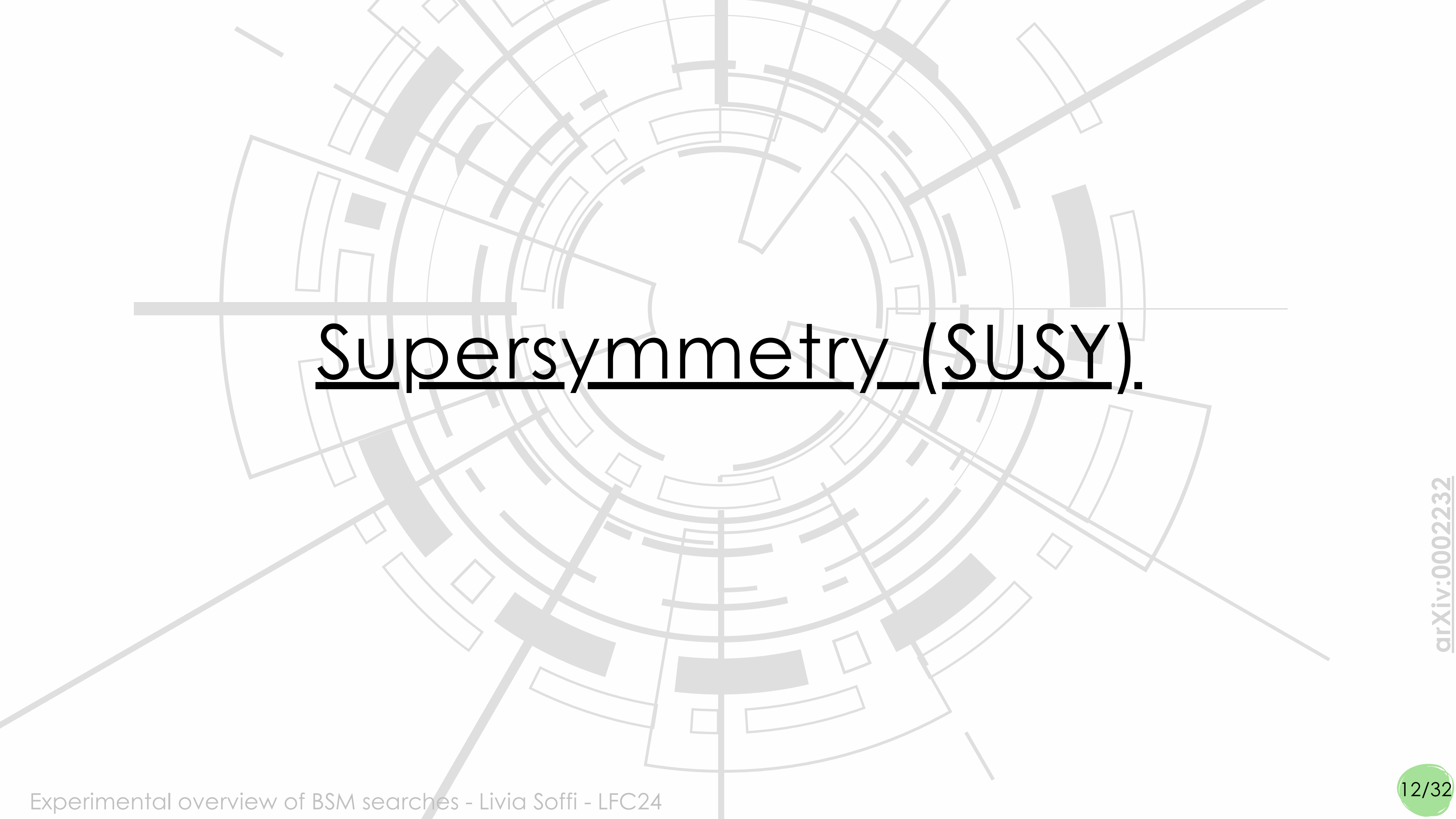
$\tan \beta$



CMS-PAS-SUS-23-018

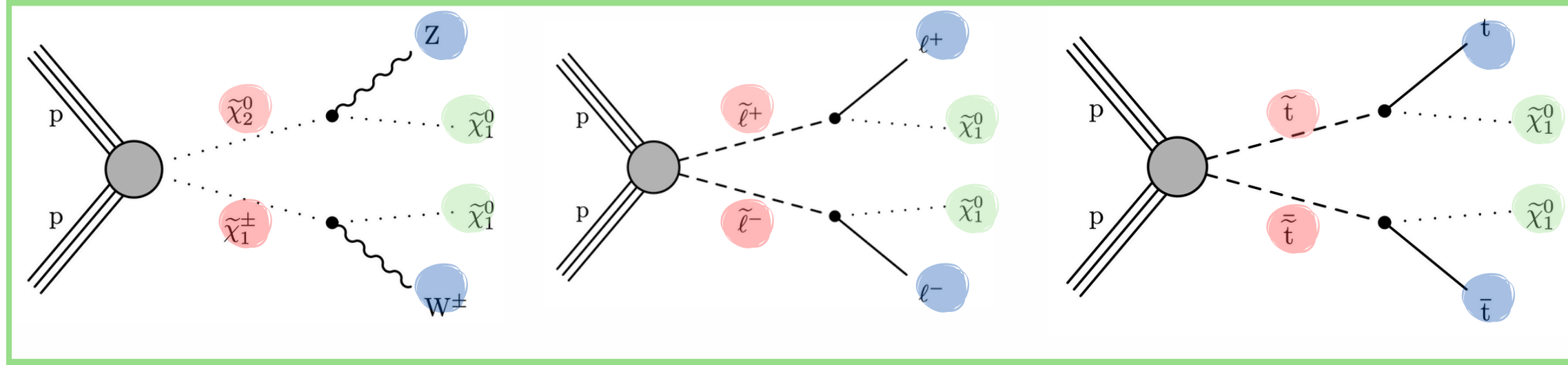
first time at the LHC

Backup

The background of the slide features a detailed, light-gray schematic of a particle detector's cross-section. It shows concentric rings representing different detector layers, with various rectangular and curved segments indicating the placement of sensors and support structures. A prominent horizontal line bisects the diagram, passing through the center where the title is located.

Supersymmetry (SUSY).

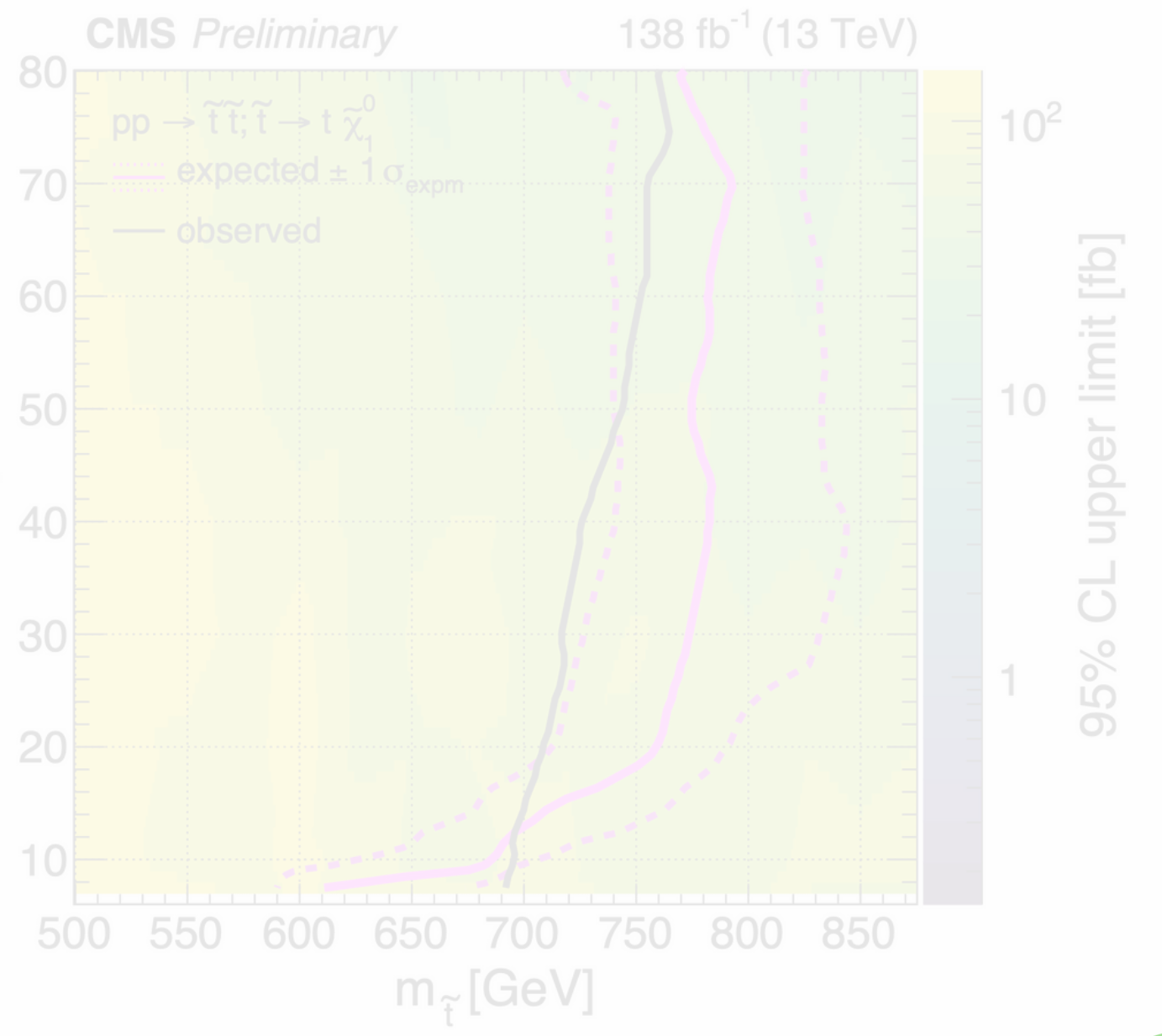
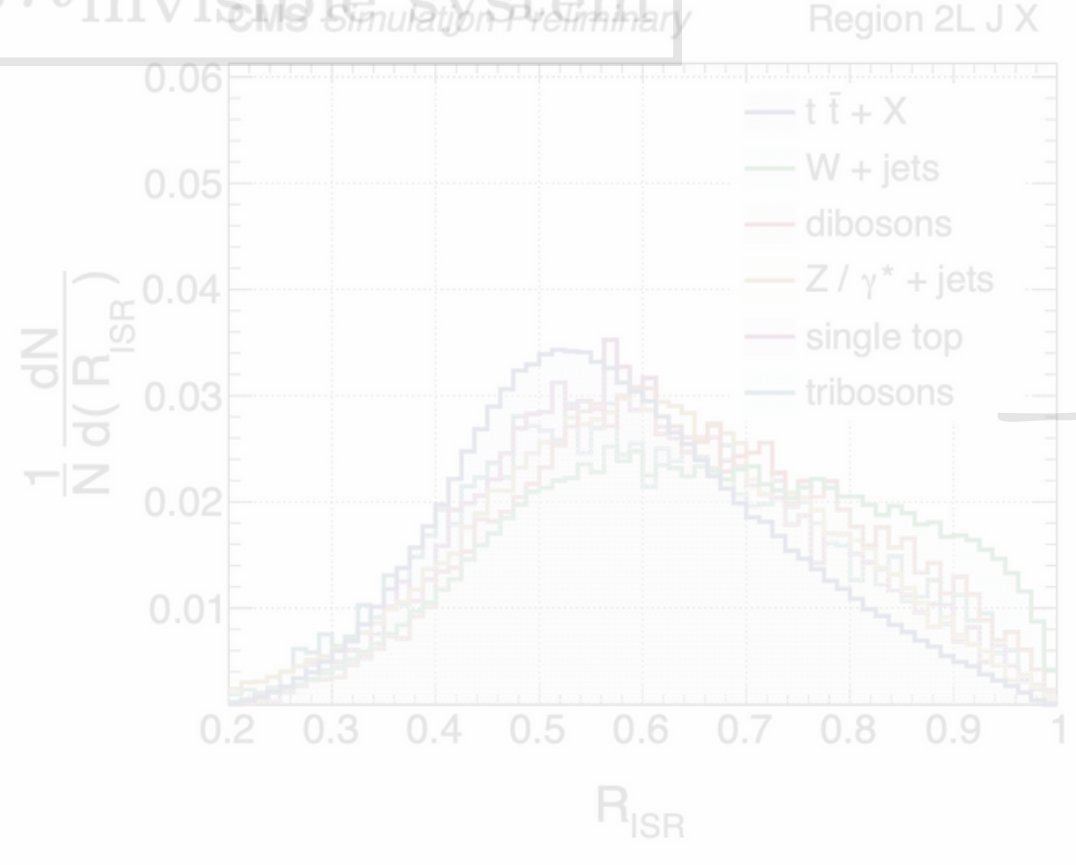
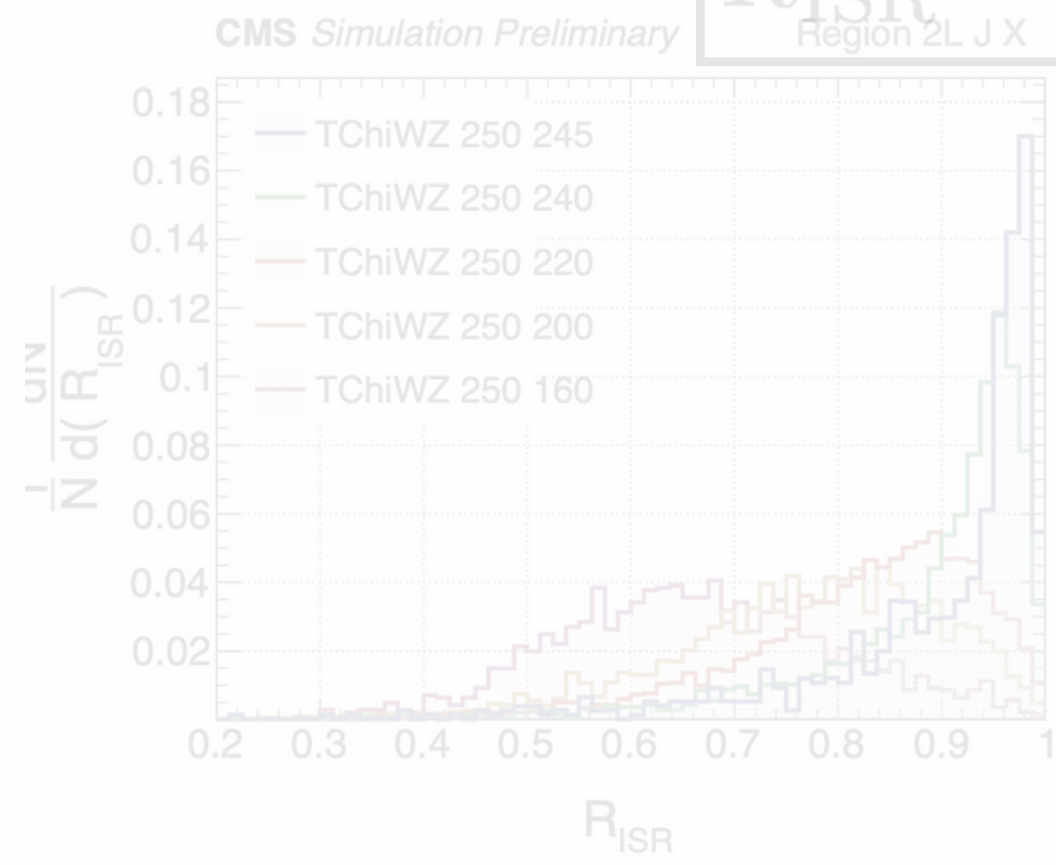
Compressed supersymmetry scenarios



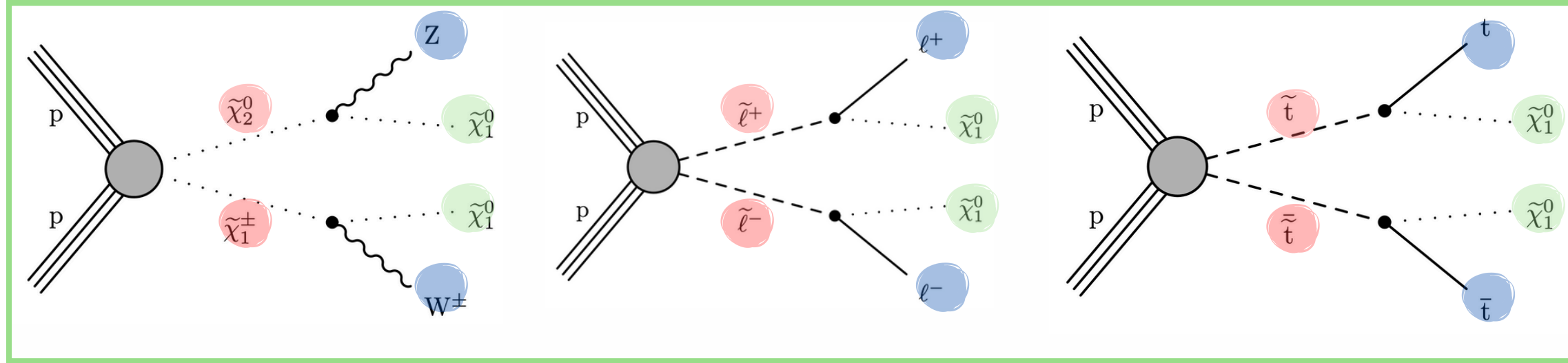
Events categorized based on lepton or (b)jets multiplicity and kinematic variables sensitive to mass splittings

$3\text{GeV} < \Delta m(\text{red} - \text{green}) < 200\text{GeV}$ \rightarrow low- p_T visible objects
 \rightarrow very little missing energy

$$R_{\text{ISR}} \sim m_{\text{invisible system}}$$



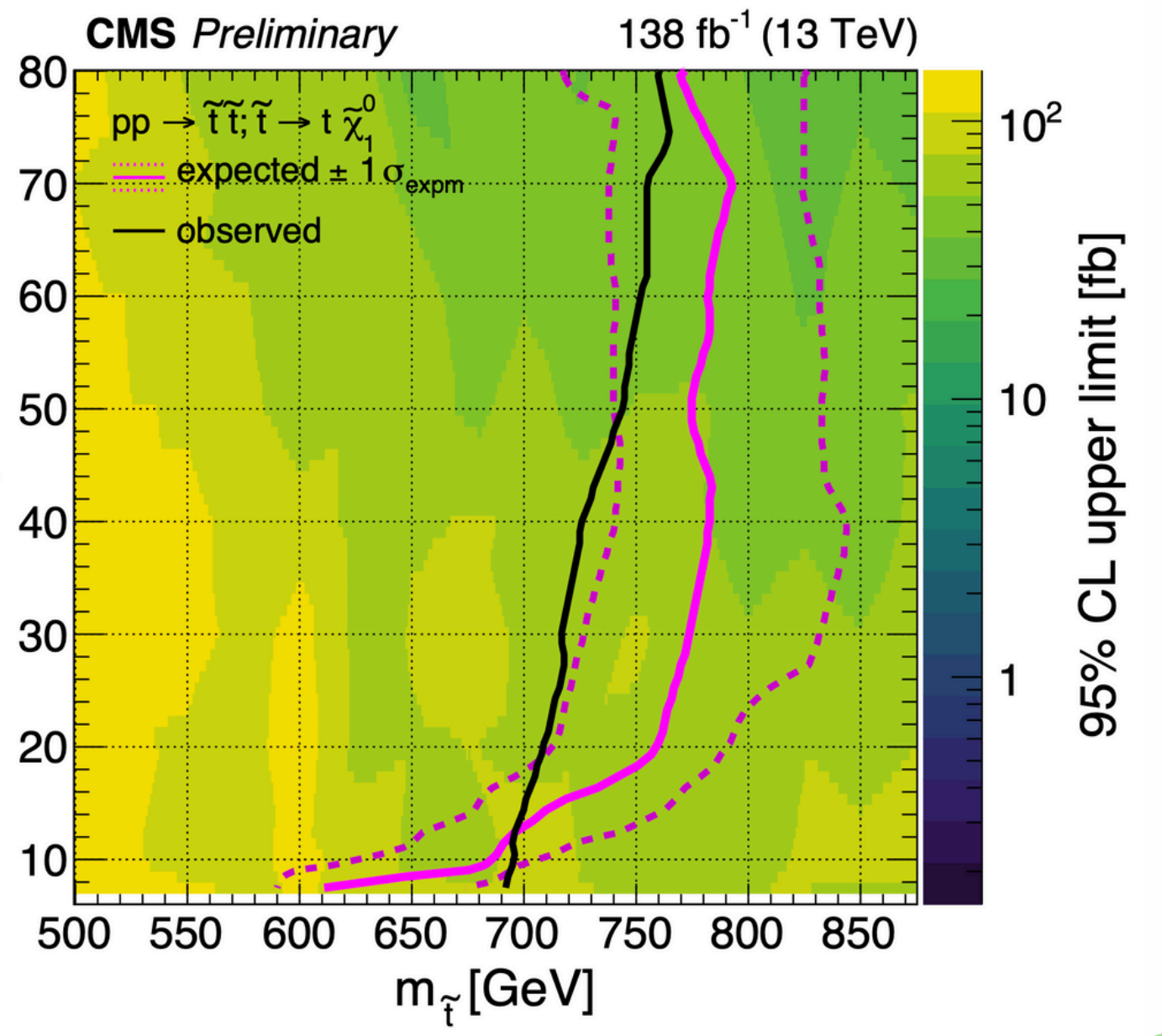
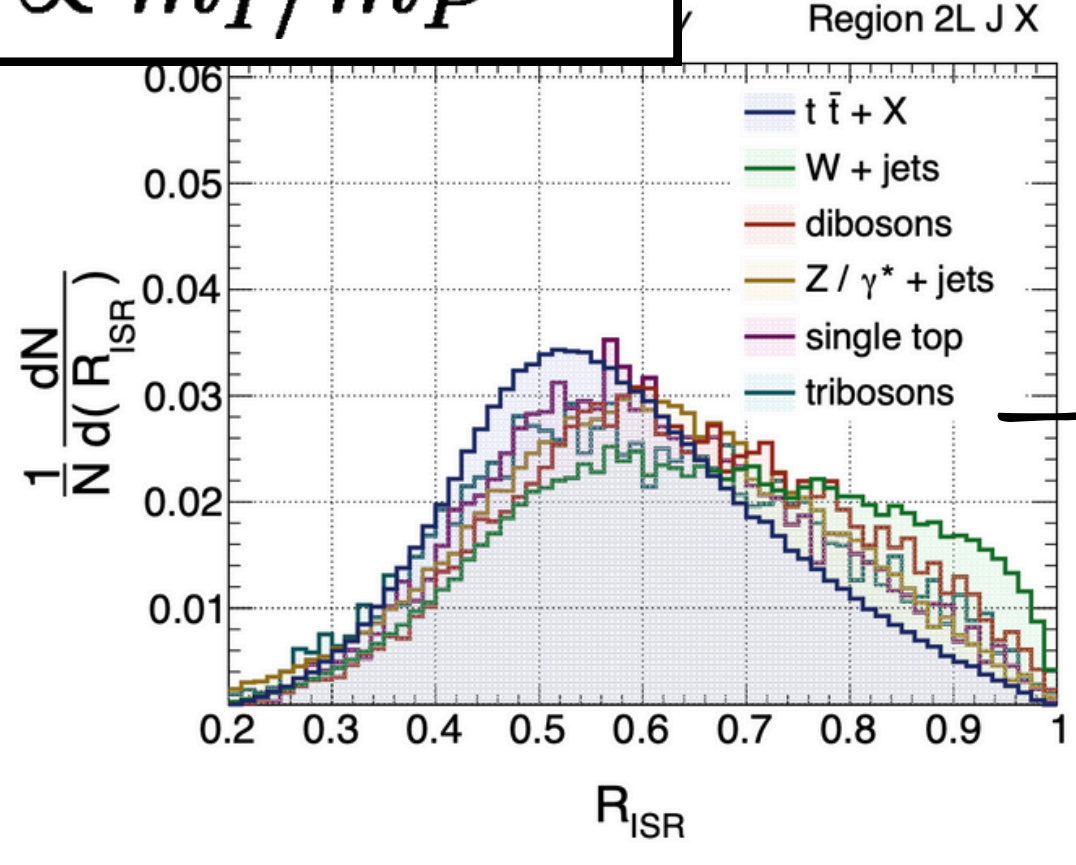
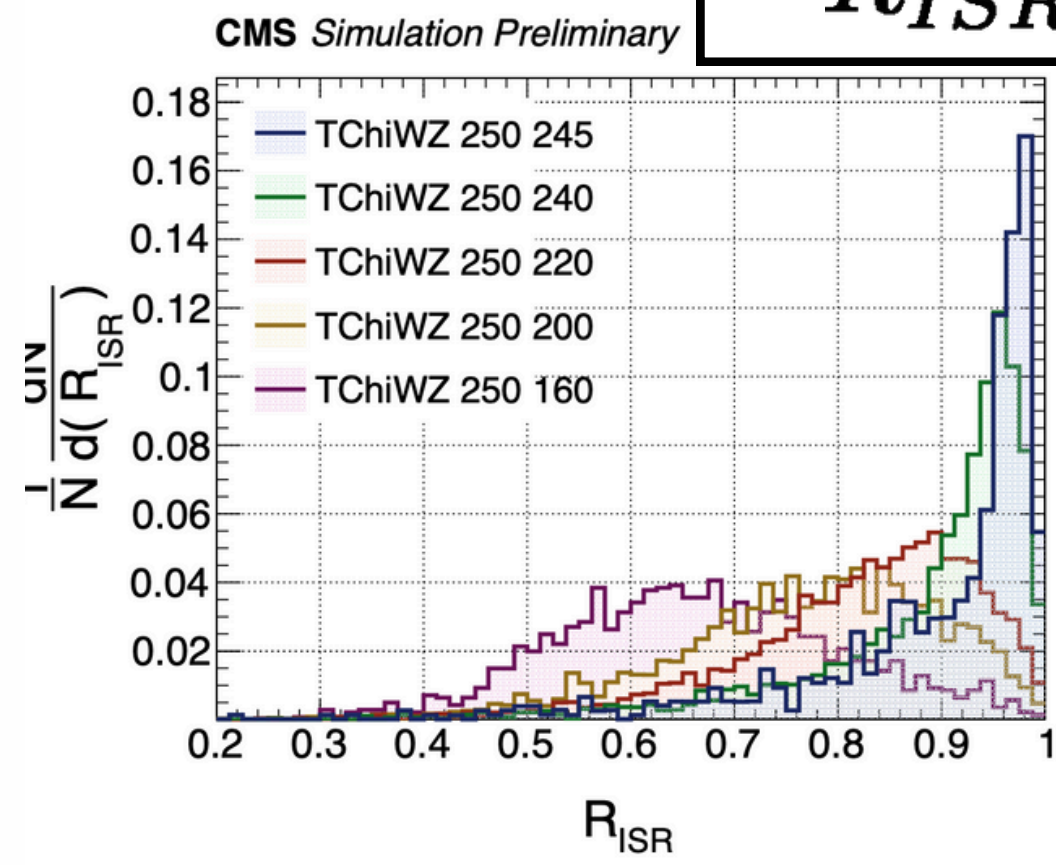
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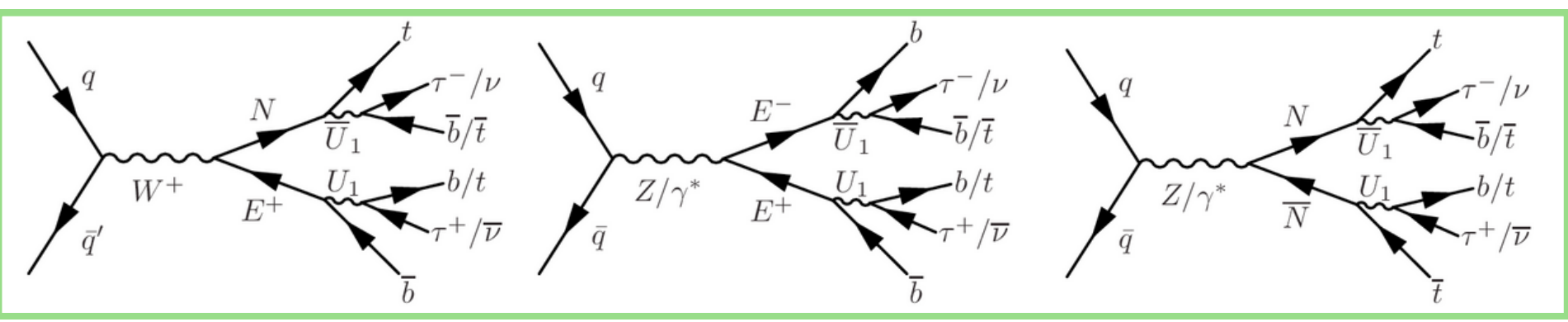
$$R_{ISR} \propto m_I / m_P$$





Heavy Fermions

Vector Like Leptons (VLLs).

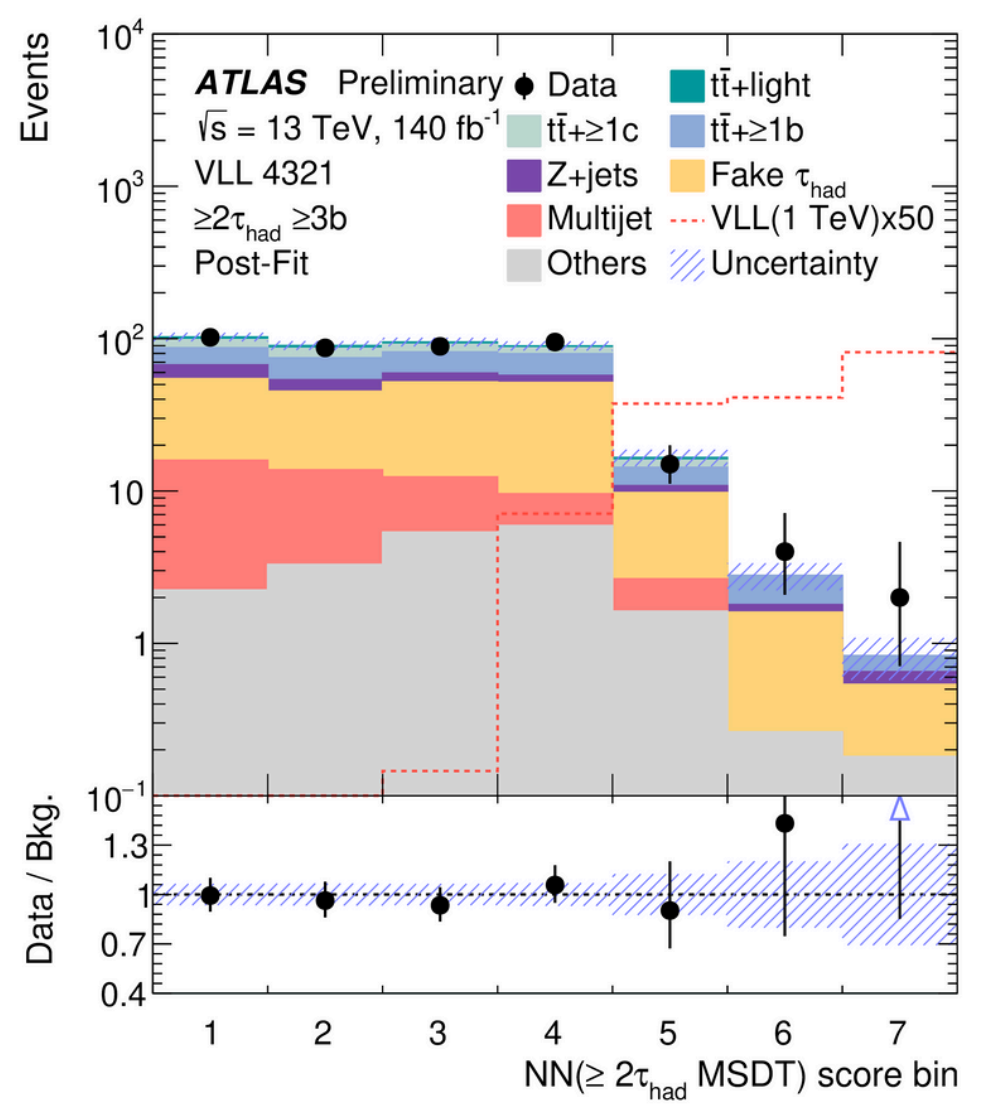


Existing result from CMS w/ local 2.8σ excess at mass of 600 GeV disfavoured

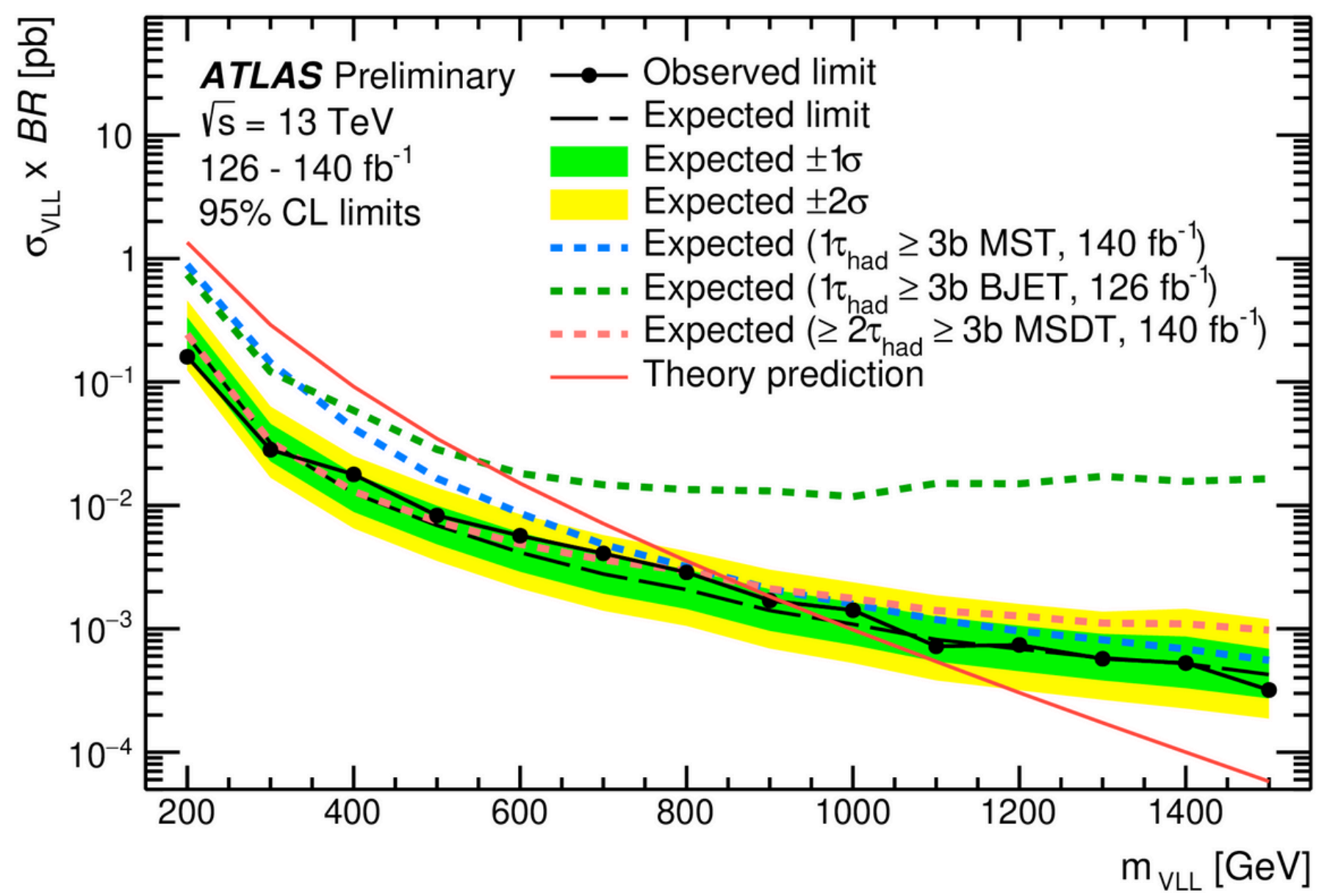
"4321 model" explored

Signature: large # jets, *b*-jets, and multiple \mathcal{T}_h

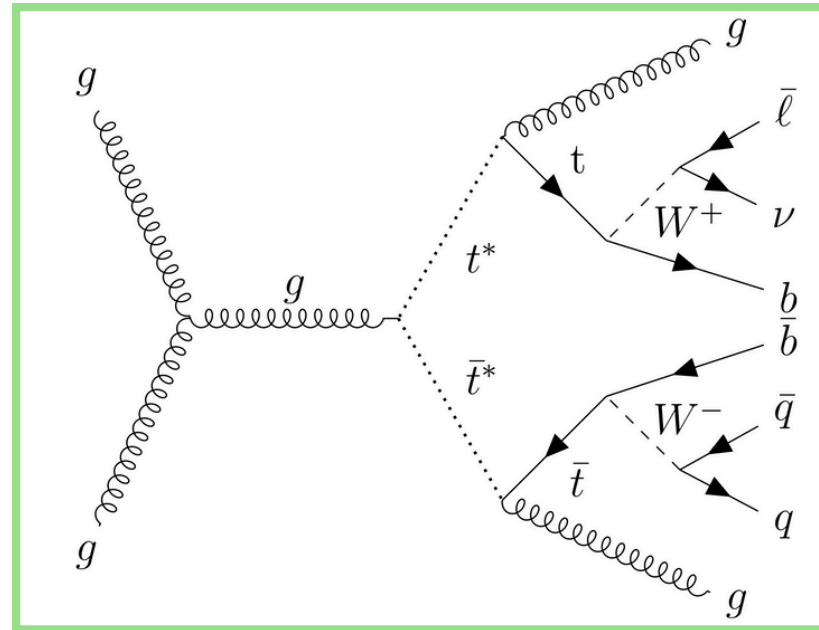
Neural network exploits the complex kinematic of the final state to discriminate the signal



Observed (expected) limit on the VLL mass at 910 GeV (970 GeV)

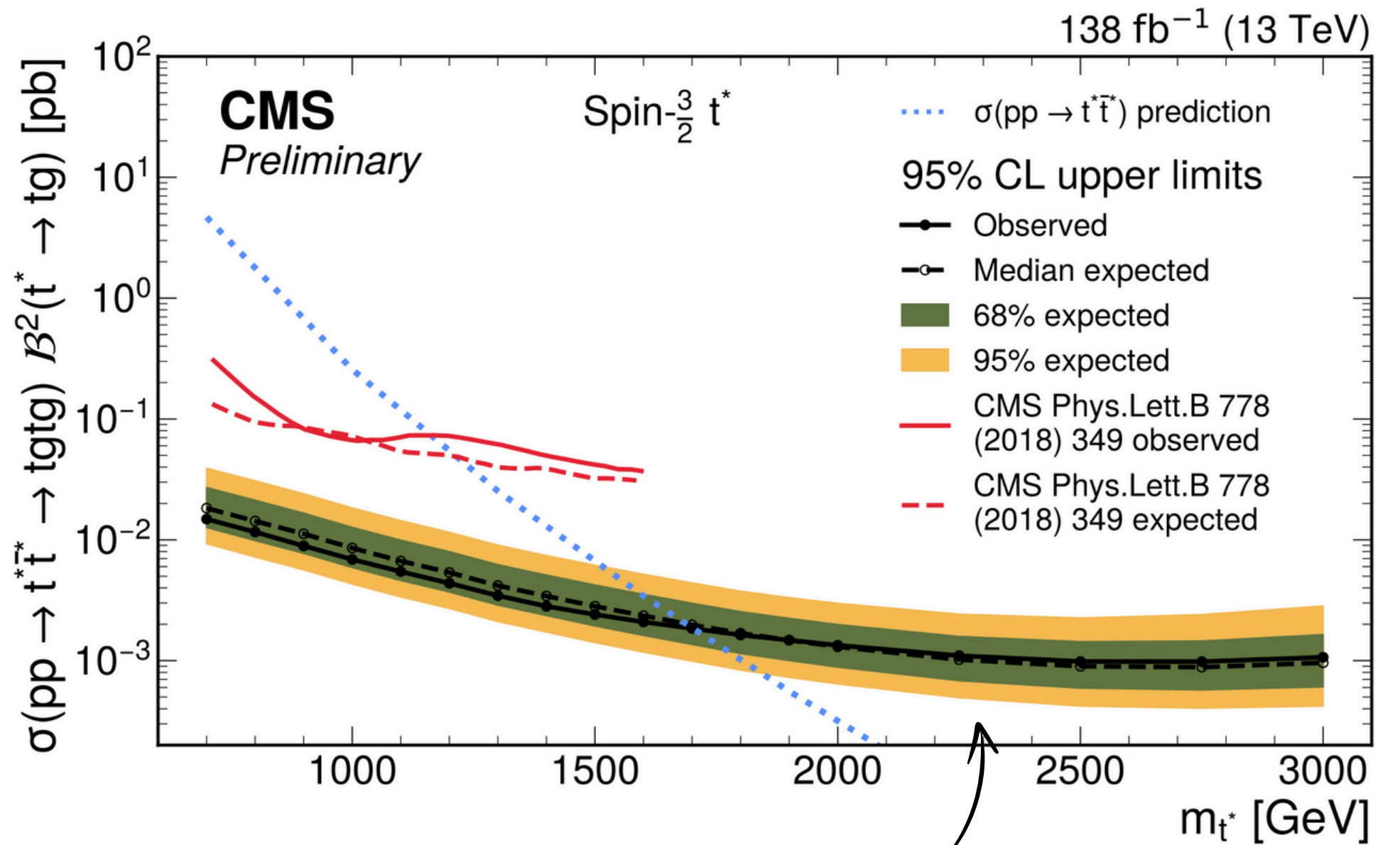
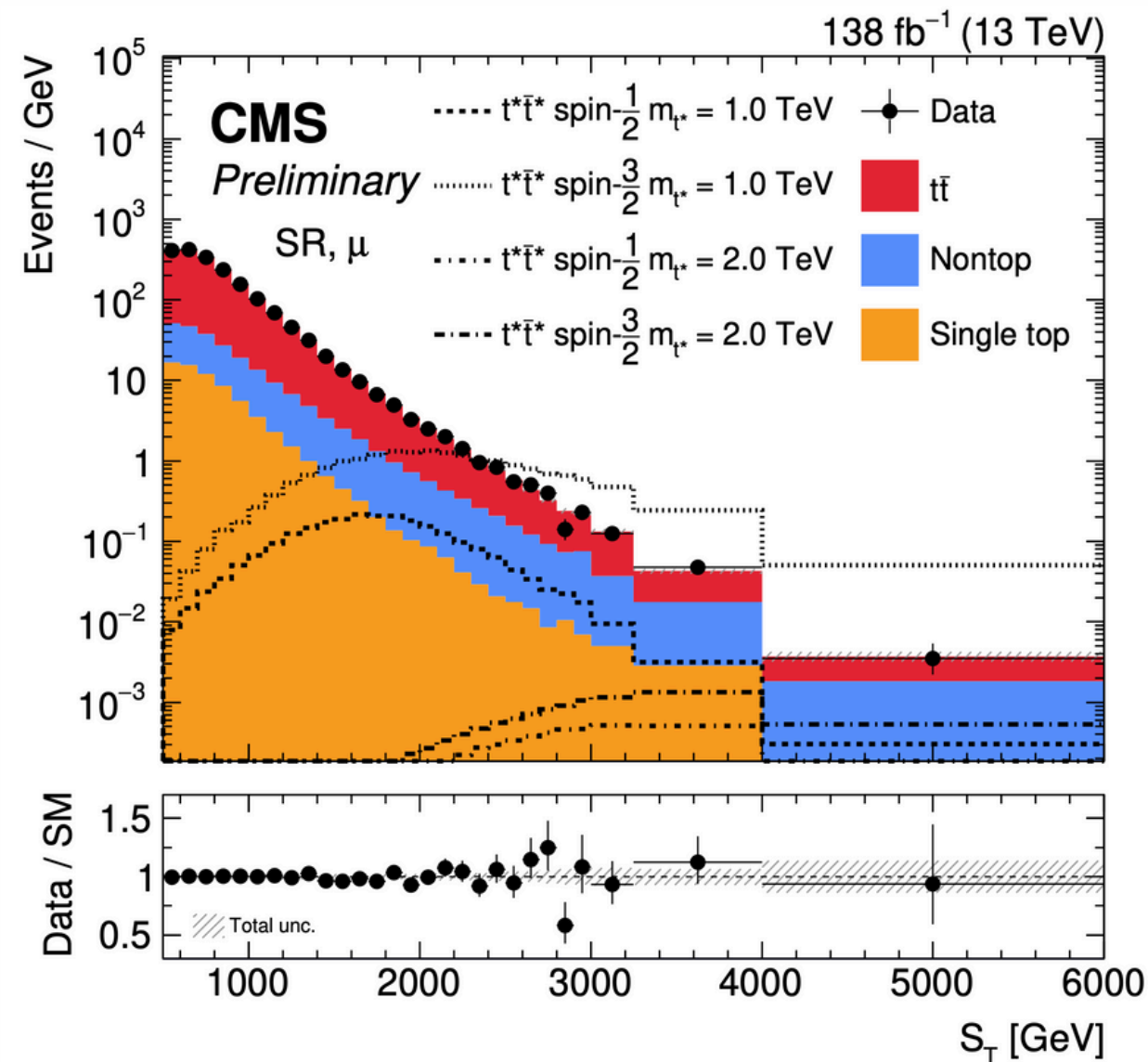


Pair production of excited top (t^*).



$$S_T = p_T^\ell + p_T^{\text{miss}} + \sum_i p_{T,i}^{\text{jet}}$$

Quarks as non fundamental particles can have substructure and could exist in excited states



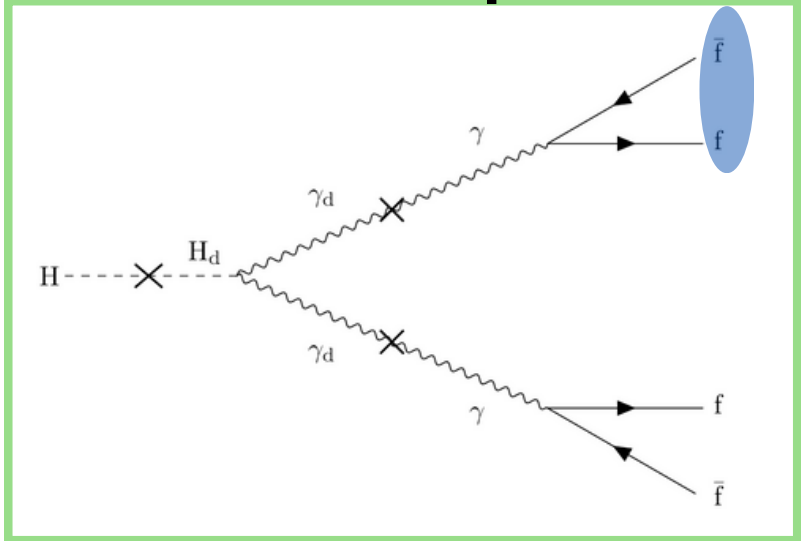
Improved reach w/ full Run 2 data and doubled mass range explored

Beyond Standard

Strategies

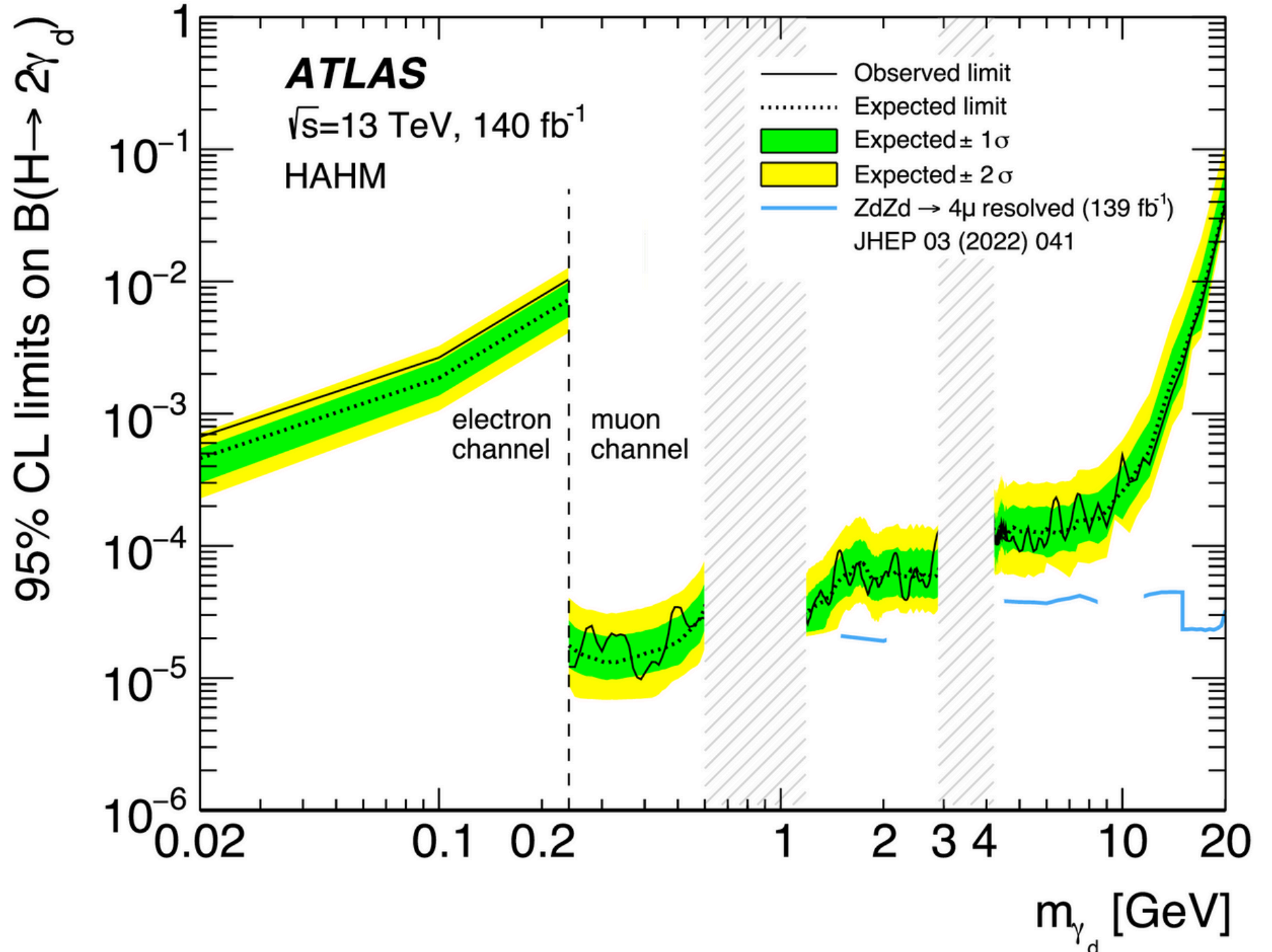
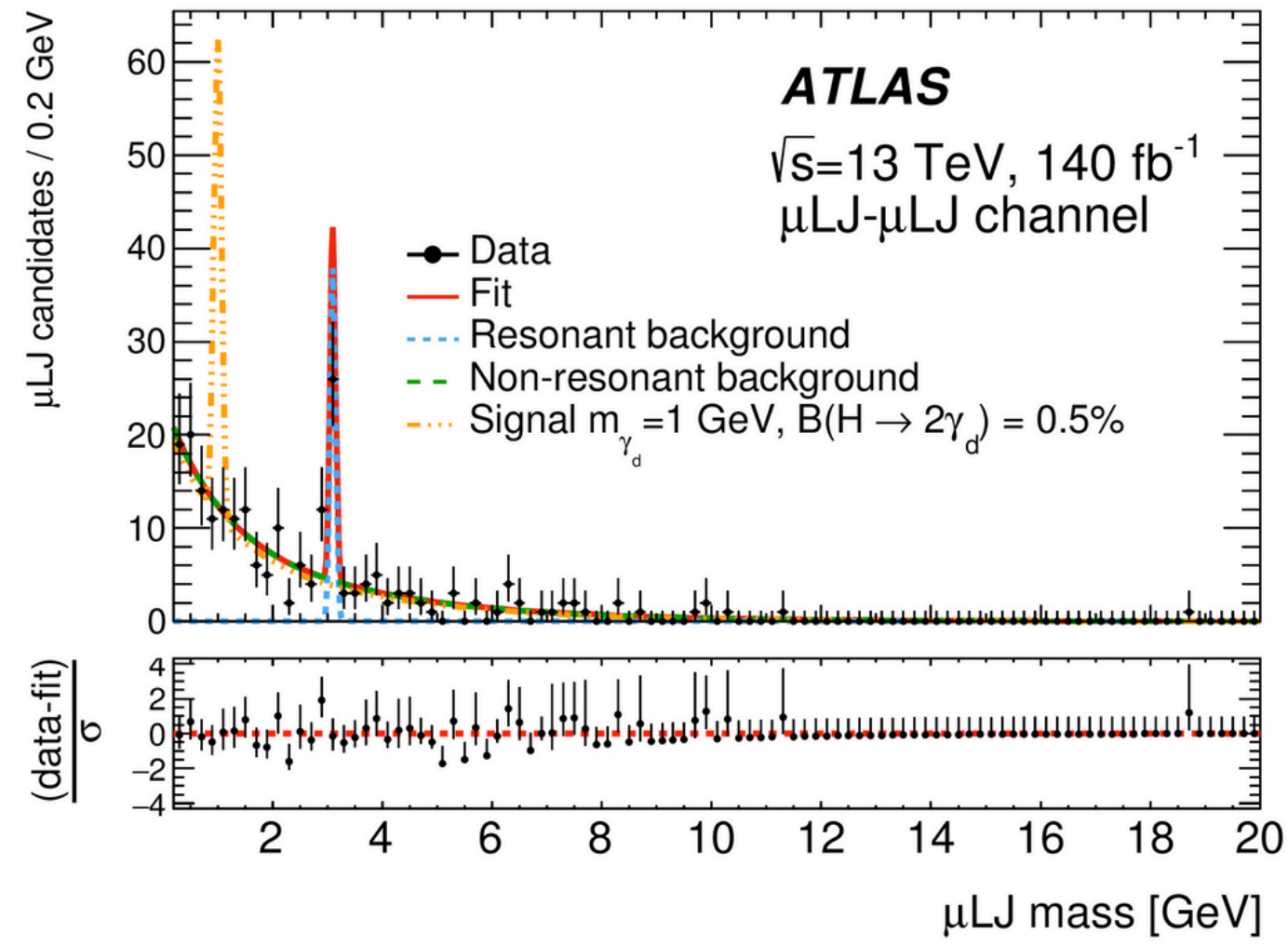
- *Identifying merged objects*
- *Accessing low energies*

Search for neutral particles decaying promptly to collimated pairs of leptons



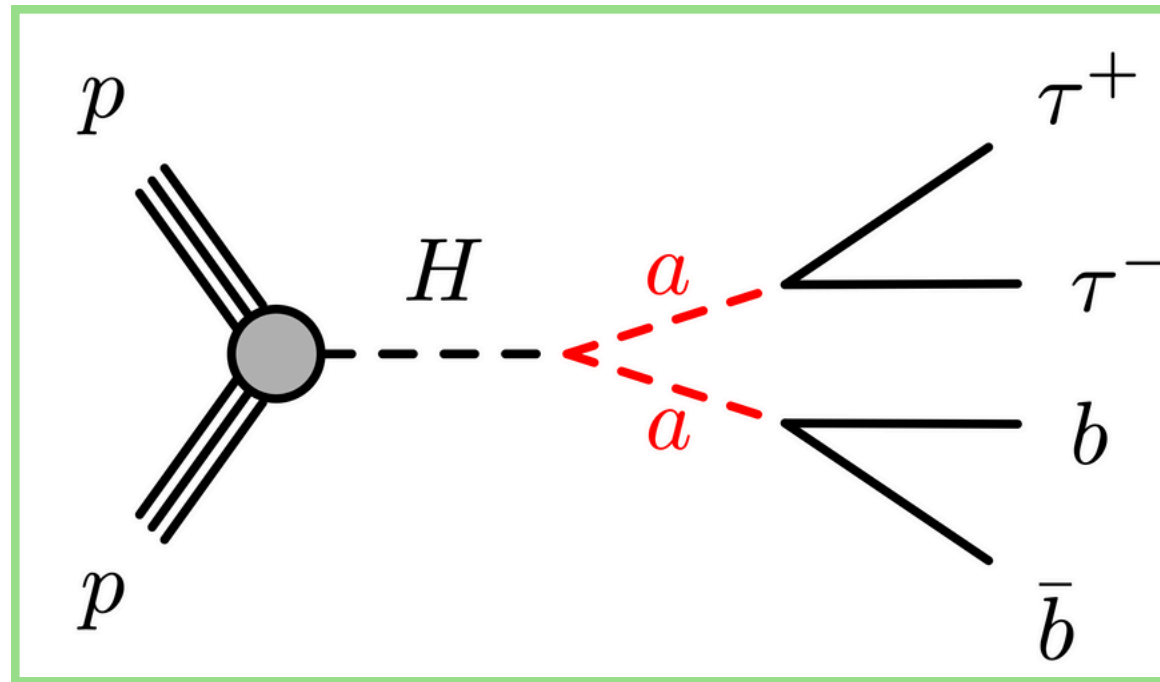
LeptonJets (LJs): highly collimated pairs of electrons or muons from light neutral particles decay

Dedicated reconstruction and ID of merged dilepton pairs

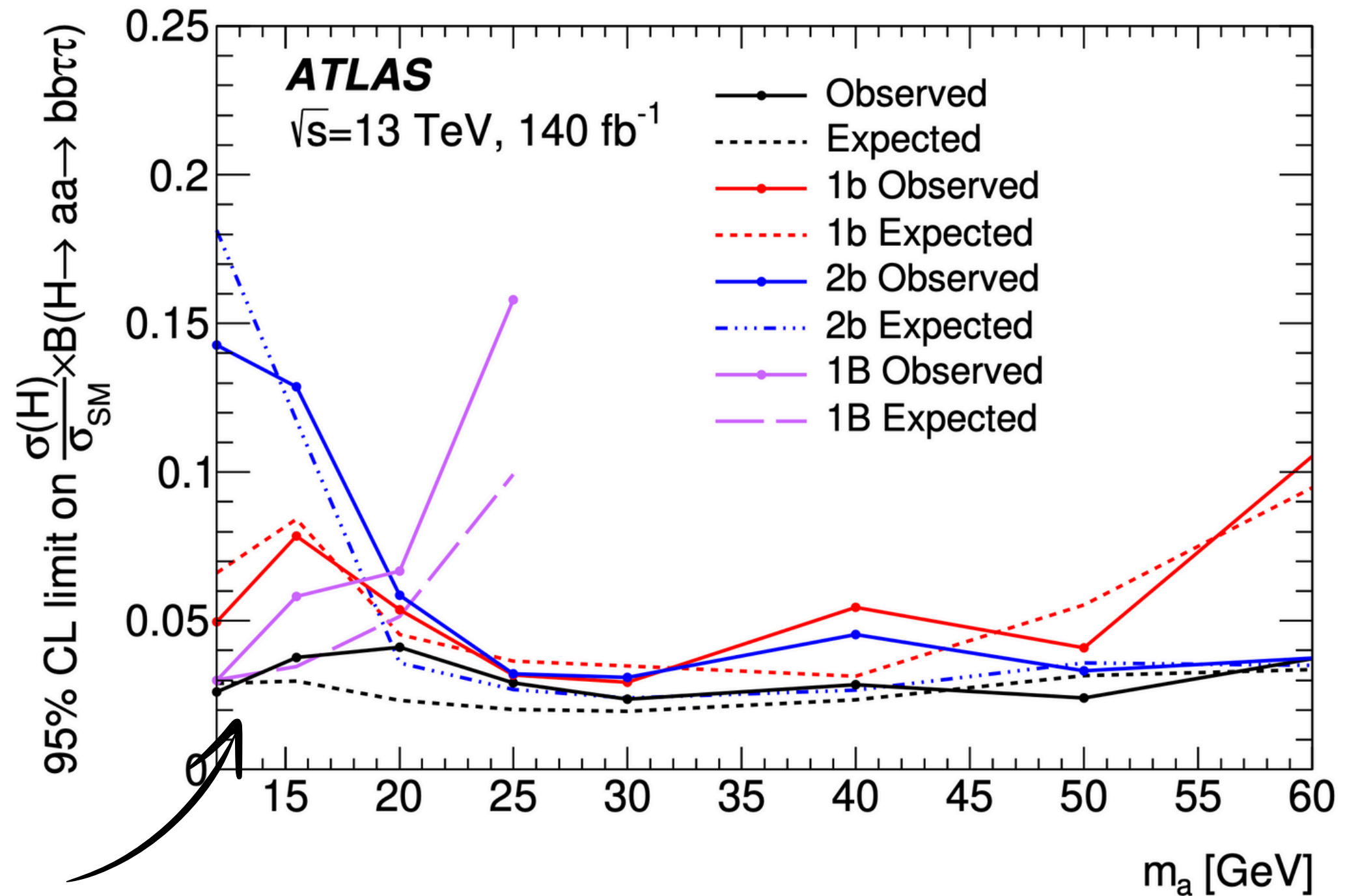


Exotic decays of the SM Higgs boson

Search for decays of the Higgs boson into a pair of pseudoscalar particles decaying into $b\bar{b}\tau\tau$



Novel, **dedicated algorithm** to identify low mass merged, “**double b -quark**” jets (**B**) from $a \rightarrow b\bar{b}$

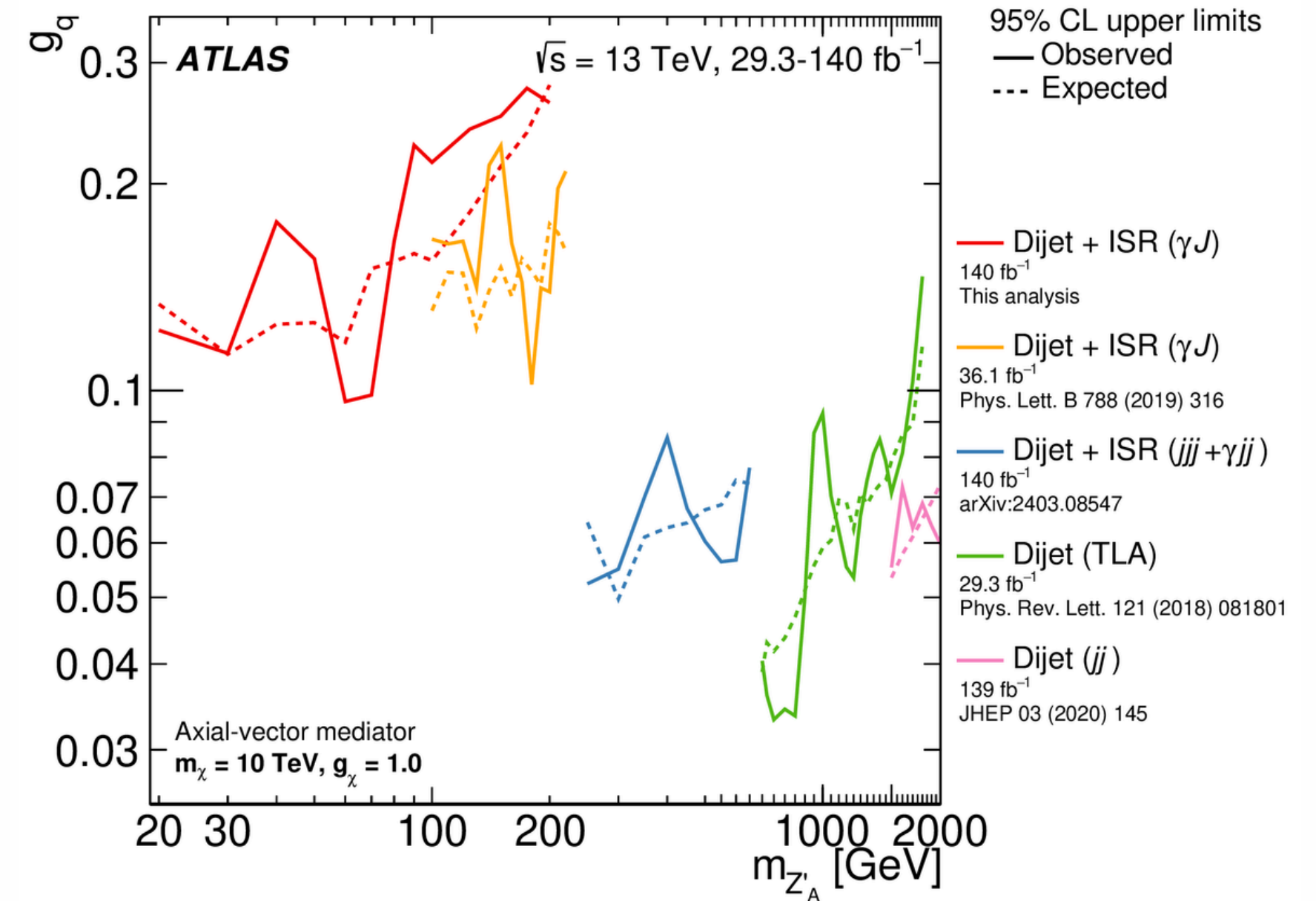
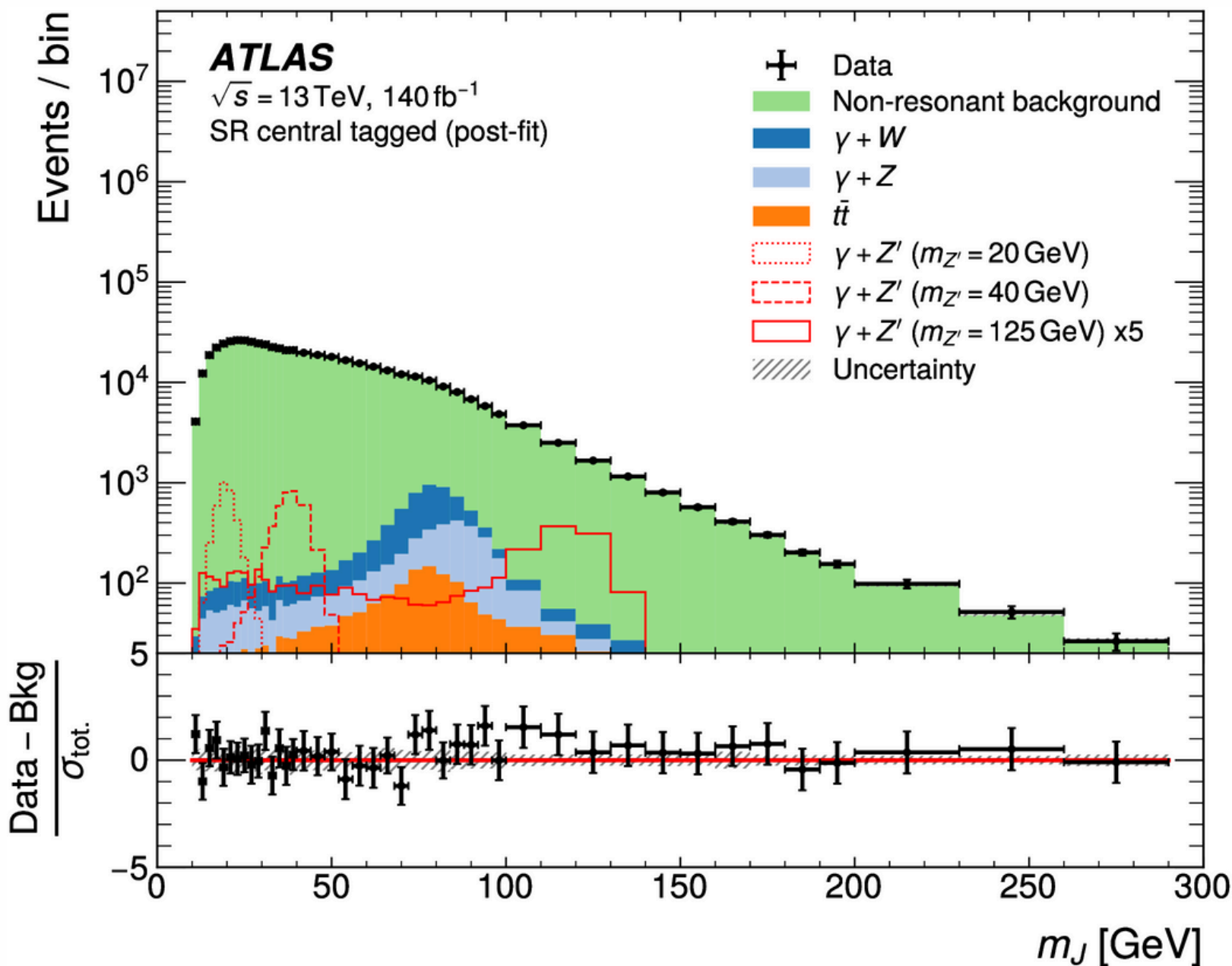
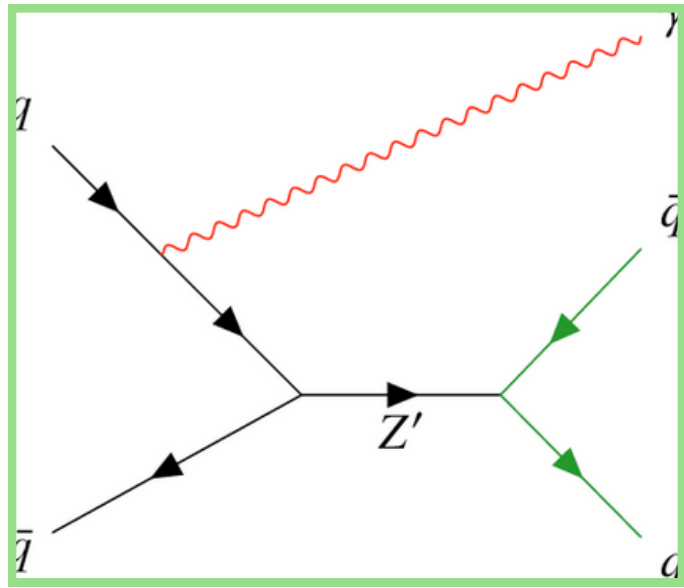


B categories sensitive at low-mass

Search for low-mass resonances into

hadrons + ISR photon

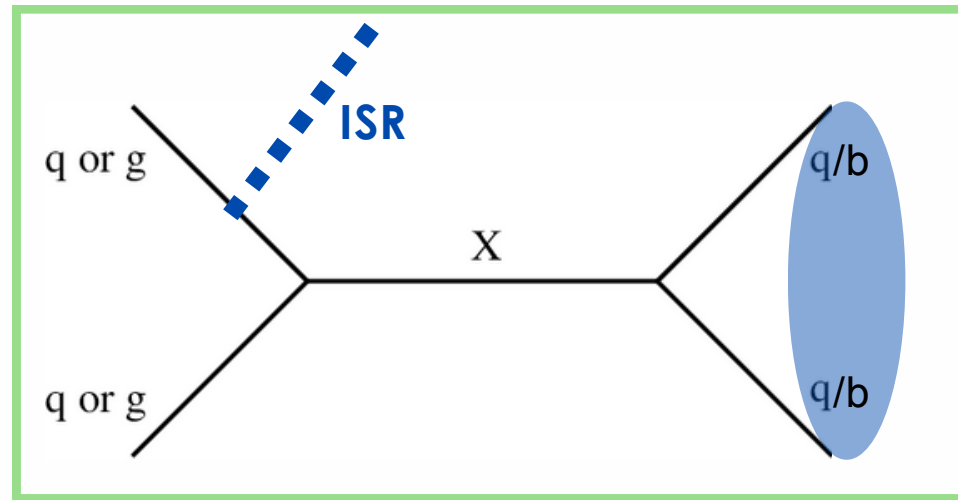
Photon from initial state radiation, which is used as a trigger to circumvent limitations on the maximum data recording rate.



Search for low-mass resonances into

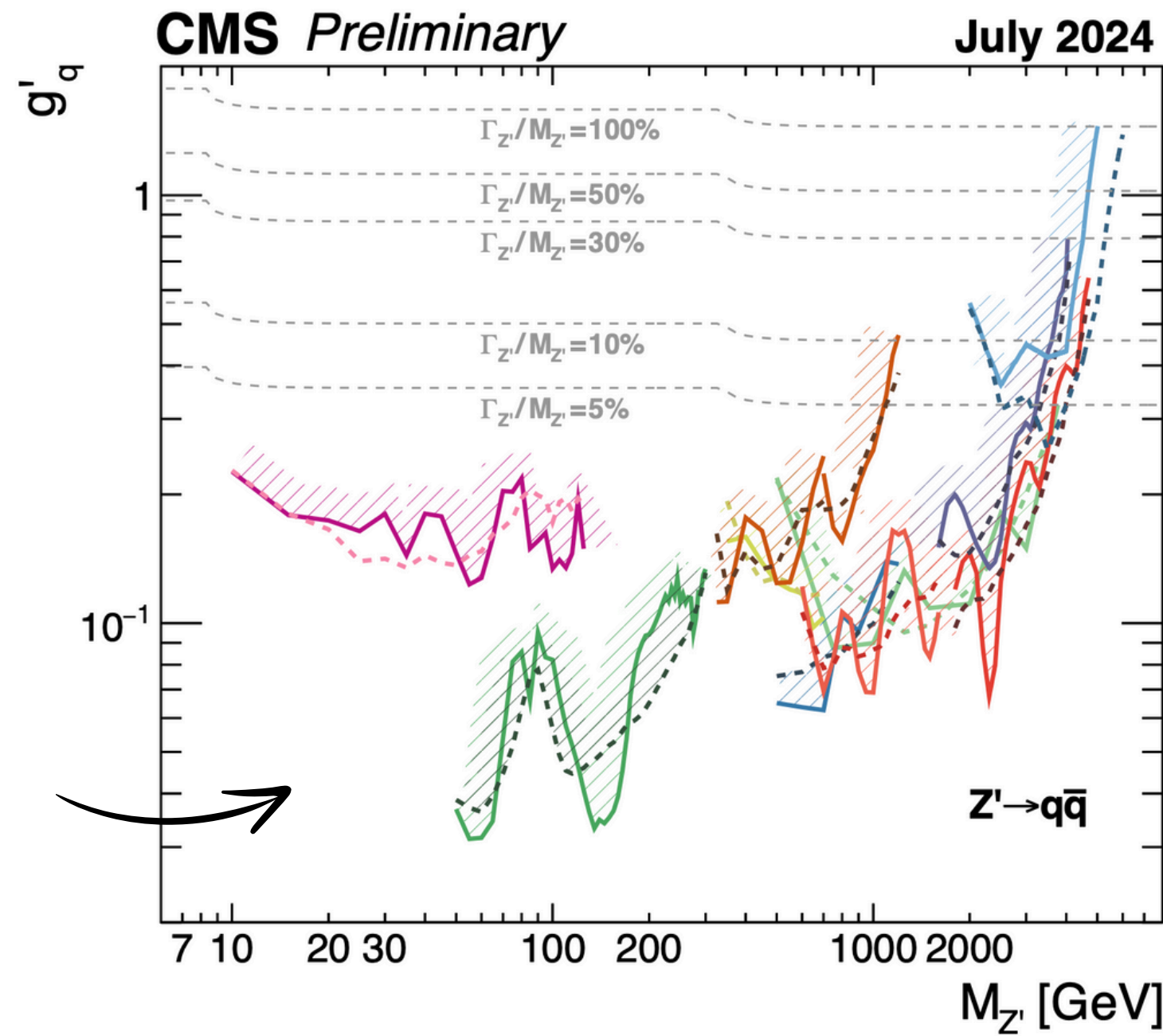
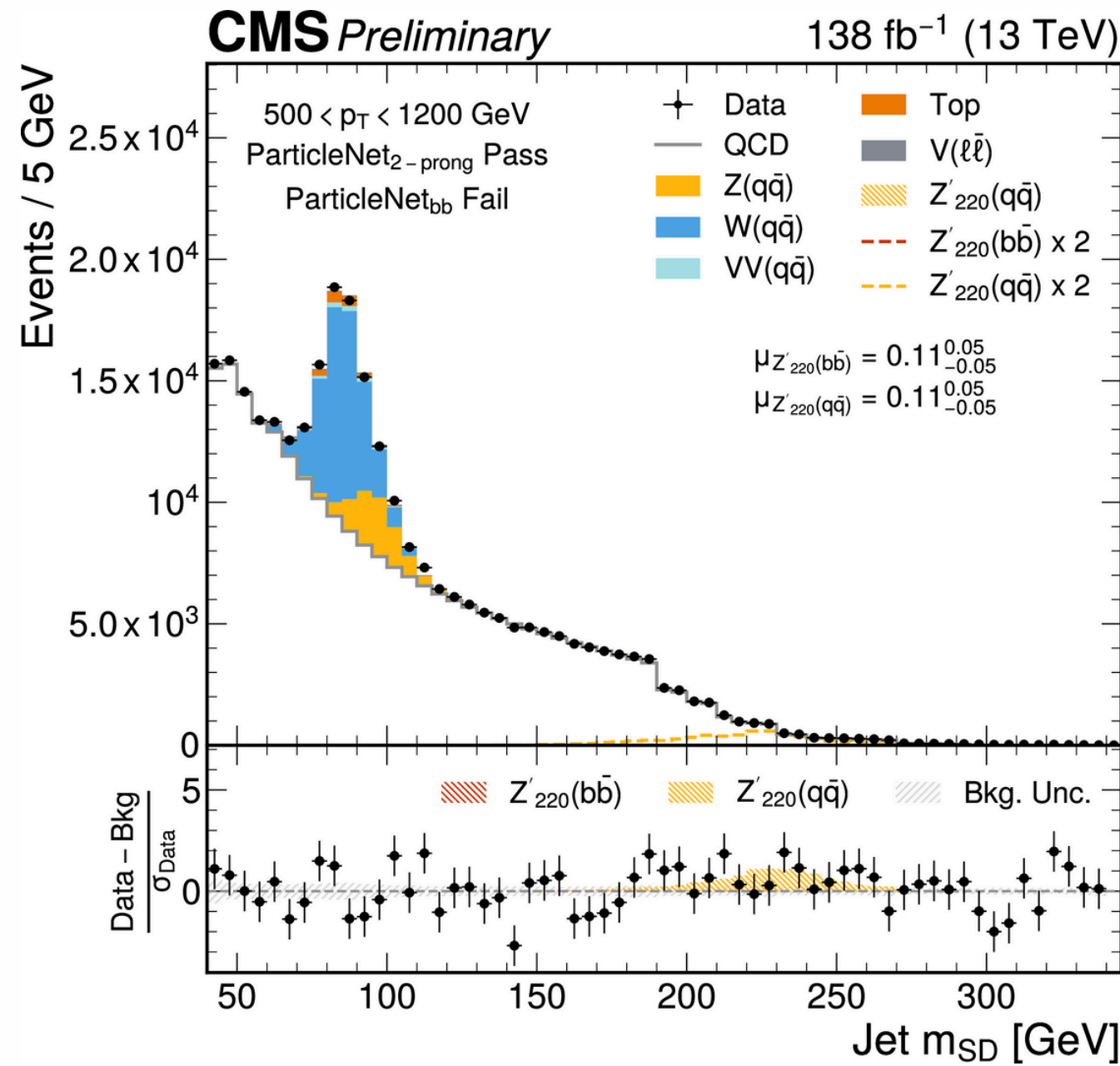


hadrons + ISR



ParticleNet algorithm reconstructs **Large Radius Jet w/ 2 pronged substructure**

CMS-PAS-EXO-24-007



- 95% CL exclusions**
- ▨ Observed
 - - - Expected
 - $\Gamma_{Z'}/M_{Z'} < \sim 5\%$**
 - $t\bar{t}$ resonance, (JHEP 2019, 031)
35.9 fb⁻¹, 13 TeV
 - $\Gamma_{Z'}/M_{Z'} < \sim 10\%$**
 - Boosted dijet+ γ (PRL 123, 231803)
35.9 fb⁻¹, 13 TeV
 - Boosted dijet (EXO-24-007)
138 fb⁻¹, 13 TeV
 - Dijet+ISR jet (PLB 805, 135448)
18.3 fb⁻¹, 13 TeV
 - Dijet b-tagged (PRL 120, 201801)
19.7 fb⁻¹, 8 TeV
 - Dijet scouting (PRL 117, 031802)
19.7 fb⁻¹, 8 TeV
 - Dijet scouting (JHEP 2018, 130)
35.9 fb⁻¹, 13 TeV
 - Dijet (JHEP 2020, 033)
138 fb⁻¹, 13 TeV
 - $\Gamma_{Z'}/M_{Z'} < \sim 30\%$**
 - Broad dijet (JHEP 2018, 130)
35.9 fb⁻¹, 13 TeV
 - $\Gamma_{Z'}/M_{Z'} < \sim 100\%$**
 - Dijet χ (EPJC 78, 789)
35.9 fb⁻¹, 13 TeV

CMS-EXO-Summary - Plots

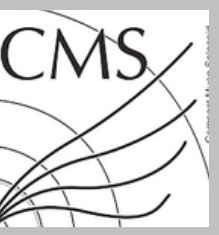
Backup

Beyond Standard

Signatures

- *Probing the TeV scale*
- *Long-lived particles*
- *Innovative usage of the detector*

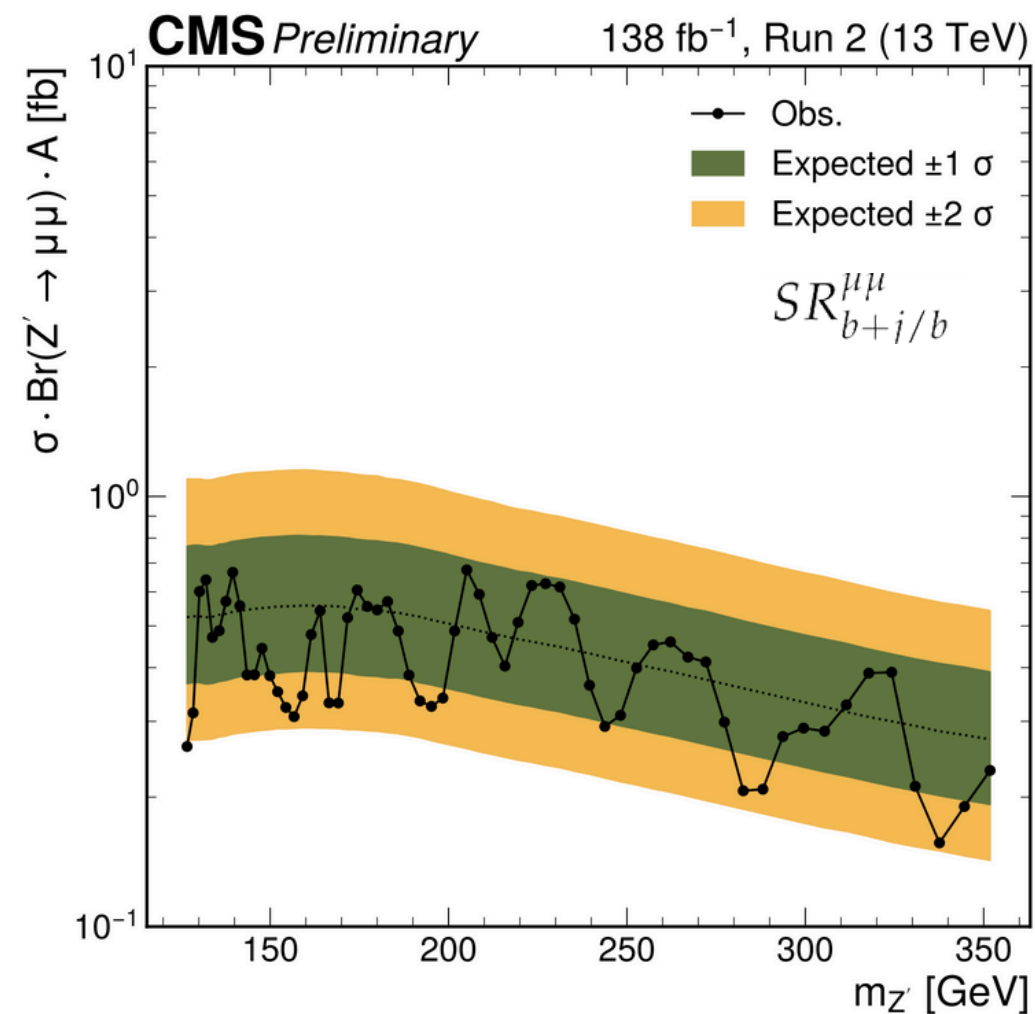
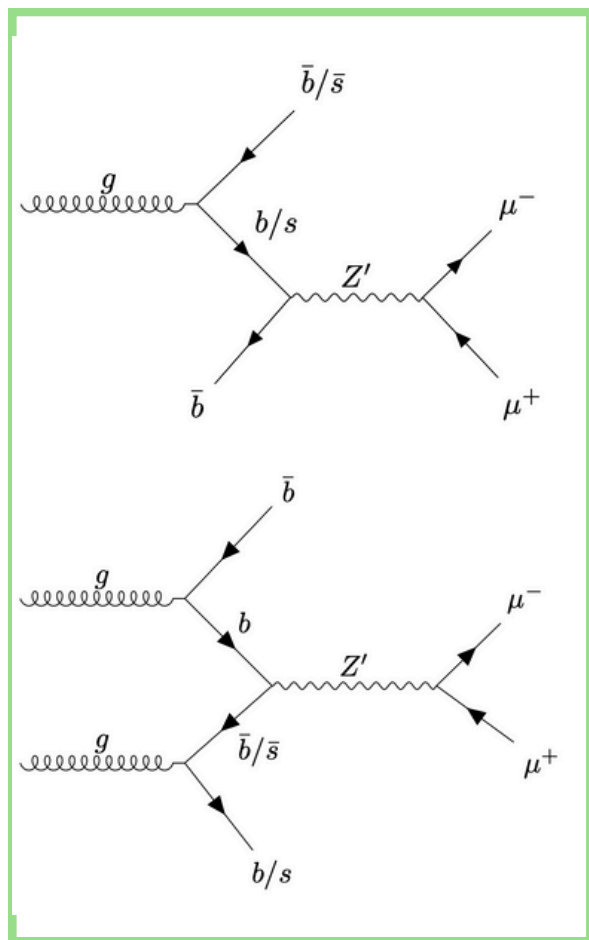
Searches for energetic dileptons w/ b-jets



Less conventional dilepton searches beyond inclusiveness in number of jets

Resonant Z' in dimuon decay + b-jets

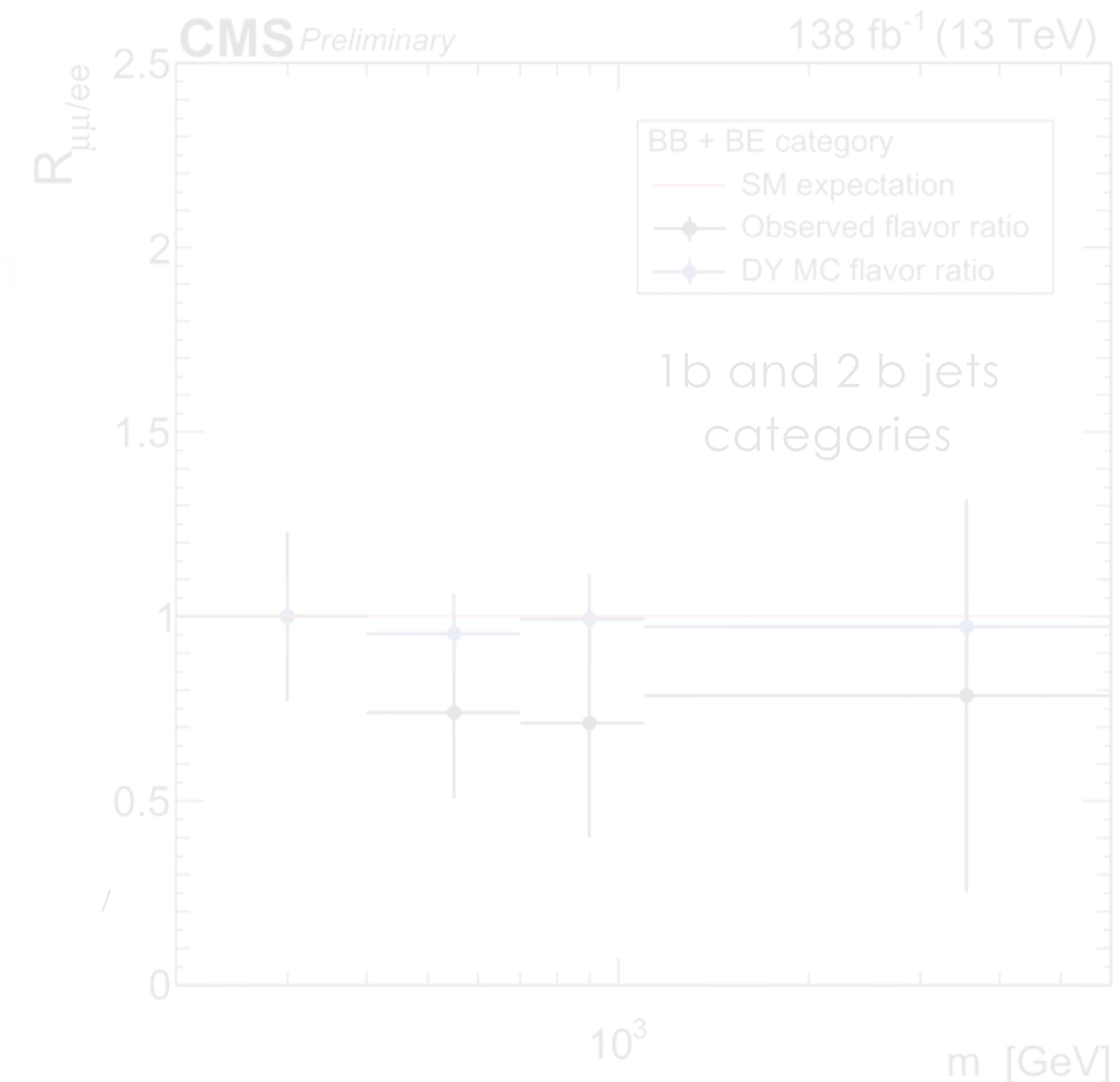
Complementary **result at high mass**
(up to 2 TeV) already published



Backup

Non-resonant dilepton + b-jets

Lepton flavor universality tested by comparing dimuon and dielectron mass vs # b-jets.



Backup

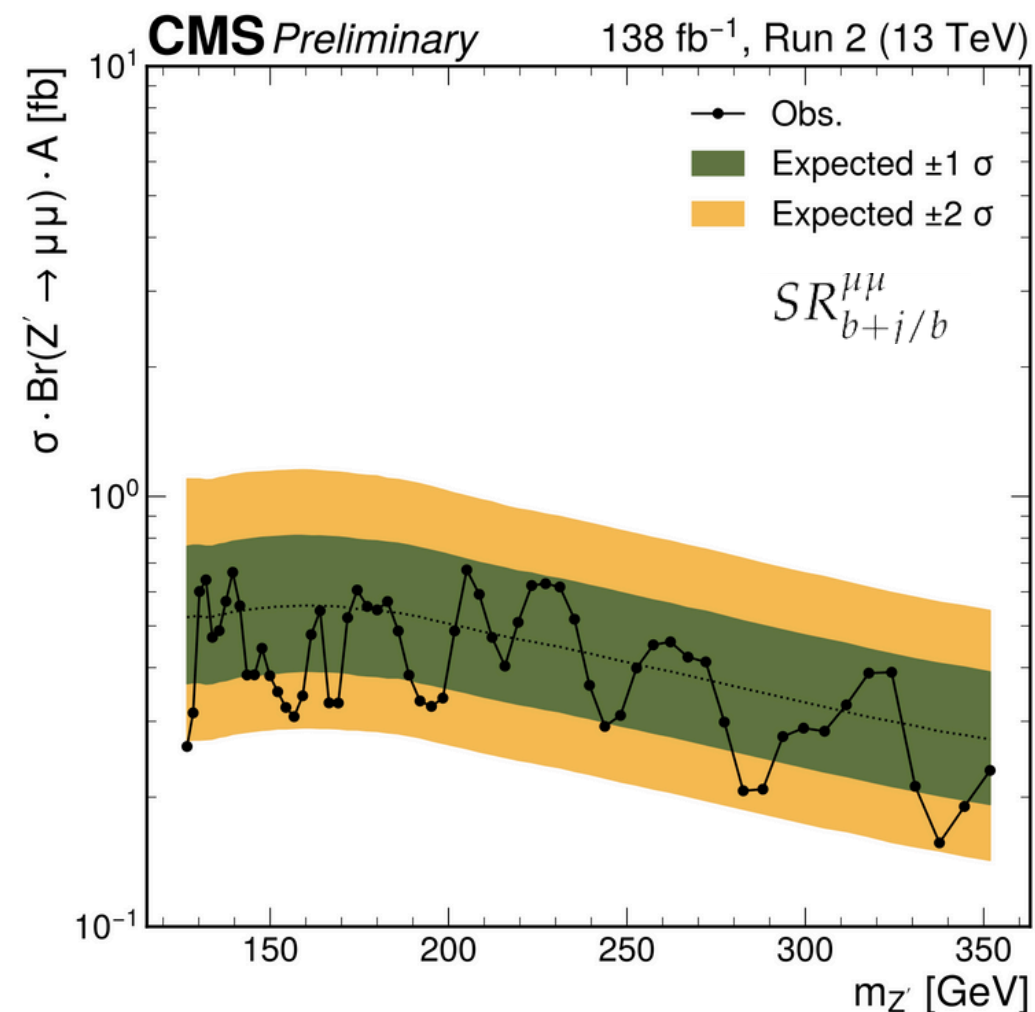
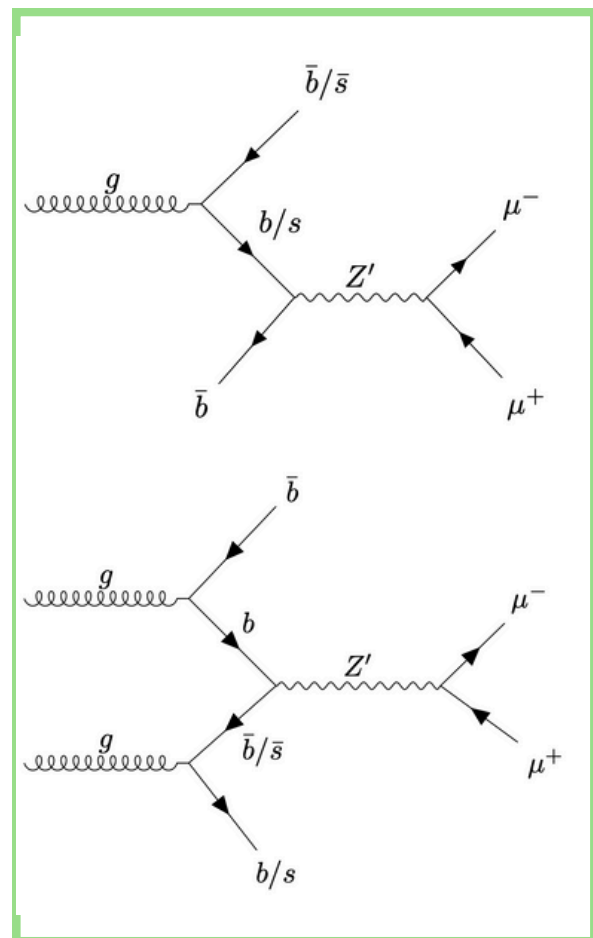
Searches for energetic dileptons w/ b-jets



Less conventional dilepton searches beyond inclusiveness in number of jets

Resonant Z' in dimuon decay + b-jets

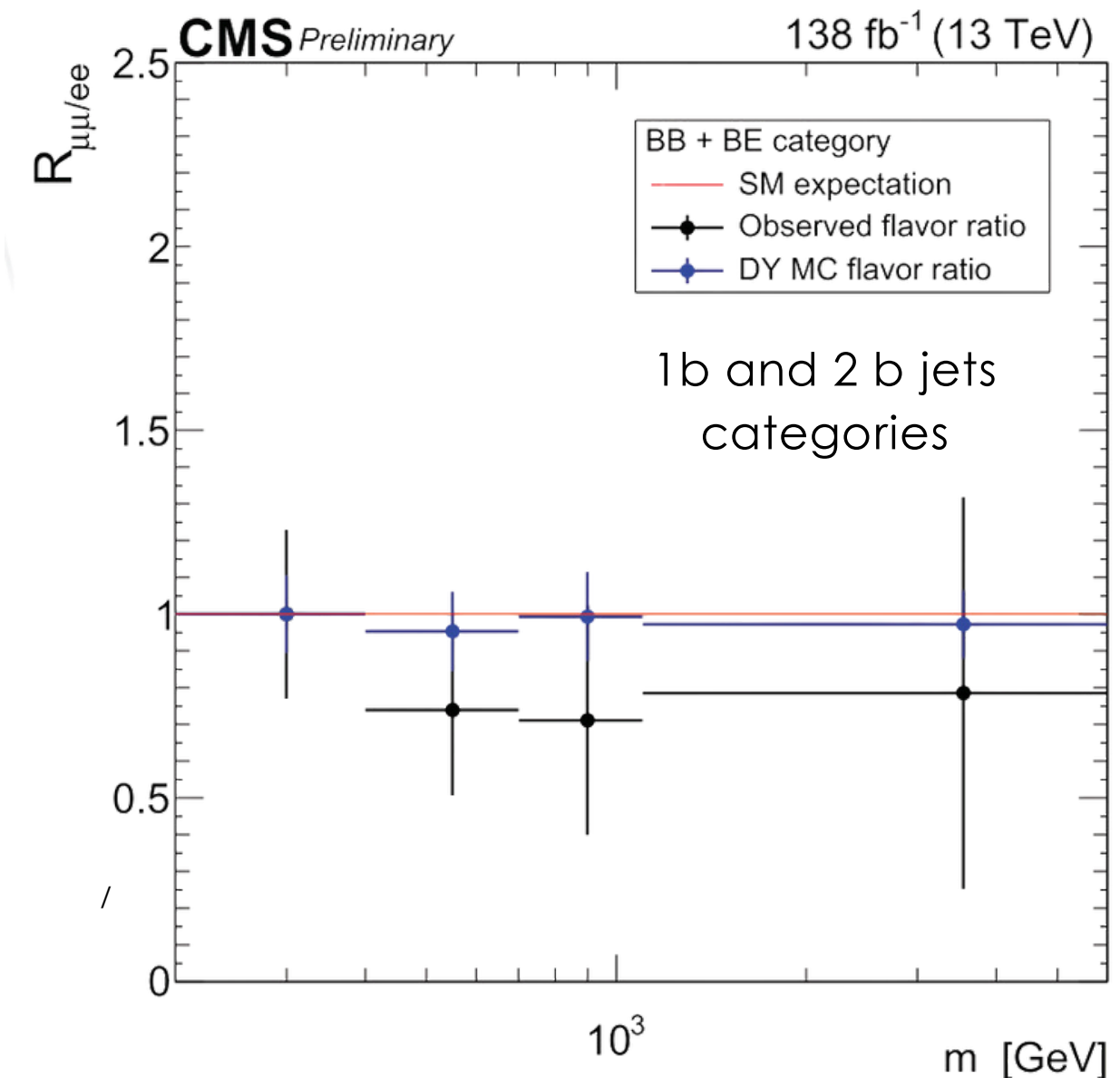
Complementary **result at high mass**
(up to 2 TeV) already published



Backup

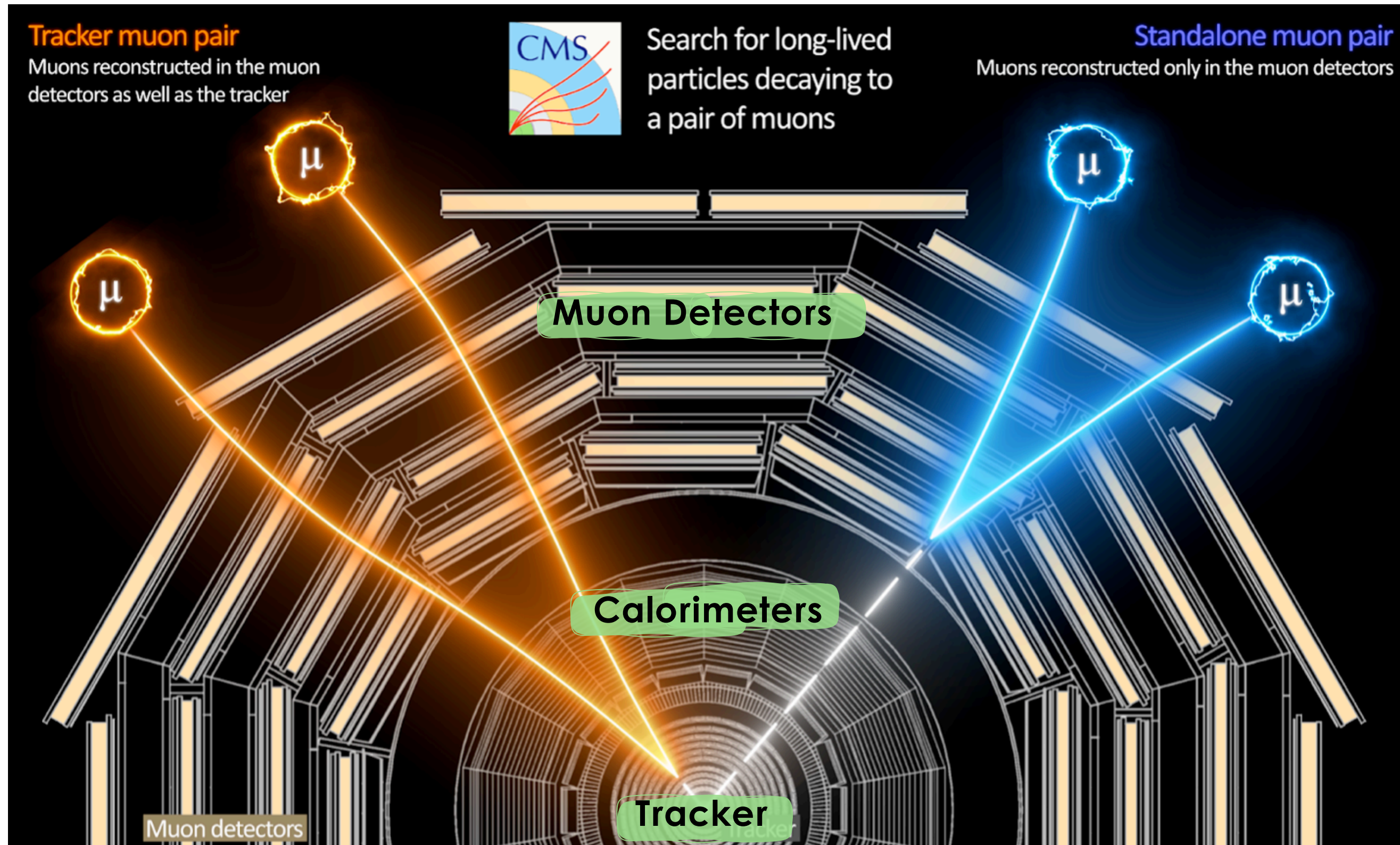
Non-resonant dilepton + b-jets

Lepton flavor universality tested by comparing dimuon and dielectron mass vs # b-jets.



Backup

Searches for Long Lived Particles: Decays in Tracker, Calorimeters and Muon Detectors



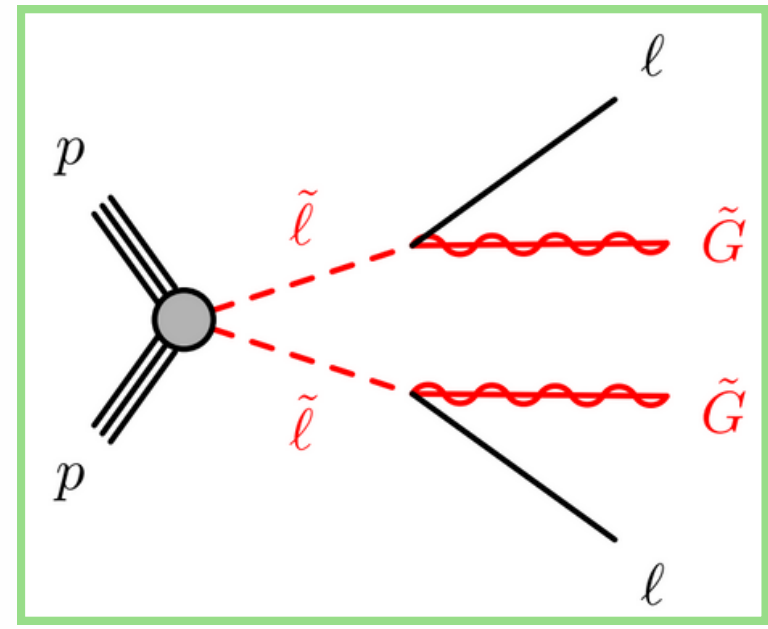
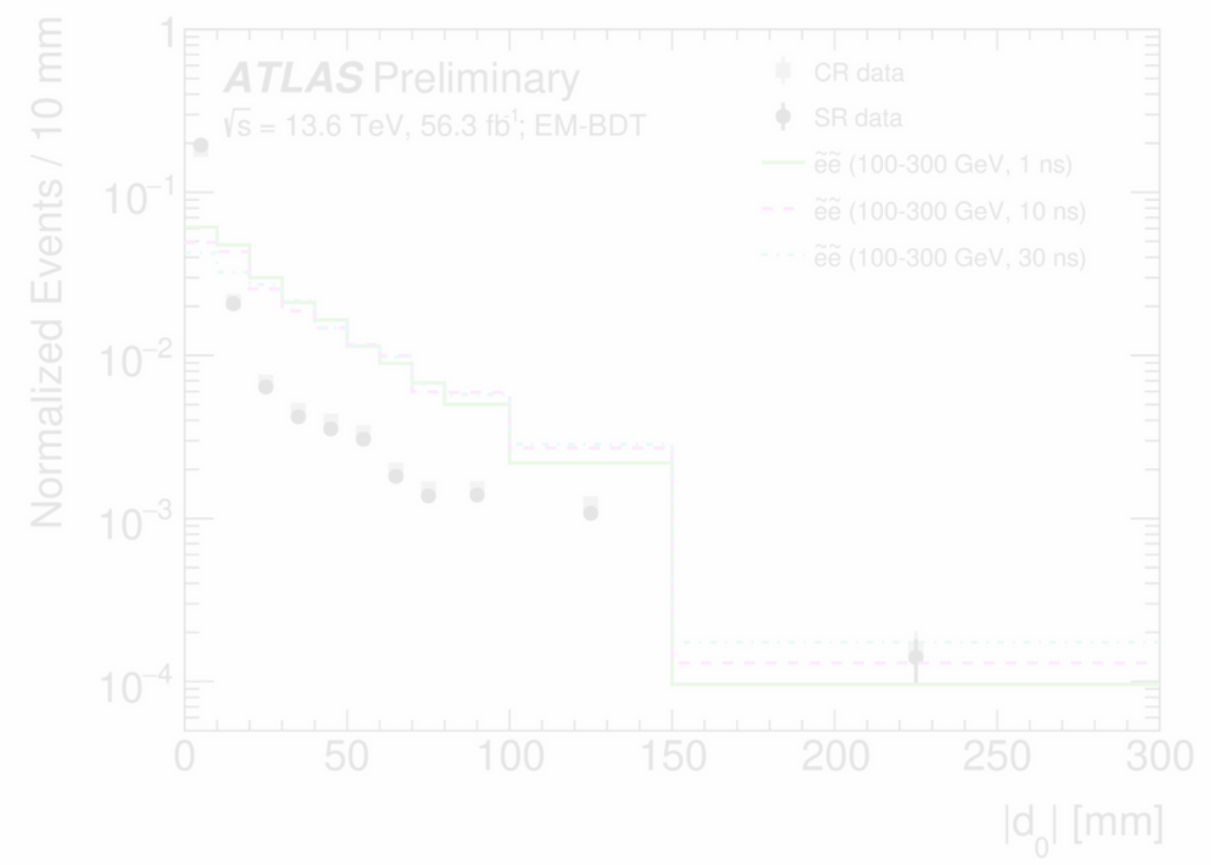


Searches for Long Lived Particles: Decays in Tracker, Calorimeters and Muon Detectors

Search for displaced leptons in 13 TeV and 13.6 TeV

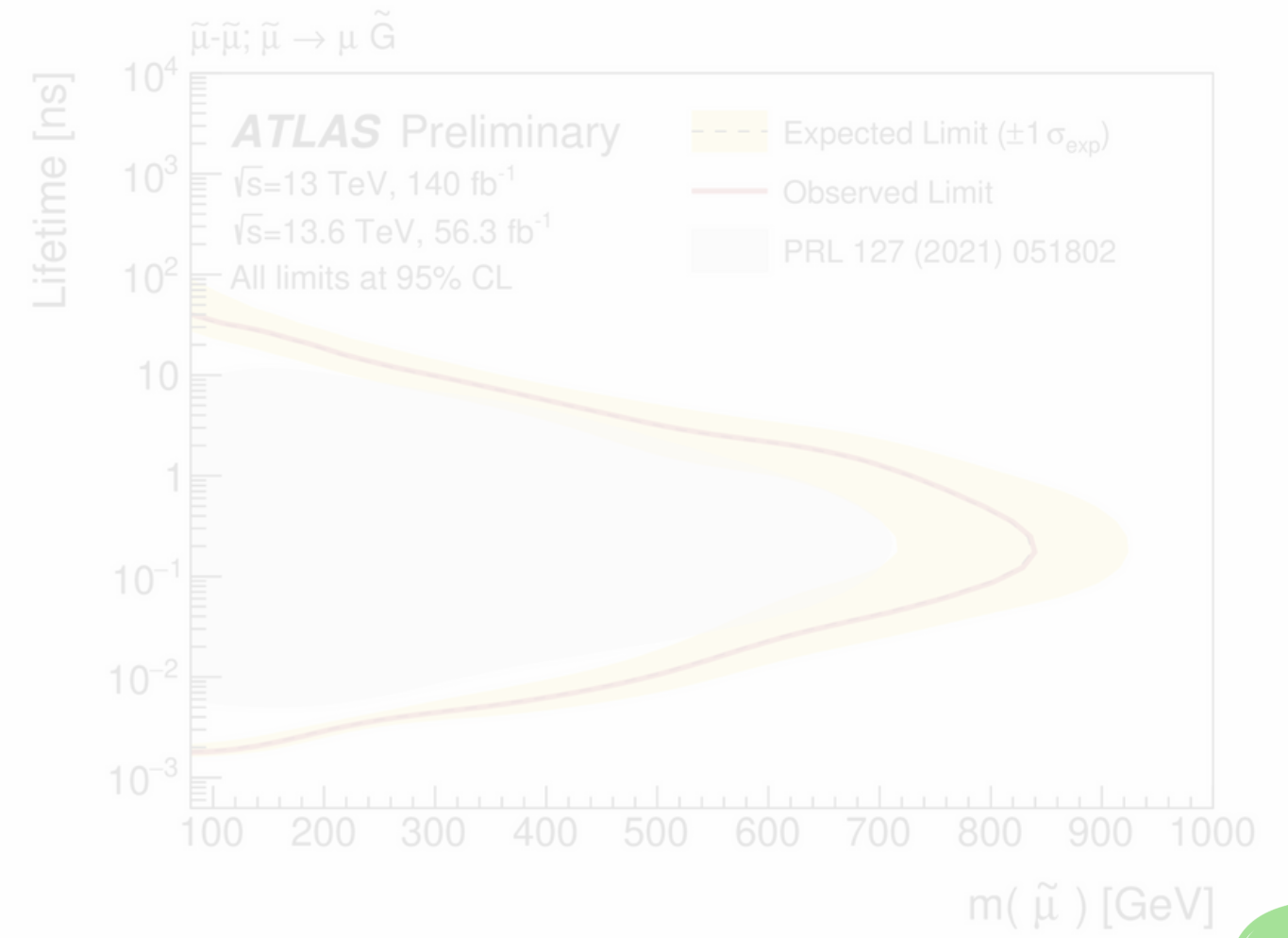
Large Radius Tracking: designed to increase efficiency for decay products of LLPs.

LRT run in the HLT for the first time at Run 3



Enhanced discovery reach beyond prior searches through several **novel additions.**

95% CL exclusion contours for long-lived selectrons (smuons and staus, see backup)



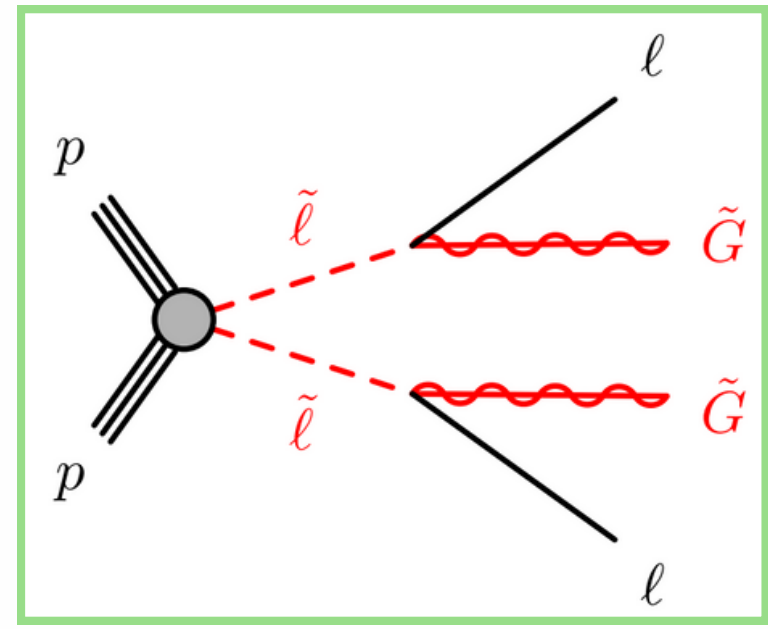
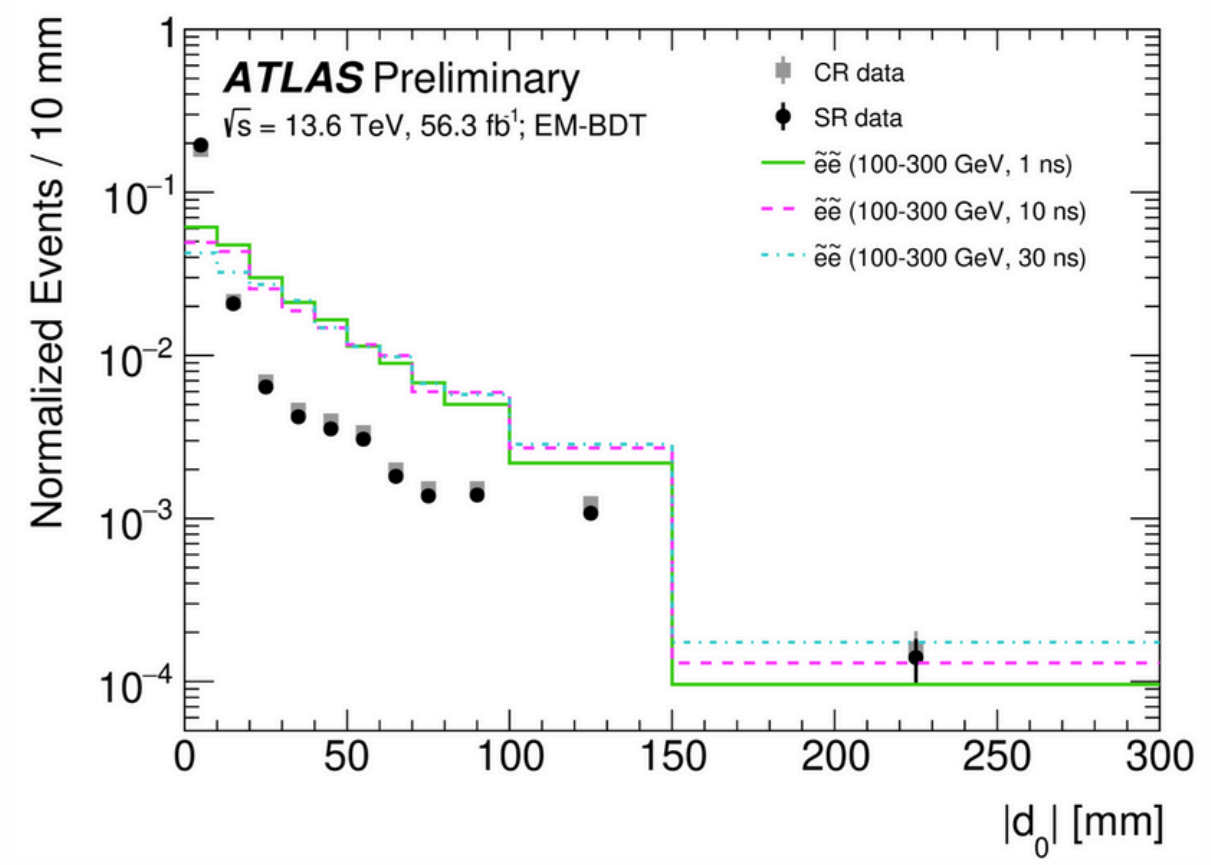


Searches for Long Lived Particles: Decays in Tracker, Calorimeters and Muon Detectors

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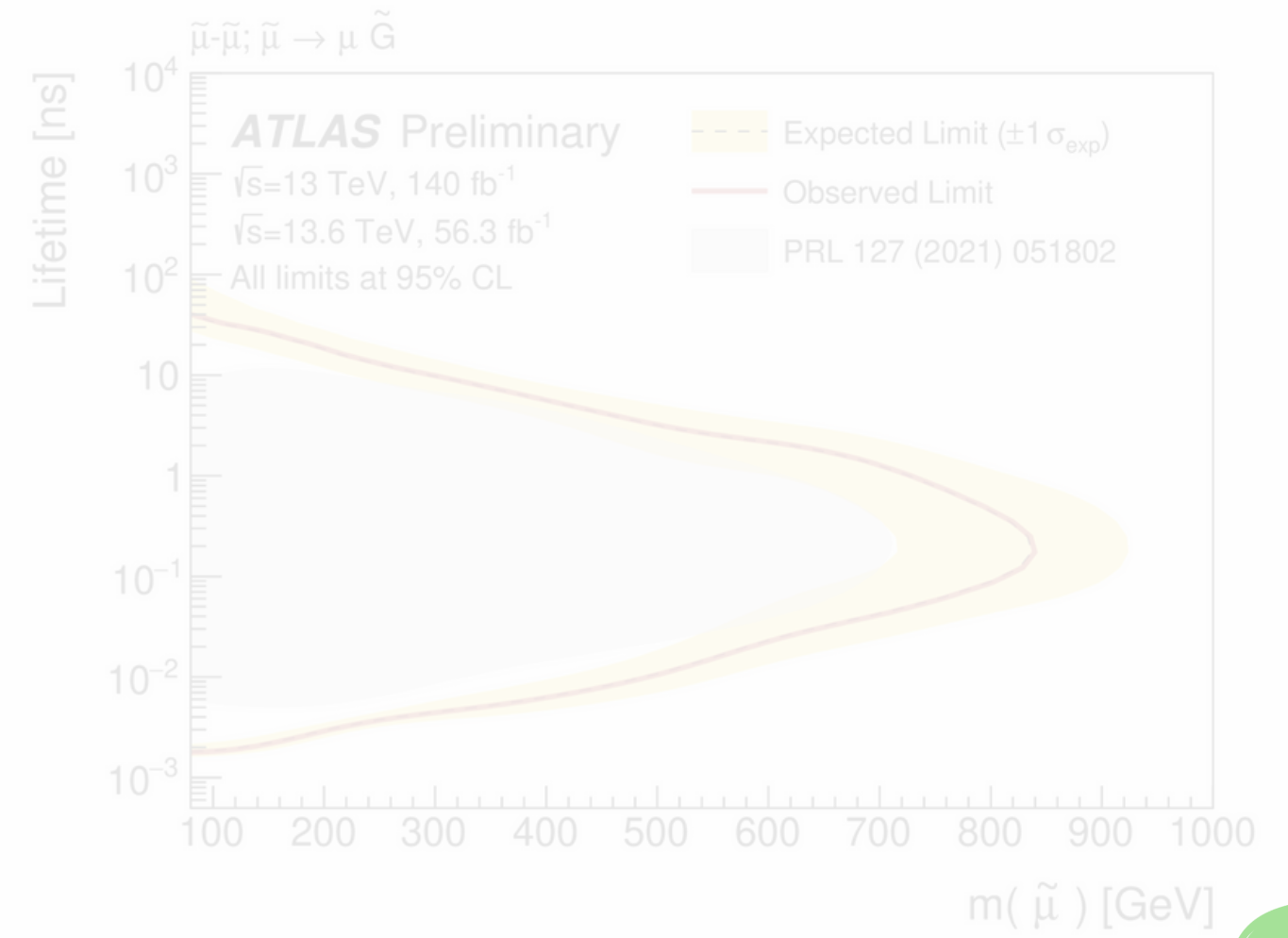
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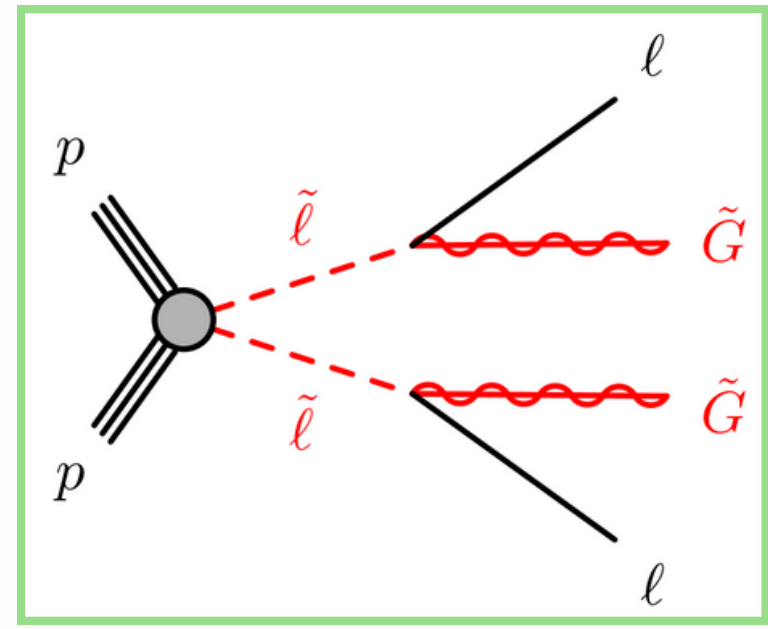
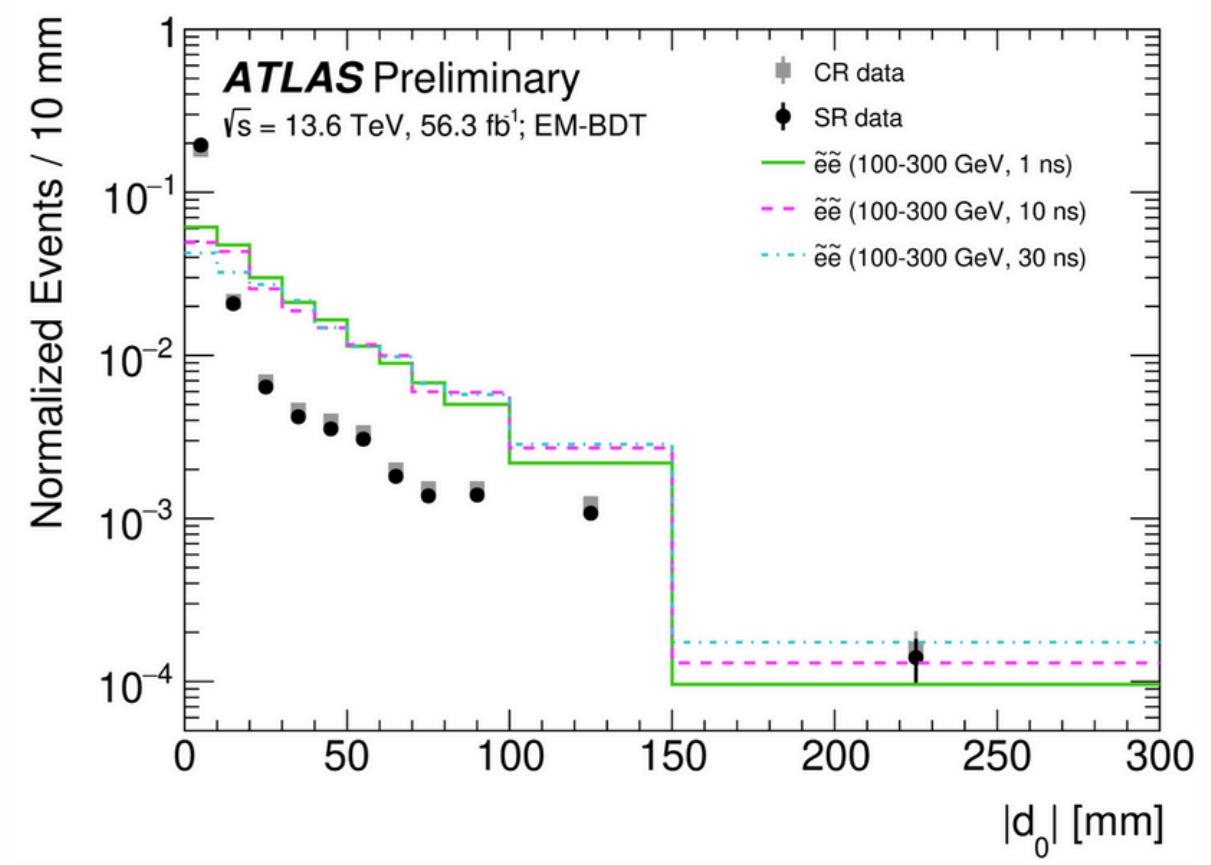


Searches for Long Lived Particles: Decays in Tracker, Calorimeters and Muon Detectors

Search for displaced leptons in 13 TeV and 13.6 TeV

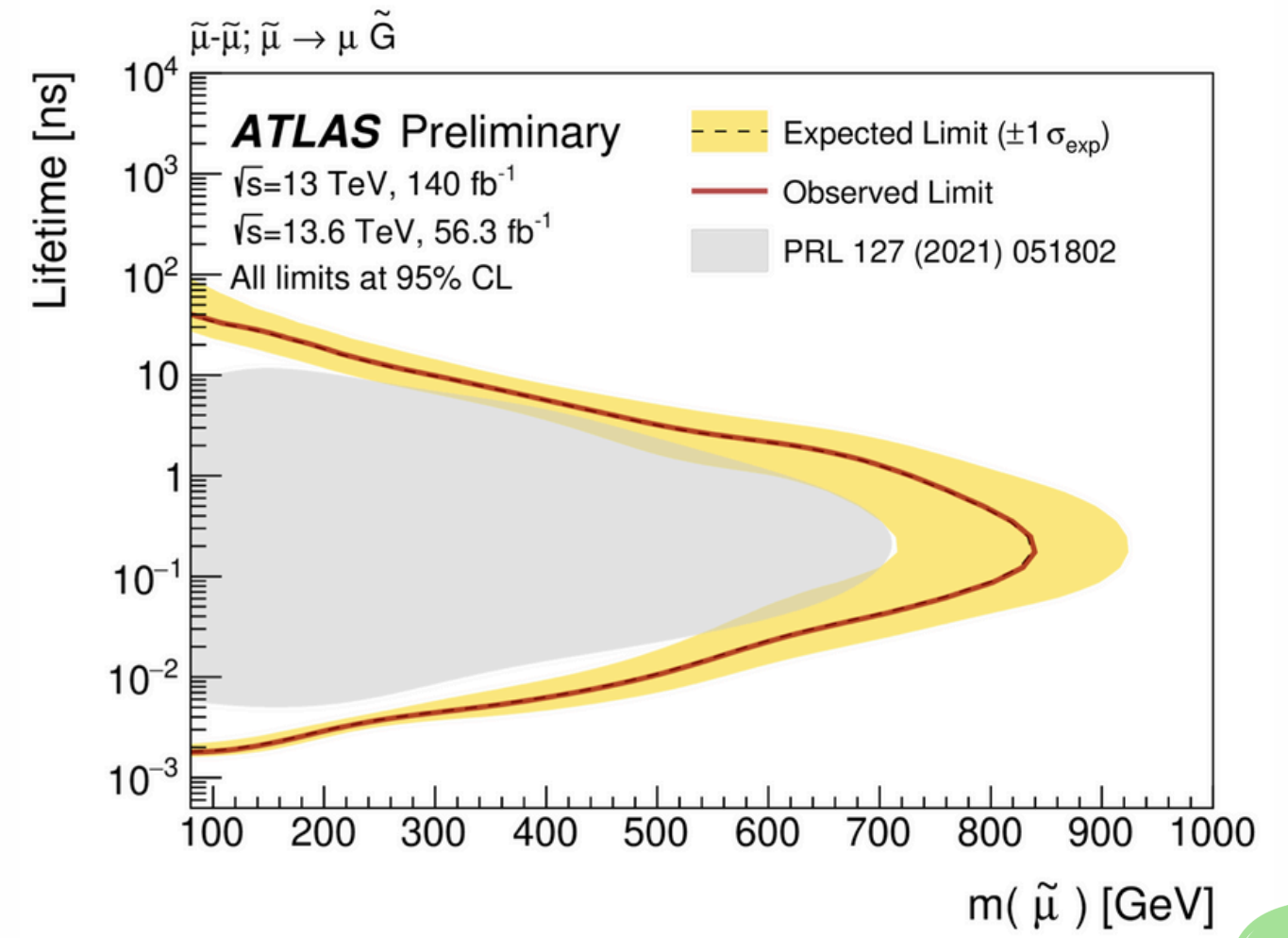
Large Radius Tracking: designed to increase efficiency for decay products of LLPs.

LRT run in the HLT for the first time at Run 3



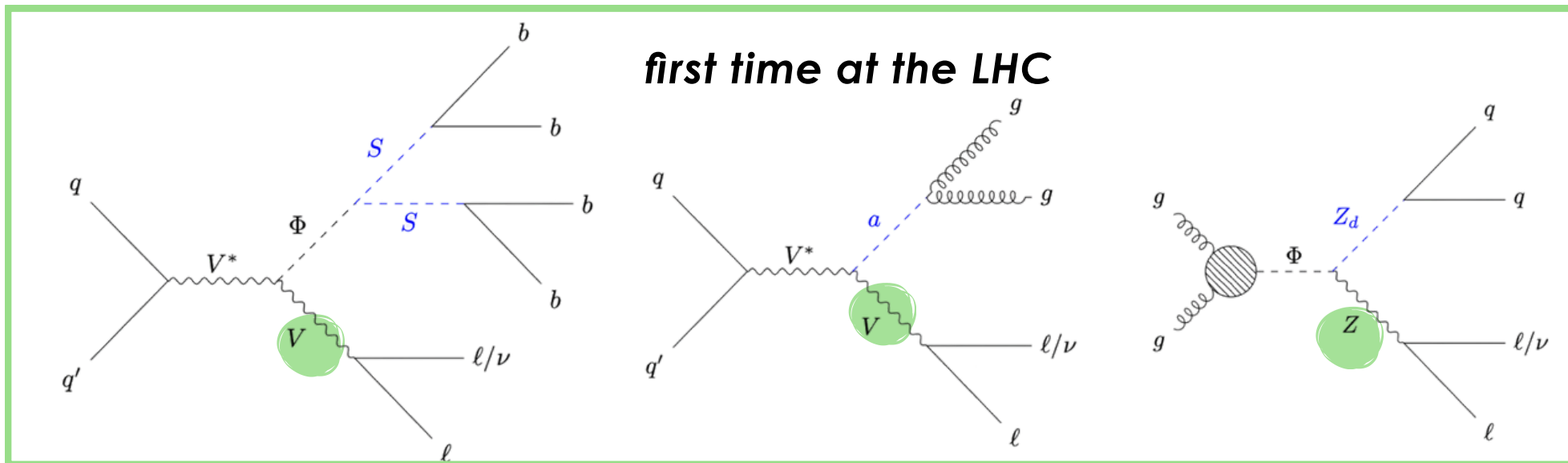
Enhanced discovery reach beyond prior searches through several **novel additions.**

95% CL exclusion contours for **long-lived selectrons (smuons and staus, see backup)**



Searches for Long Lived Particles: Decays in Tracker, **Calorimeters** and Muon Detectors

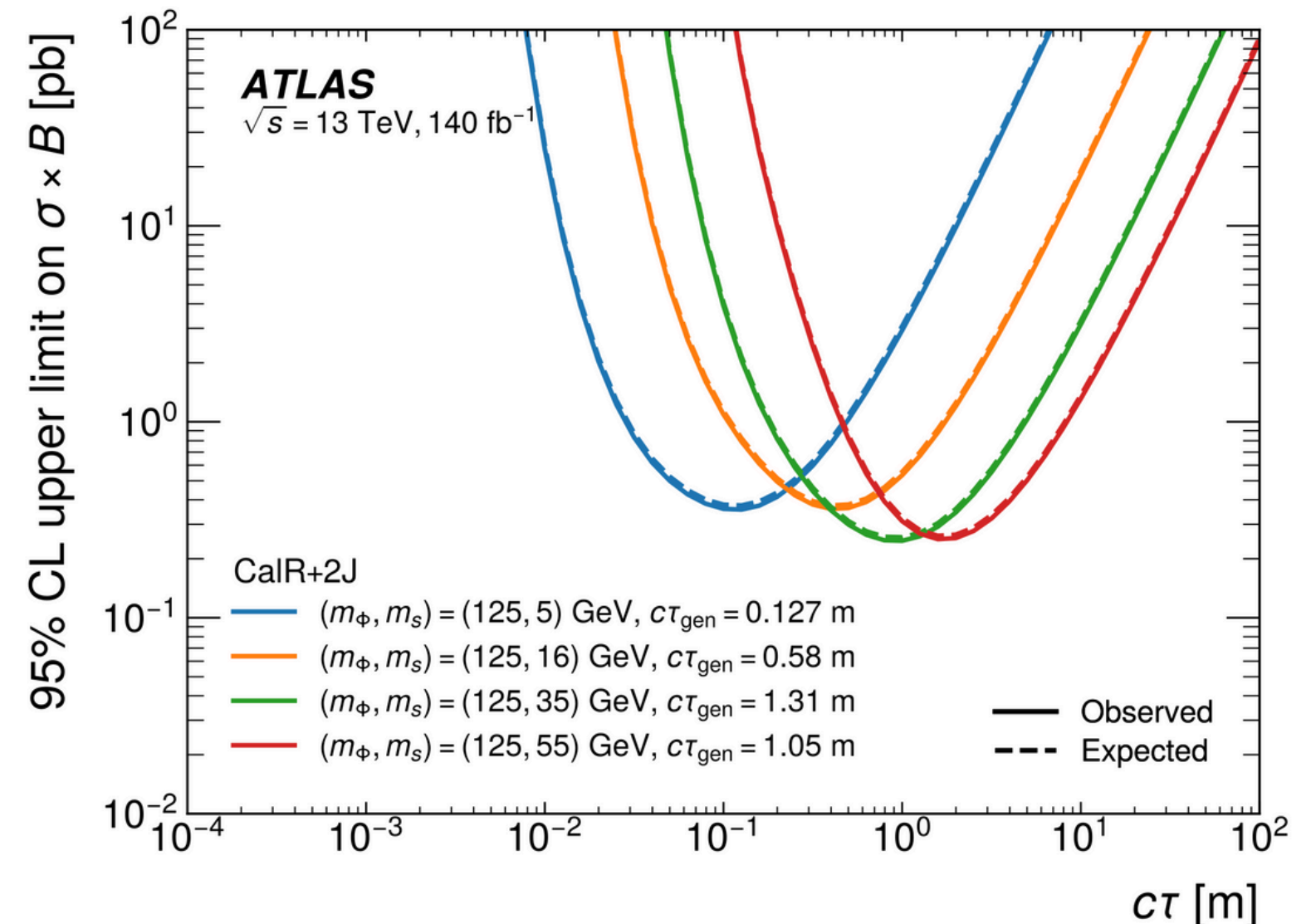
Search for neutral long-lived particles that decay into displaced jets in the calorimeter w/ leptons or jets



● == **additional object to trigger** the event + access low-mass/boost regions (enhance sensitivity)

CalRatio: LLPs that decay after the electromagnetic calorimeter have very low electromagnetic component

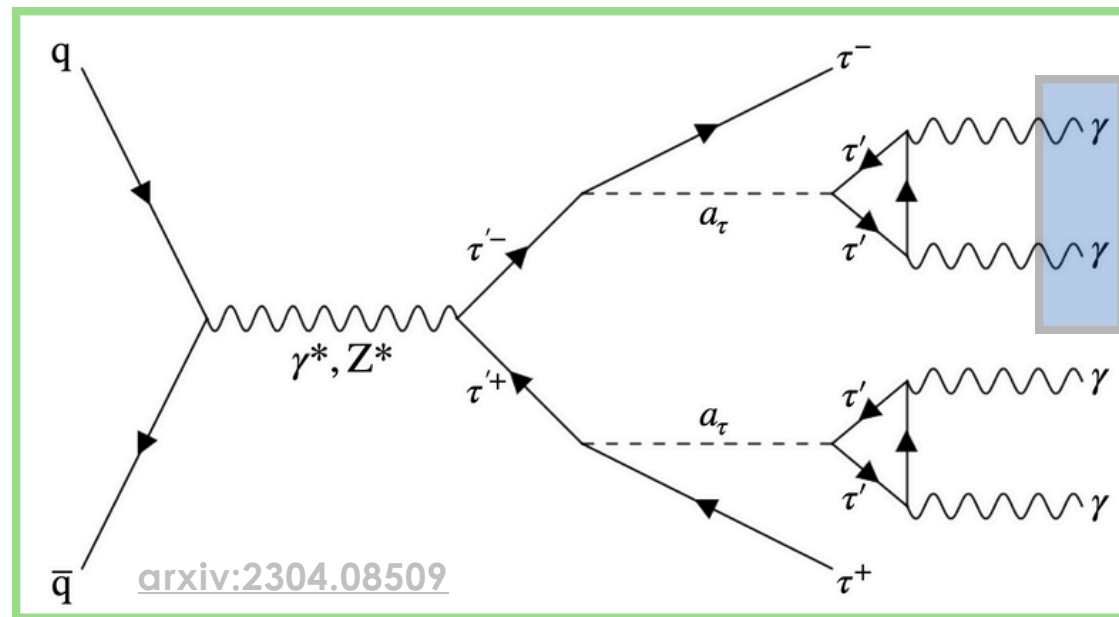
← few cm -- tens of m →



x3 improvements w.r.t. previous searches

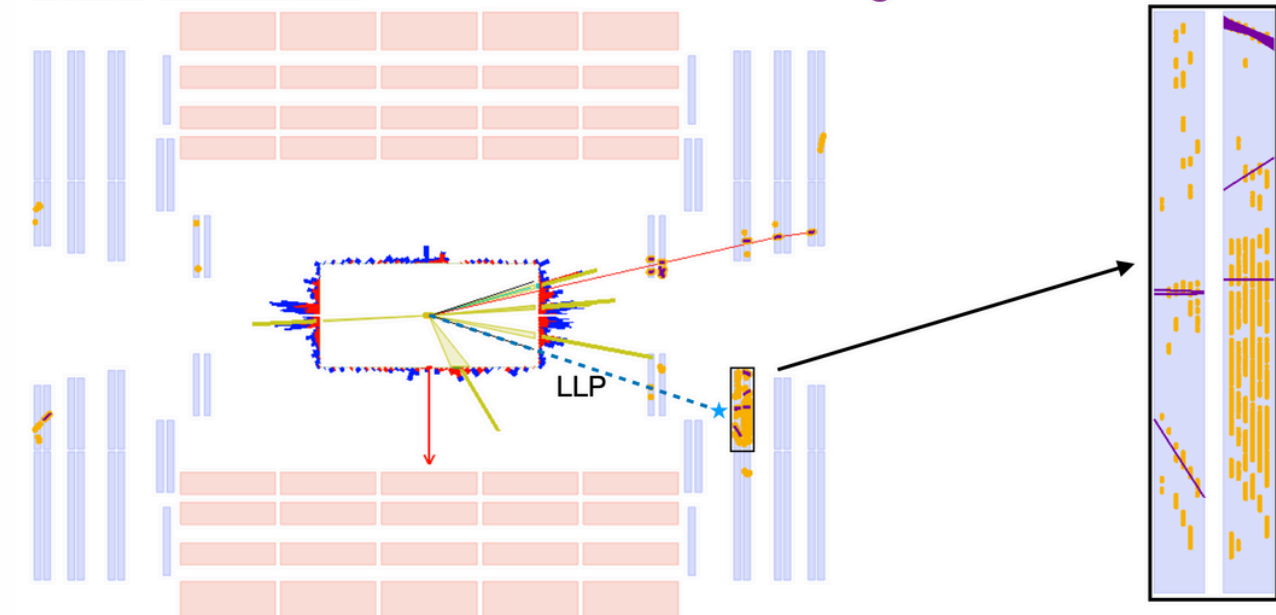
Searches for Long Lived Particles: Decays in Tracker, Calorimeters and Muon Detectors

Vector Like Leptons via LLP decays in the muon system

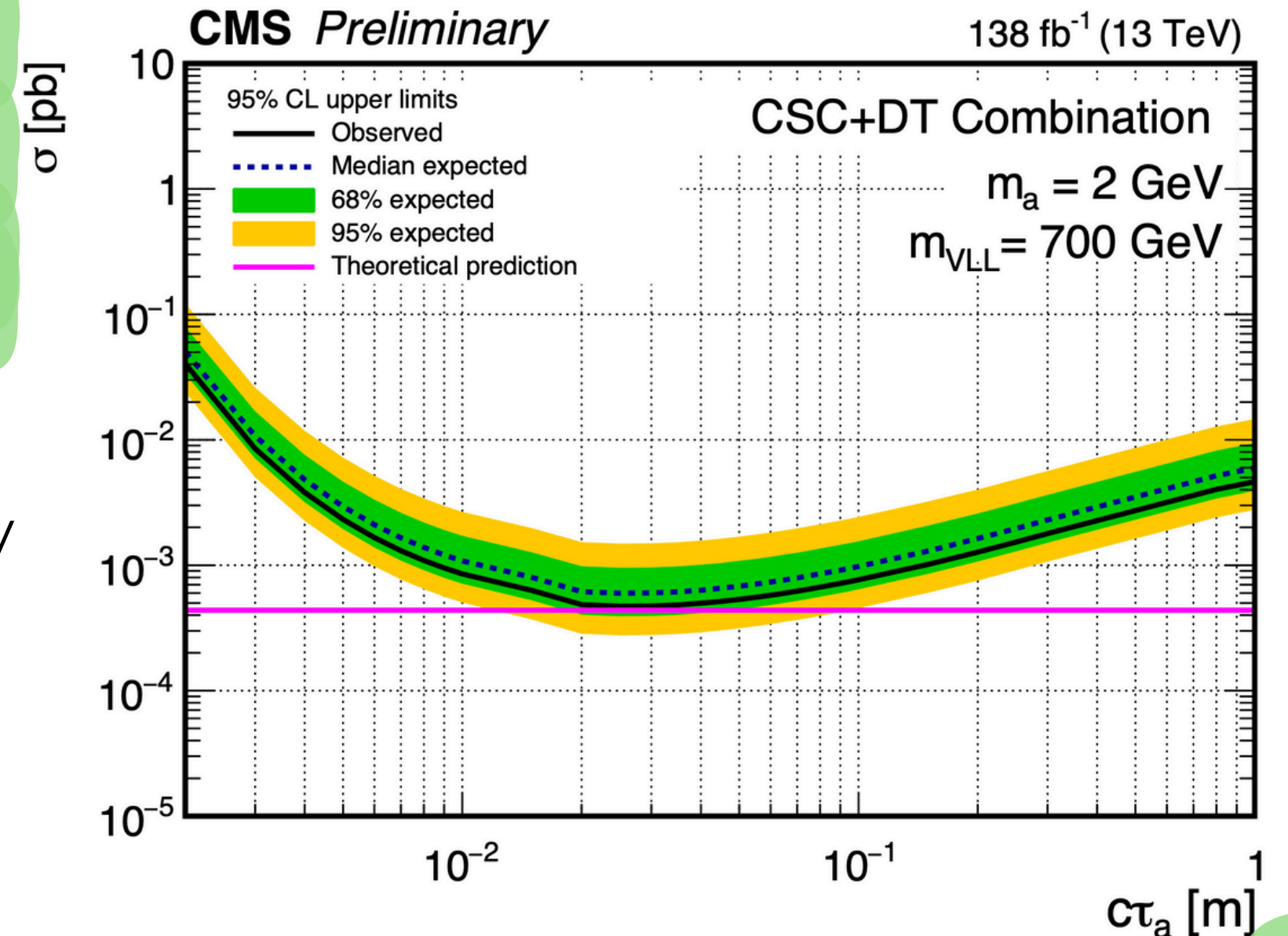


Muon Detector Shower (MDS): cascade of secondary particles produced by high energy particles crossing muon detectors

CMS Simulation ~1100 rechits & 33 segments in ME-2/1



high-multiplicity MDS



Beyond Standard

Model

Strategies

Signatures

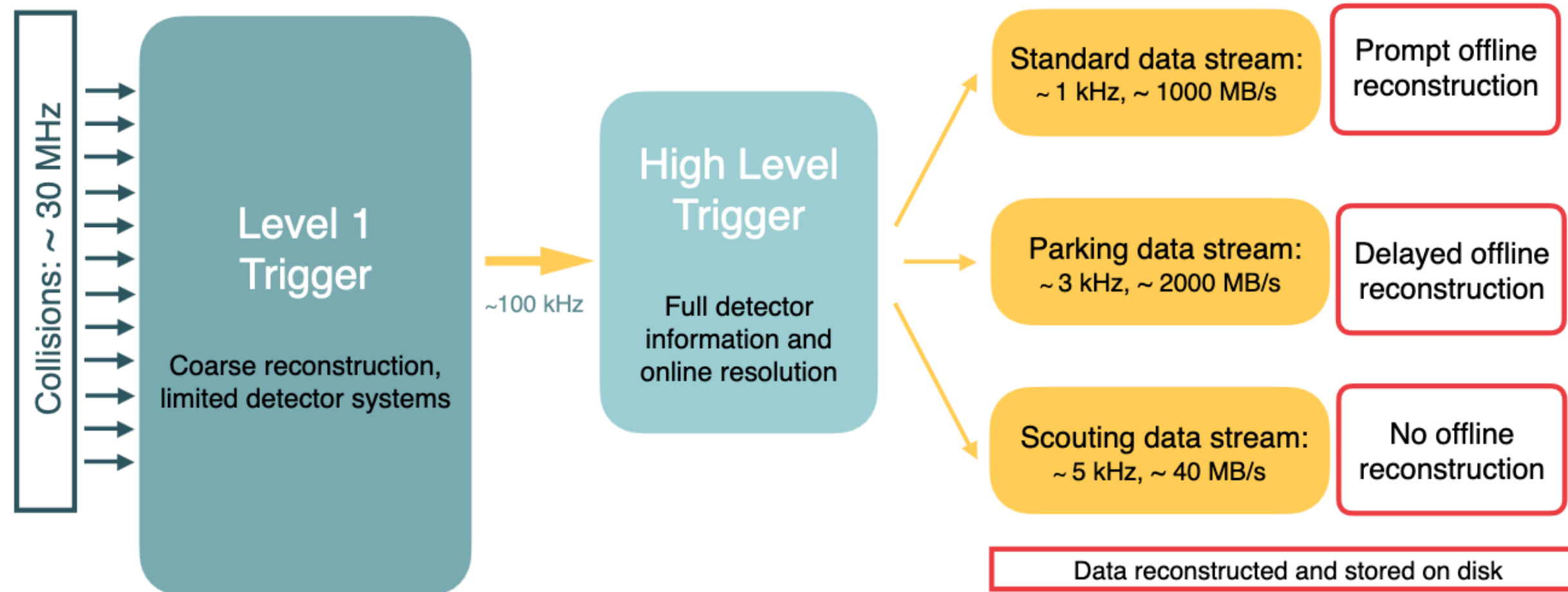
Tools

- *Dedicated data streams*
- *Ad-hoc triggers for LLPs at Run 3*

Scouting opportunities at Run 2 & 3



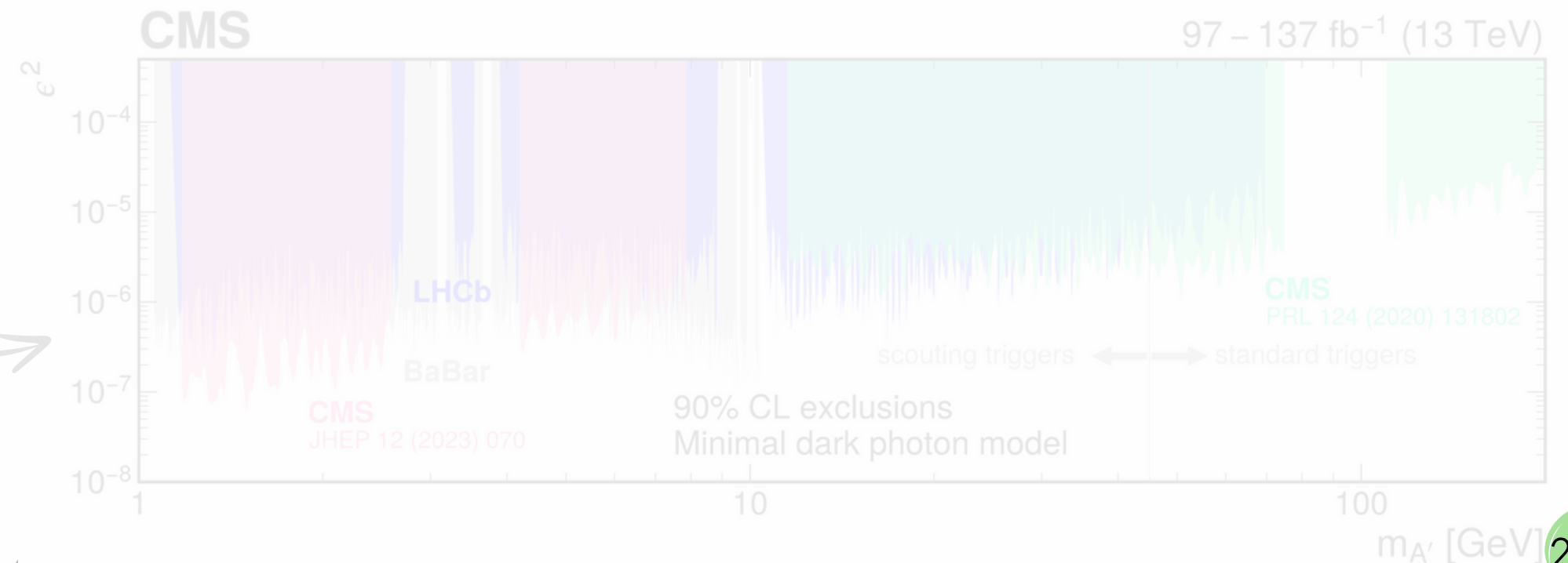
Data flow for a typical 2018 data-taking scenario



arXiv:2403.16134

Size ↘ Rate ↗

Scouting in Run 2 explored simple objects: low-mass dimuon spectra

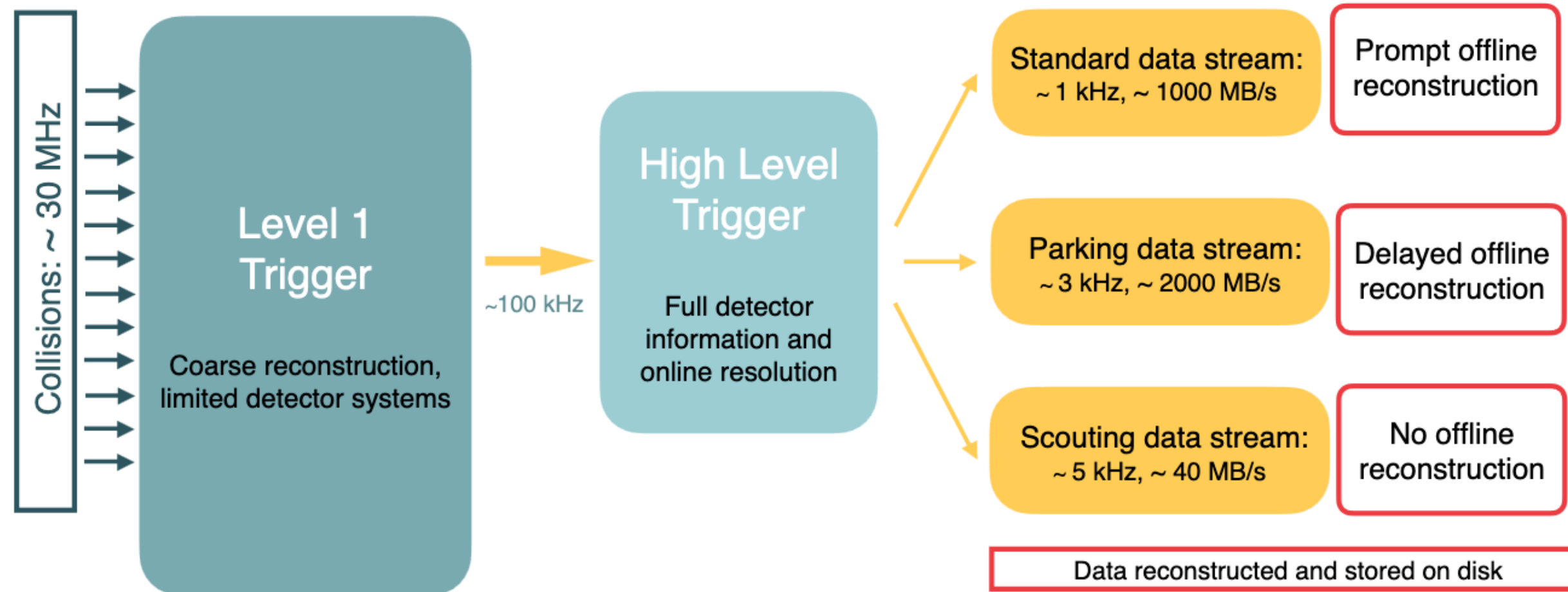


arXiv:2403.16134

Scouting opportunities at Run 2 & 3



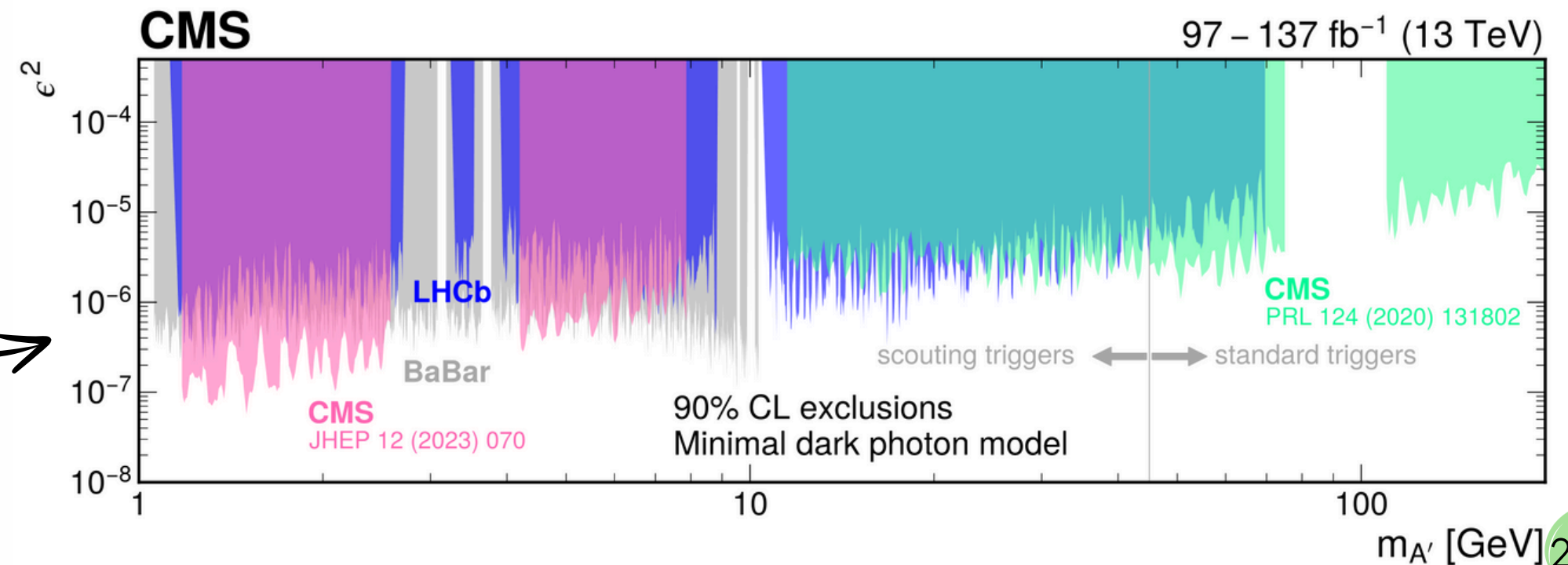
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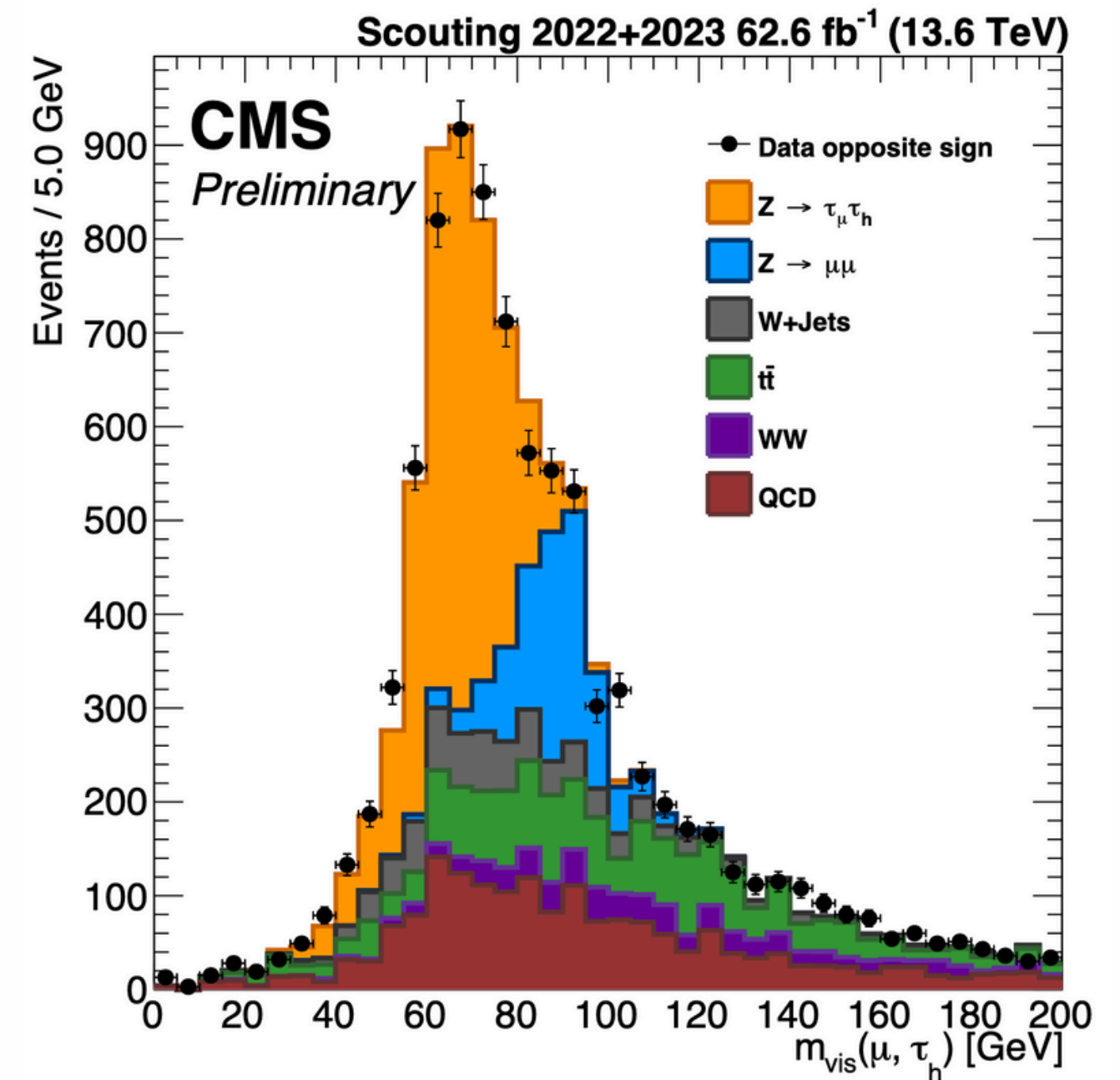
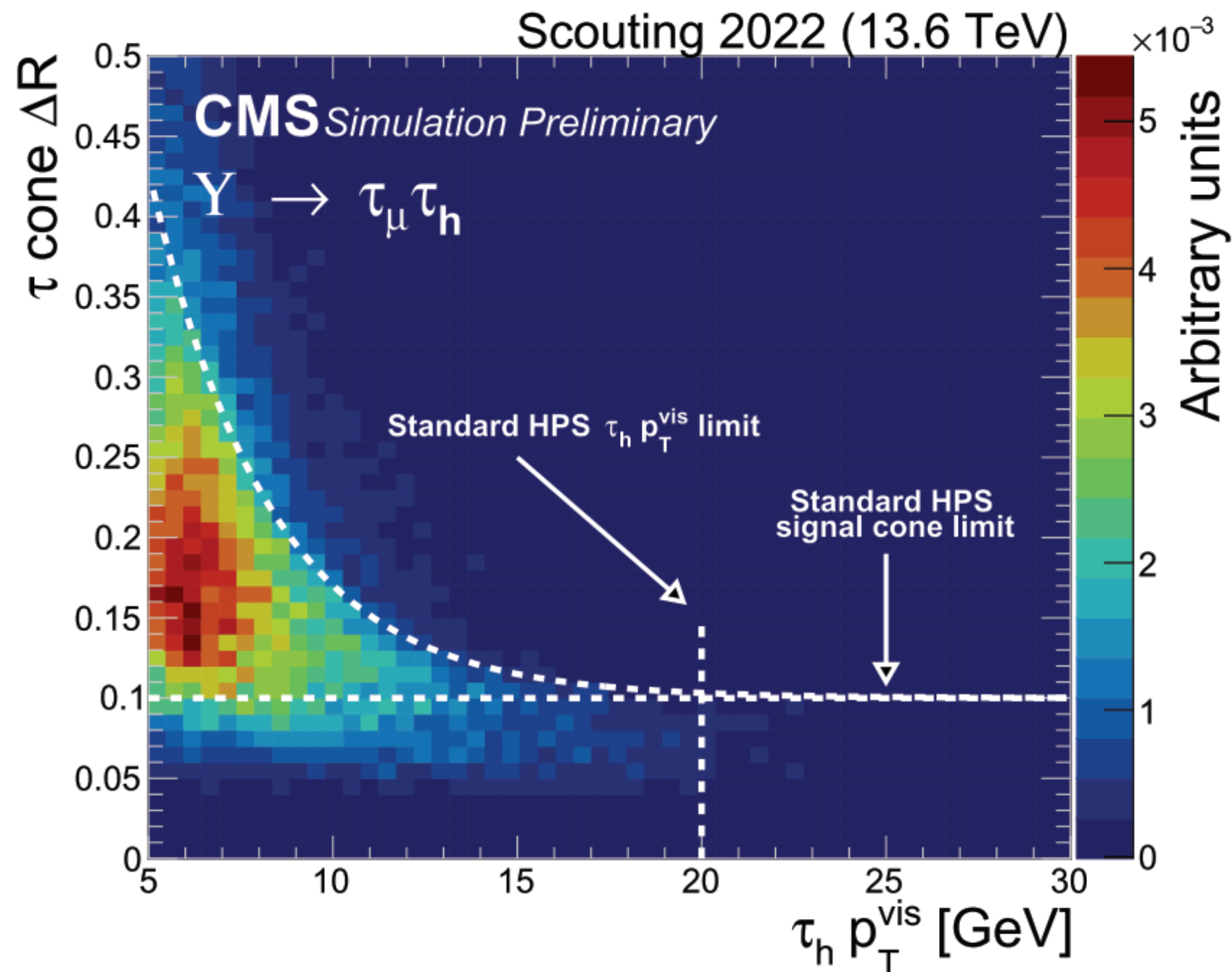
Scouting opportunities at Run 3



Scouting Run 3: more elaborated objects, tau leptons reconstruction
from all info stored in scouting dataset

dynamical tau cone definition vs p_T

first time in Scouting data



CMS NOTE-2024/006

Backup

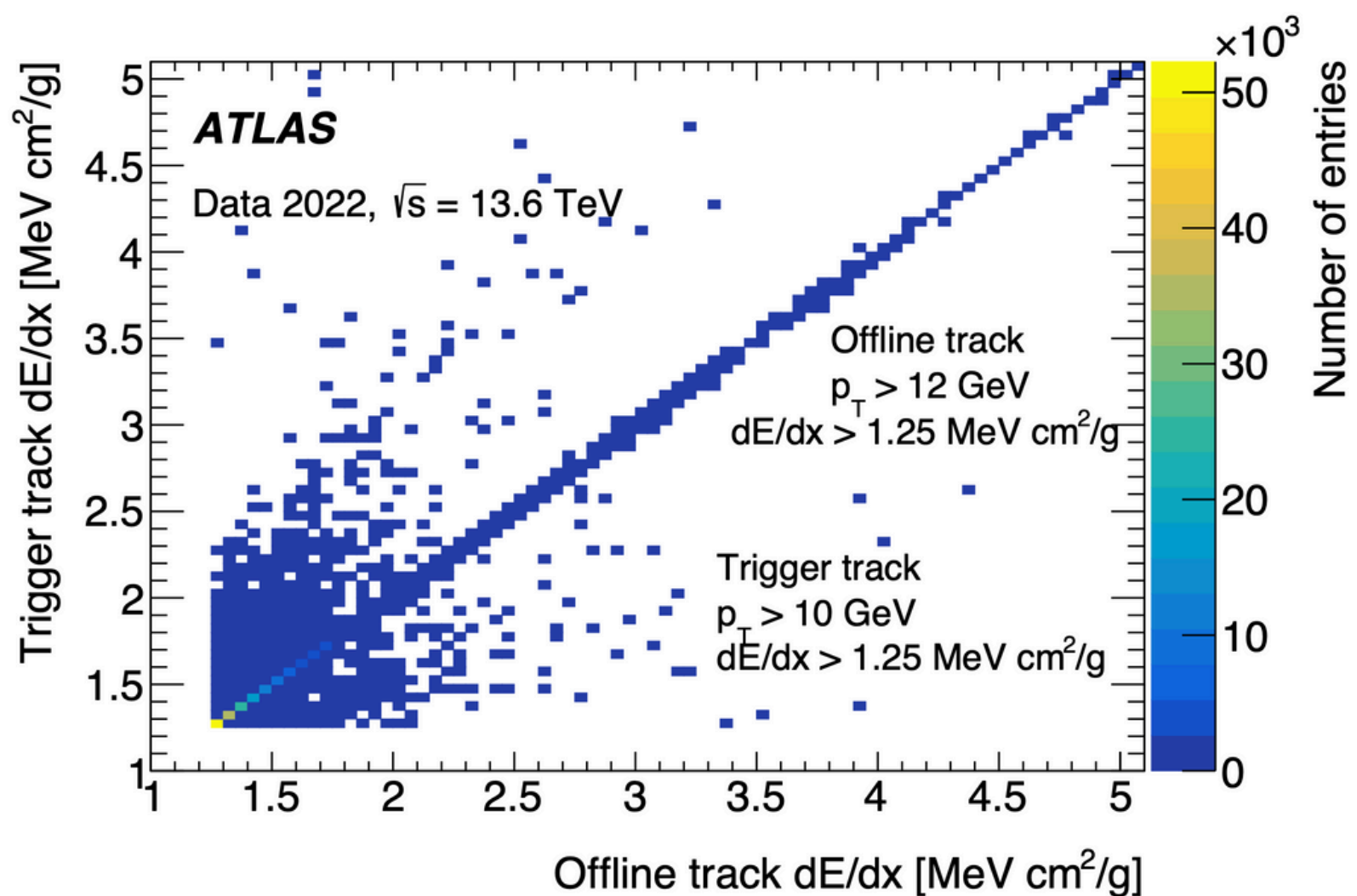


Innovative trigger strategies at Run 3



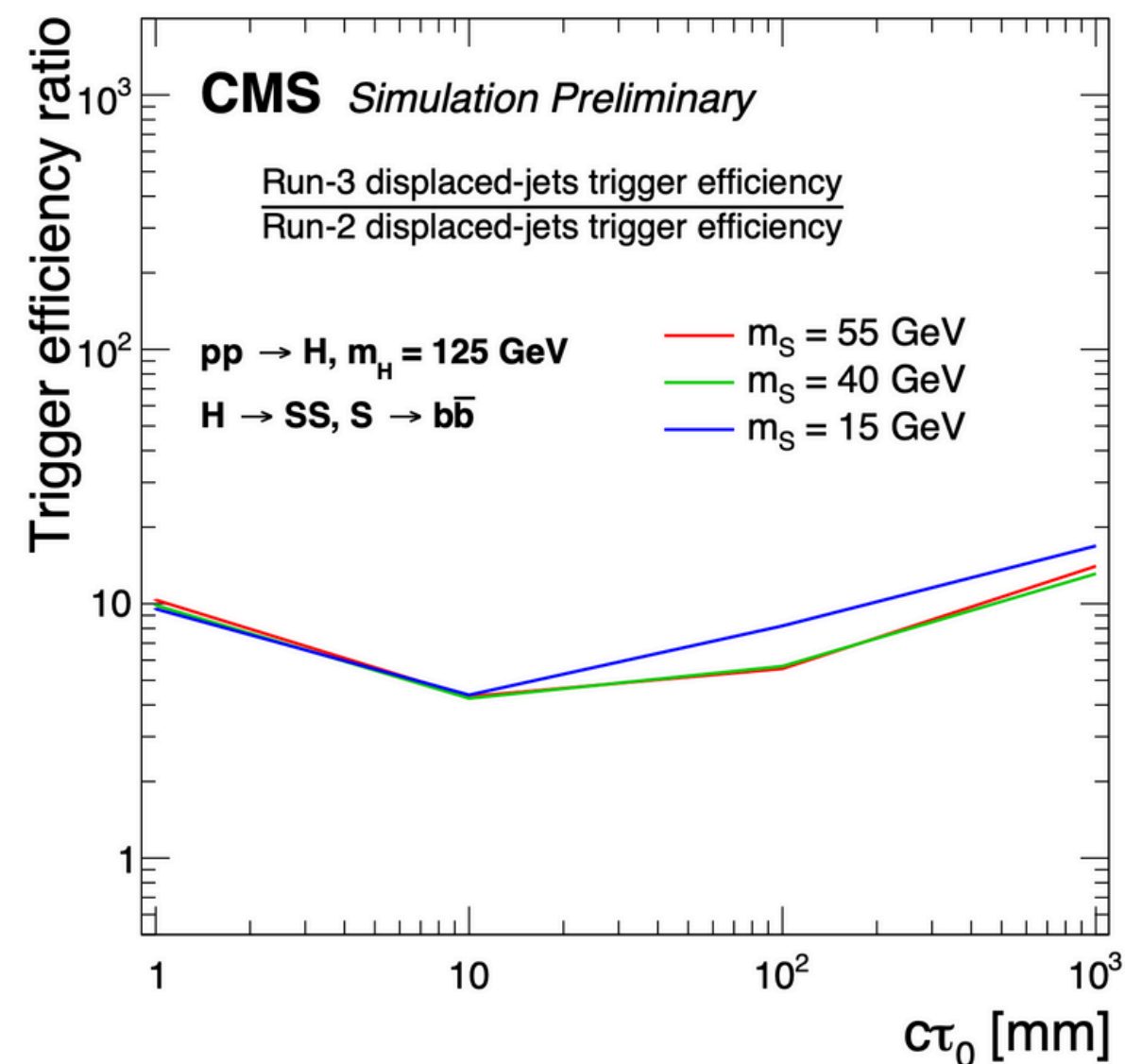
Run 3 physics program **expands the scope of searches for BSM** with addition of dedicated LLPs triggers

dE/dx handle to **identify new heavy charged particles**



arXiv:2401.06630

Displaced-jets tagging in Run 3 search brings up to x10 improvements w.r.t. Run 2.



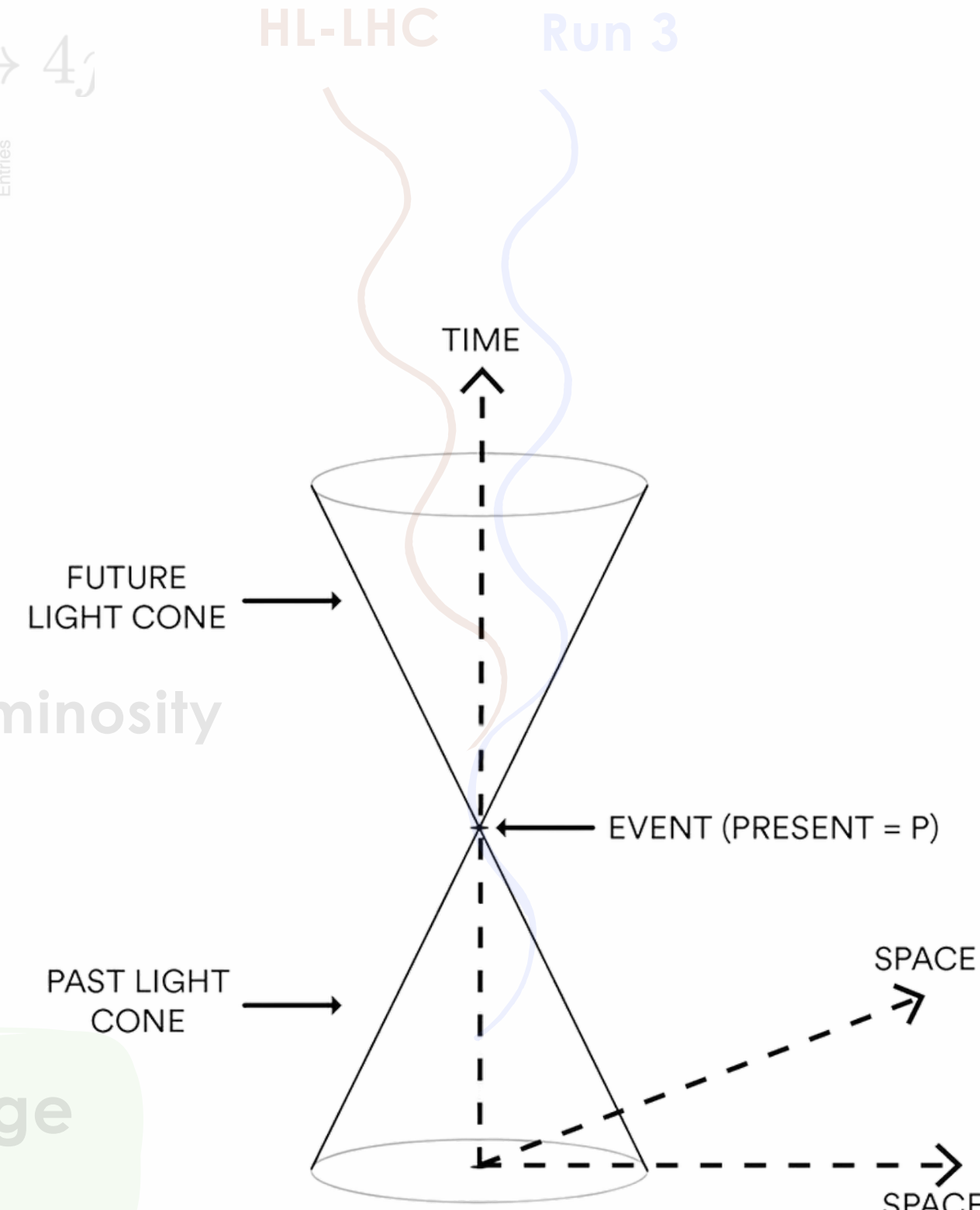
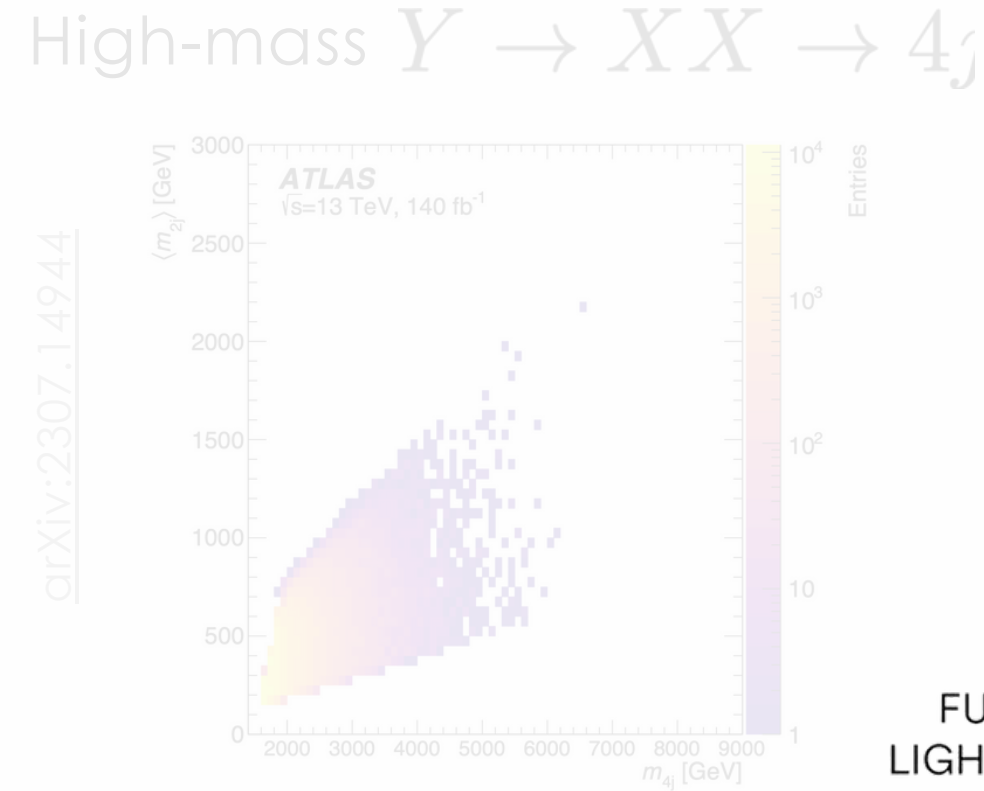
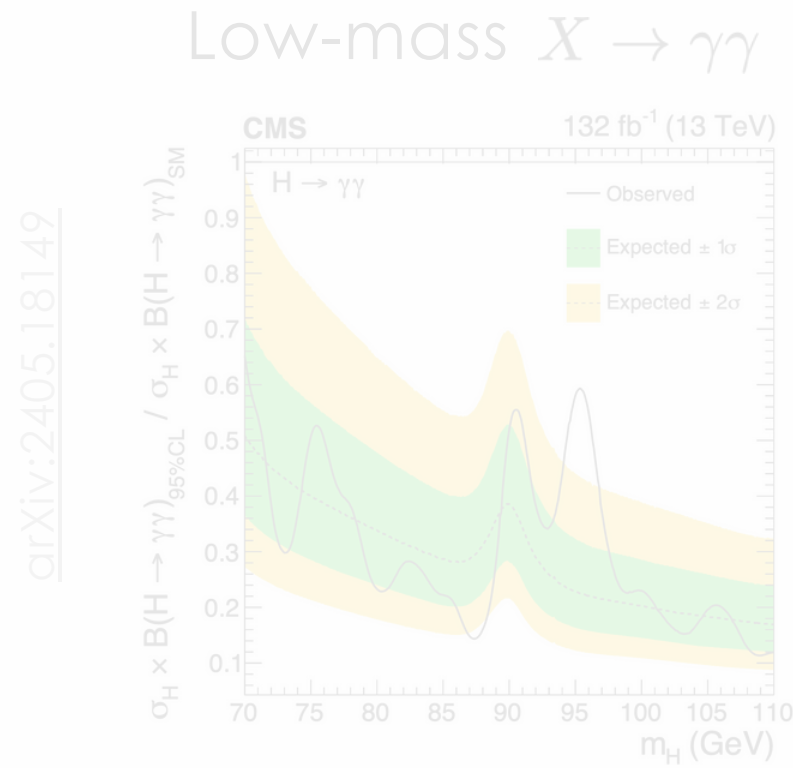
CMS-DPS-2023-043

BSM searches in our light-cone

Run 3 provides a powerful platform to explore new physics through combination of **higher energy**, **increased luminosity**, and **improved experimental techniques**



Some excesses around to chase..e.g.:



HL-LHC will significantly increase physics reaches: gains from **high luminosity** and **new detector capabilities**



e.g. Long Lived Particles searches and Particle ID with timing detectors

Next years will provide massive amount of new knowledge and we are expecting to exceed expectations!

BSM searches in our light-cone

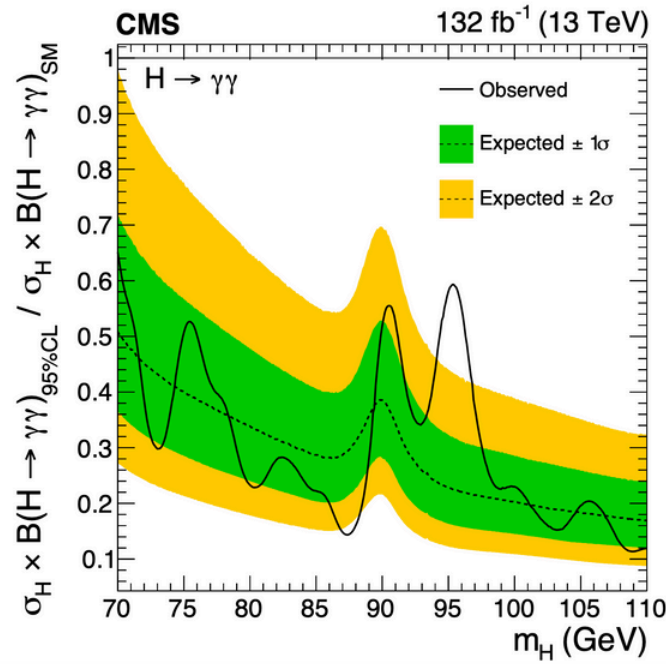
Run 3 provides a powerful platform to explore new physics through combination of **higher energy**, **increased luminosity**, and **improved experimental techniques**



Some excesses around, w/o Run 3 result yet, to chase..e.g.:

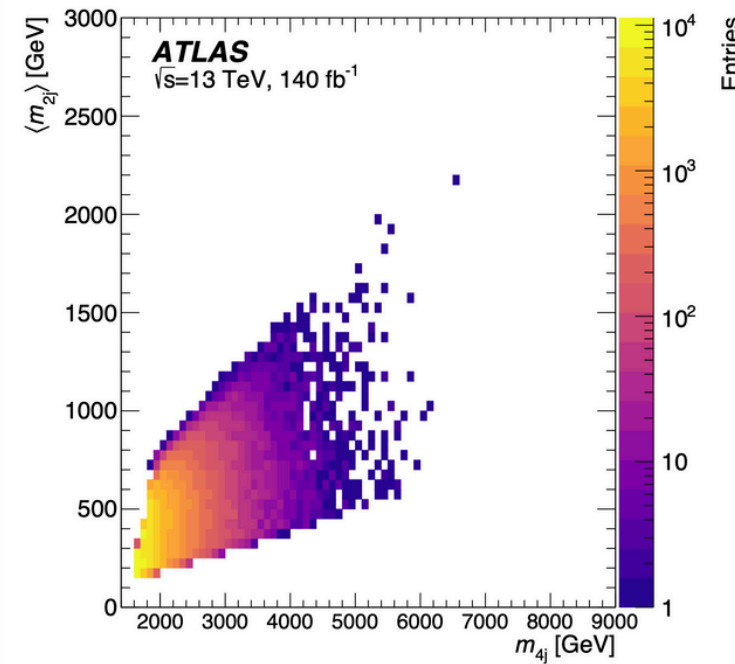
arXiv:2405.18149

Low-mass $X \rightarrow \gamma\gamma$



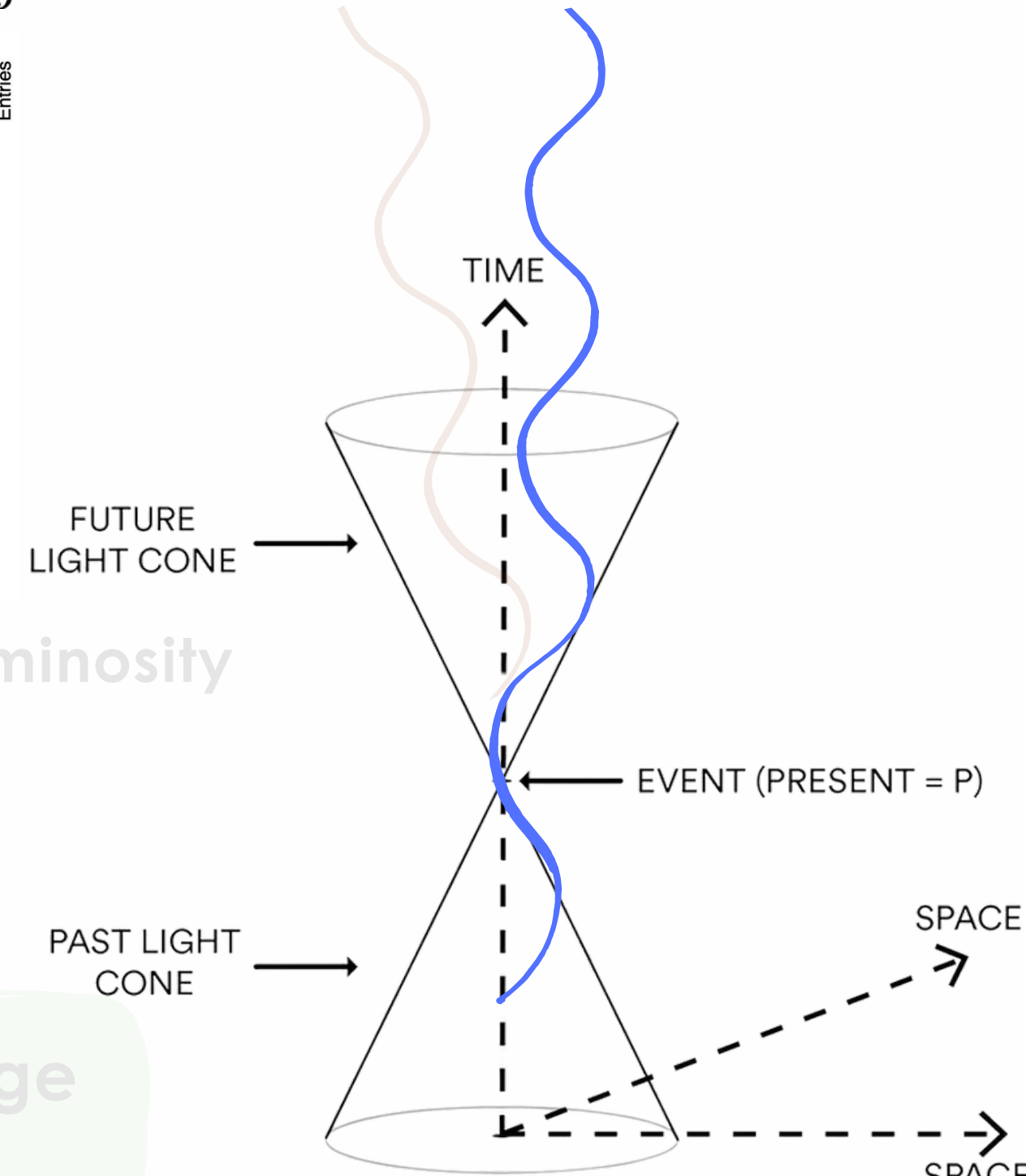
High-mass $Y \rightarrow XX \rightarrow 4j$

arXiv:2307.14944



HL-LHC

Run 3



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e.g. Long Lived Particles searches and Particle ID with timing detectors

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BSM searches in our light-cone

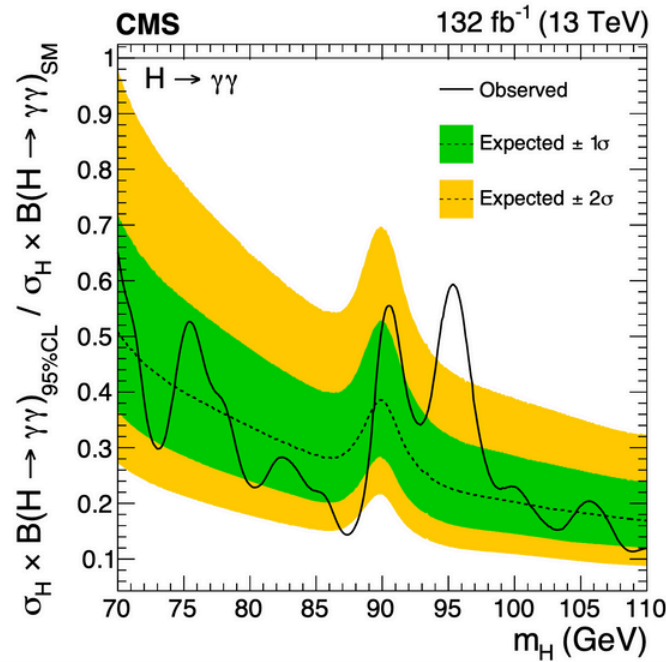
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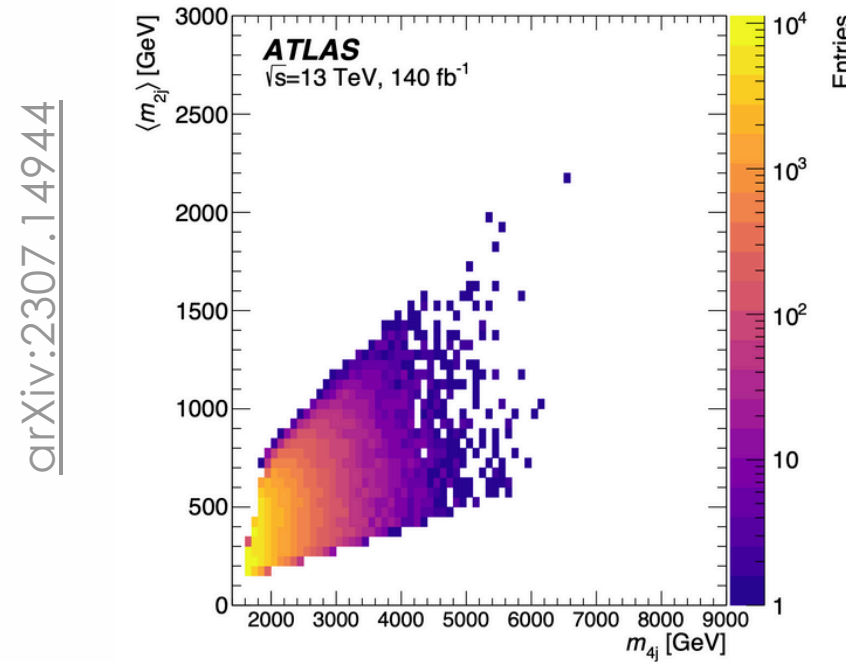
Some excesses around, w/o Run 3 result yet, to chase..e.g.:

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Low-mass $X \rightarrow \gamma\gamma$

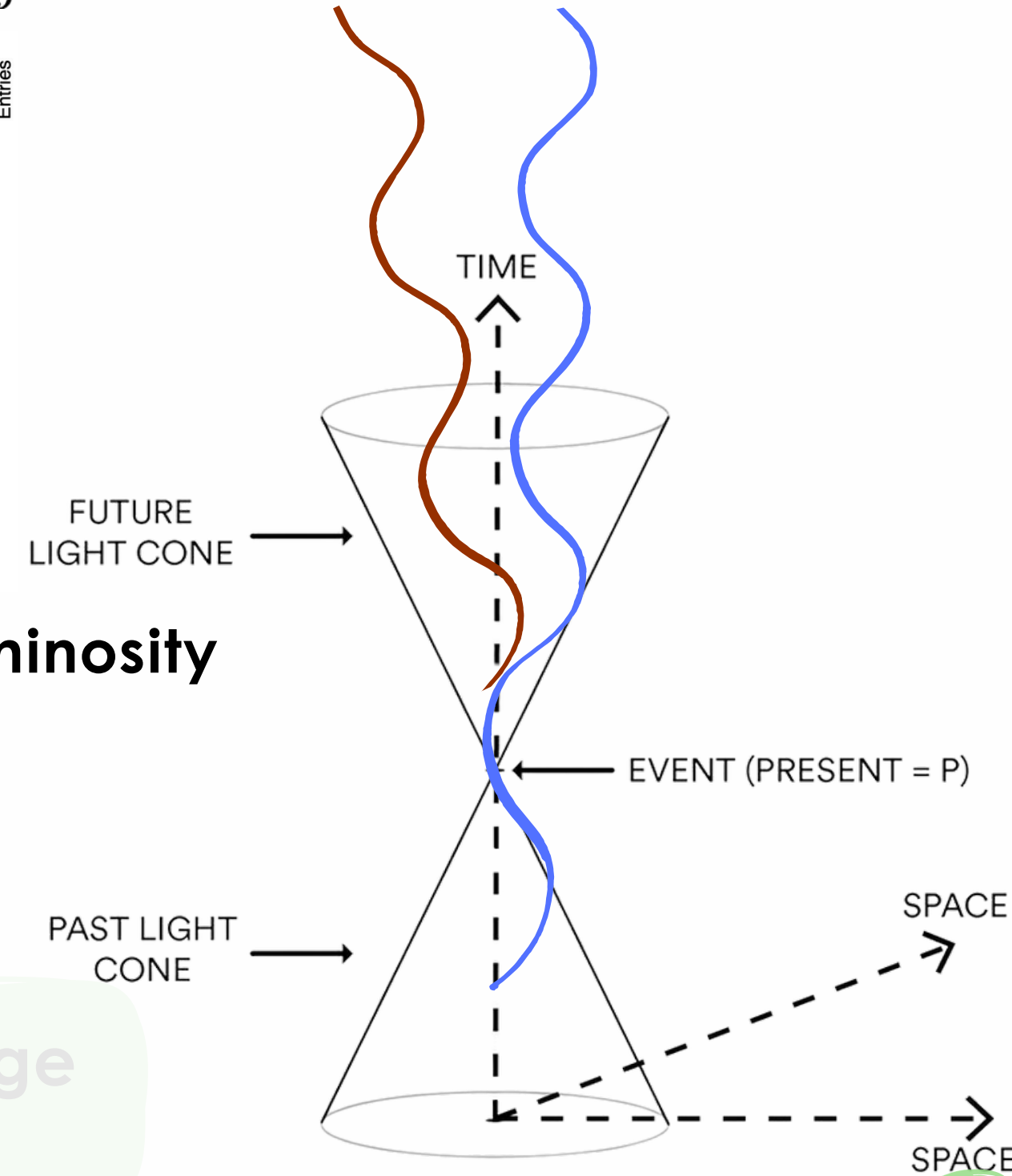


High-mass $Y \rightarrow XX \rightarrow 4j$



arXiv:2307.14944

HL-LHC Run 3



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BSM searches in our light-cone

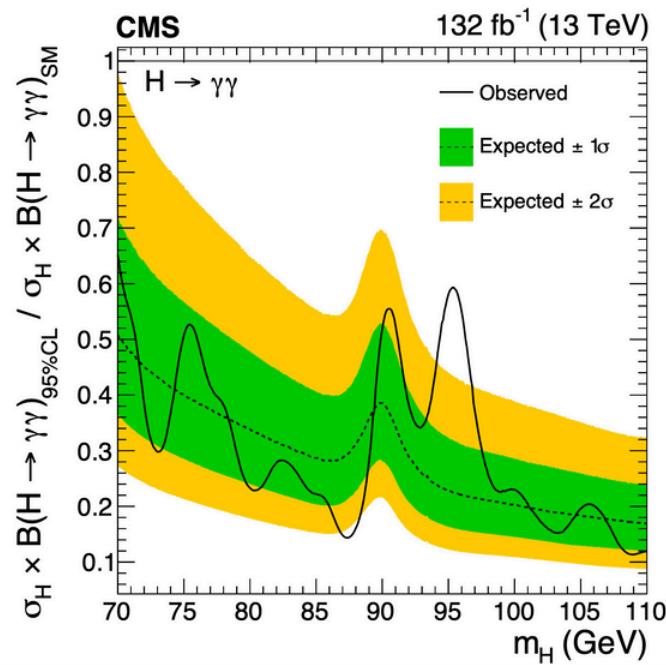
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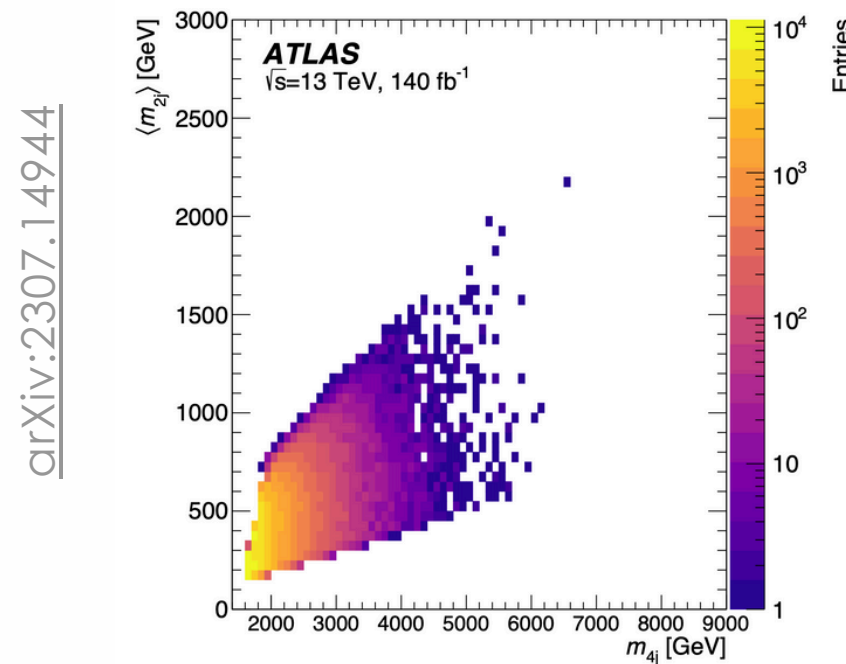
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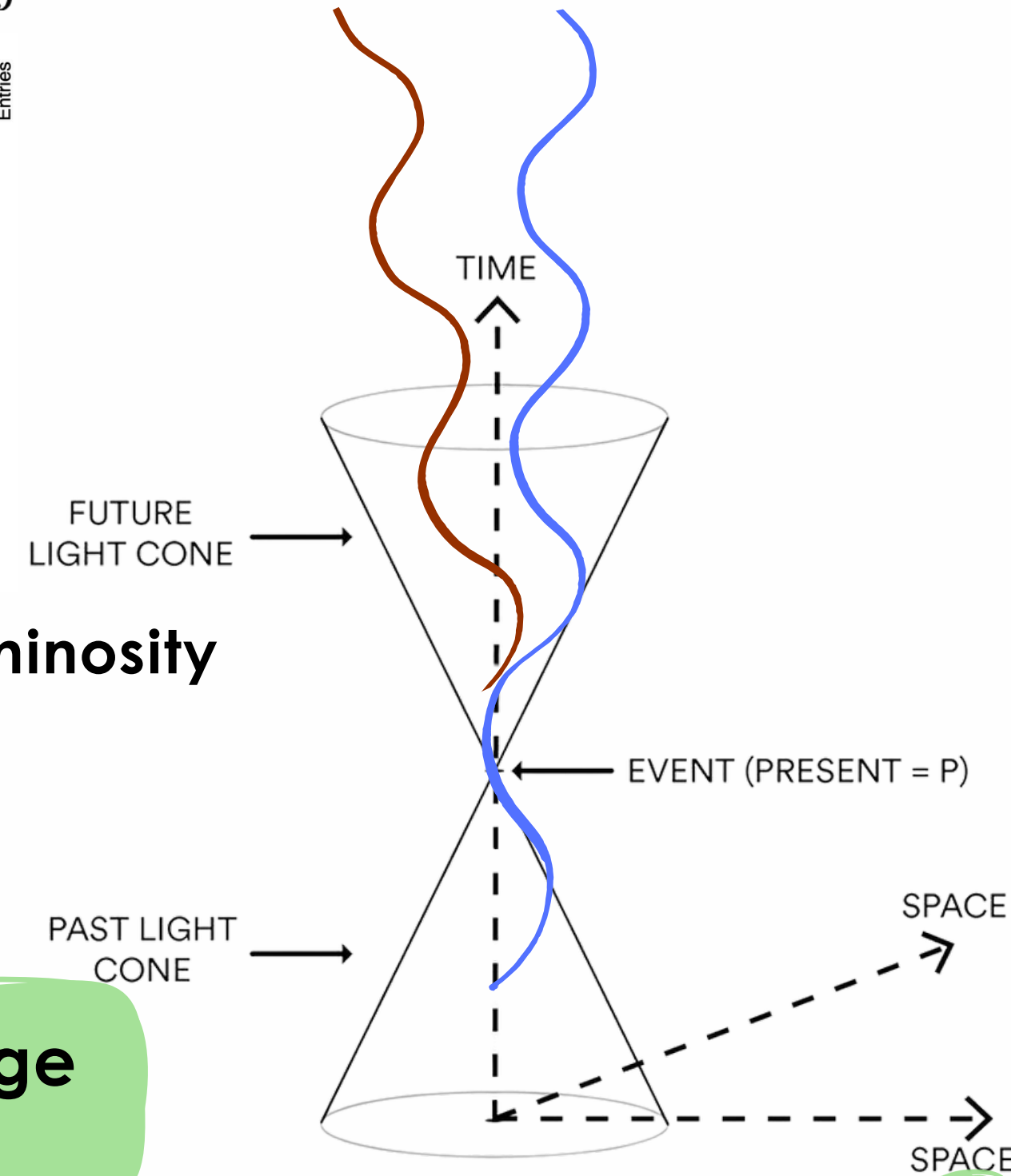


High-mass $Y \rightarrow XX \rightarrow 4j$



arXiv:2307.14944

HL-LHC Run 3



HL-LHC will significantly increase physics reach: gains from **high luminosity** and **new detector capabilities**

e.g. Long Lived Particles searches and Particle ID with timing detectors



Next years will provide massive amount of new knowledge and we are expecting to exceed expectations!

BSM searches in our light-cone

14:00 → 18:00 **Collider and BSM**

Conveners: Daniele Barducci (Istituto Nazionale di Fisica Nucleare), Natascia Vignaroli (Istituto Nazionale di Fisica Nucleare)

14:00 **BSM experimental overview**

Speaker: Giuliano Gustavino (CERN)

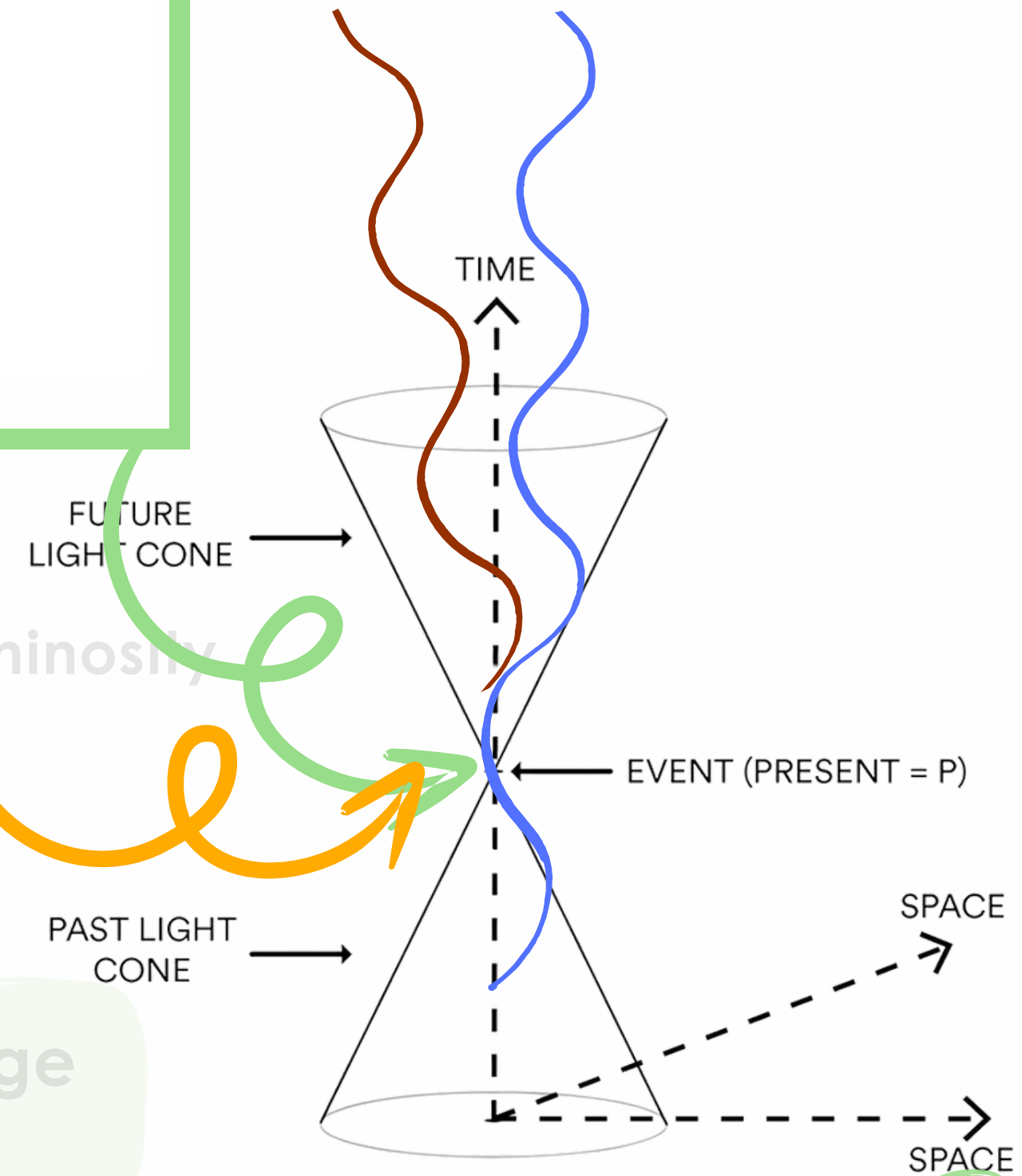
14:35 **Searches for BSM, future prospects**

Speaker: Guglielmo Coloretti (University of Zurich (UZH))

combination of higher energy, techniques

HL-LHC

Run 3



2024: the newly formed **BSM LHC WG**

- will **extend the existing work of the LHC DM and LLP WGs** to other BSM scenarios, under a common structure, together with the other **LHC experiments + members of the Theory community**
- consolidated and broad overview of **BSM LHC physics program** and of **current state of the art and plans** from LHC experiments

The background features a complex, light gray geometric pattern that resembles a cross-section of a particle detector or a network of connections. It consists of concentric circles, radial lines, and various rectangular and curved segments, creating a technical and abstract aesthetic. The text is centered over this pattern.

Thank you for
listening!



Backup

ATLAS Leptoquark summary

ATLAS Leptoquark searches - 95% CL exclusion

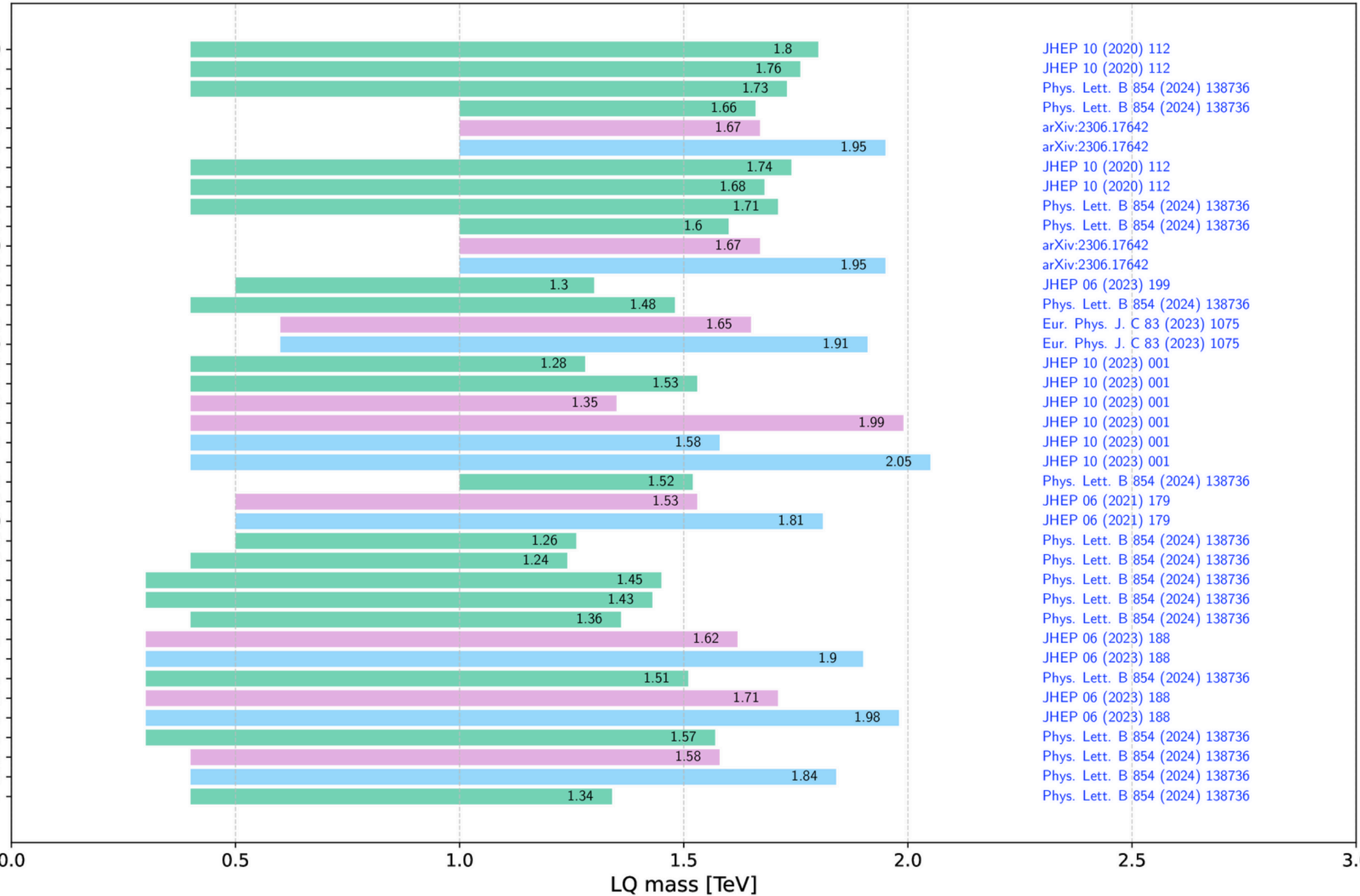
Status: July 2024

ATLAS Preliminary

$\sqrt{s}=13\text{ TeV}, 139\text{ fb}^{-1}$

LQ(qe)
LQ(qμ)
LQ(qτ)
LQ(qν/ql)

- Scalar (pair) BR(LQ → je)=1.0
- Scalar (pair) BR(LQ → ce)=1.0
- Scalar (pair) BR(LQ → be)=1.0
- Scalar (pair) BR(LQ → te)=1.0
- Vector (Min) (pair) BR(LQ → te)=1.0
- Vector (YM) (pair) BR(LQ → te)=1.0
- Scalar (pair) BR(LQ → jμ)=1.0
- Scalar (pair) BR(LQ → cμ)=1.0
- Scalar (pair) BR(LQ → bμ)=1.0
- Scalar (pair) BR(LQ → tμ)=1.0
- Vector (Min) (pair) BR(LQ → tμ)=1.0
- Vector (YM) (pair) BR(LQ → tμ)=1.0
- Scalar (pair) BR(LQ → jτ)=1.0
- Scalar (pair) BR(LQ → bτ)=1.0
- Vector (Min) (pair) BR(LQ → bτ)=1.0
- Vector (YM) (pair) BR(LQ → bτ)=1.0
- Scalar (single+non res.+pair) λ(bτ)=1.0
- Scalar (single+non res.+pair) λ(bτ)=2.5
- Vector (Min) (single+non res.+pair) λ(bτ)=1.0
- Vector (Min) (single+non res.+pair) λ(bτ)=2.5
- Vector (YM) (single+non res.+pair) λ(bτ)=1.0
- Vector (YM) (single+non res.+pair) λ(bτ)=2.5
- Scalar (pair) BR(LQ → tτ)=1.0
- Vector (Min) (pair) BR(LQ → tτ)=1.0
- Vector (YM) (pair) BR(LQ → tτ)=1.0
- Scalar (pair) BR(LQ → bv)=1.0
- Scalar (pair) BR(LQ → tv)=1.0
- Scalar (pair) BR(LQ → te)=0.5
- Scalar (pair) BR(LQ → tμ)=0.5
- Scalar (pair) BR(LQ → tτ)=0.5
- Vector (Min) (pair) BR(LQ → be)=0.5
- Vector (YM) (pair) BR(LQ → be)=0.5
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- Vector (YM) (pair) BR(LQ → bτ)=0.5
- Scalar (pair) BR(LQ → bτ)=0.5

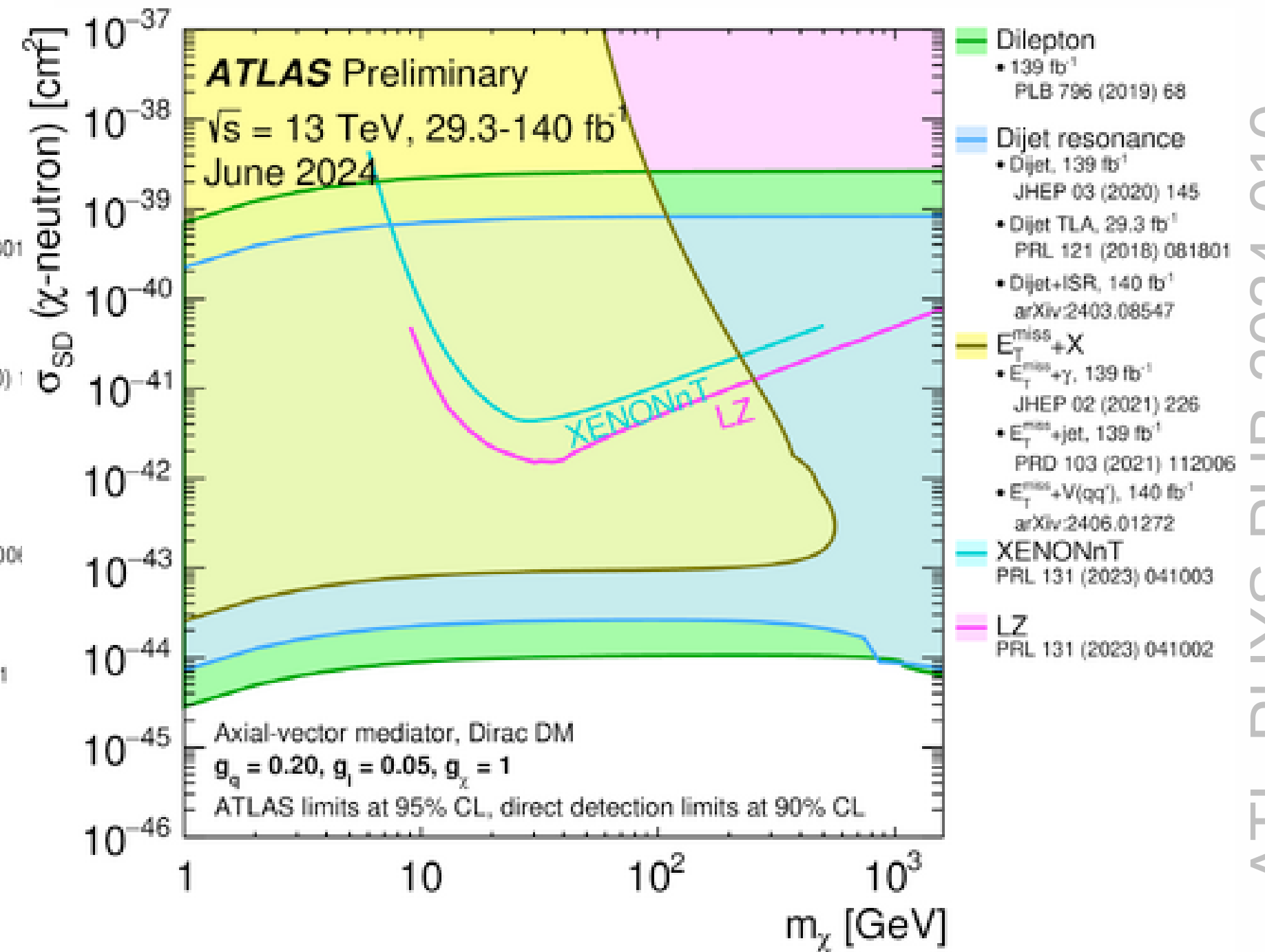
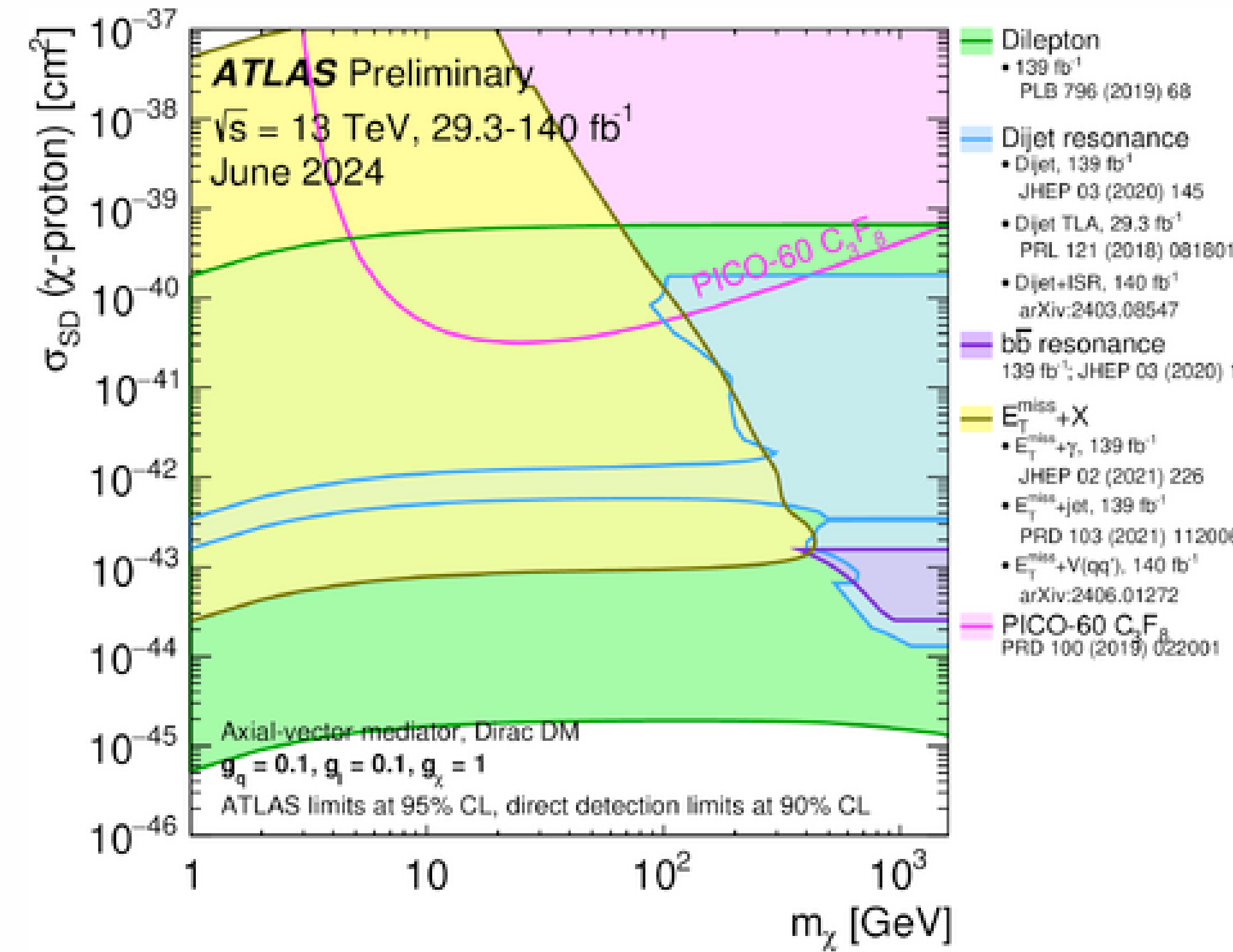


JHEP 10 (2020) 112
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 Phys. Lett. B 854 (2024) 138736
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 Phys. Lett. B 854 (2024) 138736
 Eur. Phys. J. C 83 (2023) 1075
 Eur. Phys. J. C 83 (2023) 1075
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 Phys. Lett. B 854 (2024) 138736

j refers to u, d, or s quark

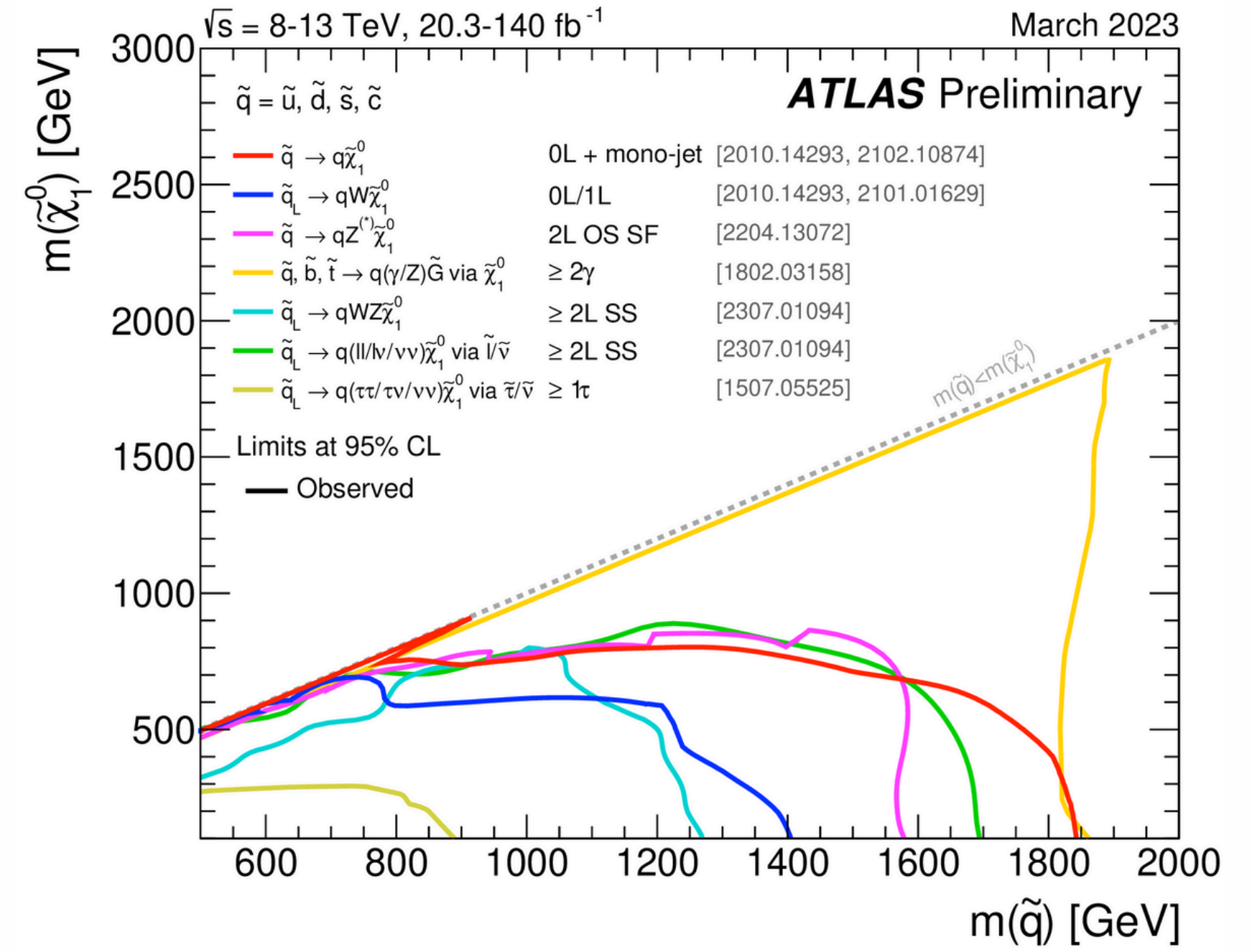
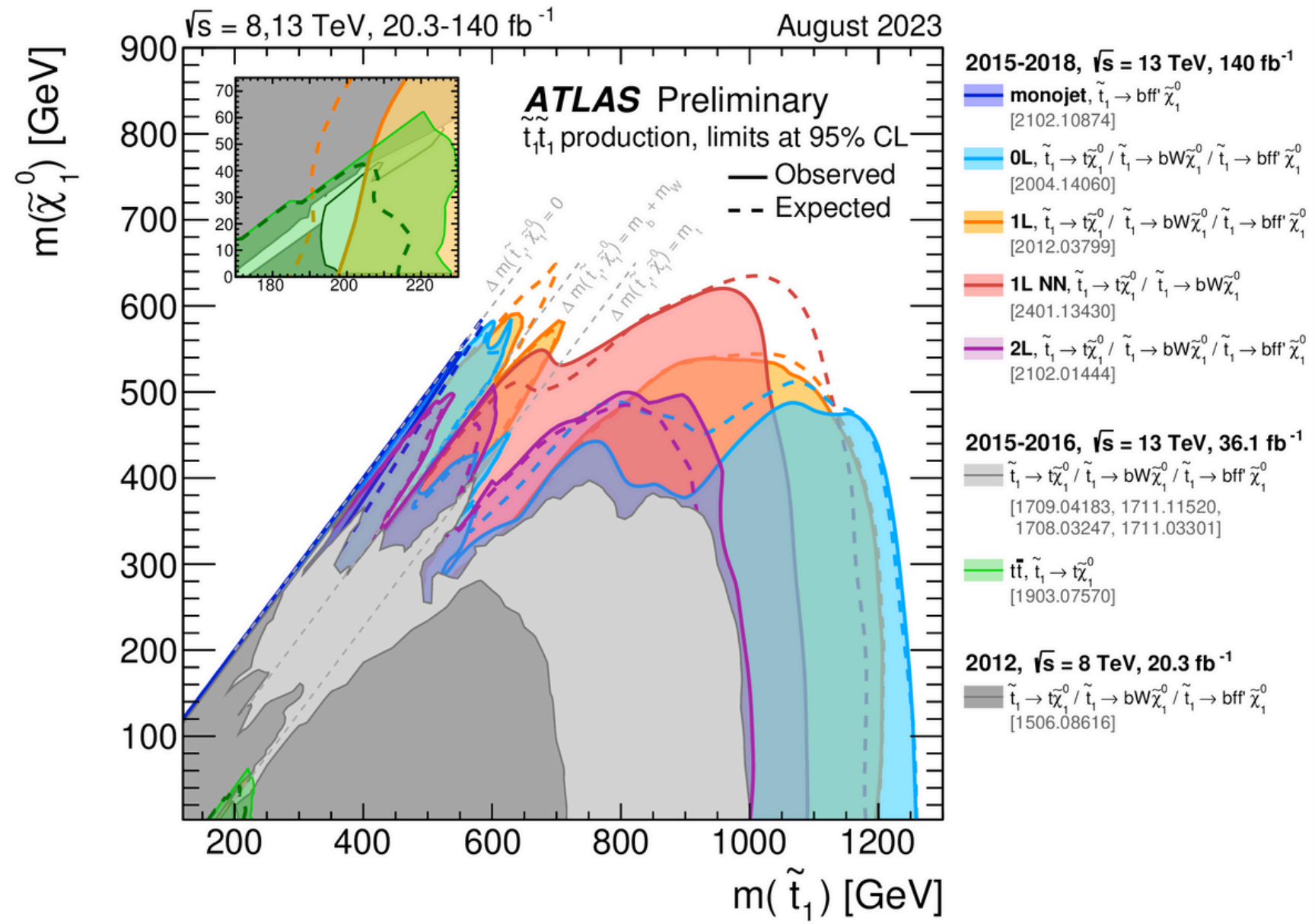
Scalar
Vector (Yang-Mills)
Vector (Minimal)

ATLAS Dark Matter summary



ATL-PHYS-PUB-2024-010

ATLAS SUSY summary



ATL-PHYS-PUB-2024-014

CMS Heavy Resonances summary



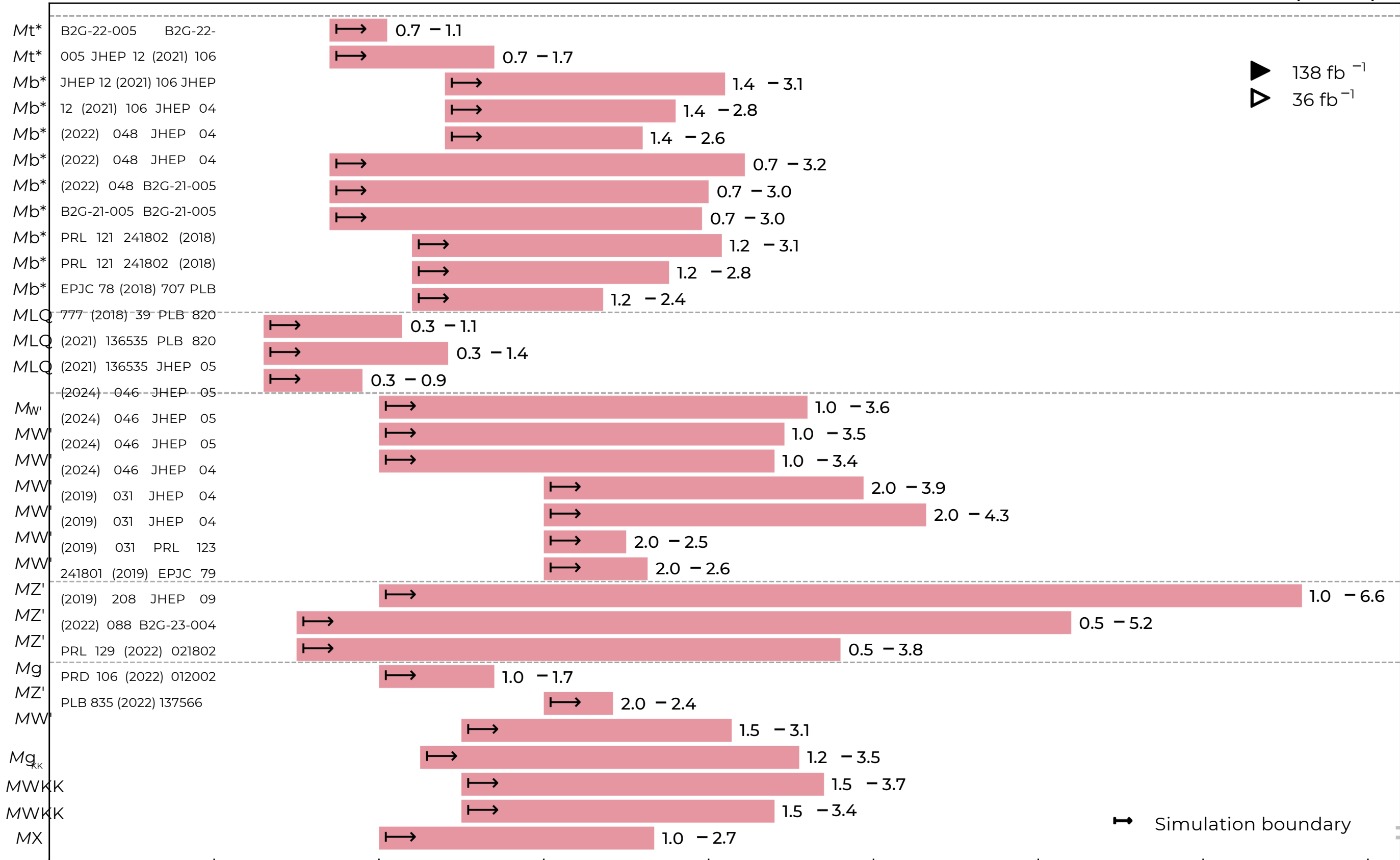
July 2024

Overview of CMS B2G Results

CMS Preliminary

36 – 138 fb⁻¹ (13 TeV)

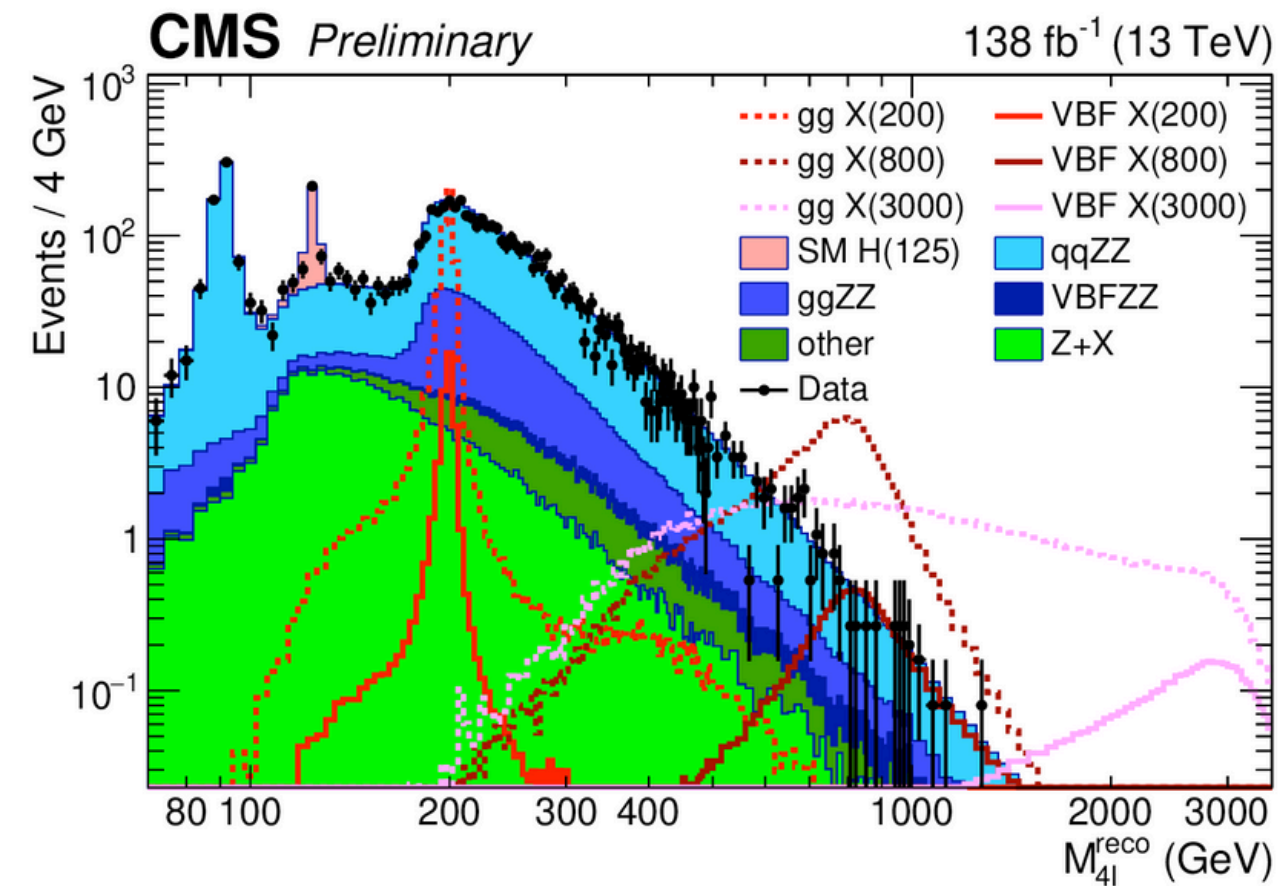
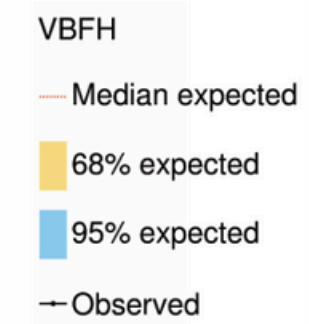
- Resonances**
- Excited quarks**
 - ▶ $t^*t^* \rightarrow t\bar{t}g, \ell$ (spin-1/2)
 - ▶ $t^*t^* \rightarrow t\bar{t}g, 1$ (spin-3/2)
 - ▶ $b^* \rightarrow tW \rightarrow bq\bar{q}q\bar{q}$ (LH+RH)
 - ▶ $b^* \rightarrow tW \rightarrow bq\bar{q}q\bar{q}$ (RH)
 - ▶ $b^* \rightarrow tW \rightarrow bq\bar{q}q\bar{q}$ (LH)
 - ▶ $b^* \rightarrow tW \rightarrow bq\bar{q}l\nu$ (LH+RH)
 - ▶ $b^* \rightarrow tW \rightarrow bq\bar{q}l\nu$ (RH)
 - ▶ $b^* \rightarrow tW \rightarrow bq\bar{q}l\nu$ (LH)
 - ▶ $b^* \rightarrow tW \rightarrow blq\bar{q}$ (LH+RH)
 - ▶ $b^* \rightarrow tW \rightarrow blq\bar{q}$ (RH)
 - ▶ $b^* \rightarrow tW \rightarrow blq\bar{q}$ (LH)
 - ▷ $L\bar{Q}L\bar{Q} \rightarrow b\bar{b}$ (scalar)
 - ▷ $L\bar{Q}L\bar{Q} \rightarrow t\bar{t}$ (scalar)
 - ▷ $L\bar{Q}L\bar{Q} \rightarrow t\bar{t}\tau$
 - ▷ $W' \rightarrow tb, 1$ (RH) $M > M' R_w$
 - ▶ $W' \rightarrow tb, 0$ (LH)
 - ▶ $W' \rightarrow tb, 0$ (RH)
 - ▶ $W' \rightarrow tb, 1$ (LH, $M/W'=1\%$)
 - ▶ $W' \rightarrow tb, 1$ (RH, $M/W'=1\%$)
 - ▶ $W' \rightarrow tb, 1$ (LH, $M/W'=10\%$)
 - ▶ $W' \rightarrow tb, 1$ (RH, $M/W'=10\%$)
 - ▷ $Z' \rightarrow t\bar{t}$ ($M/Z'=30\%$)
 - ▷ $Z' \rightarrow t\bar{t}$ ($M/Z'=10\%$)
 - ▷ $Z' \rightarrow t\bar{t}$ ($M/Z'=1\%$)
 - KK & others**
 - ▷ Stealth $\tilde{g} \rightarrow \tilde{\chi}^0_1 \bar{q}q + \text{jets}, M\tilde{\chi}^0_1 = 0.2\text{TeV}$
 - ▷ $Z' \rightarrow t\bar{t} \rightarrow tZt/tHt \rightarrow l\nu + \text{jets}$ ($M_T=1.5\text{TeV}$)
 - ▶ $W' \rightarrow Tb/Bt$ ($M_{VLQ}=2/3M_{W'}$)
 - ▶ $gKK \rightarrow gR \rightarrow gWW$ (\mathcal{O}) ($M_R/M_{gKK}=0.5$)
 - ▶ $WKK \rightarrow RW \rightarrow WWW$ ($\mathcal{O}+1$) l
 - ▶ $WKK \rightarrow RW \rightarrow WWW$ (\mathcal{O})
 - ▶ $X \rightarrow aa \rightarrow b\bar{b}b\bar{b}$ ($M_a=0.1\text{TeV}, M_X N/f=8$)



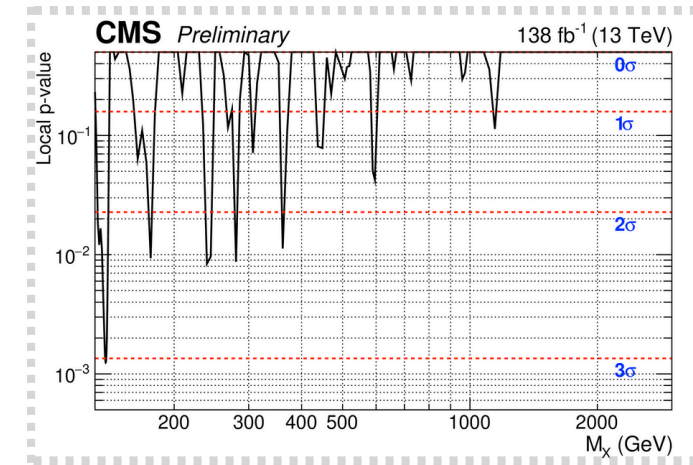
Search for high mass $H \rightarrow ZZ \rightarrow 4\text{leptons}$

$$130\text{GeV} < M_X < 3\text{TeV} \quad 0 < \Gamma_X/M_X < 0.3$$

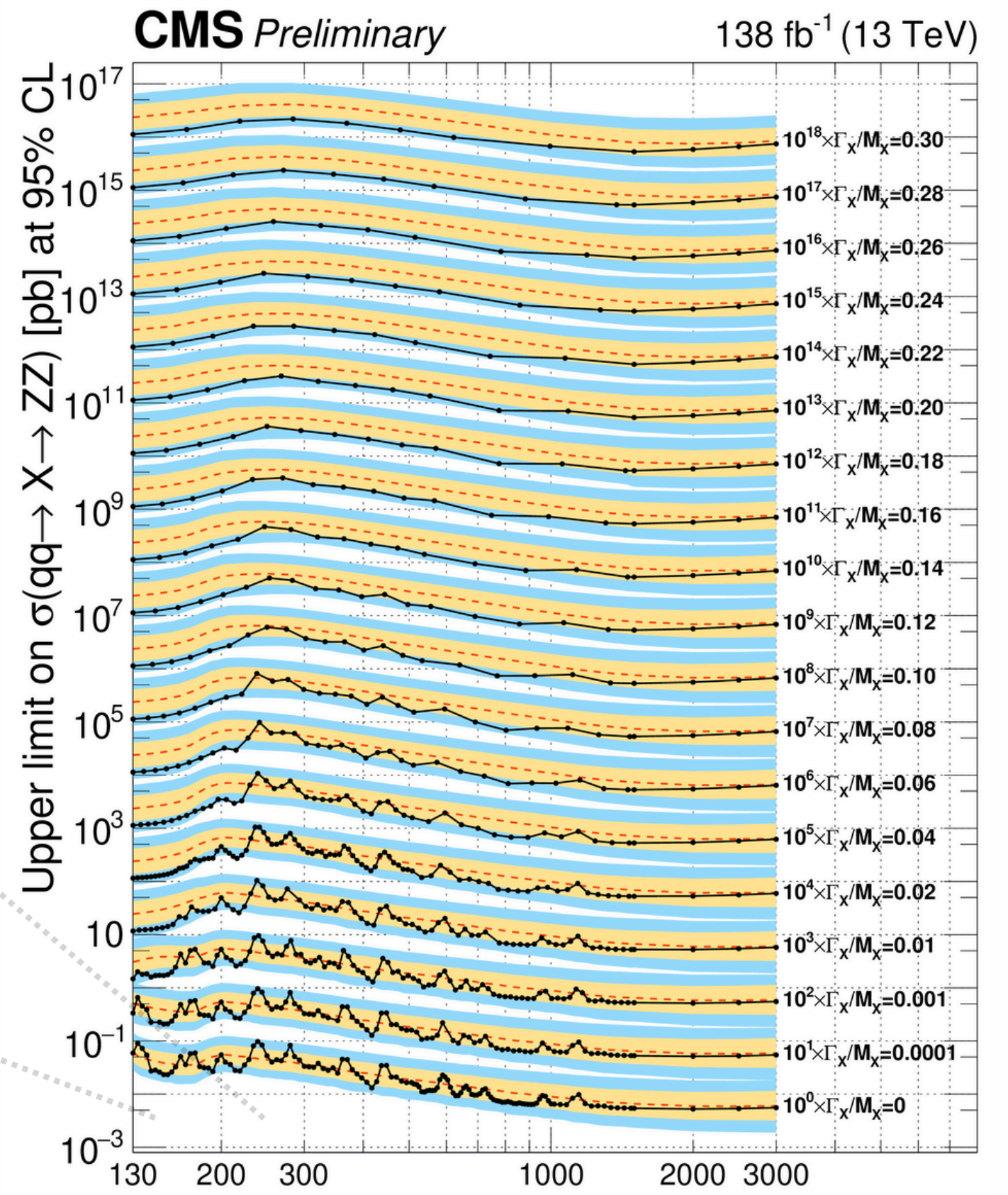
fVBF, fraction of VBF production considered as a parameter in the model together with mass and width



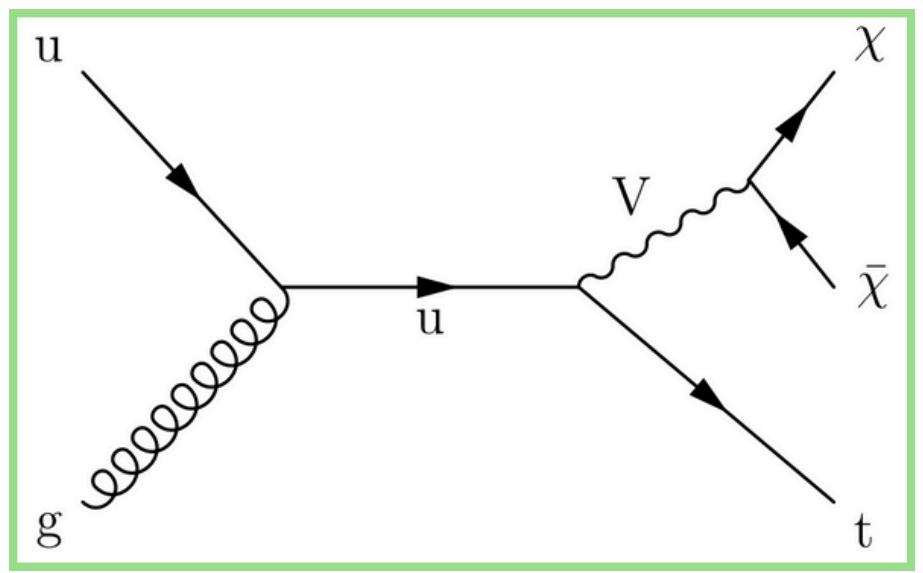
- largest excess at 138.1 GeV: 3 sigma local 1.9 global



- large X width leads to sizable interference: considered for ggF and VBF: 9.5% to 18% of syst. unc.

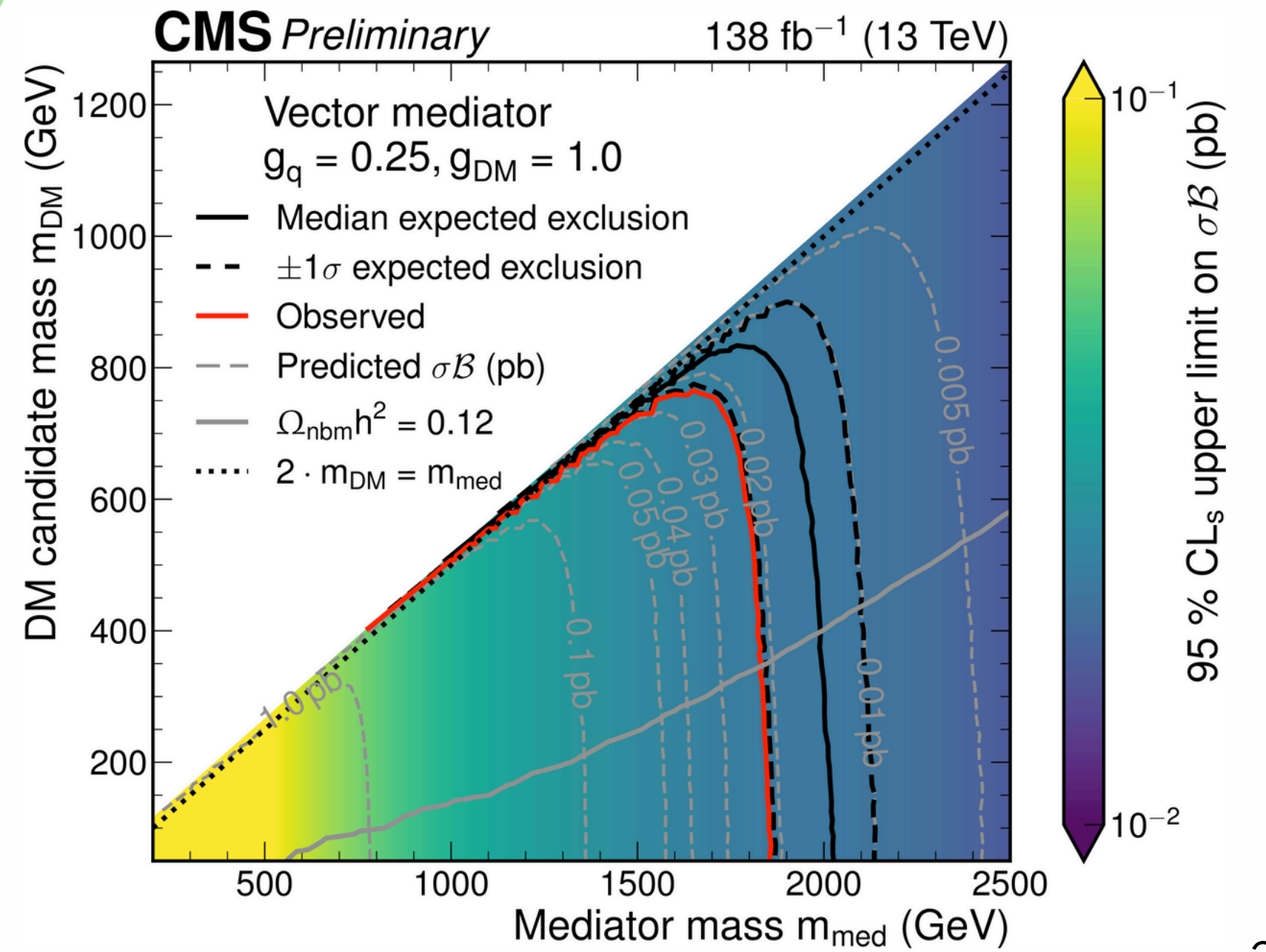
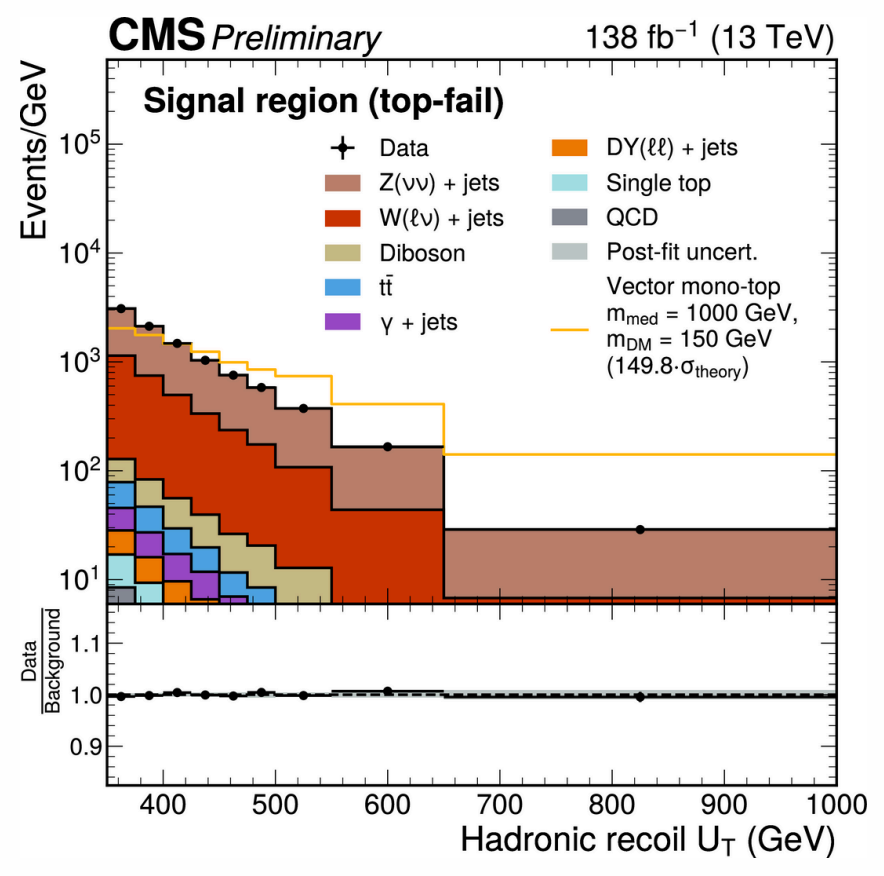
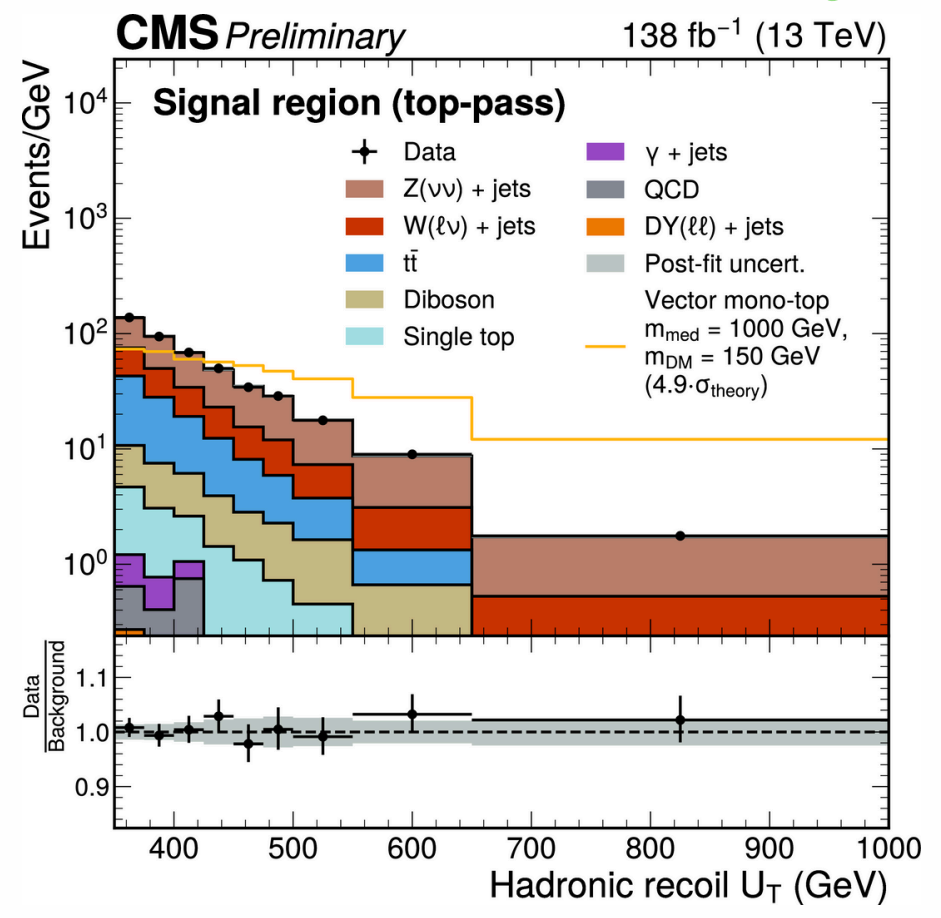


Search for new physics with a mono-top signature



ParticleNet: Graph neural network distinguishes AK15 jets from hadronic decay of top quark from QCD radiation.

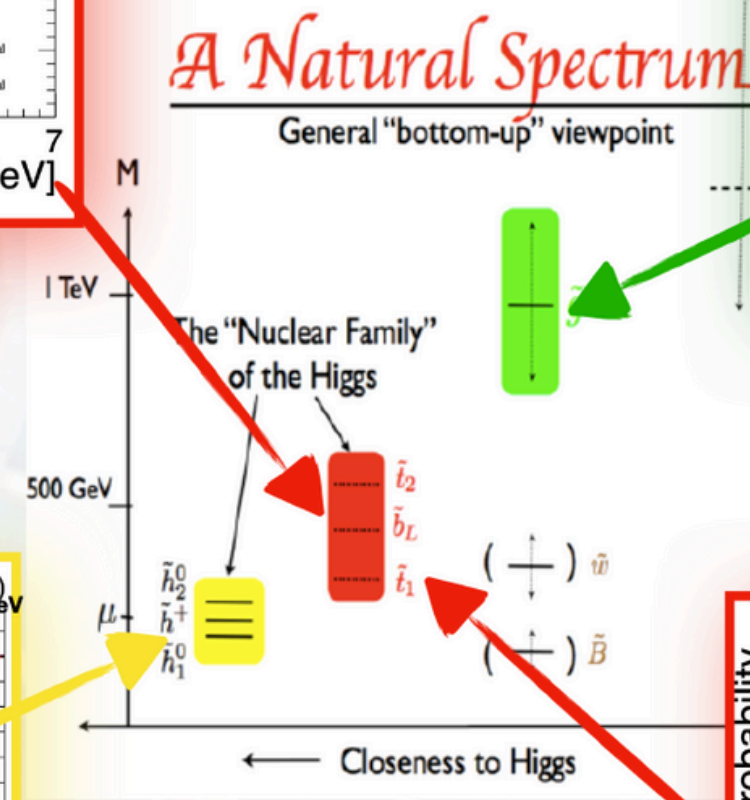
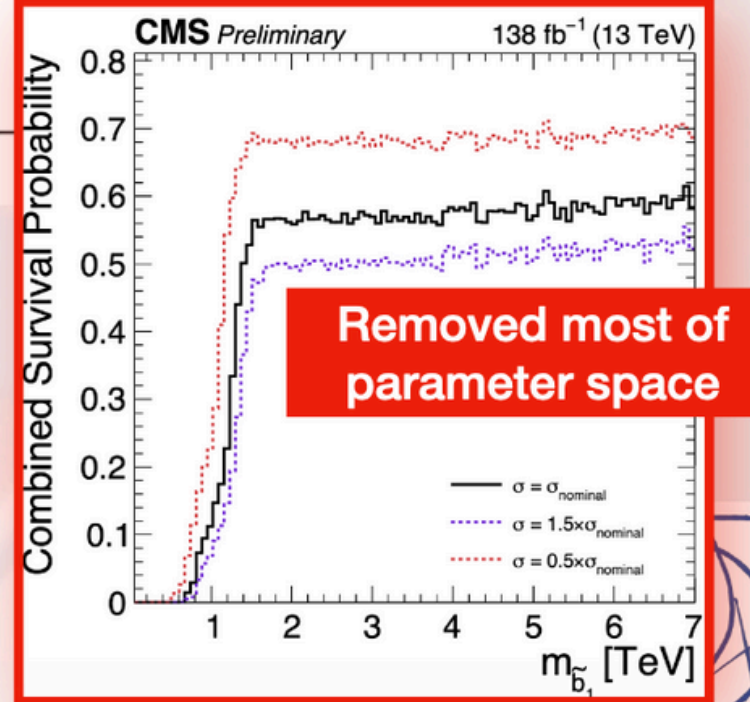
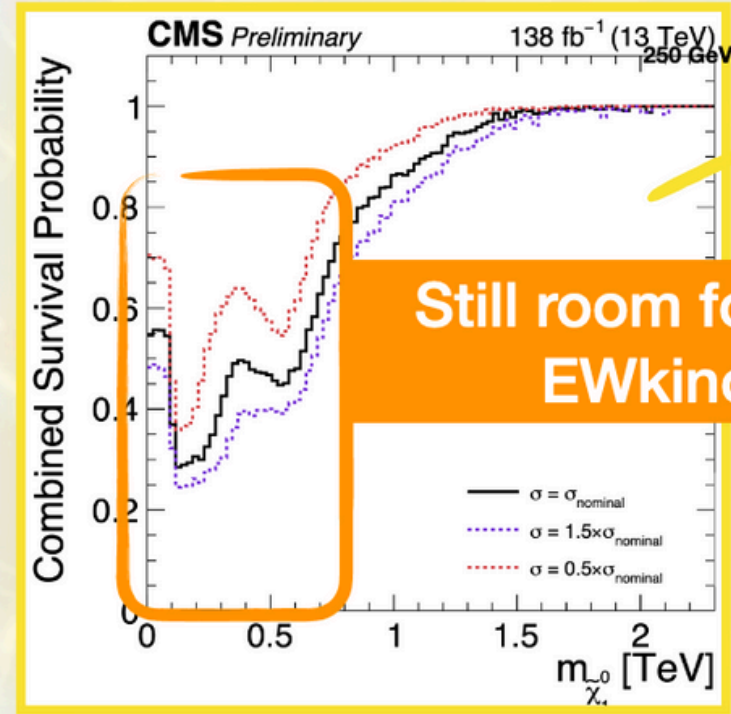
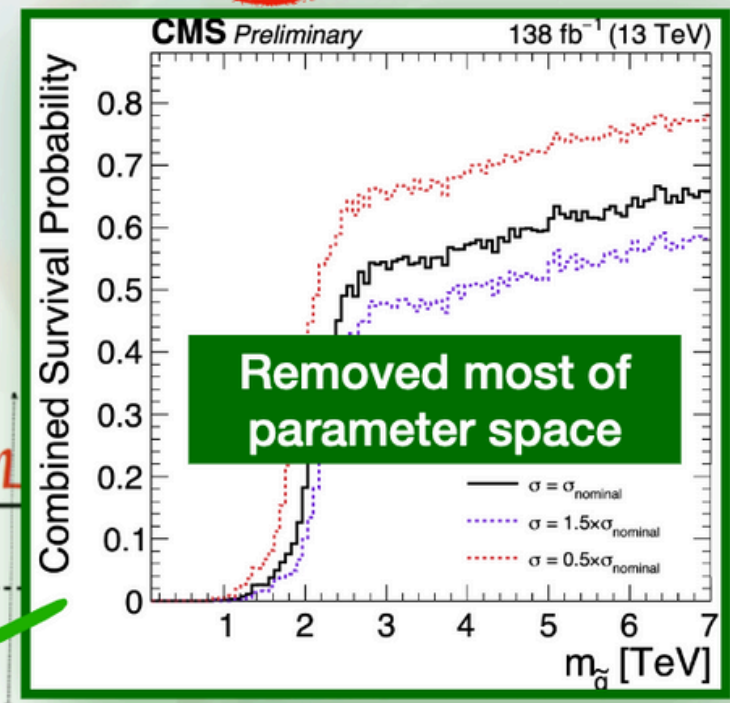
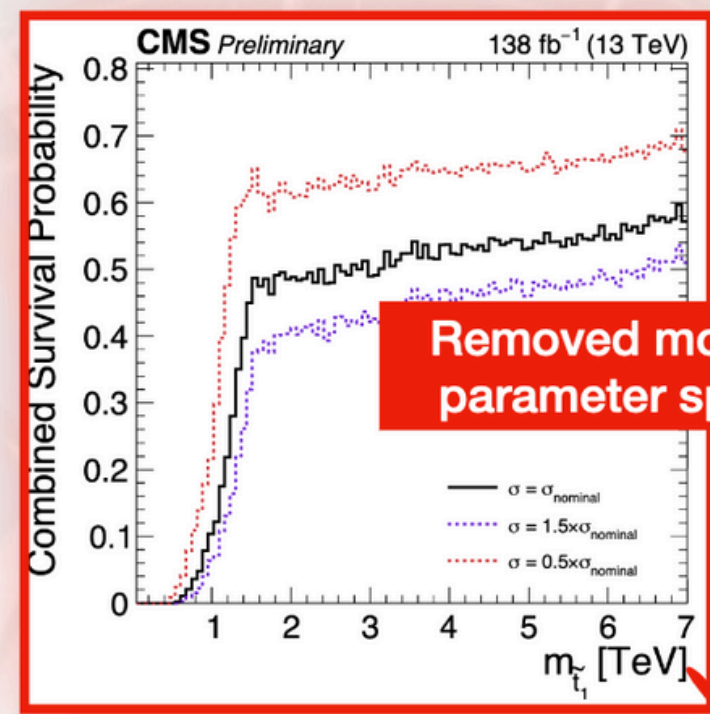
7 CRs defined to estimate major background processes in the pass and fail SRs from data in the CRs.



pMSSM interpretation of Run 2 SUSY results

- Performed first statistical combination of SUSY searches with full Run2 luminosity
- In the framework of phenomenological MSSM (pMSSM): 19 free parameters
- Useful tool to identify weak spots in our program
- Gives us a big picture under realistic assumptions (e.g., on relative branching ratios)
- quantified as fraction of tested models that survive the exclusion

CMS-PAS-SUS-24-004 **new**

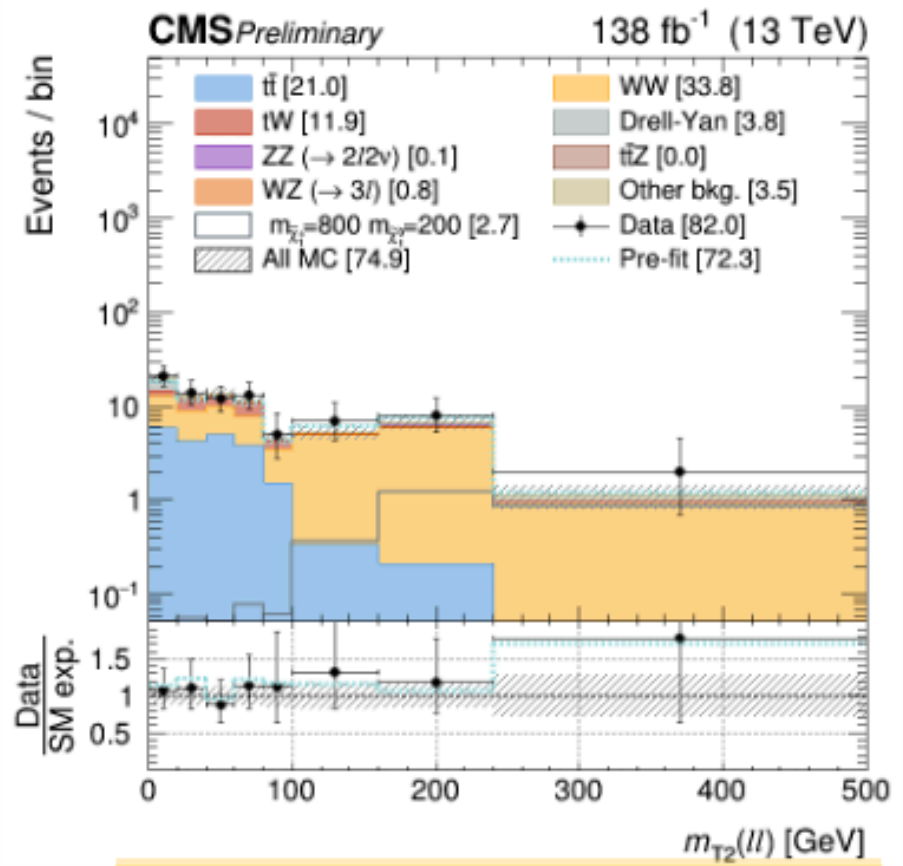
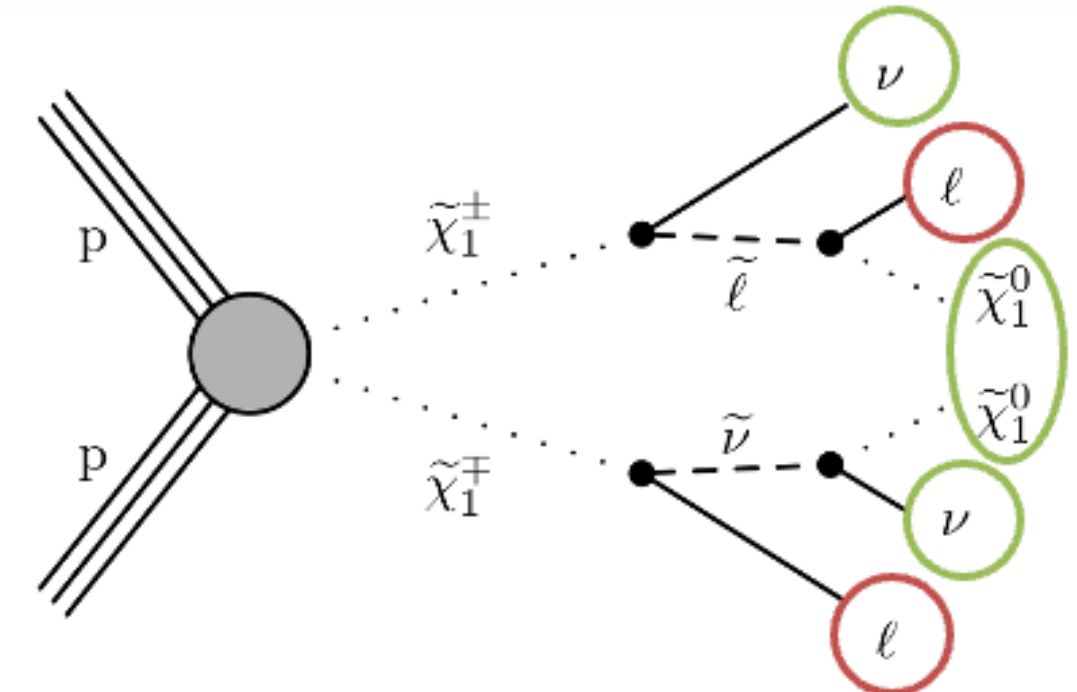


Search for charginos and stops in 2LOS final state

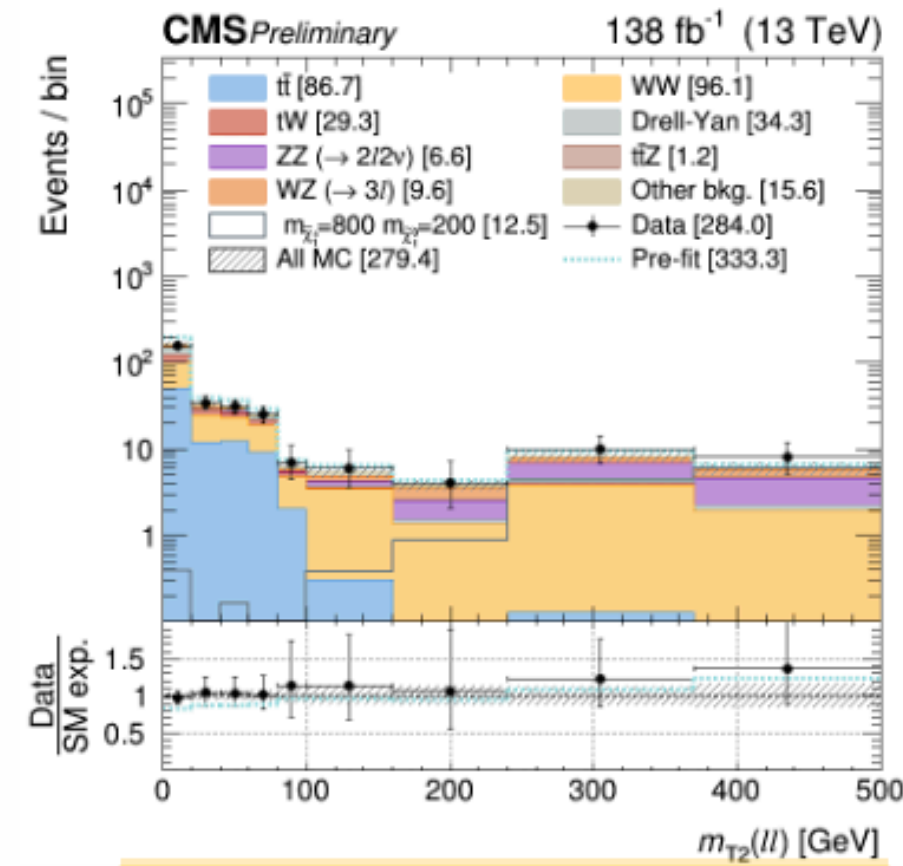


- Novel analysis probing for **direct chargino pair production** in final states with two oppositely charged leptons and **large MET** (>160 GeV):
- SRs are defined in terms of MET bins, jet content, and lepton flavour

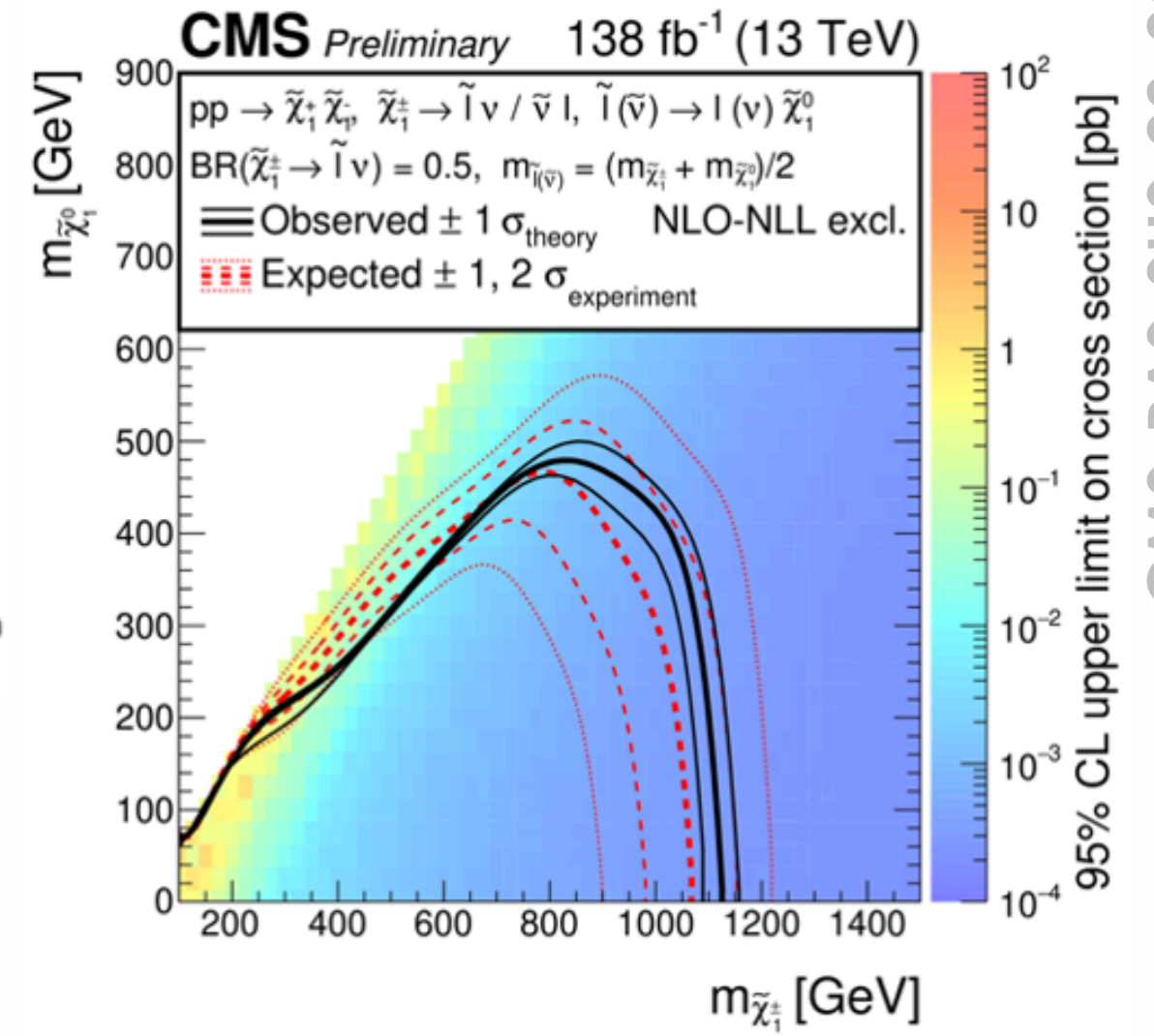
- Main backgrounds coming from $t\bar{t}$ and WW production, which are normalized at low m_{T2}
- The signal is extracted via a **Simultaneous fit to observed m_{T2} distribution in all the SRs.**



220 < p_T^{miss} < 280 GeV
 $n_{\text{jets}}=0, \text{DF}$

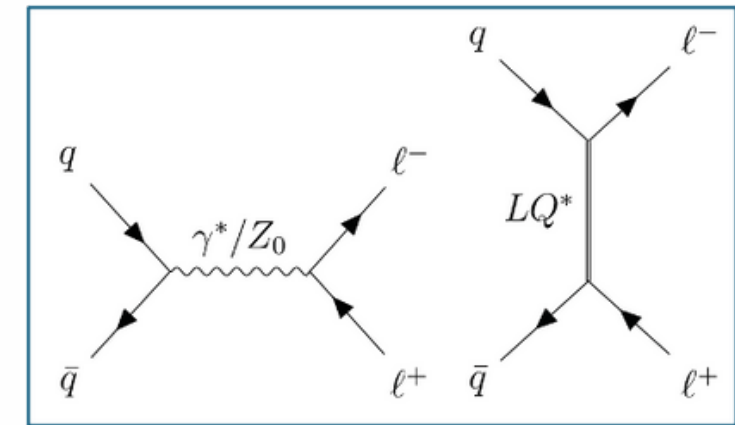


$p_T^{\text{miss}} > 380$ GeV
 $n_{\text{B-jets}}=0, \text{SF}$



t-channel scalar and vector leptoquark in the high mass dimuon and dielectron

- First search for 8 nonresonant leptoquarks coupling up and down quarks to electrons and muons in dilepton masses $m_{\ell\ell} > 500$ GeV using the full Run-2 dataset
 - S_{eu}, S_{ed} - scalar LQs coupling u/d quarks to electrons (R_2 family, RL couplings)
 - $S_{\mu u}, S_{\mu d}$ - scalar LQs coupling u/d quarks to muons (\tilde{R}_2 family, RL couplings)
 - V_{eu}, V_{ed} - vector LQs coupling u/d quarks to electrons (U_3 family, LL couplings)
 - $V_{\mu u}, V_{\mu d}$ - vector LQs coupling u/d quarks to muons (U_3 family, LL couplings)



- t-channel LQ effects sensitive to LQ-fermion coupling y_{LQ}^4 (pure LQ exchange) and y_{LQ}^2 (interference with the SM Drell-Yan process which proceeds via γ^*/Z^0)
- 95% CL upper limits exclude scalar LQ masses upto 5 TeV for $|y_{LQ}| > 1.2$, and vector LQ masses upto 5 TeV for $|y_{LQ}| > 1.5$. Best limits so far on first and second generation scalar and vector LQs.

