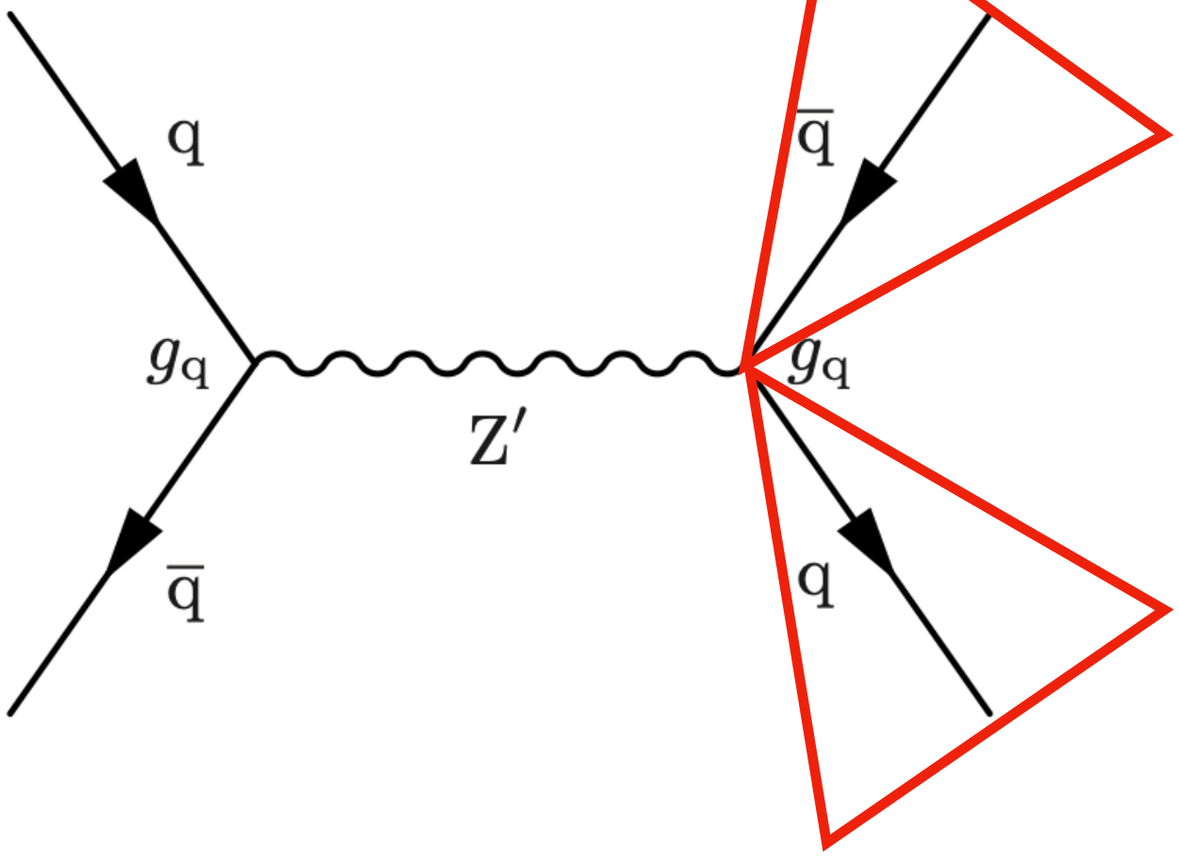
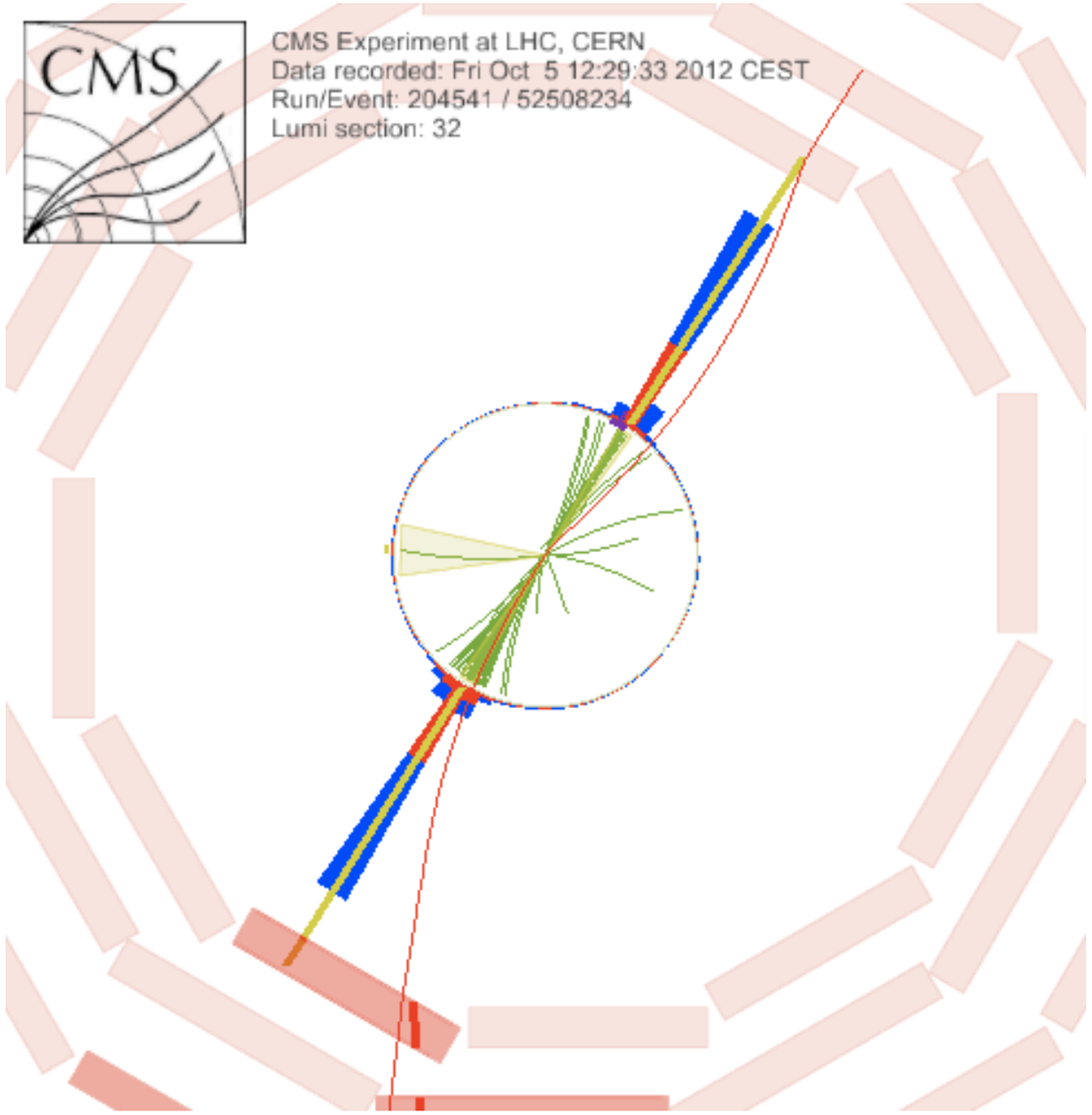
Searches Using Unconventional Signatures and New Techniques

Cristián Peña
on behalf of the ATLAS and CMS collaborations

Searches for new resonances





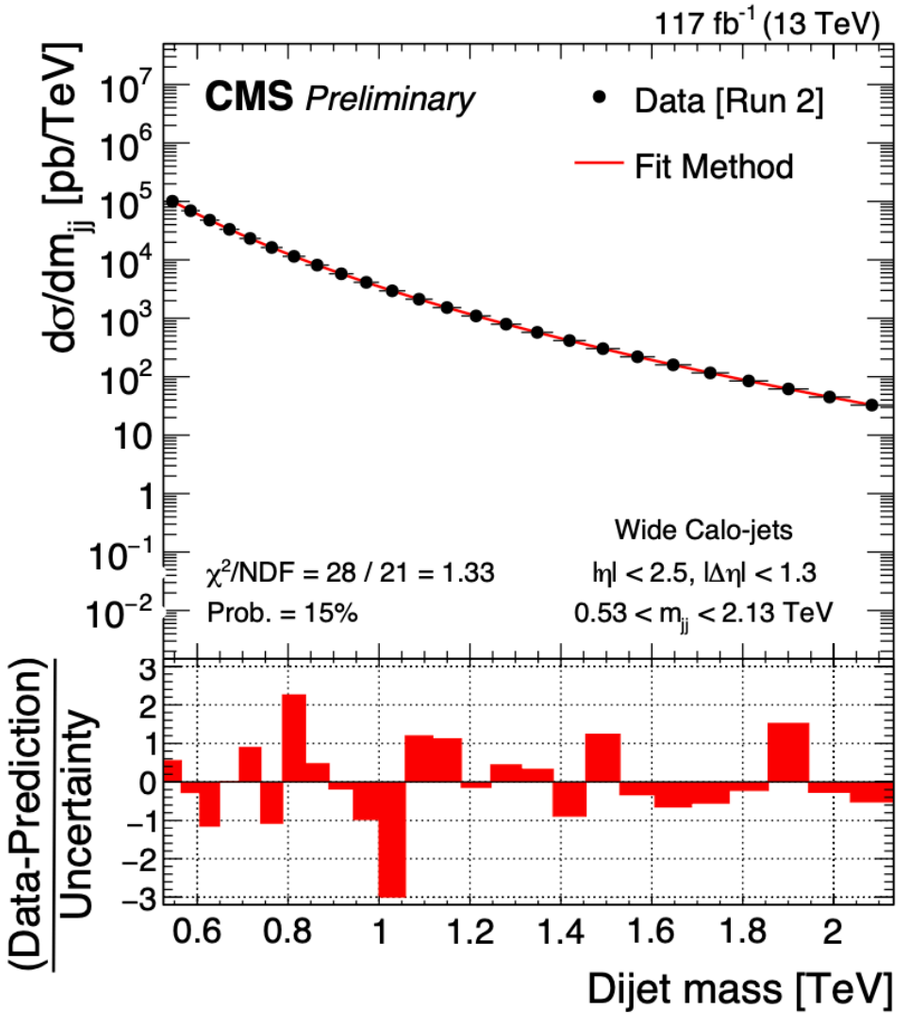
CMS Run2 Dijet Scouting

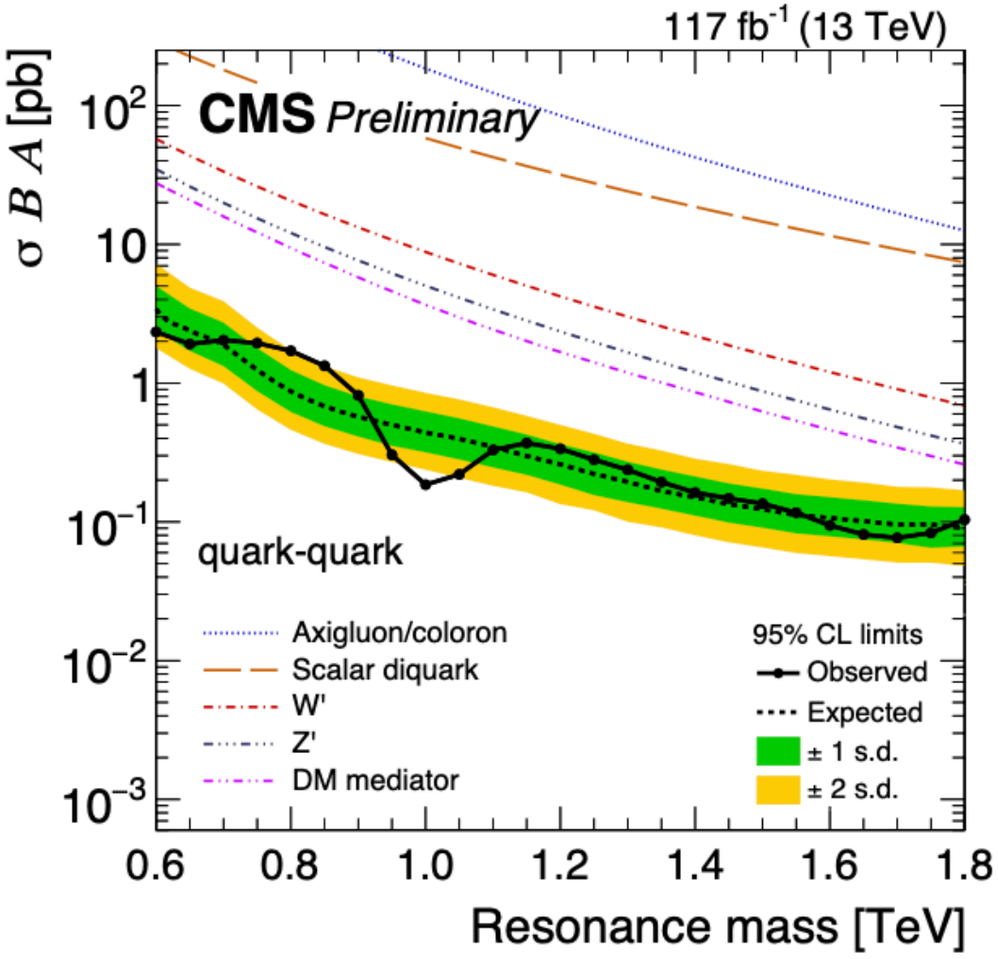
BRAND NEW

CMS-PAS-EXO-23-004

Access low mass resonances using data scouting

Scouting: reduce event info to gain trigger rate (low mass)





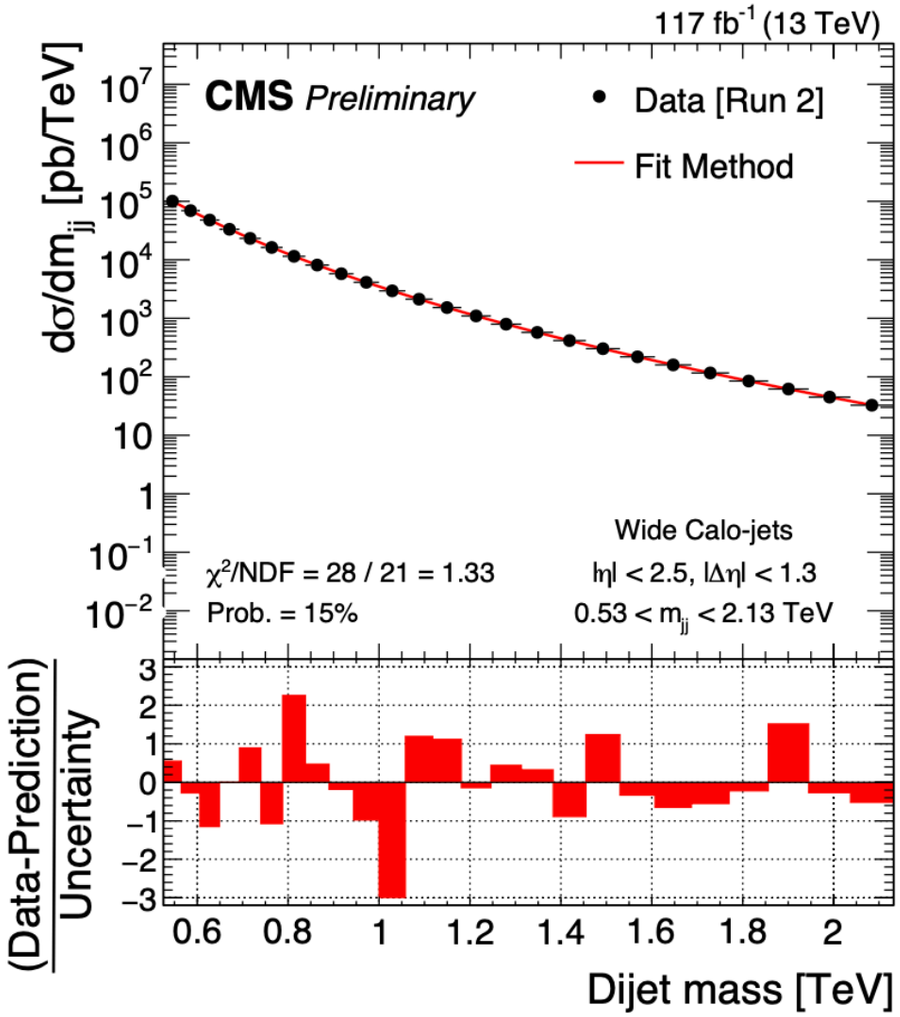
Data scouting probes new hadronic resonances down to 600 GeV

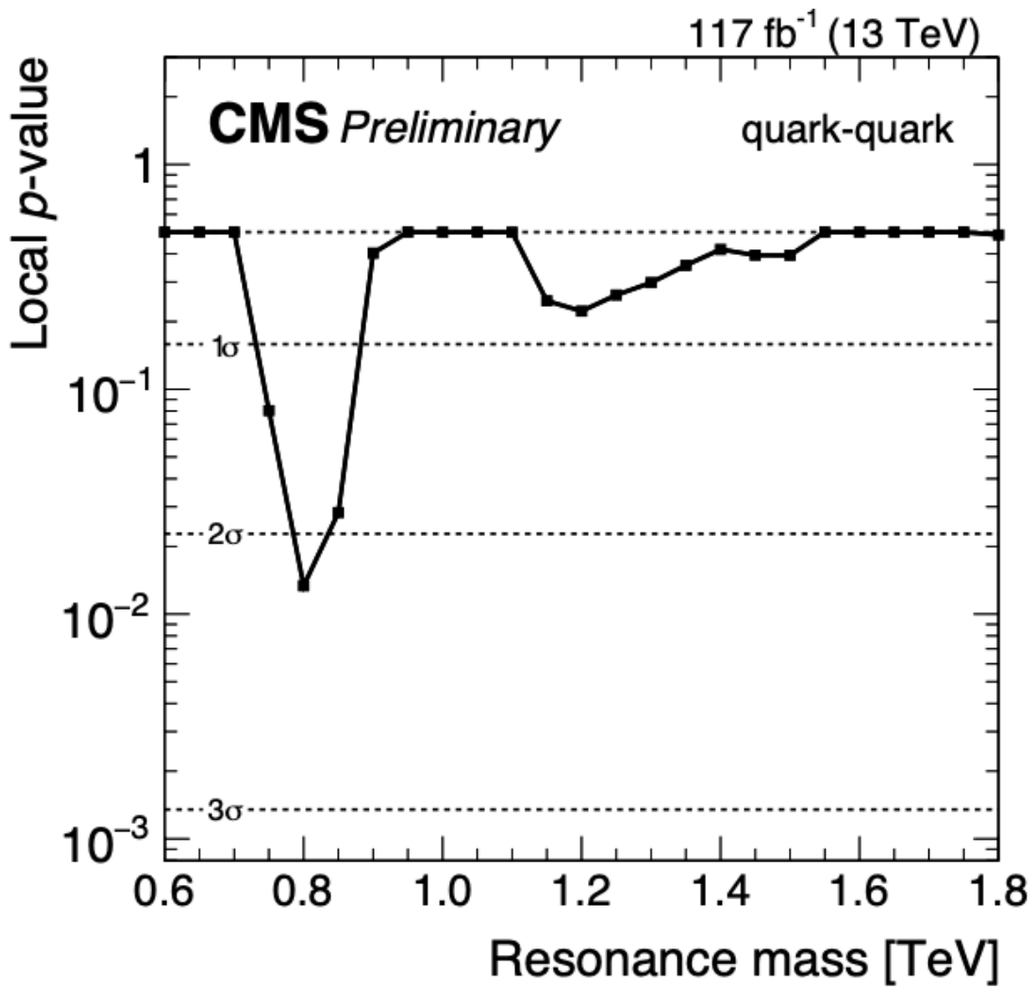
CMS Run2 Dijet Scouting

CMS-PAS-EXO-23-004

Access low mass resonances using data scouting

Scouting: reduce event info to gain trigger rate (low mass)

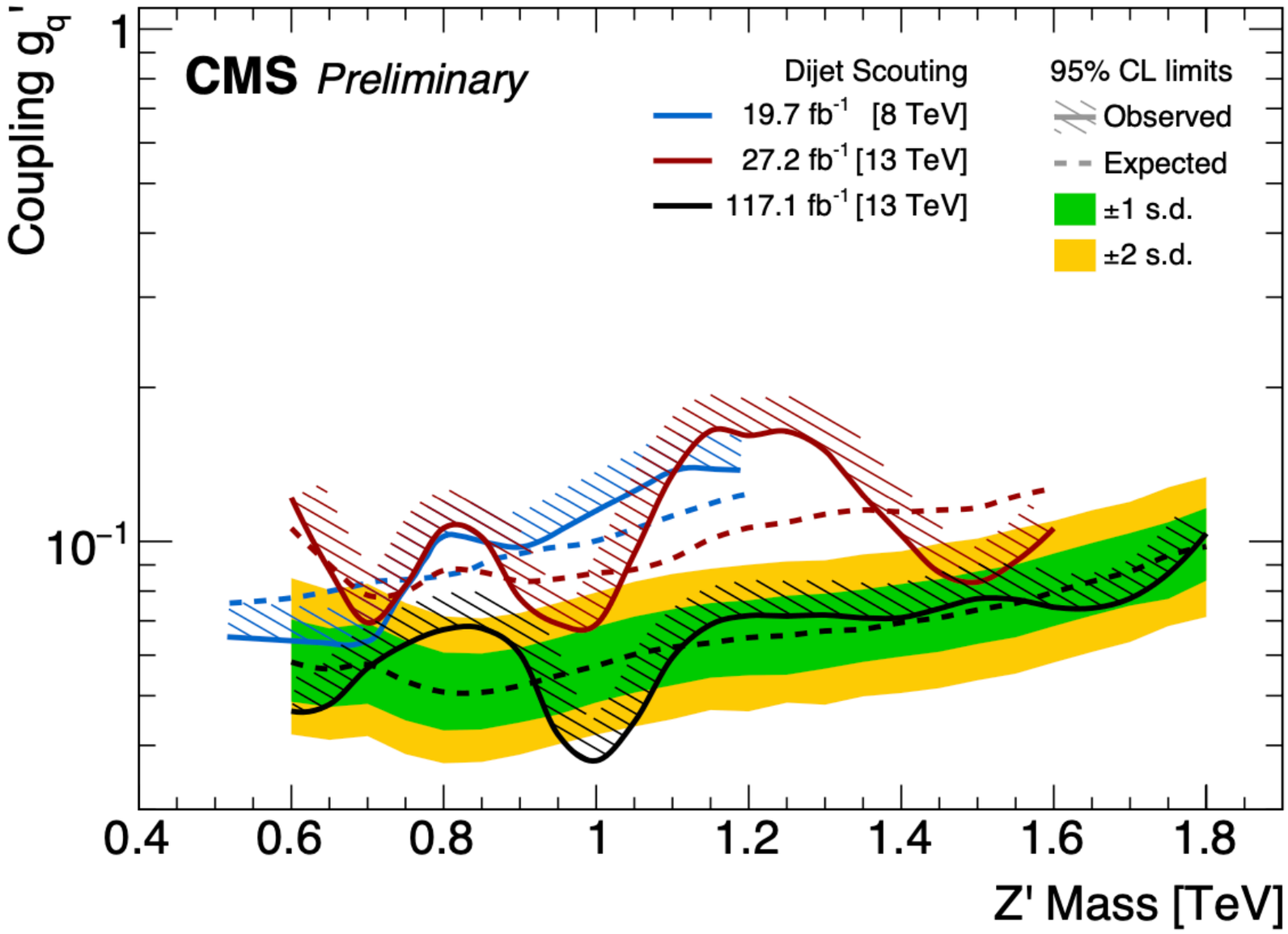




Largest excess (~2σ) found at around 800 GeV

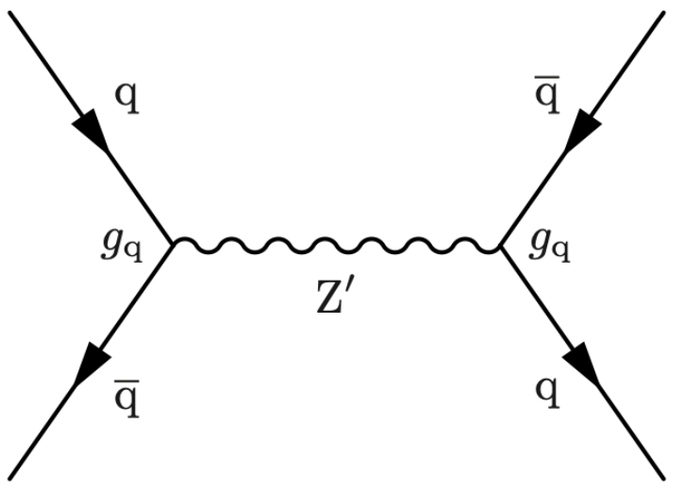
CMS Run2 Dijet Scouting

CMS-PAS-EXO-23-004

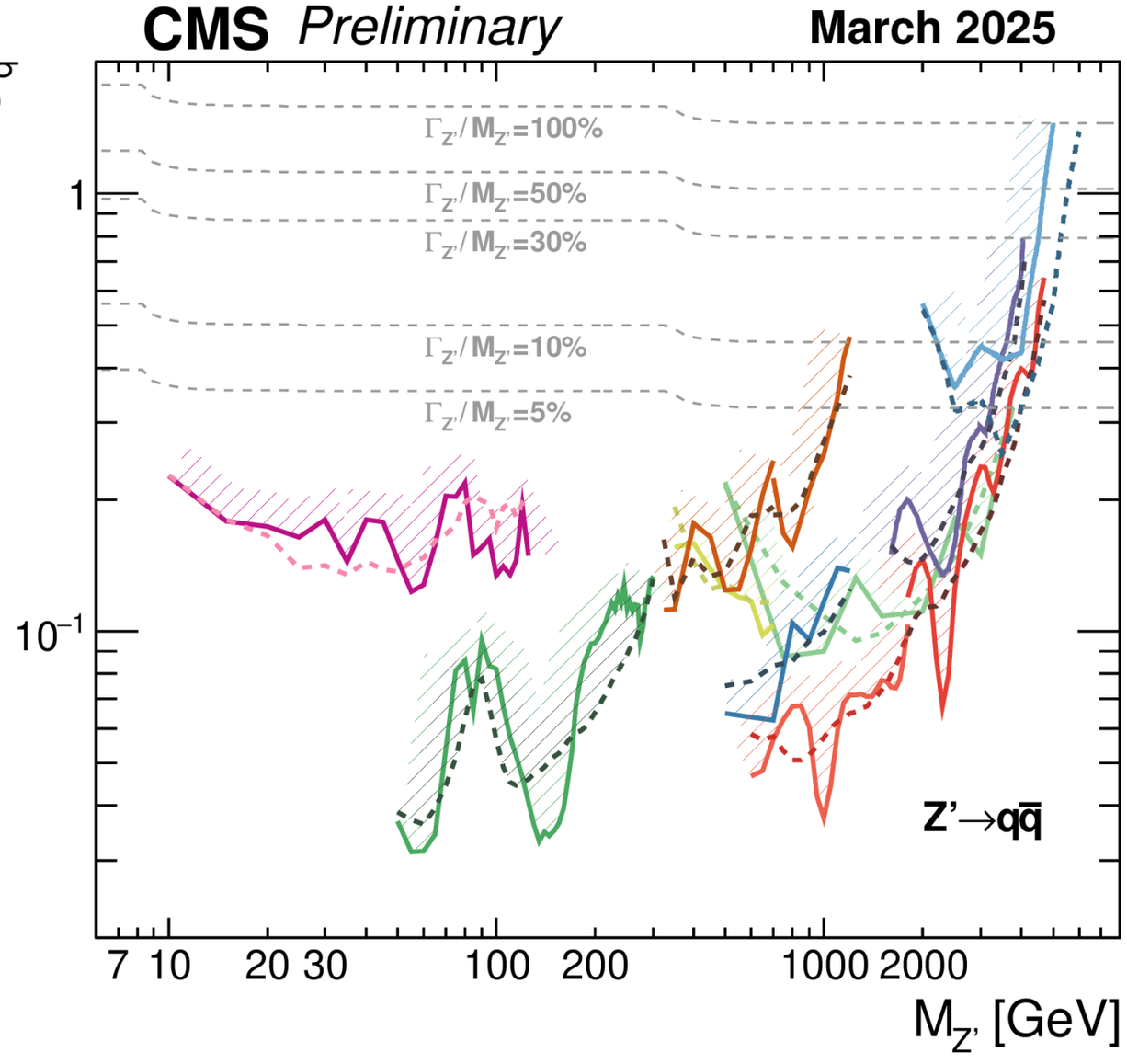


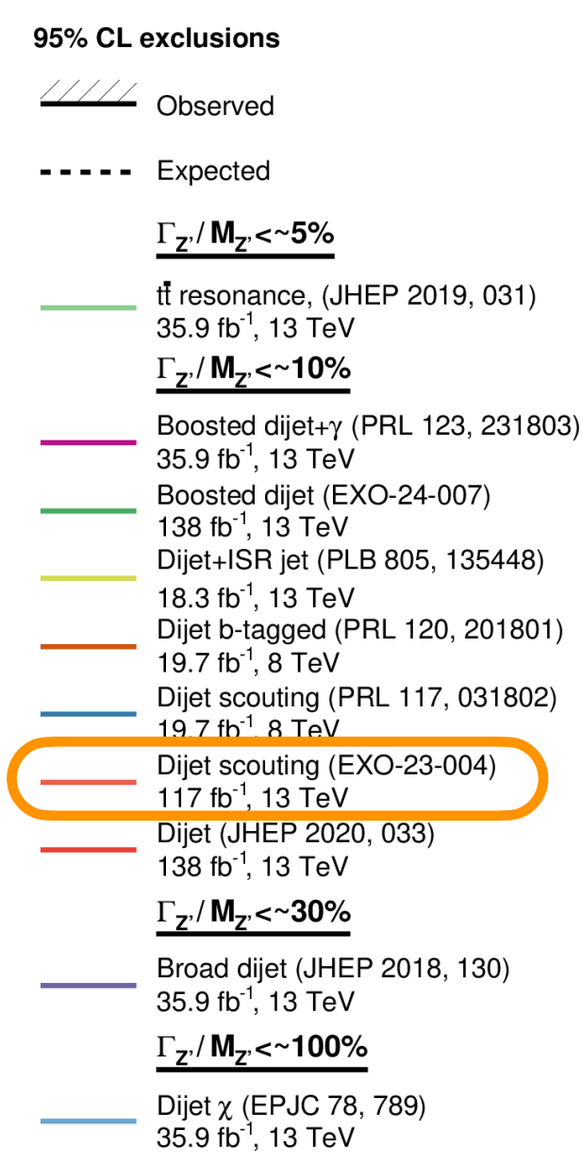
Run2 dijet scouting search significantly improves sensitivity across the whole mass range [0.6-1.8 TeV]

Searches for new resonances



CMS Summary plot



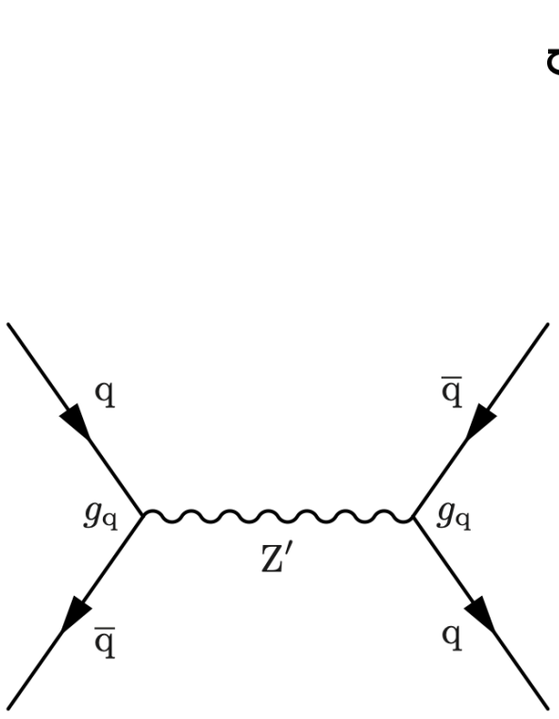


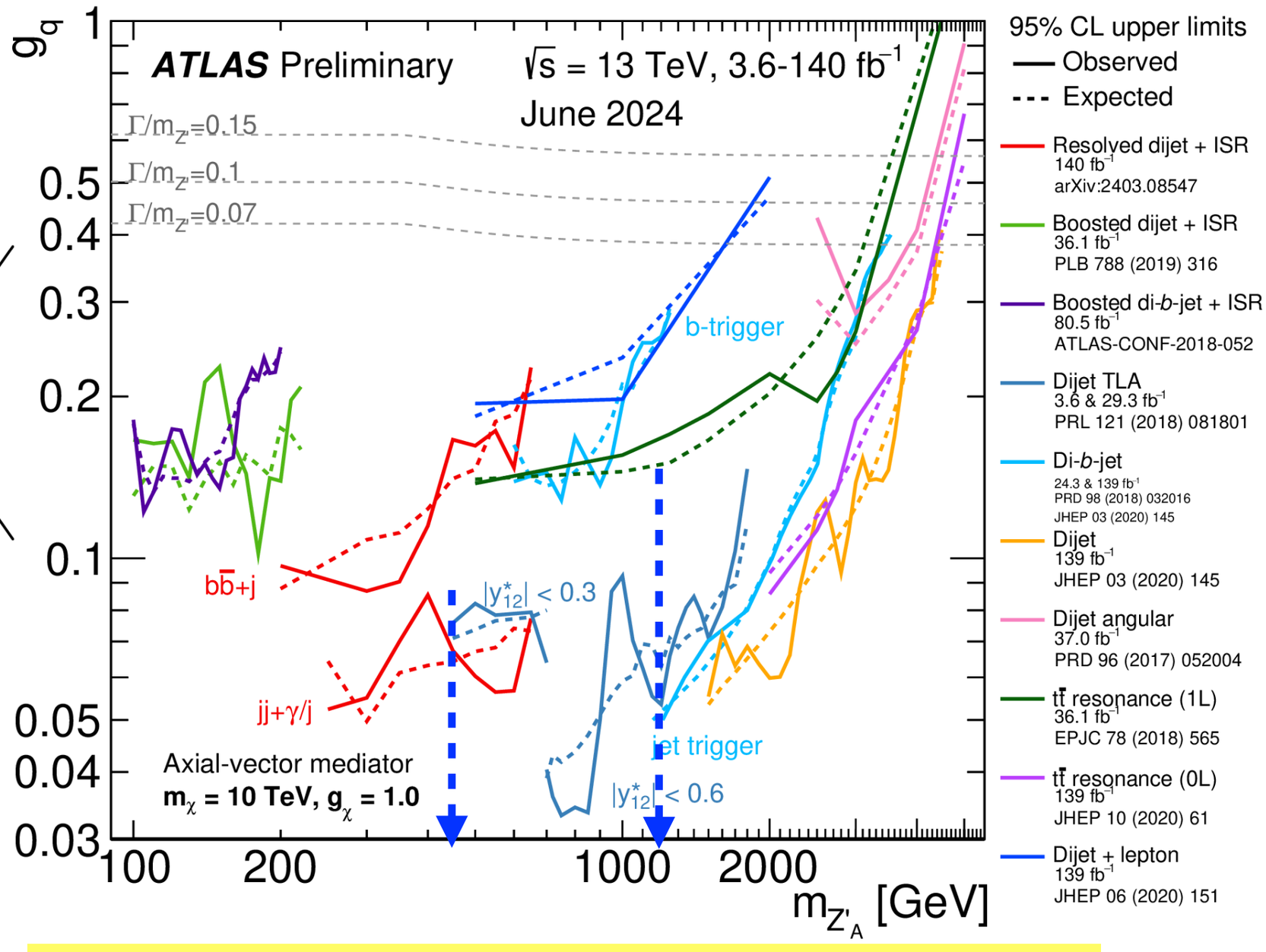
EXO-23-004 provides best CMS sensitivity for $M_{Z'}$ in 600-1800 GeV

Searches for new resonances

Trigger Level Jets Search: *PRL **121** (2018) 081801*

Summary plots: ATL-PHYS-PUB-2024-010





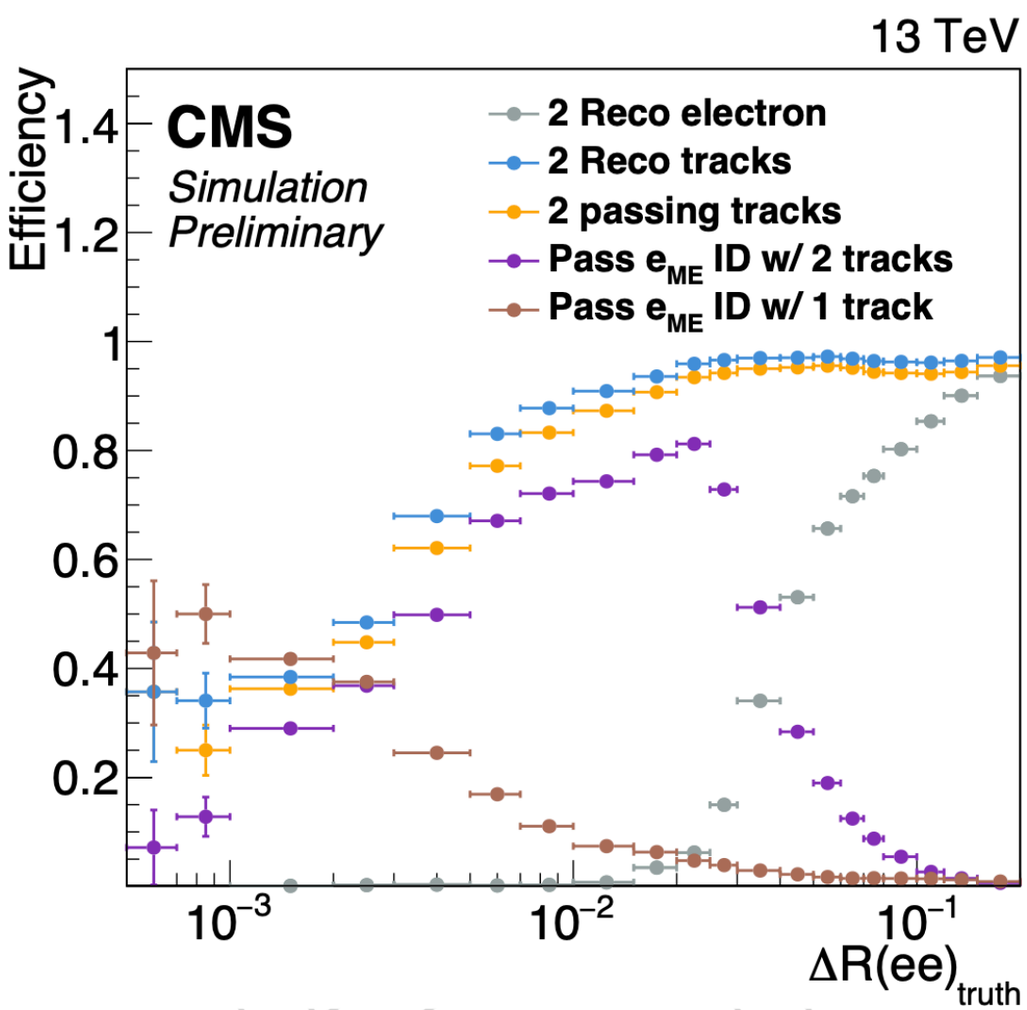
Unique coverage from ~700-1200 GeV

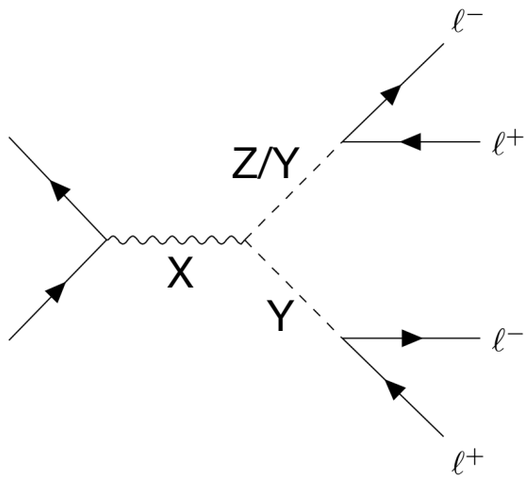
Searches for new resonances

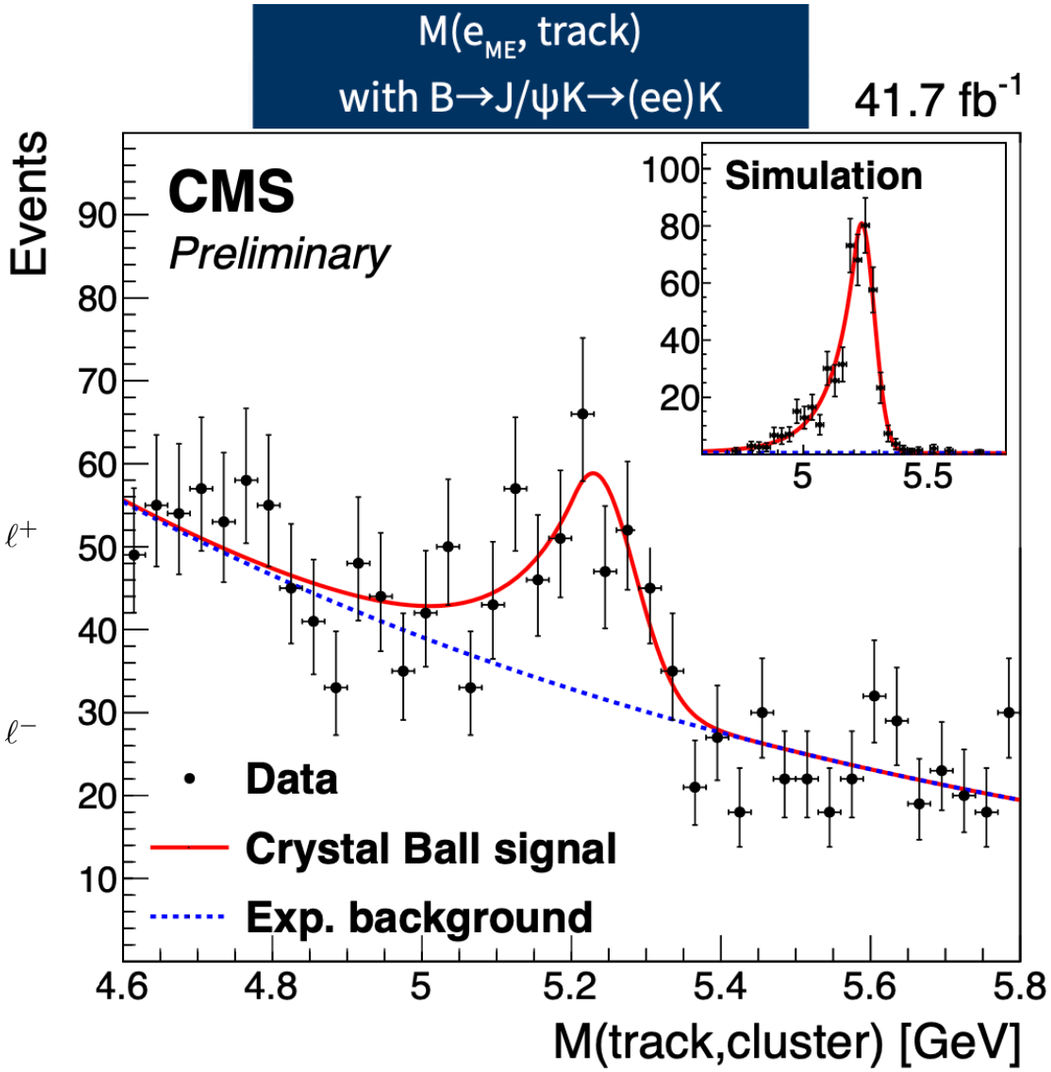
CMS-PAS-EXO-24-006

New resonances in 4 lepton final state

New technique: highly boosted leptons







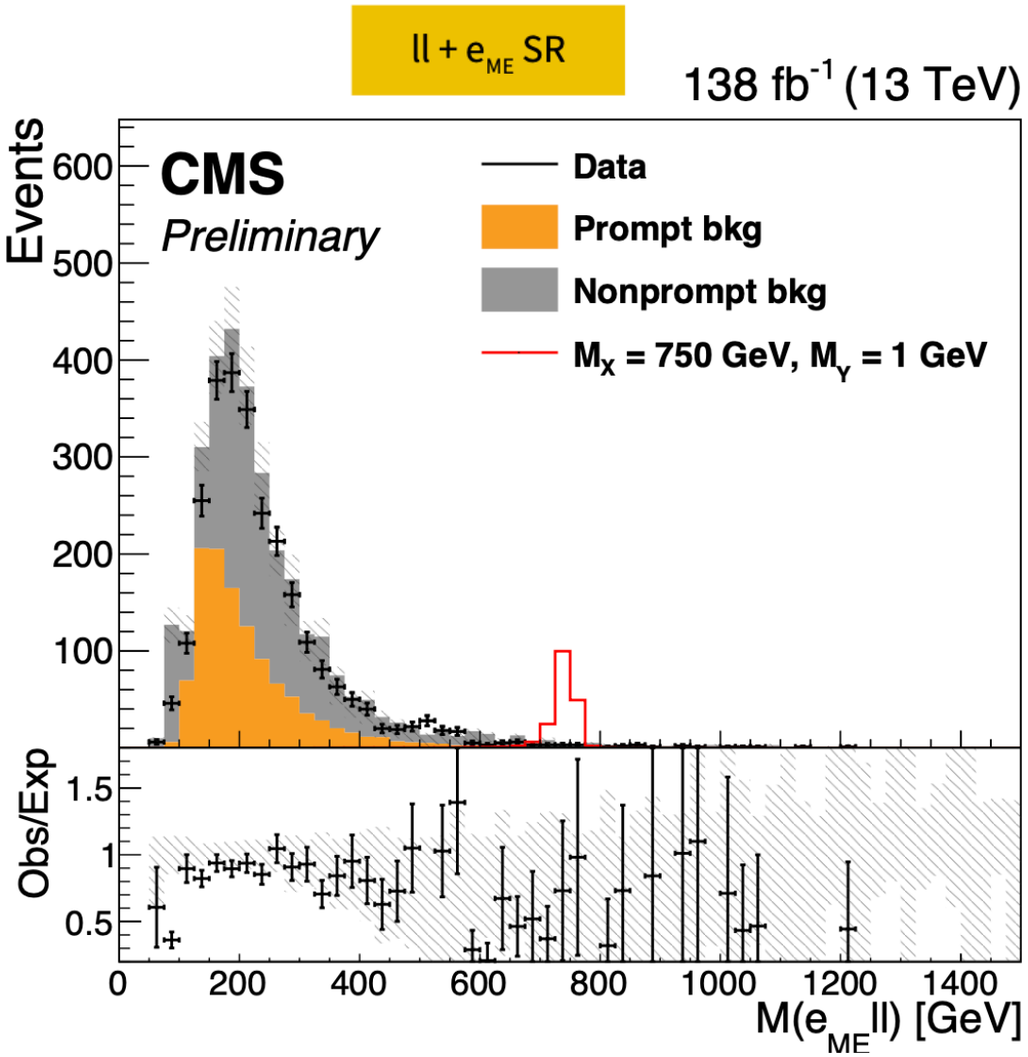
New merged-electron reconstruction recovers efficiency for highly boosted leptons

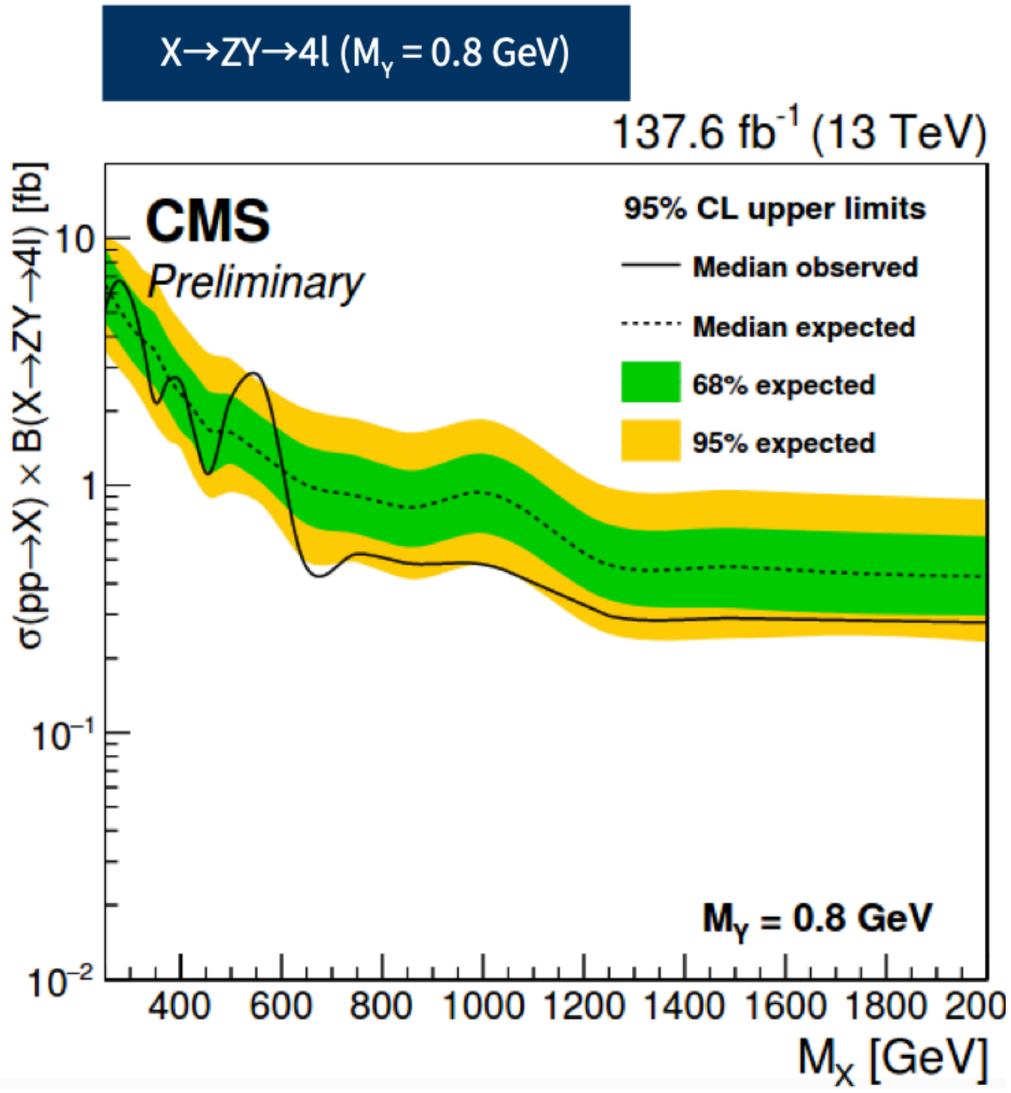
Searches for new resonances

CMS-PAS-EXO-24-006

New resonances in 4 lepton final state

New technique: highly boosted leptons



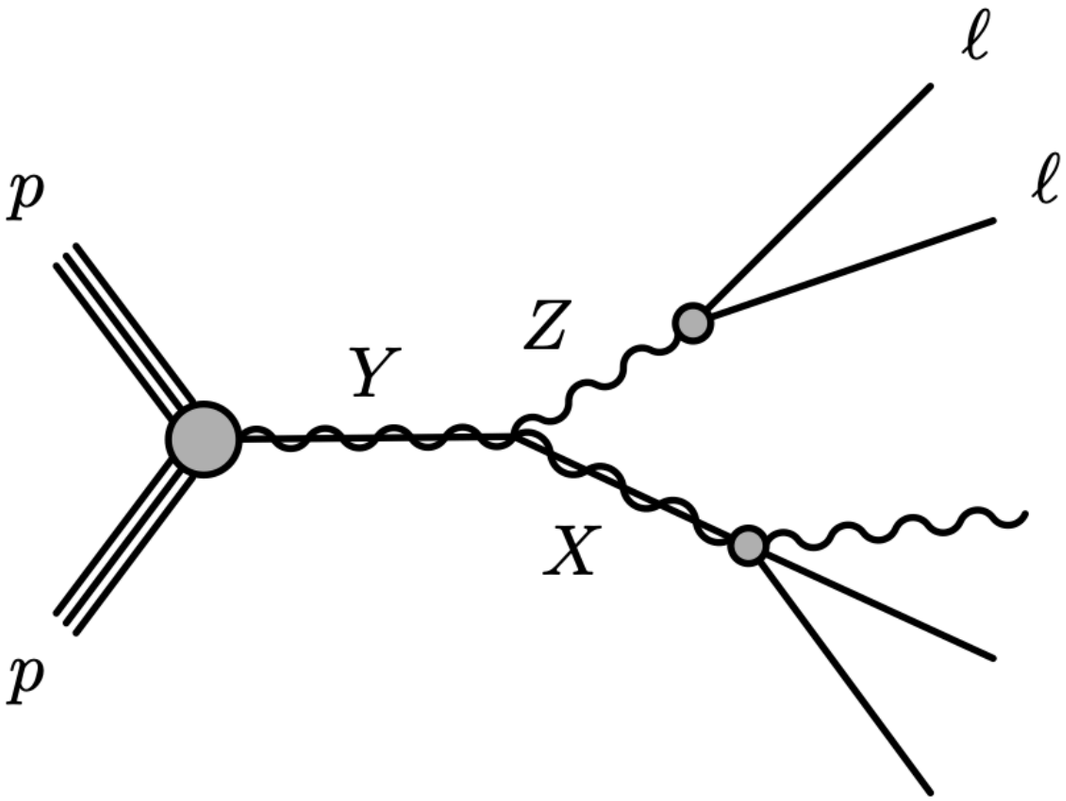


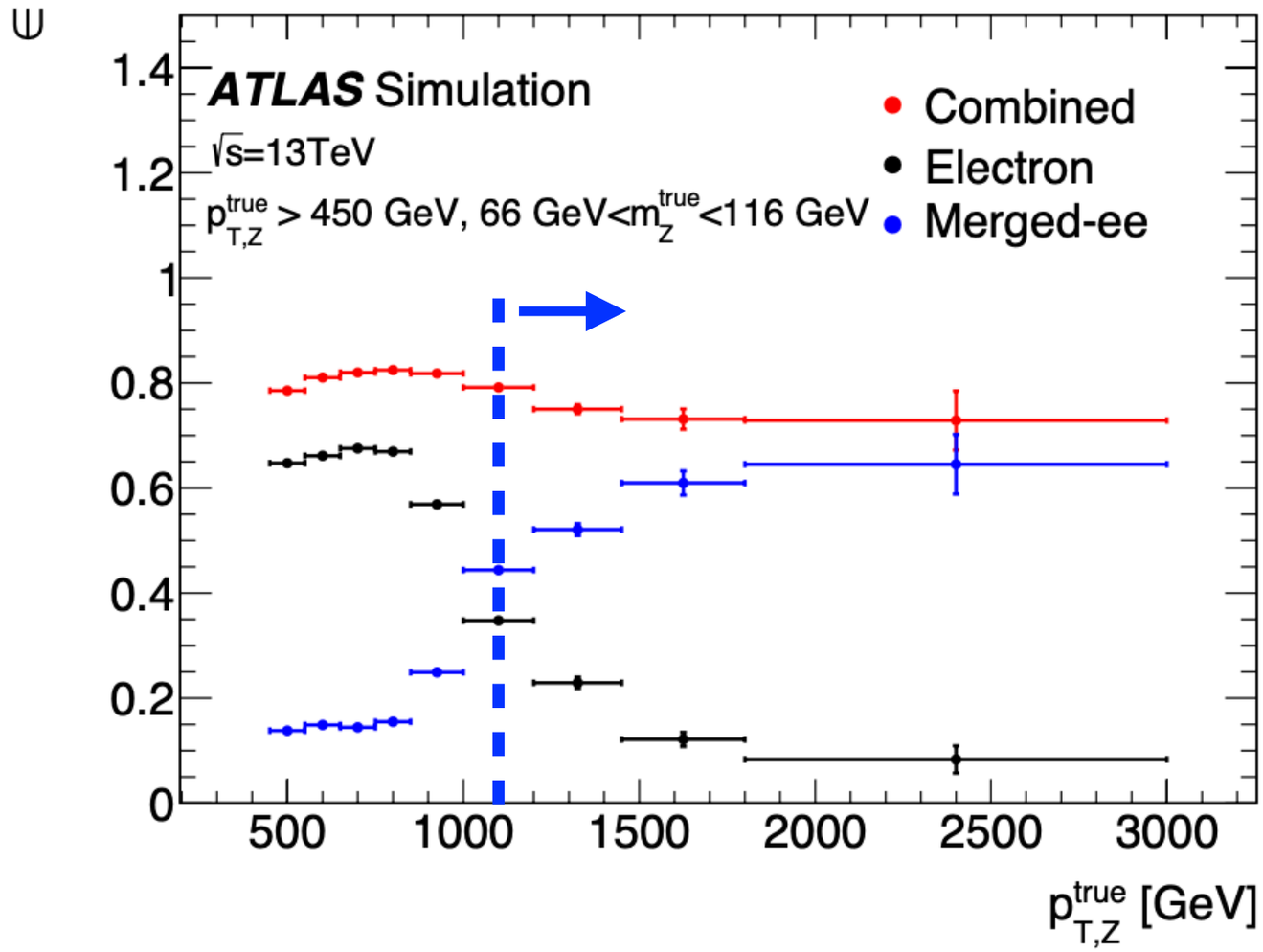
New reconstruction techniques maintains sensitivity to very light and highly boosted resonances

Searches for new resonances

JHEP **06** (2023) 036

New resonances in association with a Z boson



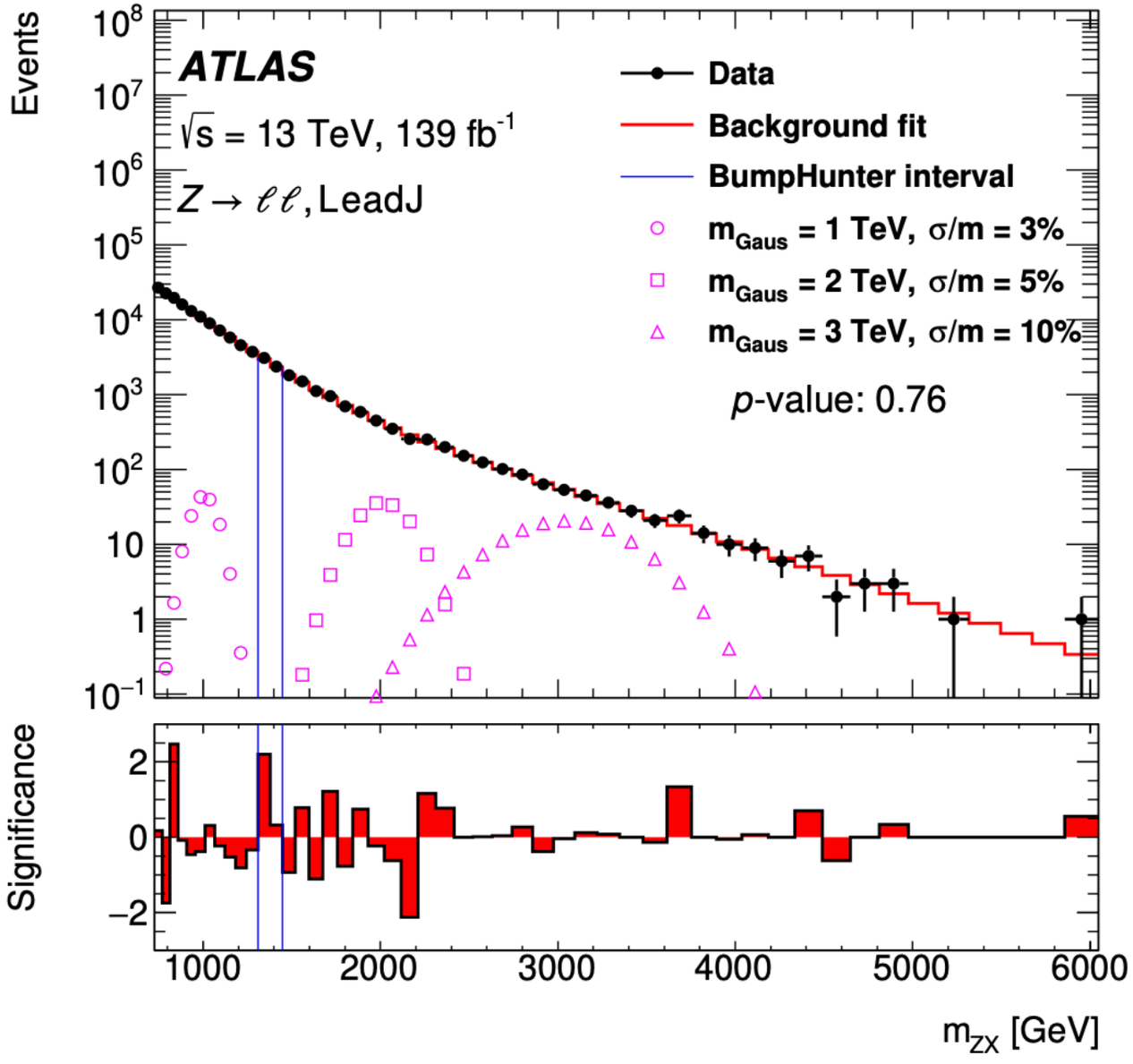


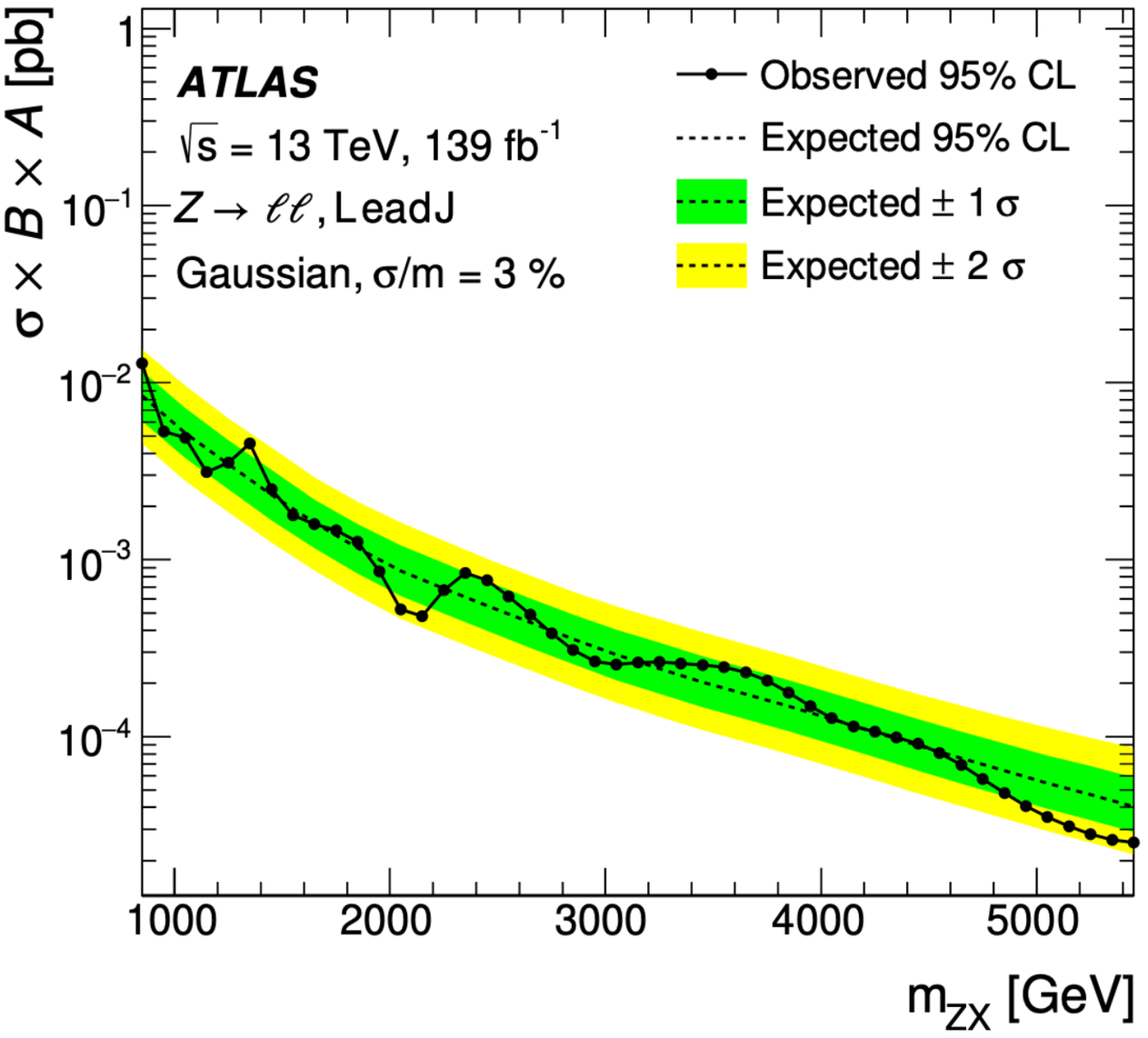
New signature using merged di-electrons from boosted Z decays

Searches for new resonances

JHEP **06** (2023) 036

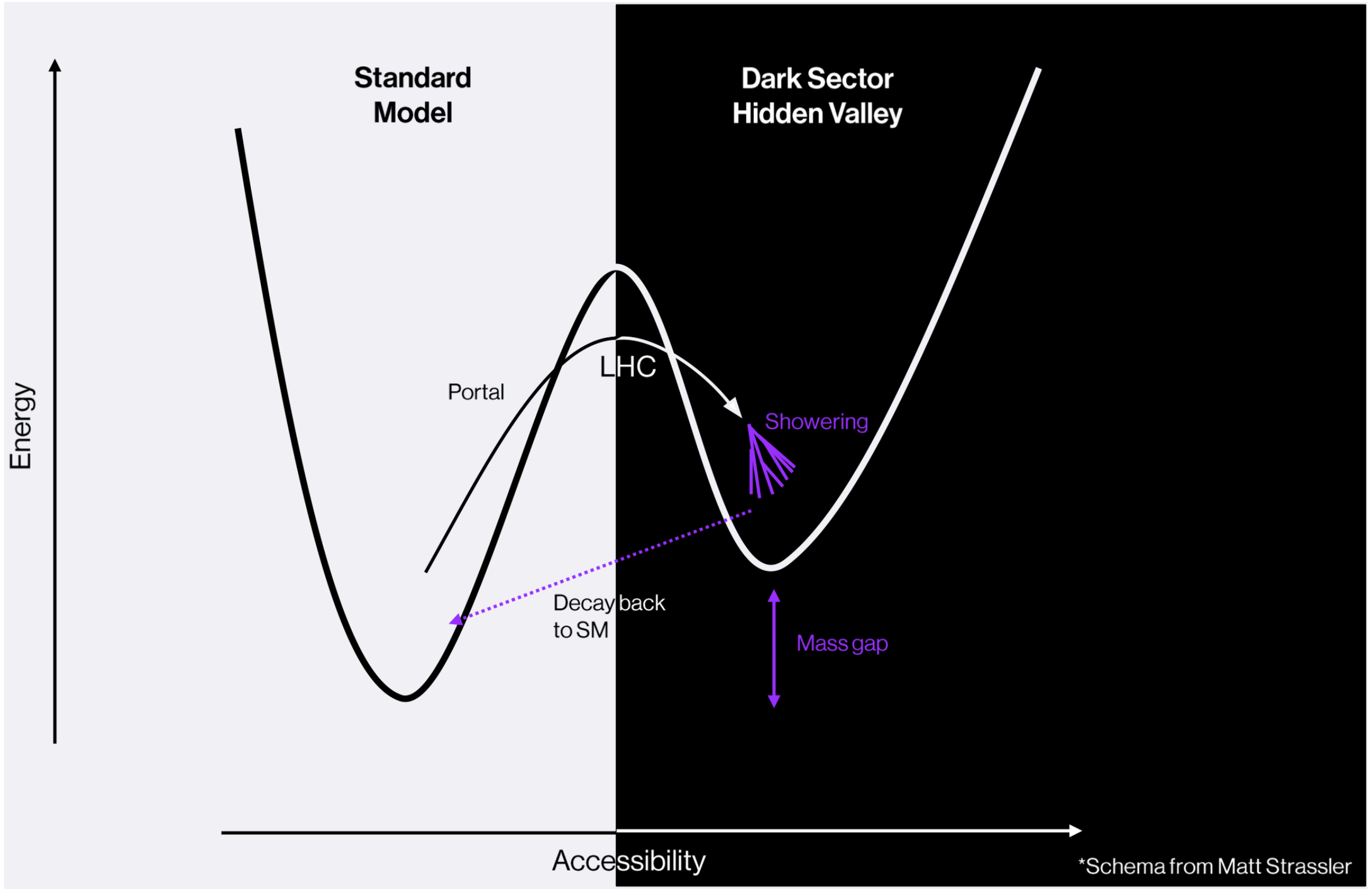
New resonances in association with a Z boson





Model independent approach.
Probes high mass spectra with boosted Z

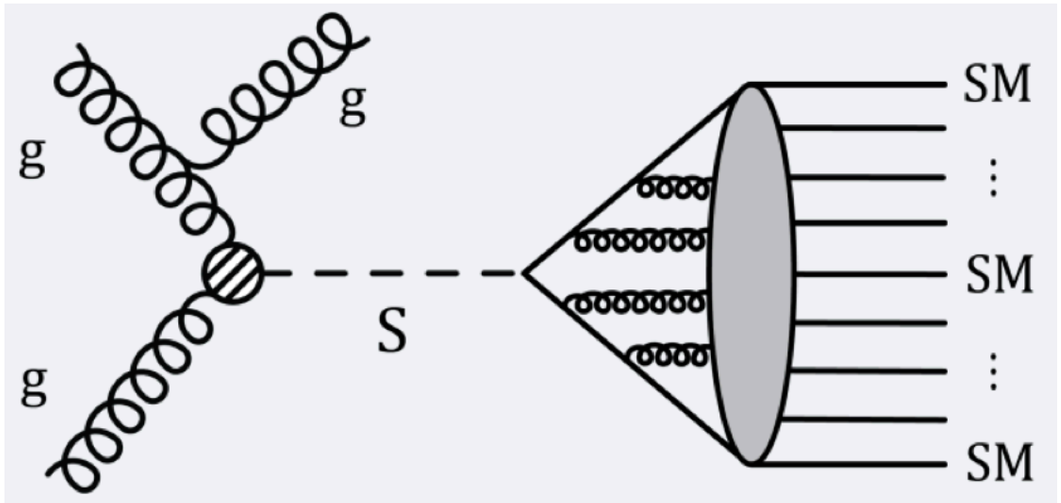
Dark Sectors: SUEP



LHC is a great tool to probe portals to dark sectors

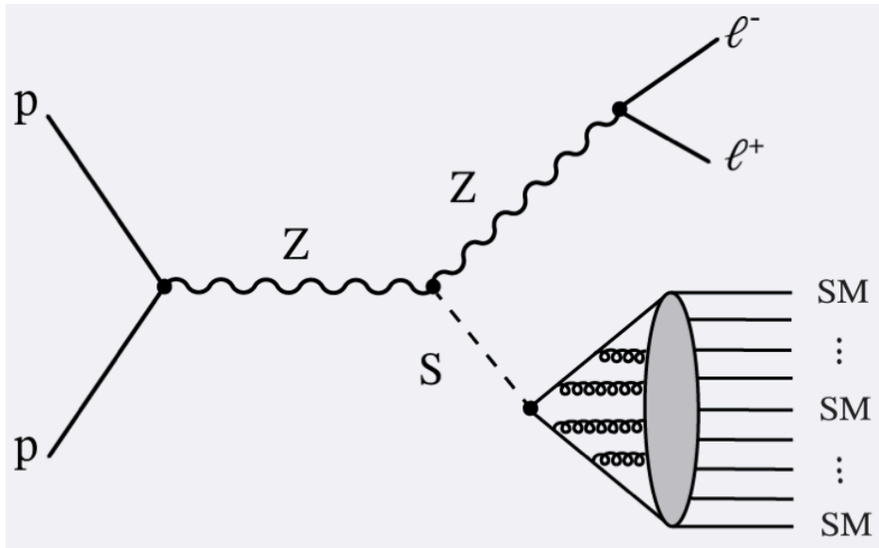
SUEP Landscape

Gluon fusion

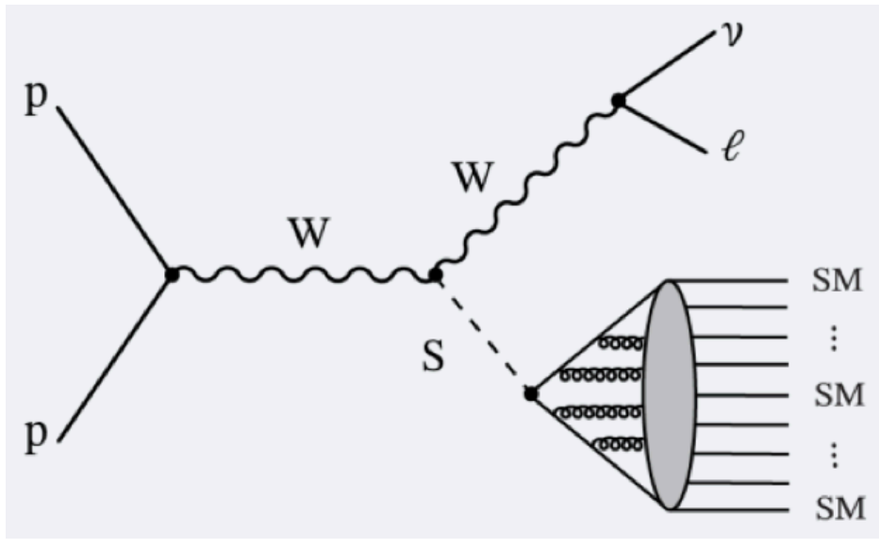


EXO-23-002, first SUEP search
PRL 133 (2024) 191902

CMS-PAS-EXO-23-003: ZH channel

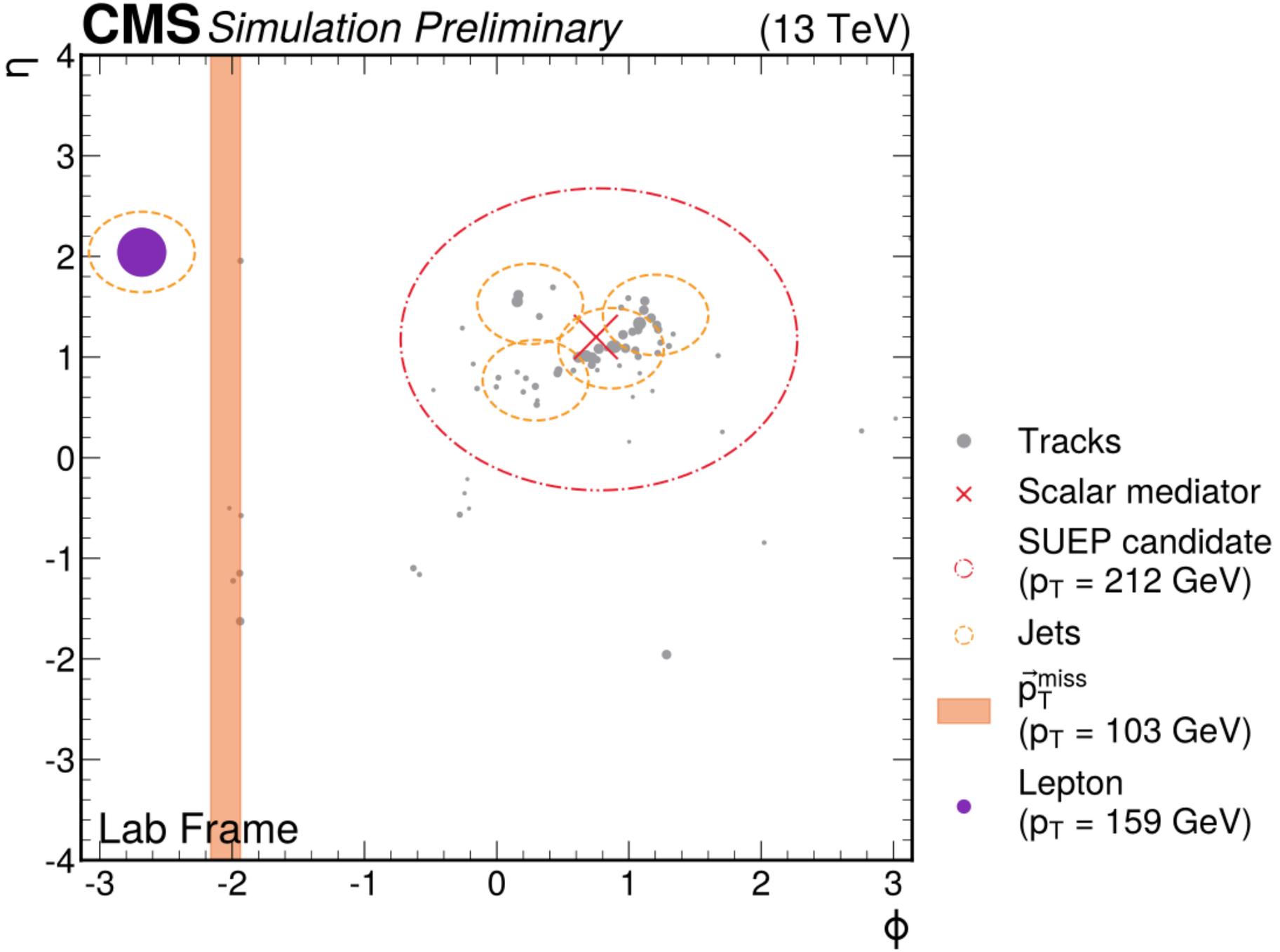


Associated production with a V boson



CMS-PAS-EXO-24-030: WH channel

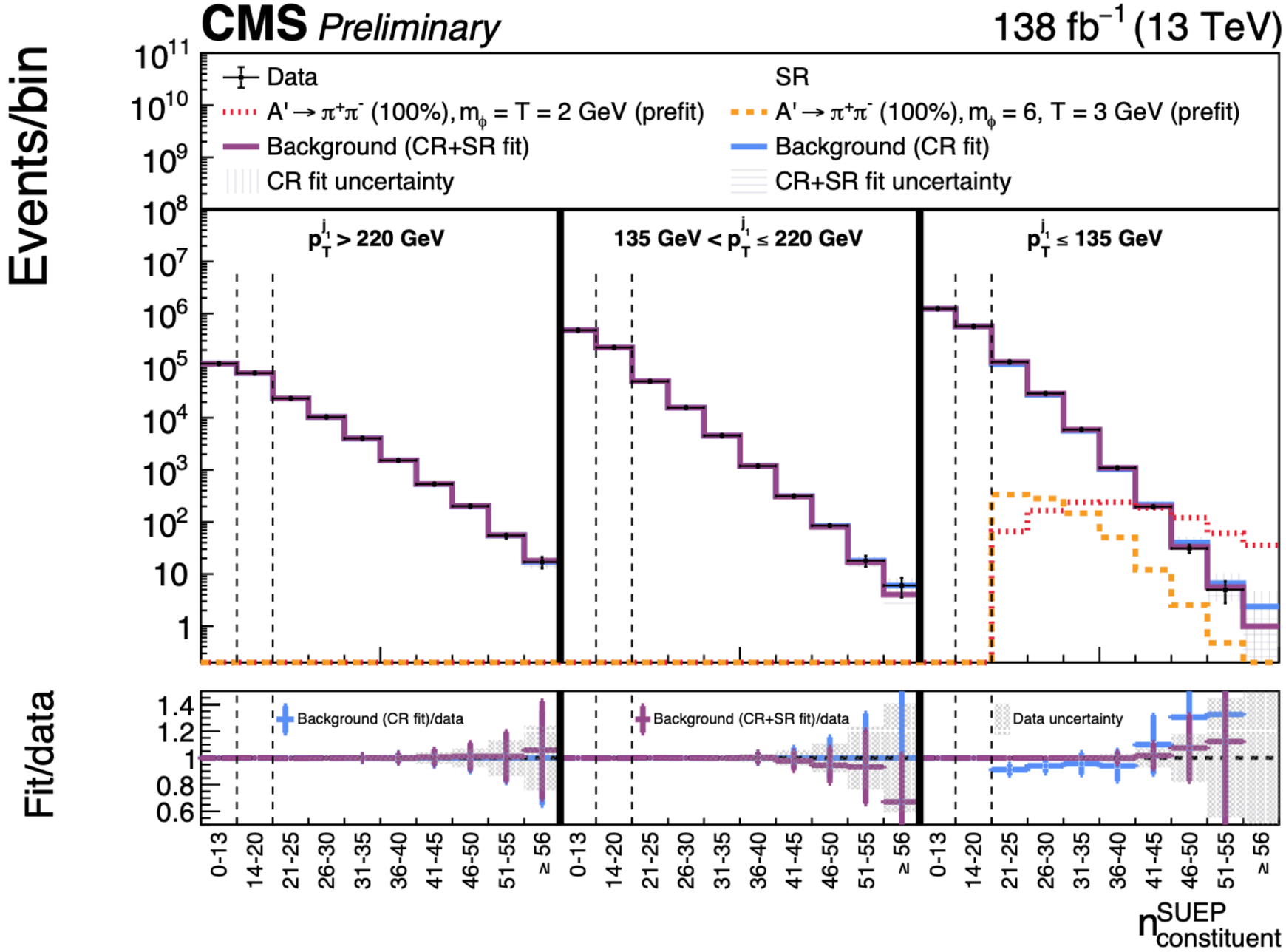
SUEP Signature



Signature: large number of tracks in a wide cluster

ZH SUEP Results

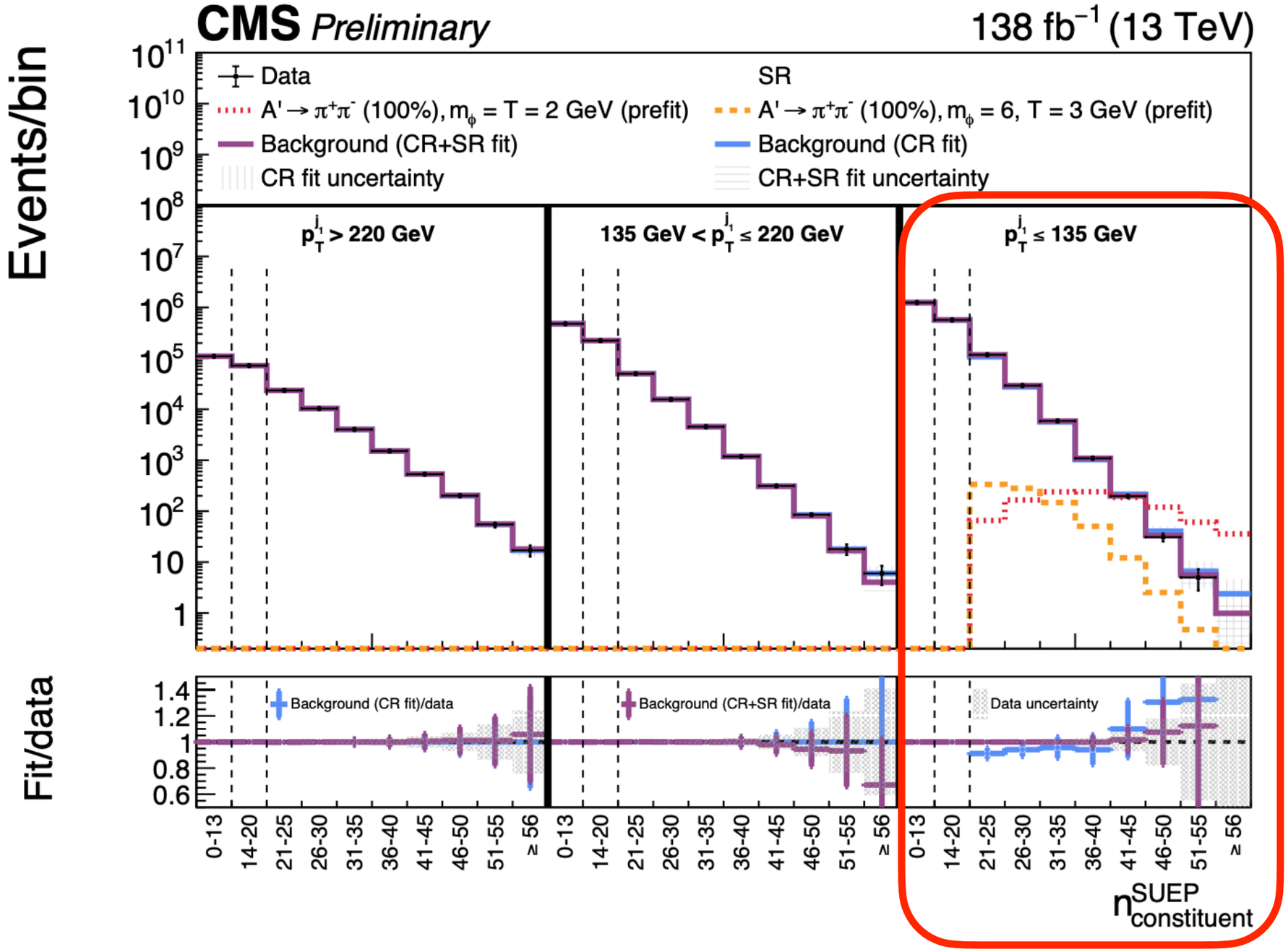
CMS-PAS-EXO-23-003



Data driven (extended ABCD) estimate in SUEP track multiplicity

ZH SUEP Results

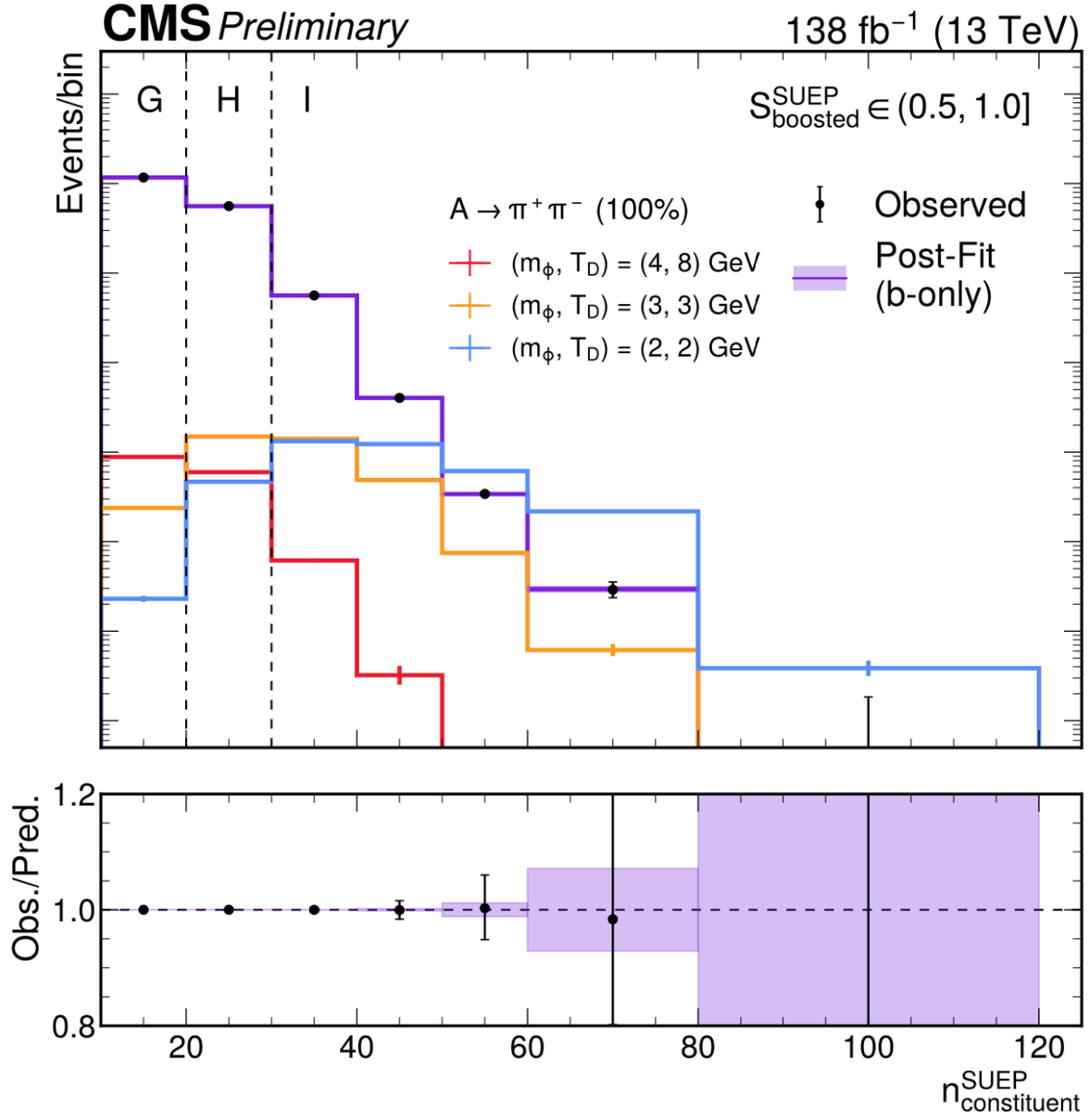
CMS-PAS-EXO-23-003



Signal would show up at **large SUEP track multiplicity**

WH SUEP Results

CMS-PAS-EXO-24-030



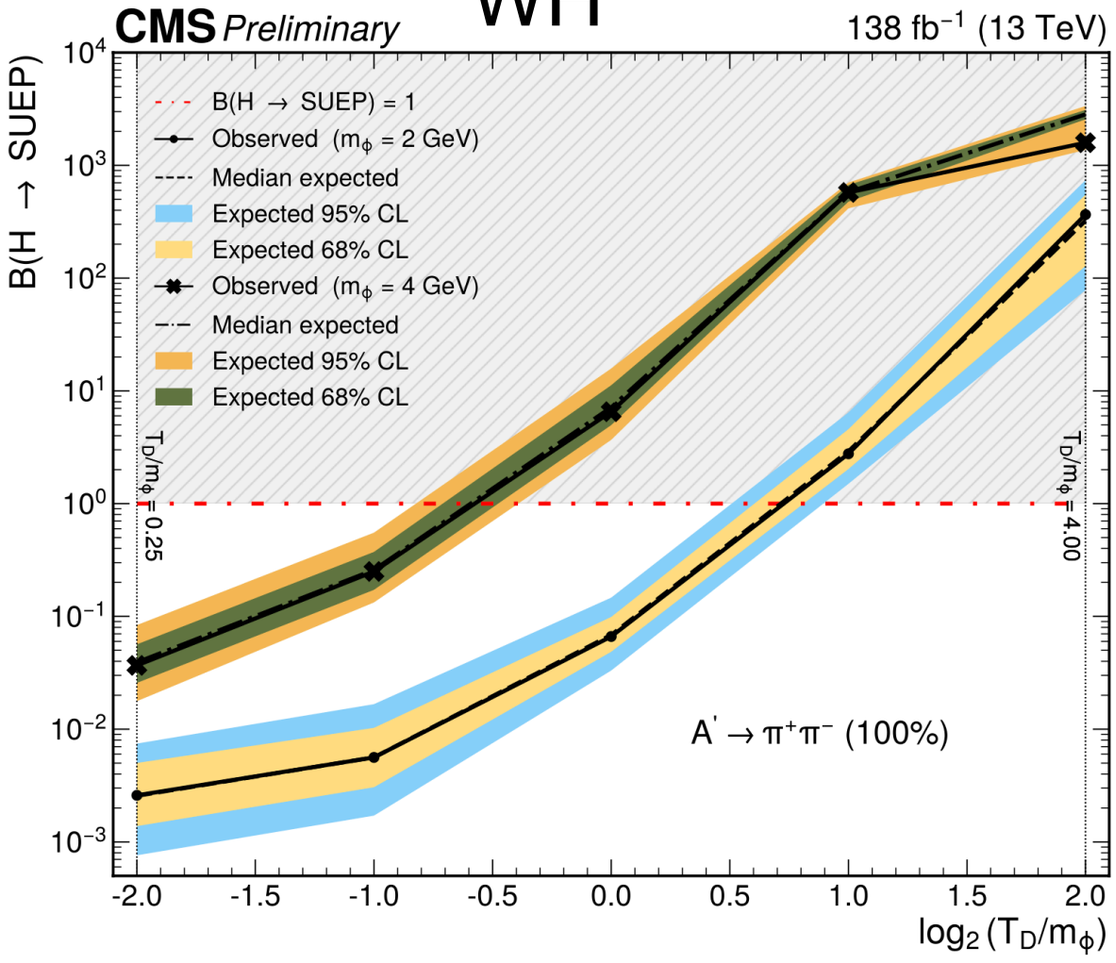
Data driven (extended ABCD) estimate in SUEP track multiplicity

No significant excess observed in WH and ZH searches

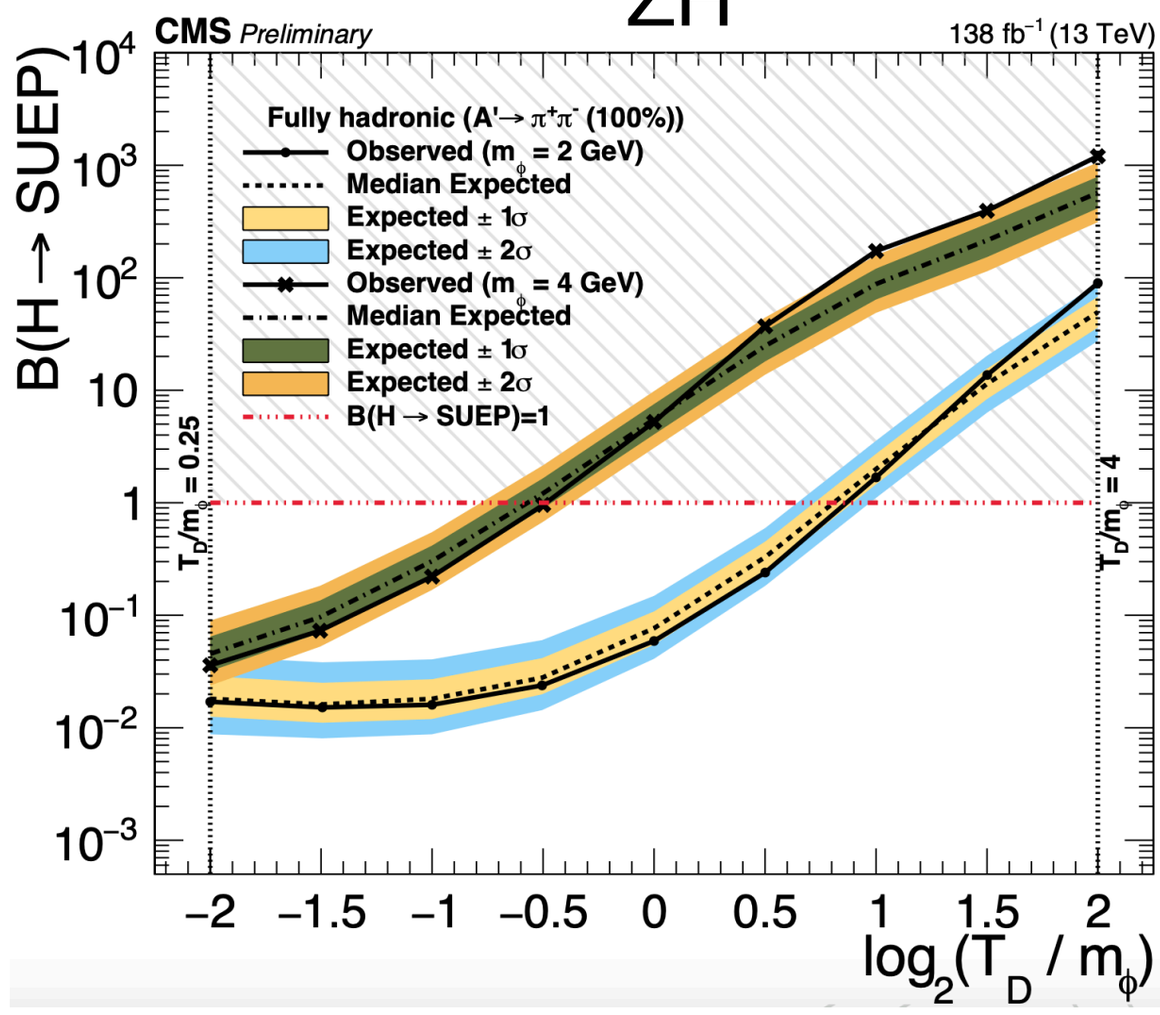
SUEP Expected Limits: WH & ZH

Results interpreted as Higgs BR to SUEP

WH



ZH



Associated vector boson production provides unique sensitivity of the Higgs (portal) decaying to SUEP

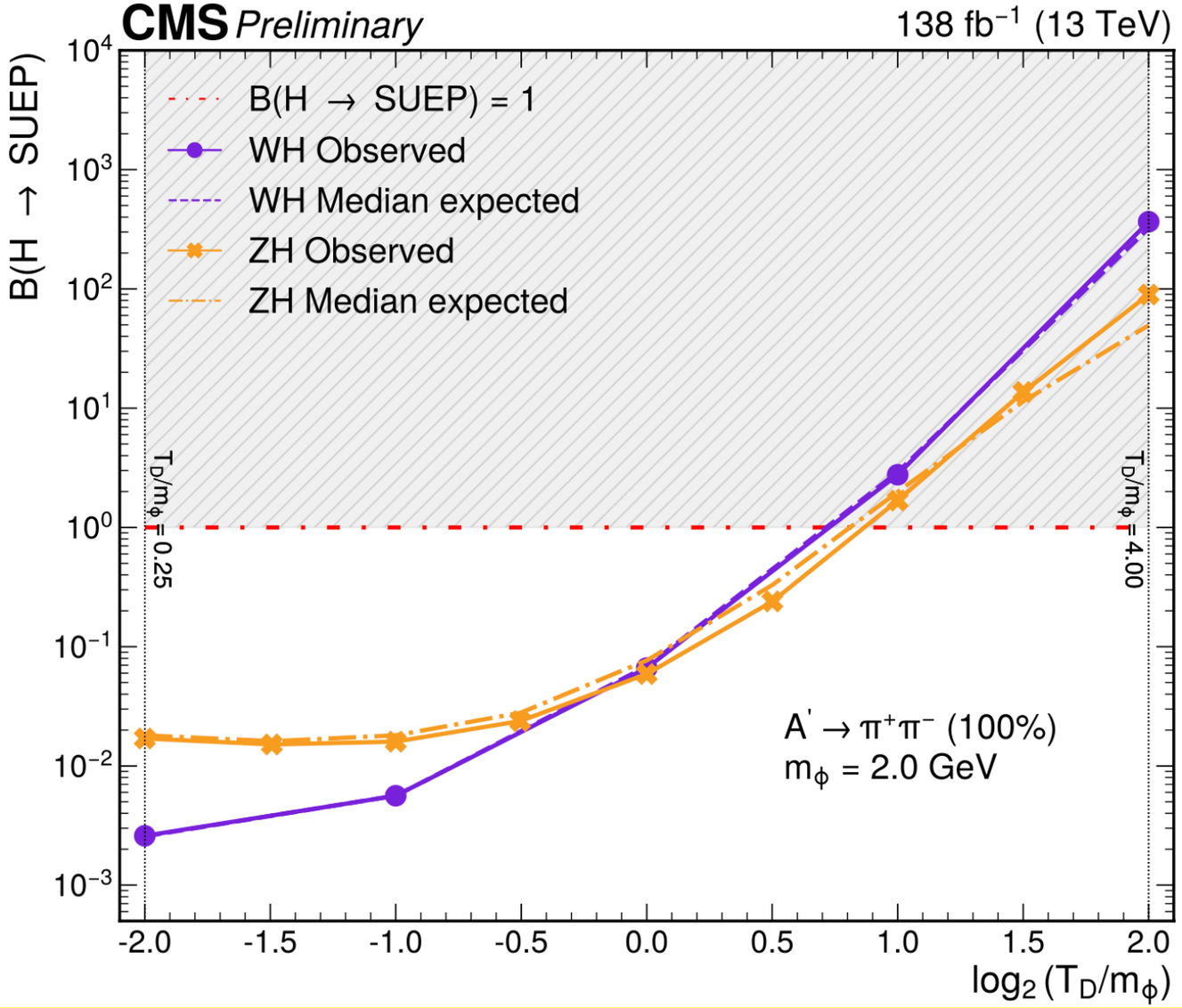
BR(H to SUEP) ~1e-2

SUEP Expected Limits: WH & ZH

BRAND NEW

CMS-PAS-EXO-24-030

WH and ZH sensitivity comparison



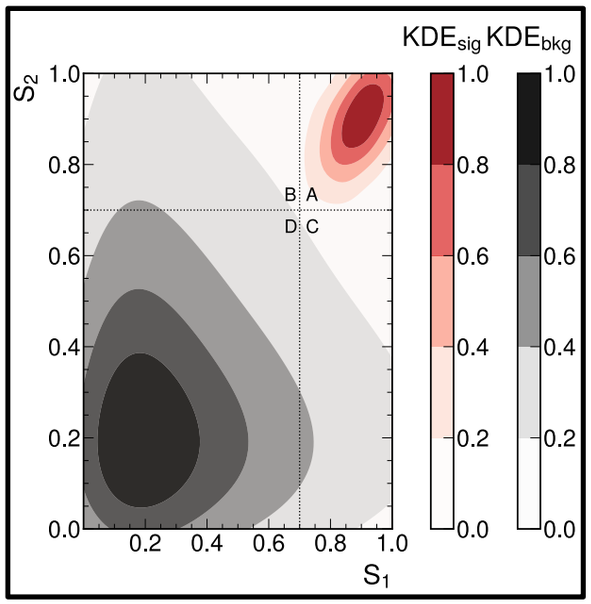
WH and ZH searches provide complimentary and comparable sensitivity → enables combination

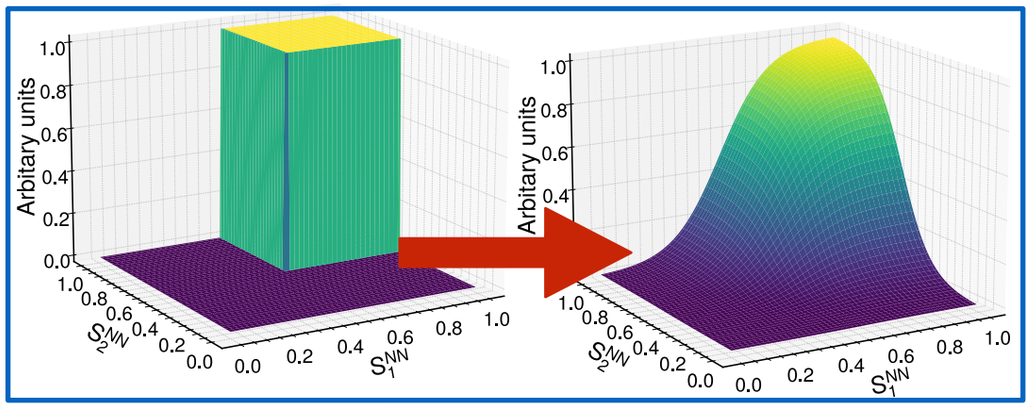
New method: ABCDisCoTEC

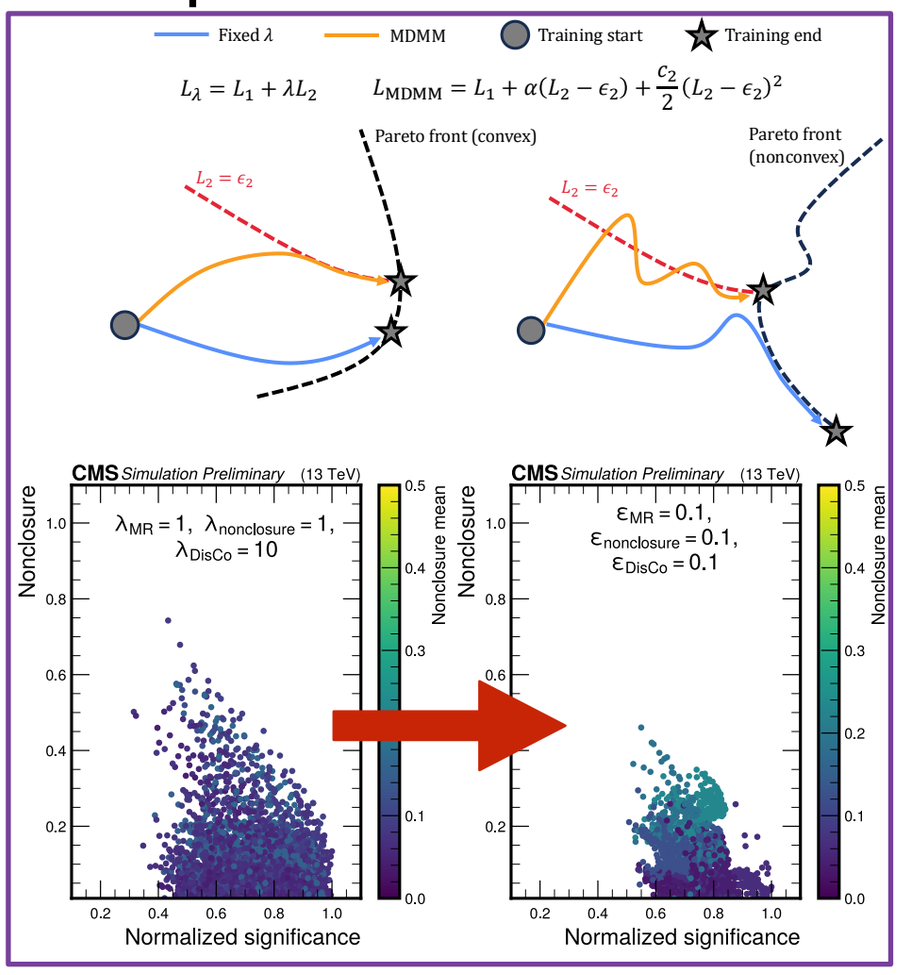
BRAND NEW

CMS-PAS-MLG-23-003

Enables data-driven background estimate by training a NN that produce 2 uncorrelated outputs

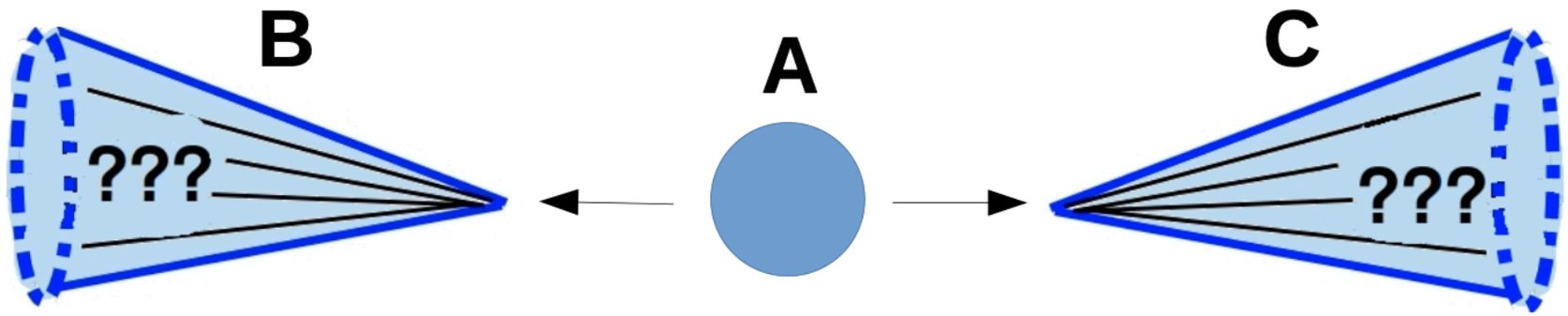




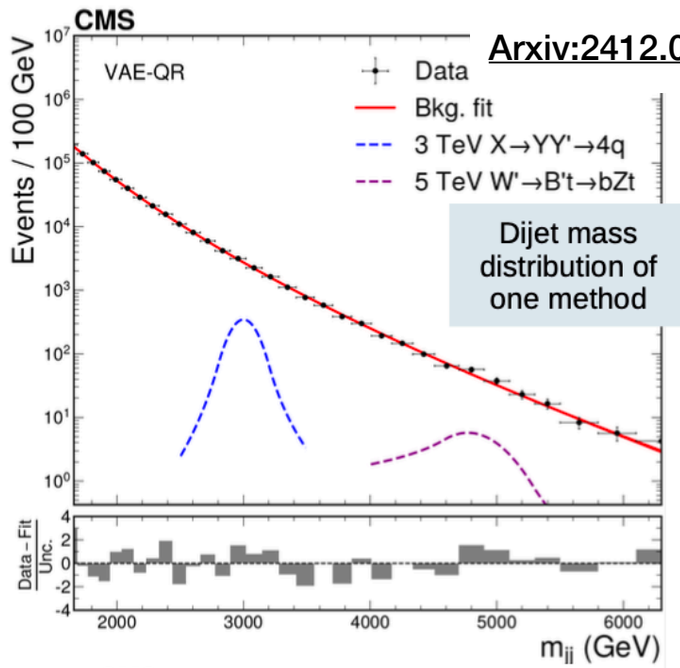


- Optimization achieved with modified differential method of multipliers (MDMM)
  - Closure is ensured as constraint in the loss function
- Method used in recent SUSY search (CMS-PAS-SUS-23-001)
  - with more CMS analyses to follow

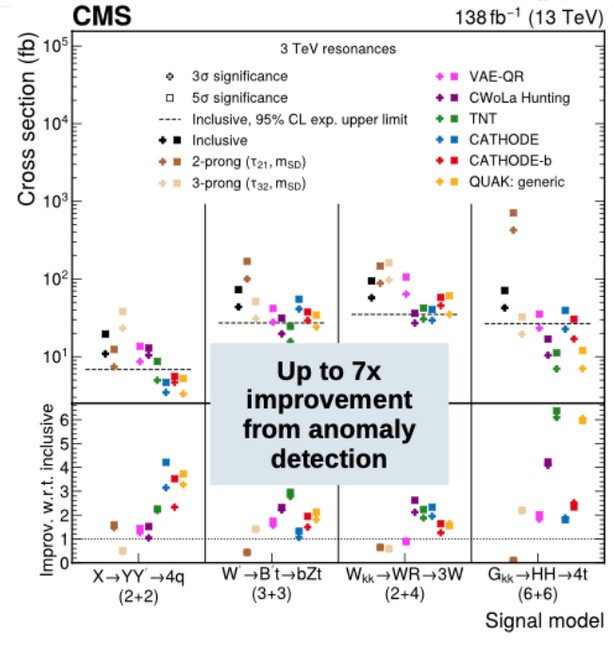
CMS Dijet Anomaly Search



- Generic search for heavy resonance decaying to two daughters, decaying hadronically
  - → produce jets with ‘anomalous’ substructure
- Use 5 different ML-based anomaly detection methods to tag ‘anomalous’ jets
- Demonstrated discovery sensitivity to wide range of signal models



Arxiv:2412.03747

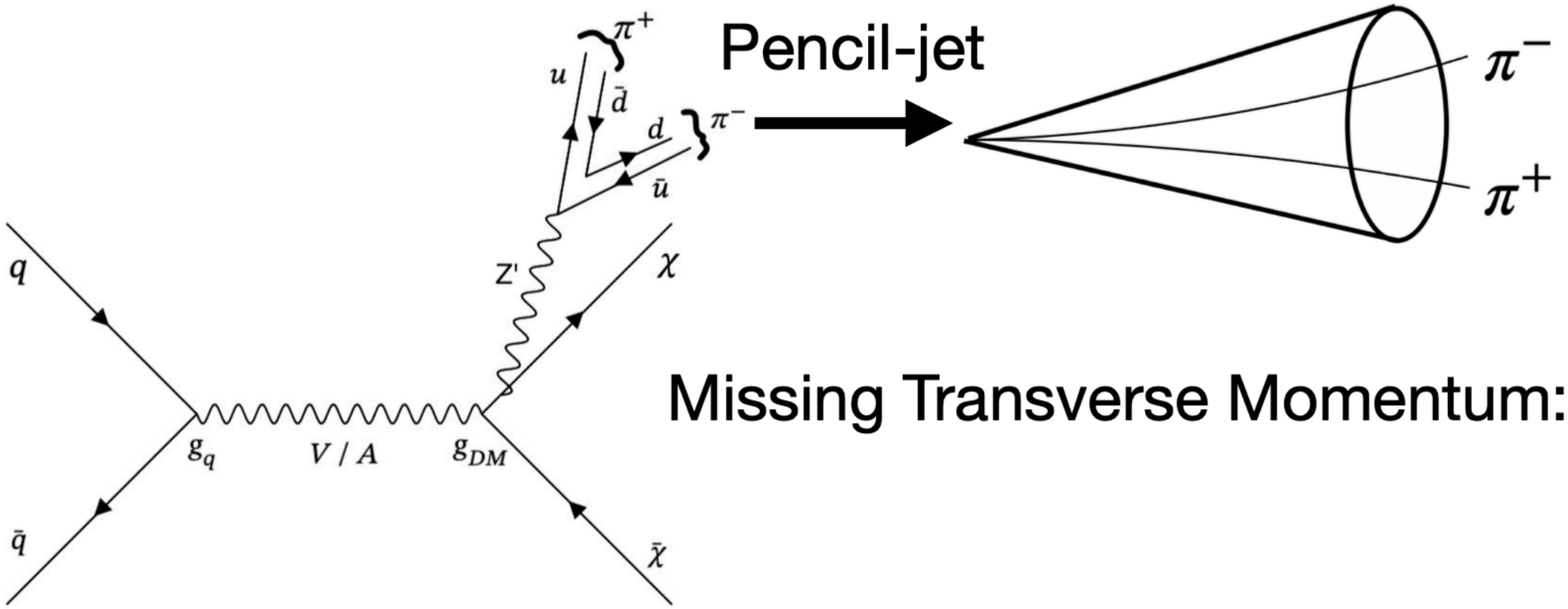


See M. Montella's Talk for ATLAS Anomaly Detection

CMS “pencil-jet” Search

CMS-PAS-SUS-23-017

Search for dark matter (DM) with a light Z’



Missing Transverse Momentum: MET

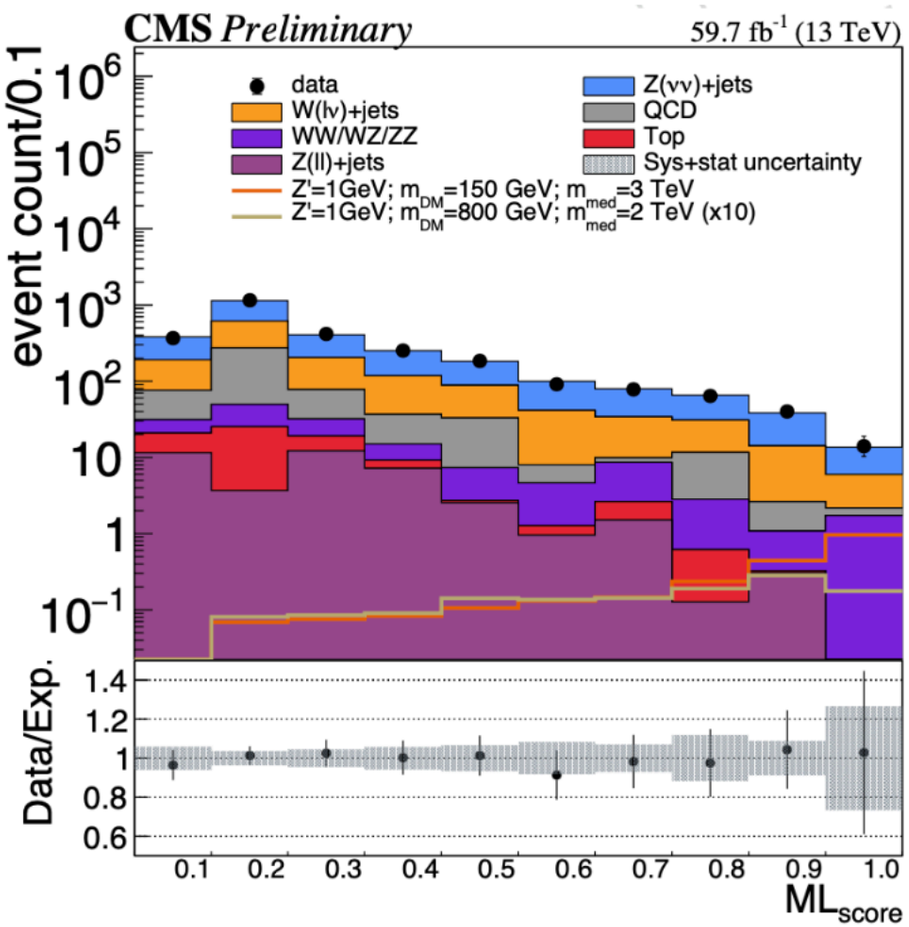
First LHC search targeting DM recoiling against

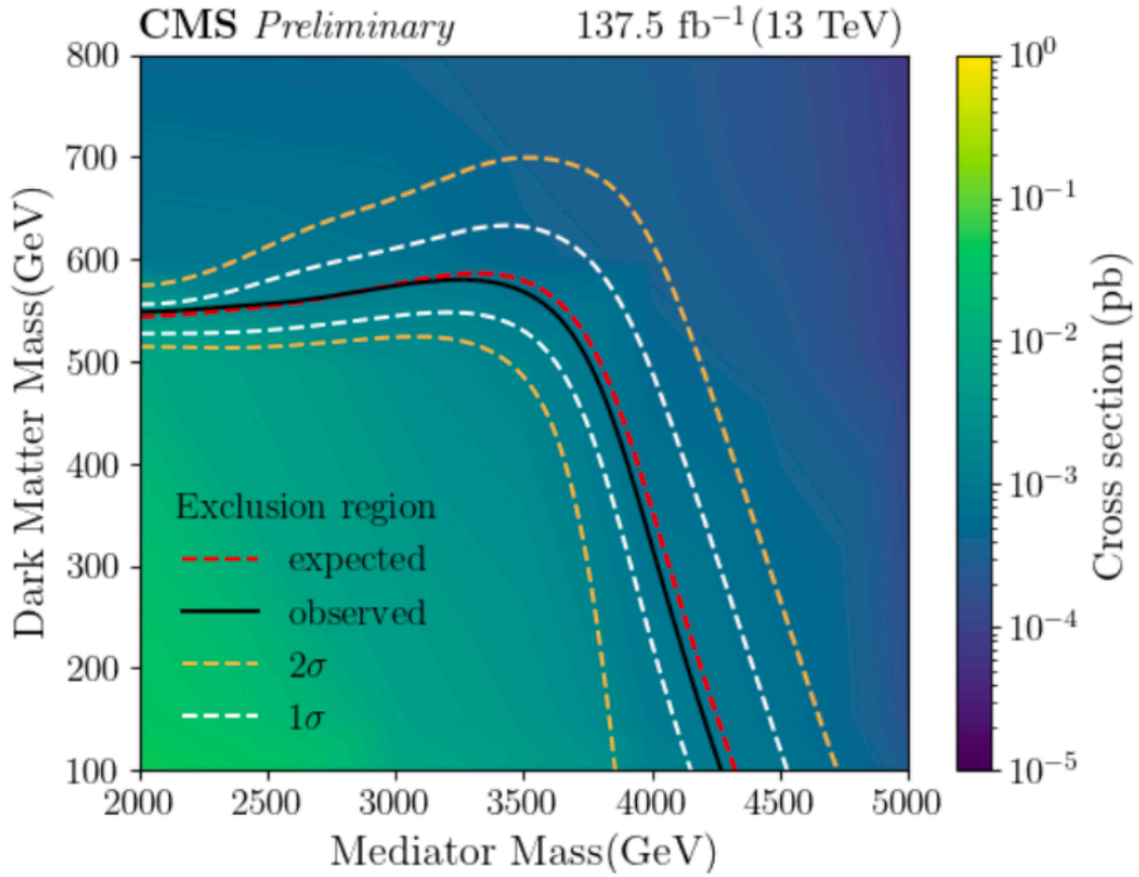
a **narrow and low-hadron-multiplicity object (“pencil-jet”)**

CMS “pencil-jet” Search

CMS-PAS-SUS-23-017

Train a ML discriminator on the pencil-jet properties:
energy fraction of leading track, deltaR, mass



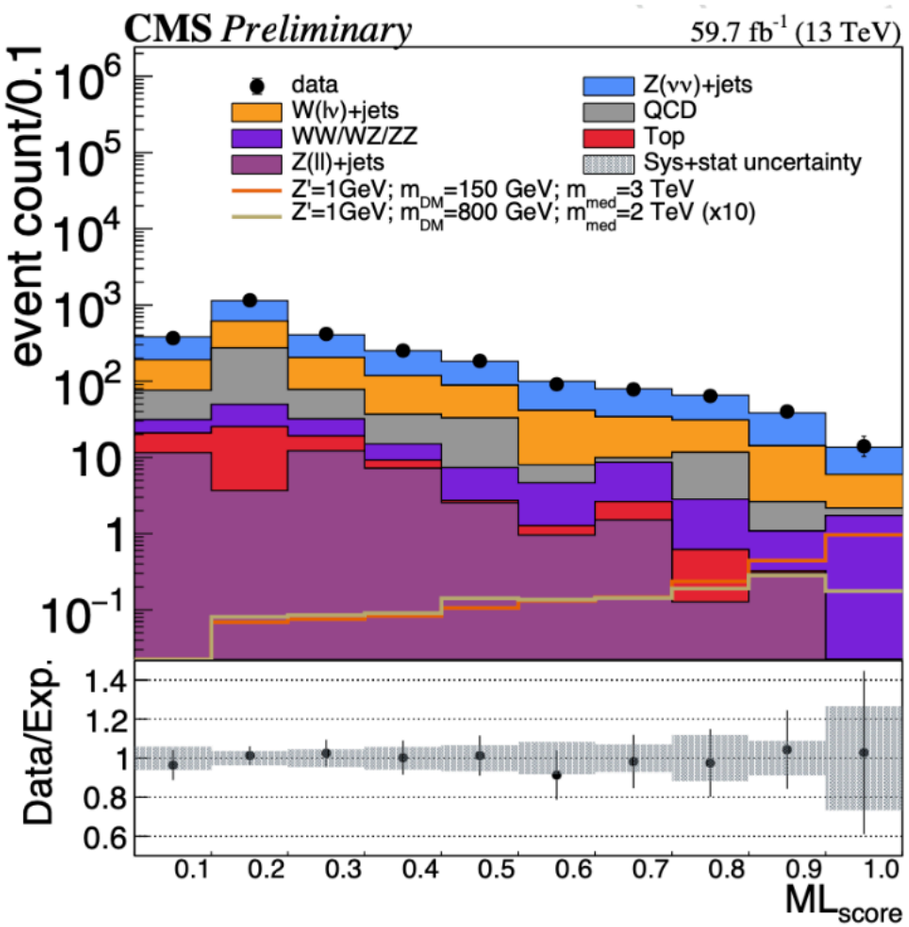


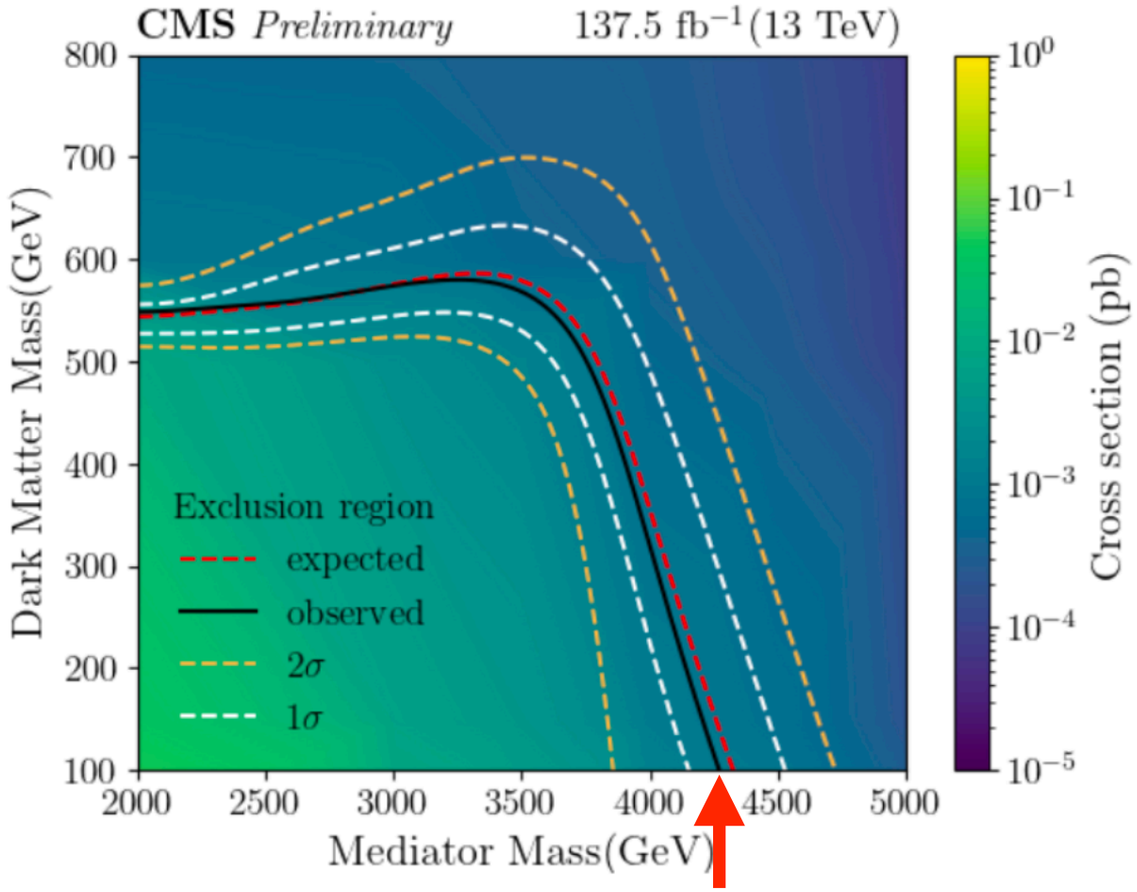
Exclude mediator masses up to 4.2 TeV for DM mass of 100 GeV

CMS “pencil-jet” Search

CMS-PAS-SUS-23-017

Train a ML discriminator on the pencil-jet properties:
energy fraction of leading track, deltaR, mass





Exclude mediator masses up to 4.2 TeV for DM mass of 100 GeV

Outlook

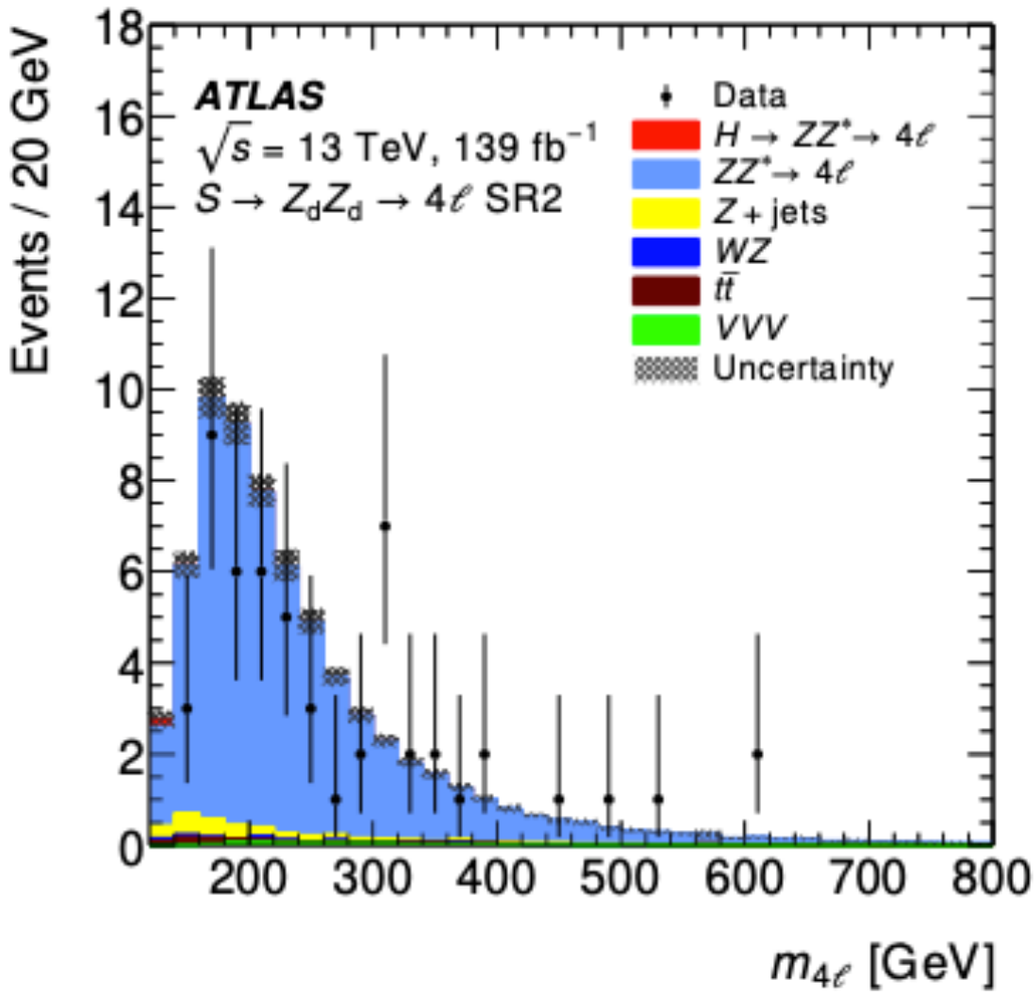
- **Unconventional signatures and new techniques** enhance the LHC physics program
  - **Provide access to unexplored regions**
- Presented 6 **brand new results from CMS**
- Will continue the **“leave no stone unturned”** paradigm
  - New and improved **unconventional signatures and techniques** will remain key!

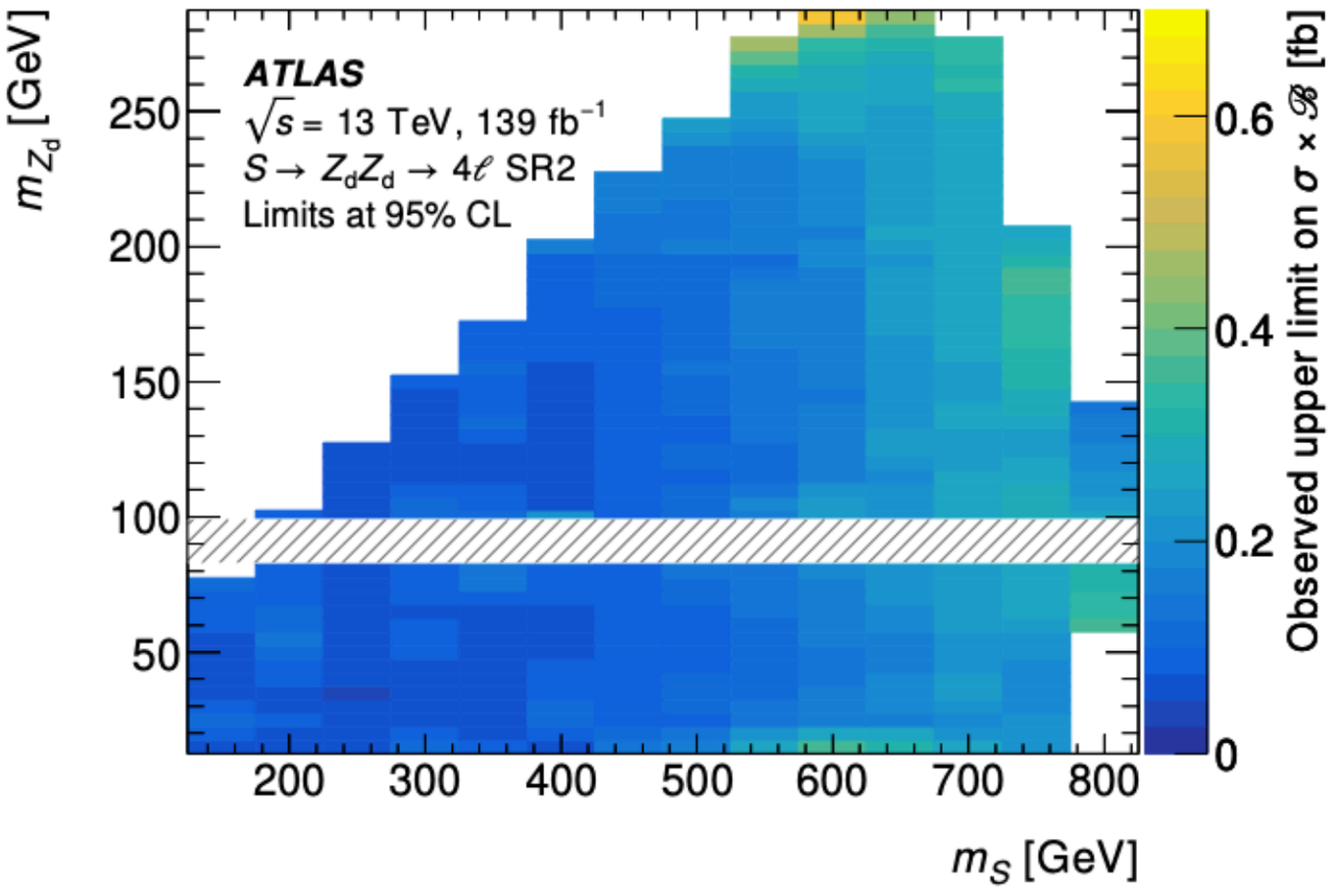
Backups

Searches for new resonances

arXiv:2410.16781

New scalar decaying to 2 spin-1 boson in 4 lepton final state





Probes new **scalar (S) and spin-1 boson (Zd)** masses with **4-lepton high mass spectrum**