



Mt. Washington



Three Fingered Jack

When is 8 TeV better than 13 TeV?

Tom Tong

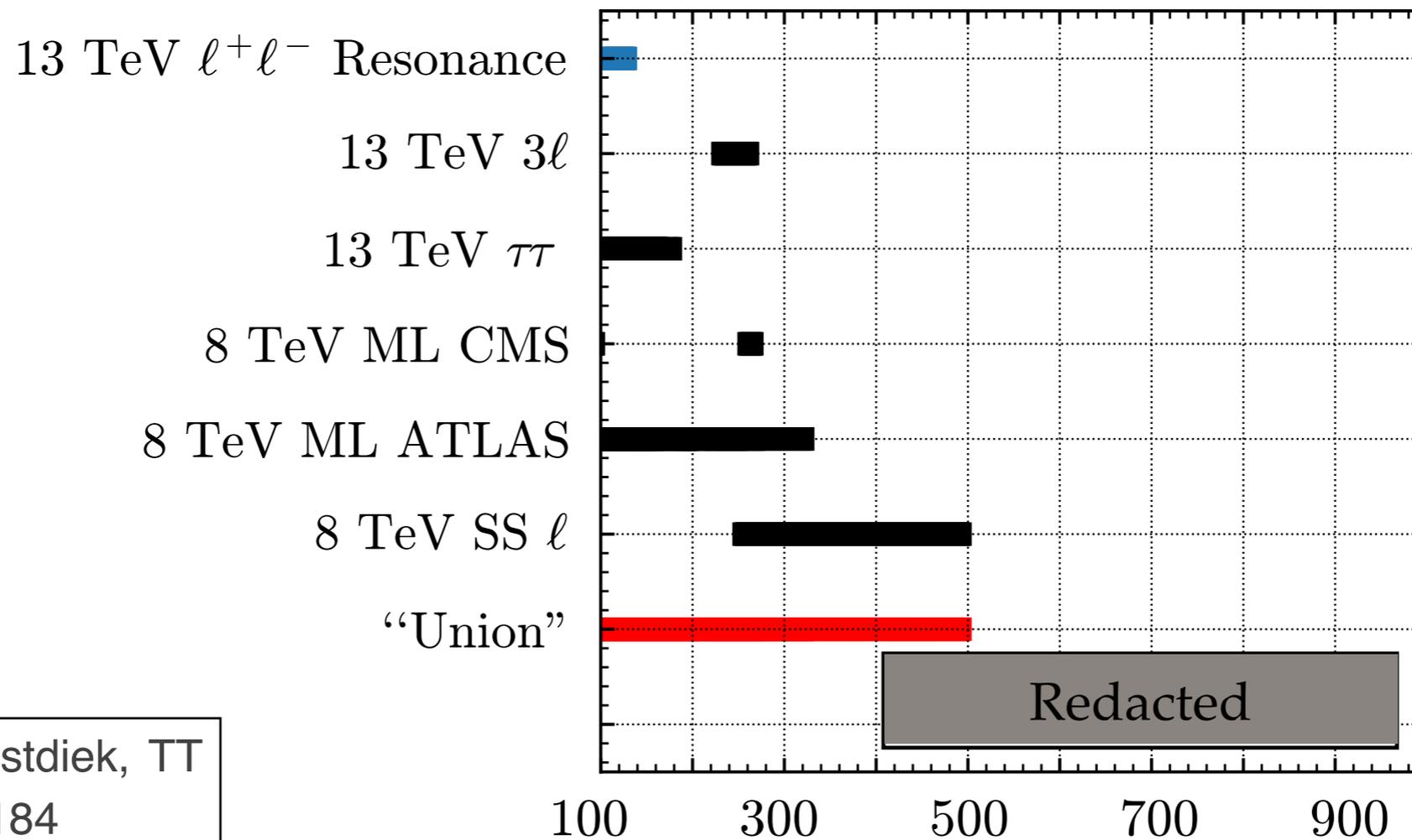
University of Oregon

1809.10183 and 1809.10184
with *Graham Kribs, Adam Martin, Bryan Ostdiek*

PHENO 2019 May 7th

Really?

Really?

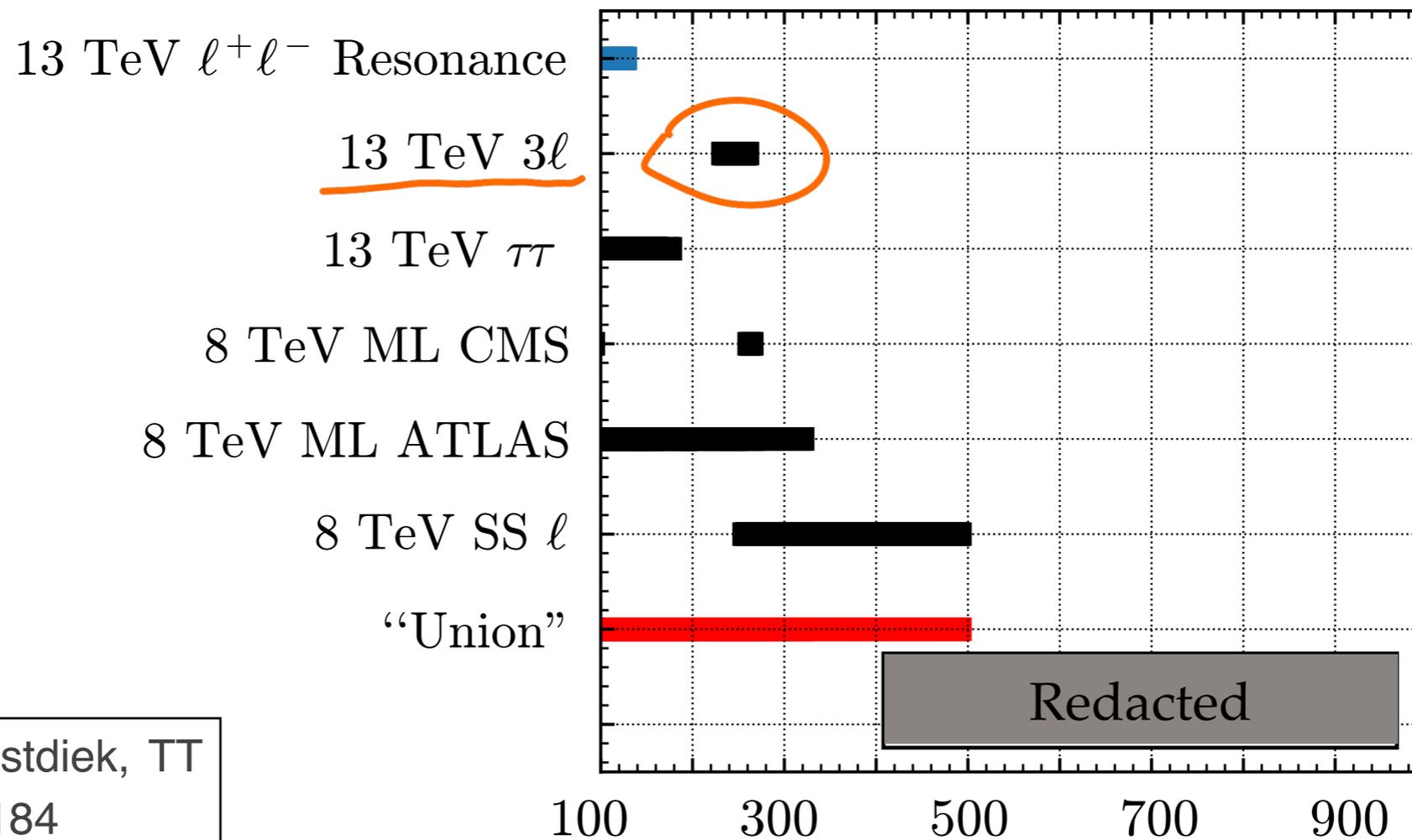


Kribs, Martin, Ostdiek, TT
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DM mass (GeV)

Exclusion plot from our recast of several ATLAS searches motivated by some underlying dark matter model.

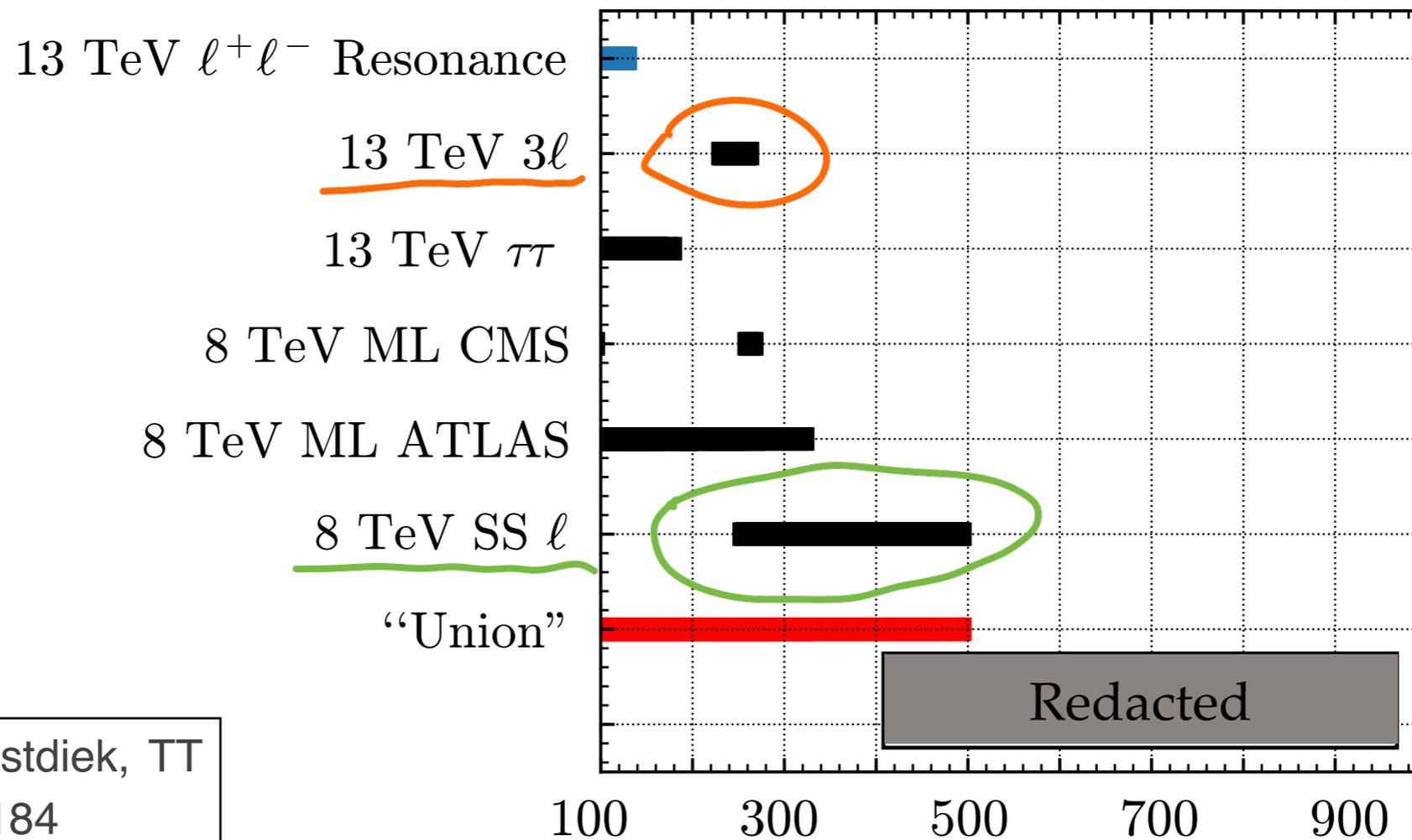
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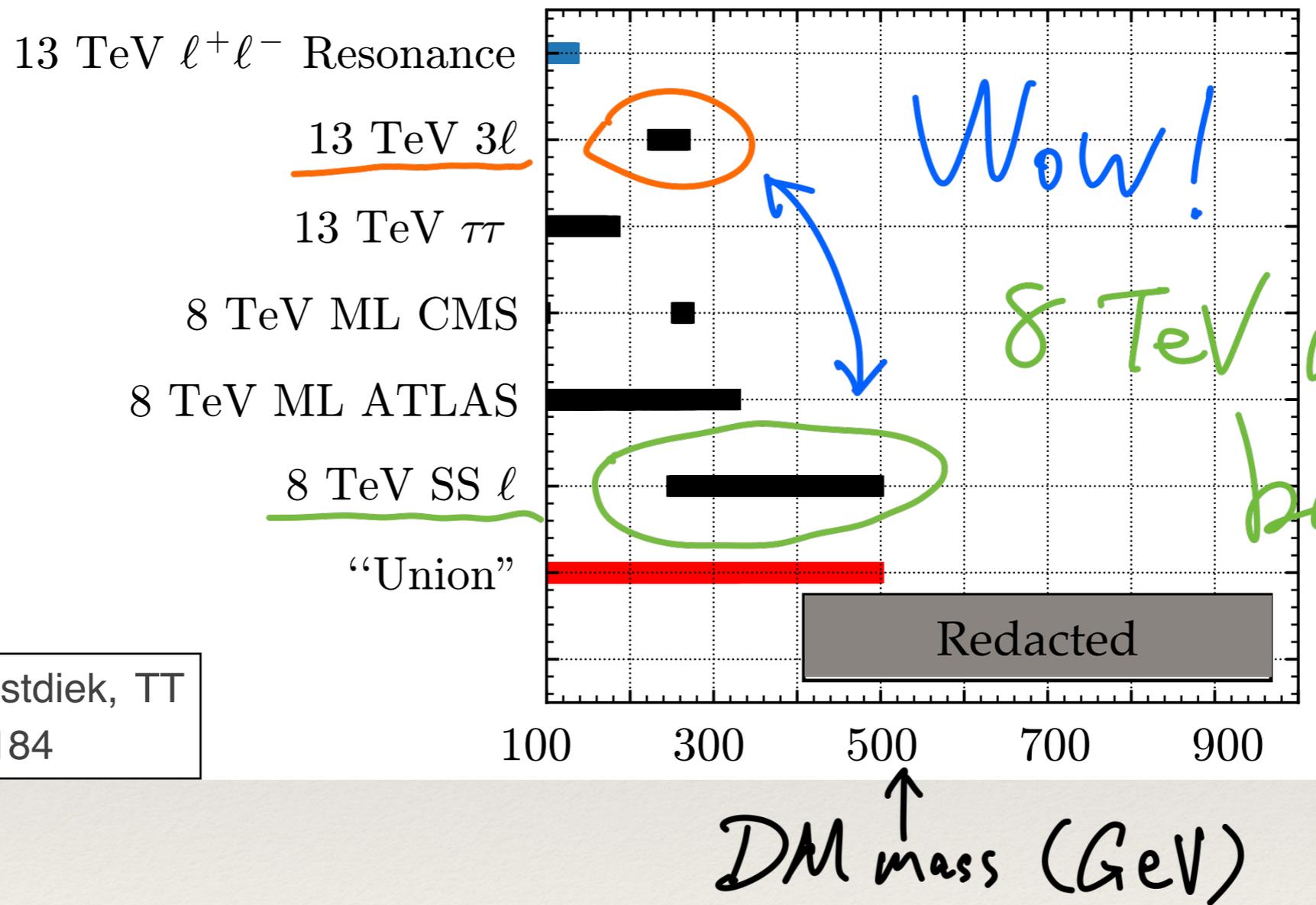


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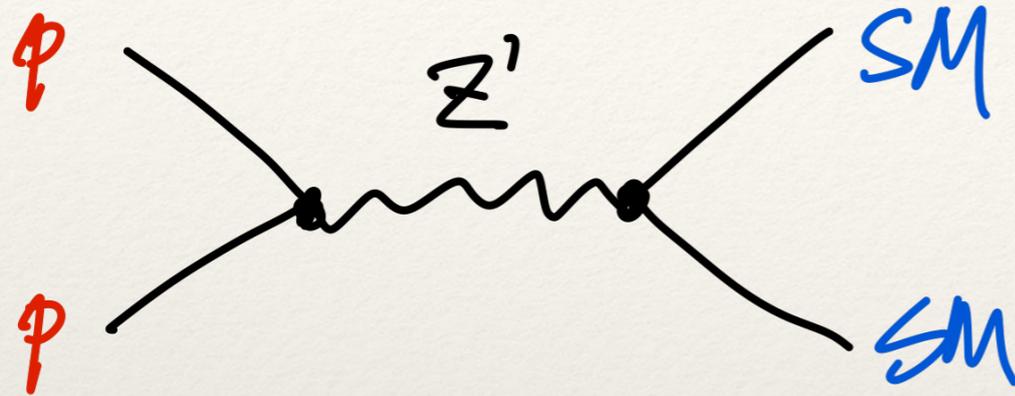


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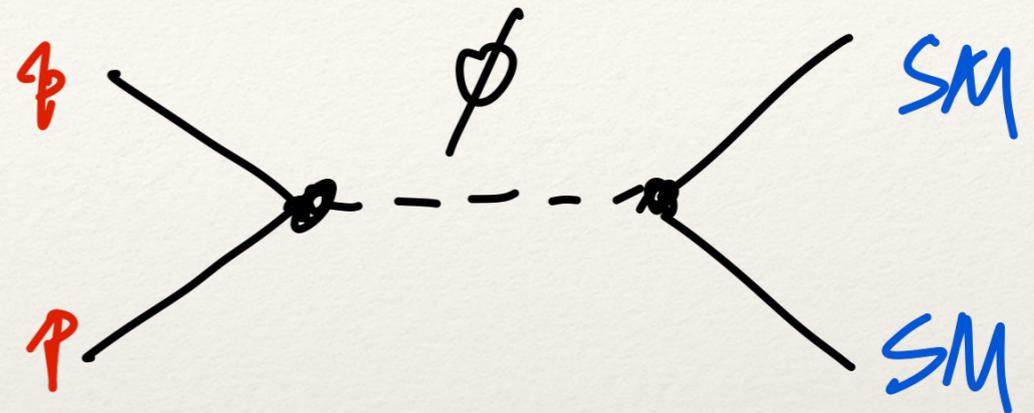
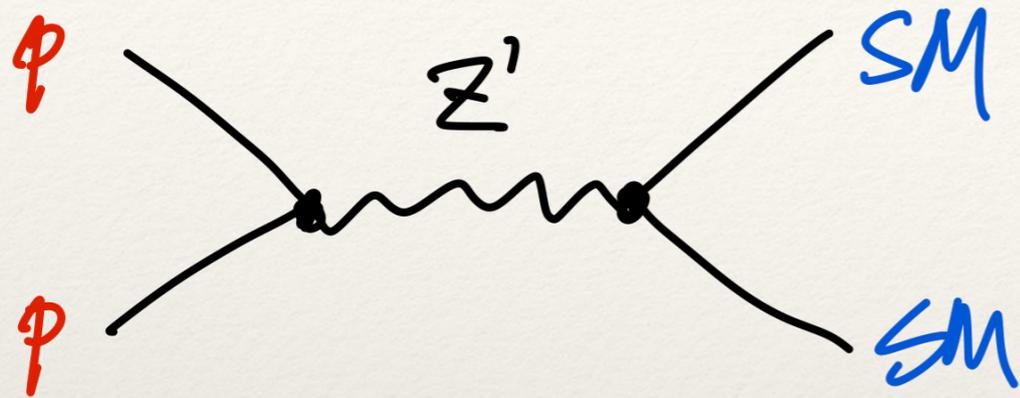
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BSM models well studied

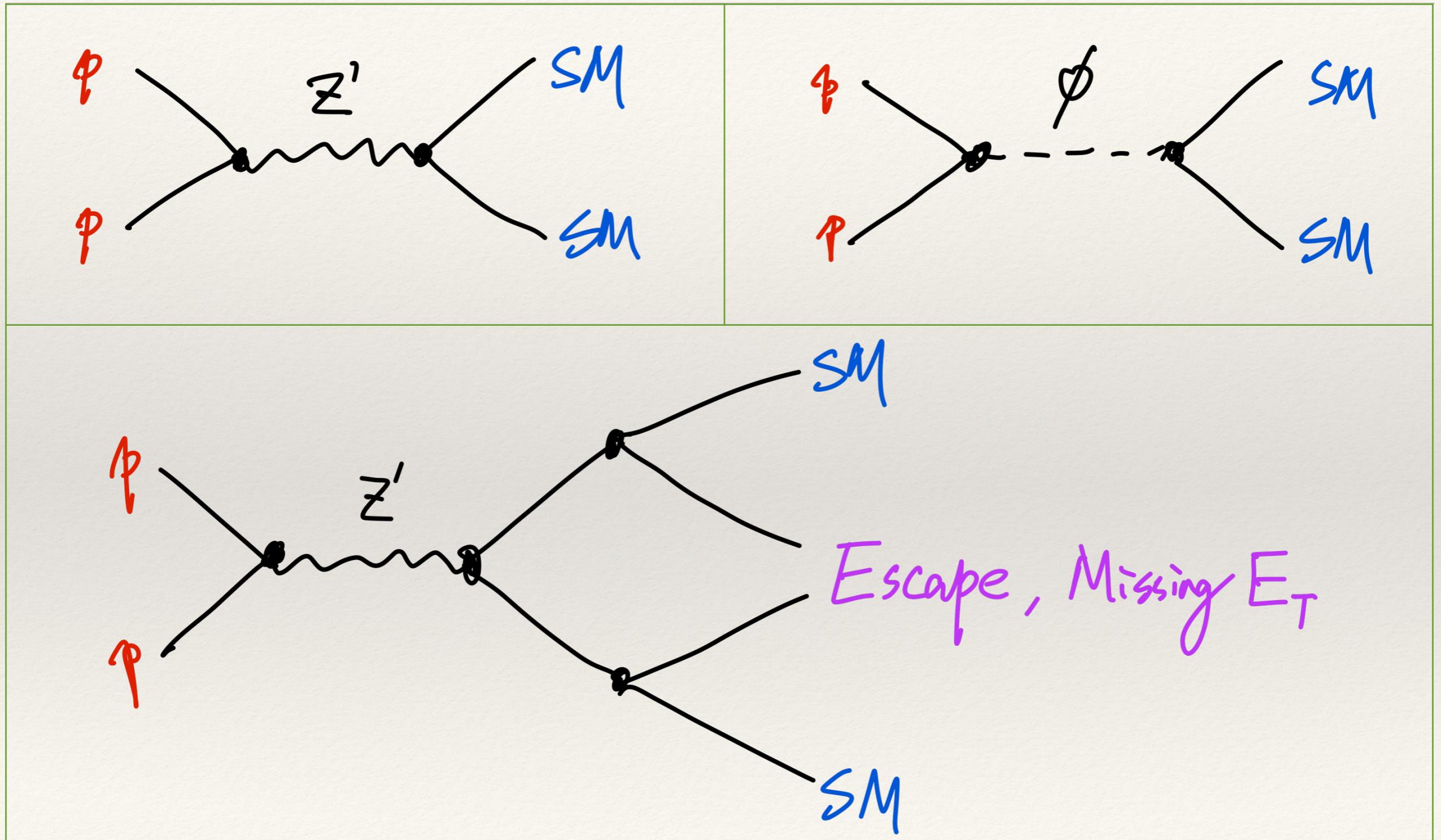
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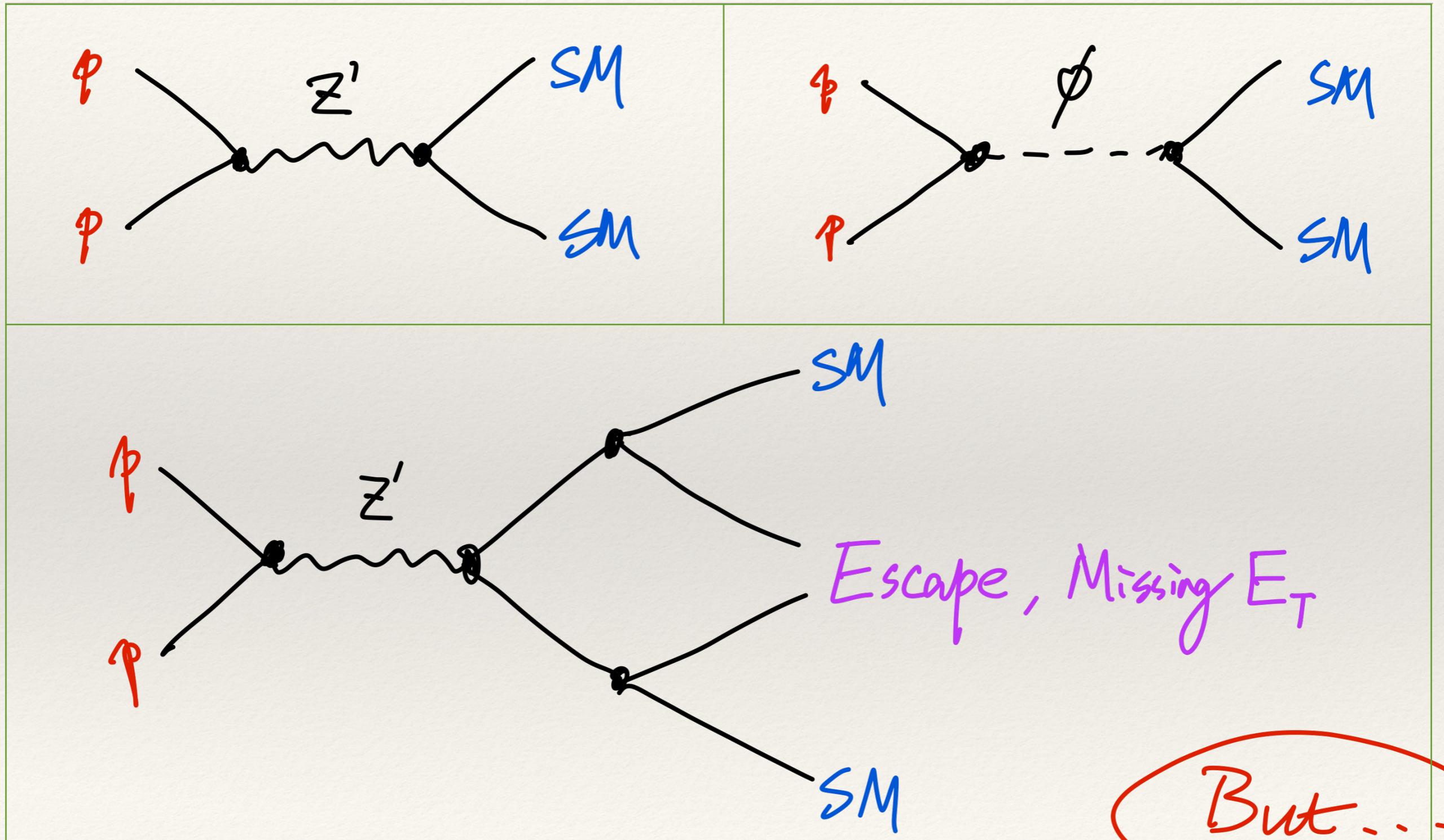
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What Model ?

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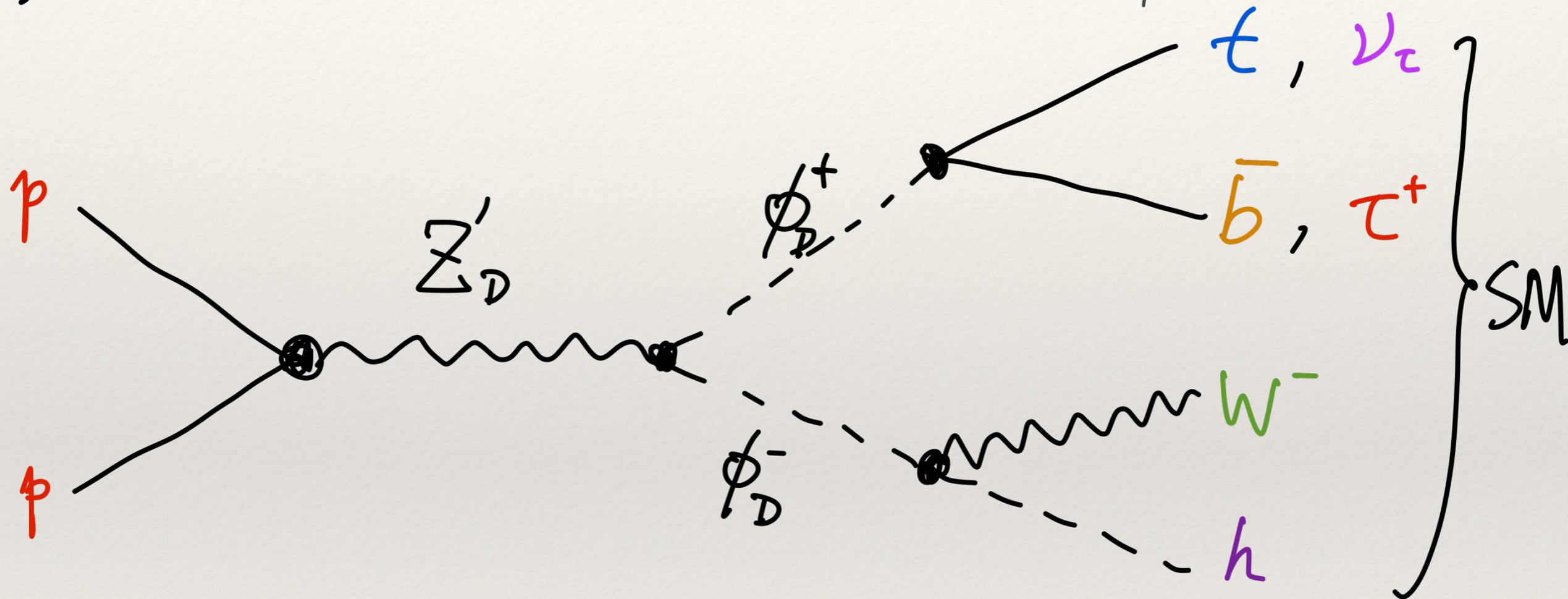


Consider a heavy dark sector with a vector Z' and a scalar ϕ

$(m_\phi \sim 10^2 \text{ GeV})$

What Model ?

☆ Consider a heavy dark sector with a vector Z' and a scalar ϕ ($m_\phi \sim 10^2 \text{ GeV}$)

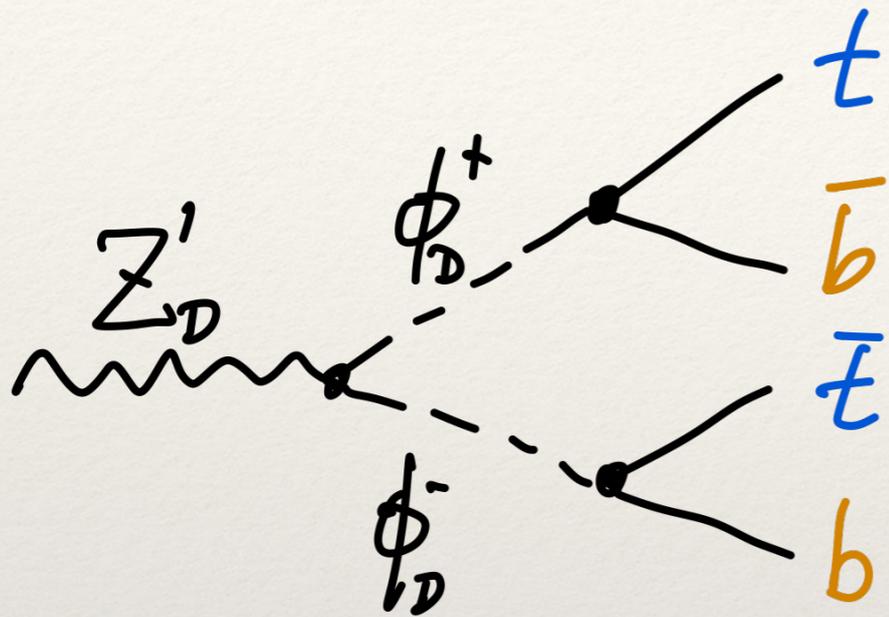


☆ The dark Z' can be resonantly produced @ LHC, and decays into a pair of dark scalar ϕ

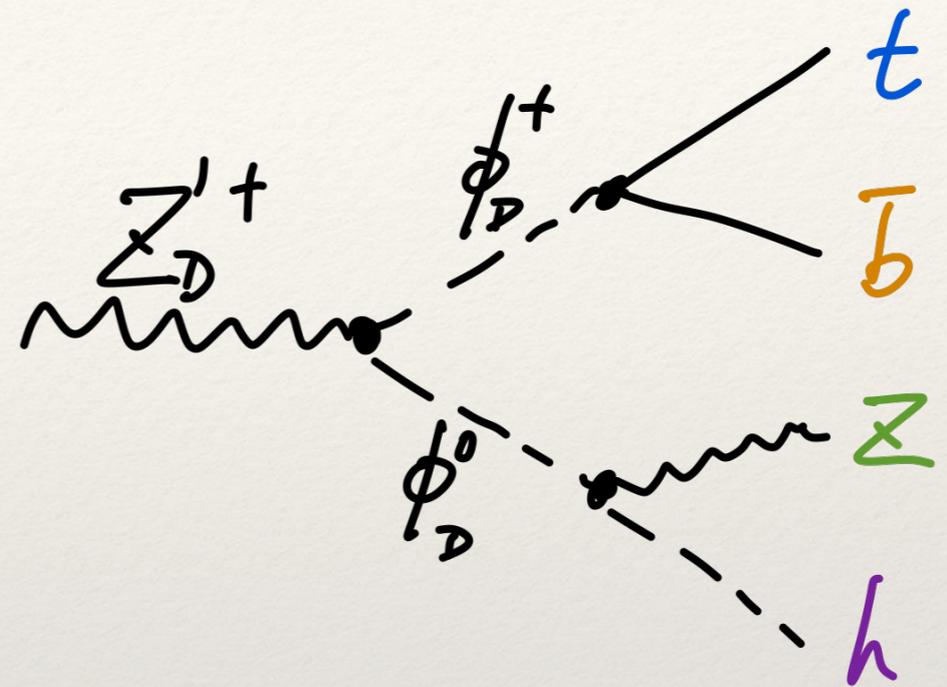
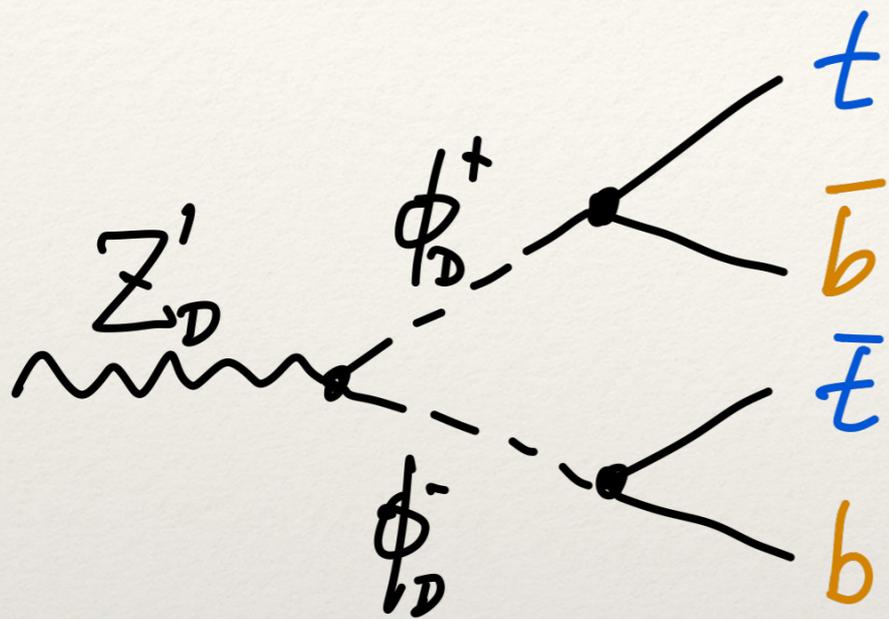
☆ The dark scalar ϕ then will fully decay back to SM final states.

Some final states

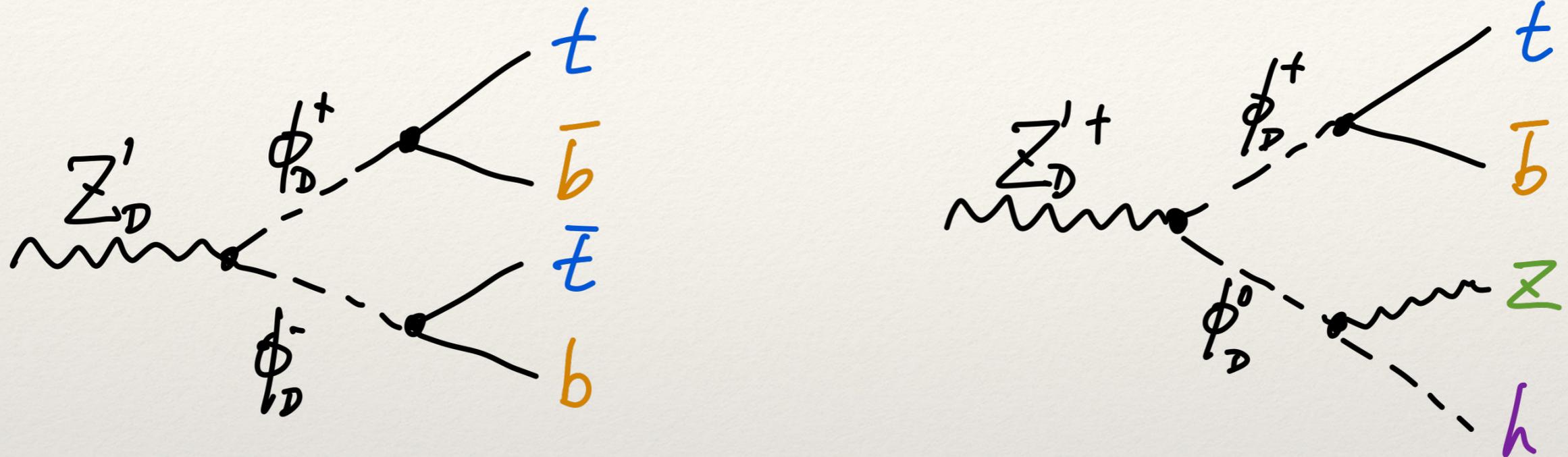
Some final states



Some final states



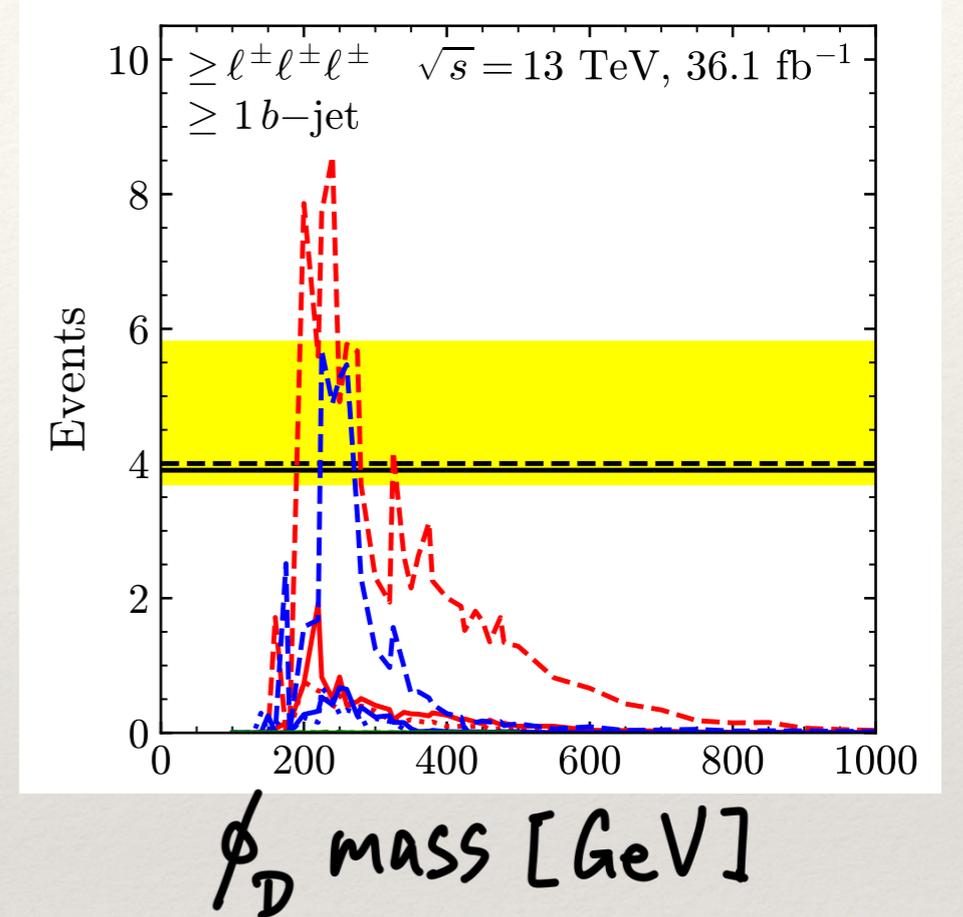
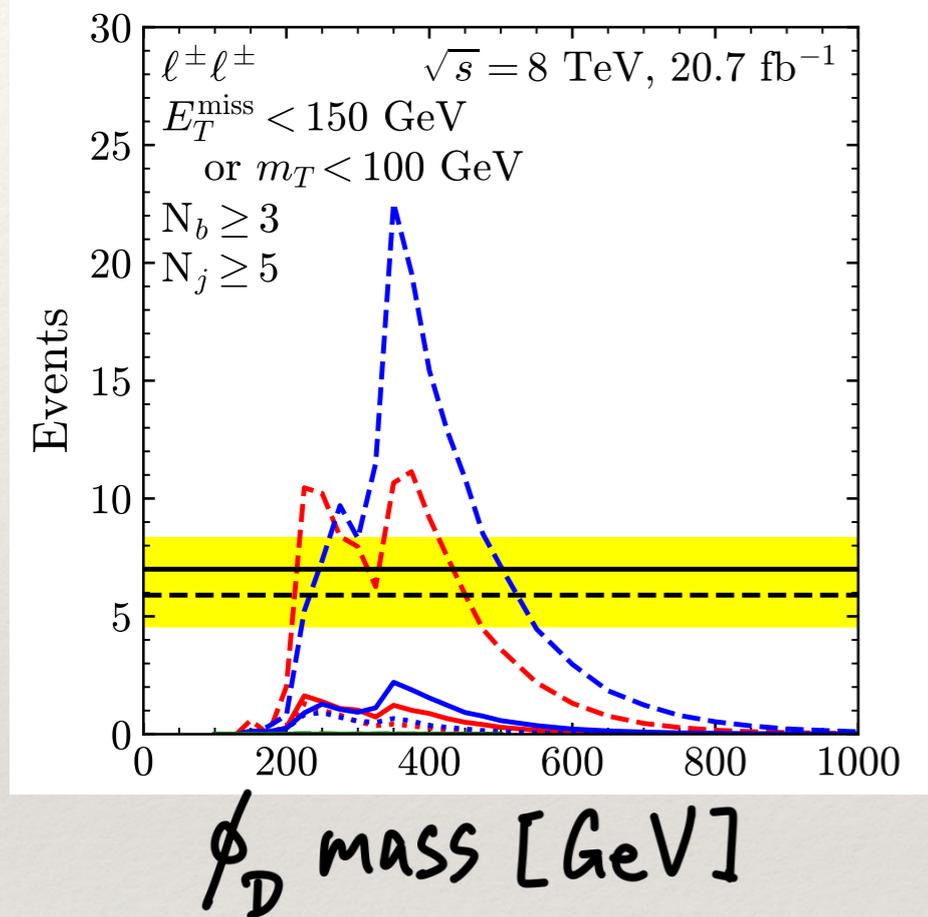
Some final states



In the ϕ_D mass range roughly about 200 GeV ~ 400 GeV, these are the major final states of SM particles. Several characteristic features of such processes are:

- ❖ The ϕ_D are pair produced
- ❖ Multiple b -jets
- ❖ Low missing energy other than some ν

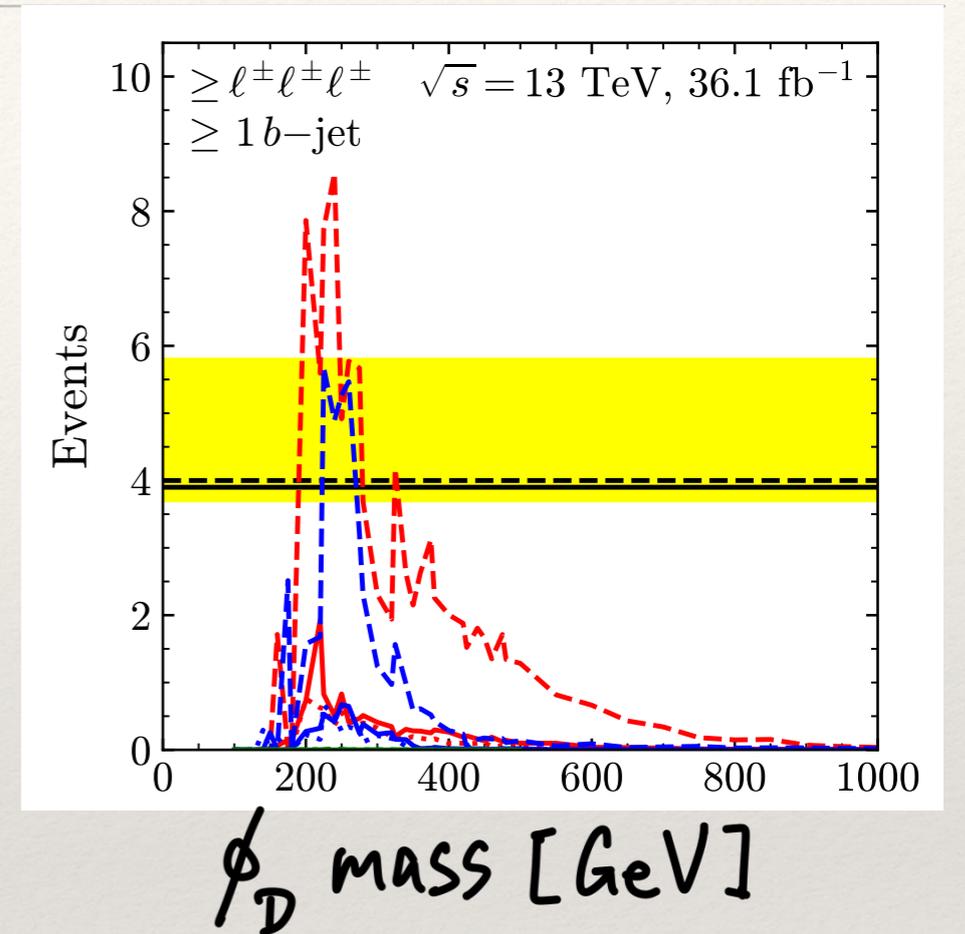
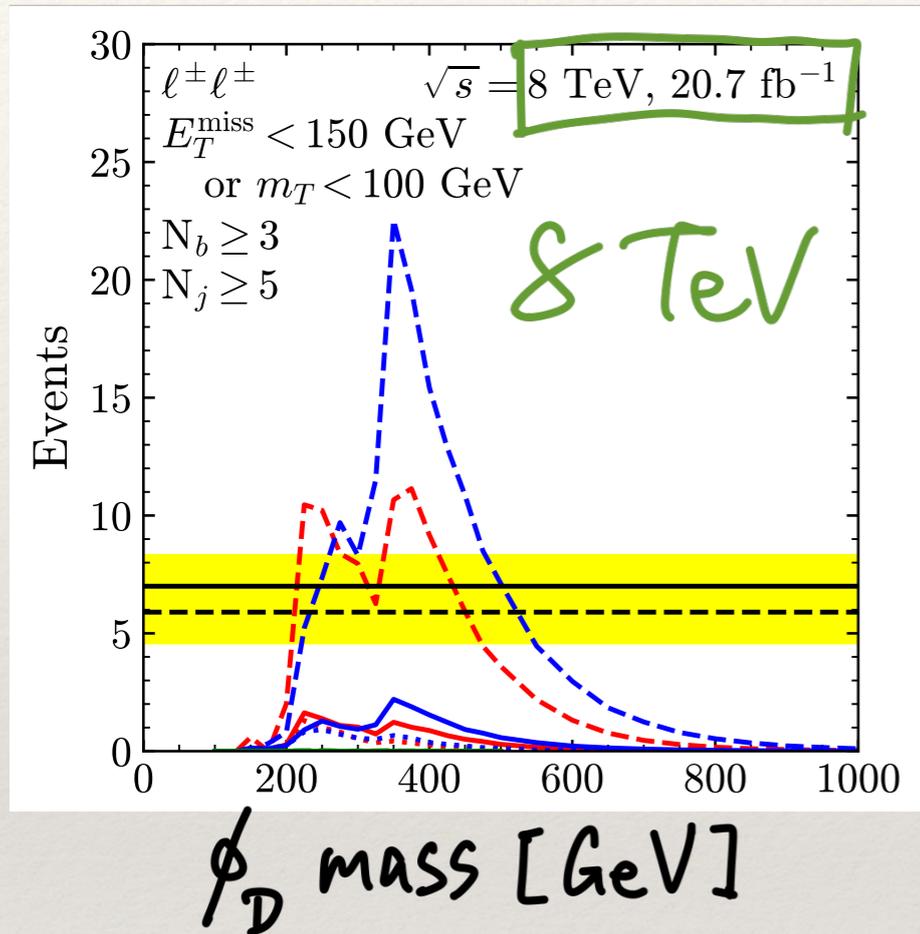
Here's the recast



ATLAS searches for SUSY with final states of two same sign leptons.

Recast on 8 TeV search resulted a larger exclusion than the same on 13 TeV.

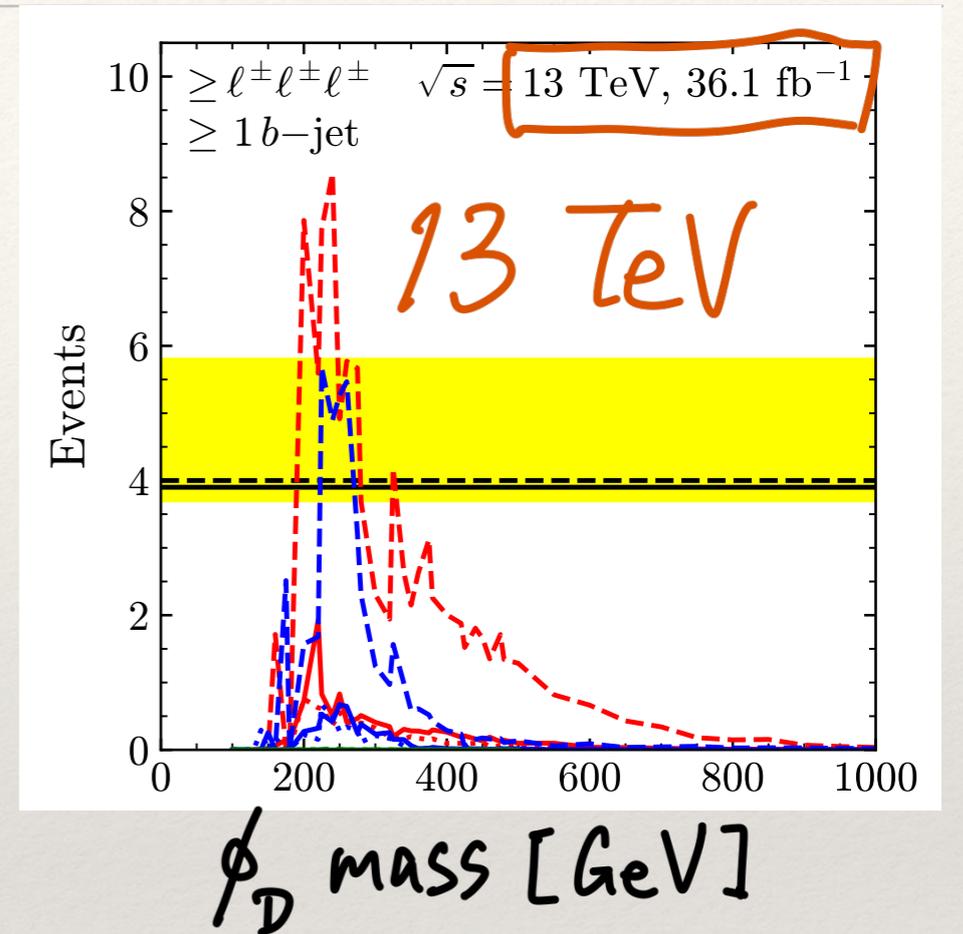
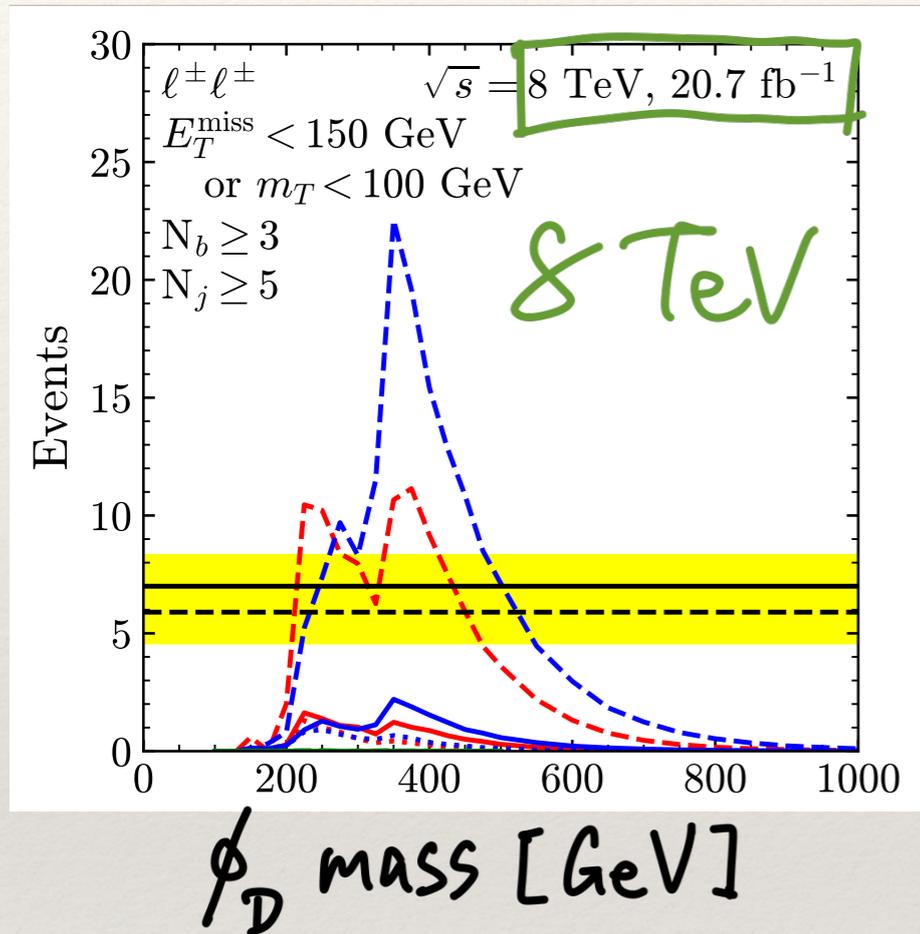
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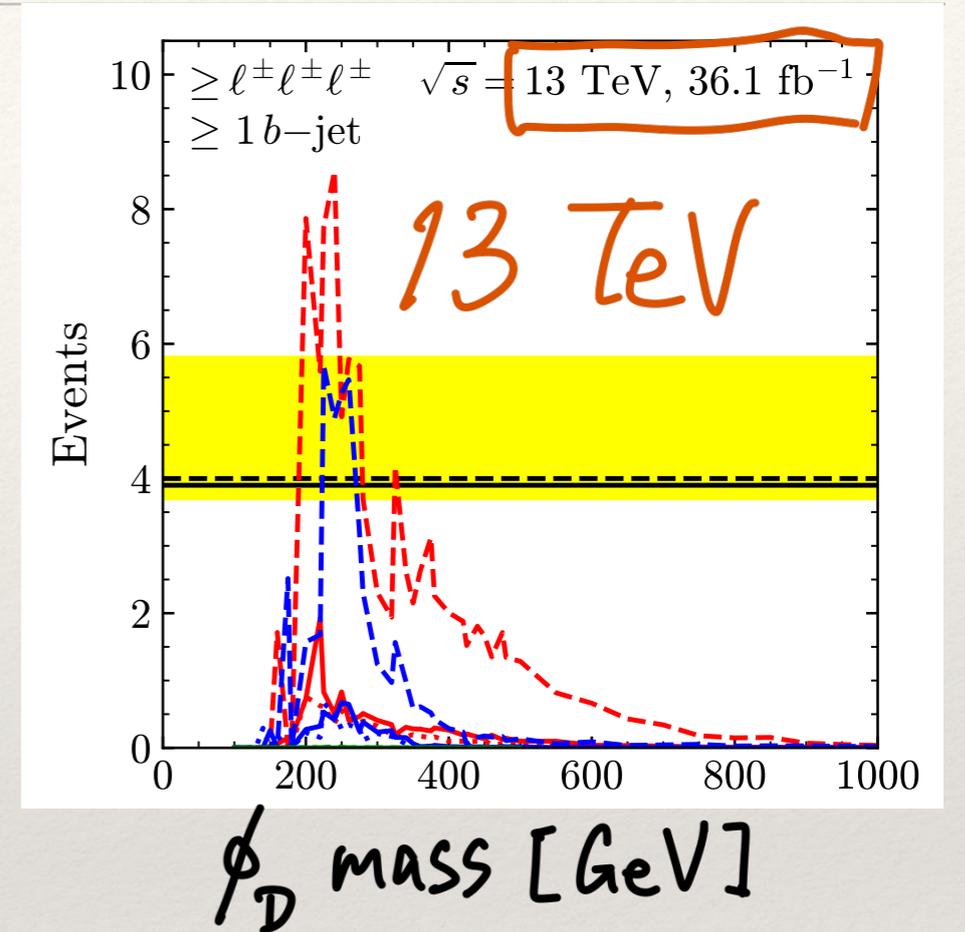
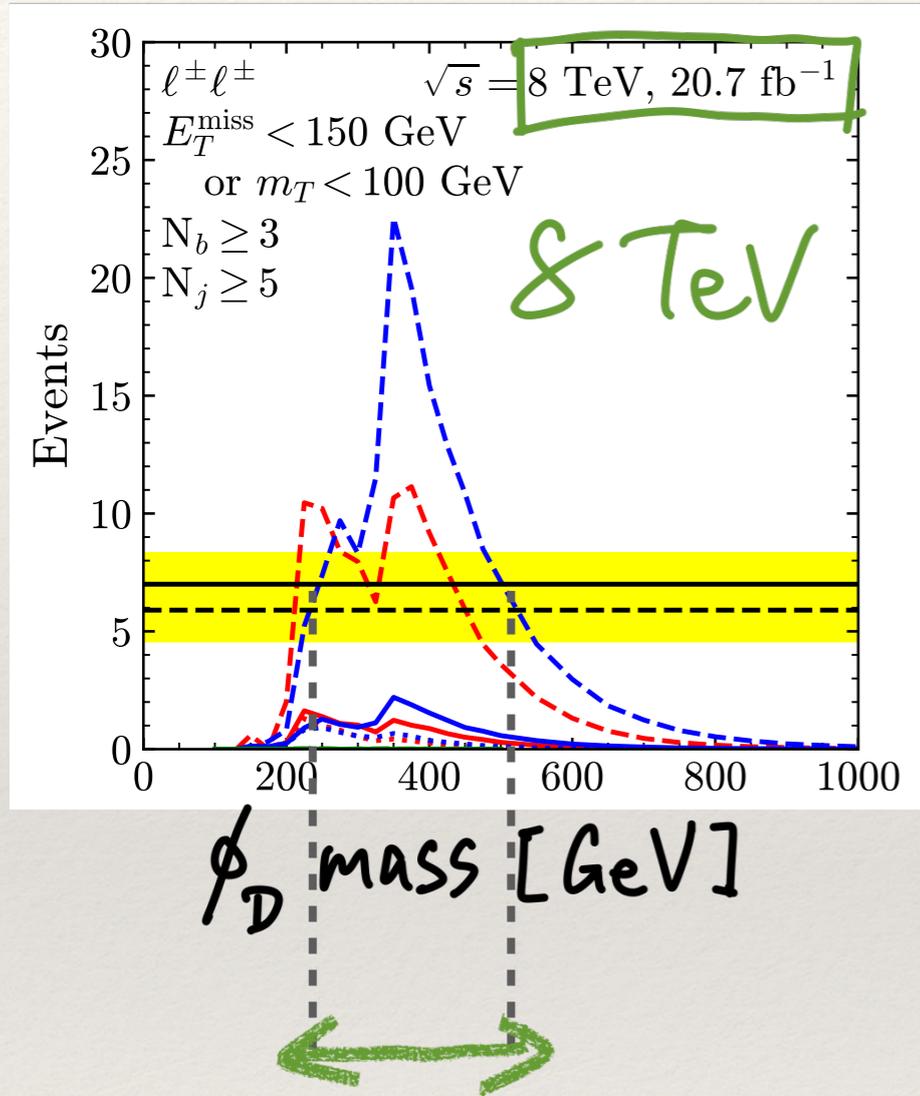
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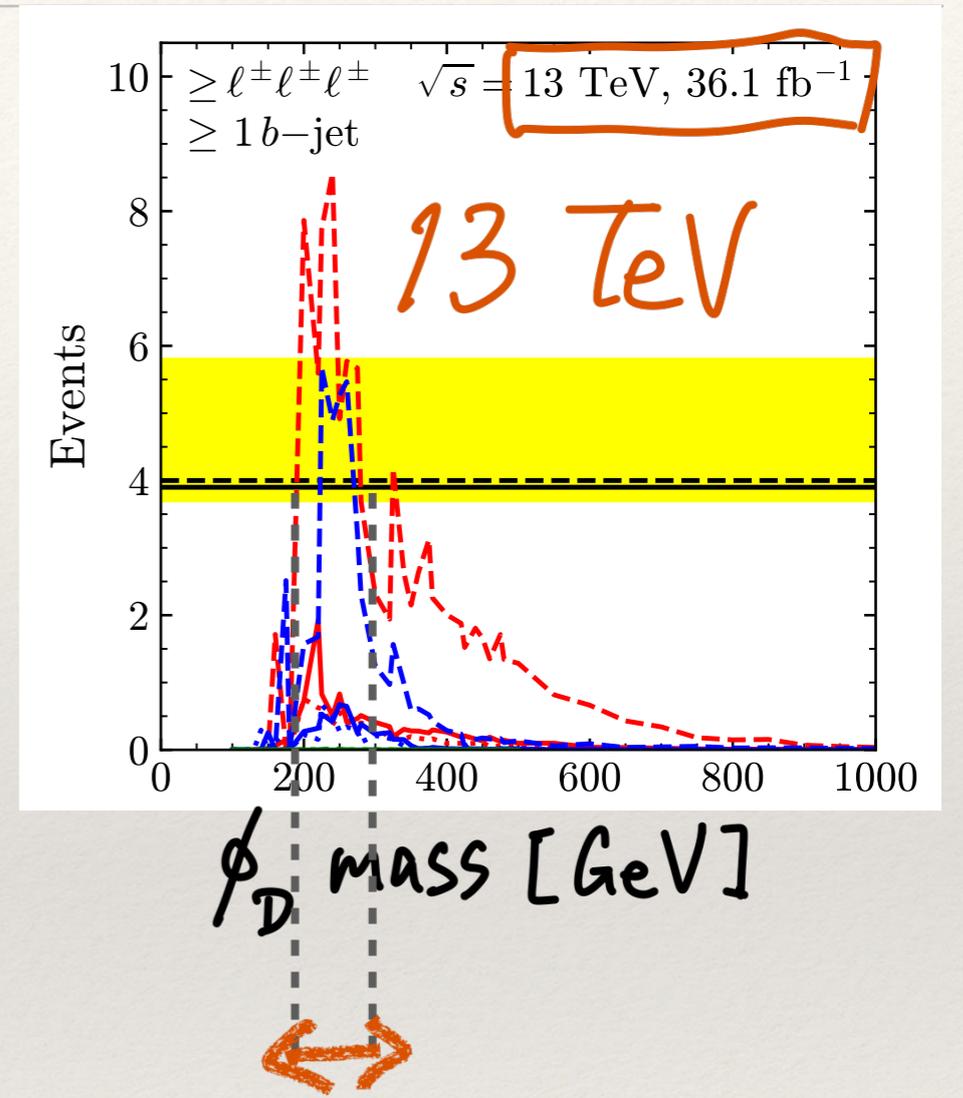
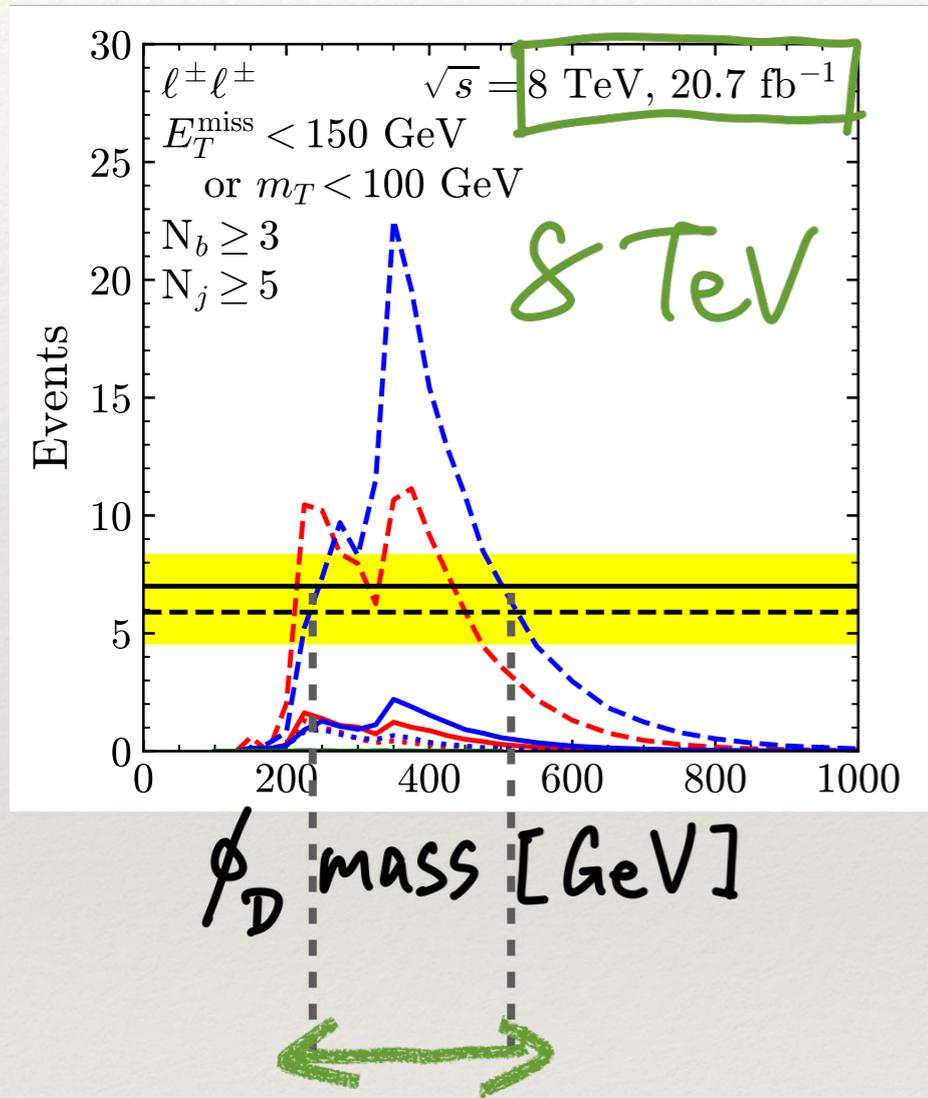
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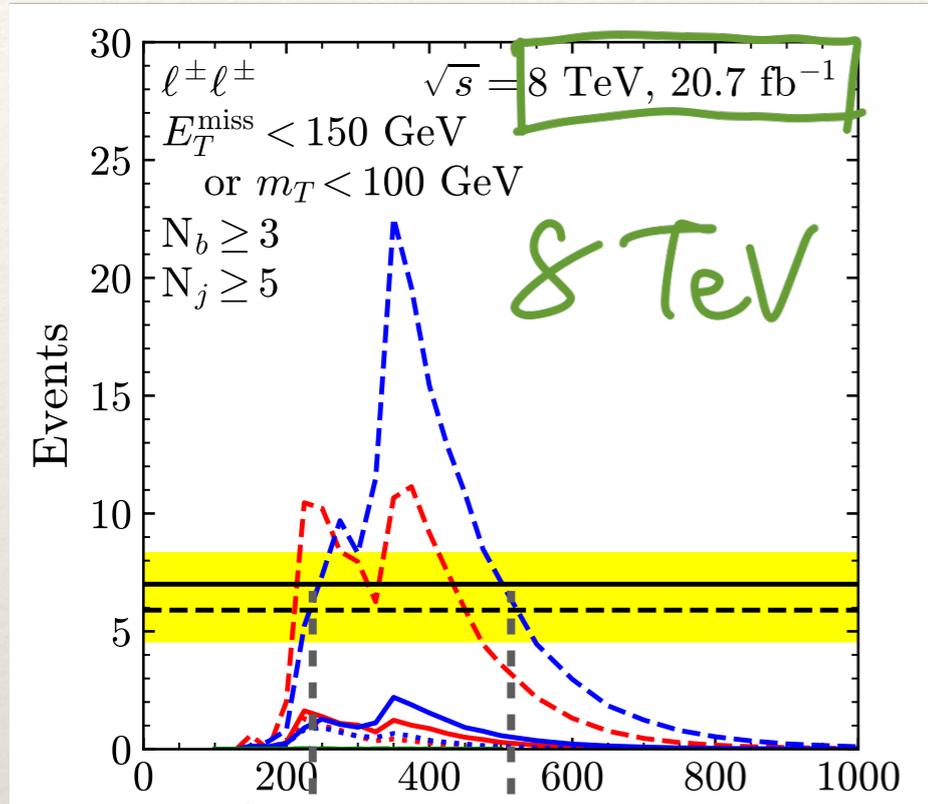
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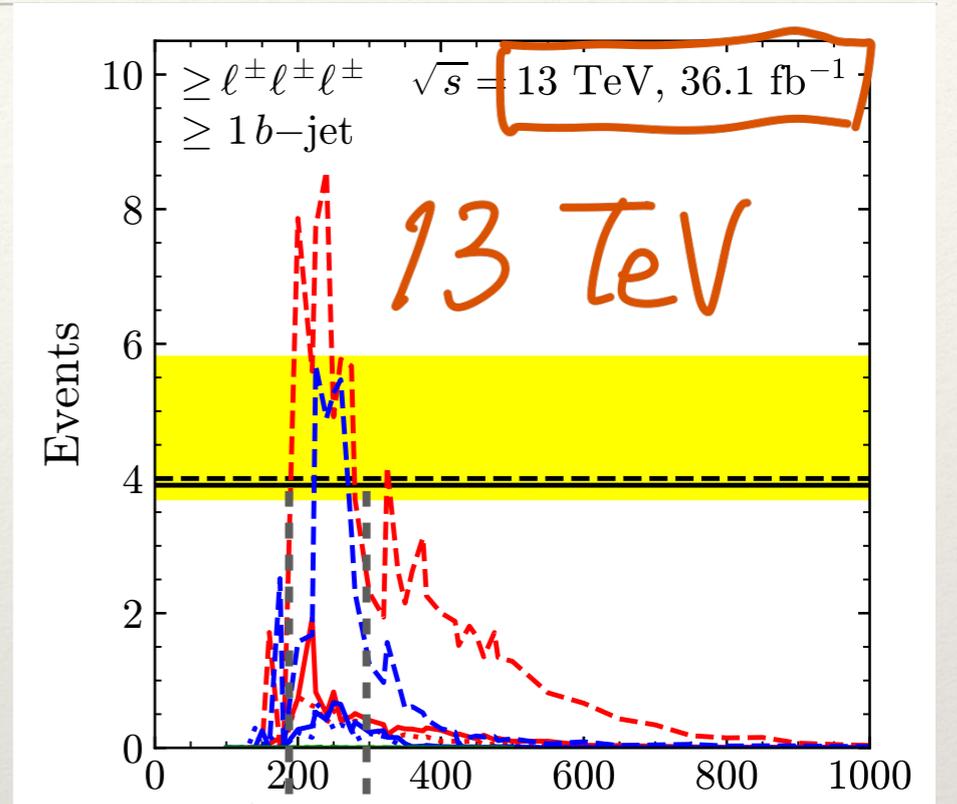
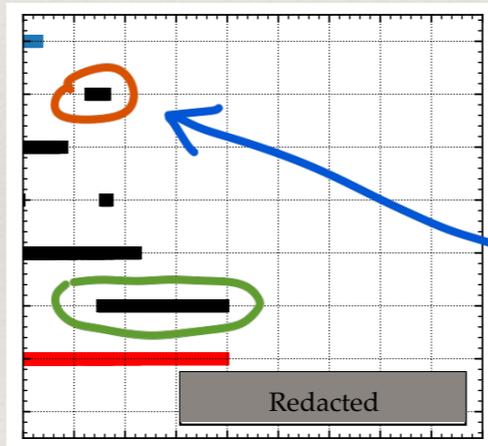
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ϕ_D mass [GeV]



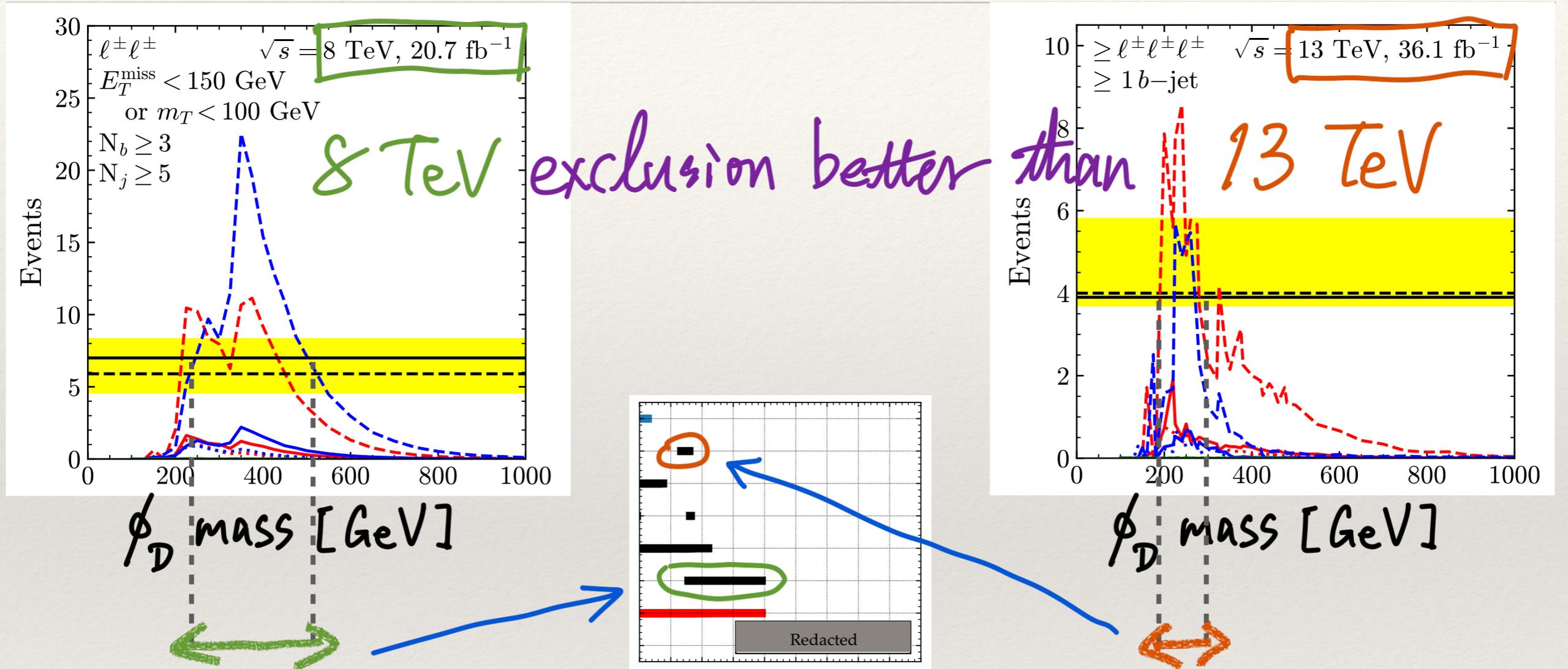
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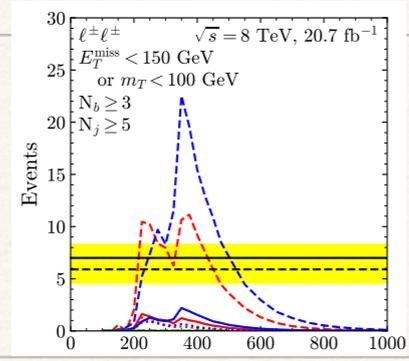
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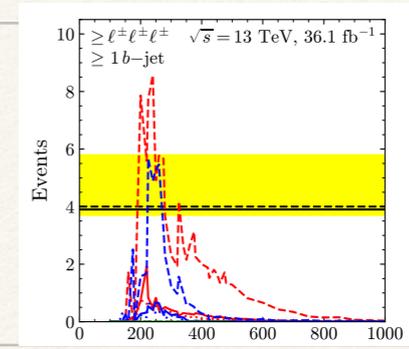
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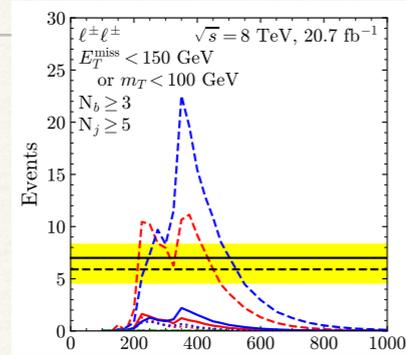


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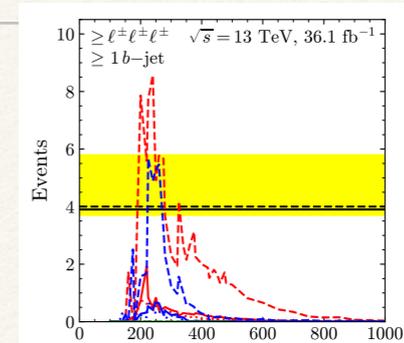


WHY ?



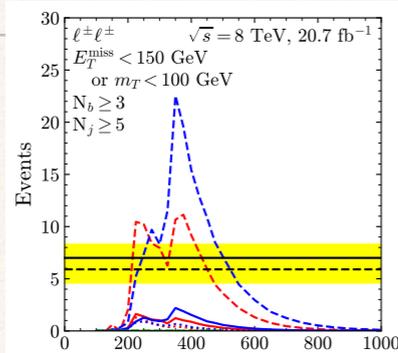


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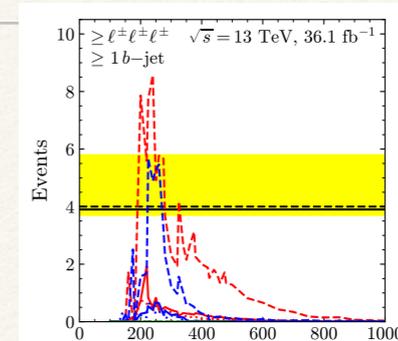


8 TeV search:

- ❖ ATLAS-CONF-2013-007, same sign lepton, has three signal regions.
- ❖ One region requires at least three b -jets.
- ❖ And is looking at small MET.



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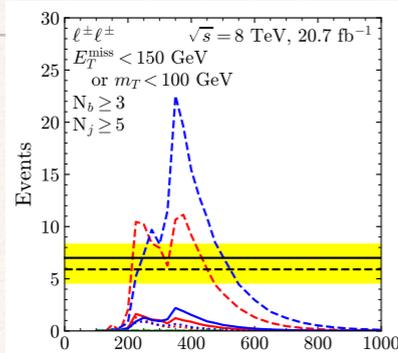


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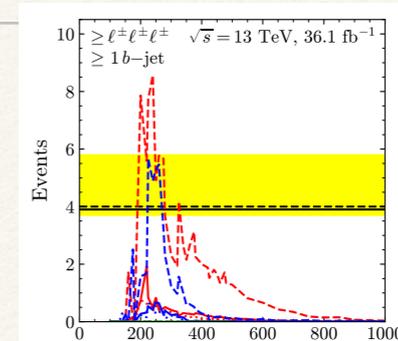
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13 TeV search:

- ❖ *JHEP 09* (2017) 084, also same sign lepton, has 19 signal regions.
- ❖ None of them requires three b -jets or more.
- ❖ All regions except one either require large **Effective Mass** or large MET.



WHY?

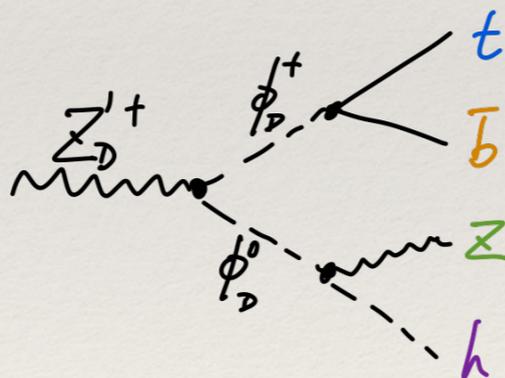
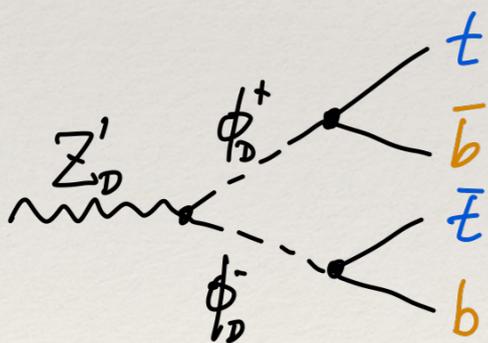


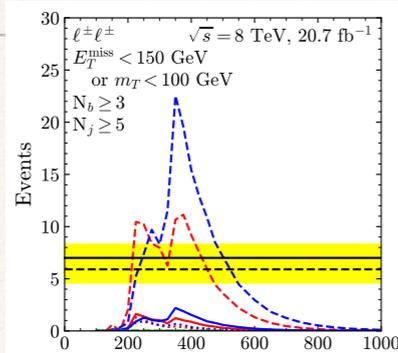
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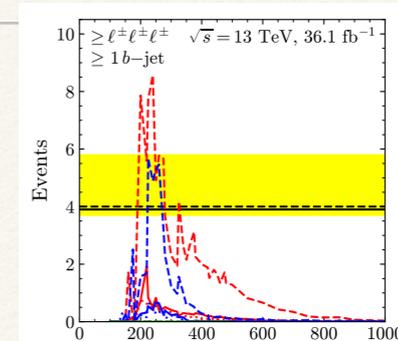
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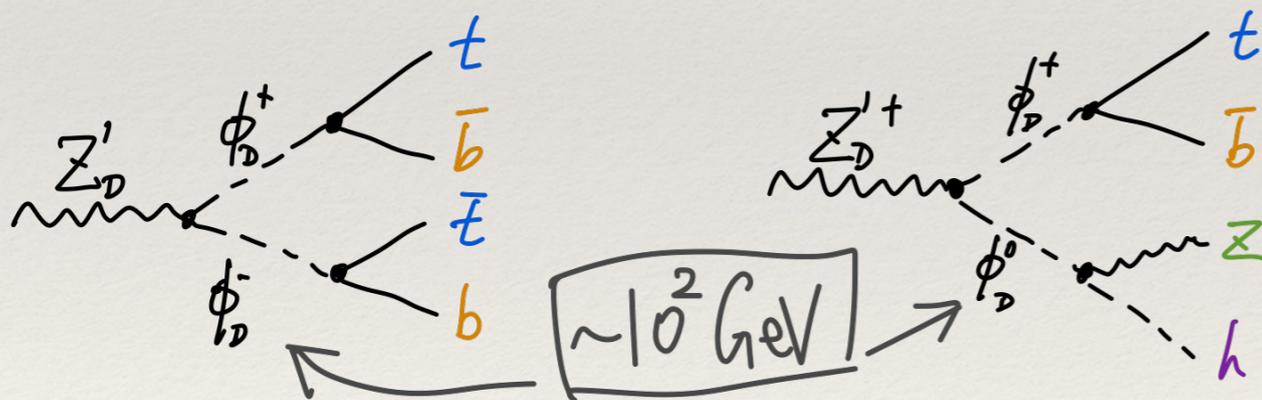


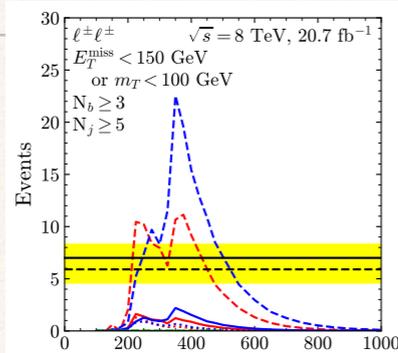
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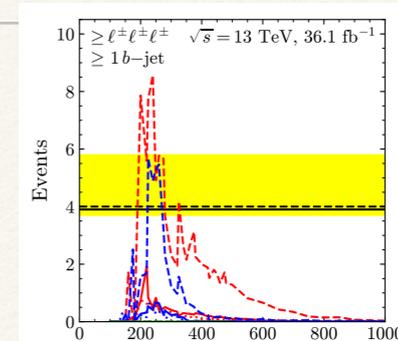
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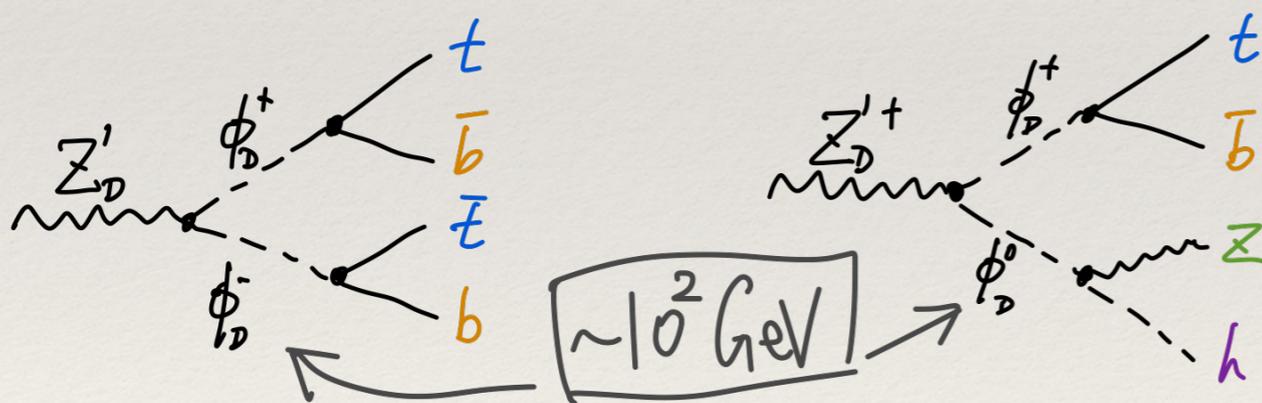


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Remember, the characteristic features of our final states are:

Multiple b -jets

$M_{\text{eff}} < 1 \text{ TeV}$

Low MET

A closer look at 13 TeV

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)



JHEP 09 (2017) 084



CERN-EP-2017-108
5th October 2017

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Rpc2L2bS	$\geq 2\text{SS}$	≥ 2	≥ 6	> 25	> 200	> 600	> 0.25	–
Rpc2L2bH	$\geq 2\text{SS}$	≥ 2	≥ 6	> 25	–	> 1800	> 0.15	–
Rpc2Lsoft1b	$\geq 2\text{SS}$	≥ 1	≥ 6	> 25	> 100	–	> 0.3	$20,10 < p_{\text{T}}^{\ell_1}, p_{\text{T}}^{\ell_2} < 100 \text{ GeV}$
Rpc2Lsoft2b	$\geq 2\text{SS}$	≥ 2	≥ 6	> 25	> 200	> 600	> 0.25	$20,10 < p_{\text{T}}^{\ell_1}, p_{\text{T}}^{\ell_2} < 100 \text{ GeV}$
Rpc2L0bS	$\geq 2\text{SS}$	$= 0$	≥ 6	> 25	> 150	–	> 0.25	–
Rpc2L0bH	$\geq 2\text{SS}$	$= 0$	≥ 6	> 40	> 250	> 900	–	–
Rpc3L0bS	≥ 3	$= 0$	≥ 4	> 40	> 200	> 600	–	–
Rpc3L0bH	≥ 3	$= 0$	≥ 4	> 40	> 200	> 1600	–	–
Rpc3L1bS	≥ 3	≥ 1	≥ 4	> 40	> 200	> 600	–	–
Rpc3L1bH	≥ 3	≥ 1	≥ 4	> 40	> 200	> 1600	–	–
Rpc2L1bS	$\geq 2\text{SS}$	≥ 1	≥ 6	> 25	> 150	> 600	> 0.25	–
Rpc2L1bH	$\geq 2\text{SS}$	≥ 1	≥ 6	> 25	> 250	–	> 0.2	–
Rpc3LSS1b	$\geq \ell^{\pm} \ell^{\pm} \ell^{\pm}$	≥ 1	–	–	–	–	–	veto $81 < m_{e^{\pm} e^{\pm}} < 101 \text{ GeV}$
Rpv2L1bH	$\geq 2\text{SS}$	≥ 1	≥ 6	> 50	–	> 2200	–	–
Rpv2L0b	$= 2\text{SS}$	$= 0$	≥ 6	> 40	–	> 1800	–	veto $81 < m_{e^{\pm} e^{\pm}} < 101 \text{ GeV}$
Rpv2L2bH	$\geq 2\text{SS}$	≥ 2	≥ 6	> 40	–	> 2000	–	veto $81 < m_{e^{\pm} e^{\pm}} < 101 \text{ GeV}$
Rpv2L2bS	$\geq \ell^{-} \ell^{-}$	≥ 2	≥ 3	> 50	–	> 1200	–	–
Rpv2L1bS	$\geq \ell^{-} \ell^{-}$	≥ 1	≥ 4	> 50	–	> 1200	–	–
Rpv2L1bM	$\geq \ell^{-} \ell^{-}$	≥ 1	≥ 4	> 50	–	> 1800	–	–

A closer look at 13 TeV

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)



JHEP 09 (2017) 084



CERN-EP-2017-108
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Rpc2Lsoft1b	$\geq 2\text{SS}$	≥ 1	≥ 6	> 25	> 100	–	> 0.3	$20,10 < p_{\text{T}}^{\ell_1}, p_{\text{T}}^{\ell_2} < 100 \text{ GeV}$
Rpc2Lsoft2b	$\geq 2\text{SS}$	≥ 2	≥ 6	> 25	> 200	> 600	> 0.25	$20,10 < p_{\text{T}}^{\ell_1}, p_{\text{T}}^{\ell_2} < 100 \text{ GeV}$
Rpc2L0bS	$\geq 2\text{SS}$	$= 0$	≥ 6	> 25	> 150	–	> 0.25	–
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Rpc2L1bS	$\geq 2\text{SS}$	≥ 1	≥ 6	> 25	> 150	> 600	> 0.25	–
Rpc2L1bH	$\geq 2\text{SS}$	≥ 1	≥ 6	> 25	> 250	–	> 0.2	–
Rpc3LSS1b	$\geq \ell^{\pm} \ell^{\pm} \ell^{\pm}$	≥ 1	–	–	–	–	–	veto $81 < m_{e^{\pm} e^{\pm}} < 101 \text{ GeV}$
Rpv2L1bH	$\geq 2\text{SS}$	≥ 1	≥ 6	> 50	–	> 2200	–	–
Rpv2L0b	$= 2\text{SS}$	$= 0$	≥ 6	> 40	–	> 1800	–	veto $81 < m_{e^{\pm} e^{\pm}} < 101 \text{ GeV}$
Rpv2L2bH	$\geq 2\text{SS}$	≥ 2	≥ 6	> 40	–	> 2000	–	veto $81 < m_{e^{\pm} e^{\pm}} < 101 \text{ GeV}$
Rpv2L2bS	$\geq \ell^{-} \ell^{-}$	≥ 2	≥ 3	> 50	–	> 1200	–	–
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Rpv2L1bM	$\geq \ell^{-} \ell^{-}$	≥ 1	≥ 4	> 50	–	> 1800	–	–

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Rpc2Lsoft1b	$\geq 2\text{SS}$	≥ 1	≥ 6	> 25	> 100	–	> 0.3	$20,10 < p_{\text{T}}^{\ell_1}, p_{\text{T}}^{\ell_2} < 100 \text{ GeV}$
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Rpc3L1bH	≥ 3	≥ 1	≥ 4	> 40	> 200	> 1600	–	–
Rpc2L1bS	$\geq 2\text{SS}$	≥ 1	≥ 6	> 25	> 150	> 600	> 0.25	–
Rpc2L1bH	$\geq 2\text{SS}$	≥ 1	≥ 6	> 25	> 250	–	> 0.2	–
Rpc3LSS1b	$\geq \ell^{\pm} \ell^{\pm} \ell^{\pm}$	≥ 1	–	–	–	–	–	veto $81 < m_{e^{\pm} e^{\pm}} < 101 \text{ GeV}$
Rpv2L1bH	$\geq 2\text{SS}$	≥ 1	≥ 6	> 50	–	> 2200	–	–
Rpv2L0b	$= 2\text{SS}$	$= 0$	≥ 6	> 40	–	> 1800	–	veto $81 < m_{e^{\pm} e^{\pm}} < 101 \text{ GeV}$
Rpv2L2bH	$\geq 2\text{SS}$	≥ 2	≥ 6	> 40	–	> 2000	–	veto $81 < m_{e^{\pm} e^{\pm}} < 101 \text{ GeV}$
Rpv2L2bS	$\geq \ell^{-} \ell^{-}$	≥ 2	≥ 3	> 50	–	> 1200	–	–
Rpv2L1bS	$\geq \ell^{-} \ell^{-}$	≥ 1	≥ 4	> 50	–	> 1200	–	–
Rpv2L1bM	$\geq \ell^{-} \ell^{-}$	≥ 1	≥ 4	> 50	–	> 1800	–	–

A closer look at 13 TeV

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)



JHEP 09 (2017) 084



CERN-EP-2017-108
5th October 2017

Search for supersymmetry in final states with two same-sign or three leptons and jets using 36 fb^{-1} of $\sqrt{s} = 13 \text{ TeV}$ pp collision data with the ATLAS detector

The ATLAS Collaboration

Signal region	$N_{\text{leptons}}^{\text{signal}}$	$N_{b\text{-jets}}$	N_{jets}	$p_{\text{T}}^{\text{jet}}$ [GeV]	$E_{\text{T}}^{\text{miss}}$ [GeV]	m_{eff} [GeV]	$E_{\text{T}}^{\text{miss}}/m_{\text{eff}}$	Other
Rpc2L2bS	$\geq 2\text{SS}$	≥ 2	≥ 6	> 25	> 200	> 600	> 0.25	–
Rpc2L2bH	$\geq 2\text{SS}$	≥ 2	≥ 6	> 25	–	> 1800	> 0.15	–
Rpc2Lsoft1b	$\geq 2\text{SS}$	≥ 1	≥ 6	> 25	> 100	–	> 0.3	$20,10 < p_{\text{T}}^{\ell_1}, p_{\text{T}}^{\ell_2} < 100 \text{ GeV}$
Rpc2Lsoft2b	$\geq 2\text{SS}$	≥ 2	≥ 6	> 25	> 200	> 600	> 0.25	$20,10 < p_{\text{T}}^{\ell_1}, p_{\text{T}}^{\ell_2} < 100 \text{ GeV}$
Rpc2L0bS	$\geq 2\text{SS}$	$= 0$	≥ 6	> 25	> 150	–	> 0.25	–
Rpc2L0bH	$\geq 2\text{SS}$	$= 0$	≥ 6	> 40	> 250	> 900	–	–
Rpc3L0bS	≥ 3	$= 0$	≥ 4	> 40	> 200	> 600	–	–
Rpc3L0bH	≥ 3	$= 0$	≥ 4	> 40	> 200	> 1600	–	–
Rpc3L1bS	≥ 3	≥ 1	≥ 4	> 40	> 200	> 600	–	–
Rpc3L1bH	≥ 3	≥ 1	≥ 4	> 40	> 200	> 1600	–	–
Rpc2L1bS	$\geq 2\text{SS}$	≥ 1	≥ 6	> 25	> 150	> 600	> 0.25	–
Rpc2L1bH	$\geq 2\text{SS}$	≥ 1	≥ 6	> 25	> 250	–	> 0.2	–
Rpc3LSS1b	$\geq \ell^{\pm} \ell^{\pm} \ell^{\pm}$	≥ 1	–	–	–	–	–	veto $81 < m_{e^{\pm} e^{\pm}} < 101 \text{ GeV}$
Rpv2L1bH	$\geq 2\text{SS}$	≥ 1	≥ 6	> 50	–	> 2200	–	–
Rpv2L0b	$= 2\text{SS}$	$= 0$	≥ 6	> 40	–	> 1800	–	veto $81 < m_{e^{\pm} e^{\pm}} < 101 \text{ GeV}$
Rpv2L2bH	$\geq 2\text{SS}$	≥ 2	≥ 6	> 40	–	> 2000	–	veto $81 < m_{e^{\pm} e^{\pm}} < 101 \text{ GeV}$
Rpv2L2bS	$\geq \ell^{-} \ell^{-}$	≥ 2	≥ 3	> 50	–	> 1200	–	–
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Only one signal region has no requirements on MET and Effective Mass.

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Make sense ↻

Signal region	$N_{\text{leptons}}^{\text{signal}}$	$N_{b\text{-jets}}$	N_{jets}	$p_{\text{T}}^{\text{jet}}$ [GeV]	$E_{\text{T}}^{\text{miss}}$ [GeV]	m_{eff} [GeV]	$E_{\text{T}}^{\text{miss}}/m_{\text{eff}}$	Other
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Many Other Searches

Google bing

Baidu 百度 Yandex



YAHOO!



DuckDuckGo

Many Other Searches

Search	\sqrt{s} [TeV]	Comments
ATLAS search for a CP-odd Higgs boson decaying to Zh [142]	8	Veto events with more than 2 b-tagged jets kills efficiency
ATLAS search for $t\bar{t}$ resonances [143]	8	Must have exactly one lepton. We have too many jets, confuses search
CMS Pair produced leptoquark [144]	8	Looking for $b\bar{b}\tau^+\tau^-$. Has minor sensitivity to overall rates, would do better with shape analysis but not enough data is provided to recast this.
ATLAS search for SUSY in final states with multiple b-jets [145]	13	Looking for heavy states, so demands large E_T^{miss} and m_{eff}
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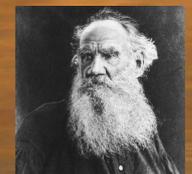
Kribs, Martin, Ostdiek, TT
1809.10184

Many Other Searches

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All happy families are alike; each unhappy family is unhappy in its own way.

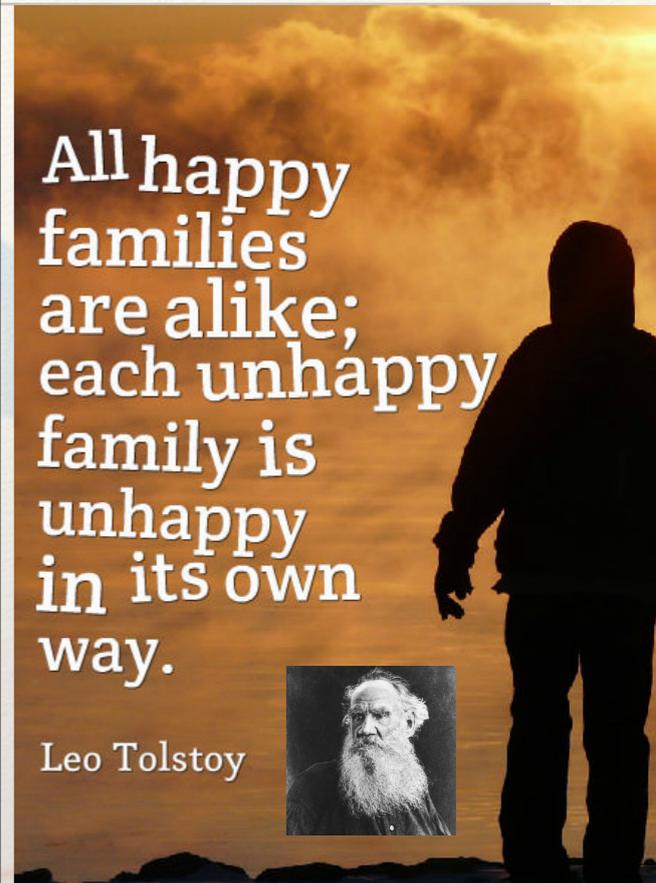
Leo Tolstoy



Kribs, Martin, Ostdiek, TT
1809.10184

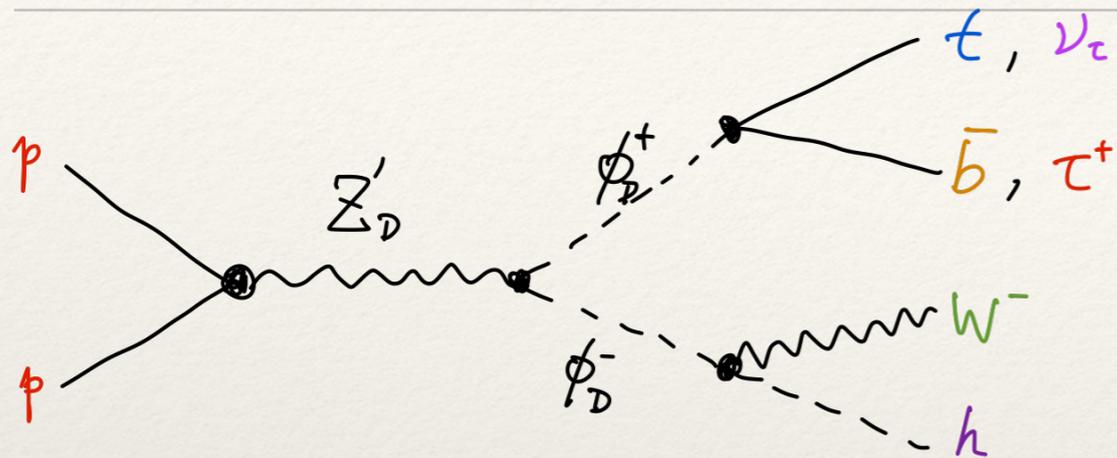
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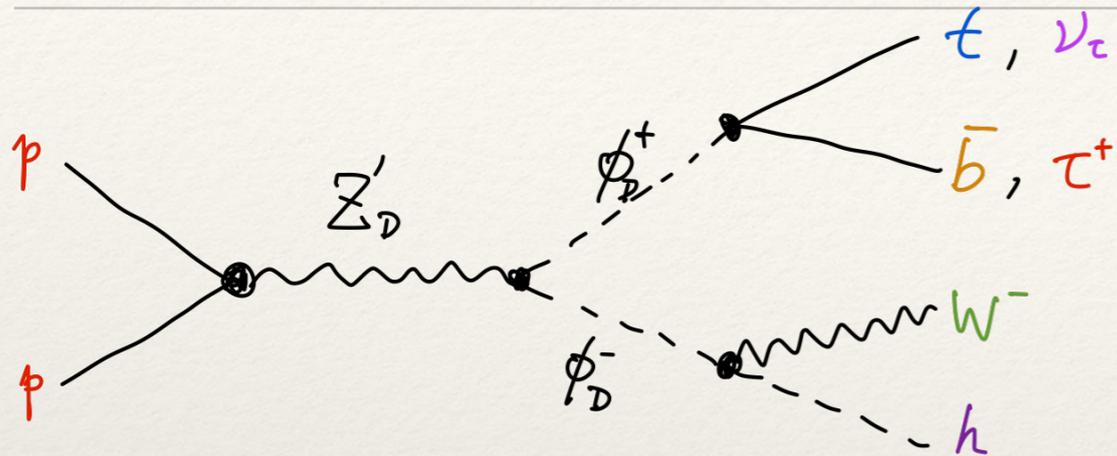


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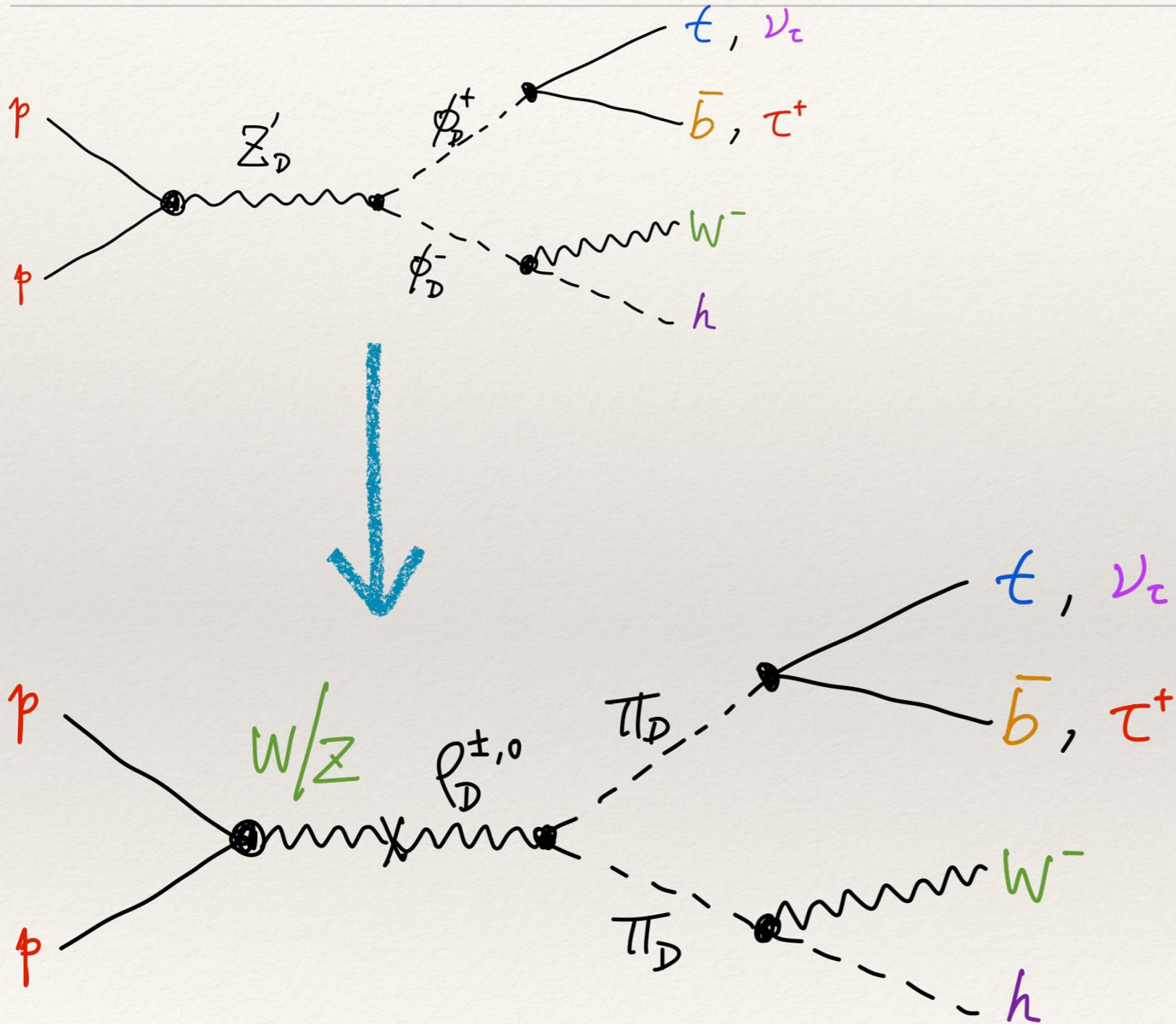
UV interpretation



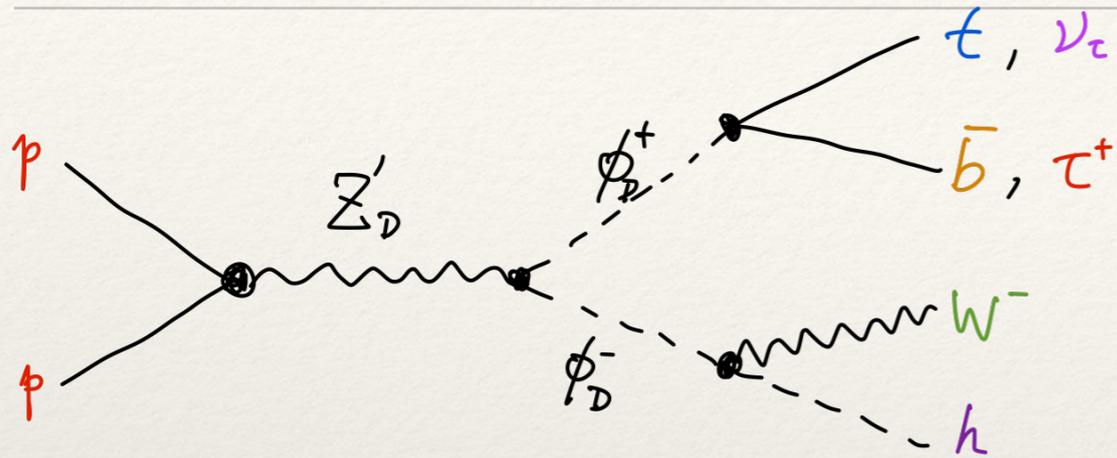
UV interpretation



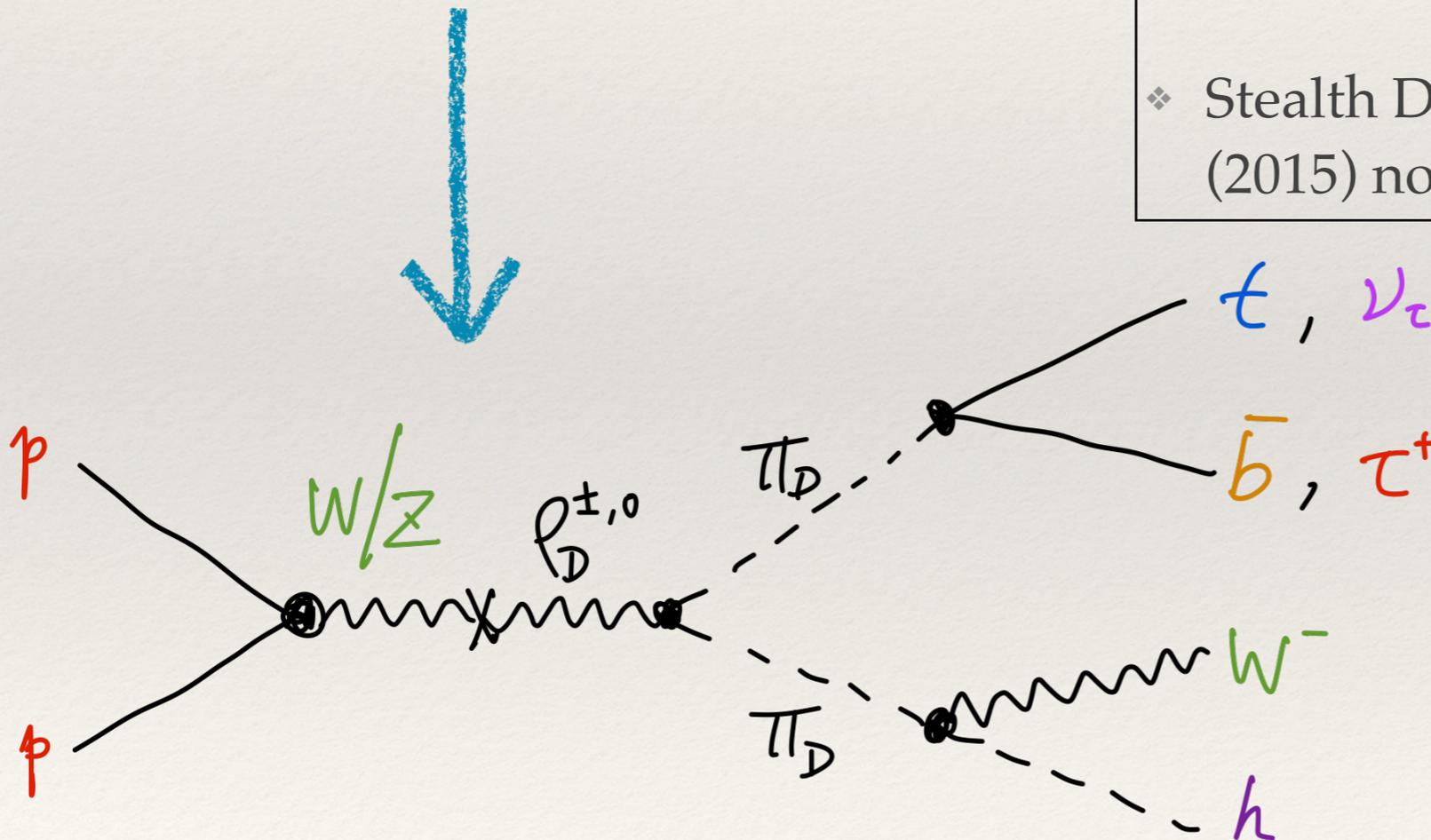
UV interpretation



UV interpretation



- ❖ Bosonic Technicolor, *Nucl. Phys.* B347 (1990) 625–650
- ❖ Strongly-coupled Induced EWSB, *JHEP* 03 (2015) 017
- ❖ Stealth Dark Matter, *Phys. Rev.* D92 (2015) no. 7, 075030



Summary

- ❖ We studied a dark sector model within the reach of **LHC**.
- ❖ So far **8 TeV** analysis yielded the strongest constraints.
- ❖ **13 TeV** searches have various issues, including **b**-jets, **Effective Mass** and **MET**, etc.
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- ❖

Summary

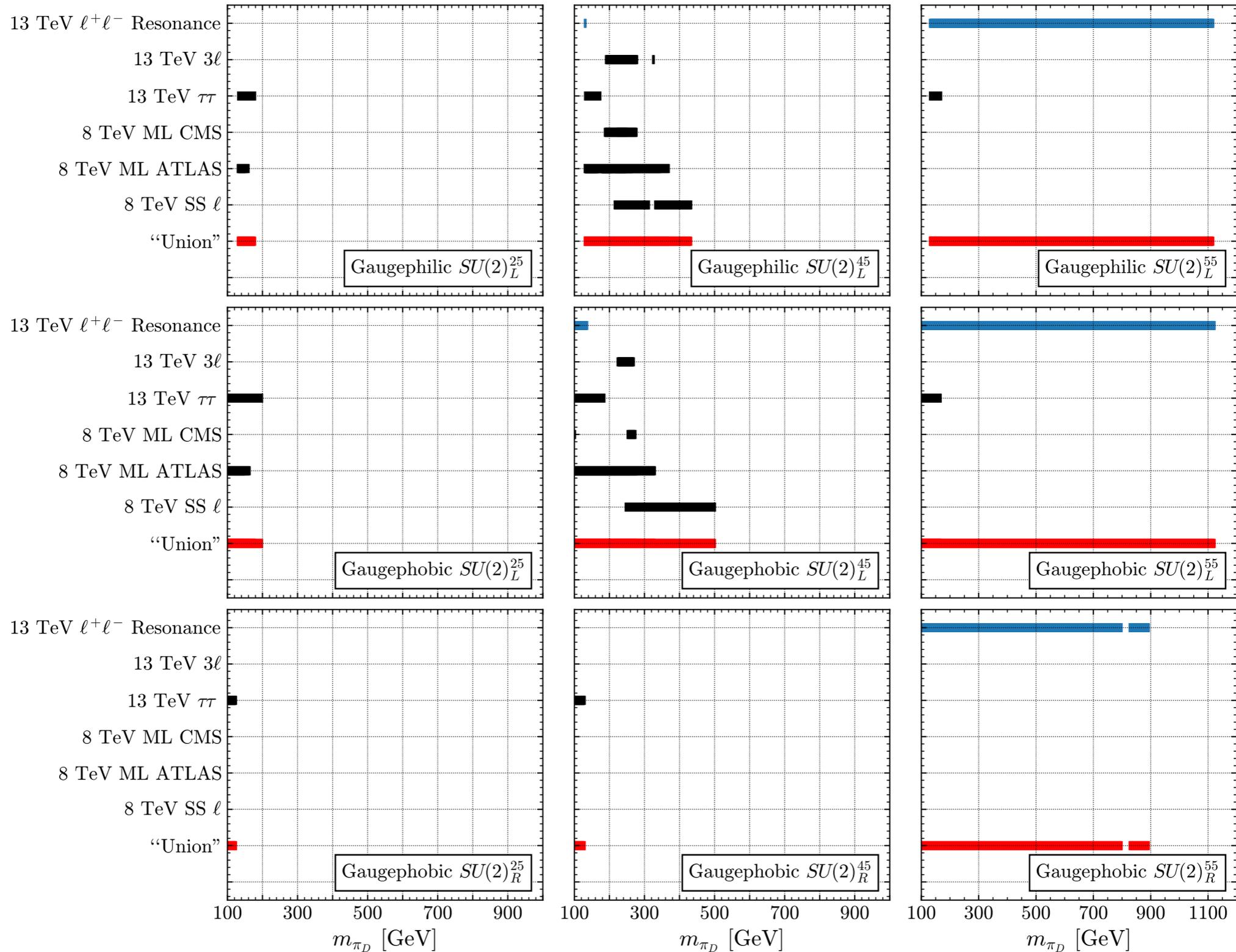
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- ❖ **STAY TUNED!**

Thank you!

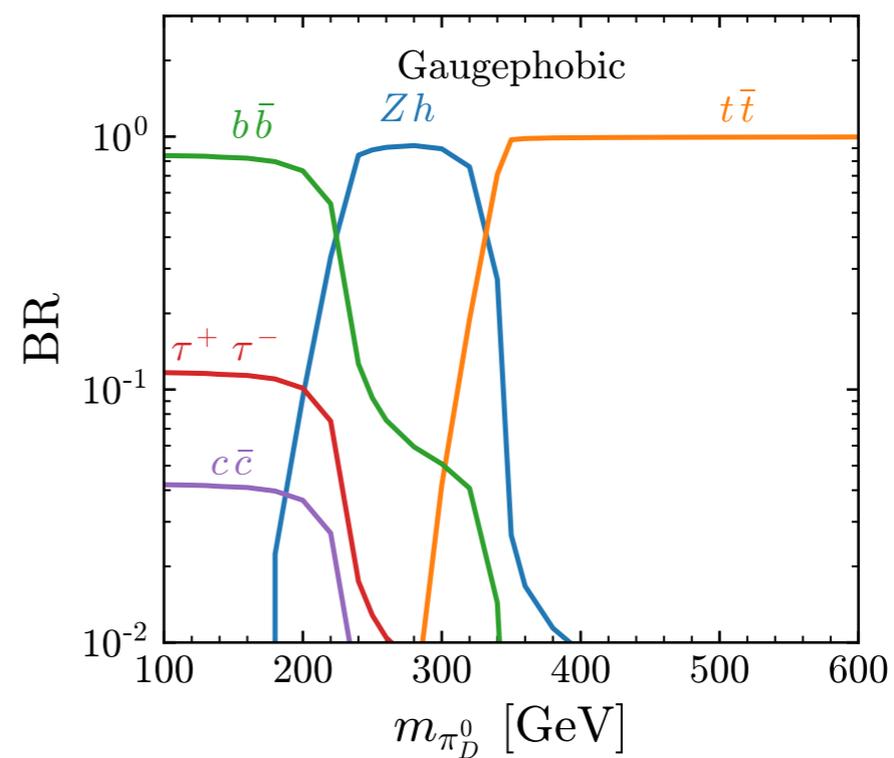
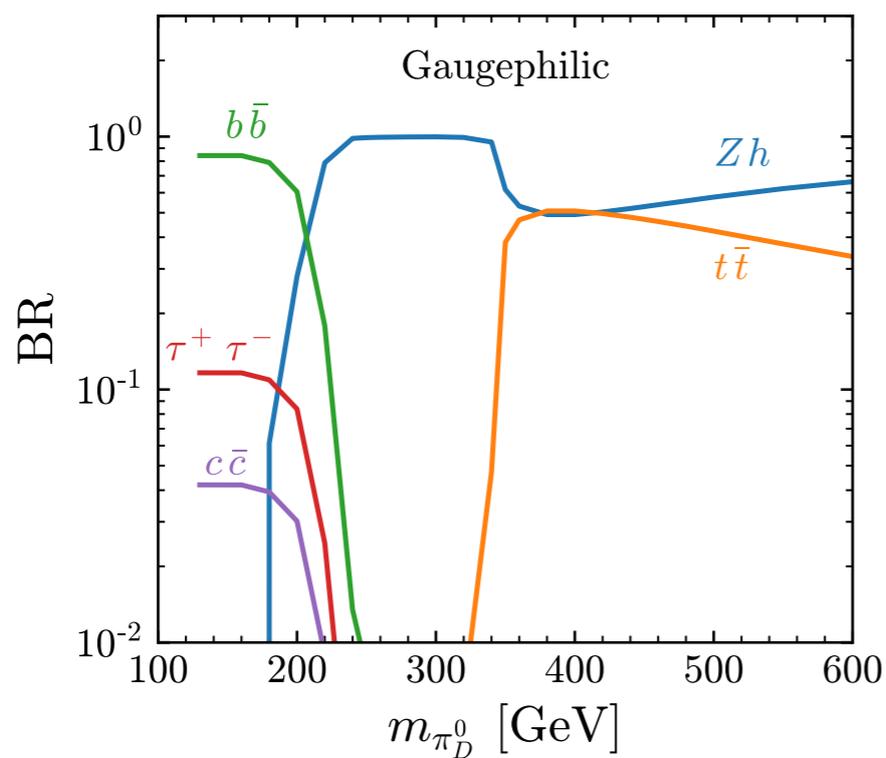
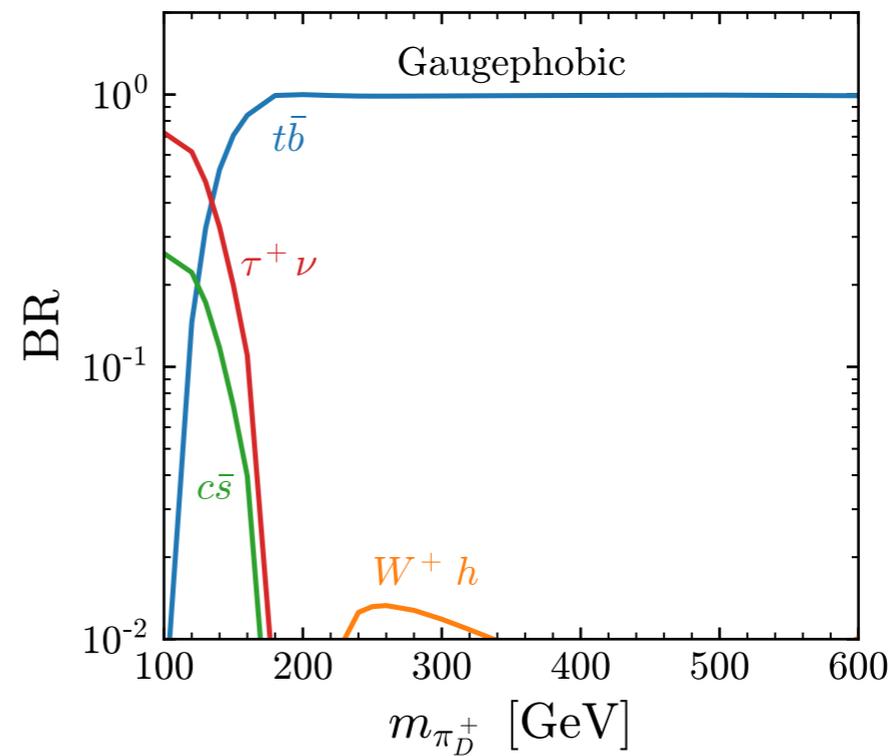
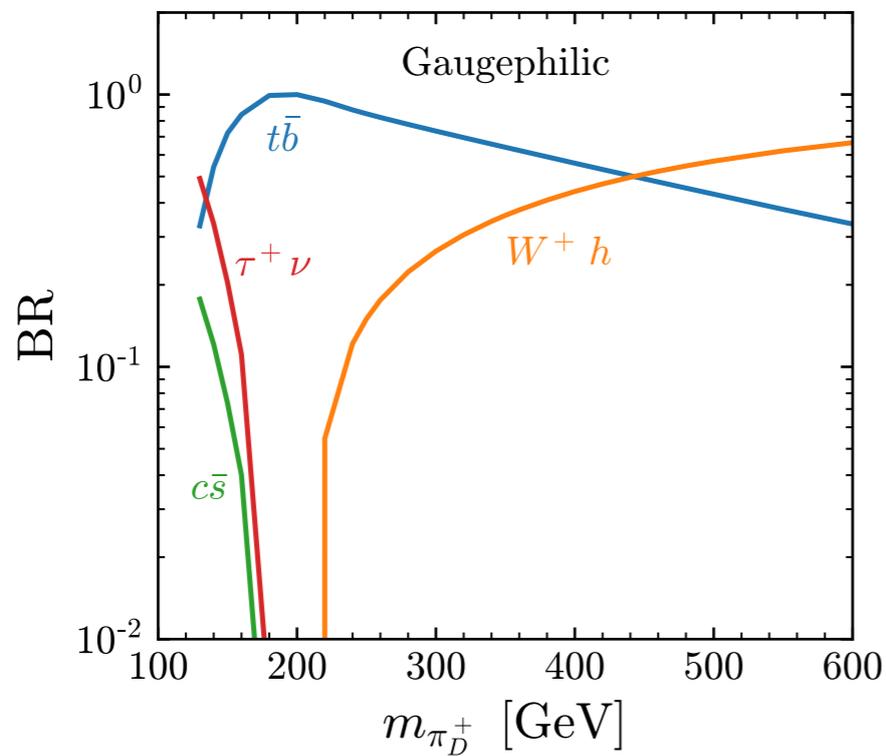
Have a nice



Back up money plot



Back up money plot



Back up money plot

