Search for the production of an excited bottom quark decaying to tW in proton-proton collisions at $\sqrt{s}$ = 13.6TeV

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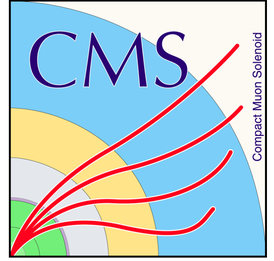
OutLine



- Introduction
- Run2 Results Overview
- Run3 New
- Run3 Results
- Summary

Introduction

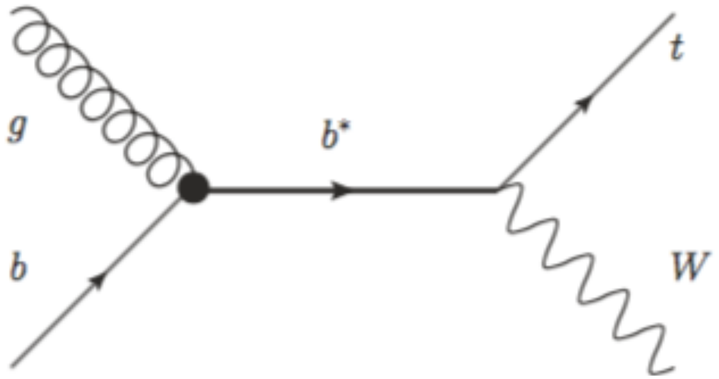
- In LHC, b* can be produced in g+b by strong interaction:

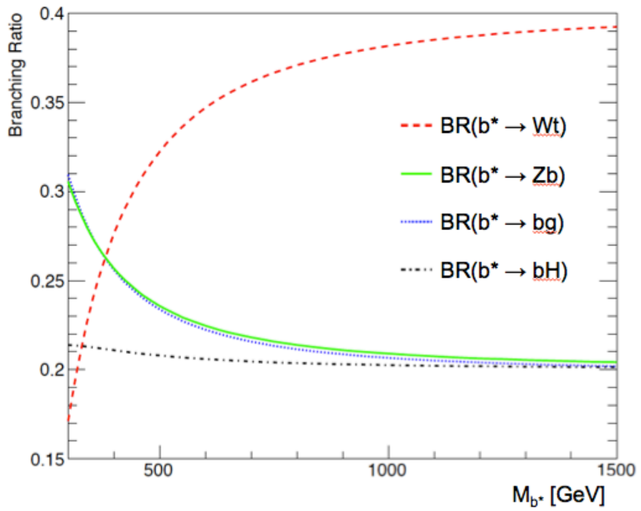
$$\mathscr{L} = \frac{g_s}{2\Lambda} G_{\mu,\nu} \bar{b} \sigma^{\mu,\nu} (\kappa_L^b P_L + \kappa_R^b P_R) b^* + h.c$$

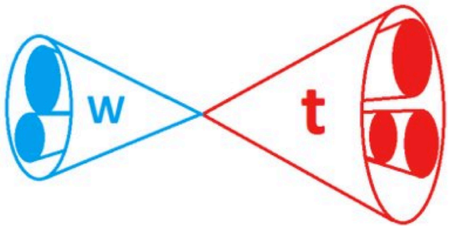
- And decays via tW by the weak interaction:

$$\mathscr{L} = \frac{g_2}{\sqrt{2}} W_\mu^+ \bar{t} \gamma^\mu (g_L P_L + g_R P_R) b^* + h.c$$

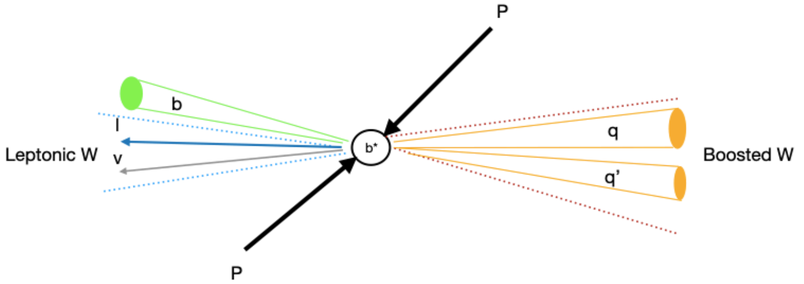
- tW channel dominates when $M_{b^*} > 400\text{GeV}$.
  3 final states:



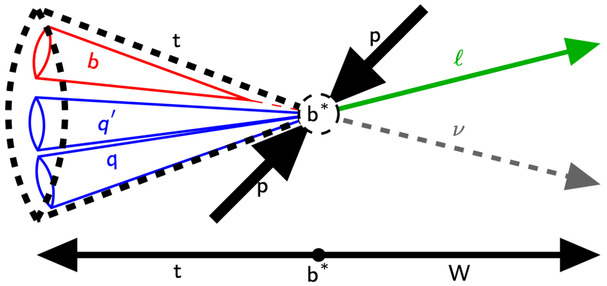




All hadronic[1]



Leptonic top + Hadronic W[2]



Hadronic top + Leptonic W[3]

Run2 Results Overview

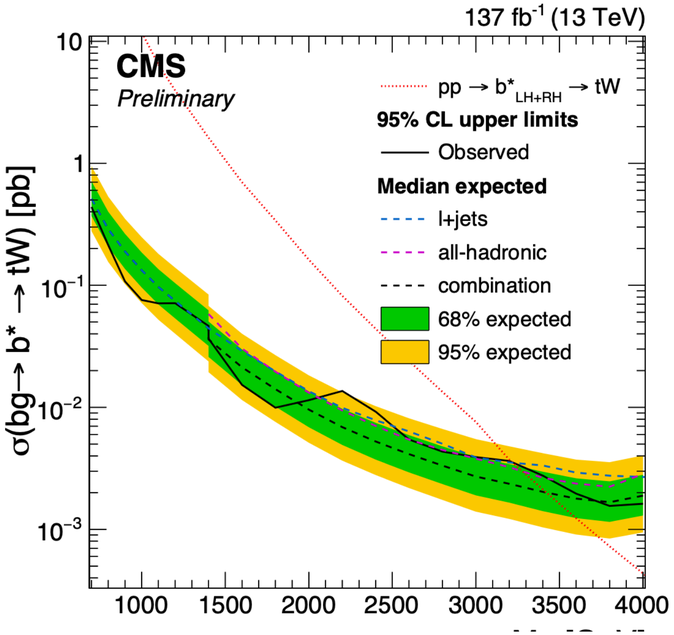
- Existing Run2 results:
  - b* search in full hadronic final state at13TeV in CMS, B2G-19-003.
  - b* search in lepton + jet channel at 13TeV in CMS, B2G-20-010.
  - b* search in tW channel at 13TeV in CMS, B2G-21-005.
- B2G-19-003 and B2G-20-010 had been combined in Run2.

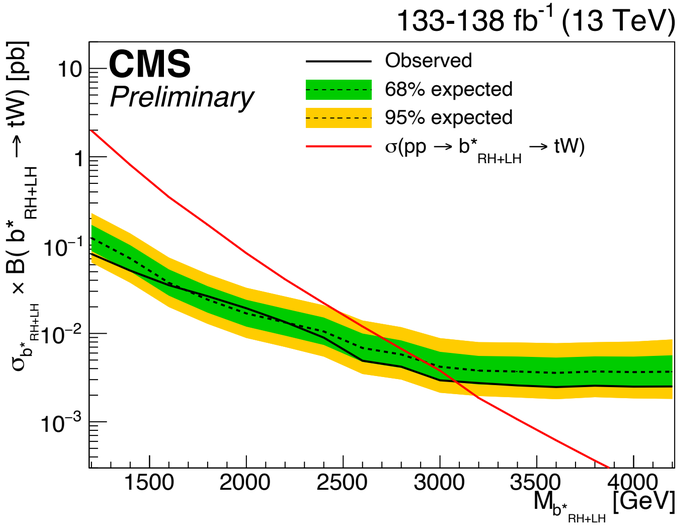
Mass limits [TeV]

Chirality	Median expected l+jets	Median expected all-hadronic	Median expected combination	Observed combination
LH	2.95	2.95	3.09	2.95
RH	3.02	3.02	3.17	3.03
VL	3.22	3.28	3.43	3.22

- B2G-21-005:

Limit (TeV)	LH	RH	VL
Observed	2.3	2.7	3.1
Expected	2.3	2.4	2.9





Run3 Overview

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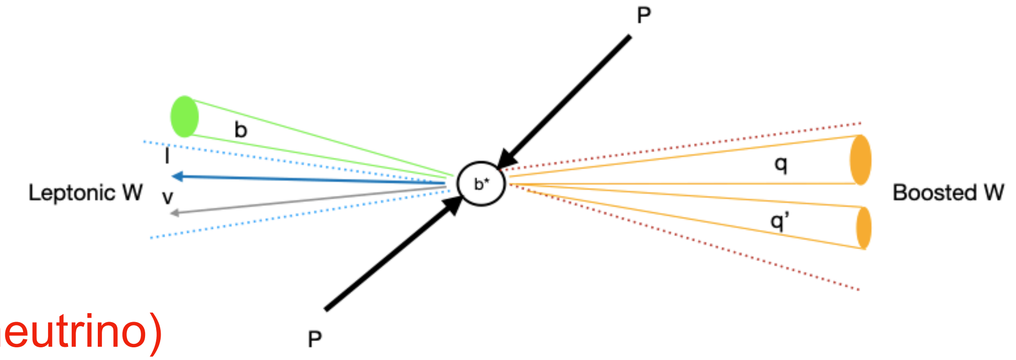
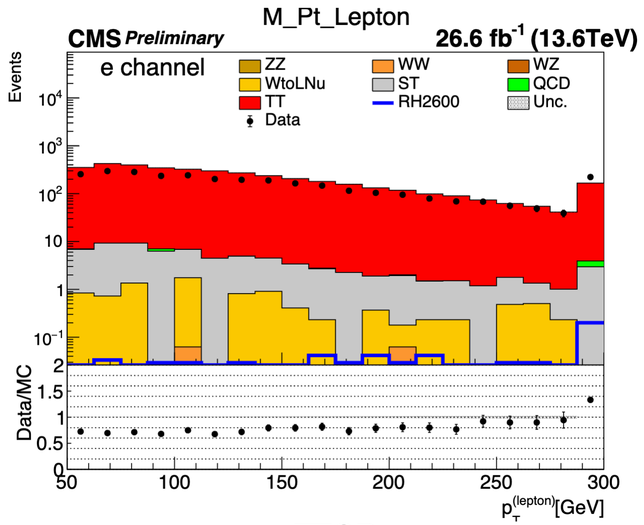
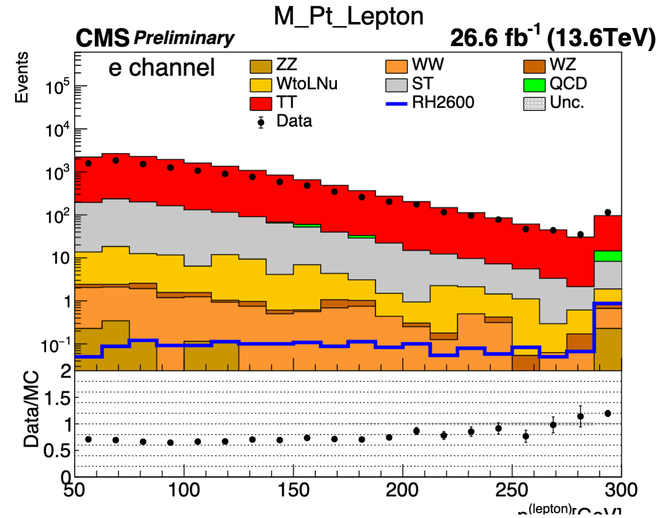
- We choose leptonic top + hadronic W as our final state.
  Final state:
  high pt Top: lepton, neutrino and b jet + Boosted W jet.
- Advantage of this final state:
  Only one lepton: easy to trigger, efficiency is known
  Leptonic Top and hadronic W: we can obtain invariant mass of b*(only 1 neutrino)



- Run3 update: preselections(b tag and W tag method,See back up) , using machine learning(planned).
- Run3 status:
  - ★ MC signal samples(b*->tW @13.6 TeV, 1.2TeV-4.2TeV) have been produced successfully.
  - ★ Data/MC in preselection region and TTCR looks fine.
  - ★ Set expected limit with 13.6 TeV b* signal.
  - ★ Working on applying corrections and systematics.



TTCR



Preselection

Run3 Analysis Strategy

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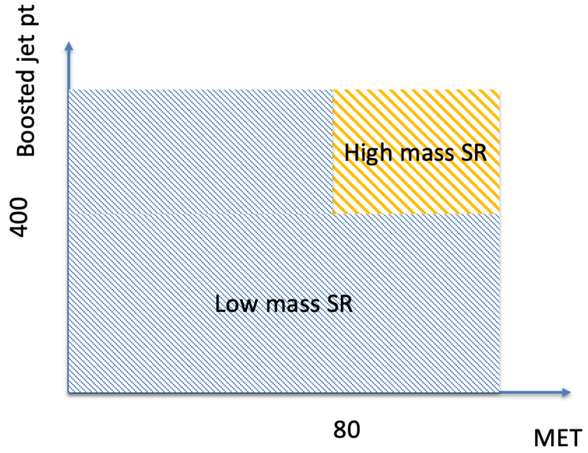
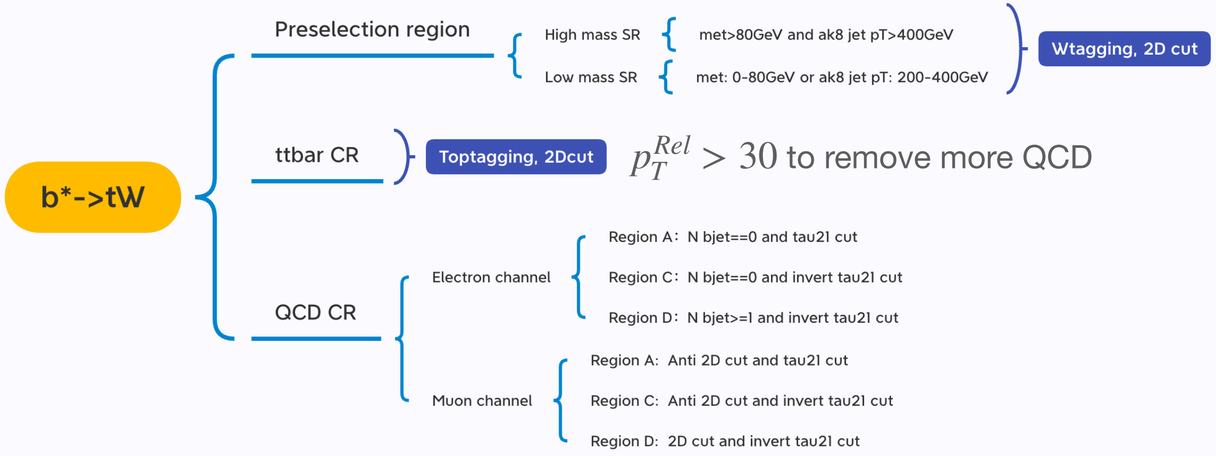
- SR definition: ✔
  - Cut optimization performed in preselection region to improve limit sensitivity.
  - Additional MET and AK8 jet pT selections are used to defined two SRs:
    - chosen by compromise between the expected sensitivity and M_{tW} distribution statistical precision.
- $t\bar{t}$ template take from MC, the uncertainties will be constrained by simultaneous fit to $t\bar{t}$ CR and SRs.
- QCD background will be predicted from data driven(ABCD method): both shape and normalization. ✔
- The other backgrounds are predicted from MC directly. ✔
- Using ML to enhance the separation between signal and background(Planned). NEW
- Fit high/low mass SR, QCD CRs and TTCR simultaneously(Future).
- Use asymptotic CLs method to set limit. (combine tool) ✔



Region definition



Run3 Early Results

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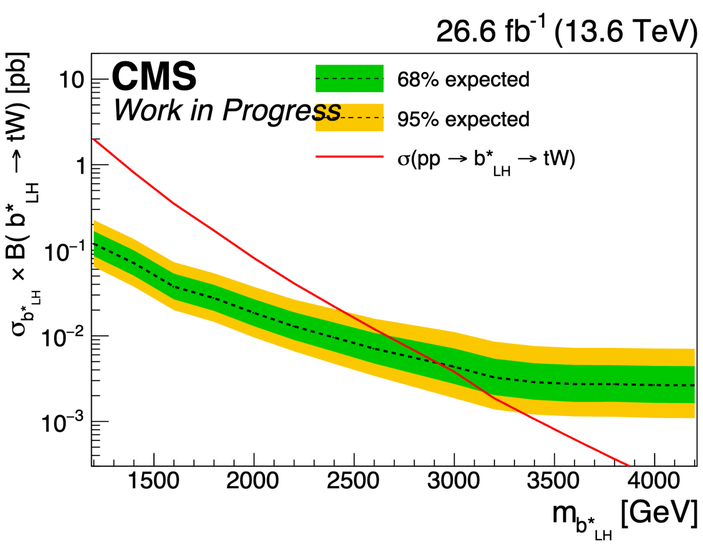
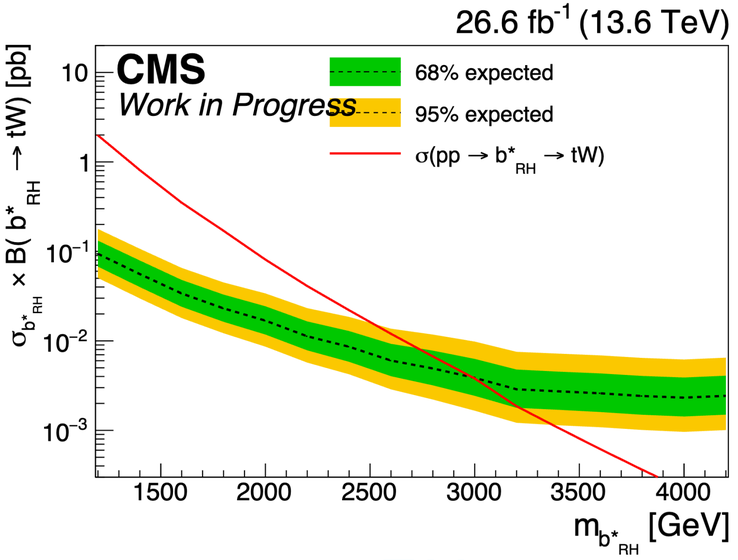
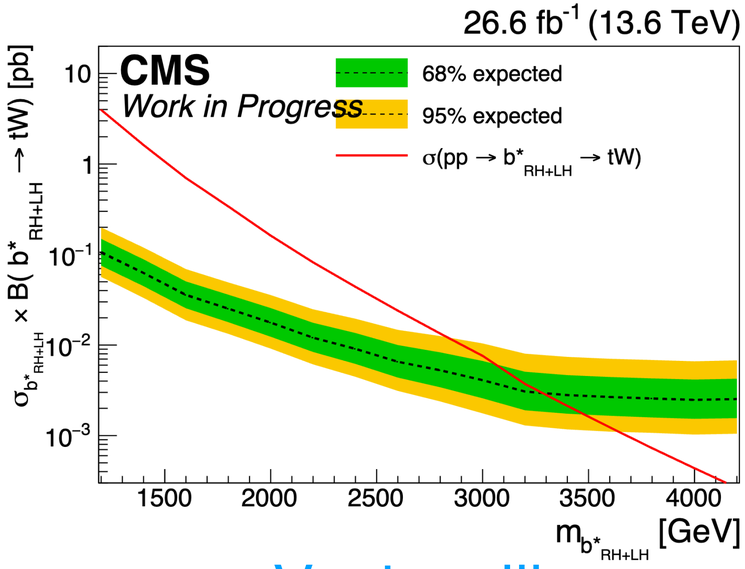
- Search b* on M_{tW} distribution. Combine High/Low mass SRs and Ele/Mu channels.
- Use asymptotic CLs method to set limit (combine tool).



LH



RH



Vector -like

- The expected mass exclusion limits on a b* decaying to tW are 2.9 TeV (LH), 3.0 TeV (RH), 3.3 TeV (Vector -like).

Summary

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- Search for b* decaying to tW in leptonic top channel using Run3 data.
  - Analyzing 2022PostEE data now.
  - Working on applying corrections and systematics .
  - Set expected limit with 13.6TeV b* signal.
- An optimistic Timeline:
  - End of September: We hope all the necessary corrections will be in place.
  - End of October: We aim to have all the systematics fully implemented and all data included
  - Mid December: Draft version of the AN may be ready for review.
  - Next January: We aim to give an engaging and informative CADI talk.
  - April of 2026: We hope to get pre-approval.
  - We hope to get approval before 2026.10.

Back up: Run3 Preselections

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- Muon Trigger:
  HLT_Mu50 || HLT_CascadeMu100 || HLT_HighPtTkMu100

- Electron Trigger:
  HLT_Ele115_CaloIdVT_GsfTrkIdT || HLT_Ele30_WPTight_Gsf || HLT_Photon200

- Exactly one lepton:
  - pT > 53 GeV, $|\eta| < 2.4, \Delta R(closedbjet, lepton) < 2$
  - 2D cut: $\Delta R(ak4jet, lepton) > 0.4$ or $p_T^{rel} > 15GeV$
  - Muon ID: Tight ID
  - Electron ID: Electron_mvaNoIso_WP90 NEW Ele ID

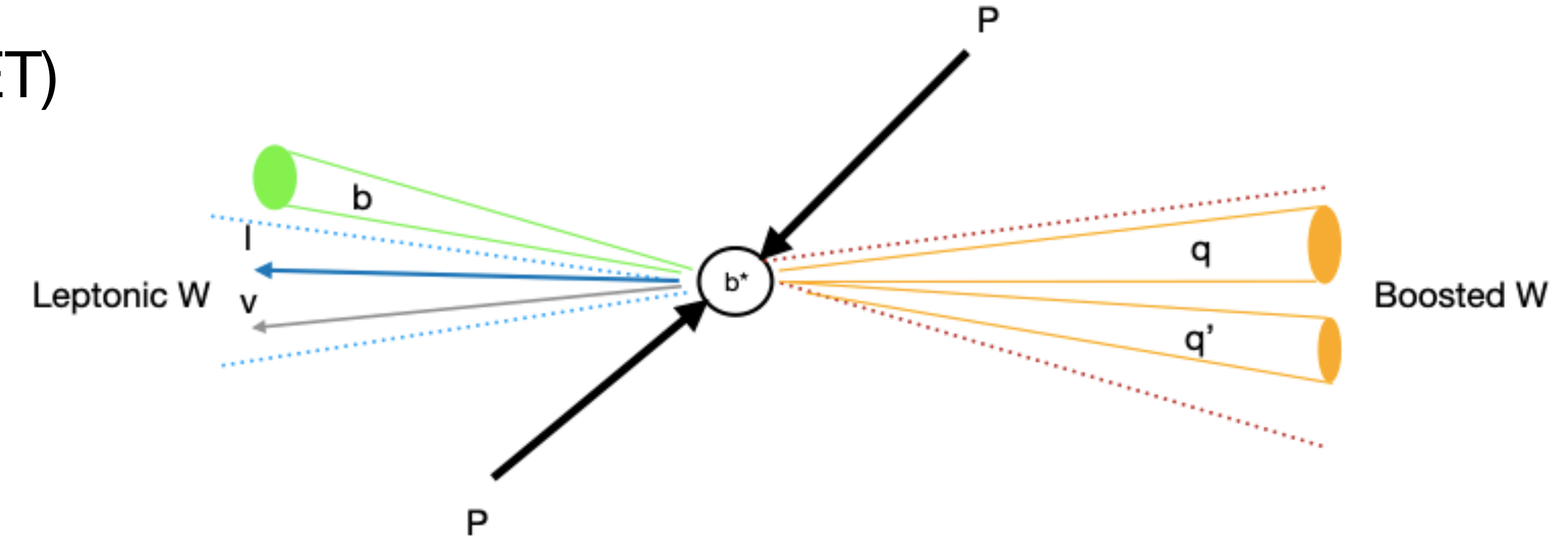
- At least one b-tagged AK4 jet:
  - pT > 30 GeV, $|\eta| < 2.4$ NEW btag method
  - Medium WP of the robustParticleTransformer b Tagging
  - Jet VetoMaps applied

- Exactly one W-tagged AK8 jet:
  - pT > 200 GeV, $|\eta| < 2.4$ NEW W tag method
  - Medium WP of the paticleNet W tagger
  - $\Delta R(AK4jet, AK8jet) > 0.8$

Reconstruction

Top： b-jet + lepton + neutrino(MET)

W: FatJet



- For $p_z(\nu)$:

Assume leptonic W is onshell, $p_z(\nu)$ can be obtained by solving quadratic equation:

- 0 real solution: $p_z(\nu)$ = real part of the solution
- 2 real solution: $p_z(\nu)$ = solution closest to $p_z(lepton)$

- For multiple b-jets candidates:
  The reconstructed top mass is closest to 172.5GeV is chosen.

QCD estimation(ABCD method)

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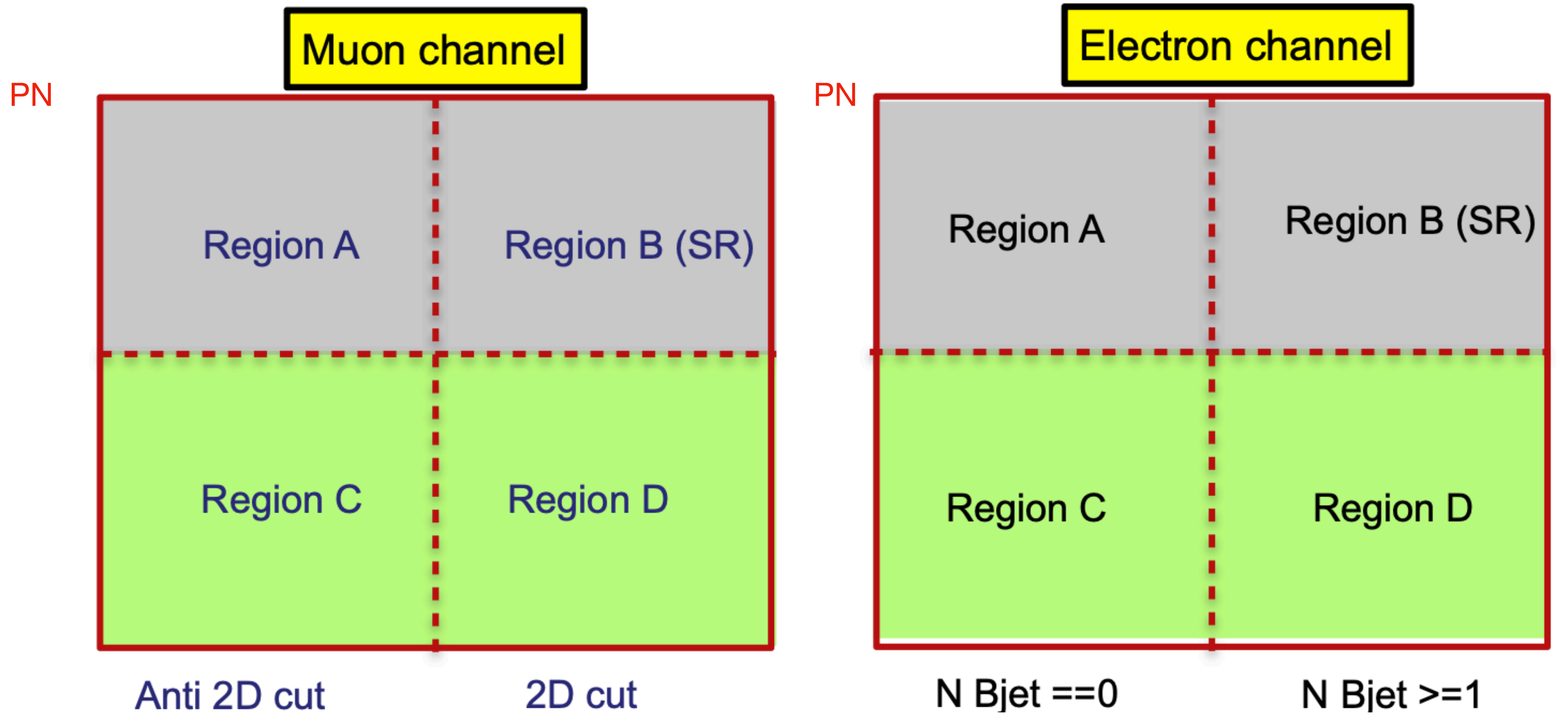
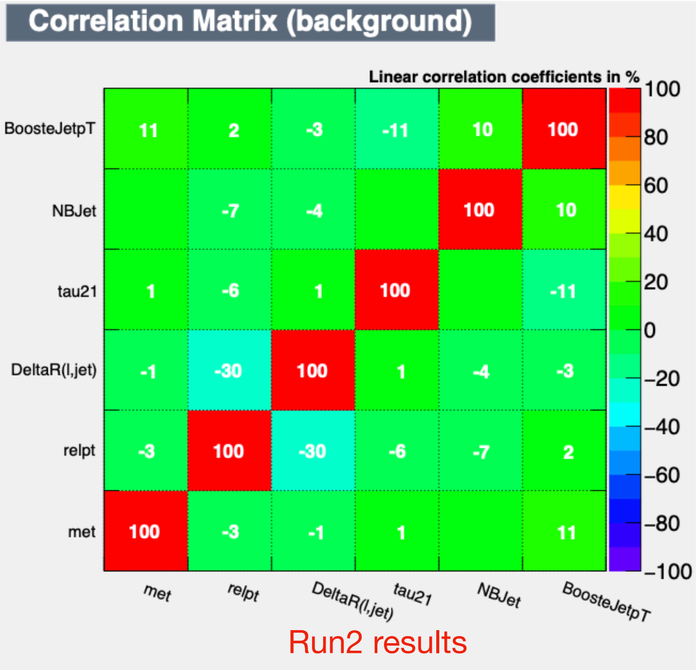
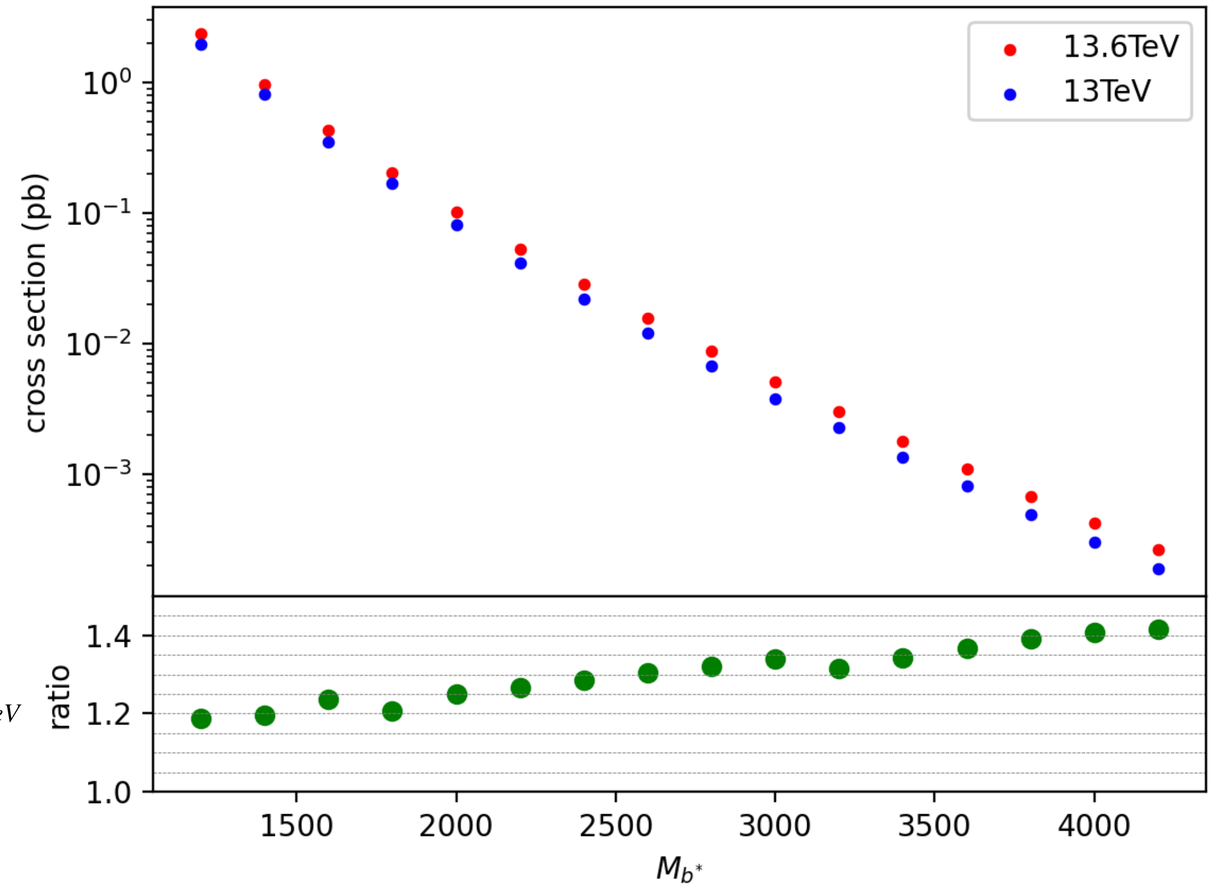
- Splitting phase space by 2 **uncorrelated** observables:
  - Muon: pN Wtagger and 2D cut (not optimal for electron channel due to electron have isolation in trigger).
  - Electron: pN Wtagger and N_{bjet} ;
- SR can be evaluated as: $N_B = (N_A/N_C) * N_D \,.\, N_i = Data - nonQCDMC(i = A, C, D)$.
- **QCD shape: Do ABCD method for each MtW bin.**





Back up

- b* -> tW XS comparison.
- XS values from MadGraph5.



Ratio = $XS_{13.6TeV}/XS_{13TeV}$