BOOSTED GGF H(BB)

FIRST SEARCH FOR BOOSTED HIGGS→BB WITH CMS

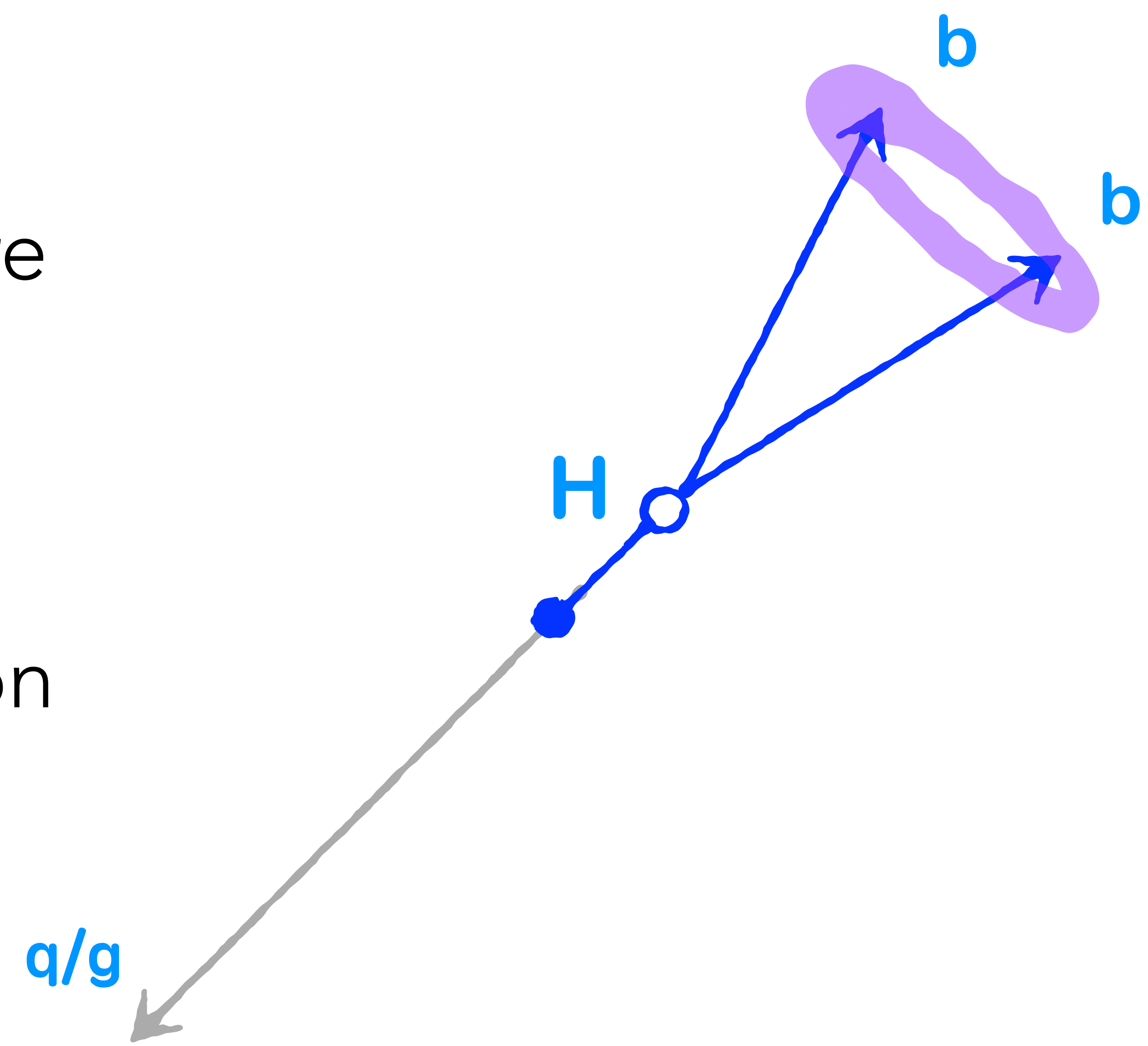
HIGGS COUPLINGS 2017
INSTITUTE FOR THEORETICAL PHYSICS
HEIDELBERG UNIVERSITY
HEIDELBERG, GERMANY

NOVEMBER 9, 2017

Javier Duarte
Fermilab

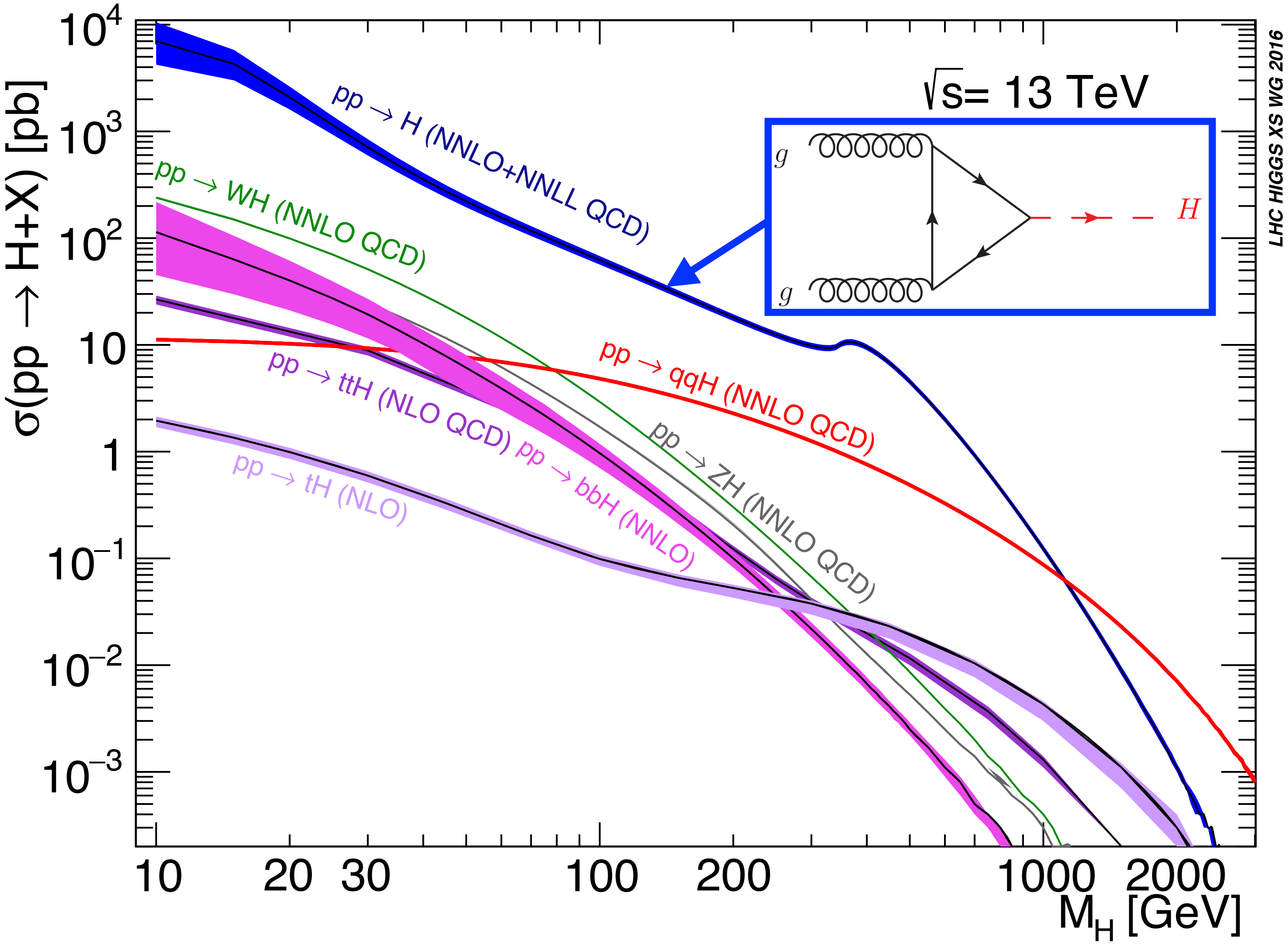
OUTLINE

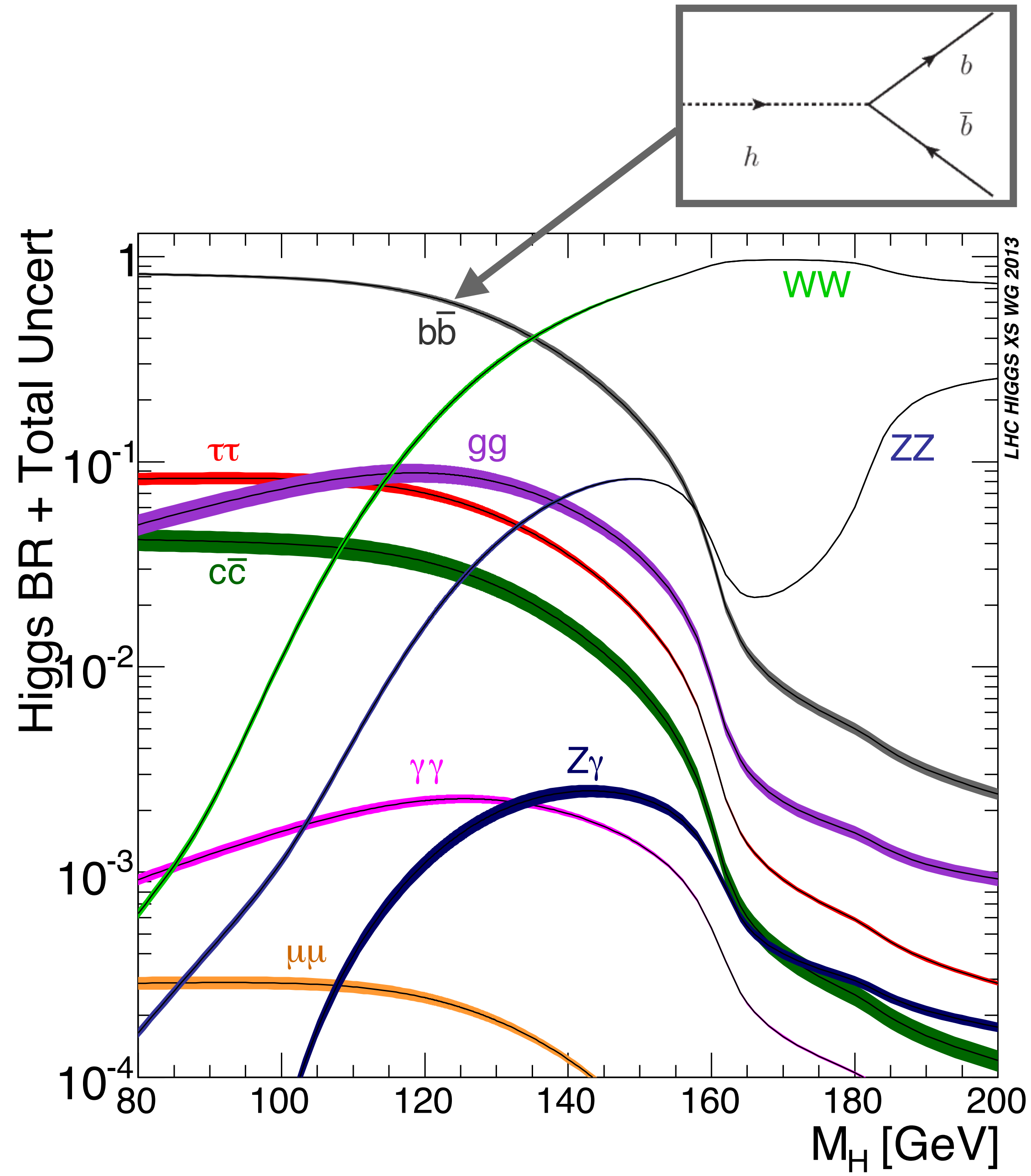
- Motivation
- Higgs tagging
  - Jet mass and substructure
  - Double-b tagging
- Event selection
- Data-driven QCD estimation
- Systematics
- Results
- Summary and outlook



HIGGS AS A DIJET SEARCH?

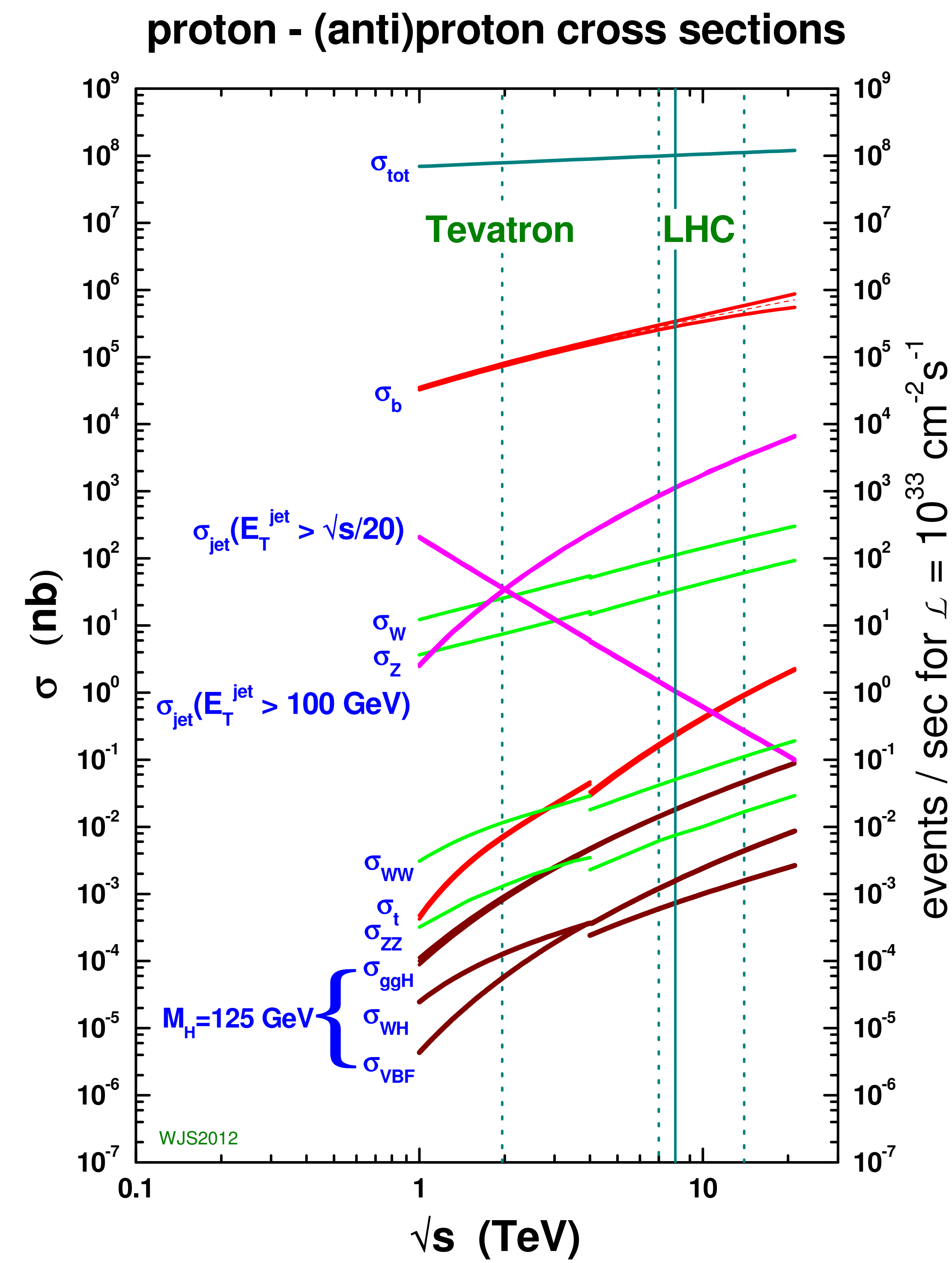
- Largest Higgs production/decay mode is gg → H → bb (>50%)

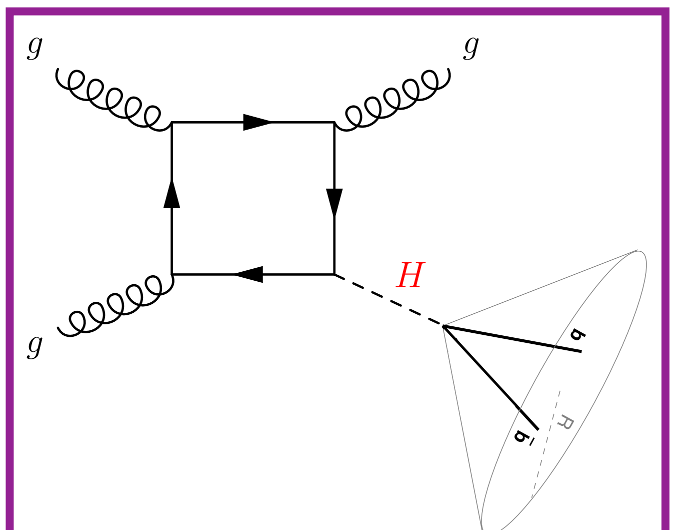




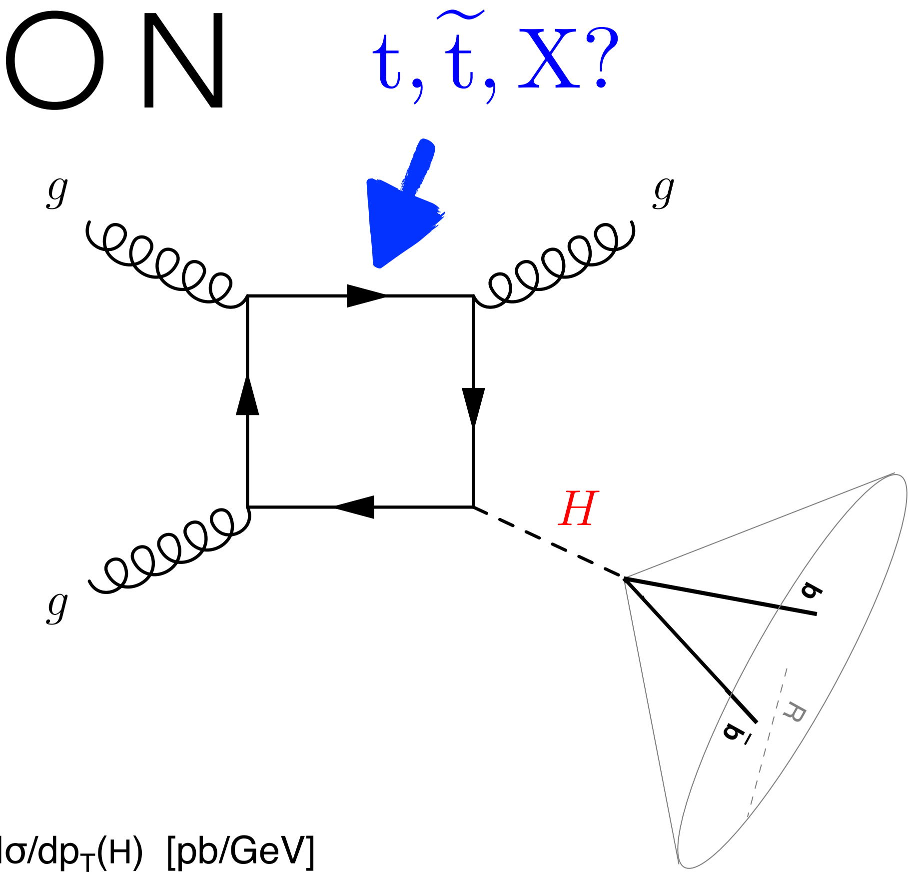
HIGGS AS A DIJET SEARCH?

- Largest Higgs production/decay mode is gg → H → bb (>50%)
- But, background is also immense
  - QCD b production is 10^7 times larger
- Using large Lorentz boost, machine learning, and jet substructure, we can achieve S/B ~ 1/10

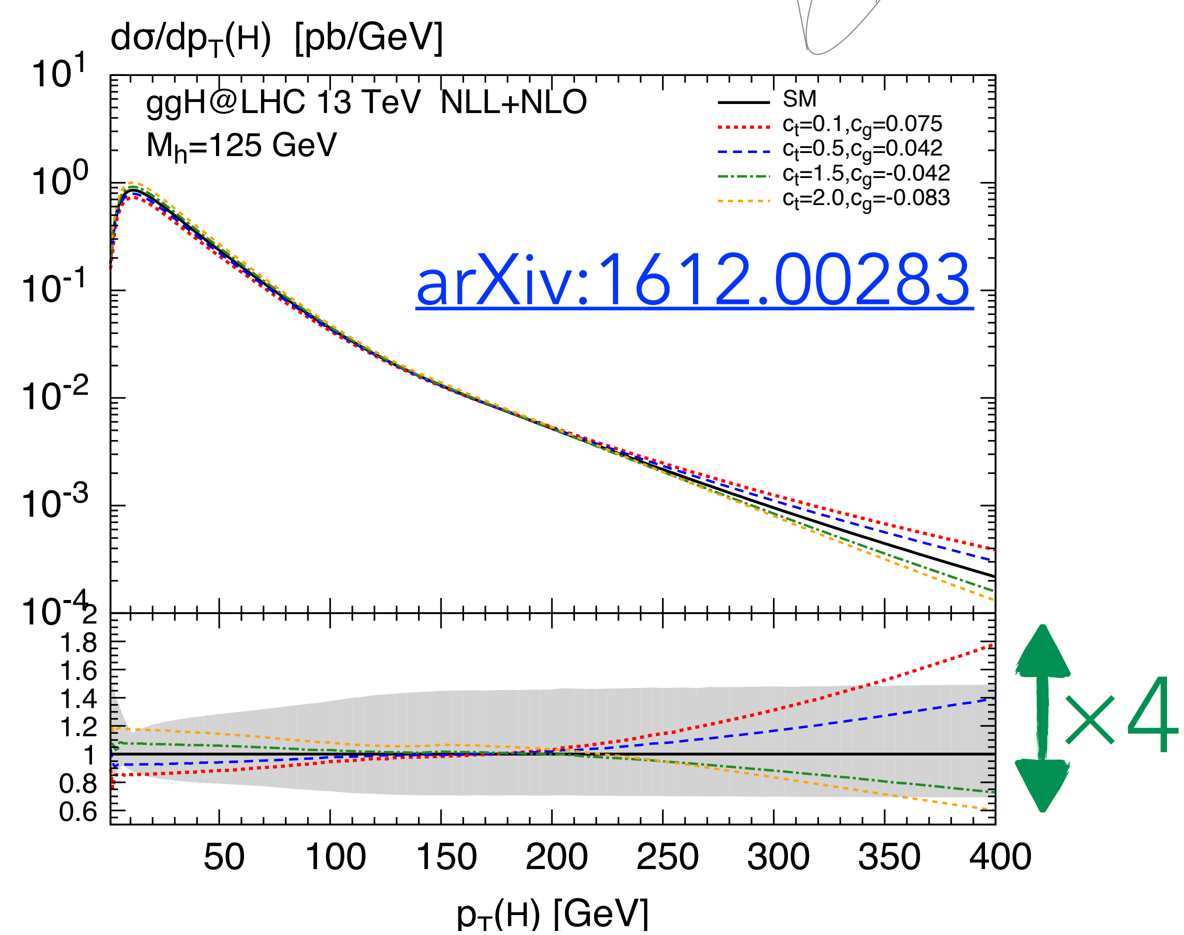




MOTIVATION



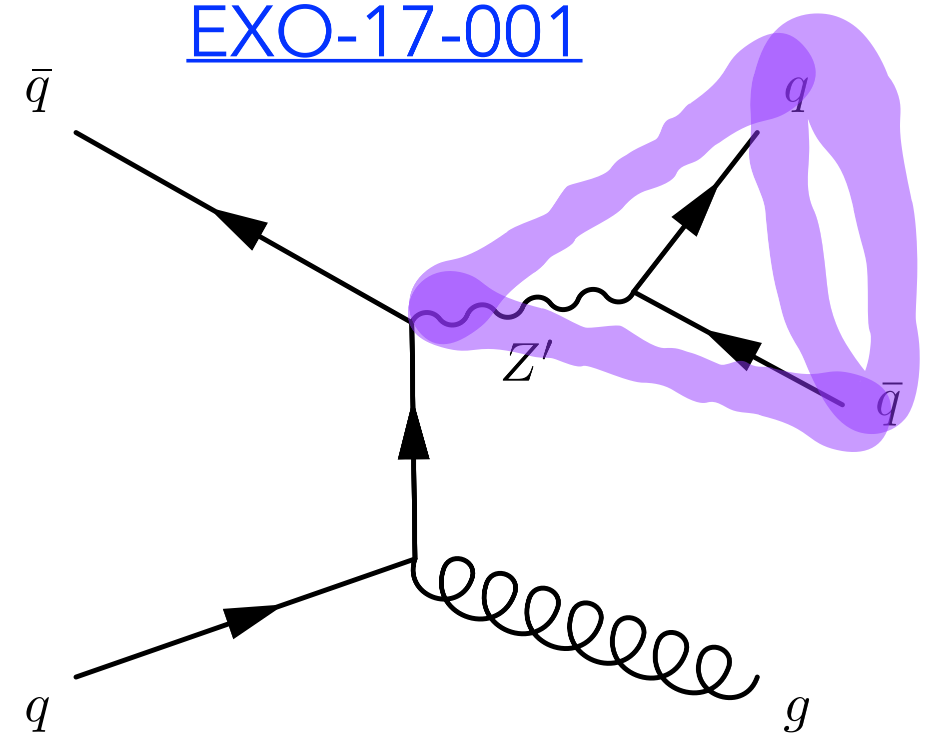
- We can access this process in the boosted dijet topology
- Probing Higgs couplings at high momentum transfer (Q) accesses large new physics energy scale (Λ)

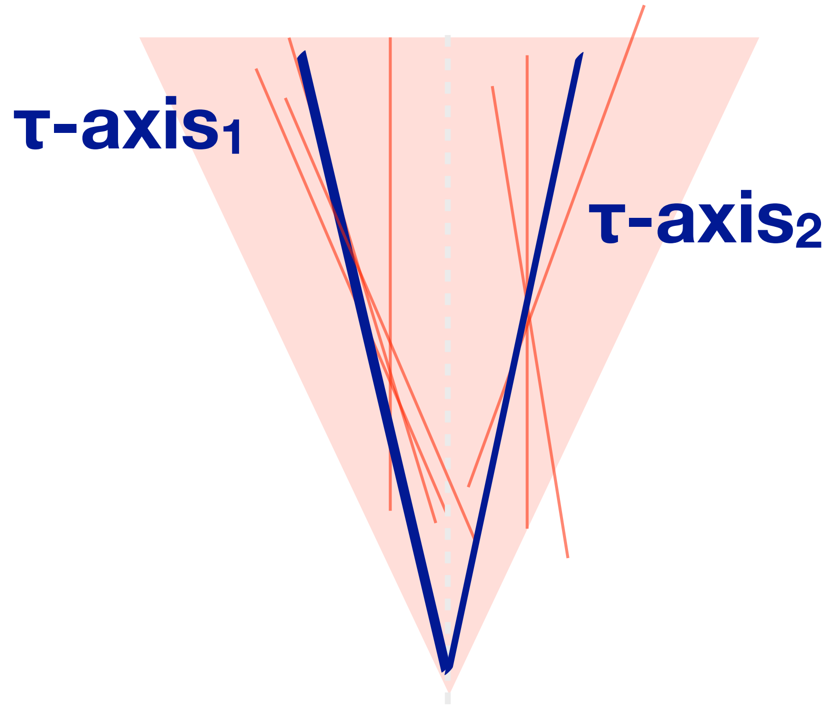


SO HOW CAN WE DO IT?

- Inspiration from boosted techniques?
  - ✔ Use an ISR jet to get above the trigger threshold
  - ✔ Require one boosted fat jet
  - ✔ Substructure and jet grooming to enhance S/B
  - ✔ Data-driven background estimate
- Inspiration from machine learning and b-tagging?
  - ✔ Double b-tagger selects fat jets containing two b-quarks

EXO-17-001





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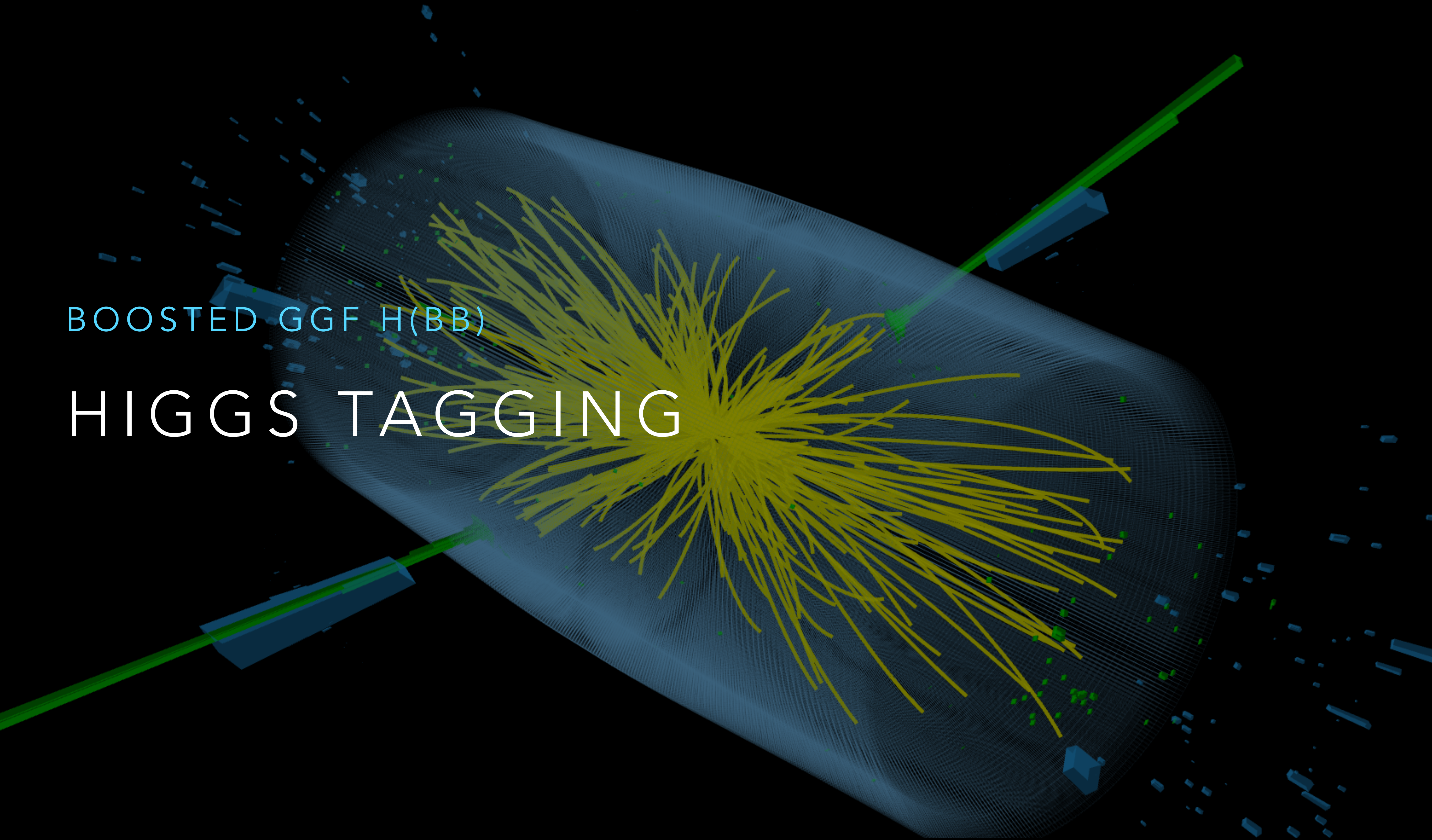
HIGGS TAGGING



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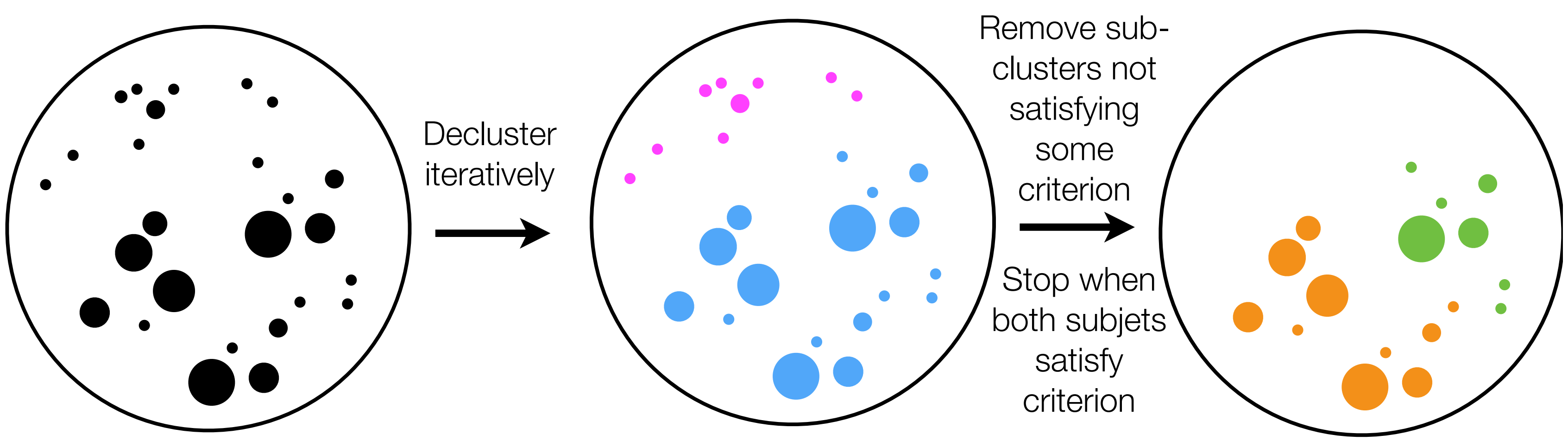
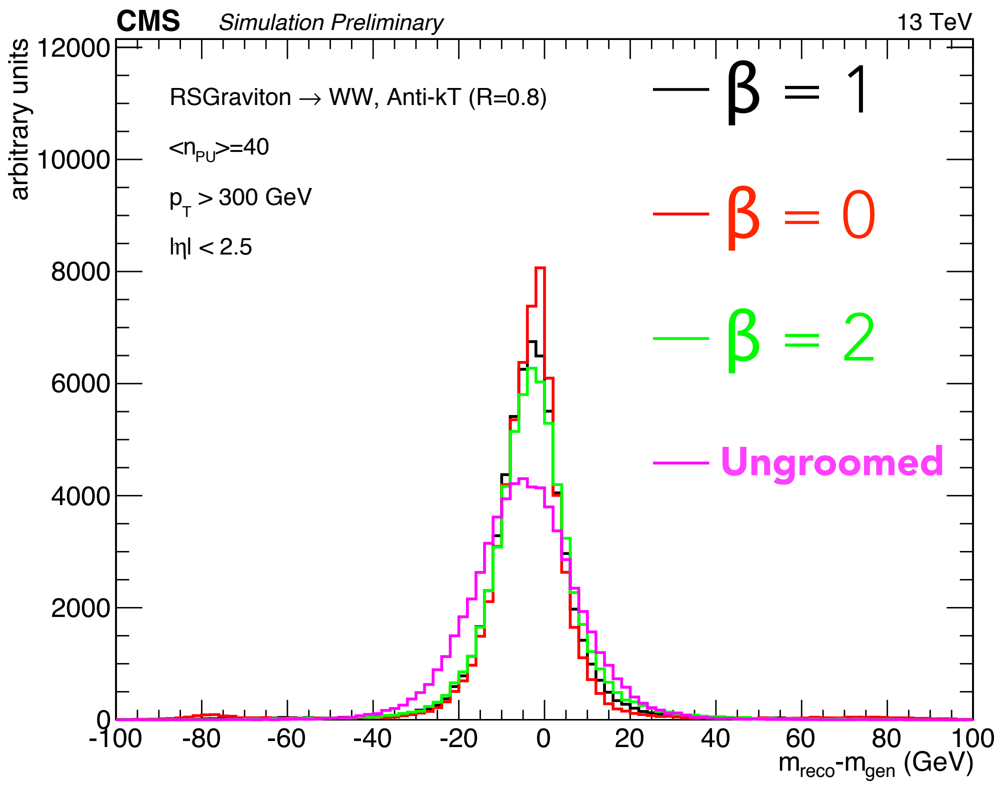
arXiv:1307.0007
arXiv:1402.2657

JET MASS

- Provides good separation between W/Z/H-jets and q/g jets
- Grooming removes soft and wide-angle radiation (soft drop / modified mass drop tagger)



Soft Drop Condition: $$\frac{\min(p_{T1}, p_{T2})}{p_{T1} + p_{T2}} > z_{\text{cut}} \left(\frac{\Delta R_{12}}{R_0} \right)^{\beta}$$



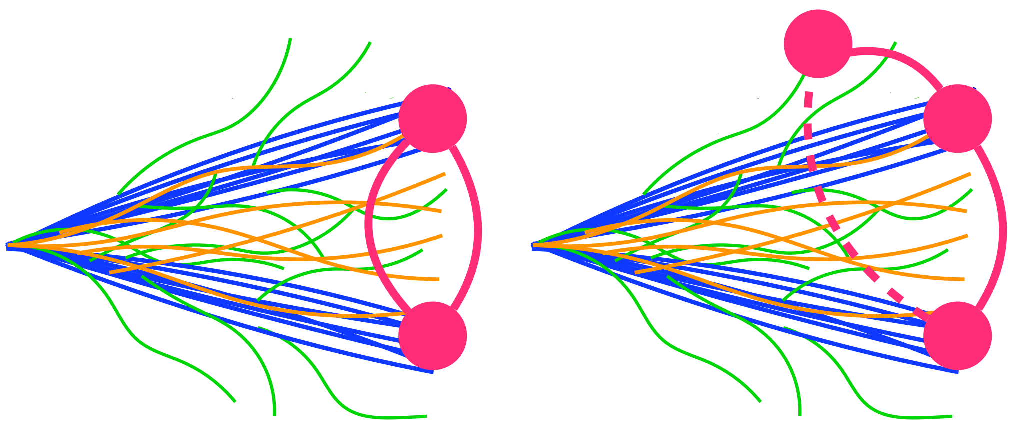
CMS: $z_{\text{cut}} = 0.1$, $\beta = 0$

arXiv:1609.07483

JET SUBSTRUCTURE

- How many "prongs" are in the jet?
- Generalized energy correlation functions are sensitive to N-point correlations within a jet
  - Two-pronged jets have ${}_2e_3 \ll ({}_1e_2)^2$
- Stable under grooming

$$N_2^{\beta} = \frac{{}_2e_3^{\beta}}{({}_1e_2^{\beta})^2} \quad \beta = 1$$



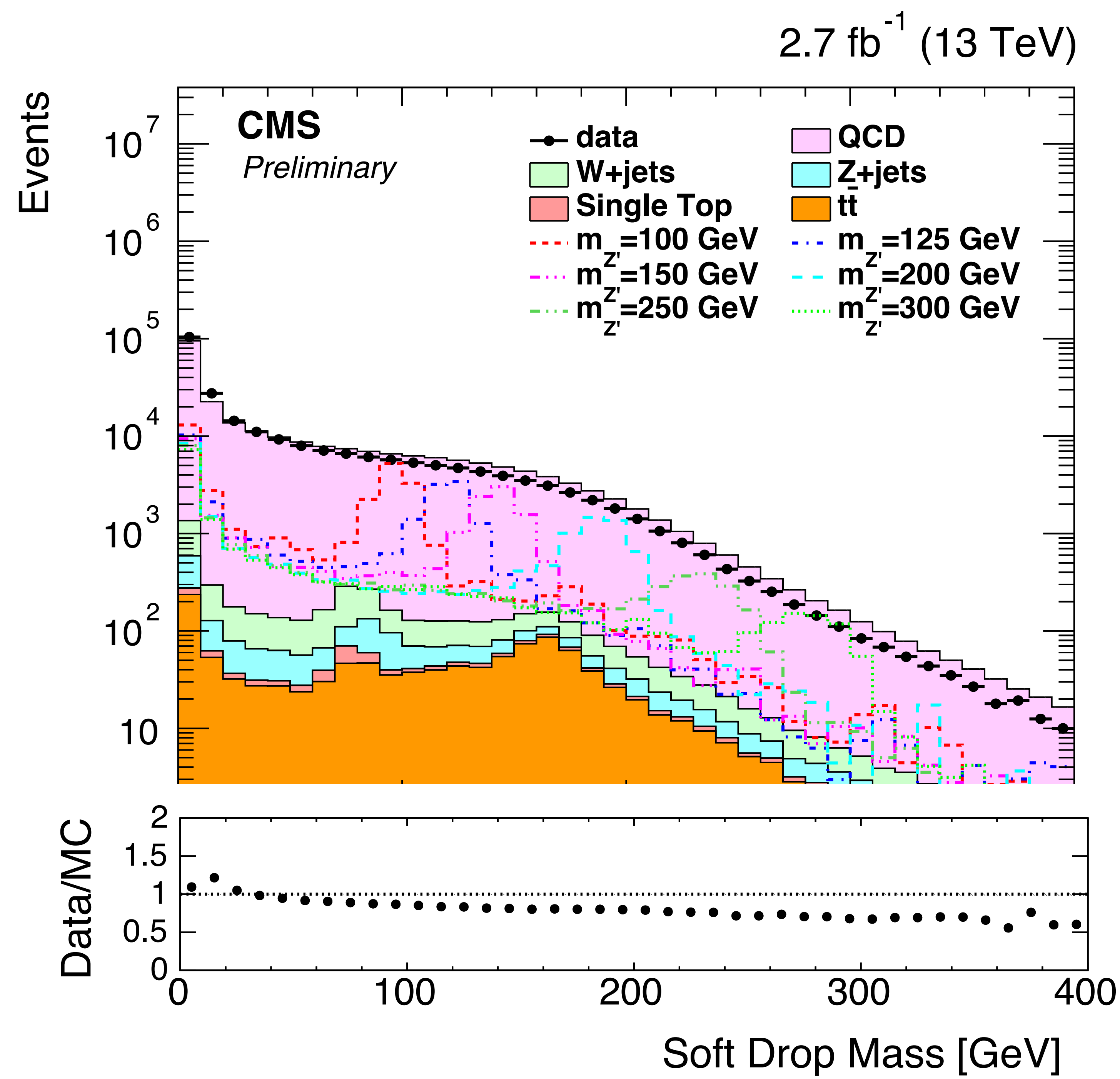
$${}_1e_2^{\beta} = \frac{1}{p_{\mathrm{T}J}^2} \sum_{1\leq i<j\leq n_J} p_{\mathrm{T}i}p_{\mathrm{T}j}\Delta R_{ij}^{\beta}$$

$${}_2e_3^{\beta} = \frac{1}{p_{\mathrm{T}J}^3} \sum_{1\leq i<j<k\leq n_J} p_{\mathrm{T}i}p_{\mathrm{T}j}p_{\mathrm{T}k} \min\{\Delta R_{ij}^{\beta}\Delta R_{ik}^{\beta}, \Delta R_{ij}^{\beta}\Delta R_{jk}^{\beta}, \Delta R_{ik}^{\beta}\Delta R_{jk}^{\beta}\}$$

BACKGROUNDS

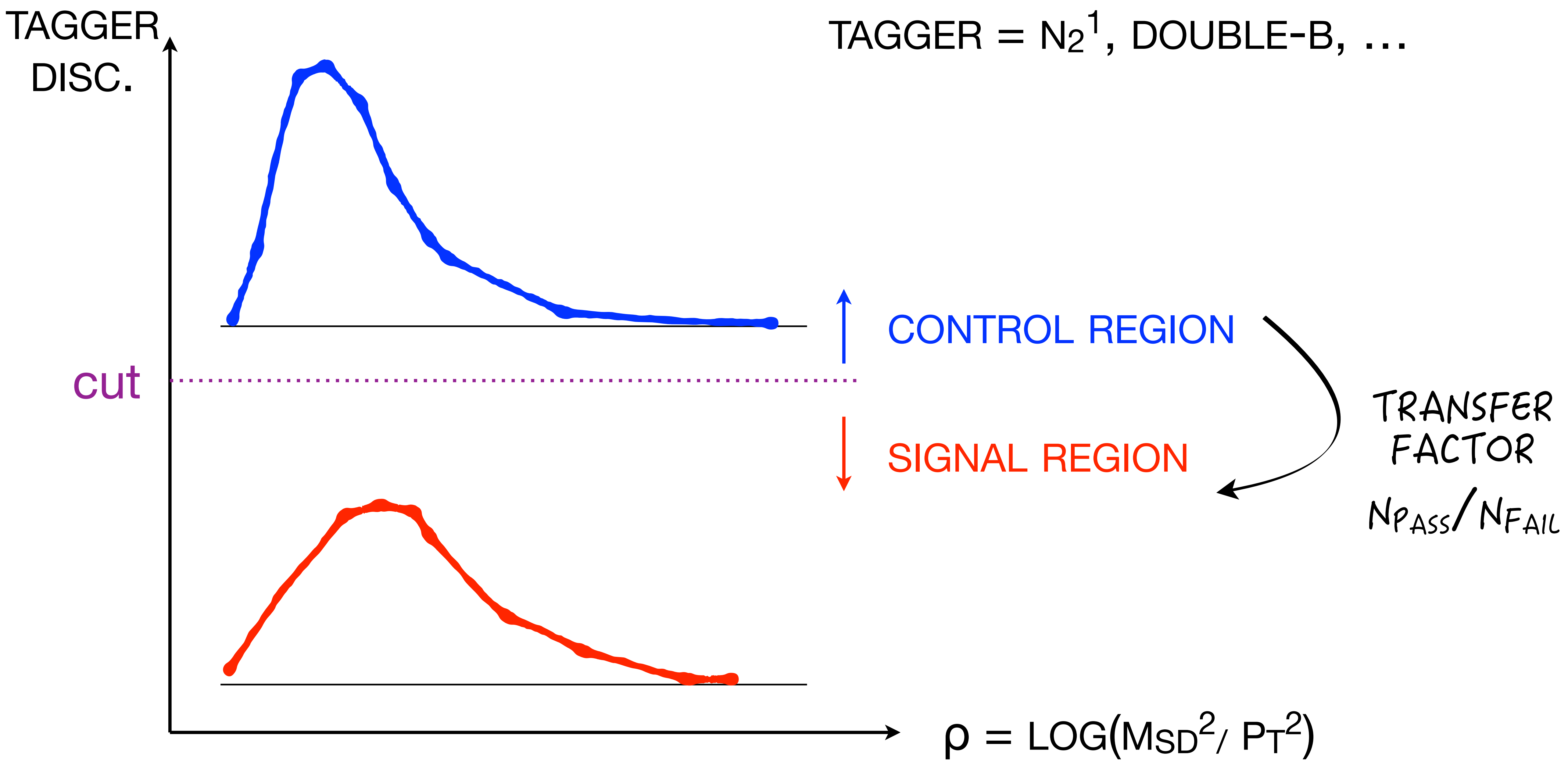
EXO-16-030

- Difficult to use the QCD Monte Carlo to predict the background in this phase space
- Fitting this mass distribution directly requires high order polynomial → large background uncertainties
- Can we try a data-driven sideband prediction?



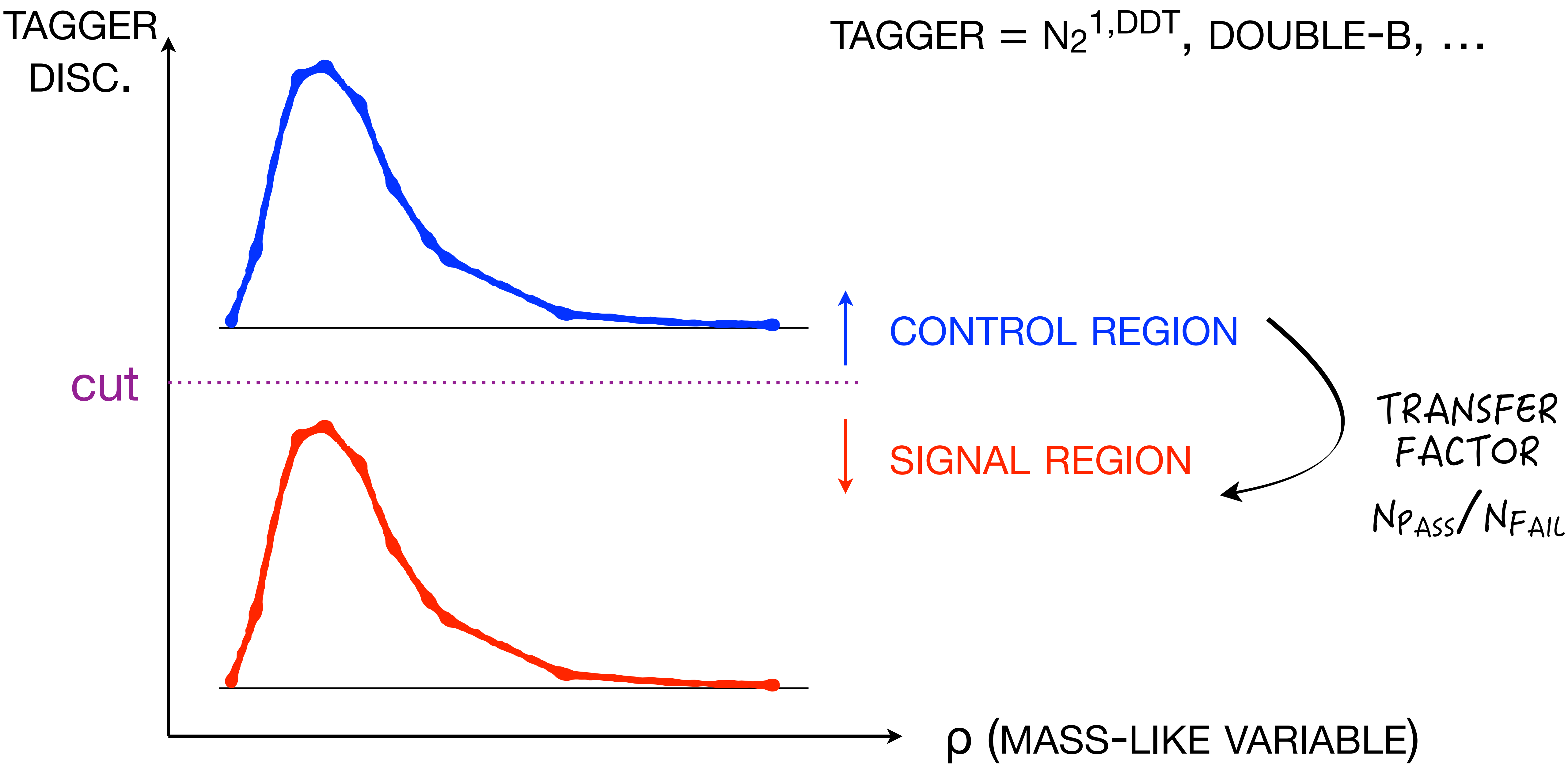
SIDEBAND QCD PREDICTION

- Can we predict the QCD jet mass distribution from region failing the tagger?
  - Potential problem: does tagger sculpt jet mass distribution?



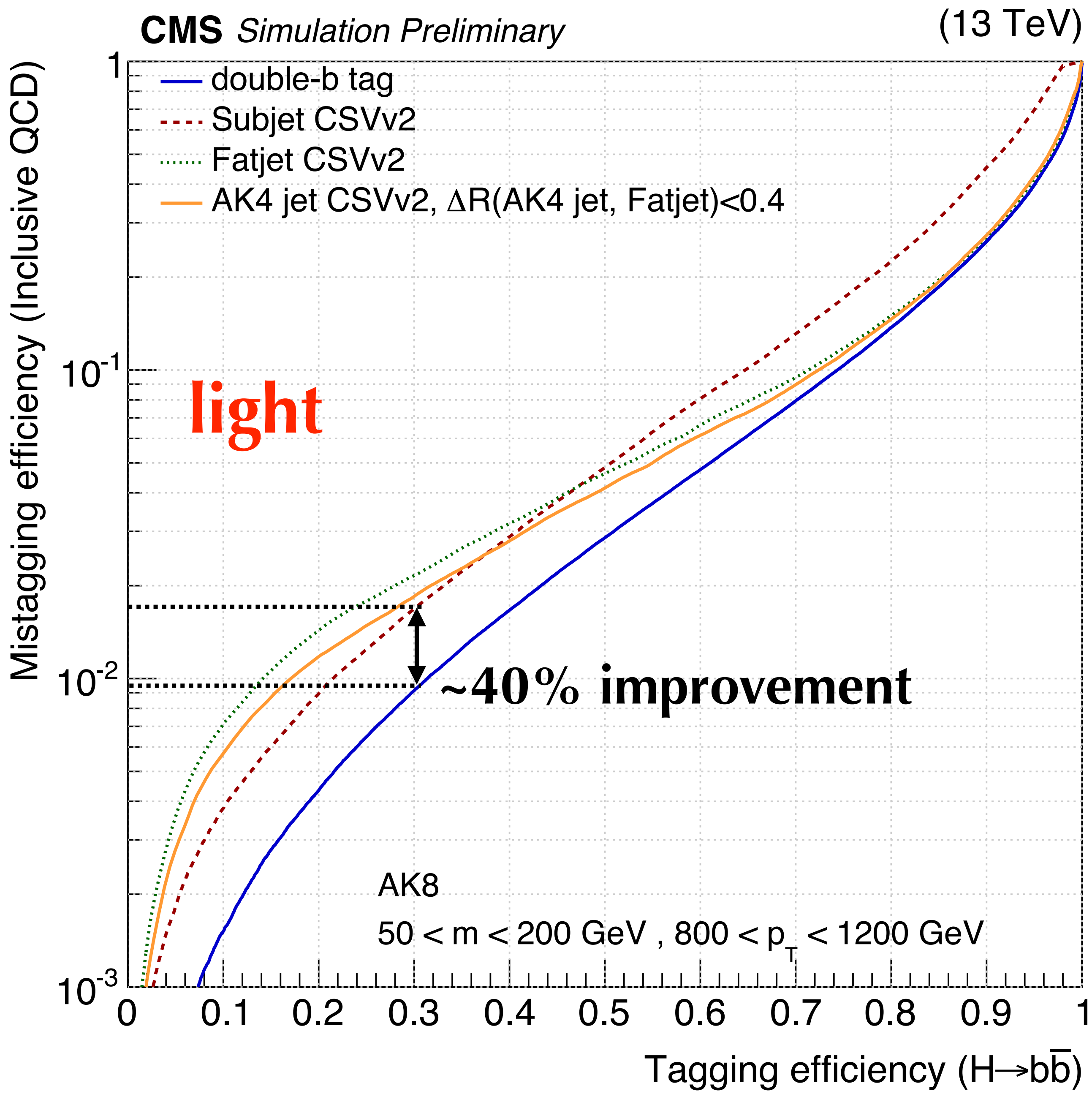
SIDEBAND QCD PREDICTION

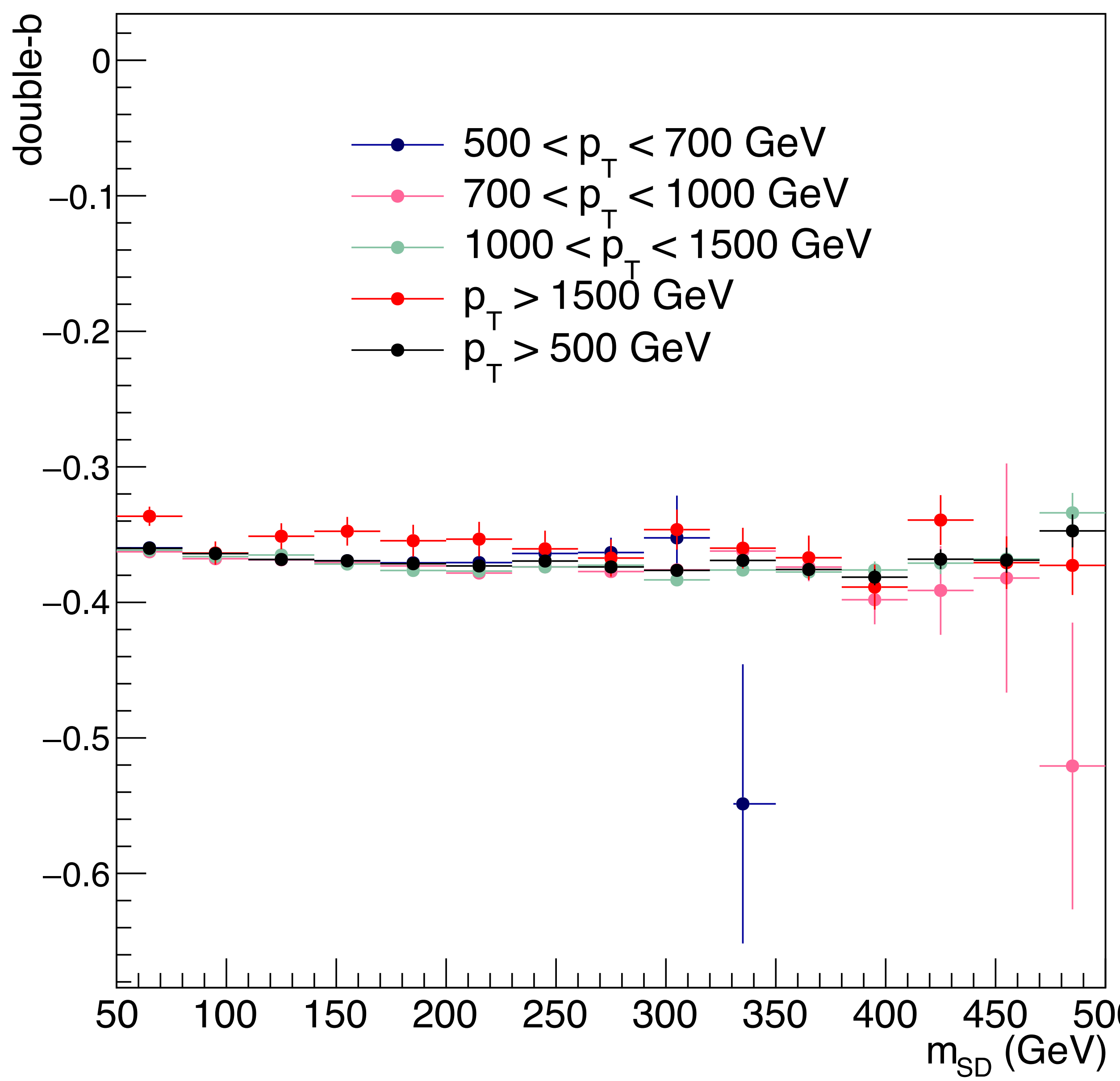
- Can we predict the QCD jet mass distribution from region failing the tagger?
  - Solution: use a tagger that is decorrelated from jet mass and p_T



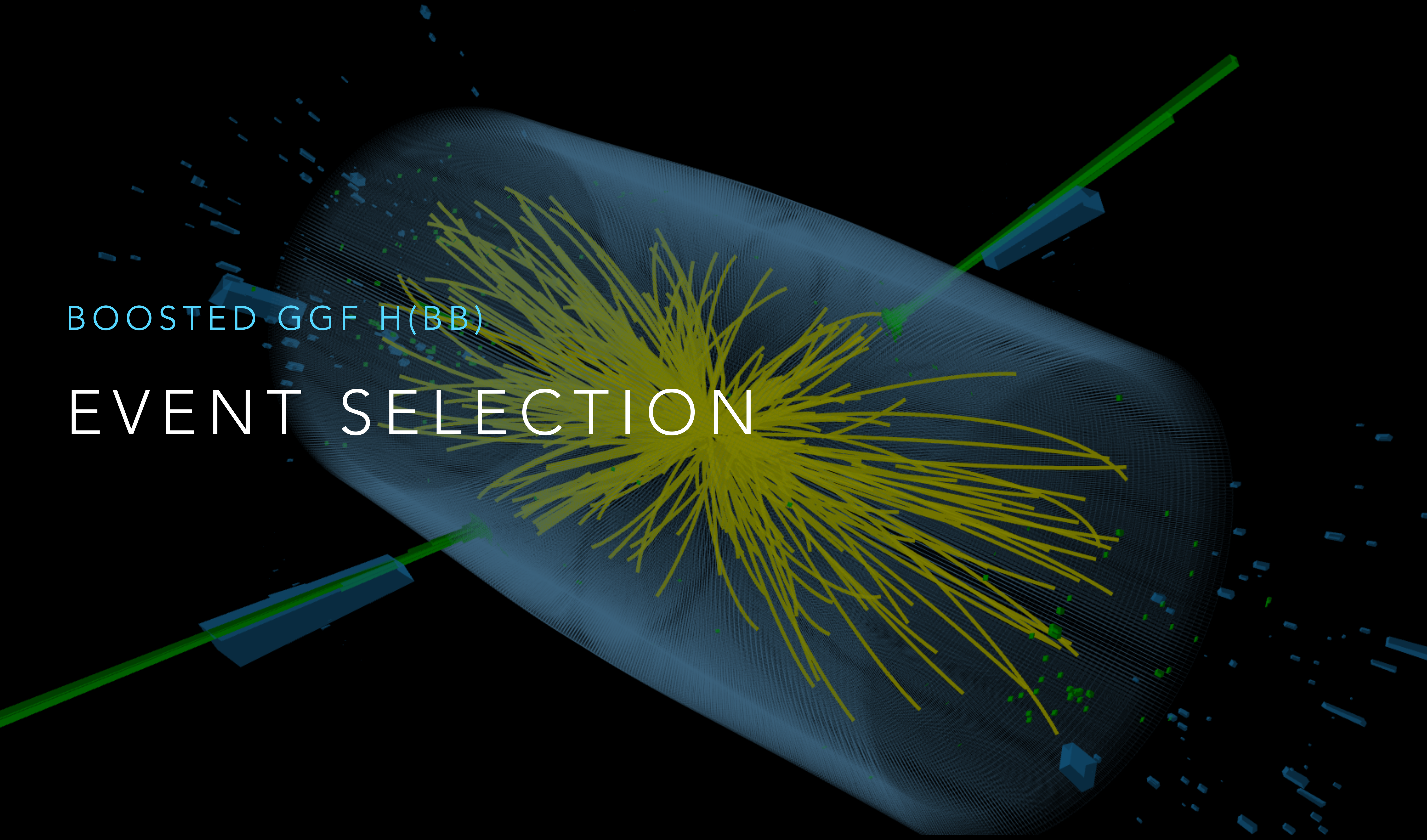
DOUBLE-B TAGGER

BTV-15-002





- Combines tracking and vertexing information in a multivariate classifier with 27 observables
- No strong correlations in double-b tagger versus m_{SD} or p_T in QCD background



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EVENT SELECTION

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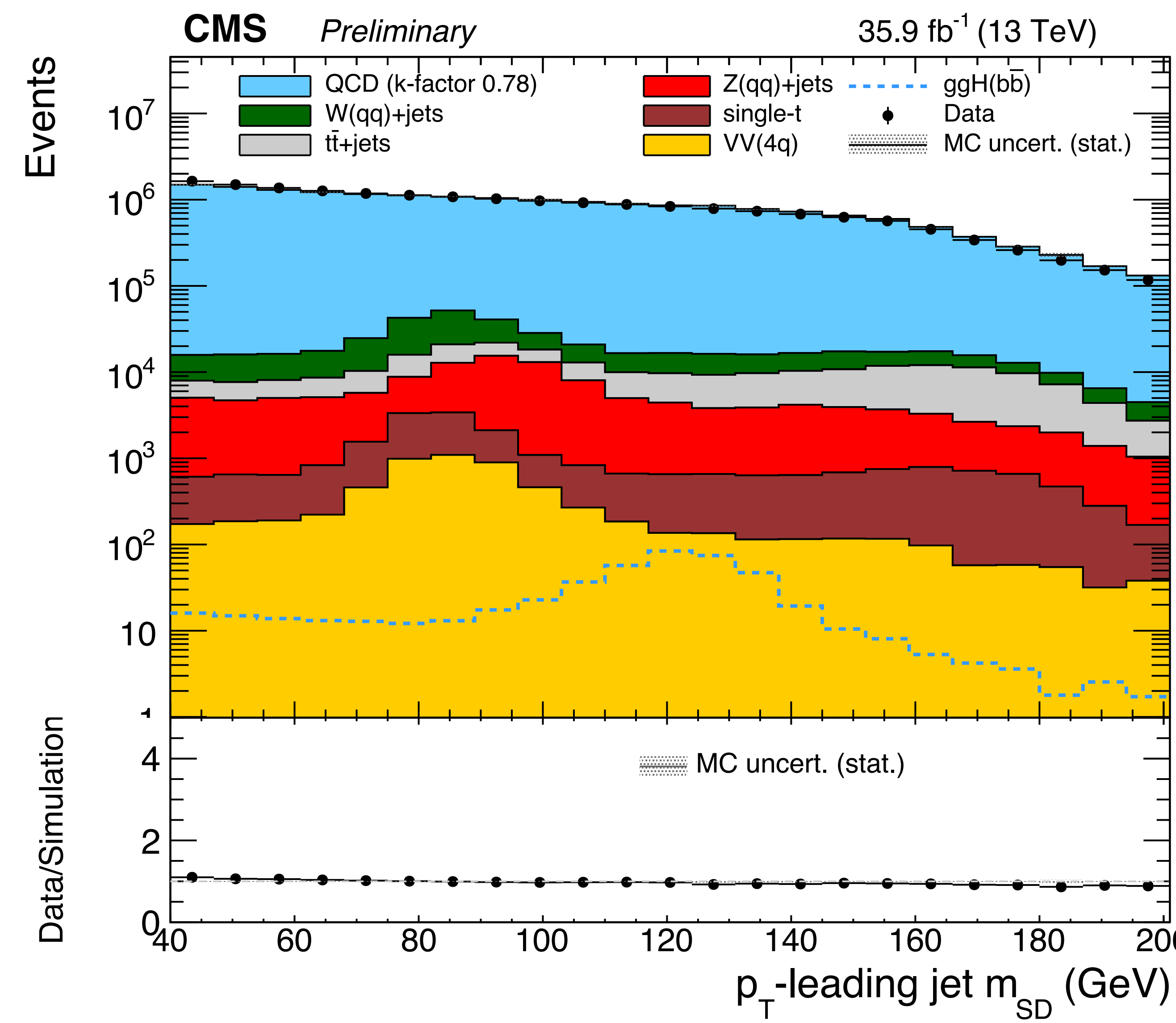
EVENT SELECTION

- Online: high p_T single jet or large hadronic activity
  - p_T > 360 GeV (m > 30) or $\Sigma\, p_T$ > 900 GeV
- Offline: Highest p_T jet
  - p_T > 450 GeV, $|\eta| < 2.5$
  - jet mass m_{SD} > 40 GeV
- lepton veto, p_T^{miss} veto
- $-6.0 < \rho = \log(m_{SD}^2 / p_T^2) < -2.1$

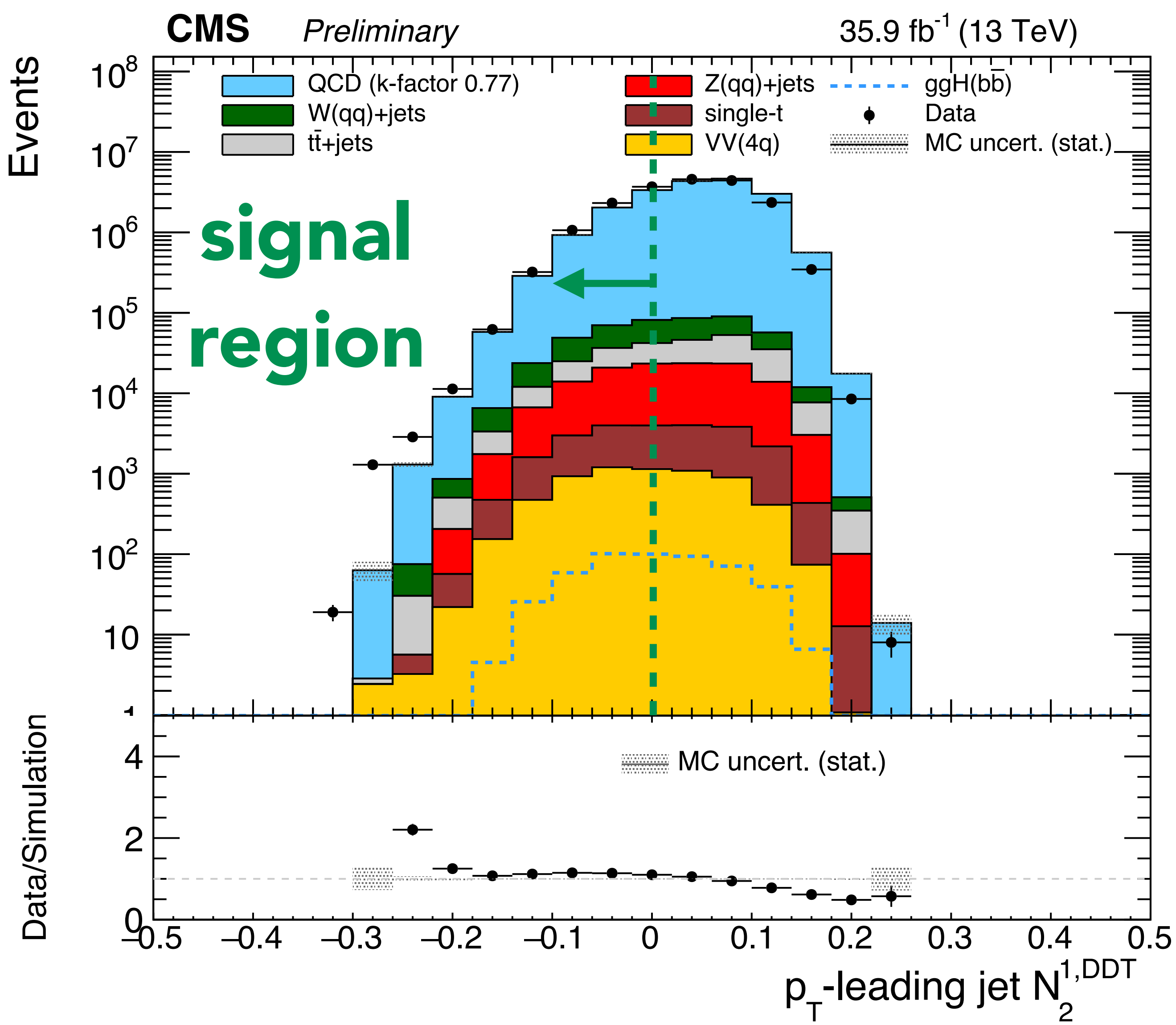


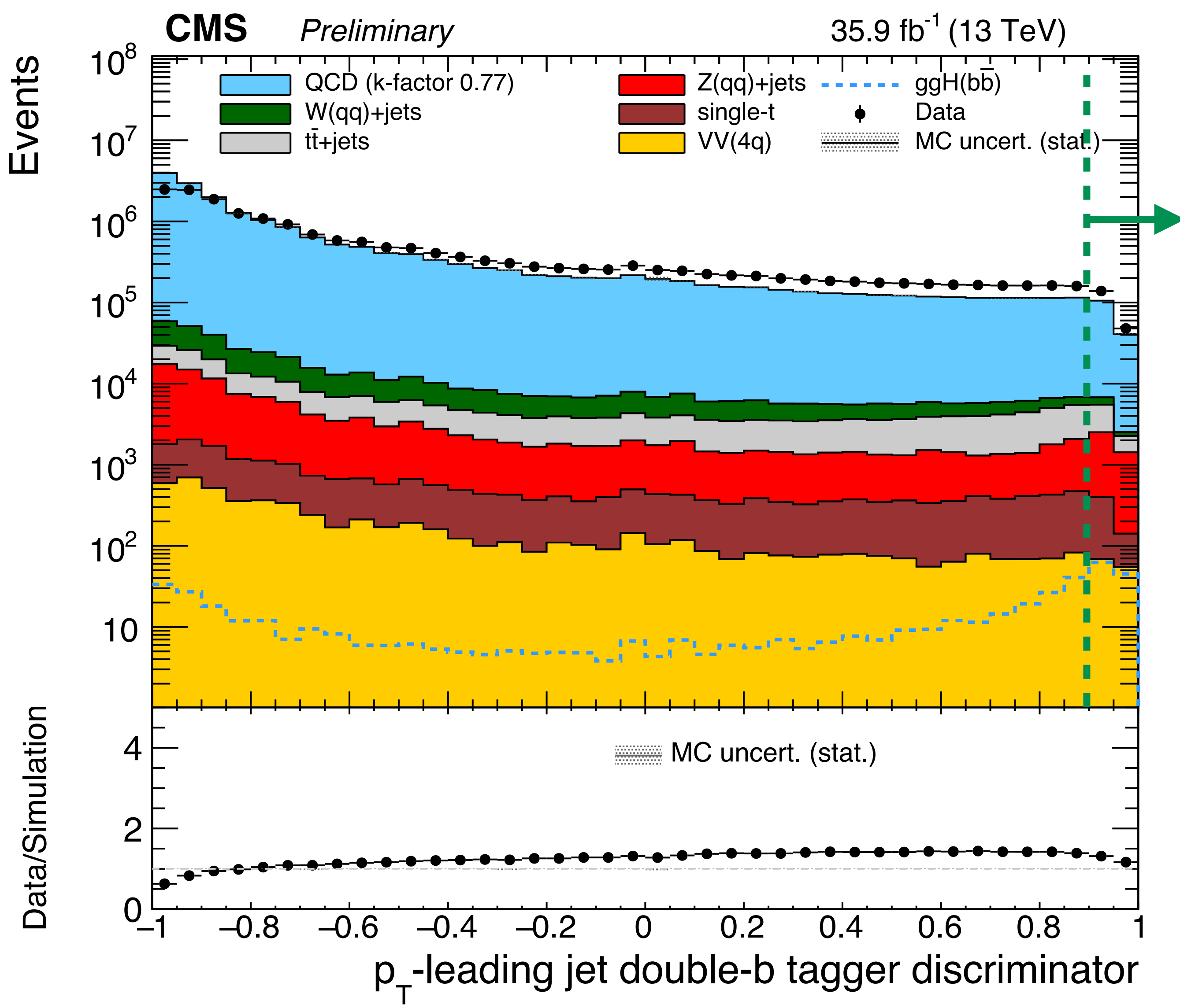
EVENT SELECTION

HIG-17-010

Substructure: two prong discrimination, ~50% sig. efficiency, 26% bkg. efficiency

Double-b tagger: ~30% sig. efficiency, 1% bkg. efficiency (tight working point)

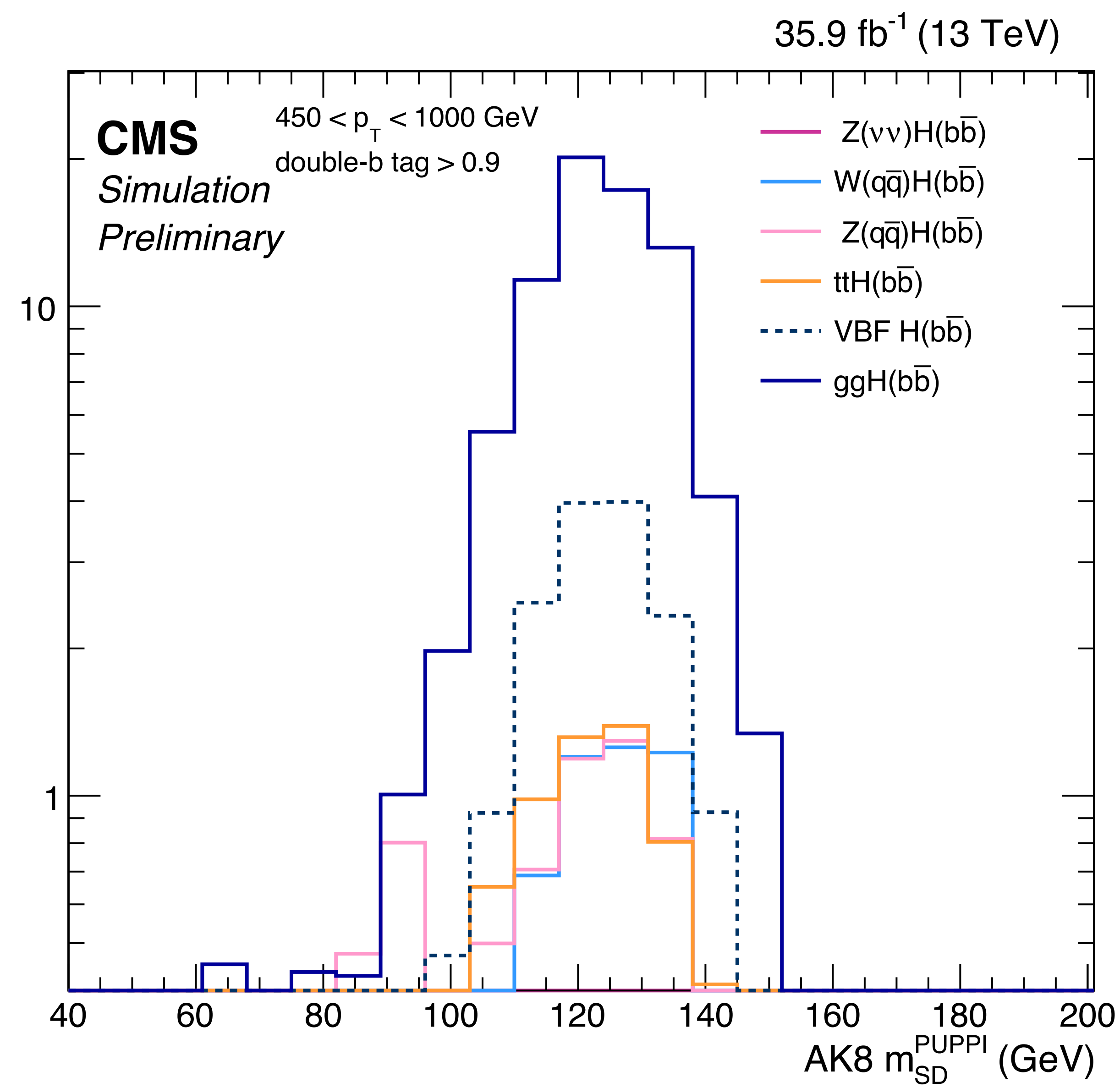


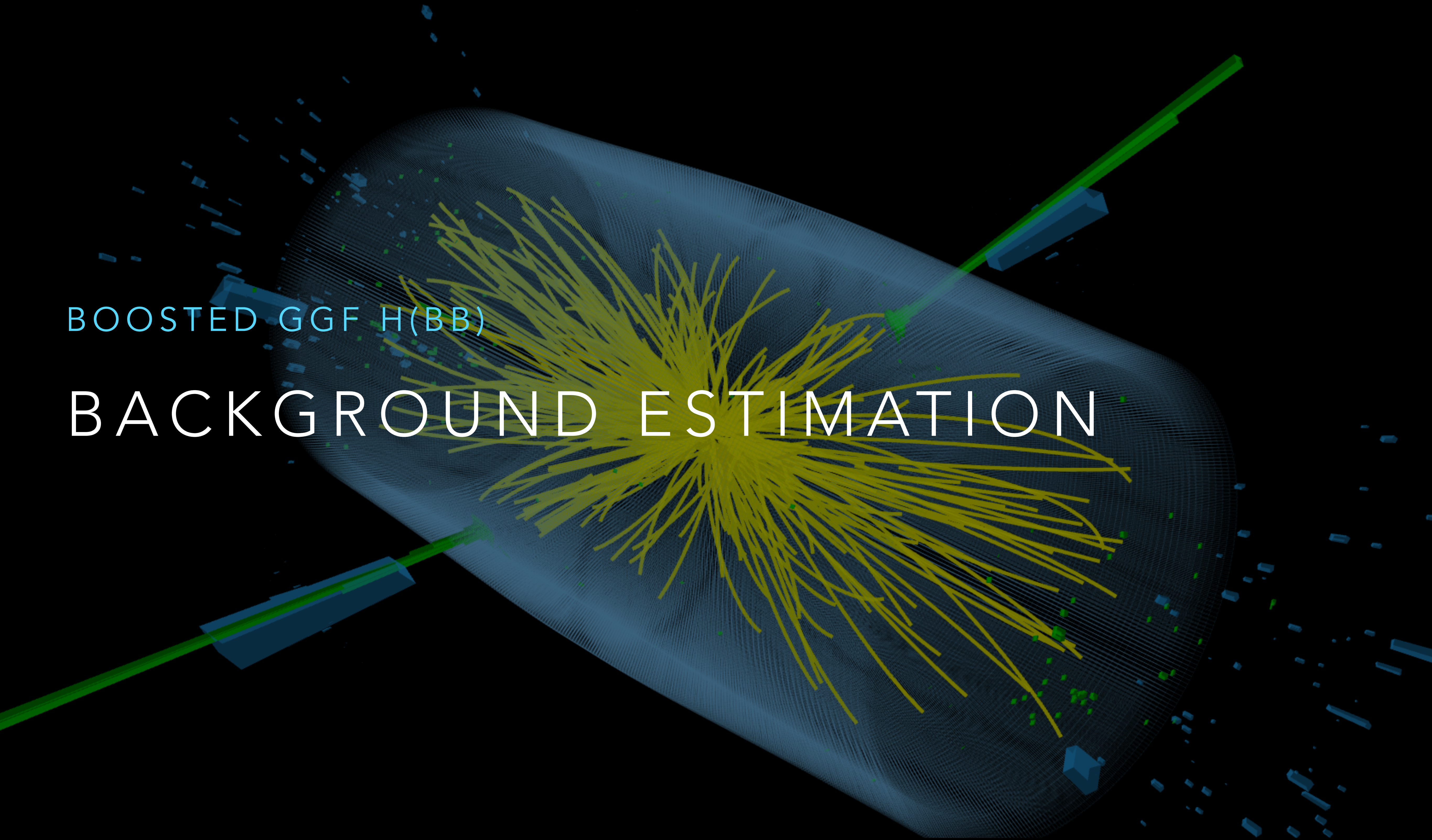


HIG-17-010

SIGNAL COMPOSITION

- Analysis is inclusive in Higgs production mode
- Signal contributions after kinematic + substructure + double-b selection are
  - 74% ggF
  - 12% VBF
  - 8% VH
  - 6% ttH





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BACKGROUND ESTIMATION

BACKGROUND STRATEGY

- Backgrounds estimated from data
  - **QCD** (90%): from failing double b-tag region × **TF**
  - tt+jets (3%): from 1μ control region
- Backgrounds estimated from MC including NLO QCD + EWK corrections and jet mass, resolution, and substructure tagging scale factors
  - W/Z+jets (5%)
  - single-t, VV (<1%)

QCD transfer factor

$$N^{\mathrm{QCD}}_{\mathrm{pass}}(m_{\mathrm{SD}}, p_{\mathrm{T}}) = R_{\mathrm{p/f}}(\rho, p_{\mathrm{T}}) \cdot N^{\mathrm{QCD}}_{\mathrm{fail}}(m_{\mathrm{SD}}, p_{\mathrm{T}})$$

- If the double-b tagger were completely uncorrelated from jet mass and p_{T}, the transfer factor would be flat

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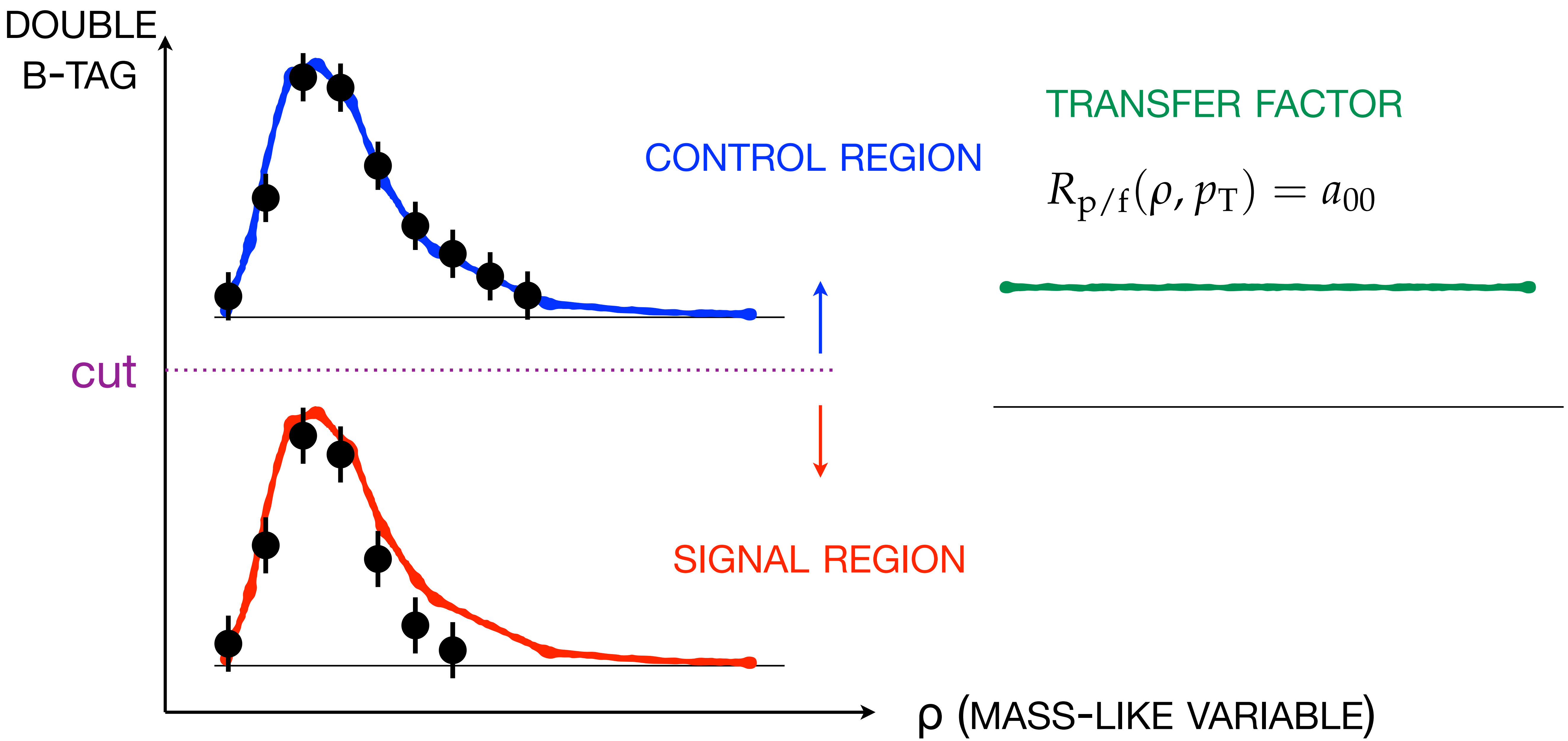
$$N_{\text{pass}}^{\text{QCD}}(m_{\text{SD}i}, p_{\text{T}j}) = \boxed{\left(\sum_{k,\ell} a_{k\ell}\rho_{ij}^{k} p_{\text{T}j}^{\ell}\right)} \cdot N_{\text{fail}}^{\text{QCD}}(m_{\text{SD}i}, p_{\text{T}j})$$

- If the double-b tagger were completely uncorrelated from jet mass and p_T, the transfer factor would be flat
- **Taylor expand** as a polynomial in **ρ** and p_T to parameterize any small correlations

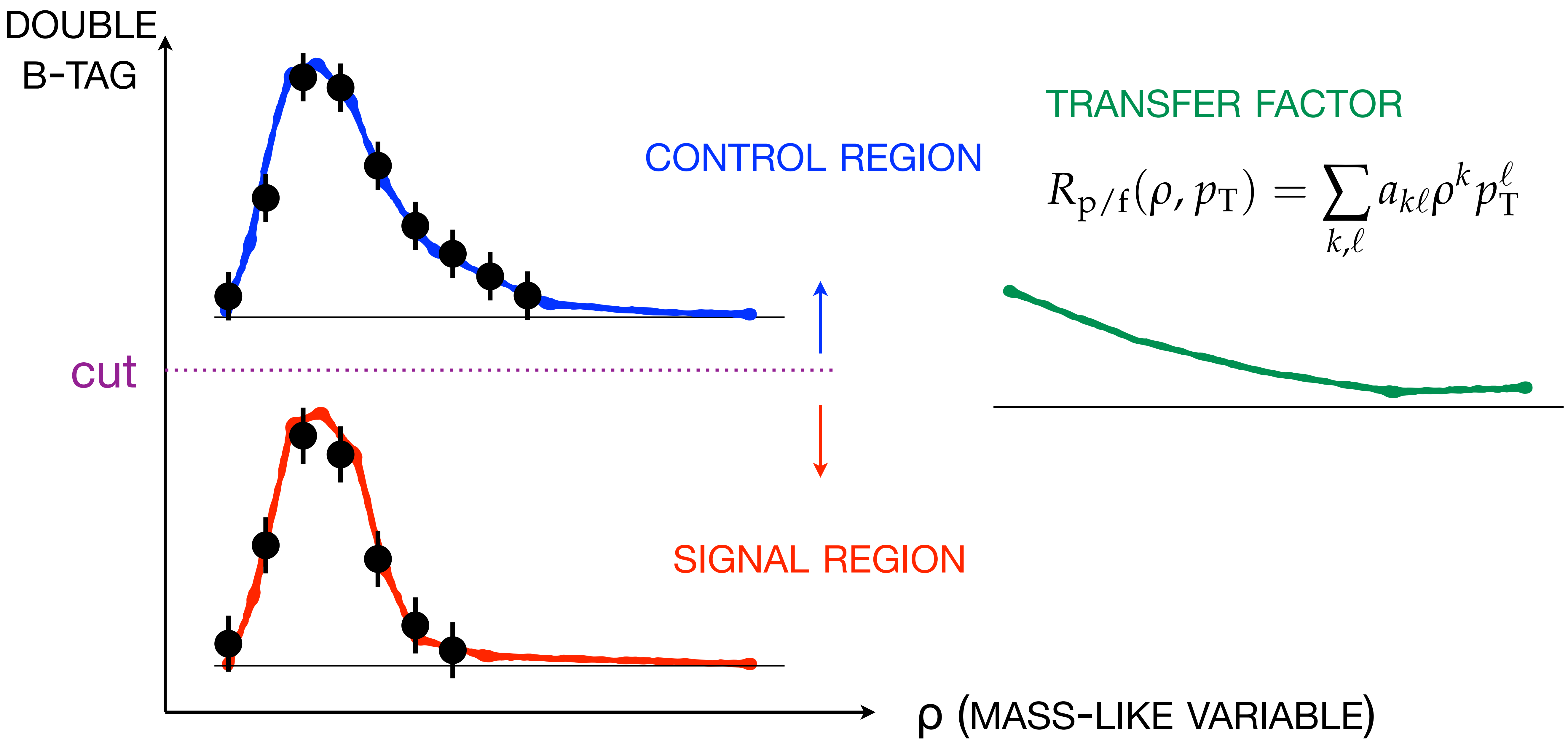
FITTING TRANSFER FACTOR

- Pre-fit both regions have the same predicted shape

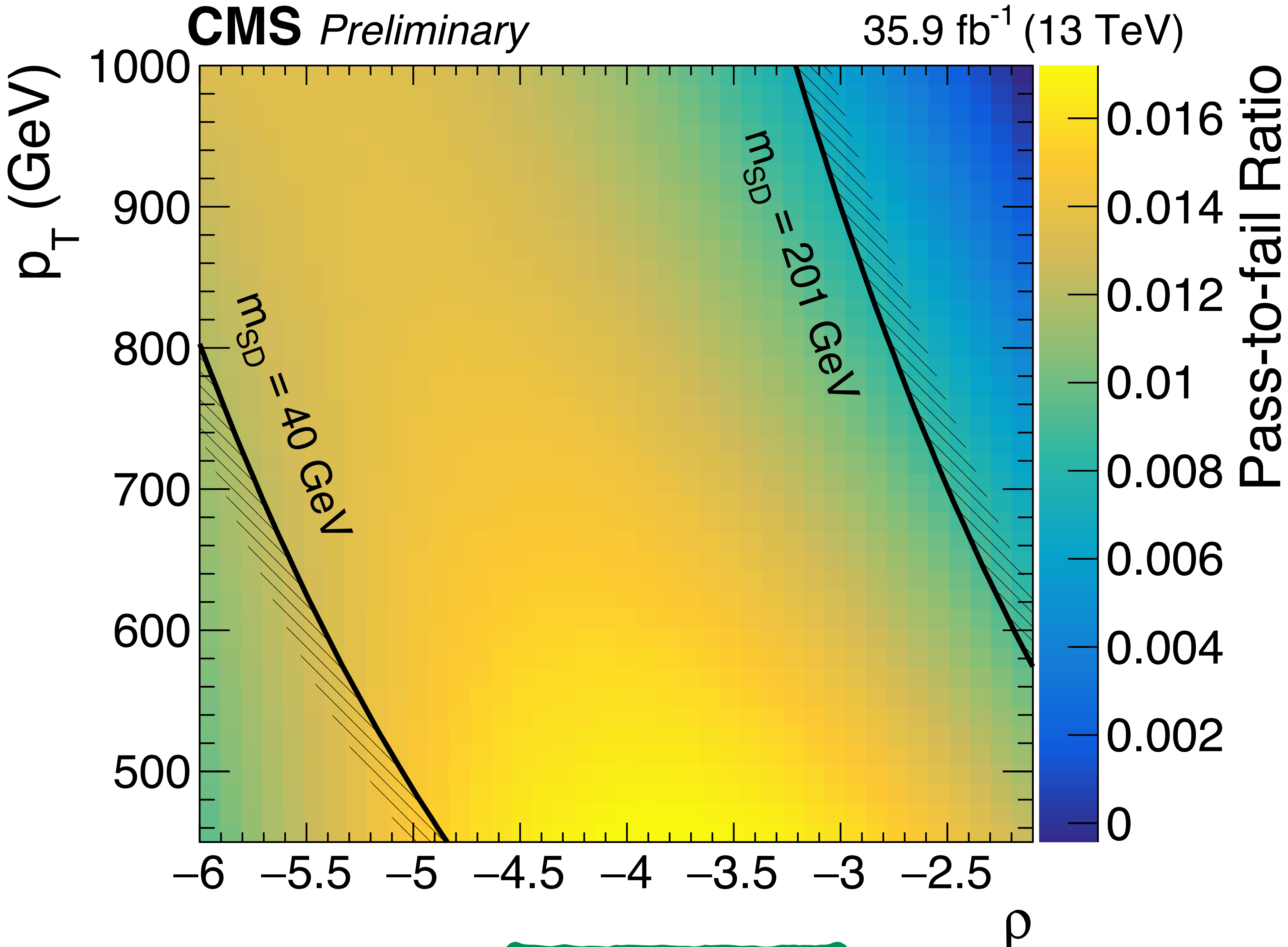


FITTING TRANSFER FACTOR

- Post-fit signal region has slightly different shape with the ratio given by the polynomial transfer factor



QCD TRANSFER FACTOR

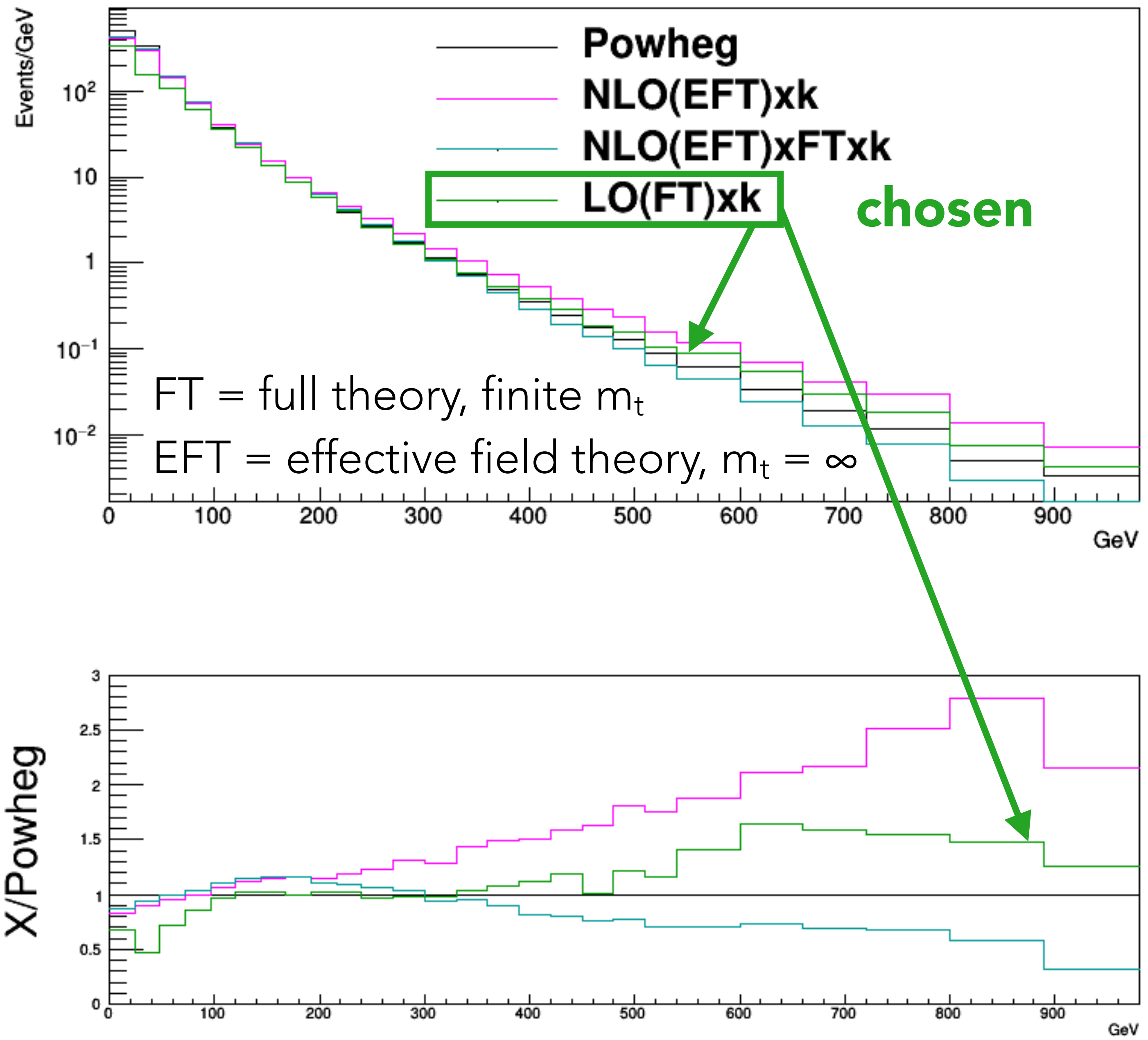


$$N_{\text{pass}}^{\text{QCD}}(m_{\text{SD}i}, p_{\text{T}j}) = \boxed{\left(\sum_{k,\ell} a_{k\ell}\rho_{ij}^{k} {p_{\text{T}}}_{j}^{\ell}\right)} \cdot N_{\text{fail}}^{\text{QCD}}(m_{\text{SD}i}, p_{\text{T}j})$$

HIGGS P_T MODELING

More details: https://indico.cern.ch/event/675782/contributions/2766455/

- LO H+0–2jet (MadGraph) Pythia CKKW-L merged, finite m_t
- NLO H+1jet finite m_t up to $1/m_t^4$ expansion: arXiv:1609.00367
- NNLO H+1jet, $m_t = \infty$, p_T^H up to ~200 GeV arXiv:1508.02684
- Two factorized systematic uncertainties:
  - 30% overall normalization
  - 30% linear change in slope (no effect on overall norm.)



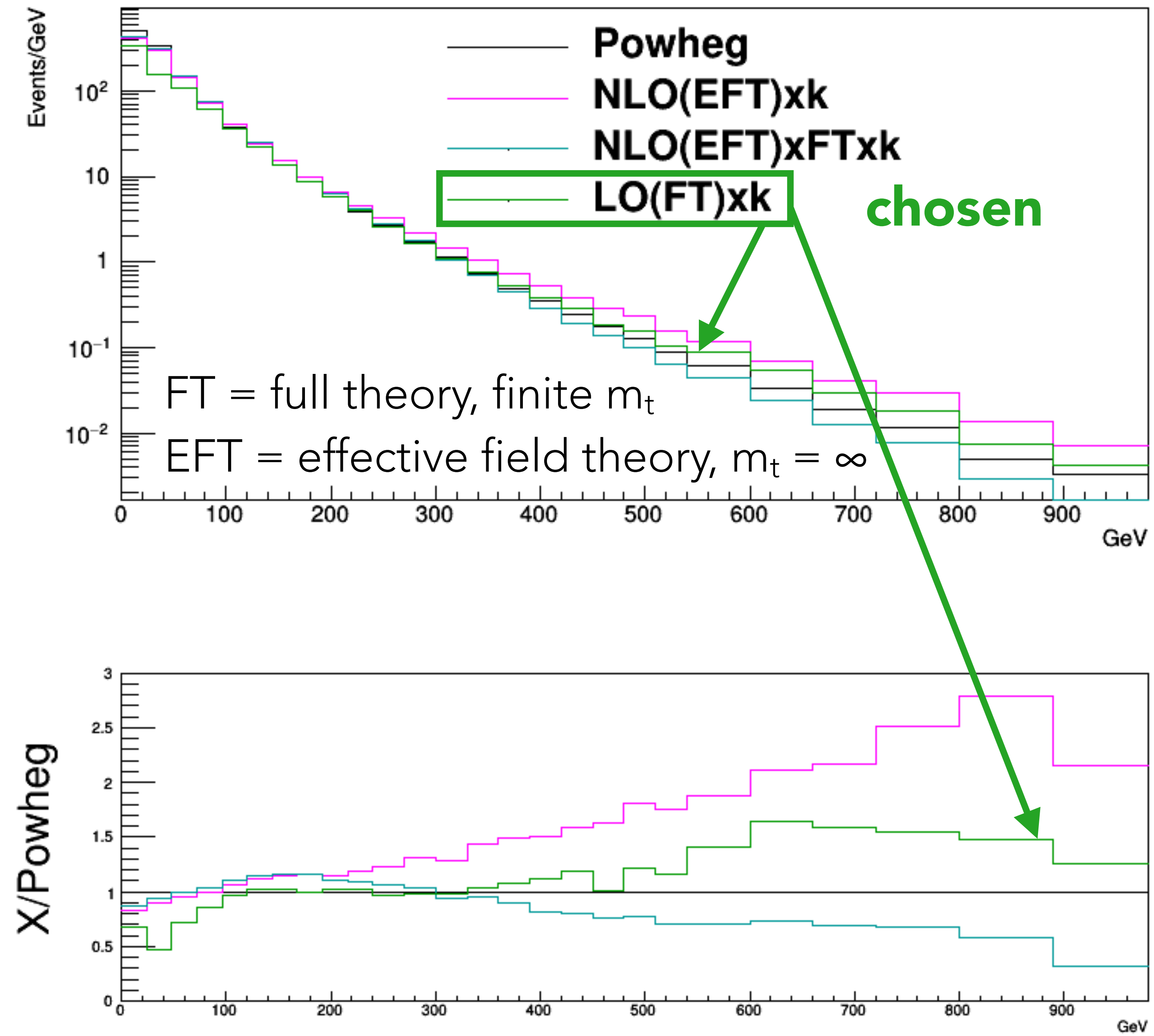
$$\text{ggF H(NNLO} + m_t) = \text{Powheg}(1 \text{ jet } m_t) \times \frac{\text{MG LO } 0-2 \text{ jet } m_t}{\text{Powheg}(1 \text{ jet } m_t)} \times \frac{\text{NLO 1 jet } m_t}{\text{LO 1 jet } m_t} \times \frac{\text{NNLO 1 jet } m_t \to \infty}{\text{NLO 1 jet } m_t \to \infty}$$

CKKW merged | factor of 2 | factor of 1.25

HIGGS p_T MODELING

More details: https://indico.cern.ch/event/675782/contributions/2766455/

- We quote 31.7 fb ggF H(bb) cross section for leading reco. jet p_T > 450 GeV, |η| < 2.5
- Other (more recent) sources quote ~6-9 fb
- Differences come from:
  - Parton shower (35%)
  - Reconstruction (25%)
  - Leading p_T jet selection (25%)
- Corresponding ME-level cross section for Higgs p_T > 450 GeV is 15.1 fb



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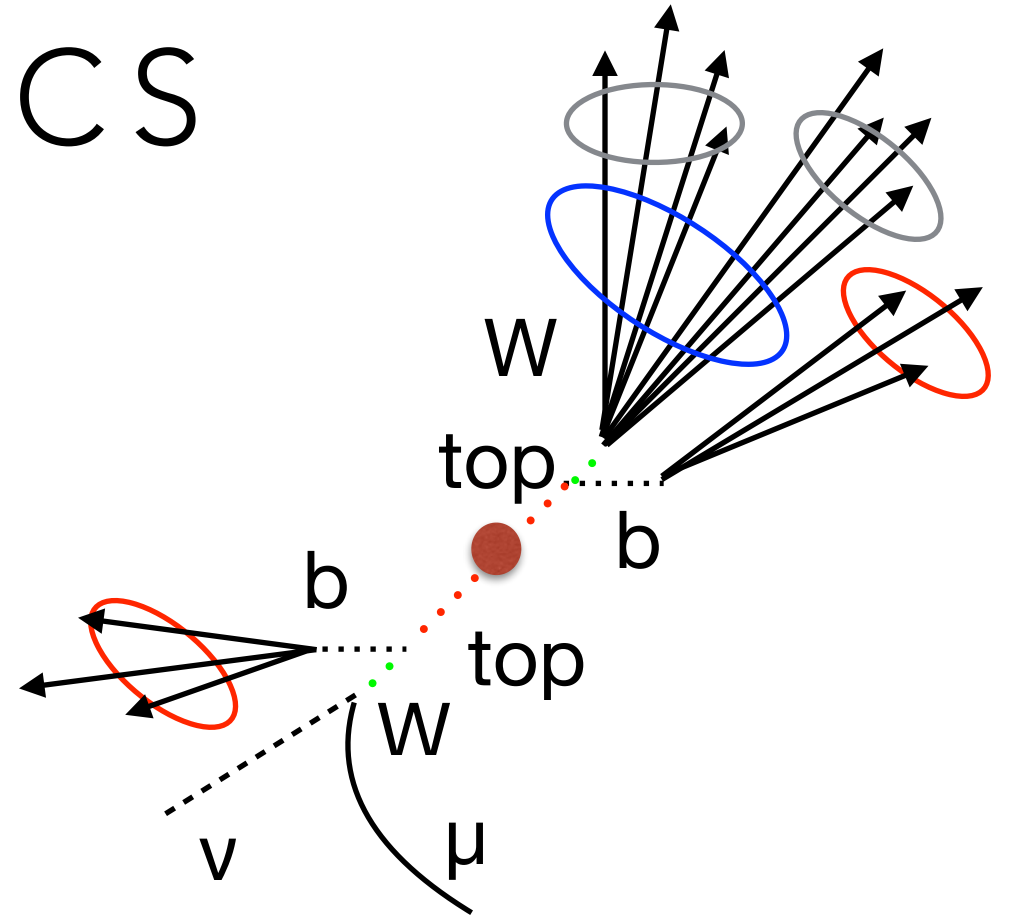
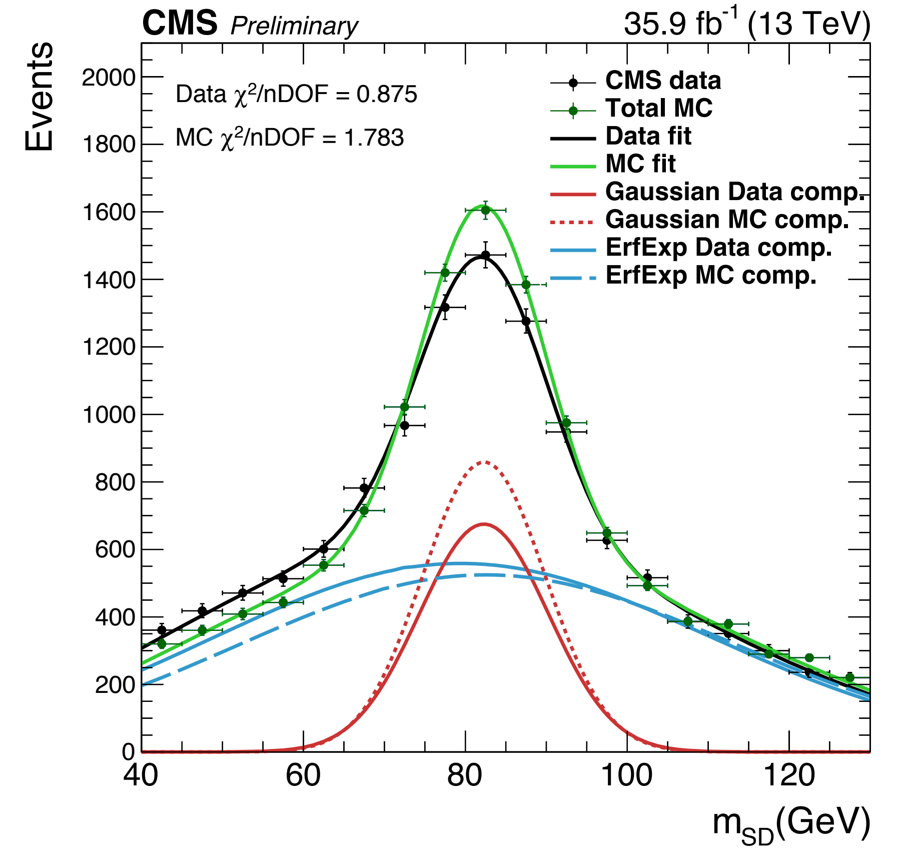
CKKW merged — factor of 2 — factor of 1.25

SYSTEMATICS

Systematic uncertainty source	Type (shape or normalization)	Relative size (or description)
QCD transfer factor	both	profile $a_{k\ell}$ and QCD normalization
Luminosity	normalization	2.5%
V-tag ($N_2^{1,DDT}$) efficiency	normalization	4.3%
Muon veto efficiency	normalization	0.5%
Electron veto efficiency	normalization	0.5%
Trigger efficiency	normalization	4%
Muon ID efficiency	shape	up to 0.2%
Muon isolation efficiency	shape	up to 0.1%
Muon trigger efficiency	shape	up to 8%
$t\bar{t}$ normalization SF	normalization	from 1μ CR: 8%
$t\bar{t}$ double-b mis-tag SF	normalization	from 1μ CR: 15%
W/Z NLO QCD corrections	normalization	10%
W/Z NLO EWK corrections	normalization	15% – 35%
W/Z NLO EWK ratio decorrelation	normalization	5% – 15%
double-b tagging efficiency	normalization	4%
Jet energy scale	normalization	up to 10%
Jet energy resolution	normalization	up to 15%
Jet mass scale	shape	shift m_{SD} peak by $\pm0.4\%$
Jet mass resolution	shape	smear m_{SD} distribution by $\pm9\%$
Jet mass scale p_T	normalization	0.4%/100 GeV (p_T)
Monte Carlo statistics	normalization	-
H p_T correction (gluon fusion)	both	30%



- Signal systematic uncertainties from merged W sample in semi-leptonic ttbar events (external constraint)
- SM candles: presence of W/Z(bb) in final jet mass distribution provides in-situ constraint
- Higgs p_T correction uncertainty of 30%



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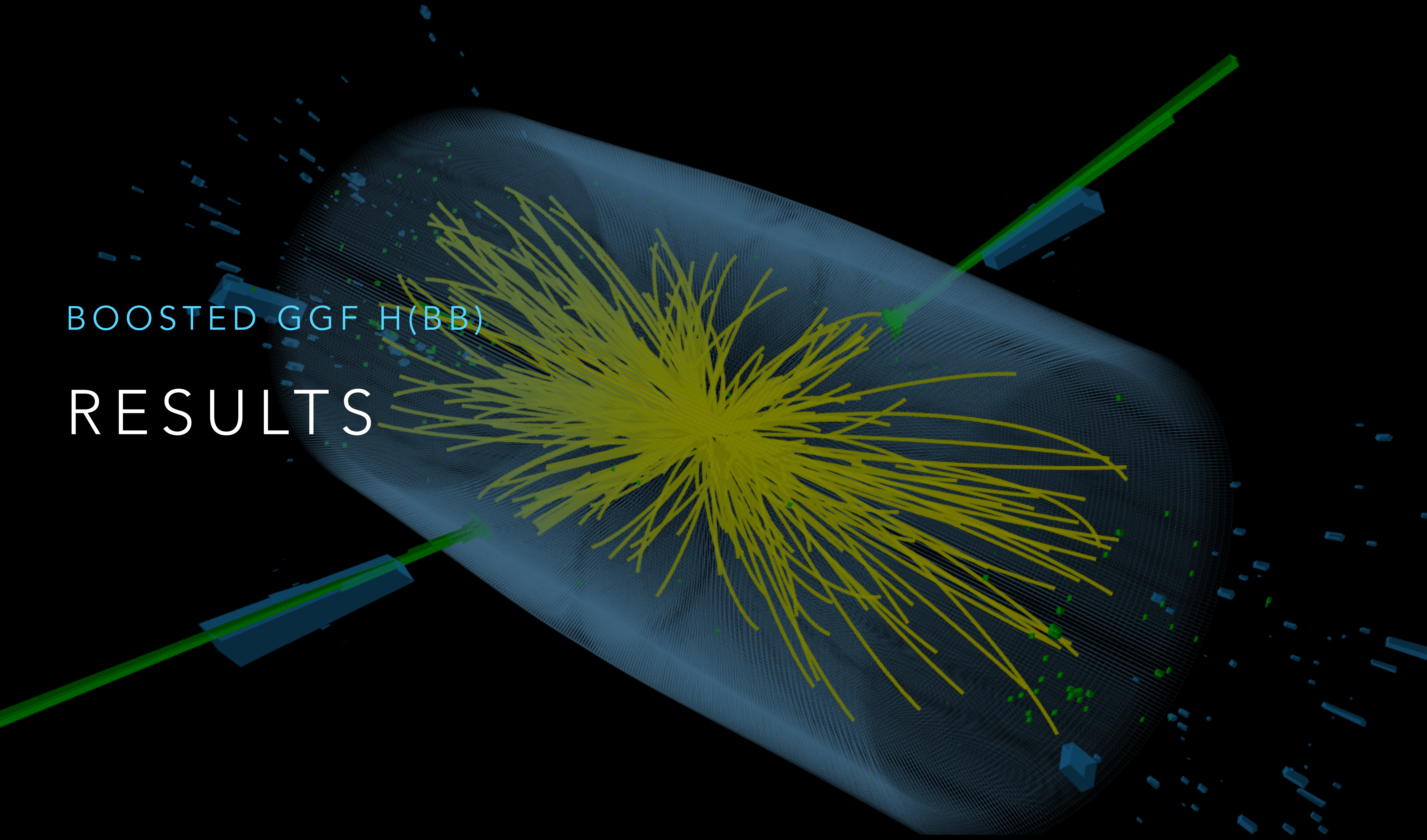
RESULTS



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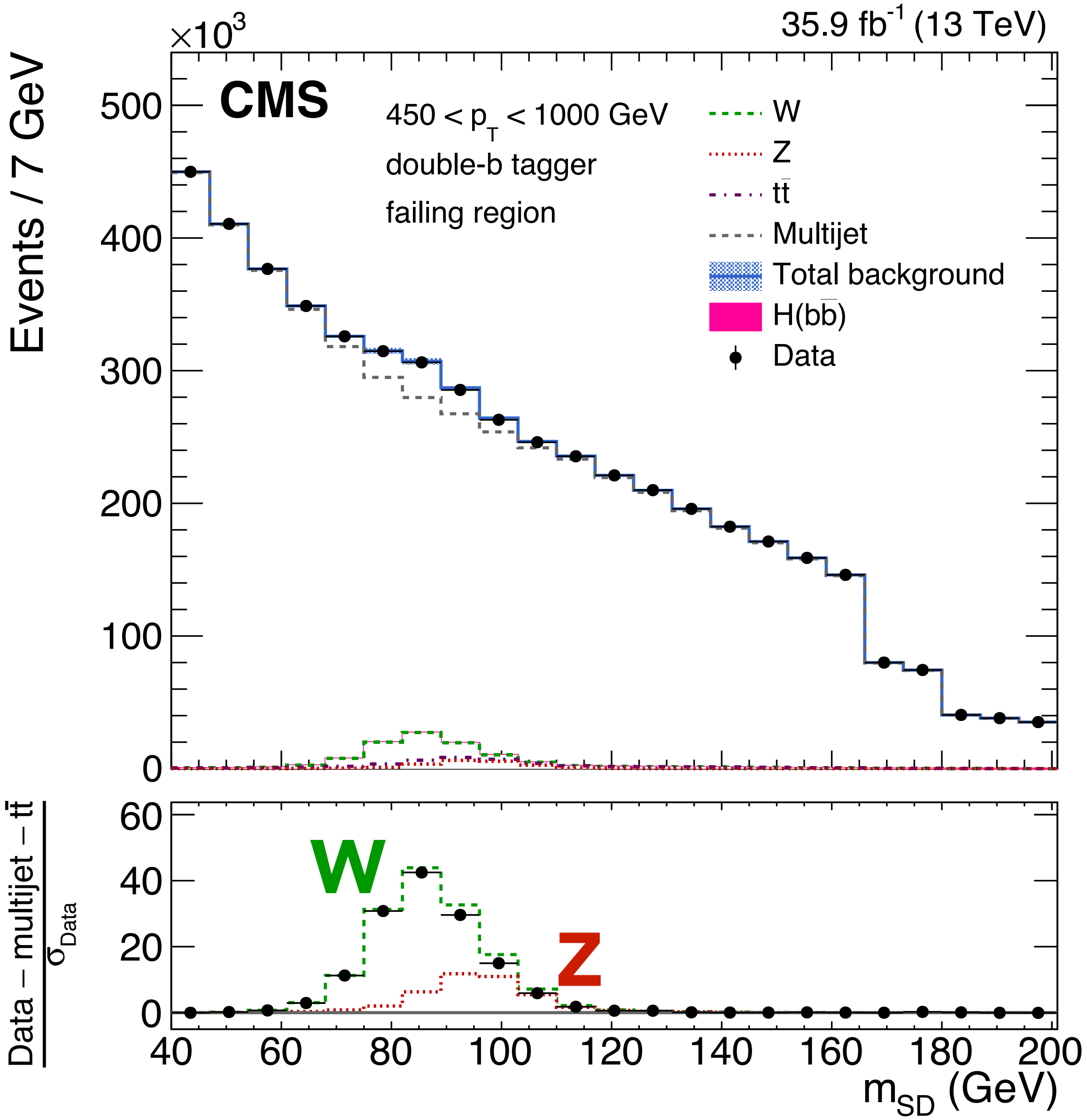
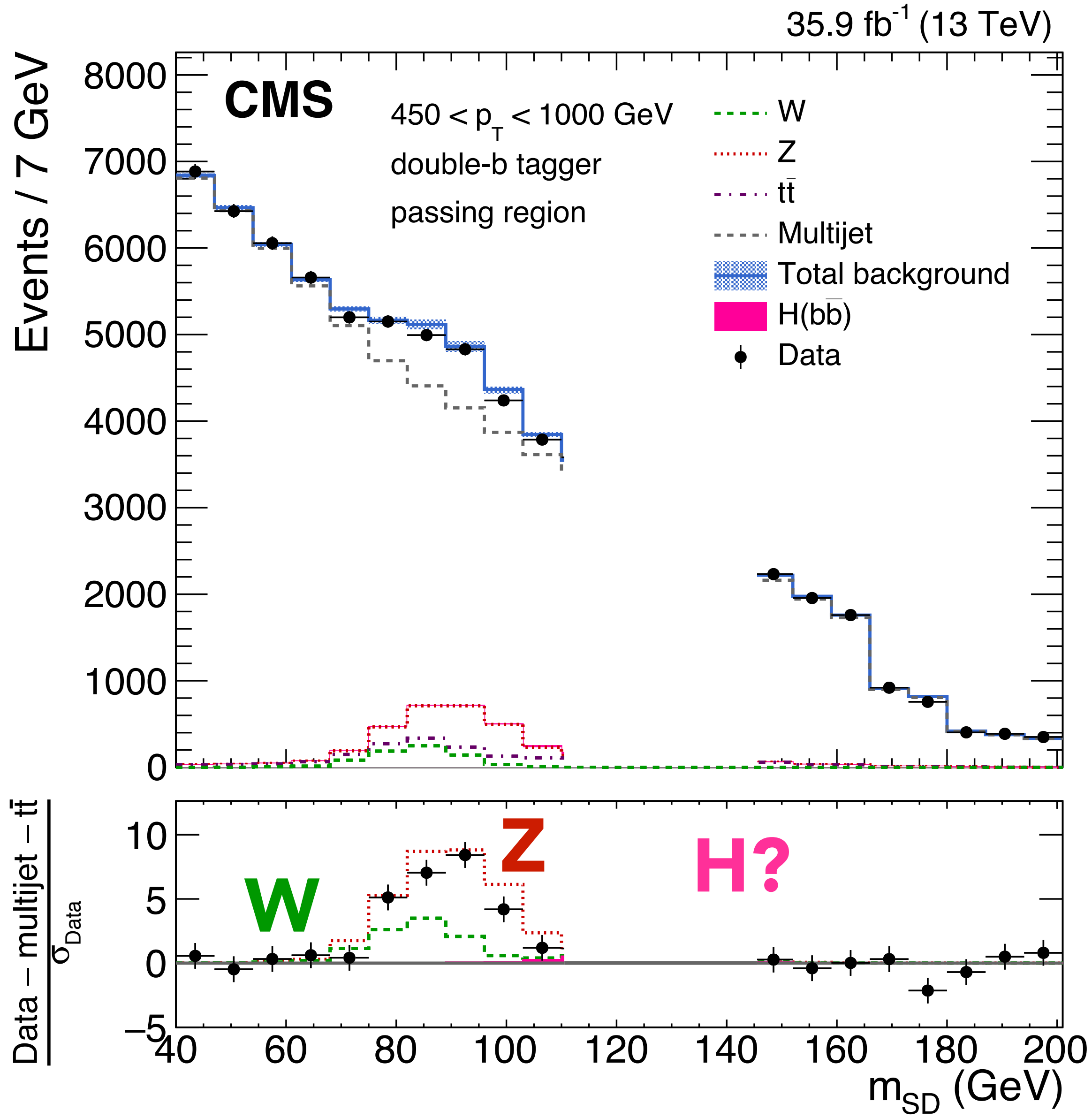
FIT RESULTS

- Simultaneous fit for Z(bb) and H(bb)
- All p_T categories





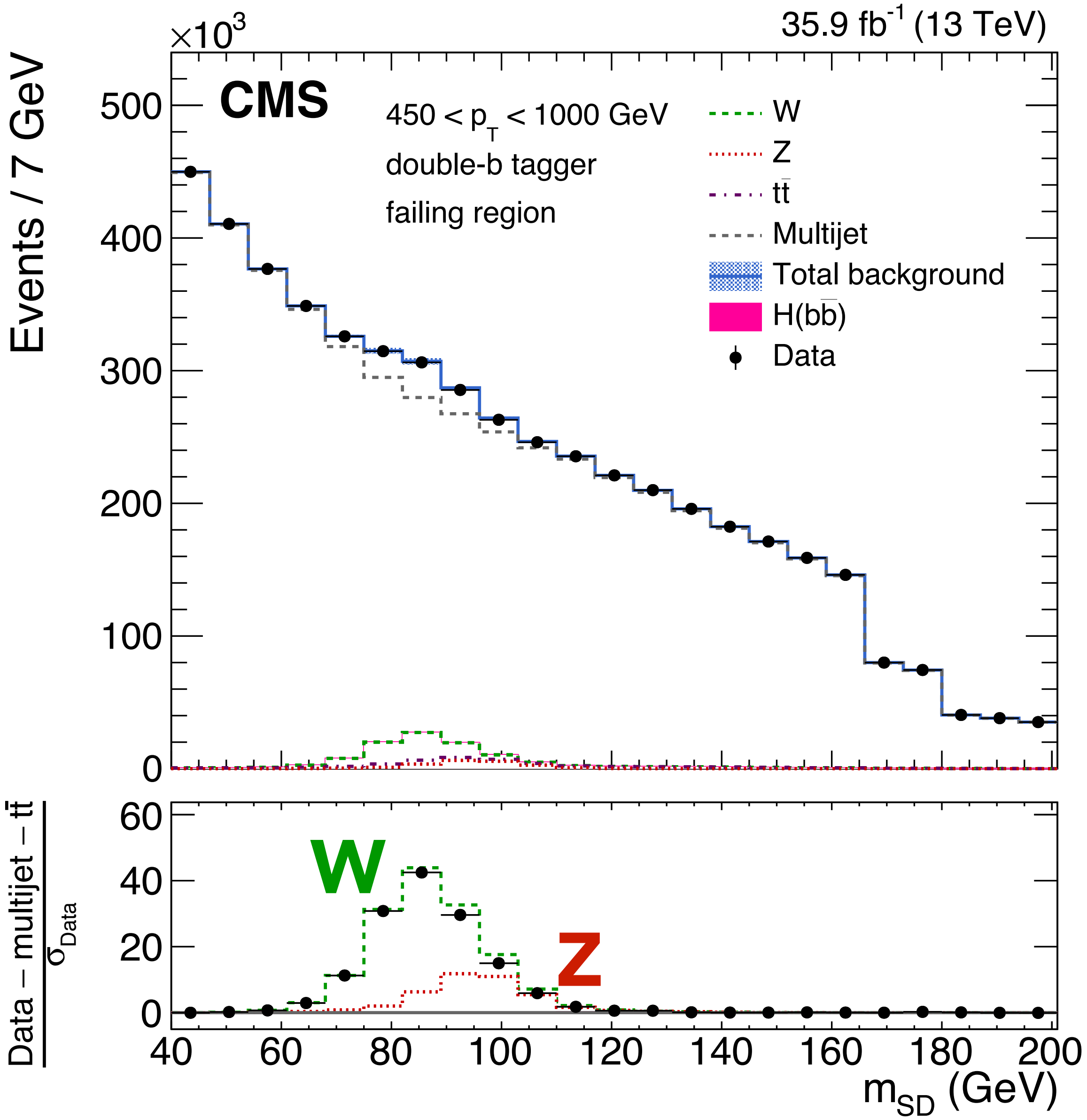
SM candles: Z(bb) peak provides in-situ constraint of H(bb) signal systematics

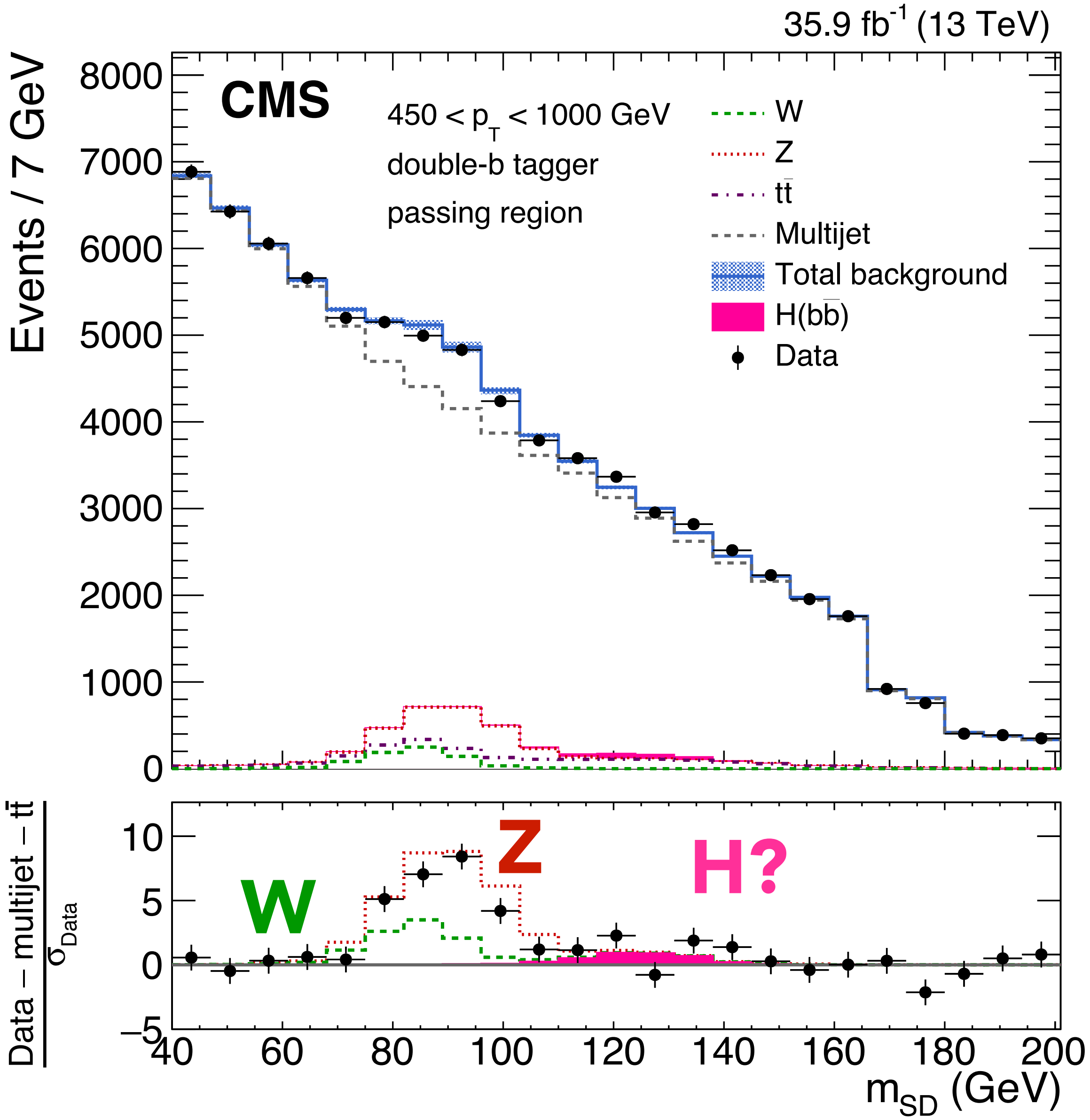
observed Z(bb) significance: 5.1σ, $\mu_Z = 0.78^{+0.23}_{-0.19}$

HIG-17-010

FIT RESULTS

- Simultaneous fit for Z(bb) and H(bb)
- All p_T categories





observed H(bb) significance:

1.5σ, $\mu_H = 2.3^{+1.8}_{-1.6}$

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FIT RESULTS

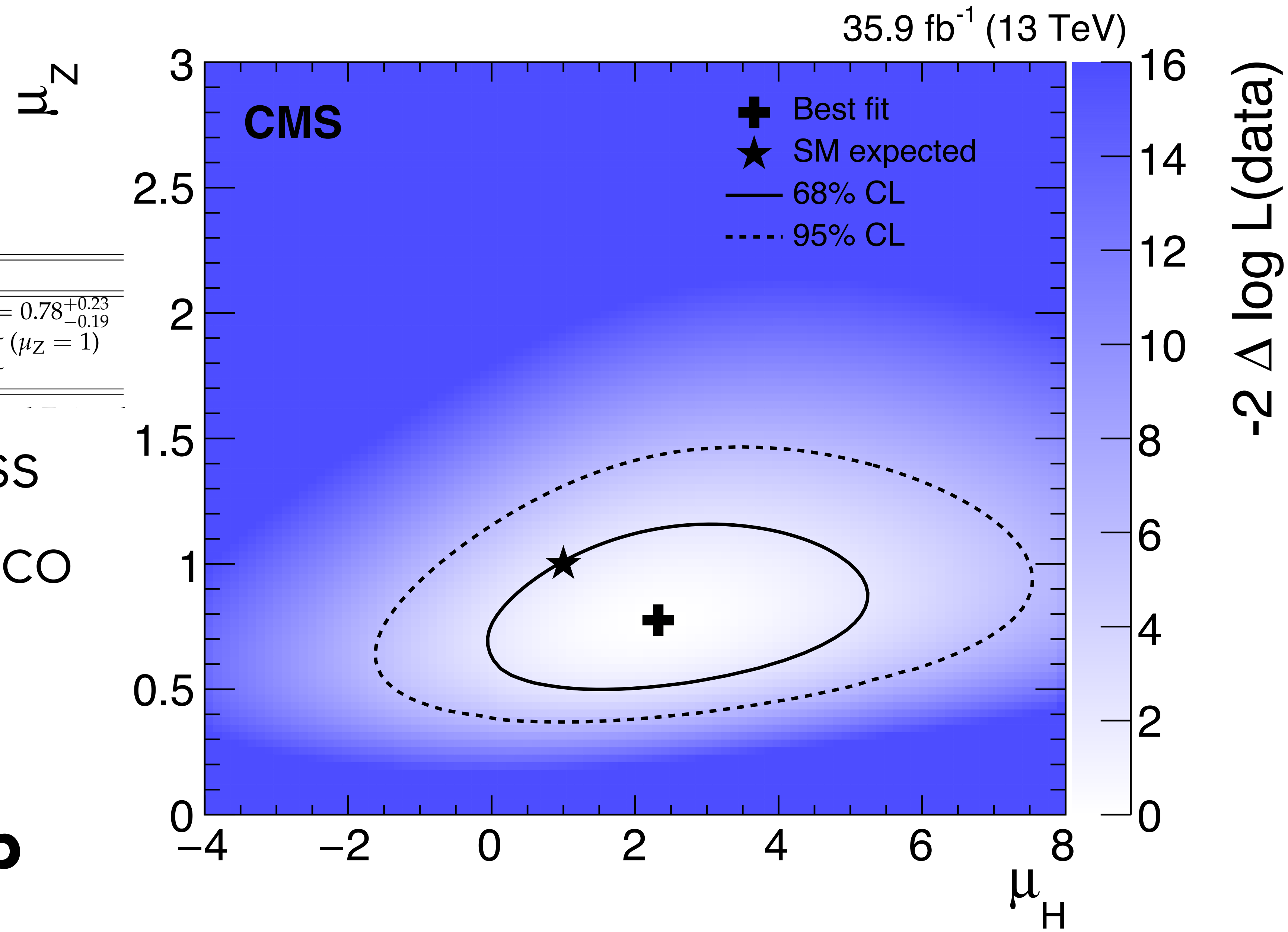
- Two dimensional likelihood scan

	H	H no p_T corrections	Z
Observed best fit	$\mu_H = 2.3^{+1.8}_{-1.6}$	$\mu'_H = 3.2^{+2.2}_{-2.0}$	$\mu_Z = 0.78^{+0.23}_{-0.19}$
Expected significance	0.7σ ($\mu_H = 1$)	0.5σ ($\mu'_H = 1$)	5.8σ ($\mu_Z = 1$)
Observed significance	1.5σ	1.6σ	5.1σ

measured visible cross sections for leading reco jet p_T > 450 GeV:

$\sigma_H = 74^{+51}_{-49}$ fb

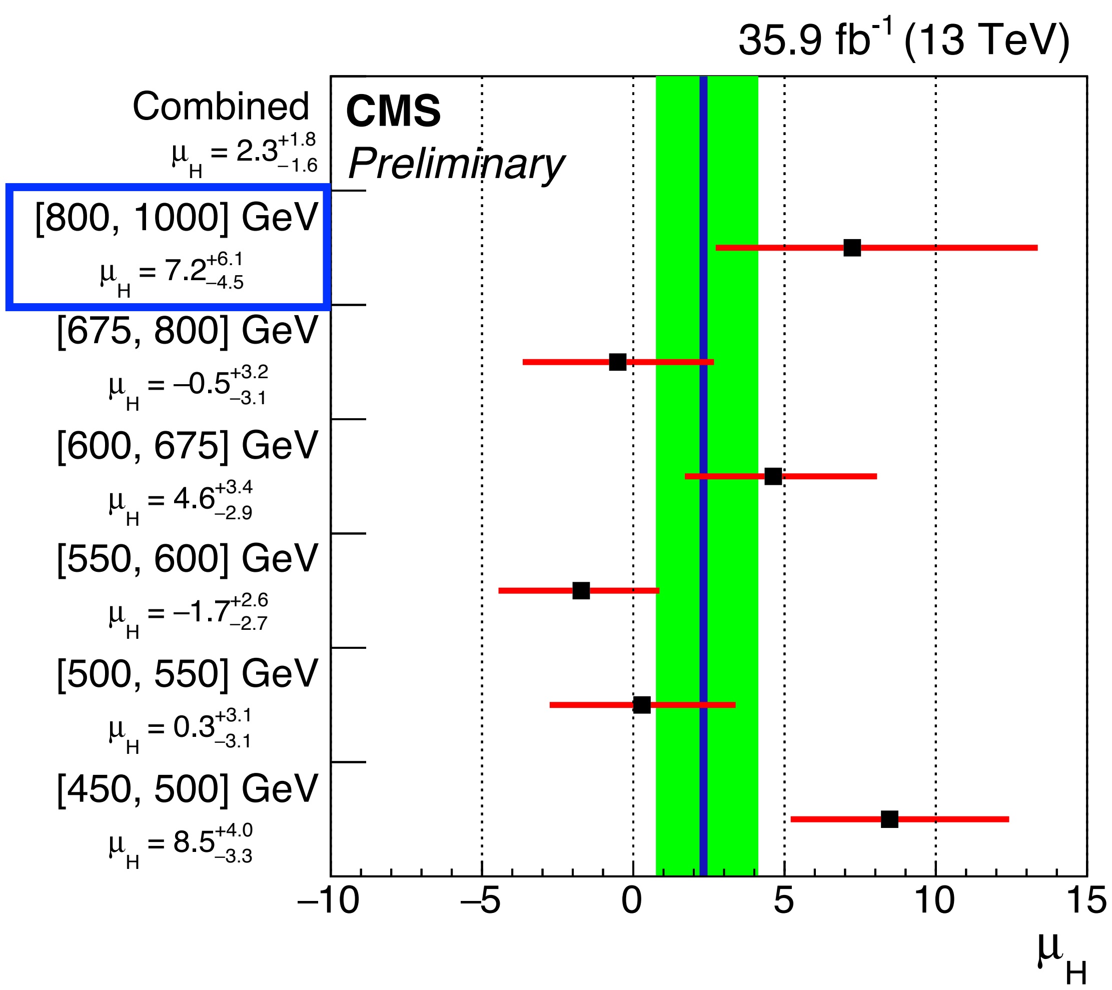
$\sigma_Z = 0.85^{+0.26}_{-0.21}$ pb

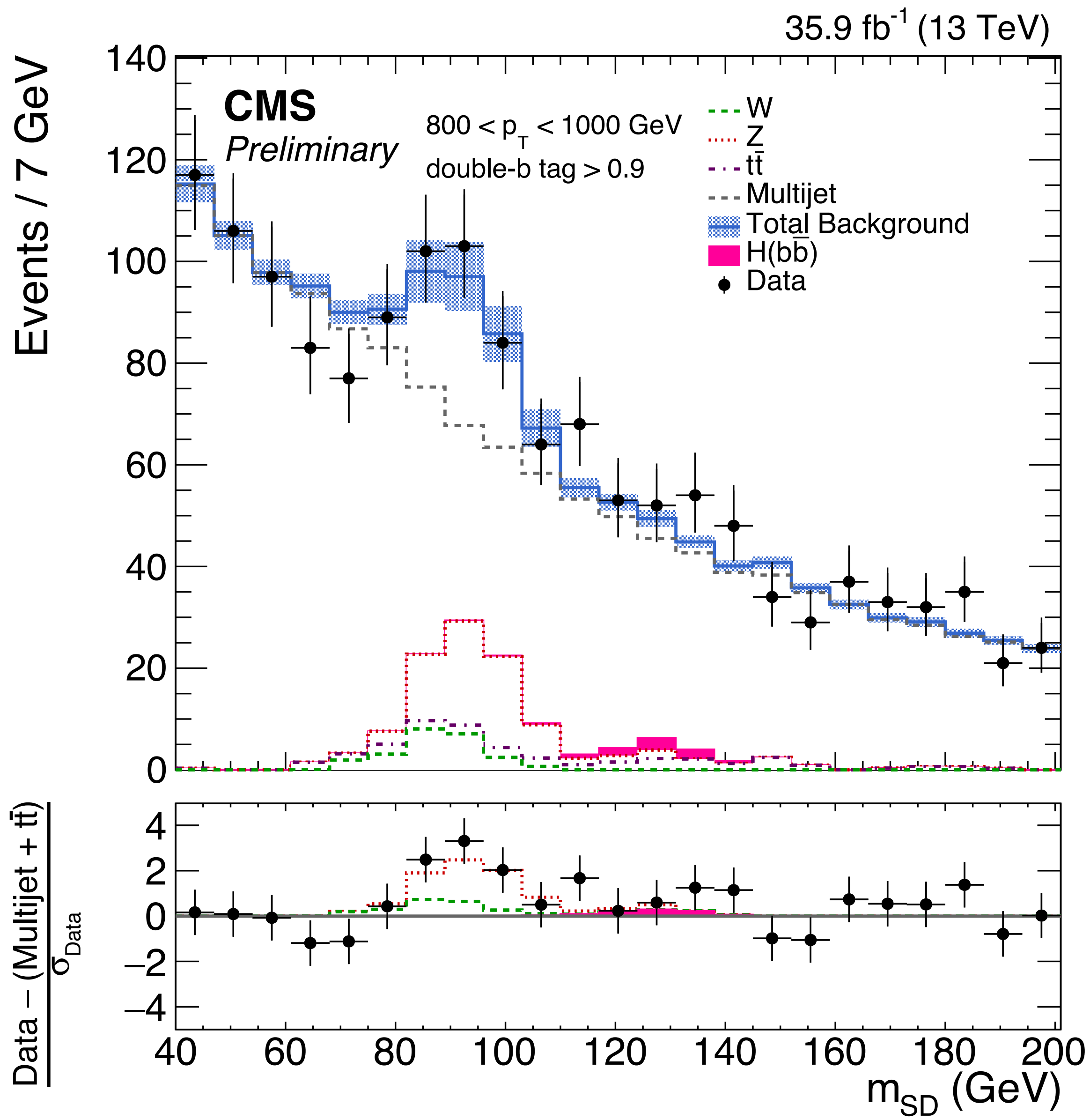


HIG-17-010

p_T CATEGORIES

- Probing Higgs production up to p_T = 1 TeV!





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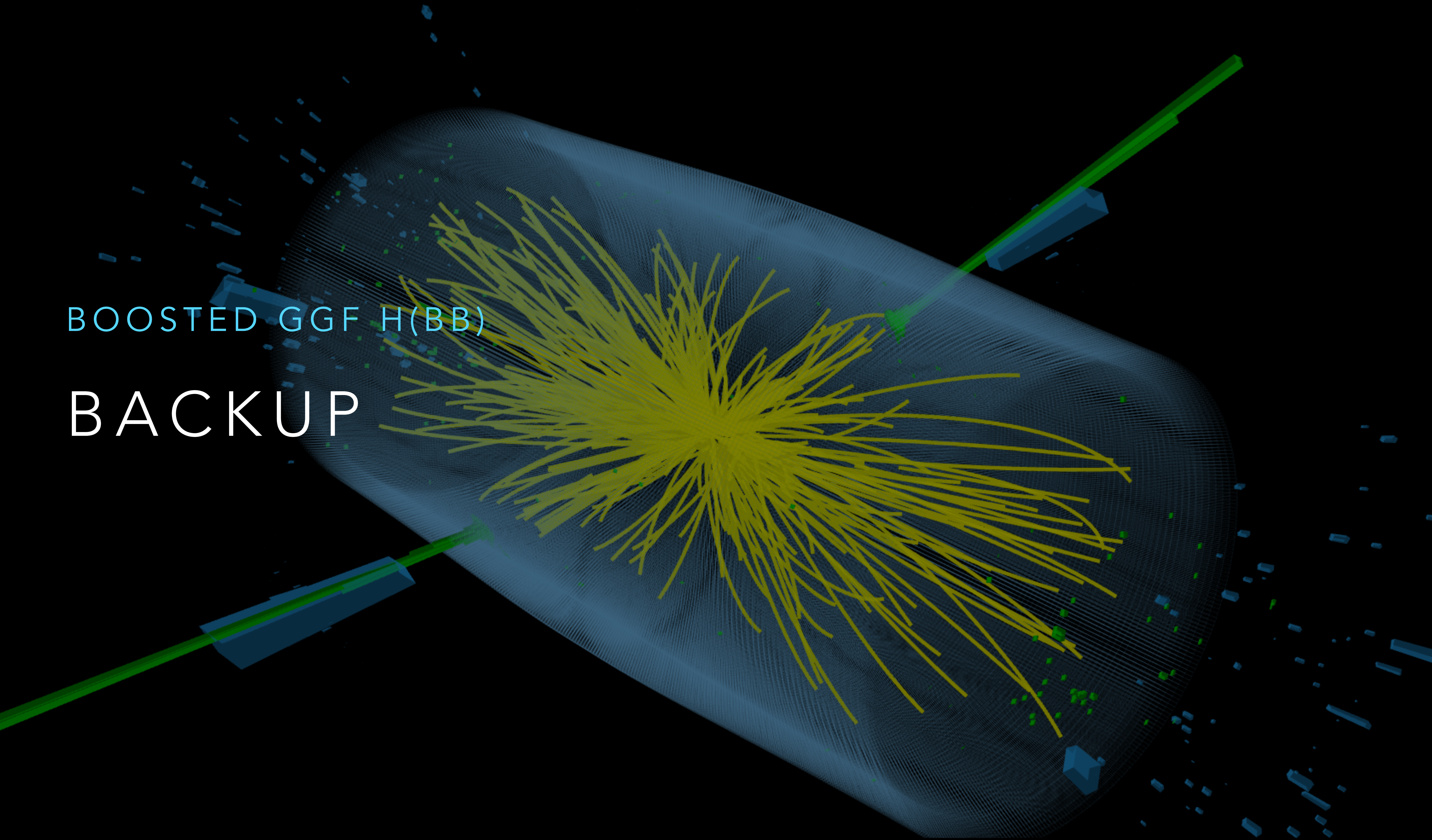
SUMMARY AND OUTLOOK

- First LHC search for gg → H → bb in boosted topology
  - First observation of Z(bb) in single-jet topology, 5.1σ observed (5.8σ expected)
  - Observed significance of H(bb) is 1.5σ (0.7σ expected)
- Search probes **previously unexplored** regions of Higgs phase space
- **New** and **generic** strategy to search for boosted hadronic Higgs decays
  - Future prospects are bright: same search may have ~3σ expected H(bb) significance for 2016+2017+2018 data
  - Probing **Higgs boson p_T** up to **1 TeV** and beyond…

BOOSTED GGF H(BB)

BACKUP



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QCD TRANSFER FACTOR

- If the double b-tagger were completely uncorrelated from jet mass and p_T, the transfer factor would be flat
- Taylor expand as a polynomial in **ρ** and p_T to parameterize any small correlations

- F-test determined 2nd order in **ρ** and 1st order in p_T is sufficient to fit the ratio

$$N^{\mathrm{QCD}}_{\mathrm{pass}}(m_{\mathrm{SD}}, p_{\mathrm{T}}) = R_{\mathrm{p/f}}(\rho, p_{\mathrm{T}}) \cdot N^{\mathrm{QCD}}_{\mathrm{fail}}(m_{\mathrm{SD}}, p_{\mathrm{T}})$$

$$N^{\mathrm{QCD}}_{\mathrm{pass}}(m_{\mathrm{SD}i}, p_{\mathrm{T}j}) = \boxed{\left(\sum_{k,\ell} a_{k\ell}\rho^{k}_{ij} {p_{\mathrm{T}}}^{\ell}_{j}\right)} \cdot N^{\mathrm{QCD}}_{\mathrm{fail}}(m_{\mathrm{SD}i}, p_{\mathrm{T}j})$$

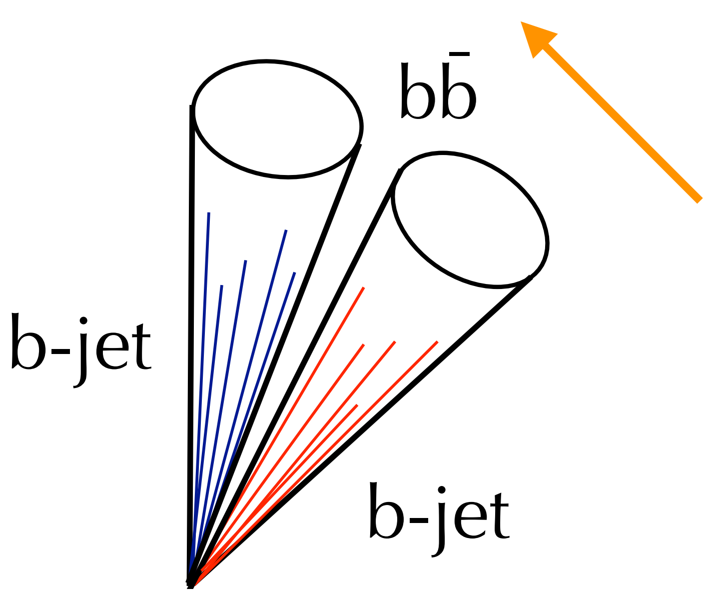
BOOSTED H(BB)

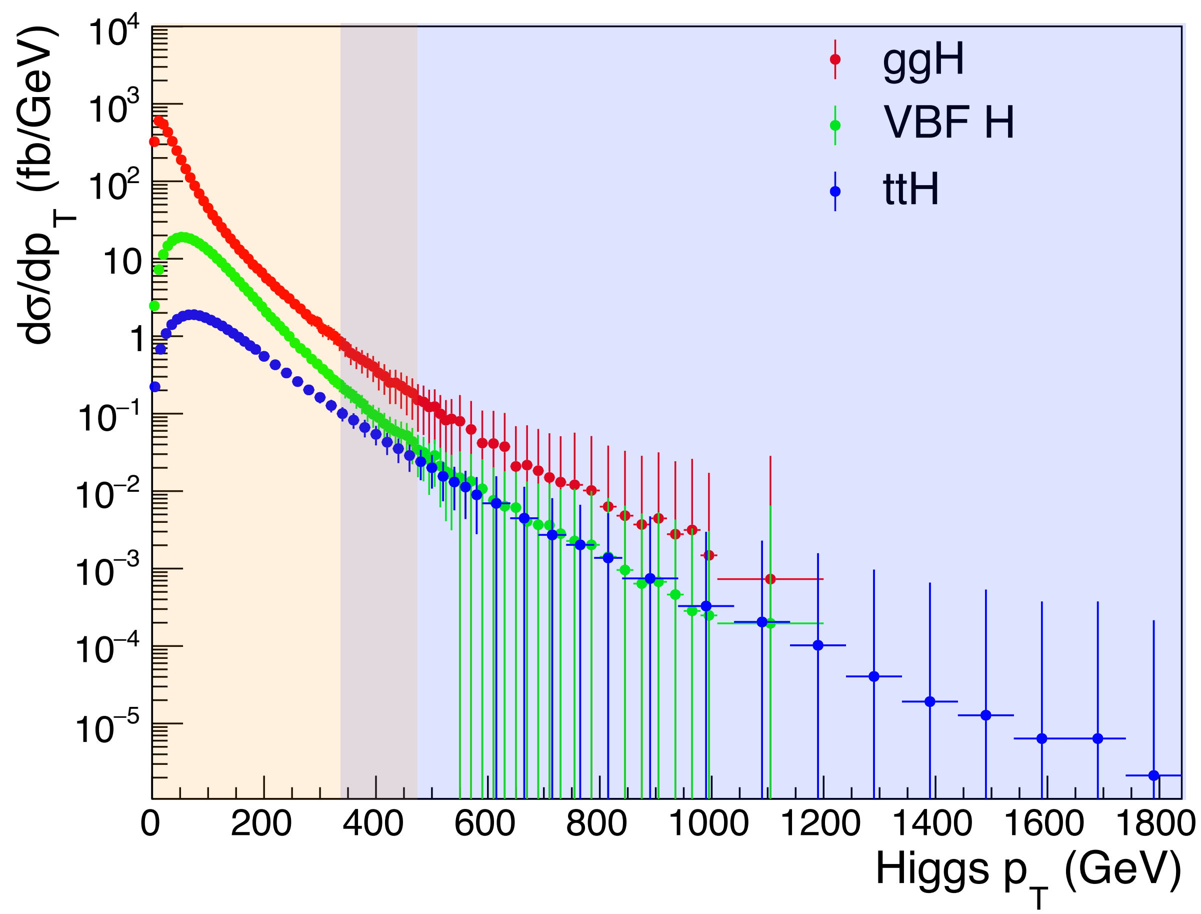
- With large boost, both b quarks merge into a single large radius jets
- How can we best exploit the presence of the b-quarks in the jet in a tagger?

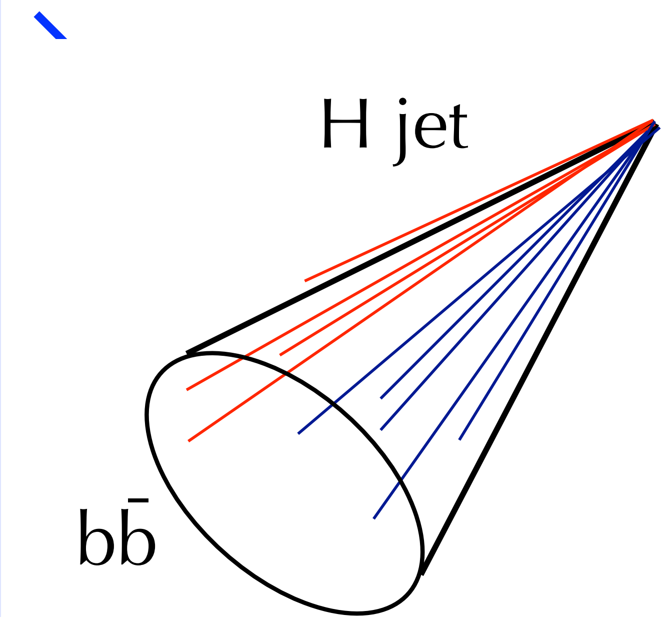
two separated b-jets (R=0.4)

$$\Delta R(b\bar{b}) \sim 2m_H/p_T$$

one merged double b-jet (R=0.8)







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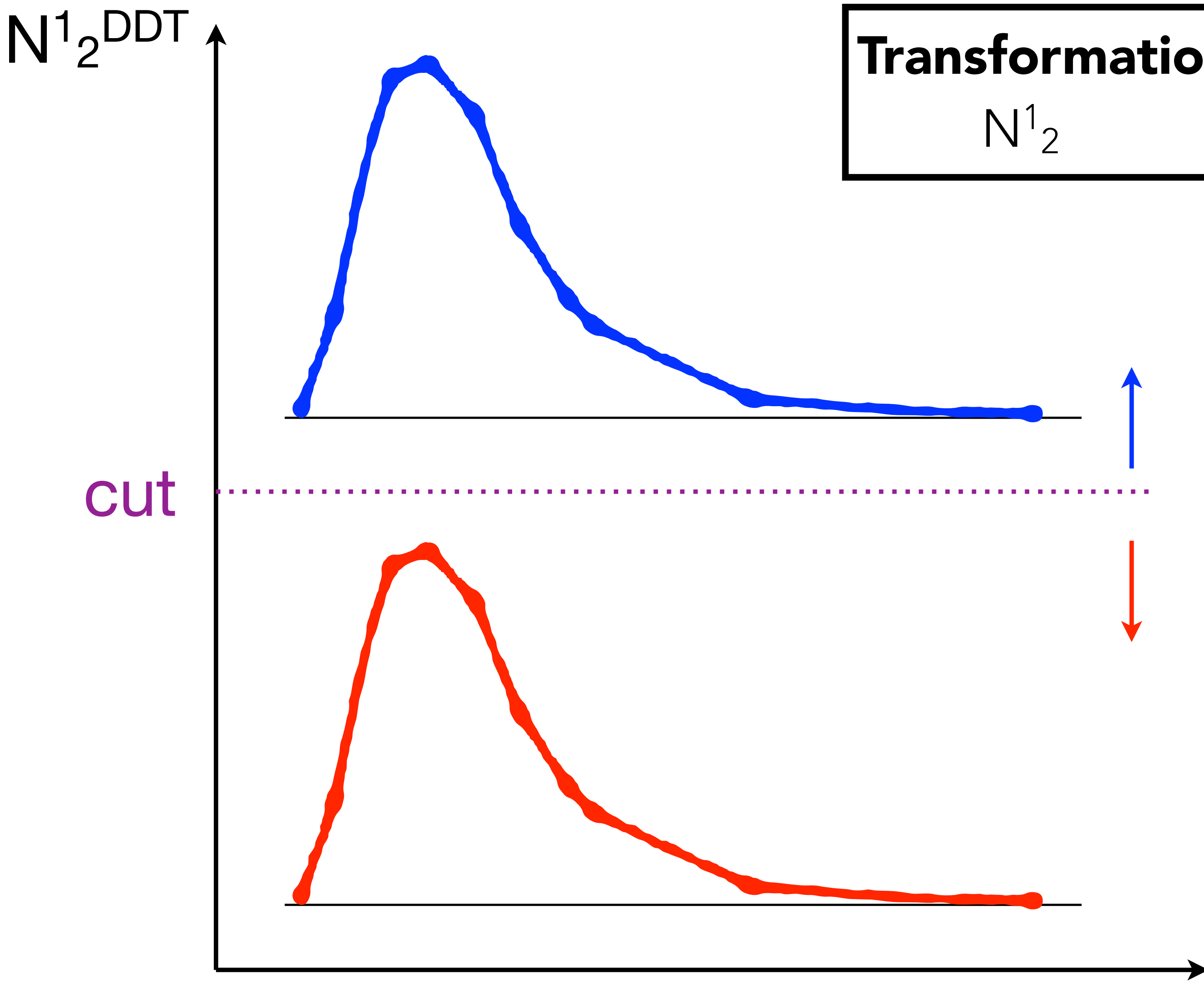
Fermilab

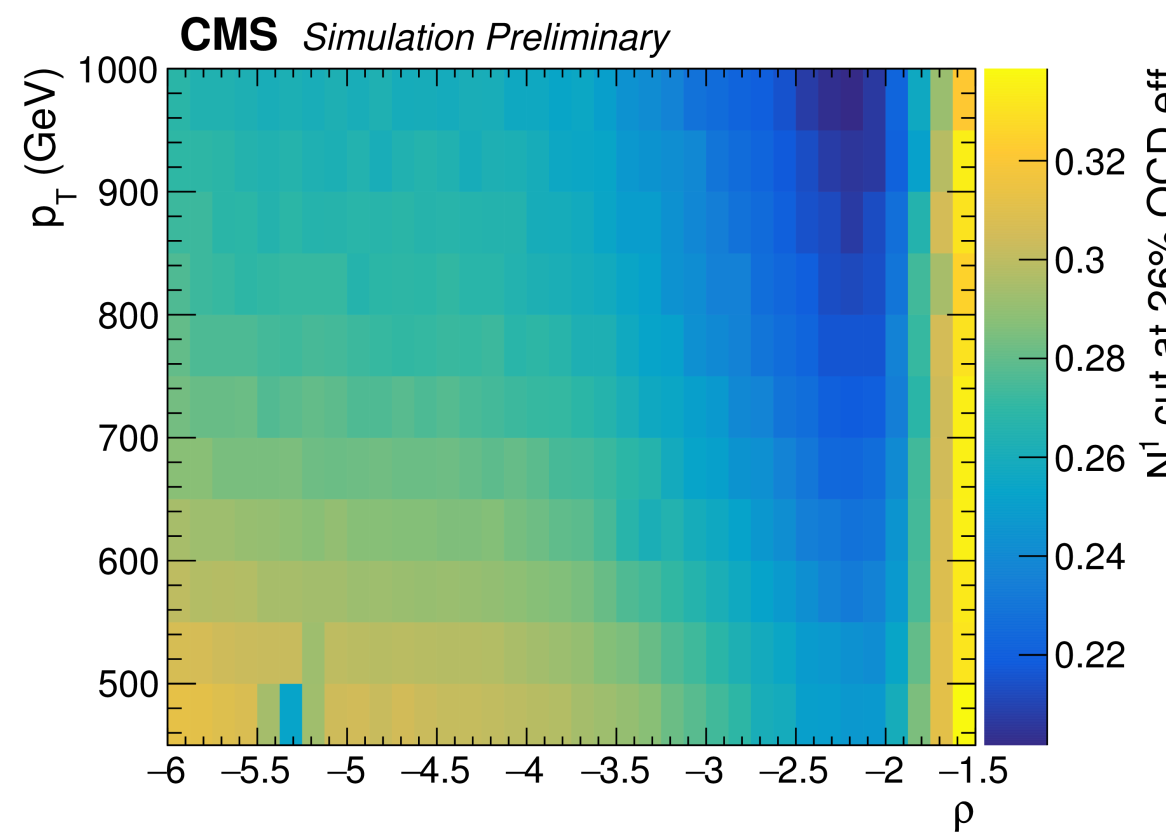
SIDEBAND QCD PREDICTION

- Solution: define new substructure variable intended to be decorrelated from jet mass

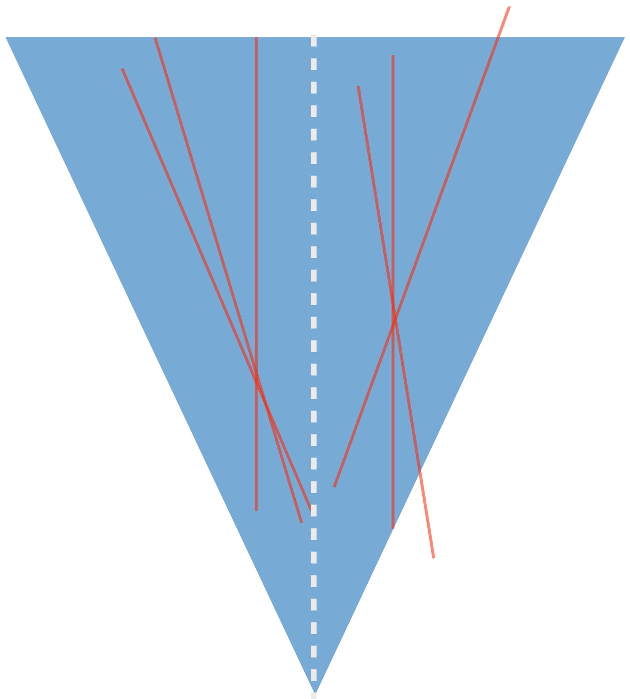
Transformation:

$N^1_2 \rightarrow N^{1\,DDT}_2 = N^1_2 - N^1_{2\,(26\%\ \text{quantile})}$

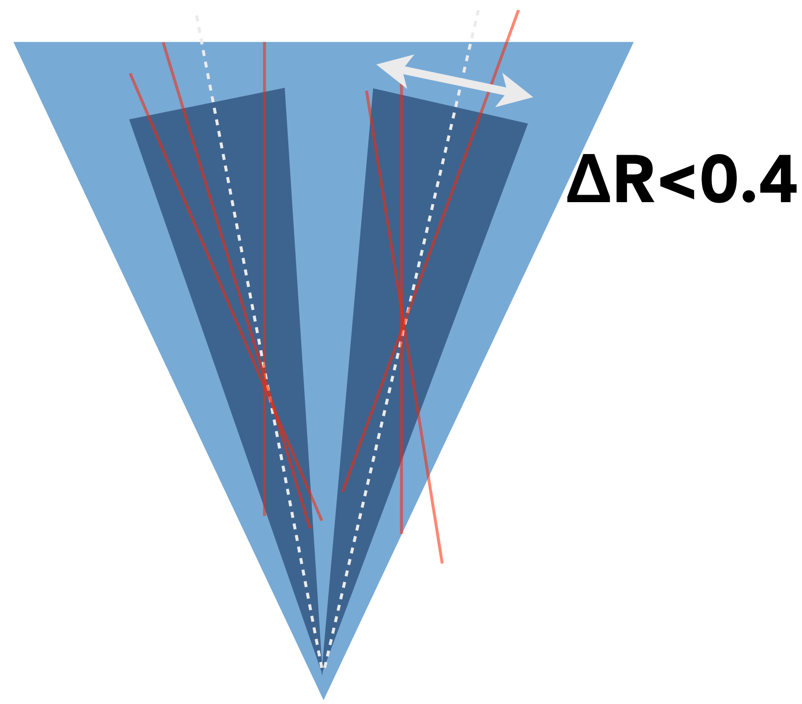




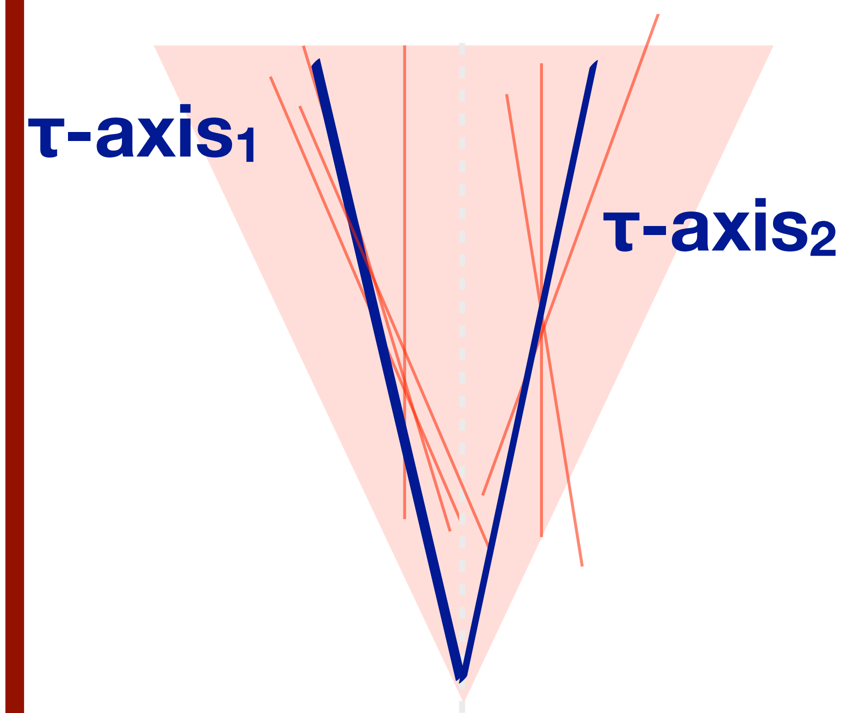
MULTIPLE APPROACHES



fatjet



subjets



double-b

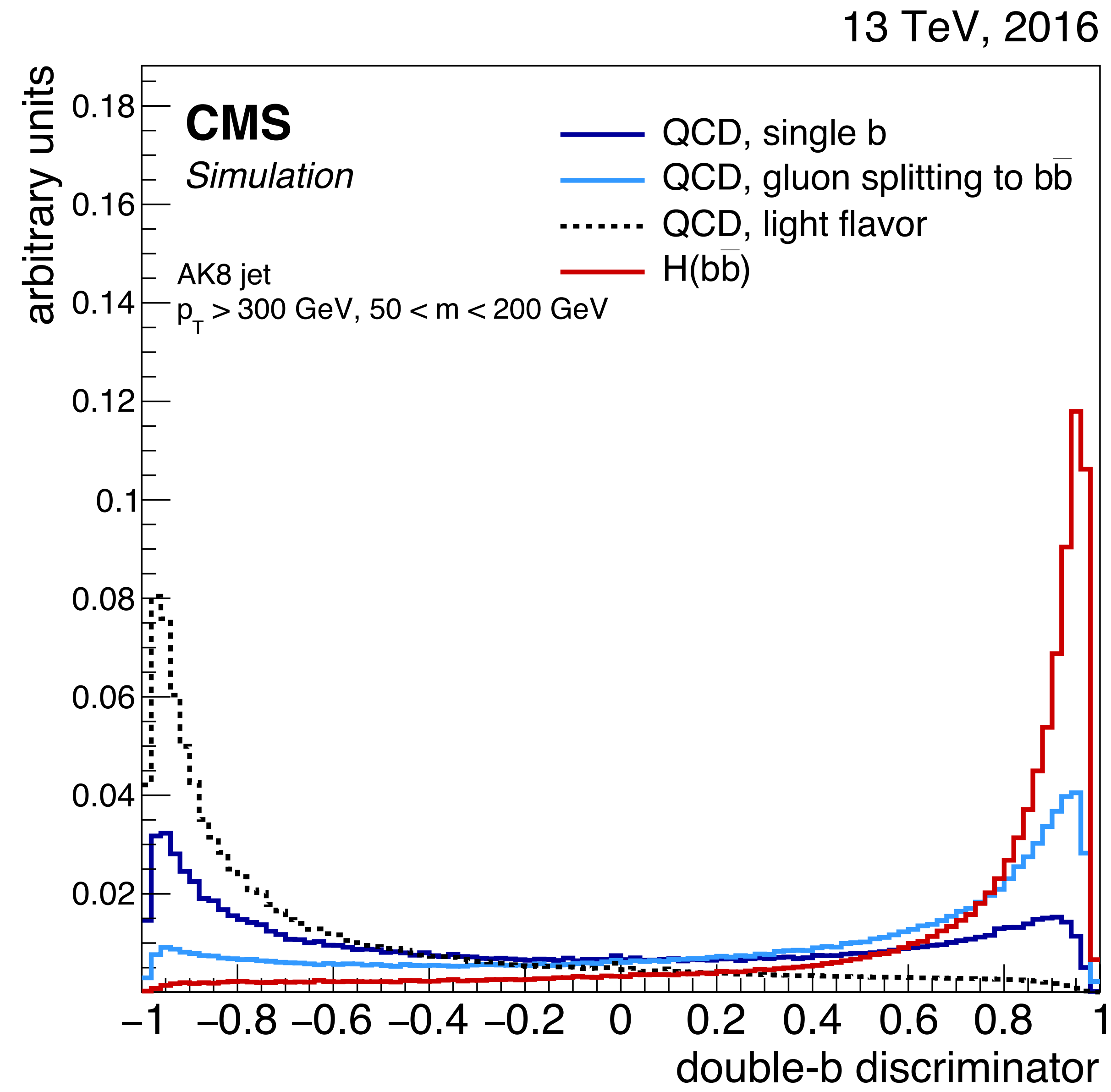
- Based on standard b-tagging algorithm
- Not designed for two b's in the same jet

- Defines sub-jets
- Standard b-tagging applied to each subject

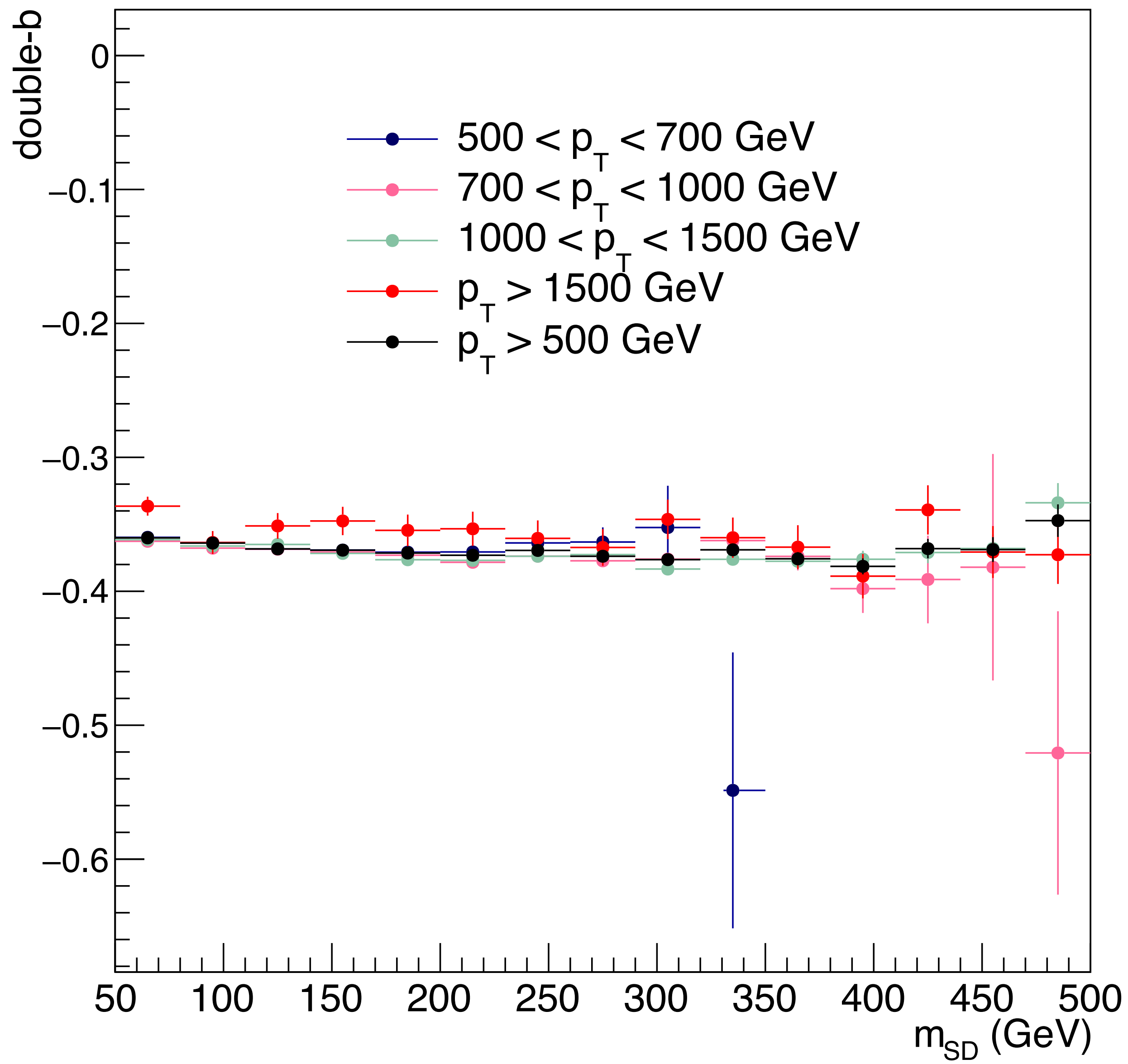
- Identifies two b hadron decay chains in the same fat jet
- Does not define subjects, but uses N-subjettiness axes

DOUBLE B-TAGGER

- Combines tracking and vertexing information in a multivariate classifier with 27 observables
- Targets the bb signal with additional aims:
  - jet mass and p_T independent
  - cover a very wide p_T range
  - inputs are chosen to avoid p_T correlation
    - e.g. no ΔR-like variables, no substructure info



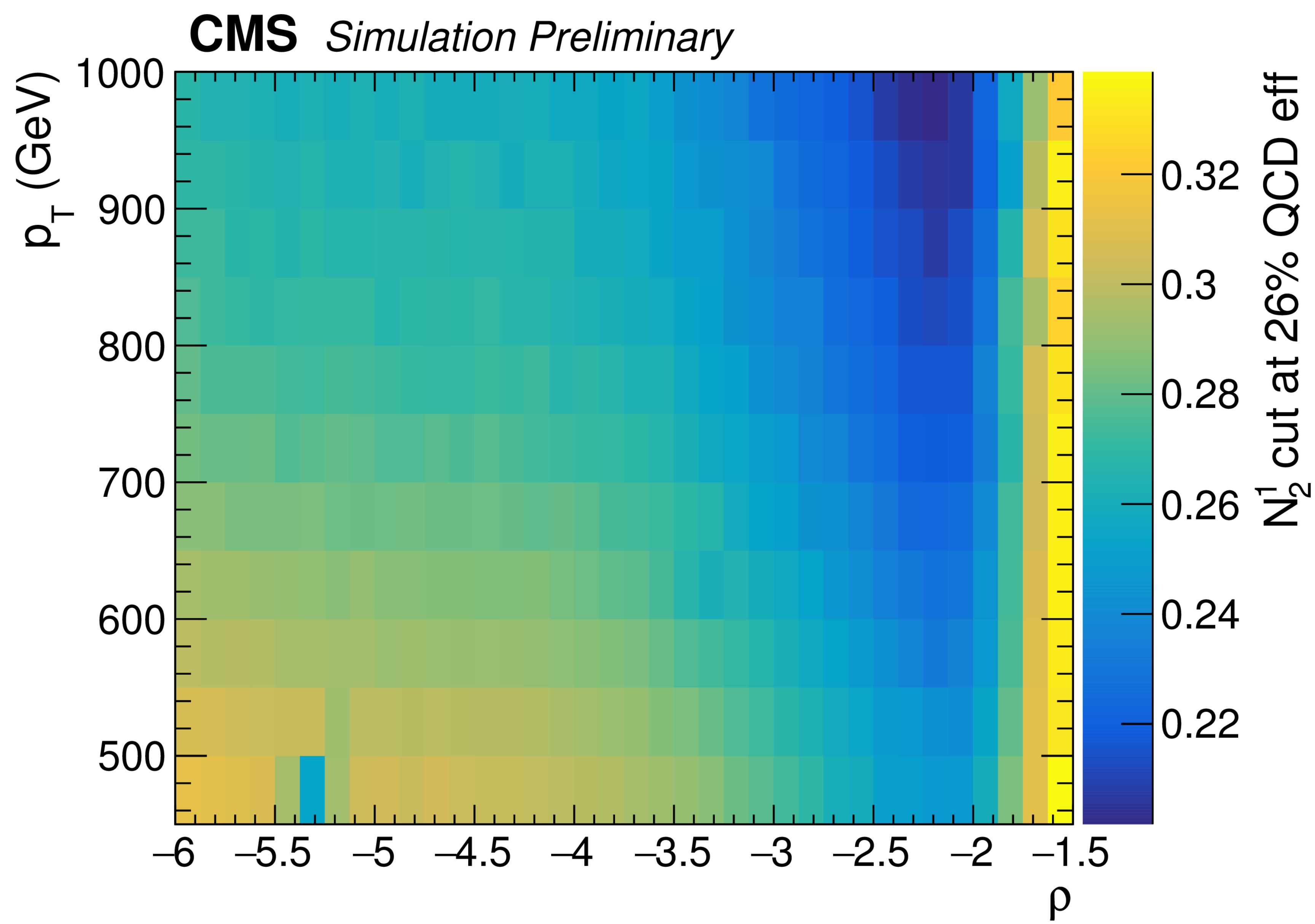
CORRELATIONS?



- No strong correlations in double-b tagger versus m_{SD} or p_T in QCD background

$N^1_2{}^{DDT}$

- Cut value map used to transform N^1_2



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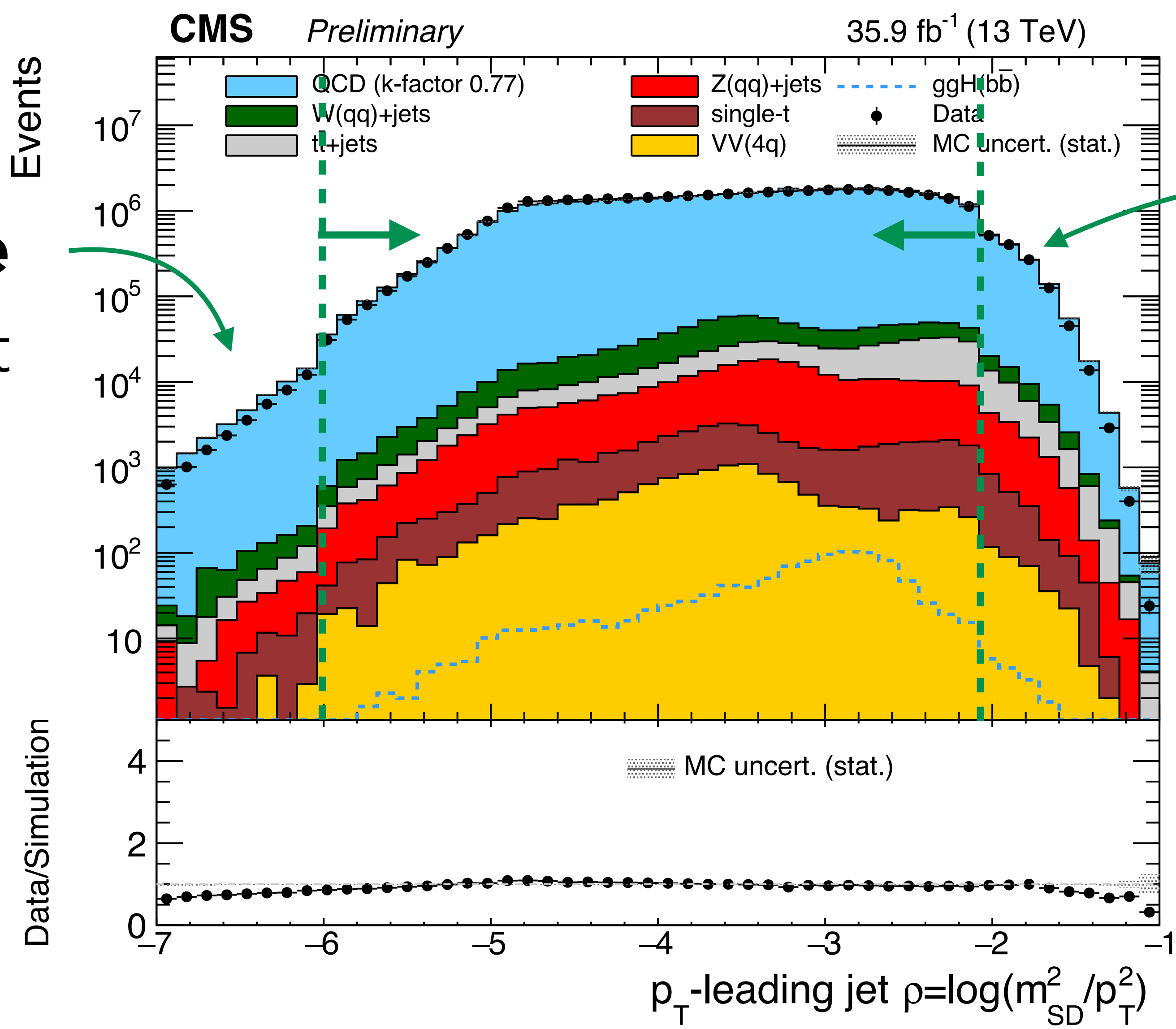
EVENT SELECTION

$-6.0 < \rho < -2.1$

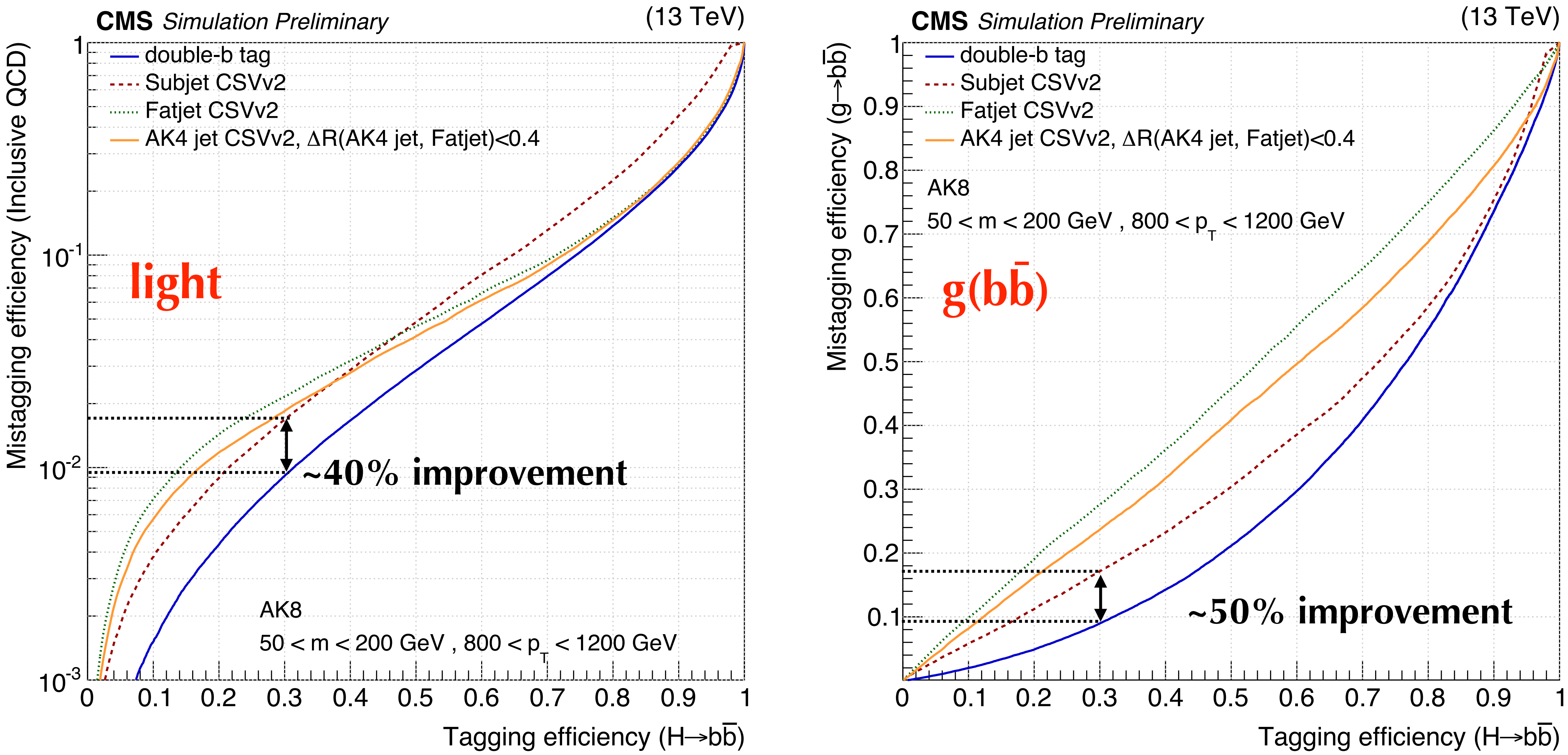
non-perturbative regime of the soft drop mass calculation



finite cone effects from the AK8 jet clustering

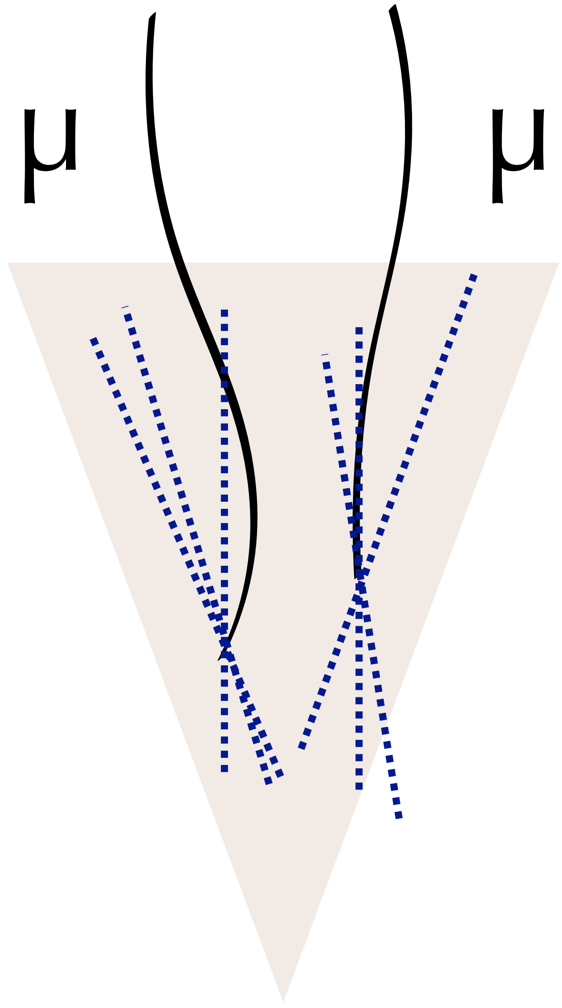
Javier Duarte
Fermilab

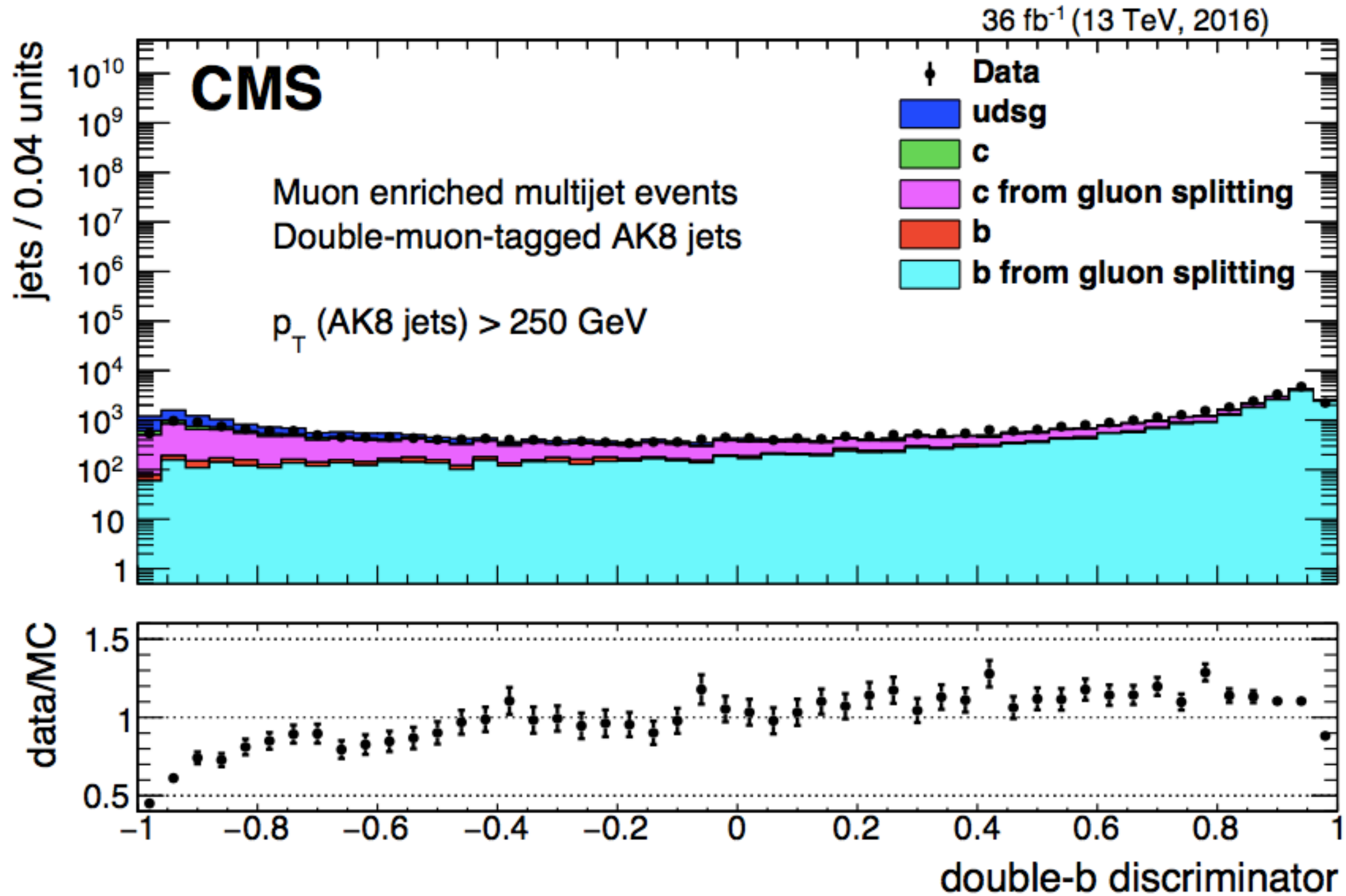
EFFICIENCY AND MIS-TAG



- Mis-tag is reduced by more than 40% at 30% signal efficiency for a tight working point

EFFICIENCY IN DATA

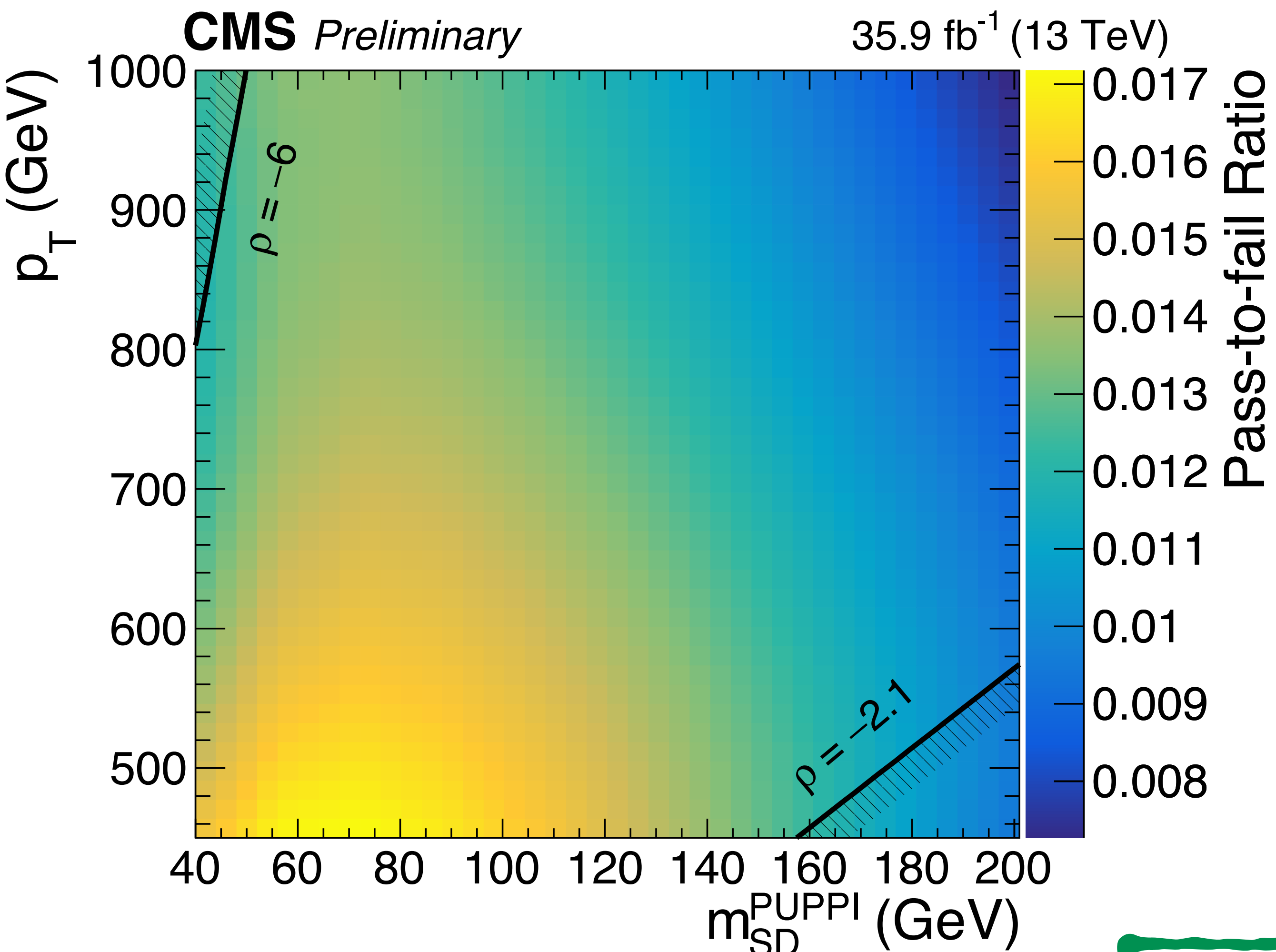


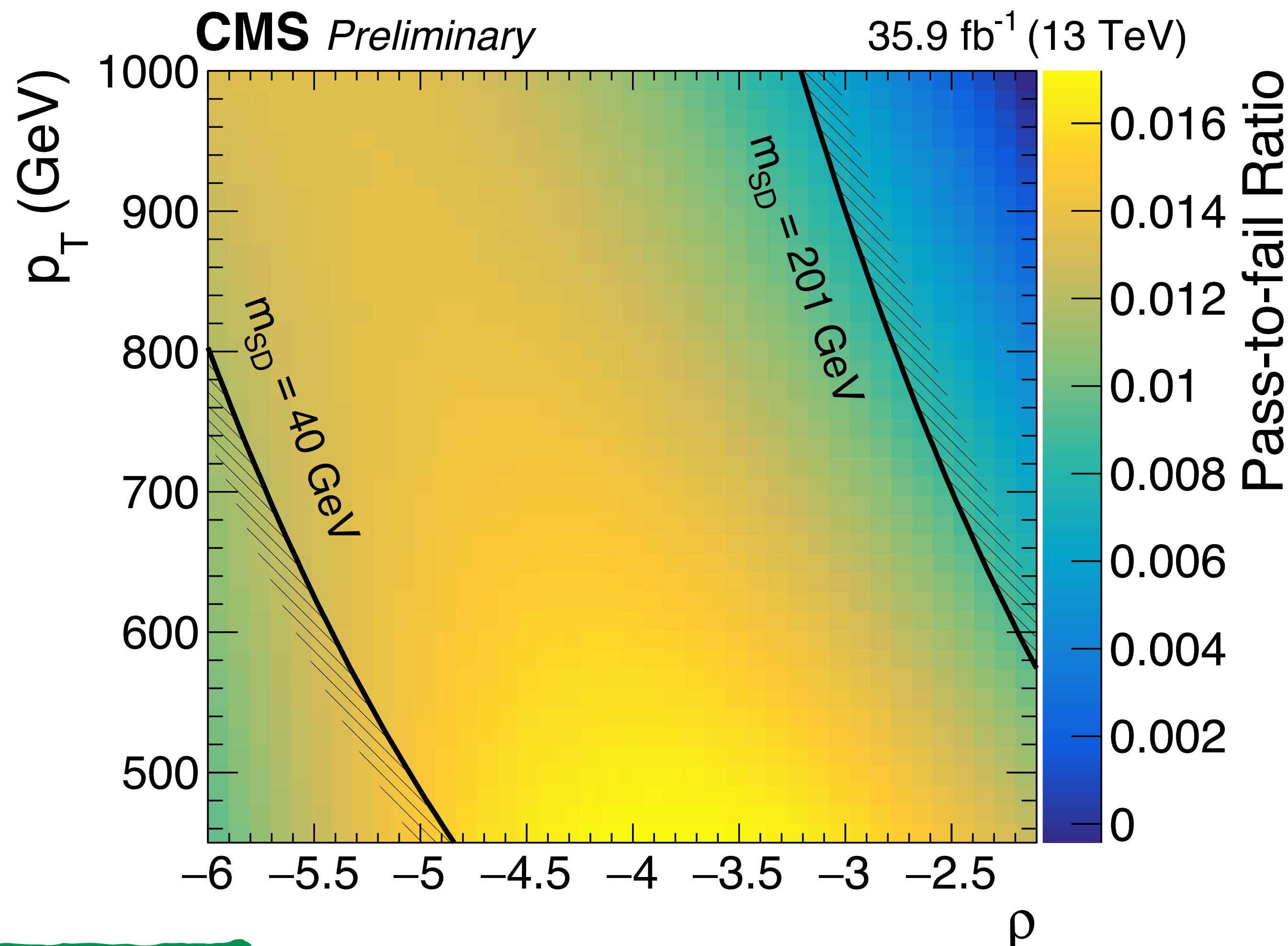


- Using g(bb) jet as proxy in double muon tagged jet sample
- Associated data/MC uncertainty 3-5%

FINAL TRANSFER FACTOR

- Two views of the same transfer factor function





$$N^{\mathrm{QCD}}_{\mathrm{pass}}(m_{\mathrm{SD}i}, p_{\mathrm{T}j}) = \left(\sum_{k,\ell} a_{k\ell}\,\rho^{k}_{ij}\,{p_{\mathrm{T}}}^{\ell}_{j}\right) \cdot N^{\mathrm{QCD}}_{\mathrm{fail}}(m_{\mathrm{SD}i}, p_{\mathrm{T}j})$$

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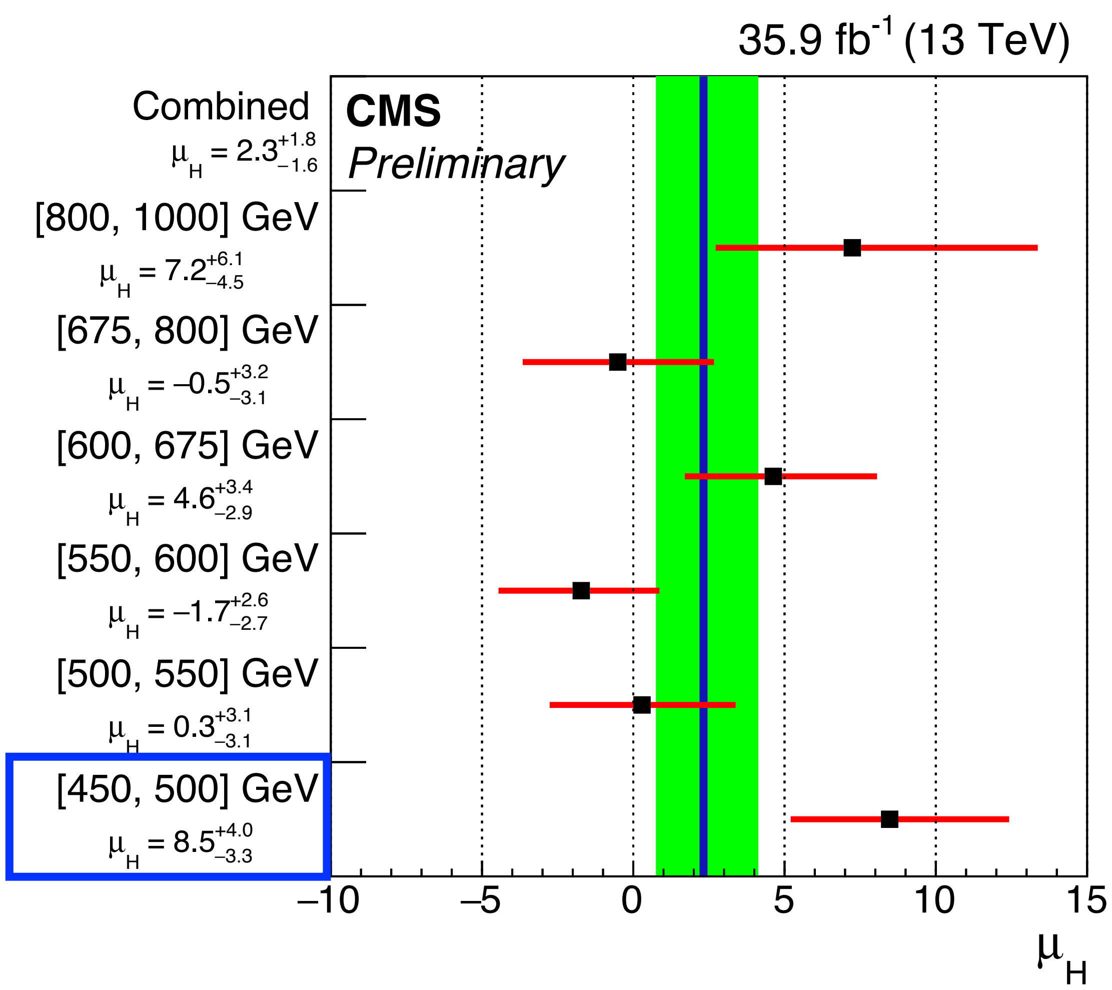
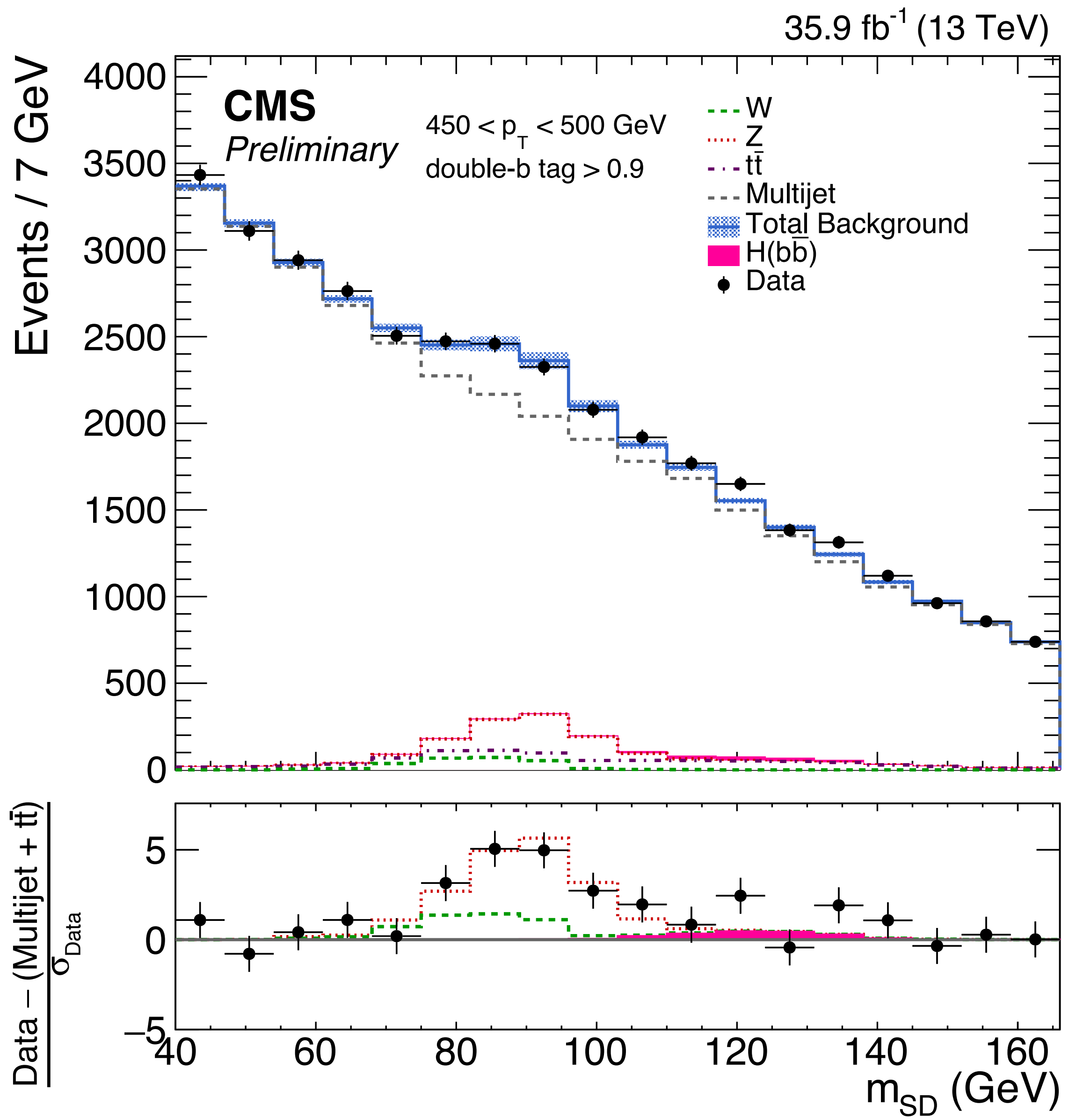
p_T CATEGORIES





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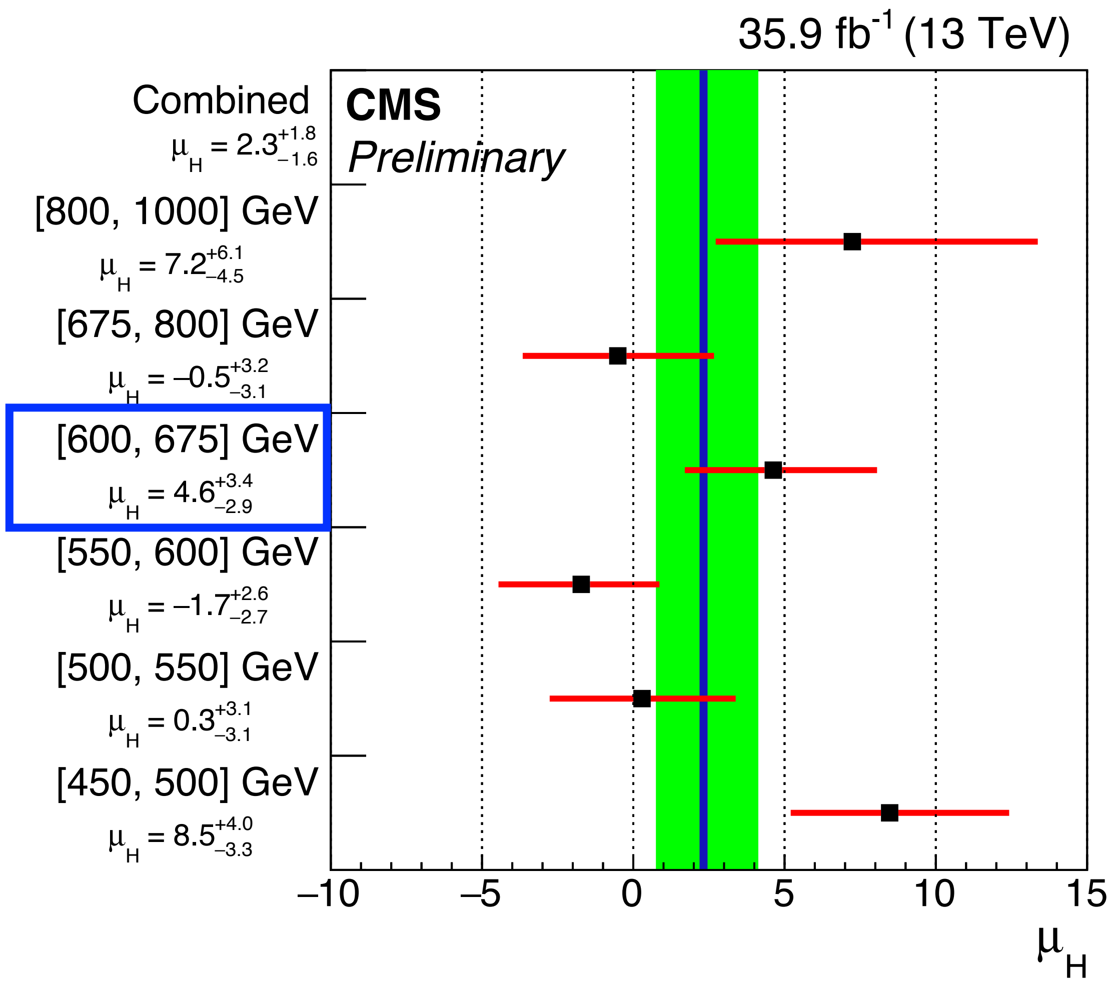
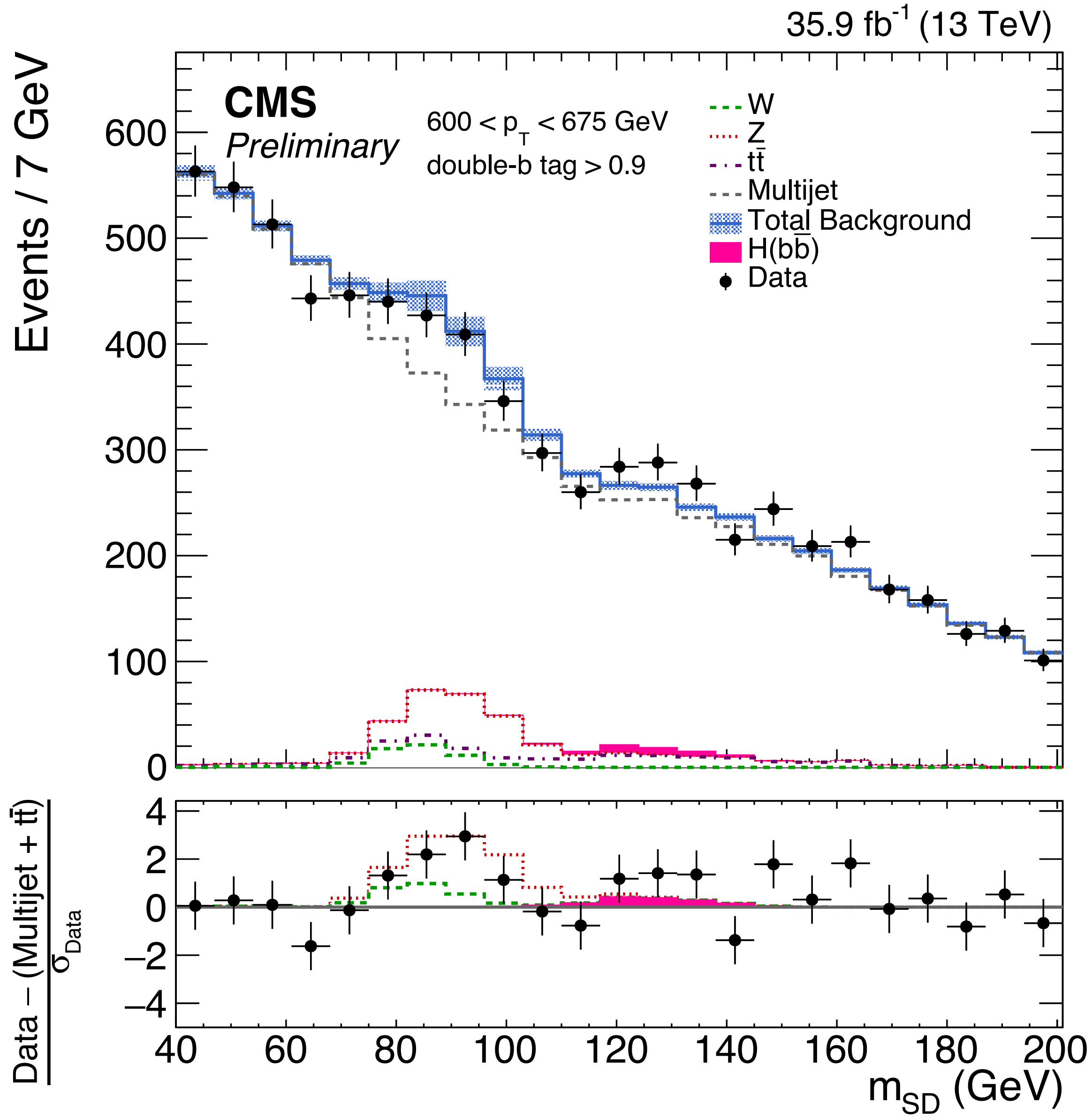
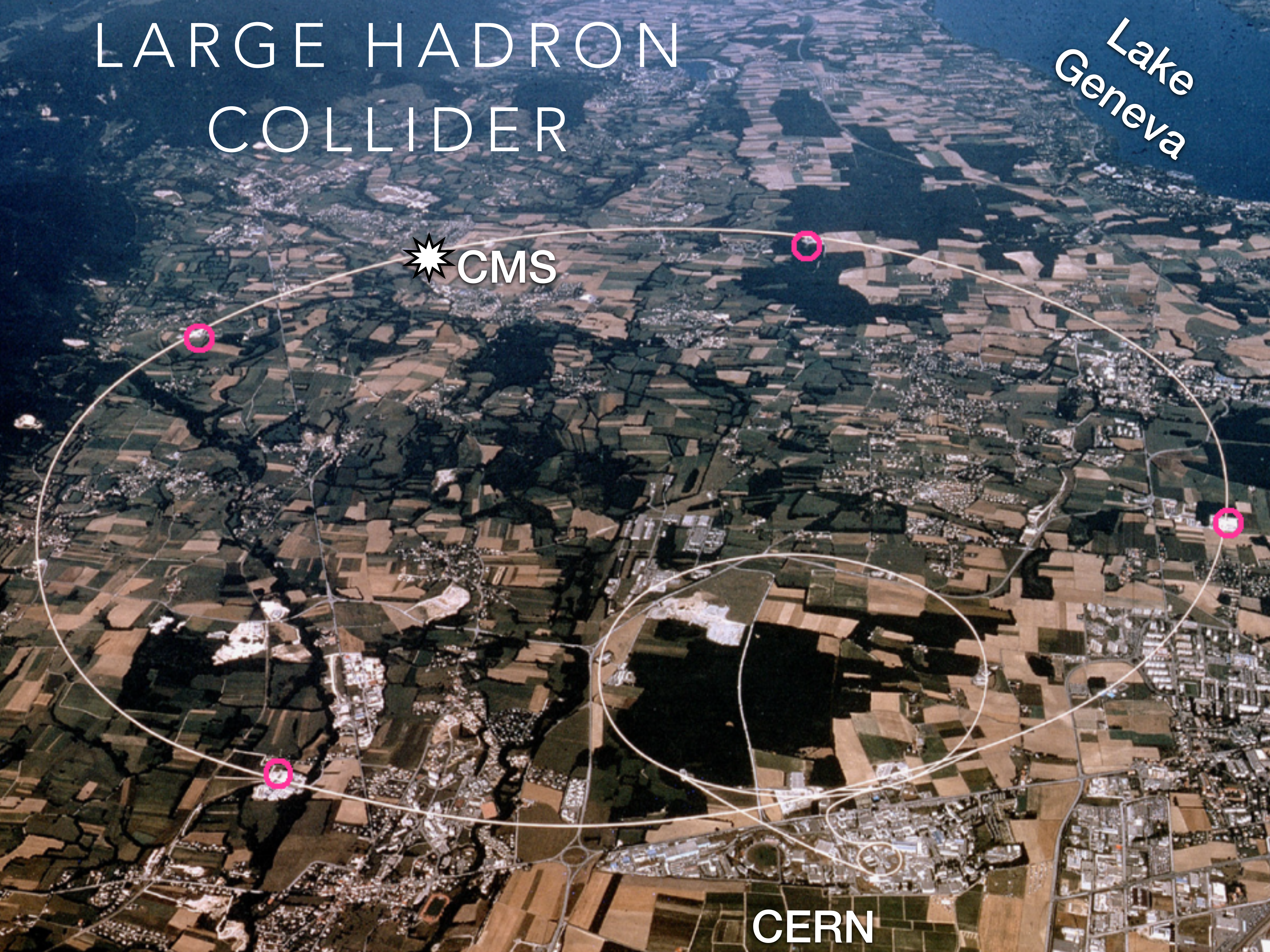
P_T CATEGORIES







LARGE HADRON
COLLIDER
Lake
Geneva
CMS
CERN

What is the best Higgs p_T :Options

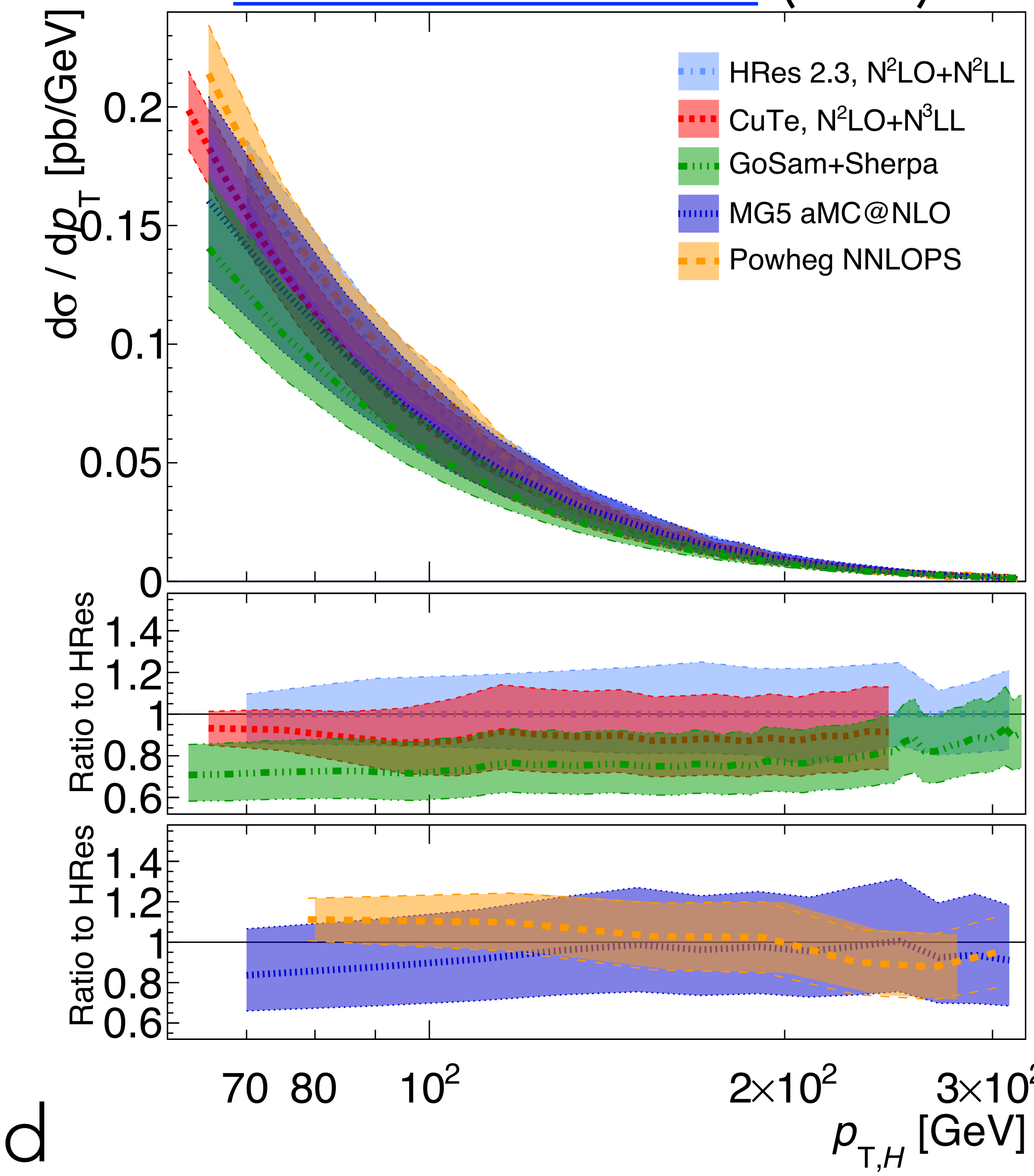
- The key is to identify two different effects
  - Finite top mass effect
  - NNLO differential corrections

- What are the orders known:
  - Differential EFT : NNLO H+1jet production
  - Finite top mass : almost NLO
  - At MC level EFT : NLO H+0/1/2jet
  - At MC level finite top mass : LO 0/1/2

HIGGS PT SPECTRUM

arXiv:1610.07922 (YR4)

- Other CMS Higgs results use Powheg: 1 jet + m_t, arXiv:1111.2854
- We want to account for both effects of **higher order corrections** and **finite top mass**
  - No real NLO + finite top mass calculation available in the literature
-
-
-

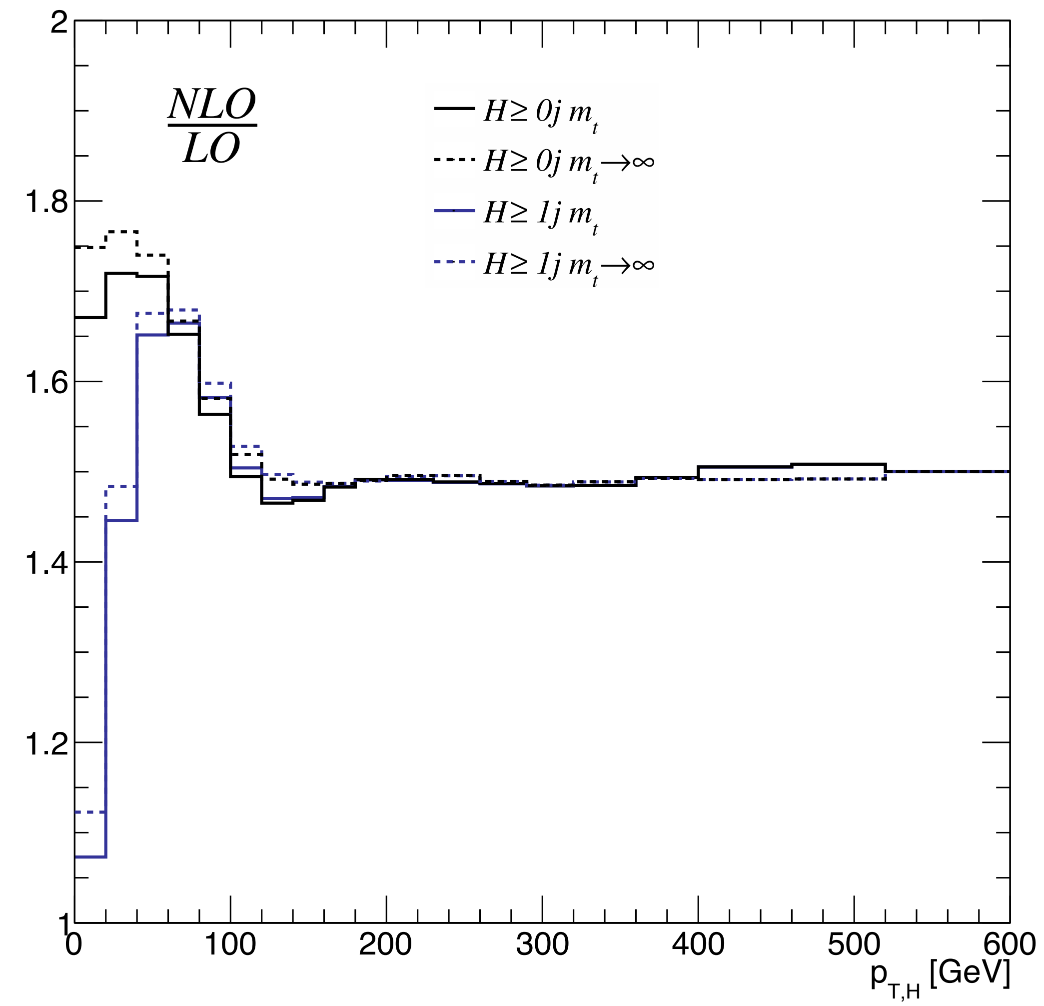


≪ 1 TeV

Disclaimer: we made an educated choice and assigned a reasonable uncertainty, but it's not the only possible choice. We also provide results with CMS standard Powheg sample

HIGGS PT SPECTRUM

- Other CMS Higgs results use Powheg: 1 jet + m_t, arXiv:1111.2854
- We want to account for effects of higher order corrections and finite top mass
  - No real NLO + finite top mass calculation available in the literature
- Adopt a factorized approach:
- LO H+0-2jet, finite m_t, p_t^H up to 600 GeV, including WW acceptance cuts arXiv:1410.5806 → We build on this
-
-



$$\text{ggF H(NNLO} + m_{\text{t}}) = \text{Powheg(1 jet } m_{\text{t}}) \times \frac{\text{MG LO } 0-2 \text{ jet } m_{\text{t}}}{\text{Powheg(1 jet } m_{\text{t}})}$$

CKKW merged

HIGGS PT SPECTRUM

- Other CMS Higgs results use Powheg: 1 jet + m_t, arXiv:1111.2854
- We want to account for both effects of higher order corrections and finite top mass
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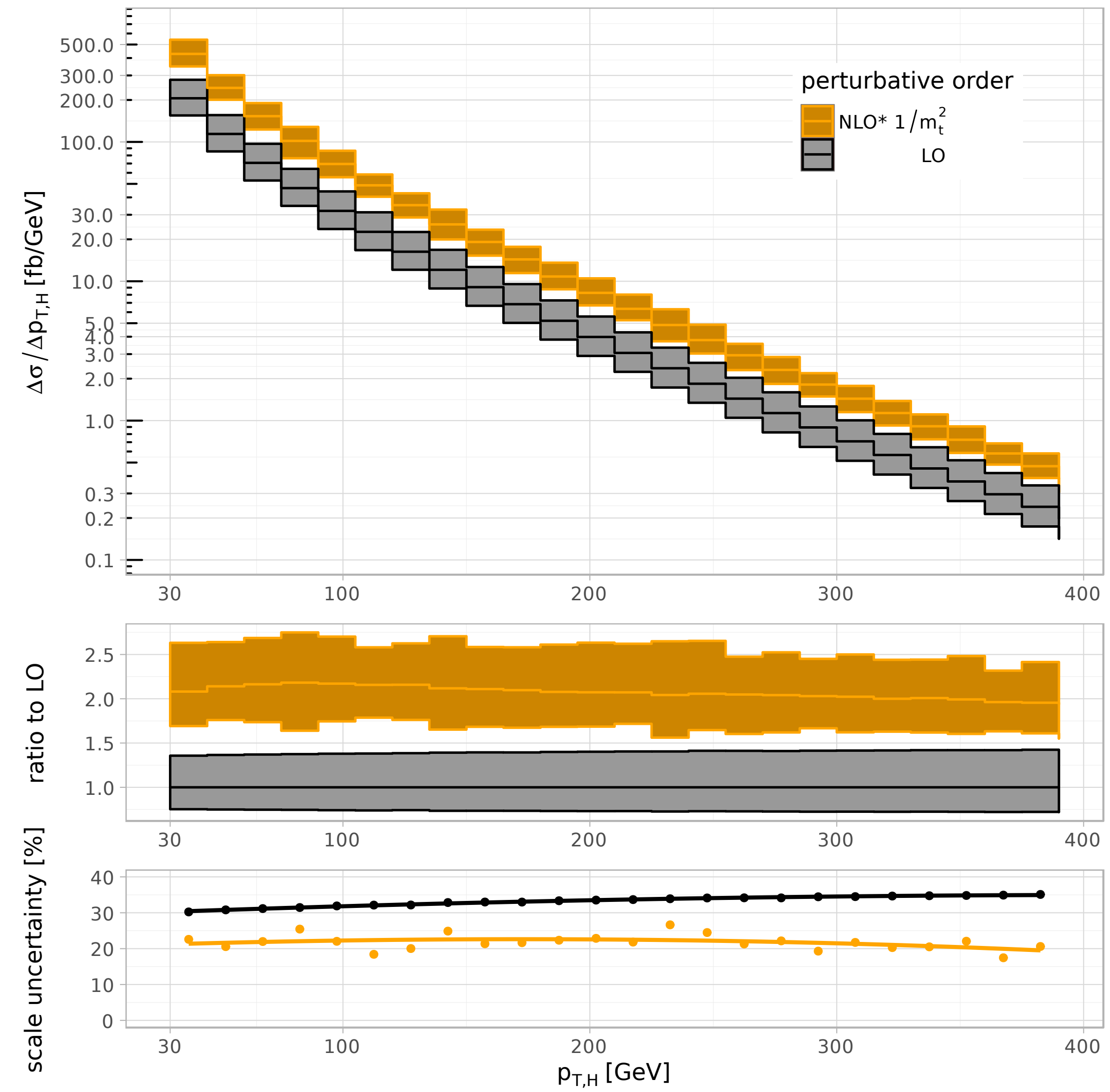
- NLO H+1jet finite m_t up to $1/m_t^4$ expansion: arXiv:1609.00367
-

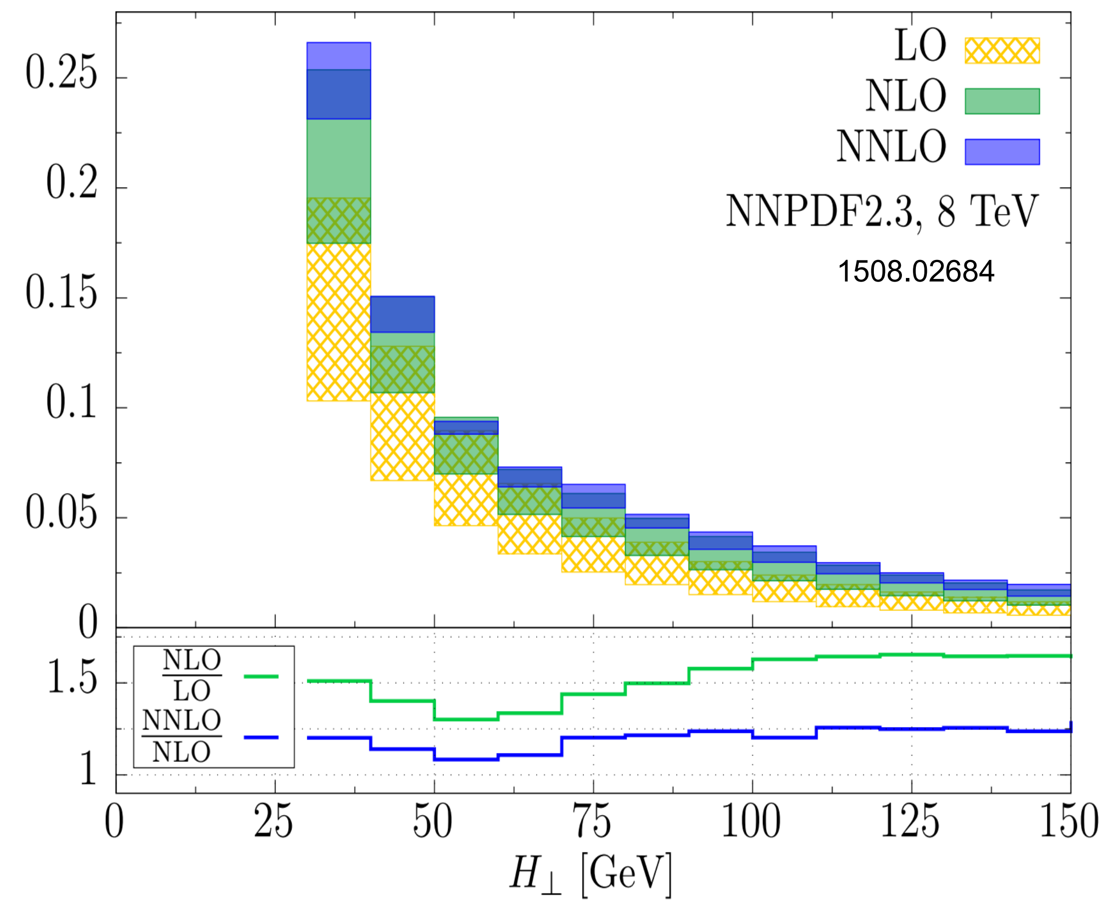


$$\text{ggF H(NNLO} + m_t) = \text{Powheg}(1 \text{ jet } m_t) \times \frac{\text{MG LO } 0-2 \text{ jet } m_t}{\text{Powheg}(1 \text{ jet } m_t)} \times \frac{\text{NLO 1 jet } m_t}{\text{LO 1 jet } m_t}$$

CKKW merged   factor of 2

HIGGS PT SPECTRUM

- Other CMS Higgs results use Powheg: 1 jet + m_t, arXiv:1111.2854
- We want to account for both effects of higher order corrections and finite top mass
  - No real NLO + finite top mass calculation available in the literature
- Adopt a factorized approach:
- LO H+0-2jet, finite m_t, p_t^H up to 600 GeV, including WW acceptance cuts arXiv:1410.5806 → We build on this
- NLO H+1jet finite m_t up to $1/m_t^4$ expansion: arXiv:1609.00367
- NNLO H+1jet, $m_t = \infty$, p_T^H up to ~200 GeV, arXiv:1408.5325, arXiv:1302.6216, arXiv:1504.07922, arXiv:1505.03893, arXiv:1508.02684

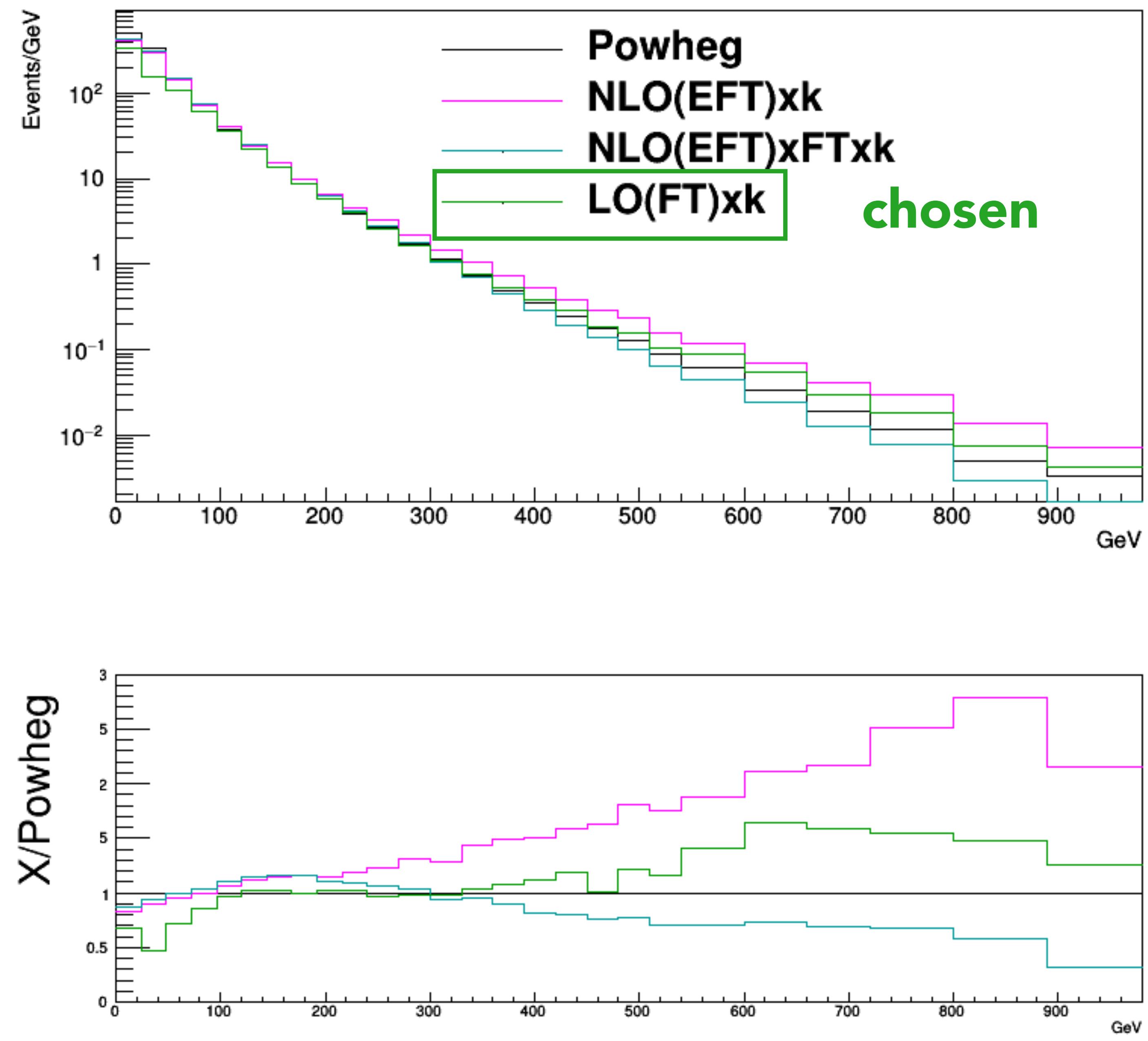


$$\text{ggF H}(\text{NNLO} + m_t) = \text{Powheg}(1 \text{ jet } m_t) \times \frac{\text{MG LO } 0-2 \text{ jet } m_t}{\text{Powheg}(1 \text{ jet } m_t)} \times \frac{\text{NLO } 1 \text{ jet } m_t}{\text{LO } 1 \text{ jet } m_t} \times \frac{\text{NNLO } 1 \text{ jet } m_t \to \infty}{\text{NLO } 1 \text{ jet } m_t \to \infty}$$

CKKW merged | factor of 2 | factor of 1.25

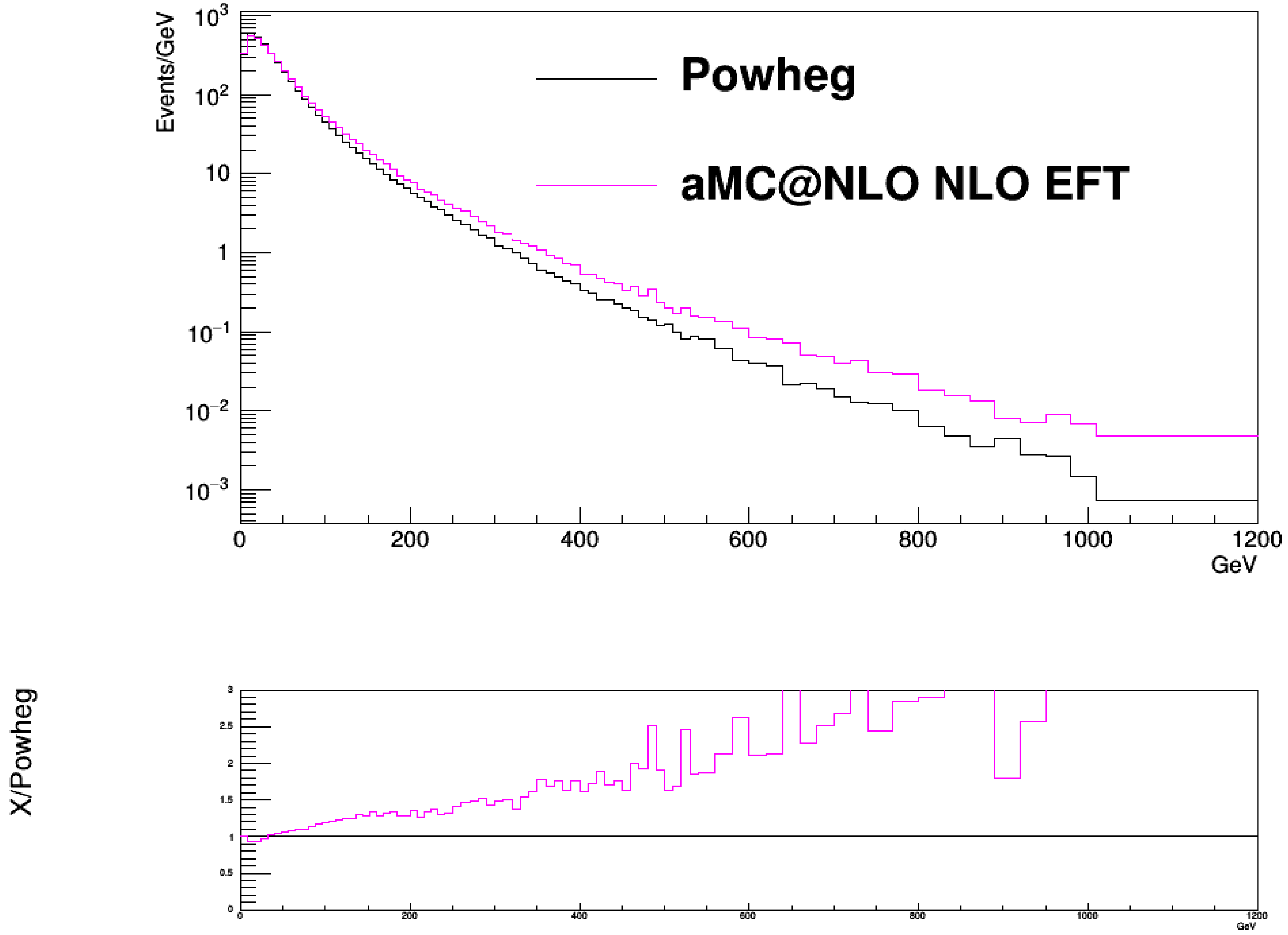
HIGGS P_T SPECTRUM

- Pythia version of CKKW-L merged 0,1,2jet LO finite top mass
- ME generation in aMC@NLO (ptj > 20) with xqcut = 30 GeV
- CKKW shower is extended down to a merging scale of TMS = 20 GeV
- Two factorized systematic uncertainties:
  - 30% overall normalization
  - 30% linear change in slope (no effect on overall norm.)



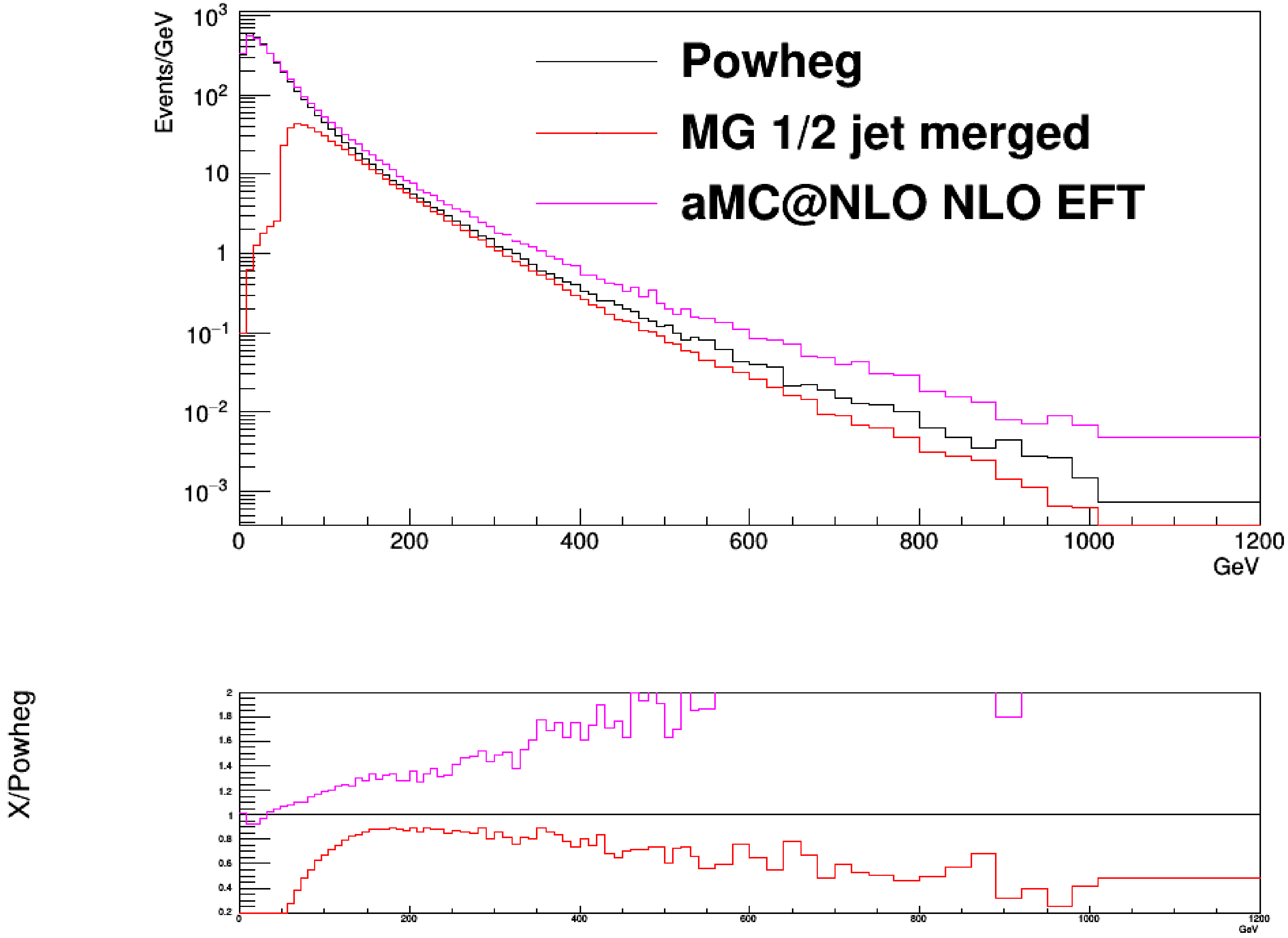
Going to EFT

- When going to EFT large gain



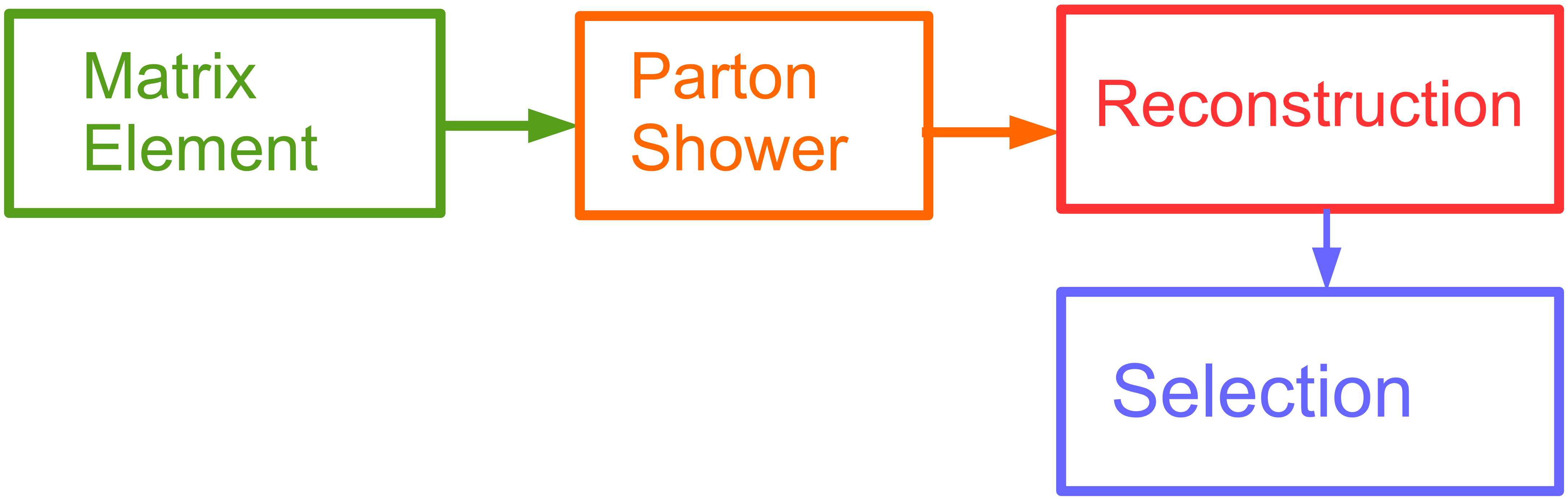
Going to EFT

- Adding the finite top mass merged LO its lower



What are differences in our numbers?

- Chain from ME to Reconstruction

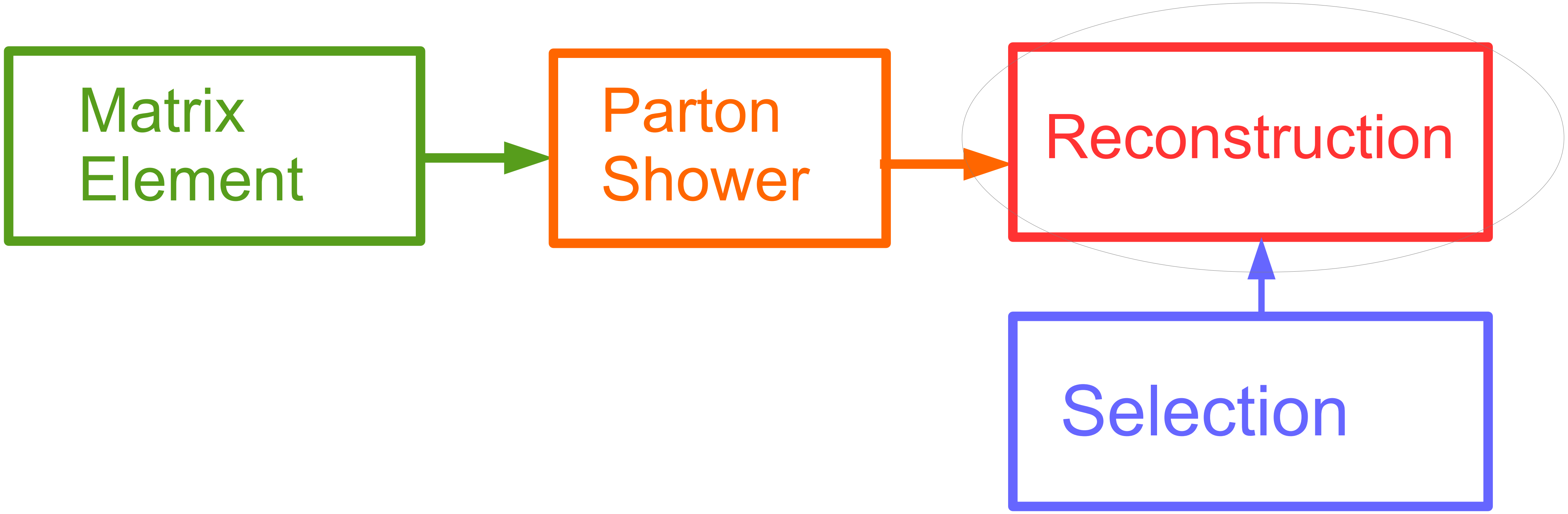


In the paper quote a number on :

Selected Higgs Jets with p_T > 450 GeV

Back tracking

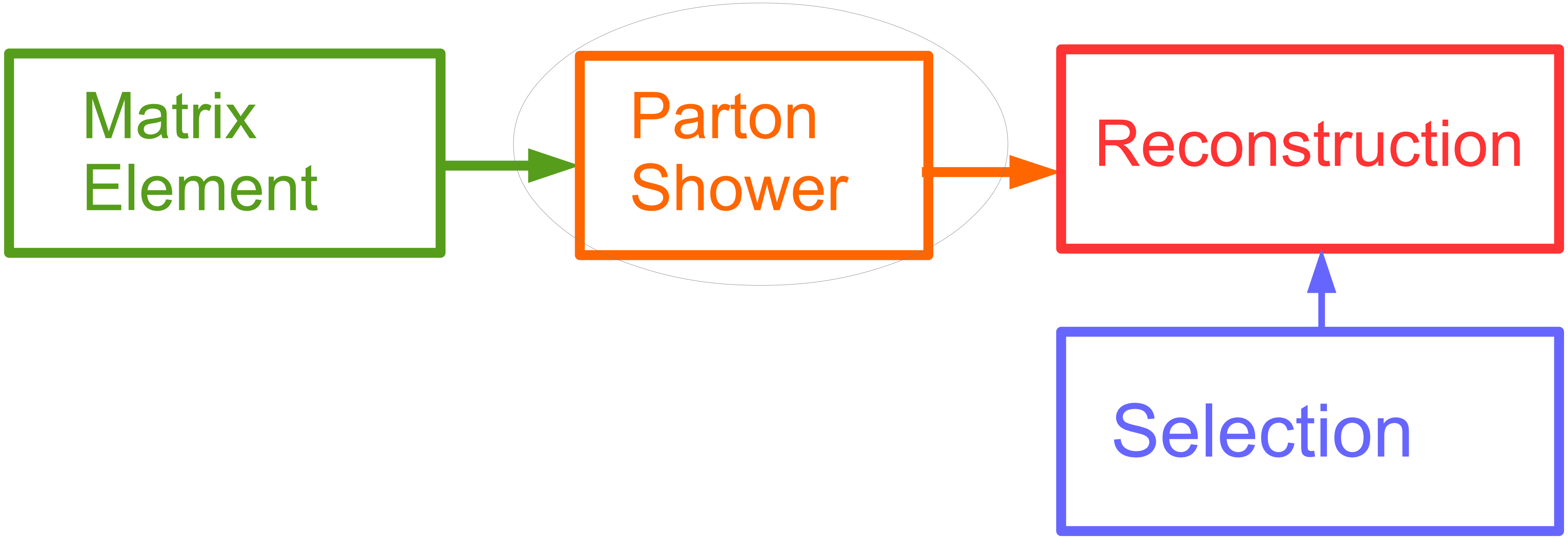
- Chain from ME to Reconstruction



Our reconstructed cross section for our sample is : 26.2 fb
(-25% for other processes/selection)

Back tracking

- Chain from ME to Reconstruction

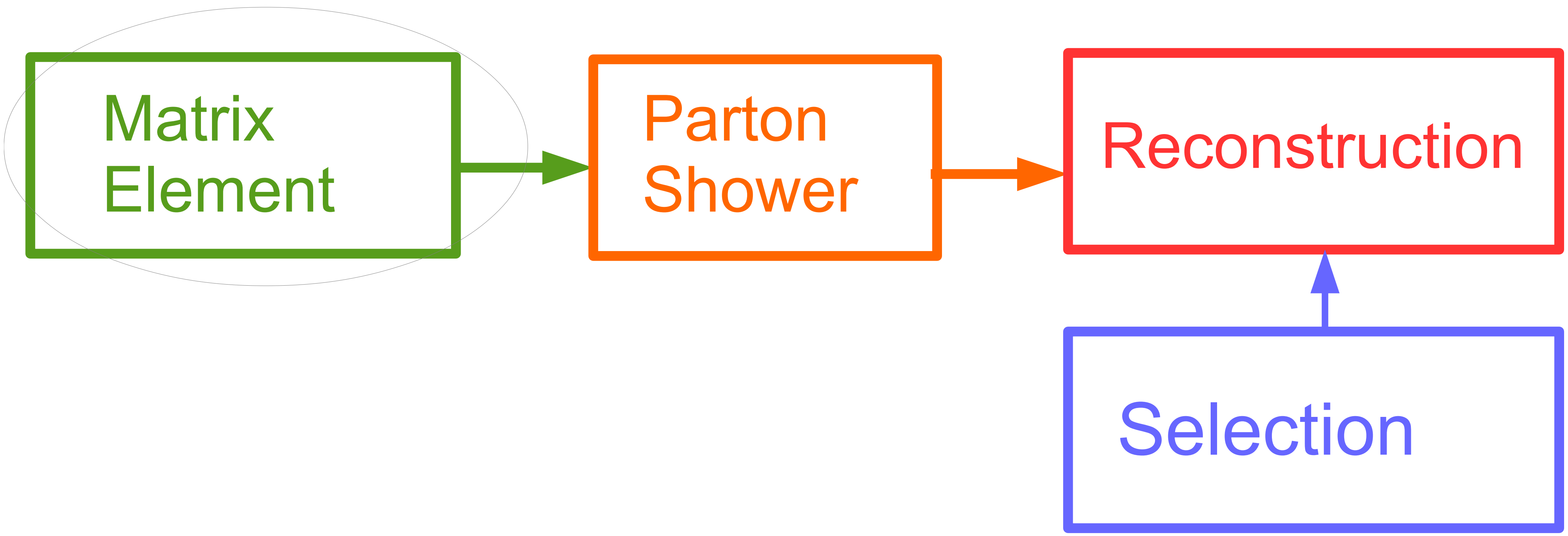


Our parton shower level cross section for p_T Higgs > 450 GeV is : <u>20.8 fb</u>

(-25% reco smearing pushes lower p_T Higgs to higher p_T)

Back tracking

- Chain from ME to Reconstruction

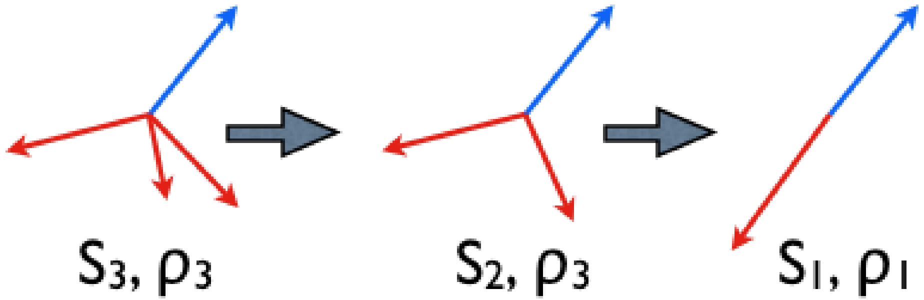


Our ME level cross section for p_T Higgs > 450 GeV is : 15.1 fb (-35% parton shower pushes low p_T to higher p_T) Reminder table is : 8.9 fb

CKKW-L [L.Lönnblad, JHEP 05 (2002) 046, L.Lönnblad and S.Prestel,JHEP 03 (2012) 019]

Idea: Reduce the dependence to the merging scale MS.

- Start by generate events with $N_1..N_2$ ME partons, hard and well separated
- Assume an event with n ME partons, reconstruct the possible shower histories, pick one according to the occurence probabilities



- Each clustering step i is characterized by the emission scale ρ_i, reweight by the product of $\alpha_s(\rho_i)/\alpha_s(ME)$
- For i=2..n (!=N_2):
  - Generate one emission ρ with ρ_i as starting scale.
  - If $\rho > \rho_{i+1} \Rightarrow$ reject the event.
    - This is equivalent to the product of Sudakovs $\Pi(\rho_i, \rho_{i+1})$, i=2..n-1.
- if not HME: generate an emission at $\rho < \rho_n$, if $\rho >$MS $\Rightarrow$ reject the event.
- if HME, accept the event and start shower with ρ_n.

Practical use: Madgraph 5

Essential parameters for matching/merging:

- ickkw
  - Applies the α_s reweighting at each QCD vertex in the ME calculation. K_T-MLM, Shower-K_T:1 CKKW-L, UMEPS:0
- xqcut
  - Defines the minimal K_T between the partons (+beam) at ME level.
- auto_ptj_mjj
  - Set to False: leaves the xqcut be the only cut applied to ME partons⇒ ptj, mmjj=0
- maxjetflavor
  - QCD partons with pdgId≤maxjetflavor are affected by xqcut ptj,etc... Otherwise, affected by ptb, mmbb, etc... That means that for a n-Flavour prediction, maxjetflavor = n

Practical use: main89.cc

- main89ckkwl.cmnd: CKKWL. Essential parameters are
  - `Merging:TMS = XXX.`
    - `The merging scale`
  - `Merging:Process = UUU`
    - `Type of process, e.g.  pp>LEPTONS,NEUTRINOS`
  - `Merging:nJetMax = WWW`
    - `Maximal number of additional jets in the matrix element`
  - `Merging:doPTLundMerging = on`
    - `Set the merging scale definition to` $P_{T,evol}$ `(cfr definition in the manual)`
- main89umeps.cmnd: UMEPS. Essential parameters are
  - `Merging:TMS = XXX.`
  - `Merging:Process = (e.g.)  pp>LEPTONS,NEUTRINOS`
  - `Merging:nJetMax = WWW`
  - `Merging:doUMEPSTree = on`
    - `Reweight events according to the UMEPS prescription for tree-level configurations)`