DNN-based identification of additional b jets for a differential ttbb cross section measurement

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INTRODUCTION

Motivation

- Modeling of $t\bar{t}b\bar{b}$ process is notoriously challenging because of its multi-scale nature (large top quark mass, low bottom quark mass)
- $t\bar{t}b\bar{b}$ process is the irreducible significant background of $t\bar{t}H(b\bar{b})$ and $t\bar{t}t\bar{t}$ process

➡ $t\bar{t}b\bar{b}$ measurement with Run 2 data published as TOP-22-009

On my poster

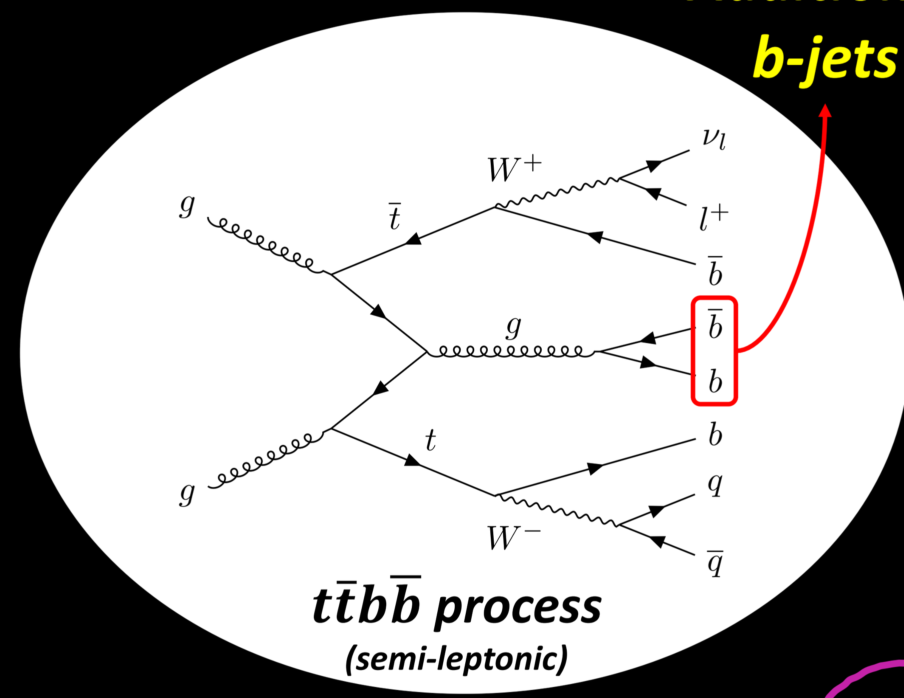
- Aim to **identify the two b jets not from top quark decay to facilitate the measurement**

Event Samples

- 2016, 2017 and 2018 MC simulated samples
- Many different modelling approaches with wide range of predictions and large uncertainties in the modelling
  - 4 FS $t\bar{t}b\bar{b}$: Where the b mass is included and additional b jets are calculated in the ME
  - 5FS $t\bar{t}(+jet)$: Where the b is treated as massless and additional b jet radiation is mostly generated in the PS

Event Selections

- Exactly **one** isolated **electron or muon**
- **≥ 6 jets** & **≥ 4 b-tagged jets** (medium WP)



Highest pT

Matchable events: with two assigned jets

Jet1	Jet2	Jet3	Jet4	Category
1	1	0	0	0
1	0	1	0	1
1	0	0	1	2
0	1	1	0	3
0	1	0	1	4
0	0	1	1	5
Other combination				6

Jet permutation categories

Non-matchable events: without two assigned jets

METHODOLOGY

Event-by-Event Approach

- **Four b-tagged jets** are selected
- Sorting the selected b-tagged jets by p_T to identify six possible permutations
- Definition of add. b jets: matched to b-jet not from top on generator level (ΔR matching)
- Each combination is assigned to one category
- It becomes **multi-classification** problem

NN ARCHITECTURE

Deep Learning Structures

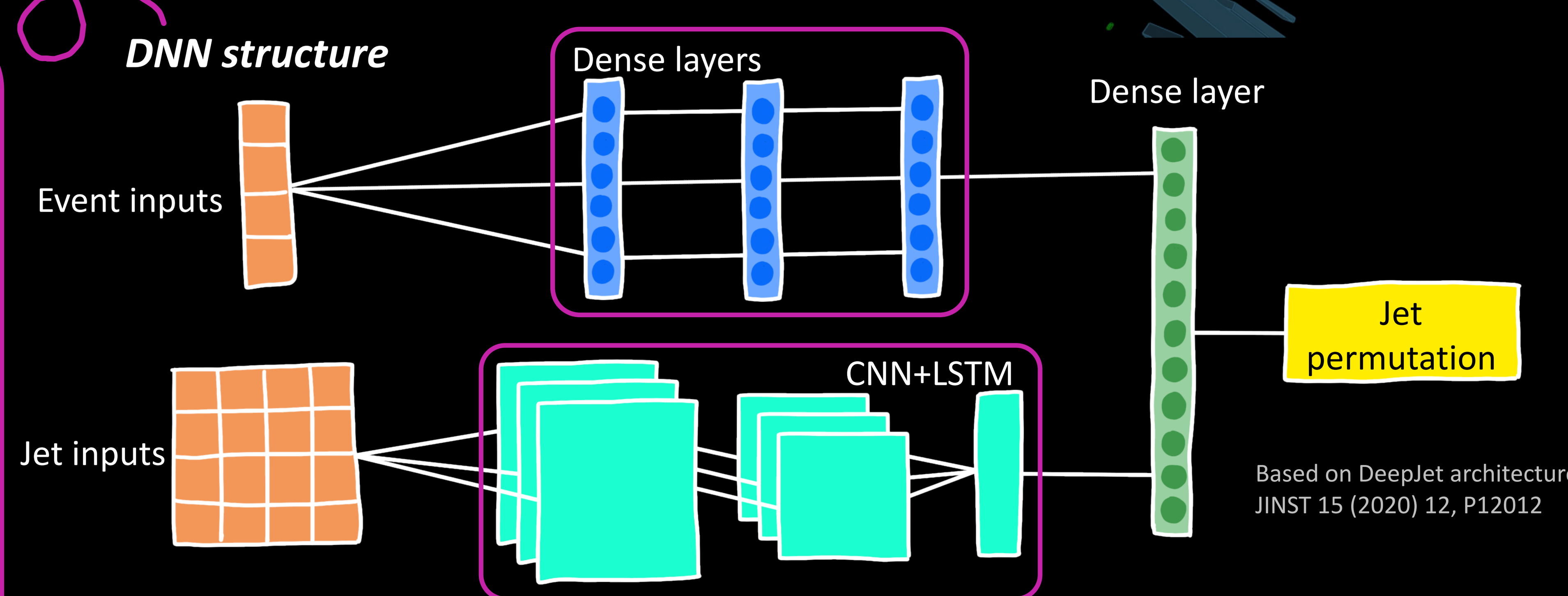
- Dense and [Convolutional & LSTM (Long Short-Term Memory)] layers are used
- Dropout and early stopping methods are used to prevent overfitting

Input Variables (#=50)

- **Global event variables** (#=30, N_{jets}, N_{bjets}, $p_{T\,lepton}$ …)
- **Jet variables** (#=20, p_T, η, $\Delta R_{jet\&lep}$ …)

➡ Neural network predicts which permutation is the pair of add. b jets

DNN structure



Based on DeepJet architecture JINST 15 (2020) 12, P12012

RESULTS

Improved Efficiencies with DNN

- Only matchable events are used for training
- Matching eff. = $\frac{N_{correct}}{N_{signal}}$ / Reconstructed eff. = $\frac{N_{correct}}{N_{matchable}}$

	Reco. eff.	Matching eff.	One jet correct	Both jets wrong	Non matchable
😄 DNN [%]	**57.0**	**48.8**	30.9	5.9	14.4
🙂 min. ΔR [%]	**47.8**	**41.0**	33.6	11.0	14.4

💡 *Add. b jets are often close together, so selecting the closest two b jets often already finds the correct ones*

~ **9% increased** identification efficiency!

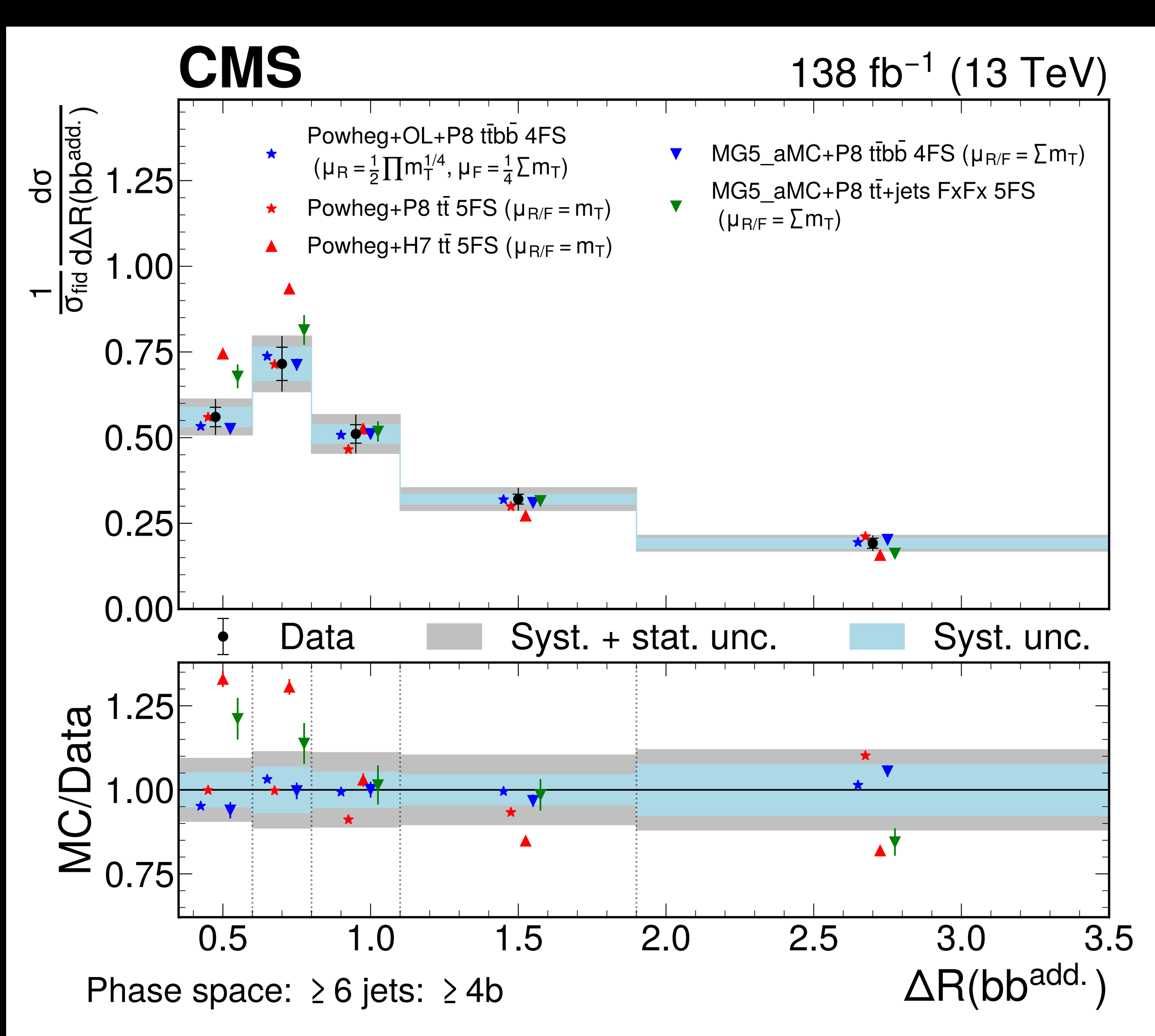
➡ This algorithm is used to **define eight observables** for which differential cross section measurement is performed in TOP-22-009

Pros and Cons

👍 Direct access to the b jets not from top quark decays in differential cross section results

👎 Large migrations between reconstruction and generator level definitions of observables due to limited accuracy of DNN

👎 Less bins in the differential measurement



Normalized differential cross section for ΔR_{bb}

There are a bunch more results in the paper!