LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Employing Matrix Elements in the Search for Higgs Self-coupling

DPG conference in Karlsruhe

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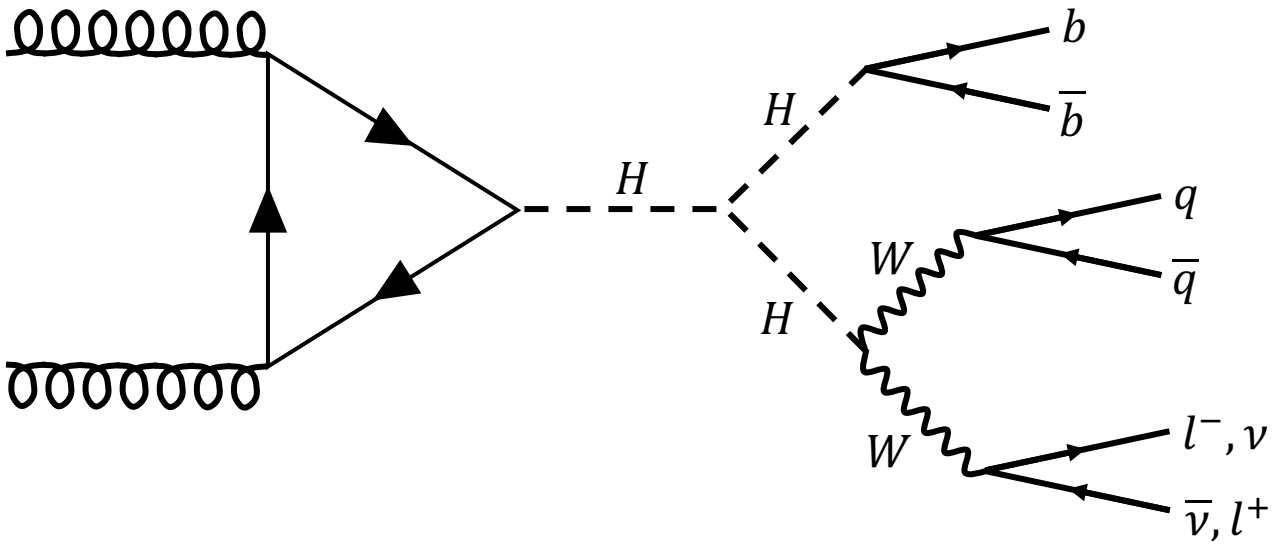
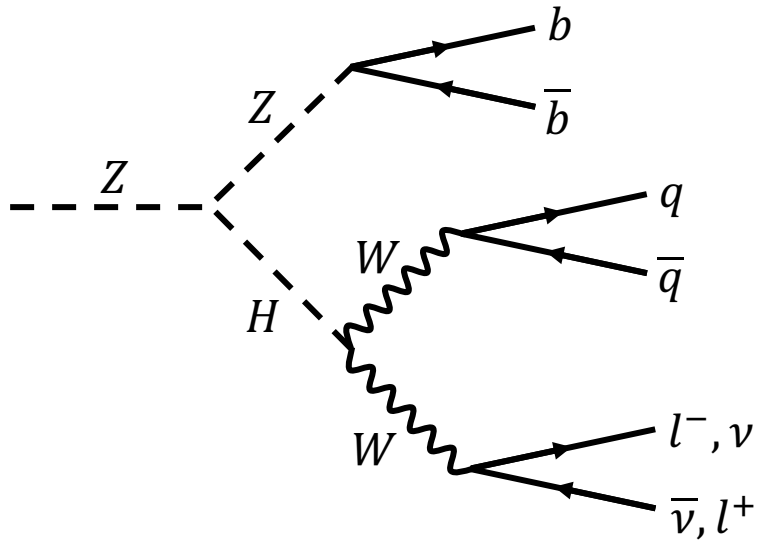
Edis Hrustanbegovic

FSP ATLAS
Erforschung von Universum und Materie

Higgs Self-coupling



- Predicted by Standard Model (not yet observed)
- Small cross section
- More likely Background process ($Z \rightarrow HZ$)



Matrix Element Method

- Calculate weight $W(x|\alpha)$ to observe an event x given a hypothesis α

$$W(x|\alpha) = \int |\langle \psi_f | H_\alpha | \psi_i \rangle|^2 \, d\phi(f)$$

- ψ_f: Final state
- H_α: Hamilton operator for hypothesis α
- ψ_i: Initial state
- $d\phi(f)$: Phase space

→ Weight represents a measure of likelyhood

MoMEMta

- C++ software package for calculating weights
- Four-momenta of final state particles as inputs
- Uses „blocks“ to construct desired decay

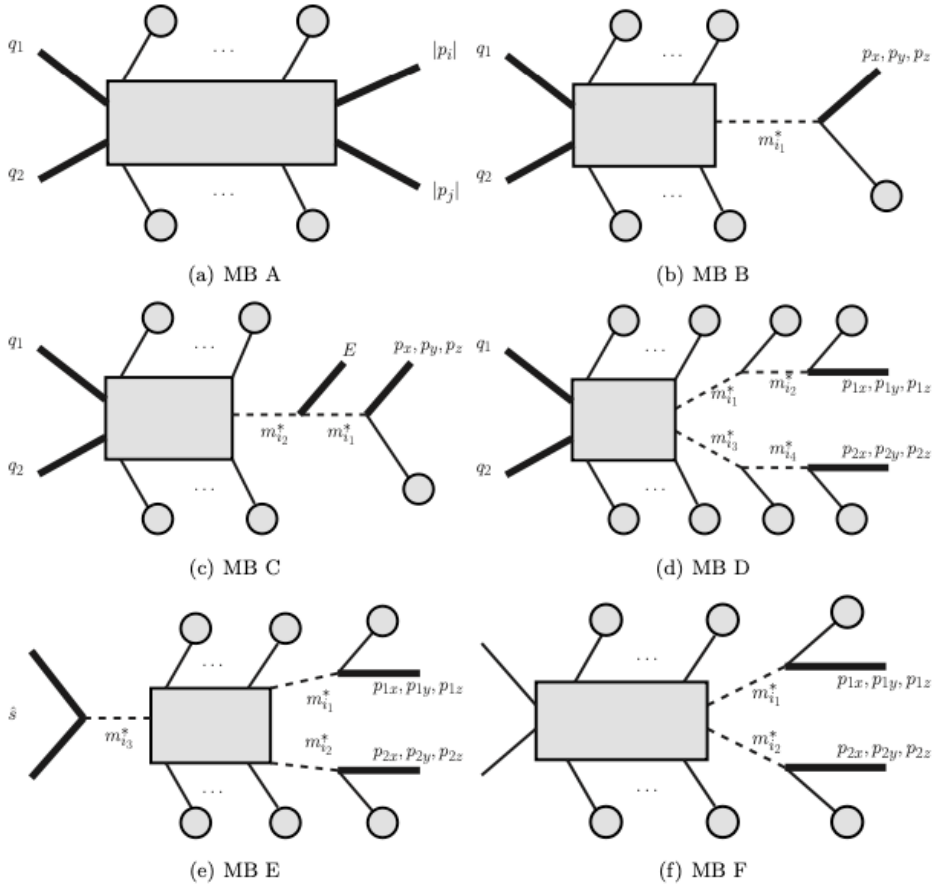
Main block	Topology	Removes...	For
A	$(q_1, q_2) \to p_1 + p_2$	q_1, q_2, $\lvert p_1\rvert$, $\lvert p_2\rvert$	
B	$(q_1, q_2) \to s_{12}(\to p_1 + p_2)$	q_1, q_2, p_1	s_{12}
C	$(q_1, q_2) \to s_{123} \to p_3 + s_{12}(\to p_1 + p_2)$	q_1, q_2, p_1, $\lvert p_3\rvert$	s_{12}, s_{123}
D	$(q_1, q_2) \to s_{134}(\to p_4 + s_{13}(\to p_1 + p_3))+ s_{256}(\to p_6 + s_{25}(\to p_2 + p_5))$	q_1,q_2, p_1, p_2	s_{13}, s_{134}, s_{25}, s_{256}
E	$(q_1, q_2) \to (s_{1234}, y) \to s_{13}(\to p_1 + p_3)+ s_{24}(\to p_2 + p_4)$	q_1, q_2, p_1, p_2	s_{1234}, y, s_{13}, s_{24}
F	$(q_1, q_2) \to s_{13}(\to p_1 + p_3) + s_{24}(\to p_2 + p_4)$	p_1, p_2	q_1, q_2, s_{13}, s_{24}
G	$(q_1, q_2) \to s_{12}(\to p_1 + p_2) + s_{34}(\to p_3 + p_4)$	q_1, q_2, $\lvert p_1\rvert$, $\lvert p_2\rvert$, $\lvert p_3\rvert$, $\lvert p_4\rvert$	s_{12}, s_{34}

q_i: Bjorken fraction
p_i: Four-momentum
$s_{ij\ldots} = (p_i + p_j + \cdots)^2$
y: Rapidity

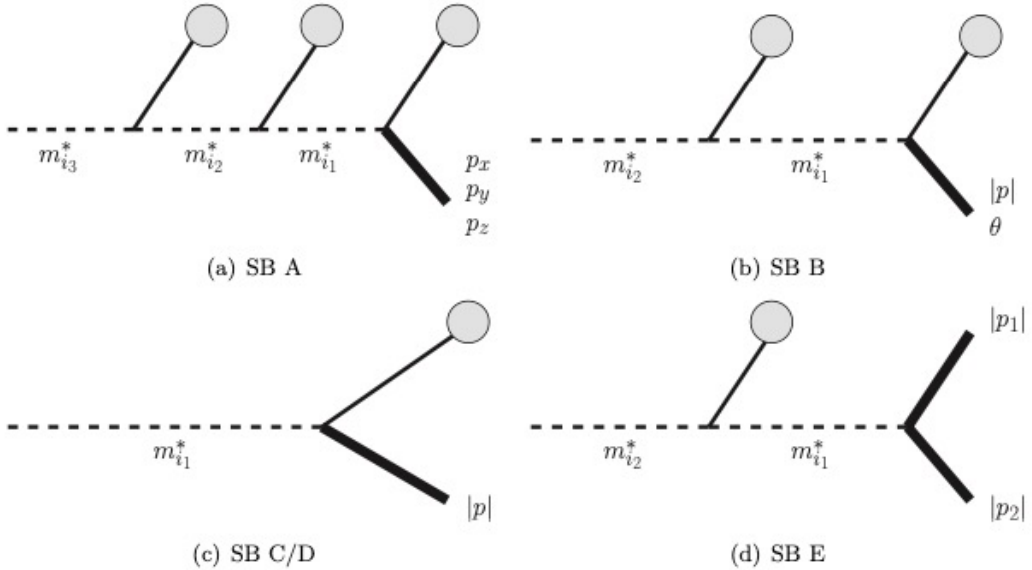
[https://doi.org/10.1140/epjc/s10052-019-6635-5]

Main and Secondary Blocks

Main blocks

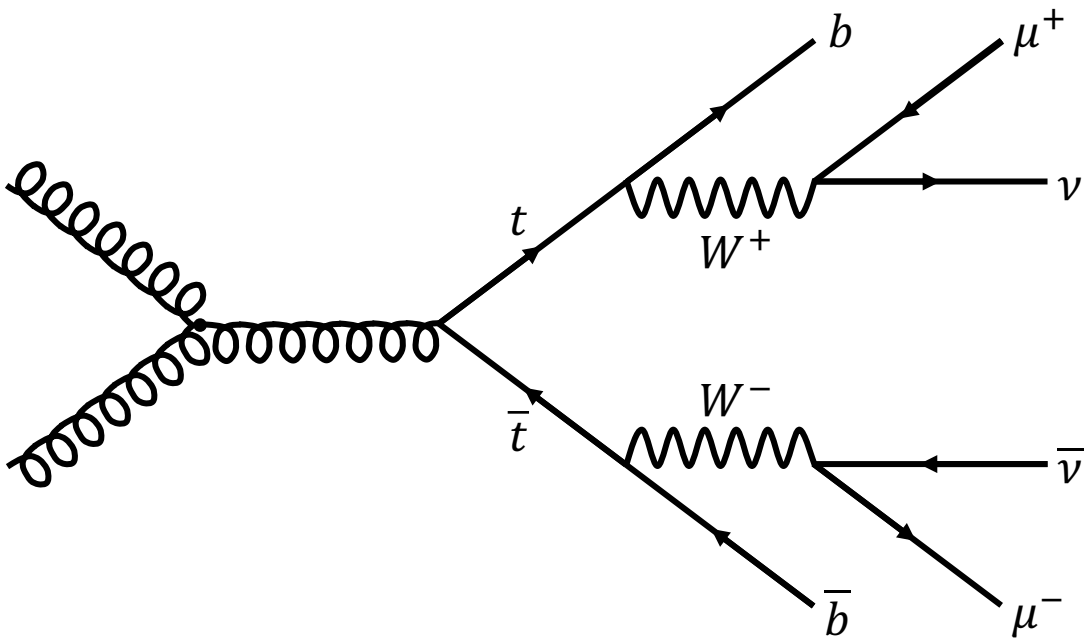


Secondary blocks



- Dashed lines: Decaying particles
- Lines with blobs: Input paticles
- Lines without blob: Reconstructed particles
- Secondary blocks can only be attached to lines with blob

$t\bar{t}$ fully leptonic Decay



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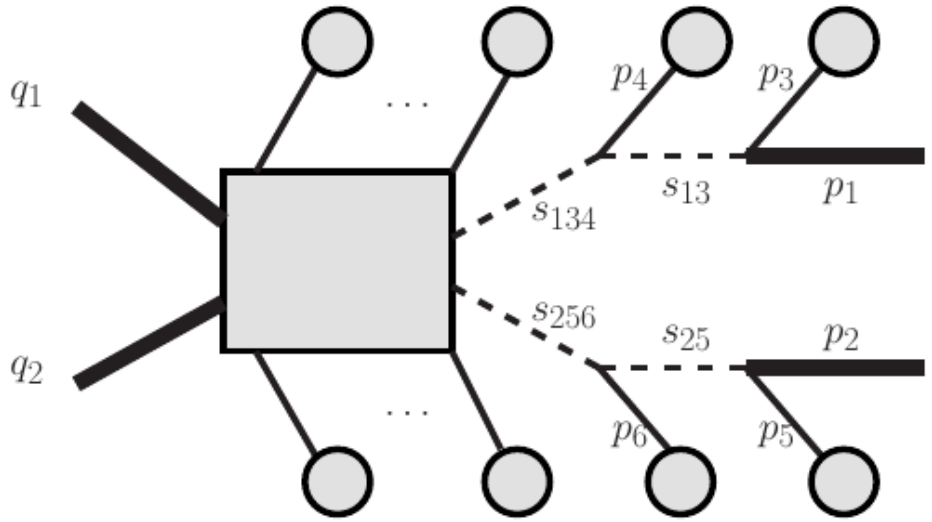
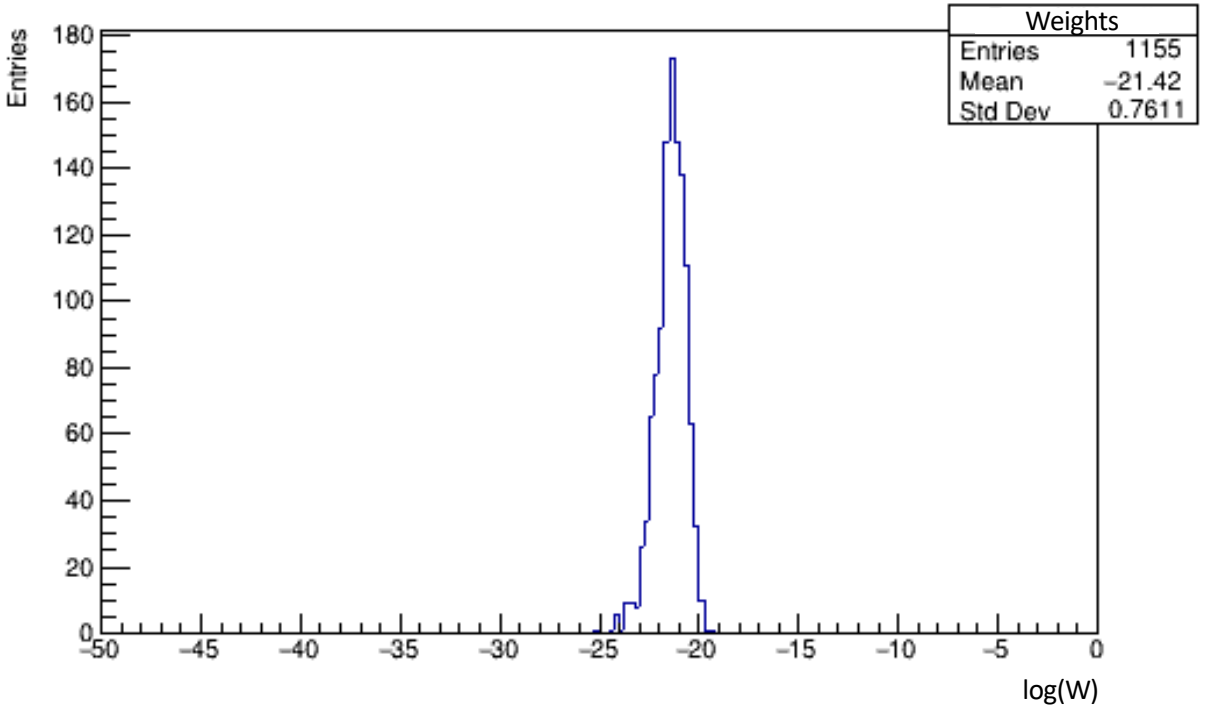


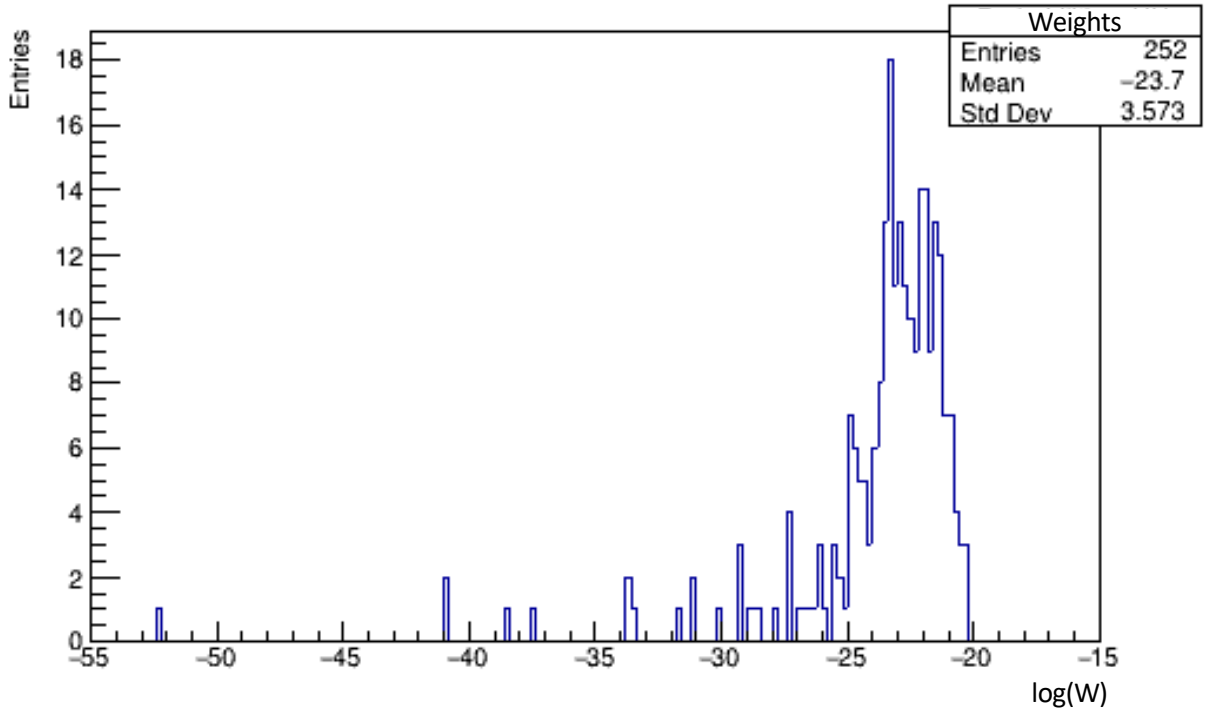
Main block D
[http://arxiv.org/abs/1007.3300v2]

$t\bar{t}$ fully leptonic Decay

Weights under $t\bar{t} \rightarrow \mu^{-}\mu^{+}$hypothesis



$t\bar{t}$ fully leptonic final states as inputs

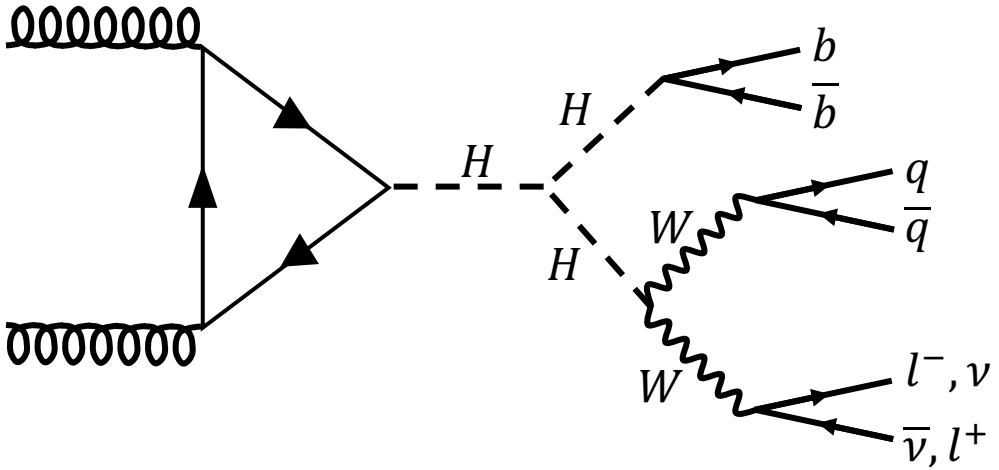


HH final states as inputs

How to construct Higgs Self-coupling?

Requirements for block:

- 6 final state particles
- Only 3 dashed lines



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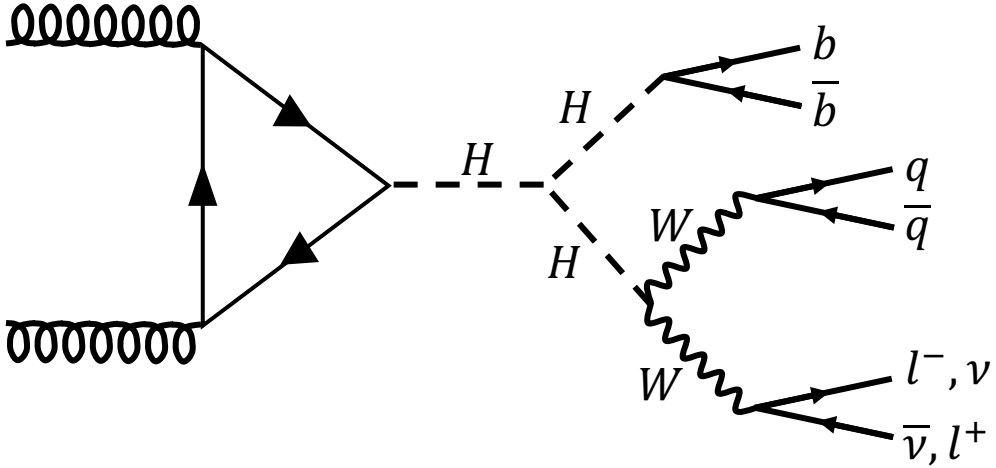
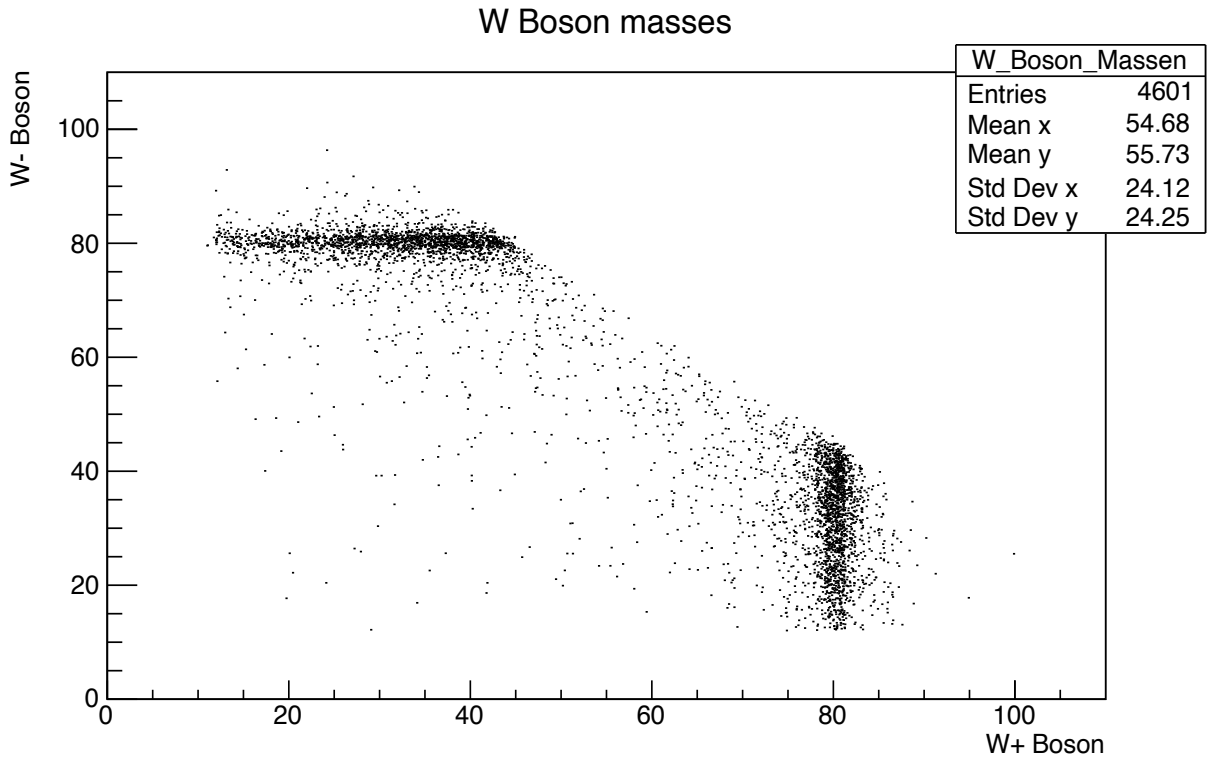
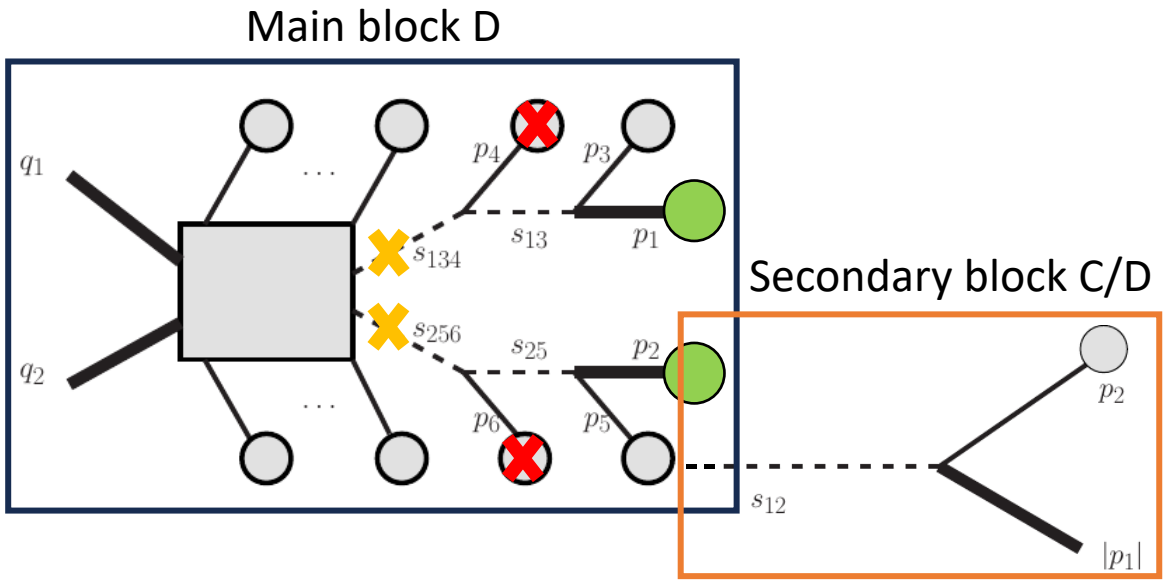
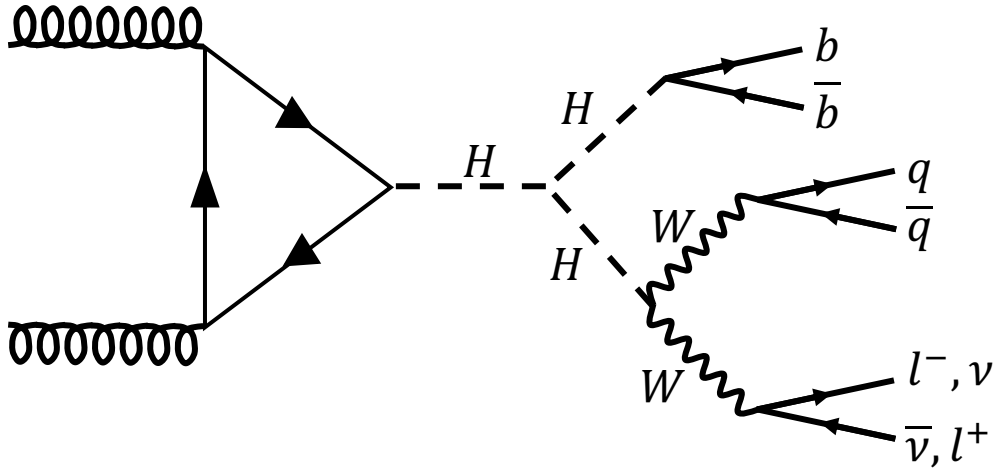




Higgs Self-coupling in MoMEMta





Main block D changes

- Set $p4 = p6 = 0$ → No need for dashed lines $s134$ & $s256$
- Make $p1$ & $p2$ inputs
- $p2$ is sum of virtuel W-boson daughters

Higgs Self-coupling in MoMEMta

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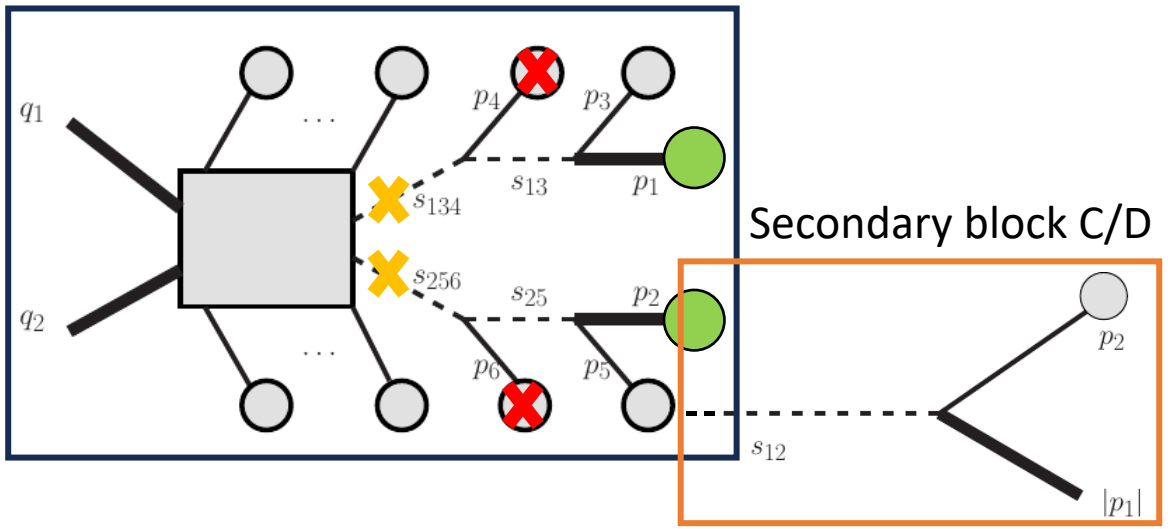
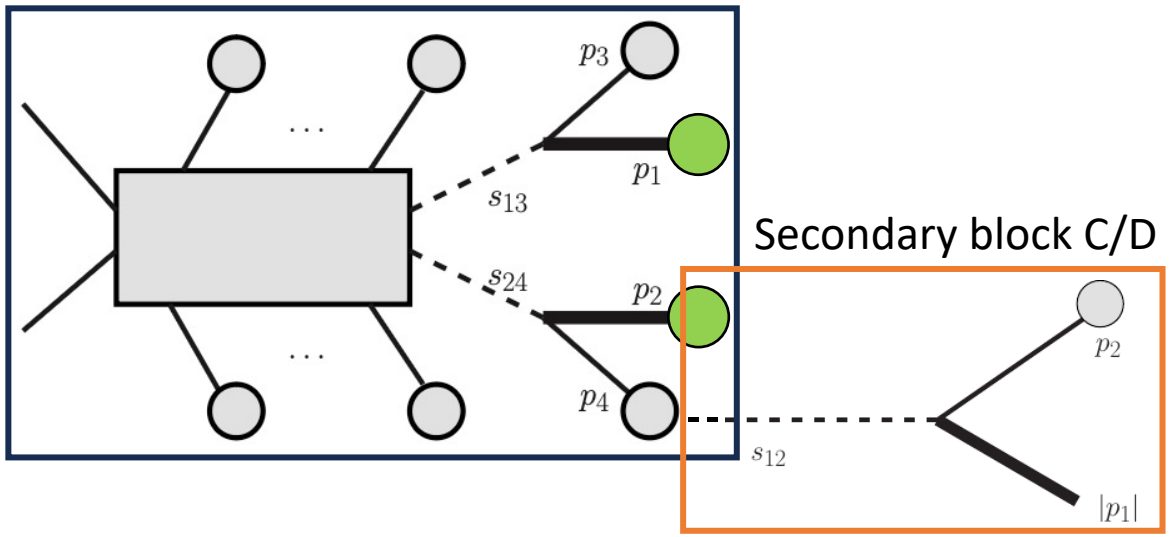
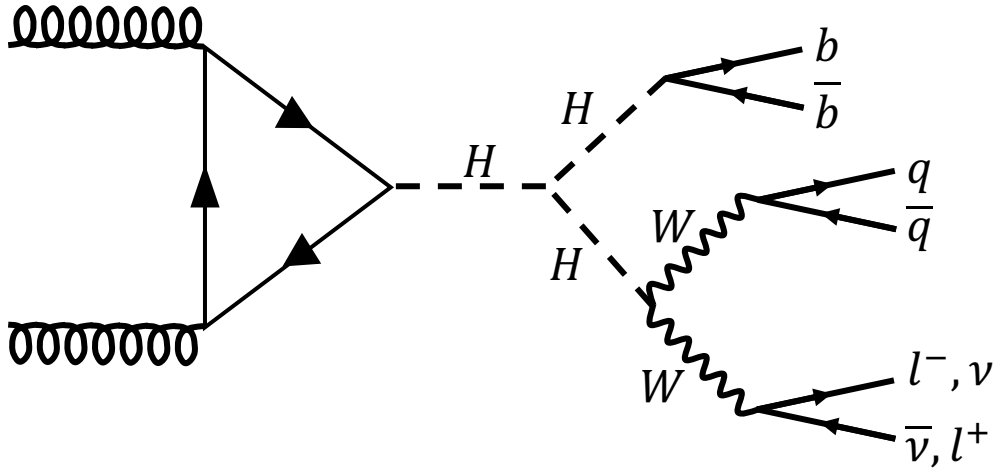


Main block F





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Main block F changes

- Make $p1$ & $p2$ inputs

Outlook

- Calculate weights of multiple HH events and compare them to HZ events
- Use jets instead of particles
- Train neural network for integral calculation