

# MAKING THE MOST OF VBF

*1st MiniWorkshop on theoretical advances in MEMs*

*Louvain-la-Neuve, 27.05.2013*

CHRISTOPH ENGLERT

*(Durham / Glasgow)*





status by the end of 2012

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- Higgs decays to photons
- huge background in the 2jet category, a no-go?

$\sqrt{s}$	7 TeV		8 TeV		
$\sigma \times B(H \rightarrow \gamma\gamma)$ [fb]	39		50		FV
Category	$N_D$	$N_S$	$N_D$	$N_S$	(C
Unconv. central, low $p_{Tl}$	2054	10.5	2945	14.2	
Unconv. central, high $p_{Tl}$	97	1.5	173	2.5	
Unconv. rest, low $p_{Tl}$	7129	21.6	12136	30.9	
Unconv. rest, high $p_{Tl}$	444	2.8	785	5.2	
Conv. central, low $p_{Tl}$	1493	6.7	2015	8.9	
Conv. central, high $p_{Tl}$	77	1.0	113	1.6	
Conv. rest, low $p_{Tl}$	8313	21.1	11099	26.9	
Conv. rest, high $p_{Tl}$	501	2.7	706	4.5	
Conv. transition	3591	9.5	5140	12.8	
2-jet	89	2.2	139	3.0	
All categories (inclusive)	23788	79.6	35251	110.5	

[ATLAS `12]



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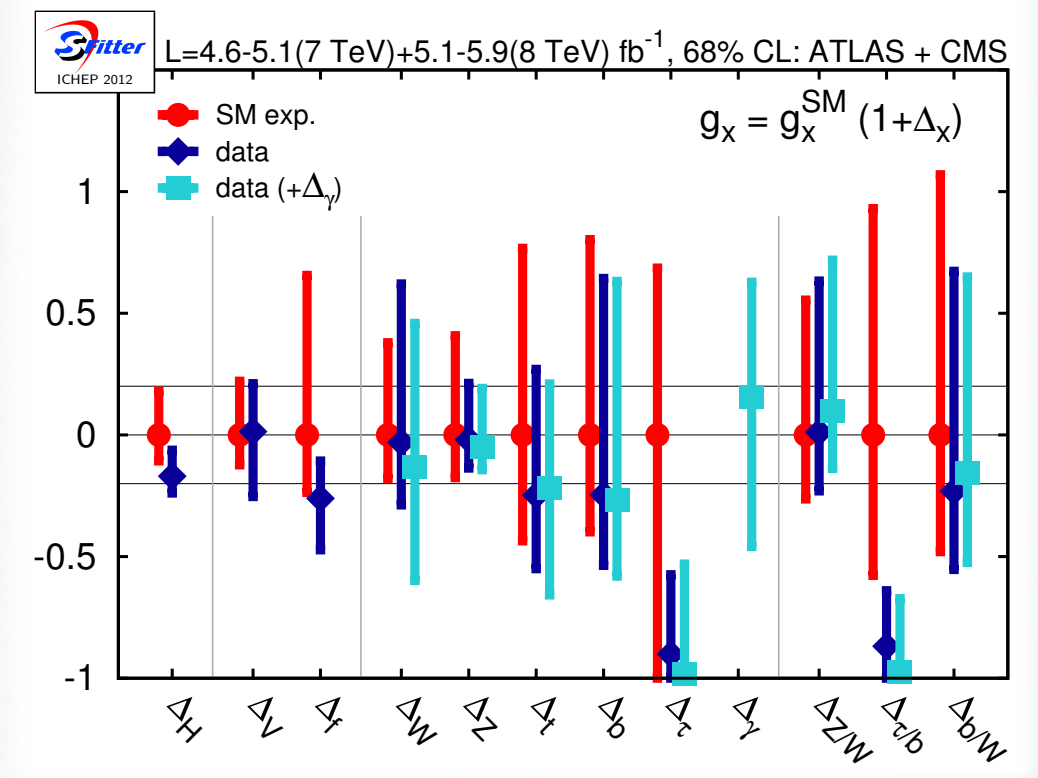
$$\frac{g_\tau^2}{g_\gamma^2} = \frac{\text{BR}(h \rightarrow \tau\tau)}{\text{BR}(h \rightarrow \gamma\gamma)}$$

- disentangle production modes in a global fit

$$\sum_p \sigma_p \times \text{BR}_d \sim \sum_p \frac{\Gamma_p \Gamma_d}{\Gamma_{\text{tot}}} \sim \sum_p \frac{g_p^2 g_d^2}{\sum_{\text{modes}} g_k^2}$$

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[ATLAS '12]



[Plehn, Rauch '12]



# ways to improve

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[Andersen, CE, Spannowsky '12]

[CE, Takeuchi, Spannowsky '12]

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  - Do we need to be overly smart?

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  - Do we need to be overly smart?
- you're naturally driven towards the matrix element method

**best possible outcome:  
yes, yes, probably not.**

$$\tilde{Q}_n = -\log \left[ \frac{|\mathcal{M}^{\text{WBF}}(pp \rightarrow (h \rightarrow \gamma\gamma)j^n)|^2}{|\mathcal{M}^{\text{GF}}(pp \rightarrow (h \rightarrow \gamma\gamma)j^n)|^2} \right]$$

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- new physics is a shift along the x-axis, effective theory is fine
- reconstructible final state -- get the kinematics from mapping the hadronized event onto partonic 2+3 kinematics based on pseudorapidity, transverse momentum & overall boost [Fisher, Becker, Kirkby '95]  
[Dobbs '05]



avoid most of the technicalities  
[MadWeight]

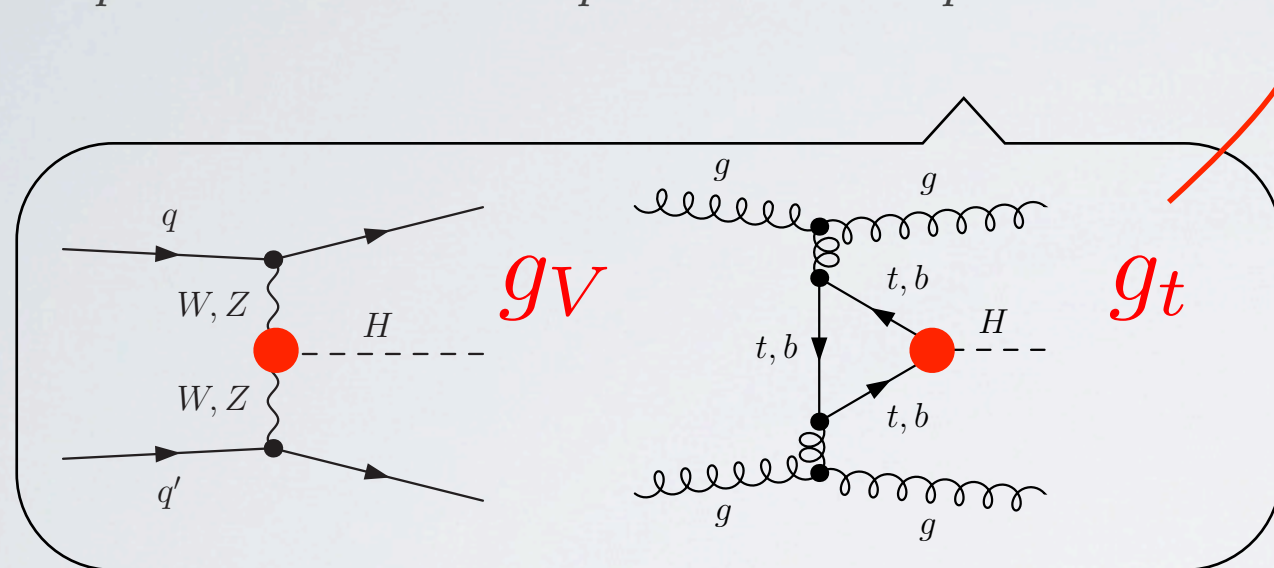


- extract SM-like couplings means fit of the observed signal count

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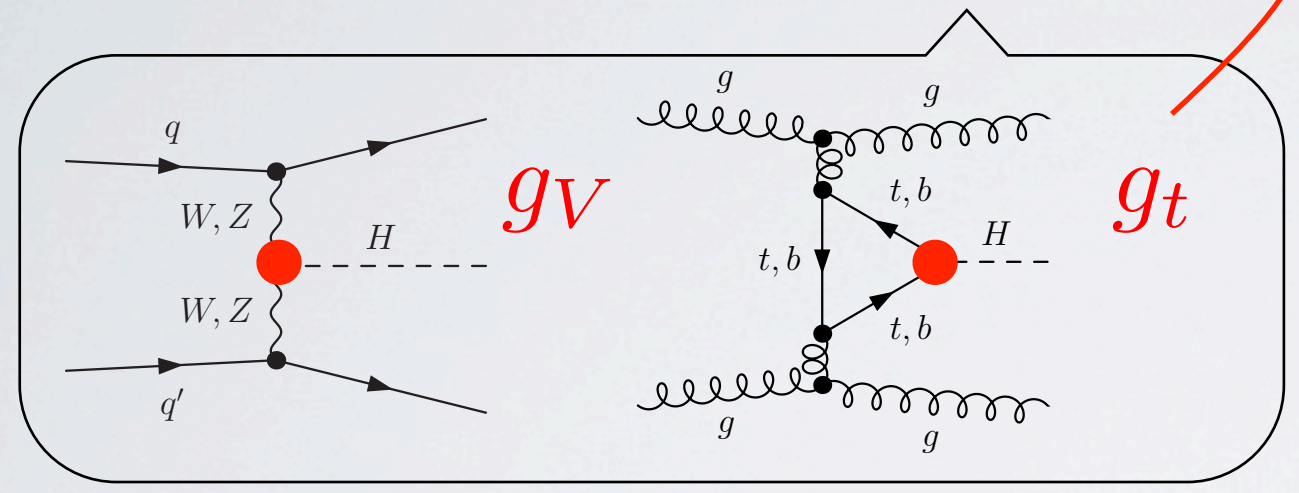
- mixture of production modes systematically limits a global fit



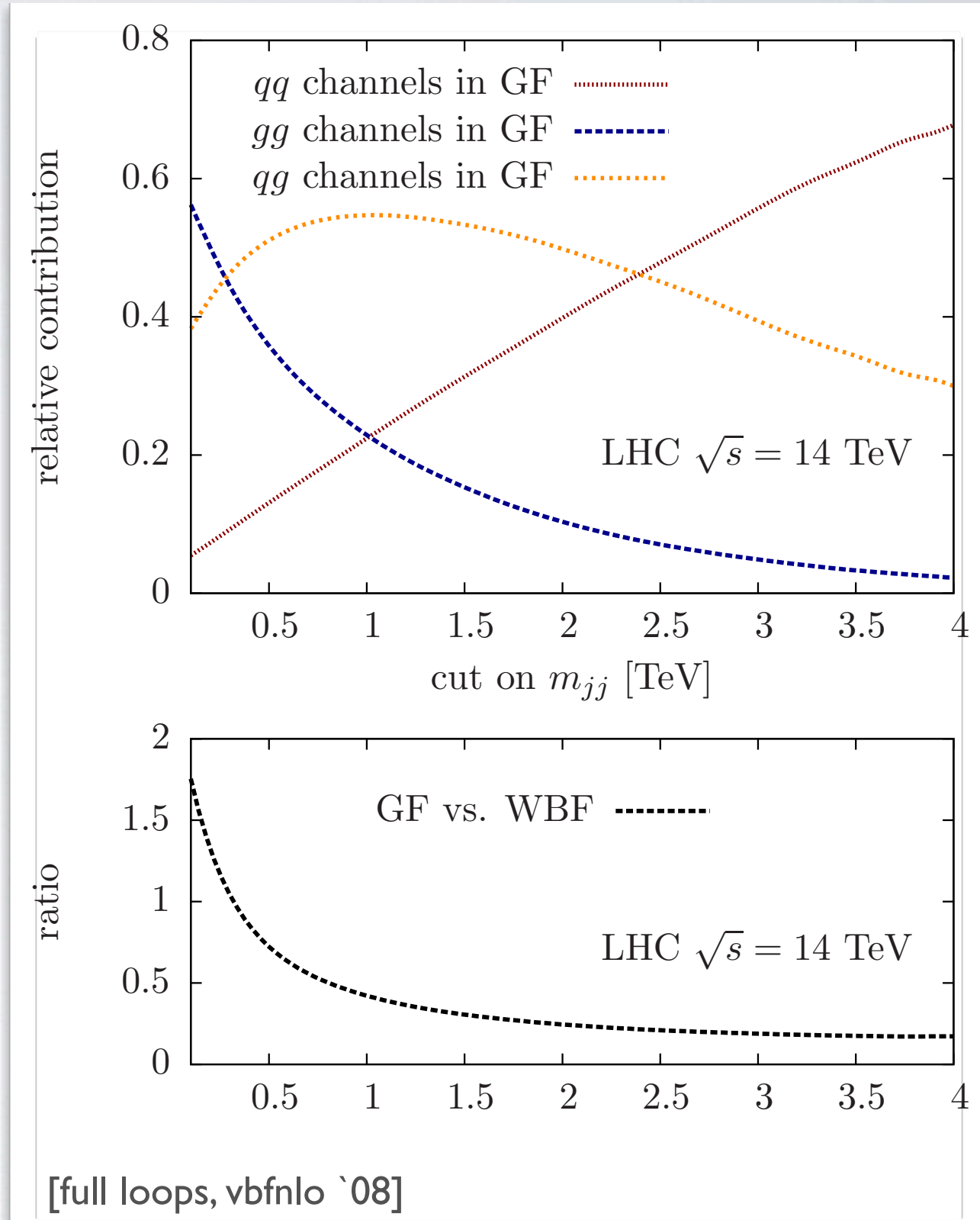
# traditional approaches in vbf:

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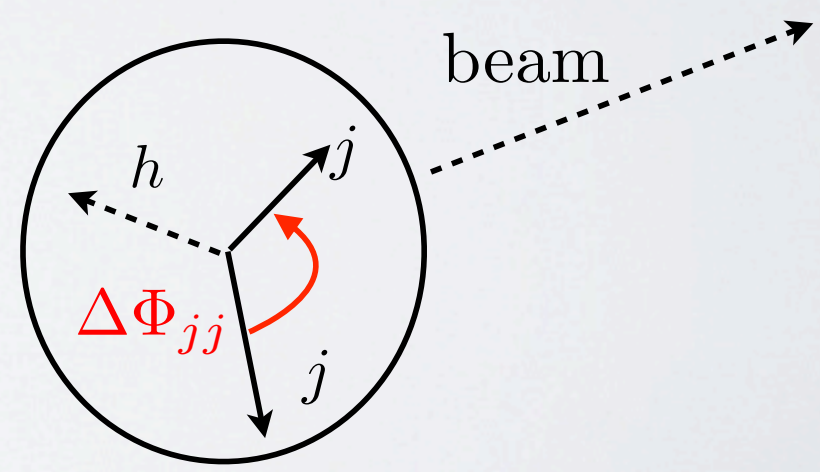
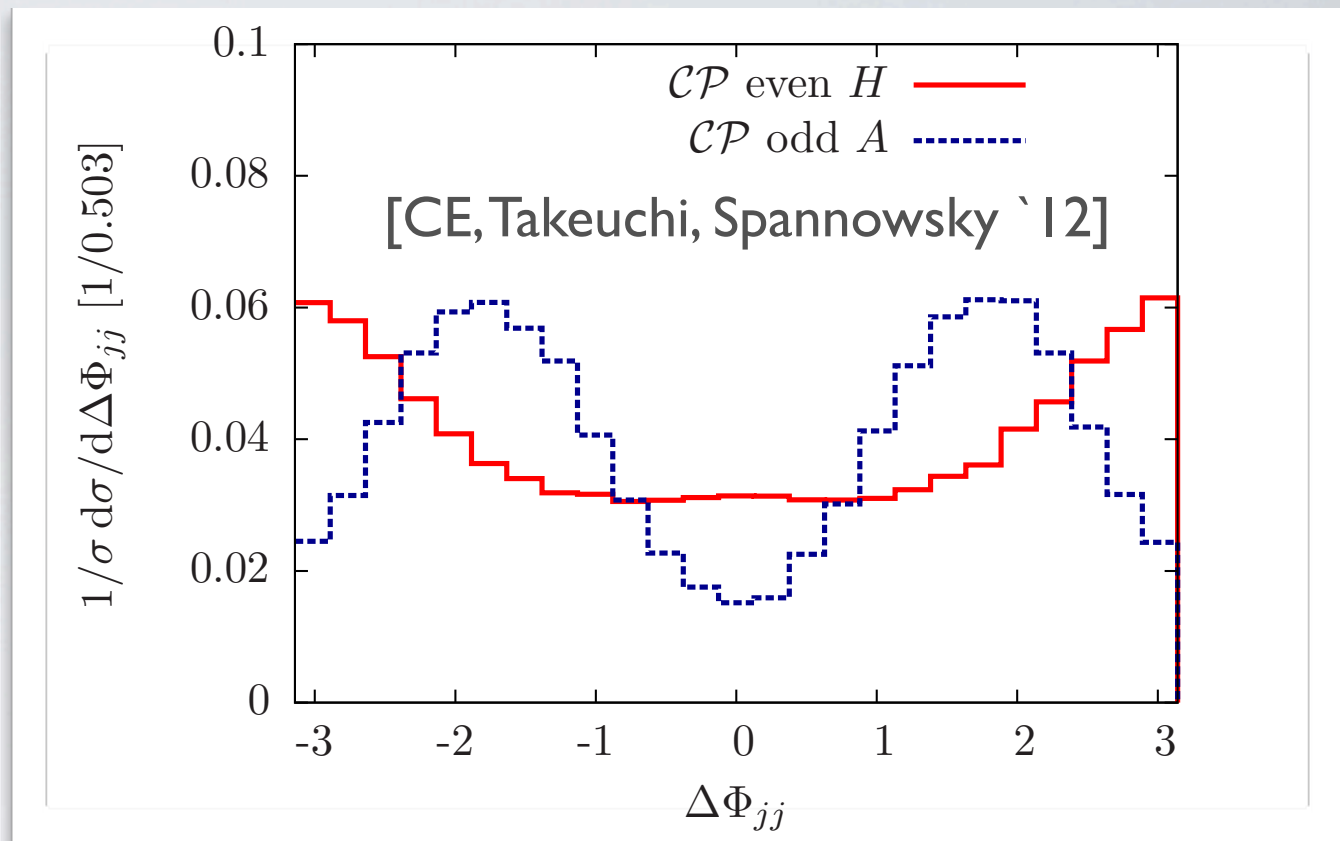
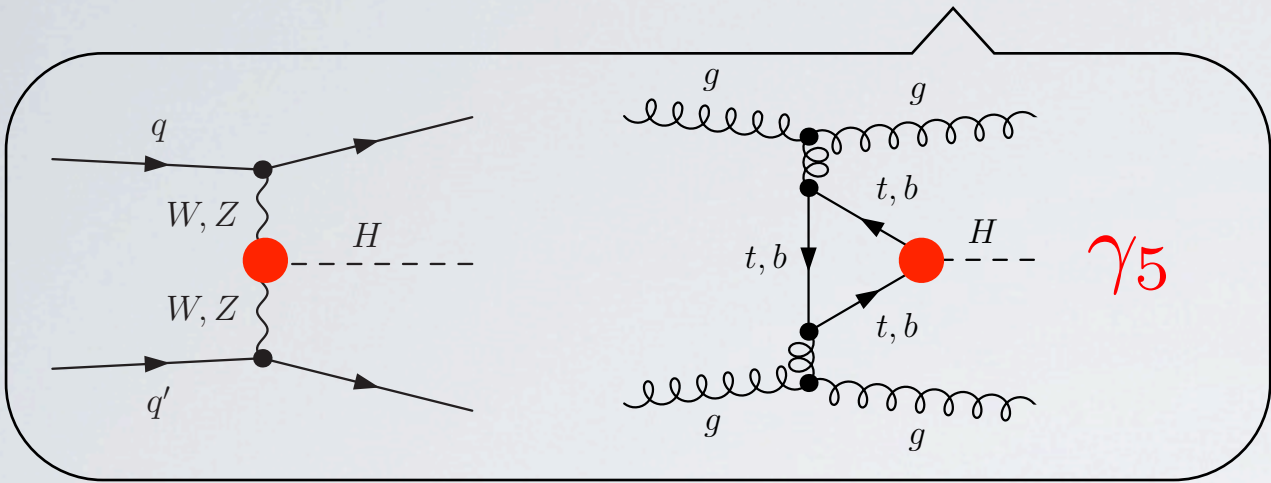
- mixture of production modes systematically limits a global fit
- additional kinematic separation theoretically challenging and costly !!



# less traditional (but effective):

*color flow*

- QCD amplitudes know a lot



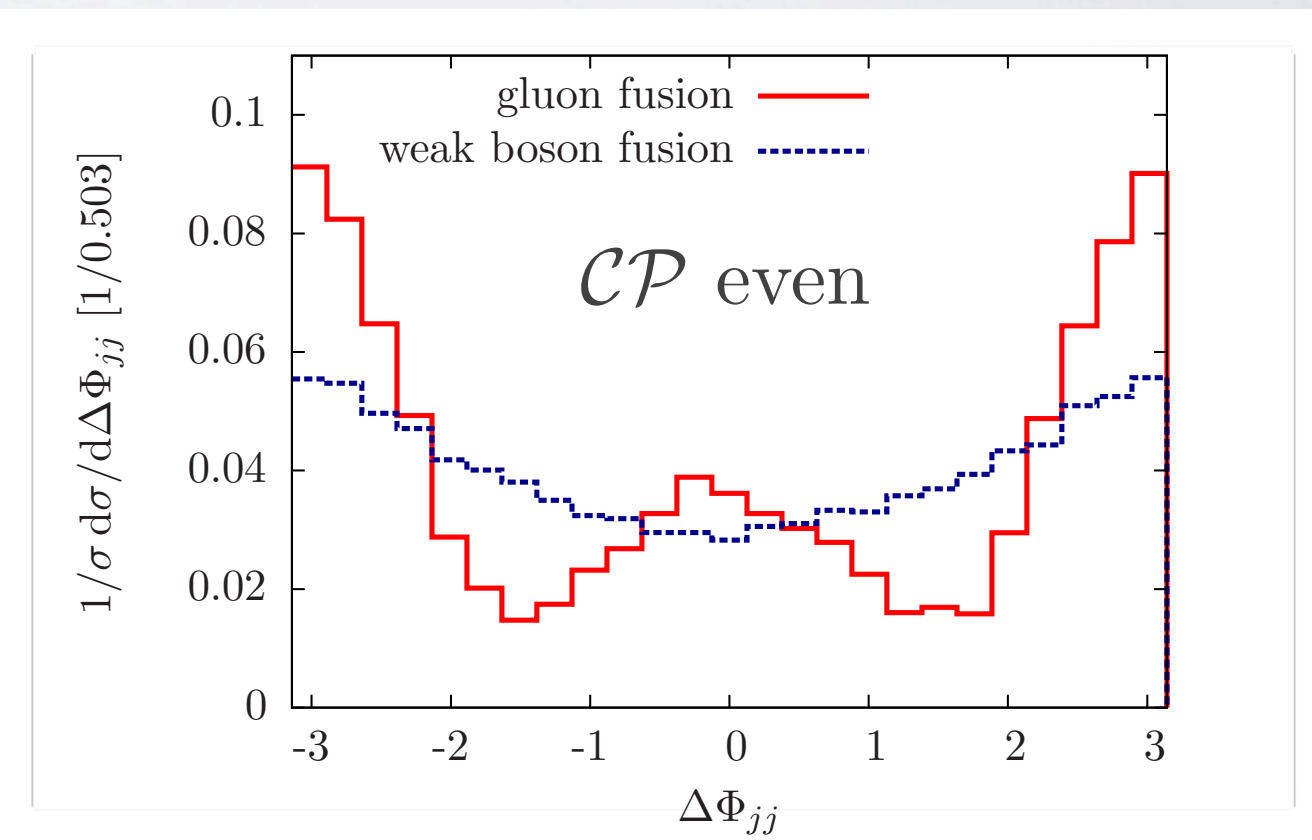
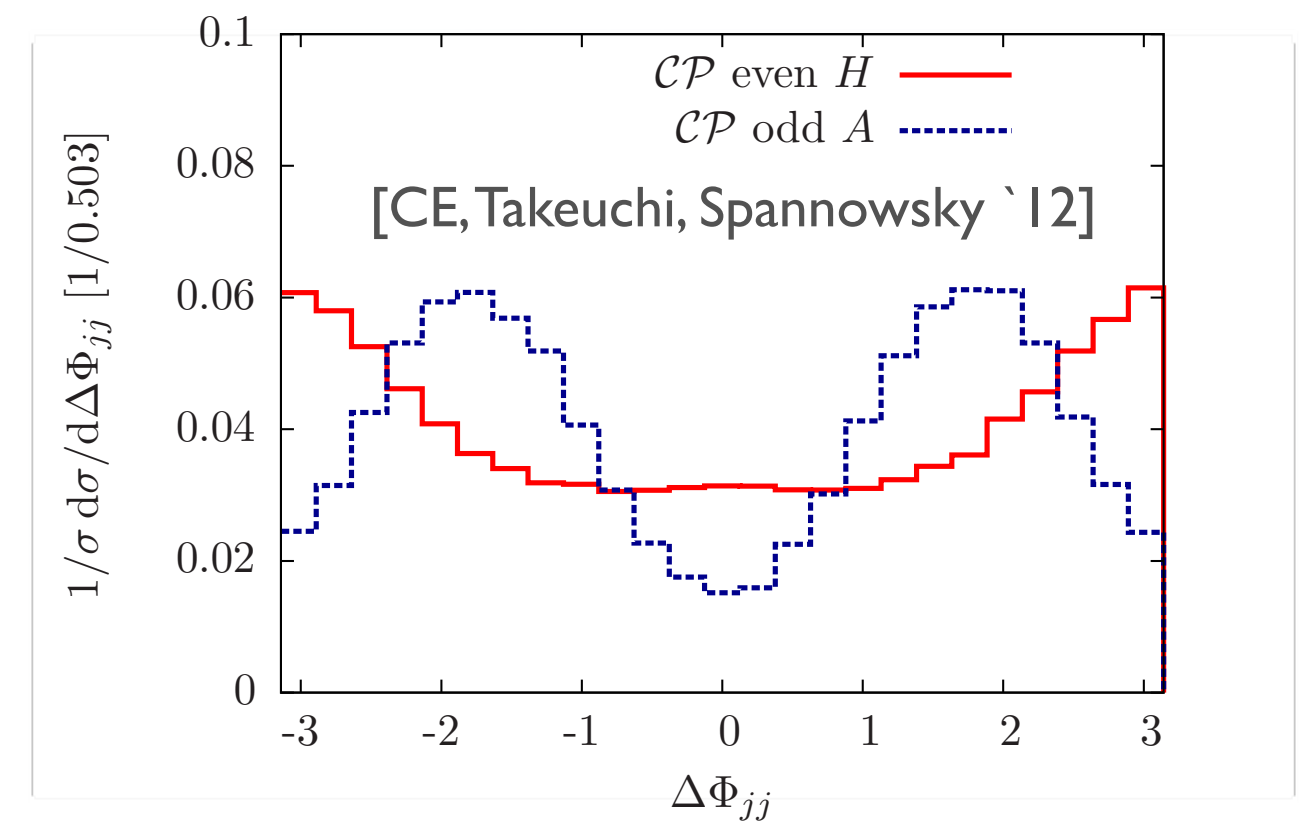
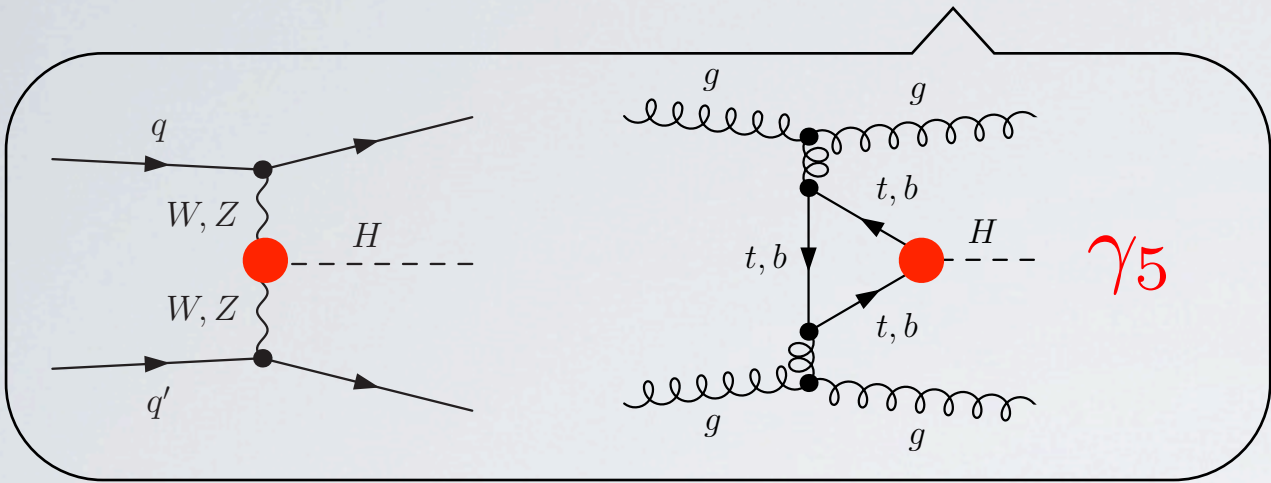
[Plehn, Rainwater, Zeppenfeld '12]



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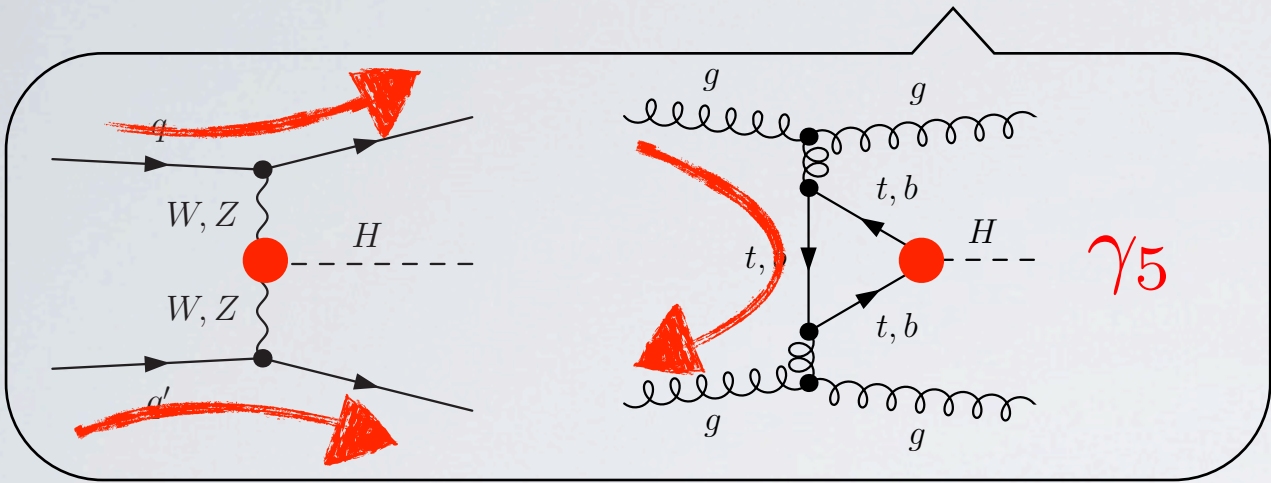
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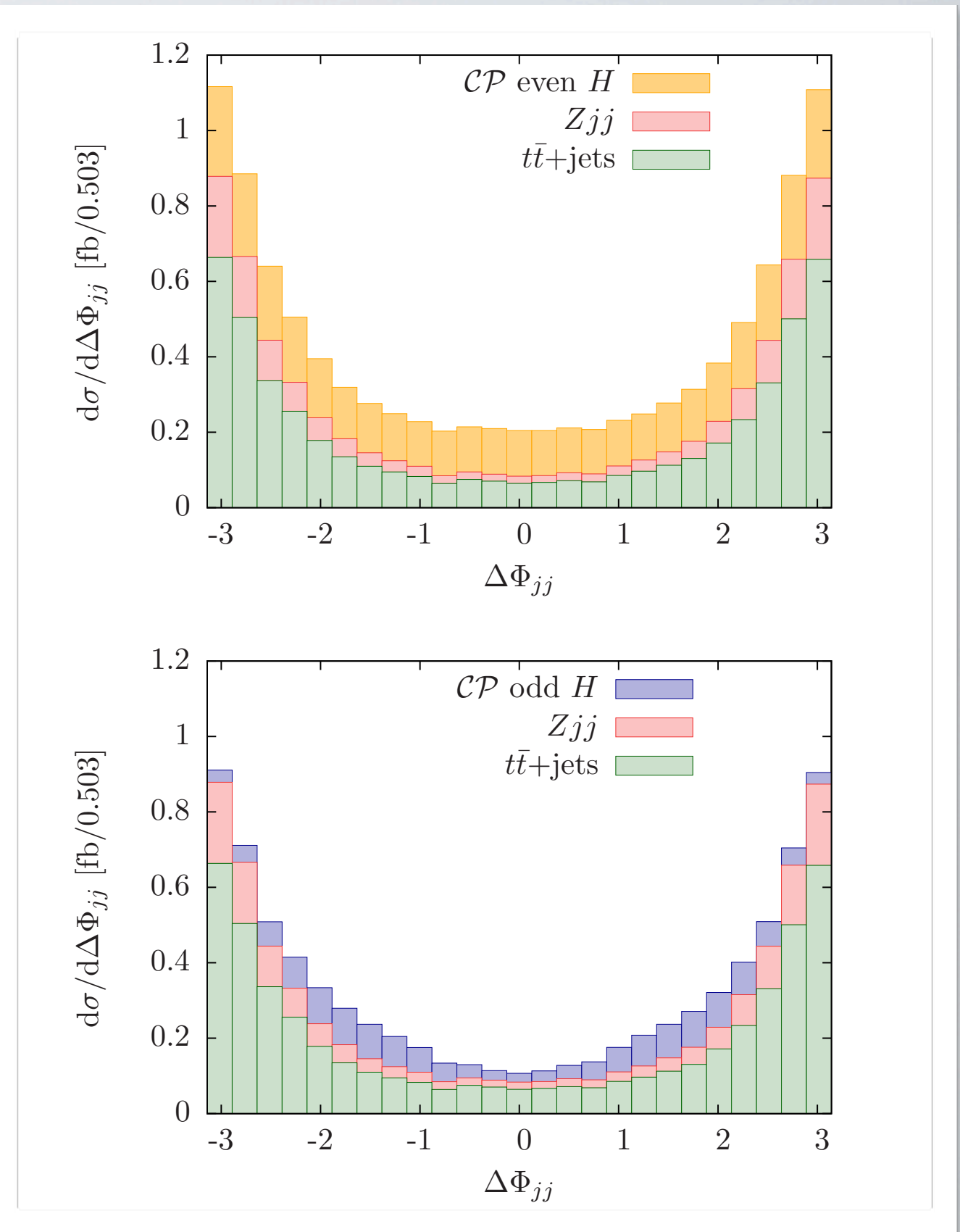
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- energy momentum flow is a coherent function of CP, couplings
- event shape observables are designed to capture that in the most effective way

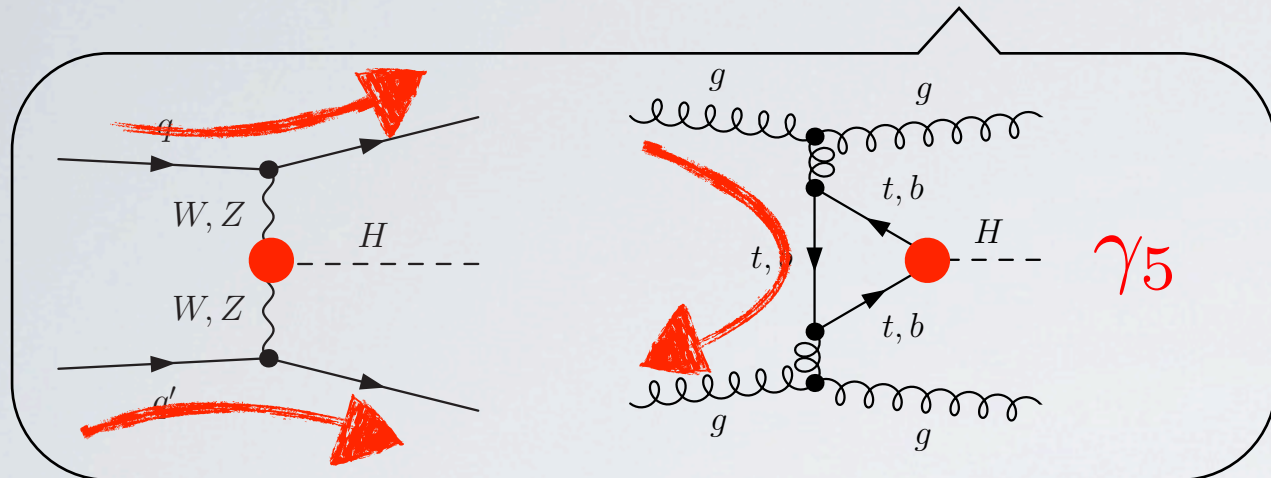




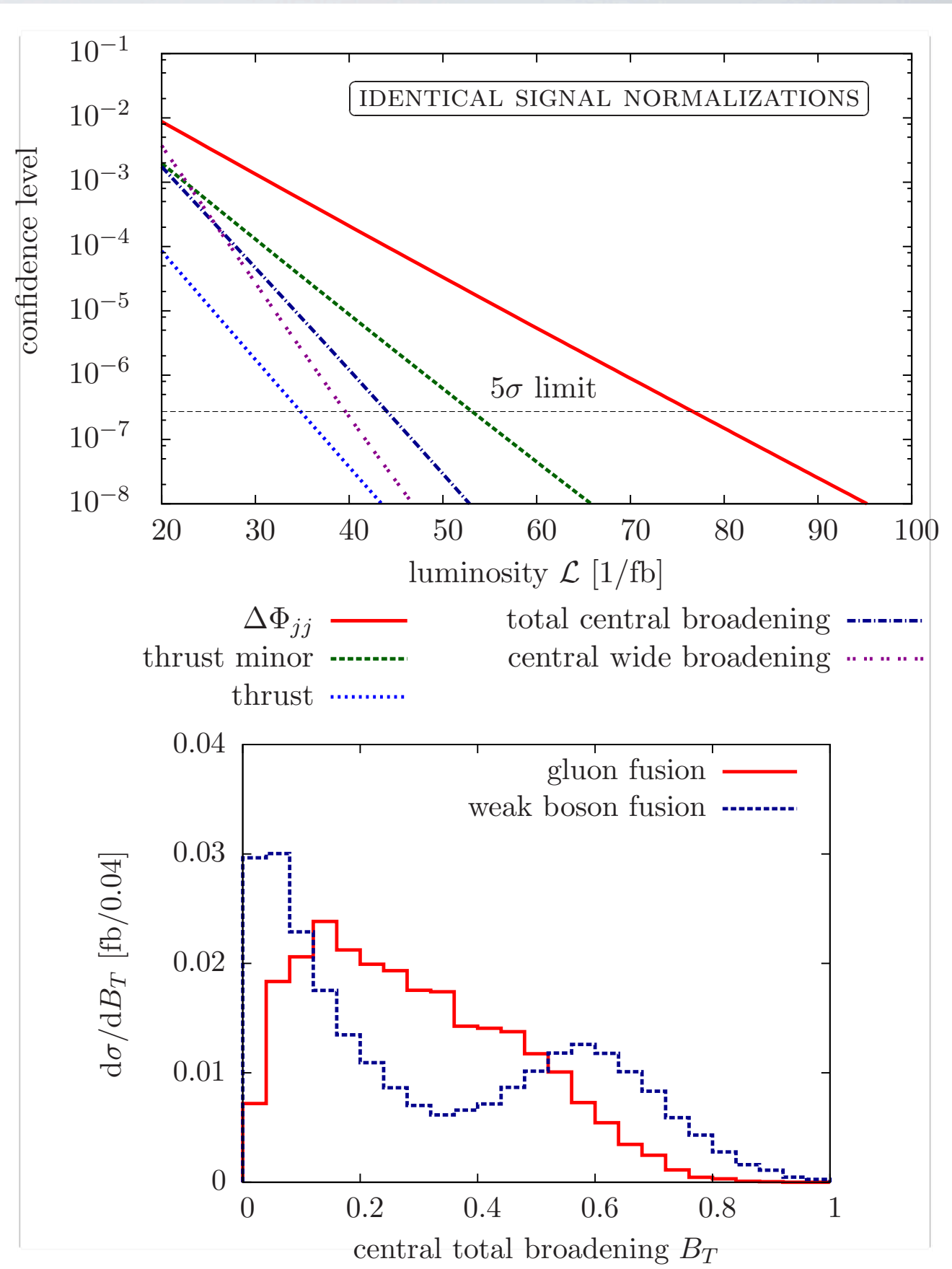
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- energy momentum flow is a coherent function of CP, couplings
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- use this for WBF/GF separation
- combining both: **matrix elements**

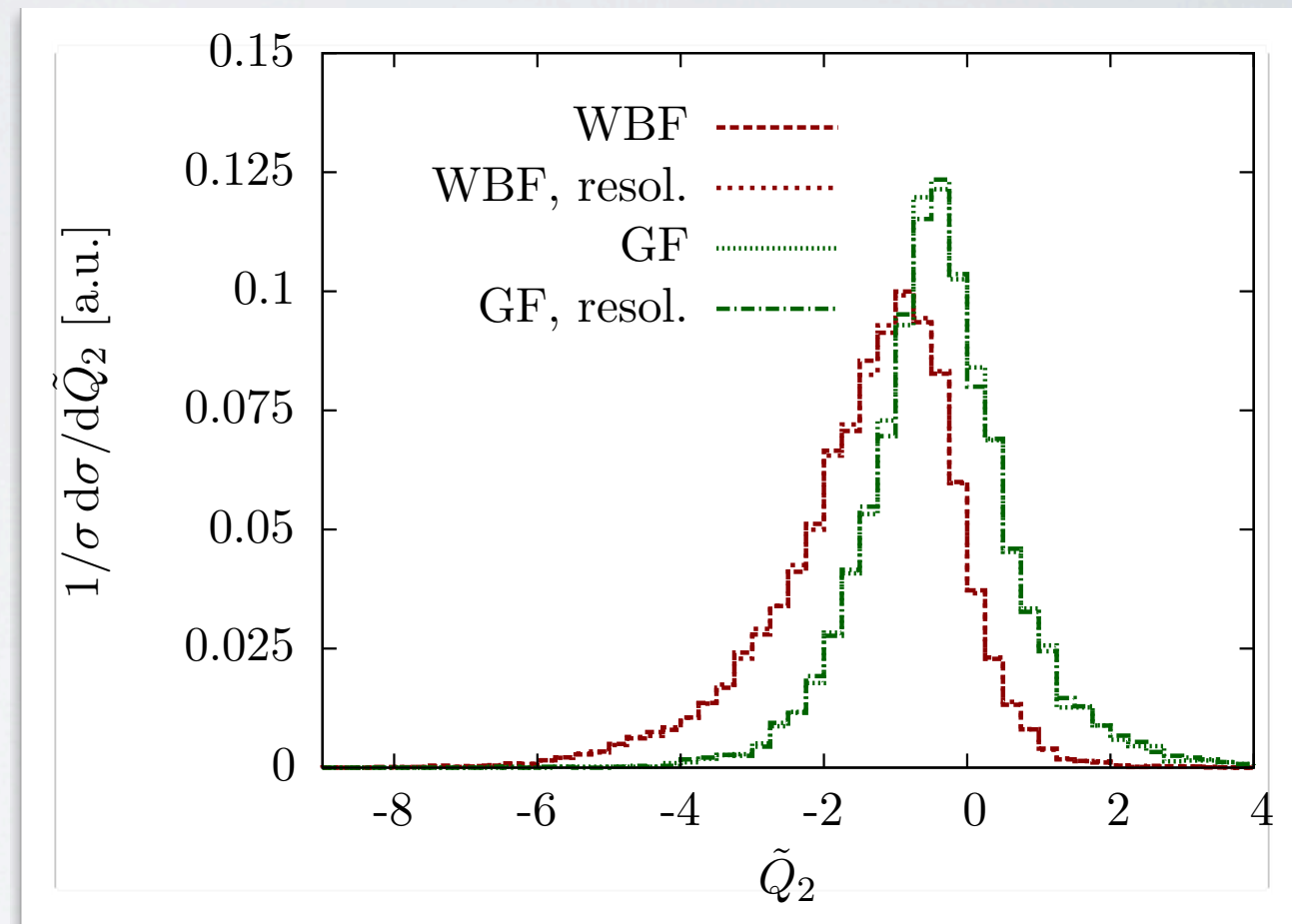
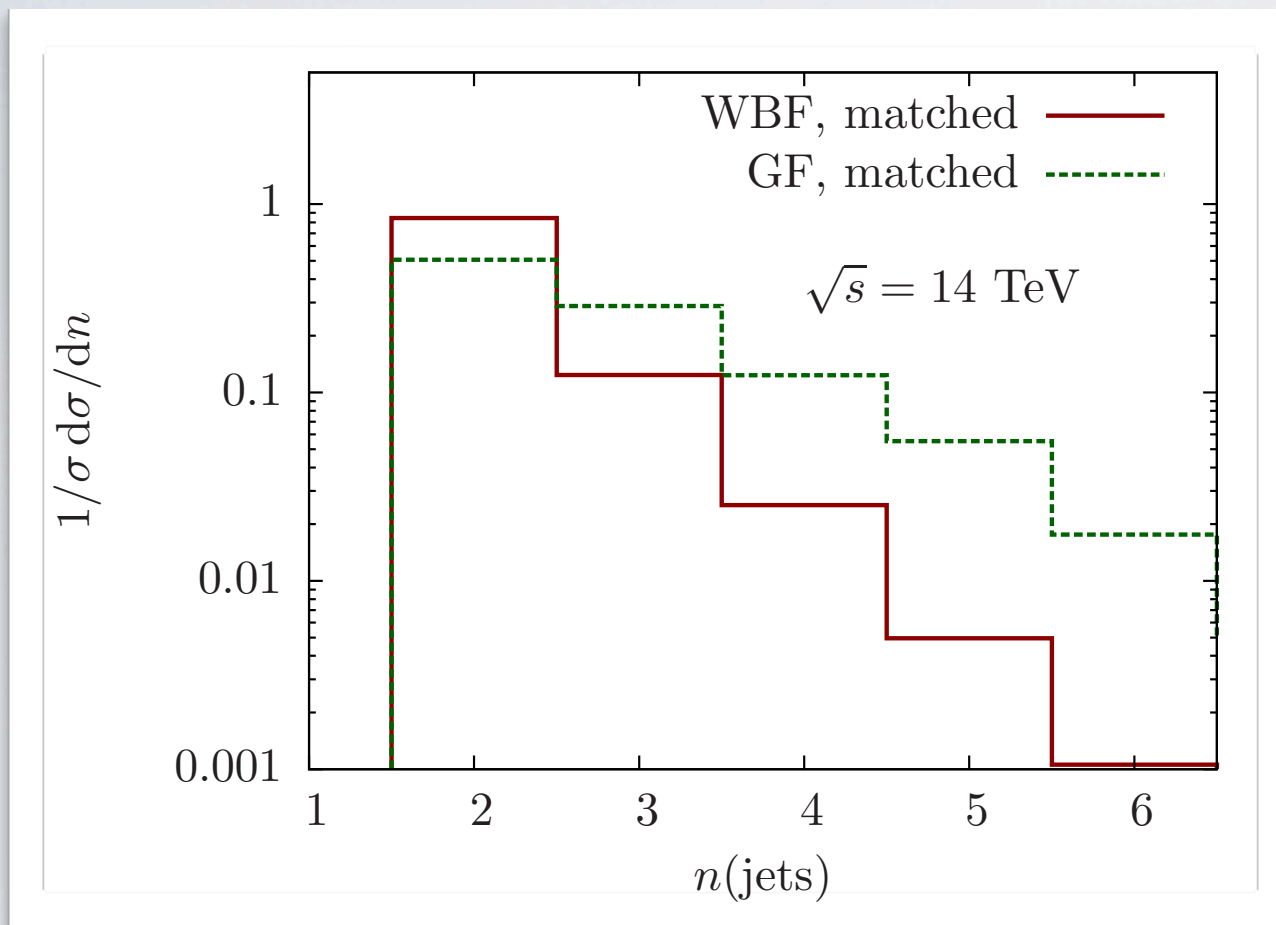


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[MG v4]

[MG v4, heft]

- in practice  $n \leq 3$  is enough to get the nitty-gritty



- detector resolution effects unimportant (smearing fitted to  $h \rightarrow \gamma\gamma$ )



# best of both worlds

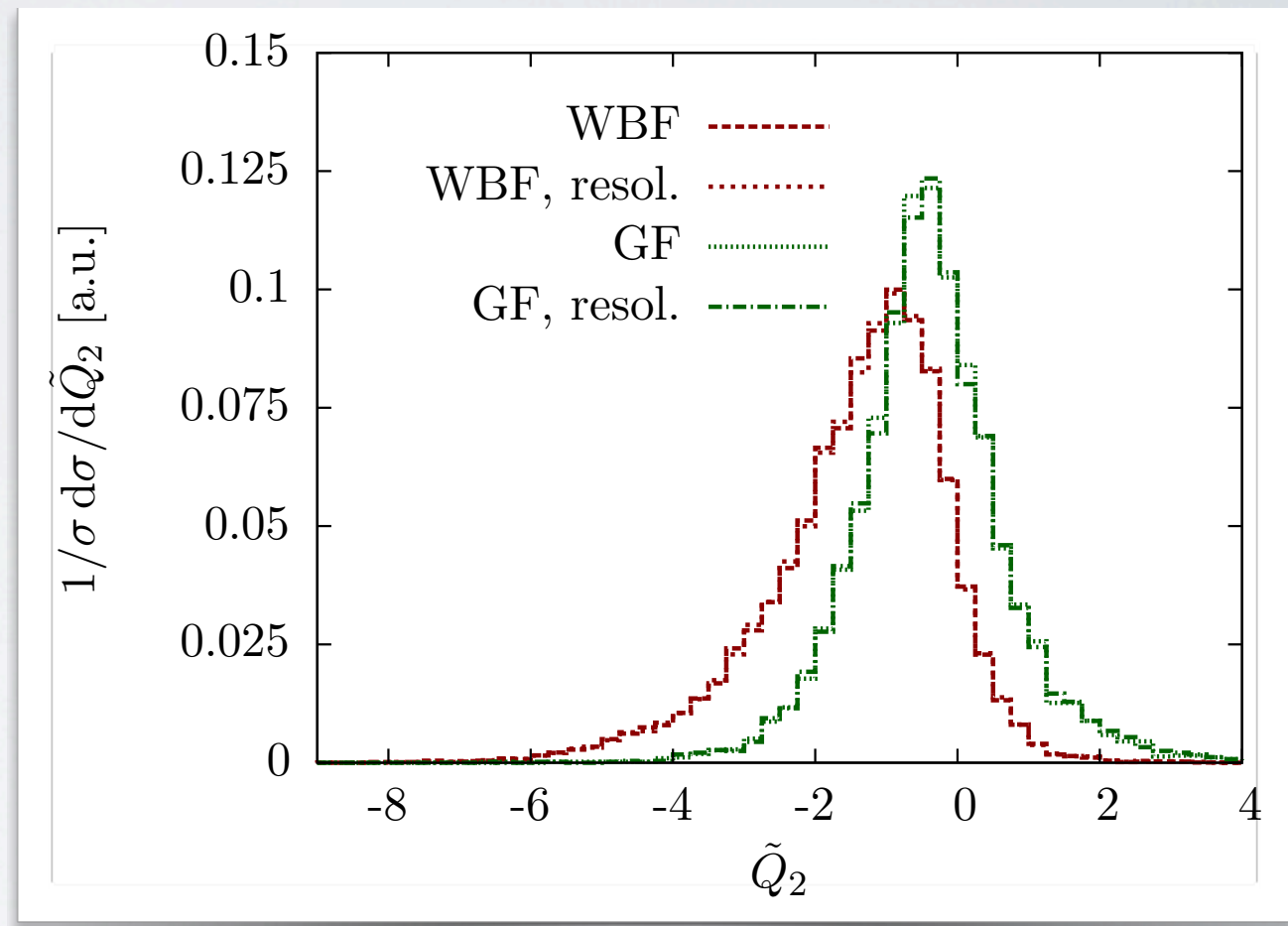
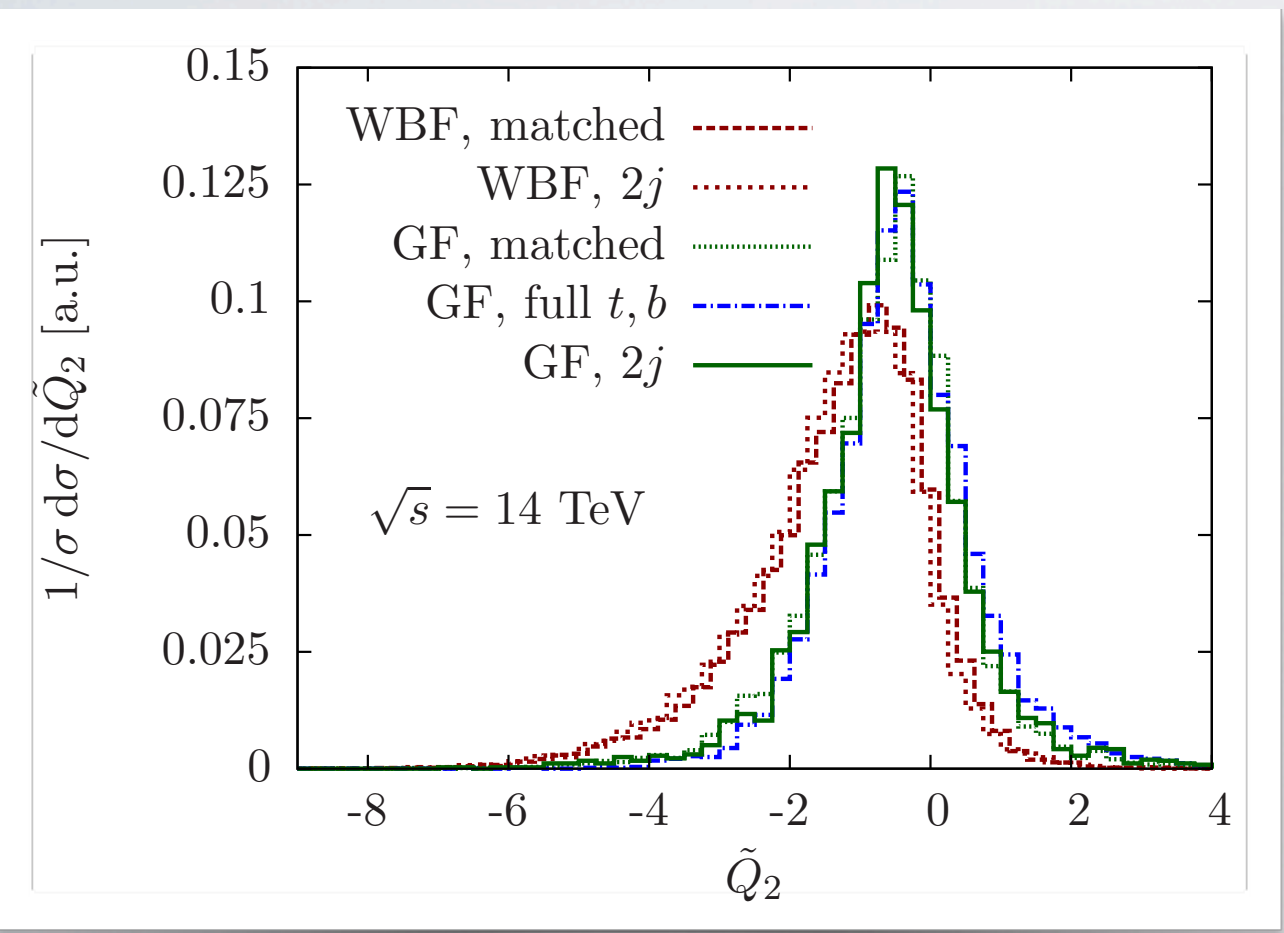
*matrix elements*

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[MG v4, left]

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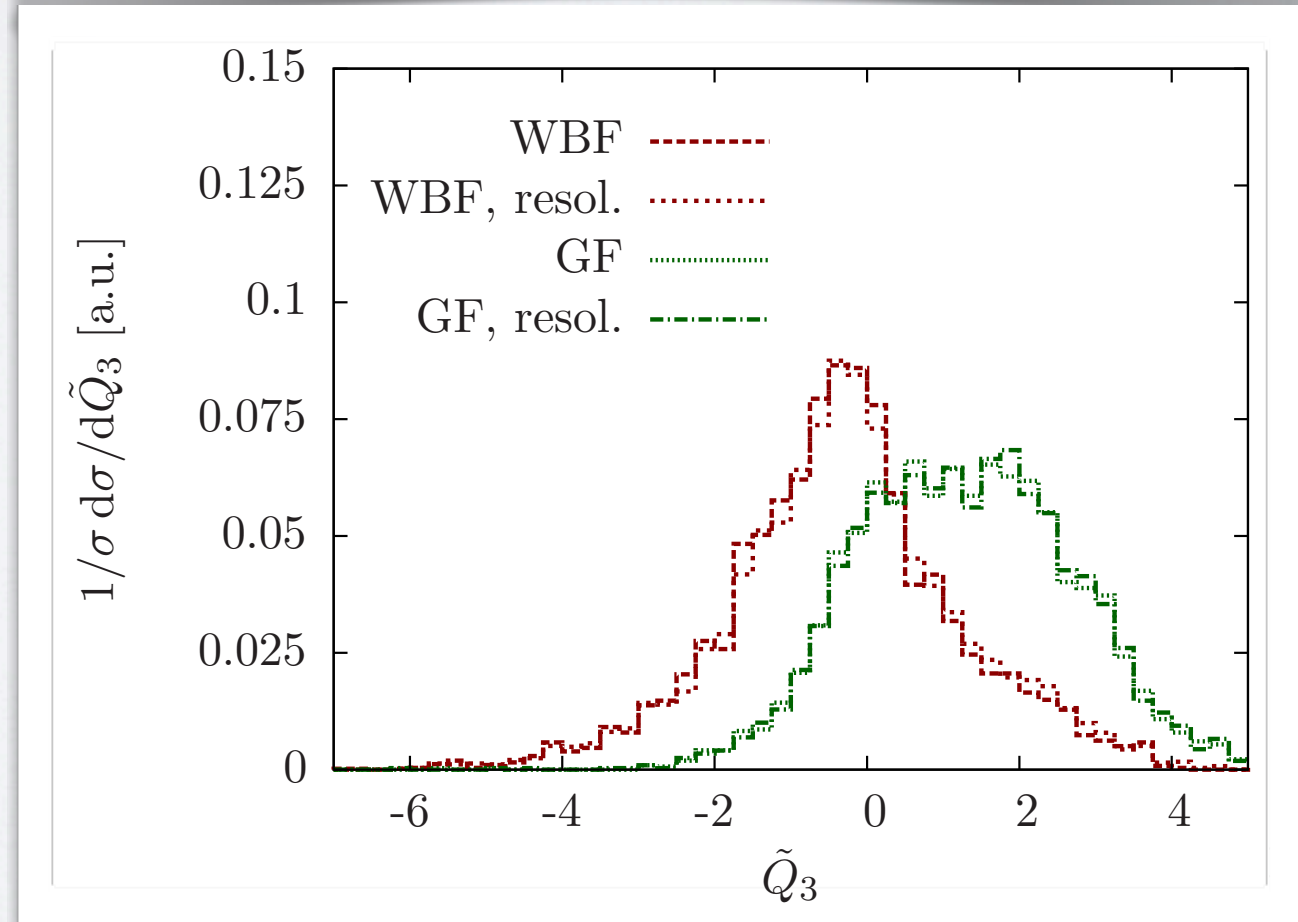
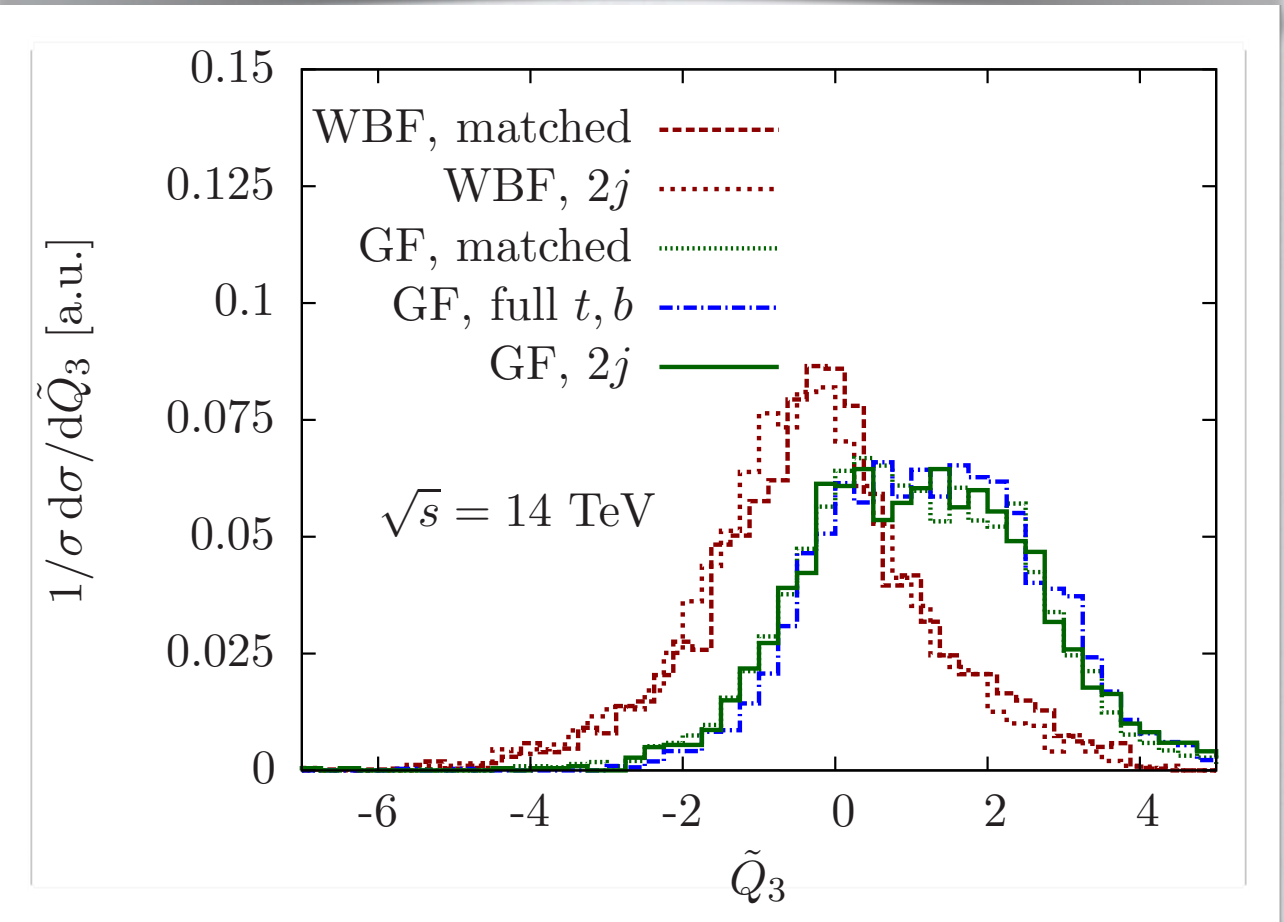
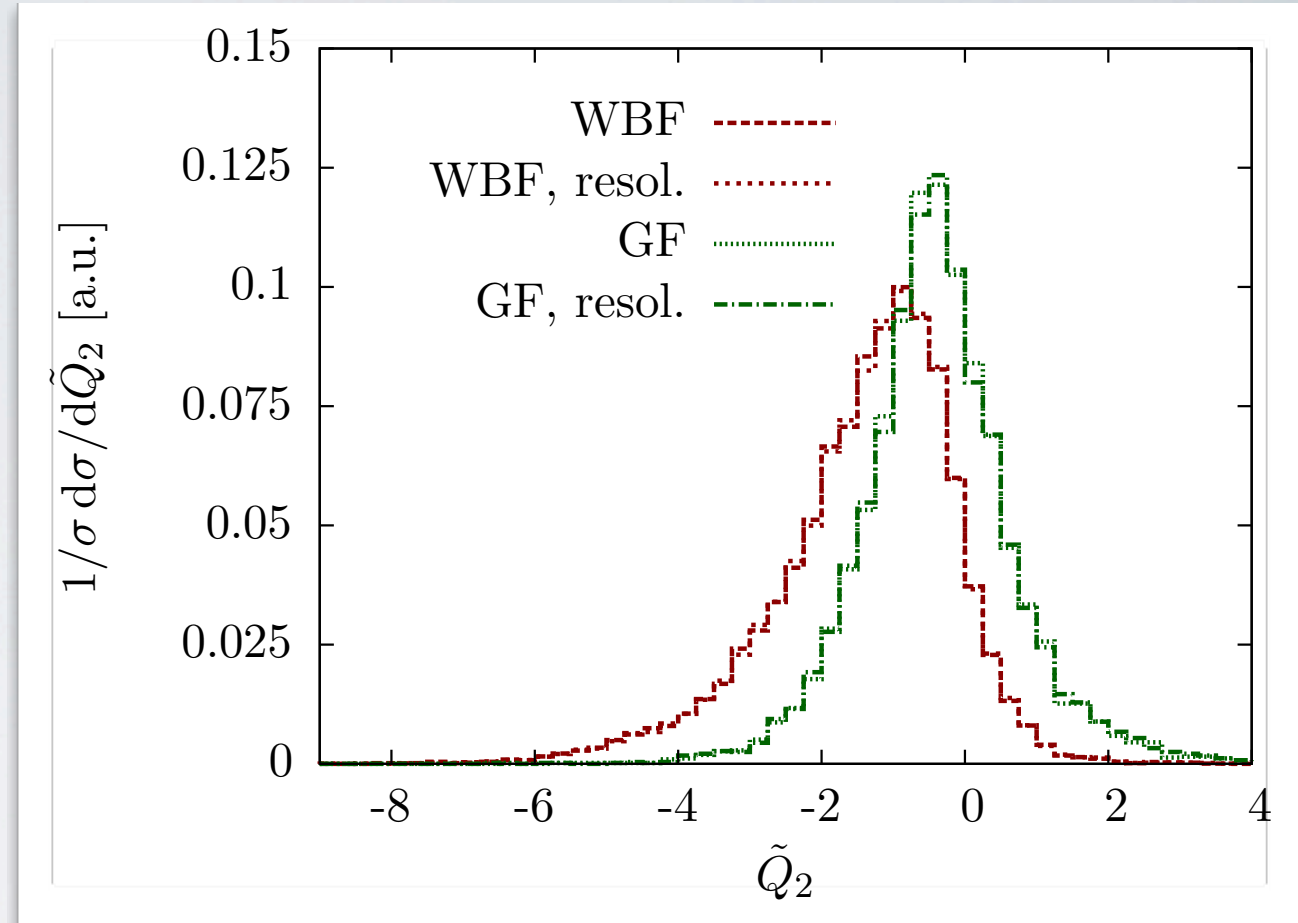
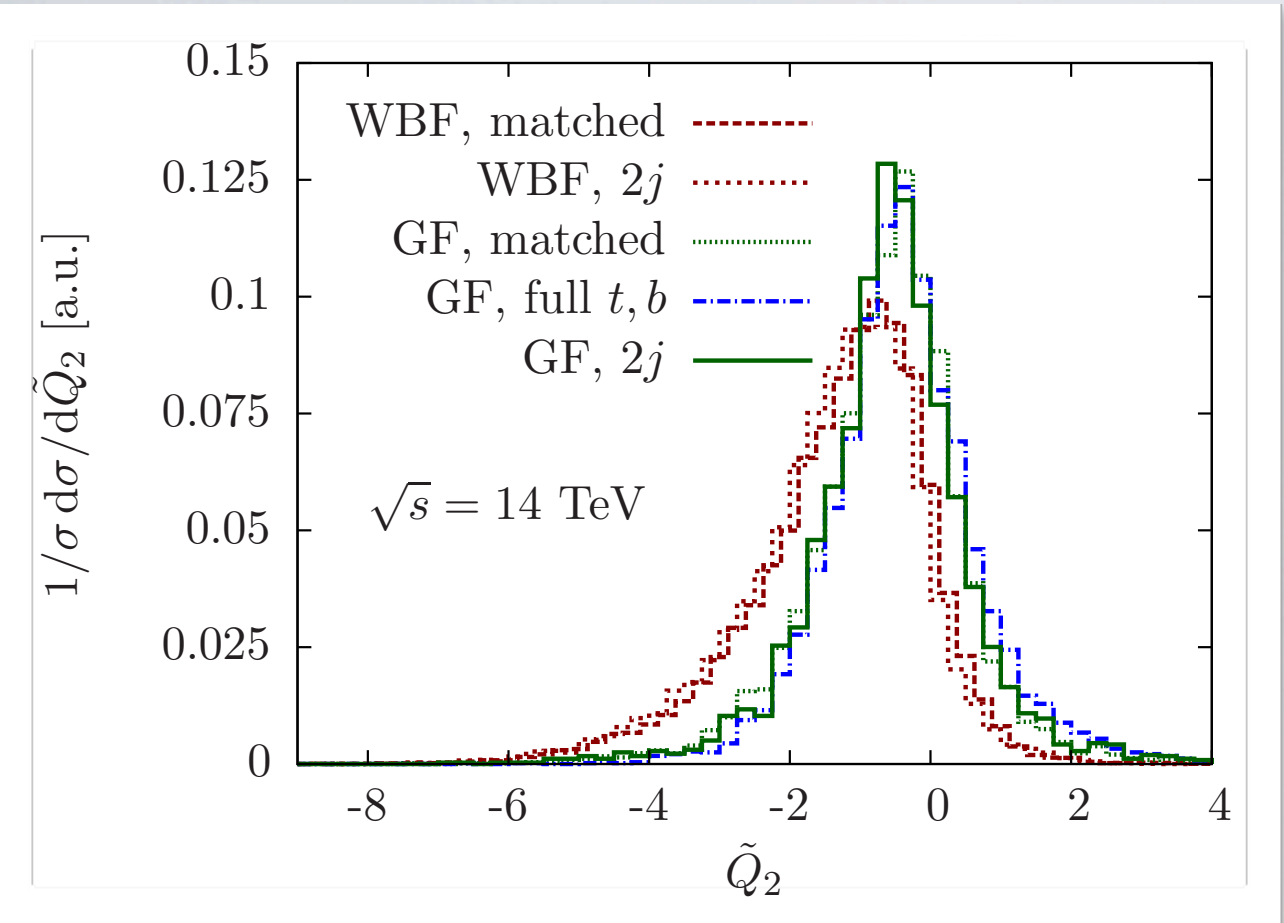
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[Sherpa] [Herwig++] [vbfno]

- results are stable wrst different showers, HEFT vs full, matching, pdfs...

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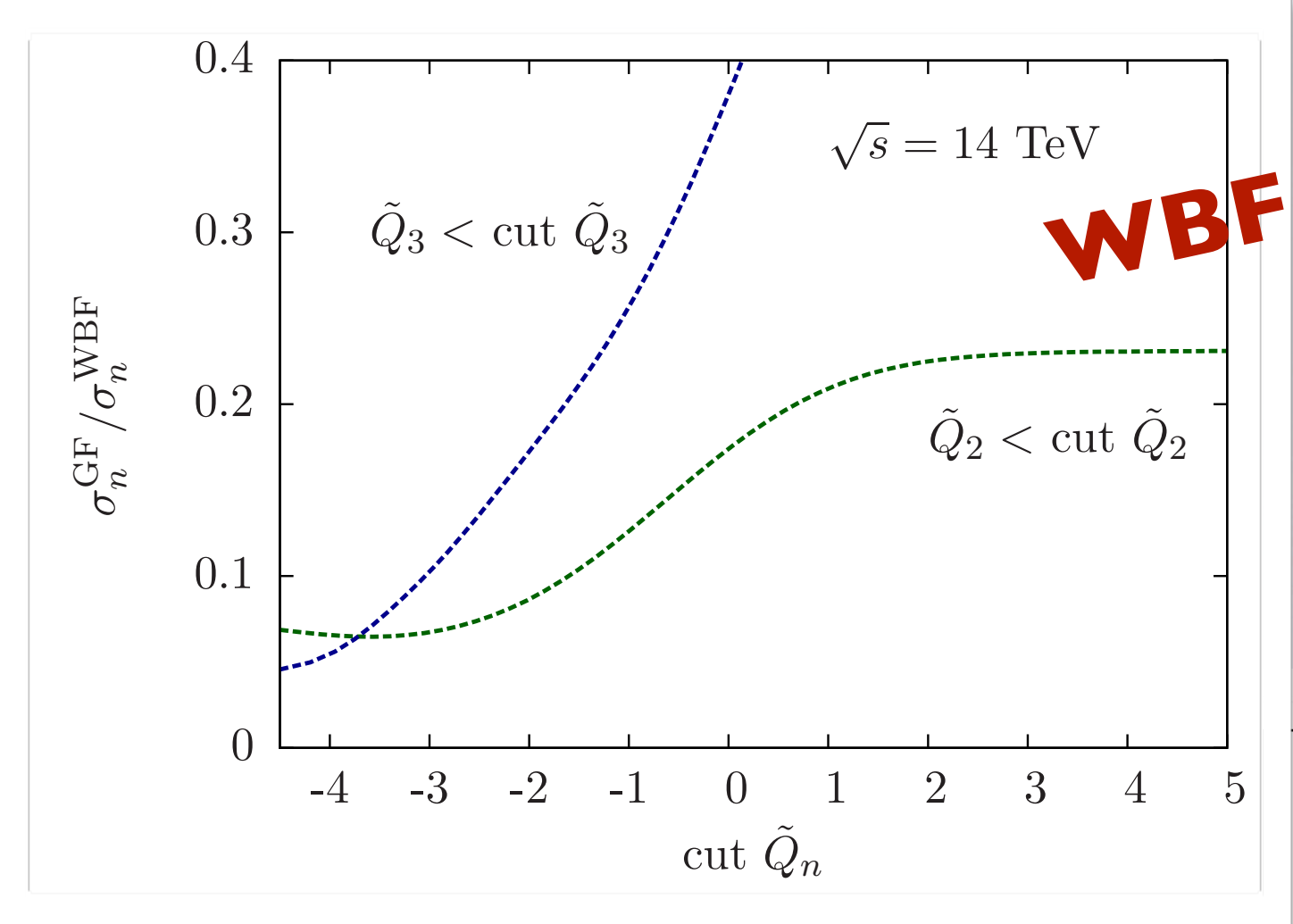
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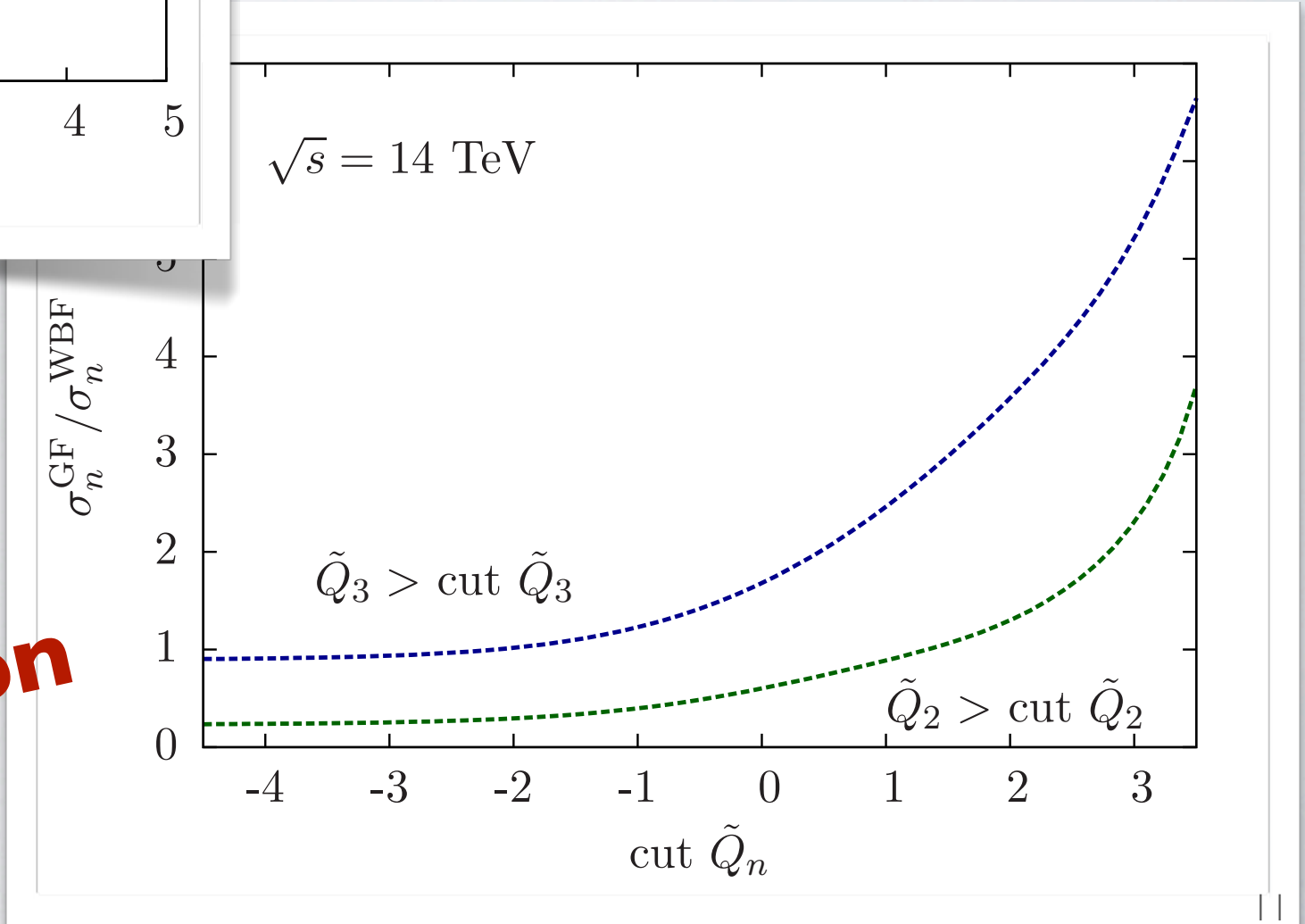
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**WBF purification**

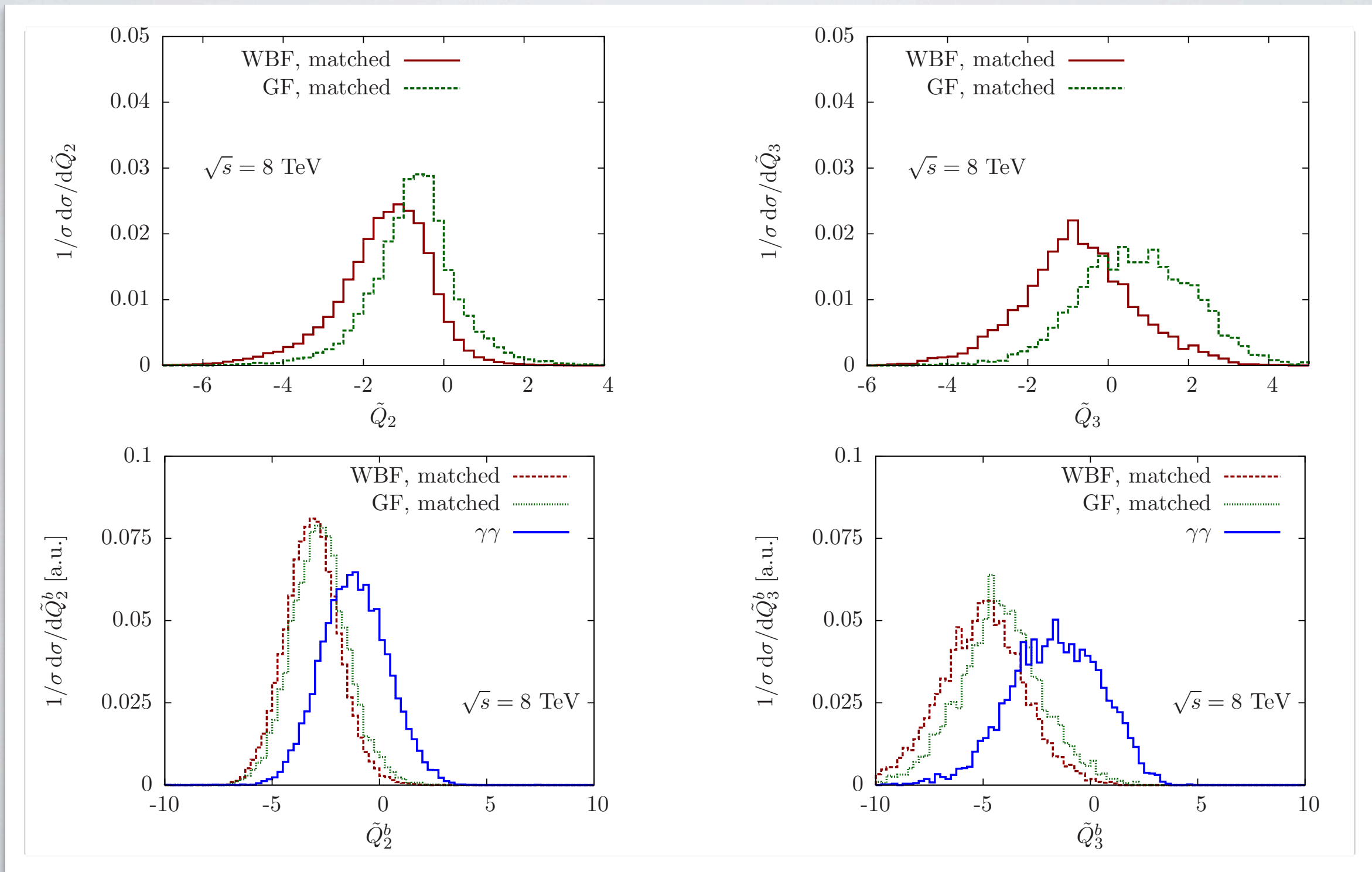
**GF purification**



# S/B enhancements

- straightforward generalization to irreducible backgrounds in vbf searches

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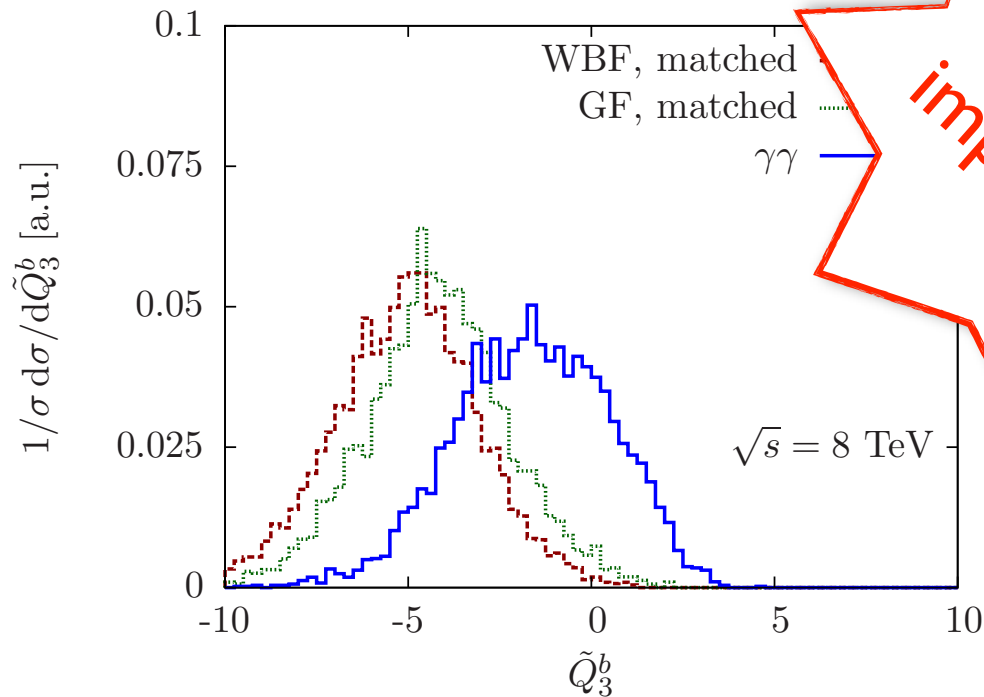
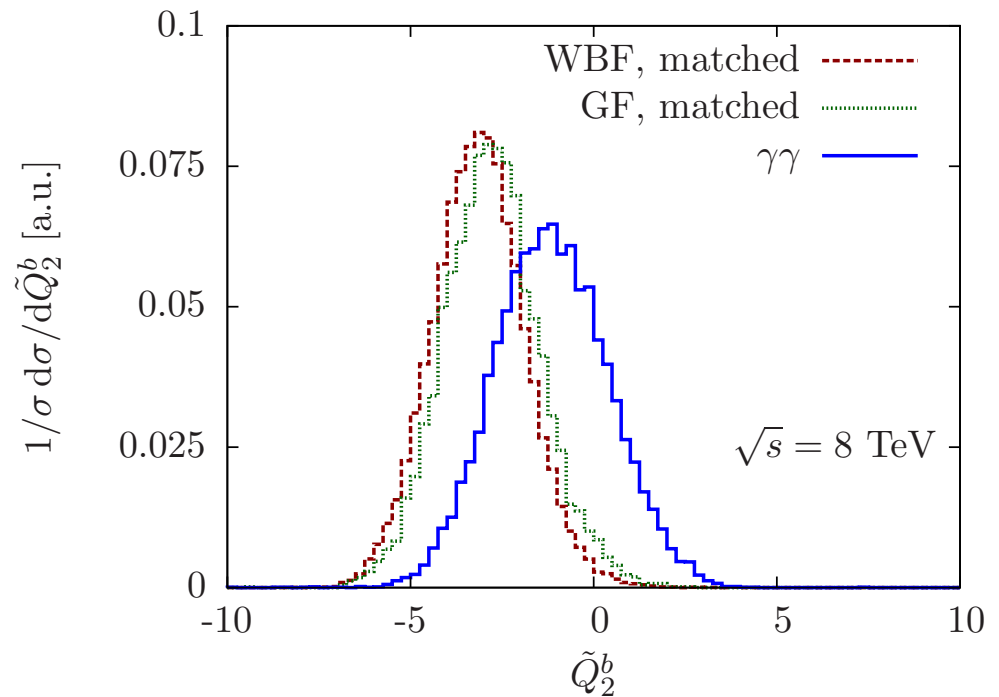
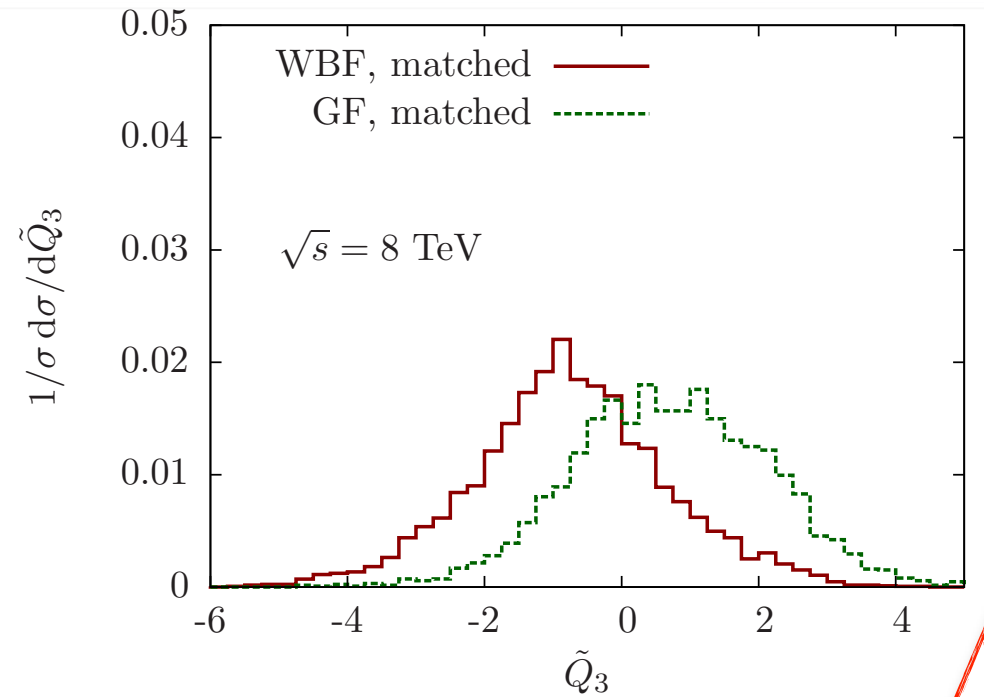
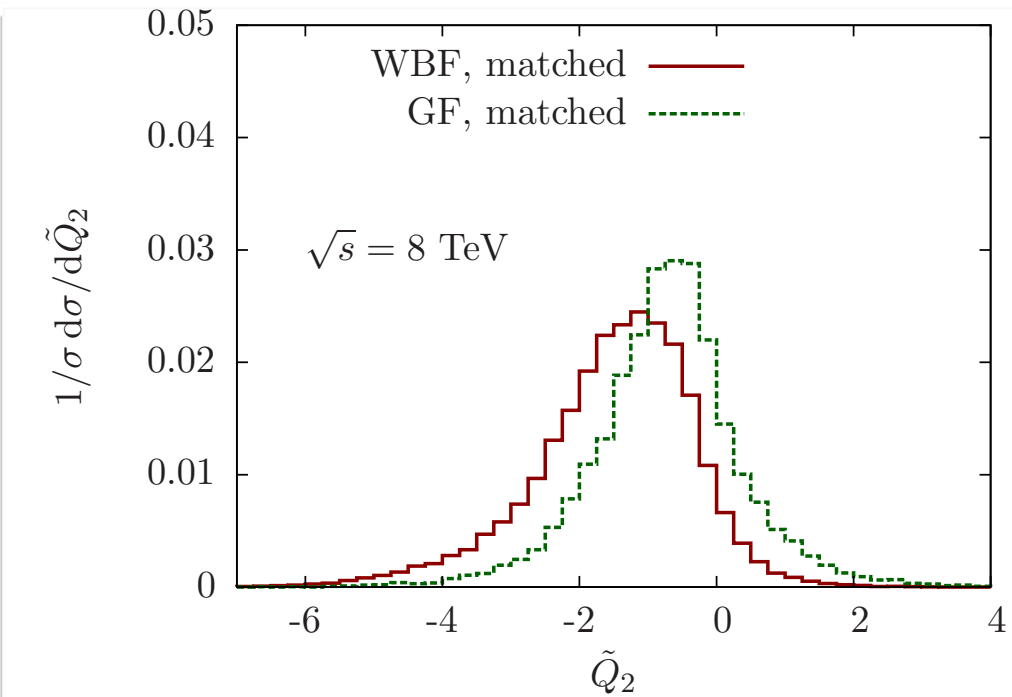




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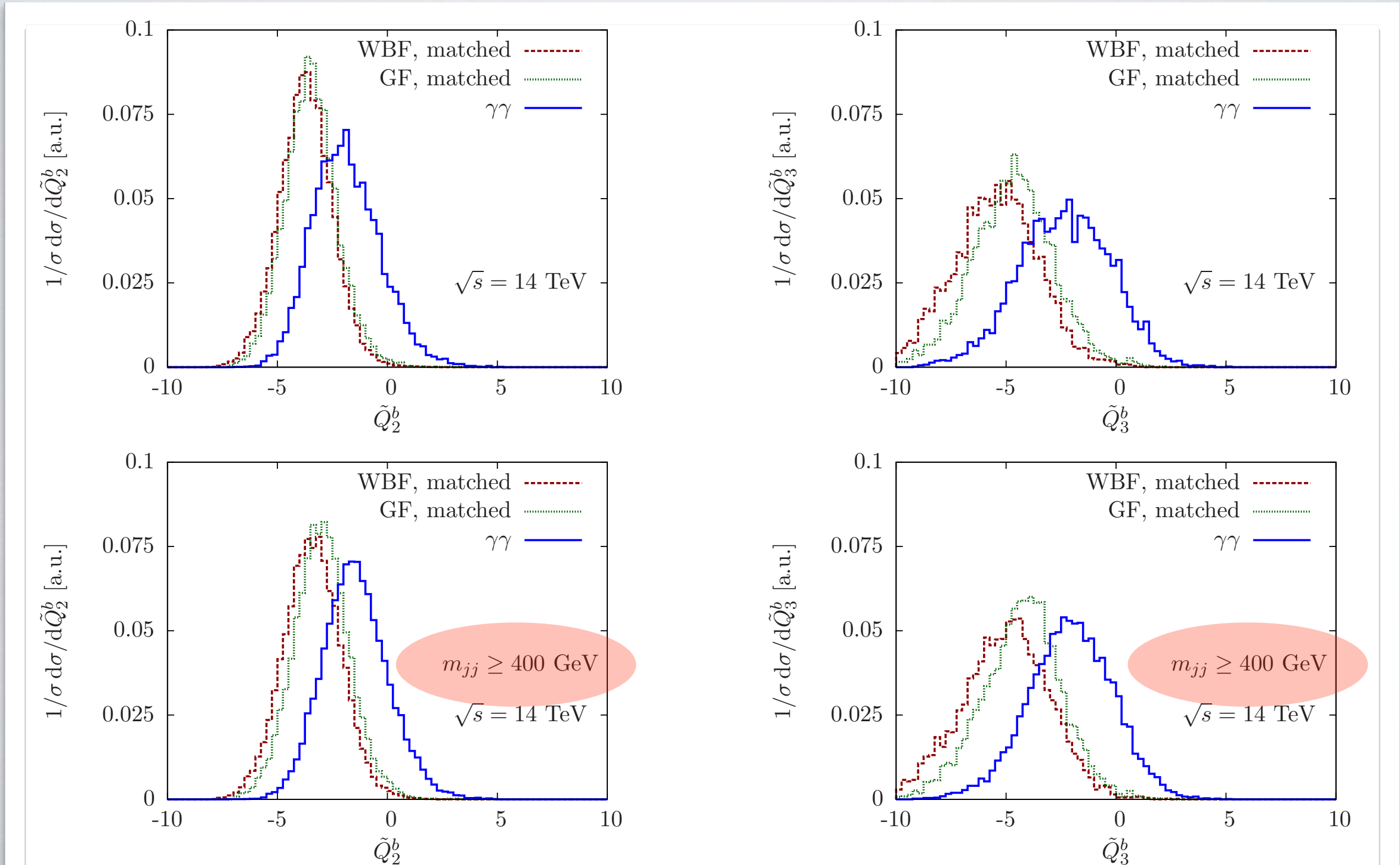


**$\mathcal{O}(100\%)$   
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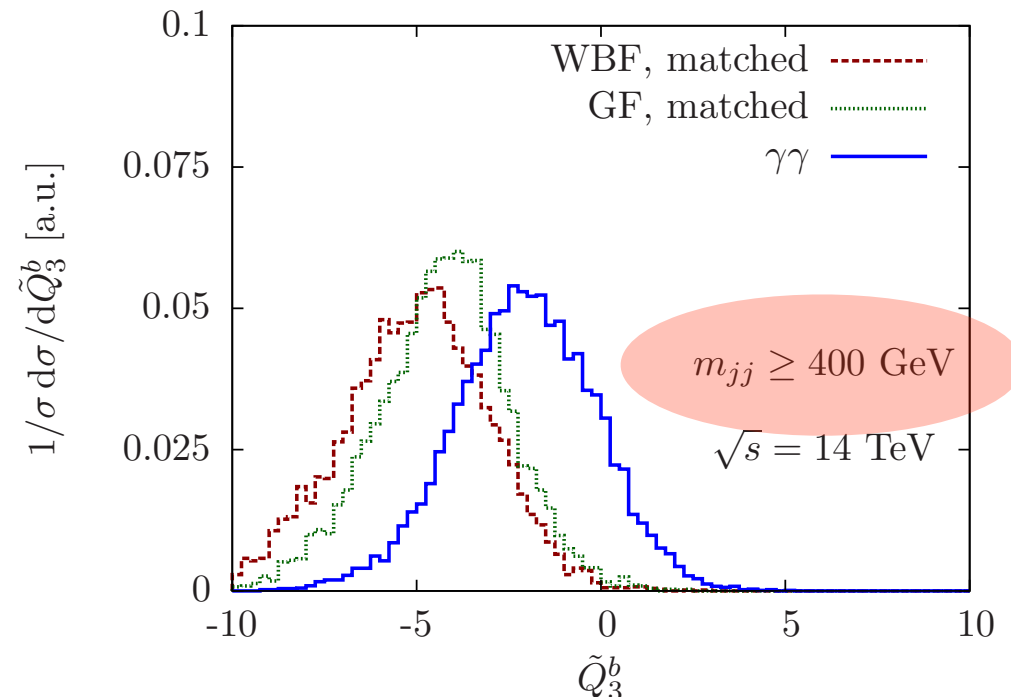
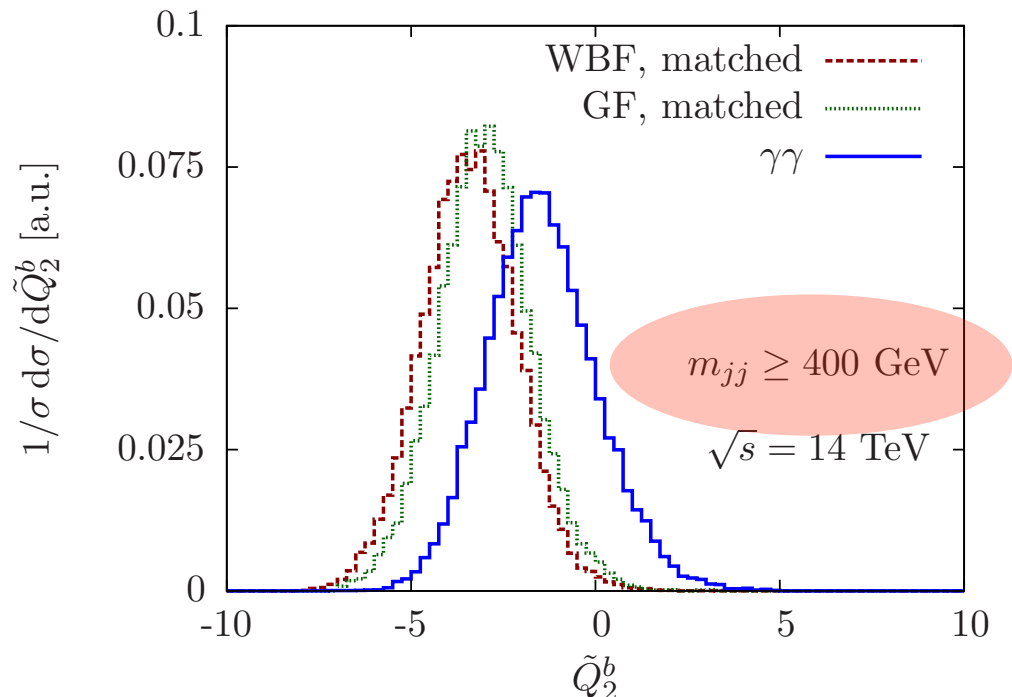
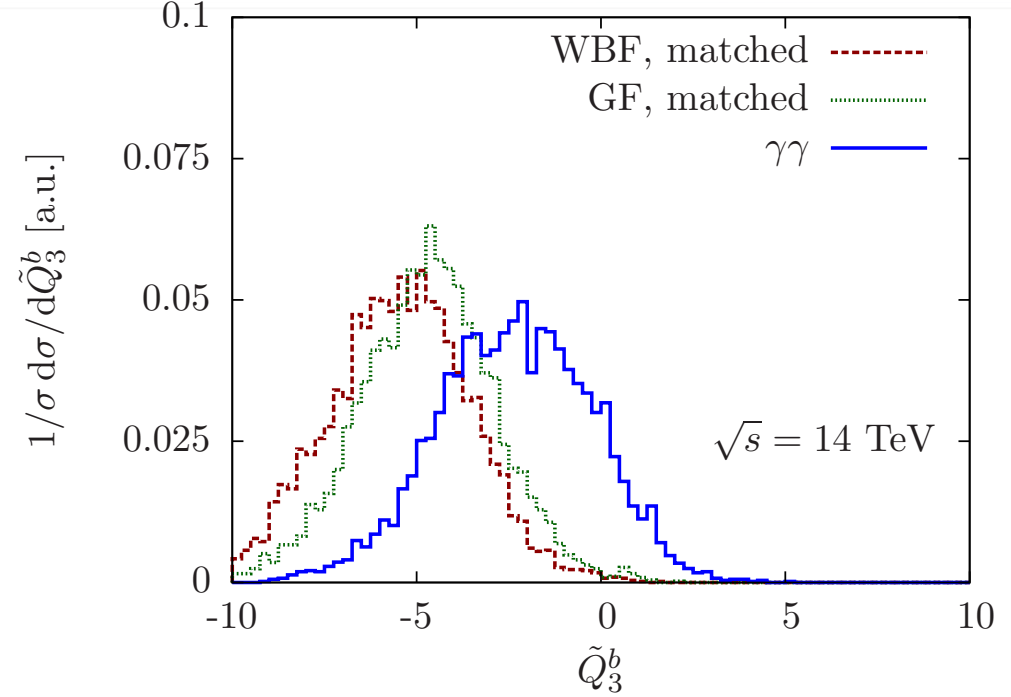
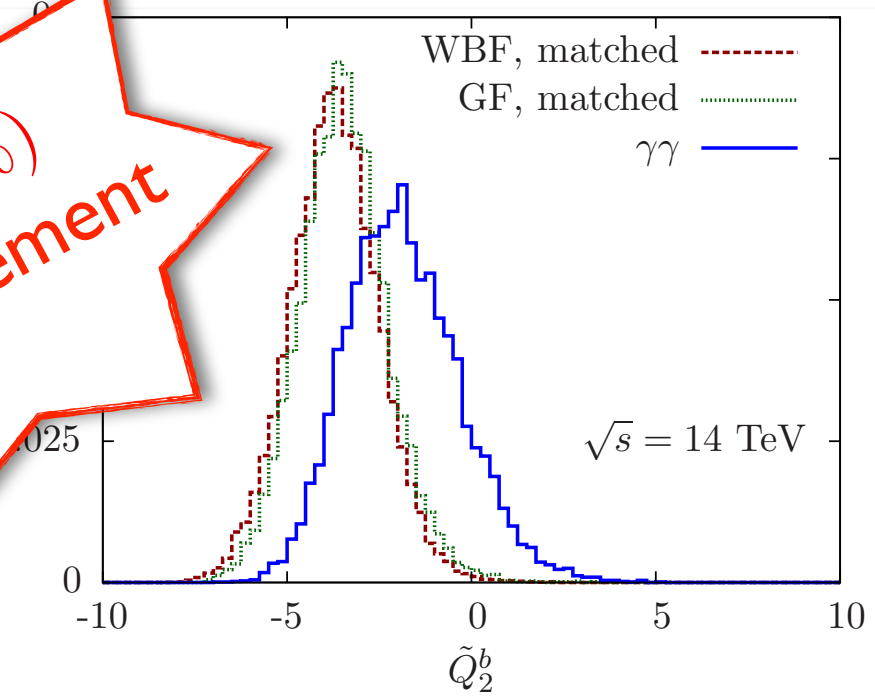


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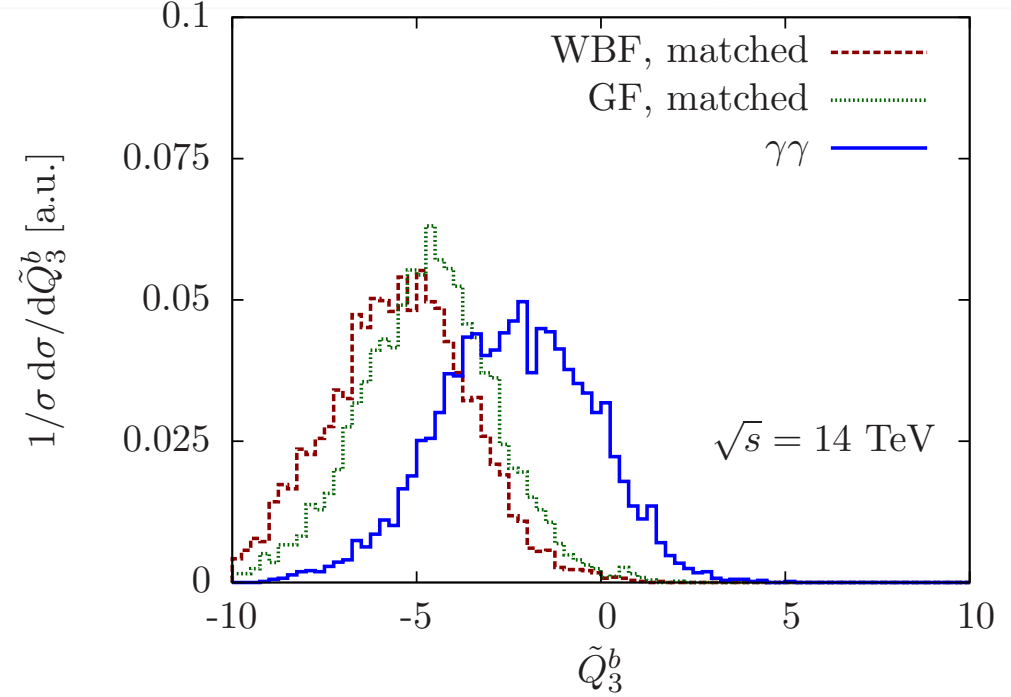
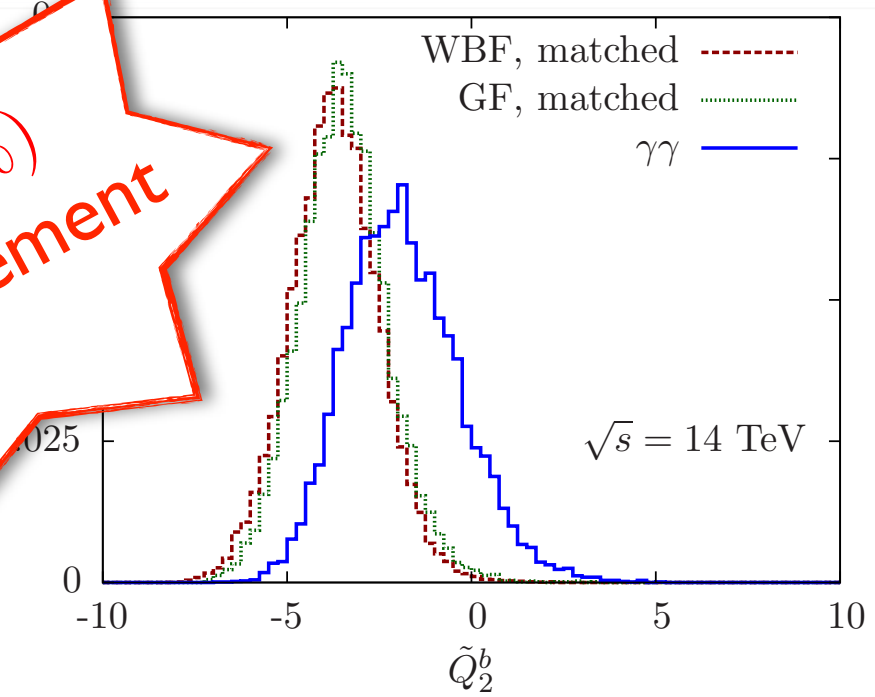


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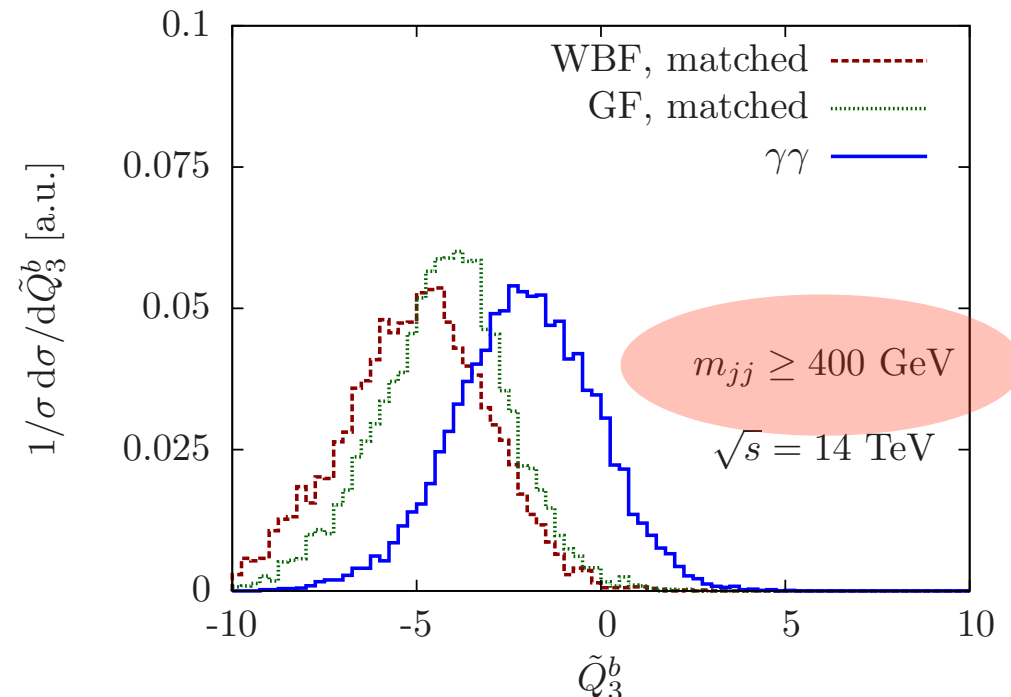
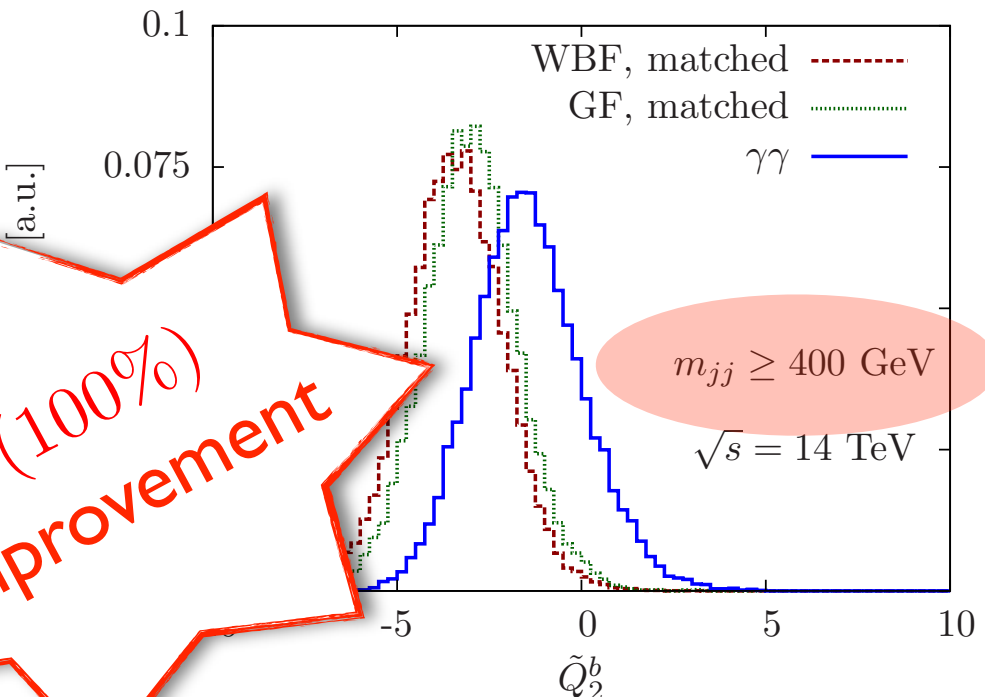
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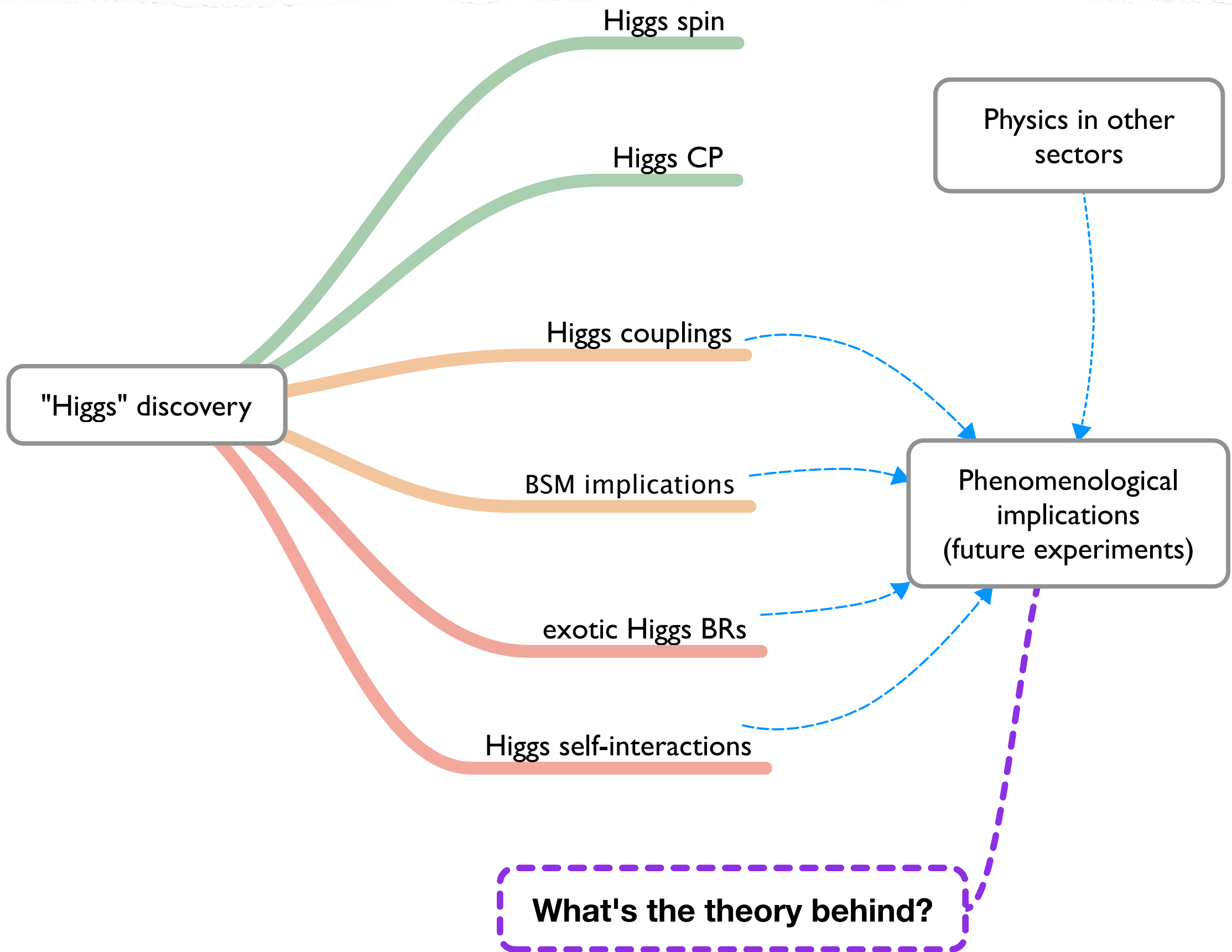
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- **making the most of VBF** at the LHC naturally forces MEMs upon you
- I showed you the quickest approach to MEM in VBF, improvements possible all over the place: *shower games, NLO, transfer functions*
- already in a we find  $\sim 1$  improvements of S/B for **present and future searches** that add to existing QCD suppression techniques in WBF
- **good prospects for WBF vs. GF discrimination**: improve Higgs coupling measurements
- phenomenological QCD and its interplay with the ELW sector allows to sharpen the LHC search potential

first time we have a clear view on the Fermi scale...





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