Constraining the Charm Yukawa and Higgs–quark Universality

MG5_aMC@NLO Femto workshop
Kavli IPMU   March 26, 2015

Kohsaku Tobioka
KEK, Tel Aviv U, Weizmann Institute

with Gilad Perez, Yotam Soreq, Emmanuel Stamou
(arXiv:1503.00290)

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IPMU Softball team (2010)

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Introduction

why charm-Yukawa?

Higgs in Standard Model

Spin, Charge   Mass   Coupling

Higgs in Standard Model

Spin, Charge Mass Coupling

Neutral Scalar: Higgs?

Higgs in Standard Model

Spin, Charge Mass Coupling

Neutral Scalar: Higgs?

Measure Unknown SM parameter

Higgs in Standard Model

Spin, Charge Mass Coupling

Neutral Scalar: Higgs?

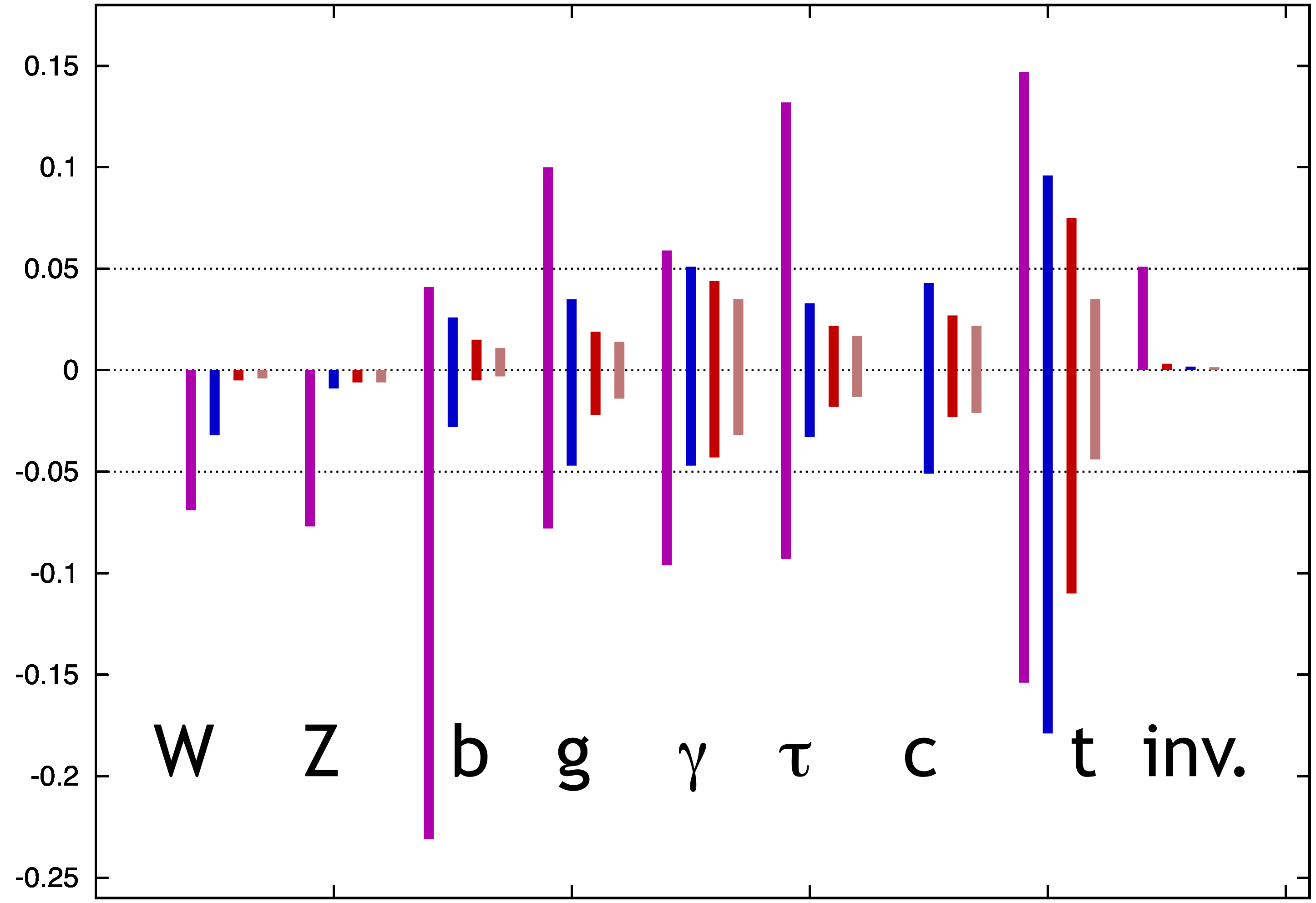
Measure Unknown SM parameter

Predicted as $y_X \simeq \sqrt{2}\frac{m_X}{v}$. Over-constraining SM

⇒Window of Beyond SM

Peskin 2012/ ILC-TDR

$g(hAA)/g(hAA)|_{SM}-1$ LHC/ILC1/ILC/ILCTeV



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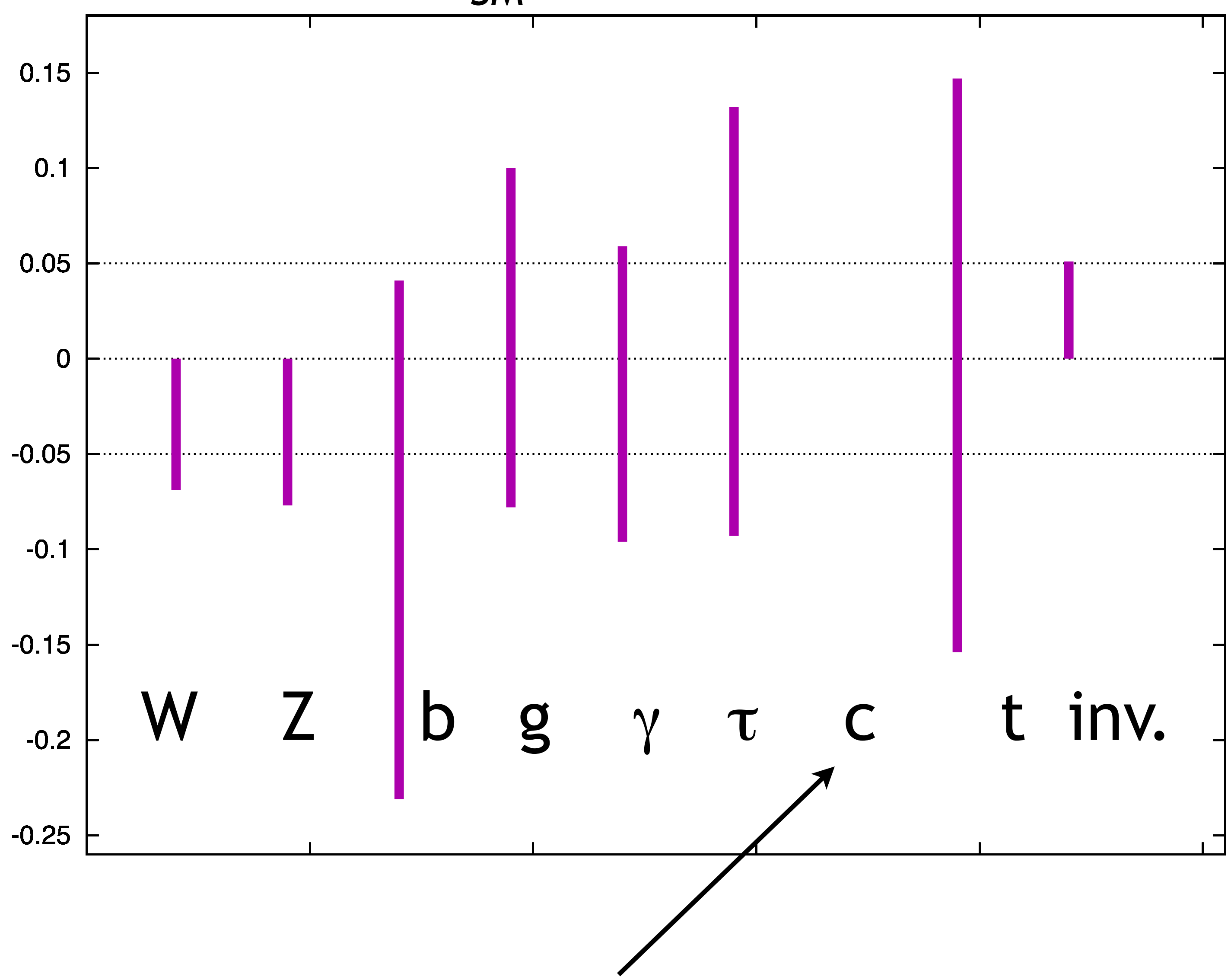
$g(hAA)/g(hAA)|_{SM}-1$ LHC



What can we do at LHC?

Outline

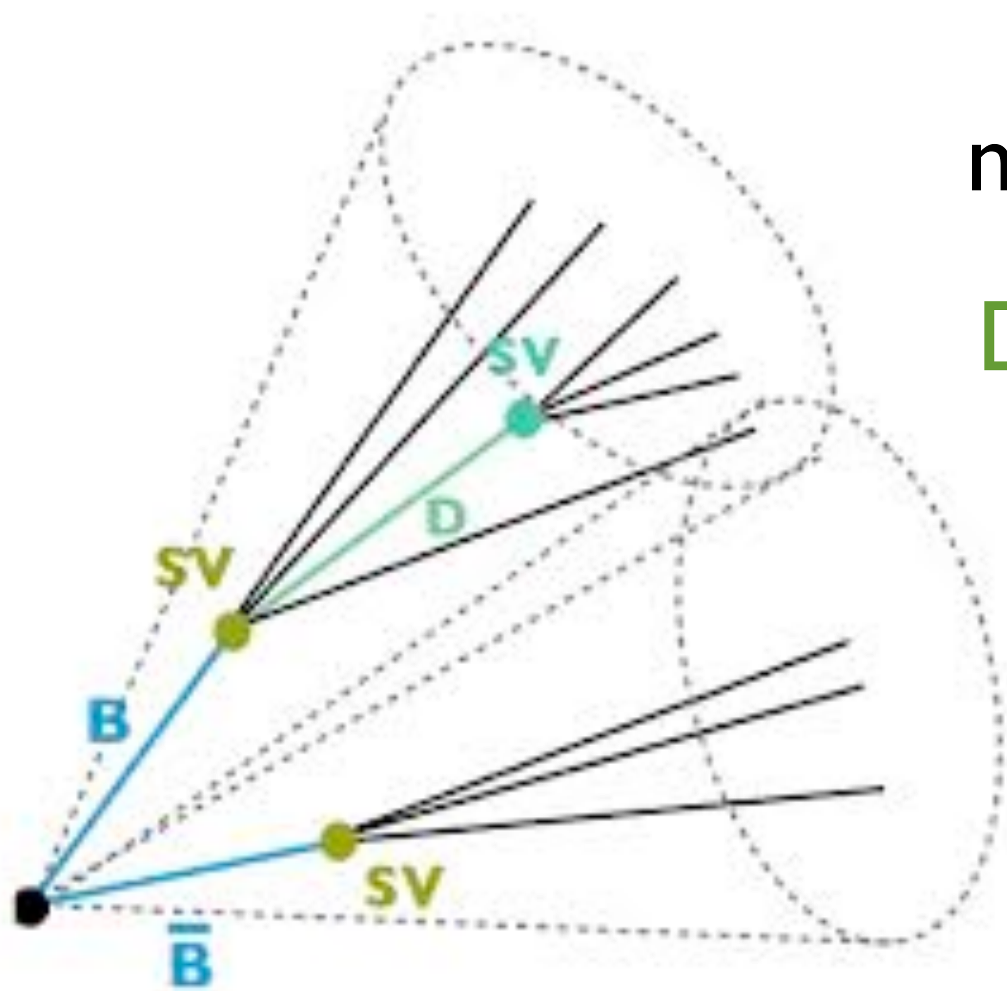
- Recasting $VH \to bb$ study for charm Yukawa
- Other measurements: Total width, J/psi+γ, Global Analysis
- Future prospects

Recast

b-tagging to study H→bb

b-jet is distinguished from other jets

Secondary Vertex: B-meson is long-lived ~440μm/c
fly in the detector

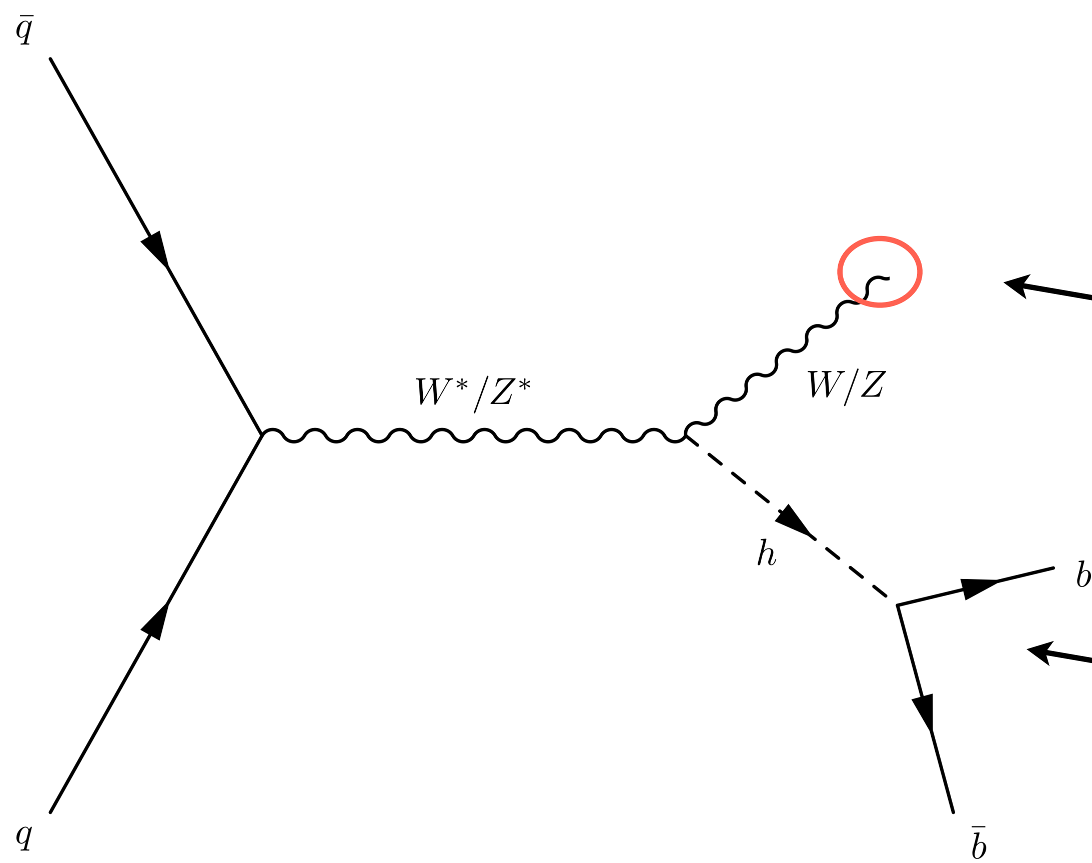


main *issue*: Mistag

D-meson, also long-lived
~120-310μm/c

c-jet 4-40%,
light jet: O(0.1-1)%

VH (Associated) production



Z→νν 0lep, W→lν 1lep

Z→ll 2lep

W/Z reconstructed

categorize by p_T^V

2 b-tags required

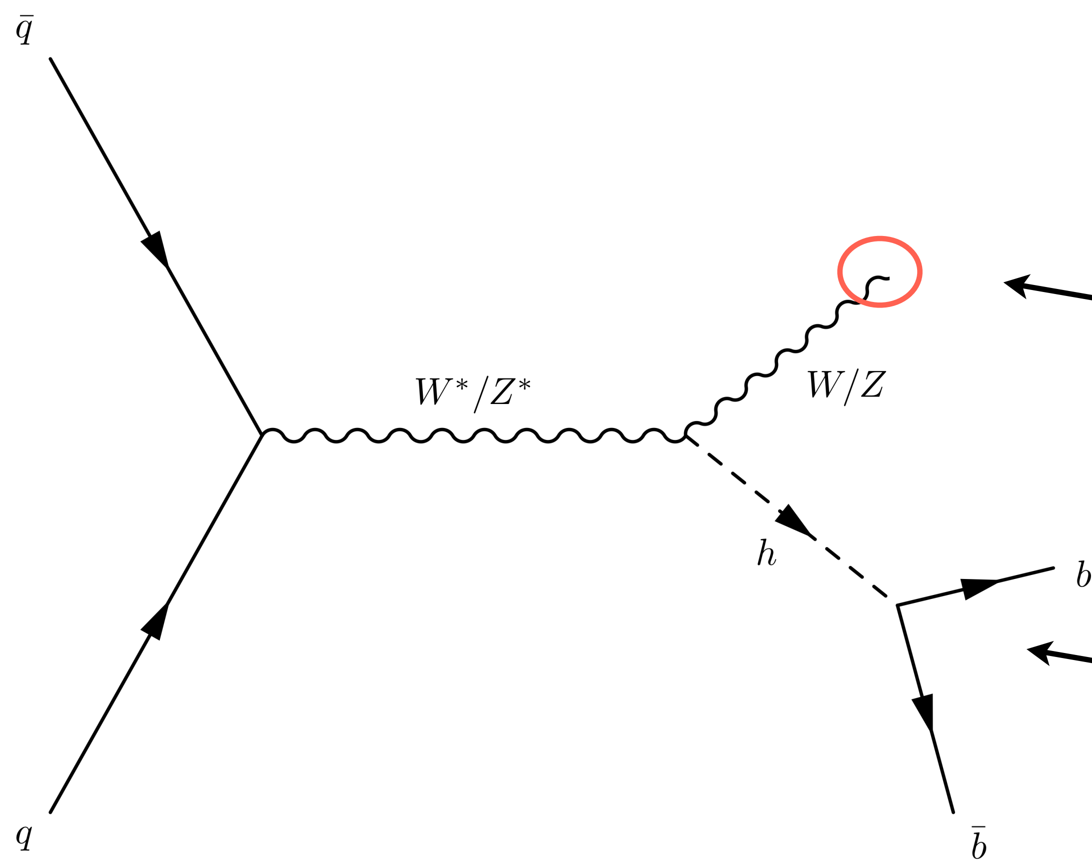
ATLAS	Med	Tight	CMS	Loose	Med1	Med2	Med3
ϵ_b	70%	50%	ϵ_b	88%	82%	78%	71%
ϵ_c	20%	3.8%	ϵ_c	47%	34%	27%	21%

$$S^{VH} = \mathcal{L} \cdot \sigma \cdot \mathrm{Br}_b \cdot \epsilon_{b_1} \epsilon_{b_2} \cdot \epsilon$$

Signal strength

$$\mu_b = \frac{S^{VH}_{obs}}{S^{VH}_{exp}} = \frac{\mathcal{L} \cdot \sigma \cdot \mathrm{Br}_b \cdot \epsilon_{b_1} \epsilon_{b_2} \cdot \epsilon}{\mathcal{L} \cdot \sigma_{SM} \cdot \mathrm{Br}_b^{SM} \cdot \epsilon_{b_1} \epsilon_{b_2} \cdot \epsilon} = \frac{\sigma \cdot \mathrm{Br}_b}{\sigma_{SM} \cdot \mathrm{Br}_b^{SM}}$$

VH (Associated) production



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$$S^{VH} = \mathcal{L} \cdot \sigma \cdot \mathrm{Br}_b \cdot \epsilon_{b_1} \epsilon_{b_2} \cdot \epsilon$$

Signal strength

$$\mu_{bb}^{\mathrm{ATLAS}} = 0.52 \pm 0.32 \pm 0.24,$$
$$\mu_{bb}^{\mathrm{CMS}} = 1.0 \pm 0.5\ ,$$

info of H-bb coupling

ATLAS [arXiv:1409.6212] CMS [arXiv:1310.3687] Phys.Rev. **D89** (2014) 012003

What if H→cc is enhanced?

$$\mu_b = \frac{S^{VH}_{obs}}{S^{VH}_{exp}} = \frac{\cancel{\mathcal{L}} \cdot \sigma \cdot \mathrm{Br}_b \cdot \epsilon_{b_1}\epsilon_{b_2} \cdot \cancel{\epsilon}}{\cancel{\mathcal{L}} \cdot \sigma_{SM} \cdot \mathrm{Br}_b^{SM} \cdot \epsilon_{b_1}\epsilon_{b_2} \cdot \cancel{\epsilon}}$$

$$\Rightarrow \frac{\sigma \cdot \mathrm{Br}_b \cdot \epsilon_{b_1}\epsilon_{b_2} + \sigma \cdot \mathrm{Br}_c \cdot \epsilon_{c_1}\epsilon_{c_2}}{\sigma_{SM} \cdot \mathrm{Br}_b^{SM} \cdot \epsilon_{b_1}\epsilon_{b_2}}$$

$$= \mu_b + \frac{\mathrm{Br}_c^{SM}}{\mathrm{Br}_b^{SM}} \frac{\epsilon_{c_1}\epsilon_{c_2}}{\epsilon_{b_1}\epsilon_{b_2}} \mu_c$$

$$\mathrm{Br}^{\mathrm{SM}}(h \to c\bar{c}) = 2.9\%$$

$$\mathrm{Br}^{\mathrm{SM}}(h \to b\bar{b}) = 58\%$$

$$\epsilon_{c/b} \equiv \frac{\epsilon_{c1}\epsilon_{c2}}{\epsilon_{b1}\epsilon_{b2}}$$

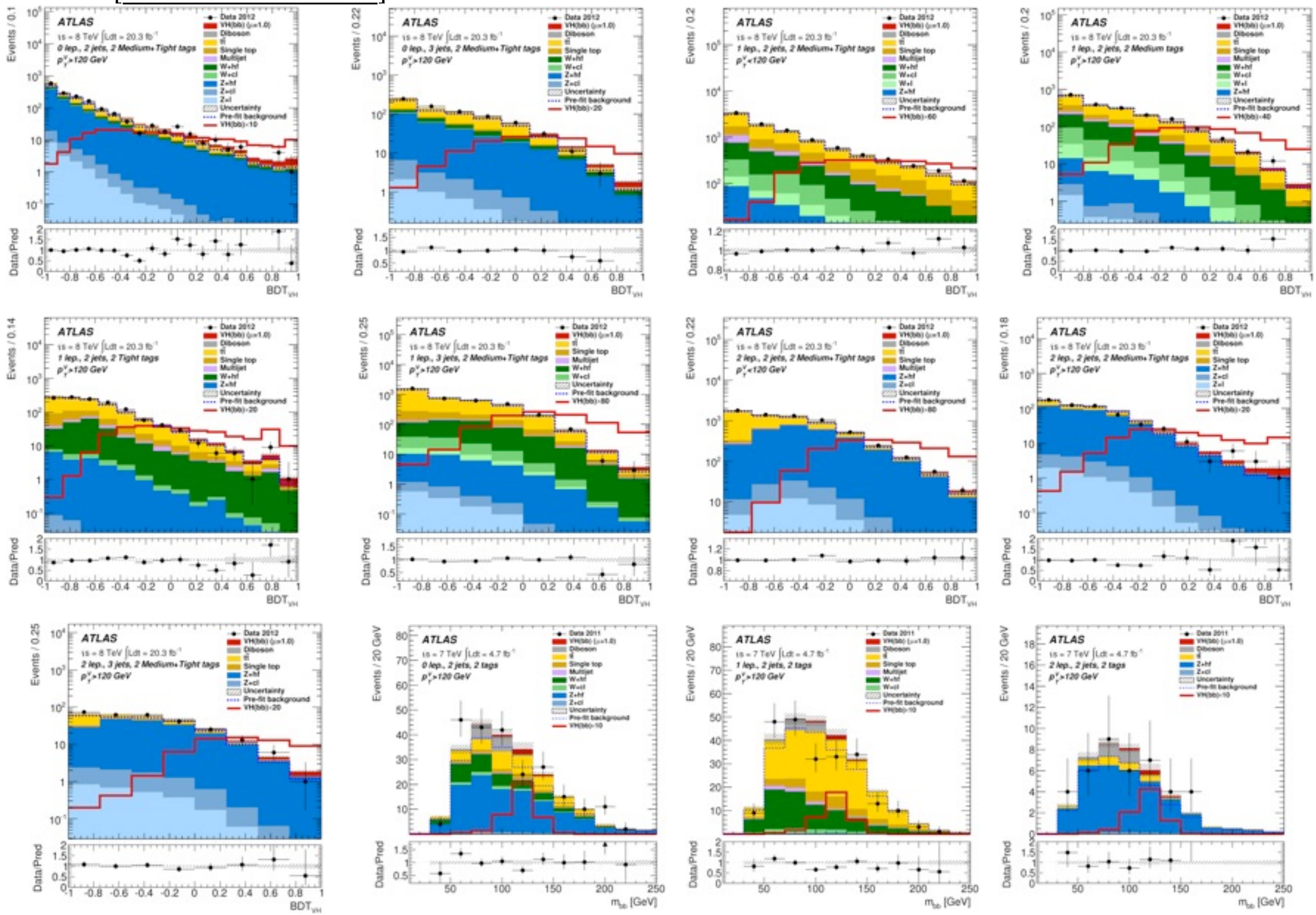
$$\mu_b + (0.05\,\epsilon_{c/b})\mu_c$$

Large $\epsilon_{c/b}$, more sensitive to μ_c
but only constrain a combination (degeneracy)

⇨ Need very different working points $\epsilon_{c/b}$

Collect info from ATLAS, use S/B>2.5%

ATLAS [arXiv:1409.6212]



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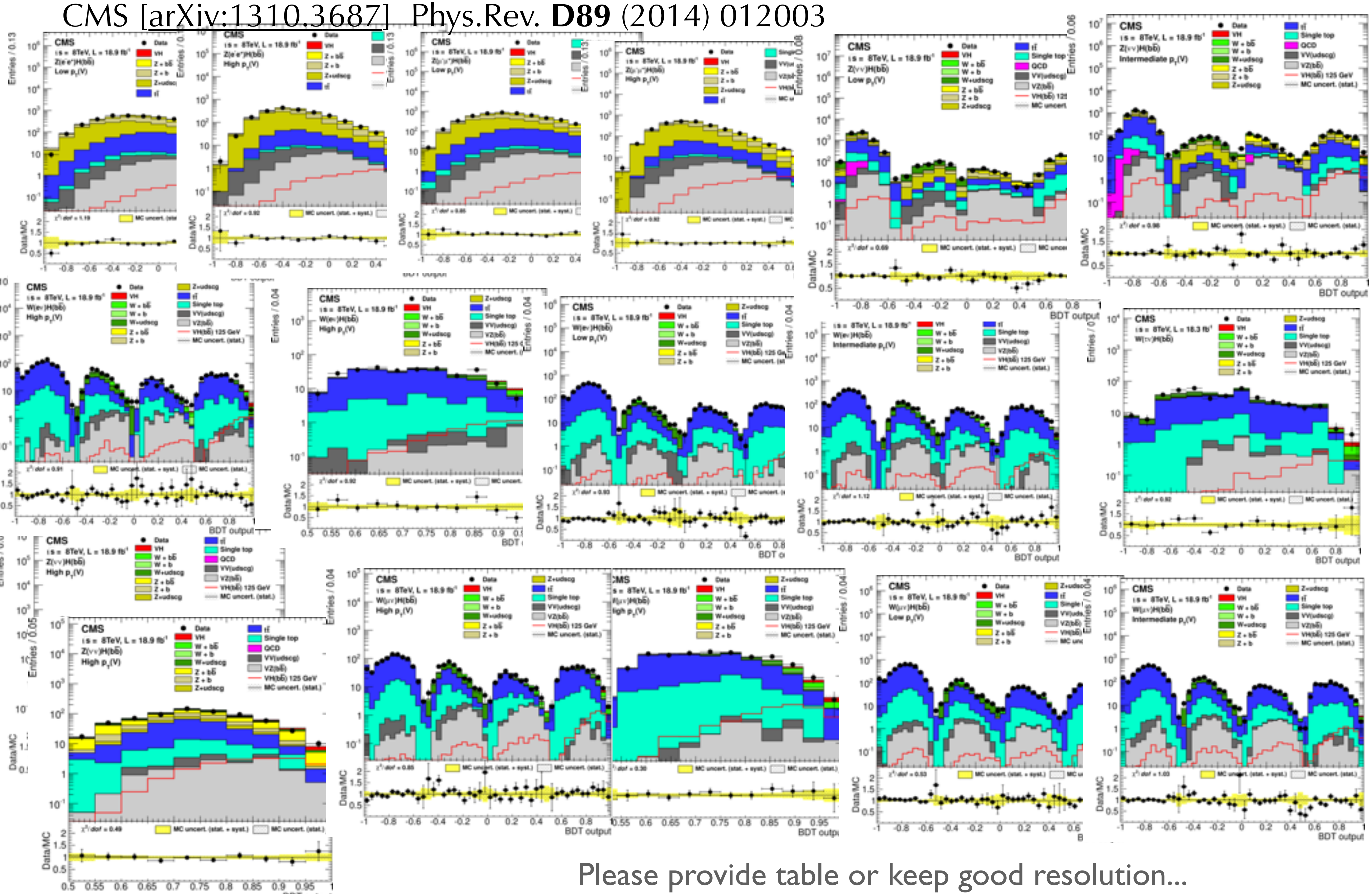

Please provide table or keep good resolution...

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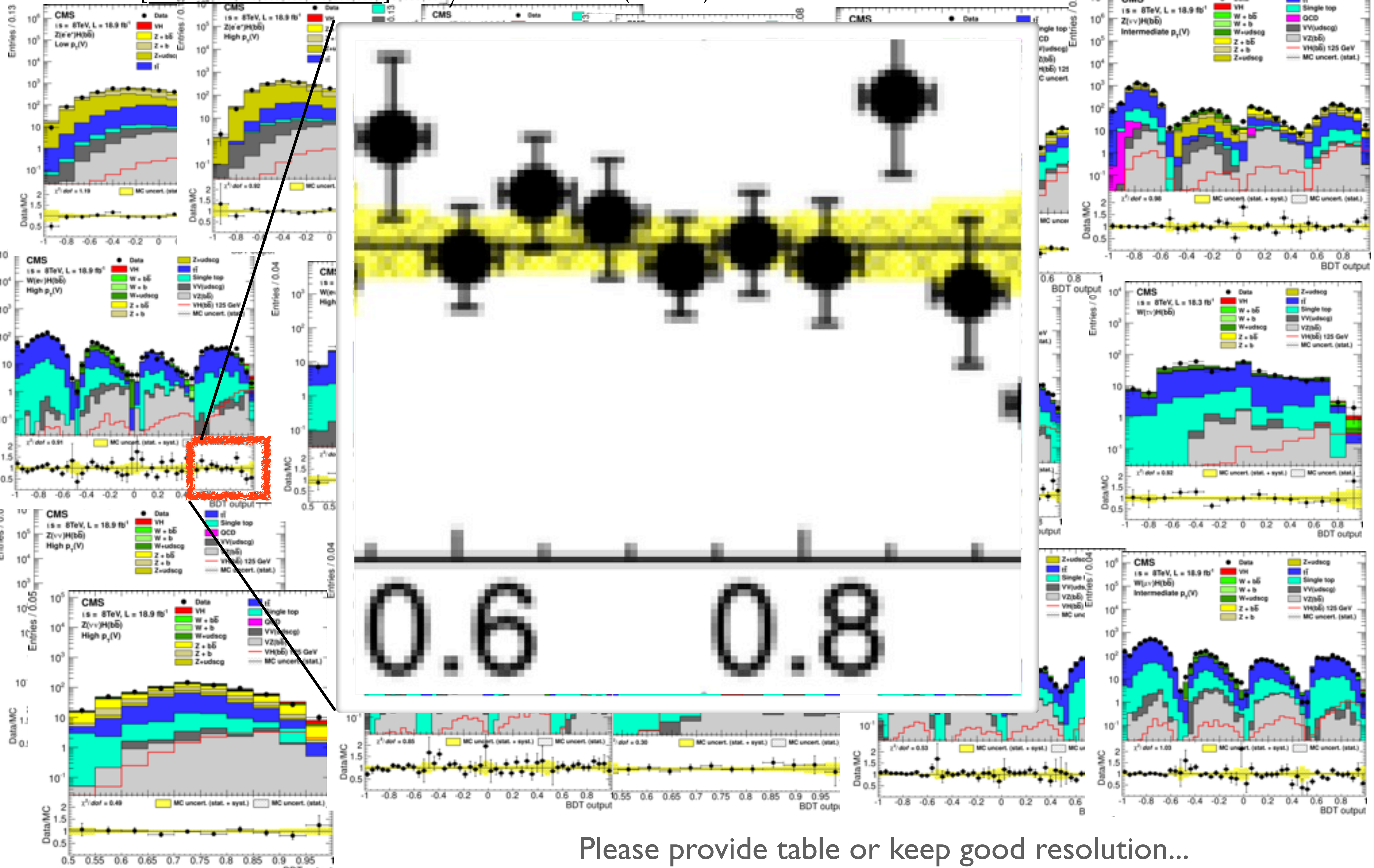

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Disentangle degeneracy

$\mu_b + (0.05\ \epsilon_{c/b})\mu_c$ ATLAS&CMS have different working points

	1st Tag	2nd Tag	$\epsilon_{c/b}$
(a)ATLAS	Med	Med	8.2×10^{-2}
(b)ATLAS	Tight	Tight	5.9×10^{-3}
(c)CMS	Med1	Med1	0.18
(d)CMS	Med2	Loose	0.19
(e)CMS	Med1	Loose	0.23
(f)CMS	Med3	Loose	0.16

$$L(\mu) = \prod_i P_{poiss}(k_i, N_{SM,i}^{BG} + \mu N_{SM,i}^{signal}).$$

Disentangle degeneracy

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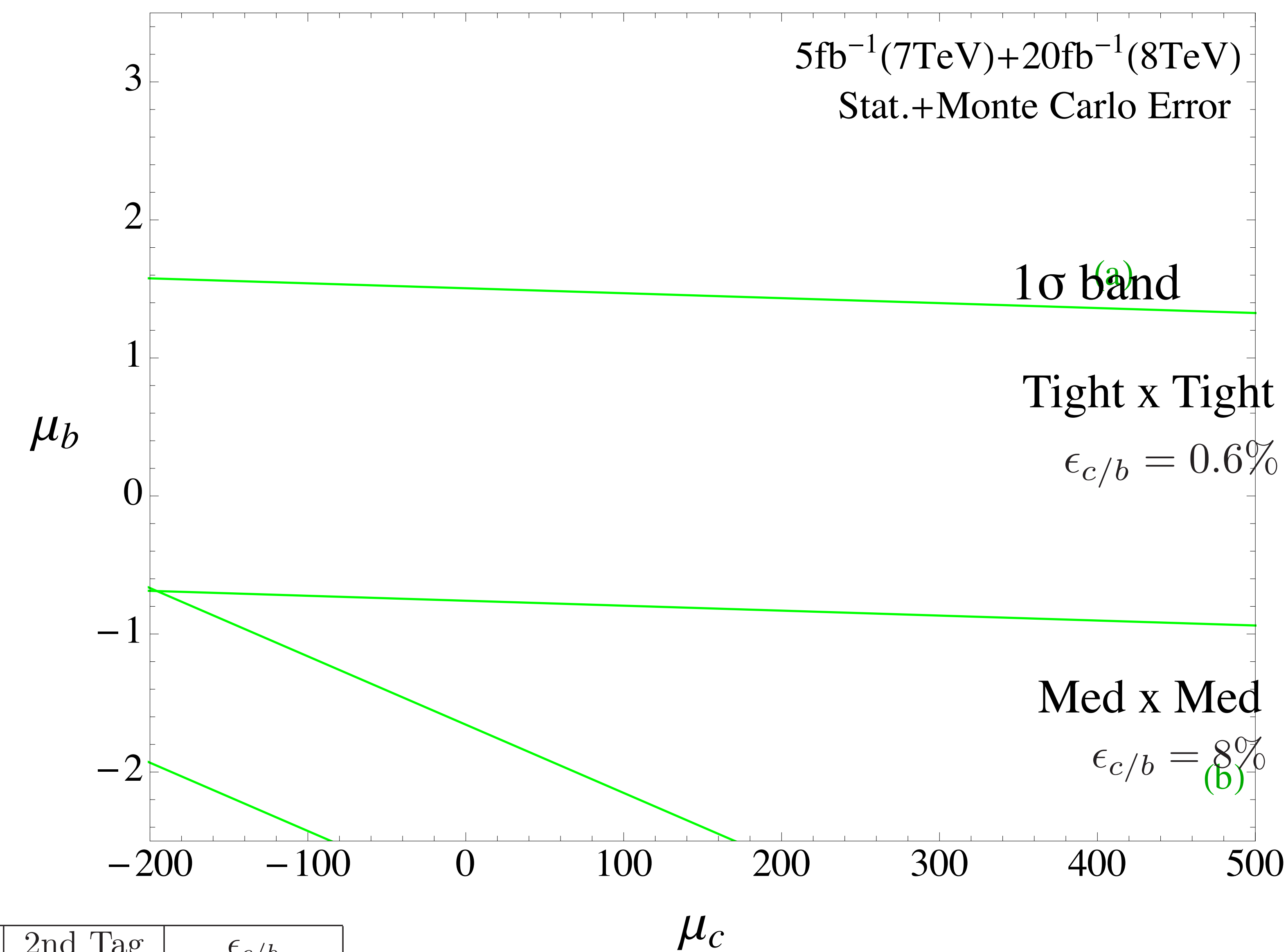

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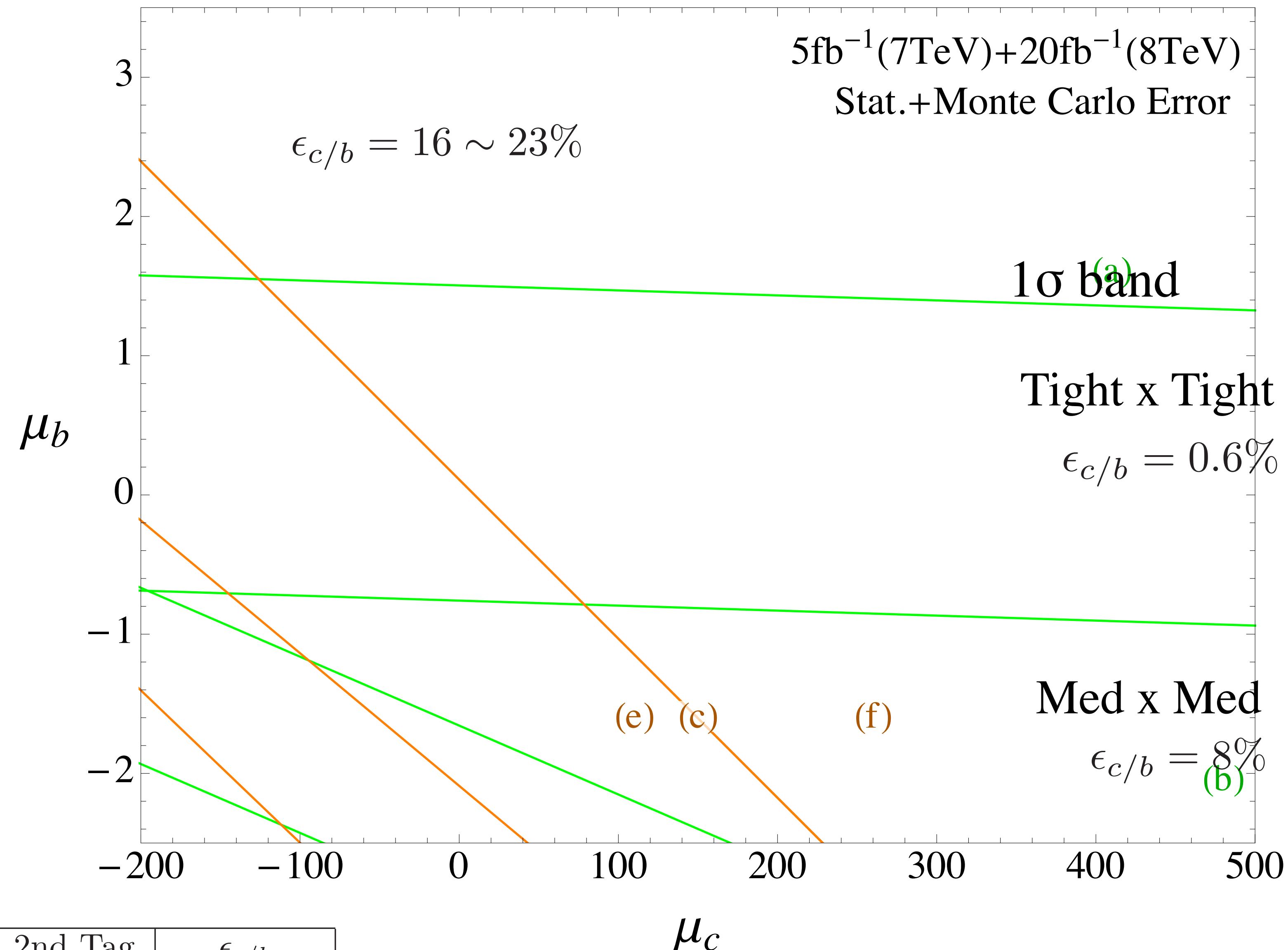

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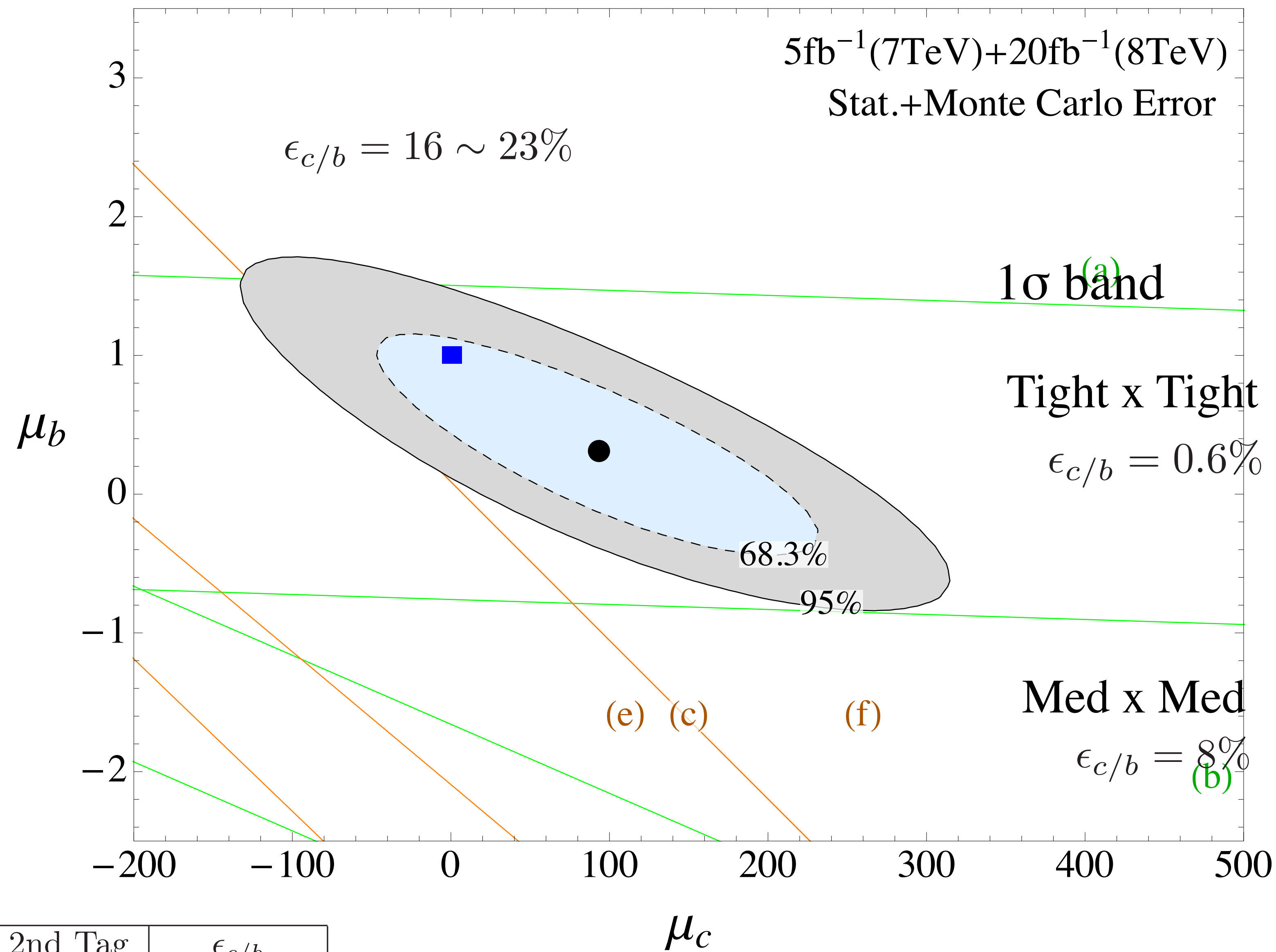

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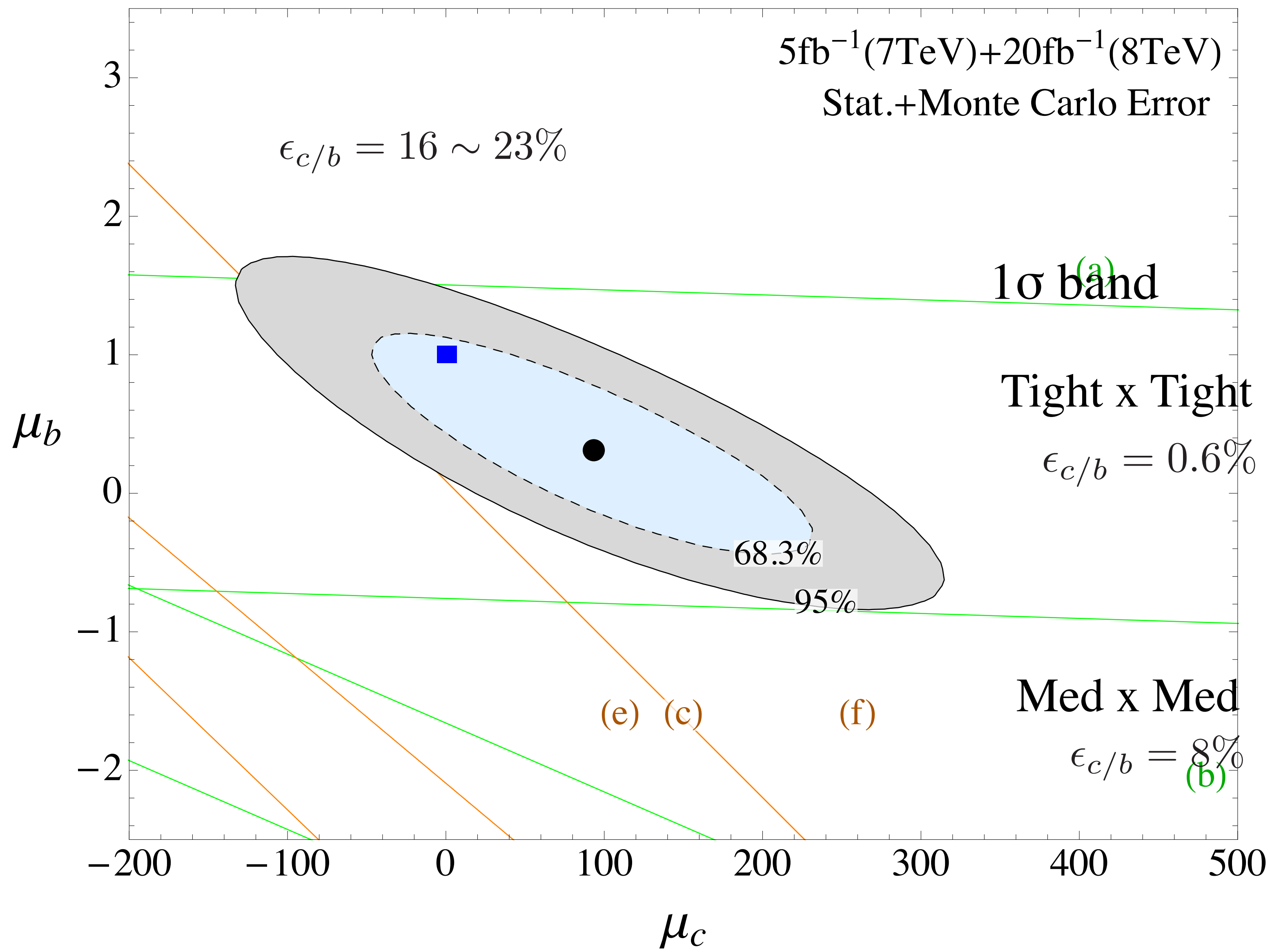


profiled μ_b

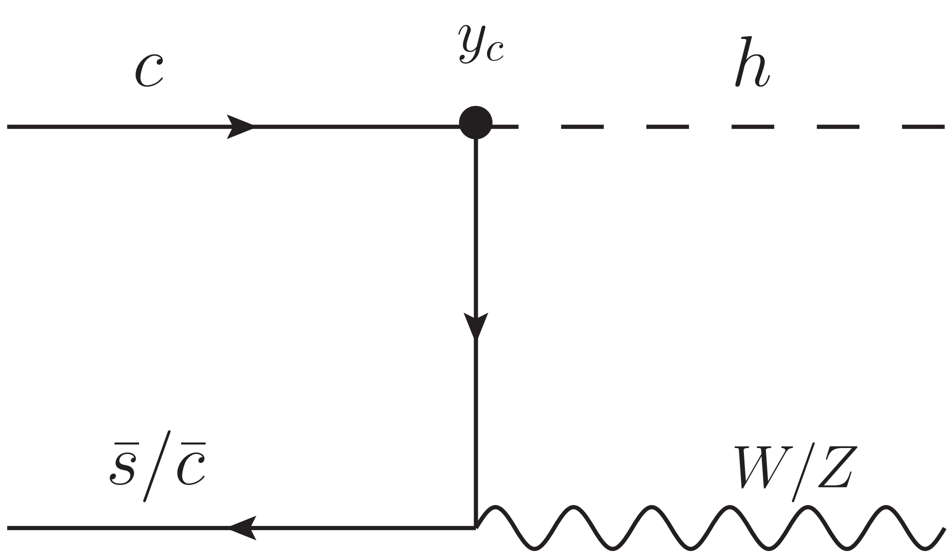
First bound on signal strength!

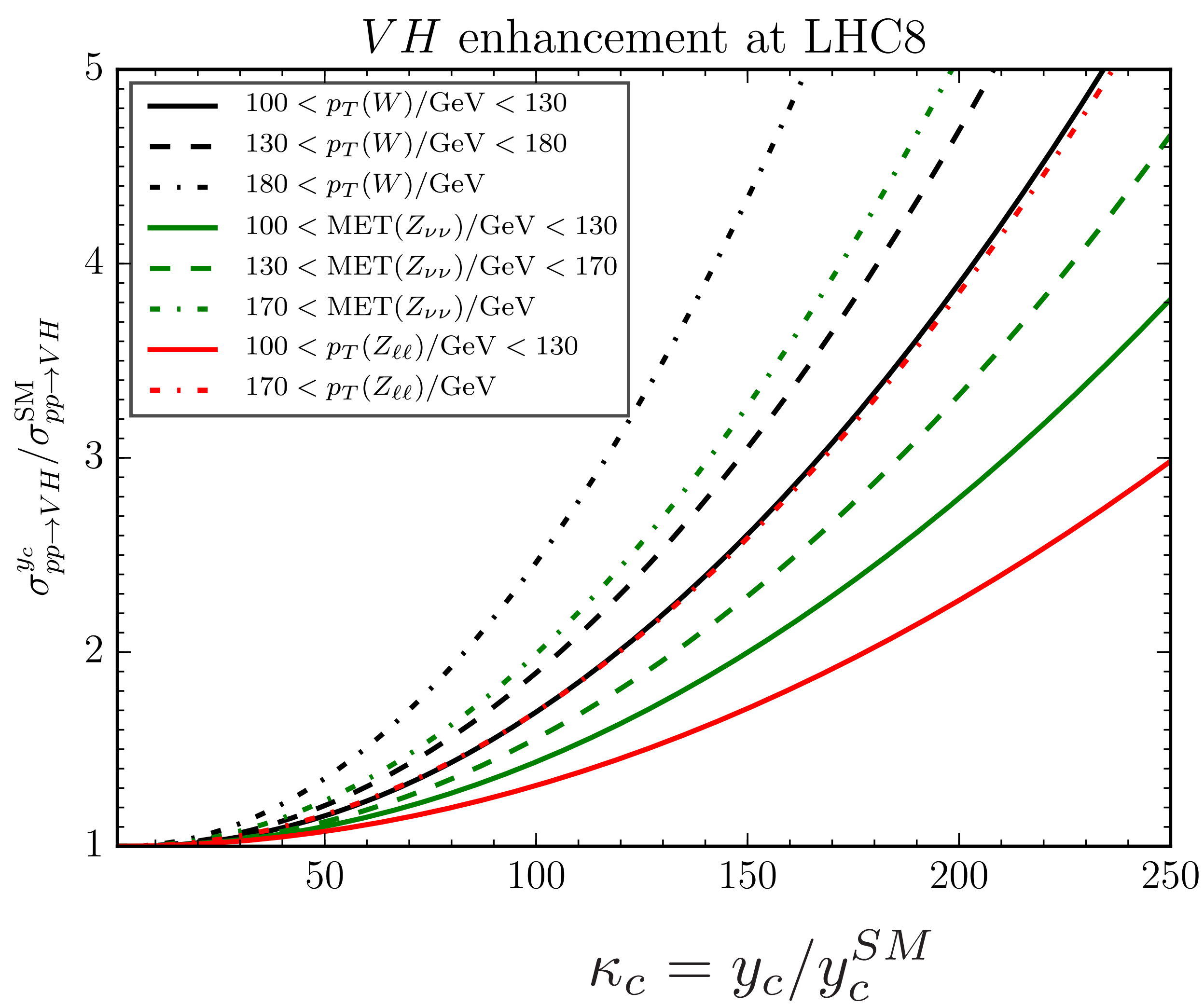
$$\mu_c = 95^{+90(175)}_{-95(180)} \text{ at } 68.3(95)\% \text{ CL.}$$

New Production

Decay Br(H→cc)=100%, still μ_c=34

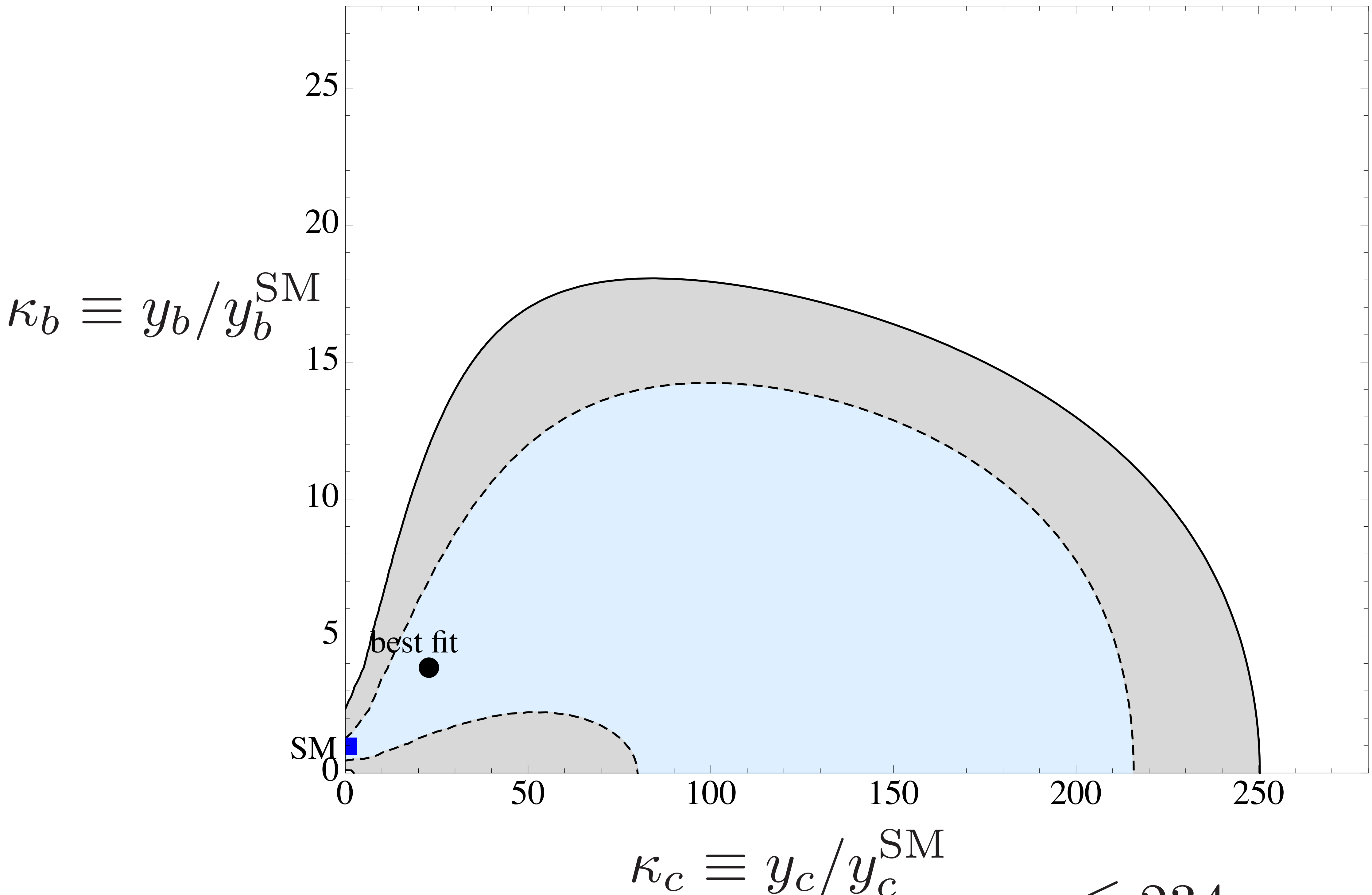
At large coupling $\kappa_c = y_c/y_c^{SM}$ ~100
switch on new production





estimated by MG5

First direct bound on Charm Yukawa

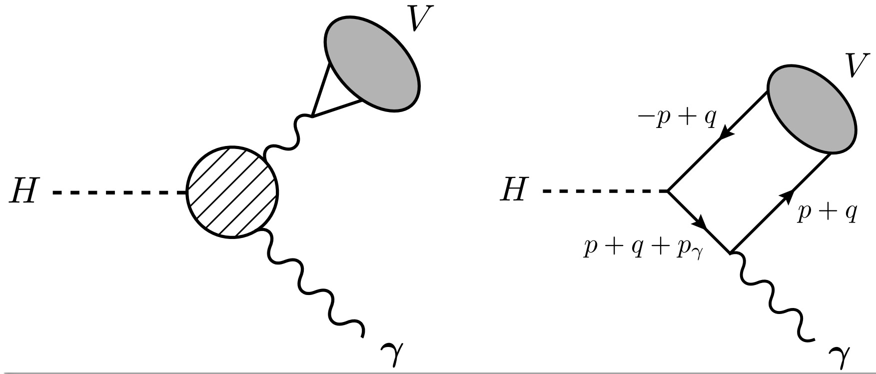


$\kappa_c \lesssim 234$

Other Measurements

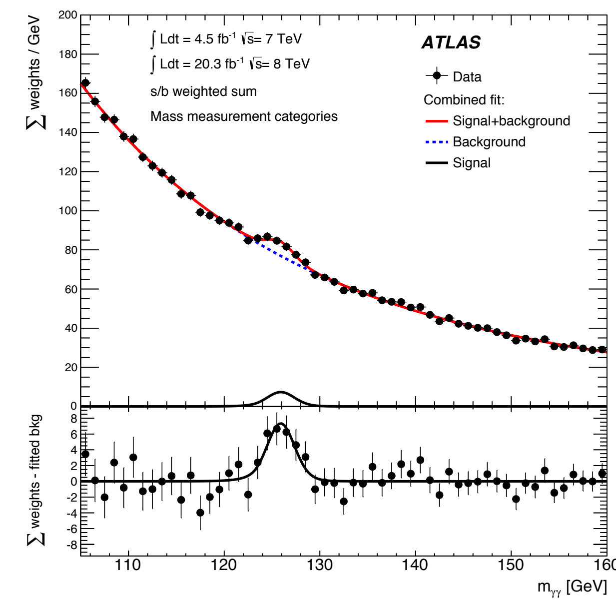
1. Exclusive decay

$$h \to J/\psi\gamma$$



$$\sigma \cdot \mathrm{Br}(H \to J/\psi\gamma) < 33\mathrm{fb}^{-1}$$

2. Total width

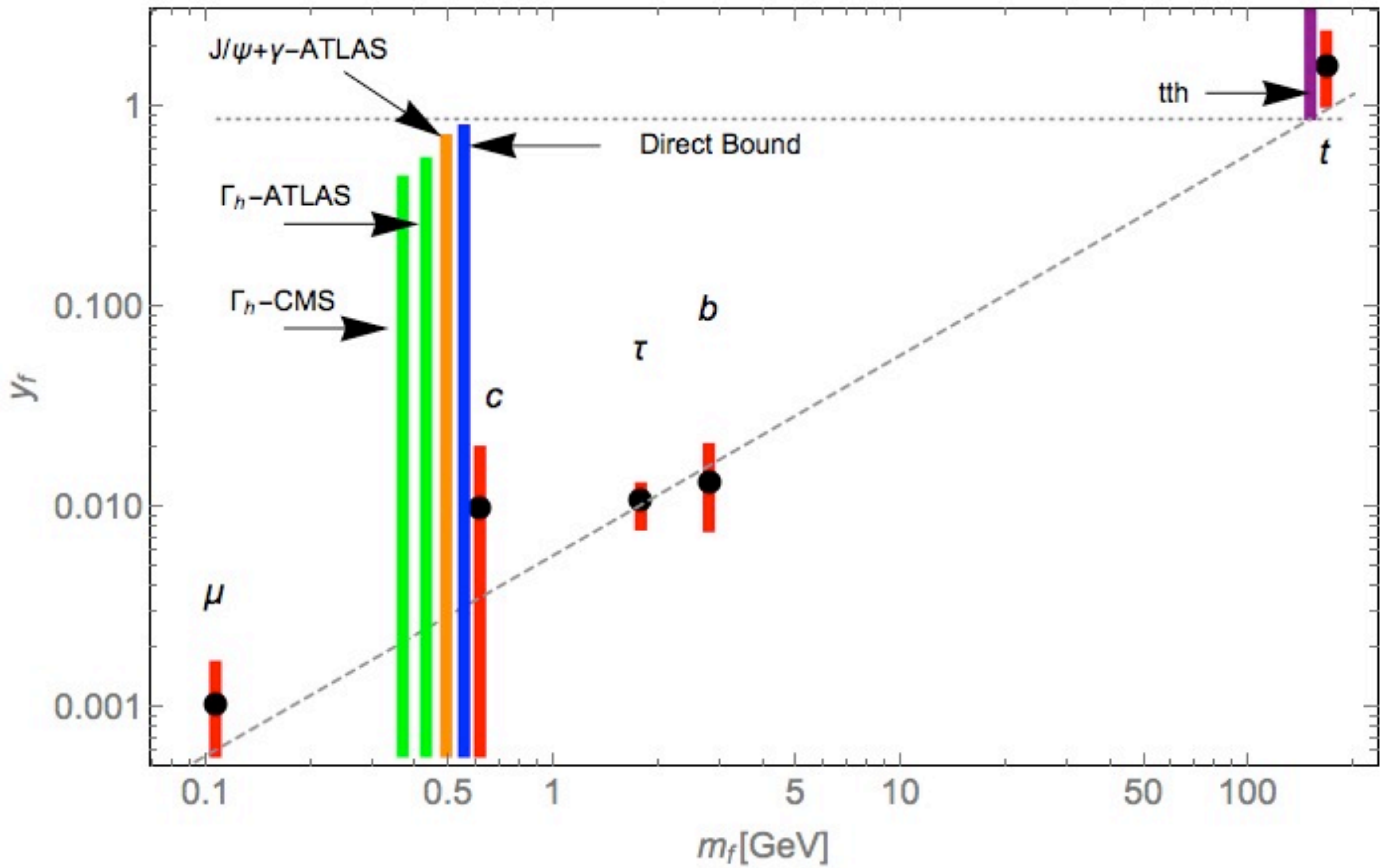


ATLAS: 2.6 GeV, CMS: 1.7 GeV

3. Global Analysis

EW precision + Other Higgs measurements

Current LHC constraints



$0.5 < \varkappa_b < 1.4$

$\varkappa_c < 6$

Top-charm coupling is non-universal, yt≠yc!!

Future LHC

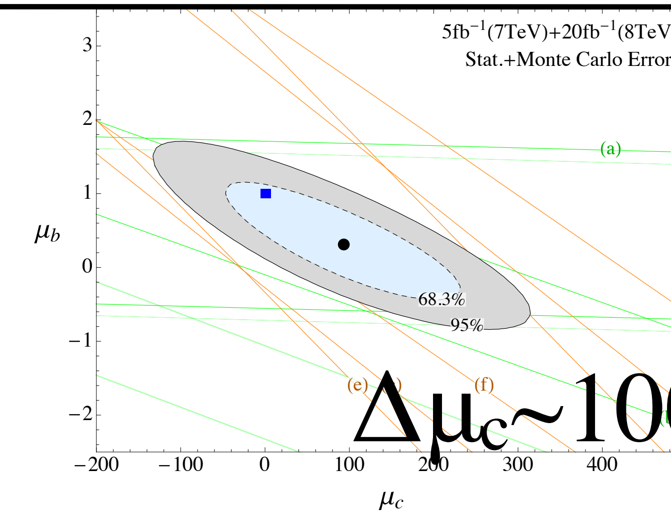
Future LHC

Future prospect of VH→bb

$\Delta\mu_b$=0.14 @ATLAS Med

ATL-PHYS-PUB-2014-011 (1- and 2-lep channels)

Thanks ATLAS for providing tables!



$\Delta\mu_c$~100

use charm-tagging for 1-lep to disentangle μ_c

	ϵ_b	ϵ_c	$\epsilon_{\rm light}$	
Med:	70,	20,	1.25	(%)
	↓	↓	↓	
C-tag:	13,	19,	0.5	

Scharm study[arXiv:1501.01325]

Future LHC

Future prospect of VH→bb

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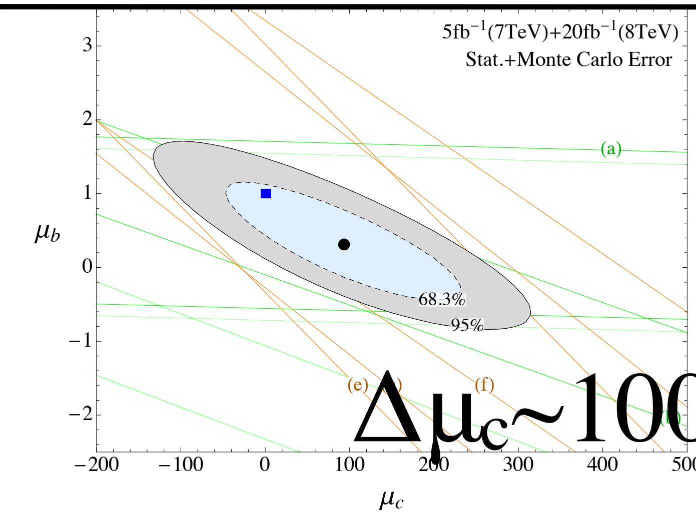

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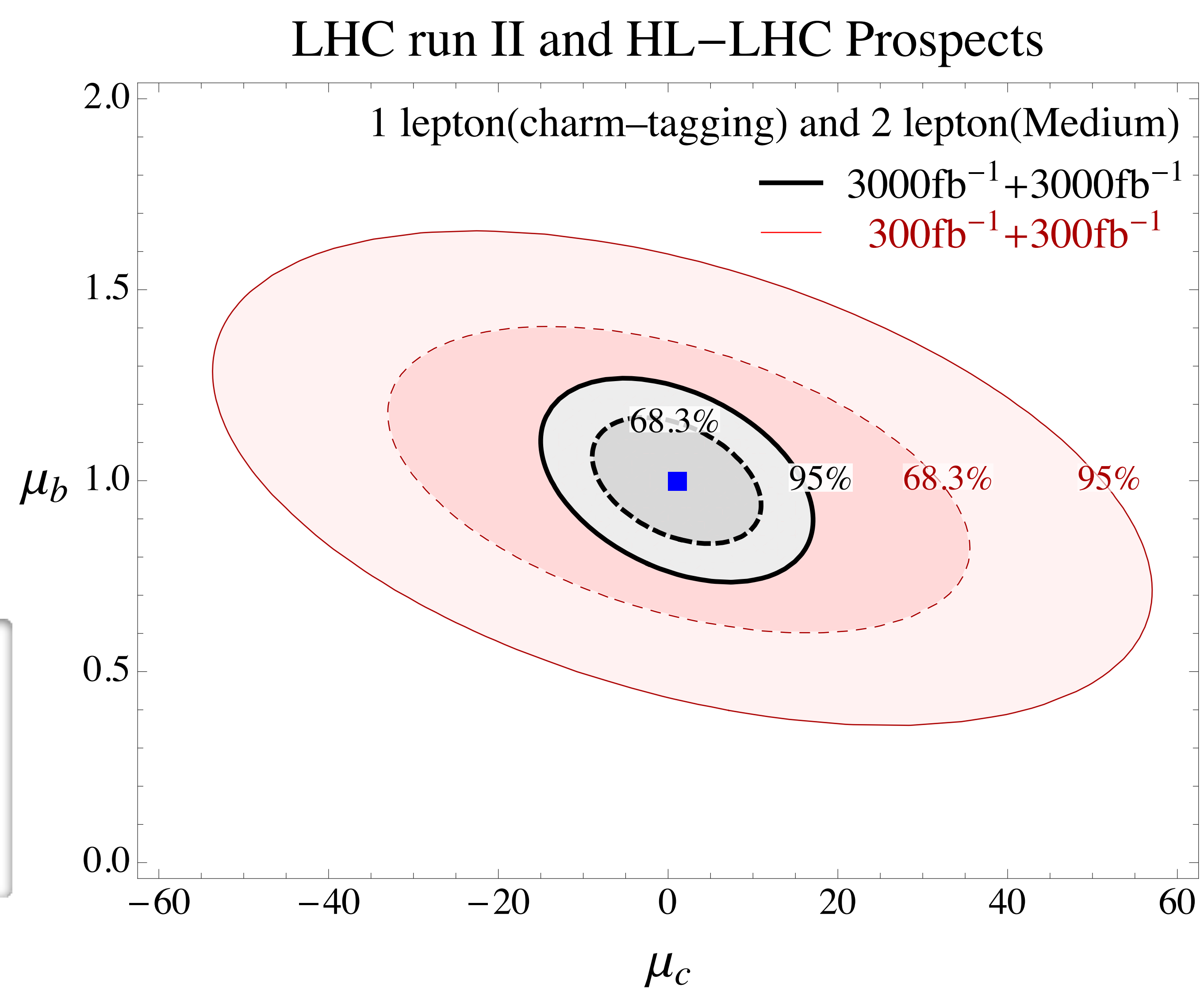
Scharm study[arXiv:1501.01325]

$\Delta\mu_c$=23 Run II
=6.5 HL-LHC



Summary

- Recasting VH study gives first bound on μ_c
 To extract it, we need different tagging points

$$\mu_c = 95^{+90(175)}_{-95(180)} \text{ at } 68.3(95)\% \text{ CL.}$$

- charm-Yukawa bounds

$$\frac{y_c}{y_c^{\rm SM}} \lesssim 234,\ 120\,(140),\ 220,\ 6.2,$$

VH recast — Total width — Exclusive decay ($h \to J/\psi\gamma$) — Global fit

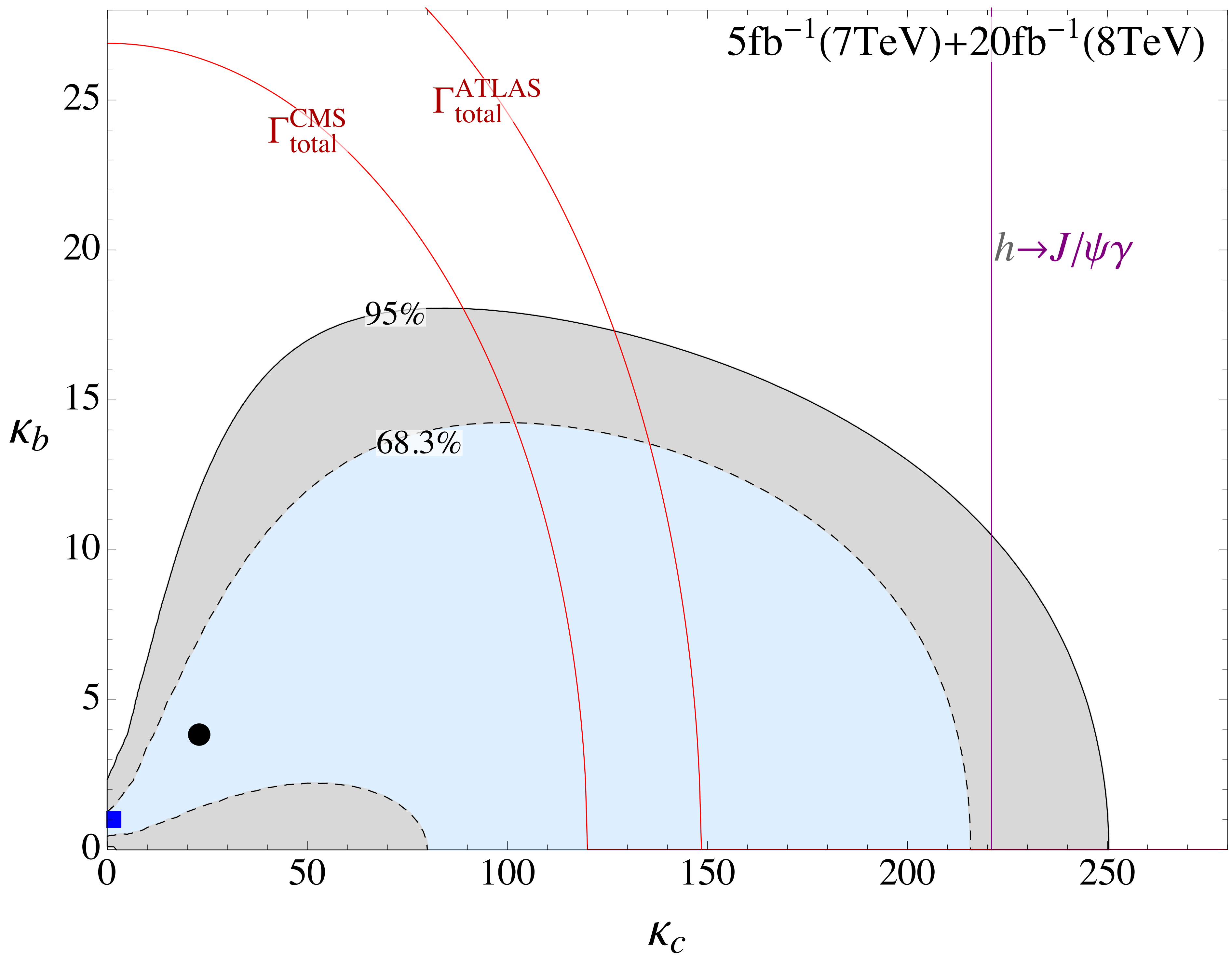
- Future sensitivity with charm-tagging

$\Delta\mu_c$=23 Run II
=6.5 HL-LHC

Thank you

תודה רבה

Backup



5fb^{-1}(7TeV)+20fb^{-1}(8TeV)
$\Gamma_{\rm total}^{\rm CMS}$
$\Gamma_{\rm total}^{\rm ATLAS}$
$h \to J/\psi\gamma$
95%
68.3%
κ_b
κ_c
0
5
10
15
20
25
0
50
100
150
200
250