HH pair searches

combination with wwγγ, bbγγ, bbττ, bbbb

Xiaohu SUN
--- --- --- --- ---
01-06-2015
IHEP

CDS entry
[wwγγ]https://cds.cern.ch/record/1967498
[bbττ]https://cds.cern.ch/record/1967500
[combination]https://cds.cern.ch/record/1984111/

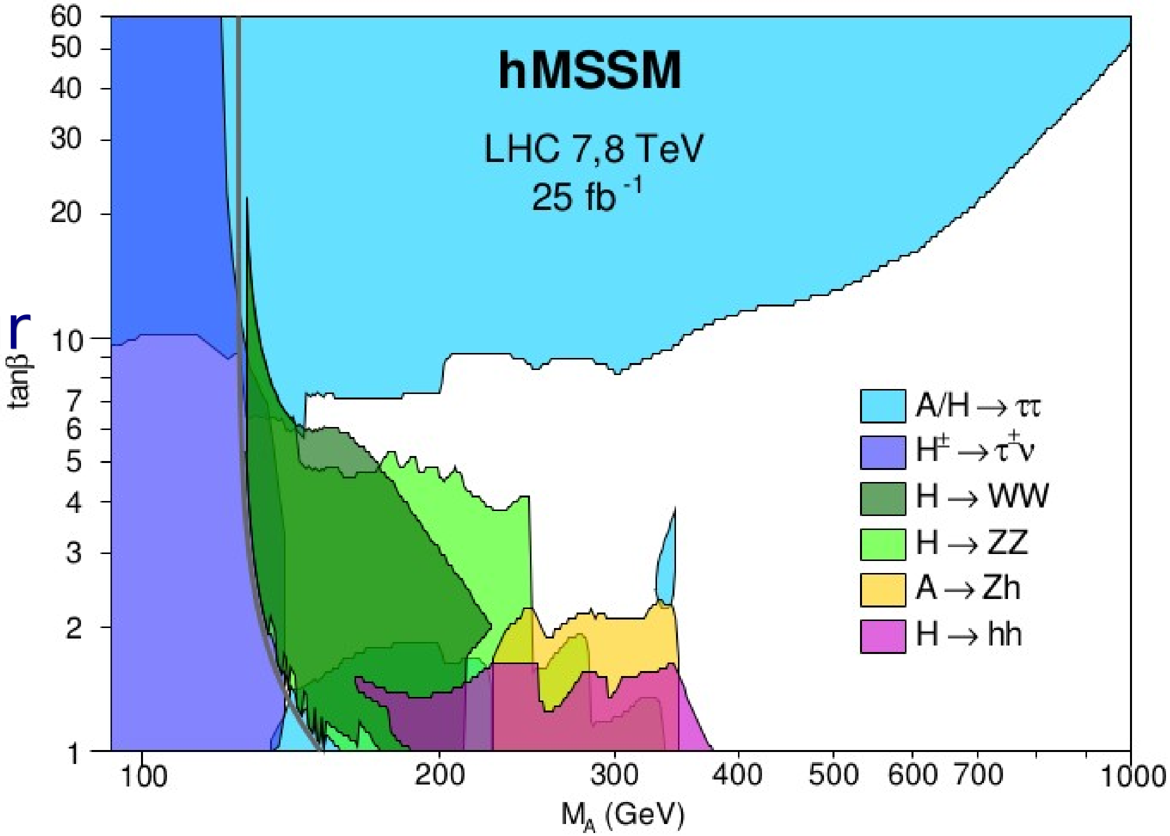
Higgs approval:
https://indico.cern.ch/event/387805/

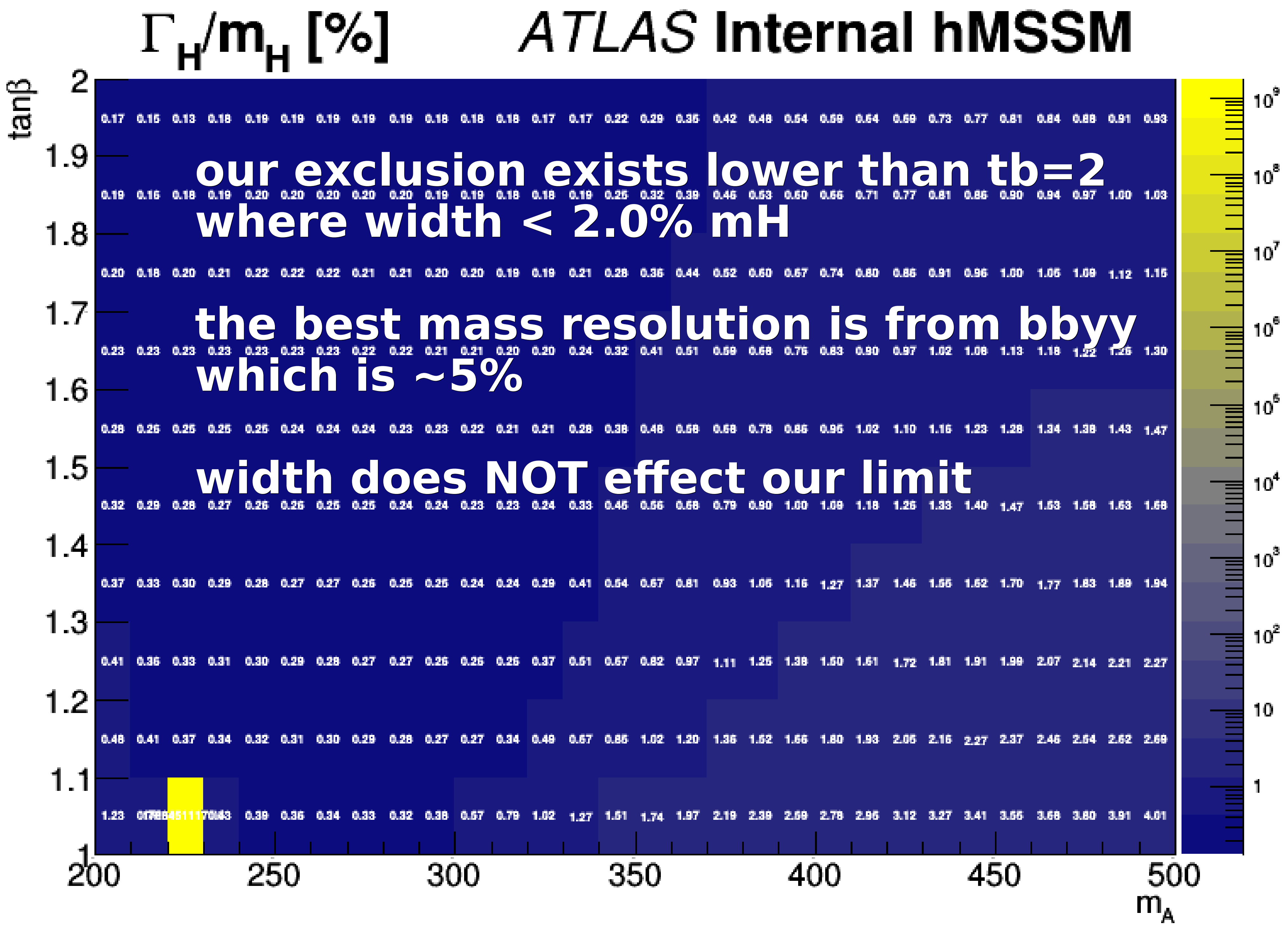
hMSSM interpretation

- In hMSSM, we do not have width large enough challenging our mass resolution; we can safely use the currently limit obtained with NWA in signal (giving up 2HDM due to width previously)

- mH is NOT equal to mA, instead, mH is spreading around, giving us exclusions in even lower mA; but our interpretation is still made in **tb vs mA**

- Non-SM BR(h->WW/yy/bb/tautau) must be taken into account

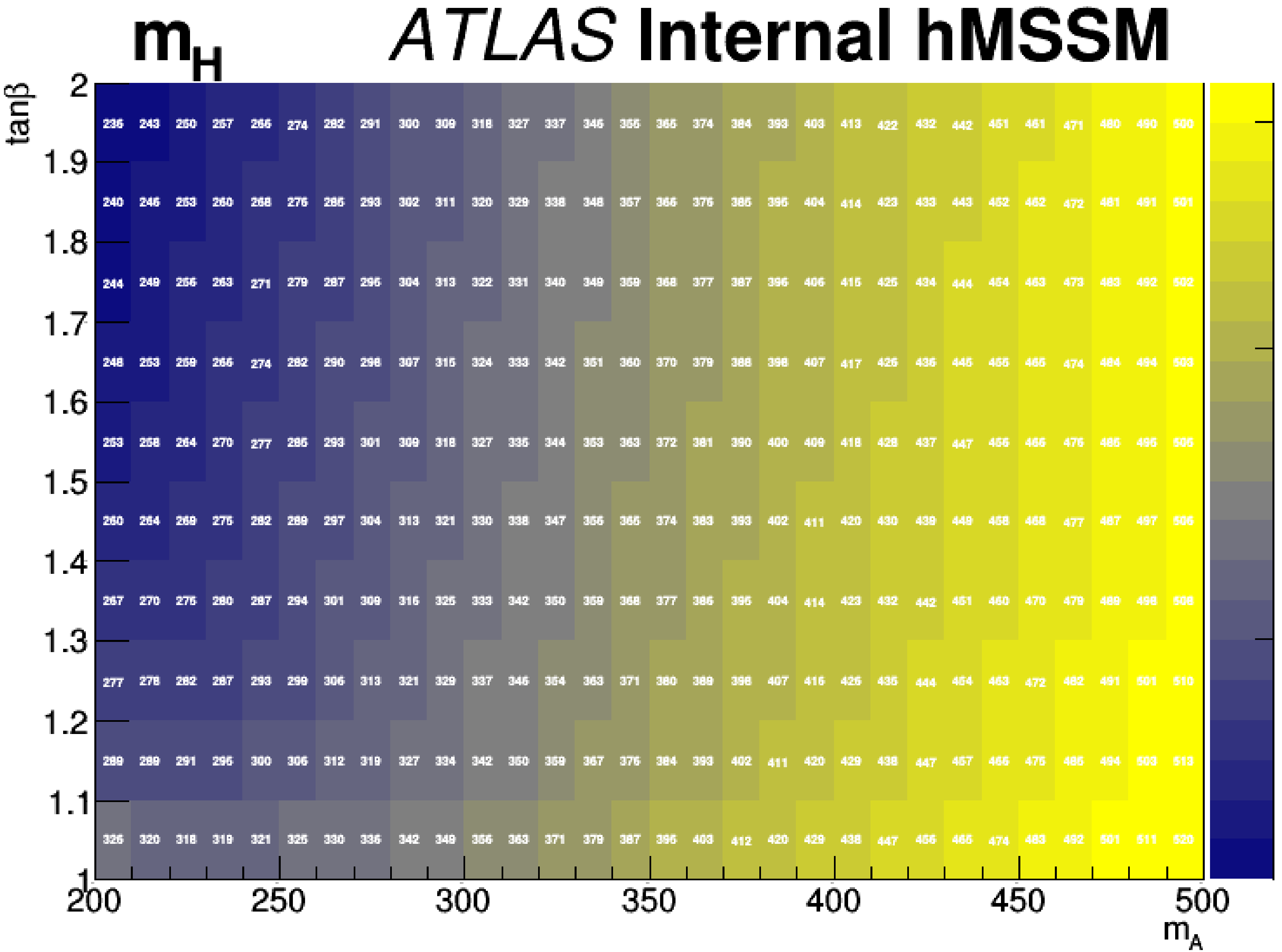




our exclusion exists lower than tb=2
where width < 2.0% mH

the best mass resolution is from bbyy
which is ~5%

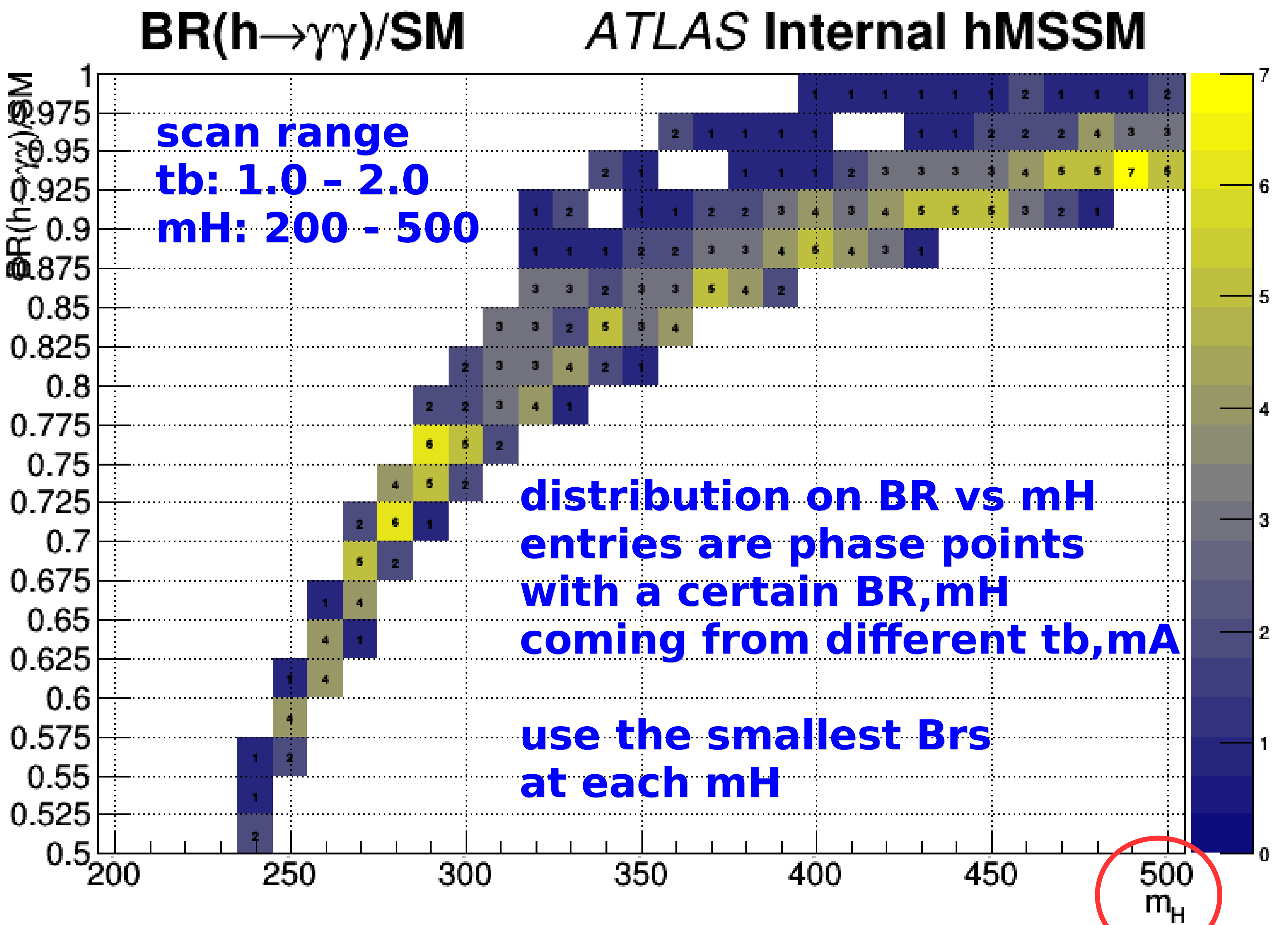
width does NOT effect our limit

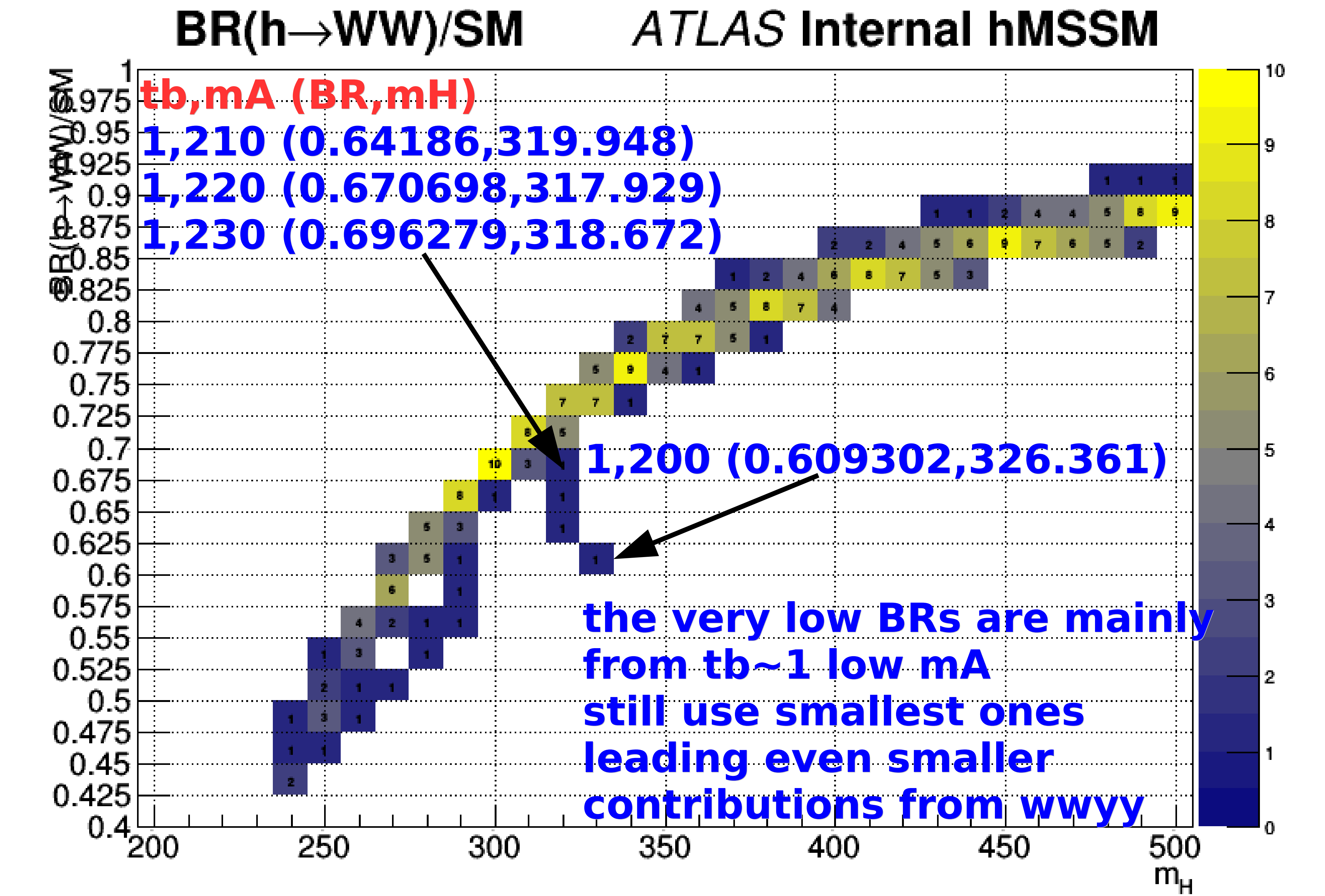


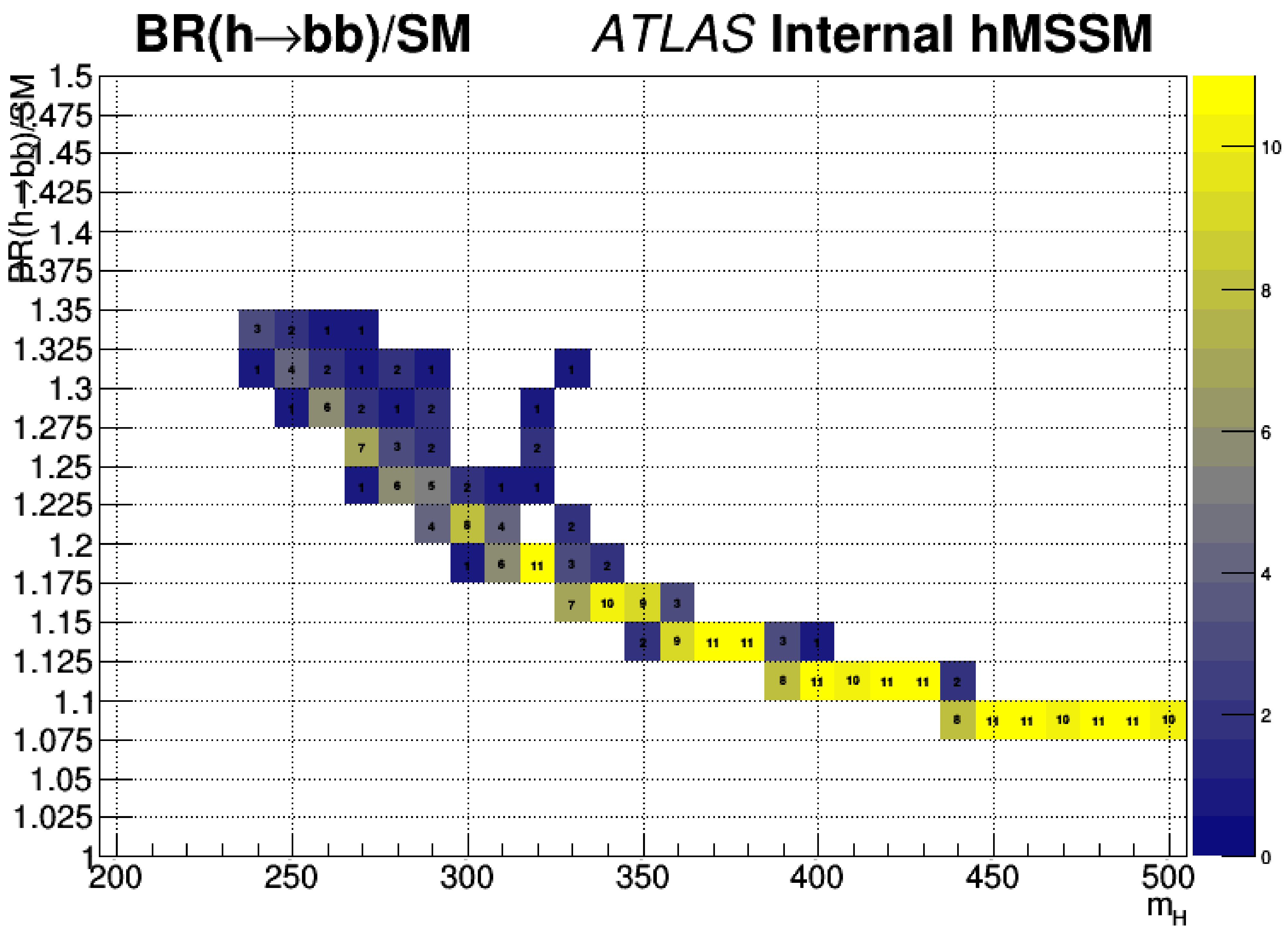
m_H
ATLAS Internal hMSSM
tanβ
m_A
236 243 250 257 266 274 282 291 300 309 318 327 337 346 355 365 374 384 393 403 413 422 432 442 451 461 471 480 490 500
240 246 253 260 268 276 285 293 302 311 320 329 338 348 357 366 376 385 395 404 414 423 433 443 452 462 472 481 491 501
244 249 256 263 271 279 287 296 304 313 322 331 340 349 359 368 377 387 396 406 415 425 434 444 454 463 473 483 492 502
248 253 259 266 274 282 290 298 307 315 324 333 342 351 360 370 379 388 398 407 417 426 435 445 455 465 474 484 494 503
253 258 264 270 277 285 293 301 309 318 327 335 344 353 363 372 381 390 400 409 418 428 437 447 456 466 476 486 495 505
260 264 269 275 282 289 297 304 313 321 330 338 347 356 365 374 383 393 402 411 420 430 439 449 458 468 477 487 497 506
267 270 275 280 287 294 301 309 316 325 333 342 350 359 368 377 386 395 404 414 423 432 442 451 460 470 479 489 498 508
277 278 282 287 293 299 306 313 321 329 337 346 354 363 371 380 389 398 407 416 426 435 444 454 463 472 482 491 501 510
289 289 291 295 300 306 312 319 327 334 342 350 359 367 376 384 393 402 411 420 429 438 447 457 466 475 485 494 503 513
326 320 318 319 321 325 330 336 342 349 356 363 371 379 387 395 403 412 420 429 438 447 456 465 474 483 492 501 511 520

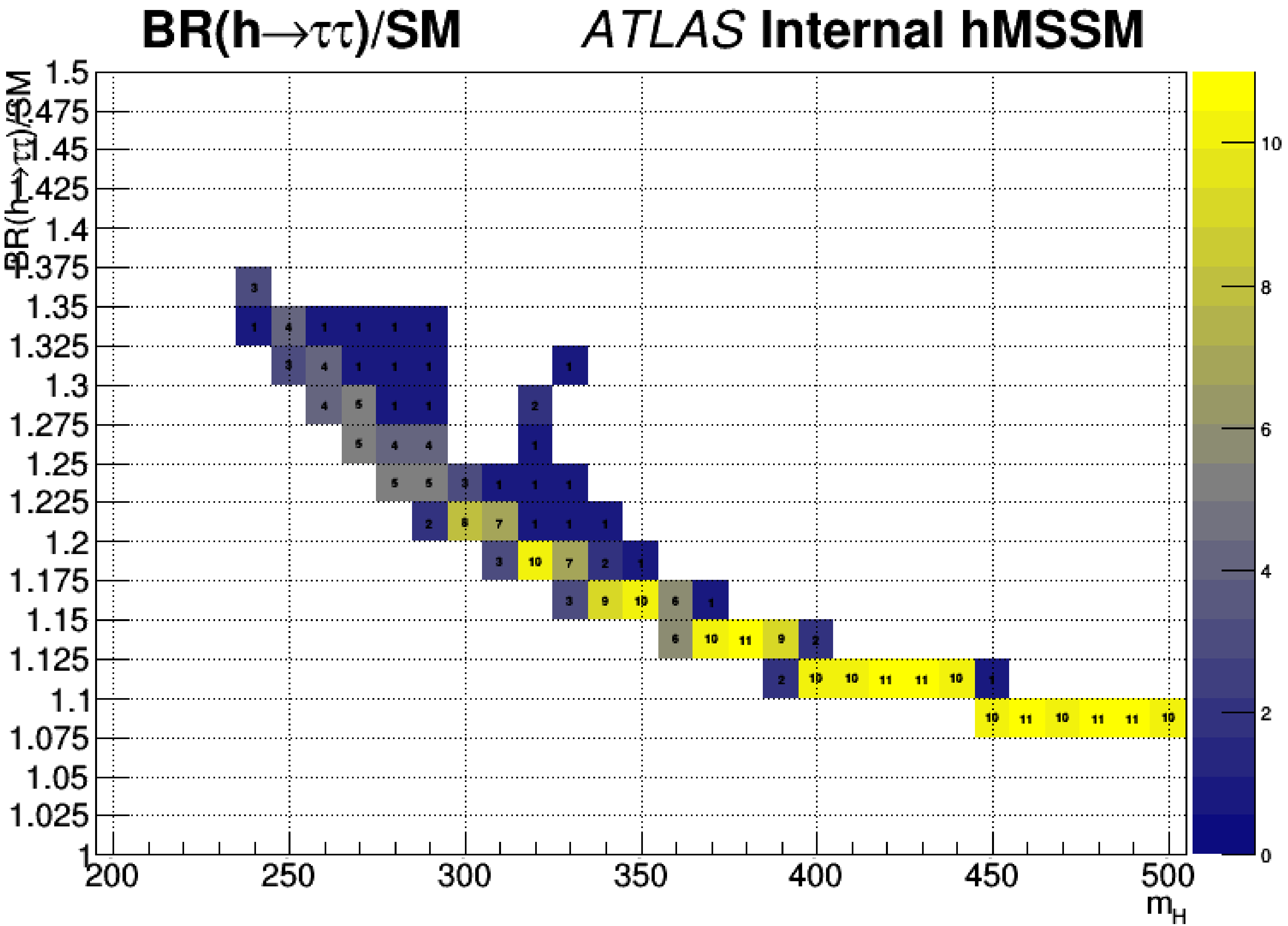
hMSSM h decay BRs

- We take into account of non-SM BRs of h decays in all channels: bbyy, bbtautau, wwyy and bbbb
- BRs are set to non-SM values as a function of mH (not mA)
- BRs are not constant for all phase points with the same mH in tb-vs-mA plane (a same mH appears several times from different tb,mA and they have different BRs)
- Use always the smallest BRs; this simplifies the parametrization (less limits less toys to run, making this feasible) and is conservative (smaller BRs, smaller yields, high limits, less exclusions)


BR(h→γγ)/SM
ATLAS Internal hMSSM
scan range
tb: 1.0 - 2.0
mH: 200 - 500
distribution on BR vs mH
entries are phase points
with a certain BR,mH
coming from different tb,mA
use the smallest Brs
at each mH
BR(h→γγ)/SM
m_H


BR(h→WW)/SM
ATLAS Internal hMSSM
tb,mA (BR,mH)
1,210 (0.64186,319.948)
1,220 (0.670698,317.929)
1,230 (0.696279,318.672)
1,200 (0.609302,326.361)
the very low BRs are mainly
from tb~1 low mA
still use smallest ones
leading even smaller
contributions from wwyy
BR(h→WW)/SM
m_H


BR(h→bb)/SM
ATLAS Internal hMSSM
BR(h→bb)/SM
m_H

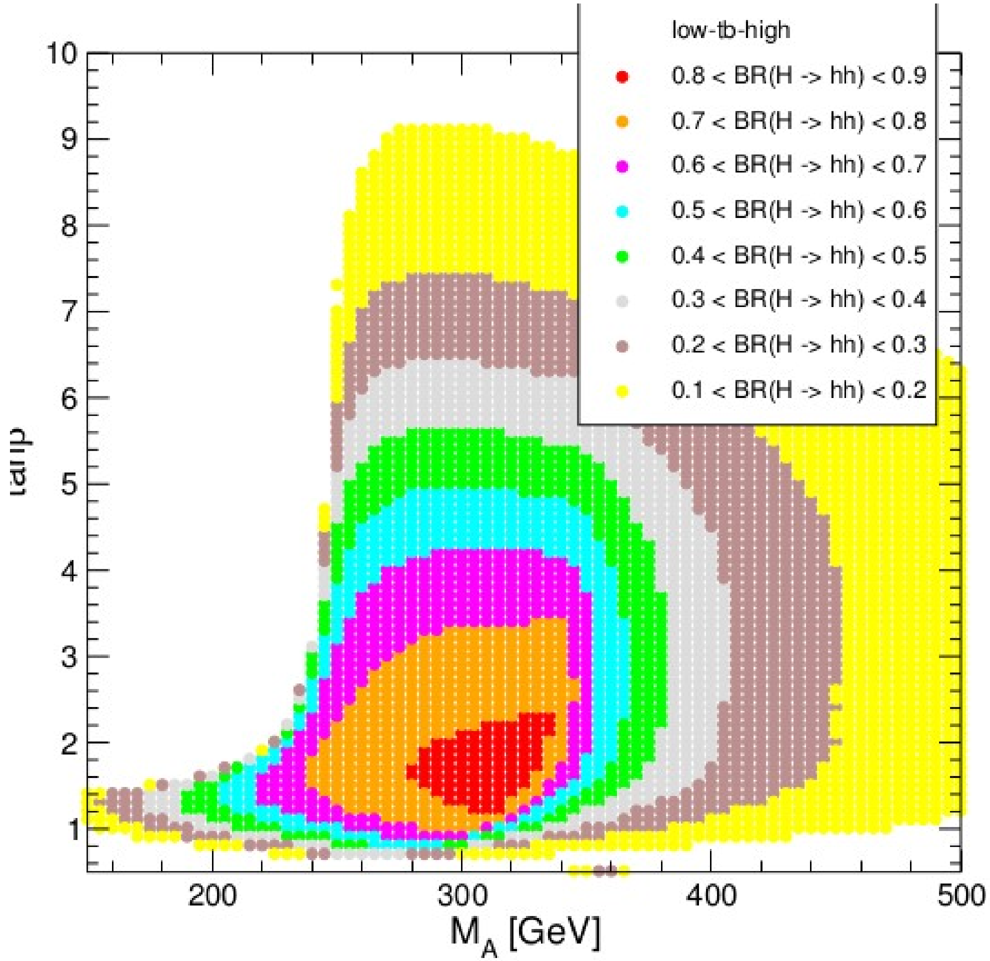

BR(h→ττ)/SM
ATLAS Internal hMSSM
BR(h→ττ)/SM
m_H
200
250
300
350
400
450
500
1
1.025
1.05
1.075
1.1
1.125
1.15
1.175
1.2
1.225
1.25
1.275
1.3
1.325
1.35
1.375
1.4
1.425
1.45
1.475
1.5
0
2
4
6
8
10

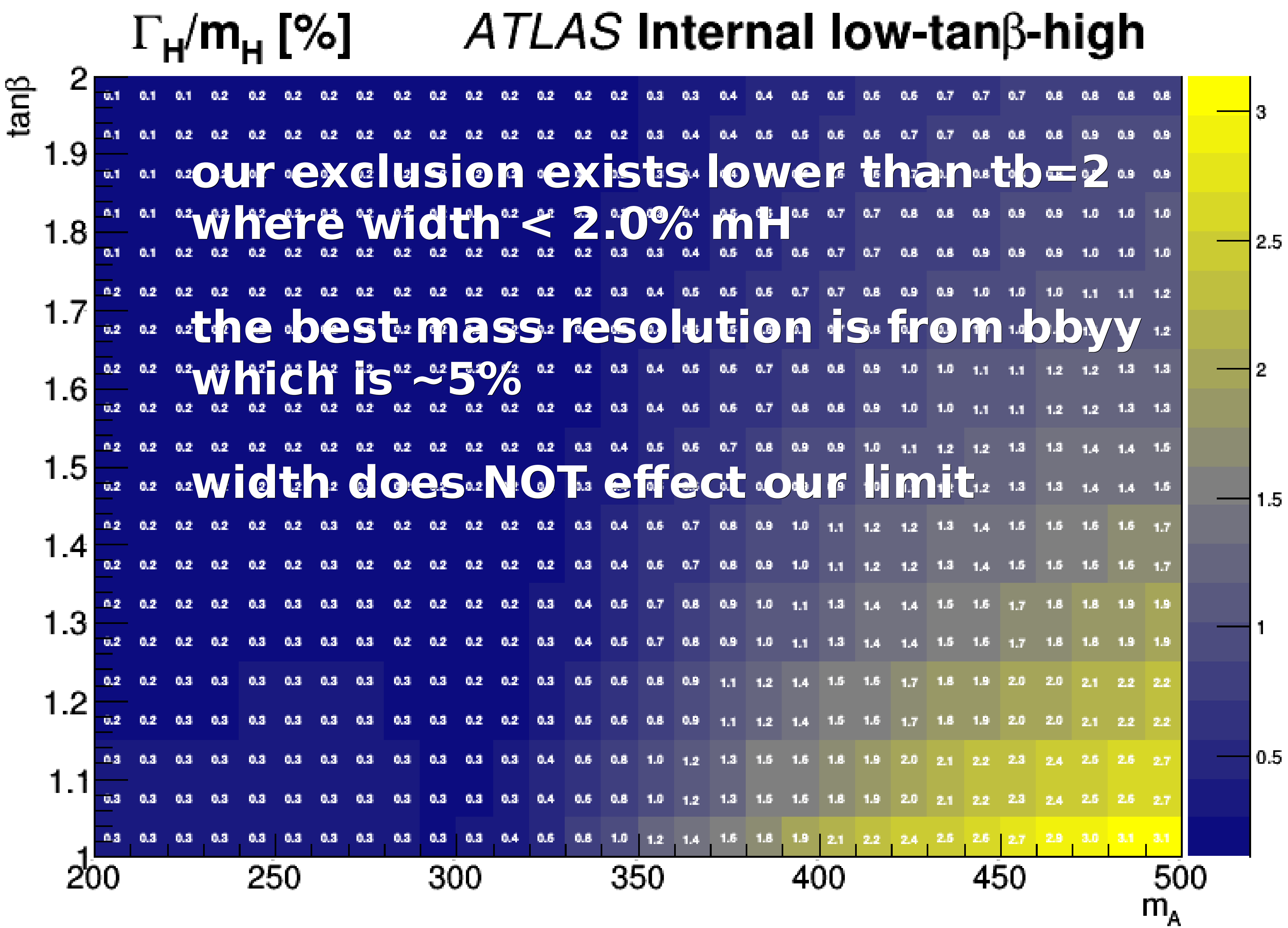
low-tb-high interpretation

- Similar to hMSSM, we do not have width large enough challenging our mass resolution in low-tb-high; we can safely use the currently limit obtained with NWA in signal

- mH is NOT equal to mA, instead, mH is spreading around, giving us exclusions in even lower mA

- Non-SM BR(h->WW/yy/bb/tautau) must be taken into account

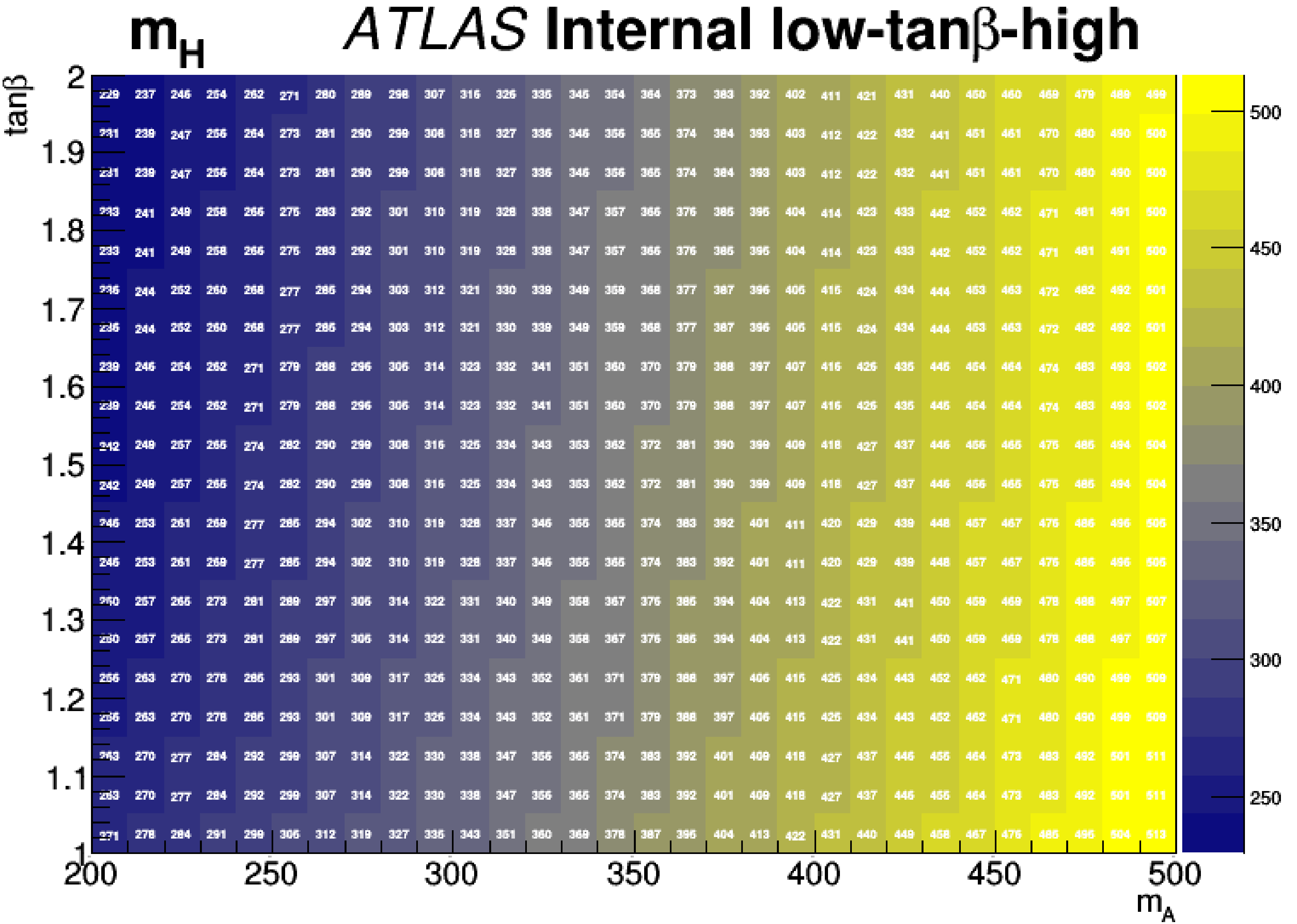


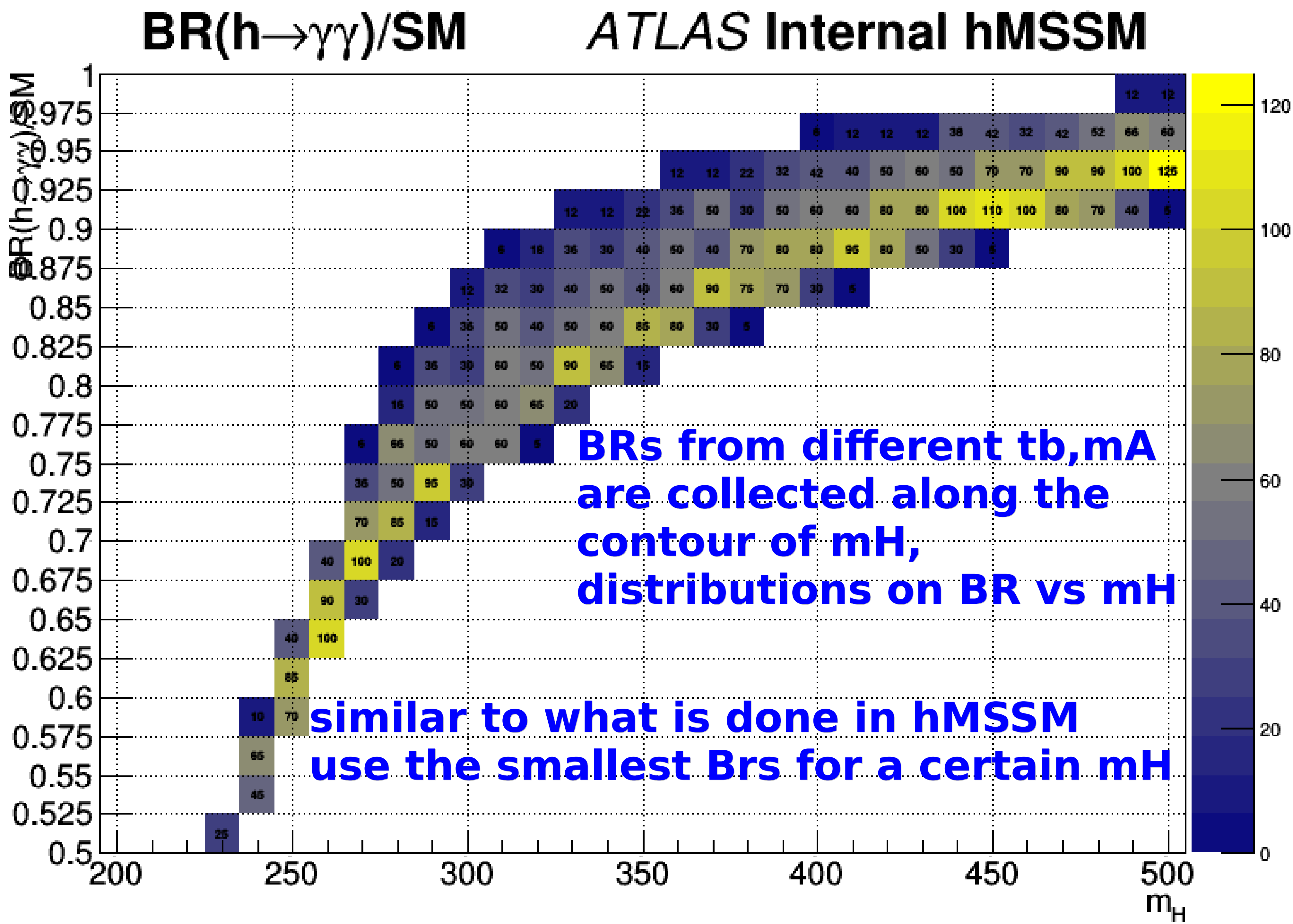


our exclusion exists lower than tb=2 where width < 2.0% mH

the best mass resolution is from bbyy which is ~5%

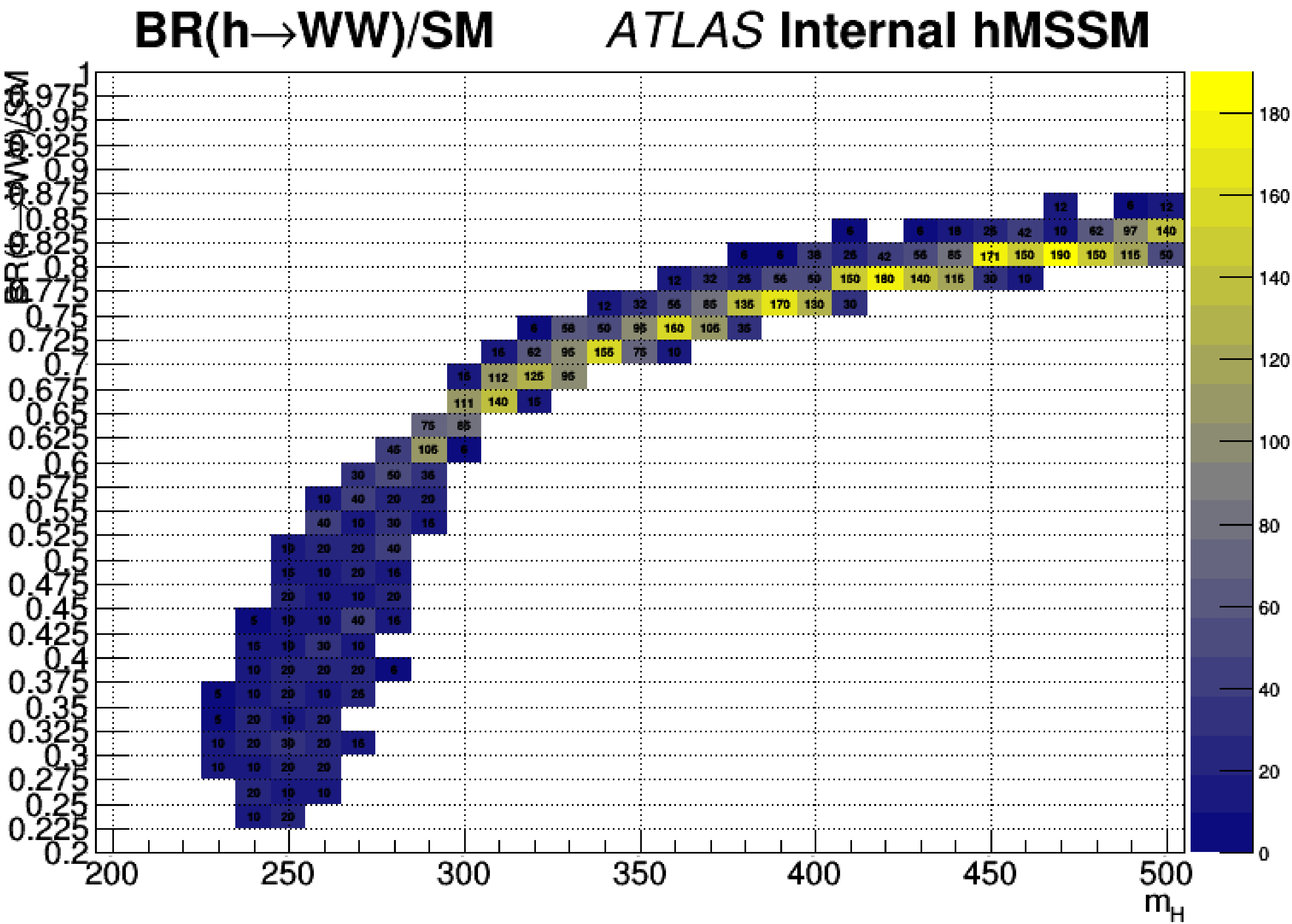
width does NOT effect our limit

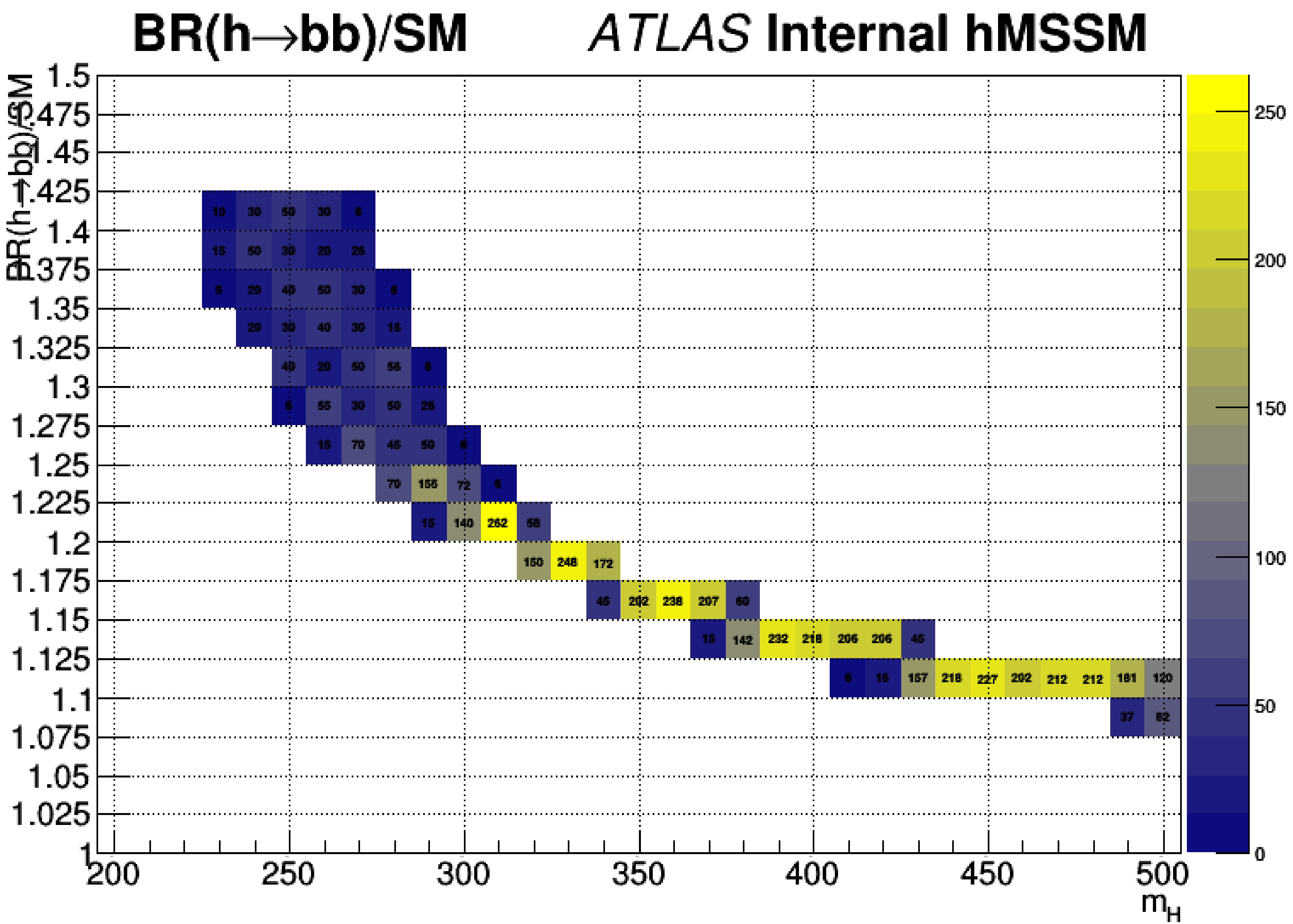

m_H
ATLAS Internal low-tanβ-high
tanβ
m_A
200
250
300
350
400
450
500
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2
250
300
350
400
450
500

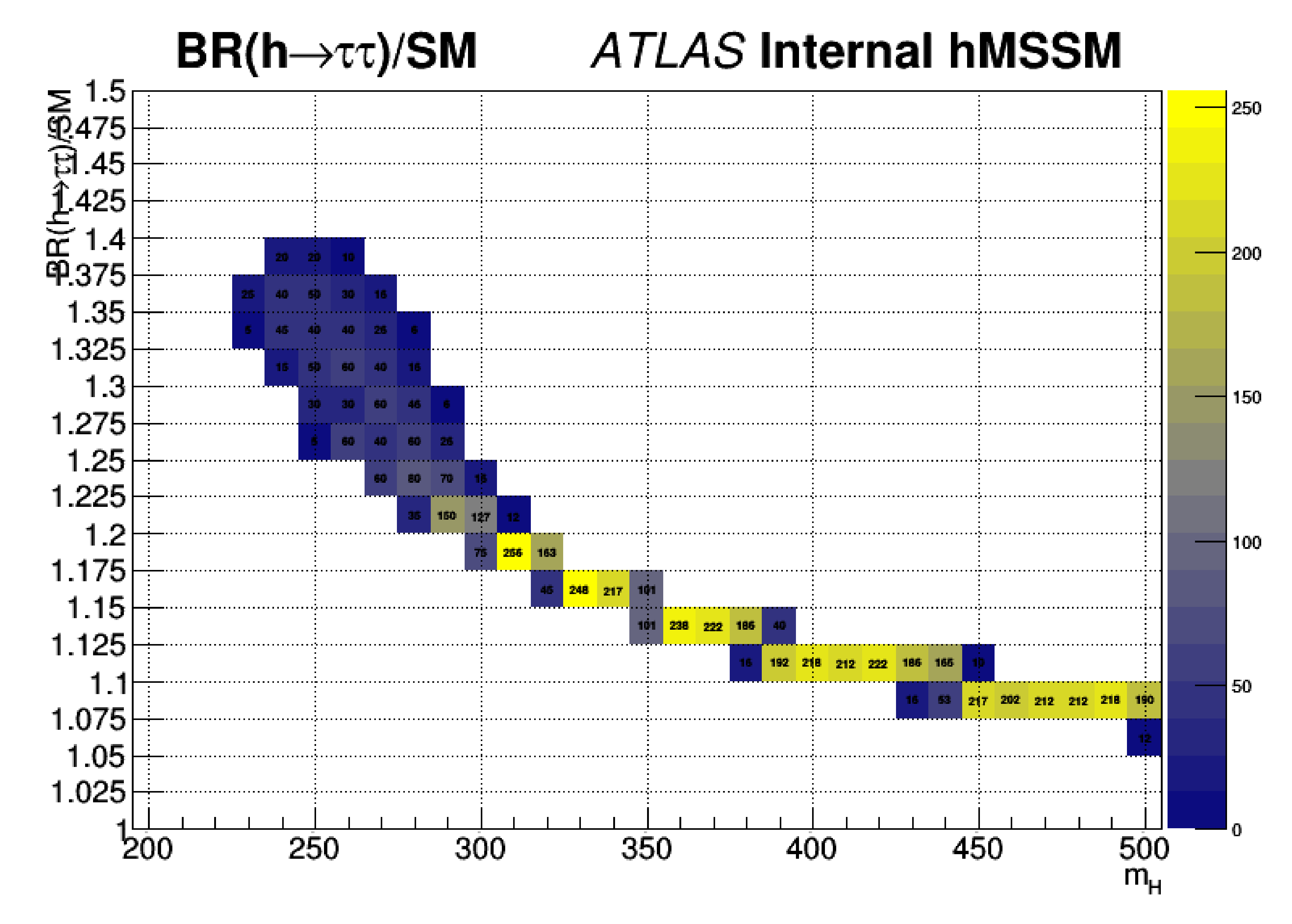


BRs from different tb,mA are collected along the contour of mH, distributions on BR vs mH

similar to what is done in hMSSM use the smallest Brs for a certain mH


BR(h→WW)/SM
ATLAS Internal hMSSM
BR(h→WW)/SM
m_H
200
250
300
350
400
450
500
0
20
40
60
80
100
120
140
160
180


BR(h→bb)/SM
ATLAS Internal hMSSM
BR(h→bb)/SM
m_H
10 30 50 30 6
15 50 30 20 26
5 20 40 50 30 6
20 30 40 30 16
40 20 50 56 6
6 55 30 50 26
15 70 45 50 6
70 156 72 6
15 140 262 56
150 248 172
45 202 238 207 60
15 142 232 218 206 206 45
6 16 157 218 227 202 212 212 181 120
37 82


BR(h→ττ)/SM
ATLAS Internal hMSSM
BR(h→ττ)/SM
m_H

Theoretical uncertainties - *reminder*

- Theoretical uncertainties estimated with variations on PDF/scale/radiation are being reproduced with a larger number of events
- Procedures are not changed since last time
- Now we produced **1.2M** events -> 10 times of the the statistics of last time, since the beginning of this week
- /afs/cern.ch/work/x/xiaohu/public/HH-TheoUncer/
  - **MERGED/**: all samples merged into a single file
  - **BAK/**: separated samples

* all follows instructions from Paul T as used in AZh

Uncertainties – combined analysis

- evaluate **grouped** uncertainties with the script pointed by Carl
- Previously, fit to **obsData** -> small mu, leading to the relative uncertainties very large... sigma/small_mu
- Now, fit to asimovData with **mu=1** (1pb injected signal)

the gamma_terms

300GeV
low mass

Symmetrized by (up+down)/2

Set of nuisance parameters	Impact on signal strength
Total	1.230
DataStat	1.000
FullSyst	0.706
TemplateStat	0.427
Jets	0.242
Leptons	0.229
Signal theory	0.145
Btagging	0.106
MET	0.081
Lumi	0.063
Photons	0.006

Uncertainties – combined analysis

- 500 low mass: lower stat+syst uncertainties

Set of nuisance parameters	Impact on signal strength
Total	0.466
DataStat	0.310
FullSyst	0.344
Jets	0.202
TemplateStat	0.132
Leptons	0.119
Signal theory	0.097
Btagging	0.029
MET	0.024
Lumi	0.015
Photons	0.002

Uncertainties – combined analysis

- 500 high mass: introducing bbbb, more statistics -> lowers stat uncert

Set of nuisance parameters	Impact on signal strength
Total	0.216
DataStat	0.126
FullSyst	0.176
Jets	0.139
Btagging	0.083
TemplateStat	0.043
Signal theory	0.032
Lumi	0.024
Leptons	0.018
MET	0.001
Photons	0.000

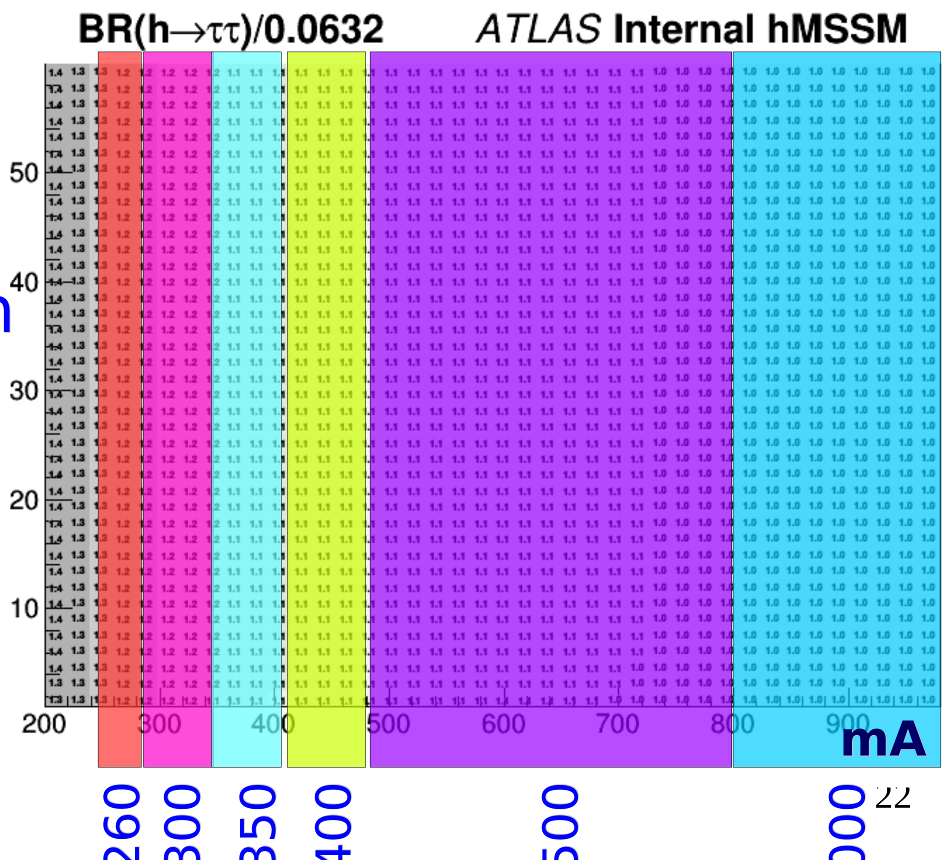
Uncertainties – combined analysis

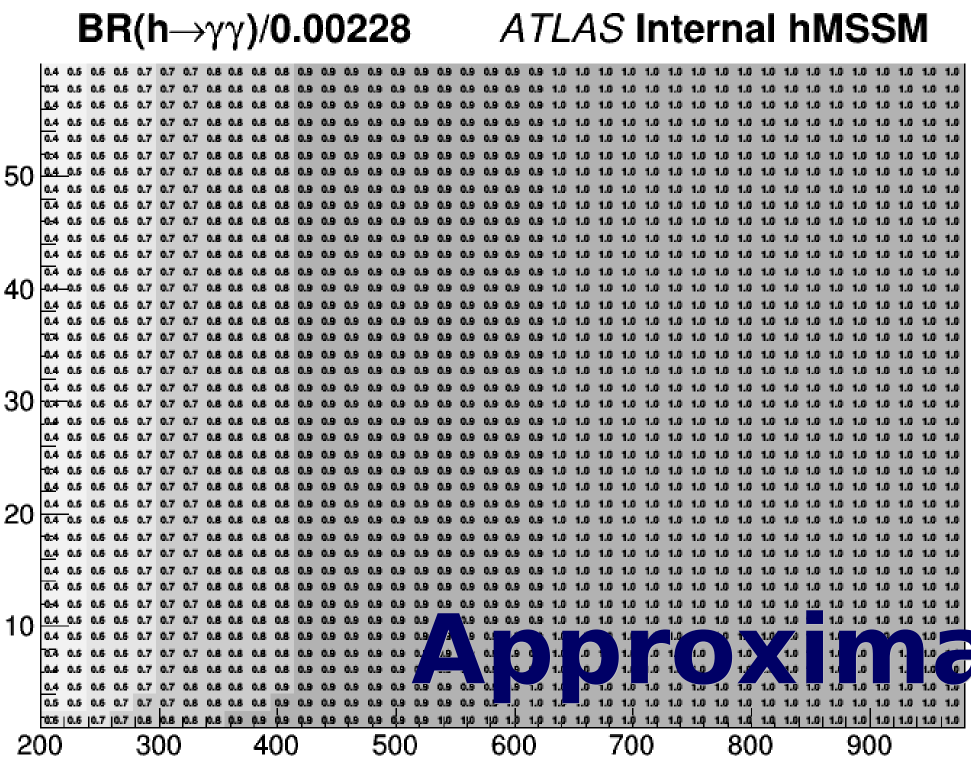
- nonres (bbbb+bbyy+bbtt+wwyy)

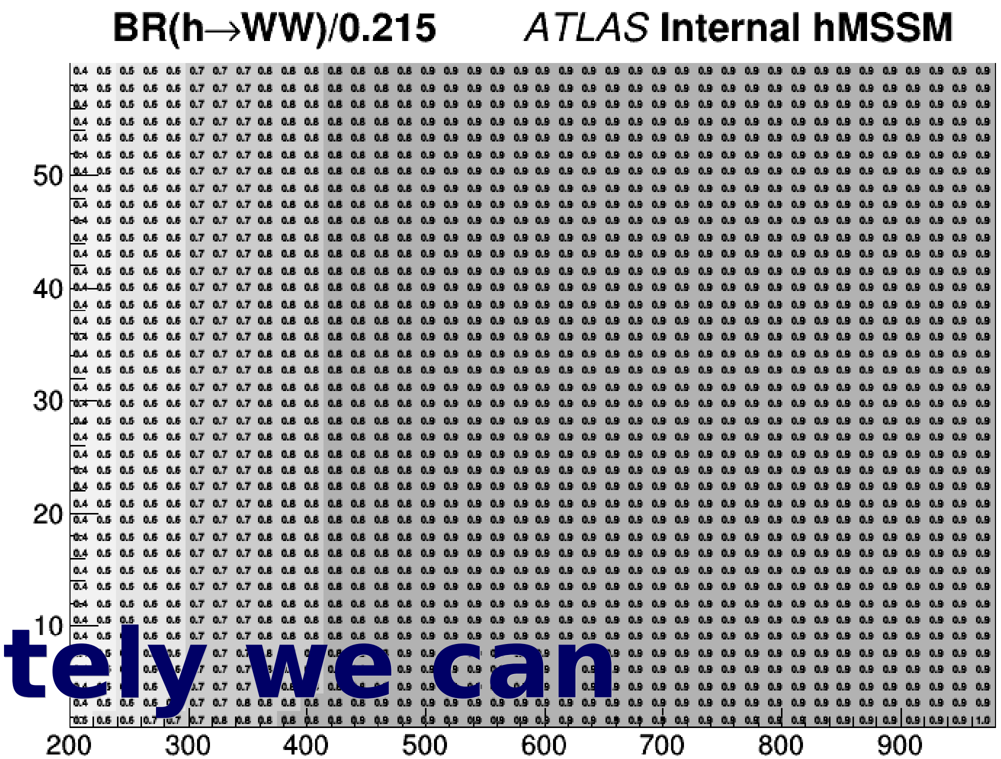
Set of nuisance parameters	Impact on signal strength
Total	0.285
DataStat	0.238
FullSyst	0.156
Btagging	0.081
Jets	0.051
TemplateStat	0.038
Signal theory	0.025
Leptons	0.011
Photons	0.007
MET	0.005
Lumi	0.000

hMSSM Interpretation

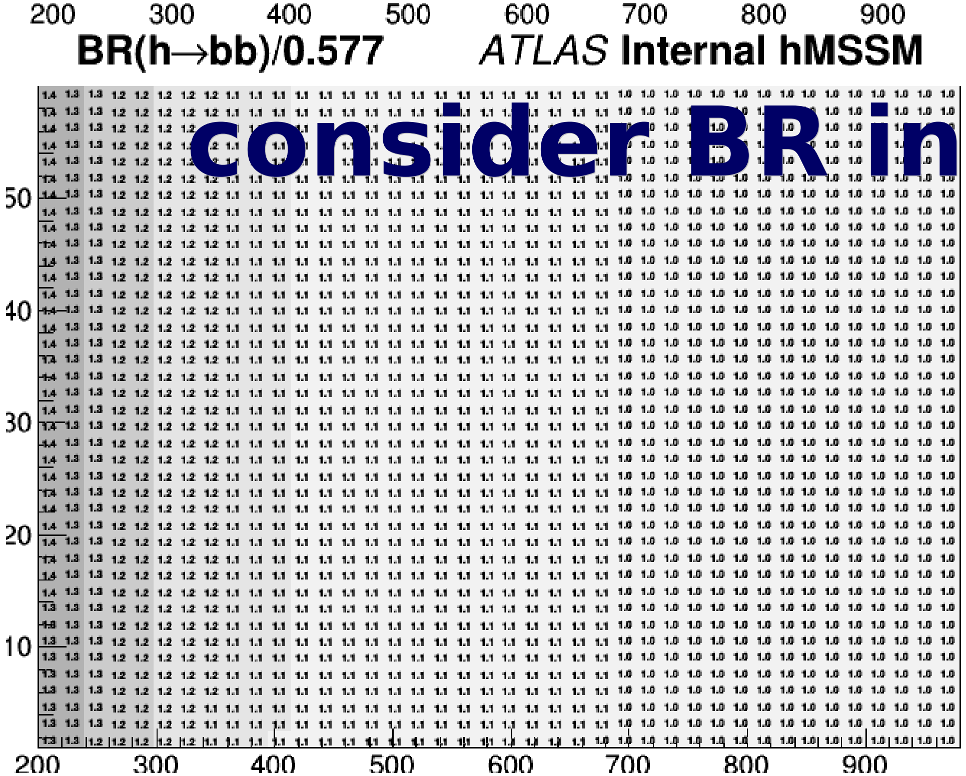
- Many thanks to Nikos and Allison, we have **another new map file** for hMSSM last week
  - the strangely small BR_H_hh is fixed
- The **non-SM BR** of h decays should be taken into account in the combined limits
- BR(h->yy/ww/bb/tautau) is a function of mH but ***NOT dependent*** on tb, we can simplify the parametrization
- Limit is a function of
  - mH
  - BR(h-yy/ww/bb/tt)
- BRs are a group of ***fixed*** values according to mH

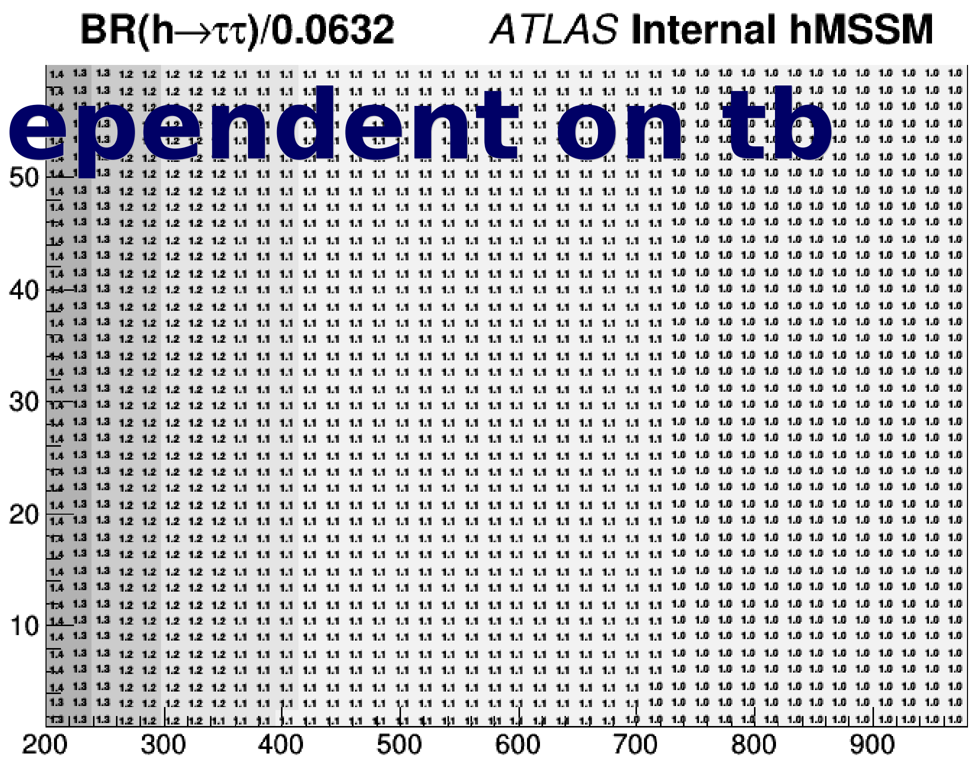


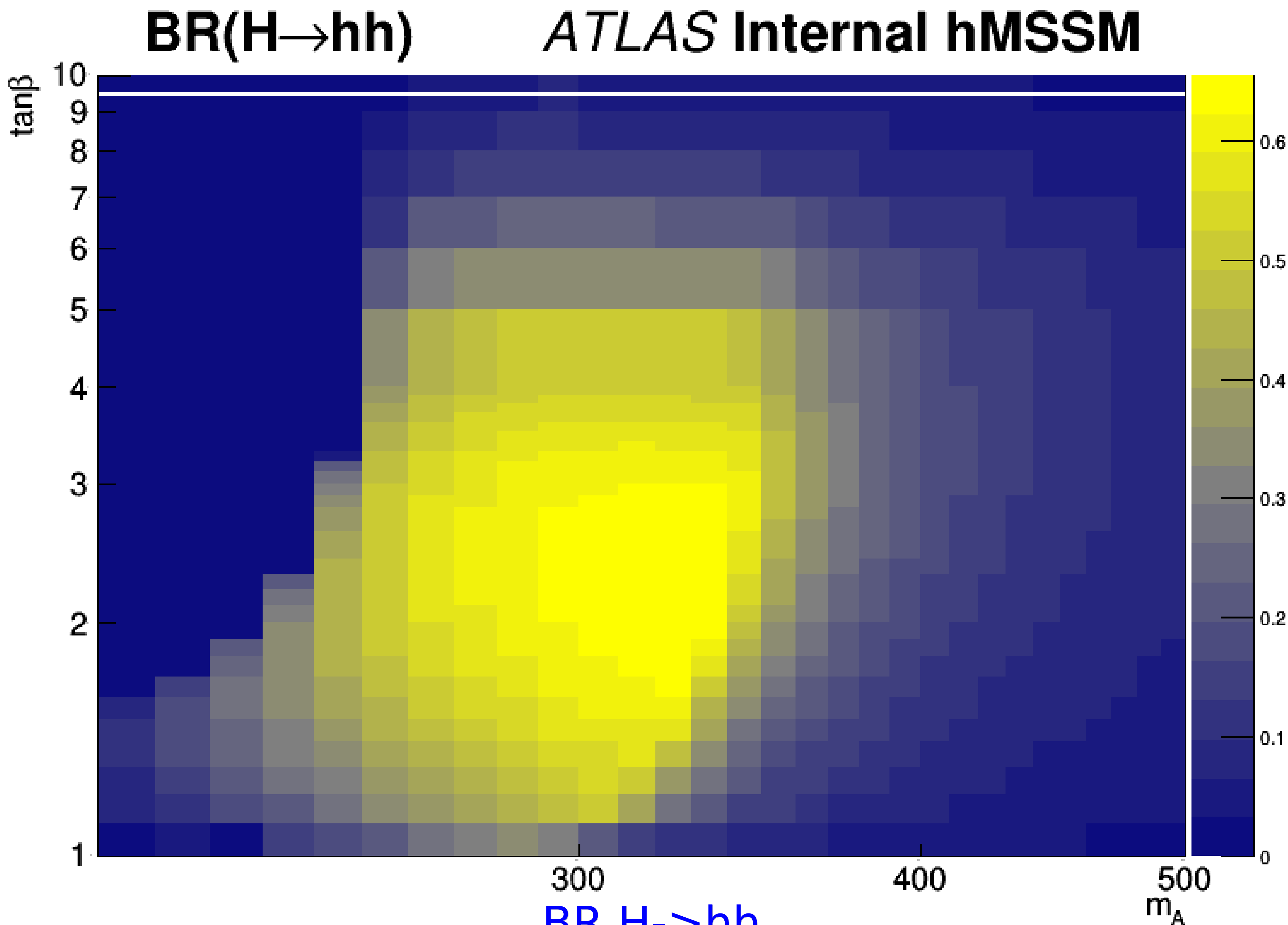




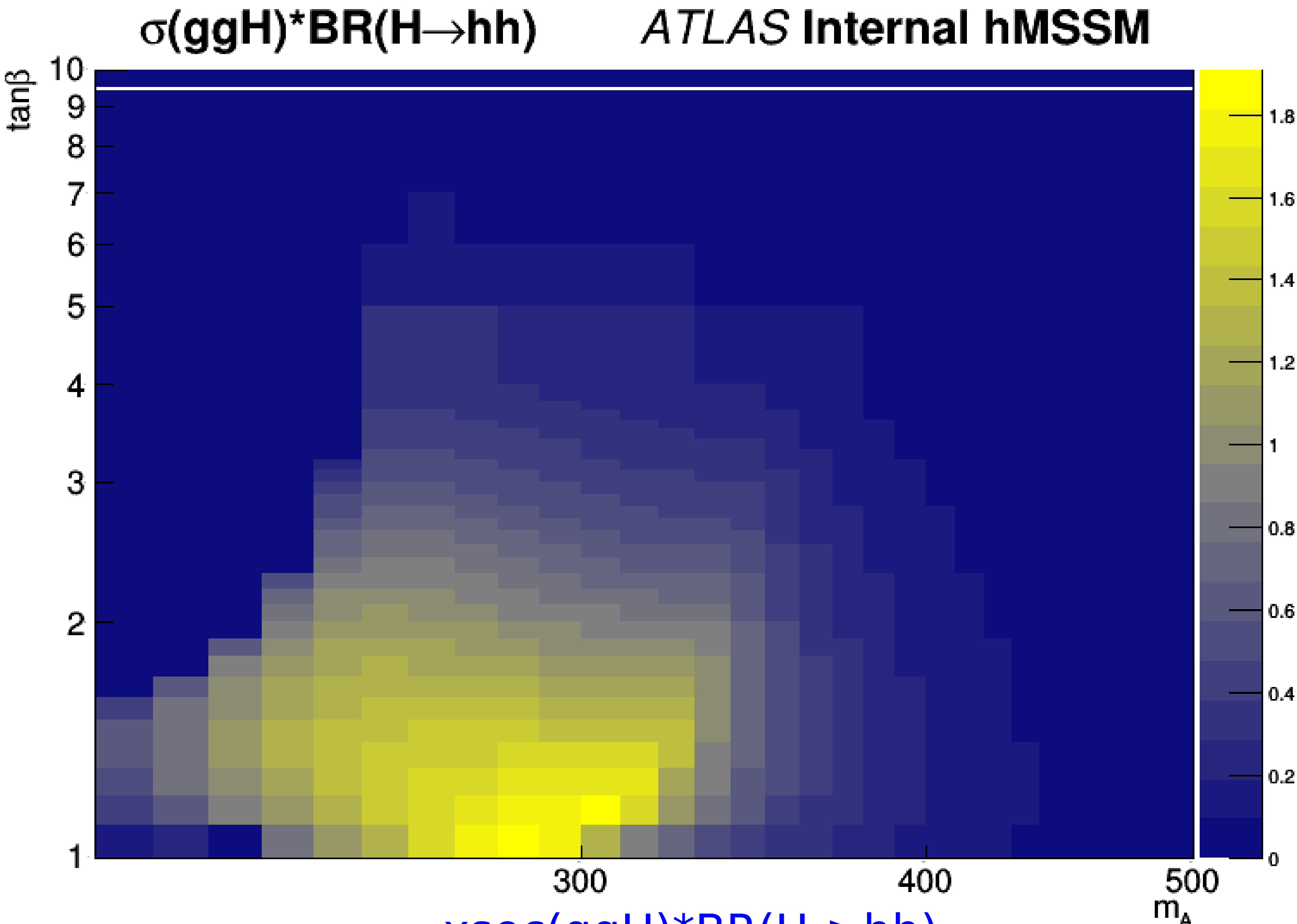
Approximately we can consider BR independent on tb





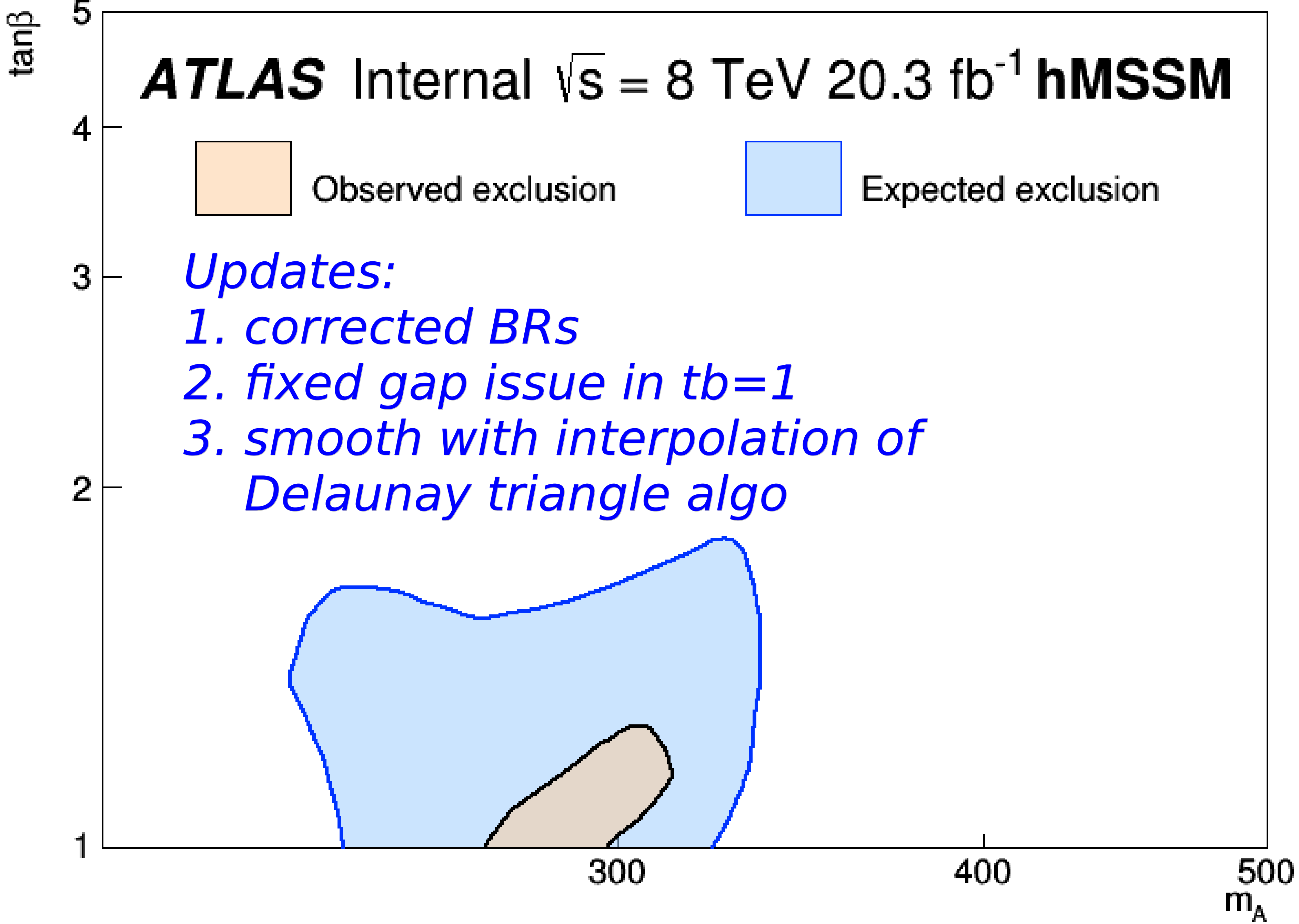

BR(H→hh)
ATLAS Internal hMSSM
tanβ
10
9
8
7
6
5
4
3
2
1
300
400
500
m_A
0.6
0.5
0.4
0.3
0.2
0.1
0

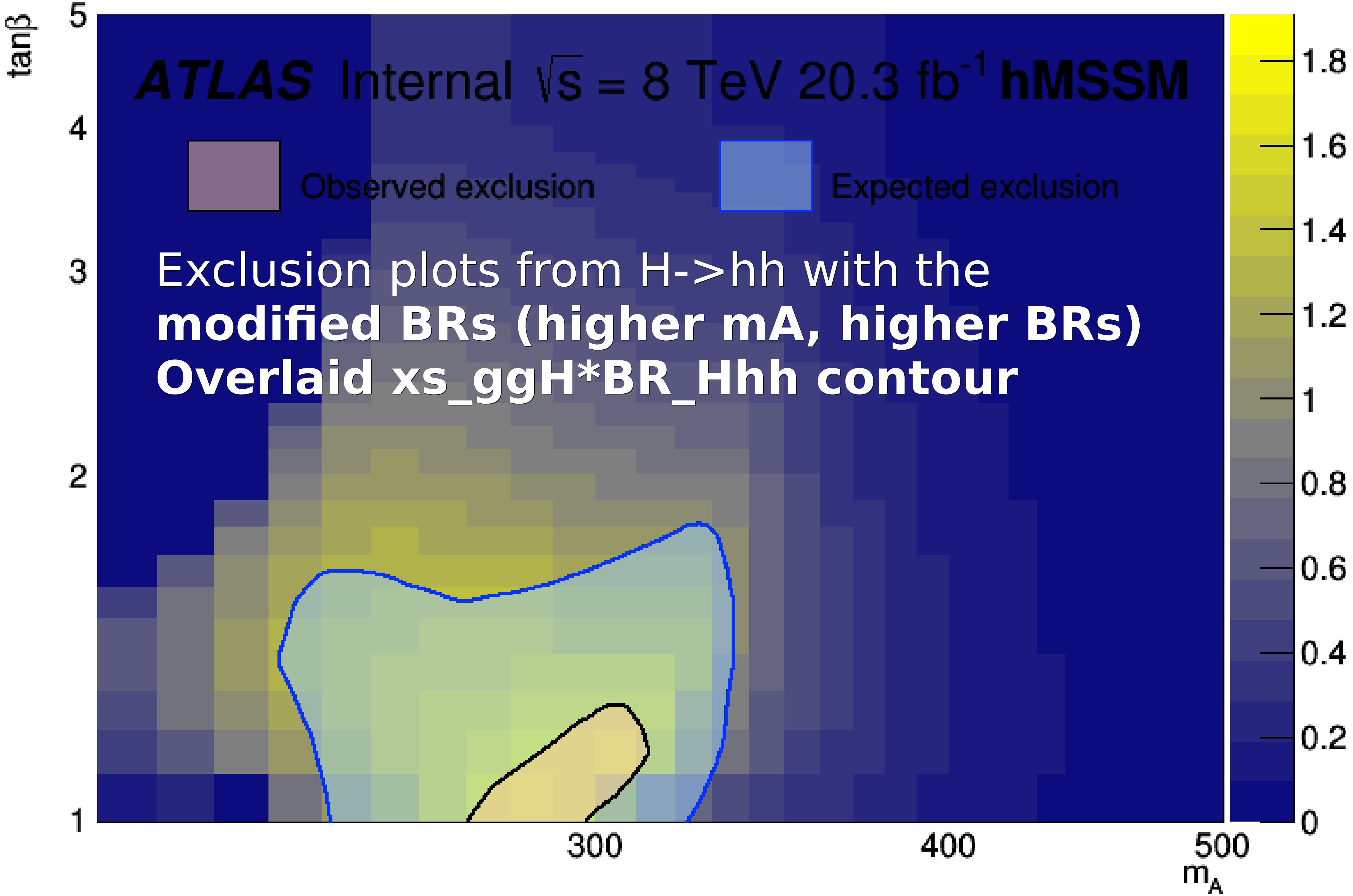
BR H->hh



xsec(ggH)*BR(H->hh)

In SVN paper draft




ATLAS Internal √s = 8 TeV 20.3 fb-1 hMSSM
Observed exclusion
Expected exclusion
Exclusion plots from H->hh with the
modified BRs (higher mA, higher BRs)
Overlaid xs_ggH*BR_Hhh contour
tanβ
1
2
3
4
5
300
400
500
mA
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8

hMSSM – BR rescales

- Parametrization grid definition on mH,BRs

	260	300	350	400	500	800/1000
BR(yy)	0.6	0.7	0.8	0.8	0.9	1.0
BR(ww)	0.6	0.7	0.8	0.8	0.9	0.9
BR(bb)	1.2	1.2	1.2	1.1	1.1	1.0
BR(tautau)	1.2	1.2	1.2	1.1	1.1	1.0

* rounding to 0.1

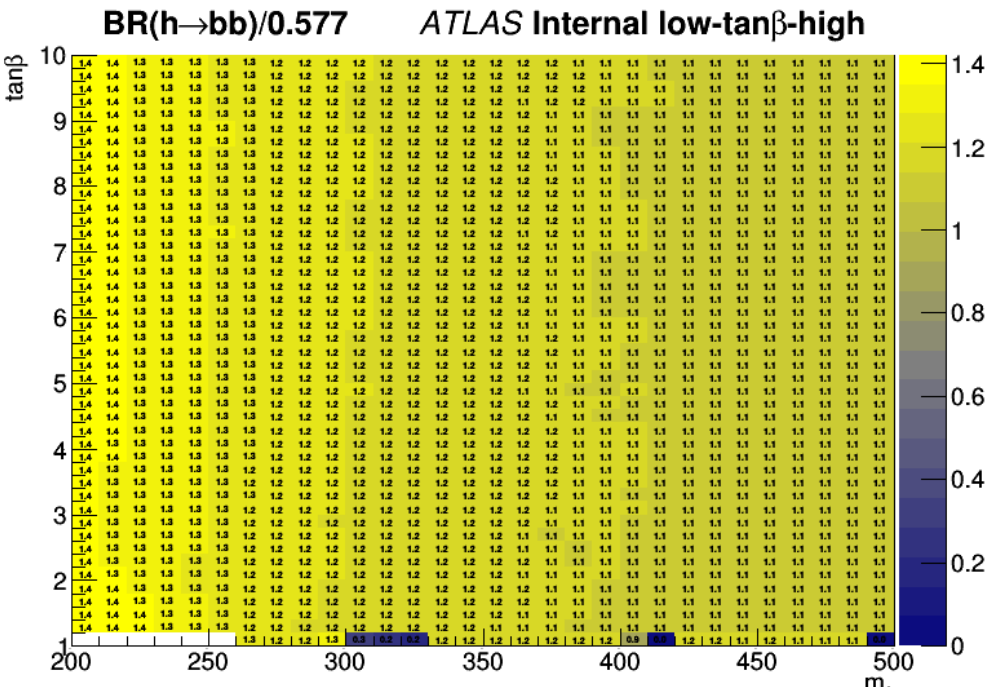
hMSSM – channel rescales

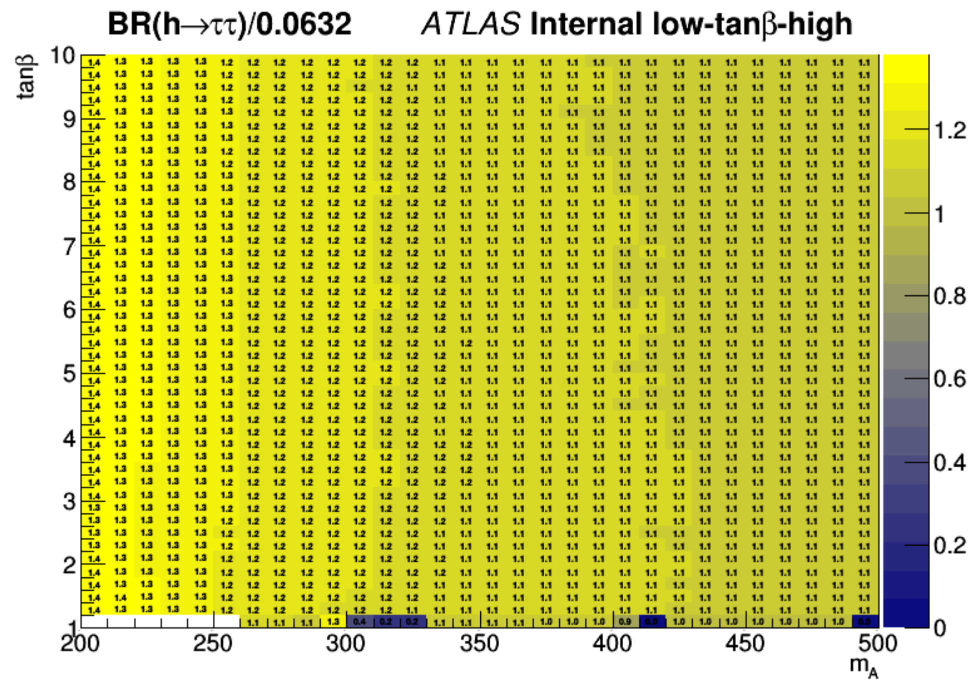
- translate BR rescales into channel rescales

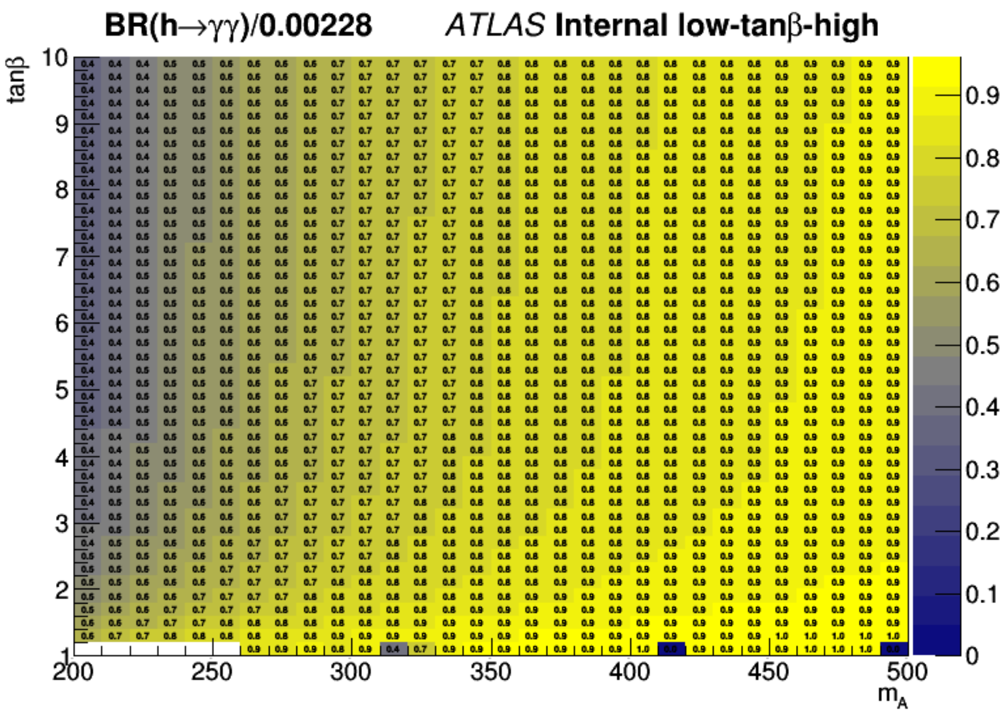
	260	300	350	400	500	800/1000
bbyy	**0.72**	**0.84**	**0.96**	**0.88**	**0.99**	**-**
wwyy	**0.36**	**0.49**	**0.64**	**0.64**	**0.81**	**-**
bbtautau	**1.44**	**1.44**	**1.44**	**1.21**	**1.21**	**1.0**
bbbb	**-**	**-**	**-**	**-**	**1.21**	**1.0**

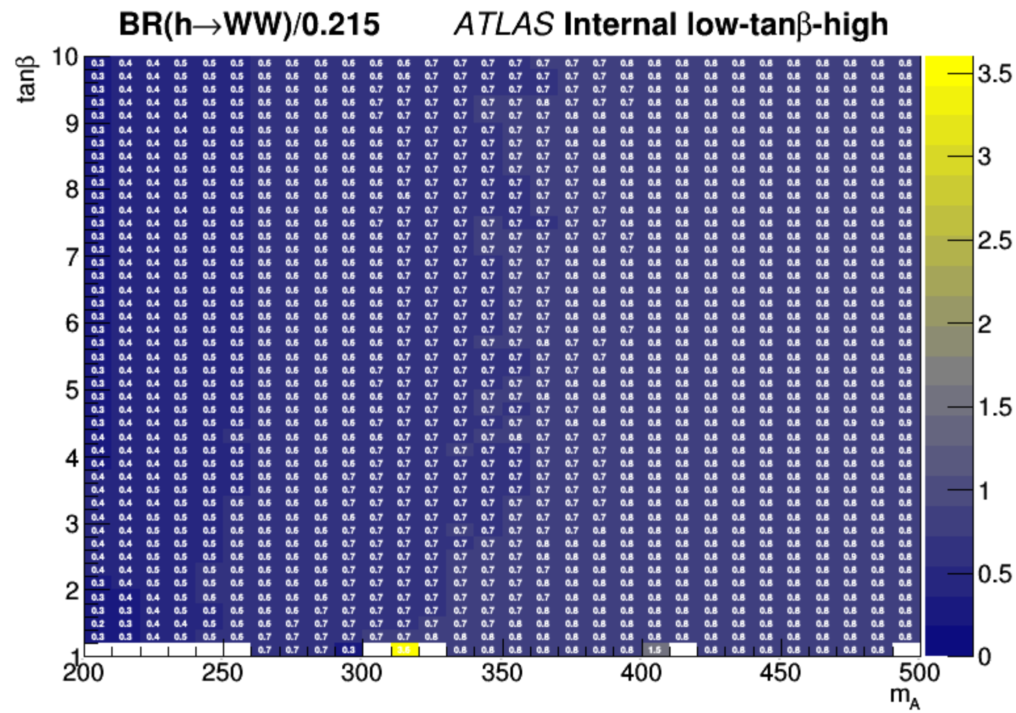
low-tb-high

- BR map in plain files from Sven
  - tb~1, numeric instability, missing points;
  - inspired by Nikos, ask Sven to run the calculation with tb=1.01;
  - merged into the map file
- Similarly, we do the parametrization on limit by mH and group of fixed Brs(h-bb/tt/ww/yy)
- Using the same BRs configuration as **hMSSM**, since the BRs are quite similar
- Actually low-tb-high BRs seem to be a bit higher, so using hMSSM BRs is conservative in limits

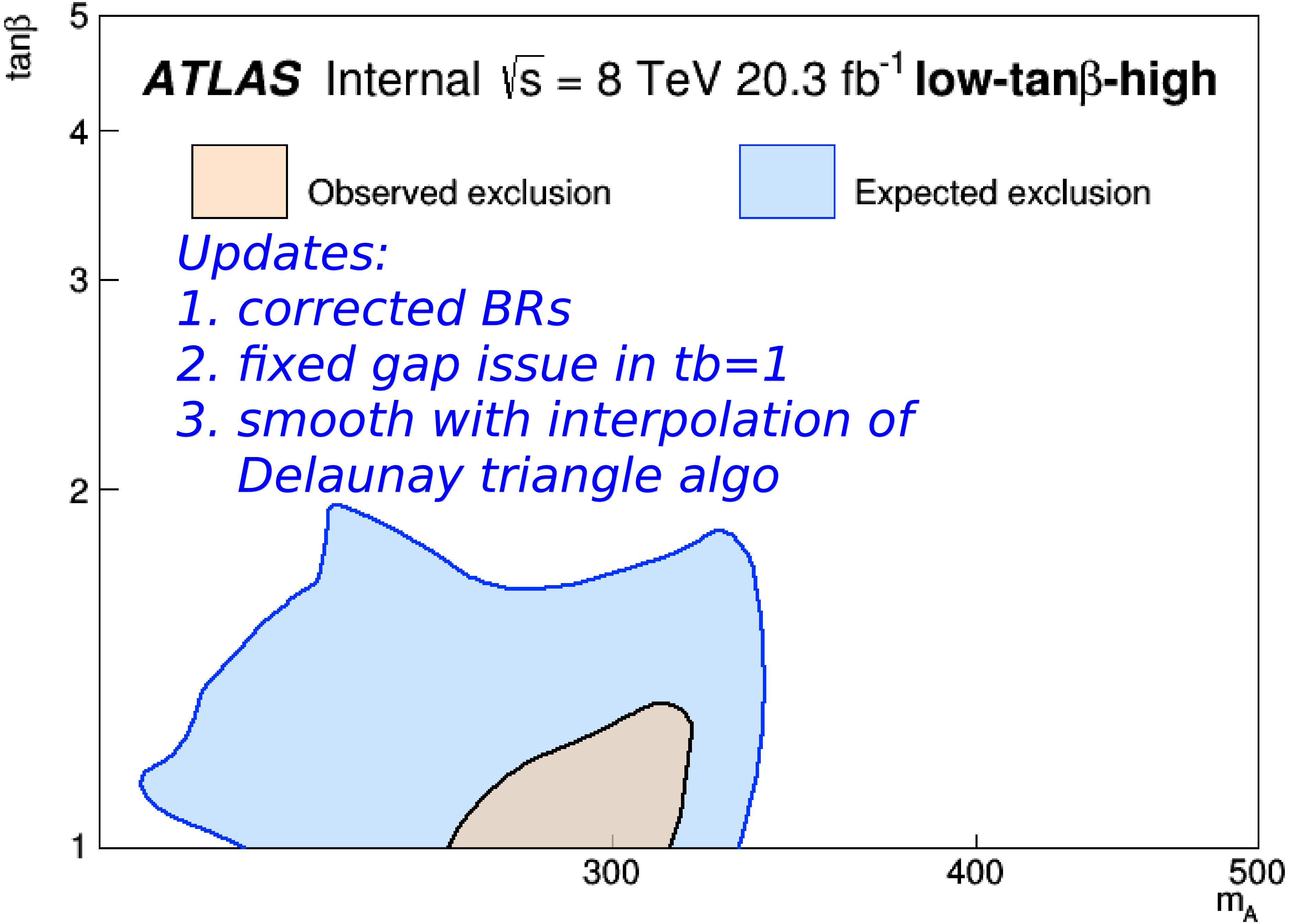




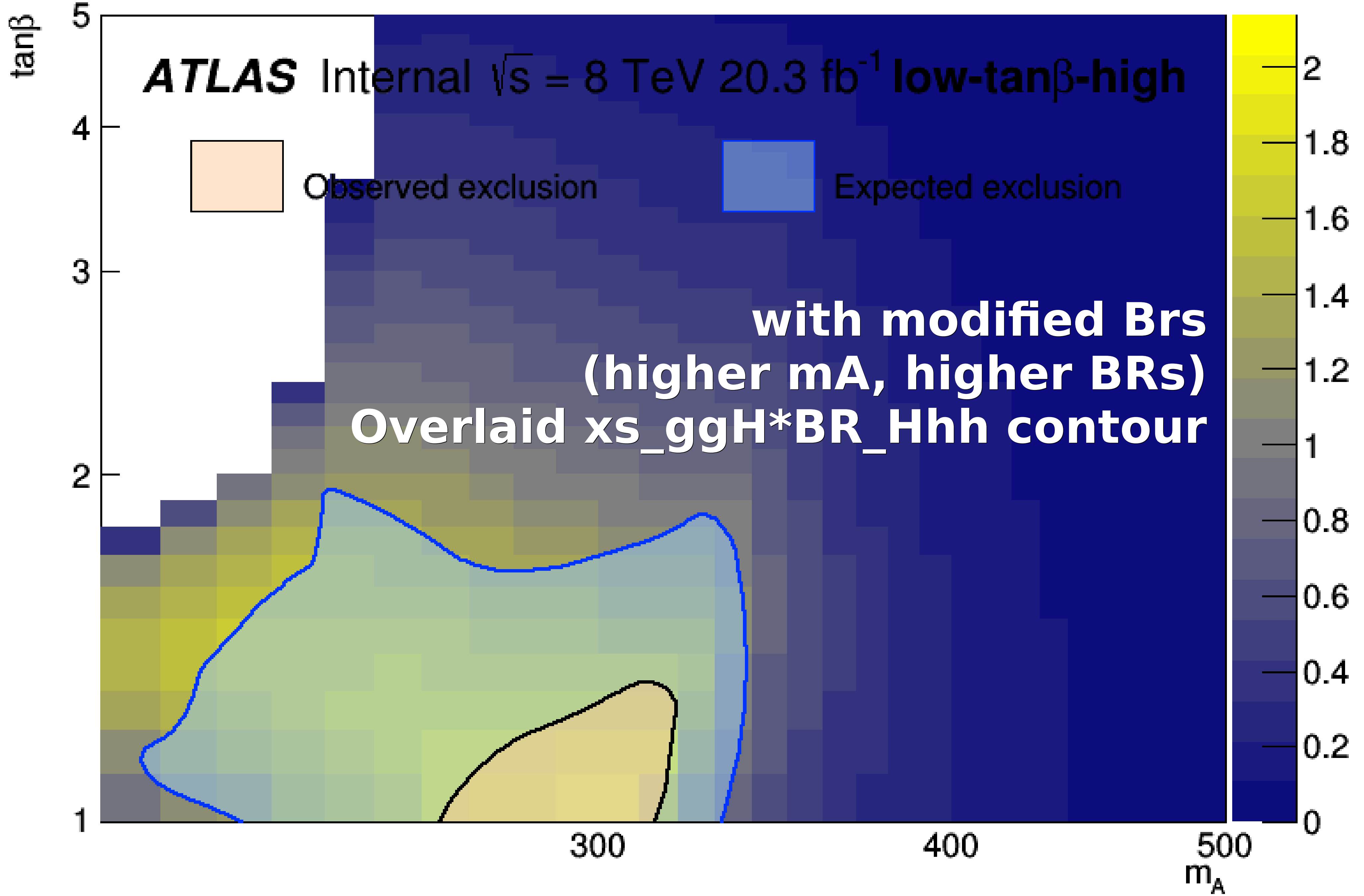




30% variation on BR_h_bb



https://twiki.cern.ch/twiki/bin/view/LHCPhysics/HXSWG3LowTanB

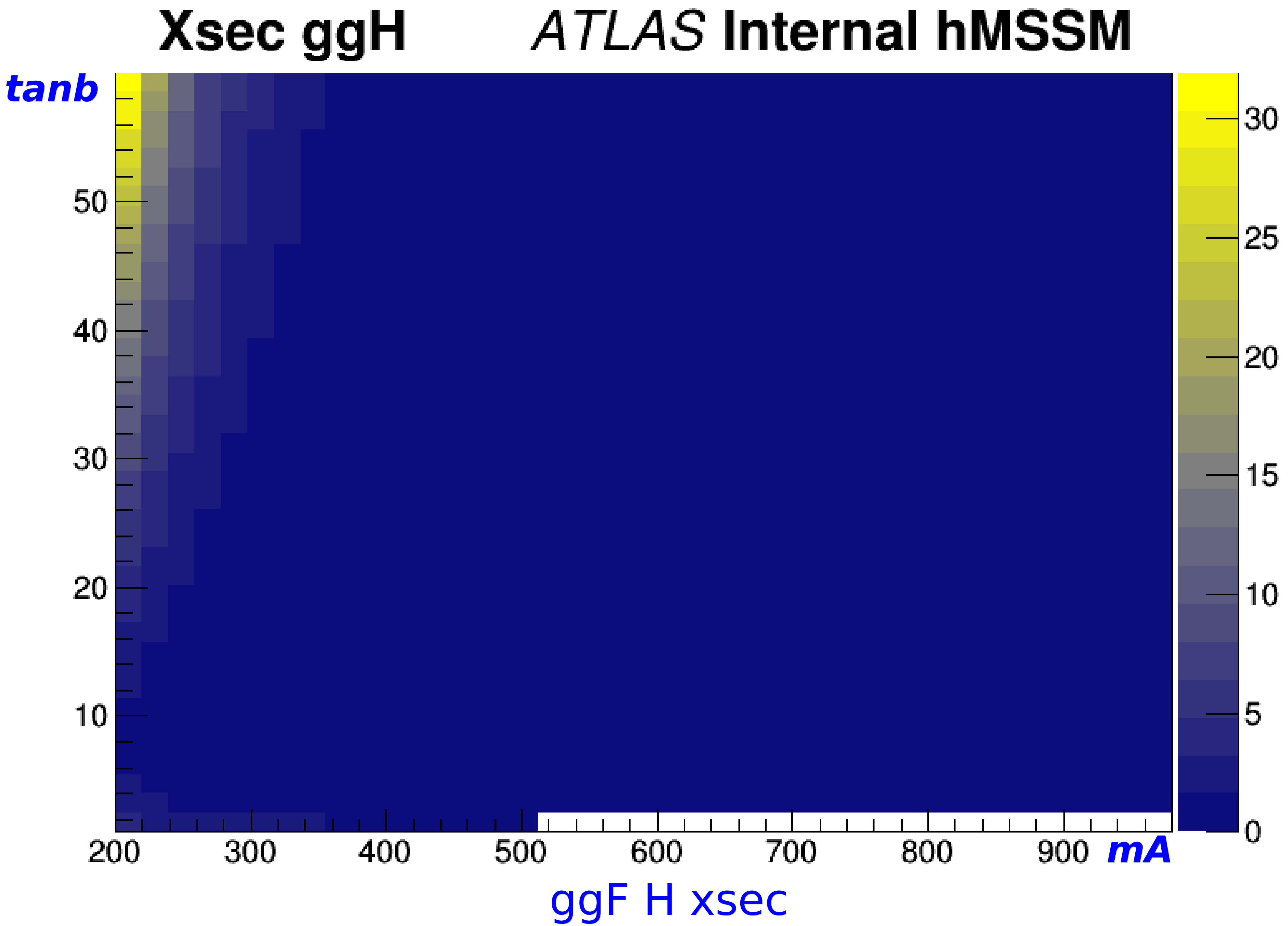


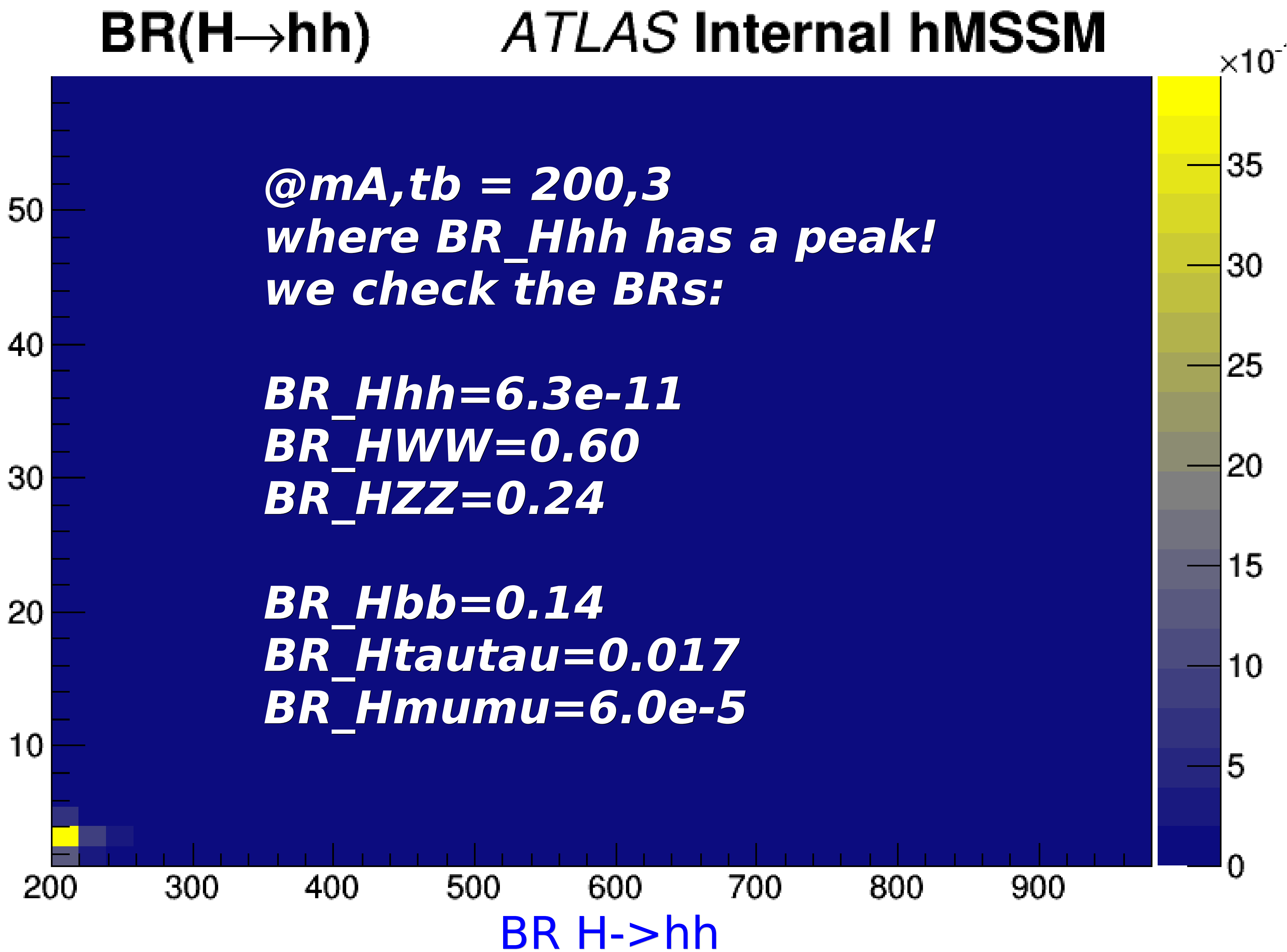
https://twiki.cern.ch/twiki/bin/view/LHCPhysics/HXSWG3LowTanB

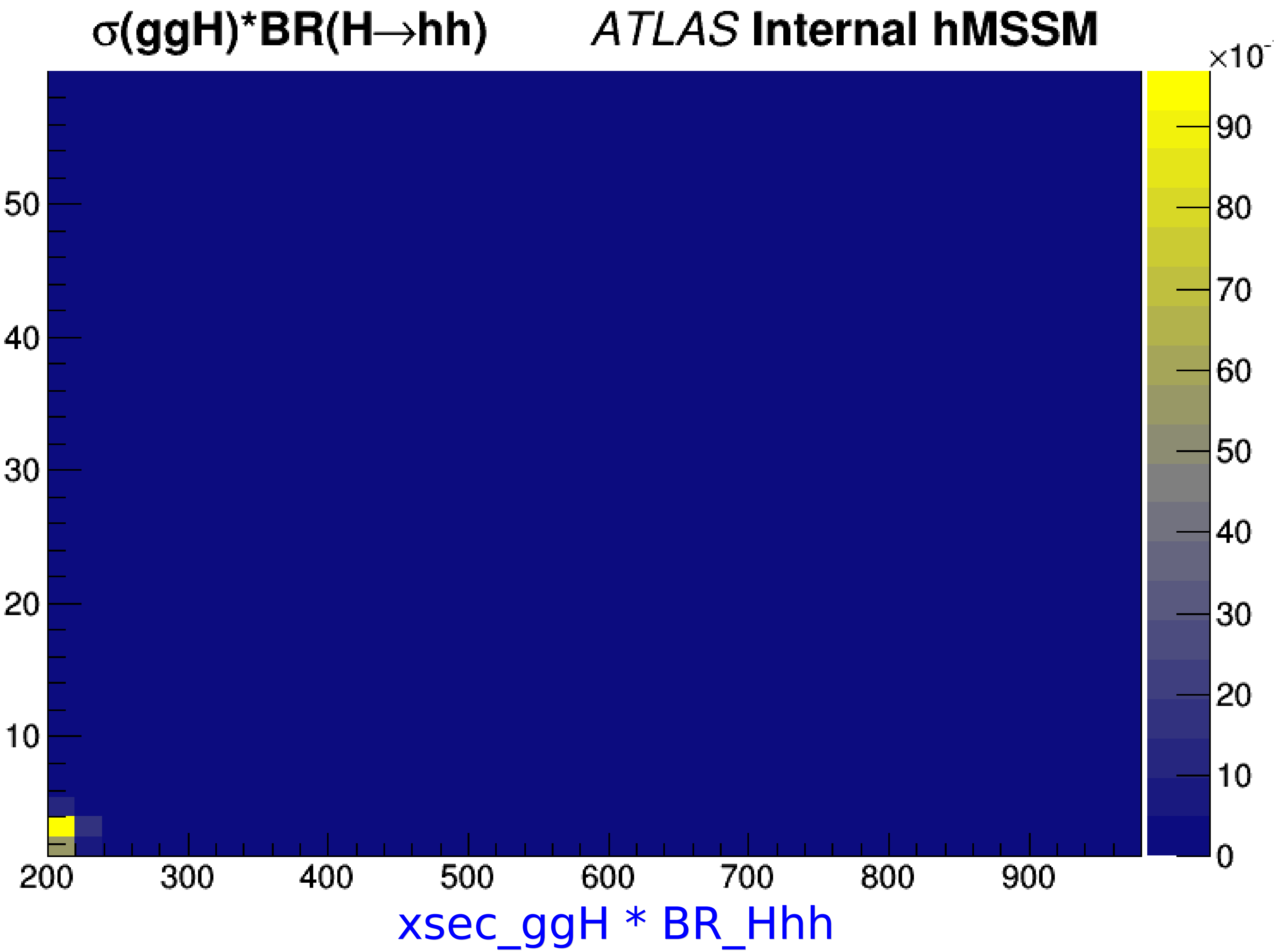
Summary

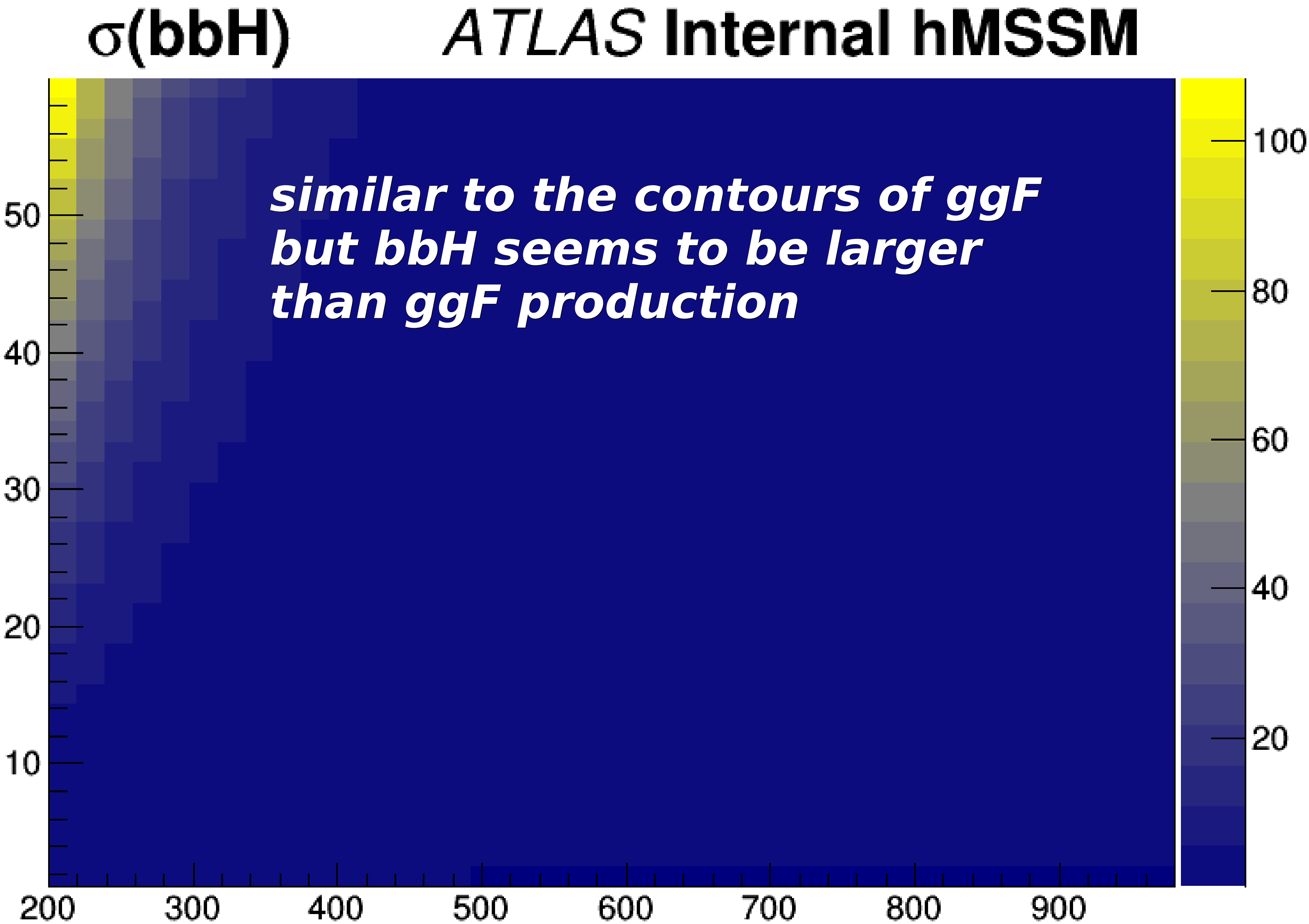
- Reminder: **1.2M** events, for signal **theoretical** uncertainty estimation
- Uncertainty table with **symmetrized** errors; 1pb injected asimov data is used; in general, uncertainties decrease along mass
- **hMSSM & low-tanb-high**, updated with smoother graphs and corrected BRs, already in SVN draft in svn

backup

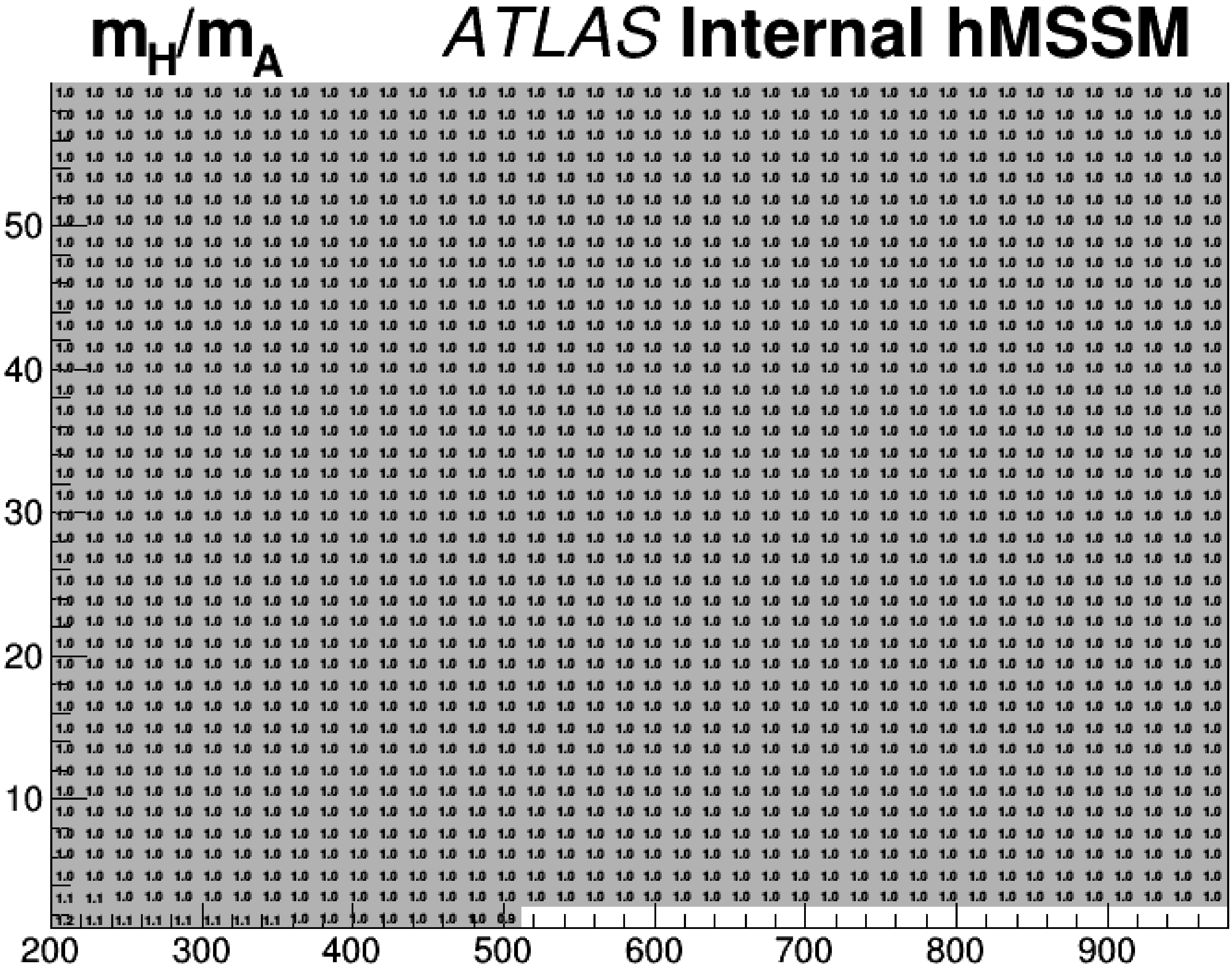

Xsec ggH
ATLAS Internal hMSSM
tanb
50
40
30
20
10
200
300
400
500
600
700
800
900
mA
30
25
20
15
10
5
0
ggF H xsec


BR(H→hh)
ATLAS Internal hMSSM
@mA,tb = 200,3
where BR_Hhh has a peak!
we check the BRs:
BR_Hhh=6.3e-11
BR_HWW=0.60
BR_HZZ=0.24
BR_Hbb=0.14
BR_Htautau=0.017
BR_Hmumu=6.0e-5
10
20
30
40
50
200
300
400
500
600
700
800
900
BR H->hh
×10
0
5
10
15
20
25
30
35

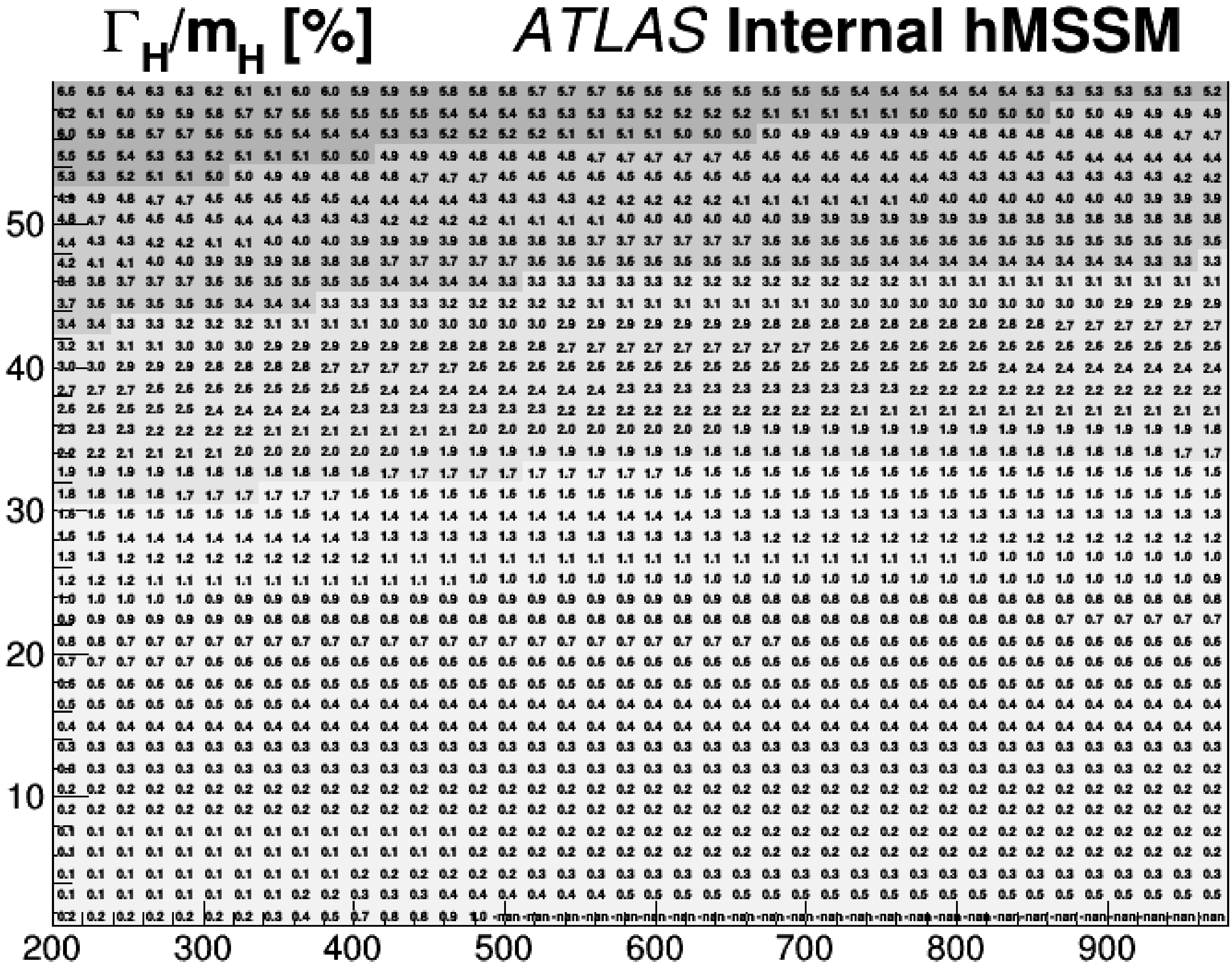

σ(ggH)*BR(H→hh)
ATLAS Internal hMSSM
50
40
30
20
10
200
300
400
500
600
700
800
900
xsec_ggH * BR_Hhh
90
80
70
60
50
40
30
20
10
0



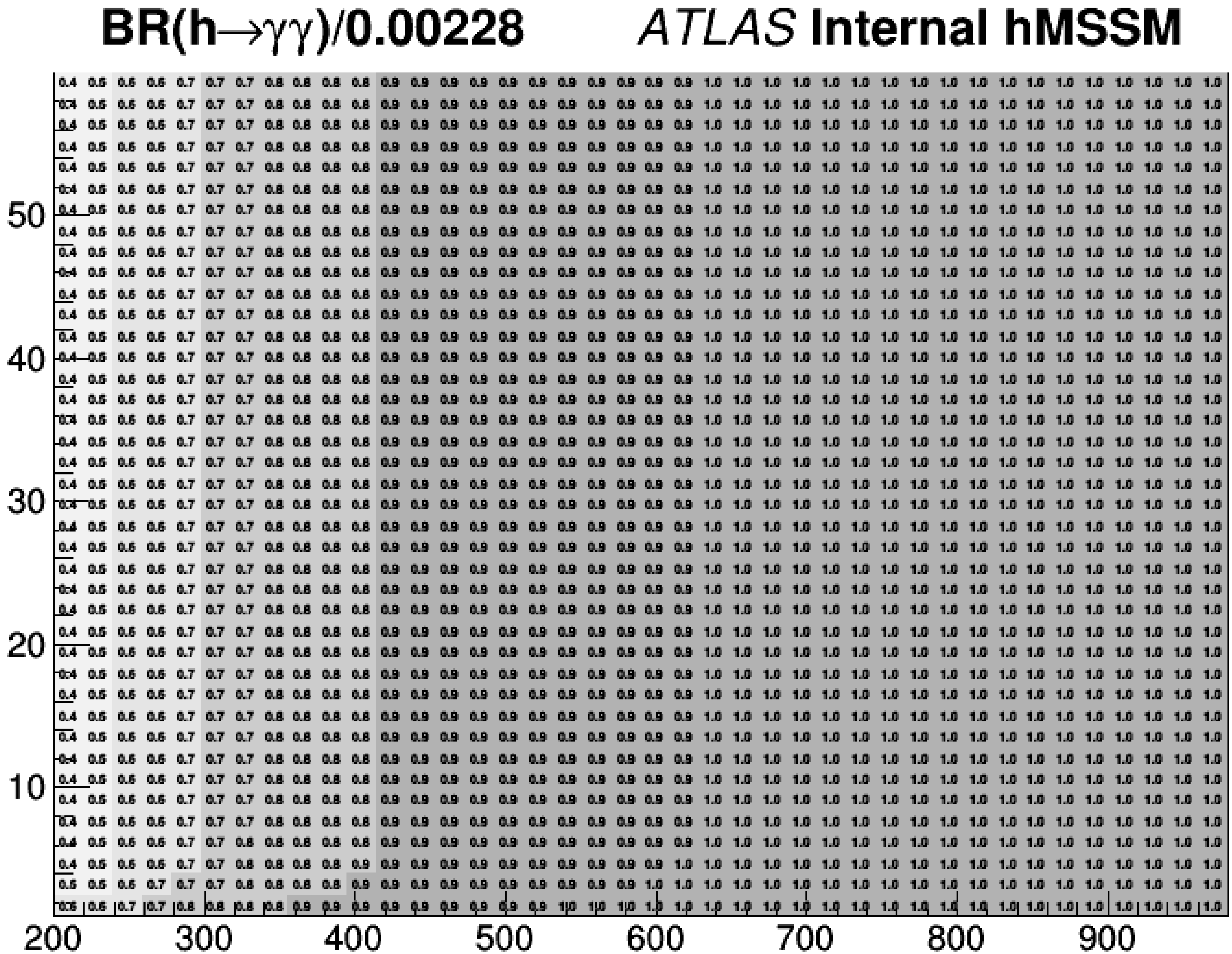
bbH production (Santander)



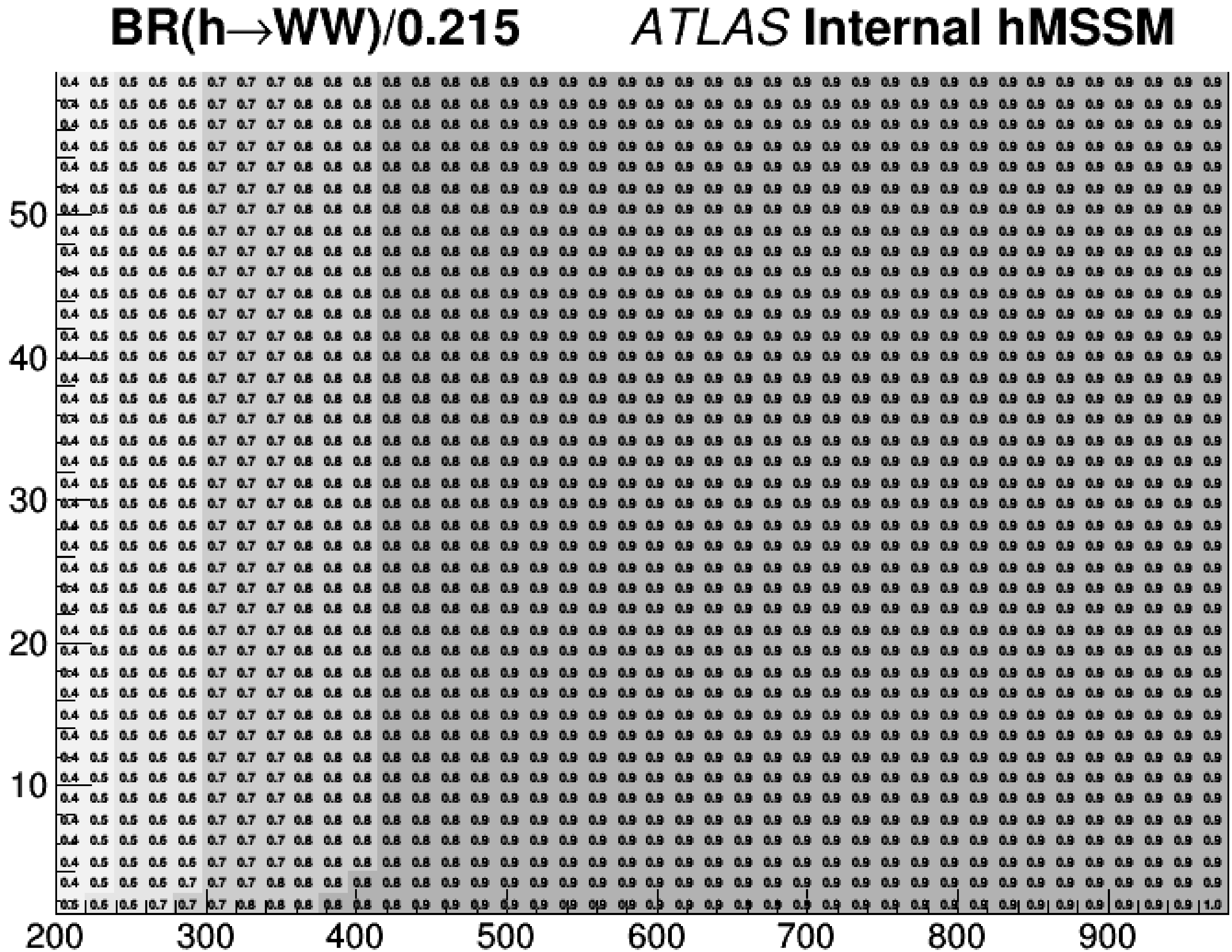
spreading around mA ~10%



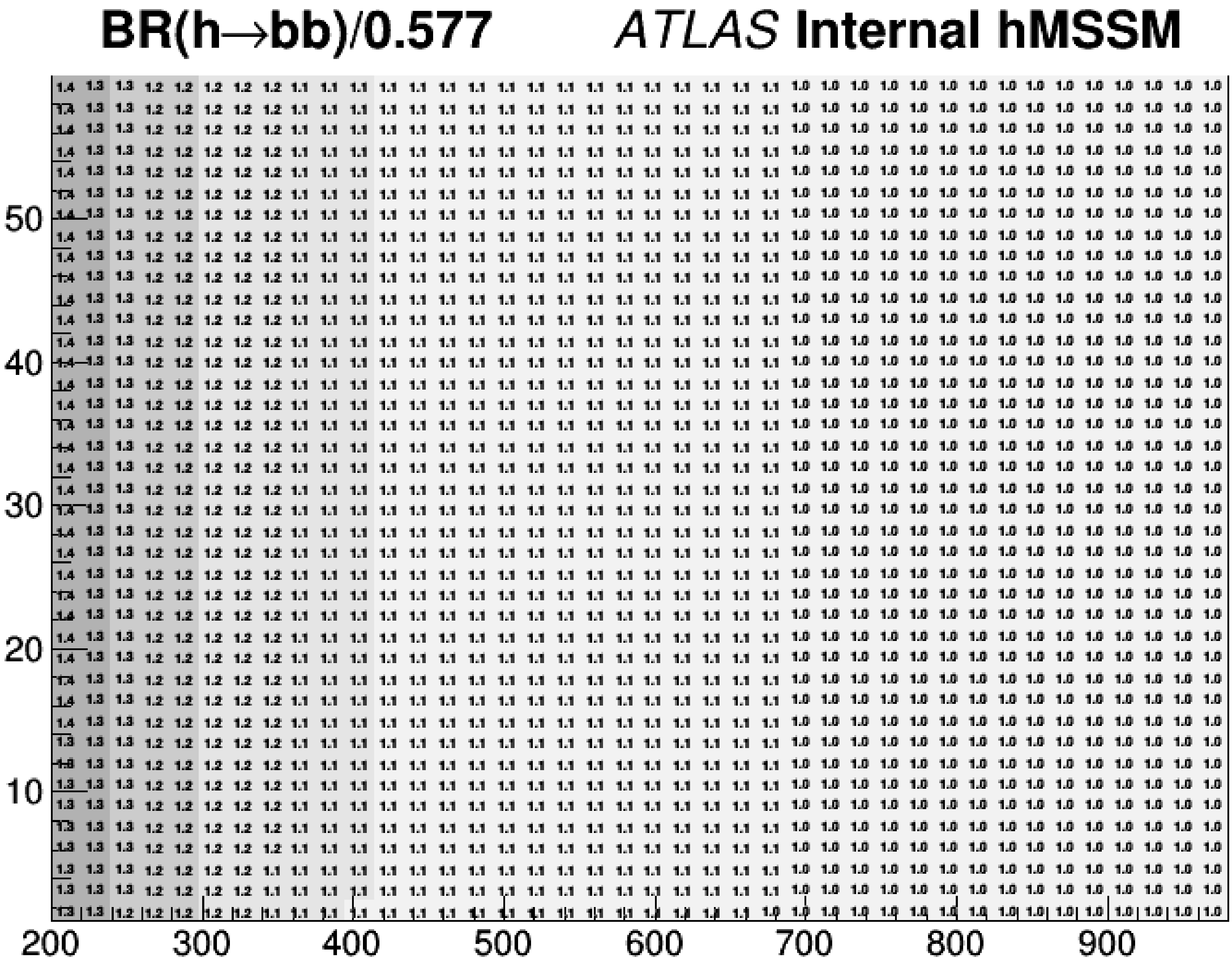
below tb=25 width<1%m(H)



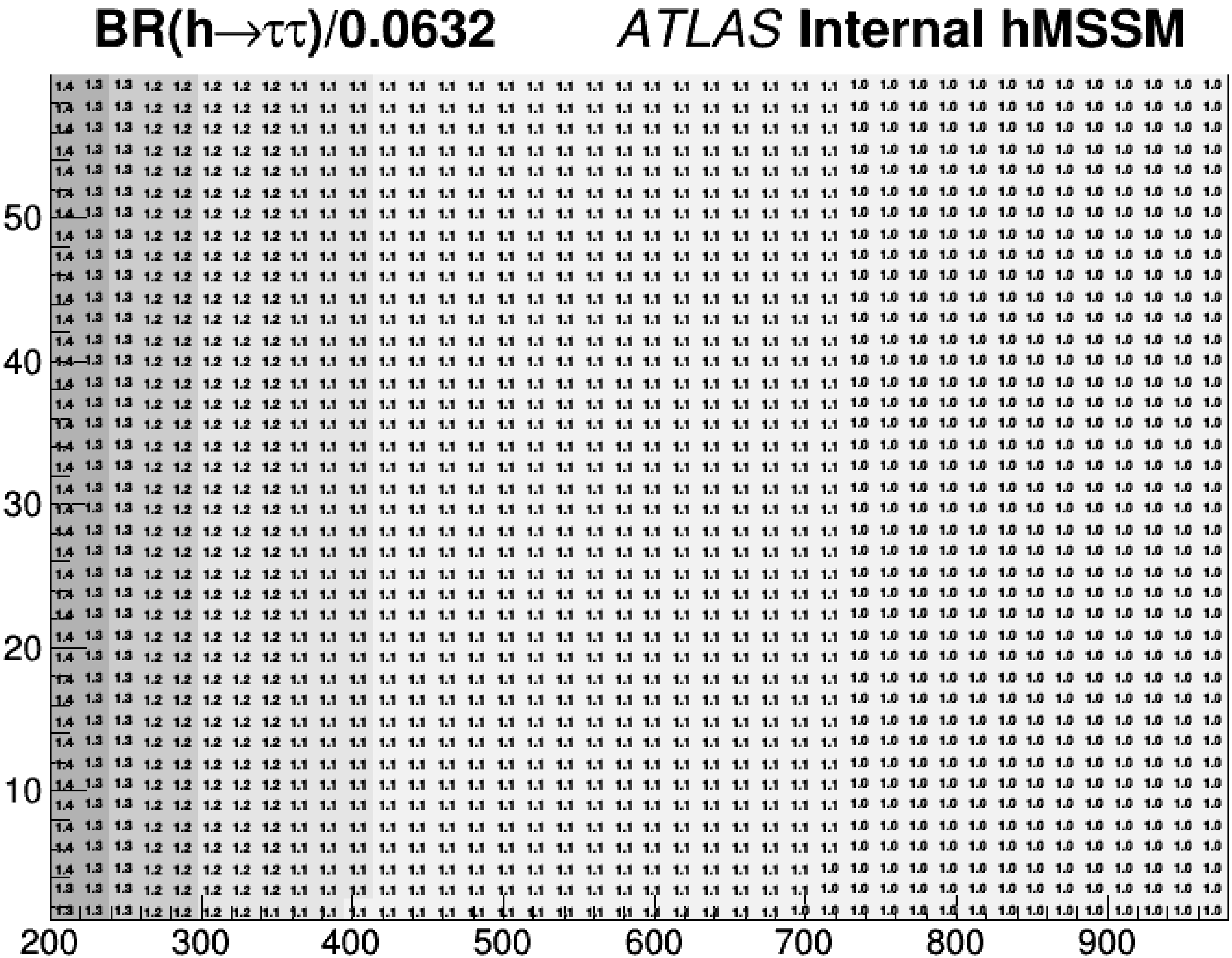
40% variations away from SM BR



50% variations away from SM BR



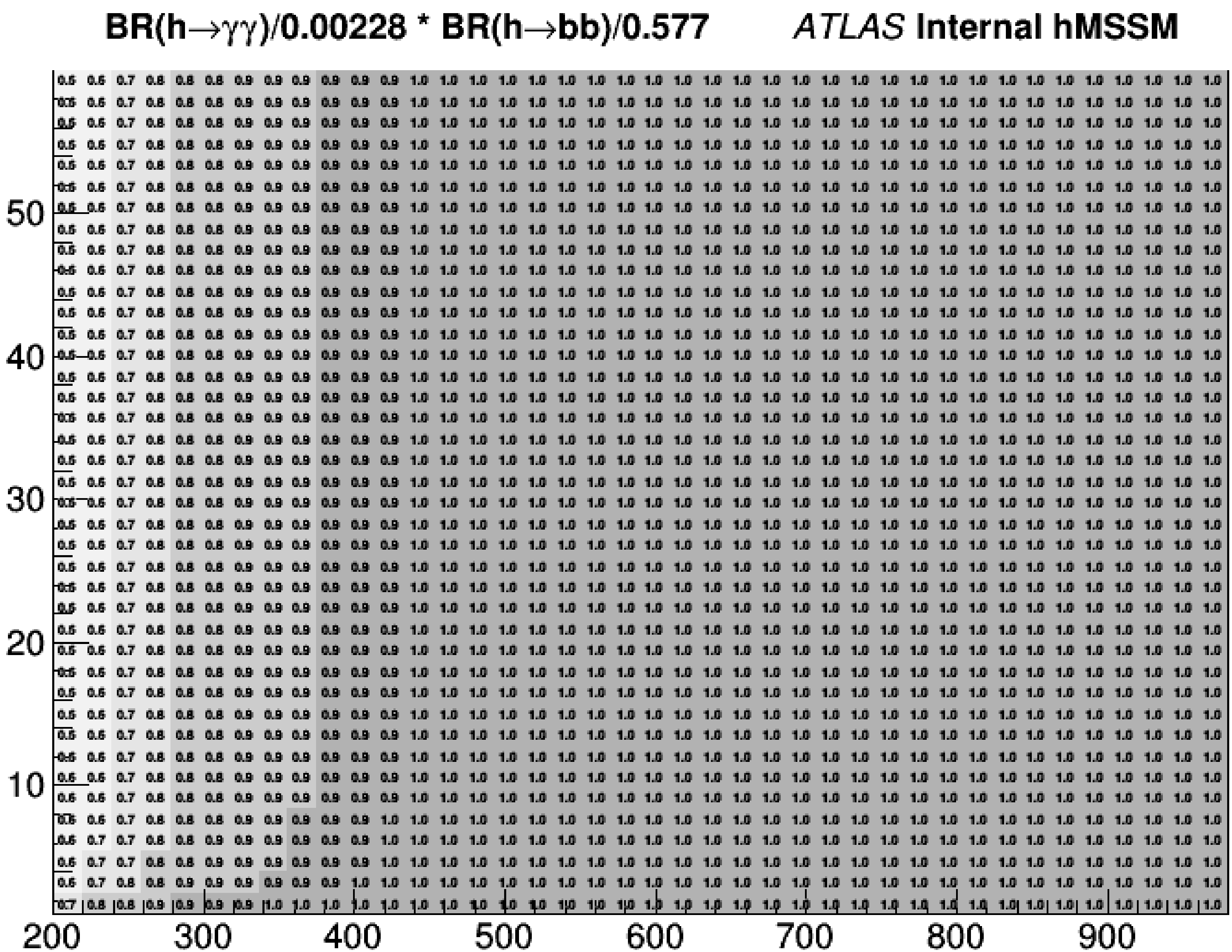
30% variations away from SM BR



30% variations away from SM BR

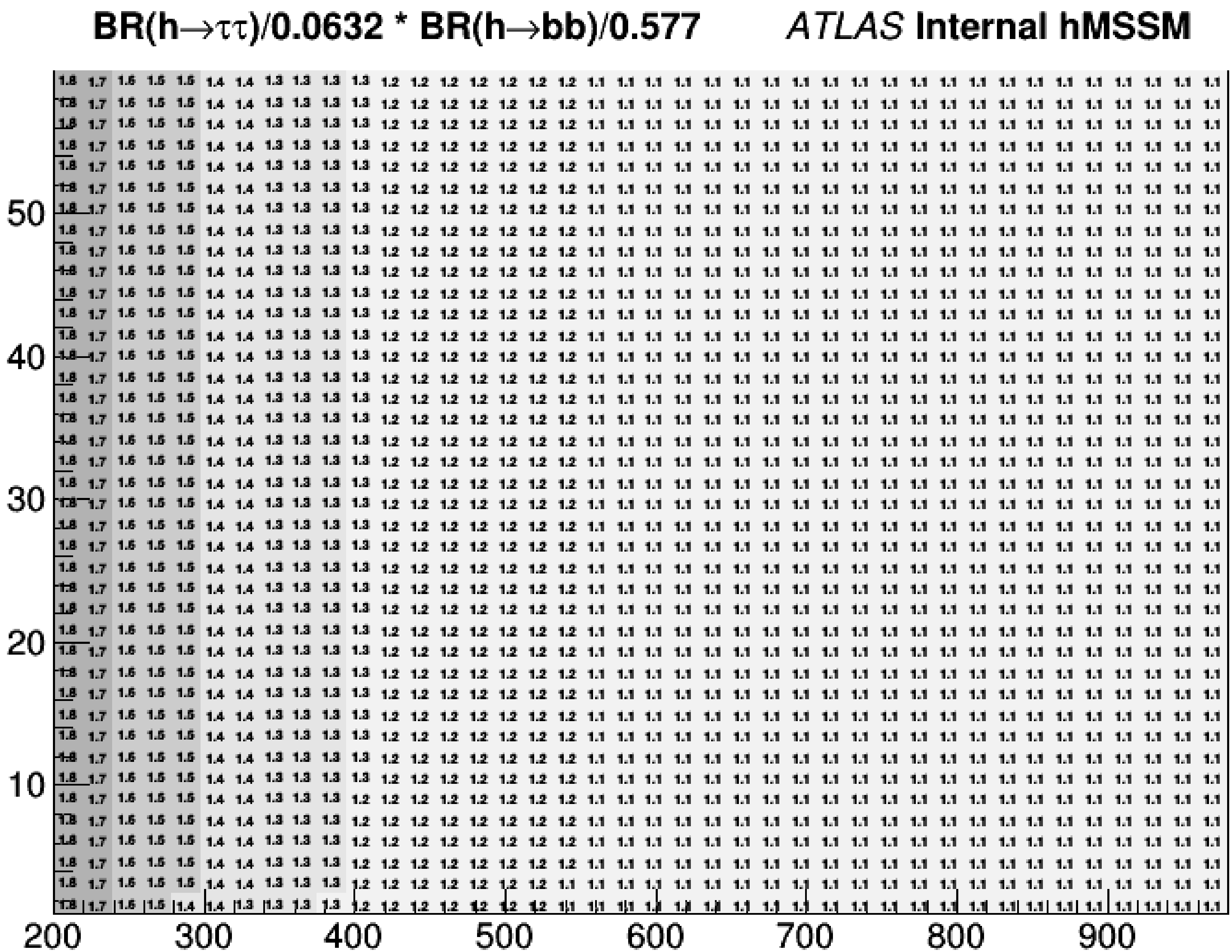
hMSSM Interpretation - **BR*BR**

- bbyy is rescaled by BR(bb)BR(yy)
- bbtautau is rescaled by BR(bb)*BR(tautau)
- wwyy is rescaled by BR(yy)BR(WW)
- bbbb is rescaled by BR(bb)^2
- these BR **products** make the rescaling in each channel **quadratically** larger/smaller
  - e.g. BR variation=30% -> limit variation=69%
- if the couplings are rescaled in the same way, the rescaling on products will be “squared”, such as hbb/htautau, hww/hyy
  - affecting channels: bbtautau, bbbb, wwyy



scales on hyy and hbb cancel

fortunately, bbyy variates < 30%

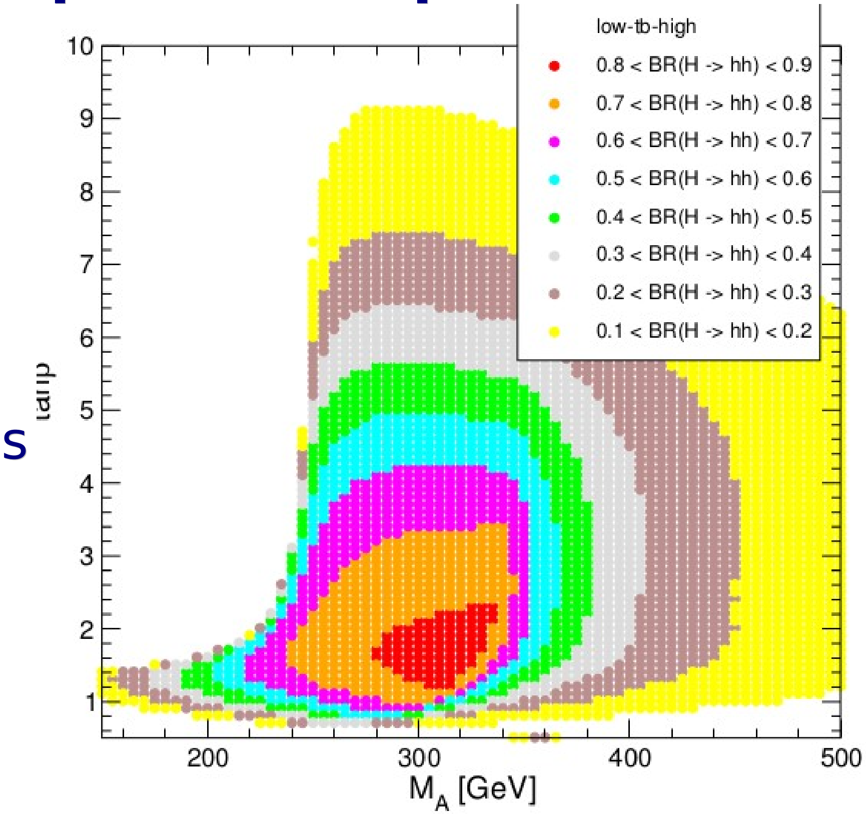


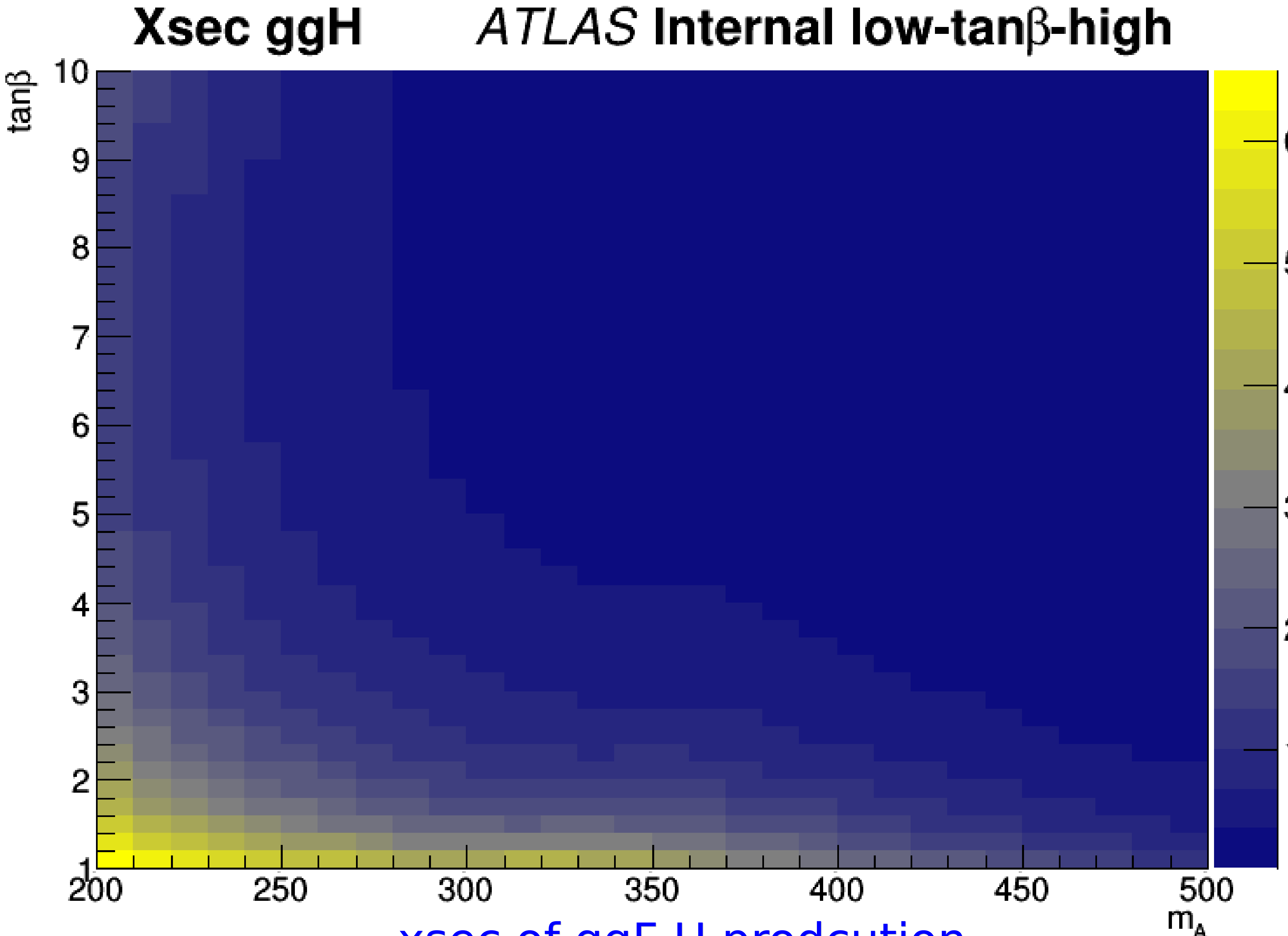
60% variation on BRtt*BRbb

low-tb-high

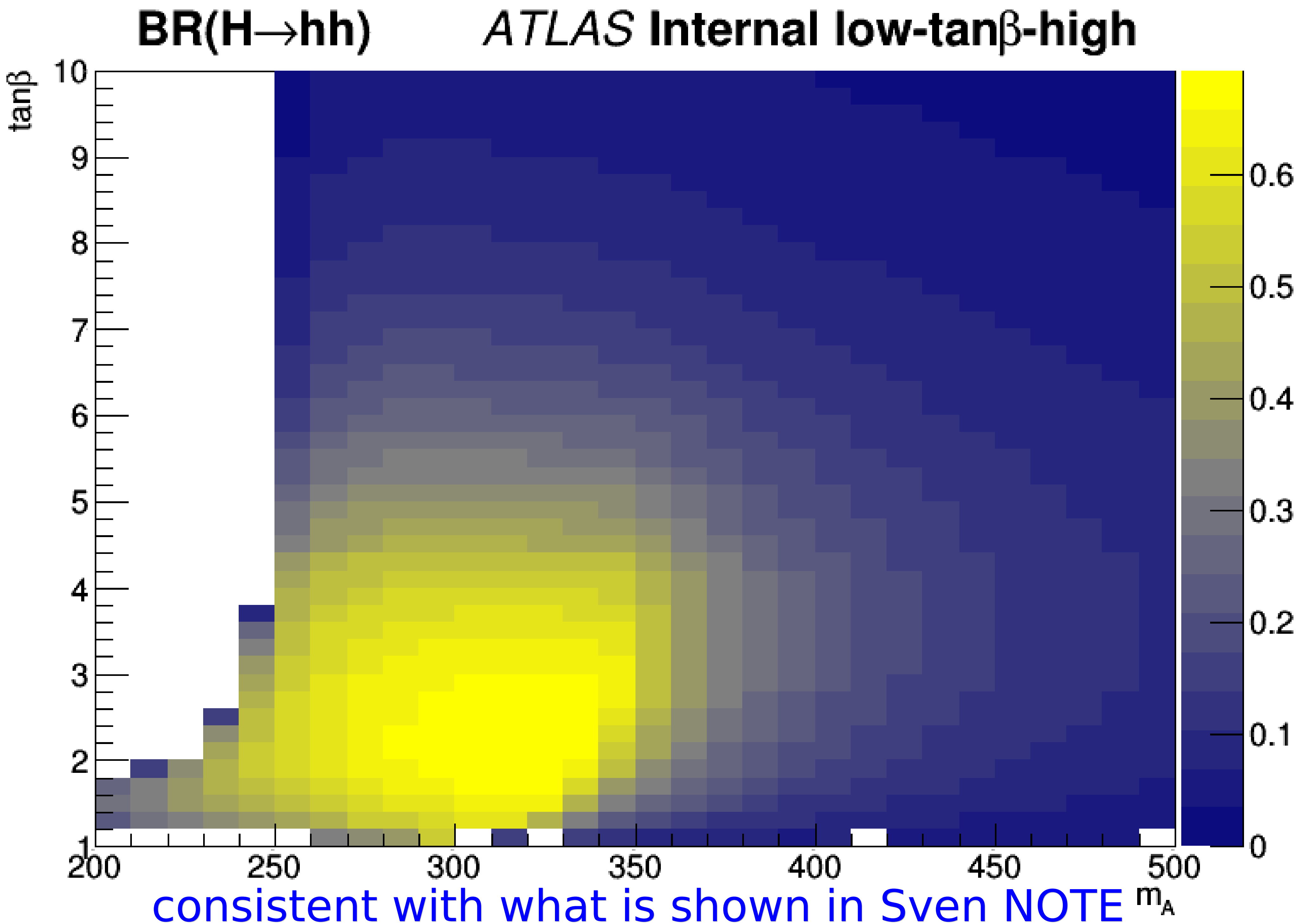
- BR map in plain files from Sven
  - some incomplete phase points in very low tanb and mA region (theoretically unstable)
  - some duplicated phase points due to technical issues
- I have stripped out all duplicated phase points and converted available points into **ntuple and map** formats

- XS map from Stefan, but the current numbers are only used for giving an idea of xs and scale uncertainties
- I have merged them into our **map** files

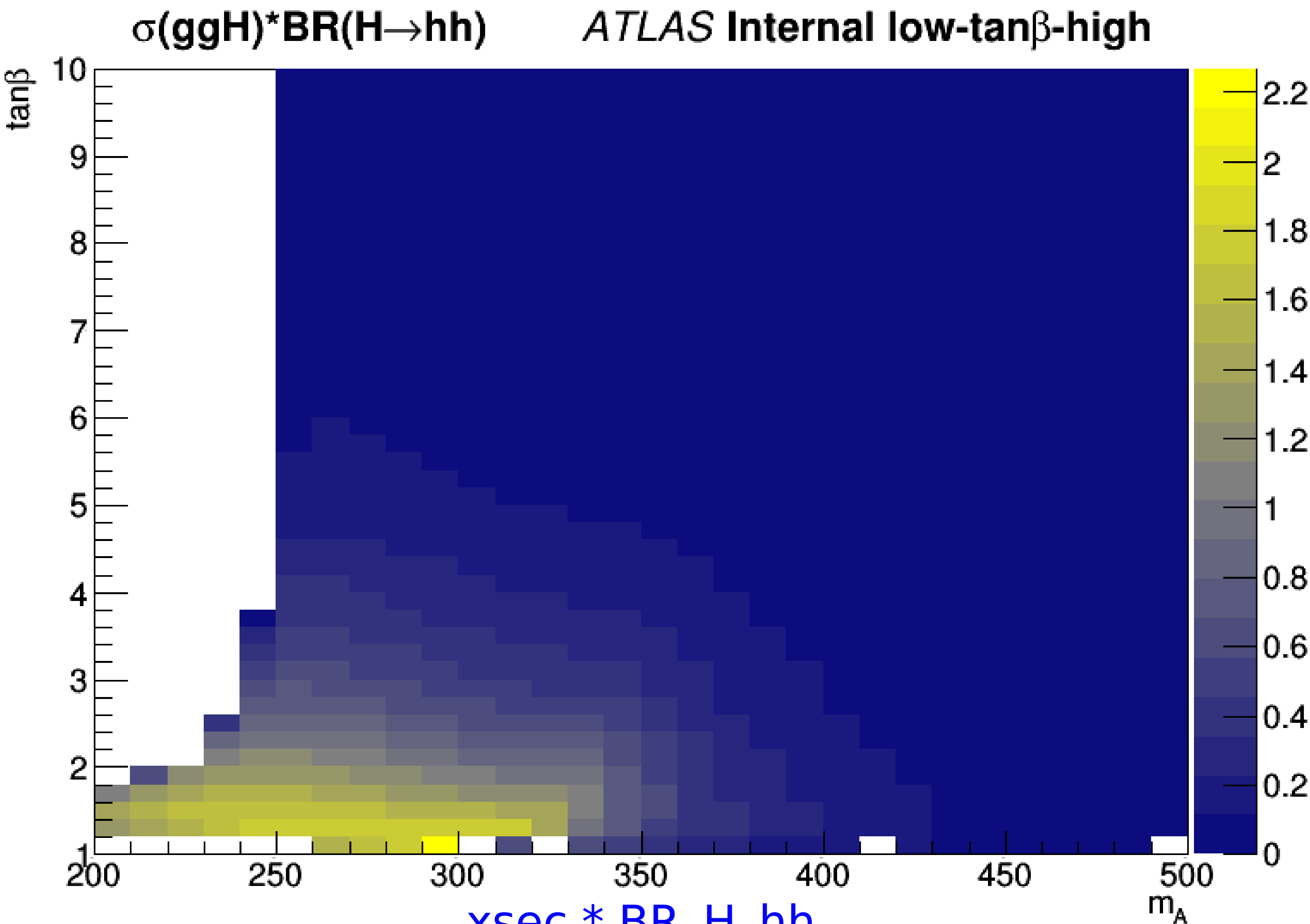




xsec of ggF H prodcution

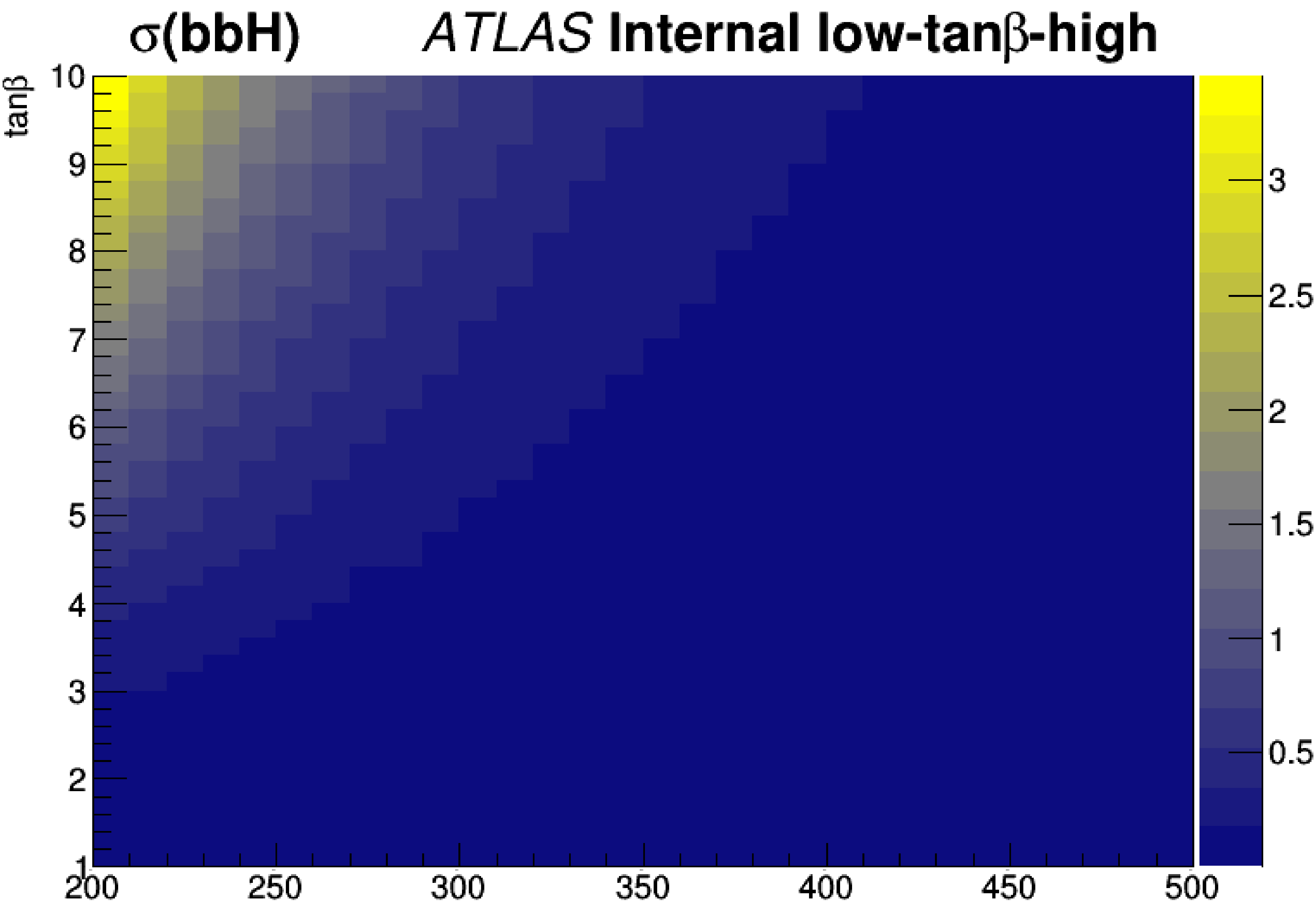


consistent with what is shown in Sven NOTE

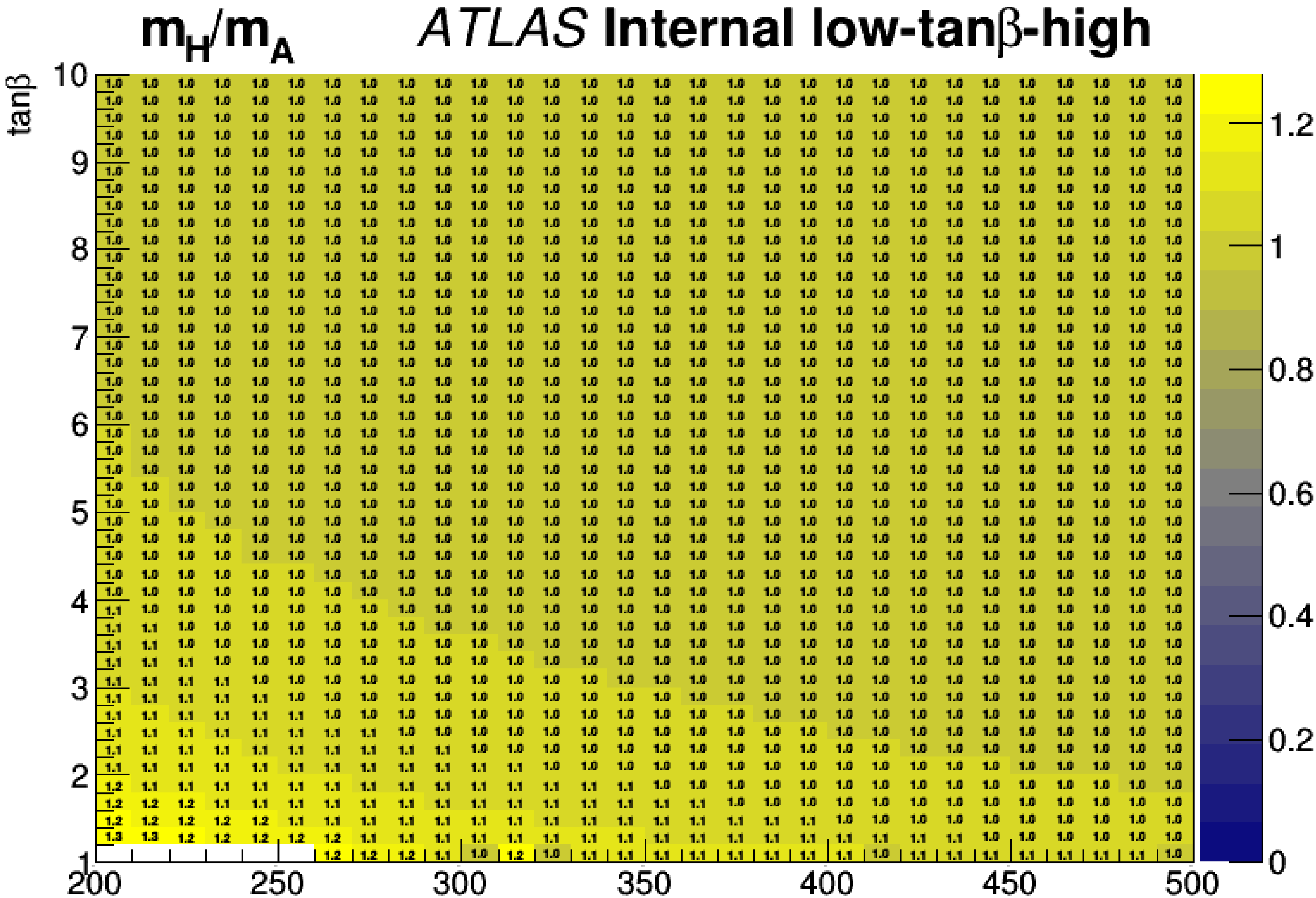


σ(ggH)*BR(H→hh)
ATLAS Internal low-tanβ-high
tanβ
10
9
8
7
6
5
4
3
2
1
200
250
300
350
400
450
500
m_A
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0

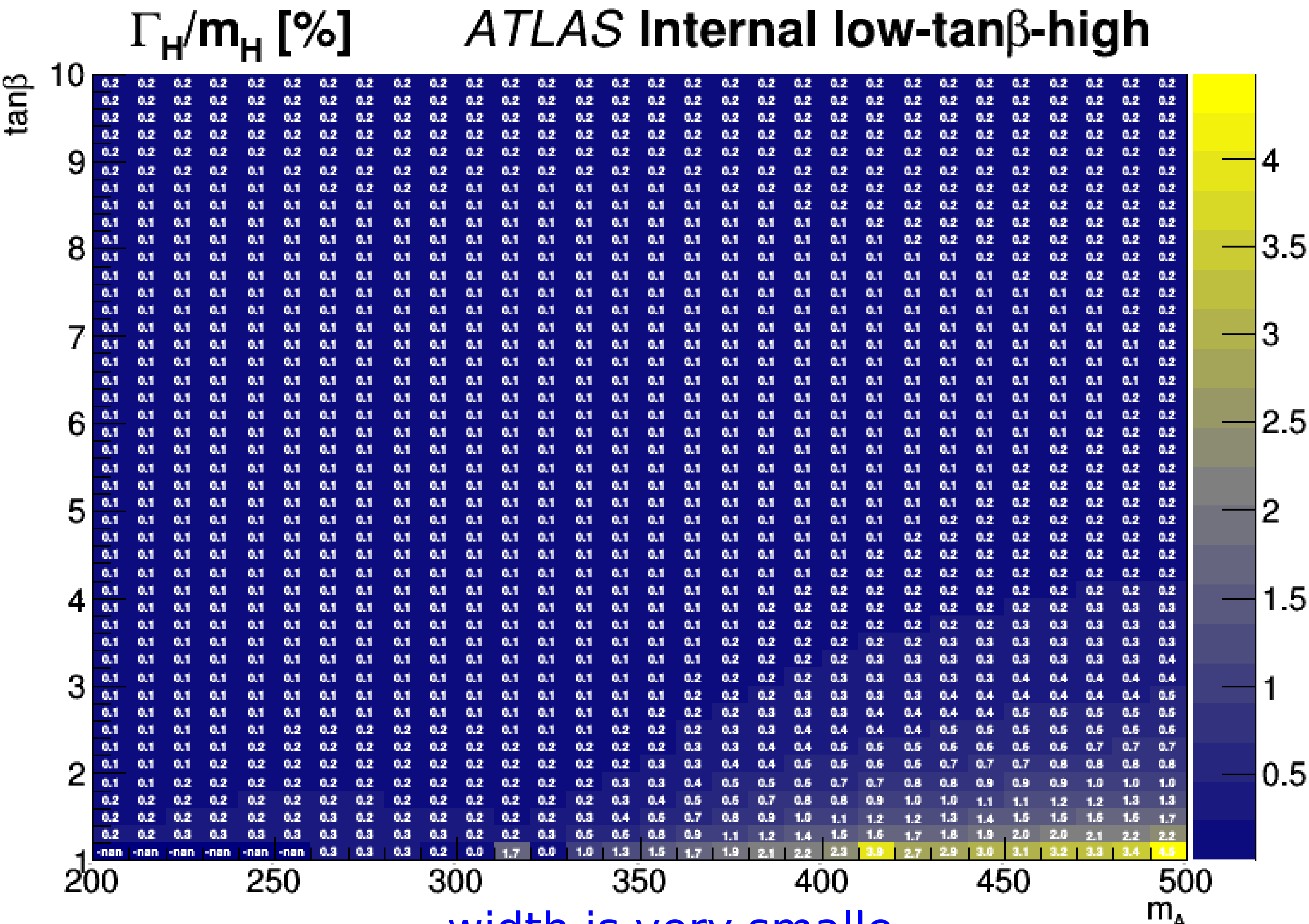
xsec * BR_H_hh



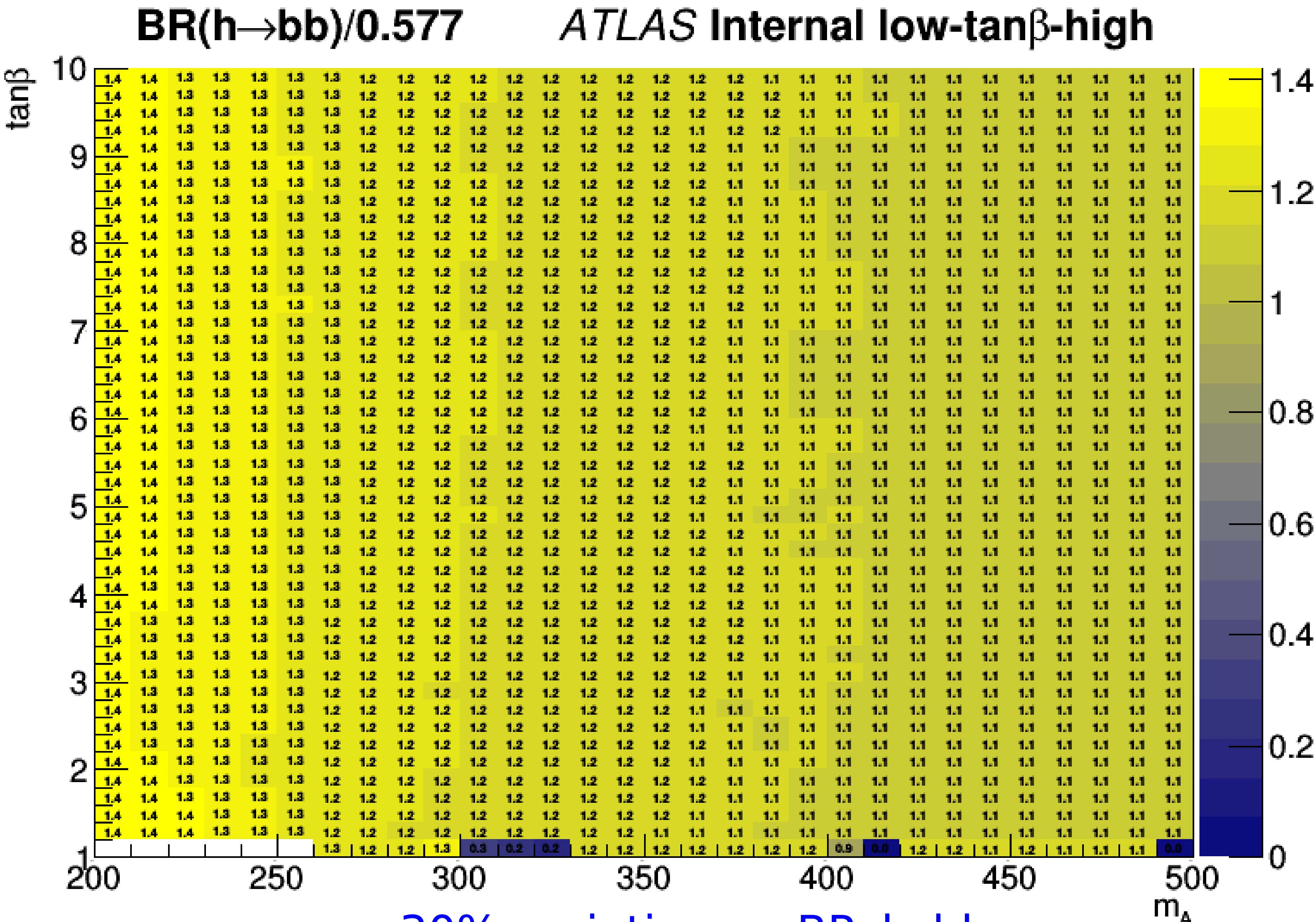
bbH production can help in high-tb



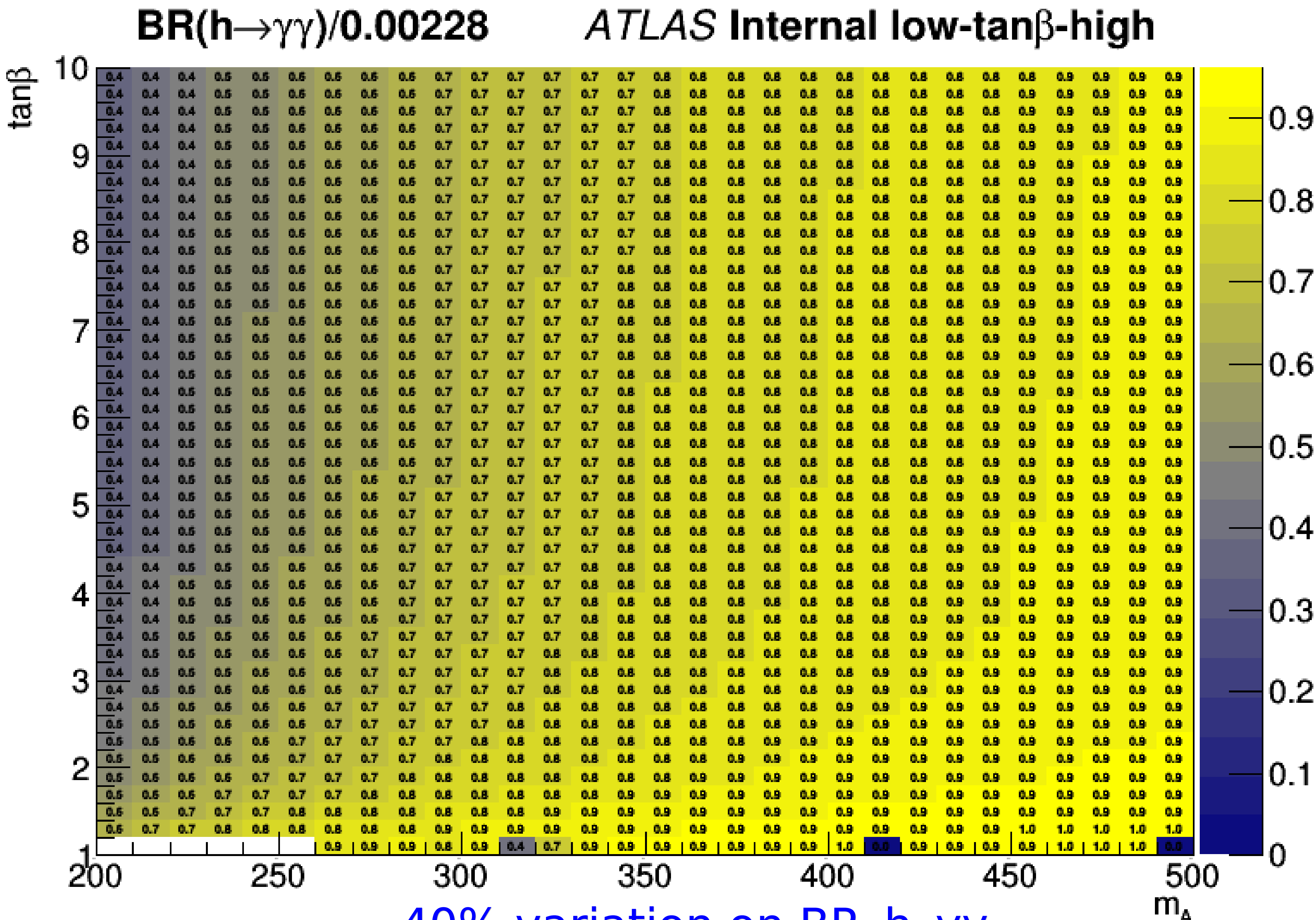
mH has 30% spreading away from mA



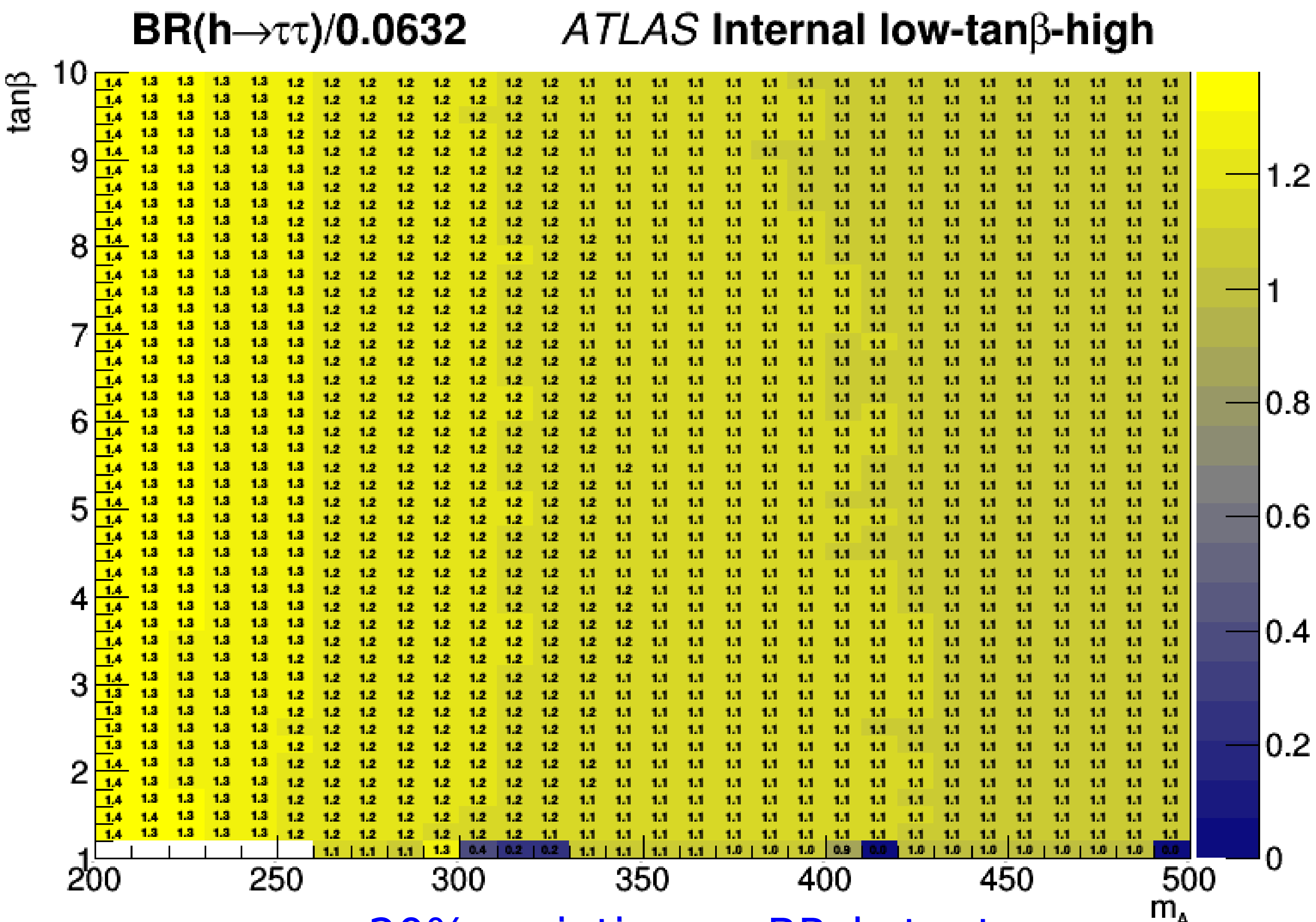
width is very smalle



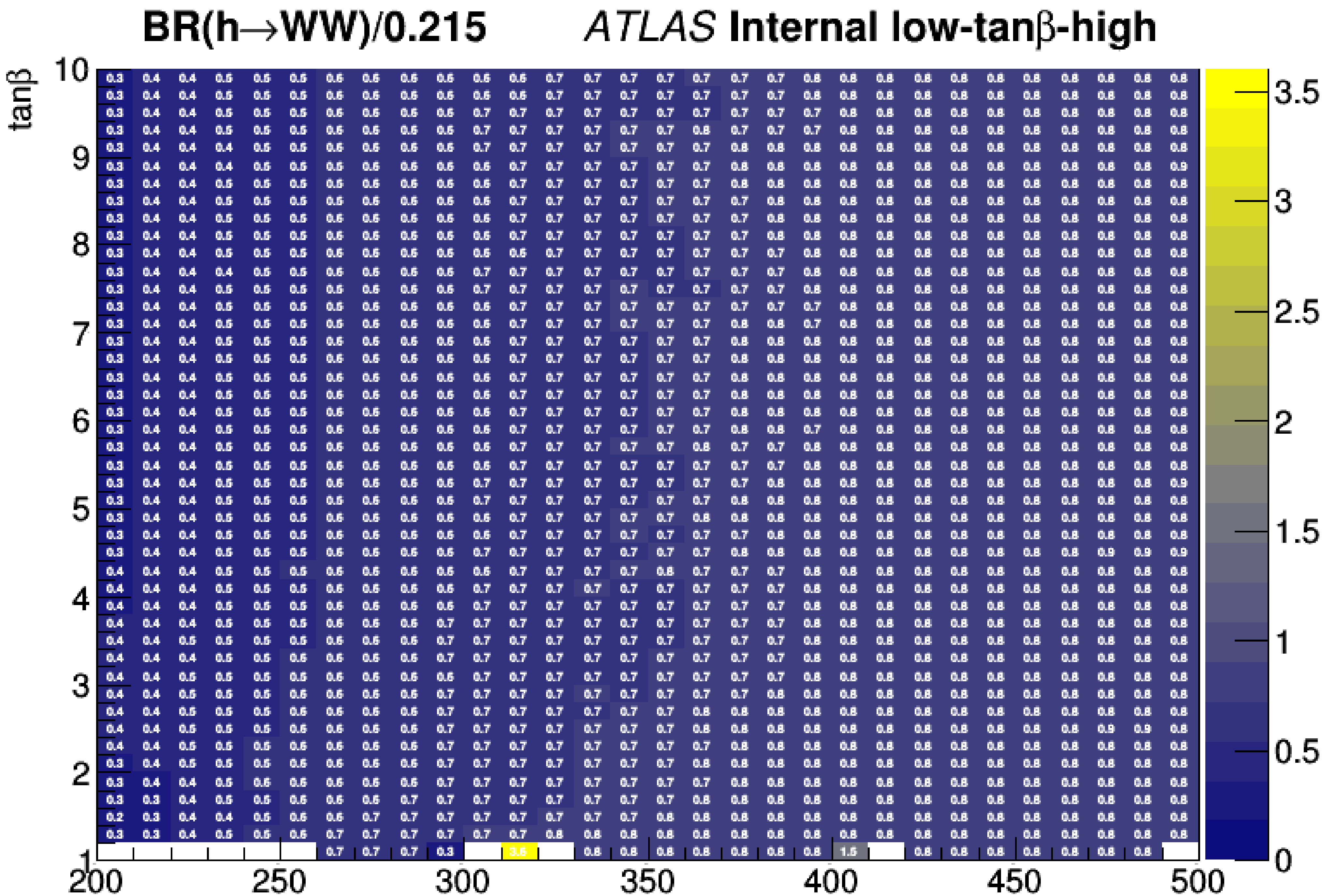
30% variation on BR_h_bb



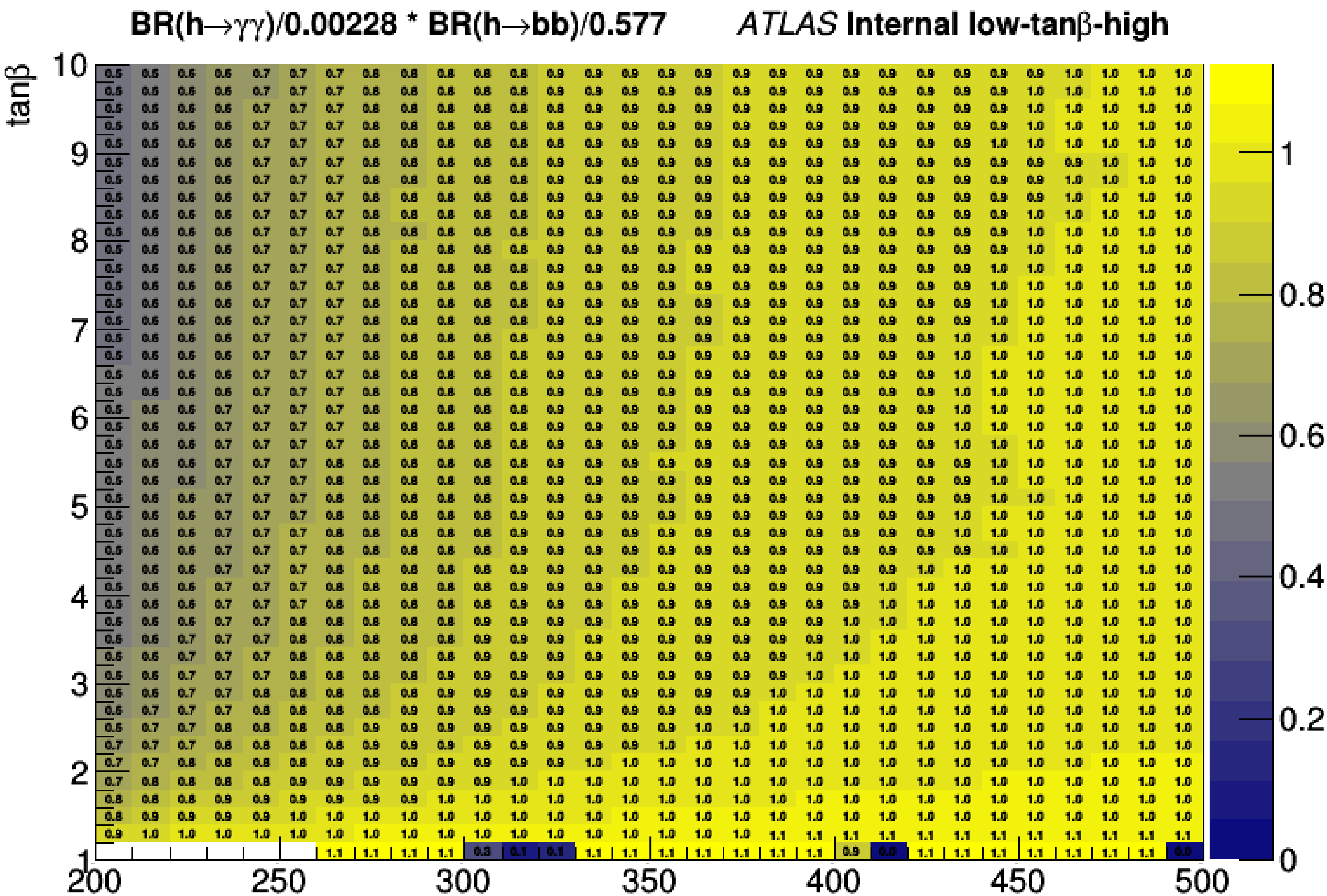
40% variation on BR_h_yy



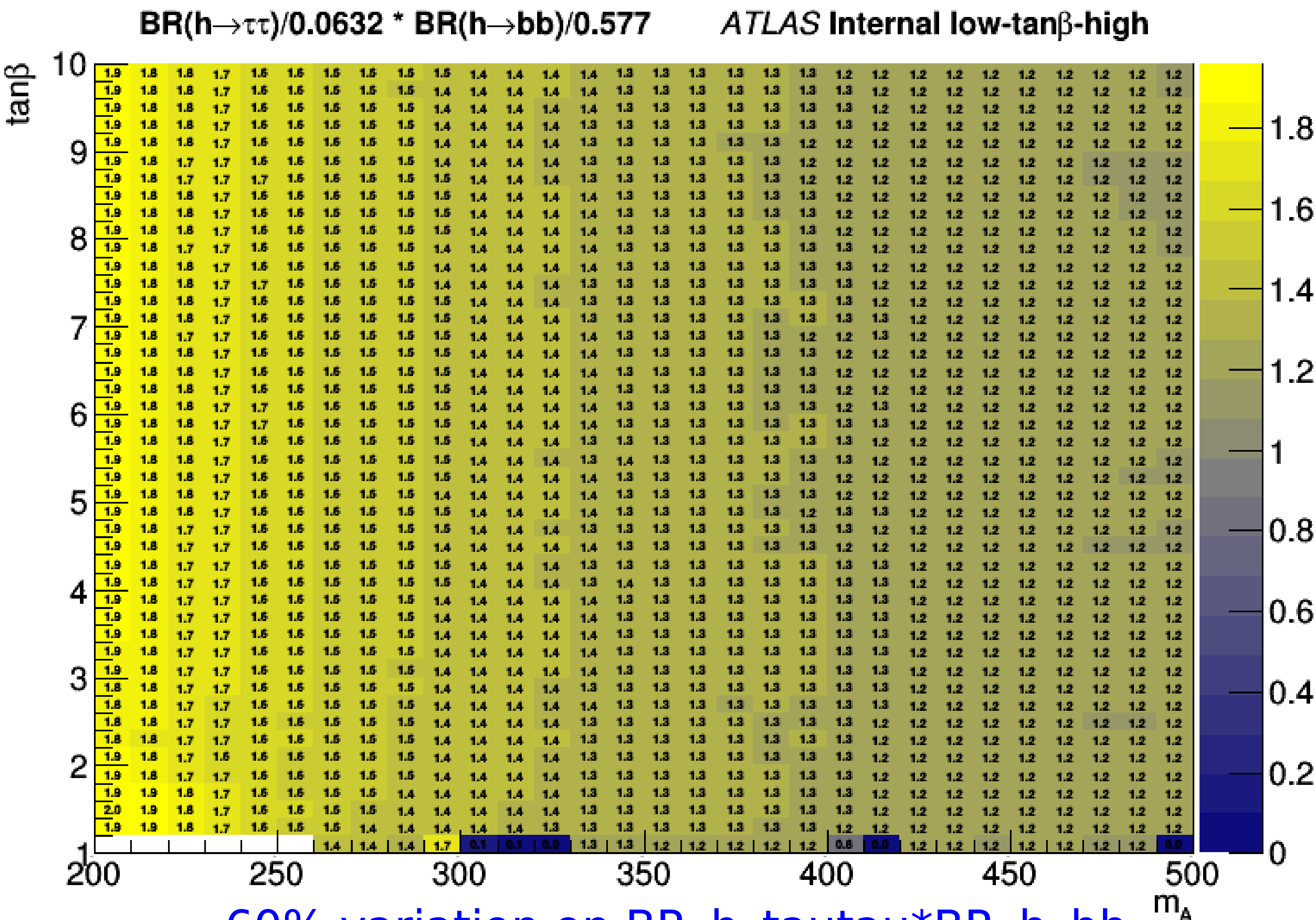
20% variation on BR_h_tautau



40% variation on BR_h_tautau



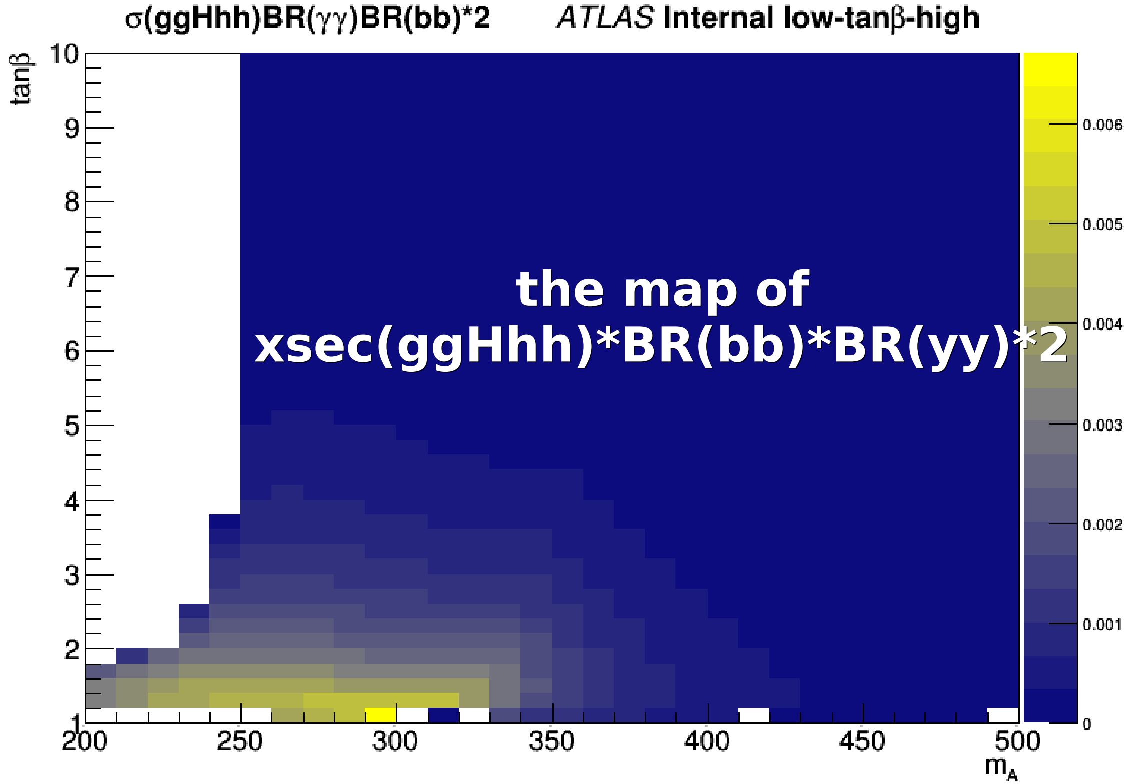
30% variation on BR_h_yy*BR_h_bb

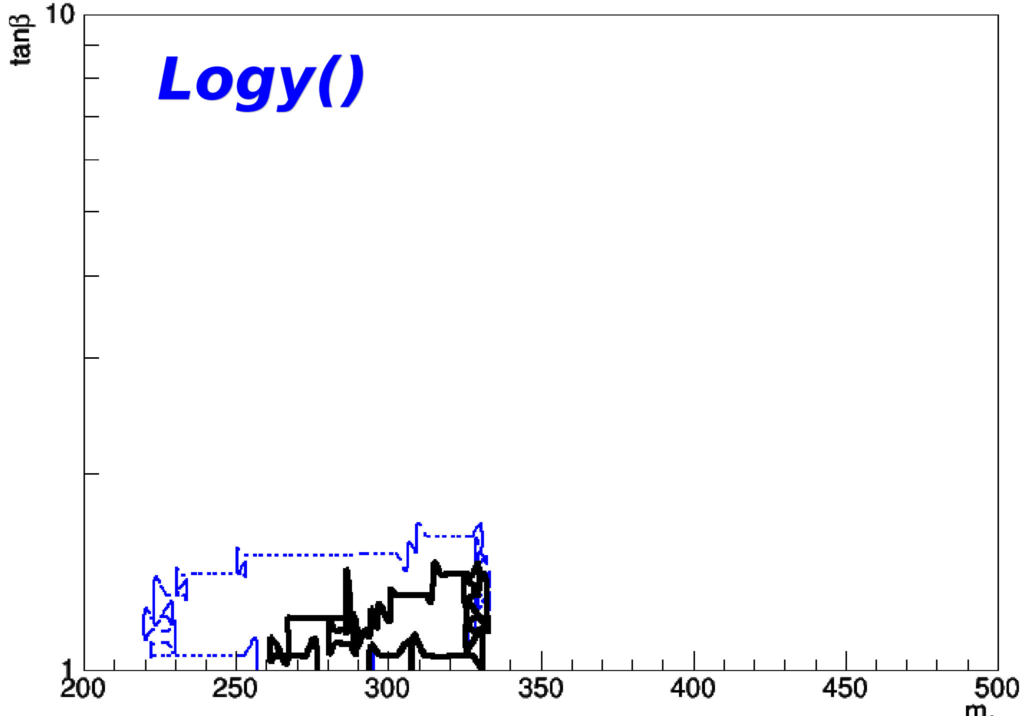


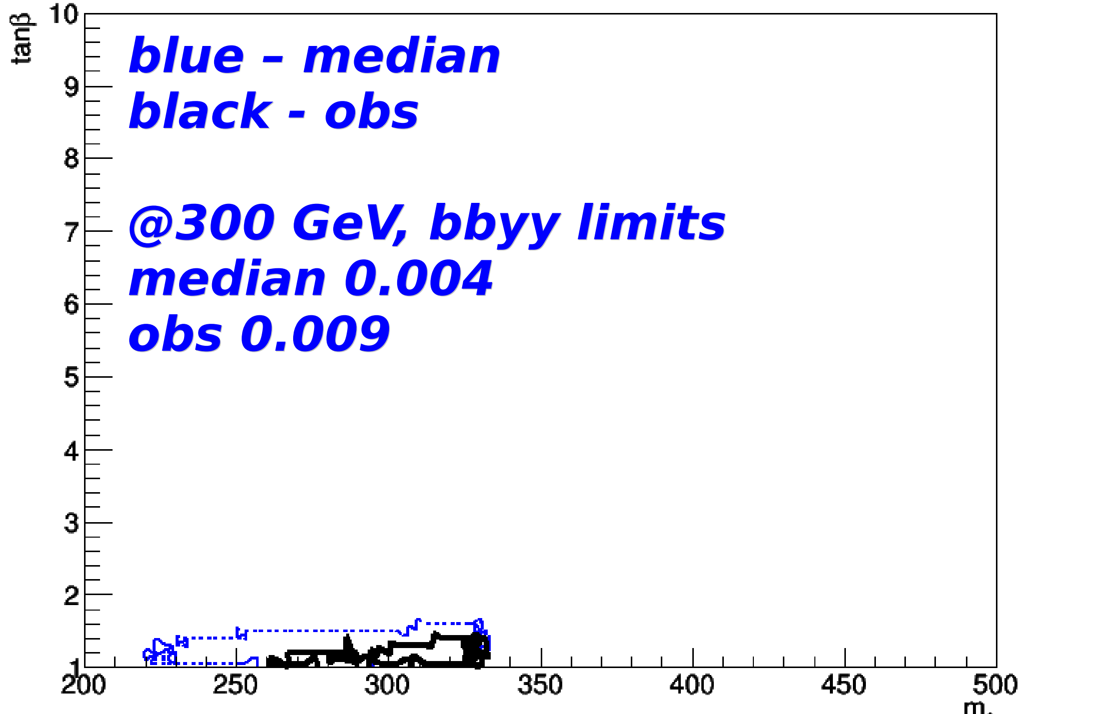
60% variation on BR_h_tautau*BR_h_bb

bbyy exclusions low-tb-high

- make a preliminary exclusion plot for bbyy on the value of xsec(ggHhh)BR(bb)BR(yy)*2
- the exclusion is seen in very low tanb region
- maybe better to use logY

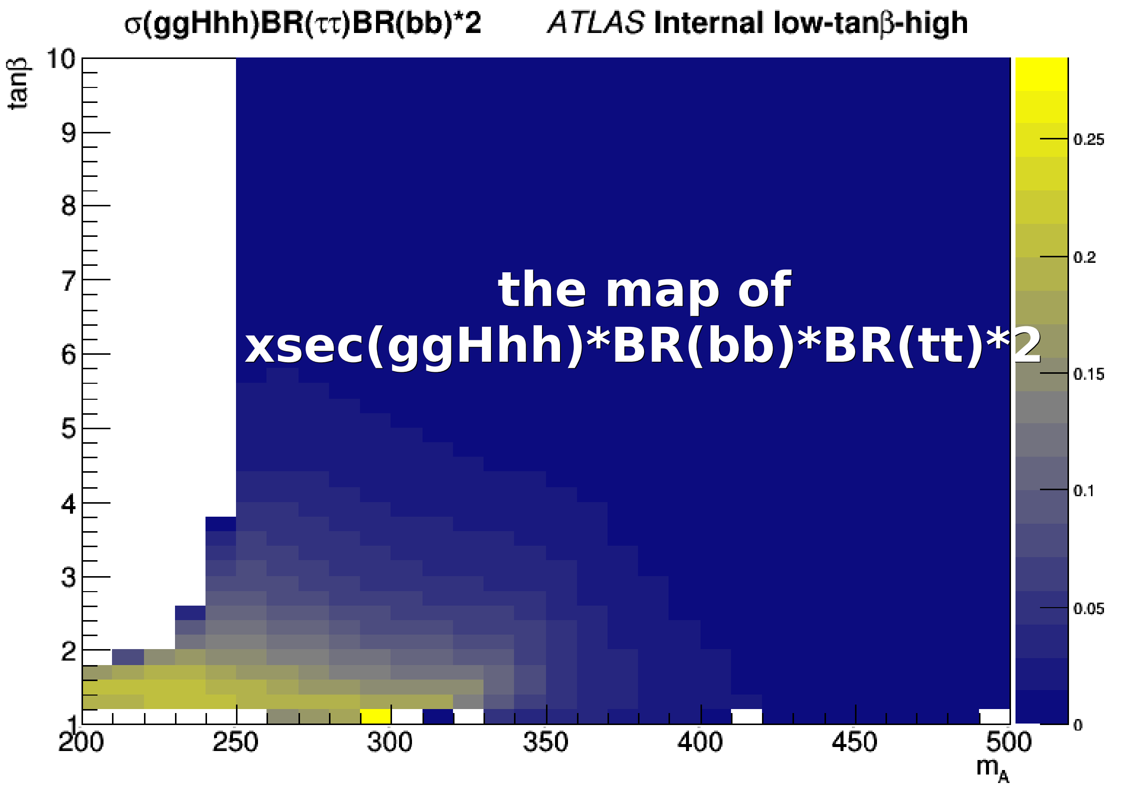


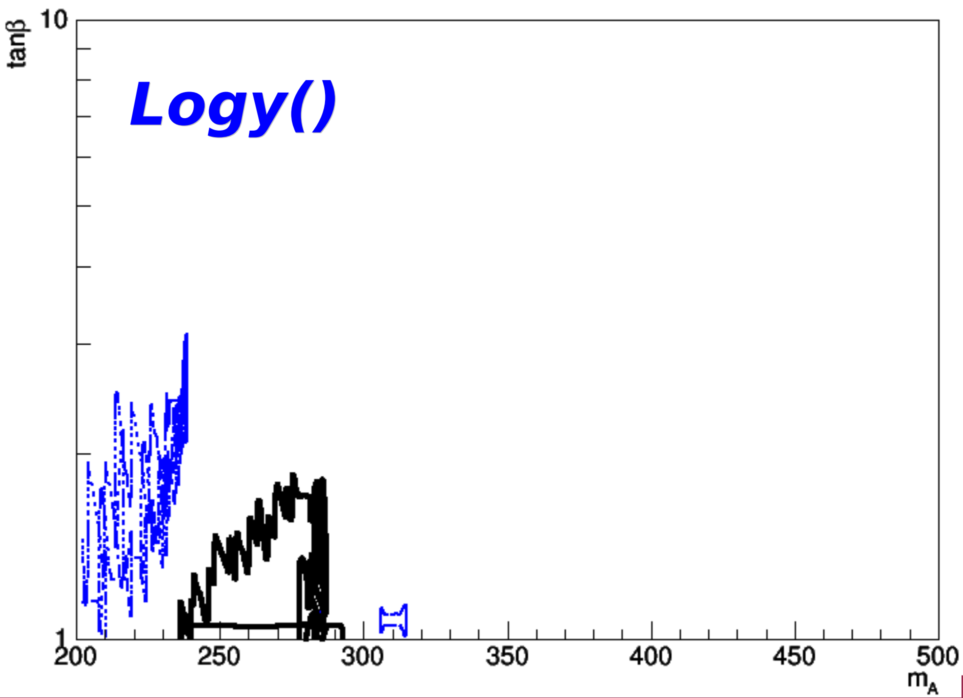


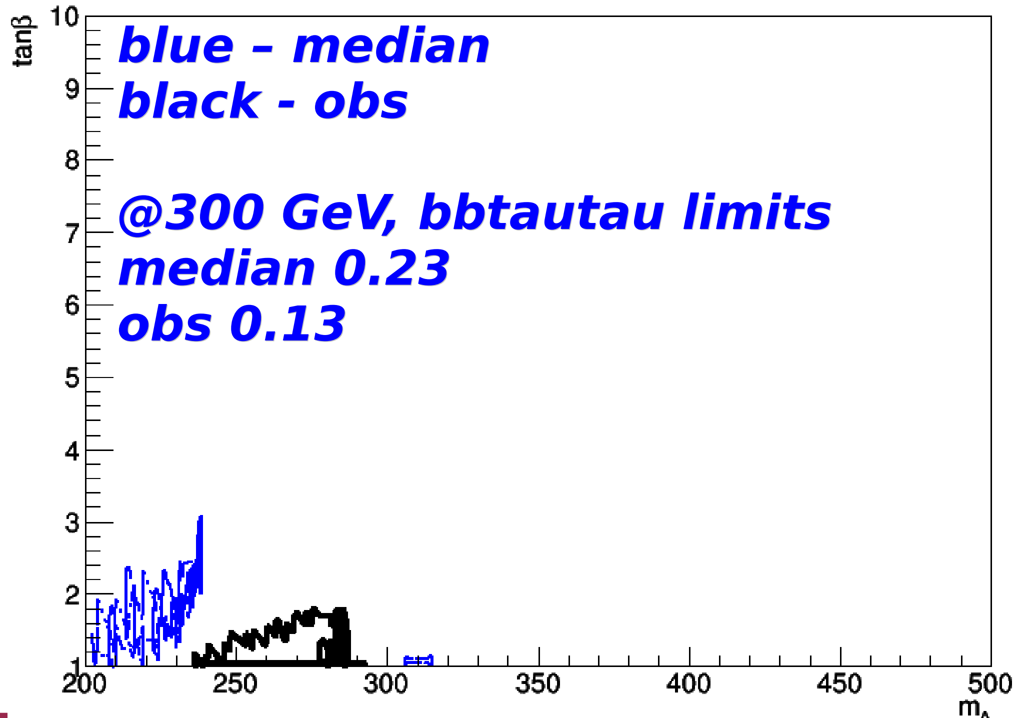


bbtt exclusions low-tb-high

- make a preliminary exclusion plot for bbtautau on the value of xsec(ggHhh)BR(bb)BR(tautau) *2
- the exclusion is seen in very low tanb region
- maybe better to have logY

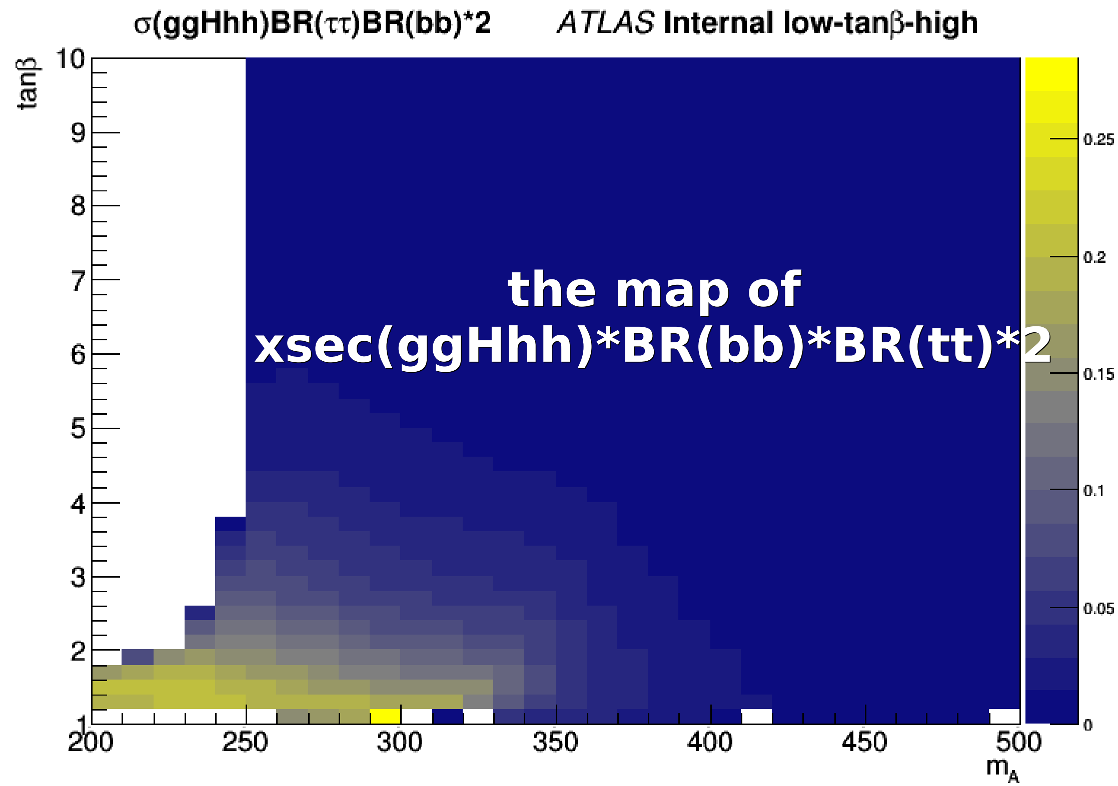


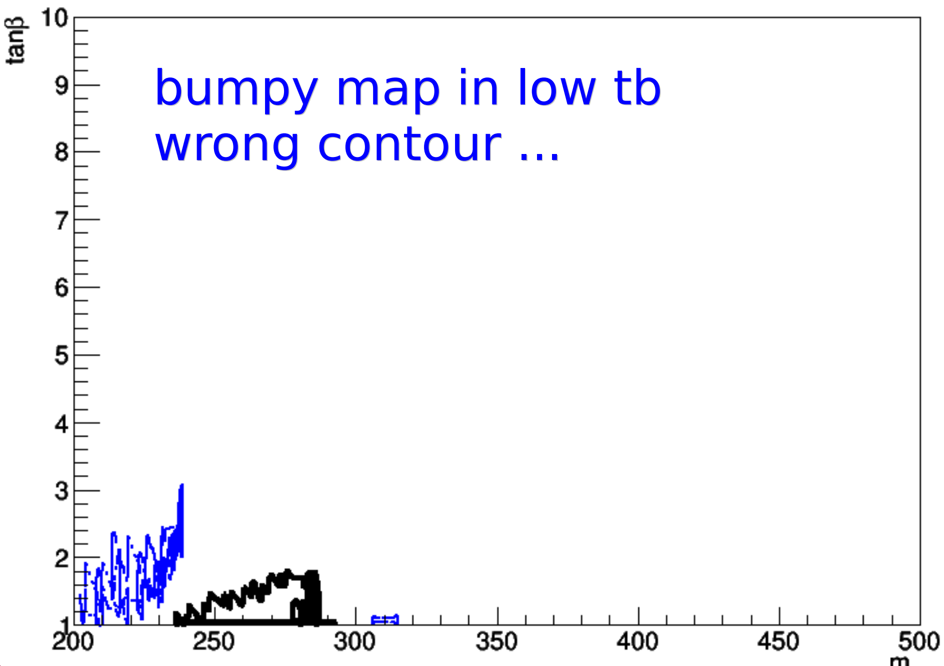


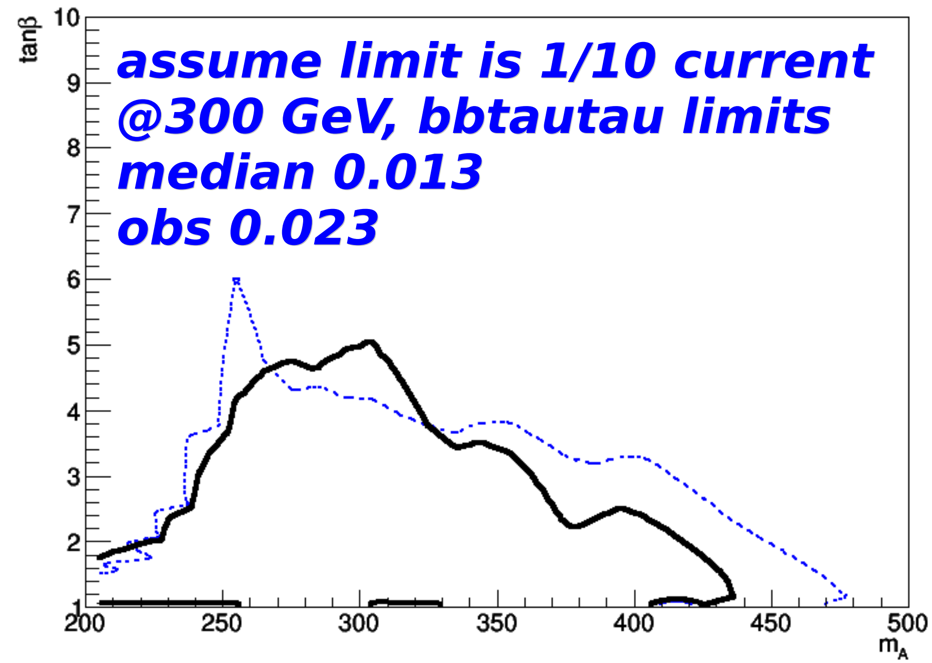


bbtt exclusions low-tb-high

- In very low tb, there are theoretically ***unstable*** phase points -> contour failures ...
- justify the exclusion script itself does not have any problem. assume limit is 10 times better, i.e. 1/10*current limit (plot on the right)







Theoretical uncertainties

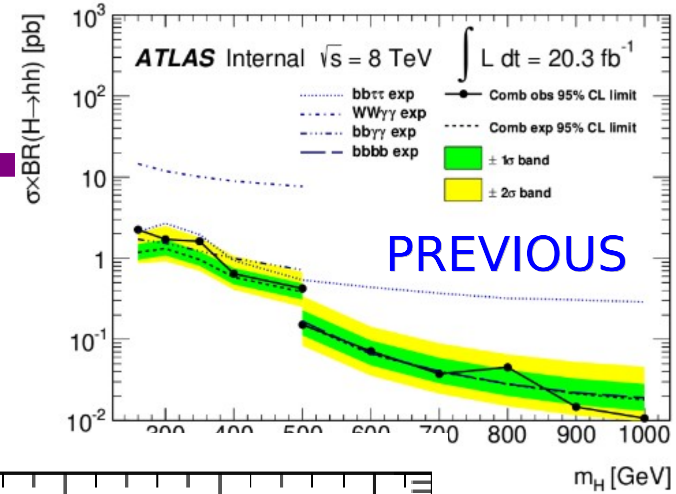
- The uncertainties do not have a specific pattern along mass
- but fluctuation seems to be large
- in agreement to use averaged value in all masses

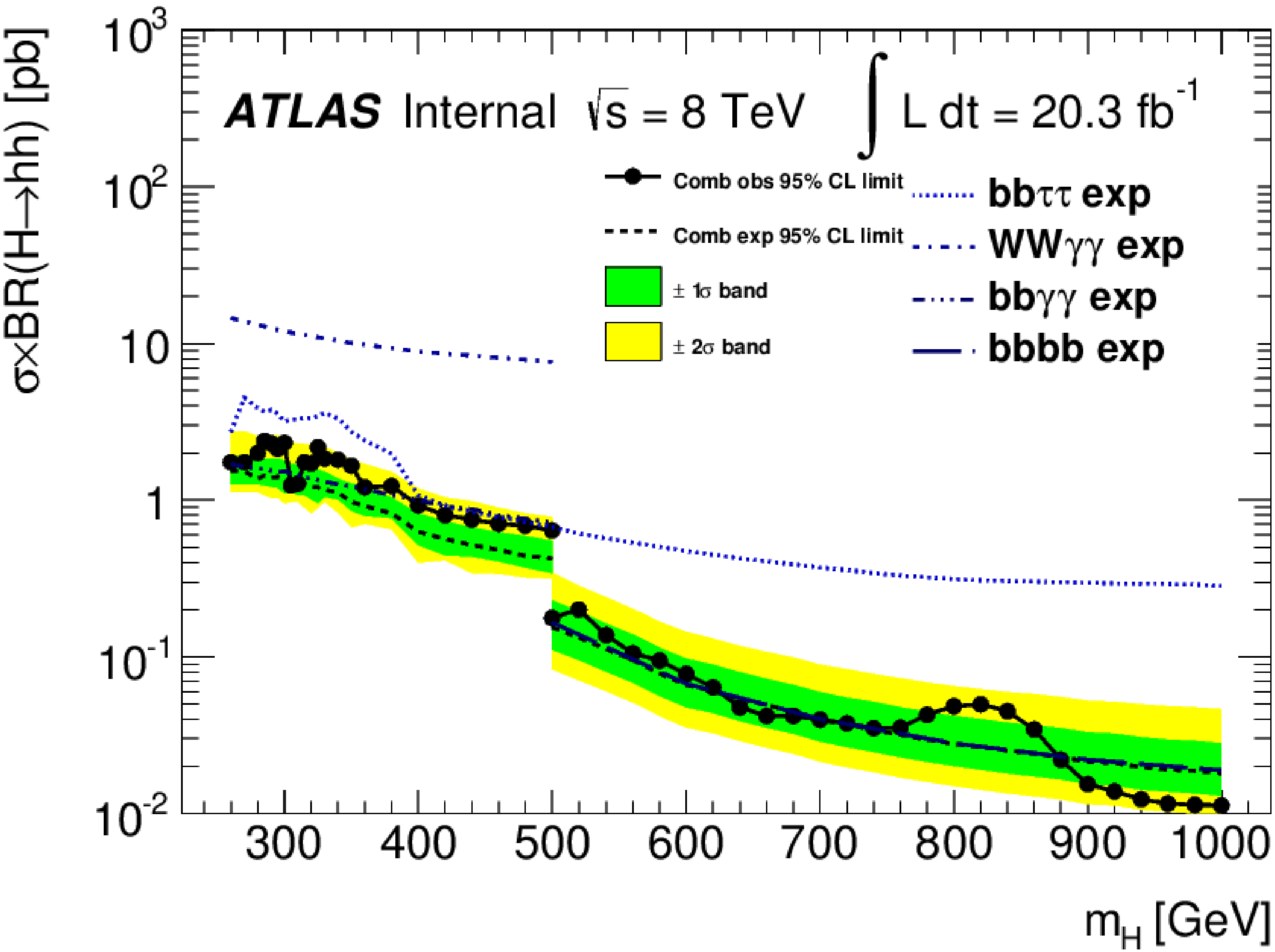
bbtautau	PDF		ISR, SFR		Scale	
	Low	High	Low	High	Low	High
Resonant(260)	1.1	18.2	14.8	54.5	15.2	54.5
Resonant(300)	4.7	8.0	9.9	14.7	10.3	32.0
Resonant(350)	21.6	12.7	36.3	21.7	22.5	30.7
Resonant(400)	20.8	2.3	41.7	14.3	47.9	20.5
Resonant(500)	4.2	2.2	25.0	7.2	33.3	12.6
Resonant(1000)	33.3	5.0	33.3	11.5	33.3	5.2
non-resonant	11.8	3.5	29.4	5.8	39.2	12.7

Mass **wwyy**	260	300	350	400	500	Sm_hh
SCALE	2.2%	2.8%	3.2%	1.6%	2.3%	2.2%
PDF	4.6%	2.7%	7.0%	6.9%	1.9%	4.0%
ISRFSR	6.7%	4.1%	2.7%	3.7%	3.2%	1.7%

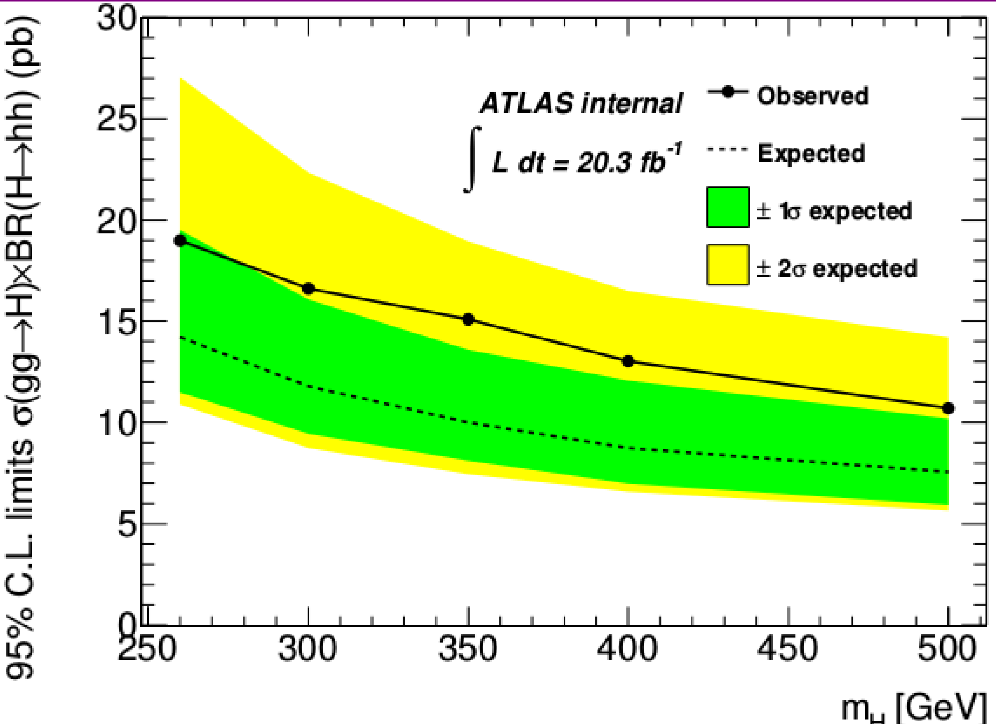
Interpolated mass points

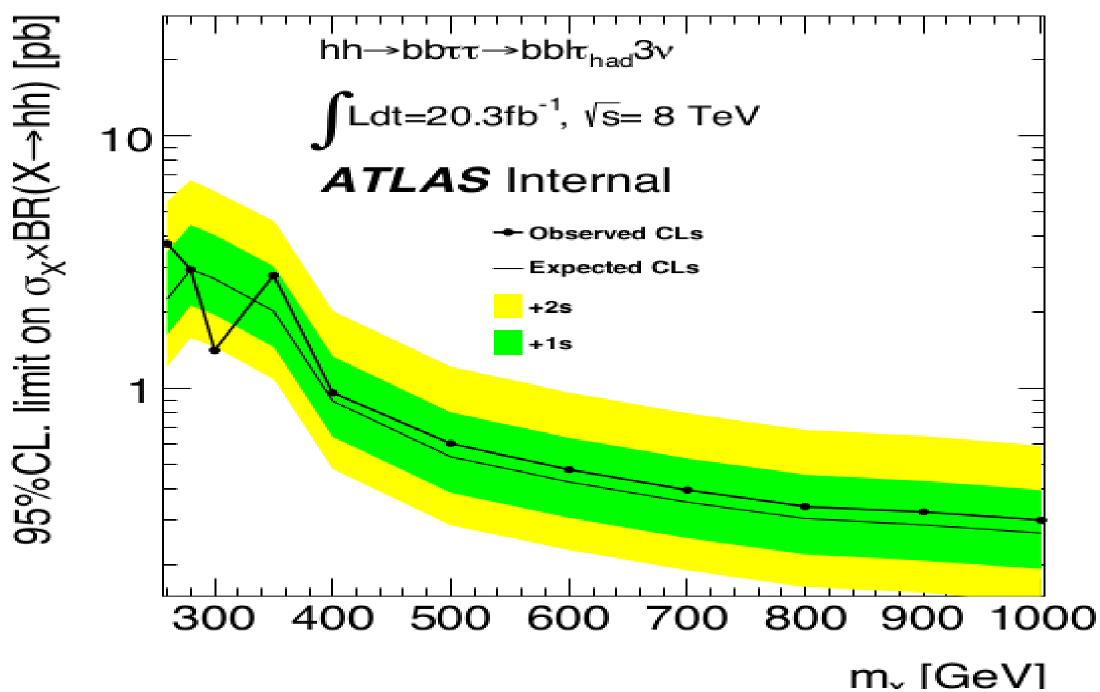
- In both low mass and high mass regions, more mass points are interpolated from available points

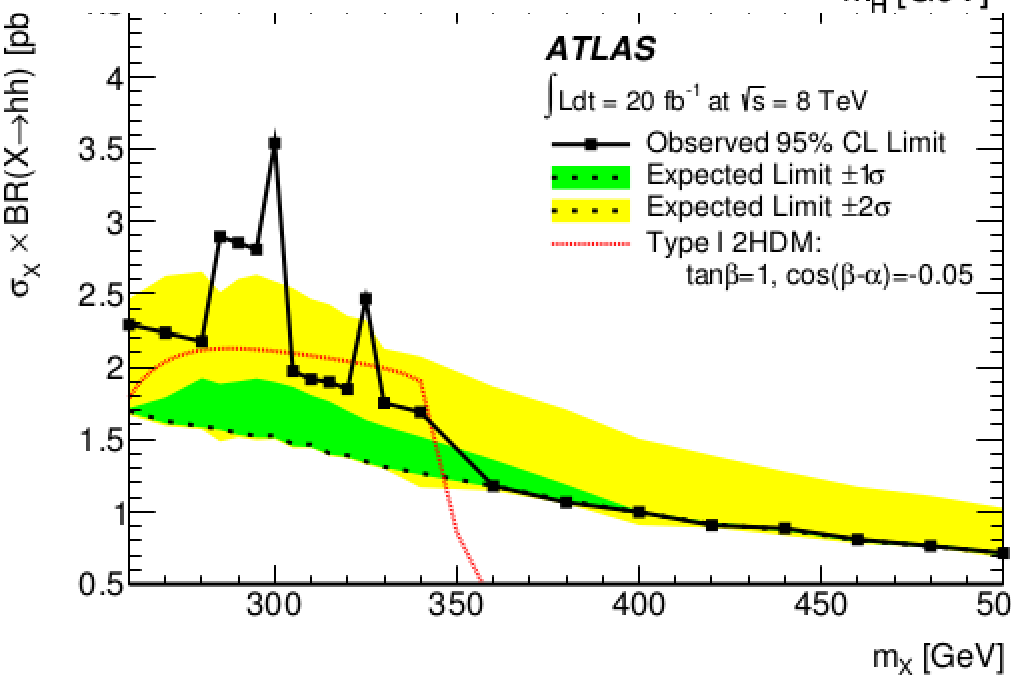


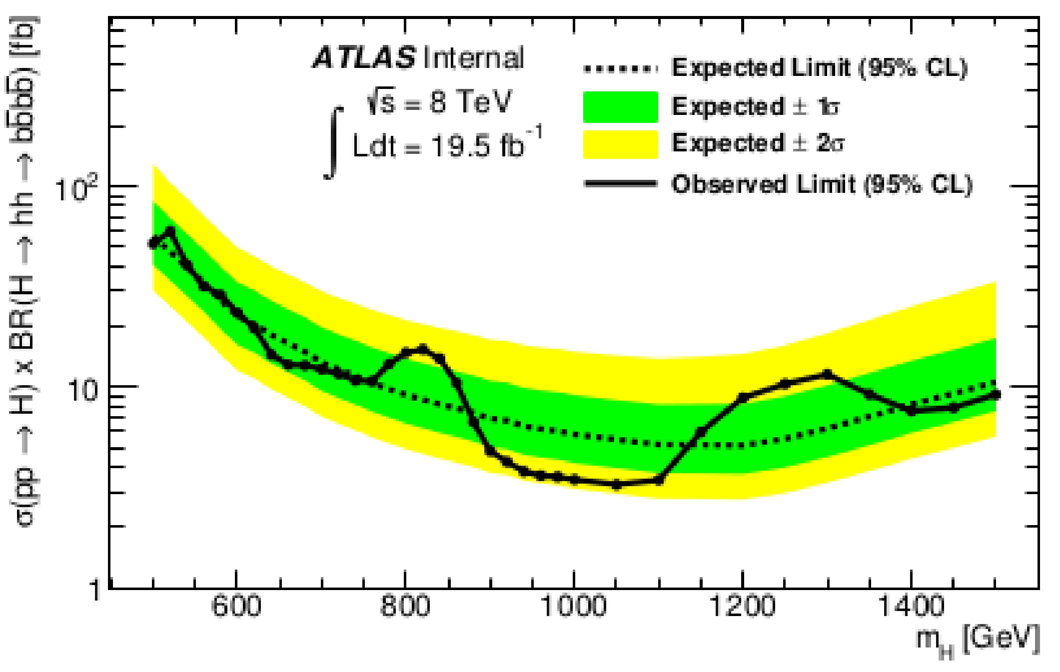


Channel limits [res]

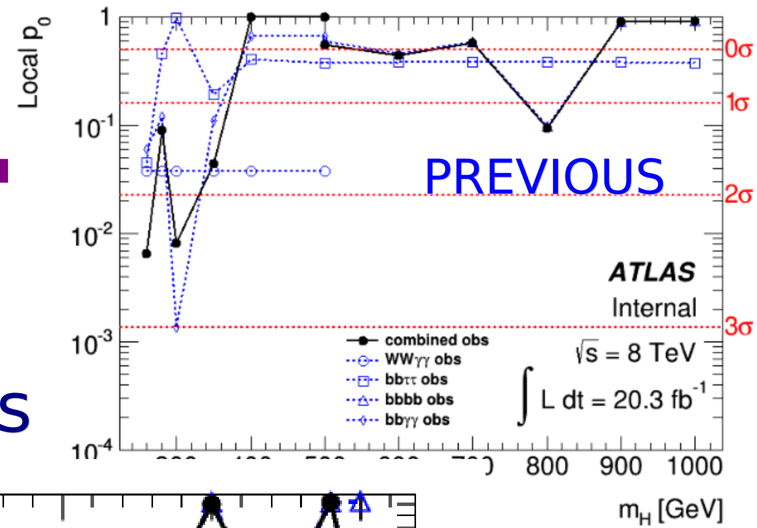




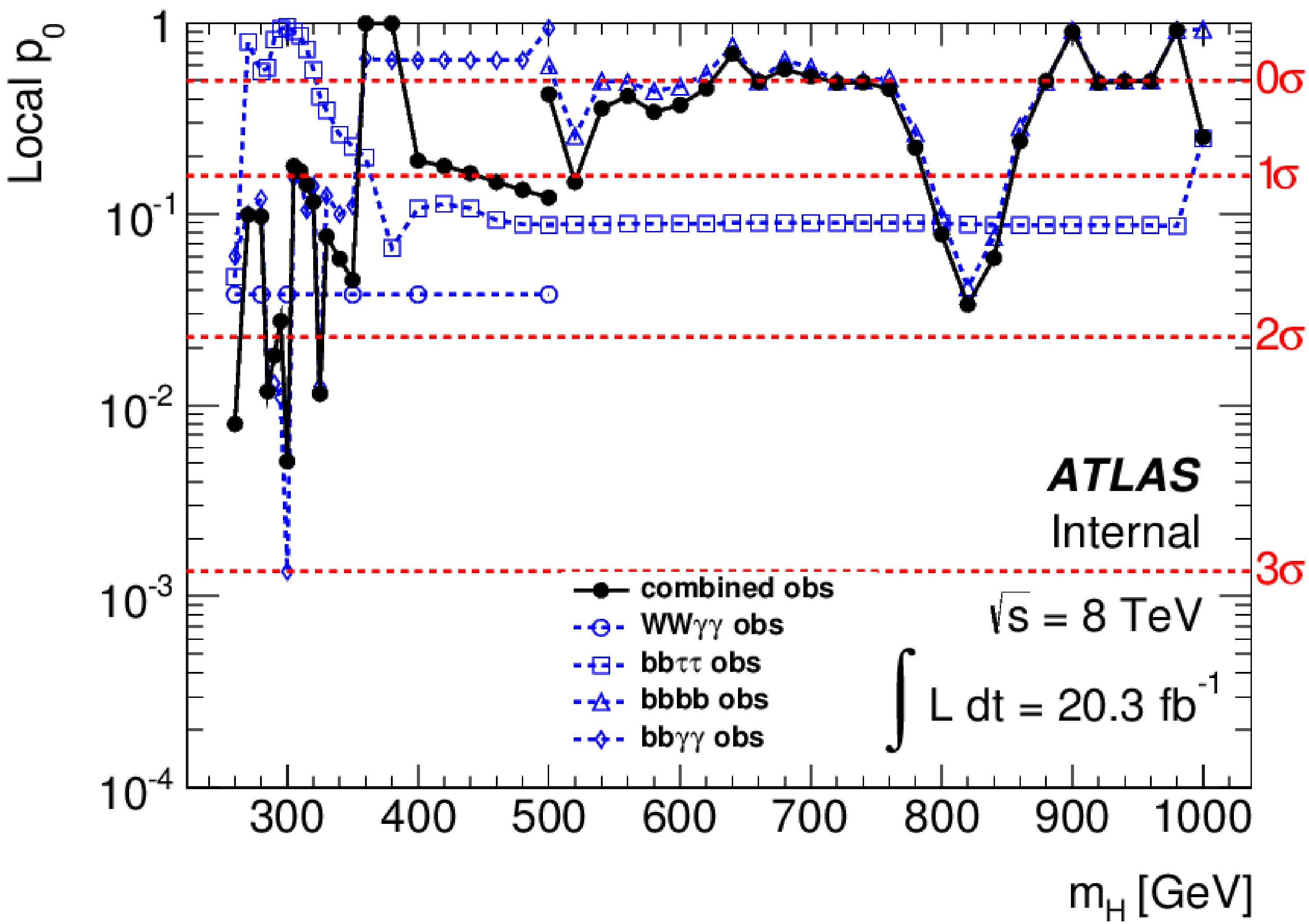




Interpolated mass points



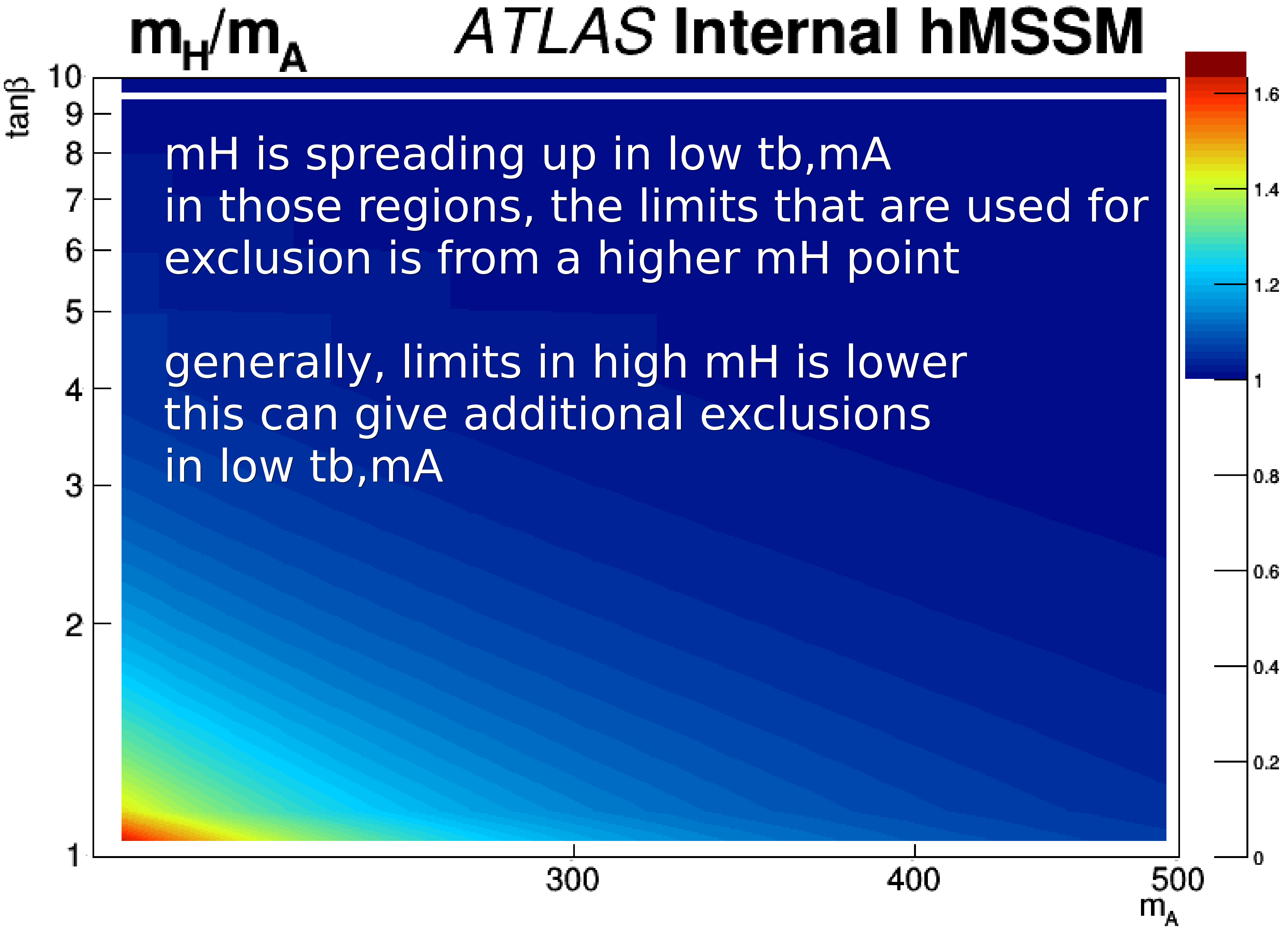
- In both low mass and high mass regions, more mass points are interpolated from available points



Theoretical uncertianties

- Theoretical uncertainties are estimated with variations on PDF/scale/radiation → three nuisance parameter are created for them respectively
- For PDF uncert, compare MSTW2008lo68 and NNPDF to nominal sample cteq6l1
- For factorization/renormalization uncert, compare
  - cteq6l1_facDn_renDn
  - cteq6l1_facNo_renDn
  - cteq6l1_facUp_renNo
  - cteq6l1_facDn_renNo
  - cteq6l1_facNo_renUp
  - cteq6l1_facUp_renUp
- For ISR/FSR uncert, compare isr_up/dn and fsr_up/dn

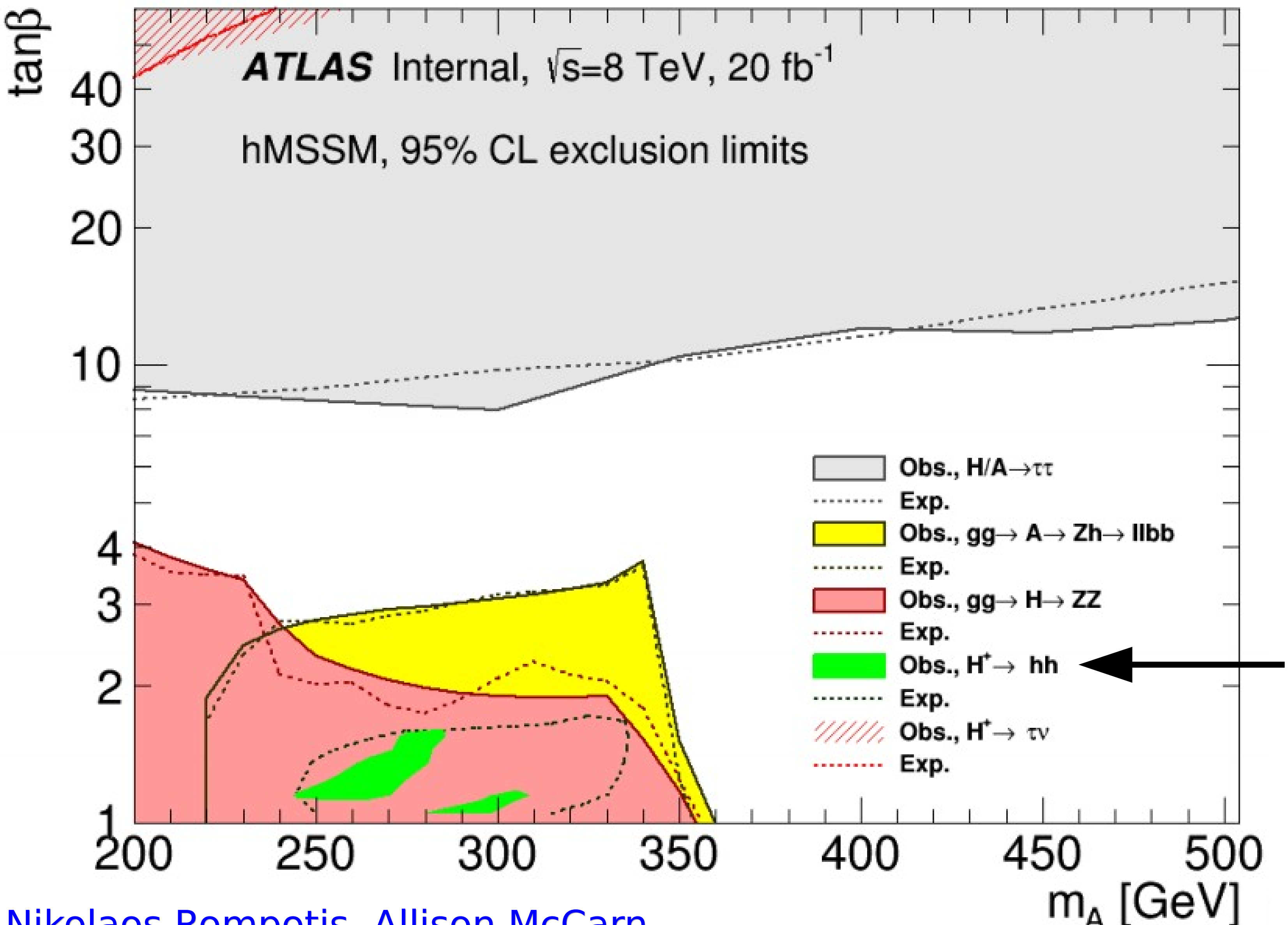
  * all follows instructions from Paul T as used in AZh



mH is spreading up in low tb,mA
in those regions, the limits that are used for exclusion is from a higher mH point

generally, limits in high mH is lower
this can give additional exclusions
in low tb,mA

hMSSM – compared to other channels



Nikolaos Rompotis, Allison McCarn

https://indico.cern.ch/event/393422/contribution/3/material/slides/0.pdf