The charged Higgs boson at LEP

Towards the final combination

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- A preliminary combination occured for the summer 2001 conferences.
- Since then, the 4 expts have finalized their results :

  (ALEPH 2002, L3 2003, DELPHI 2004 and OPAL hopefully soon)
- It's time to go a step forward just before the final words on this subject from LEP

Introduction

- Charged Higgs boson (H^6) : colorless, spinless, electrically charged particle.
- INSTANT EVIDENCE OF PHYSICS BEYOND THE STANDARD MODEL
- Appears in any Two-Higgs-Doublet Models (2HDM)

Basics

- $\sigma(e^+e^- \rightarrow H^+H^-) = k(1-4m^2_H/s)^{3/2}$
- (ew)radiative corrections are small (~5%)

- Decay modes : cs, $\tau\nu$ and W*A
- Branching fractions depend on type of 2 Higgs Doublet Model (2HDM)

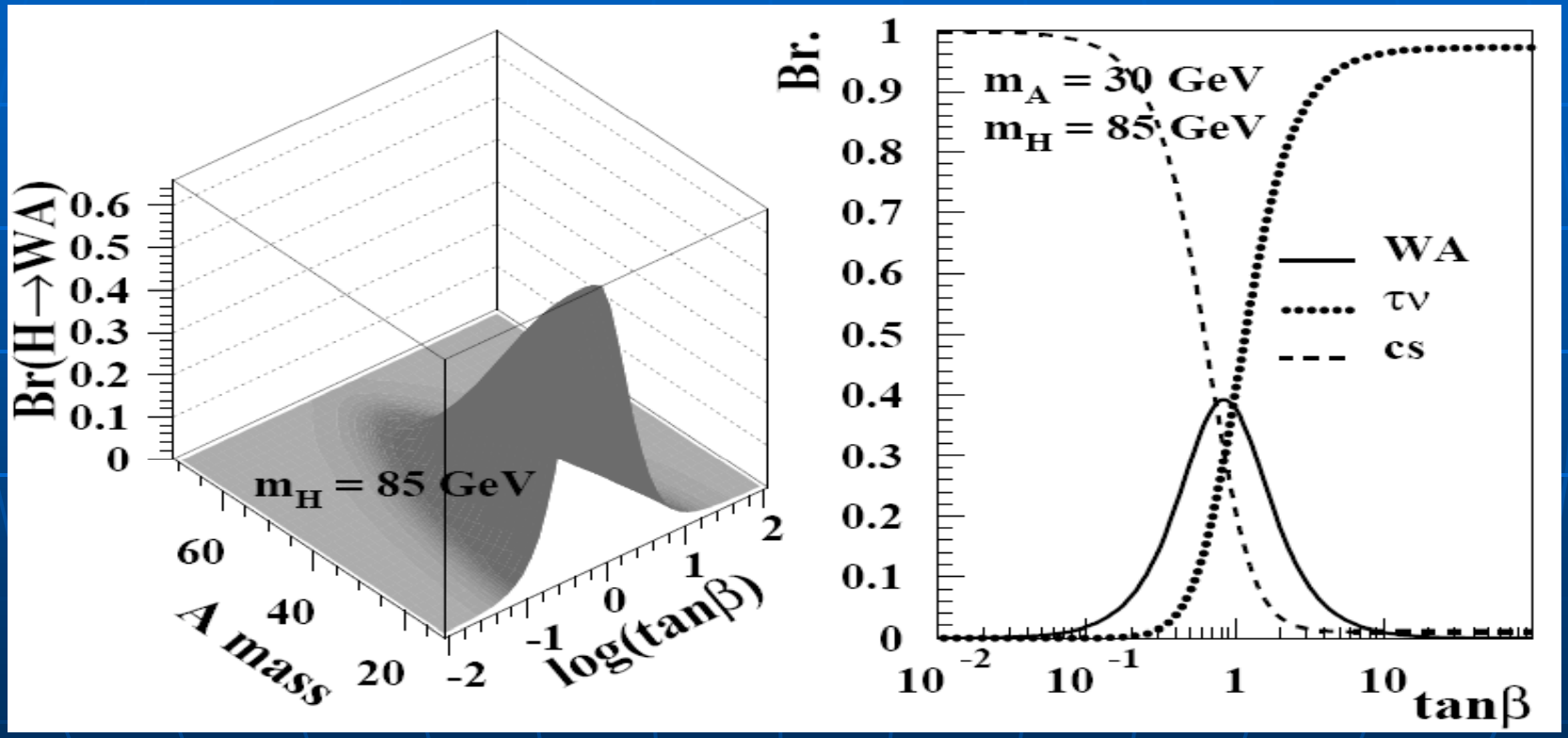
- Dominant background : W pairs

List of available searches

Exp't (Ref.)	Final state	$\sqrt{s}$ (GeV)	$\mathcal{L}$ (pb^{-1})	m_{H} range (GeV/c^2)	# samples
ALEPH [1]	$\mathrm{H^+H^-} \to cscs$	189 - 209	630	45 - 100	22
	$\mathrm{H^+H^-} \to cs\tau\nu$	189 - 209	630	55 - 100	
	$\mathrm{H^+H^-} \to \tau\nu\tau\nu$	189 - 209	630	45 - 100	
DELPHI [2]	$\mathrm{H^+H^-} \to cscs$	183 - 209	650	40 - 100	43
	$\mathrm{H^+H^-} \to cs\tau\nu$	183 - 209	625	40 - 100	
	$\mathrm{H^+H^-} \to \tau\nu\tau\nu$	183 - 209	620	40 - 100	
	$\mathrm{H^+H^-} \to \mathrm{W^*A}\tau\nu$	189 - 209	600	40 - 100	
	$\mathrm{H^+H^-} \to \mathrm{W^*AW^*A}$	189 - 209	600	40 - 100	
L3 [3]	$\mathrm{H^+H^-} \to cscs$	183 - 209	685	50 - 100	12
	$\mathrm{H^+H^-} \to cs\tau\nu$	183 - 209	685	50 - 100	
	$\mathrm{H^+H^-} \to \tau\nu\tau\nu$	183 - 209	685	50 - 100	
OPAL [4]	$\mathrm{H^+H^-} \to cscs$	183 - 209	670	40 - 100	45
	$\mathrm{H^+H^-} \to cs\tau\nu$	183 - 209	670	40 - 100	
	$\mathrm{H^+H^-} \to \tau\nu\tau\nu$	183 - 209	680	45 - 100	
	$\mathrm{H^+H^-} \to \mathrm{W^*A}\tau\nu$	189 - 209	600		
	$\mathrm{H^+H^-} \to \mathrm{W^*AW^*A}$	189 - 209	600		

2HDM type II

- One Higgs doublet provides masses for up-type quarks, the other for down-type quarks (~MSSM)



- For large A masses, or |log(tanb)| > 1, only cs and τν channels contribute.

2HDM type II (cont'd.)

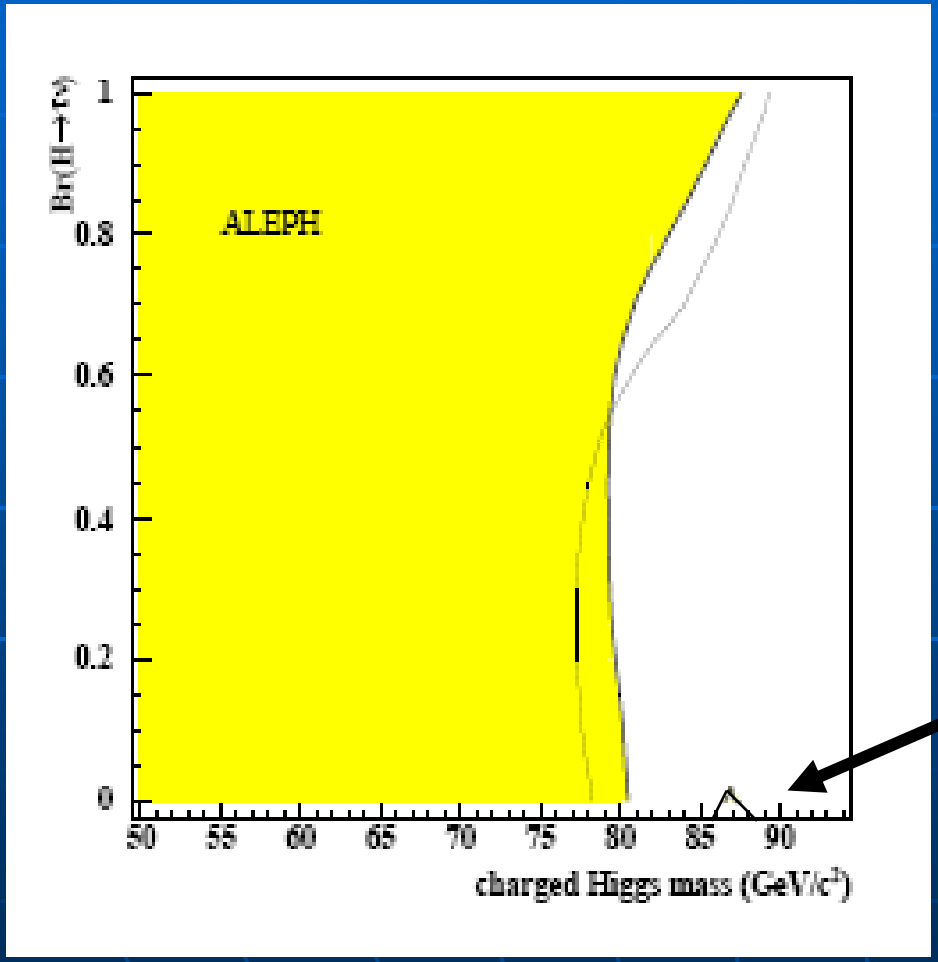
- (Historical) assumption : the cs and $\tau\nu$ channels exhaust the H^+ decay width.

- Plots are B($H^+ \rightarrow \tau\nu$) vs H^+ mass.

  cs $\rightarrow$ low tanβ

  $\tau\nu$ $\rightarrow$ high tanβ

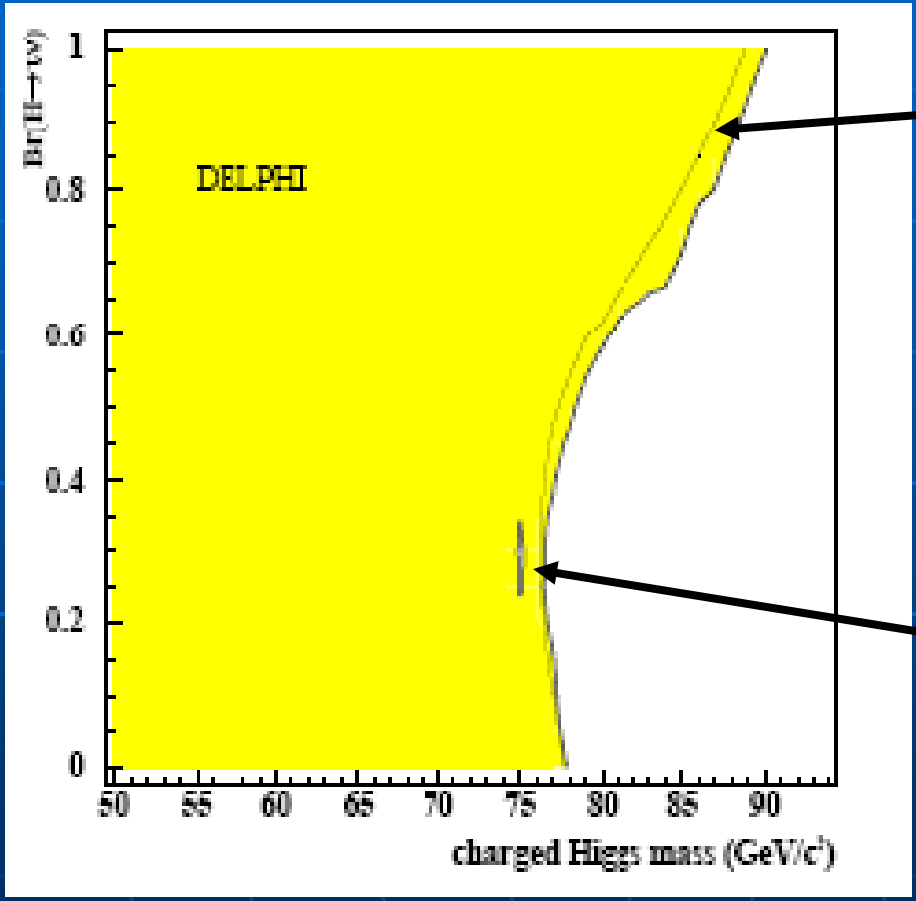
2HDM type II : ALEPH final



Small data excess in leptonic and small deficit in hadronic channel

Note the (observed) exclusion beyond the W mass in the hadronic channel

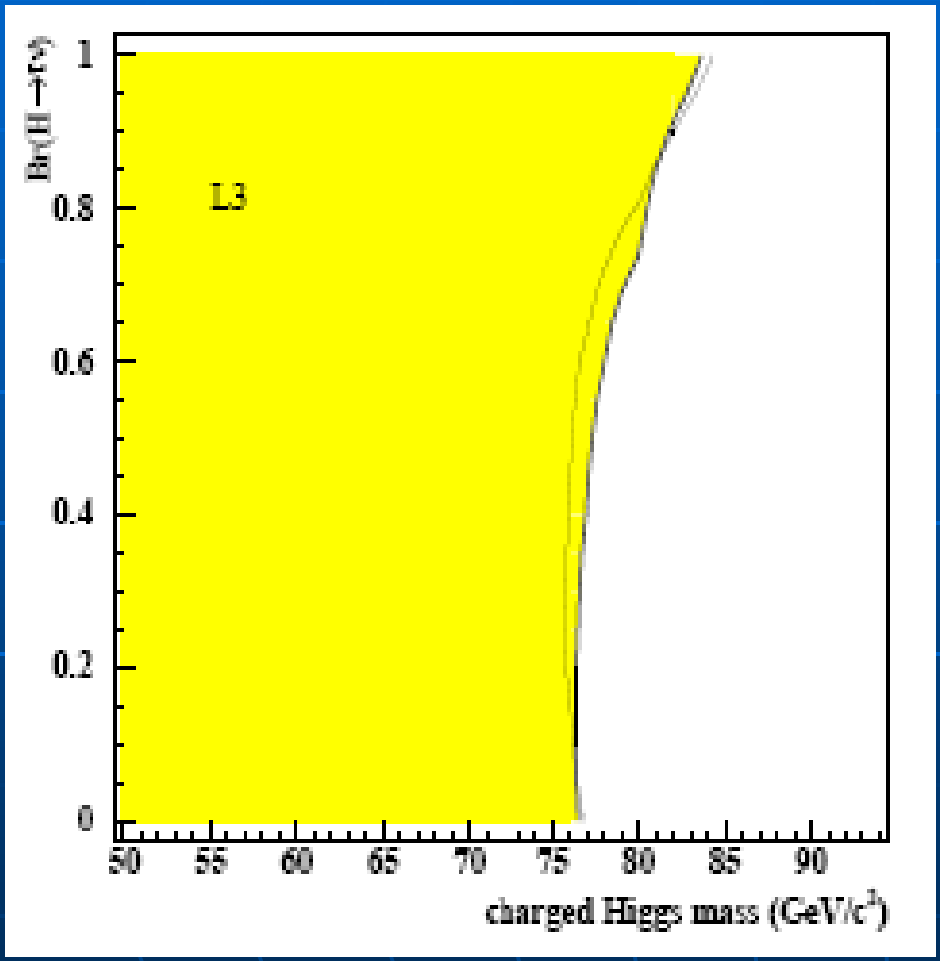
2HDM type II : DELPHI final



Small deficit

Note a small excess
in the mixed channel

2HDM type II : L3 final

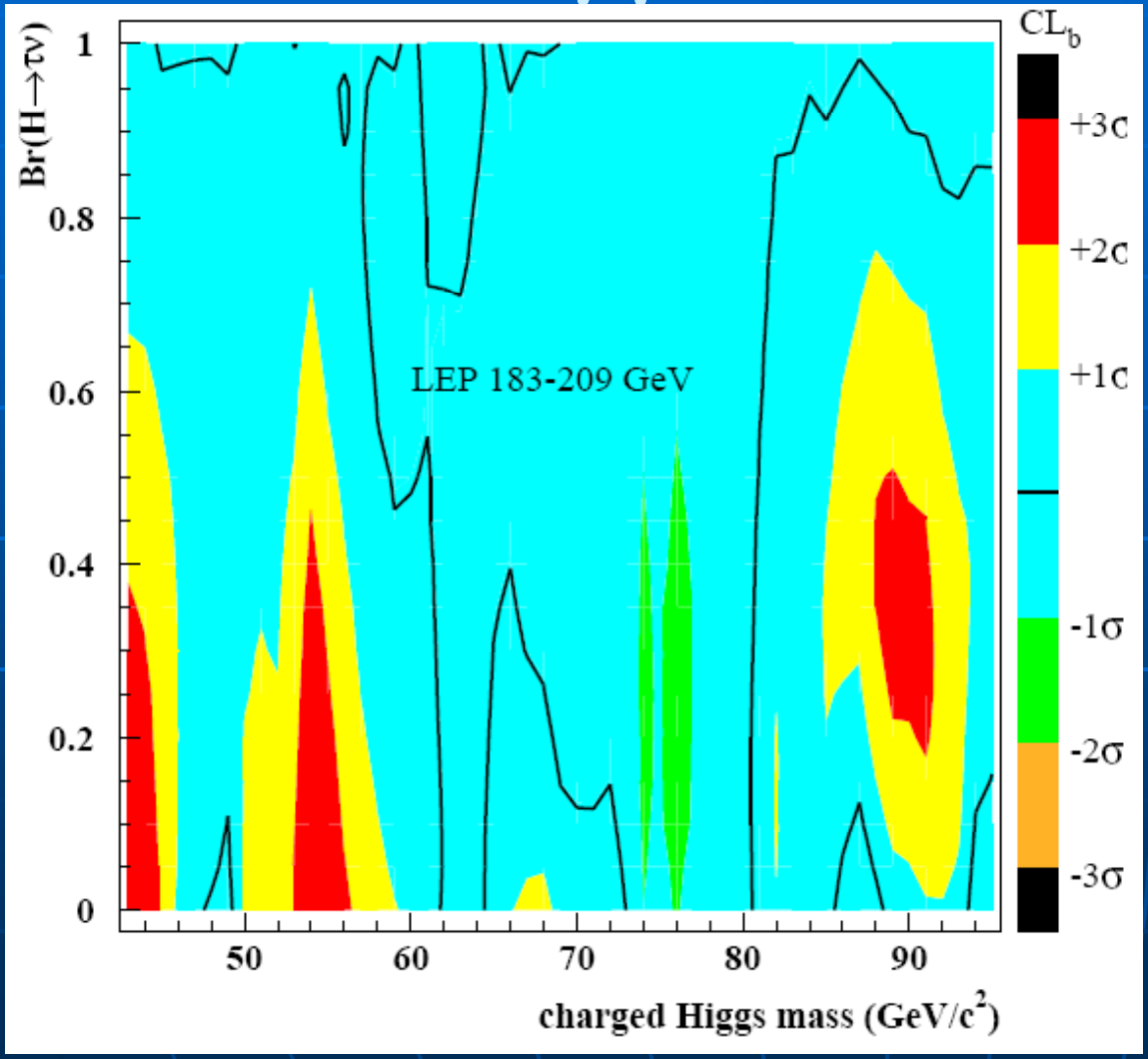


Almost perfect agreement between observation and expectation

2HDM type II : final results

Experiment:	ALEPH	DELPHI	L3
Total: Int. luminosity (pb^{-1}):	630	620	685
Backg. exp. / Events obs.			
$(c\bar{s})(\bar{c}s)$:	2806.0/2742	2179.3/2179	2473.8/2578
$(c\bar{s})(\tau^+\nu)$:	289.3/280	1122.8/1129	494.5/470
$(\tau^+\nu)(\tau^-\bar{\nu})$:	39.8/45	73.6/ 66	149.8/147
Events in all channels:	3135.1/3067	3375.7/3374	3118.1/3195
Limit exp.(median)/ observed	GeV/c^2	GeV/c^2	GeV/c^2
for B=0:	78.2/80.4	77.7/77.8	76.8/76.6
for B=1:	89.2/87.8	88.9/90.1	84.3/83.7
for any B:	77.1/79.3	76.3/74.4	75.7/76.4

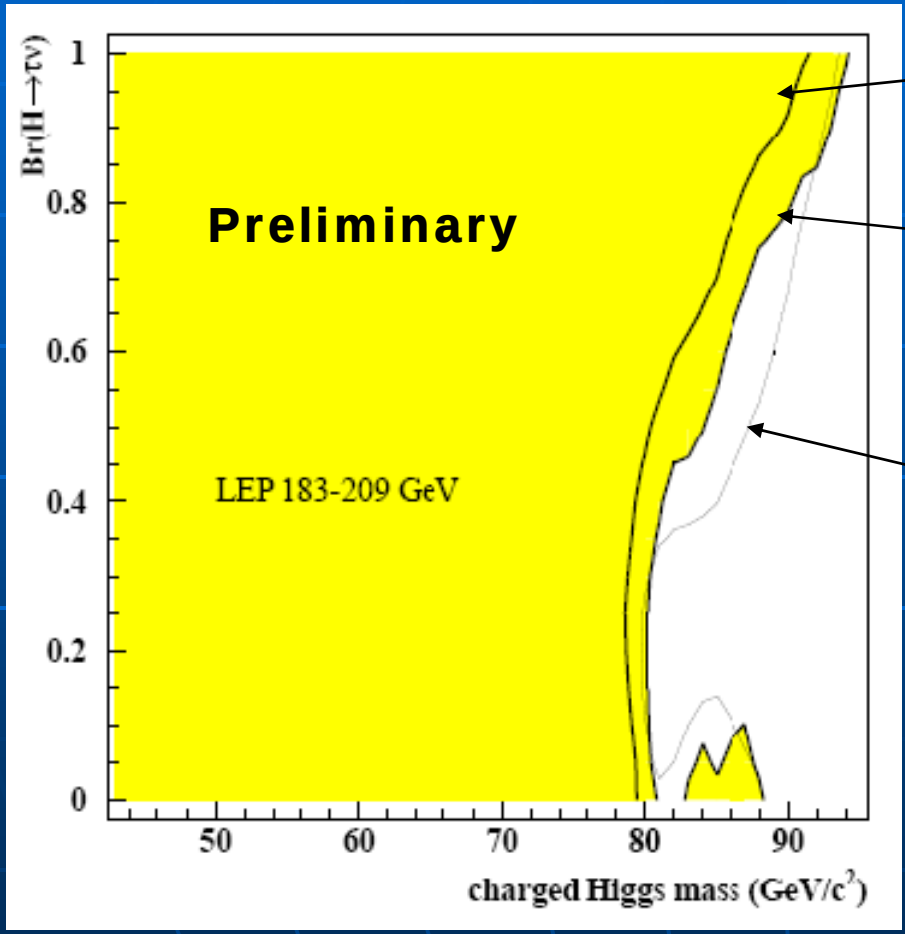
2HDM type II : combination



Contours based on the observed p-values CL_b

3 zones show an excess above 2σ, far from the expected limit

2HDM type II : combination



Obs. exclusion @ 99.7%

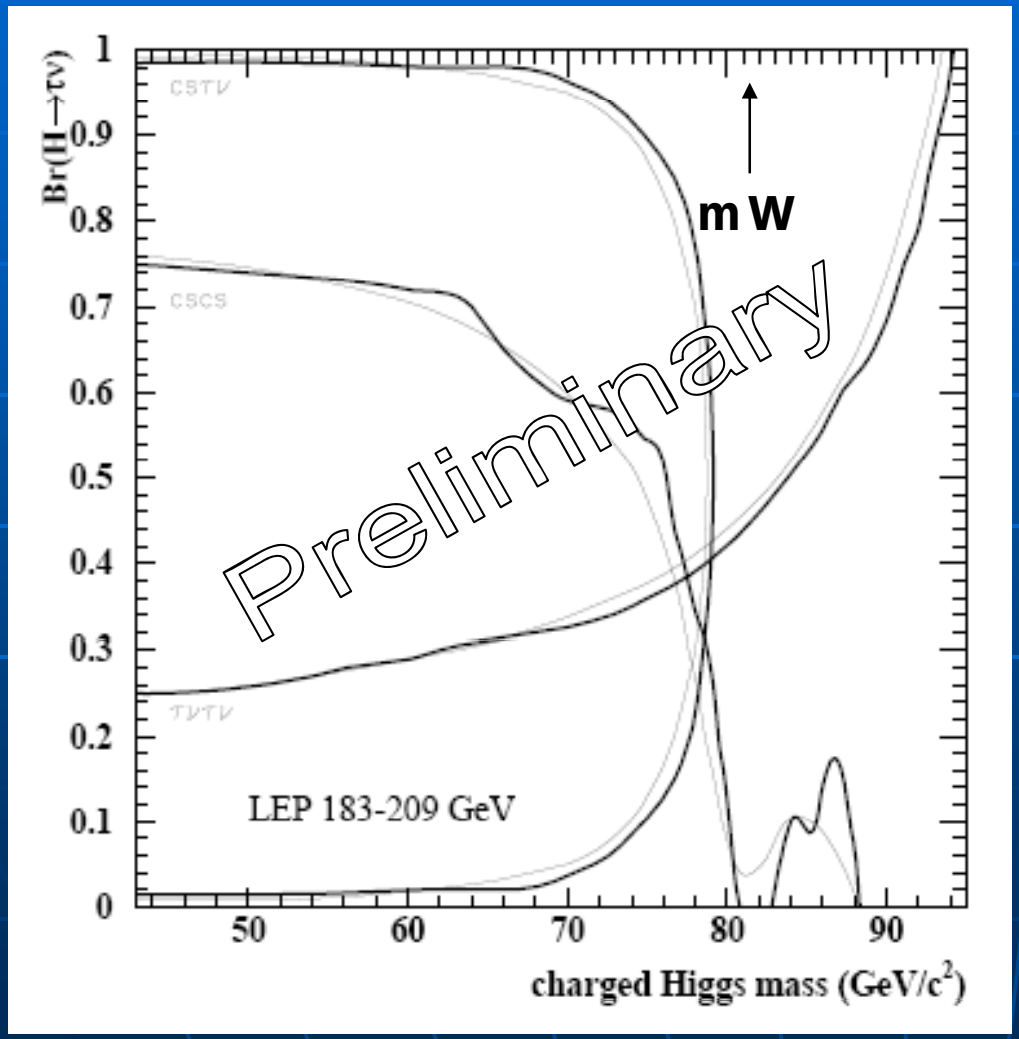
Obs. exclusion @ 95%

Expected excl. @ 95%

Small overall excess in the mixed channel.

Exclusion limit > mW nearly everywhere

2HDM type II : combination

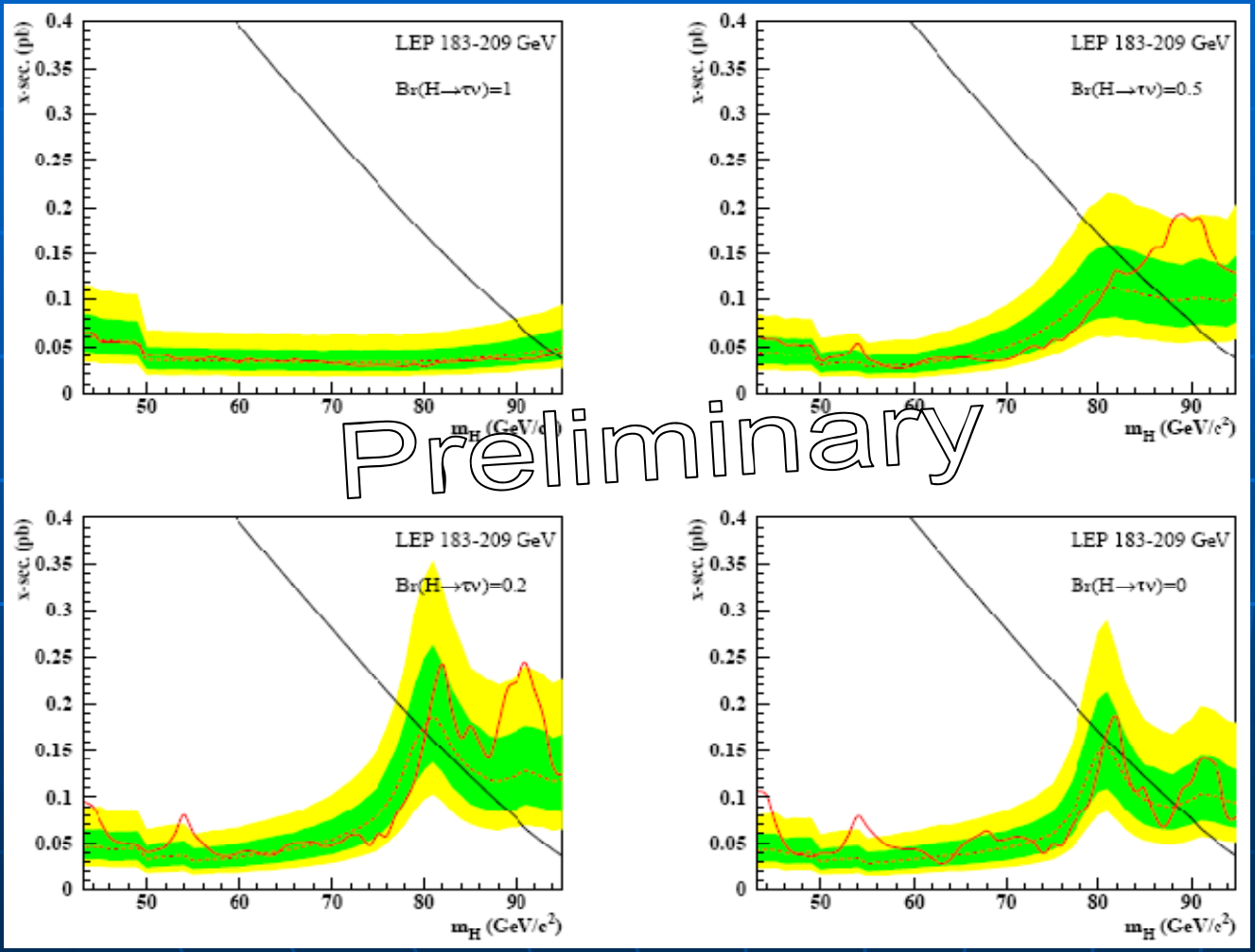


Contribution of the 3 channels separately

	Mass limit (95% CL) in GeV/c^2
B($H^+ \to \tau^+\nu$)=0	
Limit expected (median) :	88.3
Limit observed :	80.8 (*)
B($H^+ \to \tau^+\nu$)=1	
Limit expected (median) :	93.5
Limit observed :	94.2
Any B($H^+ \to \tau^+\nu$)	
Limit expected (median):	79.7
Limit observed :	80.1

Preliminary

2HDM type II : combination



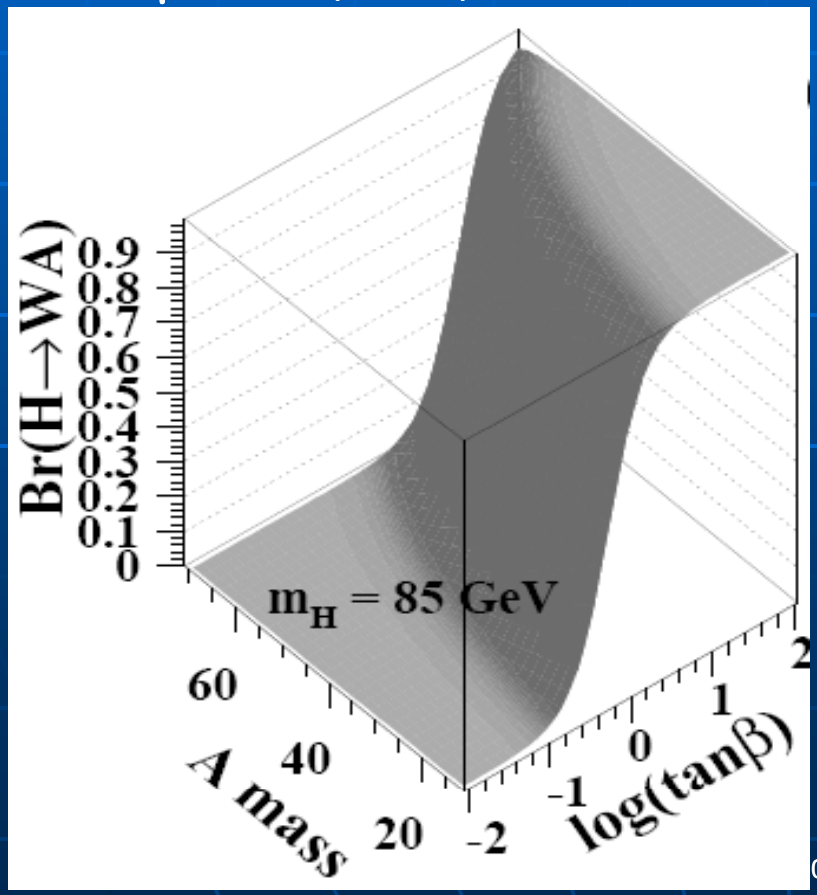
95% CL bound on x-sect., for 4

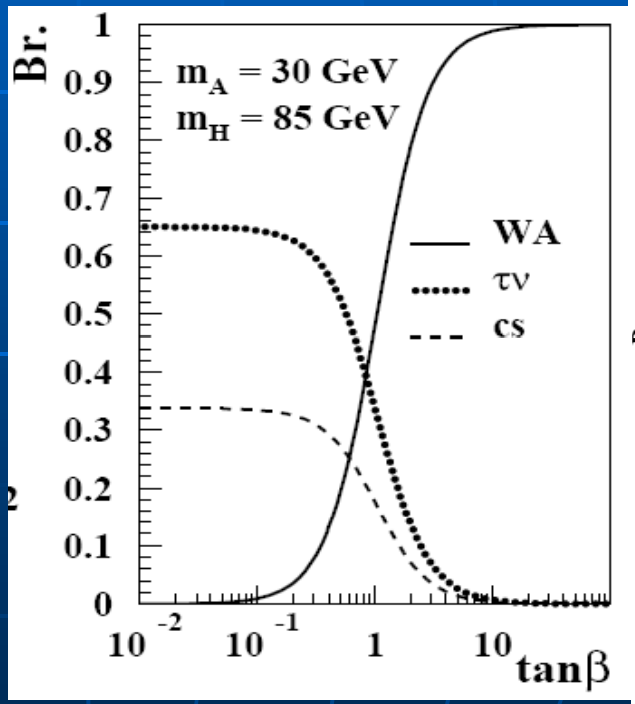
B(H → τν)

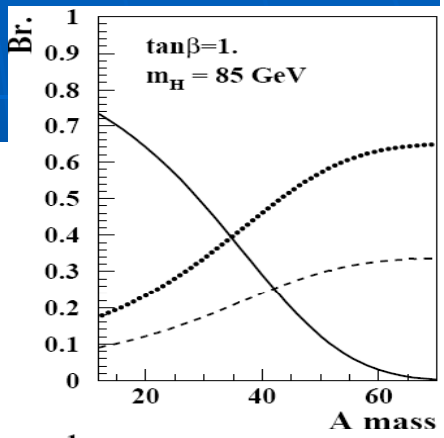
The values of mW used in background simulations has a strong impact on the limits.

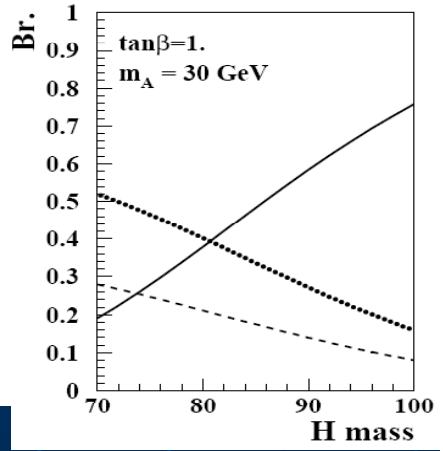
2HDM type I

- One Higgs doublet provides masses to all (up- and down-type) quarks (~SM)









2HDM type I (cont'd.)

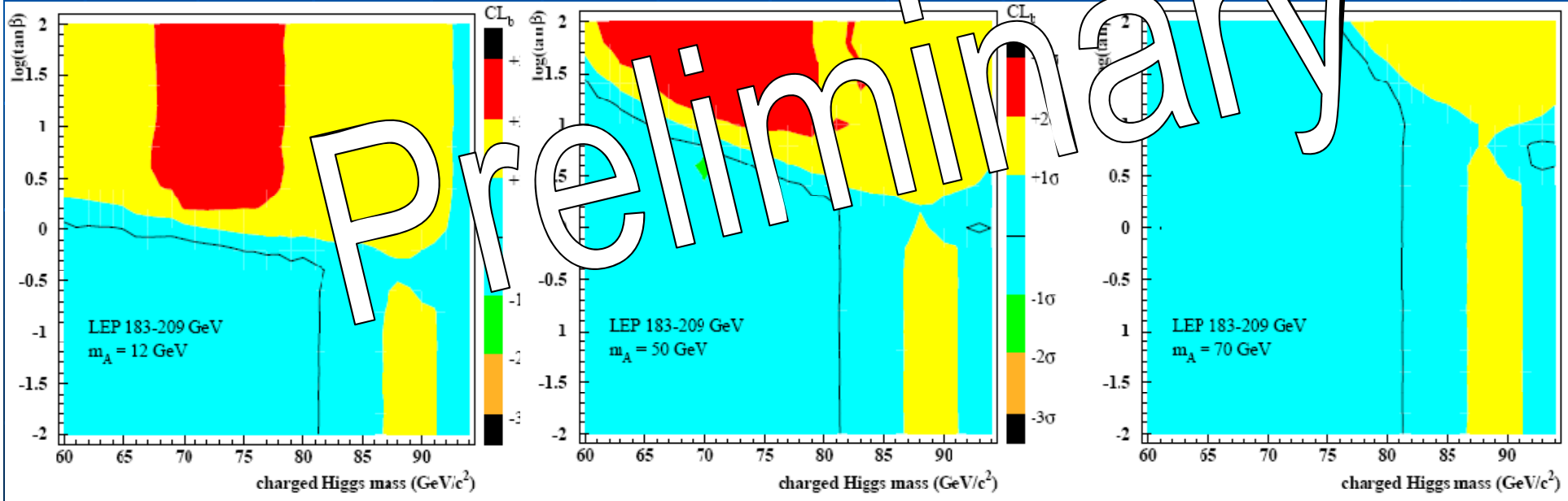
- Need a scan in a 3-dim space : m_{H^+}, m_A, and tanβ

- Conservatively, when there was an overlap between 2 channels, the one with the lowest expected sensitivity was ignored to avoid double counting
  W*AW*A and cscs as an exemple

2HDM type I : combination

Contours based on the observed p-values CL_b

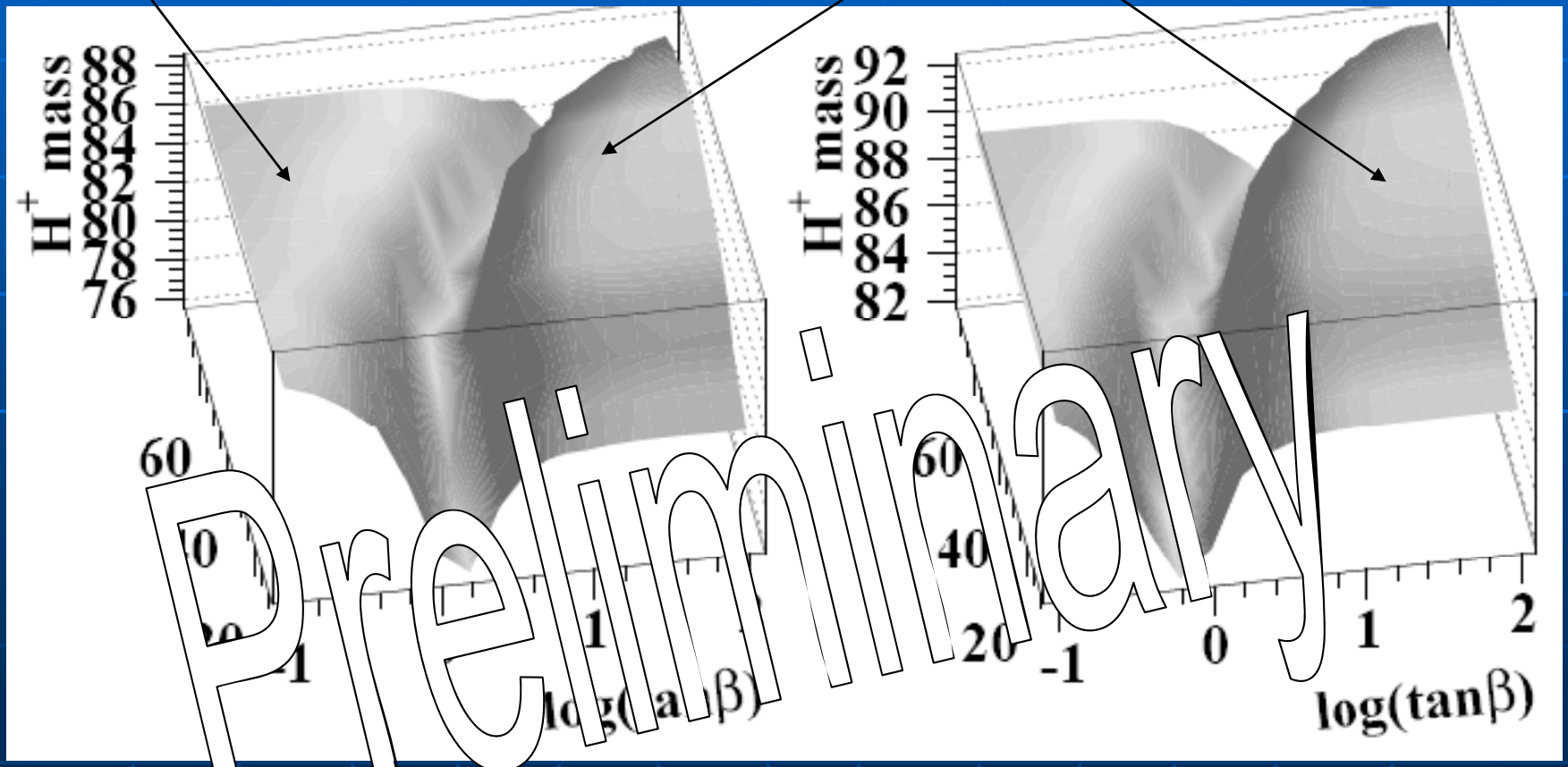
Excess (< 3σ) in the W*A regions, for low and intermediate A masses



2HDM type I : combination

Pure fermionic decays

Pure bosonic decays



Preliminary

Observed

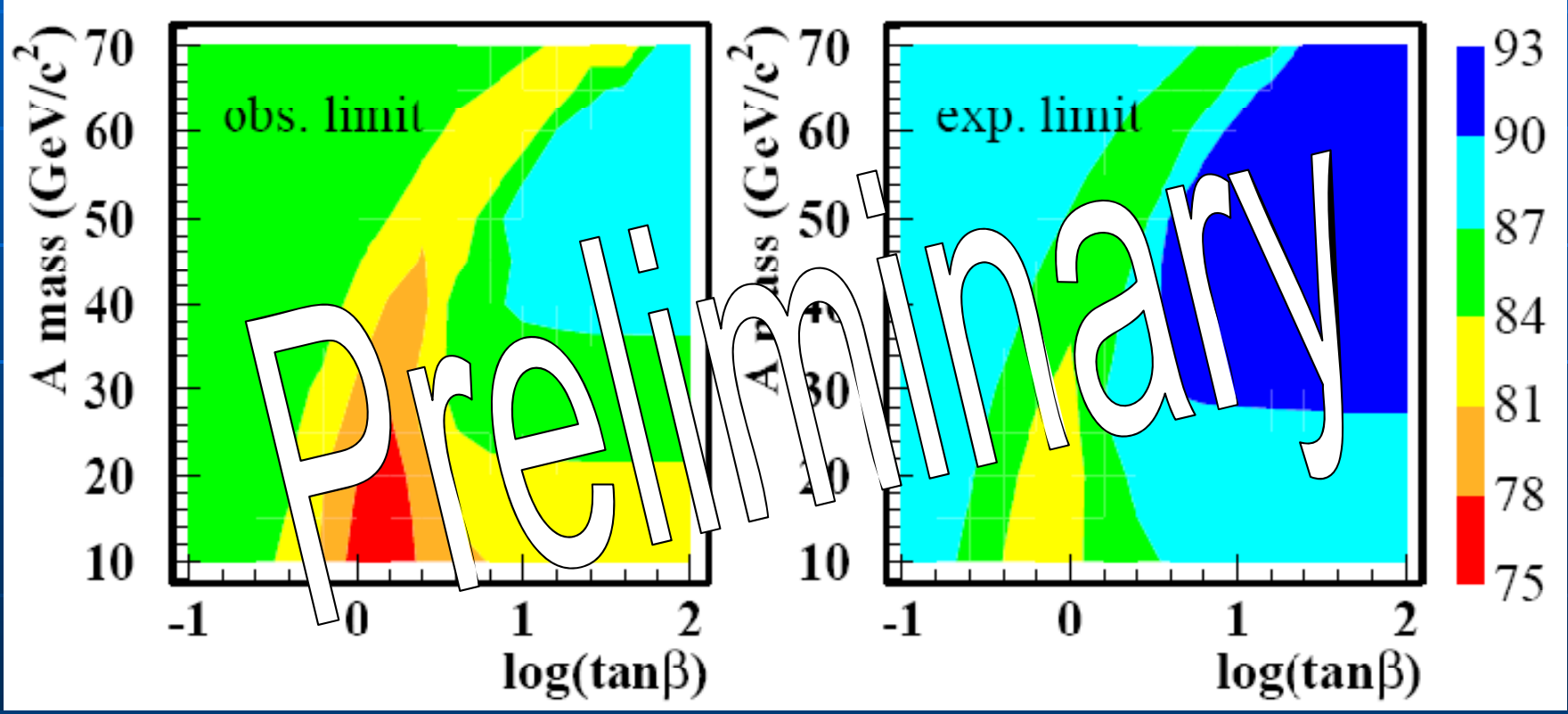
95% CL limits

Expected

2HDM type I : combination

Everywhere, the limit is found in a region where an excess is observed :

So, there is a systematic shift (~3 GeV) between obs. and expect.



Conclusions

- Still preliminary, but nearly final.
- In the historical scenario (2HDM type II like) with fermionic decay channels alone

$$m_H > 80.1 \text{ GeV}$$

(limited by WW background and W mass)

- NEW ! Exploration for a 2HDM type I (with mA > 12 GeV)

$$m_H > 76.1 \text{ GeV}$$

due to a slight excess w.r.t. the expectation

Lessons for the future

- We noticed too late that the expts have chosen different W mass in their simul.

  (A : 80.45 ; D : 80.40 ; L3 : 80.356 ; O : 80.33)

- **It is impossible to correct for that !**
- Overlapping channels should be treated with care, in order to avoid the (perhaps too) conservative approach used here. It would have been possible here with an explicit anti-btag in the cs channel