Outlook

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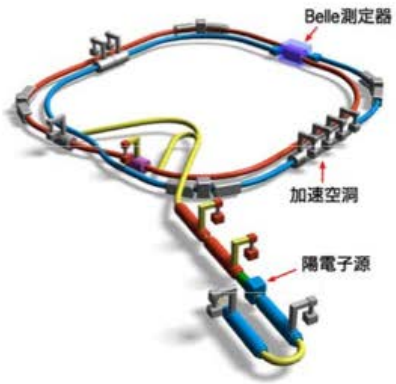
Grand H^+ plan

General strategy

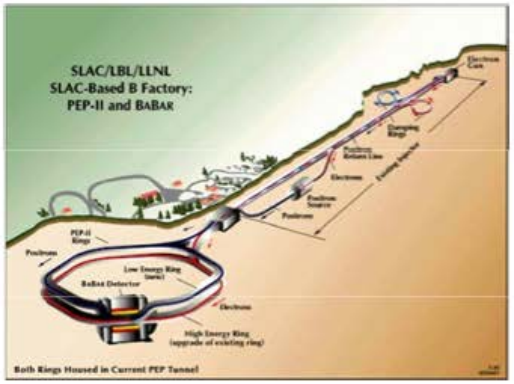
- First achieve **discovery of H^+** – *could* become the first definite discovery of BSM physics
- Then, like for H^o, **make precision measurements** of the H^+ mass, total width, spin, couplings => indication of *specific* BSM scenario

Sequence of contributions from accelerators

- **B-superfactories** provide indirect H^+ detection
- **LHC** provides first direct detection of light H^+ and (after upgrade) of heavy H^+
- **e+e- colliders** provide direct even higher mass H^+ discovery and high precision H^+ measurements



B-Factories

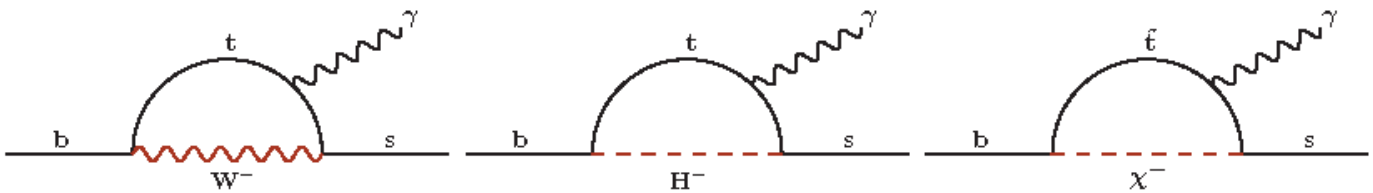


772M & 467M $B\bar{B}$ events accumulated!

Indirect H+ detection

1. Inclusive branching ratio of $B \to X_s \gamma$

Contributing loops:



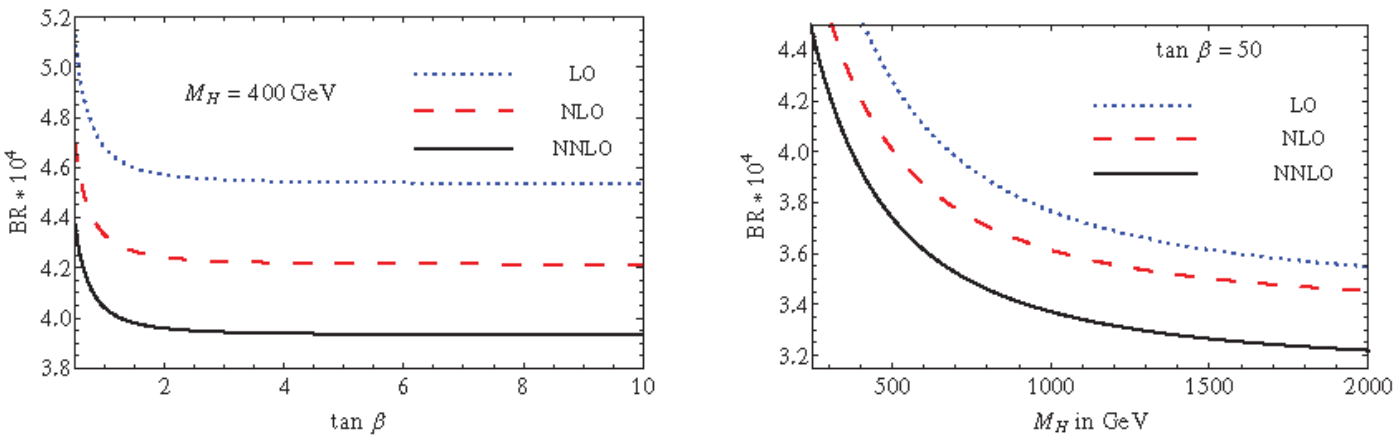
Main operator: $\mathcal{O}_7$
but higher order contributions from $\mathcal{O}_1, \ldots, \mathcal{O}_8$.

- Charged Higgs loop always adds constructively to the SM penguin
- Chargino loops can add constructively or destructively

$\to$ Cancellation possible in SUSY but not in the THDM 2!

$B \to X_s\gamma$

- SM contributions known to NNLO accuracy
- THDM contributions known to NNLO accuracy
- SUSY contributions known partially to NNLO accuracy



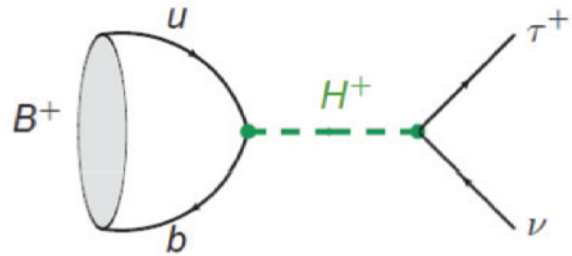
T. Hermann, M. Misiak, M. Steinhauser, arXiv:1208.2788

Experimental values (HFAG 2012): $\mathrm{BR}(\bar{B} \to X_s\gamma) = (3.43 \pm 0.21 \pm 0.07) \times 10^{-4}$

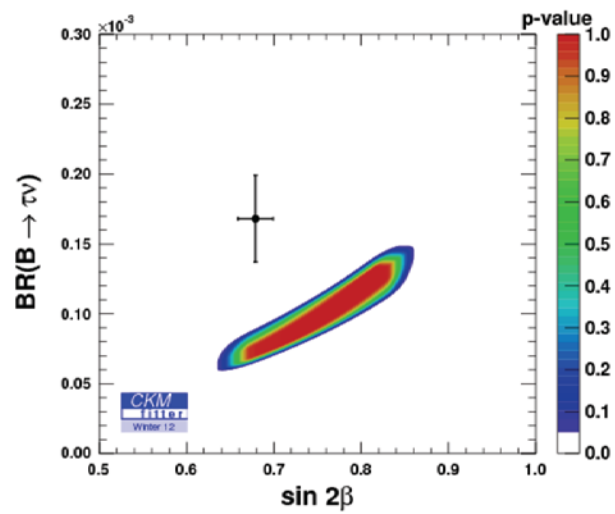
SM prediction: $\mathrm{BR}(\bar{B} \to X_s\gamma) = (3.08 \pm 0.24) \times 10^{-4}$

2. sin(2β) versus B→τν before the summer

- Tension: sin(2β) and $\mathcal{B}$(B→τν):
  - ~3σ effect.
  - $\mathcal{B}$ (B→τν) is too high or sin (2β) too low.
- Enhanced BF: not explained by B_d decay constant f_{Bd} (10% LQCD).
- Charged Higgs contribution (sensitive to H-b-u)? [opposite to the data].

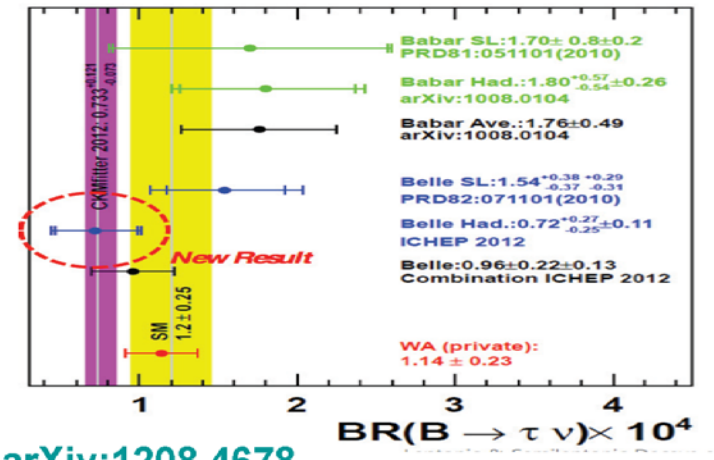


$$B(B^+ \to \tau^+ \nu) = B_{SM} \times \left(1 - \frac{m_B^2}{m_{H^+}^2} \tan^2\beta\right)^2$$

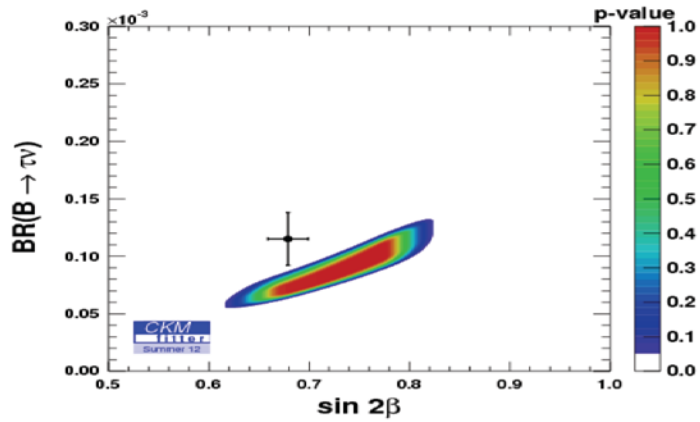


sin(2β) versus B→τν after the summer

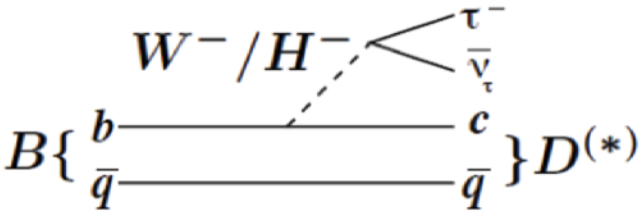
- A new value from Belle: decrease of the world average.
  - 1.6σ effect.
- Hadronic τ decays.
- Improvement: treatment of peaking backgrounds.



arXiv:1208.4678



3. Ratio $B \to D^{(*)}\tau\nu / B \to D^{(*)}\tau l$



$$\frac{d\Gamma_\tau}{dq^2} = \frac{G_F^2 |V_{cb}|^2 |\mathbf{p}|q^2}{96\pi^3 m_B^2}\left(1-\frac{m_\tau^2}{q^2}\right)^2 \left[\left(\underbrace{|H_{++}|^2 + |H_{--}|^2}_{\text{Vector Meson D*}} + |H_{00}|^2\right)\left(1+\frac{m_\tau^2}{2q^2}\right) + \frac{3}{2}\frac{m_\tau^2}{q^2}\underbrace{|H_{0t}|^2}_{\text{Charged Higgs}}\right]$$

$$R(D) = \frac{Br(\bar{B} \to D\tau\nu)}{Br(\bar{B} \to D\ell\nu)} \qquad R(D^*) = \frac{Br(\bar{B} \to D^*\tau\nu)}{Br(\bar{B} \to D^*\ell\nu)}$$

SM: $R(D) = 0.297 \pm 0.017$ $\qquad$ $R(D^*) = 0.252 \pm 0.003$

PRD 85 094025

- B-factory study (complex to perform in a collider).
- Leptonic decays of the τ.
- Full reconstruction of a tag B.
- Identify e or μ and reconstruct a D meson.

cH+/-arged 2012 Uppsala
8-11 October 2012

Cibrán Santamarina
U. Santiago de Compostela

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Ratio $B \to D^{(*)}\tau\nu / B \to D^{(*)}\tau l$

BaBar:

-3.4σ away from SM

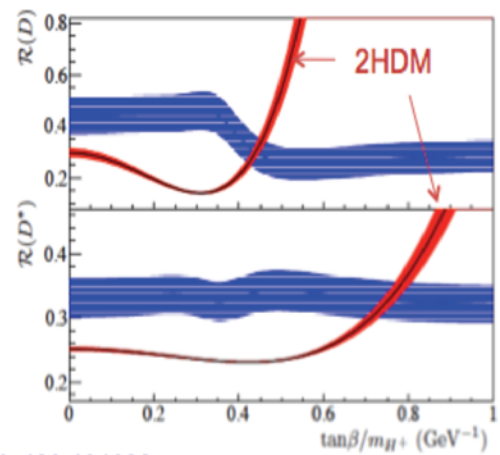
-Excludes 2HDM type II Model at 99.8% CL.

Belle:

-Supports indication of larger than expected rates.

-Should be able to reduce uncertainties to the BaBar level.

	R(D)	R(D*)
BABAR	0.440 ± 0.071	0.332 ± 0.029
SM	0.297 ± 0.017	0.252 ± 0.003
Difference	2.0 σ	2.7 σ



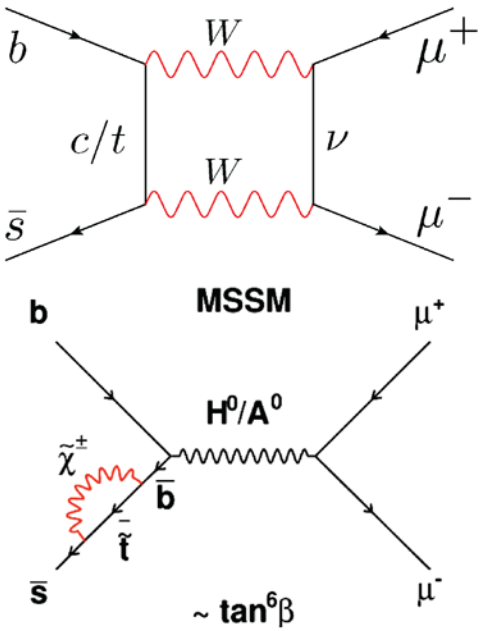
$R(D) \to \tan\beta/m_H = 0.44 \pm 0.02$

$R(D^*) \to \tan\beta/m_H = 0.75 \pm 0.04$

PRL 109 101802

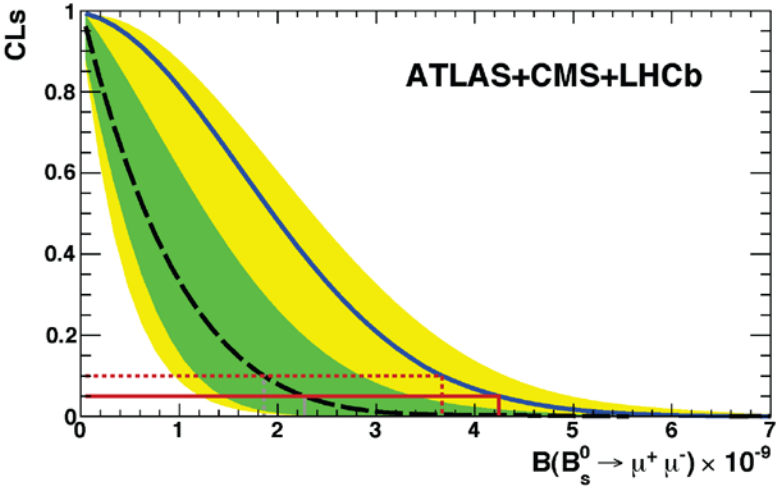
LHC

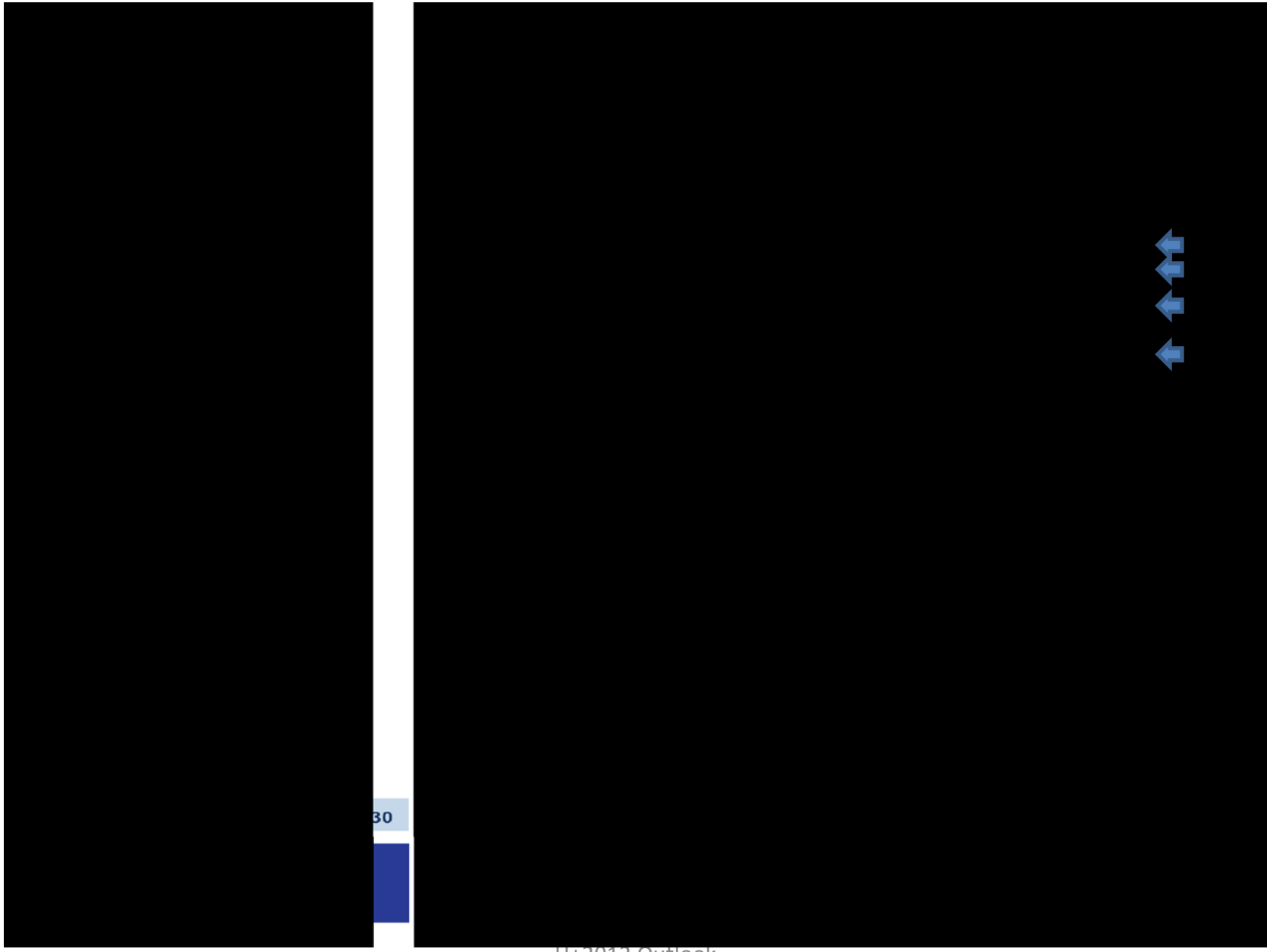
4. $B_s^0 \to \mu^+\mu^-$



LHCb: PRL 108 231801,
CMS PAS BPH-12-009
LHCb-CONF-2012-017
ATLAS-COM-CONF-2012-090

- Strongly suppressed in SM: GIM & helicity.
- $\mathcal{B}^{SM}$ ($B_s^0 \to \mu^+\mu^-$) = (3.5 ± 0.2) × 10^{-9}. JHEP 1010 009 & arXiv:1012.1447.
- SUSY: enhancement of this decay by $\tan^6\beta$.
- Other possibilities: extra dimensions, little Higgs, Technicolor,…
- $\mathcal{B}^{LHCb} < 4.5\times10^{-9}$ @ 95% CL. (7.7 [CMS]).
- $\mathcal{B}^{LHC} < 4.2\times10^{-9}$ @ 95 % C.L.
- Squeezing New Physics.

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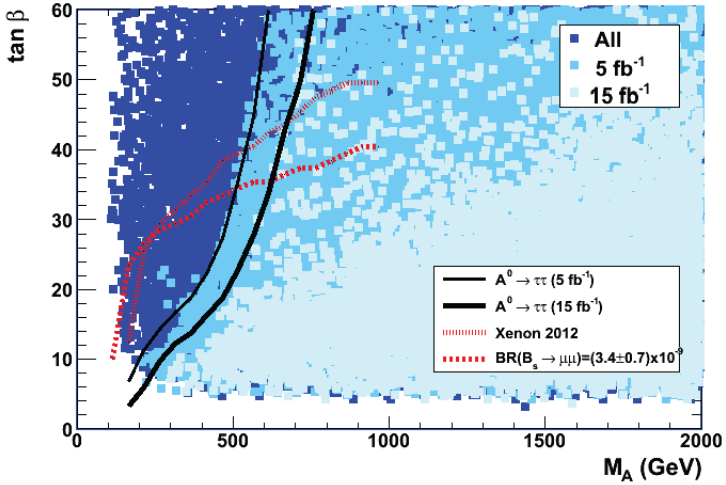
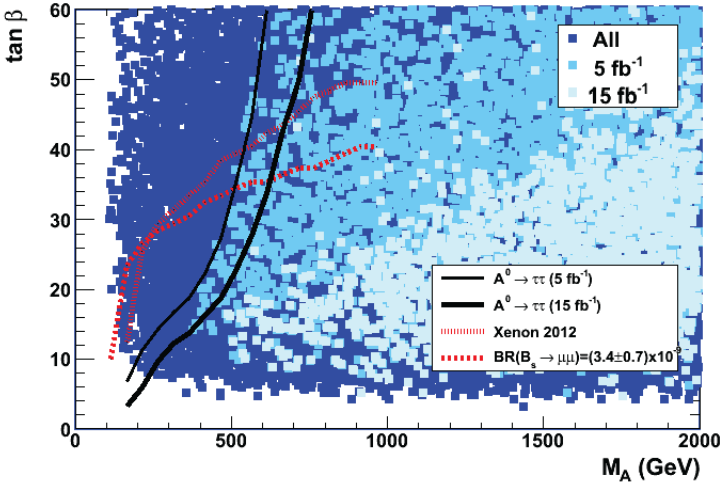
Constraints on the MSSM

Constraints from flavour physics, dark matter direct detection, SUSY and Higgs searches

Without Higgs decay rate constraints



With Higgs decay rate constraints

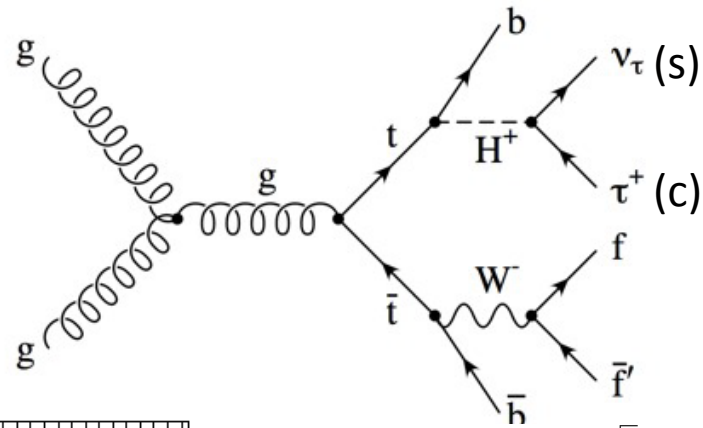


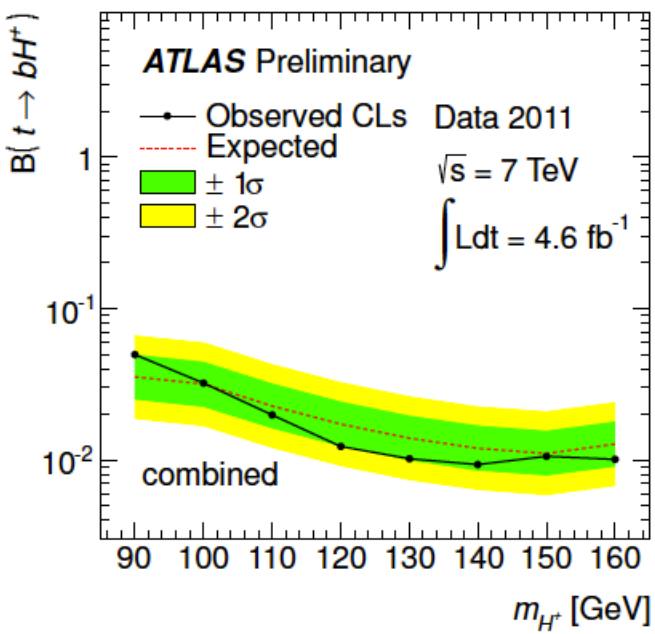
A. Arbey, M. Battaglia, FM, Eur.Phys.J. C72 (2012) 1906

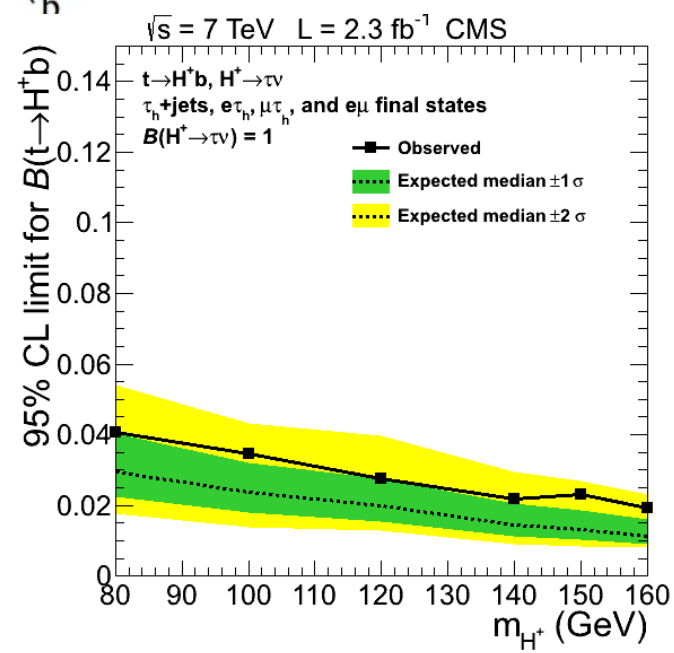
Once putting everything together the allowed region is really squeezed!

LHC direct searches

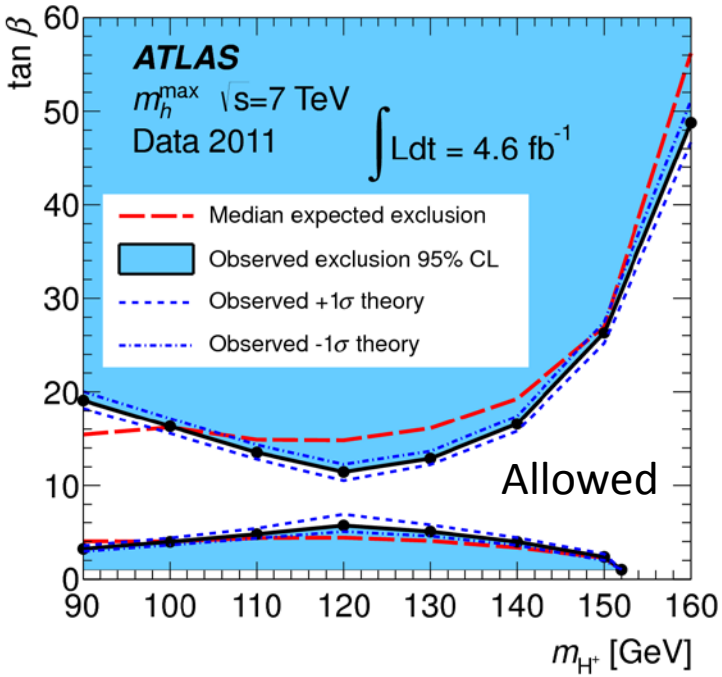
Upper limits on B(t->bH+)





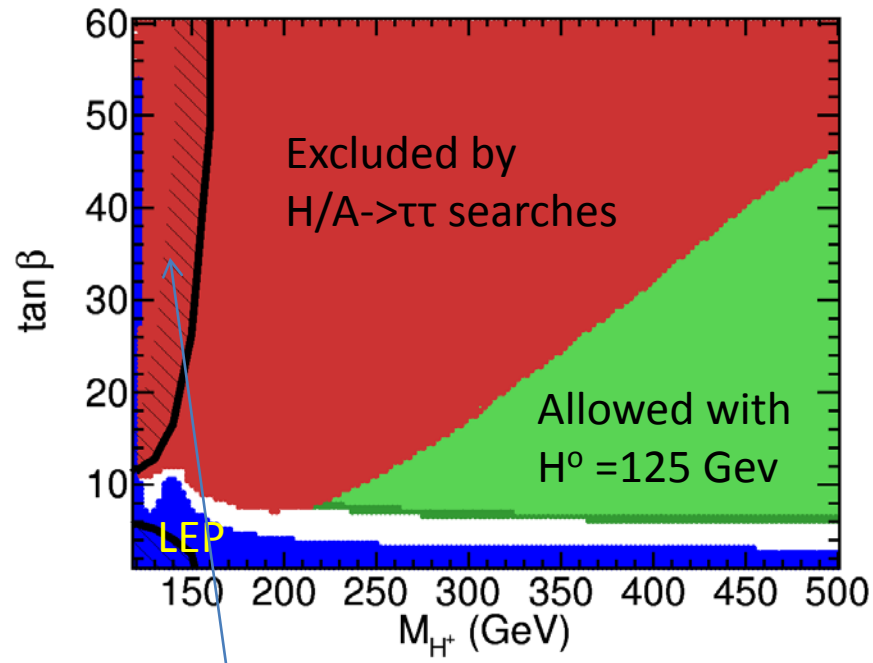


Constraints on MSSM parameter space from H^+ and $H^o \to \tau^+\tau^-$ searches at LHC



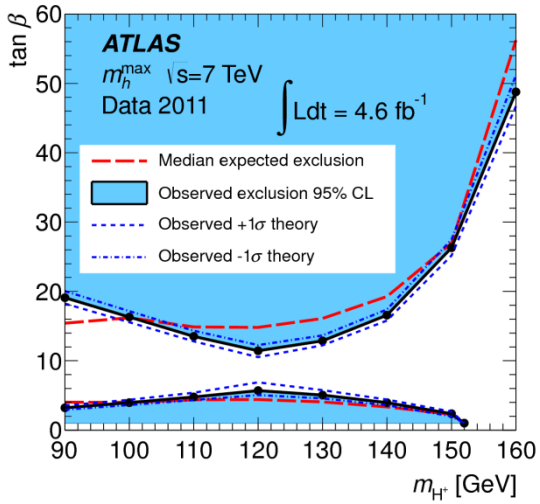
Published in JHEP, vol. 1206, pp. 39, 2012

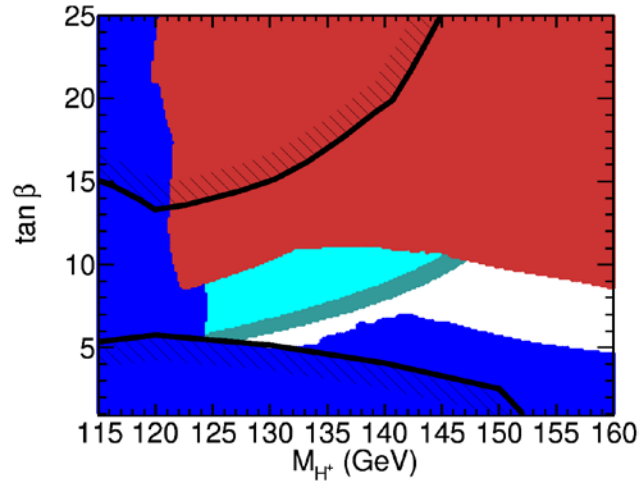
Upper limit on tan β ? M_h-max, X_t=-2TeV



Excluded by H+ searches

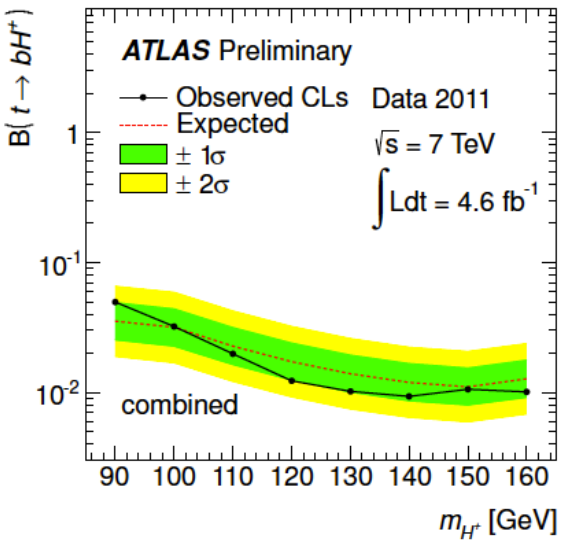
Alternative MSSM interpretation: M_H = 126 GeV

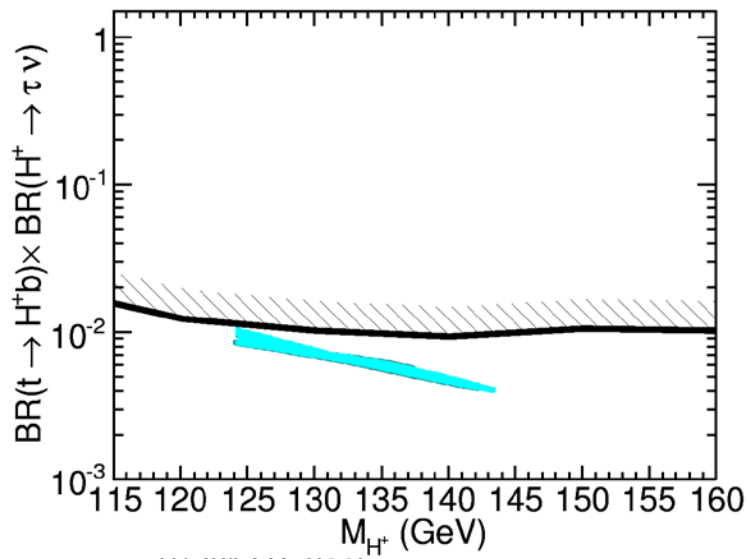




M_H = 125.7+-2.6 GeV
ATLAS/CMS exclusion
LEP exclusion
ATLAS Direct H+

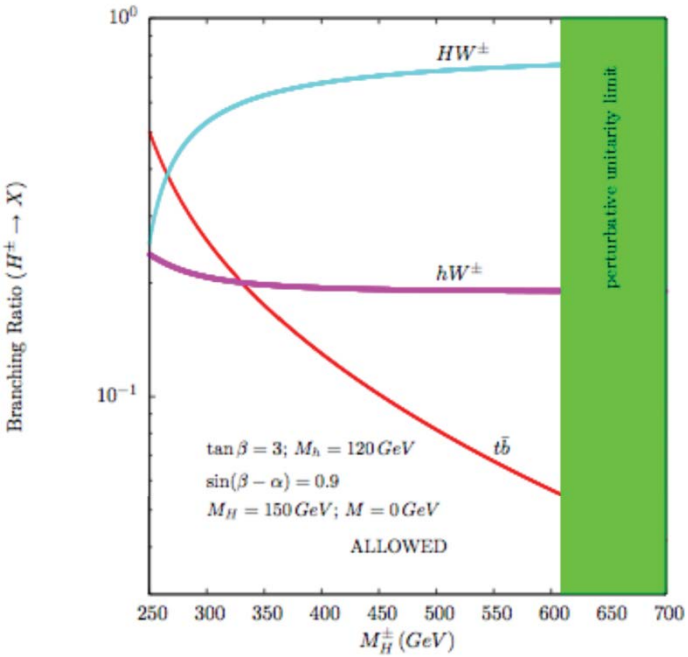
$$\mu = 1\ \mathrm{TeV}$$
$$M_{\mathrm{SUSY}} = 1\ \mathrm{TeV}$$
$$X_t = 2.3\, M_{\mathrm{SUSY}}$$

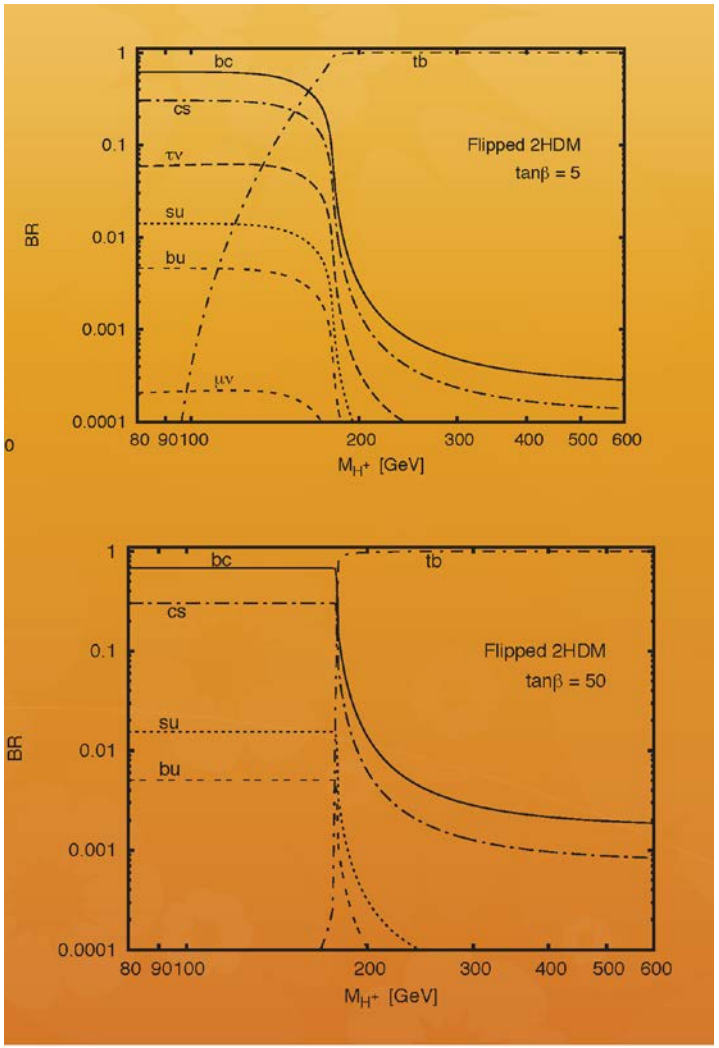




Sofar we have been looking for the light H+ decaying to $\tau\nu_\tau$ and cs and the heavy H+ to tb

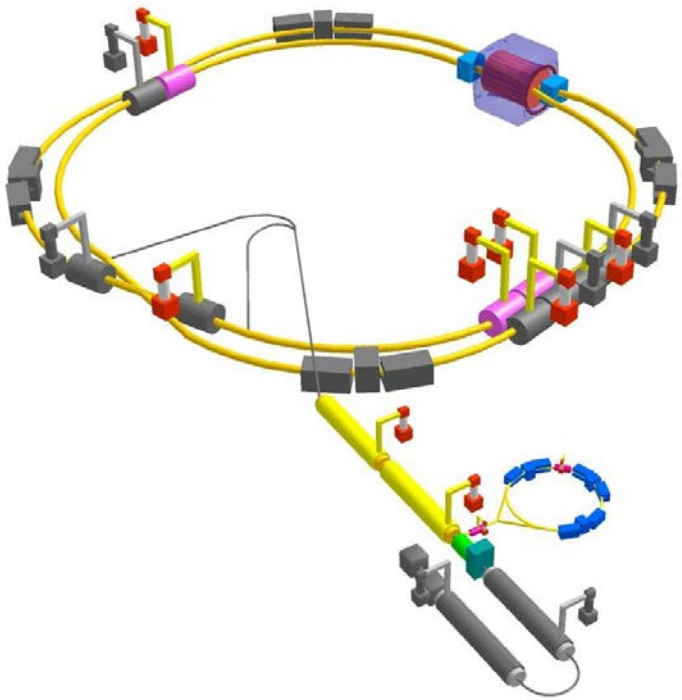
In the Flipped Model the light H+ Decays predominantly to bc
And the heavy Higgs could in certain Models decay to H^oW^+ or h^oW^+





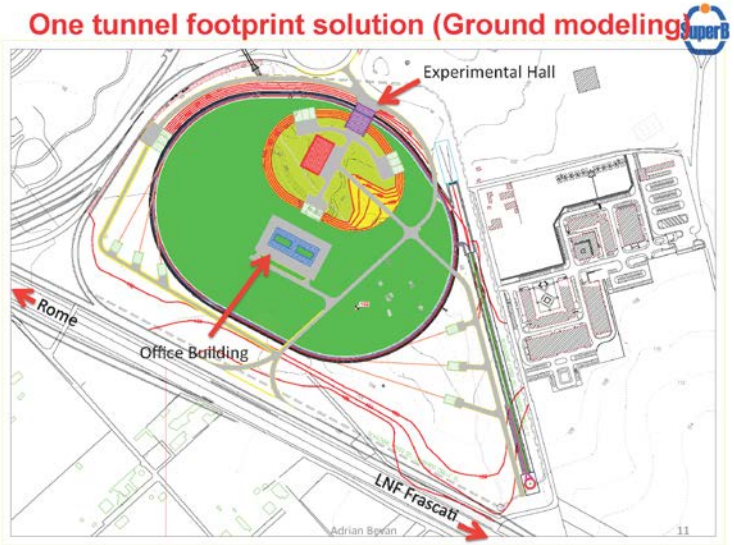
And this morning we heard about H+->cs, cb, ts, W gamma, WZ from Jaime Hernández so we need to keep an open mind as to what H+ decay states to look for….

Super B factories



SuperKEKB
Japan

SuperB
Tor Vergata
Italy



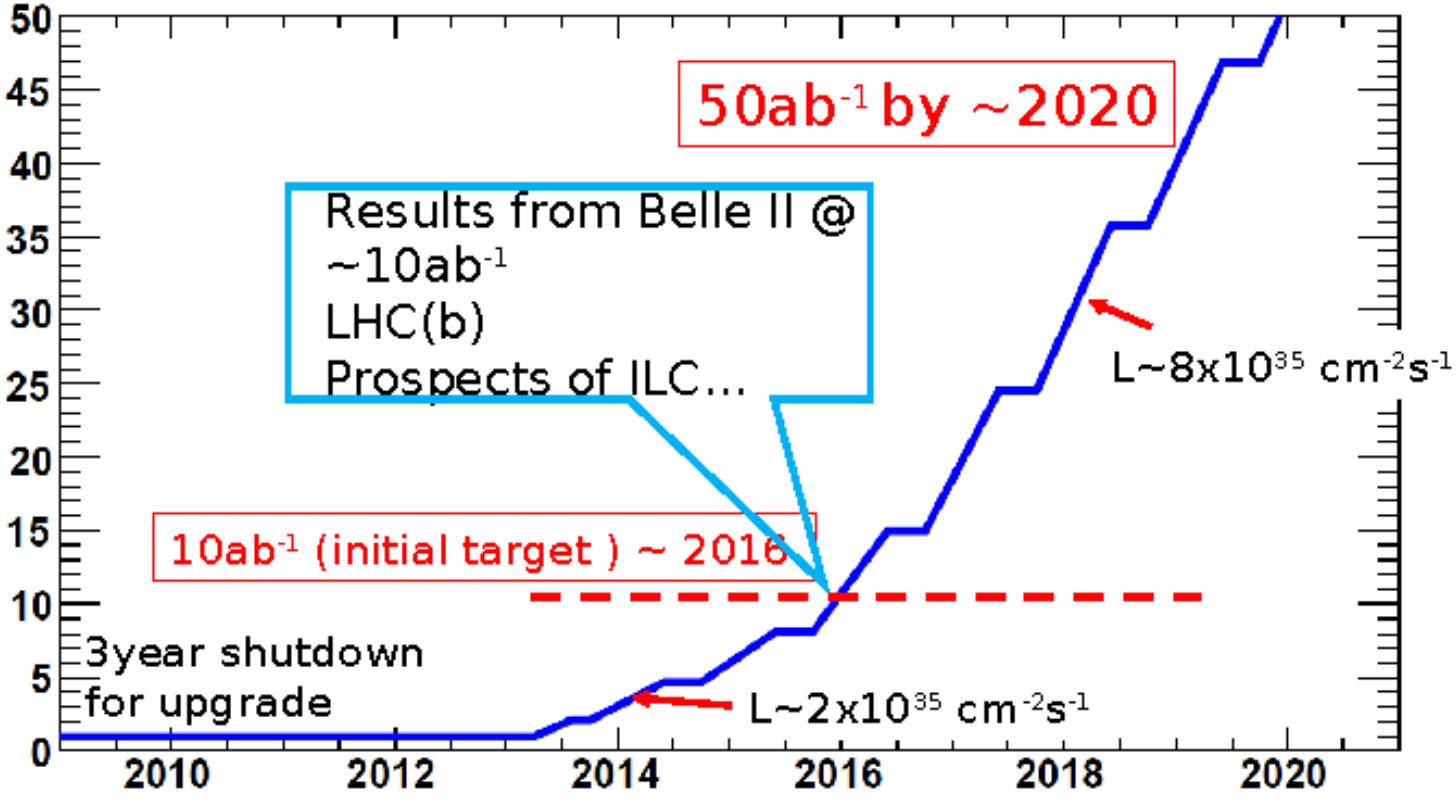


Figure 1: SuperKEKB luminosity prospects

LHC upgrade to $L=5*10^{35}cm^{-2}s^{-1}$ and $\sqrt{s}$=13-14 TeV

LHC 10 year plan

	J	F	M	A	M	J	J	A	S	O	N	D
2011		1	2	3	4	5	6	7	8	9	IONS	
2012			1	2	3	4	5	6	7	8	IONS	
2013	LS1 - SPLICE CONSOLIDATION											
2014									RECOM	RECOM	1	2
2015	1	2	3	4	5	6	7	8	9	10	IONS	
2016		1	2	3					8	9	IONS	
2017		1	2	3	4	5	6	7				
2018	LS2											
2019		1	2	3	4	5	6	7	8	9	IONS	
2020		1	2	3					8	9	IONS	
2021		1	2	3	4	5	6	7	8	9	IONS	
2022	HL-LHC upgrade											

LS1

PHYSICS AT 6.5/7 TeV

LS2

“ULTIMATE” PHYSICS

LS3

HL-LHC

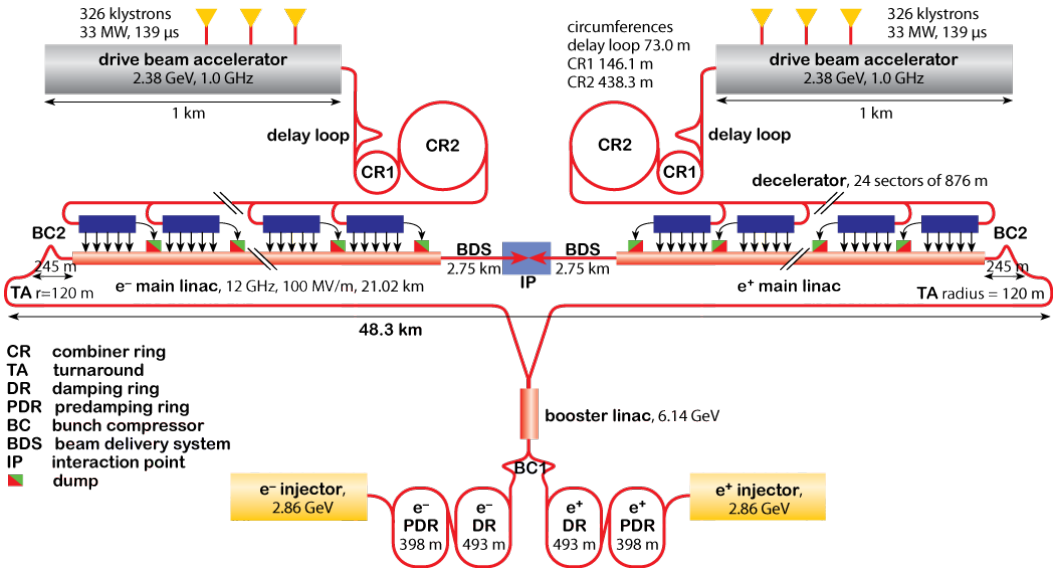
≈ 300 fb^{-1} at 6.5-7 TeV

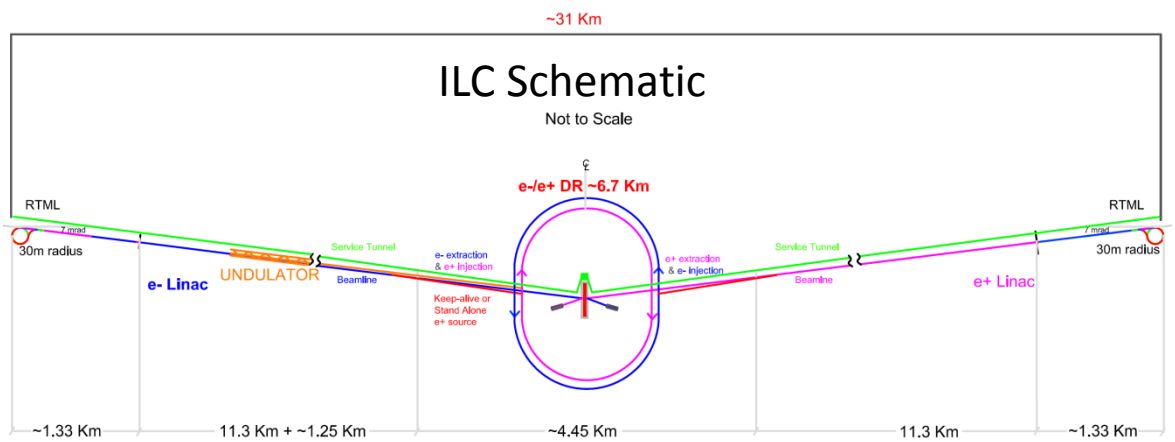
~3000 fb^{-1} at 6.5-7 TeV

Technical stop or shutdown
Proton physics
Ion Physics
Recommissioning

NB: not yet approved

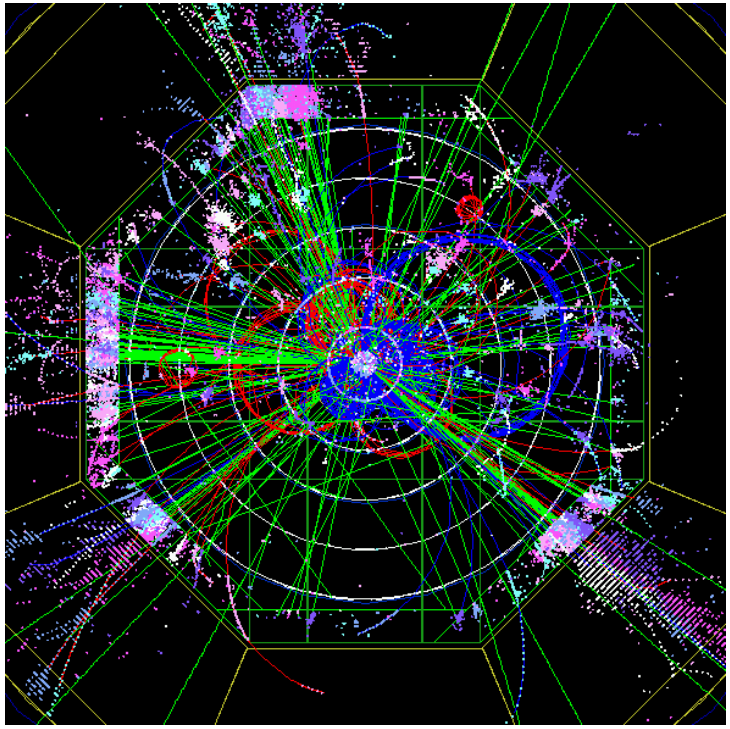
Overall Layout of CLIC (3 TeV)

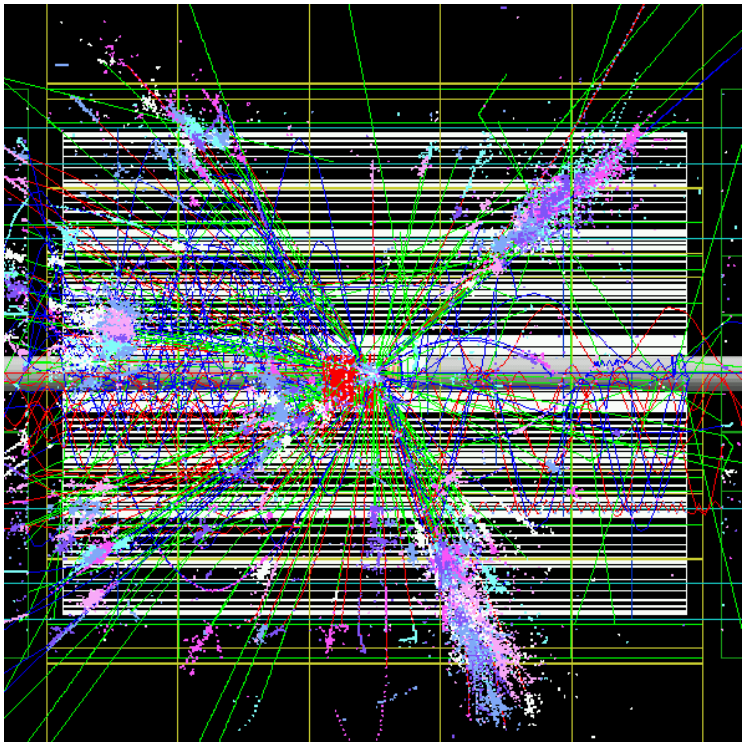




Schematic Layout of the 500 GeV Machine

e+e- → H+H- → tbtb

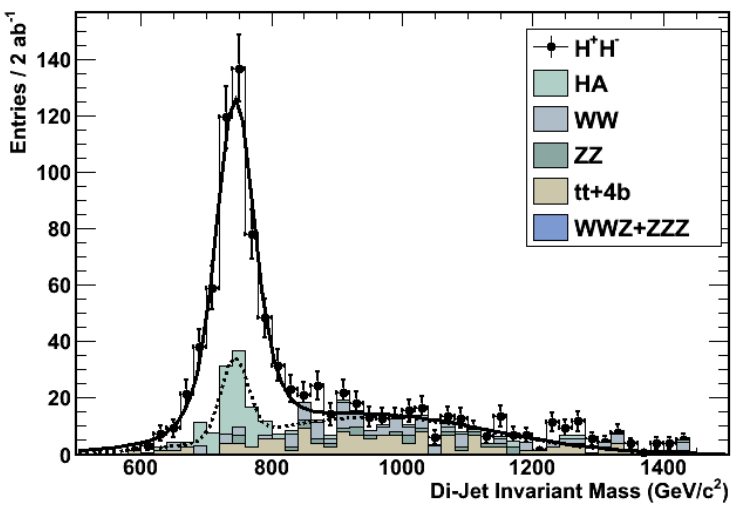


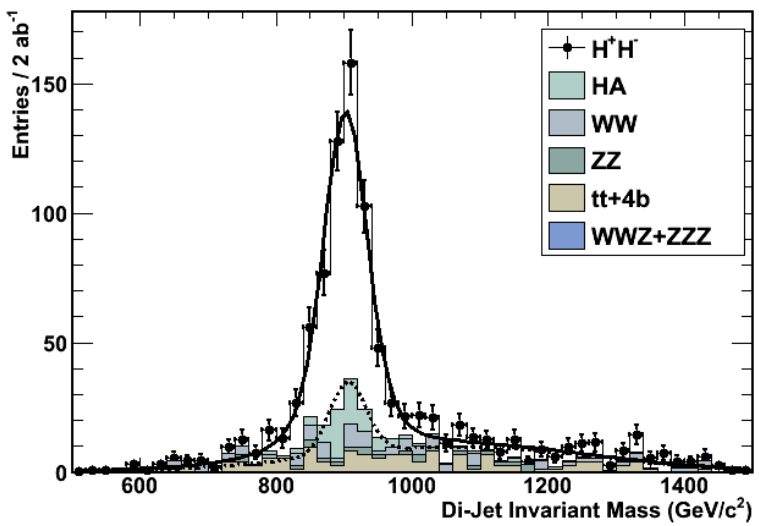


Start from analysis of H+H- for CERN-2004-005 CLIC Physics Report later extended and published as Coniavitis & Ferrari, PRD 75 (2007) 015004

H+ Mass and Width Reconstruction:

Kinematic Fit with Equal Mass Constrain,
anti-kt semi-exclusive jet clustering





Signal + SM Bkg
6-par Fit
MH = (744.3+/-2.0 (stat)) GeV
Γ_H = (17.0+/-4.7) GeV

Signal + SM Bkg
6-par Fit
MA = (901.4+/-1.9 (stat)) GeV
Γ_H = (18.9+/-4.4) GeV

We have this year made a discovery of a new boson, the recordings of which we are now poised to investigate thoroughly over the next two years.

This investigation will add new momentum to our research because it will not be based on speculation but on high statistics, precise experimental observations.

What new discoveries may be waiting, beyond the detailed investigation of the properties of the Higgs-like boson, we do not know, but many of our earlier assumptions will have to be abandoned and new ideas will appear as a consequence of what detailed properties of the Higgs-like boson we find.

Because of this year's discovery we currently live in new times in which new knowledge about the fundamental properties of matter may soon be gained.

There is a good chance that the detailed analysis in 2013 and 2014 of the some 2*25 fb^{-1} to be collected at LHC before the end of 2012 LHC run will lead to a significant change of the current landscape in High Energy Physics by the autumn 2014.

We hope to see you all back in Uppsala for the Charged Higgs Workshop in autumn 2014.