

# CP VIOLATIONS (AND MORE) FROM LHCB

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# Outline

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- Open problems in HEP/cosmological physics
- EW baryogenesis in a nutshell
- Status of the SM after 2<sup>nd</sup> year of LHC
- Results from LHCb at  $\sqrt{s} = 7$  TeV
  - CP violations
  - Limits on SuSy parameter space ( $m_0$ ,  $m_{1/2}$  &  $\tan\beta$ )
  - Limits on Heavy RH Majorana neutrino
- Summary

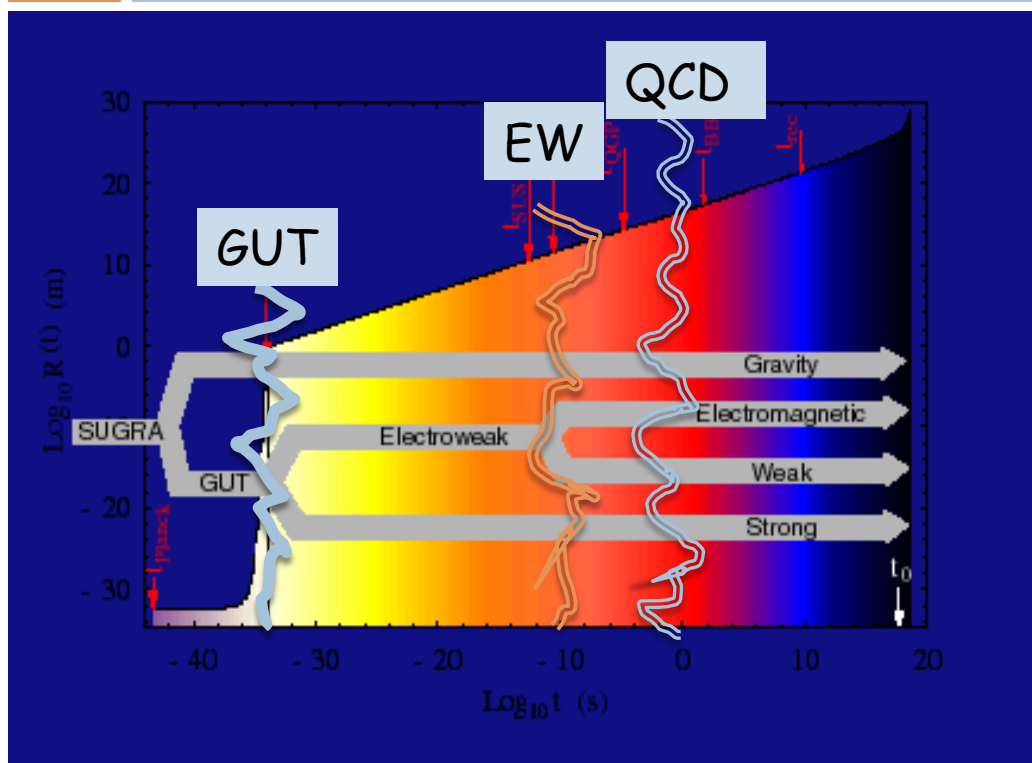
# Open problems in HEP/Cosmology

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- Baryon asymmetry ← CP Violations ✓
- Dark Matter ← SuperSymmetries ?
- Dark Energy } ← Vacuum Energy ?
- Inflation }

# Sakharov's Baryogenesis

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- 1) Baryon number violations
- 2) CP violations
- 3) Strong phase transition

EW baryogenesis does not work in the minimal SM for 2 reasons:

- 1) EW phase transition is not strong
- 2) CP violations are suppressed in the quark-gluon plasma

Possible  
Solutions  
Beyond SM

SUSY Higgs  
doublet

4<sup>th</sup> Heavy  
quarks

Heavy right  
Neutrinos

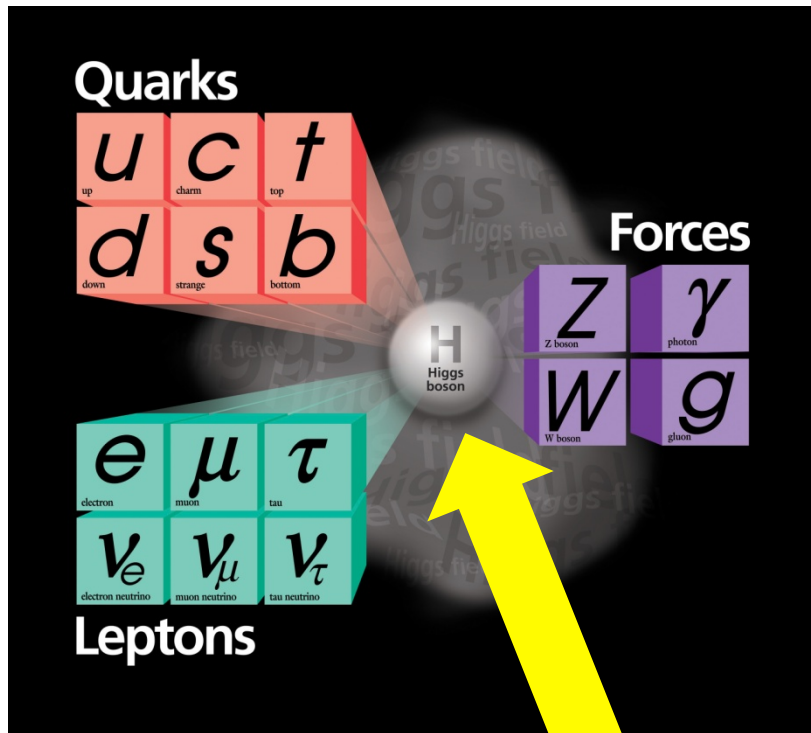
New Physics

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# The Standard Model

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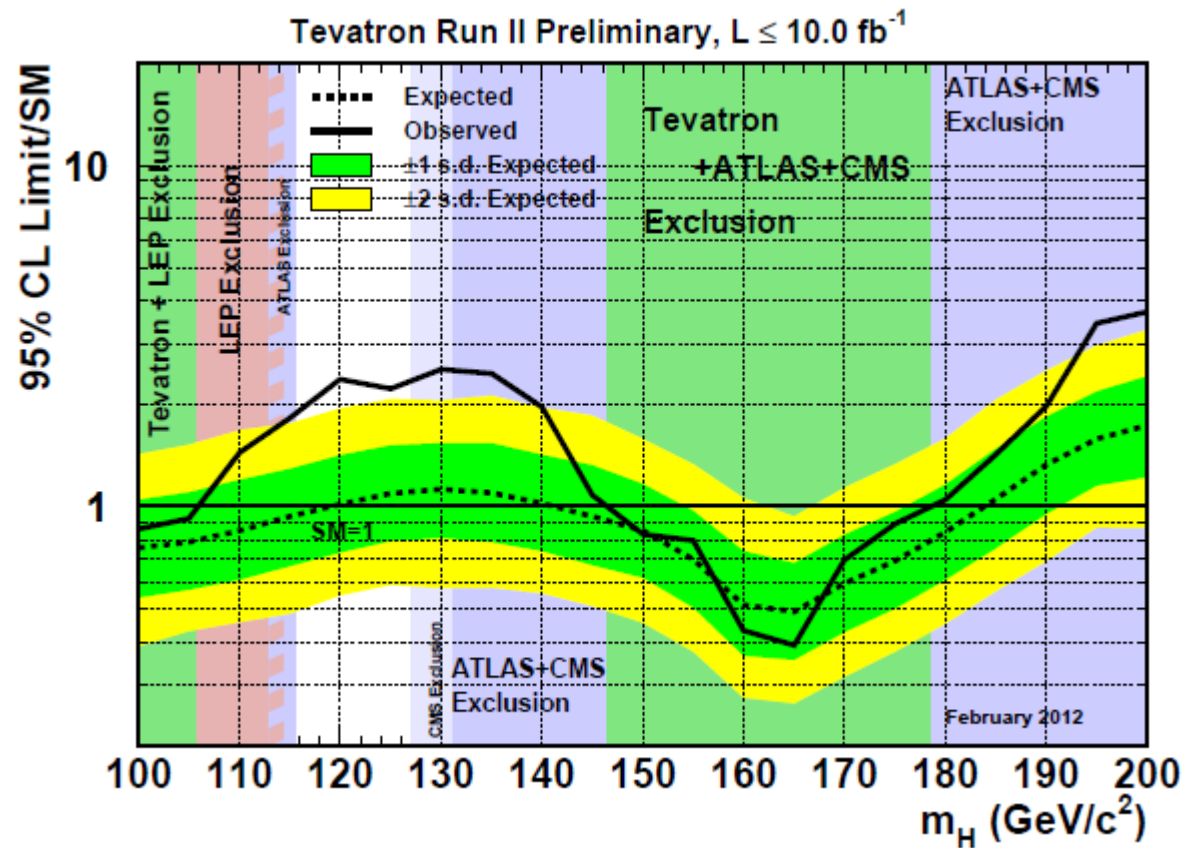
A very successful model with a number of free independent parameters:

- Number of generations
- Yukawa couplings of quarks and leptons to the Higgs field (3x4 constants)
- CKM matrix (3 angles + 1 phase) for quarks and leptons
- Vacuum Energy (i.e. Higgs mass)

Has the Higgs been discovered ?

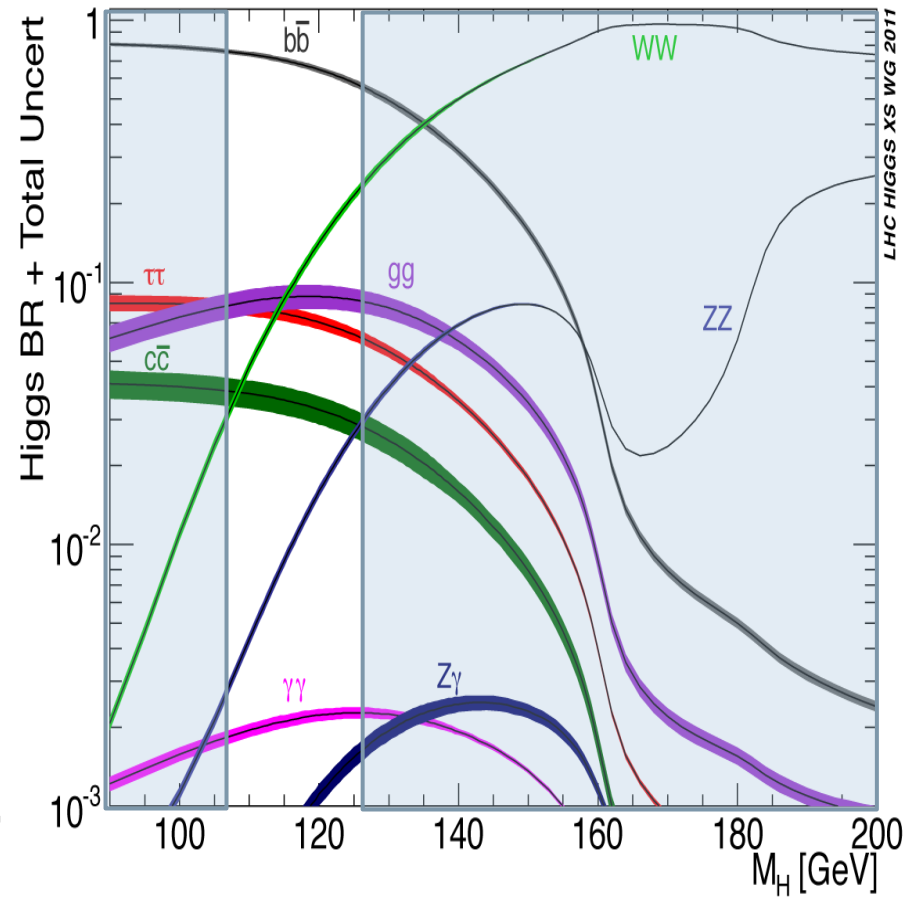
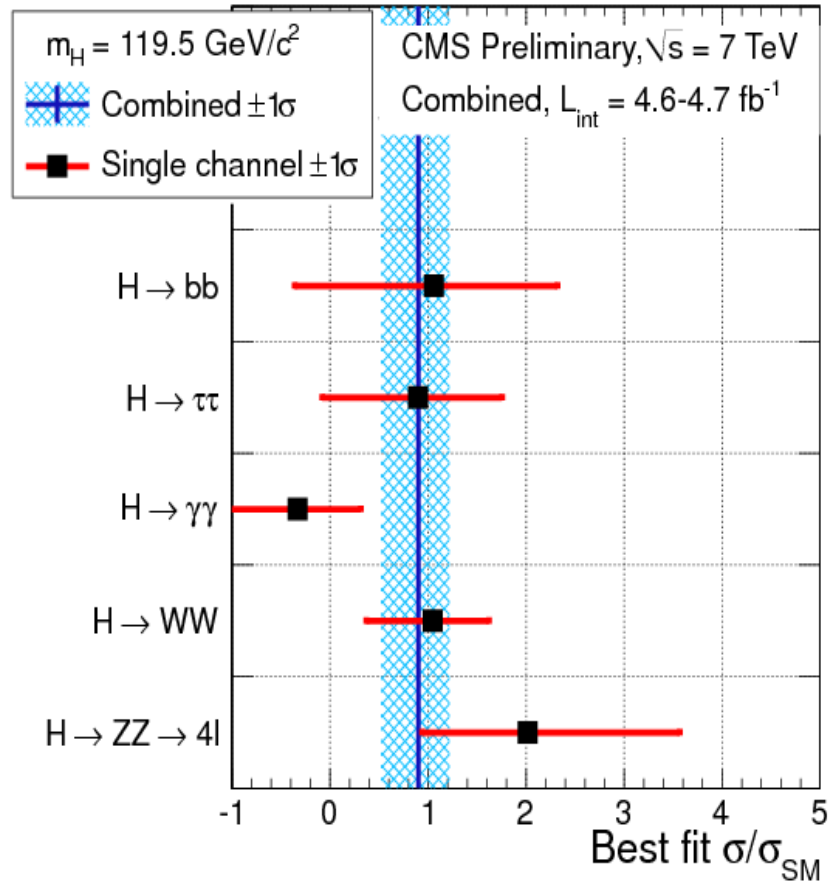
# Not yet, I am afraid !

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# The complicated rules of the game

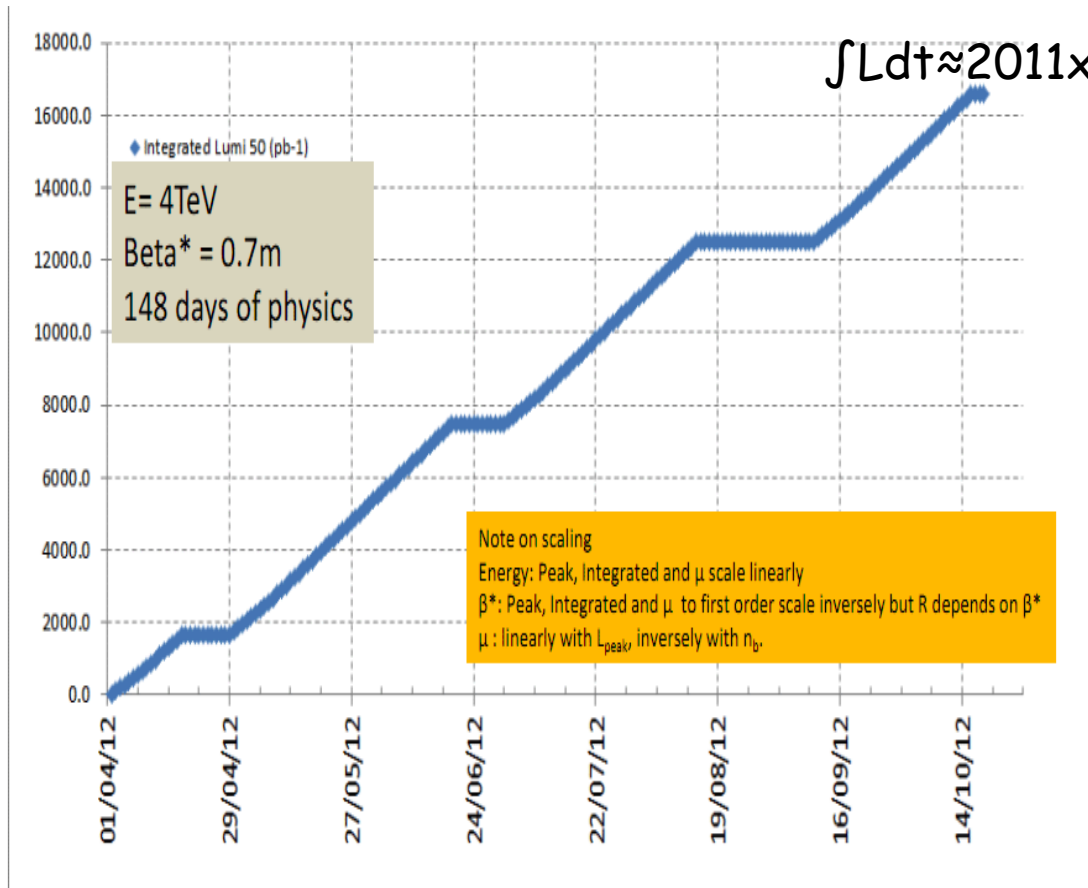
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# LHC (tentative) plan for the coming years

(CERN Press Release 5/4/2012)

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December 7, 2011

S. Myers LHCC

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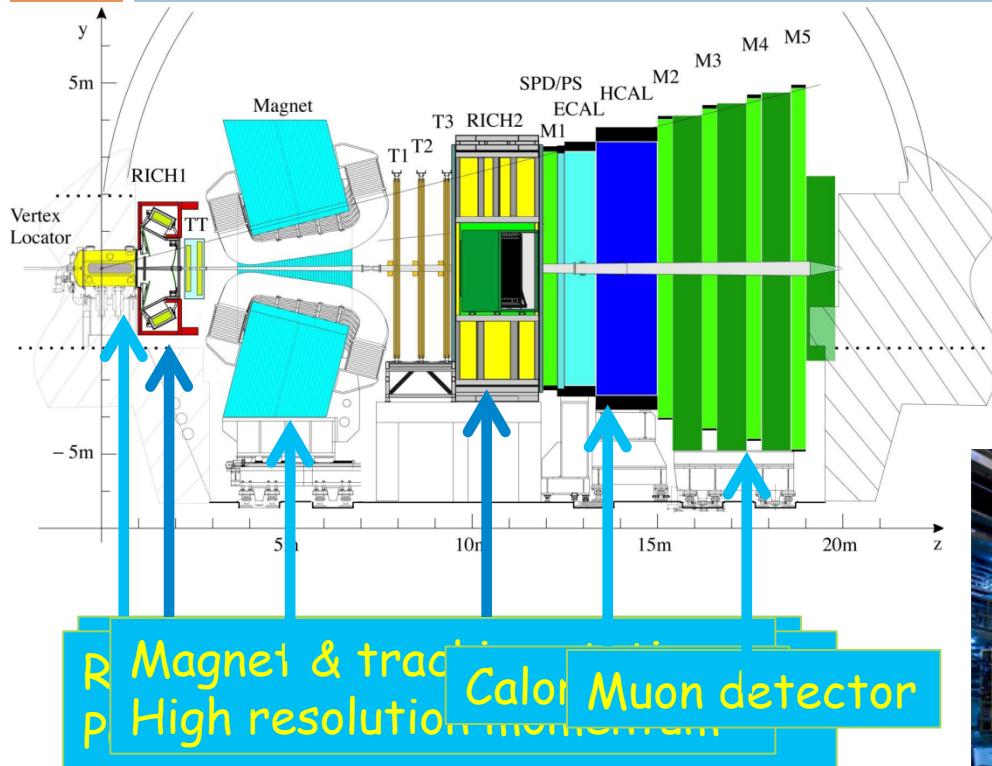
- The LHC is now scheduled to run until the end of 2012, when it will go into its first long technical shutdown.
- In late 2014 it will restart running at  $\sqrt{s} = 13$  TeV, with the ultimate goal of ramping up to the full design energy of 14 TeV.
- SuperLHC (14+ TeV &  $2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ ) to follow.





# LHCb detector

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A single arm spectrometer covering the very forward cone  $1.3 \leq \eta \leq 5$  ( $30 \leq \theta \leq 300$  mrad) optimized for heavy mesons decays reconstruction



More details in :  
 Alves A.A et al. J. Instrum 3 (2008) S08005



## CP violation in D meson decays

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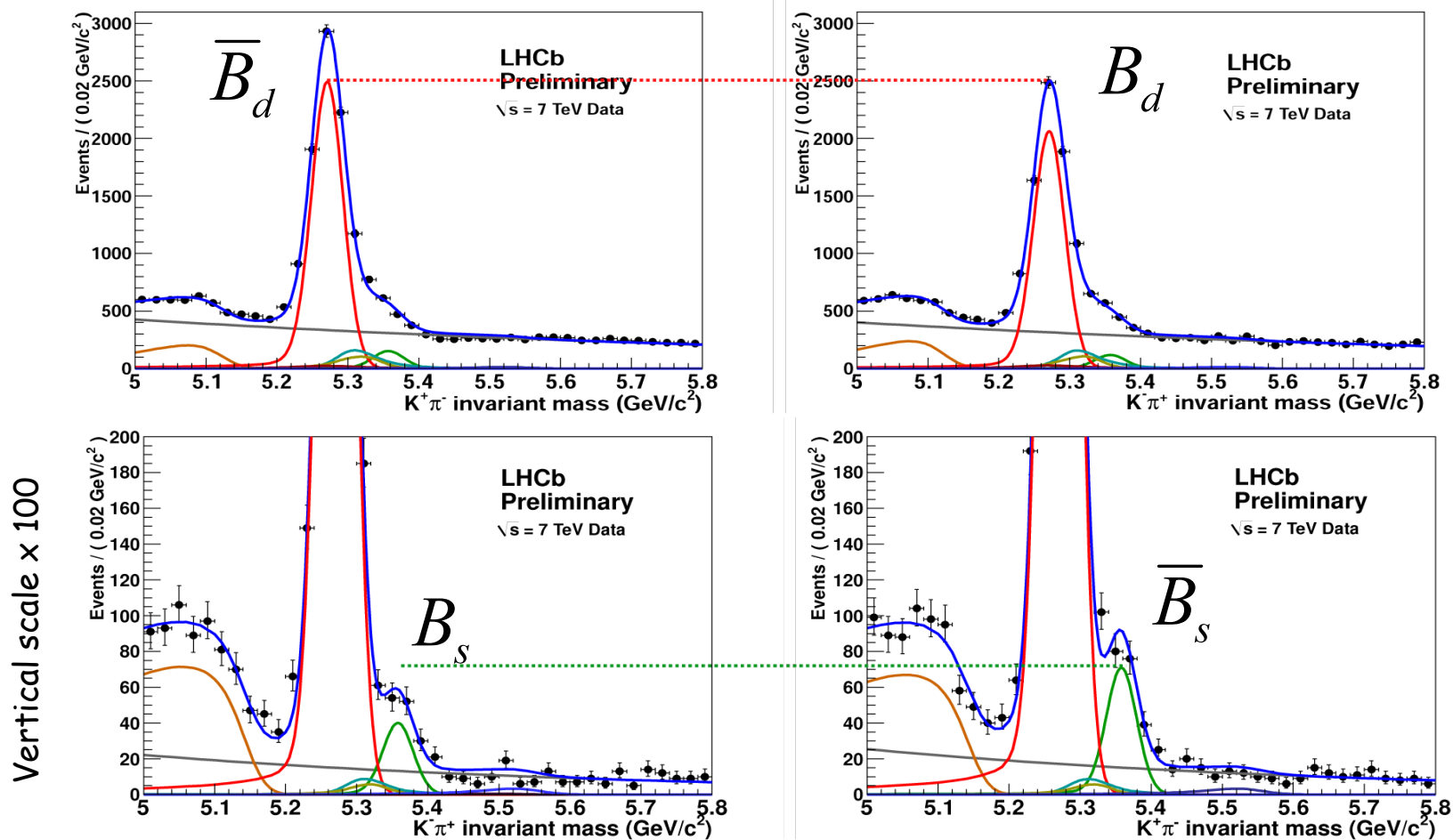
- LHCb has measured the time-integrated difference in CP asymmetry between  $D^0 \rightarrow K^- K^+$  and  $D^0 \rightarrow \pi^- \pi^+$  decays

$$\Delta A_{CP} = -0.82 \pm 0.21 \text{ (stat.)} \pm 0.11 \text{ (syst) \%}$$

using  $580 \text{ pb}^{-1}$  of 2011 data

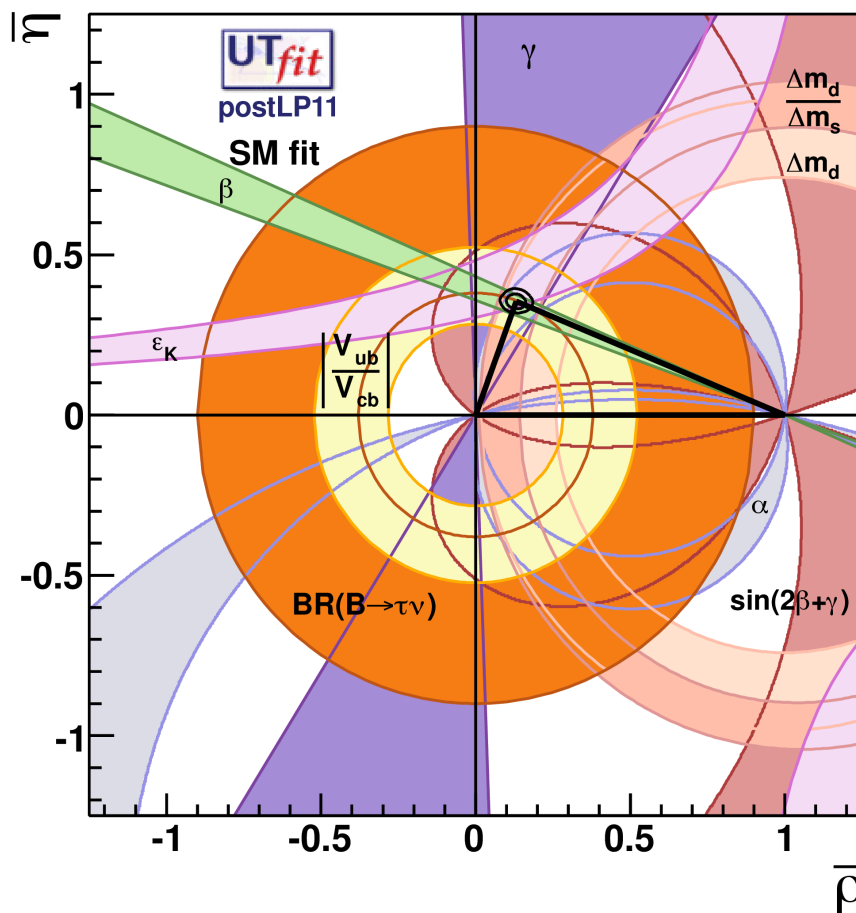
- Combining the statistical and systematic uncertainties in quadrature, the significance of the measured deviation from zero is 3.5
- At  $1\sigma$  level with the current HFAG world-average.

# Evidence for direct CP violations also in $B_s$ decays (arXiv:1202.6251v1)



# Status of CKM triangle after 2 years of LHCb

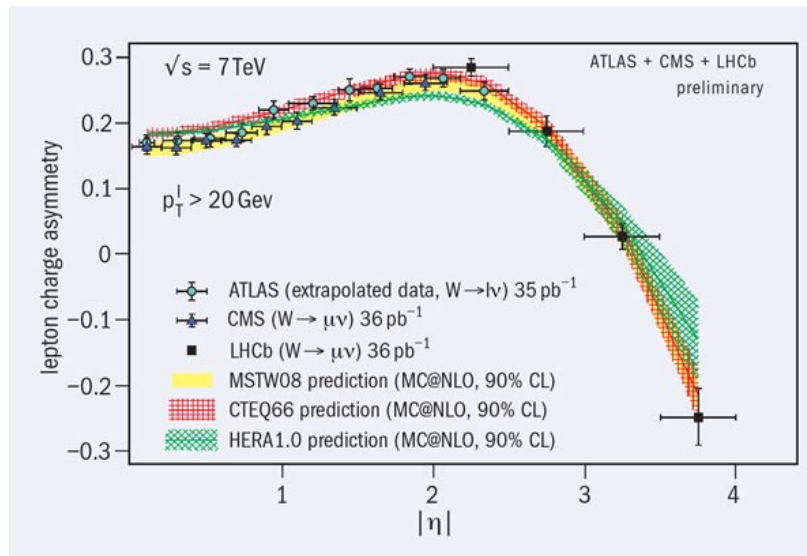
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Standard  
Model  
wins !!

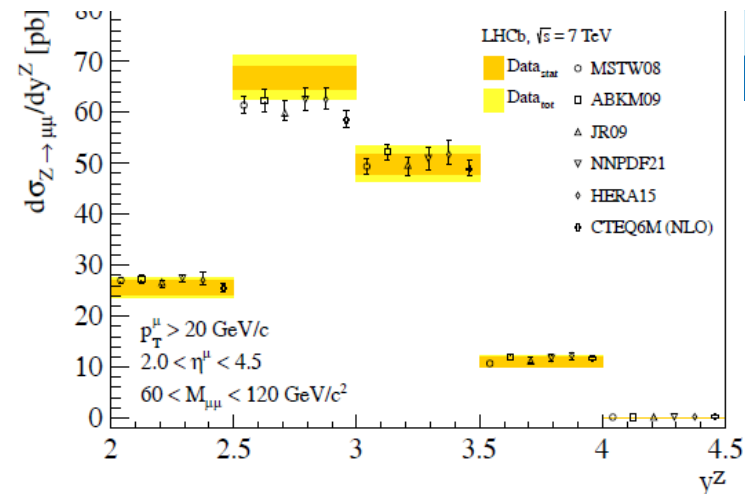
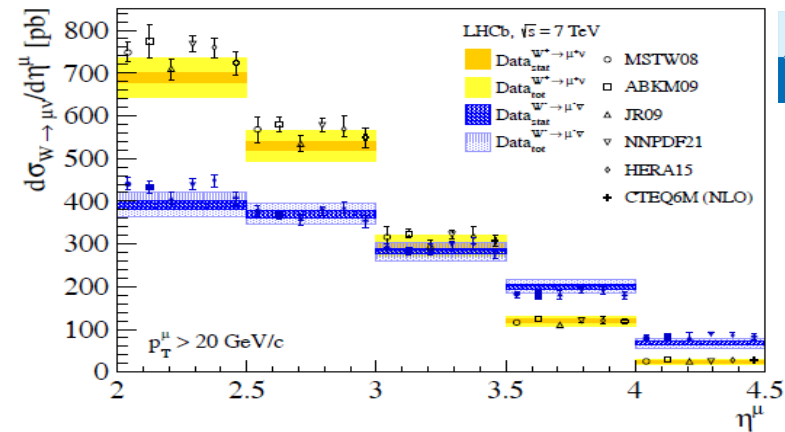
# Differential Cross sections and charge asymmetry

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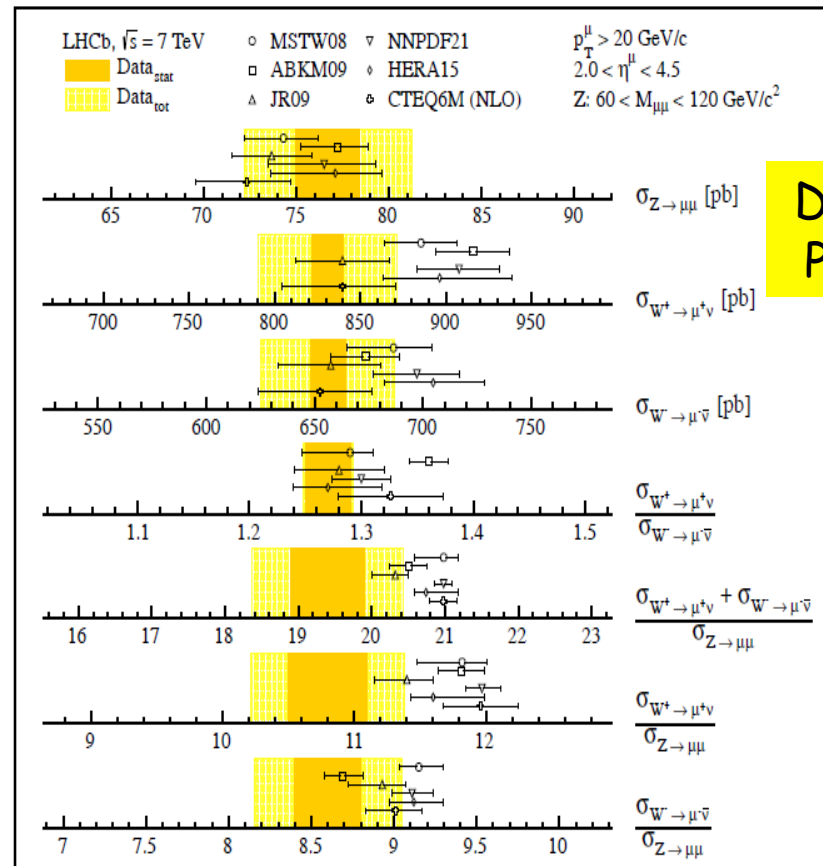
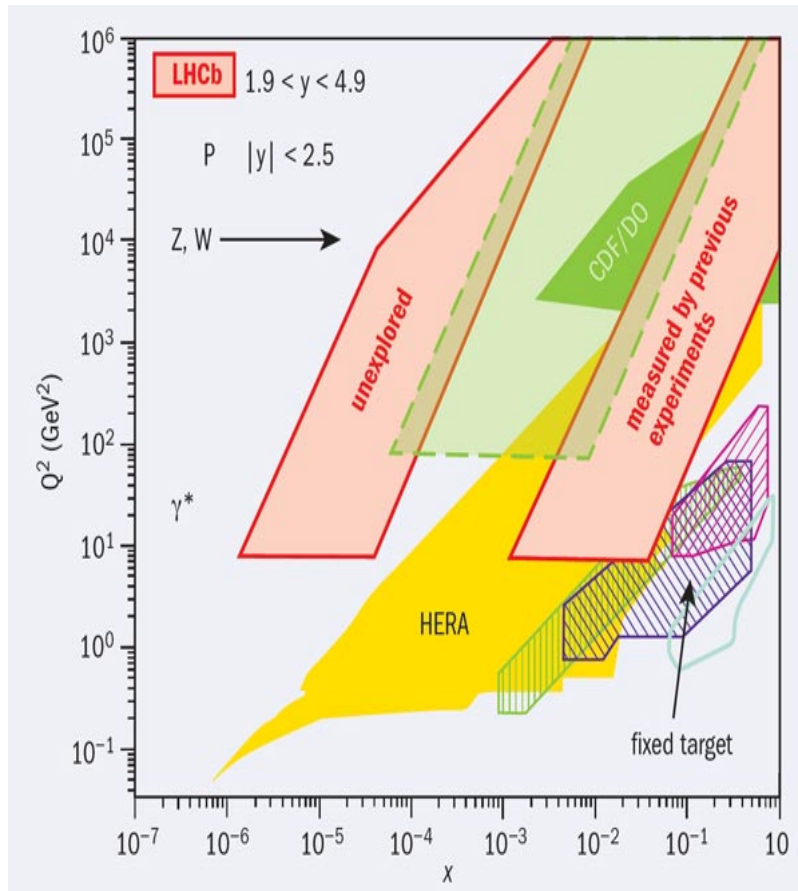


Important test for the reliability of background predictions to the Higgs search channel

$$H \rightarrow WW \rightarrow 2\ell 2\nu$$



# EW physics at LHCb/Crucial test of SM



Different PDF sets

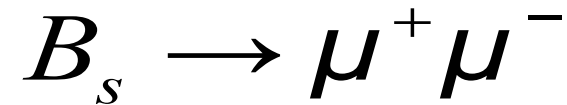
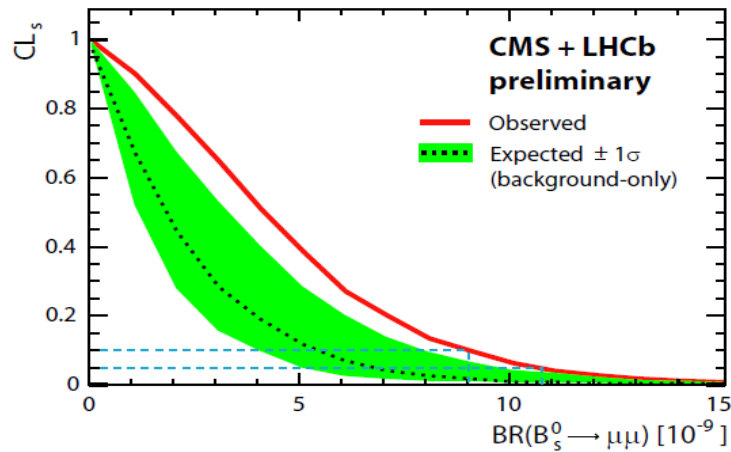
<http://arxiv.org/pdf/1204.1620v1>

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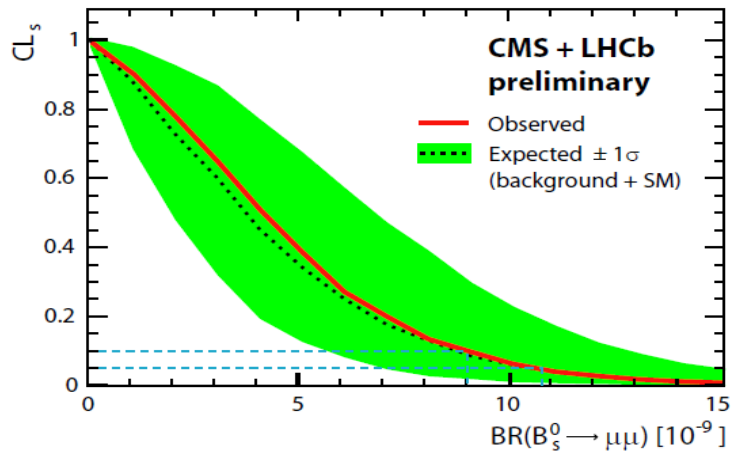
# The "golden" channel for NP

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In the SM the BR is predicted to be very small:

$$BR(B_s \rightarrow \mu\mu)_{SM} = (3.2 \pm 0.2) \cdot 10^{-9}$$



LHCb + CMS Upper Limit @ 95% CL

$$BR \leq 1.08 \cdot 10^{-8}$$

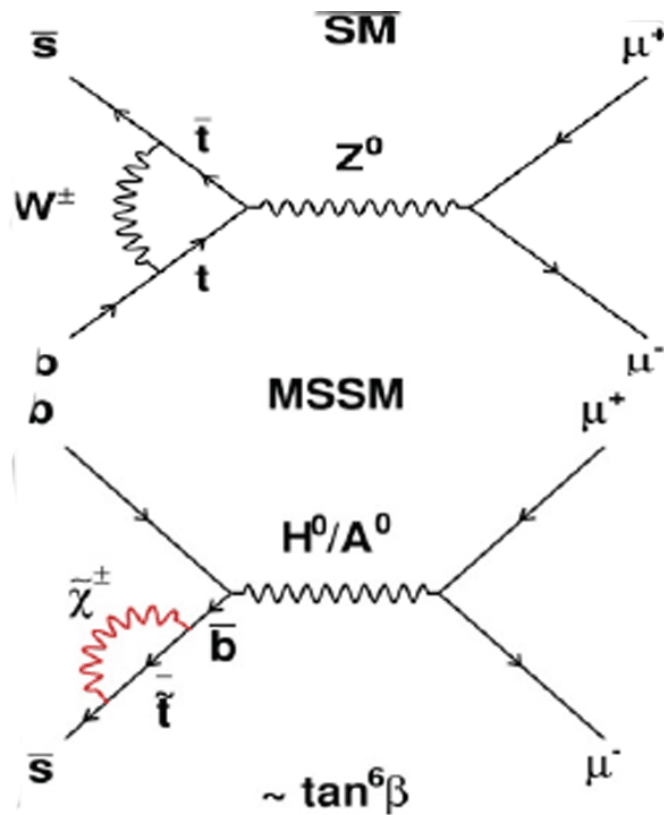
LHCb-CONF-2011-047

CMS PAS BPH-11-019

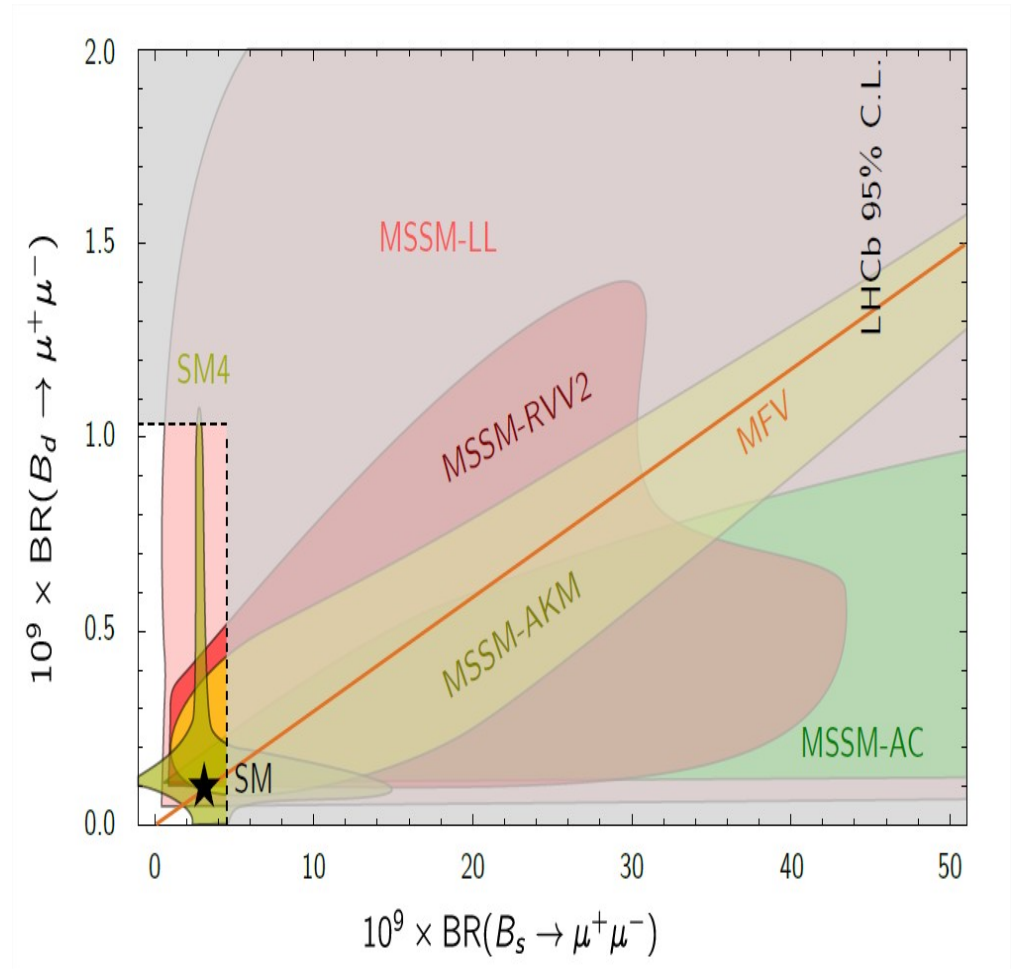
8 August 2011

# Indirect Limits on SuperSymmetry from $B_s/B_d$ decays

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<http://arxiv.org/pdf/1201.5600v2>

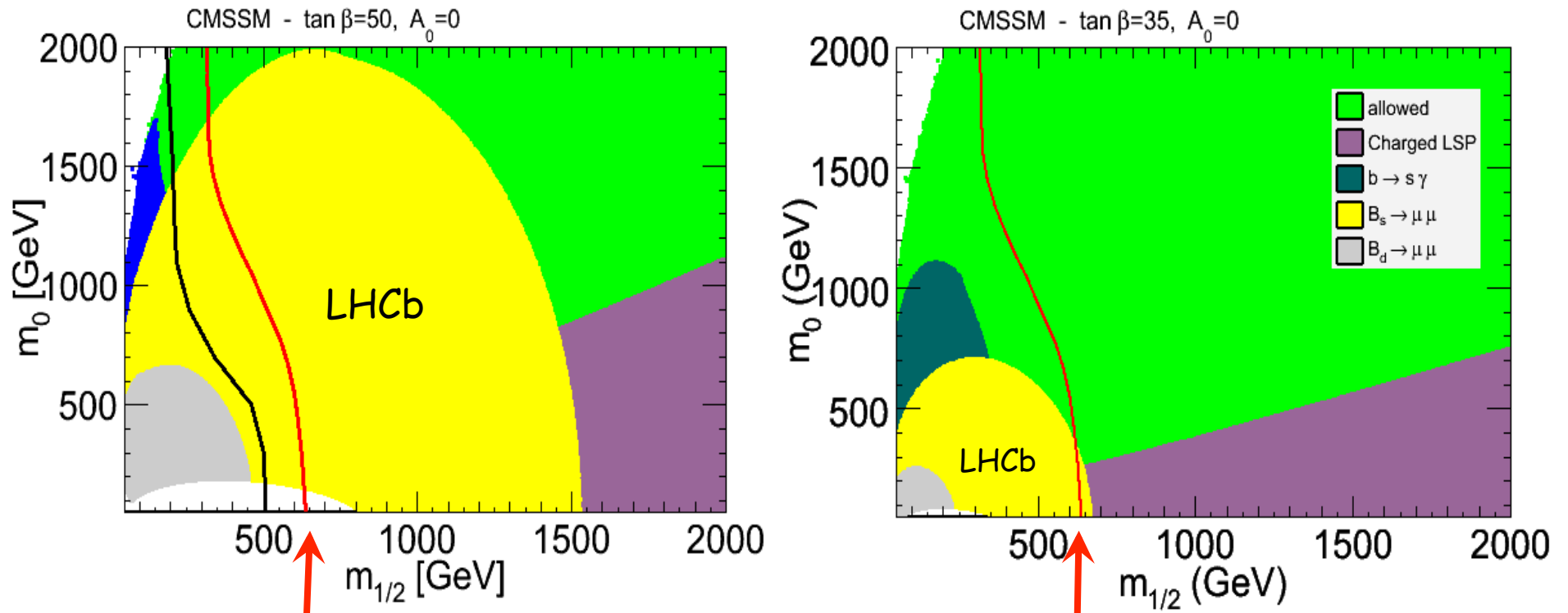




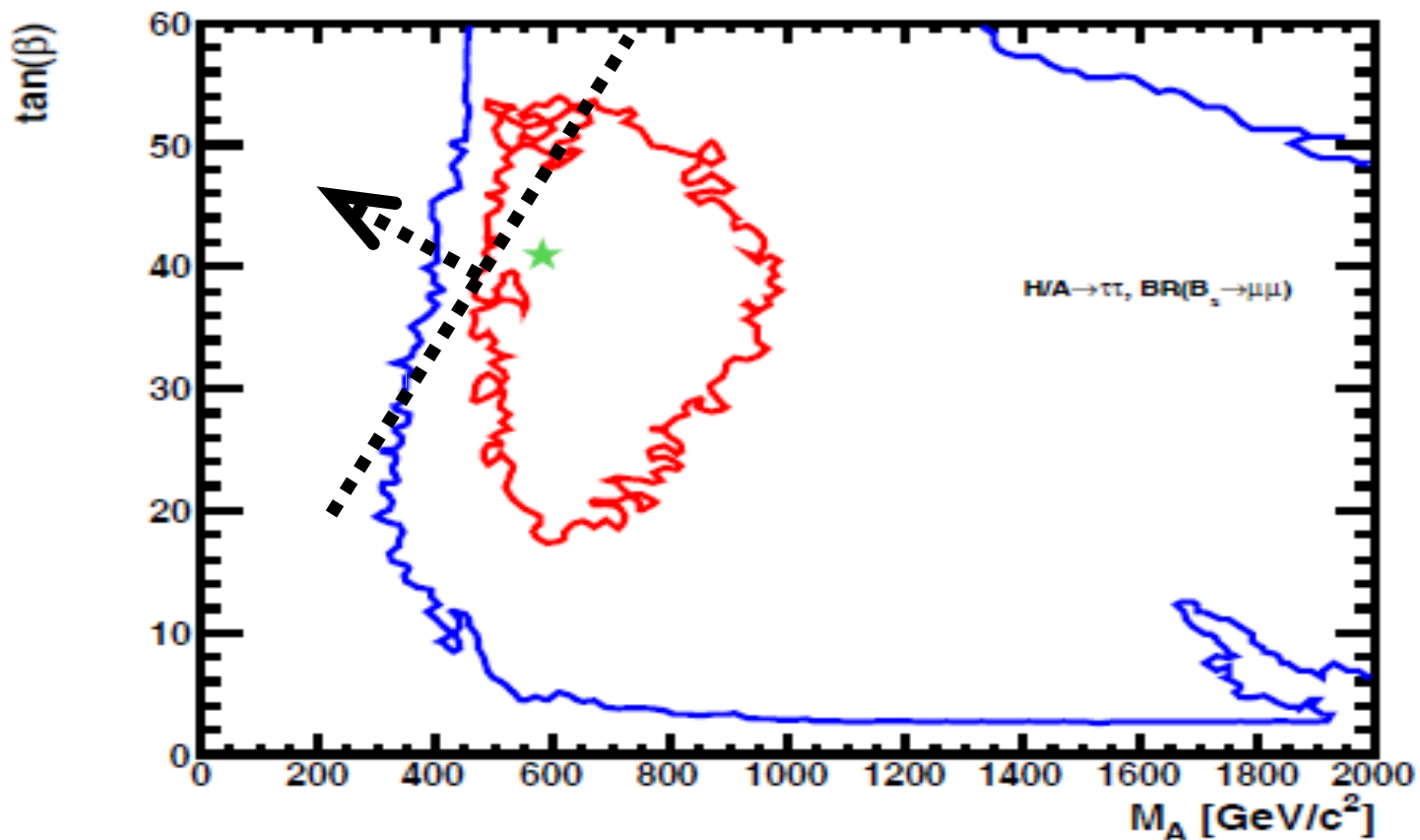
# New exclusion plots

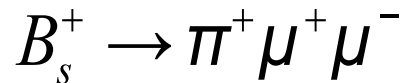
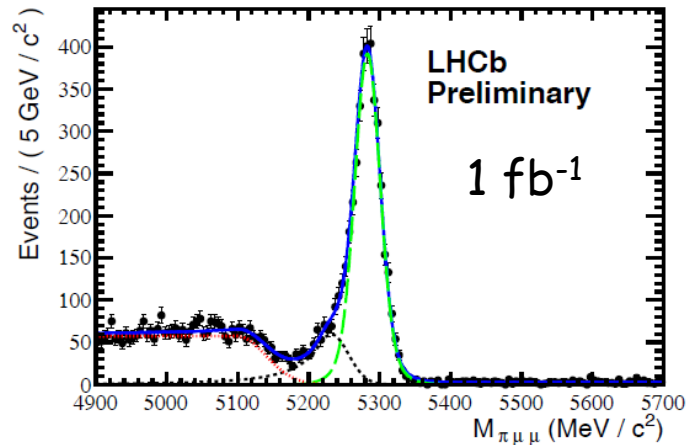
<http://moriond.in2p3.fr/QCD/2012/TuesdayMorning/Nazila.pdf>

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**CMS direct search limits**





LHCb-CONF-2012-006  
April 5, 2012

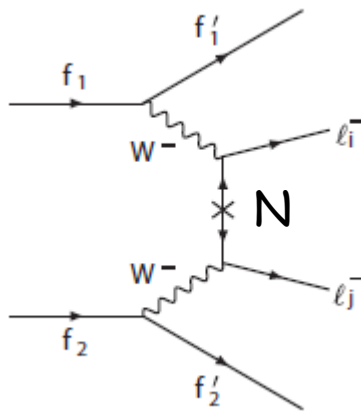
- The rarest decay even observed
- The predicted SM branching fraction is

$$BR(B_s^+ \rightarrow \pi^+ \mu^- \mu^+) = (1.96 \pm 0.21) 10^{-8}$$

- LHCb result at  $5.1\sigma$  CL is

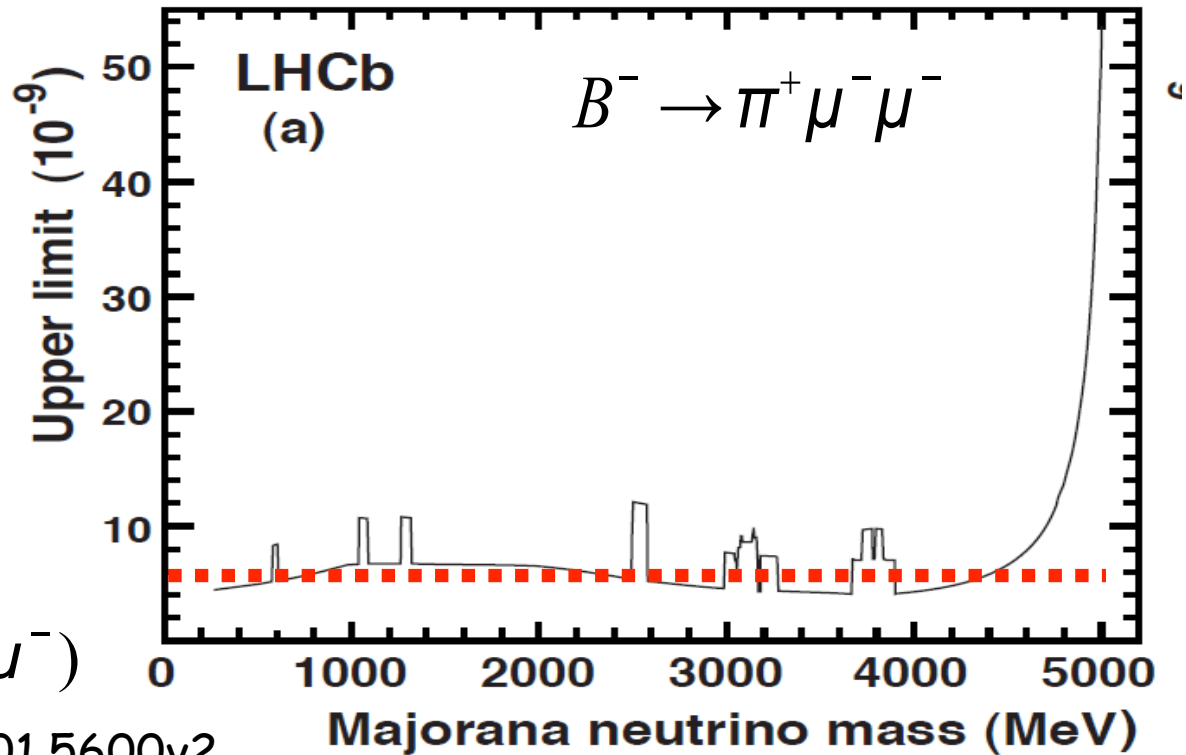
$$BR = [2.4 \pm 0.6 \text{ (stat.)} \pm 0.2 \text{ (syst.)}] 10^{-8}$$

- Decay of a B-meson equivalent to the nuclear ( $0\nu 2\beta$ ) decay
- Characteristic signature is 2 same sign leptons + meson



$$m_N \approx \text{Inv.Mass}(\pi^+, \mu^-)$$

<http://arxiv.org/pdf/1201.5600v2>



# Summary

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- Standard model is very successful
- LHC (+Tevatron) data are at present not inconsistent with a Higgs mass in the range 115-126  $GeV/c^2$ , that is also favored by EW precision measurements.
- On the contrary  $m_H < 115$  or  $m_H > 126$   $GeV/c^2$  are excluded
- CP violation phenomenology from the CKM mechanism is very well established
- No hints of New Physics until now

# Thank You for Your attention !

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## Particle Physics

~~COSMOLOGY~~ MARCHES ON

