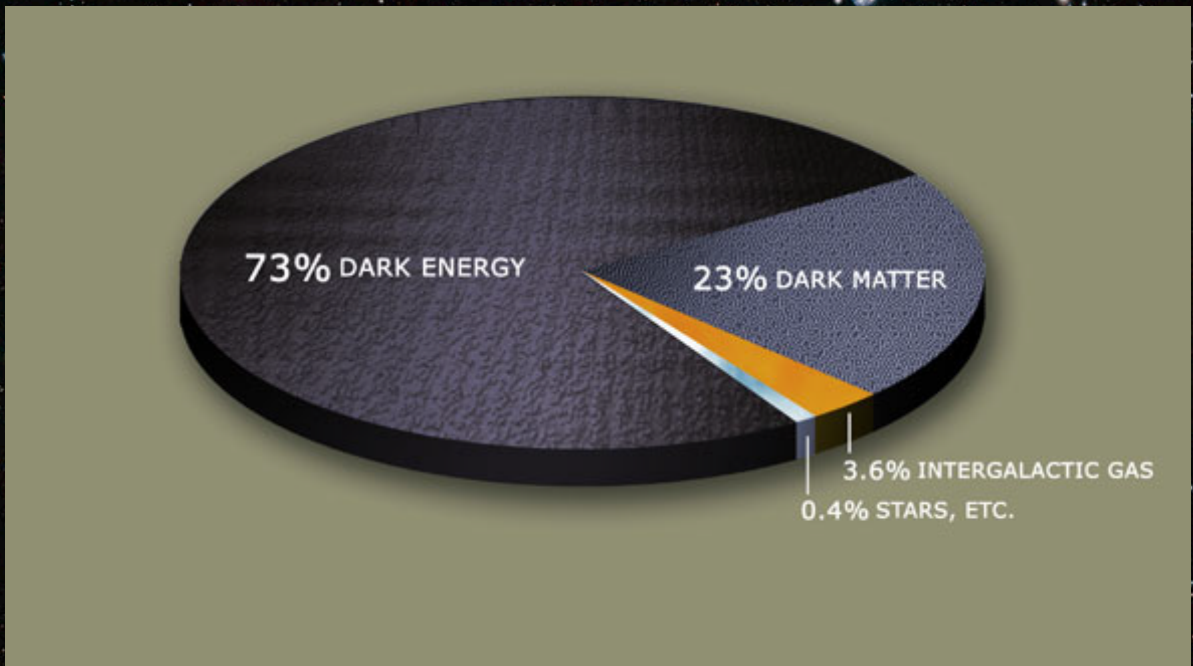
Test of the Standard Model in rare decays at the LHC

Gaia Lanfranchi
(CERN/INFN)

Laboratório de Instrumentação e Física Experimental de Partículas
November, 21st 2012

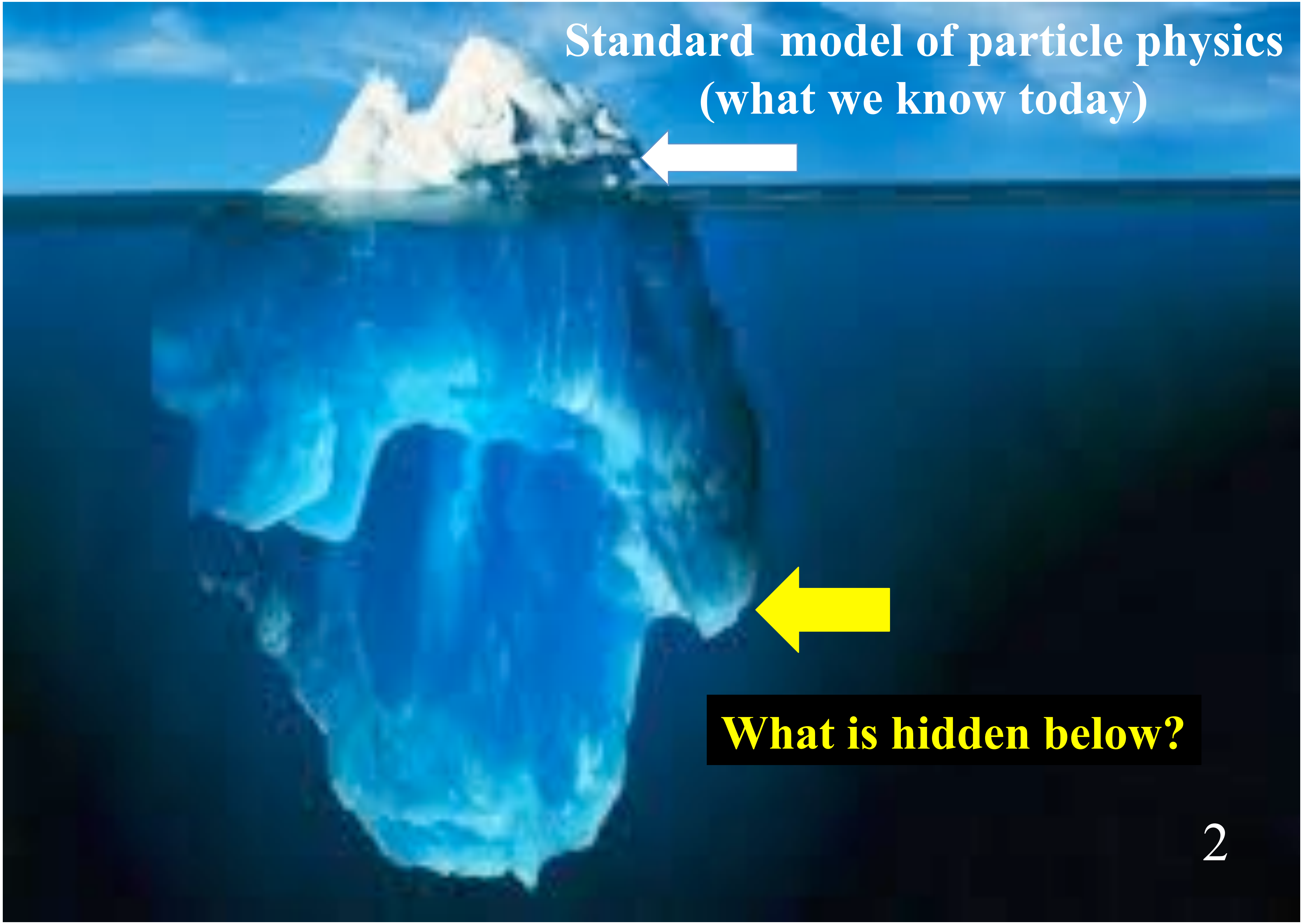
We live in a world where only 4% of the matter is known
This tiny fraction of matter is well described by the "Stardard Model" of particle physics….
..which nevertheless is not able to explain:

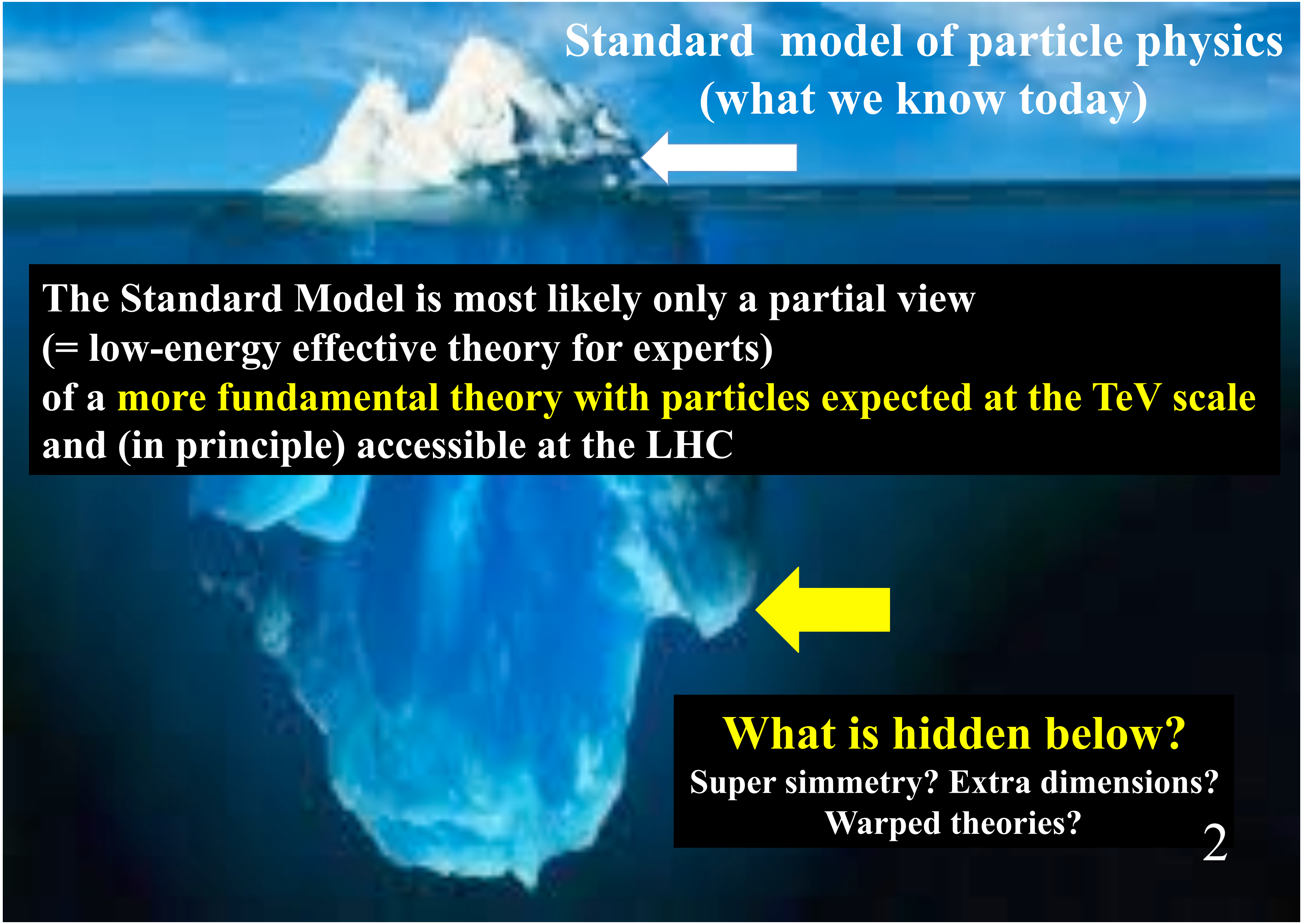
- → why 3 generations of quarks and leptons?
- → why so different masses (m (e) ~0.5 eV → m(top) ~176 GeV)
- → why 4 fundamental interactions and why so different scales?



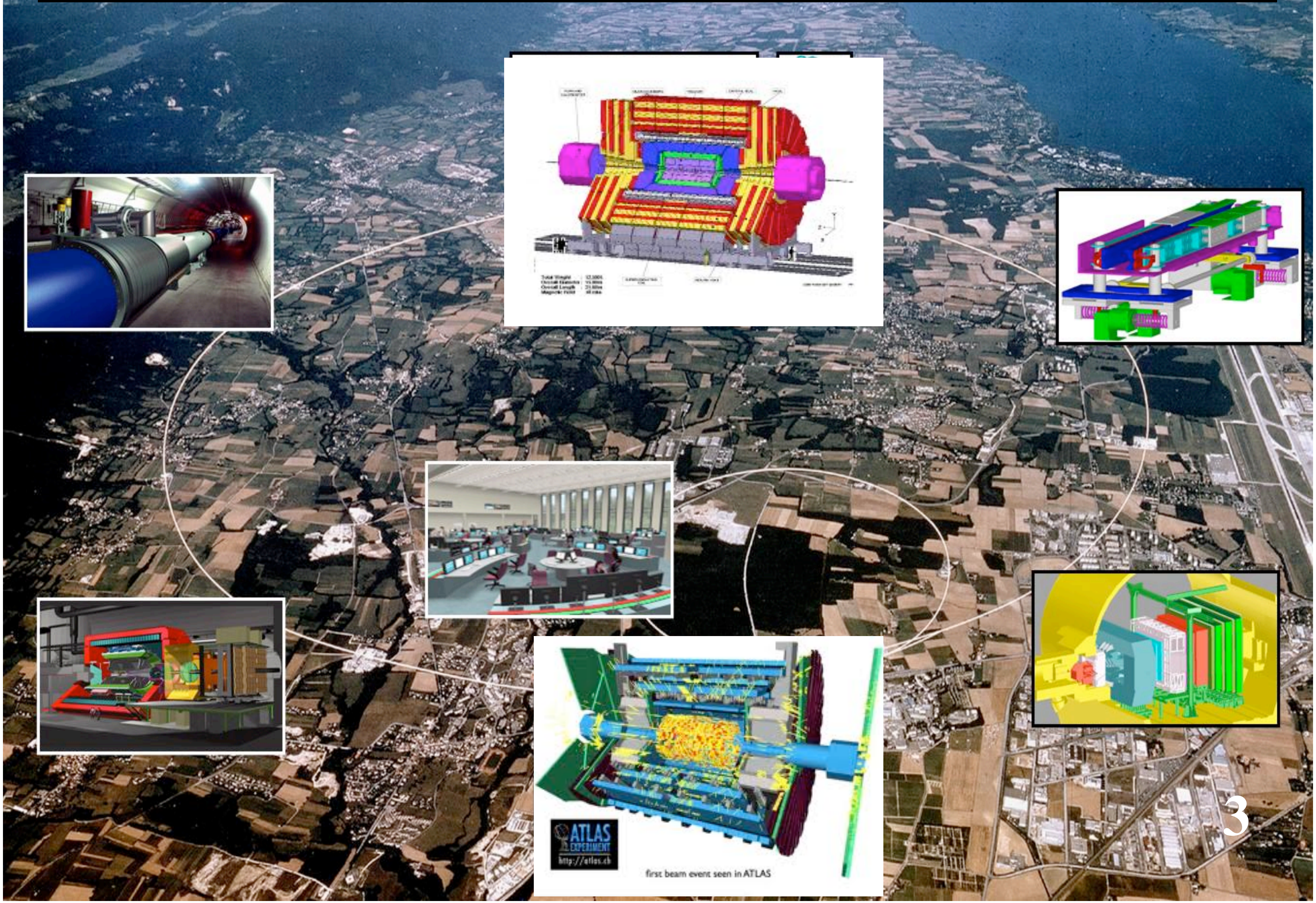
Standard model of particle physics (what we know today)

The Standard Model cannot be the ultimate theory as it is incomplete and contains too many free parameters like the fermion masses and couplings

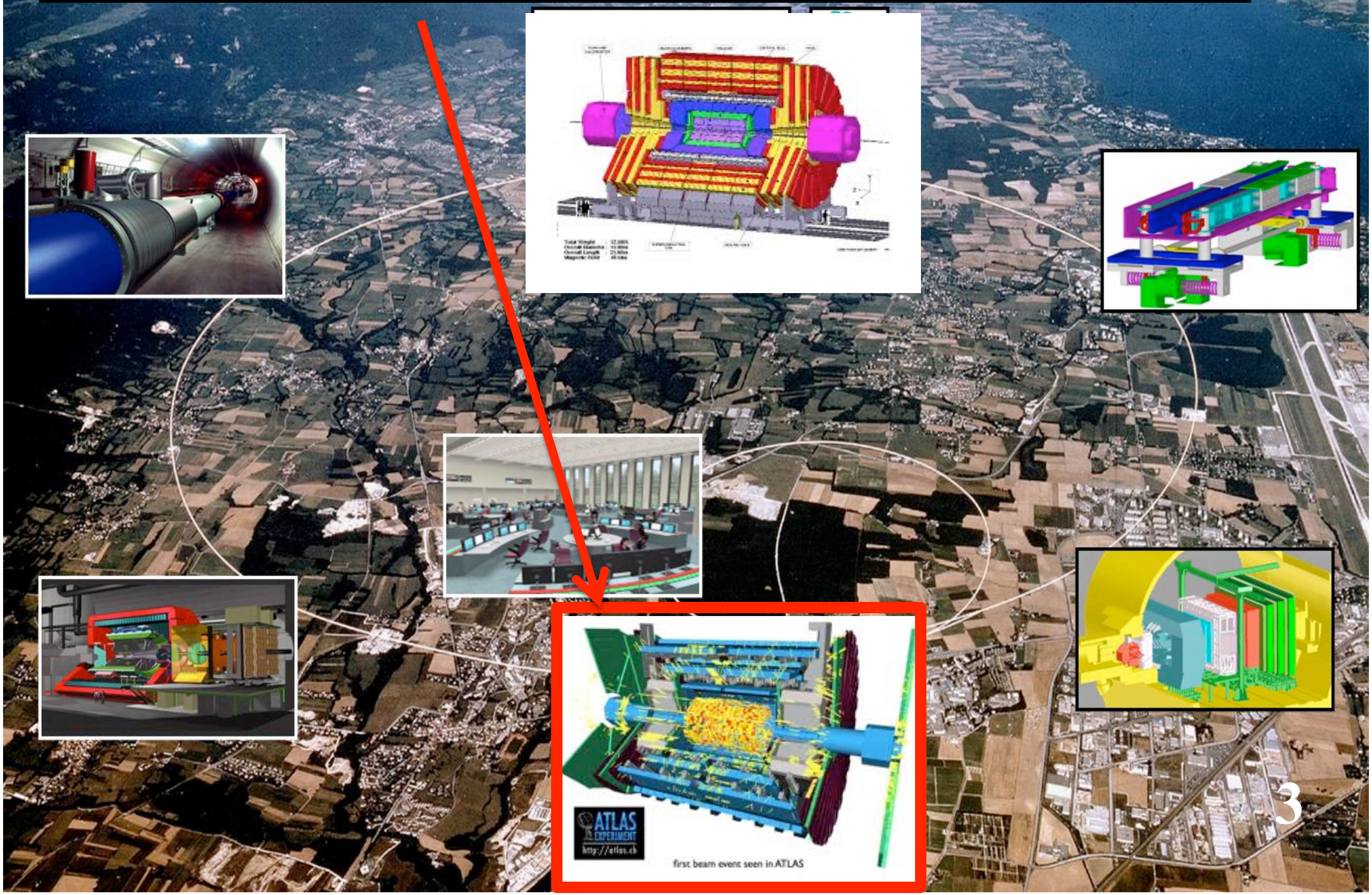

Standard model of particle physics
(what we know today)
What is hidden below?


Standard model of particle physics
(what we know today)
The Standard Model is most likely only a partial view
(= low-energy effective theory for experts)
of a more fundamental theory with particles expected at the TeV scale
and (in principle) accessible at the LHC
What is hidden below?
Super simmetry? Extra dimensions?
Warped theories?

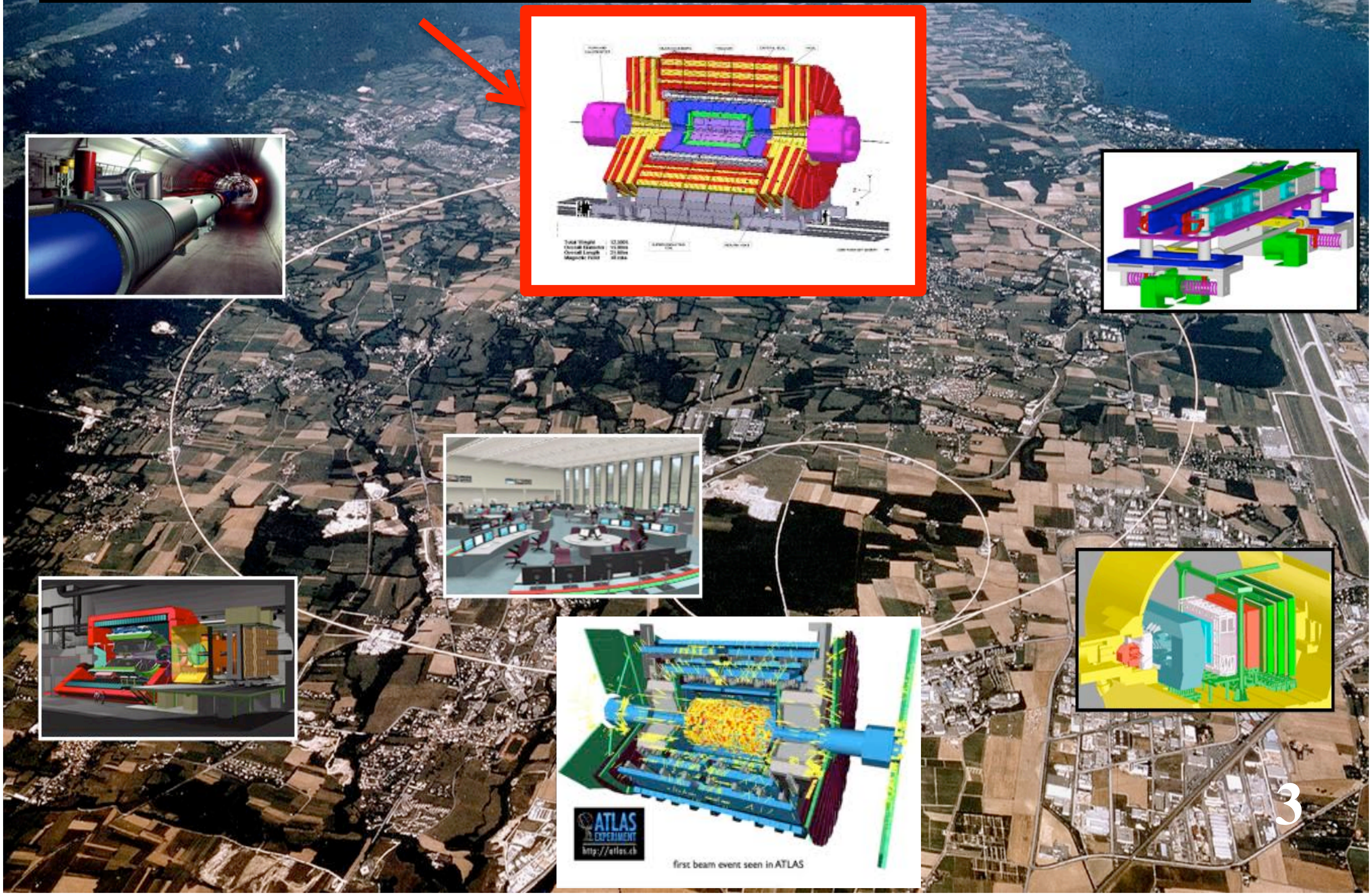
The LHC was built to answer these questions….



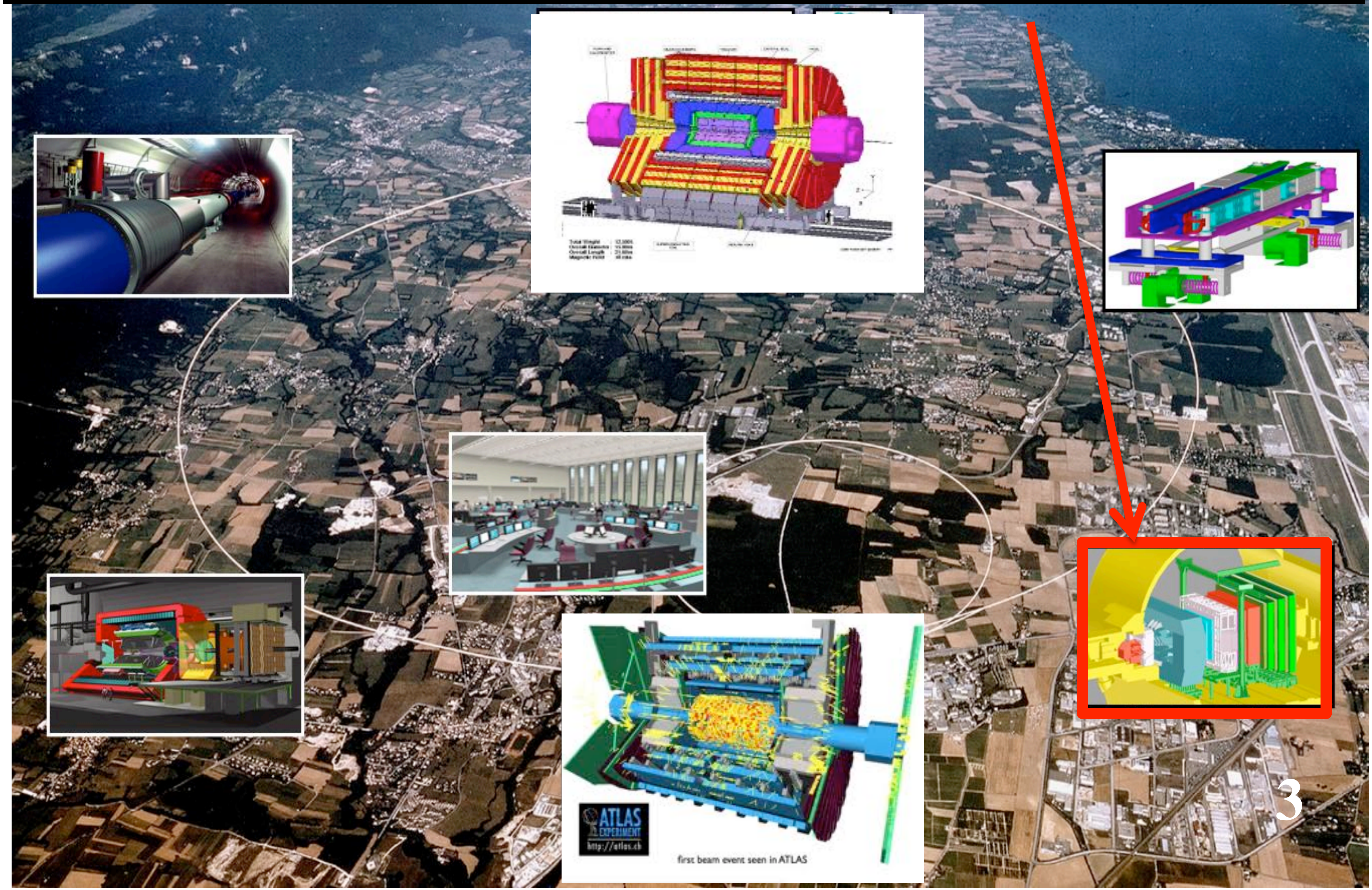
….with two giant (and beautiful) "general purpose" detectors: ATLAS…



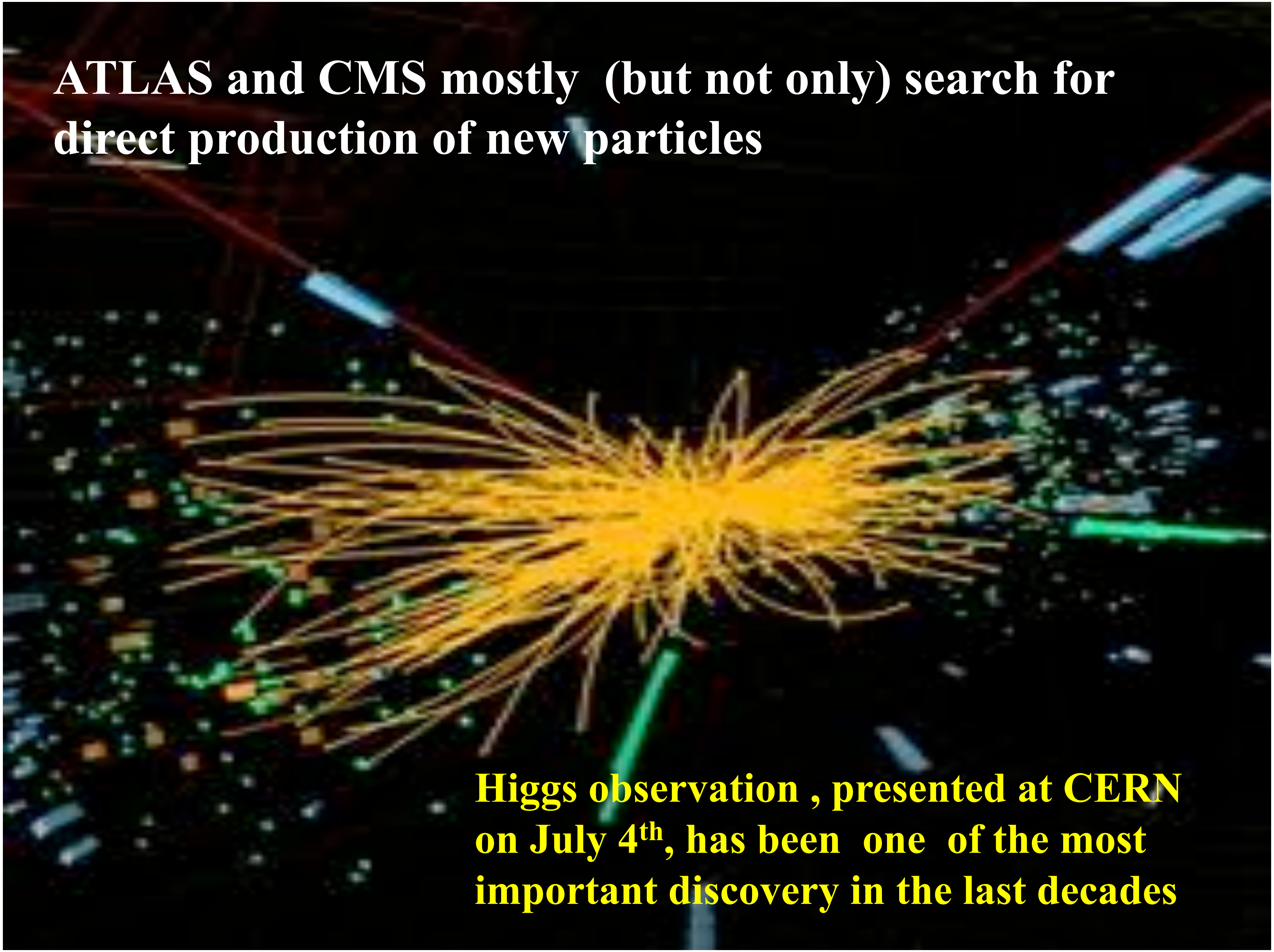
….with two giant (and beautiful) “general purpose” detectors: …and CMS



….and a (small) detector, LHCb, mostly dedicated to the study of CP violation and rare decays in the b-system:

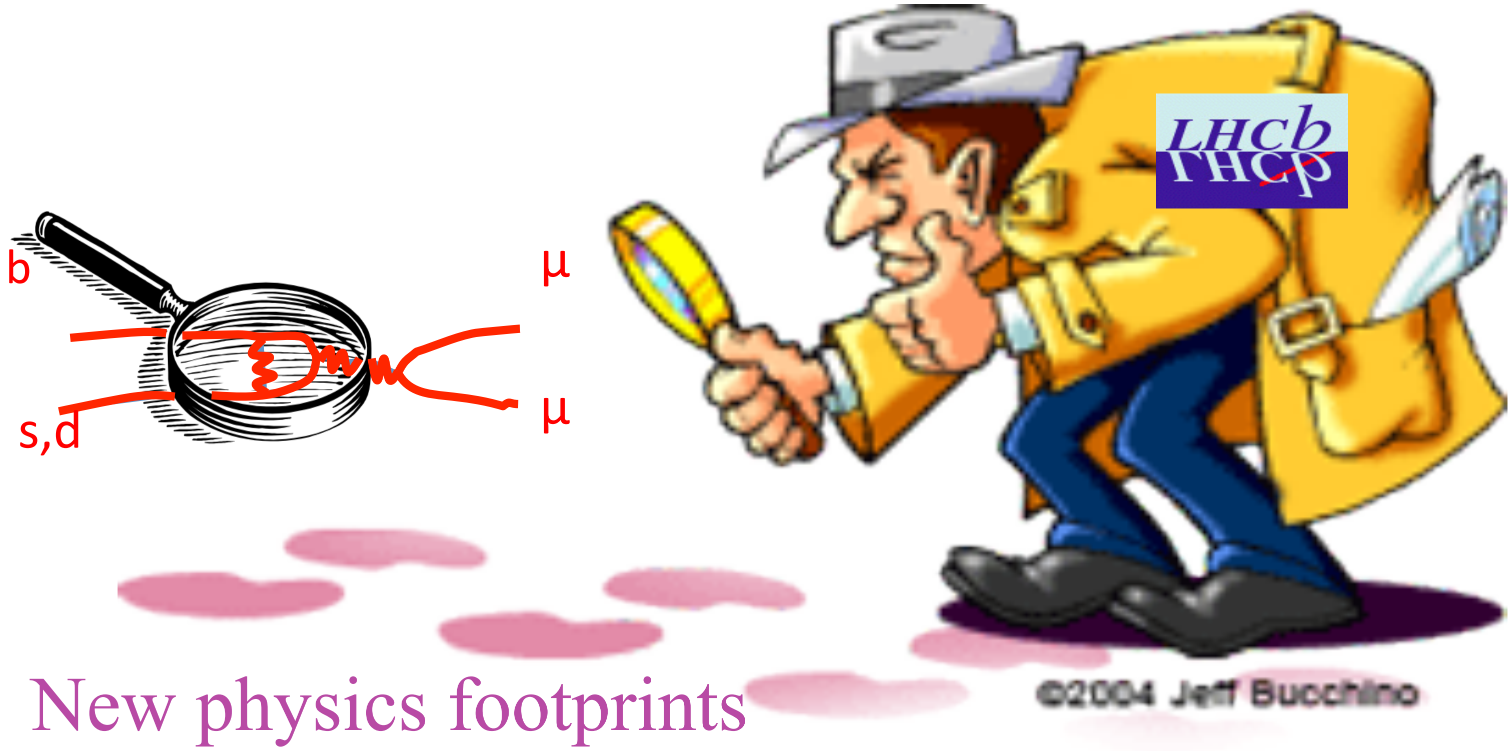


ATLAS and CMS mostly (but not only) search for direct production of new particles



Higgs observation , presented at CERN on July 4th, has been one of the most important discovery in the last decades

LHCb mostly (but not only) searches for quantum corrections in the decays of known particles and **look for deviations from the SM predictions** ("indirect search")…..



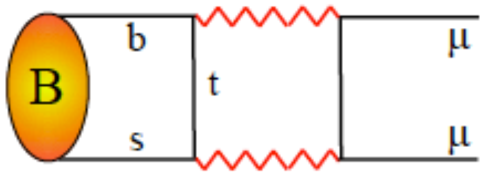
..in particular in the **branching fraction of the decay of the Bs meson into a muon pair** **(the topic of this talk)**

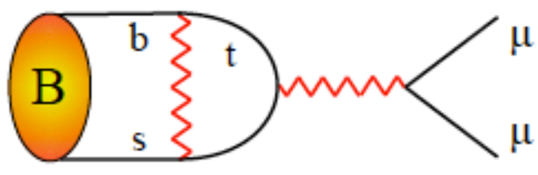
Why the decays $B_s \to \mu\mu$ and $B^0 \to \mu\mu$ are important ?

These modes are a unique source of information about flavor physics beyond the SM:

- theoretically very clean (virtually no long-distance contributions)
- particularly sensitive to FCNC scalar currents and FCNC Z-penguins

Leading SM diagrams





Why the decays $B_s \to \mu\mu$ and $B^0 \to \mu\mu$ are important ?

These modes are a unique source of information about flavor physics beyond the SM:

- theoretically very clean (virtually no long-distance contributions)
- particularly sensitive to FCNC scalar currents and FCNC Z-penguins

Leading SM diagrams

These decays are very rare :

Theorists have calculated that, in the Standard Model, the $B_s \to \mu\mu$ decay should occur about 3 times in every billion total decays of the B_s meson and the $B^0 \to \mu\mu$, about 1 time every 10 billions:

$$BR(B_s \to \mu\mu)\ (t=0) = (3.54 \pm 0.30) \times 10^{-9}$$
$$BR(B_0 \to \mu\mu)\ (t=0) = (1.07 \pm 0.10) \times 10^{-10}$$

Buras et al, arXiv:1208.0934

De Bruyn et al., PRL 109, 041801 (2012) uses LHCb-CONF-2012-002

Standard Model predictions (for experts)

Latest SM predictions :

$BR(B_s \to \mu\mu)$ (t=0) = $(3.23 \pm 0.27) \times 10^{-9}$

$BR(B_0 \to \mu\mu)$ (t=0) = $(1.07 \pm 0.10) \times 10^{-10}$

Buras et al, arXiv:1208.0934

where f(Bs) = 227± 8 MeV has been used, averaging from recent lattice inputs:

Mc Neile et al., PRD 85 (2012) 031503
Na et al., arXiv:1202.4919, Bazavov et al. arXiv 1112.3051

To compare with experiment we need a time integrated branching fraction, taking into account the finite width of the B_s system:

$$BR(B_s \to \mu^+\mu^-)^{\langle t \rangle} = \frac{1}{1-y_s} \cdot BR(B_s \to \mu^+\mu^-)^{t=0} = (3.54 \pm 0.30) \cdot 10^{-9}$$

De Bruyn et al., PRL 109, 041801 (2012)
uses LHCb-CONF-2012-002

Why the decays $B_s \to \mu\mu$ and $B^0 \to \mu\mu$ are important ?

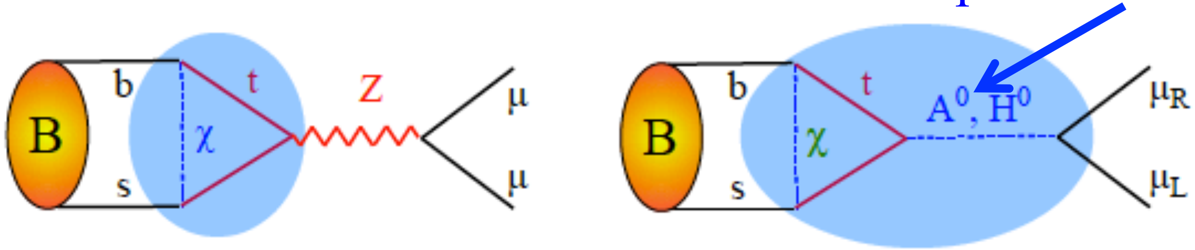
These modes are a unique source of information about flavor physics beyond the SM:

- theoretically very clean (virtually no long-distance contributions)
- particularly sensitive to FCNC scalar currents and FCNC Z-penguins

Leading SM diagrams

Non-SM Higgs particles contribution

possible non SM contributions



Relevant for BR = O(SM)

Possible large enhancement (e.g. SUSY @ large tanβ)

.. But new virtual particles present in the loops could enhance (or suppress) these branching fractions with respect to the SM predictions

That is why the search for $B_s \to \mu\mu$ decay started more than 28 years ago….

VOLUME 53, NUMBER 14 PHYSICAL REVIEW LETTERS 1 OCTOBER 1984

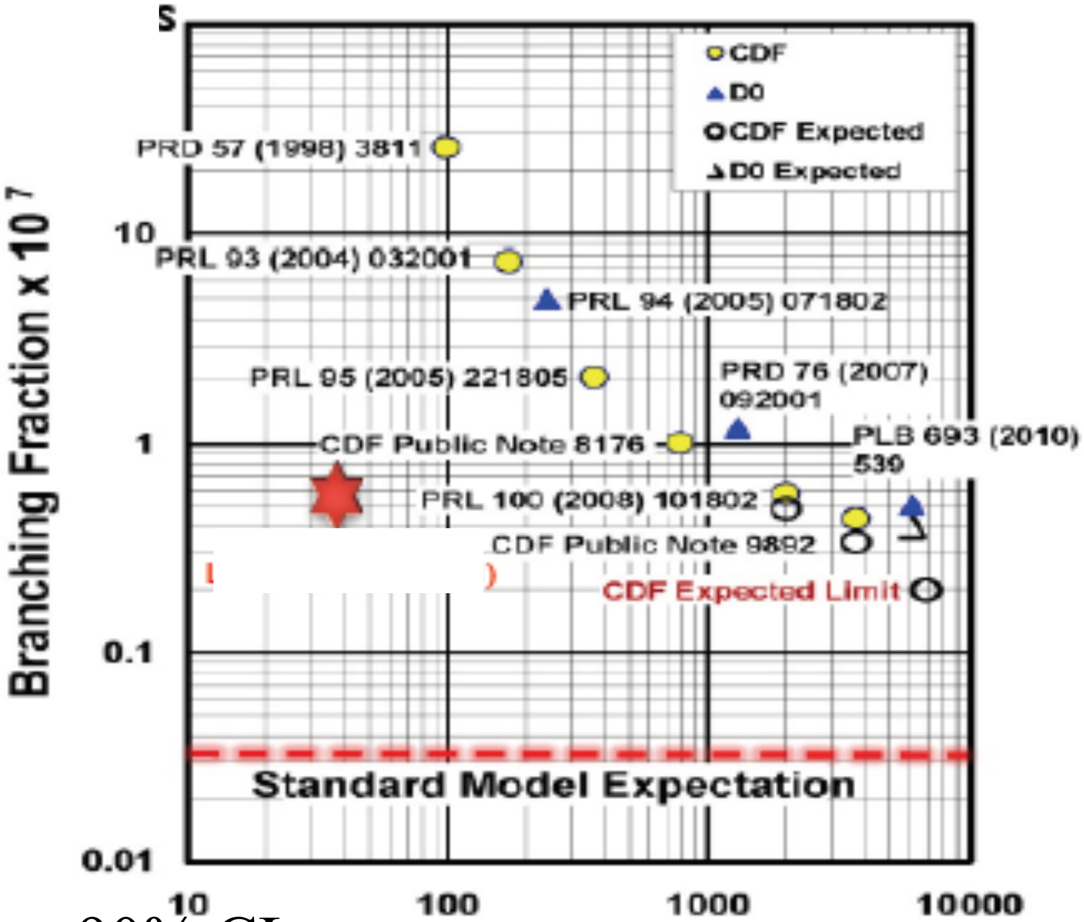
Upper Limit on Flavor-Changing Neutral-Current Decays of the *b* Quark

P. Avery, C. Bebek, K. Berkelman, D. G. Cassel, J. W. DeWire, R. Ehrlich, T. Ferguson, R. Galik, M. G. D. Gilchriese, B. Gittelman, M. Halling, D. L. Hartill, S. Holzner, M. Ito, J. Kandaswamy, D. L. Kreinick, Y. Kubota, N. B. Mistry, F. Morrow, E. Nordberg, M. Ogg, A. Silverman, P. C. Stein, S. Stone, D. Weber, and R. Wilcke[a]
Cornell University, Ithaca, New York 14853

Et al.. Cleo experiment, PRL, 1984

If there is a neutral Higgs (h^0) with mass less than twice that of the τ lepton, its dominant decay modes would be into $s\bar{s}$ and $\mu^+\mu^-$. Some electroweak models[18] predict a sizable rate for the decay $B \to h^0 X$. We have used dimuon events to obtain an upper limit on $R_B(B \to h^0 X) \times R_B(h^0 \to \mu^+\mu^-)$. We find a 90%-confidence-level upper limit of 5×10^{-4} for $m_{h^0} > 3.2$ GeV. We can ex-

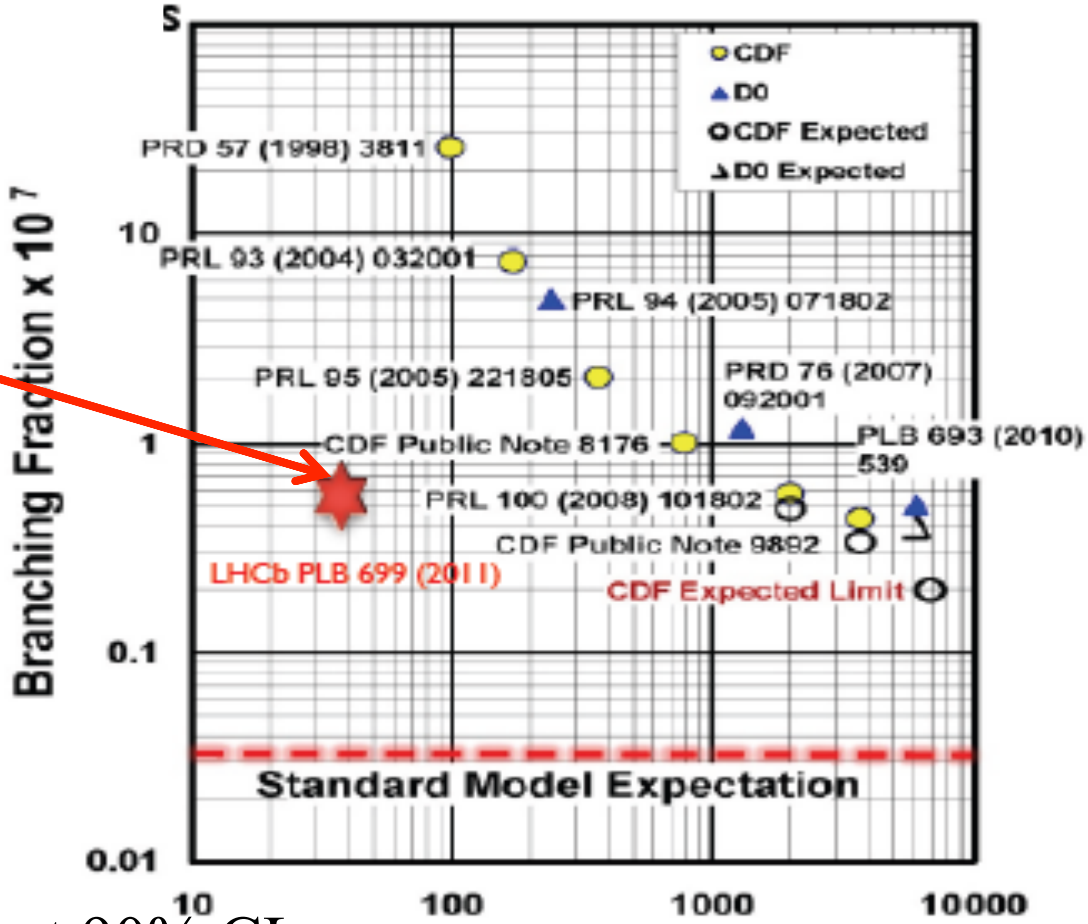
$B_s \to \mu\mu$: 1998-2010 – the Tevatron era



- 2010: limits from Tevatron at 90% CL:
  - CDF (~3.7 fb^{-1}) $BR(B_s \to \mu\mu) <$ **36×10^{-9} (@90% CL)** ~ 11 times SM
  - D0 (~6.1 fb^{-1}) $BR(B_s \to \mu\mu) <$ **42×10^{-9} (@90% CL**

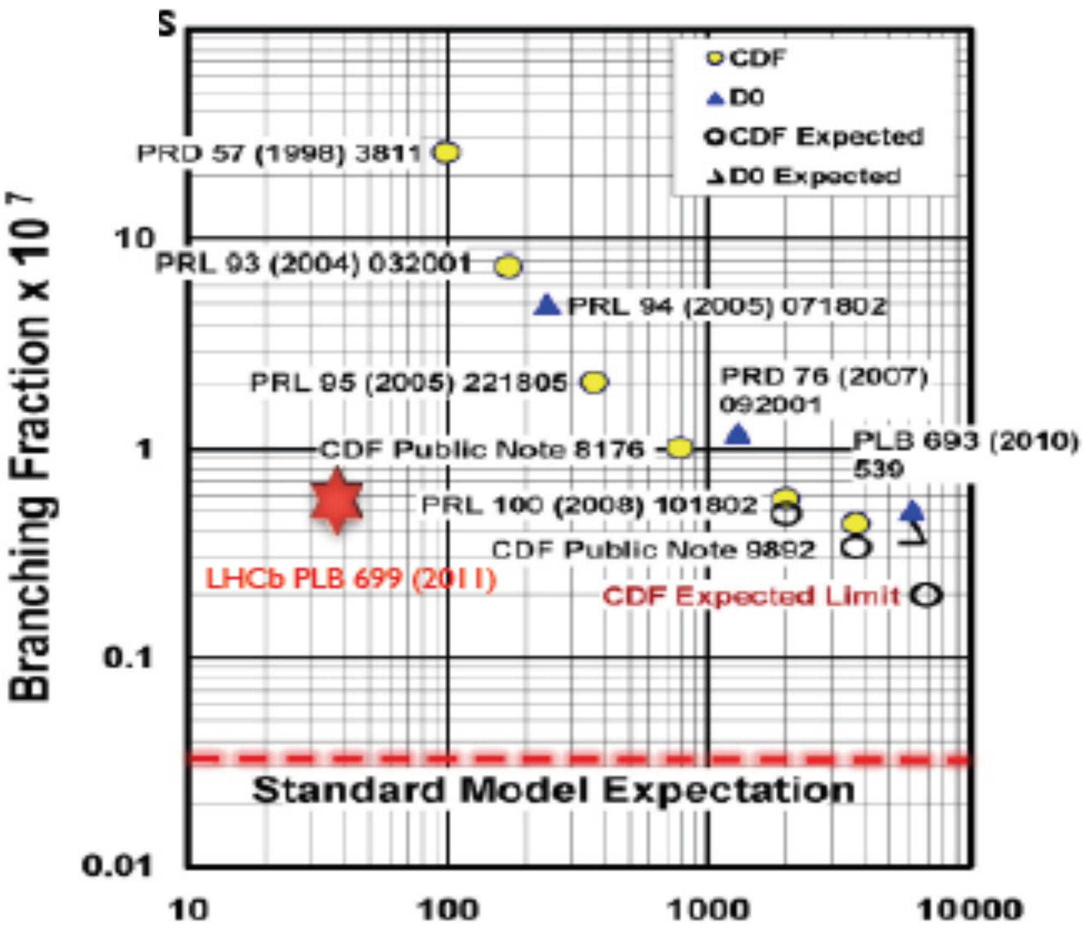
winter conferences 2011: the new born LHCb enters in the game

LHCb, 0.036 fb^{-1}
10 months old



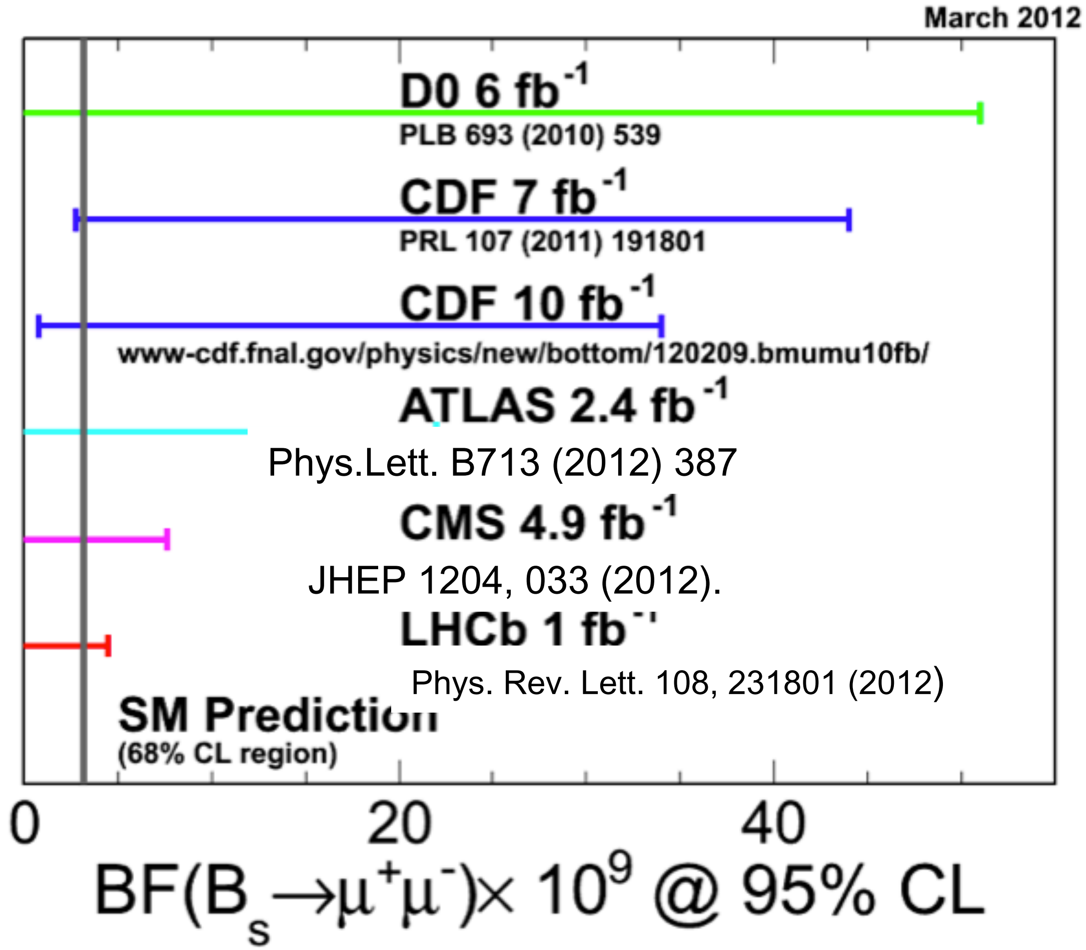
- 2010: limits from Tevatron at 90% CL:
  - CDF (~3.7 fb^{-1}) BR($B_s \rightarrow \mu\mu$) < **36×10^{-9} (@90% CL)** ~ 11 times SM
  - D0 (~6.1 fb^{-1}) BR ($B_s \rightarrow \mu\mu$) < **42×10^{-9} (@90% CL)**
  - **→ LHCb (0.036 fb^{-1}) BR($B_s \rightarrow \mu\mu$)< 40 x 10^{-9} @ 90%CL**

winter conferences 2011:
the new born LHCb enters in the game



$B_s \to \mu^+\mu^-$: 2011- june 2012 experimental results from the LHC and Tevatron

Nice race all around the world to push down the limit:



LHCb and CMS very close to Have a sensitivity to observe $B_s \to \mu^+\mu^-$ events with SM rates

No big enhancements were allowed any longer

LHCb-CONF-2012-017
CMS-PAS-BPH-12-009
ATLAS-CONF-2012-061

LHC combination (June 2012): BR($B_s \to \mu^+\mu^-$)<4.2 x 10^{-9} @ 95% CL

20 March 2012:

The $B_s \to \mu^+\mu^-$ result with $1fb^{-1}$ of 2011 data was just sent to PRL!

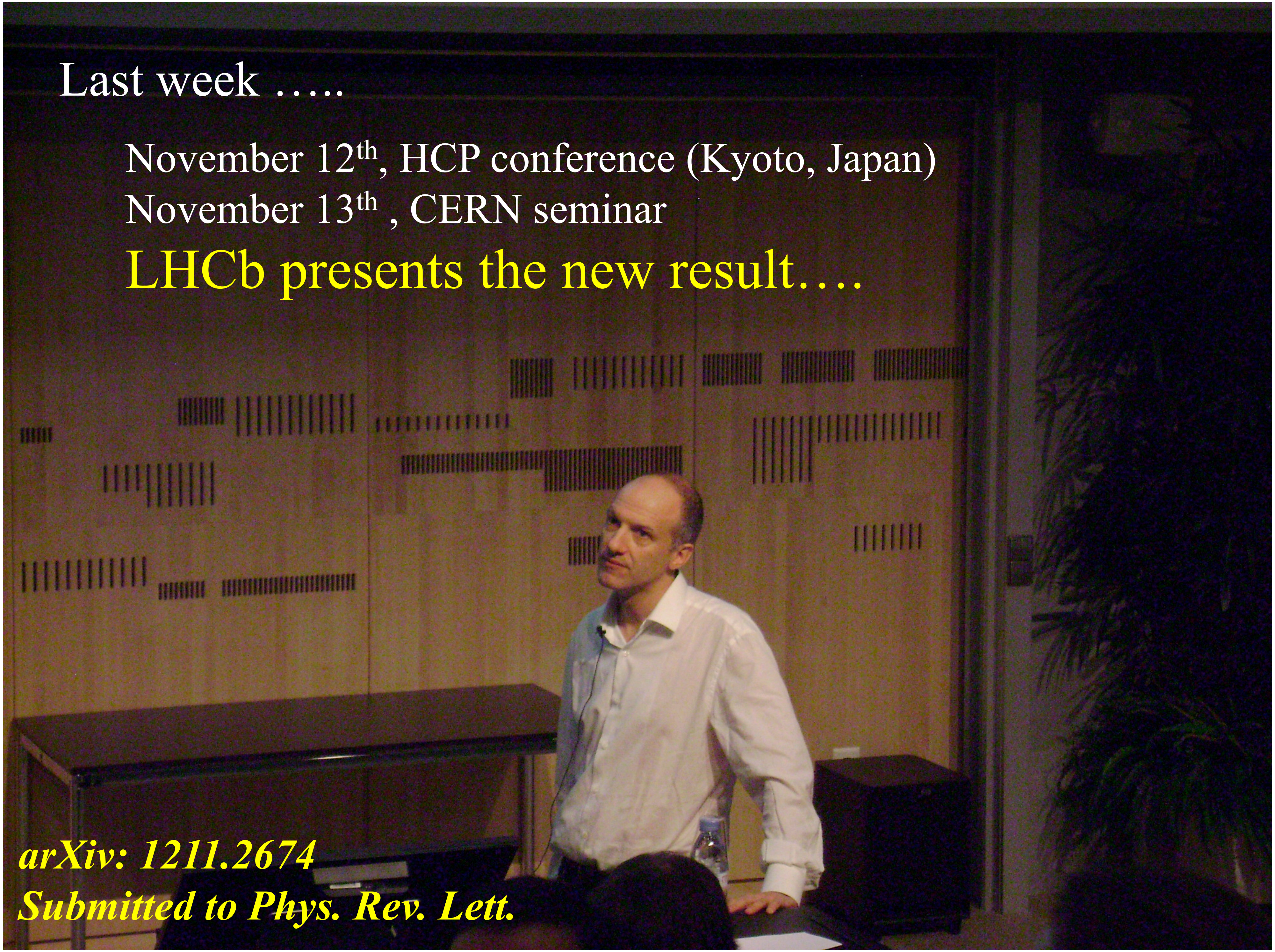
$BR(B_s \to \mu^+\mu^-) < 4.5 \times 10^{-9}$ @ 95% CL

Phys. Rev. Lett. 108, 231801 (2012)

Last week …..

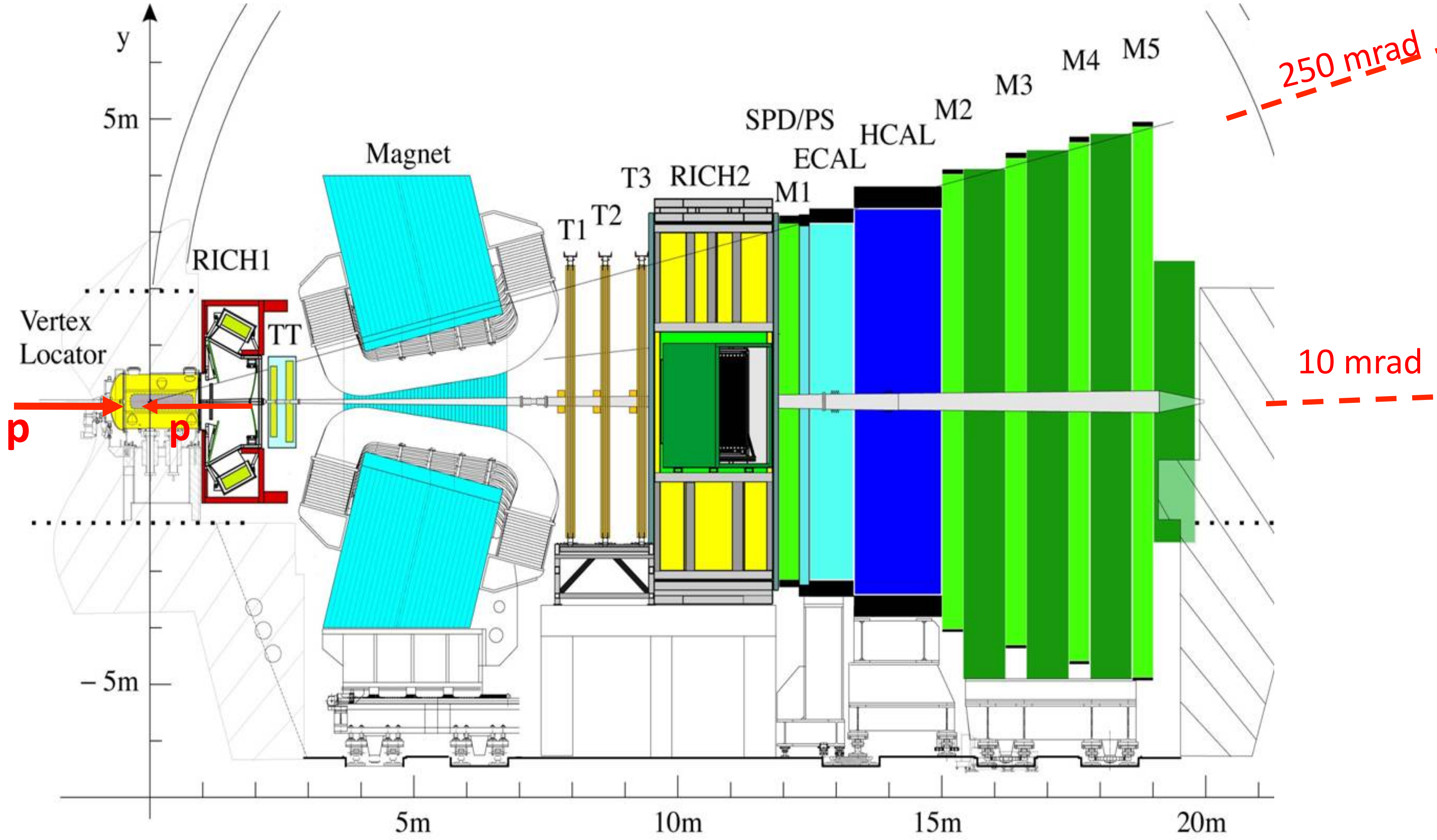
November 12th, HCP conference (Kyoto, Japan)
November 13th , CERN seminar

LHCb presents the new result….

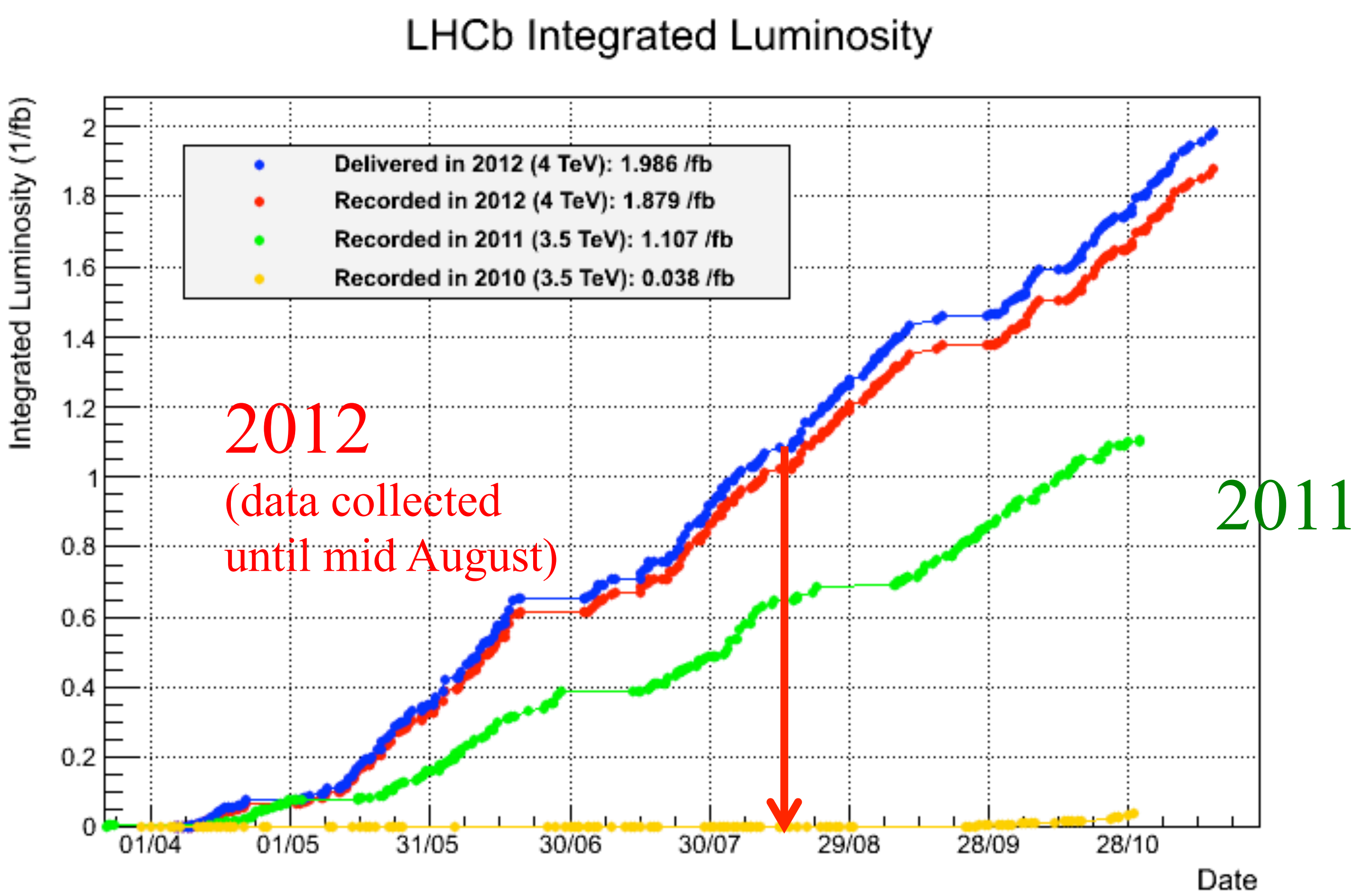


arXiv: 1211.2674
Submitted to Phys. Rev. Lett.

LHCb detector



The data sample



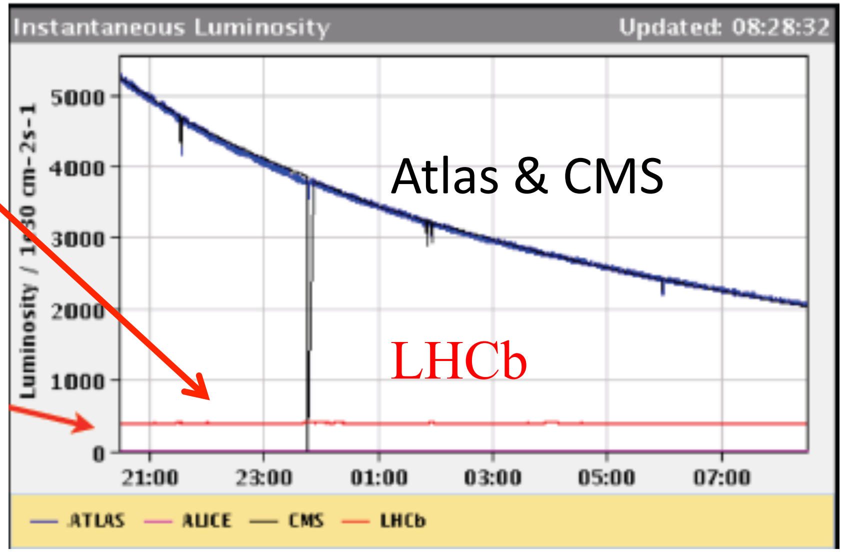
1.0 fb^{-1} at 7 TeV + 1.1 fb^{-1} at 8 TeV

(the results based on 2011 dataset already published have been re-evaluated and combined with those obtained with the 2012 dataset: the result supersede the previous publication)

$B_{s,d} \rightarrow \mu\mu$ @ LHCb: the four strong points

1) Constant luminosity: 4 x 10^{32} cm^{-2} s^{-1}, 1262 colliding bunches,

→ number of pp interactions per crossing (8 TeV) ~ 1.8



$B_{s,d} \rightarrow \mu\mu$ @ LHCb: the four strong points

1) Constant luminosity: 4 x 10^{32} cm^{-2} s^{-1}, 1262 colliding bunches,

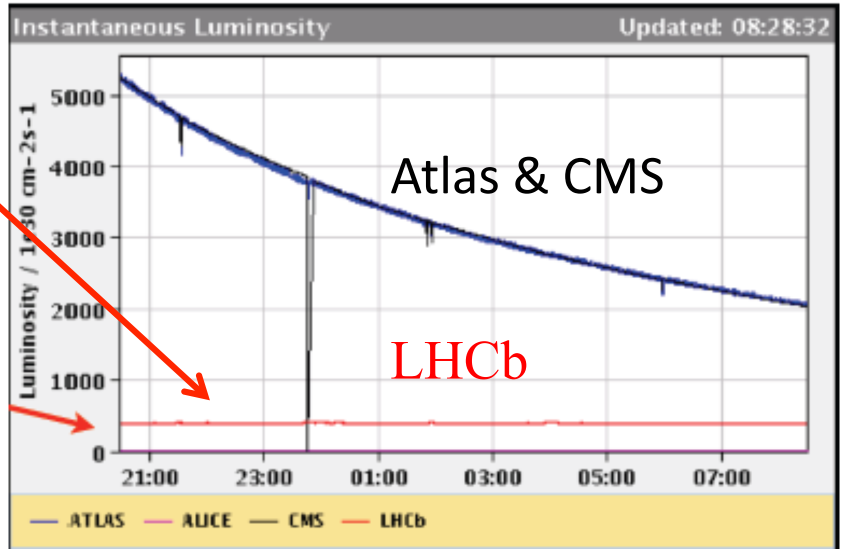
→ number of pp interactions per crossing (8 TeV) ~ 1.8

2) Huge cross section:

σ(pp→bbX) @ 7 TeV ~ 300 μb

→ at L = 4 x10^{32} cm^{-2} s^{-1}

120,000 bb produced every second!



$B_{s,d} \rightarrow \mu\mu$ @ LHCb: the four strong points

1) Constant luminosity: 4×10^{32} cm^{-2} s^{-1}, 1262 colliding bunches,

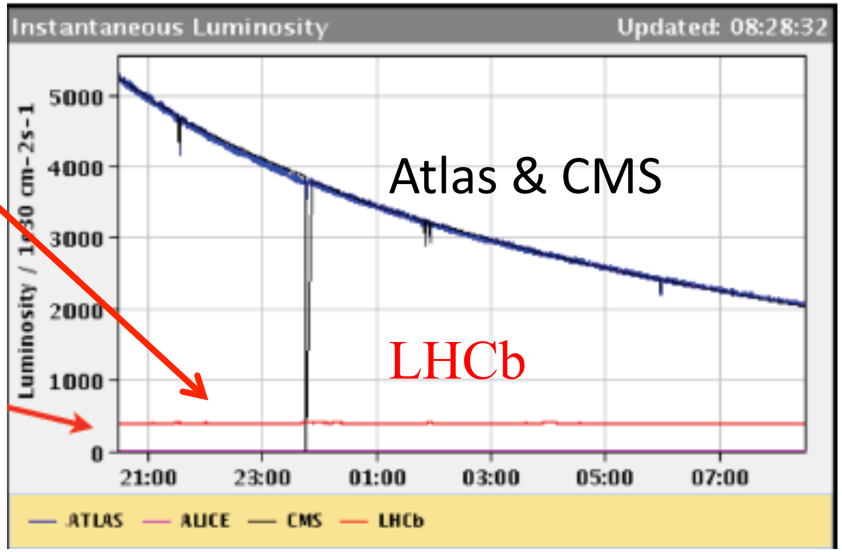
→ number of pp interactions per crossing (8 TeV) ~ 1.8

2) Huge cross section:

$\sigma(pp \rightarrow bbX)$ @ 7 TeV ~ 300 μb

→ at L = 4×10^{32} cm^{-2} s^{-1}

120,000 bb produced every second!



3) Large acceptance

(bb are produced forward/backward):

→ LHCb acceptance $1.9<\eta<4.9$

and very low trigger thresholds:

→ ε(acceptance x trigger) for $B_{sd} \rightarrow \mu\mu$ ~ 10%

$B_{s,d} \to \mu\mu$ @ LHCb: the four strong points

1) Constant luminosity: 4 x 10^{32} cm^{-2} s^{-1}, 1262 colliding bunches,

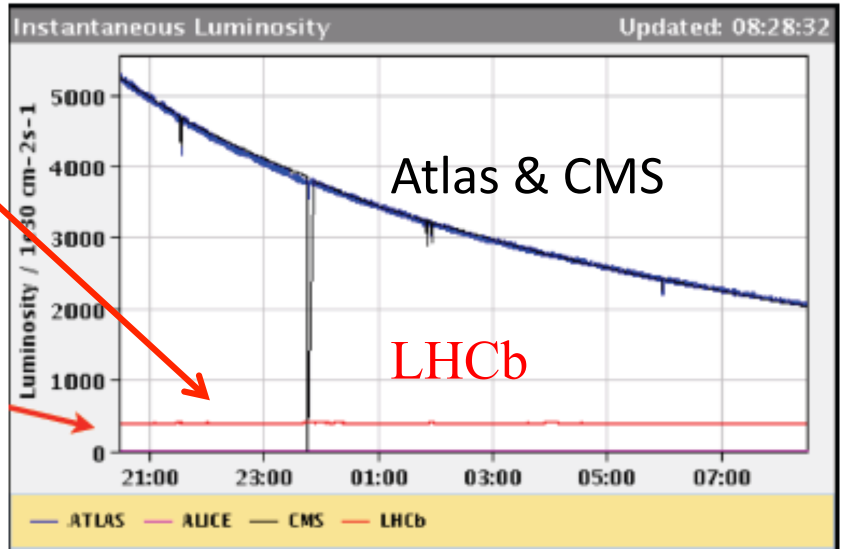
→ number of pp interactions per crossing (8 TeV) ~ 1.8

2) Huge cross section:

σ(pp→bbX) @ 7 TeV ~ 300 μb

→ at L = 4 x10^{32} cm^{-2} s^{-1}

120,000 bb produced every second!



3) Large acceptance

(bb are produced forward/backward):

→ LHCb acceptance 1.9<η<4.9

and very low trigger thresholds:

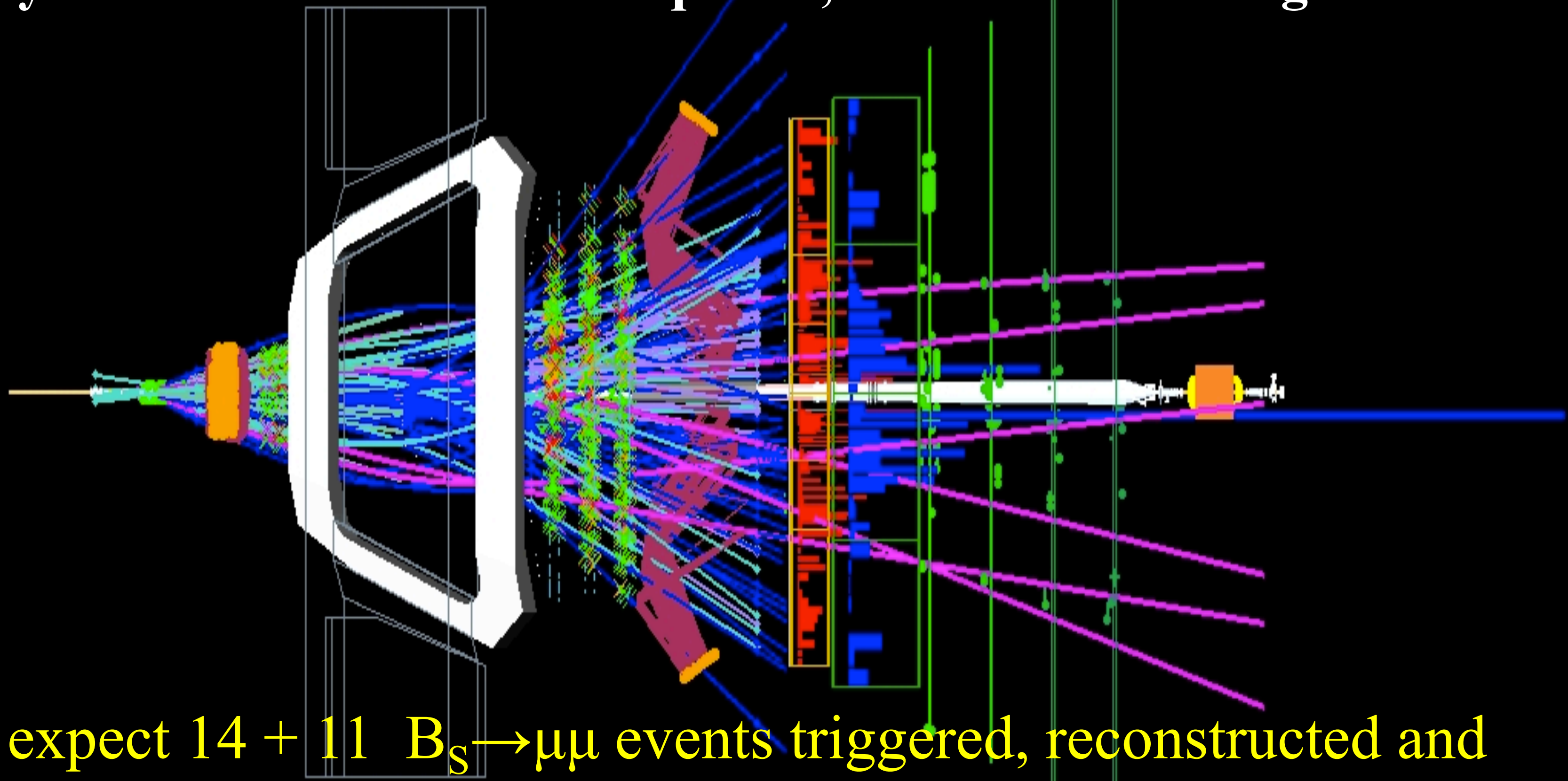
→ ε(acceptance x trigger) for B_{sd}→μμ~ 10%

4) Large boost:

→ average flight distance of B mesons ~ 1 cm

…. But in a harsh environment!

- **σ(pp, inelastic) @ $\sqrt{s}$=7 TeV ~ 80 mb**
  - **~100 tracks per event in LHCb pileup conditions**
  - **only 1/300 event contains a b quark , and we are looking for BR~3 10^{-9}**



We expect 14 + 11 $B_S \rightarrow \mu\mu$ events triggered, reconstructed and selected in 1.1 (8 TeV) + 1.0 (7 TeV) fb^{-1} if BR = BR(SM):

→ Our problem is clearly the background….

$B_{s,d} \to \mu\mu$ @ LHCb: how to reduce the background

1) Highly selective trigger

2) Very good momentum resolution:

→To have a narrow region where to look for the signal

→ **$\delta p/p \sim 0.4\%$ --0.6% for p = (5 -100) GeV/c**

3) Good muon identification:

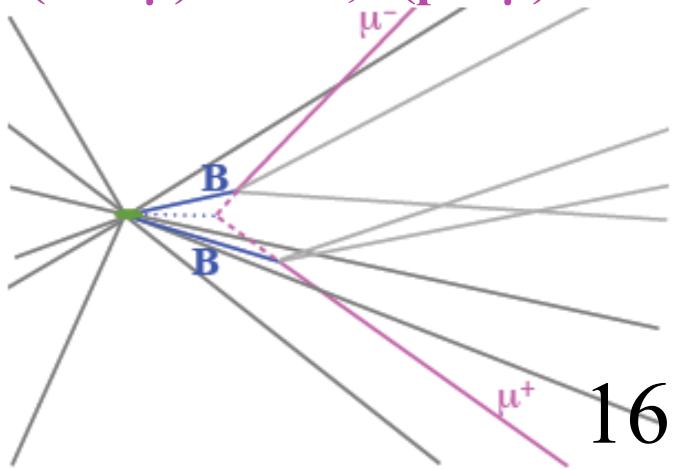
→ To reduce the amount of hadrons misidentified as muons

→ for this analysis: $\varepsilon(\mu\to\mu) \sim 98\%$, $\varepsilon\pi\to\mu \sim 0.6\%$, $\varepsilon(K\to\mu) \sim 0.3\%$, $\varepsilon(p\to\mu) \sim 0.3\%$

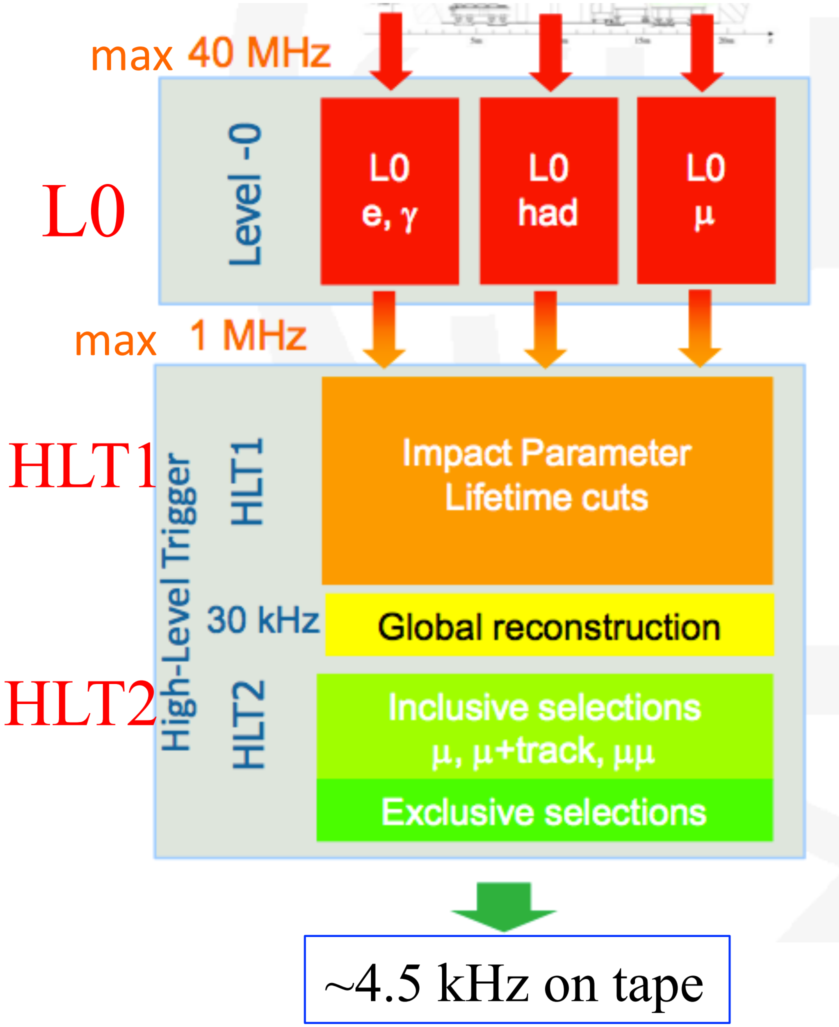
4) excellent vertex and IP resolution:

→ To separate a displaced secondary vertex from the track Proton-proton interaction vertex

→ $\sigma(IP) \sim 25\ \mu m$ @ $p_T = 2$ GeV/c



LHCb trigger for $B_{s,d} \to \mu\mu$



~ 1 kHz to muon lines

10 millions of events/sec

Single- μ: p_T> 1.76 GeV/c
μμ: sqrt(p_{T1} x pT2)> 1.6 GeV/c

1 million of events/sec

add impact parameter cuts
add invariant mass $M_{\mu\mu}$ cuts and/or displaced vertex

4500 events/sec

In 2012 (until mid of August) **we collected about 2 billions of events** …..

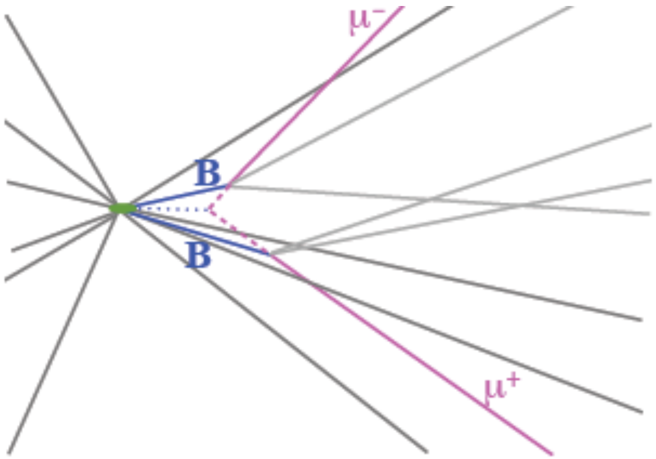
.. and we are looking for
~14 $B_{s,} \to \mu\mu$ events !

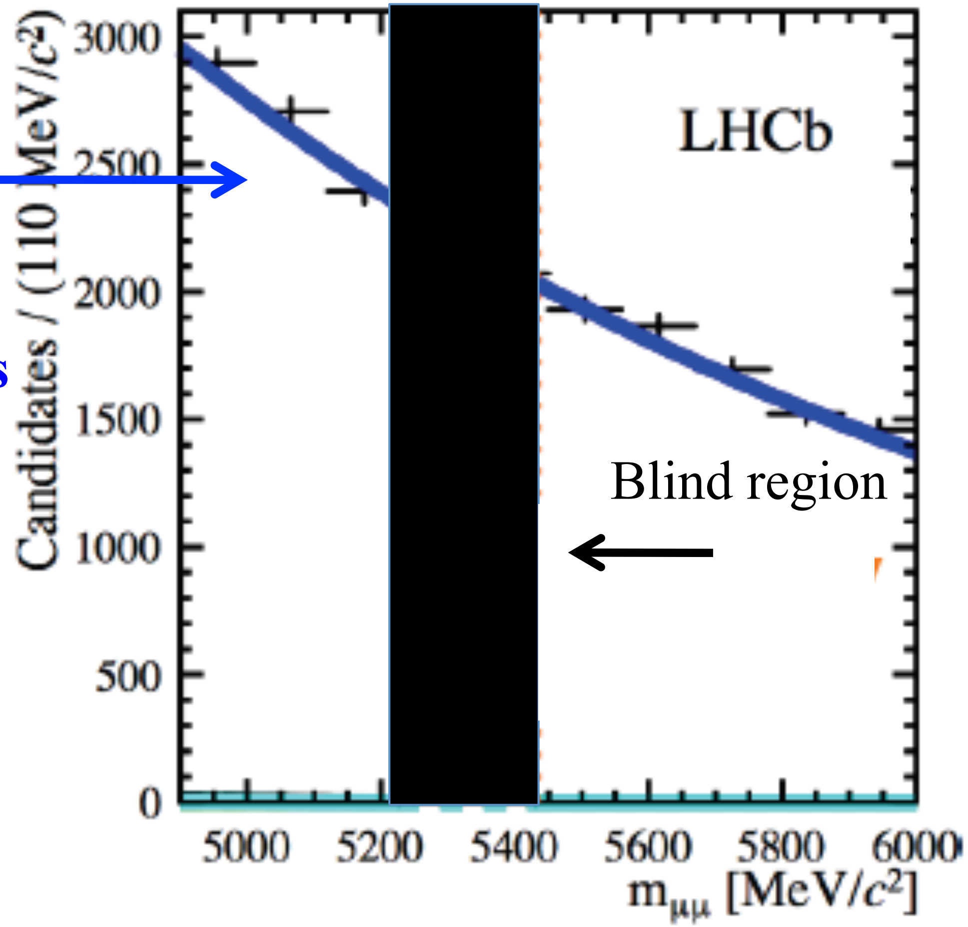
LHCb analysis strategy: selection

- Soft selection:

pairs of opposite charge muons making a vertex displaced with respect to the primary vertex & M(μμ) in the range [4900-6000] MeV/c2. The signal regions, defined by a window of ± 60 MeV around the B_d and B_s mass peaks, have been blinded until the analysis was finalized

After the selection still a lot of background fully dominated by **random combination of real muons from semi-leptonic decays of two different b's**



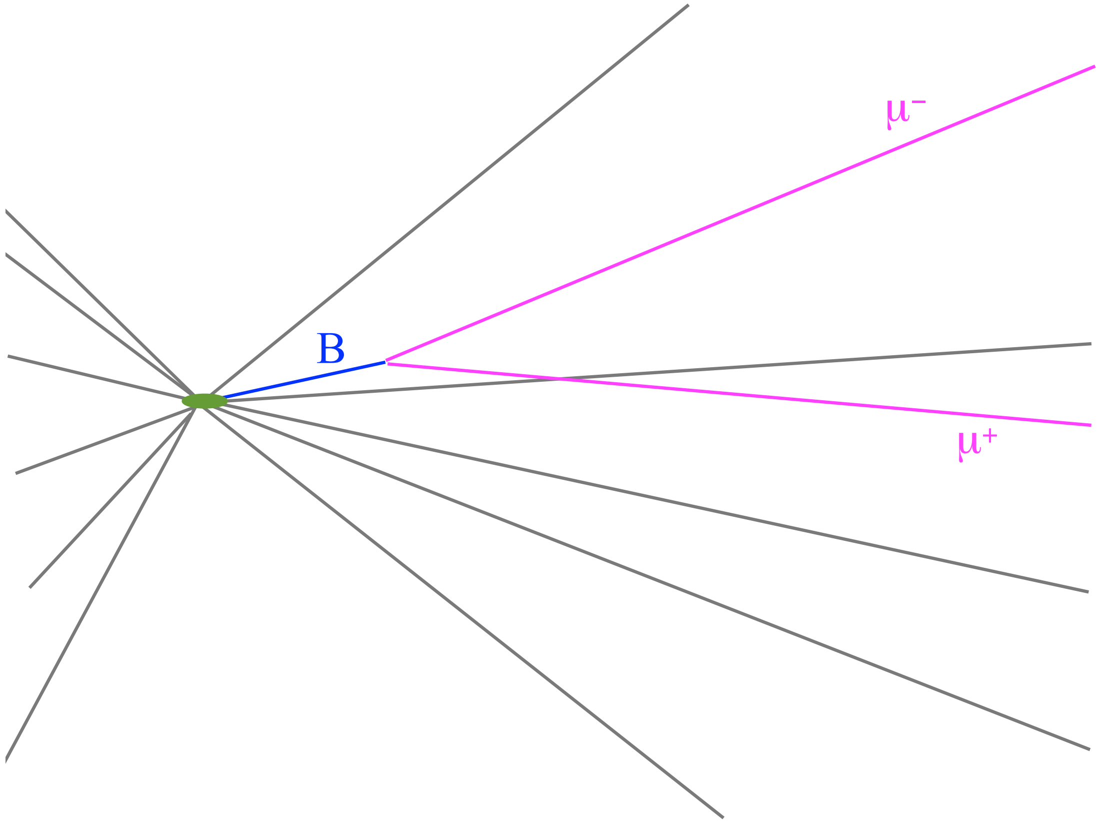


LHCb analysis strategy: BDT

- Discrimination between S and B via Multivariate Discriminant BDT (Boosted Decision Tree) with 9 input variables:

→ B candidate: proper time, impact parameter, transverse momentum, B isolation

→ muons: min pT, min IP significance, distance of closest approach, muon isolation, cosP

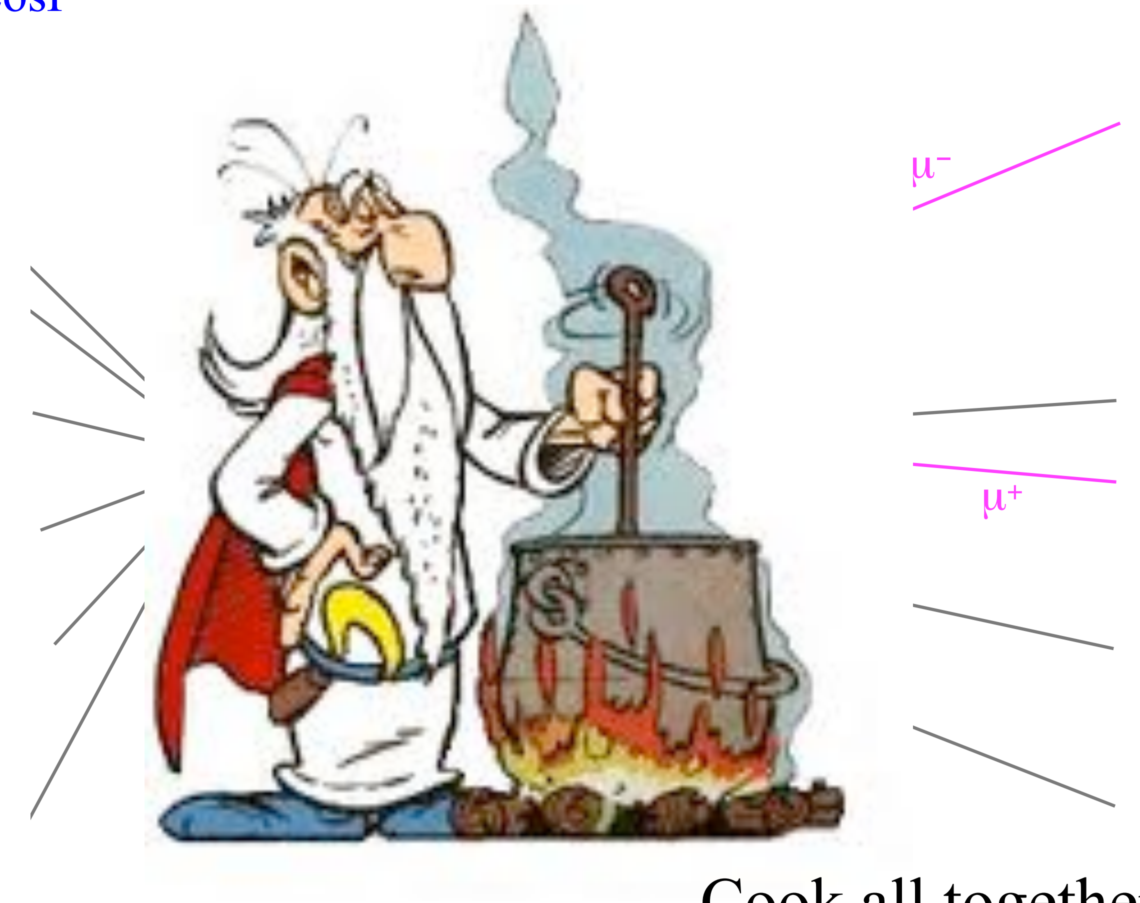


LHCb analysis strategy: BDT

- Discrimination between S and B via Multivariate Discriminant BDT (Boosted Decision Tree) with 9 input variables:

→ B candidate: proper time, impact parameter, transverse momentum, B isolation

→ muons: min pT, min IP significance, distance of closest approach, muon isolation, cosP

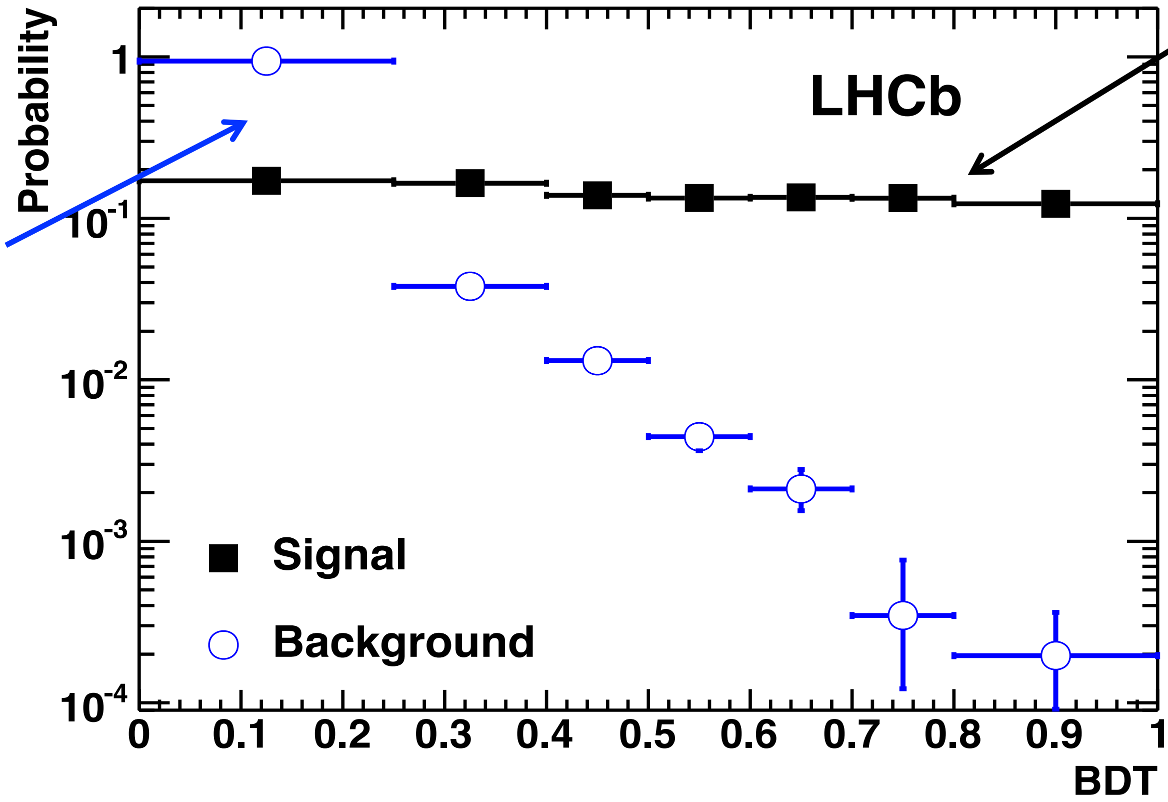


Cook all together…..

LHCb analysis strategy: BDT

- Discrimination between S and B via Multivariate Discriminant BDT (Boosted Decision Tree) with 9 input variables:
  - → B candidate: proper time, impact parameter, transverse momentum, B isolation
  - → muons: min pT, min IP significance, distance of closest approach, muon isolation, cosP

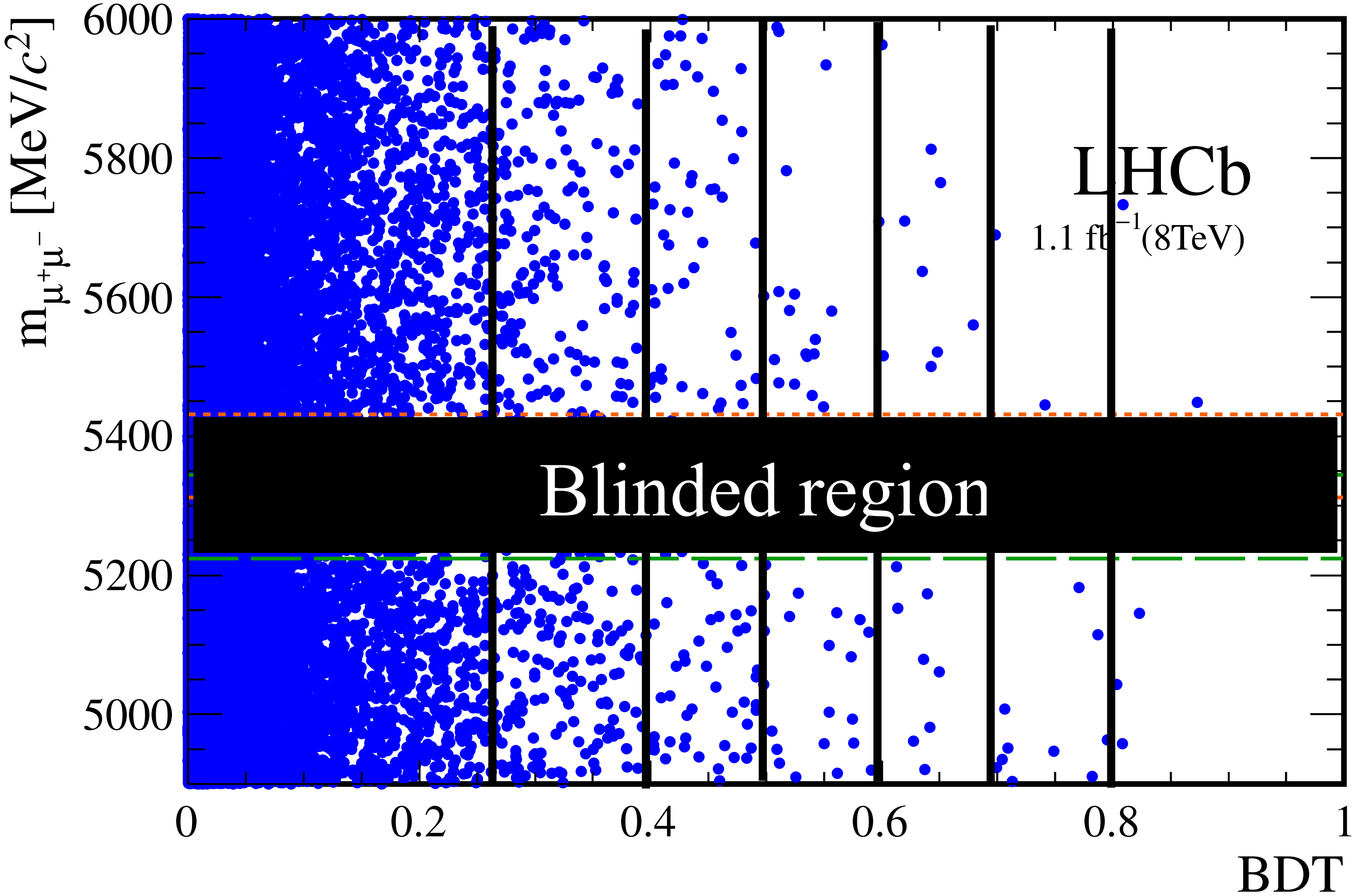
Peaked at zero for background



Flat between 0 and 1 for signal

Crucial ingredient here are the IP and vertices resolutions

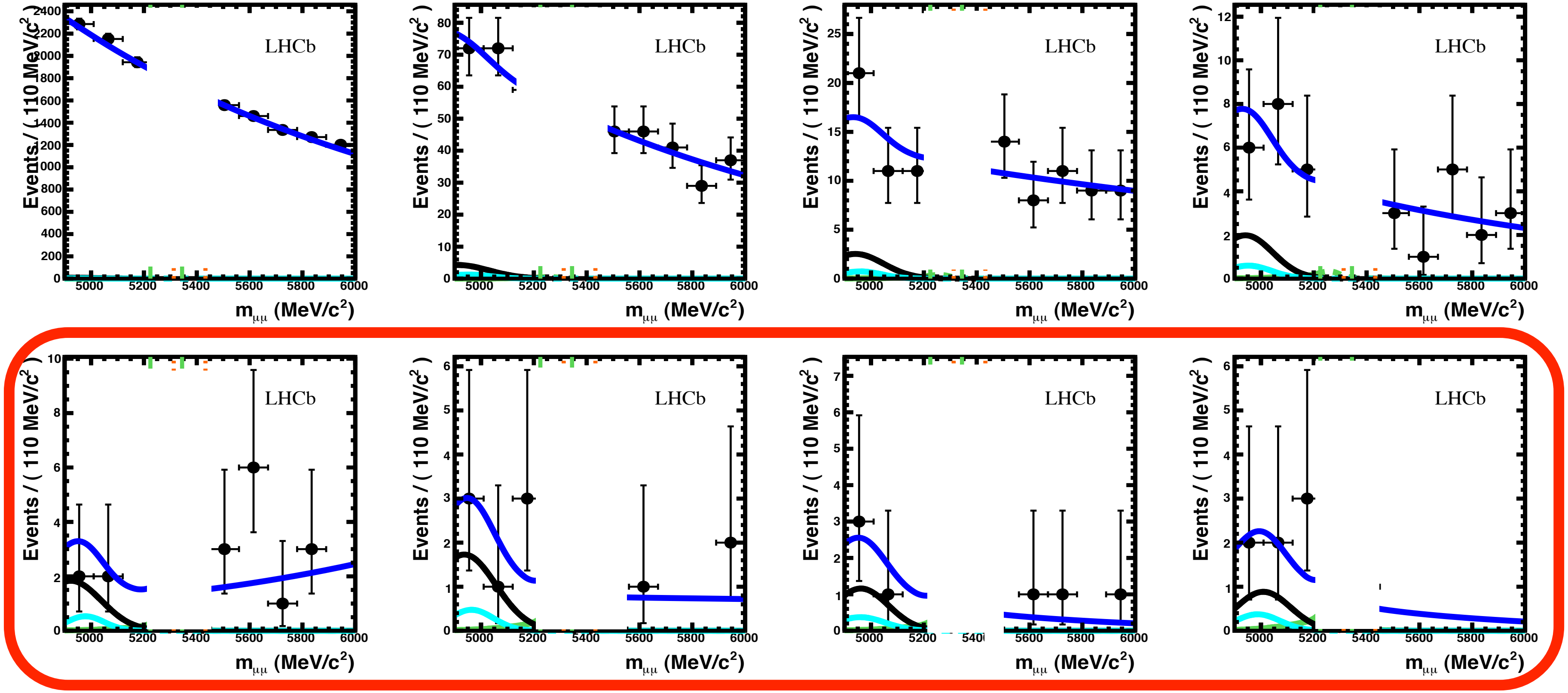
Dimuon mass versus BDT



The BDT is binned in 8 bins (for 2011 data) and 7 bins (for the 2012 data)

Dimuon invariant mass distributions in BDT bins

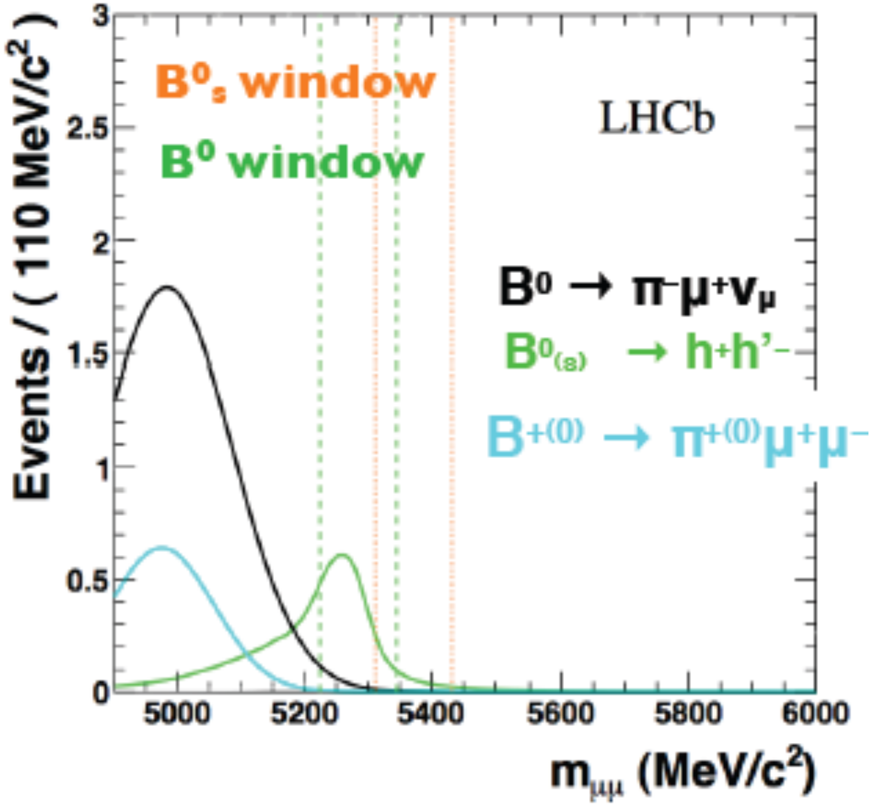
- Dimuon invariant mass distributions in BDT bins for the data sample collected at 7 TeV:



The combinatorial background in the signal regions is interpolated from mass sidebands assuming an exponential shape

LHCb analysis strategy: exclusive background

Several exclusive backgrounds pollute the low mass sidebands and have to be taken into account in order to not bias the evaluation of the combinatorial background in the signal regions. **The B→ hh' (h=π,K misidentified as μ) is the only background that pollutes the signal regions, namely the B^0 one**.



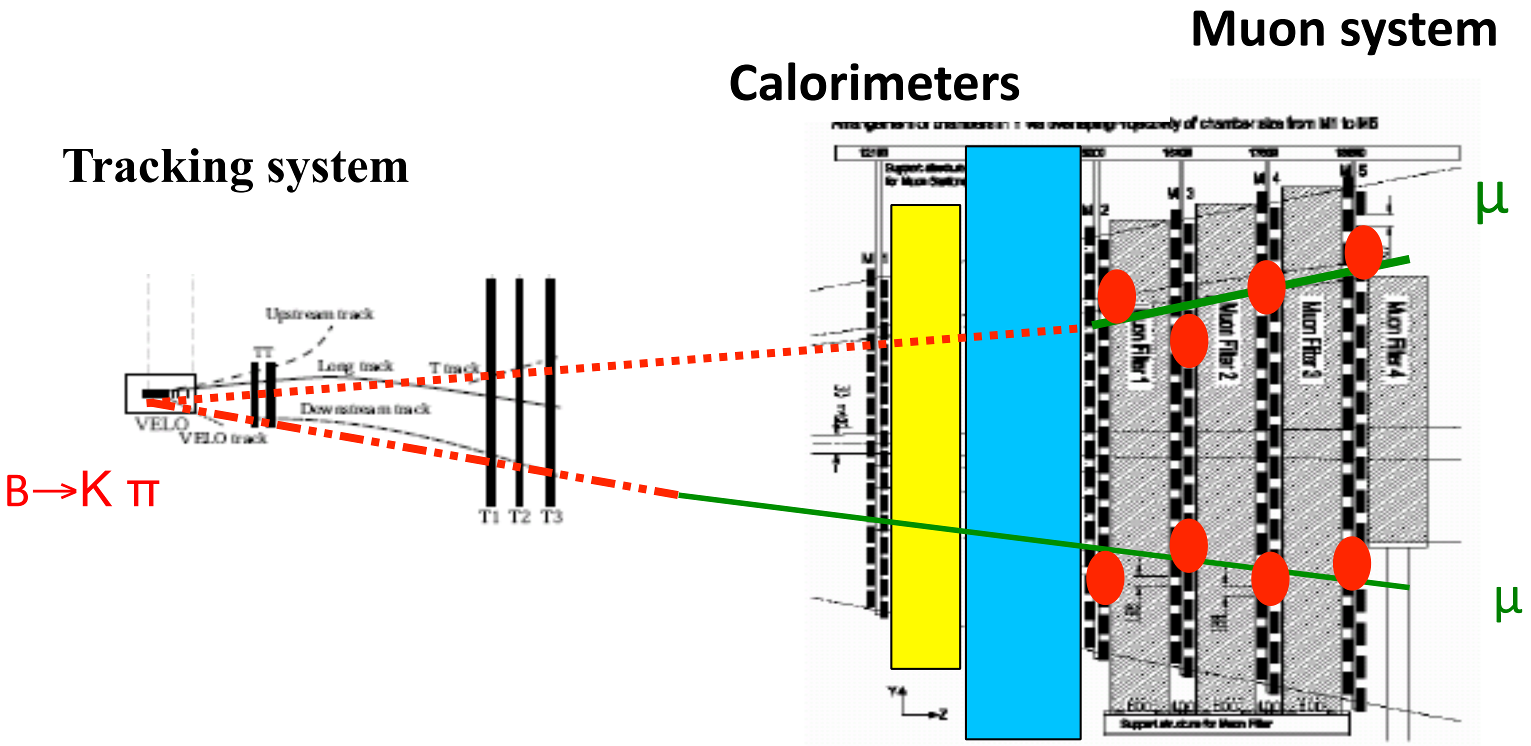
Yields for $M_{\mu\mu}$=[4900,6000] MeV/c^2 and BDT>0.8:

$B^0 \to \pi^- \mu^+ \nu_\mu$	4.04 ± 0.28
$B^{+(0)} \to \pi^{+(0)} \mu^+ \mu^-$	1.32 ± 0.39
$B^0_{(s)} \to h^+ h'^-$	1.37 ± 0.11

Evaluated with high stat MC samples weighted by misID probability measured in data and normalized with B+→J/ψK+

exclusive background: B→hh' with double misID

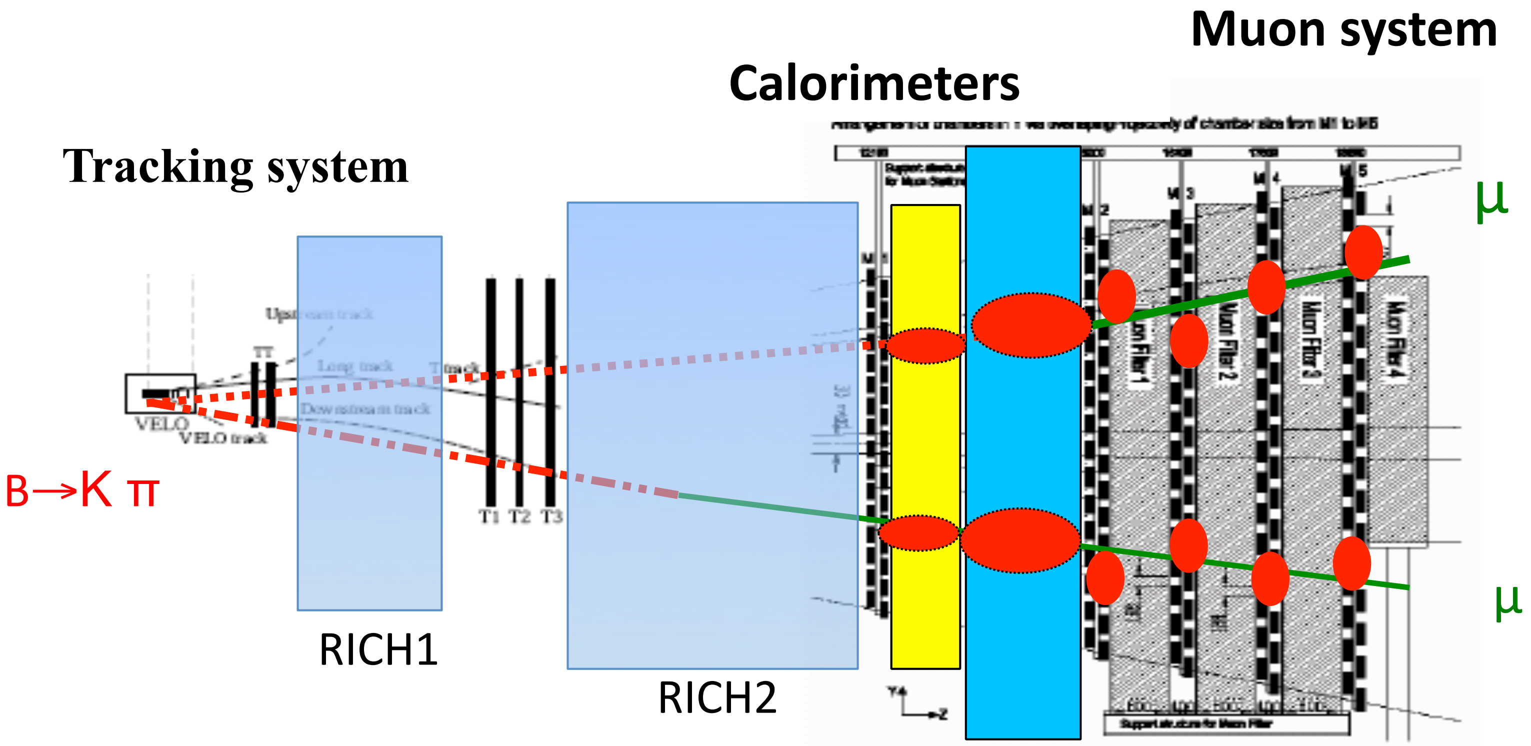
The B→ hh' (h=π,K misidentified as muons) is the only background that pollutes the signal regions, mostly the B^0 one.



B→hh → μμ : **0.94 x 10^{-4}** after muon chamber matching

exclusive background: B→hh’ with double misID

The B→ hh’ (h=π,K misidentified as muons) is the only background that pollutes the signal regions, mostly the B^0 one.

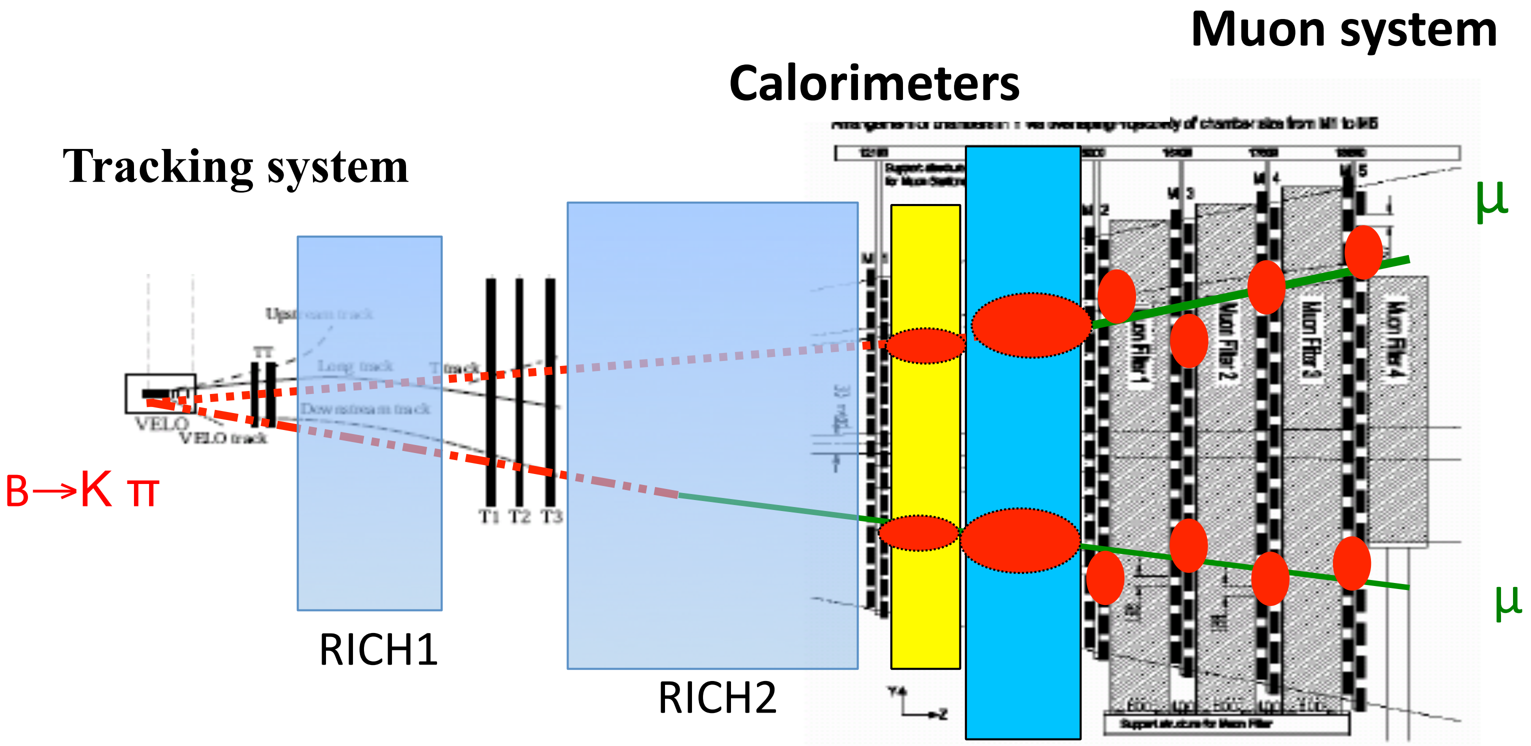


B→hh → μμ : **0.94 x 10^{-4}** after muon chamber matching

0.18x10^{-4} after global likelihood cut

exclusive background: B→hh' with double misID

The B→ hh' (h=π,K misidentified as muons) is the only background that pollutes the signal regions, mostly the B^0 one.



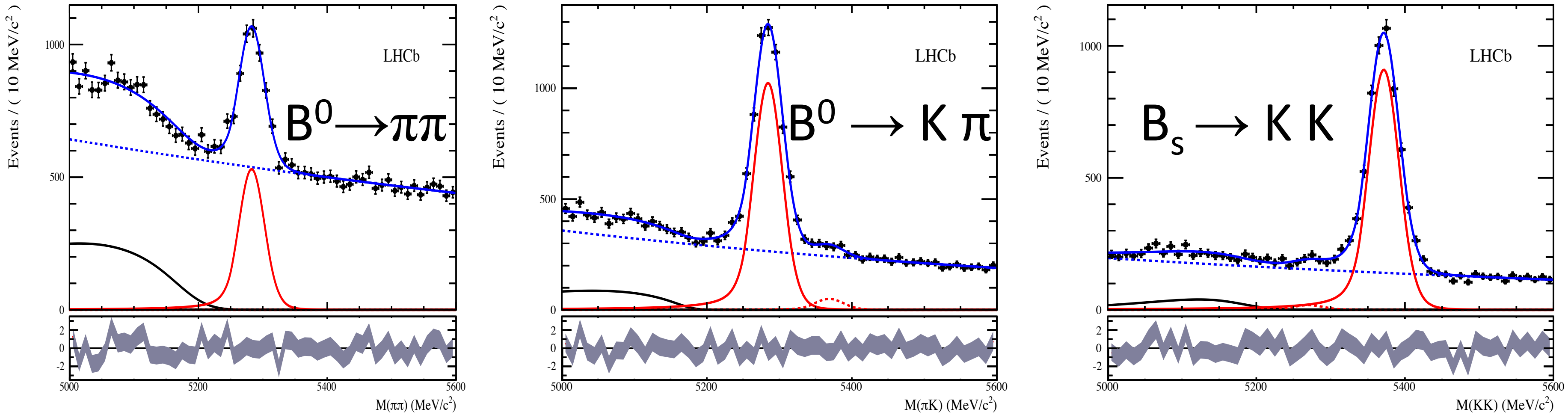
$B \to hh \to \mu\mu$: **0.94×10^{-4}** after muon chamber matching

0.18×10^{-4} after global likelihood cut

8 TeV **$\to 0.76^{+0.26}_{-0.18}$ in B_s and $4.1^{\,1.7}_{-0.8}$ in the B^0 mass regions**

B→hh' as calibration channel: mass peaks

We use B→ππ, B→K π and B_s→KK decays to determine the position of the mass peaks and the mass resolution



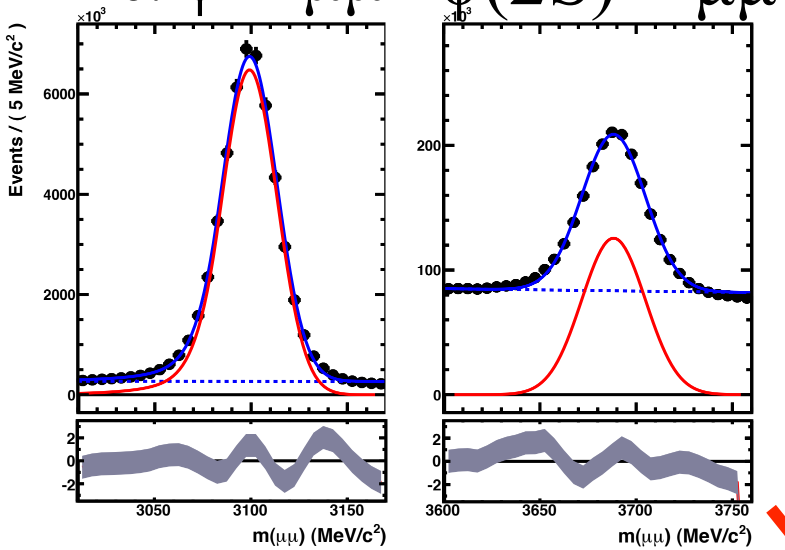
8 TeV data

m_{B^0}	$(5284.36 \pm 0.26_{\text{stat}} \pm 0.13_{\text{syst}})$ MeV$/c^2$
$m_{B^0_s}$	$(5371.55 \pm 0.41_{\text{stat}} \pm 0.16_{\text{syst}})$ MeV$/c^2$

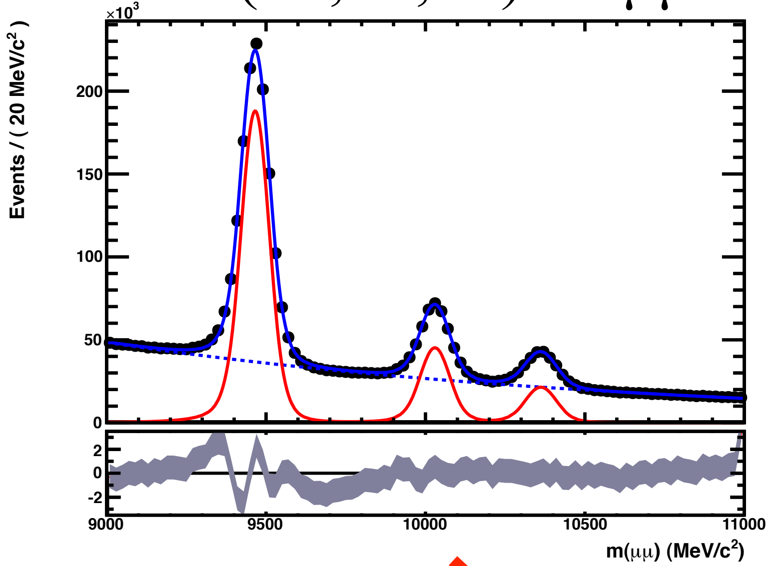
Peak positions at 7 TeV and 8 TeV agree better than $5x10^{-4}$

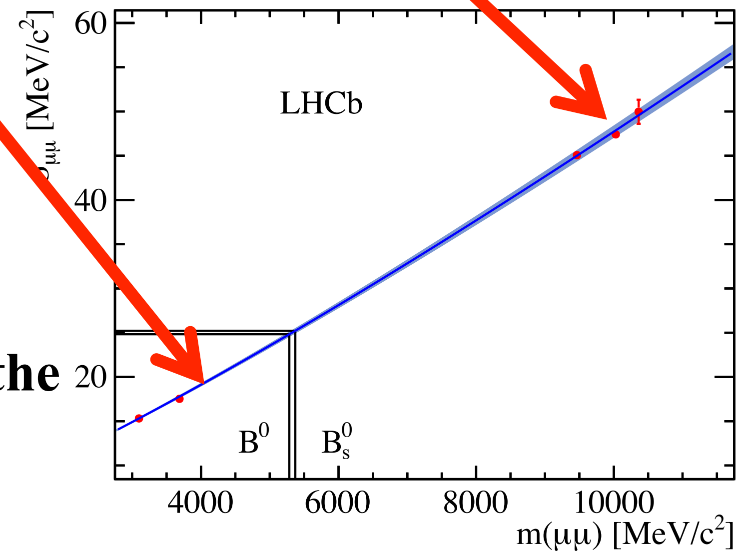
J/ψ, $\psi(2S)$, $\Upsilon(1S,2S,3S)$ calibration channels: mass resolution

$J/\psi\rightarrow\mu\mu$ $\psi(2S)\rightarrow\mu\mu$



$\Upsilon(1S,2S,3S)\rightarrow\mu\mu$



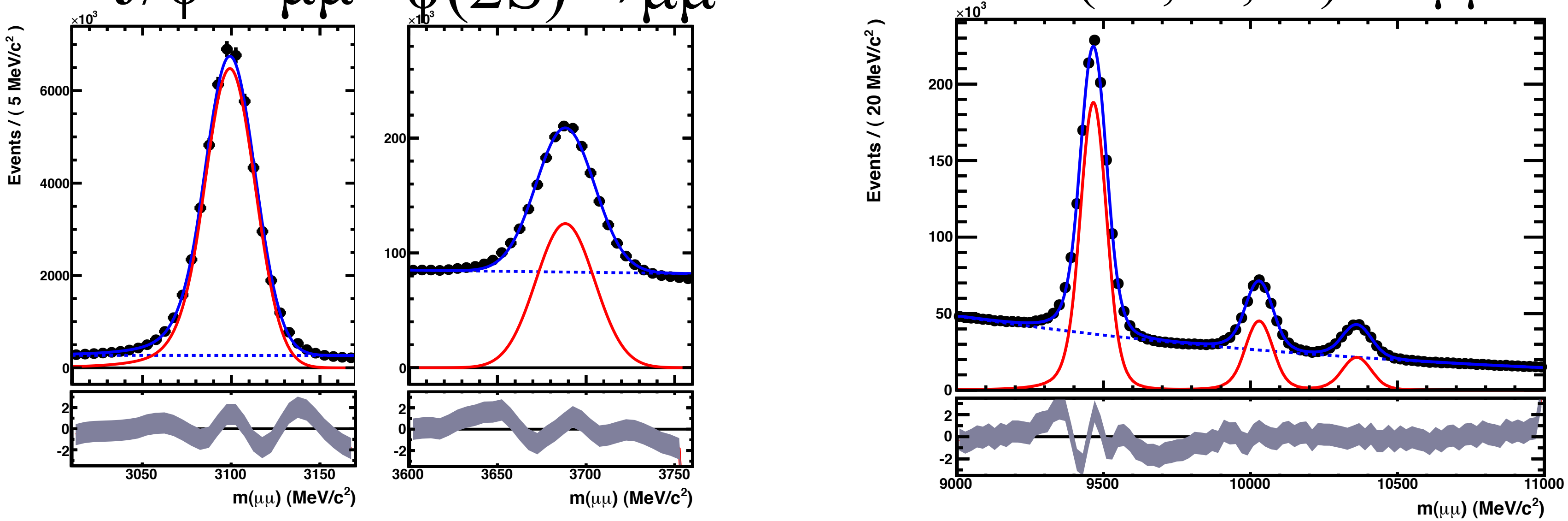


Use dimuon resonances at different mass scales, measure the resolutions and interpolate at the B^0 and B_s mass values.

Compare with the resolution obtained from the B→hh' sample.

J/ψ, ψ(2S), Υ(1S,2S,3S) calibration channels: mass resolution

J/ψ→μμ   ψ(2S)→μμ   Υ(1S,2S,3S) → μμ



The results of the two methods are in agreement:

$$\sigma_{B^0} = (24.82 \pm 0.20_{\rm stat} \pm 0.41_{\rm syst})\ {\rm MeV}/c^2$$
$$\sigma_{B^0_s} = (25.22 \pm 0.21_{\rm stat} \pm 0.41_{\rm syst})\ {\rm MeV}/c^2$$

1% difference observed between 7 TeV and 8 TeV data

The B(s) →μμ mass lineshape is parametrized as a Crystal Ball function with a transition point of the radiative tail determined from simulated events smeared to reproduce the measured resolution


Tired?
We are almost there…

Normalization strategy
(or how to convert a number of events into a BR)

$$N(B_{s,d} \to \mu^+\mu^-) = L \times \sigma(pp \to b\bar{b}) \times f_{s,d} \times BR(B_{s,d} \to \mu^+\mu^-) \times \epsilon^{\rm trg}_{\rm sig}\epsilon^{\rm rec}_{\rm sig}\epsilon^{\rm sel}_{\rm sig}$$

Normalization strategy
(or how to convert a number of events into a BR)

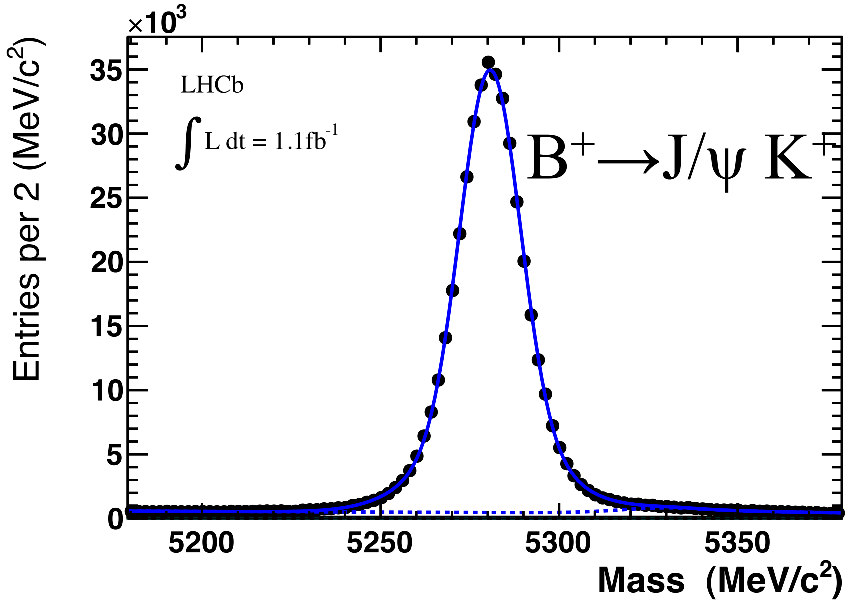
$$N(B_{s,d} \to \mu^+\mu^-) = L \times \sigma(pp \to b\bar{b}) \times f_{s,d} \times BR(B_{s,d} \to \mu^+\mu^-) \times \epsilon_{\rm sig}^{\rm trg} \epsilon_{\rm sig}^{\rm rec} \epsilon_{\rm sig}^{\rm sel}$$

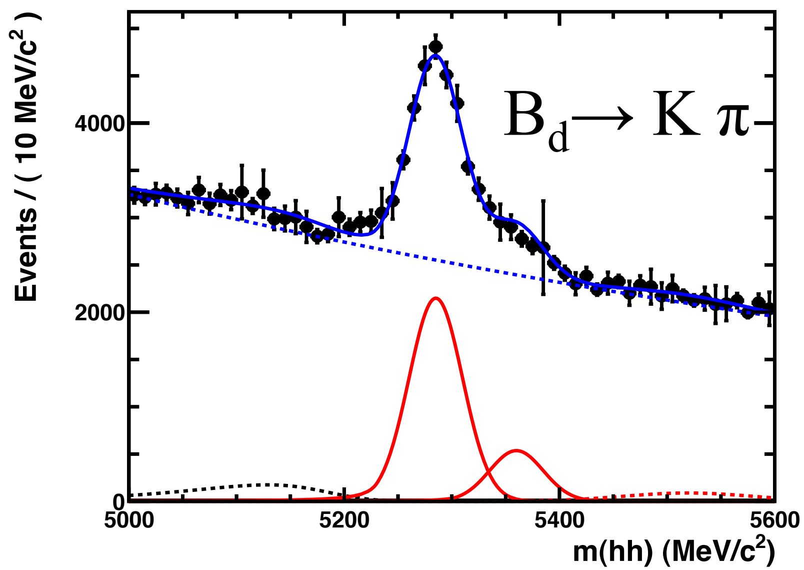
$$L \times \sigma(pp \to b\bar{b}) = \frac{N(\text{cal})}{f_{cal} \times BR(\text{cal}) \times \epsilon_{\rm cal}^{\rm trg} \epsilon_{\rm cal}^{\rm rec} \epsilon_{\rm cal}^{\rm sel}}$$

Normalization strategy
(or how to convert a number of events into a BR)

$$N(B_{s,d} \to \mu^+\mu^-) = \boxed{L \times \sigma(pp \to b\bar{b})} \times f_{s,d} \times BR(B_{s,d} \to \mu^+\mu^-) \times \epsilon^{\rm trg}_{\rm sig}\epsilon^{\rm rec}_{\rm sig}\epsilon^{\rm sel}_{\rm sig}$$

$$L \times \sigma(pp \to b\bar{b}) = \frac{N(\mathrm{cal})}{f_{cal} \times BR(\mathrm{cal}) \times \epsilon^{\rm trg}_{\rm cal}\epsilon^{\rm rec}_{\rm cal}\epsilon^{\rm sel}_{\rm cal}}$$





We use two normalization channels: $B^+ \to J/\psi\, K^+$ and $B_d \to K\,\pi$

Normalization strategy
(or how to convert a number of events into a BR)

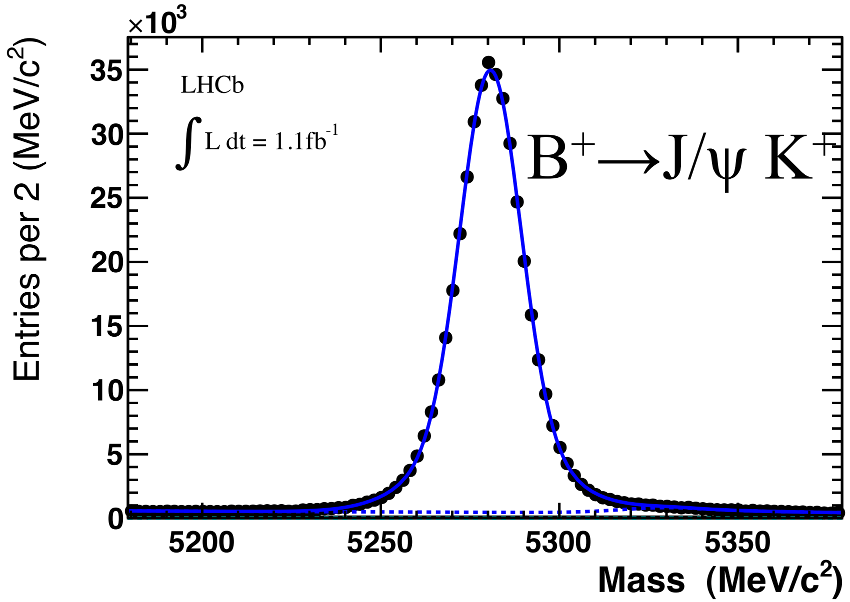
From PDG

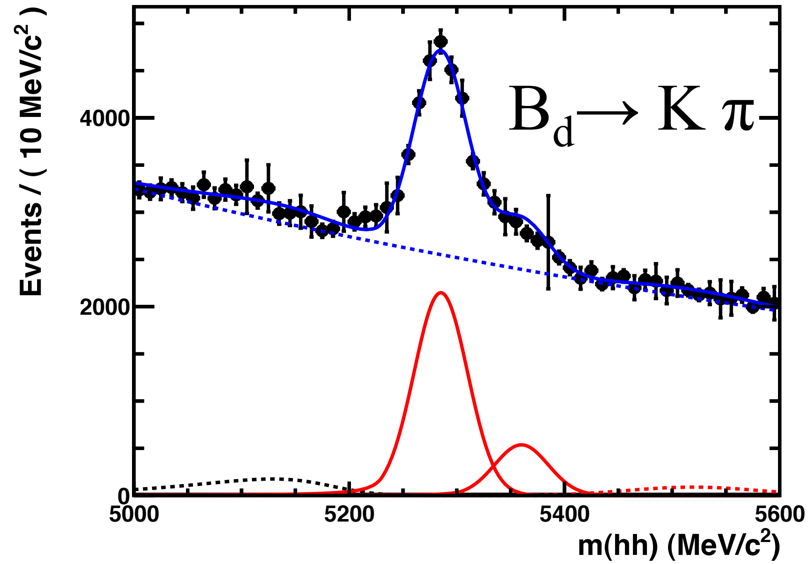
$$BR(B_{s,d} \to \mu^+\mu^-) = BR(\mathrm{cal}) \times \frac{\epsilon^{\mathrm{trg}}_{\mathrm{cal}}\,\epsilon^{\mathrm{rec}}_{\mathrm{cal}}\,\epsilon^{\mathrm{sel}}_{\mathrm{cal}}}{\epsilon^{\mathrm{trg}}_{\mathrm{sig}}\,\epsilon^{\mathrm{rec}}_{\mathrm{sig}}\,\epsilon^{\mathrm{sel}}_{\mathrm{sig}}} \times \frac{f_{cal}}{f_{s,d}} \times \frac{N(B_{s,d} \to \mu^+\mu^-)}{N(\mathrm{cal})}$$

measured on data

Evaluated on MC and cross-checked with data

measured on data





We use two normalization channels: $B^+ \to J/\psi\, K^+$ and $B_d \to K\,\pi$

Normalization strategy
(or how to convert a number of events into a BR)

$$BR(B_{s,d} \to \mu^+\mu^-) = \alpha_{B_{s,d}\to\mu^+\mu^-} \times N(B_{s,d} \to \mu^+\mu^-)$$

Results for 8 TeV data (equivalent table for 7 TeV data)

	$\mathcal{B}$ $(\times 10^{-5})$	$\frac{\epsilon^{\rm REC}_{\rm cal}\epsilon^{\rm SEL\vert REC}_{\rm cal}}{\epsilon^{\rm REC}_{\rm sig}\epsilon^{\rm SEL\vert REC}_{\rm sig}}$	$\frac{\epsilon^{\rm TRIG\vert SEL}_{\rm cal}}{\epsilon^{\rm TRIG\vert SEL}_{\rm sig}}$	N_{cal}	$\alpha^{cal}_{B_d\to\mu^+\mu^-}$ $(\times 10^{-11})$	$\alpha^{cal}_{B_s\to\mu^+\mu^-}$ $(\times 10^{-10})$
$B^+ \to J/\psi K^+$	6.01 ± 0.21	0.494 ± 0.016	0.932 ± 0.012	$424\,222 \pm 1452$	7.24 ± 0.39	2.83 ± 0.27
$B^0 \to K^+\pi^-$	1.94 ± 0.06	0.817 ± 0.028	0.057 ± 0.002	$14\,579 \pm 1110$	6.93 ± 0.67	2.71 ± 0.34

The two channels give consistent results hence we take the average (8 TeV data)

$$\alpha_{B^0_s\to\mu^+\mu^-} = (2.80 \pm 0.25) \times 10^{-10}$$
$$\alpha_{B^0\to\mu^+\mu^-} = (7.16 \pm 0.34) \times 10^{-11}$$

In ±60 MeV

Normalization strategy
(or how to convert a number of events into a BR)

$$BR(B_{s,d} \to \mu^+\mu^-) = \alpha_{B_{s,d}\to\mu^+\mu^-} \times N(B_{s,d} \to \mu^+\mu^-)$$

Results for 8 TeV data (equivalent table for 7 TeV data)

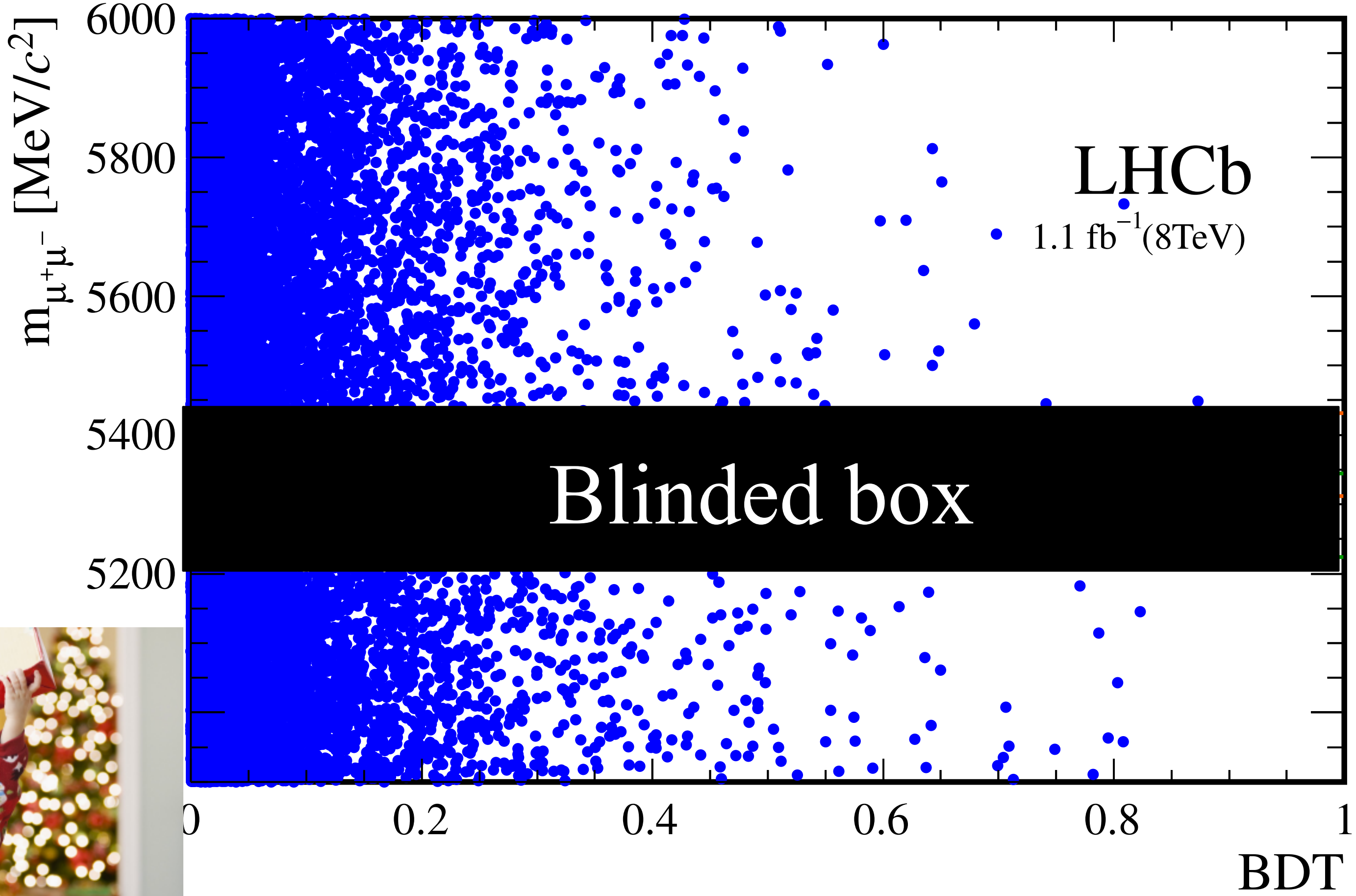
In practice, if you divide the BR by alpha you will get the number of events we expect in the dataset at 8 TeV…. If BR(SM) = $3.5\text{x}10^{-10}$, which is the number?

$$\alpha_{B^0_s\to\mu^+\mu^-} = (2.80 \pm 0.25) \times 10^{-10}$$
$$\alpha_{B^0\to\mu^+\mu^-} = (7.16 \pm 0.34) \times 10^{-11}$$

In ±60 MeV

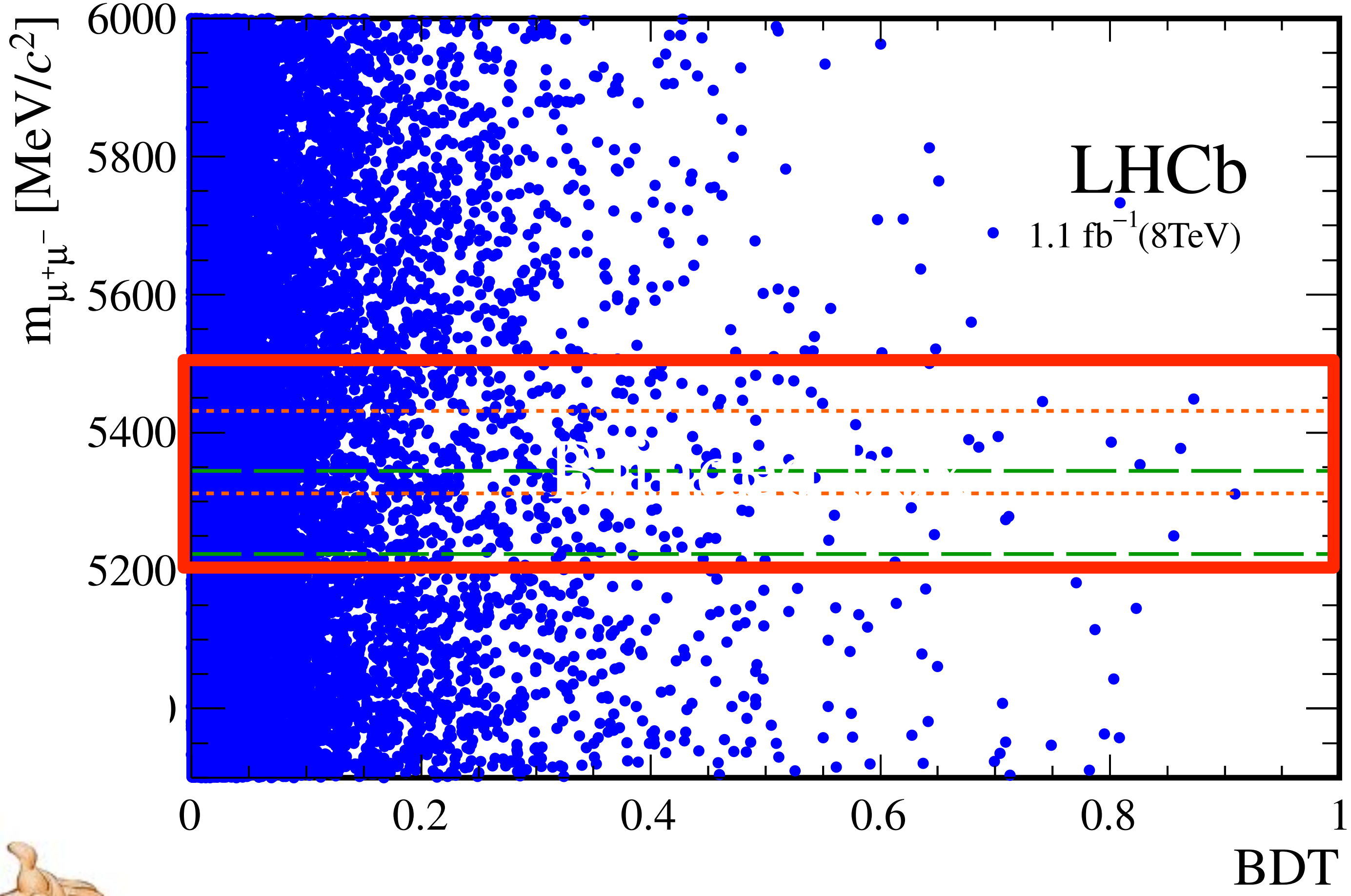
Results

mass versus BDT
2012 blinded data



The $B_{s,d} \rightarrow \mu\mu$ group in the morning of October 25th….

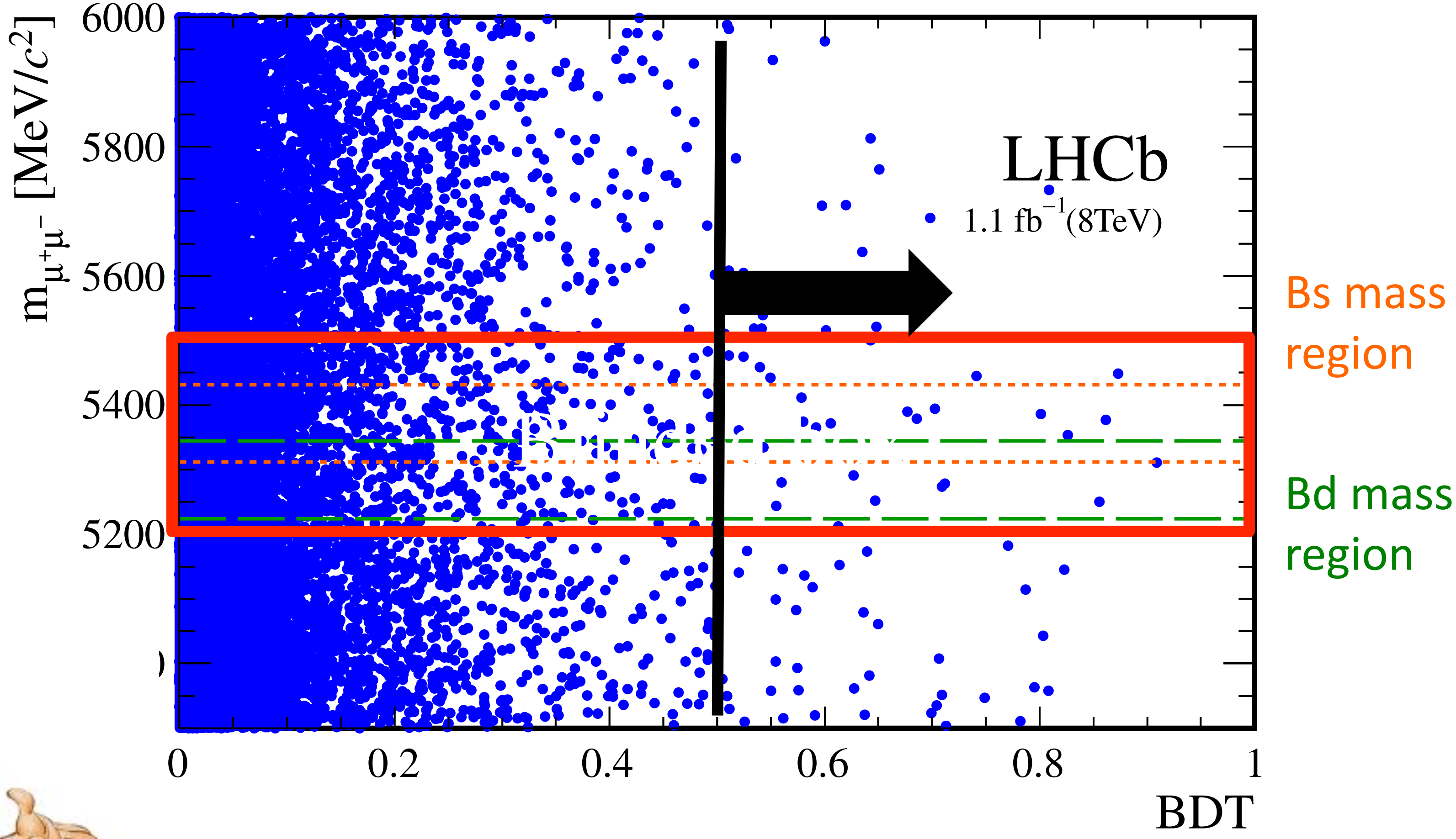
mass versus BDT
2012 unblinded data



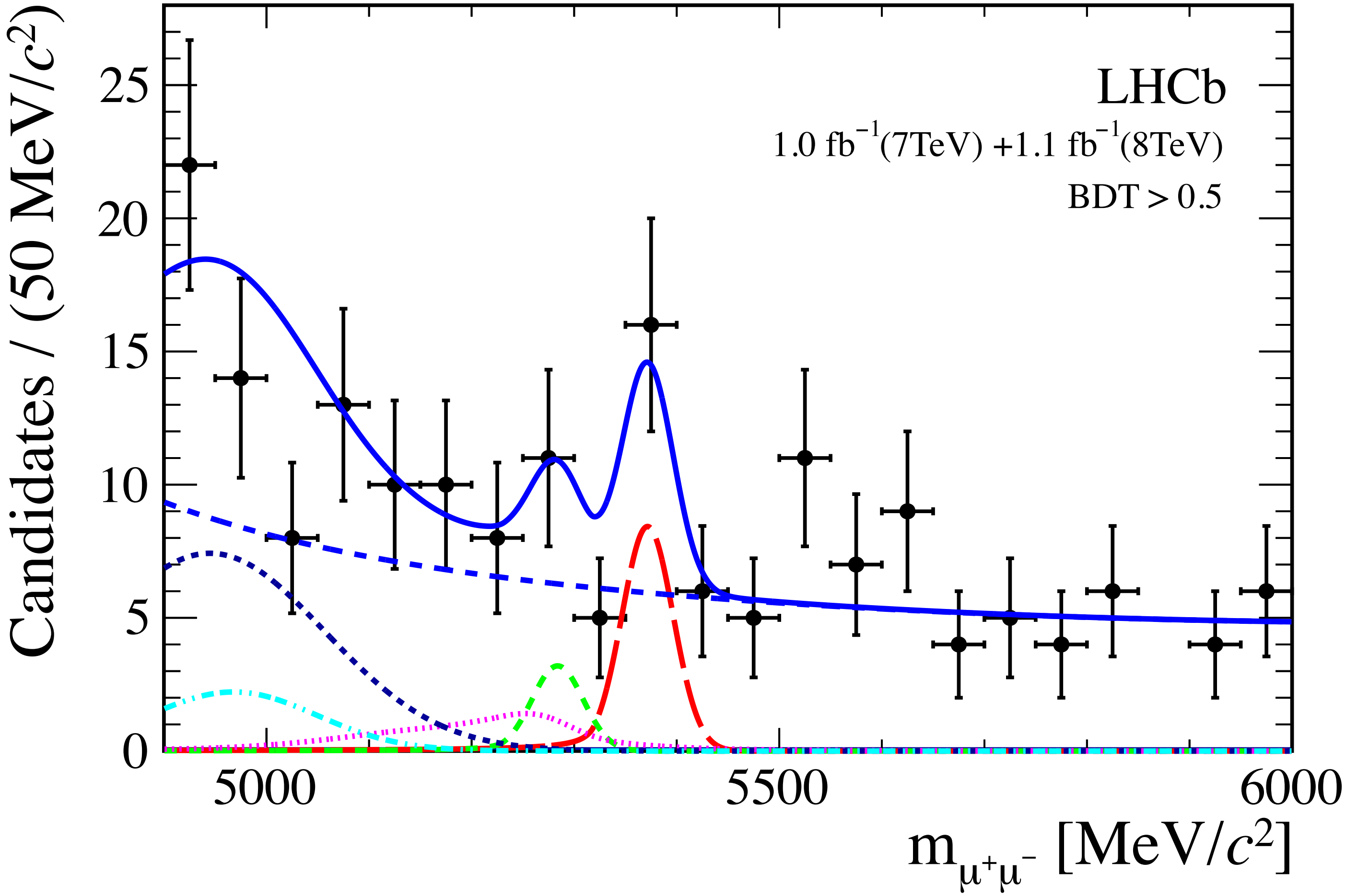
Bs mass region

Bd mass region

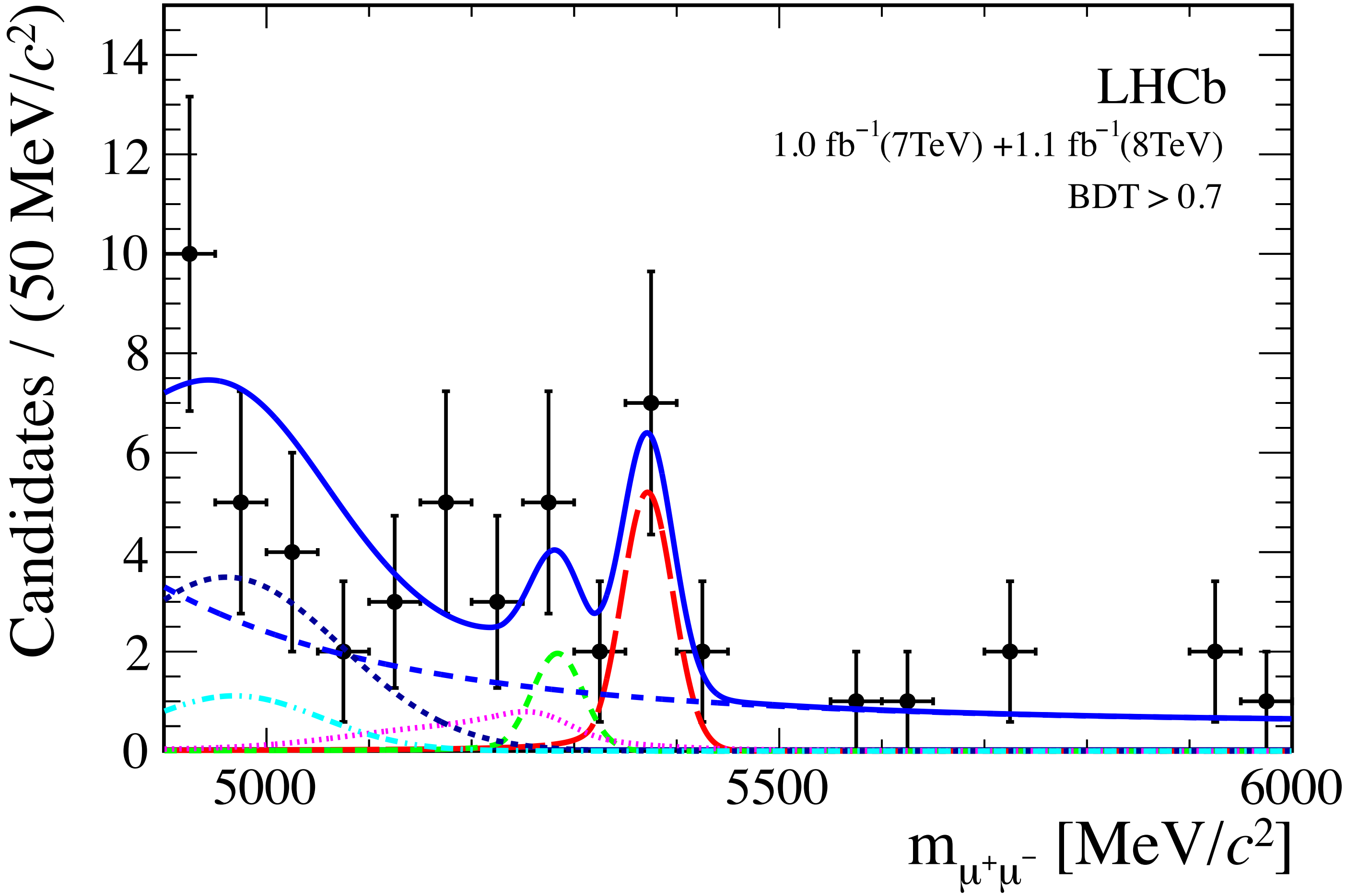
mass versus BDT
2012 unblinded data



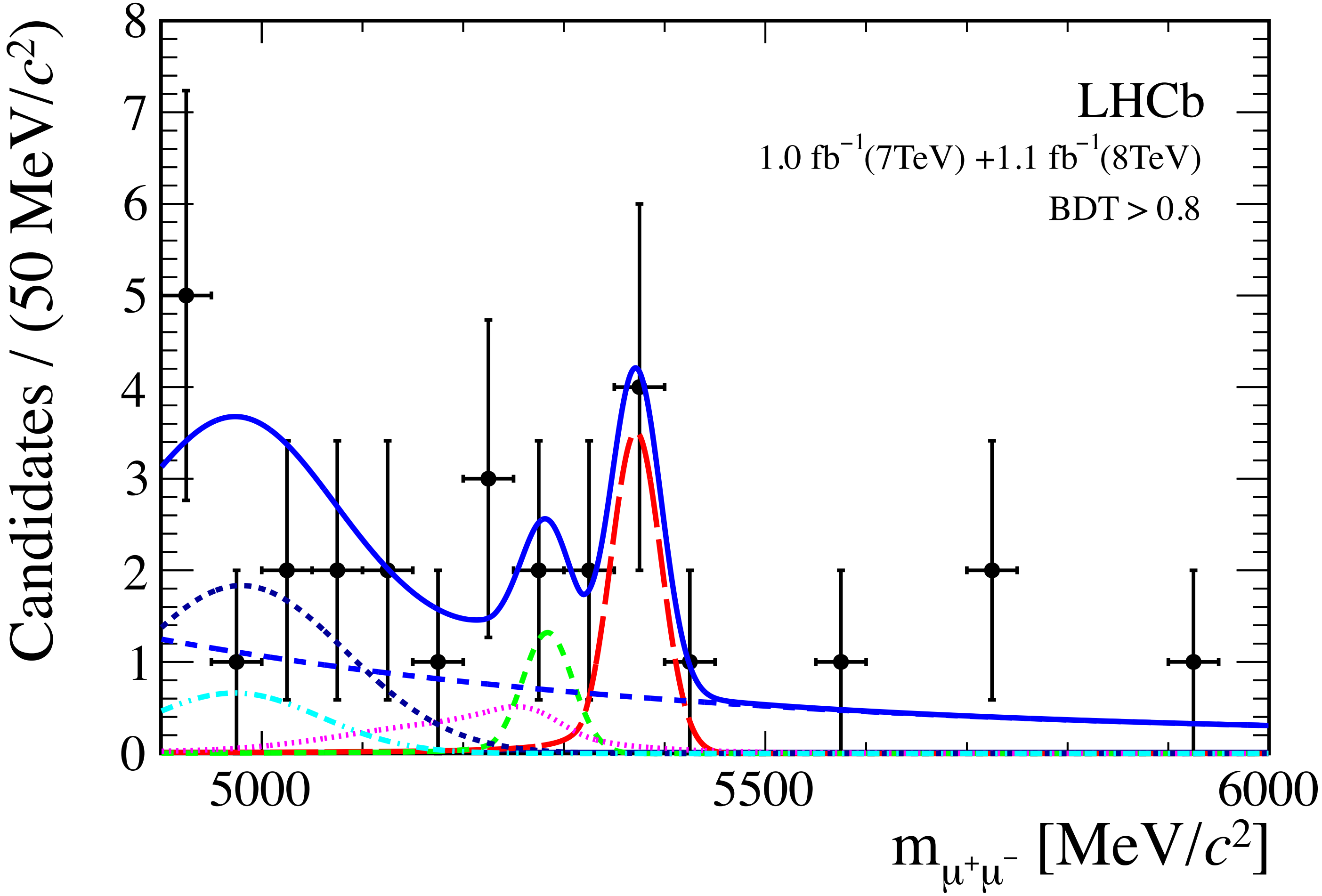
Combined dataset: BDT>0.5



Combined dataset: BDT>0.7



Combined dataset: BDT>0.8



Observed and expected events

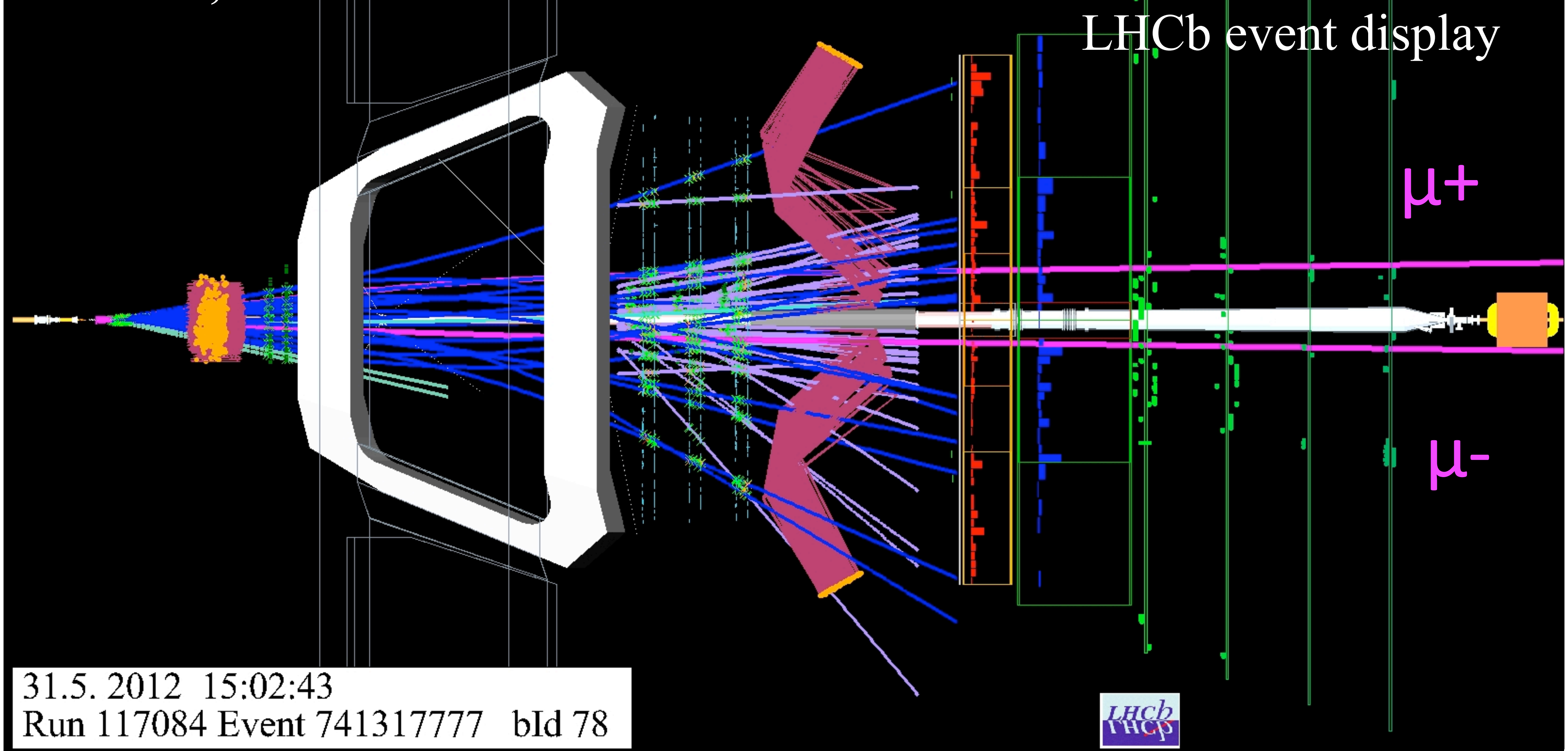
7 TeV data

Mode	BDT bin	0.0 – 0.25	0.25 – 0.4	0.4 – 0.5	0.5 – 0.6	0.6 – 0.7	0.7 – 0.8	0.8 – 0.9	0.9 – 1.0
$B_s^0 \to \mu^+\mu^-$	Exp. comb. bkg	1880^{+33}_{-33}	$55.5^{+3.0}_{-2.9}$	$12.1^{+1.4}_{-1.3}$	$4.16^{+0.88}_{-0.79}$	$1.81^{+0.62}_{-0.51}$	$0.77^{+0.52}_{-0.38}$	$0.47^{+0.48}_{-0.36}$	$0.24^{+0.44}_{-0.20}$
(2011)	Exp. peak. bkg	$0.13^{+0.07}_{-0.05}$	$0.07^{+0.02}_{-0.02}$	$0.05^{+0.02}_{-0.02}$	$0.05^{+0.02}_{-0.01}$	$0.05^{+0.02}_{-0.01}$	$0.05^{+0.02}_{-0.01}$	$0.05^{+0.02}_{-0.01}$	$0.05^{+0.02}_{-0.01}$
	Exp. signal	$2.70^{+0.81}_{-0.80}$	$1.30^{+0.27}_{-0.23}$	$1.03^{+0.20}_{-0.17}$	$0.92^{+0.15}_{-0.13}$	$1.06^{+0.17}_{-0.15}$	$1.10^{+0.17}_{-0.15}$	$1.26^{+0.20}_{-0.17}$	$1.31^{+0.28}_{-0.25}$
	Observed	1818	39	12	6	1	2	1	1
$B^0 \to \mu^+\mu^-$	Exp. comb. bkg	1995^{+34}_{-34}	$59.2^{+3.3}_{-3.2}$	$12.6^{+1.6}_{-1.5}$	$4.44^{+0.99}_{-0.86}$	$1.67^{+0.66}_{-0.54}$	$0.75^{+0.58}_{-0.40}$	$0.44^{+0.57}_{-0.38}$	$0.22^{+0.48}_{-0.20}$
(2011)	Exp. peak. bkg	$0.78^{+0.38}_{-0.29}$	$0.40^{+0.14}_{-0.10}$	$0.31^{+0.11}_{-0.08}$	$0.28^{+0.09}_{-0.07}$	$0.31^{+0.10}_{-0.08}$	$0.30^{+0.10}_{-0.07}$	$0.31^{+0.10}_{-0.08}$	$0.30^{+0.11}_{-0.08}$
	Exp. cross-feed	$0.43^{+0.13}_{-0.13}$	$0.21^{+0.04}_{-0.04}$	$0.16^{+0.03}_{-0.03}$	$0.15^{+0.03}_{-0.02}$	$0.17^{+0.03}_{-0.03}$	$0.17^{+0.03}_{-0.02}$	$0.20^{+0.03}_{-0.03}$	$0.21^{+0.05}_{-0.04}$
	Exp. signal	$0.33^{+0.10}_{-0.10}$	$0.16^{+0.03}_{-0.03}$	$0.13^{+0.02}_{-0.02}$	$0.11^{+0.02}_{-0.02}$	$0.13^{+0.02}_{-0.02}$	$0.13^{+0.02}_{-0.02}$	$0.15^{+0.02}_{-0.02}$	$0.16^{+0.03}_{-0.03}$
	Observed	1904	50	20	5	2	1	4	1

8 TeV data

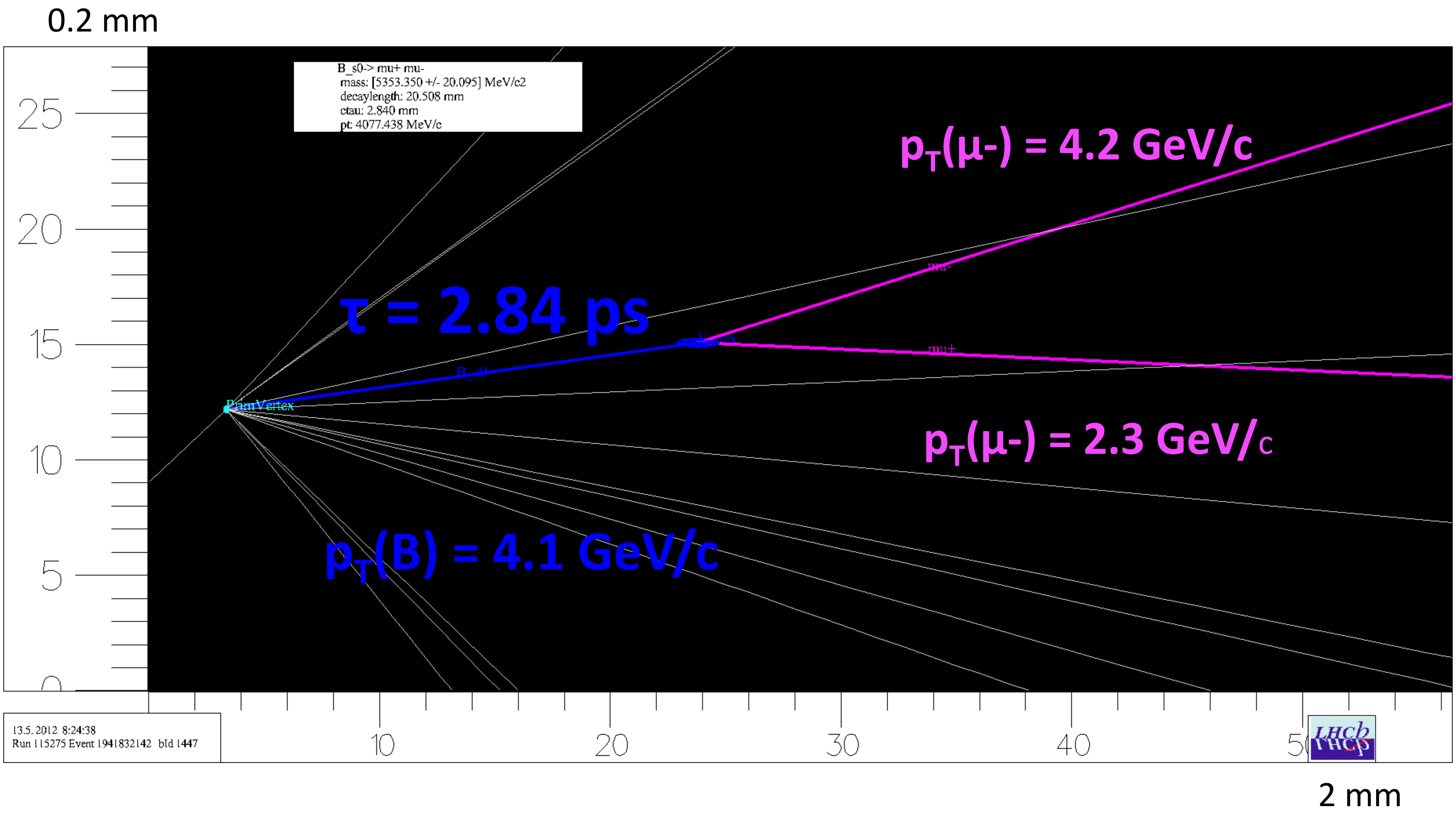
Mode	BDT bin	0.0 – 0.25	0.25 – 0.4	0.4 – 0.5	0.5 – 0.6	0.6 – 0.7	0.7 – 0.8	0.8–1.0
$B_s^0 \to \mu^+\mu^-$	Exp. comb. bkg	2345^{+40}_{-40}	$56.7^{+3.0}_{-2.9}$	$13.1^{+1.5}_{-1.4}$	$4.42^{+0.91}_{-0.81}$	$2.10^{+0.67}_{-0.56}$	$0.35^{+0.42}_{-0.22}$	$0.39^{+0.33}_{-0.21}$
(2012)	Exp. peak. bkg	$0.250^{+0.08}_{-0.07}$	$0.15^{+0.05}_{-0.04}$	$0.08^{+0.03}_{-0.02}$	$0.08^{+0.02}_{-0.02}$	$0.07^{+0.02}_{-0.02}$	$0.06^{+0.02}_{-0.02}$	$0.10^{+0.03}_{-0.03}$
	Exp. signal	$3.69^{+0.59}_{-0.52}$	$2.14^{+0.37}_{-0.33}$	$1.20^{+0.21}_{-0.18}$	$1.16^{+0.18}_{-0.16}$	$1.17^{+0.18}_{-0.16}$	$1.15^{+0.19}_{-0.17}$	$2.13^{+0.33}_{-0.29}$
	Observed	2274	65	19	5	3	1	3
$B^0 \to \mu^+\mu^-$	Exp. comb. bkg	2491^{+42}_{-42}	$59.5^{+3.3}_{-3.2}$	$13.9^{+1.6}_{-1.5}$	$4.74^{+1.00}_{-0.89}$	$2.10^{+0.74}_{-0.61}$	$0.55^{+0.50}_{-0.31}$	$0.29^{+0.34}_{-0.19}$
(2012)	Exp. peak. bkg	$1.49^{+0.50}_{-0.36}$	$0.86^{+0.29}_{-0.22}$	$0.48^{+0.16}_{-0.12}$	$0.44^{+0.15}_{-0.11}$	$0.42^{+0.14}_{-0.10}$	$0.37^{+0.13}_{-0.09}$	$0.62^{+0.21}_{-0.15}$
	Exp. cross-feed	$0.63^{+0.10}_{-0.09}$	$0.36^{+0.07}_{-0.06}$	$0.20^{+0.04}_{-0.03}$	$0.20^{+0.03}_{-0.03}$	$0.20^{+0.03}_{-0.03}$	$0.20^{+0.03}_{-0.03}$	$0.36^{+0.06}_{-0.05}$
	Exp. signal	$0.44^{+0.06}_{-0.06}$	$0.26^{+0.04}_{-0.04}$	$0.14^{+0.02}_{-0.02}$	$0.14^{+0.02}_{-0.02}$	$0.14^{+0.02}_{-0.02}$	$0.14^{+0.02}_{-0.02}$	$0.26^{+0.04}_{-0.03}$
	Observed	2433	59	19	3	2	2	2

$B_{s,d} \rightarrow \mu\mu$ candidate



$M(\mu\mu) = 5353.4$ MeV/c^2, BDT = 0.826, τ=2.84 ps

$B_{s,d} \rightarrow \mu\mu$ candidate: zoom

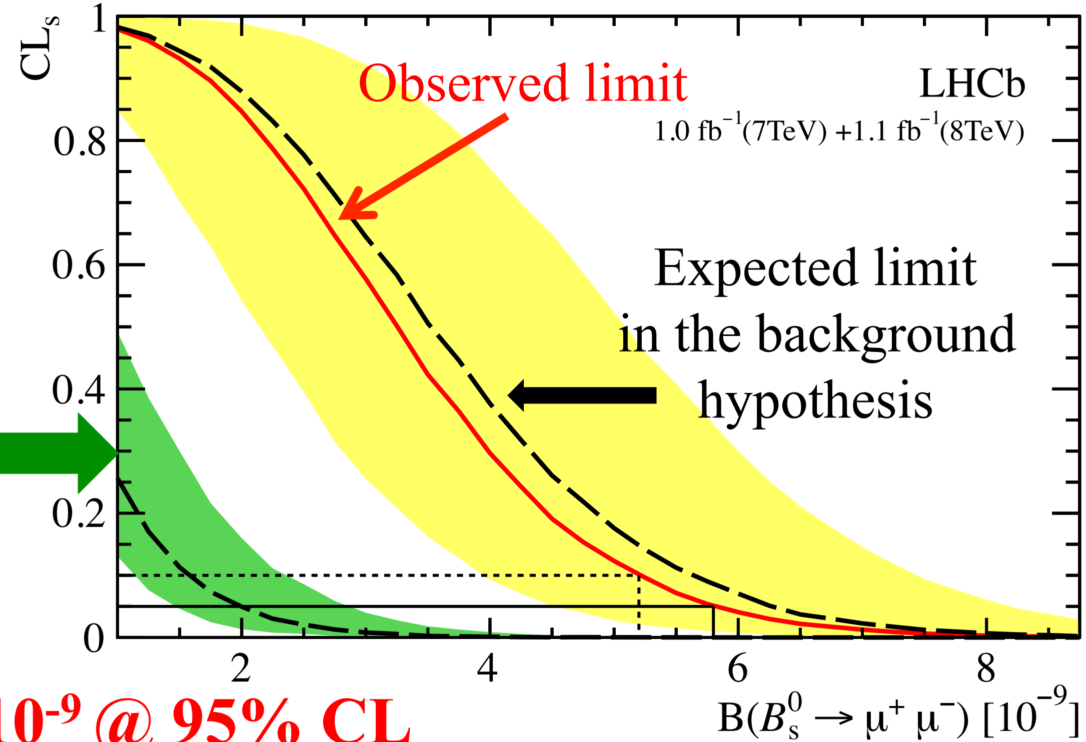


$B_s \rightarrow \mu\mu$: sensitivity

7 TeV (1 fb^{-1}) + 8 TeV (1.1 fb^{-1}):

bkg-only p-value: 5.3×10^{-4}
(3.5 σ signal significance)

Expected limit
in the background
hypothesis



Double sided limit:

$1.1 \times 10^{-9} < BR(B_s \rightarrow \mu\mu) < 6.4\ 10^{-9}$ @ 95% CL

Where the lower and upper limits are evaluated
at CLs+b=0.975 and CLs+b=0.025, respectively

$B_s \to \mu\mu$ branching fraction

- Unbinned maximum likelihood fit to the mass spectra:

  - 8 BDT bins of 7 TeV and 7 BDT bins at 8 TeV are treated simultaneously
  - fit mass range [4900-6000] MeV/c

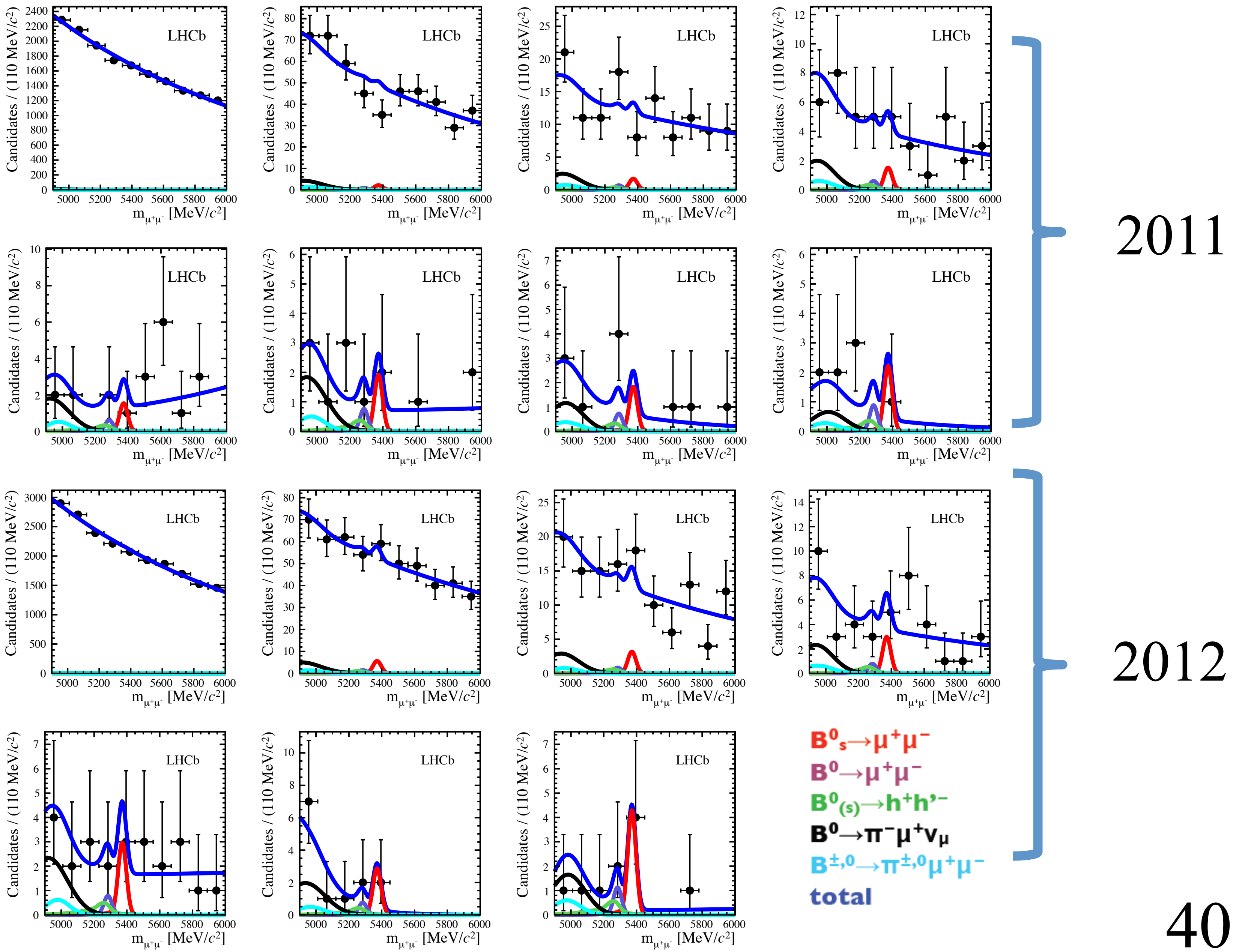
- Free parameters: BR($B_s \to \mu\mu$), BR($B_s \to \mu\mu$) and combinatorial background

- The signal yield in each BDT bin is constrained to the expectation from $B \to hh'$ calibration

- The yields and BDT and mass shapes for all the relevant exclusive background are constrained to their expectations obtained with simulated events reweighted for the misidentification probability obtained with data

- Additional systematic studies on background composition/ parameterization:
  - Add the $Bs \to K \mu \nu$ component to the exclusive background
  - Change the combinatorial pdf from single to double exponential, to account for
  - Possible residual contributions from Λb and Bc decays

Fit slices: 8 BDT bins for 2012 and 7 BDT bins for 2011



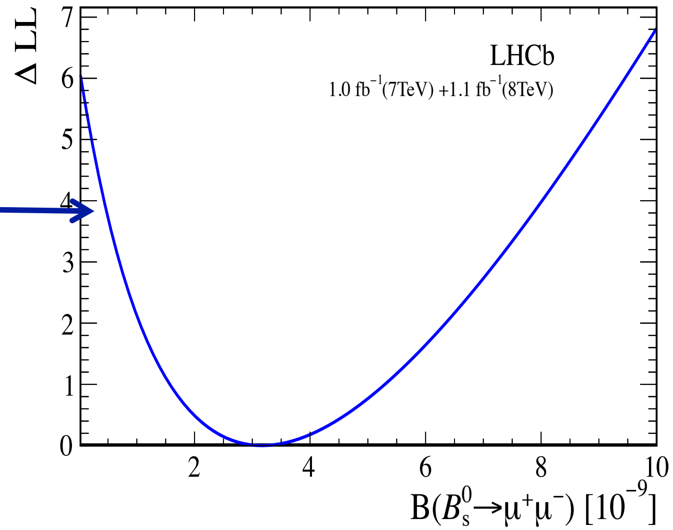
Combined dataset: BR($B_s \to \mu\mu$)

7 TeV (1 fb^{-1}) + 8 TeV (1.1 fb^{-1}):

$$BR(B_s \to \mu\mu) = (3.2\ ^{+1.5}_{-1.2}) \times 10^{-9}$$

SM expectation: (3.54±0.30) x 10^{-9}

Profile likelihood with nuisance parameters floated within their errors



Systematics from nuisance parameters and background modes:

$$BR(B_s \to \mu\mu) = 3.2\ ^{+1.4}_{-1.2}\,(stat)\ ^{+0.5}_{-0.2}\,(syst) \times 10^{-9}$$

Fully dominated by statistical error

BR($B_s \rightarrow \mu\mu$): 7 TeV vs 8 TeV results

- 7 TeV (1.0 fb^{-1}):

  BR($B_s \rightarrow \mu\mu$) = $(1.4^{+1.7}_{-1.3}) \times 10^{-9}$

  p-value: 0.11

- 8 TeV (1.1 fb^{-1}):

  BR($B_s \rightarrow \mu\mu$) = $(5.1^{+2.4}_{-1.9}) \times 10^{-9}$

- Results from 7 TeV and 8 TeV are compatible within 1.5 σ

$B^0 \to \mu\mu$: upper limit

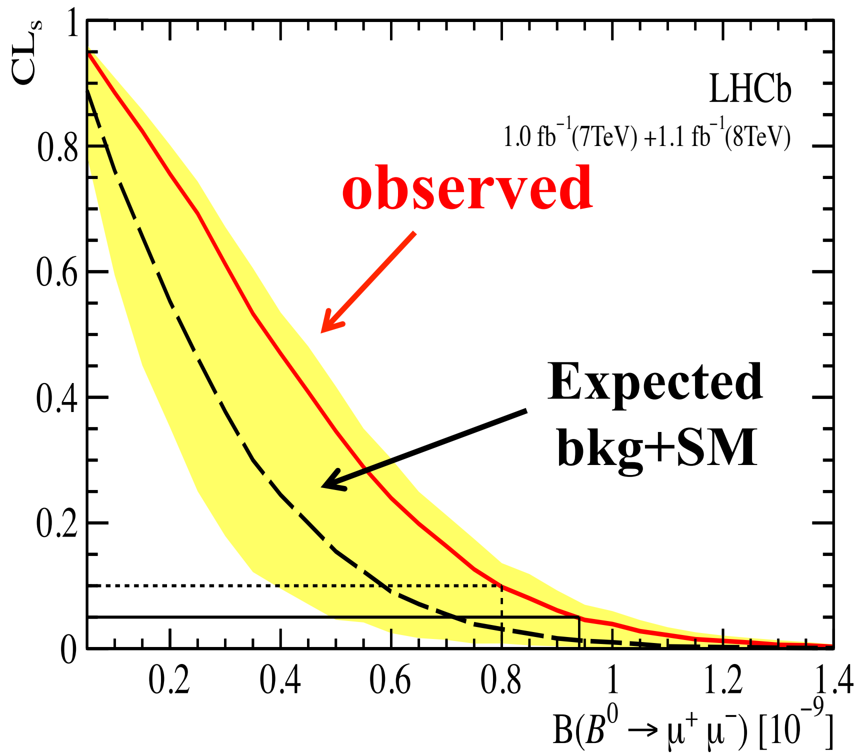
Use CLs method to evaluate the compatibility with background-only (CL_b) and Signal+background hypothesis (CLs+b): the 95% CL upper limit is defined at $CLs = CL_{s+b}/CL_b = 0.05$

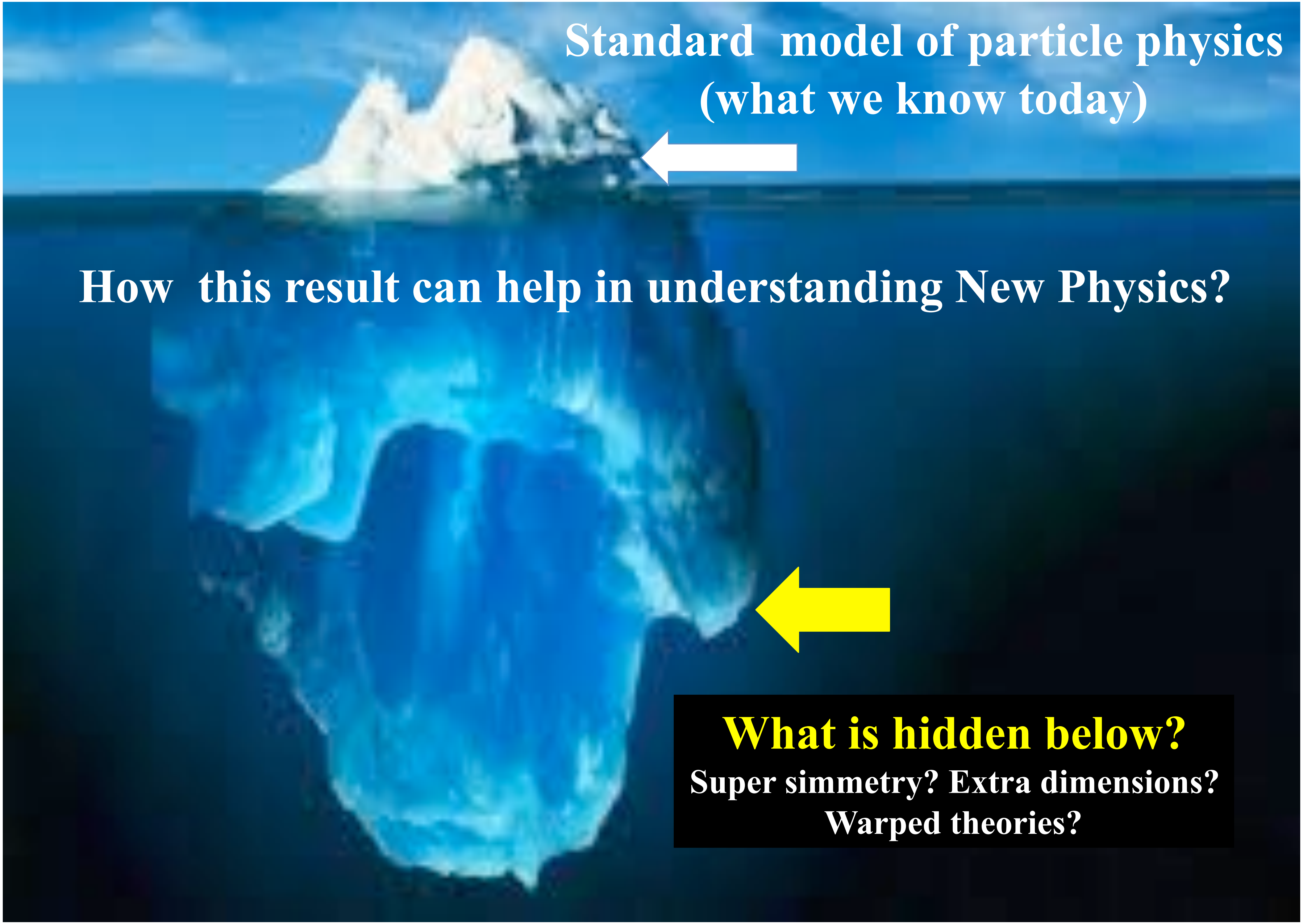
7 TeV (1 fb^{-1}) + 8 TeV (1.1 fb^{-1})

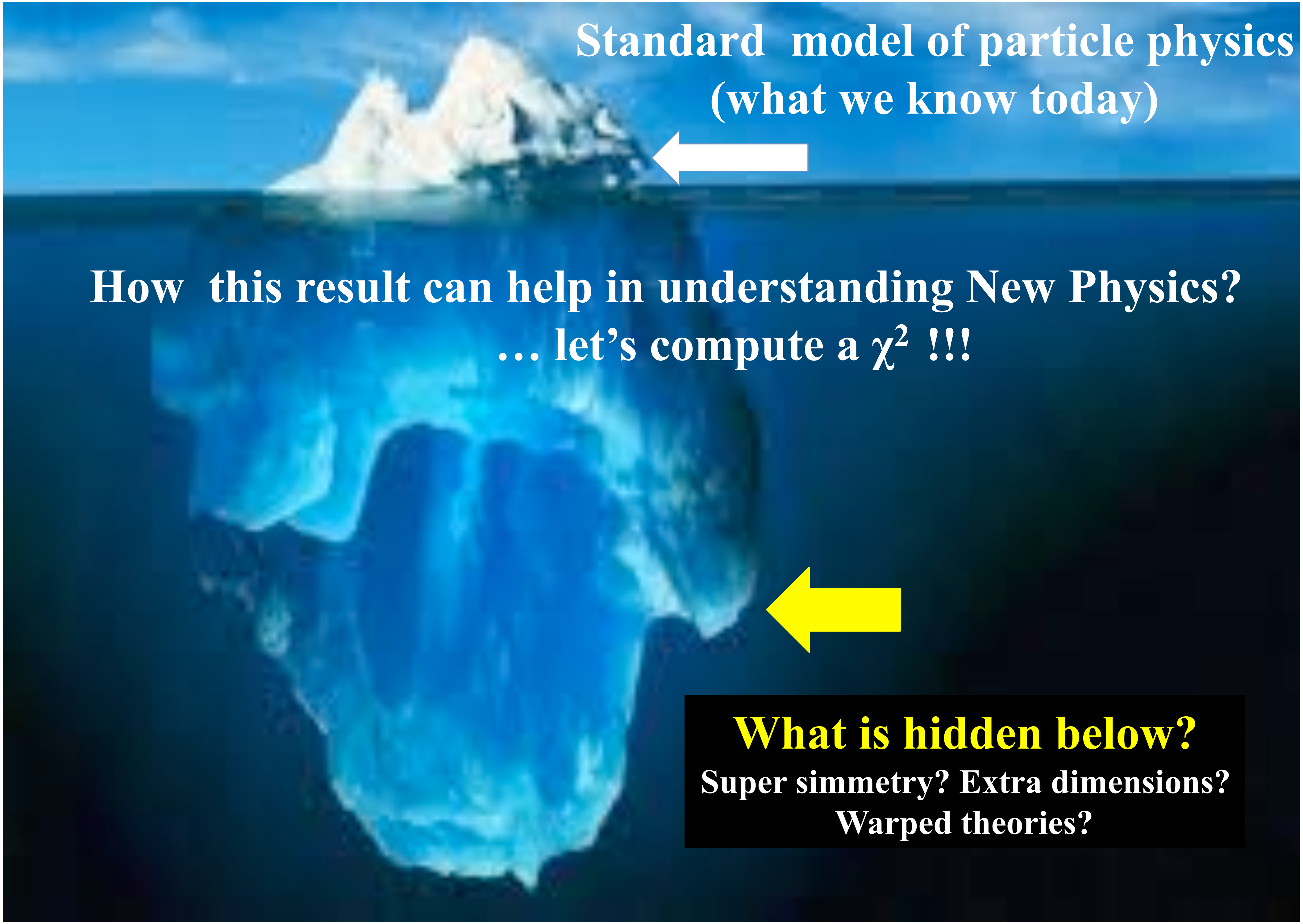
observed upper limit:
$BR(B_d \to \mu\mu) < 9.4 \times 10^{-10}$ at 95%CL

Expected limit:
$BR(B_d \to \mu\mu) < 7.1 \times 10^{-10}$ at 95% CL

Compatibility with the background hypothesis: p-value = $1-CL_b$ = 11%




Standard model of particle physics
(what we know today)
How this result can help in understanding New Physics?
What is hidden below?
Super simmetry? Extra dimensions?
Warped theories?


Standard model of particle physics
(what we know today)
How this result can help in understanding New Physics?
… let's compute a χ^2 !!!
What is hidden below?
Super simmetry? Extra dimensions?
Warped theories?

BR($B_s \rightarrow \mu\mu$) and Global Fits

An example: MasterCode (J. Ellis et al.) (http://www.cern.ch//mastercode)
Goal: perform global fits to measured quantities (including direct searches) and build a χ^2. compare with prediction from a given model (CMSSM, NUMH1, mSugra, etc.)

$$\chi^2 = \sum_i^N \frac{(C_i - P_i)^2}{\sigma(C_i)^2 + \sigma(P_i)^2} + \sum_i^M \frac{\left(f^{\rm obs}_{{\rm SM}_i} - f^{\rm fit}_{{\rm SM}_i}\right)^2}{\sigma(f_{{\rm SM}_i})^2}$$
$$+ \chi^2(b \rightarrow s\gamma) + \chi^2(g_\mu - 2) + \chi^2(\Omega h^2) + \chi^2(m_h)$$
$$+ \chi^2(\,{\rm BR}(B_s \rightarrow \mu\mu)\,) + \chi^2({\rm LHC}) + \chi^2({\rm XENON100})$$

Recent Experimental Data!

N: number of observables studied

M: SM parameters: $\Delta\alpha_{\rm had}, m_t, M_Z$

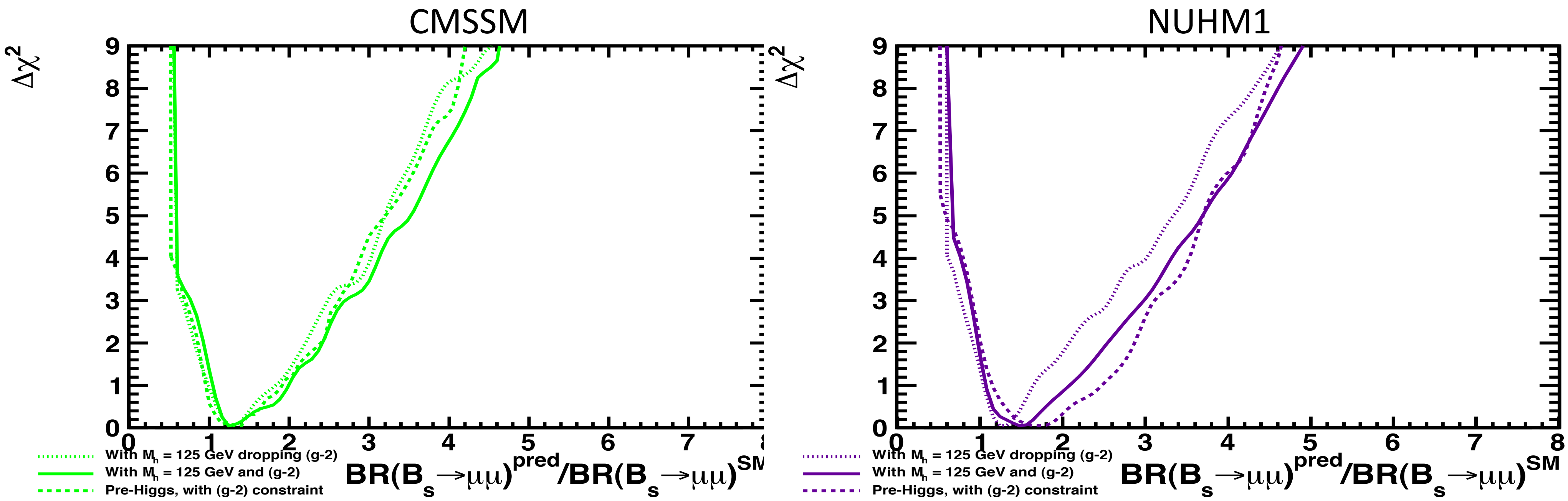
C_i: experimentally measured value (constraint)

P_i: MSSM parameter-dependent prediction for the corresponding constraint

Impact of $B_s \rightarrow \mu^+\mu^-$ on global SUSY fits

- Global fit include many results:
  - Higgs and SUSY searches at LHC, dark matter searches at XENON100, EW and B physics measurements (such as $b \rightarrow s\gamma$, $B^+ \rightarrow \tau\nu$, $B_s \rightarrow \mu\mu$), g–2
- Two variants of the MSSM:
  - $\Delta\chi^2$ profiles for $B_s \rightarrow \mu\mu$ (state as of December 2011)

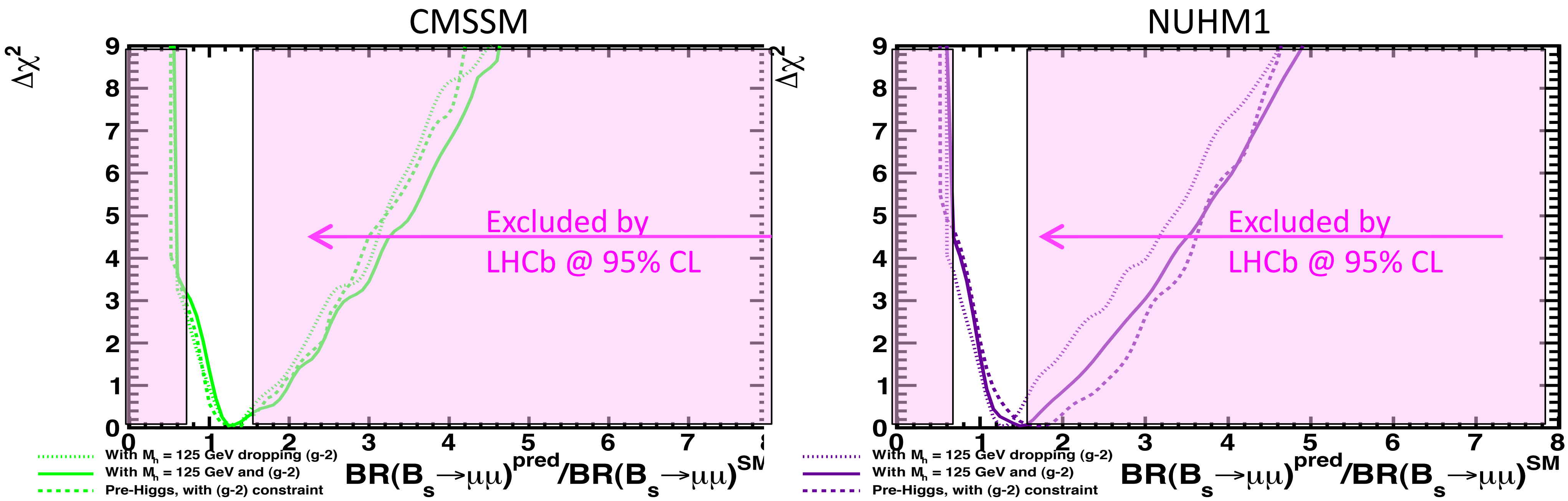
O. Buchmueller et al.
arXiv:1112.3564



Impact of $B_s \to \mu^+\mu^-$ on global SUSY fits

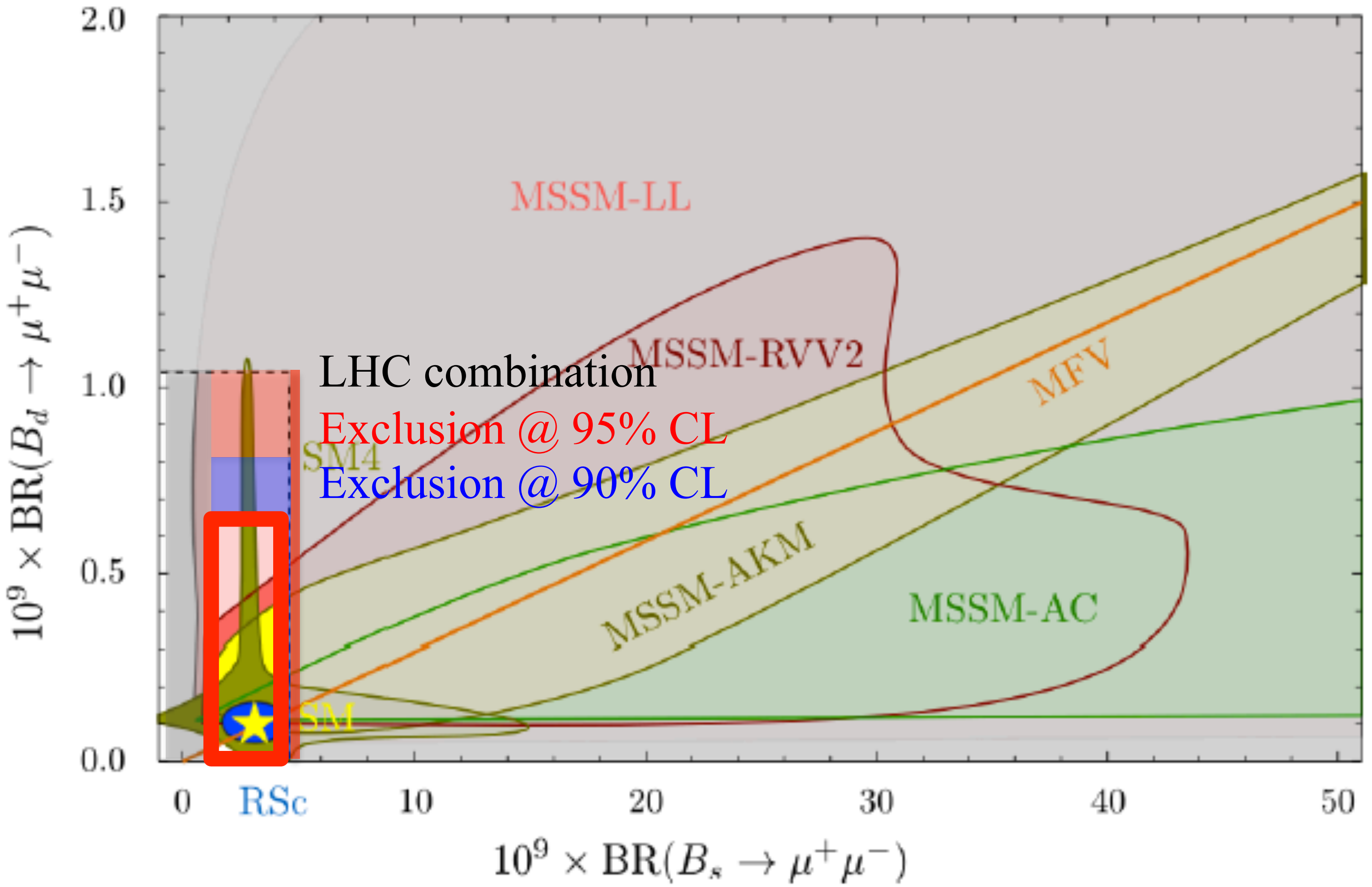
- Global fit include many results:
  - Higgs and SUSY searches at LHC, dark matter searches at XENON100, EW and B physics measurements (such as $b \to s\gamma$, $B^+ \to \tau\nu$, $B_s \to \mu\mu$), g–2
- Two variants of the MSSM:
  - $\Delta\chi^2$ profiles for $B_s \to \mu\mu$ (state as of December 2011)

O. Buchmueller et al.
arXiv:1112.3564



NP in $B_s \to \mu^+\mu^-$: model dependent view

D. Straub, arXiv 1205.6094



Correlation between BR($B_s \to \mu\mu$) and BR($B_d \to \mu\mu$) in MFV, SM4 and 4 SUSY models
gray area + red area is ruled out experimentally at 95% CL, blue area at 90%


CERN seminar, November 13th, 11 am…

…few hours later the blogs!

NewScientist **Physics & Math**

search New Scientist | Go » | Log in | My New Scientist

Home | News | In-Depth Articles | Blogs | Opinion | TV | Galleries | Topic Guides | Last Word | Subscribe | Dating | Look for Science Jobs

SPACE | TECH | ENVIRONMENT | HEALTH | LIFE | PHYSICS&MATH | SCIENCE IN SOCIETY | Cookies & Privacy

Home | Physics & Math | News

Rare particle's decay confounds hunt for new physics

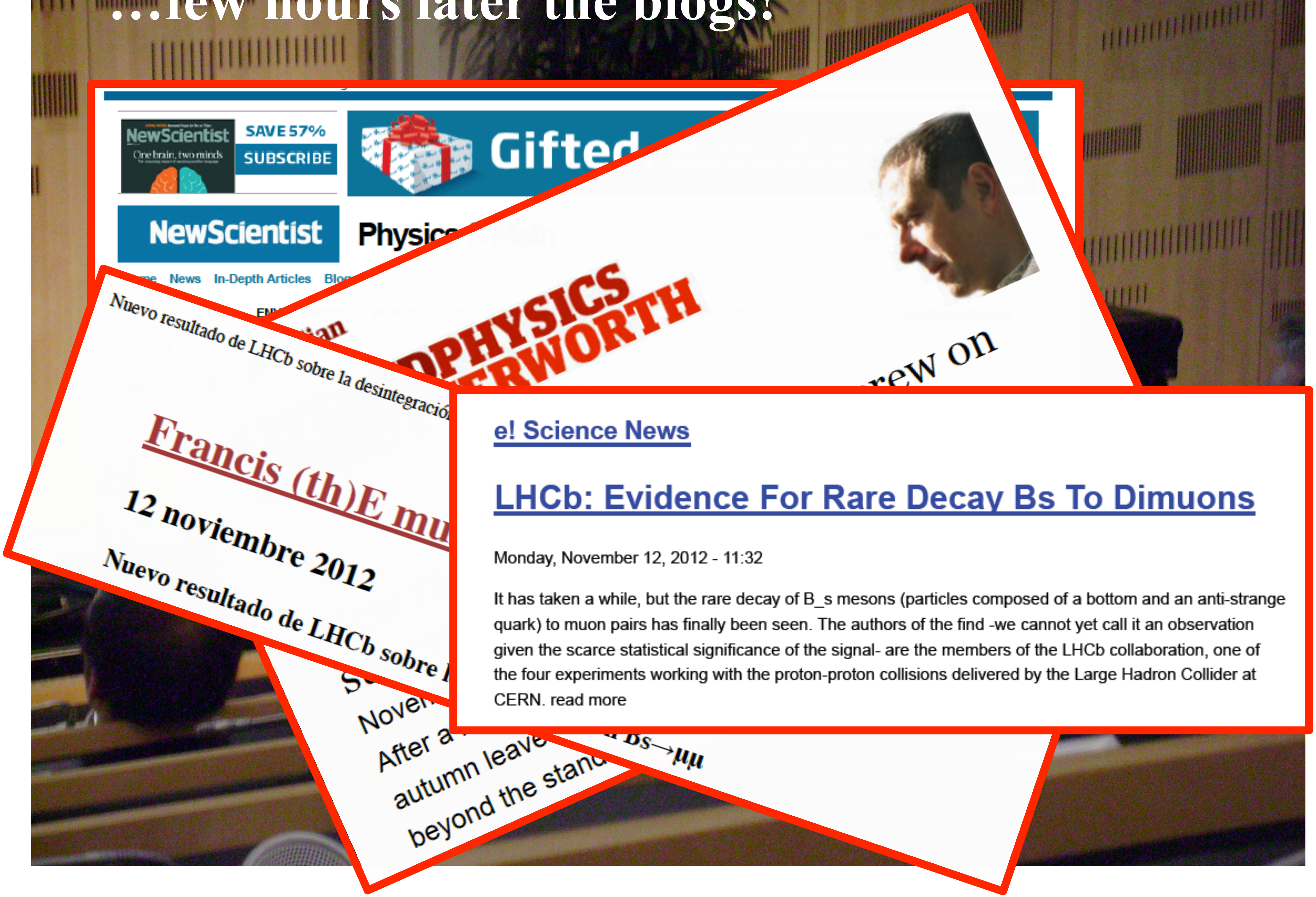
16:58 12 November 2012 by Jacob Aron

For similar stories, visit the The Large Hadron Collider Topic Guide

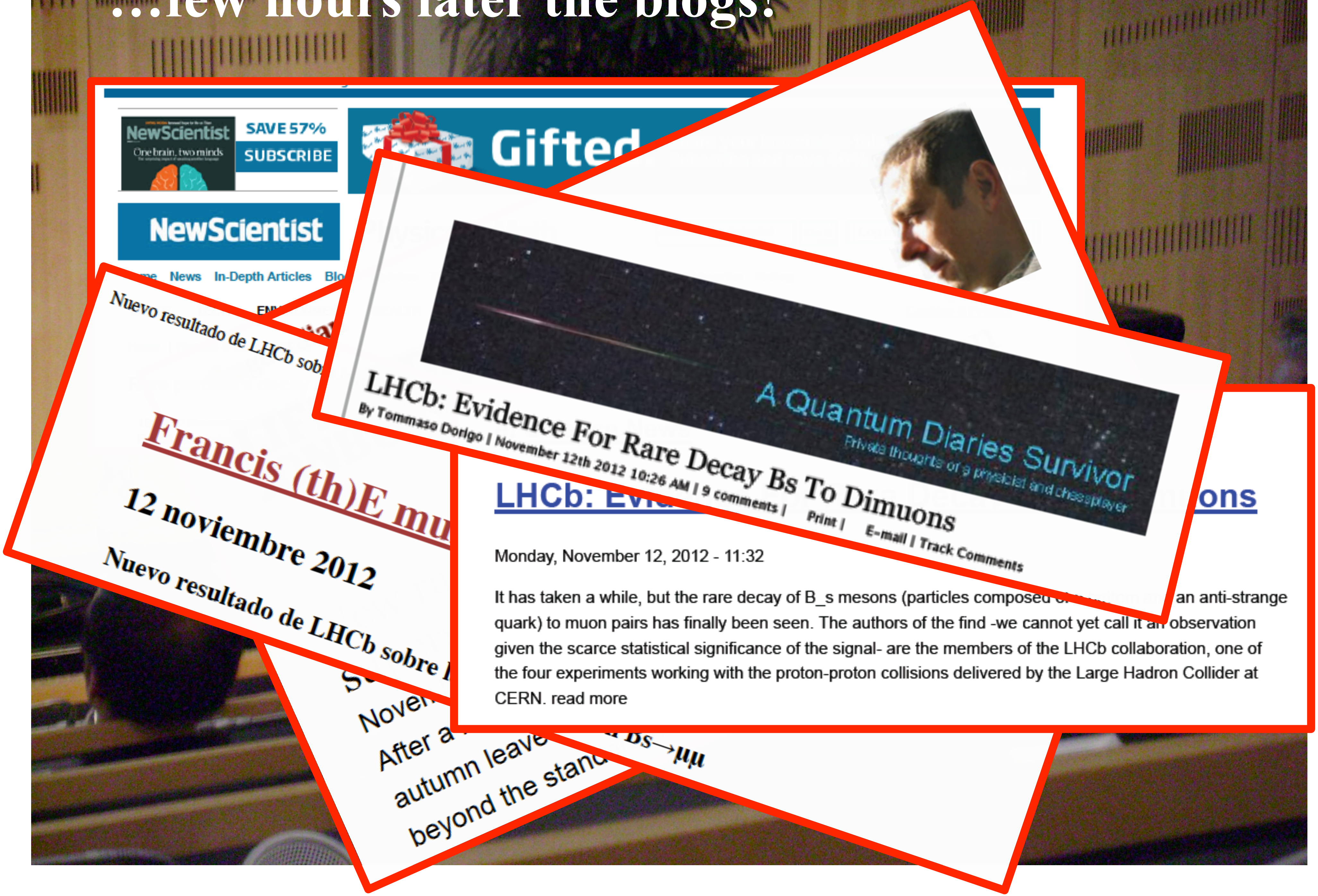
…few hours later the blogs!

…few hours later the blogs!

...few hours later the blogs!

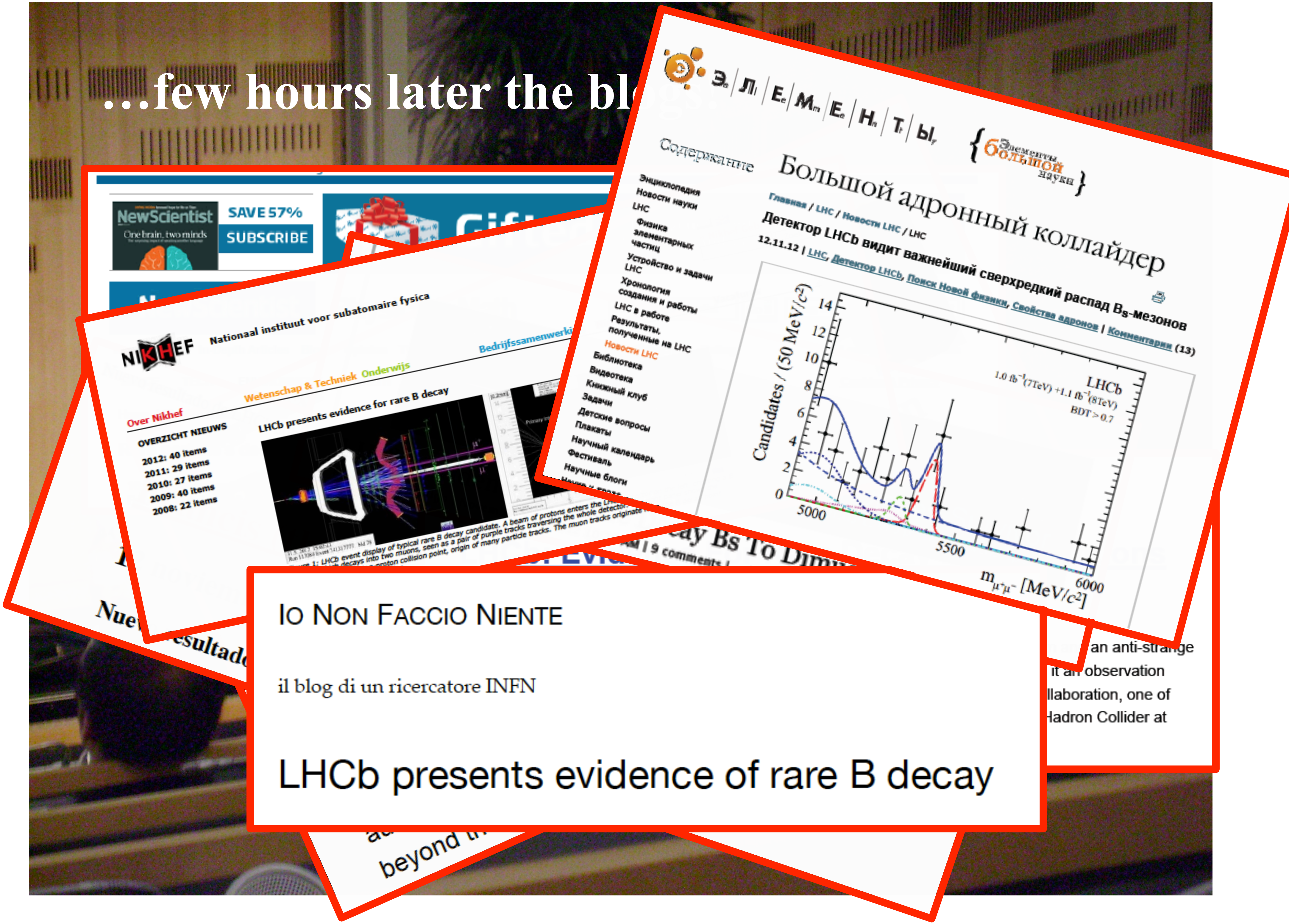


...few hours later the blogs!



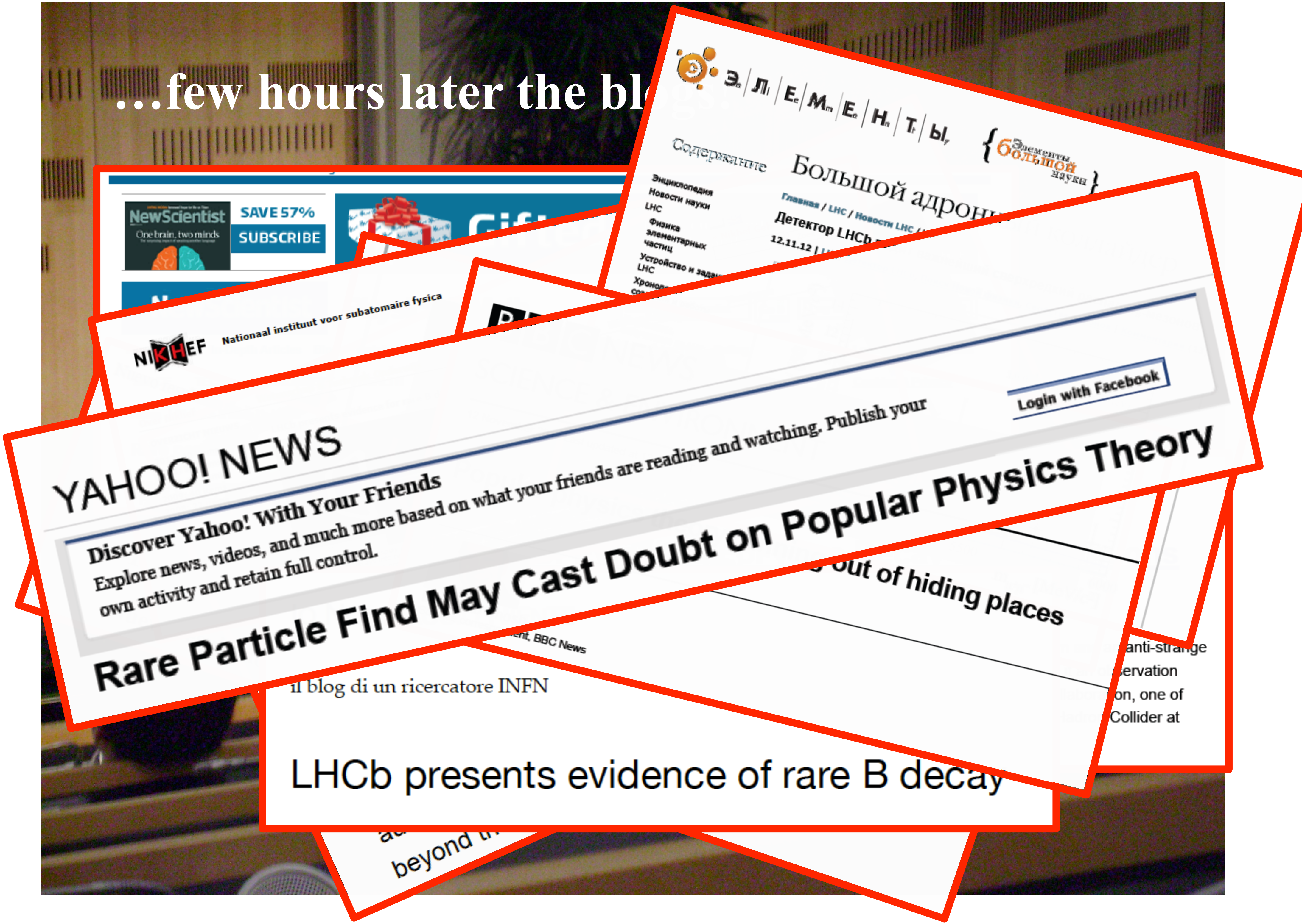
…few hours later the blogs!

…few hours later the blogs!


…few hours later the bl
NewScientist
SAVE 57%
SUBSCRIBE
One brain, two minds
NIKHEF
Nationaal instituut voor subatomaire fysica
Bedrijfssamenwerki
Wetenschap & Techniek
Onderwijs
Over Nikhef
OVERZICHT NIEUWS
2012: 40 items
2011: 29 items
2010: 27 items
2009: 40 items
2008: 22 items
LHCb presents evidence for rare B decay
Элементы
Элементы большой науки
Содержание
Энциклопедия
Новости науки
LHC
Физика элементарных частиц
Устройство и задачи LHC
Хронология создания и работы
LHC в работе
Результаты, полученные на LHC
Новости LHC
Библиотека
Видеотека
Книжный клуб
Задачи
Детские вопросы
Плакаты
Научный календарь
Фестиваль
Научные блоги
Большой адронный коллайдер
Главная / LHC / Новости LHC / LHC
Детектор LHCb видит важнейший сверхредкий распад Bs-мезонов
12.11.12 | LHC, Детектор LHCb, Поиск Новой физики, Свойства адронов | Комментарии (13)
Candidates / (50 MeV/c²)
LHCb
BDT > 0.7
5000
5500
6000
m_{μ+μ-} [MeV/c²]
ay Bs To Dim
9 comments
Nue
esultad
an anti-strange
it an observation
llaboration, one of
Hadron Collider at
beyond
Io Non Faccio Niente
il blog di un ricercatore INFN
LHCb presents evidence of rare B decay

…few hours later the bl

…few hours later the bl



Conclusions -1/2

- LHCb has presented an updated search for $B_s \to \mu\mu$ combining 7 TeV (1.0 fb^{-1}) and 8 TeV (1.1 fb^{-1}) data
- The data in the B^0 signal region are consistent with background expectation and we put the world's best upper limit: **$BR(B^0 \to \mu\mu) < 9.4 \times 10^{-10}$ @ 95% CL.**
- We see an excess of $B_s \to \mu\mu$ signal above background expectation with p-value of **5.3×10^{-4}** corresponding to **3.5σ** signal significance and a branching fraction:

$$\mathbf{BR(B_s \to \mu\mu) = 3.2\,^{+1.5}_{-1.2} \times 10^{-9}}$$

- **This is the first evidence for the decay $B_s \to \mu\mu$**

Conclusions -2/2

- But this is not the end!
  - CMS is expected to present a new (and very competitive!) result very soon
  - ATLAS will follow
  - LHCb, CMS and ATLAS will combine the results and possibly

reach a 5 σ observation in a few months..

… and then we continue with the $B^0 \to \mu\mu$!

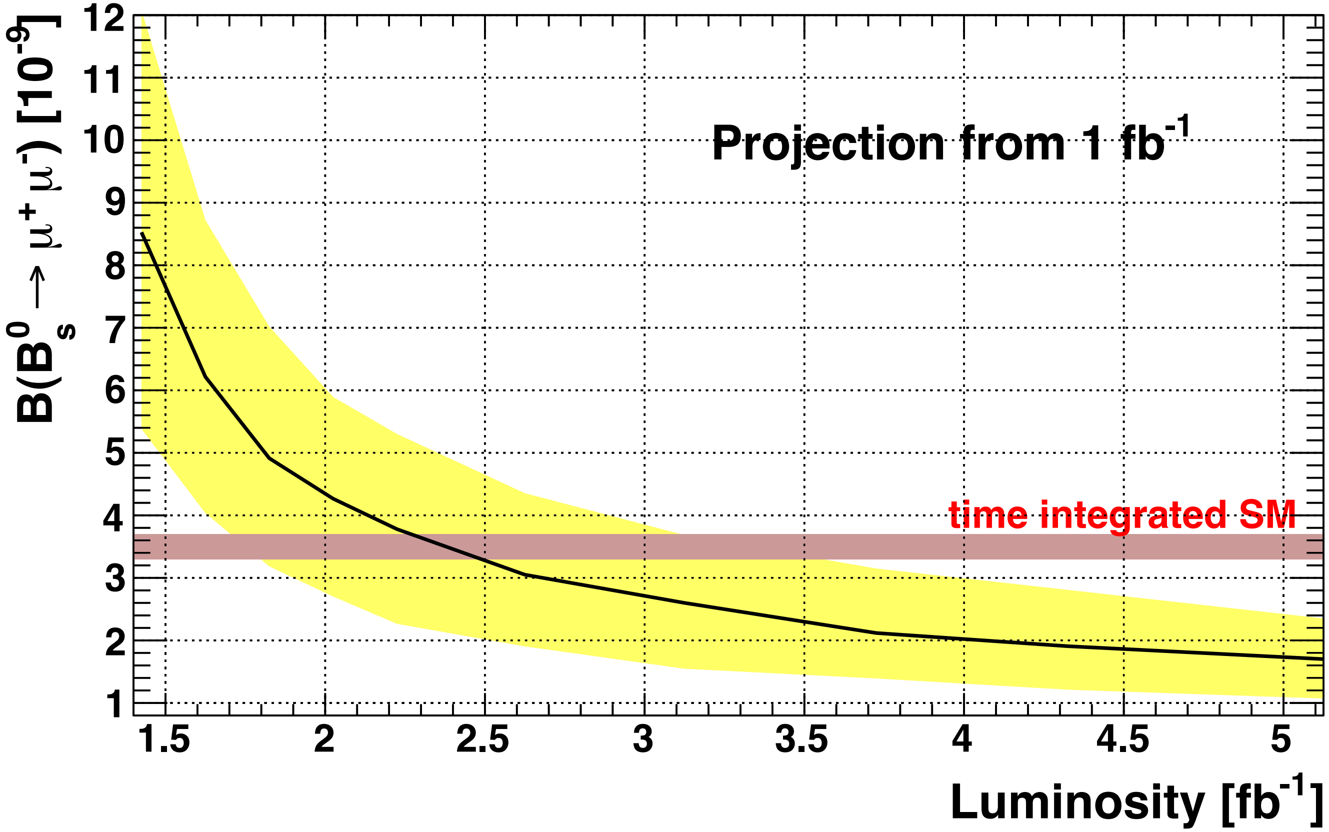
... to be continued.....

Thanks for your attention

The LHCb $B_s \to \mu\mu$ group, 2012

Spares

LHCb projection from 2011 data



30% probability to have a 3 sigma signal significance with 1 fb-1 (2011) + 1 fb-1 (2012)

The models: 1.) CMSSM (or mSUGRA):

⇒ Scenario characterized by

$$m_0,\ m_{1/2},\ A_0,\ \tan\beta,\ \mathrm{sign}\,\mu$$

$$\left.\begin{array}{l} m_0 : \text{universal scalar mass parameter} \\ m_{1/2} : \text{universal gaugino mass parameter} \\ A_0 : \text{universal trilinear coupling} \end{array}\right\}\ \text{at the GUT scale}$$

$\tan\beta$: ratio of Higgs vacuum expectation values

$\mathrm{sign}(\mu)$: sign of supersymmetric Higgs parameter

⇒ particle spectra from renormalization group running to weak scale

The models: 2.) NUHM1: (Non-universal Higgs mass model)

Assumption: no unification of scalar fermion and scalar Higgs parameter at the GUT scale

⇒ effectively M_A or μ as free parameters at the EW scale

⇒ besides the CMSSM parameters

M_A or μ

Further extension: NUHM2:

Assumption: no unification of the Higgs parameters at the GUT scale

⇒ effectively M_A and μ as free parameters at the EW scale

⇒ besides the CMSSM parameters

M_A and μ

Global fits: input data

EW observables
(largest inpact M_W, $A^e_{LR,}$ A^b_{FB})

Flavour physics observables
(largest inpact b→ s γ, Bs→μμ)

$(g\text{-}2)_\mu$
Higgs Mass
Cold Dark matter density
LHC direct searches

Observable	Source Th./Ex.	Constraint
m_t [GeV]	[39]	173.2 ± 0.90
$\Delta\alpha^{(5)}_{\rm had}(m_Z)$	[38]	0.02749 ± 0.00010
M_Z [GeV]	[40]	91.1875 ± 0.0021
Γ_Z [GeV]	[24] / [40]	$2.4952 \pm 0.0023 \pm 0.001_{\rm SUSY}$
$\sigma^0_{\rm had}$ [nb]	[24] / [40]	41.540 ± 0.037
R_l	[24] / [40]	20.767 ± 0.025
$A_{\rm fb}(\ell)$	[24] / [40]	0.01714 ± 0.00095
$A_\ell(P_\tau)$	[24] / [40]	0.1465 ± 0.0032
R_b	[24] / [40]	0.21629 ± 0.00066
R_c	[24] / [40]	0.1721 ± 0.0030
$A_{\rm fb}(b)$	[24] / [40]	0.0992 ± 0.0016
$A_{\rm fb}(c)$	[24] / [40]	0.0707 ± 0.0035
A_b	[24] / [40]	0.923 ± 0.020
A_c	[24] / [40]	0.670 ± 0.027
$A_\ell({\rm SLD})$	[24] / [40]	0.1513 ± 0.0021
$\sin^2\theta^\ell_{\rm w}(Q_{\rm fb})$	[24] / [40]	0.2324 ± 0.0012
M_W [GeV]	[24] / [40]	$80.399 \pm 0.023 \pm 0.010_{\rm SUSY}$
${\rm BR}^{\rm EXP}_{b\to s\gamma}/{\rm BR}^{\rm SM}_{b\to s\gamma}$	[41] / [42]	$1.117 \pm 0.076_{\rm EXP}$ $\pm 0.082_{\rm SM} \pm 0.050_{\rm SUSY}$
${\rm BR}(B_s \to \mu^+\mu^-)$	[27] / [37]	$(< 1.08 \pm 0.02_{\rm SUSY}) \times 10^{-8}$
${\rm BR}^{\rm EXP}_{B\to\tau\nu}/{\rm BR}^{\rm SM}_{B\to\tau\nu}$	[27] / [42]	$1.43 \pm 0.43_{\rm EXP+TH}$
${\rm BR}(B_d \to \mu^+\mu^-)$	[27] / [42]	$< (4.6 \pm 0.01_{\rm SUSY}) \times 10^{-9}$
${\rm BR}^{\rm EXP}_{B\to X_s\ell\ell}/{\rm BR}^{\rm SM}_{B\to X_s\ell\ell}$	[43]/ [42]	0.99 ± 0.32
${\rm BR}^{\rm EXP}_{K\to\mu\nu}/{\rm BR}^{\rm SM}_{K\to\mu\nu}$	[27] / [44]	$1.008 \pm 0.014_{\rm EXP+TH}$
${\rm BR}^{\rm EXP}_{K\to\pi\nu\bar\nu}/{\rm BR}^{\rm SM}_{K\to\pi\nu\bar\nu}$	[45]/ [46]	< 4.5
$\Delta M^{\rm EXP}_{B_s}/\Delta M^{\rm SM}_{B_s}$	[45] / [47, 48]	$0.97 \pm 0.01_{\rm EXP} \pm 0.27_{\rm SM}$
$\frac{(\Delta M^{\rm EXP}_{B_s}/\Delta M^{\rm SM}_{B_s})}{(\Delta M^{\rm EXP}_{B_d}/\Delta M^{\rm SM}_{B_d})}$	[27] / [42, 47, 48]	$1.00 \pm 0.01_{\rm EXP} \pm 0.13_{\rm SM}$
$\Delta\epsilon^{\rm EXP}_K/\Delta\epsilon^{\rm SM}_K$	[45] / [47, 48]	$1.08 \pm 0.14_{\rm EXP+TH}$
$a^{\rm EXP}_\mu - a^{\rm SM}_\mu$	[49] / [38, 50]	$(30.2 \pm 8.8 \pm 2.0_{\rm SUSY}) \times 10^{-10}$
M_h [GeV]	[26] / [51, 52]	$> 114.4 \pm 1.5_{\rm SUSY}$
$\Omega_{\rm CDM}h^2$	[29] / [53]	$0.1109 \pm 0.0056 \pm 0.012_{\rm SUSY}$
$\sigma^{\rm SI}_p$	[23]	$(m_{\tilde\chi^0_1}, \sigma^{\rm SI}_p)$ plane
jets $+ \not{E}_T$	[16, 18]	$(m_0, m_{1/2})$ plane
$H/A, H^\pm$	[19]	$(M_A, \tan\beta)$ plane

Exclusive backgrounds

Measurements:

$\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-) = (2.3 \pm 0.6(\text{stat.}) \pm 0.1(\text{syst.})) \cdot 10^{-8}$; LHCb collab., arXiv:1210.2645

$f_c \cdot \mathcal{B}(B_c^+ \to J/\psi l^+ \nu X) = 5.2^{+2.4}_{-2.1} \cdot 10^{-5}$ CDF collab., PRL 81 (1998) 2432

$B^0 \to \pi\mu\nu_\mu$ and $B^0(s) \to h^+h^-$ Particle Data Group

Theoretical estimates:

$$\frac{\mathcal{B}(B^0 \to \pi^0\mu^+\mu^-)}{\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)} = 0.47^{+0.22}_{-0.18}$$

W.-F. Wang and Z.-J. Xiao,, arXiv:1207.0265

$\mathcal{B}(B^0_s \to K^-\mu^+\nu_\mu) = (1.27 \pm 0.49) \times 10^{-4}$ W.-F. Wang and Z.-J. Xiao,, arXiv:1207.0265

$\mathcal{B}(\Lambda_b^0 \to p\mu^-\nu) = (1.59 \pm 0.84) \cdot 10^{-4}$ A. Datta, arXiv:hep-ph/9504429

I. Bigi et al., JHEP 1109 (2011) 012

Limits and sensitivity

$B^0 \to \mu^+\mu^-$

UL are quoted at 95%CL

	Expected UL (bkg)	Expected UL (SM+bkg)	Observed UL	Observed 1-CLb
7 TeV	9.4×10^{-10} *	10.5×10^{-10}	13.0×10^{-10} *	0,19 *
8 TeV	9.6×10^{-10}	10.5×10^{-10}	12.5×10^{-10}	0,16
7TeV + 8TeV	6.0×10^{-10}	7.1×10^{-10}	9.4×10^{-10}	0,11

*published results:
UL = 10.3×10^{-10}
1-CLb = 0.60

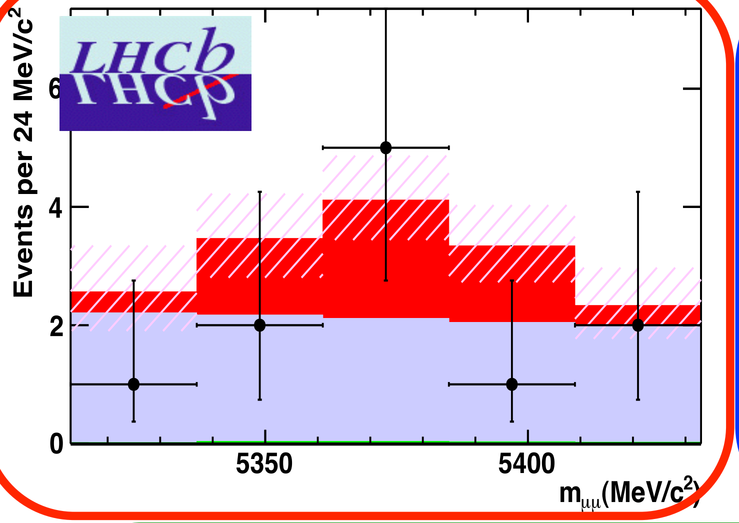
$B^0_s \to \mu^+\mu^-$

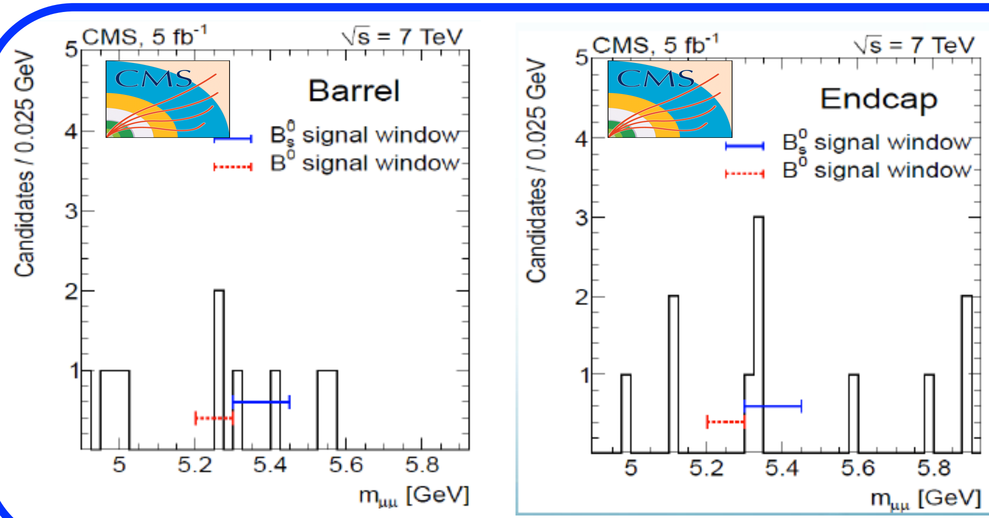
7 TeV
1-CLb = 0.11
UL = 5.1×10^{-9} at 95% CL

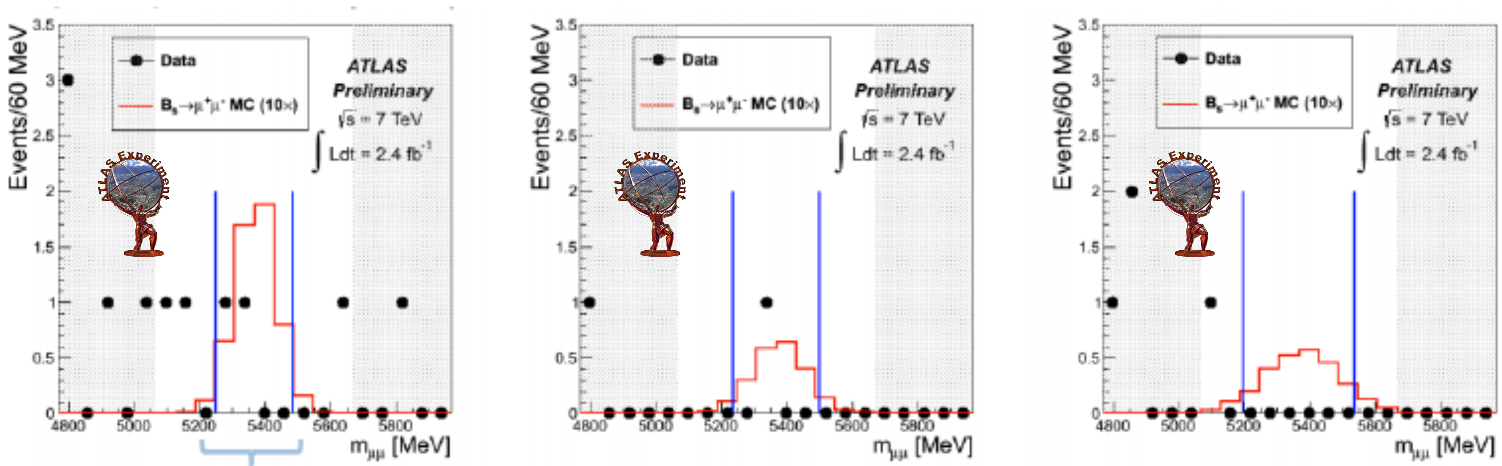
to be compared with published:
1-CLb = 0.18
UL = 4.5×10^{-9} at 95% CL

$B_s \rightarrow \mu\mu$:LHC results on spring 2012

The Bs→μμ signal was slowly emerging from data…

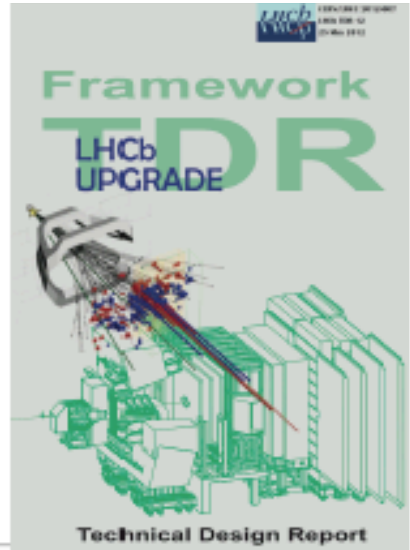






….. But which is the BR? 3 σ observation possible if BR=BR(SM) at the LHC with 2011+2012 data

...tomorrow!



2012: LHCb Upgrade Framework TDR

http://cdsweb.cern.ch/record/1443882/files/LHCB-TDR-012.pdf

- 2018: expect $L_{int} = 5\ fb^{-1}$
- 2028: expect $L_{int} = 50\ fb^{-1}$

Type	Observable	Current precision	LHCb 2018	**Upgrade** ($50\,fb^{-1}$)	Theory uncertainty
B^0_s mixing	$2\beta_s\ (B^0_s \to J/\psi\ \phi)$	0.10 [9]	0.025	0.008	~ 0.003
	$2\beta_s\ (B^0_s \to J/\psi\ f_0(980))$	0.17 [10]	0.045	0.014	~ 0.01
	$A_{fs}(B^0_s)$	6.4×10^{-3} [18]	0.6×10^{-3}	0.2×10^{-3}	0.03×10^{-3}
Gluonic penguin	$2\beta^{eff}_s(B^0_s \to \phi\phi)$	–	0.17	0.03	0.02
	$2\beta^{eff}_s(B^0_s \to K^{*0}\bar{K}^{*0})$	–	0.13	0.02	< 0.02
	$2\beta^{eff}(B^0 \to \phi K^0_S)$	0.17 [18]	0.30	0.05	0.02
Right-handed currents	$2\beta^{eff}_s(B^0_s \to \phi\gamma)$	–	0.09	0.02	< 0.01
	$\tau^{eff}(B^0_s \to \phi\gamma)/\tau_{B^0_s}$	–	5 %	1 %	0.2 %
Electroweak penguin	$S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\,GeV^2/c^4)$	0.08 [14]	0.025	0.008	0.02
	$s_0\,A_{FB}(B^0 \to K^{*0}\mu^+\mu^-)$	25 % [14]	6 %	2 %	7 %
	$A_I(K\mu^+\mu^-; 1 < q^2 < 6\,GeV^2/c^4)$	0.25 [15]	0.08	0.025	~ 0.02
	$\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$	25 % [16]	8 %	2.5 %	~ 10 %
Higgs penguin	$\mathcal{B}(B^0_s \to \mu^+\mu^-)$	1.5×10^{-9} [2]	0.5×10^{-9}	0.15×10^{-9}	0.3×10^{-9}
	$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B^0_s \to \mu^+\mu^-)$	–	~ 100 %	~ 35 %	~ 5 %
Unitarity triangle angles	$\gamma\ (B \to D^{(*)}K^{(*)})$	~ 10–$12°$ [19, 20]	4°	0.9°	negligible
	$\gamma\ (B^0_s \to D_s K)$	–	11°	2.0°	negligible
	$\beta\ (B^0 \to J/\psi\ K^0_S)$	0.8° [18]	0.6°	0.2°	negligible
Charm CP violation	A_Γ	2.3×10^{-3} [18]	0.40×10^{-3}	0.07×10^{-3}	–
	ΔA_{CP}	2.1×10^{-3} [5]	0.65×10^{-3}	0.12×10^{-3}	–

b fragmentation f_s/f_d

LHCb measured has 2 independent measurements (at 7 TeV):

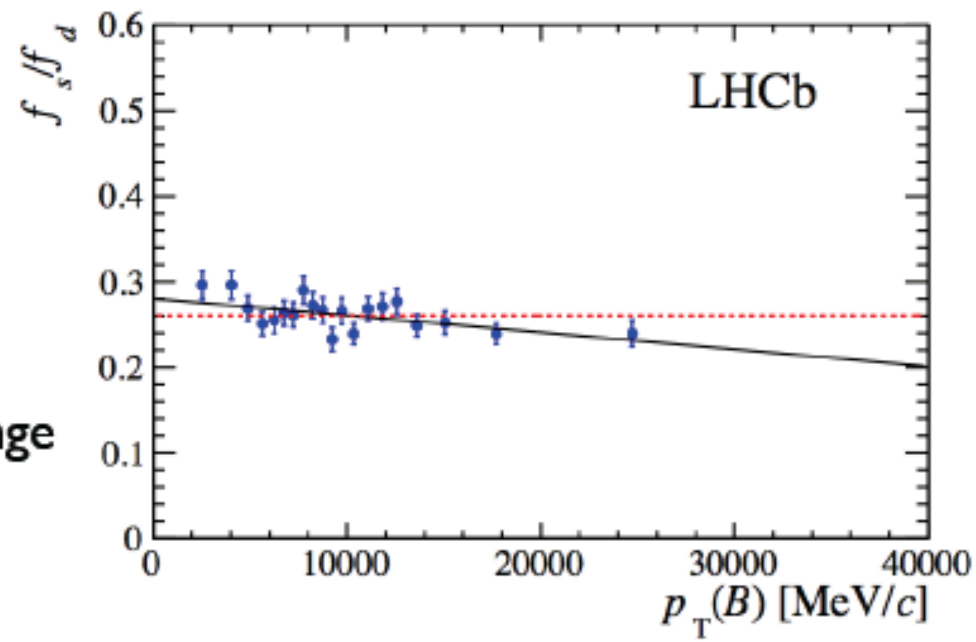
- ratio of $B^0_s \rightarrow D_s \mu X$ to $B \rightarrow D^+ \mu X$ [PRD85 (2012) 032008]
- ratio of $B^0_s \rightarrow D^-_s \pi^+$ to $B^0 \rightarrow D^- K^+$ and $B^0 \rightarrow D^- \pi^+$ [LHCb-PAPER-2012-037 in preparation]

new

updated at HCP

Combined result at 7 TeV

$$f_s/f_d = 0.256 \pm 0.020$$



Found to be moderately dependent on p_T:
- effect $\leq 1\sigma$ for the considered p_T range
  $\rightarrow$ dependence is ignored

For 8 TeV data, check the $\sqrt{s}$ dependence of f_s/f_d by looking at $B^0_s \rightarrow J/\psi\phi$ / $B^\pm \rightarrow J/\psi K^\pm$ ratio ==> stable within 1.5 σ