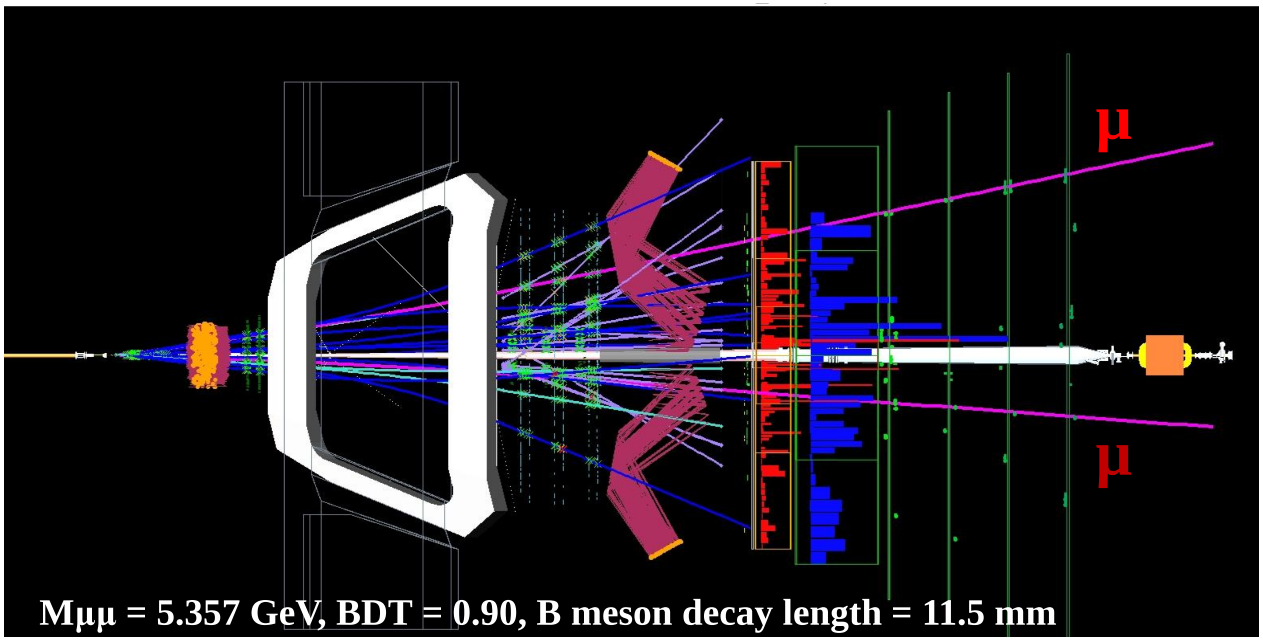
Статус поиска распада $B_s \to 2\mu$ в LHCb. Новогодняя научная сессия ОФВЭ

27 Декабря 2011



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ПИЯФ

OUTLOOK

- Introduction. Recent $B_{s,d} \rightarrow 2\ \mu$ results
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- $B_s \rightarrow 2\ \mu$ analysis jungle. Normalization channels. BDT response and invariant mass resolution calibrations
- Background estimates
- Extraction of the limit. Results and future plans
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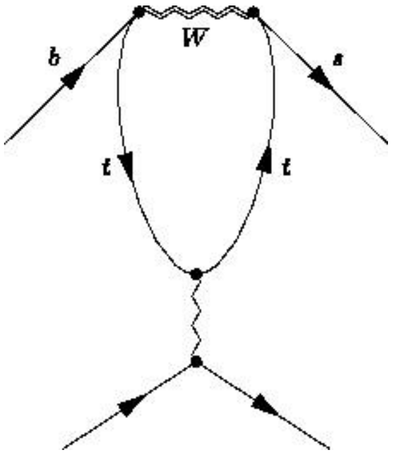
- Conclusions

Introduction. B mesons penguin diagram decays

- SM forbids flavor-changing neutral currents (FCNC) diagrams
- FCNC can be introduced by penguin one loop diagrams
- If some B-meson decays can be realized only via penquin diagram decay, these decays can be sensitive to the new physics



Decay examples: $B_s \to 2\mu$, $B_d \to K^*\mu^+\mu^-$, $B_d \to K^*\gamma$, $B_s \to \varphi\gamma$, etc.

..and many of them now can be studied at LHCB detector

Introduction. $B_s \to 2\,\mu$ decay. Existing upper limits

- Observed upper limits at the Tevatron and LHC *before summer 2011*:
- CDF observed limit at $L = 3.7\ fb^{-1}$: Br ($\mathbf{B_s \to 2\mu}$) < 4.3 $\times 10^{-8}$ (95% CL)

  Br ($\mathbf{B_d \to 2\mu}$) < 7.6 $\times 10^{-8}$ (95% CL), [CDF public note 9892]
- D0 observed limit at $L = 6.1\ fb^{-1}$: Br ($\mathbf{B_s \to 2\mu}$) < 5.1 $\times 10^{-8}$ (95% CL),

  Phys. Lett. B **693**, 539 (2010), [arXiv:1006.3469]
- LHCB published observed limit at $L = 37\ pb^{-1}$: Br ($\mathbf{B_s \to 2\mu}$) < 5.6 $\times 10^{-8}$,

  Br ($\mathbf{B_d \to 2\mu}$) < 1.5 $\times 10^{-8}$ at 95% CL, Phys. Lett. B**699** 330 (2011), [hep-ex/1103.2465]

  LHCB provided approximately the same result as CDF with 100 times less integrated luminosity! (more higher cross –section, better geometric and muon pT acceptance)

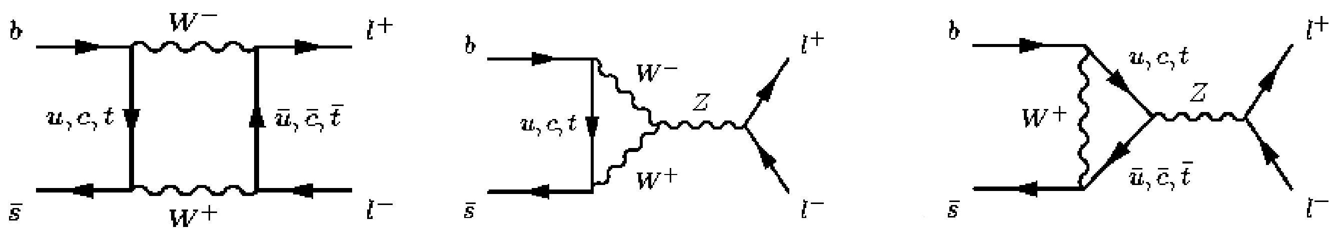
- ...but *last summer news* from CDF arXiv: 1107.2304 [hep-ex] **:**

  $0.46 \times 10^{-8} < BR < 3.9 \times 10^{-8}$ @ 90% CL , (BR=1.8+ 1.1 -0.9) $\times 10^{-8}$

  Not confirmed. Huge signal fluctuation ??

Physics motivation: $B_s \to 2\mu$ Standard Model diagrams

- $B_s \to 2\mu$ is double suppressed decay: FCNC process and helicity suppressed



$$BR(B_q \to l^+l^-) \approx \frac{G_F^2 \alpha^2 M_{B_q}^3 f_{B_q}^2 \tau_{B_q}}{64\pi^3 \sin^4\theta_W} |V_{tb}V_{tq}^*|^2 \sqrt{1 - \frac{4m_l^2}{M_{B_q}^2}}$$

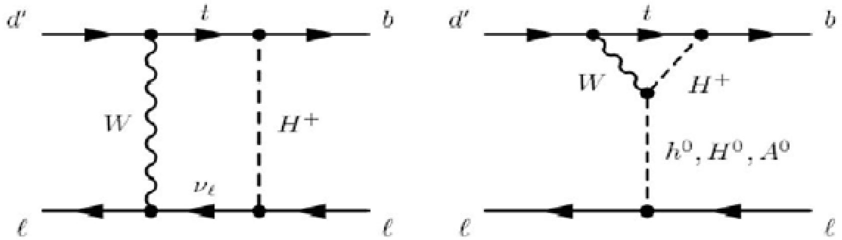
$$\left\{ M_{B_q}^2 \left(1 - \frac{4m_l^2}{M_{B_q}^2}\right) c_S^2 + \left[M_{B_q} c_P + \frac{2m_l}{M_{B_q}} (c_A - c_A') \right]^2 \right\}.$$

- As a result SM diagrams give branching ratios:

Br(**$B_s \to 2\mu$**) =(3.2±0.2) x10^{-9}, Br(**$B_d \to 2\mu$**) = (1.1±0.1) x10^{-10} ,
(A.J.Buras: arXiv:1012.1447, E. Gamiz et al: Phys.Rev.D 80 (2009) 014503)

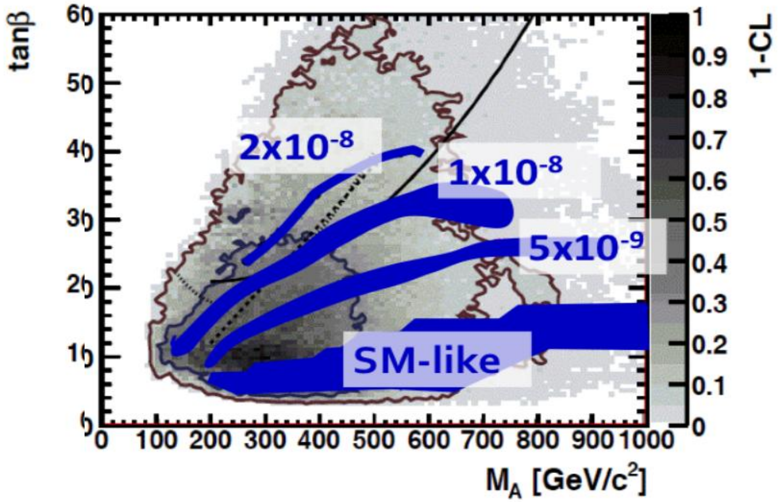
Physics motivation: MSSM models

- $B_s \to 2\mu$ branching ratio can be very sensitive to the SUSY diagrams contributions. Two Higgs-Dublet (2HDM) model provides a big contribution in the region of the large tan β



$$BR(SUSY) \propto BR(SM) \cdot \frac{m_b^4 \cdot (\tan\beta)^6}{m_{H^0}^4}$$

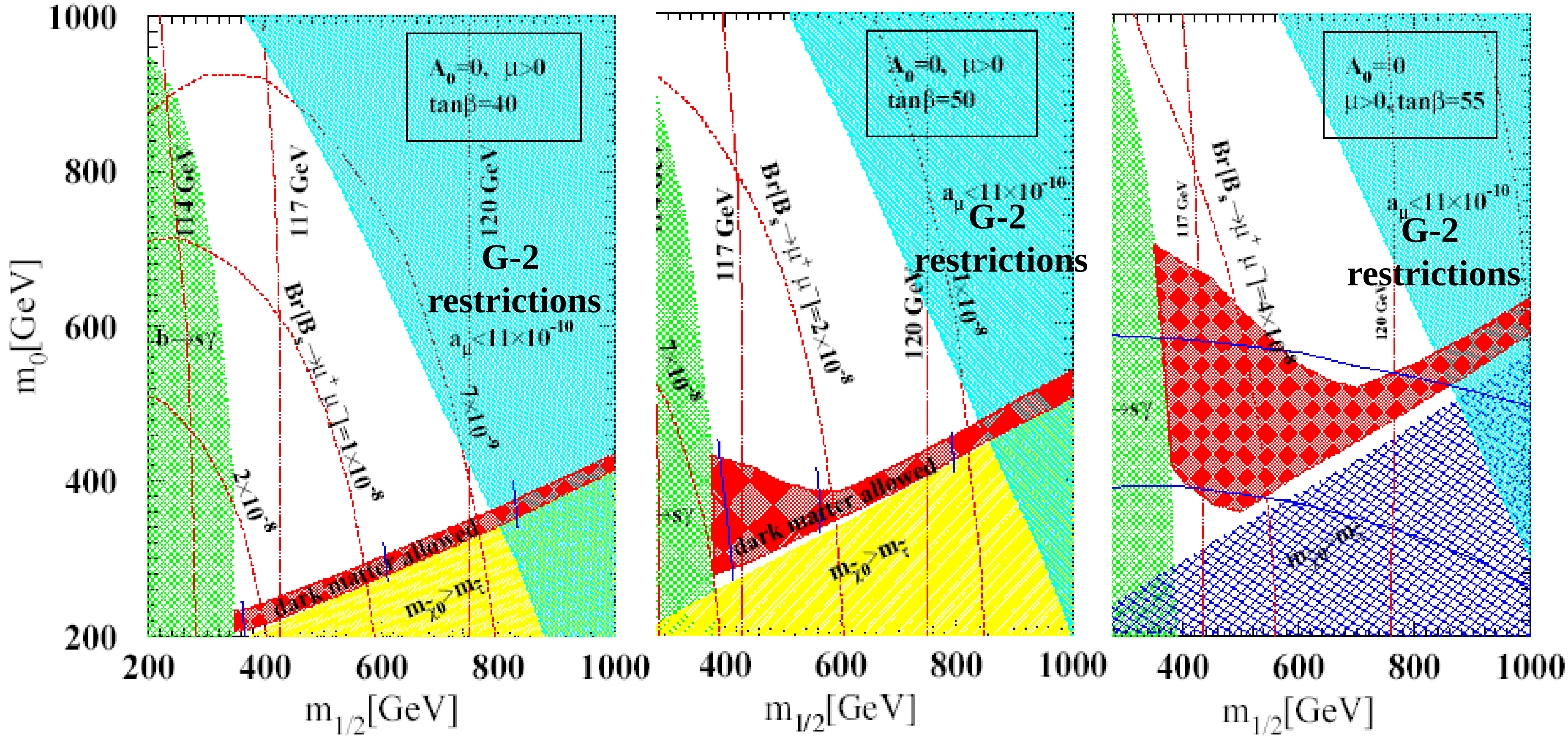
- NUHM1 model. The indirect $B_s \to 2\mu$ search power (blue regions) can be comparable with the results of direct SUSY searches (gray region):



Physics motivation: mSUGRA model

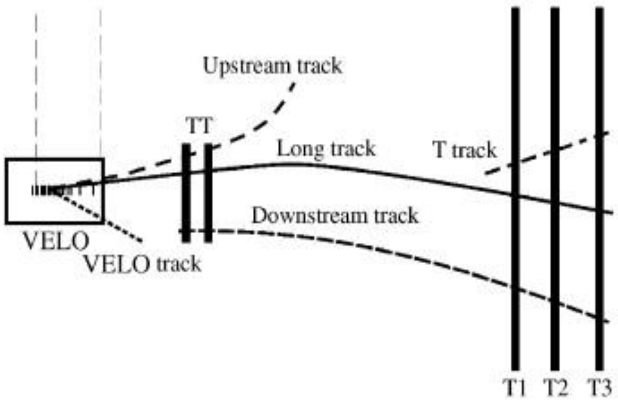
- Evaluation of the $Br(B_s \to 2\mu)$ behavior for the different mSUGRA model parameters

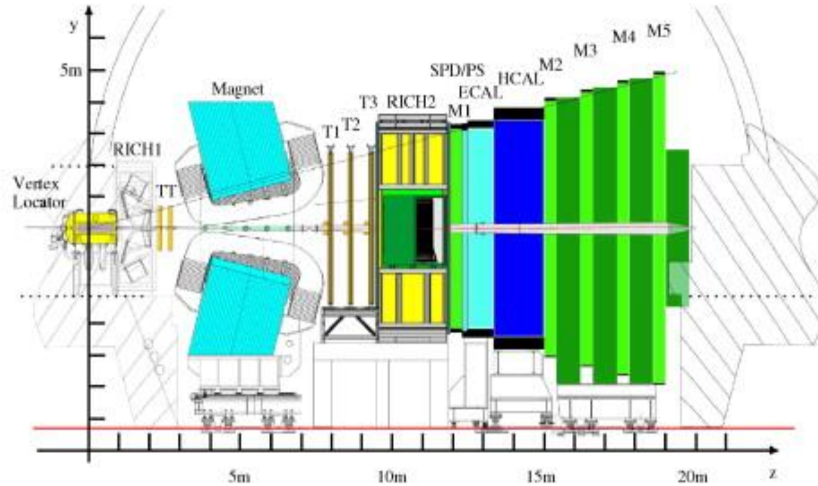
G-2 collab. David Hertzog: "We are central to the US Intensity Frontier.."



- If we believe to the G-2 experiment restriction (light blue color) we have very exiting time on LHCB now, because LHCB has a plan to reach the sensitivity $Br(B_s \to 2\mu) \sim 7\text{-}8 \times 10^{-9}$ (90% CL) with the 2011 year experimental data

LHCb detector

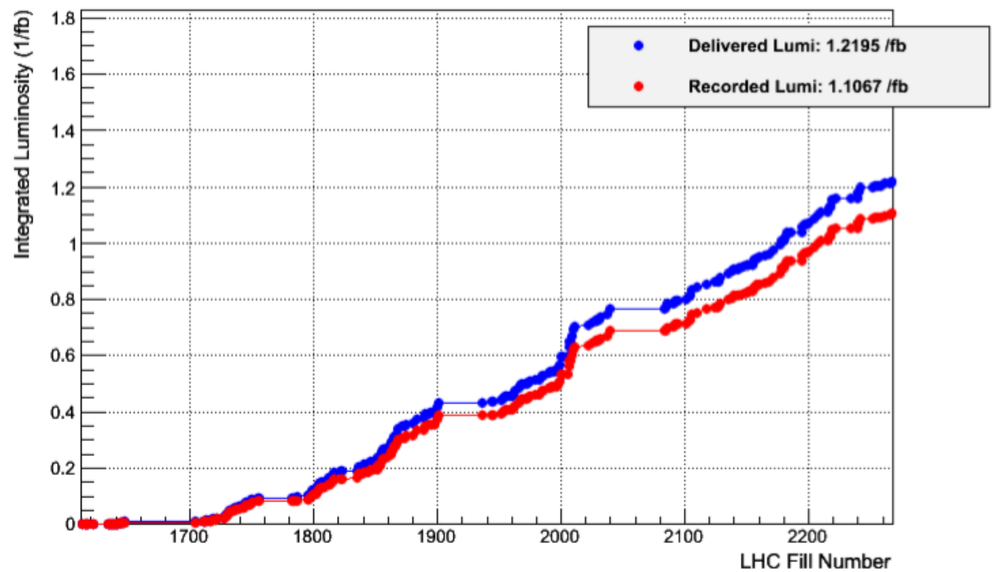




Detectors are critical for the analysis:

- M1, M2, M3, M4, M5 – muon stations
- VELO (Vertex Locator) – vertex detector
- TT, T1,T2,T3 – tracking stations
- RICH1, RICH2 – Cherenkov detectors

Data taking efficiency close to 91 % including data quality!



Fast facts

- Luminosity and interactions
  - $\sigma_{\text{inelastic}}$(pp, $\sqrt{s}=7$ TeV) = *60 mb*, $\sigma(bb) = 245.6 \pm 28.9\ \mu b$
  - Number of bunches - *1296*
  - $L_{max} = 4 \times 10^{32}$, $<L> \sim 2.65 \times 10^{32}\ cm^{-2}s^{-1}$
  - Average number of interactions $\nu = 1.6$
  - The total recorded luminosity (today), $\int Ldt = 1100\ pb^{-1}$
  - 10^{11} b decays in our acceptance
- Parameters are relevant to the $B_S \to \mu\mu$ analysis
  - $\int Ldt = 370\ pb^{-1}$ used for the last $B_S \to \mu\mu$ analysis
  - muon identification efficiency : $\varepsilon(\mu\mu) \sim 98\%$
  - misidentification rate $\varepsilon(h \to \mu) < 1\%$ *for* $p > 10\ GeV/c$
  - invariant mass resolution : $\sigma\ (M\ Bs,d \to \mu\mu) = 26\ MeV/c^2$
  - impact parameter resolution: $\sigma(IP) = 25\ \mu m$ at $pT = 2\ GeV/c$

Main backgrounds

- $b\bar{b} \to \mu\mu X$ events
- ➢ can be suppressed using different geometric and kinematic criteria
- photoproduction dimuon background
- ➢ Isolated muons with a possible contribution to the B_s mass region (removed at pT(B)> 500 MeV/c)
- misidentified muons from $B_{d/s} \to h^+h^-$ decays (

➢ contribution from $B_{d/s} \to h^+h^-$ can be calculated from $B_{d/s} \to h^+h^-$ MC with a known misidentification probablity measured in data

➢Resulting misID expectations for the 300 pb^{-1}:

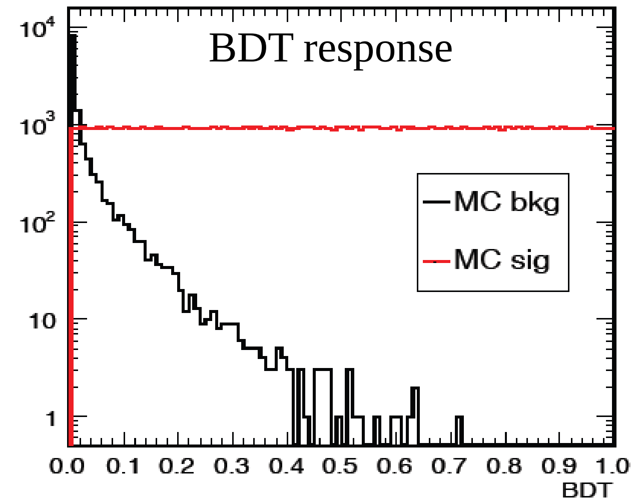
0.5±0.4 misID events in B_s mass region

2.5±0.5 misID events in B_d mass region

- After reconstruction the SM prediction for *300* pb^{-1} is 3.4 (0.32) $B_S\ (B_d) \to \mu\mu$ events

Strategy. Key points of the analysis

- **Selection conditions**
  - Muon trigger used
  - Preliminary selections to reduce datasets size
  - Blind signal region $5306 < M_{Bs} < 5426$ MeV
- **Signal and background training**



- Use $\boldsymbol{B_s \to 2\mu}$ and $\boldsymbol{bb \to \mu\mu X}$ Monte–Carlo to train the Boosted Decision Tree method
- **Signal calibration**
- Use the control channel $\boldsymbol{B \to hh}$
- **Normalization**
- Use $B^+ \to J/\Psi K^+$, $B_S \to J/\Psi\varphi$, $B^0 \to \pi^- K^+$ to calculate the total number of Bs mesons
- **Upper limit calculation**
- Use the signal and normalization channel efficiency to calculate the normalization factor
- Use the predicted background and number of observed events with the modified frequentist CLs method to estimate the upper limit and confidence level

List of input parameters for Boosted Decision Tree method

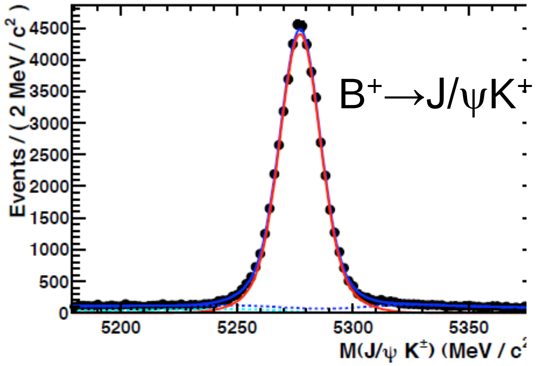
- A decision tree is able to split the phase space into a large number of hypercubes , where each can be identified as "signal-like" or "background-like"

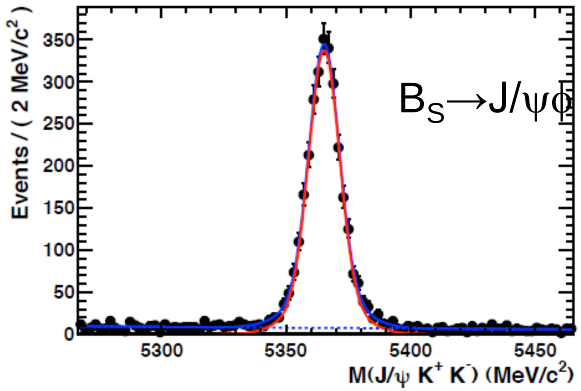
- The phase space in the analysis is defined by 9 input parameters:

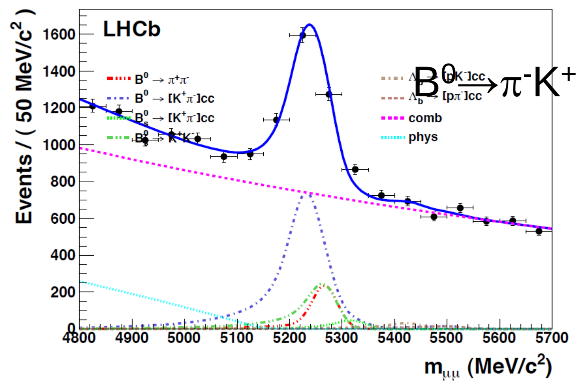
  - ✓ Transverse momentum of the $\boldsymbol{B_s}$ - *meson*
  - ✓ Minimum muon ***pT***
  - ✓ Cosine of the $\boldsymbol{B_s}$ polarization angle, ***cos P***
  - ✓ $\boldsymbol{B_s}$ meson impact parameter, ***IP_Bs***
  - ✓ Minimum distance between muon tracks, ***DOCA***
  - ✓ Muon track impact parameter significance, ***IPS_μ***
  - ✓ $\boldsymbol{B_s}$ time life , $\boldsymbol{t(B_s)}$
  - ✓ Muon ***isolation***
  - ✓ $\boldsymbol{B_s}$ ***isolation***

Normalization channels

- To calculate the $\mathbf{B_s \to \mu^+\mu^-}$ branching ratio we need to know the total number of Bs mesons and next to use this number for the normalization
- We have used 3 normalization channels :







Normalization channel branching — **Fragmentation ratio** $f_s / f_d = 0.267^{+0.021}_{-0.020}$ *combined LHCB measurements

$$\mathrm{BR} = \mathrm{BR}_{\rm cal} \times \frac{\epsilon^{\rm REC}_{\rm cal}\,\epsilon^{\rm SEL|REC}_{\rm cal}\,\epsilon^{\rm TRIG|SEL}_{\rm cal}}{\epsilon^{\rm REC}_{\rm sig}\,\epsilon^{\rm SEL|REC}_{\rm sig}\,\epsilon^{\rm TRIG|SEL}_{\rm sig}} \times \frac{f_{\rm cal}}{f_{B^0_q}} \times \frac{N_{B^0_q\to\mu^+\mu^-}}{N_{\rm cal}} = \alpha_{\rm cal} \times N_{B^0_q\to\mu^+\mu^-}$$

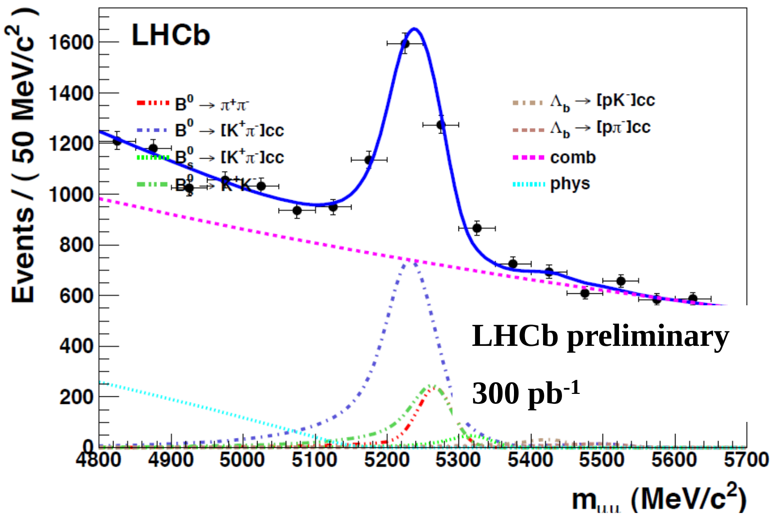
Calculated from MC — **Measured from data** — **Number of events in normalization channel**

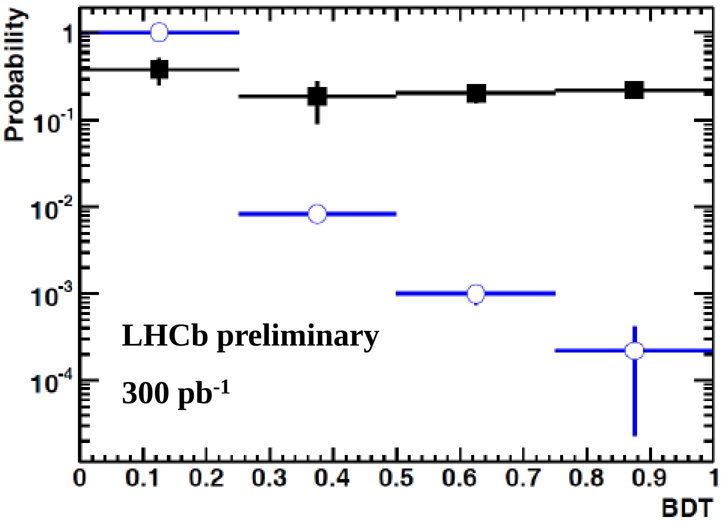
Final numbers for 370 pb^{-1}

	$\mathcal{B}$ $(\times 10^{-5})$	$\frac{\epsilon^{\rm REC}_{\rm norm}\epsilon^{\rm SEL\|REC}_{\rm norm}}{\epsilon^{\rm REC}_{\rm sig}\epsilon^{\rm SEL\|REC}_{\rm sig}}$	$\frac{\epsilon^{\rm TRIG\|SEL}_{\rm norm}}{\epsilon^{\rm TRIG\|SEL}_{\rm sig}}$	$N_{\rm norm}$	$\alpha^{\rm norm}_{B^0\to\mu^+\mu^-}$ $(\times 10^{-10})$	$\alpha^{\rm norm}_{B^0_s\to\mu^+\mu^-}$ $(\times 10^{-9})$
$B^+ \to J/\psi K^+$	6.01 ± 0.21	0.48 ± 0.014	0.95 ± 0.01	$124\,518 \pm 2\,025$	2.23 ± 0.11	0.83 ± 0.08
$B^0_s \to J/\psi\phi$	3.4 ± 0.9	0.24 ± 0.014	0.95 ± 0.01	$6\,940 \pm 93$	2.96 ± 0.84	1.11 ± 0.30
$B^0 \to K^+\pi^-$	1.94 ± 0.06	0.86 ± 0.02	0.049 ± 0.004	$4\,146 \pm 608$	1.98 ± 0.34	0.74 ± 0.14

BDT response calibration

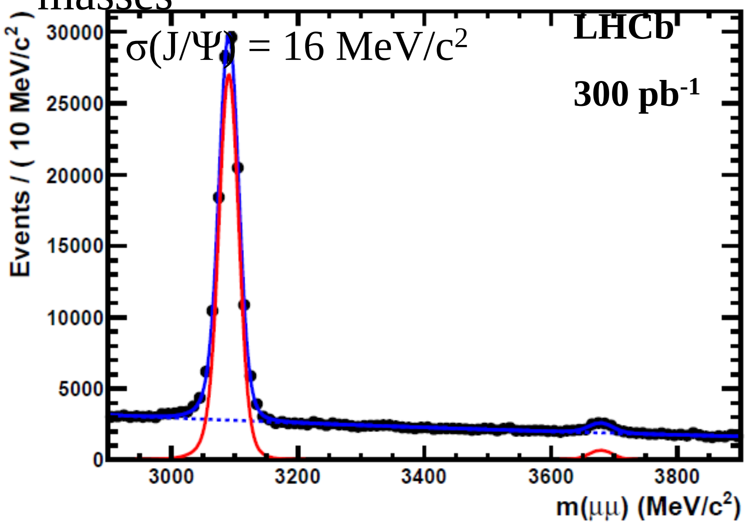
- ❑ For the calibration of signal BDT response we have used the data from B mesons hadronic decays - $B_{d/s} \to h^+h^-$ ($B_{d/s} \to$ KK,πK, ππ)
- ❑ The main advantage is same topology as $B_s \to \mu^+\mu^-$. The problem is a difference between muon and hadronic trigger. As a result for the signal calibration only events triggered independently from the - $B_{d/s} \to h^+h^-$ signal were used
- ❑ The calibration results:
- ➢ the probability density function for the signal is almost flat (dark squares on the plot)
- ➢ the probability density function (blue circles on the plot) for the combinatorial background is obtained from the dimuons in the $B_s \to \mu^+\mu^-$ mass sidebands

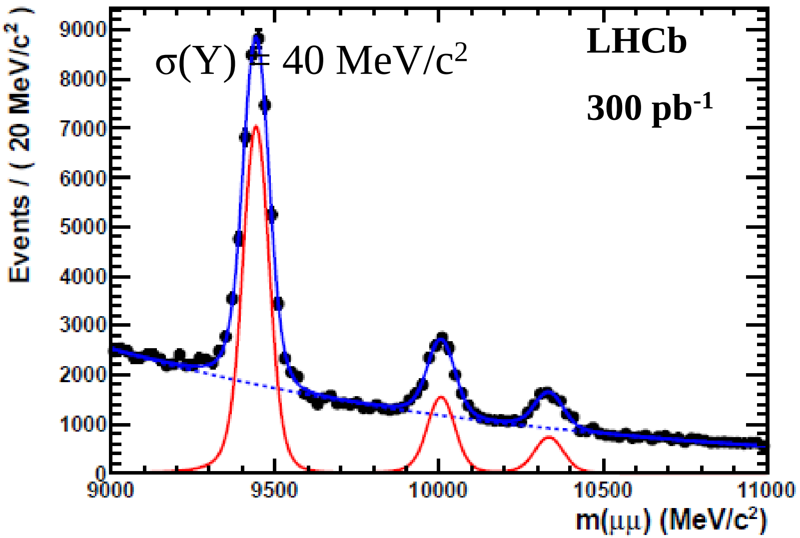




Invariant mass calibration

- Invariant mass shape modeled by a Crystal Ball function (Gaussian core portion + low end tail)
- To calculate the resolution we interpolate dimuon resonances (J/ψ, $\psi(2s)$, Upsilons) masses





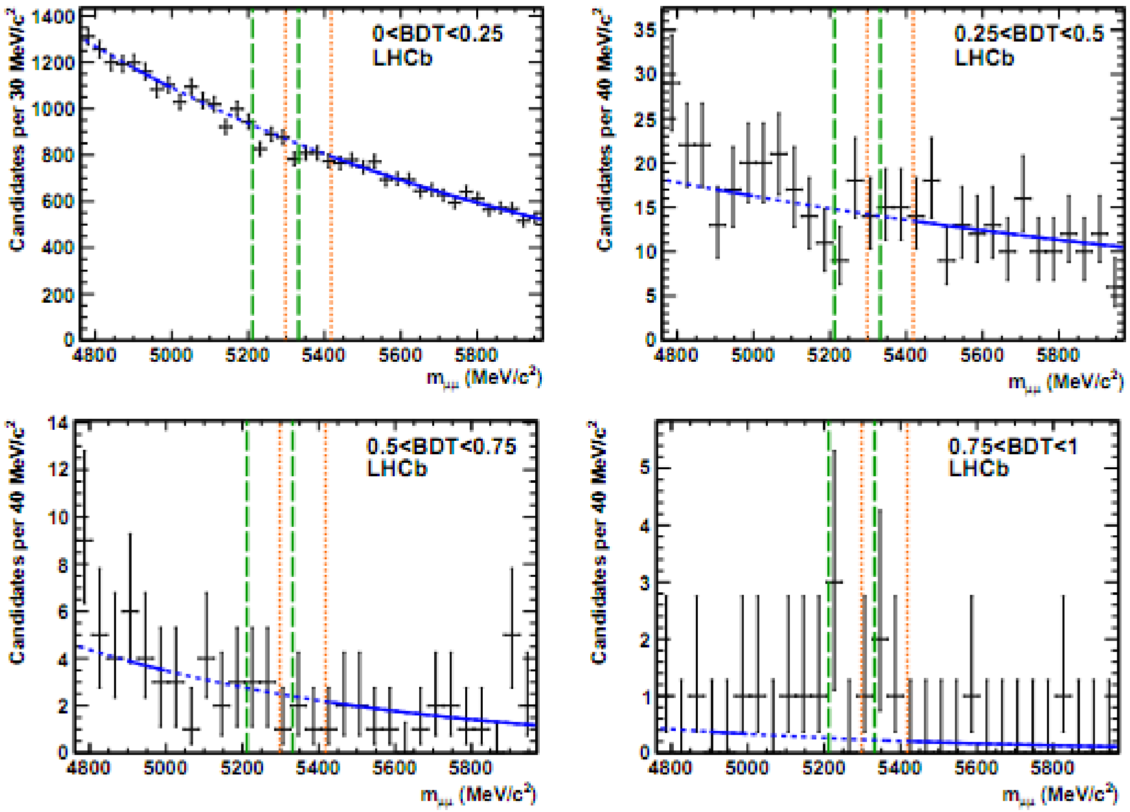
- As a result we have : $\sigma(B_s) = (24.6 \pm 0.2 \pm 1.0)$ MeV/c^2

  $\sigma(B_d) = (24.3 \pm 0.2 \pm 1.0)$ MeV/c^2

- The calculated resolutions were checked up with the invariant mass shape of $B_s \rightarrow K^+K^-$ and $B^0 \rightarrow K^+\pi^-$ decays

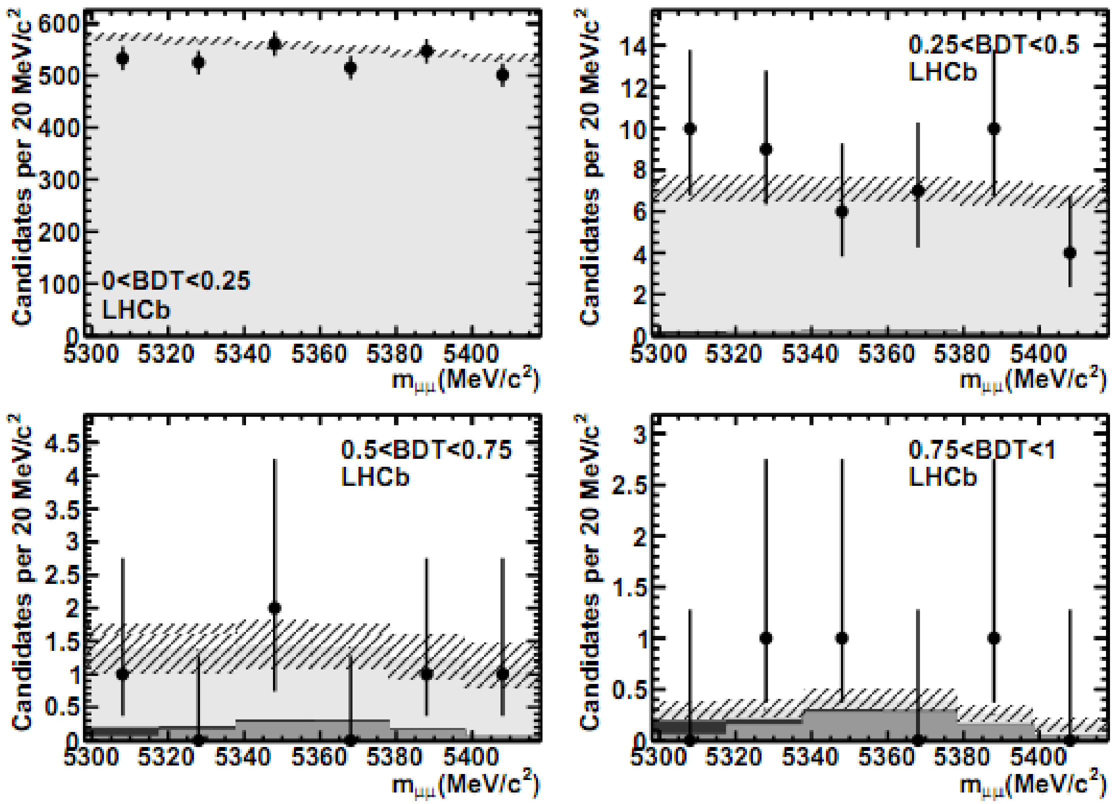
Background estimates

- The combinatorial background estimate was derived from a fit of the mass sidebands for BDT bins with the blind signal region
- The systematics of the backround prediction was studied using the exponential, double exponential and linear fitting functions



B_s Signal mass region for BDT response bins

❑ As we can see we have good enough agreement between expected background , Standard Model predictions and number of events observed in the signal region



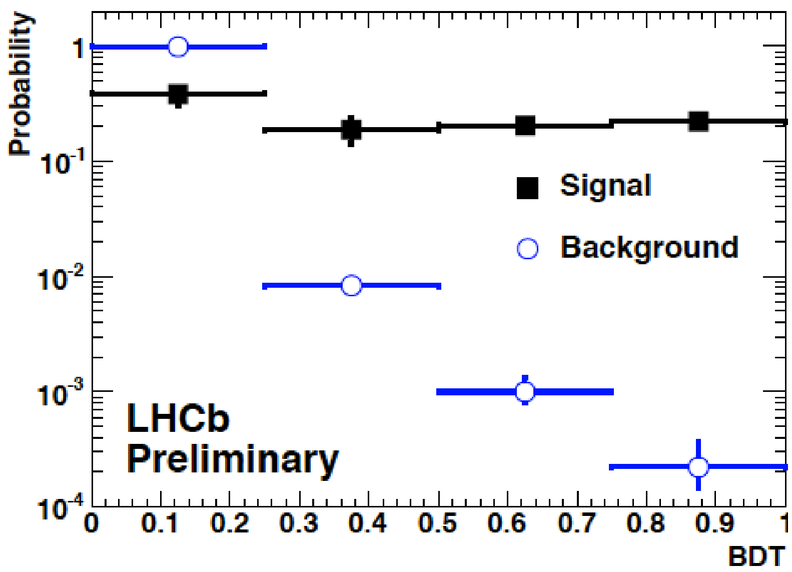
black dots are data; the light grey shows the contribution of the combinatorial background; the dark grey the contribution of SM $B_s \rightarrow 2\mu$ events

Expected combinatorial background events, expected peaking and signal events (SM branching)

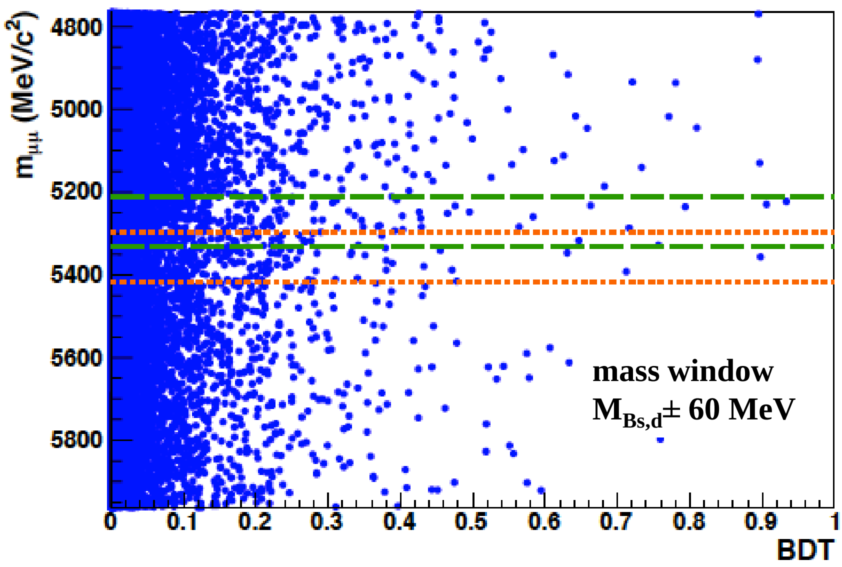
Invariant mass [MeV/c^2]		BDT 0. – 0.25	BDT 0.25 – 0.5	BDT 0.5 – 0.75	BDT 0.75 – 1.
5298 – 5318	Expected comb. bkg	$575.5^{+8.8}_{-8.0}$	$6.96^{+0.63}_{-0.57}$	$1.19^{+0.39}_{-0.35}$	$0.111^{+0.083}_{-0.068}$
	Expected peak. bkg	$0.126^{+0.037}_{-0.030}$	$0.124^{+0.037}_{-0.030}$	$0.124^{+0.037}_{-0.030}$	$0.127^{+0.038}_{-0.031}$
	Expected signal	$0.059^{+0.023}_{-0.022}$	$0.0329^{+0.0128}_{-0.0095}$	$0.0415^{+0.0120}_{-0.0088}$	$0.0411^{+0.0135}_{-0.0099}$
	Observed	533	10	1	0
5318 – 5338	Expected comb. bkg	$566.8^{+8.3}_{-8.8}$	$6.90^{+0.61}_{-0.55}$	$1.16^{+0.38}_{-0.34}$	$0.109^{+0.079}_{-0.063}$
	Expected peak. bkg	$0.052^{+0.023}_{-0.018}$	$0.054^{+0.026}_{-0.019}$	$0.052^{+0.024}_{-0.018}$	$0.051^{+0.023}_{-0.018}$
	Expected signal	$0.205^{+0.073}_{-0.074}$	$0.114^{+0.040}_{-0.031}$	$0.142^{+0.036}_{-0.028}$	$0.142^{+0.042}_{-0.031}$
	Observed	525	9	0	1
5338 – 5358	Expected comb. bkg	$558.2^{+8.1}_{-8.6}$	$6.84^{+0.59}_{-0.54}$	$1.14^{+0.37}_{-0.33}$	$0.106^{+0.078}_{-0.060}$
	Expected peak. bkg	$0.024^{+0.029}_{-0.012}$	$0.025^{+0.026}_{-0.012}$	$0.024^{+0.027}_{-0.012}$	$0.025^{+0.025}_{-0.012}$
	Expected signal	$0.38^{+0.14}_{-0.14}$	$0.213^{+0.075}_{-0.058}$	$0.267^{+0.065}_{-0.047}$	$0.265^{+0.077}_{-0.058}$
	Observed	561	6	2	1
5358 – 5378	Expected comb. bkg	$549.8^{+8.0}_{-8.4}$	$6.77^{+0.57}_{-0.52}$	$1.11^{+0.36}_{-0.32}$	$0.103^{+0.073}_{-0.057}$
	Expected peak. bkg	$0.0145^{+0.0220}_{-0.0091}$	$0.0151^{+0.0230}_{-0.0091}$	$0.0153^{+0.0232}_{-0.0096}$	$0.015^{+0.023}_{-0.010}$
	Expected signal	$0.38^{+0.14}_{-0.14}$	$0.213^{+0.075}_{-0.057}$	$0.267^{+0.065}_{-0.047}$	$0.265^{+0.077}_{-0.057}$
	Observed	515	7	0	0
5378 – 5398	Expected comb. bkg	$541.5^{+8.8}_{-8.3}$	$6.71^{+0.55}_{-0.51}$	$1.09^{+0.34}_{-0.31}$	$0.101^{+0.070}_{-0.054}$
	Expected peak. bkg	$0.0115^{+0.0173}_{-0.0088}$	$0.0116^{+0.0177}_{-0.0090}$	$0.0118^{+0.0179}_{-0.0090}$	$0.0118^{+0.0179}_{-0.0088}$
	Expected signal	$0.204^{+0.073}_{-0.074}$	$0.114^{+0.040}_{-0.031}$	$0.142^{+0.036}_{-0.028}$	$0.141^{+0.042}_{-0.031}$
	Observed	547	10	1	1
5398 – 5418	Expected comb. bkg	$533.4^{+8.7}_{-8.2}$	$6.65^{+0.53}_{-0.49}$	$1.07^{+0.34}_{-0.30}$	$0.098^{+0.068}_{-0.051}$
	Expected peak. bkg	$0.0089^{+0.0136}_{-0.0068}$	$0.0088^{+0.0133}_{-0.0068}$	$0.0091^{+0.0138}_{-0.0070}$	$0.0090^{+0.0137}_{-0.0068}$
	Expected signal	$0.058^{+0.024}_{-0.021}$	$0.0323^{+0.0128}_{-0.0093}$	$0.0407^{+0.0120}_{-0.0087}$	$0.0402^{+0.0137}_{-0.0097}$
	Observed	501	4	1	0

Extraction of the limit

BDT distribution for signal and background



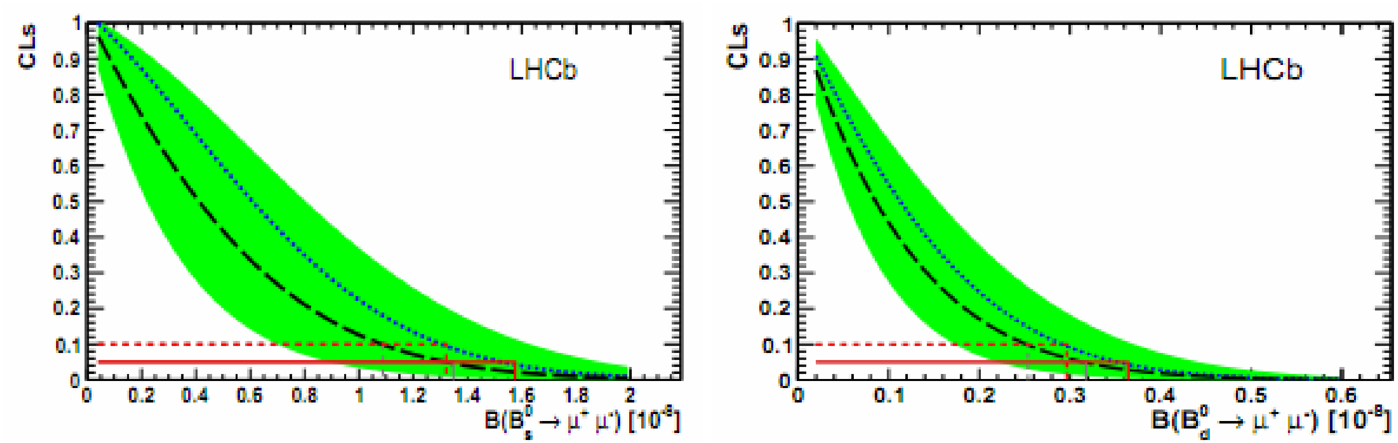
μμ mass – BDT response plane



- ❑ The CLs analysis was performed in 2D space *(dimuon mass – BDT response)*
- ❑ For the each observed event we calculated a probability to be compatible with the Signal + Background hypothesis or only Background hypothesis as a function of the branching ratio. Next we exclude the assumed branching ratio value at a given confidence level

LHCB upper limit with the 370 pb^{-1} 2011 data

Results of CLs analysis for $B_s \to 2\mu$ and $B_d \to 2\mu$ decays



$Br(B_s \to 2\mu)$ upper limit with 370 pb^{-1}

		at 90% CL	at 95% CL	CL_b
2011	expected limit	1.1×10^{-8}	1.4×10^{-8}	
	observed limit	1.3×10^{-8}	1.6×10^{-8}	0.95
2010+2011	expected limit	1.0×10^{-8}	1.3×10^{-8}	
	observed limit	1.2×10^{-8}	1.4×10^{-8}	0.93

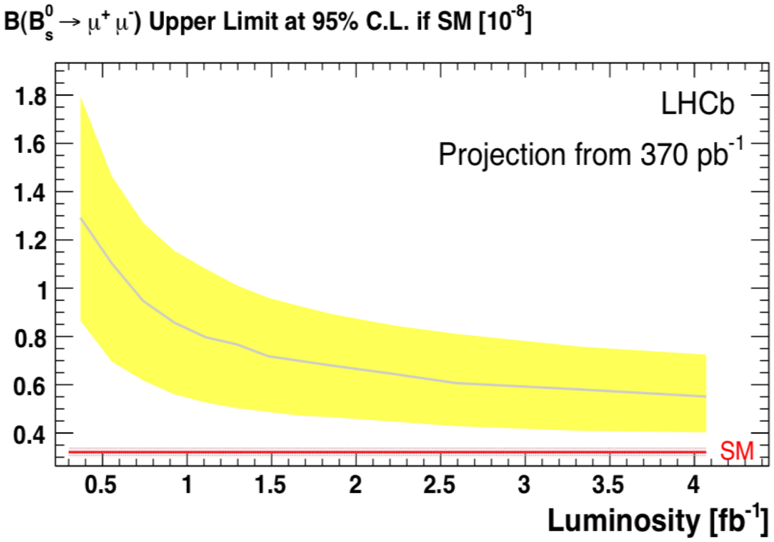
$Br(B_d \to 2\mu)$ upper limit with 370 pb^{-1}

		at 90% CL	at 95% CL	CL_b
2011	expected limit	2.5×10^{-9}	3.2×10^{-9}	
	observed limit	3.0×10^{-9}	3.6×10^{-9}	0.68
2010+2011	expected limit	2.4×10^{-9}	3.0×10^{-9}	
	observed limit	2.6×10^{-9}	3.2×10^{-9}	0.61

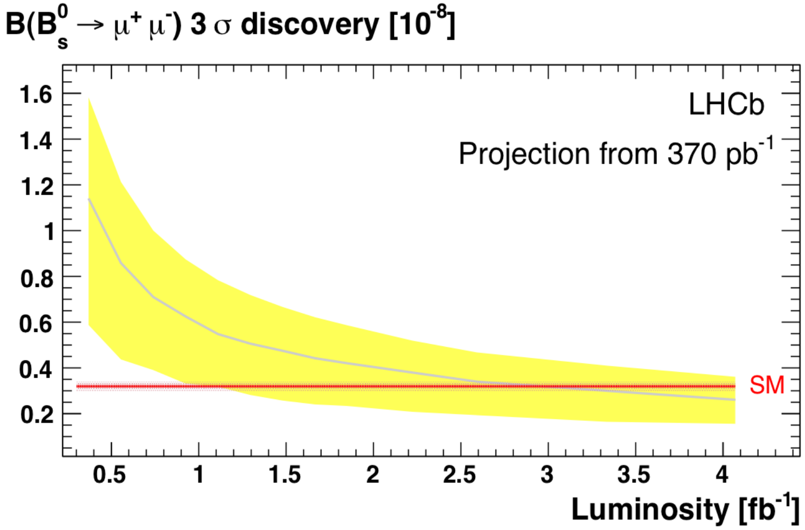
Combination with 2010 data (37pb^{-1}), ***$Br < 1.4 \times 10^{-8}$ at 95 % CL***
Improvement with the factor ~4 by comparison with the 2010 data result!

Future plans. 2012 year

Exclusion curves for the $B_s \to \mu^+ \mu^-$ branching

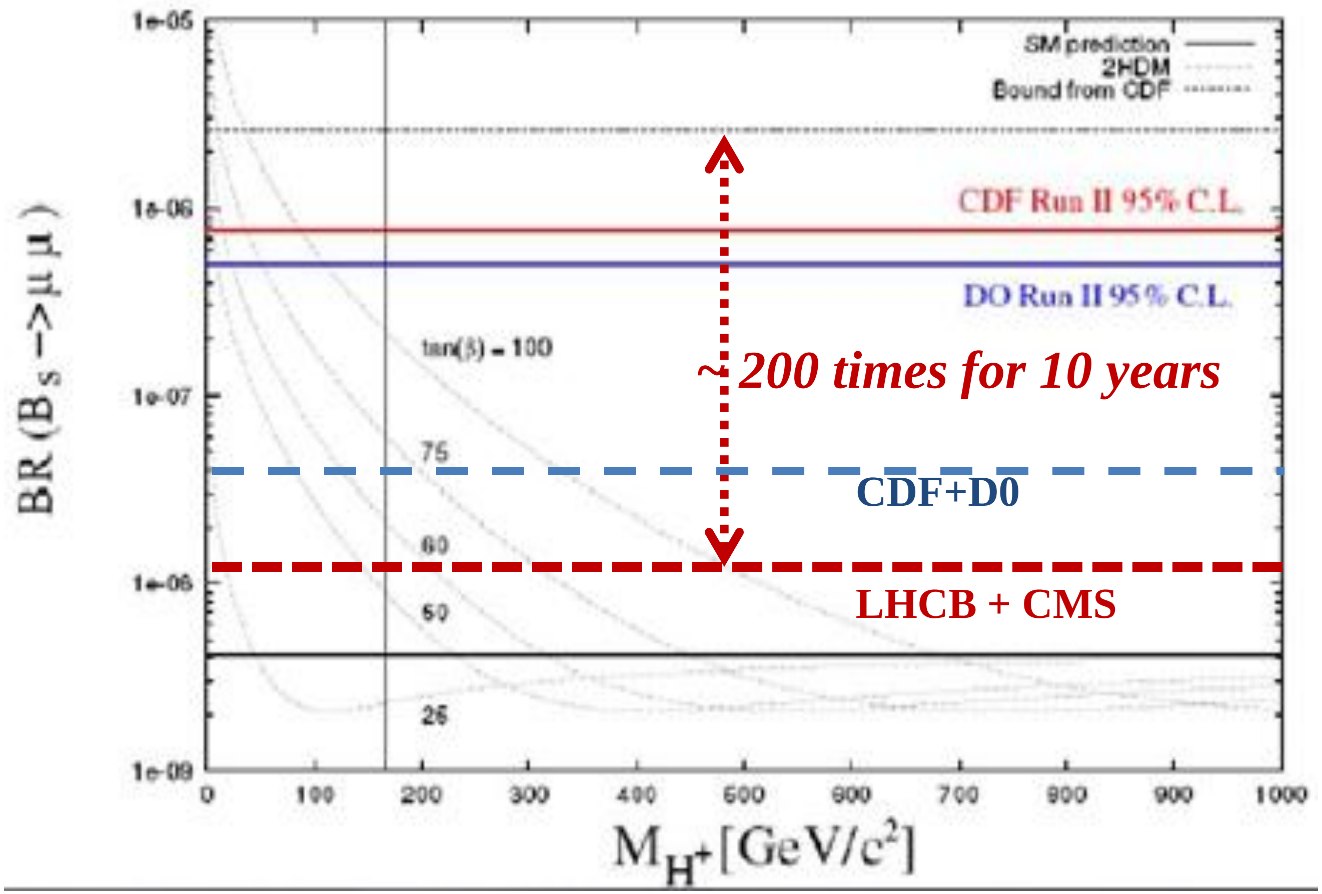


3 sigma evidence curves



- We have a chance to exclude $B_s \to \mu^+ \mu^-$ decay on the level Br =5.5÷11 x 10^{-9} at the 95% CL with the recorded integrated luminosity 1.1 fb^{-1}
- .. or to provide 3 sigma evidence for the Br = 3.3÷8 x 10^{-9} (3.3 x 10^{-9} SM level!)

Tevatron and LHC progress in $B_s \to \mu^+ \mu^-$ search



Conclusions

- LHCb with the integrated luminosity ***370 pb^{-1}*** provided the upper limits - ***$Br(B_s \to \mu^+ \mu^-) < 1.4 \times 10^{-8}$*** at 95 % CL and ***$Br(B_d \to \mu^+ \mu^-) < 3.2 \times 10^{-9}$*** at 95 % CL
- LHCB-CMS combined result ***$Br(B_s \to \mu^+ \mu^-) < 1.1 \times 10^{-8}$*** at 95 % CL (CMS result ***$Br(B_s \to 2\mu) < 1.8 \times 10^{-8}$*** (95 % CL)
- Excess of the $B_s \to \mu^+ \mu^-$ events reported by CDF (hep-ex/1107.2304) not confirmed
- LHCb plans: to reach the sensitivity ***$Br(B_s \to 2\mu) = 8 \times 10^{-9}$*** (95 % CL) with the existing integral luminosity ***$L = 1.1\ fb^{-1}$***
- We hope to get a ***3 σ*** evidence or better for the ***$B_s \to 2\mu$*** SM signal with the additional integrated luminosity ***$L = 1.5\ fb^{-1}$*** in the next 2012 year

- ***PNPI participation:*** ***we are in primary authors in two last LHCb $B_s \to 2\mu$ papers:*** **hep-ex/1103.2465, arXiv:1112.1600v2**

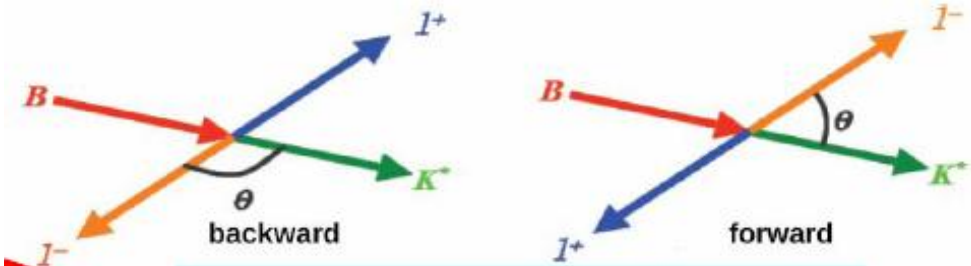
С наступающим Новым Годом!

Backup slides

Search for NP in Bd→K*μ+μ-

- The rare decay B0→ K0μ+μ− is a b →s, flavour changing neutral current decay, mediated by electroweak box and penguin diagrams in the SM
- New particles (beyond the SM)can enter in competing loop-order diagrams resulting in large deviations from SM predictions

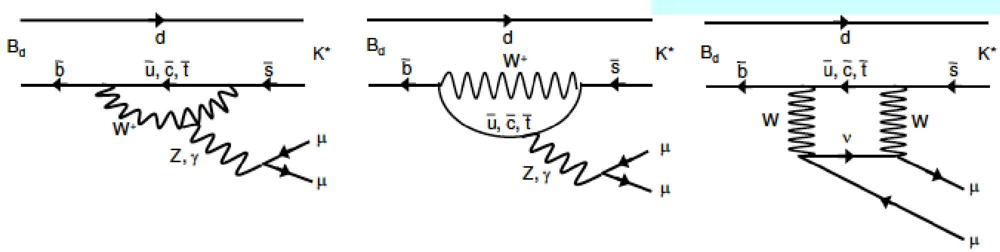
$$A_{FB} = \int \frac{d^2 B(B \to K^* \mu^+ \mu^-)}{d\cos\theta} sgn(\cos\theta)$$



θ = angle between μ^+ & B in the dilepton rest frame

q^2 = dilepton invariant mass

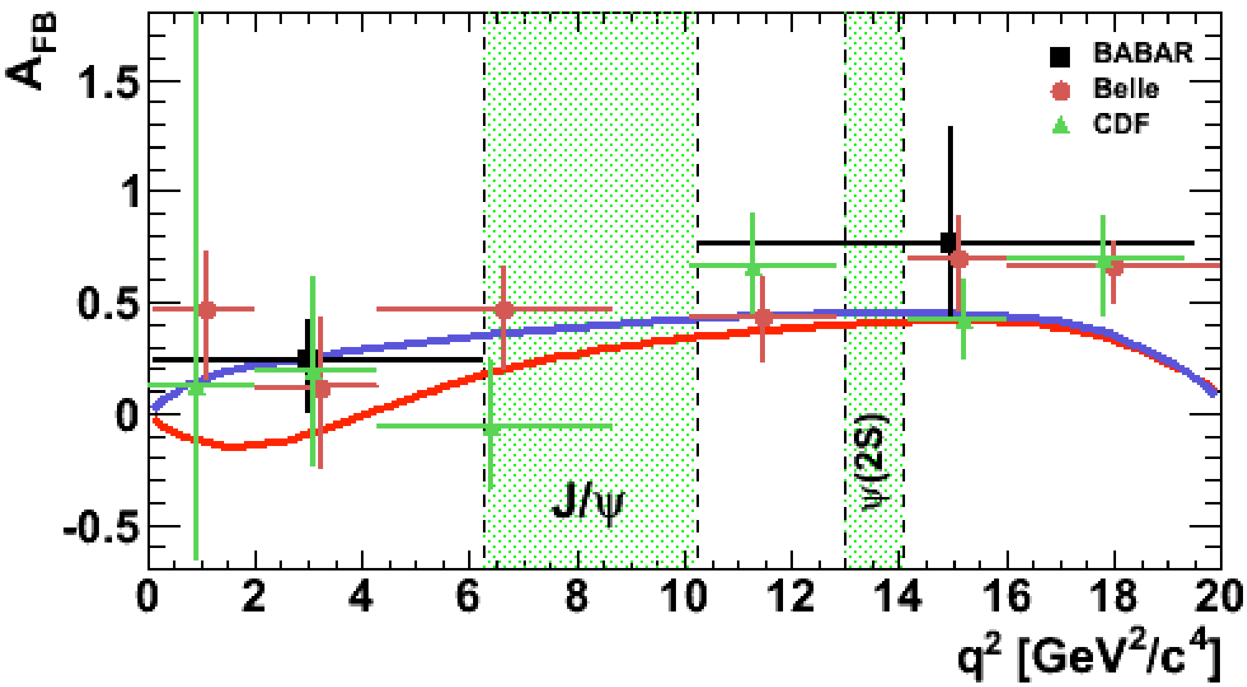
$$A_{FB}\left(s = m^2_{\mu^+\mu^-}\right) = \frac{N_F - N_B}{N_F + N_B}$$



- Forward-backward asymmetry A_{FB} of lepton system as a function of lepton invariant mass (q^2) is sensitive to the helicity structure of New Physics

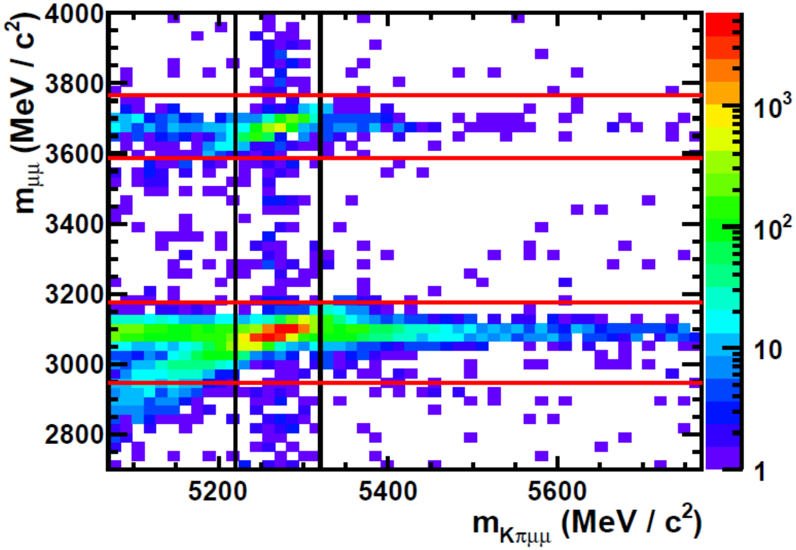
Search for NP in Bd→K*μ+μ-

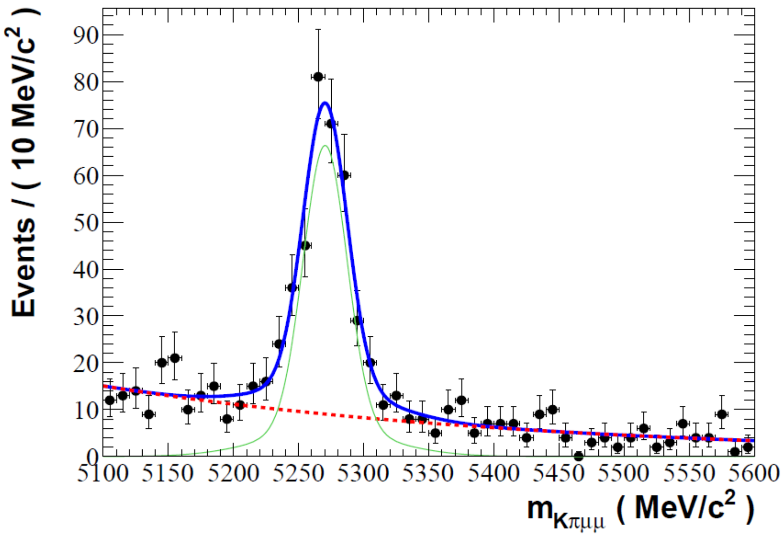
- Results from CDF and B-factories show possible disagreement with SM at low q^2
- Despite Standard model predictions experiments demonstrate positive magnitudes for the A_{FB} in the region $0 < q^2 < 4$ GeV^2/c^4



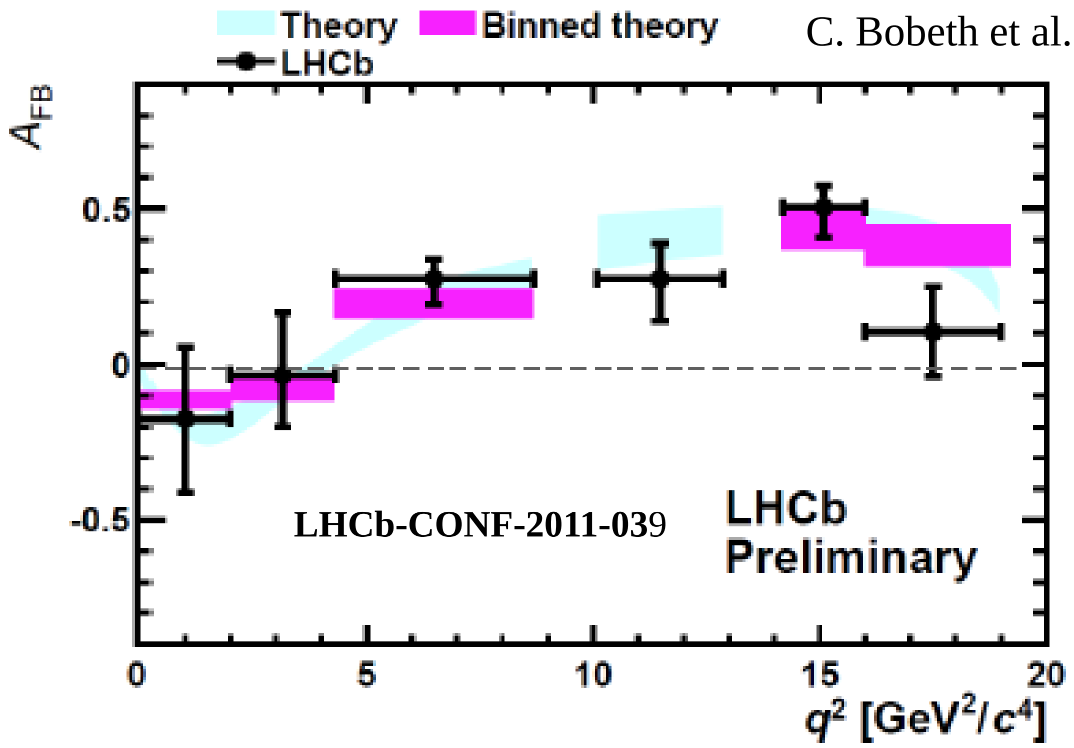
Search for NP in Bd→K*μ+μ-

- Veto decays in J/Ψ and Ψ(2S) resonance regions
- Events selection using Boosted Decision Tree from sample of 309 pb^{-1}





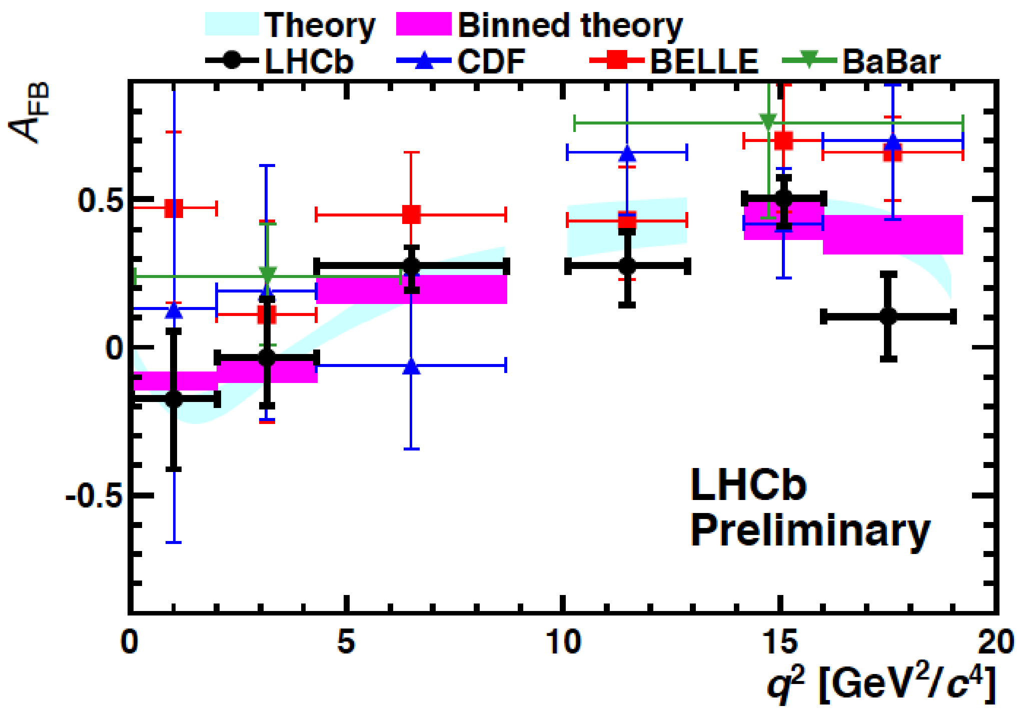
Search for NP in Bd→K*μ+μ-



C. Bobeth et al. [arXiv:1105.0376v2]

- ➢Data are consistent with the SM predictions at present sensitivity and indicate for the first time that the asymmetry is changing sign as predicted by the SM
- ➢LHCb result based on 309 pb-1 and 300 candidates

Search for NP in Bd→K*μ+μ-



BaBar [PRD **79** (2009)], Belle [PRL **103** (2009)], CDF [PRL **106** (2011)]

CP violation in Charm

CP-violating asymmetries in charm provide a unique probe of physics beyond the Standard Model (SM)

- SM charm physics is (almost) CP conserving
- New Physics can enhance CP-violating observables

CP violation in charm not observed

CERN seminar yesterday, paper submitted to PRL

http://arxiv.org/abs/1112.0938

CP violation in Charm

$$A_{\rm raw}(f) \equiv \frac{N(D^{*+}\to D^0(f)\pi^+) - N(D^{*-}\to \overline{D}^0(\bar f)\pi^-)}{N(D^{*+}\to D^0(f)\pi^+) + N(D^{*-}\to \overline{D}^0(\bar f)\pi^-)}$$

D flavour tagged with slow pion from D*

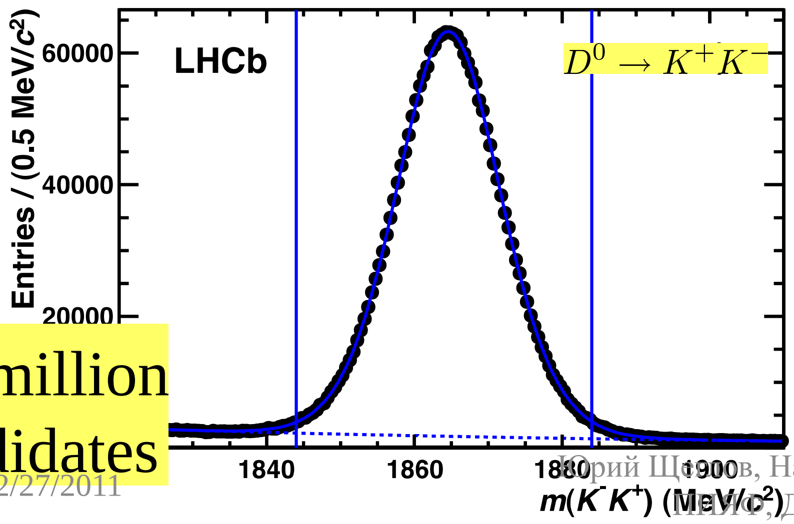
Physics Detector Productio

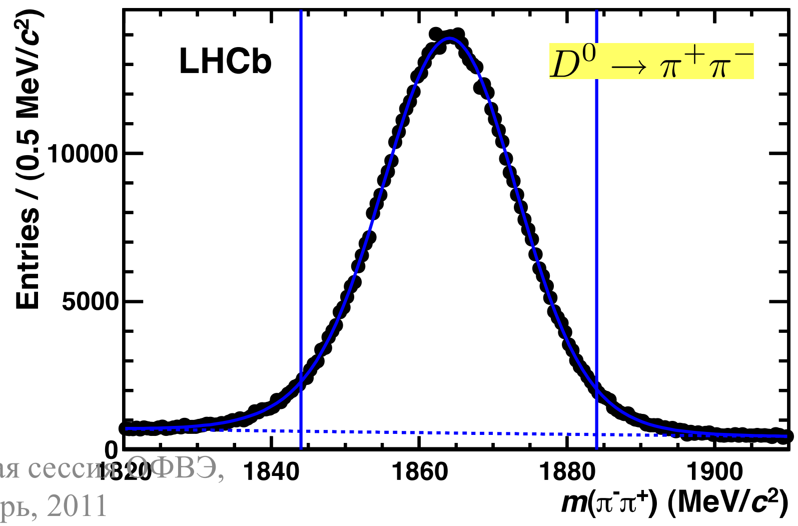
$$A_{\rm RAW}(f)^* = A_{CP}(f) + A_{\rm D}(f) + A_{\rm D}(\pi_{\rm s}) + A_{\rm P}(D^{*+})$$

n

1 kHz of trigger bandwidth allocated to charm

$$\Delta A_{CP} \equiv A_{CP}(K^-K^+) - A_{CP}(\pi^-\pi^+),$$
$$= A_{\rm RAW}(K^-K^+)^* - A_{\rm RAW}(\pi^-\pi^+)^*$$



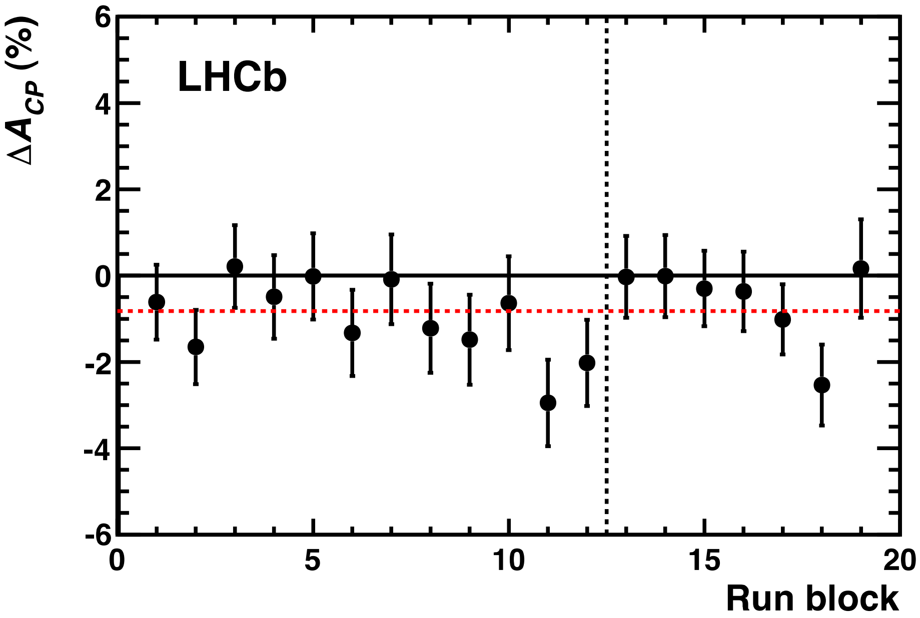


1.4 million candidates

CP violation in Charm

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

First 3.5σ evidence for CP violation in charm sector!

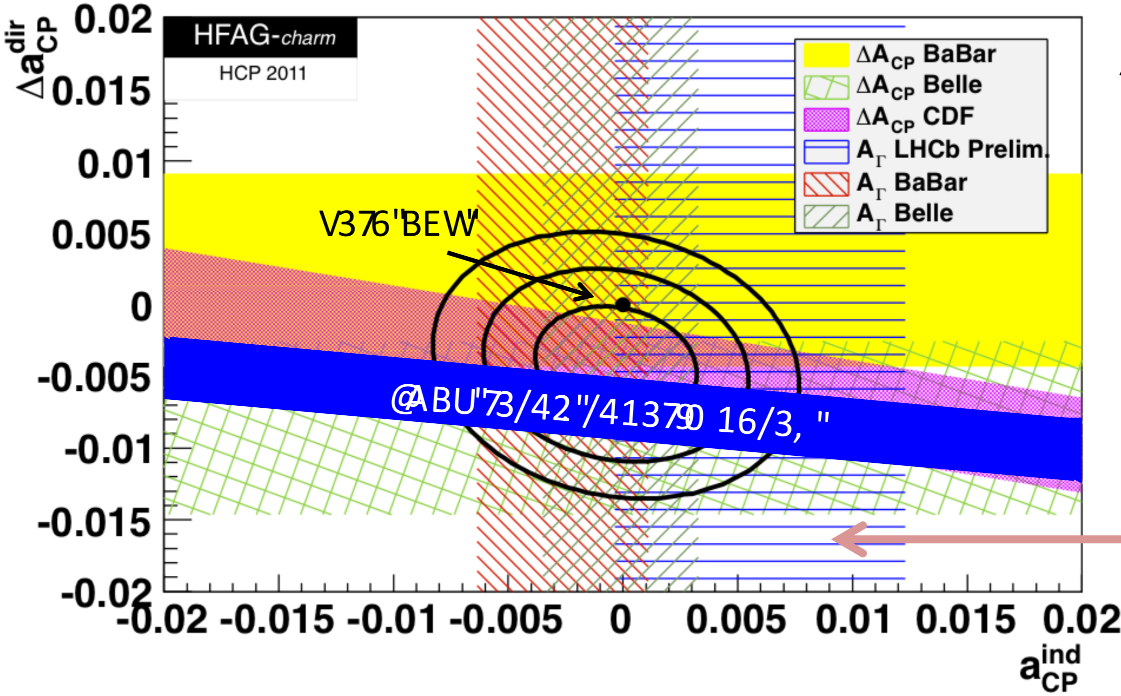


Analysis based on 60 % of collected data. Update on full dataset for Winter Conferences.

In addition parallel measurement possible using semi-leptonic B decays to tag D flavour

Result stable over time different magnet polarities and changing cuts

CP violation in Charm



$$\Delta A_{CP} \equiv A_{CP}(K^-K^+) - A_{CP}(\pi^-\pi^+)$$
$$= [a_{CP}^{\rm dir}(K^-K^+) - a_{CP}^{\rm dir}(\pi^-\pi^+)] + \frac{\Delta\langle t\rangle}{\tau} a_{CP}^{\rm ind}$$

Measure essentially direct CP

2010 LHCb study of indirect CP violation [LHCb-CONF-2011-046]

Result attracting theoretical interest

Before LHCb result consensus measurement at this level signified NP (Phys Rev D75 (2007) 036008])

Conclusion now being revisited (e.g arXiv:1111.5000)