IGFAE-LHCb highlights

Cibrán Santamarina

LIP-IGFAE meeting 2019, 26th April, Santiago

Size of Spanish Groups

From María José Costa-RECFA report-SPAIN LHC

ATLAS	IFAE	IFIC	UAM	Total
Seniors	10	17	4	31
Postdocs	4	6	0	10
Students	7	10	3	20

LHCb	ICCUB	IFIC	iGFAE	Salle_URL	Total
Seniors	4	2	8	3	14
Postdocs	1	2	6	2	9
Students	5	4	11	0	20

CMS	CIEMAT	IFCA	UAM	U.Oviedo	Total
Seniors	17	14	1	6	38
Postdocs	4	3	1	1	9
Students	4	7	0	5	16

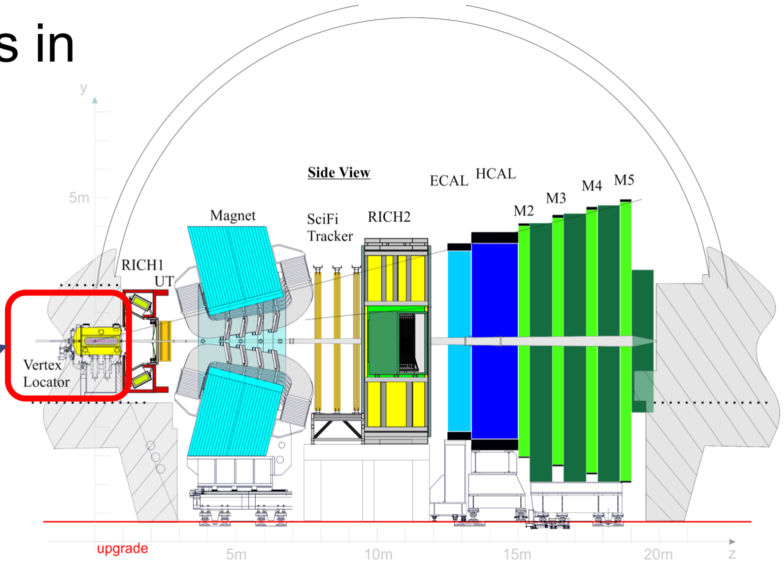
MoEDAL	IFIC
Seniors	6
Postdocs	2

- People overall: 61 (ATLAS), 63 (CMS), 43 (LHCb), 8 (MoEDAL).
- Spanish representation within the collaborations in terms of M&O authors (2.4% ATLAS, 3% CMS, 4.7% LHCb, 12% MoEDAL)
- The experimental and theoretical communities collaborate via the Spanish LHC networks
  •and the CPAN (National Centre for Particle, Astroparticle and Nuclear Physics).

LHCb Upgrade

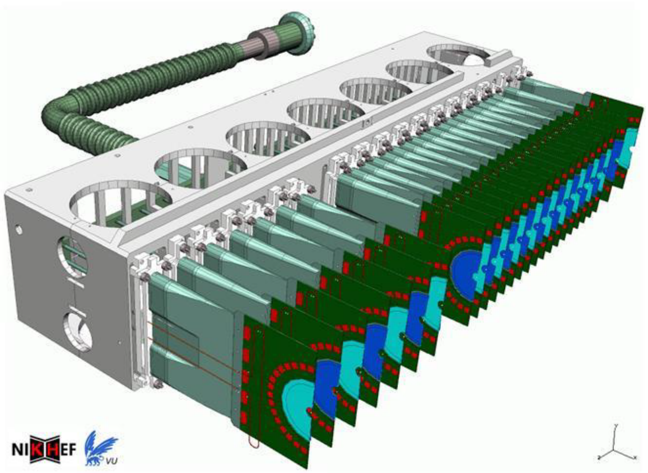
- Goal: 5x current luminosity 2×10^{33} cm^{-2} s^{-1}
- Double the present yield: collect 5 fb^{-1}/y in run 3 and run 4
- Improve trigger efficiency on hadronic channels and on rare decays
- Expand the scope to the lepton flavor sector, electroweak physics, QCD and exotics searches
- Actions:
  - Remove the current hardware trigger of 1MHz
  - New front-end and back-end electronics in most of the sub-detectors
  - New tracking system

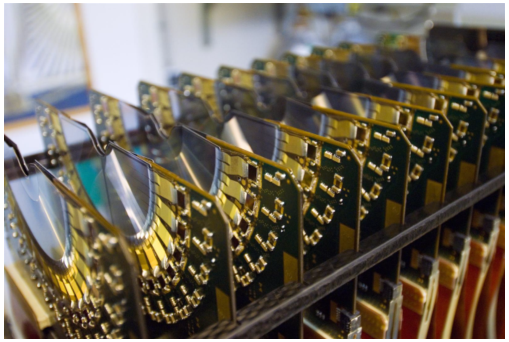
IGFAE Contribution to the vertex detector

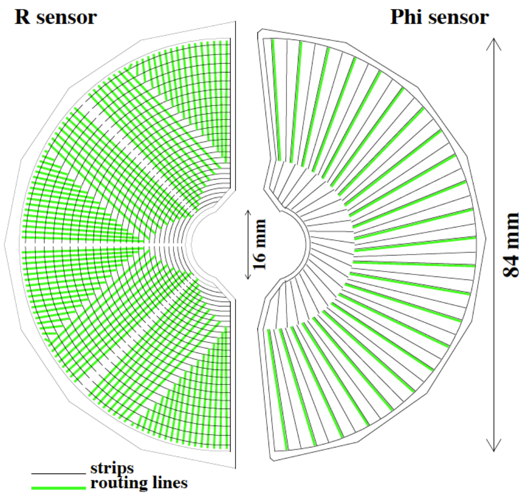


Current VELO

- Silicon strip detector 84 sensors (R + φ measurements per module). 2048 channels (strips per sensor).
- Capable of 1 MHz readout.
- Exists in 2 retractable halves and can move. The closest distance of the active silicon to the LHC beam is 8.2 mm.
- Radiation hard,7×10^{14} $1MeVn_{eq}cm^{-2}$ for full lifetime.
- CO_2 cooling.

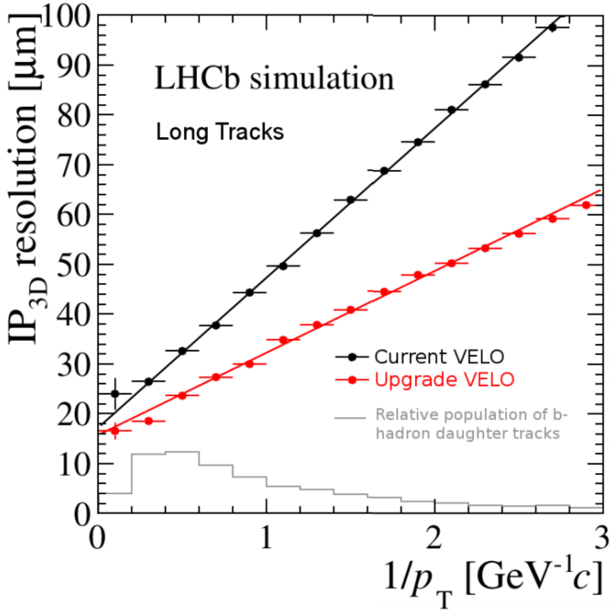


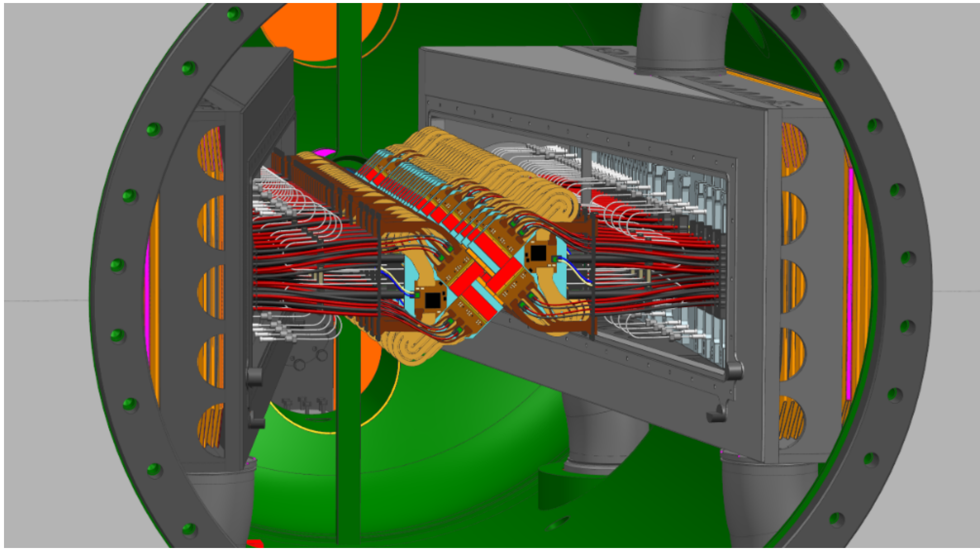




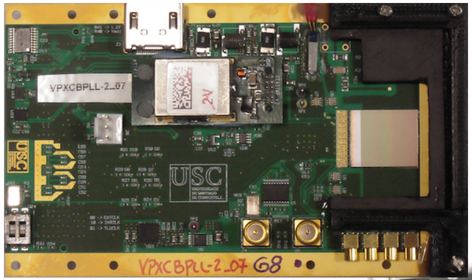
VELO Upgrade

- **Primary tracking and vertexing detector** surrounding the collision region
  - In high vacuum (separated from the LHC vacuum by a RF foil)
- **Pixel** technology (currently r/φ microstrip)
  - **More robust track reconstruction performance**
  - Better resolution
  - Closer to beam (8.1mm to 5.1mm). **Retractable halves**.
- **Faster readout (1MHz to 40MHz)**
- New ASIC VeloPix, based on TimePix family
- New micro-channel evaporative CO_2 cooling
- Some figures:
  - 52 modules, 624 VeloPix ASICs
  - Detector active area 0.12 m²
  - **~41 M pixels** (**55x55 μm²**)
  - HV tolerance of 1000V
  - **Trigger-less readout ~2.9 Tbit/s**
  - Highly non-uniform radiation. Up to 4MGy



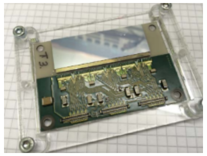


Sensors & Electronics (IGFAE/USC)

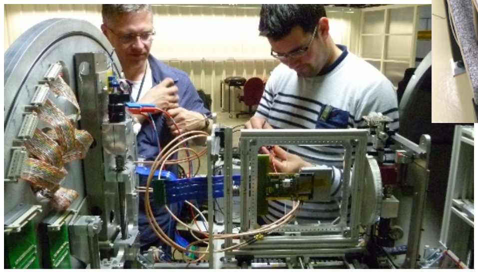


IGFAE/USC contributions to (already since 2008):

- **Sensors:**
  - Technology choice (strips vs pixels)
  - R&D, sensor design, prototype construction
  - Radiation resistance certification (neutron irradiations).

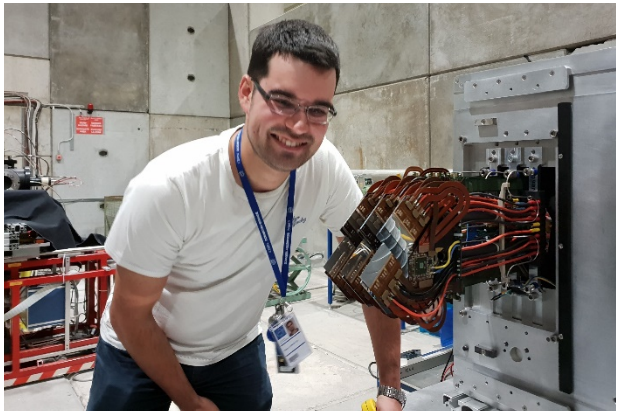


- **Front-end electronics qualification (VeloPix ASIC):**
  - Design and construction ASIC PCB carrier, Needle Probe Card
  - HV, High Speed Data Tapes and Vacuum Feed Through testing PCBs
  - Electronic Design Review (https://indico.cern.ch/event/725985/)
  - Radiation hardness:
    - Single Event Effects studies
    - Total Ionization Dose certification (up to 400 Mrad) in the USC X-ray facility.
  - Testing and quality assurance



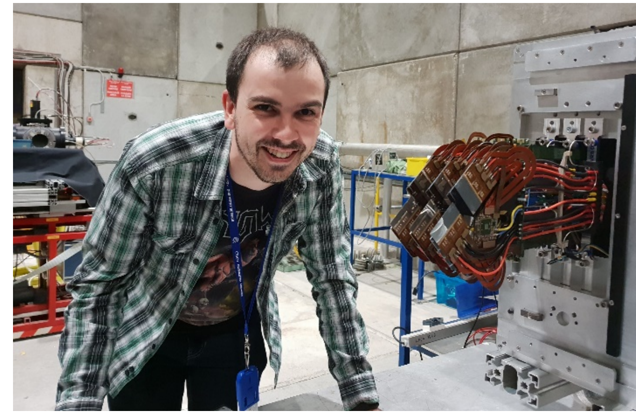
- **Back-end electronics and firmware development:**
  - Workshop for the integration of VELO detector in the LHCb framework
  - 2 RO setups, based on Intel and Xilinx FPGAs, running at IGFAE/USC

VELO Upgrade: 1st full readout chain test-beam



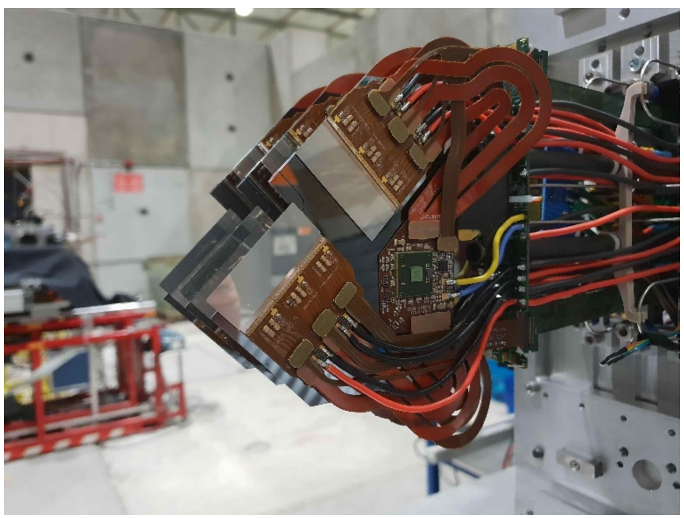
Front-end electronics expert (IGFAE/USC)

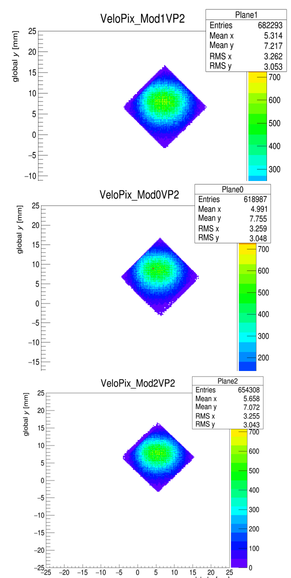
VELO DAQ and firmware coordinator

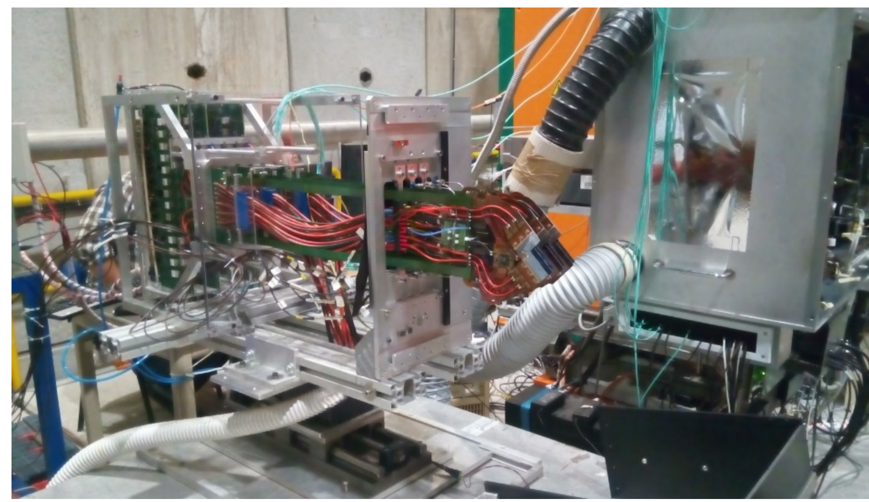


Back-end electronics expert (IGFAE/USC)

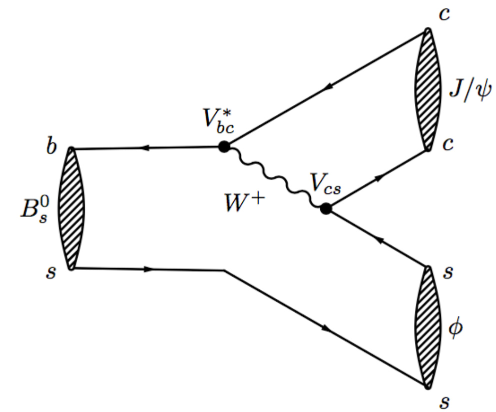
Main firmware developer







$B_s^0 \rightarrow J/\psi\phi$



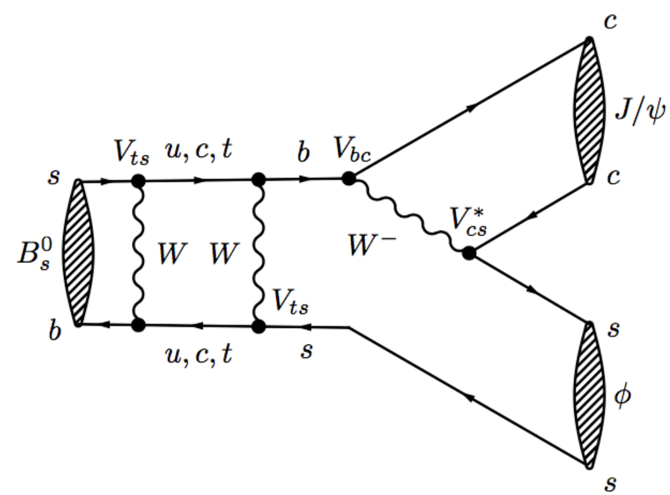
The time dependent asymmetry of $B_s^0 \rightarrow (c\bar{c})(s\bar{s})$ decays is given by:

$$A_{CP}(t) = \frac{\Gamma_{B_s^0(t)\rightarrow J/\psi\phi} - \Gamma_{\bar{B}_s^0(t)\rightarrow J/\psi\phi}}{\Gamma_{B_s^0(t)\rightarrow J/\psi\phi} + \Gamma_{\bar{B}_s^0(t)\rightarrow J/\psi\phi}} = \frac{-\Im\lambda_{J/\psi\phi}\sin\Delta m t}{\cosh\frac{1}{2}\Delta\Gamma t + \Re\lambda_{J/\psi\phi}\sinh\frac{1}{2}\Delta\Gamma t}$$

Where

$$\lambda_{J/\psi\phi} = \left(\frac{q}{p}\right)_{B_s^0}\left(\eta_{J/\psi\phi}\frac{\bar{A}_{J/\psi\phi}}{A_{J/\psi\phi}}\right) = (-1)^l\left(\frac{V_{tb}^*V_{ts}}{V_{tb}V_{ts}^*}\right)\left(\frac{V_{cb}V_{cs}^*}{V_{cb}^*V_{cs}}\right)$$

$$\Im\lambda_{J/\psi\phi} = (-1)^l\sin(-2\beta_s)$$



Which means we can access to β_s in time dependent analyses of these modes.

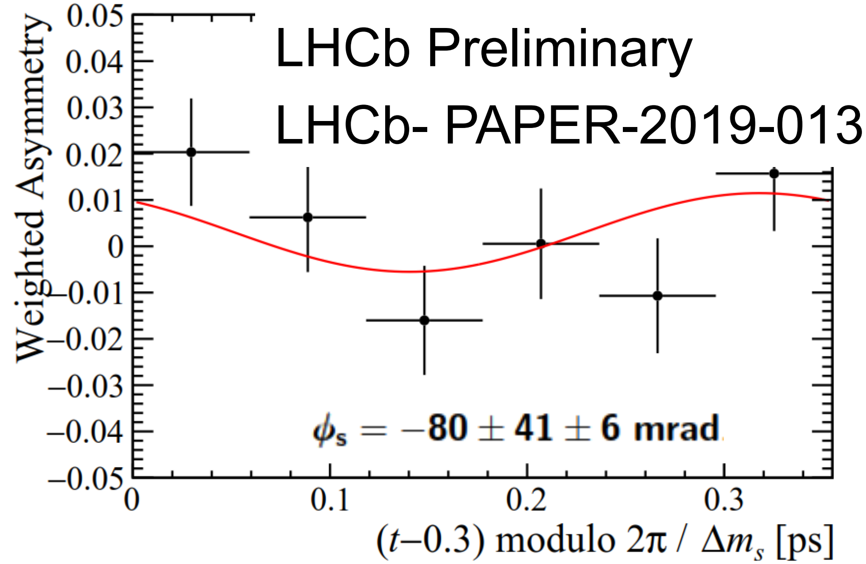
$\phi^{c\bar{c}}_s = -2\beta_s$

- Theoretically clean:

$$\phi_s^{SM} = -0.0368^{+0.00096}_{-0.00068} \text{ [rad]}$$

[UTfit]

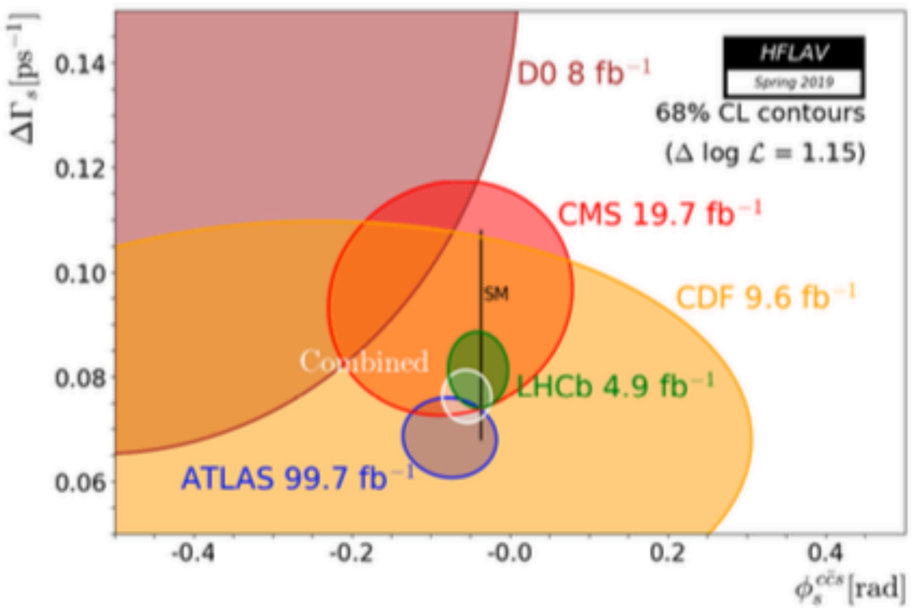
- Updated measurement with 2015 and 2016 data
- Improved tagging power at (4.73 ± 0.34)% (3.73% in Run1)
- Coordinated by V. Chobanova
- Miriam Lucio PhD (happened today)



Parameter	Value
ϕ_s [rad]	$-0.080 \pm 0.041 \pm 0.006$
$\lvert\lambda\rvert$	$1.006 \pm 0.016 \pm 0.006$
$\Gamma_s - \Gamma_d$ [ps^{-1}]	$-0.0041 \pm 0.0024 \pm 0.0015$
$\Delta\Gamma_s$ [ps^{-1}]	$0.0772 \pm 0.0077 \pm 0.0026$
Δm_s [ps^{-1}]	$17.705 \pm 0.059 \pm 0.018$
$\lvert A_\perp\rvert^2$	$0.2457 \pm 0.0040 \pm 0.0019$
$\lvert A_0\rvert^2$	$0.5186 \pm 0.0029 \pm 0.0024$
$\delta_\perp - \delta_0$	$2.64 \pm 0.13 \pm 0.10$
$\delta_\parallel - \delta_0$	$3.061^{+0.084}_{-0.073} \pm 0.037$

$\phi^{c\bar{c}}_s = -2\beta_s$

Combined with latest ATLAS results



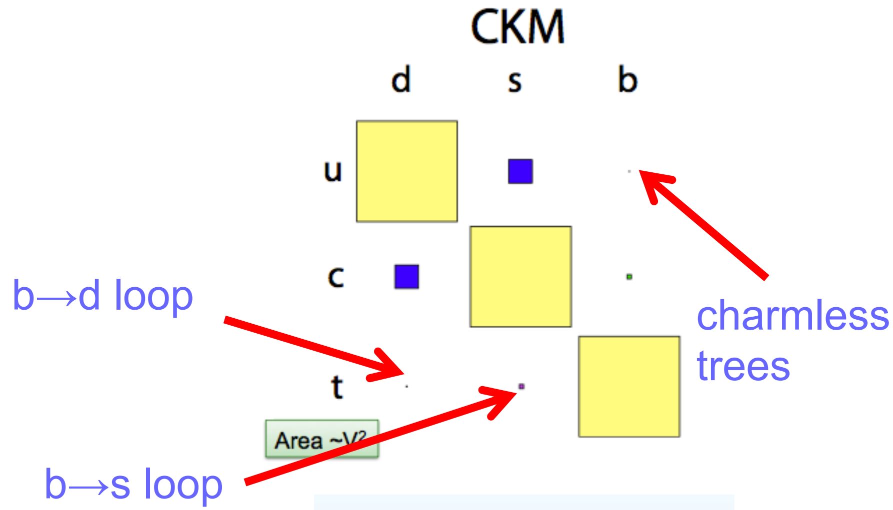
New HFLAV average

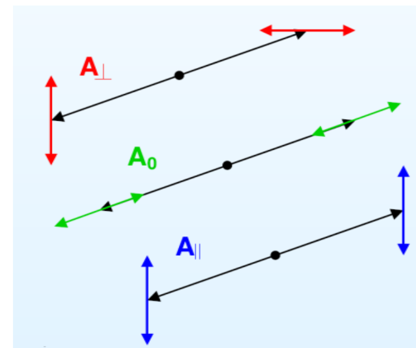
$$\phi_s = -0.0544 \pm 0.0205$$

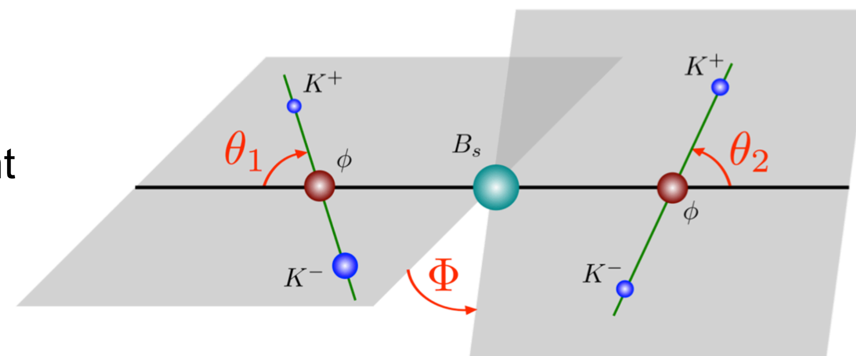
$$\Delta\Gamma_s = 0.0762 \pm 0.0033\ \mathrm{ps}^{-1}$$

Charmless $B \to V_1 V_2$

- Suppressed compared to charmed:
  - $b \to u$ tree.
  - $b \to s$, $b \to d$ loops.
- More sensitive to NP.
- Mediated by three smallest CKM matrix elements.
- V_1 and V_2: angular momentum L = 0,1,2.
- High longitudinally polarization expected:
  - Additional effects (rescattering) could produce smaller polarizations.
- Angular pdf depends on:
  - Polarization fractions: $|A_0|^2$, $|A_{||}|^2$, $|A_\perp|^2$
  - Strong phases: $\delta_{||}$, $\delta_\perp$
  - If final state is common to B_s^0 and $\bar{B}_s^0$:
    - CP–violating phase: $\phi_{(s)}$ in time dependent analyses.
  - If final state is not common to the B mesons CP: asymmetries.



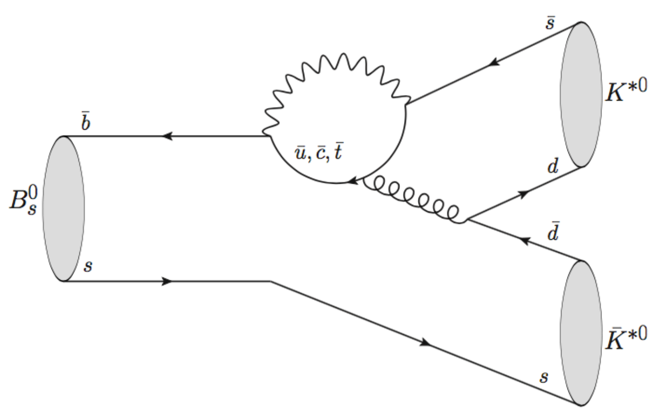


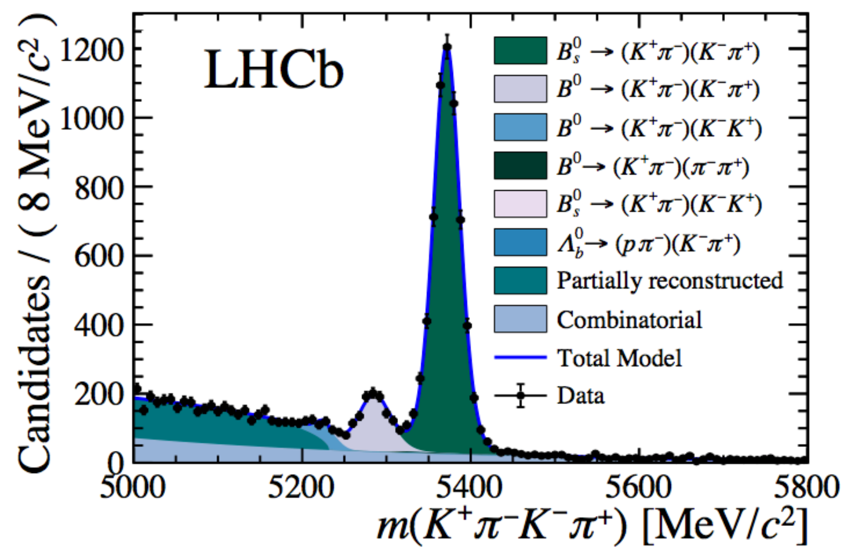


$B_s^0 \to K^{*0}\bar{K}^{*0}$

- Time dependent analysis.
- Paradigm: new particles may enter the loop.
- Original approach:
  - Extended m($K\pi$) range: 750−1600 MeV/c^2 :
    - Scalar: $K_0^*(1430)^0$ + Non Res
    - Vector: $K^*(892)^0$
    - Tensor: $K_2^*(1430)^0$
- 3×3=9 decay channels. Common $\phi_s^{d\bar{d}}$ phase assumed. **SM predicts it to be 0**.
- Tagged, time-dependent, angular and 2-body invariant mass analysis.
- More than 6000 candidates with Run-1 data.

Channel	Decay	Polarization amplitudes
Channel #1	$B_s^0 \to (K^+\pi^-)_0^*(K^-\pi^+)_0^*$	SS
Channel #2	$B_s^0 \to (K^+\pi^-)_0^*\bar{K}^*(892)^0$	SV
Channel #3	$B_s^0 \to K^*(892)^0(K^-\pi^+)_0^*$	VS
Channel #4	$B_s^0 \to (K^+\pi^-)_0^*\bar{K}_2^*(1430)^0$	ST
Channel #5	$B_s^0 \to K_2^*(1430)^0(K^-\pi^+)_0^*$	TS
Channel #6	$B_s^0 \to K^*(892)^0\bar{K}^*(892)^0$	VVo, VV∥, VV⊥
Channel #7	$B_s^0 \to K^*(892)^0\bar{K}_2^*(1430)^0$	VTo, VT∥, VT⊥
Channel #8	$B_s^0 \to K_2^*(1430)^0\bar{K}^*(892)^0$	TVo, TV∥, TV⊥
Channel #9	$B_s^0 \to K_2^*(1430)^0\bar{K}_2^*(1430)^0$	TTo, TT∥1, TT⊥1, TT∥2, TT⊥2





JHEP 1803 (2018) 140

Julián García PhD

$B_s^0 \to K^{*0}\bar{K}^{*0}$

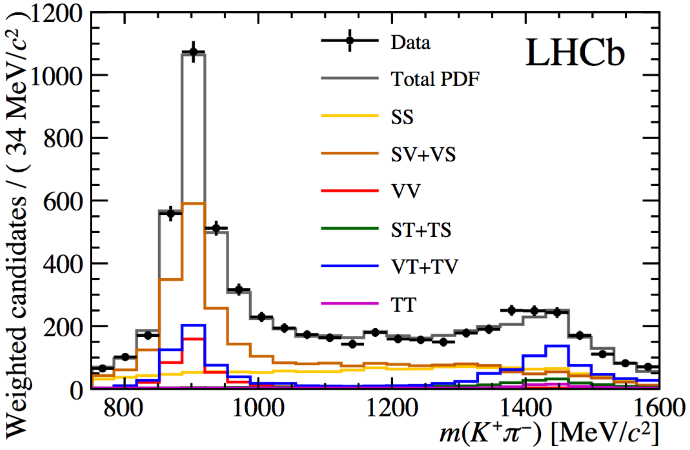
- First measurement of $\phi_s^{d\bar{d}}$, using $B_s^0 \to (K^+\pi^-)(K^-\pi^+)$ decays (including $B_s^0 \to K^{*0}\bar{K}^{*0}$), $\phi_s^{d\bar{d}}$ = **−0.10 ± 0.13 ± 0.14 rad**. [JHEP 1803 (2018) 140]

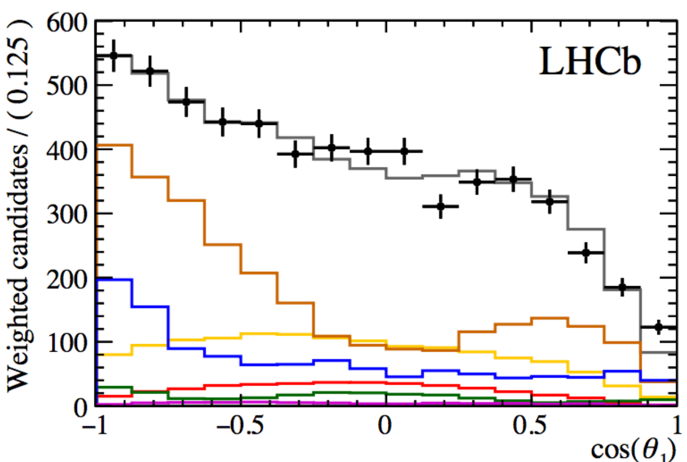
- CP-asymmetry determination: $|\lambda|$ = **1.035 ± 0.034 ± 0.089**.

- Compatible with SM.

- Additional 37 observables, including polarization amplitudes. Confirmed low longitudinal VV polarization:

$$f_L = 0.208 \pm 0.032 \pm 0.046$$





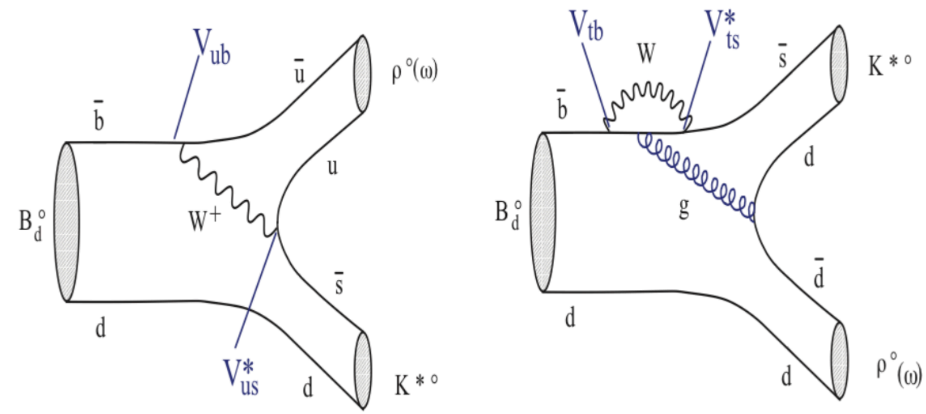
JHEP 1803 (2018) 140

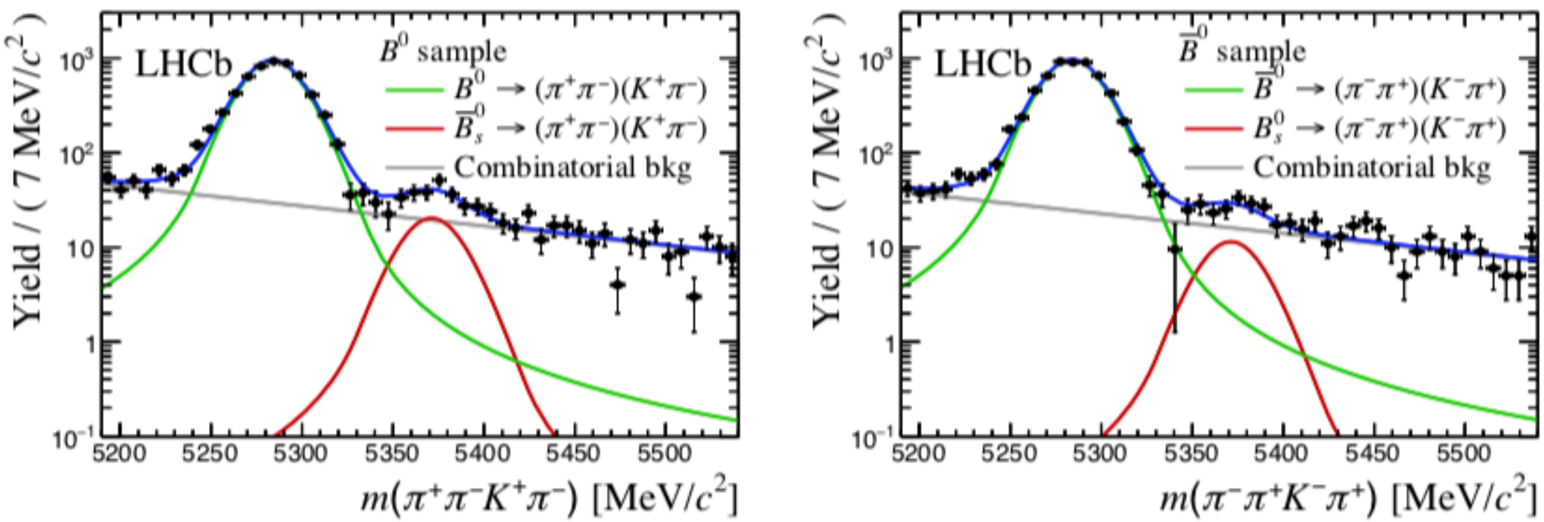
$B^0 \to \rho^0 K^{*0}$

arXiv:1812.07008

María Vieites PhD

- Proceeds via:
  - A doubly Cabibbo suppressed tree
  - A gluonic b → s penguin
- Vector partner of $B^0 \to K\pi$
- **Self tagged mode!**
- World largest data sample by more than one order of magnitude increase from precedent studies.
- Triple products very sensitive to BSM.





$\sim 11k$ signal events in $B^0 + \overline{B}^0$

$B^0 \to \rho^0 K^{*0}$

arXiv:1812.07008

María Vieites PhD

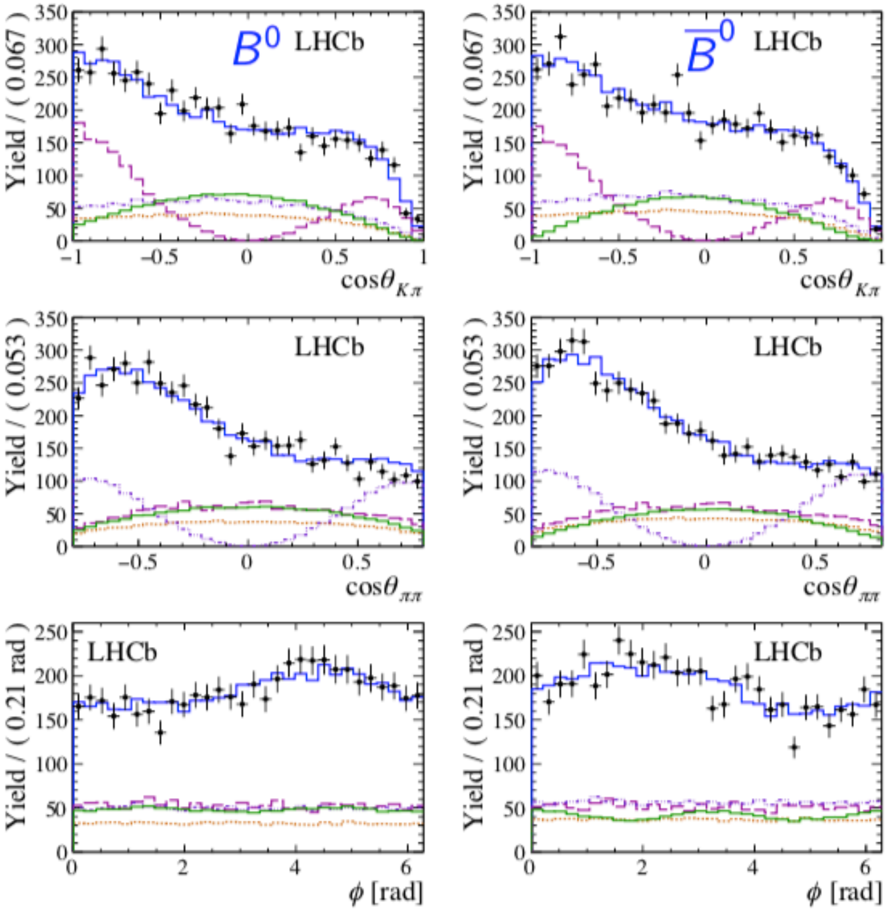
VV: $\rho K^*, \omega K^*$

VS: $\rho(K\pi), \omega(K\pi)$

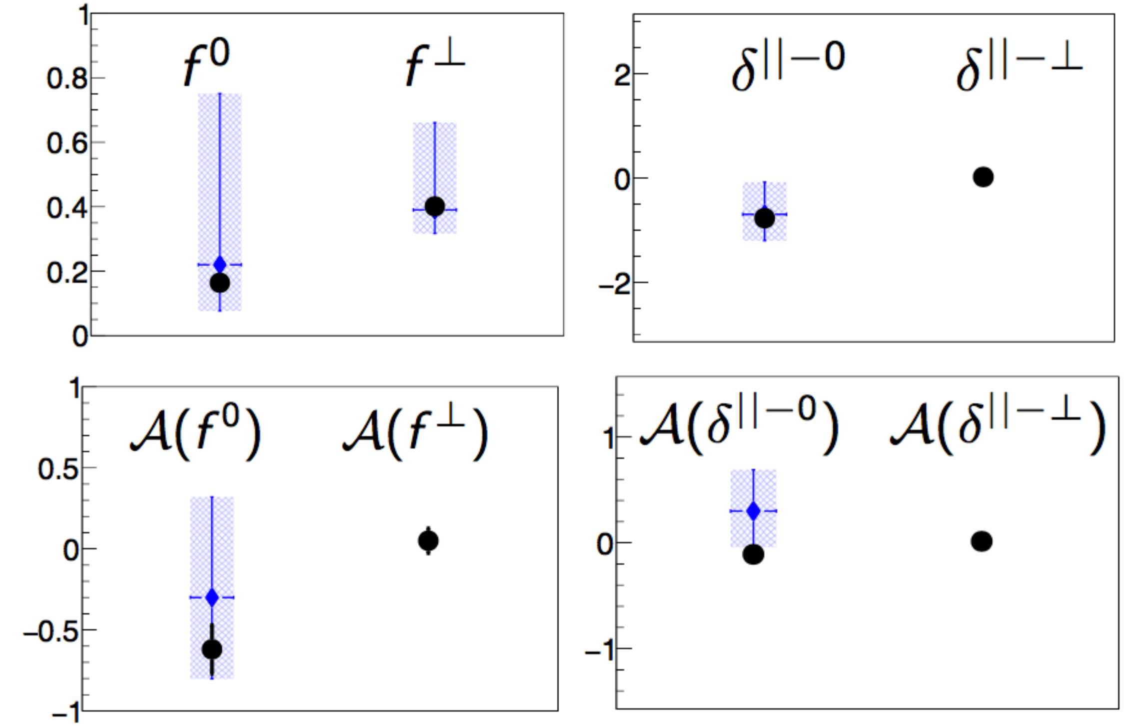
SV: $[f_0(500), f_0(980), f_0(1370)]K^*$

SS: $[f_0(500), f_0(980), f_0(1370)](K\pi)$

- 5D model (2-body invariant masses + helicity angles):
  - 14 amplitudes describing $B^0 \to (\pi^+\pi^-)(K^+\pi^-)$ decays in the quasi-two-body approach using the Isobar model.
- Amplitude fit:
  - Un-binned ML fit simultaneous in year and trigger categories for B^0 and anti-B^0 (8 subsamples) using **MultiNest.**
  - LHCb acceptance accounted for with simulation.
- Systematic uncertainties:
  - Dominant: *VV* channels, $B^0 \to a_1(1260)^- K^+$ + pollution; *S*-waves, parameters in the mass propagators and experimental resolution.



$B^0 \to \rho^0 K^{*0}$

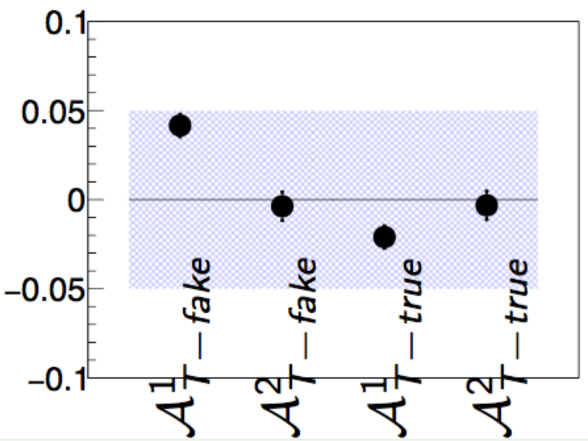


Fit results (stats. and syst. uncertainties included)

Theoretical predictions (QCDF) with uncertainties

Nucl.Phys.B774:64,2007

Strong and weak phase differences ($\delta^{||-\perp}$) between perpendicular and parallel polarization amplitudes found to be very small, in agreement with theory prediction.



Int.J.Mod.Phys.A19:2505,2004

	Observable	QCDF from Ref. [4]	pQCD from Ref. [11]	This work
$f^0_{\rho K^*}$	CP average	$0.22^{+0.03+0.53}_{-0.03-0.14}$	$0.65^{+0.03+0.03}_{-0.03-0.04}$	$0.164 \pm 0.015 \pm 0.016$
	CP asymmetry	$-0.30^{+0.11+0.61}_{-0.11-0.49}$	$0.0364^{+0.012}_{-0.011}$	$-0.62 \pm 0.09 \pm 0.12$
$f^\perp_{\rho K^*}$	CP average	$0.39^{+0.02+0.27}_{-0.02-0.07}$	$0.169^{+0.027}_{-0.018}$	$0.401 \pm 0.016 \pm 0.027$
	CP asymmetry	$--$	$-0.0771^{+0.0197}_{-0.0186}$	$0.050 \pm 0.039 \pm 0.066$
$\delta^{\|\|-0}_{\rho K^*}$	Strong phase [rad]	$-0.7^{+0.1+1.1}_{-0.1-0.8}$	$-1.61^{+0.02}_{-3.06}$	$-0.772 \pm 0.085 \pm 0.047$
	Weak phase [rad]	$0.30^{+0.09+0.38}_{-0.09-0.33}$	$-0.001^{+0.017}_{-0.018}$	$-0.109 \pm 0.085 \pm 0.047$
$\delta^{\|\|-\perp}_{\rho K^*}$	Strong phase [rad]	$\equiv 0$	$0.01^{+0.02}_{-4.3}$	$3.160 \pm 0.035 \pm 0.034$
	Weak phase [rad]	$\equiv 0$	$-0.003^{+0.025}_{-0.024}$	$0.014 \pm 0.035 \pm 0.034$

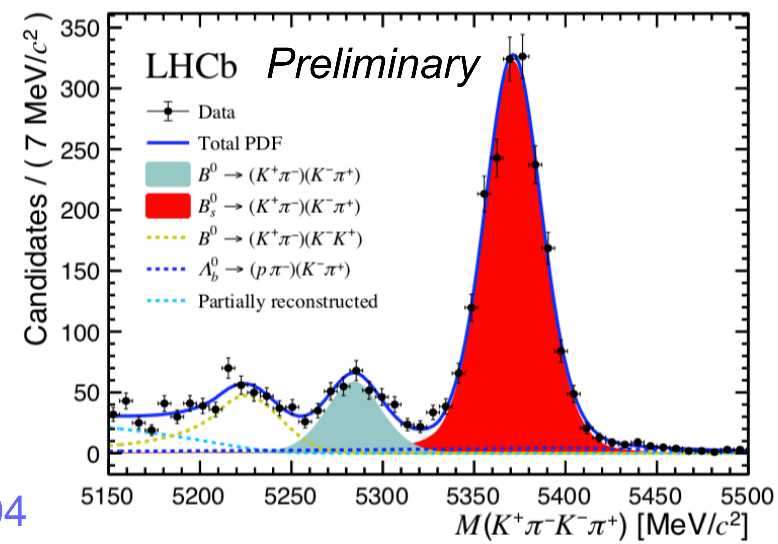
$B^0 \to K^{*0}\bar{K}^{*0}$

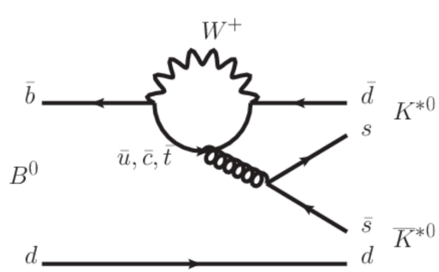
- U-spin partner of $B_s^0 \to K^{*0}K^{*0}$ decay.
  - Can be used to control penguin pollution from subleading amplitudes
- First LHCb analysis of $B^0 \to K^{*0}K^{*0}$.
  - Evidence by BaBar with
    $\mathcal{B} = (1.28\,^{+\,0.35}_{-\,0.30} \pm 0.11) \times 10^{-6}$
    $f_L = 0.80\,^{+\,0.10}_{-\,0.12} \pm 0.06$
  - Also analyzed by Belle with
    $\mathcal{B} = (0.26\,^{+\,0.33}_{-\,0.29}\,^{+\,0.10}_{-\,0.08}) \times 10^{-6}$
- Longitudinal polarization very high compared with $B_s^0 \to K^{*0}K^{*0}$.
- Untagged and time-integrated analysis.
- Assuming $\Delta\Gamma \sim 0$ and CP violation negligible in the mixing and in the decay.

$$\frac{d^5\Gamma}{d\cos\theta_1 d\cos\theta_2 d\phi dm_1 dm_2} = \frac{9}{8\pi}\sum_{i=1}^{6}\sum_{j\geq i}\mathcal{R}e[A_i A_j^* F_{ij}\delta_{\eta_i\eta_j}]$$

$$F_{ij} = \Phi_4(m_1, m_2) f_i f_j^* (2 - \delta_{ij})$$

i	A_i	f_i
1	A_0	$\cos\theta_1 \cos\theta_2 \mathcal{M}_1(m_1)\mathcal{M}_1(m_2)$
2	$A_{\parallel}$	$\frac{1}{\sqrt{2}} \sin\theta_1 \sin\theta_2 \cos\phi \mathcal{M}_1(m_1)\mathcal{M}_1(m_2)$
3	$A_{\perp}$	$\frac{i}{\sqrt{2}} \sin\theta_1 \sin\theta_2 \sin\phi \mathcal{M}_1(m_1)\mathcal{M}_1(m_2)$
4	A_S^+	$-\frac{1}{\sqrt{6}}(\cos\theta_1 \mathcal{M}_1(m_1)\mathcal{M}_0(m_2) - \cos\theta_2 \mathcal{M}_0(m_1)\mathcal{M}_1(m_2))$
5	A_S^-	$-\frac{1}{\sqrt{6}}(\cos\theta_1 \mathcal{M}_1(m_1)\mathcal{M}_0(m_2) + \cos\theta_2 \mathcal{M}_0(m_1)\mathcal{M}_1(m_2))$
6	A_{SS}	$-\frac{1}{3}\mathcal{M}_0(m_1)\mathcal{M}_0(m_2)$

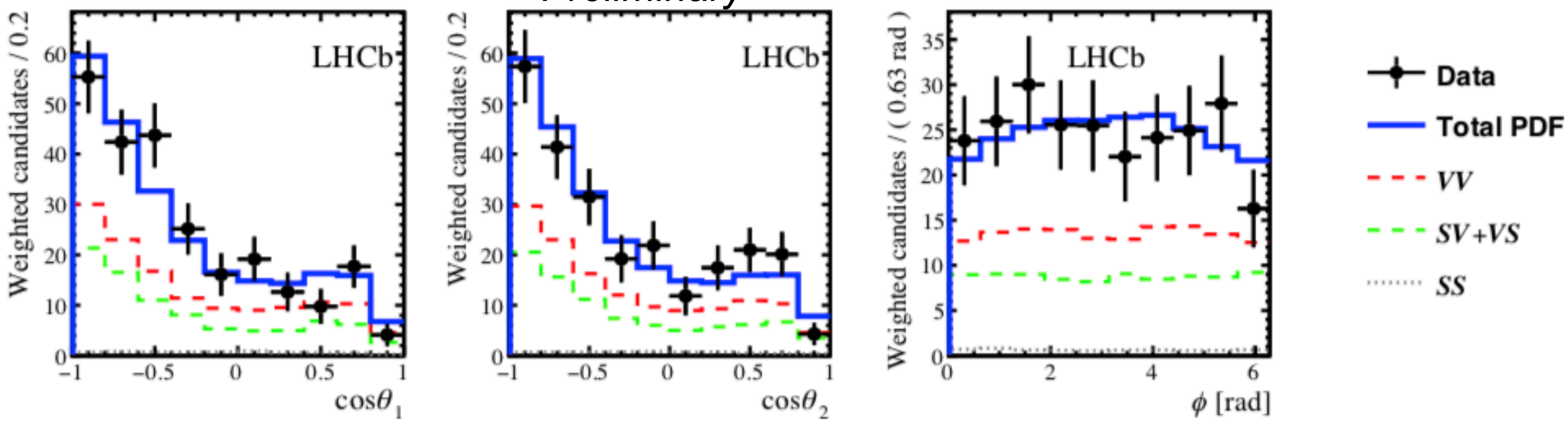




LHCb-PAPER-2019-004
Brais Sanmartín PhD

$B^0 \to K^{*0}\bar{K}^{*0}$

Preliminary



Parameter	$B^0 \to K^{*0}\overline{K}^{*0}$	$B_s^0 \to K^{*0}\overline{K}^{*0}$
f_L	$0.724 \pm 0.051 \pm 0.016$	$0.240 \pm 0.031 \pm 0.025$
$x_{f_\parallel}$	$0.42 \pm 0.10 \pm 0.03$	$0.307 \pm 0.031 \pm 0.010$
$\|A_S^-\|^2$	$0.377 \pm 0.052 \pm 0.024$	$0.558 \pm 0.021 \pm 0.014$
$x_{\|A_S^+\|^2}$	$0.013 \pm 0.027 \pm 0.011$	$0.109 \pm 0.028 \pm 0.024$
$x_{\|A_{SS}\|^2}$	$0.038 \pm 0.022 \pm 0.006$	$0.222 \pm 0.025 \pm 0.031$
$\delta_\parallel$	$2.51 \pm 0.22 \pm 0.06$	$2.37 \pm 0.12 \pm 0.06$
$\delta_\perp - \delta_S^+$	$5.44 \pm 0.86 \pm 0.22$	$4.40 \pm 0.17 \pm 0.07$
δ_S^-	$5.11 \pm 0.13 \pm 0.04$	$1.80 \pm 0.10 \pm 0.06$
δ_{SS}	$2.88 \pm 0.35 \pm 0.13$	$0.99 \pm 0.13 \pm 0.06$
$f_\parallel$	$0.116 \pm 0.033 \pm 0.012$	$0.234 \pm 0.025 \pm 0.010$
$f_\perp$	$0.160 \pm 0.044 \pm 0.012$	$0.526 \pm 0.032 \pm 0.019$
$\|A_S^+\|^2$	$0.008 \pm 0.013 \pm 0.007$	$0.048 \pm 0.014 \pm 0.011$
$\|A_{SS}\|^2$	$0.023 \pm 0.014 \pm 0.004$	$0.087 \pm 0.011 \pm 0.011$
S–wave fraction	$0.408 \pm 0.050 \pm 0.017$	$0.694 \pm 0.016 \pm 0.010$

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Brais Sanmartín PhD

$B^0 \to K^{*0}\overline{K}^{*0}$

- The accumulated candidates sample is about seven times larger than the precedent ones.
- f_L = 0.724 ± 0.051 (stat.) ± 0.016 (syst.).
- The decay branching fraction is determined improving the previous statistical uncertainty by a factor 2:

$$\mathcal{B}(B^0 \to K^{*0}\overline{K}^{*0}) = (8.0 \pm 0.9\,(\mathrm{stat}) \pm 0.4\,(\mathrm{syst})) \times 10^{-7}$$

- The previous two measurements, in conjunction with the $B_s^0 \to K^{*0}K^{*0}$ results allow to estimate the longitudinal branching fraction ratio:

$$R_{sd} = \frac{\mathcal{B}(B_s^0 \to K^{*0}\overline{K}^{*0}) f_L(B_s^0 \to K^{*0}\overline{K}^{*0})}{\mathcal{B}(B^0 \to K^{*0}\overline{K}^{*0}) f_L(B^0 \to K^{*0}\overline{K}^{*0})} \frac{1-y^2}{1+y\cdot\cos\phi_s}$$

$$R_{sd} = 3.48 \pm 0.32\,(\mathrm{stat}) \pm 0.19\,(\mathrm{syst}) \pm 0.08\,(f_d/f_s) \pm 0.02\,(y,\phi_s) = 3.48 \pm 0.38$$

- There is a theoretical prediction for it:

$$R_{sd}^{\mathrm{theory}} = 16.4 \pm 5.2$$

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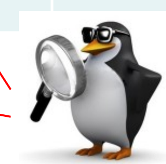
S. Descotes-Genon, J. Matias, and J. Virto, Phys.Rev.D76(2007)074005,arXiv:0705.0477.

Polarization Summary of $B \to V_1 V_2$

- Large Longitudinal polarization confirmed in $b \to u$ tree dominated decays ($f_L \sim 1$) .
- Penguin decays show intermediate-small longitudinal polarization fractions.
  - Exception in $B^0 \to K^{0*}\overline{K}^{*0}$.
  - Polarization puzzle.
  - Would $b \to d q\bar{q}$ show higher f_L than $b \to s q\bar{q}$ penguins?

=0.716+0.051-0.052

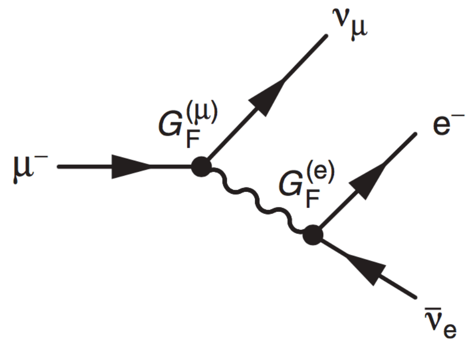
Decay	$B^0 \to \rho^+\rho^-$ BaBar	$B^0 \to \rho^0\rho^0$ BaBar-Belle-LHCb	$B^0 \to \rho^0 K^{*0}$ BaBar LHCb	$B_s^0 \to \phi\phi$ LHCb-CDF	$B_s^0 \to K^{*0}\overline{K}^{*0}$ LHCb	$B^0 \to K^{0*}\overline{K}^{*0}$ BaBar LHCb (prel.)	$B^0 \to \phi K^{*0}$ BaBar-Belle-LHCb	$B_s^0 \to \phi \overline{K}^{*0}$ LHCb
f_L	$0.978^{+0.025}_{-0.022}$	$0.714^{+0.055}_{-0.062}$ USC	0.40±0.14 0.164±0.022 USC	0.361±0.022	0.201±0.070 USC	$0.80^{+0.12}_{-0.13}$ 0.724±0.053 USC	0.497±0.017 USC	0.51±0.16 USC

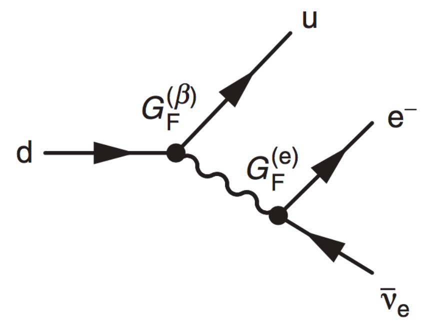


$b \to d q\bar{q}$ penguin contribution

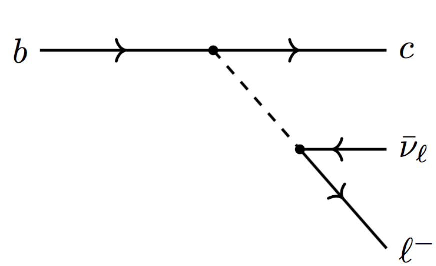
Lepton Flavor Universality

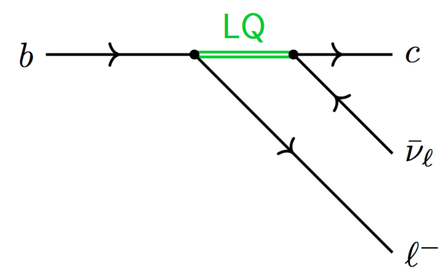
- In the SM the weak interaction to charged leptons and the corresponding neutrino is universal ($G^{(e)} = G^{(\mu)} = G^{(\tau)}$).
  - Confirmed with high precision in $Z^0 \rightarrow l^+l^-$



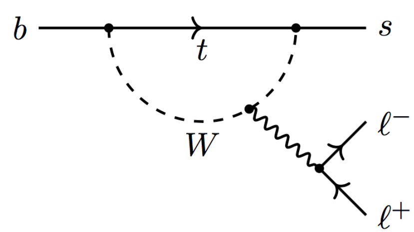


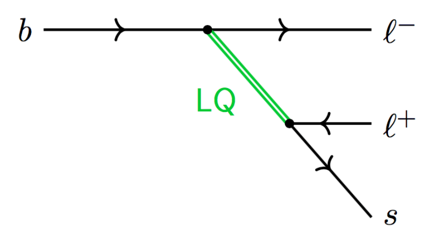
- NP: could violate LU.
  - Charged Higgs.
  - Heavy W (W′).
  - Leptoquarks…
- Lepton universality tests in **tree-level decays**.
  - Abundant $b \rightarrow cl\nu$ semileptonic decay.
  - Well known in the SM.
  - Possible NP coupling mainly to 3rd family.





- Lepton universality tests in **rare (loop-level) decays.**
  - $b \rightarrow sll$
  - Forbidden at tree-level in SM
  - Sensitive to NP contributions in loops



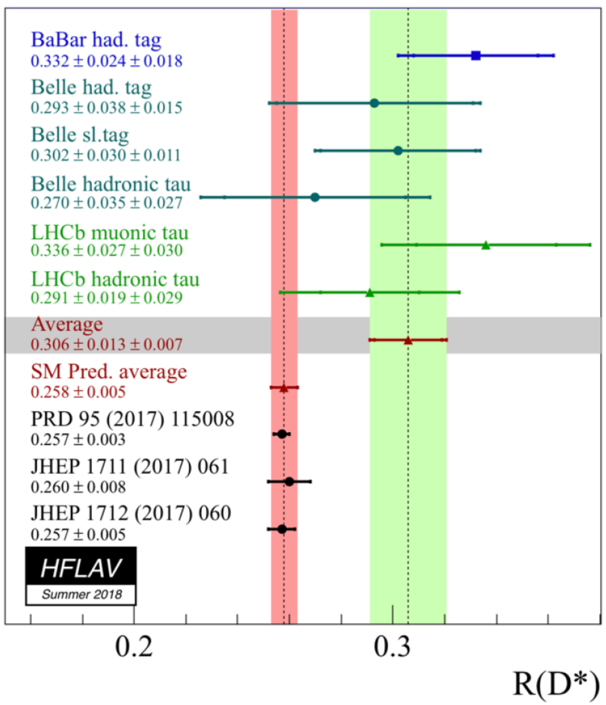


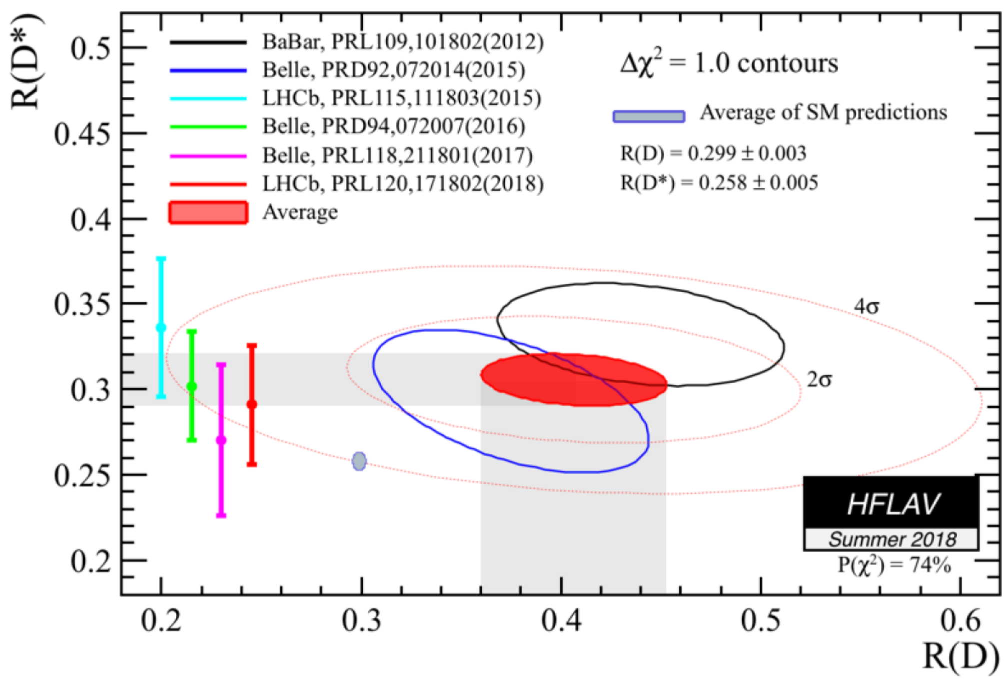
Lepton Flavor Universality

Test of LFU at tree level. Sensitive to charged Higgs bosons and leptoquarks

$$R(D^{(*)}) = \frac{\mathcal{B}(\bar{B}^0 \to D^{(*)+} \boldsymbol{\tau^-} \bar{\nu}_\tau)}{\mathcal{B}(\bar{B}^0 \to D^{(*)+} \boldsymbol{\mu^-} \bar{\nu}_\mu)}$$

- *Measurement of the ratio of the $\boldsymbol{B^0 \to D^{*-}\tau^+\nu_\tau}$ and $\boldsymbol{B^0 \to D^{*-}\mu^+\nu_\mu}$ branching fractions using three-prong tau-lepton decays,* ***Phys. Rev. Lett. 120, 17802 (2018).***
- *Test of lepton flavour universality by the measurement of the $\boldsymbol{B^0 \to D^{*-}\tau^+\nu_\tau}$ branching fraction using three-prong decays,* ***Phys. Rev. D 97, 072013 (2018).***
- Review of Lepton Universality tests in B decays. ***J.Phys. G46 (2019) no.2, 023001.***

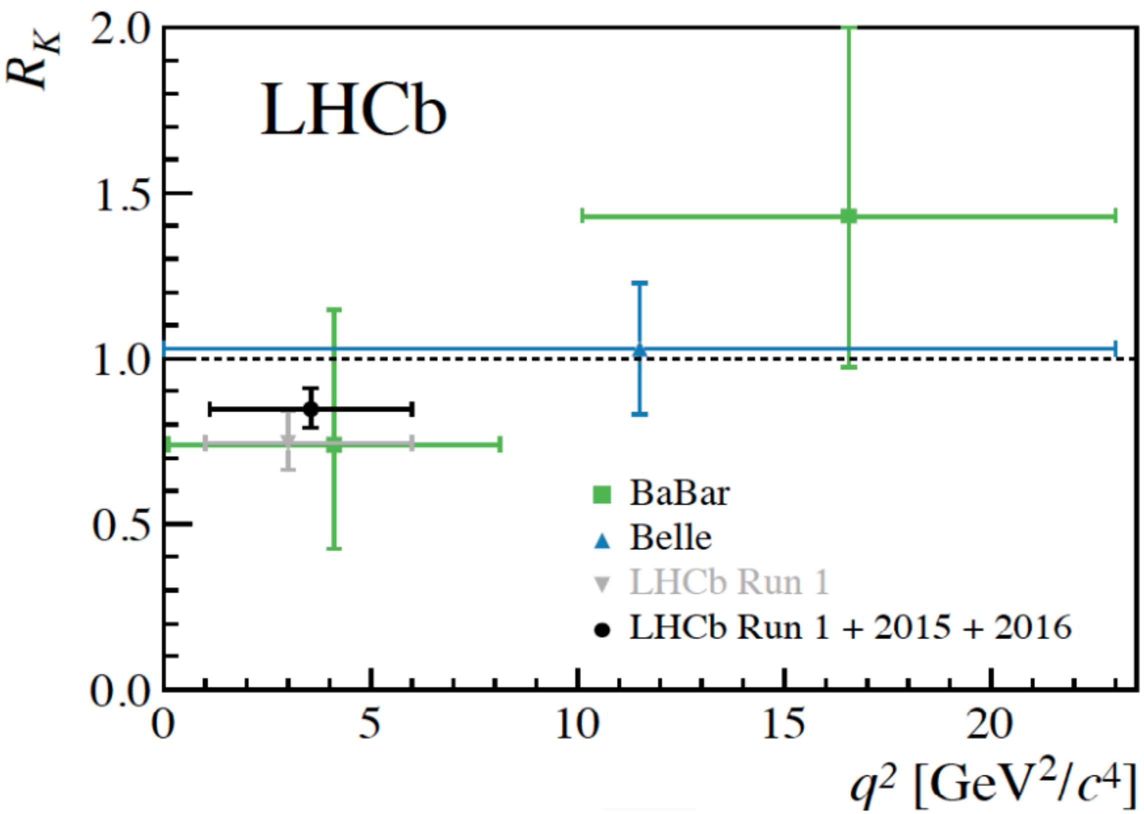




Lepton Universality in rare decays, R_K

$$R_K \equiv \frac{B(B^+ \to K^+\mu^+\mu^-)}{B(B^+ \to K^+e^+e^-)}$$

- **Theoretically clean**
- **Stringent test of LFU**



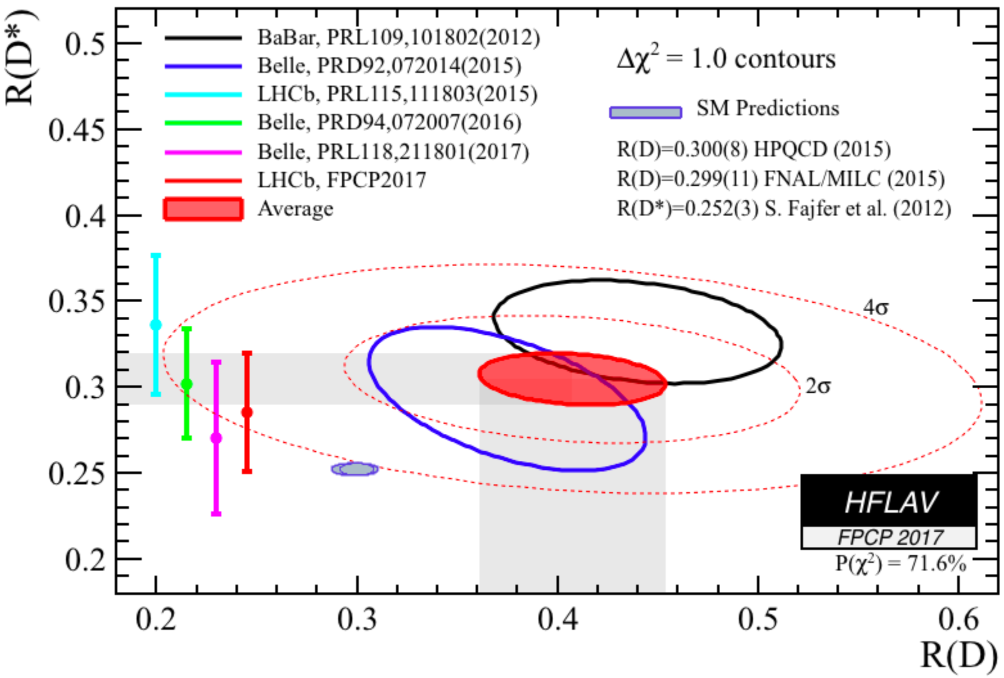
•LHCb update

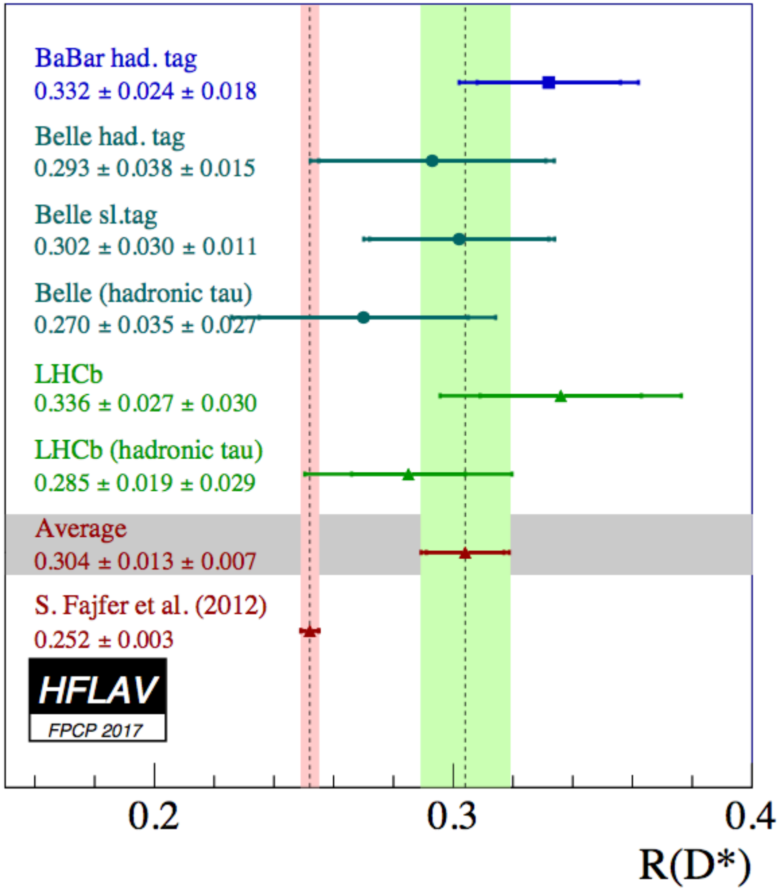
$$R_K^{[1.1,6]} = 0.846^{+0.060+0.016}_{-0.054-0.014}$$

•From 2.6σ to 2.5σ deviation wrt SM

Summary of R_D and R_{D*}

- Average of different final states an experiments.
- Including additional measurements, discrepancy of **4.1σ**. With SM.
- Possible BSM scenarios (H^+, W′, LQs).





Proton-lead collisions

Nuclear modification factor.

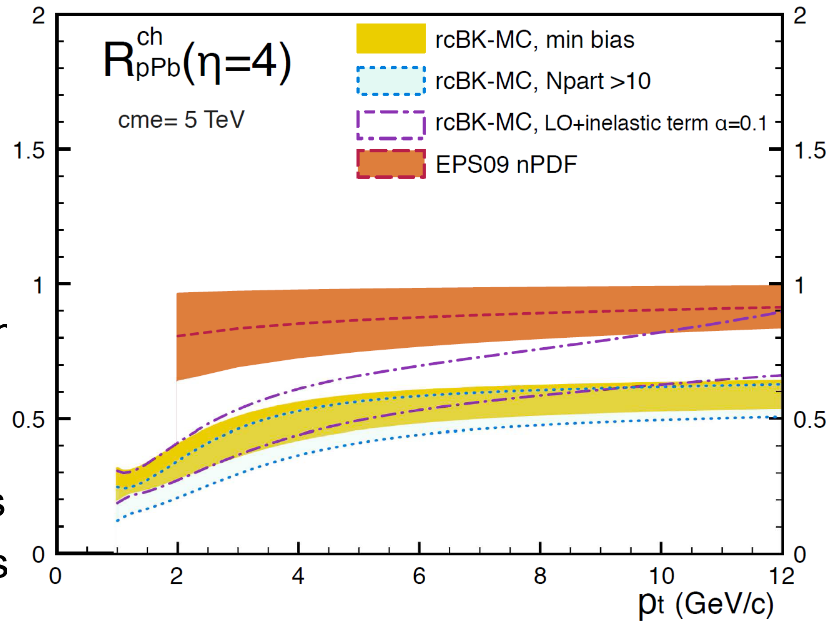
For a incoherent superposition of nucleon-nucleon collisions $R_{\mathbf{pPb}} = \mathbf{1}$

Study **prompt charged** particle production.

Charged particle multiplicities can yield informatior on Cold Nuclear Matter effects (**CNM**) in **p-Pb** collisions.

CNM effects are also expected in **Pb-Pb** collisions

LHCb can access uncovered phase space regions



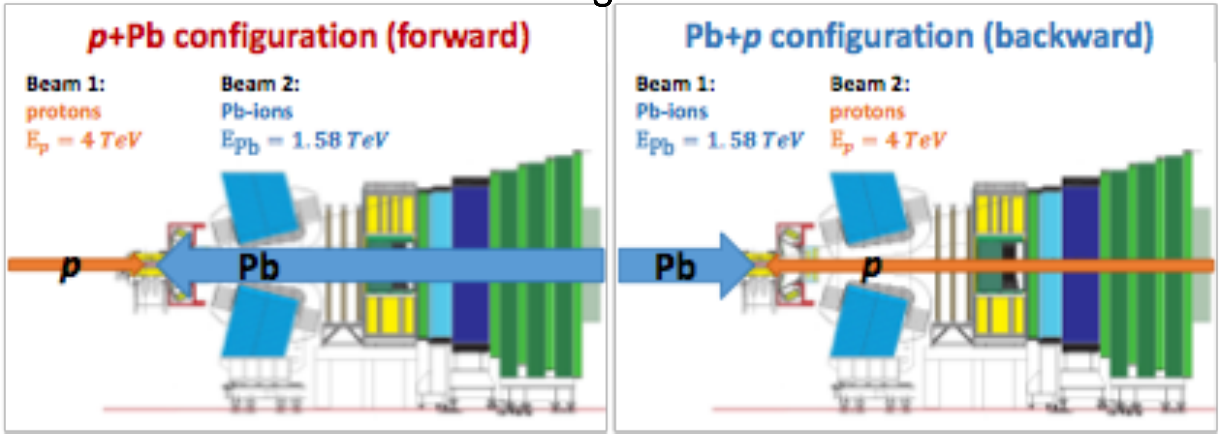
J. L. Albacete, C. Marquet doi:10.1016/j.ppnp.2014.01.004

Three different observables can be measured in different ranges

$$R_{p\mathrm{Pb}}, \quad 1.5 < \eta < 4.5$$

$$R_{\mathrm{Pb}p}, \quad 2.5 < \eta < 5.5$$

$$R_{\mathrm{FB}} = \frac{R_{p\mathrm{Pb}}}{R_{\mathrm{Pb}p}}, \quad 2.5 < \eta < 4.5$$

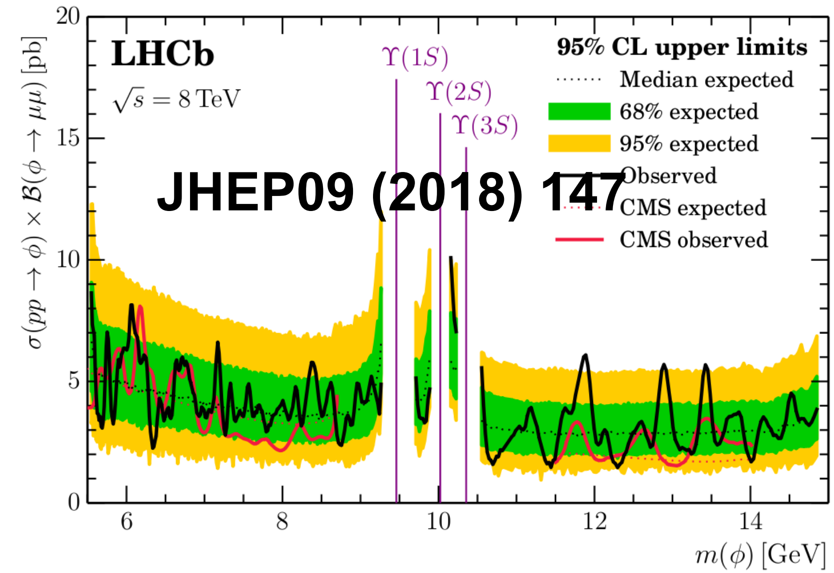


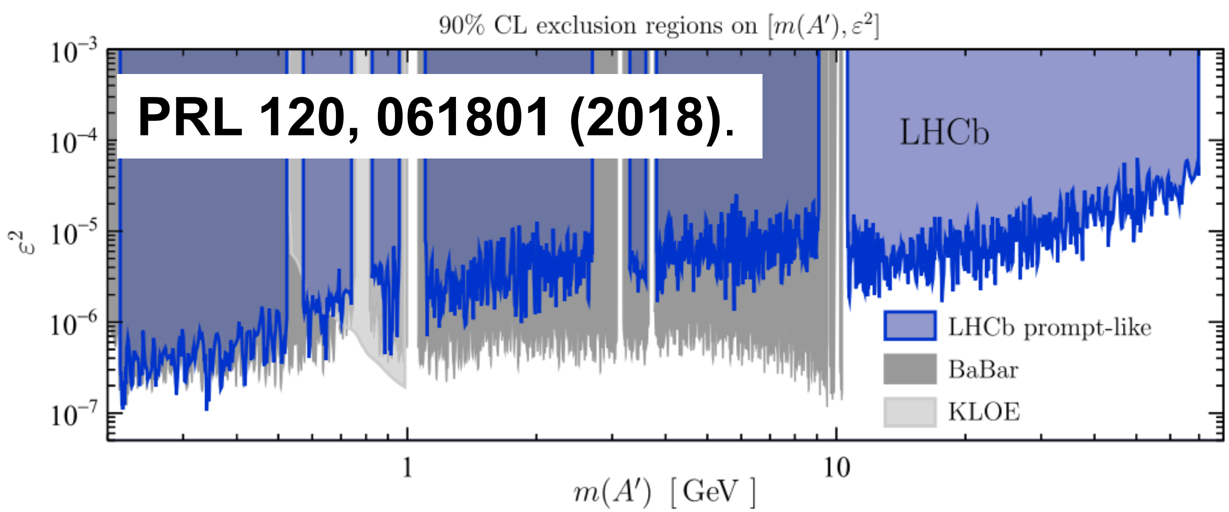
BSM searches

Exotica

BSM Higgses (→ **WP2 de ERC-StG**)

Dark photons, Axion Like Particles…





Carlos Vázquez PhD

Xabier Cid coordination

Rare decays (kaon et al.)

- Expertise in identification, online tracking and trigger.
- Low pt muon trigger (~80 MeV)
  - Use LHCb as a leading experiment in kaons/hyperons (**ERC-StG**)

PERIOD	Efficiency ($K \rightarrow \mu\mu$)
2011	~ 1%
2012	~2.4 %
Run-II (expected)	~18 %
Full sw trigger	O(100%)

Summary

- The LHCb upgrade is ongoing.
  - Santiago is deeply committed to the new VELO commissioning.
    - Also construction and instalation.
  - Involvement in the HLT upgrade proposed also.
- LHCb Santiago has a wide physics program at LHCb.
  - It has produced many results, some of them among the most cited.