Beyond the SM searches with LHCb. Highlights from 2018.

High Energy Physics Group

Universidade de Santiago de Compostela (USC)
Instituto Galego de Física de Altas Enerxías (IGFAE)

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USC
UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

XUNTA DE GALICIA

gain
AXENCIA DE INNOVACIÓN

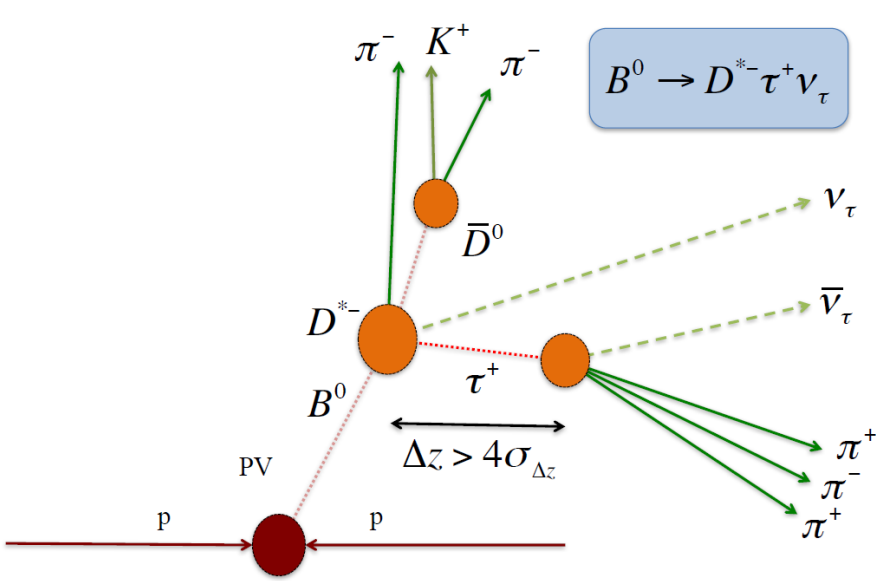
EXCELENCIA MARÍA DE MAEZTU

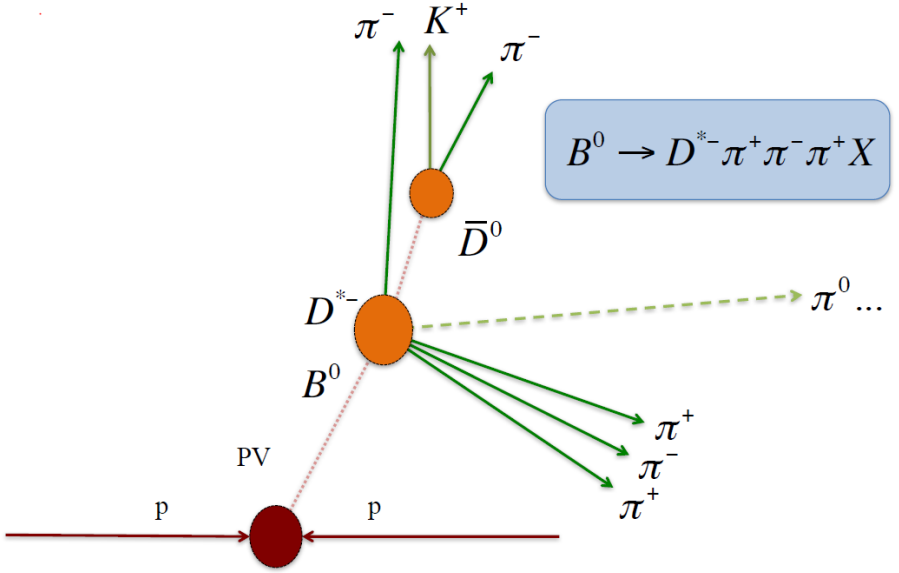
Lepton flavour universality tests

- *Measurement of the ratio of the $B^0 \to D^{*-}\tau^+\nu_\tau$ and $B^0 \to D^{*-}\mu^+\nu_\mu$ branching fractions using three-prong tau-lepton decays,* ***Phys. Rev. Lett. 120, 17802 (2018).***

- *Test of lepton flavour universality by the measurement of the $B^0 \to D^{*-}\tau^+\nu_\tau$ 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.***





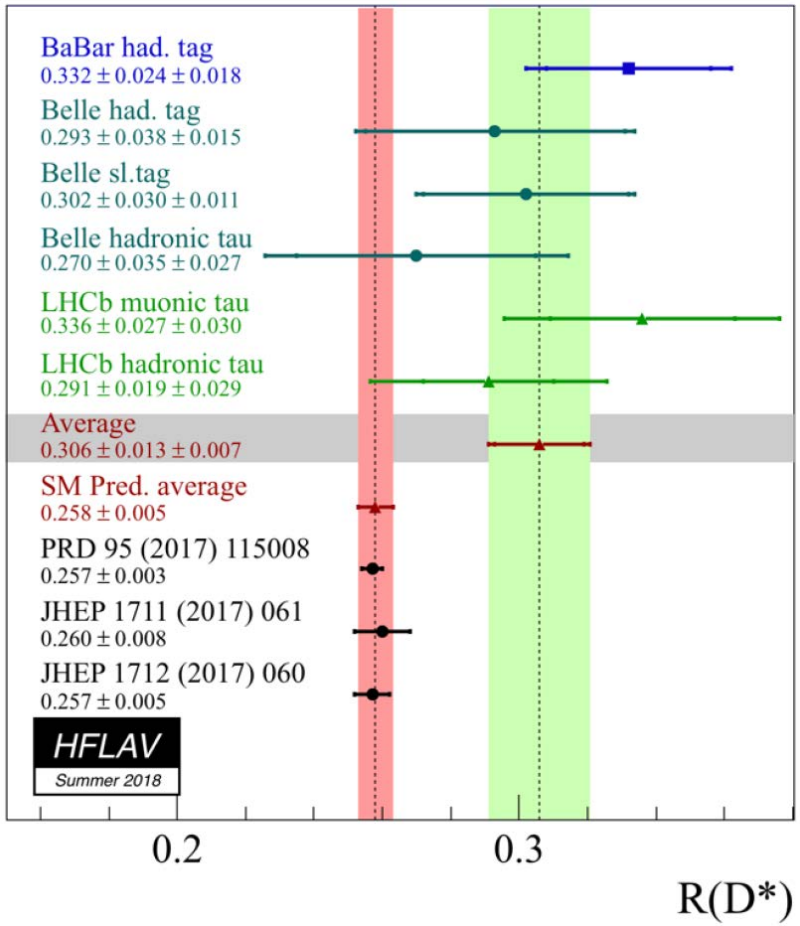
$$K_{had}(D^*) = \frac{BR(B^0 \to D^{*-}\tau^+\nu_\tau)}{BR(B^0 \to D^{*-}\pi^+\pi^-\pi^+)}$$

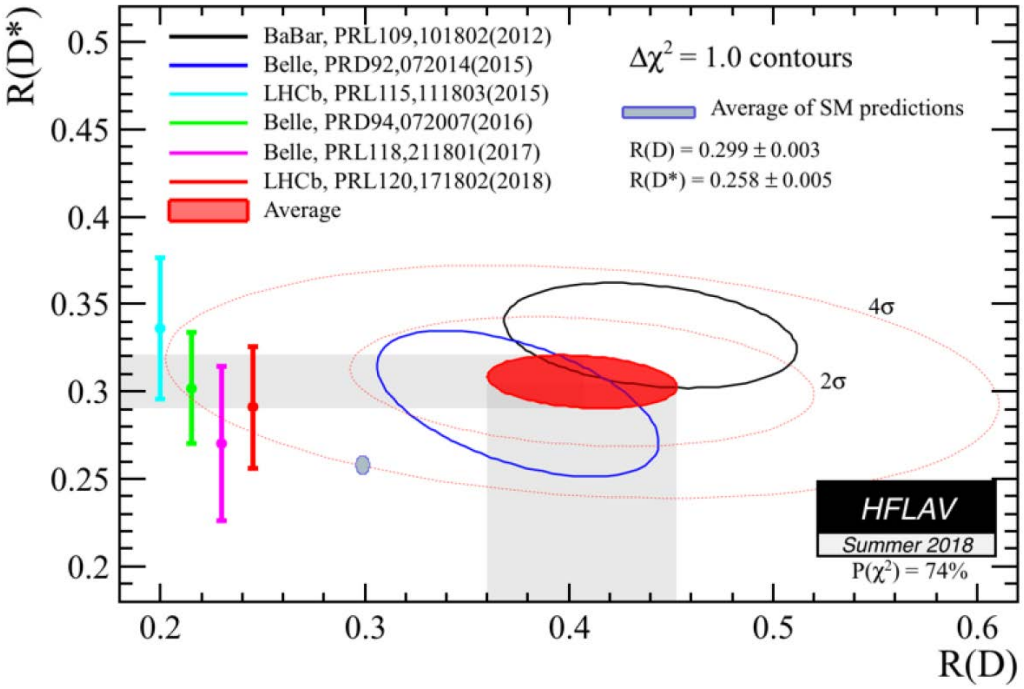
$$R(D^*) = K_{had}(D^*) \times \frac{BR(B^0 \to D^{*-}\pi^+\pi^-\pi^+)}{BR(B^0 \to D^{*-}\mu^+\nu_\mu)}$$

$$R(D^*) = 0.291 \pm 0.019 \pm 0.028$$

$$R(D^*)^{SM} = 0.258 \pm 0.005$$

Lepton flavour universality tests





$R(D^*)$ World average **3.0 σ above SM prediction.**

$R(D^*) + R(D)$ measurements show an **overall 3.8 σ tension with the SM**.

New measurements in a variety of decay channels are being performed.

CP-violating phase in $B_s^0 \to (K^+\pi^-)(K^-\pi^+)$ decays

First measurement of the CP-violating pase $\phi_s^{d\bar{d}}$ in $B_s^0 \to (K^+\pi^-)(K^-\pi^+)$ decays, **JHEP03 (2018) 140**.

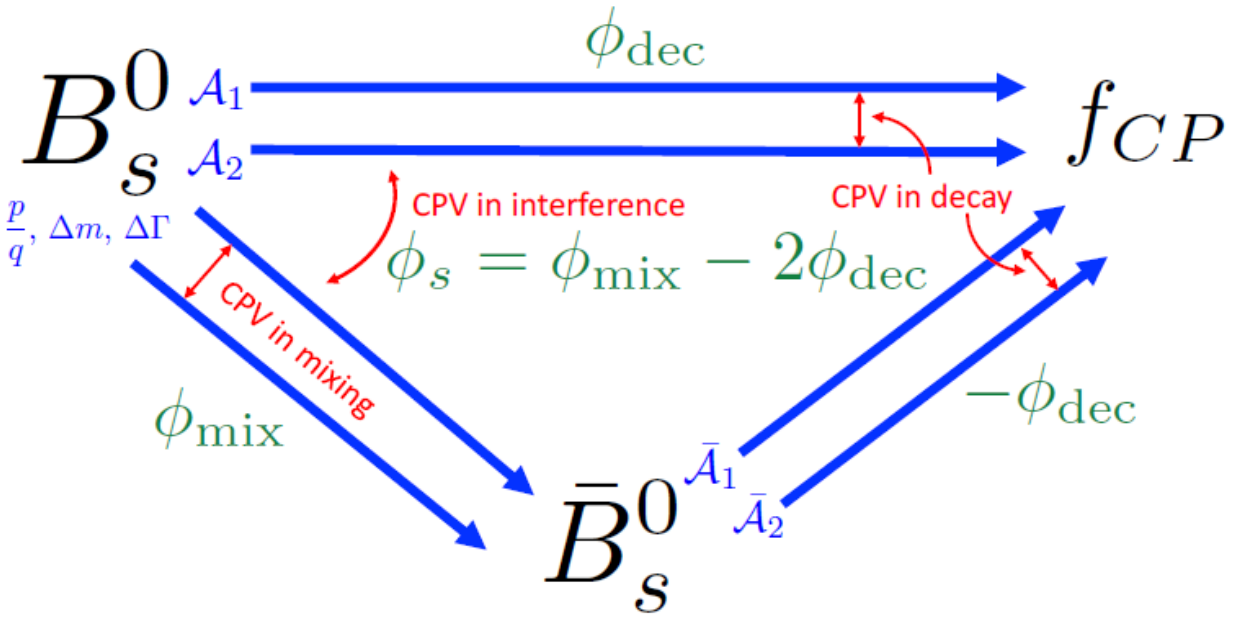
Julián García Pardiñas Thesis.

CPV in decay:

- $P(B_s^0 \to f) \neq P(\bar{B}_s^0 \to f)$
- $|\bar{\mathcal{A}}_f / \mathcal{A}_f| \neq 1$

CPV in mixing:

- $P(B_s^0 \to \bar{B}_s^0) \neq P(\bar{B}_s^0 \to B_s^0)$
- $|q/p| \neq 1$



CPV in the interference between decay and mixing:

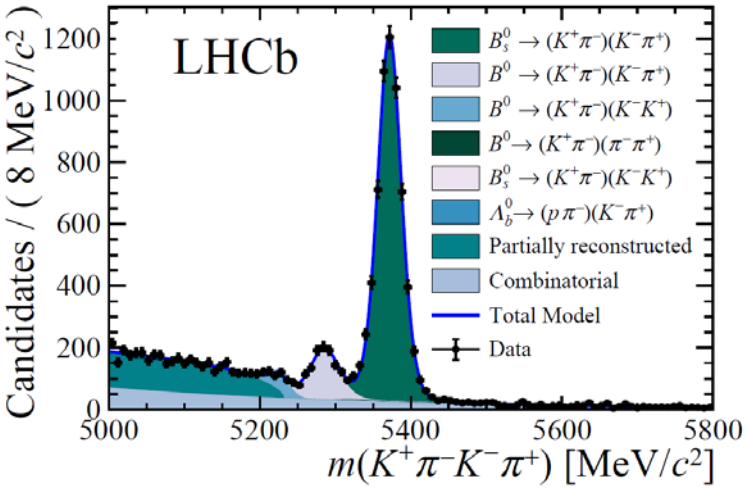
- $P(B_s^0 \to f) \neq P(B_s^0 \to \bar{B}_s^0 \to f)$
- $\arg(\lambda) \neq 0$

CP-violating phase in $B_s^0 \to (K^+\pi^-)(K^-\pi^+)$ decays

Very complex decay-time dependent angular analysis to 9 different final states and 19 interfering amplitudes.

Leading contribution of a penguin (loop) diagram

Decay
$B_s^0 \to (K^+\pi^-)_0^*(K^-\pi^+)_0^*$
$B_s^0 \to (K^+\pi^-)_0^*\overline{K}^*(892)^0$
$B_s^0 \to K^*(892)^0(K^-\pi^+)_0^*$
$B_s^0 \to (K^+\pi^-)_0^*\overline{K}_2^*(1430)^0$
$B_s^0 \to K_2^*(1430)^0(K^-\pi^+)_0^*$
$B_s^0 \to K^*(892)^0\overline{K}^*(892)^0$
$B_s^0 \to K^*(892)^0\overline{K}_2^*(1430)^0$
$B_s^0 \to K_2^*(1430)^0\overline{K}^*(892)^0$
$B_s^0 \to K_2^*(1430)^0\overline{K}_2^*(1430)^0$

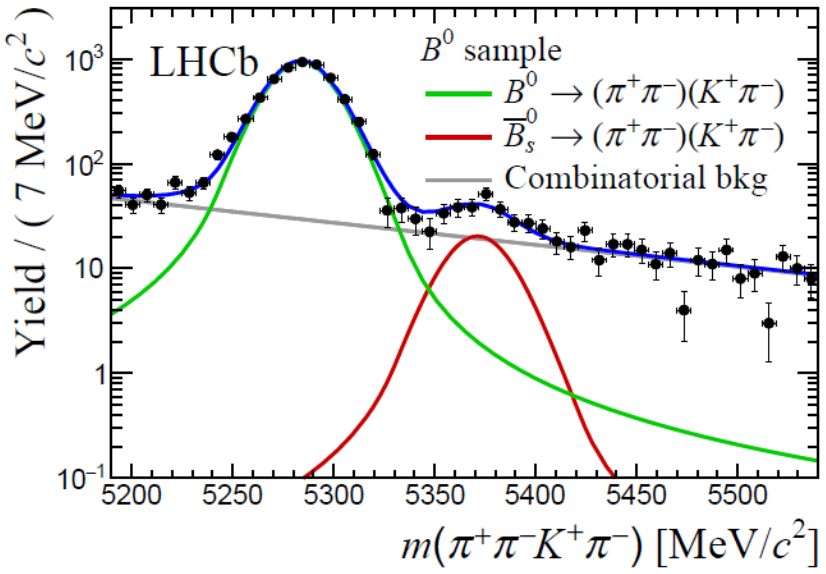


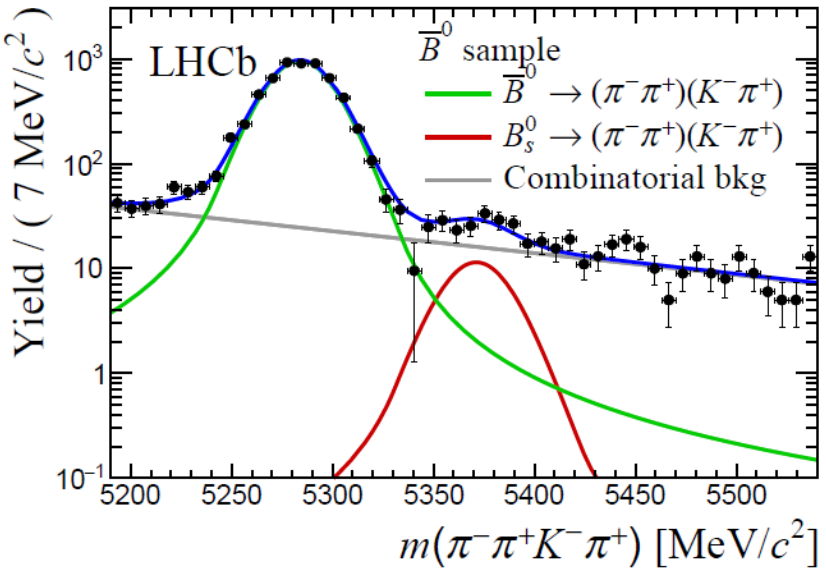
- Measure *CP*-averaged fractions, f, and strong phase differences, δ, for **19 different amplitudes**
- In particular:
  - $\mathbf{f_L^{VV} = 0.208 \pm 0.032 \pm 0.046}$ - small value (as in previous - [JHEP 07 (2015) 166])
  - $\mathbf{f^{SS} = 0.225 \pm 0.010 \pm 0.069}$ - large value
  - $\mathbf{f^{VV} = 0.067 \pm 0.040 \pm 0.024}$ - small value
- Measure CP-violation parameters
  - $\phi_s^{d\bar{d}} = (\mathbf{-0.10 \pm 0.13 \pm 0.14})\,\mathrm{rad}$
  - $|\lambda| = (\mathbf{1.035 \pm 0.034 \pm 0.089})$
- **SM wins again!**

Study of the $B_s^0 \to \rho(770)^0 K^*(892)^0$ decay

Study of the $B_s^0 \to \rho(770)^0 K^*(892)^0$ *decay with an amplitude analysis of* $B_s^0 \to (\pi^+\pi^-)(K^+\pi^-)$ decays, arXiv:1812.07008, **Submitted to JHEP**.

María Vieites Díaz Thesis.





- Fit model accounting for 10 decay channels leading to 14 interfering amplitudes. **Leading contribution of penguin (loop) diagrams**.

- **Small longitudinal polarisation fraction** and **significant direct CP asymmetry** measured in the $B_s^0 \to \rho(770)^0 K^*(892)^0$ decay mode.

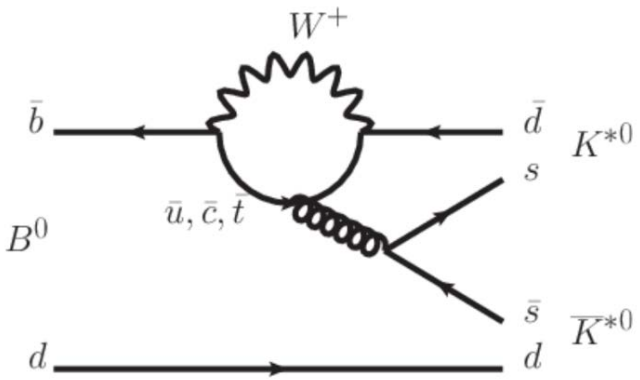
$$\tilde{f}^0_{\rho K^*} = 0.164 \pm 0.015 \pm 0.022 \quad \text{and} \quad \mathcal{A}^0_{\rho K^*} = -0.62 \pm 0.09 \pm 0.09$$

Study of the $B^0 \to (K^+\pi^-)(K^-\pi^+)$ decay

Paper to be submitted soon for publication (January 2019).

Brais Sanmartín Sedes Thesis.

- 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 $B^0 \to K^{*0}K^{*0}$.
- 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.



- A preliminary precision of **±0.051 (stat.) ± 0.016 (syst.)** is achieved in f_L.
- Also, the decay branching fraction is determined improving the previous statistical uncertainty by a factor of 2:

$$R_{sd} = \frac{\mathcal{B}(B_s^0 \to K^{*0}\overline{K}^{*0}) f_L(B_s^0 \to K^{*0}\overline{K}^{*0})}{\mathcal{B}(B^0 \to K^{*0}\overline{K}^{*0}) f_L(B^0 \to K^{*0}\overline{K}^{*0})} \frac{1-y^2}{1+y\cdot\cos\phi_s} = \boldsymbol{x.xx} \pm \mathbf{0.38}$$

$$y = \Delta\Gamma_s/(2\Gamma_s) \qquad R_{sd}^{\text{theory}} = 16.4 \pm 5.2$$

Heavy Ions in LHCb

Nuclear modification factor.
For a incoherent superposition of nucleon-nucleon collisions $R_{\mathrm{pPb}} = 1$

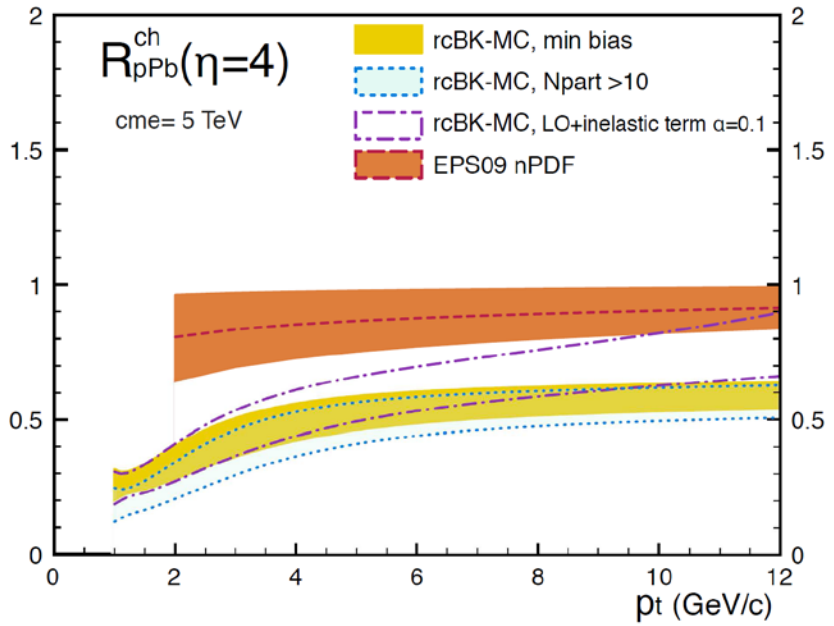
$$R_{pPb} = \frac{\frac{d^2\sigma_{pPb}}{dp_T d\eta}}{A\frac{d^2\sigma_{pp}}{dp_T d\eta}}$$

Study **prompt charged** particle production.

Charged particle multiplicities can yield information 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

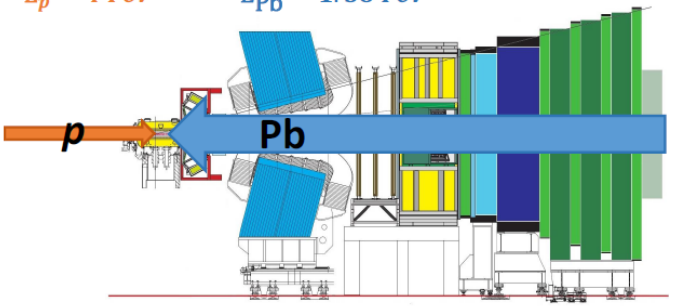
$$R_{pPb}, \quad 1.5 < \eta < 4.5$$

$$R_{Pbp}, \quad 2.5 < \eta < 5.5$$

$$R_{FB} = \frac{R_{pPb}}{R_{Pbp}}, \quad 2.5 < \eta < 4.5$$

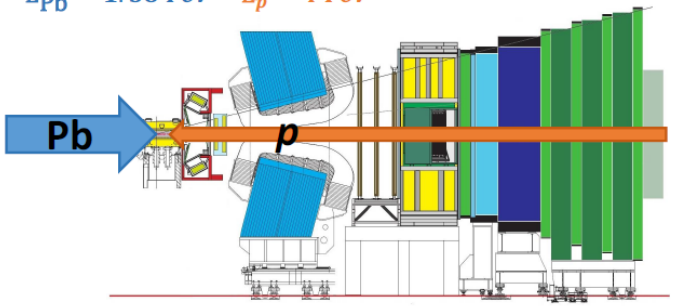
***p*+Pb configuration (forward)**

Beam 1: protons $E_p = 4\ TeV$
Beam 2: Pb-ions $E_{Pb} = 1.58\ TeV$



Pb+*p* configuration (backward)

Beam 1: Pb-ions $E_{Pb} = 1.58\ TeV$
Beam 2: protons $E_p = 4\ TeV$



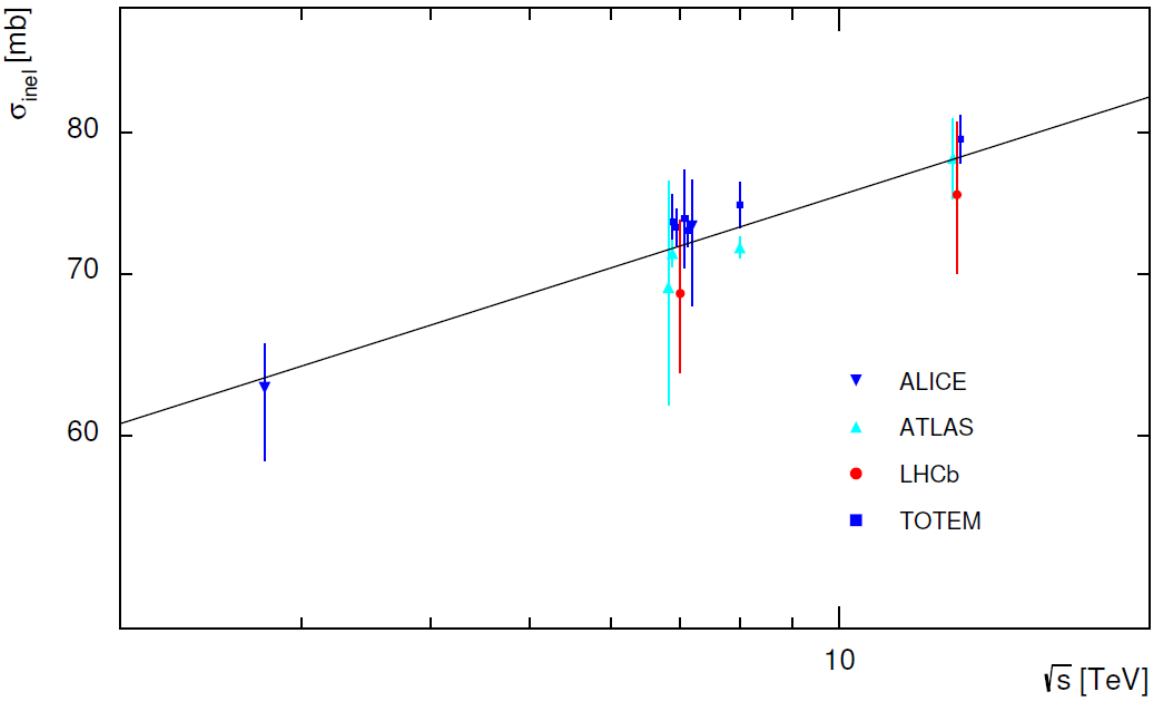
pp inelastic cross-section

*Measurement of the inelastic **pp cross-section*** at a centre-of-mass energy of 13 TeV, **JHEP06 (2018) 100**.

Part of Álvaro Dosil Suárez Thesis.

Fundamental quantity in the phenomenology of high-energy hadronic interactions.

Important also for the description of air showers induced by cosmic rays.



Fiducial cross-section $\sigma_{\rm acc}(\sqrt{s} = 13\,\text{TeV}) = 62.2 \pm 0.2 \pm 2.5(\text{lumi})\,\text{mb}$

Extrapolated **total cross-section** $\sigma_{\rm inel}(\sqrt{s} = 13\,\text{TeV}) = 75.4 \pm 3.0(\text{exp}) \pm 4.5(\text{extr})\,\text{mb}$

Publications, 2018

(A. A. Alves Junior, P. Baladron, M. Borsato, A. Brea Rodriguez A. Casais Vidal, V. Chobanova, X. Cid Vidal, J.Dalseno, M. Lucio Martinez, D. Martinez Santos, C. Prouve, M. Ramos Pernas, M. Romero Lamas)

"Search for dark photons produced in 13 TeV pp collisions", Phys. Rev. Lett. 120, 061801 (2018)
"Search for a dimuon resonance in the Y mass region", JHEP 08 (2018) 147
"Likelihood Analysis of the pMSSM11 in Light of LHC 13-TeV Data ", EPJC78 (2018) no.3, 256
"Likelihood Analysis of the Sub-GUT MSSM in Light of LHC 13-TeV Data" EPJC78 (2018) no.2, 158
"Probing SUSY effects in Ksmm" JHEP 1805 (2018) 024
"Resolving the alpha ambiguity in B->rho rho", JHEP 11 (2018) 193
"Measurement of the inelastic pp cross-section at a centre-of-mass energy of 13 TeV" (2018), JHEP 06 (2018) 100

"Prospects for measurements with kaons at LHCb", https://arxiv.org/abs/1808.03477 (accepted in JHEP)
"New Axion Searches at Flavor Factories", arXiv:1810.09452", (accepted in JHEP)
"The strange side of LHCb," https://arxiv.org/abs/1808.02006 (submitted to PRL)

Publications, 2018

(A. A. Alves Junior, P. Baladron, M. Borsato, A. Brea Rodriguez A. Casais Vidal, V. Chobanova, X. Cid Vidal, J.Dalseno, M. Lucio Martinez, D. Martinez Santos, C. Prouve, M. Ramos Pernas, M. Romero Lamas)

Reports/CONF notes:

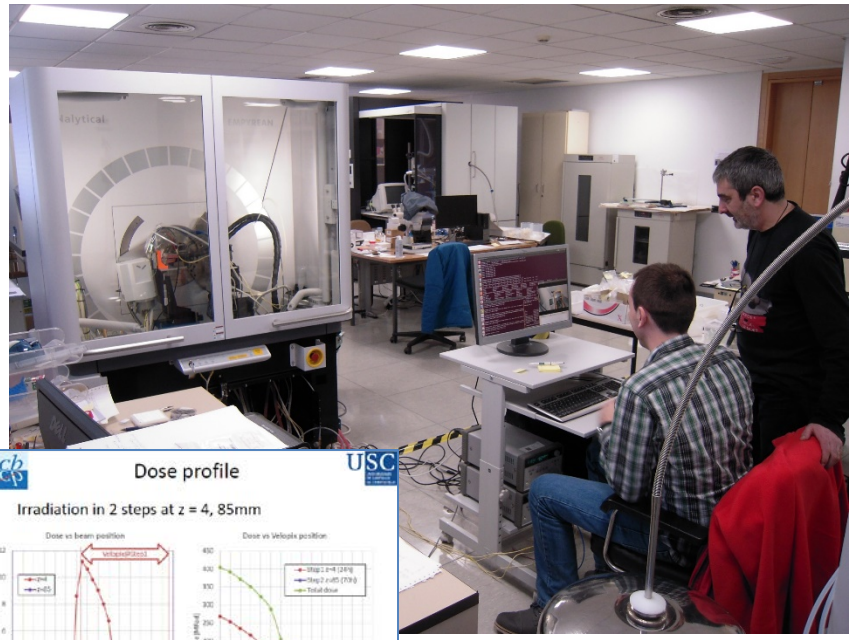
"Physics case for an LHCb Upgrade II Opportunities in flavour physics, and beyond, in the HL-LHC era", CERN-LHCC-2018-027
"Opportunities in Flavour Physics at the HL-LHC and HE-LHC", CERN-LPCC-2018-05
"Beyond the Standard Model Physics at the HL-LHC and HE-LHC", CERN-LPCC-2018-05
"Prospects for searches for long-lived particles after the LHCb detector upgrades" LHCb-CONF-2018-006
"LHCb projections for proton-lead collisions during LHC Runs 3 and 4" LHCb-CONF-2018-006

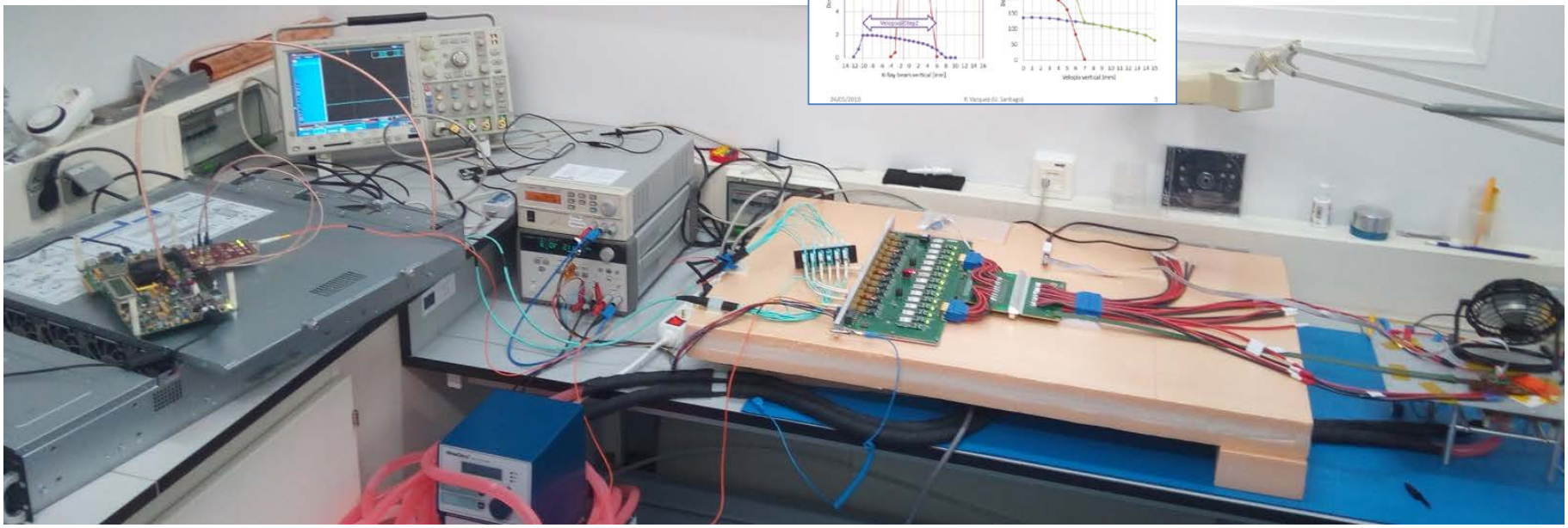
Outreach:

Xabier Cid-Vidal and Ramon Cid, Lead ions and Coulomb's Law at the LHC (CERN), Phys. Educ. 53 024002

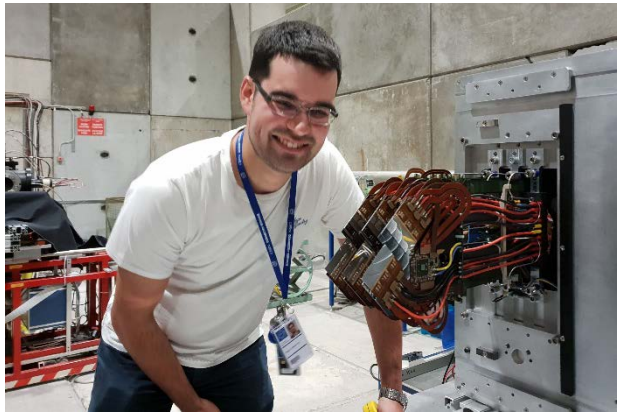
Velo upgrade: readout chain electronics

- *Front-end qualification (VeloPix ASIC)*
  - *Electronics Design Review*
  - *Total Ionizing Dose tests up to 400 Mrad done with an USC X-ray facility*
- *Back-end development*
  - *Workshop for the integration of Velo detector in the LHCb framework*
  - 2 readout setups, based on Intel and Xilinx FPGAs, running at USC

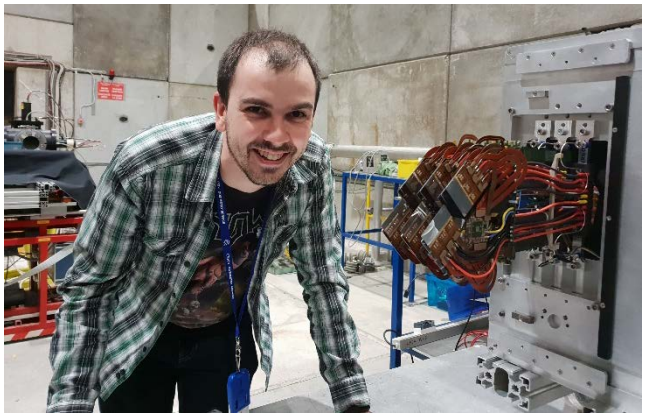




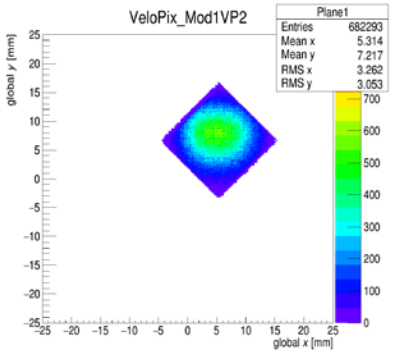
Velo Upgrade: first full readout chain testbeam (CERN Oct18)

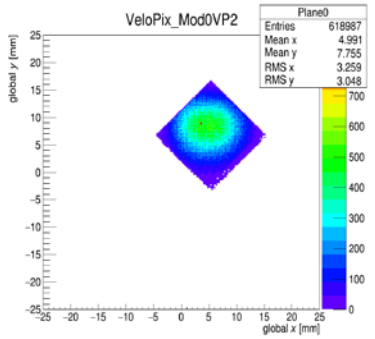


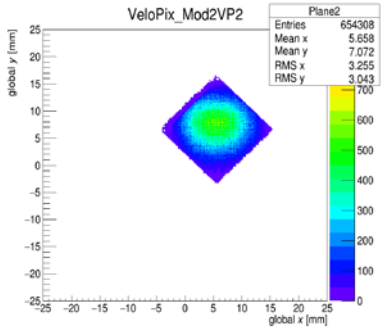
Front-end electronics expert (USC)
Current Velo upgrade readout coordinator

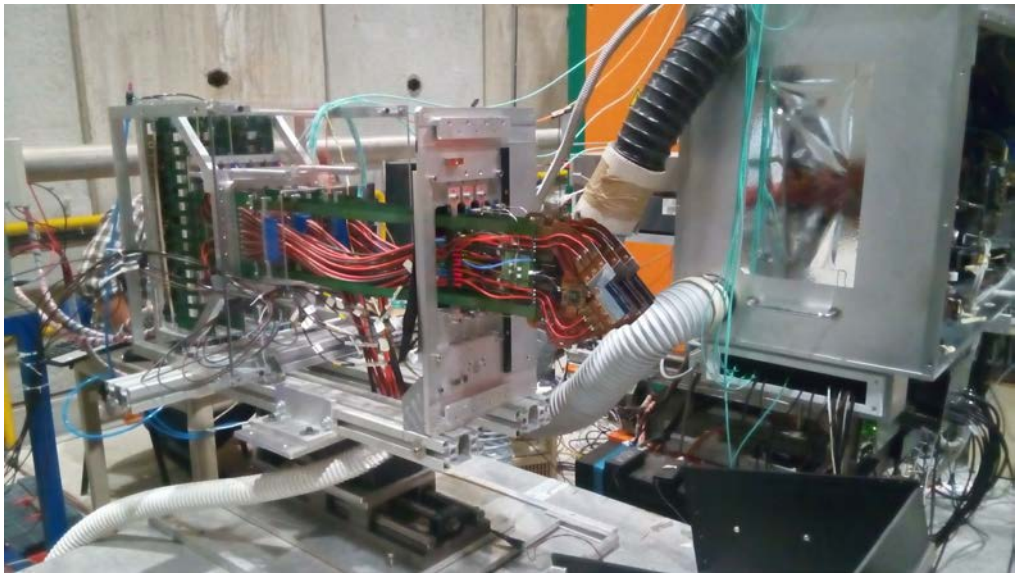


Back-end electronics expert (USC)



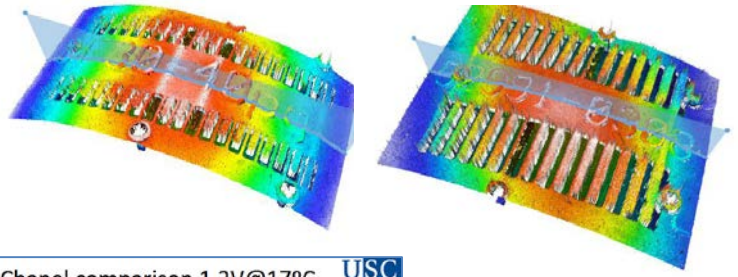


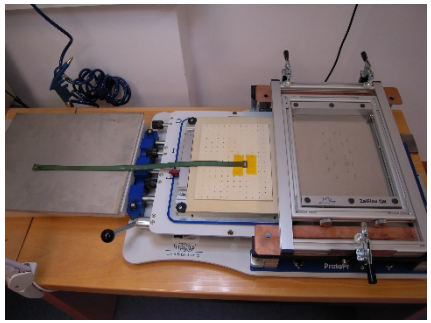


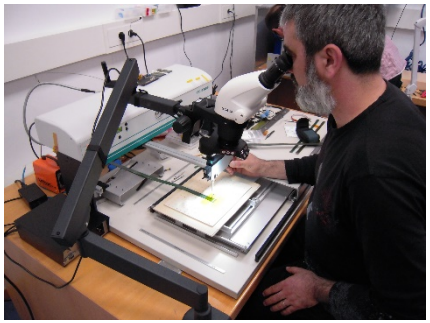


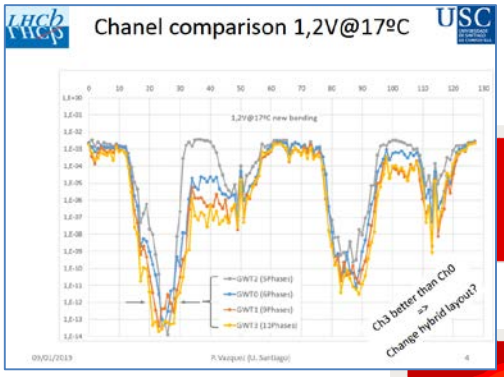
Velo Upgrade: hardware production

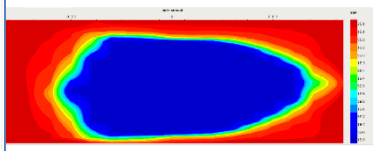
- *Production Readiness Review*
- *High speed cables design, assembly and testing*
- *High voltage cable assembly and testing*

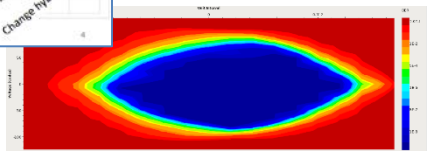


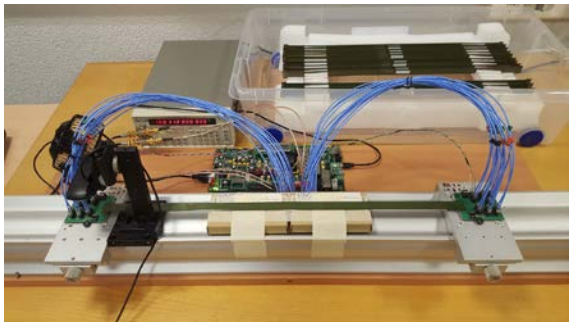


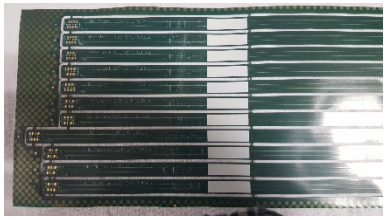


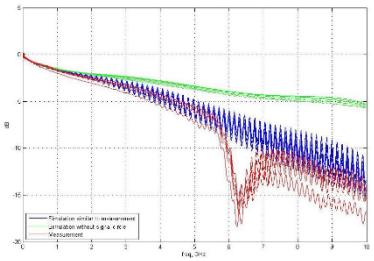


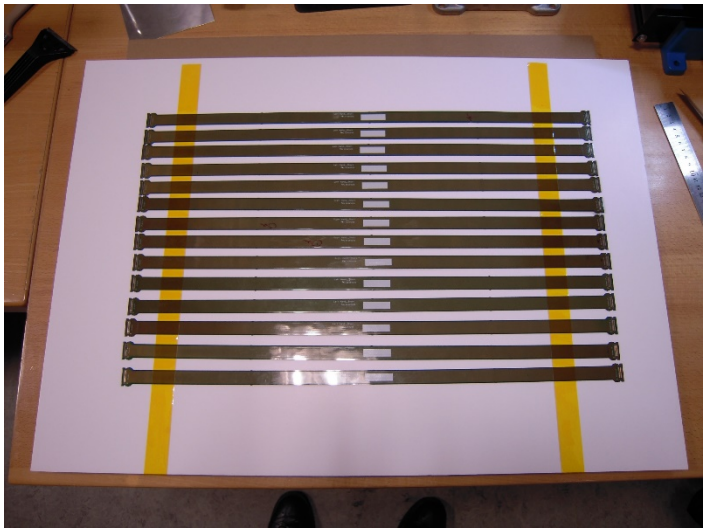












Backup slides