Imperial College
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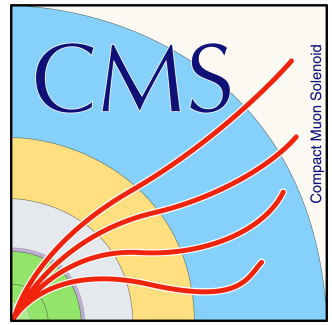

Probing lepton flavour universality in $B^{\pm(0)} \to K^{\pm(0*)}\ell^+\ell^-$ decays at CMS

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Post-doc: Dr Matthias Komm

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2. Theory
2.1 Lepton Universality in the Standard Model

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4.1 New data set
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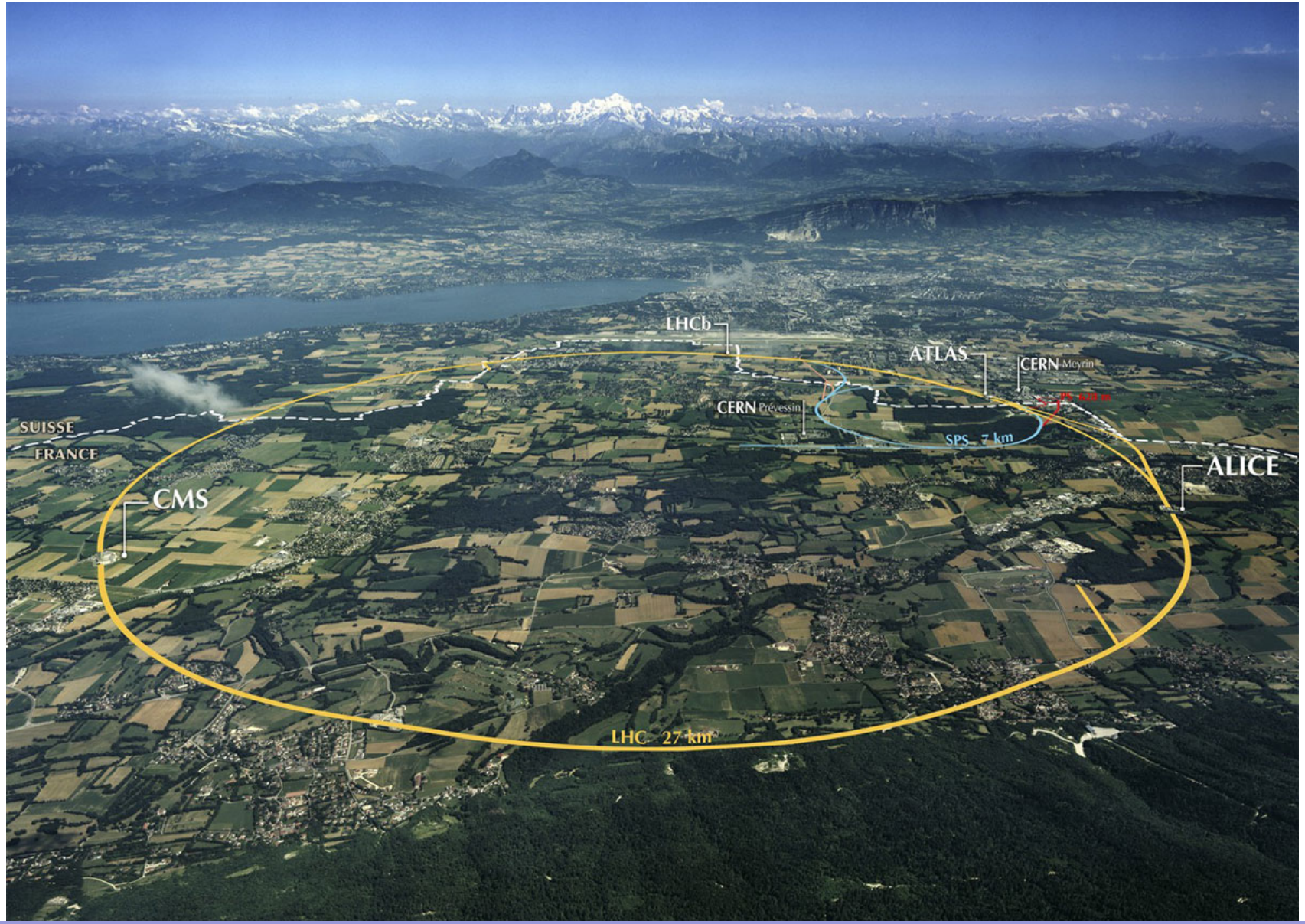
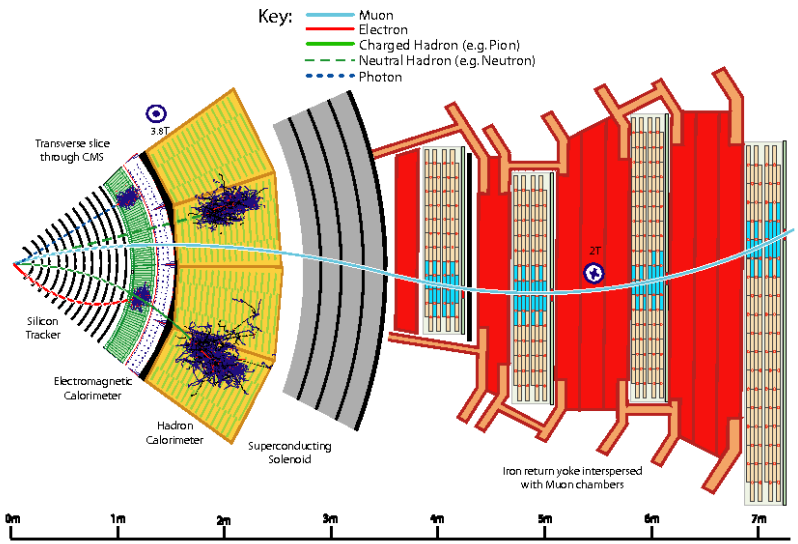
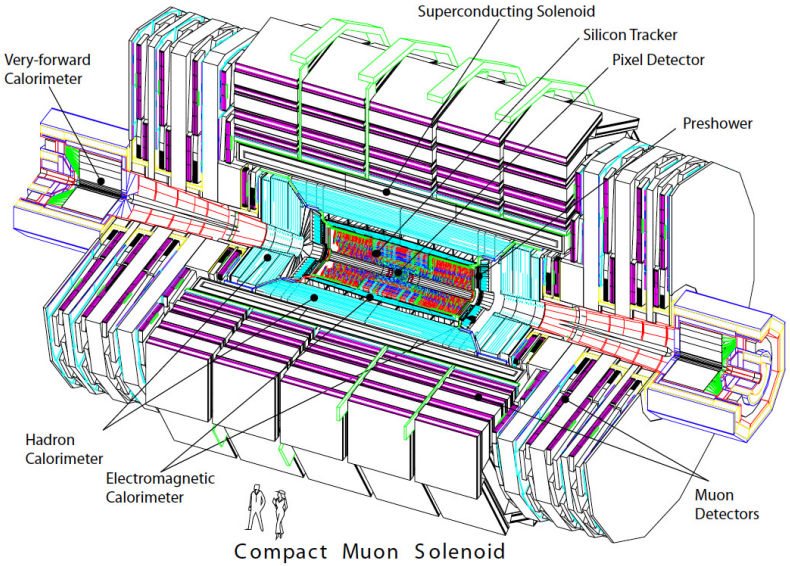
5. Conclusions

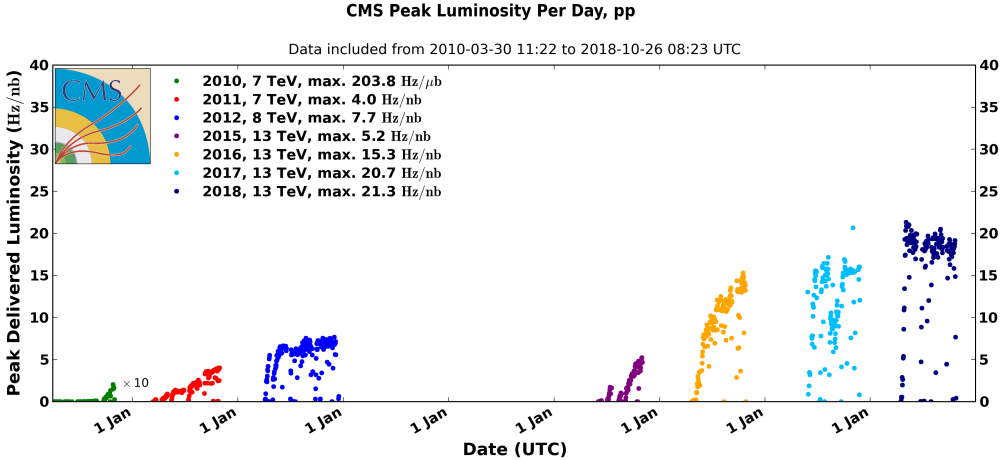
The Large Hadron Collider



The CMS detector







Diagrams from [1, 2, 3]

Lepton Universality in the Standard Model

- the SM does not necessarily predict that the weak gauge bosons ($Z^0, W^{\pm}$) couple with the same strength to different lepton generations but it has been observed to be the case thus far
- LU might be probed in $b \to s\ell^+\ell^-$ decays as the process cannot happen at tree level but only through loop diagrams which are sensitive to New Physics

Looking at observables such as:

$$R_X = \frac{\mathcal{B}(B \to X\mu^+\mu^-)}{\mathcal{B}(B \to Xe^+e^-)} \tag{1}$$

Lepton Universality in the Standard Model

To cancel experimental and theoretical uncertainties, a double ratio is calculated instead:

$$R_X = \frac{\mathcal{B}(B \to X\mu^+\mu^-)}{\mathcal{B}(B \to XJ/\psi(\to \mu^+\mu^-))} \Big/ \frac{\mathcal{B}(B \to Xe^+e^-)}{\mathcal{B}(B \to XJ/\psi(\to e^+e^-))} \quad (2)$$

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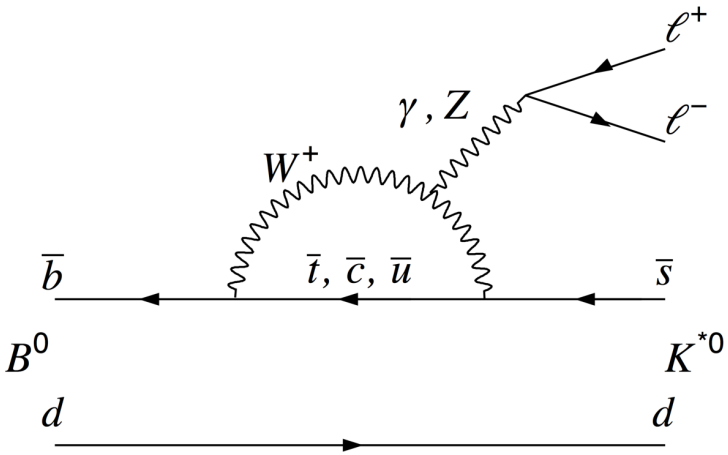
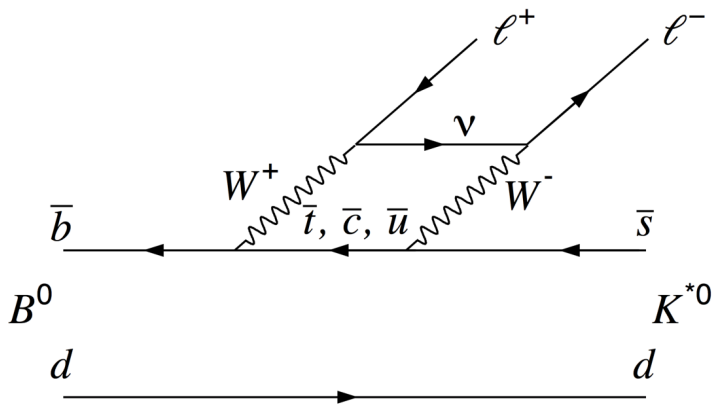


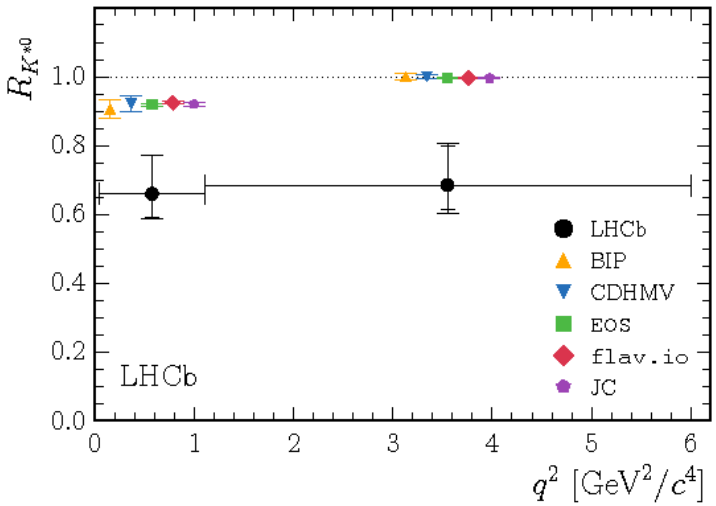
(a) $b \to s\ell\ell$ transition via penguin diagram.

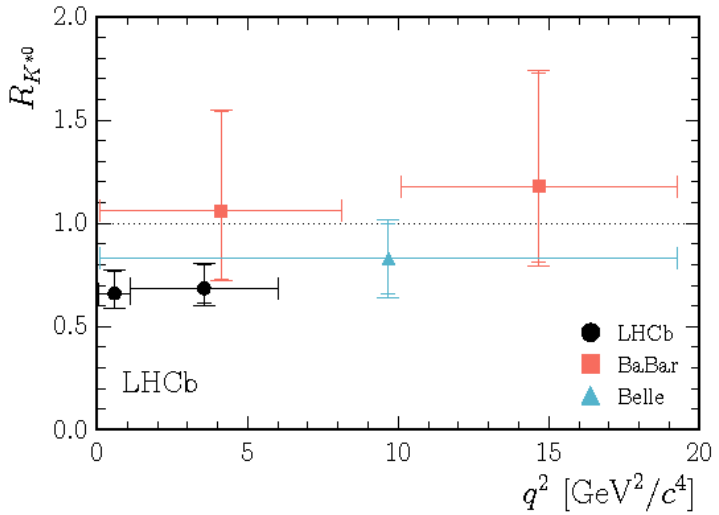


(b) $b \to s\ell\ell$ transition via box diagram.

Figure 2: Feynmann diagrams presenting the $B^0 \to K^{*0}\ell^+\ell^-$ rare decay process in the SM [4].

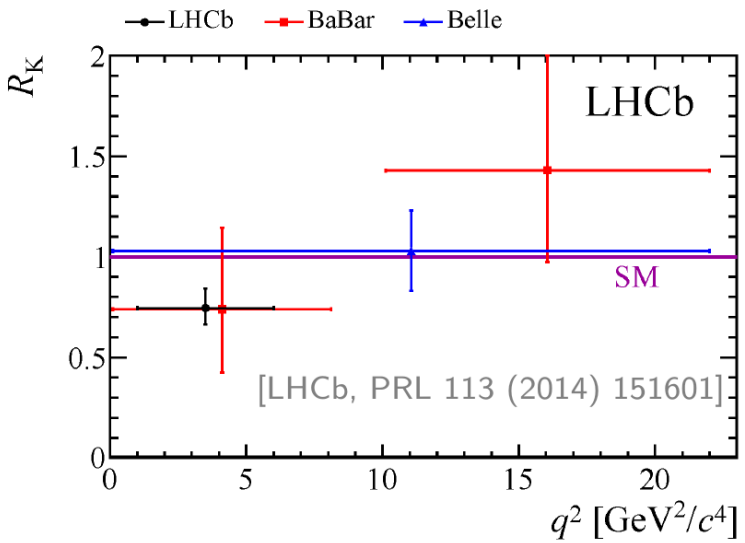
B-anomalies observed so far





$$R_X = \frac{\mathcal{B}(B \to X\mu^+\mu^-)}{\mathcal{B}(B \to Xe^+e^-)}$$

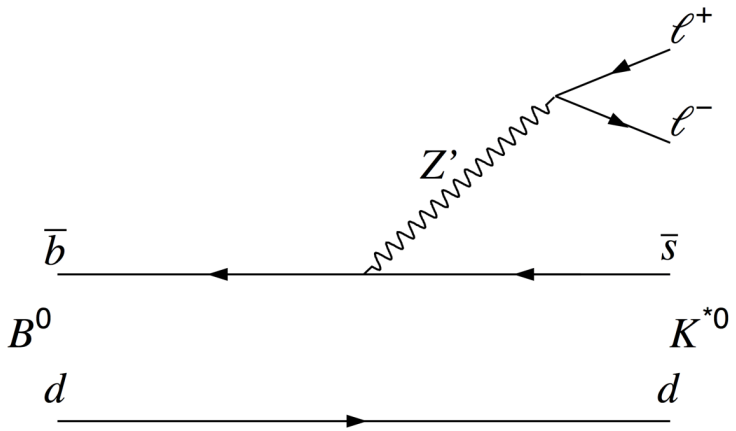
$$q^2 = m^2_{\ell\ell}$$



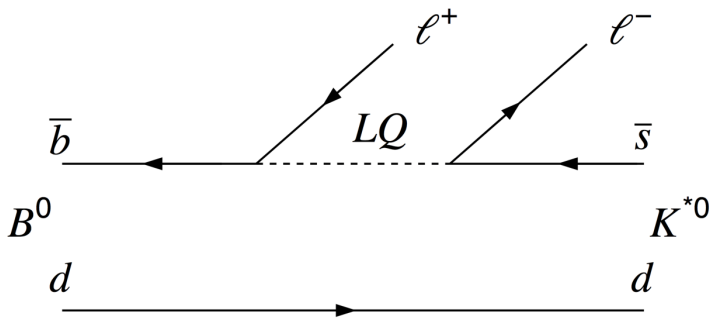
Plots from [4, 5]

New theoretical models

Possible New Physics hypotheses to explain the B-anomalies seen:



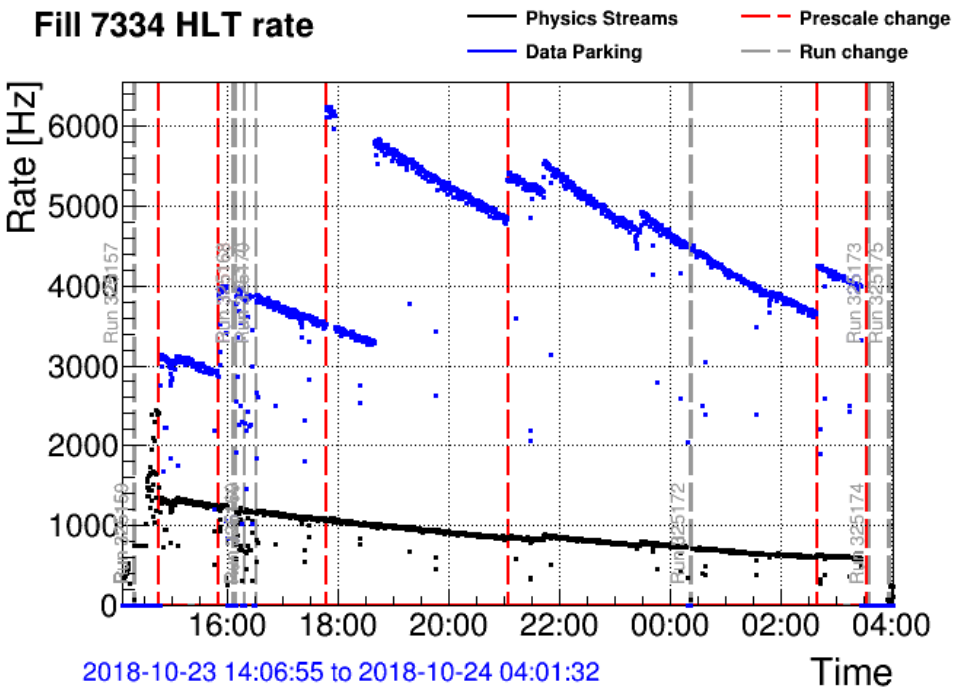
(a) $b \to s\ell\ell$ transition at tree-level via a new gauge boson, Z'.



(b) $b \to s\ell\ell$ transition at tree-level via a leptoquark, LQ.

B-parking at CMS

The Imperial College CMS group initiated and has spearheaded the CMS B-physics parking activity, resulting in a new and unique data set which contains about 10^{10} B meson decays at the end of RUN-2, in 2018.



Neural Networks used in data analysis

The central element of NN is an artificial neuron which calculates the *response* y to a given vector of *inputs* $\mathbf{x}$:

$$y = h\Big(\sum_{i=1}^{n} w_i x_i + w_o\Big) \tag{3}$$

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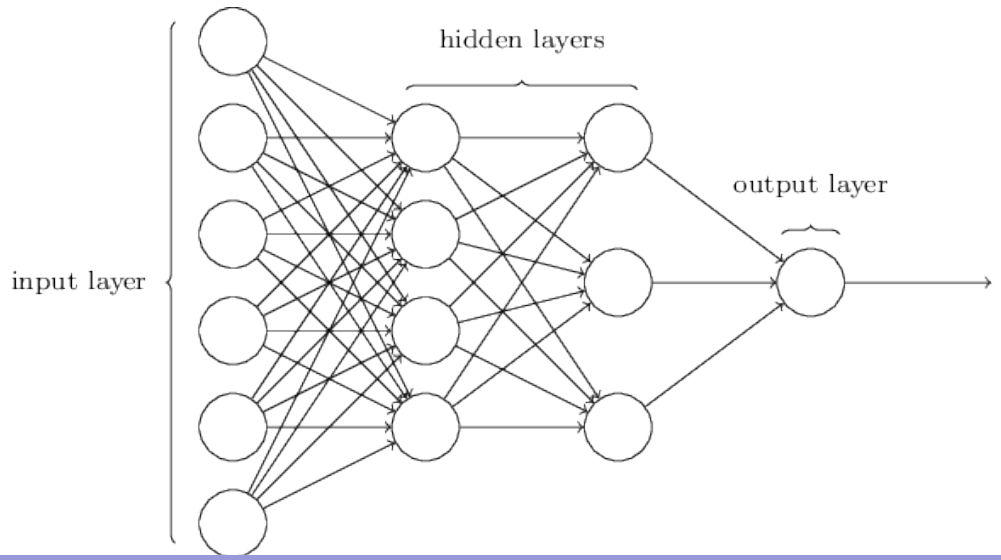
The aim of this PhD project will be to employ a state-of-the-art neural network in order to minimise backgrounds, as well as enhance reconstruction efficiencies for $B^{\pm(0)} \to K^{\pm(0*)}\ell^+\ell^-$ decays.



Conclusions

- Lepton Universality is **not a prediction** of the SM but measurements observed to be the case
- hints on LU violation were observed by a few of experiments
- LU can be probed in decay processes that would involve loop diagrams in the SM
- **CMS** is currently the only experiment that could cross-check these results
- the greatest challenge for the **CMS** B-parking data is the large background and reconstruction precision
- my PhD will involve developing a state-of the art NN to reduce background effects and make a contribution to the precision measurement on R_K and R_{K*} based on CMS data

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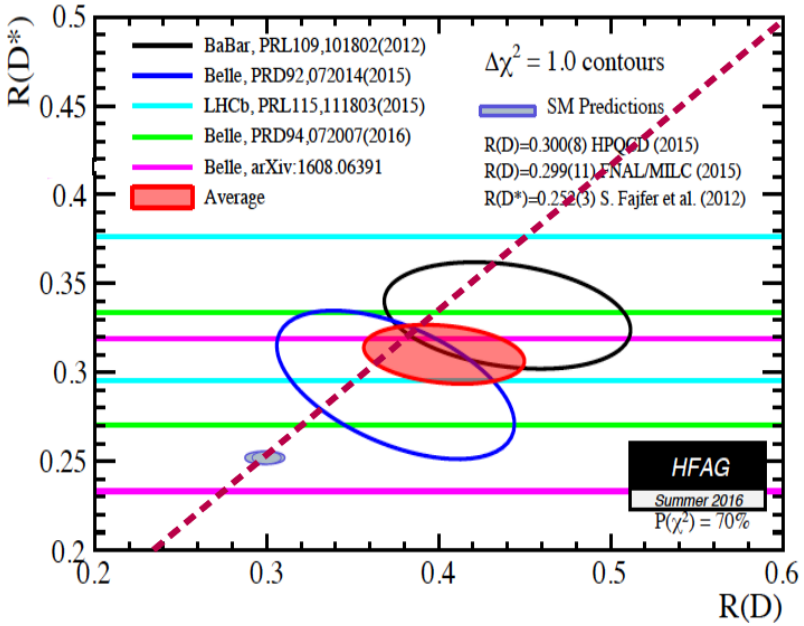
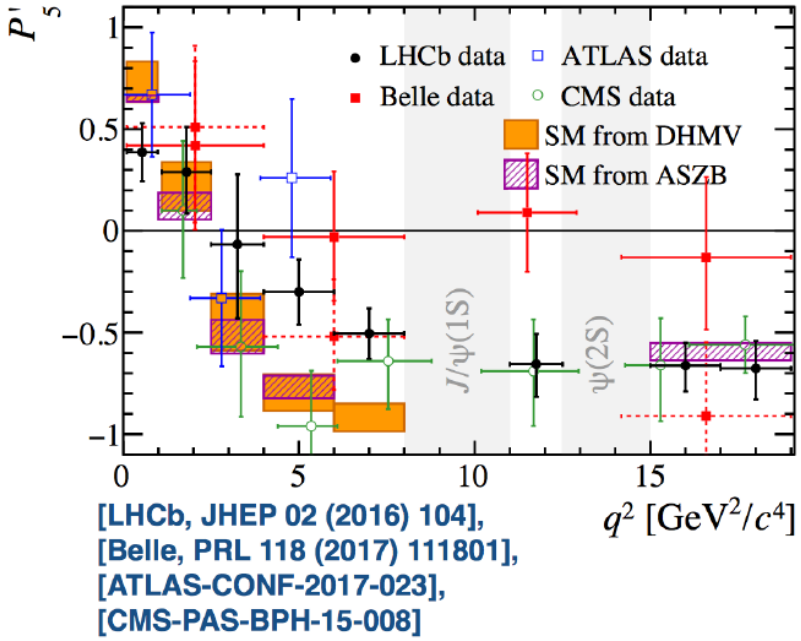
Thank you for your attention!

Back-up slides

B-anomalies observed so far





Plots from [5, 6]

Domain adaptation adversarial neural network

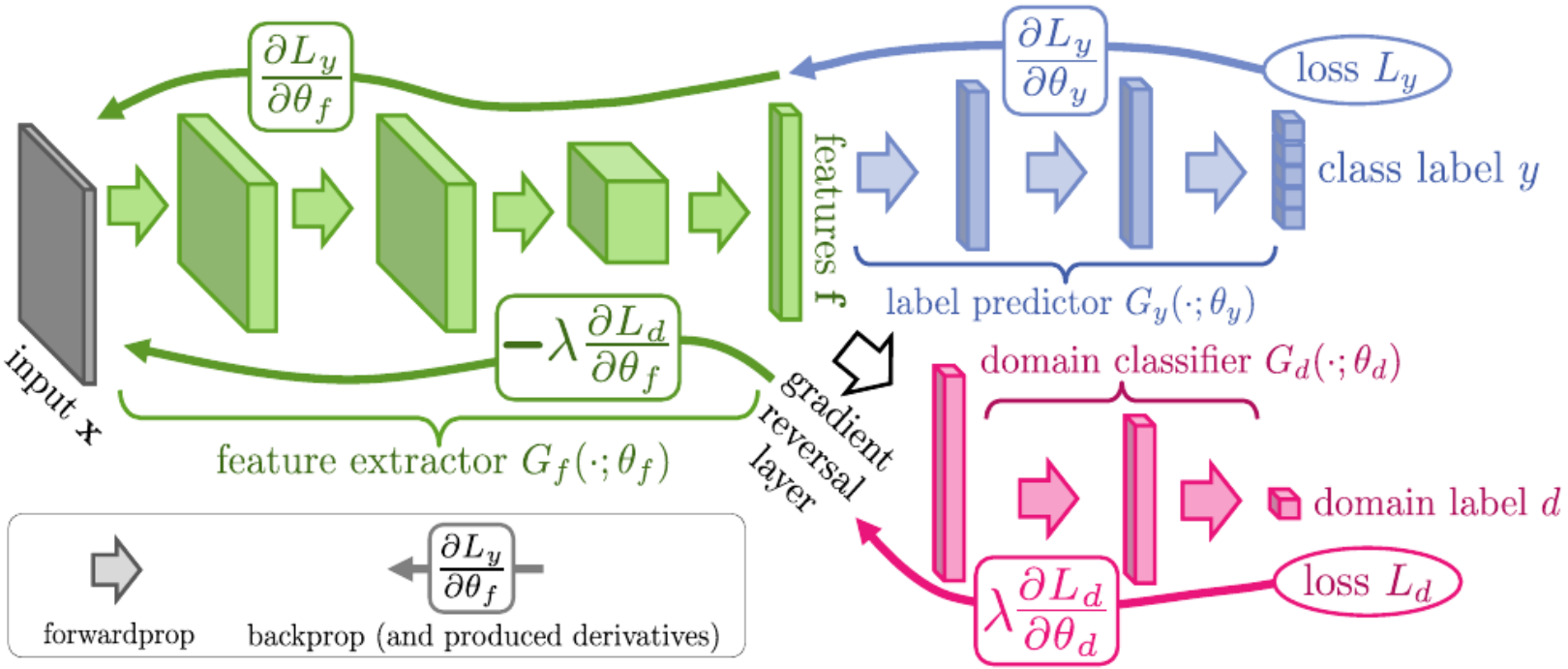


Figure from [7]

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