HEPLike - tool for experimental likelihood evaluation

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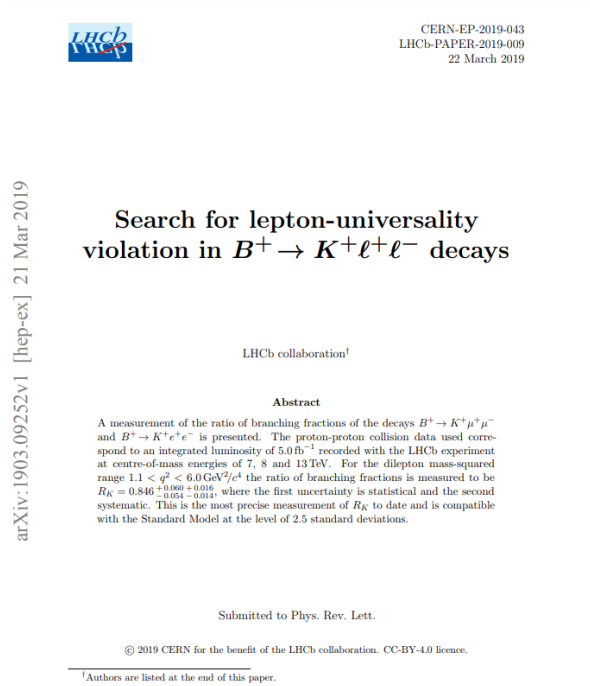
(Re)interpreting the results of new physics searches at the LHC,
London, April 2-4, 2019

HEP results

⇒ How do we publish results?



CERN-EP-2019-043
LHCb-PAPER-2019-009
22 March 2019

Search for lepton-universality violation in $B^+ \to K^+\ell^+\ell^-$ decays

LHCb collaboration[†]

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Submitted to Phys. Rev. Lett.

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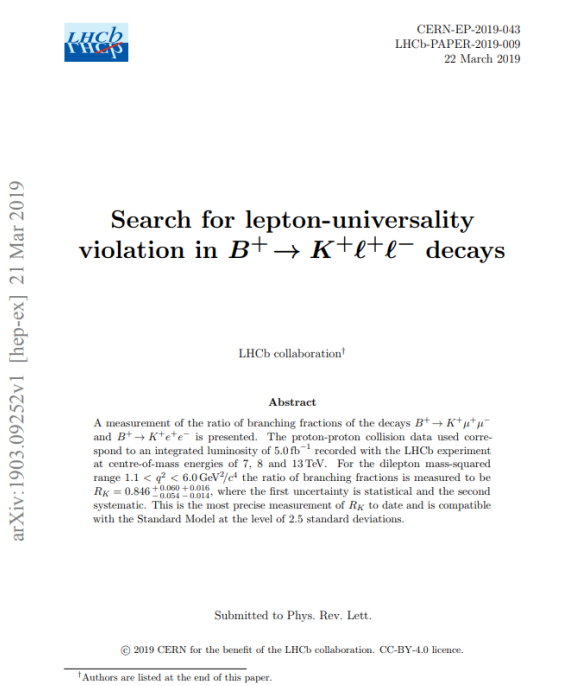

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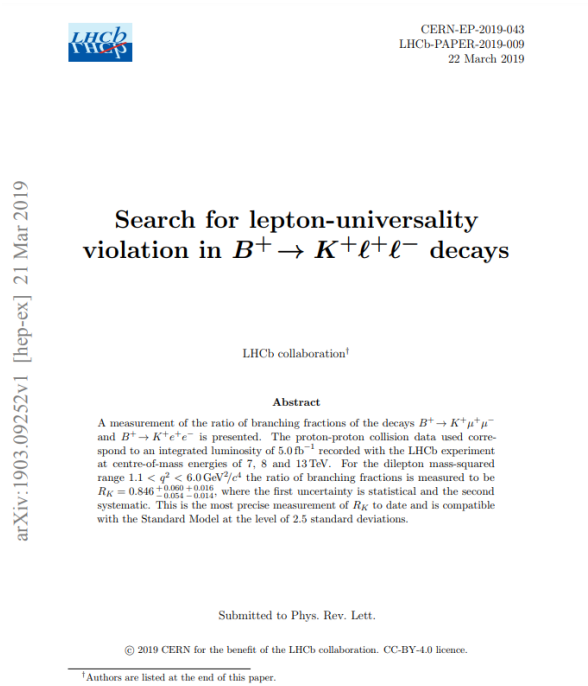

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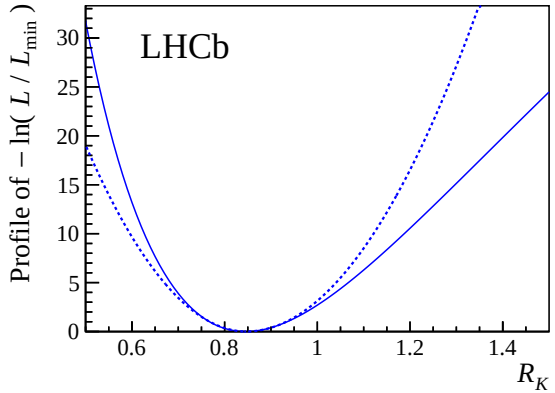

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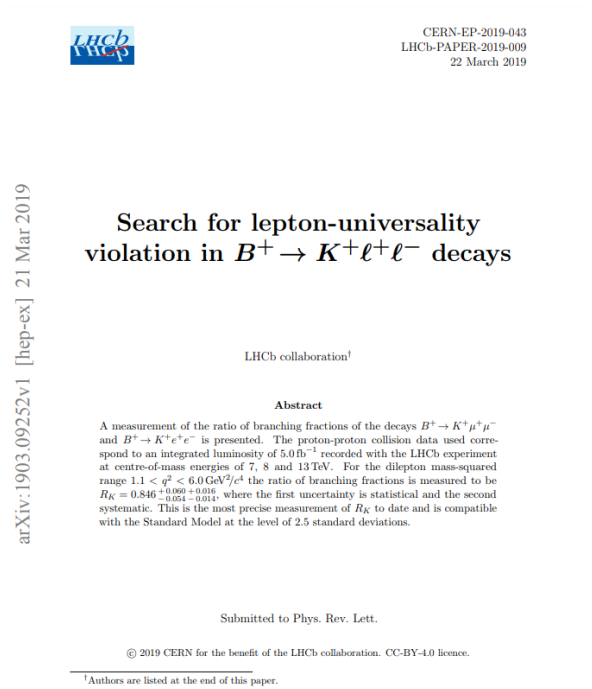

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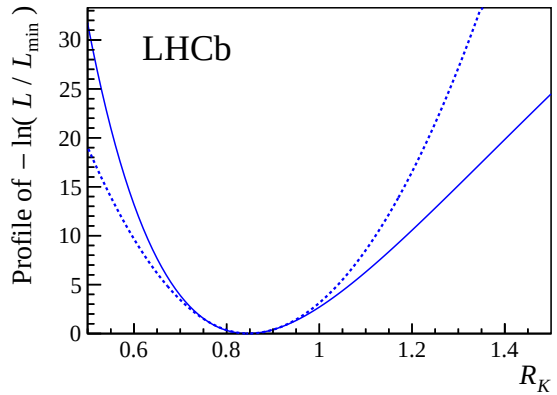
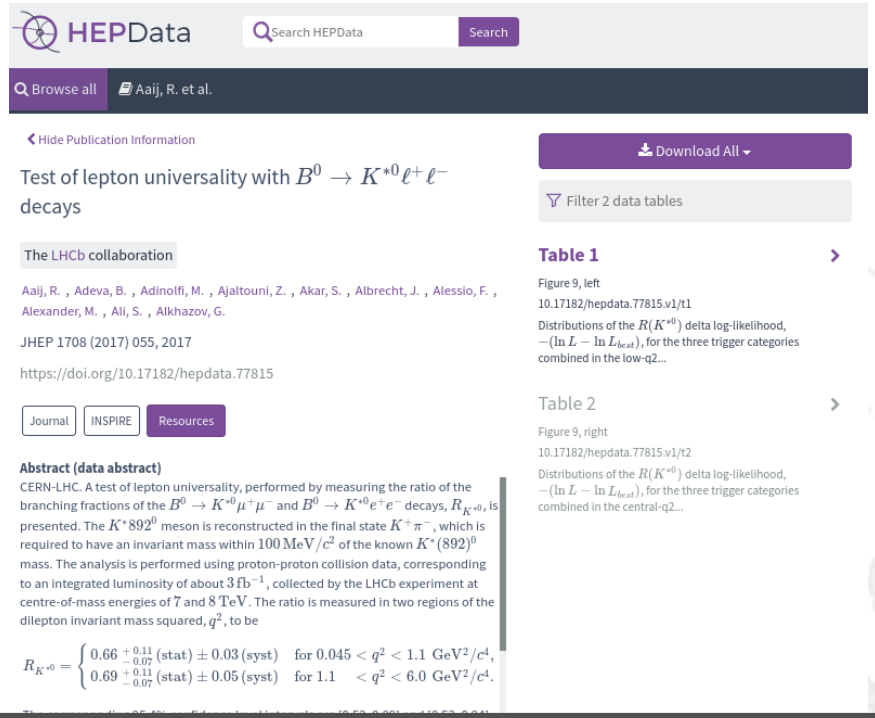




$$R_K = 0.846^{+0.060+0.016}_{-0.054-0.014}$$

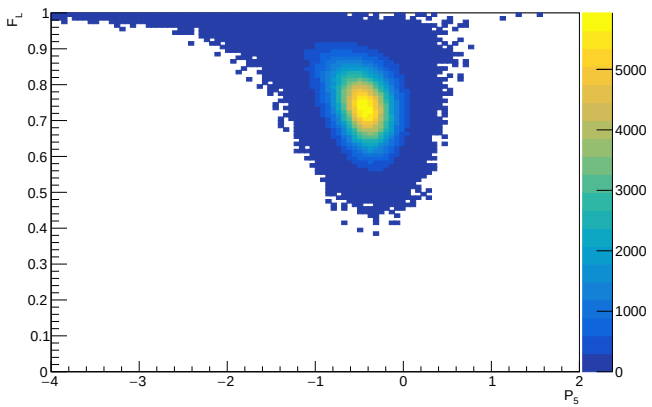
HEP results

⇛ How are the results used?

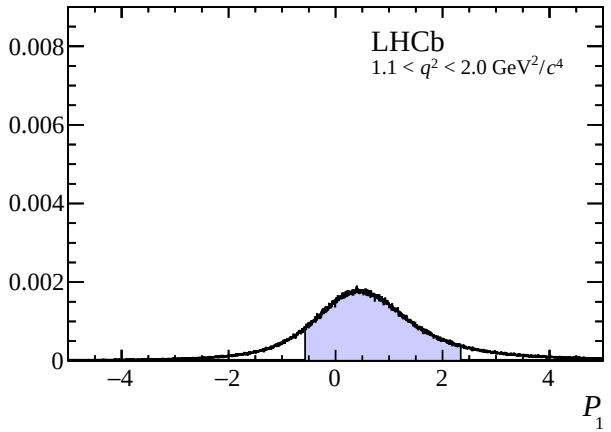
⇛ Correlations are neglected

	F_{L}	S_3	S_4	S_5	A_{FB}	S_7	S_8	S_9
F_{L}	1.00	−0.13	−0.14	0.01	−0.03	0.10	−0.03	−0.01
S_3		1.00	−0.06	0.09	0.07	−0.02	0.01	−0.07
S_4			1.00	−0.19	−0.09	−0.05	0.12	0.07
S_5				1.00	−0.01	0.05	−0.02	0.10
A_{FB}					1.00	−0.01	−0.10	0.10
S_7						1.00	0.07	−0.05
S_8							1.00	−0.01
S_9								1.00

⇛ Non Linear effects are forgotten



⇛ Errors are being symmetrized



HEP results

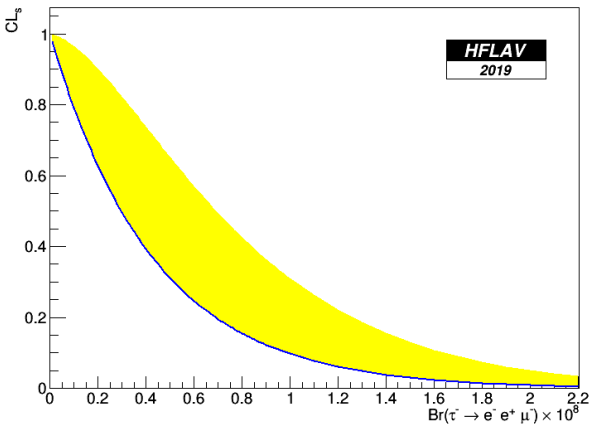
⇛ How are the results used?

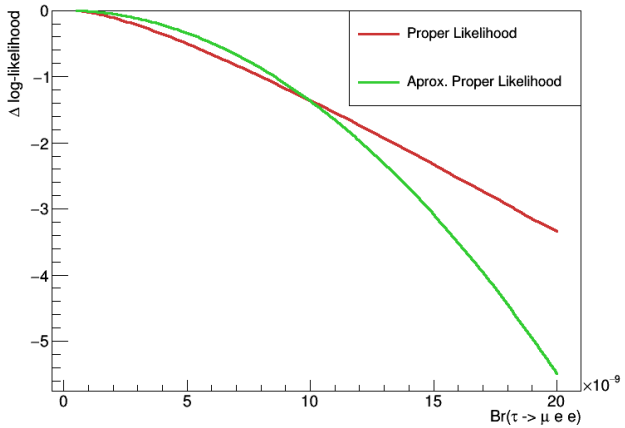
⇛ Interpreting Upper limits [HLFAV, 90% UL]:

$$\mathcal{B}(\tau \to \mu\mu e) < 9.9 \times 10^{-9}$$

⇛ People interpret this assuming it's a gaussian centered around 0 and width $\frac{9.9\times10^{-9}}{1.64}$.

⇛ Usually a full p-value scan is published:





⇛ The examples go on and on...

The idea

$\Rightarrow$ The theory and experimental community need to work together about proper interpretation.

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HEPLike

⇛ High Energy Physics Likelihood (HEPLike).

- Open source software.
- With separate database of measurements.
- Statistics library.
- Can be interfaced with existing codes.

⇛ It constructs the experimental likelihoods for you!

⇛ Does work with both the χ^2 and (log-)likelihood fits.

⇛ Useful utilities for creating citations and database search.

HEPLike

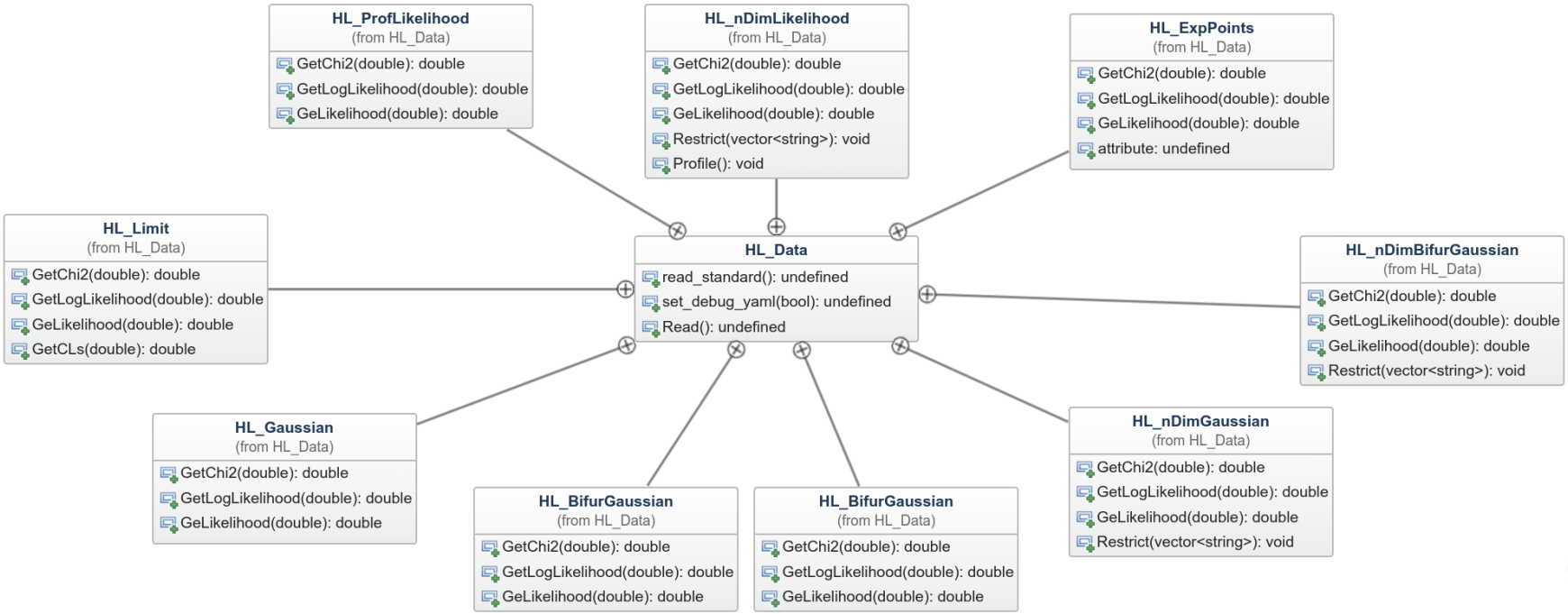
$\Rightarrow$ The are couple of measurement types:

- Upper limits,
- Single measurement with symmetric uncertainty,
- Single measurement with asymmetric uncertainty,
- Multiple measurements with symmetric uncertainty,
- Multiple measurements with asymmetric uncertainty,
- One dimensional likelihood function,
- n-dimensional likelihood function.

Bonus

In addition we provide a way for the future that the experiments can publish the dataset.

HEPLike - code structure



Measurement encoding, `H1_Data`

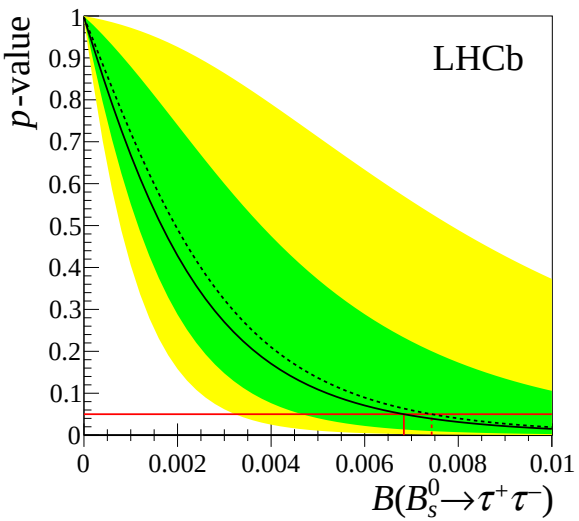
⇛ Measurements are stored in `YAML` file:

```
BibCite: Aaij:2017vbb                                                  1
BibEntry: '@article{Aaij:2017vbb,                                      2
      author          = "Aaij, R. and others",                         3
      title           = "{Test of lepton universality                  4
                          with $B^{0} \rightarrow                      5
                         K^{*0}\ell^{+}\ell^{-}$ decays}",             6
      collaboration   = "LHCb",                                        7

      }                                                                19
      ,                                                                20
DOI: 10.1007/JHEP08(2017)055                                           21
Process: R_{Kstar^{*}}                                                 22
FileName: RKstar.yaml                                                  23
Name: RKstar                                                           24
Source: HEPDATA                                                        25
SubmissionYear: 2017                                                   26
PublicationYear: 2018                                                  27
Arxiv: 1705.05802                                                      28
Collaborations: LHCb                                                   29
Kinematics: q2>1.1 && q2<6.                                            30
HLAuthor: Gal Anonim                                                   31
HLEmail: gal.anonim@ifj.edu.pl                                         32
HLType: HL_ProfLikelihood                                              33
```

Upper limits, HL_Limit

⇛ Example of published p-value scans:



⇛ Information coded as:

Cls :

- [0.0, 1.0]
- [1.0e−10, 0.977091694706]
- [2.0e−10, 0.954375824297]
- [3.0e−10, 0.93200355343]
- [4.0e−10, 0.910630700546]
- [5.0e−10, 0.889382721809]

Upper limits, HL_Limit

$$pdf(x) = \frac{1}{2^{1/2}\Gamma(1/2)} x^{1/2-1} e^{-x/2}, \tag{1}$$

which had the cumulative distribution function defined as:

$$cdf(x) = \frac{1}{\Gamma(1/2)} \gamma(1/2, x/2). \tag{2}$$

In the above equations the $\Gamma(x)$ and $\gamma(k, x)$ correspond to Gamma and incomplete gamma functions. By revering the $cdf(x)$ one can obtain the χ^2 value:

$$\chi^2 = cdf^{-1}(1-p), \tag{3}$$

and if needed the log-likelihood:

$$-\log(\mathcal{L}) = \frac{1}{2}\chi^2, \tag{4}$$

Single measurement, symmetric error, `HL_Gaussian`

Backup