Hunting new physics through improved tests of Lepton Flavour Universality with ATLAS at HL-LHC
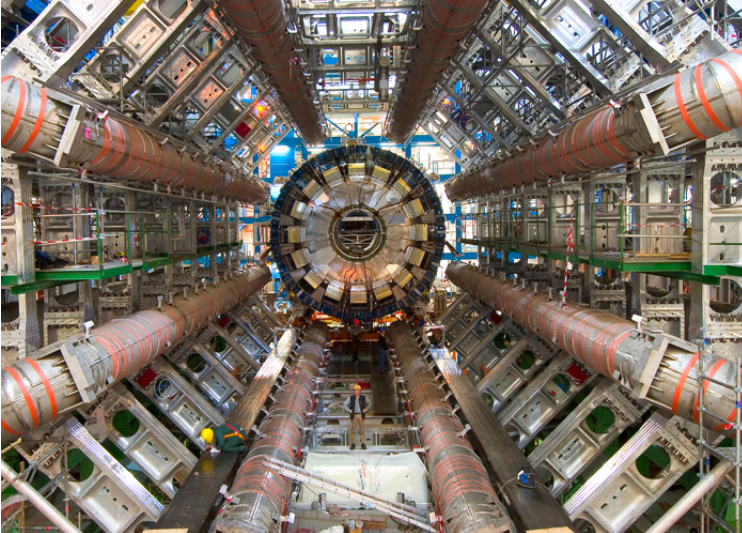
18/07/2019

$$\frac{BR(W \to \tau\nu)}{BR(W \to \mu\nu)} = ???$$

What is lepton universality, and what are we testing? (in a nutshell)

- One of the fundamental axioms of the Standard Model
  - The lepton couplings (g_l) where $l = e, \mu, \tau$ to the vector bosons are equal
    - ($g_\mu = g_e = g_\tau = g$)
  - Several experiments (from LHCb, BaBar, Belle, LEP) have been made to test this assumption by measuring the ratio of branching ratios and partial widths of various decays
  - The light/light lepton ratios ($\left|\frac{g_\mu}{g_e}\right|$) are consistent with SM predictions at high and low momentum transfer, but $\left|\frac{g_\tau}{g_e}\right|$ at high momentum transfer not as much...

$$R(D^{(*)}) = \frac{BR(\bar{B} \to D^{(*)}\tau^-\bar{\nu})}{BR(\bar{B} \to D^{(*)}l^-\bar{\nu})}$$

$$\frac{BR(W \to \tau\nu)}{BR(W \to e\nu)} = 1.043 \pm 0.024,$$

$$\frac{BR(W \to \tau\nu)}{BR(W \to \mu\nu)} = 1.070 \pm 0.026.$$

Ex: LHCb, BaBar, Belle found this ratio to be ~3.4-3.8 sigma deviation from SM prediction

What we are ultimately trying to measure (for now)

LEP, Particle Data Group averages; 1.8 and 2.7 sigma deviation from SM prediction
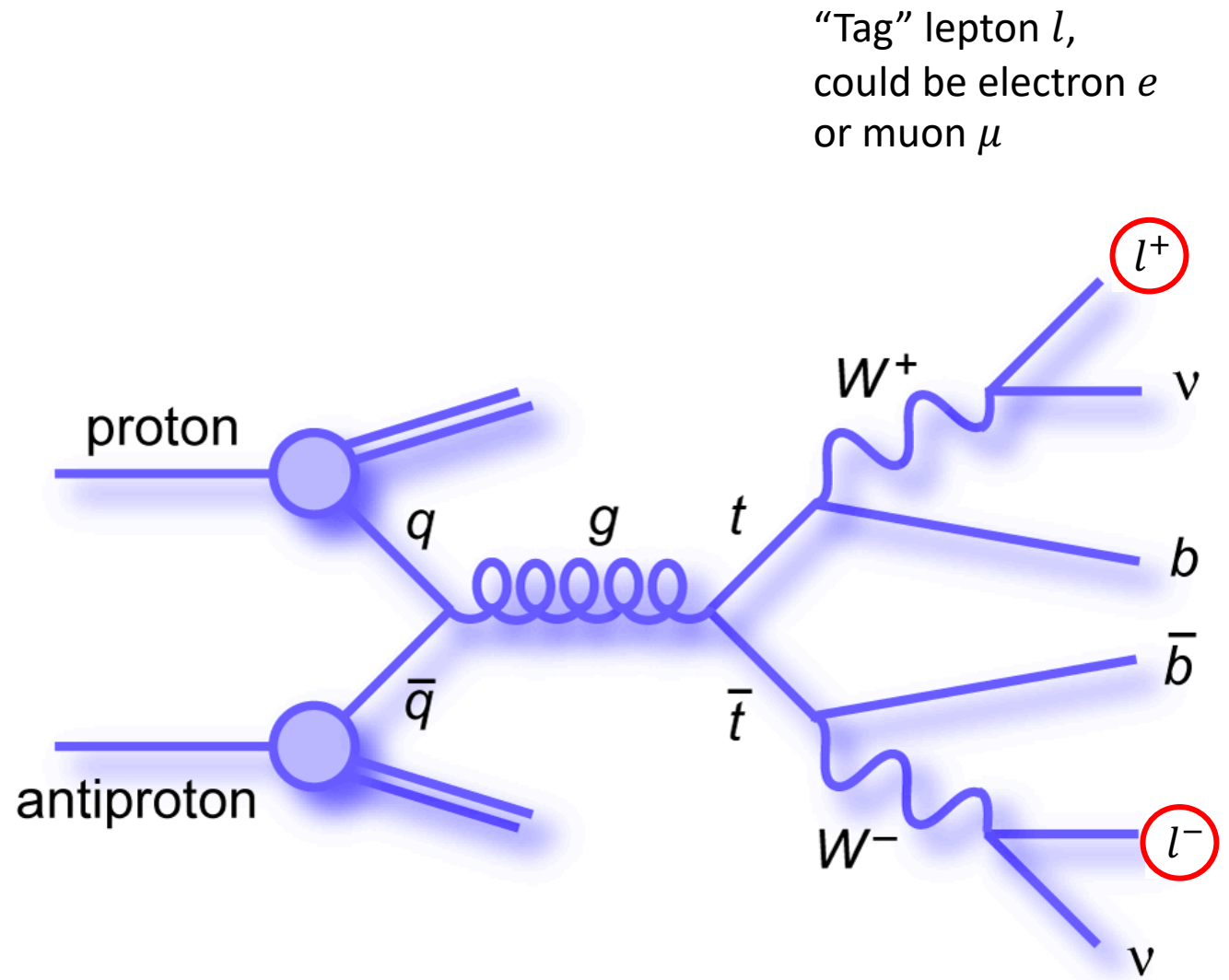
Measurement strategy

- At LEP, $e^-e^+ \rightarrow W^-W^+$ was used to measure the ratios of branching ratios and achieved 2.5% for electron and muon channels
  - At LHC, uncertainty on the efficiency of reconstructing hadronic τ decays is larger than 2.5%, so we use leptonic decays of τ leptons
    - $\rightarrow$ looking at dilepton $t\bar{t}$ events
- Tag-and-probe approach

Our measurement strategy

Tag-and-probe approach for looking at dilepton $t\bar{t}$ events

1) Trigger 1 lepton (μ, e)
2) Require 2 b-jets
3) Require 2nd lepton (μ)
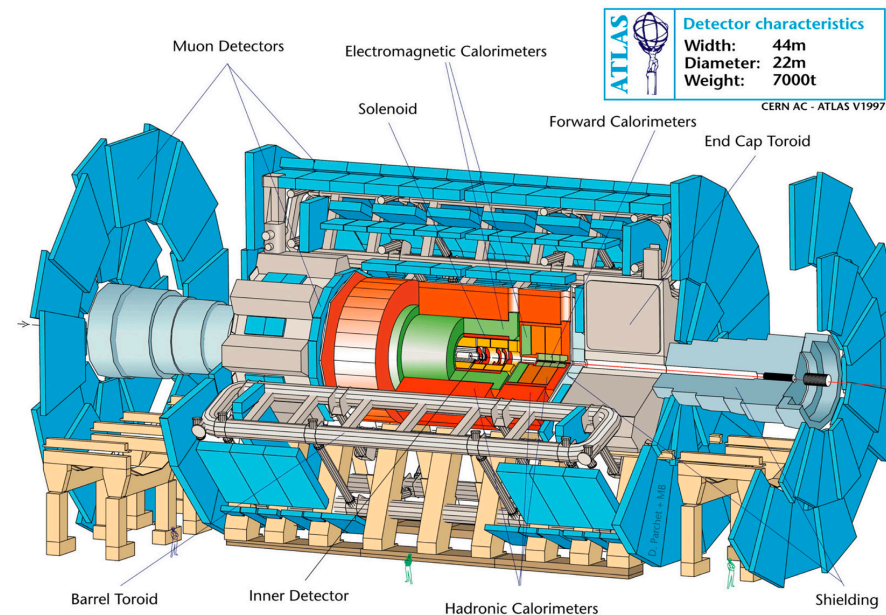
"Tag" lepton l, could be electron e or muon μ

proton
antiproton

q g t $\bar{q}$ $\bar{t}$

W^+ l^+ ν b $\bar{b}$ W^- l^- ν

"Probe" lepton l, could be prompt muon μ or tau τ

$\tau \to l\nu\nu$

Measurement strategy
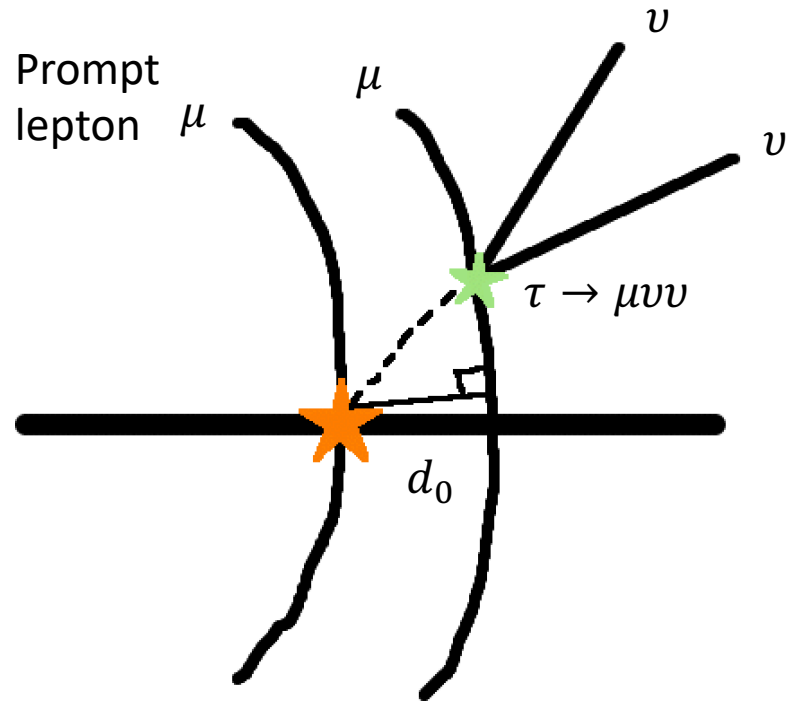
- Distinguish leptons from τ decays than leptons directly from $W^{\mp}$ by:
  - Decay parameter (d_0)
 - Difference in lepton p_t spectra caused by sharing of the τ momenta between decay products

Prompt lepton μ

μ

υ

υ

$\tau \rightarrow \mu \upsilon \upsilon$

d_0

Muon Detectors

Electromagnetic Calorimeters

Solenoid

Forward Calorimeters

End Cap Toroid

Barrel Toroid

Inner Detector

Hadronic Calorimeters

Shielding

Detector characteristics
Width: 44m
Diameter: 22m
Weight: 7000t

CERN AC - ATLAS V1997

Measurement and Analysis strategy

- Examine d_0-eμ and d_0-$\mu\mu$ channels with various event generators (ATL-FAST-2 (AF2) and Powheg Herwig 7 (f-PH7)) and compare to nominal (we use Pythia); below plots include all p_t bins

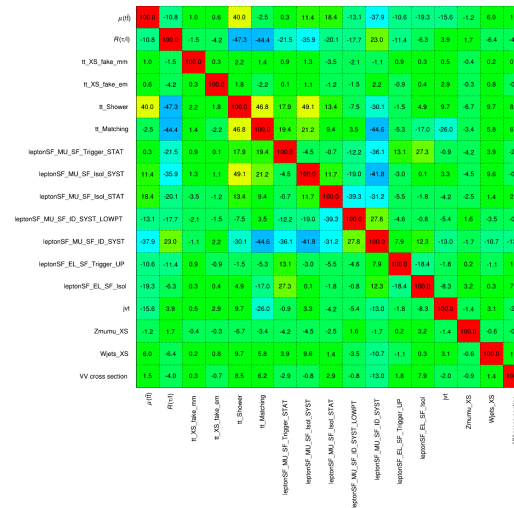D0_em: Comparison of AF2-DOWN, AF2-UP and f-PH7 fits to AF2-nominal
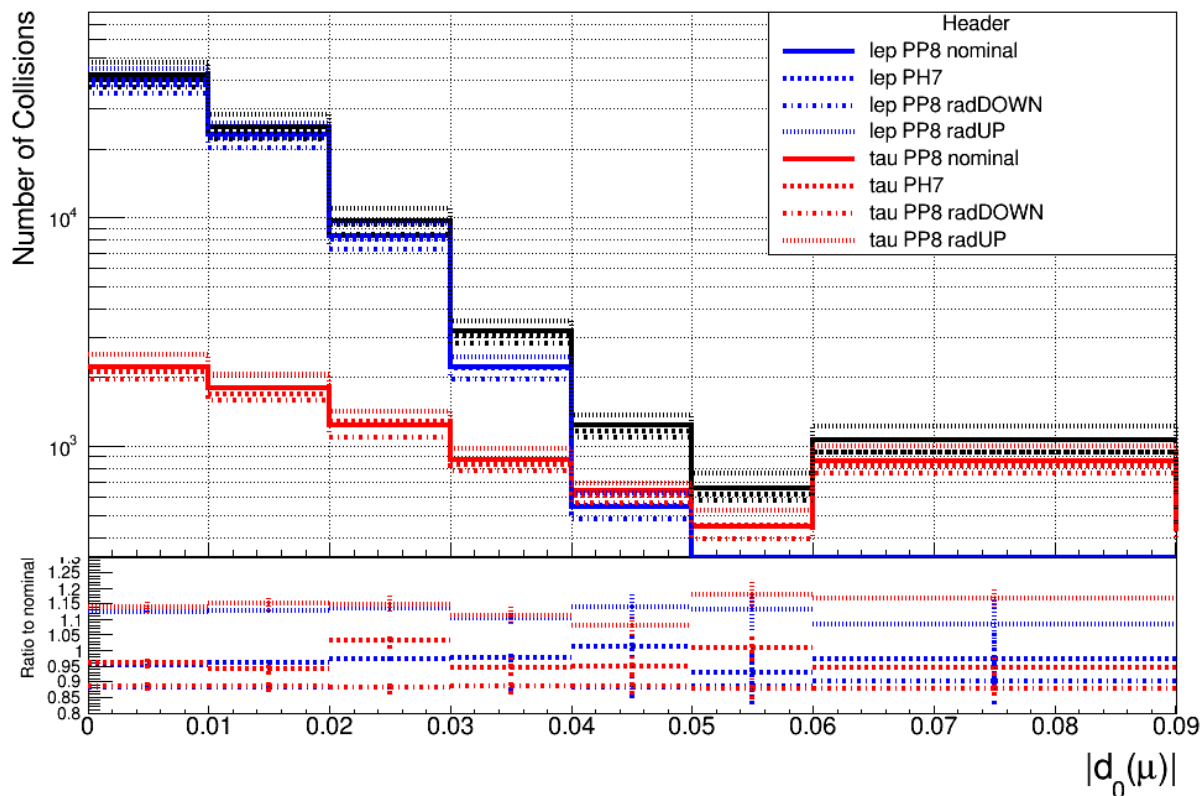
D0_mm: Comparison of AF2-DOWN, AF2-UP and f-PH7 fits to AF2-nominal
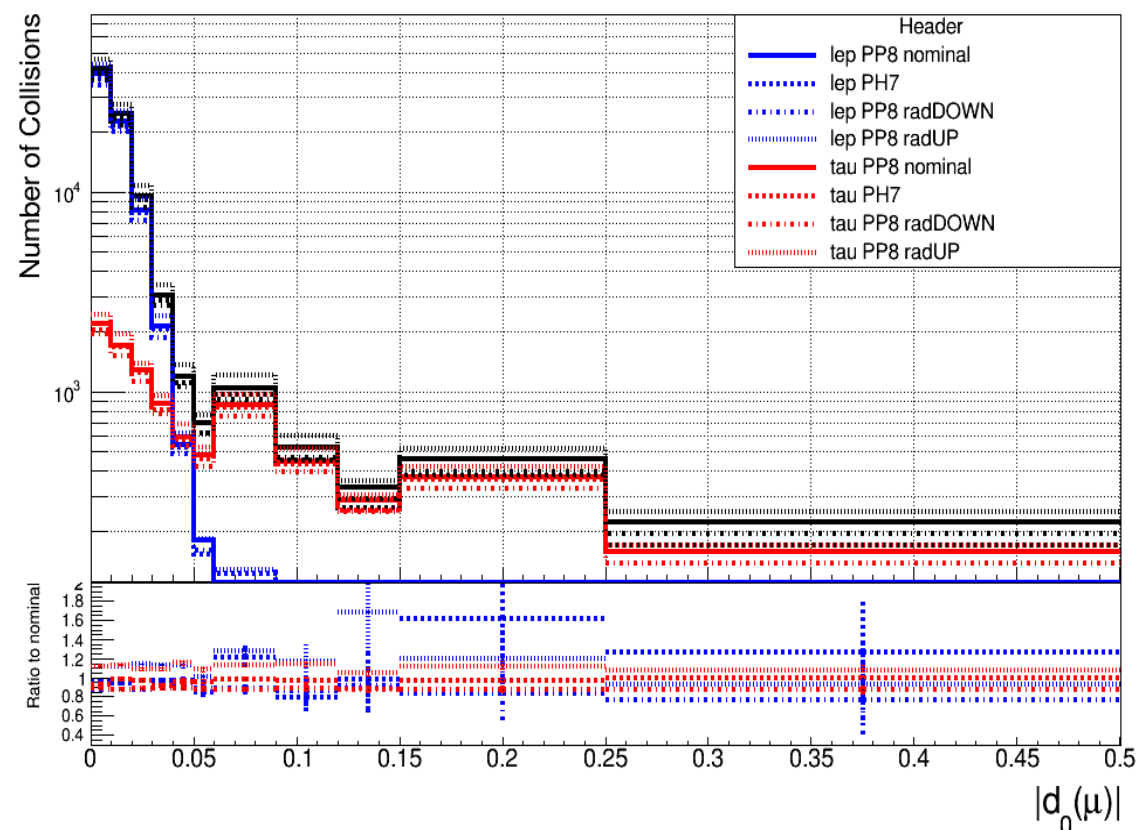
Measurement and Analysis strategy

- Examine d_0-eμ and d_0-$\mu\mu$ channels with various event generators (ATL-FAST-2 (AF2) and Powheg Herwig 7 (f-PH7)) and compare to nominal (we use Pythia)

- Currently Asimov

- These channels have a lot of systematic and statistical uncertainties that are investigated with TREx-Fitter

Correlation matrix

- For all inputted uncertainties, gives correlation between them
- Ideally, we do not want any correlation between our uncertainties

Nuisance Parameter Ranking Plot

- Ranks greatest (top) to least (bottom) dominance of systematic uncertainties and fit parameters in overall nominal uncertainty ($\mu(t\bar{t})$... right)?
- Much of our analysis is currently dominated by Monte Carlo uncertainties (the γs)
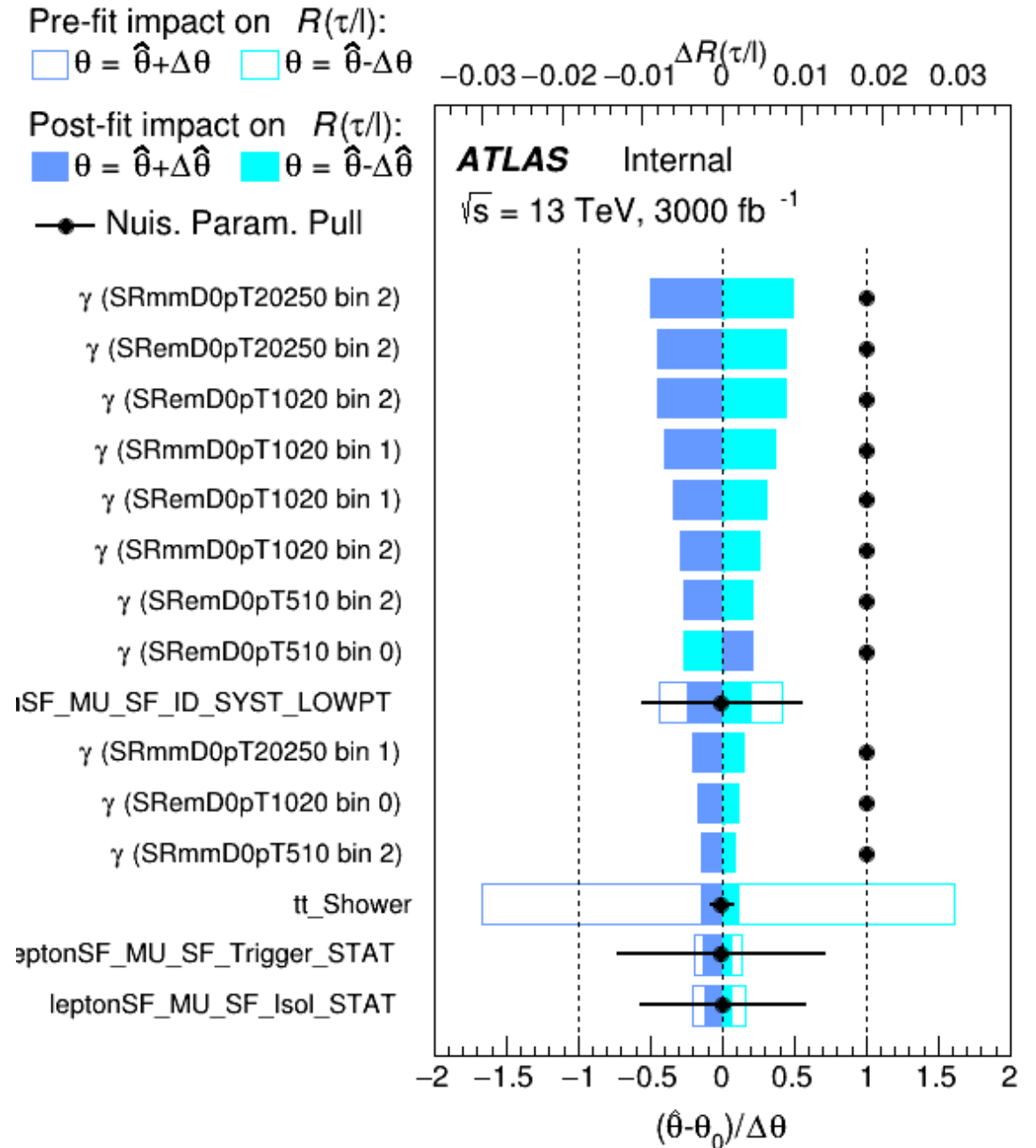
Abroad experiences! Thank you I have had a wonderful time so far!!!