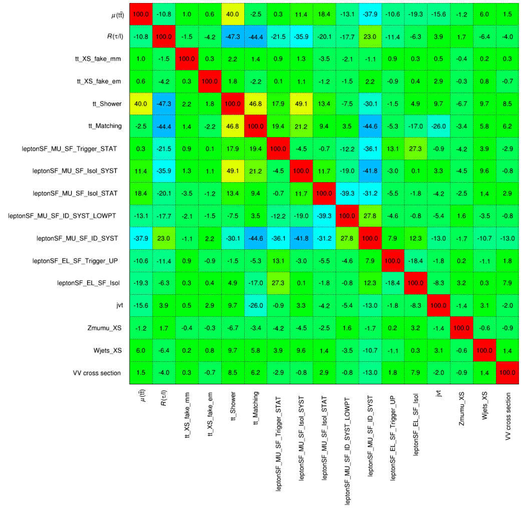
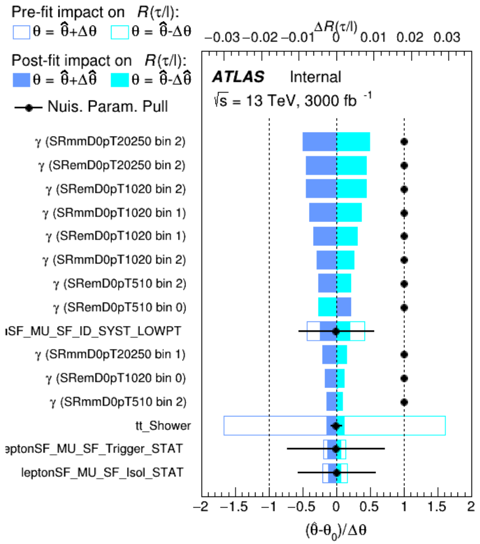
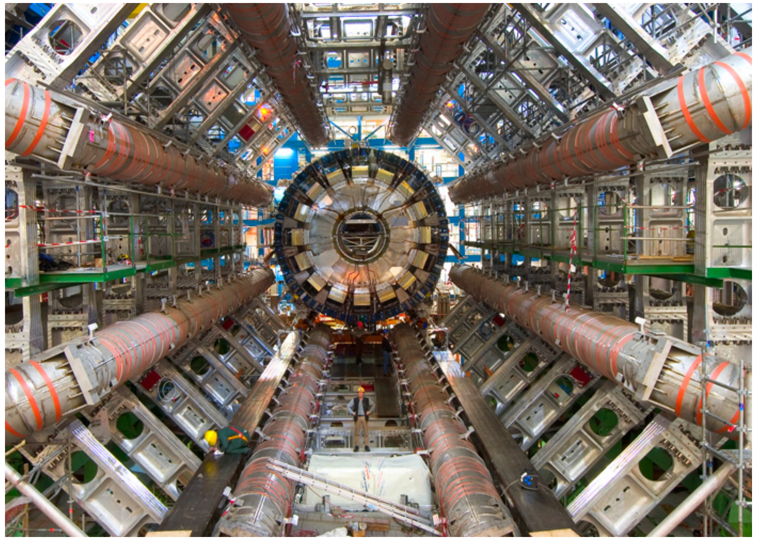




Hunting new physics through improved tests of Lepton Flavour Universality with ATLAS at HL-LHC

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
    - $(g_\mu = g_e = g_\tau = \mathrm{g})$
  - 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…

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

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

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

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

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

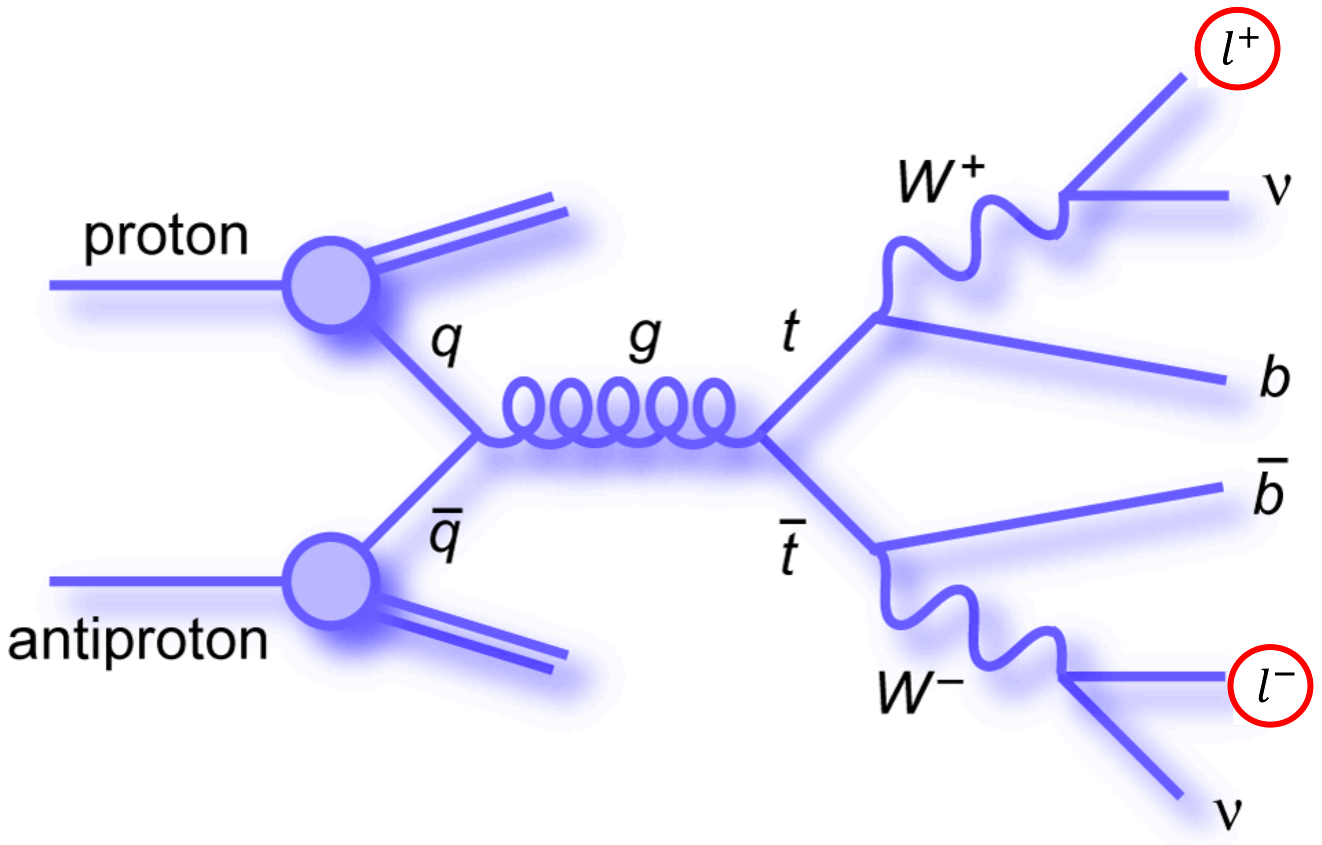
- At LEP, $e^-e^+ \rightarrow W^-W^+$ was used to measure the ratios of branching ratios and achieved 2.5% for electron and muon channels
  - At LHC, uncertainty on the efficiency of reconstructing hadronic τ decays is larger than 2.5%, so we use leptonic decays of τ leptons
    - → looking at dilepton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

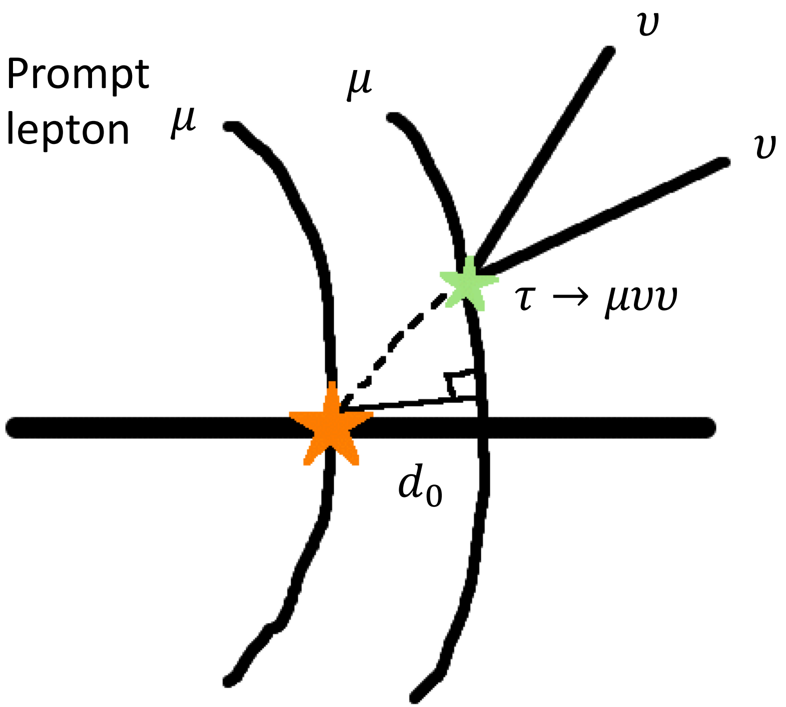
“Tag” lepton l, could be electron e or muon μ



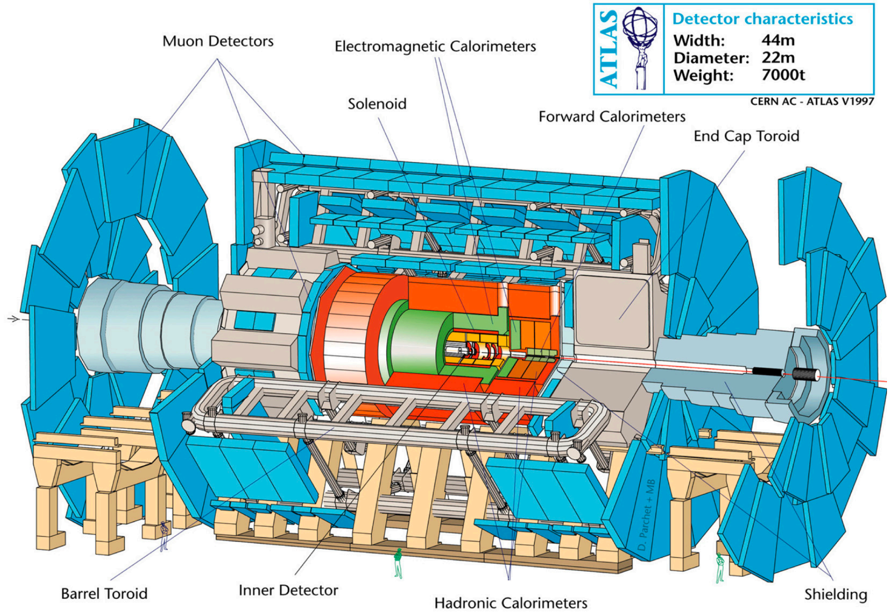
“Probe” lepton l, could be prompt muon μ or tau τ

$\tau \to l\upsilon\upsilon$

Measurement strategy

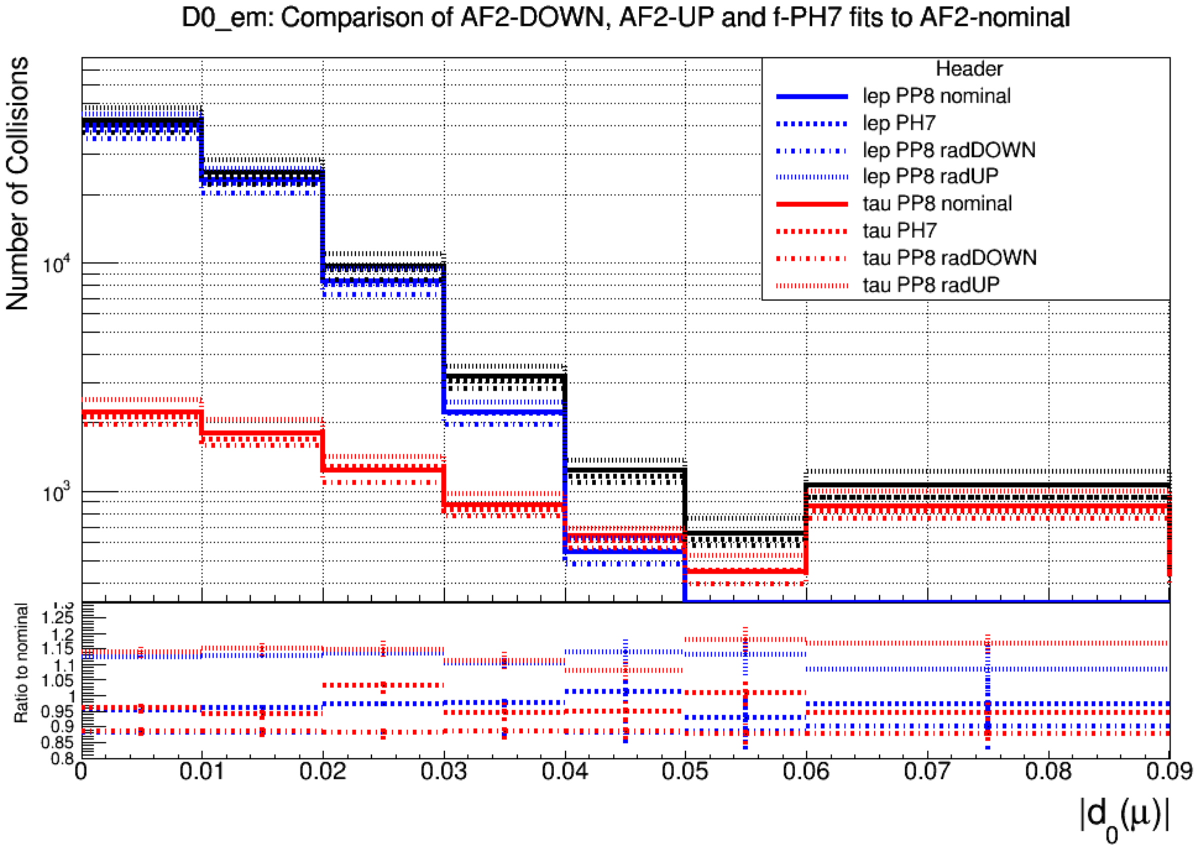


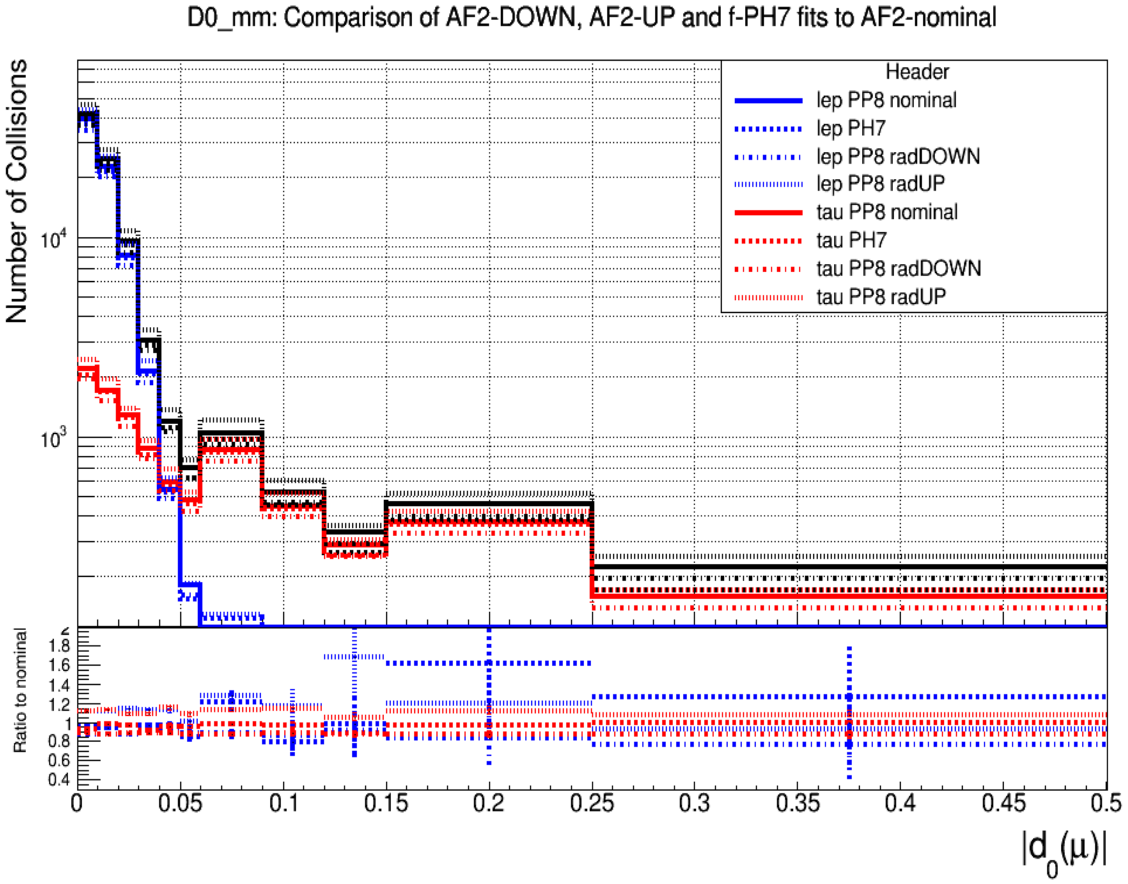
- Distinguish leptons from τ decays than leptons directly from $W^{\mp}$ by:
  - Decay parameter (d_0)
  - Difference in lepton p_t spectra caused by sharing of the τ momenta between decay products



Measurement and Analysis strategy

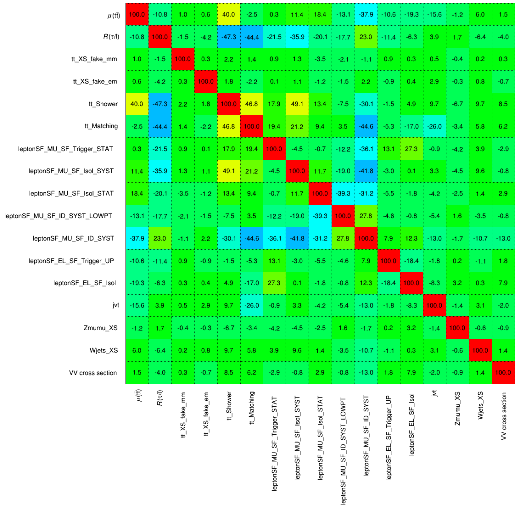
- Examine d_0-eμ and d_0-$\mu\mu$ channels with various event generators (ATL-FAST-2 (AF2) and Powheg Herwig 7 (f-PH7)) and compare to nominal (we use Pythia); below plots include all p_t bins

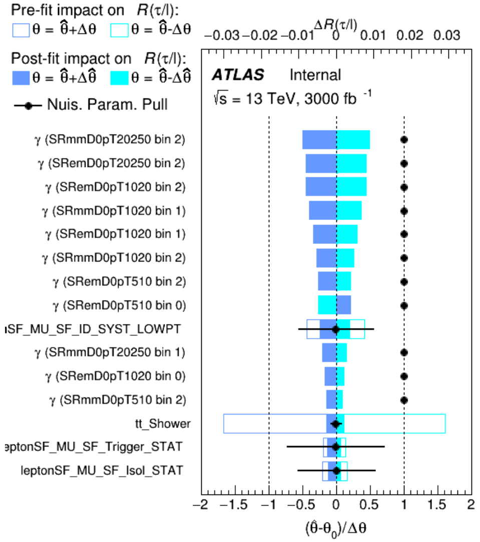




Measurement and Analysis strategy

- 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





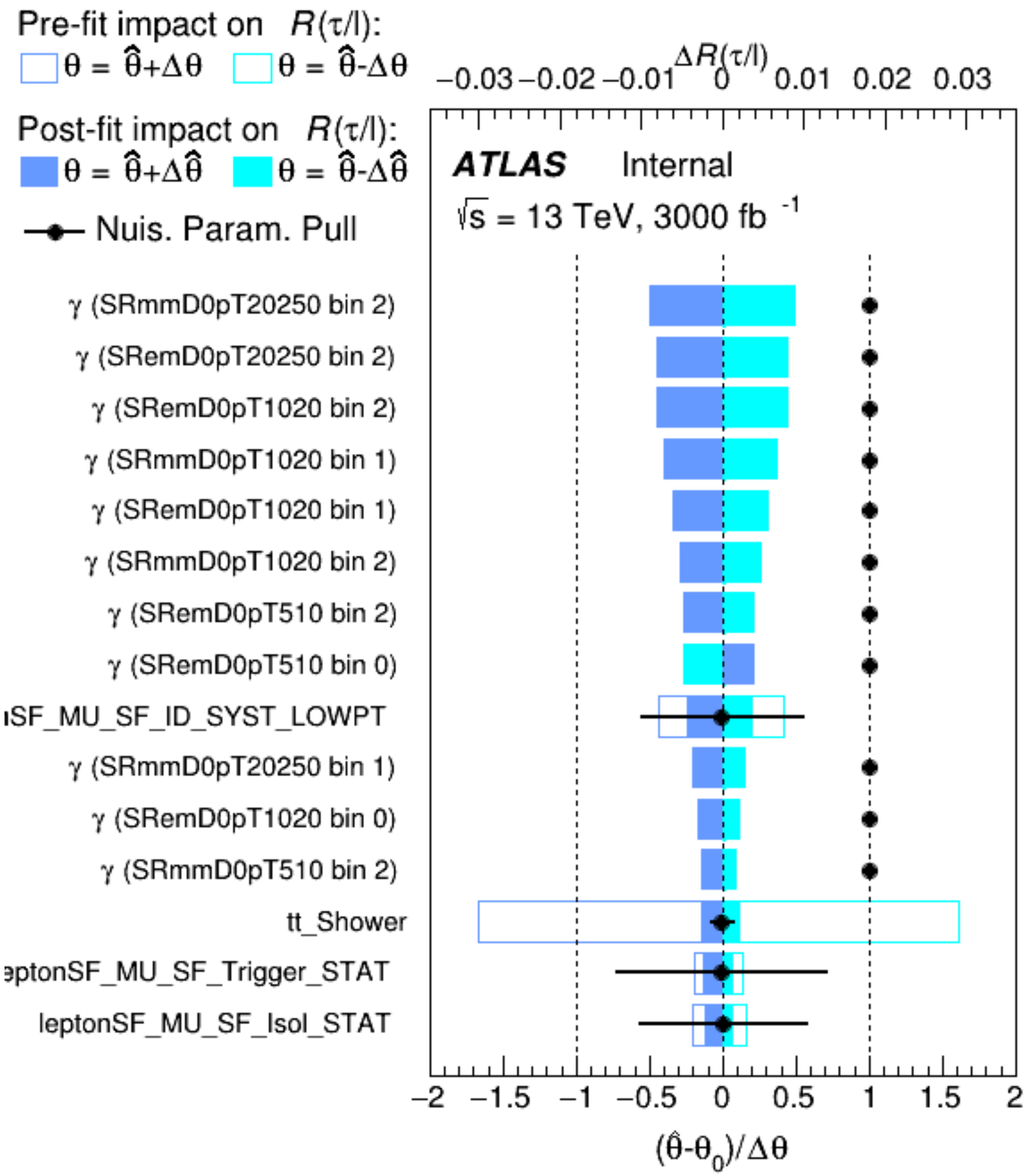
	$\mu(t\bar{t})$	$R(\tau/l)$	tt_XS_fake_mm	tt_XS_fake_em	tt_Shower	tt_Matching	leptonSF_MU_SF_Trigger_STAT	leptonSF_MU_SF_Isol_SYST	leptonSF_MU_SF_Isol_STAT	leptonSF_MU_SF_ID_SYST_LOWPT	leptonSF_MU_SF_ID_SYST	leptonSF_EL_SF_Trigger_UP	leptonSF_EL_SF_Isol	jvt	Zmumu_XS	Wjets_XS	VV cross section
$\mu(t\bar{t})$	100.0	-10.8	1.0	0.6	40.0	-2.5	0.3	11.4	18.4	-13.1	-37.9	-10.6	-19.3	-15.6	-1.2	6.0	1.5
$R(\tau/l)$	-10.8	100.0	-1.5	-4.2	-47.3	-44.4	-21.5	-35.9	-20.1	-17.7	23.0	-11.4	-6.3	3.9	1.7	-6.4	-4.0
tt_XS_fake_mm	1.0	-1.5	100.0	0.3	2.2	1.4	0.9	1.3	-3.5	-2.1	-1.1	0.9	0.3	0.5	-0.4	0.2	0.3
tt_XS_fake_em	0.6	-4.2	0.3	100.0	1.8	-2.2	0.1	1.1	-1.2	-1.5	2.2	-0.9	0.4	2.9	-0.3	0.8	-0.7
tt_Shower	40.0	-47.3	2.2	1.8	100.0	46.8	17.9	49.1	13.4	-7.5	-30.1	-1.5	4.9	9.7	-6.7	9.7	8.5
tt_Matching	-2.5	-44.4	1.4	-2.2	46.8	100.0	19.4	21.2	9.4	3.5	-44.6	-5.3	-17.0	-26.0	-3.4	5.8	6.2
leptonSF_MU_SF_Trigger_STAT	0.3	-21.5	0.9	0.1	17.9	19.4	100.0	-4.5	-0.7	-12.2	-36.1	13.1	27.3	-0.9	-4.2	3.9	-2.9
leptonSF_MU_SF_Isol_SYST	11.4	-35.9	1.3	1.1	49.1	21.2	-4.5	100.0	11.7	-19.0	-41.8	-3.0	0.1	3.3	-4.5	9.6	-0.8
leptonSF_MU_SF_Isol_STAT	18.4	-20.1	-3.5	-1.2	13.4	9.4	-0.7	11.7	100.0	-39.3	-31.2	-5.5	-1.8	-4.2	-2.5	1.4	2.9
leptonSF_MU_SF_ID_SYST_LOWPT	-13.1	-17.7	-2.1	-1.5	-7.5	3.5	-12.2	-19.0	-39.3	100.0	27.8	-4.6	-0.8	-5.4	1.6	-3.5	-0.8
leptonSF_MU_SF_ID_SYST	-37.9	23.0	-1.1	2.2	-30.1	-44.6	-36.1	-41.8	-31.2	27.8	100.0	7.9	12.3	-13.0	-1.7	-10.7	-13.0
leptonSF_EL_SF_Trigger_UP	-10.6	-11.4	0.9	-0.9	-1.5	-5.3	13.1	-3.0	-5.5	-4.6	7.9	100.0	-18.4	-1.8	0.2	-1.1	1.8
leptonSF_EL_SF_Isol	-19.3	-6.3	0.3	0.4	4.9	-17.0	27.3	0.1	-1.8	-0.8	12.3	-18.4	100.0	-8.3	3.2	0.3	7.9
jvt	-15.6	3.9	0.5	2.9	9.7	-26.0	-0.9	3.3	-4.2	-5.4	-13.0	-1.8	-8.3	100.0	-1.4	3.1	-2.0
Zmumu_XS	-1.2	1.7	-0.4	-0.3	-6.7	-3.4	-4.2	-4.5	-2.5	1.6	-1.7	0.2	3.2	-1.4	100.0	-0.6	-0.9
Wjets_XS	6.0	-6.4	0.2	0.8	9.7	5.8	3.9	9.6	1.4	-3.5	-10.7	-1.1	0.3	3.1	-0.6	100.0	1.4
VV cross section	1.5	-4.0	0.3	-0.7	8.5	6.2	-2.9	-0.8	2.9	-0.8	-13.0	1.8	7.9	-2.0	-0.9	1.4	100.0

Correlation matrix

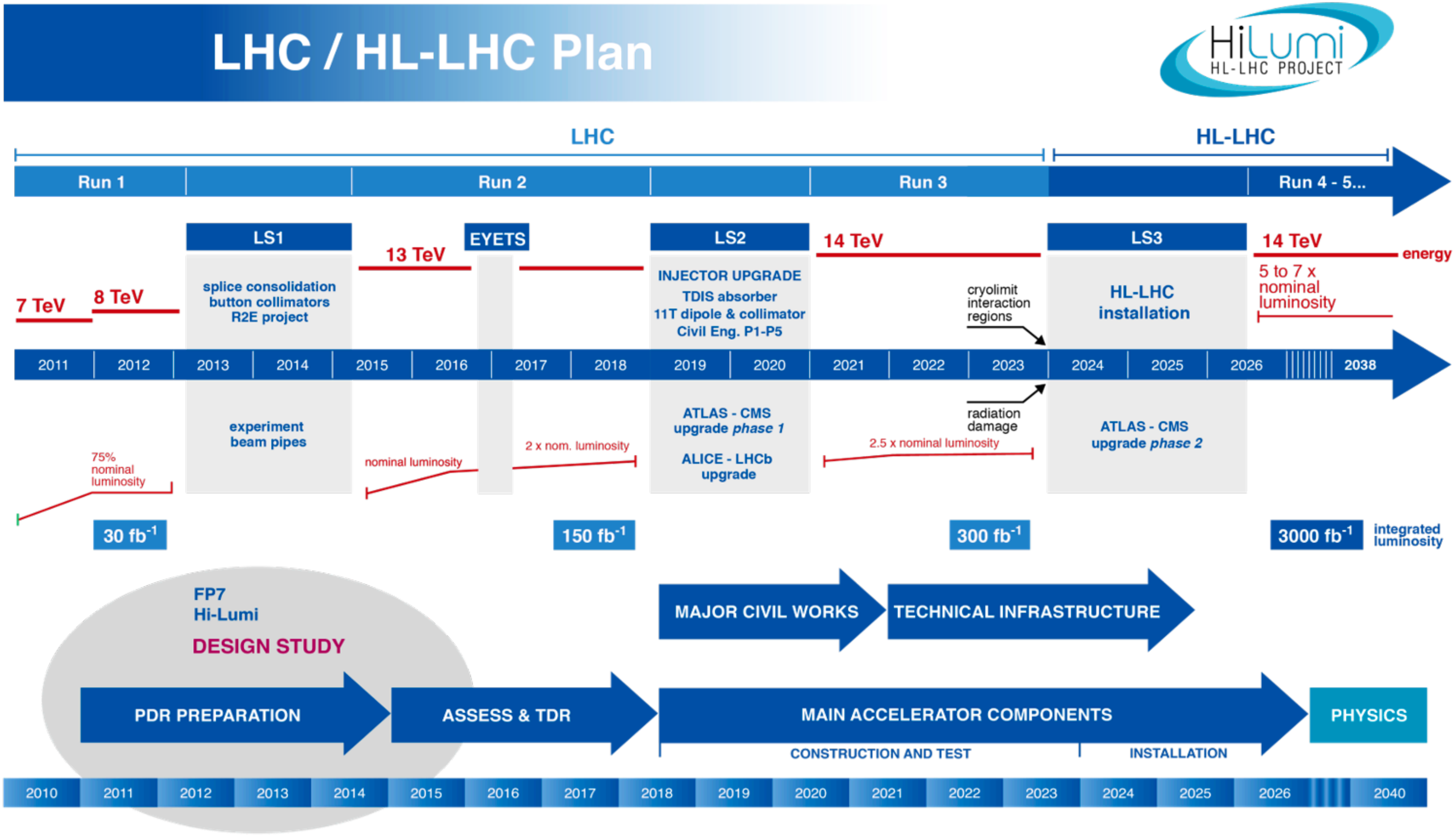
- For all inputted uncertainties, gives correlation between them
- Ideally, we do not want any correlation between our uncertainties

Nuisance Parameter Ranking Plot

- Ranks greatest (top) to least (bottom) dominance of systematic uncertainties and fit parameters in overall nominal uncertainty
- Much of our analysis is currently dominated by Monte Carlo uncertainties (the γs)



Why is this important?



Abroad experiences! Thank you I have had a wonderful time so far!!!