EXTRACTING SD INFORMATION FROM $B\to K^{(*)}l^+l^-$ DECAYS

Luca Silvestrini
INFN, Rome

- Introduction
- Current $b \to s\, ll$ fits
- Future projections
- Conclusions

Based on M. Ciuchini, M. Fedele, E. Franco, S. Mishima, A. Paul, L.S. & M. Valli, JHEP 1606 (2016) 116; M. Ciuchini, A.M. Coutinho, M. Fedele, E. Franco, A. Paul, L.S., M. Valli, EPJ C77 (2017) 688 and work in progress

Many thanks to M. Fedele and M. Valli!

HEPfit

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INTRODUCTION

- Extracting short-distance information from exclusive B decays requires controlling the relevant hadronic matrix elements
- For $B \to K^{(*)} l^+ l^-$, this task is easier than for nonleptonic decays, but still highly nontrivial
- Not only a game of Form Factors, but also of charming penguins...

A GAME OF SEVERAL SCALES

- $\mu \gg m_t, M_W$: possible NP contributions to local D=6 operators in H_{eff}
- $\mu \sim m_t, M_W$: SM contributions to local D=6 operators in H_{eff} (top penguins + boxes + current-current):

$$\mathcal{H}_{\rm eff} = \frac{4G_F}{\sqrt{2}} \sum_{p=u,c} V_{pb}V_{ps}^* \Big\{ C_2(M_W)(\bar{s}_L\gamma_\mu p_L)(\bar{p}_L\gamma^\mu b_L) + C_{7(8)}(M_W)\frac{e(g_s)}{16\pi^2} m_b \bar{s}_L \sigma_{\mu\nu} F(G)^{\mu\nu} b_R + C_9(M_W)\frac{\alpha_e}{4\pi}(\bar{s}_L\gamma_\mu b_L)(\bar{\ell}\gamma^\mu\ell) + C_{10}(M_W)\frac{\alpha_e}{4\pi}(\bar{s}_L\gamma_\mu b_L)(\bar{\ell}\gamma^\mu\gamma^5\ell) + \ldots \Big\}$$

- $m_t > \mu > m_b$: C_2 contributes with large logs to $C_{7,8,9}$, leading to $C_9(m_b) \sim 4$

A GAME OF SEVERAL SCALES

- $\mu \sim m_b$: compute matrix elements
  - effect of C_2 crucial
    - computable in the infinite m_b limit, away from the charm threshold (quark-hadron duality fails badly close to J/ψ)

      Beneke Feldmann '00; Beneke, Feldmann, Seidl '01; BBNS '09
    - nonfactorizable power corrections to the infinite mass limit can only be estimated non-perturbatively
    - only one estimate from LCSR valid at low q^2

      Khodjamirian, Mannel, Pivovarov, Wang '10

EXTRACTING SD INFORMATION

- Charm loop matrix element contributes to decay amplitudes together with possible NP contributions to C_7 and C_9 - can we disentangle them?
  - charm long-distance contribution expected to become more important close to charm threshold
  - a $C_{7,9}^{NP}$ contribution should depend on helicity and on q^2 according to the corresponding FF
  - C_9^{NP} might break lepton universality

PARAMETERIZING OUR IGNORANCE

- Let us introduce a parameterization for the NP contribution of the hadronic Hamiltonian:

$$H_V^0 = -iN\left\{\left(C_9^{\rm eff}+\tilde h_0^1\right)\tilde V_{L0}+\frac{m_B^2}{q^2}\left[\frac{2m_b}{m_B}\left(C_7^{\rm eff}+\tilde h_0^0\right)\tilde T_{L0}\right]\right\}$$

$$H_V^\pm = -iN\left\{\left(C_9^{\rm eff}+\tilde h_0^1\right)V_{L\pm}+\frac{m_B^2}{q^2}\left[\frac{2m_b}{m_B}\left(C_7^{\rm eff}+\tilde h_0^0\right)T_{L\pm}-16\pi^2\left(h_\pm^0+q^2h_\pm^1+q^4h_\pm^2\right)\right]\right\}$$

Jäger & Camalich '12, Ciuchini et al. '15

- $\tilde h_0^0$ can be interpreted as a ΔC_7, $\tilde h_0^1$ as a ΔC_9, while $h_\pm$ have no SD equivalent

BAYESIAN FIT

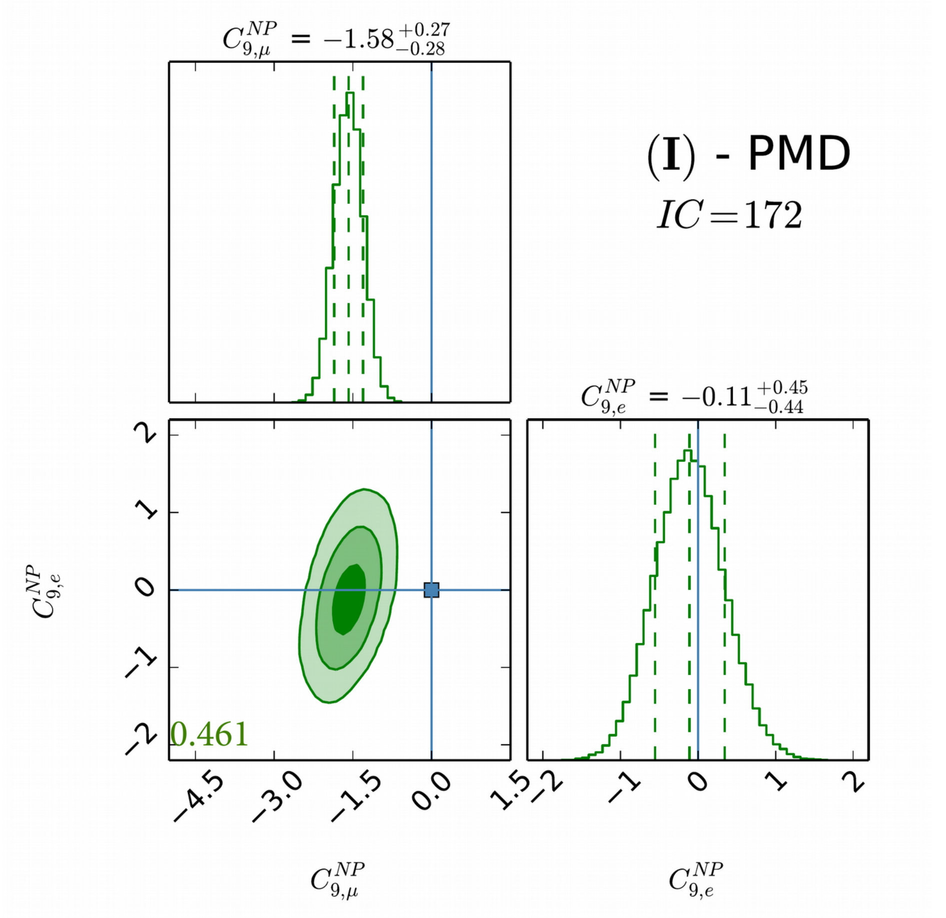
- Compute all amplitudes using QCD factorization and form factors from LQCD (Bailey et al. '15) and LCSR (Bharucha, Straub & Zwicky '15)
- add hadronic contributions and
  - use LCSR calculation from KMPW at low q^2 (1 GeV^2) only (PDD)

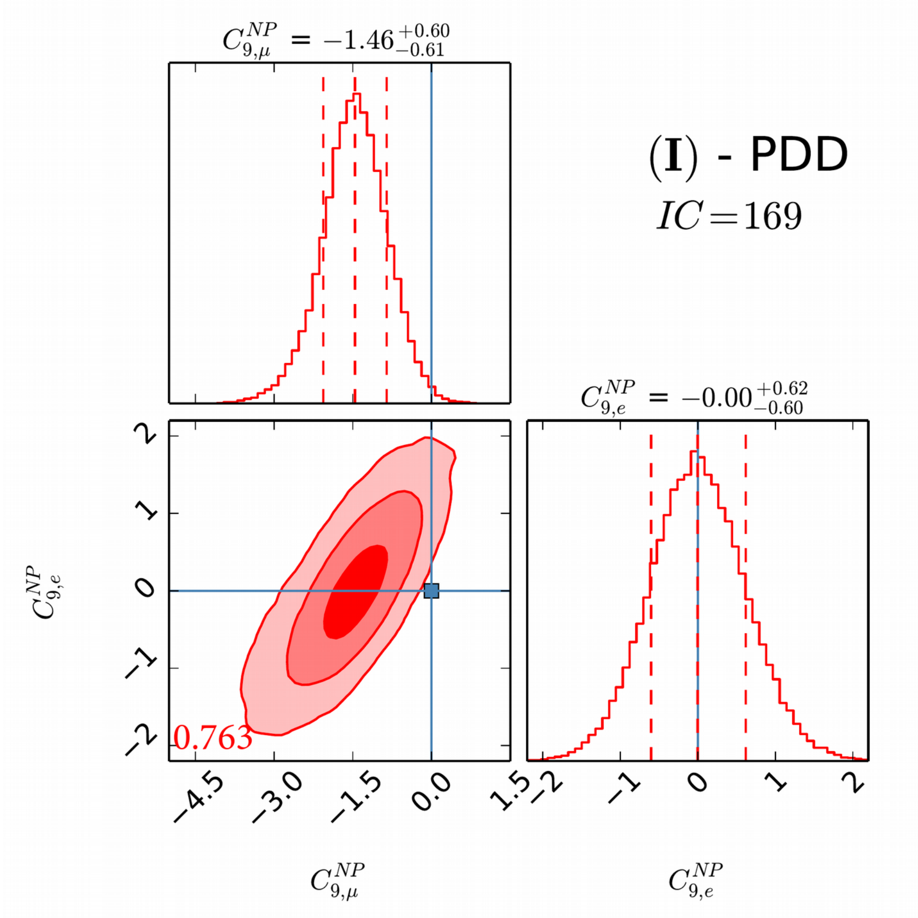
    or
  - extrapolate LCSR calculation to larger q^2 using unitarity (PMD)
- fit all available experimental data using the HEPfit code
- compare different models using $IC = -2\overline{\log L} + 4\sigma^2_{\log L}$

- LUV absent in the SM; LUV observation would be a clean signal of NP
- What kind of NP contribution is preferred by current data?
  - NP in electrons or muons or both?
  - NP in vector or axial vector or both?
- Estimate of hadronic uncertainties crucial to answer questions above

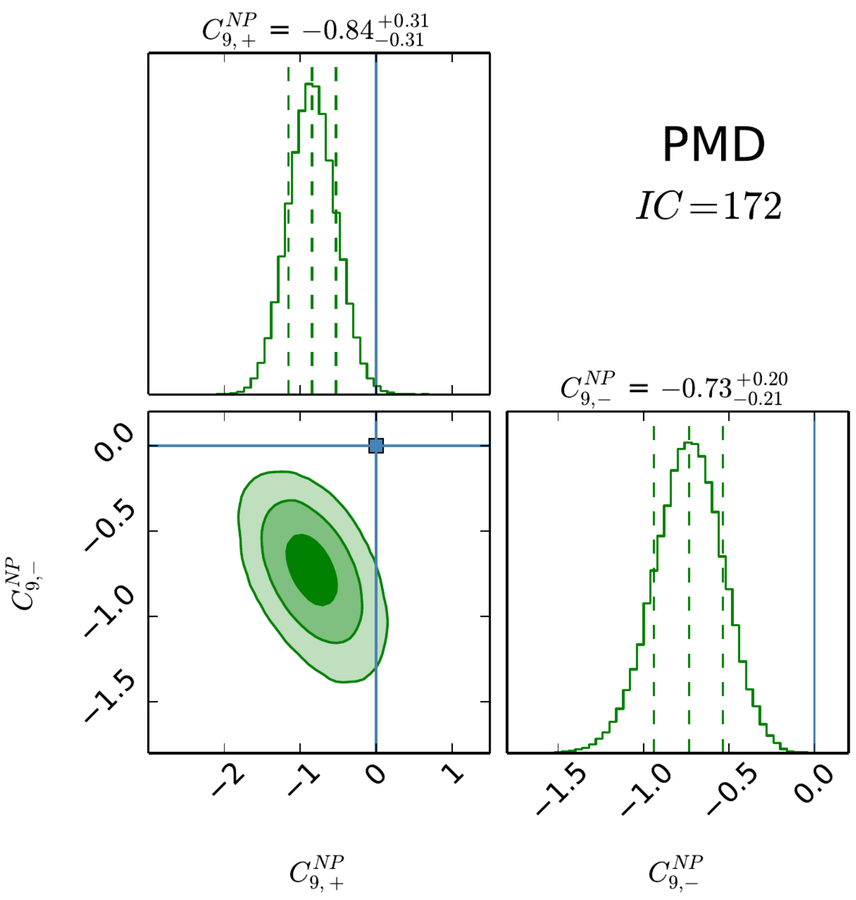
See also Jäger & Camalich '12, '14; Beaujean, Bobeth & Van Dyk, '13; Hurth & Mahmoudi '13; Altmannshofer & Straub '14; Descotes-Genon, Hofer, Matias & Virto '14, '15; Hurth, Mahmoudi & Neshatpour '16; Capdevila, Descotes-Genon, Hofer & Matias '17; Chobanova et al. '17; Altmannshofer, Niehoff, Stangl & Straub '17; Capdevila et al. '17; Altmannshofer, Stangl & Straub '17; Hiller & Nisandzic '17; Geng et al. '17; D'Amico et al. '17; Celis, Fuentes-Martin, Vicente & Virto '17; … ; For model-dependent analyses see Alonso, Grinstein & Camalich '14; Hiller & Schmaltz '14, '15; Ghosh, Nardecchia & Renner '14; Glashow, Guadagnoli & Lane '14; Gripaios, Nardecchia & Renner '14; Sahoo & Mohanta '15; Crivellin, D'Ambrosio & Heeck '15; Crivellin et al. '15; Celis et al. '15; Greljo, Isidori & Marzocca '15; Calibbi, Crivellin & Ota '15; Falkowski, Nardecchia & Ziegler '15; Carmona & Goertz '15; Chiang, He & Valencia '16; Becirevic, Sumensari & Zukanovich Funchal '16; ...

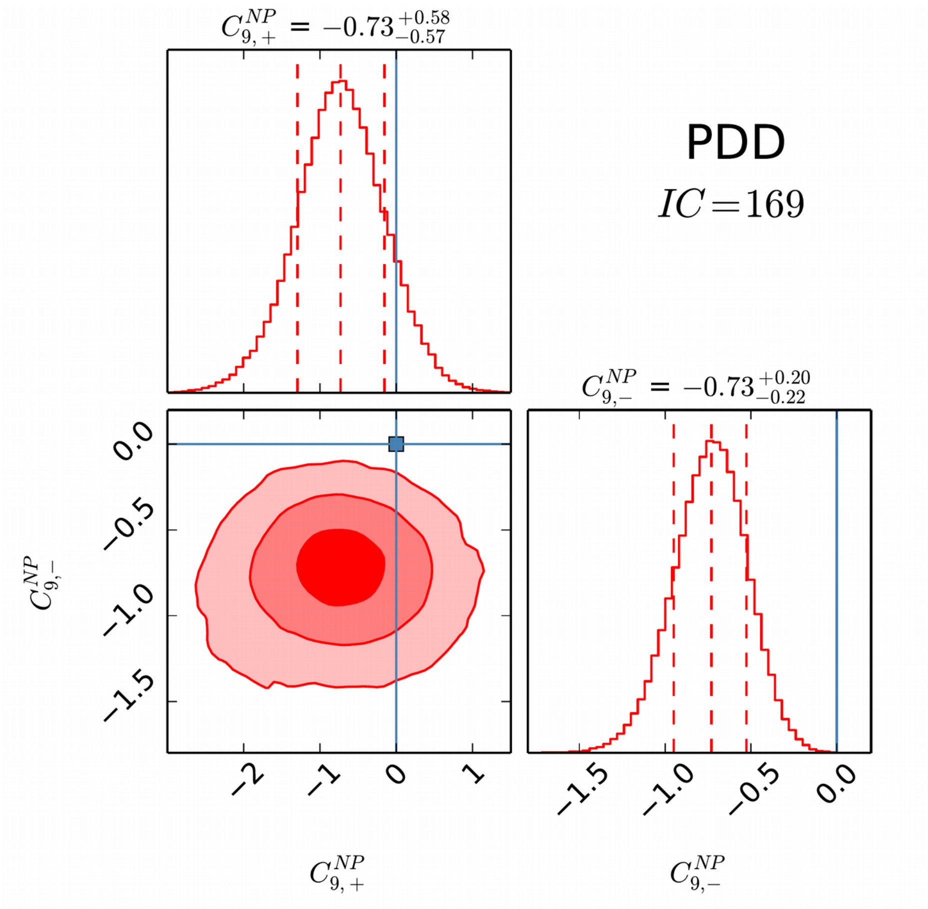
NP IN C_9^μ AND C_9^e



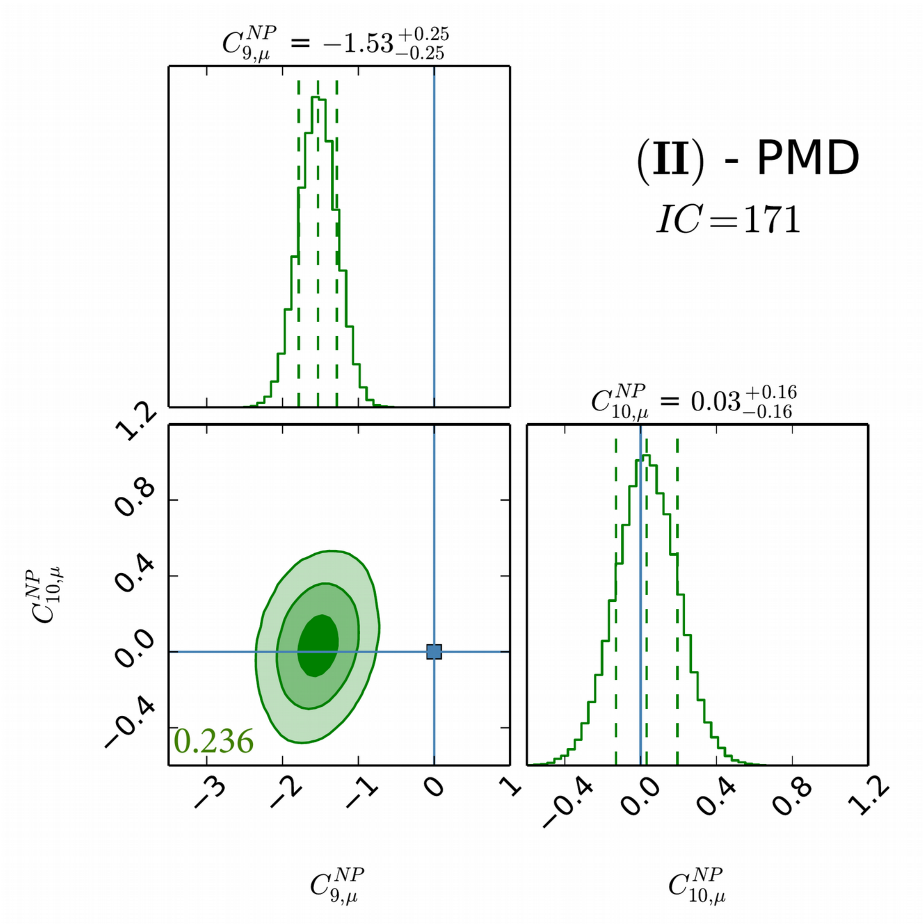


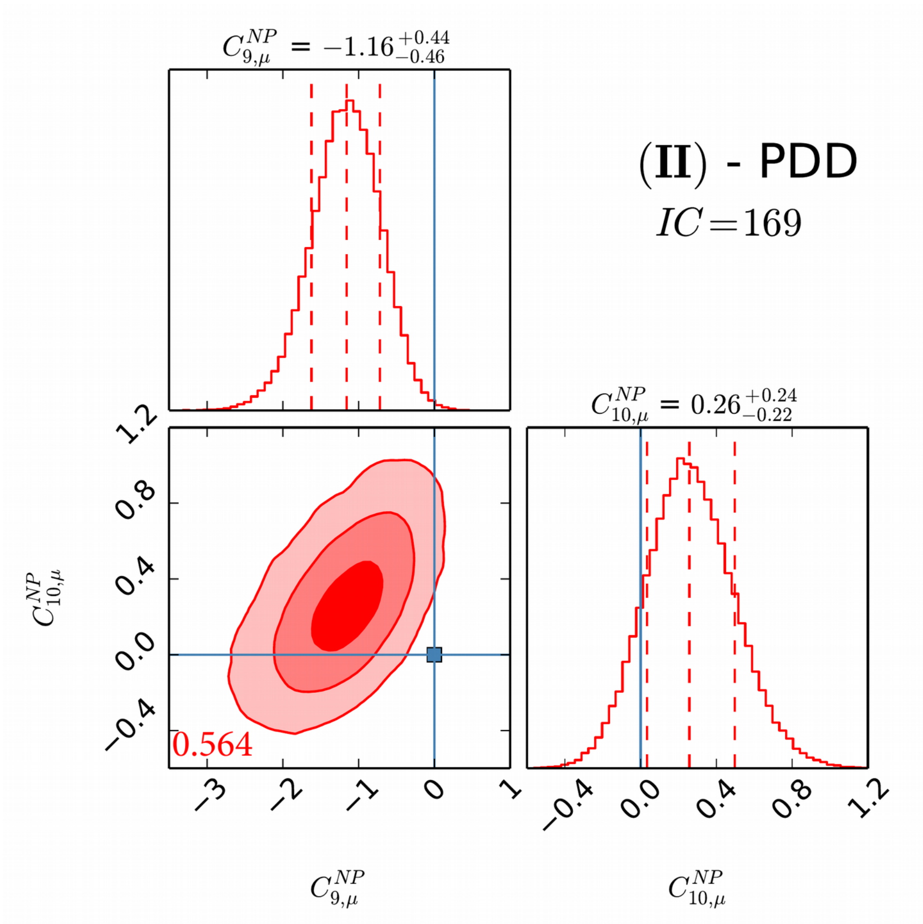
NP IN C_9^μ AND C_9^e



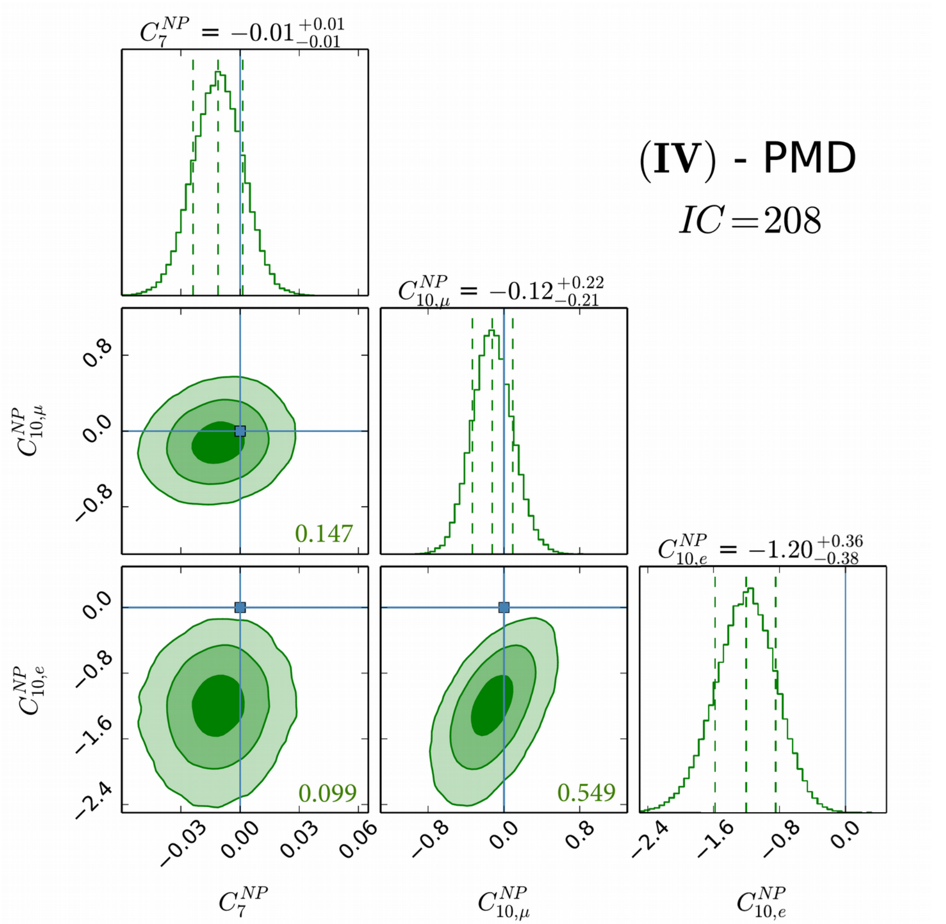


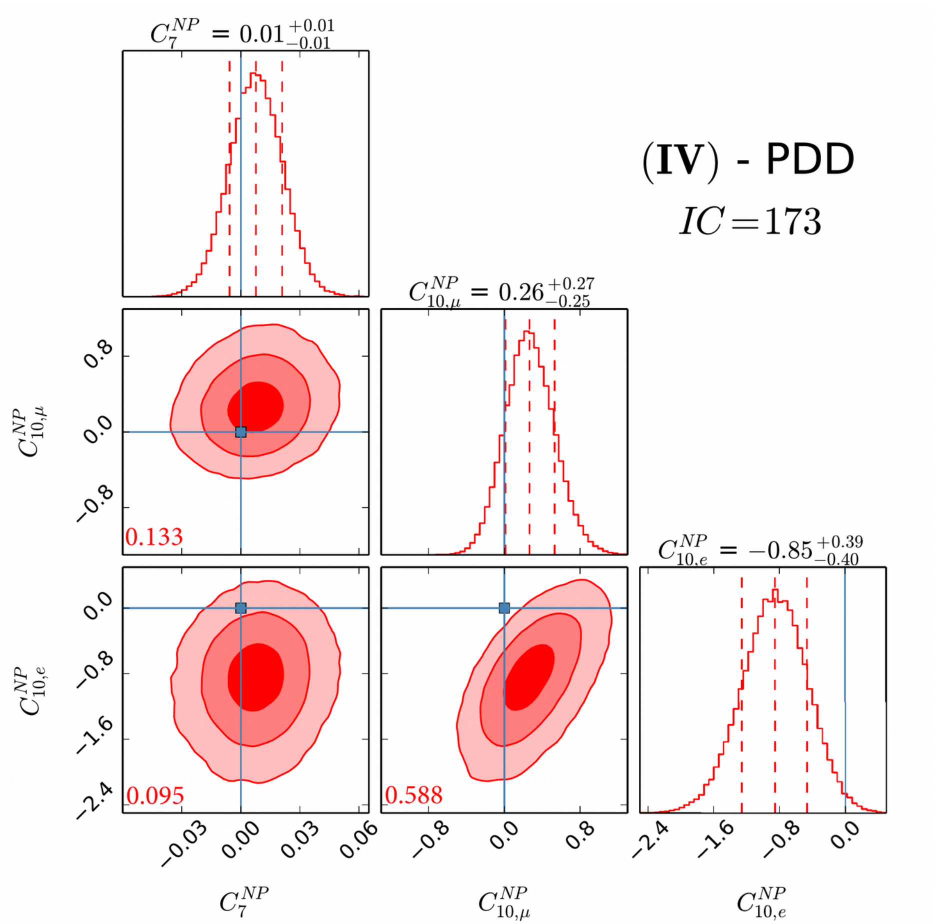
NP IN C_9^μ AND C_{10}^μ



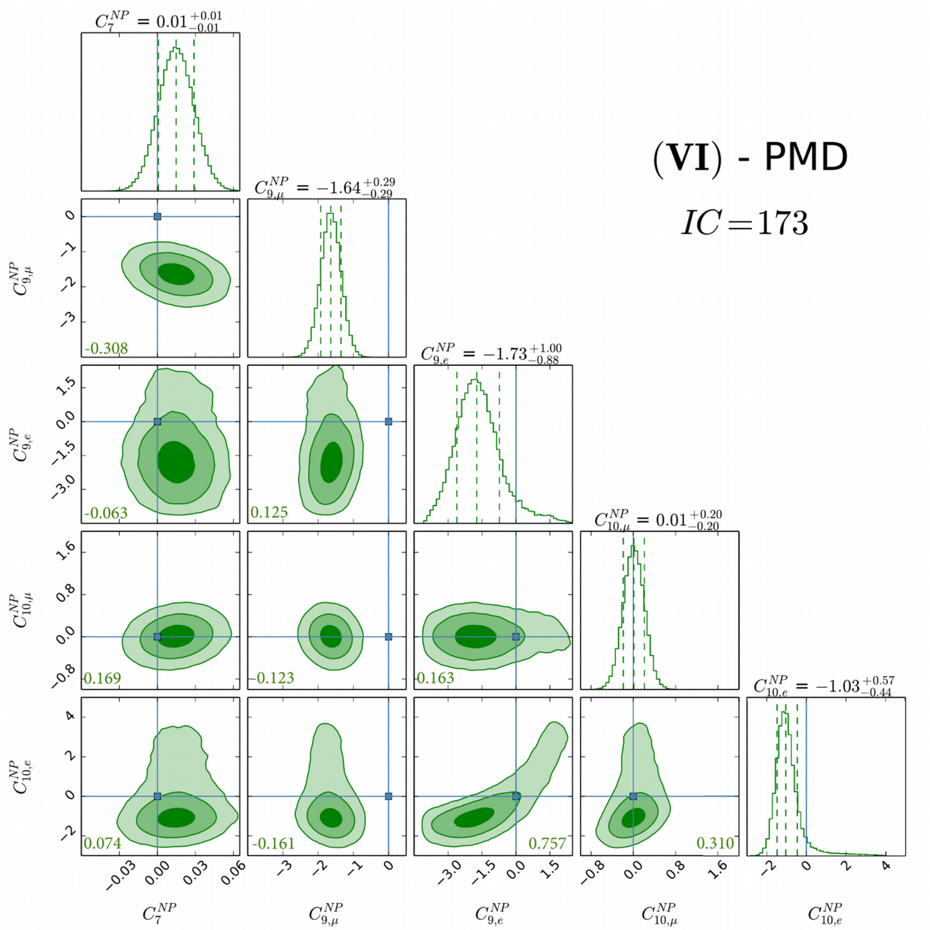


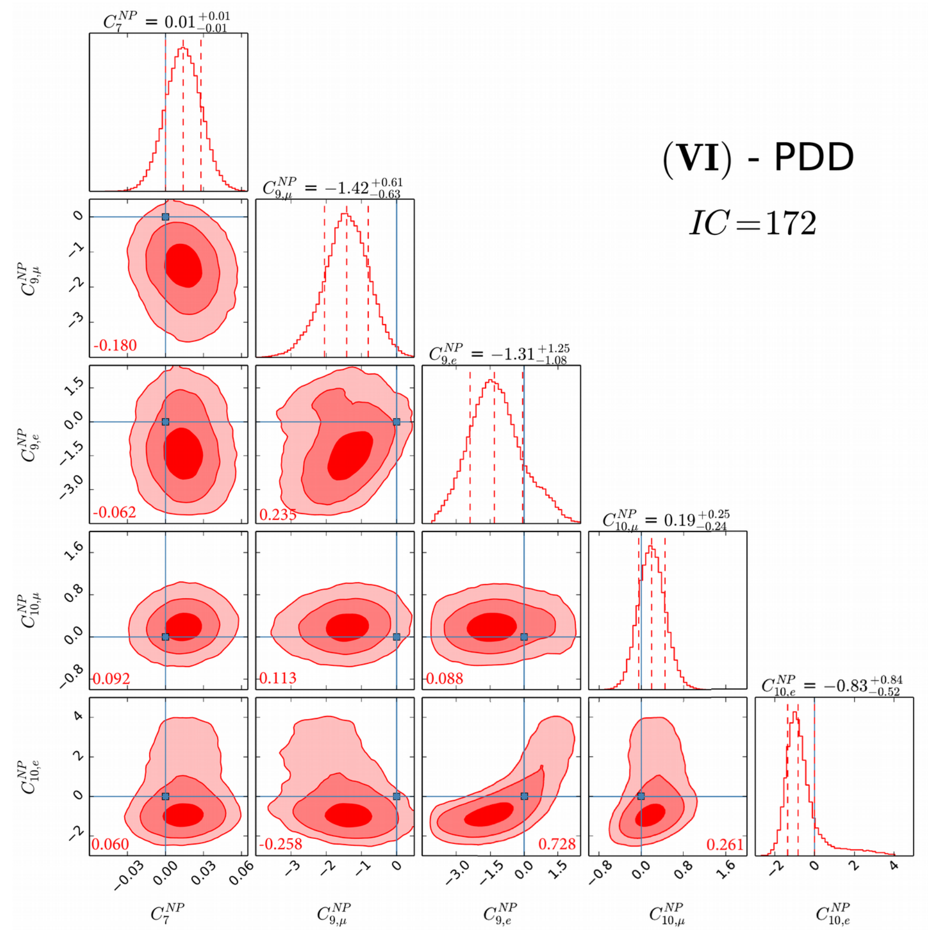
NP IN C_7, C_{10}^{μ} AND C_{10}^{e}





NP IN C_7, $C_{9,10}^{e,\mu}$



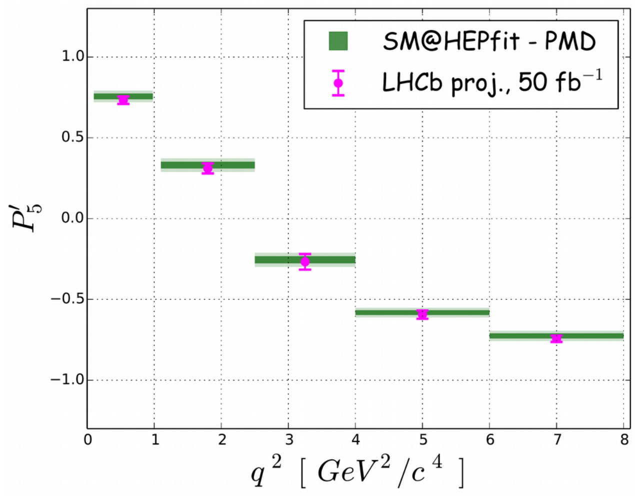


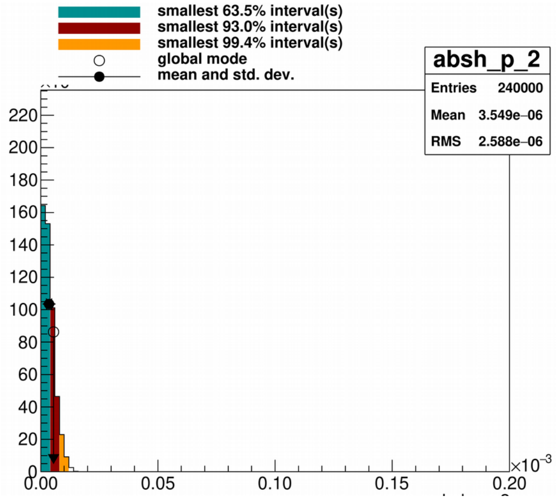
FUTURE PROJECTIONS

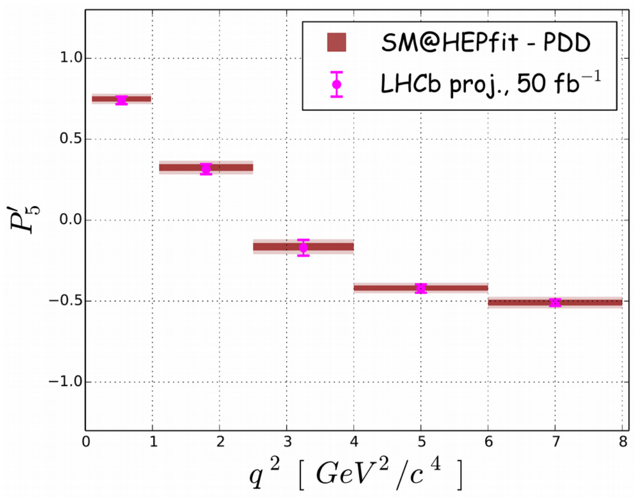
- Choose a theory setup (SM or NP; rising or non-rising charm loop)
- Generate experimental results from current best fit point in the given setup
- Assume future exp errors scaling LHCb statistical errors to 50/fb (roughly /6) and including BelleII estimates
- Fit parameters from generated data

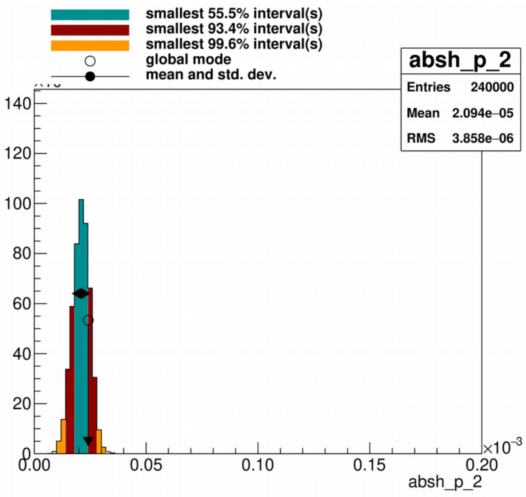
See also Hurth, Mahmoudi, Martinez Santos & Neshatpour '17; Albrecht, Bernlochner, Kenzie, Reichert, Straub, Tully '17

SM PROJECTION



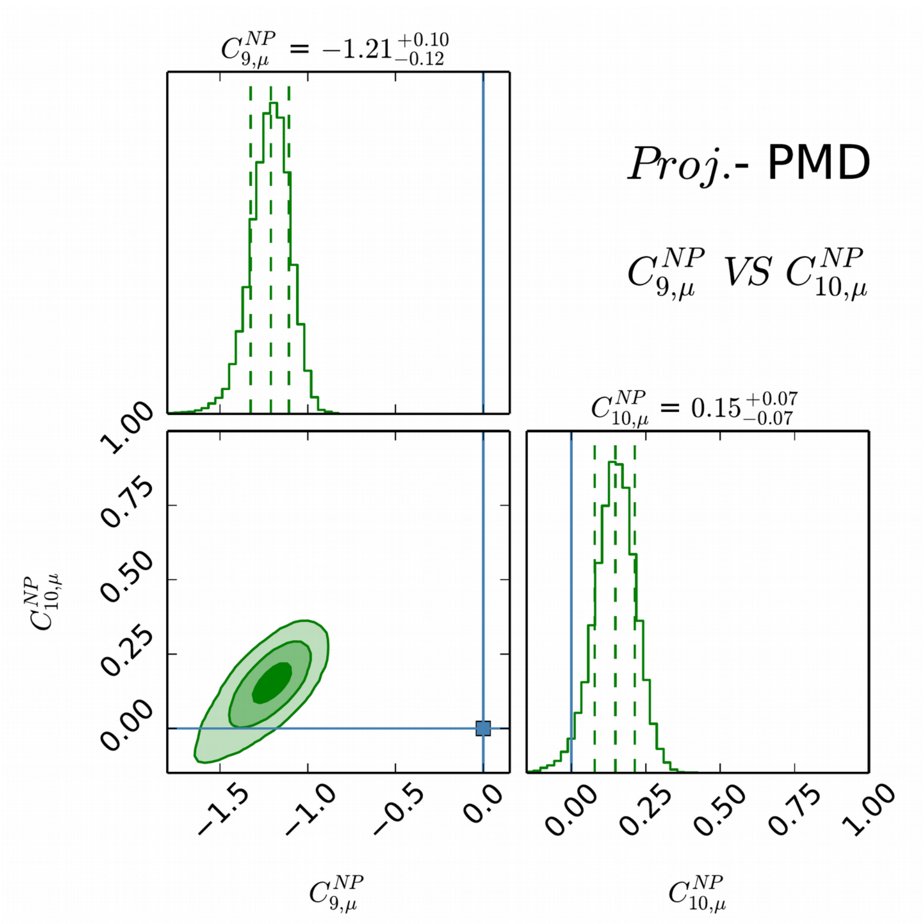


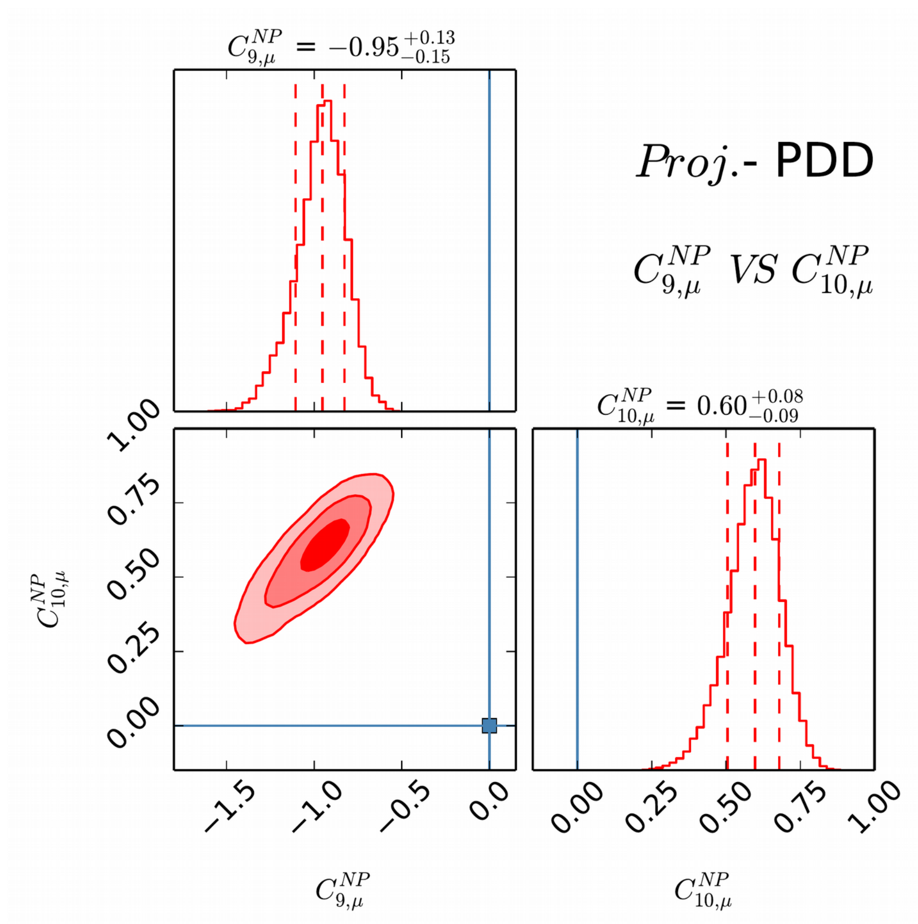




PRELIMINARY!

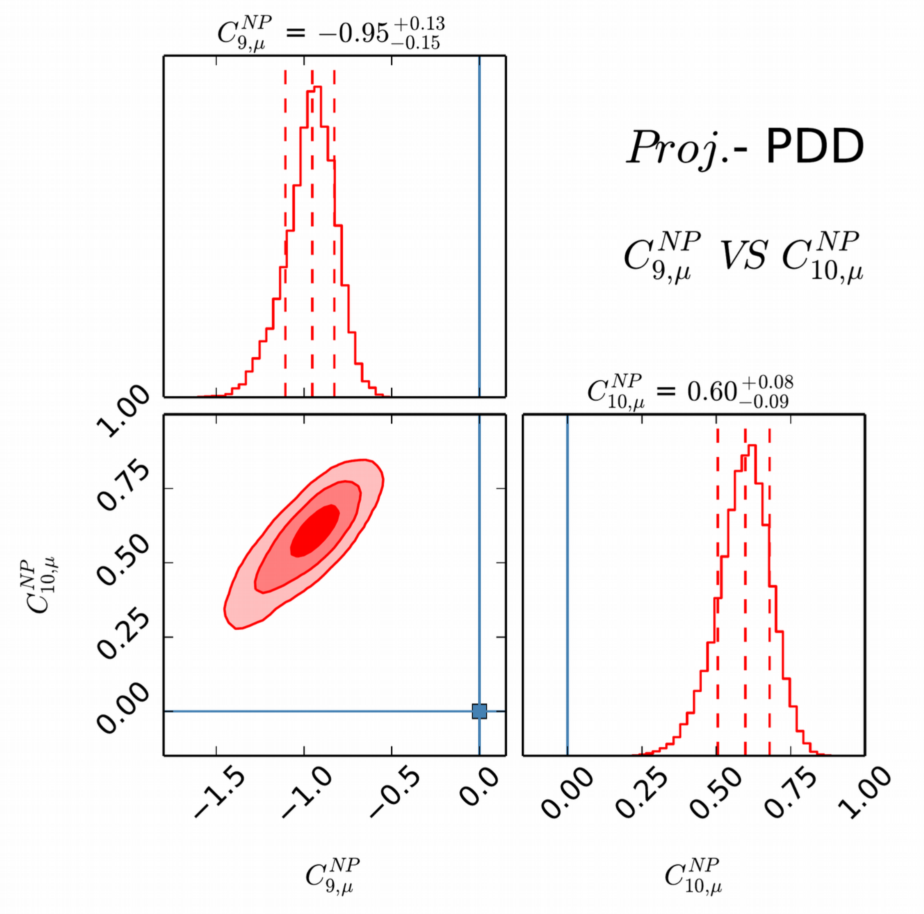
NP PROJECTION

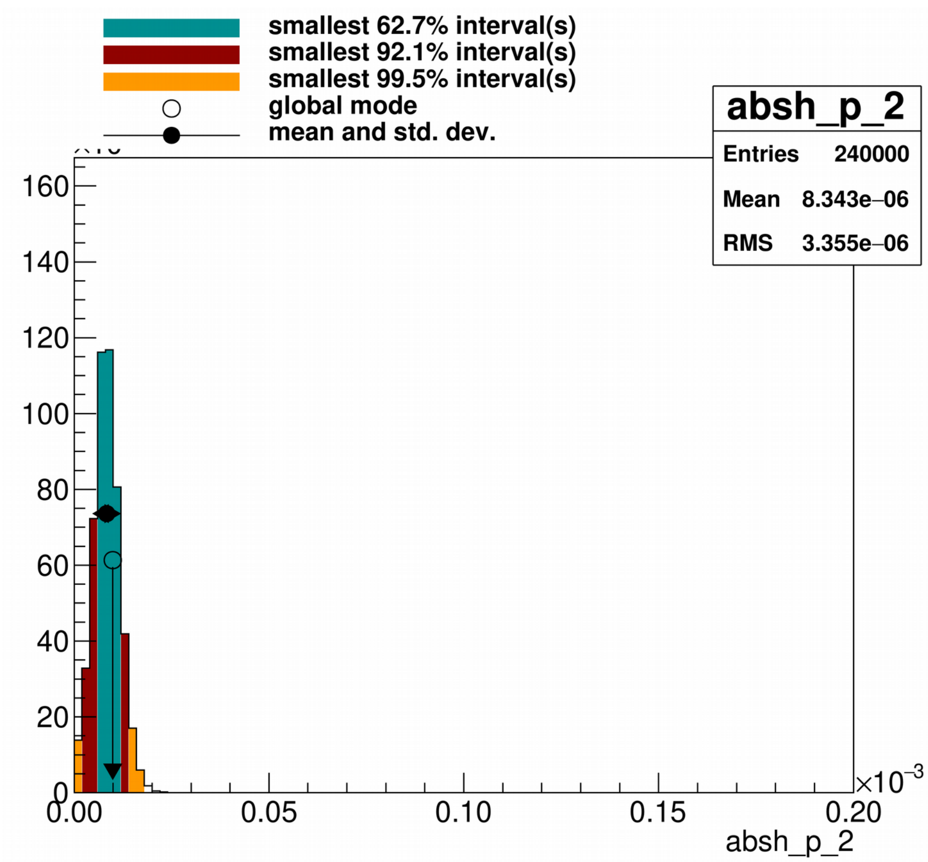




PRELIMINARY!

NP PROJECTION





PRELIMINARY!

CONCLUSIONS

- Current data hints at NP in $b \to s l^+ l^-$ transitions
- A conservative estimate of hadronic uncertainties results in deviations from the SM at the ~3σ level due to LUV
- With the same assumptions, NP in C_{10}^e as viable as NP in C_9^μ
- still too early to draw conclusions on the details of the possible NP structure

CONCLUSIONS II

- LHCb upgrade + Belle II have the full power to disentangle hadronic contributions from NP ones even in the absence of theoretical progress
- Improvements in FF calculations and possible breakthroughs in charming penguins would further increase the NP sensitivity