P5' Status Report

Reamining systematics and approximate profiled FC
or "How we spent our xmas vacation"

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Introduction

- We have estimated the remaining systematics uncertainties, only one missing;
  - Efficiency shape
  - Mass distribution
  - Feed-through background
  - Uncertainty from fixed `pdf` parameters Still missing
    - Will describe the proposed solution, after the discussion with the StatCom
- Statistical uncertainties
  - After long and hard discussion with StatCom, against our scientific opinion, validated with data, the outcome was that **none** of the many methods we proposed to estimate the statistical uncertainties were good enough,
  - we had implement yet a different method to compute the statistical uncertainty;
    - the proposed solution is to build the Neyman construction
    - the full 2D construction is simply impossible: time estimate $\mathcal{O}(years)$
    - instead, we agreed upon a 1D FC approach by profiling the likelihood on data at fixed P_1 (P_5') values.
    - here will describe the procedure and preliminary results;

Systematics uncertainties: Efficiency shape

- Fit high statistics control regions ($J/\psi/\psi(2S)$) usig the efficiency and compare F_L with word-average values

J/ψ 165 000 signal events
  - $F_L = 0.537 \pm 0.002$ (stat) vs 0.571 ± 0.007 (stat+syst)

$\psi(2S)$ for completeness also here, lower stat:
  - $F_L = 0.538 \pm 0.008$ (stat) vs $0.463^{+0.028}_{-0.040}$ (stat+syst)

- Then uncertainties on F_L is propagated (with 200 toy experiments) to other bins

q^2 bin	P_1	P'_5
0	± 0.017	± 0.005
1	± 0.048	± 0.060
2	± 0.093	± 0.065
3	± 0.094	± 0.045
5	± 0.083	± 0.059
7	± 0.100	± 0.060
8	± 0.068	± 0.041

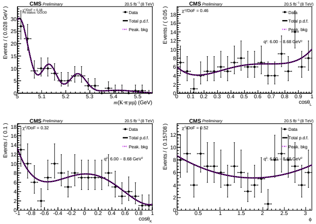
Systematics: Mass distribution

- it is used in the final fit on data
  - `pdf` used is a two-gaussian with common mean
  - separately for correctly and wrongly tagged events
  - the parameters (mean, four σ and two ratios) are taken from the high statistics MC
- we use the two control samples ($J/\psi, \psi(2S)$) to fit all params of the mass distribution and compare the results on P_1 and P_5'
- The maximum changes in the measured values in the two control channels when the parameters are varied are taken as the systematic uncertainty for all q^2 bins.
- The maximum change of P_1 is 0.012, of P_5' is 0.019.

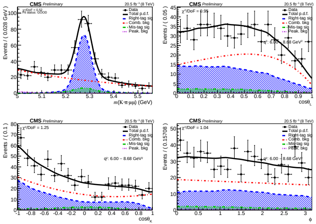
Systematics: Feed-through background

- In bins just below or above the resonances, there could be a contamination from $B^0 \to \mathrm{J}/\psi K^{*0}$ and $B^0 \to \psi' K^{*0}$ feed-through events
- Feed-through is modelled by a dedicated `pdf` for bin 3 and 5, using control region simulation

An example for bin 3 just below the J/ψ control region



Fit with additional pdf component



(barely visible in purple)

q^2 bin	P1	P5p
3	± 0.004	± 0.012
5	± 0.012	± 0.020
7	± 0.011	± 0.024

Systematics: Uncertainty from fixed pdf parameters

Last systematics to be evaluated

- In the final pdf some of the parameters (F_L, F_S, and A_S) are fixed from BPH-13-010
- Our initial idea was to get uncertainties (and correlation) from previous work (based on same dataset) and propagate to P_1 and P_5'
  - fit with fixed values randomly chosen via a 3D gauss around (F_L, F_S, and A_S)
  - preliminary results were produced (not the most important syst for any bin)
  - but we got some criticism from StatCom:
    - we would have not taken into account the correlation between the fixed
- Different approach based on toy (once again!)
  - generate a large statistics [$\mathcal{O}(100 \times \text{Data})$] toy using as pdf the one with data best fit parameters;
  - fit the toy with all parameters free to float
  - compare the statistical errors of P_1 and P_5' with the ones of a fit with three params fixed;
  - syst uncert to reproduce the scale factor
  - the scale factor between free and partially-fixed fit is precisely the correlation coefficient
    - see *e.g.* Bivariate Normal Distribution
- Unless there are objection, we will proceed with this second option.

Statistical uncertainties

One dimensional Feldman-Cousins approach, profiling the likelihood on data at fixed P_1 (P_5') values.

Procedure description in the PAS

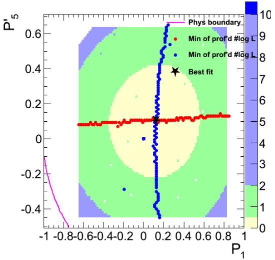
To ensure correct coverage for the uncertainties of the angular observables, the Feldman-Cousins method [?] is used with nuisance parameters. Two main sets of pseudo-experimental samples are generated to compute the coverage for the two angular obervables P_1 and P_5', respectively. The first (second) set, used to compute the coverage for P_1 (P_5'), is generated by assigning values to the other observables as obtained by profiling the likelihood on data at fixed P_1 (P_5') values. When fitting the pseudo-experimental samples the same fit procedure as in data is applied.

What it means in the following, together with preliminary results

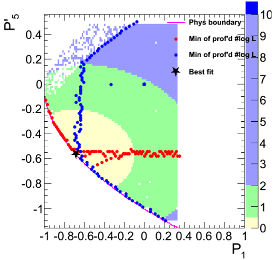
Procedure description

- start from the 2D $\mathcal{L}(P_1, P_5')$ computed on data, taking into account the physical boundaries
- Then we profile it vs P_1 and P_5', respectively
  - if we hit a physical boundary, the minimum can be along the boundary itself
- Then we generate 100 (data-like size) toys using as input parameters P_1 and P_5'.
  - To save CPU time not for all points, but we start around $\Delta \log \mathcal{L} = 0.5$

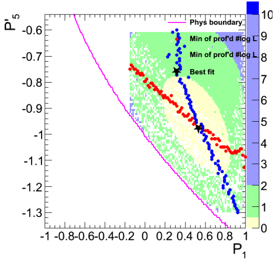
Bin 0



Bin 1



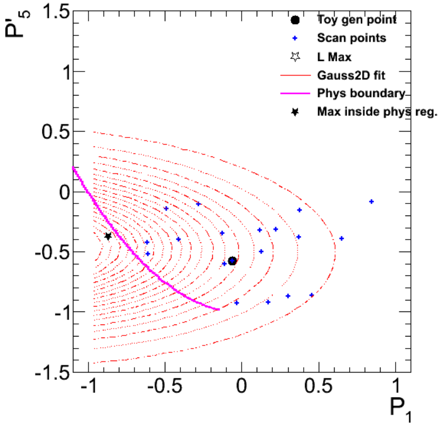
Bin 2



Procedure description (cont'ed)

Each toy is fitted with the full pdf as done for data

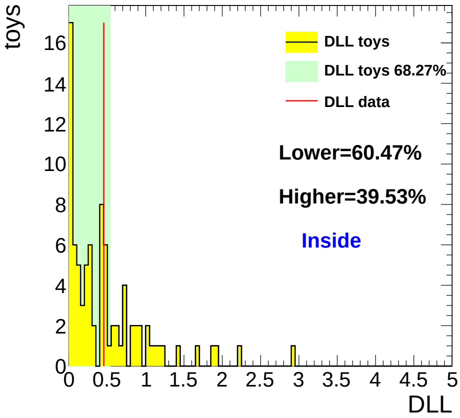
- we repeat the fit with 20 different set of 20 initial values of P_1 and P'_5
  - the 20 points are chosen randomly a 2D gaussian distribution around the toy generator point;
  - or around the min of a fully free fit if it converges
  - the results of the 20 fits provide 20 likelihood values in 20 sets of (P_1, P'_5),
  - to find the absolute max, we fit the 20 values with a 2D gauss function
  - the max must be inside the physical region
- Eventually, we have 100 toys, and 100 values for the likelihood.



Procedure description (cont'ed)

- We compute $\Delta \log \mathcal{L}$ for each toy (compared with the min along the profile) [black histo]$\rightarrow$
- and $\Delta \log \mathcal{L}$ for data for that gen point [red line]$\rightarrow$
- **ratio**=(# toys with DLL(toy)<DLL(Data))/(#toys)
- If **ratio** $< 68.27\%$ [green area]$\rightarrow$ then generation point is inside the 1σ boundary for data, otherwise it's outside.
  - In principle there should be 100 toys
  - some failure (10-15%) due to gauss2D fit failure to be investigated
  - some job failing (batch system): recover
  - should we fit the DLL(toys) distribution? With what? χ^2(#DoF?)?
- repeat for $P_1(P_5')$ upper(lower) bound: 4 "directions"

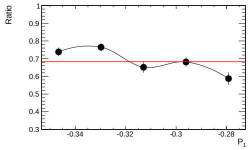
One example of DLL toy distribution compared with DLL(Data) (red)

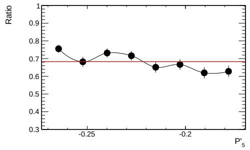


Some numbers

- The procedure is complex, and very time consuming
  - Each toy, for which we scan 20 points, takes about 1h of CPU
  - Each Gen Point has 100 toys
  - We need to evaluate approx 5-10 GenPoints per directions (x4), for each bin (x7)
  - The math is left as a simple exercise to to class

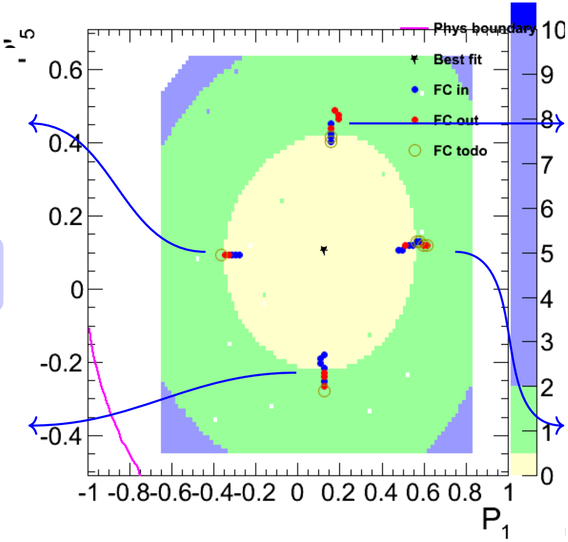
  hint $\approx 3.5 \cdot 10^5$ fits, $> 10kjobs$, $\mathcal{O}(1 \cdot 10^5)$ CPU-hours, babysitting time `you-don't-want-to-know`
- Lot of babysitting!
  - Each time a set of GenPoint finish, we have to evaluate if we crossed the 1σ boundary
  - if not, decide which new GenPoints should be submitted
- On top of that, the local batch system we are using is not working well
  - If we submit at once too many jobs, it just collapses, leaving the jobs in a weird state which must be recovered by hand. Happened twice last week.
  - We have a full support from local IT, so situation is improving, but still quite close to a nigthmare
- Have I said lot of babysitting? It is not, by all means, *just CPU*

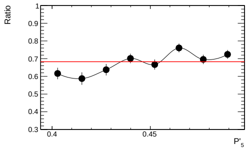


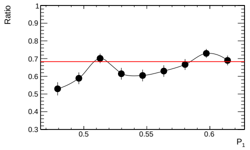


Done

Done

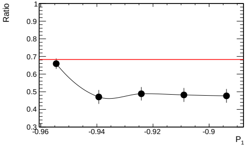


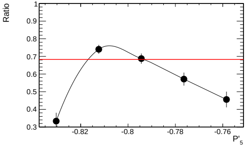


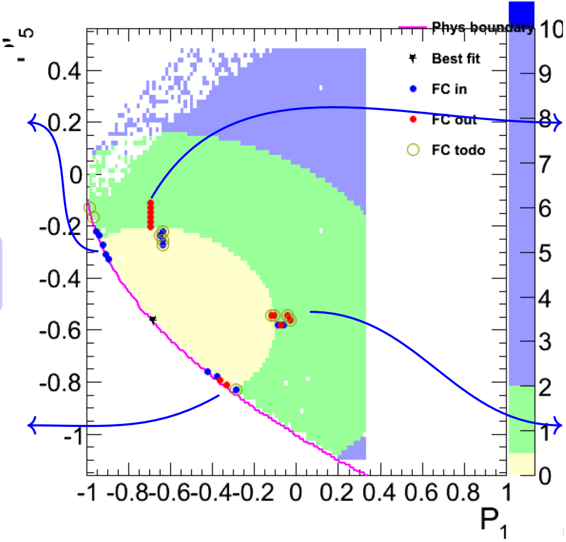


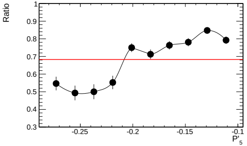
Done

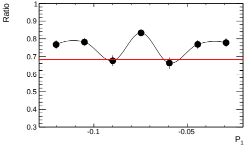
one strange gen point









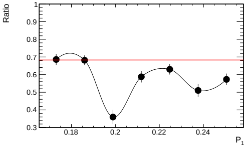


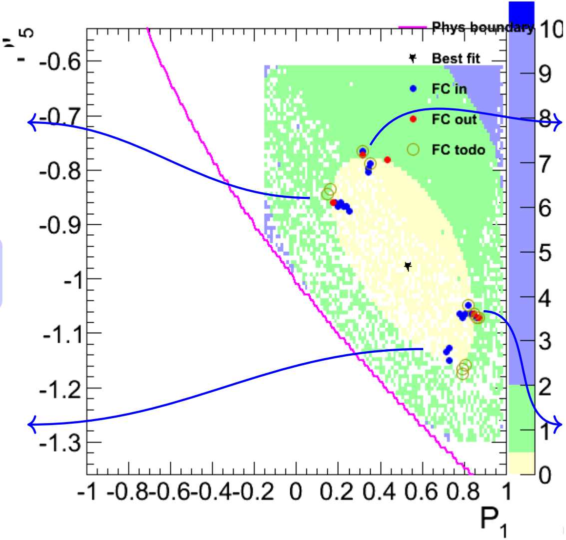
Need more GP

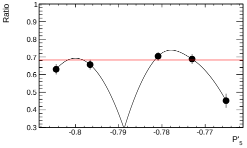
Strange GP

Done

More GP: fluctuations?

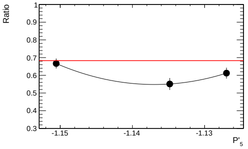


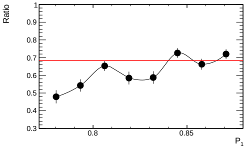


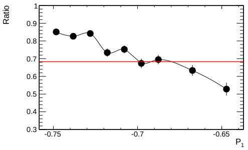


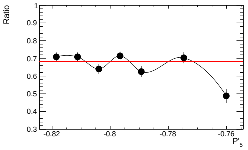
More GP / more GP

More GP: fluctuations? / Almost done



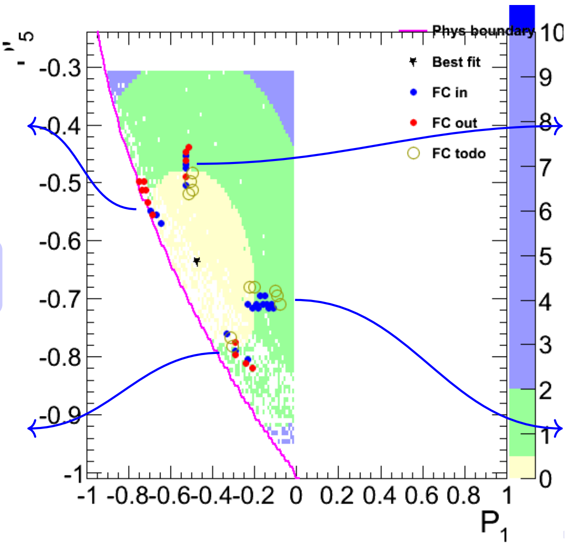


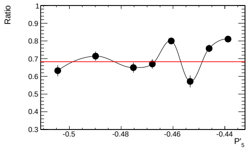


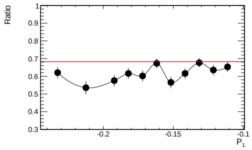


Done

more GP



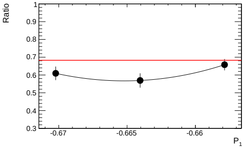


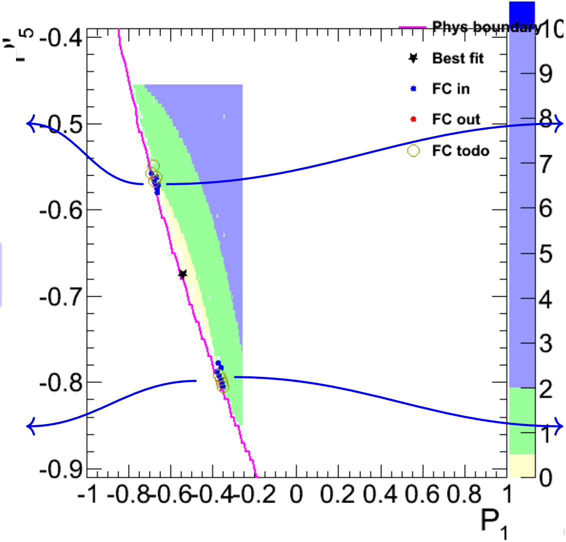


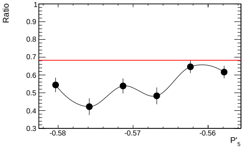
Fluctuation?

more GP

Bin 5

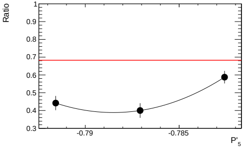


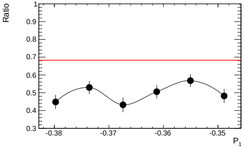


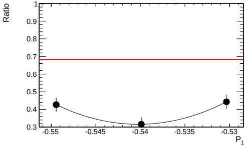


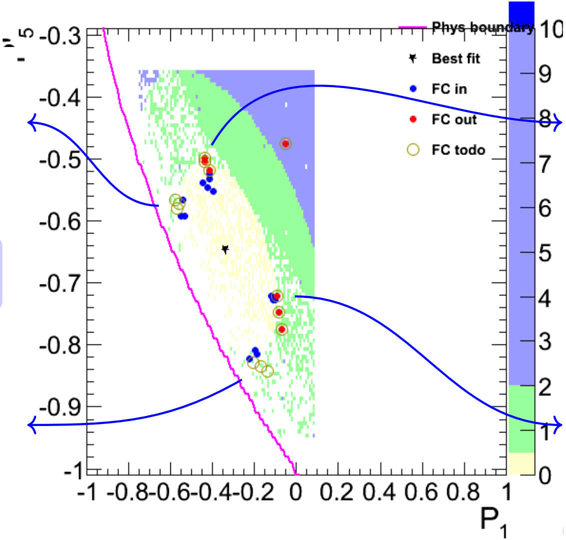
$$\frac{\text{more GP}}{\text{more GP}}$$

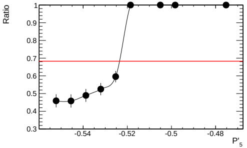
$$\frac{\text{more GP}}{\text{more GP}}$$





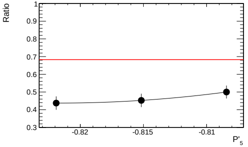


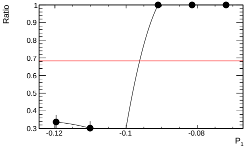


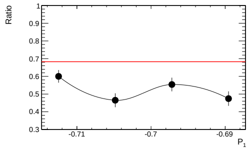


$$\frac{\text{more GP}}{\text{more GP}}$$

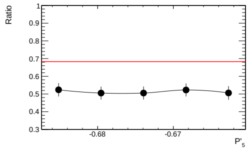
$$\frac{\text{Weird ratio==1}}{\text{Weird ratio==1}}$$

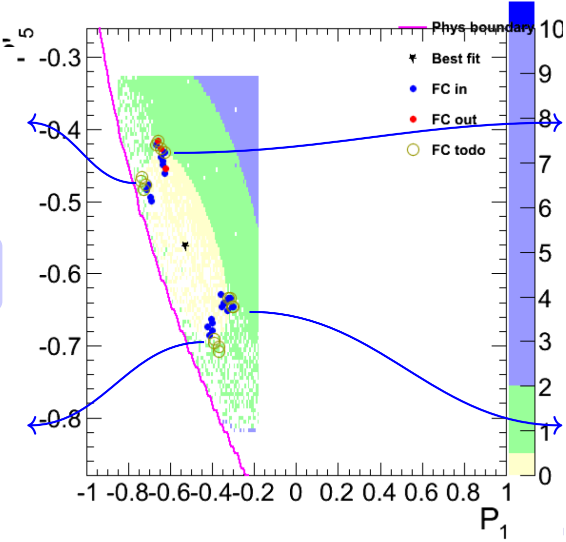


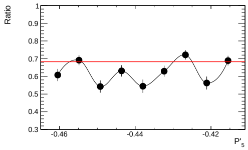




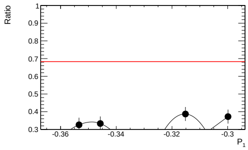
more GP / more GP ∼flat







more GP / strange



Summary

Statistical uncertainties

- We have implemented the 1D likelihood profiling FC
- Running it takes an awful lot of CPU and **human** time in babysitting;
- Preliminary results have been shown;
  - The crossing from inside to outside 1σ is not as clear as expected
    - More gen point to be evaluated already ran, to be resubmitted
    - Try a linear fit of the ratio;
    - Try to increase the # of toys more CPU and more babysitting, hurrah!
    - Investigate the failed gauss2D fit
  - When the crossing is clear, the 1σ boundaries are quite close to the $\Delta \log \mathcal{L} = 0.5$ surprise![a]

[a] No, wait. We did proved that, no surprise, sorry.

Systematics uncertainties

- Almost all done;
- only one missing, but we have a plan how to evaluate it;
- it should not take long, just a matter to find the time to run the free fit on large toy.

Documentation

- We are updating constantly the documentation (PAS and AN) as soon as we have stable results;
- We still strongly want to go to Moriond!.

Additional stuff

Additional or backup slides

Bibliography I