$B^0 \to K^\star \mu\mu$ status report

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Introduction

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- Systematic uncertainties
  - fixed parameters syst: description and results
  - summary table

latest presentations:

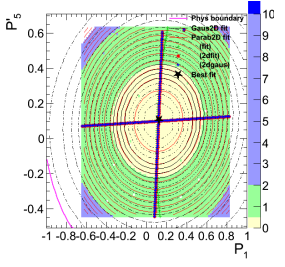
- BPAG 7/2/2017 Alessio
- Physics Plenary during CMS Week 2/2/2017 Mauro
- BPAG 10/1/2017 Stefano

- PAS-15-008
- AN
- TWiki
- HN

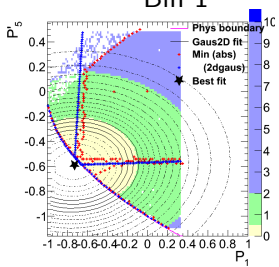
Procedure description

- start from the 2D $\mathcal{L}(P_1, P_5')$ computed on data, taking into account the physical boundaries
- Then we fit it with a bivariate gaussian function and profile it vs P_1 and P_5', respectively, looking for maximum along the profile;
  - more robust than consider just the absolute maximum of the $\mathcal{L}$ along the profile.
  - 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 $\Delta \log \mathcal{L} = 0.5$

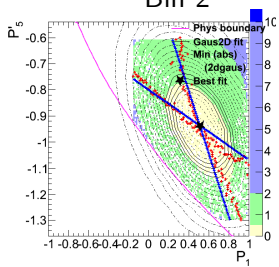
Bin 0



Bin 1



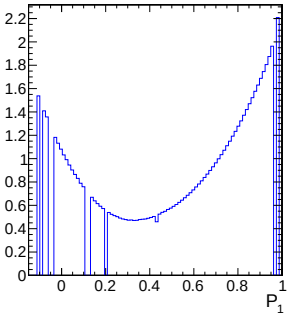
Bin 2



(Intermezzo) Best fit evaluation

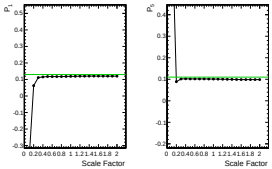
- Since we use the bivariate Gaussian fit for the evaluation of the profile, we investigated its usage also to evaluate the best fit;
  - This is more stable against fluctuation of the $\mathcal{L}$ computed on data which can artificially create false minima
  - safe against fit failures for some P_1, P_5' points
    - ⋆ also, is it the same procedure we apply for the FC.
  - We compared the absolute maximum of the $\mathcal{L}(P_1, P_5')$ computed as before with the maximum of the bivariate Gaussian inside the physical region;
  - Fit range is varied scaling *preliminary* statistical uncertainties (FC): form 0.1σ to 2σ.
  - Difference is small compared to the statistical uncertainties
- for coherence, we prefer to use this method to evaluate the best fit, with fit range $[-1\sigma, +1\sigma]$

An example of $\mathcal{L}(P_1; P_5')$ showing a small downward fluctuation creating a false minimum

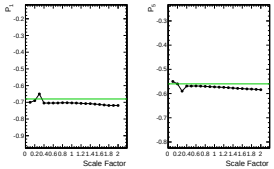


- Left P_1, Right P_5';
- Scale factor: fit range $[-x\sigma, +x\sigma]$
- vertical axis range is $[-1\sigma, +1\sigma]$ wrt to the central value for P_1, P_5'
- Green line is value for absolute maximum of $\mathcal{L}(P_1, P_5')$ for converged fits

Bin 0



Bin 1



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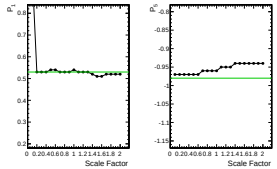
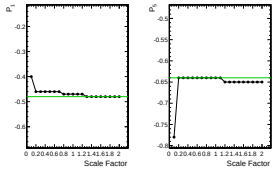
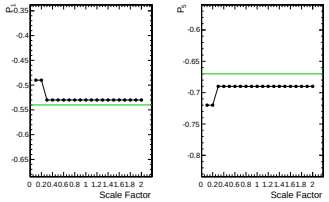


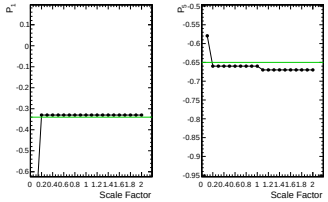
Bin 3



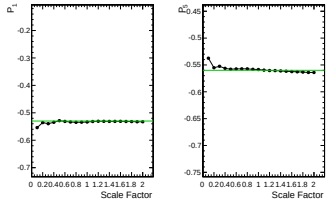
Bin 5



Bin 7



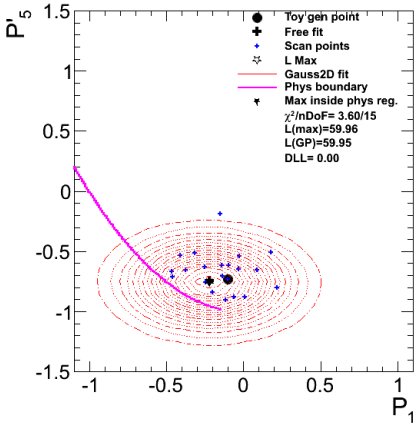
Bin 8



Procedure description (cont'ed)

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

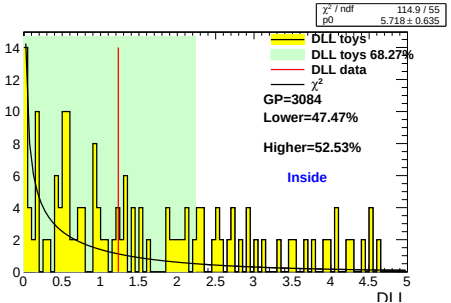
- we repeat the fit with 20 different set of 20 initial values of P_1 and P_5'
  - to find the absolute max, we fit the 20 values with a 2D gauss function
  - the max must be inside the physical region
- Eventually, we have 100 toys, and 100 values for the likelihood.



Procedure description (cont'ed)

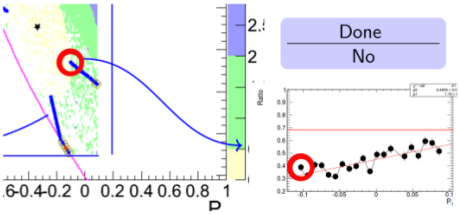
- We compute $\Delta \log \mathcal{L}$ for each toy
  - compared with the min along the profile
  - [black/yellow histo]→
- and $\Delta \log \mathcal{L}$ for data for that gen point
  - [red line]→
- **ratio**=(# toys with DLL(toy)<DLL(Data))/(#toys)
- If **ratio** $< 68.27\%$
  - [green area]→
- then generation point is inside the 1σ boundary for data, otherwise it's outside.
- repeat for $P_1(P_5')$ upper(lower) bound: 4 "directions"

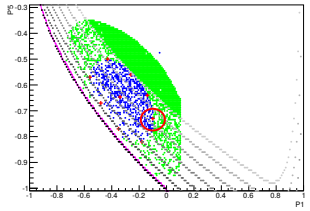
An example of DLL toys distribution compared with DLL(Data) (red)

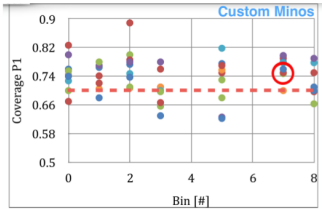


Since last presentation: Bug found!

- In almost all the cases, the FC agrees well with the expectation: $DLL \sim 0.5$ region
  - these expectation were crosschecked with extensive coverage studies, based on toys
  - a procedure which is very similar, if not identical, to the FC (but only for 8 points)
- We had some cases (2 for bin 7 and 2 for bin 8) where the two method disagrees considerably. Investigate!
- Bug found! We generated the toys w/o efficiency (only `pdf`) and fit w/ eff
  - Surprising that so many fit worked and the FC results looked fine!
- Bug fixed and rerun FC!
  - Luckily, given the large experience and debugging, the procedure is now working very smoothly,



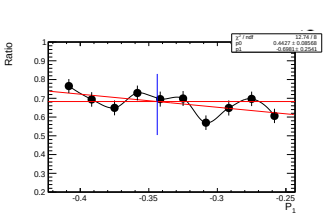


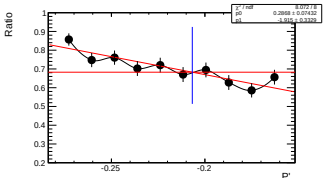


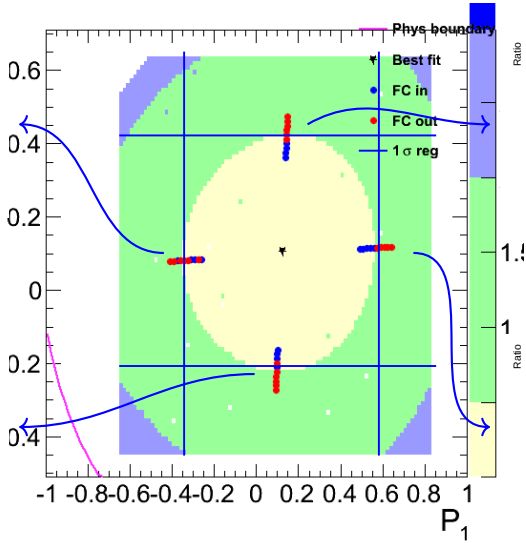
Results for FC

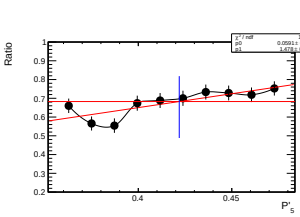
- Next slides are the results for FC for all the bins;
- The "ratio" plots are the actual results of the FC, as described before
- we perform a linear fit of the ratio vs $P_1(P_5')$
- consider the crossing of the linear fit with ratio= .6827 as the statistical uncertainty for each region
- we scan more points in case the slope is quite flat.
- the procedure is complete

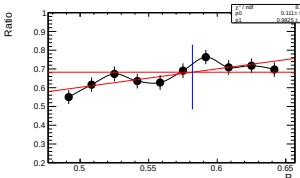
Bin 0 NEW











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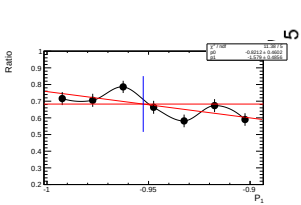
Bin 1 NEW



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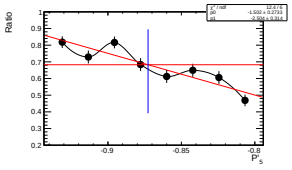

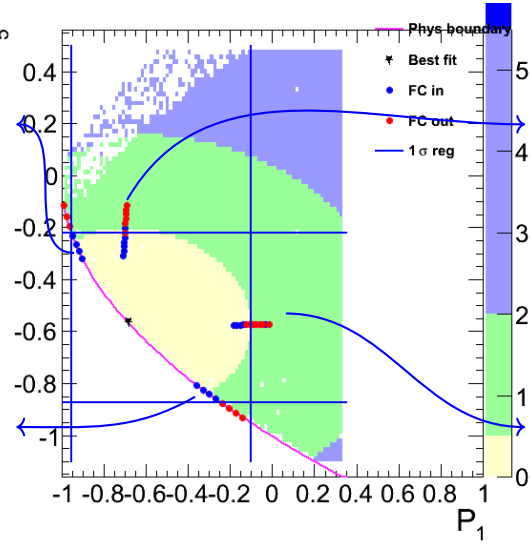

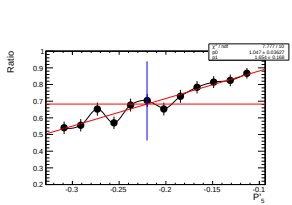

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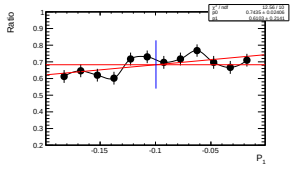
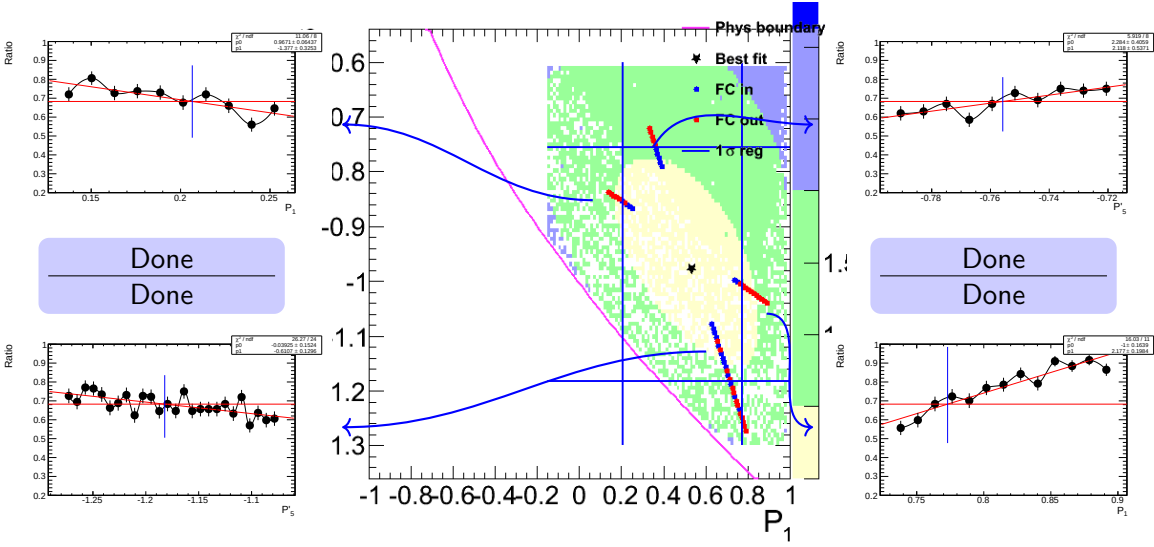


Bin 2 NEW



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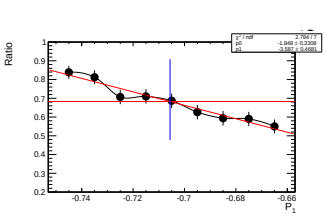
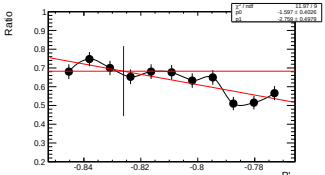
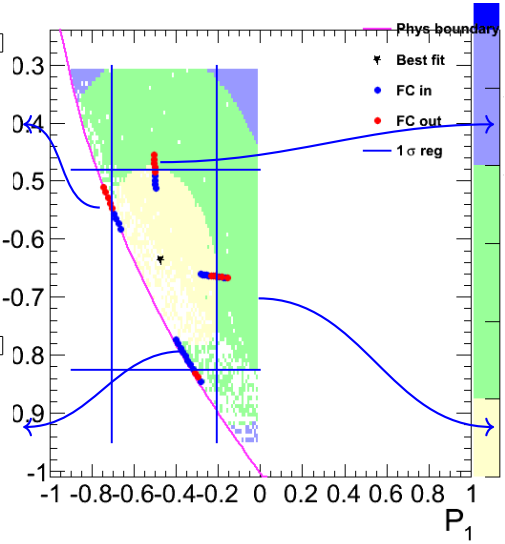
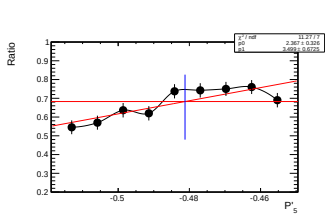
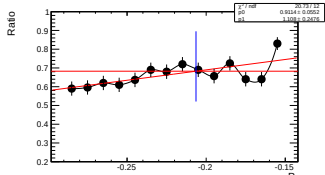
Bin 3 NEW











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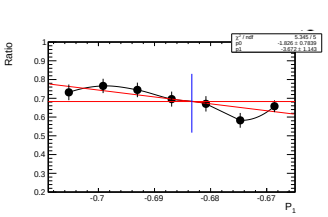
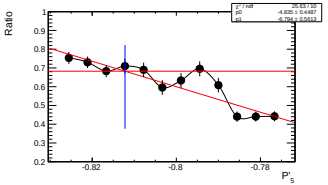
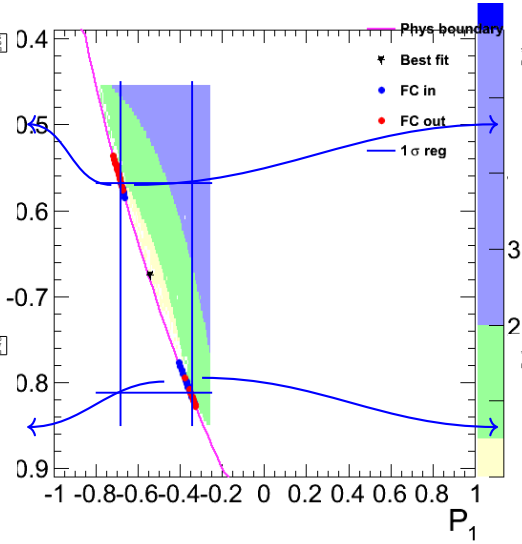
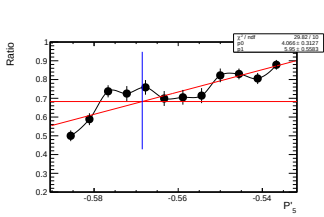
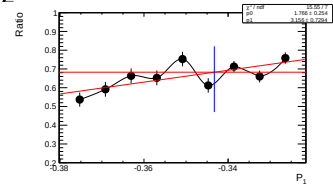
Bin 5 NEW











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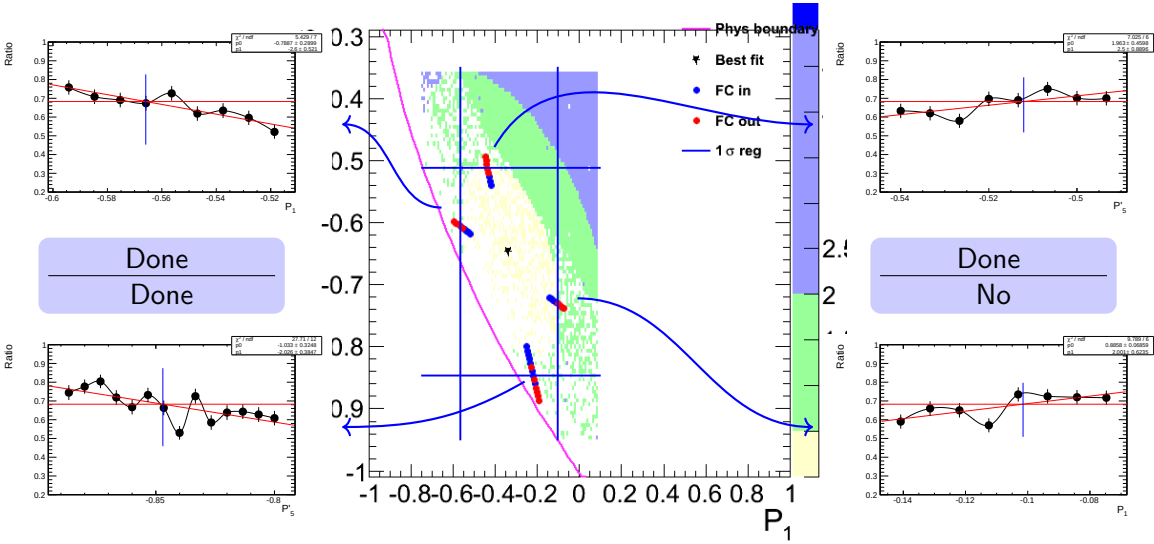
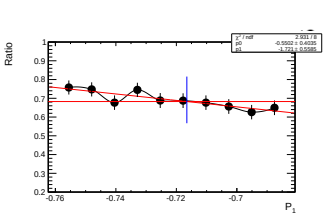
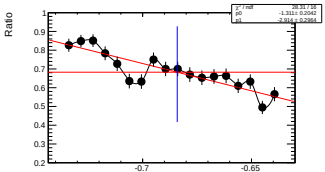
Bin 7 NEW


Phys boundary
Best fit
FC in
FC out
1 σ reg
Ratio
P1
P'5
Done
Done
Done
No

Bin 8 NEW





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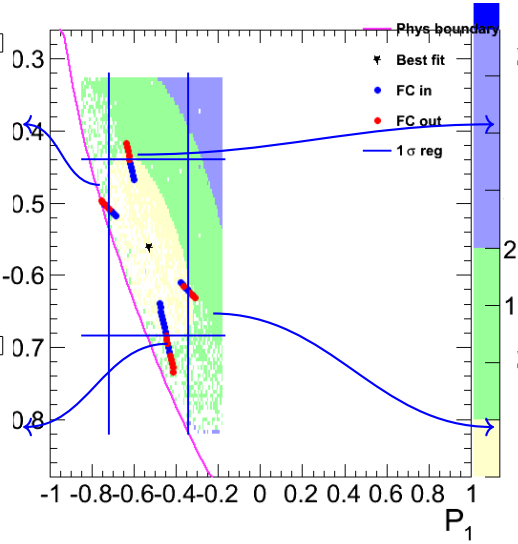
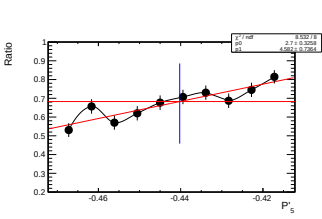
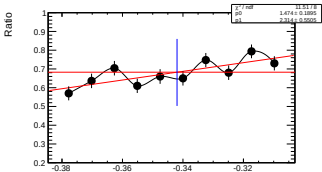






Done

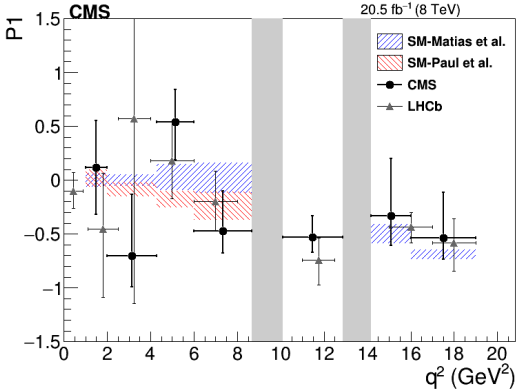
Done

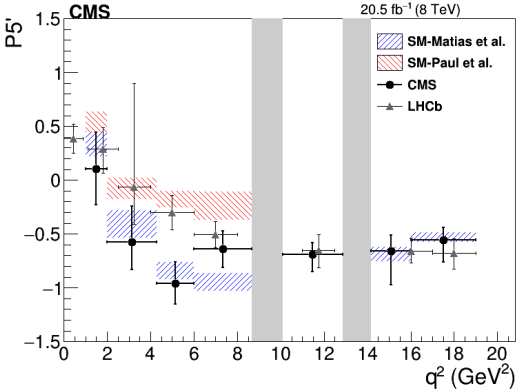
Summary of results

Results and confidence level (68%)

Bin	P_1 Fit		P_5' Fit	
0	0.119	$^{+0.46}_{-0.47}$	0.101	$^{+0.32}_{-0.31}$
1	−0.685	$^{+0.58}_{-0.27}$	−0.567	$^{+0.34}_{-0.31}$
2	0.533	$^{+0.24}_{-0.33}$	−0.957	$^{+0.22}_{-0.21}$
3	−0.470	$^{+0.27}_{-0.23}$	−0.643	$^{+0.15}_{-0.19}$
5	−0.531	$^{+0.2}_{-0.14}$	−0.690	$^{+0.11}_{-0.14}$
7	−0.329	$^{+0.24}_{-0.23}$	−0.664	$^{+0.13}_{-0.2}$
8	−0.533	$^{+0.19}_{-0.19}$	−0.559	$^{+0.12}_{-0.12}$

Results





Statistical error only!

Comparison with $\Delta \log \mathcal{L} = 0.5$

Results and confidence level $\Delta \log \mathcal{L} = 0.5$

Bin	P_1	FC	CM	Hyb	P_5'	FC	CM	Hyb
0	0.12	$^{+0.46}_{-0.47}$	$^{+0.44}_{-0.463}$	$^{+0.42}_{-0.447}$	0.10	$^{+0.32}_{-0.31}$	$^{+0.313}_{-0.333}$	$^{+0.313}_{-0.333}$
1	-0.69	$^{+0.58}_{-0.27}$	$^{+0.59}_{-0.267}$	$^{+0.537}_{-0.25}$	-0.57	$^{+0.34}_{-0.31}$	$^{+0.35}_{-0.29}$	$^{+0.35}_{-0.29}$
2	0.53	$^{+0.24}_{-0.33}$	$^{+0.333}_{-0.36}$	$^{+0.297}_{-0.32}$	-0.96	$^{+0.22}_{-0.21}$	$^{+0.23}_{-0.163}$	$^{+0.23}_{-0.163}$
3	-0.47	$^{+0.27}_{-0.23}$	$^{+0.307}_{-0.25}$	$^{+0.283}_{-0.23}$	-0.64	$^{+0.15}_{-0.19}$	$^{+0.18}_{-0.183}$	$^{+0.18}_{-0.183}$
5	-0.53	$^{+0.2}_{-0.14}$	$^{+0.153}_{-0.137}$	$^{+0.16}_{-0.14}$	-0.69	$^{+0.11}_{-0.14}$	$^{+0.097}_{-0.12}$	$^{+0.107}_{-0.123}$
7	-0.33	$^{+0.24}_{-0.23}$	$^{+0.257}_{-0.23}$	$^{+0.25}_{-0.227}$	-0.66	$^{+0.13}_{-0.2}$	$^{+0.143}_{-0.17}$	$^{+0.143}_{-0.17}$
8	-0.53	$^{+0.19}_{-0.19}$	$^{+0.217}_{-0.21}$	$^{+0.207}_{-0.2}$	-0.56	$^{+0.12}_{-0.12}$	$^{+0.137}_{-0.143}$	$^{+0.137}_{-0.143}$

FC: Feldman-Cousins — CM: $DLL < 0.5$ — Hyb: bayesan approach on profiled $\mathcal{L}$

In red the most significant (?) differences

Numbers

- Number of points in the P_1, P_5' space investigated: 903
- Number of toys generated: 90 300
- Number of UML fit performed in total: 1 900 000
- Number of jobs submitted: $\sim$ 90 000
- Maximum number of jobs running at once: 750
- Average wall clock time for a job: $\sim 1.6\ h$
- Total wall clock time by all jobs: $\sim 5.2 \cdot 10^8\ s = 15\,000\ h = 6\,000\ d = 1.65\ y$
- Actual time spent so far $\sim$ 2.5 mounth, not counting the two months spent by Alessio with his coverage study to try and demonstrate that this effort was not needed.
- and ~~counting~~ **STOP** ...

Last Systematics: Uncertainty from fixed pdf parameters

- In the final pdf some of the parameters (F_L, F_S, and A_S) are fixed from BPH-13-010
- evaluate the impact of the uncertainties on these fixed parameter as a systematic uncertainties for this analysis
- this systematic would have been considered inside the statistical one, if we would have been able to fit our data with all free-floating parameters
- 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
    - ★ scan (P_1, P_5') plane with ~ 100 points (depending on bin), evaluate $\mathcal{L}(P_1, P_5')$, and fit with a bivariate Gaussian (as in the FC procedure)
    - ★ evaluate statistical from $\Delta \log \mathcal{L} = 0.5$ form the bivariate Gaussian function
  - 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

Results Uncertainty from fixed pdf parameters

	P_1					P_5'				
		systematics			stat		systematics			stat
Bin	this	largest	tot	w/o this		this	largest	tot	w/o this	
0	0.00	0.05	0.058	0.058	$^{+0.46}_{-0.47}$	0.093	0.093	0.116	0.070	$^{+0.32}_{-0.31}$
1	0.00	0.062	0.088	0.088	$^{+0.58}_{-0.27}$	0.119	0.119	0.153	0.097	$^{+0.34}_{-0.31}$
2	0.126	0.126	0.175	0.122	$^{+0.24}_{-0.33}$	0.070	0.119	0.161	0.145	$^{+0.22}_{-0.21}$
3	0.076	0.094	0.131	0.106	$^{+0.27}_{-0.23}$	0.063	0.106	0.138	0.123	$^{+0.15}_{-0.19}$
5	0.00	0.175	0.215	0.215	$^{+0.2}_{-0.14}$	0.200	0.2	0.246	0.144	$^{+0.11}_{-0.14}$
7	0.108	0.112	0.245	0.220	$^{+0.24}_{-0.23}$	0.095	0.112	0.188	0.162	$^{+0.13}_{-0.2}$
8	0.00	0.078	0.131	0.131	$^{+0.19}_{-0.19}$	0.00	0.041	0.072	0.072	$^{+0.12}_{-0.12}$

in red the bins where this syst is the largest

NB: this systematic uncertainty is actually statistical in nature

Summary on systematics

Systematic uncertainty	$P_1(10^{-3})$	$P_5'(10^{-3})$
Simulation mismodeling	1–33	10–23
fitting bias	5–78	10–119
MC statistical uncertainty	29–73	31–112
Efficiency	17–100	5–65
Kπ mistagging	8–110	6–66
Background distribution	12–70	10–51
Mass distribution	12	19
Feed-through background	4–12	3–24
F_L, F_S, A_S uncertainty propagation	0–126	0–200
Angular resolution	2–68	0.1–12
Total systematic uncertainty	58–245	72–246

Conclusion

Statistical uncertatities

- After three mounths of hard work, countless submitted jobs and almost 2 million fit performed we are almost exactly were we started.
- the statistical uncertaities are very close if not identical to the one estimated with the "minos" method, that we presented in october last year. And whose correct coverage we proved about same time;
- hopefully, at least, this huge work can show that if somebody propose a method for statistical uncertaities evaluation, and proves that that methods provide the correct coverage, well, maybe, that method does provide results with correct coverage even if cannot be extented to the general case with some theoretical proof.

systematic uncertaities

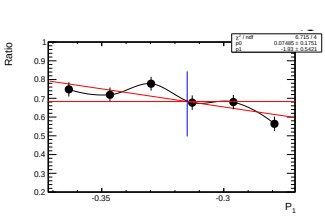
- Last syst evaluated

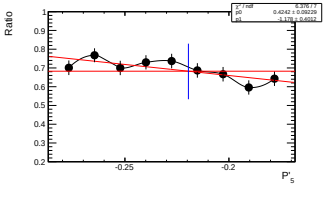
Now focus on updating the documentation to provide the ARC and get green light

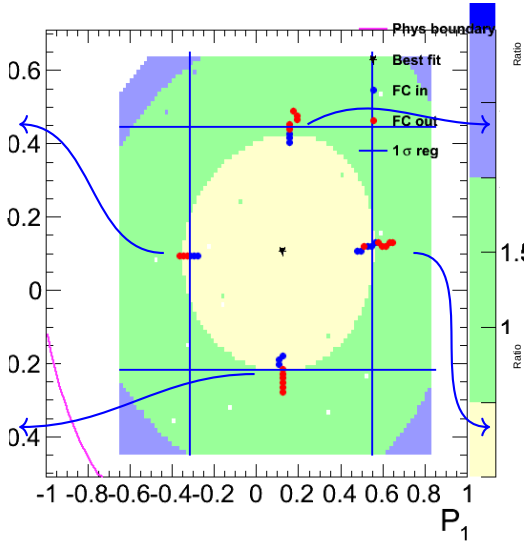
Additional stuff

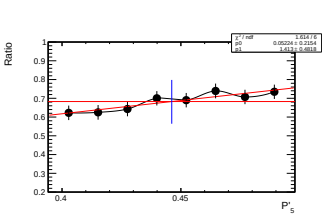
Additional or backup slides

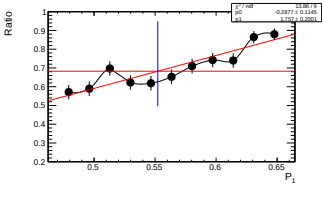
Bin 0 OLD











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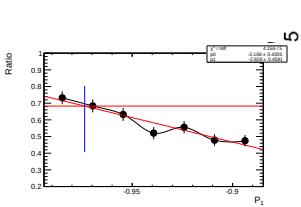

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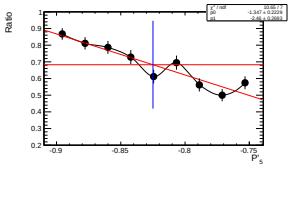

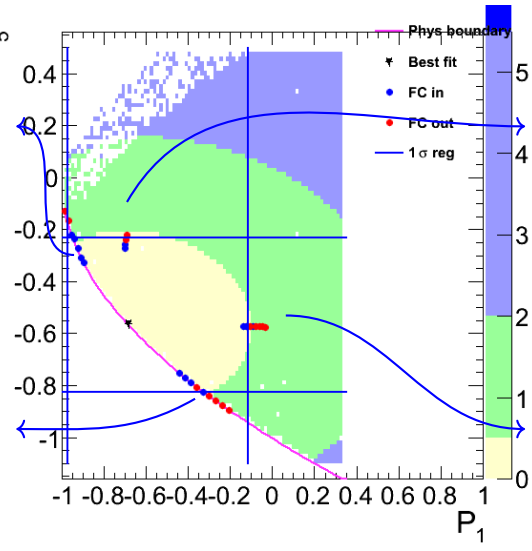

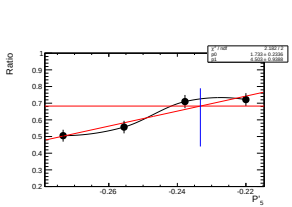

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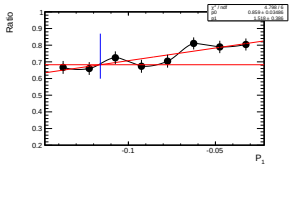

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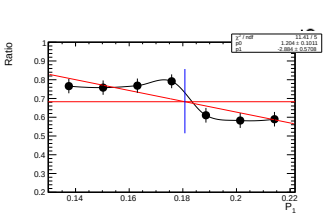

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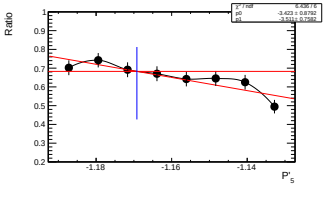

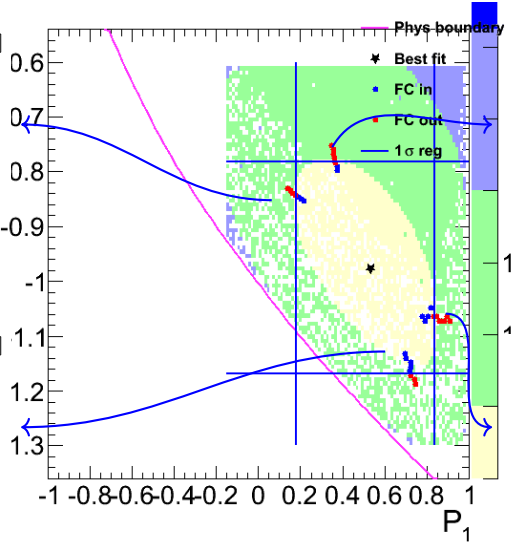

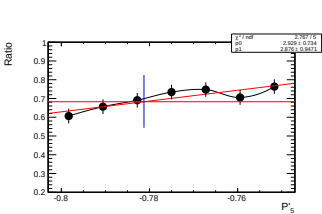

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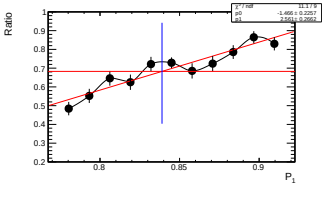

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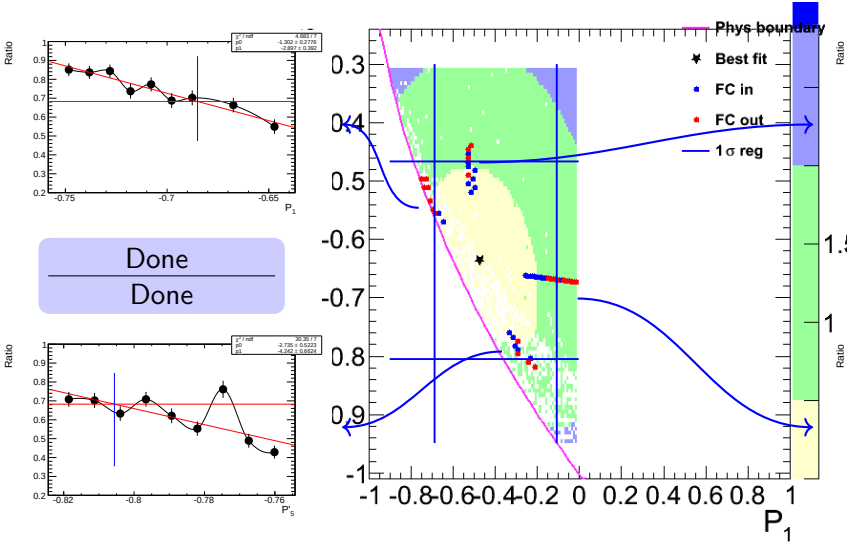

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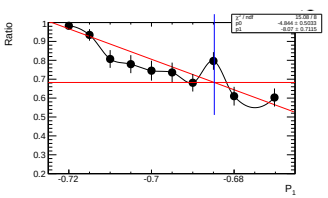

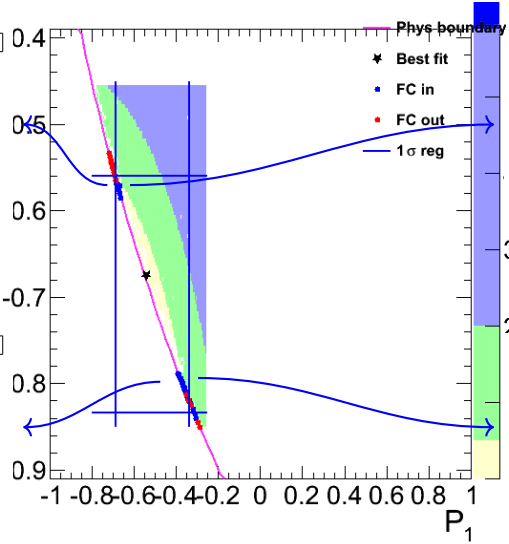

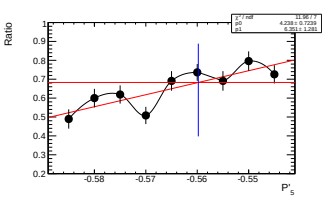

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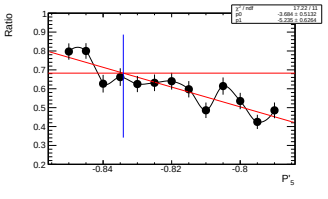

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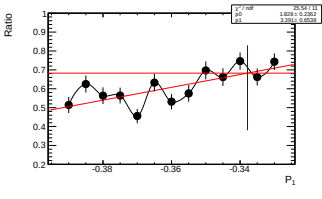

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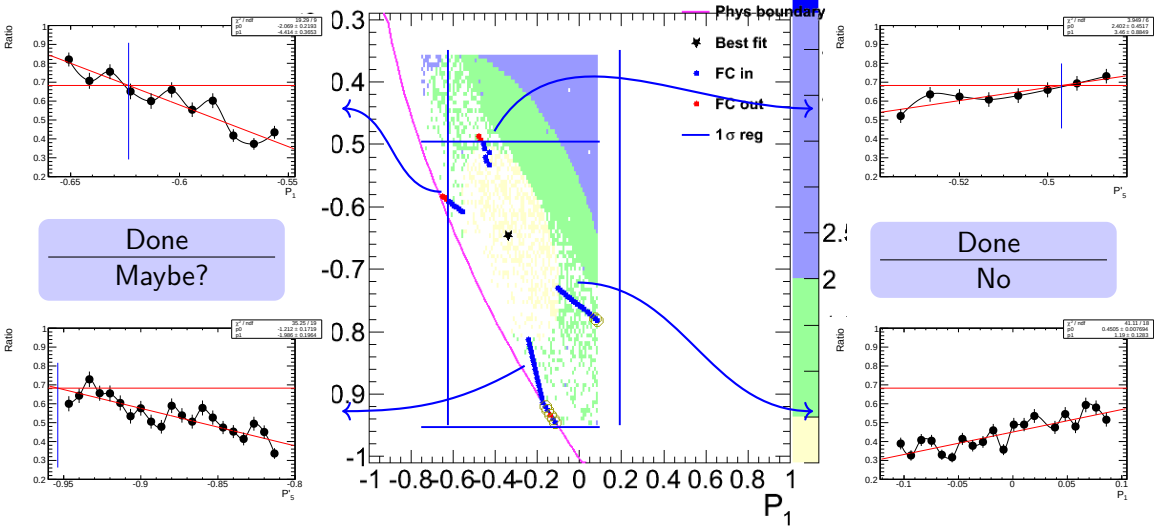
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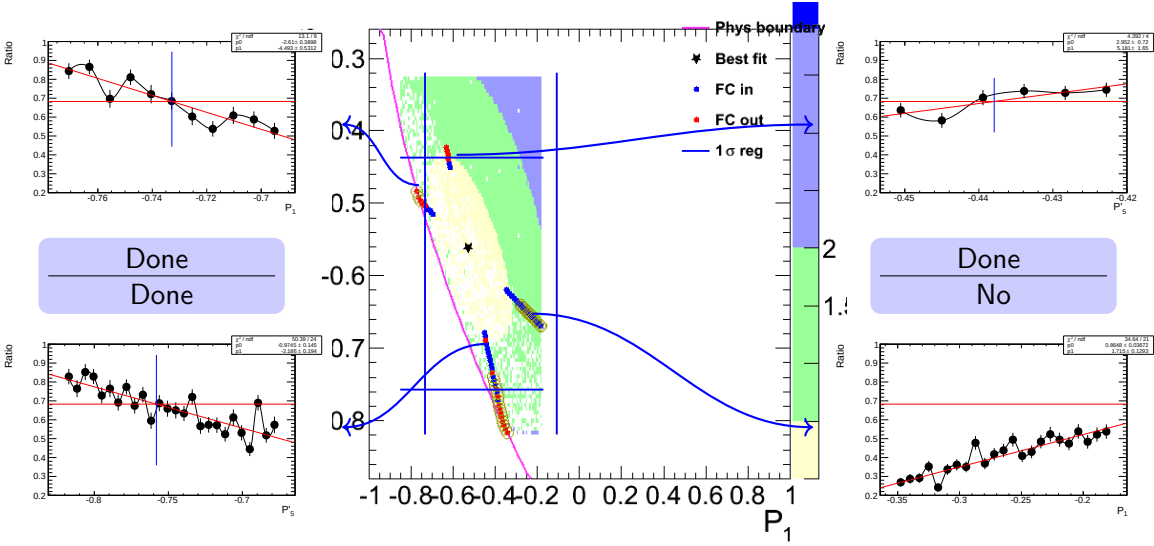
Best fit
FC in
FC out
1 σ reg
Ratio
P1
P'5
Done
Maybe?
Done
No

Bin 8 OLD


Phys boundary
Best fit
FC in
FC out
1 σ reg
Ratio
P1
P'5
Done
Done
Done
No

Bibliography I