$|\lambda| \neq 1$ fit

In a single decay channel, all CP violation is governed by the parameter

$\lambda = (q/p)\cdot(\bar{A}/A)$

q/p from mixing.

$\bar{A}/A$ from decay.

For us, in the standard model, with standard CKM phase conventions:

$q/p = e^{-2i\phi}$ (depends on heavy stuff; likely to be affected by new physics)

$\bar{A}/A = \pm 1$ (depends on light stuff; not likely to be modified by new physics)

only λ is indpendent of phase convention.

Getting things (hopefully) by their proper name:

CP Violation in the decay ==> $|\bar{A}/A| \neq 1$ B^0_s decays more/less to final state, than $\bar{B}^0_s$
also called direct CP violation.

CP Violation in the mixing ==> $|q/p| \neq 1$ CP eigenstates has more B^0_s, than $\bar{B}^0_s$
called indirect CP violation.
gives A_{sl}

==> Both of these generally cause $|\lambda| \neq 1$

CP Violation in the interference of decay and mixing ==> $|\lambda|=1$

Lenz/Nierste call this “mixing-induced” (I did not find the term used anywhere else ...)

If $|\lambda|=1$ then our decay mode alone cannot sort out whether the CP violation is direct or indirect, though other experiments could (eg one could measure A_{sl})

Today, we modify the fitter to allow for $|\lambda|\neq 1$; we shall call:

$\mathrm{Im}(\lambda) \equiv S$

$\mathrm{Re}(\lambda) \equiv C$

Very little of this is expected in the SM; story here is a bit convoluted:

$A_{sl} = \Delta\Gamma/\Delta M \tan(\phi_s)$

Last time I noted the contradiction that $-1 < A_{sl} < 1$ while $-\infty < \Delta\Gamma/\Delta M \tan(\phi_s) < -\infty$.

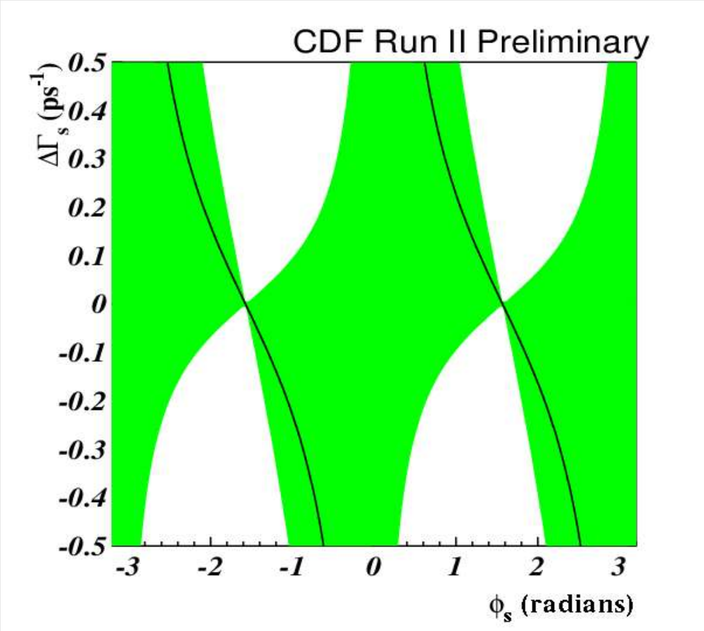
That is because the above relation derives from:

$A_{sl} = \Gamma_{12}/M_{12} \sin(\phi_s)$

and the expectation from new physics models that has

$\Delta\Gamma = 2\Gamma_{12}/\cos(\phi_s)$ and $\Delta M = 2M_{12}$

Meaning $\Delta\Gamma$, ϕ_s are not independent and plot here is probably incorrect!



Correct starting point is: $A_{sl} = \Gamma_{12}/M_{12} \sin(\phi_s) = 5.4 \times 10^{-3} \sin(\phi_s)$

Also $A_{sl} = (1-(q/p)^4) / (1+(q/p)^4)$

$\Longrightarrow |q/p| = |\lambda| = 1 - A_{sl}/2 = 1.00 \pm 0.0027$

$$|\lambda| = 1.00 \pm 0.0027$$

Fit details: Same angular distributions. Different time dependence:

$$|\bar{f}_\pm(t)|^2 =$$
$$\frac{\mathcal{N}_\pm^2}{4|\lambda|^2}\left[((1+|\lambda|^2)\pm 2\mathcal{C})e^{-\Gamma_L t} + ((1+|\lambda|^2)\mp 2\mathcal{C})e^{-\Gamma_H t} + \left(\pm 4\mathcal{S}\sin\Delta m t - 2(1-|\lambda|^2)\cos\Delta m t\right)e^{-\Gamma t}\right],$$
$$|f_\pm(t)|^2 =$$
$$\frac{\mathcal{N}_\pm^2}{4}\left[((1+|\lambda|^2)\pm 2\mathcal{C})e^{-\Gamma_L t} + ((1+|\lambda|^2)\mp 2\mathcal{C})e^{-\Gamma_H t} - \left(\pm 4\mathcal{S}\sin\Delta m t - 2(1-|\lambda|^2)\cos\Delta m t\right)e^{-\Gamma t}\right],$$
$$\bar{f}_+(t)\bar{f}_-^{\,*}(t) =$$
$$\frac{\mathcal{N}_+\mathcal{N}_-}{4|\lambda|^2}\left[-e^{-\Gamma t}\left(2(1+|\lambda|^2)\cos\Delta m t + 4i\mathcal{C}\sin\Delta m t\right) + e^{-\Gamma_L t}\left((1-|\lambda|^2)+2i\mathcal{S}\right) + e^{-\Gamma_H t}\left((1-|\lambda|^2)-2i\mathcal{S}\right)\right],$$
$$f_+(t)f_-^*(t) =$$
$$\frac{\mathcal{N}_+\mathcal{N}_-}{4}\left[e^{-\Gamma t}\left(2(1+|\lambda|^2)\cos\Delta m t + 4i\mathcal{C}\sin\Delta m t\right) + e^{-\Gamma_L t}\left((1-|\lambda|^2)+2i\mathcal{S}\right) + e^{-\Gamma_H t}\left((1-|\lambda|^2)-2i\mathcal{S}\right)\right],$$

Different normalizing factors (a formula in the NIM draft was corrected!):

$$\mathcal{N}_\pm = \frac{1}{4|\lambda|^2}\left[\left[(\tau_H+\tau_L)(1+|\lambda|^2)^2 \pm 2\mathcal{C}\cdot(\tau_L-\tau_H)(1+|\lambda|^2)\right] + \frac{\tau}{1+\Delta m^2\tau^2}\cdot\left[\pm 4\mathcal{S}\cdot\left(1-|\lambda|^2\right)\Delta m\tau - 2\left(1-|\lambda|^2\right)^2\right]\right]^{-\frac{1}{2}} \quad (31)$$

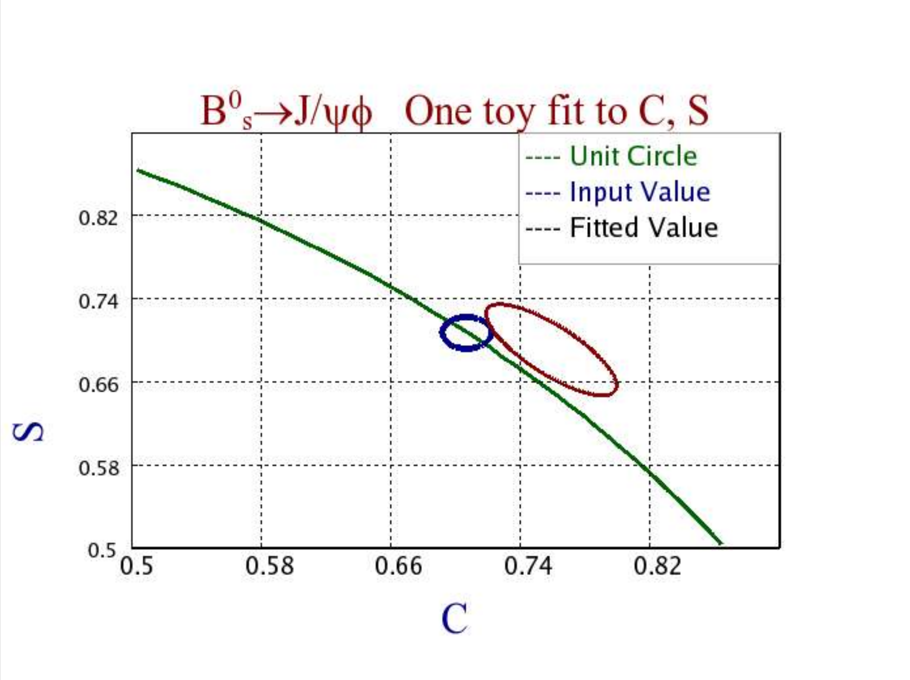
And slightly different analytic normalization for detector sculpting

+ same treatment of angular distributions and all detector effects...

Floating $\sin(2\beta_s)$ and $\cos(2\beta_s)$. Would detect direct CPV or indirect CPV.. neither of which is expected.
The importance of this fitter is that it is a cross-check of the analysis: matter/antimatter differences, float sin(2βs) with proper normalization of the fit function, check that the cos(2βs) is consistent with sin(2βs), check where the most sensitivity comes from....

We generate at the S.M. expectation that $\sin^2(2\beta_s) + \cos^2(2\beta_s) = 1$

```
dcpv001.fit   One toy experiment with perfect tagging and resolution.
4K events. Contours are 68% CL. Detector sculpting off (both gen, fit)
```

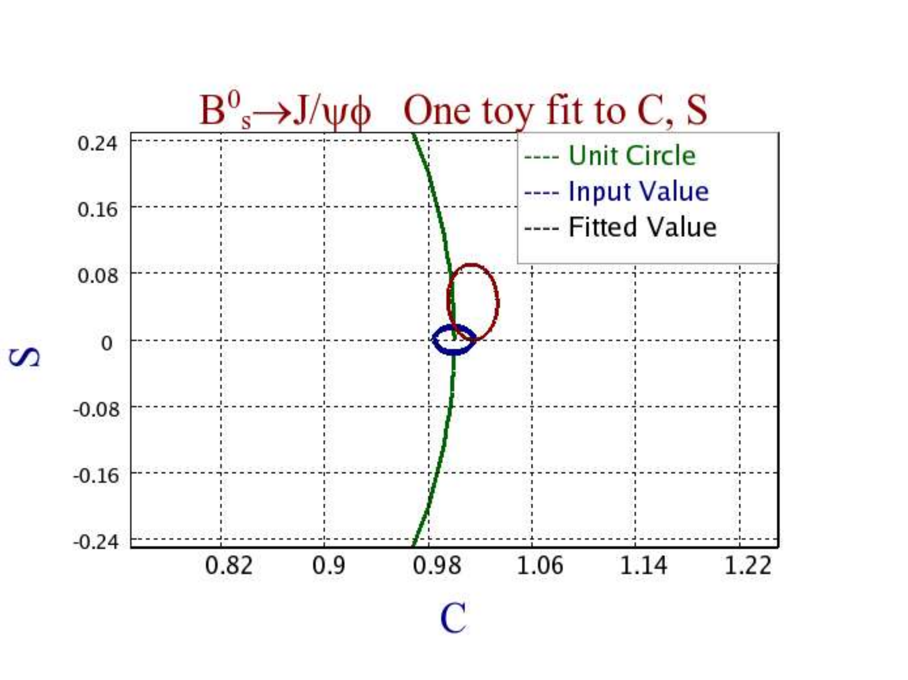


$2\beta_s = \pi/4$

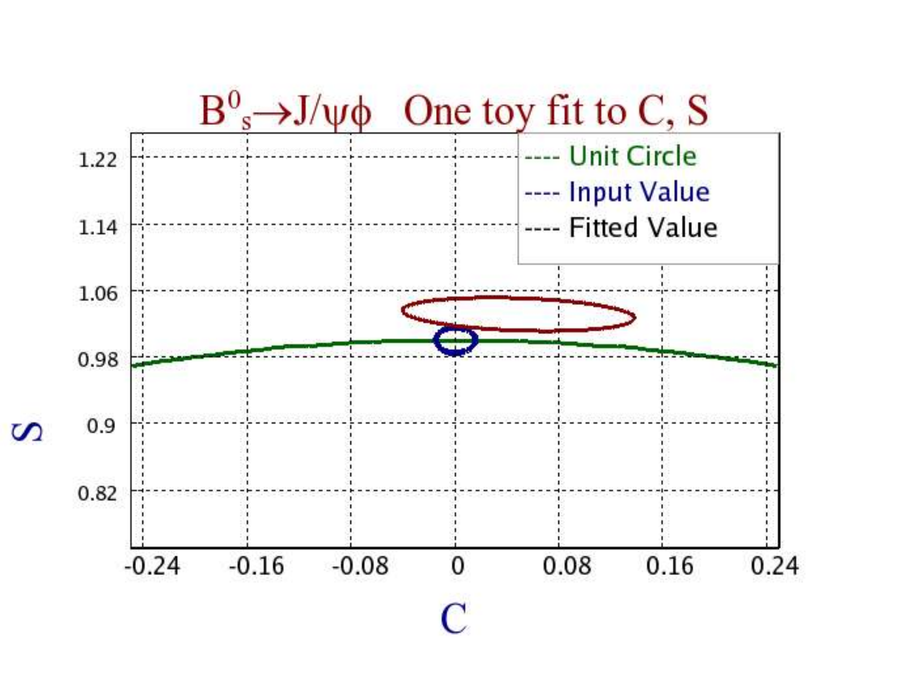
Comments: it appears that the fitter has an easy time figuring out that $|\lambda|=1$. I presume it can do that by "knowing about" the ratio of $B^0_s/\overline{B}^0_s$ feeding this decay channel.

Some other interesting cases:

$2\beta_s = 0$

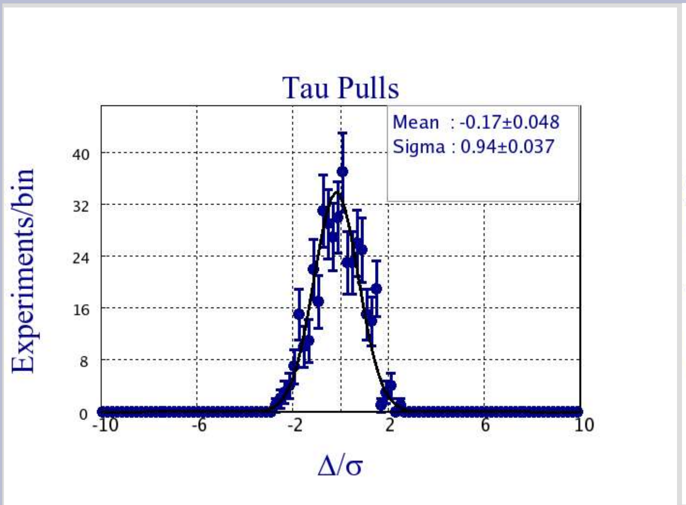


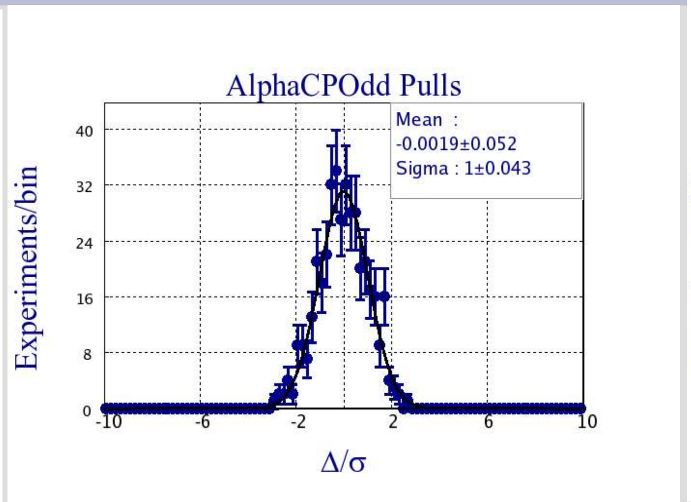
$2\beta_s = \pi/2$

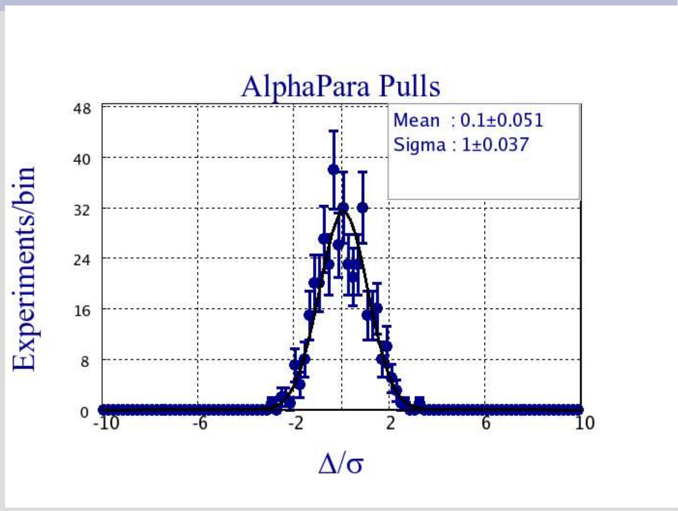


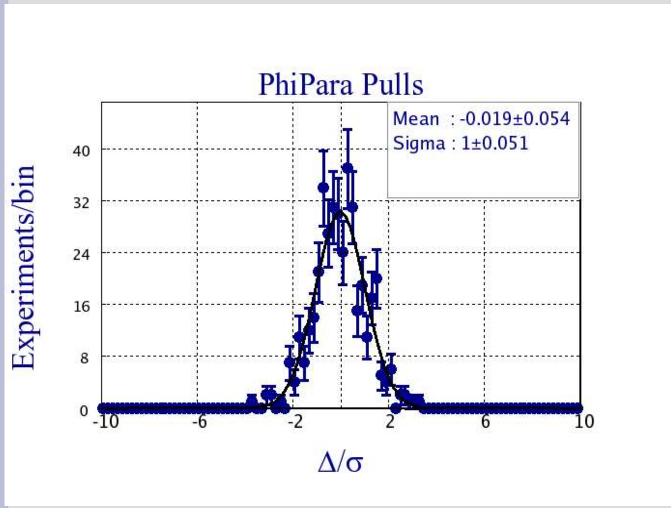
Pull distributions with a high-stat run (no efficiency, no smearing, no dilution)

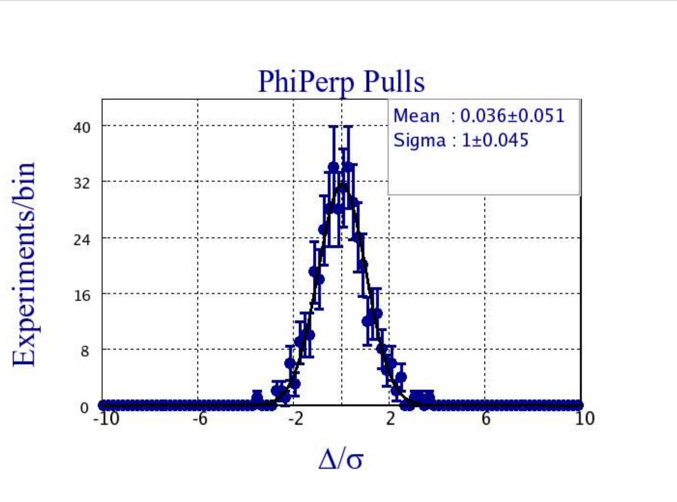
4K events/run; 400 runs, $\beta_s = 0$

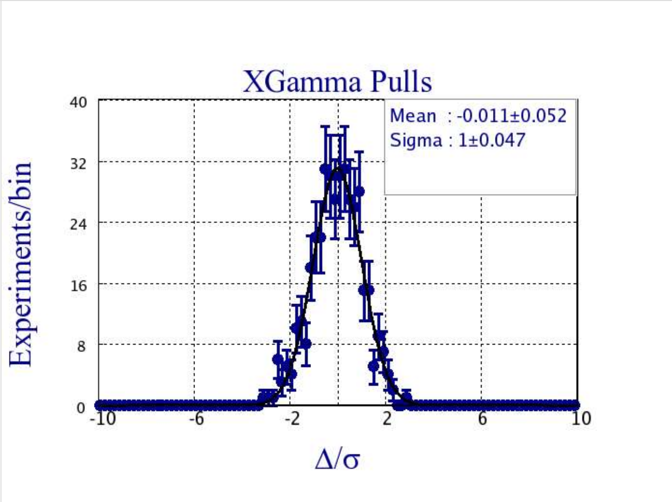


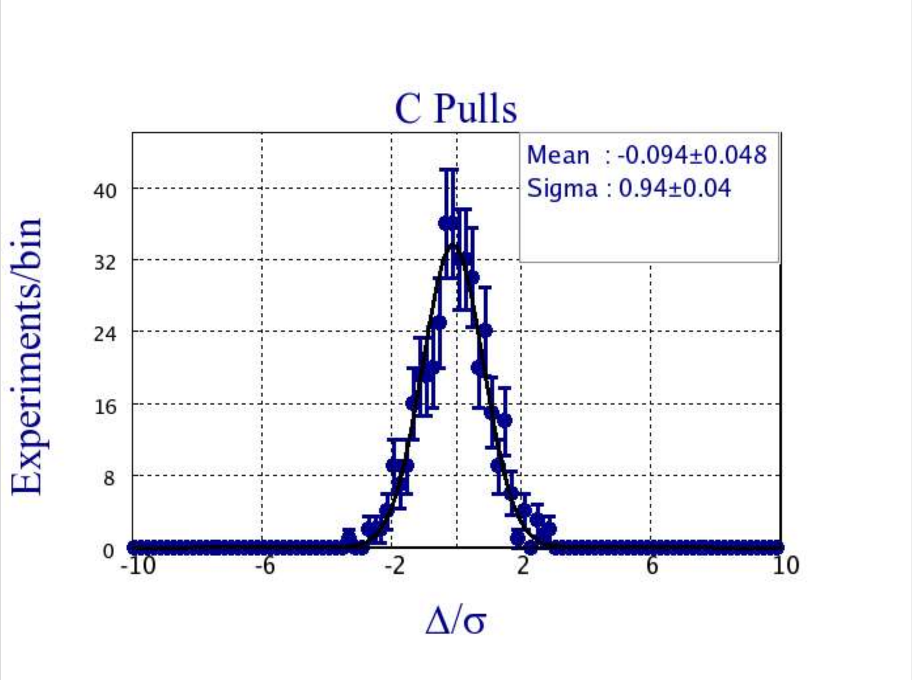




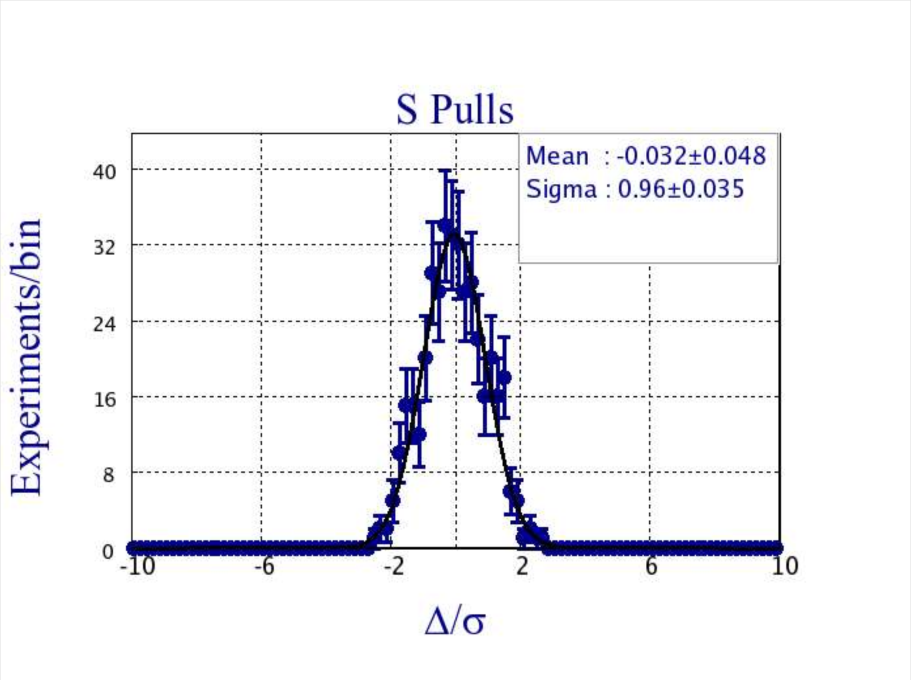






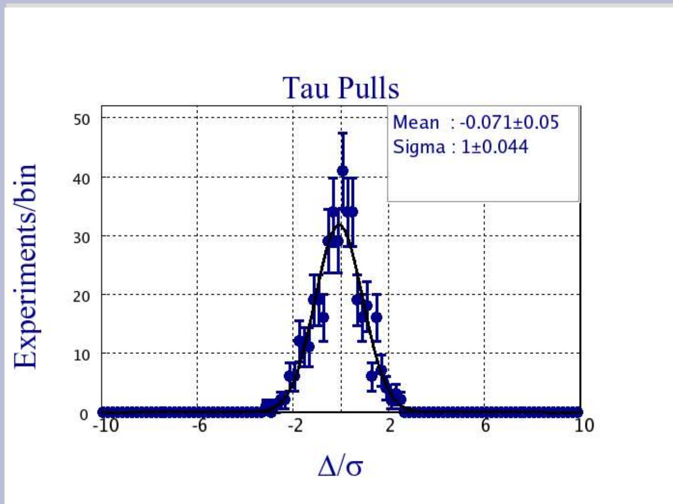


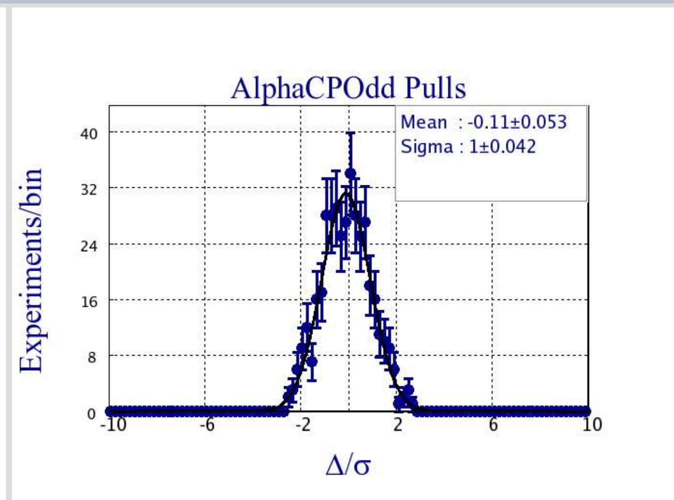
C Pulls
Mean : -0.094±0.048
Sigma : 0.94±0.04
Experiments/bin
Δ/σ

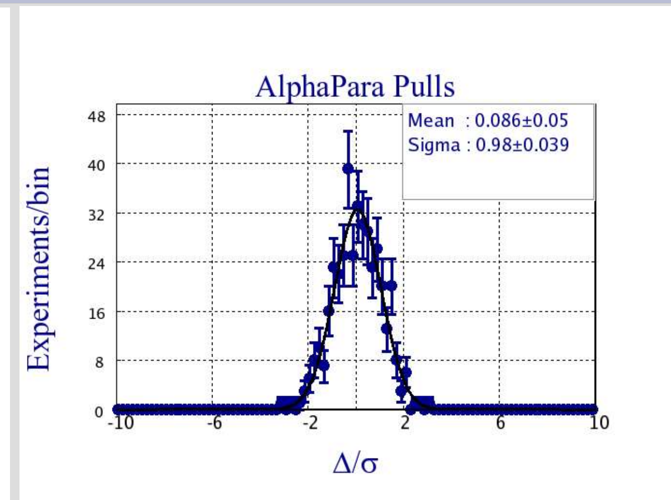


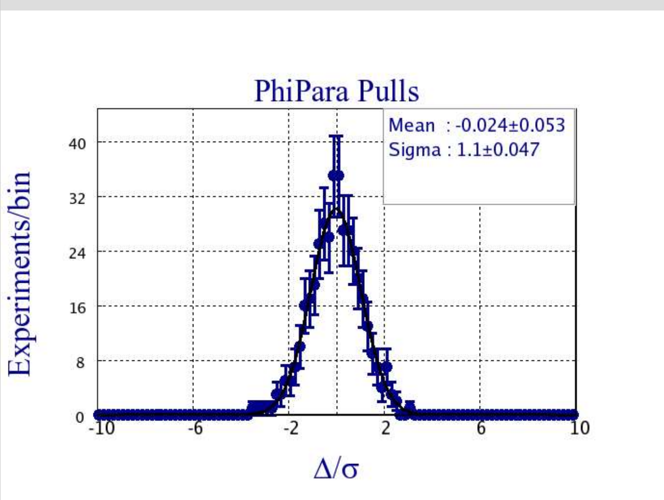
S Pulls
Mean : -0.032±0.048
Sigma : 0.96±0.035
Experiments/bin
Δ/σ

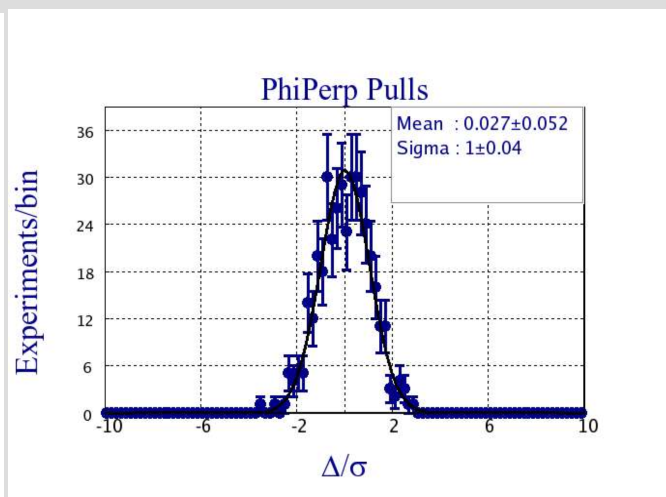
$\beta_s = \pi/8$

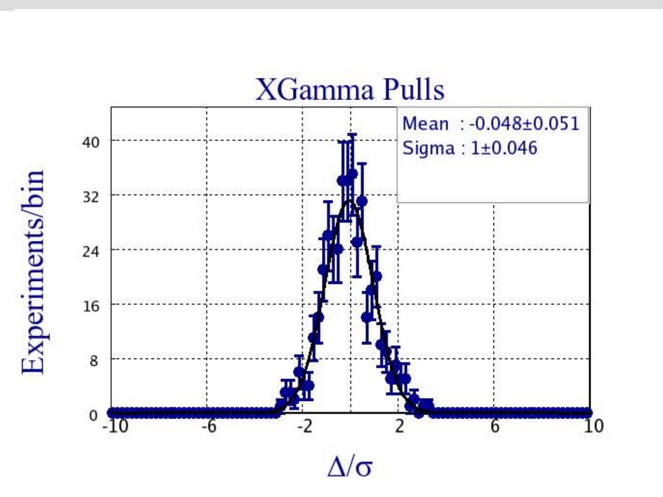

Tau Pulls
Mean : -0.071±0.05
Sigma : 1±0.044
Experiments/bin
Δ/σ

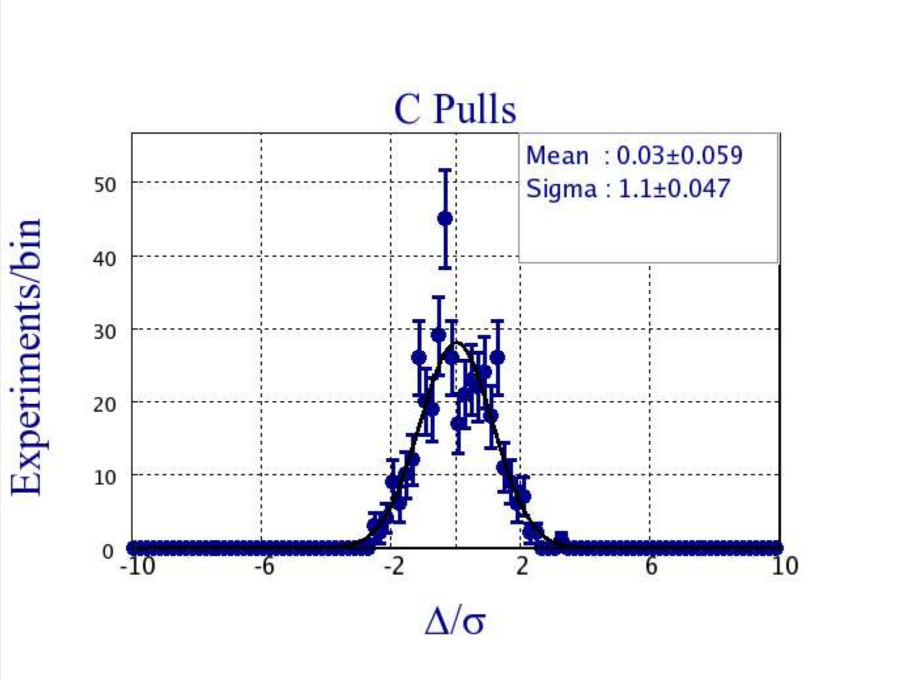

AlphaCPOdd Pulls
Mean : -0.11±0.053
Sigma : 1±0.042
Experiments/bin
Δ/σ

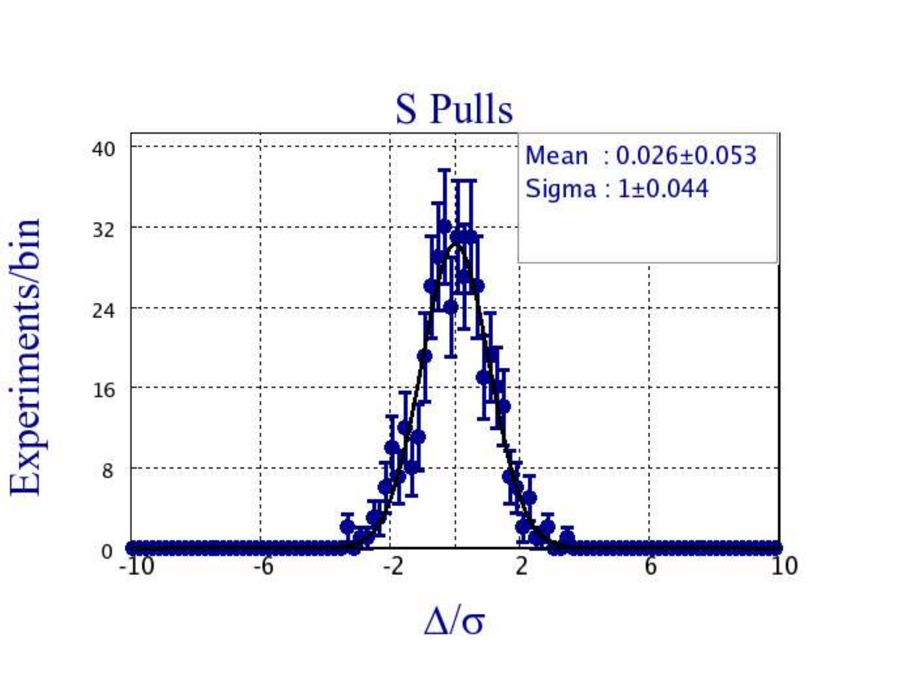

AlphaPara Pulls
Mean : 0.086±0.05
Sigma : 0.98±0.039
Experiments/bin
Δ/σ


PhiPara Pulls
Mean : -0.024±0.053
Sigma : 1.1±0.047
Experiments/bin
Δ/σ

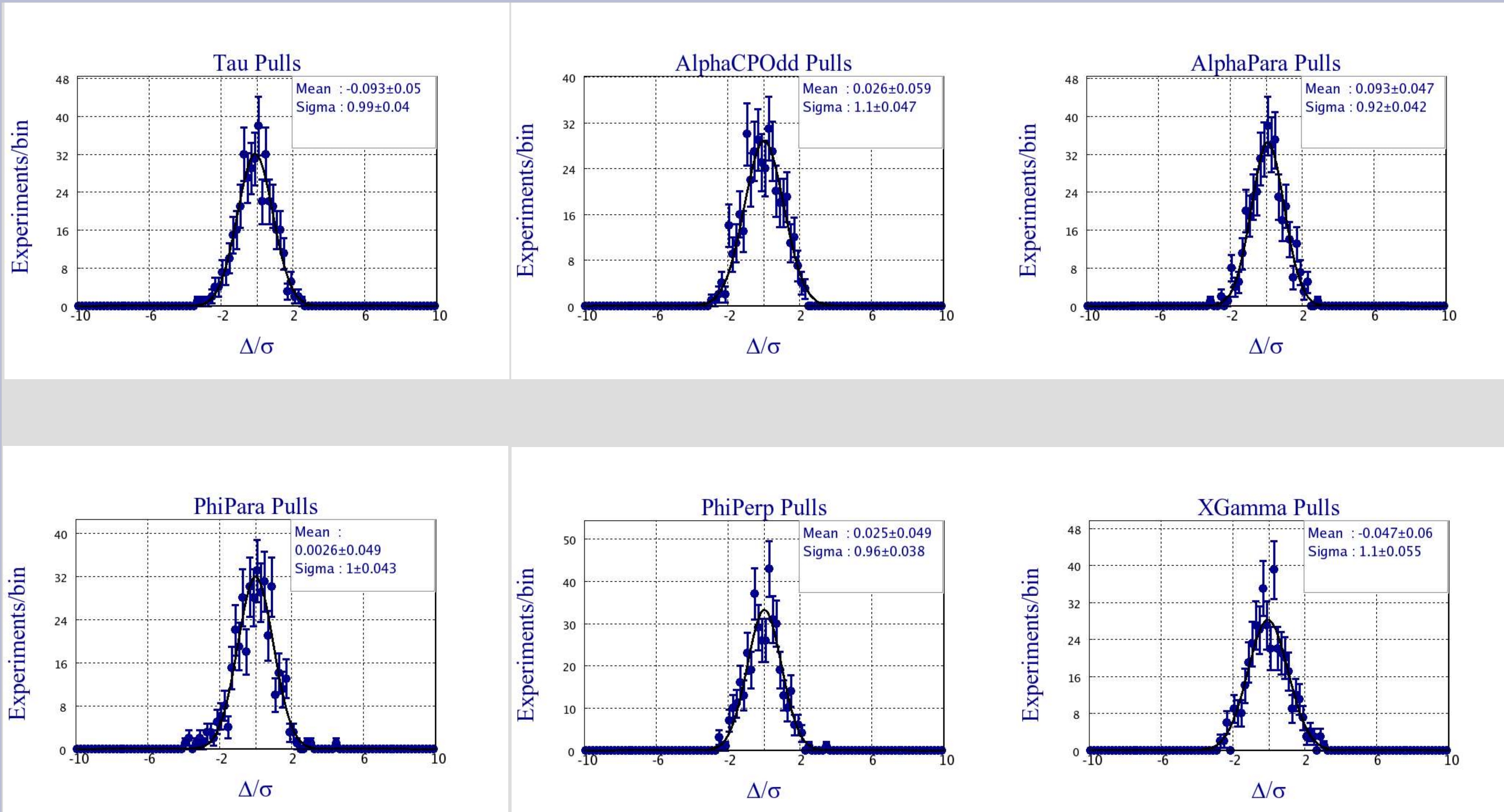

PhiPerp Pulls
Mean : 0.027±0.052
Sigma : 1±0.04
Experiments/bin
Δ/σ

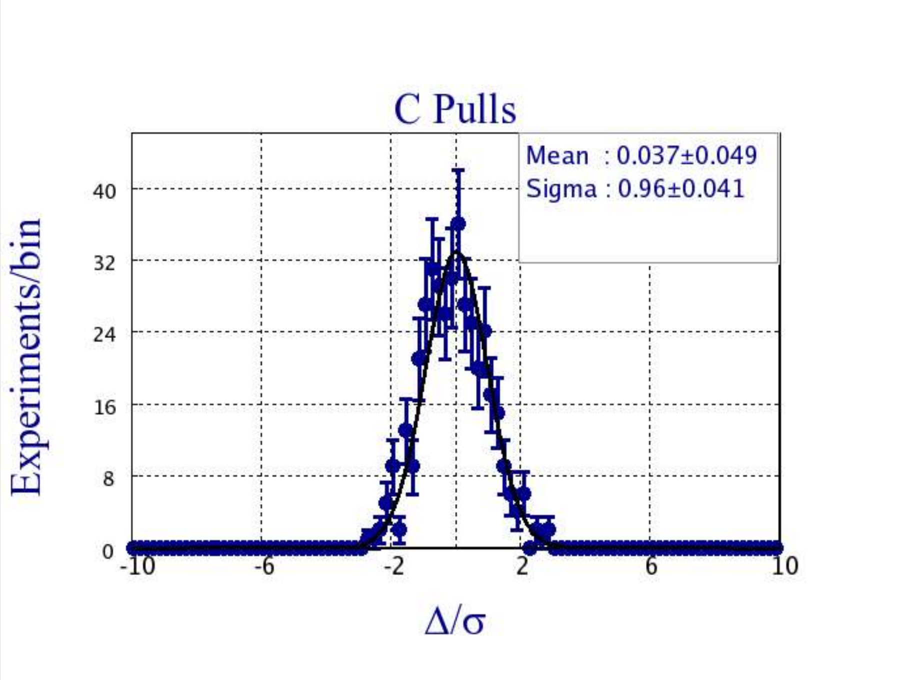

XGamma Pulls
Mean : -0.048±0.051
Sigma : 1±0.046
Experiments/bin
Δ/σ

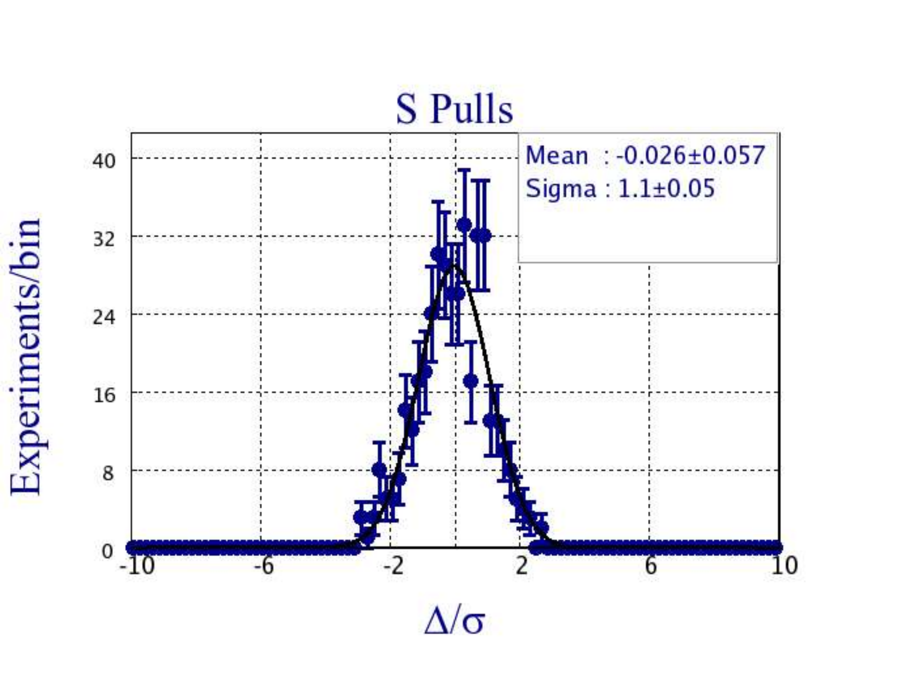

C Pulls
Mean : 0.03±0.059
Sigma : 1.1±0.047
Experiments/bin
Δ/σ


S Pulls
Mean : 0.026±0.053
Sigma : 1±0.044
Experiments/bin
Δ/σ

$\beta_s = \pi/4$

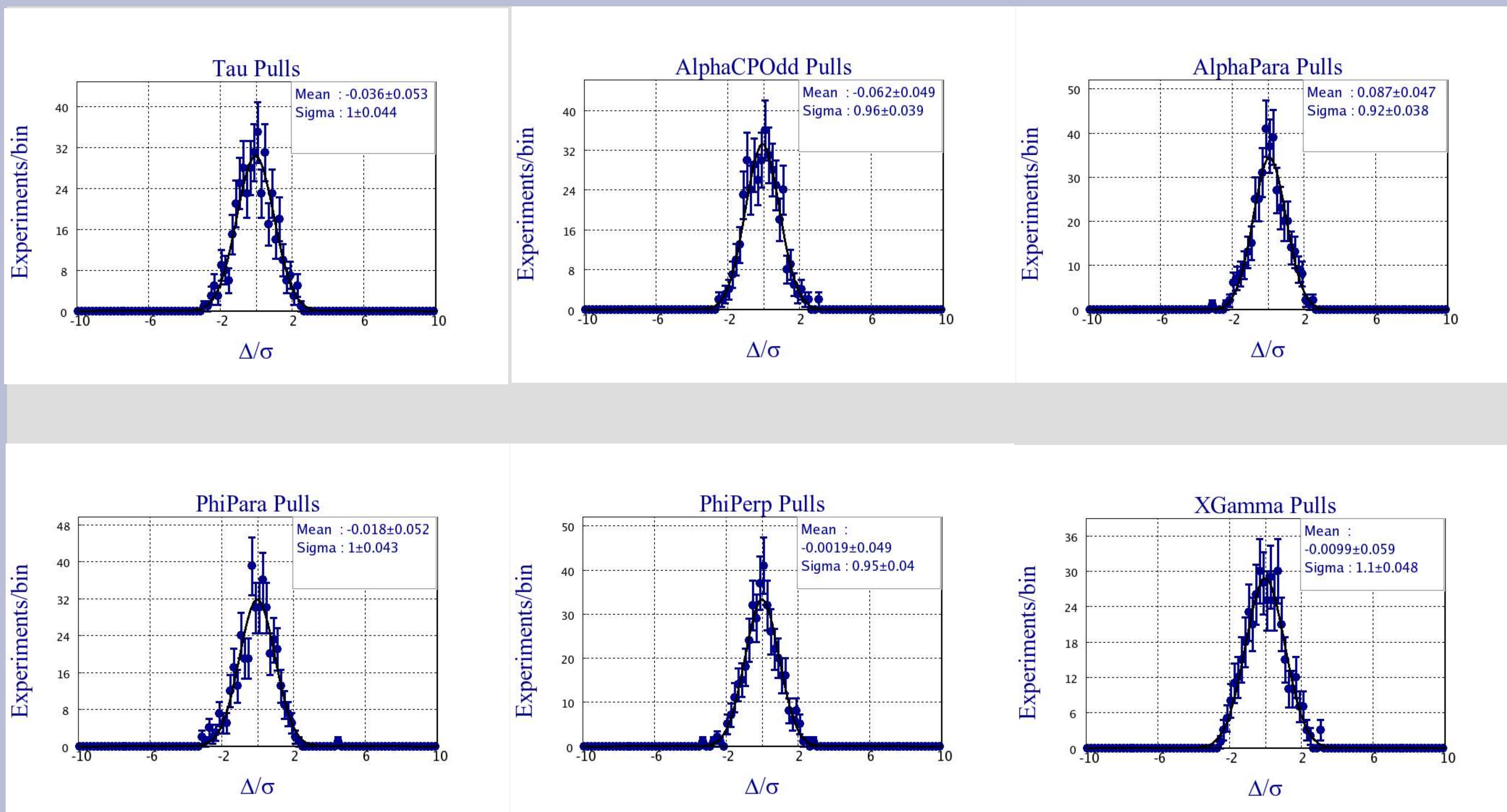

Tau Pulls
Mean : -0.093±0.05
Sigma : 0.99±0.04
AlphaCPOdd Pulls
Mean : 0.026±0.059
Sigma : 1.1±0.047
AlphaPara Pulls
Mean : 0.093±0.047
Sigma : 0.92±0.042
PhiPara Pulls
Mean : 0.0026±0.049
Sigma : 1±0.043
PhiPerp Pulls
Mean : 0.025±0.049
Sigma : 0.96±0.038
XGamma Pulls
Mean : -0.047±0.06
Sigma : 1.1±0.055
Experiments/bin
Δ/σ

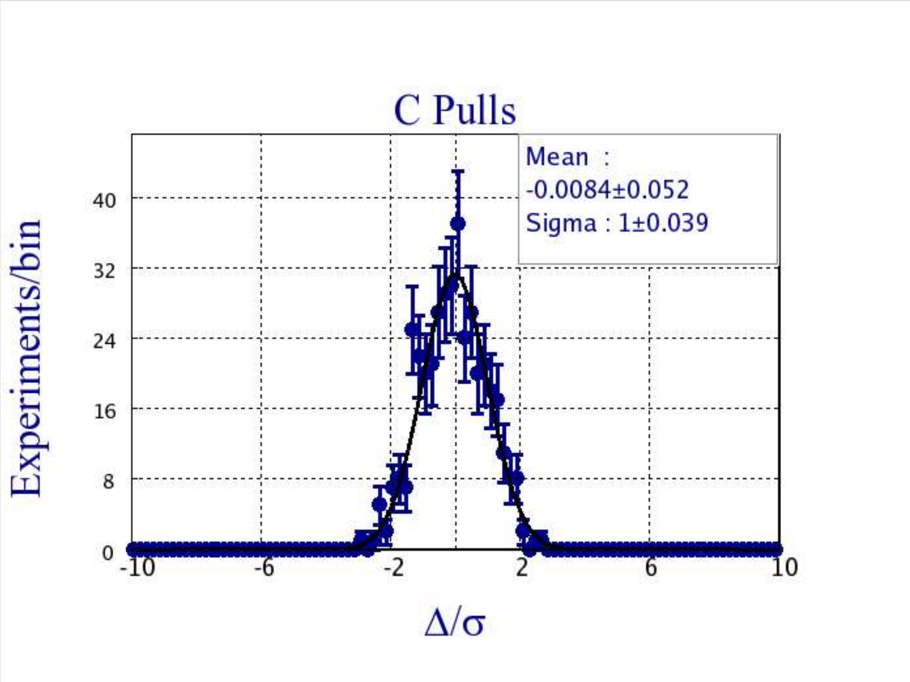

C Pulls
Mean : 0.037±0.049
Sigma : 0.96±0.041
Experiments/bin
Δ/σ

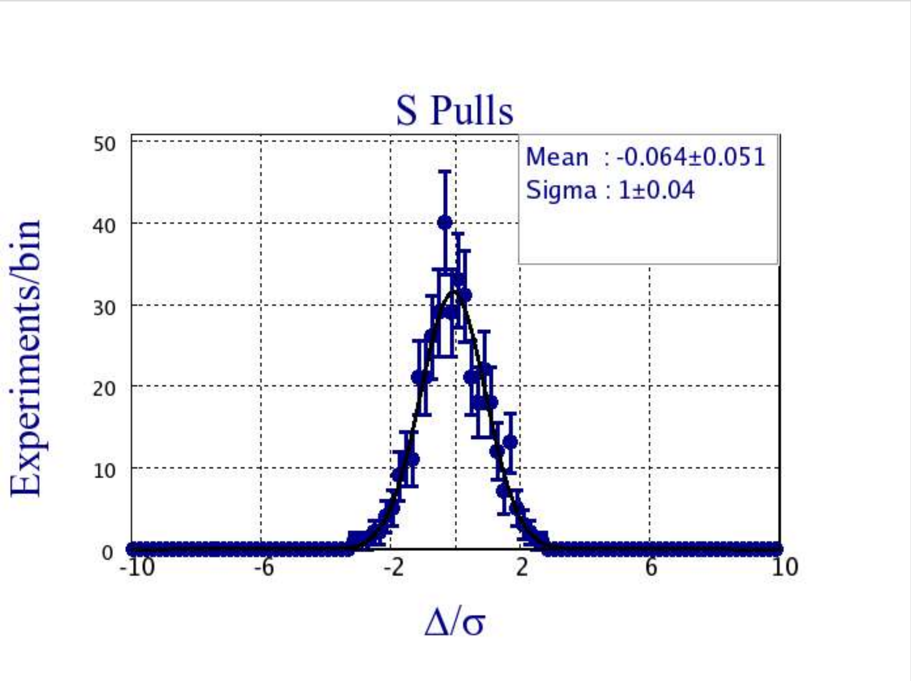

S Pulls
Mean : -0.026±0.057
Sigma : 1.1±0.05
Experiments/bin
Δ/σ

check analytic norm: what we are looking for is no further change, over and above the plots in the previous set of slides. The detector sculpting which is introduced should be corrected for, exactly.

Other effects (detector resolution and dilution) are trivial and already checked.



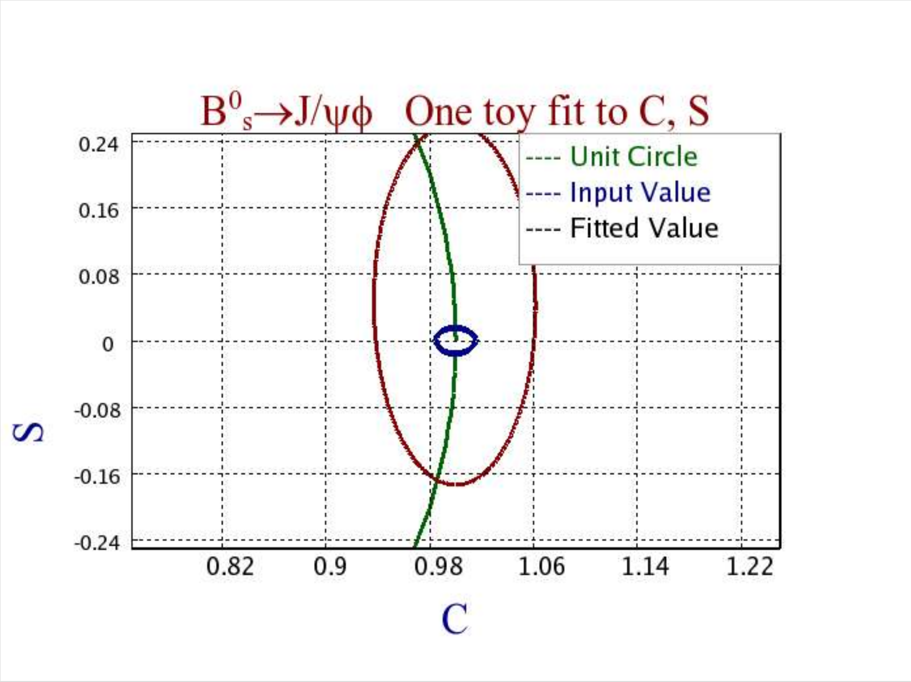




... so the analytic normalization seems to still work...

D=0.2 & perfect resolution :

- fitter loses ability to sort out $|\lambda|$
- $\sigma(C) < \sigma(S)$



untagged analyses generally do not converge to reasonable values...
(no surprise there, since this fit has an additional degree of freedom).

Conclusion:

* Fitter integrated with efficiency, resolution, dilution, passes the basic checks.

* Needs to be integrated with background model, EPE dilutions, & cet.

* A good agreement with $|\lambda|=1$ is a sanity check; could be additional support for this analysis (with 1.3 fb-1?)

* Disagreement would have to be re-evaluated with FC confidence intervals to see if it is real or not. If it were, it could haunt us a little....