How to measure γ from $B_s \to D_s K\pi\pi$ decays ?

Group Meeting Heidelberg

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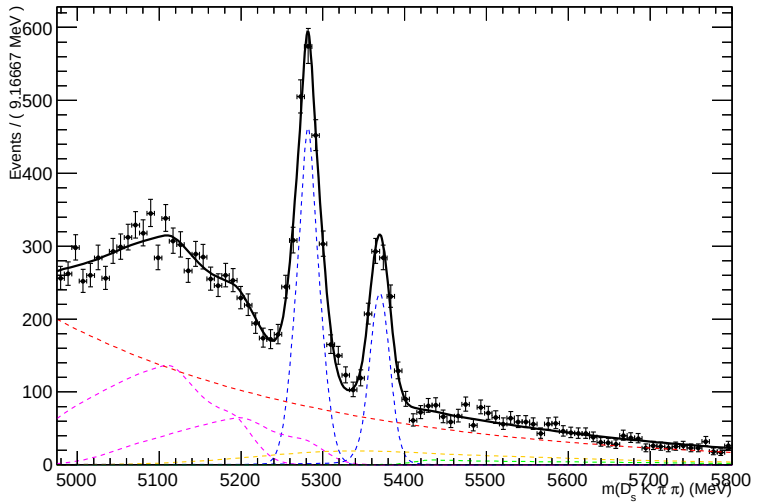
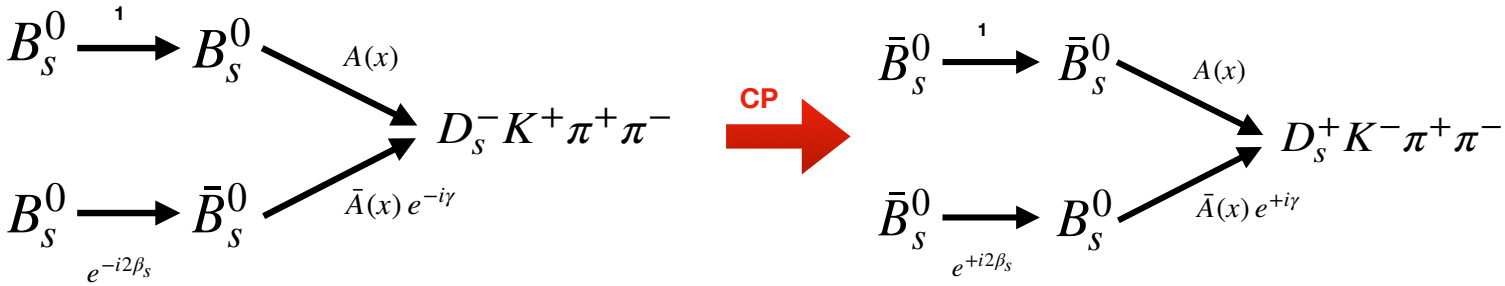
Status: $B_s \to D_s K\pi\pi$

- Have selected 1500 signal events (Run1 data)
- Acceptance/Resolution studies ongoing (see Matthieu's last talk)
- **Today: Sensitivity studies**





Full time-dependent amplitude PDF:

$$
\begin{aligned}
P(x,t,q_t,q_f) \propto [&\left(|A(x)|^2 + |\bar{A}(x)|^2\right) \cosh\left(\frac{\Delta\Gamma\, t}{2}\right) \\
&+ q_t q_f \left(|A(x)|^2 - |\bar{A}(x)|^2\right) \cos\left(\Delta m_s\, t\right) \\
&- 2\mathrm{Re}\left(A(x)^* \bar{A}(x)\, e^{-iq_f(\gamma - 2\beta_s)}\right) \sinh\left(\frac{\Delta\Gamma\, t}{2}\right) \\
&- 2q_t q_f \mathrm{Im}\left(A(x)^* \bar{A}(x)\, e^{-iq_f(\gamma - 2\beta_s)}\right) \sin\left(\Delta m_s\, t\right)] e^{-\Gamma t}
\end{aligned}
$$

$q_t = +1, 0, -1$ for a B_s^0, no-, ($\bar{B}_s^0$) tag
$q_f = +1$ (-1) for $D_s^- K^+ \pi\pi$ ($D_s^+ K^- \pi\pi$) final states.

Phasespace-integrated PDF:

$$\begin{aligned}\int P(x,t,q_t,q_f)\mathrm{d}x \propto [&\cosh\left(\frac{\Delta\Gamma\, t}{2}\right)\\ &+ q_t q_f \left(\frac{1-r^2}{1+r^2}\right)\cos\left(m_s\, t\right)\\ &- 2\left(\frac{\kappa\, r\cos(\delta - q_f(\gamma-2\beta_s))}{1+r^2}\right)\sinh\left(\frac{\Delta\Gamma\, t}{2}\right)\\ &- 2q_t q_f \left(\frac{\kappa\, r\sin(\delta - q_f(\gamma-2\beta_s))}{1+r^2}\right)\sin\left(m_s\, t\right)]e^{-\Gamma t}\\ &= [\cosh\left(\frac{\Delta\Gamma\, t}{2}\right) + q_t q_f\, \mathbf{C}\cos\left(m_s\, t\right)\\ &- \kappa\, \mathbf{D}_{q_f}\sinh\left(\frac{\Delta\Gamma\, t}{2}\right) - q_t\, \kappa\, \mathbf{S}_{q_f}\sin\left(m_s\, t\right)]e^{-\Gamma t}\end{aligned}$$

$$r \equiv \frac{\sqrt{\int |\bar{A}(x)|^2\mathrm{d}x}}{\sqrt{\int |A(x)|^2\mathrm{d}x}},\ \kappa\, e^{i\delta} \equiv \frac{\int A(x)^*\bar{A}(x)\mathrm{d}x}{\sqrt{\int |A(x)|^2\mathrm{d}x}\sqrt{\int |\bar{A}(x)|^2\mathrm{d}x}}$$

Amplitude Analysis

Time-integrated, flavor averaged PDF:

$$\int P(x, t, q_t, q_f)\, \mathrm{d}t\, \mathrm{d}q_t\, \mathrm{d}q_f \propto \left(|A(x)|^2 + |\bar{A}(x)|^2\right) \equiv |A^{eff}(x)|^2$$

- No sensitivity to γ
- Useful to identify contributing amplitude components

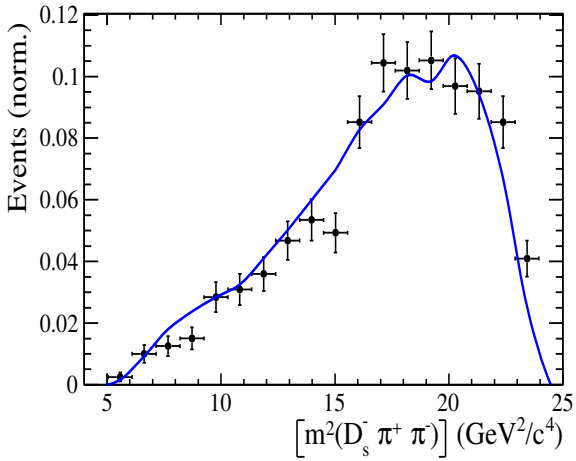
Time-integrated, flavor averaged fit

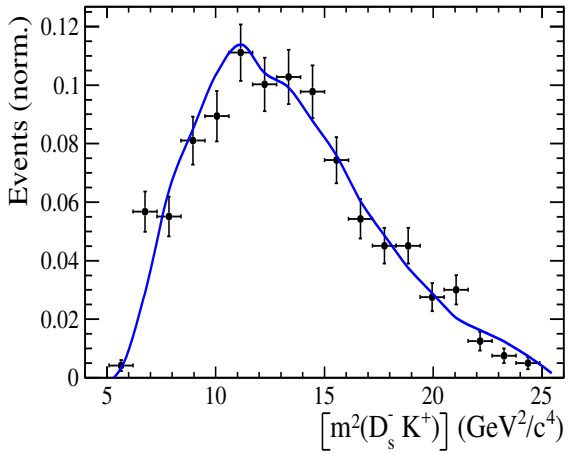
- MINT2 fitter, used for $D \to 4\pi$ [JHEP05(2017)143]
- Amplitude for *eg* $B_s \to Ds^- (K_1(1270)^+ \to K^+ \rho)$:
  $A_i^{eff}(x) = BW_{K_1}(m^2_{K\pi\pi})\, BW_\rho(m^2_{\pi\pi})\, S_f$
- Sum over intermediate state amplitudes:
  $A^{eff}(x) = \sum_i a_i^{eff}\, A_i^{eff}(x)$

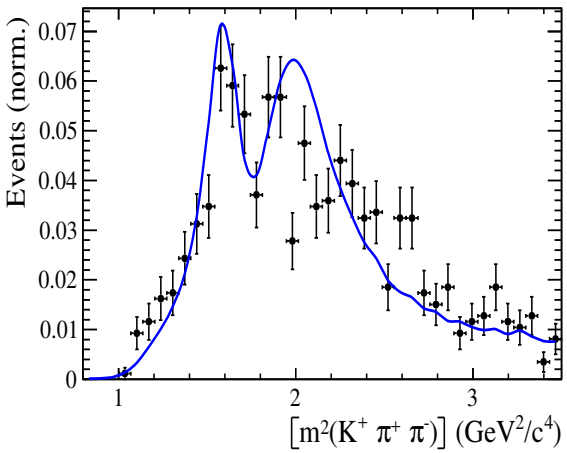
Very preliminary fit

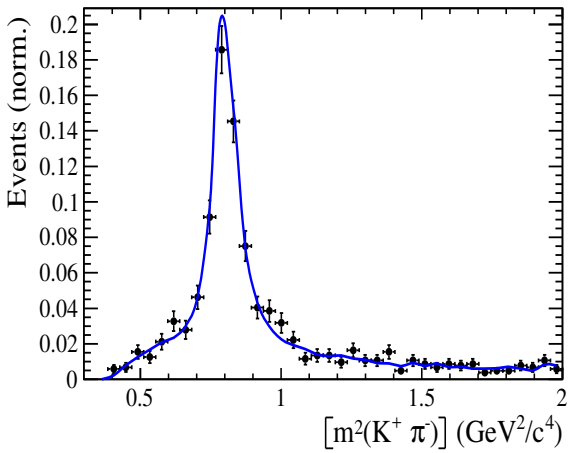
- Signal region data, assuming $f_{Bkg} = 0$
- Assuming flat efficiency ($\epsilon(x) = 1$)
- Just for illustration, don't take it too seriously !

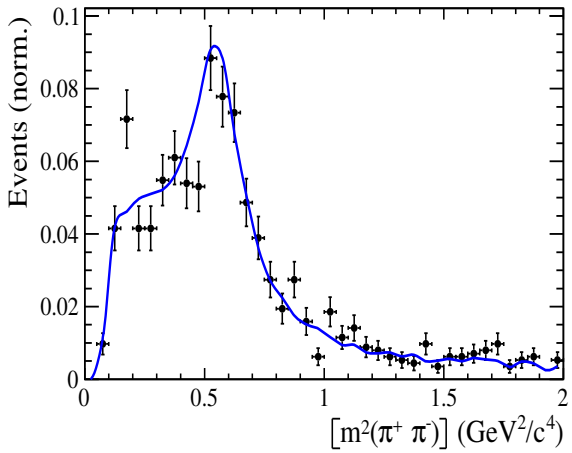
Amplitude Fit: $B_s \to D_s K \pi \pi$











Fit fractions

$$F_i^{eff} = \frac{\int |a_i^{eff} A_i^{eff}(x)|^2 \, dx}{\int |A^{eff}(x)|^2 \, dx}$$

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(1) Bs0->K(1)(1270)+(->K(0)*(1430)0(->K+,pi-),pi+),Ds- = 0.0520926 +/- 0.0145326
(2) Bs0->K(1)(1270)+(->K*(892)0(->K+,pi-),pi+),Ds- = 0.090921 +/- 0.0214
(3) Bs0->K(1)(1400)+(->K*(892)0(->K+,pi-),pi+),Ds- = 0.315657 +/- 0.0320033
(4) Bs0->K*(1410)+(->K*(892)0(->K+,pi-),pi+),Ds- = 0.127998 +/- 0.0175661
(5) Bs0->NonResS0(->Ds-,pi+),K*(892)0(->K+,pi-) = 0.0265594 +/- 0.0114541
(6) Bs0[D]->NonResV0(->Ds-,pi+),K*(892)0(->K+,pi-) = 0.0108669 +/- 0.0069929
(7) Bs0->NonResA0(->sigma10(->pi+,pi-),Ds-),K+ = 0.0715845 +/- 0.0247102
(8) Bs0->NonResV0(->Ds-,K+),sigma10(->pi+,pi-) = 0.139525 +/- 0.0321404
(9) Bs0->K(1)(1270)+(->rho(770)0(->pi+,pi-),K+),Ds- = 0.16488 +/- 0.0379784
(10) Bs0->K(1)(1400)+(->rho(770)0(->pi+,pi-),K+),Ds- = 0.071005 +/- 0.0218139
(11) Bs0->K*(1410)+(->rho(770)0(->pi+,pi-),K+),Ds- = 0.0766048 +/- 0.014699
(12) Bs0->NonResA0(->rho(770)0(->pi+,pi-),Ds-),K+ = 0.0210193 +/- 0.0104696
 sum = 1.16871 +/- 0.0595647(fit)
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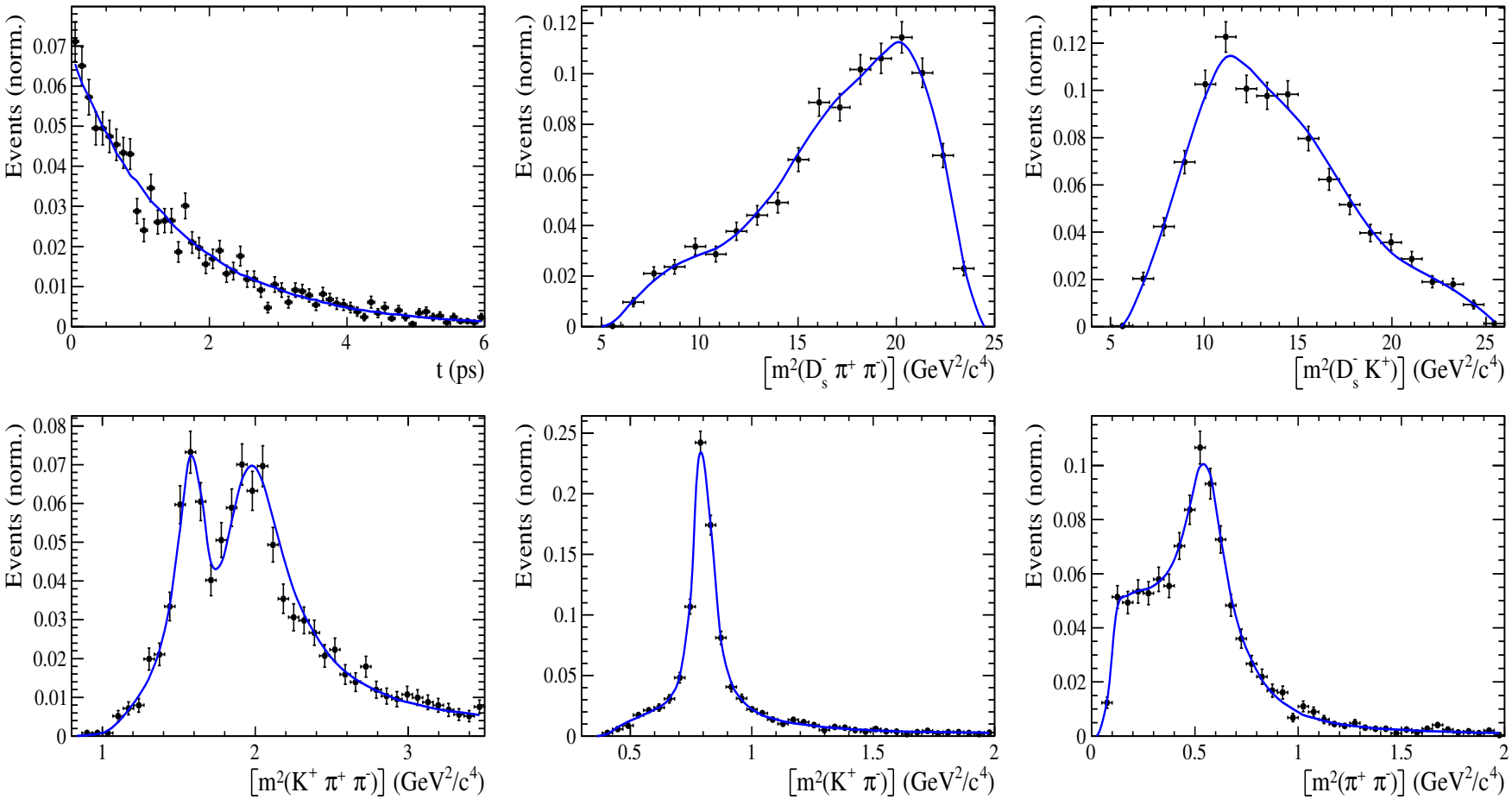
Sensitivity Studies

- Developed time-dependent MINT extension
- Generate toys with different values for κ
- Compare sensitivity to γ fitting with **full PDF** and with **phasespace-integrated PDF**

Assumptions

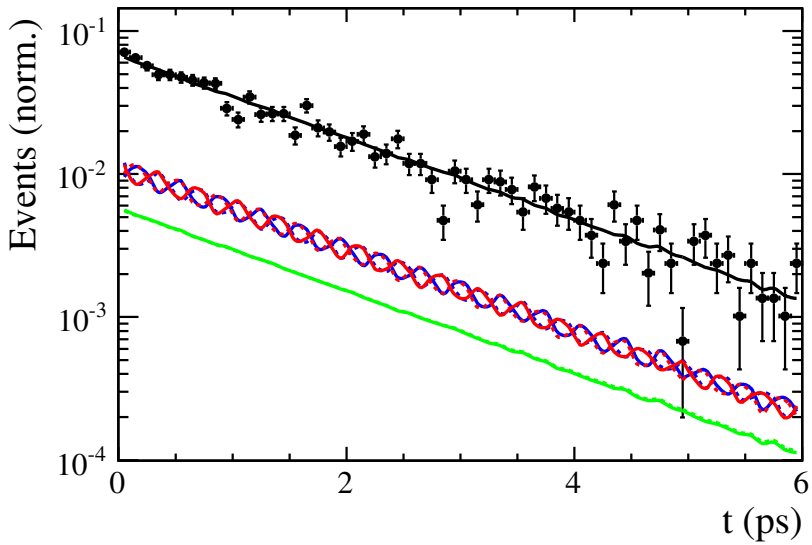
- Use amplitudes from flavor-averaged, time-integrated fit
- $r = 0.4$ (ratio of CKM elements)
- PDG values for: $\tau, \Delta m_s, \Delta\Gamma, \beta_s$
- $\epsilon(x,t) = const.$, perfect resolution
- $\epsilon_{Tag} = 0.66, < \omega >= 0.4$
- $N_{signal} = 3000$ (Run1+15/16 data)

Example Toy-Fit: $B_s \to D_s K\pi\pi$



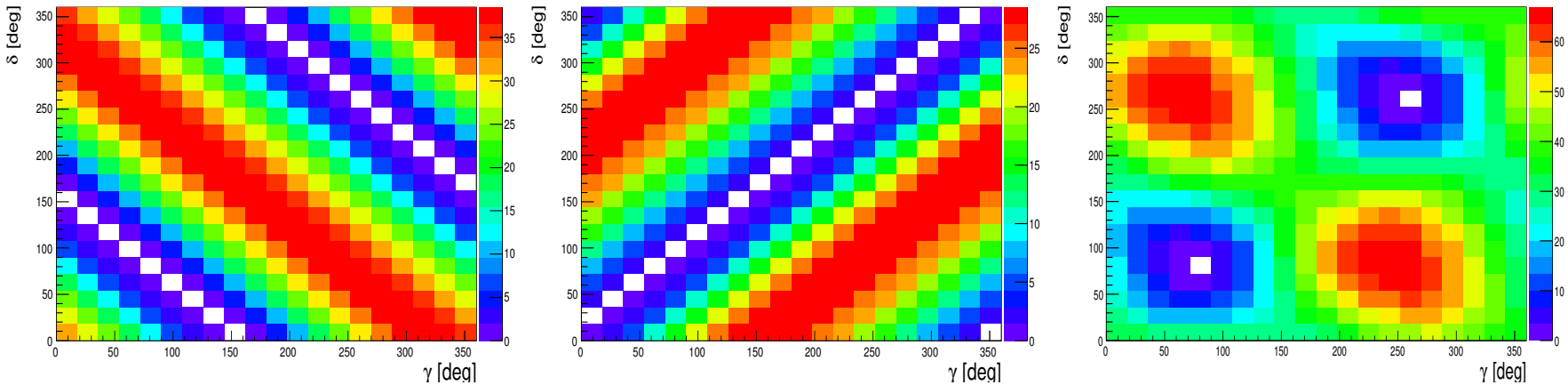
Example Toy-Fit: $B_s \to D_s K\pi\pi$

- $B_s(\bar{B}_s) \to D_s^- K^+\pi\pi$
- $B_s(\bar{B}_s) \to D_s^+ K^-\pi\pi$
- *Untagged* $\to D_s^- K^+\pi\pi\,(D_s^+ K^-\pi\pi)$



Likelihood Scan

$D_s^+ K^- \pi\pi$ $D_s^- K^+ \pi\pi$ Combined



Generated values:

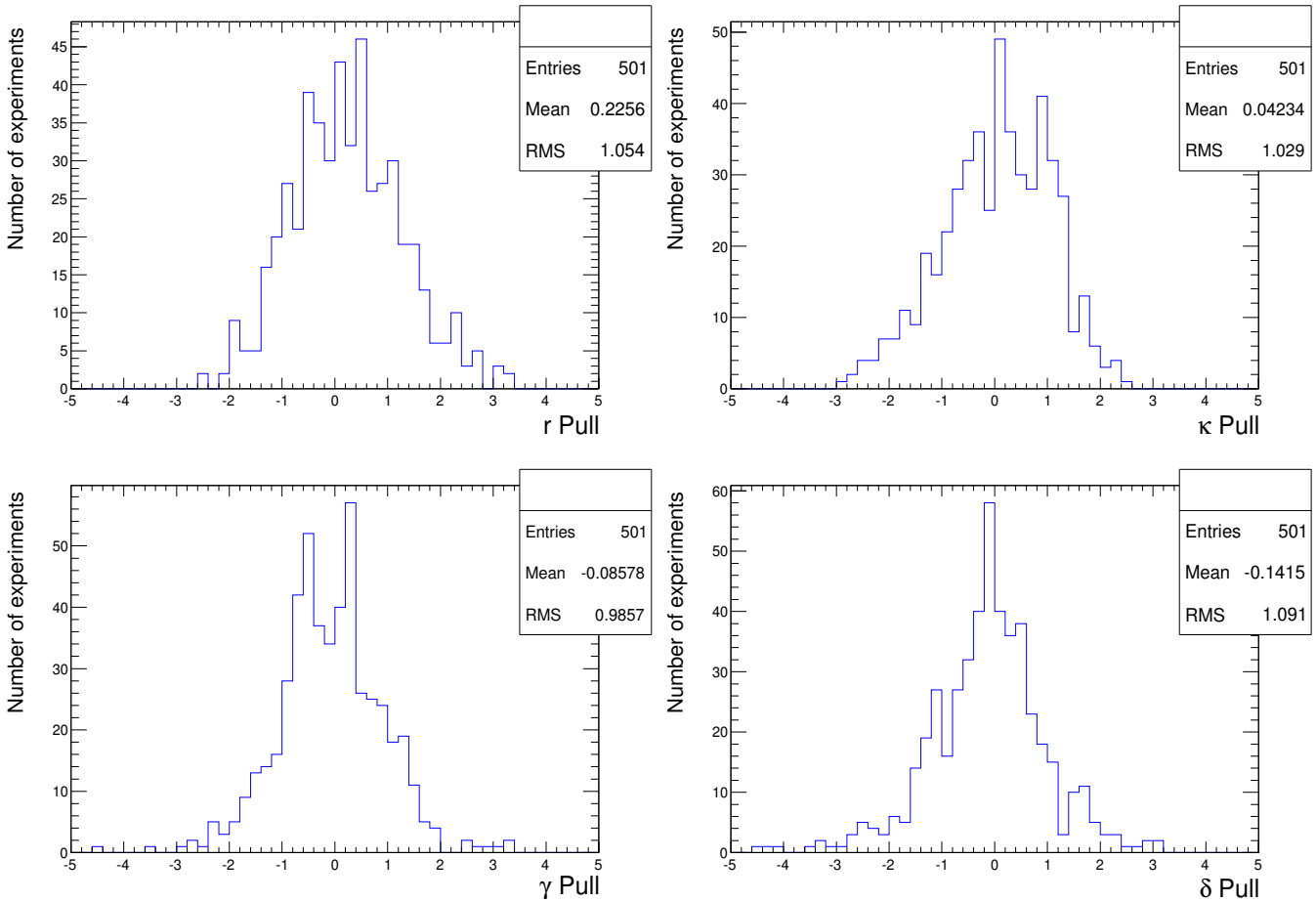
$\gamma = 70°, \delta = 100°$

Fit result:

$\gamma = 74 \pm 15°, \delta = 84 \pm 15°$

$(\gamma = 254 \pm 15°, \delta = 264 \pm 15°)$

Fit Validation



	Generated	Full PDF	Phasespace integrated
r	0.4	0.38 ± 0.06	unstable
κ	0.2	0.23 ± 0.13	0.2 (fixed)
δ	100	99 ± 22	unstable
γ	70	70 ± 17	unstable

	Generated	Full PDF	Phasespace integrated
r	0.4	0.44 ± 0.07	0.43 ± 0.11
κ	0.4	0.41 ± 0.14	0.4 (fixed)
δ	100	101 ± 19	95 ± 41
γ	70	69 ± 16	66 ± 40

	Generated	Full PDF	Phasespace integrated
r	0.4	0.41 ± 0.08	0.39 ± 0.11
κ	0.6	0.60 ± 0.13	0.6 (fixed)
δ	100	98 ± 17	92 ± 25
γ	70	68 ± 17	65 ± 28

	Generated	Full PDF	Phasespace integrated
r	0.4	0.42 ± 0.09	0.39 ± 0.09
κ	1.0	0.96 ± 0.03	1.0 (fixed)
δ	100	100 ± 17	100 ± 17
γ	70	66 ± 17	67 ± 17

Conclusion

$B_s \to D_s K\pi\pi$

- **Estimated sensitivity to γ:**
  17° independent of κ using TD-amplitude fit
  17° (40°) for $\kappa = 1$ ($\kappa = 0.4$) using phasespace-integrated fit
- **ToDo:**
  Reimplement time-acceptance/resolution from B2DX-Fitter in MINT