Experimental aspects of B→DK at 10^{36}

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Introduction

- Goal: estimate of reach in γ of B → DK analysis at 10 ab^{-1}
  - Look for modes that are experimentally and theoretically clean & easy
  - Systematics will be important, look at modes where we have some understanding of systematic issues
  - Focus on Gronau-London-Wyler ($B^- \rightarrow D^0_{CP} K^-$) and Atwood-Dunietz-Soni ($B^- \rightarrow D^0$bar K^-), [D*, K* modes not considered]

- Outline
  - Examine existing GLW analysis, project stat+sys errors on observables at 10 ab-1
  - Examine ADS analysis effort, project stat+sys errors on observables for 10 ab-1
  - Combine GLW and ADS projections and look at impact on measurement of γ

- Caveat
  - There are many unknowns parameters in this prediction that play important role precision extrapolation (strong phases, rB, systematic uncertainties)
  - Will consider optimistic and pessimistic assumptions for unknowns

Gronau-London-Wyler – Introduction

- Method: measure BFs for $B^- \rightarrow D^0_{(CP)}K^-$
- Observables sensitive to γ

$$r_B = \frac{A(b \to u)}{A(b \to c)}$$

$$R_{CP\pm} = 2\frac{\Gamma(B^- \to D^0_{CP\pm}K^-) + \Gamma(B^+ \to D^0_{CP\pm}K^+)}{\Gamma(B^- \to D^0 K^-) + \Gamma(B^- \to \overline{D}^0 K^-)} = 1 + r_B^2 \pm 2r_B \cos d_B \cos g$$

$$A_{CP\pm} = \frac{\Gamma(B^- \to D^0_{CP\pm}K^-) - \Gamma(B^+ \to D^0_{CP\pm}K^+)}{\Gamma(B^- \to D^0_{CP}K^-) + \Gamma(B^- \to \overline{D}^0_{CP}K^-)} = \frac{\pm 2r_B \sin d_B \sin g}{1 + r_B^2 + 2r_B \cos d_B \sin g}$$

- 4 measurements: R_{CP+}, R_{CP-}, A_{CP+}, A_{CP-}
  - Actually only 3 independent measurements as ACP+ and ACP- measure the same combination of unknowns up to a sign
- 3 unknowns: γ, r_B, δ_B(strong phase)

Gronau-London-Wyler – Experimental status

	BaBar (89M BB)	Belle (86M BB)
A_{CP+}	$0.07 \pm 0.17 \pm 0.06$	$0.06 \pm 0.19 \pm 0.04$
A_{CP-}	-	$-0.19 \pm 0.17 \pm 0.05$
R_{CP+}	$(8.8 \pm 1.6 \pm 0.5)/(8.31 \pm 0.35 \pm 0.20) =$ $1.06 \pm 0.20 \pm ???$	$1.21 \pm 0.25 \pm 0.14$
R_{CP-}	-	$1.41 \pm 0.27 \pm 0.15$

- Notes
  - RCP± measured as double ratio

$$R_{CP\pm} = 2\,\frac{\Gamma(B^- \to D^0_{CP\pm}K^-) + \Gamma(B^+ \to D^0_{CP\pm}K^+)}{\Gamma(B^- \to D^0 p^-) + \Gamma(B^- \to \overline{D}^0 p^-)} \Bigg/ \frac{\Gamma(B^- \to D^0 K^-) + \Gamma(B^+ \to \overline{D}^0 K^+)}{\Gamma(B^- \to D^0 p^-) + \Gamma(B^- \to \overline{D}^0 p^-)}$$

  - BaBar result does not publish double ratio, only its components
    - Systematics on ratio components correlated, cannot trivially combined them.
    - Will assume Belle/BaBar similar here and use Belle systematic

Gronau-London-Wyler – Extrapolated precision

- Statistical error on A_{CP} and R_{CP}
  - Assume sqrt(N) scaling: 100x more data, errors reduce by factor 10
  - **$s(A_{CP})_{stat}$ = 1.6% at 10 ab^{-1}, $s(R_{CP})_{stat}$ = 2.0% at 10 ab^{-1},**

- Systematic uncertainty on A_{CP}
  - Magnitude at 100M BB pairs = 0.05-0.06
  - Breakdown of systematic uncertainty as advertised:

    Belle: 5% = 2.4-3.4% yield extraction +
    3.2% detector charge asymmetry +
    1% PID charge asymmetry

    BaBar: 6% = 4% detector charge asymmetry +
    4% yield extraction

  - How will this scale with lumi?
    - Yield extraction component will scale with lumi (signal/bkg shapes fitted from data)
    - Detector charge asymmetry measured from B → $D^0_{CP}\,\pi$- control sample (BaBar), will improve with increased statistics, but may not scale entirely by sqrt(N)
  - Estimate at 10 ab-1:
    - 0.4% yield ext (sqrtN) + 1-3% charge asym. (opt-pess). → 1.1% - 3%

Gronau-London-Wyler – Experimental precision

- Systematic uncertainty on R_{CP}
  - Magnitude at 100M BB pairs = 0.15 (Belle)
    - No systematic estimate from BaBar on ratio of ratios
  - Breakdown of systematic uncertainty sources
    - BaBar does not have a syst estimate on this ratio
    - Belle PRD not rich with details, indicates sys.err mostly yield extraction
  - Alternative approach: what detector systematic don't cancel in ratio of BF's

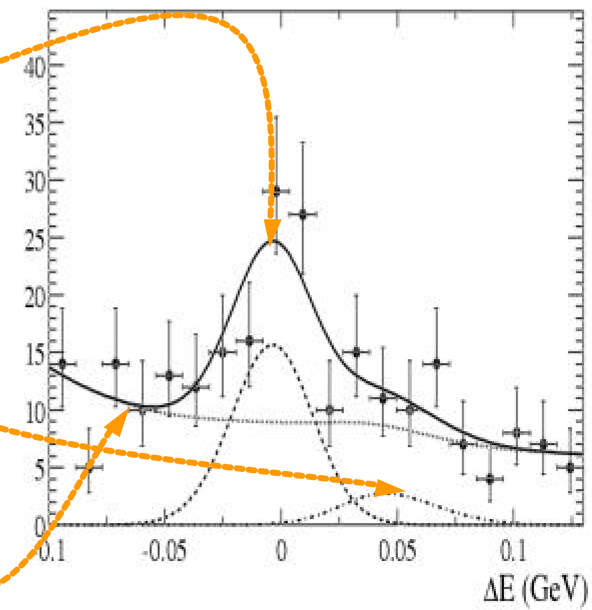
$$R_{CP\pm} = 2\frac{\Gamma(B^- \to D^0_{CP\pm}K^-) + \Gamma(B^+ \to D^0_{CP\pm}K^+)}{\Gamma(B^- \to D^0 K^-) + \Gamma(B^- \to \overline{D}^0 K^-)}$$

    - Mainly D^0_{CP} vs D^0 selection: yield extraction (sqrtN), daughter PID (1-2%?)
  - Estimate at 10 ab^{-1}:
    - 1.5% from yield (sqrt N) + 1-4% from PID (opt-pess) = 2.1 - 5%

- Summary of errors on GLW observables at 10 ab-1
  - **R_{CP} = 0.02 stat Å (0.02-0.05) sys**
  - **A_{CP} = 0.016 stat Å (0.015-0.04) sys**

Gronau-London-Wyler – Adjusting for detector performance

- Sensitivity to detector performance
  - So far have assumed that BaBar and 'super BaBar' have similar detector performance.
  - Look at effects of
    - different tracking resolution (mD/DE resolution),
    - PID performance (peaking bkg),
    - increased continuum (or other non-BB) background (flattish background)
- Crude ToyMC study on $B^- \rightarrow D^0_{CP} K^-$ yield fit
  - +/-30% change in $\Delta E, m(D^0)$ resolution gives ~20% change in stat error on yield
  - PID performance change has marginal effect (x4 increase of K/pi misID rate has negligible impact on yield error)
  - Factor 2 increase in continuum bkg gives a 23% larger stat error on the signal yield
  - Present $D^0_{CP}K^-$ analysis has still some room for improvement for continuum suppression…



Atwood-Dunietz-Soni -- Introduction

- Method: Measure BF($B^- \rightarrow [K^+\pi^-]_{D0} K^-$)
  - Interference between (DCB B decay + CF D decay) and (CF B decay + DCS D decay), D^0 to flavor eigenstate
- Observables sensitive to γ

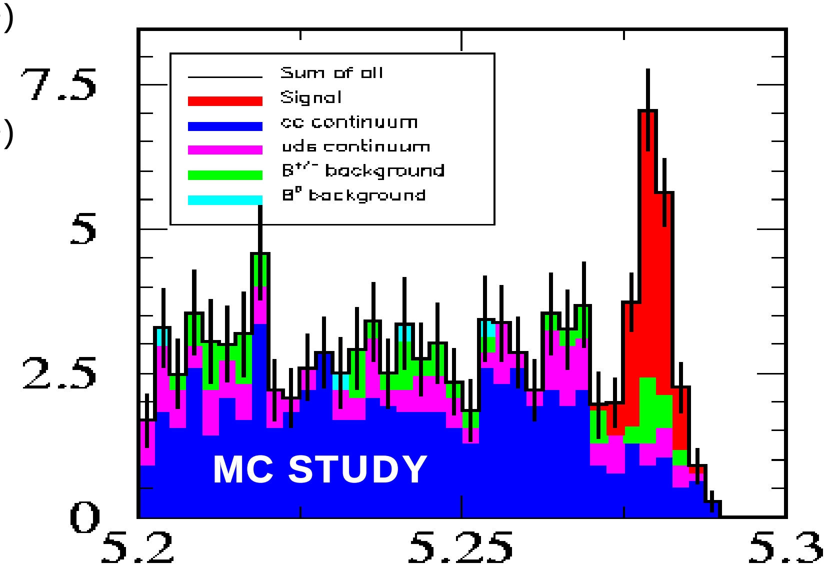
$$R_{\pm}^{ADS} = \frac{\Gamma(B^{\mp} \rightarrow [K^{\pm} p^{\mp}]_{D^0} K^{\mp})}{\Gamma(B^{\mp} \rightarrow D^0 K^{\mp})} = r_B^2 + r_D^2 + r_B r_D \cos(d_B + d_D \pm g)$$

$$r_D \equiv \sqrt{\frac{B(D^0 \rightarrow K^+ p^-)}{B(D^0 \rightarrow K^- p^+)}} \approx 0.0624$$

- 2 measurements per D^0 mode
- 2 unknowns (γ, δ_B) + 1 unknown per D^0 mode (δ_D)
- Need at least two D^0 modes for ADS-only constraint on γ (4 measurements with 4 unknowns)
  - But single ADS mode can be combined with GLW results to provide additional constraints
  - δ_D could also be measured by CLEO-C (one less unknown)

Atwood-Dunietz-Soni – Experimental status, extrapolation

- BaBar: measurement in progress, Belle unknown
  - No public result yet, but work in progess → have good estimates of stat and sys uncertainties
- Statistical error R^{ADS} ($D^0 \to K\pi$)
  - Depends strongly on BF($B^- \to [K^+\pi^-]_{D0} K^-$), which is not measured up to know. Estimates range from $[0\text{-}10]\times10^{-7}$
    - 0 if rB=0.1 and fully destructive interf, 10x10-7 if rB=0.2 and constructive interf
  - MC Study: assuming BF of 5x10-7 yield is 13 events at 100 fb-1 (at 21% eff.) → error = 35% at 100 fb-1, 3.5% at 10 ab-1
    - If BF=1x10-7, stat error 10.8% (10 ab^{-1})
    - If BF=2x10-7, stat error 6.3% (10 ab^{-1})
    - If BF=10x10-7, stat error 2.2% (10 ab^{-1})
  - Stat error on BF($B^- \to D^0 K^-$) (denominator of R^{ADS}) is negligible compared to BF($B^- \to [K^+\pi^-]_{D0} K^-$) contribution



Atwood-Dunietz-Soni – Extrapolation

- Systematic error on R^{ADS} ($D^0 \rightarrow K\pi$)

$$R_{\pm}^{ADS} = \frac{\Gamma(B^- \rightarrow \overline{D}^0 K^-)}{\Gamma(B^- \rightarrow D^0 K^-)}$$

  - *Nearly all systematic uncertainties cancel in ratio*, only left with yield extraction systematics, which scale like sqrt(N) and PID asymmetry (~1%)
  - Toy MC study shows that yield extraction systematic about half of statistical error
  - Systematic at 10 ab-1 = 1-5%, depending on BF

- Errors on R^{ADS} from other D^0 decays
  - $D^0 \rightarrow K^- \pi^+ \pi^0$ and $D^0 \rightarrow K^- \pi^+ \pi^- \pi^+$ require investigation of Dalitz plots, systematics of full Dalitz analysis unknown
  - Quasi two-body analysis will probably give sensitivity similar to $K^-\pi^+$ (higher BF and lower acceptance roughly cancel)

- Summary of errors on ADS observables at 10 ab-1
  - **$D^0 \rightarrow K^- p^+$: R_{ADS} = (2-10)% stat Å (1-5)% sys (dep. on BF)**
  - Additional D^0 modes expected to have similar sensitivity, but Dalitz issues complicates analysis and prediction for $10ab^{-1}$

Atwood-Dunietz-Soni – Adjusting for detector performance

- What happens to prediction of tracking resolution, PID performance, backgrounds are different at 10^{36}?
  - Tracking resolution: 30% change in $m(D^0)/\Delta E$ resolution will give ~20% change in stat error
  - PID performance: negligible effect, except at very low BF
  - Backgrounds: may go up due to additional non-BB backgrounds. ADS continuum suppression already BaBar state-of-the art. Increase in background by factor 2 results 10-60% increase of stat error, depending on BF
    - At BF=1x10-7: Stat err 11% → 18% (60% increase)
    - At BF=2x10-7: Stat err. 6.3% → 7.5%
    - At BF=5x10-7: Stat err. 3.5% → 3.9%
    - At BF=10x10-7: Stat err. 2.2% → 2.4% (10% increase)

Translating B→DK results in measurement of γ

- Projected uncertainties:
  - **GLW: s(R_{CP}) = 0.02 stat Å (0.021-0.05) sys**
    s(A_{CP}) = 0.016 stat Å (0.015-0.04) sys

    \+ ~30% uncertainty due to tracking,PID, bkg changes
  - **ADS: s(R_{ADS}) = (2-10)% stat Å (1-5)% sys**

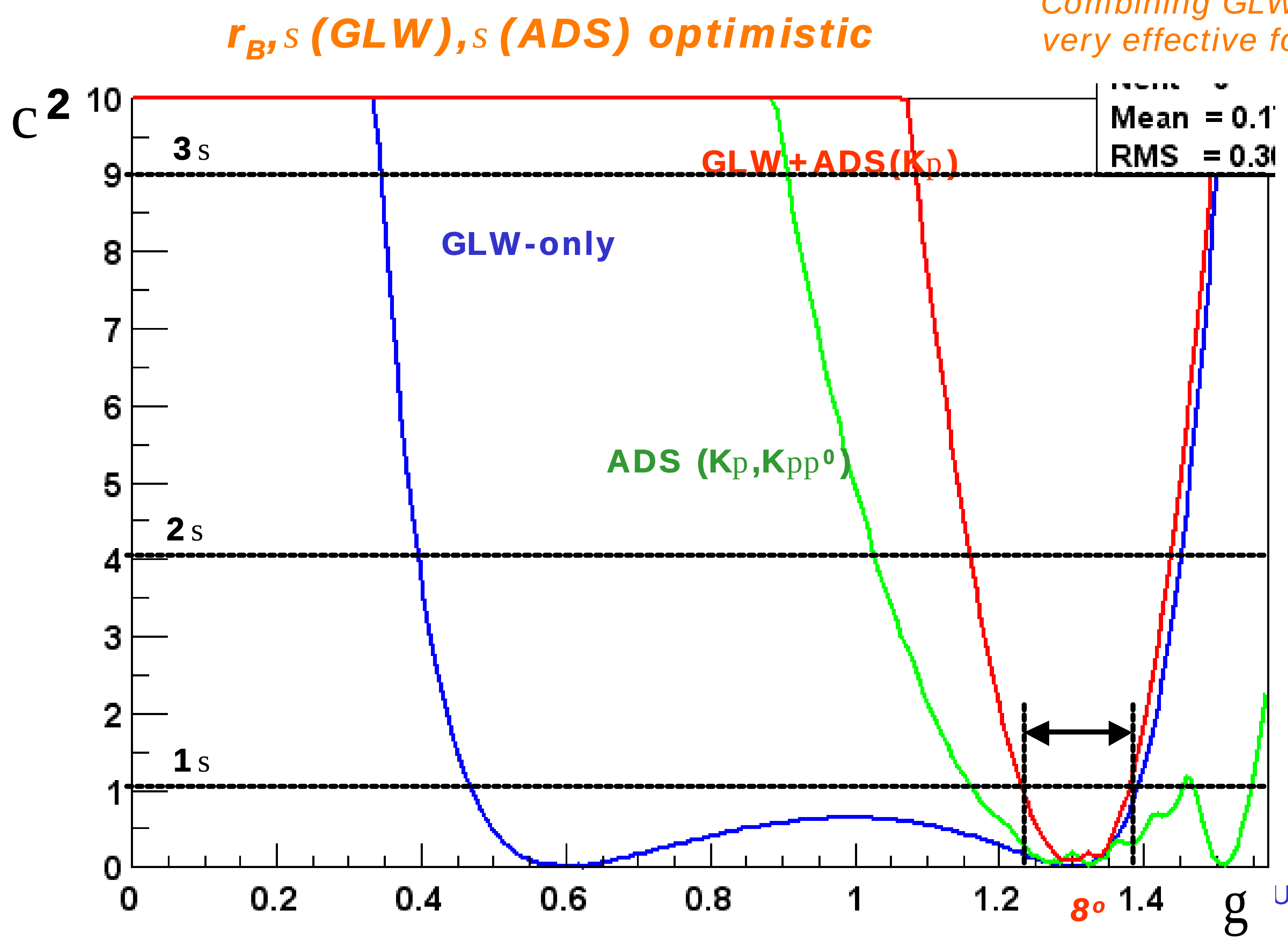
    \+ ~20-60% uncertainty due to bkg changes

- Resulting experimental resolution on γ also depends strongly on true values of γ, strong phases, and most importantly r_B
  - Sensitivity of both methods proportional to r_B^2 (r_B ~ 0.1-0.3)
  - Projection on gamma resolution are somewhat speculative…
  - Will run through a few scenarios

Translating B→DK results in measurement of γ

- $\gamma_{true}=60^o$, $r_{Btrue}=0.2$, $\delta B_{true}=15^o$, $\delta_{Dtrue}=30^o$, $\sigma(R_{CP})=0.03$, $\sigma(A_{CP})=0.02$, BF(ADS)=5x10^{-7}

Combining GLW+ADS very effective for g



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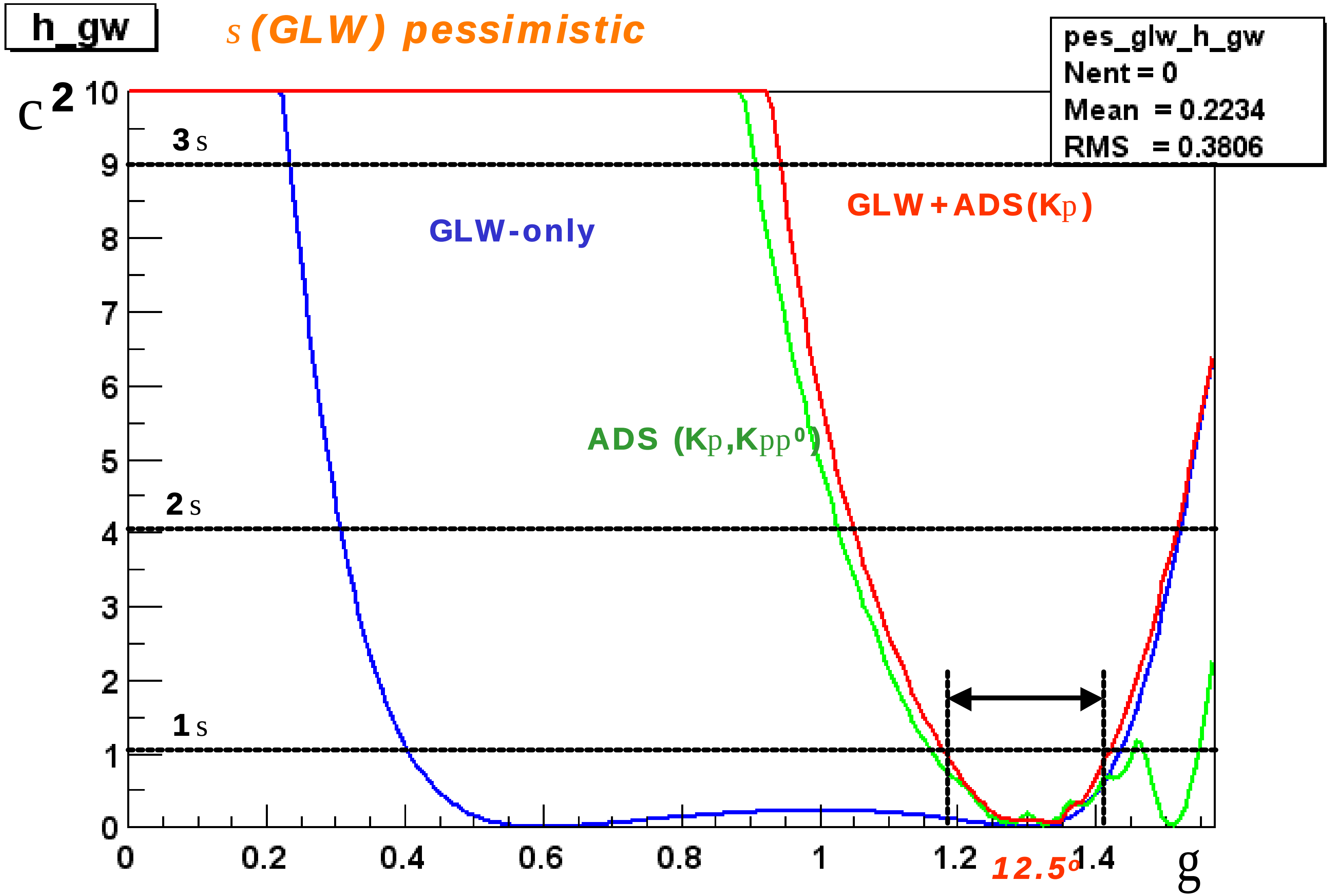
Translating B→DK results in measurement of γ

- $\gamma_{true}=60^o$, $r_{Btrue}=0.2$, $\delta B_{true}=15^o$, $\delta_{Dtrue}=30^o$, **σ(R$_{CP}$)=0.05, σ(A$_{CP}$)=0.045**, BF(ADS)=5x10^{-7}



Translating B→DK results in measurement of γ

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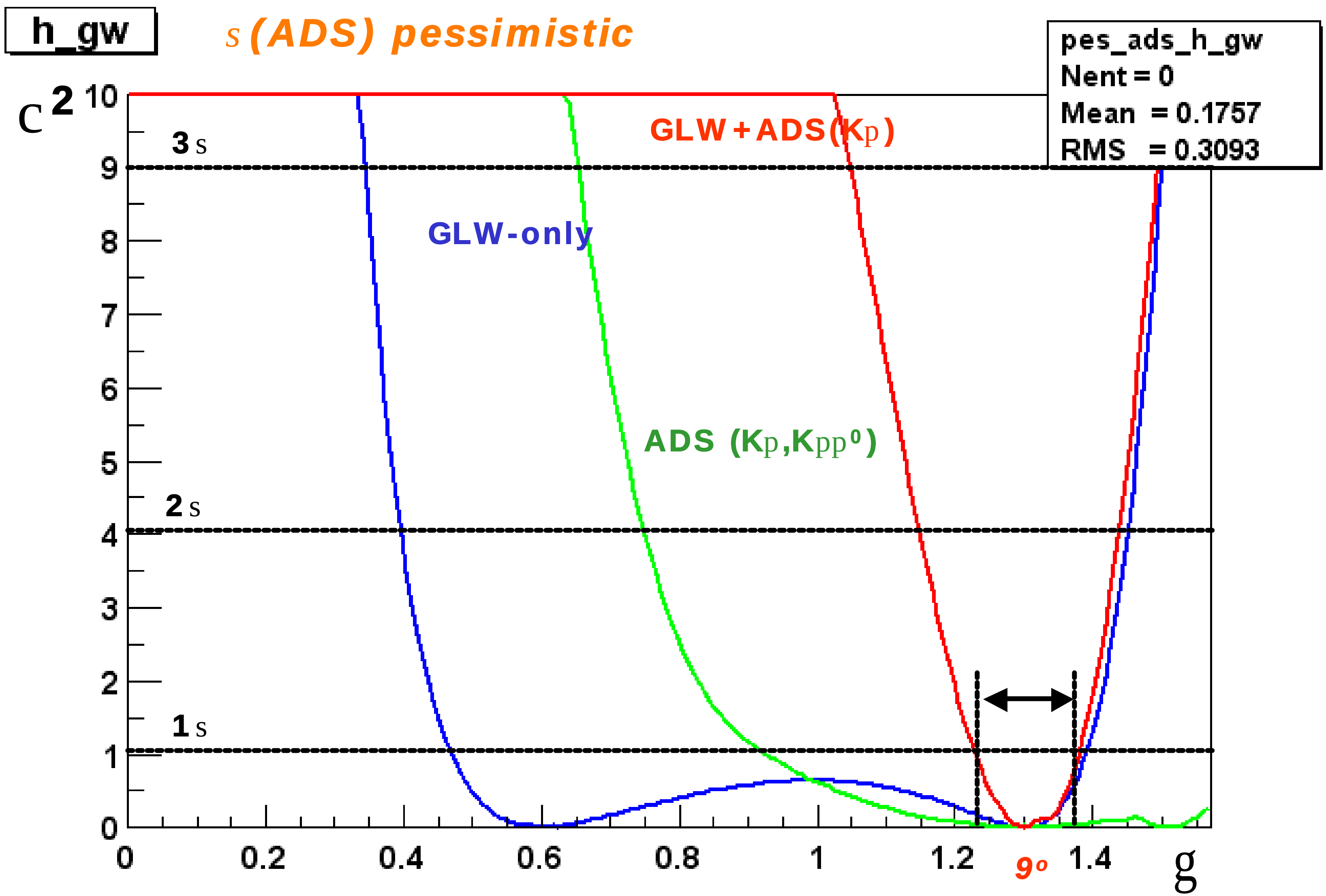
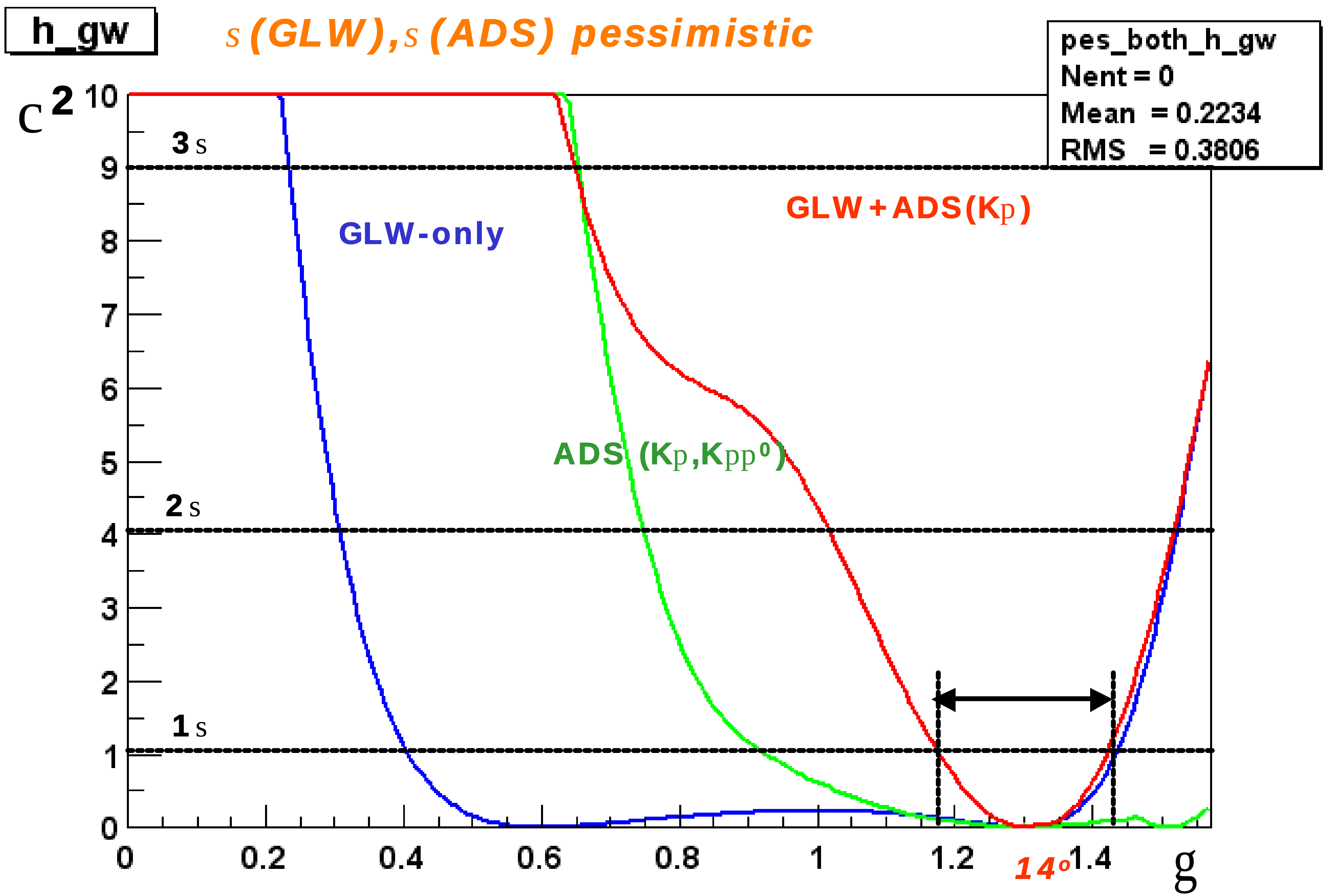


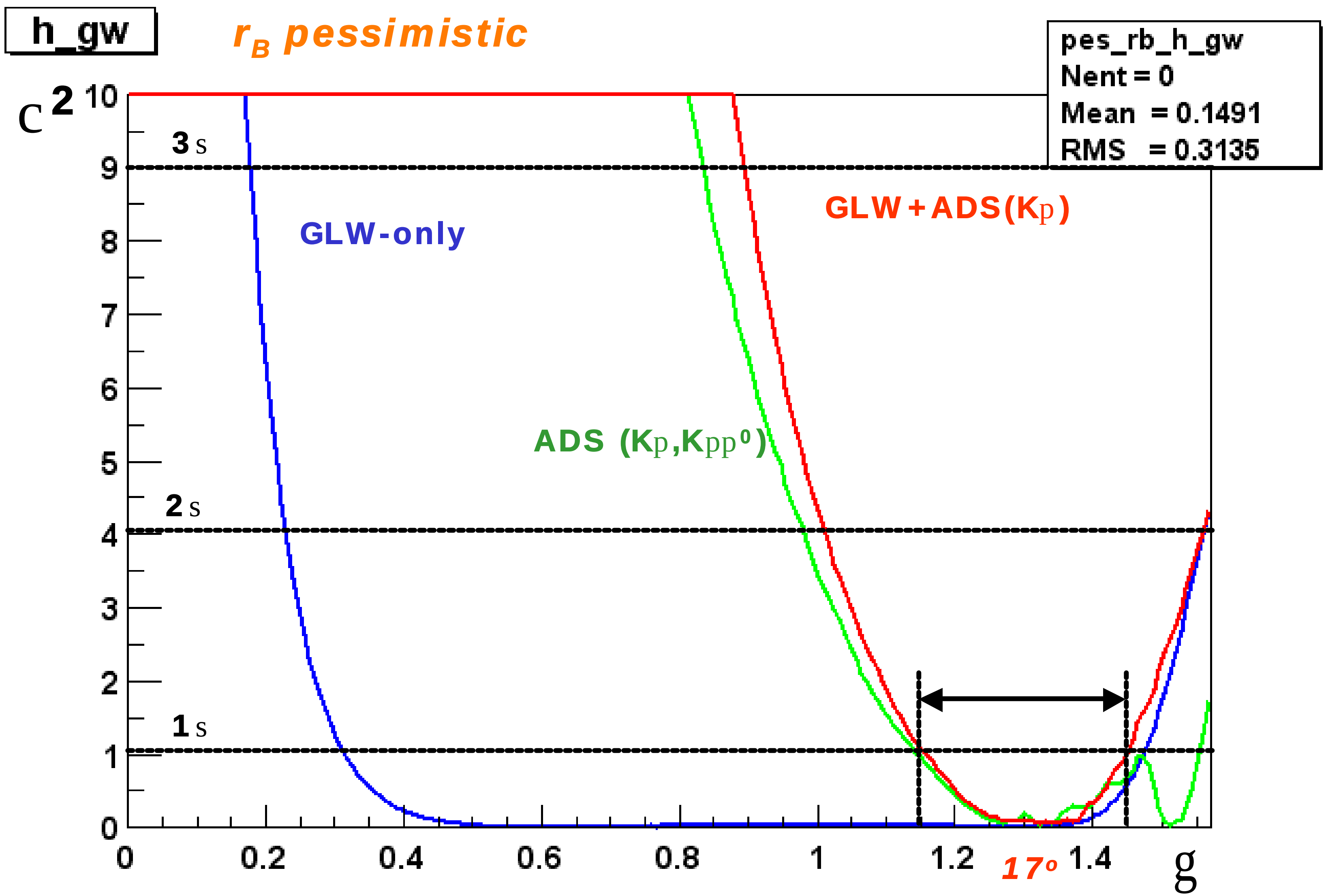
Translating B→DK results in measurement of γ

- γ_{true}=60°, r_{Btrue}=0.2, δB_{true}=15°, δ_{Dtrue}=30°, s (R_{CP})=0.05, s (A_{CP})=0.045, BF(ADS)=1x10^{-7}



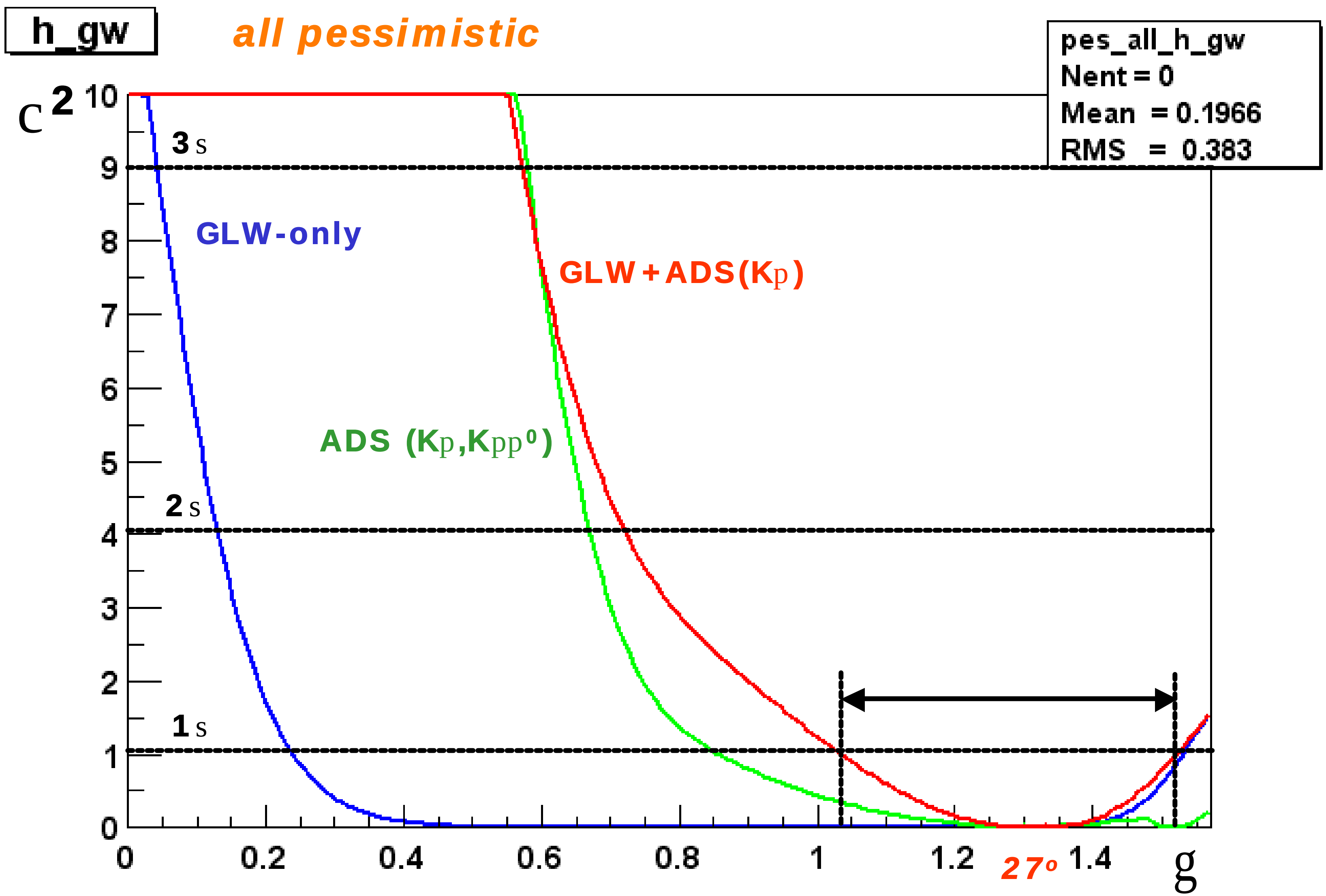
Translating B→DK results in measurement of γ

- $\gamma_{true}=60^o$, $\mathbf{r_{Btrue}=0.1}$, $\delta B_{true}=15^o$, $\delta_{Dtrue}=30^o$, $\sigma(R_{CP})=0.03$, $\sigma(A_{CP})=0.02$, $BF(ADS)=5\times10^{-7}$



Translating B→DK results in measurement of γ

- $\gamma_{true}=60^o$, $r_{Btrue}=0.1$, $\delta B_{true}=15^o$, $\delta_{Dtrue}=30^o$, $\sigma(R_{CP})=0.05$, $\sigma(A_{CP})=0.045$, BF(ADS)=1×10^{-7}



Summary

- Error on GLW and ADS observables may not be strongly systematics dominated (yet) at 10 ab^{-1}
  - **GLW: s(R_{CP}) = 0.02 stat Å (0.021-0.05) sys**
    s(A_{CP}) = 0.016 stat Å (0.015-0.04) sys

    + ~30% uncertainty due to tracking,PID, cont. bkg changes
  - **ADS: s(R_{ADS}) = (2-10)% stat Å (1-5)% sys**

    + ~20-60% uncertainty due to cont. bkg changes
  - Systematic errors relatively well behaved because many 'difficult' systematics (absolute tracking, PID efficiencies) cancel in ratio of BFs used in these methods
  - Level of continuum background may become dominant factor in error on these measurements
- Precision of resulting measurement of γ depends on many additional factors (true values of r_B, γ, strong phases)
  - Optimistic scenario gives error around 8^0, but pessimistic scenarios can go much lower ($15\text{-}25^0$)
  - Several factors are resolution on γ are 'luck factors' (e.g. true value of rB) that are not in experimenters hands
  - If r_B is low (0.1) measurement of g from B→DK by 'regular' B-factories unlikely
- **There exist several other methods to measure g from other B→DK decays (multi body decays, Dalitz analyses etc) that are not covered in this talk**
  - Combining many modes will help