Forward-Backward Asymmetry in $B^{\pm} \rightarrow J/\psi\, K^{\pm}$ at the DØ Experiment

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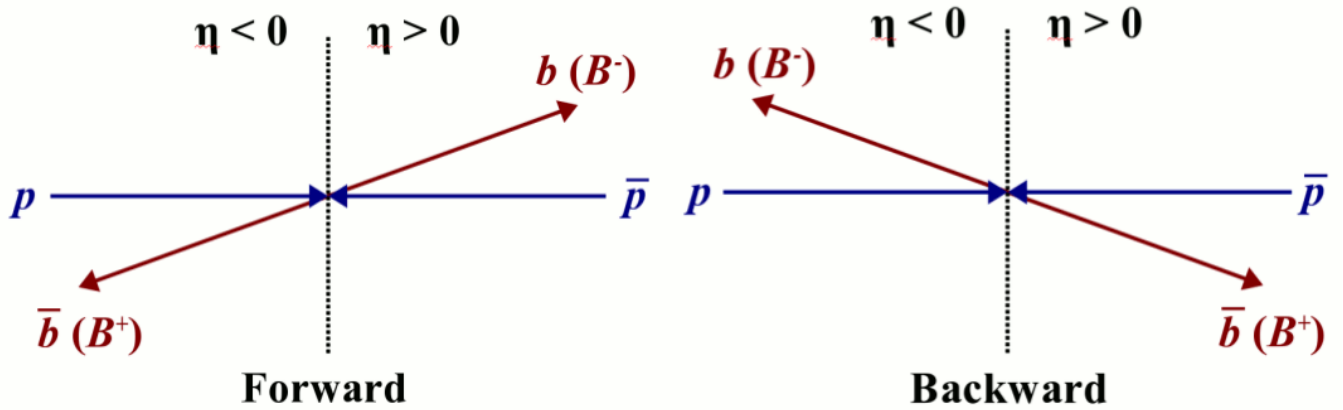
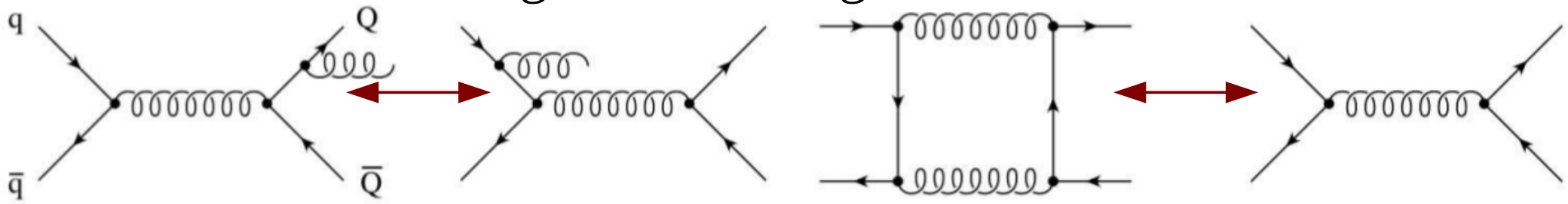
Moriond Electroweak – 17 March 2014 – Young Scientist Forum

A Few Definitions

- Tevatron DØ RunII: $p\bar{p}$ collisions at $\sqrt{s}$ = 1.96 TeV
- Forward / Backward: $q_{FB} = -q_B \, \mathrm{sign}(\eta_B) = 1$ or -1

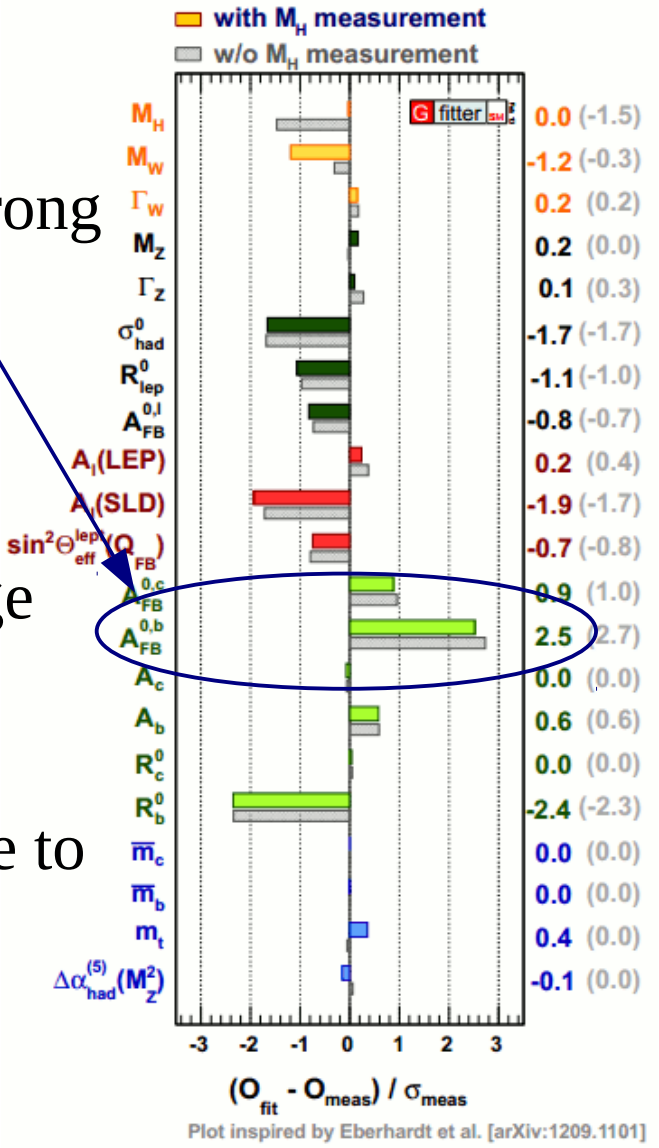


- $A_{FB} = (N_F - N_B) / (N_F + N_B)$
- This asymmetry (analagous to top quark A_{FB}) comes from interference of higher-order diagrams:



Motivation

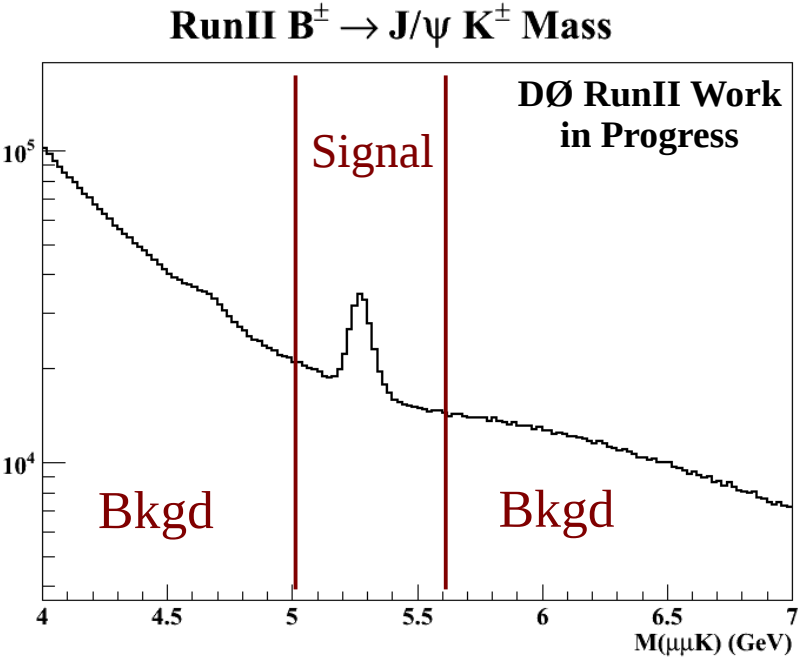
- A_{FB} of $b\bar{b}$ production is an interesting quantity:
  - EW: $Z \rightarrow b\bar{b}$ asymmetry from LEP shows a strong pull against the SM fit
  - QCD: large measured values of $t\bar{t}$ A_{FB}
- No hadron collider measurement yet for $b\bar{b}$!
  - hadronization makes finding intial quark charge difficult in a jet-based analysis
  - Fully reconstructed $B^{\pm}$ decays reduce hadronization issues and avoid ambiguities due to B^0 / $\bar{B}^0$ flavor oscillations
- DØ has many practical advantages:
  - $p\bar{p}$ initial state, reversing magnet polarities, extensive μ coverage

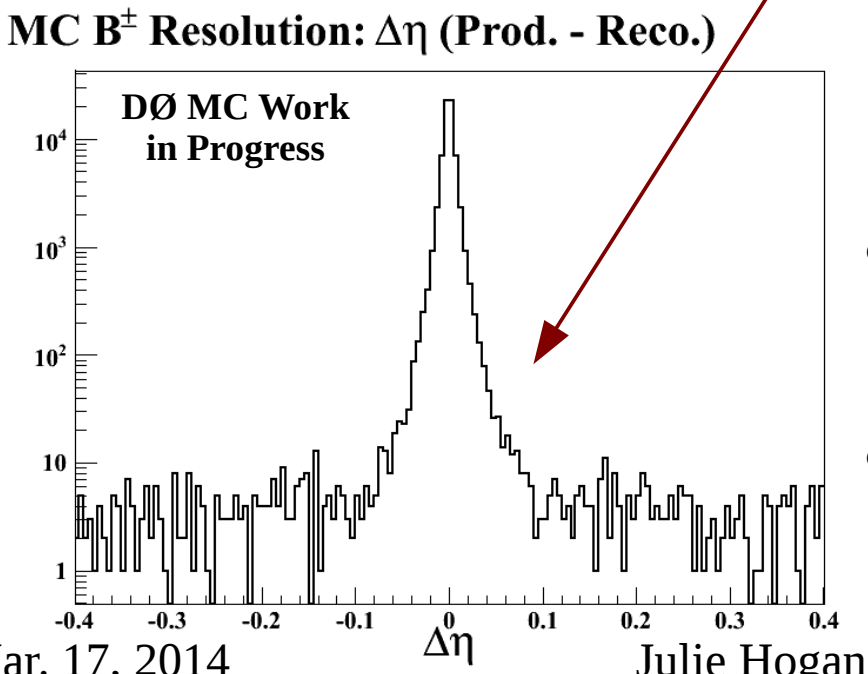


arXiv:1306.0571v2 [hep-ph]

Selection Overview

- $\mu^+\mu^-$ pair (J/ψ) + track ($K^\pm$ candidate) = $B^\pm$ candidate
- Monte Carlo: carefully weighted to simulate expected signal data
- Important region near $\eta = 0$: F/B definition is ambiguous due to detector η resolution





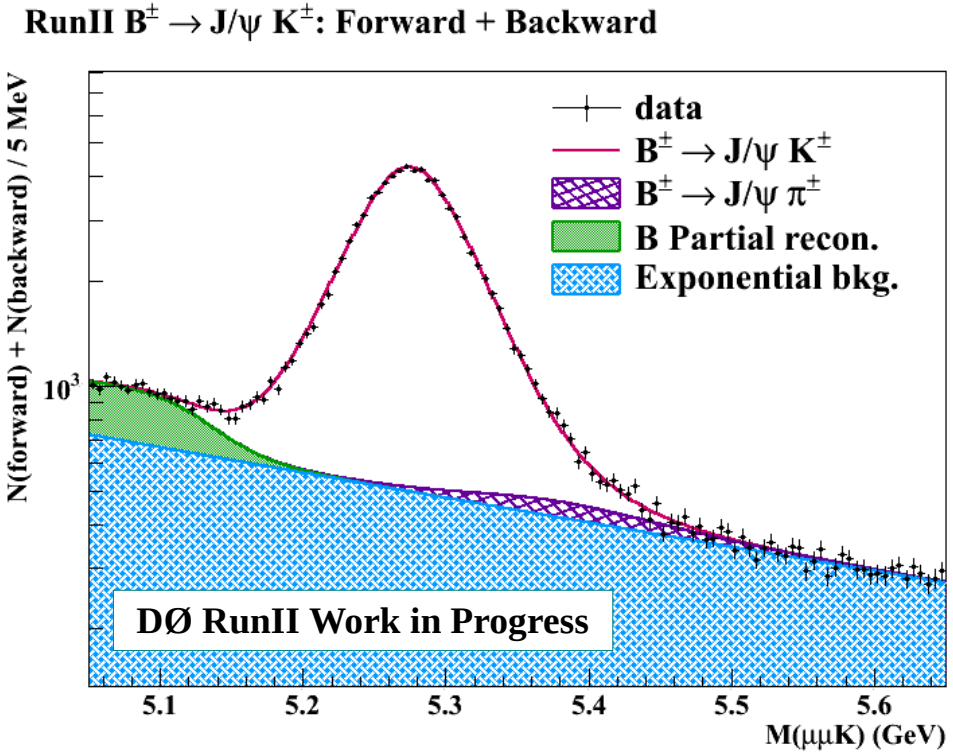
- For good F/B agreement of $b,\bar{b} \rightarrow B^\pm \rightarrow B^\pm$(reco) we reject $|\eta| < 0.1$
- BDT for background rejection, cut chosen to minimize A_{FB} uncertainty

Minimum Log-Likelihood Fit

- Events weighted to correct for reconstruction asymmetries
- 4 components with event fractions and blinded asymmetries

$$\mathrm{LLH} = -2\sum_{n=1}^{N} w_n \ln\left(\frac{1}{2}\mathcal{L}_n\right)$$

$$\mathcal{L}_n = \alpha[f_S(1+q_{FB}A_S)S + f_P(1+q_{FB}A_P)P + f_T(1+q_{FB}A_T)T] + [1-\alpha(f_S+f_P+f_T)](1+q_{FB}A_E)E$$



Signal: $B^{\pm} \to J/\psi\, K^{\pm}$ double Gaussian

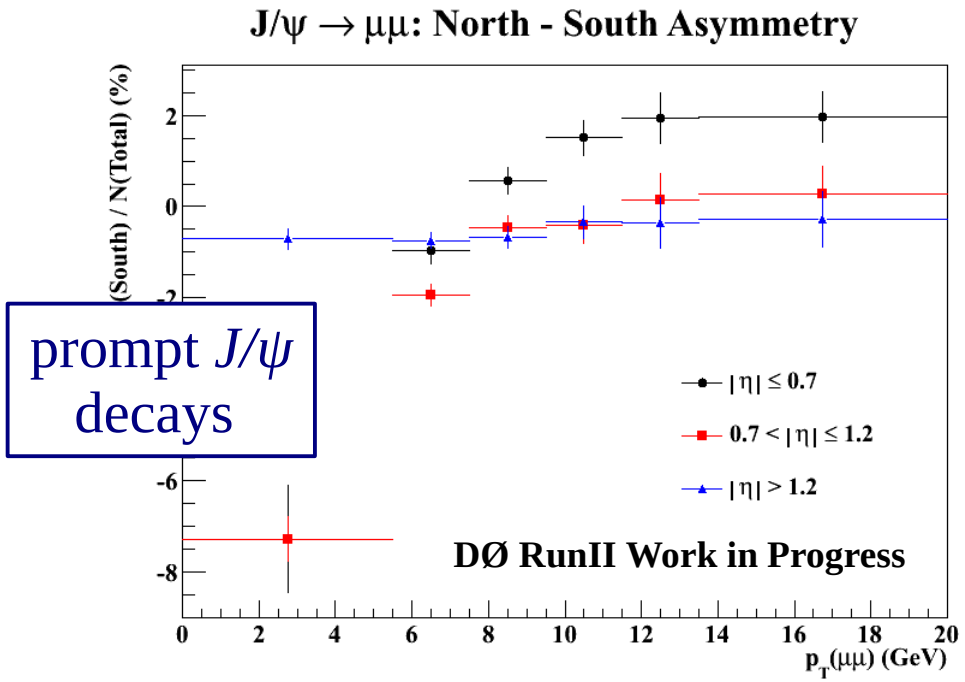
Pion: $B^{\pm} \to J/\psi\, \pi^{\pm}$ shifted double Gaussian

Threshold: partial $B^{\pm}$ reconstruction

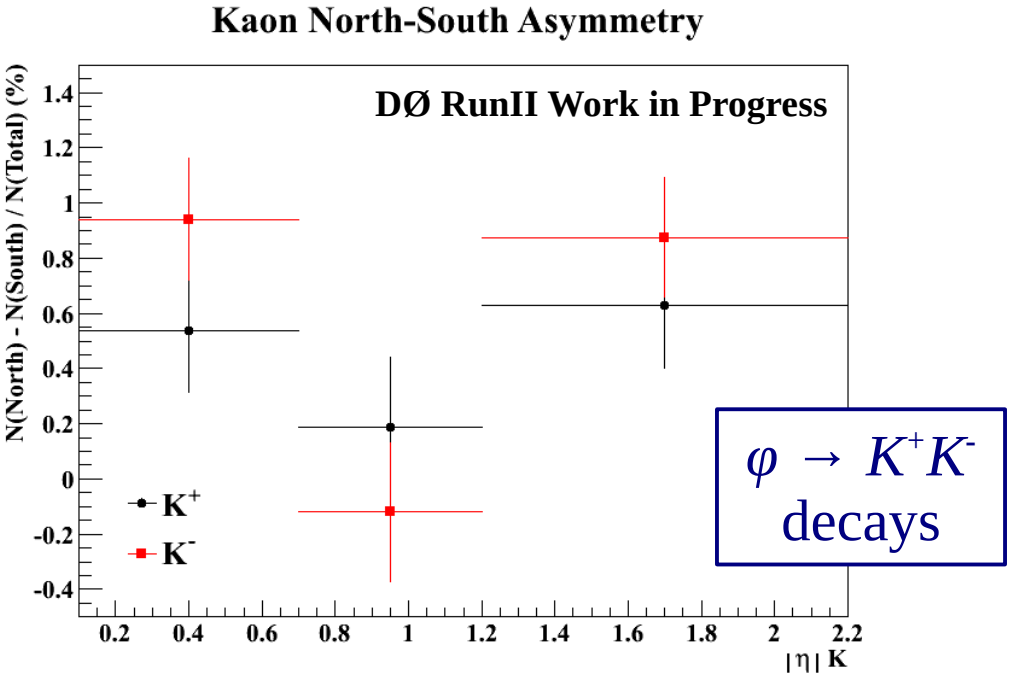
Exponential: combinatoric background

Reconstruction Asymmetries

- Reconstruction asymmetries of J/ψ or $K^{\pm}$ must be corrected
- Asymmetries between $\eta < 0$ and $\eta > 0$ used to set $\varepsilon_{\eta<0} = \varepsilon_{\eta>0}$ with a corrective weight, based on event-by-event kinematics
- Corrections confirmed with a weighted average over the kinematic bins: i.e. $A(J/\psi) = \frac{1}{N}\sum N_i(B^{\pm} \to J/\psi K^{\pm}) A_i(J/\psi)$



prompt J/ψ decays



$\varphi \to K^+K^-$ decays

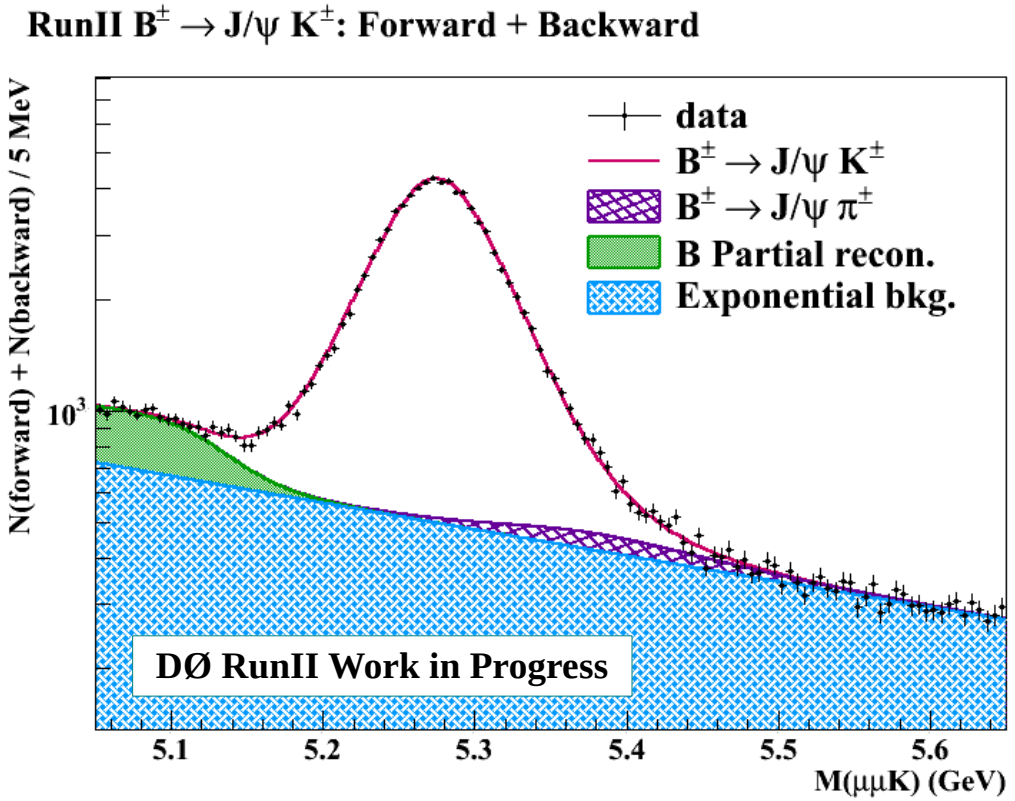
Blinded Fit Result

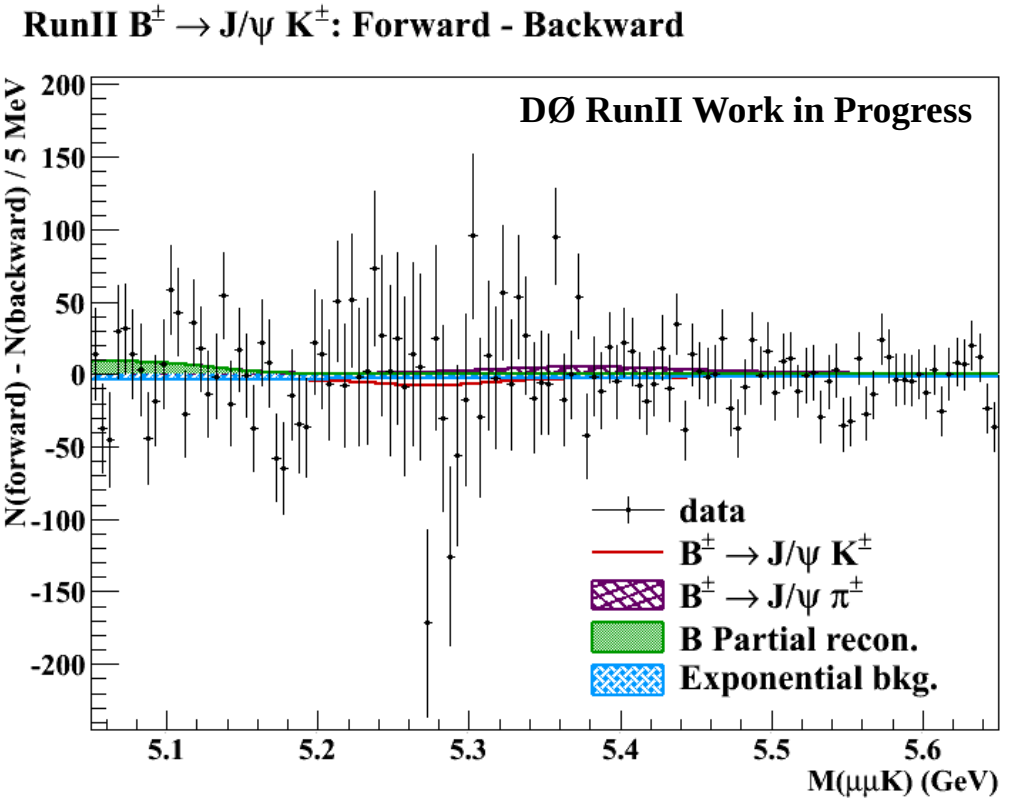
(sign of η_B randomized)

78596 $B^{\pm} \rightarrow J/\psi\, K^{\pm}$ evts: A_{FB} = [-0.137 ± **0.307(stat.)**]%

Randomized Fit → Consistent with zero

A(J/ψ, $K^{\pm}$) consistent with expectations from cross-check





Summary

- Analysis is moving through the review process toward unblinding and publication
- Reconstruction asymmetries involve new methods, receiving significant examination before unblinding
- Future steps:
  - Extend from $B^{\pm}$ to $b\bar{b}$, possibly in kinematic bins, i.e. $M(b\bar{b})$, $|\eta|$, etc.
  - Get a SM prediction for DØ from MC @ NLO
  - If applicable, interpret results in light of appropriate new physics models

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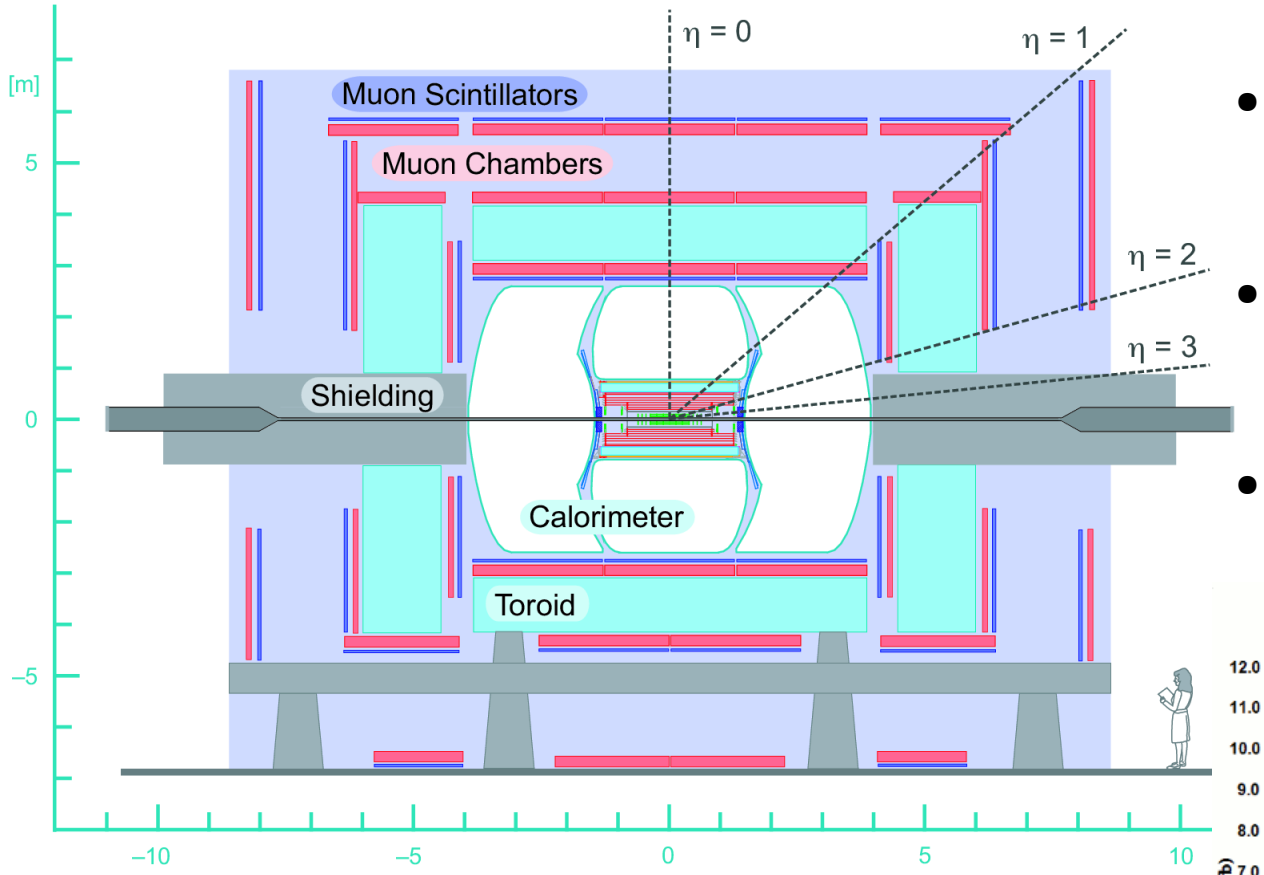
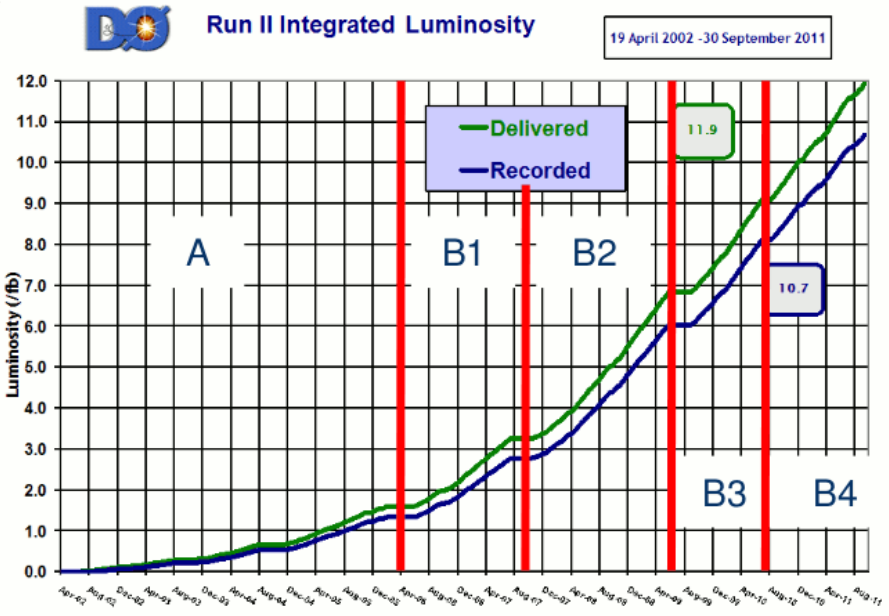
Thank you!

Backup

Dzero Detector



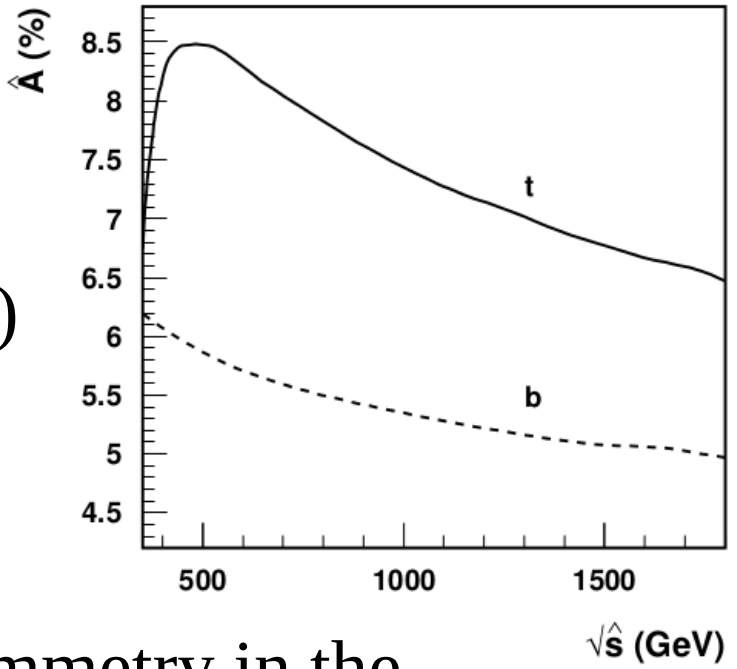
- Central tracking: silicon microstrip & fiber trackers
- Liquid argon / uranium calorimeter
- Muon tracking



- Regular reversal of solenoid & toroid polarities
- RunII → 10.4 fb^{-1} recorded

Theoretical Sources

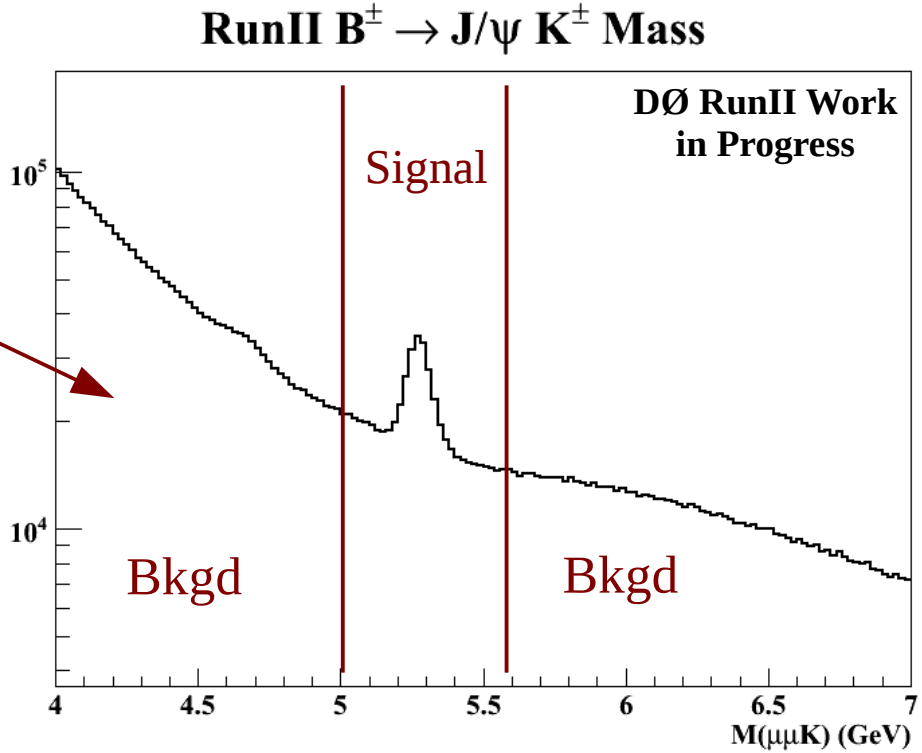
- Forward-Backward Asymmetry of Hadroproduced Heavy Quarks in QCD (Phys.Lett.B 195, 1987)
  - Suggests exploiting $B^{\pm} \rightarrow J/\psi\, K^{\pm}$



- Charge Asymmetry of Heavy Quarks at Hadron Colliders, (Phys.Rev.D 59,1999)
  - Angular-integrated asymmetry at Tevatron energies of ~4-5%
- Bottom Quark Forward-Backward Asymmetry in the Standard Model and Beyond (PRL 111, 2013)
  - NLO prediction based on CDF detector settings and a jet based analysis. Inclusive $A_{FB} = (0.48 \pm 0.12)\%$

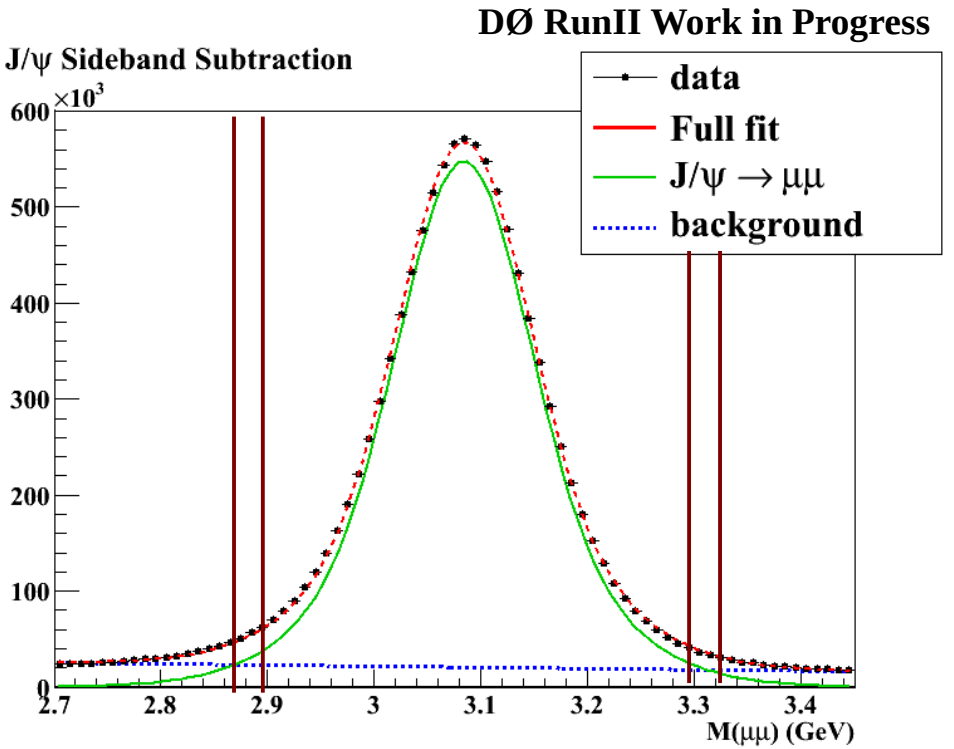
Event Selection

- Full RunII data – 10.4 fb^{-1}
- $\mu^+\mu^-$ pair (J/ψ) + track ($K^\pm$ candidate) = $B^\pm$ candidate
- General selection criteria:
  - 2.7 GeV < J/ψ mass < 3.45 GeV
  - 4.0 GeV < $B^\pm$ mass < 7.0 GeV
  - μ's: p_T > 1.5 GeV; $|\eta|$ < 2.1
  - $K^\pm$: p_T > 0.7 GeV
    2+ SMT and 2+ CFT hits
  - J/ψ: 2D Pointing Angle > 0
  - $B^\pm$: p_T < 20 GeV; decay length significance > 3
    vertex χ^2 < 16; 2D Pointing Angle > 0.8



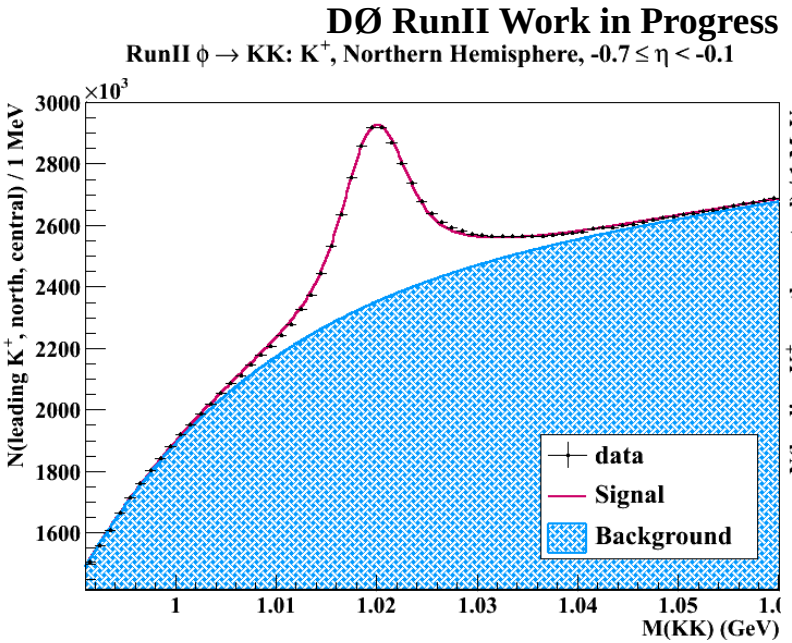
Reconstruction Asymmetries

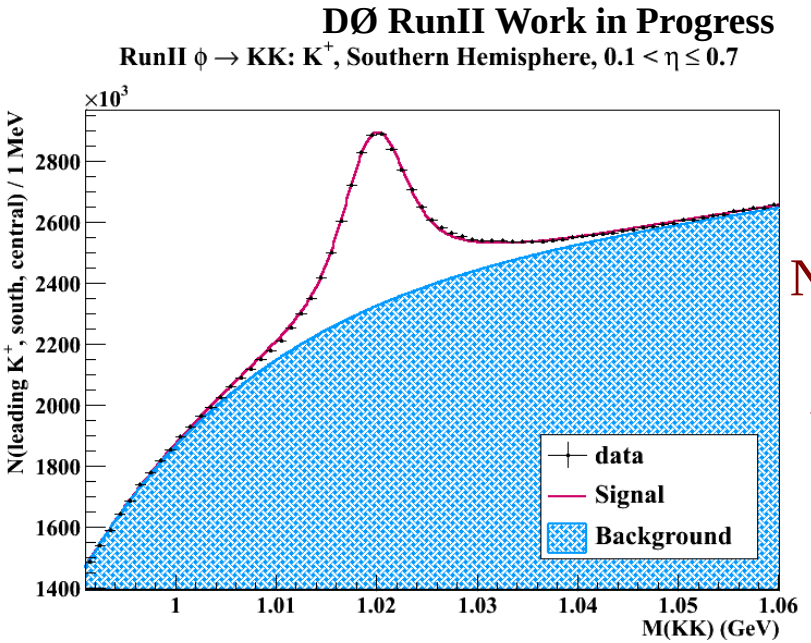
- Asymmetries between $\eta < 0$ and $\eta > 0$ calculated on separate samples in bins of $|\eta|$ and/or p_T
- J/ψ: prompt particles
  - identical selection with requirement of low decay length significance
  - Est. 2% $B^{\pm}$ fraction
- Sideband sub. of bkgd:
  - Peak 2.9 GeV – 3.3 GeV



Reconstruction Asymmetries

- Kaons: sample of $\varphi \rightarrow K^+K^-$ decays with selection to reproduce kinematics of kaons in $B^{\pm} \rightarrow J/\psi\, K^{\pm}$
- Binned by charge and $|\eta|$ of leading kaon
- Simultaneous fits to North & South side data to calculate A_{NS} for each bin:





K^+, central $|\eta|$

NSig = (1.3 ± 0.004)e7

A_{NS} = (0.54 ± 0.22)%

Blinded B^+ / B^- Fit Results

(sign of η_B randomized)

B^+ Fit → 39241 Signal
$A_{FB} = (0.142 \pm 0.431)\%$

B^- Fit → 39319 Signal
$A_{FB} = (-0.419 \pm 0.433)\%$

Randomized Fits → consistent with zero
Averaged A_{FB} → consistent with full fit
Averaged $A(J/\psi, K^{\pm})$ correction → consistent with full fit