Tevatron Results on $B_s \to \mu\mu$, $B_s \to K^*\mu\mu$

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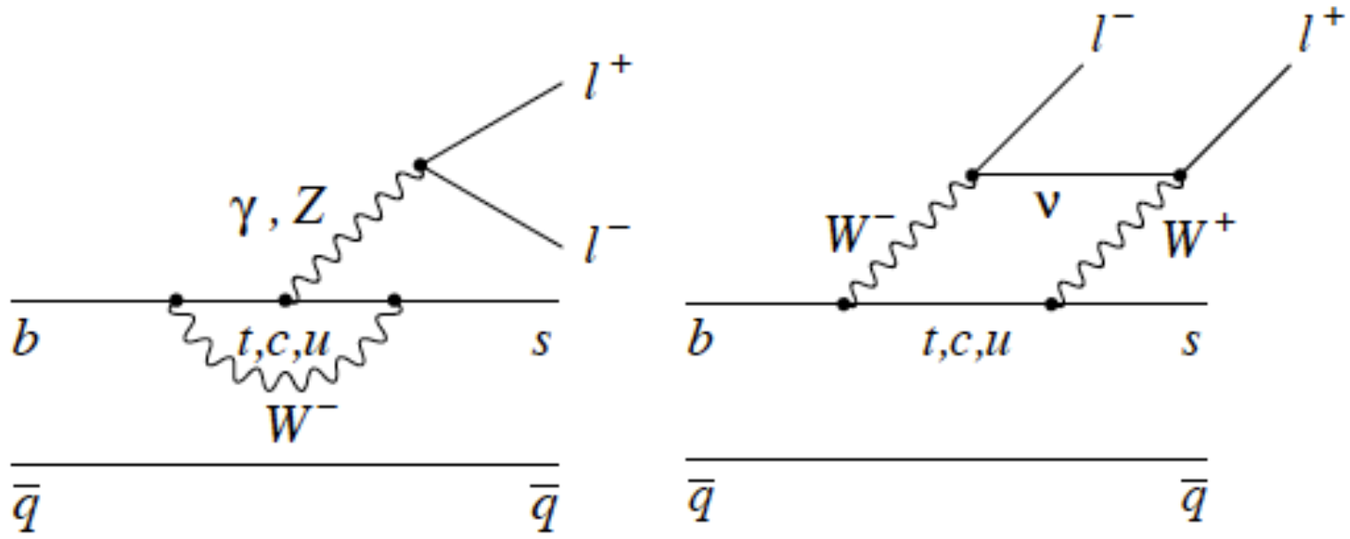
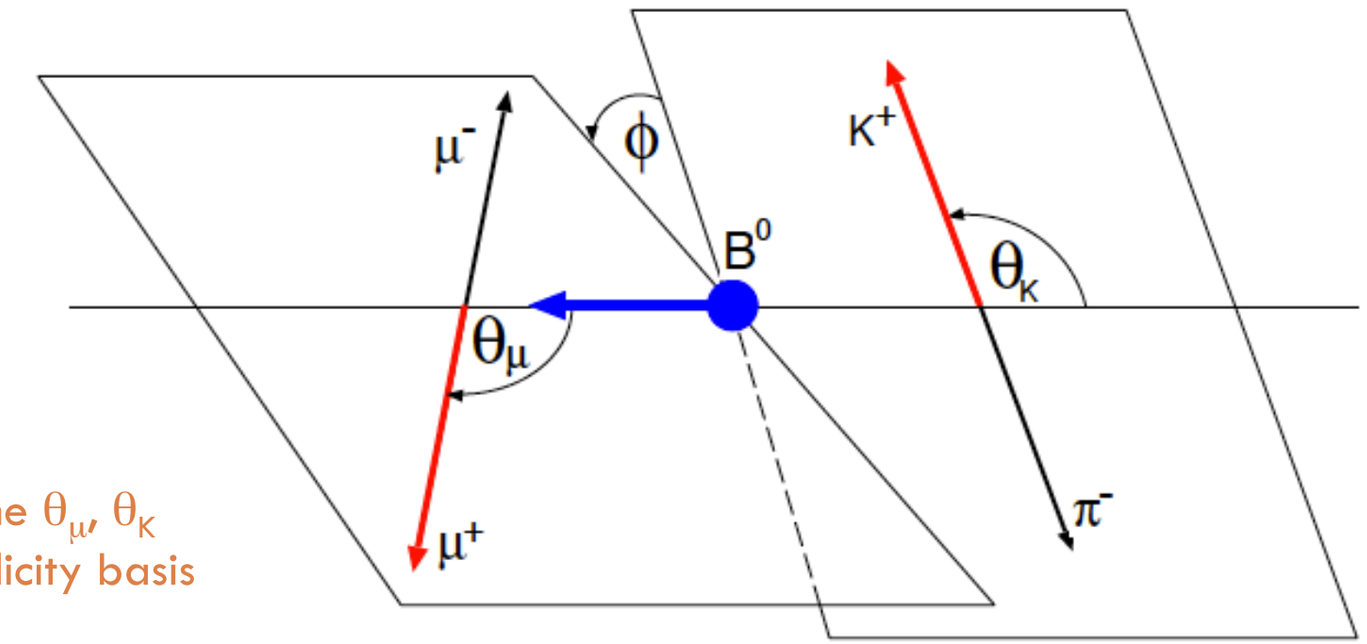
CKM 2010 9th September 2010

$B^0 \rightarrow K^{*0}(K^+\pi^-)\mu\mu$

- Non-resonant decays via box or penguin process
- BR($B^0 \rightarrow K^{*0}\mu\mu$) ~$10^{-6}$
- Physics beyond the SM
  - ➡ Possible increase in BR
  - ➡ Modify the decay kinematics
- Measure: BR, A_{FB}, K^* Longitudinal Polarisation





Define θ_μ, θ_K in helicity basis

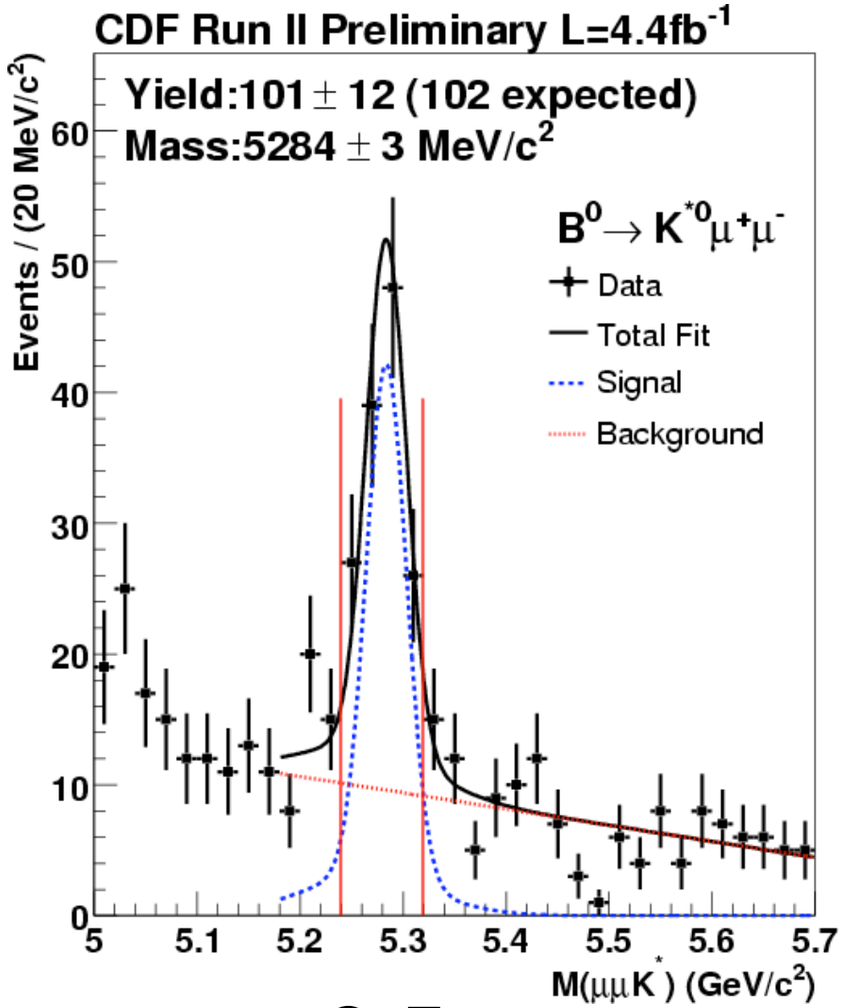
$$A_{\mathrm{FB}}(q^2) = \frac{\Gamma\left(q^2, \cos\theta_\mu > 0\right) - \Gamma\left(q^2, \cos\theta_\mu < 0\right)}{\Gamma\left(q^2, \cos\theta_\mu > 0\right) + \Gamma\left(q^2, \cos\theta_\mu < 0\right)}$$

CDF Latest Result

- CDF Note 10047 4.4fb^{-1}
- Optimized over previous published result (PRD 79:011104, 2009)
- Improved Particle ID
  - ➡ Muon: Likelihood ID - cleaner dimuon candidates
  - ➡ Kaon, pion: combined log likelihood from ToF and dE/dx reducing combinatorial background
- Makes use of neural networks for B signal selection

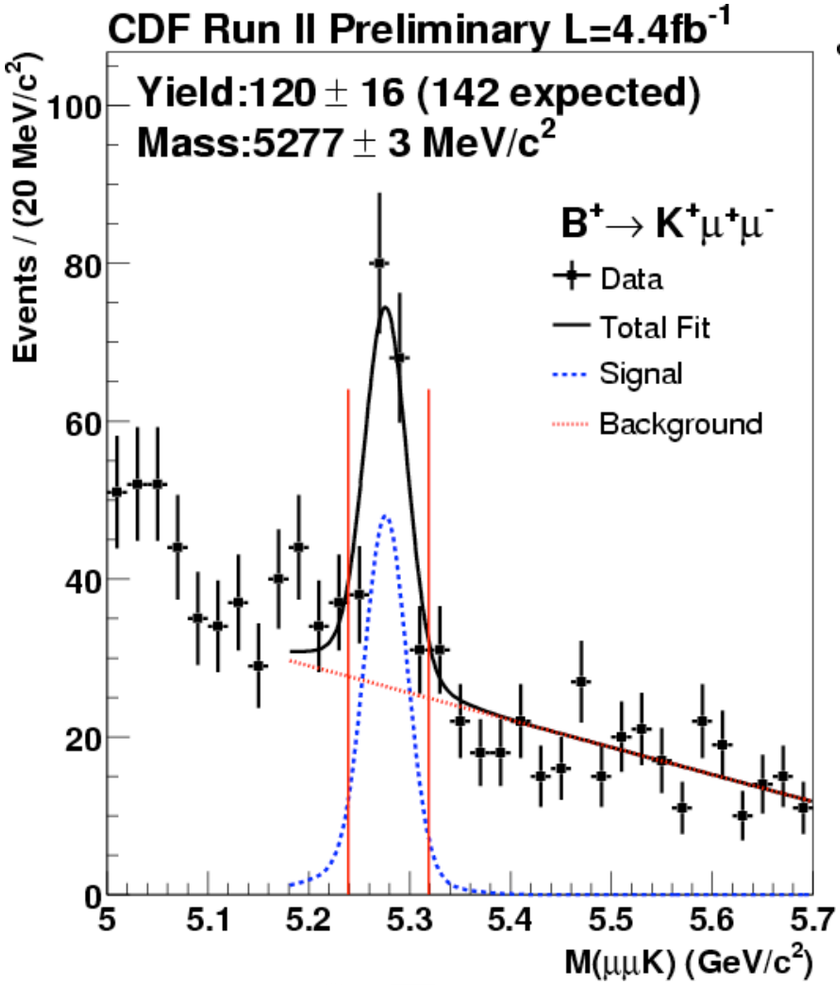
Observation of Decays

$B^+ \to K^+\mu^+\mu^-$



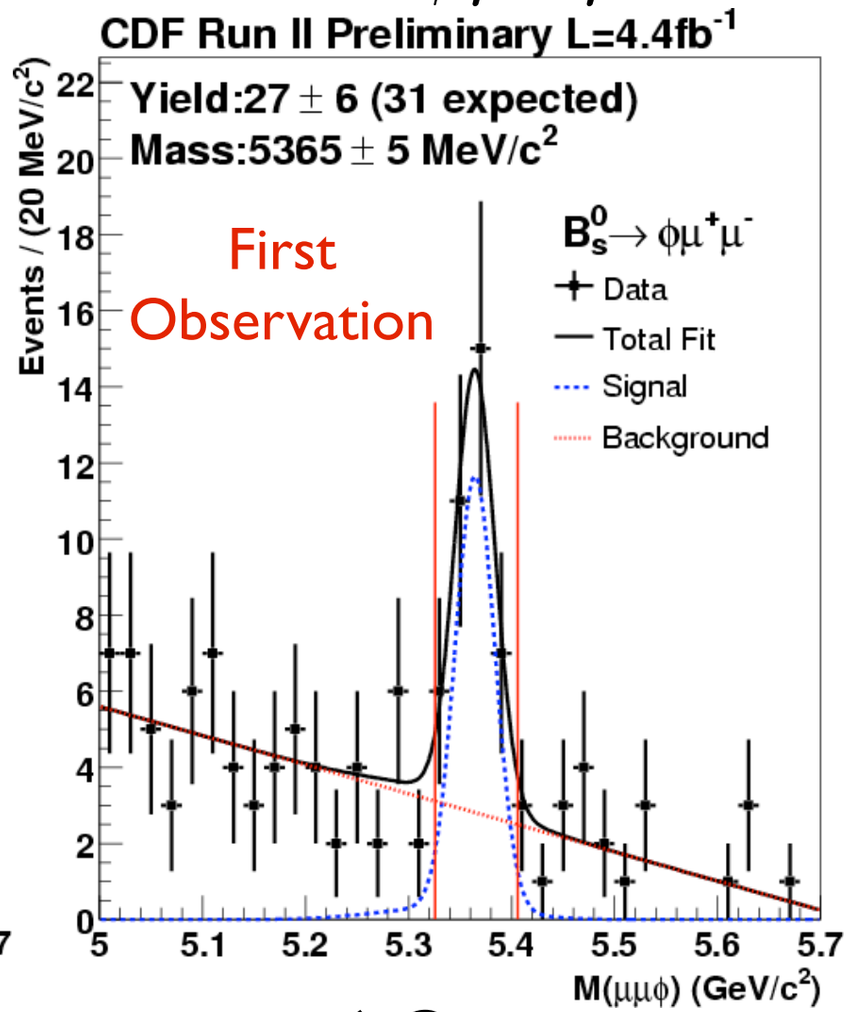
8.5σ

$B^0 \to K^{*0}\mu^+\mu^-$



9.7σ

$B^0 \to \phi\mu^+\mu^-$

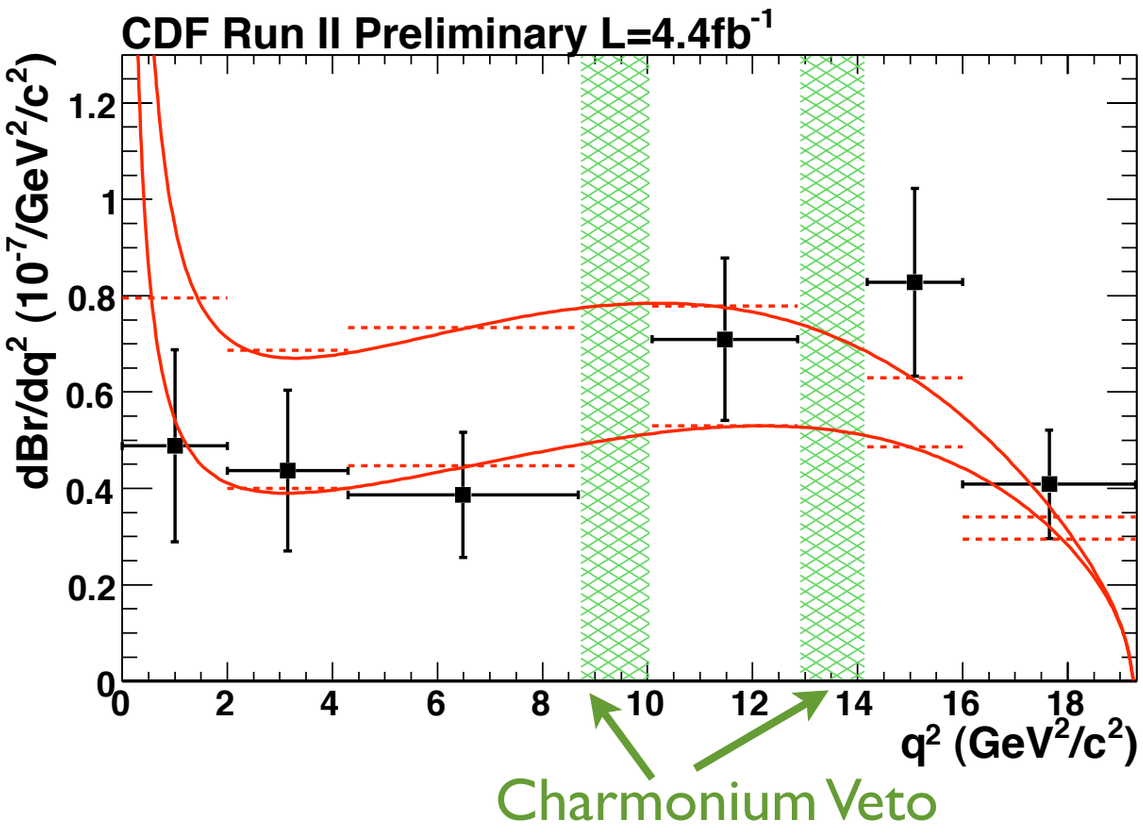


6.3σ

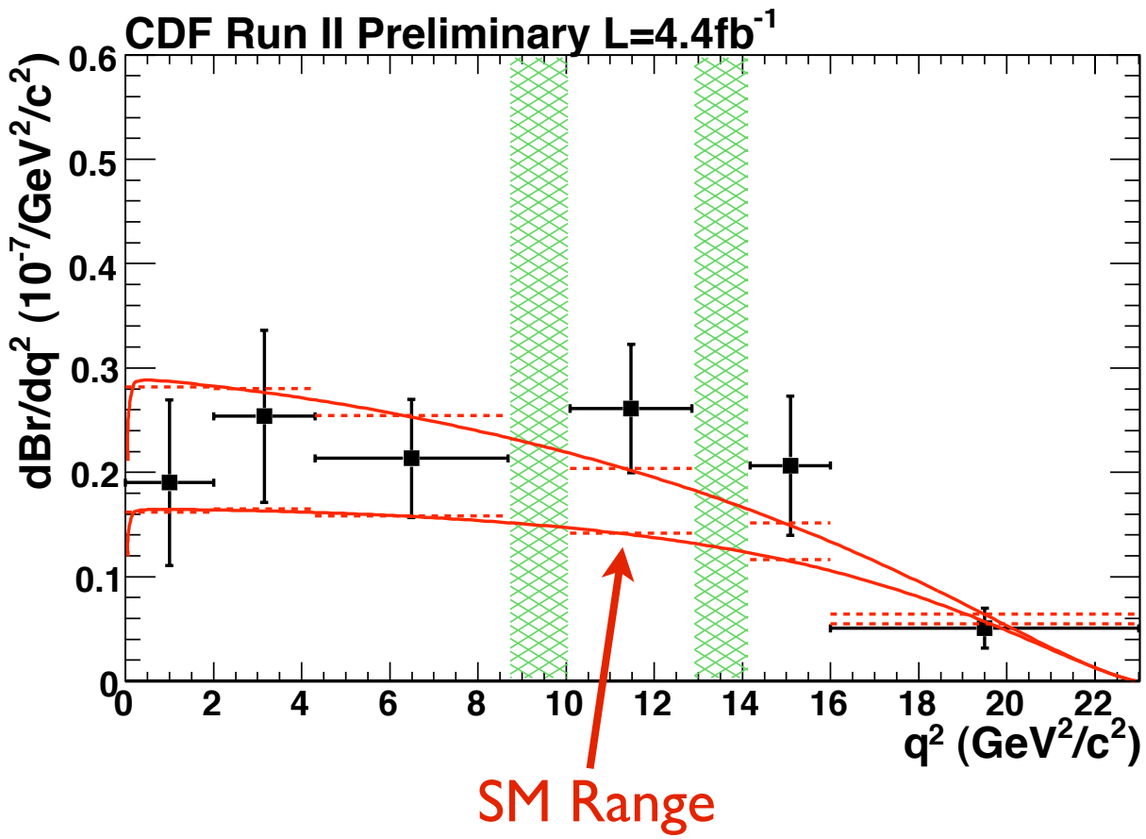
Branching Ratios (XX± stat ± syst) x 10^{-6}		
0.38±0.05±0.03	1.06±0.14±0.09	1.44±0.33±0.56

Differential Branching Fraction

$$B^0 \to K^{*0}\mu^+\mu^-$$



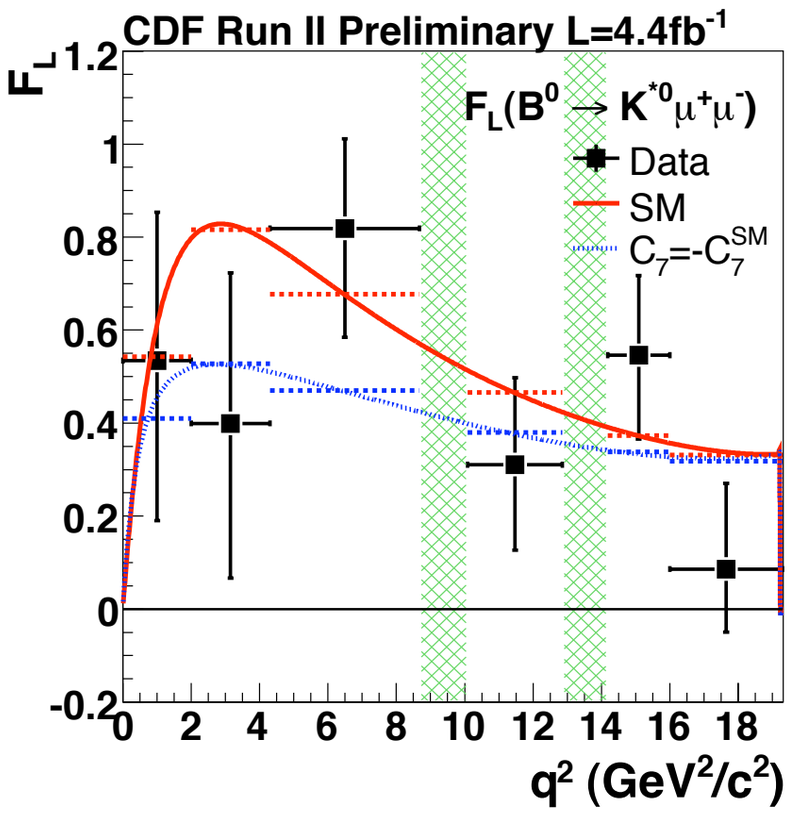
$$B^+ \to K^+\mu^+\mu^-$$

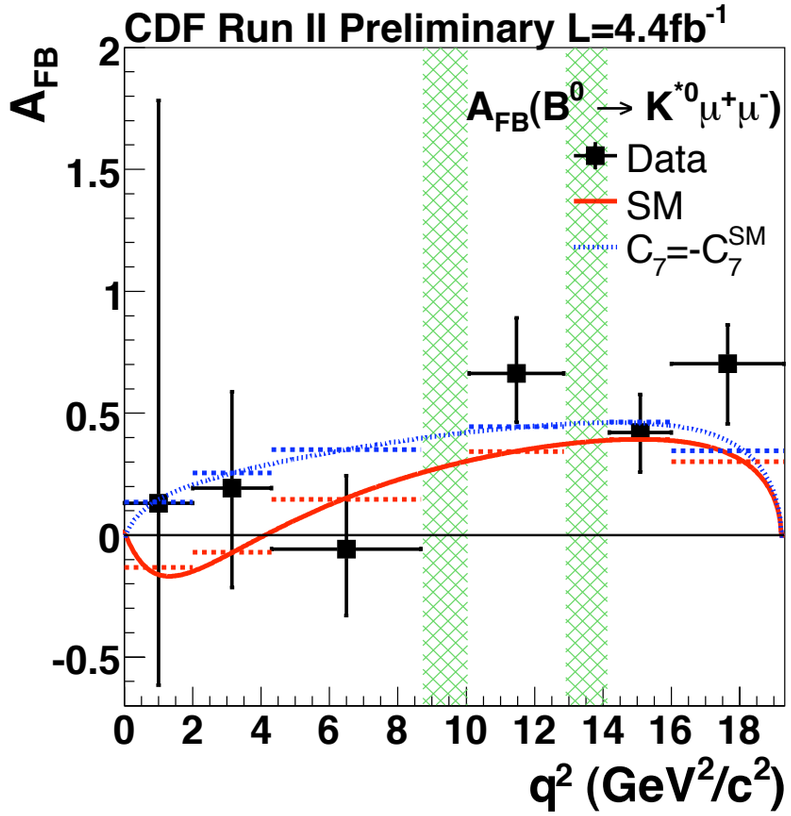


- $q^2 = m^2(\mu\mu)c^2$

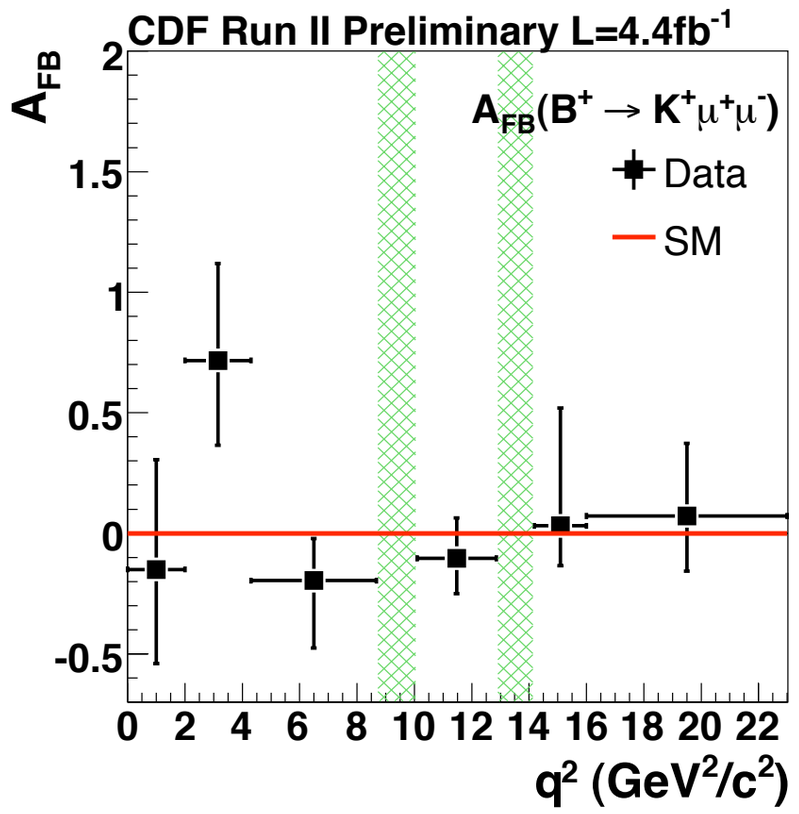
F_L and A_{FB} measurements

$B^0 \to K^{*0}\mu^+\mu^-$





$B^+ \to K^+\mu^+\mu^-$



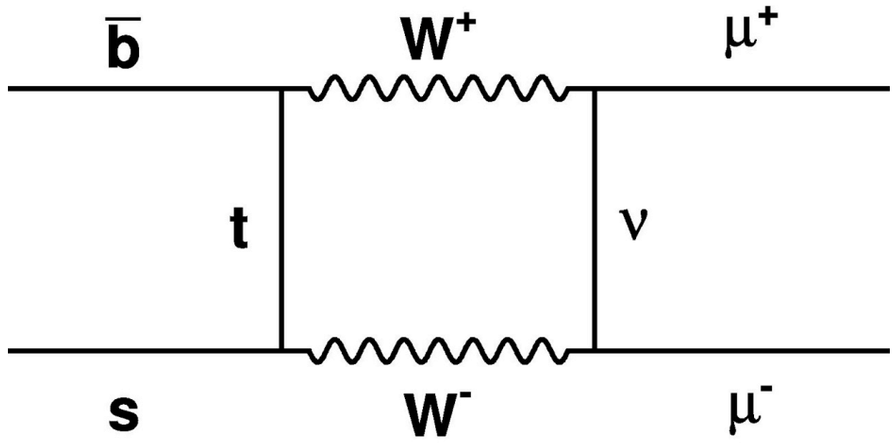
$$P_s(\cos\theta_K) \propto \frac{3}{2} F_L \cos^2\theta_K + \frac{3}{4}(1 - F_L)(1 - \cos^2\theta_K)$$

For B^+, set $F_L = 1$

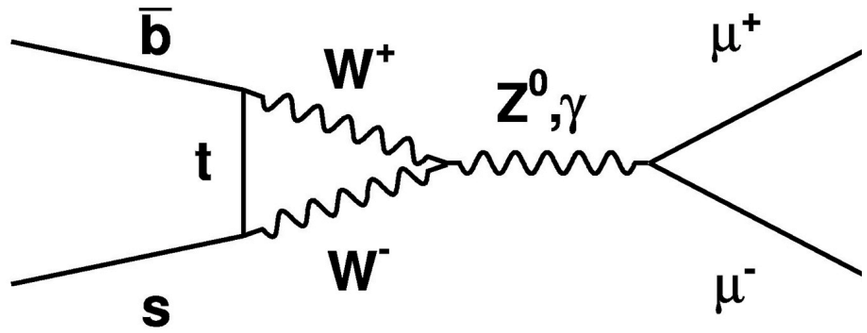
$$P_s(\cos\theta_\mu) \propto \frac{3}{4} F_L (1 - \cos^2\theta_\mu) + \frac{3}{8}(1 - F_L)(1 + \cos^2\theta_\mu) + A_{FB}\cos\theta_\mu$$

$B_S \rightarrow \mu\mu$

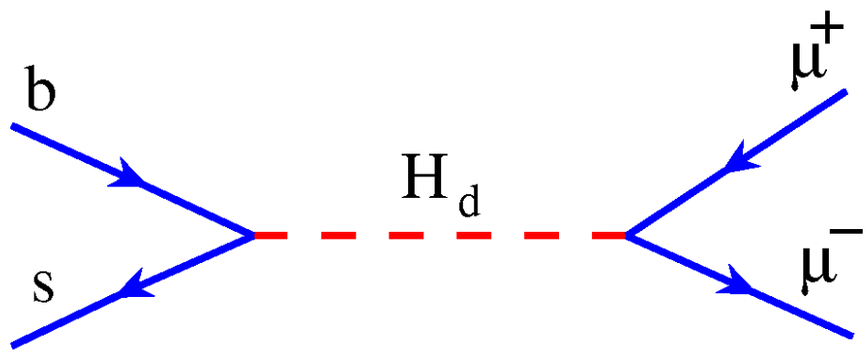
- Current SM Prediction:
  Buras: hep-ph/0904.4917
  - ➡ $BR(B_s \rightarrow \mu\mu) = (3.6 \pm 0.3) \times 10^{-9}$
  - ➡ $BR(B_d \rightarrow \mu\mu) = (1.1 \pm 0.1) \times 10^{-10}$



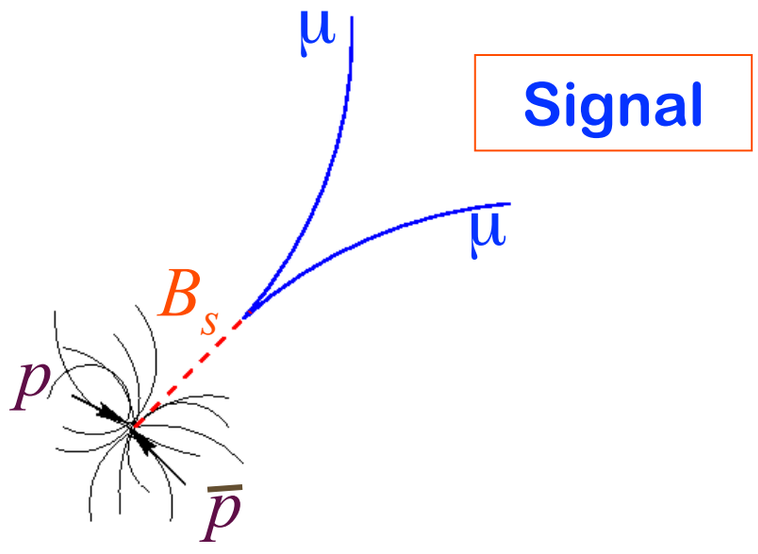
- Can be enhanced by the presence of non-SM physics
  - ➡ MSSM ($BR \propto \tan^6\beta$)
  - ➡ GUT SO(10)
  - ➡ SUSY R-parity violating models
  - ➡ Flavour Violating models



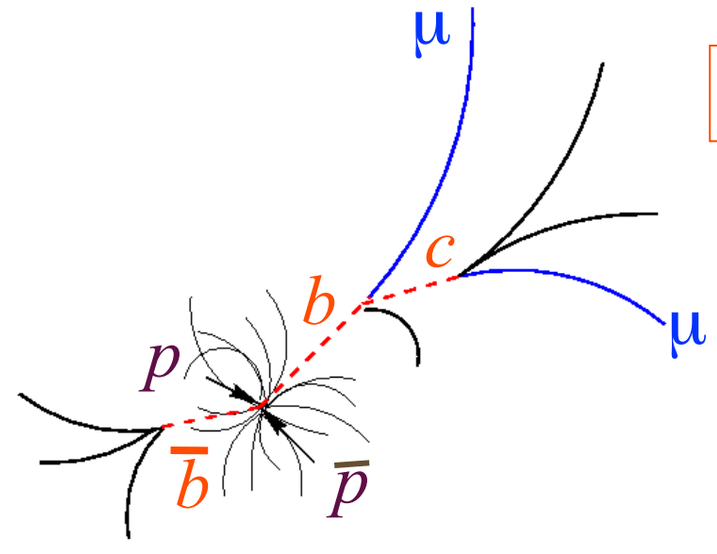
- SM signal beyond detectors sensitivity.



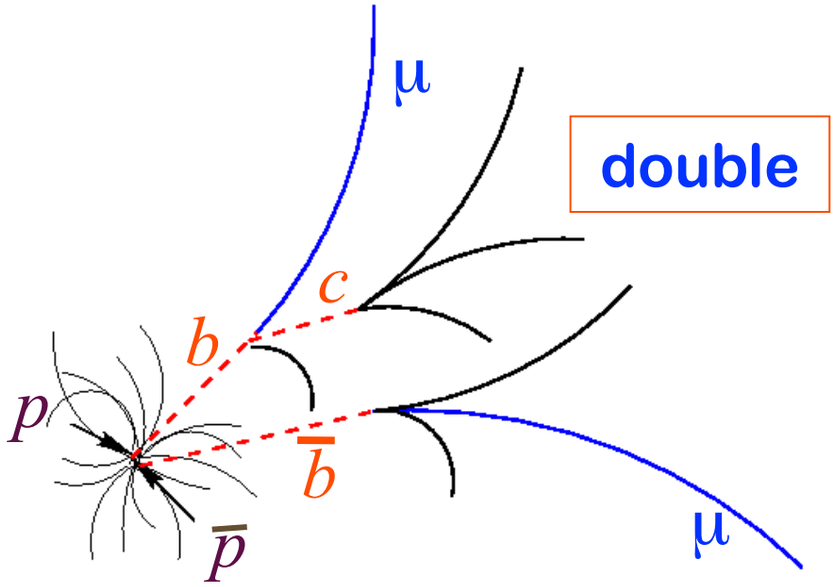
Signal & Background



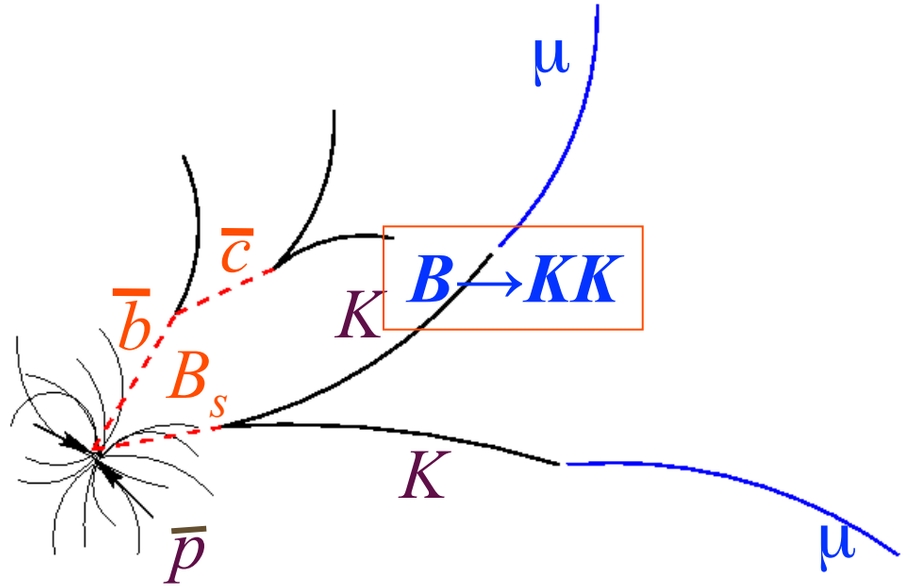
Signal



sequential



double



Outline of Measurement

$$\mathcal{B}\left(B_s^0 \to \mu^+\mu^-\right) = \frac{N(B_s^0)}{N(B^+)} \cdot \frac{\epsilon_{B^+}}{\epsilon_{B_s}} \cdot \frac{f_u}{f_s} \cdot \mathcal{B}(B^+)$$

1. Measure number of possible signal events in B_s mass window

Outline of Measurement

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1. Measure number of possible signal events in B_s mass window
2. Normalise to number of $B^+ \to J/\psi K^+$ events

Outline of Measurement

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1. Measure number of possible signal events in B_s mass window
2. Normalise to number of $B^+ \to J/\psi K^+$ events
3. Correct for relative reconstruction efficiencies

Outline of Measurement

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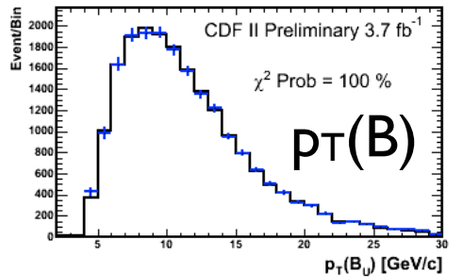
1. Measure number of possible signal events in B_s mass window
2. Normalise to number of $B^+ \to J/\psi K^+$ events
3. Correct for relative reconstruction efficiencies
4. Correct for Fragmentation Functions and Branching ratio.
   Particle Data Group (W.M. Yao et al.). 2006.
   Both CDF and D0 use the LEP numbers.

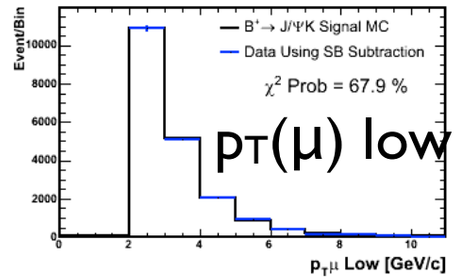
   f_u/f_s is the dominant source of systematic uncertainties at 15%

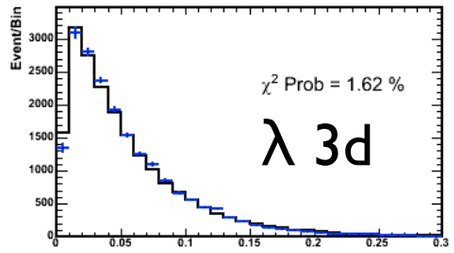
CDF's Most Recent Result

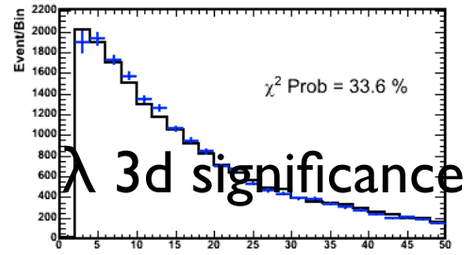
- <u>CDF Note 9892</u>
- Based on published analysis
- More Data
  - ➡ Added 1.7fb^{-1}
  - ➡ Additional tracking acceptance - gain of 12%
- Background is modelled using sideband regions in mass
- MC is compared with $B^+ \rightarrow J/\psi K^+$ data.

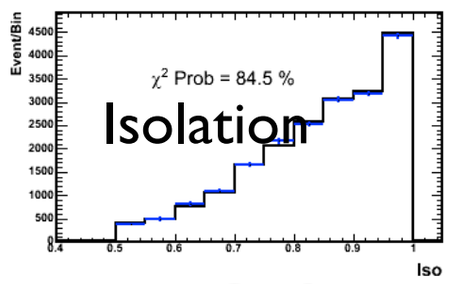
$B^+ \rightarrow J/\psi K^+$ Variables

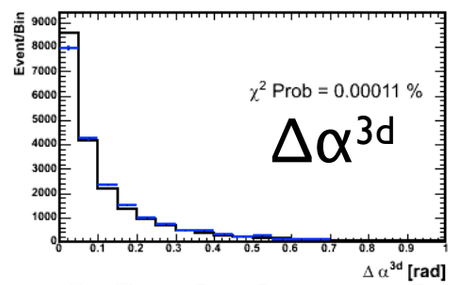




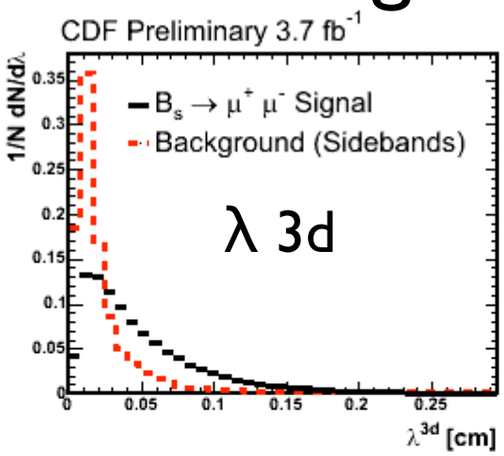


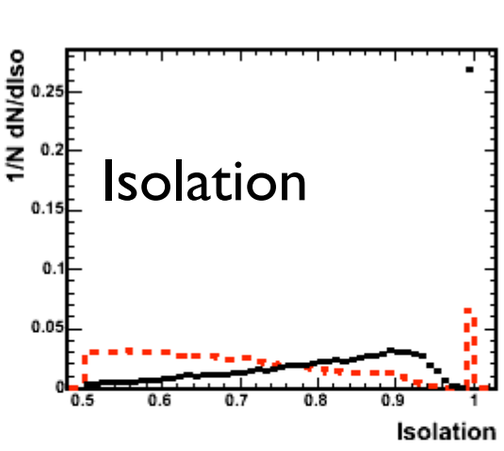






MC Signal cf Sidebands





CDF's Most Recent Result

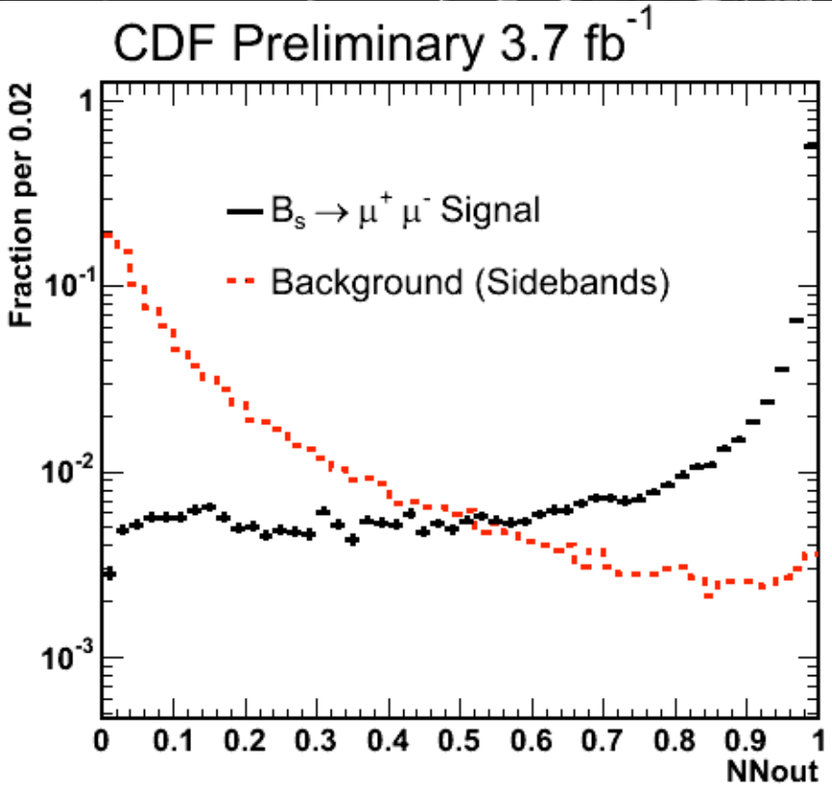
95% CL

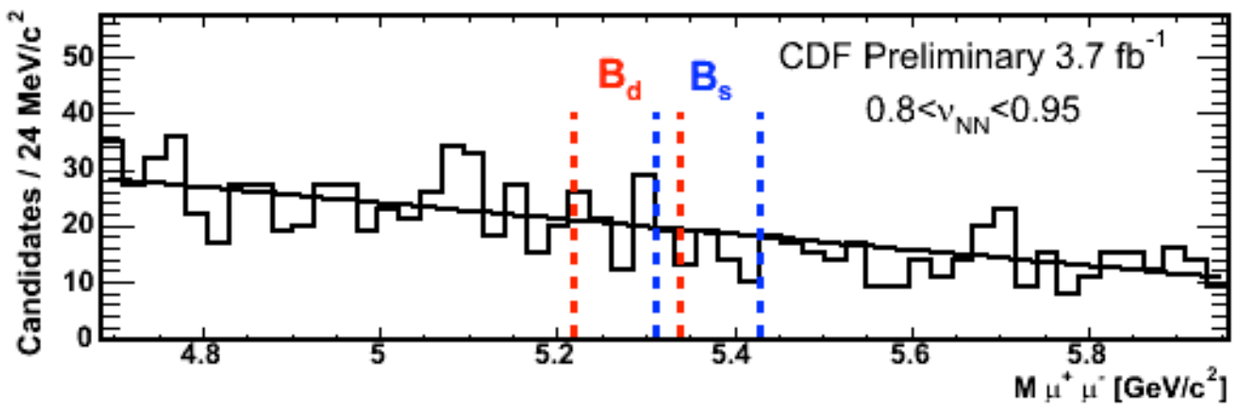
$\mathcal{B}(B^0) < 7.6 \times 10^{-9}$

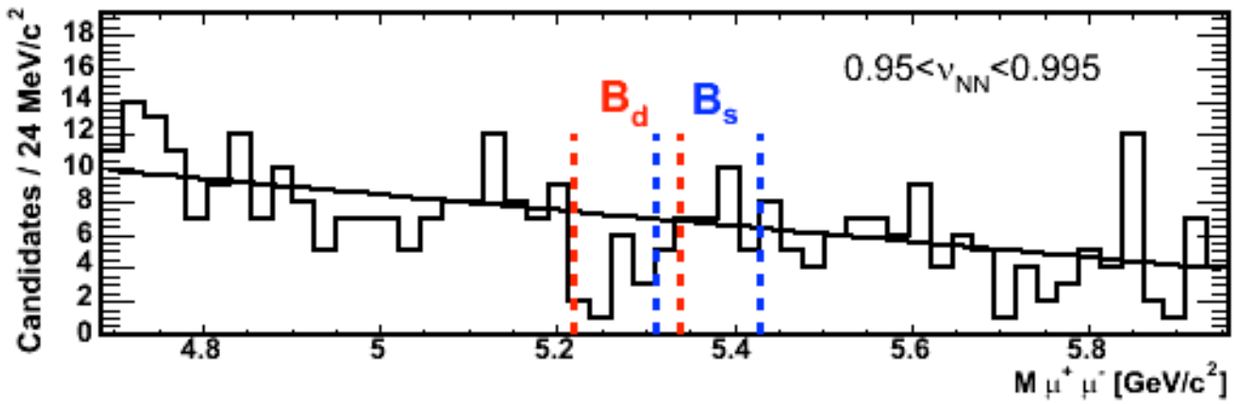
$(9.9 \times 10^{-9}$ expected)

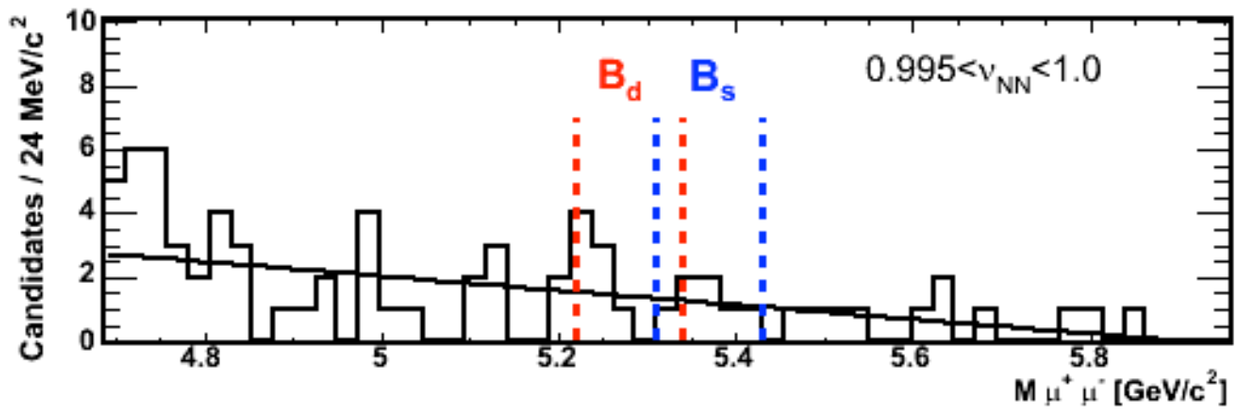
$\mathcal{B}(B_s) < 43 \times 10^{-9}$

$(33 \times 10^{-9}$ expected)









D0's Latest Result (Summer 2010)

- arXiv:1006.3469v1 [hep-ex]
  submitted to Phys. Lett. B
- 6.1fb^{-1} data (split into Run 2a 1.3fb^{-1} and Run 2b 4.8fb^{-1})
- Many improvements

➡ Acceptance Gain (Muons ~10%, Trigger ~16%)

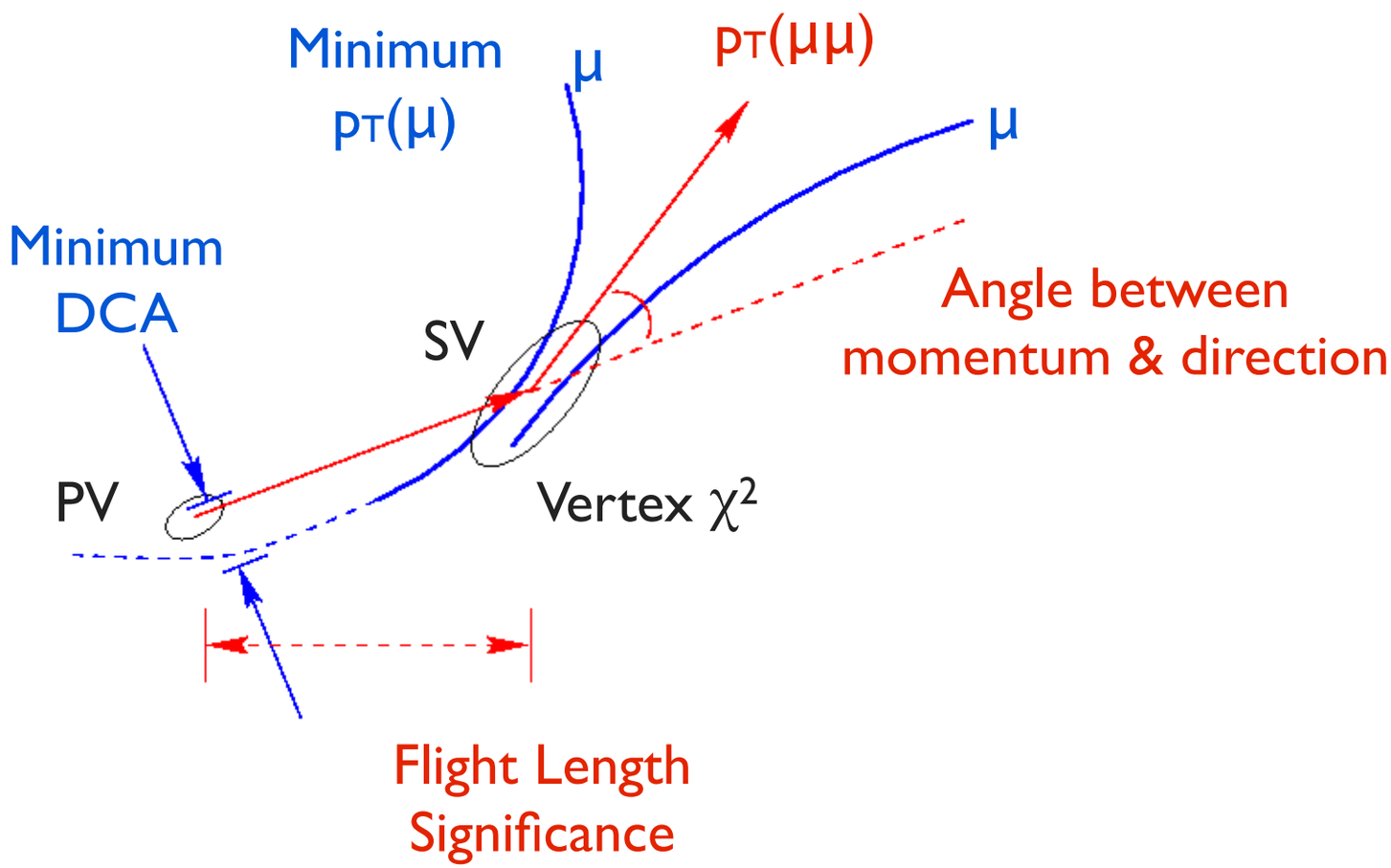
➡ Bayesian Neural Networks

➡ Improved understanding of discriminating variables

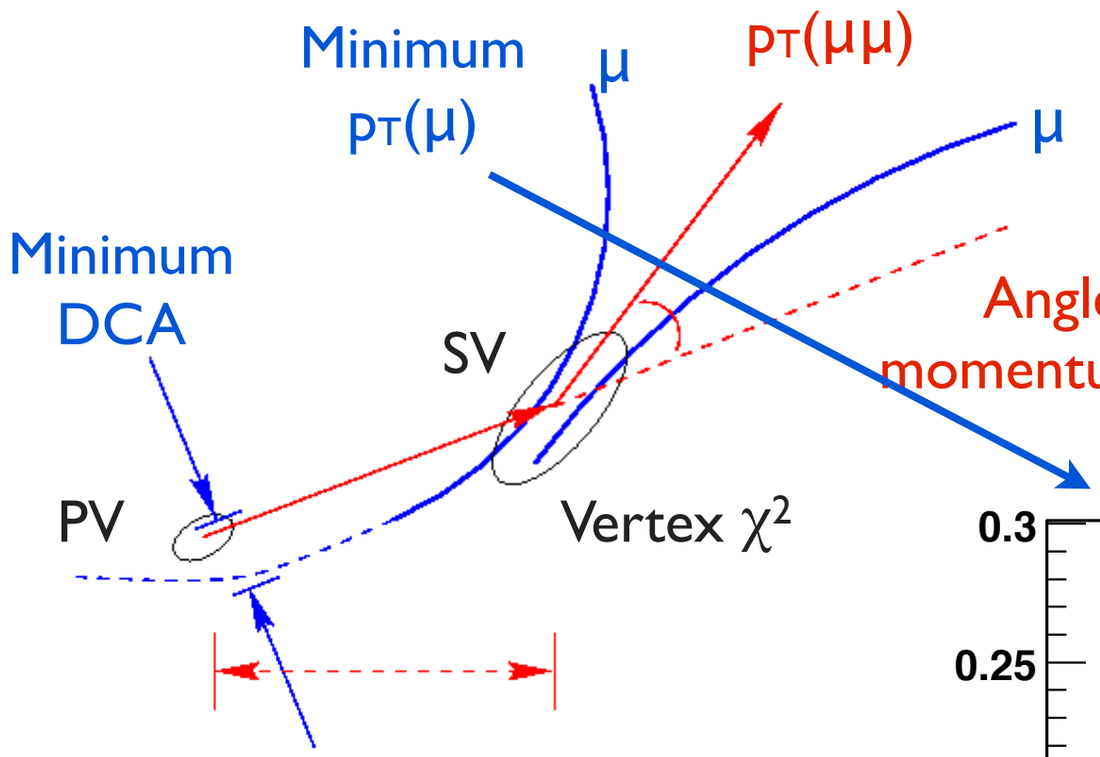
➡ Improved MC and Data modelling

➡ 2D fit of BNN output and mass spectrum

Background Reduction

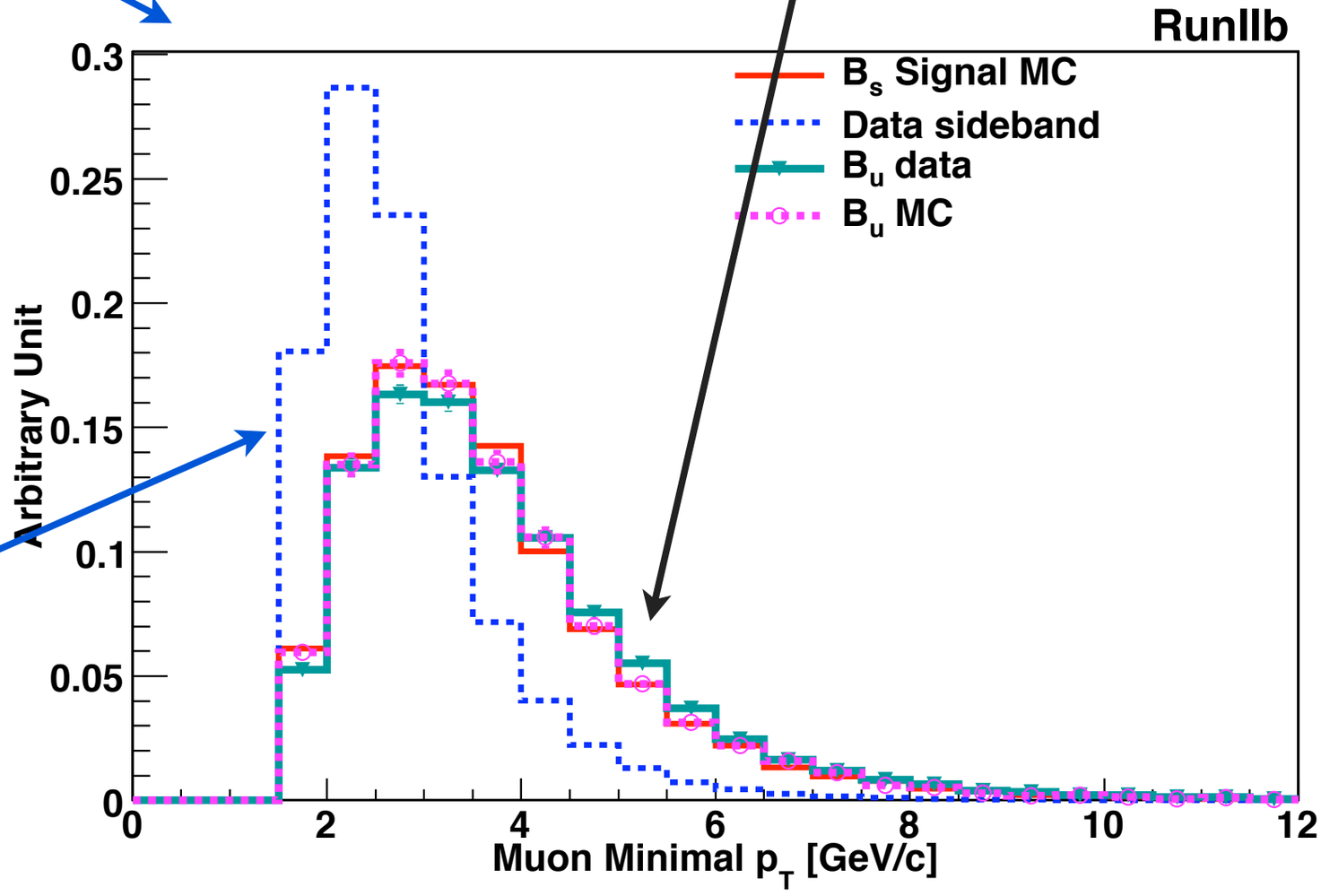


Background Reduction



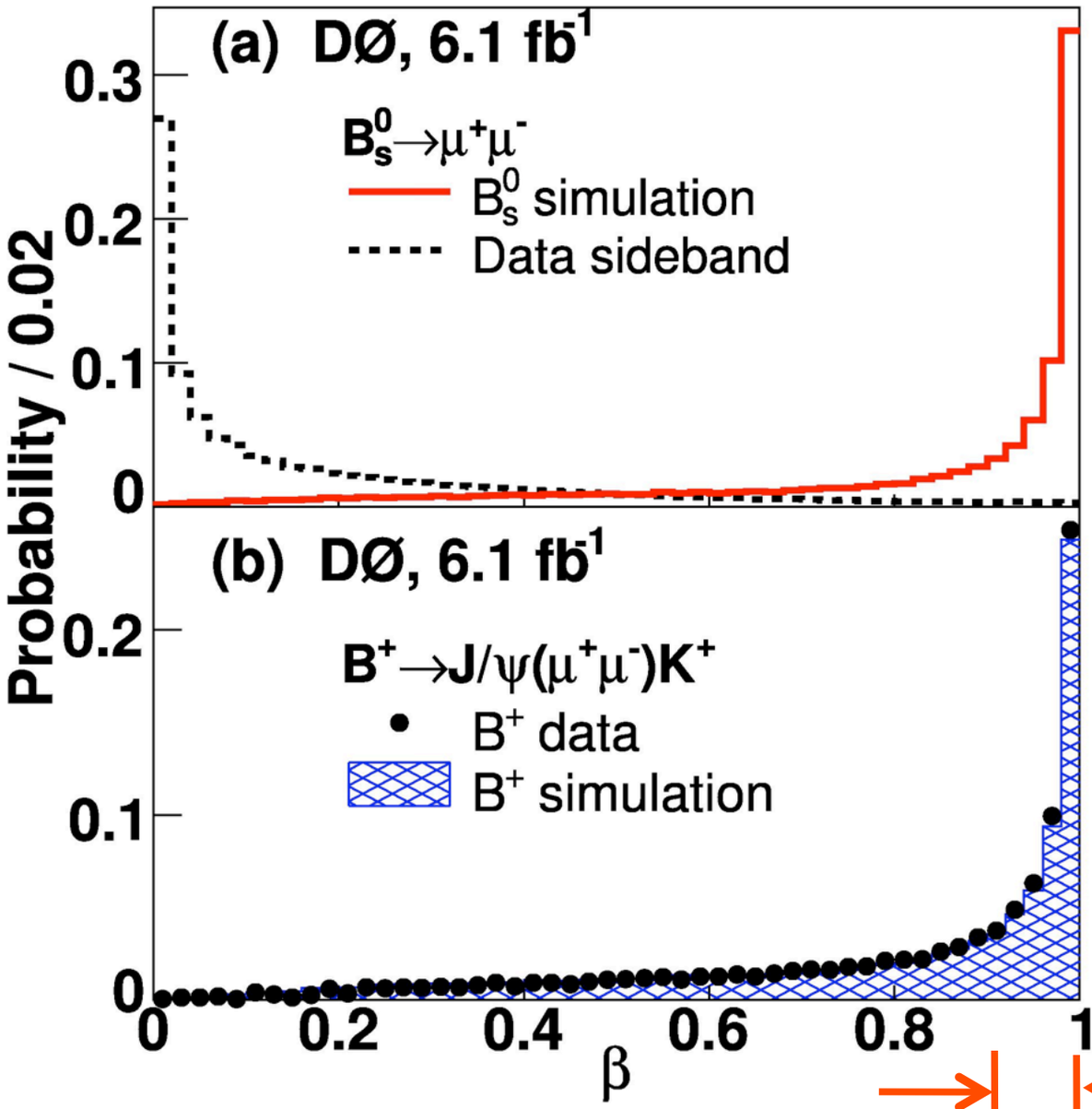
Signal MC
$J/\psi K^+$ data & MC

sidebands

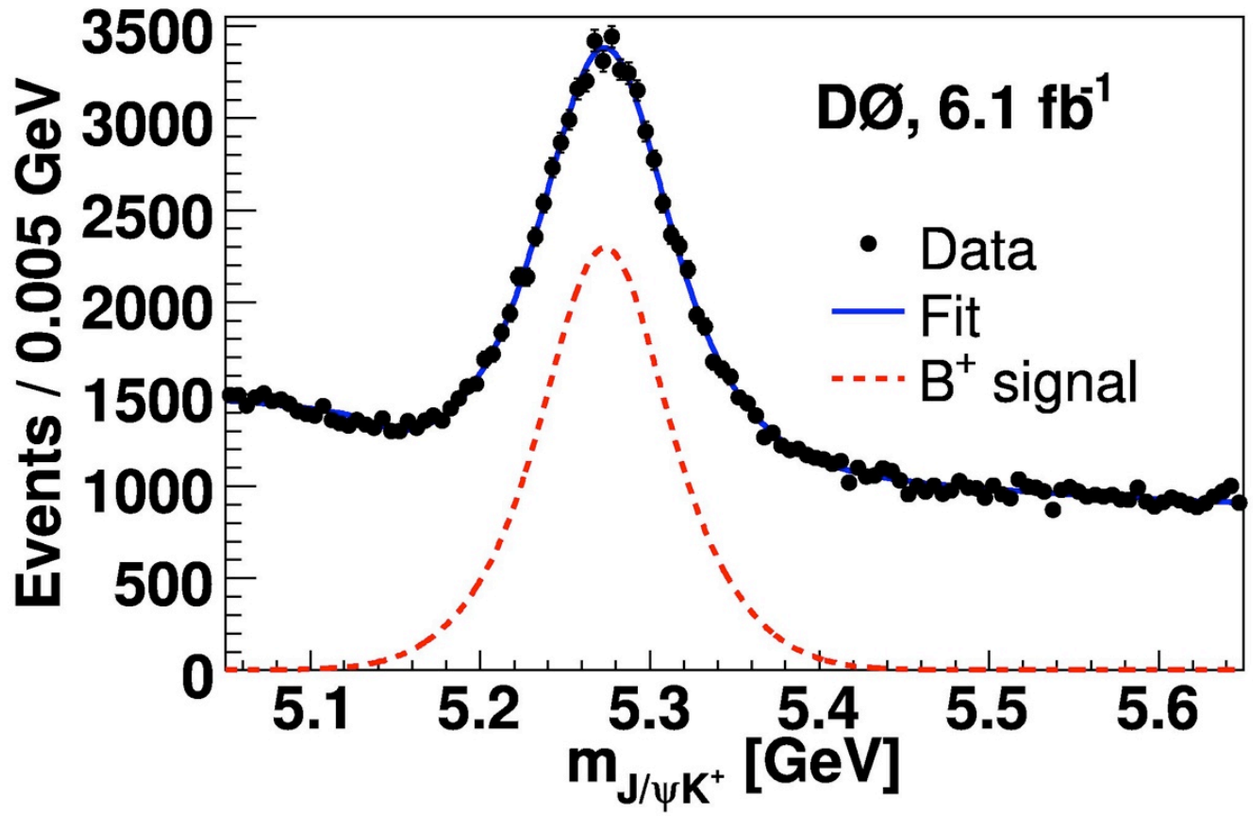


Background Reduction

Bayesian Neural Network



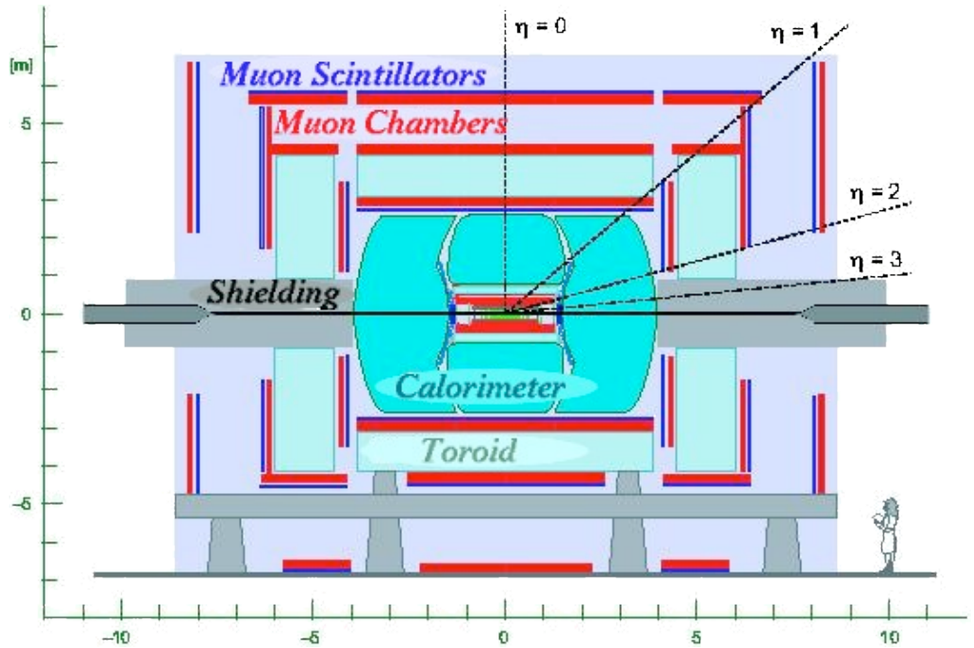
$B^+ \to J/\psi K^+$ Calibration Sample

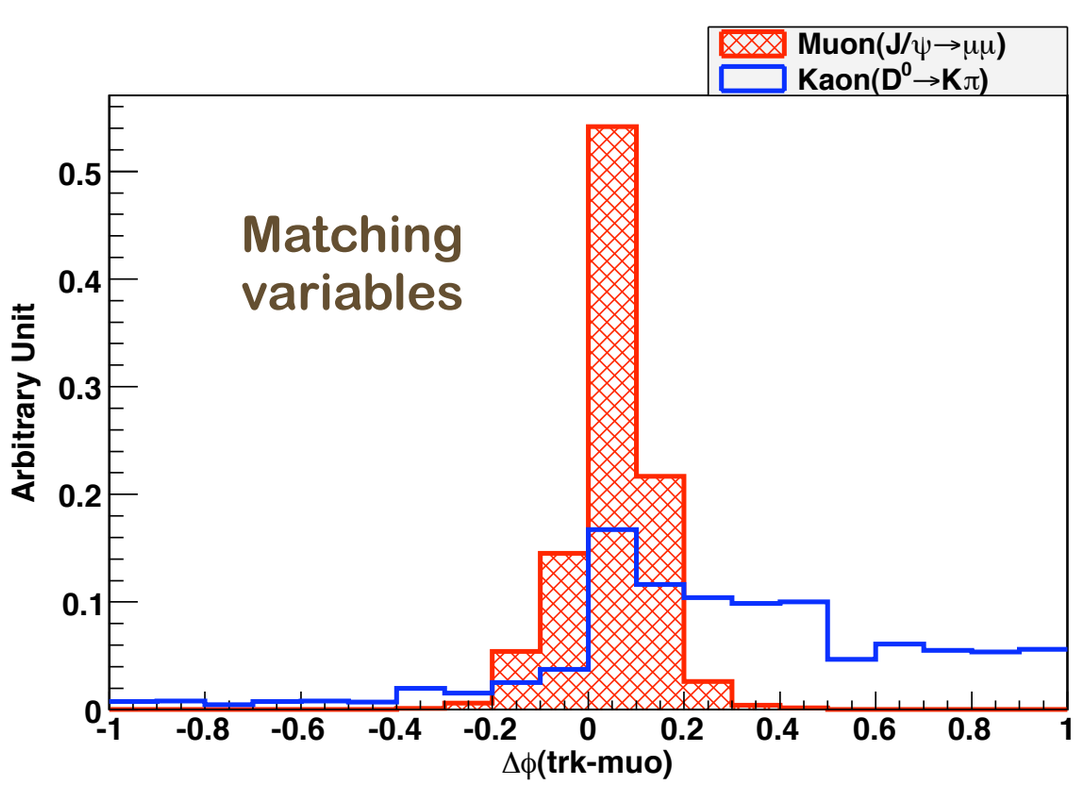


Expect ~3 signal events in our data with these cuts

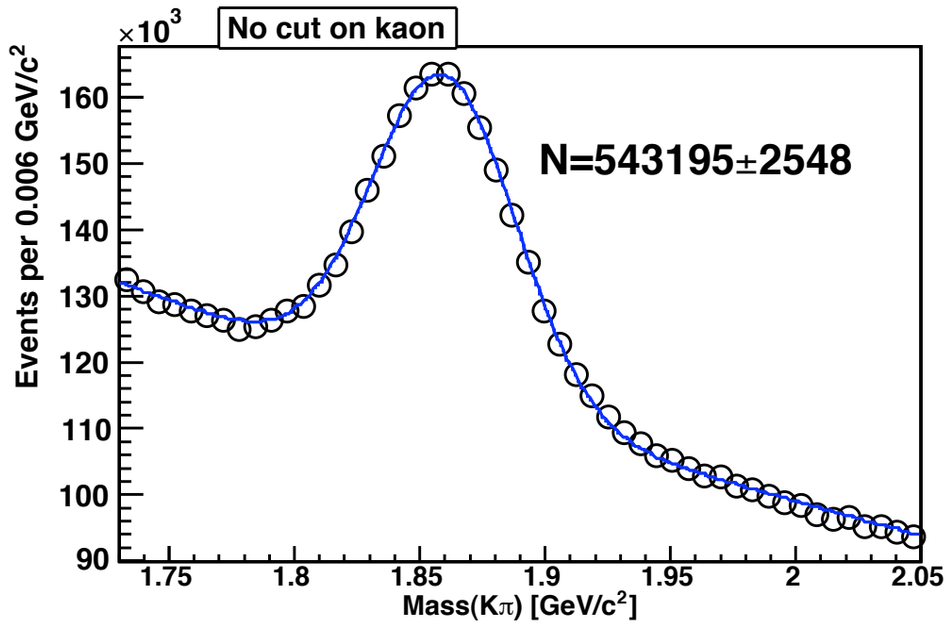
B → hh

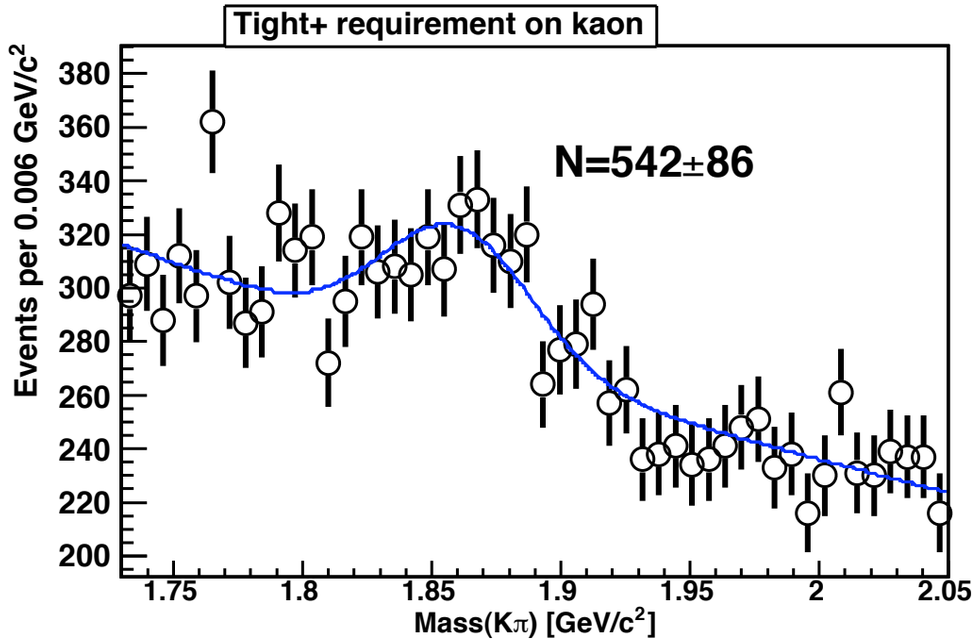
10-20 λ before outer muon layers





$$B^- \to D^0 \mu\nu, D^0 \to K^-\pi^+$$

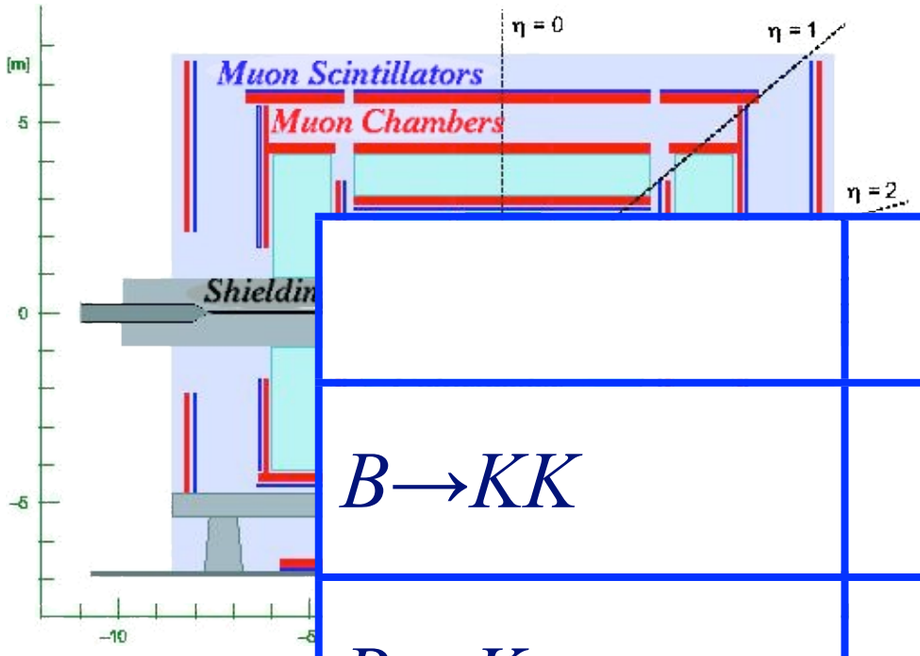




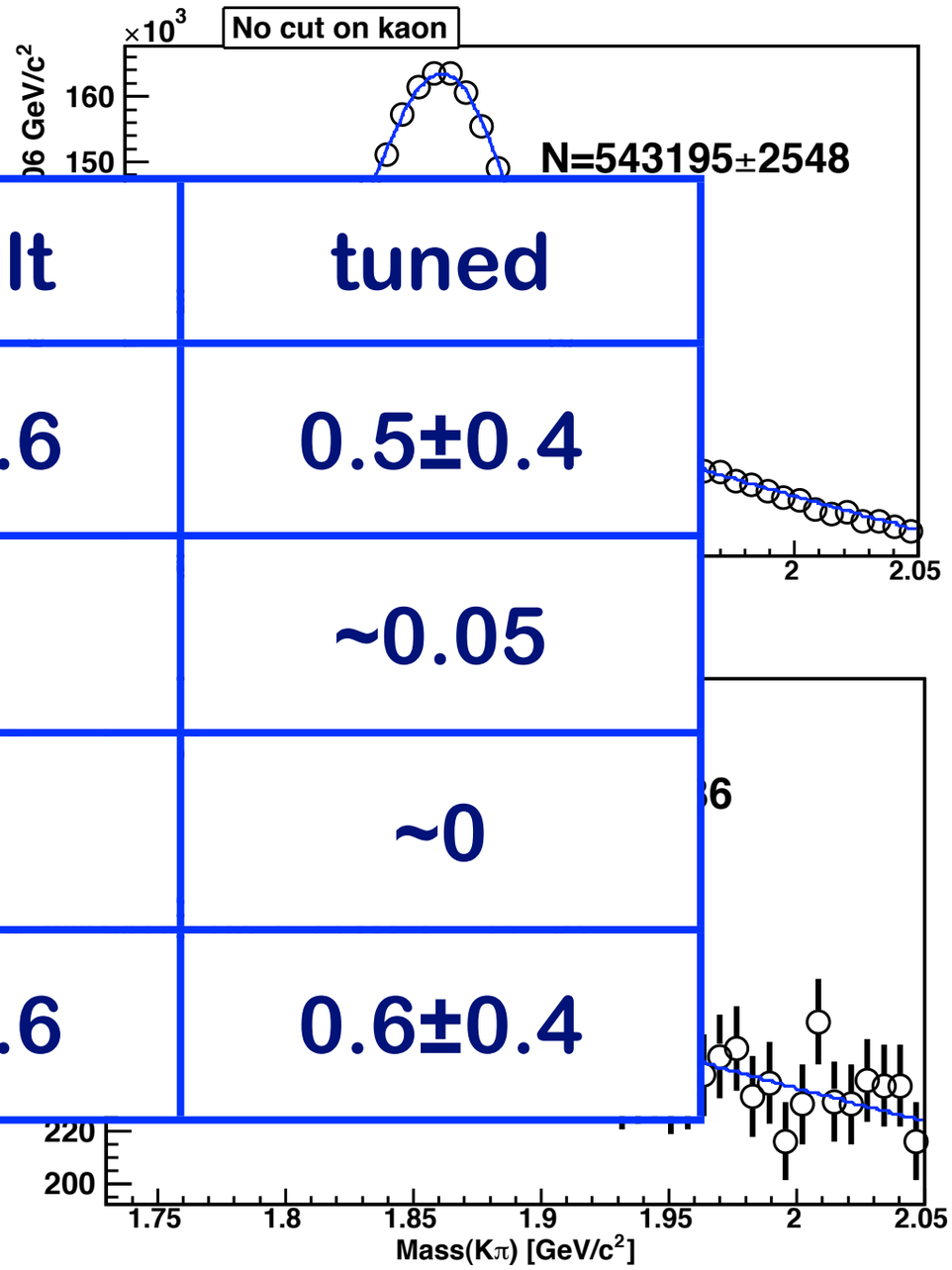
After penetration + matching cuts

B → hh

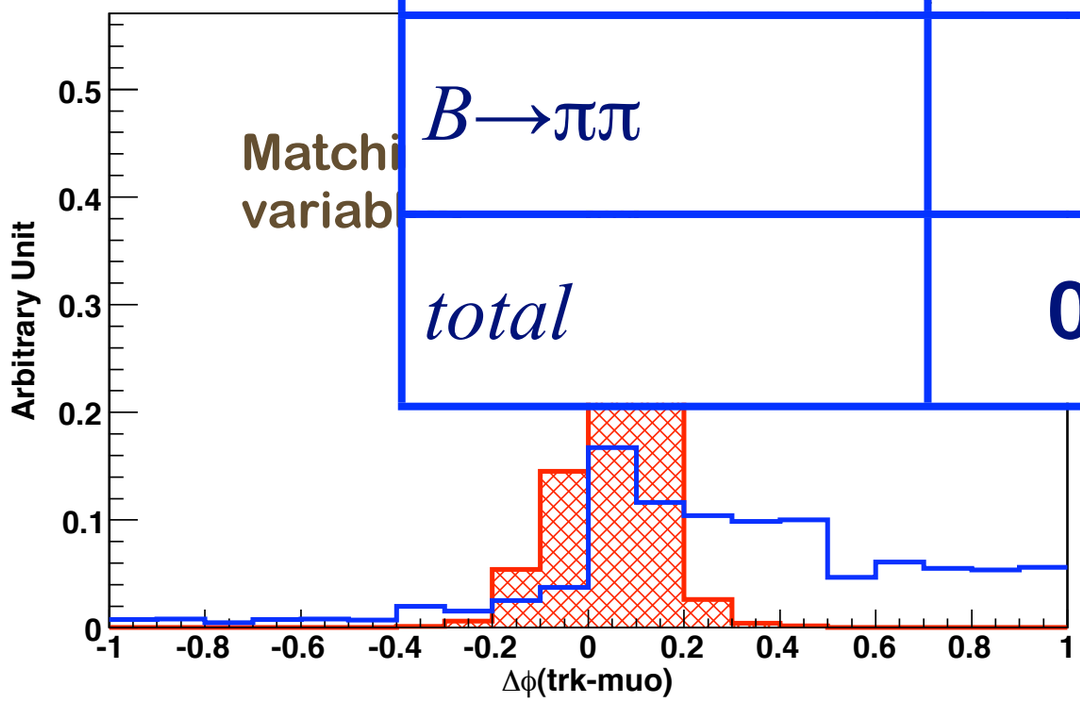
10-20 λ before outer muon layers



$B^- \to D^0 \mu\nu, D^0 \to K^- \pi^+$



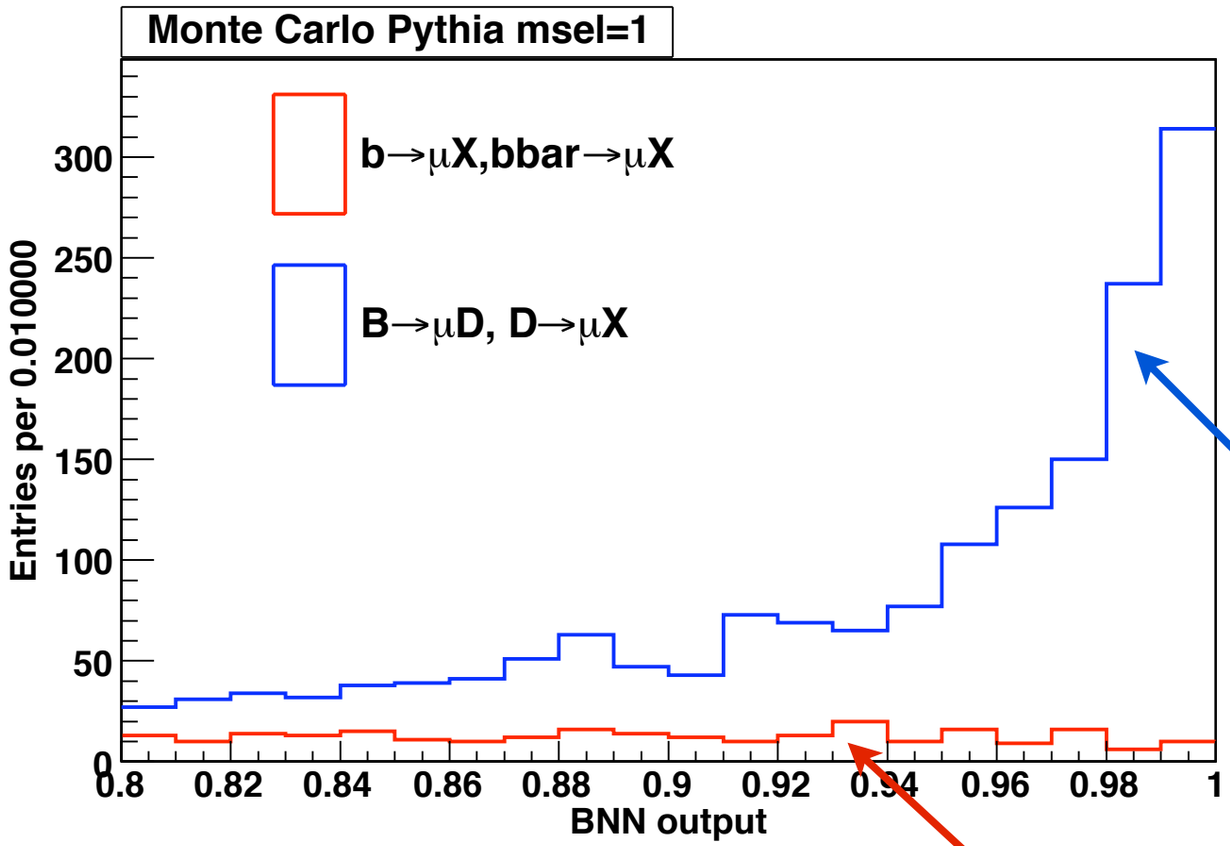
	default	tuned
$B \to KK$	0.8±0.6	0.5±0.4
$B \to K\pi$	~0.1	~0.05
$B \to \pi\pi$	~0	~0
total	0.9±0.6	0.6±0.4



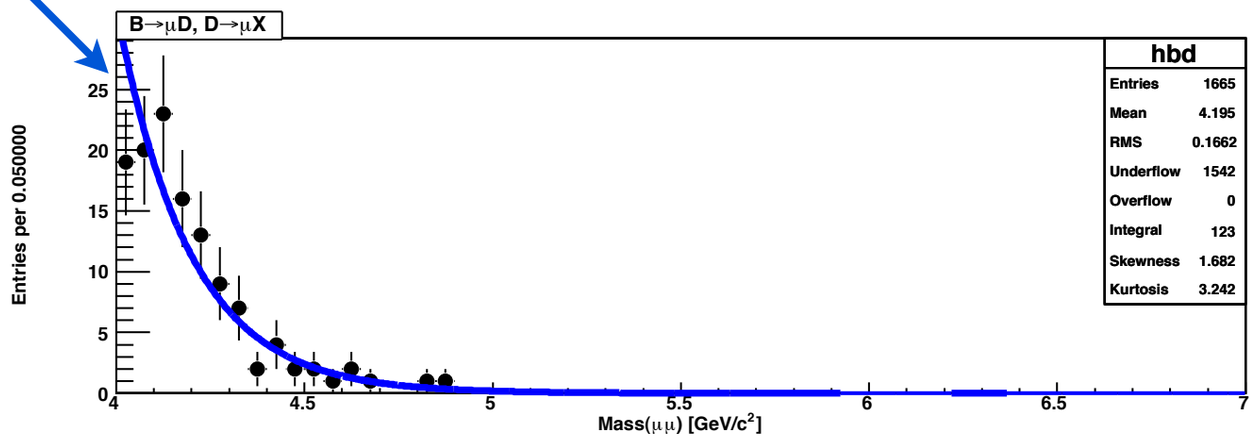
After penetration + matching cuts

Signal Extraction

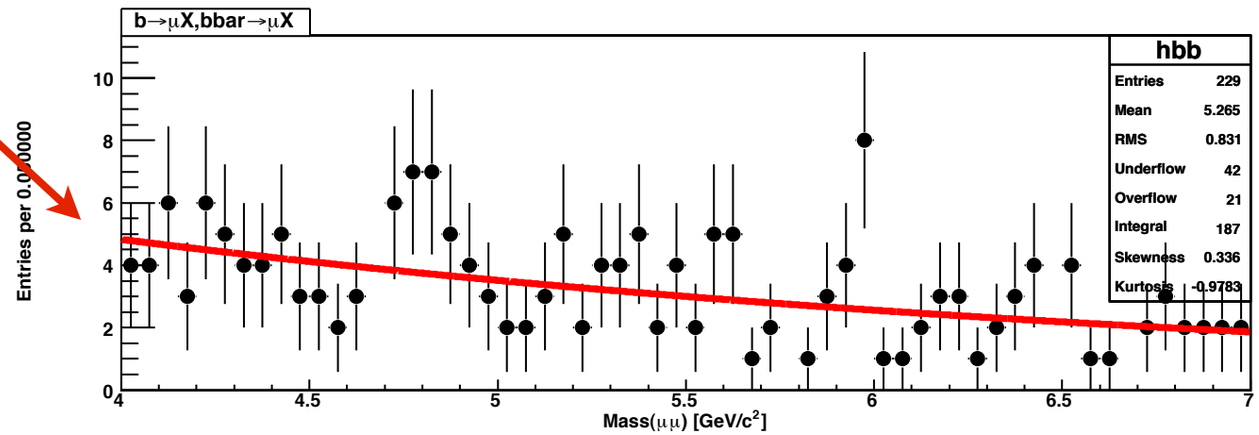
- 2D fit to m(μμ) and BNN



Sequential

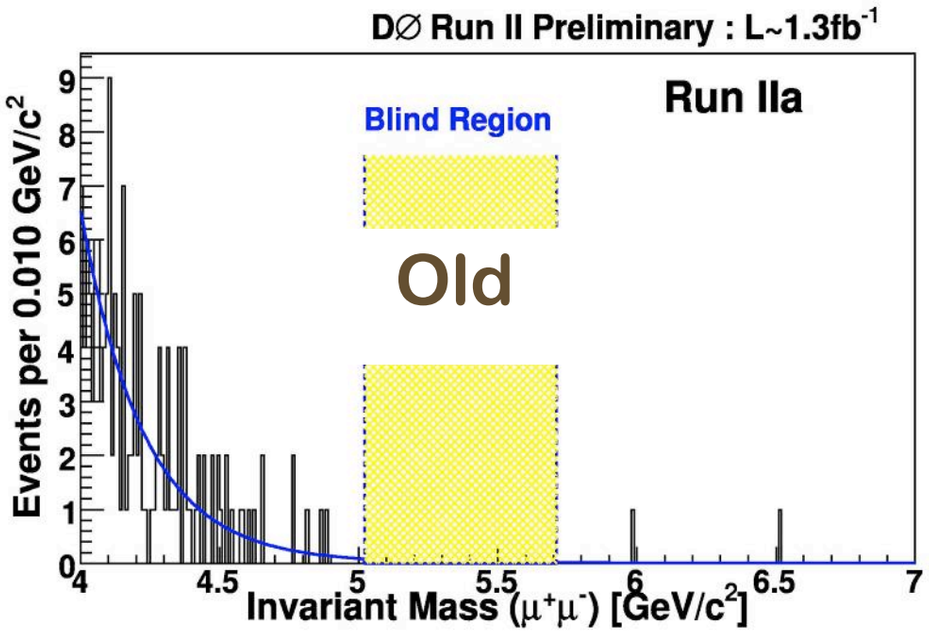


Double



- Background Shape from BNN, normalisation from m(μμ)

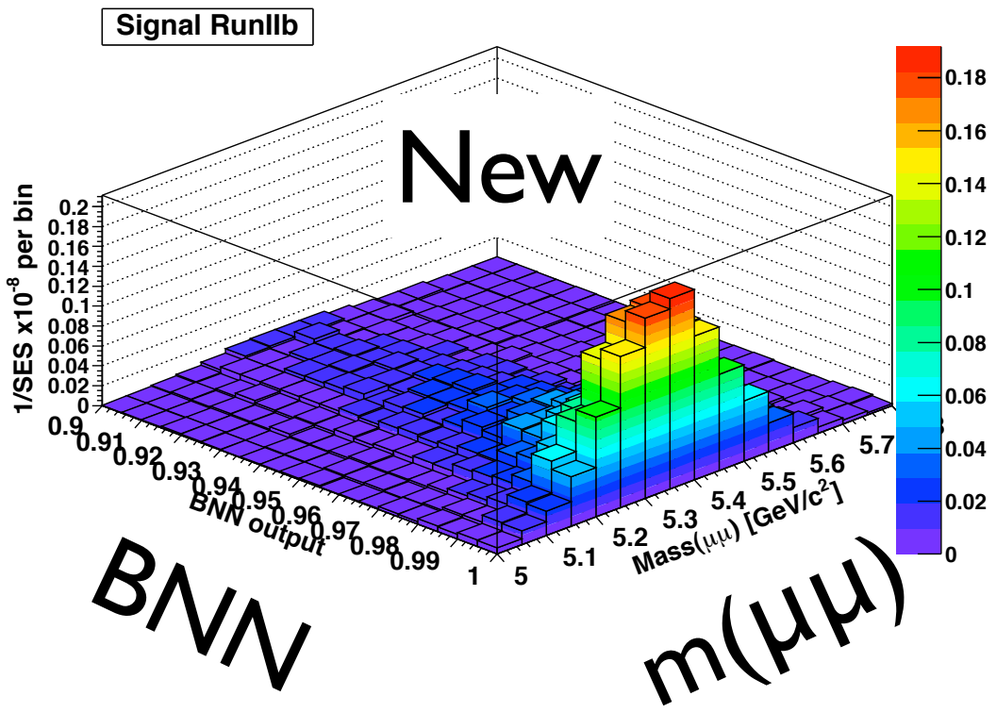
Comparisons

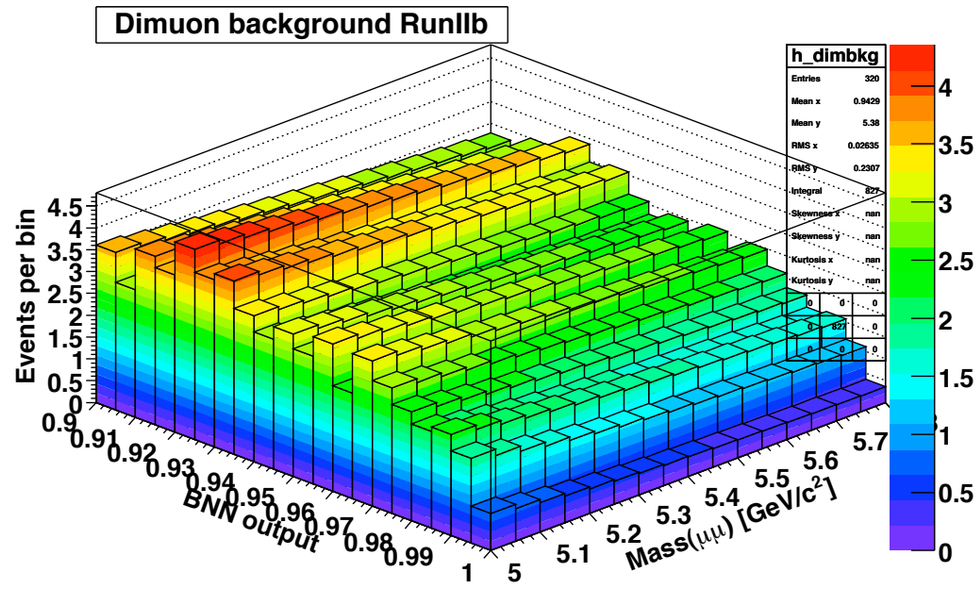


Old: 1D counting events in signal region

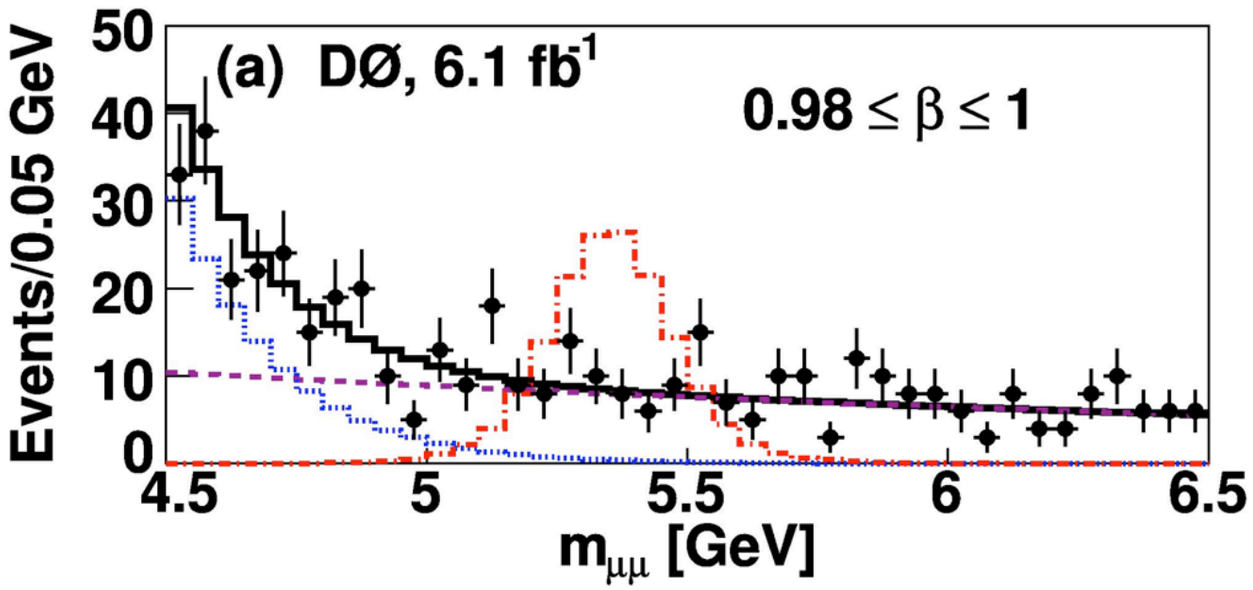
New: 2D including shape in signal region

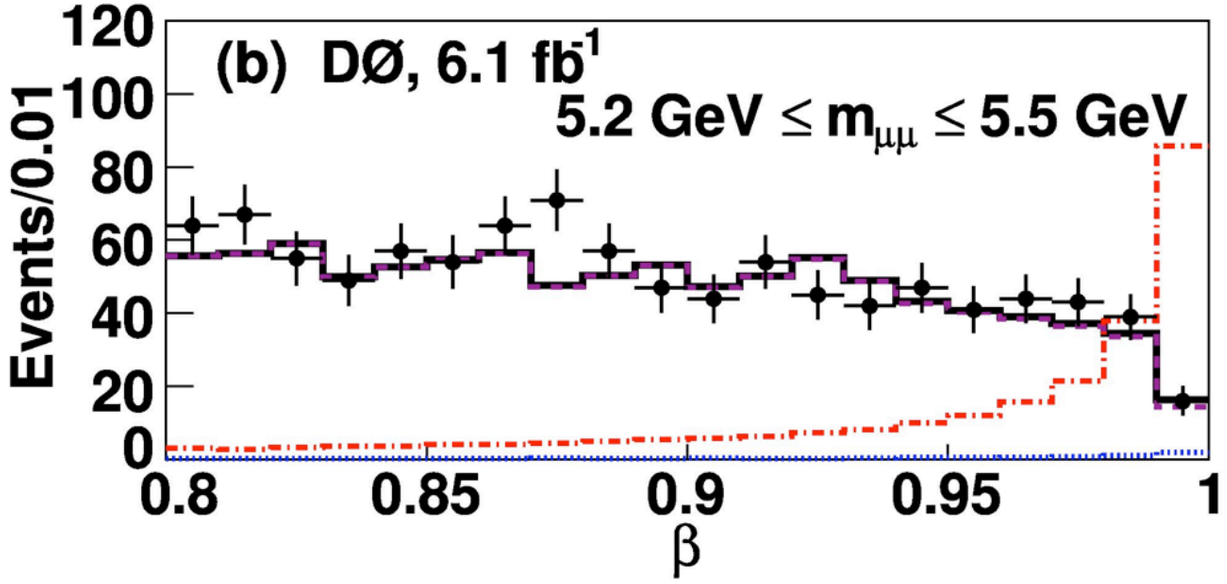
~40% improvement in expected limit New/Old





D0 Results





In highest sensitivity region:

51 ± 4 expected bkg events,

55 data events

BF < 51 x 10^{-9} (95% CL)

14x SM

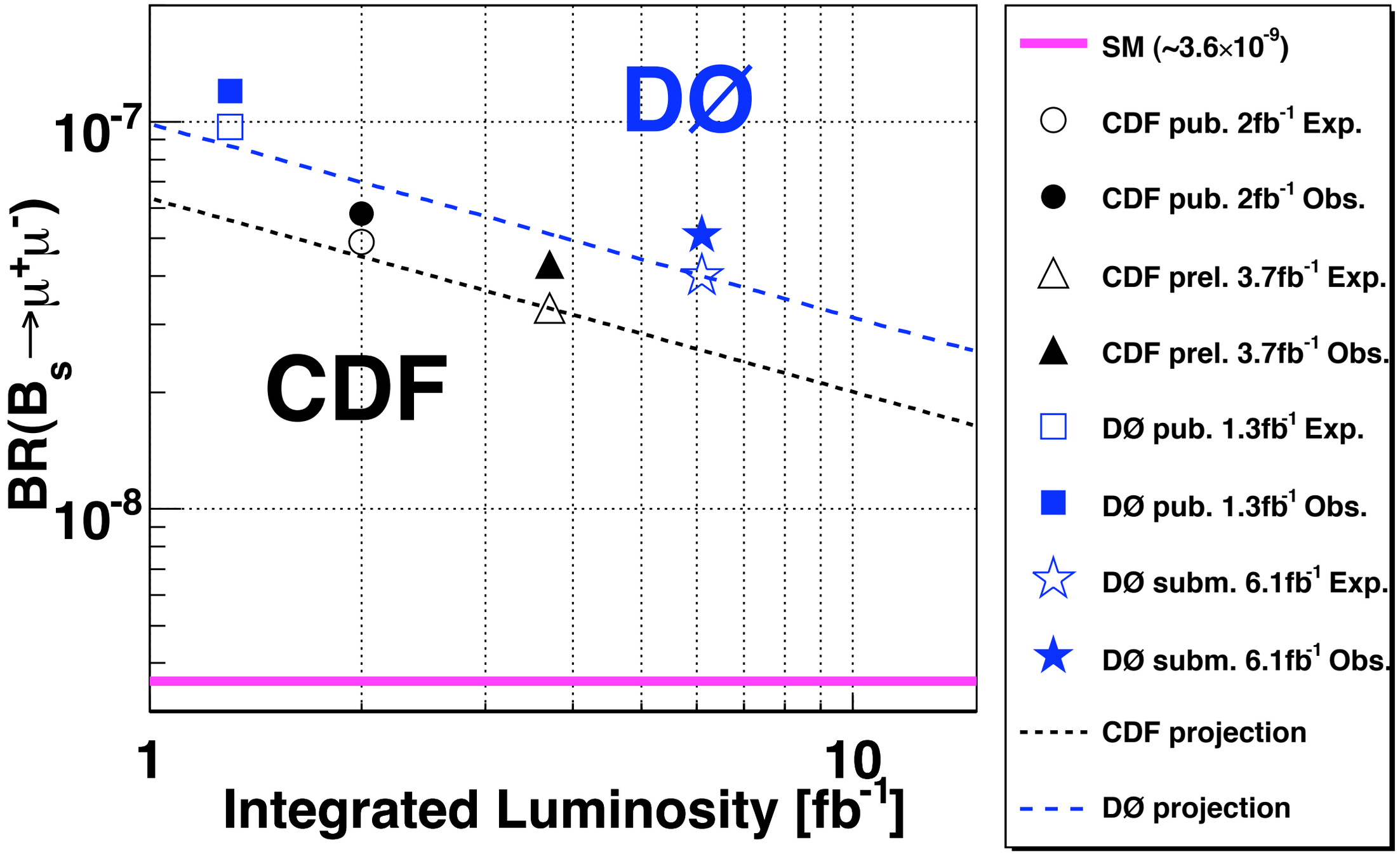
Expected limit: 40 x 10^{-9}

11x SM

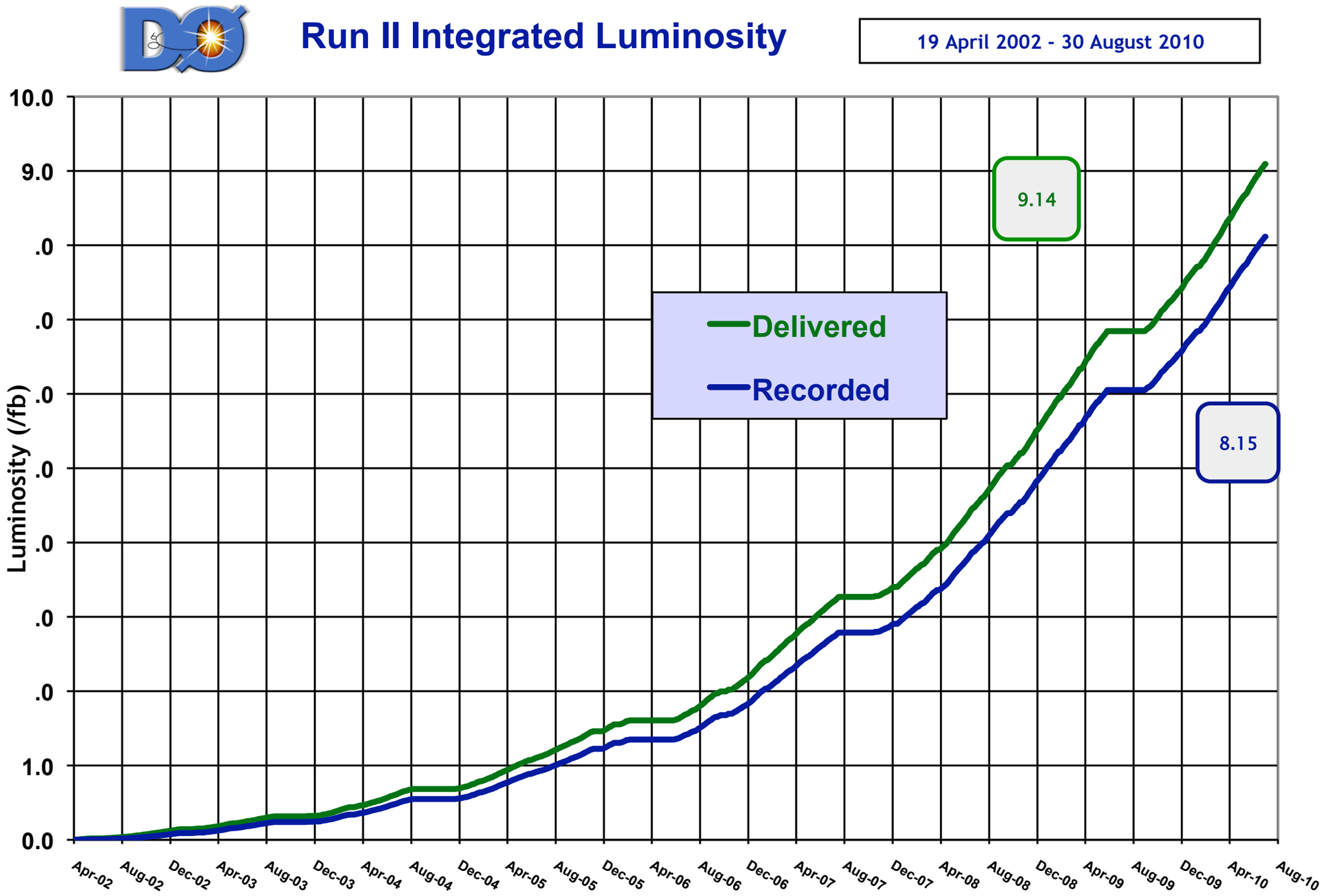
arXiv:1006.3469v1 [hep-ex]

Comparison of Results

Upper Limits on BR($B_s \to \mu^+\mu^-$) at 95% C.L. at Tevatron

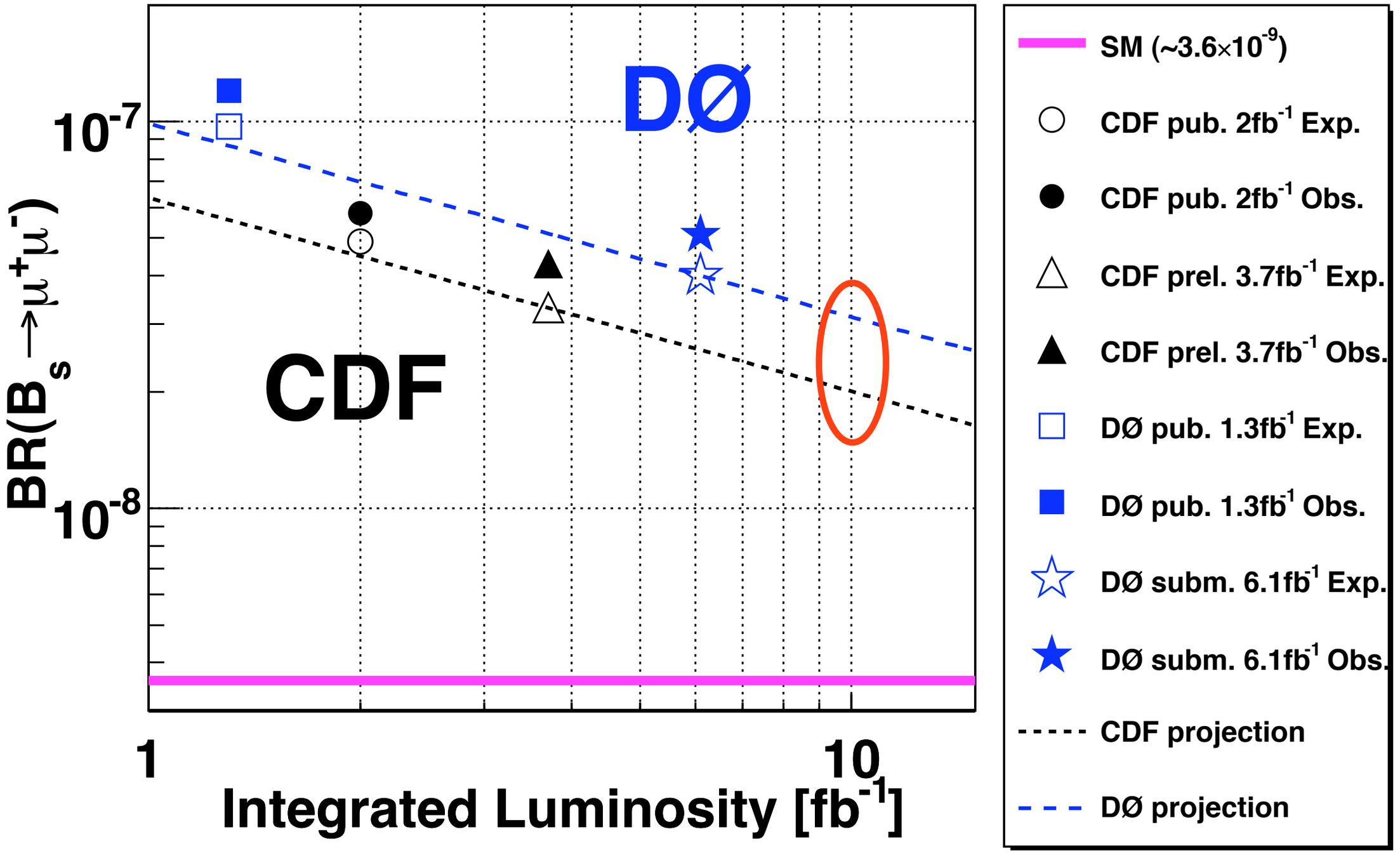


Prospects - Current Data Taking



2011 and Beyond

Upper Limits on BR($B_s \to \mu^+\mu^-$) at 95% C.L. at Tevatron



Summary

- Results on search for FCNC at the Tevatron presented.
- $B \rightarrow K^{*}\mu\mu$ (CDF 4.4 fb^{-1})
  - ➡ First measurement of A_{FB} in hadron collisions and competitive with B factories
    First observation of $B_s \rightarrow \Phi\mu\mu$ (rarest B_s decay observed)
- $B \rightarrow \mu\mu$ (D0 new result 6.1fb^{-1}) B(Bs) < 51 x 10^{-9}
  - ➡ CDF World Best 3.7fb^{-1} B(Bs) < 43 x 10^{-9}
  - ➡ No evidence of Physics beyond the SM
- Additional data being collected, 8fb^{-1} on tape
  - ➡ Expect 10fb^{-1} by Summer 2011, and possibly 16fb^{-1} in 2014.