Rare B decays at Tevatron

(Rare Decays of Heavy Flavor)

- Rare decays motivations
- Detectors
- Analyses/results $D \rightarrow (\pi)\mu\mu$, $B \rightarrow (\phi)\mu\mu$
- Prospects & Summary

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HCP06 Durham, NC

Rare B (and charm) decays

- Rare:
  - Suppressed in the Standard Model
  - Small branching ratios $\sim<10^{-5}$
  - Most likely a limit "observation"

- Rare B decays (in general):
  - Charmless mesonic and baryonic
  - Radiative
  - Leptonic
    - $b \rightarrow (s,d)\ ll$ including FCNCs, LFV, LNV
    - $B \rightarrow ll$ from $b \rightarrow s,d$
    - $B^+ \rightarrow l\nu$ from $b \rightarrow u$

- Rare Leptonics covered here

$D^0 \rightarrow \mu^+\mu^-$ (CDF)

$D^+ \rightarrow \mu^+\mu^-\pi^+$ (DØ)

$B_{s(d)} \rightarrow \mu^+\mu^-\phi$ (DØ)

$B_{s(d)} \rightarrow \mu^+\mu^-$ (CDF&DØ)

  - Analyses of other (e, μ) leptonics are in progress

Motivations (H→*ll*h modes)

- Probing for New Physics
  - Look for excess in modes suppressed in SM
- The biggest interest is in FCNC decays:
  - A remarkable tool to search/constrain New Physics
  - Charm: c→u transition
    - probes flavor sector not accessible in b-FCNCs
  - B-FCNCs: (most often) b→s transition
    - b→s γ a NP search and constraint workhorse for years
      - ✓Not easily experimentally accessible in hadron collider environment
- High sensitivity to exclusive dilepton B and Charm modes at CDF+DØ
  - Dilepton (esp μμ) modes are clean in theory and experiment

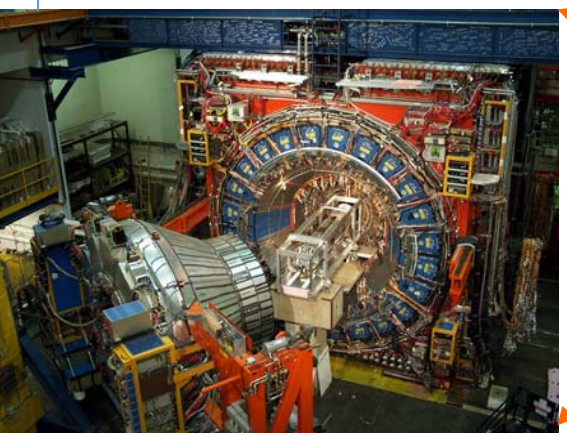
B production and detection at Tevatron

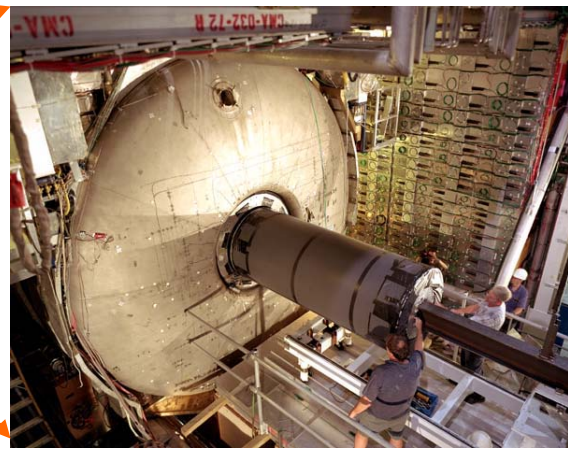
Tevatron is great for heavy flavor:

- *b* cross-section x1000 larger than e^+e^- B factories
- All B species are produced (B^0, B^+, Λ_b, B_s, etc…)

However,

- QCD production is even larger (x1000)
- Triggering is a challenge: collision rate 1.7 MHz → tape write limit ~100Hz





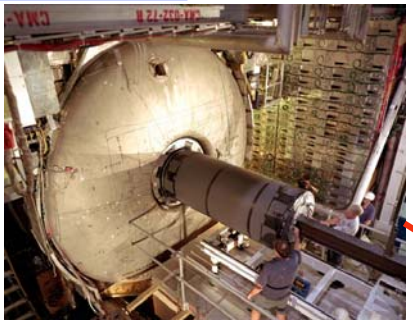
CDF:

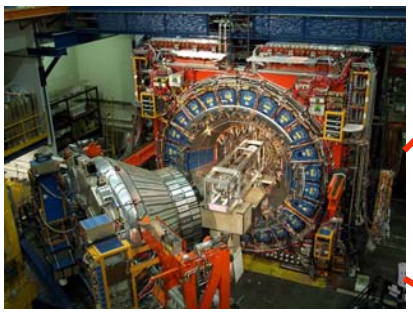
- Excellent silicon vertex detector
- Good momentum and mass resolutions

DØ:

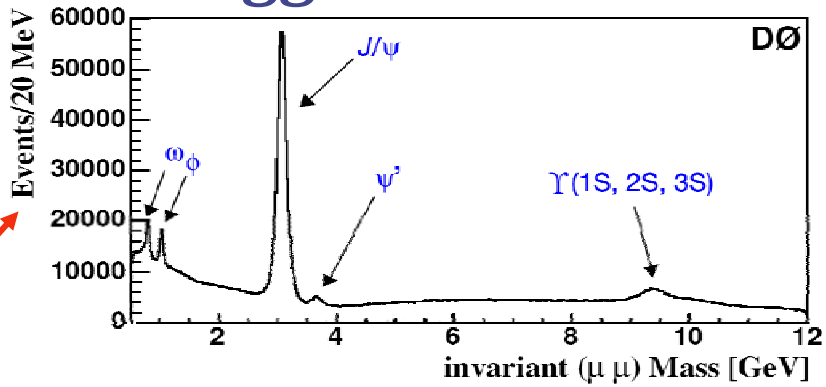
- Extended muon coverage
- New silicon detector was installed in March

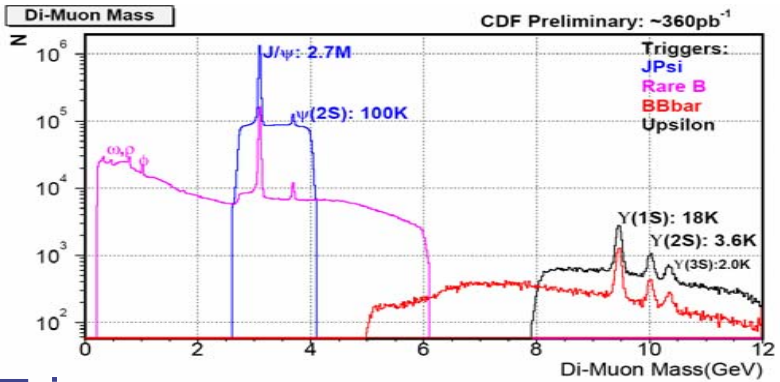
B(and charm) detection at Tevatron: triggers



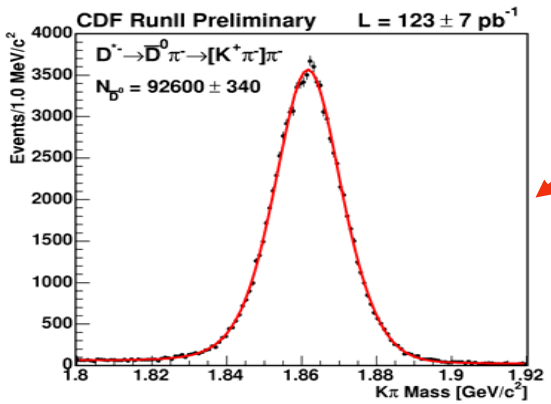


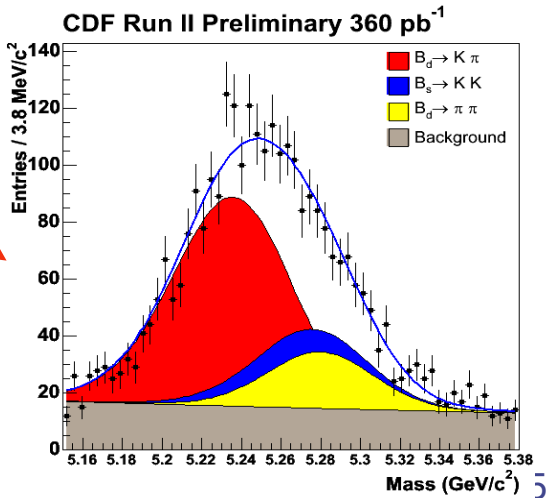
Dimuon trigger(s)





Two (displaced) Track Trigger
[charm and B]





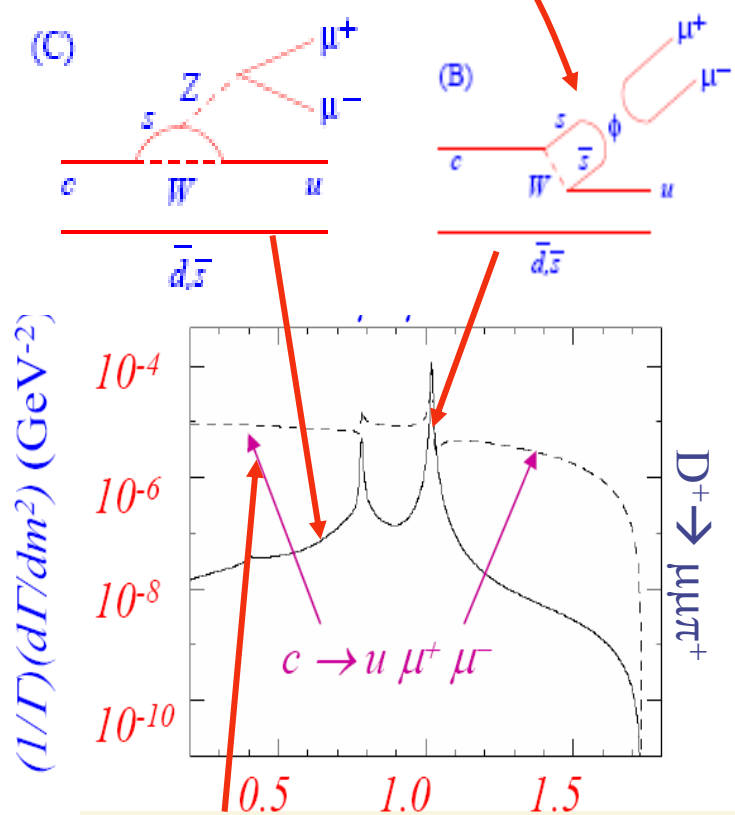
Rare Charm decays

- FCNCs: $D^0 \to \mu\mu$, $D^+ \to ll\pi^+$, $D^+_s \to \mu\mu K^+$
- FCNC^2, LFV,LNV: $D_x \to ll^{(')}$ (h)

- FCNCs: c→u transition
  - GIM suppression works well in SM (no top in the loop)
    - Long-range effects (decays via resonances) dominate the Bratio
    - $B(D \to \mu\mu) \sim 10^{-13}$ $B(D \to h\mu\mu) \sim 10^{-9}$

- NP probes in flavor sector other than in b→s(d) or s→d

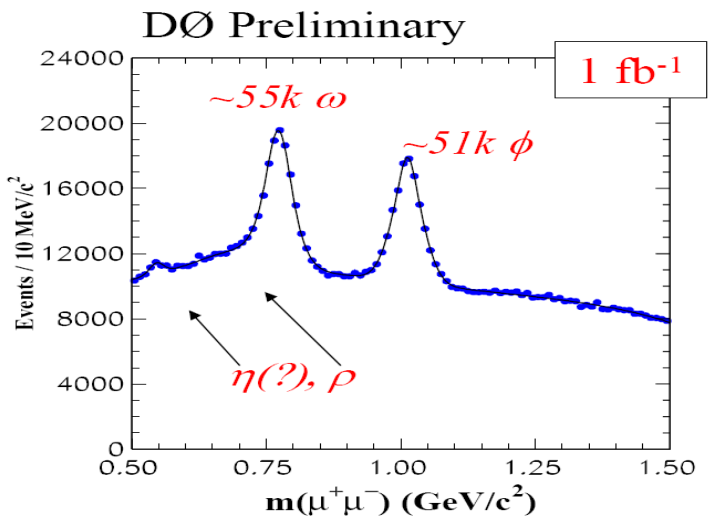
- Up-to experimental values are possible in R-parity violating or some non-universal SUSY



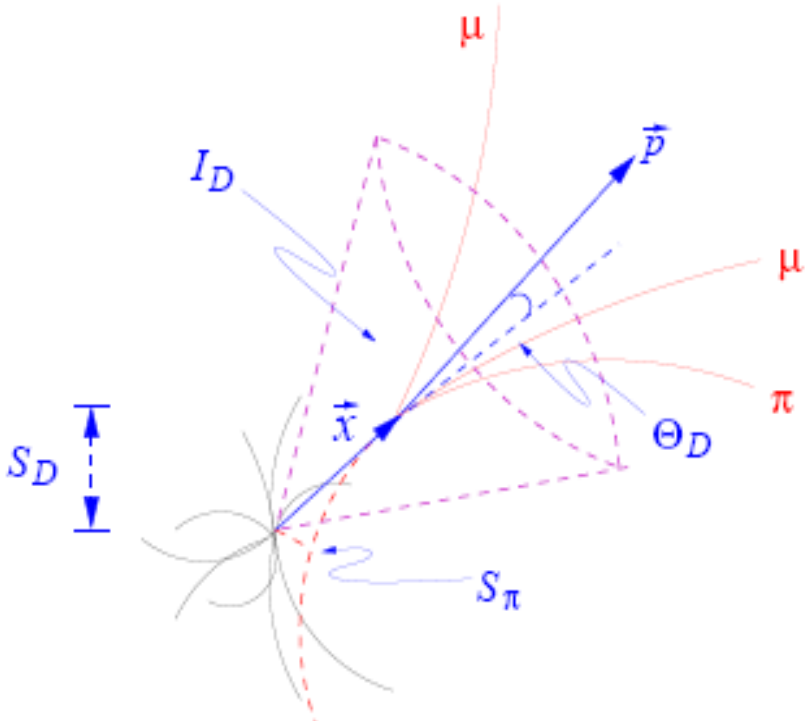
RPV:
Burdman et al. hep-ph/0112235

DØ: Rare Charm decays $D^+ \rightarrow \mu\mu\pi^+$

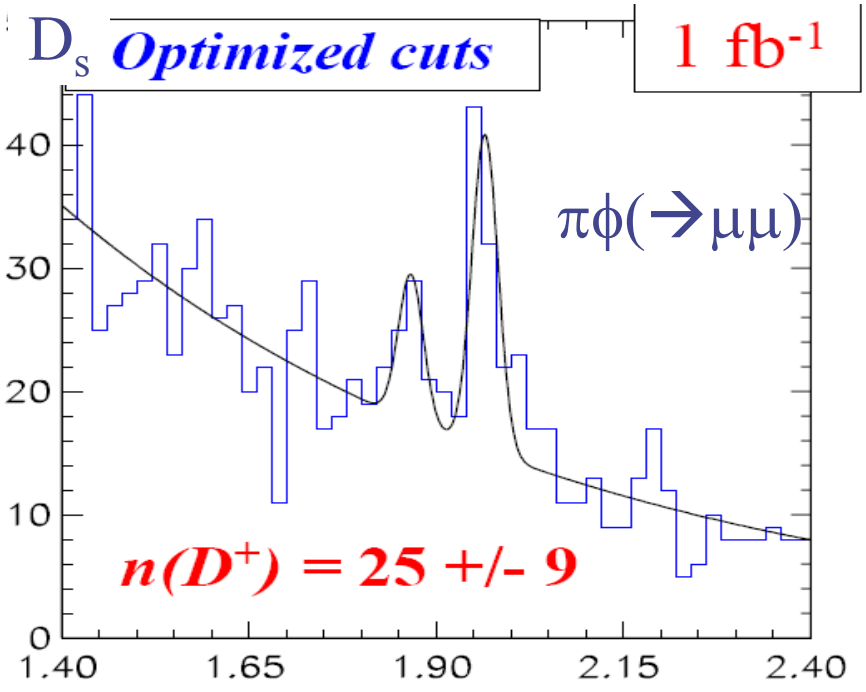
- Use dimuon trigger sample
- MC for signal; data sidebands for bg
- Start with $D^+ \rightarrow \pi^+\phi(\rightarrow \mu\mu)$

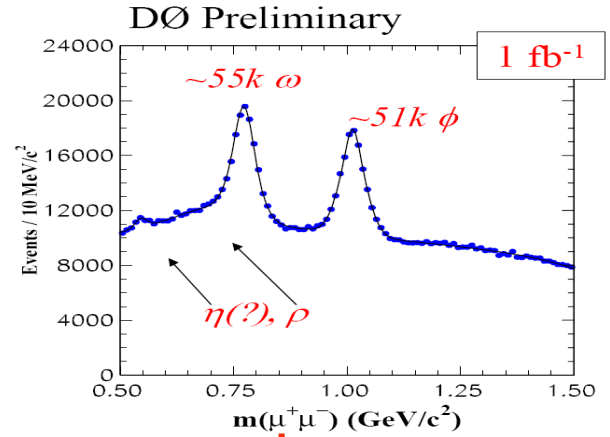


- Maximize eff/[0.82+$N_{bgd}^{1/2}$] for D_s on
  - vtx and π displacement significance (S_D, S_π)
  - Collinearity (vertex vs D candidate p) Θ_D
  - Track Isolation of D candidate I_D

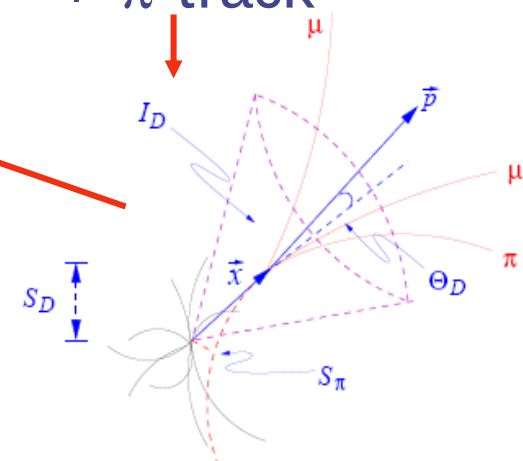


DØ: Rare Charm decays $D^+ \rightarrow \mu\mu\pi^+$





+ π track



☞ $B[D^+\rightarrow\pi\phi(\rightarrow\mu\mu)]=(1.75\pm0.7\pm0.5)\times10^{-6}$

DØ: Rare Charm decays $D^+ \rightarrow \mu\mu\pi^+$

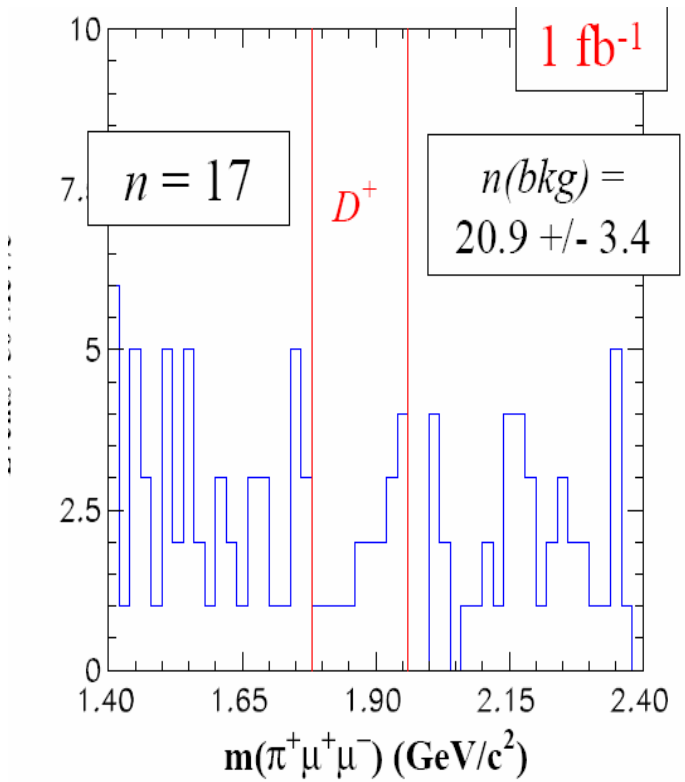
- Now look off resonance
- Optimize for D^+ with the same variables
  - Larger D^+ lifetime allows to cut tighter
- Then open signal box
  - Observe 17 while expecting 21 events
- Set a limit (world best)

$B[D^+ \rightarrow \mu^+\mu^-\pi^+] < 4.7\times10^{-6}$ @ 90% CL

PDG: 8.8×10^{-6} @ 90% CL

- New limit on RPV couplings

$\lambda_{22k}\lambda_{21k} < 0.002$



$0.2 < m(\mu\mu) < 0.96$ GeV/c^2
$1.06 < m(\mu\mu) < 1.76$ GeV/c^2

CDF: Rare Charm decays

- FCNCs
  - $D^0 \to \mu^+\mu^-$
  - $D^+ \to l^+l^-\pi^+$, $D^+_s \to \mu^+\mu^-K^+$
- Others ($FCNC^2$, LFV,LNV) $D_x \to ll h$

- Use two (displaced) track trigger sample
- Normalize to $D \to hh$ or $D \to hhh$ (h=K,pi)
  - Signal mode naturally comes in the same sample
  - Normn Bratios are large → good statistics

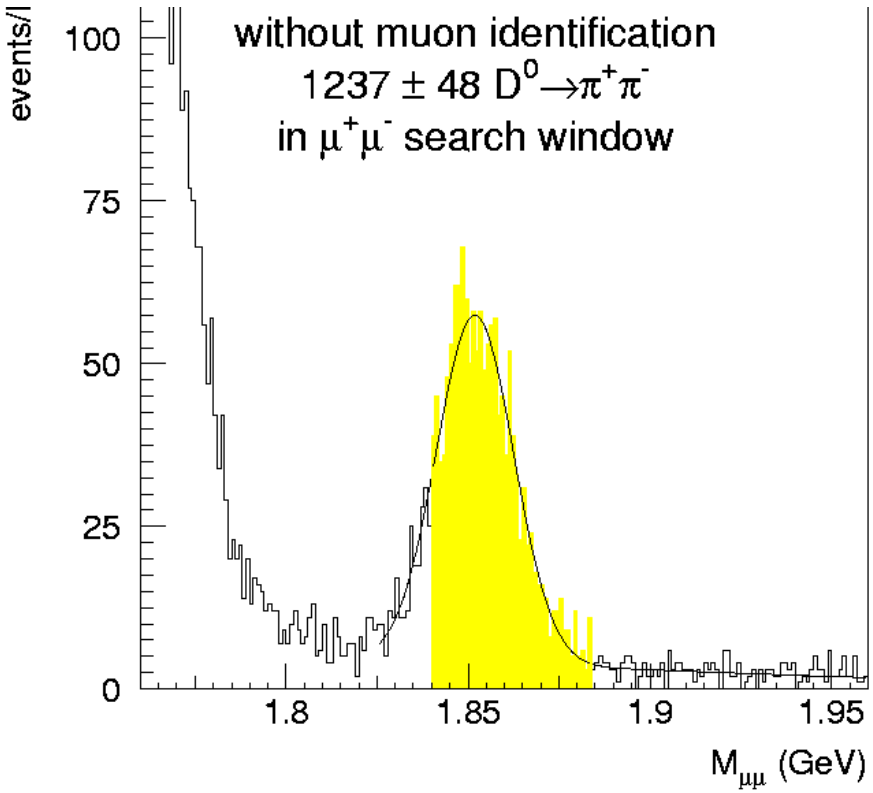
  - Get peak/resonant N_{bg} by applying $h \to \mu$ fake rates
  - Get combinatoric N_{bg} from sidebands
  - "Unblind" by looking at lepton ID

- Available results: $D^0 \to \mu^+\mu^-$ for 68 pb^{-1}

- Work on other modes is in progress and is expected with an analysis of 1 fb^{-1} of data
  - should achieve sensitivity comparable to that available now (PDG ← BaBar/Cleo-c/Belle/Hera-B/DØ)

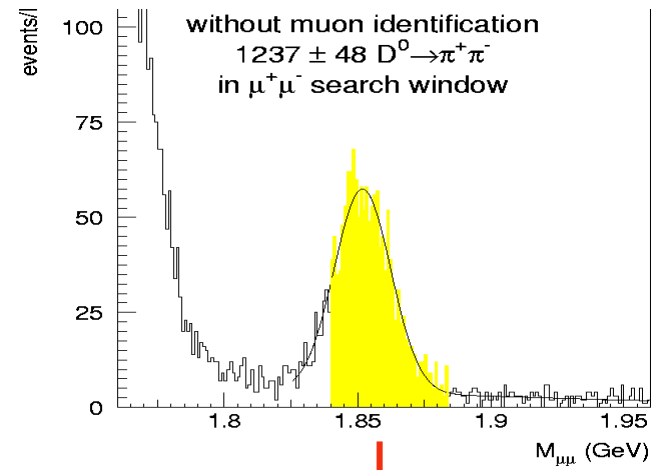
CDF: $D^0 \rightarrow \mu\mu$ search (69 pb^{-1})

- Normalize to $D^0 \rightarrow \pi^+\pi^-$
  - Blind from μID
  - $1.840 < m_{\mu\mu} < 1.882$ GeV
- Maximize eff/[$1.5+N_{bg}^{1/2}$] using:
  - Track and vertex impact parameter
  - Two-track opening angle
  - D candidate isolation

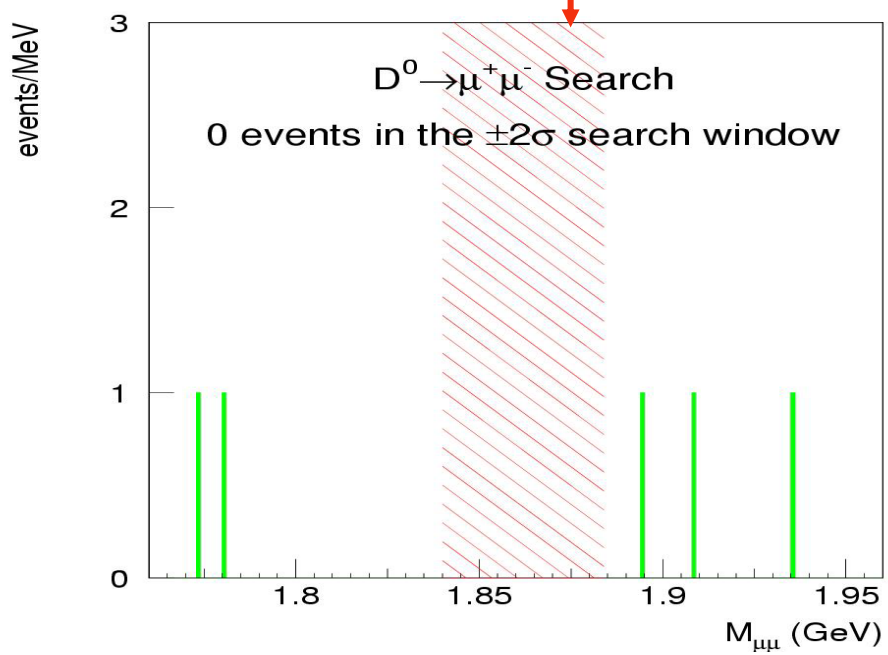


CDF: $D^0 \rightarrow \mu\mu$ search (69 pb^{-1})

- Background expected:
  - $[1.5 \pm 0.7]_{combinatoric} + [0.3 \pm 0.1]_{misID}$
- With μID observe 0 events



Muon ID



$B(D^0 \rightarrow \mu\mu) < 2.5 \times 10^{-6}$ @ 90% C.L.
PRD 68, 091101 2003

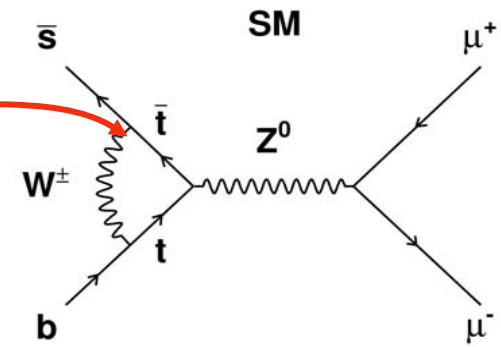
Now superseded by result from BaBar
$B(D^0 \rightarrow \mu\mu) < 1.3 \times 10^{-6}$ @ 90% C.L.
cf $B_{SM} \sim 10^{-13}$

- With 1 fb^{-1} expect ~×10-20 improvement (to ~ 1×10^{-7})

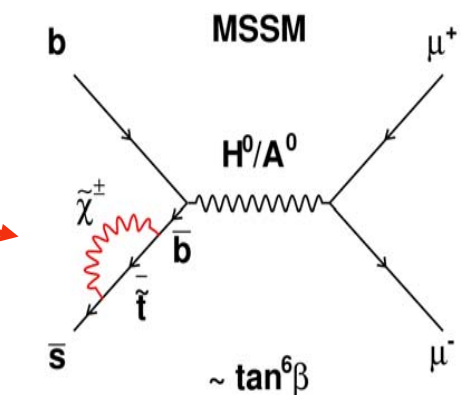
Rare B-decays

- FCNCs
  - $B_{s(d)} \rightarrow \mu^+\mu^-$, ee
  - $(B/B_s/B+/\Lambda_b) \rightarrow l^+l^-h$
- (FCNC^2, LFV,LNV, etc) $B_x \rightarrow ll^{(')}(h)$

- FCNCs are suppressed in SM
  - Much softer suppression than in $D \rightarrow llh$
  - Thanks to the top in the loop



- Probe $b \rightarrow s(d)$ transition
- Up-to experimental values are possible in NP scenarios
  - R-parity violating SUSY
  - numerous SUSY/2HDM scenarios with large $\tan\beta$
  - In SUSY the contribution is up to $\sim \tan^6\beta/M_H^4$
    - $\sim\tan^4\beta$ in 2HDM
- $B_s \rightarrow \mu^+\mu^-$ is becoming golden
  - One of the leading (by citation) analyses at CDF and D0
  - Have a chance to see NP at Tevatron



Rare B-decays: Experiment

- FCNCs
  - $B_{s(d)} \rightarrow \mu^+\mu^-$, ee
  - $(B/B_s/B+/\Lambda_b) \rightarrow l^+l^-h$
- (FCNC^2, LFV,LNV, etc) $B_x \rightarrow ll^{(')}(h)$

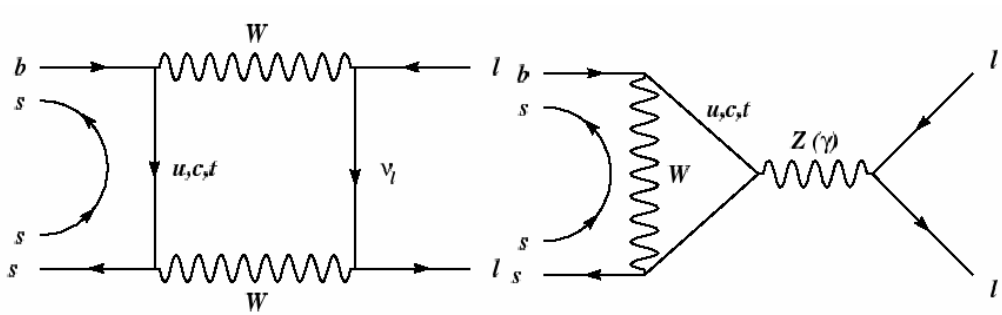
- Common steps

- Use a normalization mode
  - CDF and DØ can normalize to dimuon $H_b \rightarrow (h)J/\psi$ for dimuon rare B modes
  - CDF specific: $B \rightarrow$ ee, eμ search uses $B \rightarrow hh$ (two track trigger samle)
    - Analysis is in progress
  - Benefits: smaller statistical and systematic uncertainties

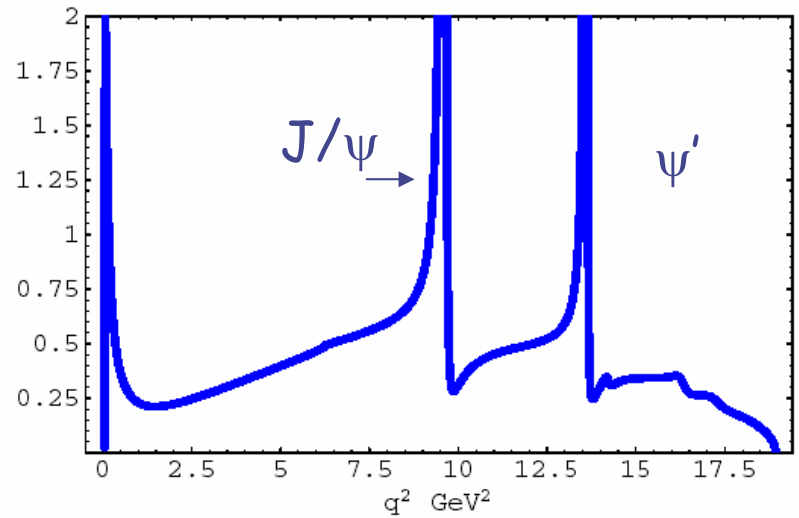
- Background (mostly combinatoric) is estimated from sidebands
  - Discriminate based on vertex and dilepton ID
  - Use either a likelihood or a box cut
- MC for signal
- "Blind" optimization for best sensitivity

DØ: Search for $B_s \rightarrow \phi\mu^+\mu^-$

- SM prediction (non-resonant): BR: $\sim 1.6\times10^{-6}$
- 2HDM/SUSY: enhancement possible
  - depending on parameters of $\tan\beta$ and M_{H+}
- Prior published limit [CDF Run I]: 6.7×10^{-5} @ 95% C.L.
- long-term goal: investigate $b \rightarrow s\, l^+ l^-$ FCNC transitions in B_s meson

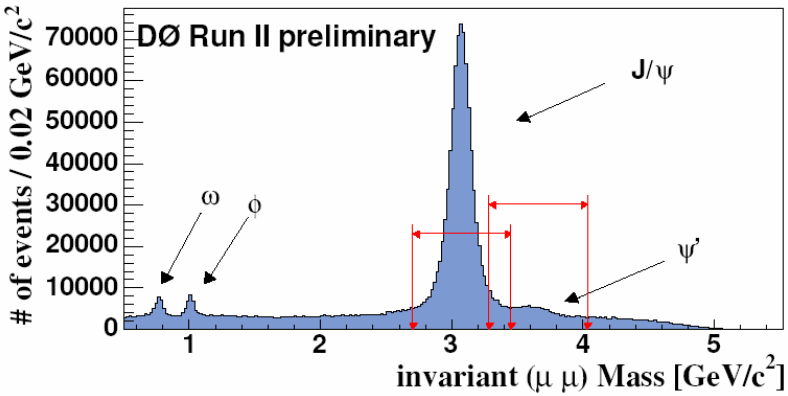


Dilepton mass spectrum in b -> s *l l* decay



DØ: Search for $B_s \rightarrow \phi\, \mu^+\mu^-$

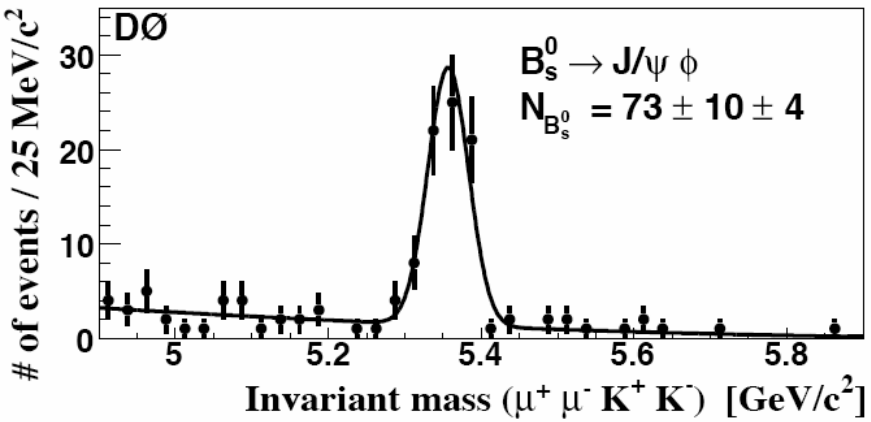
- 300 pb^{-1} of dimuon data
- normalize to resonant decay $B_s \rightarrow J/\psi\, \phi$
- For non-resonant decay: cut out ψ and ψ'



- Blind analysis: minimize eff/[1+$N_{bg}^{½}$] on random grid using:
  - Pointing angle (collinearity)
  - Decay length significance
  - Isolation

- $0.5 < M(\mu\mu) < 4.4$ GeV/c^2
- ϕ candidate: $1008<M<1032$ MeV/c^2
- good vertex
- $p_t(B_s$ cand.$) > 5$ GeV/c

- Background modeled from sidebands
- Use same cuts for $B_s \rightarrow J/\psi\, \phi$ and off-resonance search mode



DØ: Limit on $B_s \rightarrow \phi\, \mu^+\mu^-$

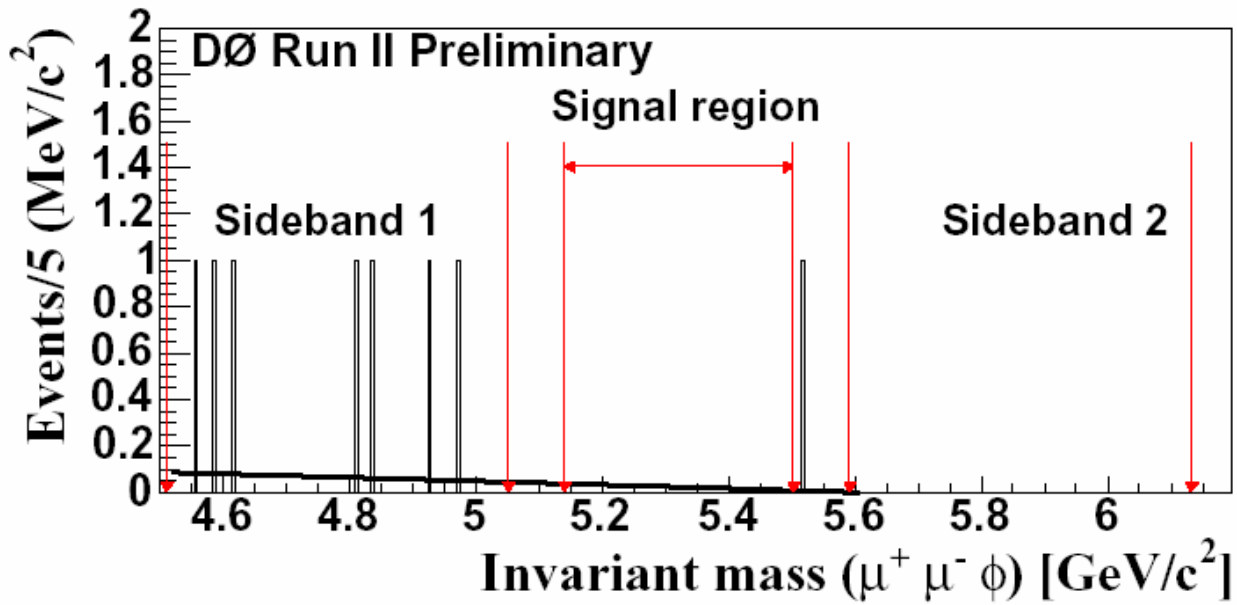
- expected background: 1.6 ± 0.4 events
- observe zero events in signal region

  $BR(B_s \rightarrow \phi\, \mu^+\mu^-)/BR(B_s \rightarrow J/\psi\, \phi) < 4.4 \times 10^{-3}$ @ 95% C.L.

  Using central value for $BR(B_s \rightarrow J/\psi\, \phi) = 9.3\times10^{-4}$ PDG2004:

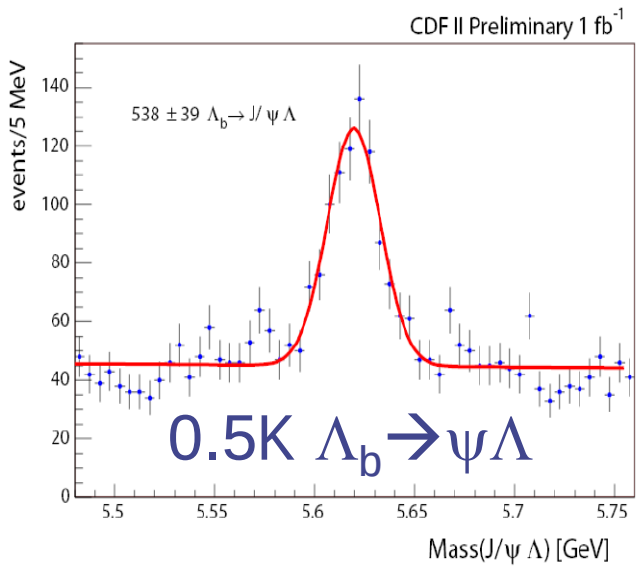
  $BR(B_s \rightarrow \phi\, \mu^+\mu^-) < 4.1\times10^{-6}$ @ 95% C.L. hep-ex/0604015

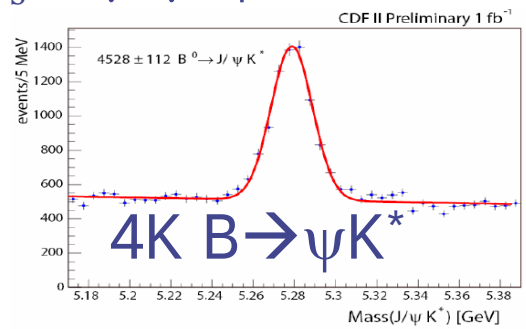
x10
improvement
w.r.t previous limit

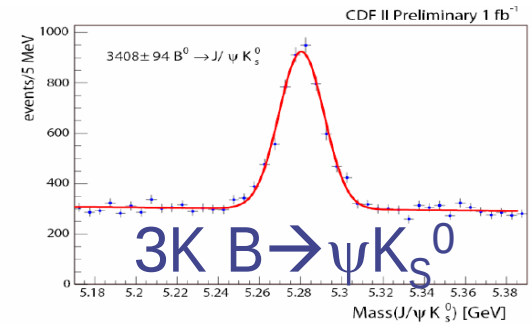


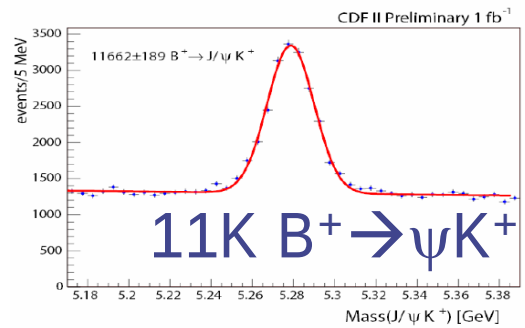
CDF: B-FCNCs

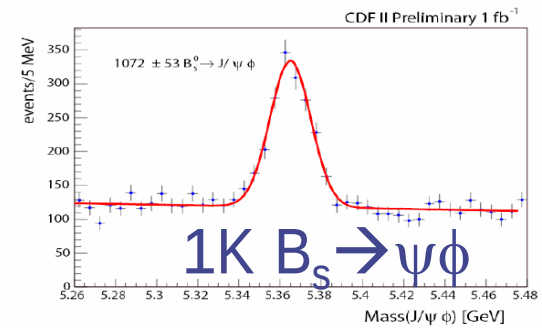
- Use $H_b \rightarrow J/\psi h$ mode as normalization for corresponding to $H_b \rightarrow \mu^+\mu^- h$
  - $B^+ \rightarrow J/\psi K^+$ is used for $B_{s(d)} \rightarrow \mu^+\mu^-$
- Results are available for $B_{s(d)} \rightarrow \mu^+\mu^-$ only
- (With some guess): for $B \rightarrow \mu^+\mu^- h$ expect yields comparable to B-factories and sensitivity to $B_s \rightarrow \mu^+\mu^-\phi$





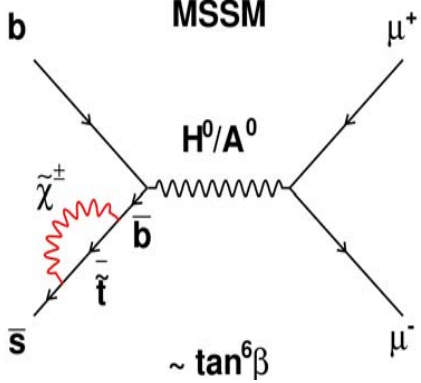






- The yield plots are rough estimates of normalization signal available for analyses
  - Actually optimized for lifetime analysis .. Actual numbers for this analysis can be different

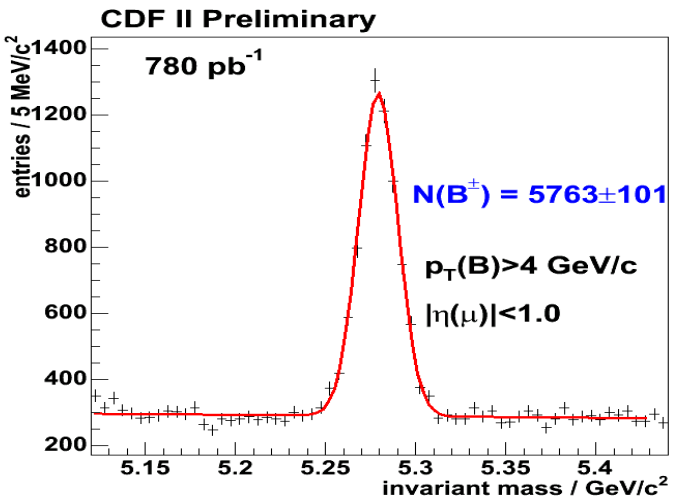
$B_{s(d)} \rightarrow \mu^+\mu^-$ Search

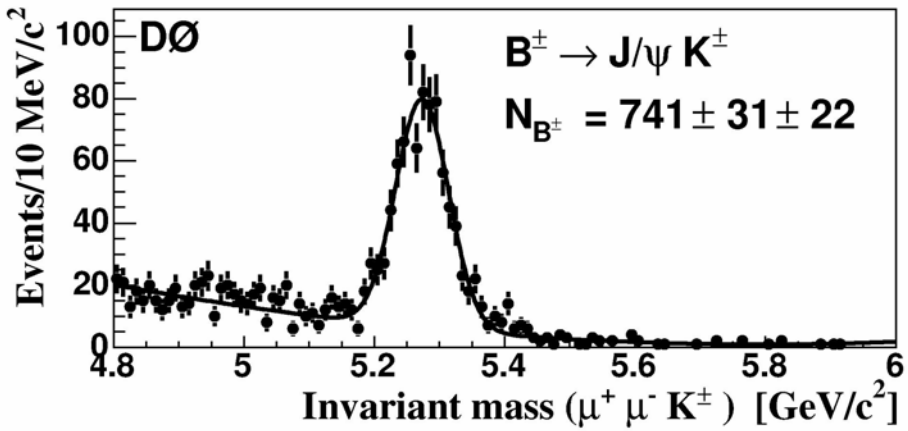


- Still not observed:
  - $B_{SM}(B_s \rightarrow \mu^+\mu^-) \sim 5\times10^{-9}$ cf $B_{exp} < 1.5\times10^{-7}$ @95% CL
  - $B_{SM}(B_d \rightarrow \mu^+\mu^-) \sim 1\times10^{-10}$ cf $B_{exp} < 4.0\times10^{-8}$ @95% CL
- Normalize to $B+ \rightarrow J/\psi\ K^+$ decays

- Construct discriminant to select Bs signal and suppress bgd
- MC simulation for signal and mass sidebands for bgd estimate
- Optimize on minimum expected 90% C.L. upper limit (95% CL for DØ)

Normalization mode

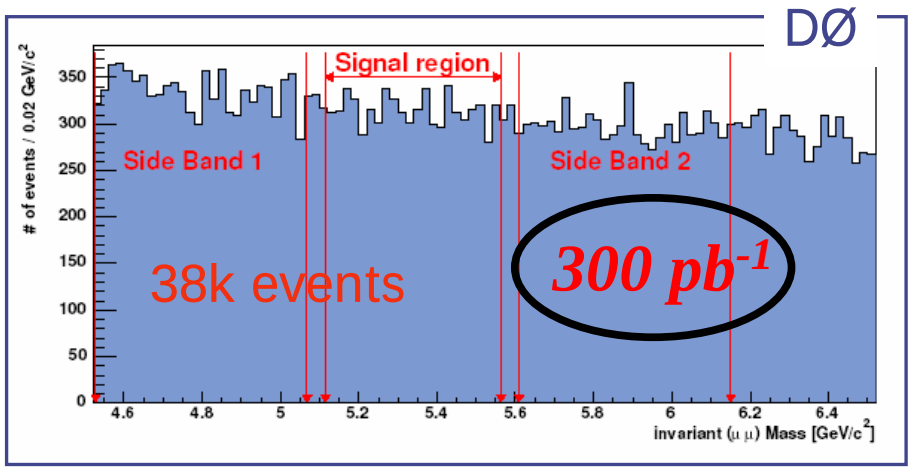


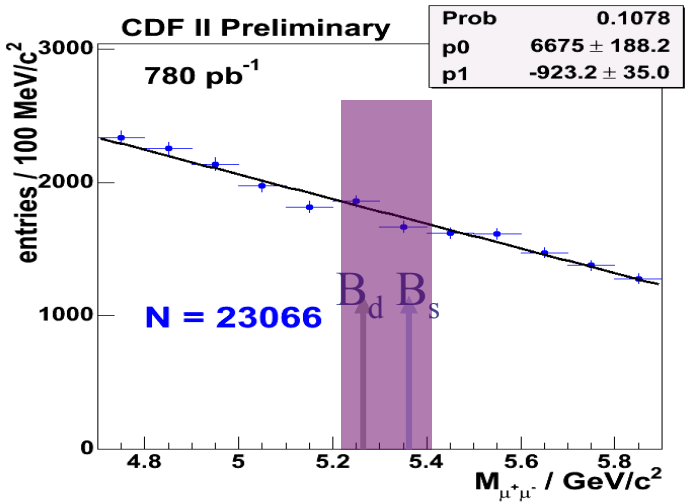


$B_{s(d)} \rightarrow \mu^+\mu^-$ pre-selection

- **Pre-selection DØ:**
  - $4.5 < m_{\mu\mu} < 7.0$ GeV/c^2
  - $p_T(\mu)>2.5$ GeV/c
  - $|\eta(\mu)| < 2$
  - $p_T(B_s$ cand.$)>5.0$ GeV/c
  - good vertex

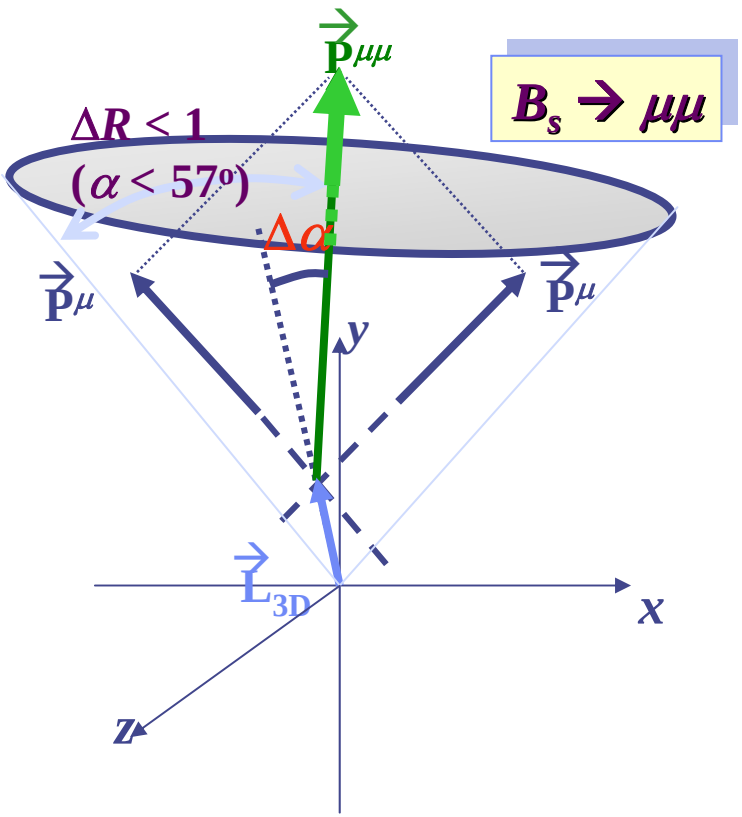
- **Preselection CDF:**
  - $4.669 < m_{\mu\mu} < 5.969$ GeV/c^2
  - $p_T(\mu)>2.0$ GeV/c
  - $p_T(B_s$ cand.$)>4.0$ GeV/c
  - $|\eta(B_s)| < 1$
  - good vertex, displaced in 3D by 2σ





Potential sources of background:
- continuum $\mu\mu$ Drell-Yan
- sequential semi-leptonic b->c->s decays
- double semi-leptonic bb-> $\mu\mu$X
- b/c->μx+fake, fake + fake

CDF: $B_{s(d)} \rightarrow \mu^+\mu^-$ Signal vs. Bgd Discrimination



- $\mu^+\mu^-$ mass, M
- Proper decay-length (λ):

$$\lambda = \frac{cL_{3D}M}{|\vec{p}(B)|}$$

- Isolation (Iso):

$$Iso = \frac{p_T(B)}{p_T(B) + \sum_i p_T^i(\Delta R_i < 1)}$$

(fraction of p_T from $B \rightarrow \mu\mu$ within $\Delta R = (\Delta\eta^2 + \Delta\phi^2)^{1/2}$ cone of 1)

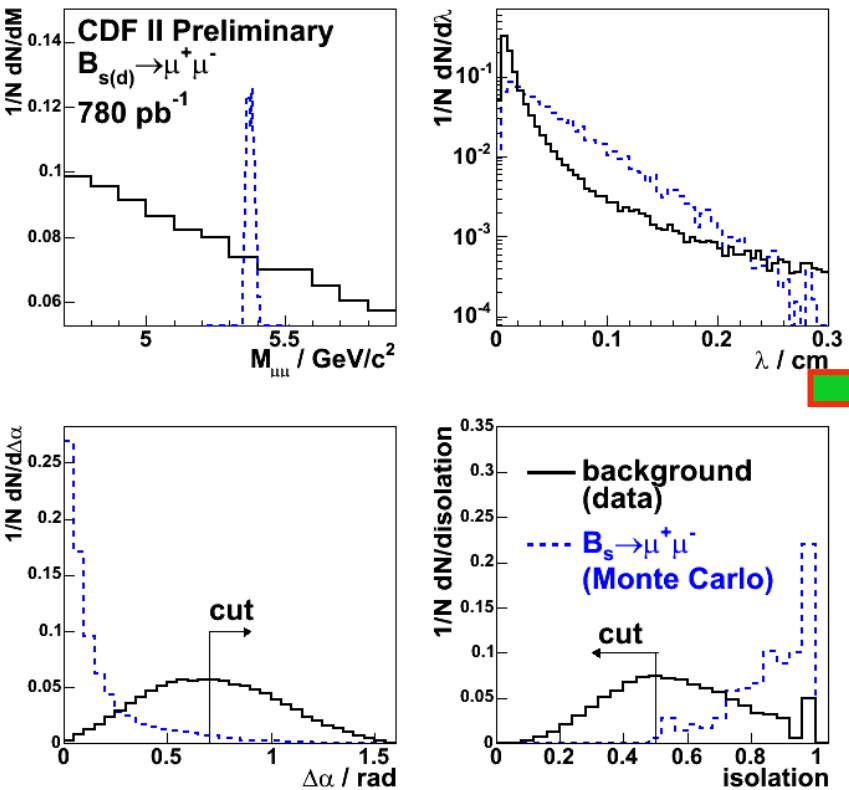
- "pointing ($\Delta\alpha$)": $\Delta\alpha = \angle(\vec{p}(B) - \vec{L}_{3D})$

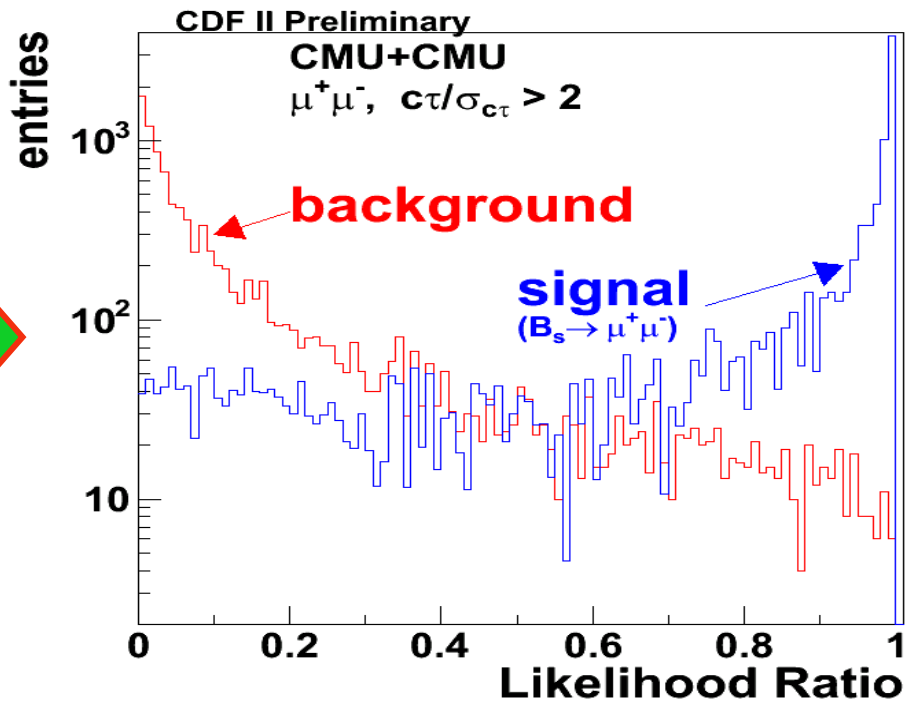
(3D angle between B_s momentum and decay axis)

CDF: $B_{s(d)} \rightarrow \mu^+\mu^-$ Signal vs. Bgd Discrimination

- Construct Likelihood discriminant
  - Mass not in the likelihood

$$LH = \frac{\prod_i P_s(x_i)}{\prod_i P_s(x_i) + \prod_i P_b(x_i)}$$

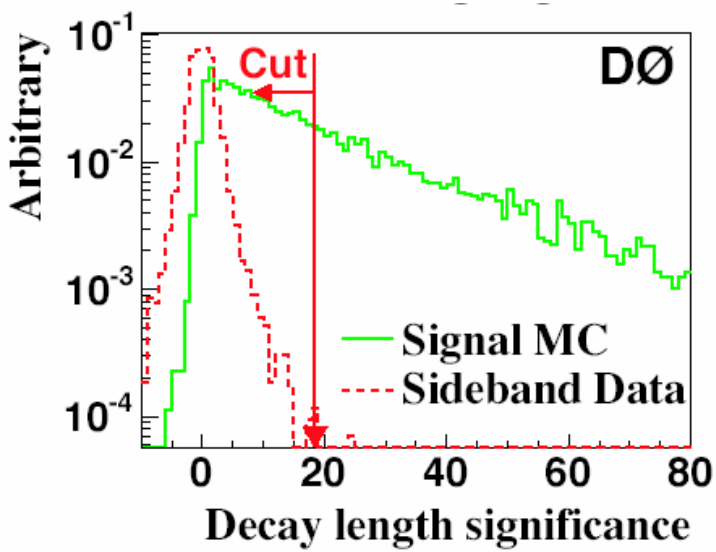


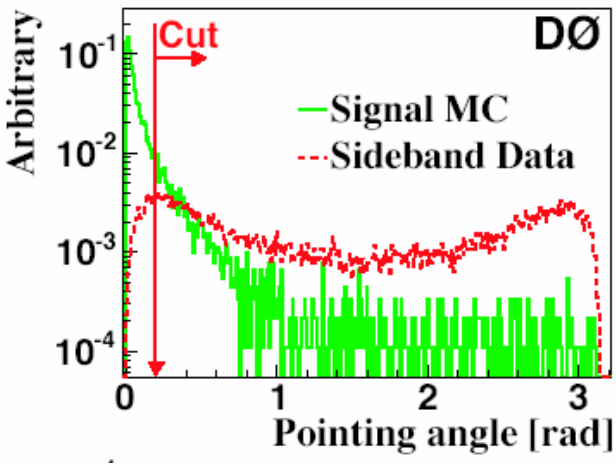


- **Optimal cut: LH>0.99**

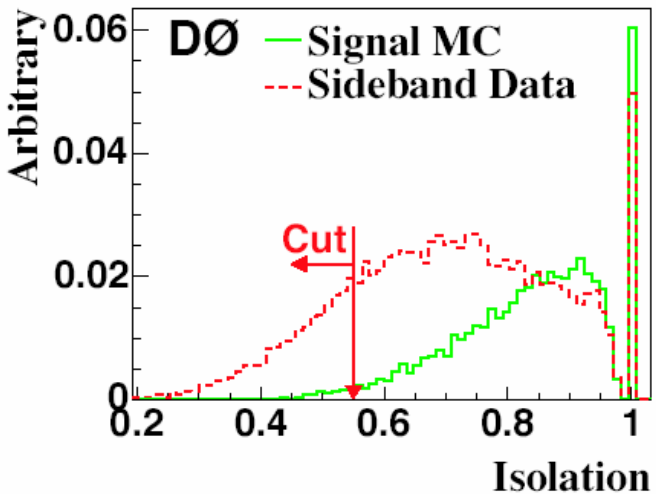
DØ: $B_s \rightarrow \mu^+\mu^-$ optimization

- optimize cuts using:
  - angle between $p(\mu^+\mu^-)$ and L_{xy} vectors (pointing consistency)
  - transverse decay length significance $L_{xy}/\sigma(L_{xy})$
  - isolation in cone around B_s candidate





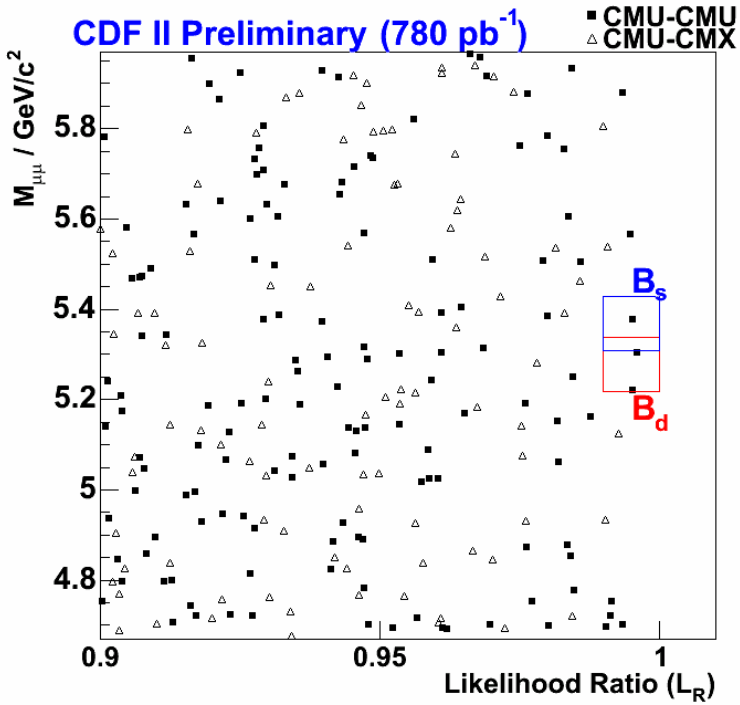
- Random Grid Search
- maximize $\varepsilon/(1.+\sqrt{B})$



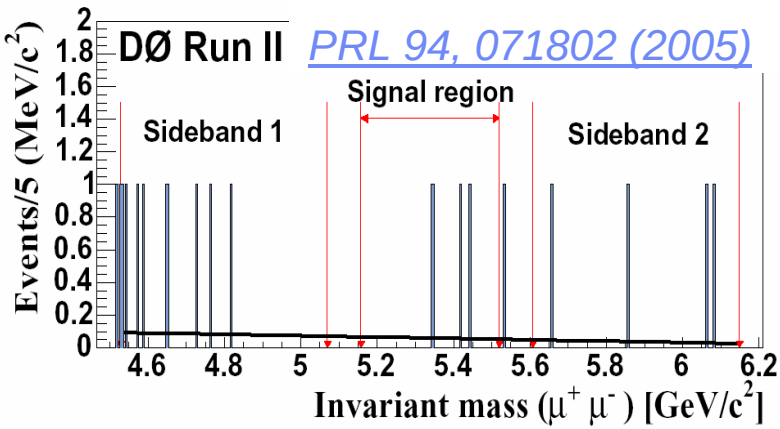
$B_{s(d)} \rightarrow \mu^+\mu^-$ results

- CDF (780 pb^{-1}):
  - $\langle BR^{90\%\ CL} \rangle = 9.1\times10^{-8}$
  - B_s $N_{bg}=[1.1\pm0.4]_{comb}+[0.2\pm0.06]_{B\rightarrow hh}$
  - B_d $N_{bg}=[1.1\pm0.4]_{comb}+[1.4\pm0.2]_{B\rightarrow hh}$
  - Observe
  - $N_{Bs}=1 \rightarrow Br(B_s\rightarrow\mu\mu) <$ **1.0×10^{-7}@ 95% CL**
  - $N_{Bd}=2 \rightarrow Br(B_d\rightarrow\mu\mu) <$ **3.0×10^{-8}@ 95% CL**

Both CDF B_s and B_d results are ~×2 better than the previous result



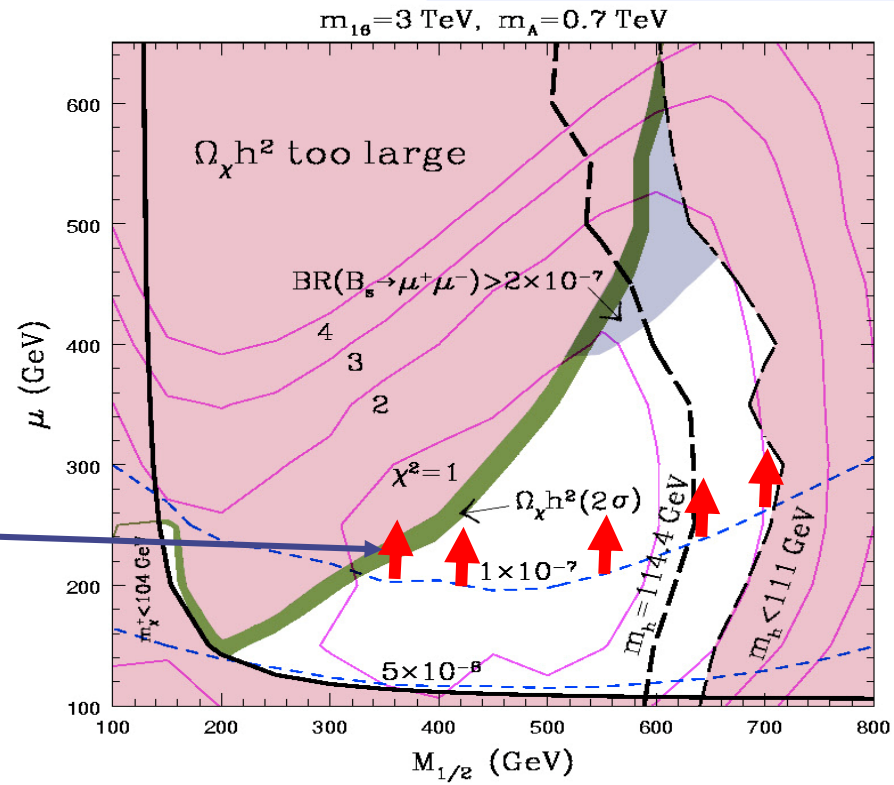
- DØ (300 pb^{-1}):
  - observe 4, expect 4.3 ± 1.2
  - DØ mass resolution is not sufficient to separate B_s from B_d. Assume no B_d contribution.
  - $\rightarrow Br(B_s\rightarrow\mu\mu) < 4.0\times10^{-7}$ **@ 95% CL**
- DØ (1 fb^{-1}) work in progress:
  - Expect $Br(B_s\rightarrow\mu\mu) <$ **2.3×10^{-7}@ 95% CL**



$B_{s(d)} \rightarrow \mu^+\mu^-$ in SO(10) Grand Unification Model

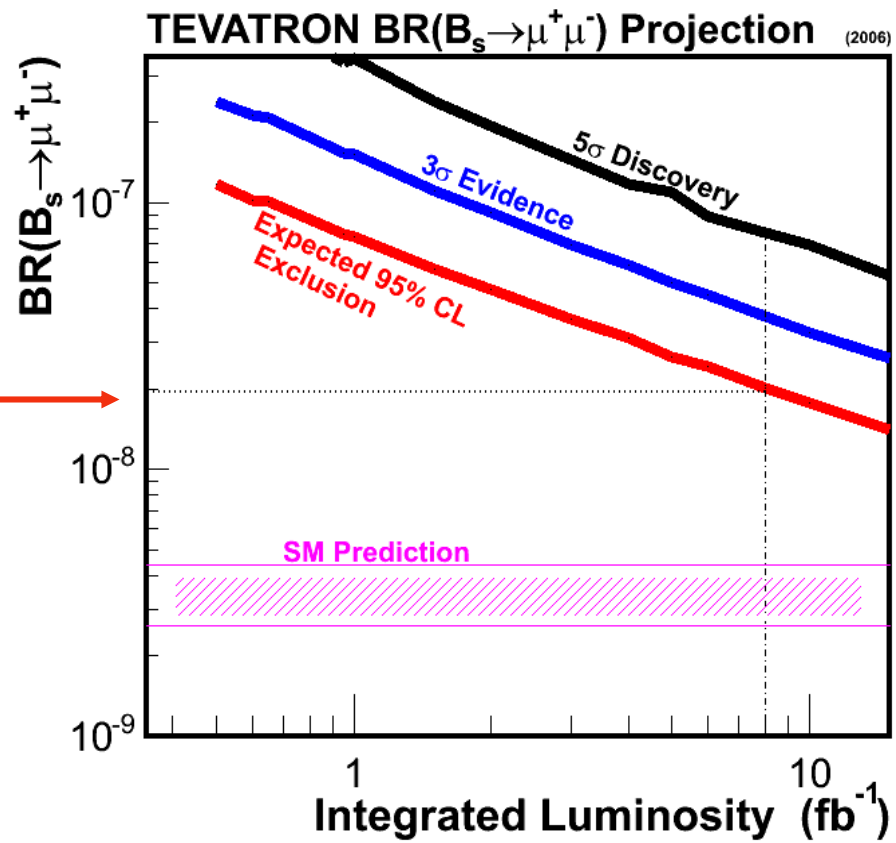
R. Dermisek *et al.*, hep-ph/0507233 (2005)

- This model is especially sensitive to $Br(B_s \rightarrow \mu\mu)$
- With Yukawa unification $\tan\beta \sim 50$
  - → $Br(Bs \rightarrow \mu\mu)$ is naturally enhanced
- Model allows massive neutrinos
- Consistent with WMAP (Green)
- Excluded by theory/experiments (pink)
- Excluded by old $Bs \rightarrow \mu\mu$ analysis (light blue)
- **Red arrows indicate exclusion from our new result!!!**
  - **Result ~ M_A>0.65 TeV**
- Remaining white region is allowed



Projected Sensitivity to $B_{s(d)} \rightarrow \mu^+\mu^-$

- At Tevatron Run II: expect to go as low as $Br[B_s \rightarrow \mu^+\mu^-] \sim 1\text{-}2 \times 10^{-8}$
  - Projection based on current sensitivity
- No sensitivity to SM level branching ratio



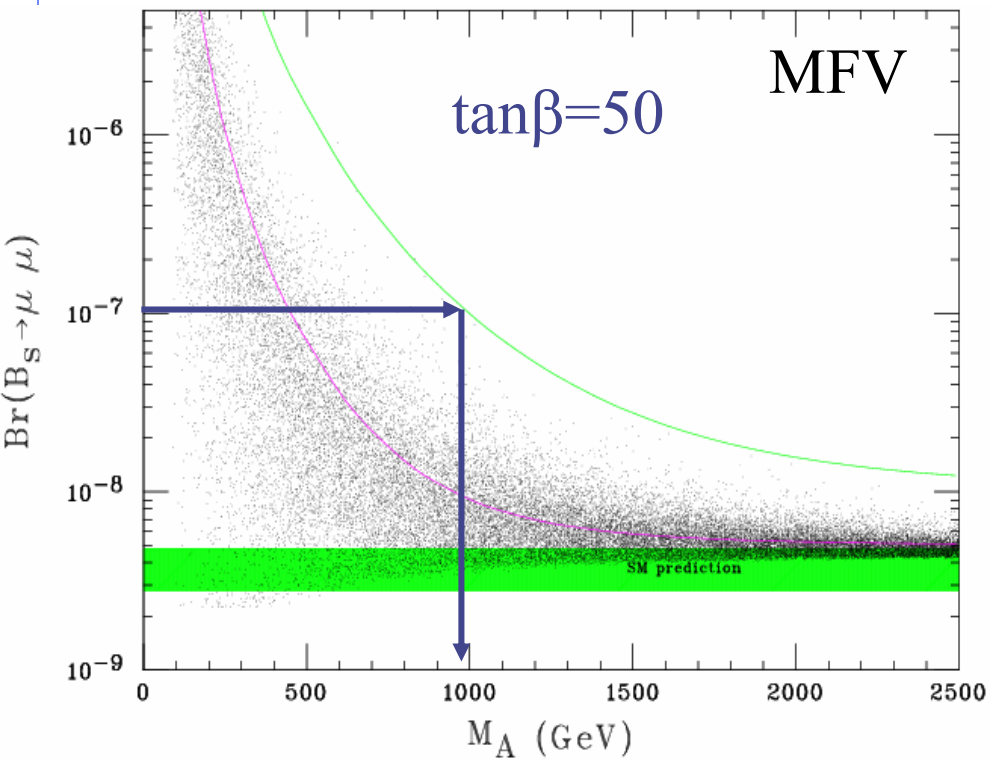
- CMS/ATLAS have a potential to measure $B_s \rightarrow \mu^+\mu^-$ at SM level with a couple of years of data [e.g. hep-ex/0509009]

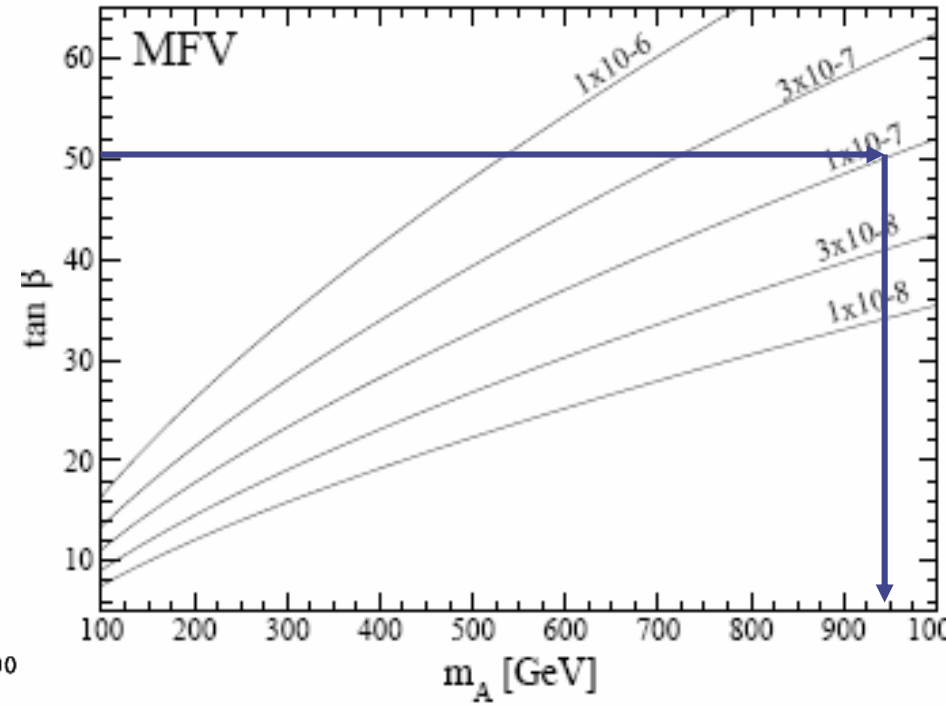
MSSM

- It is possible to constrain m_A or/and $\tan\beta$ given an **observation** of $B_s \rightarrow \mu\mu$
  - using $BR(B_s \rightarrow \mu\mu) \sim \tan^6\beta / m_A^4$

Dedes, Huffman
PLB600 (2004) 261

Kane, Kolda, Lannon
hep-ph/0310042





- Given Minimal Flavor Violation ↔ flavor change from CKM only
  - Substantial enhancement is possible in non-MFV case

Summary

- CDF and DØ provide new insights into the Rare decays with world best results

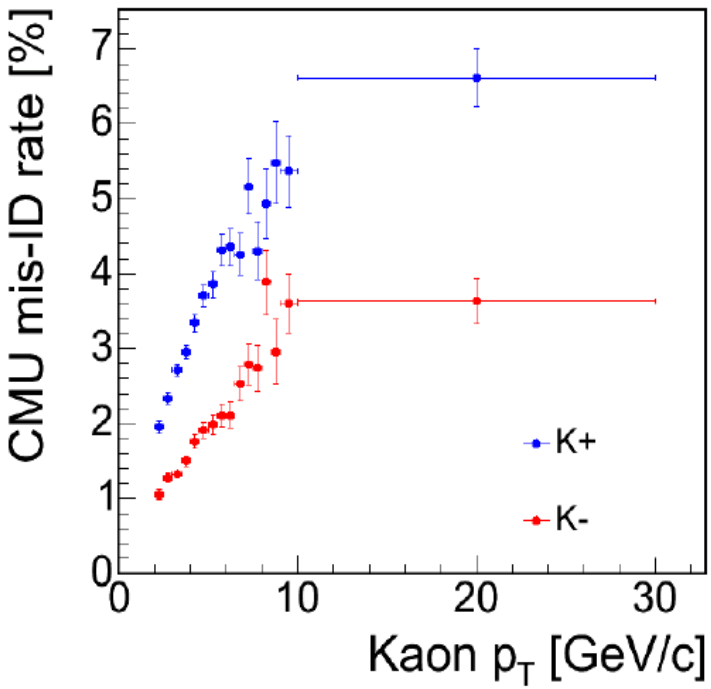
- $Br(B_s \rightarrow \mu\mu) < 8 \times 10^{-8}$ at 90% C.L. (CDF 780 pb^{-1})
- $Br(B_d \rightarrow \mu\mu) < 2.3 \times 10^{-8}$ at 90% C.L. (CDF 780 pb^{-1})
  - Prospect for $Br(B_s \rightarrow \mu\mu) \sim 1\text{-}2 \times 10^{-8}$ in Run II still holds
    - Vital for large tanβ supersymmetry
- $Br(B_s \rightarrow \mu\mu\phi) < 4.1 \times 10^{-6}$ at 95% C.L. (DØ 0.45 fb^{-1}) hep-ex/0604015

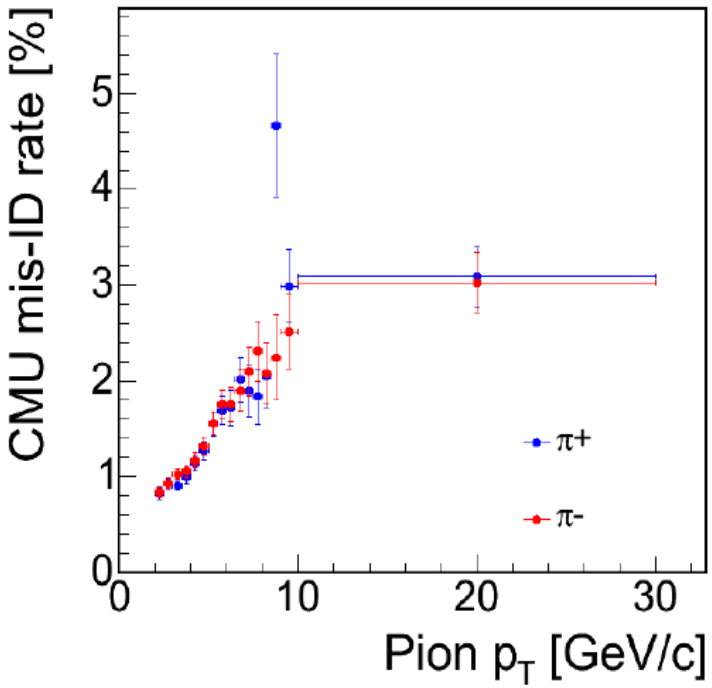
- $Br(D \rightarrow \mu\mu) < 2.4 \times 10^{-6}$ at 90% C.L. (CDF 69 pb^{-1}) PRD 68, 091101 2003
  - superseded by BaBar
- $Br(D^+ \rightarrow \mu\mu\pi^+) < 4.7 \times 10^{-6}$ at 90% C.L. (DØ 1 fb^{-1})
- $Br(D^+ \rightarrow \phi\pi^+ \rightarrow \mu\mu\pi^+) = (1.75 \pm 0.7 \pm 0.5) \times 10^{-6}$ at 90% C.L. (DØ 1 fb^{-1})

BACKUP SLIDES

CDF: Fake rates K,π→μ

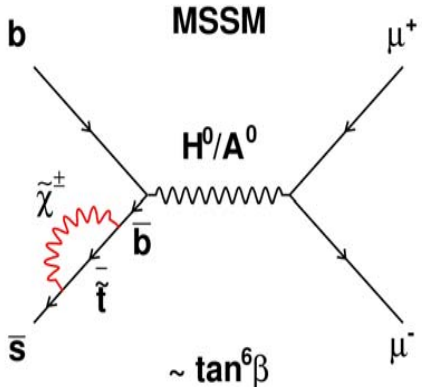
- The rates are measured from $D^* \to \pi\, D(K\pi)$ sample
- Fake rates are essential for rare D-decays
  - Less so for rare B-decays due to smaller B→hh Bratios [~ $(V_{cb}/V_{cs})^2$~0.01 suppression]
    - Can become essential for B→μμ due to its small value and good exp sensitivity





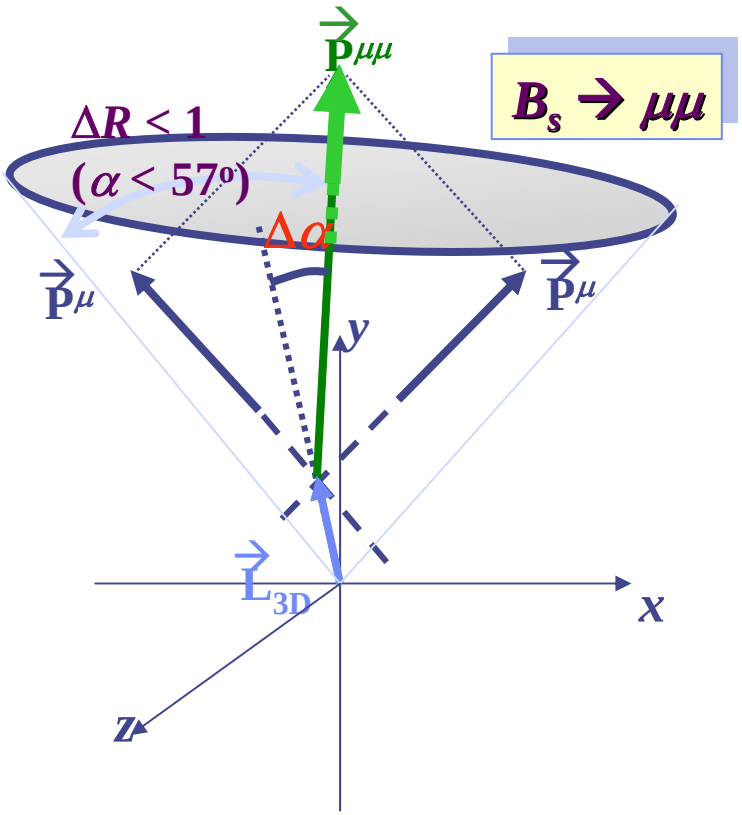
Rare B-decays

- FCNCs
  - $B_{s(d)} \rightarrow \mu^+\mu^-$, ee
  - $(B/B_s/B+/\Lambda_b) \rightarrow l^+l^-h$
- (FCNC^2, LFV,LNV, etc) $B_x \rightarrow ll^{(')}(h)$



- In SUSY/2HDM
  - With the available experimental sensitivity, dimuons are in a sweet spot to probe (heavy) Higgs sector
    - Electrons don't couple as strong, taus are too elusive
- Bratio measurement becomes a "precision" challenge for $H_b \rightarrow \mu\mu h$
  - $\rightarrow$Need to measure shapes [(a)symmetries] to probe for NP
- $B_s \rightarrow \mu^+\mu^-$ is a powerful for large tanβ SUSY and models with scalar exchange
  - Due to the helicity suppression in SM, NP scalar exchange can become noticeable
  - Combined with trilepton mode at low tanβ can restrict SUSY a lot
  - The mode is becoming golden
    - numerous theory papers
    - One of the leading (by citation) analyses at CDF and D0

$B_{s(d)} \rightarrow \mu^+\mu^-$ Signal vs. Bgd Discrimination



- $\mu+\mu-$ mass, M: $|M-M_B|<60$ MeV/c^2 (2.5σ)

sidebands: 2×0.5 GeV/c^2 on the sides

signal: $|M-5279|<60$ MeV/c^2 (B_d^0) or $|M-5279|<60$ MeV/c^2 (B_s^0)

- Proper decay-length (λ): $$\lambda = \frac{cL_{3D}M}{|\vec{p}(B)|}$$

- Isolation (Iso):

$$Iso = \frac{p_T(B)}{p_T(B) + \sum_i p_T^i(\Delta R_i < 1)}$$

(fraction of p_T from $B \rightarrow \mu\mu$ within $\Delta R=(\Delta\eta^2+\Delta\phi^2)^{1/2}$ cone of 1)

- "pointing ($\Delta\alpha$)": $$\Delta\alpha = \angle(\vec{p}(B) - \vec{L}_{3D})$$

(3D angle between B_s momentum and decay axis)

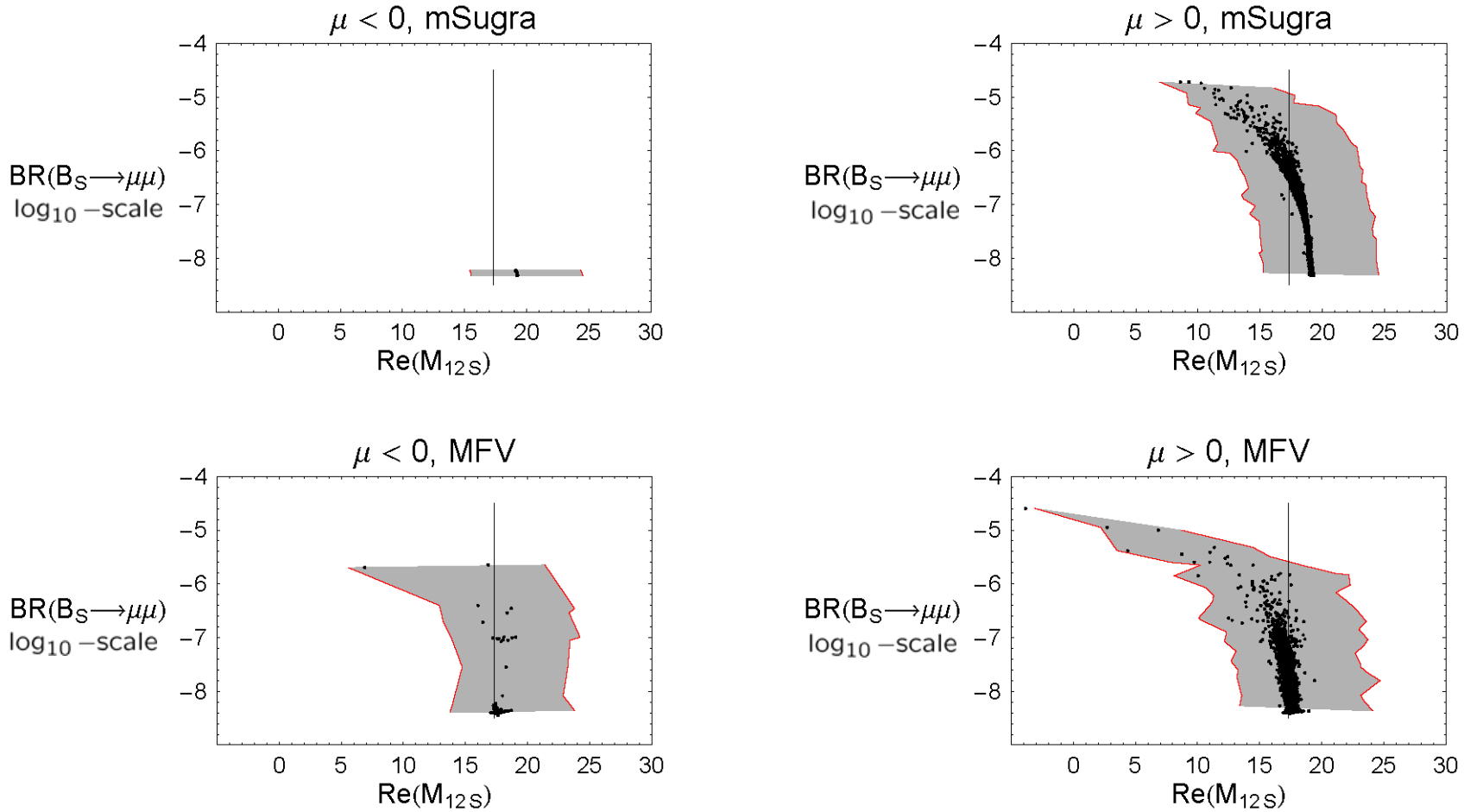
B→hh Contribution Summary

Mode	Br (10^{-6})	<Nbkg> in Bs Window CMU-CMU	<Nbkg> in Bs Window CMU-CMX	<Nbkg> in Bd Window CMU-CMU	<Nbkg> in Bd Window CMU-CMX
$B_d \to \pi\pi$	5.5±0.4	0.007±0.002	0.0013±0.0004	0.081±0.015	0.014±0.004
$B_d \to K\pi$	18.9±0.7	0.004±0.001	0.0008±0.0002	0.46±0.08	0.087±0.019
$B_d \to KK$	0.2±0.2	~0	~0	0.001±0.001	~0
$B_s \to \pi\pi$	7.0±7.0	0.03±0.03	0.005±0.0005	0.005±0.004	0.001±0.001
$B_s \to K\pi$	7.7±7.7	0.049±0.048	0.009±0.009	0.051±0.050	0.010±0.010
$B_s \to KK$	35.1±7.8	0.073±0.020	0.016±0.005	0.54±0.13	0.12±0.03
Total B→hh		0.16±0.06	0.03±0.01	1.14±0.16	0.23±0.04

- Total bkg = combinatoric + B→hh
- Modes with limits only (except B→Kπ) are negligible
- B→Kπ limit is near theory prediction

ΔM_{B_s} vs $B_s \to \mu\mu$

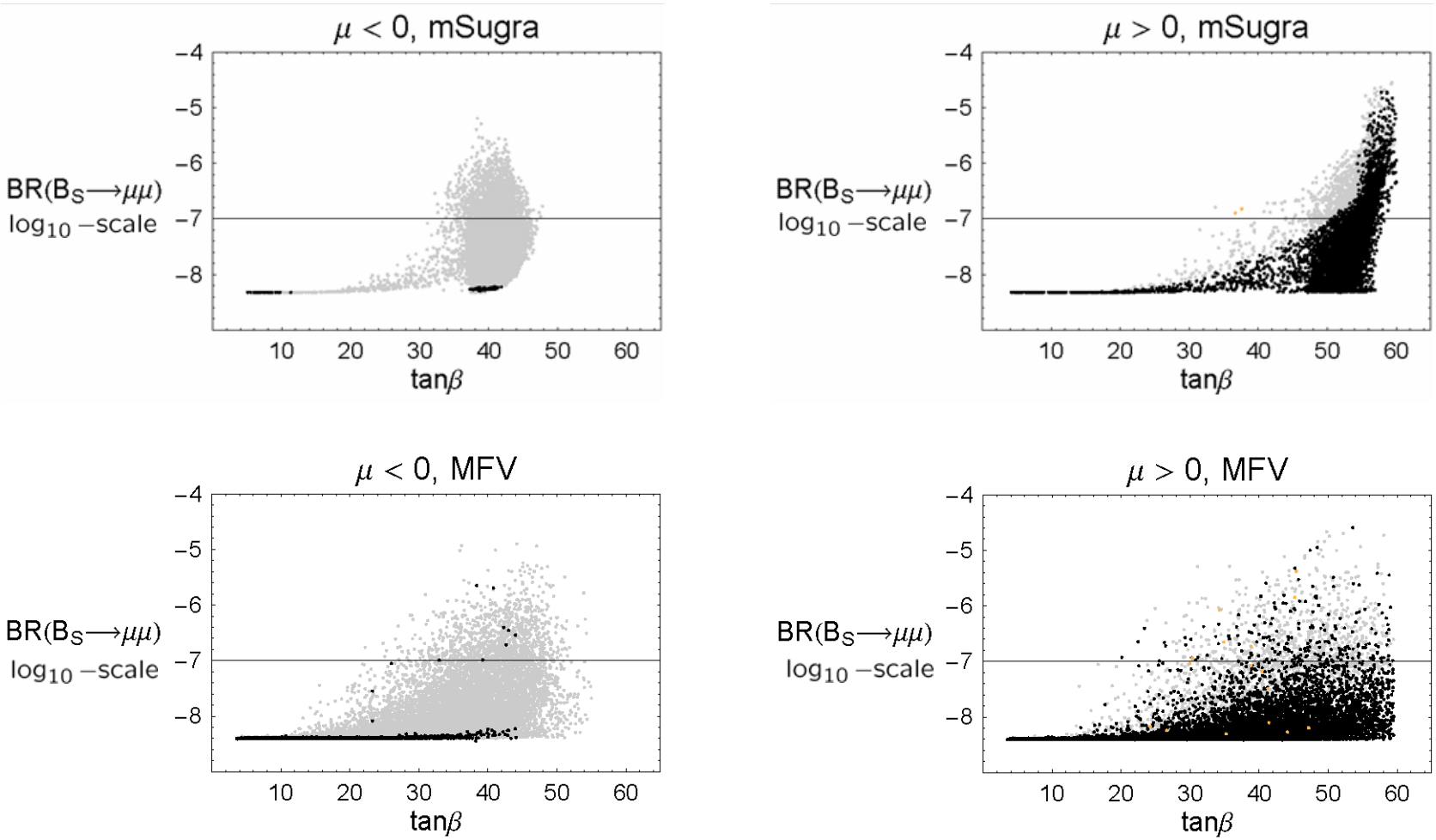
E. Lungi et al.
hep-ph/0605177



gray: theory errros on ΔM_{Bs}
line: measurement

$\tan\beta$ vs $B_s \longrightarrow \mu\mu$

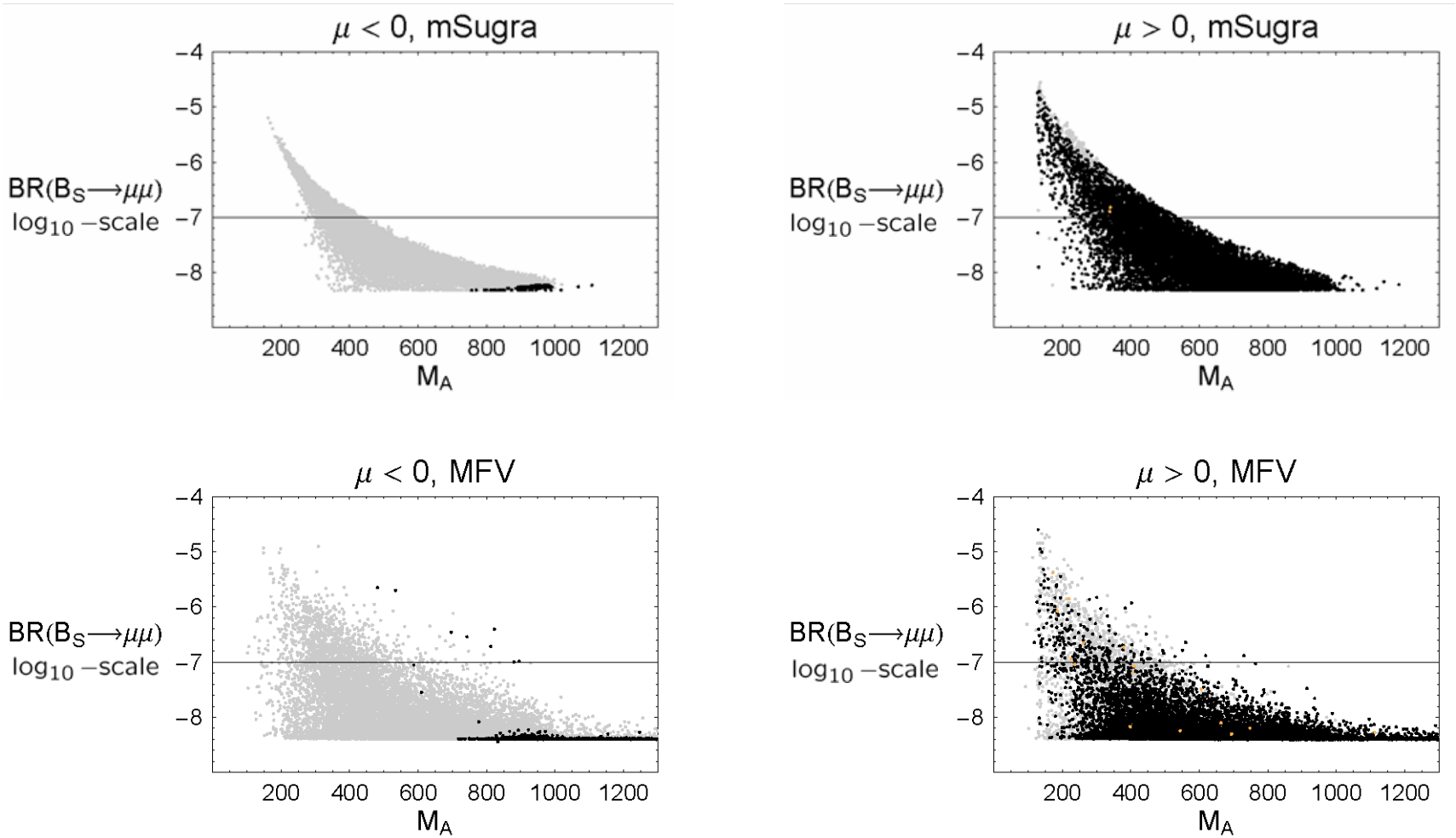
E. Lungi et al.
hep-ph/0605177



gray: excluded by FCNC data
orange: opposite sign for the b→ s γ amplitude

M_A vs $B_s \to \mu\mu$

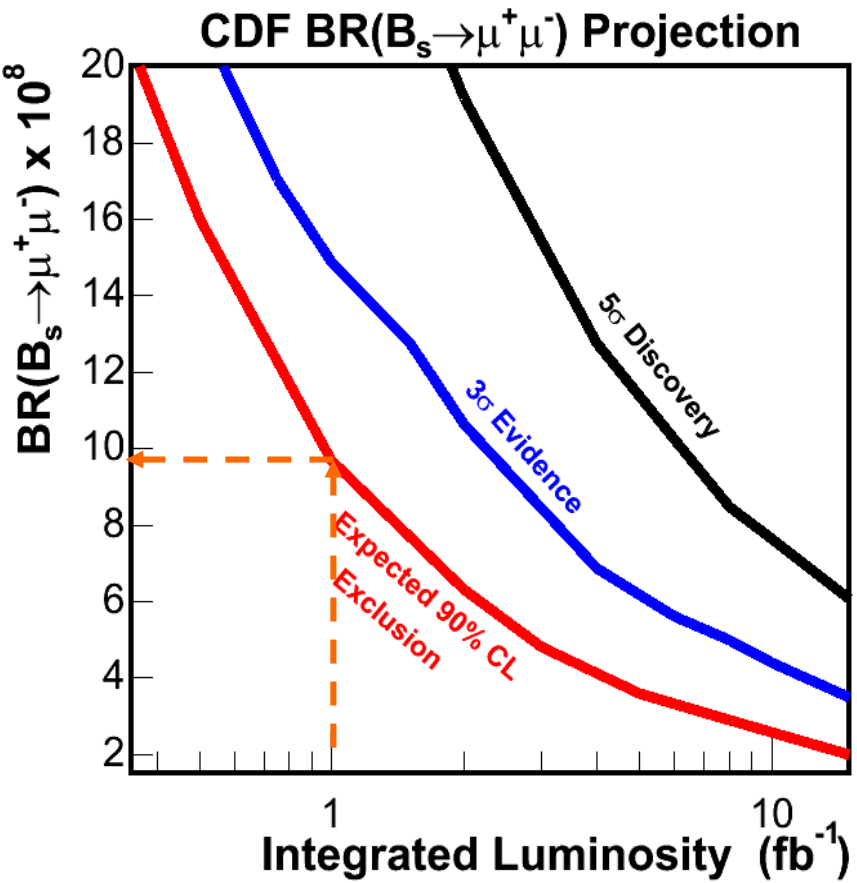
E. Lungi et al.
hep-ph/0605177



gray: excluded by FCNC data
orange: opposite sign for the b→ s γ amplitude

$B_s \rightarrow \mu\mu$ Prospects

Simplistic: no improvement to analysis
→scale N_{bg} and N_{B+} linearly with Lumi
→ recalculate
→ at best ~2×10^{-8} at 90% CL



- Optimistic:
~ 1/Lumi
  - Additional handles on bgd exist:
    tighter muon ID (require CMP)
    calorimeter isolation
    additional 2D pointing
    use mass resolution model in LH
  - Combine with D0

→BR($B_s \rightarrow \mu\mu$) ≈ 1×10^{-8} at 90% CL is possible within Run II (by 09?)

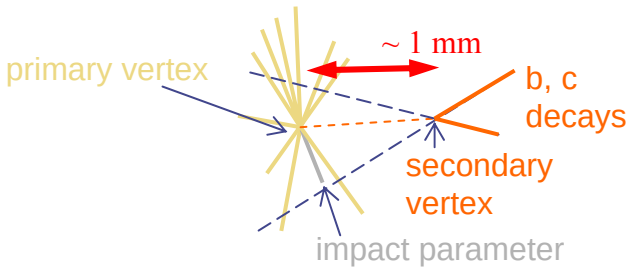
- Can be measured at SM level by CMS at LHC after 2-3 years of data taking (by 10?)

Triggers used

All are input to the various Level-3 triggers
That use the offline quality information

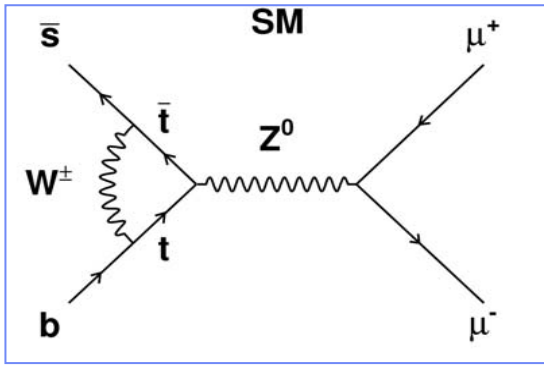
- Dimuon trigger
  - p_T>1.5GeV, |η|<0.6
    p_T>2GeV, 0.6<|η|<1
  - p_T, ϕ, muon ID used to cut on tracks
  - Used for ψ,Y,B→μμ(+X)

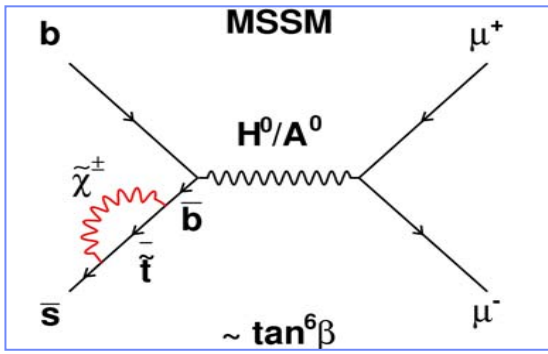
- Two Track Trigger
  - p_T>2GeV, |η|<1
  - p_T, ϕ, d_0 info used to cut on 2 tracks
  - Used for: B,D→hadrons ; D→μμ



B(D)→μμ: Theoretical motivations. Current limits.

- Flavor Changing Neutral Current. Loop contribution only in SM.
  - $Br_{SM}(B_s \to \mu^+\mu^-) = (3.4 \pm 0.5) \times 10^{-9}$
  - $Br_{SM}(B_d \to \mu^+\mu^-) = (1.00 \pm 0.14) \times 10^{-10}$ (hep-ph/0303060)
  - $Br_{SM}(D^0 \to \mu^+\mu^-) \sim 3*10^{-13}$ (GIM suppressed)
- Only upper experimental limit exists:
  - $Br_{exp}(B_s \to \mu^+\mu^-) < 2.0 \times 10^{-6}$ 90% C.L. CDF RunI @100/pb.
  - $Br_{exp}(B_d \to \mu^+\mu^-) < 1.6 \times 10^{-7}$ 90% C.L. Belle '03 @78/fb.
  - $Br_{exp}(D^0 \to \mu^+\mu^-) < 4.1(4.2)*10^{-6}$ 90% C.L. BEATRICE(E771)





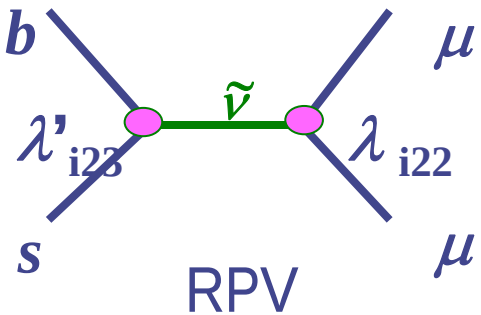
mSUGRA,SO(10)

- Limits are far away from the SM value: can test for a possible new physics.

- MSSM: $Br(B \to \mu^+\mu^-)$ enhanced by $\tan\beta > 10$ terms $\sim \tan^6\beta$. Up to 100 over the SM prediction.
- R-parity violating models give tree level contributions. Not heavily constrained by other observables.

- Can be seen in Run2 (esp. $B_s \to \mu\mu$)

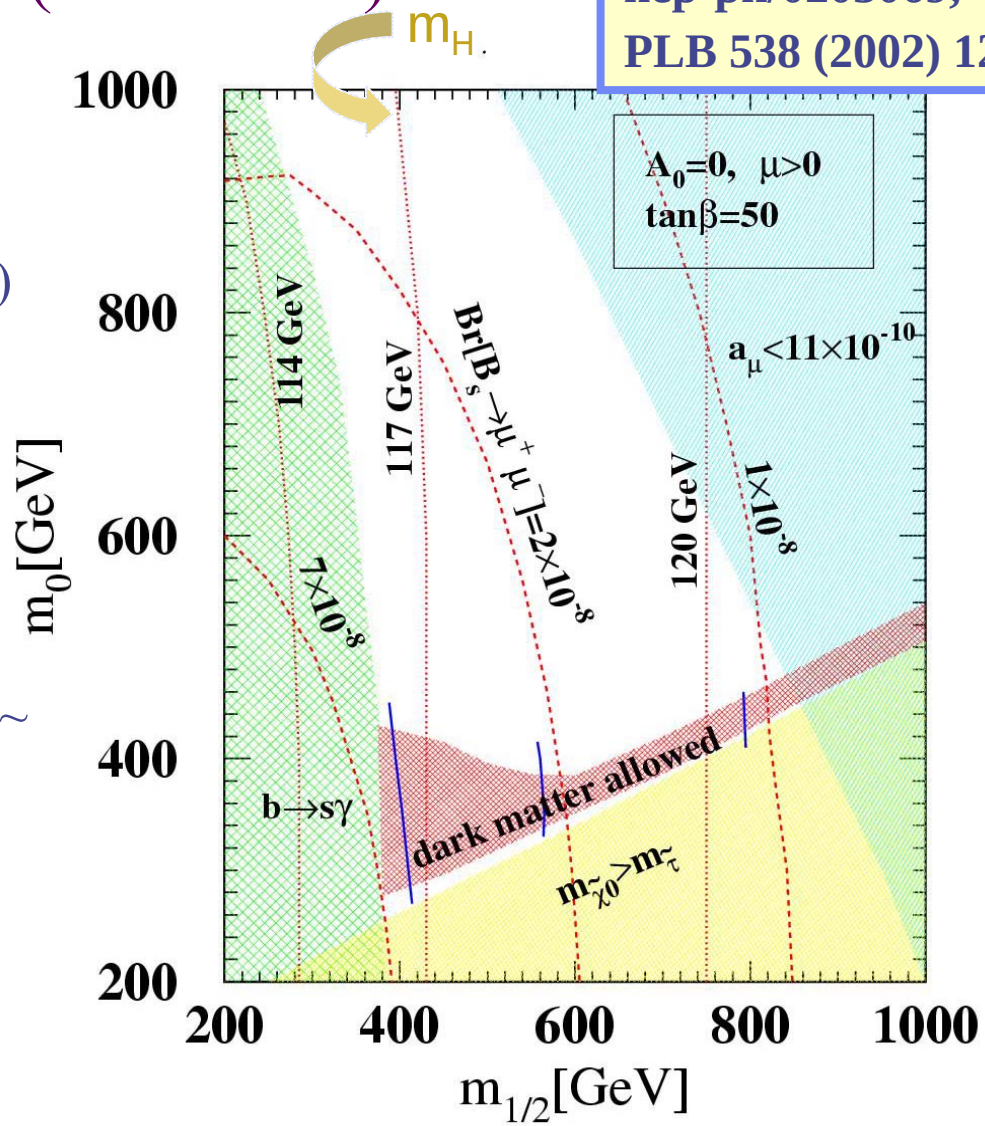
- Other models enhance less. E.g., universal extra dimensions. Up to +70% for $B_s \to \mu^+\mu^-$



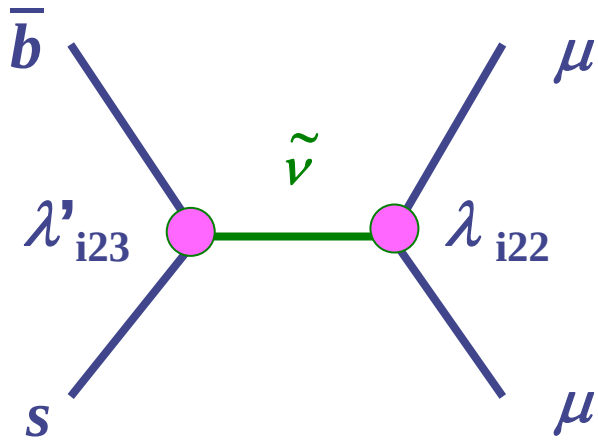
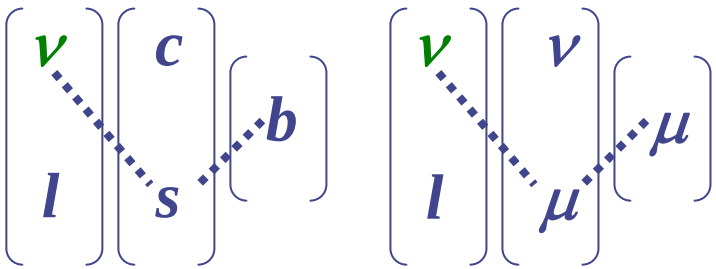
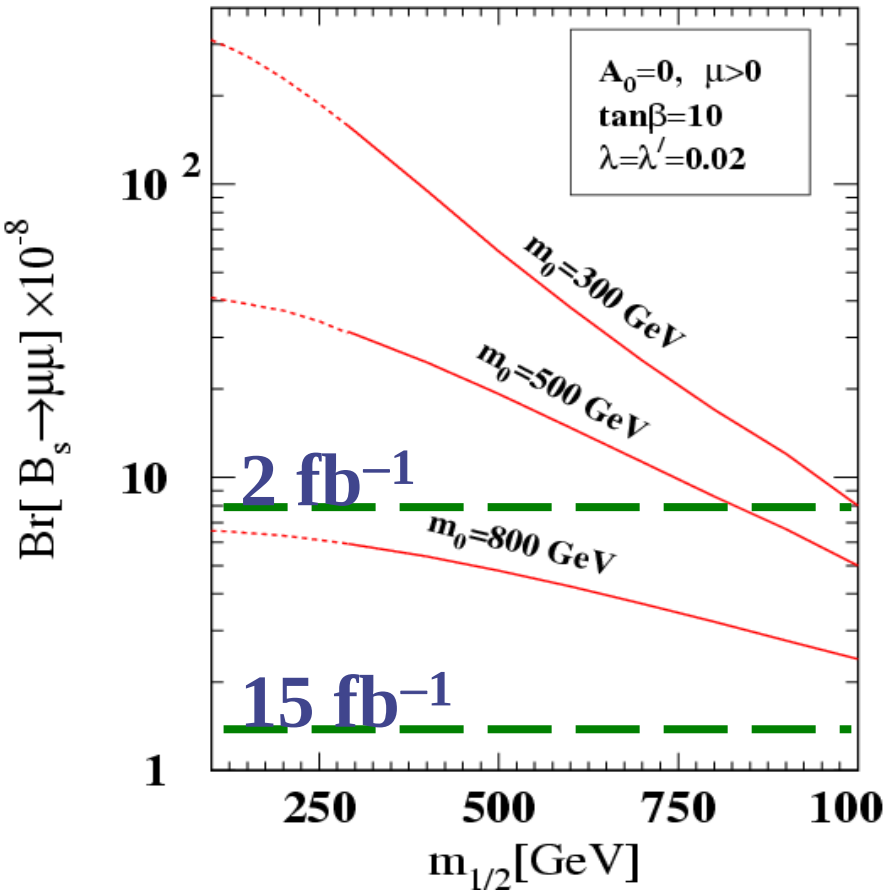
Motivations: $B_s \rightarrow \mu^+\mu^-$ (mSUGRA)

R. Arnowitt *et al.*, hep-ph/0203069, PLB 538 (2002) 121

- Overlap with measured δa_μ (BNL) in mSUGRA parameter space.
- Overlap with dark matter=LSP allowed region.
- Eliminate large parameter space (~ all for tanβ>40), with $Br(B_s \rightarrow \mu^+\mu^-) \sim 10^{-8}$ in Run2



R_P Violation: *Br* vs. $m_{1/2}$

R. Arnowitt *et al.*, hep-ph/0203069, PLB 538 (2002) 121

e.g., $W_{TRPV} = \lambda_{ijk} L_i L_j E_k + \lambda'_{ijk} L_i Q_j D_k + \lambda''_{ijk} U_i D_j D_k$