Status of Search for Rare Decays $D^0 \rightarrow \mu^+\mu$ and $B_s \rightarrow \mu^+\mu^-$ Using CDF Run2 Data

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Apr 6, 2003

APS Meeting

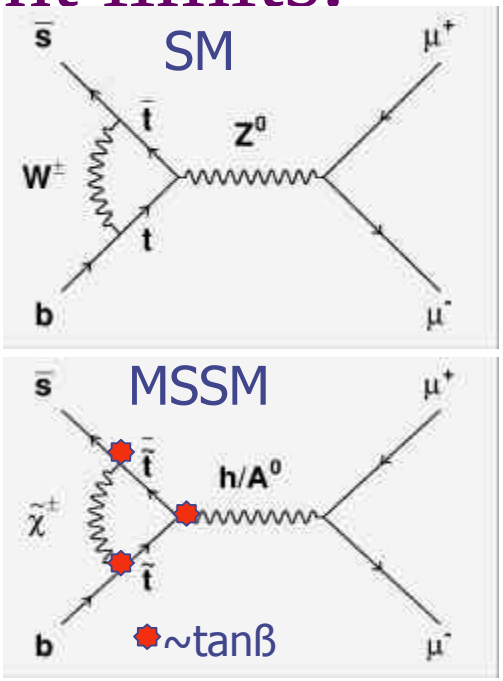
Philadelphia, PA

Outlines

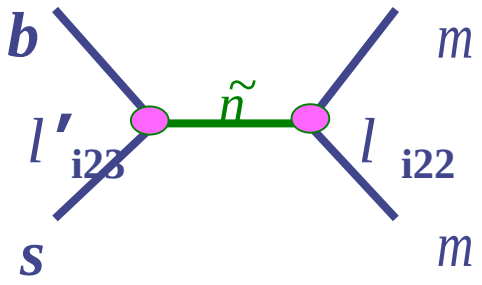
- Theoretical motivations. Existing limits
- CDF Run2
- Br($D^0 \rightarrow \mu^+\mu^-$): measurement, results.
- Br($B_s \rightarrow \mu^+\mu^-$) measurement status.
  - Signal box. Cuts.
  - Background: MC, data.
  - PR plots.
- Summary

Theoretical motivations. Current limits.

- Flavor Changing Neutral Current.
  Loop contribution only in SM.
  - $Br_{SM}(B_s \rightarrow \mu^+\mu^-)=(3.5\pm1.0)*10^{-9}$
  - $Br_{SM}(D^0 \rightarrow \mu^+\mu^-)\sim3*10^{-13}$ (GIM suppressed)
- Only upper experimental limit exists:
  - $Br_{exp}(B_s \rightarrow \mu^+\mu^-)<2.0*10^{-6}$ 90% C.L.
    CDF RunI @100/pb.
  - $Br_{exp}(D^0 \rightarrow \mu^+\mu^-)<4.1(4.2)*10^{-6}$ 90% C.L.
    BEATRICE(E771)



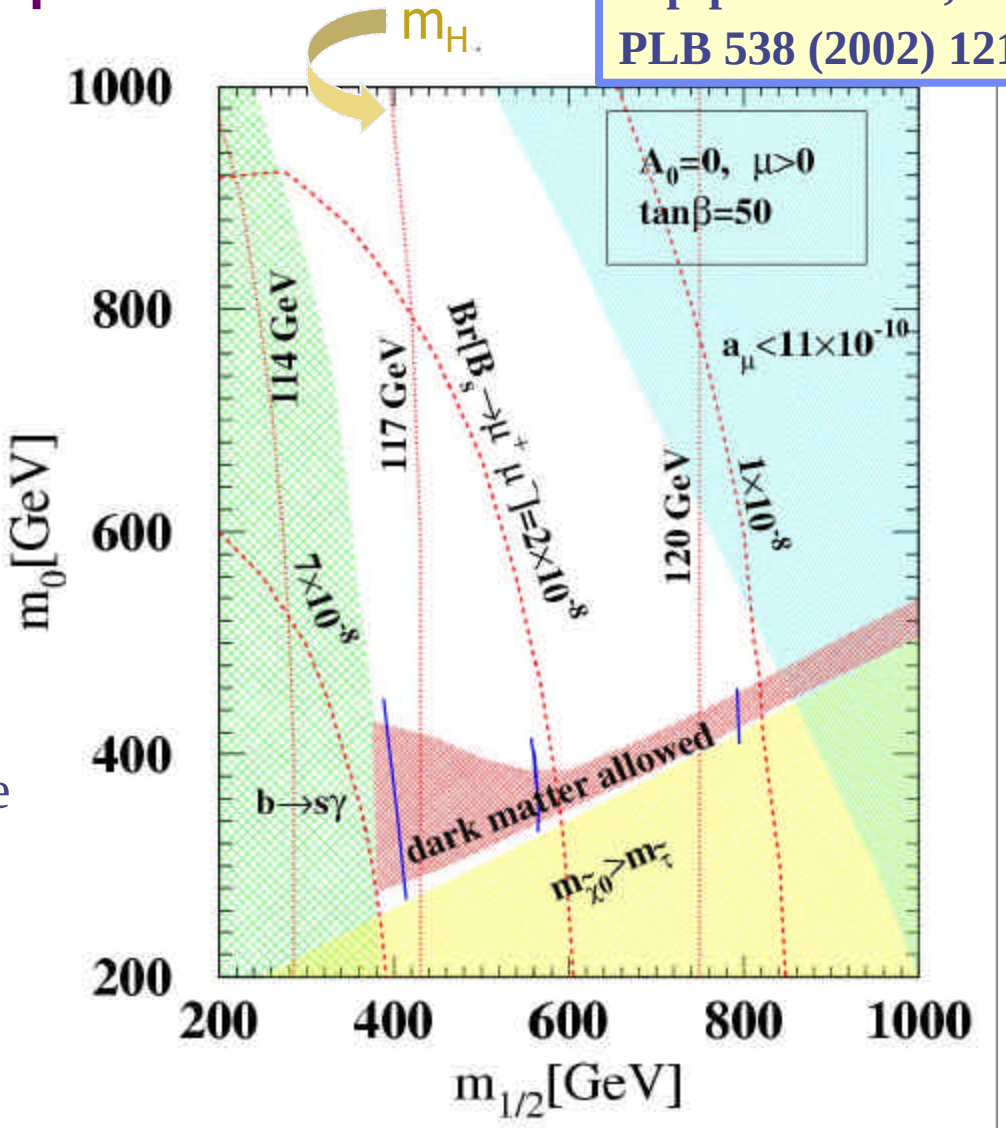
- Limits are far away from the SM value: can test for a possible new physics.
- MSSM: Br(B→μ⁺μ⁻) enhanced by tanß>10 terms ~tan⁶ß.
  Up to ~100 over the SM prediction.
  Run2 @15/fb is promising for mSUGRA.
- R-parity violating models can give tree level contributions.
  Some models can yield $Br(D^0 \rightarrow \mu^+\mu^-)\sim3.5*10^{-6}$.
- Universal extra dimensions. Up to ~+70% for $B_s \rightarrow \mu^+\mu^-$



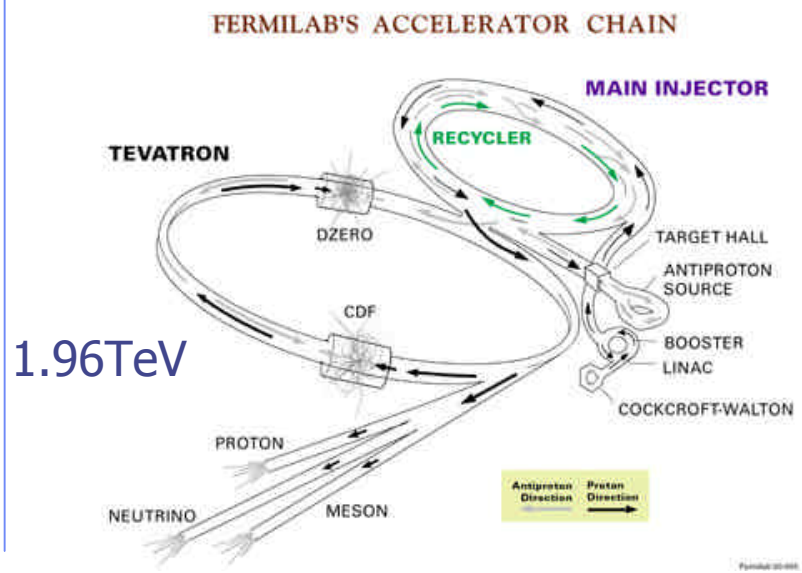
Motivations: $B_s \rightarrow \mu^+\mu^-$

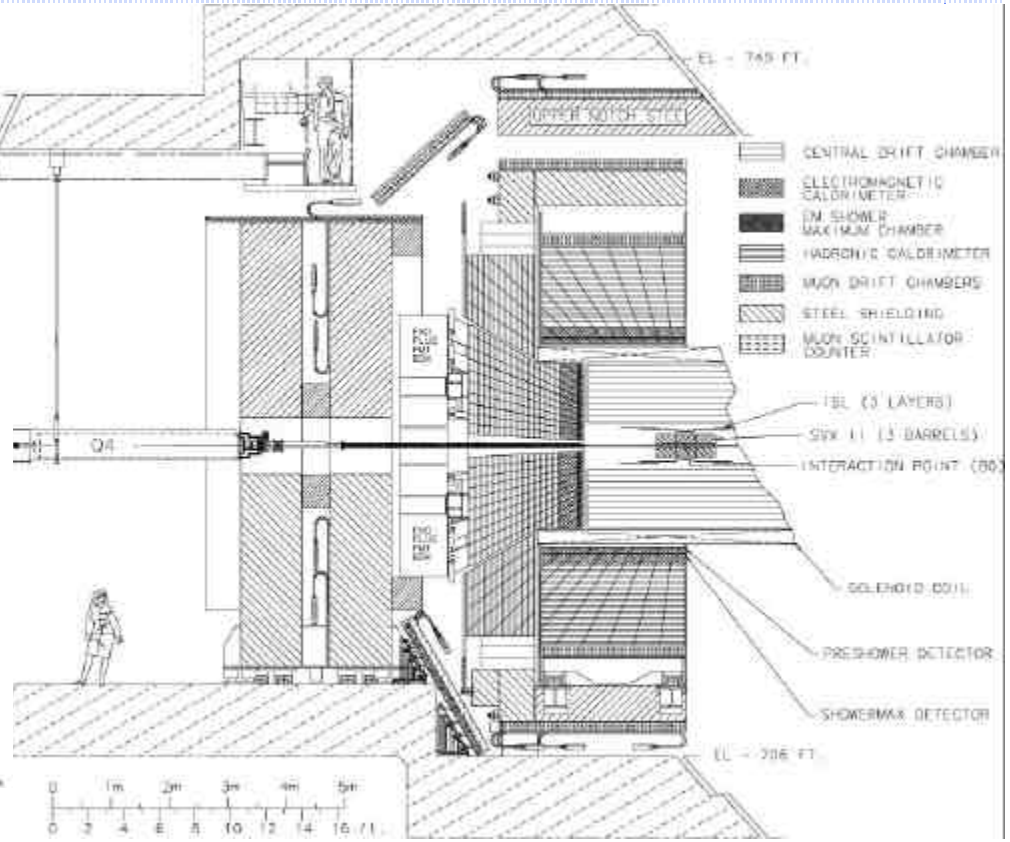
- Overlap with measured da_μ (BNL) in mSUGRA parameter space.
- Overlap with dark matter=LSP allowed region.
- Eliminate large parameter space (~ all for tanß>40), with $Br(B_s \rightarrow \mu^+\mu^-) \sim 10^{-8}$ in Run2 (15/fb)

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



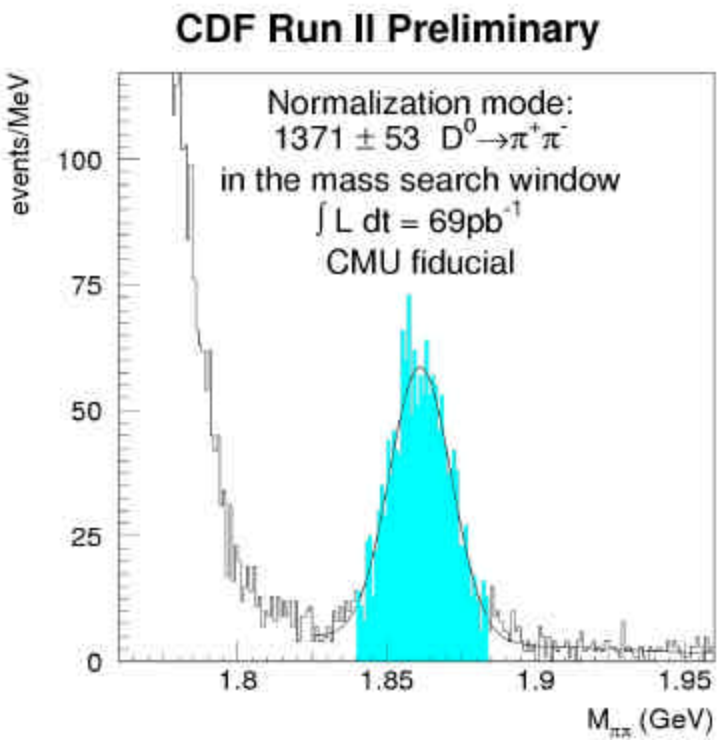
CDF Run2.





- σ(Inelastic)~60mb. L ~$4*10^{31}cm^{-2}s^{-1}$ ($60pb^{-1}$ with silicon by Jan 2003)
  - Plan: ~$8*10^{31}cm^{-2}s^{-1}$ (2/fb in Run2a); ~$2*10^{32}cm^{-2}s^{-1}$ (15/fb Run 2)
- 1.7MHz collision→16kHz L1 trigger→250Hz L2→60Hz L3/logging rate.
  - ~80% of the triggers are B physics
- Better silicon coverage (x2), better muon detection, improved tracking.
- Better triggers: lower track p_T, higher efficiency.

$D^0 \rightarrow mm$ search using CDF Run2 Data



- Use $D^{*\pm} \rightarrow D^0 p^{\pm}$ tagged events
- Use $D^0 \rightarrow pp$ as a normalization mode.
- Cuts:
  - $|d_0(\text{track}, p)| > 120$ μm, $|d_{xy}(D^0)| < 150$ μm
  - ?f (μμ)>0.085
- Background:
  - combinatorial (from right sideband) – expect 1.5±0.7
  - misidentification (punch-through) – expect $N(D^0 \rightarrow pp) * P(\text{misID})^2 \approx 0.3 \pm 0.1$

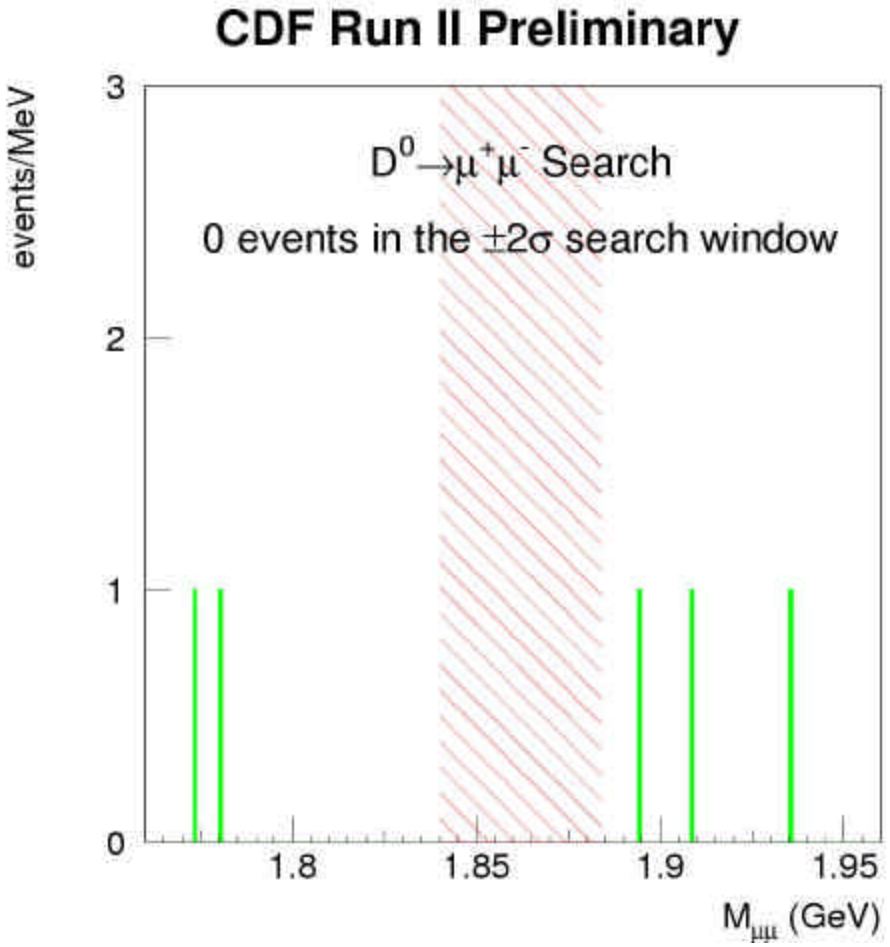
$$Br(D^0 \rightarrow mm) \leq \frac{N_{CL}(D^0 \rightarrow mm)}{N(D^0 \rightarrow pp)} \frac{\varepsilon(D^0 \rightarrow pp)}{\varepsilon(D^0 \rightarrow mm)} Br(D^0 \rightarrow pp)$$

≈ 1.012 $\approx 1.43 \cdot 10^{-3}$

$D^0 \rightarrow mm$ search using CDF Run2 Data

- Br($D^0 \rightarrow mm$)<$2.4*10^{-6}$ at 90% C.L.
- Br($D^0 \rightarrow mm$)<$3.1*10^{-6}$ at 95% C.L.

- This result improves on the existing limits by almost a factor of 2 ($4.1*10^{-6}$ from BEATRICE, and $4.2*10^{-6}$ from E771 at 90% C.L.)

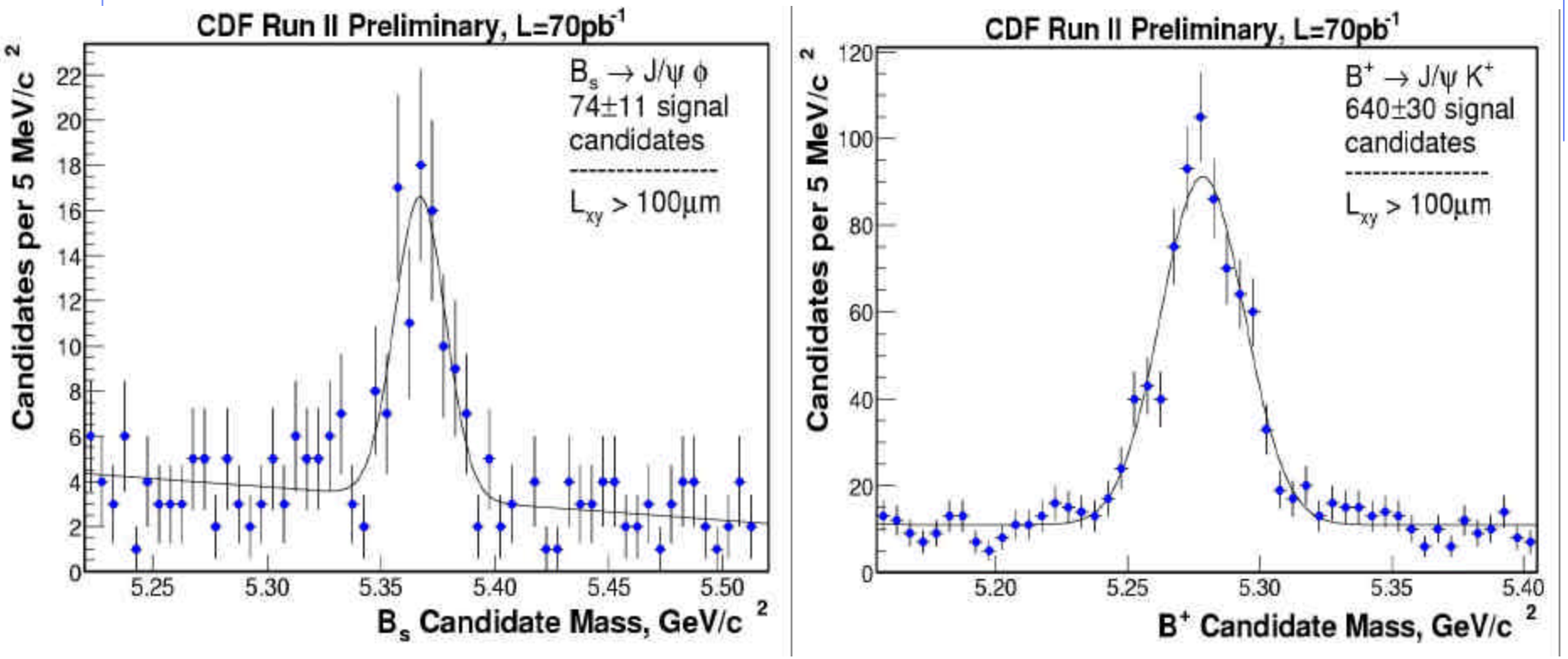


Br($B_s \to \mu^+\mu^-$) measurement: formula

$$BR(B_s^0 \to m^+m^-) = \frac{N(B_s \to m^+m^-)}{2 \cdot s_{B_s^0} \cdot \int Ldt \cdot e \cdot a}$$

- $s_{Bs} = s_{Bd}\, f_s/f_d$. Before cross section measurement is available:
  - Extrapolate from Run1: s_{Bd}=2.39 ± 0.32±0.44μb
  - use $B_d \to$ J/psiK to normalize ($B_s \to$ J/psi f is an alternative).
- a – acceptance improved ~x2 (vs 6.25% in Run1) due to the increased silicon coverage, better trigger efficiency.
- e= e(trigger)·e(reco)·e(z vtx)·e(id)·e(analysis cuts)≈0.52· e(analysis cuts)
  - analysis cuts -- choose similar to Run1 to repeat/cross check.
  - e(trigger|CMU,CMP)=0.868 ±0.045
  - e(reco)=($e_{COT} e_{\mu reco} e_{\mu qual} e_{SVX}$)^2=0.636 ±0.017
  - e(z vtx)=0.951 ±0.001 ±0.005

Normalization signals

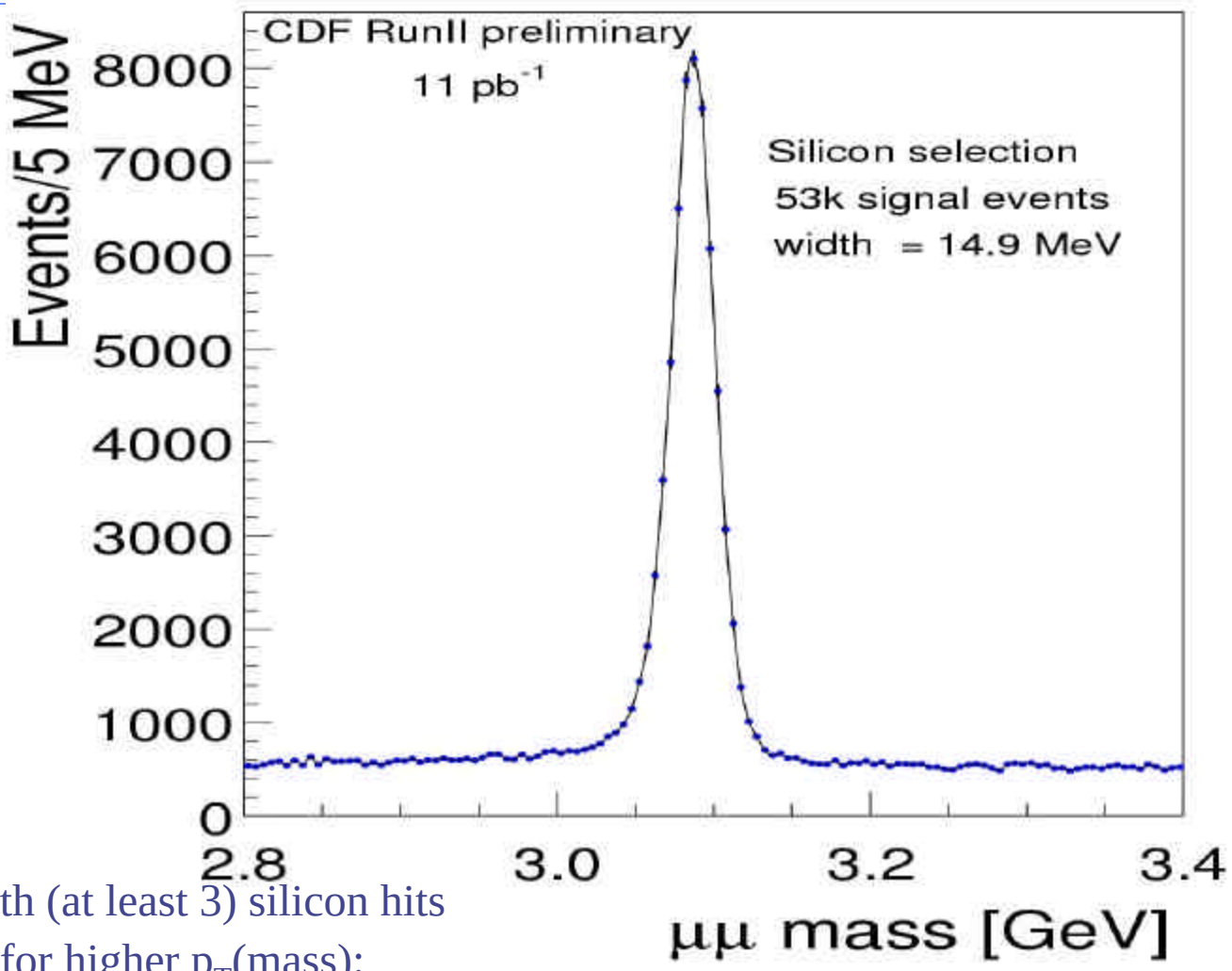


- Choose the decay modes closest in signature and with high statistics to normalize.

Signal box. Cuts.

- Blind analysis. Signal inside the box.
- Cuts: [To be optimized. Run1 values are quoted in parentheses]
  - $p_T^{\mu}>2$GeV, $|?^B|<1$, $p_T^B>6$GeV – baseline.
  - 4.269GeV<M<4.469GeV -- PDG value ±100MeV. ~3s window (estimated from MC)
  - $c\tau=L_{xy}M/p_T$ -- (>100μm in Run1) – 2D cτ
  - ?f (p_T^B,vtx) – (<0.1) – 2D pointing.
  - Iso= $p_T^B/(p_T^B+\text{sum}(p_T|R<1))$ – (>0.75) – B candidate track isolation.

Dimuon mass resolution



- Tracks with (at least 3) silicon hits
- Increases for higher p_T(mass):
  - $\sigma(m_?)$~60MeV

Background source and rejection.

- Source of background (similar to $D^0 \rightarrow mm$ case):
  - resonant: B→hh – h misidentified as muon (small at $>10^{-8}$sensitivity)
  - non-resonant/combinatorial:
    - b bbar, charm production, etc.
  - To estimate:
    - MC simulation
    - use data outside the signal box(sidebands)
- Cuts optimized to maximize the signal sensitivity with minimal background:
    - Expect to get better rejection than in Run1

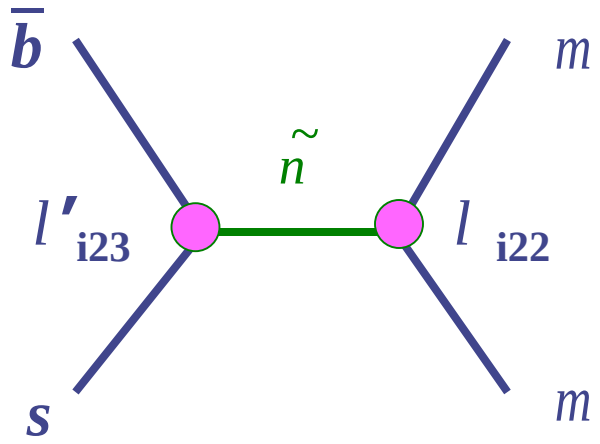
Summary

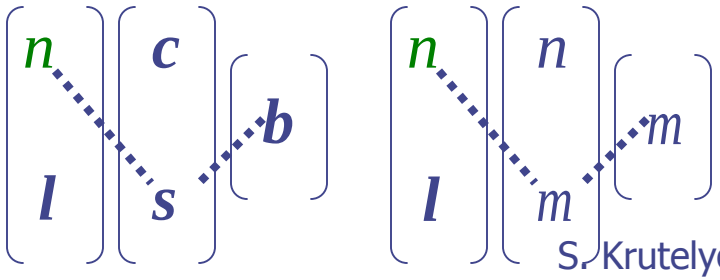
- CDF collaboration produces competitive measurements of rare decays.
- Br($D^0 \rightarrow mm$)<$2.4*10^{-6}$ at 90% C.L.
- We expect to have Br($B_{d(s)} \rightarrow mm$) measurement comparable with Run1 results to come soon, and results significantly improving Run1 limit in summer.

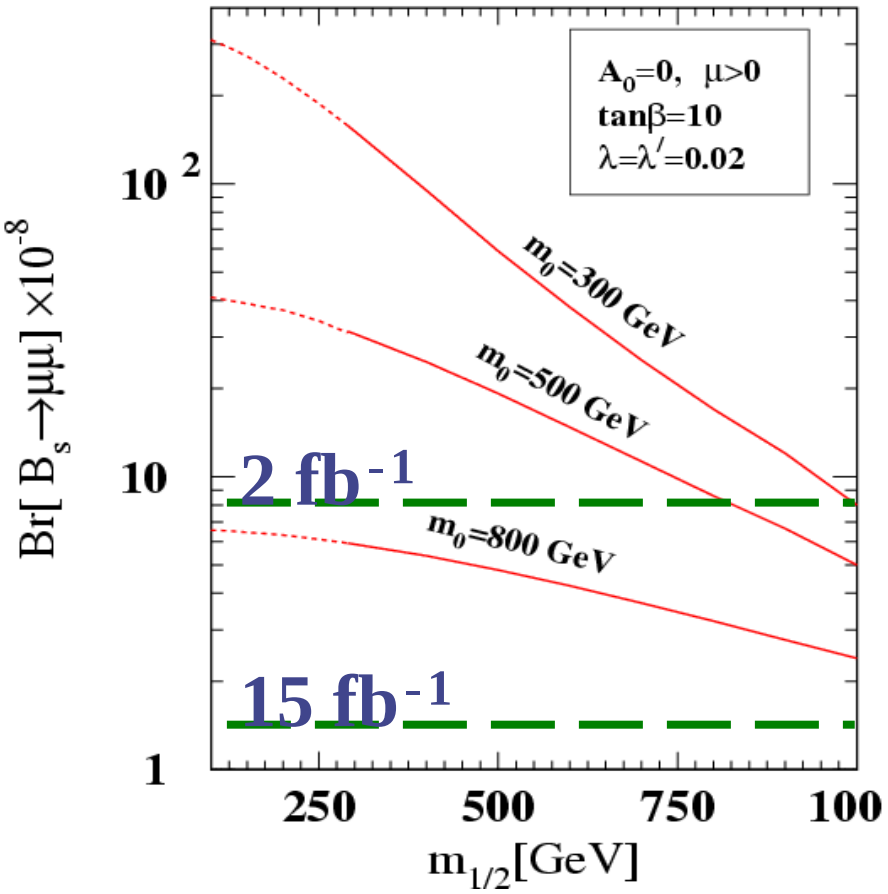
R_P Violation: *Br* vs. $m_{1/2}$

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

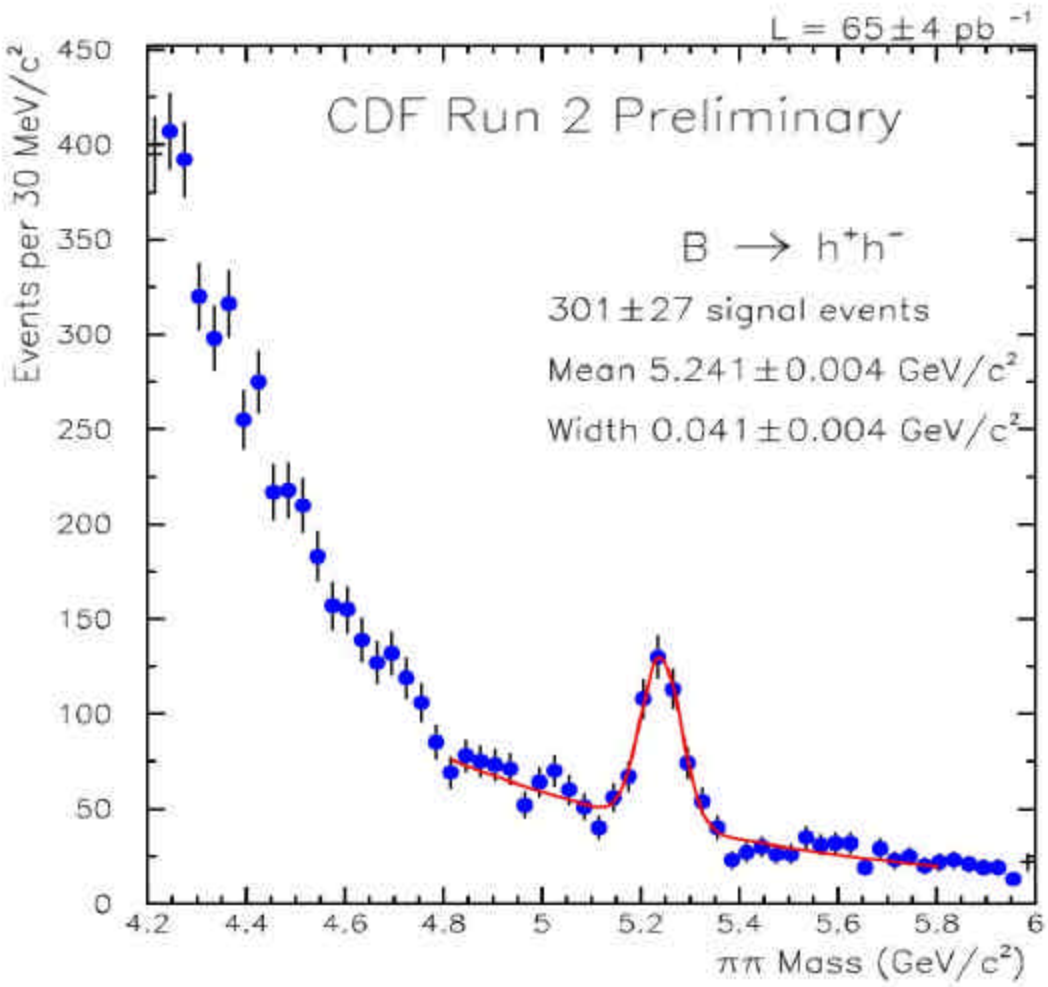
e.g., $W_{TRPV} = \lambda_{ijk} L_i L_j E_k + \lambda'_{ijk} L_i Q_j D_k + \lambda''_{ijk} U_i D_j D_k$







B→hh PR plot


L = 65 ± 4 pb⁻¹
CDF Run 2 Preliminary
B → h⁺h⁻
301 ± 27 signal events
Mean 5.241 ± 0.004 GeV/c²
Width 0.041 ± 0.004 GeV/c²
Events per 30 MeV/c²
ππ Mass (GeV/c²)
0
50
100
150
200
250
300
350
400
450
4.2
4.4
4.6
4.8
5
5.2
5.4
5.6
5.8
6

$B_{d(s)} \rightarrow \mu\mu$: Run I Results

CDF, PRD 57, 3811 (1998)

$\int L dt$ = 98 pb^{-1} (~5 x 10^{12} collisions)

B_d: 5.205-5.355 GeV/c^2

B_s: 5.300-5.450 GeV/c^2

N_{obs} = 1 with 5.344 GeV/c^2
(consistent with an expectation from the Standard Model backgrounds)

$Br(B_d \rightarrow \mu\mu) < 8.6 \times 10^{-7}$ (95% C.L.)

$Br(B_s \rightarrow \mu\mu) < 2.6 \times 10^{-6}$ (95% C.L.)