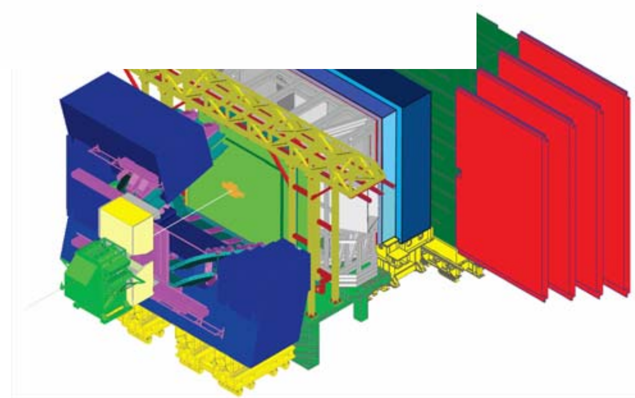
LHCb sensitivity to the LFV $B^0_{d,s} \rightarrow e^{\pm}\mu^{\mp}$ decays and interpretation in the context of the Pati-Salam $SU(4)_C$ model

W. Bonivento and N.Serra
University and INFN of Cagliari - Italy

on behalf of the LHCb Collaboration



Leptoquarks

Leptoquarks (LQ) carry both baryon number (B) and lepton number (L)

Expected in some extensions of the SM:
- SO(10) grand unification
- extended technicolor models
- compositeness

Possible quantum numbers of LQ →assuming interaction with the ordinary SM fermions are dimensionless and invariant under the SM gauge group

Spin	$3B+L$	$SU(3)_c$	$SU(2)_W$	$U(1)_Y$	Allowed coupling	
0	-2	$\bar{3}$	1	1/3	$\bar{q}^c_L \ell_L$ or $\bar{u}^c_R e_R$	
0	-2	$\bar{3}$	1	4/3	$\bar{d}^c_R e_R$	
0	-2	$\bar{3}$	3	1/3	$\bar{q}^c_L \ell_L$	
1	-2	$\bar{3}$	2	5/6	$\bar{q}^c_L \gamma^\mu e_R$ or $\bar{d}^c_R \gamma^\mu \ell_L$	
1	-2	$\bar{3}$	2	$-1/6$	$\bar{u}^c_R \gamma^\mu \ell_L$	
0	0	3	2	7/6	$\bar{q}_L e_R$ or $\bar{u}_R \ell_L$	
0	0	3	2	1/6	$\bar{d}_R \ell_L$	
1	0	3	1	2/3	$\bar{q}_L \gamma^\mu \ell_L$ or $\bar{d}_R \gamma^\mu e_R$	Pati-Salam
1	0	3	1	5/3	$\bar{u}_R \gamma^\mu e_R$	
1	0	3	3	2/3	$\bar{q}_L \gamma^\mu \ell_L$	

FCNC and LFV in B decays as a window on leptoquarks

Model independent constraints on leptoquarks from rare processes

Sacha Davidson[1], David Bailey[2], Bruce A. Campbell[3]   Z. Phys. C 61, 613–643 (1994)

Indirect searches: look for them e.g. in meson decays

LQ give rise to effective four fermion interactions

Best limits with SM suppressed decays: FCNC and LFV →leptoquark interactions remove the SM suppression

… with B decays

Beyond B→eμ which is discussed afterwards, interesting decays are:

a) FCNC, lepton flavor conserving

	90% U.L.		S.M. expectation
$B^0_s \to \mu^+\mu^-$	$1.7 \cdot 10^{-7}$	CDF	$(3.5\pm0.9)\cdot 10^{-9}$
$B^0_d \to \mu^+\mu^-$	$2.3 \cdot 10^{-8}$	CDF	$(1.04\pm0.34)\cdot 10^{-10}$
$B^0_d \to e^+e^-$	$6.1 \cdot 10^{-8}$	BABAR	$(2.34\pm0.33)\cdot 10^{-15}$
$B^0_s \to e^+e^-$	$5.4 \cdot 10^{-5}$	CDF	
$B^0_d \to \tau^+\tau^-$	$4.1 \cdot 10^{-3}$	BABAR	$\sim 10^{-7}$

→allow to set model-independent limits on both SU(2) singlet and doublet LQ, both scalar and vector

b) lepton flavor violating

$B^0_d \to \mu\tau$	$3.8 \cdot 10^{-5}$	CLEO
$B^0_d \to e\tau$	$1.1 \cdot 10^{-4}$	CLEO

CLEO

Decay mode	Significance of signal	Upper limit (10^{-6})
$B \to K e^\pm \mu^\mp$	0.0σ	1.6
$K^* e^\pm \mu^\mp$	2.0σ	6.2
$\pi e^\pm \mu^\mp$	0.0σ	1.6
$\rho e^\pm \mu^\mp$	0.6σ	3.2
$B^+ \to K^- e^+ e^+$	0.0σ	1.0

+some other Bs decays (φ)

set limits also to SU(2) triplet LQ both scalar and vector (numbers to be worked out…, next conference!)

A specific model: the Pati-Salam $SU(4)_c$

J. Pati and A. Salam, Phys. Rev. D 10, 275 (1974).

A model incorporating quark-lepton symmetry as a local gauge symmetry.

Based on $SU(4)_c \otimes SU(2)_L \otimes G_R$ with particle content $\begin{pmatrix} u_G \\ u_R \\ u_B \\ \nu \end{pmatrix} \begin{pmatrix} d_G \\ d_R \\ d_B \\ l \end{pmatrix}$

→the lepton number as a fourth color

Symmetry breaking $SU(4)_c \rightarrow SU(3)_c \otimes U(1)_{B-L}$

gauge bosons:

- 1 LQ with coupling $\alpha_s(M_{PS})$

Spin	$3B+L$	$SU(3)_c$	$SU(2)_W$	$U(1)_Y$	Allowed coupling
1	0	3	1	2/3	$\bar{q}_L \gamma^\mu \ell_L$ or $\bar{d}_R \gamma^\mu e_R$

- 3 massless gluons

[2] A. Kuznetsov and M. Mikheev, Phys. Lett. B **329**, 295 (1994).

$$\nu_\ell = \mathcal{K}_{\ell i}\nu_i, \quad u_\ell = \mathcal{U}_{\ell p}u_p, \quad d_\ell = \mathcal{D}_{\ell n}d_n.$$

$\mathcal{K}_{\ell i}, \mathcal{U}_{\ell p}$, and $\mathcal{D}_{\ell n}$ are the unitary mixing matrices.

$$\nu_i = (\nu_1, \nu_2, \nu_3), \quad u_p = (u_1, u_2, u_3), = (u, c, t),$$
$$d_n = (d_1, d_2, d_3), = (d, s, b),$$

ν_i, u_p, and d_n are the mass eigenstates

The well-known Lagrangian of the interaction of the charged weak currents with the W bosons in our notations has the form

$$\begin{aligned}\mathcal{L}_W &= \frac{g}{2\sqrt{2}}[(\bar{\nu}_\ell O_\alpha \ell) + (\bar{u}_\ell O_\alpha d_\ell)]W^*_\alpha + h.c. = \\ &= \frac{g}{2\sqrt{2}}[\mathcal{K}^*_{\ell i}(\bar{\nu}_i O_\alpha \ell) + \mathcal{U}^*_{\ell p}\, \mathcal{D}_{\ell n}\, (\bar{u}_p O_\alpha d_n)]W^*_\alpha + h.c., \qquad (6)\end{aligned}$$

where g is the $SU(2)_L$ group constant, and $O_\alpha = \gamma_\alpha(1-\gamma_5)$. The standard Cabibbo-Kobayashi- Maskawa matrix is thus seen to be $V = \mathcal{U}^+\mathcal{D}$.

$$\mathcal{L}_X = \frac{g_S(M_X)}{\sqrt{2}}[\mathcal{D}_{\ell n}(\bar{\ell}\gamma_\alpha d^c_n) + (\mathcal{K}^+\,\mathcal{U})_{ip}(\bar{\nu}_i\gamma_\alpha u^c_p)]X^c_\alpha + h.c.,$$

only one LQ mass bound mixing independent:

$Br(\pi^0 \to \nu\bar{\nu}) < 2.9 \cdot 10^{-13}$. (from cosmological arguments) $M_X > 18\ TeV.$

the other bounds contain explicitly mixing matrix elements:
e.g.

FCNC $Br(K_L^0 \to \mu^+\mu^-) = (7.3 \pm 0.4) \cdot 10^{-9}$ [4] $\frac{M_X}{|Re(\mathcal{D}_{\mu d}\mathcal{D}^*_{\mu s})|^{1/2}} > 500 \div 600\ TeV$

LFV $Br(K_L^0 \to \mu e) < 3.3 \cdot 10^{-11}$ [12] $\frac{M_X}{|\mathcal{D}_{ed}\mathcal{D}^*_{\mu s} + \mathcal{D}_{es}\mathcal{D}^*_{\mu d}|^{1/2}} > 1200\ TeV$

unfortunately only first and second family studied in the Kuznetsov et al., paper

The only paper studying the third family uses a slightly different approach:

(d,s,b)
↕ 6 possible combinations (we name them coupling schemes)
(e,μ,τ) with diagonal couplings

Quark-lepton unification and rare meson decays

G. Valencia
Department of Physics, Iowa State University, Ames, Iowa 50011

S. Willenbrock
Department of Physics, University of Illinois, 1110 West Green Street, Urbana, Illinois 61801

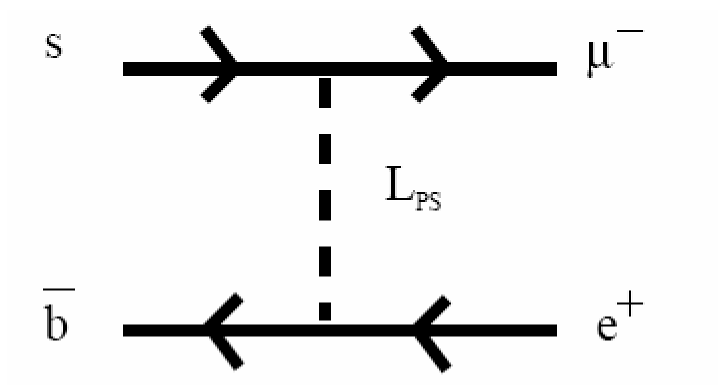
e.g. in the coupling scheme (b,s,d) ↕ (e,μ,τ)

$$BR(B^0_{d,s} \to e^+\mu^-) = \Gamma(B^0_{d,s} \to e^+\mu^-) \cdot \frac{2\pi \cdot \tau_{B(d,s)}}{h}$$

$$\Gamma(B^0_{d,s} \to e^+\mu^-) = \pi \alpha_s^2(M_{PS}) \frac{F^2_{B(d,s)} m^3_{B(d,s)} R^2}{M^4_{PS}}$$

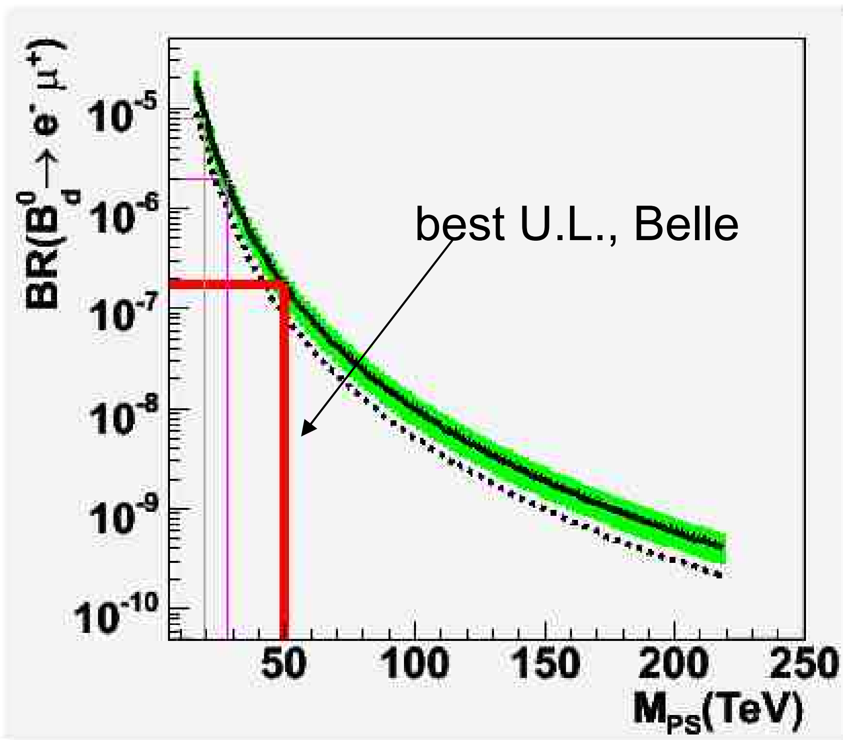
$$R = \frac{m_{B(d,s)}}{m_b} \left(\frac{\alpha_s(M_{PS})}{\alpha_s(m_t)}\right)^{-4/7} \left(\frac{\alpha_s(m_t)}{\alpha_s(m_b)}\right)^{-12/23}$$

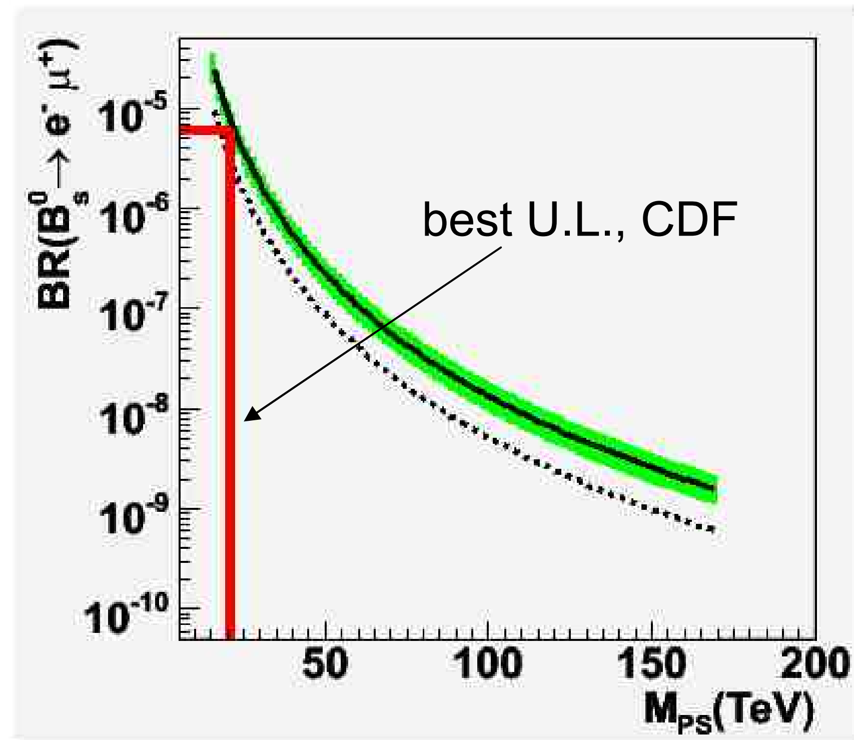
M_{PS} is the Pati-Salam leptoquark mass



PHYSICAL REVIEW D VOLUME 50, NUMBER 11 1 DECEMBER 1994

green band→theoretical error, mainly from F_B





The best limits on the M_{PS}

coupling schemes

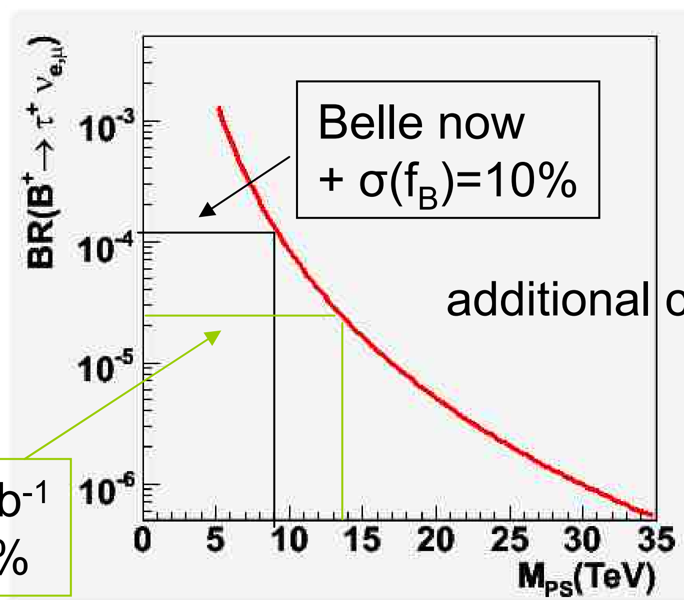
90% lower limits on M_{PS} in TeV

c.s.		$K_L \to \mu^\pm e^\mp$	$\frac{\pi^+ \to e^+\nu}{\pi^+ \to \mu^+\nu}$	$\frac{K^+ \to e^+\nu}{K^+ \to \mu^+\nu}$	$B_d^0 \to e^\pm \mu^\mp$	$B_s^0 \to e^\pm \mu^\mp$	$B^+ \to e^+\nu$	$B^+ \to \mu^+\nu$
1	$e\mu\tau$	2278	250	4.9				
2	$\mu e\tau$	2278	76	130				
3	$e\tau\mu$		250		50			28
4	$\mu\tau e$		76		50		19	
5	$\tau\mu e$			4.9		20.7	19	
6	$\tau e\mu$			130		20.7		28
90% U.L. on BRs		$< 4.7 \cdot 10^{-12}$ B871 1998	$(1.230 \pm 0.004) 10^{-4}$ PDG 1993 S.M.=(1.2352 ± 0.0005) 10^{-4}	$(2.45 \pm 0.11) \cdot 10^{-5}$ PDG 1976! S.M.=$2.57 \cdot 10^{-5}$ ± ?	$< 1.7 \cdot 10^{-7}$ BELLE 2003	$< 6.1 \cdot 10^{-6}$ CDF 1998	$< 5.4 \cdot 10^{-6}$ BELLE 2006 (P)	$< 2.6 \cdot 10^{-6}$ BELLE 2006 (P) S.M. $= (6.3 \pm 1.6) 10^{-7}$

• B and K flavor conserving decays such as $B \to \mu\mu$ forbidden without mixing

Online (workshop) monitoring at work!!!

Yesterday Belle (S.Villa) presented a measurement of
BR($B^+ \rightarrow \tau^+ \nu$)= $(1.8 \pm 0.65)10^{-4}$ to be compared with SM where BR= $(1.6 \pm 0.4)10^{-4}$
It was mentioned the possibility of setting a limit to the Pati-Salam LQ mass.
<u>Here we are</u>:
1) if we follow Valencia-Villenbrok then $K_L \rightarrow e\mu$ gives a better limit
2) if we follow Kuznetsov → it gives acess to couplings different from any other channel



Belle $50ab^{-1}$
+ $\sigma(f_B)$=5%

the 90% U.L. on non-standard contributions is $1.2 \cdot 10^{-4}$

additional contribution due to LQ

M_{LQ}> 9TeV*(some matrix element)^2

to be calculated!

Other models for B→eμ

2 papers →**higgs mediated SUSY seesaw models**

Desdes et al., Phys.Lett.B 549(2002)159
J.K.Parry, hep-ph/0606150v2

1 paper →**heavy neutrinos**

Xiao-Gang-He et al, hep-ph/0409346
and G.Valencia private communication

they all predict BR<10^{-10} → well below LHCb sensitivity

Event samples

$\sigma_{b\bar{b}}(\mu b)$	500
P(b-hadron→ μ+X)	0.1059
P(b-hadron→ e+X)	0.1059
f(b→ B_d^0)	0.405
f(b→ B_s^0)	0.099
f(b→ Λ_b)	0.099
$\epsilon_{gen}(B_s^0 \to e^\pm\mu^\mp)$	34 %
$\epsilon_{gen}(b\bar{b} \to e^\pm\mu^\mp)$	43 %

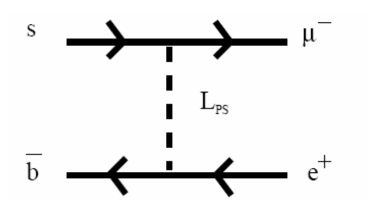
input quantities

acceptance cut for signal and background at generation: at least one b-hadron in 400mrad

	# after acceptance cuts in 2 fb^{-1}	# generated	equiv. $\mathcal{L}$
B_d^0	$1.4 \cdot 10^{11}$		
B_s^0	$3.4 \cdot 10^{10}$		
$b\bar{b} \to e^-\mu^+$	$4.9 \cdot 10^9$	$5 \cdot 10^6$	$2.05 pb^{-1}$
$b\bar{b} \to \mu^-e^+$	$4.9 \cdot 10^9$	$5 \cdot 10^6$	$2.05 pb^{-1}$

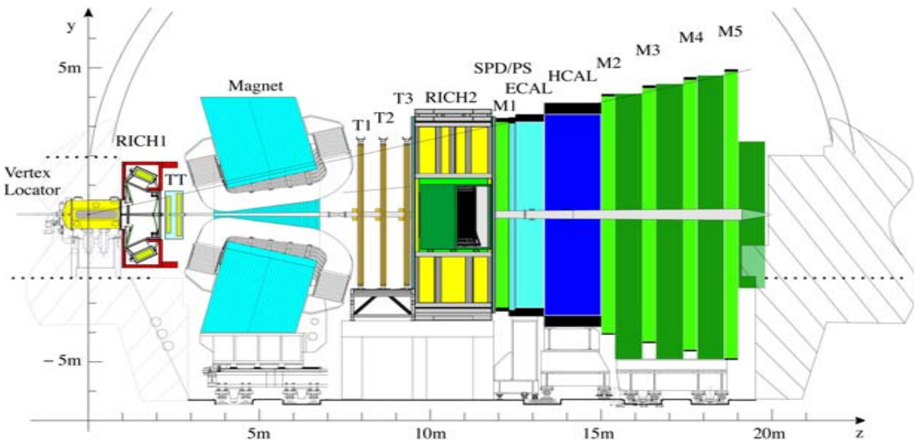
problem: only limited sample full simulation of bb→ $e^\pm\mu^\pm$ background PYTHIA+GEANT4

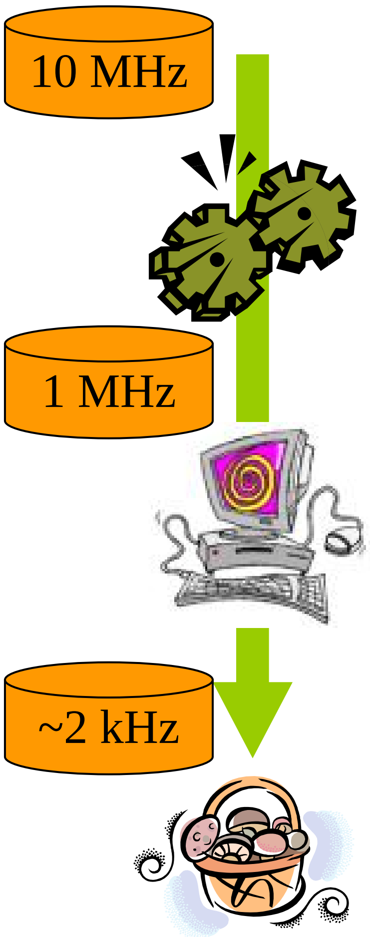
Suppose we want to study coupling scenario 4



$B_0 \to e^+\mu^-$
and
$\bar{B}_0 \to e^-\mu^+$

Trigger for B→eμ events(i)





Visible collisions

$L = 2\ 10^{32}\ cm^{-2}\ s^{-1}$

L0: [hardware]

high Pt particles

calorimeter + muons

4 μs latency

HLT [software]

1 MHz readout

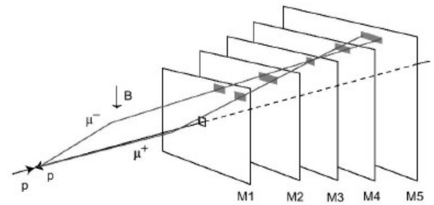
~1800 nodes farm

On tape:

Exclusive selections

Inclusive streams

Trigger for B→eμ events (ii)



for $B_0 \rightarrow e^+\mu^-$, b->X
it is the OR of e and μ L0 trigger

Type	Thresh Pt(GeV)
Electron	**2.8**
Muon	**1.1**
Di-muon Σp_T^{μ}	**1.3**

$$\varepsilon_{trg/Sel}(L0) = 0.95$$

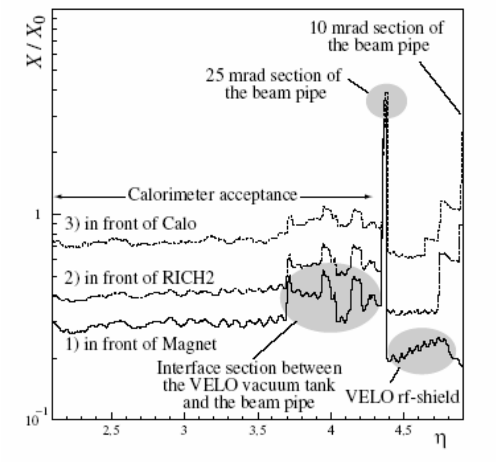
$$\varepsilon_{trg/Sel}(HLT) = 0.88$$

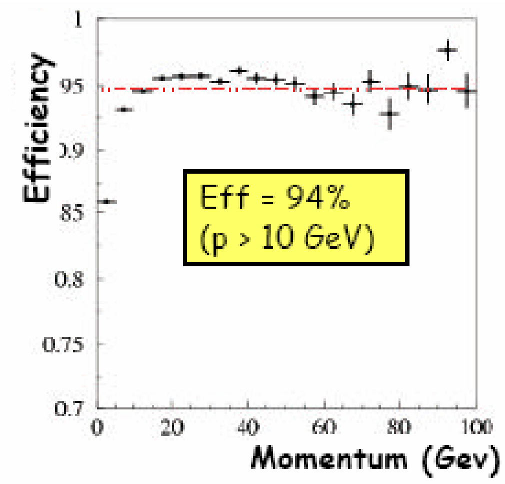
Tracking performance

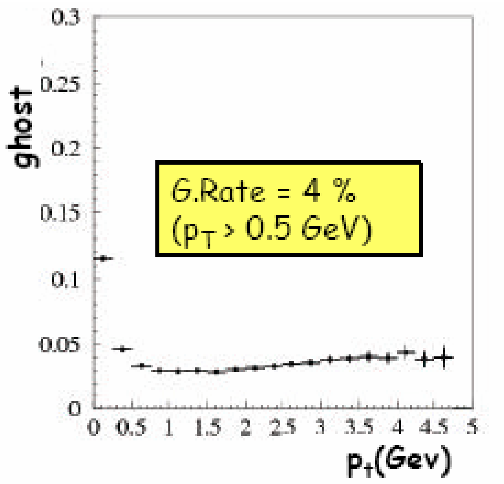
High Track density Environment

~ 50 primary particles per event

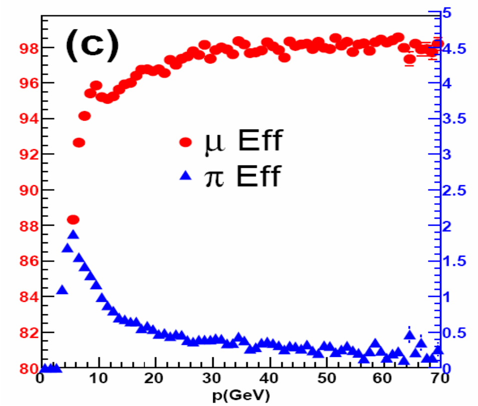
~ 50% X_0 to up RICH2 → $e^{\pm}$ bremsstrahlung







Particle ID (for B→eμ events)

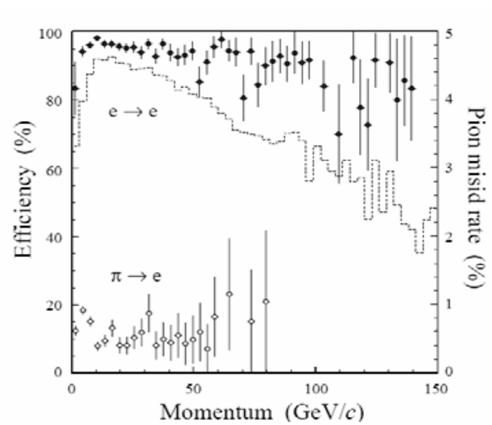


μ-π discrimination

$$X(Y)\ Dist = \frac{X(Y)_{\mathrm{extrapolation}} - X(Y)_{\mathrm{hit}}}{X(Y)_{\mathrm{padsize}}}$$

on M2-M5

$$|Dist|^2 = \frac{\sum_i^N [(X\ Dist)_i^2 + (Y\ Dist)_i^2]}{N}.$$



e-π discrimination

based on the combination of:

-E (ECAL)/p

-track- shower matching in ECAL

-E(HCAL)

-energy in the pre-shower

-bremsstrahlung

+ combination with RICH and μ-det info

ECAL: Shashlik
no long segmentation

(more realistic figures under evaluation with an updated detector description)

Event selection

designed to cut away $bb \rightarrow e^{\pm}\mu^{\pm}$ (assuming to be the dominant one)

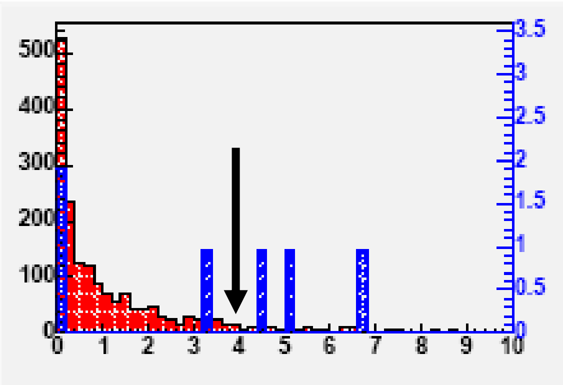
The selection cuts are similar to those of the old LHCb $B_s \rightarrow \mu^+\mu^-$ selection

particle	cut variable	units	selection
e	DLL		>0
μ	DLL		>-2
l_a^+, l_b^-	min(IP/σ_{IP})		>3.5
l_a^+, l_b^-	max(IP/σ_{IP})		>5.5
l_a^+, l_b^-	min(p_t)	GeV/c	>1.3
l_a^+, l_b^-	max(p_t)	GeV/c	>2.0
l_a^+, l_b^-	vertex fit χ^2		<4
B_s^0	p_t	GeV/c	>3
B_s^0	IP/σ_{IP}		<3.15
B_s^0	L/σ_L		>29
B_s^0	$\|\Delta M\|$	MeV/c^2	<600 (100)
B_s^0	Angle($\vec{p}$,PV-BV)	rad	0.005

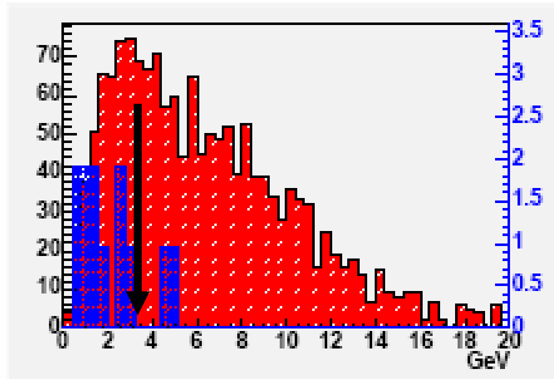
a new event selection is under study, including separation of transverse-longitudinal variables and inclusion of the lepton isolation cut as done e.g. in ATLAS or LHCb $B_s \rightarrow \mu^+\mu^-$ (see contributions at this workshop)

Event selection

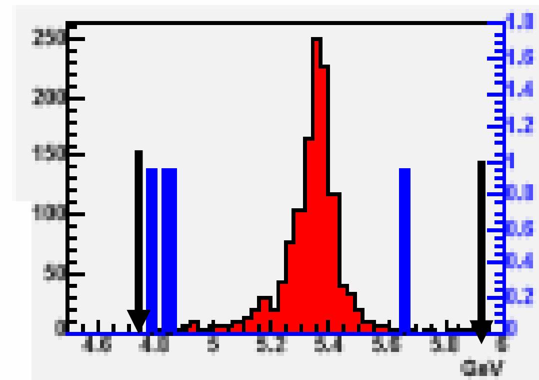
red= $B_s \to e^{\pm}\mu^{\pm}$
blue= $bb \to e^{\pm}\mu^{\pm}$



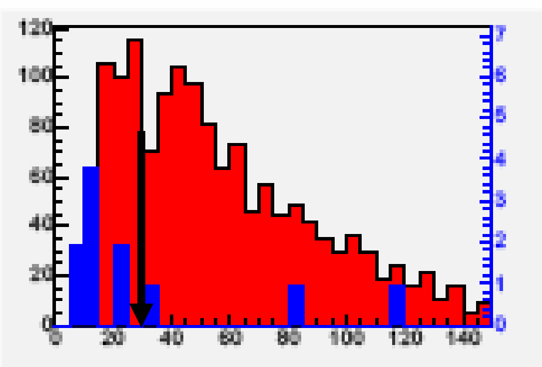
(e) l_a^+, l_b^-: vertex fit χ^2



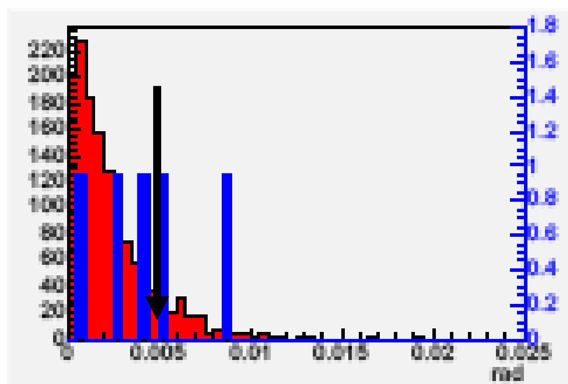
(f) B_s^0: p_t



(j) B_s^0: Inv mass



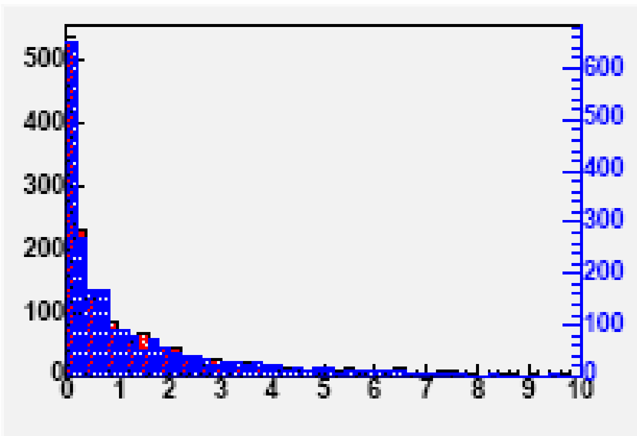
(h) B_s^0: L/σ_L



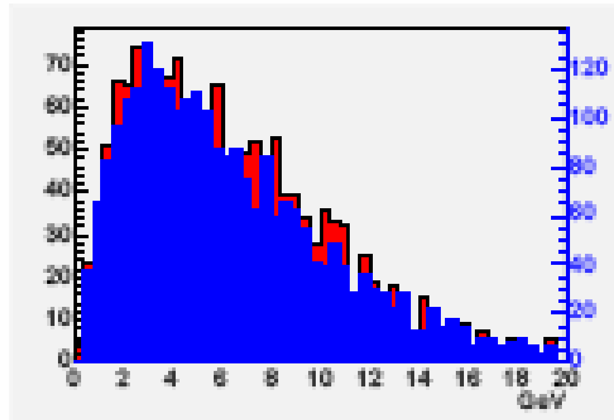
(i) B_s^0: Angle($\vec{p}$,PV-BV)

all the selection cuts applied but the one shown in the figure (mass ±600MeV)

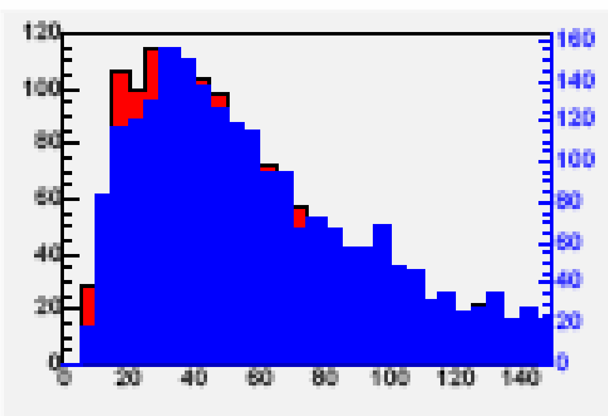
Comparison with $\mu^+\mu^-$



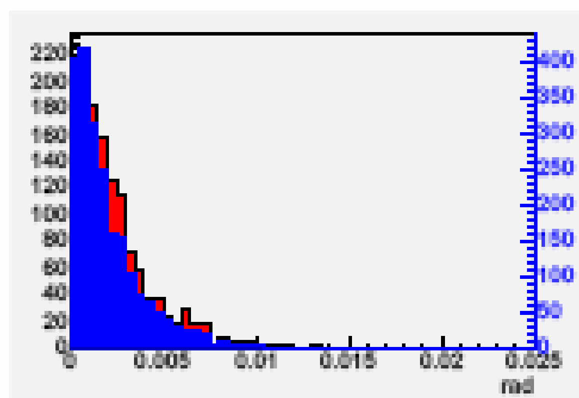
(e) l_a^+, l_b^-: vertex fit χ^2



(f) B_s^0: p_t



(h) B_s^0: L/σ_L



(i) B_s^0: Angle($\vec{p}$,PV-BV)

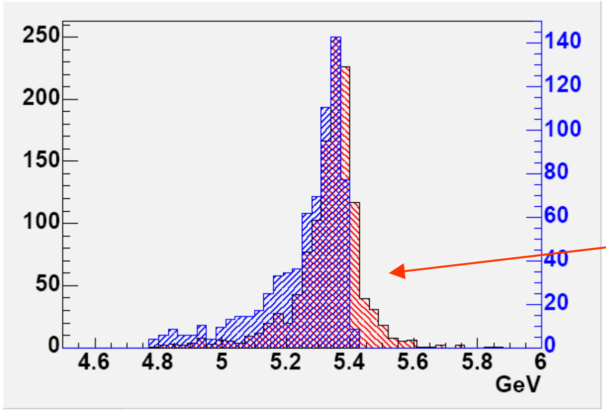
blue= $B_s \rightarrow \mu^+\mu^-$

red= $B_s \rightarrow e^{\pm}\mu^{\pm}$

very similar…

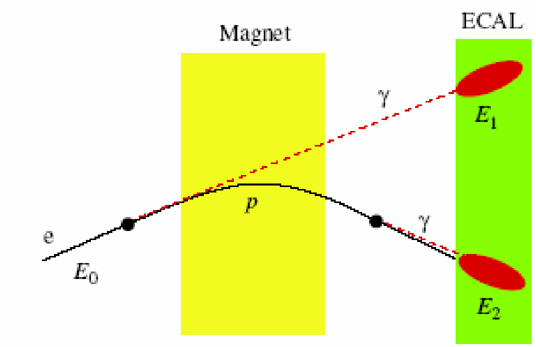
all the selection cuts applied but the one shown in the figure (mass ±600MeV)

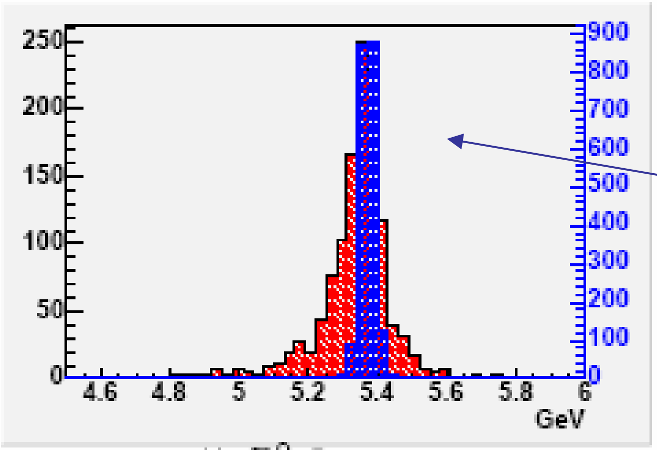
Effect of the e± bremsstrahlung



track extrapolation from the vertex detector to the calorimeter and sum over photons with distance less than x

→ core σ(M)~50MeV after bremsstrahlung correction





(j) B_s^0: Inv mass

Comparison with $\mu^+\mu^-$: σ(M)~18MeV

Selection figures

	gen.	sel. (± 600)	ϵ_{sel} (± 600)	sel. (± 100)	ϵ_{sel} (± 100)
$B_s^0 \to e^\pm\mu^\mp$	23331	1210	5.2 %		4.0 %
$B_s^0 \to \mu^+\mu^-$	25000	2051	8.2 %		
$b\bar{b} \to e^\pm\mu^\mp$	10^7	3		0	

no ε_{trig} included here

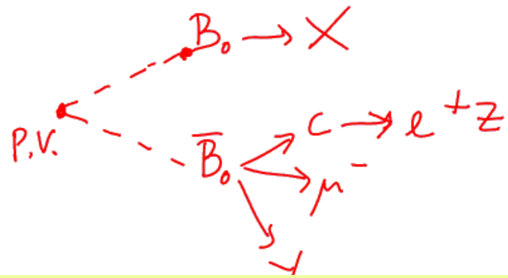
therefore
$\varepsilon_{tot}=\varepsilon_{sel}*\varepsilon_{gen}=1.4\%$

assuming efficiency flat in ±600MeV window
→ it corresponds to a 12.3 pb^{-1} bb→ $e^\pm\mu^\pm$ sample

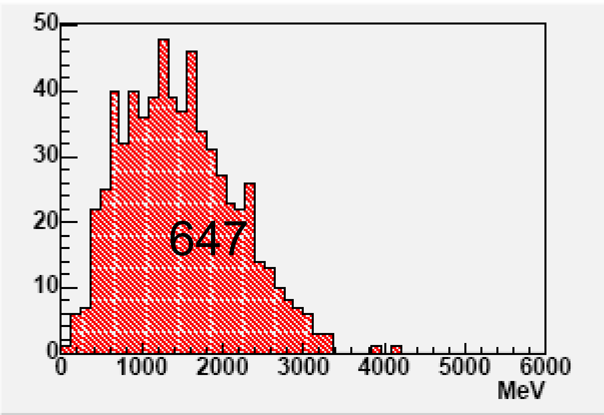
they all survive L0*HLT cuts
and they would correspond to 487 evts in 2fb-1 and 2435 evts in 10fb-1

We calculate U.L. and discovery levels assuming S/B as of 9.8pb-1 and rescaling for more luminosity as √L

Other backgrounds (i)
chain decay of a b hadron



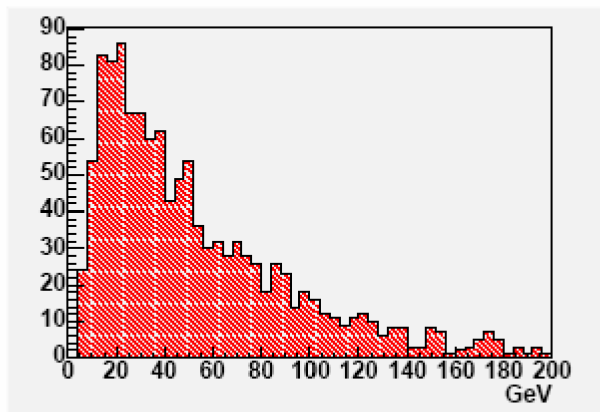
study done on a looser selection sample bb→ $e^{\pm}\mu^{\pm}$ events



Invariant mass of $e^{\pm}\mu^{\pm}$ pairs from the decay of one b hadron in
bb→ $e^{\pm}\mu^{\pm}$ events passing the preselection

1 ev with m(inv)>4GeV →would trigger the preselection
N(back)< 3.89*/4721 *(**20**)*N(bb→ $e^{\pm}\mu^{\pm}$)=
0.02* N(bb→ $e^{\pm}\mu^{\pm}$)

Other backgrounds (ii) misidentified hadrons



momentum spectrum of selected $e^{\pm}$ and $\mu^{\pm}$ from $B \rightarrow e\mu$

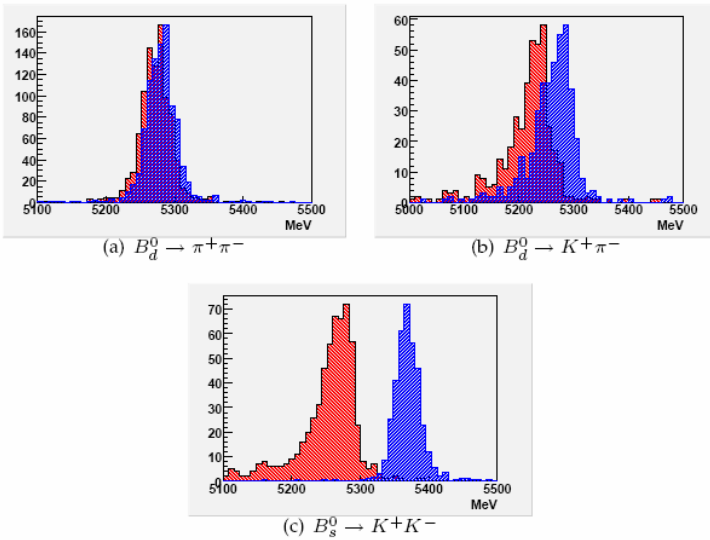
misidentifications are obtained by weighting measured PId performance with the p spectrum of selected particles

(stand-alone muon chambers!)

$P(h \rightarrow e) = 0.5\%$ $P(h \rightarrow \mu) = 0.35\%$

(a) from other B decays

decay type	BR	eff BR($B_d^0 \to e^+\mu^-$)	eff BR($B_s^0 \to e^+\mu^-$)
$B_d^0 \to \pi^+\pi^-$	$3.9 \cdot 10^{-6}$	$6.5 \cdot 10^{-11}$	$1.5 \cdot 10^{-10}$
$B_d^0 \to K^+\pi^-$	$2 \cdot 10^{-5}$	$2.7 \cdot 10^{-10}$	$7.2 \cdot 10^{-11}$
$B_s^0 \to K^+K^-$	$3.3 \cdot 10^{-5}$	$1.8 \cdot 10^{-11}$	$6.5 \cdot 10^{-11}$
$B_s^0 \to K^+\pi^-$	$4.8 \cdot 10^{-6}$	$1.2 \cdot 10^{-10}$	$2.2 \cdot 10^{-10}$
$\Lambda_b \to p\pi^-$	$2.1 \cdot 10^{-5}$	$1.5 \cdot 10^{-11}$	$1.3 \cdot 10^{-10}$
$\Lambda_b \to pK^-$	$7.8 \cdot 10^{-5}$	$5.7 \cdot 10^{-11}$	$5.1 \cdot 10^{-10}$
total		$5.5 \cdot 10^{-10}$	$1.5 \cdot 10^{-9}$



blue=with the right mass hypothesis
red=assuming a e±μ± final state

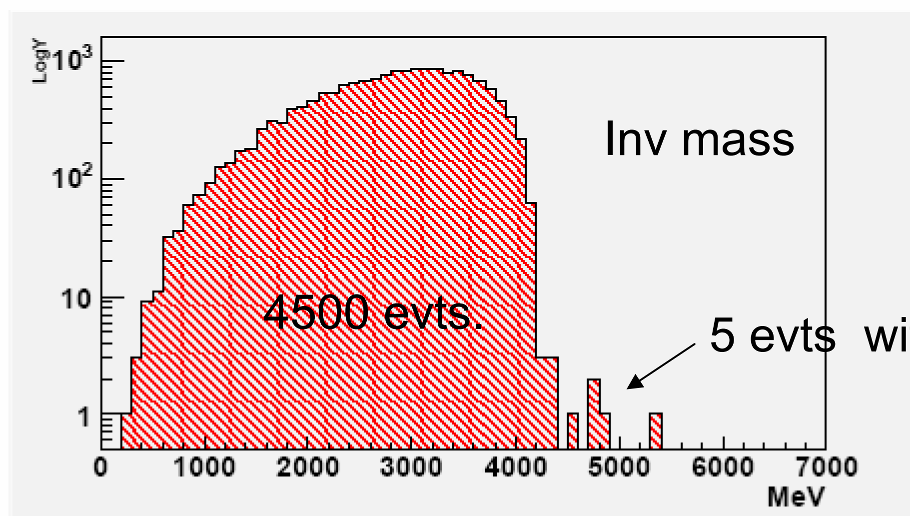
(b) one particle from the primary vertex + one b-hadron with a semi-leptonic decay → under study…

Other backgrounds (iii)

other b-hadron decays with one or more particles not reconstructed…

1) $B^+ \rightarrow J/\psi(\rightarrow \mu^+\mu^-)K^+$ BR~10^{-3}*0.06

μ^+ not reconstructed and K^+ misidentified as e^+



BR< 5/4500/10*10^{-3}*0.06* P(h→e)*P(h→μ)~10^{-12} (even without pointing cut)
→ negligible ; other backgrounds under study…

Results

The dominant background is from bb→ e±μ±

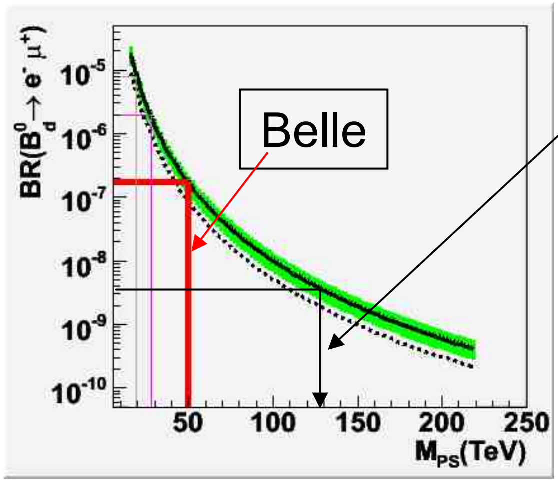
$$BR(B^0_{d,s} \to e^+\mu^-) \cdot N_{B(d,s)} + BR(\overline{B}^0_{d,s} \to e^-\mu^+) \cdot N_{\overline{B}(d,s)} < \frac{\sigma^{90C.L.}_{N(back)}}{\epsilon_{tot} \cdot \epsilon_{L0} \cdot \epsilon_{HLT}}$$

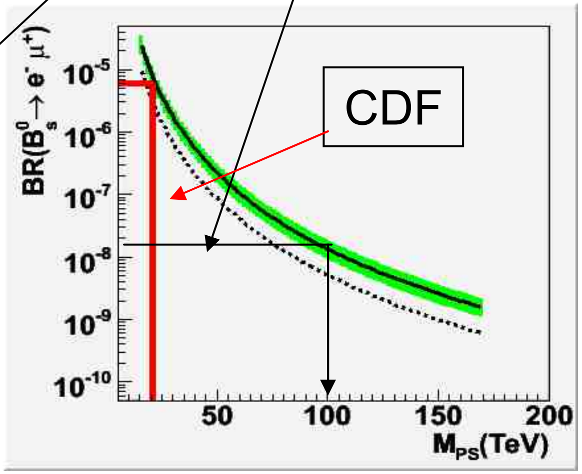
$N_{B(d,s)}$=expected # of B(d,s) in 4π

(following T.Junk, Nucl.Instrum.Meth.A434, p. 435-443, 1999)

assuming $BR(B_0)=BR(\overline{B}_0)$

decay type	90 % C.L. (2 fb^{-1})	90 % C.L. (10 fb^{-1})
$B^0_d \to e^-\mu^+$	$7.6 \cdot 10^{-9}$	$3.4 \cdot 10^{-9}$
$B^0_s \to e^-\mu^+$	$3.1 \cdot 10^{-8}$	$1.4 \cdot 10^{-8}$





The best limits on the M_{PS}

90% lower limits on M_{PS} in TeV

c.s.		$K_L \to \mu^\pm e^\mp$	$\frac{\pi^+ \to e^+ \nu}{\pi^+ \to \mu^+ \nu}$	$\frac{K^+ \to e^+ \nu}{K^+ \to \mu^+ \nu}$	$B_d^0 \to e^\pm \mu^\mp$	$B_s^0 \to e^\pm \mu^\mp$	$B^+ \to e^+ \nu$	$B^+ \to \mu^+ \nu$
1	e$\mu\tau$	2278	250	4.9				
2	μeτ	2278	76	130				
3	e$\tau\mu$		250		50			28
4	$\mu\tau$e		76		50		19	
5	$\tau\mu$e			4.9		20.7	19	
6	τeμ			130		20.7		28

130 ($B_d^0 \to e^\pm \mu^\mp$)

105 ($B_s^0 \to e^\pm \mu^\mp$)

LHCb limits

Summary and outlook

Potential improvements under study:

- new improved event selection with separation transverse/longitudinal variables and inclusion of lepton and/or B candidate isolation variable
- other background B decay channels
- understand systematics from muon-electron id., photon conversions ecc.
- Likelihood and/or neural net based selection
- studies underway to solve ambiguity among couplings in case of discovery

We are looking at the potential contributions of $B \rightarrow e\tau$, $B \rightarrow \mu\tau$, $B \rightarrow \mu e K^*$ ecc to the Pati-Salam model

Work in progress..