Inclusive Penguins for SuperBB

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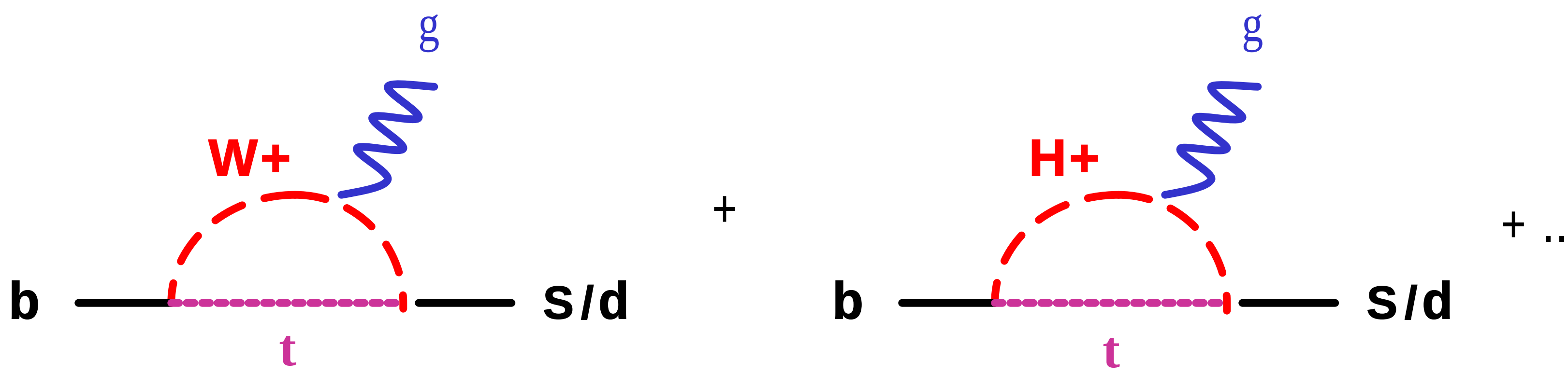
Motivation: New Physics

If SUSY exact B(b->sγ) = 0

Standard Model

SUSY



New Physics enters at same order (1-loop) as Standard Model

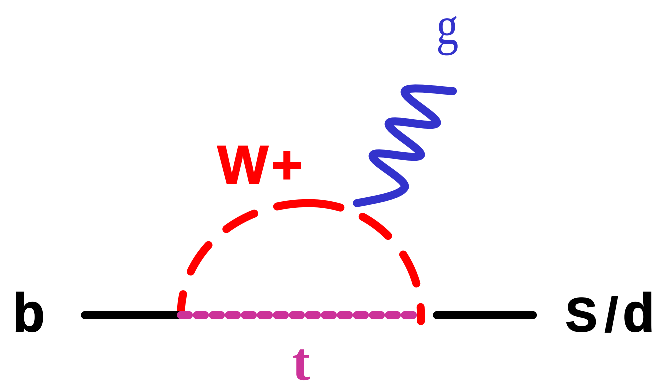
Sensitive to many models – Over 500 papers written

Photon Spectrum is also useful for HQET parameters

Measurements

Exclusive: B(B->K*γ)
B(B->ρ,$\omega\gamma$)

(see Mark Convery talk)



Inclusive: B(B->Xsγ) B(B->Xdγ) Acp(B->Xsγ)

General Considerations

1 ab^{-1} of BaBar by 2009 and 0-1 year of LHC

or

10,50 ab^{-1} SuperBaBar by 2012,16 versus 3,8 years of LHC

1. Super-BaBar must be competitive or at least complementary in the LHC era

2. Need to consider competition from direct searches (CMS/ATLAS) for new physics

3. Need to keep in mind practical theory limitations

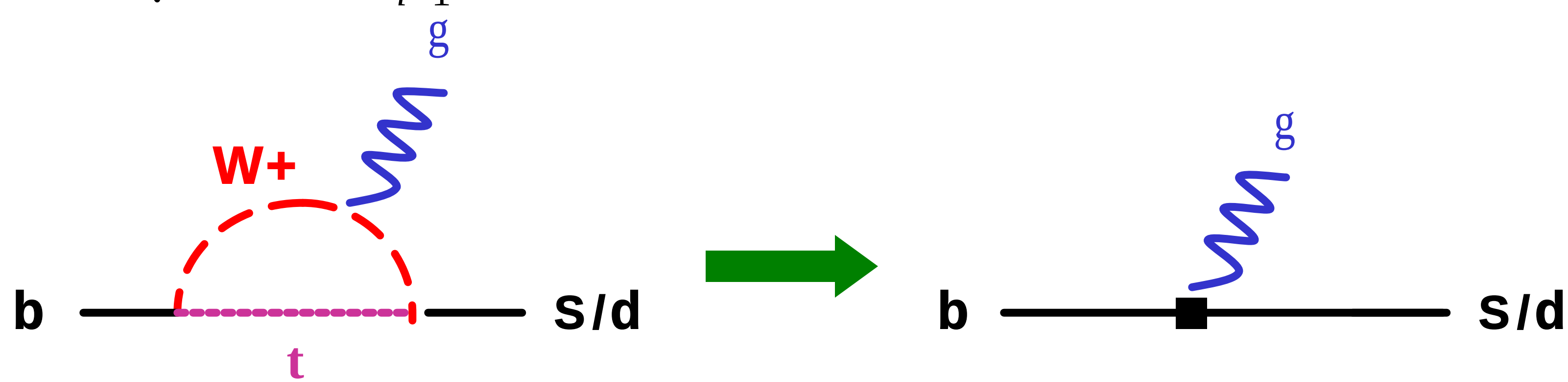
4. Need to think whether there are new analysis possible at SuperBB - not just extrapolate our current work

General Considerations

	Exclusive		Inclusive
Mode (#Events in ~1ab^{-1})	B->K*γ ~10000	B->ρ/ωγ ~100	B->Xsγ ~100000
Backgrounds	Small	Large	Large
Theory Uncertainty	Large 30-50%	Medium (in ratio) 15%	Small 10%

Penguin Theory - OPE

$$H_{eff} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts} \sum_{i=1}^{10} C_i(m) Q_i(m)$$



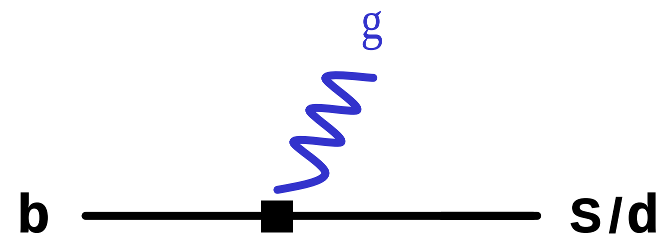
C_i : Wilson Coefficients – contains short distance (high energy) perturbative component. New physics enters here.

Q_i : Local Operators – contains long distance (lowenergy) non-perturbative component

μ(renormalization) scale dependence cancels in *C* and *Q*

Matrix Elements

$$H_{eff} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts} \sum_{i=1}^{10} C_i(m) Q_i(m)$$



<X|Q|B> are long distance (low-energy) non-perturbative component

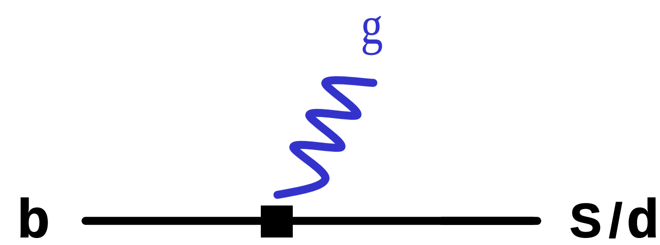
If X is exclusive state e.g | K*γ> two possibilities

1. Lattice QCD : Lattice spacing >> compton wavelength of b -> Large errors
2. QCD sum rules: Relates resonances to vacuum structure of QCD

Neither approach gives precise reliable estimates – limits exclusive physics

Inclusive Matrix Elements

$$H_{eff} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts} \sum_{i=1}^{10} C_i(m) Q_i(m)$$



If X is an inclusive state

$$\langle X | Q | B \rangle = 1 + O(\frac{1}{m_b}) + O(\frac{1}{m_b^2}) + \ldots$$

0

Leading term is short distance quark contribution and non-perturbative effects appears at $1/m_b^2$ –i.e (O(1%)) corrections

Non-perturbative corrections are parameterized by HQET parameters

Γ(B->Xsγ)

$$\Gamma(B \rightarrow X_s g) = \Gamma(b \rightarrow sg) + \Delta^{non-pert}$$

$\Delta^{\text{non-pert}}$ = *+4% correction*

Fully Inclusive Analysis can relate to parton level calculation

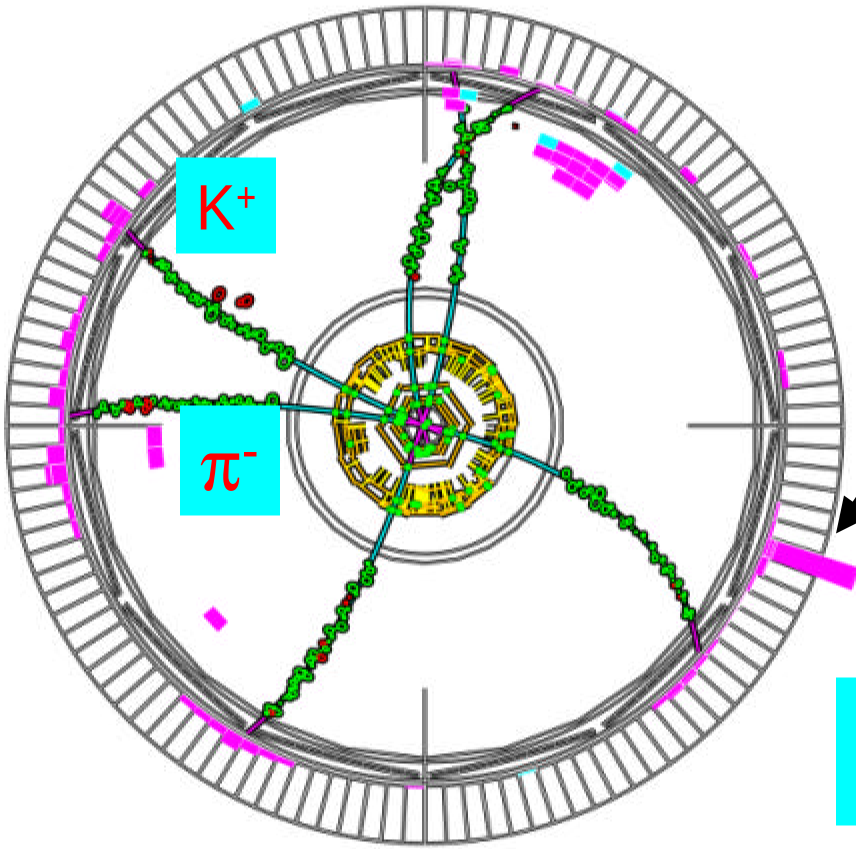
$\Gamma(b \rightarrow sg)$ Predicted to 10% error at NLO

Br(b->sγ) = 3.57 +-0.30 x10^{-4}

Optimism that at 5% NNLO prediction may be possible by ~ 2006

B->K* γ

B ? $K^*(K^+\pi^-)\gamma$



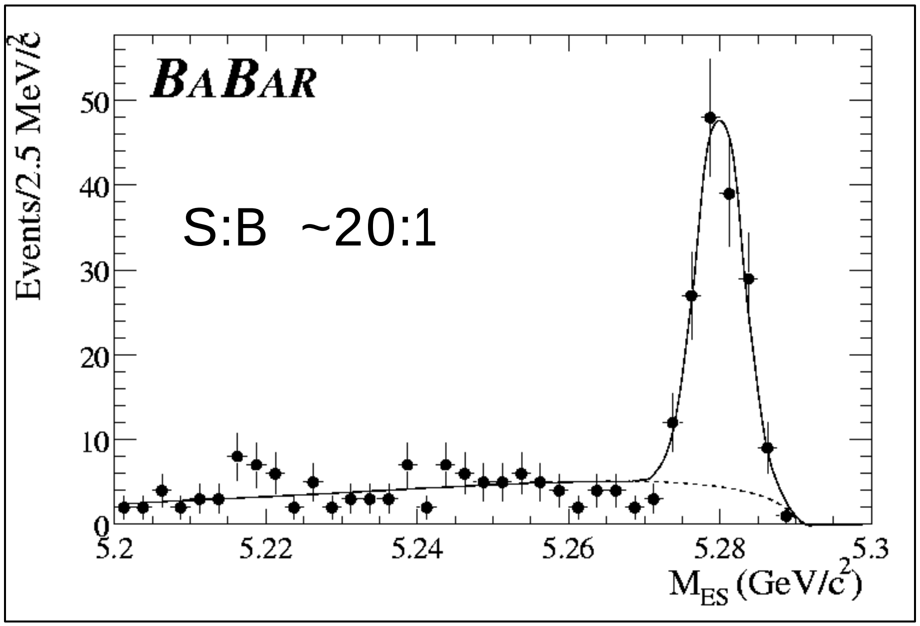
Distinctive High Energy Photon
In Crystal calorimeter

Particle ID from Cerenkov Detector
is a powerful tool for K^+/π^+ selection

K* /ρ γ group

B(B->K* γ)

	B(B->K^{0*}γ) X 10^{-5}	B(B->K^{*+}γ) X 10^{-5}
Measured	4.23+-0.40(stat) +0.22(sys)	3.83+-0.62(stat)+-0.22(sys)
Predicted	7.5+-3.0	7.5+-3.0



Luminosity (ab-1)	Precision (%)
0.02	10
1.0	1.5
10.0	0.5

Similar Precision on Acp and A+0

LHCB can measure to 1% in 1 year with S:B ~1:1

CPV in B->K*γ

$$A_{CP} = \frac{N(\overline{B}^0 \to \overline{K}^{*0}\gamma) - N(B^0 \to K^{*0}\gamma)}{N(\overline{B}^0 \to \overline{K}^{*0}\gamma) + N(B^0 \to K^{*0}\gamma)}$$

-

In SM < 1% upto 10 % in MSSM (non MFV)

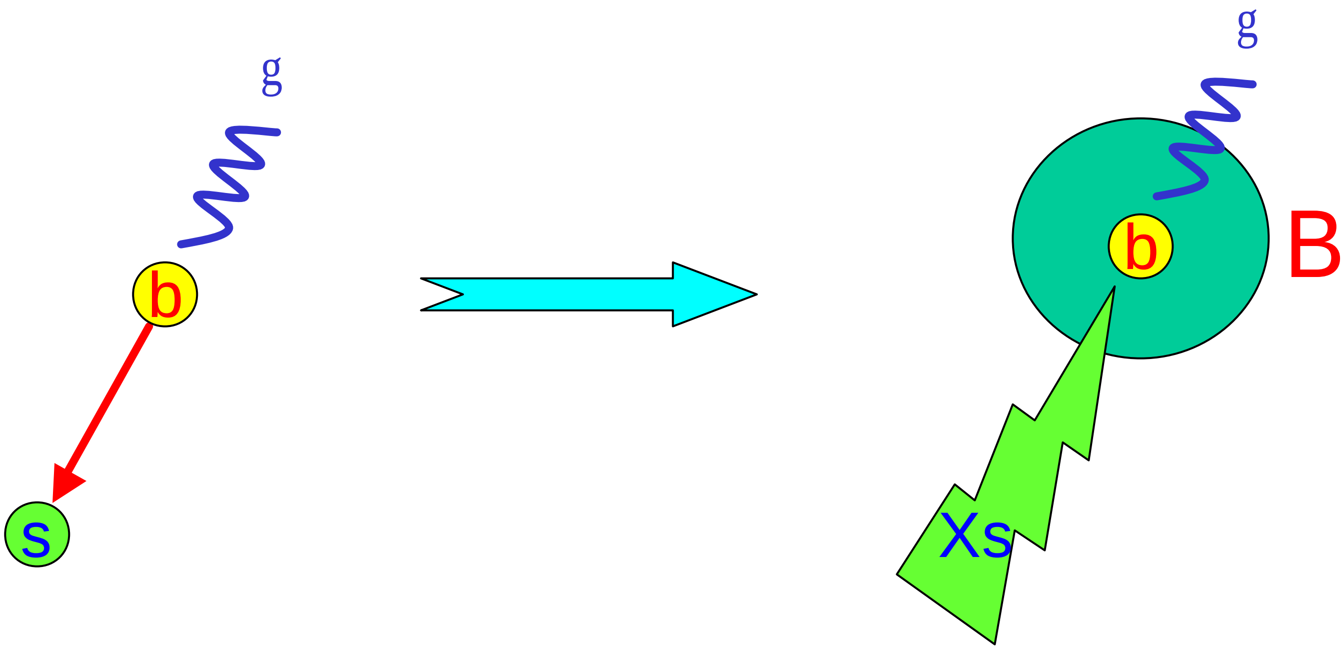
Current BaBar should eliminate interesting region. ~ 0.01

B->K*γ is probably only EM penguin measurement that LHCB can do reasonably well

Note that for SuperBB we would need to get Detector CPV faking effects understood to ~0.1 % level

Inclusive *B* -> *Xsγ*

HQET: Quark-Hadron Duality *B*(*b* -> *s*γ) = *B*(*B* -> X_sγ)

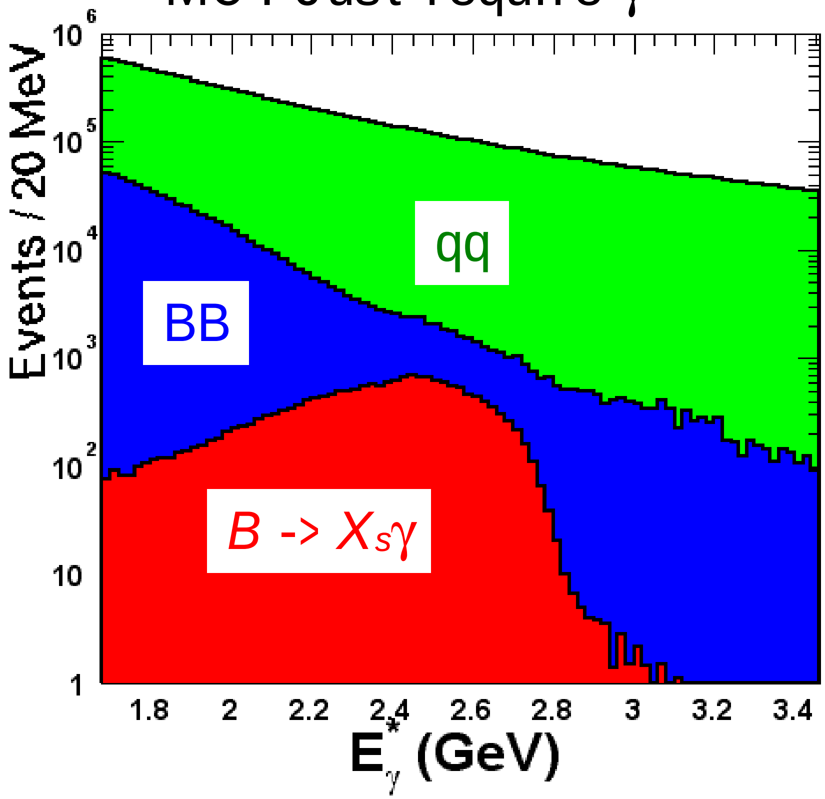


Theory: NLO B(B->Xsg)=3.57+ - 0.30 x 10^{-4} *(hep-ph/0207131)*

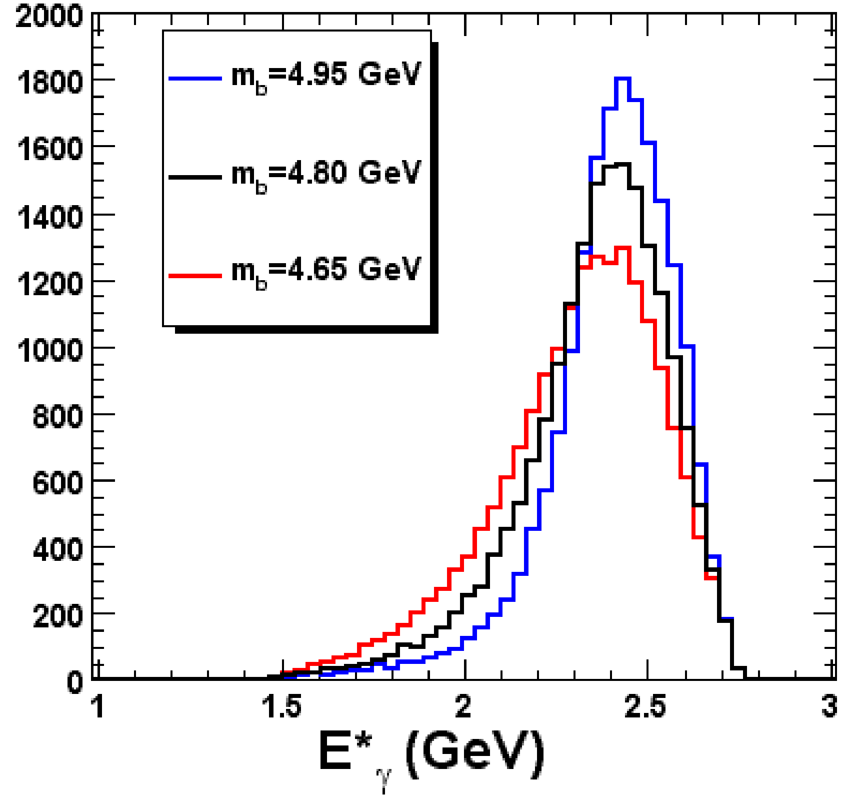
Phenomenological models of E_g *spectrum parameterized in* m_b *and* l_1.
(hep-ph/9805303) and of Xs fragmentation (JETSET) (hep-ph950891)

Experimental Challenge

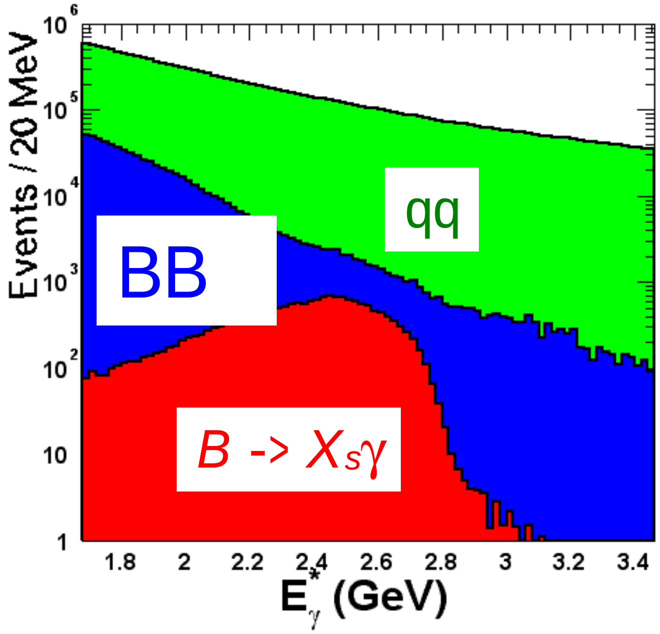
MC : Just require γ



γ Model Dependence



To reduce large backgrounds without cutting on γ or Xs
i.e a fully inclusive measurement



If require just γ bkg. ~10³.Sig.

Challenge is to reduce bkg while Minimizing stat.+sys.+model errors

Two approaches:

	Semi-Inclusive	*Fully Inclusive*
Background Rejection	*S(Exclusive States)*	*Lepton tags*
Efficiency	*3%*	*1%*
Fraction of Xs states:	*50%*	*100%*
qq bkg estimation	*Sideband subtraction*	*Off-resonance data*
BB bkg estimation	*Monte Carlo*	*M. Carlo – data validated*
X-feed bkg estimation	*Monte Carlo*	*No X-feed*
Spectral Resolution	*DMxs ~ 5 MeV*	*DE~100 MeV*
Model Dependence	*Xs, K*/Xs, Mxs cut*	*Eg*

LHC/BTeV vs BaBar

At LHC/BTeV may be able to use semi-inclusive technique
(I'm sceptical !) but is highly susceptible to biases and
Not fully inclusive

At BaBar and SuperBaBar can use fully inclusive techniques

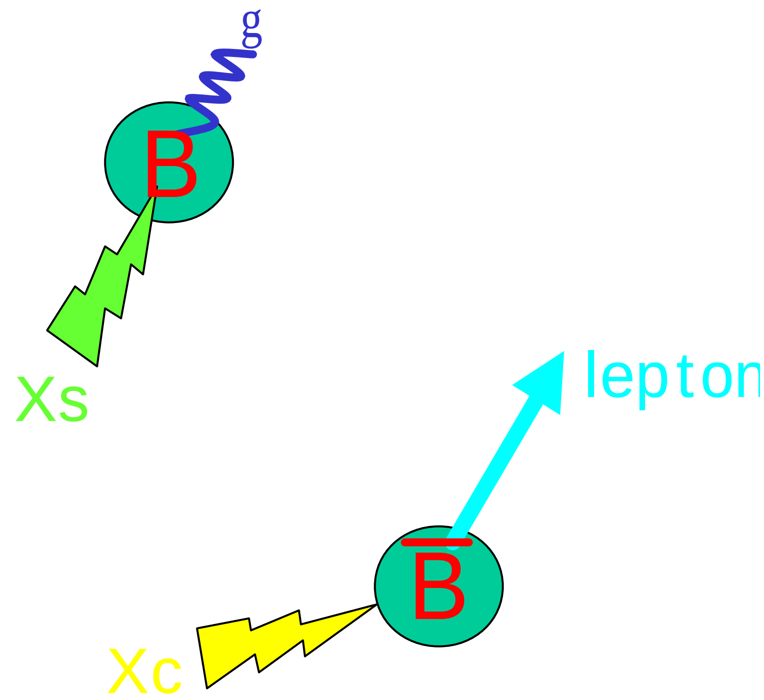
Inclusive B-Decay measurements can be done uniquely well in e+e- environment

Fully Inclusive *B* -> $X_s\gamma$

(Eisner,Schmitz,Walsh,Bucci,Brown,Libby,Veysi,Jessop)

Use lepton tags

Example of different analysis technique
Possible at high luminosity



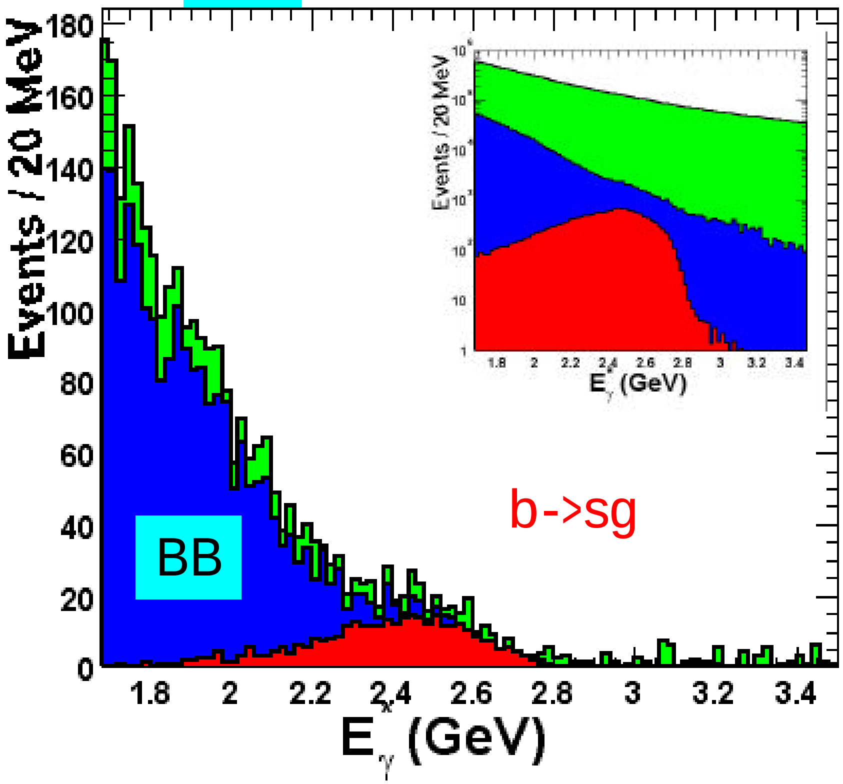
5% Efficiency for x1200 reduction in background

The tag is uncorrelated with signal B so no model dependence

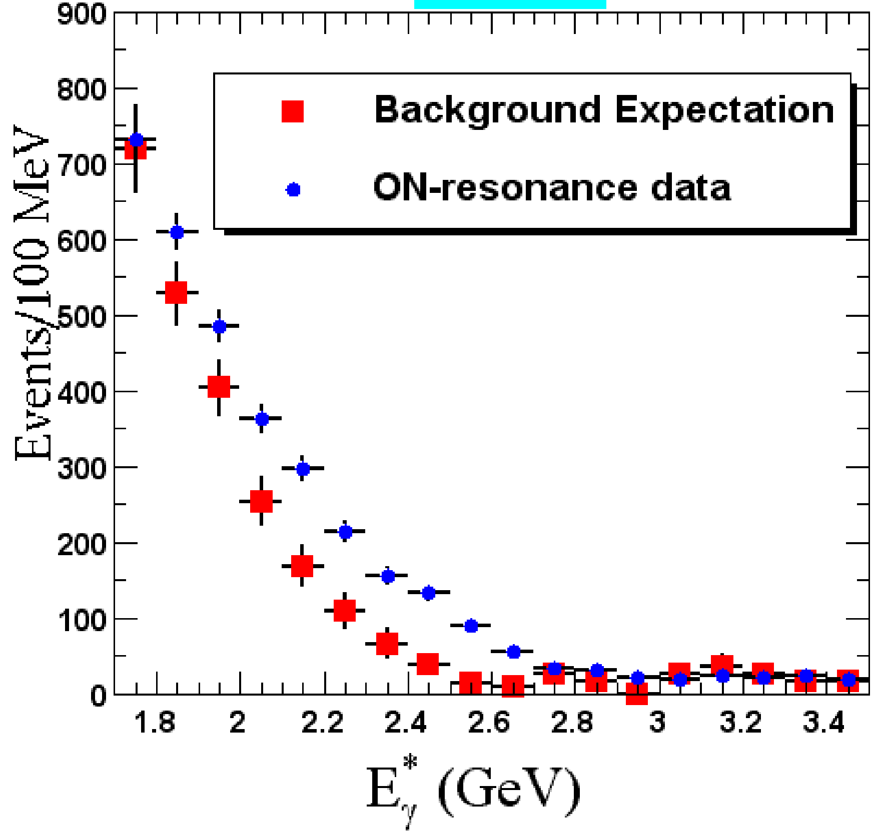
$B(B \to X_s\gamma)$

61 x 10^6 BB (54.6 fb^-1)

MC



DATA



Signal Region $2.1 < E\gamma < 2.7$ GeV

$B(B \to X_s\gamma) = 3.88 \pm 0.36(\text{stat.}) \pm 0.37(\text{sys.}) +0.43/-0.28 \text{ (Model)} \times 10^{-4}$

Errors

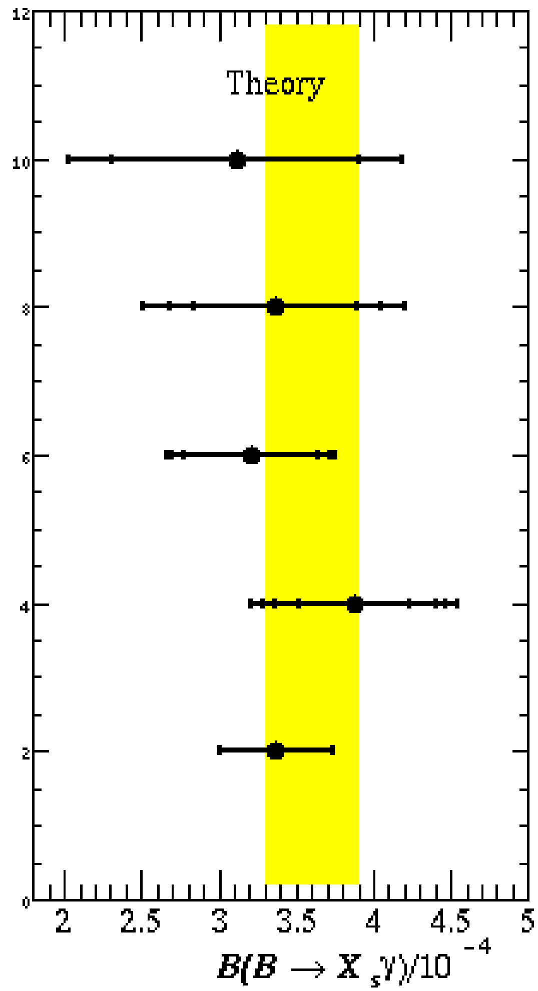
Statistical	9.1 %	Luminosity (On and off resonance)
Systematic	9.4%	Monte Carlo Modelling of BB background
Model	+6 % -11 %	Extrapolation below 2.1 GeV

Extrapolation

Lumi qb-1	Stat %	Sys %	Model %	Total %
0.05 (2002)	9.2	9.4	8.5	15.8
0.1 (now)	7.6	6.4	5.0	11.2
0.5 (2005)	3.1	3.0	5.0	6.6
10.0	0.5	0.5	2.0	2.1

An educated guess, assuming improvements in understanding BB Background and photon systematics (but not improvements in purity)

Br(B->Xsγ)



Experiment	$B \pm stat \pm syst \pm theo / 10^{-4}$
ALEPH	3.11 ± 0.80 ± 0.72
BELLE	3.36 ± 0.53 ± 0.42 ± 0.52
CLEO	3.21 ± 0.43 ± 0.27 $^{+0.18}_{-0.10}$
BABAR	3.88 ± 0.36 ± 0.37 $^{+0.43}_{-0.28}$
World Average	3.34 +- 0.38

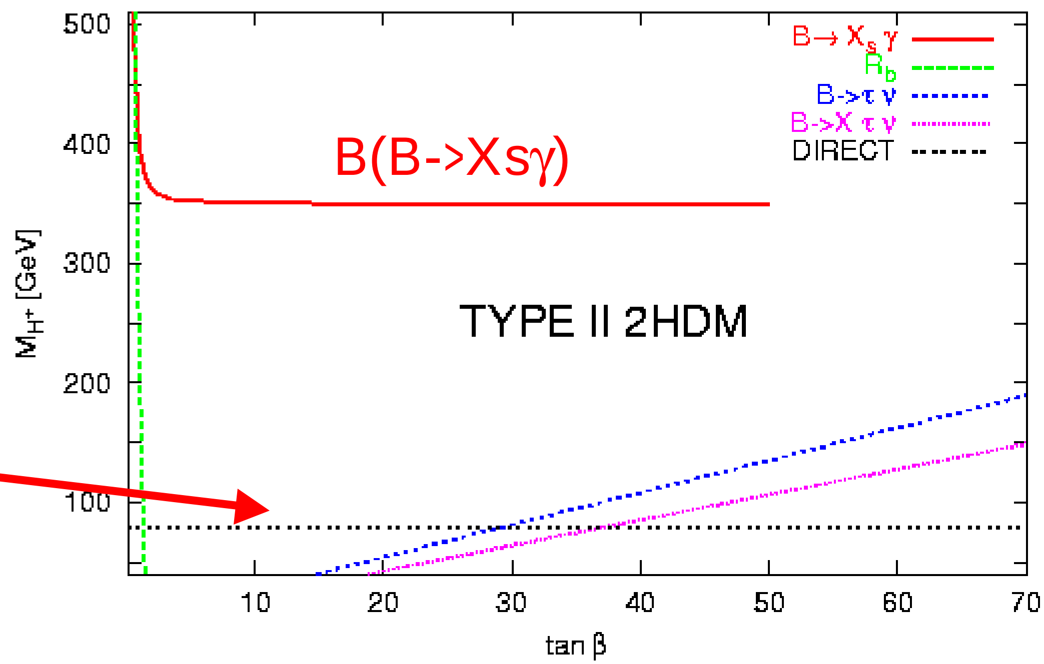
Theory: Gambino & Misiak: World Average: C.J.

Constraints from B(B->Xsγ)

(from Gambino & Misiak)

e.g Constraint on Charged Higgs in two Higgs Doublet Model

(I.e MSSM type Higgs)



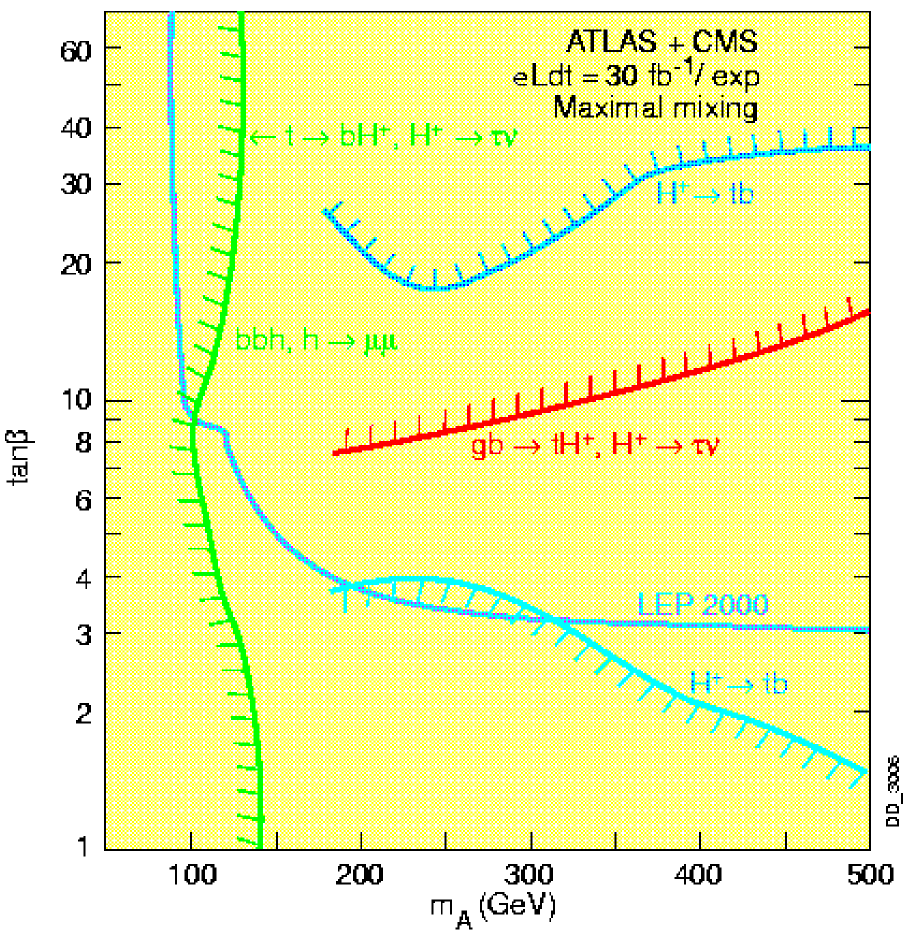
Direct search at lep

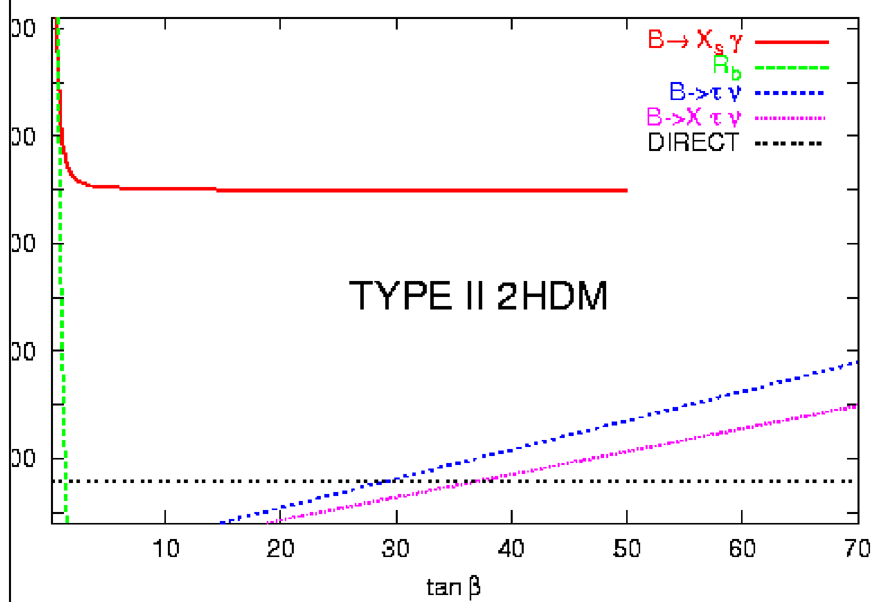
Constrain on M_H > 375 GeV(99% C.L). A 10% measurement with same BranchingFraction moves this to M_H > 475 GeV

Gambino is producing plots for extrapolated scenarios – assuming Some theory improvements (10%->5%-> ?)

Compare to Direct Search

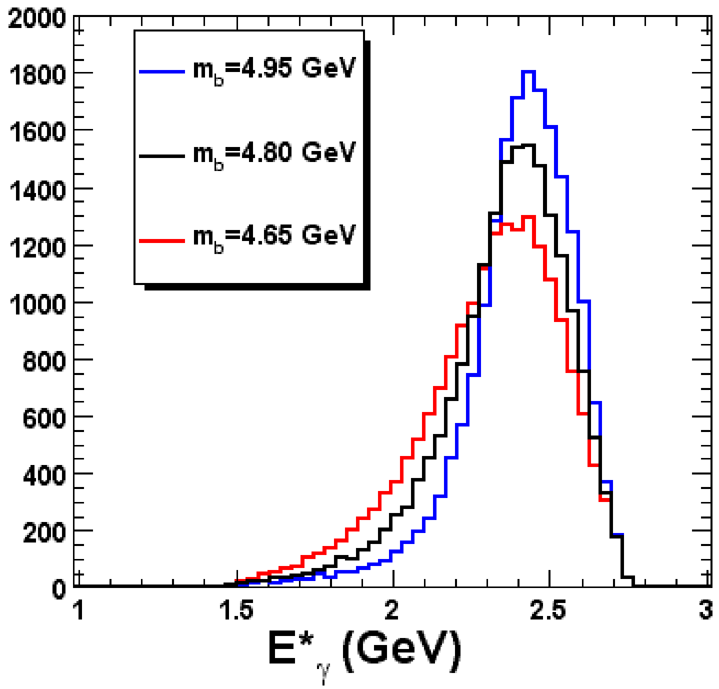
30 fb-1 LHC





Is b->s γ limit still relevent in LHC era ? – needs study

Spectrum Measurements



Eγ spectral shape is insensitive to new physics.

Shape arises from hadronic b quark Interactions inside B meson and is Universal (like a structure function)

Measurement of first and second moments can be used to extract HQET parameters that can then be used for Vub from B->Xlν

Studies now to quantify this is super BB era

Direct CPV in b->sγ

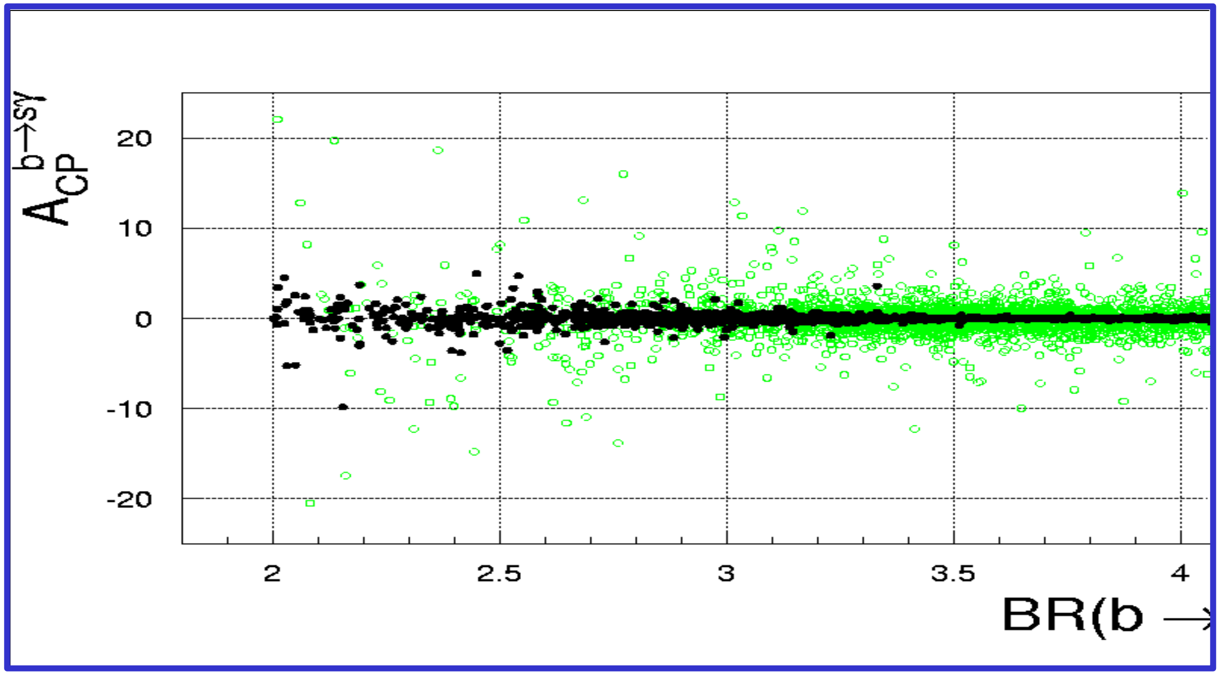
Detailed analysis for B->Xsγ at NLO:

In SM Acp(B->Xsγ) $< 0.5\ \%$ but Acp(B->Xdγ) ~ -10% and

Acp(B->Xsγ + B->Xdγ) =0.0 by CKM unitarity

New Physics can either have CKM like couplings (MFV) or not
Must respect constraints on B(B->Xsγ)

MFV constrained to < 2%



Up to ~10% in non-MFV

(Libby)

Acp(B->Xs,dγ)

Lepton Tag gives Flavor

Measure Xs+Xd (Non -SM Hurth and Mannel, hep-ph/0109041)

Mistags due to oscillations and cascade decays: (ω=0.13)

Sys Err from Detector faking CPV and background

Model Dependence and BB systematic cancels in Acp

Estimated sensitivity

Luminosity [ab^{-1}]	Statistical error [ΔA_{cp}]	Systematic error [ΔA_{cp}]
0.1	0.1	0.01
1	0.03	0.003
10	0.01	0.001 (?)
50	0.005	0.0005 (?)

Acp(B->Xsγ)

Francesca Lodovico
Steve Playfer
Andrew Eichenbaum

IN Semi-Inclusive Reconstructed final states with a charged kaon areself-tagging $\Rightarrow$ low mis-tag rate: $\omega=O(0.01)$.

Measure Xs only

In 80fb-1 Stat error 0.075 (cf . 0.10 in fully inclusive Xs+Xd)

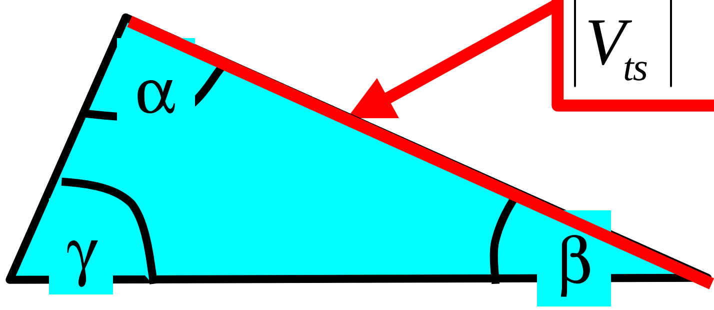
Scales in same way to higher luminosity

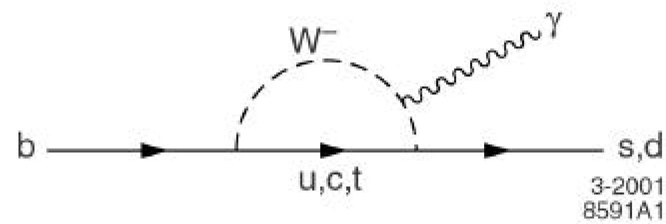
Only 50% inclusive – not clear how to relate result to theory

Libby

Rare Penguins B -> ρ,ωγ

$$\left|\frac{V_{td}}{V_{ts}}\right|^2 \propto \frac{B(B \to X_d g)}{B(B \to X_s g)}$$





Penguin analog of ΔMs/ΔMd B-mixing to over-constrain CKM ◣

Extensive effort to do this with exclusive modes (see Convery talk)

Exclusive Penguins (15-35% theory error)

ΔMs/ΔMd B-mixing 7-15% theory error

Inclusive Penguins (< 10% - from discussion no rigorous theory)

Method and Assumptions

Use standard fully inclusive lepton tag technique selection

Assumptions

1. Spectrum Xd and Xs same (Good at High E) -> efficiency same
2. s-tag with charged kaons and Ks -> exact algorithm undefined
3. Assume that K_L and $K_s \rightarrow \pi^0\pi^0$ are not reconstructed

Define

ω_s=probability of mis-tagging b ® $s\gamma$ as b ® d

ω_d=probability of mis-tagging b ® $d\gamma$ as b ® $s\gamma$

$$\left|\frac{V_{td}}{V_{ts}}\right|^2 = \frac{S'_d}{S'_s} = \frac{(1-w_s)(N_d - B_d) - w_s(N_s - B_s)}{(1-w_d)(N_s - B_s) - w_d(N_d - B_d)}$$

S'_d= true number of b ® $d\gamma$ events

S'_s= true number of b ® $s\gamma$ events

N_d= number of selected events without s-tag

$B_d = BB_d + (L_{on}/ L_{off})C_d$

BB_d=inclusive b-background without s-tag

C_d =continuum background without s-tag

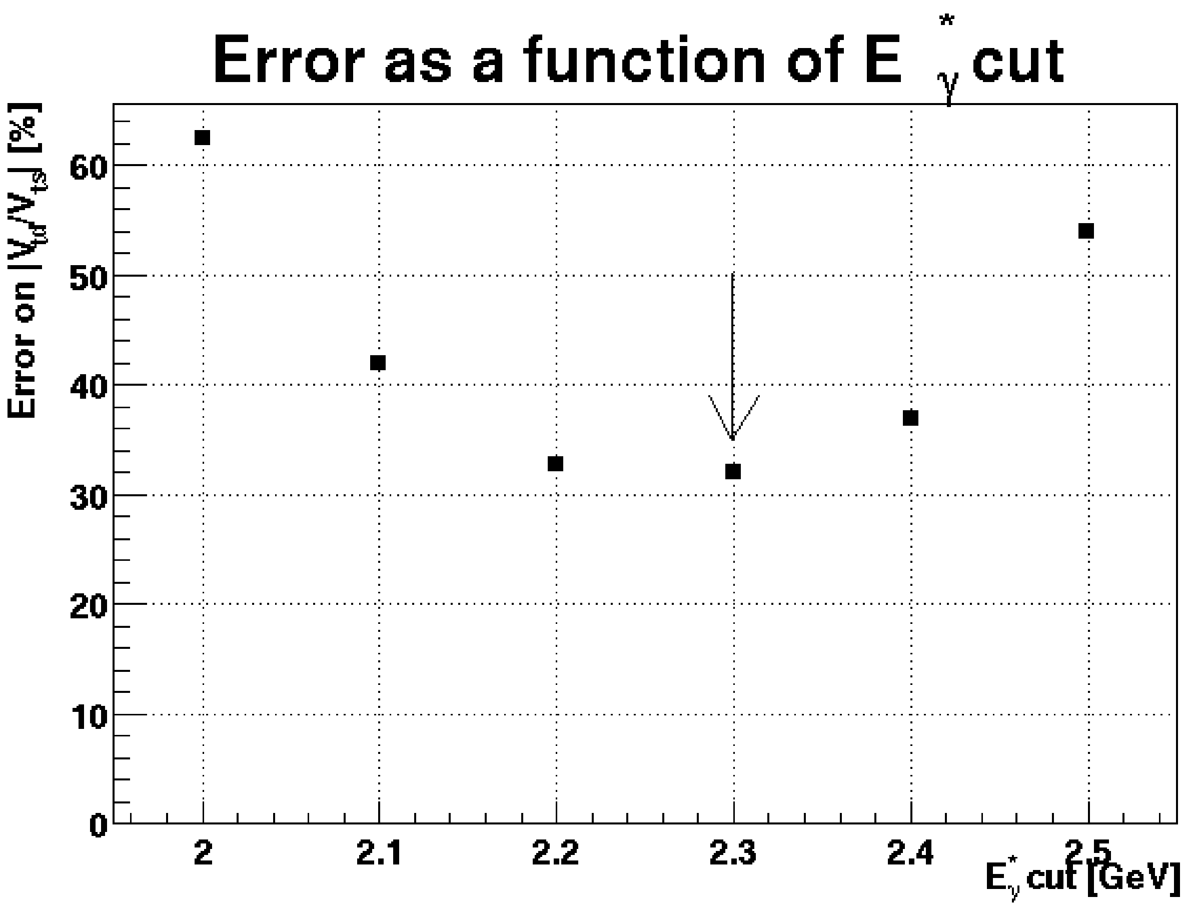
N_s, B_s, BB_s and C_s same as above with s-tag

There might be a theoretical factor required to relate to CKM ratio – ignore at present

Inputs

- ω_s=0.33 – the most optimistic case (25% K_L and 8% $K_s \rightarrow \pi^0\pi^0$ missing)
- ω_d=0.05 – a random number (*ss* popping and kaons from the other *B*-decay)
- ΔBB = 5% of BB
- L_{on}/ L_{off} = 8.6 – the present BaBar ratio
- 50% of background has an *s*-tag
  - Might expect this to be higher given significant amount of charm in background - pessimistic
- No error on mis-tag rates – this is varied later
- Error propagation on previous slides expression and plot the uncertainty as a function of E^*_γ cut and then as a function of luminosity varying inputs

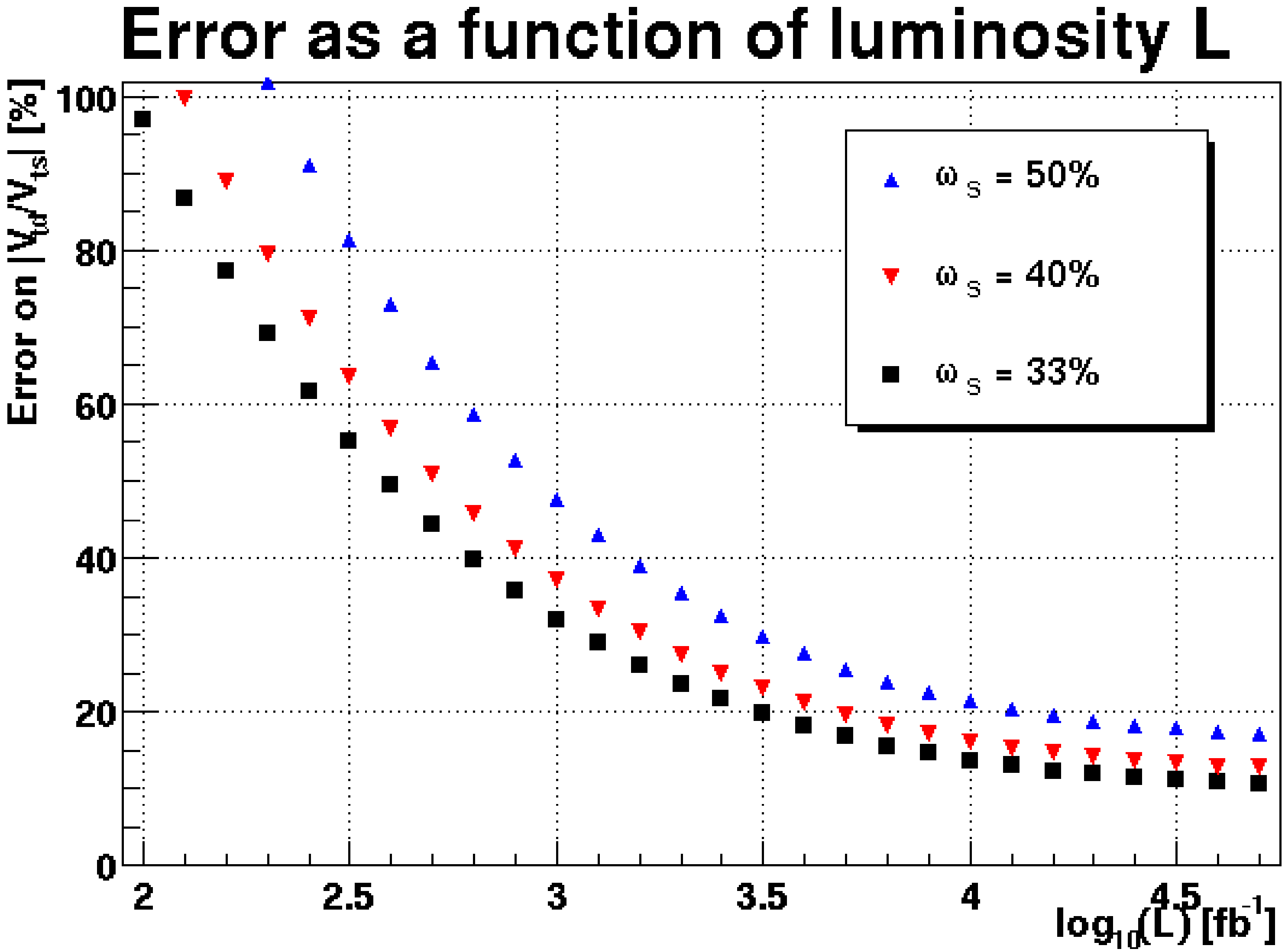
E^*_γ cut



Luminosity = 1 ab^{-1}

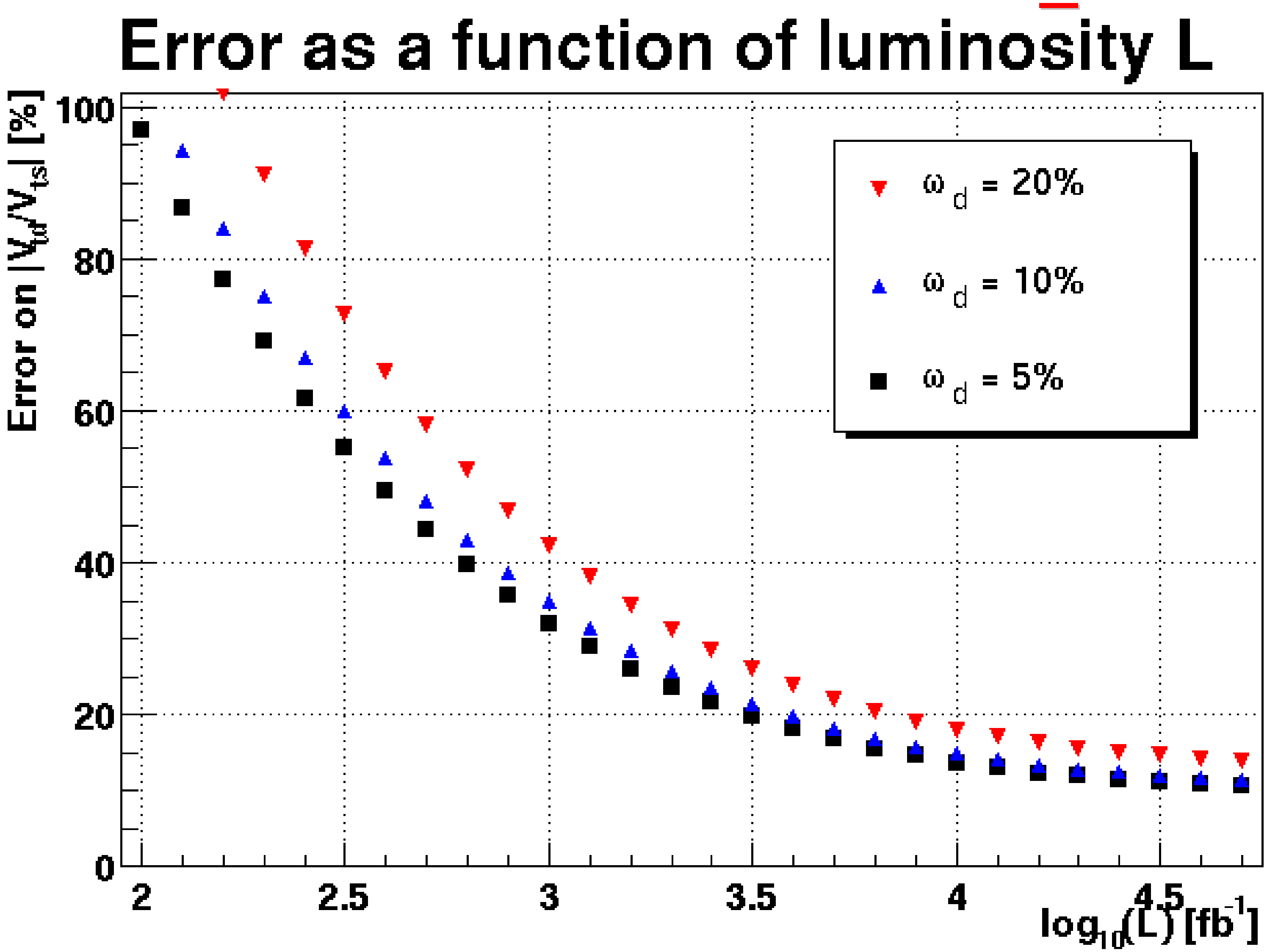
- E^*_γ> 2.3 GeV
- Cut used in all remaining plots
- Theoretical issue of 4-quark contribution to $b \circledR d\gamma$ related to $|V_{ub}|$ - probably negligible for E^*_γ>2.3 GeV (see PRD 60 034019, Ligeti *et al.)*

Variation with ω_s



100 fb^{-1} 1 ab^{-1} 10 ab^{-1} 50 ab^{-1}

Variation with ω_d



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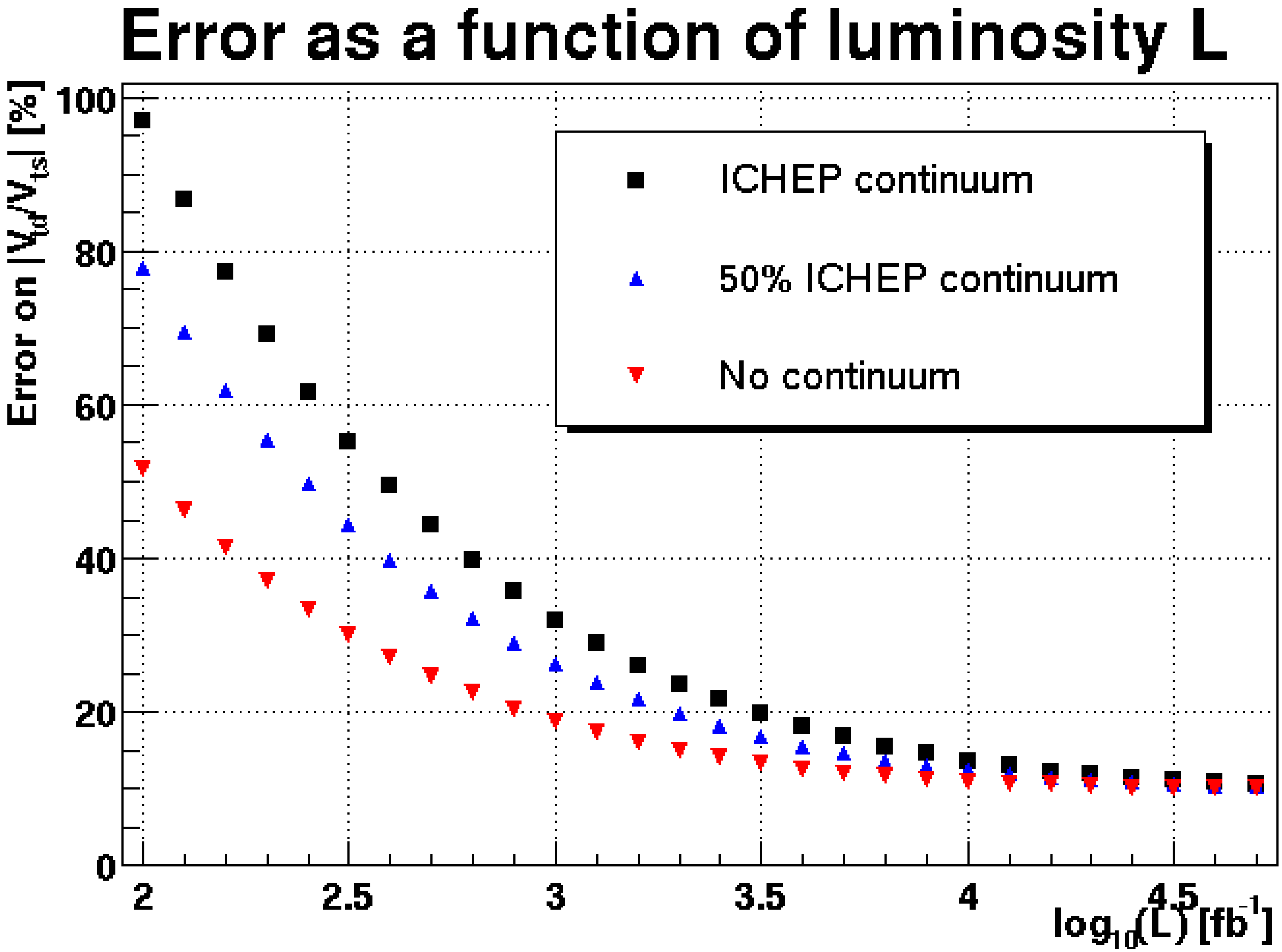
Variation with continuum bkg



100 fb^{-1} 1 ab^{-1} 10 ab^{-1} 50 ab^{-1}

Conclusions

Super BaBar offers a unique environment to study inclusive Penguin decays – no competition from LHC

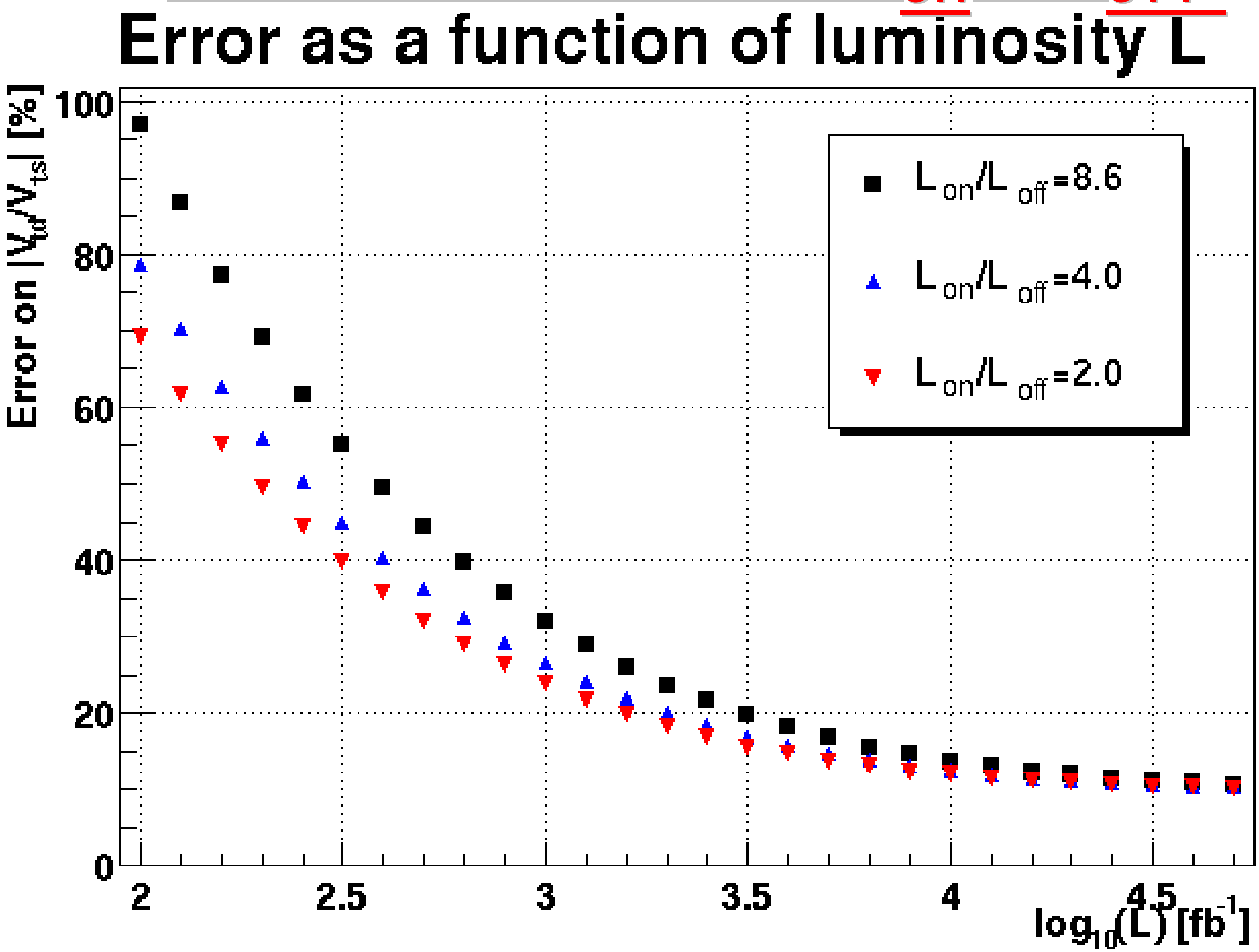
Precision measurements to < 1% can be achieved

BUT

Interest in such measurements coupled to development of precise SM predictions

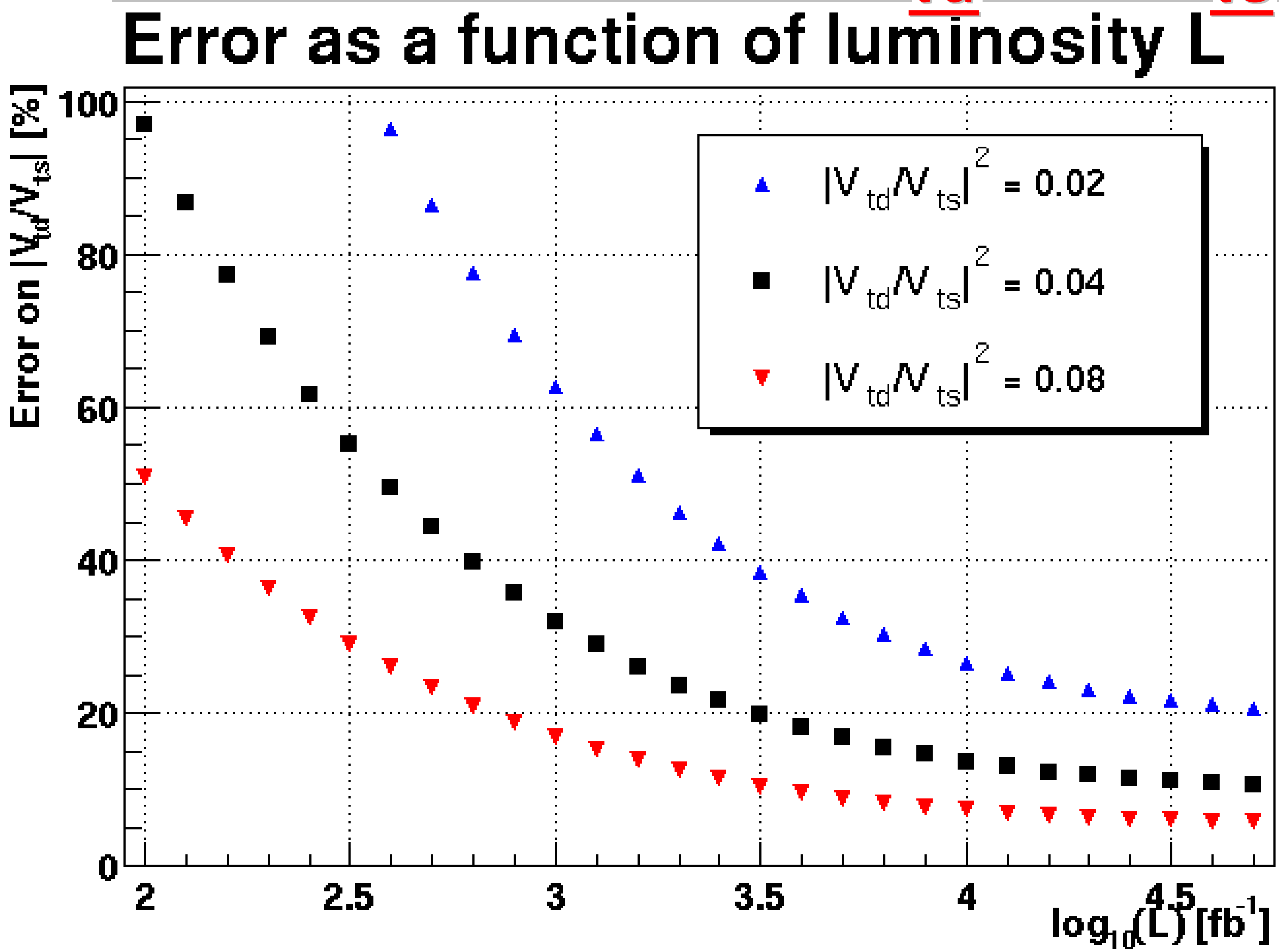
Work this summer to provide estimates and evaluate theory

Variation with L_{on}/ L_{off}



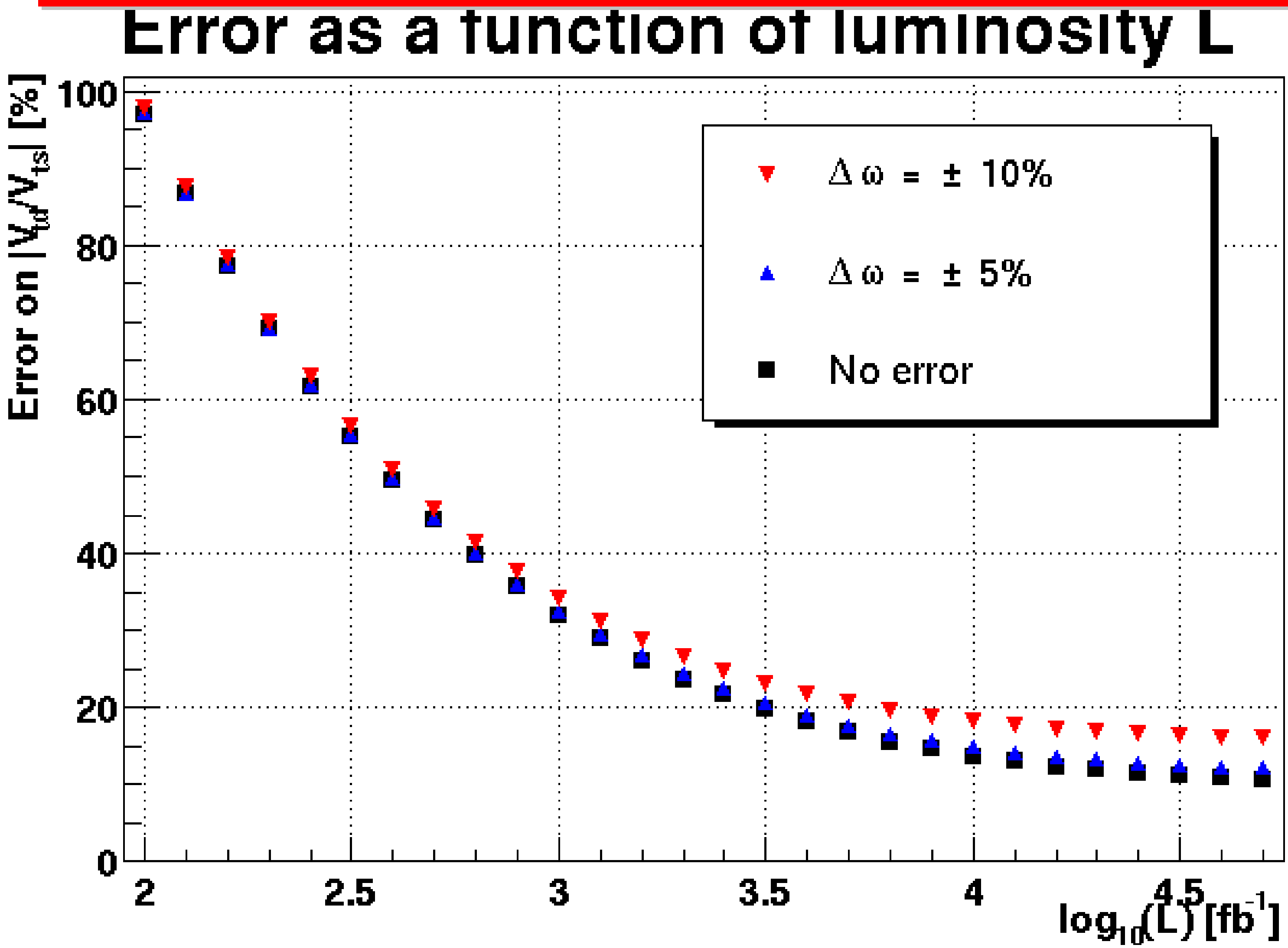
100 fb^{-1} 1 ab^{-1} 10 ab^{-1} 50 ab^{-1}

Variation with $|V_{td}|/|V_{ts}|$



100 fb^{-1} 1 ab^{-1} 10 ab^{-1} 50 ab^{-1}

Variation with mis-tag error



100 fb^{-1} 1 ab^{-1} 10 ab^{-1} 50 ab^{-1}

Variation with ΔBB