Plans for a fully-inclusive $B \to X_s\gamma$ measurement using the hadronic FEI

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Inclusive analysis meeting

April 9, 2020

Brief introduction

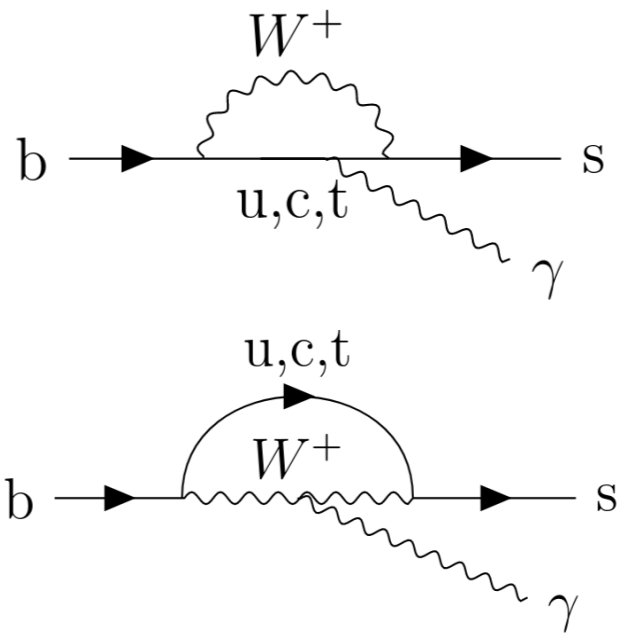
Brief Introduction

- Group from DESY: Kerstin Tackmann, Simon Wehle, Henrikas Svidras, Markus Röhrken.
- A fully-inclusive $B \to X_s\gamma$ is planned using a hadronic tag.

Content Summary

- Projections for the short-term.
- Analysis strategy.
- Early considerations for signal selection.

$B \to X_s\gamma$: motivation



- $B \to X_s\gamma$ is sensitive to SM extensions (2HDM, SUSY etc.)
- Allows to determine m_b^2 and μ_π^2 important for $|V_{ub}|$ extraction from $b \to u l \bar{\nu}$.
- An inclusive measurement minimises/changes some of the theoretical uncertainties arising in exclusive analyses.
- Hadronic tag: higher purity, E_γ measured in B rest frame.

Previous inclusive measurements (BaBar and Belle)

Year	Experiment	Measurement type	Data on res	Data off res
2007	BaBar	Hadronic	210 fb^{-1}	—
2009	Belle	No-tag/Semi-leptonic	605 fb^{-1}	68 fb^{-1}
2012	BaBar	Semi-leptonic	347 fb^{-1}	36 fb^{-1}
2012	BaBar	Sum-of-exclusive	429 fb^{-1}	45 fb^{-1}
2016	Belle	Semi-leptonic	711 fb^{-1}	90 fb^{-1}

$\rightarrow$ About 10% off-resonance data is required.

With the (upcoming) large Belle 2 dataset:

$\rightarrow$ A hadronically-tagged inclusive measurement is the goal.

Expected signal yield

Conservative Belle 2 estimation 50 $\text{fb}^{-1} \rightarrow 55 \cdot 10^6$ $\text{B}\bar{\text{B}}$ pairs by Summer 2020. (see Iijima-san's talk during B2GM.)

Given hadronic FEI tag-side efficiency (just benchmark numbers):

- 0.2 % for hadronic neutral B.
- 0.4 % for hadronic charged B.

$\rightarrow\sim$ FEI 0.3 % : 165000 evts.

Expected signal yield

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E_γ cut, GeV	$B_{(s+d)\gamma} \cdot 10^{-4}$*	Expected observable evts for 50fb^{-1}
1.7	3.20 ± 0.29	53 ± 5
1.8	3.15 ± 0.23	52 ± 4
1.9	3.07 ± 0.19	51 ± 3
2.0	2.92 ± 0.14	48 ± 2

$\rightarrow$ This is before any background treatment!

*Branching fractions from Belle semileptonic (2016)

Expected signal yield

- Assume signal efficiency & systematics as in BaBar hadronic (2009).

$\rightarrow$ eff 30% (1.9 GeV) to 65% (2.6 GeV) approximately linear increase.

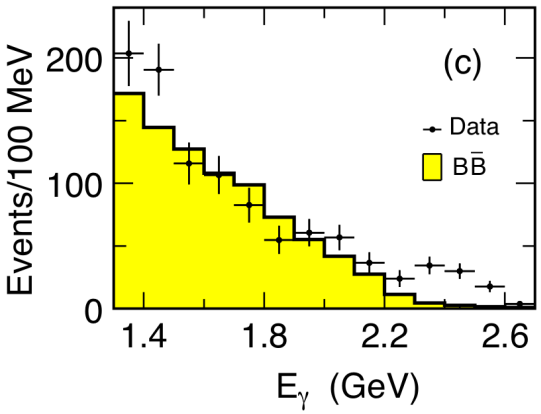
- Scale statistical error according to int. luminosity difference.

$\rightarrow$ multiply by $\sqrt{\frac{210}{50}}$.

- Central value from BaBar semileptonic (2012).

So bin-by-bin one can expect:

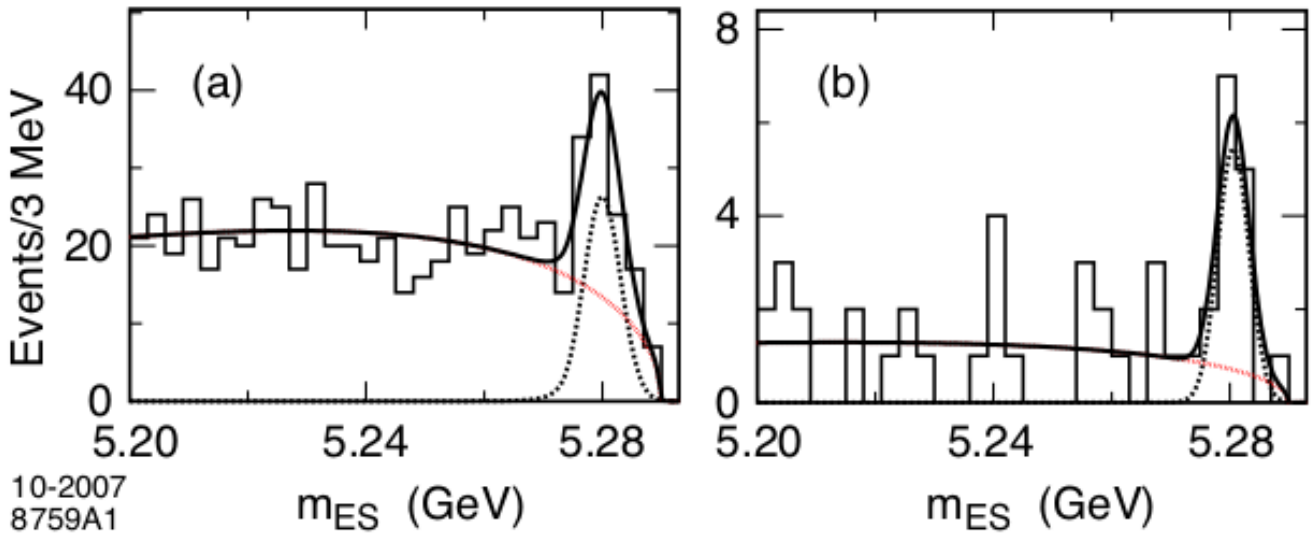
E_γ, GeV	Expected events in bin	$\frac{N}{\sqrt{N+B}}$
1.9-2.0	2 ± 6	0.71
2.0-2.1	2 ± 6	0.71
2.1-2.2	3 ± 4	1.13
2.2-2.3	4 ± 4	1.41
2.3-2.4	5 ± 4	1.67
2.4-2.5	6 ± 3	2.00
2.5-2.6	7 ± 3	2.21
2.0-2.6	27 ± 10	4.44



$\rightarrow$ approximately a fourth of events compared to this

Analysis strategy of arXiv 0711.4889 (BaBar hadronic)

- Hadronic tag with 0.3% efficiency.
- Continuum background suppressed using Fisher discriminant combining 12 event-topology variables.
- Events with photons consistent with π^0 and η, $\rho^{\pm}$ vetoed.
- M_{bc} fit/subtraction for tag-side background.
- Subtraction of $B \to X_d\gamma$ (less than 5% contribution.)



(a) $1.6\,\mathrm{GeV} < E_\gamma < 1.7\,\mathrm{GeV}$ for the charged B sample. (b) $2.3\,\mathrm{GeV} < E_\gamma < 2.4\,\mathrm{GeV}$ for the neutral B sample.

$\to$ can be used to as a preliminary benchmark to compare the analysis to.

FEI and gamma preselection

- Changed the reconstruction approach - shifted to FEI skims.
- Assessing selection variables for the analysis.

- Cleaned tracks (`pi+:eventShapeForSkims`): $d_0 < 0.5\,\text{cm}$, $|z_0| < 2\,\text{cm}$, and $p_T > 0.1\,\text{GeV}$
- Cleaned ECL clusters (`gamma:eventShapeForSkims`): $0.296706 < \theta < 2.61799$, and $E > 0.1\,\text{GeV}$

Event pre-cuts:

- $R_2 < 0.4$ (`foxWolframR2` from `modularAnalysis.buildEventShape` , calculated using all cleaned tracks and clusters)
- $n_{\text{tracks}} \geq 4$
- $n_{\text{cleaned tracks}} \geq 3$
- $n_{\text{cleaned ECL clusters}} \geq 3$
- Visible energy of event (CMS frame) $> 4\,\text{GeV}$
- $2\,\text{GeV} < E_{\text{cleaned tracks \& clusters in ECL}} < 7\,\text{GeV}$

Tag side B cuts:

- $M_{\text{bc}} > 5.24\,\text{GeV}$
- $|\Delta E| < 0.2\,\text{GeV}$
- signal probability > 0.001 (omitted for decay mode 25)

- Additional cuts on gamma:

$\rightarrow$more than 1 γ with E>1.4 GeV in CDC acceptance.

Reconstruction of events

Reconstruction of "$X_s\gamma$" uses the new Belle 2 decay string grammar '...'

- $B^+ \to \gamma$ ... with no additional cuts.

$\to$allows to use `matchMCTruth`.

- $\Upsilon(4S) \to B^+$:generic B^-:signal with 5.5 <= M <= 12.5

Still need to understand truth matching better:
$\to$ only `isSignalAcceptMissingGamma` works for B^+.
$\to$ matching at $\Upsilon(4S)$ level?

Currently a way to select $b \to s\gamma$:
`Btag_isSignal and Bsig_isSignalAcceptMissingGamma and gamma_isSignal` $\to$ `isBsgamma`.

Photon selection

Selecting only `isBsgamma` candidates.
Look which FEI rank/ gamma rank they correspond to.

FEI rank\E$_\gamma$ rank	1	2	3	all E$_\gamma$ ranks
1	82.6%	0.6%	<0.1%	83.2%
2	10.8%	0.1%	<0.1%	10.9%
3	2.8%	<0.1%	<0.1%	2.8%
4	1.3%	<0.1%	<0.1%	1.3%
5	0.6%	<0.1%	<0.1%	0.6%
6	0.4%	<0.1%	<0.1%	0.4%
7	0.2%	<0.1%	<0.1%	0.2%
8	0.2%	<0.1%	<0.1%	0.2%
9	0.1%	<0.1%	<0.1%	0.1%
10+	0.3%	<0.1%	<0.1%	0.3%
all FEI ranks	99.3%	0.7%	<0.1%	216891

NOTE: On $B^+ \to X_s\gamma$ SignalMC 12 (1 block: $50{\cdot}10^6$ evts).

Photon selection

Selecting only **NOT** `isBsgamma` candidates.
Look which FEI rank/ gamma rank they correspond to.

FEI rank\E$_\gamma$ rank	1	2	3	all E$_\gamma$ ranks
1	18.8%	0.2%	<0.1%	19.1%
2	15.2%	0.2%	<0.1%	15.4%
3	12.1%	0.2%	<0.1%	12.1%
4	10.0%	0.2%	<0.1%	10.2%
5	8.3%	0.1%	<0.1%	8.5%
6	7.0%	0.1%	<0.1%	7.1%
7	5.9%	0.1%	<0.1%	6.0%
8	5.0%	0.1%	<0.1%	5.0%
9	4.1%	0.1%	<0.1%	4.1%
10+	12.0%	0.2%	<0.1%	12.2%
all FEI ranks	98.4%	1.6%	<0.1%	16615759

Photon selection

- Selecting FEI rank/ E_γ rank 1 seems an reasonable first rough cut:

$\rightarrow$retains 82.6% of correct and 18.8% of incorrect combinations.

- Probably can be extended using other variables:

$\rightarrow$e.g. most of the incorrect combinations have FEISigProb <0.1

Summary and plans

The analysis is starting out, optimising selection, understanding distributions.

- A hadronic tag on this year's data seems possible.
- Reconstruction using FEI skims seems to give expected results.
- Need to extend work to generic MC and further optimise selections.

Thanks for your attention!
Comments and insight very welcome.

FEI sig probs isBsGamma

FEI sig prob\E$_\gamma$ rank	1	2	3	all E$_\gamma$ ranks
0.0 – 0.1	49.5%	0.3%	<0.1%	49.8%
0.1 – 0.2	12.4%	0.1%	<0.1%	12.5%
0.2 – 0.3	8.1%	0.1%	<0.1%	8.2%
0.3 – 0.4	5.9%	0.1%	<0.1%	6.0%
0.4 – 0.5	4.9%	<0.1%	<0.1%	4.9%
0.5 – 0.6	4.7%	<0.1%	<0.1%	4.7%
0.6 – 0.7	3.5%	<0.1%	<0.1%	3.5%
0.7 – 0.8	3.2%	<0.1%	<0.1%	3.2%
0.8 – 0.9	3.2%	<0.1%	<0.1%	3.2%
0.9 – 1.0	4.8%	<0.1%	<0.1%	4.8%
0.0-1.0	99.3%	0.7%	<0.1%	216891

FEI sig probs not isBsGamma

FEI prob \E$_\gamma$ rank	1	2	3	all gamma E ranks
0.0 – 0.1	98.1 %	1.5%	<0.1%	99.6%
0.1 – 0.2	0.2 %	<0.1%	<0.1%	0.2%
0.2 – 0.3	0.1%	<0.1%	<0.1%	0.1%
0.3 – 0.4	<0.1%	<0.1%	<0.1%	<0.1%
0.4 – 0.5	<0.1%	<0.1%	<0.1%	<0.1%
0.5 – 0.6	<0.1%	<0.1%	<0.1%	<0.1%
0.6 – 0.7	<0.1%	<0.1%	<0.1%	<0.1%
0.7 – 0.8	<0.1%	<0.1%	<0.1%	<0.1%
0.8 – 0.9	<0.1%	<0.1%	<0.1%	<0.1%
0.9 – 1.0	<0.1%	<0.1%	<0.1%	<0.1%
0.0-1.0	98.4%	1.6%	<0.1%	16615759

Counts isBsGamma

FEI rank\E$_\gamma$ rank	1	2	3	all E$_\gamma$ ranks
1	179171	1325	3	180499
2	23455	144	2	23601
3	6086	34	0	6120
4	2762	18	0	2780
5	1318	14	0	1332
6	867	3	0	870
7	527	1	0	528
8	344	0	0	344
9	252	1	0	253
10+	562	2	0	564
Total all FEI ranks	215344	1542	5	216891

Counts not isBsGamma

FEI rank\E$_\gamma$ rank	1	2	3	all E$_\gamma$ ranks
1	3123197	56883	124	3180204
2	2520134	42948	99	2563181
3	2012269	32729	78	2015626
4	1664149	26112	52	1690313
5	1384278	21183	45	1405506
6	1169334	17823	34	1187191
7	982165	14496	29	996690
8	823791	11931	25	835747
9	679888	9572	20	689480
10+	1995805	26500	61	2022366
all FEI ranks	16355010	260177	572	16615759