Getting Ready for Belle II

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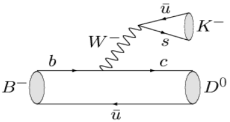
Outline

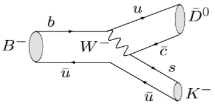
- Determination of ϕ_3 via $B^{\pm} \to D(K_S^0\pi^+\pi^-)K^{\pm}$
  - Continuum suppression
  - Variable selection
  - Comparison with Belle
- Data production
  - Dress rehearsal
  - Global cosmic run

ϕ_3 determination

- Exploit the interference between $B^- \to D^0 K^-$ and $B^- \to \bar{D}^0 K^-$ decays



color allowed
$B^- \to D^0 K^- \sim V_{cb} V^*_{us}$
$\sim A\lambda^3$



color suppressed
$B^- \to \bar{D}^0 K^- \sim V_{ub} V^*_{cs}$
$\sim A\lambda^3(\rho + i\eta)$

- Three ways to determine ϕ_3:
  - GLW method (Gronau-London-Wyler): *CP* eigenstates such as K^+K^-, $\pi^+\pi^-$, and $K^0_S\pi^0$
  - ADS method (Atwood-Dunietz-Soni): Doubly Cabibbo-suppressed decays such as $K\pi$
  - **GGSZ [1] (or Dalitz) method (Giri-Grossman-Soffer-Zupan): Multibody decays such as $K^0_S\pi^+\pi^-$, $K^0_S K^+K^-$, and $K^0_S\pi^+\pi^-\pi^0$**

[1] A. Giri, Yu. Grossman, A. Soffer and J. Zupan, Phys. Rev. D **68**, 054018 (2003).

ϕ_3 measurements

- Ultimate precision $\approx \mathbf{1}^\circ$
- Dominated by $B \to D(K^0_S\pi\pi)K$ mode
  - improvements, even modest, will have large impact on the sensitivity
- Some almost not possible at LHCb: $K^0_S\pi^0, K^0_S\pi\pi\pi^0, K^0_L\pi\pi$

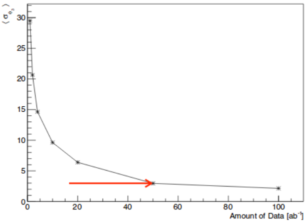
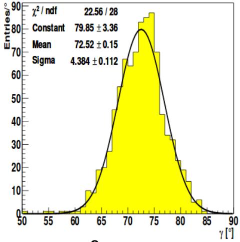


Figure: ϕ_3 sensitivity Vs amount of Belle II data collected (ab^{-1}).



- $\mathbf{K^0_S\pi^+\pi^-\pi^0}$: sensitivity of 4.4° with the full Belle II data[a]
- $\mathbf{K^0_L\pi\pi}$: impact similar to that of $J/\psi K^0_L$ on $\sin(2\phi_3)$?

[a] JHEP, **01** (2018) 82.

ϕ_3 sensitivity via $B \to D(K_S^0\pi^+\pi^-)K$ decays

- Sensitivity varies across the Dalitz bins
  - **GLW like states:** Interference of $B^- \to DK^-$, $D \to K_S^0\rho$
  - **ADS like states:** Interference of $B^- \to DK^-$, $D \to K^*\pi$
- Golden mode to determine ϕ_3!

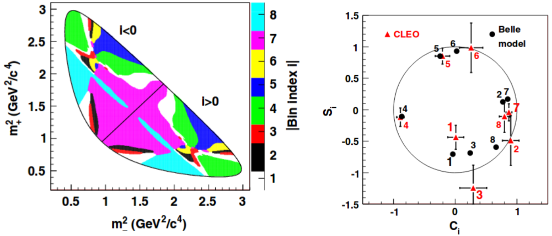


Figure: PRD **85** (2012) 112014.

- Need external inputs from charm factory: CLEO-c or BESIII for strong phase differences c_i and s_i

Preliminary study of $B \to D(K_S^0\pi\pi)K$ in Belle II

(I. Watson , May 23,2016)

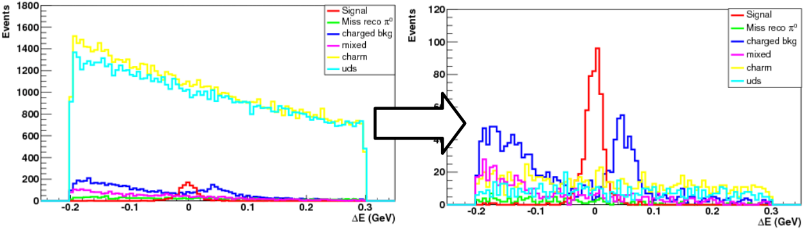
	Belle II B^+	B^-	Belle I B^+	B^-
Signal	579.3	606.0	648.6	653.0
B^+B^-	1844.2	1996.2	1412.0	1405.6
$B^0\bar{B}^0$	334.4	352.2	158.6	142.8
$c\bar{c}$	12231.5	12505.6	7480.4	7518.0
UDS	7880.3	8043.9	4280.0	4238.6
Total	22290.4	22897.9	13331.	13305.
Purity	0.026	0.027	0.049	0.049

continuum suppression !!

- Performed by I. Watson, without beam background!
- Continuum suppression was not implemented

Impact of continuum suppression on ϕ_3 study

illustration from Resmi P.K. for Belle $B \to D(K_S \pi\pi\pi^0)K$ analysis

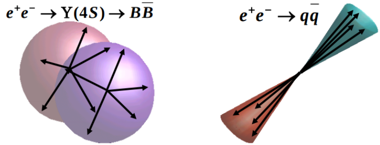


efficiency loss = 33%
background rejection = 97%

Also see PRL **106** (2011) 231803

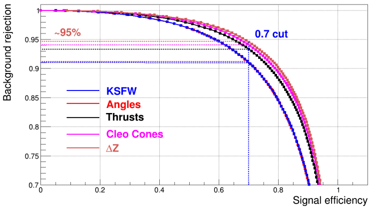
- Smarter background rejection is needed for 50 ab^{-1} Belle II data!

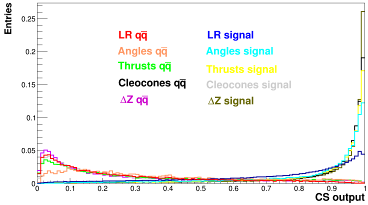
Continuum suppression

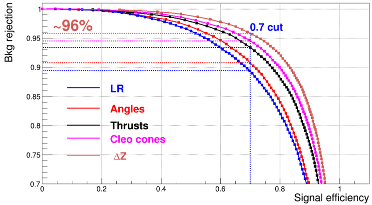


Variables:

- Likelihood ratio from 18 KSFW moments
- Magnitude of thrusts of B and rest-of-events (RoE)
- Cosine of angles of thrust axis of B and RoE, and thrust axis of B and z-axis
- Nine CLEO cones







- For **30% signal loss**, > **95% background rejection** (90% in Belle)

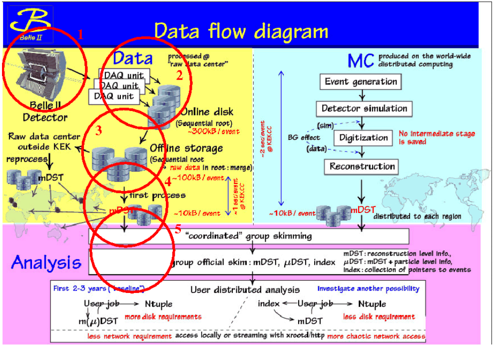
ϕ_3/γ extraction using $B \to D(K_S^0\pi^+\pi^-)K$ in Belle II

Variable/sample	I. Watson's	Ours
MC sample	MC5	MC9
data size	2.0 ab^{-1} (BGx0)	0.2 ab^{-1} (BGx0)/0.8 ab^{-1} (BGx1)
$d0$	0.5 cm	"
$z0$	1.0 cm	"
PID	Tighter cut	KID$>$0.5 for $K^{\pm}$
	Tighter cut	PiID $>$ 0.5 for $\pi^{\pm}$
$M_{K_S^0}$	0.450–0.550 GeV	"
M_{D^0}	1.85–1.88 GeV	"
M_{bc}	$>$ 5.25 GeV	"
$\mid \Delta E \mid$	0.15 GeV	"
Efficiency	**14.8% (BGx0)**	**17.0% (BGx0)** **7.9% (BGx1)**
Belle efficiency	**15.1% (BGx1)**	

Table: Selection criteria for $B \to D(K_S^0\pi\pi)K$ decay.

Sample	No beam bkg	With beam bkg
Signal	**1353**	**834**
B^+B^-	9982	7060
$B^0\bar{B}^0$	3763	2174
$c\bar{c}$	100398	60278
UDS	77588	45712
$u\bar{u}$	48656	26686
$d\bar{d}$	8342	5747
$s\bar{s}$	20590	13279
Total	191731	115224

Dress rehearsal for Belle II experiment



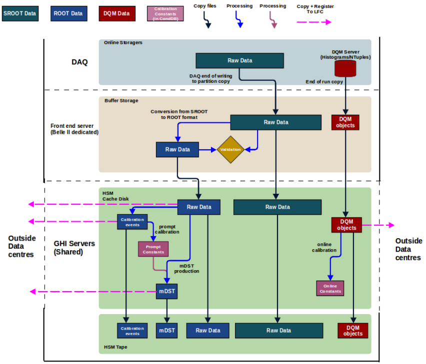
- Belle collected $\sim 1\ \mathrm{ab}^{-1}$ data for 10+ years
- Belle II $\rightarrow 50\ \mathrm{ab}^{-1}$ in ~ 5 years, *i.e.* $\sim 1\ \mathrm{ab}^{-1}$ in each month!
- It's of paramount importance to check the performance of central production system towards processing the raw data in a timely manner
- Used Grid for phase III

Dress rehearsal 3 (DR3)

- Perform in a similar way as DR2
  - phase 3 (phase 2 for DR2)
  - Grid (KEKCC for DR2)
- Need to use $q\bar{q}$ $(q = u, d, s, c, b), ee, \tau\tau, \text{and } \mu\mu$ event types with the respective cross-sections
- Produce 1 unit of 0.01 fb^{-1}
- Full rehearsal sample $\rightarrow$ 1 ab^{-1} in Grid (20 fb^{-1} for DR2)

Procedure for DR3

1. **Raw data:**
   - One unit of 0.01 fb^{-1}
   - One "run" of 0.1 fb^{-1}: 10 such units $\rightarrow$ 70 jobs
   - 100 fb^{-1}: 70,000 jobs in Grid
   - Full DR3 sample of 1 ab^{-1}
   - Transfer to KEKCC
2. **DAQ:**
   - HLT software trigger information
3. **Offline:**
   - mdst
   - Prompt calibration $\rightarrow$ mdst
4. Standalone samples:
   - Signal MC "like" samples
   - For calib/HLT performances



Comparison of CPU usage with DR2

Event type	Raw prod CPU time	Memory	Raw size (ROOT)	Raw prod log size	mdst prod CPU time	mdst size	mdst prod log size
	(sec/event)	(MB/job)	(kB/event)	(MB)	(sec/event)	(kB/event)	(MB)
$b\bar{b}$	**1.3**	**1035.3**	**49.3**	0.2	**2.1**	**11.1**	0.06
$c\bar{c}$	**1.1**	**1053.1**	**46.6**	0.3	**1.6**	**9.7**	0.10
$s\bar{s}$	**1.0**	**891.1**	**45.1**	0.1	**1.2**	**8.9**	0.06
$d\bar{d}$	**1.1**	**896.9**	**45.2**	0.1	**1.3**	**8.8**	0.06
$u\bar{u}$	**1.0**	**1078.5**	**45.0**	0.3	**1.2**	**8.8**	0.10
$\tau\tau$	**0.5**	**912.0**	**41.4**	0.2	**0.6**	**6.7**	0.06
$\mu\mu$	**0.3**	**882.7**	**40.2**	0.2	**0.4**	**6.2**	0.06

DR2 validation with release-00-09-02 :

component (physics process)	cross-section (nb)	RAW prod CPU time (sec/evt)	Memory (MB/job)	RAW size (kB/evt) (ROOT)	RAW size (kB/evt) (SROOT)	RAW prod log size (MB)	mDST prod CPU time (sec/evt)	mDST size (kB/evt)	mDST prod log size (MB)
bb	1.1	1.28	1097	31	86	2.2	0.7	4.3	1.2
cc	1.329	1.05	1097	29	83	2.6	0.6	3.3	1.2
ss	0.383	0.98	967	28	81	0.8	0.4	2.8	1.2
dd	0.401	1.08	966	28	80	0.8	0.4	2.8	1.2
uu	1.605	1.02	1113	28	81	3.1	0.4	2.8	1.2
tautau	0.919	0.59	986	25	77	1.8	0.2	1.5	1.2
mumu	1.115	0.35	972	23	76	2.2	0.1	1.0	1.2

component (physics process)	cross-section (nb)	Nevts	CPU (sec)	Raw size (ROOT, MB)	Raw size (SROOT, MB)	CPU (sec)	mDST size (MB)
bb	1.1	11000	14122	342	949	7000	40
cc	1.329	13290	14008	385	1100	6834	43
ss	0.383	3830	3731	108	314	1570	11
dd	0.401	4010	4291	112	328	1724	11
uu	1.605	16050	16389	444	1300	6844	43
tautau	0.919	9190	5386	226	716	1528	13
mumu	1.115	11480	4040	269	880	1263	11

Global Cosmic Run (GCR2)

event time available in RAWCOPPER — presence of raw data for this detector — provided by T.Hara — only with mag. field — information on QCS

RUN	DATE	Run start	Run end	Run time	PXD	SVD	CDC	TOP	ARICH	ECL	KLM	TRG	TYPE	#events	B field	comments
	mm/dd	hh:mm	hh:mm	hh:mm												
13	02/14	21:18	21:47	00:29	ON	ON	ON	OFF	OFF	ON	ON	ON		106031		
25	02/14	23:29	00:03	00:34	ON	ON	ON	ON	OFF	ON	ON	ON	trg2	124880	ON	
27	02/15	00:09	01:09	01:00	ON	ON	ON	ON	OFF	ON	ON	ON	trg2	218537	ON	
36	02/15	02:33	03:33	01:00	ON	ON	ON	ON	OFF	ON	ON	ON	trg2	219290	ON	
37	02/15	03:36	04:36	01:00	ON	ON	ON	ON	OFF	ON	ON	ON	trg2	217514	ON	
38	02/15	04:43	05:43	01:00	ON	ON	ON	ON	OFF	ON	ON	ON	trg2	226334	ON	
77	02/15	23:15	00:14	00:59	ON	ON	ON	ON	OFF	OFF	OFF	ON	trg2 || 1Hz	270567	ON	
78	02/16	00:18	01:19	01:01	ON	ON	ON	ON	OFF	OFF	OFF	ON	trg2 || 1Hz	282689	ON	
82	02/16	01:54	02:54	01:00	ON	ON	ON	ON	OFF	OFF	OFF	ON	trg2 || 1Hz	278523	ON	
83	02/16	02:57	03:57	01:00	ON	ON	ON	ON	OFF	OFF	OFF	ON	trg2 || 1Hz	279296	ON	
84	02/16	04:02	05:02	01:00	ON	ON	ON	ON	OFF	OFF	OFF	ON	trg2 || 1Hz	275814	ON	
85	02/16	05:04	06:06	01:02	ON	ON	ON	ON	OFF	OFF	OFF	ON	trg2 || 1Hz	283451	ON	
86	02/16	06:09	07:10	01:01	ON	ON	ON	ON	OFF	OFF	OFF	ON	trg2 || 1Hz	282372	ON	
87	02/16	07:12	07:35	00:23	ON	ON	ON	ON	OFF	OFF	OFF	ON	trg2 || 1Hz	107048	ON	
145	02/17	00:23	00:45	00:22	ON	ON	ON	ON	OFF	ON	ON	ON	trg2 || 1Hz	100833	ON	water leak → CDC HV off for inner
147	02/17	01:16	01:39	00:23	ON	ON	ON	ON	OFF	ON	ON	ON	trg2 || 1Hz	105205	ON	water leak → CDC HV off for inner
157	02/17	05:42	06:41	00:59	ON	ON	ON	ON	OFF	ON	ON	ON	trg2 || 1Hz	277003	ON	water leak → CDC HV off for inner
158	02/17	06:45	07:12	00:27	ON	ON	ON	ON	OFF	ON	ON	ON	trg2 || 1Hz	129156	ON	water leak → CDC HV off for inner

	Runs	Time	Events
Total	241	218 hour	399 Million
Good	121 **[51%]**	128 hour **[59%]**	35 Million **[9%]**
CDC water leak	5	3 hour	0.8 Million
QCS study	18	9 hour	12.5 Million
High trigger test	101	79 hour	360 Million

Detector	Good Runs (total = 121)
PXD	101 (83%)
SVD	95 (79%)
CDC	121 (100%)
TOP	117 (97%)
ARICH	2 (2%)
ECL	110 (91%)
KLM	102 (84%)
ALL Except ARICH	61 (**50%**)

- Database was not ready, so needed to collect all information

Summary

- Continuum suppression: $>95\%$ background rejection is achieved with 30% signal loss. Still room for improvement
- ϕ_3 extraction study is going on
- DR3 status is presented; it will be completed in a couple of weeks
- Contribution to GCR2 is also shown

Backup-Variable selections

Variable	Selection
$\mid d0 \mid$	0.5 cm
$\mid z0 \mid$	1.0 cm
K_S^0	0.450–0.550 GeV
M_{D^0}	1.85–1.88 GeV
M_{bc}	$>$ 5.25 GeV
$\mid \Delta E \mid$	$<$ 0.15 GeV

Table: Selection criteria for $B \rightarrow D(K_S^0\pi\pi)$ decay.

release	Sample	Luminosity/events
MC9	Signal MC	2×10^6 events
	Generic ($q\bar{q}$) BGx0	0.2 ab^{-1}
	(without beam background)	
	Generic ($q\bar{q}$) BGx1	0.8 ab^{-1}
	(with beam background)	
	where $q = u, d, s, c$	

Table: MC release, event type, and luminosity/events.