Quark charge identification for e+e- to qq study

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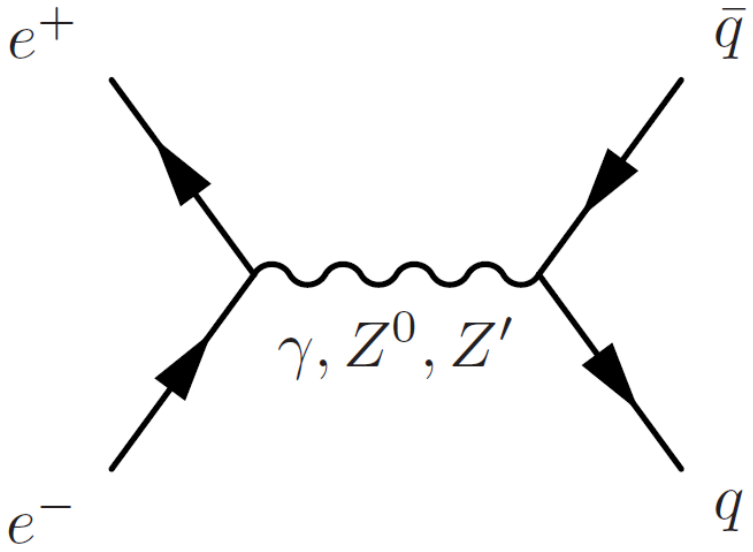
2-quark final states

- Simple electroweak process
  Low background
  Precise QED calculation
- The signal is separated from background
- The angular distribution with respect to the beam axis is provided.
- Using this angular distribution, calculate the sensitivity to new physics.

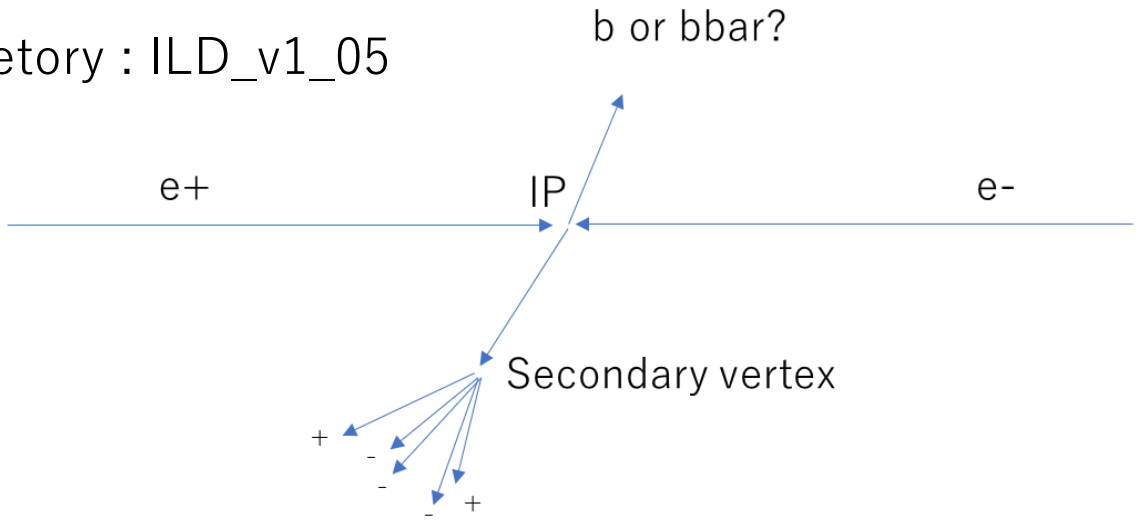


- Quark charge ID is necessary.
- the key to reconstruct events

- review previous study
- report the progress of charge ID study in detail.

Simulation condition in this talk

- DBD ILD detector geometory : ILD_v1_05
- ILCSoft Version : v01-16
- $\sqrt{s} = 250\mathrm{GeV}$
- Event sample
  - $e^+e^- \to b\bar{b}$
  - $e^+e^- \to c\bar{c}$ (to be done)



- Primary and secondary vertex finder by LCFIPlus
- Obtaining quark charge
  - Jet charge (sum charge of all tracks in the jet) ($\Sigma_{\mathrm{all}}^{\mathrm{jet}}$)
  - Vertex charge
    - Sum charge of tracks associated to the second vertex ($\Sigma_{\mathrm{vtx}}^{\mathrm{2nd}}$)
    - Sum charge of tracks associated to the third vertex (if found) ($\Sigma_{\mathrm{vtx}}^{\mathrm{3rd}}$)
    - Sum charge of tracks associated to the second & third vertices ($\Sigma_{\mathrm{vtx}}^{\mathrm{2nd}3^{\mathrm{rd}}}$)

  →use combination of these

Quark charge ID in previous study

- 2-jet clustering by Durham algorithm
- Jet1 is from $\bar{b}$. Jet2 is from b (identified by MC)
- Categorize the events by number of reconstructed vertices in 2 Jets as 6 categories of (2,2), (2,1), (2,0), (1,1), (1,0), (0,0)
- Consider the case of (2,2) for example:
  Quark charge is reconstructed using following conditions

  A : $\Sigma_{\mathrm{vtx}}^{\mathrm{2nd}3^{\mathrm{rd}}}$(Jet1) - $\Sigma_{\mathrm{vtx}}^{\mathrm{2nd}3^{\mathrm{rd}}}$ (Jet2) (condition 1)

  +events : Jet1 is positive , Jet2 is negative → correct ID

  - events : Jet1 is negative, Jet2 is positive → wrong ID

  0 events : → condition 2

  B : $\Sigma_{\mathrm{vtx}}^{\mathrm{2nd}}$ (Jet1) - $\Sigma_{\mathrm{vtx}}^{\mathrm{2nd}}$ (Jet2)

  0 events → condition 3

  C : $\Sigma_{\mathrm{all}}^{\mathrm{jet}}$ (Jet1) - $\Sigma_{\mathrm{all}}^{\mathrm{jet}}$ (Jet2)

Jet1	Jet2	条件 1	+	0	−	条件 2	+	0	−	条件 3	+	0	−	efficiancy	purity
2	2	B	57042	30046	29545	A	14822	7459	7765	C	3538	1231	2690	64.65%	65.34%
2	2	A	63328	24894	28411	B	10369	7459	7066	C	3538	1231	2690	66.22%	66.93%

Quark charge ID in previous study

- ~60% efficiency obtained
- Compare the performance between the all categories
- not satisfactory
  →improvement is necessary
- Efficiency =+events(cond1+2+3)/all events(cond1)
- Purity=+ events(cond1+2+3)/(all events − 0events(cond3))

Jet1	Jet2	条件 1	+	0	−	条件 2	+	0	−	条件 3	+	0	−	efficiancy	purity
2	2	B	57042	30046	29545	A	14822	7459	7765	C	3538	1231	2690	64.65%	65.34%
2	2	A	63328	24894	28411	B	10369	7459	7066	C	3538	1231	2690	66.22%	66.93%
2	1	B	76748	60794	44257	A	24591	21520	14683	C	10310	3542	7668	61.41%	62.63%
2	1	A	83417	55611	42771	B	18590	21520	15501	C	10310	3542	7668	61.78%	63.01%
2	0	B	19239	67602	9065	A	29456	19469	18677	C	9045	3217	7207	60.20%	62.29%
2	0	A	42781	29199	23926	B	6000	19469	3730	C	9045	3217	7207	60.29%	62.39%
1	1	B	28157	31528	17870	C	15262	4985	11281	-				55.98%	59.83%
1	0	B	35064	39606	23072	C	18700	6355	14551	-				55.01%	58.83%
1	0	C	46805	15357	35580	B	5299	6355	3703	-				53.31%	57.01%
0	0	C	18113	5532	13611	-				-				48.62%	57.10%

b quark charge ID

- There are two groups of B hadrons from b and $\bar{b}$.
- Charge ID (considering decay mode)
- $\bar{b}$ decays to only the right half of the table
- Ignore $B^0 - \bar{B}^0$ ossilation
- we study how to optimize charge ID in each case.
- In the previous study, charges were calculated collectively.
  →efficiency upgrade

- $B^{\pm}$ and B^0 become a large part of the generated B hadrons.
- B_c^+ and B_c^- are ignored.

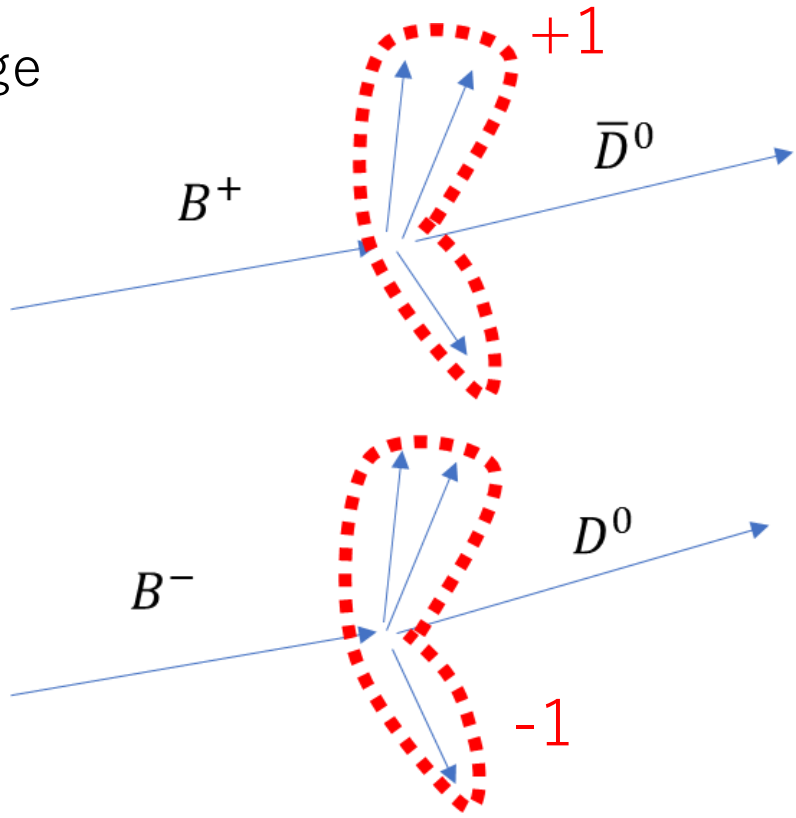
- Pick up B^+ and B^0 (B^- and $\bar{B}^0$) in this talk

charge=-1	charge=0		charge=+1
b		$\bar{b}$	
$B^- \ \bar{u}b$	$\bar{B}^0 \ \bar{d}b$	$B^0 \ d\bar{b}$ 42.2%	$B^+ \ u\bar{b}$ 41.9%
$B_c^- \ \bar{c}b$	$\bar{B}_s^0 \ \bar{s}b$	$B_s^0 \ s\bar{b}$ 8.0%	$B_c^+ \ c\bar{b}$
$\Xi_b^- \ dsb$	$\Lambda_b^0 \ udb$	$\overline{\Lambda_b^0} \ \bar{u}\bar{d}\bar{b}$ 6.4%	$\Xi_b^+ \ \bar{d}\bar{s}\bar{b}$ 0.61%
$\Omega_b^- \ ssb$	$\Xi_b^0 \ usb$	$\overline{\Xi_b^0} \ \bar{u}\bar{s}\bar{b}$ 0.59%	$\Omega_b^+ \ \bar{s}\bar{s}\bar{b}$ 0.010%

Identifying B^+ or B^-

- The branching ratio of $B^+ \to \bar{D}^0 X$ is 79%
- In the case of B^+ decay, sum charge in the second vertex tend to be +
- In the case of B^- decay, sum charge in the second vertex tend to be -

Decay modes	PDG Probability	MC Probability
$B^+ \to \bar{D}^0 X$	79%	70.51%
$B^+ \to D^- X$	9.9%	9.81%
$B^+ \to D^0 X$	8.6%	4.21%
$B^+ \to D_s^+ X$	7.9%	4.80%
$B^+ \to D^+ X$	2.5%	1.65%



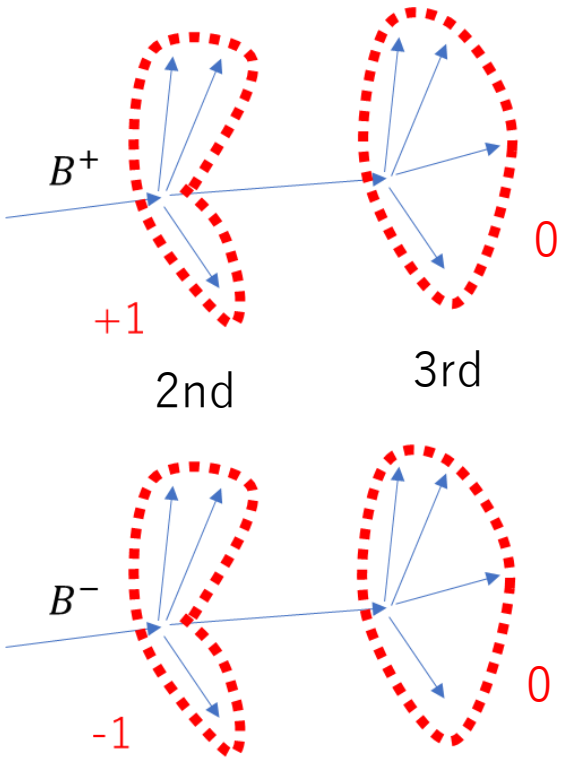
Identifying B^+ or B^-

- 1 associate each jet to b/bbar quark with MC information
- 2.associate vertices in the jet to b hadron in the quark
- 3 investigate the vertex charges of $B^{\pm}$ and B^0 separately

particle	B+(all decay)			B-		
number of vertex	1	2		1	2	
		2nd	3rd		2nd	3rd
symbol	$\Sigma_{\mathrm{vtx}}^{2\mathrm{nd}3\mathrm{rd}}$	$\Sigma_{\mathrm{vtx}}^{2\mathrm{nd}}$	$\Sigma_{\mathrm{vtx}}^{3\mathrm{rd}}$	$\Sigma_{\mathrm{vtx}}^{2\mathrm{nd}3\mathrm{rd}}$	$\Sigma_{\mathrm{vtx}}^{2\mathrm{nd}}$	$\Sigma_{\mathrm{vtx}}^{3\mathrm{rd}}$
charge<0	8.67%	8.06%	22.8%	56.3%	73.8%	23.0%
charge=0	35.5%	18.5%	53.0%	34.9%	18.0%	53.2%
charge>0	55.7%	73.3%	24.0%	8.70%	8.13%	23.7%

B+ : sum charge in the second vertex tend to be +

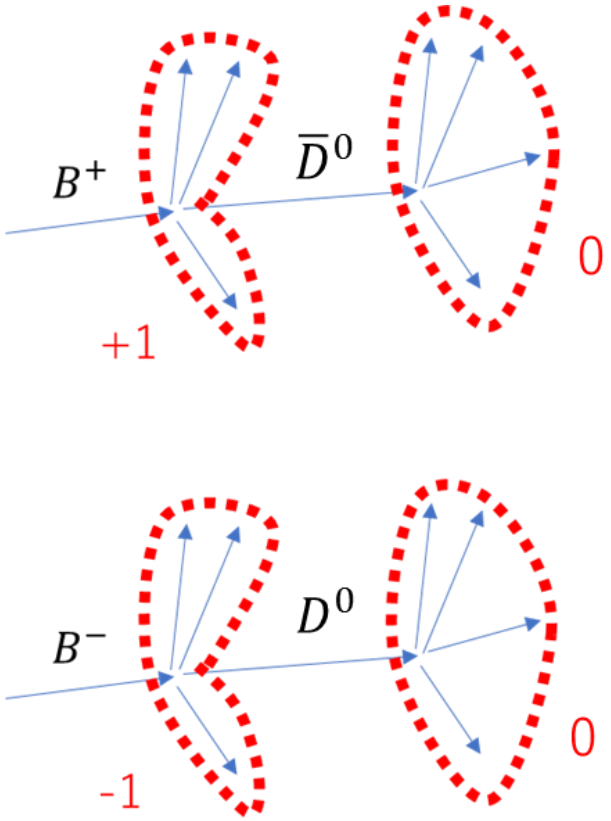
B− : sum charge in the second vertex tend to be −



Identifying B^+ or B^-

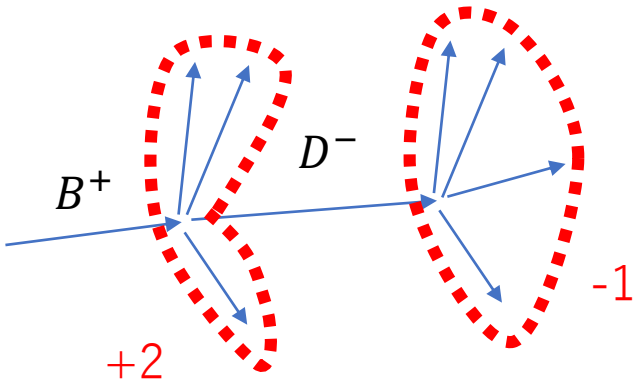
- When B^+ decays to $\bar{D}^0$, charge ID is similar to one on the previous page
- If we can calculate charges in two vertices separately, charge ID will improve more
- It is important to separate to two vertices

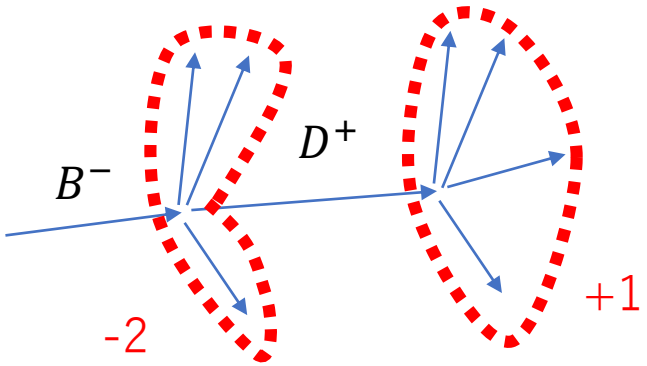
Decay mode	$B^+ \to \bar{D}^0$ X(79%)			$B^- \to D^0$ X		
number of vertex	1	2		1	2	
		2nd	3rd		2nd	3rd
charge<0	7.52%	7.21%	16.6%	54.5%	74.7%	22.2%
charge=0	38.6%	18.1%	6.07%	37.8%	17.3%	60.5%
charge>0	53.8%	74.6%	22.6%	7.65%	7.87%	17.1%



Identifying B^+ or B^-

- Charge ID is possible when we can find charged particles
- When B^+ decays to D^-, the second vertex charge tend to be more positive.

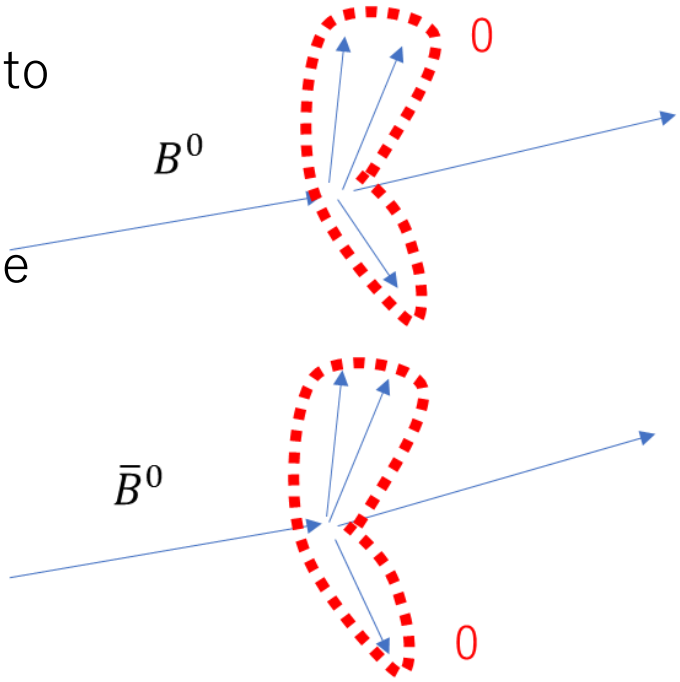




Decay mode	$B^+ \to D^- X$(9.9%)			$B^- \to D^+ X$		
number of vertex	1	2		1	2	
		2nd	3rd		2nd	3rd
charge<0	17.2%	7.85%	67.6%	64.6%	87.3%	9.20%
charge=0	20.0%	8.75%	20%	19.5%	7.67%	18.3%
charge>0	62.7%	83.3%	12.3%	15.8%	4.98%	72.4%

Identifying B^0 or $\bar{B}^0$

- In the case of B^0 decay ,vertex charge tends to be neutral
- But ,if we can see the decay to D^- , we can identify B^0 or $\bar{B}^0$ by separating charges in the 2nd and 3rd vertex



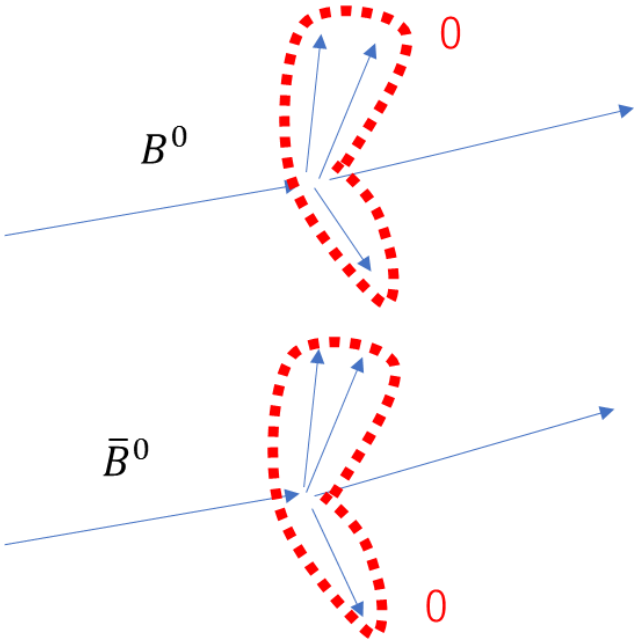
Decay modes	PDG Probability	MC Probability
$B^0 \to \bar{D}^0 X$	47.4%	40.24%
$B^0 \to D^- X$	36.9%	27.59%
$B^0 \to D_s^+ X$	10.3%	4.21%
$B^0 \to D^0 X$	8.1%	11.55%
$B^0 \to D^+ X$	<3.9%	6.91%

-1	charge=0		+1
b		$\bar{b}$	
B^- $\bar{u}b$	$\bar{B}^0$ $\bar{d}b$	B^0 $d\bar{b}$ 42.2%	B^+ $u\bar{b}$ 41.9%

Identifying B^0 or $\bar{B}^0$

- $B^0 - \bar{B}^0$ mixing is not included in the generator
- Even if we can see two vertices separately ,2nd vertex charge tend to be neutral.
- When we don't consider B^0 decays to charged particles ,charge ID is impossible.

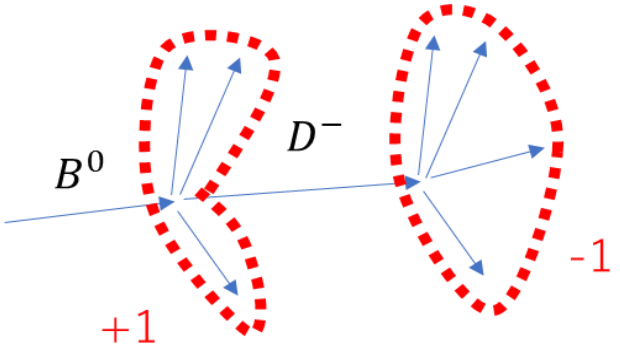
particle	B^0(all decays)			$\bar{B}^0$		
number of vertex	1	2		1	2	
		2nd	3rd		2nd	3rd
charge<0	26.5%	24.2%	38.2%	28.4%	41.8%	23.0%
charge=0	44.3%	33.4%	38.8%	44.5%	33.2%	39.2%
charge>0	29.1%	42.2%	22.8%	26.9%	24.9%	37.7%

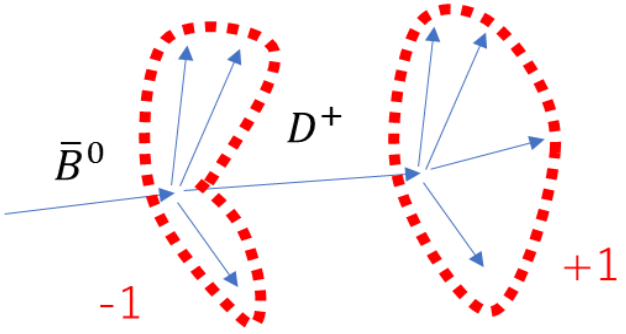


Identifying B^0 or $\bar{B}^0$

- 2 vertex :
  - ✓When B^0 decays to D^-, sum charge in the second and third vertex tend to be +1 and -1 ,separately.
  - ✓When $\bar{B}^0$ decays to D^+, sum charge in the second and third vertex tend to be -1 and +1 ,respectively.

- 1 vertex : charge ID is nearly impossible
  - ✓It is important to separate to two vertices

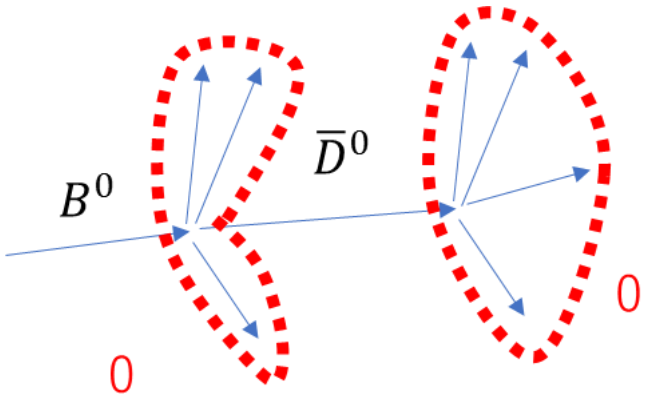


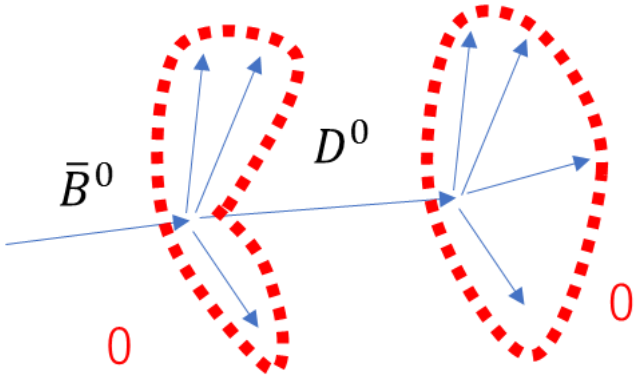


Decay mode	$B^0 \to D^- X$(36.9%)			$\bar{B}^0 \to D^+ X$		
number of vertex	1	2		1	2	
		2nd	3rd		2nd	3rd
charge<0	29.5%	11.8%	72.3%	35.4%	70.9%	10.3%
charge=0	33.2%	17.6%	17.5%	34.4%	16.7%	17.4%
charge>0	37.1%	70.5%	10.0%	30.1%	12.2%	72.1%

Identifying B^0 or $\bar{B}^0$

- The vertex charge tend to be neutral because of the decay from neutral to neutral
- charge ID is impossible.





Decay mode	$B^0 \to \bar{D}^0 X(47.4\%)$			$\bar{B}^0 \to D^0 X$		
number of vertex	1	2		1	2	
		2nd	3rd		2nd	3rd
charge<0	22.4%	20.4%	29.0%	25.5%	36.1%	19.6%
charge=0	51.7%	42.0%	51.0%	51.0%	43.2%	52.6%
charge>0	25.8%	37.4%	19.8%	23.4%	20.6%	27.6%

Summary and Plan

- The process e+e- →qq plays an important role in electroweak precision measurements.
- The key to reconstruct events in the quark pair final state (bb, cc) is quark charge identification (ID).

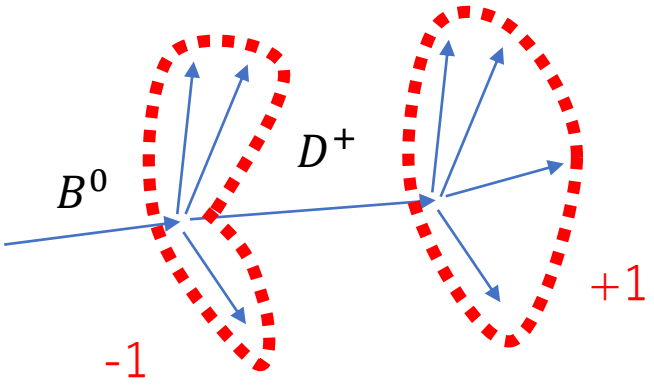
- 2 vertices category
  - ➢the energy and the number of missing tracks and whether missing track is reconstructed or not
  - ➢tracks miss-reconstructed to secondary vertices
- 1 vertex category
  - ➢Try to separate the vertex to two
- 0 vertex category
  - ➢regard the track of larger impact parameters as a vertex etc…
- vertex recovery
  - ➢We will optimize it with reference to these categories

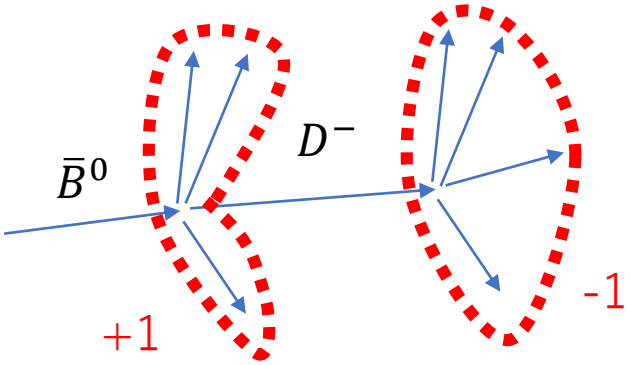
Backup

Identifying B^0 or $\bar{B}^0$

- Other decay mode

Decay mode	$B^0 \to D^+ X(<3.9\%)$			$\bar{B}^0 \to D^- X$		
number of vertex	1	2		1	2	
		2nd	3rd		2nd	3rd
charge<0	41.9%	63.8%	13.5%	24.4%	13.0%	66.7%
charge=0	34.7%	21.5%	20.9%	37.2%	19.2%	19.8%
charge>0	23.3%	14.6%	65.4%	38.2%	67.7%	13.3%





- Sum charge is converted from positive to negative.
- Wrong charge ID
- may improve by Kπ separation