Collider Exp. Physics Group Status

정지혁   장은지   최수경
CAU-HEP Center, Chung-Ang University

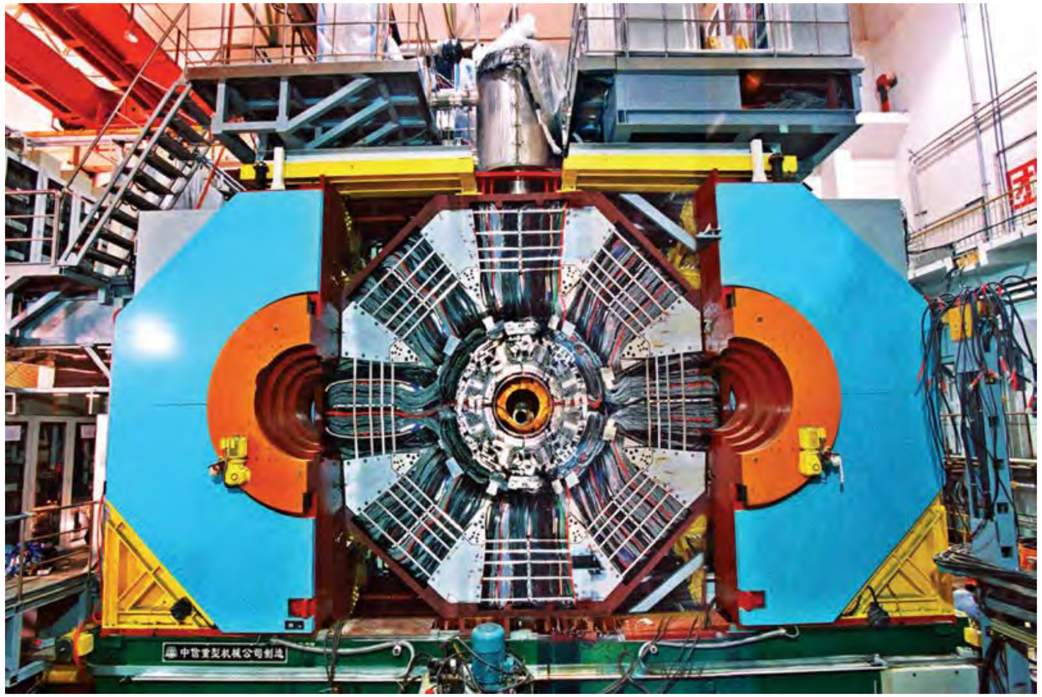
CAU-HEP Center Workshop
December 27, 2023
(곤지암 리조트)

Outline of our Report

- Activities in BESIII by JiHyeok Jeong
  - Precise Mass measurement of the $\Xi^-(\Xi^+)$ produced in $J/\psi \rightarrow \Xi^-\Xi^+$ in the BESIII experiment
- Activities in Belle (II) by Eunji Jang
  - Status of Belle II ECLTRG energy calibration and Lineshape study of the X(3872)
- An Introduction (by Sookyung Choi)
  - to Collider experiments and Collaboration (Belle (II) and BESIII)
  - to Examples of Data analysis

JiHyeok Jeong

Precise Mass measurement of the $\Xi^-\bar{\Xi}^+$ produced in $J/\psi \rightarrow \Xi^-\bar{\Xi}^+$ in BESIII Exp.



2023-12-26

Jihyeok.Jeong

2023 December 27, Workshop,
CAU-HEP Center, Chung-Ang University

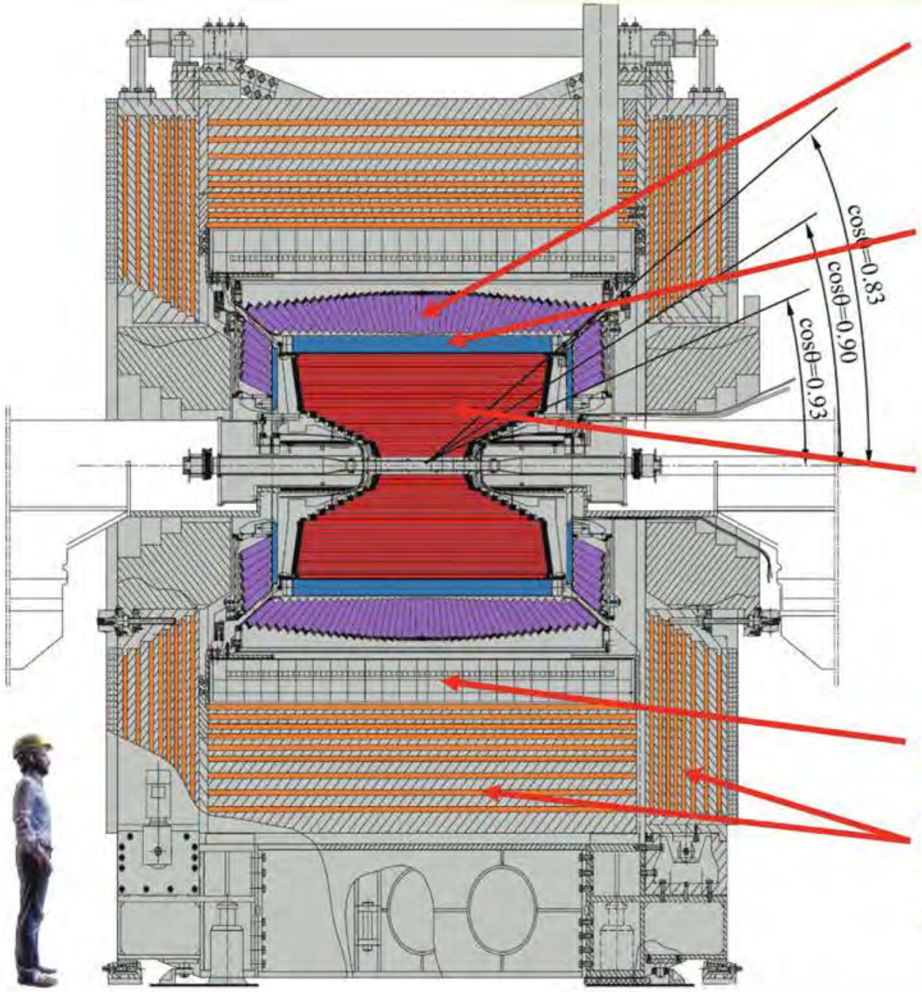
Beijing Electron-Positron Collider II (BEPCII)

Center Mass Energy: 2.00~4.95GeV
2008 - Now (BEPCII)
L_{peak}=1.1x10^{33}/cm^{2}s
Reached peak luminosity in Jan 2023
10% above the designed luminosity
Future Plan of CME: 1.8~5.0GeV

Provided by HaiBo Lee

BEijing Spectrometer III (BESII)

Has been in full operation since 2008, all subdetectors are in very good status! 2023-10



EMC: CsI crystals
$\Delta E/E$ = 2.5% @ 1 GeV - Barrel
$\Delta E/E$ = 5.0% @ 1 GeV - Endcaps

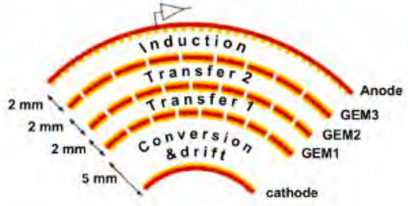
TOF:
σ_T = 80 ps Barrel
σ_T = 110 (60) ps Endcap

MDC: small cell & He gas
σ_{xy}= 130 μm
σ_p/p = 0.5% @1GeV
dE/dx = 6%

Magnet: 1T Super conducting

Muon ID: 9 layer RPC

Trigger: Tracks & Showers



Upcoming upgrade Schedules

- CGEM (Cylindrical Gas Electron Multiplier Inner Tracker) for more precise vertex measurement and complementary for MDC inner cells aging
- To increase Luminosity

Total weight 730 ton

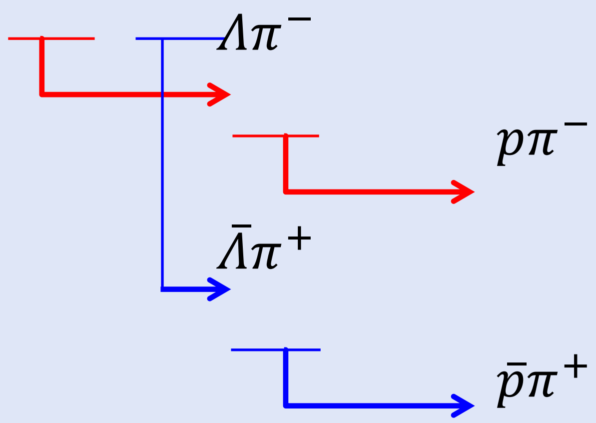
About 40,000 readout channels
Data rate: 5kHz, 50Mb/s

Motivation

Measure Ξ⁻ mass ***precisely***

Decay processes

$J/\psi \rightarrow \Xi^- \bar{\Xi}^+$



Motivation

Year	$N_{J/\psi}(\times 10^6)$
2009	224.0±1.3
2012	1088.5±4.4
2017-2019	8774.0±39.4
Total	10087±44

The number of J/ψ events(Data)

Decay Mode	Branching fraction
$J/\psi \to \Xi^-\bar{\Xi}^+$	9.7×10^{-2}
$\Xi^-(\bar{\Xi}^+) \to \Lambda\pi^-(\bar{\Lambda}\pi^+)$	99.887
$\Lambda(\bar{\Lambda}) \to p\pi^-(\bar{p}\pi^+)$	64.1
The probability of this mode	3.976543×10^{-2}

Branching fractions

The number of J/ψ events(Data)

we can expect to

3.98×10^6 in 10^{10} events

Motivation

Ξ^- MASS

The fit uses the Ξ^-, Ξ^+, and Ξ^0 masses and the $\Xi^- - \Xi^+$ mass difference. It assumes that the Ξ^- and Ξ^+ masses are the same.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1321.71±0.07 OUR FIT					
1321.70±0.08±0.05	2478 ± 68	ABDALLAH	06E	DLPH	from Z decays
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1321.46±0.34	632	DIBIANCA	75	DBC	4.9 GeV/c $K^- d$
1321.12±0.41	268	WILQUET	72	HLBC	
1321.87±0.51	195	[1] GOLDWASSER	70	HBC	5.5 GeV/c $K^- p$
1321.67±0.52	6	CHIEN	66	HBC	6.9 GeV/c $\bar{p}p$
1321.4 ±1.1	299	LONDON	66	HBC	
1321.3 ±0.4	149	PJERROU	65B	HBC	
1321.1 ±0.3	241	[2] BADIER	64	HBC	
1321.4 ±0.4	517	[2] JAUNEAU	63D	FBC	
1321.1 ±0.65	62	[2] SCHNEIDER	63	HBC	

[1] GOLDWASSER 70 uses $m_\Lambda = 1115.58$ MeV.

[2] These masses have been increased 0.09 MeV because the Λ mass increased.

Decay Mode	Branching fraction
$J/\psi \to \Xi^- \bar{\Xi}^+$	9.7×10^{-2}
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Branching fractions

The number of J/ψ events(Data)

we can expect to

3.98×10^{6} in 10^{10} events

Event generator

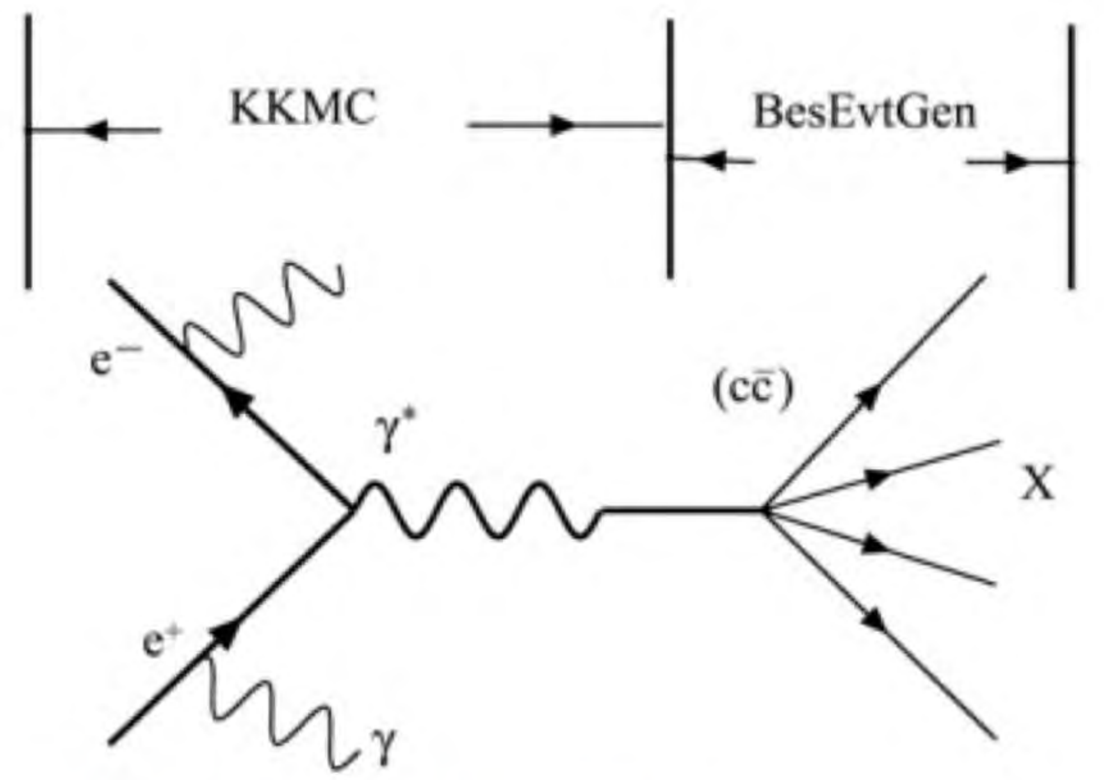


Fig. 1. Illustration of BESIII generator framework.

Data sets

Signal MC

```
Decay J/psi
1.0000    Xi-          anti-Xi+   J2BB1;
Enddecay

Decay Xi-
1.0000    Lambda0      pi-        PHSP;
Enddecay

Decay anti-Xi+
1.0000    anti-Lambda0 pi+        PHSP;
Enddecay

Decay Lambda0
1.0000    p+           pi-        PHSP;
Enddecay

Decay anti-Lambda0
1.0000    anti-p-      pi+        PHSP;
Enddecay


End
```

Decay to only set mode

Generic MC

```
Decay J/psi
# J/psi ⟶ ll
0.05971    e+   e-                   PHOTOS  VLL;
0.05961    mu+  mu-                  PHOTOS  VLL;

# J/psi ⟶ VP
0.00211    pi+ pi- pi0         OMEGA_DALITZ;
0.0056    rho0 pi0            HELAMP 1.0 0.0 0.0 0.0 1.0 3.1415926;
0.00565   rho+ pi-            HELAMP 1.0 0.0 0.0 0.0 1.0 3.1415926;
0.00565   rho- pi+            HELAMP 1.0 0.0 0.0 0.0 1.0 3.1415926;
0.00174   omega eta           HELAMP 1.0 0.0 0.0 0.0 1.0 3.1415926;
0.00075   phi   eta           HELAMP 1.0 0.0 0.0 0.0 1.0 3.1415926;
0.00045   omega pi0           HELAMP 1.0 0.0 0.0 0.0 1.0 3.1415926;
0.00046   phi   eta'          HELAMP 1.0 0.0 0.0 0.0 1.0 3.1415926;
0.000193  rho0  eta           HELAMP 1.0 0.0 0.0 0.0 1.0 3.1415926;
0.000189  omega eta'          HELAMP 1.0 0.0 0.0 0.0 1.0 3.1415926;
0.000081  rho0  eta'          HELAMP 1.0 0.0 0.0 0.0 1.0 3.1415926;
0.00002   phi eta(1405)       PHSP;

# J/psi ⟶ omega X
0.0085    omega pi+ pi+ pi- pi-    PHSP;
0.0040    omega pi+ pi- pi0        PHSP;
0.0072    omega pi+ pi-            PHSP;
0.0043    omega f_2                PHSP;
0.00305   omega K*0 anti-K0        PHSP;
0.001525  omega K*+ K-             PHSP;
0.001525  omega K*- K+             PHSP;
0.0034    omega pi0 pi0            PHSP;
0.00034   omega pi0 eta            PHSP;
0.0017    omega K+ K_S0 pi-        PHSP;
0.0017    omega K- K_S0 pi+        PHSP;
0.000085  omega K+  K-             PHSP;
0.000085  omega anti-K*0  K0        PHSP;
0.00068   omega f'_1               PHSP;
0.00014   omega f_0                PHSP;
```

Decay to all mode

Event Selection

Event selection Strategy

1. Require 6 tracks of final states & total charge = 0.

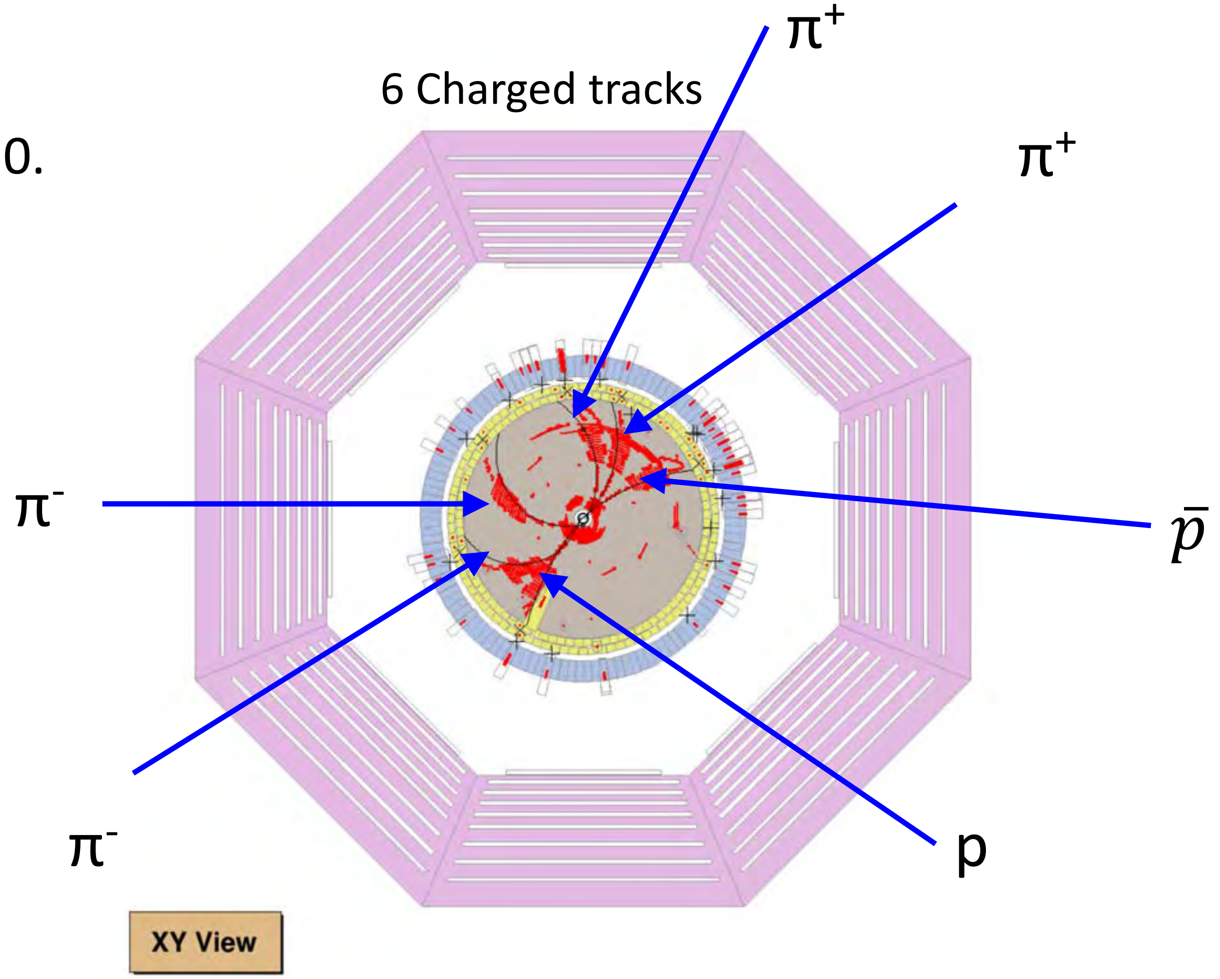
2. Select protons & pions by their momentum.

3. Require a Λ (anti-Λ) after reconstuction.

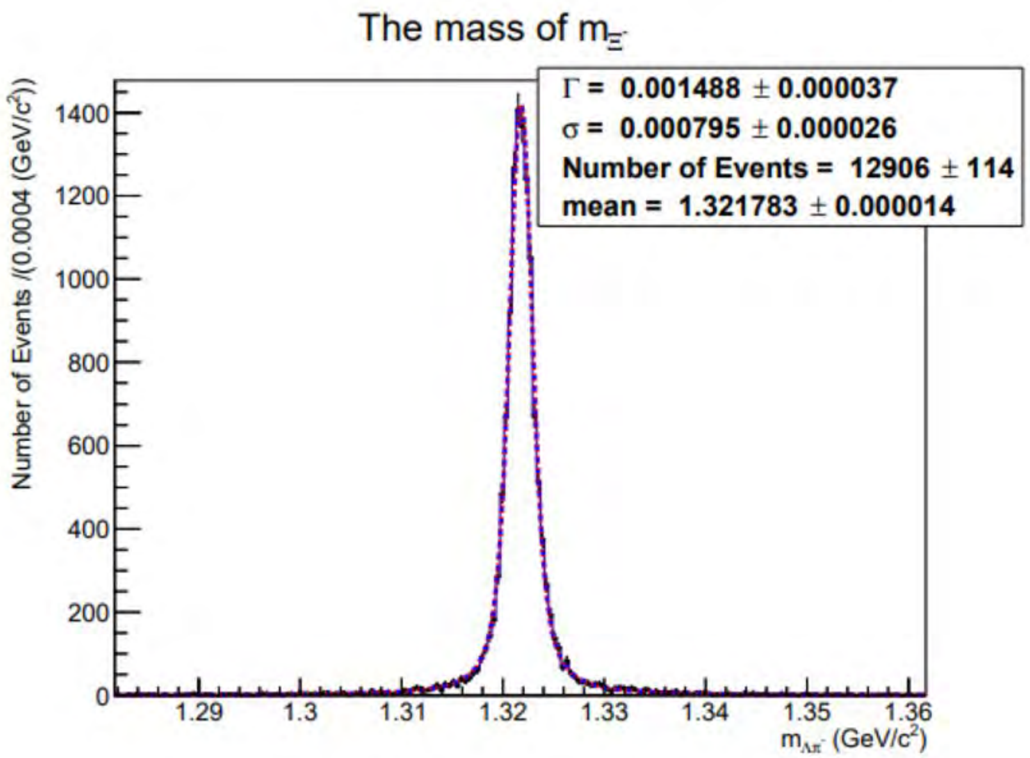
4. Select cosθ in range of detector(MDC).

5. Vertex fitting Ξ, Λ.

6. Do Energy constraints $\Xi^- \bar{\Xi}^+$ to J/ψ.



Result of Ξ^- (Signal MC)



$\left| m_{p\pi^-\pi^-} - m_{\Xi^-} \right|$ < 0.04GeV/c^2

m_{Ξ^-} Is input mass of signal mc : 1.32171 GeV

Ξ^- mass

- Mass window is 0.08GeV/c^2.
- PDF is Voigtian (Binned Likelihood)
  -Voigtian function is Gaussian⊗BreitWigner function.

$$V(x;\sigma,\gamma) \equiv \int_{-\infty}^{\infty} G(x';\sigma)L(x-x';\gamma)\,dx'$$

$$G(x;\sigma) \equiv \frac{e^{-x^2/(2\sigma^2)}}{\sigma\sqrt{2\pi}} \qquad L(x;\gamma) \equiv \frac{\gamma}{\pi(x^2+\gamma^2)}$$

- No Background fitting
- Fitting Parameters

➢ # of Events = 12906

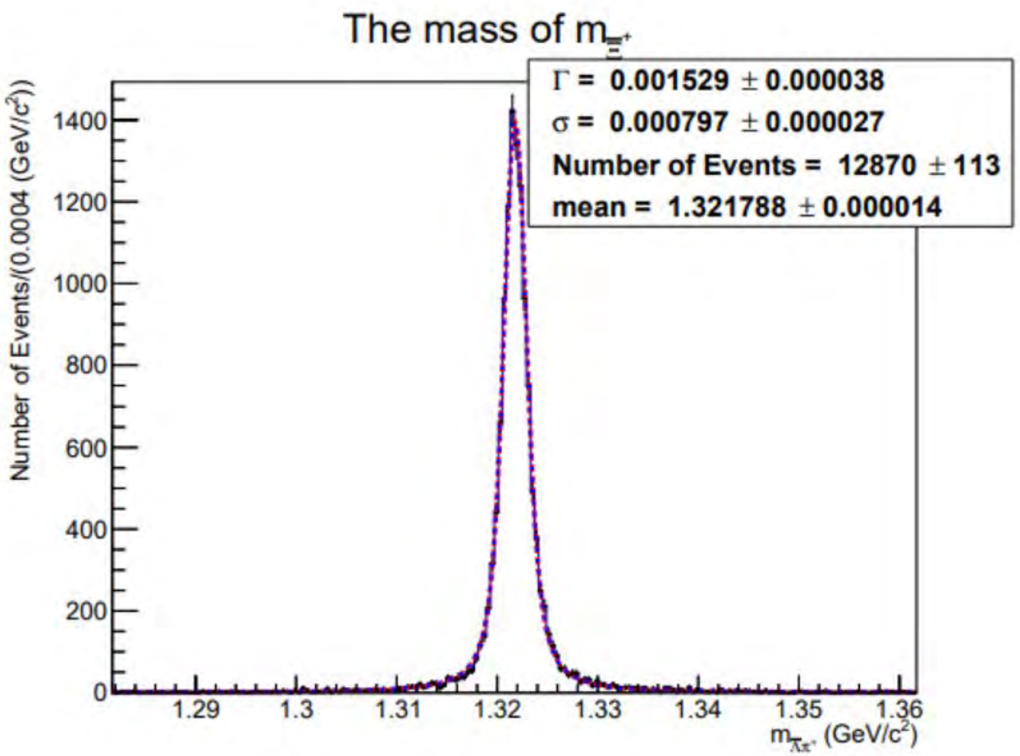
➢ Efficiency ~ 12.9%

➢ **Mass = 1.321783 ± 0.000014GeV/c^2**

➢ Gaussian's Sigma = $7.95\times10^{-4} \pm 2.6\times10^{-5}$

➢ Breit Wigner's Width = $1.488\times10^{-3} \pm 3.7\times10^{-5}$

Result of Ξ^+ (Signal MC)



Ξ^+ mass

- Mass window is 0.08GeV/c^2.
- PDF is Voigtian (Binned Likelihood)
  -Voigtian function is Gaussian⊗BreitWigner function.
- No Background fitting
- Fitting Parameters

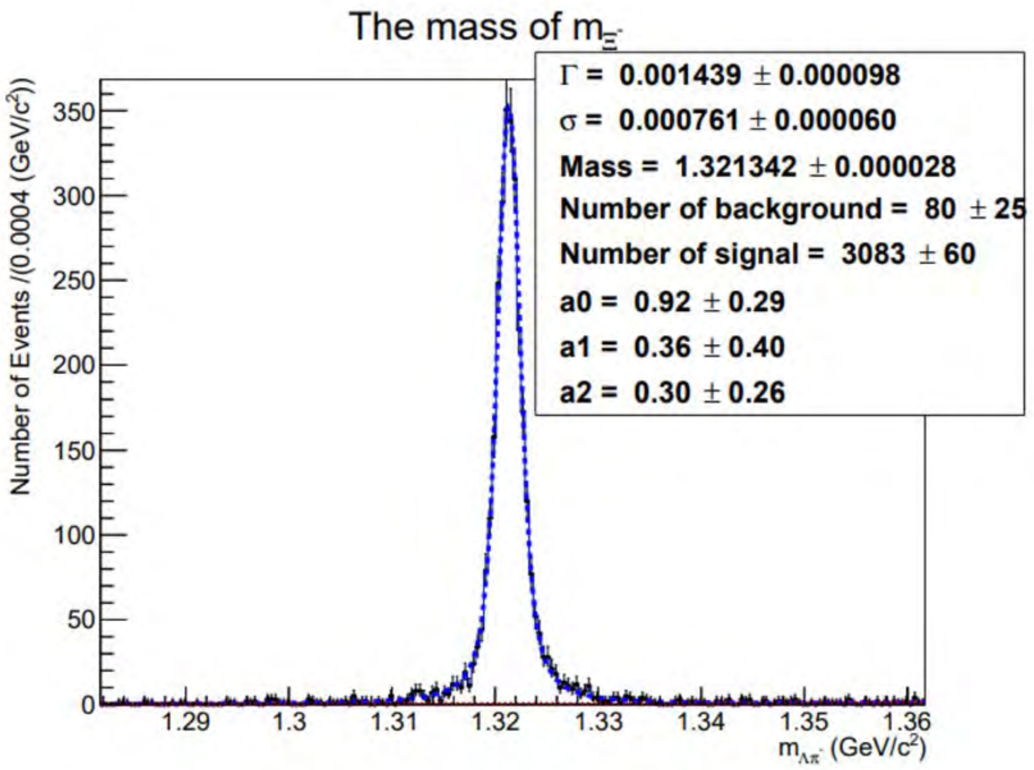
➢ # of Events = 12870;

➢ **Mass = 1.321788 ± 0.000014 GeV/c^2**

➢ Gaussian's Sigma = $7.97\times10^{-4} \pm 2.7\times10^{-5}$

➢ Breit Wigner's Width = $1.529\times10^{-3} \pm 3.8\times10^{-5}$

Result of Ξ+ (Generic MC)



$$|m_{p\pi^-\pi^-} - m_{\Xi^-}| < 0.04\text{GeV}/c^2$$

m_{Ξ^-} Is input mass of generic mc : 1.32132 GeV

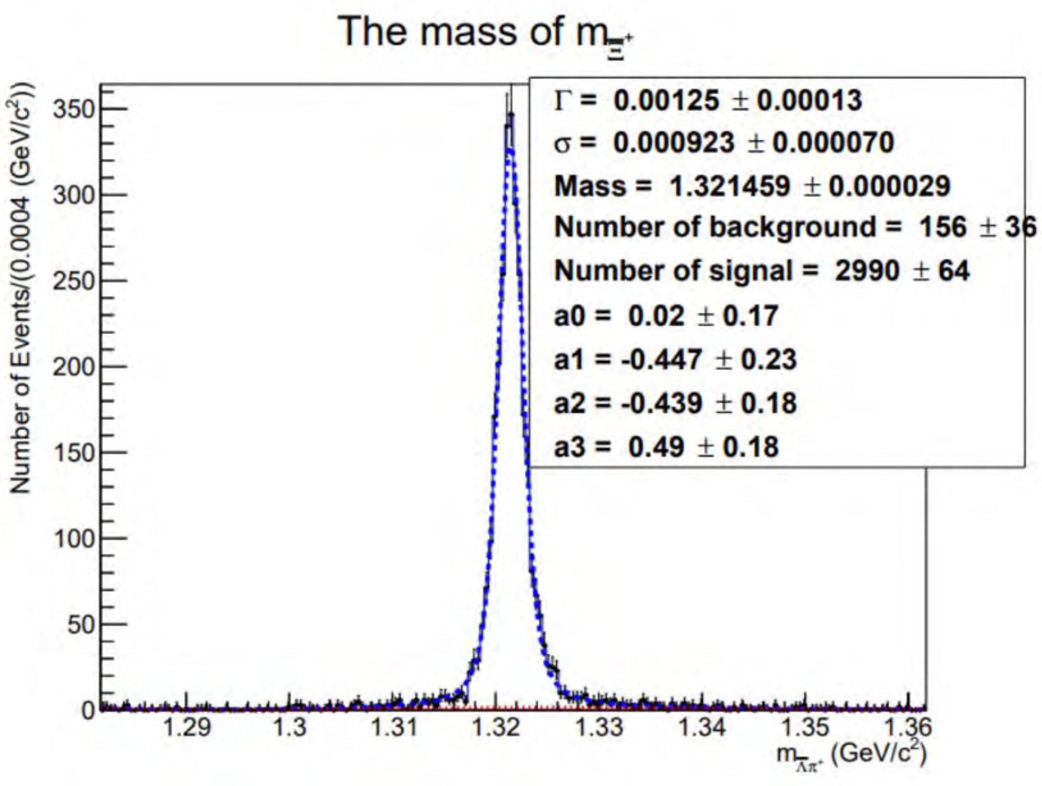
Ξ^- mass

- Using 16,833,794 J/ψ Events.
- Mass window is 0.08GeV/c^2.
- Signal PDF is Voigtian (Binned Likelihood)
- Background PDF is 2nd Chebyshev

- Fitting Parameters

- # of Events = 3083
- # of Backgrounds = 80
- **Mass = 1.321342± 0.000028GeV/c^2**
- a0 = 0.92±0.29, a1 = 0.36±0.40, a2 = 0.30±0.26,
- Gaussian's Sigma = $7.61\times10^{-4} \pm 6.0\times10^{-5}$
- Breit Wigner's Width = $1.439\times10^{-3} \pm 9.8\times10^{-5}$

Result of Ξ^+ (Generic MC)



Ξ^+ mass

- Using 16,833,794 J/ψ Events.
- Mass window is 0.08GeV/c^2.
- Signal PDF is Voigtian (Binned Likelihood)
- Background PDF is 3rd Chebyshev

- Fitting Parameters

- # of Events = 2990
- # of Backgrounds = 156
- **Mass = 1.321459± 0.000029GeV/c^2**
- a0 = 0.02±0.17, a1 = -0.447±0.23 a2 = -0.439±0.18, a3 = 0.49±0.18
- Gaussian's Sigma = $9.23 \times 10^{-4} \pm 7.0 \times 10^{-5}$
- Breit Wigner's Width = $1.25 \times 10^{-3} \pm 1.3 \times 10^{-4}$

Conclusion

Parameters	Ξ^-	$\bar{\Xi}^+$
Number of Signal	12906±114	12870±113
Mass(GeV/c^2)	1.321783±0.000014	1.321788±0.000014
σ	$(7.95\pm0.26)\times10^{-4}$	$(7.97\pm0.27)\times10^{-4}$
Γ	$(1.488\pm.037)\times10^{-3}$	$(1.529\pm0.038)\times10^{-3}$

Parameters	Ξ^-	$\bar{\Xi}^+$
Number of Signal	3083±60	2990±64
Number of Background	80±25	156±36
Mass(GeV/c^2)	1.321342±0.000028	1.321459±0.000029
σ	$(7.61\pm0.60)\times10^{-4}$	$(9.23\pm0.70)\times10^{-4}$
Γ	$(1.439\pm0.098)\times10^{-3}$	$(1.25\pm0.13)\times10^{-3}$
a_0	0.92±0.29	0.02±0.17
a_1	0.36±0.40	-0.447±0.23
a_2	0.30±0.26	-0.439±0.18
a_3	-	0.49±0.18

Ξ^- MASS

The fit uses the Ξ^-, $\overline{\Xi}^+$, and Ξ^0 masses and the Ξ^-–$\overline{\Xi}^+$ mass difference. It assumes that the Ξ^- and $\overline{\Xi}^+$ masses are the same.

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[2] These masses have been increased 0.09 MeV because the Λ mass increased.

Eunji Jang

23.12.27 CAU HEP Center Workshop

Status of Belle II ECLTRG energy calibration and X(3872) lineshape study

Eunji Jang

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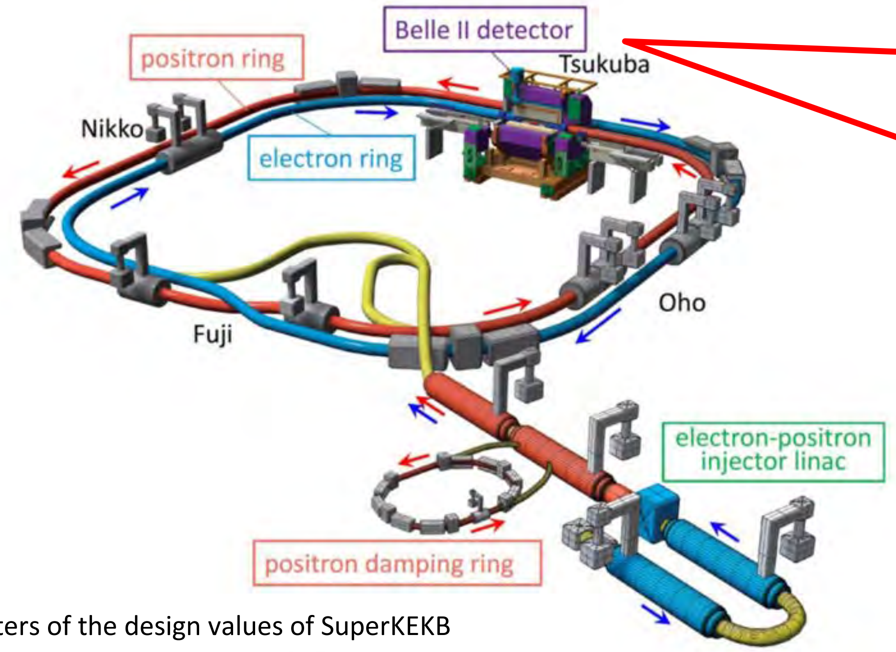
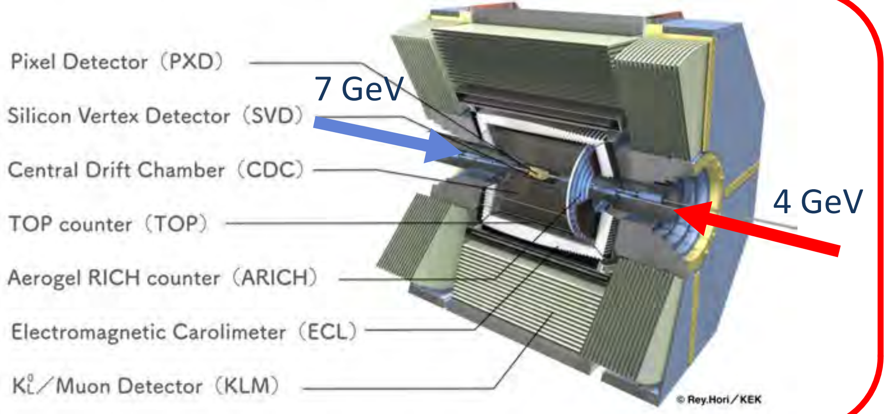
01. SuperKEKB & Belle II detector

Configuration of the SuperKEKB accelerator



Belle II detector



- Parameters of the design values of SuperKEKB

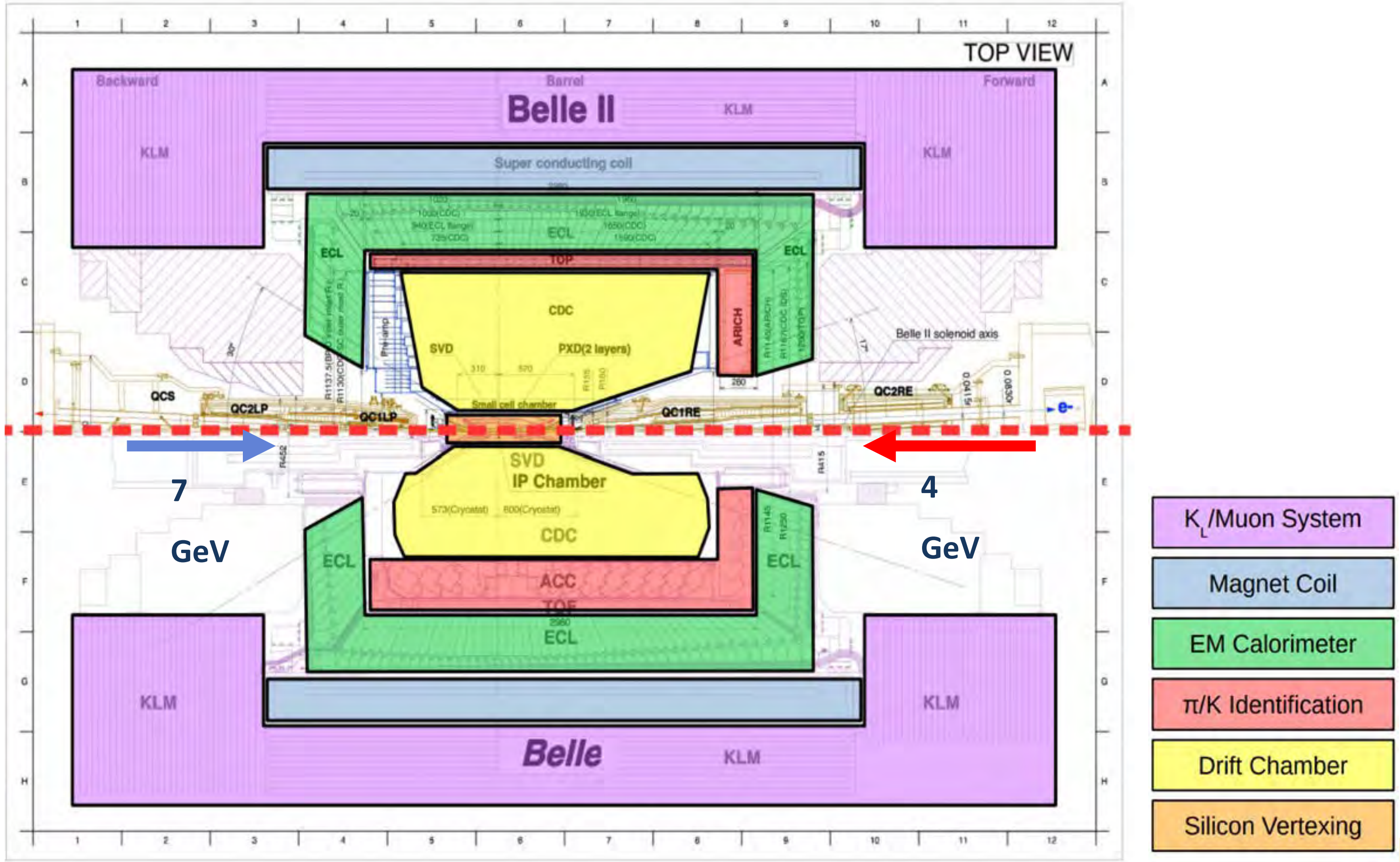
	LER (e^+)	HER (e^-)	
Energy	4.000	7.007	GeV
Half crossing angle	41.5		mrad
Horizontal emittance	3.2	4.6	nm
Emittance ratio	0.27	0.25	%
Beta functions at IP (x/y)	32 / 0.27	25 / 0.30	mm
Beam currents	3.6	2.6	A
Beam-beam parameter	0.0881	0.0807	
Luminosity	8×10^{35}		$cm^{-2}s^{-1}$

- e^+e^- asymmetric collider
- LER (e^+) : 4 GeV & HER (e^-) : 7 GeV for $\Upsilon(4S)$ resonance
- To improve the precision measurements of Standard Model (SM) parameters and search for new physics beyond the SM
- Plan to accumulate integrated luminosity : 50 ab^{-1}
- Target instantaneous luminosity : $8{\times}10^{35}\ cm^{-2}s^{-1}$ (80 μb^{-1}) (40 times higher than KEKB)

LER : low-energy accelerator ring / HER : high-energy accelerator ring

Belle II detector

Backward endcap Barrel Forward endcap



Oskar Hartbrich, 2020 Belle II Summer Workshop

Purpose:

- Highly efficient particle identification (PID)
- Precise measurements of photon energy and direction
- Cover (almost) the full solid angle
- Fast and efficient trigger system

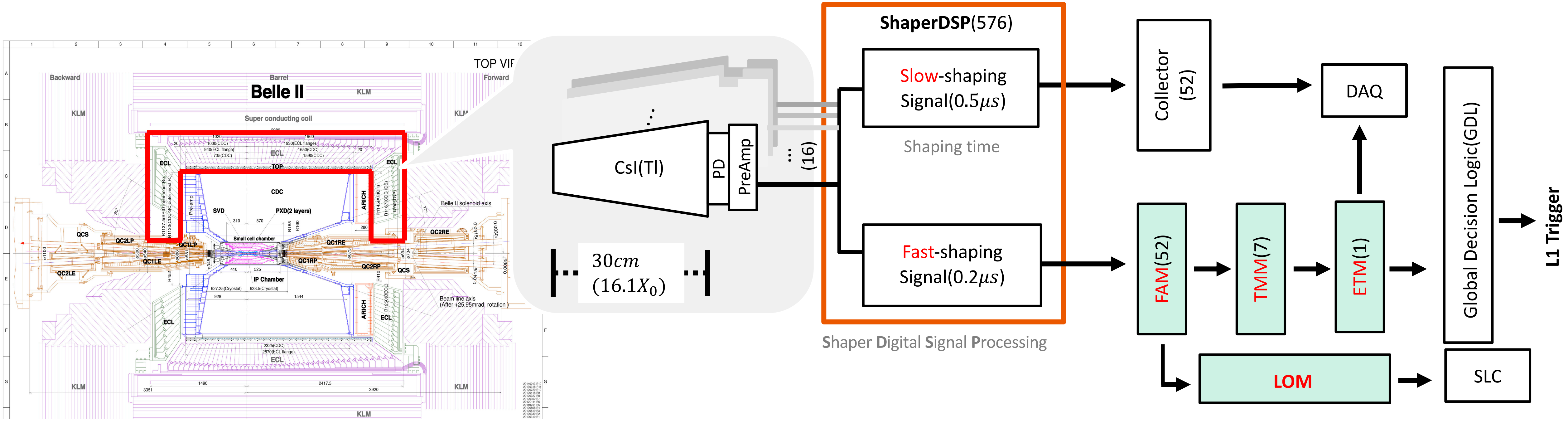
02. ECLTRG energy calibration

- **Motivation :**

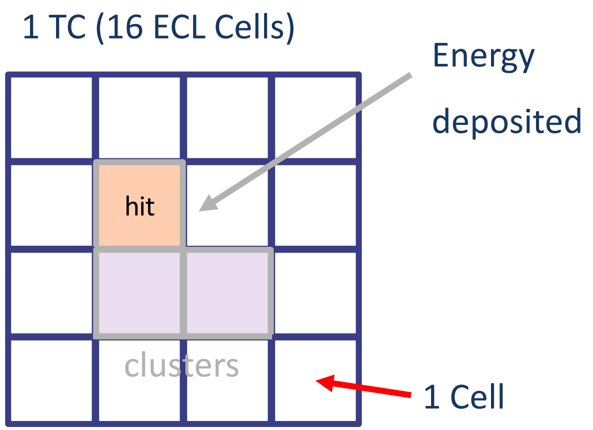
  Stable operation

  Reliable trigger signals and Improving the trigger efficiency

  More precise Luminosity Online Monitor (LOM)



Attenuator coefficient and gain



$$\sum_n 5.25 * e^n E_i^n = \sum_n \sum_j \beta_j E_j^n E_i^n$$

Gain ratio

TC energy

Cell energy

e : TC energy (ADC) from ECLTRG data

E : ECL Xtal energy in TC (GeV) from ECL data

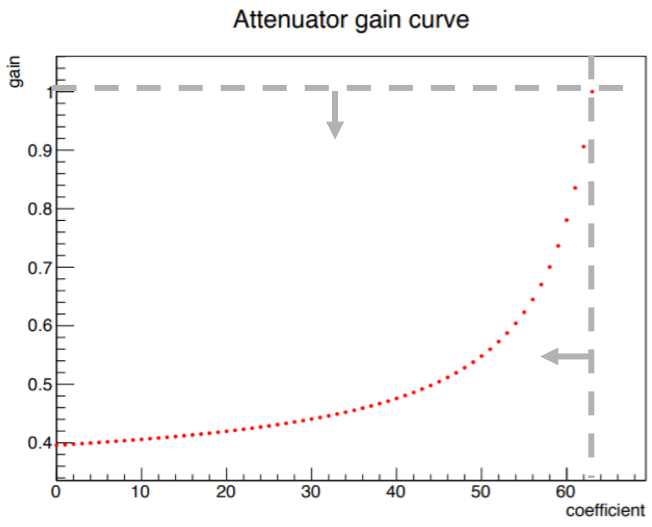
5.25 : ADC to energy conversion factor (MeV/ADC)

β : Gain ratio = new gain / old gain

n : Index of TC ID (total 576)

i, j : Index for xtal(cell) ID in a TC (~16 cells in 1 TC)

The calibration constants(β) can be obtained from this equation which is extracted by minimizing χ^2 function, $f(e^n, E_i^n, \alpha, \beta_i) = \sum_n (\alpha e^n - \sum_i \beta_i E_i^n)^2$.



Gain ratio (β) = New gain / old gain

- Continuous gain by calculating matrix (above eqation)
- Discrete gain by matching attenuator coefficient

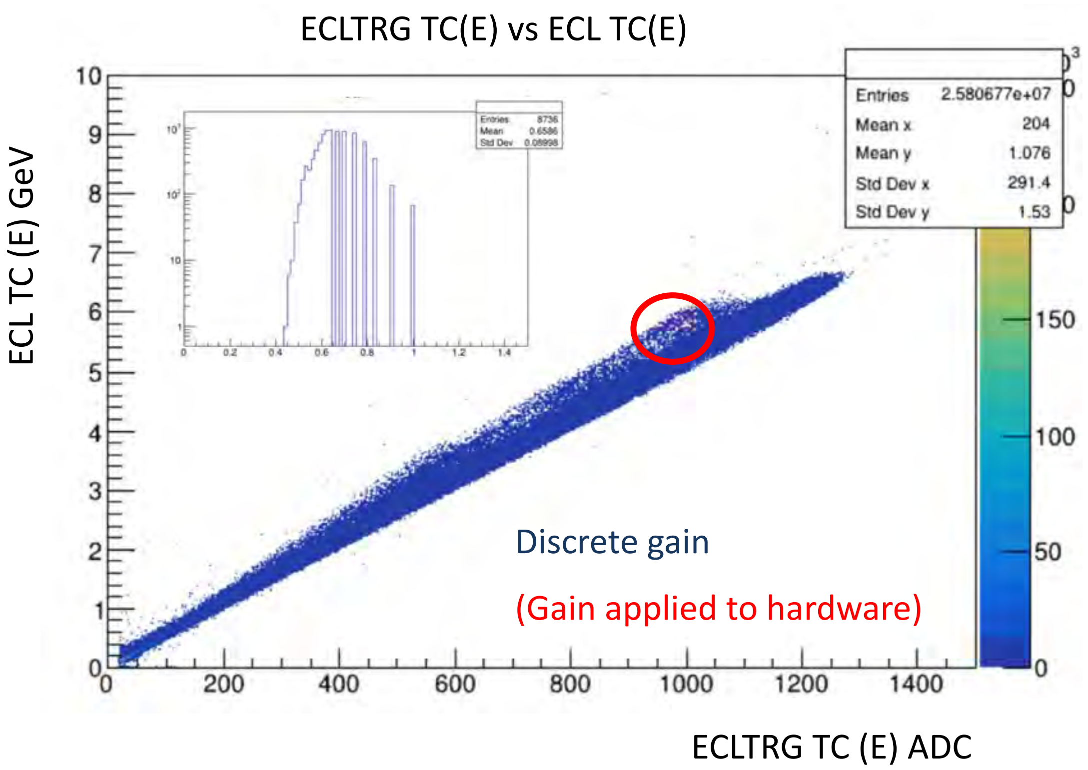
This discrete gain (as attenuator coefficient) is stored in the ShaperDSP(potentiometer).

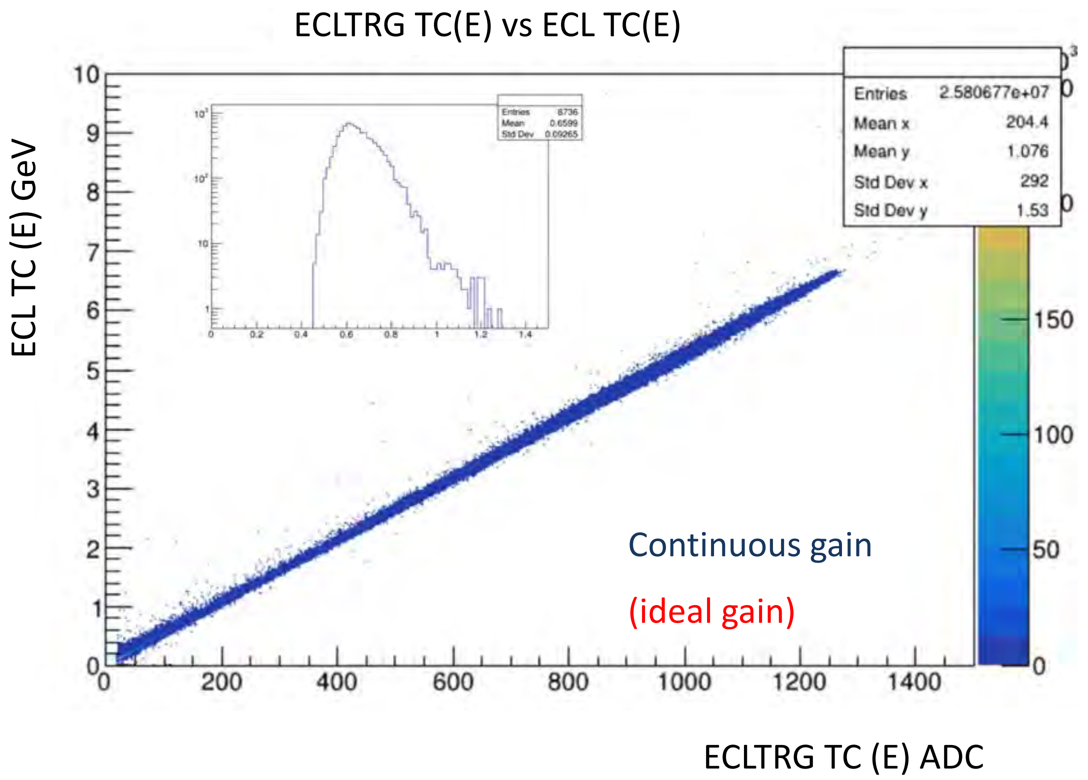
$$Gain = \frac{1 + \frac{470}{2500\left(1 - \frac{Att}{63}\right) + 240}}{1 + \frac{470}{240}}$$

Continuous gain vs discrete gain

Our purpose for proper calibration :

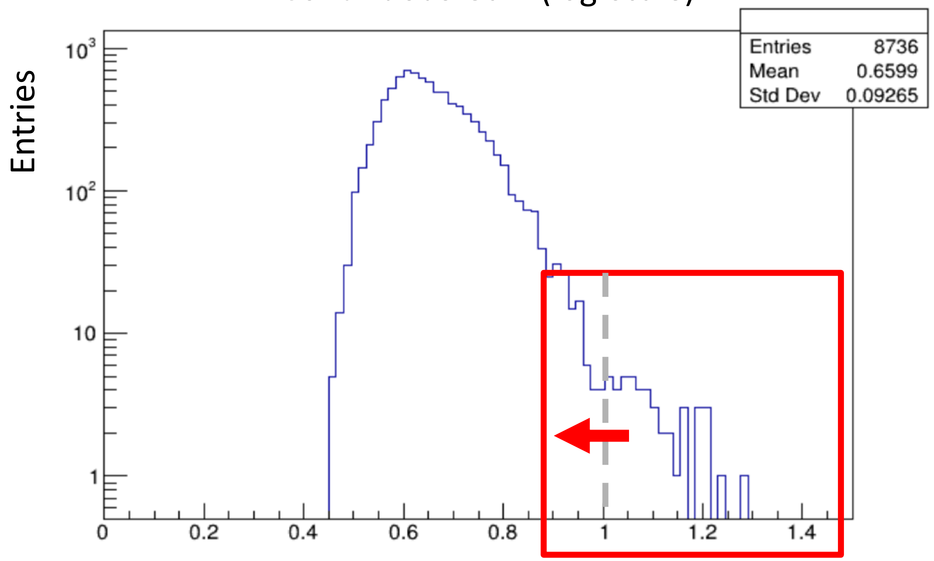
It is to reduce the high attenuator gain 'exceeding 1' by doubling the gain of the jumper.





Jumper-setting change work

Continuous Gain (log-scale)



Reference data : Physics run exp24, 2/fb

The gain must be moved to a value less than 1 for correct calibration.

We thought it would be good to change the jumper settings for the channel that is likely to be a bad channel (>=0.9).

Coefficient 63, 62 (for continuous gain >=0.9)

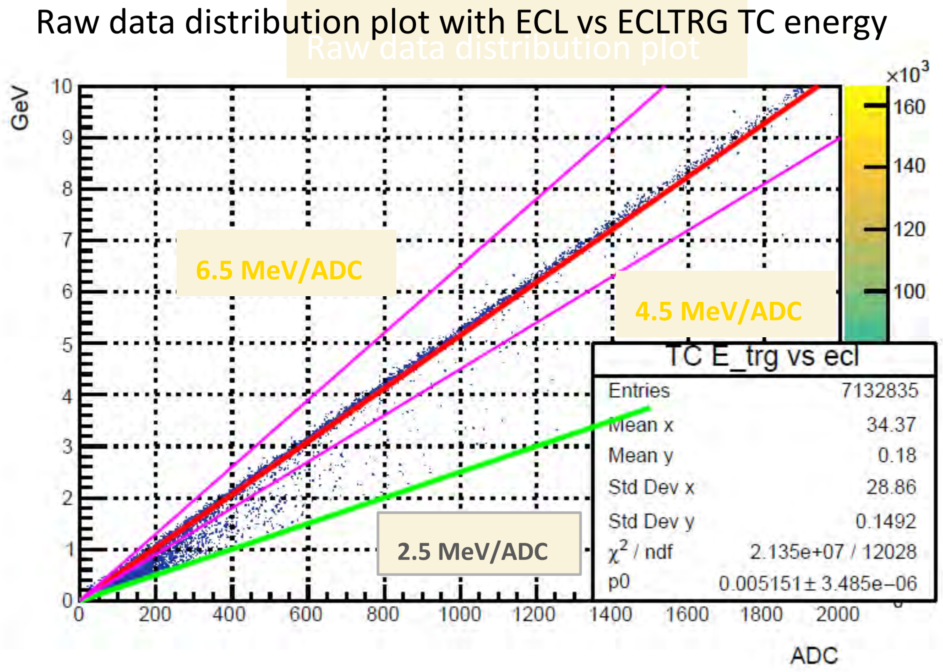
Jumper setting were changed by doubling gain.

- **Total channel's number : 144 /8736**

  (barrel 76 / forward 27 / backward 41)
- The number of channels for continuous gain >=1 is 46.

Slope range selection

Raw data distribution plot with ECL vs ECLTRG TC energy



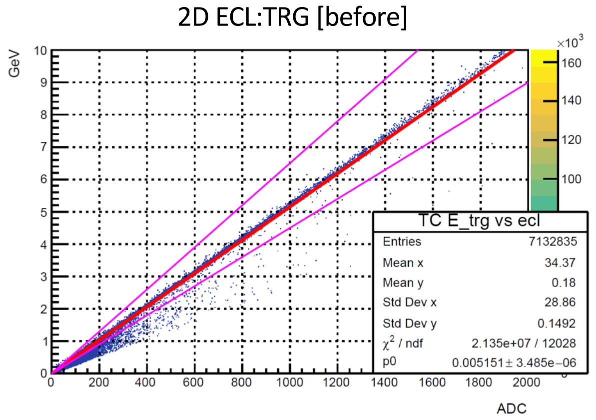
- Used data : cosmic 1h (3600k events)
- Use of attenuator coefficient obtained from cosmic run
- **Calibration range :**

  [Jumper changed channels] 2.5-6.5 MeV/ADC

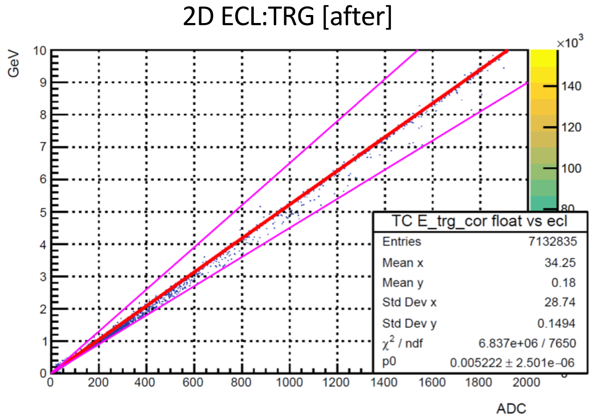
  + [Normal channels] 4.5-6.5 MeV/ADC

Updated calibration results

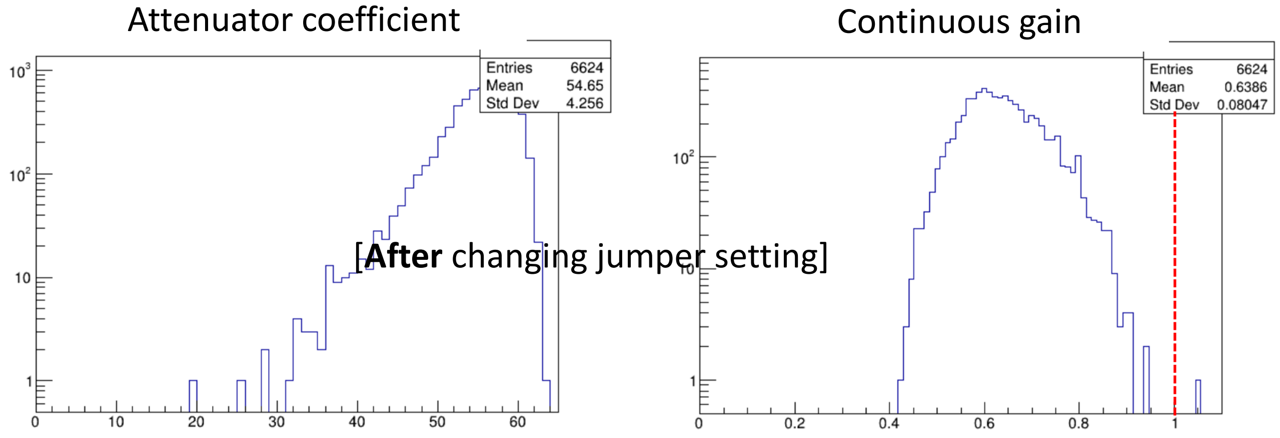
- Gain(continuous) above 0.9 channels show only 8.
- It shifted toward a relatively low coefficient or gain.



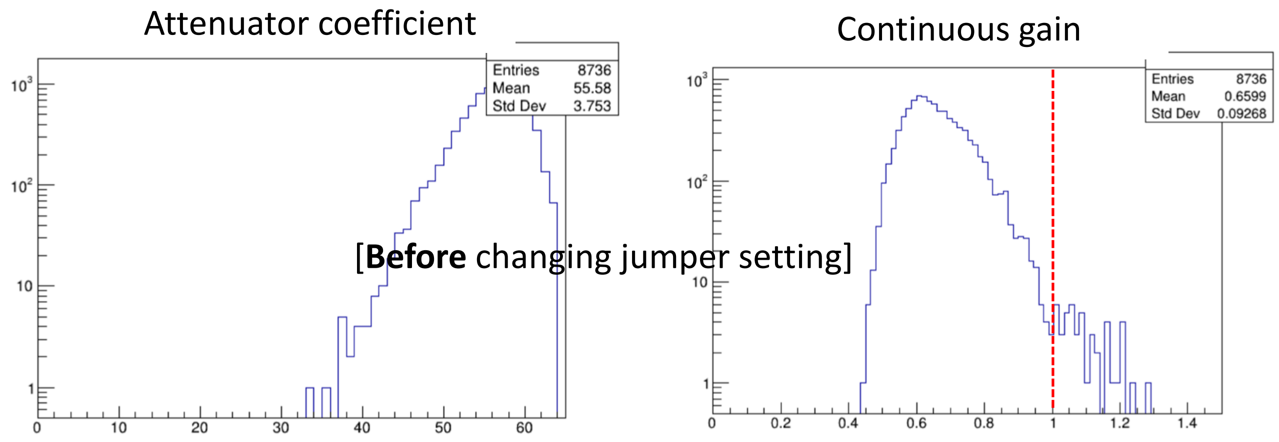
(1)

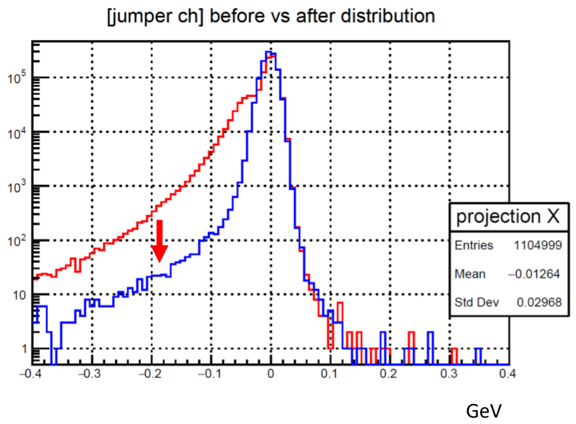


(2)

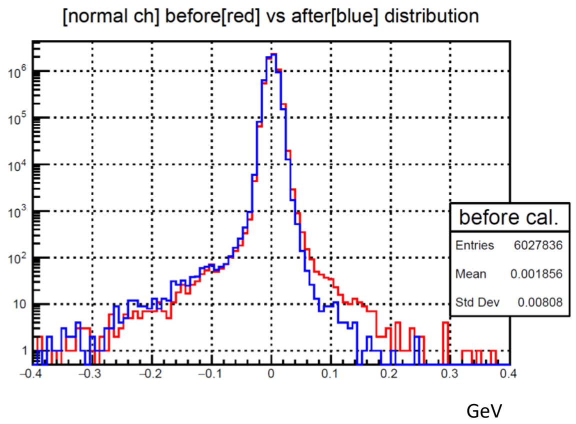


VS





(3)



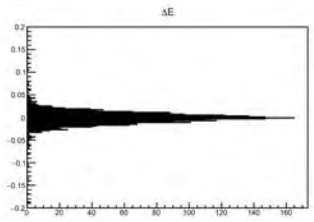
(4)

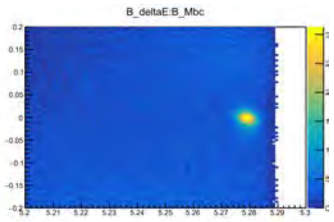
The projection plot : the energy distribution based on slope 5.25 MeV/ADC.

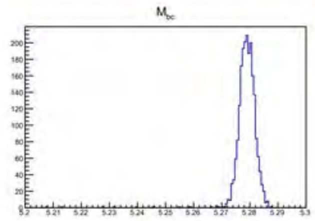
03. X(3872) lineshape

$$B \to X(3872)K$$
$$\to J/\psi\, \pi^+\pi^- K$$
$$\to \mu^+\mu^-(e^+e^-)\, \pi^+\pi^- K$$

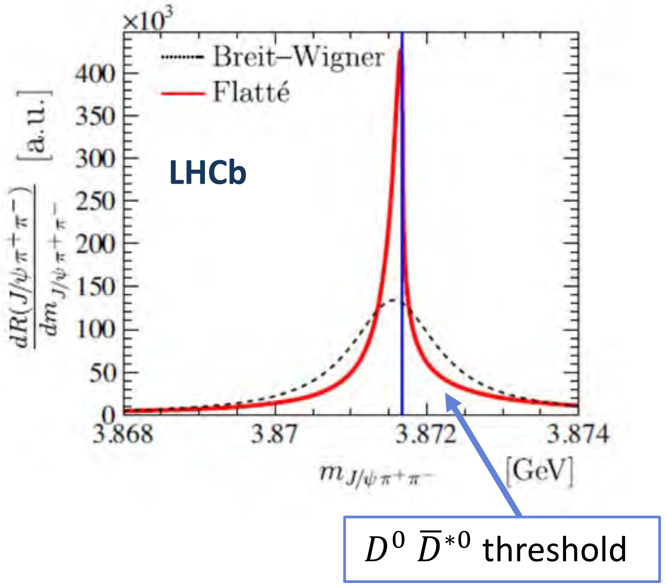
- Motivation
  - Flatte model and pole search
- In Belle (B2BII)
  - Signal MC samples for X(3872) to $J/\psi\, \pi^+\pi^-$
  - Generic MC samples for X(3872) to $J/\psi\, \pi^+\pi^-$
- Study of ‘Flatte model and pole search’ in Belle(B2BII)







Motivation



- X(3872) is exotic structure, and the structure of the state is uncertain.
- Measurement of the lineshape in various decay modes
  may help to discriminate between different options for the structure.
  → Two models are studied in the decay to $J/\psi\pi^+\pi^-$
  : **Breit-Wigner** and **Flatte-inspired parametrization (Flatte model)**.

- When using Breit-Wiger pdf, the lineshape of X(3872) is not correctly described near $D^{0,\pm}\ \overline{D}^{*0,\pm}$ threshold.
- The Breit-Wigner model is defined as an explicit expression for the energy-dependent partial width.
- The Flatte model is a function generated by considering the coupled channel effects and
  It is expected to obtain the accurate information for the X(3872).

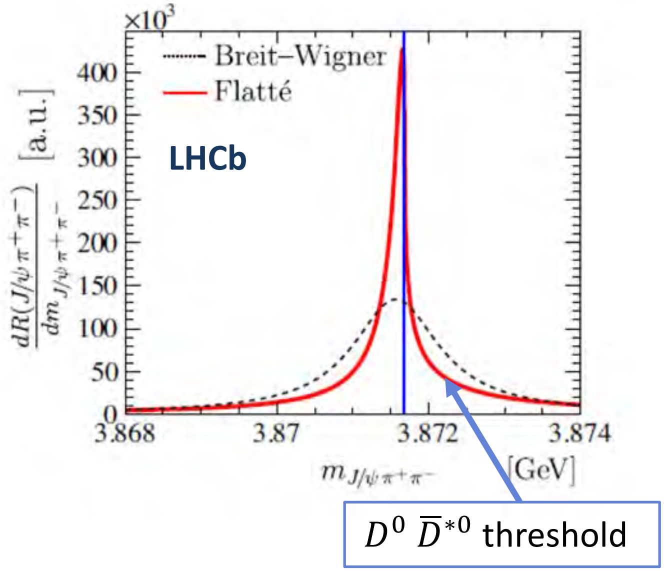
- **we aim to provide more information on the lineshape in X(3872) → $J/\psi\pi^+\pi^-$.**

A candidate for an exotic structure, X(3872)

Mass of X(3872)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
3871.65 ± 0.06 OUR AVERAGE					
$3871.64 \pm 0.06 \pm 0.01$	19.8k	[1] AAIJ	2020S	LHCB	$B^+ \to J/\psi \pi^+ \pi^- K^+$
$3871.9 \pm 0.7 \pm 0.2$	20	ABLIKIM	2014	BES3	$e^+ e^- \to J/\psi \pi^+ \pi^- \gamma$
$3871.95 \pm 0.48 \pm 0.12$	0.6k	AAIJ	2012H	LHCB	$p\, p \to J/\psi \pi^+ \pi^- X$
$3871.85 \pm 0.27 \pm 0.19$	170	[2] CHOI	2011	BELL	$B \to K \pi^+ \pi^- J/\psi$
$3873\ ^{+1.8}_{-1.6} \pm 1.3$	27	[3] DEL-AMO-SA..	2010B	BABR	$B \to \omega J/\psi K$
$3871.61 \pm 0.16 \pm 0.19$	6k	[4, 3] AALTONEN	2009AU	CDF2	$p\, \overline{p} \to J/\psi \pi^+ \pi^- X$
$3871.4 \pm 0.6 \pm 0.1$	93.4	AUBERT	2008Y	BABR	$B^+ \to K^+ J/\psi \pi^+ \pi^-$
$3868.7 \pm 1.5 \pm 0.4$	9.4	AUBERT	2008Y	BABR	$B^0 \to K^0_S\, J/\psi \pi^+ \pi^-$
$3871.8 \pm 3.1 \pm 3.0$	522	[5, 3] ABAZOV	2004F	D0	$p\, \overline{p} \to J/\psi \pi^+ \pi^- X$

($M_{D^0} + M_{D^{*0}}$ = 3871.69 ± 0.11 MeV)



X(3872) :

- Charmonium-like state
- Quantum number : $J^{PC} = 1^{++}$
- Various interpretations (proposed):
  - admixture of a molecular state
  - pure charmonium resonance
  - tetraquark
  - a cusp at the $D^0\overline{D}^{*0}$ threshold
- **The structure of the state is uncertain.**

Width of X(3872)

VALUE (MeV)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
1.19 ± 0.21 OUR AVERAGE Error includes scale factor of 1.1.						
$1.39 \pm 0.24 \pm 0.10$		15.6k	[1] AAIJ	2020AD	LHCB	$p\, p \to J/\psi \pi^+ \pi^- X$
$0.96\ ^{+0.19}_{-0.18} \pm 0.21$		4.2k	[2] AAIJ	2020S	LHCB	$B^+ \to J/\psi \pi^+ \pi^- K^+$
• • We do not use the following data for averages, fits, limits, etc. • •						
< 2.4	90		ABLIKIM	2014	BES3	$e^+ e^- \to J/\psi \pi^+ \pi^- \gamma$
< 1.2	90		CHOI	2011	BELL	$B \to K \pi^+ \pi^- J/\psi$
< 3.3	90		AUBERT	2008Y	BABR	$B^+ \to K^+ J/\psi \pi^+ \pi^-$
< 4.1	90	69	AUBERT	2006	BABR	$B \to K \pi^+ \pi^- J/\psi$
< 2.3	90	36	[3] CHOI	2003	BELL	$B \to K \pi^+ \pi^- J/\psi$

[1] Using $\chi_{c1}(3872)$ produced in inclusive b-hadron decays. Breit-Wigner parametrization.

[2] Using Breit-Wigner parametrization. Partially overlapping dataset with that of AAIJ 2020AD.

[3] Superseded by CHOI 2011 .

Citation: R.L. Workman et al. (Particle Data Group), Prog.Theor.Exp.Phys. 2022, 083C01 (2022)

Event selection and cuts

$B \to X(3872) K$
$\to J/\psi\, \pi^+\pi^- K$
$\to \mu^+\mu^- (e^+e^-)\, \pi^+\pi^- K$

Event selection (Belle)	
Kid , πid	Prob(k:pi) > 0.5 ? K : π prob(3,-1,5) > 0.99 cut for electron veto for **πid**
μid	likelihood > 0.1 && Chi2 > 0
eid	prob(3,-1,5) > 0.1
dr , dz	$\|dr\|$ < 1cm && $\|dz\|$ < 4cm
Gamma	ECL region : 12°<θ<32°, 32°< θ<130°, 130°< θ<154°
Radiative photon	E_γ threshold 0.2 GeV, Angle between the cone and the track is 2°
M_{bc}	M_{bc} > 5.2 GeV
ΔE	$\|\Delta E\|$ < 0.2 GeV
$\cos\theta_b$	$\|\cos\theta_b\|$ <0.8
R2	R2 < 0.4 (reduced Fox-Wolfram R2, defined as ratio of the i-th to the 0-th order Fox Wolfram moments.)
BCS	χ^2 for M_{bc} + ΔE + π vertex fit

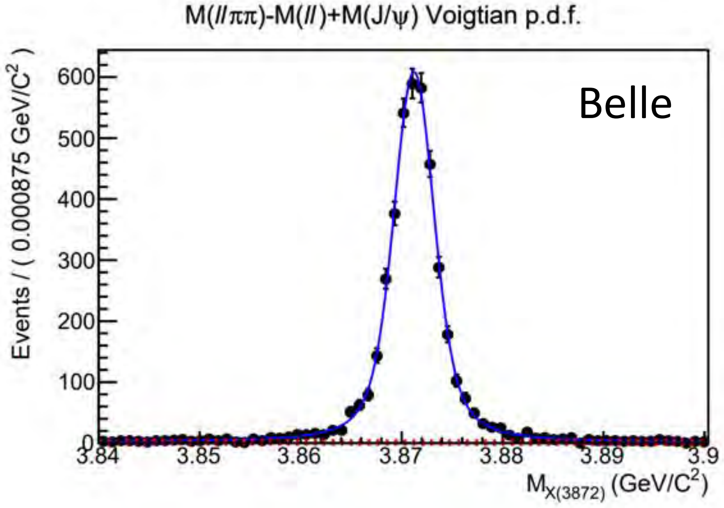
Event selection (B2BII)	
Kid , πid	Lkpi > 0.5 ? K : π eIDBelle < 0.01 (for electron veto at **πid**)
μid	muIDBelle > 0.1
eid	eIDBelle > 0.1 correctBremsBelle for radiative photon
dr , dz	$\|dr\|$ < 1cm && $\|dz\|$ < 4cm
Radiative photon	E_γ threshold 1.0 GeV, Angle between the cone and the track is 0.05 rad
M_{bc}	M_{bc} > 5.2 GeV
ΔE	$\|\Delta E\|$ < 0.2 GeV
$\cos\theta_b$	$\|\cos\theta_b\|$ <0.8
R2	R2 < 0.4
BCS	Treefit (vertex fit) for each particles
J/ψ **mass**	'3.05 < InvM J/ψ < 3.15' (for reconstruction)
X **mass**	'3.8 < InvM X < 3.92'

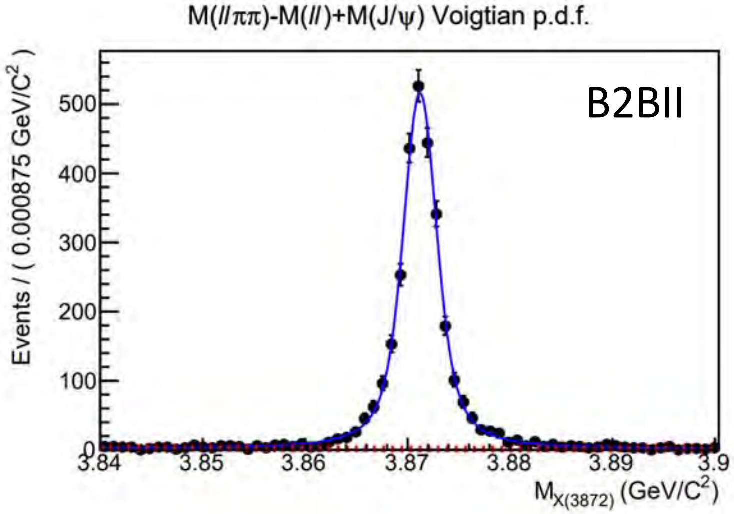
Signal MC

$B \rightarrow X(3872)K$
$\rightarrow J/\psi\, \pi^+\pi^- K$
$\rightarrow \mu^+\mu^-(e^+e^-)\, \pi^+\pi^- K$

Voigtian = Gaussian ⊗ Breit-Wigner

Input Value	particle	id	mass/GeV	width/GeV
	X(3872)	120443	3.8717	0.0

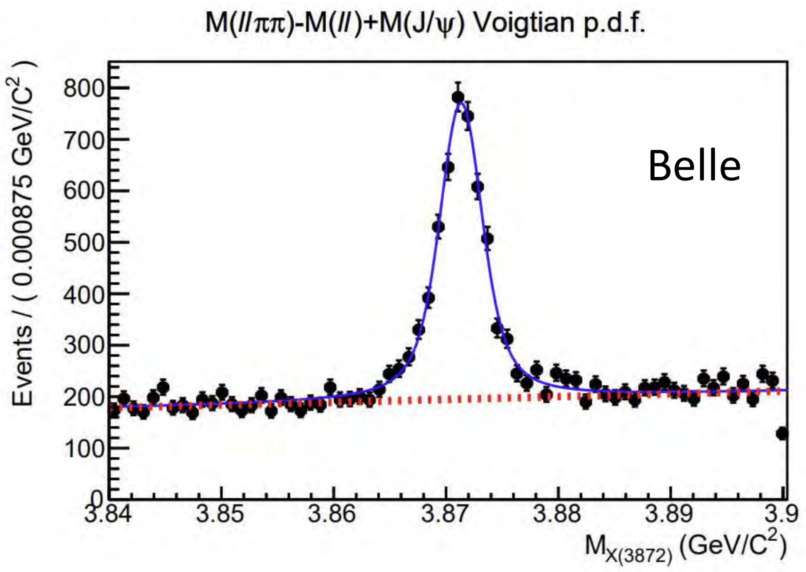


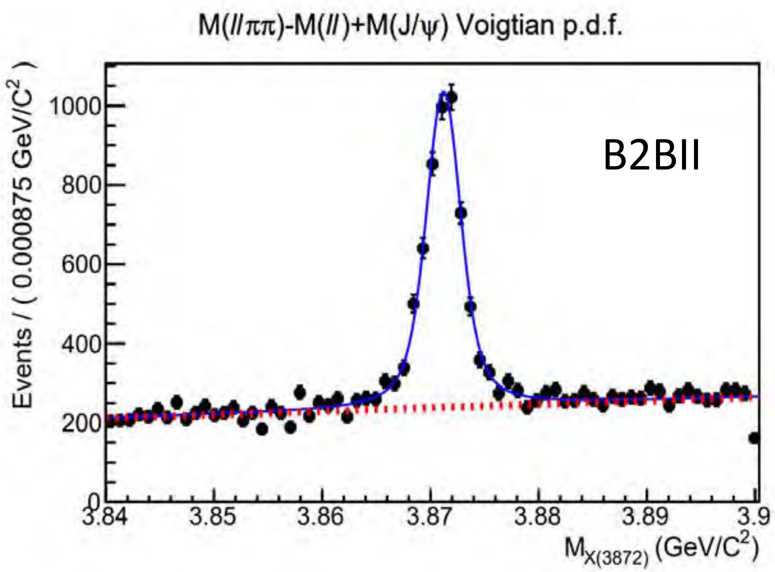


	X(3872) in Belle	X(3872) in B2BII	Truth X (Belle)	Truth X (B2BII)
Mean	3.871227 ± 0.000041	3.871214 ± 0.000042	3.871228 ± 0.000041	3.871216 ± 0.000042
Sigma	0.001517 ± 0.000083	0.00109 ± 0.00010	0.001684 ± 0.000073	0.001231 ± 0.000083
Width	0.00212 ± 0.00015	0.00224 ± 0.00016	0.00173 ± 0.00012	0.00196 ± 0.00012
Nsignal	4176 ± 70	3043 ± 60	4059 ± 65	2980 ± 55
NBkg	77 ± 28	88 ± 25	11 ± 14	1.0 ± 6.6

$B \rightarrow X(3872)K$
$\rightarrow J/\psi\, \pi^+\pi^- K$
$\rightarrow \mu^+\mu^-(e^+e^-)\, \pi^+\pi^- K$

Input Value	particle	id	mass/GeV	width/GeV
	X(3872)	120443	3.8717	0.0





	X(3872) in Belle	X(3872) in B2BII	Truth X (Belle)	Truth X (B2BII)
Mean	3.871333 ± 0.000058	3.871203 ± 0.000044	3.871244 ± 0.000041	3.871181 ± 0.000033
Sigma	0.00130 ± 0.00019	0.00123 ± 0.00013	0.001628 ± 0.000070	0.001114 ± 0.000068
Width	0.00248 ± 0.00043	0.00164 ± 0.00031	0.00156 ± 0.00012	0.00198 ± 0.00011
Nsignal	3889 ± 142	4333 ± 139	3538 ± 61	4389 ± 69
NBkg	13433 ± 172	16649 ± 178	25 ± 15	57 ± 20

Flatte model with LHCb results

X(3872) to $J/\psi\ \pi^+\pi^-$ decay mode in inclusive b-hadron decays

Yu.S Galashnikova and A. V. Nefediev , PRD 80, 074004 (2009)

Results of Flatte model

In the $J/\psi\pi^+\pi^-$ channel the X(3872) lineshape as a function of the energy with respect to the $D^0\bar{D}^{*0}$ threshold,

$E \equiv m_{J/\psi\pi^+\pi^-} - (m_{D^0} + m_{D^{*0}})$, can be written as

$$\frac{dR(J/\psi\pi^+\pi^-)}{dE} \propto \frac{\Gamma_\rho(E)}{|D(E)|^2}$$

$$D(E) = E - E_f + \frac{i}{2}[g(k_1 + k_2) + \Gamma_\rho(E) + \Gamma_\omega(E) + \Gamma_0].$$

- $\Gamma_\rho(E)$: contribution $J/\psi\pi^+\pi^-$ channel to the the width of X(3872)
- Energy parameter $E_f = m_0 - (m_{D^0} + m_{D^{*0}})$
- Mass parameter $m_0 = m_{D^0} + m_{\bar{D}^0} + m_{\pi^0}$
- Effective coupling constant for X(3872) and$D^0\bar{D}^{*0}$ threshold, g
- Relative momenta of the decay products

$$k_1 = \sqrt{2\mu_1 E}\ ,\ \ k_2 = \sqrt{2\mu_2(E-\delta)}$$

isospin splitting btw the 2 channels $\delta = 8.2MeV$,

$$\mu_1 = \frac{m_{D^0} m_{D^{*0}}}{m_{D^0} + m_{D^{*0}}},\ \ \mu_2 = \frac{m_{D^+} m_{D^{*-}}}{m_{D^+} + m_{D^{*-}}}$$

Specified free parameters : g, f_ρ, f_ω, Γ_0 and optional (?) parameter m_0

- Partial widths for $J/\psi\ \pi^+\pi^-$ and $J/\psi\ \pi^+\pi^-\pi^0$

Mass and width :

Get the value

by fitting with

BW function

$$\Gamma_\rho(E) = f_\rho \int_{2m_\pi}^{M(E)-m_{J/\psi}} \frac{dm'}{2\pi} \frac{q(m',E)\Gamma_\rho}{(m'-m_\rho)^2 + \frac{\Gamma_\rho^2}{4}}\ ,\ (\rho^0 \to \pi^+\pi^-)$$

$$\Gamma_\omega(E) = f_\omega \int_{3m_\pi}^{M(E)-m_{J/\psi}} \frac{dm'}{2\pi} \frac{q(m',E)\Gamma_\omega}{(m'-m_\omega)^2 + \frac{\Gamma_\omega^2}{4}}\ ,(\omega \to \pi^+\pi^-\pi^0)$$

$$q(m',E) = \sqrt{\frac{\left[M^2(E) - (m'+m_{J/\psi})^2\right]\left[M^2(E) - (m'-m_{J/\psi})^2\right]}{4M^2(E)}}$$

$M(E) = E + (m_{D^0} + m_{D^{*0}})$, f_ρ and f_ω : effective couplings

Unknown channel width Γ_0

Flatte model (coupled channels analysis) and pole search

R. Aaij et al., PRD 102, 092005 (2020)

$$\frac{dR(J/\psi\pi^+\pi^-)}{dE} \propto \frac{\Gamma_\rho(E)}{|D(E)|^2}$$

$$D(\boldsymbol{E}) = \boldsymbol{E} - E_f + \frac{i}{2}\left[g\,(k_1 + k_2) + \Gamma_\rho(\boldsymbol{E}) + \Gamma_\omega(\boldsymbol{E}) + \Gamma_0\right],$$

$$\boldsymbol{E} \equiv \boldsymbol{m}_{J/\psi\pi^+\pi^-} - (\boldsymbol{m}_{D^0} + \boldsymbol{m}_{D^{*0}})$$

$$E_f = m_0 - (m_{D^0} + m_{D^{*0}}) \qquad m_0 = m_{D^0} + m_{\bar{D}^0} + m_{\pi^0}$$

$$k_1 = \sqrt{2\mu_1 E}\,,\ k_2 = \sqrt{2\mu_2(E-\delta)}\,,$$

$$\delta = (m_{D^+} + m_{D^{*-}}) - (m_{D^0} + m_{D^{*0}})$$

$$\mu_1 = \frac{m_{D^0} m_{D^{*0}}}{m_{D^0} + m_{D^{*0}}},\quad \mu_2 = \frac{m_{D^+} m_{D^{*-}}}{m_{D^+} + m_{D^{*-}}}$$

$$\Gamma_\rho(E) = f_\rho \int_{2m_\pi}^{M(E)} \frac{dm'}{2\pi} \frac{q(m',E)\Gamma_\rho}{(m'-m_\rho)^2 + \frac{\Gamma_\rho^2}{4}}\,,\ (\rho^0 \to \pi^+\pi^-)$$

For Intermediate resonances

$$\Gamma_\omega(E) = f_\omega \int_{2m_\pi}^{M(E)} \frac{dm'}{2\pi} \frac{q(m',E)\Gamma_\omega}{(m'-m_\omega)^2 + \frac{\Gamma_\omega^2}{4}}\,,(\omega \to \pi^+\pi^-\pi^0)$$

$$q(m',E) = \sqrt{\frac{\left[M^2(E) - (m' + m_{J/\psi})^2\right]\left[M^2(E) - (m' - m_{J/\psi})^2\right]}{4M^2(E)}}$$

$$M(E) = E + (m_{D^0} + m_{D^{*0}})$$

Par. name	values	Par. name	values
g	0.108	f_ρ	$1.8 * 10^{-3}$
$m_0(MeV)$	3864.5	f_ω	0.01
$E_f(MeV)$	−7.2	$\Gamma_0(MeV)$	1.4
$\delta(MeV)$	8.2	$\Gamma_\rho(MeV)$	149.1
$m_{D^0}(MeV)$	1864.84	$\Gamma_\omega(MeV)$	8.68
$m_{D^{*0}}(MeV)$	2006.85	$m_{J/\psi}(MeV)$	3096.9
$m_{D^+}(MeV)$	1869.66	$m_\pi(MeV)$	134.9768
$m_{D^{*-}}(MeV)$	2010.26	$\mu_1(MeV)$	966.62
$m_\rho(MeV)$	775.26	$\mu_2(MeV)$	968.70
$m_\omega(MeV)$	782.66		

($M_{D^0} + M_{\bar{D}^{*0}}$ = 3871.69 ± 0.11 MeV)

Flatte model and pole search

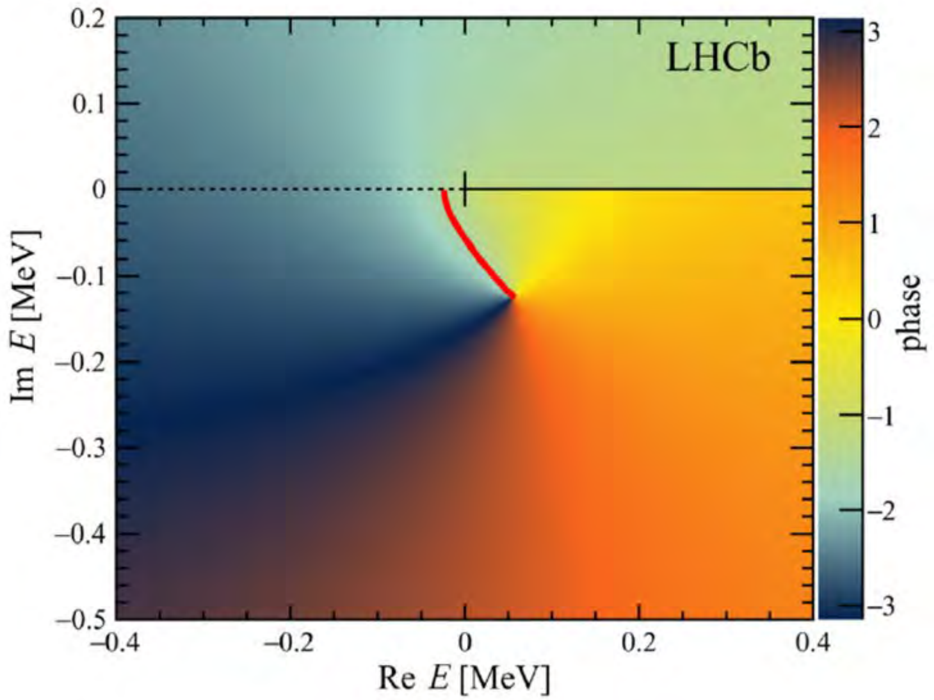
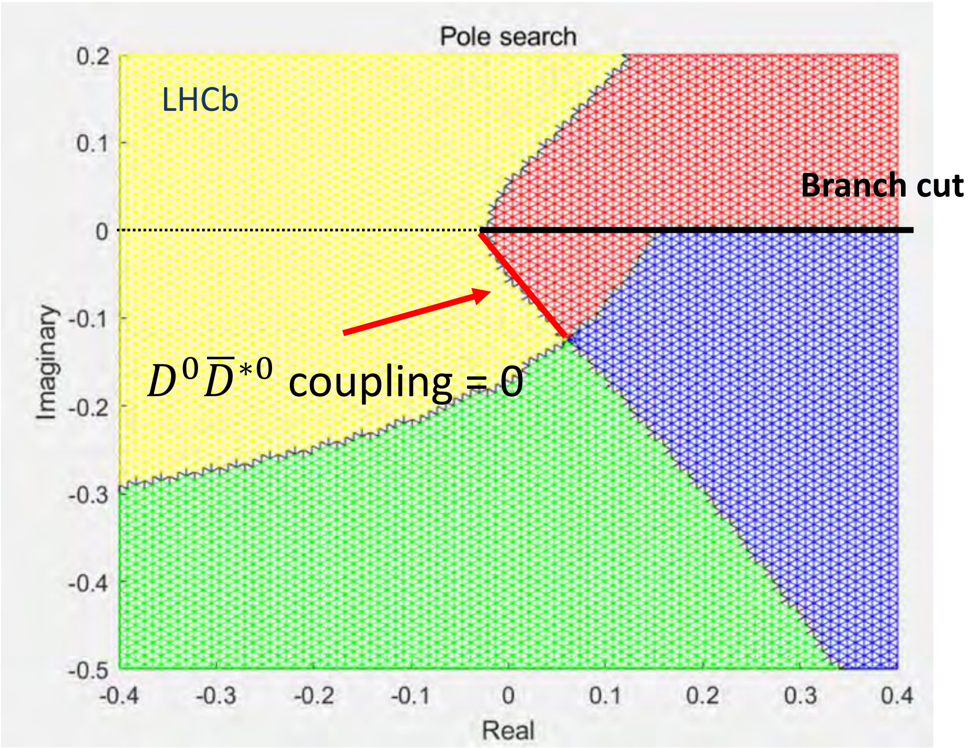


FIG. 6. The phase of the Flatté amplitude obtained from the fit to the data with $m_0 = 3864.5$ MeV on sheets I (for Im$E > 0$) and II (for Im$E < 0$) of the complex energy plane. The pole singularity is visible at $E_{\rm II} = (0.06 - 0.13i)$ MeV. The branch cut is highlighted with the black line. The trajectory of the pole taken when the couplings to all but the $D\bar{D}^*$ channel are scaled down to zero is indicated in red.



$M_{J/\psi\pi^+\pi^-}$

$= E + (m_{D^0} + m_{D^{*0}})$

$= 0.06 + 3871.69$

$= 3871.75\ MeV$

0.060 - 0.125i (MeV)

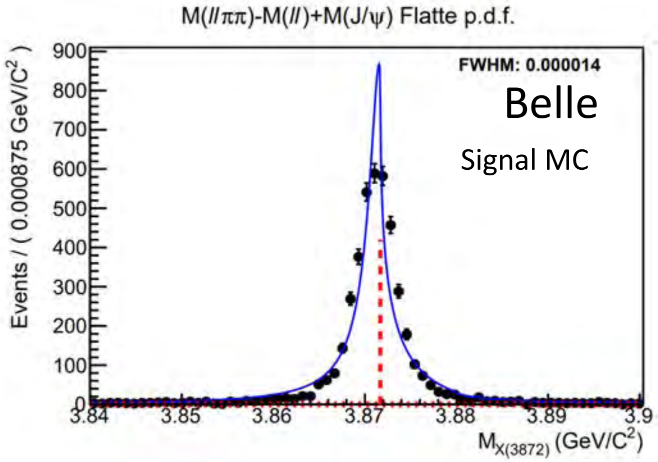
Reproduction of LHCb results

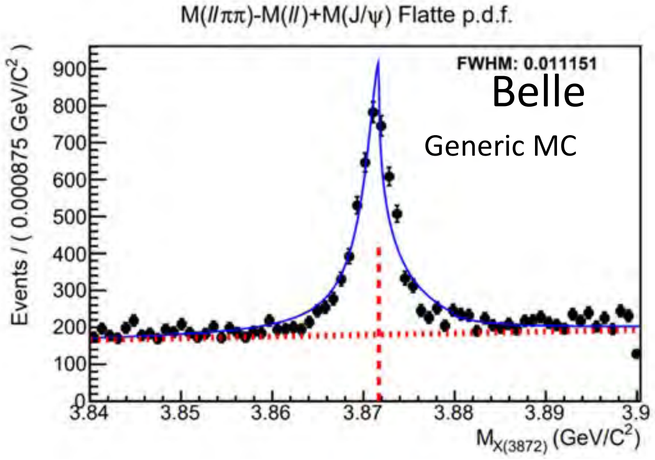
GRPF: Global complex Roots and Poles Finding algorithm https://github.com/PioKow/GRPF

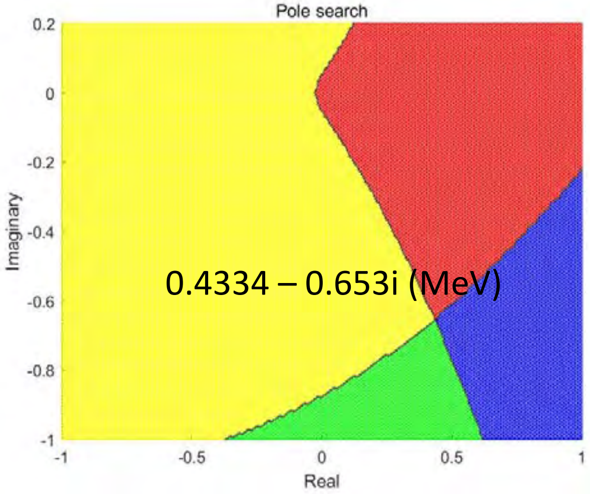
Flatte model fitting and pole search

Input Value	particle	id	mass/GeV	width/GeV
Meson	X(3872)	120443	3.8717	0.0

$B \to X(3872)K$
$\to J/\psi\, \pi^+\pi^- K$
$\to \mu^+\mu^-(e^+e^-)\, \pi^+\pi^- K$







$M_{J/\psi\pi^+\pi^-} = E + (m_{D^0} + m_{D^{*0}})$

0.4334 – 0.653i (MeV)

$M_{J/\psi\pi^+\pi^-} = 3871.69 + 0.433$
$= 3872.123\ (MeV)$

flatte	Signal MC(Belle)	Generic MC(Belle)
m_0	3.8645	3.8645
Γ_0	0.00001 ± 0.00011	0.00474 ± 0.00032
g	0.1010 ± 0.0017	0.107 ± 0.015
f_ρ	0.00010 ± 0.00097	0.0189 ± 0.0099
f_ω	0.3902 ± 0.0093	0.1736 ± 0.0097
FWHM	0.000014	0.011151
$M_{J/\psi\pi^+\pi^-}$	**3872.123**	**3872.881**

Sookyung Choi

Collider based HEP Lab and research activities

- Current Members
  - Full-time (JiHyeok Jeong(M2), Eunji Jang(g+) and Dr. Sookyung Choi)
  - Part-time (Jaekeum Lee(g+))
  - Consultant & Part-time member (Dr. Stephen Olsen)
  - Future members will arrive soon . . . .
- Participating Experiments : Belle(II) and BESIII
  - Physics interests
    - Hyperon physics (ex, Searching for CPV parameters in Hyperon (Baryon), etc)
    - XYZ physics
- Activities at CAU-HEP Center this year
  - JiHyeok Jeong : Master Thesis : "Precise Mass measurement of the $\Xi^-(\Xi^+)$ produced in $J/\psi \to \Xi^-\Xi^+$ in the BESIII experiment" and Journal Club presentation.
  - Eunji Jang : ECLTRG energy calibration and Lineshape study of the X(3872)
  - Sookyung Choi : Summer school Lecturer
    Reviewer of many drafts prepared for the Journal publication.

Belle II Collaboration

Belle II Member Composition per Country

1. Germany 221
2. Japan 181
3. USA 120
4. Italy 110
5. China 103
6. France 61
7. India 54
8. Canada 46
9. Russia 40
10. South Korea 39

Total 28 countries 122 institutes 1170 members

Provided by prof. YangSoo Kim

Achievements of Belle in 2023

- 645 publications from 2001 to now
- Still very productive : 47 publications (including submission) in 2023
- Data analysis efforts are now merging into Belle II collaboration

Belle Journal Publications
The Belle Collaboration

- Physics Publications

645. **Measurement of the Ratio of Partial Branching Fractions of Inclusive $\bar{B} \to X_u \ell \bar{\nu}$ to $\bar{B} \to X_c \ell \bar{\nu}$ and the Ratio of their Spectra with Hadronic Tagging**
M. Hohmann, P. Urquijo, et al. (Belle Collaboration), submitted to PRD
Belle preprint 2023-17, KEK Preprint 2023-30, arXiv:2311.00458 [hep-ex]

644. **Search for the baryon and lepton number violating decays $D \to p\ell$**
S. Maity, R. Garg, S. Bahinipati, V. Bhardwaj, et al. (Belle Collaboration), submitted to PRD
Belle preprint 2023-15, KEK Preprint 2023-20, arXiv:2310.07412 [hep-ex]

643. **Search for charged-lepton flavor violation in $\Upsilon(2S) \to \ell^{\mp} \tau^{\pm}$ (ℓ=e, μ) decays at Belle**
R. Dhamija, S. Nishida, A. Giri, et al. (Belle Collaboration), submitted to JHEP
Belle preprint 2023-14, KEK Preprint 2023-19, arXiv:2309.02739 [hep-ex]

642. **Observation of charmed strange meson pair production in $\Upsilon(2S)$ decays and in e^+e^- annihilation at $\sqrt{s}$ = 10.52 GeV**
B.S. Gao, W.J. Zhu, X.L. Wang, et al. (Belle Collaboration), to appear in PRD
Belle preprint 2023-12, KEK Preprint 2023-16, arXiv:2308.08900 [hep-ex]

641. **Search for a dark leptophilic scalar produced in association with $\tau^+\tau^-$ pair in e^+e^- annihilation at center-of-mass energies near 10.58 GeV**
D. Biswas, Sw. Banerjee, et al. (Belle Collaboration), submitted to PRL
Belle preprint 2023-13, KEK Preprint 2023-17, arXiv:2207.07476 [hep-ex]

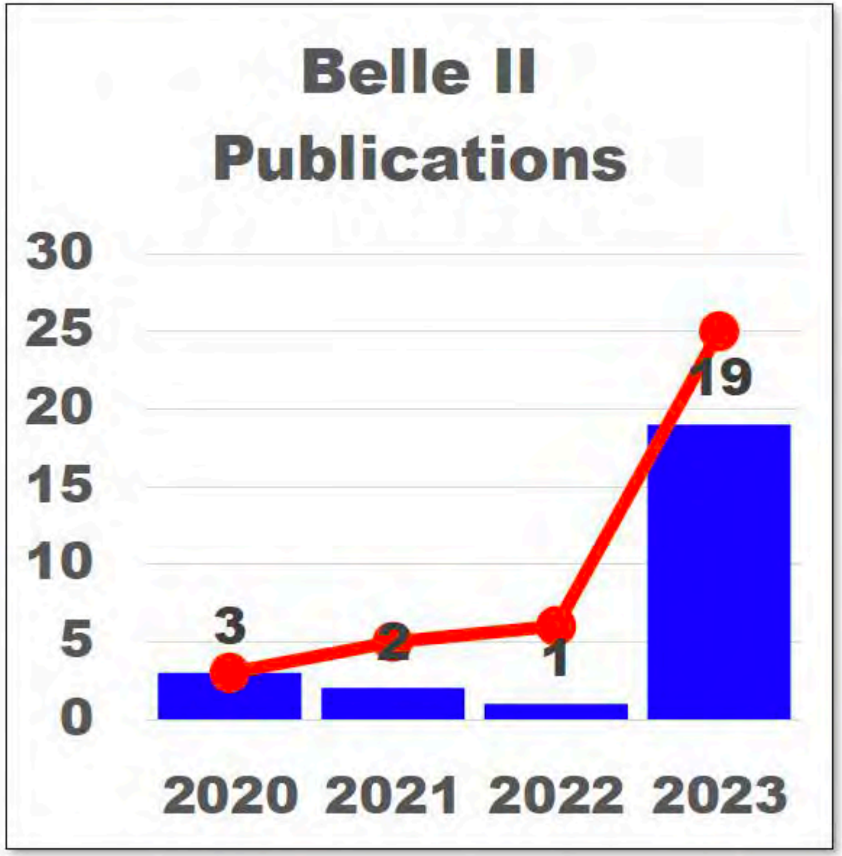
640. **Evidence of $B^0 \to p\Sigma^-\pi^-$ at Belle**
C.-Y. Chang, M.-Z. Wang, et al. (Belle Collaboration), published in PRD 108, 052011 (2023 September 22)
Belle preprint 2023-10, KEK Preprint 2023-12, arXiv:2305.18821 [hep-ex]

639. **Search for double-charmonium state with η_c J/ψ at Belle**
J.H. Yin, Y.B. Li, E. Won, et al. (Belle Collaboration), published in JHEP 2308.121 (2023 August 18)
Belle preprint 2023-11, KEK Preprint 2023-13, arXiv:2305.17947 [hep-ex]

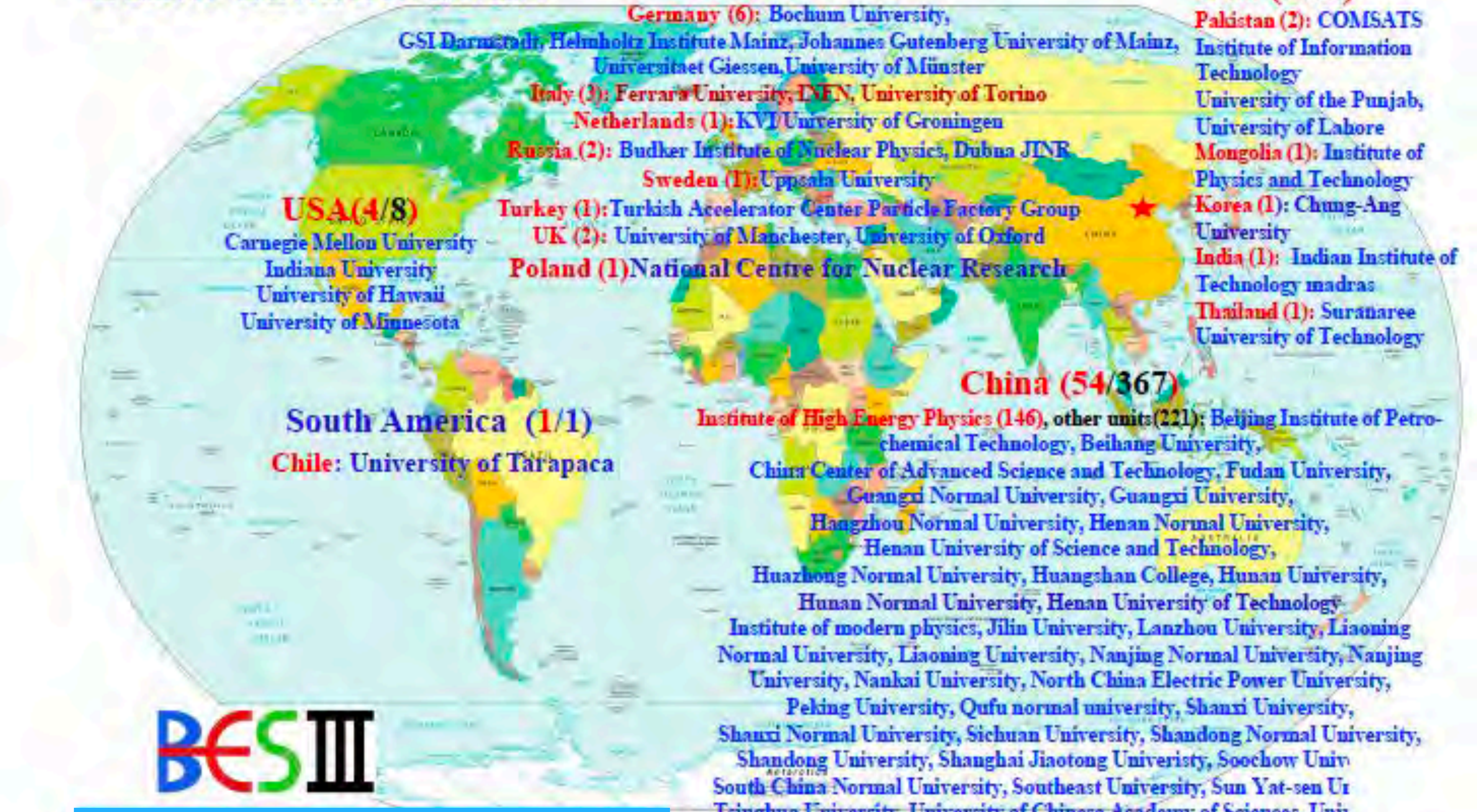
Achievements of Belle II in 2023

$B \to X_c \ell^+ \bar{\nu}_\ell$	PRD 107, 072002
Dark photon $\to \mu^+\mu^- + E_{miss}$	PRL 130, 071804
$\Gamma(\Lambda_c^+)$	PRL 130, 071802
LFV $\tau \to \ell\alpha$	PRL 130, 181803
$Z' \to \mu\mu + E_{miss}$	PRL 130, 231801
$\Gamma(\Omega_c^0)$	PRD 107, L031103
CPV $B^0 \to \pi^0\pi^0$	PRD 107, 112009
$e^+e^- \to \omega\chi_{bJ}, X_b \to \omega\Upsilon(1S)$	PRL 130, 091902
$e^+e^- \to \mu^+\mu^-\tau^+\tau^-$	PRL 131, 121802
$\Gamma(B^0)$	PRD 107, L091102
LU $B(B \to Xe\nu)/B(B \to X\mu\nu)$	PRL 131, 051804
D^0 identification method	PRD 107, 112010
CPV $B^0 \to \phi K_S^0$	PRD 108, 072012
CPV $B^0 \to K_S^0\pi^0$	PRL 131, 111803
$\lvert V_{cb}\rvert$ from $\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}_\ell$	Accepted PRD
$M(\tau)$	PRD 108, 032006
CPV $B^\pm \to DK^\pm, B^\pm \to D\pi^\pm$	JHEP 09 2023, 146
LU $B^0 \to D^{*-}\ell^+\nu$	PRL 131, 181801
$\Gamma(D_s^+)$	PRL 131, 171803
19 published in 2023	

Physics Results in 2023



BESIII Collaboration



Europe (17/115)

Germany (6): Bochum University, GSI Darmstadt, Helmholtz Institute Mainz, Johannes Gutenberg University of Mainz, Universitaet Giessen, University of Münster

Italy (3): Ferrara University, INFN, University of Torino

Netherlands (1): KVI/University of Groningen

Russia (2): Budker Institute of Nuclear Physics, Dubna JINR

Sweden (1): Uppsala University

Turkey (1): Turkish Accelerator Center Particle Factory Group

UK (2): University of Manchester, University of Oxford

Poland (1) National Centre for Nuclear Research

Asia (6/10)

Pakistan (2): COMSATS Institute of Information Technology, University of the Punjab, University of Lahore

Mongolia (1): Institute of Physics and Technology

Korea (1): Chung-Ang University

India (1): Indian Institute of Technology madras

Thailand (1): Suranaree University of Technology

USA (4/8)

Carnegie Mellon University
Indiana University
University of Hawaii
University of Minnesota

South America (1/1)

Chile: University of Tarapaca

China (54/367)

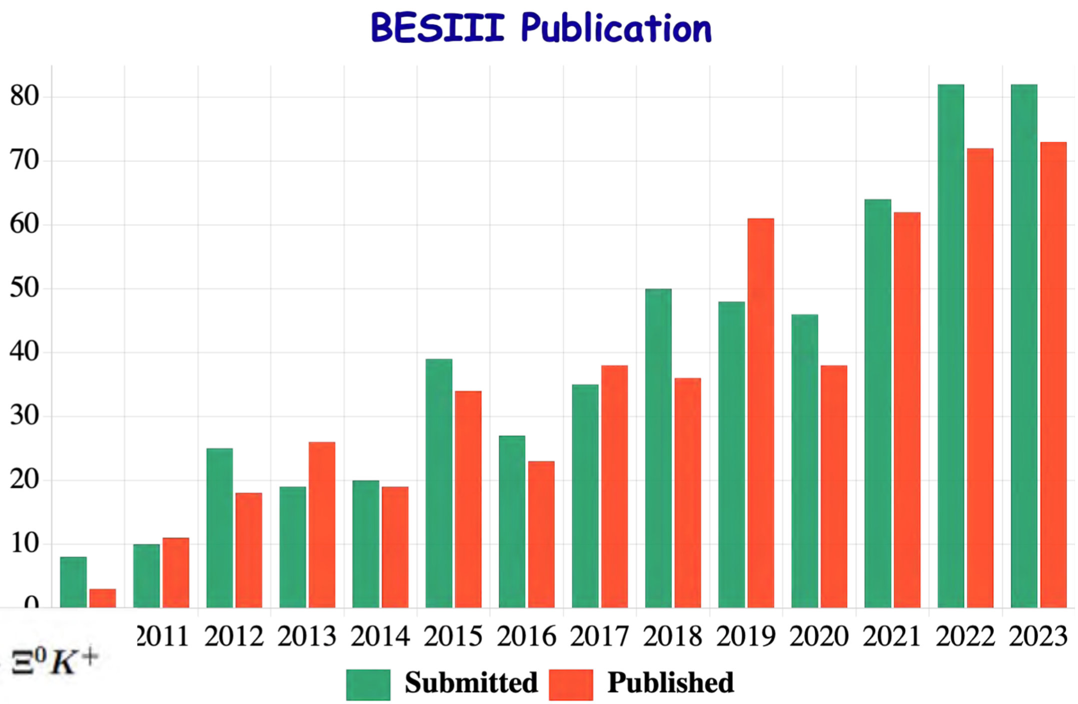
Institute of High Energy Physics (146), other units (221): Beijing Institute of Petro-chemical Technology, Beihang University, China Center of Advanced Science and Technology, Fudan University, Guangxi Normal University, Guangxi University, Hangzhou Normal University, Henan Normal University, Henan University of Science and Technology, Huazhong Normal University, Huangshan College, Hunan University, Hunan Normal University, Henan University of Technology, Institute of modern physics, Jilin University, Lanzhou University, Liaoning Normal University, Liaoning University, Nanjing Normal University, Nanjing University, Nankai University, North China Electric Power University, Peking University, Qufu normal university, Shanxi University, Shanxi Normal University, Sichuan University, Shandong Normal University, Shandong University, Shanghai Jiaotong Univeristy, Soochow Univ, South China Normal University, Southeast University, Sun Yat-sen Ur, Tsinghua University, University of Chinese Academy of Sciences, Univ Jinan, University of Science and Technology of China, University of Science and Technology Liaoning, University of South China, Wuhan University, Xinyang Normal University, Zhejiang University, Zhengzhou University, YunNan University, China University of Geosciences

BESIII

more than 600 colleagues
from 89 institutions, 16 countries

Achievements of BESIII in 2023

- 555 papers submitted, 514 published during 2010 – 2023 Dec 08
- Submitted more than 83 papers (including15 PRL) this year
- The 100th PRL paper accepted on Nov. 30



First Measurement of the Decay Asymmetry of pure W-exchange Decay $\Lambda_c^+ \to \Xi^0 K^+$

BEPCII-U plan and progress

from Chenghui

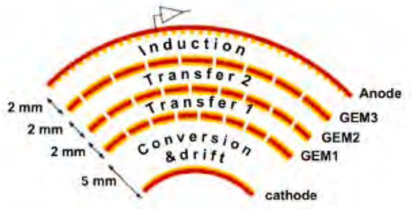
- The 1st IP insertion magnet, composed of Quad+AS, is ready now
- The 2nd and 3rd ones will be ready in 3 months.

All the procedures of BEPCII-U within IR and BESIII hall can only start July 1, 2024

- **July 1 to July 15, 2024** **The second SCQ+AS field measurement**
- **July 16 to Dec. 15, 2024** **IR disassembly & CGEM installation & Cryogenic system →IR assembly**

(2 new and 2 old sets of SC magnets & 2 ISPB & 2 Q1a & 2 Q1b & 4 Q2 placed in outside of tunnel ← indoor large space, laboratory renovation, transportation of tools and man power)

The commissioning will begin on Jan. 1, 2025.

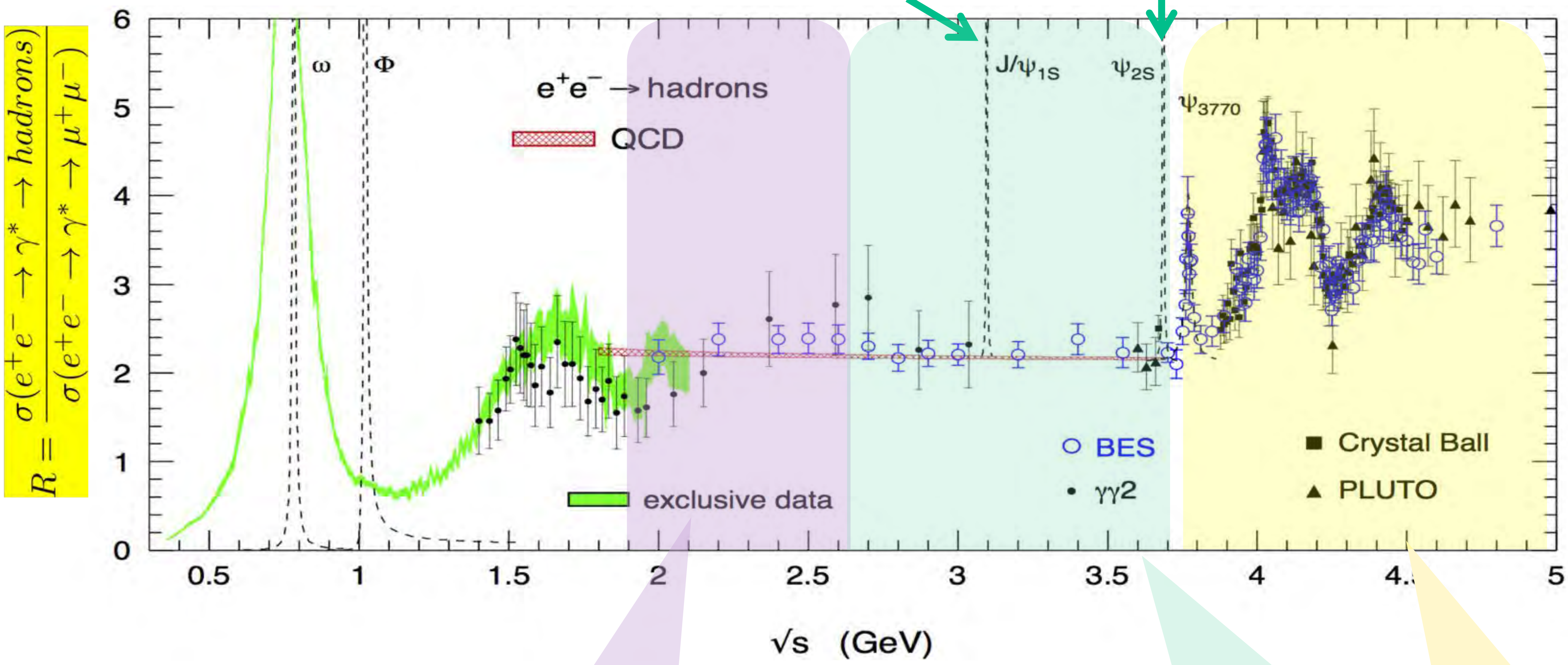


Upgrade Schedules

- CGEM (Cylindrical Gas Electron Multiplier Inner Tracker) for more precise vertex measurement and complementary for MDC inner cells aging
- To increase Luminosity

Rich Physics at τ - charm Energy Region

$\sigma(e^+e^- \to J/\psi) = 3400nb$ $\sigma(e^+e^- \to \psi(3686)) = 600nb$



Center Mass Energy: 2.00~4.95GeV
Future Plan of CME: 1.8~5.2(?)GeV

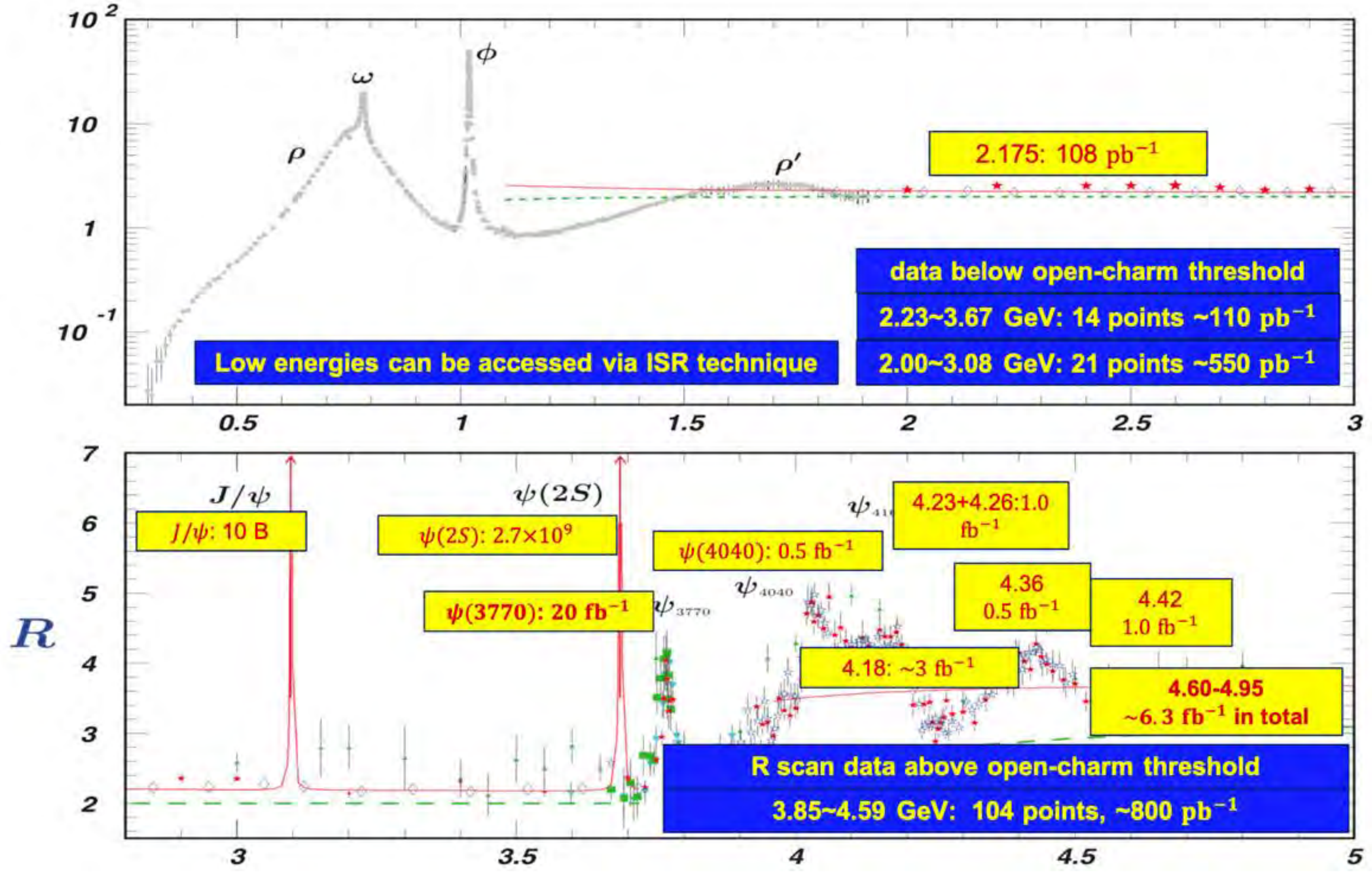
Hadron (Hyperon, Baryon) Form Factors
R values and QCD

Light hadron spectroscopy
Gluonic and exotic states
Physics with τ lepton

XYZ states
Charm Mesons
Charm baryons

BESIII Data Sets

We will collect about 20 fb^{-1} on the $\psi(3770)$ before 2024.

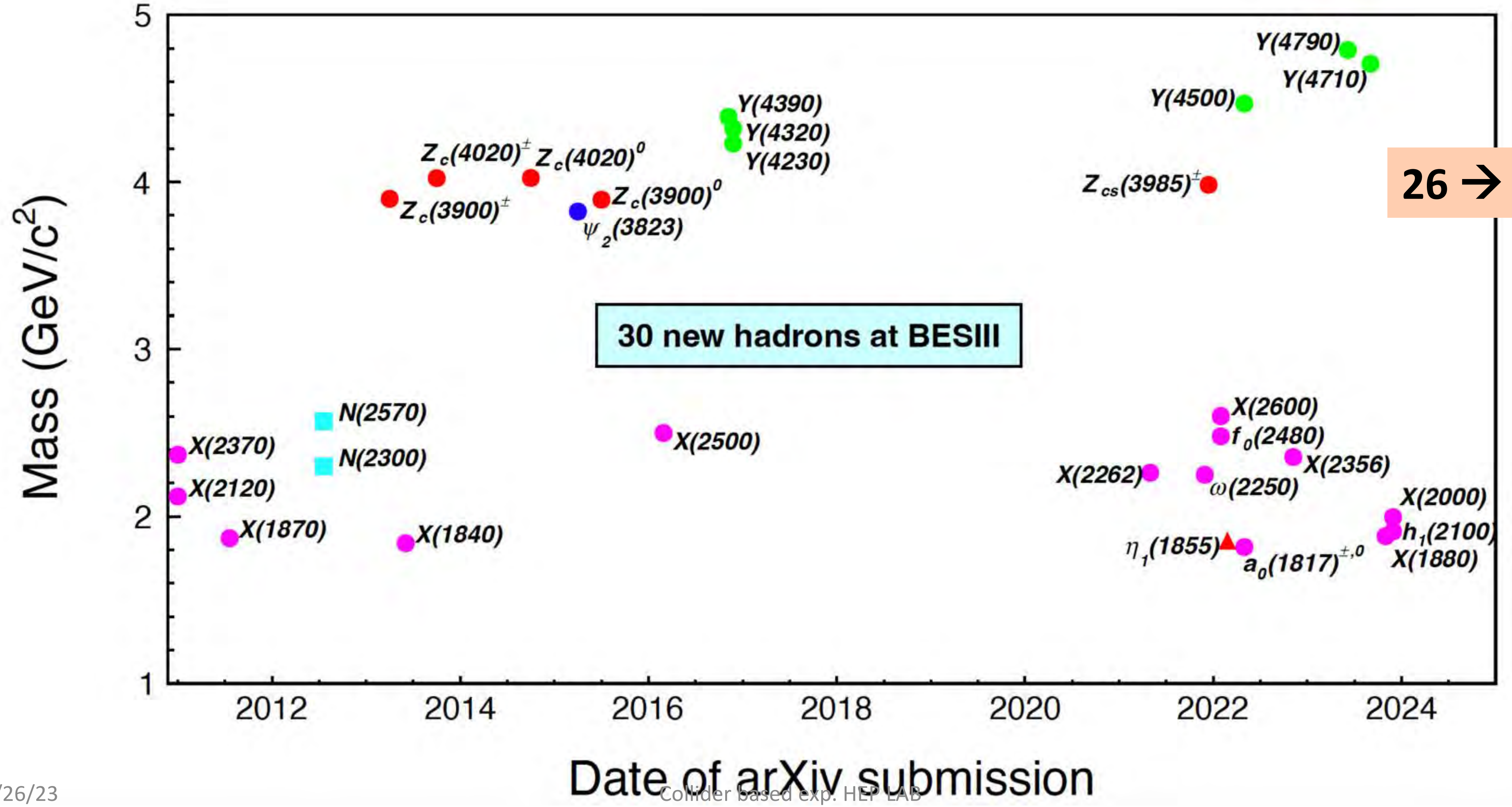


Data sets collected so far include

- 10×10^9 J/ψ events
- 2.7×10^9 ψ(2S) events
- 17 fb^{-1} ψ(3770)
- Very efficient at producing 1^{--} states
- Scan data between 2.0 and 3.08 GeV, and above 3. 74 GeV
- Large datasets for XYZ studies: Scan with >500 pb-1 per energy point The spacing of scan data is 10-20MeV
- ~130 energy points (Total >47 /fb)
- Future Plan: 1.8 – 5.2(?) GeV

- Meson and Baryon pairs productions near thresholds: Form-factors in the time-like productions, precision branching fractions, relative phase.
- Hyperon and Charmed baryon Spin polarization in productions
- CP violation with quantum-entangled pair productions of hyperons and charmed baryon

BEPCII / BESIII (record)

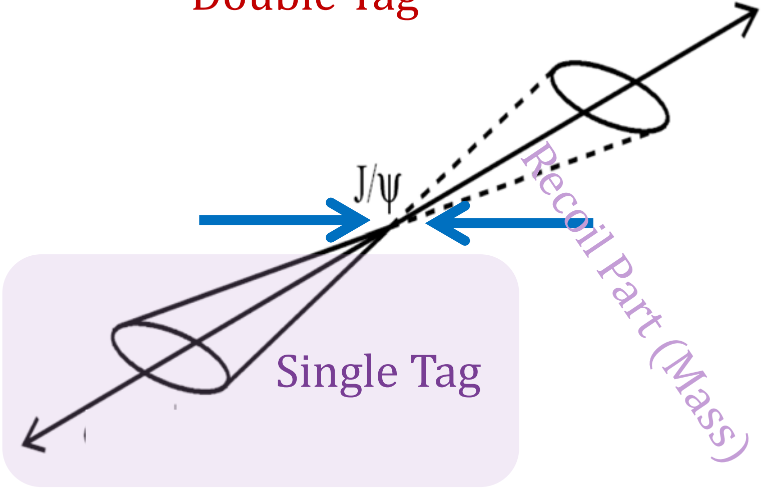


26 → 30

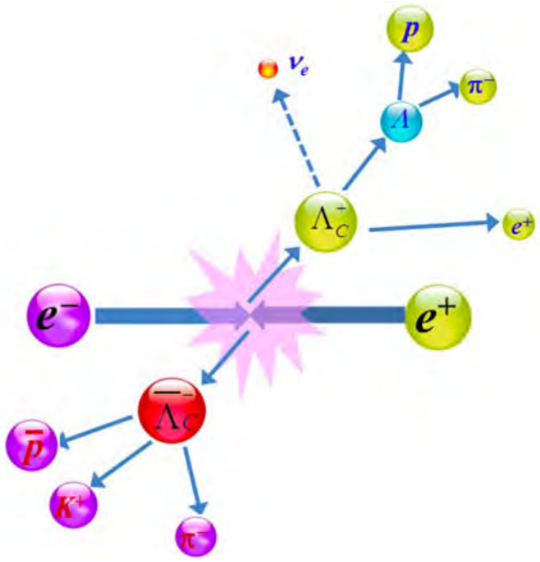
BESIII Advantages: Unique Data near to the thresholds

- Known initial 4-momentum
- Known beam energy and pair production
- Decay with neutron & π^0
- Decay with invisibles: neutrinos
- Missing mass and missing energy

Double Tag

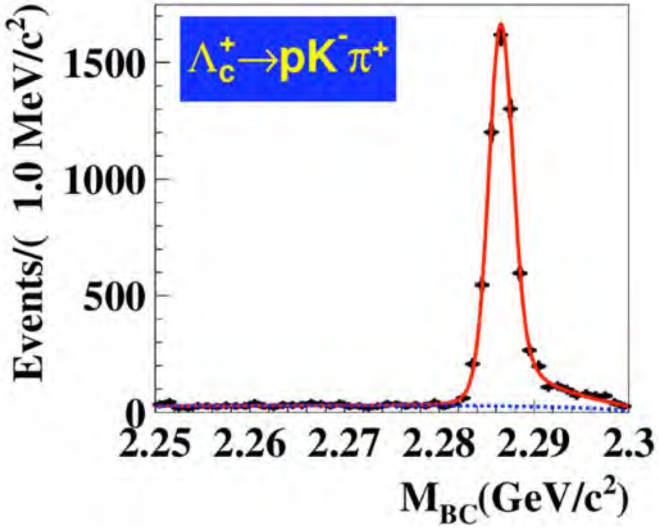


$$e^+e^- \to \Lambda_c^+\bar{\Lambda}_c^-$$



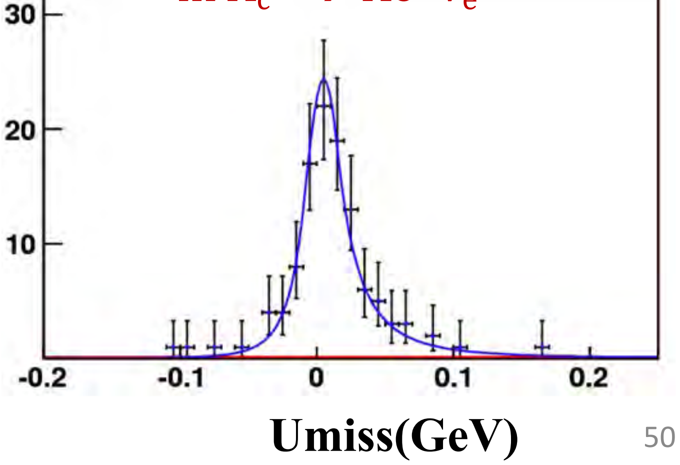
Excellent Resolution

Beam-constraint Λ_c mass



Neutrino reconstruction

in $\Lambda_c^+ \to \Lambda e^+\nu_e$

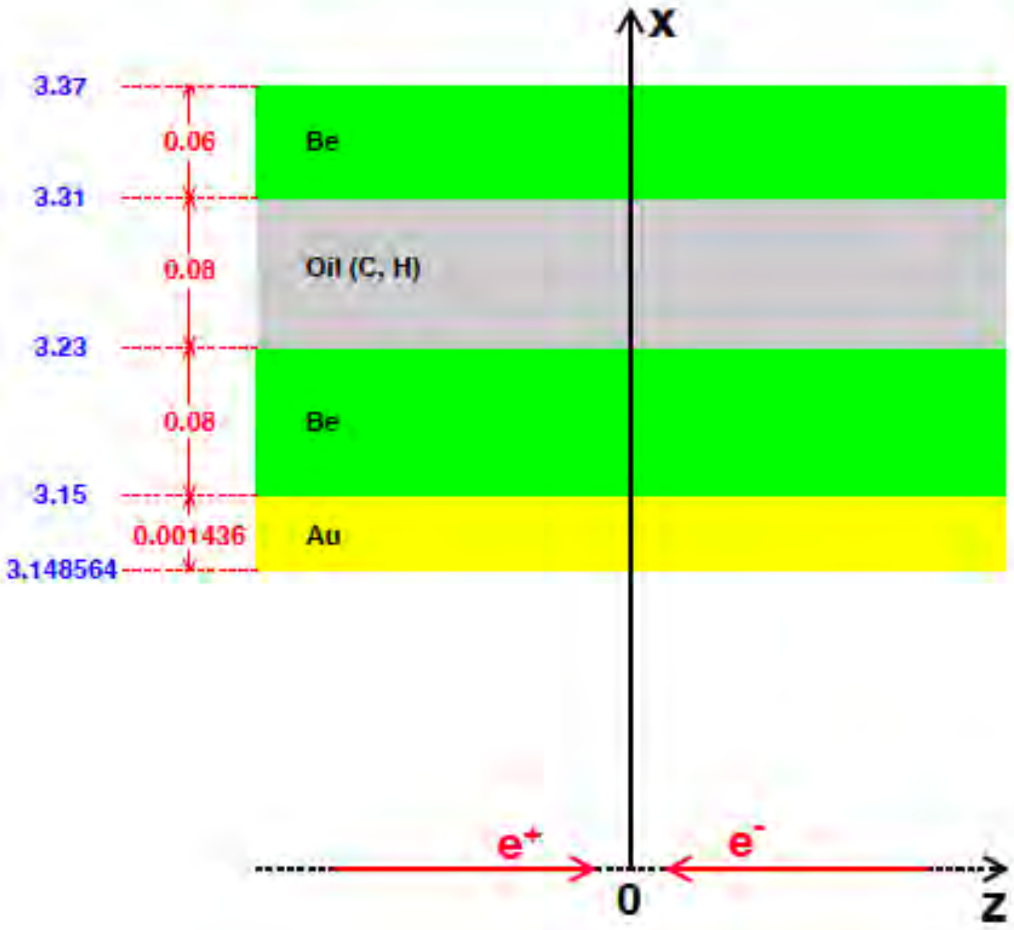


The First measurement of Hyperon-Nucleon Interaction in Collider

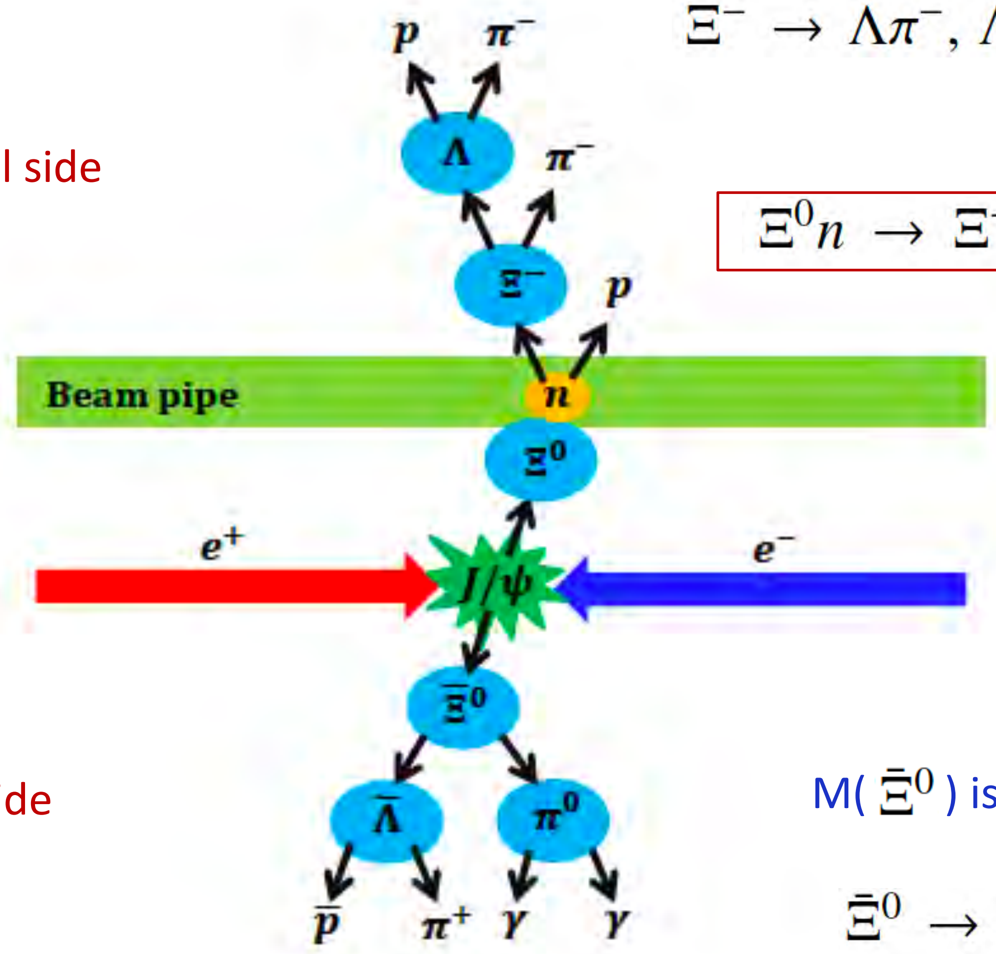
Schematic Diagram

Beam Pipe (unit: cm)

as a target material



signal process $\Xi^0 n \to \Xi^- p$



Signal side

$\Xi^- \to \Lambda\pi^-, \Lambda \to p\pi^-$

H-dibaryon ?
No evidence at current data

$\Xi^0 n \to \Xi^- p$ → $\Xi^0 + {}^9\text{Be} \to \Xi^- + p + {}^8\text{Be}$

Neutron is a component of ${}^9\text{Be}$, ${}^{12}\text{C}$ and ${}^{197}\text{Au}$ nuclei in the BP

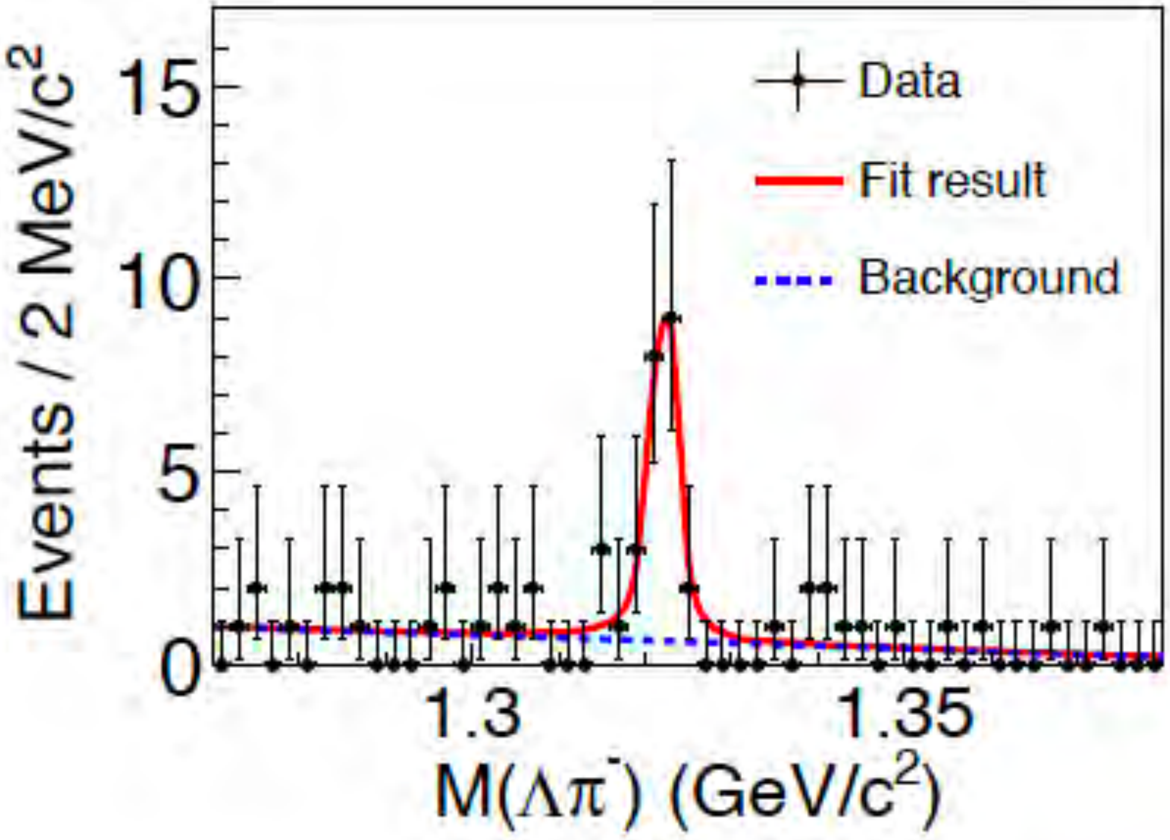
Produced at $J/\psi \to \Xi^0\bar{\Xi}^0$

Tag side

M($\bar{\Xi}^0$) is also a recoiling mass of the Ξ^0

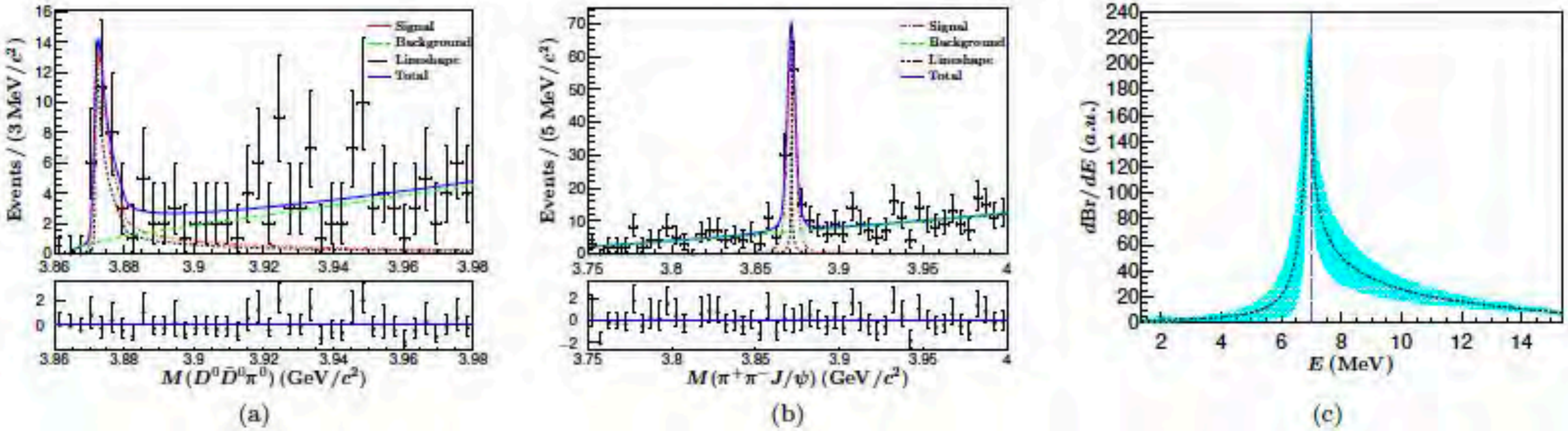
$\bar{\Xi}^0 \to \bar{\Lambda}\pi^0, \bar{\Lambda} \to \bar{p}\pi^+, \pi^0 \to \gamma\gamma$

Hyperon-Nucleon Interaction



$$\sigma(\Xi^0 n \rightarrow \Xi^- p) = (7.4 \pm 1.8_{\text{stat}} \pm 1.5_{\text{sys}})\ \text{mb}$$

A coupled-channel analysis of the $\chi_{c1}(3872)$ lineshape with BESIII data



Distributions of (a) $D^0\bar{D}^0\pi^0$ and (b) $\pi^+\pi^- J/\psi$ invariant mass.

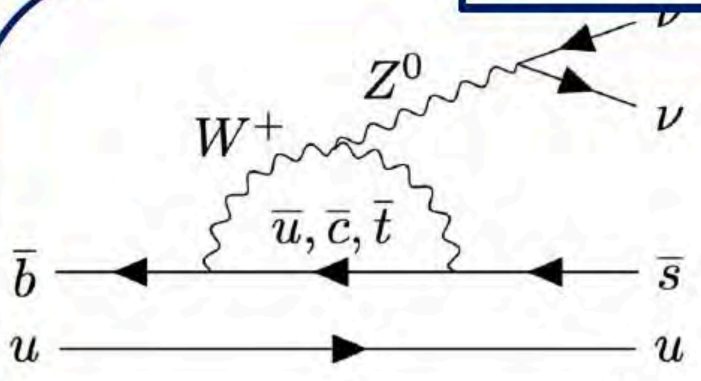
We perform a study of the $\chi_{c1}(3872)$ lineshape using the data samples of $e^+e^- \to \gamma\chi_{c1}(3872)$, $\chi_{c1}(3872) \to D^0\bar{D}^0\pi^0$ and $\pi^+\pi^- J/\psi$ collected with the BESIII detector. The effects of the coupled-channels and the off-shell D^{*0} are included in the parameterization of the lineshape. The lineshape mass parameter is obtained to be $M_X = (3871.63 \pm 0.13^{+0.06}_{-0.05})$ MeV. Two poles are found on the first and second Riemann sheets corresponding to the $D^{*0}\bar{D}^0$ branch cut. The pole location on the first sheet is much closer to the $D^{*0}\bar{D}^0$ threshold than the other, and is determined to be $7.04 \pm 0.15^{+0.07}_{-0.08}$ MeV above the $D^0\bar{D}^0\pi^0$ threshold with an imaginary part $-0.19 \pm 0.08^{+0.14}_{-0.19}$ MeV.

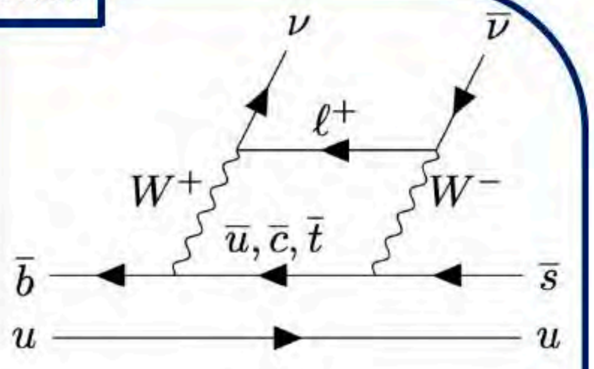
FIG. 1. Distributions of (a) $D^0\bar{D}^0\pi^0$ and (b) $\pi^+\pi^- J/\psi$ invariant mass. The black dots with error bars are the data from Ref. [19]; the blue continuous lines are the probability density functions at the best estimation; the red dotted lines are the signal shapes; the green dashed lines are the background shapes; and the black dashed lines represent the lineshape without the mass resolution considered, normalized to the signal height for comparison. (c) The $\chi_{c1}(3872)$ lineshape at the best estimation. Here, $d\mathrm{Br}/dE$ is $(g \times k_{\mathrm{eff}} + \Gamma_0)/|D(E)|^2$ in arbitrary units (a.u.). The cyan shaded band indicates the statistical uncertainty and the vertical dashed line indicates the position of the $D^{*0}\bar{D}^0$ threshold.

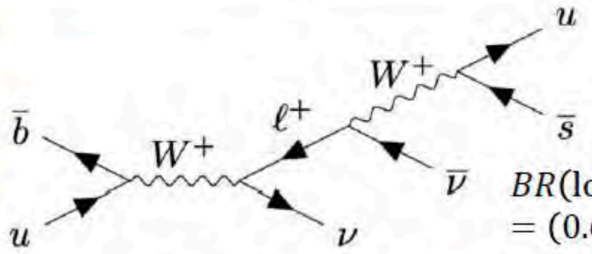
$B^+ \to K^+ \nu \bar{\nu}$ in SM / BSM

Provided by prof. M.J.Lee

Standard Model





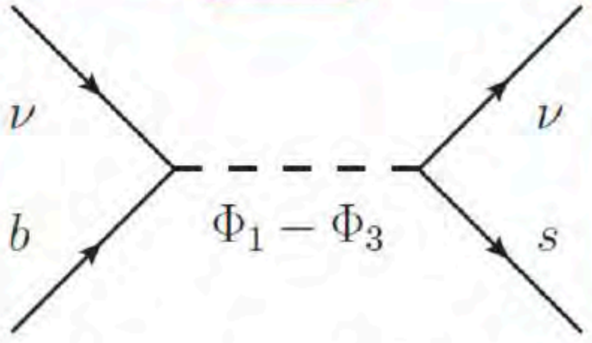


$BR(\text{long}-\text{range double}-\text{charged}) = (0.61 \pm 0.06) \times 10^{-6}$

FCNC, GIM suppressed, no hadronic uncertainties

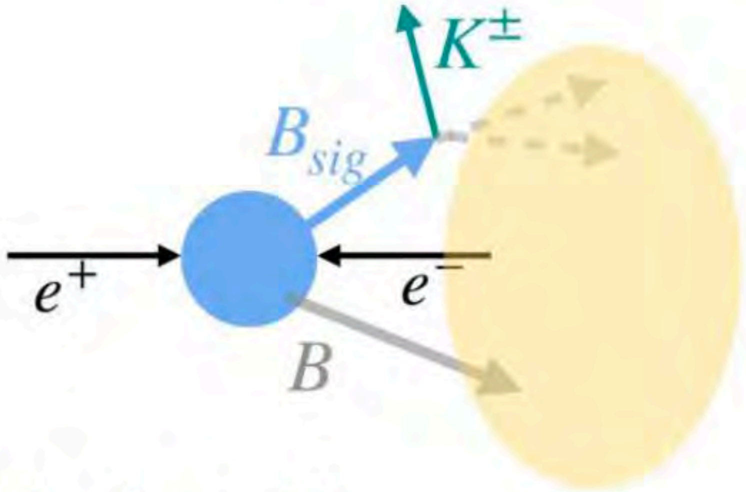
$BR(B^+ \to K^+ \nu \bar{\nu}; \text{SM}) = (5.58 \pm 0.37) \times 10^{-6}$

BSM

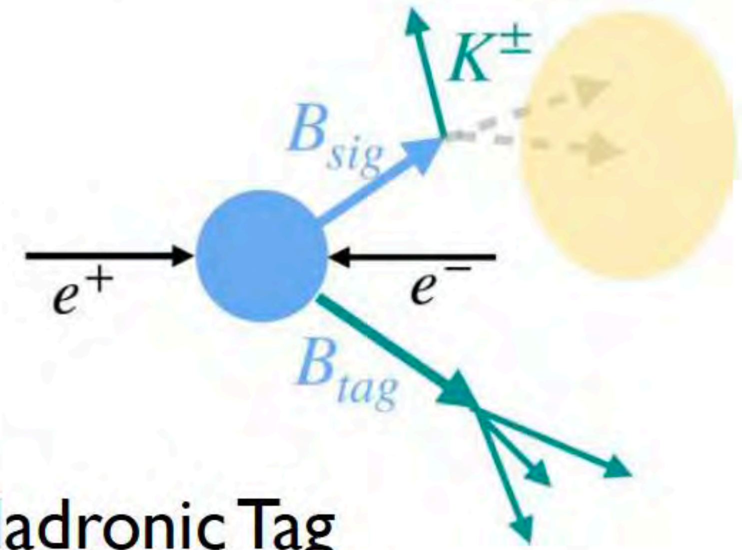


Ex. Leptoquark model or $B^+ \to K^+ X_{inv}$

Inclusive Tag Analysis / Hadronic Tag Analysis

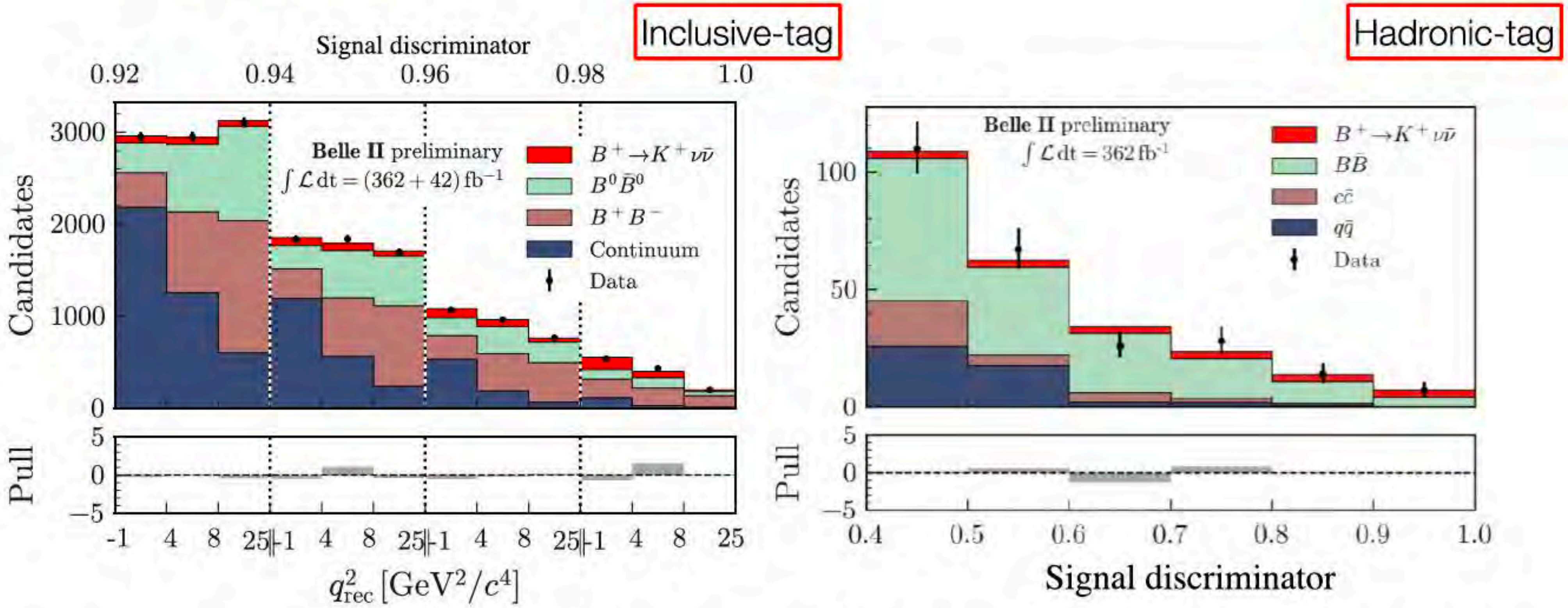


- Inclusive Tag
  - Identify objects belonging to "Rest of Event"



- Hadronic Tag
  - Reconstruct B_{tag} in one of the 35 hadronic final states

Fitting Results :



Inclusive : Fit on q^2_{rec} (mass squared of the ν pair) and BDT output / Hadronic : Fit on BDT output

First Evidence for $B^+ \to K^+ \nu\bar{\nu}$

Provided by prof. M.J.Lee

$$BR(B^+ \to K^+\nu\bar{\nu}) = [2.4 \pm 0.5\ (stat)^{+0.5}_{-0.4}(sys)] \times 10^{-5}$$

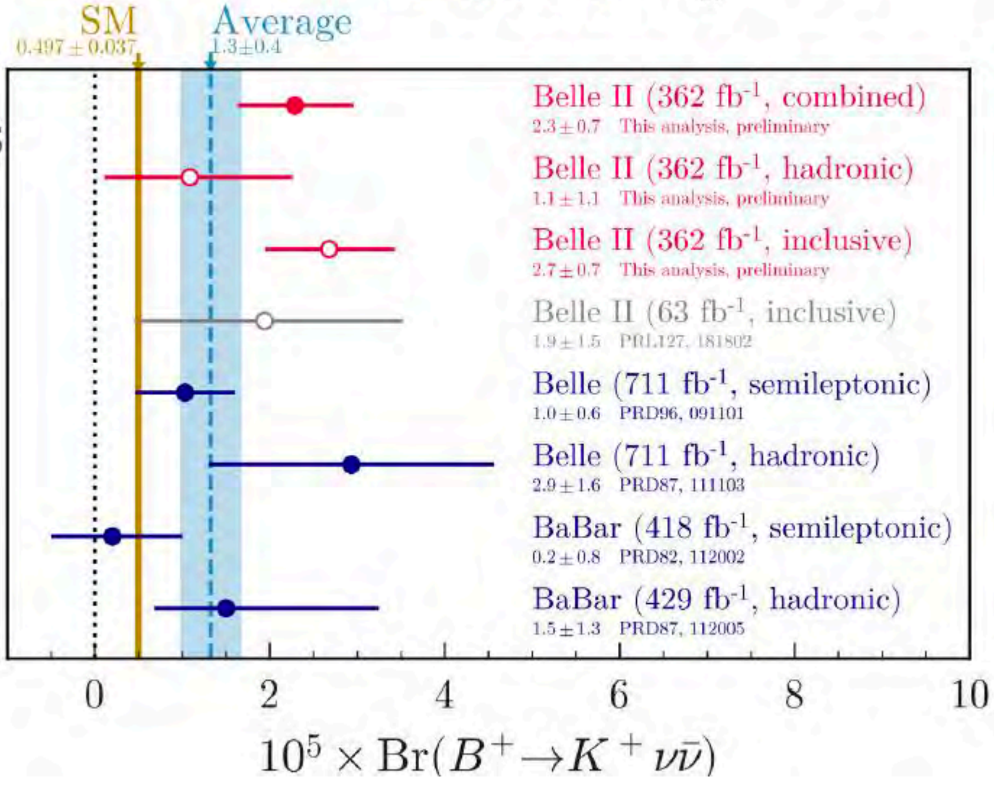
- Inclusive :

  $BR = [2.8 \pm 0.5 \pm 0.5] \times 10^{-5}$

- Hadronic :

  $BR = [1.1^{+0.9+0.8}_{-0.8-0.5}] \times 10^{-5}$

- Significance:
  - w.r.t null : 1.1σ
  - w.r.t SM : 2.8σ



Thank You

BACKUP

More and more J/ψ needed

10 billion J/ψ (4 million hyperons) →

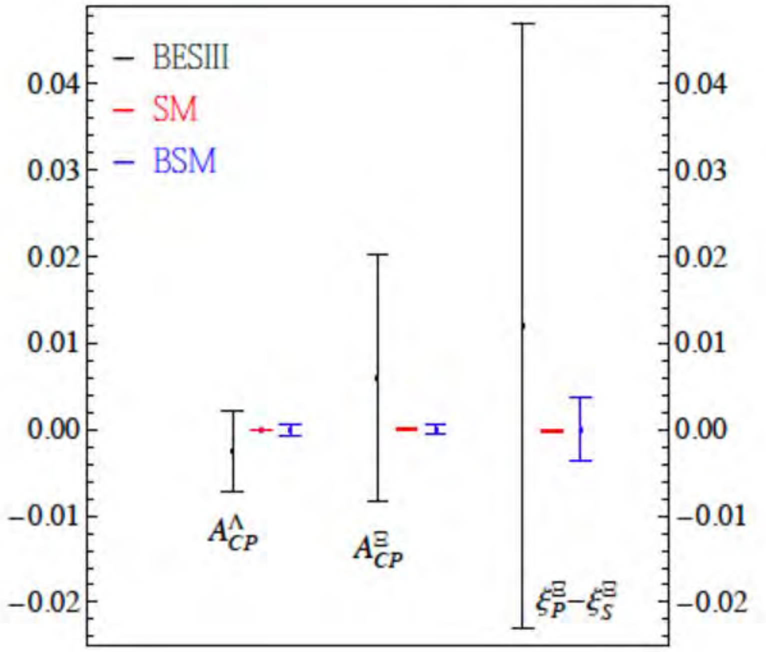
- Current technology "Topup" x 2 +
- Improved technology "monochromatic collision" x 10 +
- Someday with new facility (J/ψ factory) x 100

10^{13} J/ψ per year

- Billions of hyperons pairs produced
- Billion of hyperon pairs reconstructed
- CPV : 10^{-4} -- 10^{-5}

Challenge to the Standard Model

X.G. He et al. Sci.Bull. 67 (2022) 1840-1843:



Summary and Our Activities

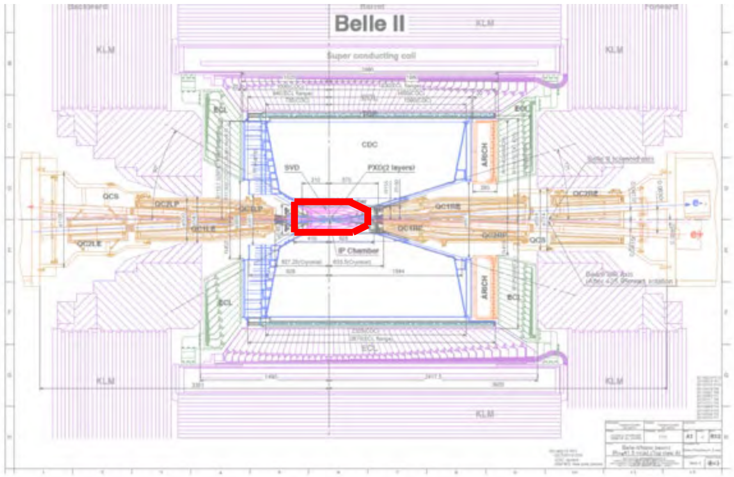
- Huge data set including 10B J/psi events is still remained with undiscovered physics.

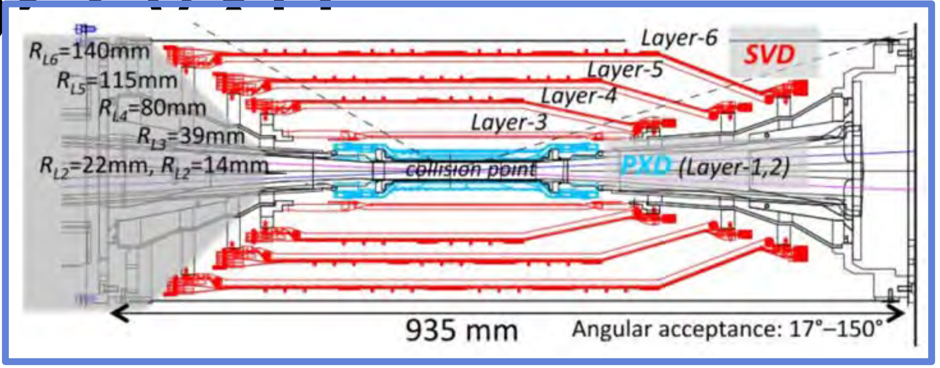
- BESIII is Extended for 10 more years, and Modest upgrades on both BEPCII and BESIII a re on-going.

- Long-term Proposal : a huge e+e- collider(CEPC), Super tau-charm factory

  at Hefei in Central China being proposed by university groups

VXD (Vertex Detector)

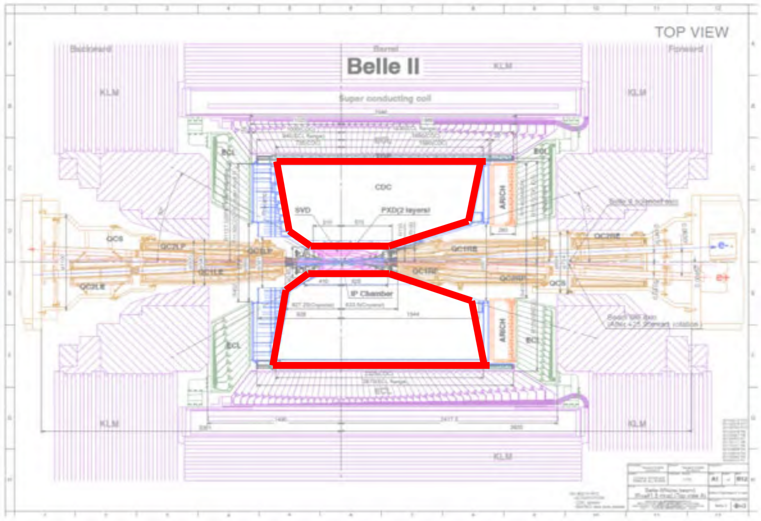


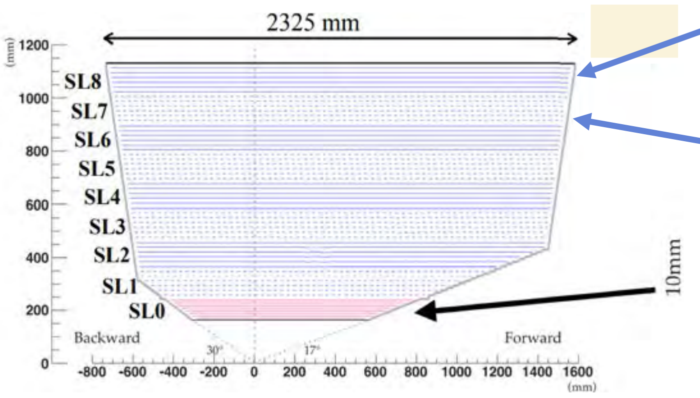


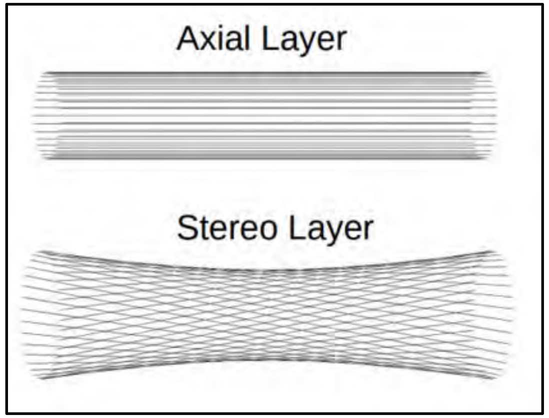
- VXD is comprised of Silicon Pixel Detector (PXD) and Silicon Vertex Detector (SVD).
- VXD provides the precise measurement of the primary and secondary vertices of short-lived particles.
- 2 layers of pixelated sensors of the DEPFET in PXD.
- 4 layers of double-sided silicon strips, DSSD in SVD.
- The main purpose of the SVD, together with the PXD and CDC is to measure the two B decay vertices for the measurement of mixing-induced CP asymmetry. In addition, the SVD measures vertex information in other decay channels involving D-meson and τ-lepton decays.

CDC (Central Drift Chamber)

ector : CDC

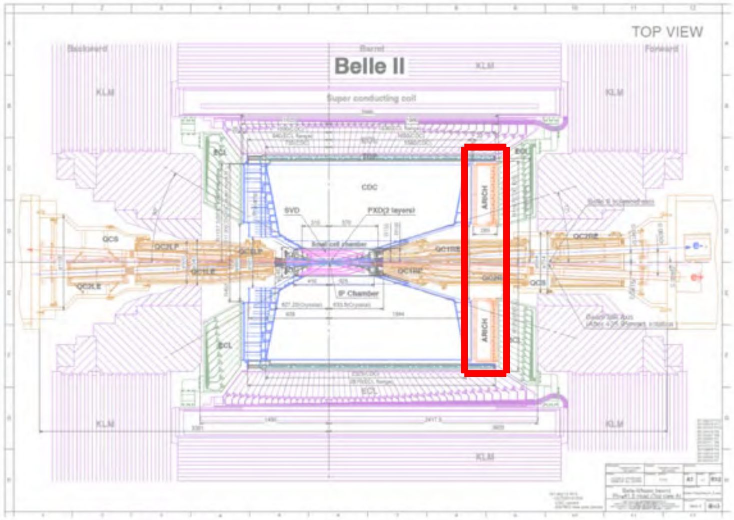


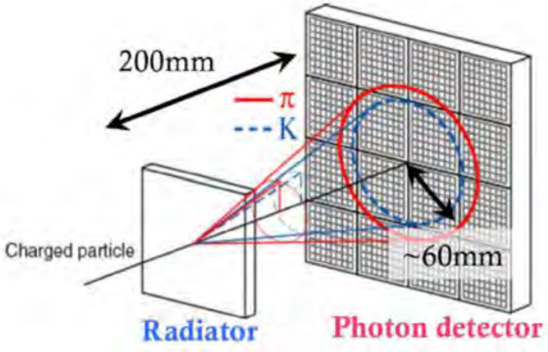


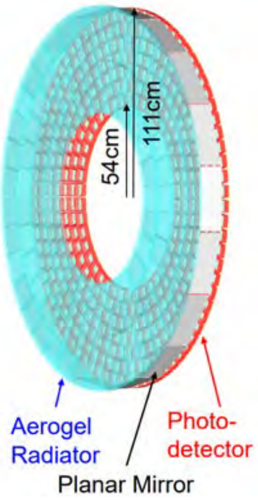


- Charged tracks reconstruction and precise momentum measurement.
- Particle identification using dE/dx information (measurements of energy loss within its gas volume).
- Charged particles ionize the gas (He:C2H6) along their flight path, giving up a small amount of kinetic energy (few keV/cm).
- 56 layers, arranged in 9 Super Layers (SL) with axial and stereo Layer.

ARICH (Aerogel Ring Imaging Cherenkov Counter)

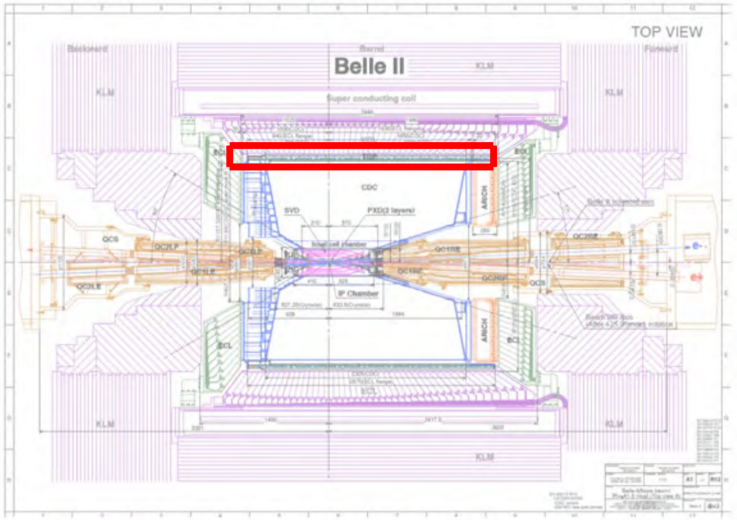


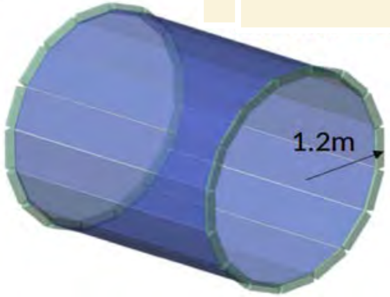


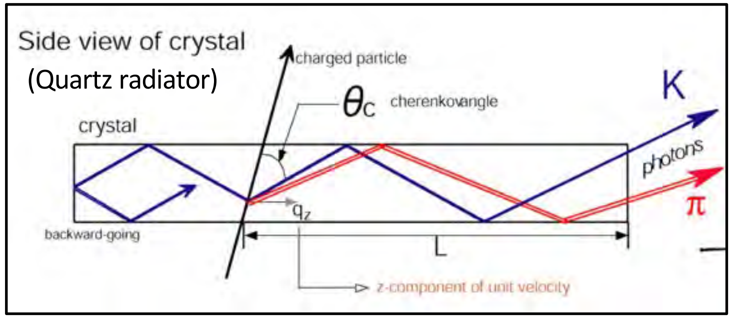


- The proximity focusing RICH detector with aerogel (ARICH), for the PID in the forward endcap.
- ARICH has been designed to separate kaons from pions over most of their momentum spectrum and to provide discrimination between pions, muons and electrons below 1 GeV/c.

TOP (Time of Propagation)

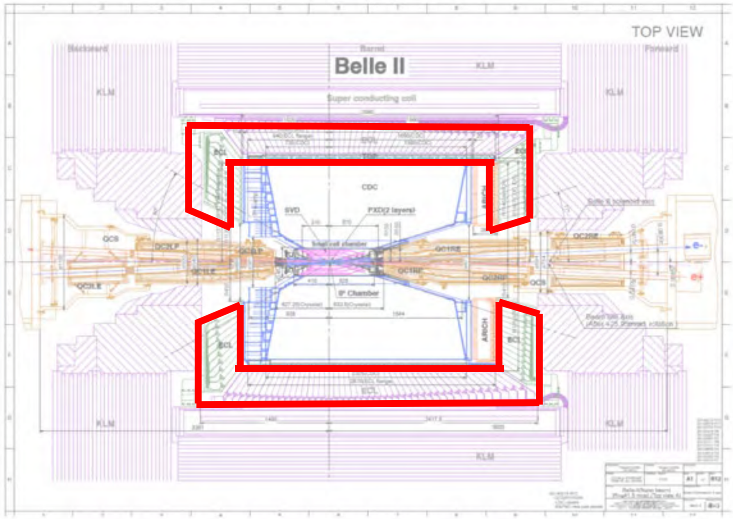


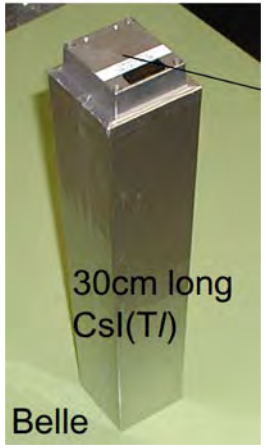




- To improve the K/π separation capability (PID in Barrel).
- The time of propagation of the Cherenkov photons internally reflected inside a quartz radiator is measure.
- 16 TOP modules are arranged in a barrel shaped array with inner radius ~ 1.2m.

ECL (Electromagnetic Calorimeter) : ECL

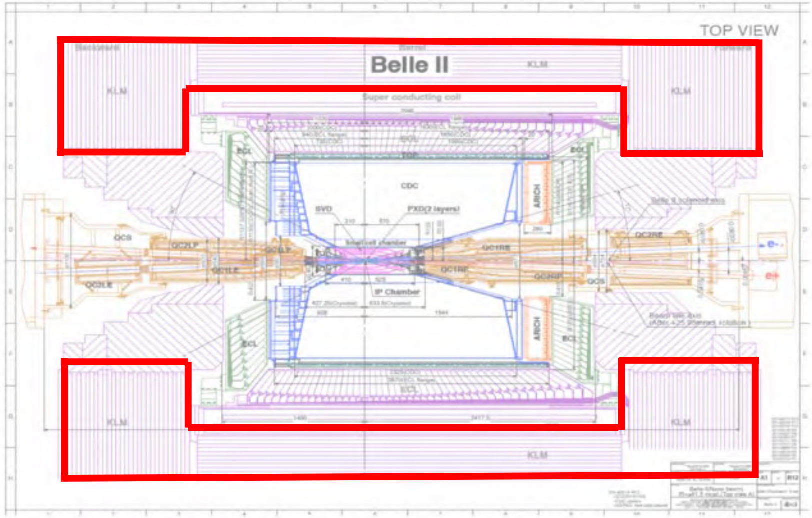


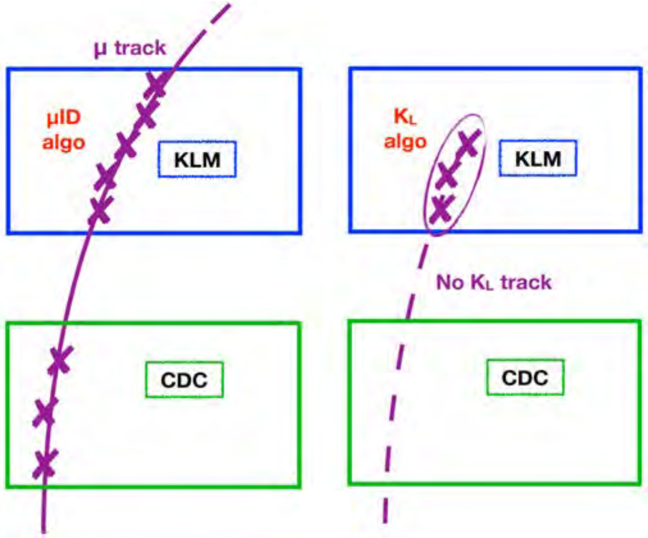


- detection of photons with high efficiency
- precise determination of the photon energy (20 MeV ~ 4 GeV) and angular coordinates (12.4°< θ <155.1°)
- electron identification
- generation of the proper signal for trigger
- on-line and off-line luminosity measurement.

tor : KLM

KLM (K-long and Muon Detector)





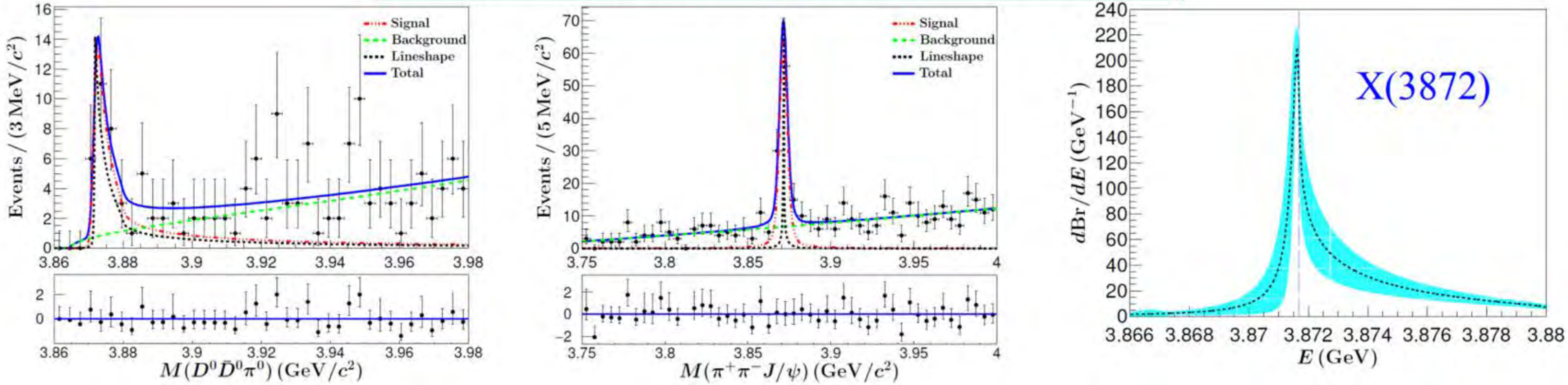
- Belle II solenoid has a large iron return yoke to catch magnetic field outside of the “inner volume”
- Muons in Belle II momentum region are almost perfect minimum ionising particles (MIPs).
- K_L^0 can shower and deposit their energy in the return yoke.

31st Lepton Photon Conference 2023

Chang-Zheng Yuan, IHEP, Beijing

BESIII *preliminary*

X(3872) line shape @ BESIII



Pole positions

Two sheets with respect to $D^{*0}\bar{D}^0$ branch cut

- Sheet I: $E - E_X - g\sqrt{-2\mu(E - E_R + i\Gamma/2)}$
- Sheet II: $E - E_X + g\sqrt{-2\mu(E - E_R + i\Gamma/2)}$

$E_{\rm I} = (7.04 \pm 0.15^{+0.07}_{-0.08}) + (-0.19 \pm 0.08^{+0.14}_{-0.19})i$ MeV

$E_{\rm II} = (0.26 \pm 5.74^{+5.14}_{-38.32}) + (-1.71 \pm 0.90^{+0.60}_{-1.96})i$ MeV

Parameters	BESIII *(prelim.)*	LHCb
g	$0.16 \pm 0.10^{+1.12}_{-0.11}$	$0.108 \pm 0.003^{+0.005}_{-0.006}$
$Re[E_I]$ [MeV]	$7.04 \pm 0.15^{+0.07}_{-0.08}$	7.10
$Im[E_I]$ [MeV]	$-0.19 \pm 0.08^{+0.14}_{-0.19}$	-0.13
$\Gamma(\pi^+\pi^- J/\psi)/\Gamma(D^0\bar{D}^{*0})$	$0.05 \pm 0.01^{+0.01}_{-0.02}$	0.11 ± 0.03
FWHM (MeV)	$0.44^{+0.13}_{-0.35}{}^{+0.38}_{-0.25}$	$0.22^{+0.06}_{-0.08}{}^{+0.25}_{-0.17}$
Z	0.18	0.15

$\dfrac{|K_2| - |K_1|}{|K_1| + |K_2|}$

Weinberg's compositeness: $Z = 1$: pure elementary state; $Z = 0$: pure bound (composite) state.

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Z is the probability of finding a compact component in the wave function.

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$B \to X(3872)(\to D^0 \bar{D}^{*0})K$

2 decay modes for $D^{*0} \to D^0\gamma$ and $D^0\pi^0$

6 decay modes for D^0:

$D^0 \to K^-\pi^+,\quad K^-\pi^+\pi^0,\quad K^-\pi^+\pi^-\pi^+,$
$K_S^0\pi^+\pi^-,\quad K_S^0\pi^+\pi^-\pi^0,\quad K^+K^-$

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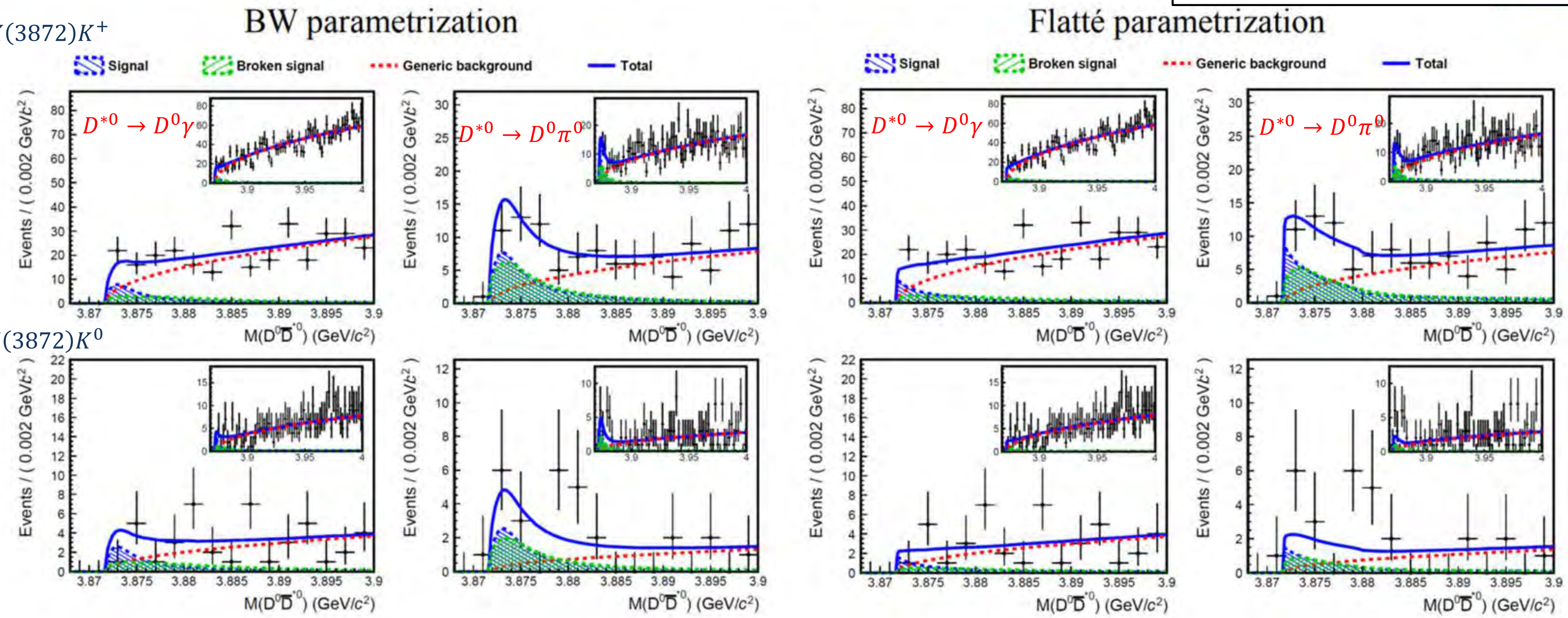
X(3872) line shape @ Belle

$B^+ \to X(3872)K^+$

$B^0 \to X(3872)K^0$



$$m_{\rm BW} = 3873.71^{+0.56}_{-0.50}({\rm stat}) \pm 0.13({\rm syst})\ {\rm MeV}/c^2,$$
$$\Gamma_{\rm BW} = 5.2^{+2.2}_{-1.5}({\rm stat}) \pm 0.4({\rm syst})\ {\rm MeV}.$$

- Fit $D^0\bar{D}^{*0}$ mode only, not a coupled-channel analysis
- BW is favored over Flatté parametrization
- coupled-channel analysis highly recommended

g >0.075 at 90% credibility