Report on NPC Activities

- Introduction of NPC and Physics Subjects
- Individual Analysis Status & Takizawa-san's Comment
- Contributions other than Analyses

Norihito Muramatsu

New Hadron Workshop, 28 Feb, 2011 @ RIKEN

NPC = Nuclear Physics Consortium

18 people from hadron physics community have made the consortium with interests to analyze Belle data from Mar 2009.

- RCNP, Osaka Univ. : ***T. Nakano, S. Ajimura, T. Hotta, Y. Morino, N. Muramatsu***
- Tokyo Institute of Technology : ***M. Uchida, T. Shibata, N. Kobayashi***
- Kyoto Univ. : ***M. Niiyama,*** *H. Fujioka*
- Tohoku Univ. : ***H. Kanda,*** *K. Miwa*
- Univ. of Miyazaki : ***T. Matsuda, T. Motoda***
- Gifu Univ. : ***K. Nakazawa, M. Sumihama***
- Yamagata Univ. : ***Y. Miyachi***
- Showa Pharmaceutical Univ. : ***M. Takizawa***

Bold = NPC & NPC-II

♣ Participating from LEPS, JPARC, COMPASS, HERMES, … , and also from a theory side.

♣ Most of persons belong to NPC-II for the Belle-II experiment.

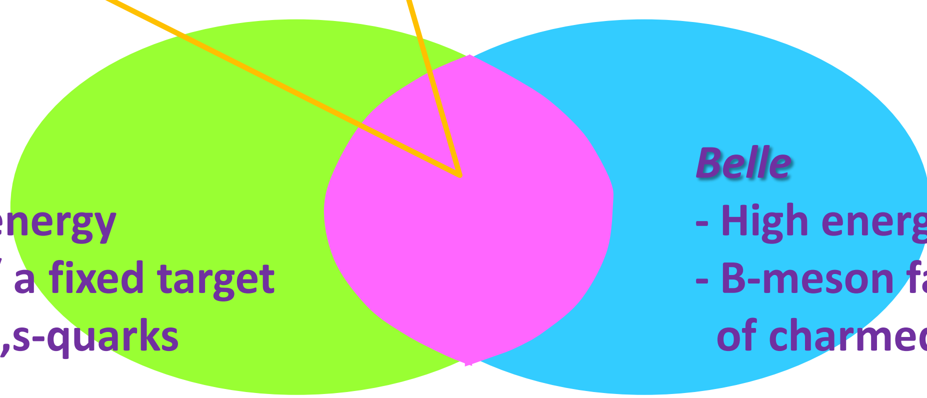
What's NPC ?

- Now NPC is one of the groups in the Belle Collaboration.
- Actually the members belong to B01, D01, E01, or not.
- However, our interests are widely overlapped with A01.

$\Rightarrow$ Closely correlated works :

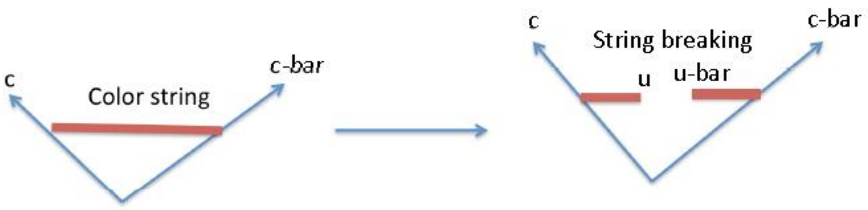
New hadron meeting by Belle-A01 + NPC

Common interests
- Exotic hadron structure (penta- & tetra-quark, molecule, …)
- Nature of scalar & axial vector mesons (glueball, mixing, …)
- Hadron-hadron correlation (bound-state, confinement, …)
- Hadron fragmentation (color string, gluon exchange, …)



Why Belle data is interesting for us?

- High statistics (Exotic & low production rate particles, high precision measurements of hadron properties)
- Large acceptance detector w/ excellent momentum resolution and PID ability

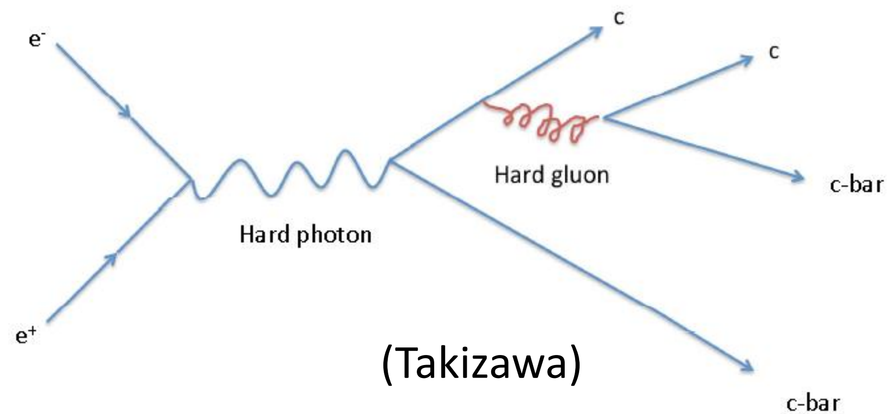


- High energy

(1) heavy quark hadrons

Produced by Υ productions,
b→c decays, and
hard gluon exchanges.

Kinetic energy term is small.



(Takizawa)

(2) Also rich production of light quark hadrons

Produced by heavy hadron decays [ΔM in b→c decays (Matsuda)]
and color string breaking in hadronization.

Dynamical structure inside hadron becomes more important.

Close to interests of lower energy experiments.

Physics Subjects

Understanding hadron structures by investigating

exotic hadrons, controversial hadrons, hadron-hadron interactions, fragmentations, …

- Light quark hadrons
  - scalar & axial vector mesons : Matsuda, Motoda
  - statistical treatment of production rates (also related to exotic hadron production rate) : Uchida
  - meson-meson interaction : Niiyama
- Fragmentation functions for light quark hadrons
  - Interference FF : Kobayashi
- Heavy quark hadrons
  - X(3872) : Muramatsu

All analyses are under way & individual status is shown from now.

Study of Light quark mesons from B decays

T. Matsuda,T. Motoda (Univ. of Miyazaki) with Prof. J. MacNaughton

Motivation:

- Nature of scalar and axial vector mesons are still discussed.

  σ, κ, $f_0(980)$, $a_0(980)$, a_1, K_1, ...

  $\Rightarrow$ molecule states, tetraquarks, glueballs or others?

  $\Rightarrow$ related to chiral symmetric structures of light quarks?

Strategy and Method:

- Construct and carry out **Partial Wave Analyses**.
- Study properties of axial vector, scalar mesons: mass, width, mass line shape, branching ratio, mixing angles, and even existence.
- Currently two reactions are being analyzed.

  1. $B^0 \rightarrow D^{*+/-}$ $\mathbf{a_1^{-/+}}$
  2. $B^+ \rightarrow J/\psi\ K_1(1270)$; $\mathbf{K_1(1270) \rightarrow \omega K}$

1. $B^0 \rightarrow D^{*+/-} a_1^{-/+}$

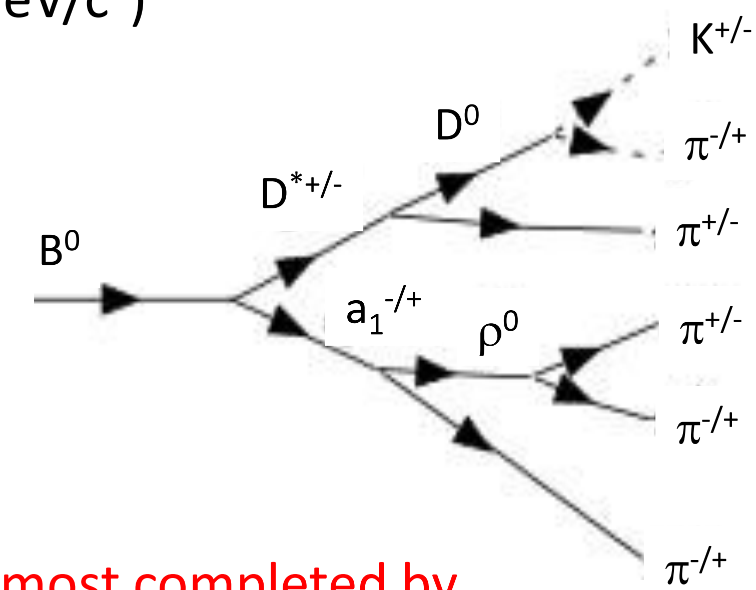
- **Mass & width of a_1** are not defined well. (PDG: M=1230±40 MeV, Γ=250~600 MeV)
- S. Leupold, POS (CD09) 051 suggests **a possibility of ρ-π molecule state**.
- Old scattering experiments : Various states are overlapped each other.

$\Rightarrow$ **Decay reaction: Initial quantum numbers are well defined**.

So far a_1 has been studied by τ decays, but **a_1 width cannot be extracted correctly**. (M_τ=1.777 GeV/c^2)

Construction of the PWA formalism

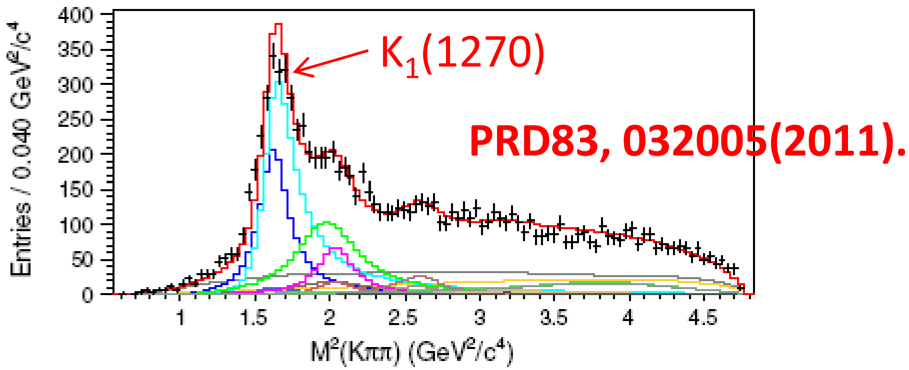
$B^0 \rightarrow D^{*+/-} + a_1^{-/+}$	$(0^- \rightarrow 1^- + 1^+)$
$a_1^{-/+} \rightarrow \rho^0 + \pi^{-/+}$	$(1^+ \rightarrow 1^- + 0^-)$
$D^{*+/-} \rightarrow D^0 + \pi^{+/-}$	$(1^- \rightarrow 0^- + 0^-)$
$\rho^0 \rightarrow \pi^+ + \pi^-$	$(1^- \rightarrow 0^- + 0^-)$

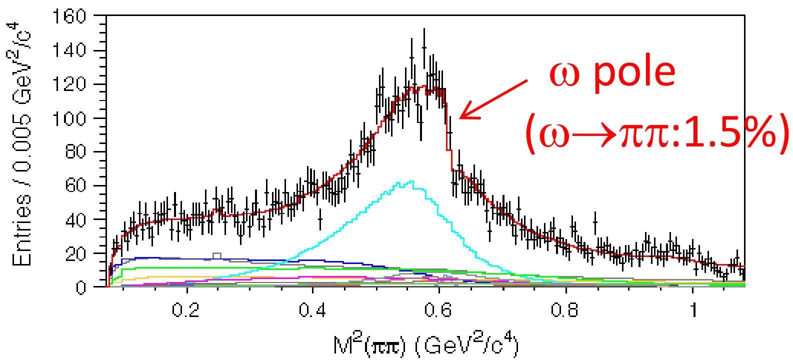


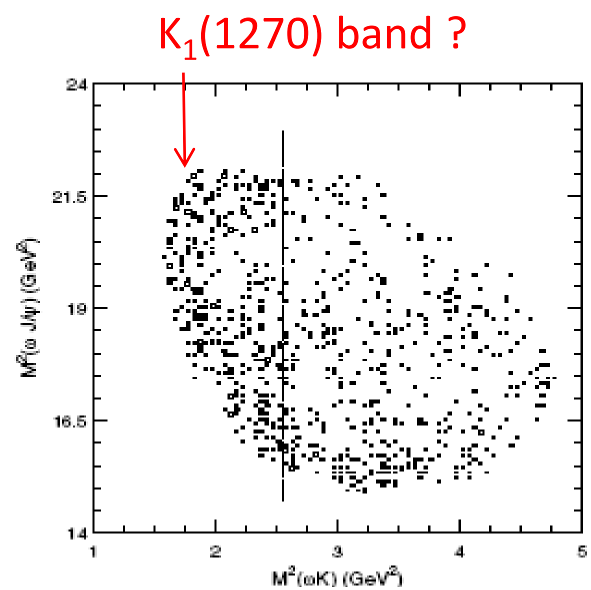
The skim code of this reaction is almost completed by Prof. J. MacNaughton. PWA programs are being produced.

2. $B^+ \to J/\psi\ K_1(1270)$; $K_1(1270) \to K\omega \to K\pi\pi\pi$

- Recently Belle renewed the mass and width of $K_1(1270)$ in **$B \to J/\psi K\pi\pi$ channel**. This must be also checked by $K\pi\pi\pi$ mode.
- $BR(K_1 \to K\omega)$ may be larger than PDG (11%) because of strong $\rho\omega$ interference.
- Skim programs for $B^+ \to J/\psi K^+\omega$ are under construction, and very preliminary skim data is being obtained.







PRL94, 182002(2005):
$Y(3940)$ production in $B^+ \to J/\psi K^+\omega$ reaction

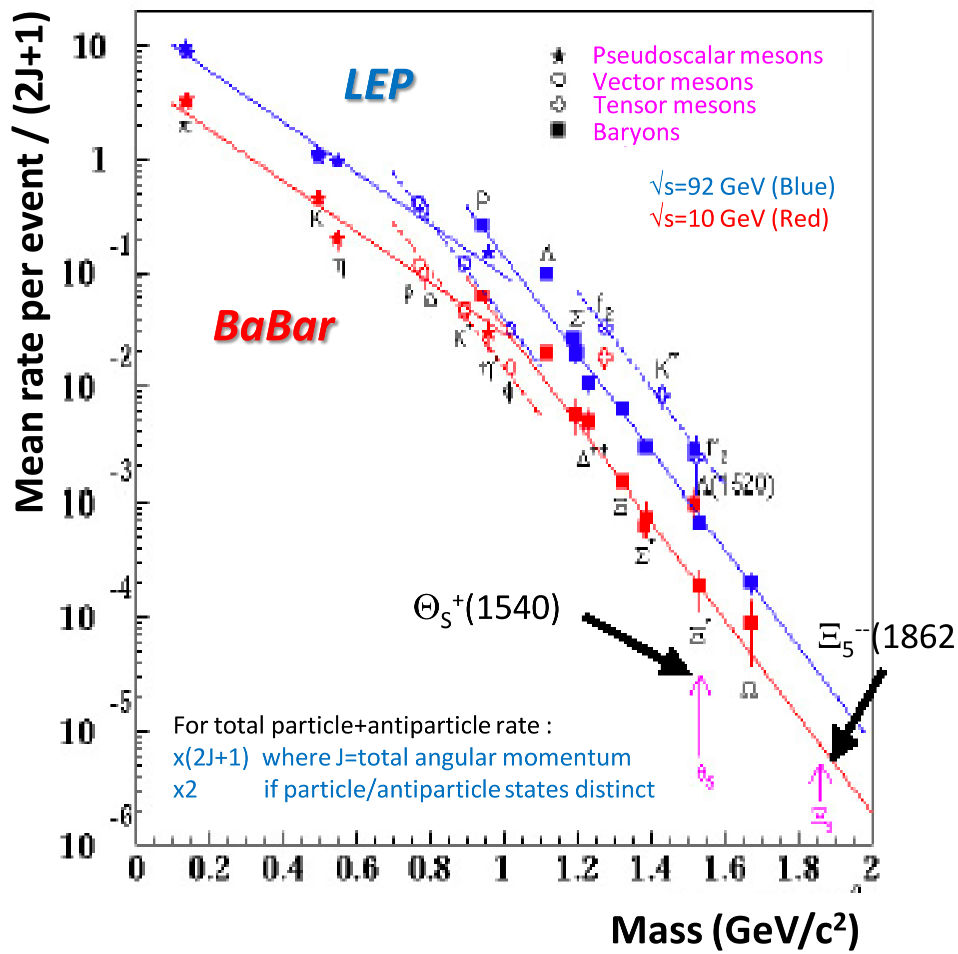
Production Rate of Light Hadrons (M. Uchida)

- Production rate of light hadrons ($q\bar{q}$/qqq) tend to be proportional to their masses. (LEP, BaBar)
- Statistical formalism
  [Y.-J. Pei, hep-ph/9610329]

$$< N >= C \cdot \frac{2J+1}{C_B} \cdot (\gamma_s)^{N_s} \cdot e^{-\frac{E_{bind}}{T}}$$

- Discrepancy from the global trend indicates the different production mechanism and/or internal structure from the 2 or 3 constituent quarks.
  $\Rightarrow$ *Λ(1405) and some exotic candidate hadrons* will be examined.

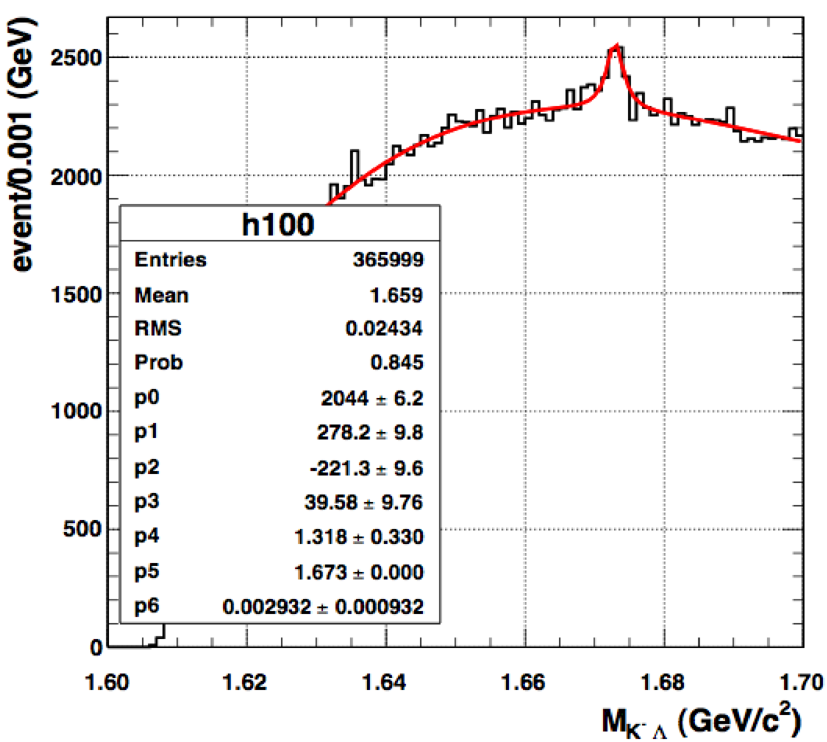
Hadron Production in e^+e^- annihilation



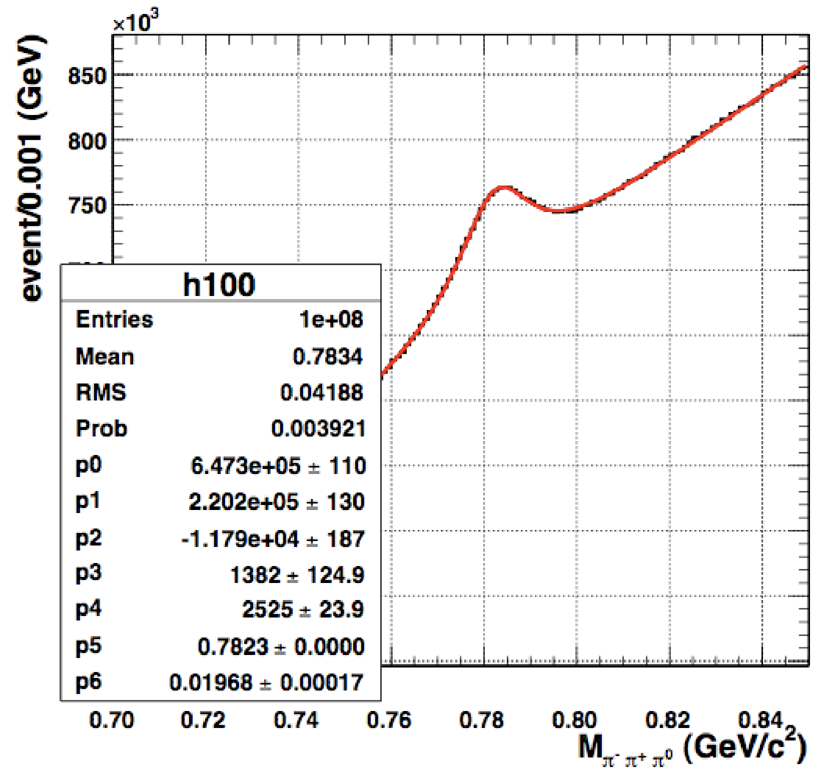
Invariant mass distributions

(36 fb^{-1} / 1000 fb^{-1})

$\Omega^- \to \Lambda K^-$: 3000 events



$\omega \to \pi^+\pi^-\pi^0$: 2.3x10^6 events



Fitting function : Breit-Wigner + Chevyshev 3rd pol.

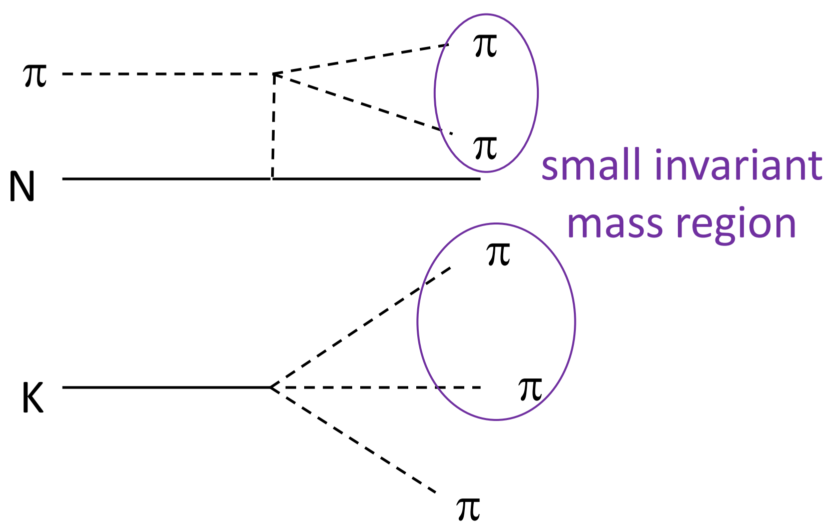
List of Hadrons under considerations

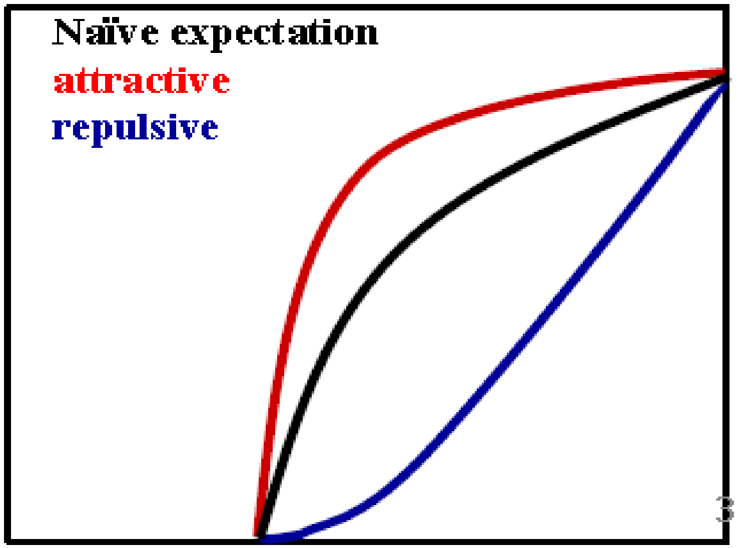
Mesons	Decay	Status
π		Cuts optimized
η	$\gamma\gamma$	Cuts optimized
η'	$\pi^+\pi^-\eta$	Cuts optimized
K		Cuts optimized
$K^*(892)$	$K\pi$	Cuts optimized
ρ	$\pi\pi$	Cuts optimized
ω	$\pi^+\pi^-\pi^0$	Cuts optimized
ϕ	K^+K^-	Cuts optimized
a^0	$\pi^0\eta$	Future plan
f^0	$\pi\pi$	Future plan

Baryons	Decay	Status
P		Cuts optimized
Δ	$N\pi$	In progress
Λ	$p\pi$	Cuts optimized
Σ	$\Lambda\gamma$	Cuts optimized
$\Sigma(1385)$	$\Lambda\pi$	In progress
$\Lambda(1405)$	$\Sigma\pi$	In progress
$\Lambda(1520)$	pK^-	Cuts optimized
Ξ	$\Lambda\pi$	Cuts optimized
Ω	ΛK^-	Cuts optimized
N(1535)	$p\eta$	Future plan

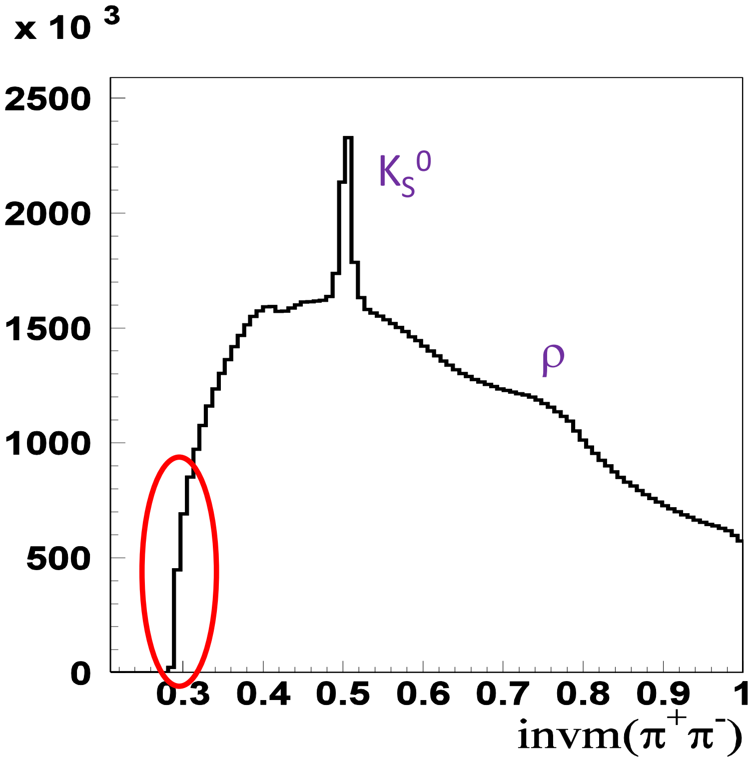
Measurements of Scattering Lengths (M. Niiyama)

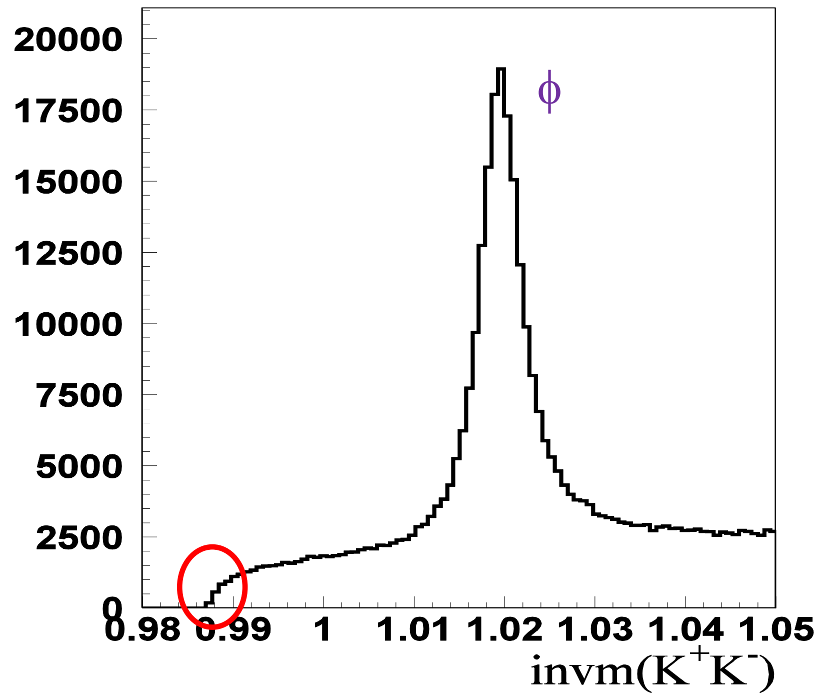
- Meson-meson scattering length is an important fundamental variable in hadron physics. While **ππ channel** has been studied in detail, **KK & Kπ channels** are not studied well.
- Analysis strategy : Using continuum data, the meson-meson invariant mass distributions will be compared with phase space in the kinematical region of relative momentum ~ 0.
- Belle data is suitable for this analysis because of (1) high statistics, (2) variations of meson pairs, and (3) good momentum resolutions [no target material, w/ vertex detector].





$\pi^+\pi^-$ and K^+K^- invariant mass spectrum





To do:
- Acceptance corrections.
- Understand compositions of invariant mass distributions.
- How to extract scattering lengths is under discussions.
- Systematic study for various meson-meson interactions.

Interference Fragmentation Function (N. Kobayashi)

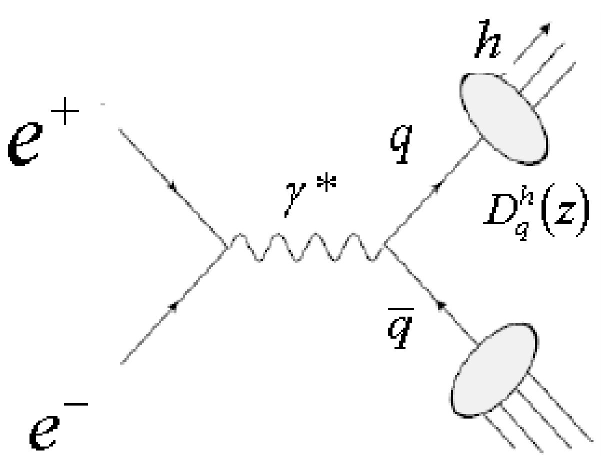
- Fragmentation Function for light quark hadrons

  $\Rightarrow$ hard scattering process + ***non-perturbative hadronization***

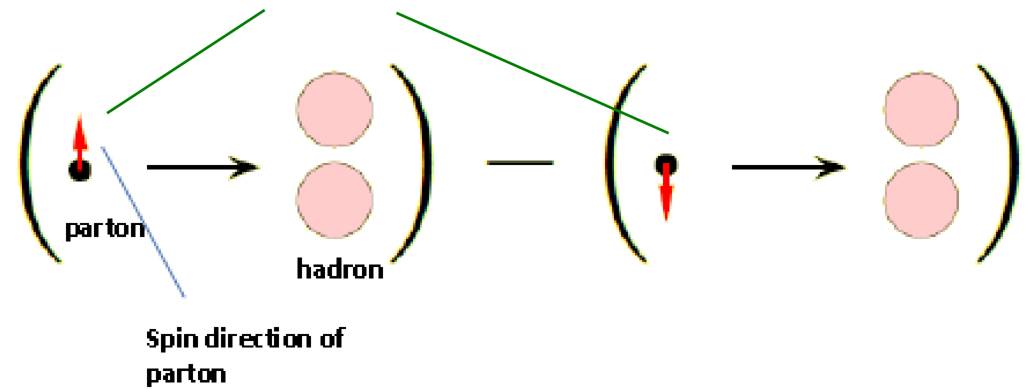
  $D_q^h(z)$: Probabilities for a quark (q) to fragment into hadron (h) depending on fractional momentum ($z=P_h/|P_q|$).

  ♣ Momentum conservation : $\sum_h \int_0^1 dz\, zD_q^h(z)=1$

- IFF ***$H_q^{\sphericalangle}(z,M_h^2)$*** : Fragmentation of a quark (q) with transverse spin into a pair of unpolarized hadrons.
- Model predictions by Jaffe et al. [PRL 80] & Radici et al. [PRD 65] for $\pi\pi$ (will be published), **KK, & Kπ** (will be analyzed by N.K.)



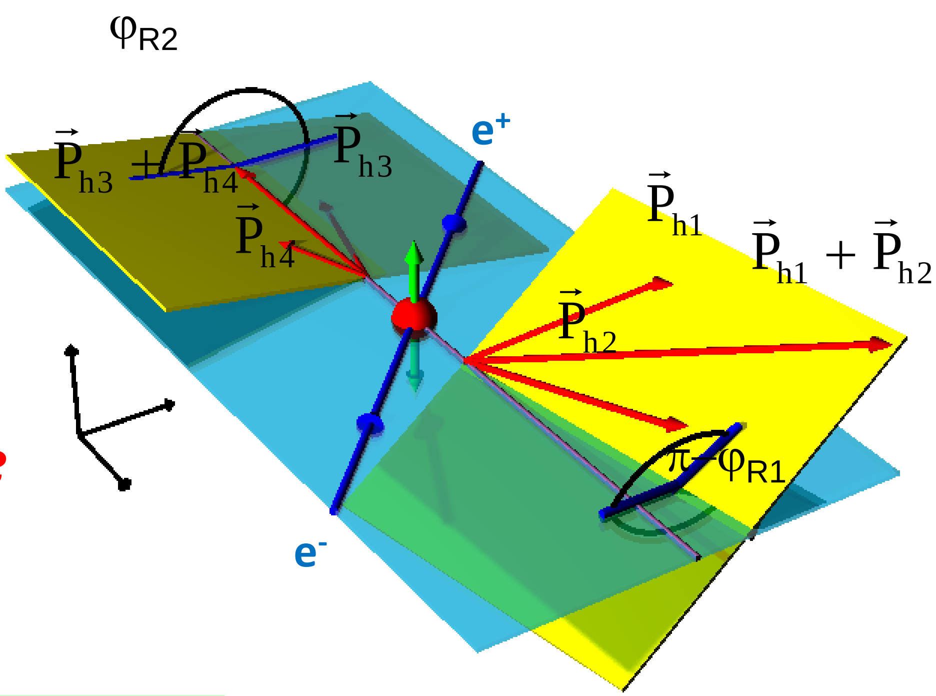
Transverse spins of back-to-back partons must be correlated.



IFF Physics framework

- Measure the relative angle ($\varphi_{1R}+\varphi_{2R}$) of two planes which individually include a hadron pair from either jet.
- Obtain an asymmetric distribution in terms of $\varphi_{1R}+\varphi_{2R}$ to ***extract modulation amplitude*** due to transverse spins of quark and anti-quark.

$e^+e^- \rightarrow (h_1h_2)_{jet1}(h_3h_4)_{jet2}X$



$$A \propto H_1^{\angle}(z_1, m_1)\overline{H}_1^{\angle}(z_2, m_2)\cos(\varphi_1 + \varphi_2)$$

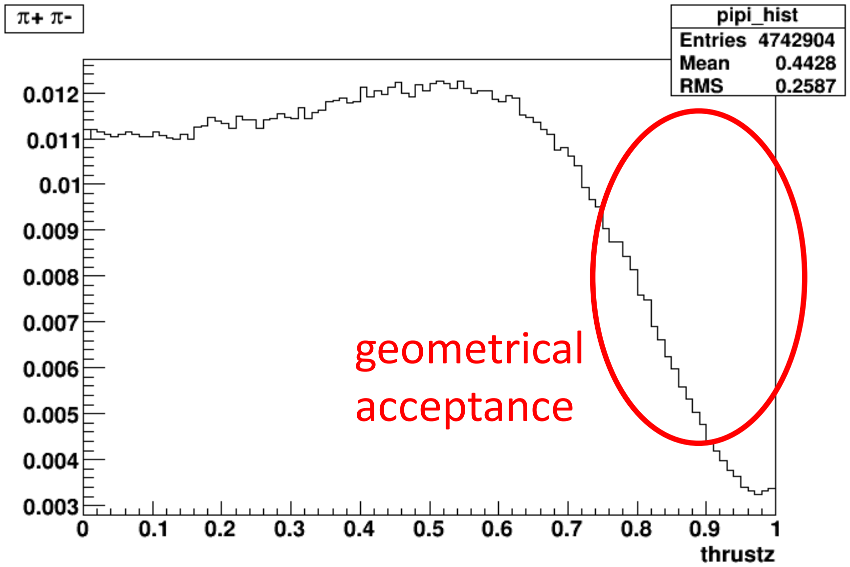
Now checking consistencies of analysis procedures and results using $\pi\pi$ mode.

Thrust :

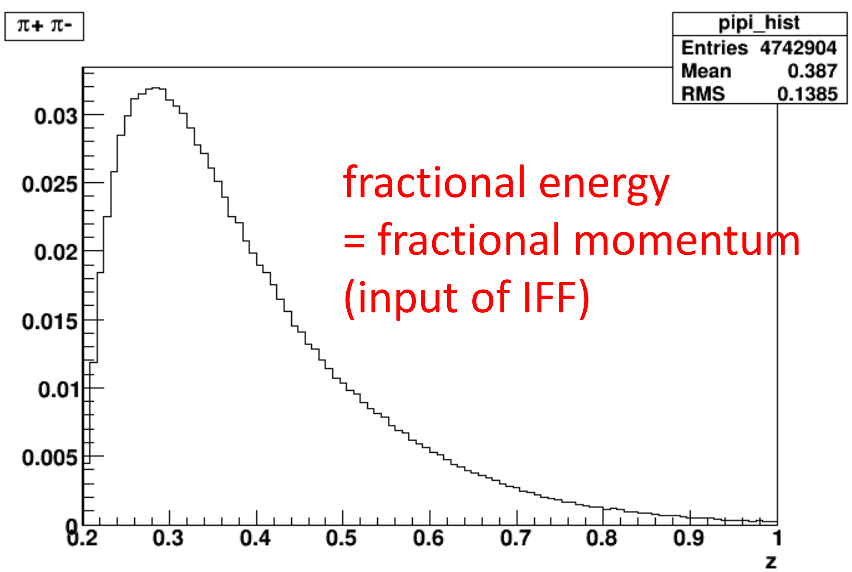
$$T^{max} = \frac{\sum_h |\mathbf{P}_\mathbf{h}^{\mathrm{CMS}} \cdot \hat{\mathbf{n}}|}{\sum_h |P_h^{\mathrm{CMS}}|}$$

Fractional energy :

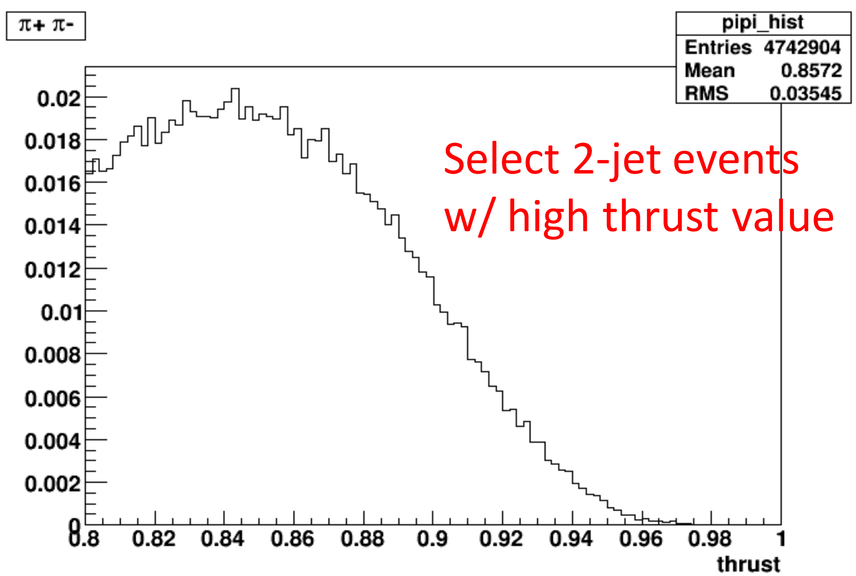
$$z = \frac{2E_h}{\sqrt{s}}, \quad \sqrt{s} = 10.52\, GeV$$



Z-component of Thrust axis



Fractional energy



Thrust

X(3872)$\rightarrow$J/$\psi\pi^0\pi^0$ in B decays (N. Muramatsu)

Discussion of C-parity

C=+1 : Γ(X(3872)$\rightarrow$J/$\psi\pi^0\pi^0$)/Γ(X(3872)$\rightarrow$J/$\psi\pi^+\pi^+$)=0 [I=1 through J/$\psi\rho$]

C=–1 : 1/2 [I=0, ex. ψ']

If X(3872) is 1^{++} DD^* molecule, this decay mode cannot be seen.

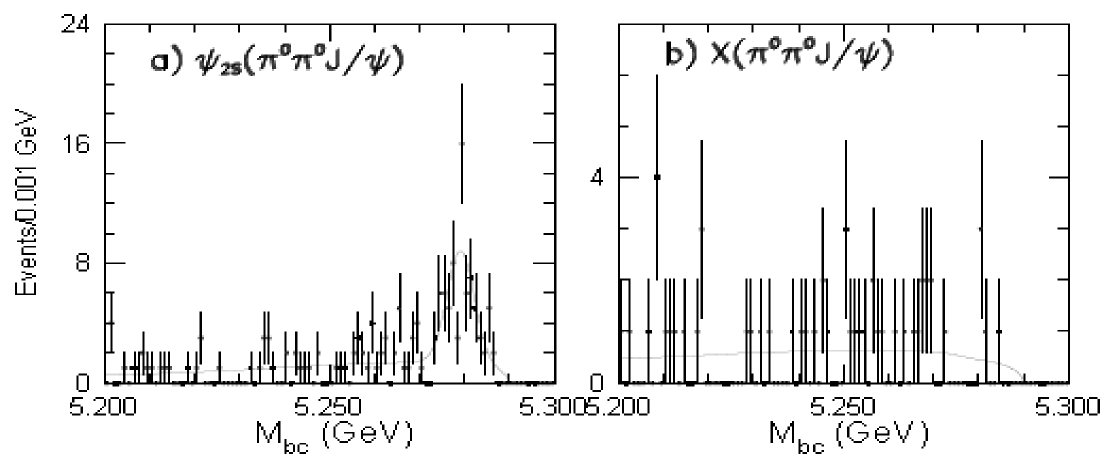
Υ(4S)$\rightarrow B^+B^-$ [51.6%] ; $B^{+-}\rightarrow K^{+-}$X(3872) ; X(3872)$\rightarrow$J/$\psi\pi^0\pi^0$

Υ(4S)$\rightarrow B^0\overline{B^0}$ [48.4%] ; $B^0\rightarrow K^0$ X(3872) ; $K_S\rightarrow\pi^+\pi^-$ [50% x 69.20%] ; X(3872)$\rightarrow$J/$\psi\pi^0\pi^0$

Previous measurement at Belle : hep-ex0408116 using 253 fb^{-1}

$$\frac{\Gamma(X\to\pi^0\pi^0 J/\psi)}{\Gamma(X\to\pi^+\pi^- J/\psi)} < 1.3\frac{\Gamma(\psi'\to\pi^0\pi^0 J/\psi)}{\Gamma(\psi'\to\pi^+\pi^- J/\psi)}.$$

vs. Currently increased up to 711 fb^{-1}



Before examining X(3872),

$\psi' \to J/\psi \pi^0 \pi^0$ [16.84%]

must be checked as

a control sample.

$\Rightarrow$ Now optimizing

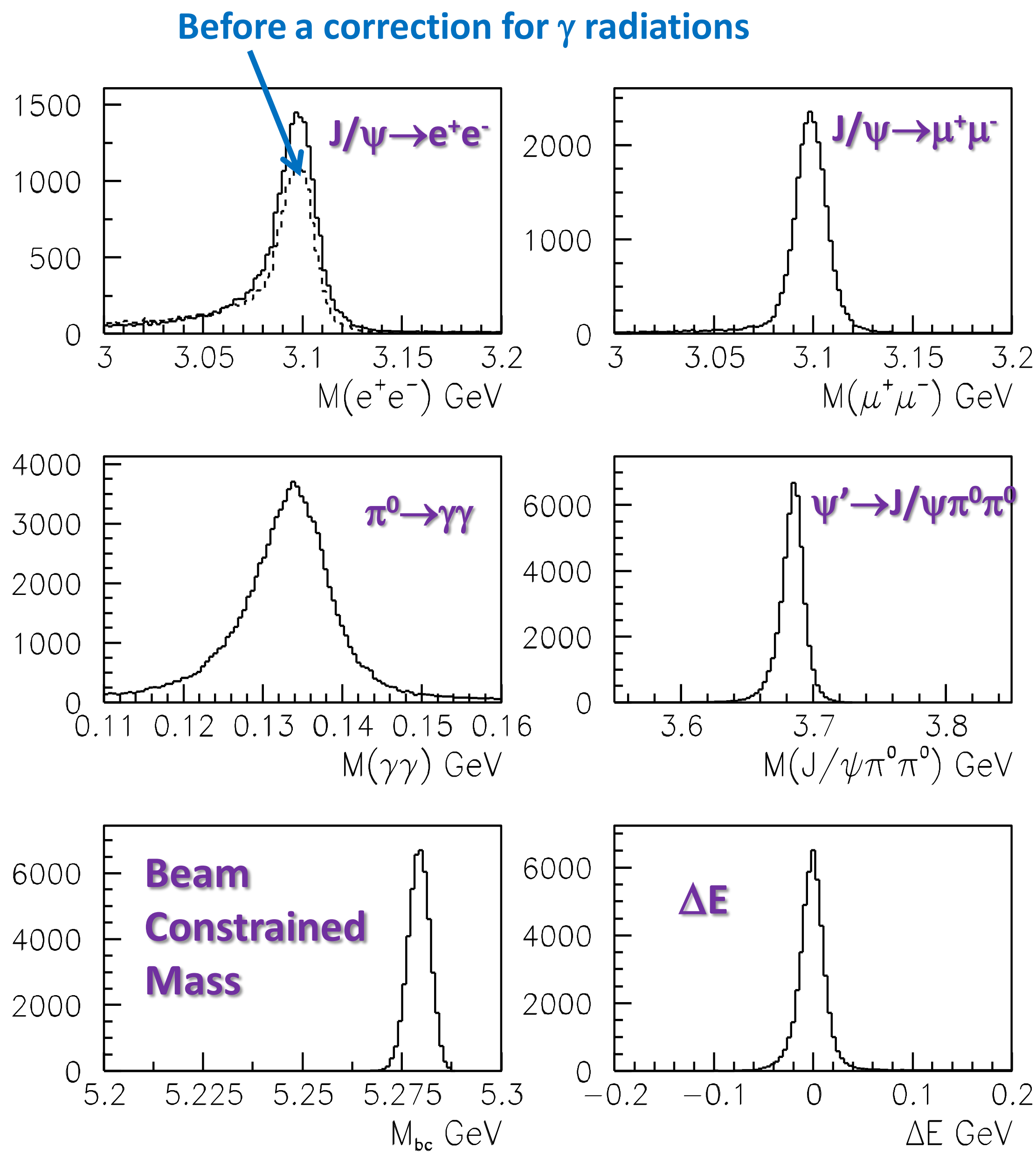
selection criteria.

Here are some snap shots

of event reconstruction

w/ ψ'-signal MC (only

$B^+ \to K^+ \psi'$) as an example.



Comments from M. Takizawa

Why so many exotic charm hadrons?

- Bound state of hadrons : Kinetic energy vs. Potential energy

  Heavier Hadron ⇒ Smaller kinetic term

- Deuteron (proton, neutron)

  Strength of the interaction between hadrons is just making the bound state of the hadrons of 1 GeV and/or above.

- Charm quark hadrons : Mass is bigger than 1 GeV

  ⇒ High possibility of forming the bound states

  ex. Many ***X, Y, Z states*** have been found.

  H_c dibaryon : Flavor singlet state w/uuddsc

  Repulsive interaction becomes ~1/2.

  T_{cc} : $ud\bar{c}\bar{c}$ exotic hadron w/ 0^+ or 1^+

- Bottom quark hadrons ⇒ More probable

♣ ***Many exotic hadrons with charm and bottom flavors.***

Contributions other than analyses

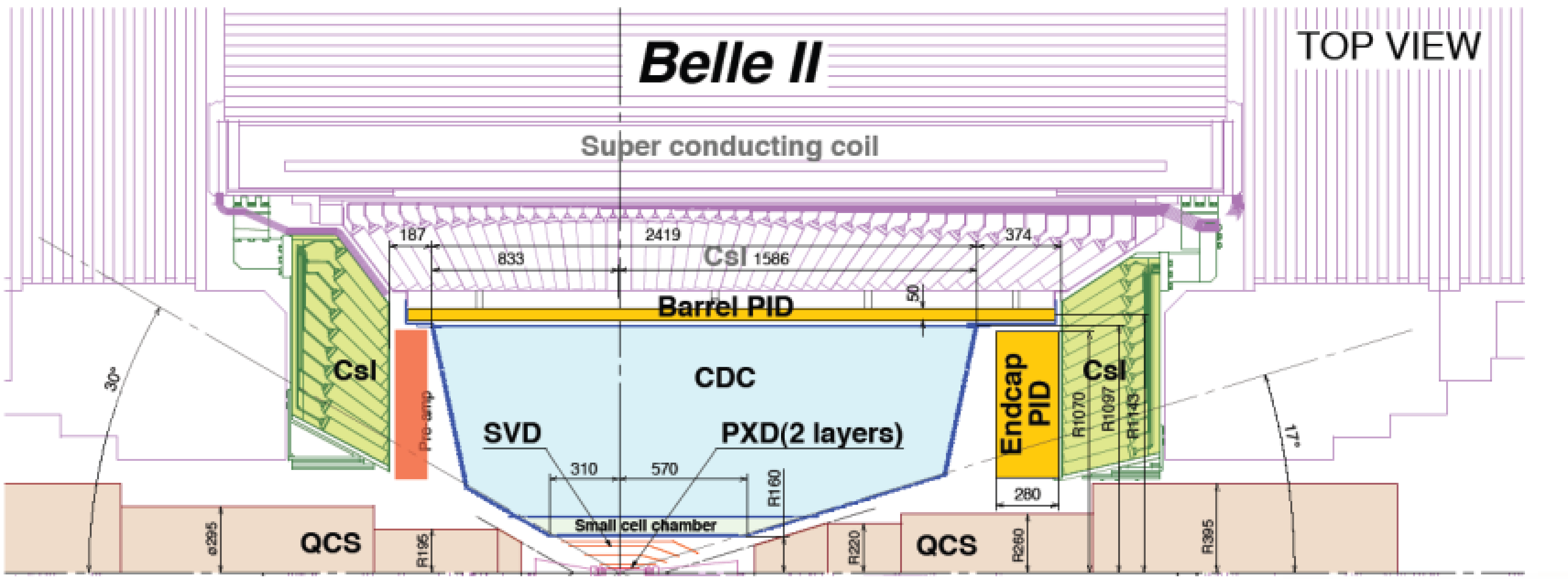
- *18 shifts in 2009* & *6 shifts in 2010*
- *Efficiency, fake rate & systematic error tables for Belle-PID*
  with great helps of Nishida-san
  (KID: Niiyama, eid/muid : Uchida, Sumihama, Muramatsu)
- *Internal referees of Belle papers* (Muramatsu, Matsuda, Niiyama, Miyachi, Uchida) $\Rightarrow$ Having physics discussions & Learning Belle analysis procedures.
- NPC-II service task : *CDC-related works* (Uchida et al.)
- Preparation of *computing environment at RCNP* (Kanda)

NPC-II Contribution

- ***Removal of Belle-CDC cables*** on 27 & 28 Dec, 2010 (Uchida, Sumihama, Matsuda, Motoda, Kobayashi)
- ***Qualification assurance for sense/potential wire*** (this summer)
- Contribution for ***CDC part of Belle II simulator***

  (Fine tuning of CDC geometry, response function, etc)

  \+ Event generation for hadron physics.



Preparations of analysis environment at RCNP computers (Kanda)

☆Motivation : To increase ***analysis speed and performance*** of NPC members, and to dig up ***analysis man powers*** inside NPC.

☆Comparisons of computing powers

	B computers	*RCNP computers*
CPU & clock	*Intel Xeon X5460 (3.16 GHz)*	*Intel Xeon X5680 (3.33 GHz)*
#CPU	*2 x 480 node*	*2 x 76 node*
Throughput/CPU	*48*	*128*
Total throughput	***2.37***	***1***
Data storage	*3.5 PB Tape + 1.5 PB HDD*	*3.5 PB*
#User	*600(FY2008)*	*~10 (current active user)*

☆ Working Status

1. *Transferring Hadron skim data and generic MC data* w/ ~1.1 TB/day.
   22% of the hadron skim data (78.5 TB) has been transferred.
   Two more months will be necessary.
2. *Construction of BASF (Belle AnalysiS Framework) environment* will start soon.

Final Remarks

- NPC has interests to understand *hadron structures and interactions* from various aspects. Belle data is new and exciting for us with many benefits. We can explore quark (and gluon) configurations *from dynamical to static ranges*.
- We have entered an ***'active phase'*** in Belle data analysis with great helps of A01 people. *We really thank to Belle-A01 for a good collaboration.*
- *We need helps & feedbacks from theorists.* Any comments & requests are very welcome.
- Hopefully we will increase man powers and raise up analysis activities with *the new computing environment*. In addition, we have started to contribute to Belle-II (*NPC-II*).