The 12th Saga-Yonsei Workshop on High Energy Physics

$B^{+} \to l^{+} X^{0}$ and B2BII

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Part I

Search for massive invisible particle X^0 in $B^+ \rightarrow l^+X^0$ decays

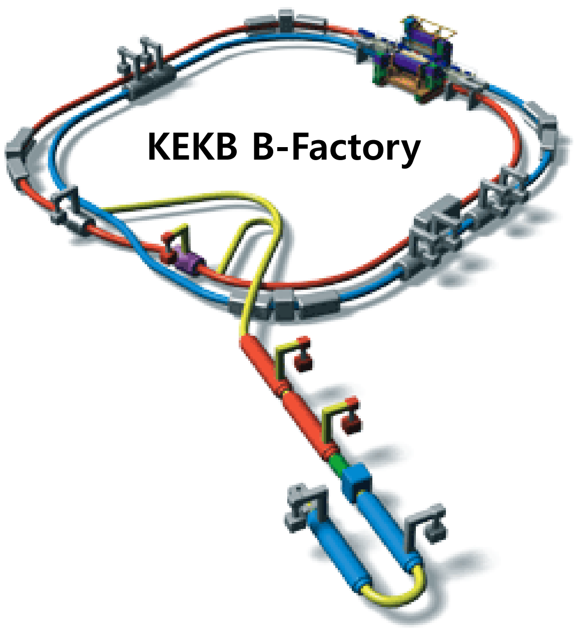
- Belle experiment
- Motivation
- Hadronic tagging method
- Event selection
- Upper limit of branching fractions
- Summary

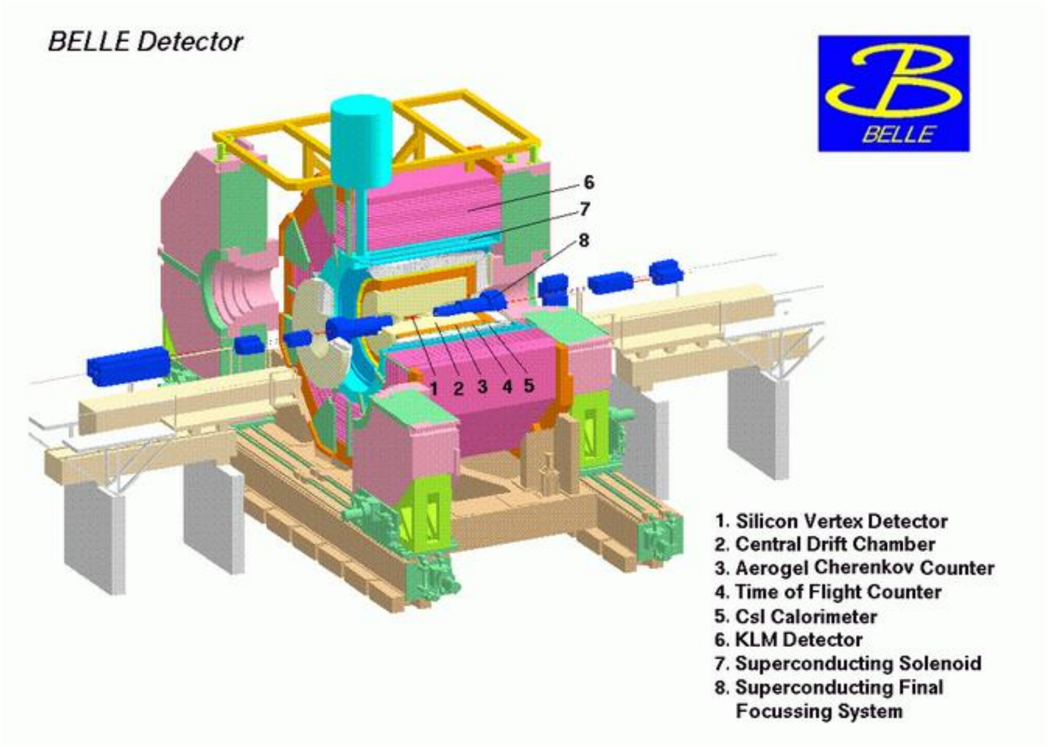
Belle experiment

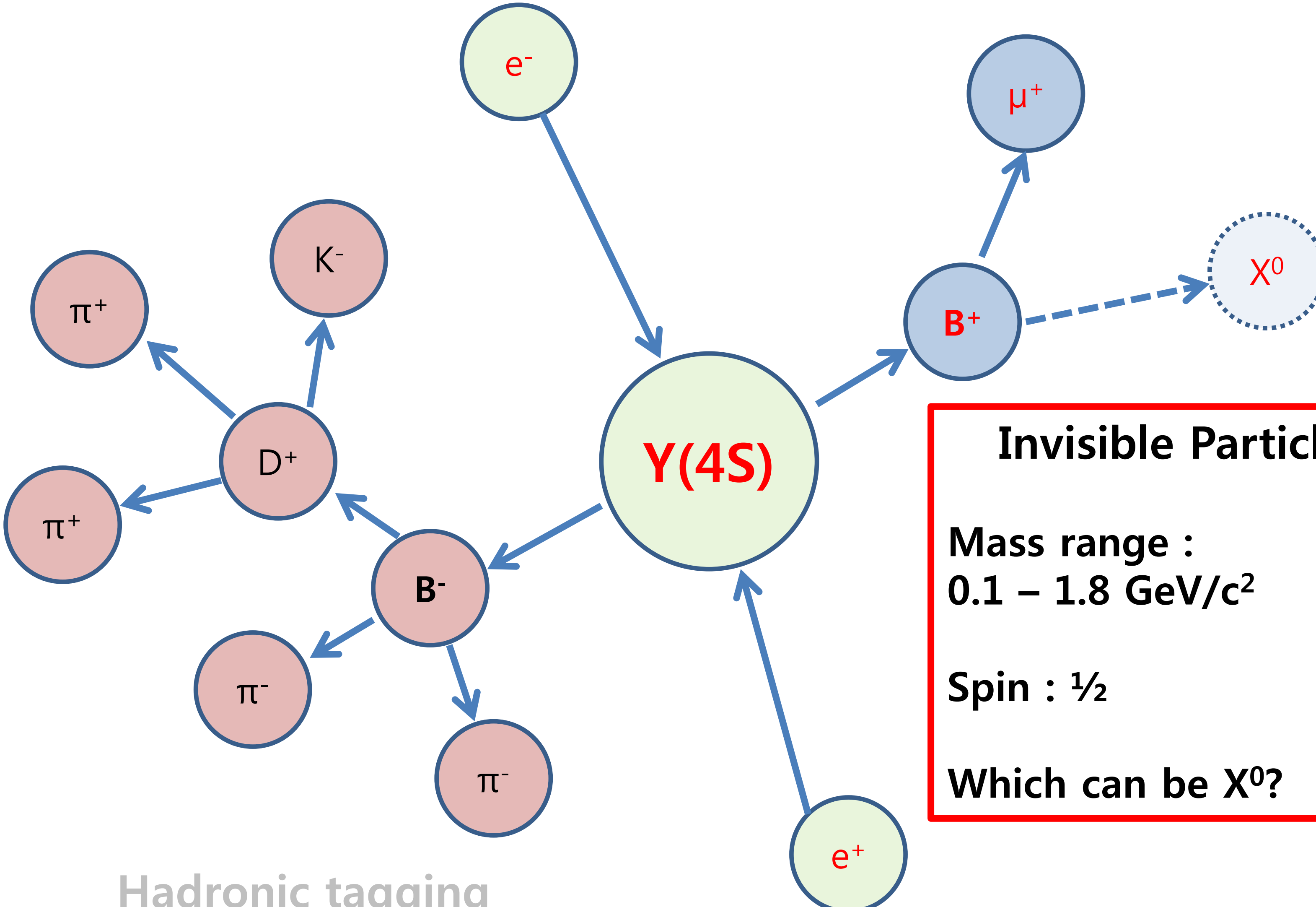
Data collected with Belle detector at KEKB asymmetric e^+e^- collider : 3.5 GeV x 8 GeV

Total of 711 fb^{-1} of data collected at Υ(4S)

→ 772M BB pairs







Hadronic tagging method

Invisible Particle X^0

Mass range :
0.1 – 1.8 GeV/c^2

Spin : ½

Which can be X^0?

Motivation

Which is candidate?

X^0

Sterile neutrino in Large Extra Dimensions

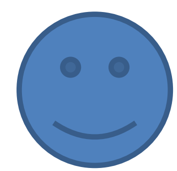
K. Agashe, N.G. Deshpande, and G.-H. Wu, Phys. Lett. B 489, 367 (2000)

Heavy neutrino

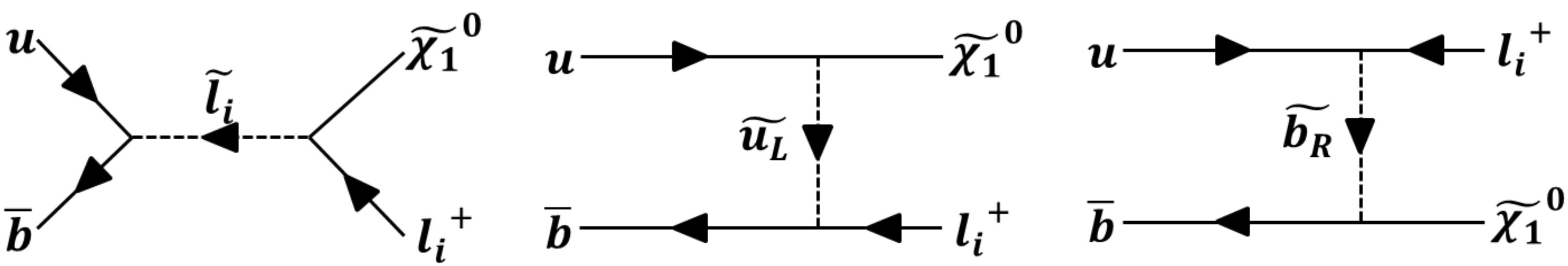
T. Asaka and M. Shaposhnikokv, Phys. B 620, 17 (2005); D. Gorbunov and M. Shaposhnikov, J. High Energy Phys. 10 (2007) 015

Lightest neutralino in the SUSY with R-parity violation

A. Dedes and H. Dreiner, Phys. Rev. D 65, 015001 (2001)



Motivation



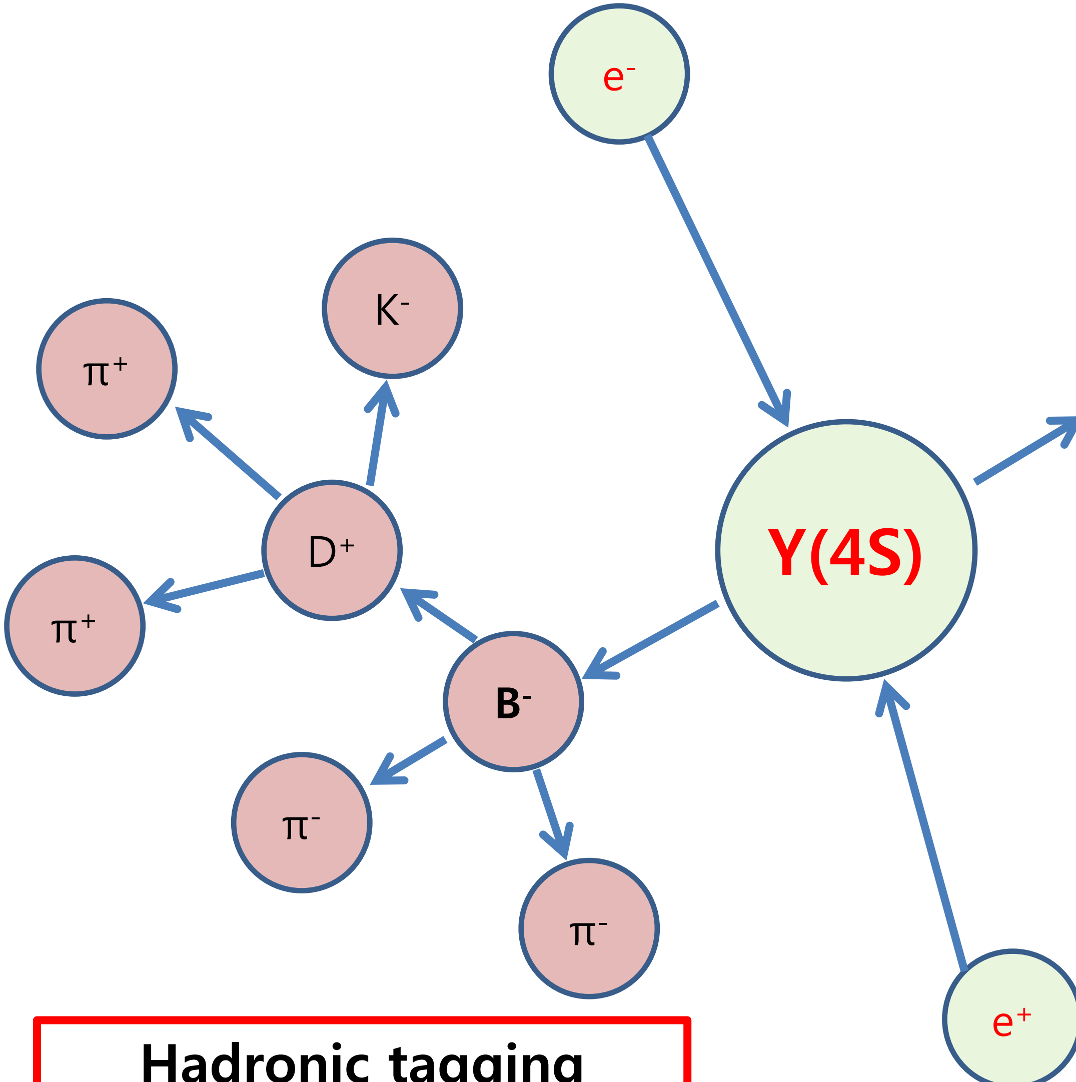
$$\Gamma(B^+ \to l_i^+ X) = \frac{\lambda'^2_{i13} g'^2 f_B^2 m_{B^+}^2 p_{l_i}^B}{8\pi(m_u + m_b)^2} \left(\frac{1}{2M_{\tilde{l}_i}^2} + \frac{1}{12M_{\tilde{u}_L}^2} + \frac{1}{6M_{\tilde{b}_R}^2} \right)^2 (m_{B^+}^2 - m_{l_i}^2 - m_{X^0}^2)$$

λ` : R-parity violating coupling constant

p_l^B : momentum of lepton at B rest frame

M_f~ : s-fermion mass

Any sensitivity of signal → New Physics!



Hadronic tagging method

Invisible Particle X^0

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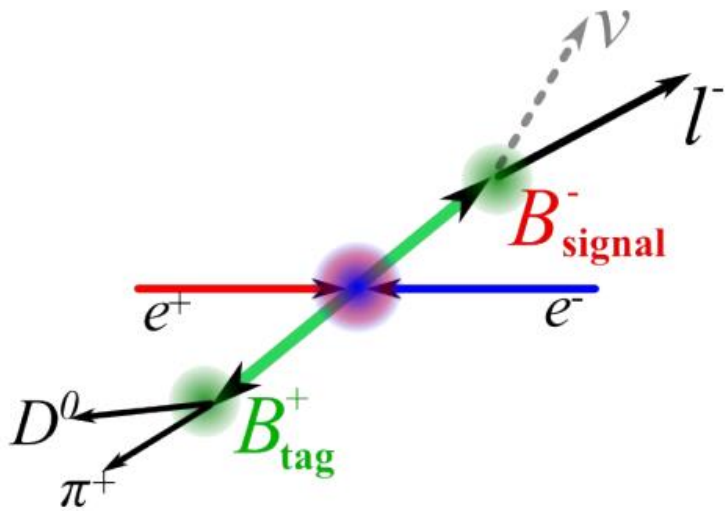
Spin : ½

Which can be X^0?

Hadronic tagging method



Good suppression of $e^+e^- \rightarrow q\bar{q}$

(q = u,d,s,c)

Knowledge of charge, flavor,

four-momentum of B_{tag} and $\mathbf{B_{sig}}$!

NIM A654, 432 (2011)

>96% of Υ(4S) → BB with nothing else produced

one B-meson is completely reconstructed from known b → c decays without ν

efficiency is low, but purity is high

Good ways to reconstruct modes with invisible particle

Event selection

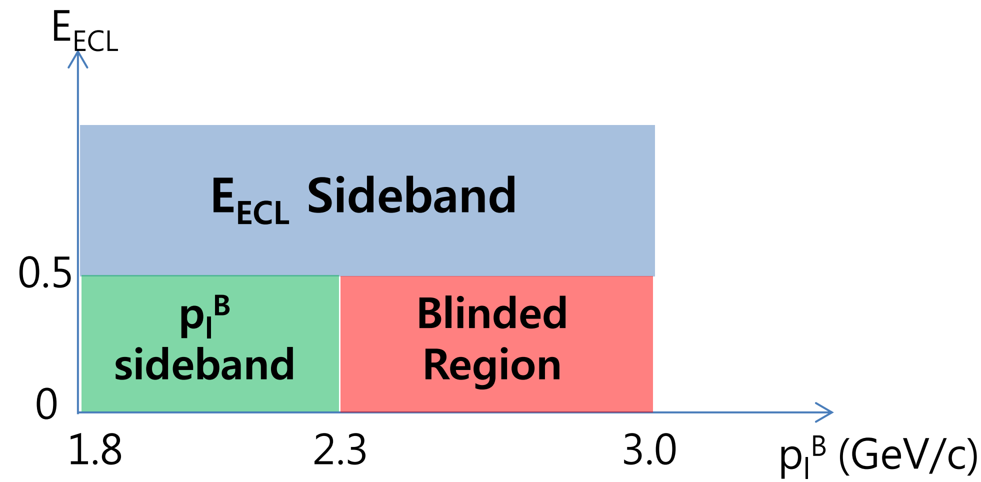
Particle Identity	Track quality	Continuum suppression
$L_e > 0.9$	$\|Dz\| < 2$ cm	$\|\cos\theta_{thrust}\| < 0.9$ for $B^+ \to e^+ X^0$
$L_\mu > 0.9$	$Dr < 0.5$ cm	$\|\cos\theta_{thrust}\| < 0.8$ for $B^+ \to \mu^+ X^0$

Quality of tagged-B meson

$|\Delta E| < 0.05$ GeV

$M_{bc} > 5.27$ GeV/c^2

$O_{NB} > e^{-6}$

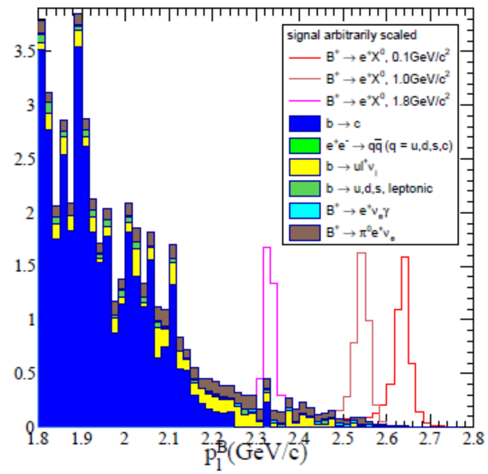


E_{ECL} : Remaining energy of ECL calorimeter (tagged-B & signal lepton)

p_l^B : signal lepton's momentum in the signal B rest frame

Upper limit of B.F.

$$\mathcal{B}(B^+ \to l^+ X^0) = \frac{N_{\text{obs}} - N_{\text{exp}}^{\text{bkg}}}{2 \cdot \epsilon_s \cdot N_{B^+B^-}}$$



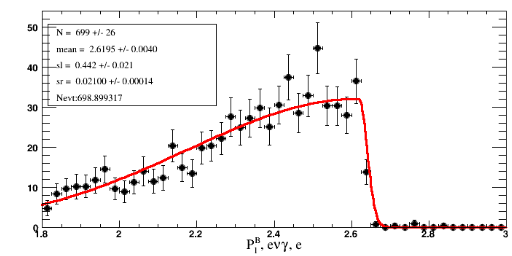
ε_s : efficiency of signal

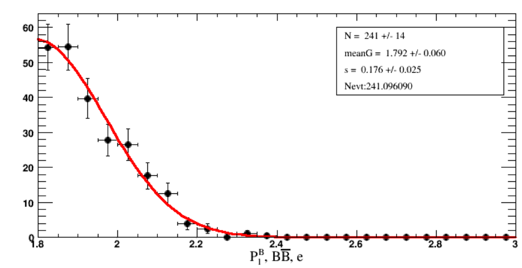
N_{B+B-} : Number of charged B meson pairs

N_{obs} : # of observed event in the signal criteria

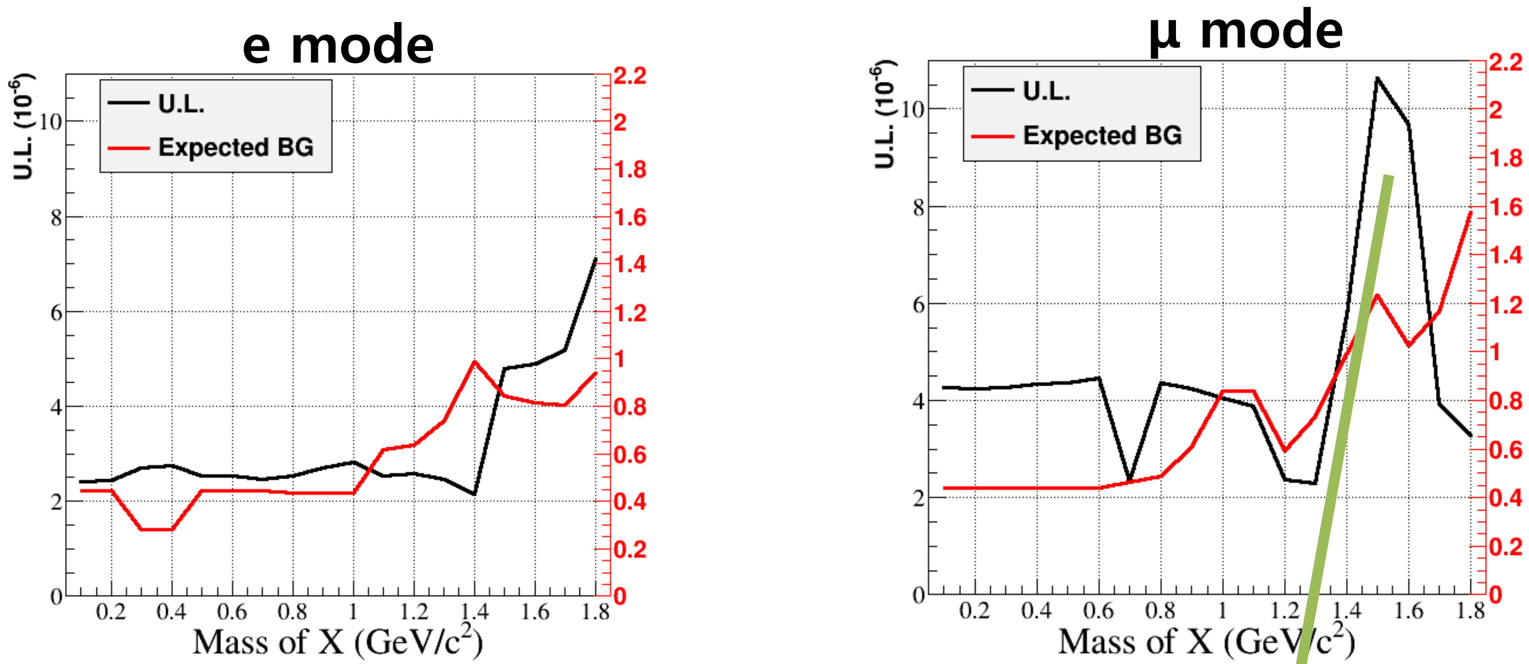
N_{exp}^{bkg} : Expected background

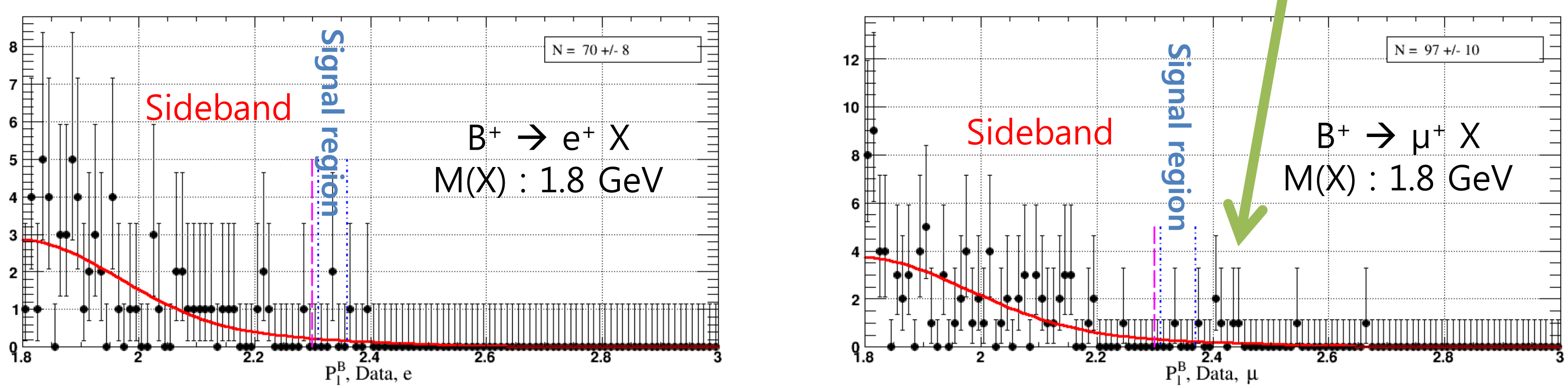
- using 1-D unbinned MaxLikelihood p_l^B fitting
- scaled with Data / MC ratio in sideband region





Upper limit of B.F.





Upper limit of B.F.

$$\xi_i = \lambda'^2_{i13}\left(\frac{1}{2M^2_{\tilde{l}_i}} + \frac{1}{12M^2_{\tilde{u}_L}} + \frac{1}{6M^2_{\tilde{b}_R}}\right)^2 = \frac{8\pi(m_u+m_b)^2\mathcal{B}(B^+\to l_i^+X^0)}{\tau_{B^+}g'^2 f_B^2 m_{B^+}^2 p_{l_i}^B\left(m_{B^+}^2 - m_{l_i}^2 - m_{X^0}^2\right)}$$

From the branching fraction upper limits

We can set bounds on the SUSY-related parameter ξ_i

Most stringent upper bound on ξ_i

$\xi_1 < 4.12 \times 10^{-14}$

$\xi_2 < 4.22 \times 10^{-14}$

Summary

* We search for $B^+ \rightarrow l^+ X^0$, where X^0 can be any invisible (and possibly massive) spin-1/2 particle.

* We successfully suppressed background by help of hadronic tagging method.

* In preliminary results, the upper limits are $O(10^{-6})$

* Assuming RPV SUSY, we can set bounds on SUSY-related parameters

* This search comes into draft step, please ready for publication.

Part II

B2BII project
Belle MDST → Belle II MDST Conversion

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Contents

Goal of B2BII

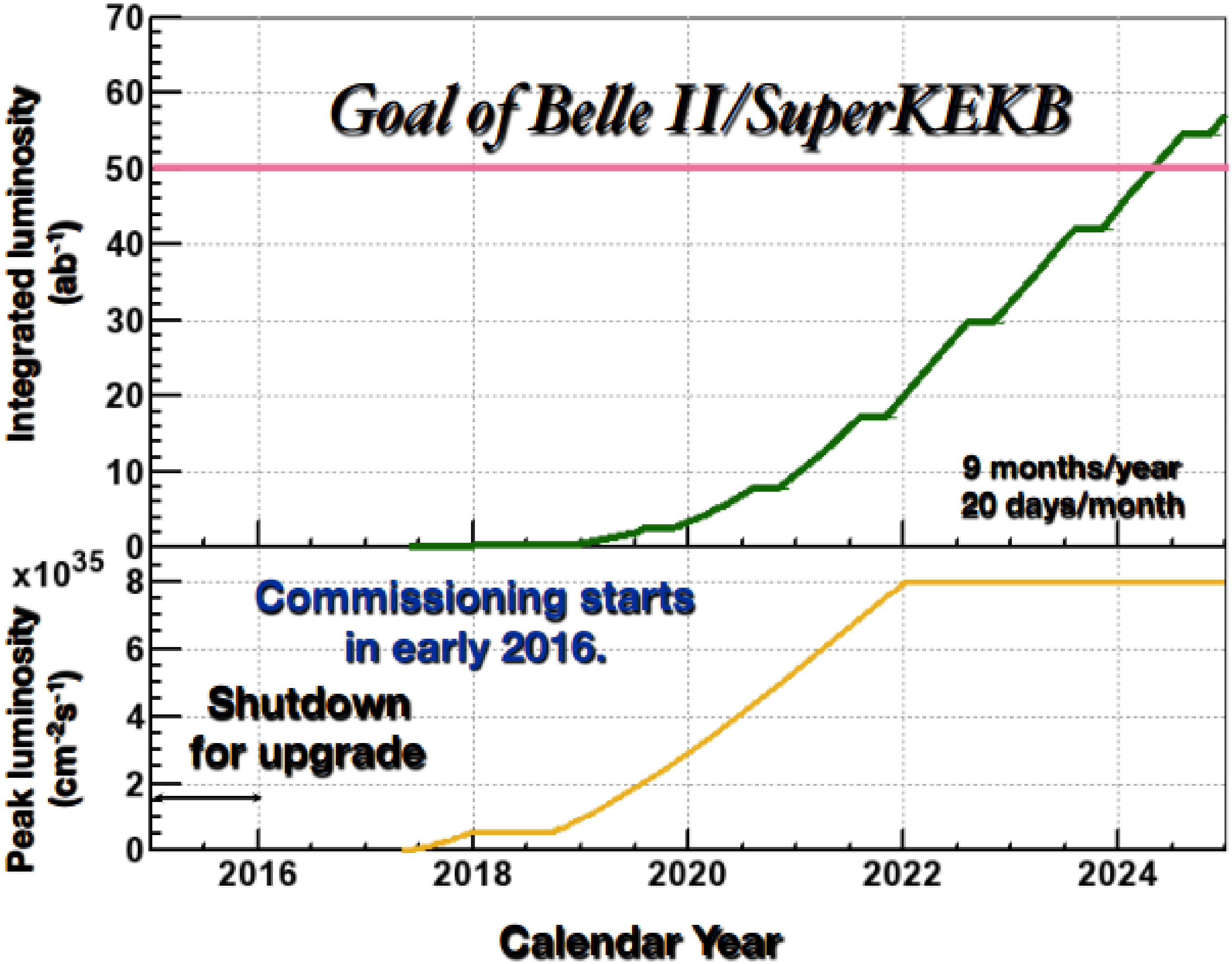
Conversion

- Tracking
- PID
- module

Validation

- Monitoring

Summary


Goal of Belle II/SuperKEKB
Integrated luminosity (ab^{-1})
70
60
50
40
30
20
10
0
9 months/year
20 days/month
x10^{35}
8
6
4
2
0
Peak luminosity (cm^{-2}s^{-1})
Commissioning starts
in early 2016.
Shutdown
for upgrade
2016
2018
2020
2022
2024
Calendar Year

MDST : Mini-data-structure-table

BASF : Belle Analysis Framework

In Belle II, BASF2 is used.

Belle & Belle II mdst data structures are different.

Goal of B2BII

read and analyze Belle MDST data within BASF2

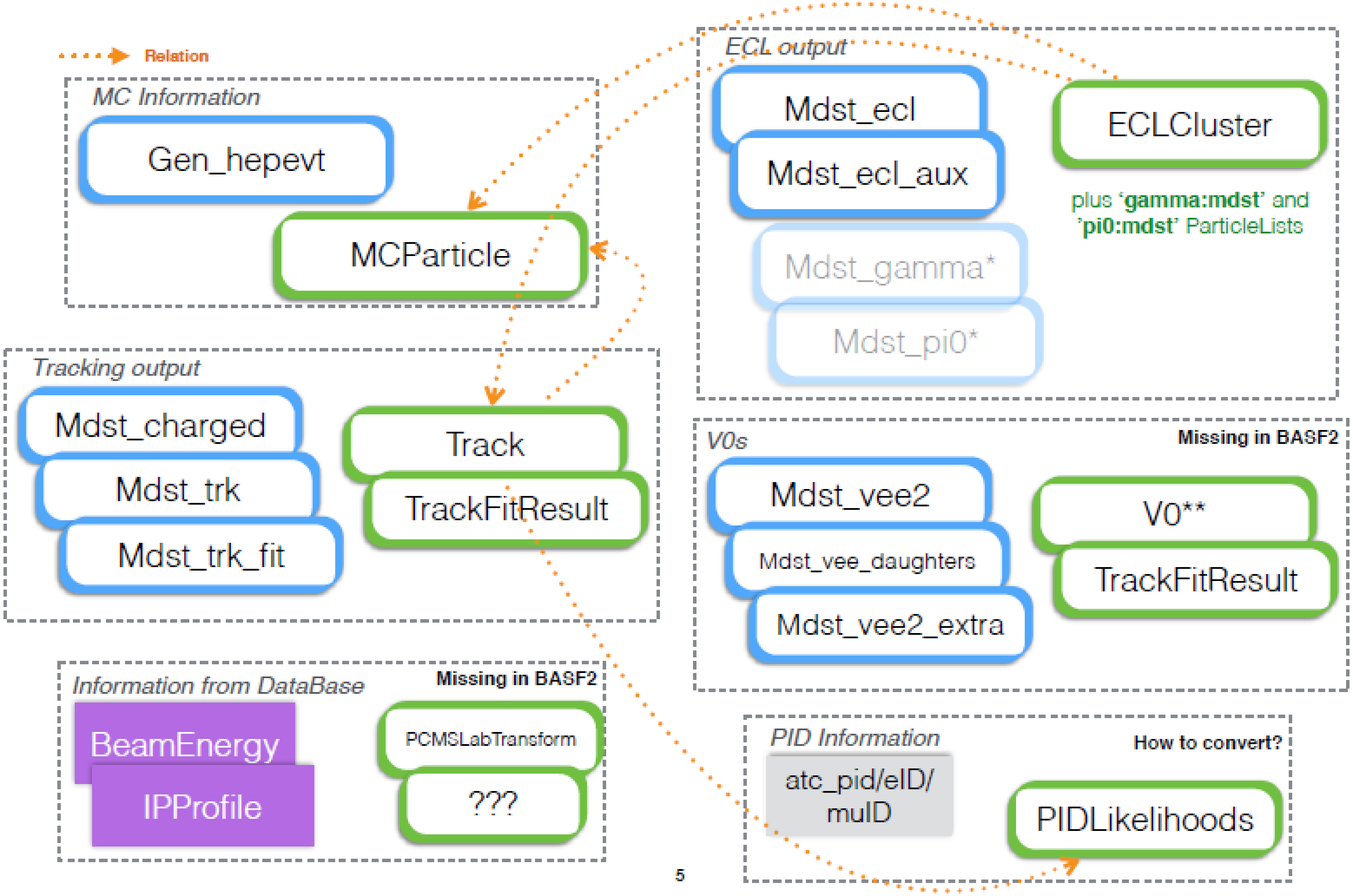
Conversion

→ read Belle MDST file (Panther tables)
→ specify which Panther tables have to be converted to perform physics analyses
→ Create conversion rules and implement them

Validation

→ write BASF and BASF2 modules that write out contents of specific MDST tables/datobjects to flat ntuple and compare them. They should match perfectly.
→ Give conversion monitoring histograms

Belle -> Belle II converter



Conversion

Tracking

Both Mdst_trk_fit and TrackFitResult internally store Helix parameters, however the Helix parameterization used by Belle and Belle II differ slightly

Belle Helix Parameterization	
d_rho	signed distance of the helix from the pivot in xy plane
phi_0	the azimuthal angle to specify the pivot wrt. helix center (range from 0 to 2pi)
kappa	1/pt (reciprocal of the transverse momentum) and the sign of kappa represents the charge of the track
d_z	is the signed distance of the helix from the pivot in the z direction
tanLambda	slope of the track (tangent of the dip angle)

Belle II Helix Parameterization	
d0	the signed distance to the perigee. The sign positive (negative) if the angle between the transverse momentum and d0 is +pi/2 (-pi/2)
phi	the angle between the transverse momentum and the x axis and in [-pi, pi]
omega	the signed curvature of the track where the sign is given by the charge of the particle
z0	the distance of the perigee from the origin in the r-z plane
cotTheta	the inverse slope of the track in the r-z plane

Conversion

Tracking

$\mathbf{a} = (d_\rho, \phi_0, \kappa, d_z, \tan\lambda)^T$ - five helix parameters

$\mathrm{a} = (d_0, \phi_0, \omega, z_0, \tan\lambda)^T$ - five helix parameters **Pivot always origin!**

$$\left.\begin{array}{rcl} d_0 & = & d_\rho \\ \phi_0 & = & \phi_0 + \frac{\pi}{2} \\ \omega & = & \frac{\kappa}{\alpha} \\ z_0 & = & d_z \\ \tan\lambda & = & \tan\lambda \end{array}\right\} \qquad \mathbf{a}_{\mathrm{BelleII}} = \mathbf{f}(\mathbf{a}_{\mathrm{Belle}})$$

$$\Sigma_{\mathrm{BelleII}} = J\Sigma_{\mathrm{Belle}}J^T \qquad J_{i,j} = \frac{\delta f_i}{\delta a^j_{\mathrm{Belle}}}$$ Jacobian matrix

Conversion

PID

If PID is not available for a given sub-detector, or it does not pass standard quality cuts, likelihoods will not be set for this detector. (i.e. PIDLikelihood::isAvailable(det) should be equal to quality cut)

atc_pid	PIDLikelihood	Notes
ACC	ARICH	quality cut: at least one likeilhood != 0, (bool)mdst_acc and mdst_acc.quality() == 0 (needs current belle_legacy version and uncommented #define HAVE_KID_ACC)
TOF	TOP	quality cut: at least one likelihood != 0, (bool)mdst_tof and mdst_tof.quality() == 0
CDC	CDC	quality cut: at least one likelihood != 0, mdst_trk.dEdx() > 0

ECL		ECL information in principle available, but not used in default config of FixMdst
KLM	KLM	quality cut: mdst_charged.muid_ID() != 0 and mdst_klm_mu_ex.Chi_2() > 0

Conversion

PID

atc_pid

```cpp
double atcPIDBelle(const Particle* particle,  const std::vector<double>& sigAndBkgHyp)
{
  int sigHyp = int(std::lround(sigAndBkgHyp[0]));
  int bkgHyp = int(std::lround(sigAndBkgHyp[1]));

  const PIDLikelihood* pid = particle->getRelatedTo<PIDLikelihood>();
  if (!pid) return 0.5;

  // ACC = ARICH
  Const::PIDDetectorSet set = Const::ARICH;
  double acc_sig = exp(pid->getLogL(hypothesisConversion(sigHyp), set));
  double acc_bkg = exp(pid->getLogL(hypothesisConversion(bkgHyp), set));
  double acc = 0.5;
  if (acc_sig + acc_bkg  > 0.0)
    acc = acc_sig / (acc_sig + acc_bkg);

  // TOF = TOP
  set = Const::TOP;
  double tof_sig = exp(pid->getLogL(hypothesisConversion(sigHyp), set));
  double tof_bkg = exp(pid->getLogL(hypothesisConversion(bkgHyp), set));
  double tof = 0.5;
  double tof_all = tof_sig + tof_bkg;
  if (tof_all != 0) {
    tof = tof_sig / tof_all;
    if (tof < 0.001) tof = 0.001;
    if (tof > 0.999) tof = 0.999;
  }
```

atc_pid

```cpp
  // dE/dx = CDC
  set = Const::CDC;
  double cdc_sig = exp(pid->getLogL(hypothesisConversion(sigHyp), set));
  double cdc_bkg = exp(pid->getLogL(hypothesisConversion(bkgHyp), set));
  double cdc = 0.5;
  double cdc_all = cdc_sig + cdc_bkg;
  if (cdc_all != 0) {
    cdc = cdc_sig / cdc_all;
    if (cdc < 0.001) cdc = 0.001;
    if (cdc > 0.999) cdc = 0.999;
  }

  // Combined
  double pid_sig = acc * tof * cdc;
  double pid_bkg = (1. - acc) * (1. - tof) * (1. - cdc);

  return pid_sig / (pid_sig + pid_bkg);
}
```

eid

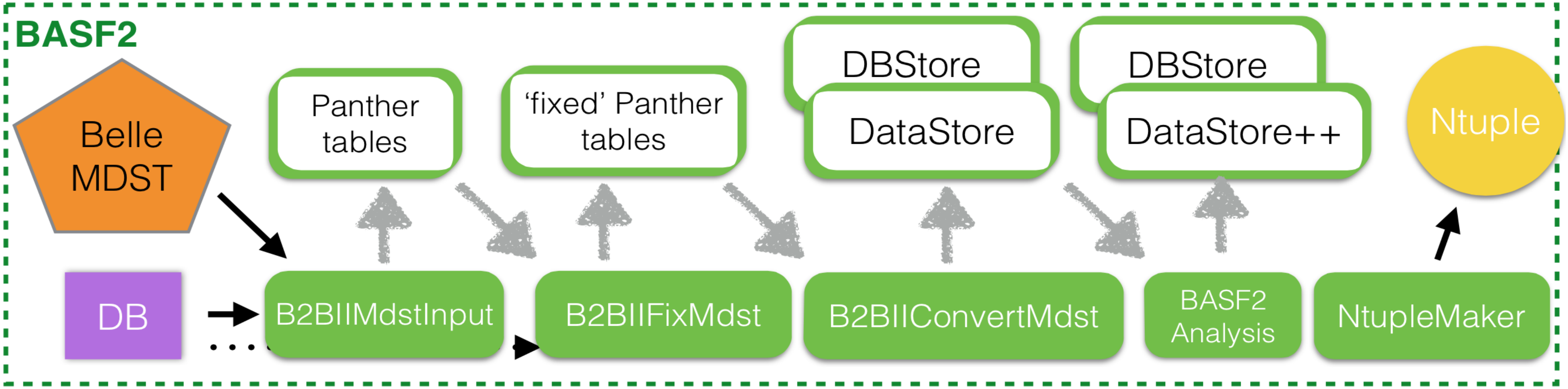
```cpp
double particleElectronECLId(const Particle* part)
{
  const PIDLikelihood* pid = part->getRelatedTo<PIDLikelihood>();
  if (!pid) return 0.5;

  Const::PIDDetectorSet set = Const::ECL;
  return pid->getProbability(Const::electron, Const::pion, set);
}
```

muid

```cpp
double muIDBelle(const Particle* particle)
{
  const PIDLikelihood* pid = particle->getRelatedTo<PIDLikelihood>();
  if (!pid) return 0.5;

  if (pid->isAvailable(Const::KLM))
    return exp(pid->getLogL(Const::muon, Const::KLM));
  else
    return 0;
}

double muIDBelleQuality(const Particle* particle)
{
  const PIDLikelihood* pid = particle->getRelatedTo<PIDLikelihood>();
  if (!pid) return 0;

  return pid->isAvailable(Const::KLM);
}
```

Conversion

Module



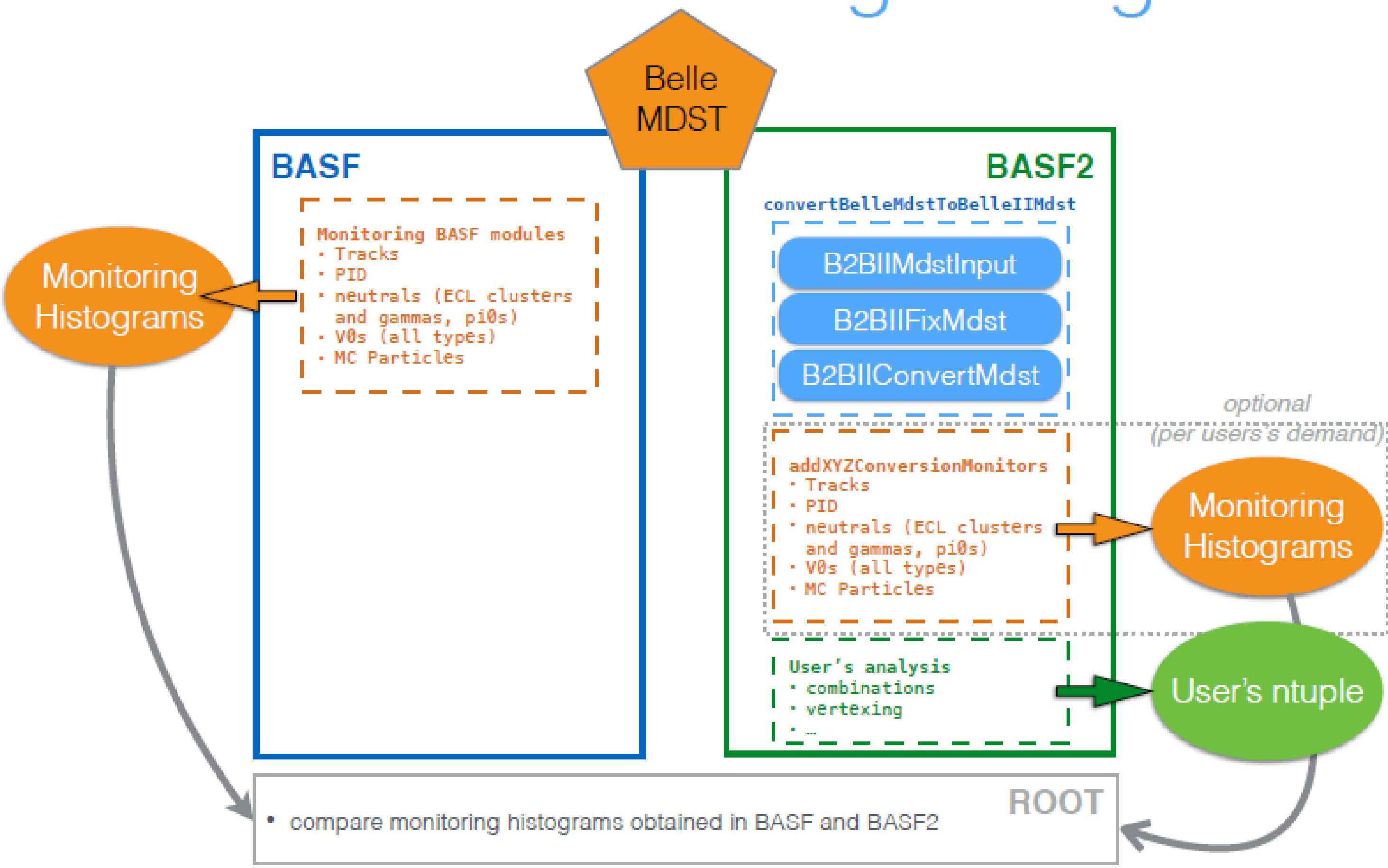
B2BIIMdstInput : Module to read Belle MDST files
B2BIIFixMdst : Used to fix the old Belle I MDST files before processing.
B2BIIConverdMdst : Converts Belle mDST objects (Panther tables and records) to Belle II MDST objects

Wrapper function 'convertBelleMdstToBelleIIMdst'

Validation

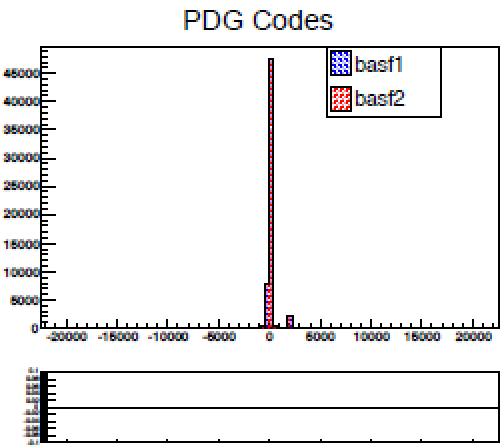
Monitoring

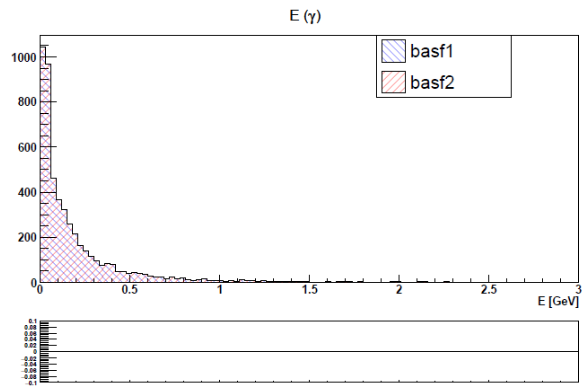
Conversion Monitoring Histograms

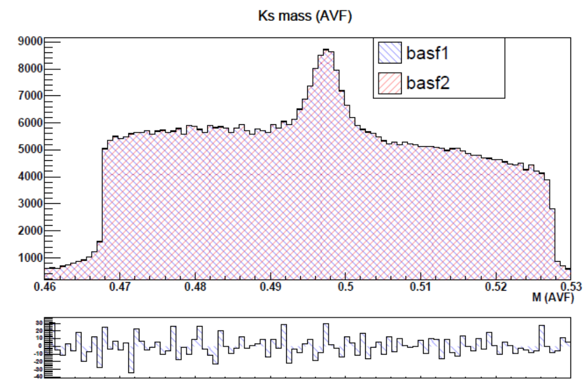


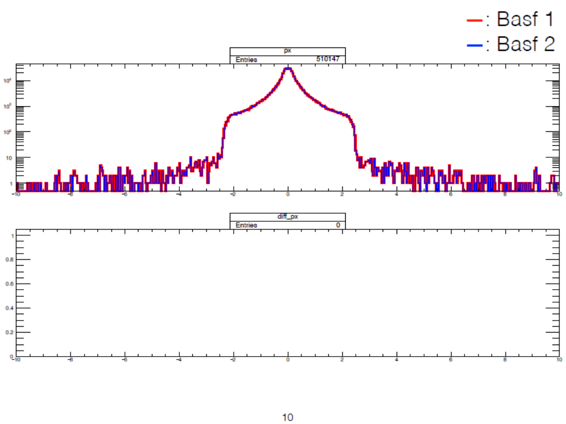
Validation

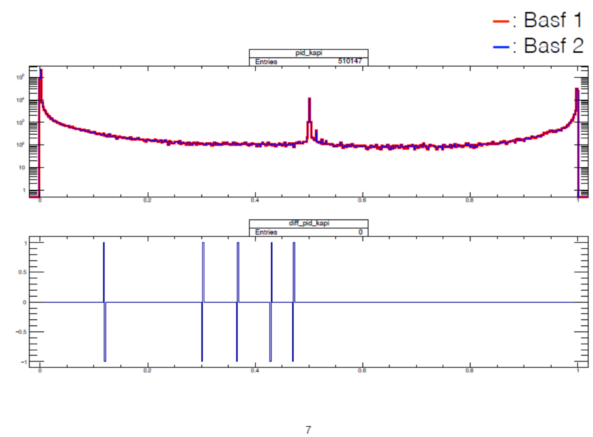
Monitoring











Summary

* B2BII aims to convert the mdst file produced in BASF to BASF2 platform, so people can analyze the Belle data under BASF2.

* Conversion and validation procedures are well-done.

* B2BII group prepare 'Monitoring histogram' system for users.

* Next plan of B2BII group is to analyze some decay channel with B2BII.

Thank you for listening!

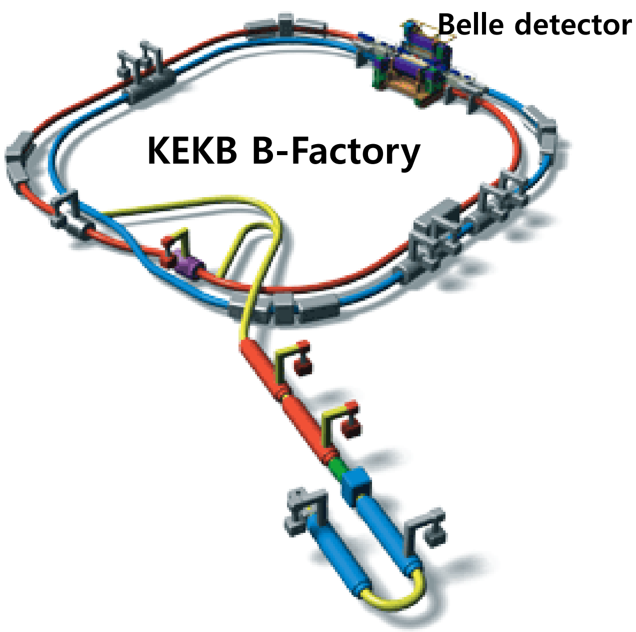
BACKUP

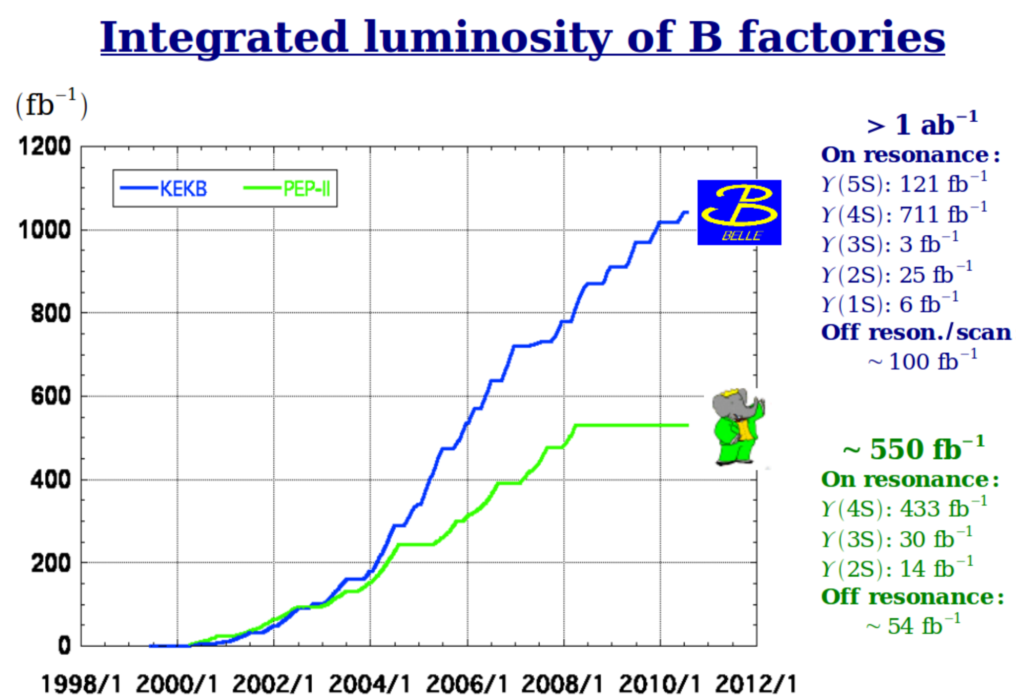
Belle experiment

Data collected with Belle detector at KEKB asymmetric e^+e^- collider : 3.5 GeV x 8 GeV

Total of 711 fb^{-1} of data collected at Υ(4S)

→ 772M BB pairs





Used sample

Signal MC

mode	Mass of X	Amount
$B^+ \to e^+ X$	0.1, 0.2, … 1.8 GeV	2,000,000 events for each mass of X
$B^+ \to \mu^+ X$	0.1, 0.2, … 1.8 GeV	2,000,000 events for each mass of X

We have 18 kinds of X for different mass

Background MC

Mode	Process	Amount
Generic MC	BB, qq	5 streams
RareB	$b \to s, d$	50 streams
Ulnu	$B \to X_u l\nu$	20 streams
$e\nu\gamma$	$B^+ \to e\nu\gamma$	1000 streams
$\mu\nu\gamma$	$B^+ \to \mu\nu\gamma$	1000 streams
π^+K^0	$B^+ \to \pi^+K^0$	500 streams
$\pi^0 e\nu$	$B^+ \to \pi^0 e\nu$	300 streams
$\pi^0 \mu\nu$	$B^+ \to \pi^0 \mu\nu$	300 streams

Separately generated! ($e\nu\gamma$ through $\pi^0\mu\nu$)

Used skim

SKIM PATH

Hadronic Tagging → LX_SKIM → ANALYSIS_CODE

LX_SKIM

- 1 charged particle not used in Full_recon →call it ‘c’
- (Charge of c) x (Charge of tagged B) = -1
- Momentum of c(LAB frame) >1.0 GeV

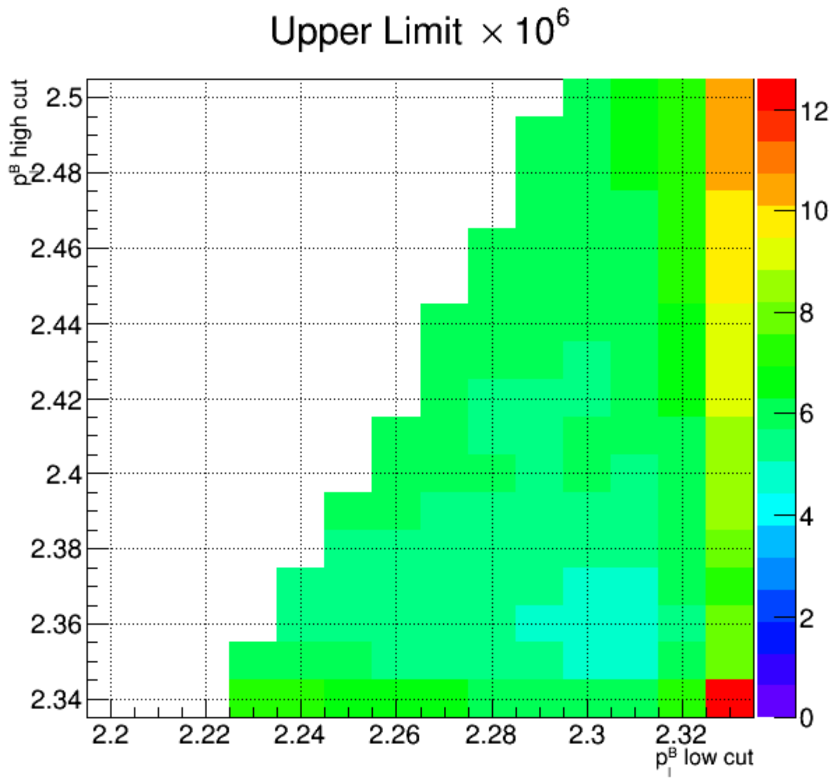
Optimization

$$\text{Mean of U.L.} = \frac{\sum_{n=0}^{6} Yield_{U.L.}(BG_{est};n) \cdot Poisson(BG_{est};n;1000)}{\sum_{n=0}^{6} Poisson(BG_{est};n;1000) \cdot N(B\overline{B}) \cdot \varepsilon_{sig}}$$

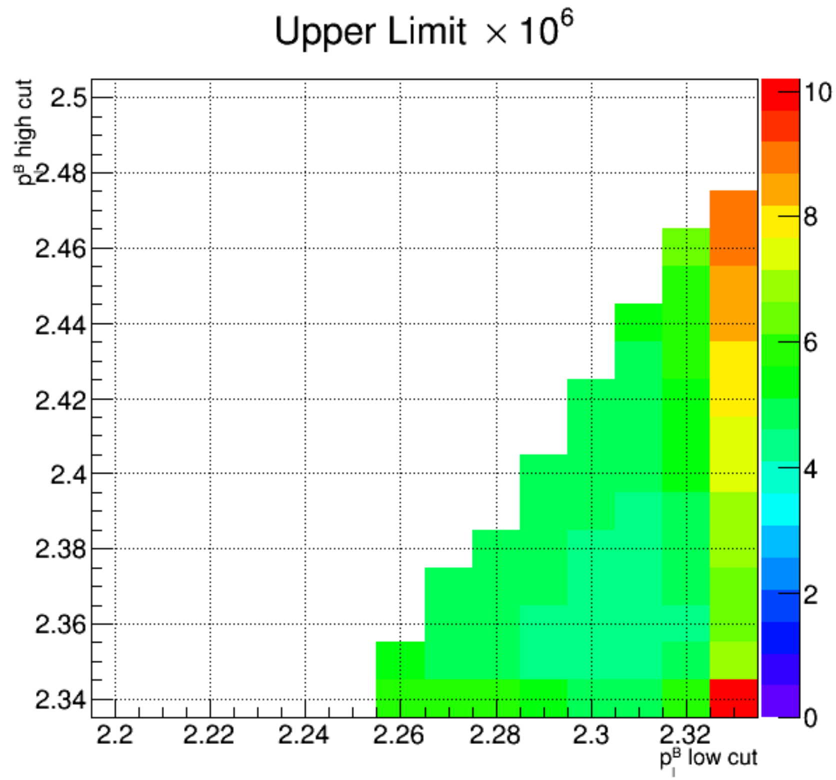
- **n : # of observed events in signal region.**
- **Yield_{U.L.} : U.L. of Yields using POLE program**
- **Poisson : # of values of 1,000 events have Poisson dist**

Optimization

Mean of upper limit of branching fraction based on MC for each p_l^B criteria



$B^+ \rightarrow e^+ X$
M(X) : 1.8 GeV/c^2



$B^+ \rightarrow \mu^+ X$
M(X) : 1.8 GeV/c^2