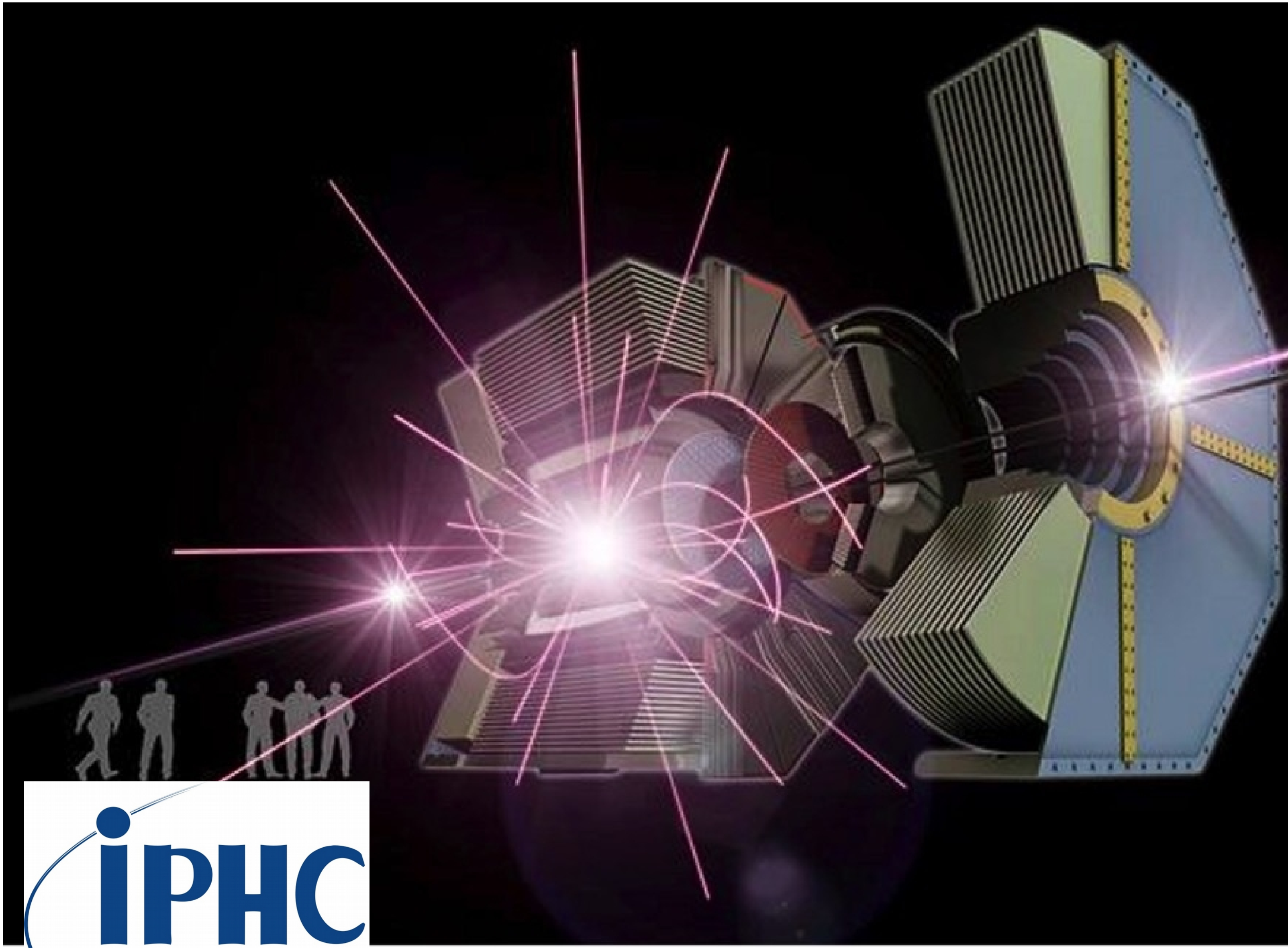
SuperKEKB induced background study and preparation of Belle II analysis



I. Particle physics and New physics

II. SuperKEKB & Belle II

III. BEAST

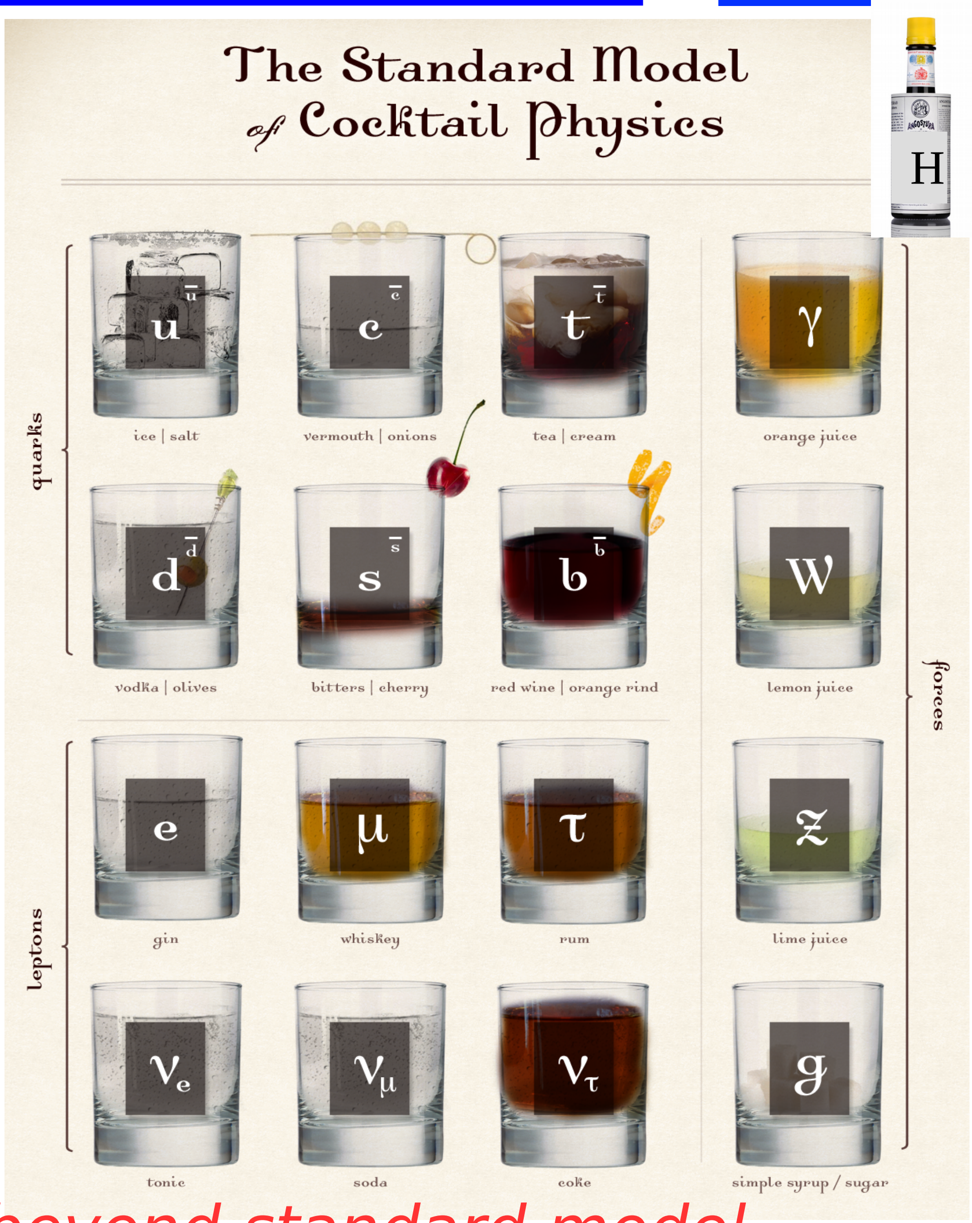
IV. Preparation of Physics analysis

Institut Pluridisciplinaire Hubert CURIEN STRASBOURG

Daniel Cuesta

Introduction : Particle physics

Elementary constituent of matter and their interactions are very precisely described by the « standard model »



Successes of SM, e.g. :

- Higgs discovery ~50 years after prediction
- Bosons W and Z

Quantity	Measured (GeV)	SM prediction (GeV)
Mass of W boson	80.387 ± 0.019	80.390 ± 0.018
Mass of Z boson	91.1876 ± 0.0021	91.1874 ± 0.0021

But it is an effective theory, does not explain, e.g.:

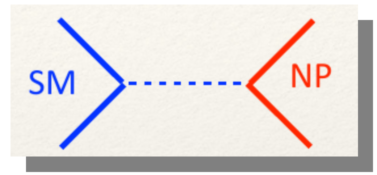
- Amplitude of Matter anti-matter asymmetry
- Inclusion of gravity at higher energy
- Neutrino masses
- Dark matter
- …

Looking for physics beyond standard model

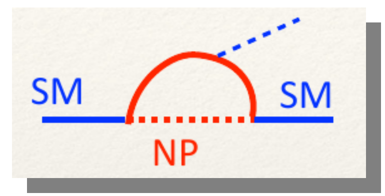
Searching for new physics

Two ways :

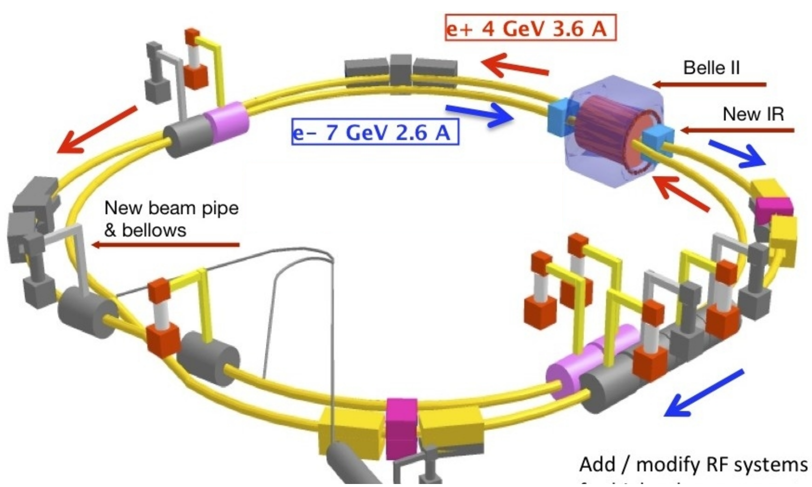
- Producing new heavy particles
  → *Energy frontier* : CMS, ATLAS

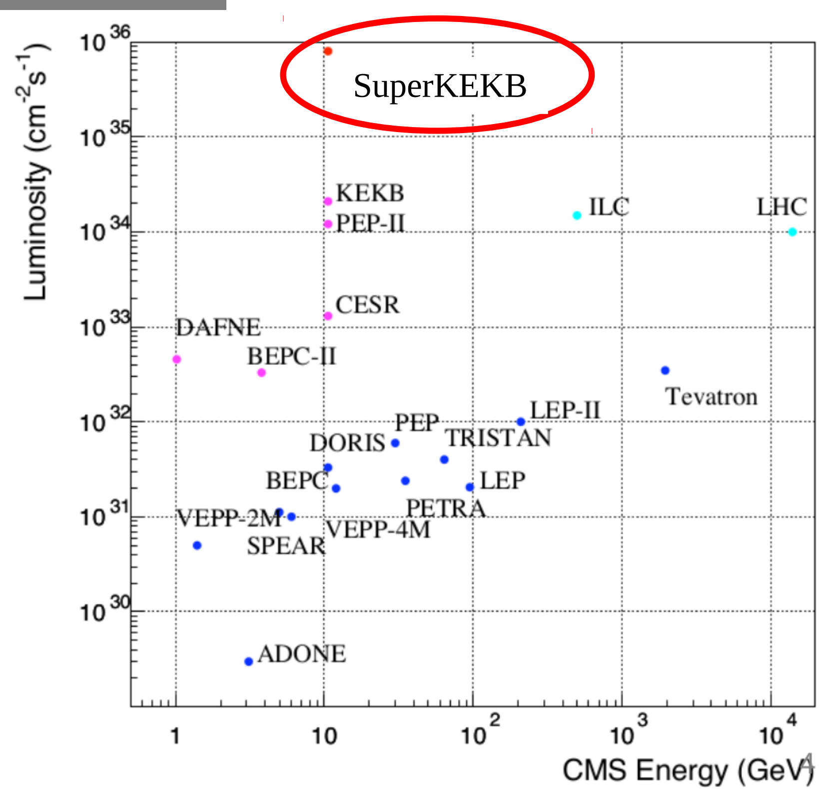


- Producing extremly rare processes
  → *Intensity frontier* : Belle II, LHCb,...



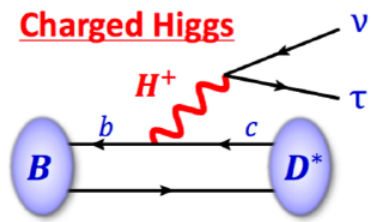
- e^+e^- → Very clean environment
- High Luminosity → Huge amount of data
  - Highest ever luminosity

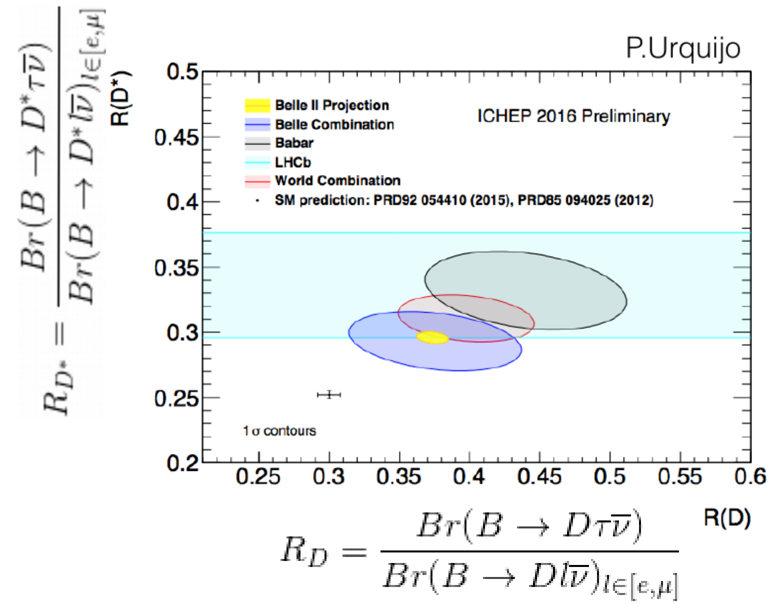




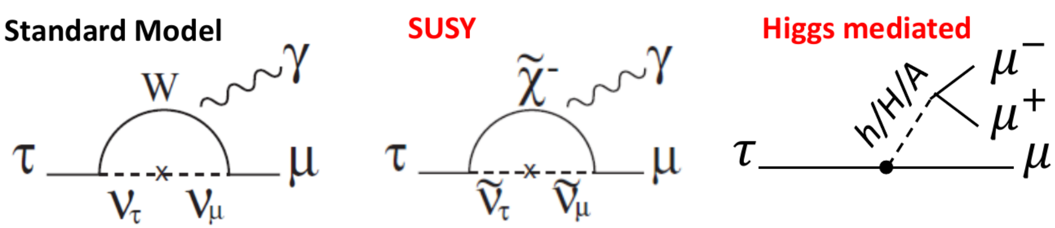
New physics at Belle II

- *R(D*) vs R(D)*
  - Sensitive to charged Higgs
  - Already 2~3 σ
  - Same Measurement with Belle II resolution → 12σ

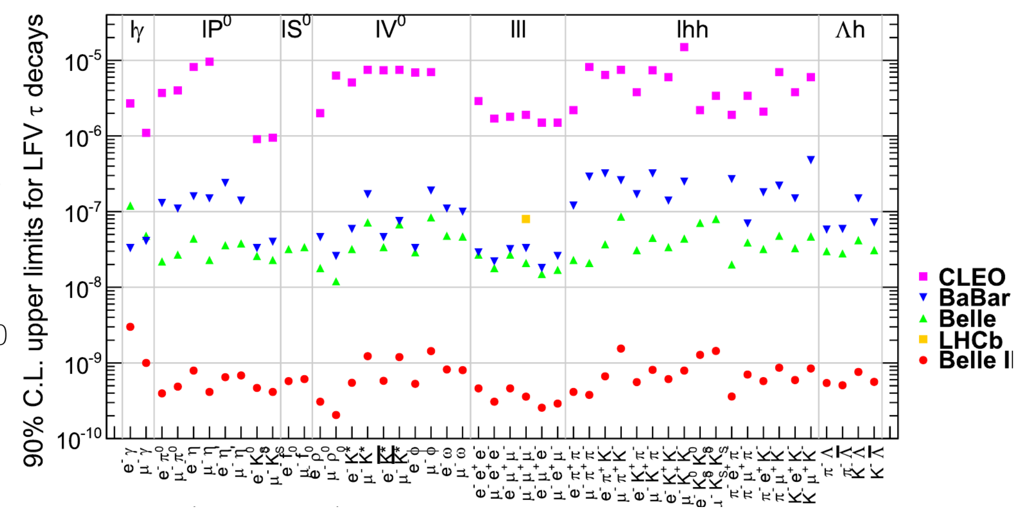




- *Lepton flavour violation*



  - SM with neutrino oscillations → Br<10^{-50}
  - Many SM extensions → Br ~10^{-8}
  - Belle II sensitivity [10^{-10},10^{-9}]

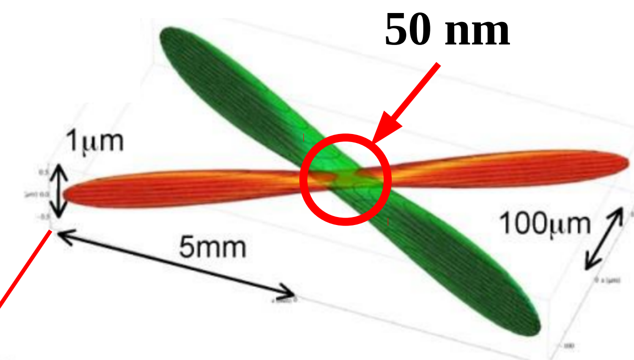


SuperKEKB

Highest Luminosity ever reached : 8 10^{35} cm^{-2} s^{-1}

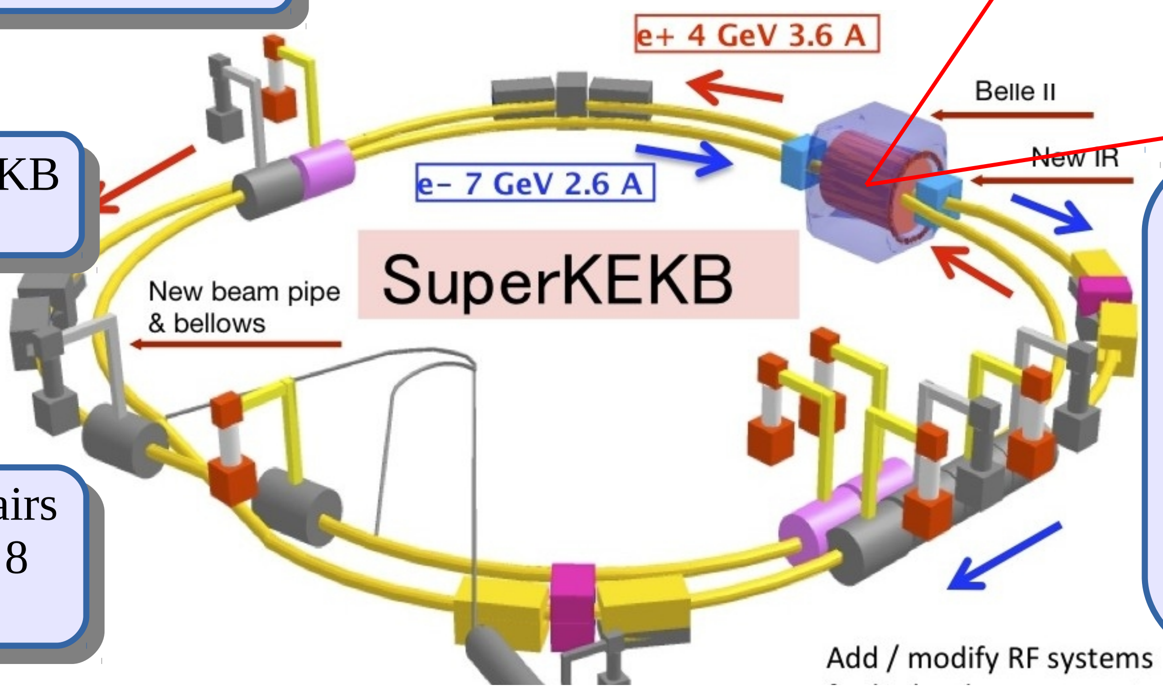
X40 > KEKB

$$\mathcal{L} \propto \frac{I}{\sigma_{beam}}$$



Current 2x > KEKB

Beam size 20x < KEKB
→ **Nano Beam**



5 10^{10} b, c and τ pairs over a period of 8 years

Schedule :

- Phase I: *2016 Single beams*
- Phase II: *Feb-July 2018 First collisions*
- Phase III: *End 2018 Physics run*

Nano beams and high luminosity induce a very large amount of background particles

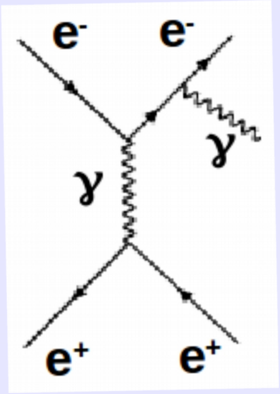
Background processes

Single Beam

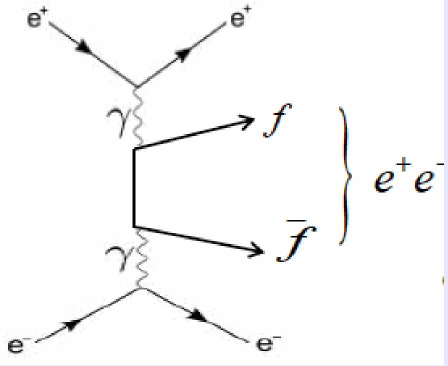
- Touschek : *Elastic scattering between particles within the same bunch*
- Beam gas : *Coulomb scattering between beam particles and atoms inside the vacuum tube*
- Synchrotron : *Radiation emitted by charged particles bended in a magnetic field*
- Injection noise : *New bunches continously injected are unstable and lose particles*

Beam Beam

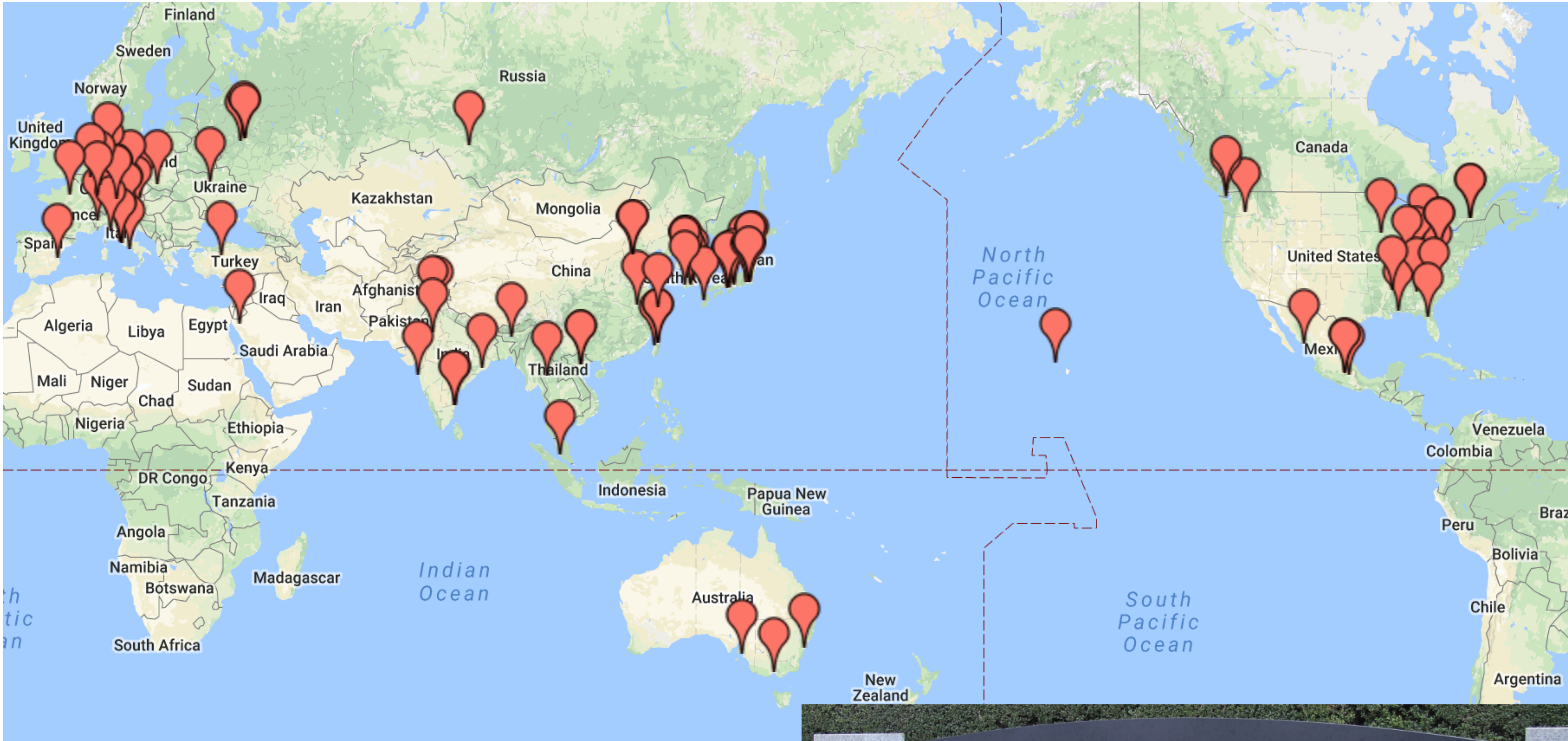
- Radiative Bhabha : *e^+e^- scattering with ISR or FSR*



- Two photon pair QED production : *e^+e^- scattering with pair production*



Belle II Collaboration

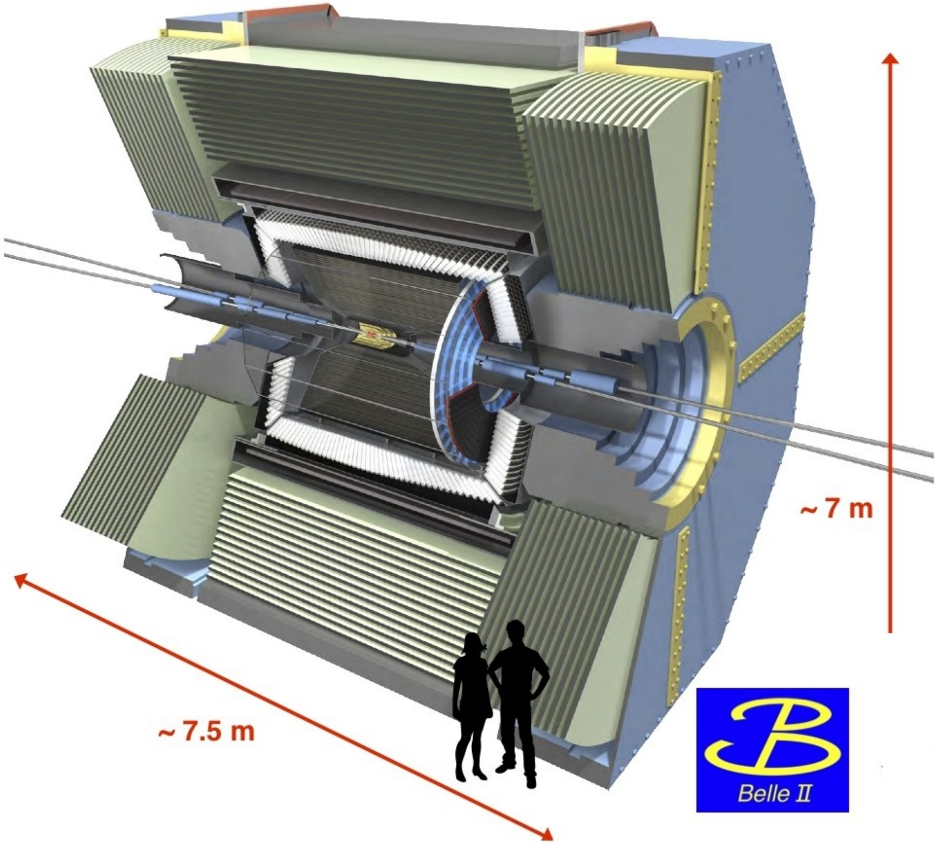


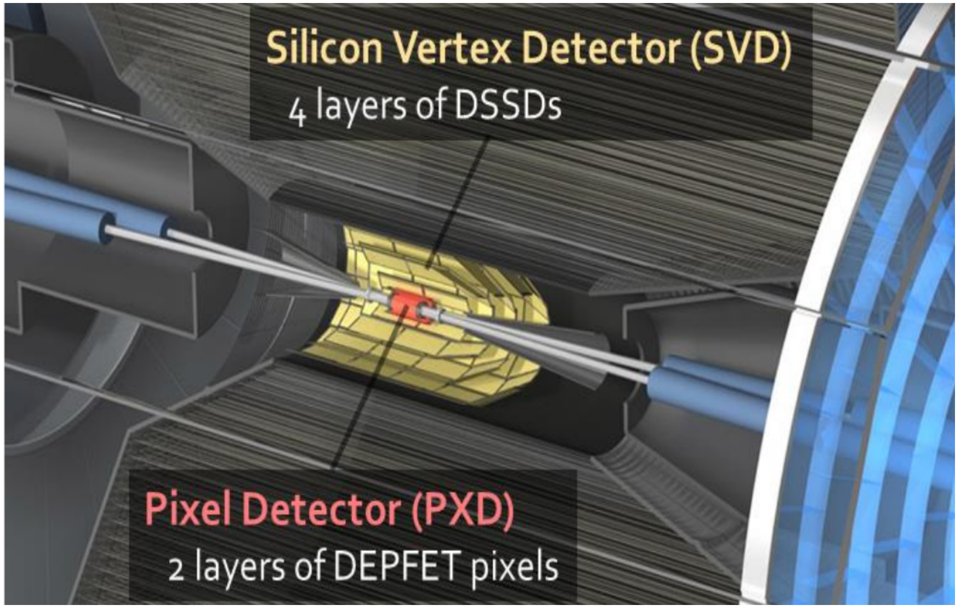
~700 physicists 25 countries

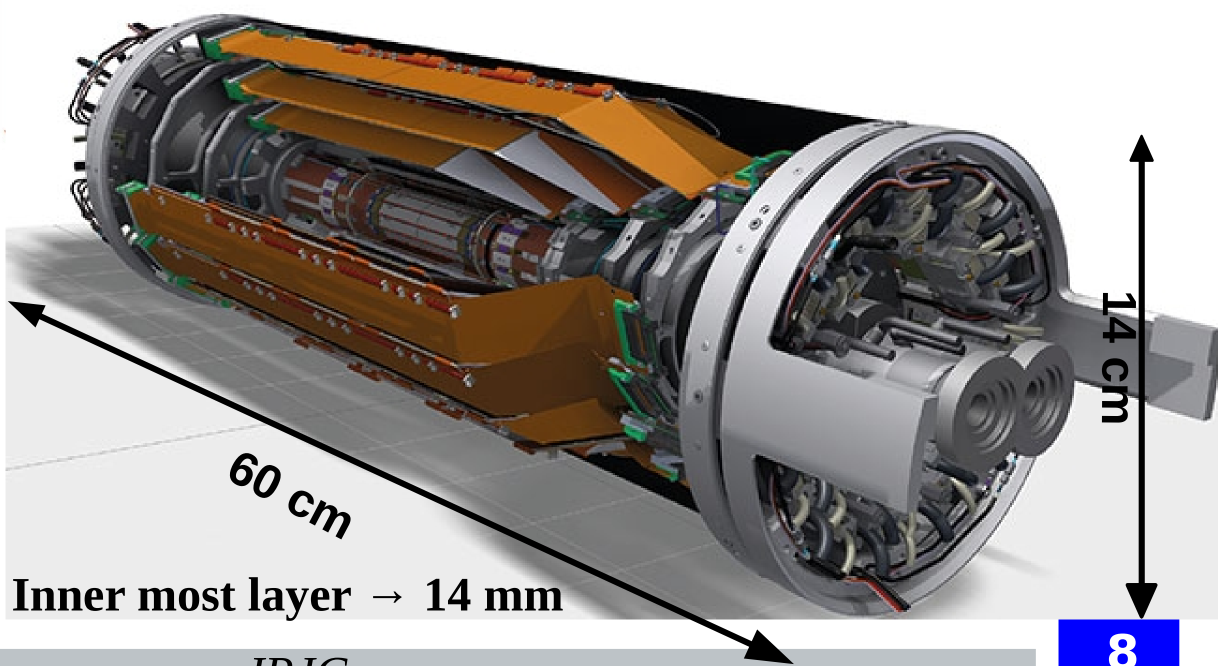
3 general meetings per year

at KEK in Tsukuba, Japan

Belle II detector







Inner most layer → 14 mm

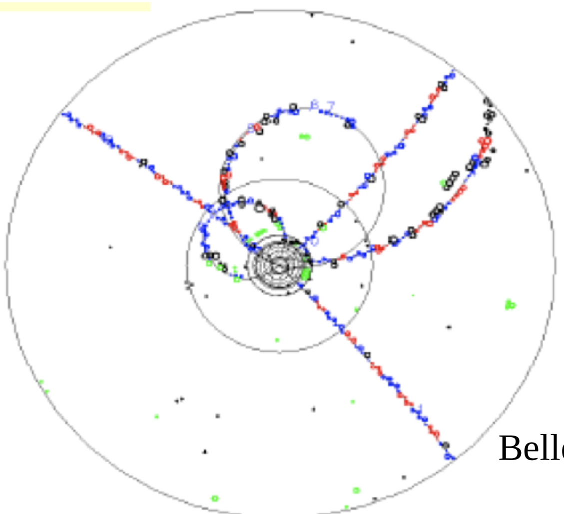
Flavour physics oriented detector:

- Asymetric
- Particle Identification
  - ARICH
  - TOP
  - CDC

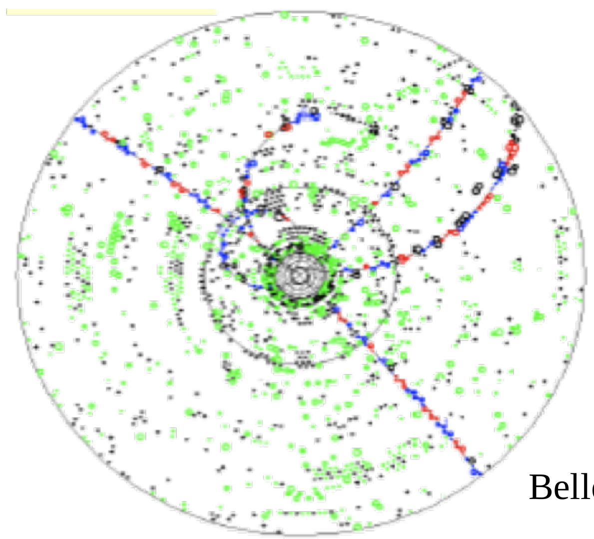
Beam Exorcism for A Stable belle II experiment

High luminosity → Large amount of background besides collision products:

- 50% Energy deposition in calorimeter
- 90 % occupancy in Vertex detector



Belle



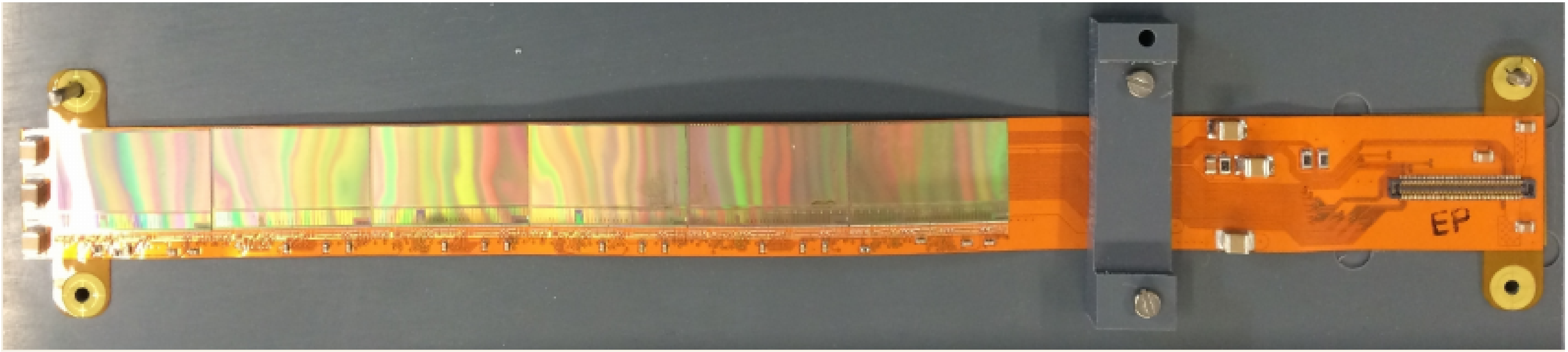
Belle II

Understand and control background mandatory for Belle II physics program
And the safety of detectors

Dedicated background study during the BEAST II commissioning
IPHC participation with PLUME ladders

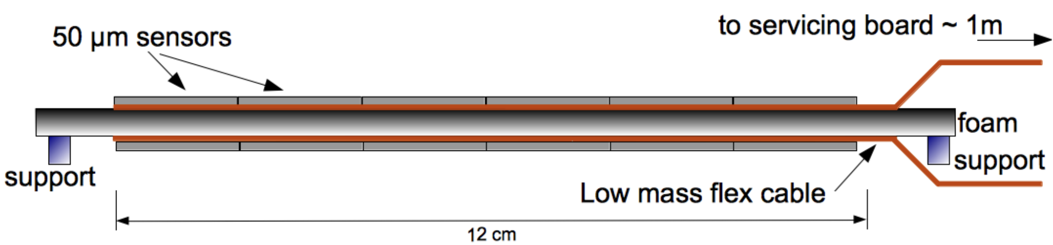
PLUME ladder

R&D in perspective of an inner tracker for the ILC made by a collaboration of Bristol , DESY and IPHC

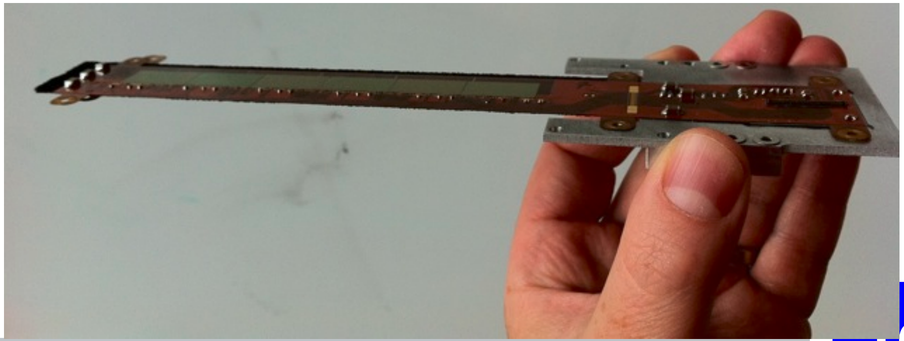


2x6 CMOS sensors provided by IPHC

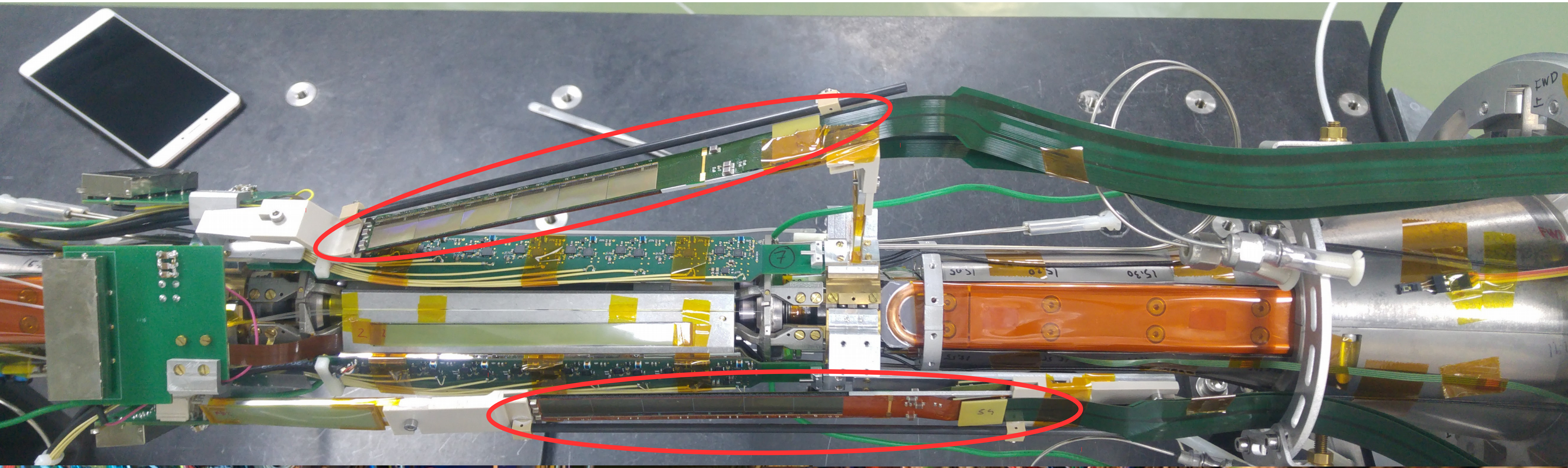
- Double sided detection
- Spatial resolution : 3µm
- 8 10^6 pixels
- Very low mat. budget : 0,4 % X_0

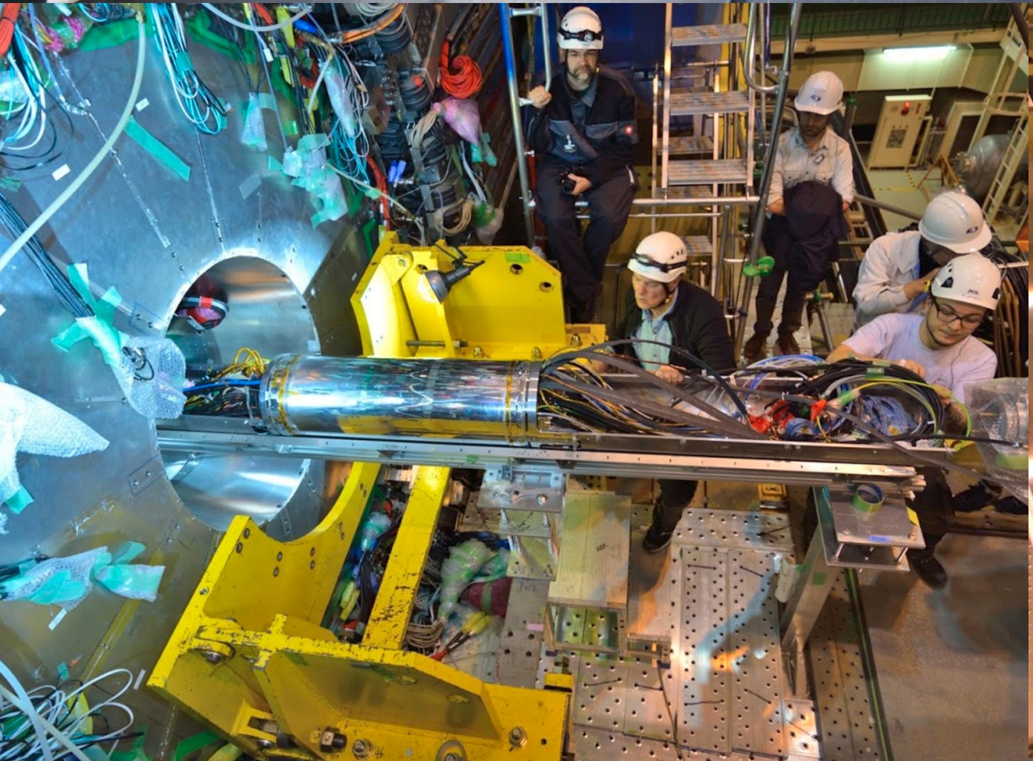


Longitudinal view



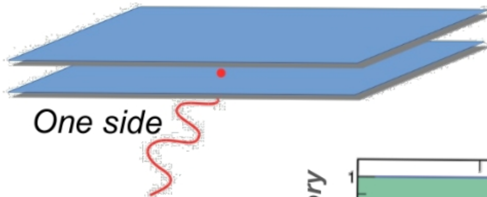
BEAST installation on site

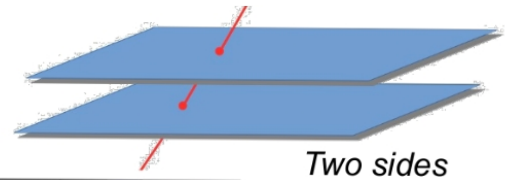




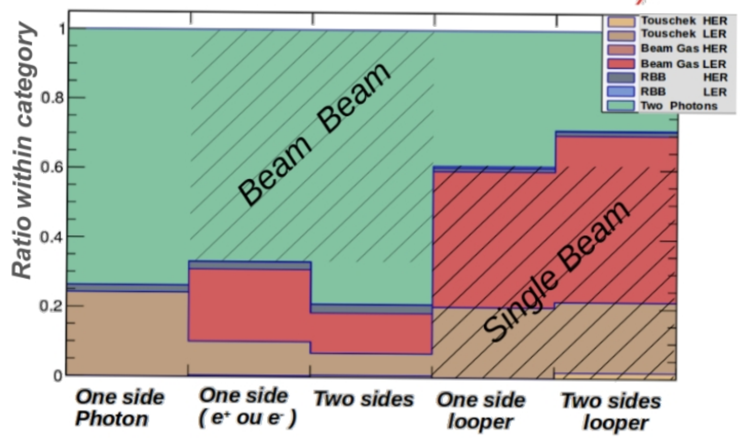
Background analysis with PLUME

Background analysis with PLUME ladders is based on **correlation between background processes and hit patterns on PLUME**

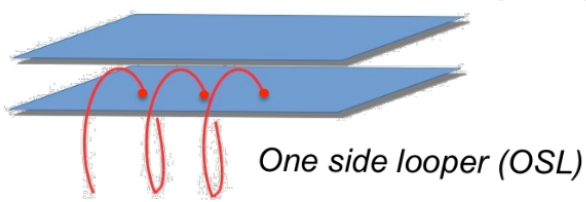


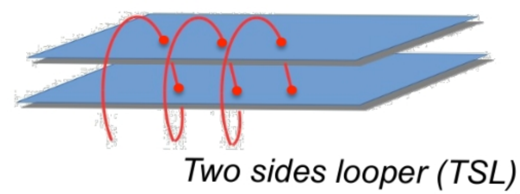


- Cross PLUME
  - Primaries from IP
  - ~15 MeV and E_{beam}



- Loop through PLUME
  - Secondaries from showers in surrounding material
  - ~ 1 MeV



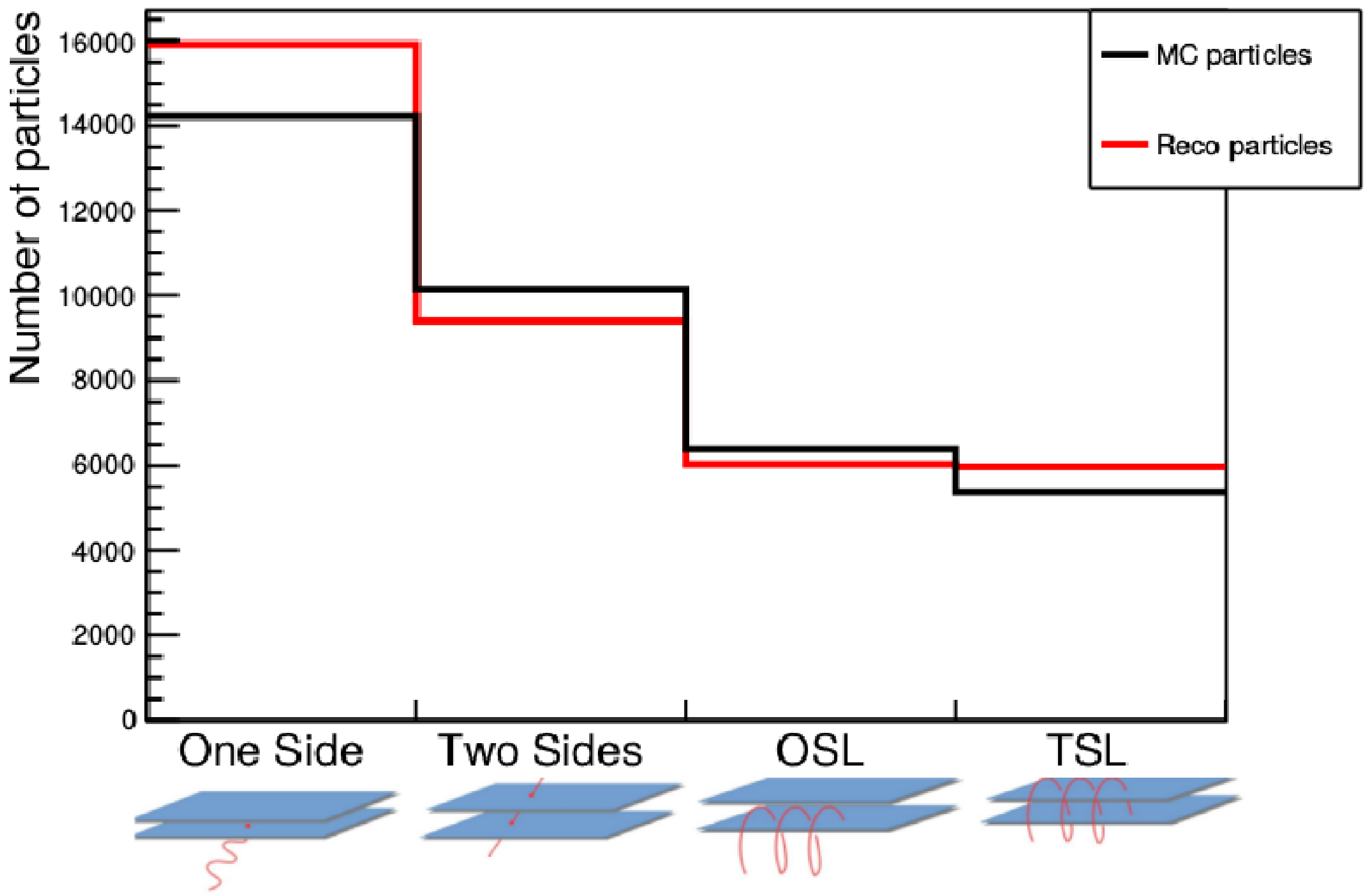


- Thanks to double sided detection :
  - Pattern recognition → Process identification
  - Track reconstruction → Momentum sensitivity and Process identification

Pattern recognition : Results

Proportion of hits properly assigned :

- One Side : 77 %
- Two Sides : 73 %
- OSL : 70 %
- TSL : 74 %



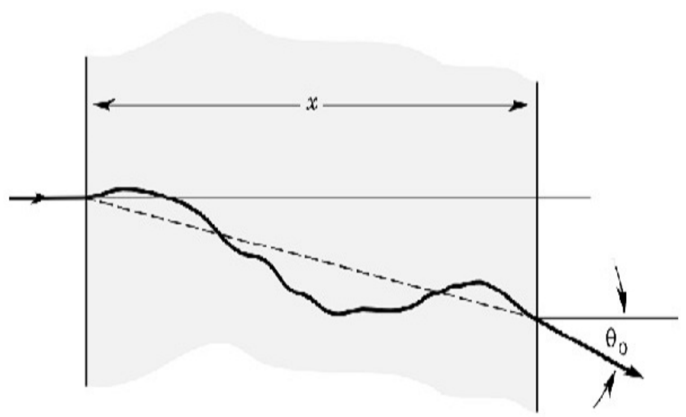
Track reconstruction

Main goal : Reconstruct track from IP ↔ Beam Beam processes

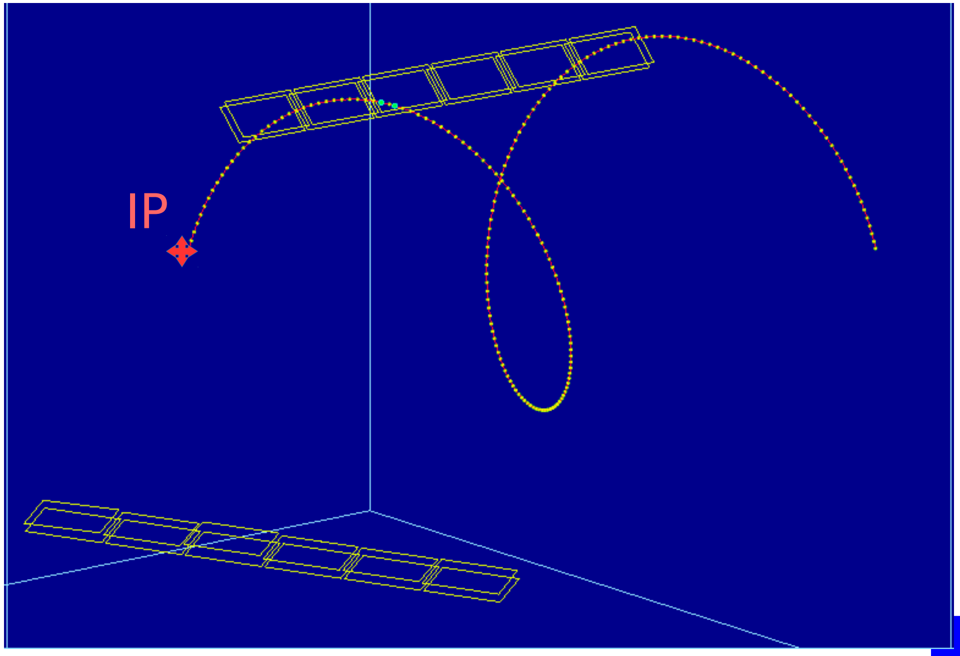
3 points to fit a track = One PLUME ladder → 2 hits + IP constrain

$$\begin{cases} x = x_0 + d_\rho \cos\phi_0 + \frac{\alpha}{\kappa}(\cos\phi_0 - \cos(\phi_0+\phi)) \\ y = y_0 + d_\rho \sin\phi_0 + \frac{\alpha}{\kappa}(\sin\phi_0 - \sin(\phi_0+\phi)) \\ z = z_0 + d_z - \frac{\alpha}{\kappa}\tan\lambda\cdot\phi, \end{cases}$$

Most of machine induced background particles have small momentum
→ Important multiple scattering with surrounding materials



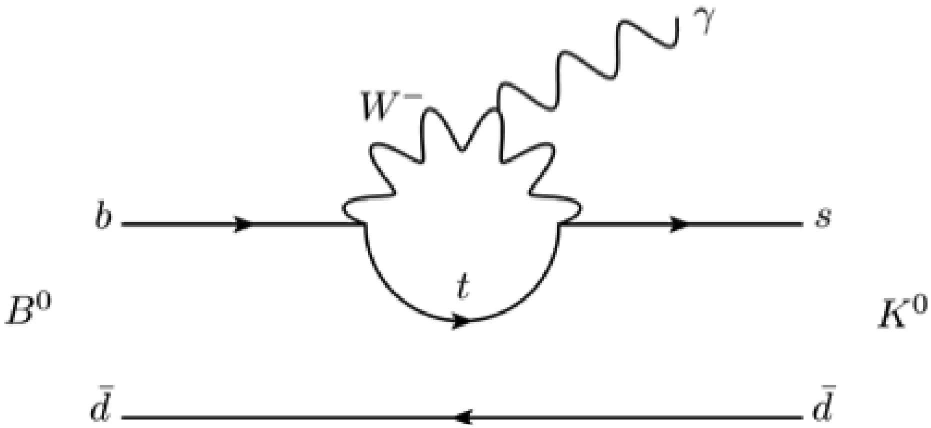
Multiple scattering
Deviation due to scatterings with atoms of the material



Physics analysis

IPHC channel

$$B^0 \rightarrow K_{res}\,\gamma \rightarrow K_s^0\pi^+\pi^-\gamma$$



Rare decay

- b → s loop diagram highly suppresed in SM

Time dependent CP violation asymmetry

- Number of **B** vs. $\overline{\textbf{B}}$ decays in function of time

Non V-A coupling in electroweak interaction:

- Polarization of gamma

➡ Search for physics beyond the standard model

Belle II measurement : CPV

Collision energy tuned to produce Υ(4s)(~10 GeV)

Υ(4s) decays in $\mathbf{B\overline{B}}$ > 96 %

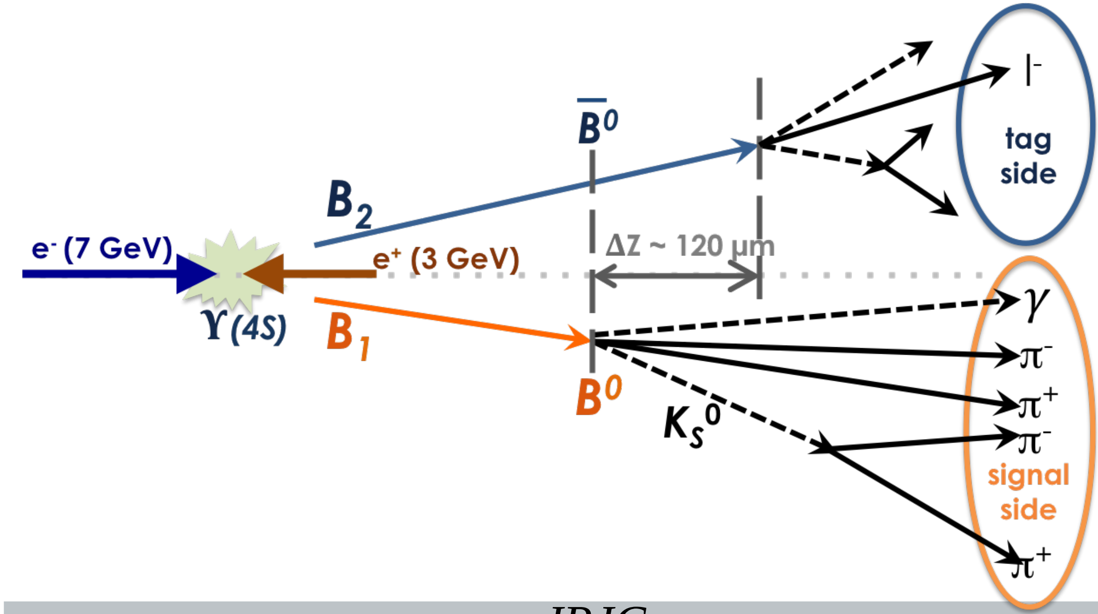
$$CPV\,Asymmetry\,(t) = \frac{\#(B^0 \to f_{CP})(t) - \#(\overline{B^0} \to f_{CP})(t)}{\#(B^0 \to f_{CP})(t) + \#(\overline{B^0} \to f_{CP})(t)}$$

B and $\mathbf{\overline{B}}$ produced in quantum coherence → $\mathbf{B \leftrightarrow \overline{B}}$ oscillations

→ *Flavour tagging*

Beam asymmetry → observable B flight distance → Time Between decays

→ *Time dependecy*



K^0_s reconstruction

K^0_s is involved in a lots of interesting channels

$B^0 \to K^0_s \pi^0 \gamma \quad B^0 \to J/\psi K_s \quad B^0 \to K^0_s K^0_s K^0_s$

- Neutral long lived particle → 2~ 3 cm

  No hits in Vertex detector
  Detection by opposite charged daughter particles

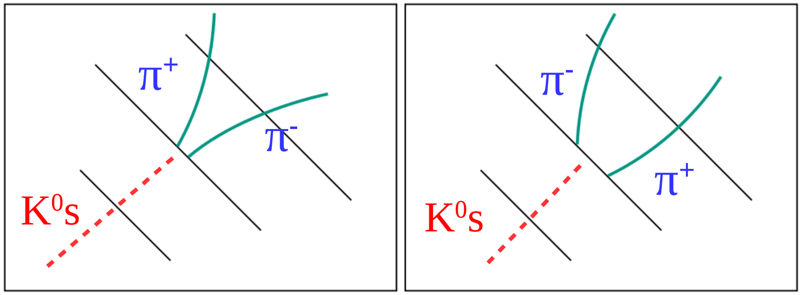


Figure 7.1.: The two possible V0 signatures after track reconstruction.

- Global Tracking extrapolated tracks to IP

  →K^0_s Momentum overestimation due to nonexistent material budget

- We are working on a dedicated tool to avoid this issue :
  - → Good momentum estimation
  - → Efficiency need to be improved

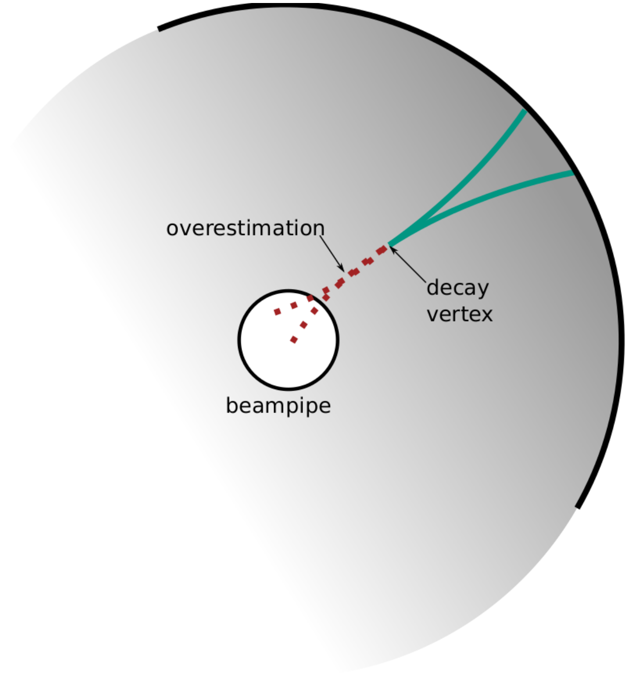
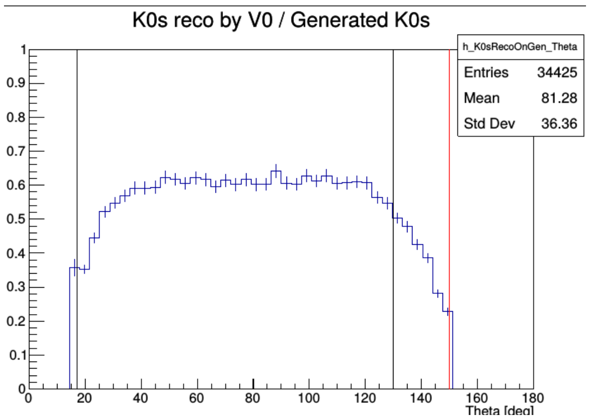


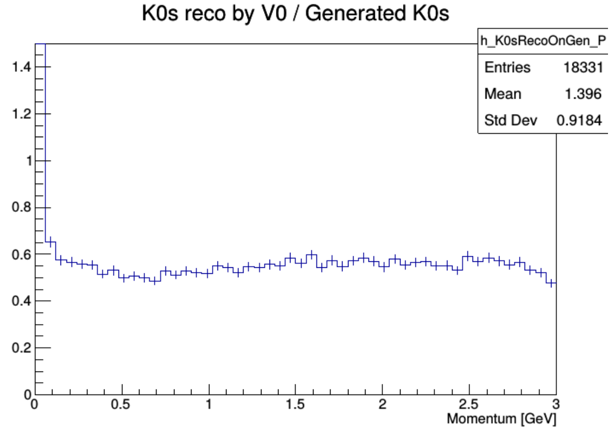
Figure 7.2.: A particle originating from a V0 decay is extrapolated to the perigee. This leads to an overestimation of the momentum.

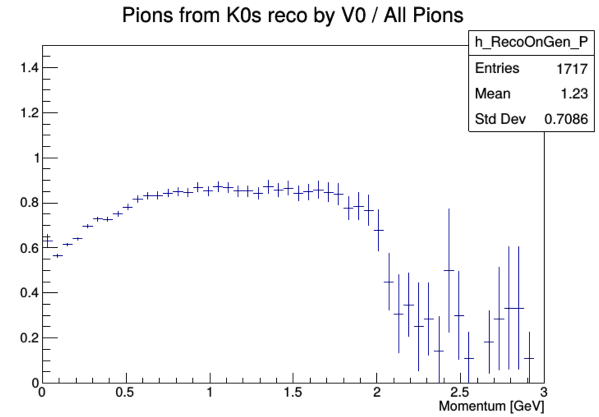
K0s performance study : Preliminary results

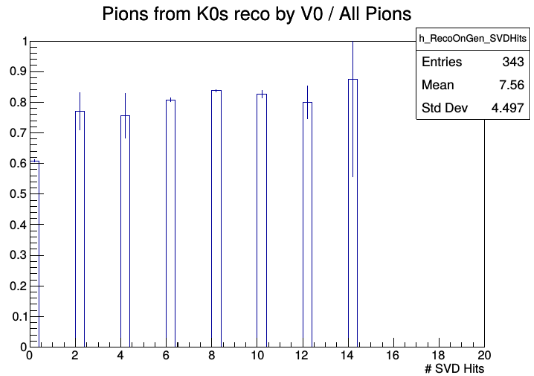
Goal : Find why some K^0_s are not reconstructed

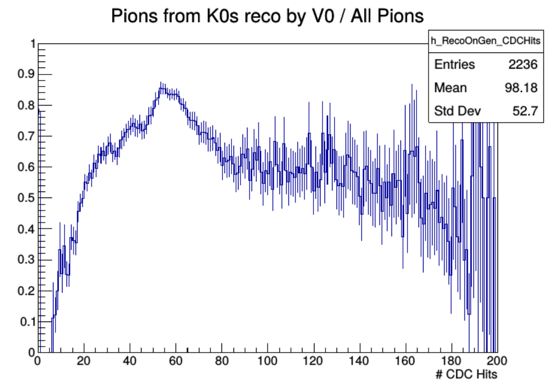
→ Study efficiencies for several parameters











No clear evidence of efficiency drop

→ Now we will focus on the vertexing

Summary

SuperKEKB :

- Highest luminosity ever
  - Large amount of backgrounds → BEAST

Belle II :

- Very sensitive for some flavour physics NP processes
  - TDCPV
  - LFV

Short term schedule :

- Phase II data taking campaign :
  - 5 months on site spring 2018 → BEAST
  - Benchmark measurement
    - K0s reconstruction performances

- Two papers : Beast and PLUME

Merci pour votre attention

Belle II