Master & PhD theses proposition (2016)

Study of the SuperKEKB induced background to prepare the physics analysis in Belle II

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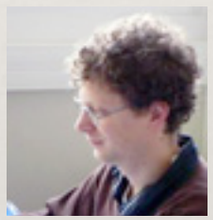
- Group: PICSEL
  www.iphc.cnrs.fr/PICSEL

The PICSEL group

- Main activities:
  - Design of CMOS pixel ultra-light detectors: ALICE upgraded ITS detector, non-HEP applications (SOLEIL, biology, medical therapy). R&D driven by the future ILC experiment. Main achievements: the STAR new HFT detector at RHIC, the Eudet Beam Telescope.
  - Belle II: contribution to the experiment commissioning and preparation of the future physics analysis. Cooperation with KEK and LAL Orsay.
- World-known know-how: attracts world-wide collaborators: Frankfurt (Fair-CBM), Berkeley (RHIC-STAR), Beijing (BEPC-BESSIII), Brookhaven (EIC), Bristol/DESY/Tel-Aviv (ILC-ILD), CERN (LHC-ALICE).
- Complementary expertise:


  - 4 staff physicists: J. Baudot, A. Besson, I. Ripp, M. Winter
    + 1 postdoc: A. Pérez Pérez
    + 1 PhD on Belle II (defense 30 Oct. 2015) + 1 PhD on ILC (defense 17 Sept. 2015).
  - 16 staff engineers (micro-electronic design + test):
    + 1 post-doc + 3 PhD students.

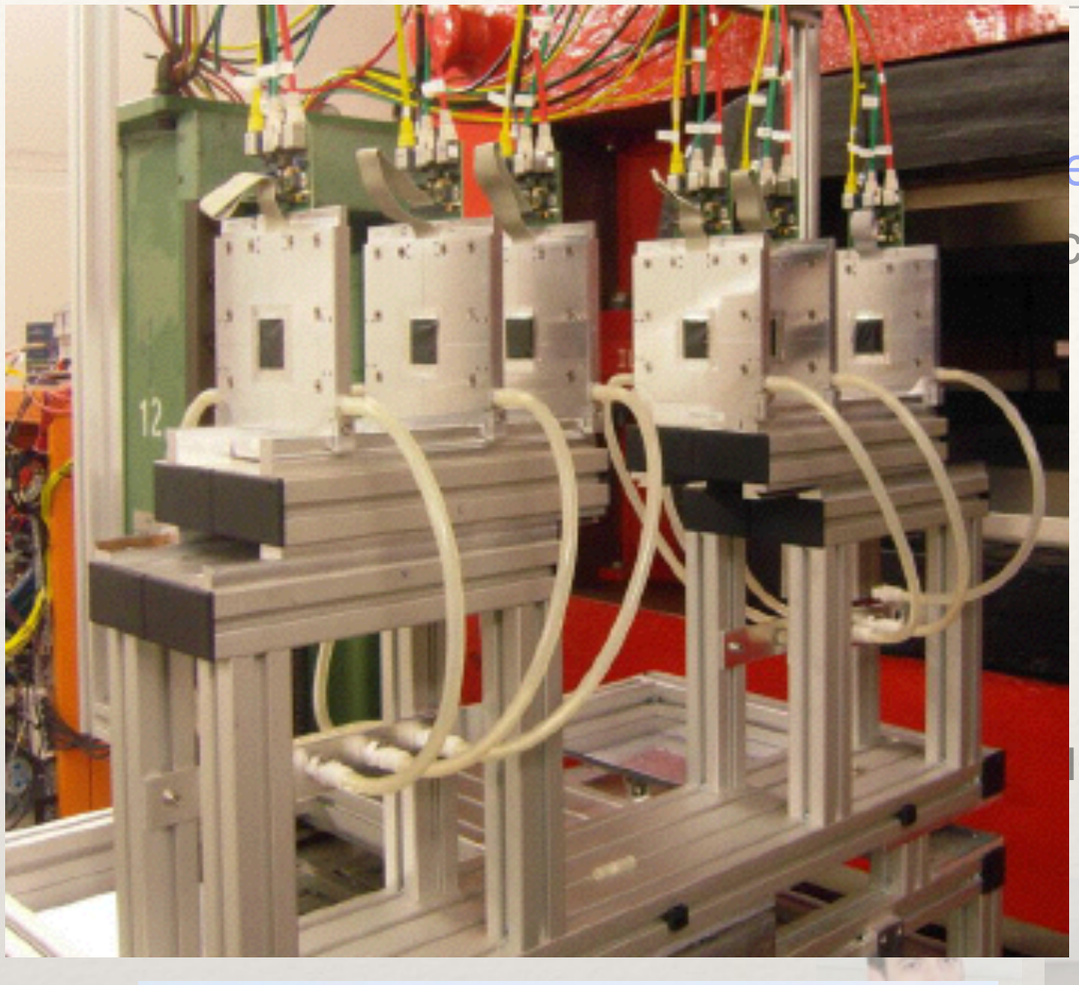
working for Belle II:


G. Claus


M. Goffe


M. Szelezniak

The PICSEL group



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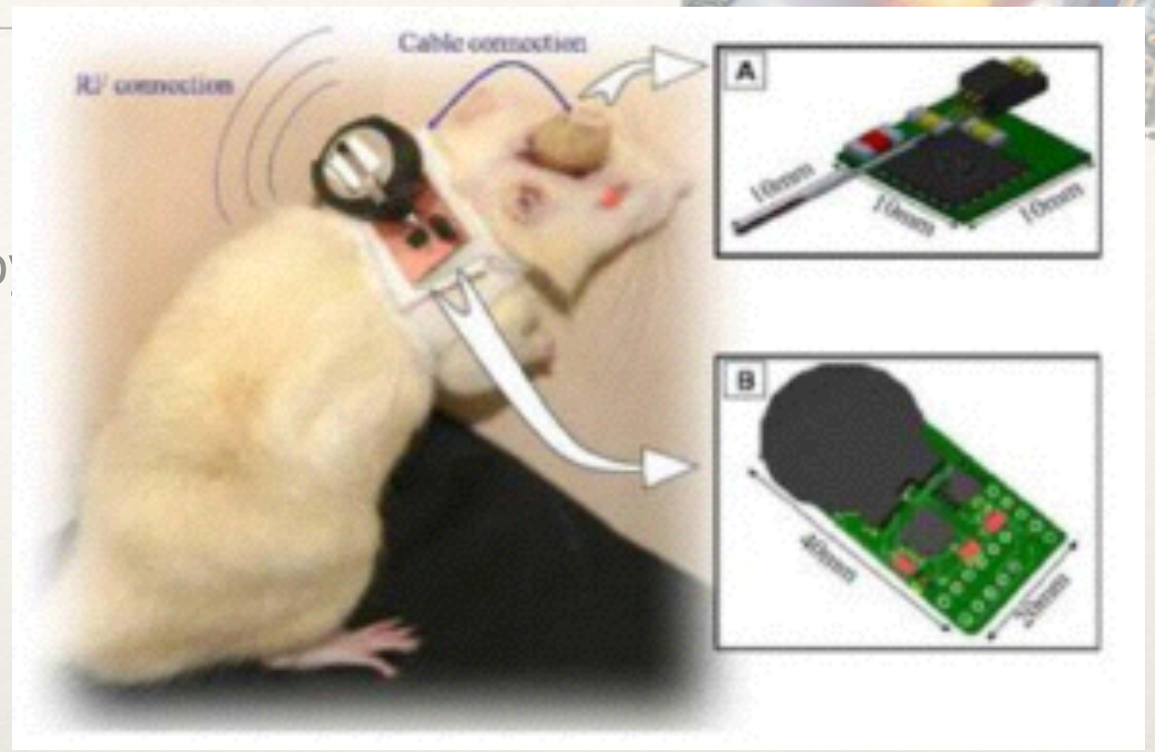
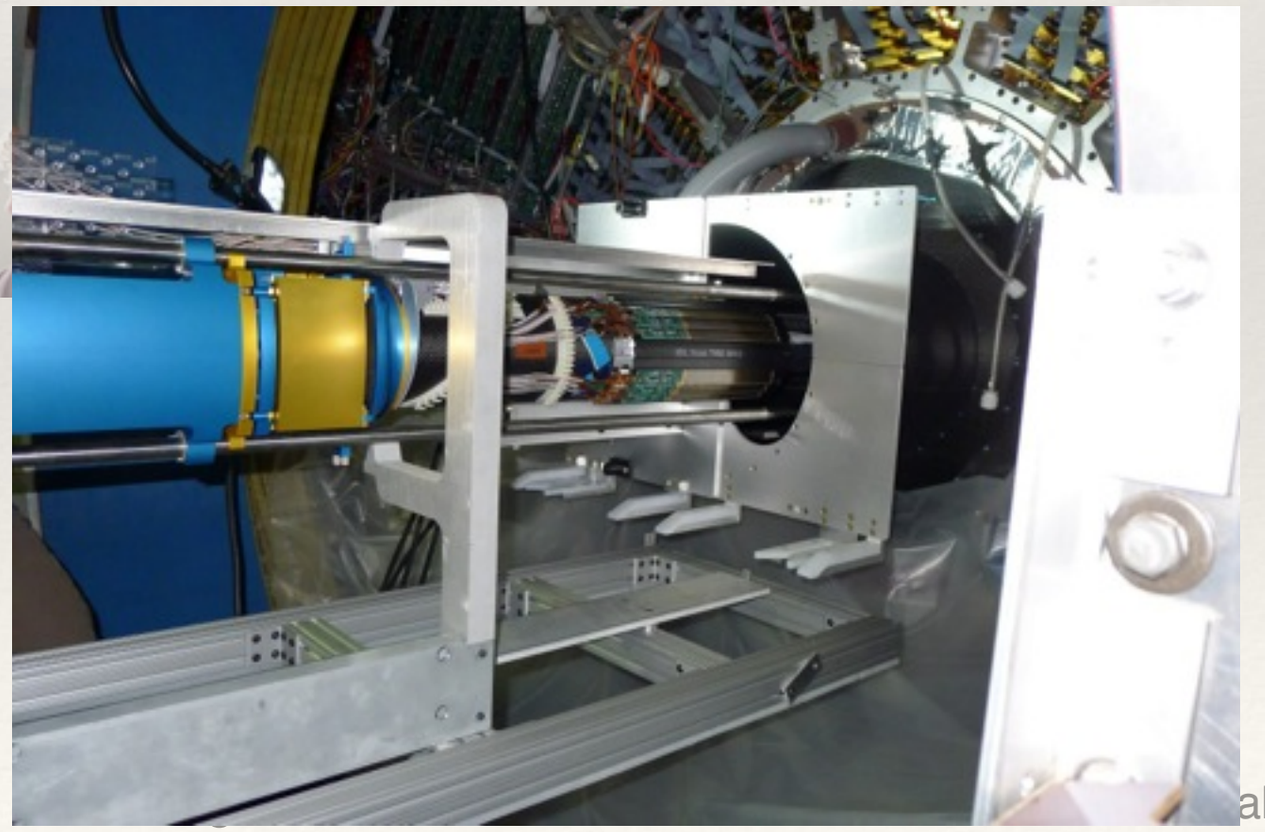


IC), Bristol/DESY/Tel-Aviv (ILC-ILD), CERN (LHC-ALICE)

- C



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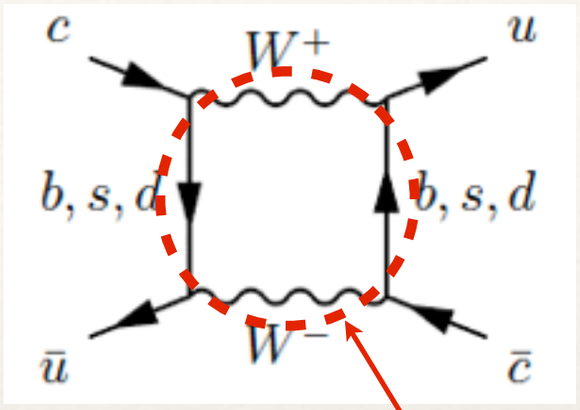
Search for BSM physics: the quantum path (1)

- Finding and understanding New Physics will not be easy!
  - ➛ pursue a global effort relying on different programs:
    - the quantum path (mainly at intensity frontier),
    - the relativistic path (mainly at energy frontier).

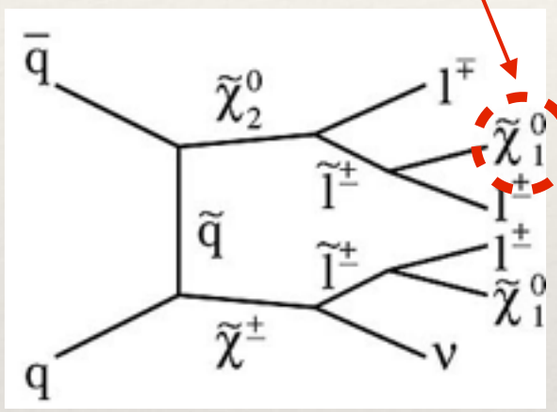
LHCb, Belle II, nEDM, etc.



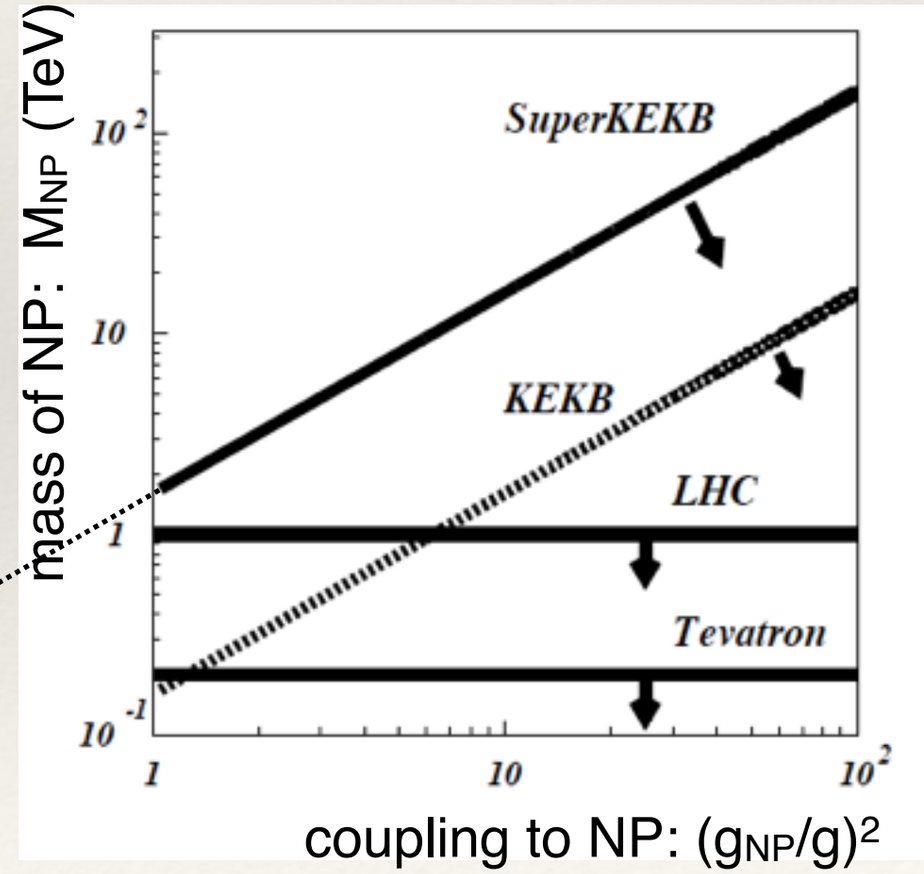
new physics?

ATLAS, CMS, etc.

new physics?

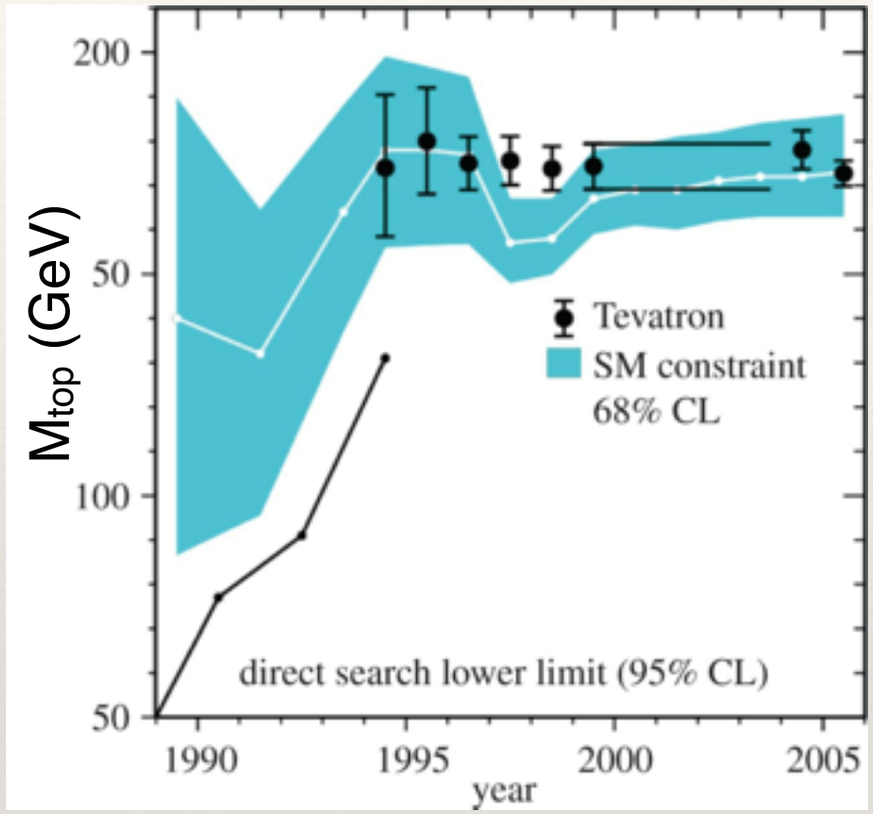


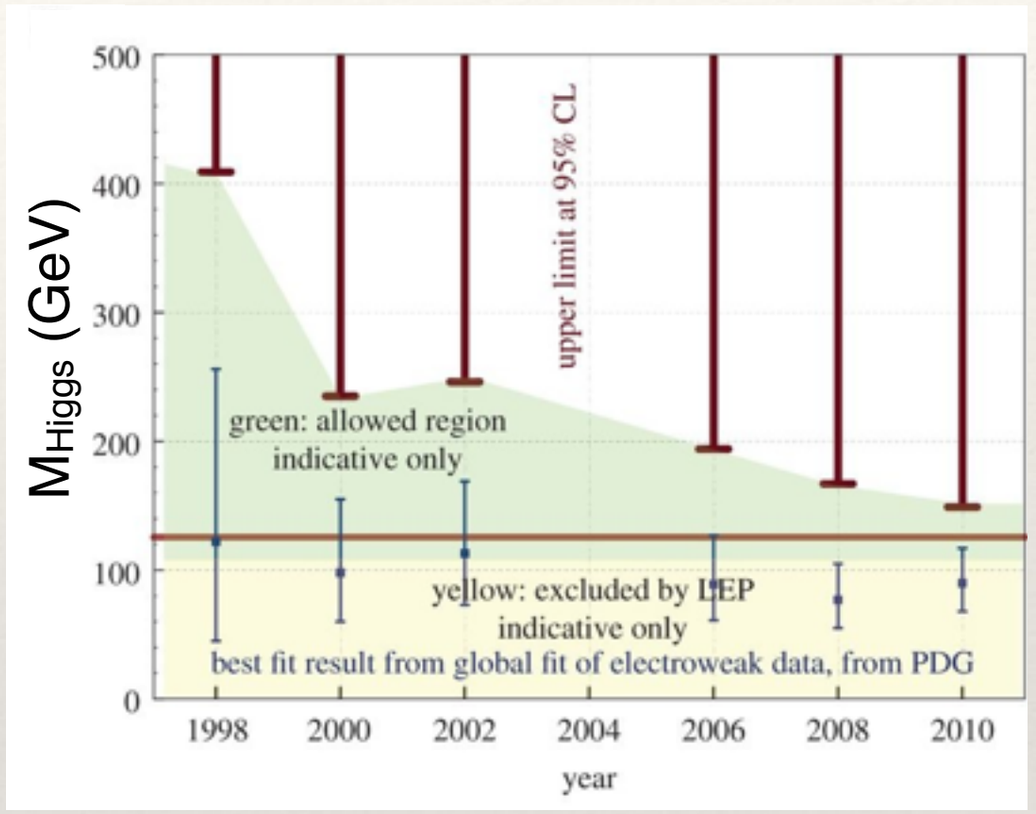
- Flavour physics is a powerful tool to search for NP, may be sensitive to a much higher NP scale than LHC.
- Moreover: sensitivity to very light new particles:
  - very light Higgs,
  - dark photon,
  - light dark matter.



Search for BSM physics: the quantum path (2)

- In the past HEP history, precise measurements sensitive to quantum corrections enabled key progresses: existence of the charm quark, of the 3rd quark family, top mass, Higgs mass, …



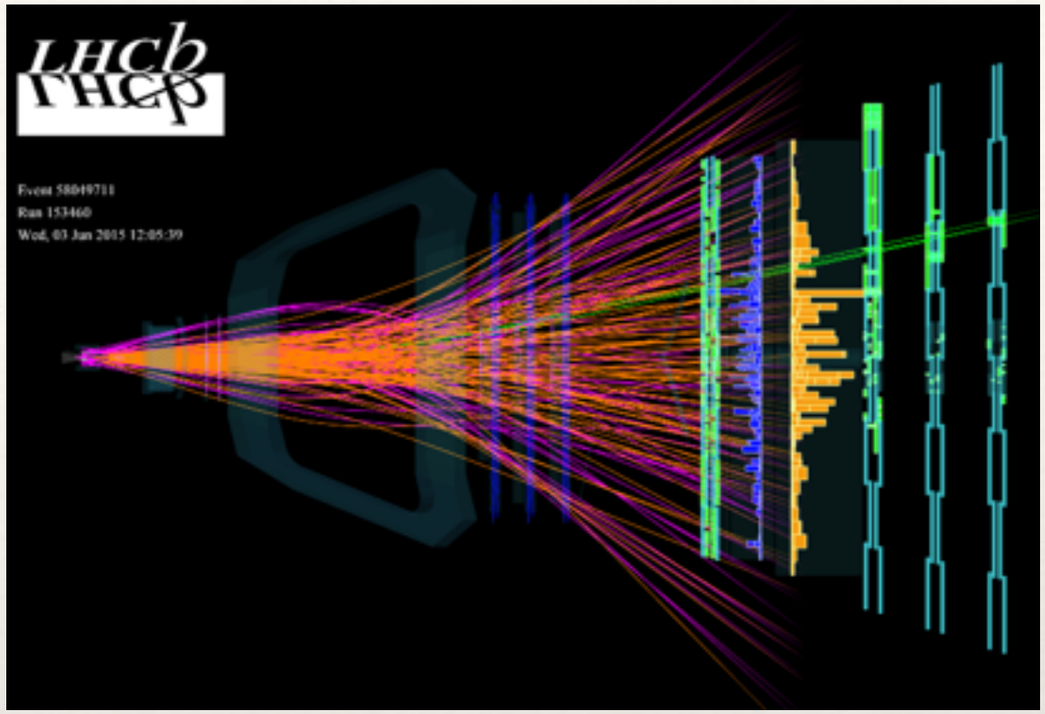


➛ Excellent sensitivity to NP but requires:

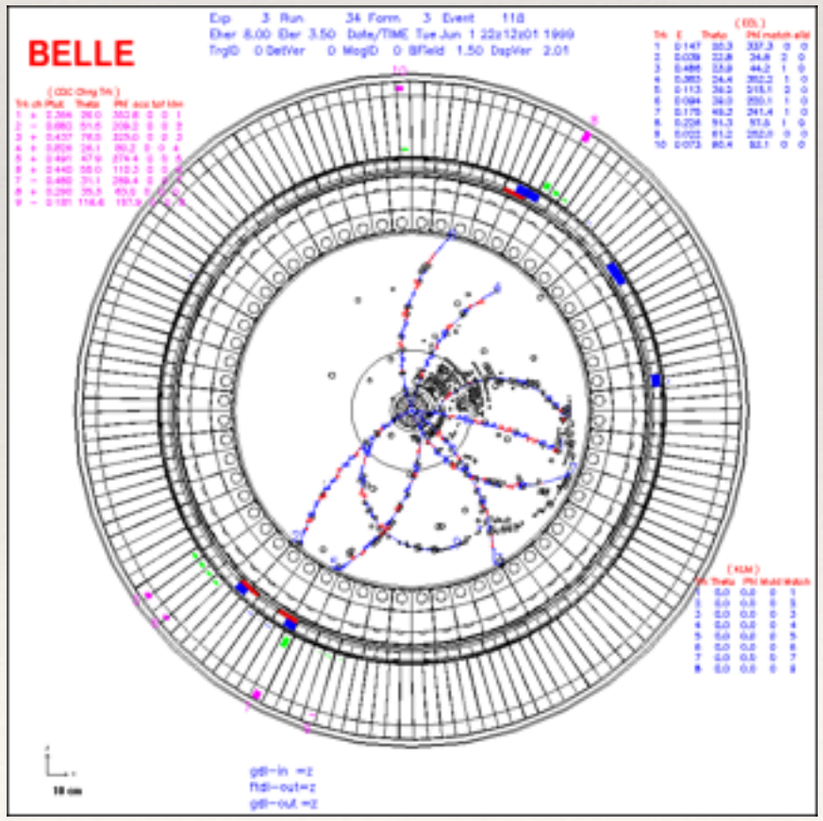
- very high statistics,
- very precise experiments,
- very precise theoretical predictions.

τ lepton, B and D meson production

- At LHC:
  - @√s = 14 TeV, luminosity = 1.5×10^{34} cm^{-2} s^{-1}
    very large cross sections: $\sigma_{bb} \sim 530$ μb.
  - Pile up: many collisions in one event.
  - All species of b-hadrons created in jets through hadronisation of quarks.
  - Large boosts ➛ B mean decay length ~ 1 cm.
  - Hadron collisions (composite): only transverse missing E and p can be measured.



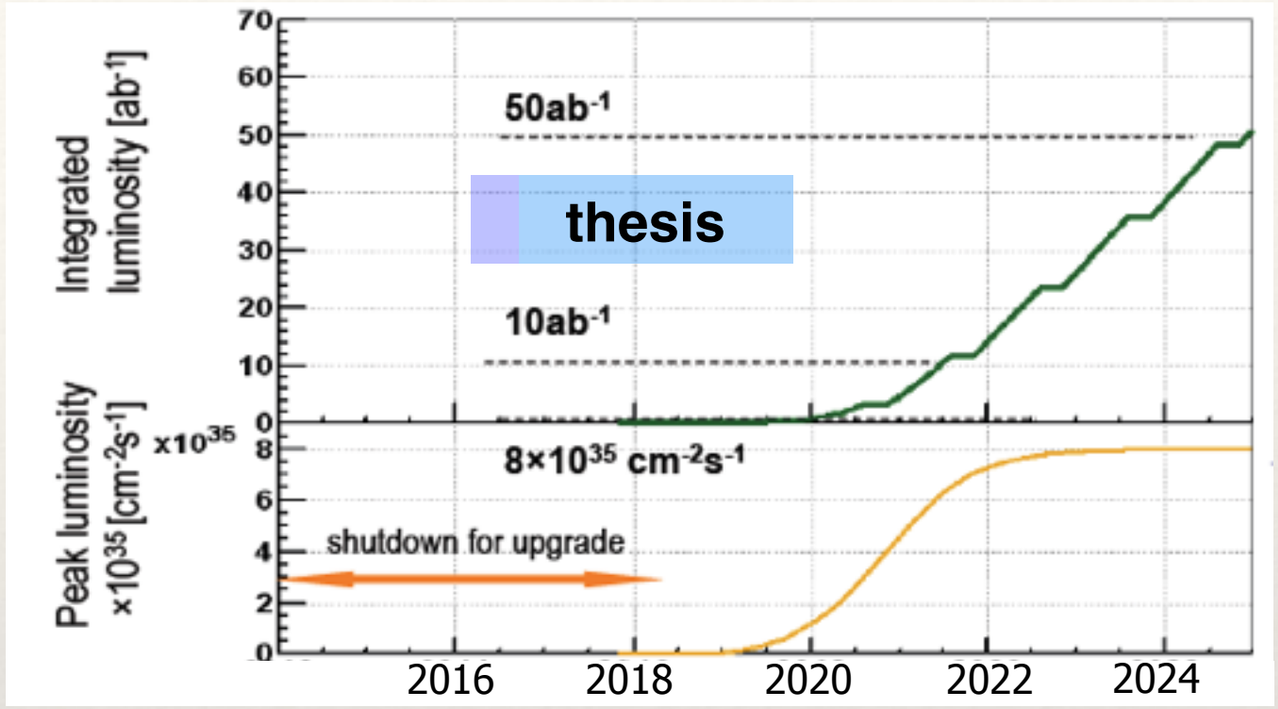
- At SuperKEKB:
  - @√s = $M_{\Upsilon} \sim 10.5$ GeV, $\sigma_{bb} \sim 1$ nb
    very high luminosity = 0.8×10^{36} cm^{-2} s^{-1}.
  - $\Upsilon(4S) \rightarrow B^0B^0, B^+B^-$, no hadronisation
    ➛ quantum correlation between mesons.
  - Machine background induced by nano-beams.
  - Boost: βγ = 0.28 ➛ B mean decay length ~ 140 μm.
  - Lepton collisions: known intial state & clean final state.



The SuperKEKB collider

- Asymmetric beams: e^- 7 GeV - e^+ 4 GeV.
  Collisions with $E_{c.m.}$ around $M_{\Upsilon(4S)}$ and $M_{\Upsilon(5S)}$.
- Technological breakthrough:
  nano-scale beam transverse size:
  ~KEKB/20 in y, $\sigma_x \times \sigma_y \sim 10\ \mu m \times 60$ nm.

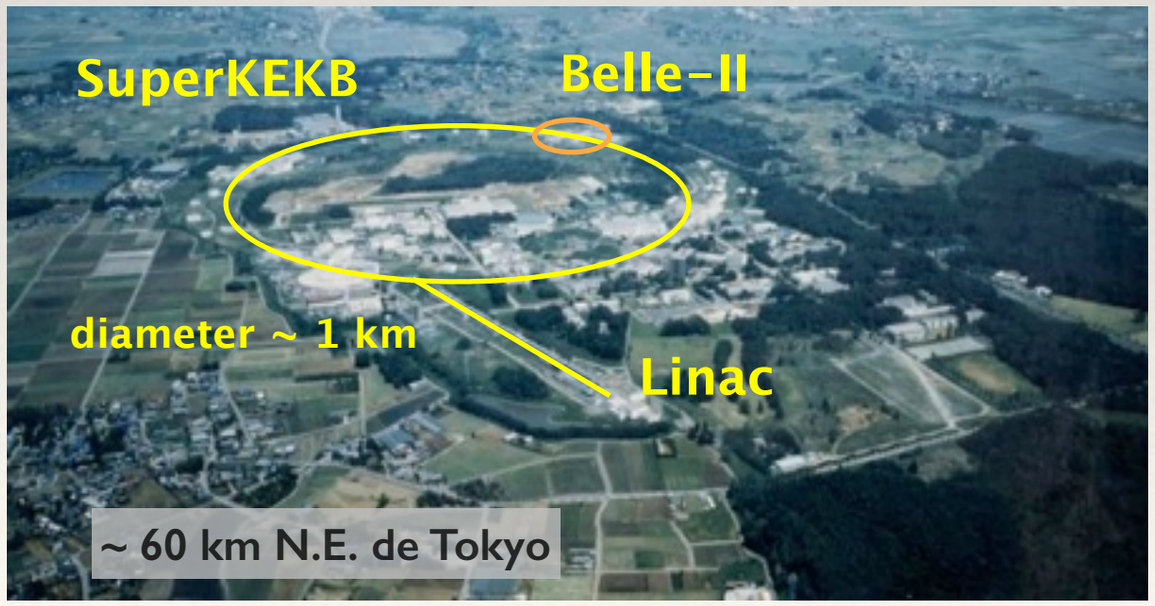
➔ Most intense collider in the world:
0.8×10^{36} cm^{-2} s^{-1}
Current world record x40.



October 2018:
start of data taking

Early 2016: BEAST II
collider commissioning

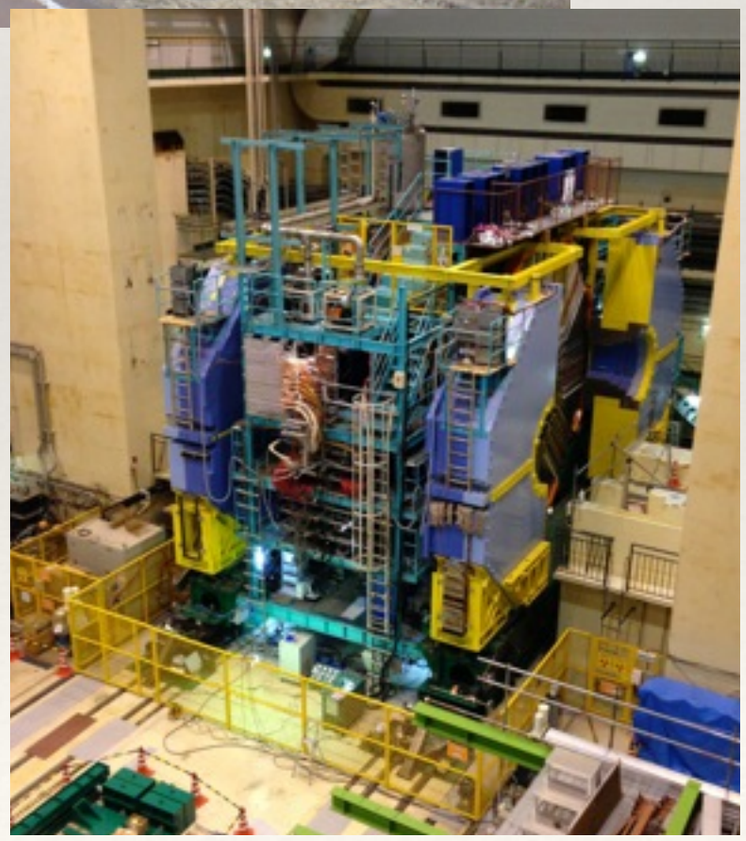
Mid 2024:
50 ab^{-1}
on tape



The Belle II experiment

KEK laboratory: in Tsukuba (Ibaraki prefecture)
~60 km NE from Tokyo.

KEK
(Tsukuba)



PhD thesis proposition: practical aspects (1)

- Financial Support: Academic marks prevail to be funded.

  Possibility to extend the contract with a teaching duty.
  Net salary: 1300 €/month (1600 € if teaching).
  2 possible ways to be funded for this thesis:
  - Ecole Doctorale de physique et chimie-physique de l'Université de Strasbourg.
  - Unistra IdEx: only for candidates with a Foreign Diploma.

- Dates: Oct. 2016-Sept 2019.

- Travels to Japan: several short term (1 week) stays at KEK + one long term (3 months?) stay in 2017.

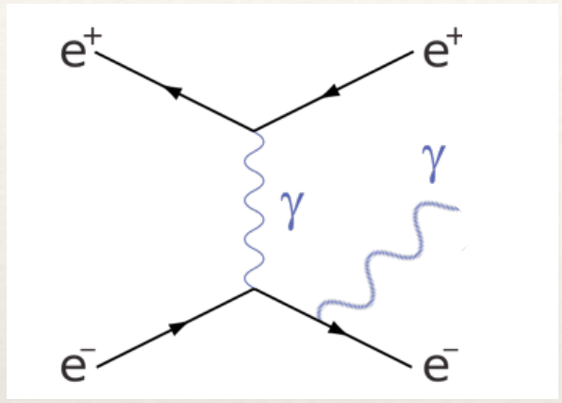
- Topic of the thesis: Study of the SuperKEKB induced background to prepare the physics analysis in Belle II, consists of two different parts:

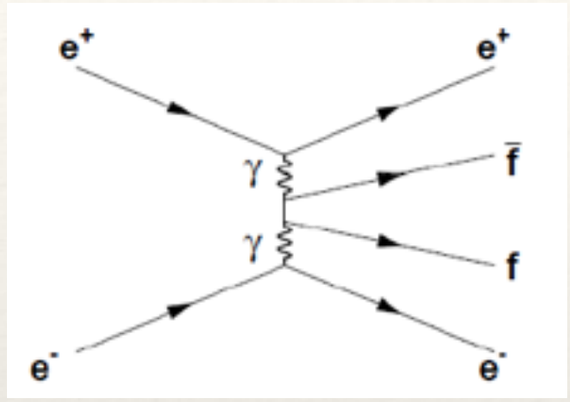
  1. Instrumentation: detector expert (but no R&D) and participate to the data analysis on a totally unexplored topic (first data with a nano-beam colliding scheme).
  2. Physics analysis: prospective physics analysis to search for physics beyond the SM which would benefit from an improved vertexing.

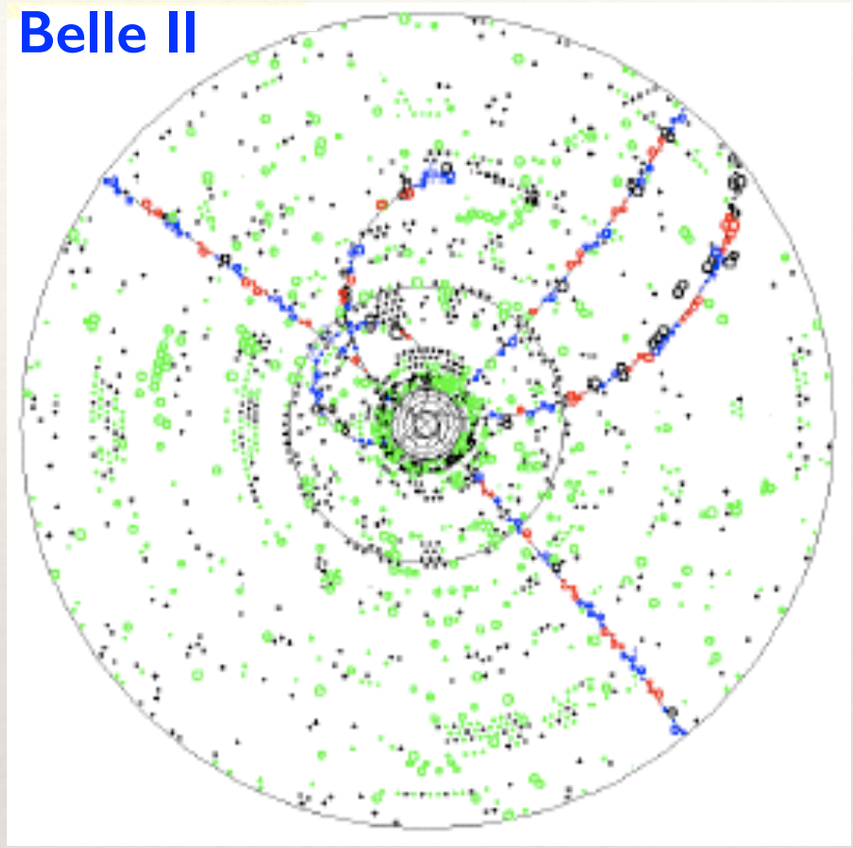
PhD thesis proposition: practical aspects (2)

Study of the SuperKEKB induced background (1)

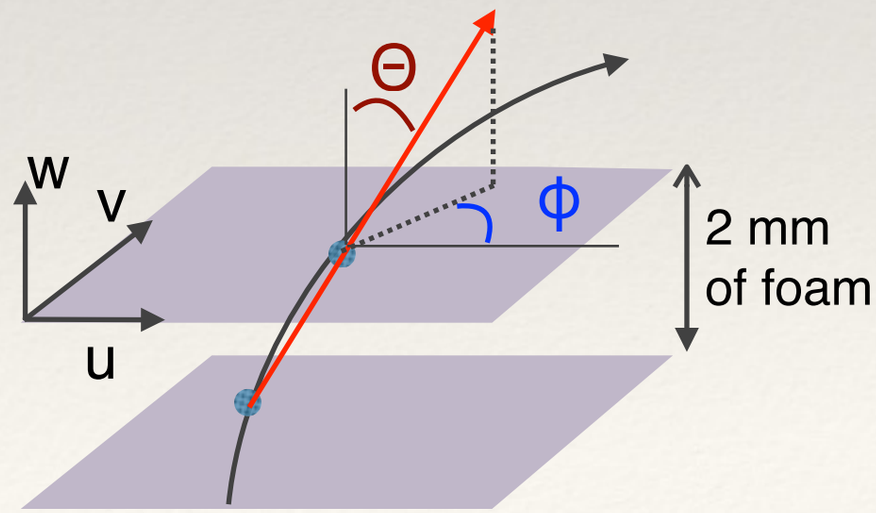
- Machine induced background = intra-beam or beam-beam interactions (QED processes) producing final state particles which will overwhelm the signal induced by the collision products.







- Characterisation of theses processes using two double-sided pixel ladders PLUME, developed at IPHC and providing unique information (very light and double-sided):
  - Measurement of the classic hit rate,
  - Tracking is possible under certain hypotheses,
  - Unique information on the track incidence.

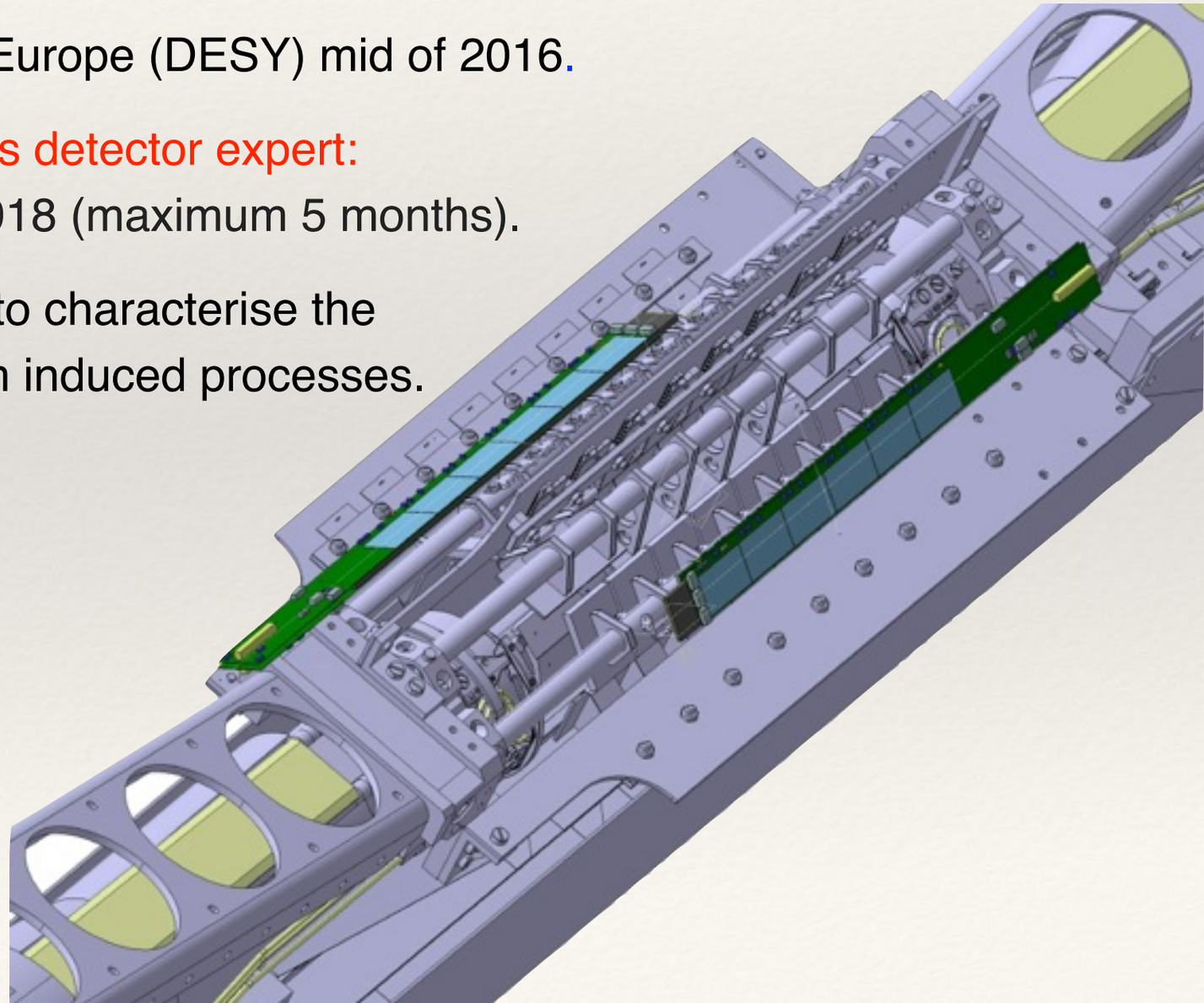


Study of the SuperKEKB induced background (2)

- Design and construction of the PLUME device: already carried out, mainly by the Engineers of the PICSEL group.
- Preparation of the data analysis: identification of relevant measurements and implementation in an already existing software framework developed in the group.

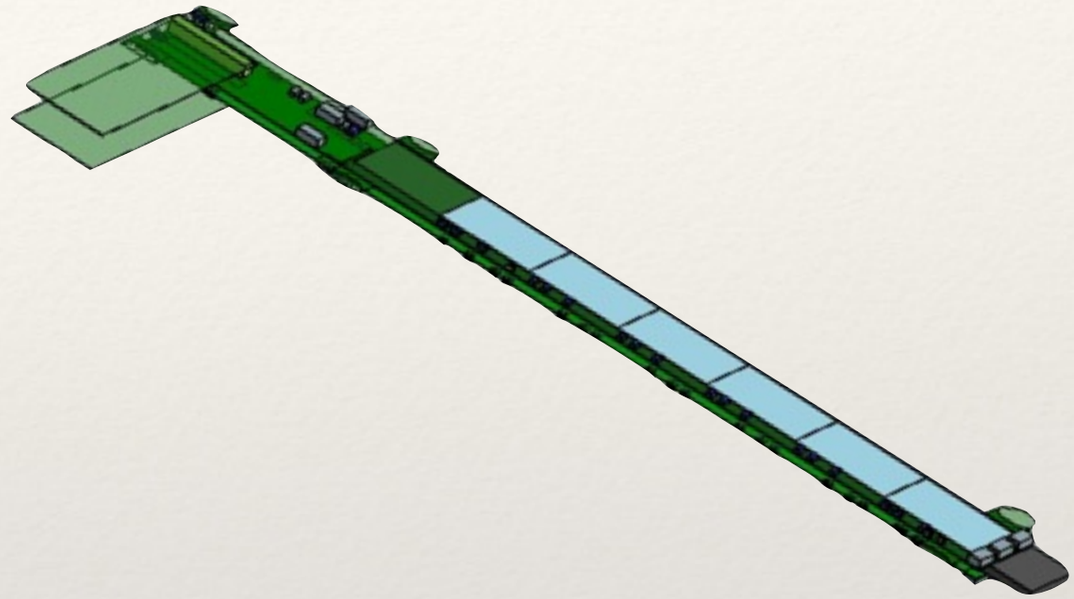
↳ **during the Master thesis**

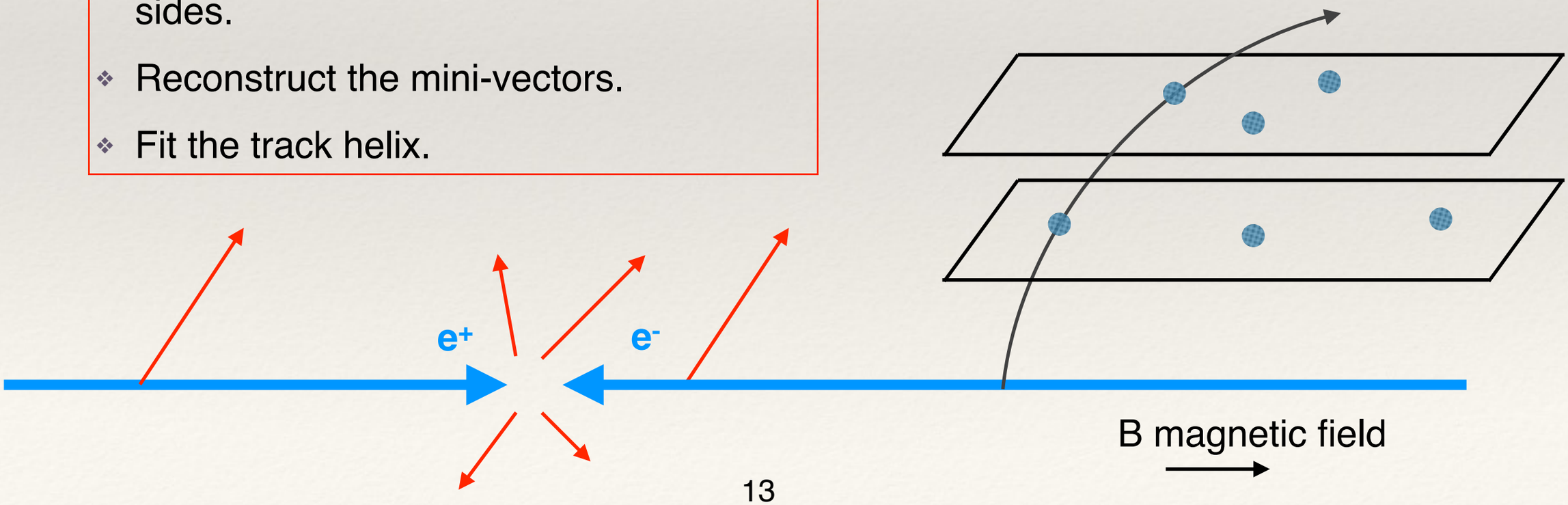
- Installation of the detector: expected in Europe (DESY) mid of 2016.
- Participation of the data taking at KEK as detector expert: scheduled from May 2017 to January 2018 (maximum 5 months).
- Data analysis (several months in 2018) to characterise the SuperKEKB intra-beam and beam-beam induced processes.
- Publication.



Master thesis

- Dates: March 2016 - June 2016 (+ possible to continue during the Summer).
- Particular goals of the Master thesis:
  - Bibliography: the Belle II experiment, its physics program, SuperKEKB, processes produced by the collider.
  - Making use of the added value of double-sided precise measurements to identify the different processes produced by SuperKEKB.
    - Classify the different kinds of signals induced by the different processes.
    - Associate 2 by 2 hits measured on both sides.
    - Reconstruct the mini-vectors.
    - Fit the track helix.

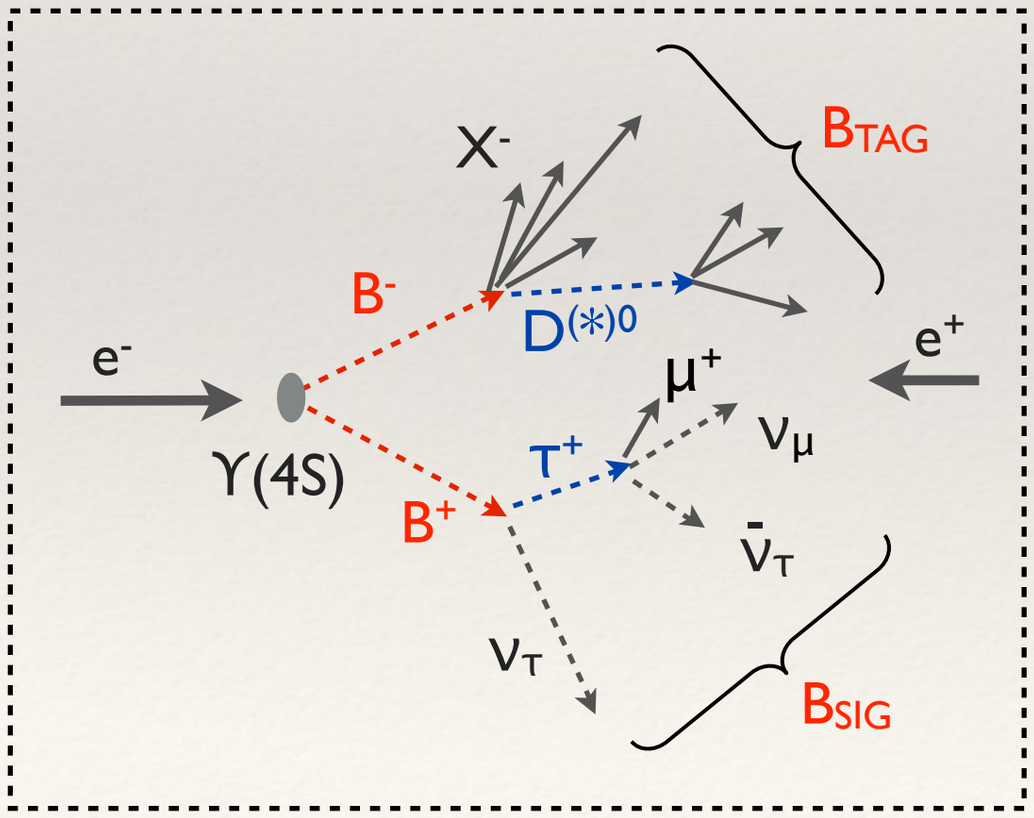




Prospective physics analysis: search for New Physics

- Main ways to search for NP in Belle II:
  - Measurement of Branching Ratios, in particular of rare decays:
    e.g. $B \to \tau\nu$, unfeasible at LHC, very sensitive to an $H^+ \to \tau\nu$ contribution.
  - Measurement of CP asymmetries in meson decays as a function of time. Sensitive to a new source of CP violation, needed to explain the observed matter dominance.
  - Direct search of light unknown particles (dark photon as a dark matter candidate, light Higgs, …).

➔ rely often on the accurate meson decay vertex reconstruction.



- Proposition of work for the thesis:
  - Improve the B_{TAG} decay vertex reconstruction: separation of B and D vertices in case of semi-inclusive vertex reconstruction.
  - Quantify with a physics benchmark to be defined.
- Possible cooperation with a theorist from Karlsruhe.

Conclusion

- Unique opportunity to contribute to the switch-on of an HEP collider experiment.
  First Belle II data during the thesis.
- Several stays in Japan.
- Very complete thesis work with physics analysis and an instrumental part.

➛ a good CV will ensue 😀 !