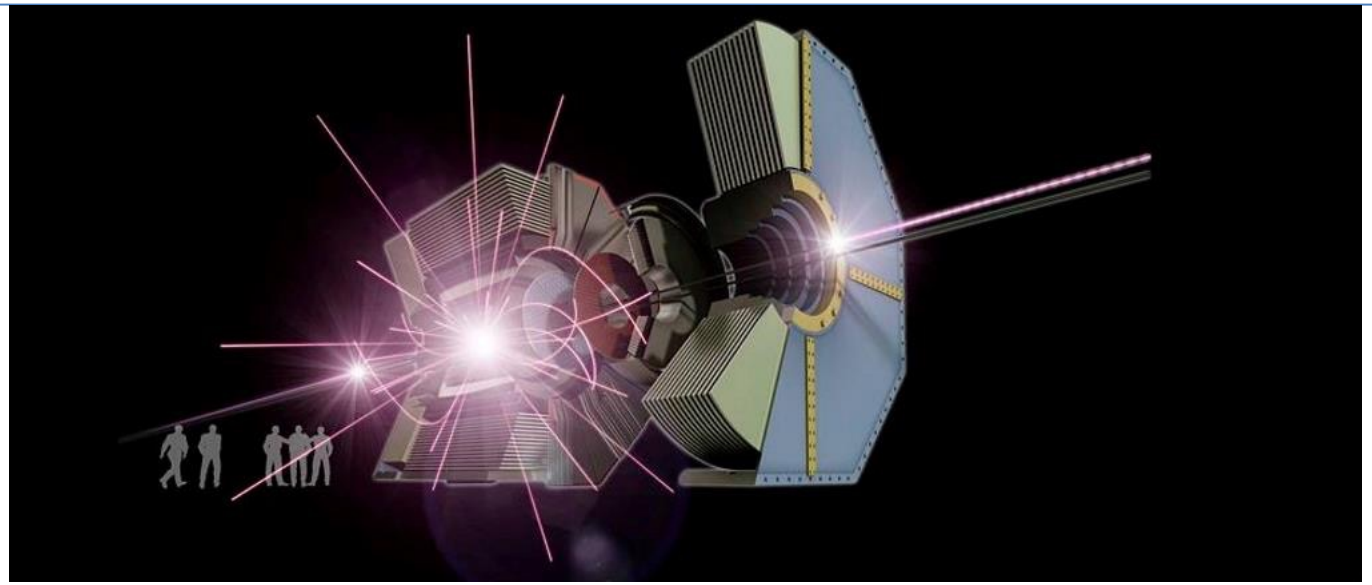
Internship & thesis proposal to Master 2 Subatomic and Astroparticle Physics

Strasbourg, 23 October 2025

https://indico.in2p3.fr/event/36917/

Presented by Jerome Baudot
For the Belle II group

A new Belle II vertex detector for beyond the Standard Model physics



Do we know:

- all symmetries?
- all particles?
- all space-time dimensions?

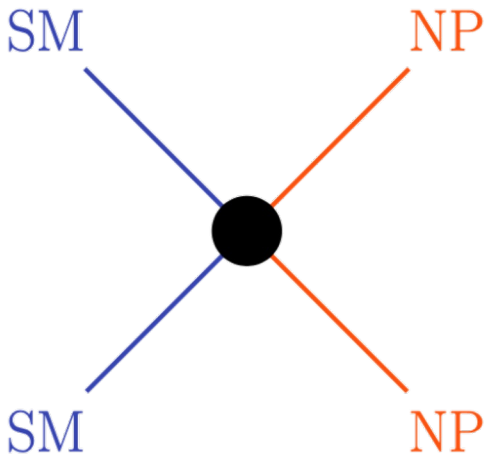
- to which extent current symmetries or asymmetries hold?

=> In particular: axial-vector coupling of weak interaction

- to which extent elementary particles are not composite?

Let's search! for Beyond Standard Model physics

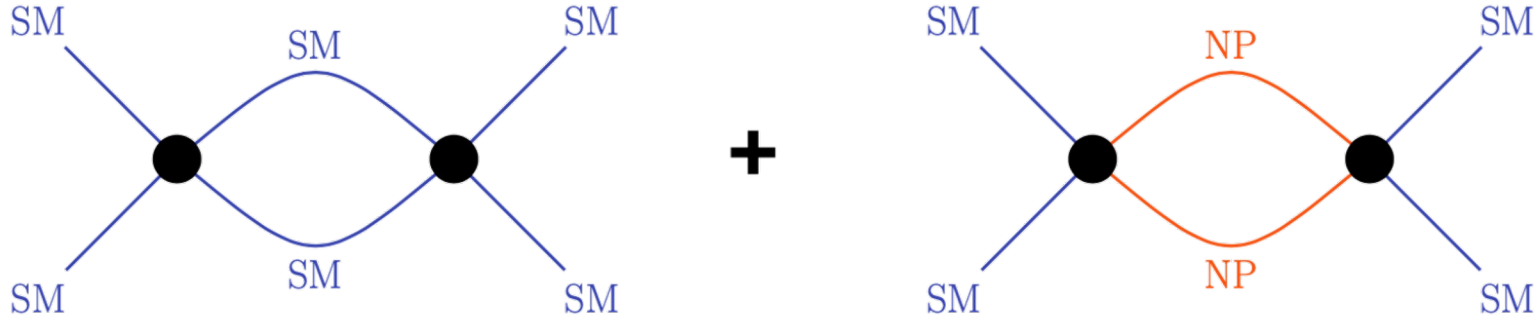
Direct detection



Limited by the centre of mass energy of the detector

=> Energy frontier: LHC

Loop effects

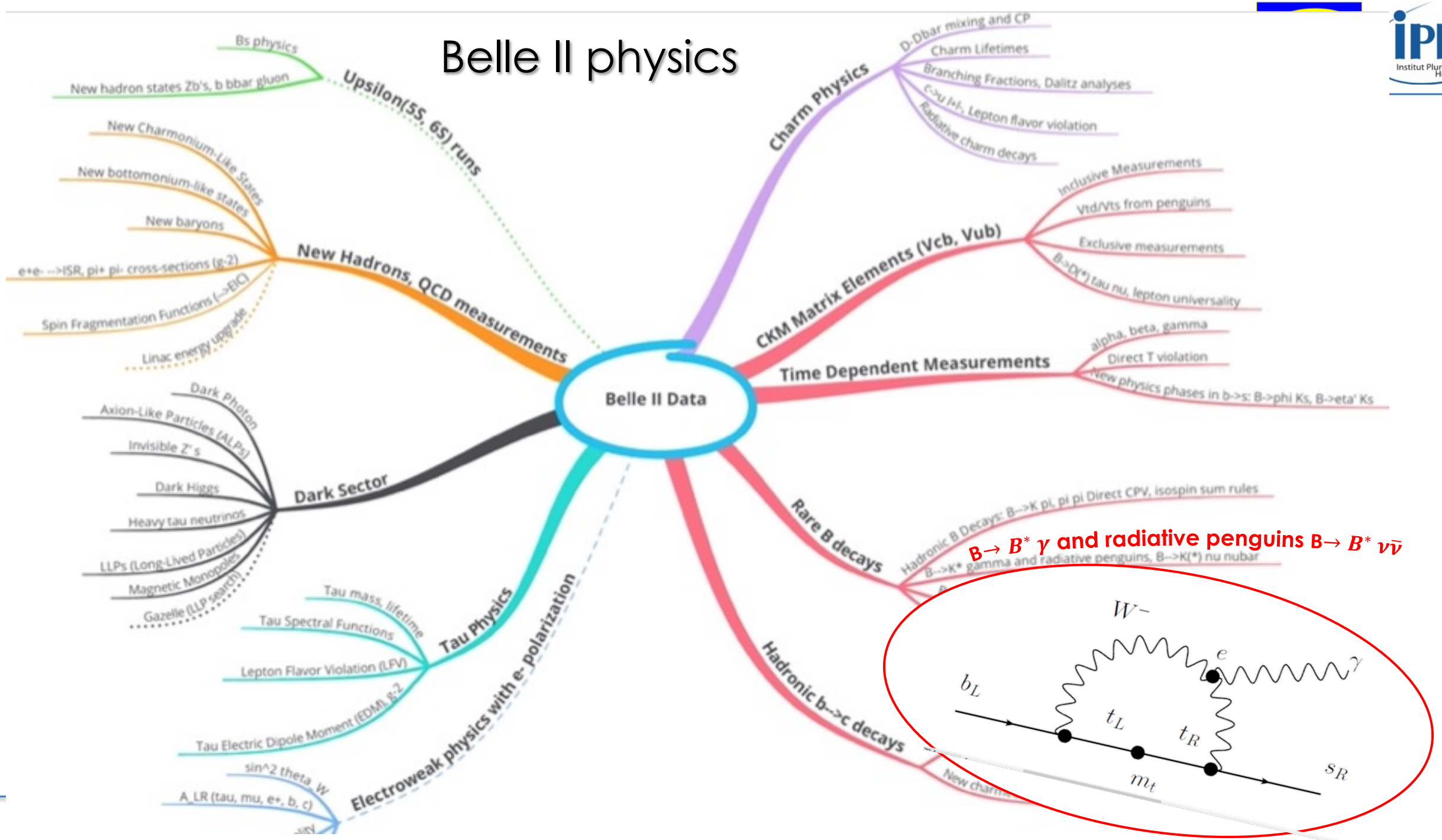


High mass particles can enter the loop ($\Delta E \Delta t \geqslant \hbar/2$)

Limited by the sensitivity to process probability change

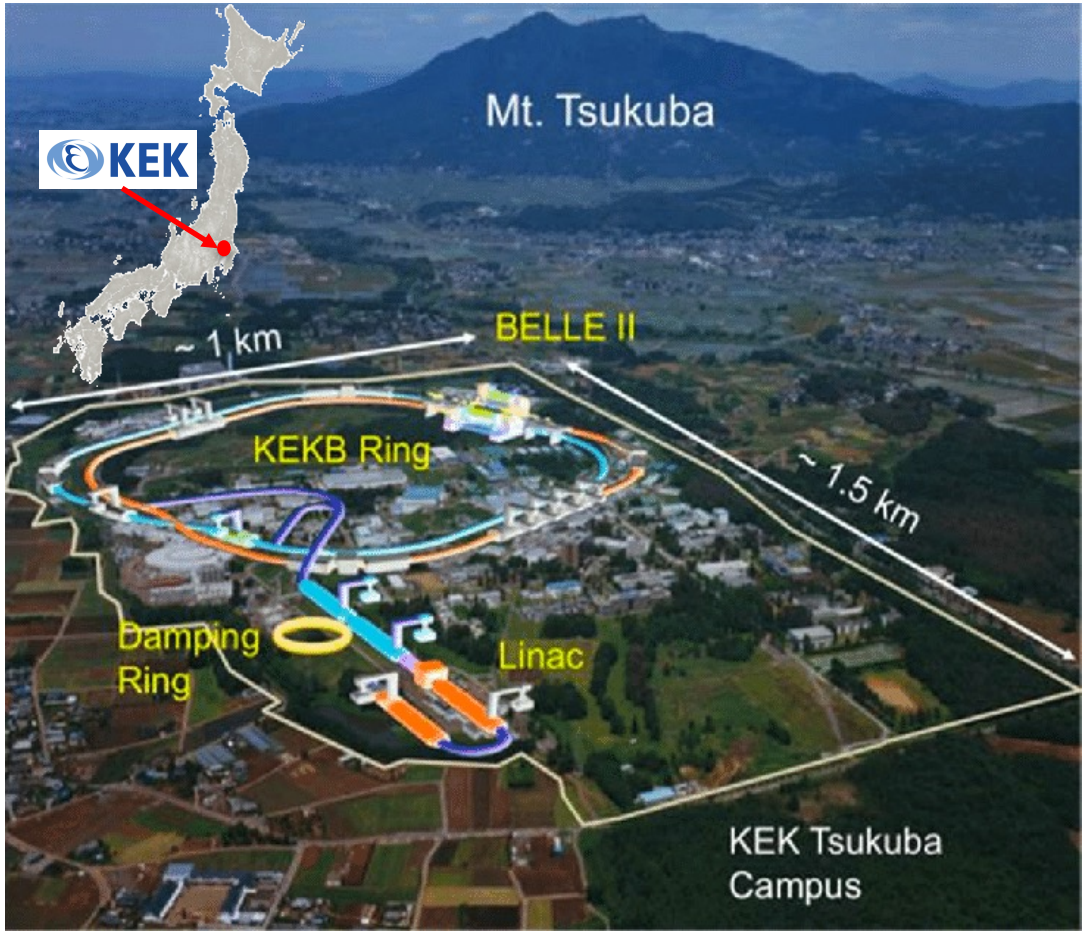
=> Intensity frontier: Belle II

Belle II physics



The place to be: KEK, Tsukuba, Japan

Modest in size and energy $\sqrt{s}$ = *10.6 GeV* …



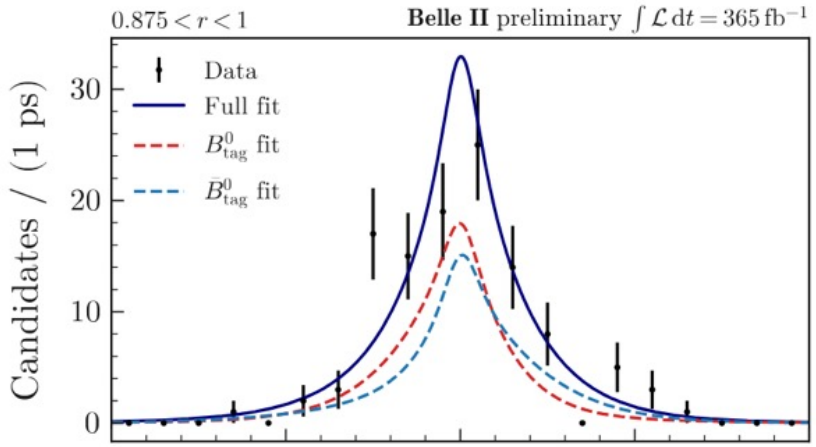
… but clean final states …

- Strasbourg's paper arXiv:2510.01331

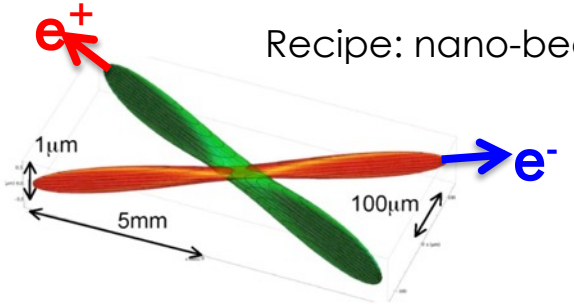
$B^0 \longrightarrow K^0_S \pi^+ \pi^- \gamma$

Branching fraction 10^{-5}

CP sensitivity 11%



… and world record luminosity: 0.5 x10^{35} cm^{-2} s^{-1} (2024)

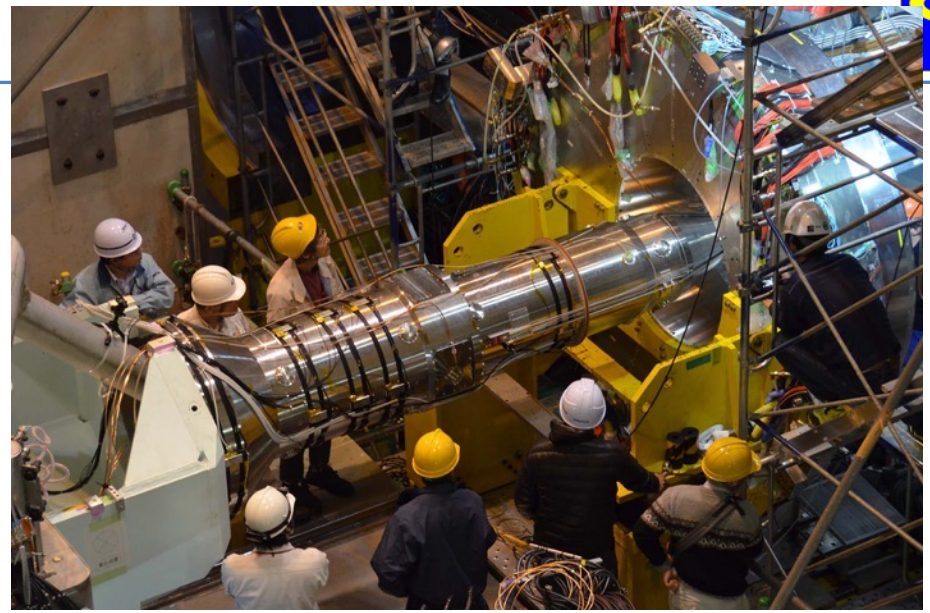


Recipe: nano-beam + marge current

We want more !

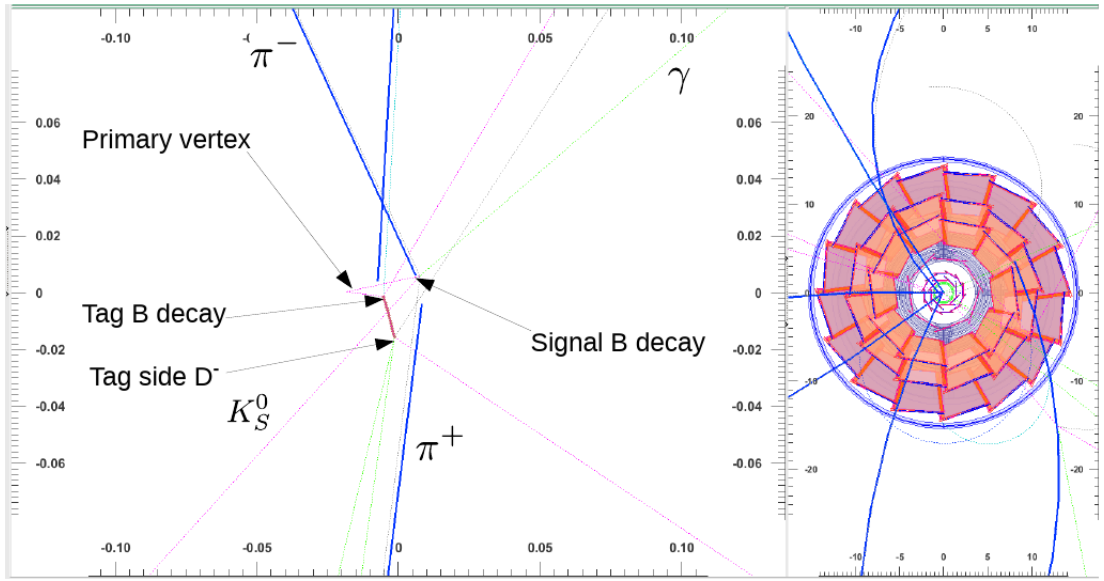
- In 6 years SuperKEKB jumps toward **6 x10^{35} cm^{-2} s^{-1}**

  => target integrated lumi: 50 ab-1



- Major impact on vertex detector

120x10^{6} hits/cm^{2}/s will exceed current limit



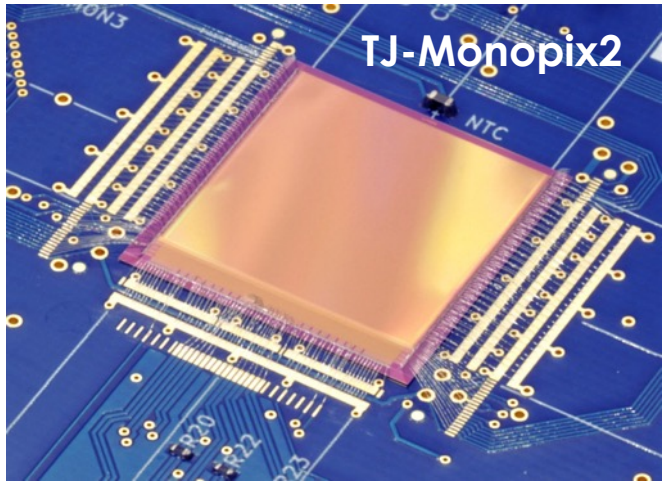
Question: How do we keep …

- Excellent position resolution ~10 µm
- Low material budget << 1% X_0 / layer

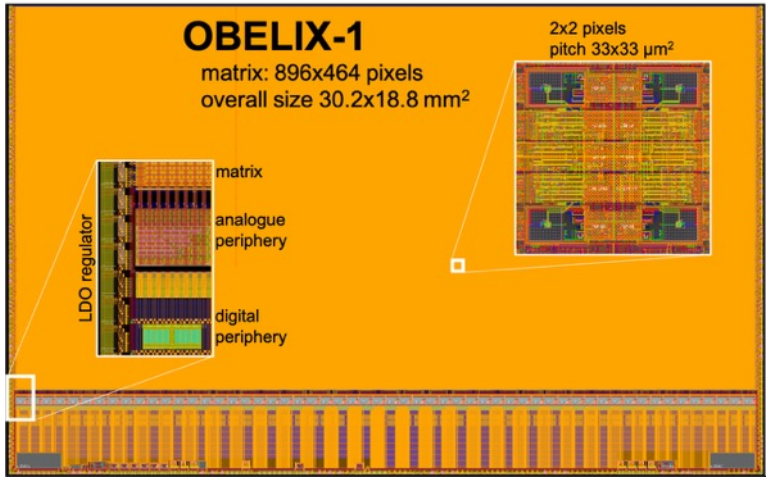
… at such high hit rate?

Answer: MAPS and the VTX project!

- Monolithic sensor: small pixels with incredible performance



2020 → 2025



- Position: 9 µm
- Timing: 50 ns
- Fine-timing: 3 ns
- Temperature: 30 °C
- Tolerant to: $3x10^{14}$ n/cm²
- Thickness: 50 µm

- The VTX is the first vertex detector of its kind: granular and fast

+ allows track-triggering

+ insensitive to synchrotron radiation

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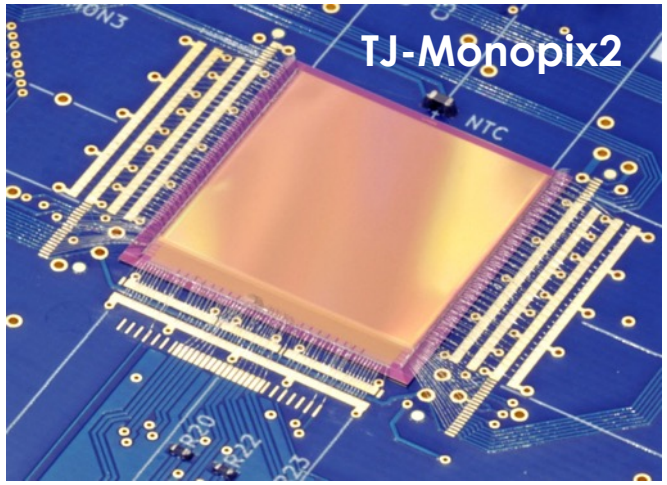

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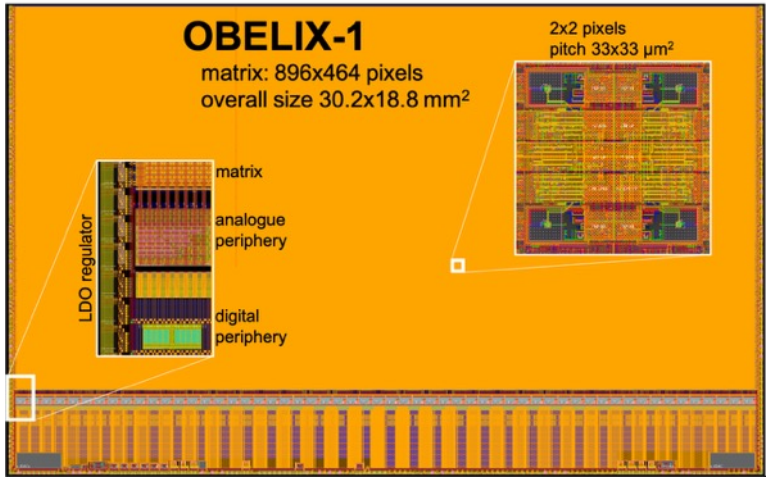

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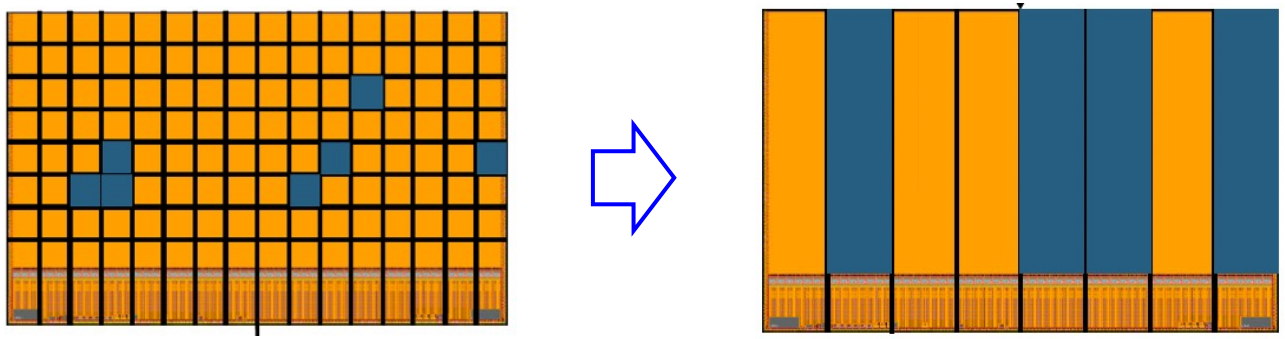
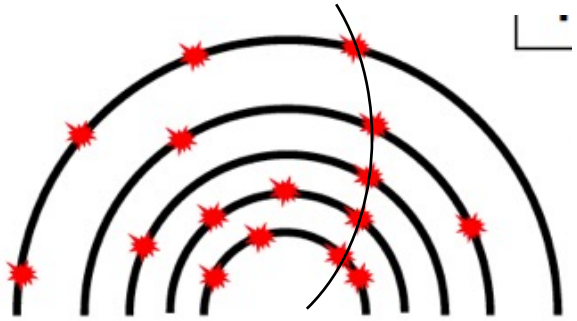
We actually did not prove that !

Topics for the internship 1/2

- Track-triggering
  - works fast-enough with reduced granularity!
  - Promising initial work with 8 strixels (Mattéo)



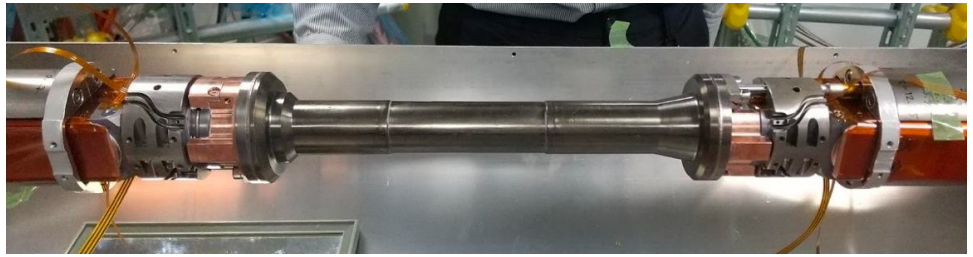


=> What is minimal number of strixels?

=> Can we get 'much' better results with 16 strixels?

Topics for the internship 2/2

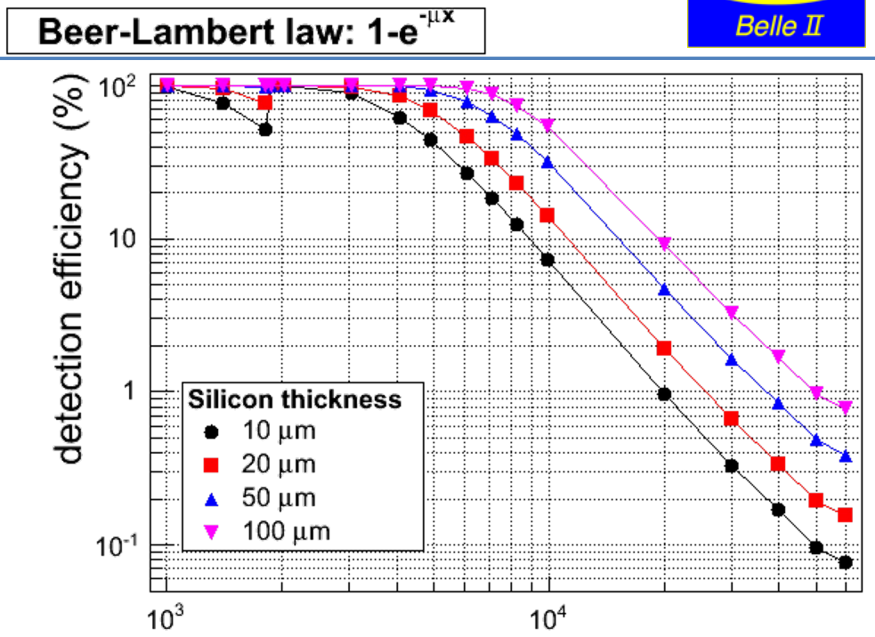
- Synchroton radiation
  - Beam pipe is thicker than 1st vertex layer => bad for precision

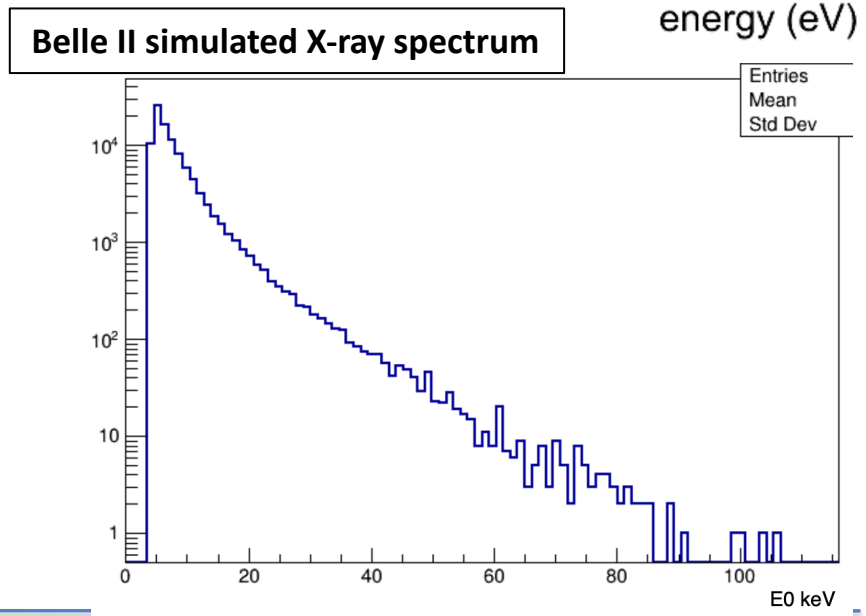


  - Reason: 10 µm gold coating to stop X-rays
    - Needed for present DEPFET pixel technology 75 µm thick
  - MAPS are thinner: 30 µm

⇒ can we get rid of the gold?

⇒ what will be the gain on resolution?





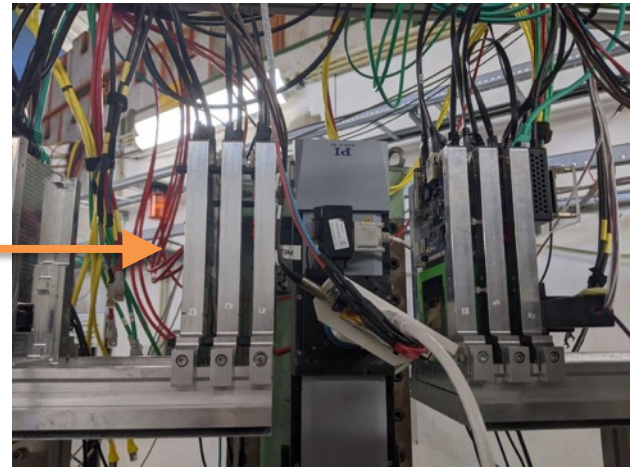
Topic for the internship

⇒ Choose 1 topic out of 2

- Both with simulated data
- Both with existing algo/code to tweak
- Both with large impact on VTX design

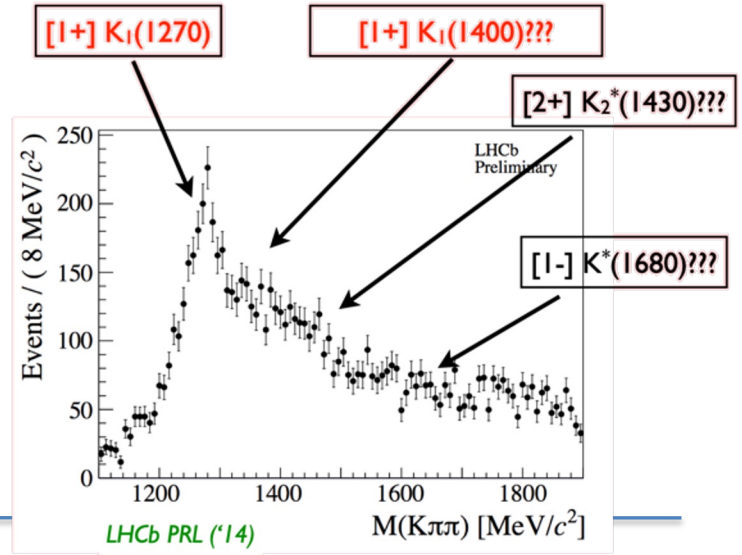
Topic for the thesis

- Continuation of internship
  - Track-trigger: simulation => experimental demonstration

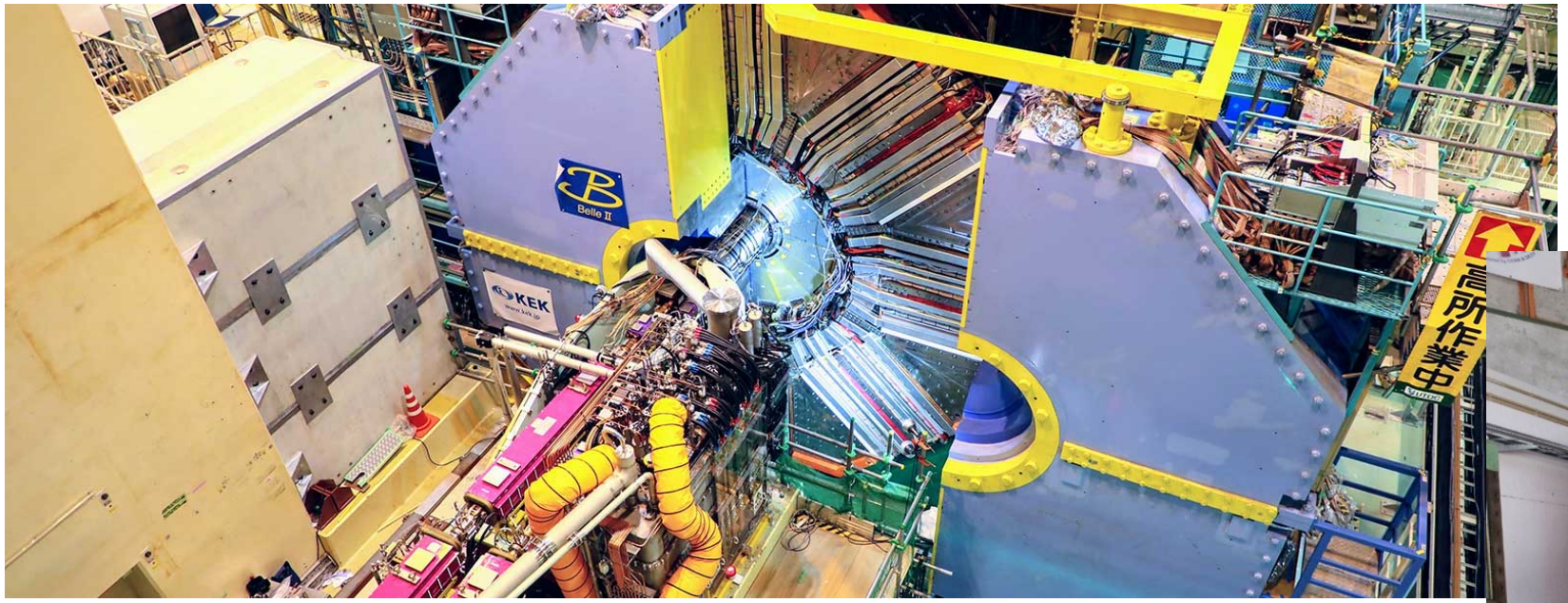


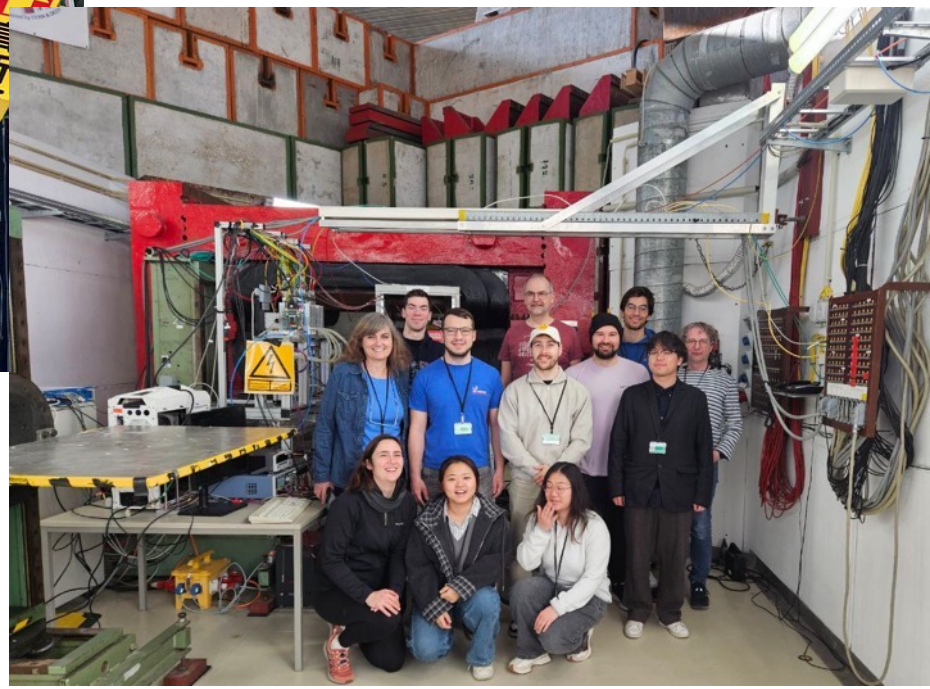
- New main part: test of OBELIX-1 sensor
  - OBELIX-1 produced mid-2026: performance matching Belle II needs?
    - Space & time resolution, hit-rate, radiation tolerance
  - Prototyping detection modules
    - Monobloc 2 cm x 14 cm x 300 µm possible?

- A bit of physics analysis (possible, not compulsory)
  - CP violation in $B^0 \to K^0_S \pi^+ \pi^- \gamma$ as a null-test of Standard Model
  - Isolating CP eigenstate in $K^* \to K\pi\pi$ system
  - New data (0.4 => 1 ab^{-1})



Time in Japan





Beam test area

Control room shifts

The Belle II IPHC team

Jérôme Baudot
PR Unistra
60 % Belle II
(40 % R&D CMOS)

Giulio Dujany
CR IN2P3
100 % Belle II

Christian Finck
CR HDR IN2P3
60 % Belle II
(40 % hadronthérapie)

Isabelle Ripp-Baudot
DR IN2P3
100 % Belle II

Pere Gironella
Postdoc
→ 12/2025

Petros Stavroulakis
doctorant Unistra
→ 11/2025

Corentin Santos
doctorant Unistra
→ 09/2026

Mattéo Maushart
doctorant Unistra
→ 09/2027

Merna Abumusabh
Doctorante ANR
→ 09/2027

Sahil Saha
doctorant QMAT
→ 09/2027

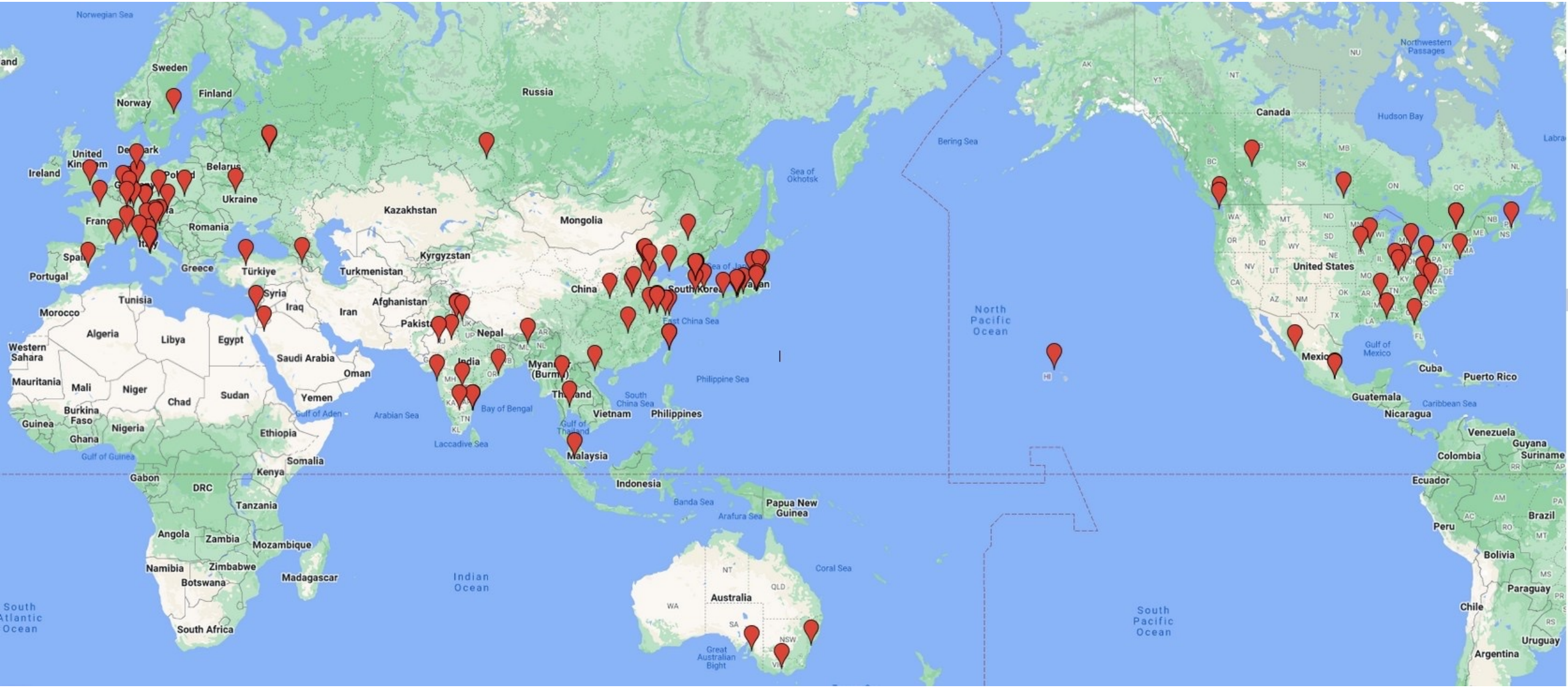
?

M2 internship 2026
doctorant → 09/2029

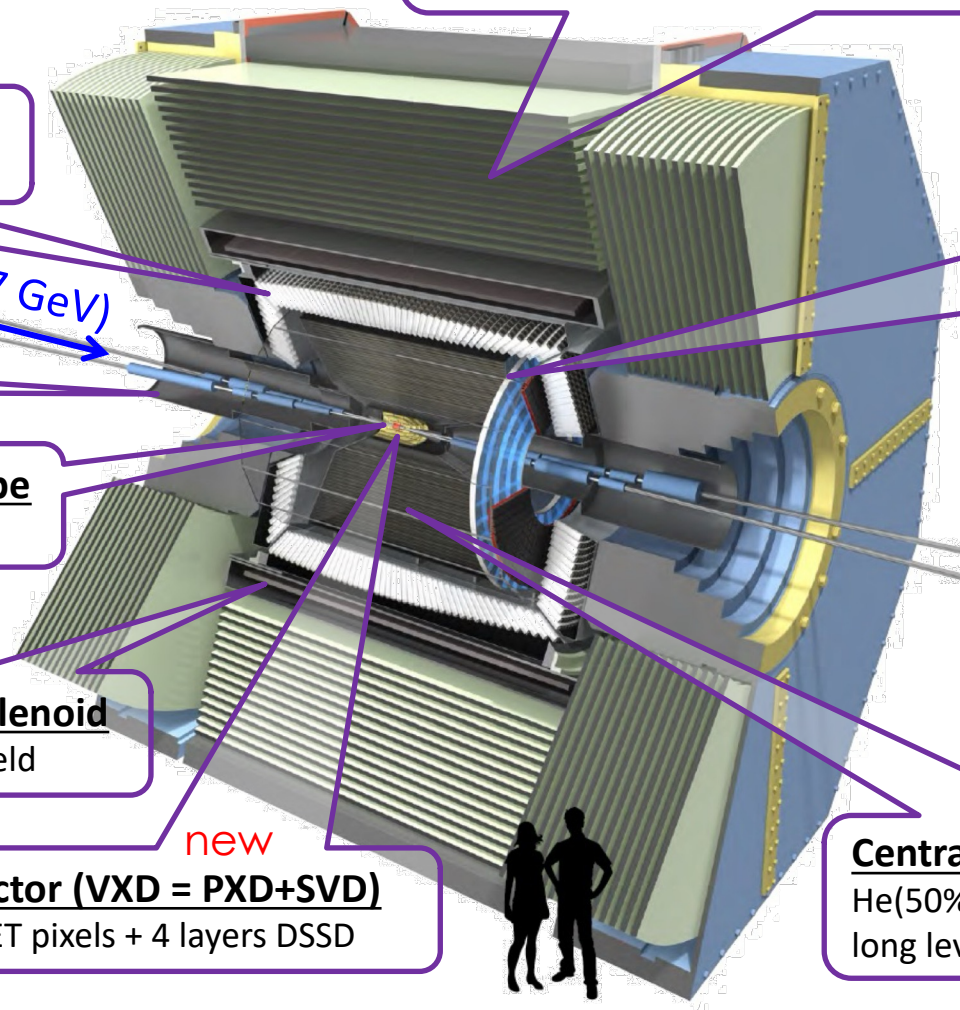
+ Engineers supporting instrumental activities:

- Current vertex detector: Jean-Sébastien Pelle, Christian Bonin
- Upgrade vertex detector: Andrei Dorhokov, Mathieu Goffe, Kader Himmi, Hung Pham, Isabelle Valin
- Computing: Jérôme Pansanel

The Belle II collaboration, O(1000) people



Belle II



KLong and muon detector (KLM) upgraded
Resistive Plate Chambers (barrel outer layers)
Scintillator + WLSF + SiPM's (end-caps , inner 2 barrel layers)

EM Calorimeter (CDC) upgraded
CsI(Tl), waveform sampling (barrel+ endcap)

electrons (7 GeV)

Particle Identification
TOP detector system (barrel)
Prox. focusing Aerogel RICH (fwd) new

new
Final focusing magnets

Beryllium beam pipe
2cm diameter new

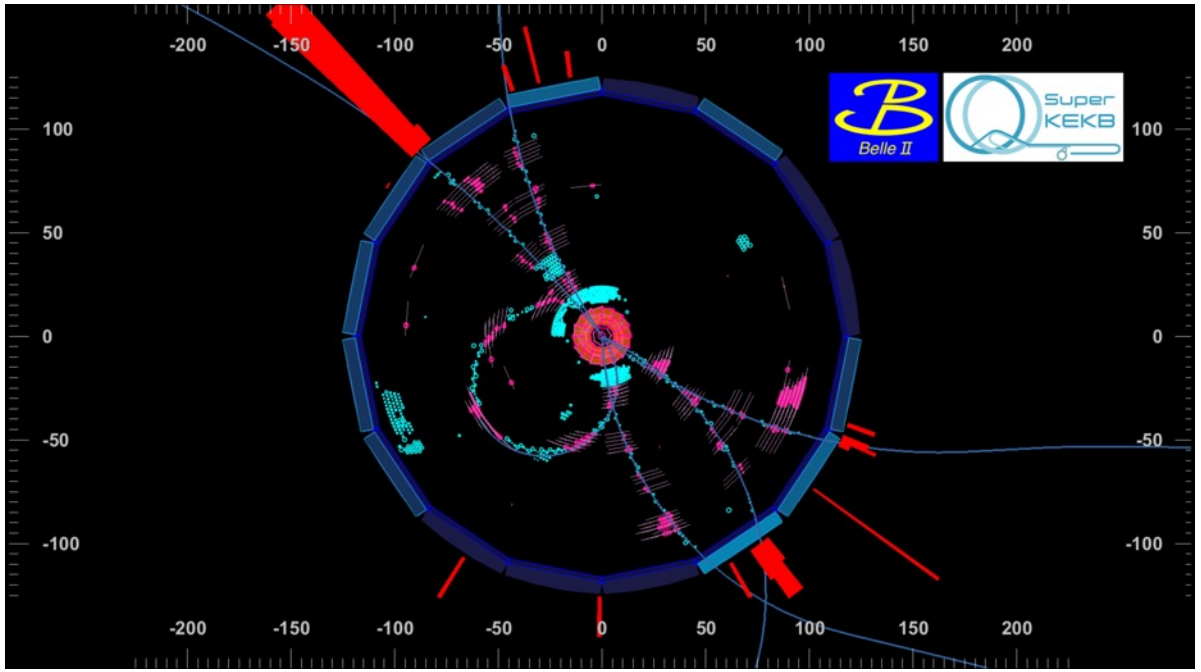
positrons (4 GeV)

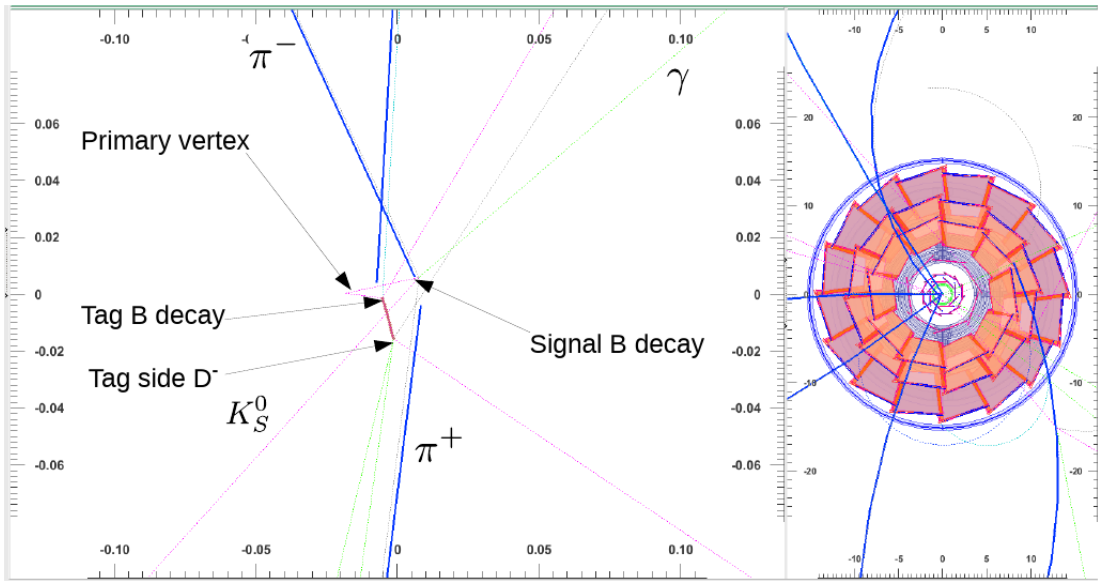
SuperCond. Solenoid
1.5 T magnetic field

new
Vertex Detector (VXD = PXD+SVD)
2 layers DEPFET pixels + 4 layers DSSD

Central Drift Chamber new
He(50%):C_2H_6(50%), small cells,
long lever arm, fast electronics

A BB event as observed in Belle




π^-
γ
Primary vertex
Tag B decay
Tag side D^-
K_S^0
Signal B decay
π^+

From VXD to VTX