Measuring the Incalculable: the Strong Nuclear Force

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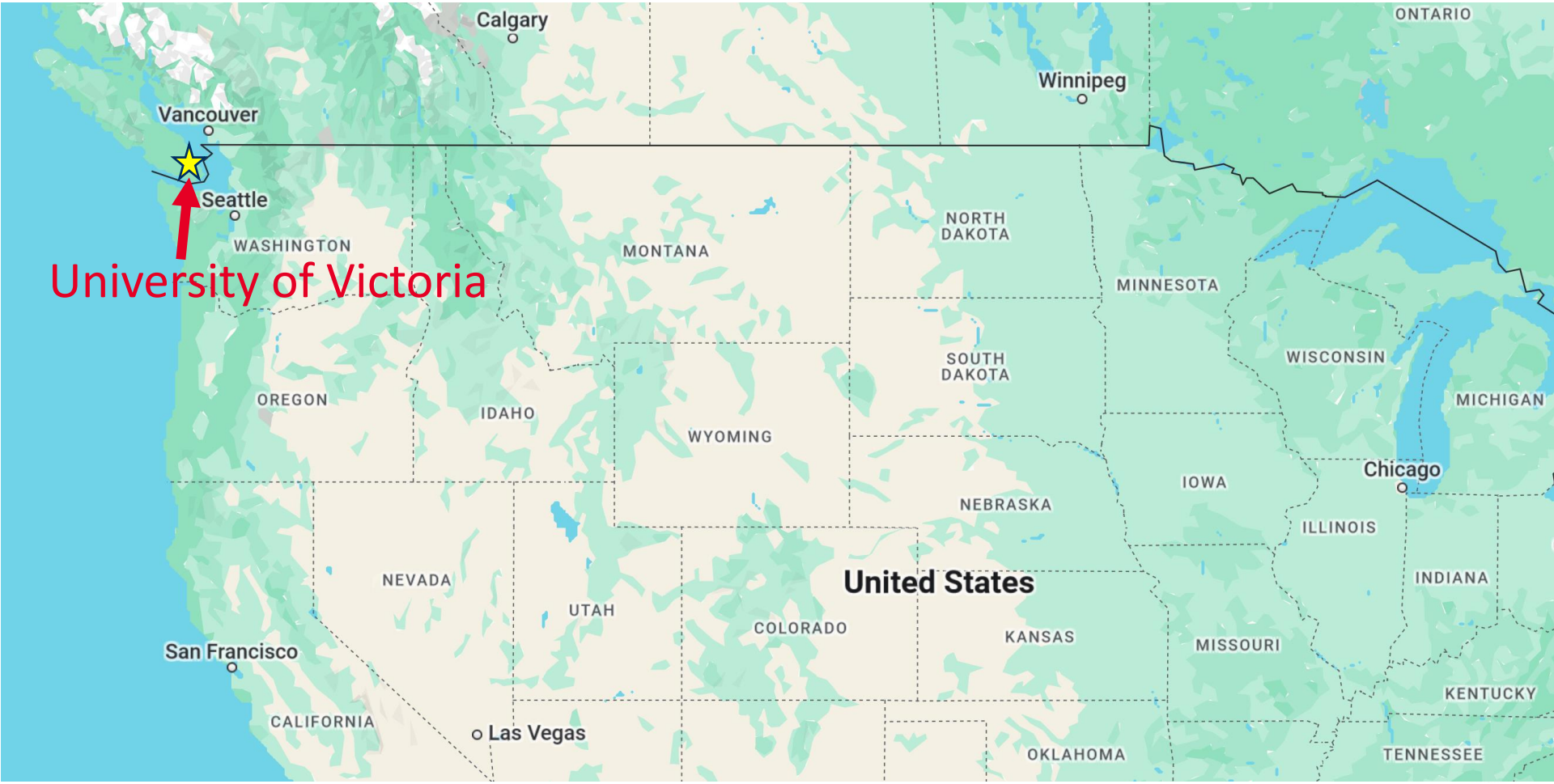
University of Victoria

The Belle II collaboration

2024-06-17

University of Victoria

About Me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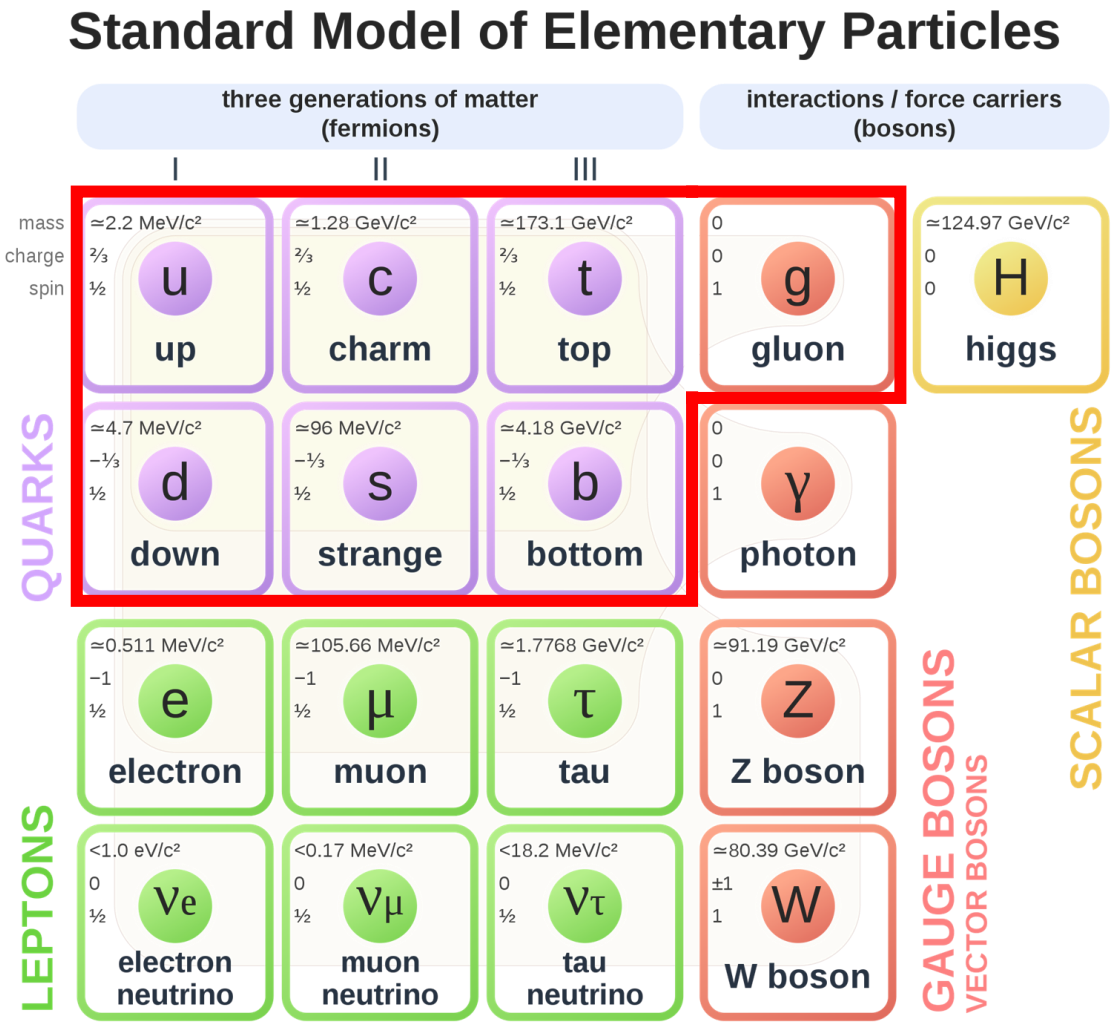
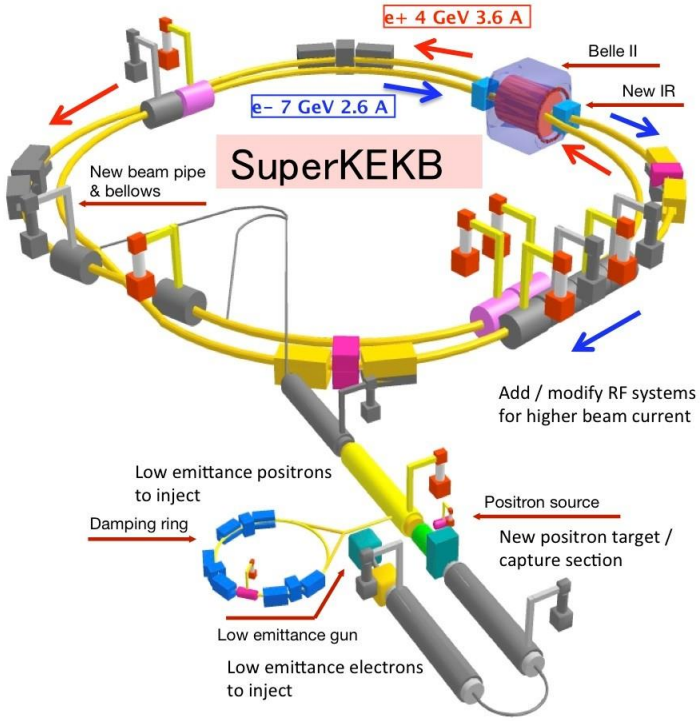
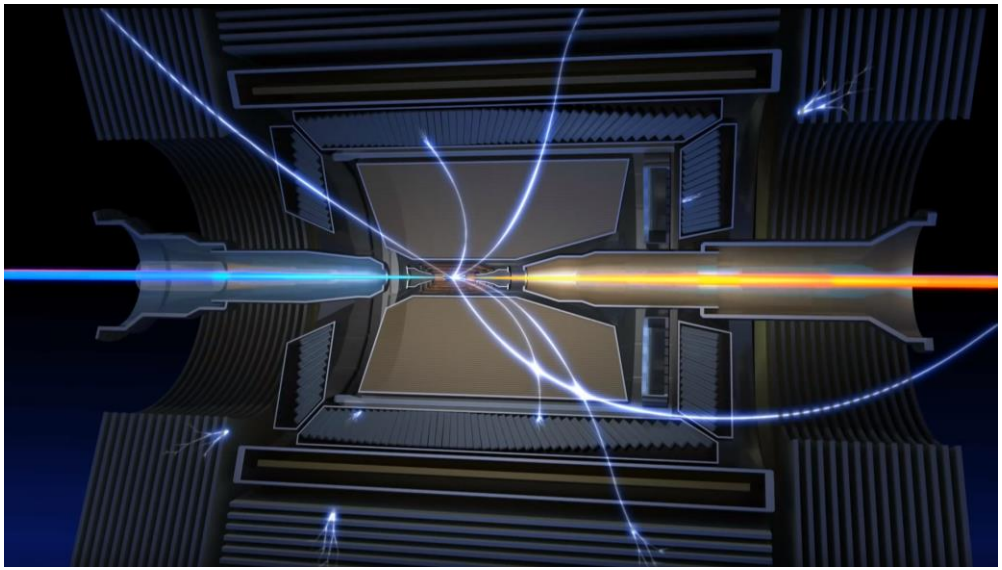
A Reminder

Strong Nuclear Force



Fast collisions = High Energy = Fancy Interactions

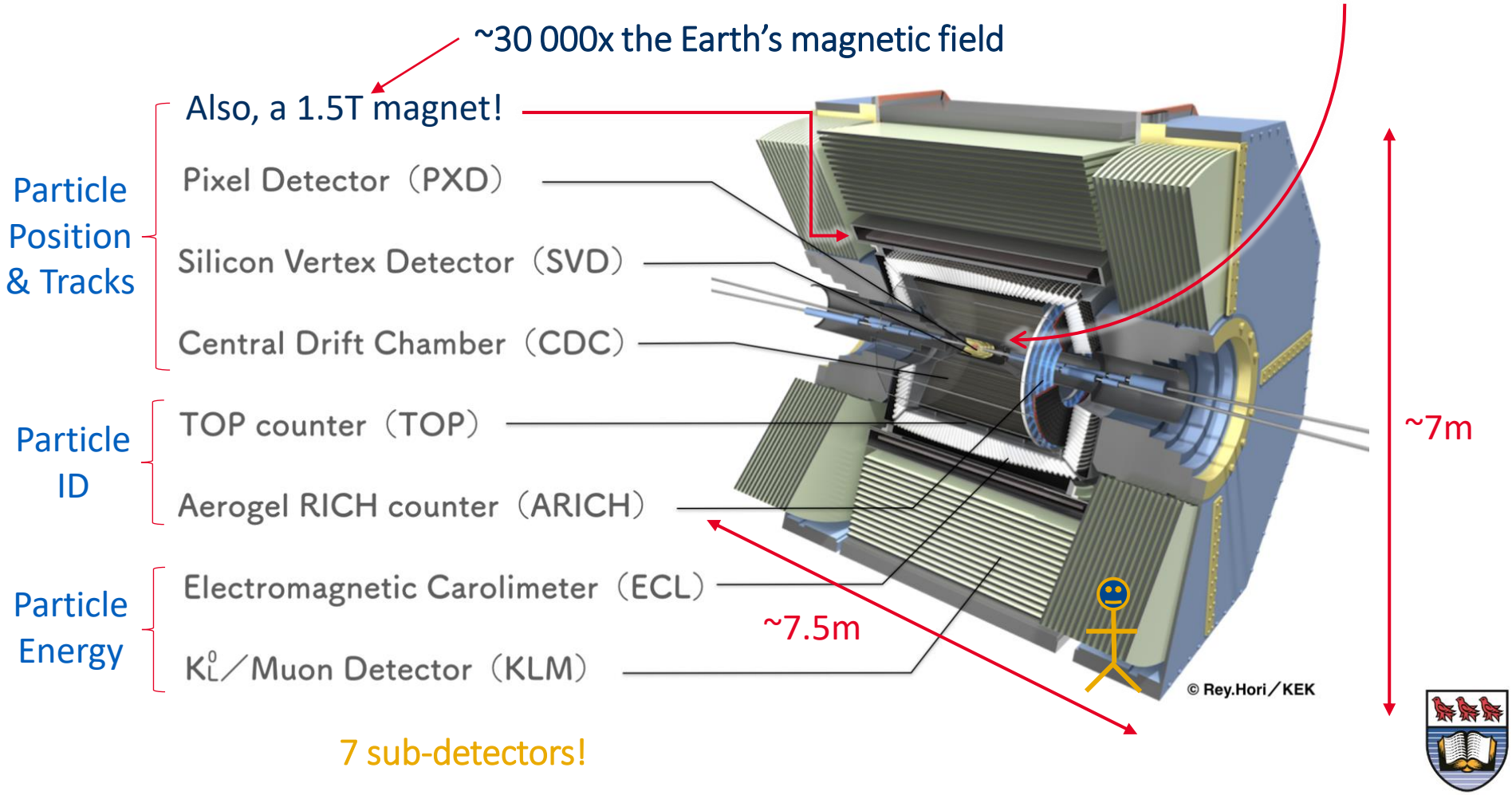




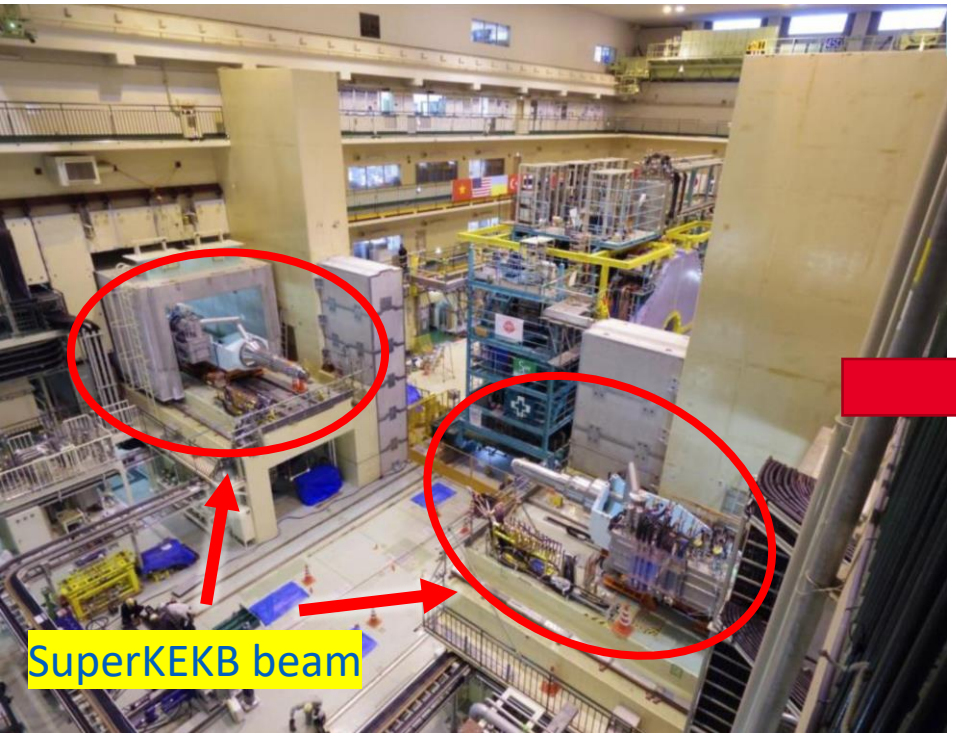
Look at what comes out and deduce what happened

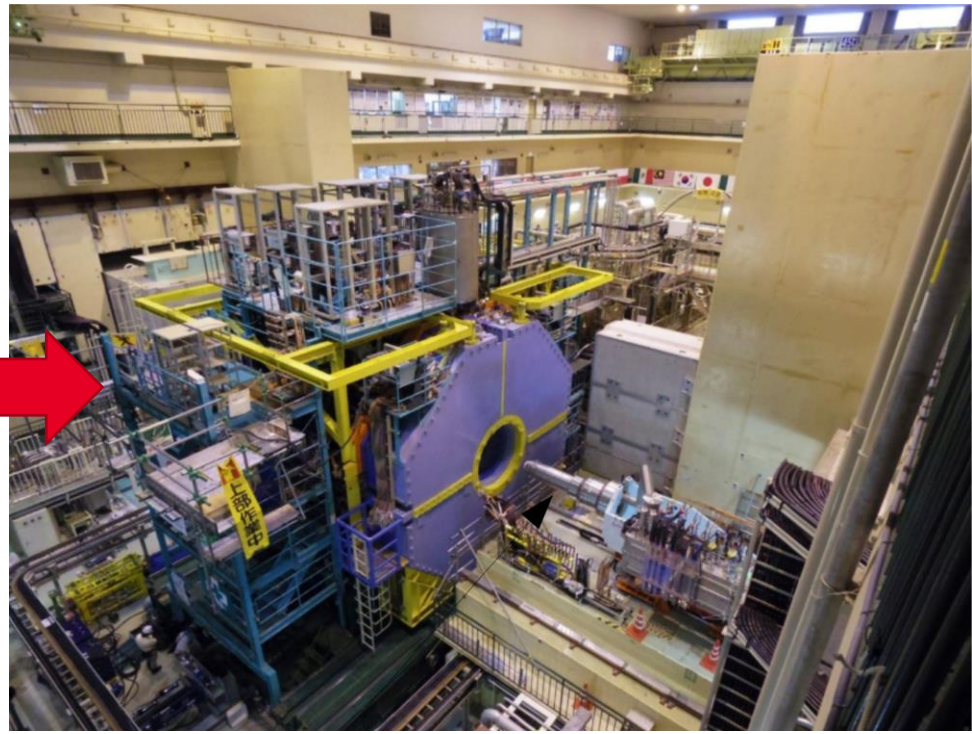
The Belle II Detector

General-purpose detector — Built like an onion around collision point



Rolling-in the Detector

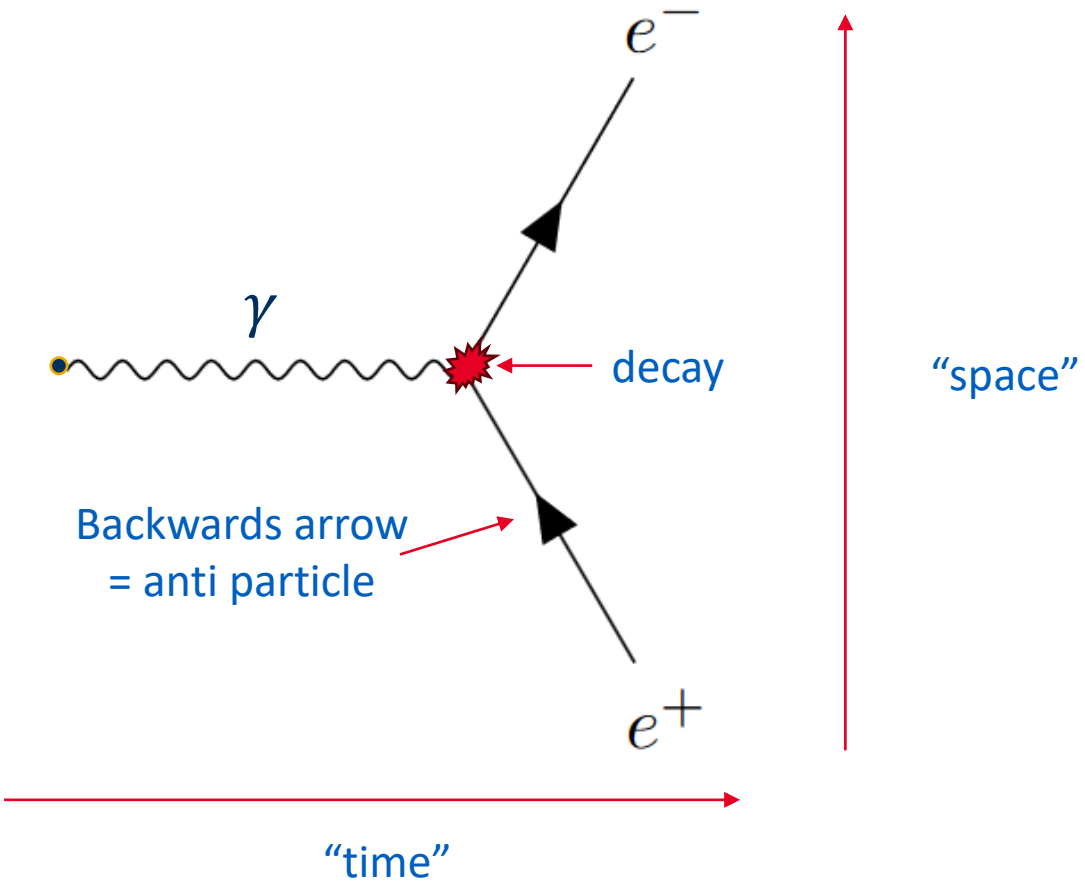




We roll-in the detector to the collision area after it is fully built.

How to Read A Feynman Diagram

Particles are short-lived, they will decay

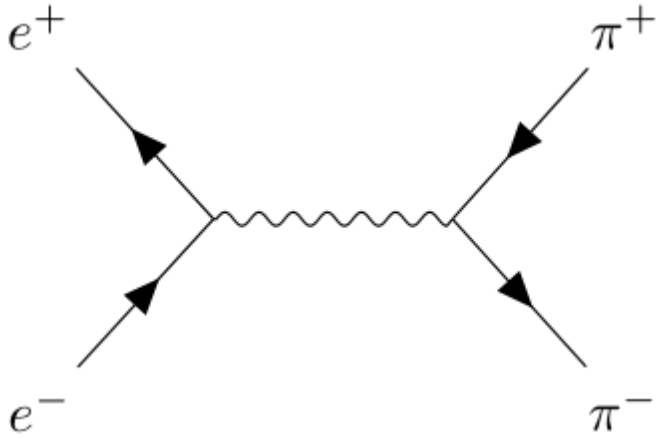


Measurement & Motivation

Measurement of $\sigma(e^+e^- \to \pi^+\pi^-)$
at $\sqrt{s} = 10.58$ GeV

Cross section
i.e. “probability”

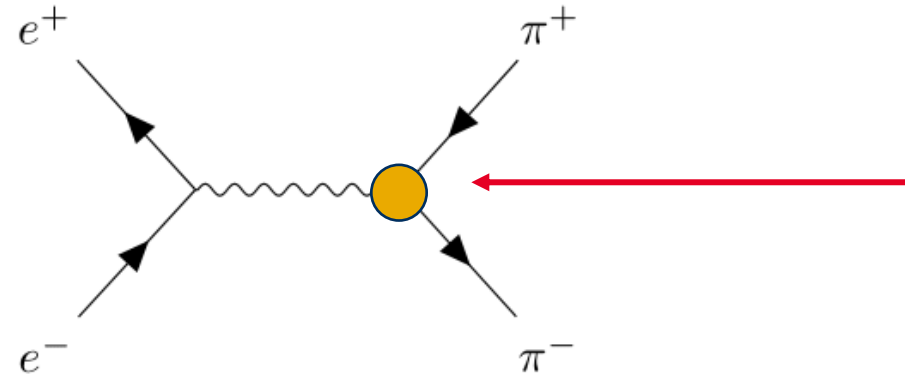
Energy of the
collision



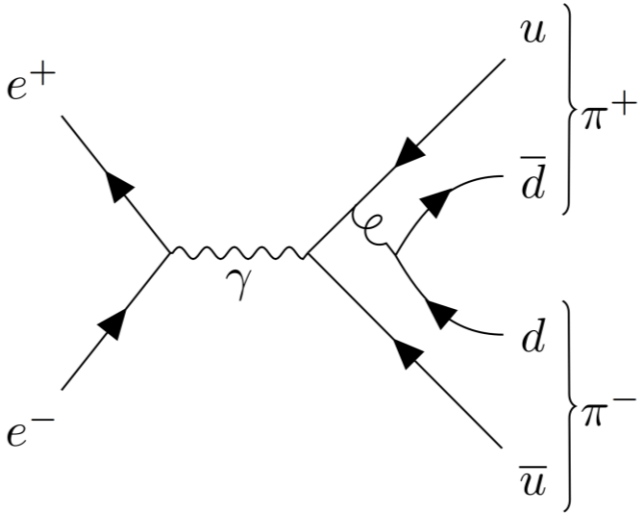
$$N_{\text{events}} = \sigma L$$

L = integrated luminosity
i.e. dataset size

Measurement & Motivation

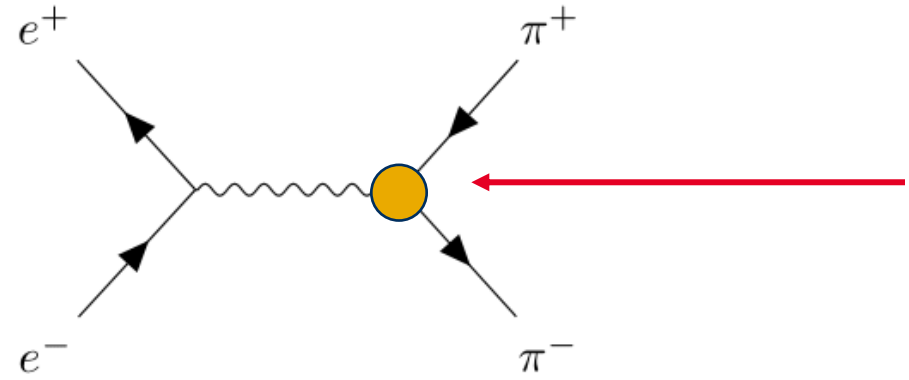


Hard to calculate!

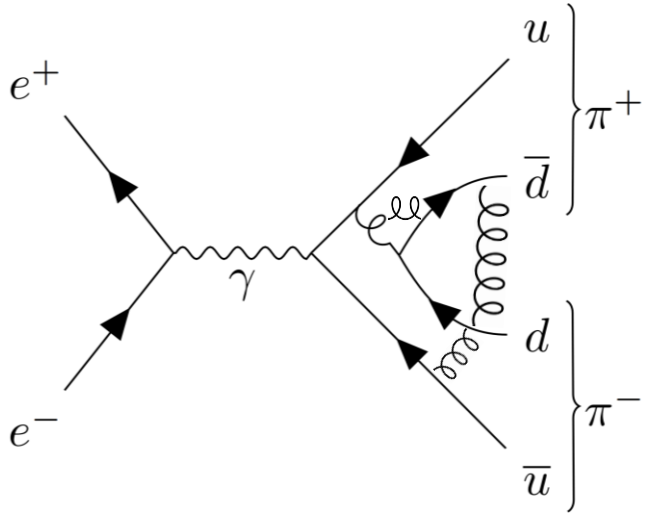


Encapsulates finer mechanisms

Measurement & Motivation



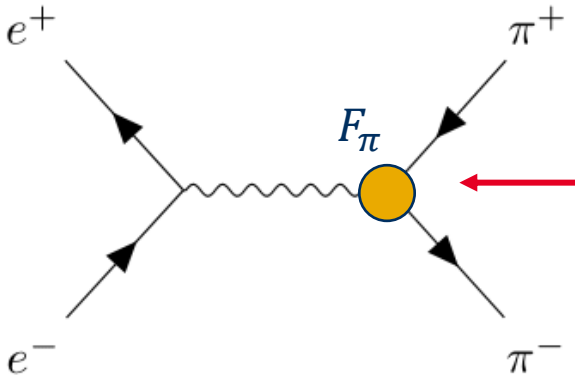
Hard to calculate!



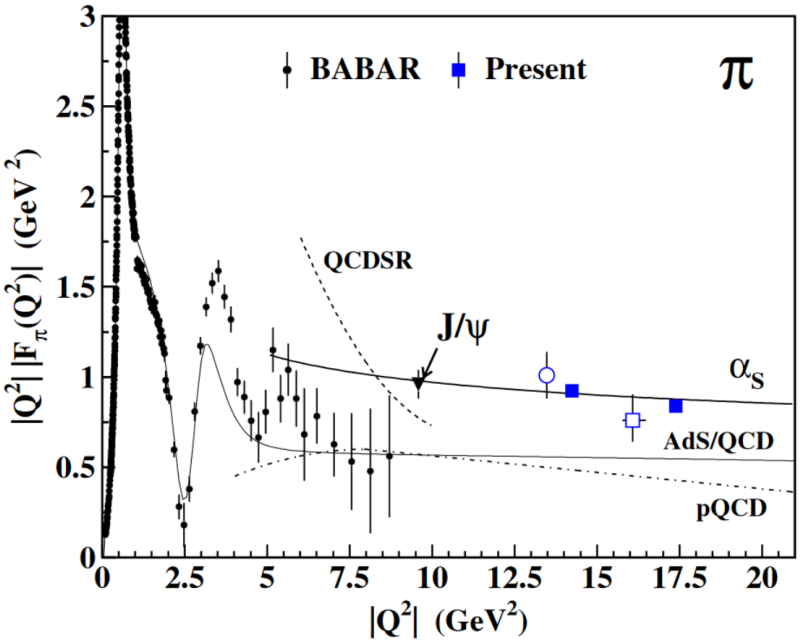
Encapsulates finer mechanisms

Non-perturbative processes

Measurement & Motivation



Describe with F_π



Form Factor:

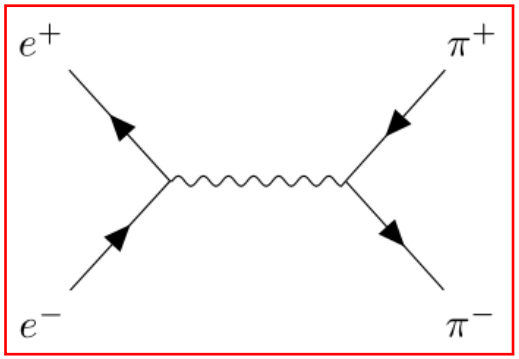
$$|F_\pi(s')|^2 = \frac{3}{\pi}\frac{s'}{\alpha_{em}^2\,\beta_\pi^3}\sigma_B(s')_{\pi\pi}$$

$$\beta_\pi = \sqrt{1-\frac{4m_\pi^2}{s'}}, \quad s' = (M_{\pi\pi})^2 = Q^2$$

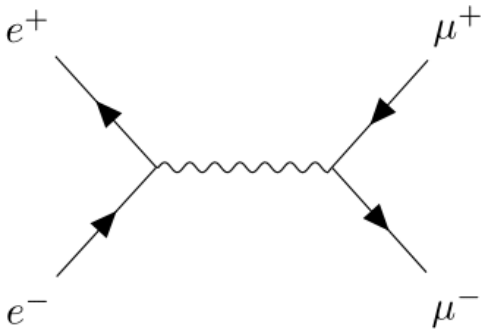
We are at $Q^2 \approx 110$ GeV

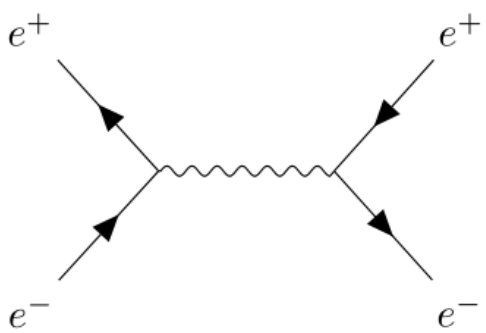
Not as Easy as it Looks…

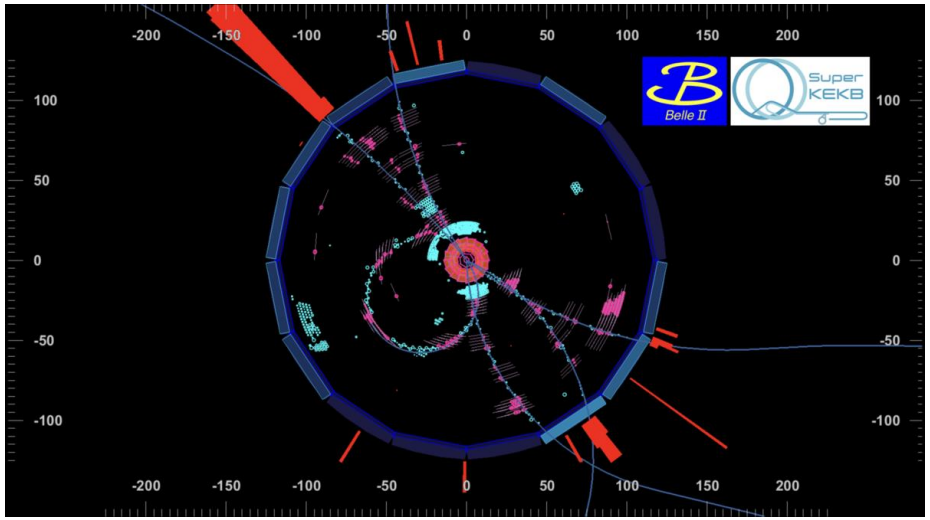
signal



background



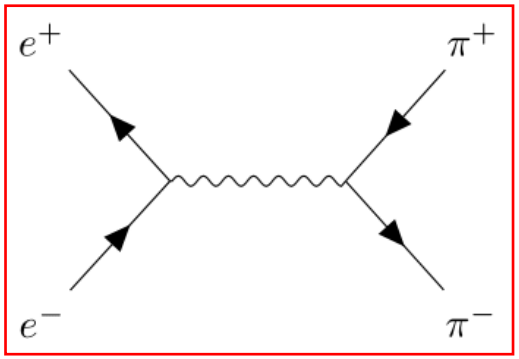




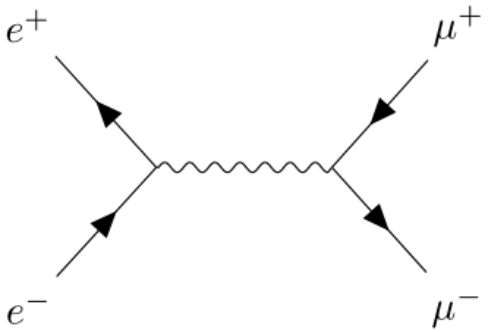
Can you tell which kind this is?

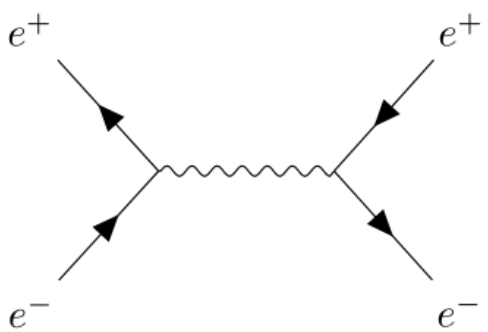
Not as Easy as it Looks…

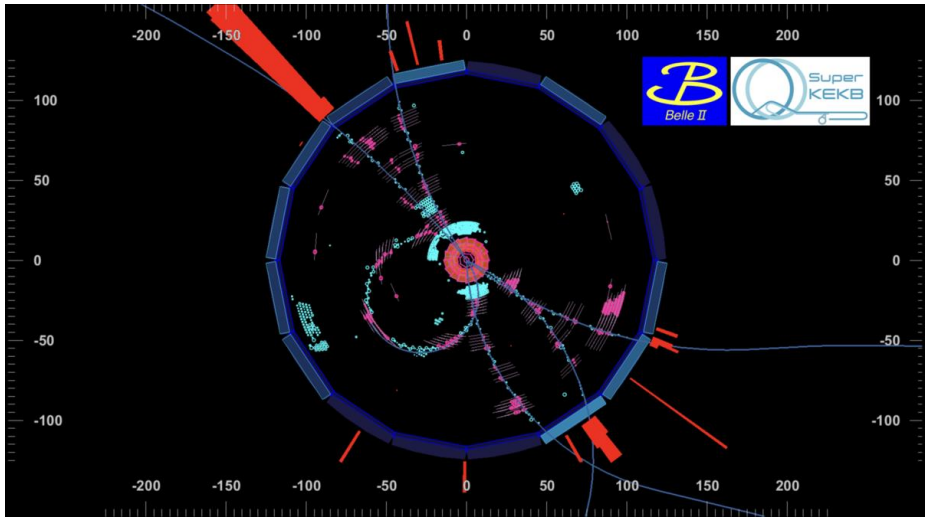
signal



background



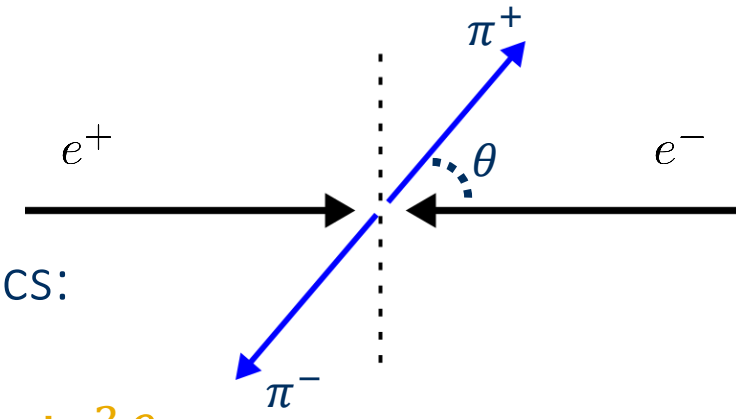




Can you tell which kind this is?

Trick question:
None of the above

Discriminating Variables



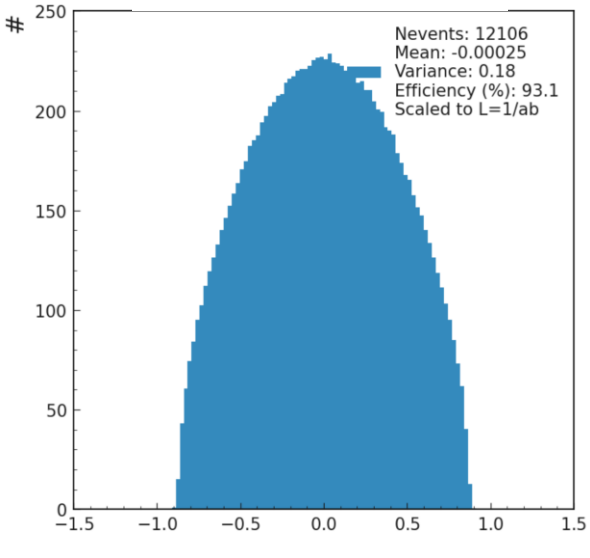
Different particles = different Physics:

e.g.

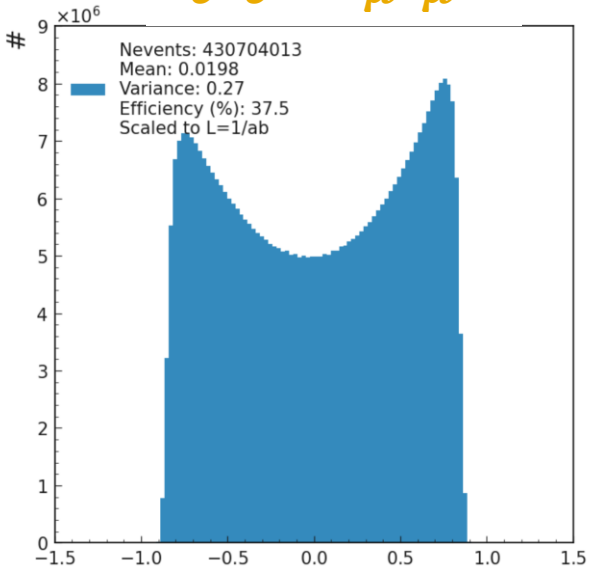
$$e^+e^- \to \pi^+\pi^- : \sigma \propto \sin^2\theta$$

$$e^+e^- \to \mu^+\mu^- : \sigma \propto 1 + \cos^2\theta$$

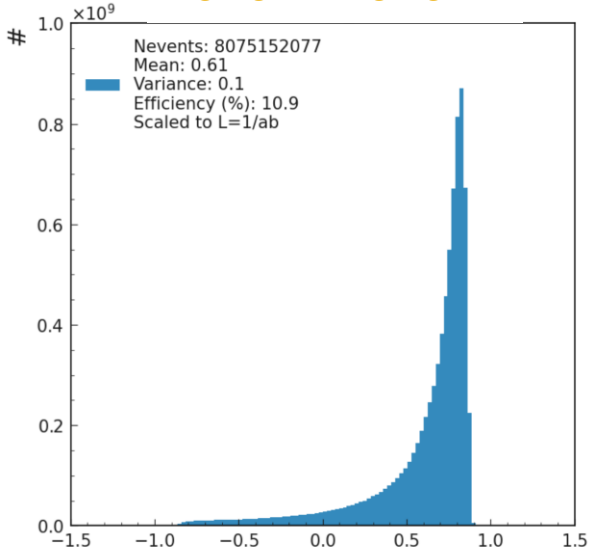
$e^+e^- \to \pi^+\pi^-$



$e^+e^- \to \mu^+\mu^-$



$e^+e^- \to e^+e^-$



$\cos\theta$

The Ultimate Metric

$$\sigma_{total}^2 = \sigma_{stat.}^2 + \sigma_{syst.}^2$$

The End

The Belle II *International* Collaboration

~1200 collaborators, ~600 authors

- ~500 students, ~450 “Physicists”, ~230 technical staff

123 Institutions
27 Countries