THE SEARCH FOR FCNC

IN THE K0TO EXPERIMENT

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Some Definitions

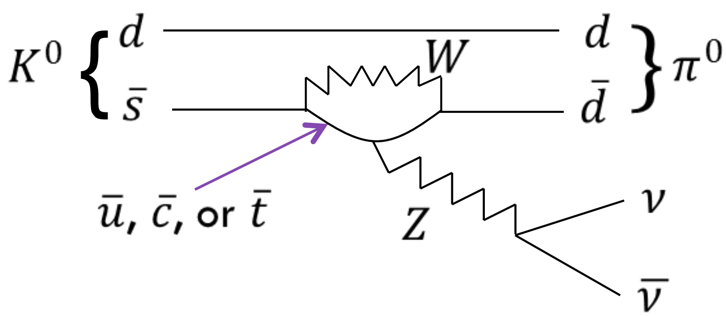
- Branching Ratio: The fraction of particles that decay via one decay mode with respect to the total number of particles that decay.
- Standard Model: Theory of fundamental particles and how they interact using the electromagnetic, strong, and weak forces.
- Feynman Diagram: Pictorial representation of the behavior of subatomic particles.

What is K0TO Doing?

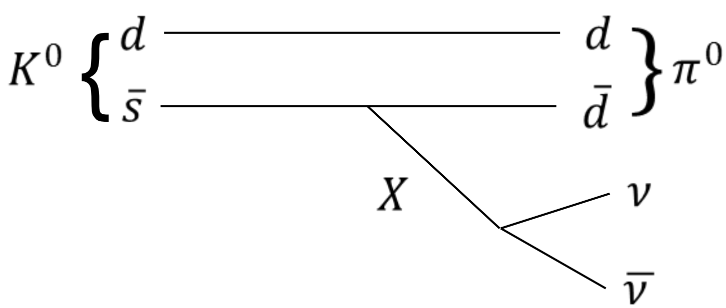
- The K0TO experiment is trying to accurately measure the branching ratio of $K_L \to \pi^0 \nu \bar{\nu}$.
- The Standard Model predicts the branching ratio of $K_L \to \pi^0 \nu \bar{\nu}$ to be about $2.8 * 10^{-11}$, which means for about every 10^{12} Kaon decays, one Kaon will decay into a π^0, neutrino, and an antineutrino.
- If the branching ratio measured by K0TO is larger than the branching ratio predicted by the Standard Model, it could mean the discovery of a new process, called Flavor Changing Neutral Current (FCNC).

$K^0 \to \pi^0 \nu \bar{\nu}$ Feynman Diagrams

The neutral Kaon, K_L, is a meson composed of a d quark and an $\bar{s}$ quark.



This decay is mediated by 2 vector bosons, the W and Z, which makes this a second order weak decay. The branching ratio of this decay is about $2.8 * 10^{-11}$.



From $\bar{s}$ to $\bar{d}$, the quark changes flavor, but keeps the same charge. This is mediated by some unknown, neutral particle (X) and is called Flavor Changing Neutral Current (FCNC).

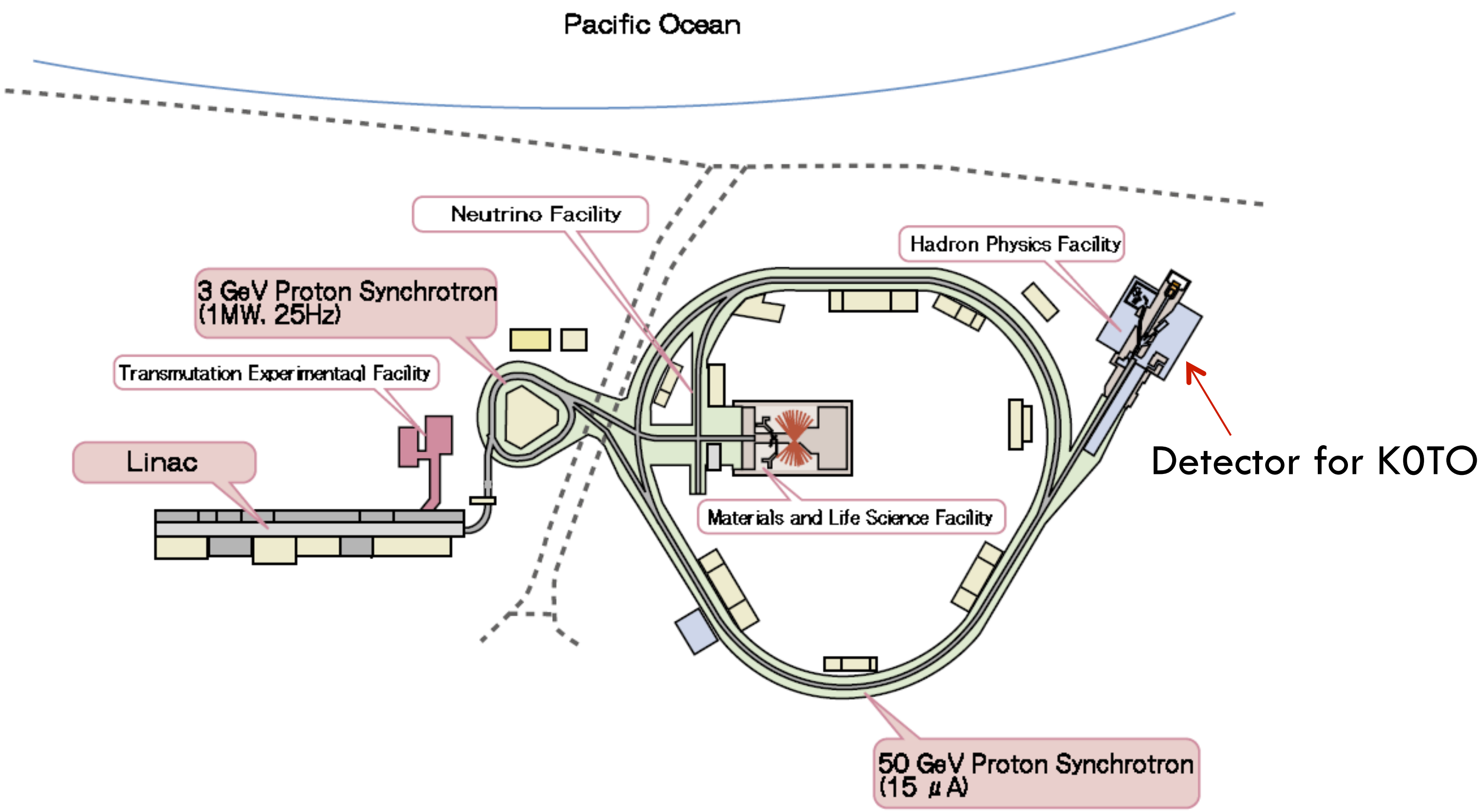
Why Should You Care?

- The discovery of FCNC could either lead to more precise limits on the Standard Model or new physics!

The Accelerator

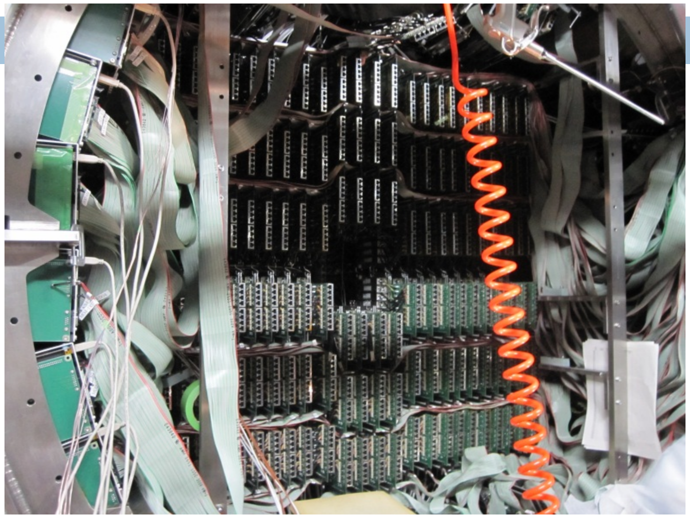
- The K0TO experiment is being hosted by the Japan Proton Accelerator Research Complex (J-PARC).
- J-PARC includes three main parts: 400-MeV normal-conducting Linac, 600-MeV superconducting Linac to increase the energy of the proton beam from 400 to 600 MeV, 3-GeV synchrotron ring, and a 50-GeV synchrotron ring.

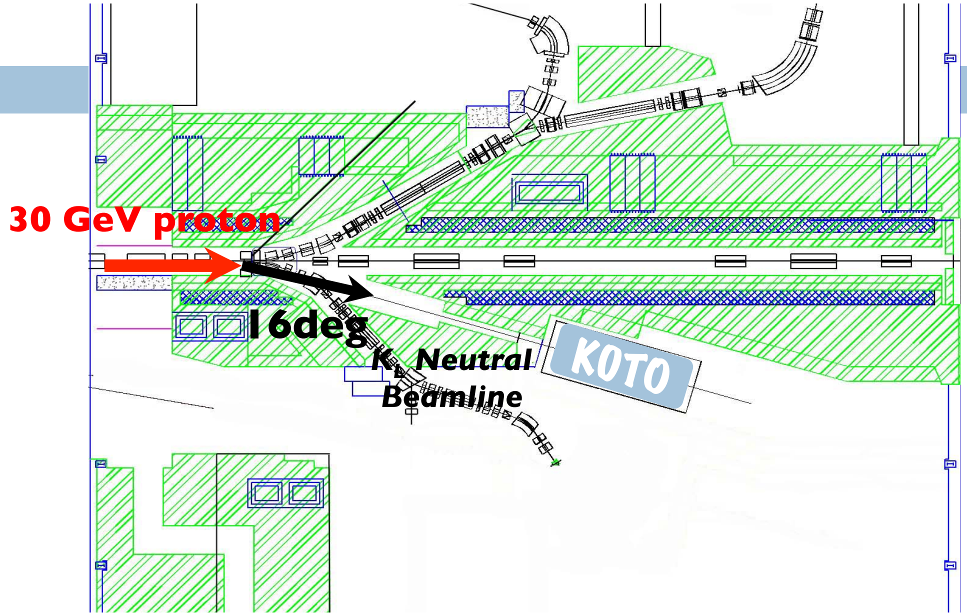
Layout of J-PARC

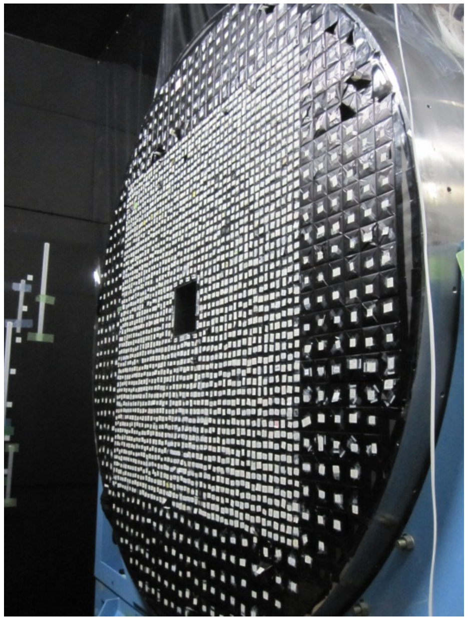


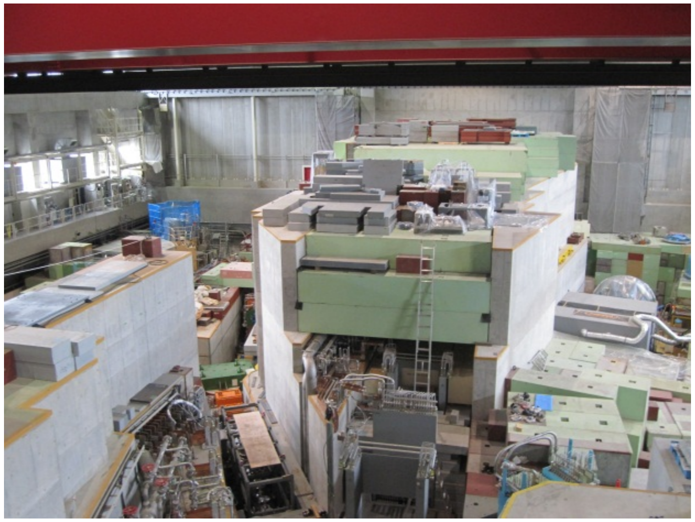
Layout of J-PARC

Facilities Pictures



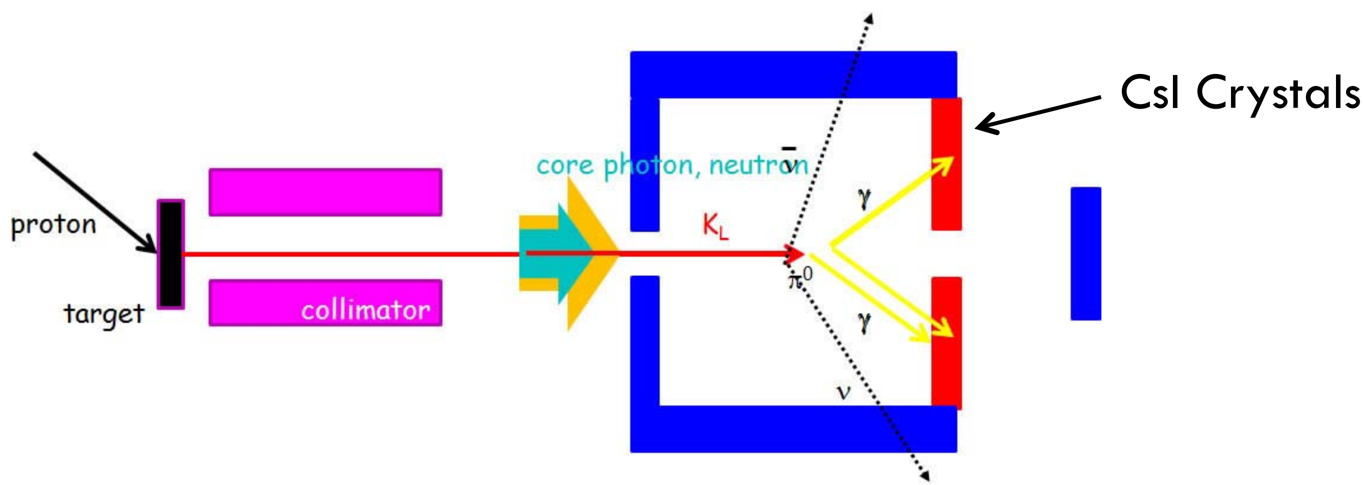




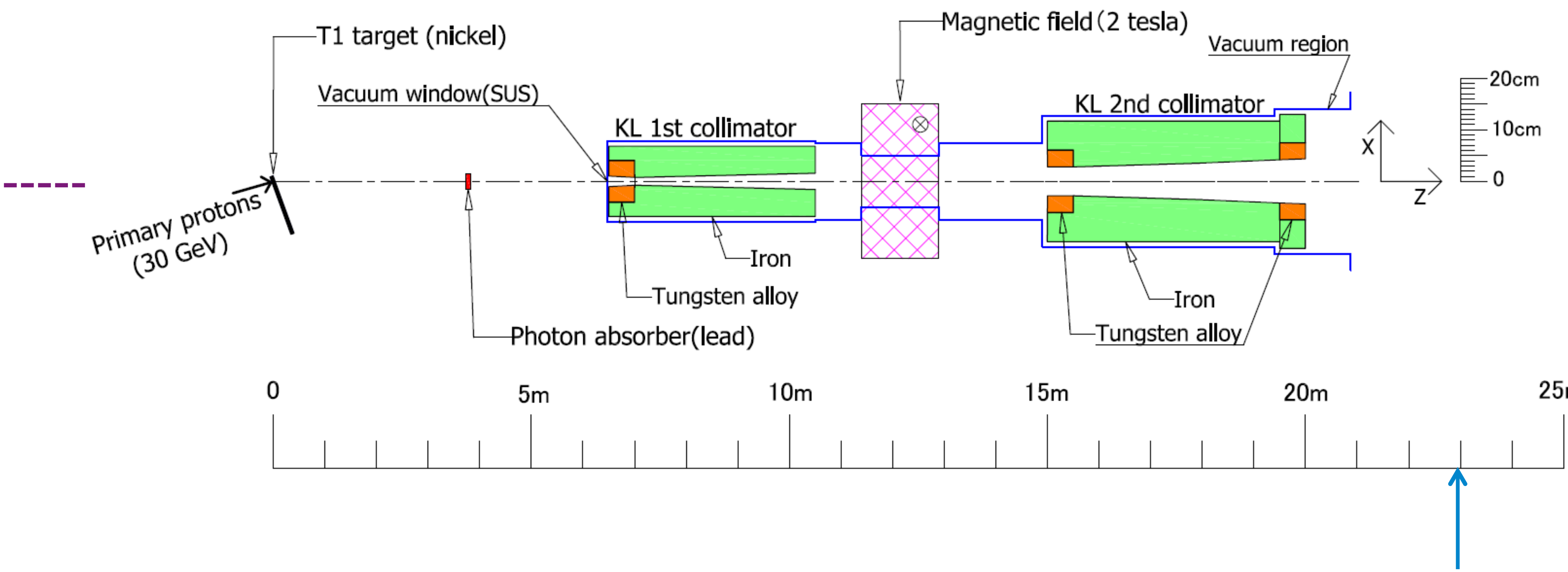


Detection Method

- Once a π^0 is produced from the K_L decay, it decays into two photons.
- These photons are then detected by CsI crystals in the detector.
- CsI Crystals → Photomultiplier Tubes → Copper wires → ADC boards (Ethernet to fiber optic cable conversion) → (fiber to Ethernet conversion) Level 1 and level 2 Trigger Boards → Power PCs → AWESOME DATA! (hopefully…)

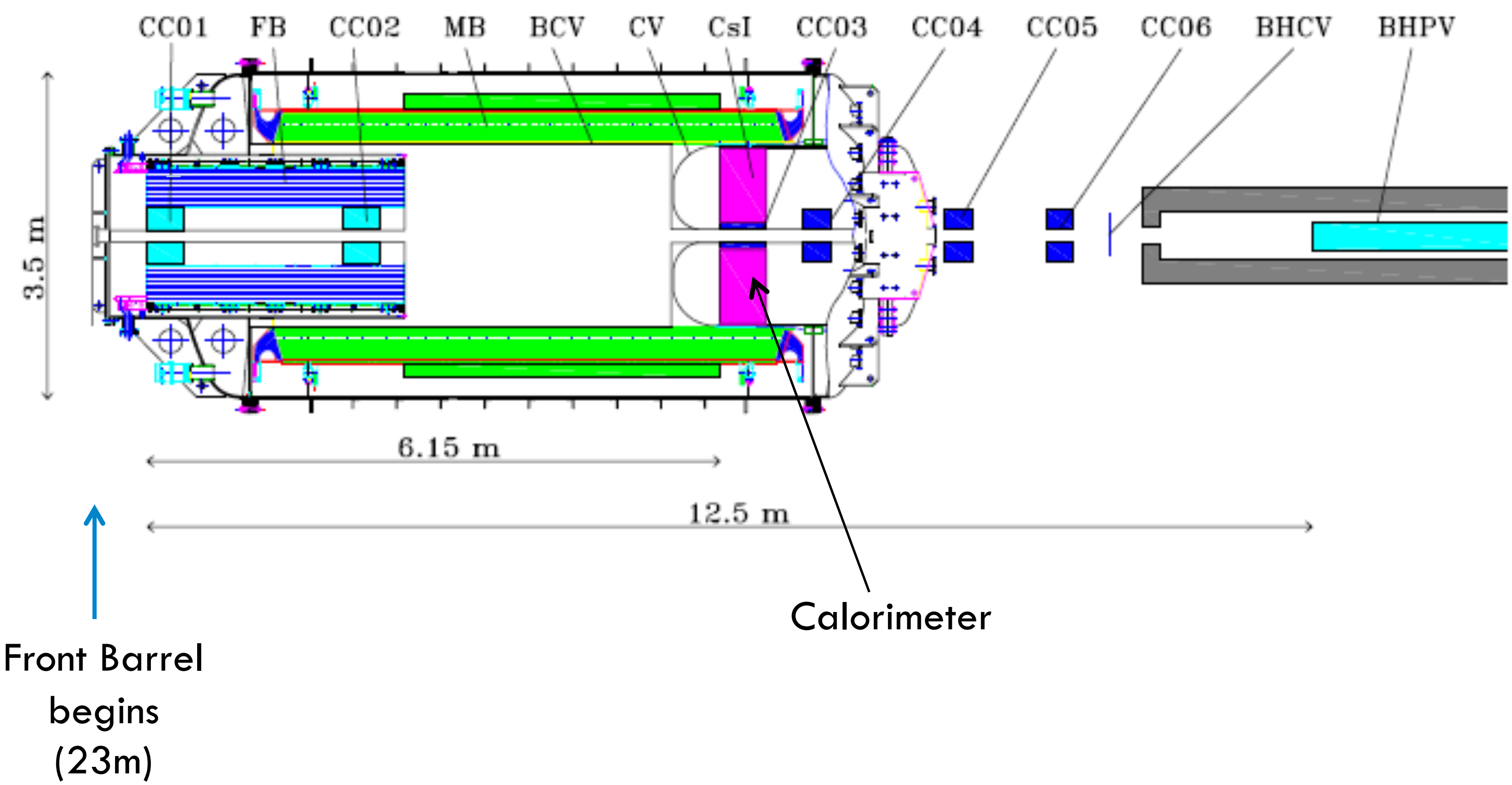


Start of the Kaon Beamline

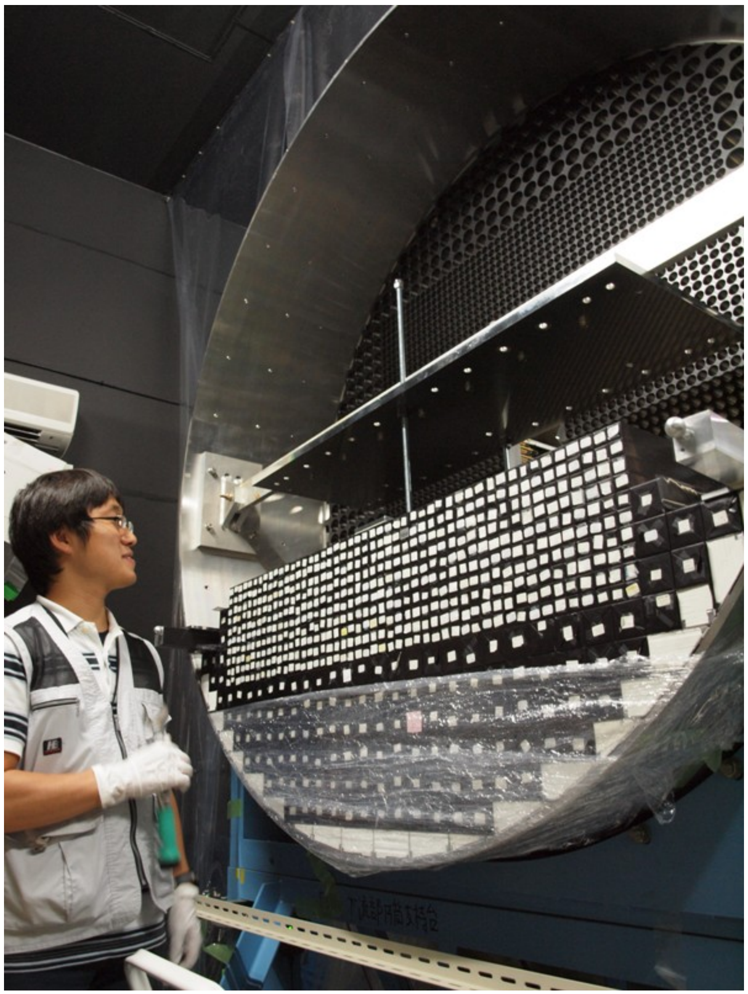


Front Barrel
begins
(23m)

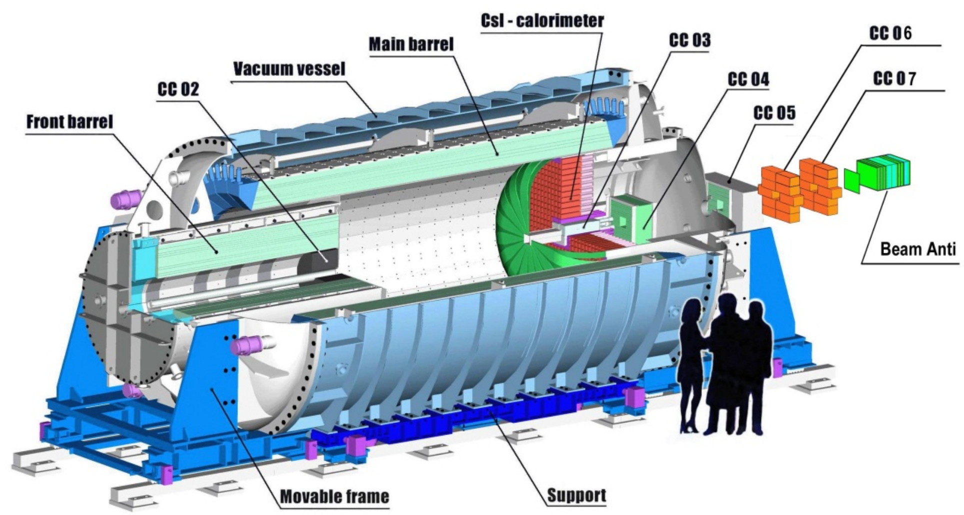
The Detector



Construction of the Detector



- Piling up CsI crystals in the calorimeter.



Modeling K_L Decay in Mathematica

- This Mathematica program models $K_L \rightarrow (\pi\mu)_{atom}\nu$.
- A $(\pi\mu)_{atom}$ occurs when a π^+ and a μ^- electrically bond together to form an atom.
- This decay is important because the $(\pi\mu)_{atom}$ decays into a π^0 and a ν. The π^0 then decays into 2 photons creating a signal that is virtually the same as the decay that we want to detect, $K^0 \rightarrow \pi^0\nu\bar{\nu}$

An Example Problem

- My goal was to maximize the fraction of Kaons that decay in the K0TO detector by solving for the optimum initial energy that the K_L beam should have.

$$N(l) = N_0 e^{-\frac{1}{l_0}l}$$

- I found that the maximum number of Kaons will decay in the detector, which is located between 26m and 29m from the start of the K_L beam, if the initial beam energy is 998.3 MeV.
- I did this by solving for l_0 and then $\beta\gamma$ and plugging γ into $E = \gamma mc^2$.

$$l_0 = \beta\gamma c\tau$$

- This energy is lower than what the actual K_L beam energy will be, which is about 2 GeV.

An Example Problem (cont.)

- Because of this initial beam energy difference, I solved for the fraction of Kaons that would decay in the 3m range in the detector.
- $E = \gamma mc^2$ → Solve for γ → Plug into $l_0 = \beta\gamma c\tau$ → use l_0 to solve for the fraction of Kaons that decay

$$N(l_1) - N(l_2) = N_0\left(e^{-\frac{l_1}{l_0}} - e^{-\frac{l_2}{l_0}}\right)$$

- This fraction turns out to be 3.17%, which is higher than what was expected.

Mounting Converters

- My task was to mount and power Fiber Optic Cables to Ethernet converters.
- These converters are useful because Ethernet signal degrades over long distances, and the ADC boards are far enough away from the trigger boards to see a signal difference.


What I Learned This Summer

- A LOT!
  - 4-vectors
  - Basics of fundamental particles and their decays
  - Basics of electronics
  - Mathematica
  - Soldering
  - Machining
- What I have learned this summer has made me even more excited about my future in physics.

Acknowledgements

- My advisor: Myron Campbell
- The research team: Monica Tecchio, Jon Ameel, Shumin Li, Craig Harabedian, Jia Xu

- References: https://sharepoint.umich.edu/lsa/physics/collaborations/k0to/default.aspx

Thanks for Listening!

QUESTIONS?

Extra

- Requires 'pencil beam', 4 cm diameter
- L0 is characteristic decay length