K0TO Experiment

$$K^0 \rightarrow \pi^0 \nu \bar{\nu}$$

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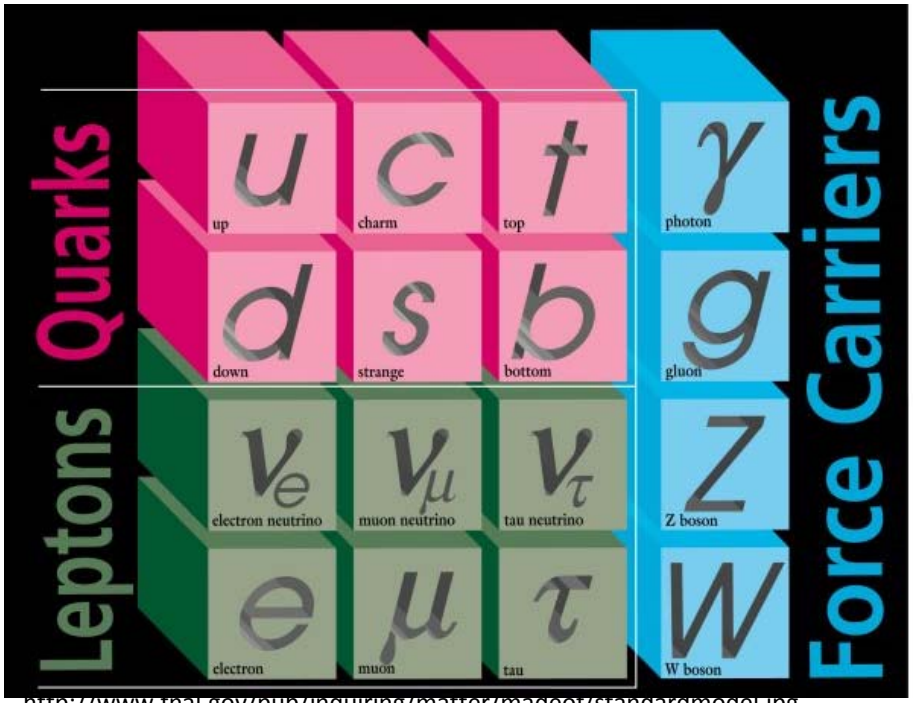
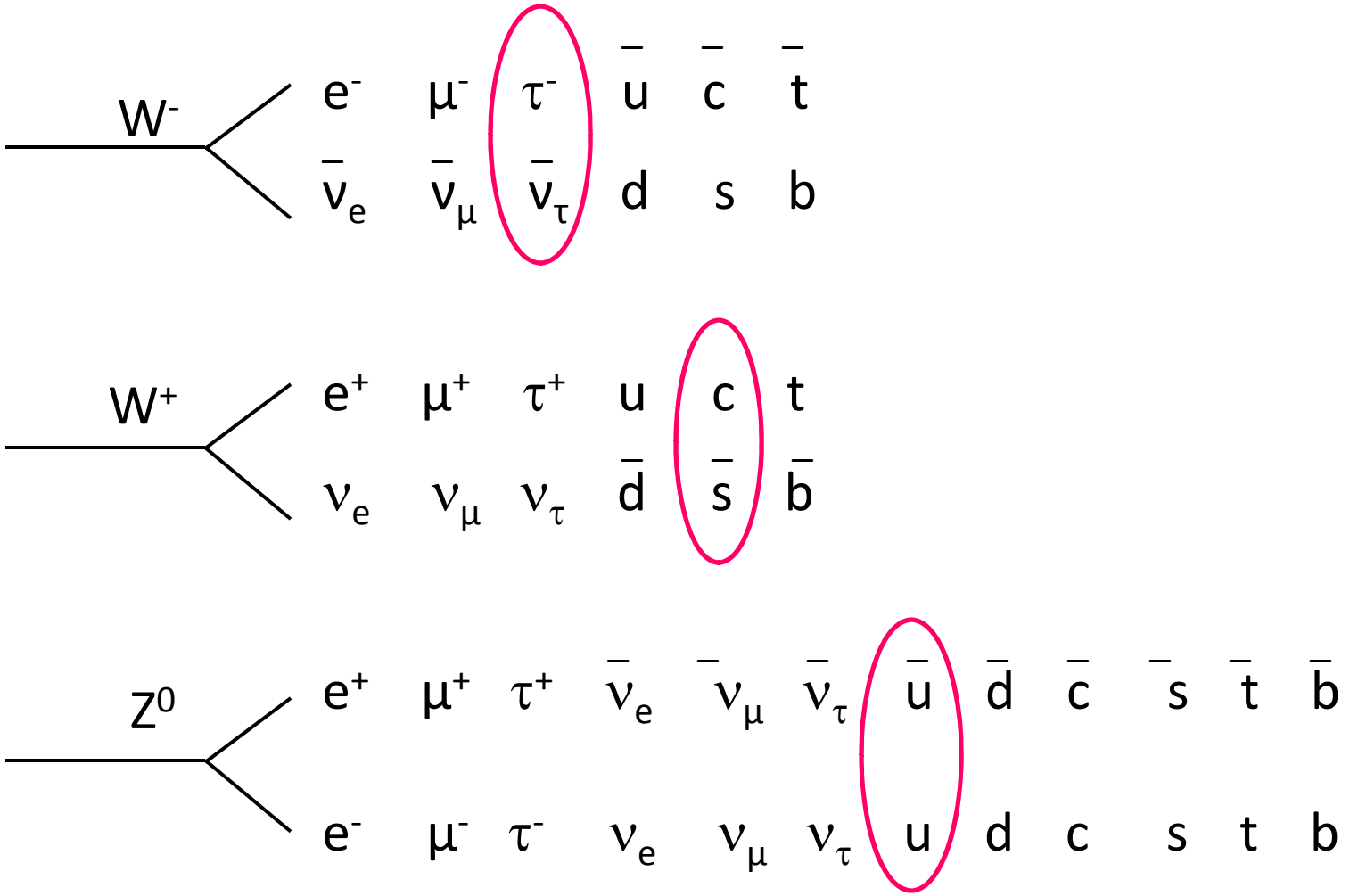
Elementary Particles

- All matter is constructed of
  - quarks and anti-quarks
  - leptons and anti-leptons
- Subatomic Particles Groups
  - Mesons
    - Combinations of a quarks and an anti-quark
  - Baryons
    - Three combinations of quarks
  - Leptons



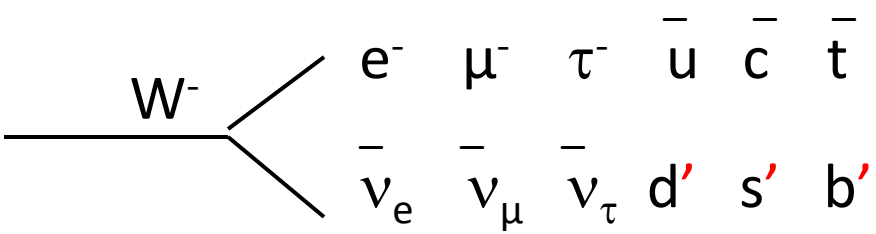
http://www.fnal.gov/pub/inquiring/matter/madeof/standardmodel.jpg

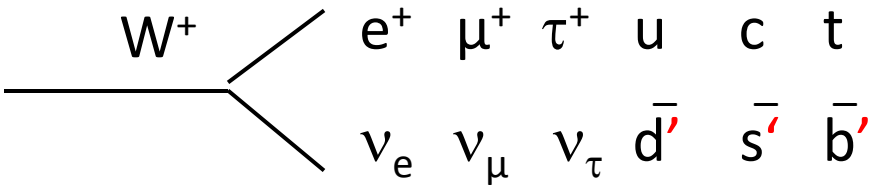
Weak Force Carriers

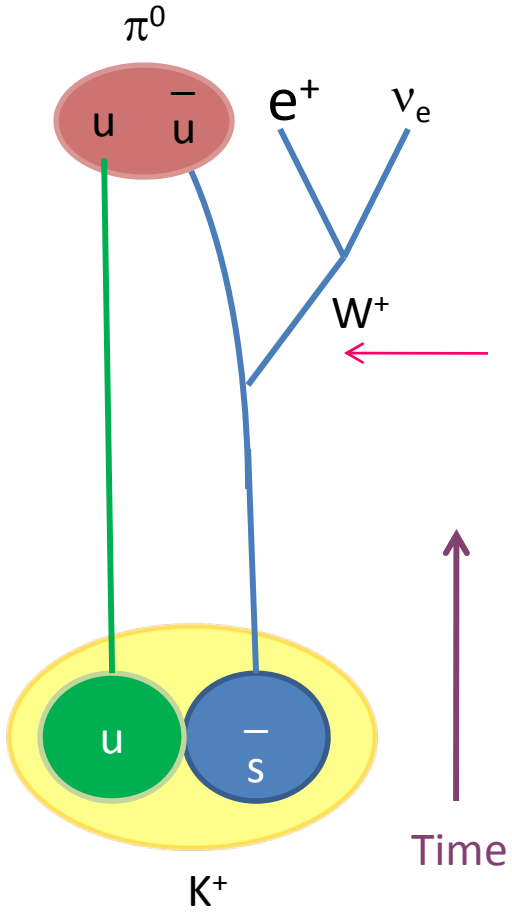


CKM Matrix

$$\begin{bmatrix} d' \\ s' \\ b' \end{bmatrix} = \begin{bmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{bmatrix} \begin{bmatrix} d \\ s \\ b \end{bmatrix}$$





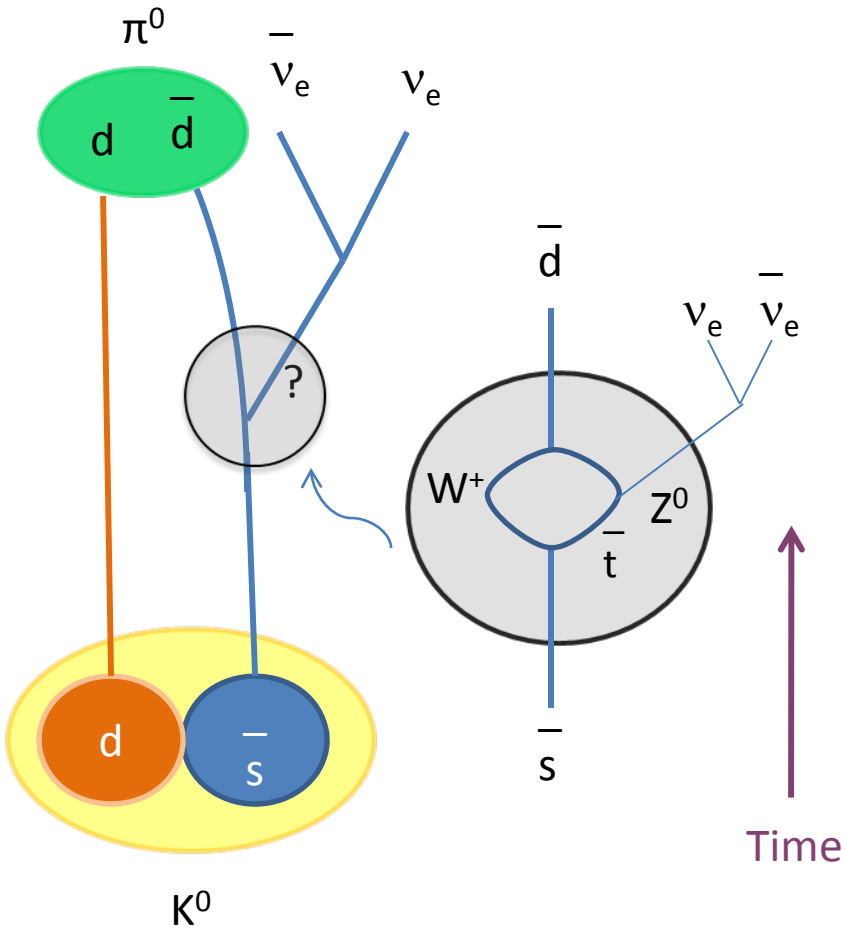


Physics Motivation

- $K^0 \rightarrow \pi^0 \bar{\nu}\, \nu$
  $\hookrightarrow \gamma\, \gamma$

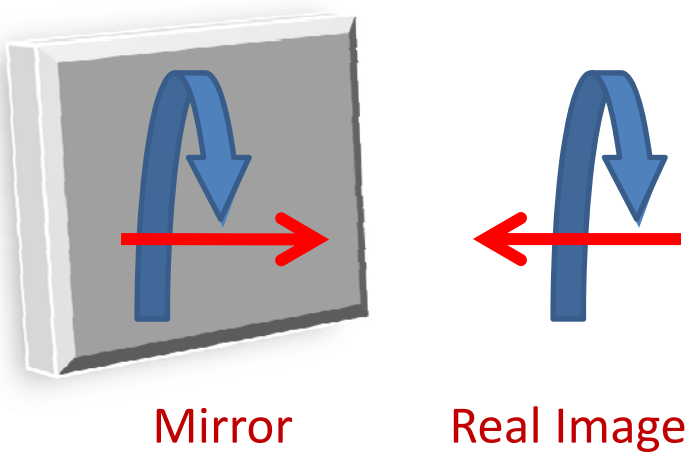
- Flavor changing neutral current decay
  - Occurring during second-order weak interactions
- Expected branching ratio

  2.8×10^{-11}



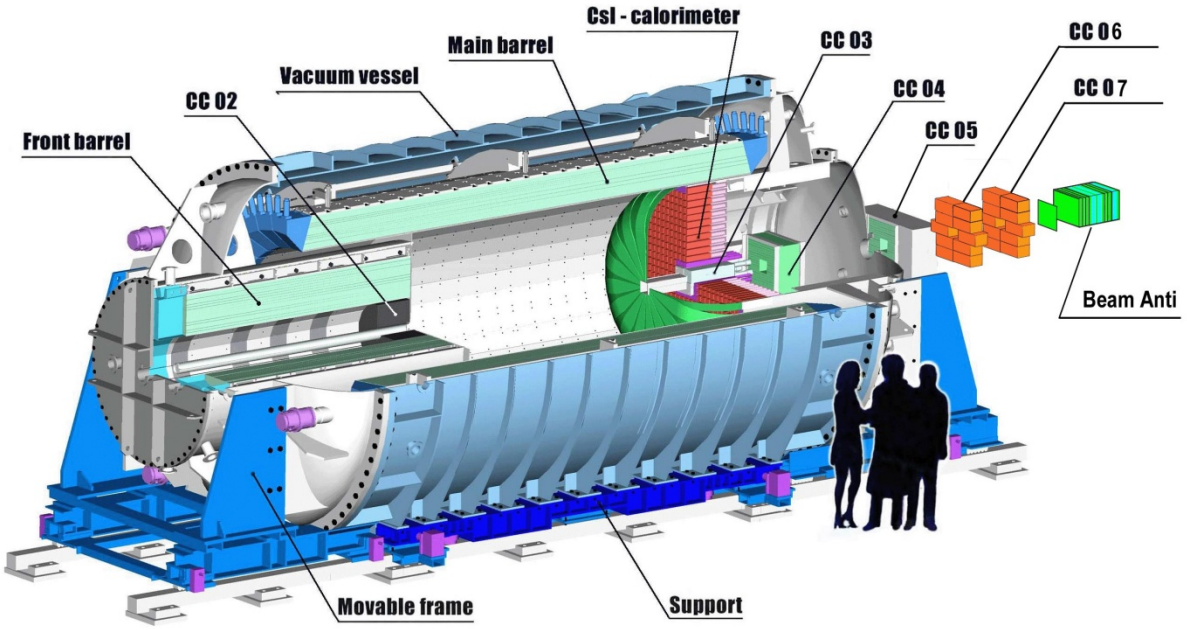
CP Symmetry

- Charge Symmetry: every particle has an antiparticle
- Parity Symmetry: reflected in a mirror
  - Changes handedness
- Charge and Parity changes
  - $\nu_{\text{Left}} \rightarrow \bar{\nu}_{\text{Right}}$
- Preponderance of matter over antimatter indicates CP violation
- CP Violation is observed in K_L^0 decays
  - 0.2%

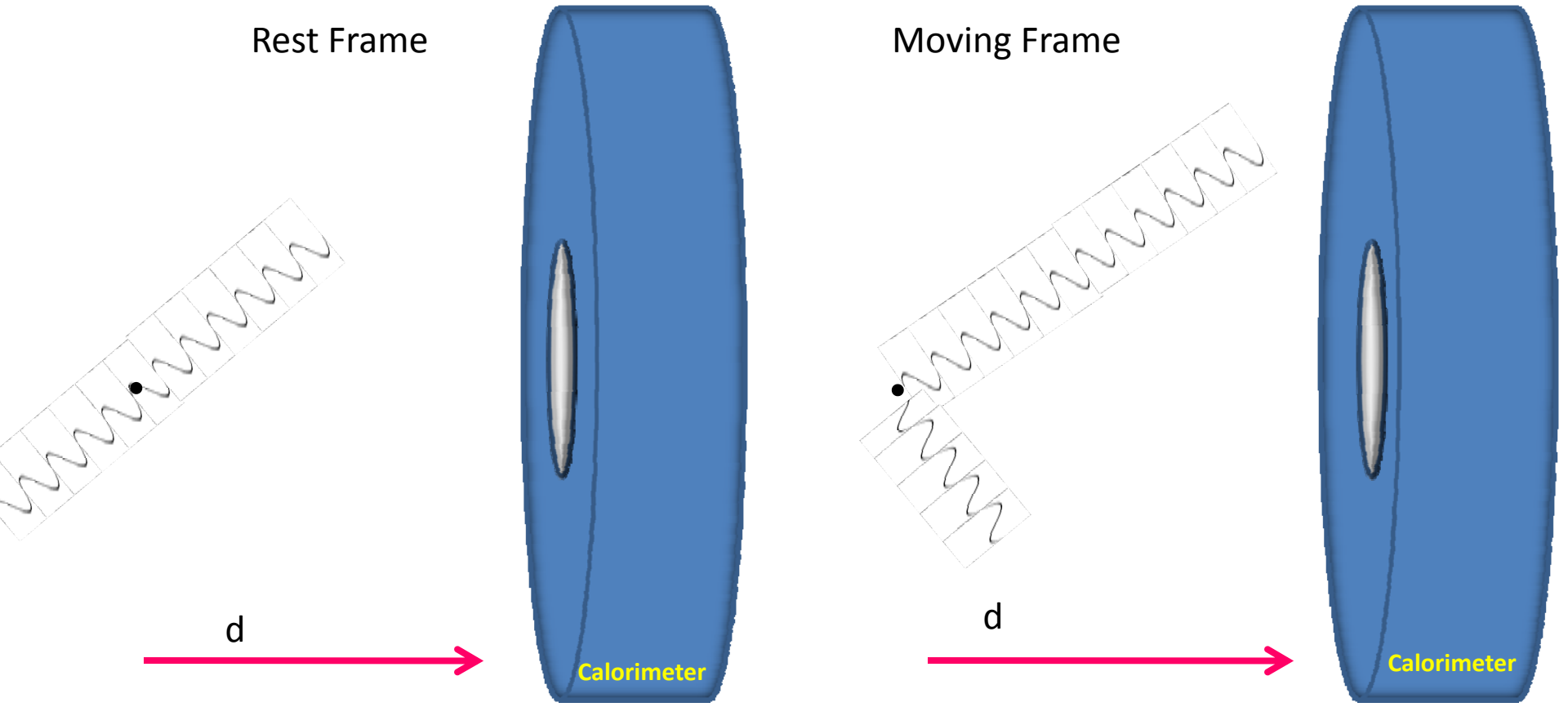


Experiment Plan

- Location: Japan Proton Accelerator Research Complex (J-PARC) in Tokai, Japan
- Essential Components:
  - Beam line
  - Calorimeter
  - DAQ
  - Trigger



REU Simulation



$m_{\pi 0}$: 134.9766 ± 0.00006 MeV/c2
Mean life: (8.4 ± 0.6) x 10^{-17} s

REU Simulation

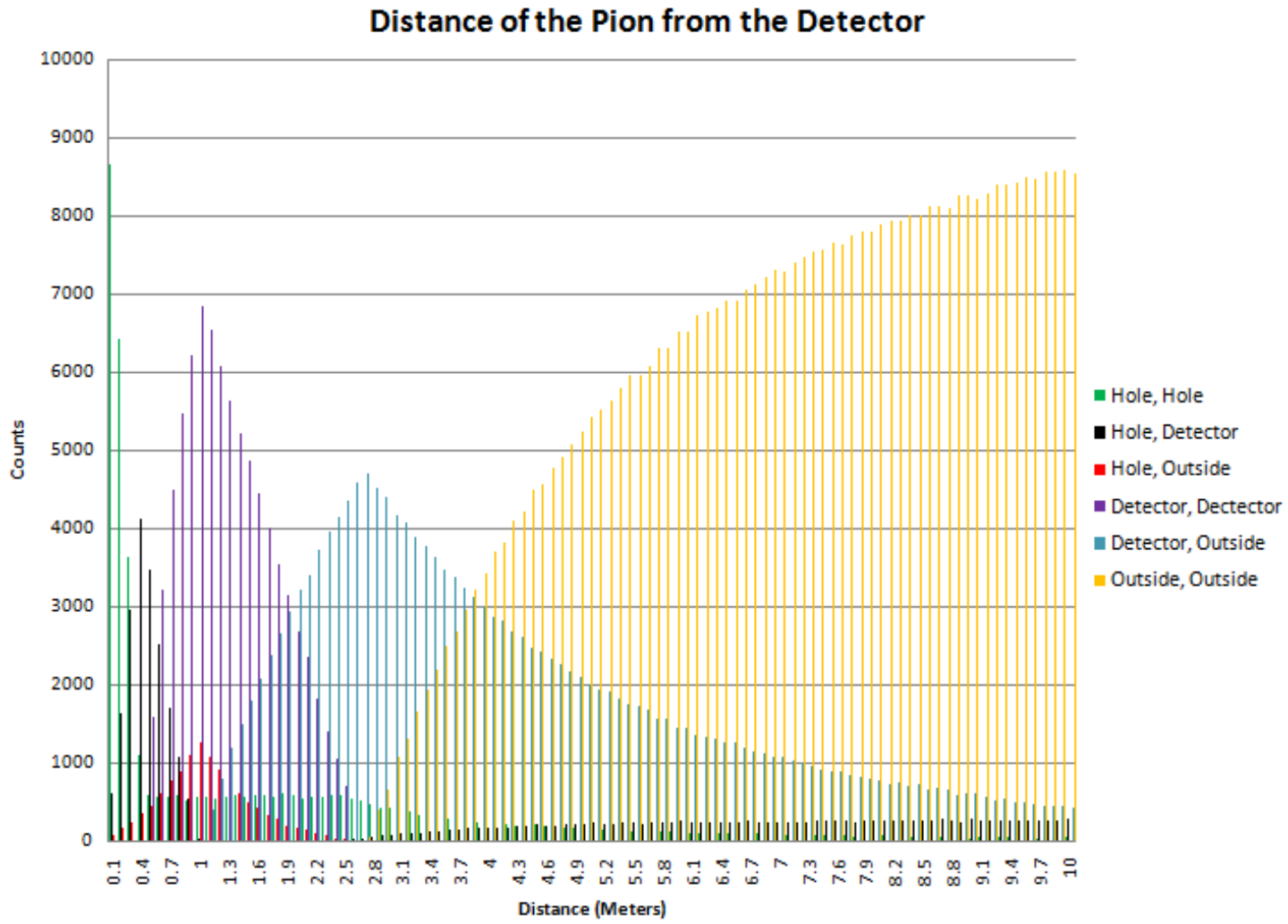
Objective:

- Generate 1,000,000 $\pi^0 \rightarrow \gamma\ \gamma$ at various distances
  - Wolfram Mathematica
- Determine whether the photons hit the detector.

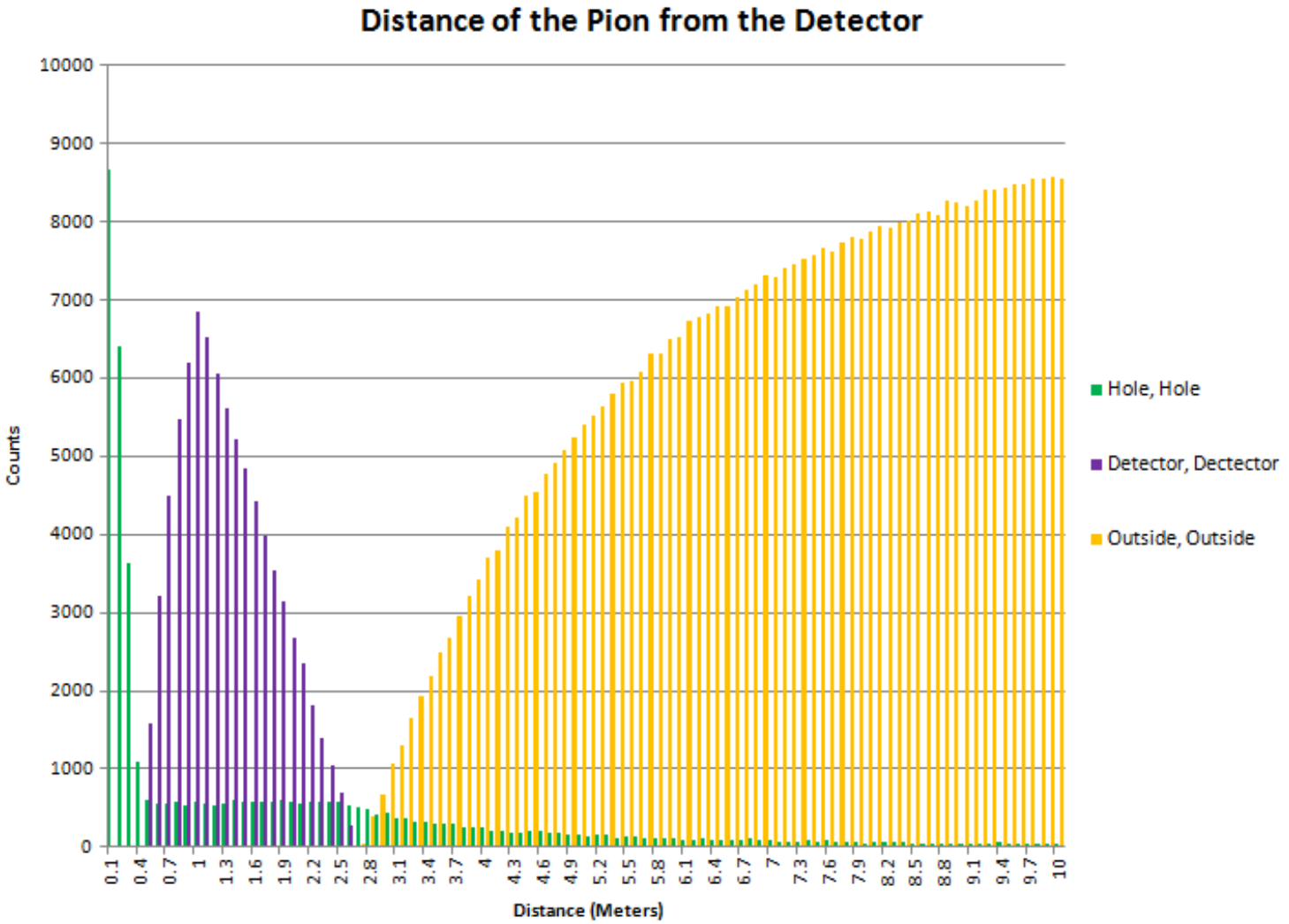
Task:

- Simulating $\pi^0 \rightarrow \gamma\ \gamma$ at random directions
- Calculate the direction of the photons in laboratory's reference frame
  - Momentum
  - Energy
  - Direction
    - θ and ϕ
- Determine the location the photons hit the detector
- Graph the acceptance rate as a function of distance

Results


Distance of the Pion from the Detector
Counts
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0.1
0.4
0.7
1
1.3
1.6
1.9
2.2
2.5
2.8
3.1
3.4
3.7
4
4.3
4.6
4.9
5.2
5.5
5.8
6.1
6.4
6.7
7
7.3
7.6
7.9
8.2
8.5
8.8
9.1
9.4
9.7
10
Distance (Meters)
Hole, Hole
Hole, Detector
Hole, Outside
Detector, Dectector
Detector, Outside
Outside, Outside

Results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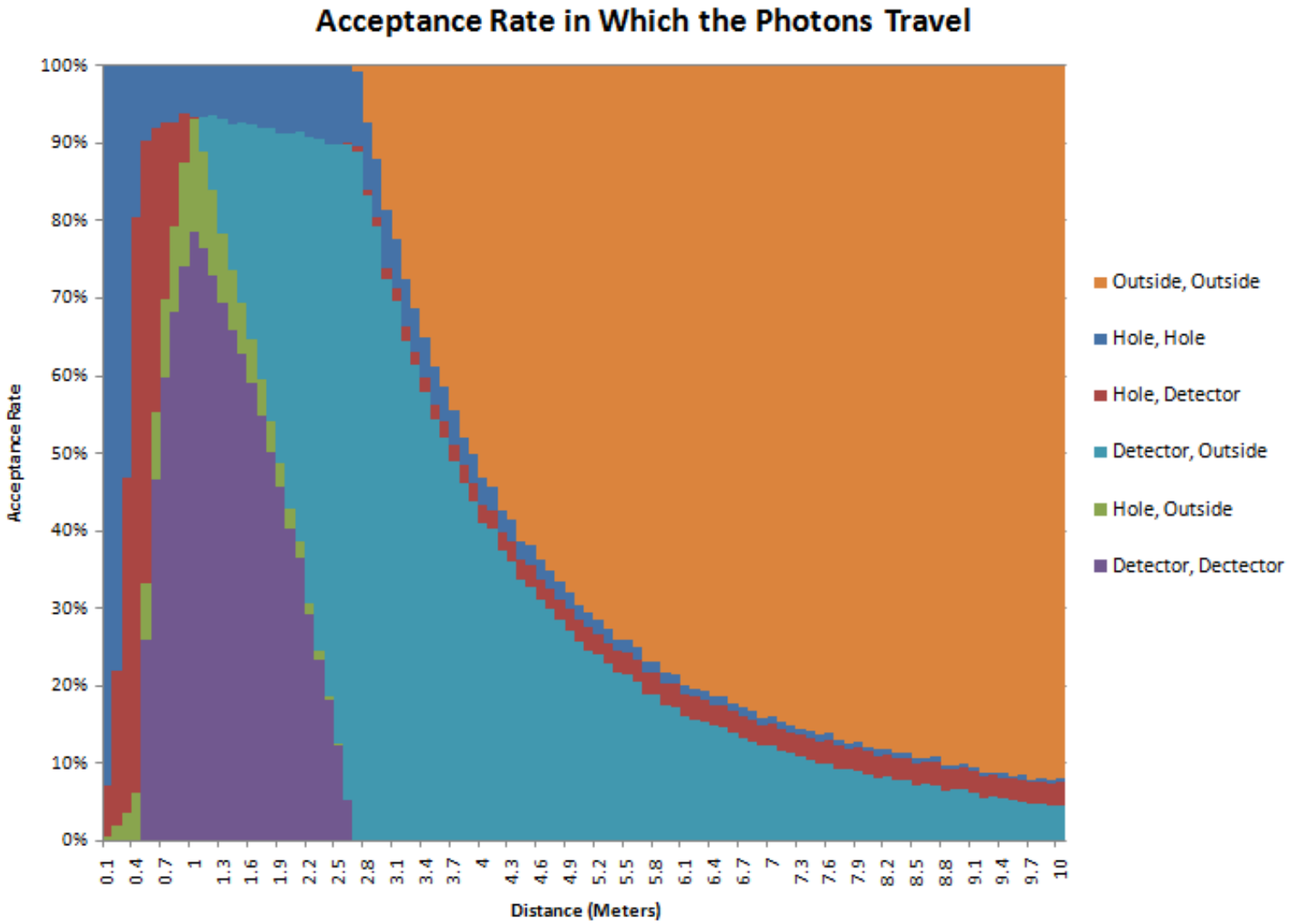
Acceptance Rate in Which the Photons Travel
Acceptance Rate
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.1
0.4
0.7
1
1.3
1.6
1.9
2.2
2.5
2.8
3.1
3.4
3.7
4
4.3
4.6
4.9
5.2
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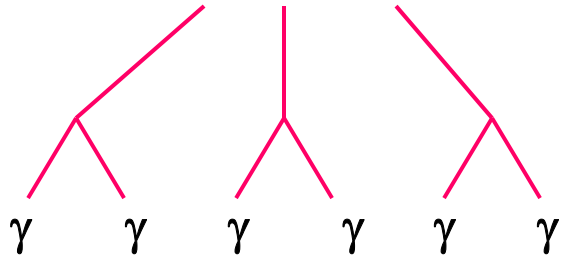
9.4
9.7
10
Distance (Meters)
Outside, Outside
Hole, Hole
Hole, Detector
Detector, Outside
Hole, Outside
Detector, Dectector

Future Goals

- Switch to more sufficient computer program
  - C++
    - Vary relativistic boost and distance
    - Generate various test
      - Simulate $K^0 \rightarrow \pi^0 \ \pi^0 \ \pi^0$



Any Questions?

Special Thanks :

- Myron Campbell
- Monica Tecchio
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- Jon Ameel
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- Bob Ball