Introduction

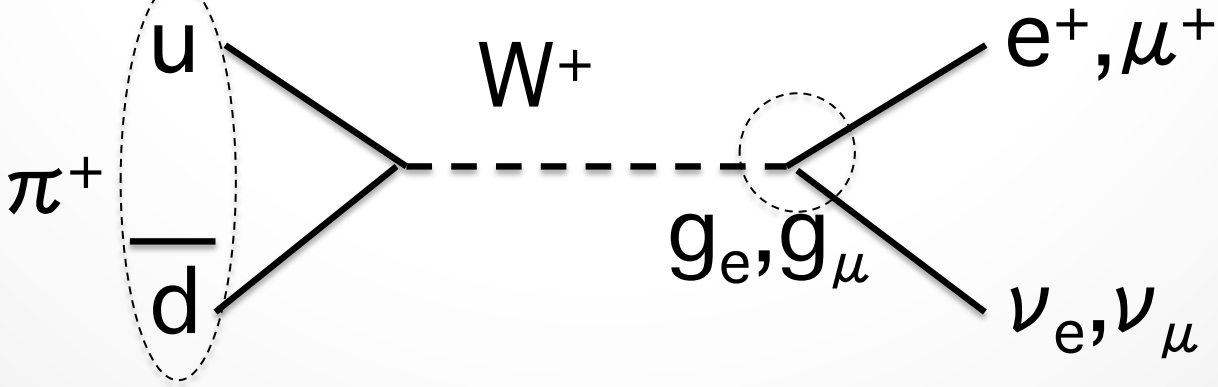
- Studying branching ratio $R=\Gamma(\pi^+\to e^+\nu_e)/\Gamma(\pi^+\to\mu^+\nu_\mu)$.
- This branching ratio R is calculated in SM.

$$R=\frac{g^2_e}{g^2_\mu}\frac{m^2_e}{m^2_\mu}\left(\frac{m^2_\pi-m^2_e}{m^2_\pi-m^2_\mu}\right)^2$$

- $m_e<<m_\mu \Rightarrow \pi\to e\nu$ decay mode is suppresed

(helicity suppression)

- g_e, g_μ:coupling constant → $g_e=g_\mu$ in SM (e-μ universality)



Introduction

- R is precisely calculated in SM

$$R^{SM}=(1.2352\pm0.0001)\times10^{-4}\quad(0.008\%)$$

- Experimental value

$R^{EXP}=(1.2265\pm0.0034\pm0.0044)\times10^{-4}(0.5\%)$ (1992 TRIUMF)

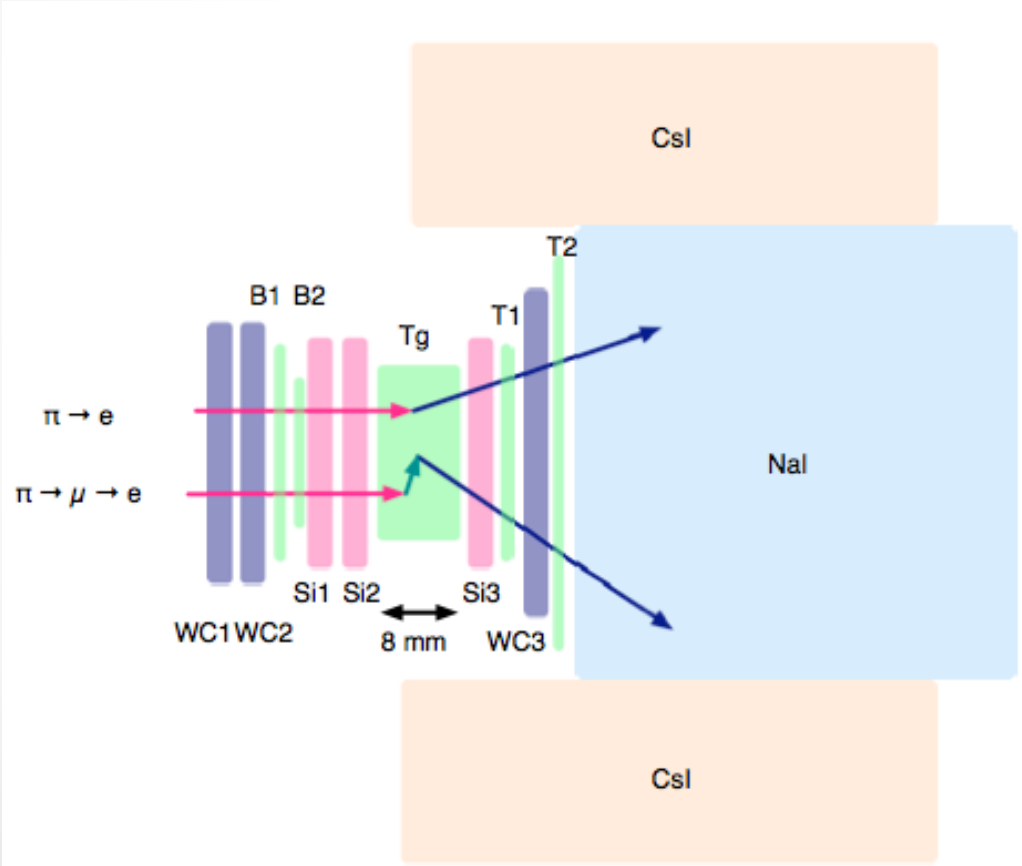
$R^{EXP}=(1.2346\pm0.0035\pm0.0036)\times10^{-4}(0.4\%)$ (1993 PSI)

↓

Measure the branching ratio more precisely than 0.1%

Detector

- PIENU experiment set up.



π^+ beam through B1,2.

↓

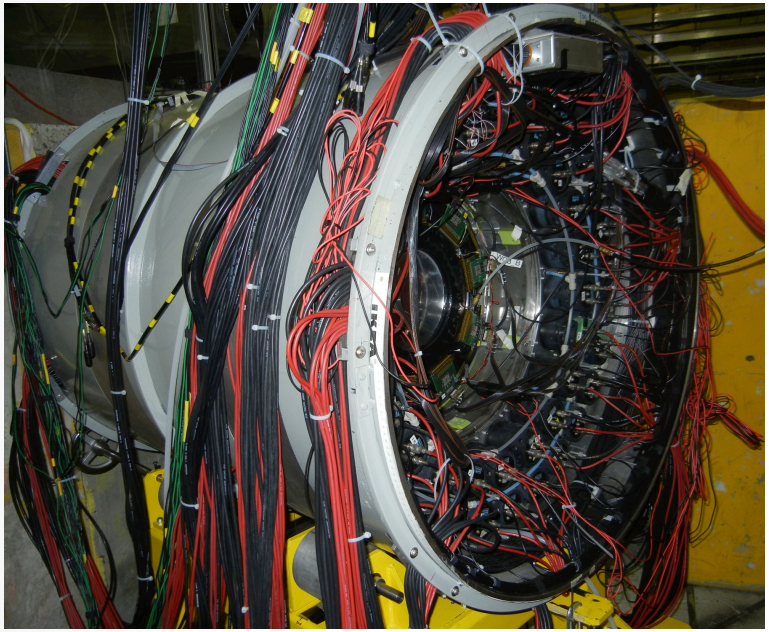
π^+ decay in Target and emit e^+.

↓

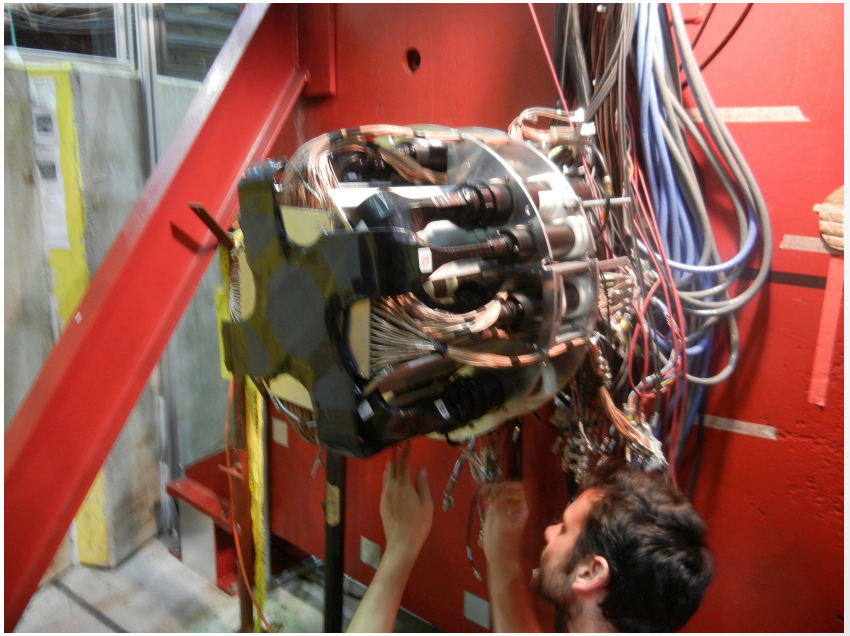
e^+ through T1,2 and detected in NaI

WC : Wire Chamber.
Ss : Silicon Strip.
B1,2,T1,2 : Plastic scintillator

Detector



NaI

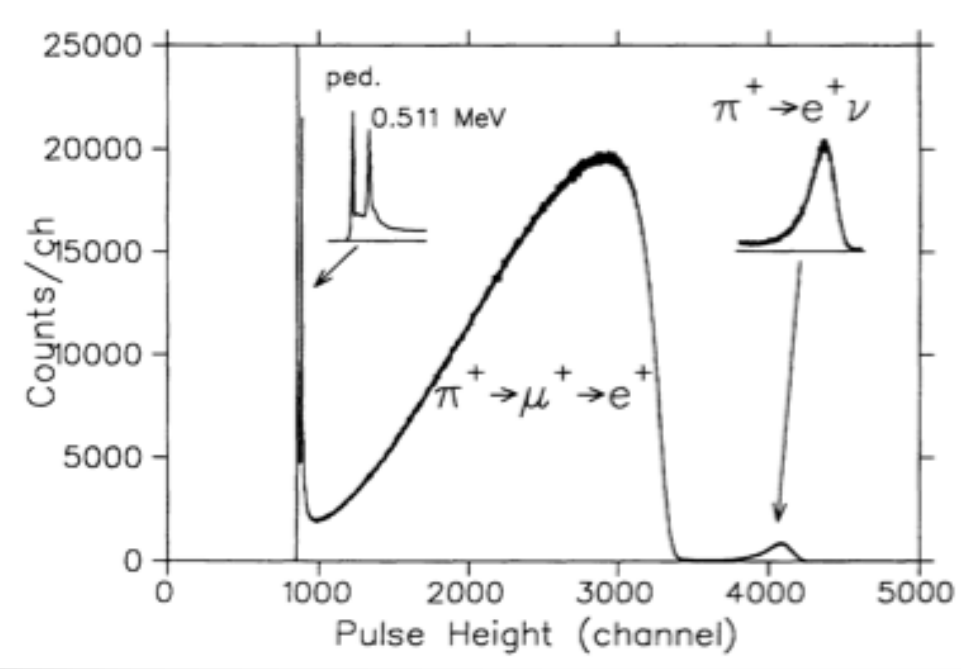


Setting up Tg,T1,T2,B1,B2,Ss

Measurement

- $\pi^+ \rightarrow e^+ \nu$ 2bodies decay: E_e=69.3MeV
- $\pi^+ \rightarrow \mu^+ \rightarrow e+ \nu \ \nu$ 3bodies decay: E_e=0~52.3MeV

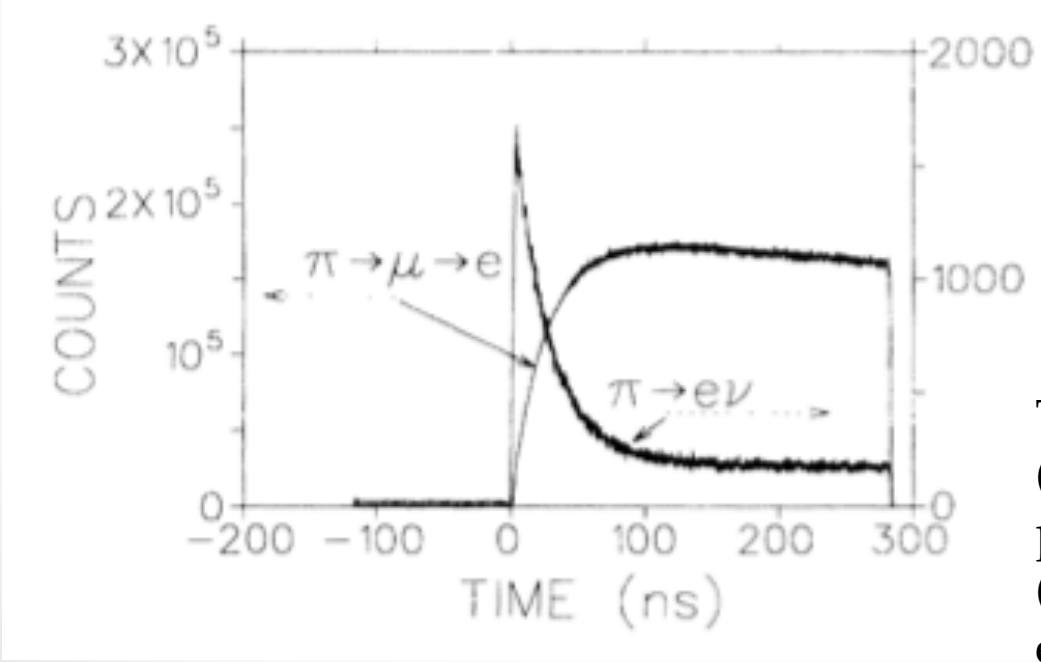
→Identify decay mode by detecting positron's energy deposit in NaI.



Positron's energy deposit in NaI scintillator.
(This figure is previous experiment spectrum in TRIUMF.)

Measurement

- Simultaneous fit time spectrum of $\pi \rightarrow e\,\nu$ and $\pi \rightarrow \mu\,\nu$ ⇨ determined raw branching ratio R_{raw}.
- Branching ratio is calculated by correcting this raw branching ratio R_{raw}.



Time spectrum for upper ($\pi \rightarrow e\nu$) and lower($\pi \rightarrow \mu\nu$) parts of the energy spectrum. (This figure is also previous experiment graph.)

PIENU experiment

- Beam time: This August ~ December in TRIUMF.

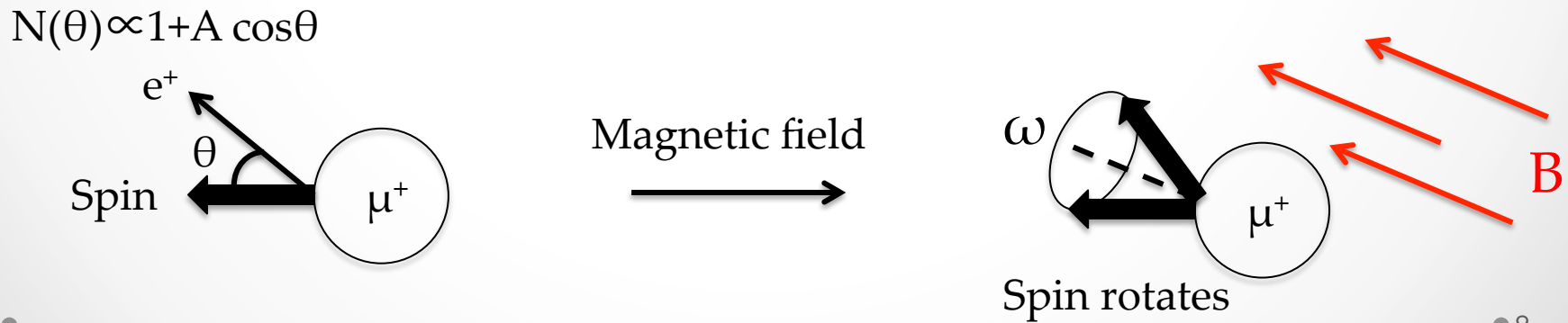
  ⇨Total ~4600 runs (~3×10^5 events/run)
- We did some special runs and data taking.
- One of this special run is "Muon polarization run".
  - Last year's run data of muon lifetime was different from world average value about 1%.

    →If muon lifetime shifts , R^{EXP} is affected!!(R is calculated by using positron time spectrum. (Life time longer → R smaller)).
  - This difference might be caused by muon polarization.
  - We did special run to understand muon polarization.
  - **To understand this problem, I studied muon spin influence in PIEUN experiment by using "Toy Monte Carlo simulation".**

Muon polarization

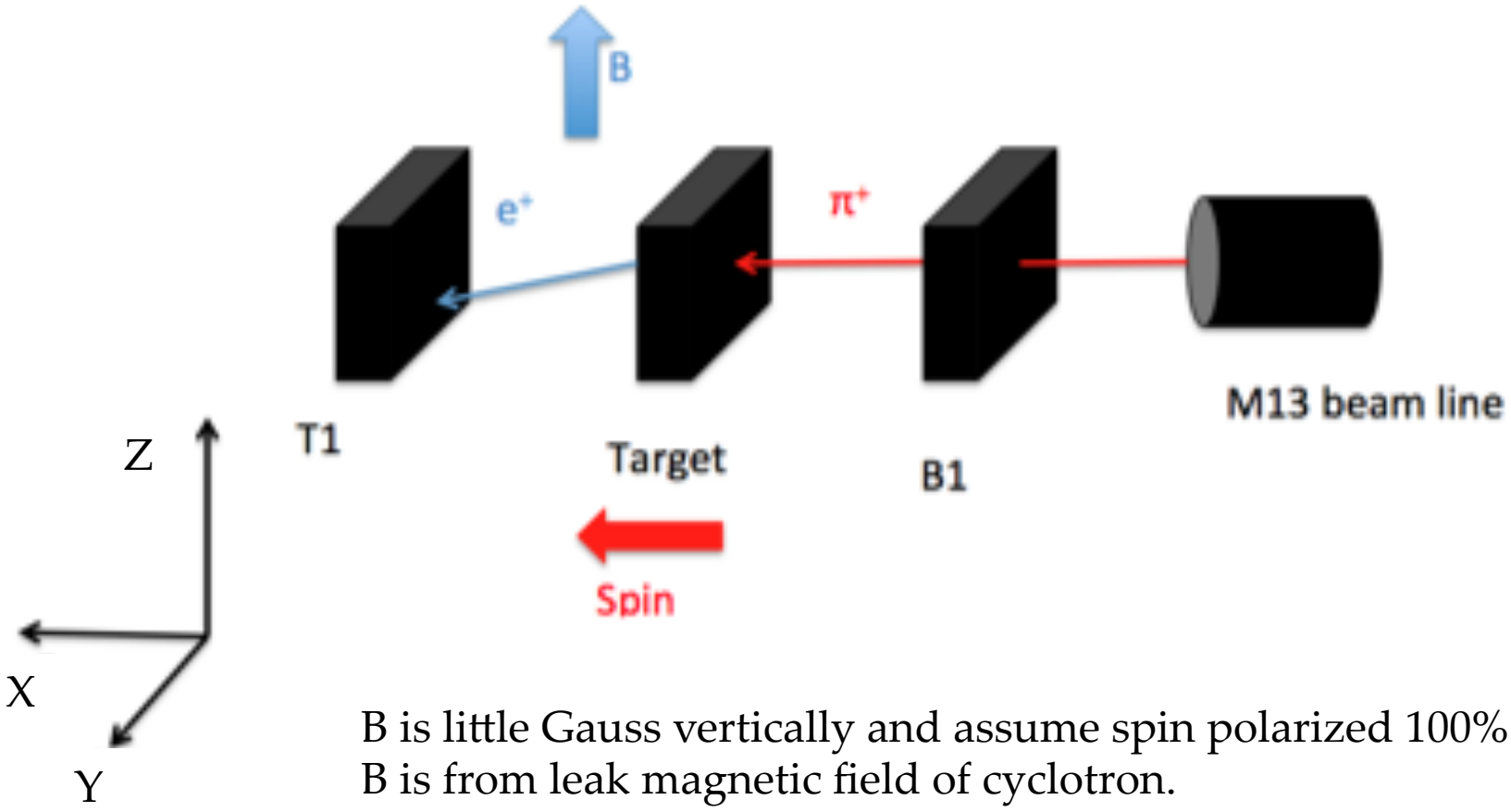
- Direction of positron depends on muon spin direction.
  →$N(\theta) \propto 1+A\cos\theta$ (A:asymmetry)
- Muon has magnetic momentum.
  →Spin rotates in magnetic field. So occurs oscillation.
- Muon spin's angular momentum ω in B can write

$$\omega = \frac{g_\mu eB}{2m_\mu} \simeq 848B \text{ [rad/us]}$$



Toy Monte Carlo simulation

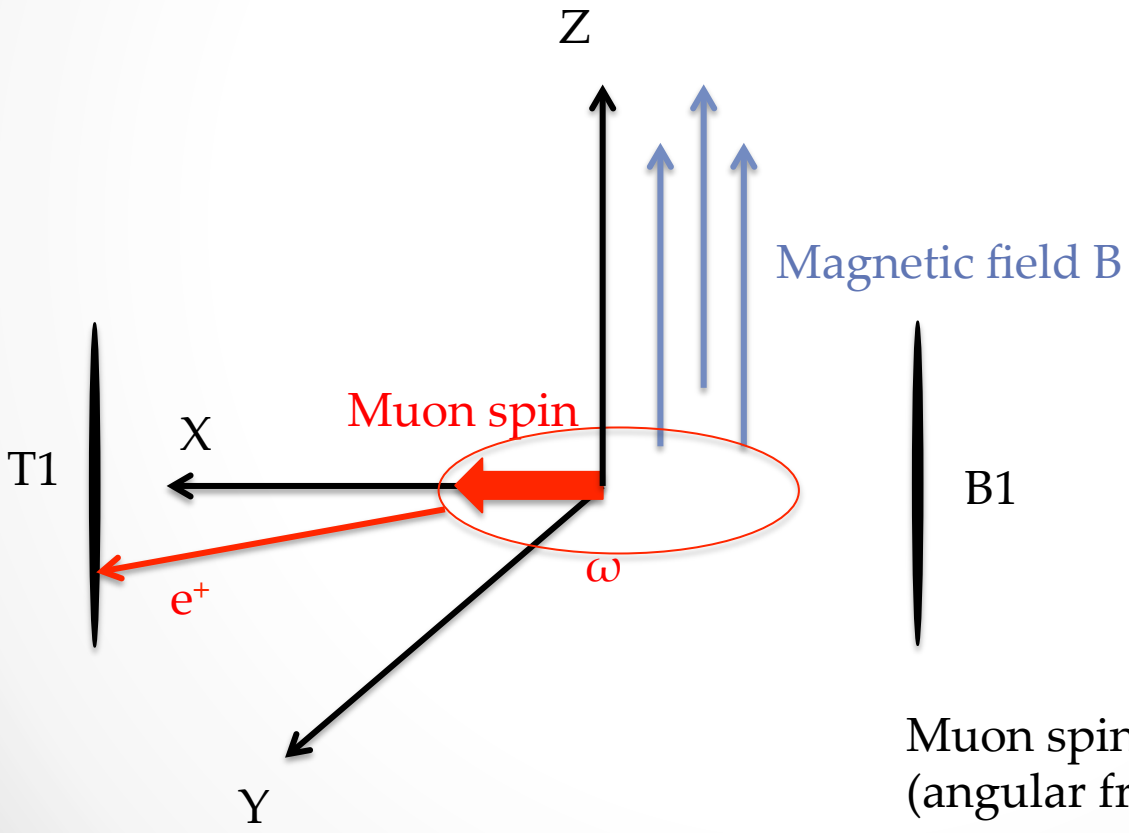
Detector schematic.



B is little Gauss vertically and assume spin polarized 100%.
B is from leak magnetic field of cyclotron.

Toy Monte Carlo simulation

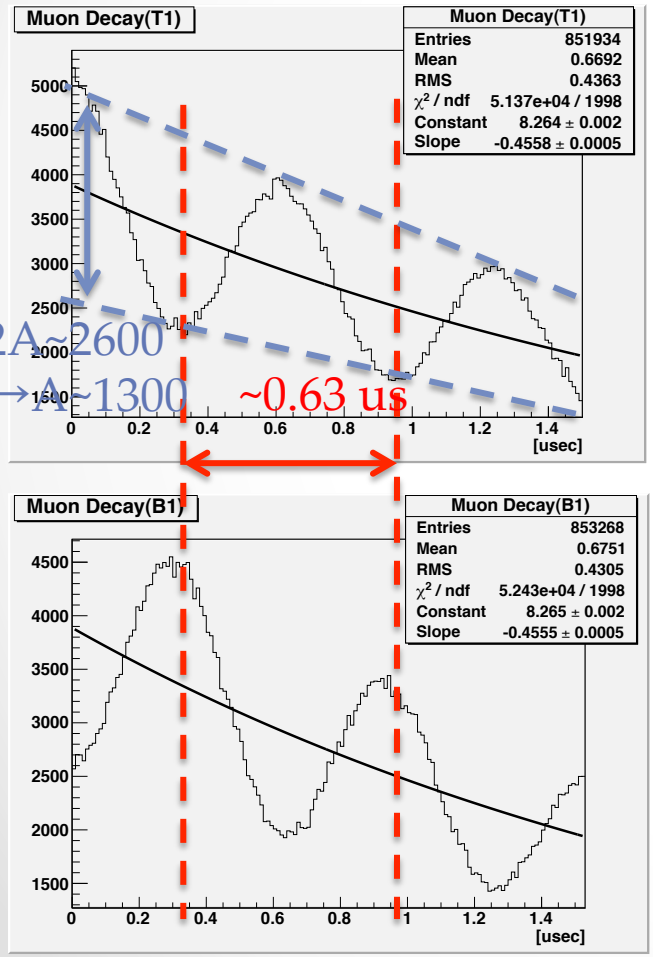
I made program for Toy MC simulation.



Muon spin rotates arround B vertically
(angular frequency ω [rad/us])

Toy Monte Carlo simulation

- Test this program. ω=10 rad/μs (T=2π/ω~0.63 μs)



- T1's plot is opposite phase B1's.
- See oscillation and frequency.
- Amplitude is estimated about 1300exp(-λt).

↓

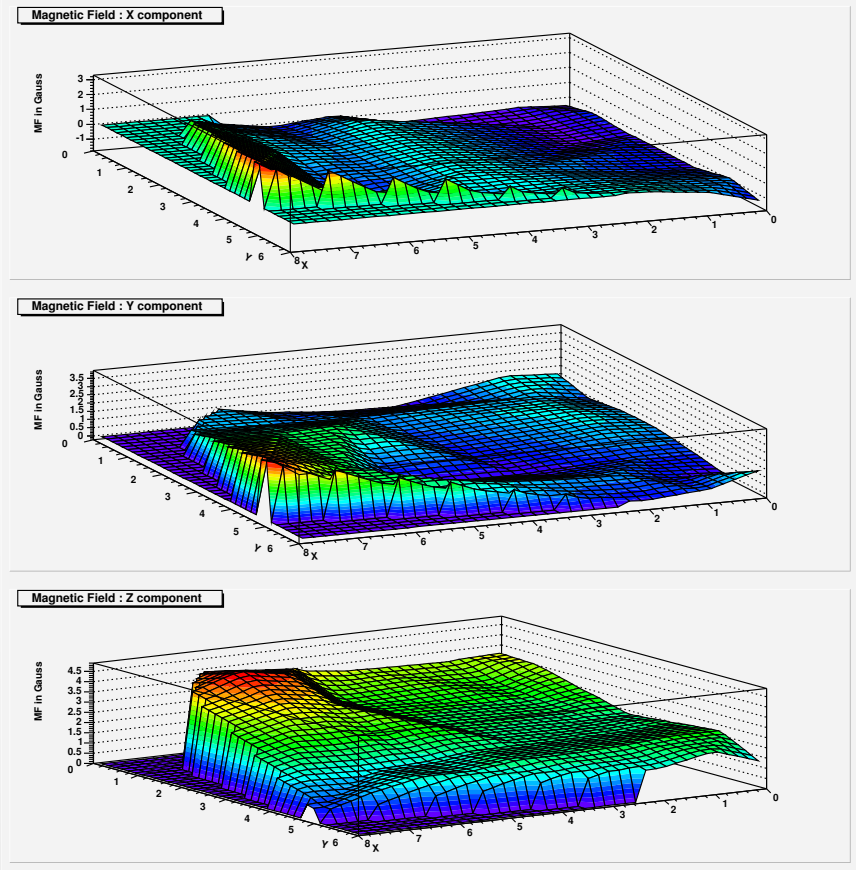
Use this program.

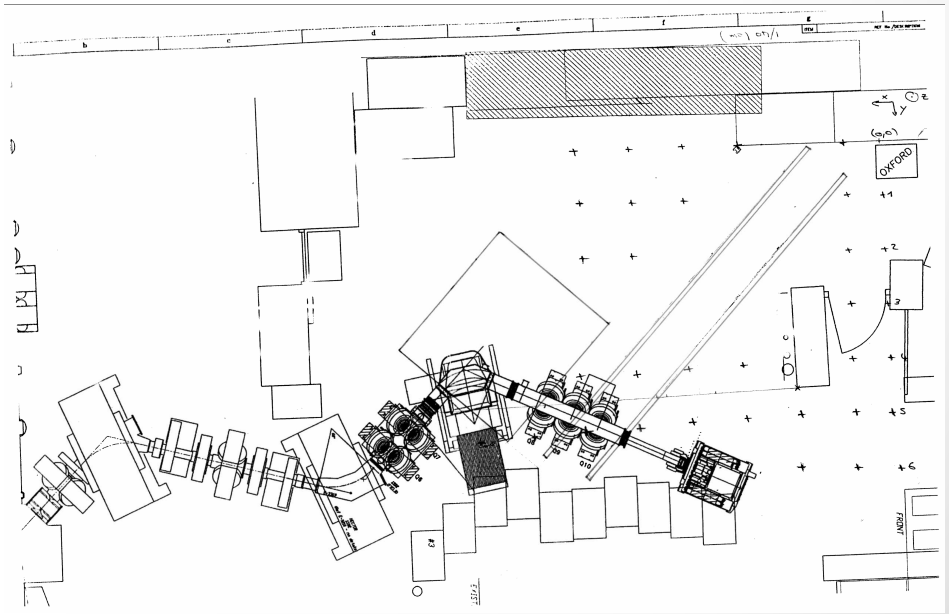
Toy Monte Carlo simulation

- Magnetic field B is from cyclotron and below 1Gauss and vertically.
- Muon life time is 2.197 μs (λ=1/2.197=0.4551 μs^{-1})
- If life time shifts ~1%, the difference between T1 (down stream) and B1(up stream) is ~ 2% .
- $\omega \simeq 848B$[rad/μs] (B[T])

  ex. B=1Gauss → ω=0.0848 rad/μs
- Use this program and study life time shifting.

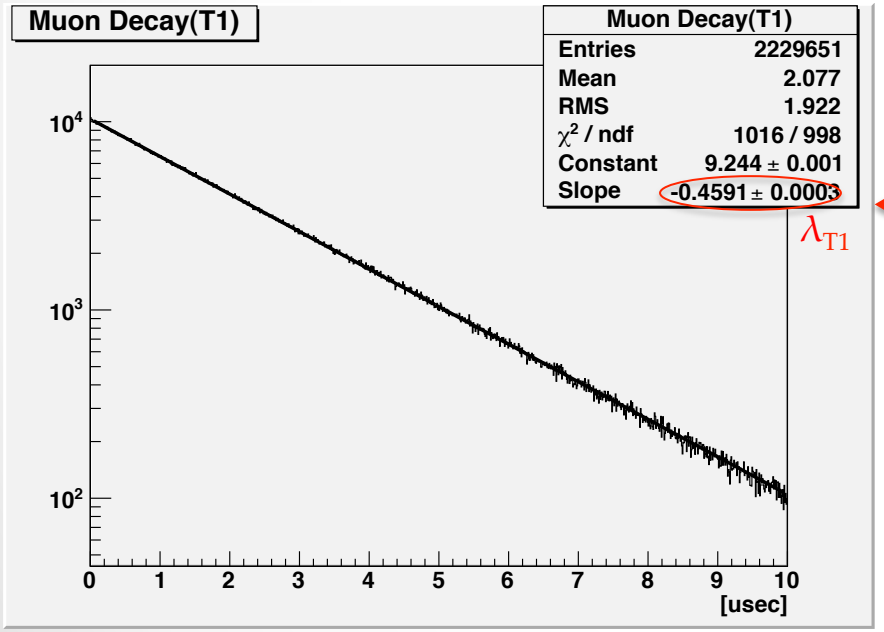
Magnetic Field Map

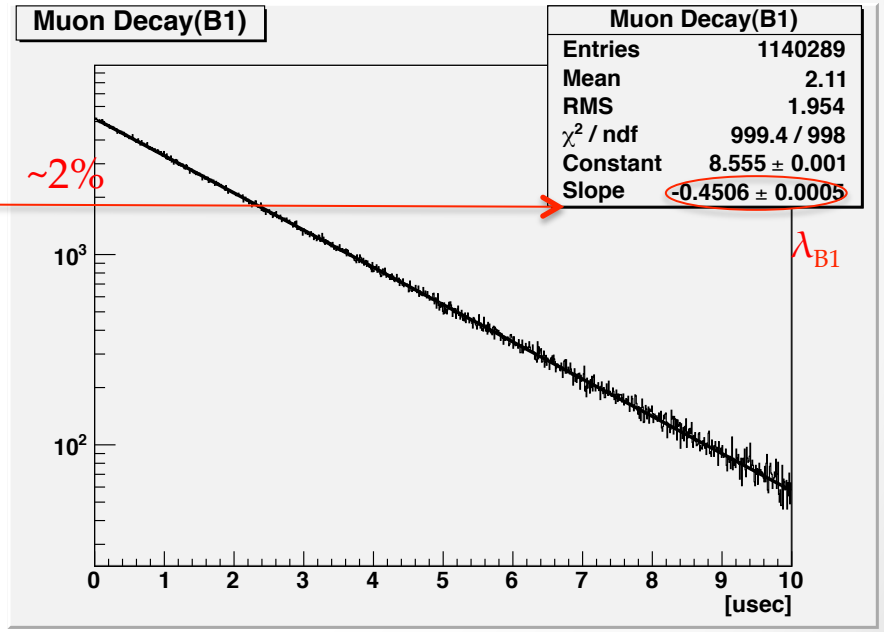




Toy Monte Carlo simulation

ω=0.060 rad/us → B~0.71 Gauss





Toy Monte Carlo simulation

- Under magnetic field B ~0.71 Gauss

$\lambda_{T1}=0.4591\pm0.0003\ \mu s^{-1}$ $\overset{1\%}{\Leftrightarrow}$ $\lambda=0.4551\ us^{-1}$ $\overset{1\%}{\Leftrightarrow}$ $\lambda_{B1}=0.4506\pm0.0005\ \mu s^{-1}$

⇩

muon life time shift ~1%

⇩

Shifting life time can occur by muon polarization.

- Now, spin direction assumes polarize 100% and asymmetry A=1/3.
- In fact, muon depolarizes in plastic scintillator.
- I haven't analyzed run data. So I will analyze run data.

Summary

- Purpose of PIENU experiment is measuring the branching ratio of $\Gamma(\pi \rightarrow e\,\nu)/\Gamma(\pi \rightarrow \mu\,\nu)$ more precisely than 0.1%.
- Beam time did this August ~ December and we took some special run and data taking.
- Result from MC simulation, it can occur shifting life time ~1% by muon polarization.
- I have to analyze run data.
- Next beam time will be acted next year.

Thank you for your attention.

Photo in Vancouver.

Back up

Positron Spectrum

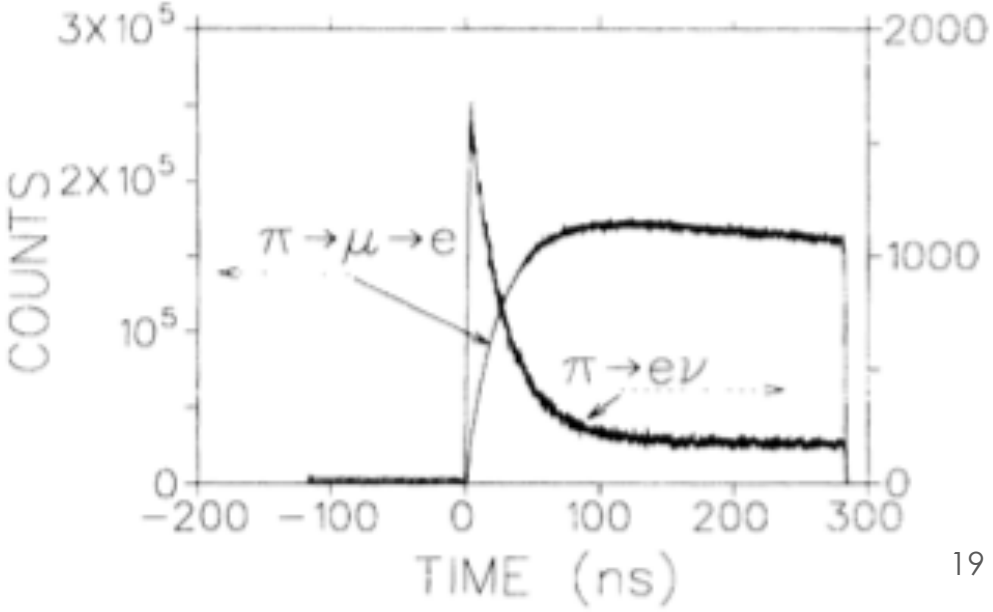
- $F(t)_{\pi e} \sim A\exp(-t/\tau_{\pi})$
- $F(t)_{\pi \mu e} \sim B(\exp(-t/\tau_{\mu})-\exp(-t/\tau_{\pi}))$

τ_{π}, τ_{μ}:π,μ life time
A,B: Amplitude of each decay mode

⇩

$R_{raw} \sim F(t)_{\pi e}/F(t)_{\pi \mu e}$

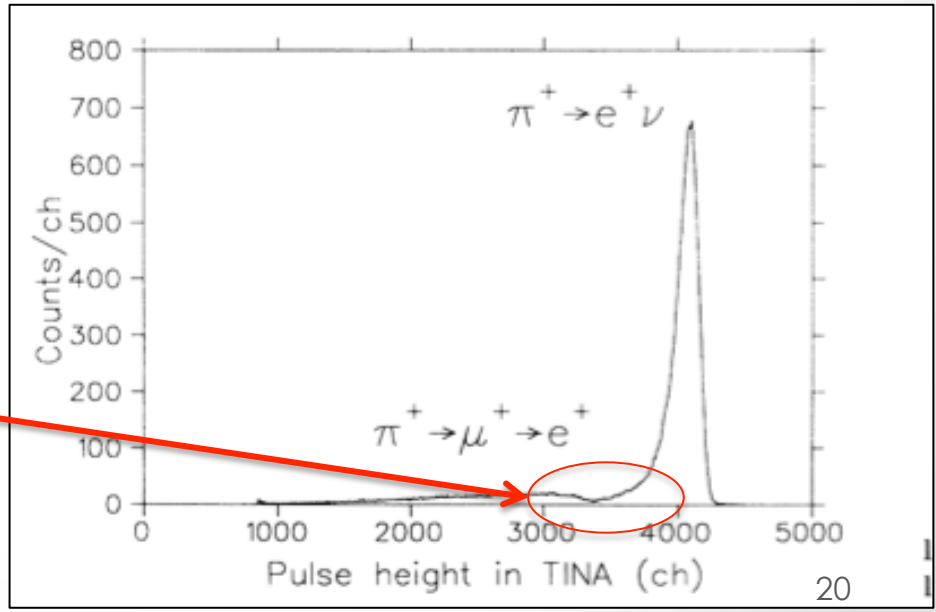
⇨**(In case life time shifts longer, R_{raw} becomes smaller.)**



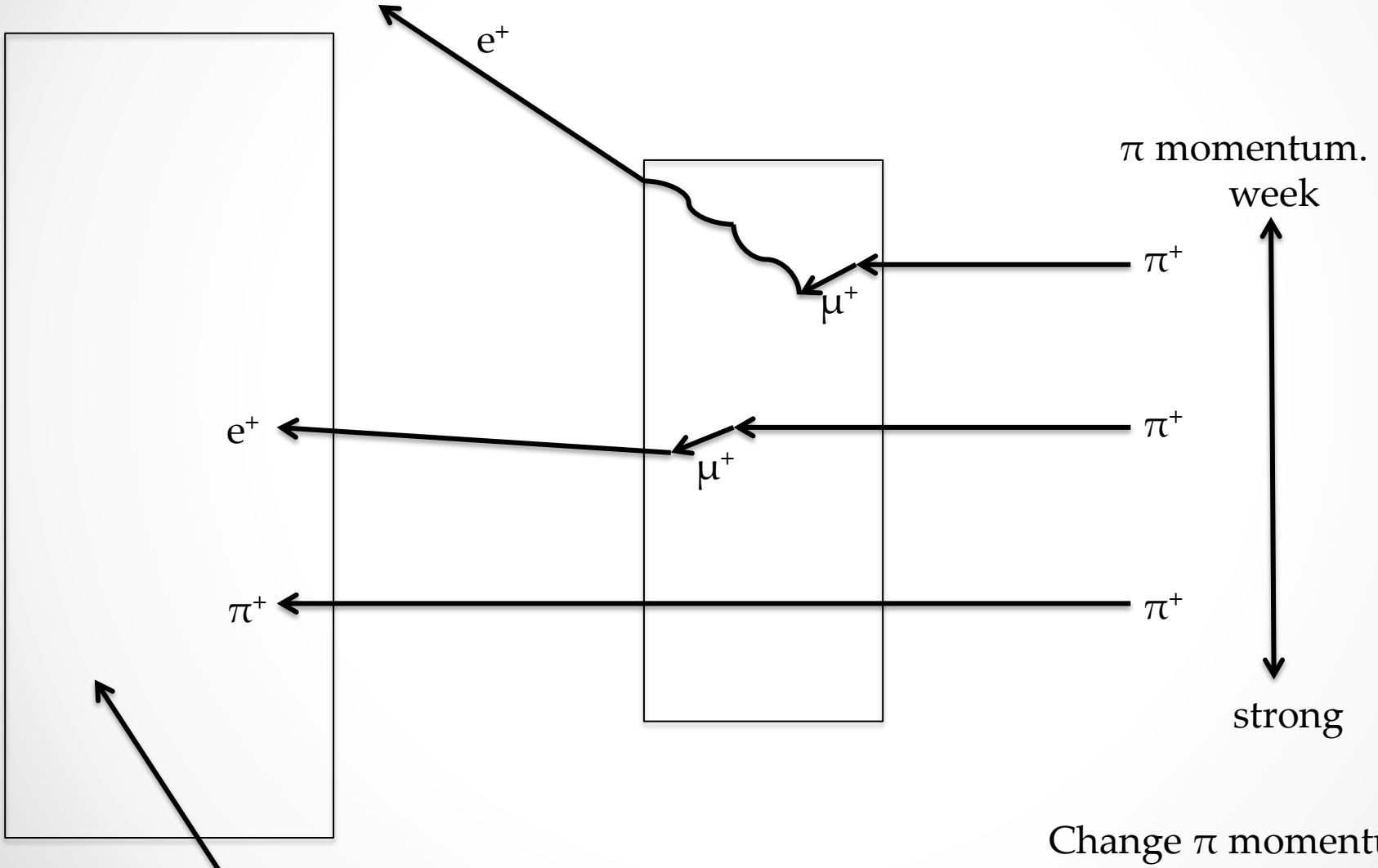
Tail correction

- Tail of the $\pi \rightarrow e\,\nu$ extend under the $\pi \rightarrow \mu \rightarrow e$ distribution because of leak current.
- We have to estimate low-energy tail and correct raw branching ratio R_{raw}. ⇨ Tail correction.

Low-energy tail extend under π→μ→e events (after π→μν decay suppressed). Estimate low-energy tail.



Special run π Momentum Scan



Change π momentum.

- Telescope counter , NaI detector.

Positron Line-shape

- We measured e^+ energy by using NaI.
- Changed positron's incident angle.
- To estimate leak current and lin-shape, we did this special run.