T-Violation Experiment using Electron Polarimeter

Rikkyo Univ. / RIKEN Jiro Murata

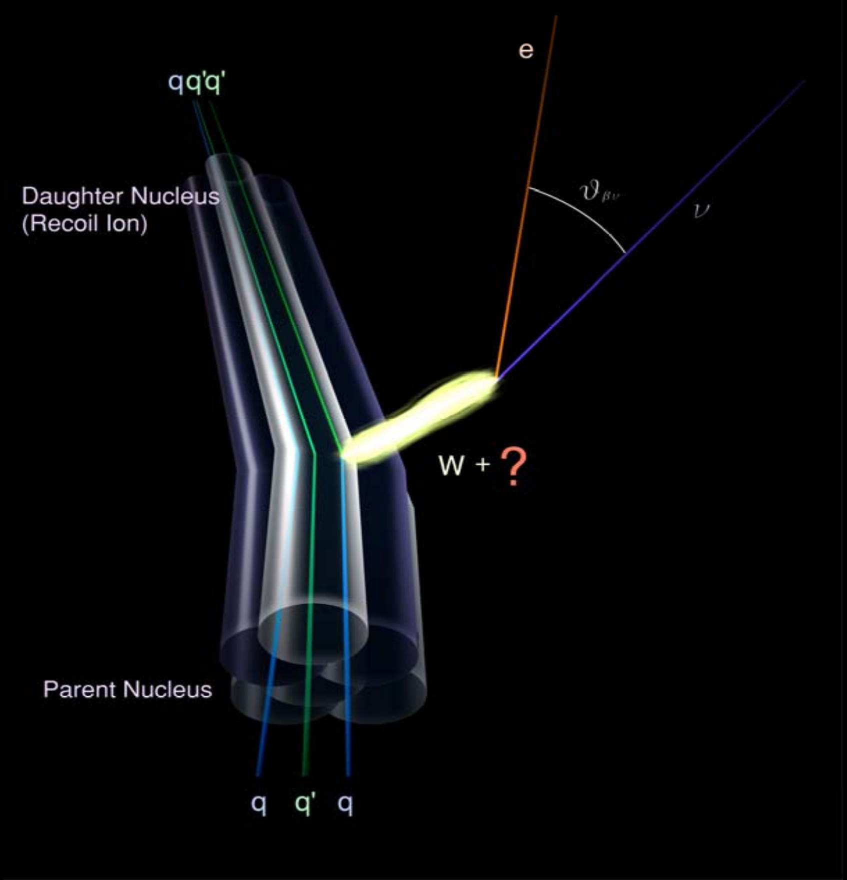
Beta Neutrino Correlation using Recoil Measurement

↓

Beta Polarization Measurement from stopped Nuclei

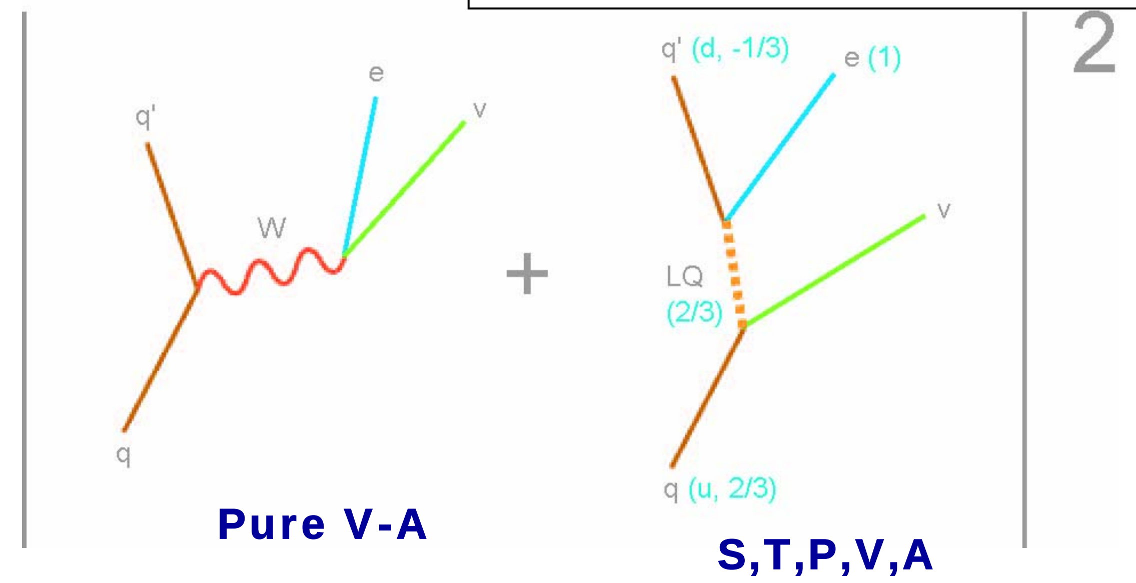
Roadmap towards Fundamental Physics with RI

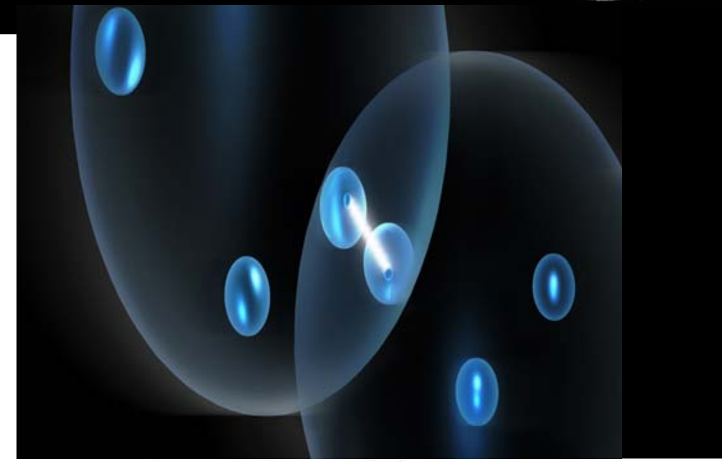
Collaboration
Rikkyo Univ. / RIKEN Asahi ANL / Titech Asahi Lab.
J. Murata, H. Kawamura, M. Uchida
and Atomic Beam Team



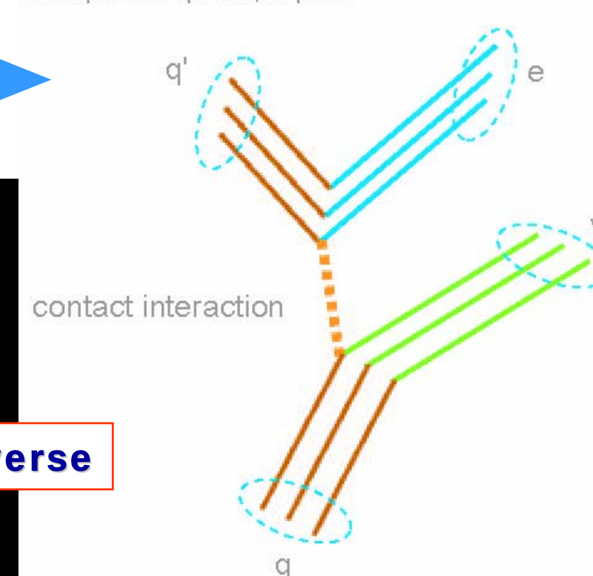
Standard Model Weak Interaction and New Physics

Leptoquark: Couple to q & l pair





Composite quark, lepton



New Interaction ⇒ **Deviation from SM V-A**

T-Violating Couplings : predictions from models of Leptoquarks (GUT, SUSY, String), θ-term, m-Higgs

Motivation: **To Explain Large Baryon / Anti-Barion Asym. in Universe**

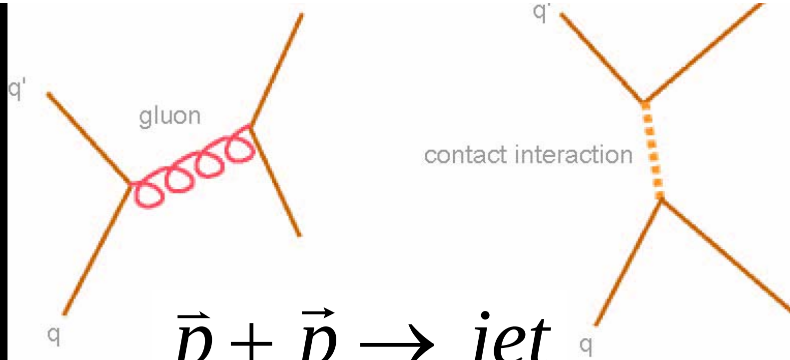
CP(T)-Violation outside CKM = Physics Beyond the SM

⇒ **Small CKM is better** ⇒ **u,d system = Radioacitve Nuclei is good system**

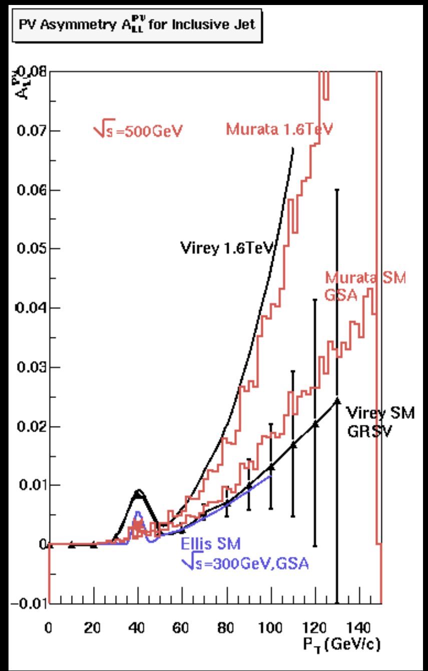
RHIC and RIBF

RHIC PHENIX exp.

beam polarizaion => precision PV meas. with SM



$$\vec{p} + \vec{p} \rightarrow jet$$



| QCD + Weak + CI |^2

Not Enough Luminosity ...

Utilizing RIBF as a Precision Weak Decay Tool

RI Beam Factory ~ Weak Boson Factory

| Weak + ? |^2

Measurable signal from interference contribution

RIBF Must have Discovery Potential in Weak Sector

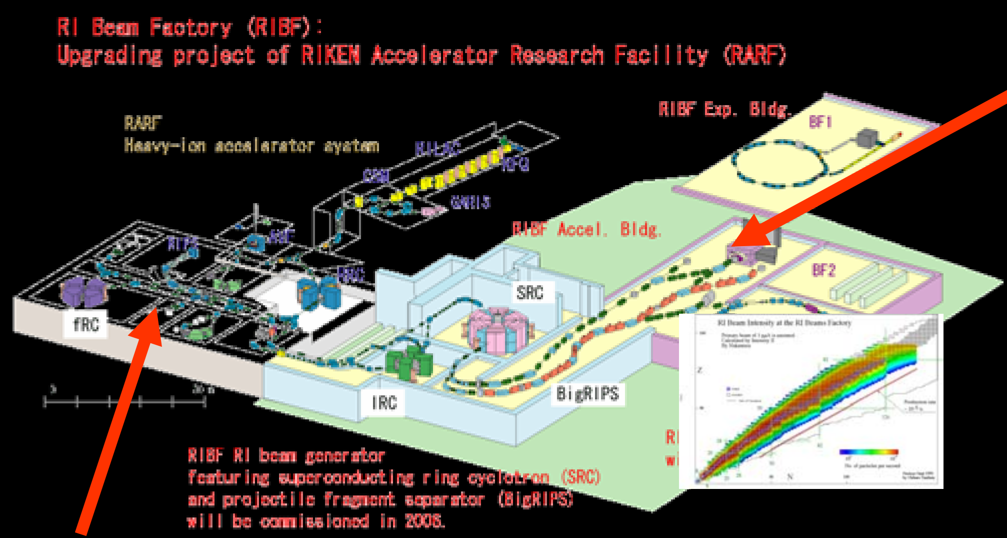
Direct Collider Search (TEVATRON, LHC)

Precision Symmetry Exp. (RHIC, HERA,K,B,LC)

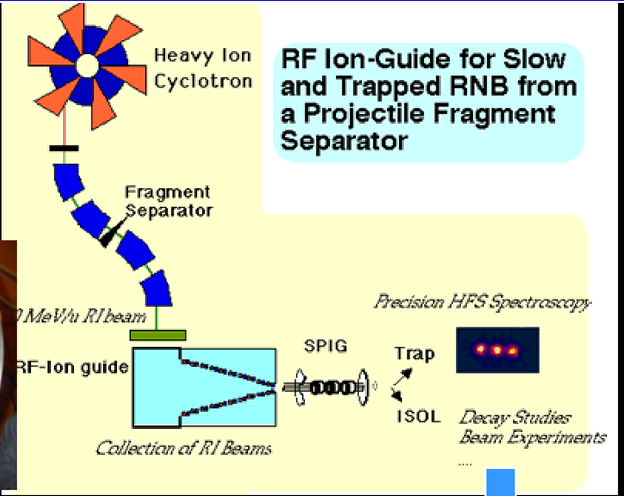
Precision Beta Decay Exp.

equivalent

Unique Slow / Stopped RI Facilities at RIBF

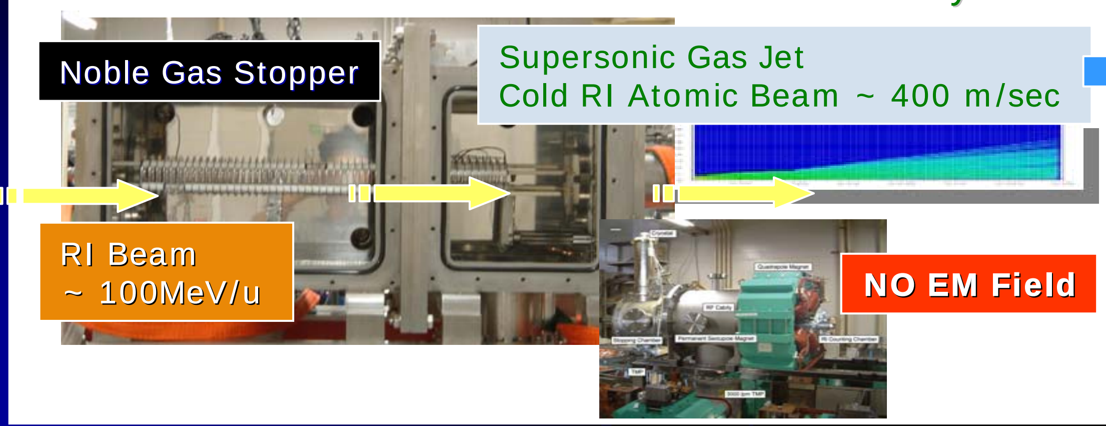


SLOWRI Facility for Atomic Physics

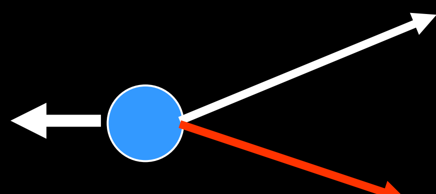


RIAB for Magnetic Moment Study using Atomic Beam Method

RI Beam Gas Catcher + Gas Jet Production System



Beta Decay in Vacuum



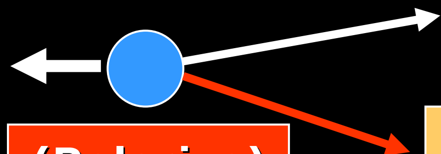
Recoil Measurement

Measurement using Slow RI

Beta Decay

$$\frac{d\omega}{dE_\beta d\Omega_\beta d\Omega_\nu} = \frac{1}{(2\pi)^5} p_\beta E_\beta (E_0 - E_\beta)^2 \cdot \left(\begin{array}{l} 1 + a\dfrac{\vec{p}_\beta \cdot \vec{p}_\nu}{E_\beta E_\nu} + b\dfrac{m}{E_\beta} + \vec{J}_I \cdot \left(A\dfrac{\vec{p}_\beta}{E_\beta} + B\dfrac{\vec{p}_\nu}{E_\nu} + D\dfrac{\vec{p}_\beta \times \vec{p}_\nu}{E_\beta E_\nu} \right) \\ + \vec{\sigma}_\beta \cdot \left(G\dfrac{\vec{p}_\beta}{E_\beta} + H\dfrac{\vec{p}_\nu}{E_\nu} + K\dfrac{\vec{p}_\beta}{E_\beta + m}\left[\dfrac{\vec{p}_\beta \cdot \vec{p}_\nu}{E_\beta E_\nu}\right] + L\dfrac{\vec{p}_\beta \times \vec{p}_\nu}{E_\beta E_\nu} + N\vec{J}_I + Q\dfrac{\vec{p}_\beta}{E_\beta + m}\left[\vec{J}_I \cdot \dfrac{\vec{p}_\nu}{E_\nu}\right] + R\vec{J}_I \times \dfrac{\vec{p}_\beta}{E_\beta} \right) \end{array} \right)$$

Precoil



Pbeta

(Polarize)

Pneutrino = - (Precoil + Pbeta)

Free Beta Decay & Recoil Measurement

$$D\vec{J}_I \cdot \frac{\vec{p}_\beta \times \vec{p}_\nu}{E_\beta E_\nu}$$

Precoil ,Pbeta , J

T-Violating
D=0 ? < 10^ -12 in SM-CKM
Non Zero D in u,d system
= New Physics Beyond the Standard Model

Current Limits

1 x 10 ^ -3 : Princeton '84

$$^{19}\vec{N}e \rightarrow {}^{19}Fe^{+}\nu_e$$

$$a\frac{\vec{p}_\beta \cdot \vec{p}_\nu}{E_\beta E_\nu}$$

Precoil ,Pbeta

Test of V-A interaction
a=1 (Fermi), -1/3 (GT) ?
⇨ New Physics Beyond the Standard Model
F/GT mixing ratio
⇨ Nuclear Structure

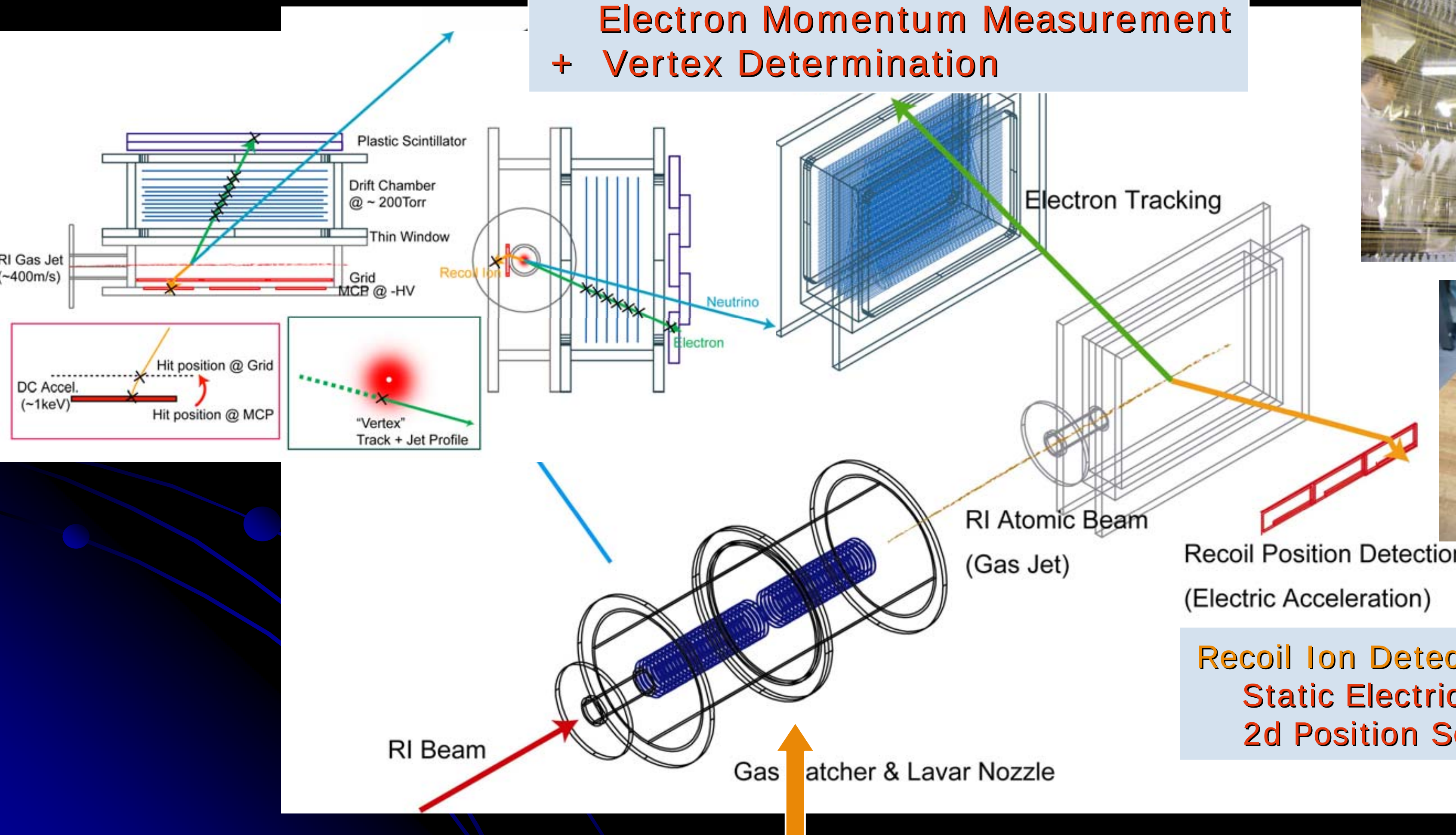
precision ~ 10 ^ -3

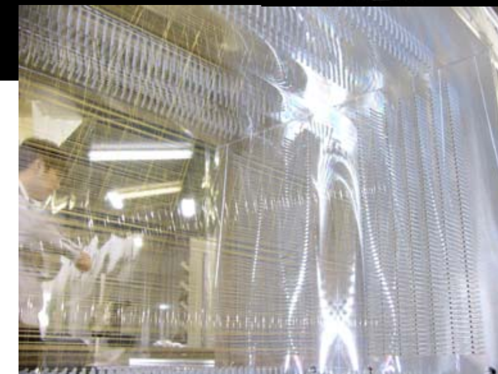
|Cs/Cv|<8% (Fermi)
|CT/CA|<13% (GT)

NO EM Field ⇨ Direct Measurement

Experimental Setup for Beta Neutrino Correlation measurement

Electron Tracking Chamber
- Electron Momentum Measurement
- \+ Vertex Determination



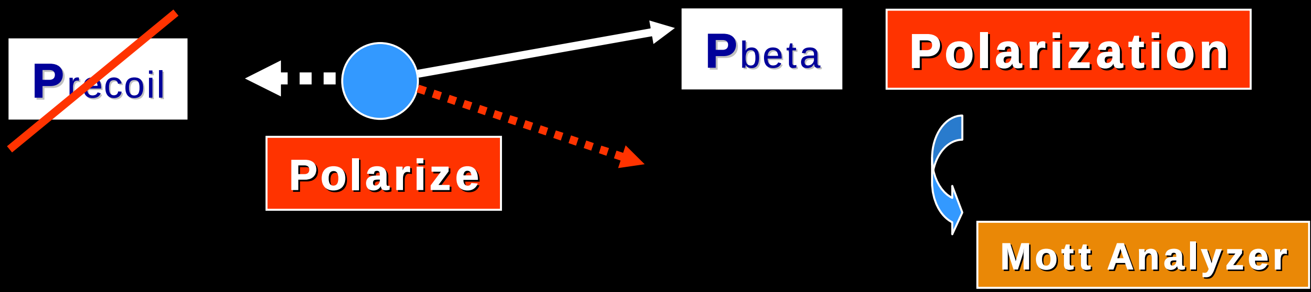


Recoil Ion Detector
- Static Electric Field Acceleration
- 2d Position Sensitive MCP

Detector Almost Ready → **R&D of Slow RI Production** **Long Range Plan**

First Step Measurement : w/o Recoil

Electron Measurement



$$R\vec{\sigma}_\beta \cdot \frac{\vec{J} \times \vec{p}_\beta}{JE_\beta}$$

Current Limits

R ^ -3

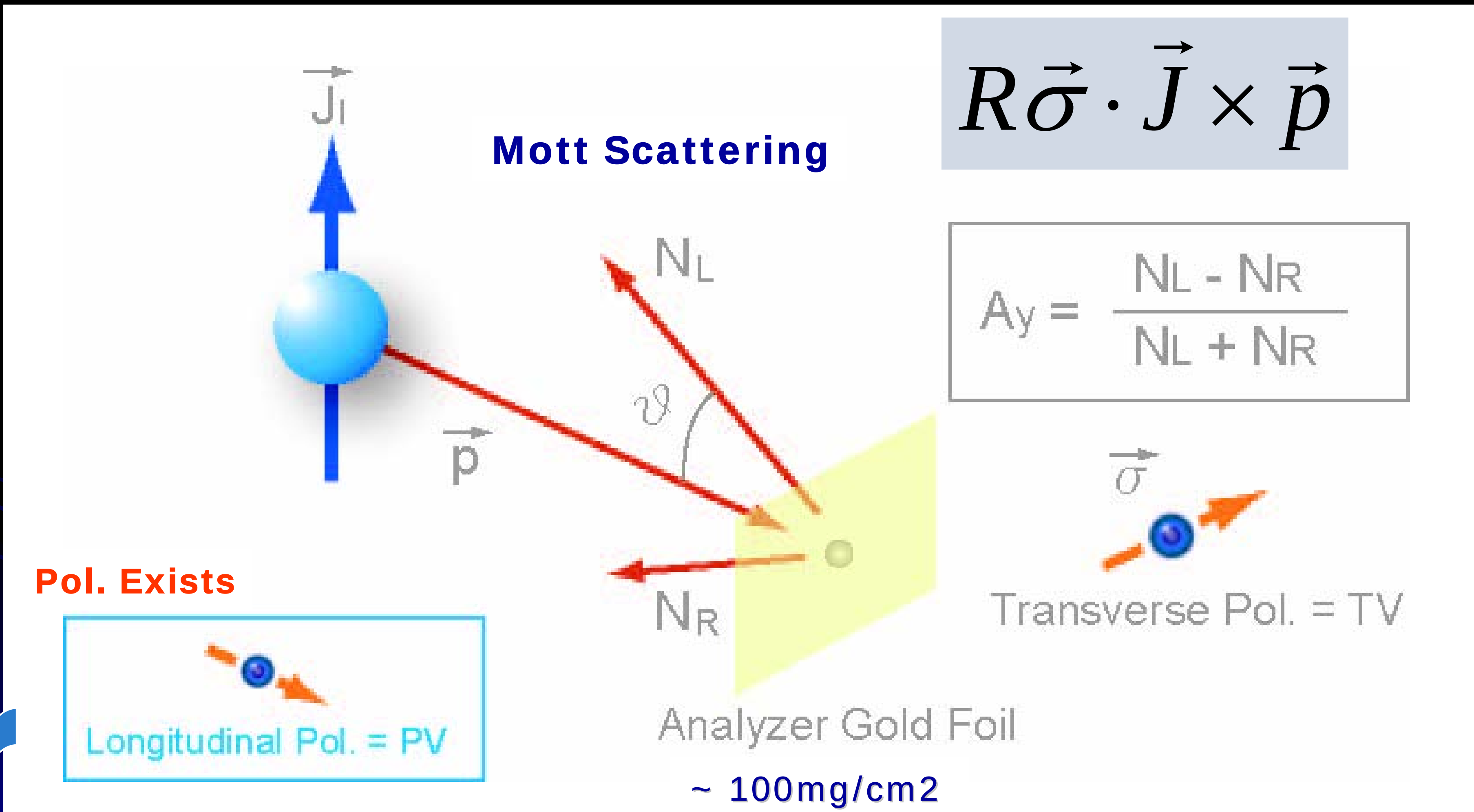
$^{19}\overrightarrow{\mathrm{Ne}} \to {}^{19}\mathrm{F}\vec{e}^{+}\nu_e$	$\vec{J}_{\mathrm{Ne}}(\vec{p}_e \times \vec{\sigma}_e)$	-79 ± 53
$\vec{\Lambda}^0 \to \pi^- \vec{p}$	$\vec{J}_{\Lambda}(\vec{p}_p \times \vec{\sigma}_p)$	-100 ± 70
$\vec{\Lambda}^0 \to \pi^- \vec{p}$	$\vec{J}_{\Lambda}(\vec{p}_p \times \vec{\sigma}_p)$	-94 ± 60
$\vec{\mu}^+ \to \vec{e}^+ \nu_e \bar{\nu}_\mu$	$\vec{J}_{\mu}(\vec{p}_e \times \vec{\sigma}_e)$	7 ± 23
$^{8}\overrightarrow{\mathrm{Li}} \to {}^{8}\mathrm{Be}\,\vec{e}^{-}\bar{\nu}_e$	$\vec{J}_{\mathrm{Li}}(\vec{p}_e \times \vec{\sigma}_e)$	0.9 ± 2.2

T-Violating TRANSVERSE polarization
R=0 or NOT ?
Non Zero R in u,d system
= New Physics Beyond the Standard Model

Best Limit : 8Li PSI '2003

Model Predictions ~ 10^-4 (CKM: 10^-12)

R-Correlation Measurement
Transverse pol. of electron from pol. Nuclei

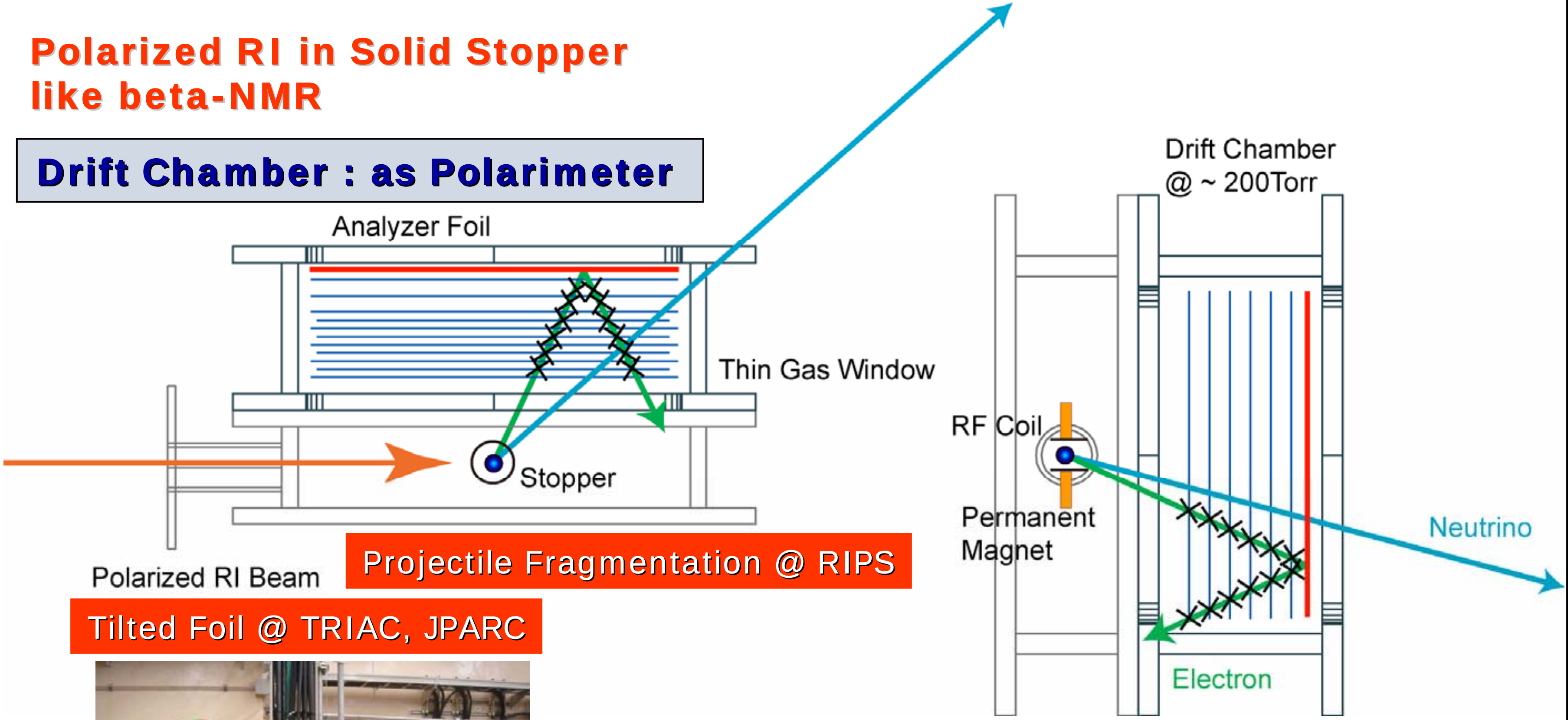


Systematic Error

Modified Setup for R-Measurement

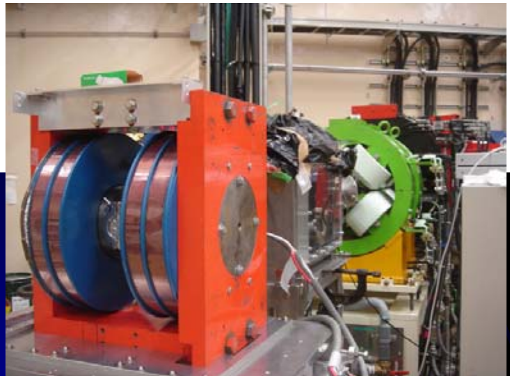
Polarized RI in Solid Stopper like beta-NMR

Drift Chamber : as Polarimeter



Projectile Fragmentation @ RIPS

Tilted Foil @ TRIAC, JPARC



Angular Resolution < 1 deg.
Full Backward Solid Angle

→ **Maxmum Mott Sensitivity**

Mott Analyzers in Previous Experiments

8Li '03 PSI

Best Limit

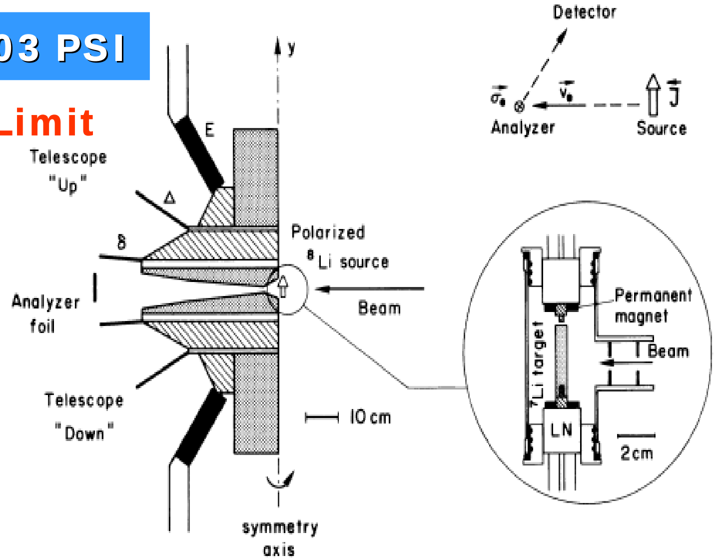


FIG. 1. On the left-hand side the main parts of the experimental setup are shown. The apparatus has 180° azimuthal symmetry about the vertical symmetry axis. Electrons emitted from ^{8}Li source are scattered on the analyzer foil and measured in two triple scintillator telescopes (δ, Δ, and E detectors). On the upper part of the right-hand side the vectors which enter into the definition of the R parameter are shown schematically. Inset: The target chamber with the permanent magnets for the magnetic holding field and the liquid-nitrogen (LN) cooling for the ^{7}Li rod.

19Ne '83 Princeton

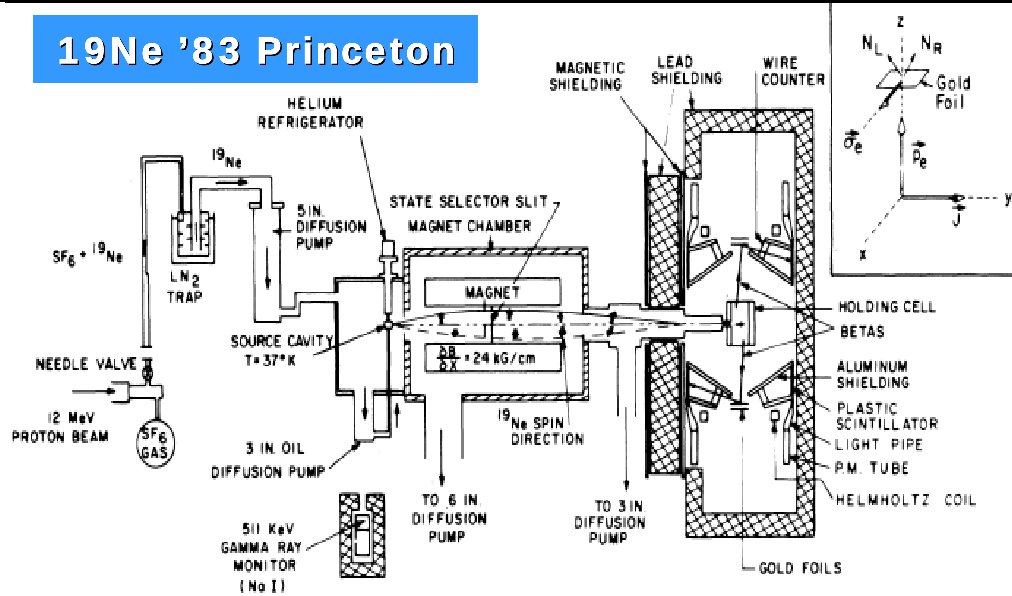
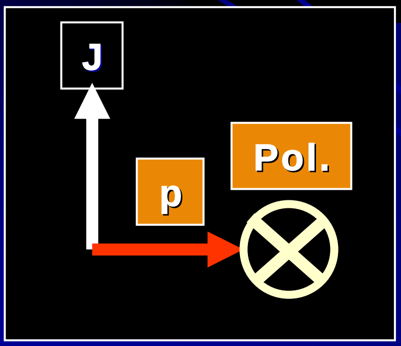
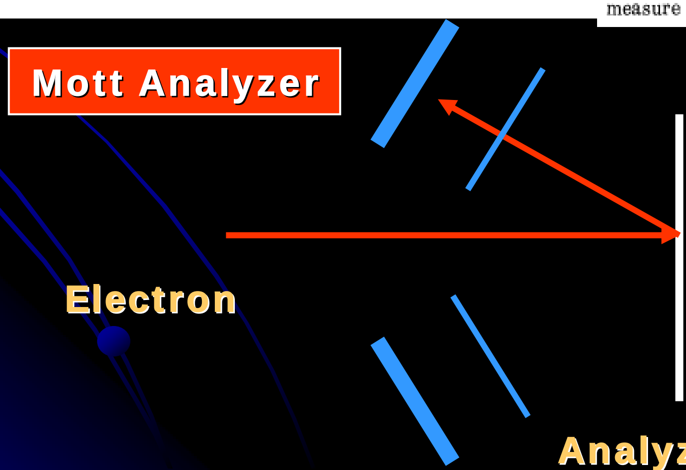


FIG. 1. Schematic illustration of the apparatus. The ^{19}Ne is produced with 12 MeV protons incident on an SF_6 target. A thermal beam of ^{19}Ne atoms is polarized by deflection in a "Stern-Gerlach" magnet. The polarized beam is captured in a holding cell surrounded by four Mott-scattering polarimeters. Each polarimeter is arranged to measure the positron polarization $\vec{\sigma}_e$ normal to the plane $\vec{p}_e$ and $\vec{J}$ (see inset).





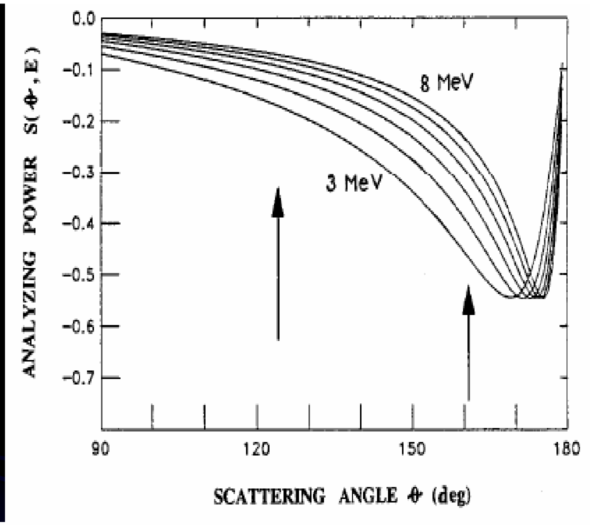
Up / Down Measurement

Integrated Measurement using Large Solid Angle Detectors

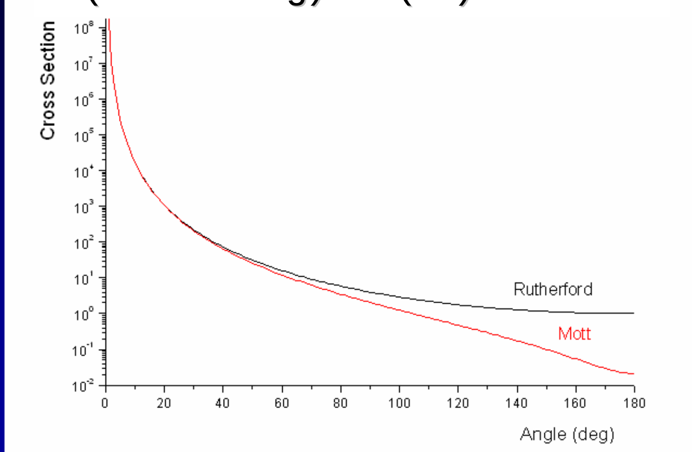
Simple, but
Loose Sensitivity, Limited Solid Angle

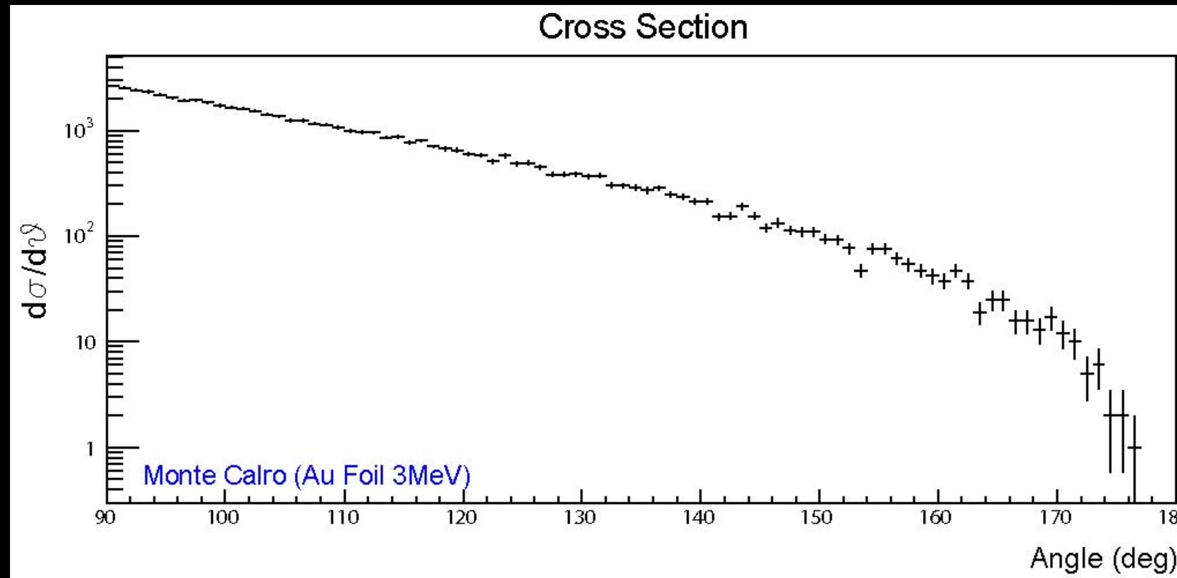
Mott Scattering Analyzing Power

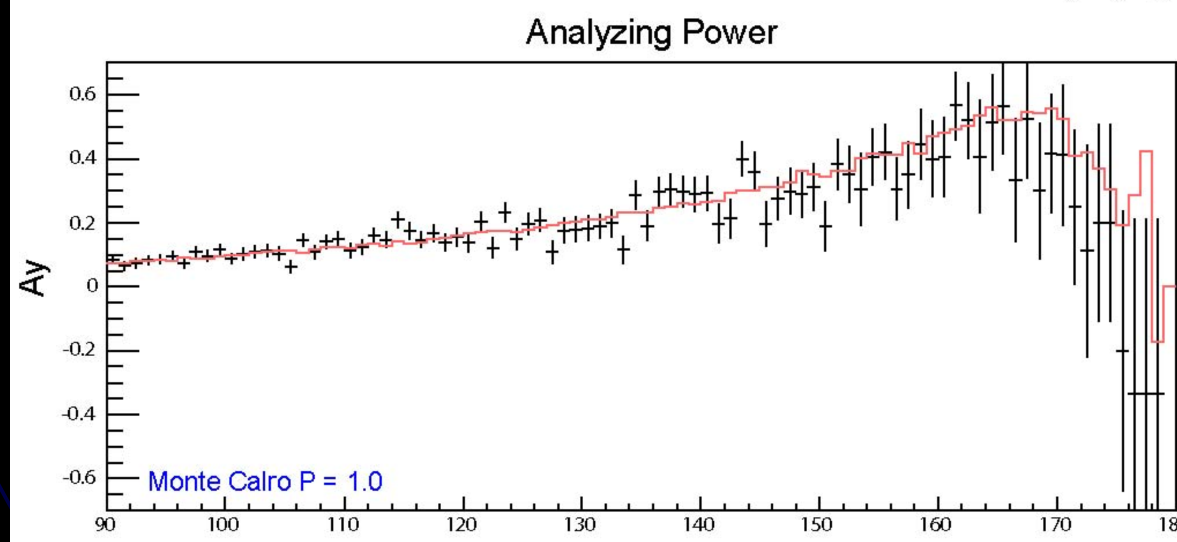
Max. Analyzing Power at Backward Angle



N(θ >100deg) / N(all) ~ 10^-5







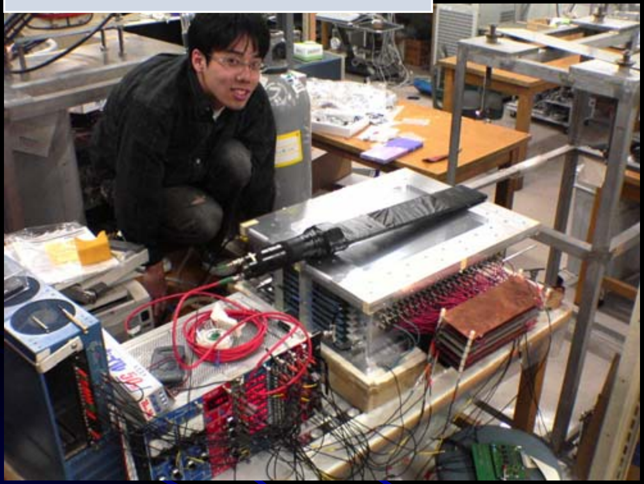
FIRST q2 Decomposed Measurement !

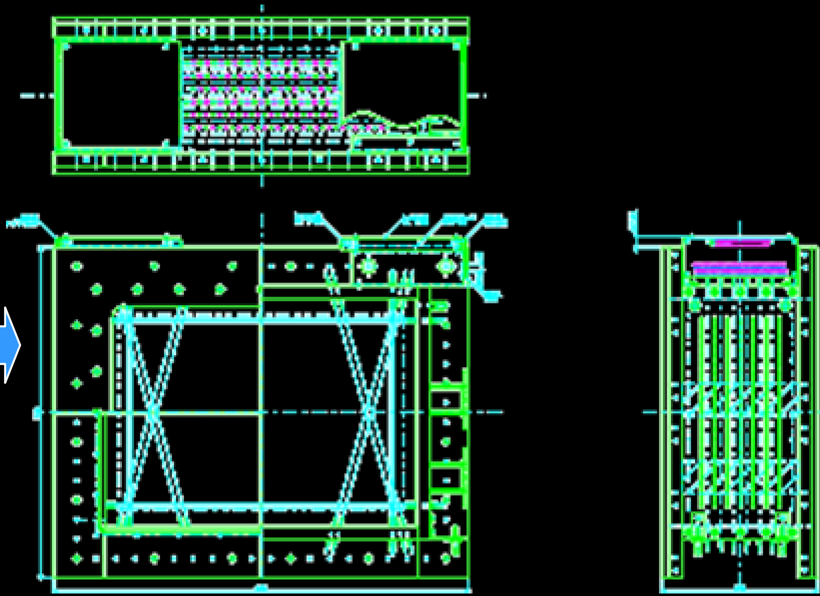
DC-Polarimeter

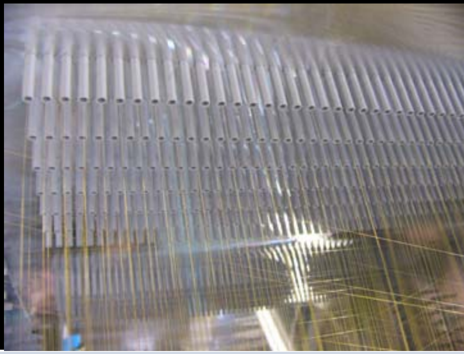
Vertex Detector : Single Track under Operation

Mott Analyzer : Multiple Track

16ch ASD preamp + CAMAC TDC

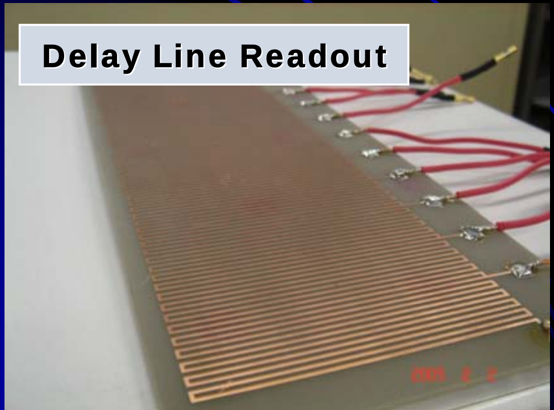


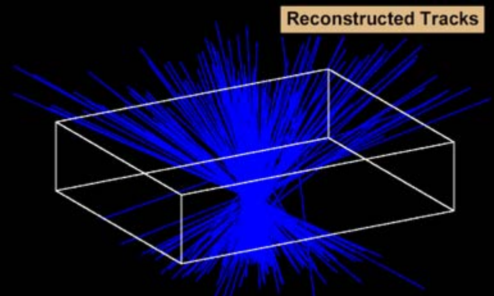


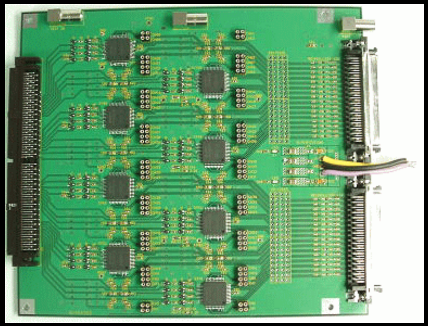


Full Channel Readout

Delay Line Readout







64ch ASD preamp x 2 + VME AMU-TDC x 2

Real Motivation at RIBF

$$R\xi = \left|M_{GT}\right|^2 \lambda_{J'J}\left[\pm 2\,\mathrm{Im}\left(C_T C_A'^{*} + C_T' C_A^{*}\right) - \frac{\alpha Z m}{p_e} 2\,\mathrm{Re}\left(C_T C_T'^{*} - C_A' C_A^{*}\right)\right]$$

$$+\,\delta_{J'J} M_F M_{GT}\sqrt{\frac{J}{J+1}}\left[\begin{array}{l} 2\,\mathrm{Im}\left(C_S C_A'^{*} + C_S' C_A^{*} - C_V C_T'^{*} - C_V' C_T^{*}\right) \\ \mp \frac{\alpha Z m}{p_e} 2\,\mathrm{Re}\left(C_S C_T'^{*} + C_S' C_T^{*} - C_V C_A'^{*} - C_V' C_A^{*}\right) \end{array}\right]$$

Contribution from pure V-A

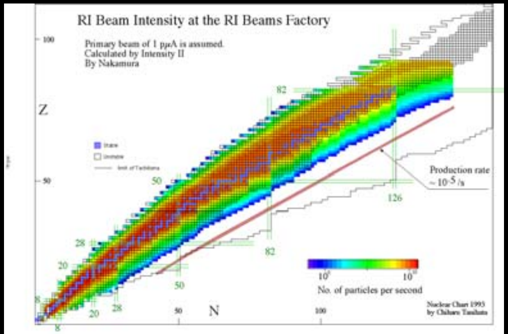
$$FSI \propto \frac{\alpha Z m}{p}$$

Experimental Sensitivity reaching Electromagnetic Final State Interaction

Evaluate FSI like CKM in K, B system (CKM = BG)

Next Step : Precision FSI Estimation by Systematic Study

→ **RIBF is suitable**



Summary & Schedule

- Systematic Study of Final State Interaction is required to probe BYSM Physics in Nuclear Beta Decay
- Beta decay in Field Free Vacuum is IDEAL for beta decay correlation measurements (RIAB, SLOWRI) : **Long Range Plan**
- 1st step measurement is R-coefficient using Stopped RI
- Electron transverse polarimeter will be completed within a few months