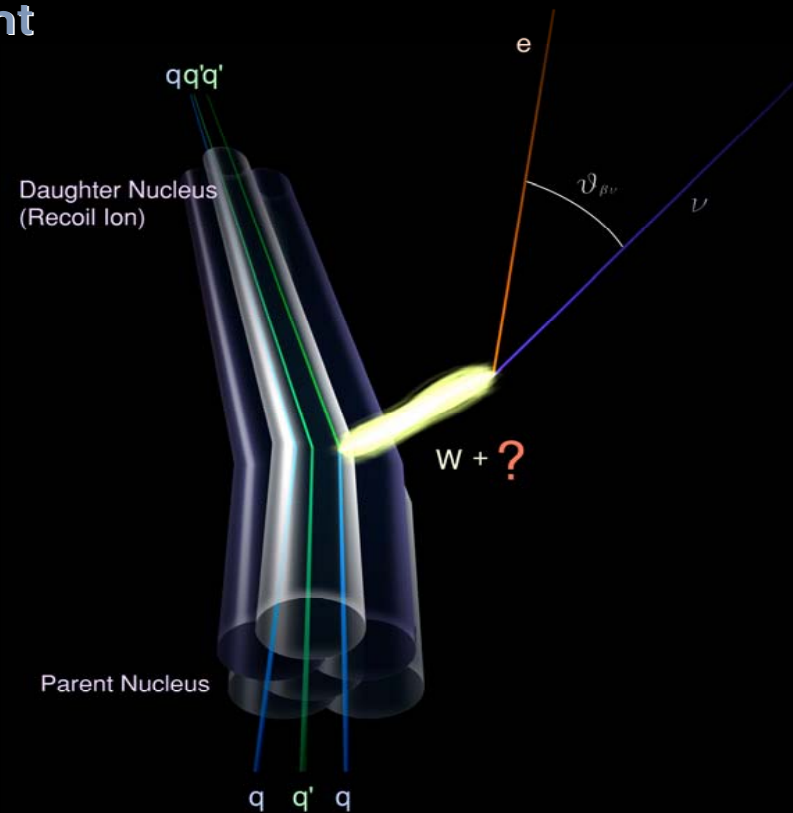


Beta Neutrino Correlation and T-Violation Experiment in Nuclear Beta Decay

Rikkyo Univ. Jiro Murata

Beta Neutrino Correlation using Recoil Measurement
from **free slow radioactive nuclei**
at RIKEN-RIBF (RIAB / SlowRI)

Beta Transverse Polarization Measurement
from **stopped polarized radioactive nuclei**
at KEK-TRIAC / RIKEN-RIBF

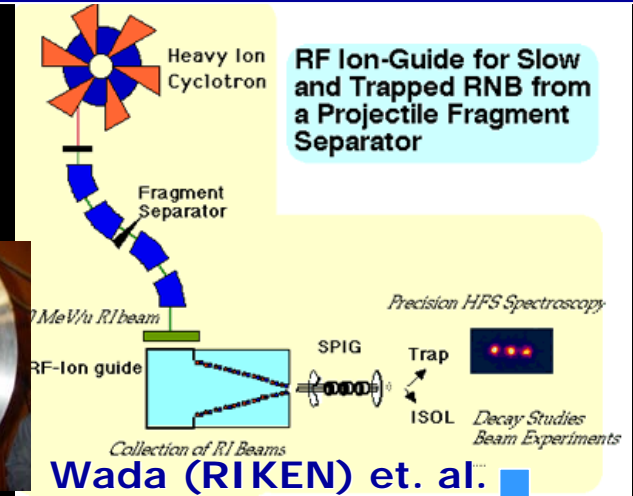
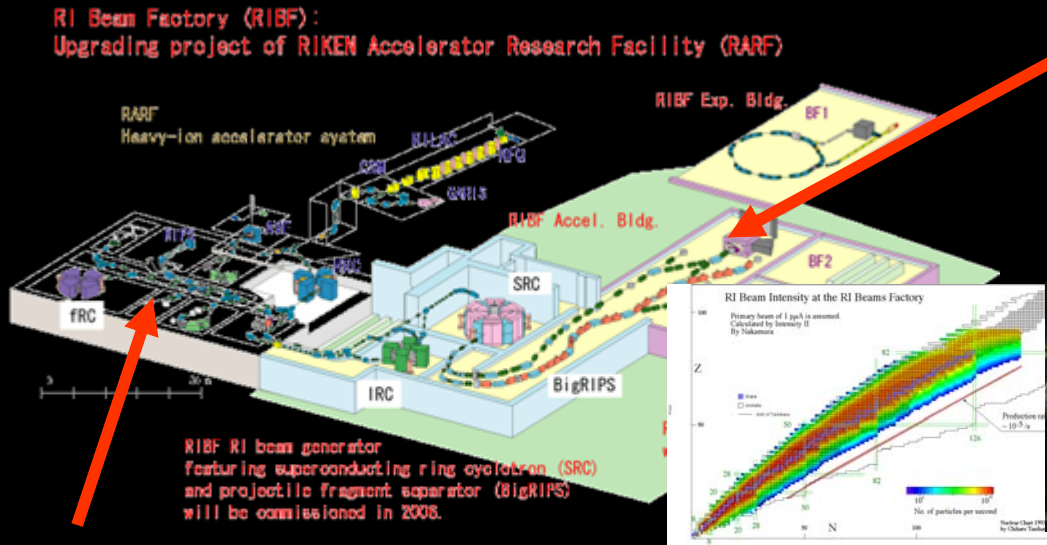


Collaboration

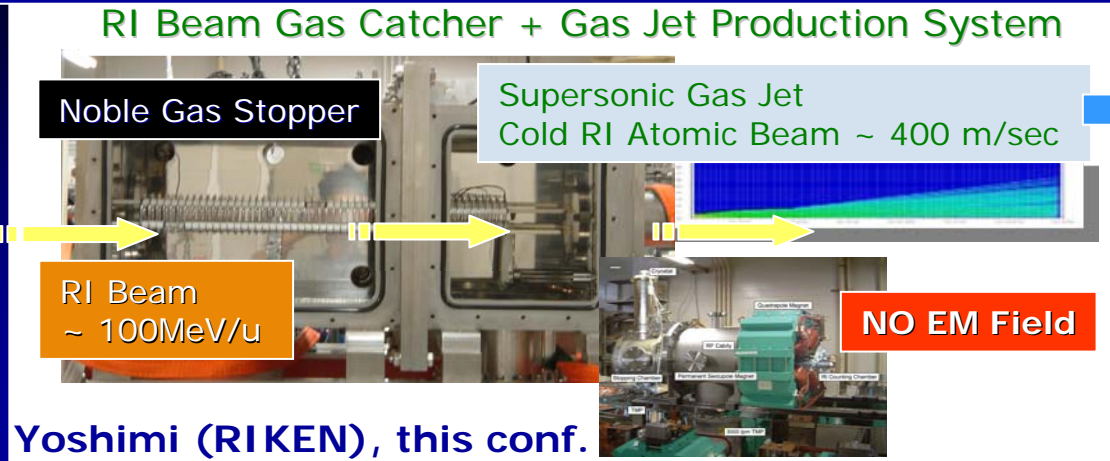
Rikkyo Univ. / RIKEN Asahi ANL / Titech Asahi Lab./KEK
 J. Murata, H. Kawamura, K. Narita, T. Suehiro,
 T. Shimoyama, T. Toyoda
 K. Asahi, D. Kameda, H. Ueno, A. Yoshimi
 M. Uchida, D. Nagae, K. Shimada
 N. Imai, K. Hirayama

Unique Slow / Stopped RI Facilities at RIBF

SLOWRI Facility for Atomic Physics

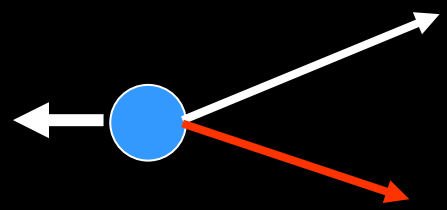


RIAB for Magnetic Moment Study using Atomic Beam Method



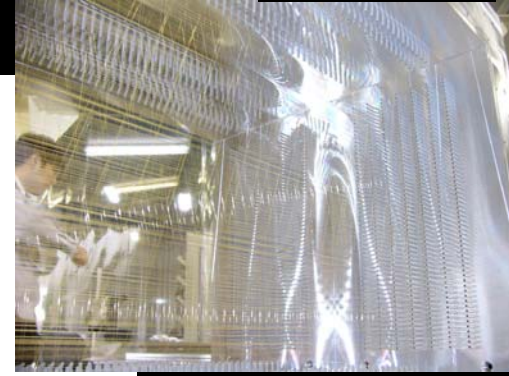
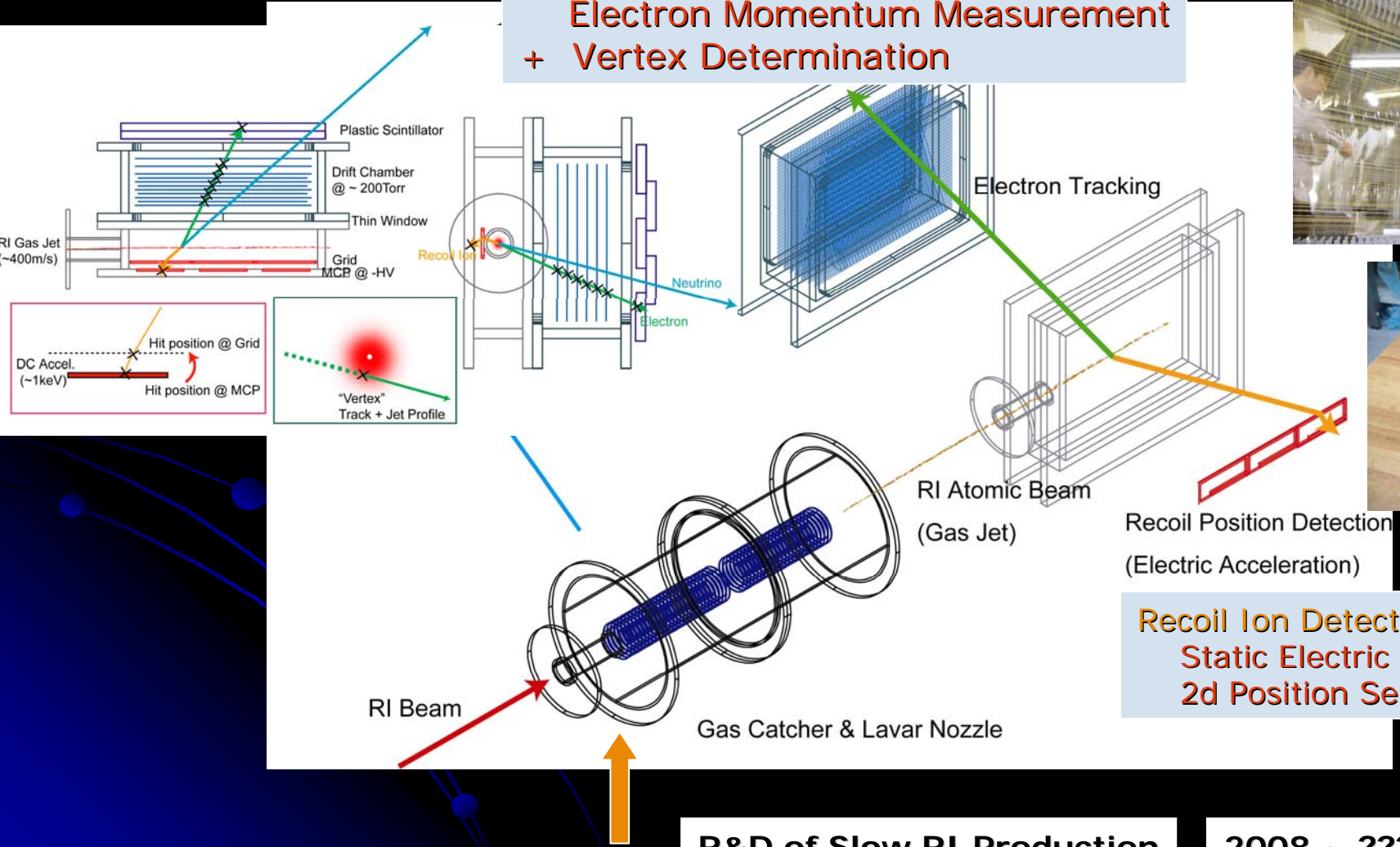
Beta Decay in Vacuum

Recoil Measurement



Experimental Setup for Beta Neutrino Correlation measurement w/o using Ion Traps

**Electron Tracking Chamber
Electron Momentum Measurement
+ Vertex Determination**



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

R&D of Slow RI Production

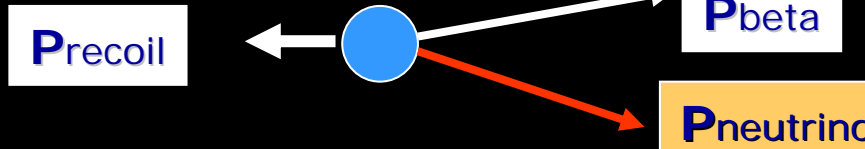
2008 ~ ???

Measurement using Slow RI

Beta Decay

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

Recoil Measurement



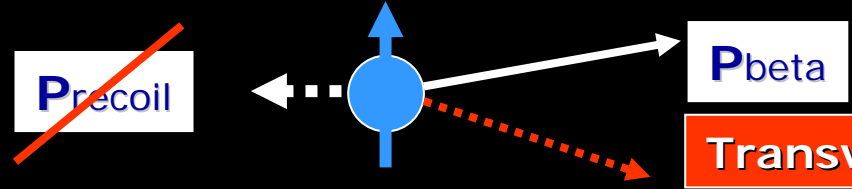
Angular Distribution

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

Test of V-A interaction
 $a=1$ (Fermi), $-1/3$ (GT) ?
 → Scaler / Tensor Int. exists ?

precision $\sim 10^{-3}$
 $|Cs/Cv| < 8\%$ (Fermi)
 $|CT/CA| < 13\%$ (GT)

Electron Measurement



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

T-Violating **TRANSVERSE** polarization
 $R=0$ or **NOT** ?

PSI '03 8Li exp.	$(-0.9 \pm 2.2) \times 10^{-3}$	$M_{LQ} > 560 \text{ GeV} / c^2$
PSI '05 muon exp.	$(-3.7 \pm 7.7 \pm 3.4) \times 10^{-3}$	PSI nTRV exp. ?

Stopped RI Facility at KEK-TRIAC

TRIAC Tokai Radioactive Ion Accelerator Complex



Super Conducting Liniac

5 - 8 MeV/u

36MeV 3uA proton beam from TANDEM

Isotope Separator Online (ISOL)

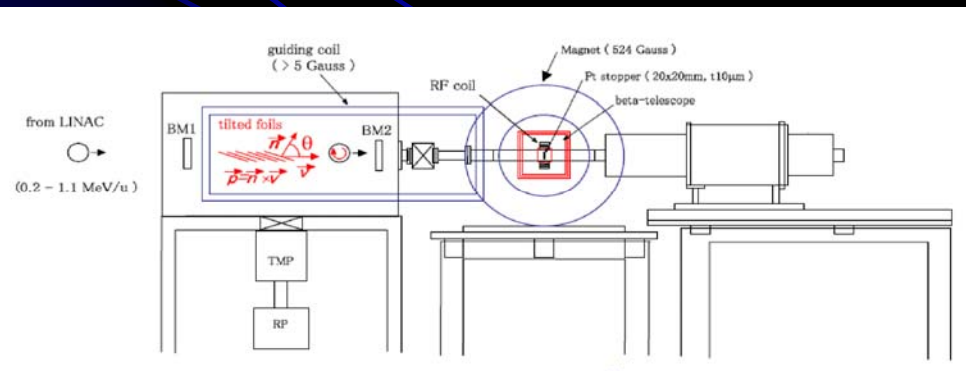
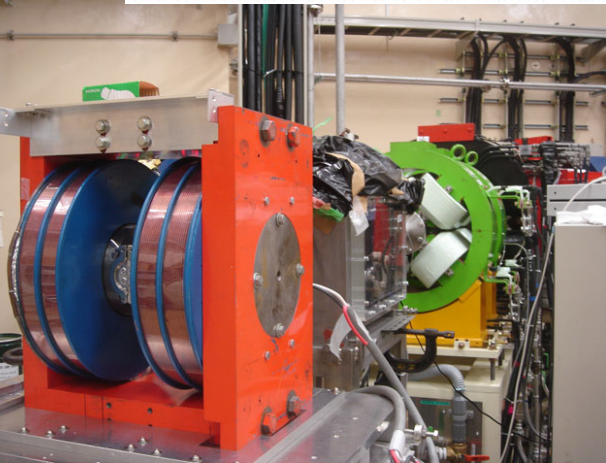
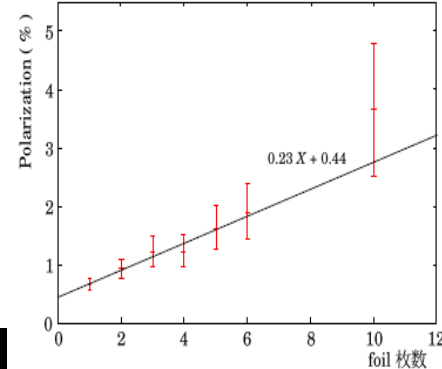
0.18 - 1.1 MeV/u

1H-11iac

ECR

SCRFG

Liniac



Unpol 8Li Beam (178keV/u)

~ % polarization

up to 10% ?



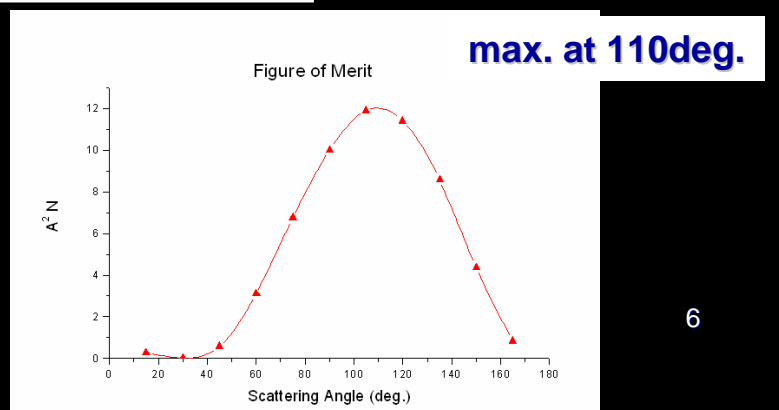
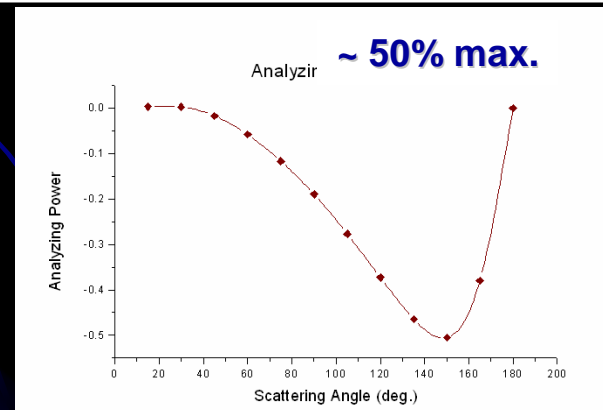
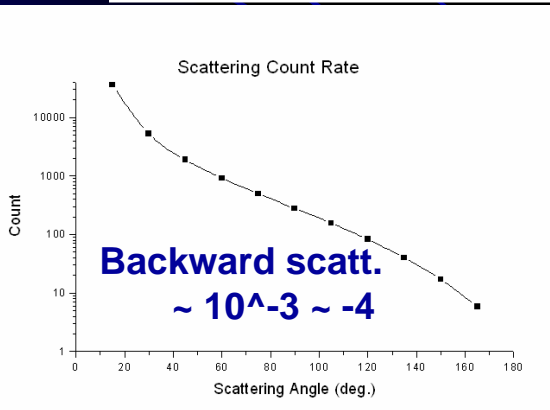
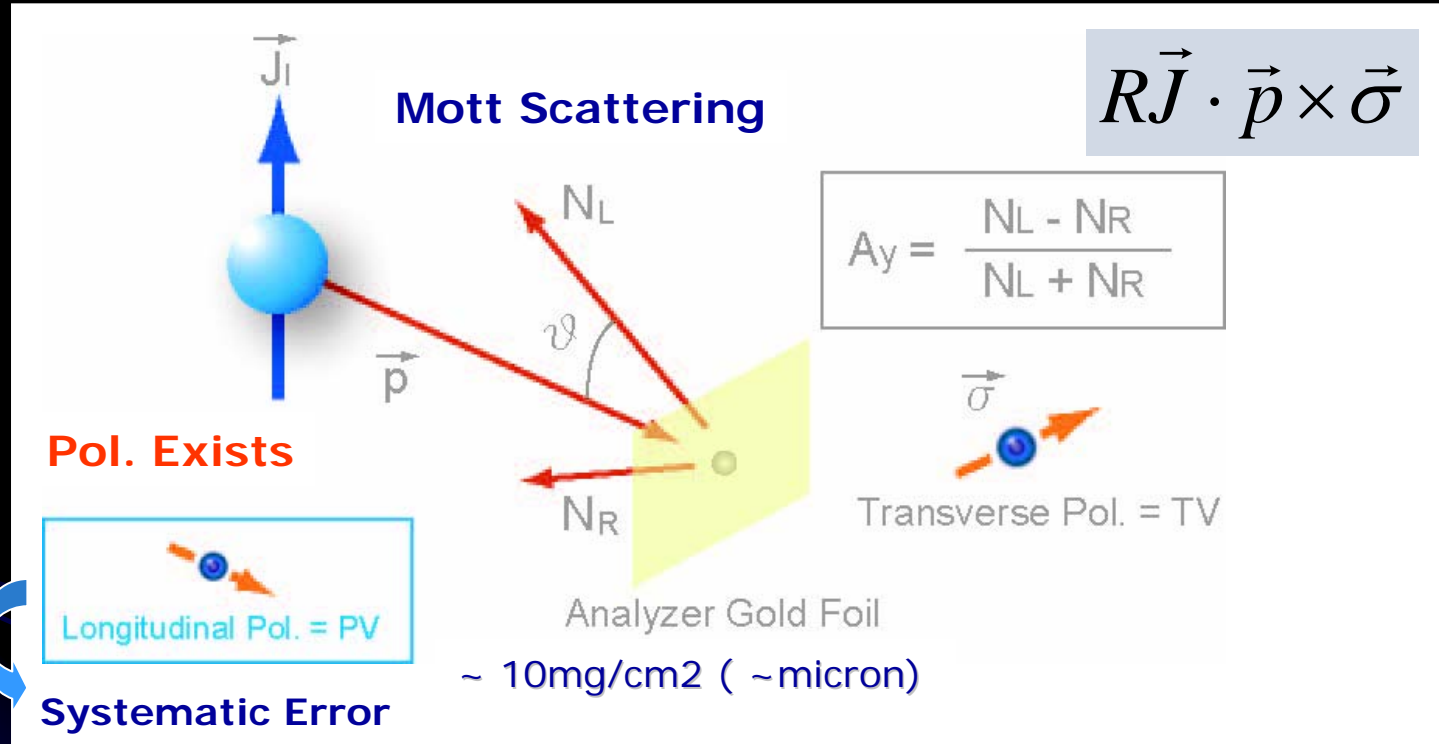
Tilted Foil : 10ug/cm² Carbon x 10 @ 70deg.

Polarized Low Energy 8Li beam is available !

2005 Hirayama et. al. (KEK)

R-Correlation Measurement

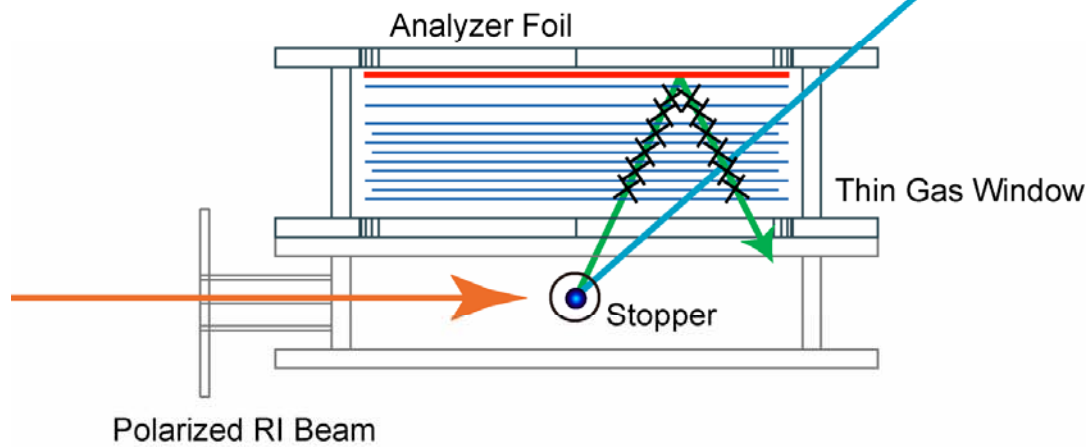
Transverse pol. of electron from pol. Nuclei



Experimental Setup for R-Measurement

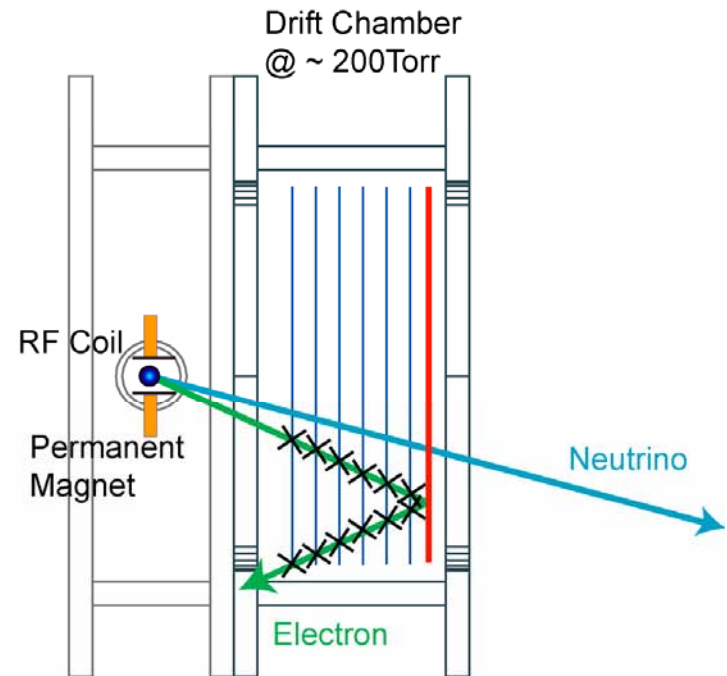
**Polarized RI in Solid Stopper
like beta-NMR**

Drift Chamber : as Polarimeter



Projectile Fragmentation @ RIPS

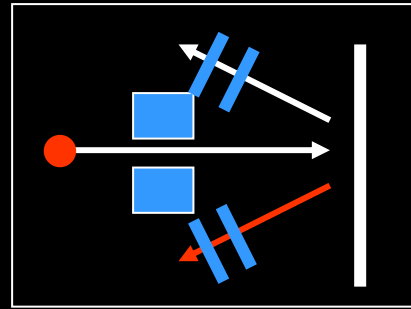
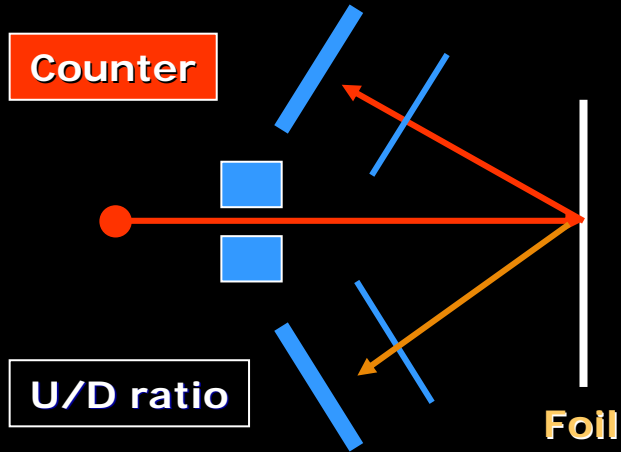
Tilted Foil @ TRIAC, KEK-JAERI



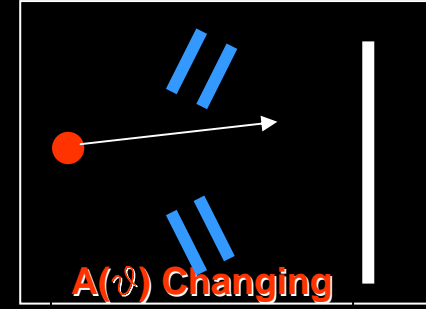
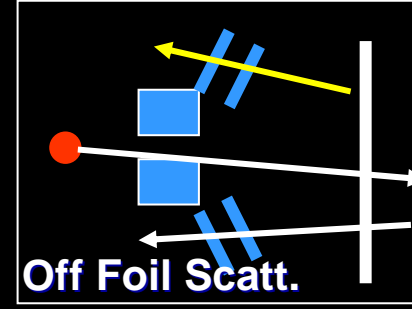
**Angular Resolution < 1 deg.
Full Backward Solid Angle**

Maximum Mott Sensitivity

Advantages of the New Points



Foil Activation



Fake Events

U/D Acceptance Changing

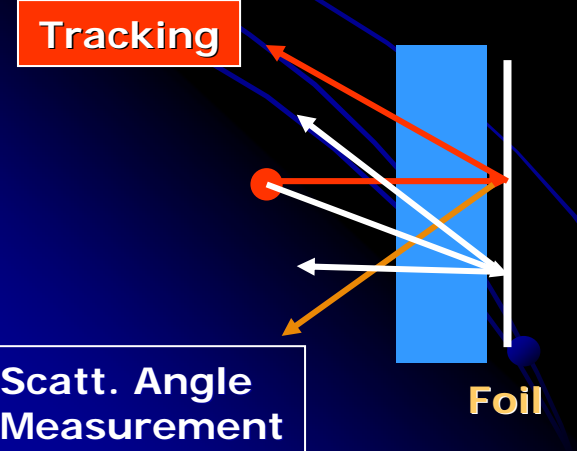
No Slits

Tracking

Large Acceptance

Select Scattering Events

Independent on Decay Asymmetry Changing

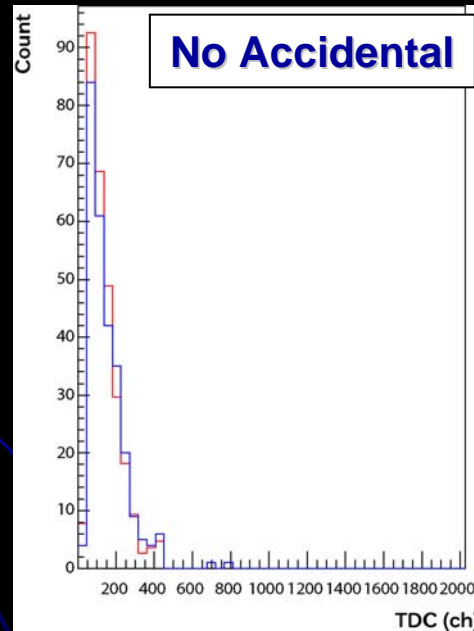
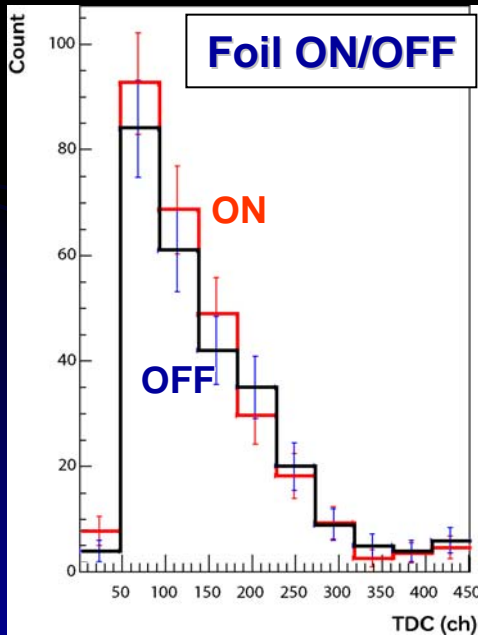
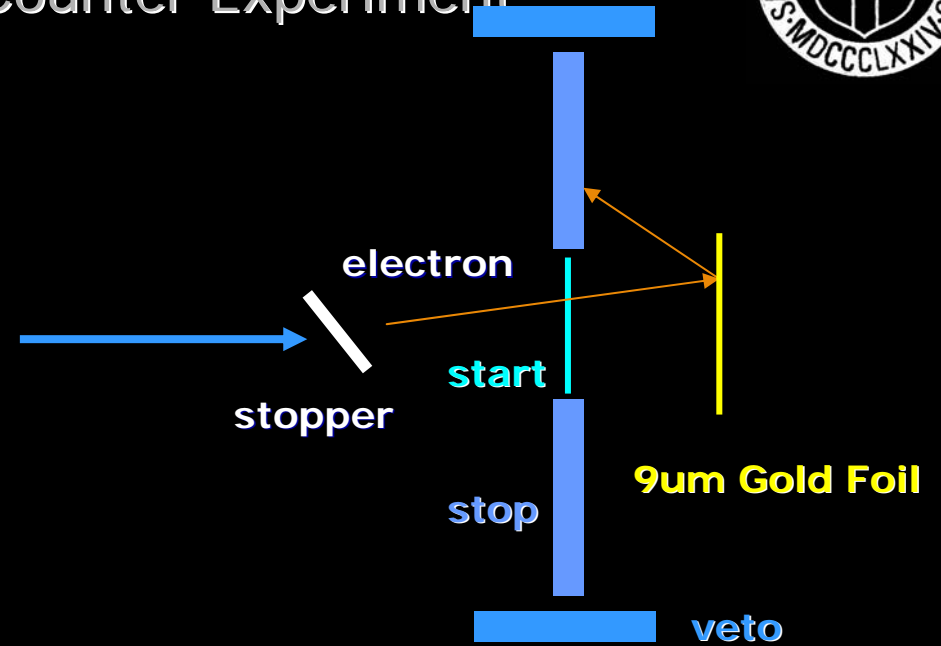


Background Rate in Counter Experiment

Test Experiment @ RIKEN-RIPS Beam Line

Polarized Secondary Beam : ^{31}Al 95MeV/u

$Q_{\beta^-} = 8.0\text{MeV}$



TDC (start – stop)

Signal / Background ~ 10%



Tracking Device -> Reject Ghost Events

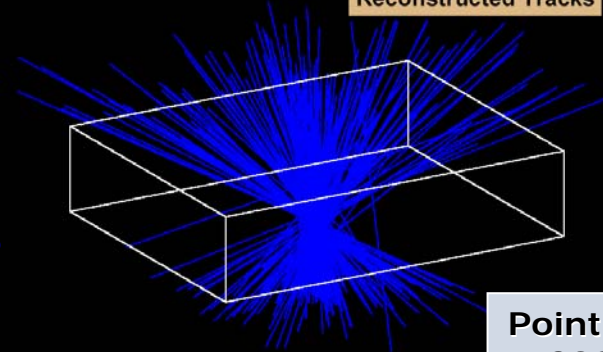
DC Polarimeter

**XX' UU' VV' Planer DC
104 Anode**

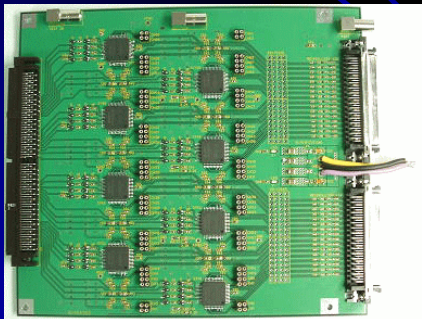
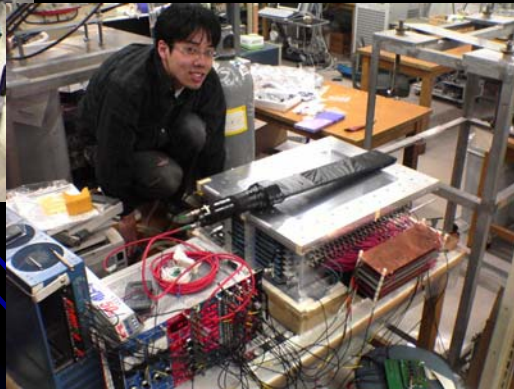
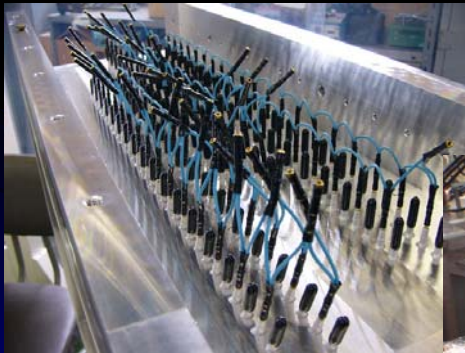
Sense 20um Au-W @ 50g x 104
 Field 100um Au-BeCu @ 150g x 110
 Cathode 100um Au-BeCu @ 150g x 413
 Total 627 Wires

Sense - Field Pitch = 10mm
 Sense - Cathode Gap = 10mm
 XX'(1/2cell off) x 40
 UU'(15.9deg.) x 32
 VV'(-15.9deg.) x 32
 Cathode(90deg.)

Reconstructed Tracks

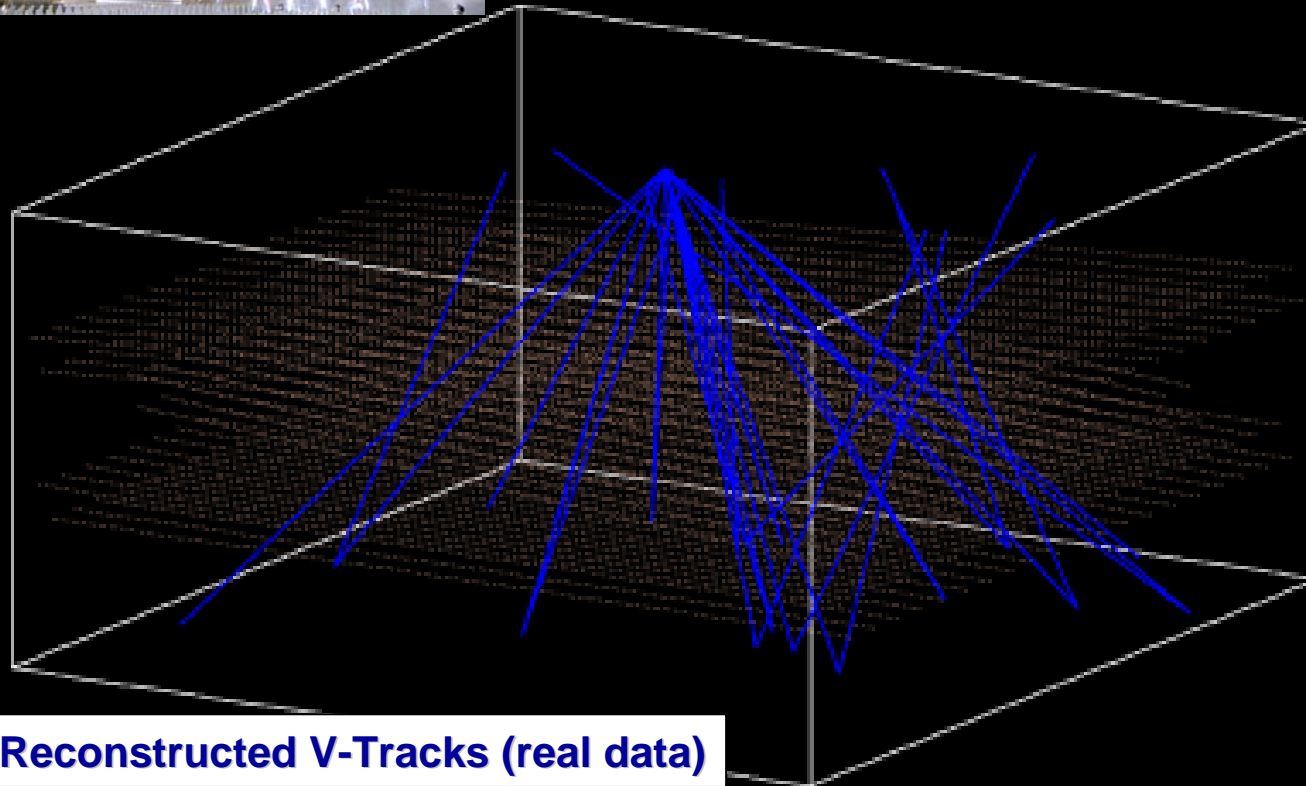
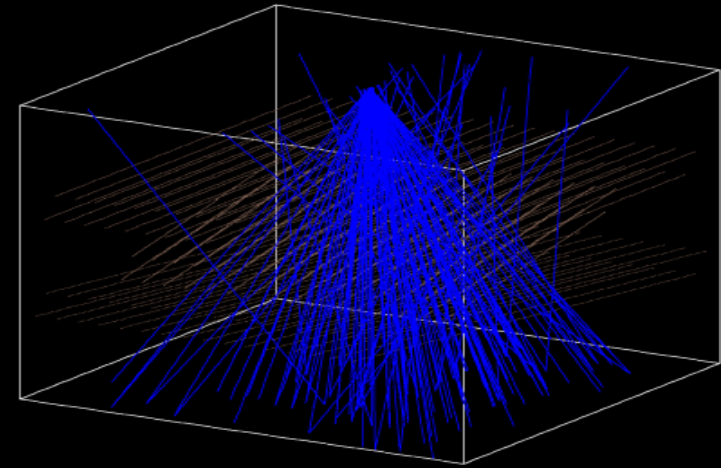
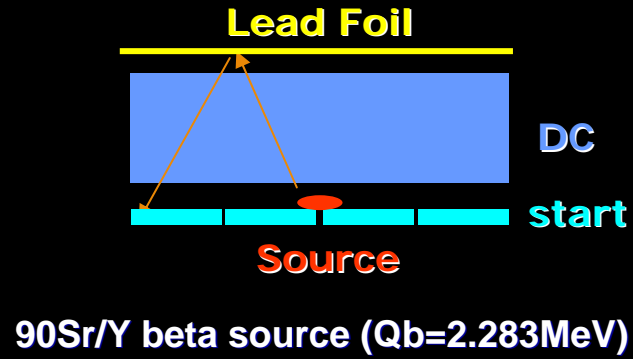
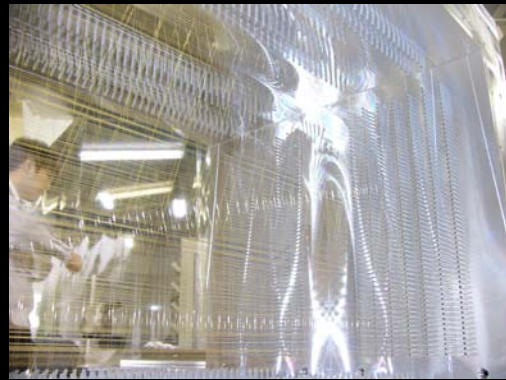


Point Source Tracks
 ~ 200 um res.

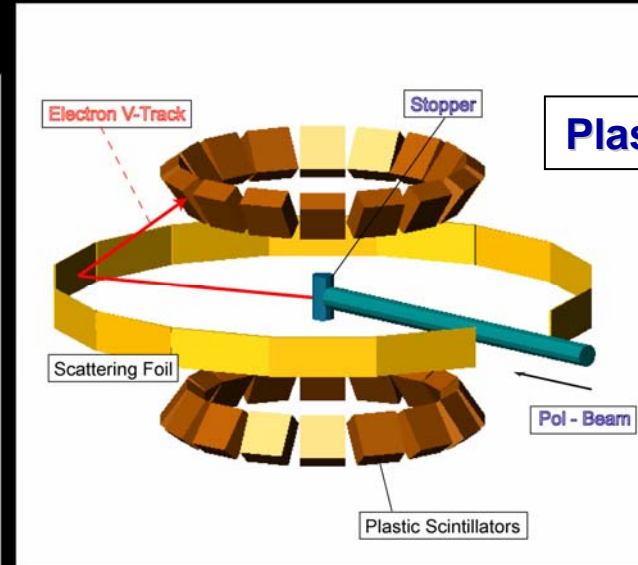
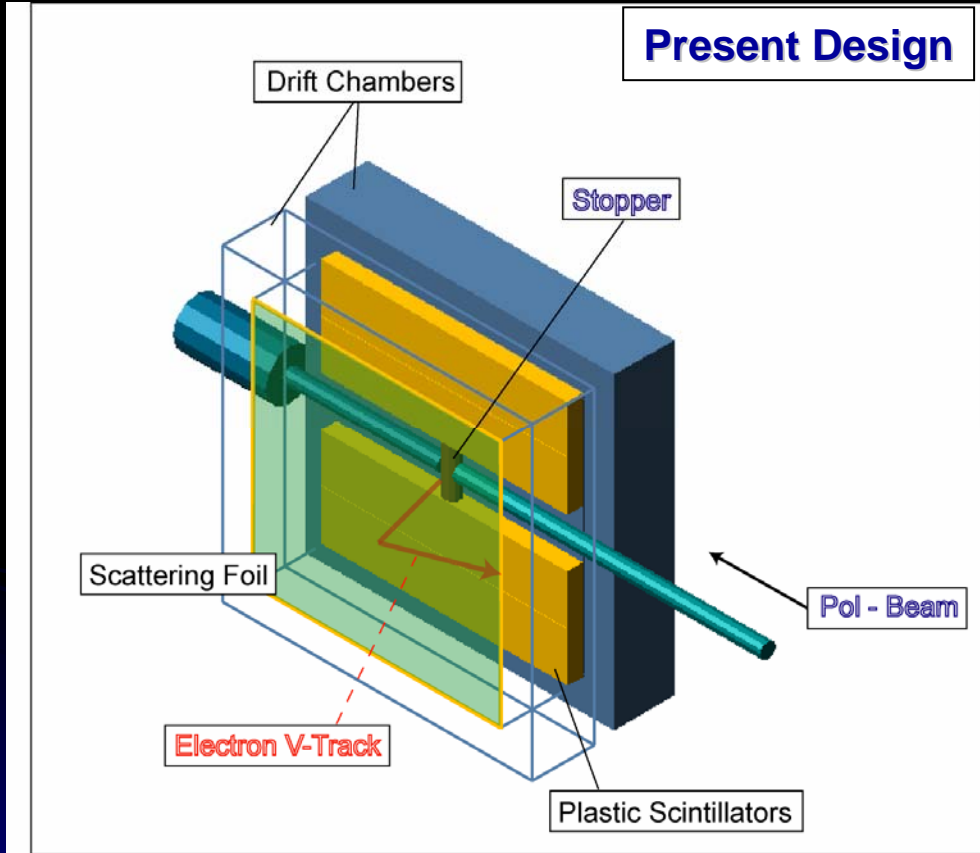


64ch ASD preamp x 2
 + VME AMU-TDC x 2

Track Reconstruction for Scattered Events



Configuration Dependence on Acceptance

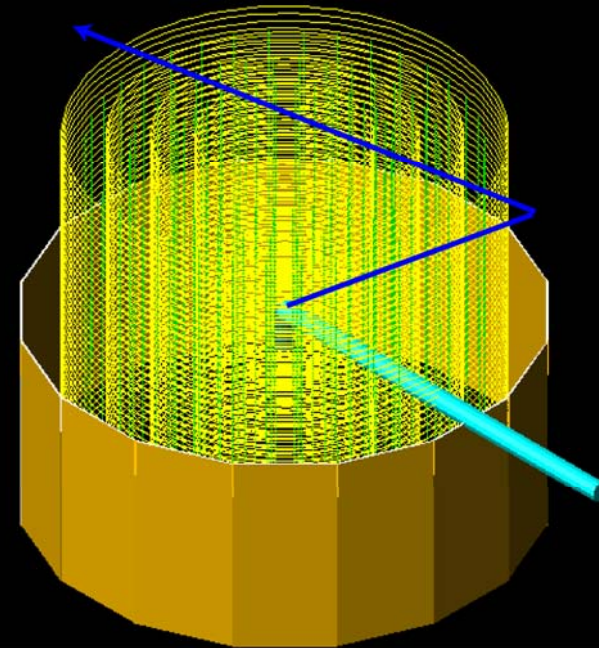


PSI 8Li Exp. type

10MeV 0.9uA 7Li(d,p)8Li
 99.9% 7Li target, GBq
 B = 7mT, Pol = 20% @LHe
 Relaxation time > 20sec
 Lead foil analyzer 35mg/cm²

Drift Chamber Polarimeter
 : Limited Solid Angle, not suitable for High Rate

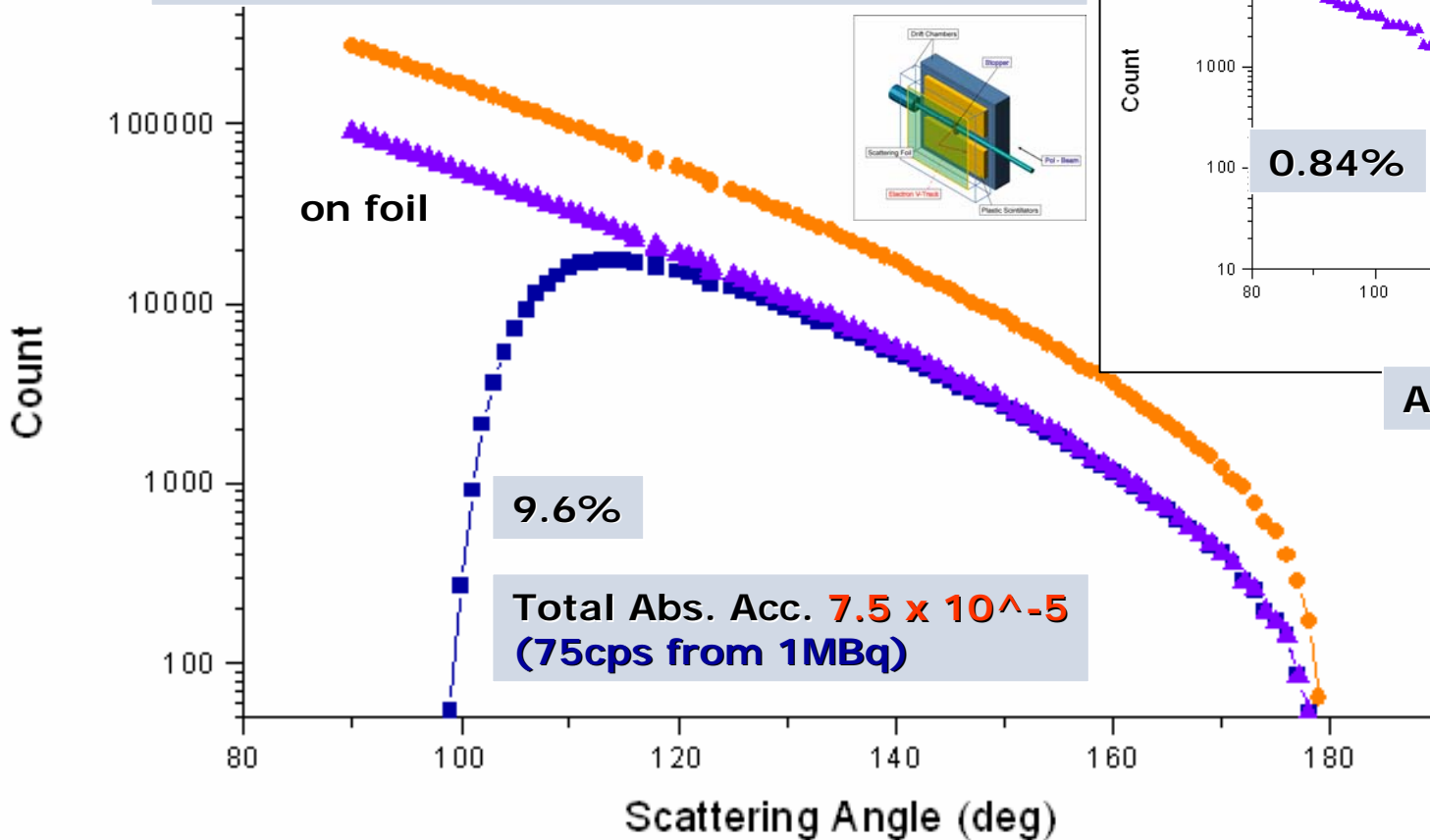
GOAL : Cylindrical MWPC Polarimeter
 : Large Solid Angle, good for High Rate



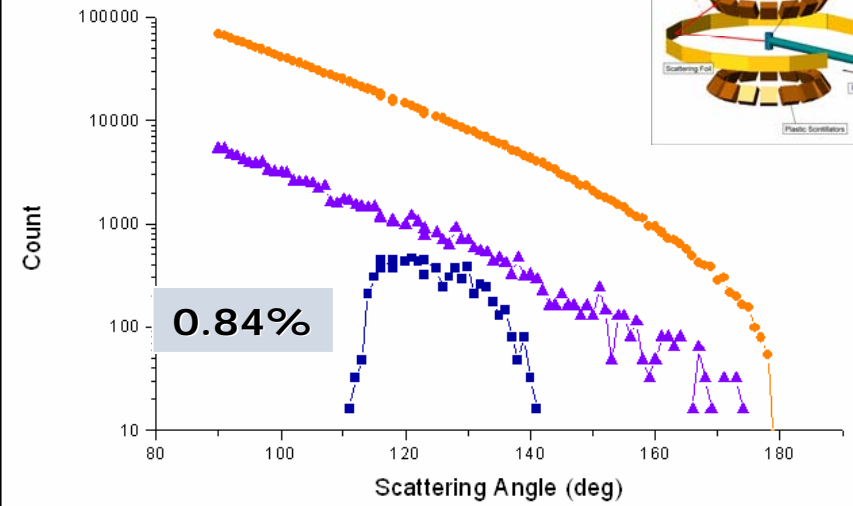
Monte-Carlo Estimation of the Acceptance

Drift Chamber Polarimeter

Over 90deg ~ 1/1270 @ 10micron Gold Foil

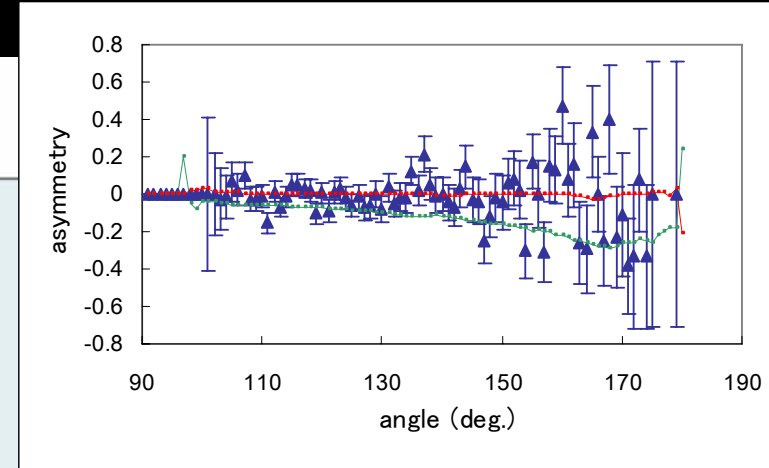
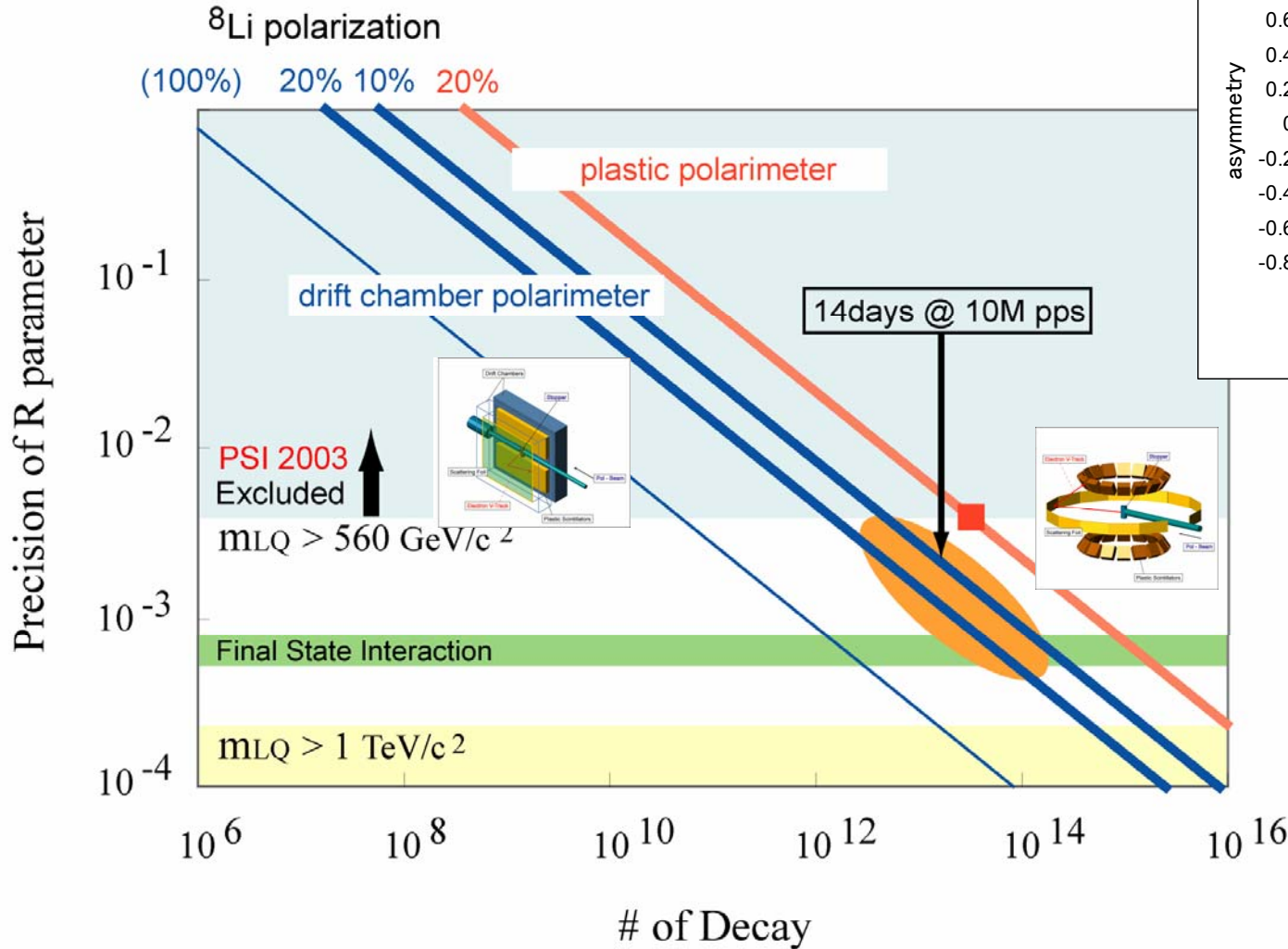


Plastic Polarimeter



Around peak FOM

Expected Sensitivity



Fitting Simulated Asymmetry

PSI '03: 700MBq, pol 10%
 TRIAC: 1-10MBq, pol 10%
 RIBF : 1 - 10GBq, pol ???

Final State Interaction

$$R\xi = |M_{GT}|^2 \lambda_{J,J} \left[\pm 2 \operatorname{Im}(C_T C_A'^* + C_T' C_A^*) - \frac{\alpha Z m}{p_e} 2 \operatorname{Re}(C_T C_T'^* - C_A' C_A^*) \right] + \delta_{J,J} M_F M_{GT} \sqrt{\frac{J}{J+1}} \left[\mp \frac{\alpha Z m}{p_e} 2 \operatorname{Re}(C_S C_T'^* + C_S' C_T^* - C_V C_A'^* - C_V' C_A^*) \right]$$

Contribution from pure V-A

Experimental Sensitivity reaching Electromagnetic Final State Interaction

$$R = (0.9 \pm 2.2) \times 10^{-3}$$

$$R_{FSI} = 0.7 \times 10^{-3}$$

Possible way is ..

1. FSI is BG, for T-Violation Physics

AND/OR

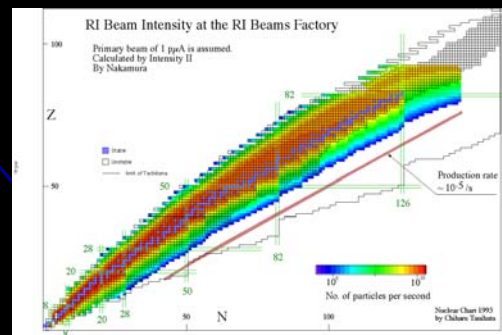
2. Study of FSI Physics

Systematic Evaluation of the FSI

1. Nuclear dep.
2. Beta energy dep.



Extract True T-Violation



Suitable for RI Beam Factory

Heavy Isotope Measurement

Nuclear Size, Structure effect, etc.

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

Summary

Status

1. Drift Chamber Polarimeter has been built.
2. Polarized ^8Li is now available at TRIAC.
3. Study of physics sensitivity is completed.
4. Stopper R&D is undergoing.
5. First test experiment using DC- polarimeter & polarized beam will be performed in early 2007

Plan

1. Perform 1st step experiment at TRIAC.
2. Upgrade.
Beam Intensity: 10^5 to 10^7 design value
Polarization: 5% to 10% using tilted foil
10% to 20% or more using optical pumping ?
3. Utilize 10^{10} pps @ RIBF
Optical Pumping in Solid
Cylindrical Proportional Counter Polarimeter