Progress Report
to the
5th J-PARC PAC Meeting

J-PARC E06 (TREK) Experiment

Measurement of T-violating Transverse Muon Polarization in $K^+ \rightarrow \pi^0 \mu^+ \nu_\mu$ Decays

E06 (TREK) Collaboration*

May 28, 2008

*Contact person : J. Imazato (jun.imazato@kek.jp)

Contents

1 Introduction

In this note we will report on the progress in preparation for the E06 (TREK) experiment since the last PAC meeting in January 2008. We have proceeded with the detector design, beam optics consideration, systematic error analysis and funding request processes. At the last meeting we mainly reported the basic R&D of the newly introduced detector elements by showing their high-rate performance in response to the comments raised by the third PAC meeting in July 2007. Based on these achievements and the readiness of the detector design, we requested stage-2 approval recommendation from the PAC. These efforts were highly regarded by the committee; however, the committee provided the following message in the minutes:

.. *Overall the PAC is impressed with the progress of E06 and feels that this is an important measurement to be made at J-PARC. However, before recommending stage-2 approval, the PAC would like to see progress by the TREK collaboration in securing the funding for the experiment both internationally and domestically and in the collaborative effort with the E14 experiment to define and design workable beamlines for both the KL and K1.1 lines.*

In this report we will answer these points by showing which kinds of efforts were actually done. We can now start the construction of the polarimeter and a part of the active target. Regarding the beamline issue we first had to work out the B1 combined magnet option of K1.1-BR as proposed in the last PAC since this might affect the whole structure of the beamline. The current conclusion will be presented. Several R&D analyses have been continued following the preliminary results presented at the last PAC meeting. The new results of the analysis of the CsI(Tl)-APD readout and the systematic error associated with the polarimeter misalignment will be reported.

Nearly two years have passed since we submitted the first proposal to the PAC. The physics environment around the transverse muon polarization is changing quickly. We would like to summarize the model description of P_T and its significance among several other channels with updated data. Finally we would like to present briefly the plan for the current year, for the polarimeter construction, target R&D *etc.*

Important documents : For reference purposes we summarize here the important documents which we submitted to PAC and FIFC up to now.

- **Proposal** (April 2006);
  http://www-ps.kek.jp/imazato/e6/proposal.pdf
- **Report to FIFC** (June 2007);
  http://www-ps.kek.jp/imazato/e6/fifc_report.pdf
- **K0.8 beam optics design report** (June 2007);
  http://www-ps.kek.jp/imazato/e6/k0.8.pdf
- **Addendum to K0.8 beam optics design** (June 2007);
  http://www-ps.kek.jp/imazato/e6/k0.8-add.pdf

- **Report to the third PAC meeting** (June 2007);
  http://www-ps.kek.jp/imazato/e06/PAC3_report.pdf
  - Statistical sensitivity estimate (Update of the proposal)
  - Systematic error analysis
  - Progress of detector R&D for upgraded elements
  - Status of collaboration and funding
  - Conclusion
  - Appendix: MC simulation of alignment calibration
- **Reprot to the forth PAC meeting** (December 2007);
  http://www-ps.kek.jp/imazato/e06/PAC4_report.pdf
  - High rate performance of the detector elements
  - Further study of the K1.1-BR beamline
  - Funding efforts and international cooperation

2 Funding efforts

In the last 5 months there have been a few positive results of our efforts for TREK experiment funding in Japan and in Canada. We are continuing further efforts aiming for full funding.

2.1 Grant-in-Aid research support in Japan

The Grand-in-Aid research support money request (Basic Research Category A) for the polarimeter construction was approved for three Japanese fiscal years 2008-2010[1]. With this money we will prepare 12 sets of polarimeter chambers and a polarimeter magnet. The cashflow is summarized in Table 1. In order to proceed with the construction of the

Table 1: Grant-in-Aid money for the polarimeter construction

Year	2008	2009	2010
Budget (MYen)	9.1 + 2.73 (*)	14.6	13.2

(*) = so-called indirect budget to the lab.

other detector elements, and for the preparation and execution of the experiment, we have recently submitted a request for a five year budget starting from this FY2008 in the newly established category of Grant-in-Aid research support of "New Science Field", by defining a field of "Search for new physics using slow particle beams at J-PARC" in collaboration with the neutron group which will look for the neutron EDM and the muon group which will look for muonium-antimuonium oscillation. We have requested nearly 1,200 MYen in total with the fraction of $\sim$350MYen for the TREK project. The result will be known in late autumn of this year.

[1]Unfortunately, the request for Basic Research Category (S) for the whole detector construction except for the target and data-taking electronics was not approved this time.

2.2 Fuding for target R&D in Canada

We have been successful in receiving a 3 year project grant from the Natural Sciences and Engineering Research Council (NSERC)–GSC-19 in Canada for the TREK experiment. Funds were requested to construct the fiber target in cooperation with other North American universities. The amount awarded was 70k\$, 130k\$, and 120k\$ for the fiscal years 2008-9, 2009-10, and 2010-11. These amounts will not be sufficient for us to construct the sized full target but they will allow us to pay for travel, hire a graduate student and post-doctoral fellow and also carry out the necessary design studies and test measurements to confirm the best target fibre readout system – including the preamplifier and phototube system (either single SiPMTs or segmented multi-anode PMTs) with the help of the TRIUMF detector shop. Professor Hasinoff (UBC) will be at CERN in June and he plans to visit the FAST group of Professor Pohl at the University of Geneve in order to learn about the detailed studies they have performed before constructing their 1600 channel $4{\times}4 \times 200$ mm^3 scintillating fibre target for the FAST experiment at PSI – which employs 2 WLS readout fibres for each 4×4 fibre. In addition to the readout tests for the scintillating fibre system we will also ask the TRIUMF design office to start a mechanical design for the target support system similar to the one constructed for the E246 target. Now that we have received NSERC support we can pursue an MOU between TRIUMF and J-PARC for our TREK work here in Canada as recommended by the third PAC meeting.

Table 2: NSERC funding for the target construction

Year	2008-9	2009-10	2010-11
Budget (kCan$)	70	130	120

2.3 Funding efforts in U.S.A. for GEM laboratory

In April 2008 the Hampton University group led by Prof. Michael Kohl submitted a pre-proposal to the US National Science Foundation (NSF) to apply for a so-called IGERT (Integrative Graduate Education and Research Traineeship) grant with the title: "Applying Today's Technology for Tomorrow's Science: An Interdisciplinary Program for Development and Application of GEM Detectors in Nuclear, Particle and Medical Physics". Upon invitation by NSF a full proposal will be due in October 2008. This proposal aims to establish a GEM detector lab on campus at Hampton University, to provide the basis for interdisciplinary research in nuclear, particle and medical physics in multiple specific research projects. The GEM-based tracking upgrade of the TREK experiment is one central application of this proposal. The lead institution of this proposal is Hampton University; in addition, Jefferson Lab, KEK, and MIT are participating institutions who will contribute with their resources and expertise.

The IGERT traineeship program is focused on supporting graduate students from minority universities in interdisciplinary and international research projects and it can also provide the necessary infrastructure of a lab. Hampton University as a Historically Black College and University (HBCU), is particularly suited for such a program. IGERT can provide funds of up to $600k per year for five years.

It is anticipated that additional funds will be required to cover the cost of the specific GEM detectors and electronics for the TREK experiment. In this regard, the group plans to apply separately to NSF within the Nuclear Physics Division for funds to construct the GEM tracking detectors for TREK. Alternatively, an application for a so-called MRI (Major Research Instrumentation) grant is currently being discussed.

In parallel, M.K. is working with a graduate student at Hampton University (Ozgur Ates) over the summer of 2008 on a baseline design for the TREK C0 and C1 detector elements. Both the schematic layout as well as a description with the GEANT4 simulation package are anticipated by the end of the summer of 2008.

The Hampton University group submitted a funding proposal to NSF in September 2007, to supplement the existing experimental nuclear physics group grant. In that proposal, the envisioned tracking ugrade of TREK was laid out as a central project. This proposal was rejected although the panel review reports were very good and the high scientific merit of TREK was recognized. The main reason for the rejection was the lack of a full approval of TREK at time of review.

Other universities in the US, University of South Caroline and Iowa State University are eagerly awaiting the stage-2 status before applying for their TREK operating and equipment funds from DOE.

3 Update of theoretical model descriptions of P_T

3.1 Importance of P_T physics

Two years have already passed since the submission of the original E06 (TREK) proposal and the LHC is going to start to run this year. New experimental data to be compared with P_T in different theoretical models have been improved in several fields and there is also new theoretical knowledge.

In this section, we would like to update our theoretical description of P_T and to confirm once again the physics impact of P_T in the LHC era. In the proposal we did not present the model parameter allowed regions in any theoretical model, because we thought it was too specific at that moment. In our review of the various theoretical models in this report, we will show some important model constraint figures.

There has been a series of workshops "Flavor Physics in the LHC Era"[1] held at CERN in 2006 with the final summary meeting in March 2007. In the working groups of "lepton" and "K- and D-mesons" the P_T physics was one of the topics with its ability to find new physics together with other T-odd quantities revealing CP violation beyond the Standard Model. In particular the unique feature to probe the Higgs dynamics with charged Higgs exchange in P_T was emphasized, which is otherwise accessible only in future high precison B-decay experiments[2]. At the moment P_T is thought to be insensitive to the Minimal Supersymmetry Standard Model (MSSM) with two Higgs doublets. Therefore, it cannot be denied that the outcome of LHC in a few years after the start has some significant meaning to P_T physics. On the other hand, it is also argued that there should be no a priori constraints on the structure of the Higgs sector and the number of its doublets. We believe it is very meaningful to pursue the study of Higgs dynamics even after SUSY particles are found; a few variants of SUSY may also produce a sizable P_T as discussed below. In the case where SUSY is not confirmed soon, the importance of new physics searches such as

P_T will become much larger. Apart from the CP violation models also, the violation of one of the fundamental discrete symmetries such as "time reversal invariance" should have a considerable impact on our understanding of nature.

3.2 Exotic scalar interactions

In the presence of the predominant T-conserving in-plane polarization, a small transverse component of P_T is described in terms of a physics parameter Imξ after factoring out the kinematical factor as

$$P_T = \mathrm{Im}\xi \cdot \frac{m_\mu}{m_K} \frac{|\vec{p}_\mu|}{[E_\mu + |\vec{p}_\mu| \vec{n}_\mu \cdot \vec{n}_\nu - m_\mu^2/m_K]}. \tag{1}$$

The quantity Imξ is non-zero when T is violated and this quantity is what we will measure with high precision. This kinematical factor shows the advantage for $K_{\mu 3}$ over K_{e3}. For the full detector acceptance there is an approximate relation of $< P_T > \sim 0.3\mathrm{Im}\xi$. We can write down the Lagrangian of a generic four fermion interaction with the coefficients for exotic interaction of scalar (G_S), pseudo-scalar (G_P), vector (G_V), and axial vector (G_A) neglecting the tensor contribution as

$$\begin{aligned} L = & - \frac{G_F}{\sqrt{2}} \sin\theta_C \, \bar{s}\gamma_\alpha(1-\gamma_5)u \, \bar{\nu}\gamma^\alpha(1-\gamma_5)\mu \\ & + G_S \, \bar{s}u \, \bar{\nu}(1+\gamma_5)\mu + G_P \, \bar{s}\gamma_5 u \, \bar{\nu}(1+\gamma_5)\mu \\ & + G_V \, \bar{s}\gamma_\alpha u \, \bar{\nu}\gamma^\alpha(1-\gamma_5)\mu + G_A \, \bar{s}\gamma_\alpha\gamma_5 u \, \bar{\nu}\gamma^\alpha(1-\gamma_5)\mu + \mathrm{h.c.} \quad , \end{aligned} \tag{2}$$

Imξ can be expressed with the imaginary part of the scalar coupling coefficent G_S as

$$\mathrm{Im}\xi = \frac{(m_K^2 - m_\pi^2)\mathrm{Im}G_S^*}{\sqrt{2}(m_s - m_u)m_\mu G_F \sin\theta_C} \tag{3}$$

where m_s and m_u are the masses of the s-quark and u-quark, respectively. Thus, P_T is induced by exotic scalar interactions such as the charged Higgs exchange. The situation is different if we look at the similar transverse muon polarization P_T in the radiative kaon decay of $K^+ \to \mu\nu\gamma$ which is caused by pseudo-scalar interaction G_P [3]. The most stringent limit to Imξ has been given by our previous E246 experiment to be $|\mathrm{Im}G_S|/G_F < 2.2\times 10^{-4}$ and this will be improved to 1×10^{-5} in the TREK experiment.

Chang and Ng[4] analyzed P_T in terms of an effective field theory using an effective Lagrangian as the sum of the Standard Model term and non-renormalizable ones resulting from integrating out the unknown degrees of freedom of new physics above a cut-off scale Λ. Our P_T physics is relevant to the dimension 6 operator in the expansion of $L^{eff} = L_{SM} + L_5/\Lambda' + L_6/\Lambda^2 + \cdots$. The charged current terms at the electroweak scale in the mass eigen-basis are

$$\begin{aligned} -L_6^{CC} = & \; C'_{V_2}(\bar{u}^i\gamma^\mu \hat{L} d^i)(\bar{e}^i\gamma_\mu \hat{L}\nu^i) + C_{S_1}^{ij.kl}(\bar{u}^i \hat{R} d^j)(\bar{e}^k \hat{L}\nu^l) \\ & - C_{S_2}^{ij.kl}(\bar{d}^i \hat{R} u^j)(\bar{\nu}^k \hat{R} e^l) - C_T^{ij,kl}(\bar{d}^i\sigma^{\mu\nu}\hat{R}u^j)(\bar{\nu}^k\sigma_{\mu\nu}\hat{R}e^l) + \mathrm{h.c.} \end{aligned} \tag{4}$$

where C_V, C_S, and C_T are the Wilson coefficients for the vector, scalar and tensor terms, respectively. The imaginary part of C_S (as well as C_T) gives rise to CP violation. The E246 result yielded

$$|\mathrm{Im}C_S^K| \leq 2 \times 10^{-3}(\Lambda/\mathrm{TeV})^2. \tag{5}$$

This will be further improved to $1 \times 10^{-4}(\Lambda/\mathrm{TeV})^2$ in the TREK experiment. In the following we will discuss a few scalar interaction models which may produce a sizeable P_T value, and which were mentioned in the proposal.

3.3 Multi-Higgs doublet model

One of the most distinct features of P_T is its high sensitivity to charged Higgs exchange at tree level. In the two-Higgs doublet model as well as in MSSM, however, no CP violation appears in the Higgs sector due to Natural Flavor Conservation (NFC). Only a small effect can be produced by loop-induced coupling (in SUSY) such as the loop-induced Flavor Changing Neutral Current (FCNC). Three Higgs doublet models (3HDM), on the other hand, may give rise to a large effect under the NFC condition with the interference of the Higgs exchange with the SM W boson exchange (Fig.1). New CP violating phases can be introduced in the charged Higgs mass matrix if the number of doublets is more than two in models without tree-level FCNCs. Historically a number of papers have applied these models to P_T as the most promising candidate theory. The coupling of quarks and leptons to the Higgs boson is expressed in terms of the Lagrangian

$$L = (2\sqrt{2}G_F)^{\frac{1}{2}} \sum_{i=1}^{2} \{\alpha_i \bar{u_L} V M_D d_R H_i^+ + \beta_i \bar{u_R} M_U V d_L H_i^+ + \gamma_i \bar{\nu_L} M_E e_R H_i^+\} + \mathrm{h.c.}, \quad (6)$$

where α_i, β_i, and γ_i are the quark and lepton couplings to the lightest charged Higgs boson,

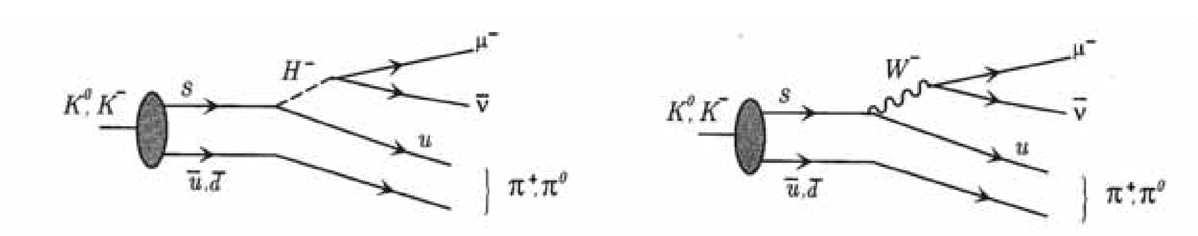


Figure 1: P_T appears as the interference of the charged Higgs boson exchange with the standard model W boson exchange.

respecively, and CP can be broken if α_i, β_i and/or γ_i have complex phases. Imξ is expressed as

$$\mathrm{Im}\xi = \frac{m_K^2}{m_H^2} \mathrm{Im}(\gamma_1 \alpha_1^*), \quad (7)$$

thus, constraining the model parameter $\mathrm{Im}(\gamma_1\alpha_1^*)$. As was discussed in the proposal, several other channels (e.g. B-meson leptonic $B \to \tau\nu$ and semi-leptonic $B \to X\tau\nu$ decay, B-meson radiative decay $b \to s\gamma$, the d quark contribution to the neutron electric dipole moment (EDM) are also sensitive to this quantity. The neutron EDM and $b \to s\gamma$ are related to the other parameter $\mathrm{Im}(\alpha_1\beta_1^*)$ of only with quark couplings directly, but these two parameters are connected by the relationship $\mathrm{Im}(\alpha_1\beta_1^*) = -(v_3/v_2)^2 \mathrm{Im}(\gamma_1\alpha_1^*)$ using the Higgs field vacuum expectation values of v_3 and v_2. The most recent data for the neutron EDM is $d_n = 3 \times 10^{-26} e$ cm[5]. Recent data for $B \to X\tau\nu$ and $b \to s\gamma$, come from OPAL and

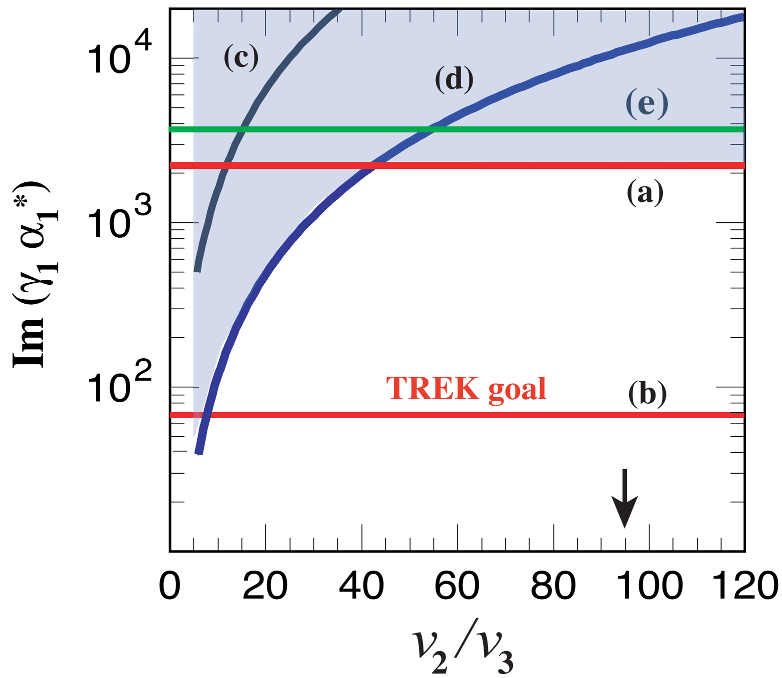


Figure 2: Constraint to the three Higgs doublet model parameters of $|\mathrm{Im}(\gamma_1\alpha_1^*)|$ and the ratio of Higgs field vacuum expectation values, v_2/v_3, with the assumption of $m_{H^+} \cong 2m_Z$. (a) is the P_T limit from the E246 experiment, (b) is P_T expectation in TREK, (c) neutron electric dipole moment (EDM) only with the d-quark contribution, (d) $b \to s\gamma$, (e) $b \to X\tau\nu$. The gray region is the excluded region. The arrow shows the most probable point of v_2/v_3 to be $m_t/m_\tau = 95$.

ALEPH[6] and Belle[7], respectively. Fig.2 shows the constraints to $|\mathrm{Im}(\gamma_1\alpha_1^*)|$ from the E246 P_T and these other channels. The TREK goal is also indicated. The important point here is the fact that in one of the scenarios discussed in [8] $v_2/v_3 \sim m_t/m_\tau$, namely the ratio of the coupling fermion mass which is now 95. In this region we see that P_T is the most stringent test of the three Higgs doublet model.

As is seen in the figure the $B \to X\tau\nu$ decay has the sensitivity next to P_T . Recently, a similar leptonic decay of $B \to \tau\nu$ has been observed at Belle and the branching ratio was determined[9]. This channel should be also very sensitive to the Higgs dynamics due to helicity suppression in the W exchange[2]. It also constrains $(\gamma_1\alpha_1^*)$ [10]. These two channels will be competitive to P_T when Super-Belle is in operation. In a semi-quantitative discussion borrowing the Higgs mass, m_H, from the two Higgs doublet model analysis in terms of $\tan\beta/m_H$, it is argued that the measured branching ratio of $B \to \tau\nu$ is already corresponding to a bound of $P_T < 0.005$[11], but the direct charged Higgs search or the B decays at Super-Belle can only put constraints as $P_T < 3 \times 10^{-4}$[11]; thereby still giving a room uniquely covered by the TREK experiment.

An interesting discussion to suggest a "finite value" of P_T was given in the CERN flavor workshop (2007) in the framework of multi-Higgs model[2]. If some Higgs dynamics is responsible for the discovered direct CP violation in the K^0 system which is described by $\mathrm{Re}(\epsilon'/\epsilon) = (1.66 \pm 0.26) \times 10^{-3}$, this effect can be converted to P_T. This $\mathrm{Re}(\epsilon'/\epsilon)$ value is equivalent to decay rate difference between $K^0 \to f$ and $\bar{K^0} \to f$ of $5{\times}10^{-6}$[12]. Since the $\Delta I = 1/2$ transition is dominant in the $K^0 \to 2\pi$ system, it should be suppressed. In the charged K^+ system of P_T, however, there should be no such suppression. Assuming the $\Delta I = 1/2$ suppression factor to be 20, we calculate a CP violation effect in the charged K^+ to be $\sim 5 \times 10^{-6} \times 20 \sim 10^{-4}$ without enhanced couplings to leptons due to v_2/v_3 mentioned above. Regarding the origin of ϵ'/ϵ, there seems to be no conclusion yet. Therefore, this kind of qualitative discussion is a strong motivation for a P_T search with a sensitivity of 10^{-4}.

3.4 SUSY models

Although the Minimal Supersymmetric Standard Model (MSSM) predicts only unobservably small P_T[13] without tuning of relevant flavor parameters, the SUSY with R-parity violation[14] or SUSY with large squark mixing[15] can also give rise to a sizeable value of P_T as was in the proposal. If R-parity violation is allowed a superpotential is defined[16] as $W = W_{MSSM} + W_{RPV}$ with

$$W_{RPV} = \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k \tag{8}$$

where $i, j = 1, 2, 3$ are generation indices with a summation implied. $L_i(Q_i)$ are the lepton (quark) doublet superfields and $\bar{E}_j(\bar{D}_j, \bar{U}_j)$ are the electron (down- and up-quark) singlet superfield. λ,λ' and λ'' are the Yukawa couplings; the former two relevant to lepton number violation and the latter relevant to baryon number violation. There are altogether 48 independent λ_{ijk}'s which should be determined experimentally.

Our P_T can be expressed in this formalism as a sum of two components of slepton exchange and down-type squark exchange as $\mathrm{Im}\xi = \mathrm{Im}\xi^{\tilde{l}} + \mathrm{Im}\xi^{\tilde{d}}$ with

$$\mathrm{Im}\xi^{\tilde{l}} = \sum_i \frac{\mathrm{Im}[\lambda_{2i2}(\lambda'_{i12})^*]}{4\sqrt{2} G_F \sin\theta_c (m_{\tilde{l}_i})^2} \cdot \frac{m_K^2}{m_\mu m_s} \tag{9}$$

$$\mathrm{Im}\xi^{\tilde{d}} = \sum_i \frac{\mathrm{Im}[\lambda'_{21k}(\lambda'_{22k})^*]}{4\sqrt{2} G_F \sin\theta_c (m_{\tilde{d}_k})^2} \cdot \frac{m_K^2}{m_\mu m_s}. \tag{10}$$

Thus, we constrain $\mathrm{Im}[\lambda_{2i2}(\lambda'_{i12})^*]/m^2_{\tilde{l}_i}$ and $\mathrm{Im}[\lambda'_{21k}(\lambda'_{22k})^*]/m^2_{\tilde{d}_k}$ (sumation is implied). The limit of these summations (assuming a common mass scale for $m_{\tilde{l}_i}$ and $m_{\tilde{d}_k}$) is plotted as a function of the mass scale for the E246 P_T limit and the TREK goal.

There are a number of experimental and theoretical efforts to analyze λ,λ' and λ'' in other channels. In a recent paper[17] and review papers[18, 19] currently updated limits are compiled also for the products $\lambda\lambda'$, $\lambda'\lambda'$, *etc.* There are 6 relevant parameters for P_T as shown in Eq.10 which are summarized in Table 3. Regarding the 3 paraneters for the down-type squark exchange, a recent analysis of the $K^+ \to \pi^+ \nu\bar{\nu}$ sets the most stringent limit of $|\lambda'^*_{i2n}\lambda'_{i1n}/m^2_{\tilde{d}n_L}| \leq 2.8 \times 10^{-5}$[20]. As for one of the slepton exchange terms, only the $|\lambda^*_{232}\lambda'_{312}|$ term is constrained to be $< 3.8 \times 10^{-7}\tilde{m}^2$[19], and the other two termes are not constrained in any other experiments. The limits of these constrained from other experiments are also shown in Fig.3 as the absolute value (not imaginary part) of the

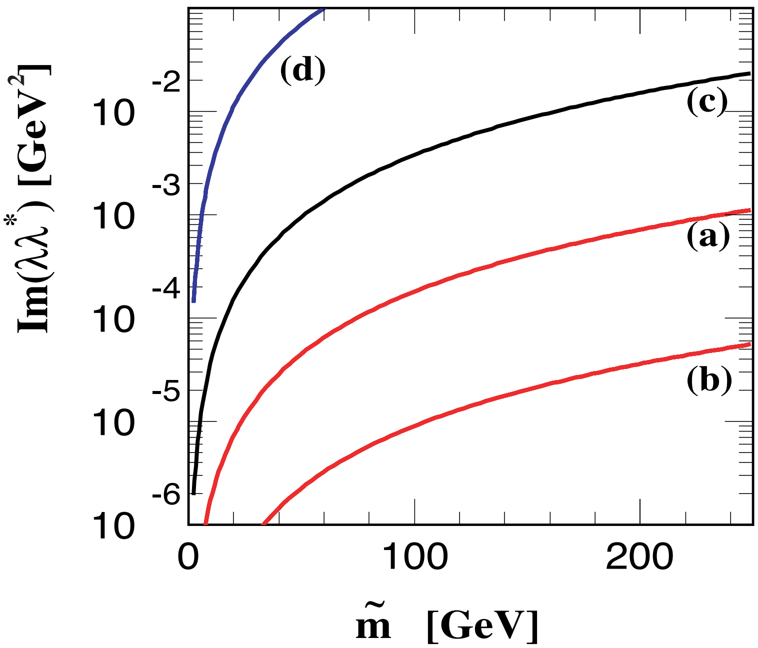


Figure 3: The constraint on $\Sigma\mathrm{Im}(\lambda\lambda')$ and $\Sigma\mathrm{Im}(\lambda'\lambda')$ in Eq.10 are plotted for the E246 result (a) and the TREK expectation (b). The limits for the individual parameters in absolute value from other experiments are also shown; (c) for $|\lambda^*_{232}\lambda'_{312}|$ from $K_L \to \mu^+\mu^-$[20], and (d) $|\lambda'^*_{22k}\lambda'_{21k}|$ from $K^+ \to \pi^+\nu\bar{\nu}$[19].

Table 3: The R-pariry violating SUSY parameters relevant to P_T and the constraints from other experiments.

	Paraneter	Upper bound	Experiment
$\mathrm{Im}\xi^{\tilde{l}}$	$\lvert\lambda^*_{232}\lambda'_{312}\rvert$	$3.8 \times 10^{-6} m^2$	$K_L \to \mu^+\mu^-$[19]
	$\lvert\lambda^*_{212}\lambda'_{112}\rvert$	no constraint	
	$\lvert\lambda^*_{222}\lambda'_{212}\rvert$	no constraint	
$\mathrm{Im}\xi^{\tilde{d}}$	$\lvert\lambda'^*_{211}\lambda'_{221}\rvert$	$2.8 \times 10^{-5} m^2$	$K^+ \to \pi^+\nu\bar{\nu}$[20]
	$\lvert\lambda'^*_{212}\lambda'_{222}\rvert$	$2.8 \times 10^{-5} m^2$	$K^+ \to \pi^+\nu\bar{\nu}$[20]
	$\lvert\lambda'^*_{213}\lambda'_{223}\rvert$	$2.8 \times 10^{-5} m^2$	$K^+ \to \pi^+\nu\bar{\nu}$[20]

individual parameters. It can be see that P_T constrains the relevant parameters most stringently.

For the SUSY model with large squark mixing[15] there is nothing to update since the proposal.

4 Progress in beamline and optics design

4.1 Design of K1.1 B1 nagnet

In the report to the last PAC meeting we discussed the necessity to recover the acceptance of the K1.1(-BR) beamline which was decreased for this channel by the presence of the preceding K1.8 beamline. Based on a beam optics calculation we proposed to construct the beamline with a combined-function magnet in place of the first bending magnet B1. The combined function magnet would have been realized by creating an n-value for B1 as $B(x) = B_0(1 - nx/\rho)$. In this optics calculation the best case was obtained with $n = -6.75$ while keeping the configuration of the other elements unchanged.

Since the introduction of a non-uniform gap may cause some technical problems, we investigated the feasibility of this kind of magnet by doing 2D magnetic field calculations. Because the component construction around the T1 target is now well advanced, and also because the original plan for K1.1-BR is the common use for K1.1 operation, it turned out that the realization of a combined-function magnet with large n-value would be very difficult. The reasons are the following:

- The non-flat gap of the magnet causes magnetization saturation at the narrow gap part. The effect is too significant already at the excitation of 0.8 GeV/c to secure a sufficiently constant field gradient dB_y/dx. The only way to avoid this situation is to lower the central dipolar field by extending the magnet length. However, the current magnet length is strictly constrained by the existing vacuum vessel and the beam line axis after the bending. A length of more than the 80 cm of the current design is impossible.

- Even for a smaller n-value the ratio of the dipole and quadrupole field is excitation dependent. It is also difficult to achieve a constant field gradient for the two different excitations of 0.8 GeV/c and 1.1 GeV/c. Fig.4 shows the field distribution at $n = -2.5$ for the excitation for 0.8 GeV/c and 1.1 GeV/c. This means that it is very unrealistic that one can construct a beamline with an optimal beam optics for both beam momenta.

Therefore, we may have to give up the very attractive idea of the combined magnet for B1, which could have increased the acceptance by 75%.

In the course of this study we found that the horizontal acceptance of the first bend B1 is also essential to obtain the highest channel acceptance in addition to the aparture of Q6. The currently fixed geometry in the vacuum vessel and the conflict with the K1.8 B1 magnet seems to constrain the actual pole width of K1.1 B1 to 26 cm. However, our beam optics calculation was based on the assumption of ± 10 cm acceptance. A calculation was performed to find the best B1 field distribution and we discovered that a sufficiently flat field distribution over the ± 10 cm can be obtained only an arrangement of shims at the pole edges. Fig.5 show the calculated field distributions for both 0.8 GeV/c and 1.1 GeV/c

excitation. If we optimize the distribution for 0.8 GeV/c, for which a much higher channel acceptance is required by our TREK experiment, the horizontal acceptance of B1 for 1.1 GeV/c becomes narrower, but it could be tolerable for the norrower K1.1 beam.

In order to obtain higher acceptance of the beamline a larger aperture of the Q6 quarupole magnet in now most important. The current design value of 30 cm diameter might be increased. We will study this point next.

4.2 Comments on the K_L beam holes

- We were informed by the E14 group that they are currently considering a 3-cm-diameter or 3-cm-square hole in the B1 yoke. This issue was checked and we drew a conclusion this hole has no influence on the magnet excitation characteristics in view of yoke saturation and gap field distribution. The hole diameter in Q1,Q2 and B2 is not yet known, but this seems to be no problem.

- The installation position resolution of B1 determines the accuracy of the hole position. Although B1 will be set in the vacuum tank, a position resolution of a few 100 μm should be quite feasible.

5 Analysis of the CsI(Tl) readout high-rate performance

5.1 APD readout

As was described in the proposal we will replace the PIN photodiode readout system of E246 with a new APD+FADC system. In the PIN readout the counting rate was limited by the long output pulse of the shaping amplifier ($\sim 10\mu$s) and the output dynamic range of the charge-sensitive preamplifier. The maximum rate was $\sim$30 kHz corresponding to a 5% of event loss. We adopted the quickly developing avalanche photo-diode (APD) with reverse bias voltage which has an internal amplification of 50-100. Currently we plan to select the 5$\times$5 mm Hamamatsu APD (S8664-55) with the gain of 50 because this model is well established for stable operation.

A prototype module was tested with a positron beam (100-400 MeV) at the Laboratory of Nuclear Science (LNS) of Tohoku University last December. The same size CsI(Tl) crystal as the real colorimeter component was equipped with one APD, and a fast amplifier developed at INR (Moscow) was employed. The basic performance of the system was confirmed with regard to 1) light-yield (signal size), 2) signal shape into FADC, and 3) signal to electronic noise ratio, and the preliminary results and features have already been reported in the last meeting. The main purpose of the test, however, was to check the ability to apply this system to a high singles rate condition. In a special run with the highest instantaneous beam rate, $\sim$40,000 pileup events were recorded to check the feasibility to analyze such events separately. The detailed analysis was performed at INR as well as at Tohoku University.

5.2 Analysis of pileup events

It was essential to find a functional form of the output pulse of the amplifier, namely the input to FADC and fit the data to this function. Although there was a significant overshoot and ringing, the main part of the signal could be simulated with the function of

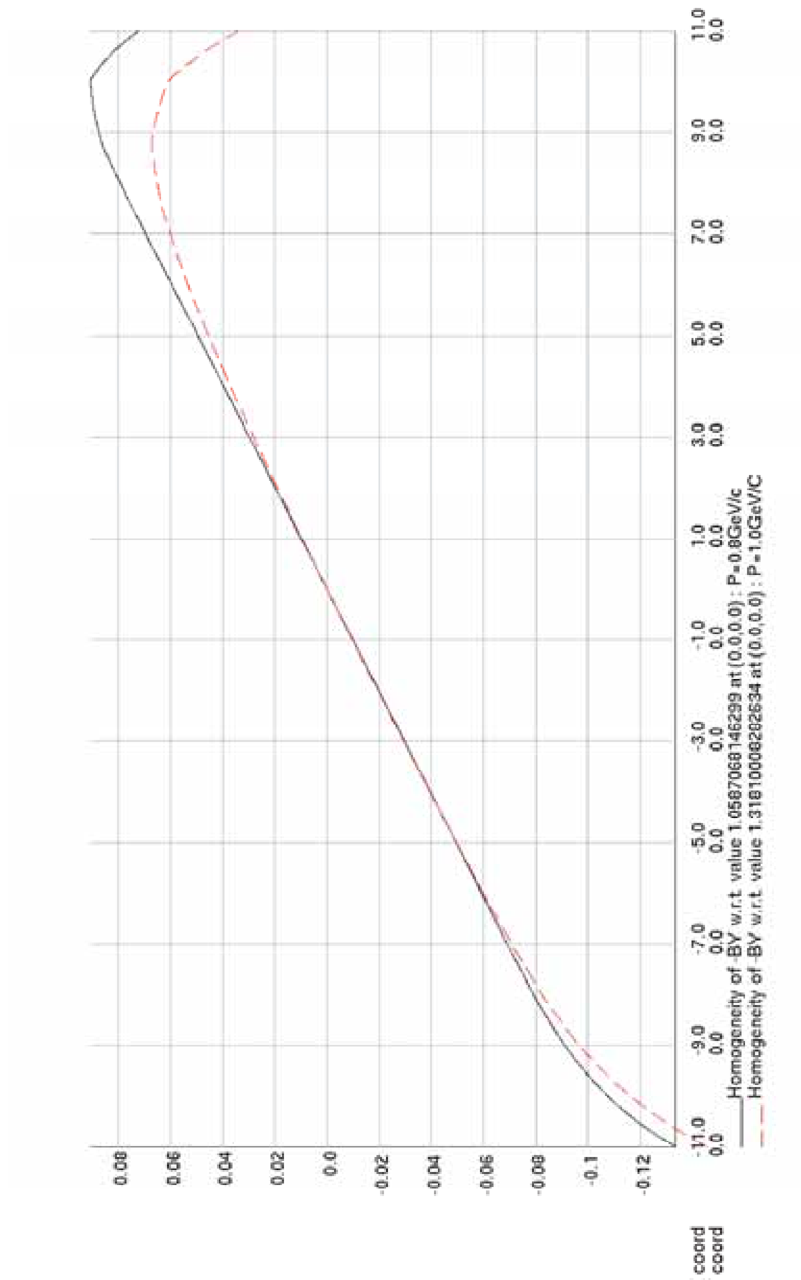


Figure 4: Field distribution along the x axis of the combined B1 magnet with $n = -2.5$ for an exitation of 0.8 GeV/c (black curve) and 1.1 GeV/c (red curve). An optimum shim was attached for the 0.8 GeV/c excitation. One sees that the effective field gradient is different for the 1.1 GeV/c excitation, and that the useful width is significantly smaller.

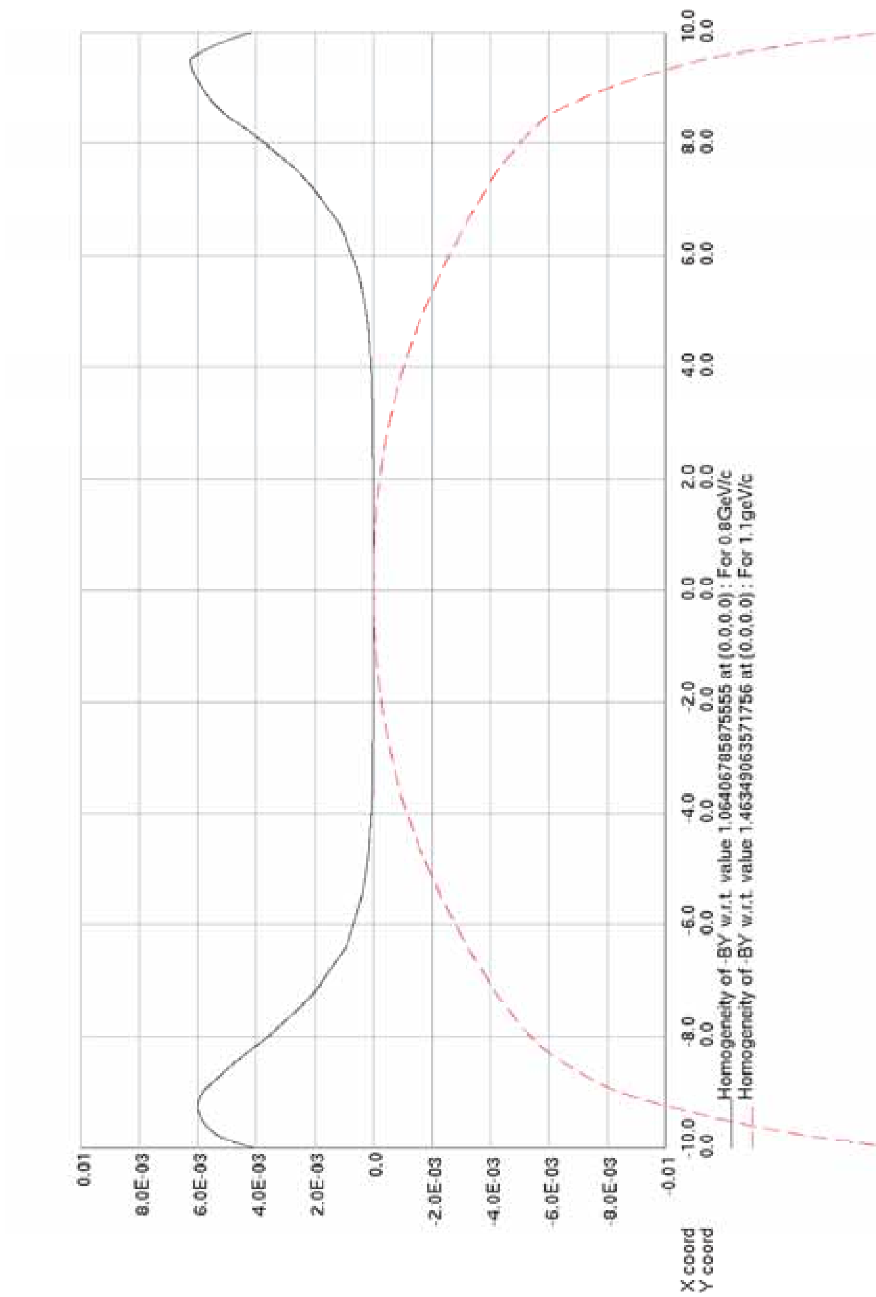


Figure 5: Field distribution along the x axis of the normal B1 magnet with $n = 0$ for an exitation of 0.8 GeV/c (black curve) and 1.1 GeV/c (red curve). The shim was optimized for both excitations. The uniform field region of less than 1% deviation can be obtained for a width of ± 10 cm for 0.8 GeV/c, whereas it is somewhat narrower for 1.1 GeV/c.

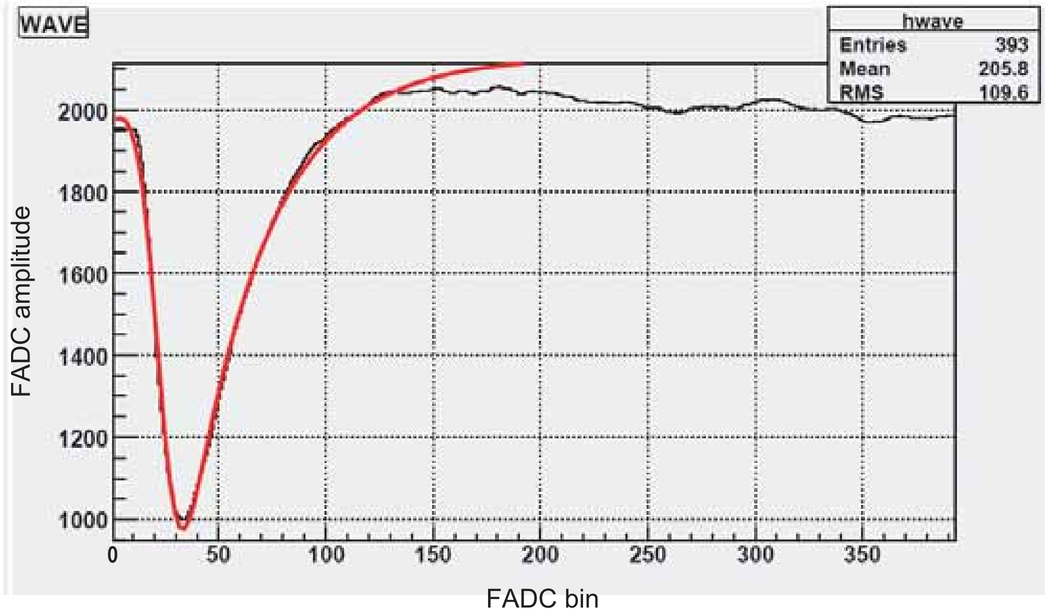


Figure 6: Signal shape of the amplifier output pulse and its fit to the function of Eq.11

$$F(x) = p_0 - p_1 e^{p_2 x}\{p_3 \times Erf(p_4 x - p_5) + p_6\} \tag{11}$$

$$Erf(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt \quad . \tag{12}$$

A typical fit for a beam energy of 400 MeV is shown in Fig.6 demonstrating fairly good agreement in the signal region. Pileup events for a certain beam energy (typical signal shape is shown in Fig.7 with a pulse width of $\sim 1.5\mu$s) were fitted to a superposition of the two fit functions and the signal size defined as the integration of the function was compared with the non-pileup single events. Fig.8 (upper) shows the signal size distribution for non-pileup events and Fig.8 (middle) shows the signal size distribution of the first pulse in the pileup events for the beam energy of 400 MeV. Good agreement can be seen in both the distribution form and in the peak position. The analysis efficiency as a function of time difference of the second pulse in the pileup events has almost flat distribution of 100% above bin 40. From these results we may conclude that if the real triggered signal is the first pulse, then events can be saved as long as the pulse separation is larger than $\sim 0.8\mu$s corresponding to 40 bins in Fig.6 and 7 as long as the second pulse is high enough. A more detailed analysis is currently underway concerning the separability of a pileup event with different height and the the analysis efficiency as the function of the separation. Regarding the pileup events with almost overlapping pulses, these can be rejected in the fit by the pulse width.

For the second pulse analysis, however, the situation is more complicated due to the presence of the overshoot and the ringing in the amplifier output. Even if the effect of the overshoot is taken into account by knowing its signal size ratio to the main negative part,

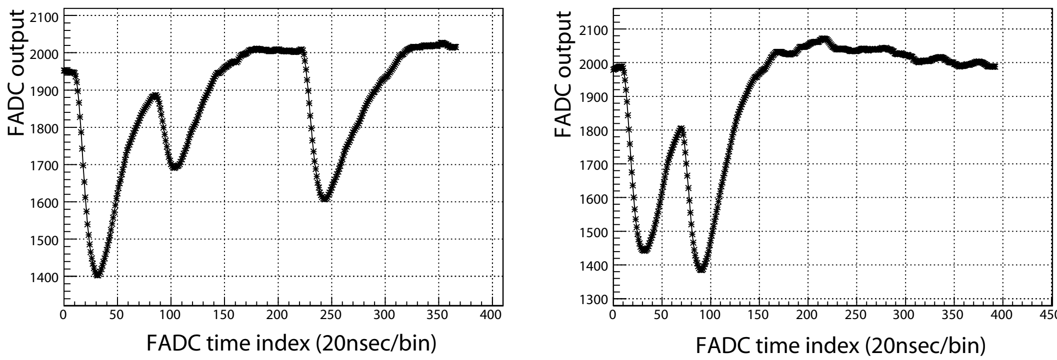


Figure 7: Signals of typical pile-up events. One horizontal unit (50 FADC channels) is 1μsec.

the signal size distribution looks quite different from the non-pileup event sample. Fig.8 (lower) shows the signal size distribution for the same beam energy when the delay time is between 40 and 80 bins. We are still investigating the reason for the bump appearing in the smaller signal size region, whether it has an amplifier origin or some analysis failure.

5.3 Necessity for an improved amplifier

The overshoot of the prototype amplifier is certainly making troubles either in the output signal or in the analysis. We have found it necessary to develop an improved amplifier. The prototype amplifier had some differential/integration function. However, the input APD signal form is a clean unipolar signal. An ideal current amplifier would be better for the present purpose to meet the requirement for pileup event analysis. A new prototype current amplifier will be completed at INR by the end of June of this year and it will be tested with cosmic ray events using the same CsI(Tl)+APD system. If the second pulse in the pileup events become reliably usable, the analysis efficiency can be increased substantially and we will not lose any significant fraction of events up to an average rate of 300-500 kHz.

6 Analysis of the most serious systematic error

6.1 Polarimeter misalignment

We have been continuing our study of the systematic errors with simulation calculations based on our experience in E246. The table of the systematic errors in E246 was reviewed thoroughly and the prospects for reducing the total size down to less than 10^{-4} in TREK is now well established. We have already reported the "potential systematic error analysis" to the third PAC meeting one year ago. There we emphasized the importance of the alignments of the active polarimeter and the muon field distribution which are the sources of "inherent" systematics in the asymmetry measurement. In order to treat this problem we presented an innovative method to perform the P_T analysis by removing any misalignment effects, the outline of which is briefly described below. The validity of this method must be demonstrated with a MC calculation with high statistics. The limited number of events (100

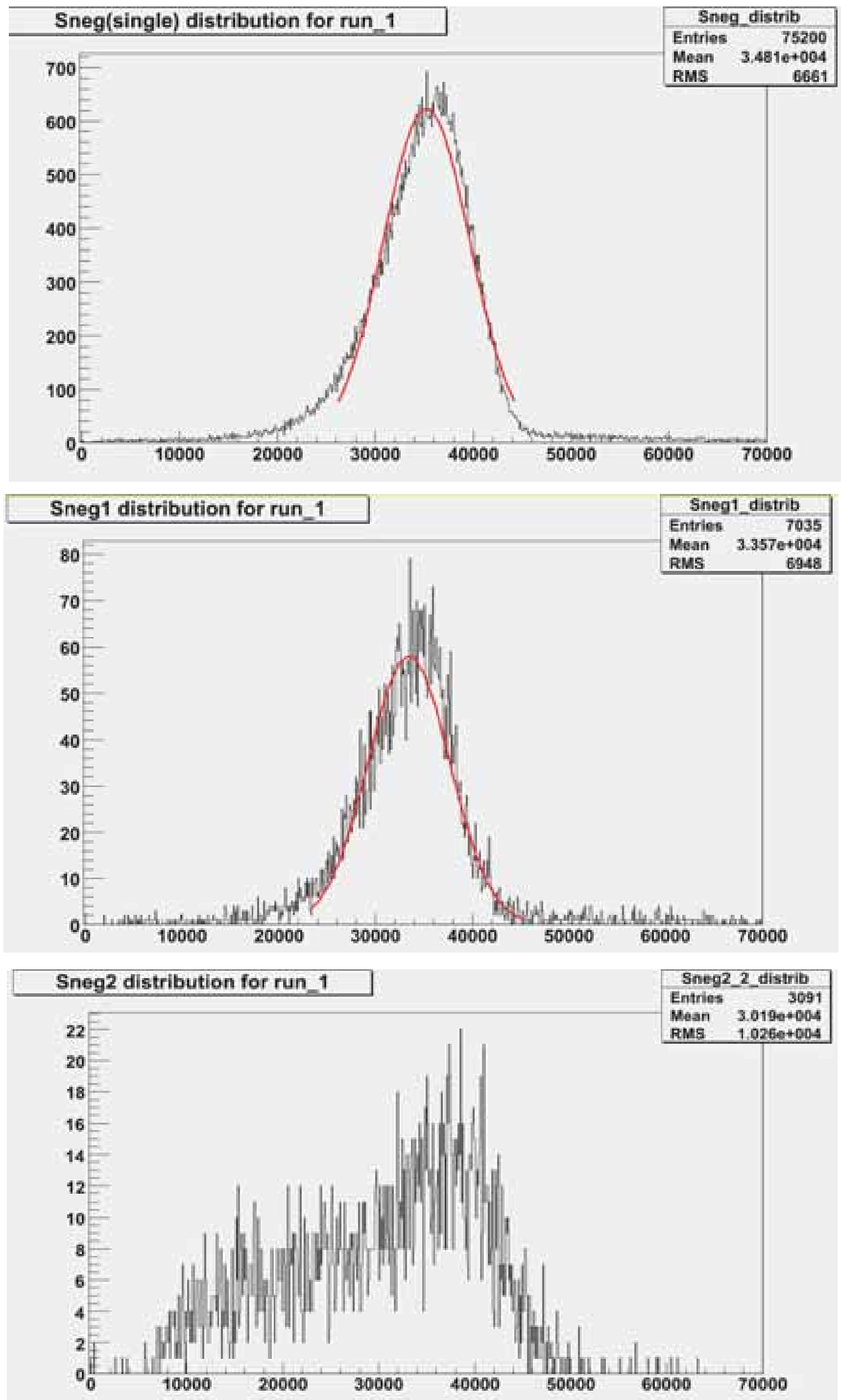


Figure 8: Signal area distribution for a) non-pileup events (upper), b) pile-up events first pulse (middle), and c) pile-up events second pulse (lower), for the 400 MeV positron beam energy.

million) in that study, however, resulted in the accuracy of $\Delta P_T = (2 \pm 7) \times 10^{-4}$, although the assumption was for an exaggerated field rotation of 5°. The necessity to improve this analysis statistically was also pointed out in the PAC meeting.

Here we report on the new results of Monte Carlo studies with much higher statistics of ~25 billion $K_{\mu 3}$ events which should correspond to $\Delta P^{av}_{sub} < 10^{-4}$. In this simulation more realistic misalignments with 10mrad field rotations were assumed. On the other hand, the Monte Carlo code and the analysis procedure were the same as the previous studies.

6.2 High statistics MC simulation

Now we describe the result briefly along with the principle of the method. As in E246 the misalignments of the polarimeter detector and the muon holding field distribution remain the most serious systematic which cannot be cancelled out either in the 12-fold rotational summation or in the π^0 forward (fwd) and π^0 backward (bwd) subtraction. The time integrated e^+ left/right asymmetry due to the misalignments can be described for arbitrary initial muon spin phase in the median planes θ_0 measured from the direction of z bean axis as,

$$\bar{A}(\theta_0) = \alpha_0[\delta_r \cos\theta_0 - \delta_z \sin\theta_0 + \eta(\theta_0)], \tag{13}$$

where δ_z and δ_r correspond to the muon field rotation for the z(beam) and r(radial) directions, respectively. α_0 is the analyzing power for the polarization determination from the e^+ asymmetry. The oscillation terms are drastically reduced by the time integration and the contribution due to imperfect cancellation of the oscillation terms is expressed as $\eta(\theta_0)$. It is noted that the misalignments of the polarimeter itself were integrated out into $\eta(\theta_0)$ and hence they are not relevant in the further discussion.

In order to extract the misalignment parameters δ_r and δ_z in the presence of a real P_T signal, we calculate two asymmetries A_{sum} and A_{sub} as a function of θ_0, i.e., the sum and difference of A_{fwd} and A_{bwd} – the asymmetries at the forward and backward pions, respectively. This leads to

$$\begin{aligned} A_{sum}(\theta_0) &= [\bar{A}_{fwd}(\theta_0) + \bar{A}_{bwd}(\theta_0)]/2 = \alpha_0[\delta_r cos\theta_0 - \delta_z sin\theta_0 + \eta(\theta_0)] && (14) \\ A_{sub}(\theta_0) &= [\bar{A}_{fwd}(\theta_0) - \bar{A}_{bwd}(\theta_0)]/2 = F(P_T, \theta_0). && (15) \end{aligned}$$

Here, $F(P_T, \theta_0)$ is the A_T asymmetry function only from a P_T origin and it does not involve any misalignment effects. Thus, we have no effects of P_T in A_{sum} and no effects of misalignments in A_{sub}, enabling the determination of $F(P_T, \theta_0)$ unaffected by the misalignments. The purpose of this MC study was to demonstrate a unique determination of the misalignments when several misalignments are existing simultaneously and to check for any bias in the analysis including a possible bias in the tracking code when using the Runge-Kutta integration method. Assuming the existence of both δ_z and δ_r the A_{sub} analysis was performed using $K_{\mu 3}$ decays 25 billion events, and P^{av}_{sub} was obtained from the averaged A_{sub} to be $P^{av}_{sub} = \alpha_0 A^{av}_{sub} = (0.3 \pm 0.6) \times 10^{-4}$. The figures presented in the PAC3 report have now been revised with higher statistics. Fig.9 shows the $A_{fwd/bwd}$ and P_{sub} dependence on θ_0 in (a) and (b), respectively. The result, which is consistent with zero within the statistical error, indicates the validity of this analysis method including the absence of any bias in the analysis code.

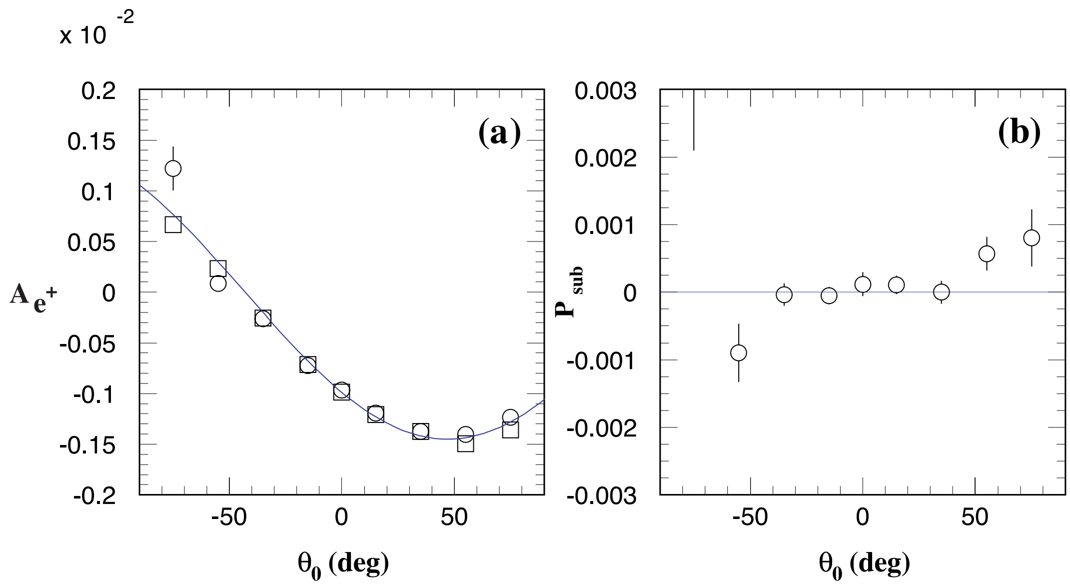


Figure 9: Results of high statistic Monte Carlo simulation for (a) the e^+ left/right asymmetry A_{e^+} as a function of θ_0 for π^0-fwd (circle) and π^0-bwd (square), and (b) $P^{av}_{sub} = \alpha_0 A^{av}_{sub}$. The input parameters were $\delta_z = \delta_r$ =10 mr and Im$\xi = 0$.

Table 4: Results of Monte Carlo simulation of the misalignment removing analysis of P_T. P^{av}_{sub} is identified as the final result of P_T in the real analysis.

Report to	Misalignments	Input of Imξ	No. of sumulated $K^+_{\mu 3}$	P^{av}_{sub}
PAC-3	$\delta_z = \delta_r = 5^\circ$	zero	10^8	$(2 \pm 7) \times 10^{-4}$
PAC-5	$\delta_z = \delta_r = 10$ mr	zero	2.5×10^{10}	$(0.3 \pm 0.6) \times 10^{-4}$

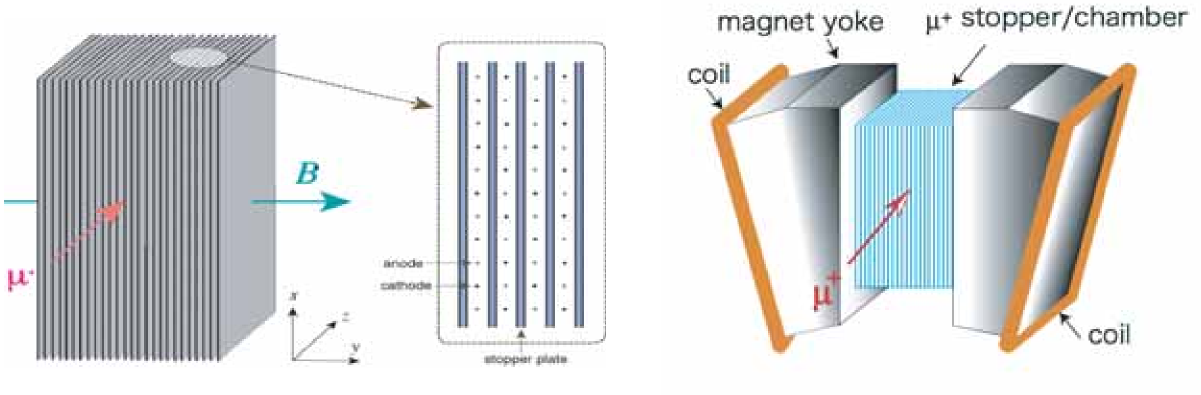


Figure 10: Schematic view of the active polarimeter with the drift chamber arrangement (left), and the configuration in the muon field magnet (right).

6.3 Policy for further systematic error studies

In order to make sure that the total size of the systematic error becomes less than 10^{-4} the result obtained now might not be sufficient in the accuracy if we consider the 90% C.L., since there are also other sources of the systematic errors to be added. Also for the case in which we see some effects for P_T, it would be preferable to have a room to improve the statistical error. However, we regard the current MC statisctics already high enough for the moment. Analysis like this must be analysis-code dependent. Especially, we have to check that the tracking code has no asymmetry bias across the magnet gap median planes. The ultimate check should be done together with the real analysis in the future.

7 Plan for this fiscal year

7.1 Polarimeter prototype production and tests

7.1.1 Current design of the active polarimeter

By using the Grant-in-Aid fund which we obtained for three years (2008-2010), we will be able to construct the polarometer chambers for the 12 sectors and a prototype of the polarimeter magnet. Since the proposal submission we have continued the design study of the active polarimeter, and the current design uses the same principle and nearly the same parameters as was described in the proposal and also reported to FIFC last year. The most dangerous and essential source of systematic errors is the geometrical alignment of the polarimeters and magnetic field relative to the main reference of the Toroidal Spectrometer system and the tracking system. In order to ensure good characteristics in view of alignment and other systematics, it is essential for the active polarimeter to have a simple structure and $left/right$ symmetry as much as possible.

What we have adopted is the parallel plate stopper array configuration with 2.5-mm thick metal stopper plates and 8-mm spacing between them. The gap serves as a drift chamber with anode wires in the mid-plane of the gap. About 30 layers will cover the entire width of the polarimeter. Fig.10 shows a schematic view of the polarimeter for one of the 12 sectors. The muons enter the polarimeter parallel to the stopper plates and are stopped with an efficiency of about 85%. As we reported to the previous PAC meeting we have already selected several candidates for the stopper metal material which have good enough characteristics in terms of the muon spin depolarization after stopping. The incident muons as well as the decay positrons are tracked with the drift chamber. The positrons are tracked using several layers of the gap drift chamber, and the initial emission angle is traced back. The angular resolution (or uncertainty) will be dominated by the multiple scattering rather than the position resolution of the chamber, so that only a moderate resolution of the chamber is required. There are several issues to be solved before proceeding to the final design and production of the 12 chambers. We will solve the issues by constructing a (1) several-layer prototype, and a (2) one-sector full-sized model within this fiscal year. The time schedule is shown in Fig.11.

7.1.2 Several-layer prototype

A prototype will be made in order to confirm the performance as a drift chamber. We will take the same mechanical structure as the real model except that the number of layers will be 5-10 and the number of wires will be minimized. We plan to test this prototype at the electron test beam facility in KEK. The items to be checked are the following:

- The basic performance as a chamber will be demonstrated. The baseline design of the readout electronics using CMOS-ASD elements developed by the KEK detector development project will be tested.
- The position resolution for the $z-$coordinate determination should be measured. Because of cost saving we have to make a compromise in adopting an elongated cell size with reduced number of anode wires. A moderate position resolution should be compatible with the scattering effects in determining the positron emission angle. The corresponding timing resolution is also an important quantity for measuring the muon decay timing as accurate as possible.
- The required $left/right$ symmetrical configuration necessarily leads to the adoption of the anode charge ratio method for 2D readout in each layer. The performance is measured and fed back to the readout electronics parameters.

7.1.3 Full scale prototype

Based on the results obtained with the several-layer prototype, we will proceed to the manufacturing of a full-sized prototype for one sector. The stopper material here should be the finally selected best candidate. The mechanical structure, wire arrangements, readout electronics (including the HV configuration) will be established. We aim to construct this full scale prototype chamber within this fiscal year and then perform a muon beam test at TRIUMF in 2009. In the test measurement, the following items will be investigated.

- We will confirm the performance as the tracker of muons which are incident parallel to the stopper plate. A forward or backward decay muon beam will be stopped in the stopper plates. The simultaneous tracking of a muon and a decay positron will be demonstrated.

- The chamber performance for a crude Michel parameter determination should be demonstrated. Two kinds of incident muon beams are necessary: one is the standard parallel incident beam and the other is the side-wise injection to realize the y-directed polarization. The energy threshold characteristics in determining the positron asymmetry will be studied.

- The muon incident point will be scanned in the y-direction and the dependence of the tracking performance on y will be studied. The z stopping distribution will also be varied. The so-called fiducial region will be defined.

- By using a decay muon beam with almost zero transverse polarization, a null positron asymmetry measurement will be performed in order to verify the symmetrical structure of the polarimeter. This test will also be performed by installing the polarimeter in the muon field magnet to provide data on the field symmetry.

- In order to optimize the wire electronics multiplexing scheme and also to see the performance in the presence of background, a high-intensity run will be performed realizing a condition such that several muons are piled-up in the polarimeter within their lifetime.

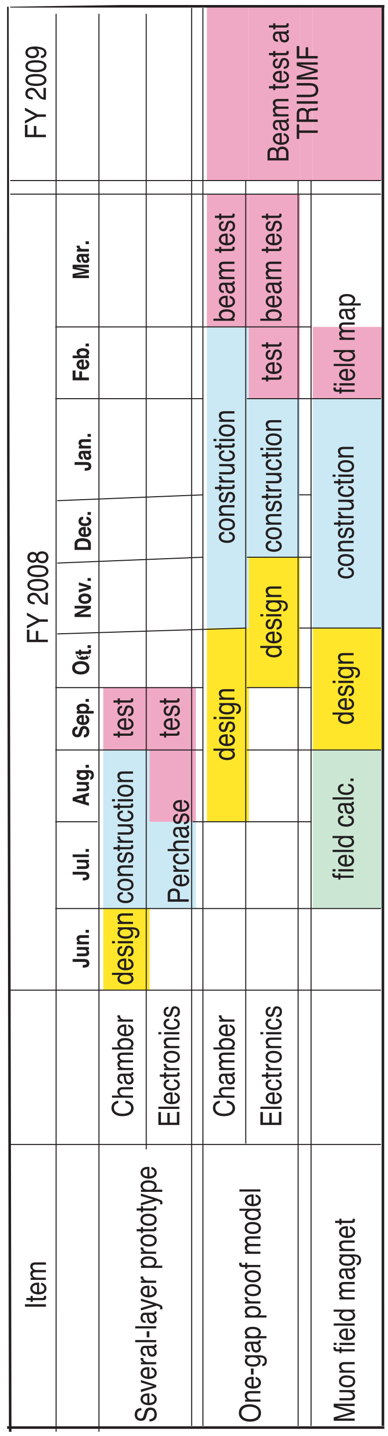
7.1.4 Muon field magnet

The muon field magnet is also a key element in reducing the systematic errors. The alignment of the field vector distribution is a "direct" systematic affecting the positron asymmetry. A magnet with high mechanical precision as well as coil current distribution is required. In the first year of the polarimeter construction, a prototype of the magnet will be constructed to determine the feasibility of the required mechanical precision. At the moment a 3D field calculation is underway to design a dipole magnet with the flattest possible field strength. After the field distribution is mapped it will be used for the TRIUMF muon beam test in 2009.

7.2 TRIUMF test experiment for MPPC radiation hardness

As was shown in the proposal and also discussed in the report to the last PAC meeting, the original plan for the target readout was to use SiMPT (Hamamatsu MPPC) in place of the single PMT readout used in E246. We reported last time the results of simulation calculations of the beam halo which might damage the semiconductor elements after a certain period of experimental running. The total integrated flux including π^+, K^+, μ^+, $e^\pm$, and n was estimated to be $\sim 10^7/\mathrm{mm}^2$ after one year of full beam run under the worst condition. On the other hand we also reported the results of radiation damage studies using a proton beam which showed that an exposure of the MPPC up to 8.0 Gy could be tolerated, corresponding to the time-integrated flux density of $5.4 \times 10^7/\mathrm{mm}^2$, but not higher. Another study using a neutron beam also indicated a similar critical flux density. As we discussed last time, the use of the MPPC is not very crucial for TREK and we suggested an alternative choice of a multi-anode PMT. However, the use of an MPPC is

Figure 11: Polarimeter prototype and full size model production in this fiscal year



still very attractive because it would enable a more compact setup which is quite essential for a high precision experiment. We have decided to pursue the problem further with a more realistic test measurement, namely using a π^+ beam with a similar momentum to the downstream particle flux expected in TREK.

We have been scheduled for 1 week of beam on the TRIUMF low energy pion channel (M13) in early July. This channel will provide a pion flux at 100 MeV/c of about 20 million π^+/sec into a spot size of 15×20 mm^2, which will give us a luminosity of about 130k π^+/sec/mm^2 at the current focus. Hence it will take about 10-20 ksec or 4-5 hours to irradiate 10^8 pions into the MPPC.

7.3 Target R&D at TRIUMF

We will be able to test the scintillating fibre pulse amplitude for minimum ionizing pions ($\sim$100 MeV/c) using the test beam port on the upgraded M13 channel. There is some excess extruded scintillating fibre material which is available at TRIUMF which we might be able to use for our new target. This material has a 1mm round hole in the centre – either from T2K or KOPIO which we can machine down to a 4×4 mm^2 or 3×3 mm^2 size. The FAST experiment chose a 1 mm diameter Bicron 692 fast WLS fibre for their readout as compared to the Kurraray Y11 WLS fibres used for the E246 ring counters. We will test both these WLS fibres and compare them with a conventional clear fibre readout fibre using the same PMT system. We will test both the small $\sim$ 1 mm^2 SiPMT as used by T2K and also the larger 3×3 mm^2 SiPMT (if available) and compare them to a Hamamatsu 16 channel multi-anode PMT (H6568-M16 or H8711-M16).

8 Status of the TREK collaboration

Recently a group from the Tokyo Institute of Technology has joined TREK and the current constituents are listed in Table 5. The number of the members has now increased to 44, not including students. The last collaboration meeting was held at KEK in February 2008, and the next meeting is planned at the University of South Carolina in October 2008.

9 Summary

In this report we emphasize that we have now received partial funding in Japan so that we can begin the preparation/construction of the active muon polarimeter, which is the most essential part of the upgraded detector. We have also been funded in Canada to build the active fiber target. Although the total funding for the whole project is not yet secured, we would like to proceed step by step with the available resources. The stage-2 condition is, however, a definite prerequisite for our colleagues in the US universities to apply for grants this fall. We would like to repeat our request to the PAC once again to recommend stage-2 approval for our TREK experiment, so that we will be able to accelerate the international cooperation in preparing for the experiment, and to facilitate further funding in Japan.

We also report our continued activity in designing the detector and in our MC simulation studies to answer some of the questions raised in the previous meetings. We hope that our progress will be recognized by the committee.

Table 5: TREK collaboration constituents

Canada	University of Saskatchewan University of British Columbia (UBC) TRIUMF University of Montreal
U.S.A.	Massachusetts Institute of Technology (MIT) University of South Carolina Iowas State University Hampton University Jefferson Laboratory
Japan	Osaka University National Defense Academy Tohoku University High Energy Accelerator Research Organization (KEK) Kyoto University Tokyo Institute of technology (TiTech)
Russia	Institute for Nuclear Research (INR)
Vietnam	University of Natural Sciences
Thailand	Kasetsart University

References

[1] "Flavor in the Era of the LHC"; http://mim.home.cern.ch/mim/FlavLHC.html

[2] I. Bigi, talk given in the CERN Flavor Workshop, http://mim.home.cern.ch/mim/FlavLHC.html

[3] M. Kobayashi, T.-T. Lin, and Y. Okada, Prog. Theor. Phys. **95**, 361 (1995).

[4] W.-F. Chang and J.N. Ng, arXiv:hep-ph/0512334 (2005).

[5] C.A. Baker *et al.*, Phys. Rev. Lett. **97** (2006) 131801.

[6] Particle Data Group, "Review of Particle Physics", J.Phys. G: Nucl. Part. Phys. **33** (2006) 1.

[7] P. Koppenburg *et al.* (Belle collaboration), Phys. Rev. Lett. **93** (2006) 061803.

[8] R. Garisto and G. Kane, Phys. Rev. **D44**, 2038 (1991).

[9] K. Ikado *et al.*, (Bell collaboraton), Phys, Rev. Lett. **97** (2006) 251802.

[10] Y. Grossman, Nucl. Phys. **B426** (1994) 355.

[11] Y. Okada, talk given in the J-PARC NP08 International Workshop, (March 2008); http://www-ps.kek.jp/jhf-np/NP08/presentations/kaon/conferenceDisplay.py.html

[12] M.S. Sozzi and I. Mannelli, arxiv:hep-ex/0312015v1 4 Dec 2003.

[13] E. Christova and M. Fabbrichesi, Phys. Lett. **B315** (1993) 113.

[14] M. Fabbrichesi and F. Vissani, Phys. Rev. **D55**, 5334 (1997).

[15] G.-H. Wu and J.N. Ng, Phys. Lett. **B392**, 93 (1997).

[16] H.Dreiner, "An Introduction to Explicit R-Parity Violation" in "Perspectives on Supersymmetry", ed. G.L. Kane (1998).

[17] S.-L. Chen *et al.*. JHEP09 (2007) 044. http://jhep.sissa.it/archive/papers/jhep092007044/jhep092007044.pdf

[18] R, Barbier *et al.*, Phys. Rept **420** (2005) 1; [hep-ph/0406039].

[19] M. Chemtob, Prog. Part. Nucl. Phys. **54** (2005) 71; [arXiv:hep-ph/0406029 2 June 2008].

[20] A. Deandrea *et al.*, JHEP **10** (2004) 038; [arXiv:hep-ph/0407216v2 20 Oct 2004].