New Results and Possibilities in K physics

May 16、2007

FPCP-07, in Bled, Slovenia

Takao Inagaki (KEK)

We will have an international meeting next week

KAON07

KAON'07

Laboratori Nazionali di Frascati dell'INFN

May 21 - 25, 2007

Home | Program | Bulletin | Speakers | Registration | Travel | Lodging | Participants | LOC | IAC | Events | Important dates | Proceedings

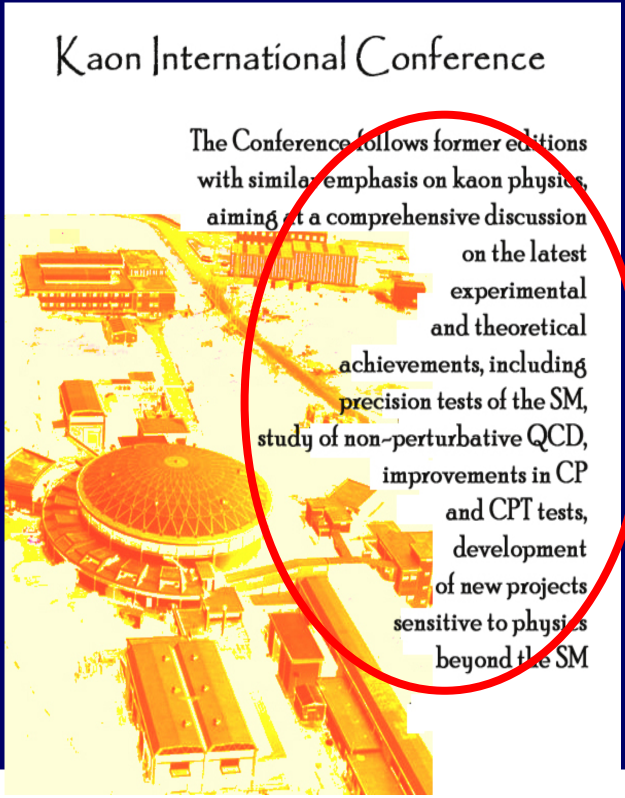
KAON'07 will be held at the
Frascati National Laboratories of INFN, Italy,
May 21-25, 2007.
It is organized in plenary
sessions including invited talks
and a selection of submitted contributions.
The deadline for abstract submission is March 25, 2007.

For any information, contact
kaon07@lnf.infn.it.

In addition to the scientific sessions,
we are planning to reserve
the afternoon of Wednesday for
the conference excursion and the
evening of Thursday for the
banquet.

KAON'07 is supported by INFN, the
University of Rome "La Sapienza"
and the University of "Roma Tre".

Previous editions: Kaon 99, Kaon 01, Kaon 05



http://www.lnf.infn.it/conference/kaon07/ (1/3)2007/05/06 14:45:43

Contents of this report

picked up from KAON agenda

- *CKM unitarity checked through Vus*
- μ *- e universality measured in K,* $\pi \rightarrow l \nu$
- *Search of other CPV*
- *New facilities*
- *Status of* $K \rightarrow \pi \nu \nu$ *experiments*

Vus

Determination with a sub-% level

Precise determination of Vus starts from two motivations

- λ =Vus is a critical ingredient in determinations of the other CKM parameters.

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

$$= \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \mathcal{O}(\lambda^4)$$

- Unitarity check: 2.2 σ below unity (PDG 2004)

$$1 - (|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2) = (3.30 \pm 1.50) \times 10^{-3}$$

E. Blucher et al., hep-ph/0512039

Theoretical efforts

Equation for Kl3 decay width

$$\Gamma_{K\ell 3} = \frac{G_F^2 M_K^5}{192\pi^3} S_{EW} (1 + \delta_K^\ell + \delta_{SU2}) C^2 \left|V_{us}\right|^2 f_+^2(0) I_K^\ell$$

Inputs from experiment, inputs from theory

S_{EW} and δ_K: Short and long distance Radiative corrections

δ_{SU2}: correction factor for charged K (0 for neutral)

C^2: Clebsh-Gordan (1 for neutral, 1/2 for charged K)

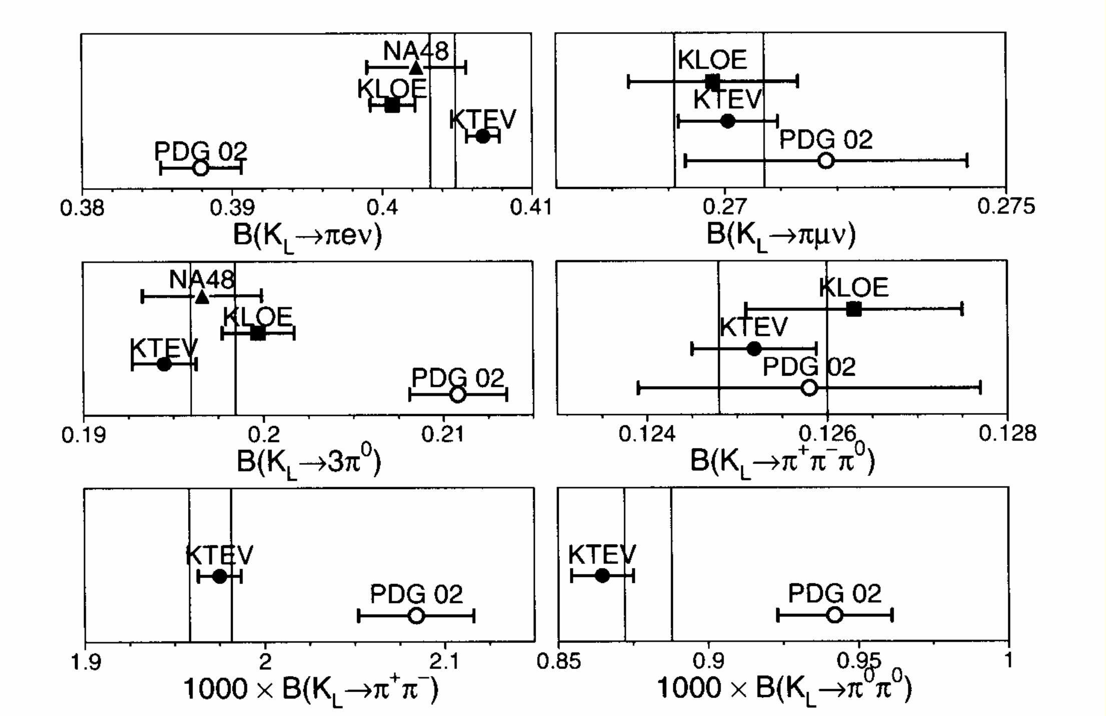
$f_+^2(0)$: form factor at zero momentum transfer

I_K: phase space integral (determined by slope of form factor)

$K\mu 3$ is more complicate than Ke3 in I_K correction, Kl2, hyperon decays have other equations with different parameters

Experimental efforts

- KTeV, KLOE, NA48 and ISTRA measured all of Kl3 decay widths together with their form factors for K_L and K^+, and KLOE measured total width and K_Se3 and K μ 2 decay widths.



Example, KL decays

Most of decay widths greatly changed.

KTeV suggests changes come from previous inadequate treatment of inner bremstralung,

Vud, which is the other ingredient for the unitarity, was also improved.

- Determined by super allowed nine beta decays of $0^+ \to 0^+$ Fermi transition.

Nucleus	ft (sec)	V_{ud}
^{10}C	3039.5(47)	0.97381(77)(15)(19)
^{14}O	3043.3(19)	0.97368(39)(15)(19)
^{26}Al	3036.8(11)	0.97406(23)(15)(19)
^{34}Cl	3050.0(12)	0.97412(26)(15)(19)
^{38}K	3051.1(10)	0.97404(26)(15)(19)
^{42}Sc	3046.8(12)	0.97330(32)(15)(19)
^{46}V	3050.7(12)	0.97280(34)(15)(19)
^{50}Mn	3045.8(16)	0.97367(41)(15)(19)
^{54}Co	3048.4(11)	0.97373(40)(15)(19)
weighted ave.		0.97377(11)(15)(19)

0.97377 ± 0.00027

***The error was improved by a factor of 2 from 0.9740(5) at 2004*.**

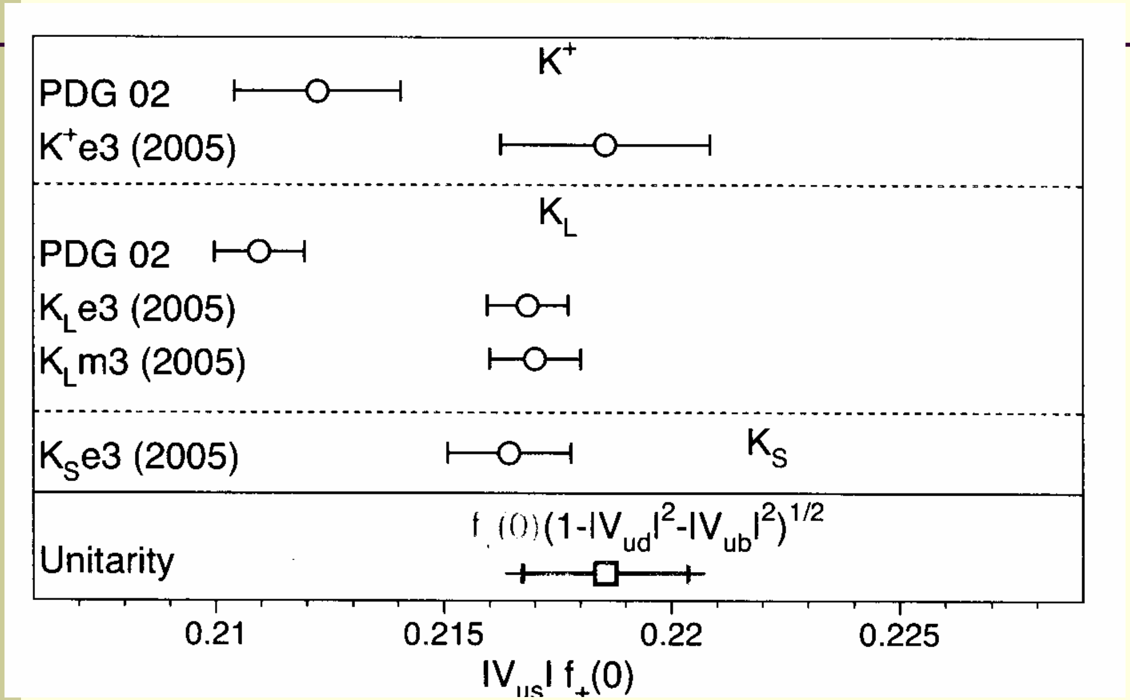
Due to global studies of nine transitions,

and reduction of error for radiative correction from quantum loop effect (3rd error) .

Neutron and pion beta decays are considered to be better in theoretical error, but they are limited by experimental errors.

⇒ room for new experiments

Vus value and unitality



|Vus| from other channels

0.2226 + 0.0026 -0.0014
from $K_{\mu 2}/\pi_{\mu 2}$

0.226 ± 0.005
from Hyperon decays

0.2225 ± 0.0034
from τ decay

|Vus| = λ = 0.2261±0.0021 for $f_+(0)$=0.961±0.008

0.2244±0.0013 0.961±0.005 ; Moriond 07

(Lacker's talk Monday)

Now, the value of |Vus| is obtained in less than 1% accuracy with maintaining unitality.

Influence, Wave ring spread or Stimulation

- ***τ decay***: $$R_\tau \equiv \frac{\Gamma[\tau^- \to \mathrm{hadrons}(\gamma)]}{\Gamma[\tau^- \to e^- \overline{\nu}_e \nu_\tau(\gamma)]},$$

  Dominant uncertainty for Vus (and Vud) determination is ms. ⇒ nice channel for ms determination.
- Unitarity check of ***the second row*** (Vcd, Vcs and Vcb)
- ***Neutron life time*** measurement

  It must be the best for Vud later, and it relates with the Big Bang nucleo-sythesis scenario.
- Various ***theoretical works***

Together with the necessarily checked issues:

Q-values of super-allowed beta decays, g_A/g_V, f_K and f_K/f_π, etc.

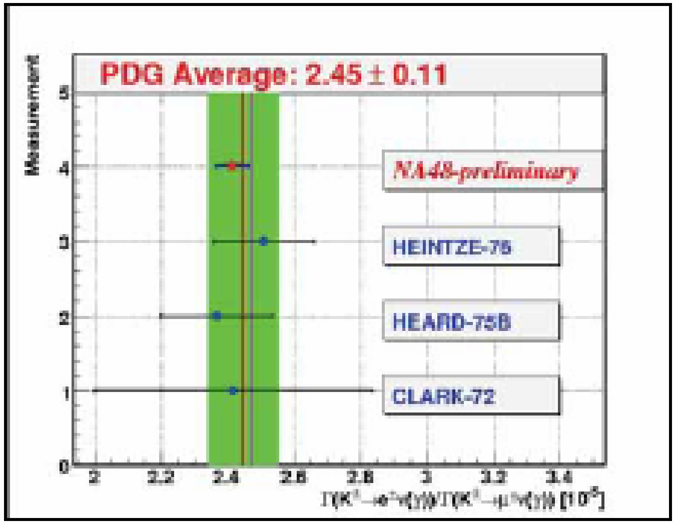
μ - e universality

NA48/2 $K_{e2}/K_{\mu2}$ in 2003

Selected events:
5329 Ke2 candidates (~14% BG mainly from Kμ2)
619179 Kμ2 (with negligible background)

Main background source high energy muon Bremsstrhalung in the LKr calorimeter

Analysis of 2004 data in ongoing ...



Preliminary 2003

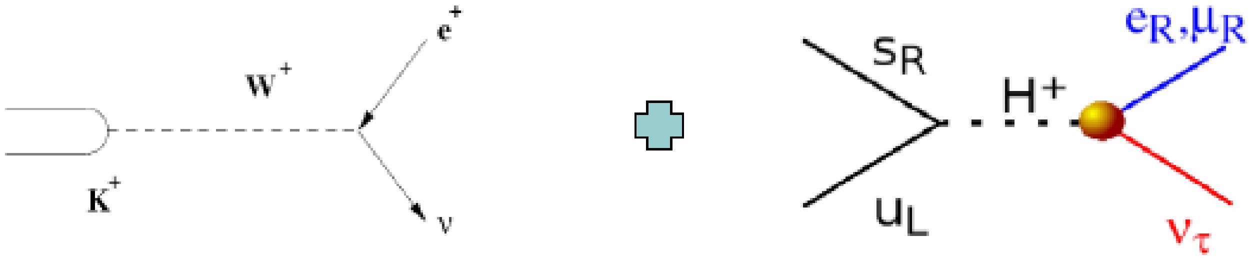
$R_K=(2.416\pm0.043_{stat}\pm0.024_{sys})\cdot10^{-5}$

2% tot err

Dedicated 2007 run:

- Statistical error <0.7%
- Direct measurement of muon Bremsstrahlung spectrum in data
- Final result total error <1%

SUSY LFV mechanism $K_{e2}/K_{\mu 2}$



$$R_K^{LFV} = \frac{\sum_i K \to e\nu_i}{\sum_i K \to \mu\nu_i} \simeq \frac{\Gamma_{SM}(K \to e\nu_e) + \Gamma(K \to e\nu_\tau)}{\Gamma_{SM}(K \to \mu\nu_\mu)} \ , \quad i = e, \mu, \tau$$

If tanβ=40 and M_{H+}=500 GeV with $|\Delta_R^{31}|^2$= $5 \cdot 10^{-4}$

⇓

$$\Delta r_{K\ SUSY}^{e-\mu} \simeq \left(\frac{m_K^4}{M_{H^\pm}^4}\right)\left(\frac{m_\tau^2}{m_e^2}\right)|\Delta_R^{31}|^2 \tan^6\beta \approx 10^{-2}$$

A. Masiero: CERN TH seminar

The effect can be as high as 2% and therefore measurable

PR D74 (2006) 011701 (A. Masiero et al.)

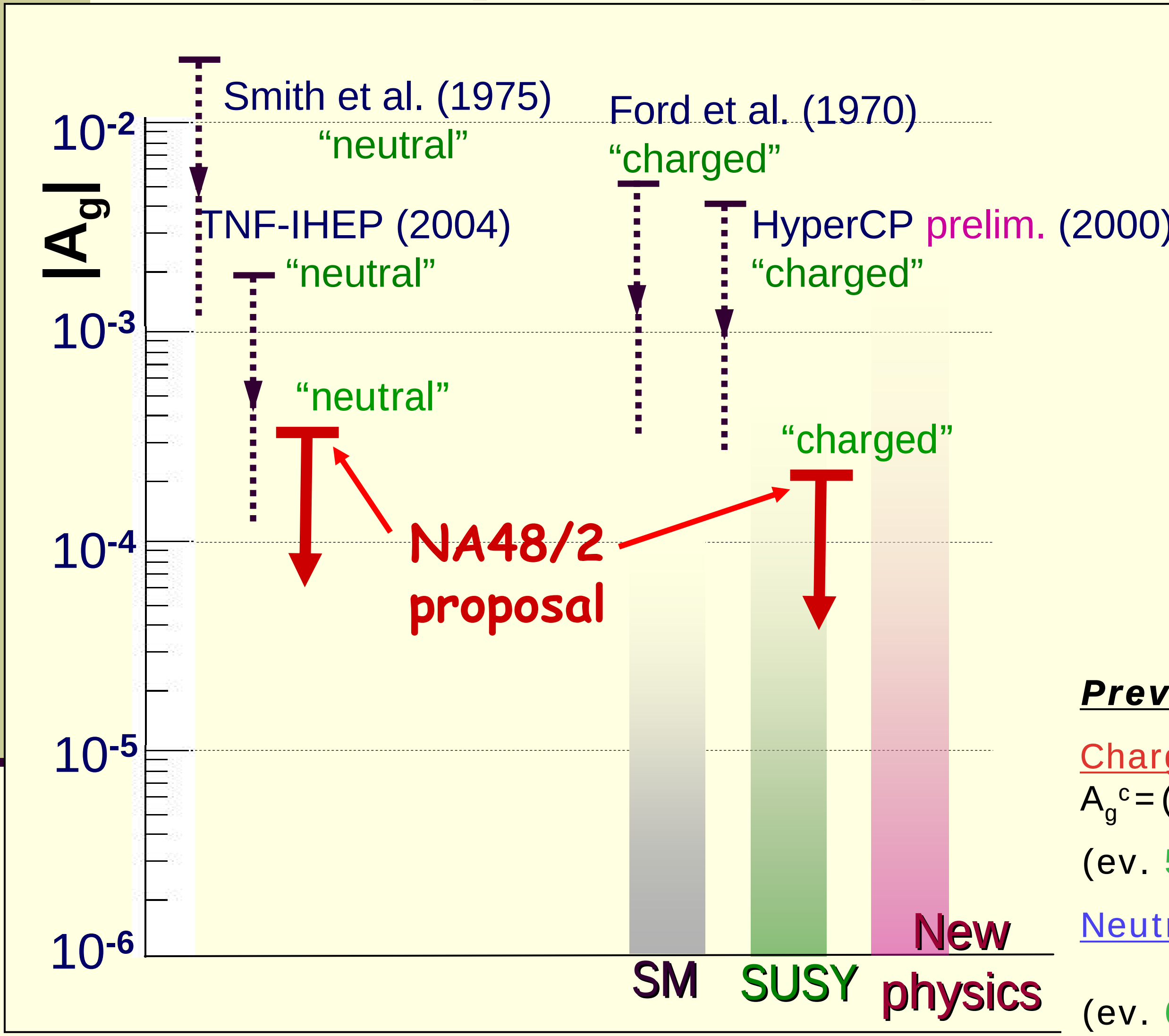
Mauro Raggi — XLII[nd] Rencontres de MORIOND EW — 16

PIENU experiment at TRIUMF plans to improve $\pi \to e\nu / \pi \to \mu\nu$

by a factor of 5 from $(1.231 \pm 0.004) \times 10^{-4}$;   < 0.1 % accuracy.

Search of other CPV

Theoretical prediction and experimental results



- **SM theoretical prediction in the range 10^{-6} - $5 \cdot 10^{-5}$**
- **Models beyond the SM predict enhancement of the A_g value**

Previous results:

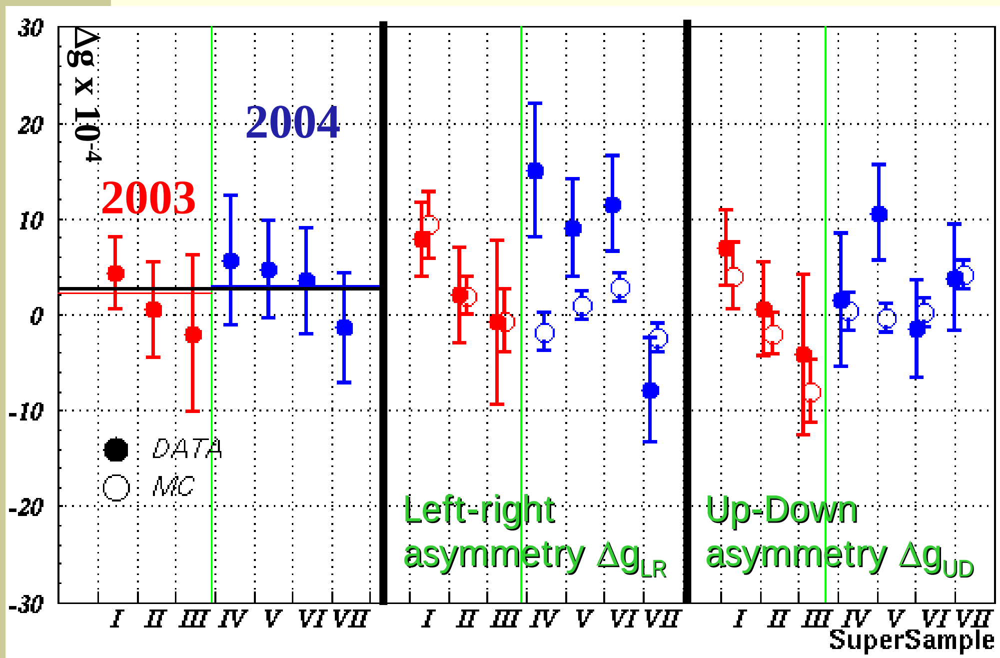
Charged mode:
$A_g^c = (22 \pm 15 \pm 37) \cdot 10^{-4}$

(ev. $54 \cdot 10^6$)

Neutral mode: $A_g^n = (2 \pm 19) \cdot 10^{-4}$

(ev. $620 \cdot 10^3$)

$K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\pi^{0}$: Results



Systematics effect		Δg x10^{-4}
LKr related	U resolution & fitting	±0.2
	LKr non-linearity	±0.1
	Showers overlapping	±0.5
Pion decay		±0.2
Spectrometer alignment & momentum scale		±0.1
Pile-up		±0.2
Trigger	L1: charged signal	±0.1
	L1: neutral signal	±0.8
	L2: MassBox	±0.6
Total		±1.2
External		±0.3

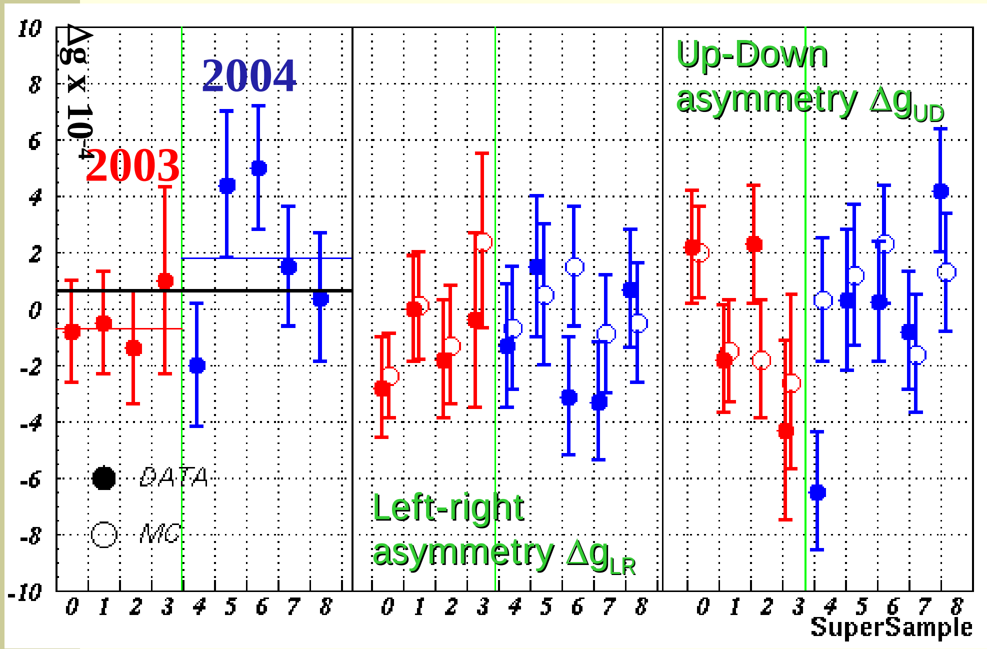
Slope difference (03+04 prelim. result):

$\Delta g = (2.7 \pm 2.0_{stat.} \pm 1.2_{syst} \pm 0.3_{ext.})\text{x}10^{-4}$

Charge asymmetry parameter (03+04 prelim. result):

$A_g^0 = (2.1 \pm 1.6_{stat.} \pm 1.0_{syst} \pm 0.2_{ext})\text{x}10^{-4} = (2.1 \pm 1.9)\text{x}10^{-4}$

$K^{\pm} \rightarrow \pi^{\pm}\pi^{+}\pi^{-}$: Results



Systematics effect		$\Delta g \times 10^{-4}$
DCH & beam related	Spectrometer alignment	±0.1
	Momentum scale	±0.1
	Acceptance and beam geometry	±0.2
Pion decay		±0.4
Pile up		±0.2
Resolution effects		±0.3
Trigger	L1: CHOD signal	±0.3
	L2: MassBox	±0.3
Total		±0.7

Slope difference (03+04 prelim. result):

$\Delta g = (0.6 \pm 0.7_{stat.} \pm 0.7_{syst})\times 10^{-4}$

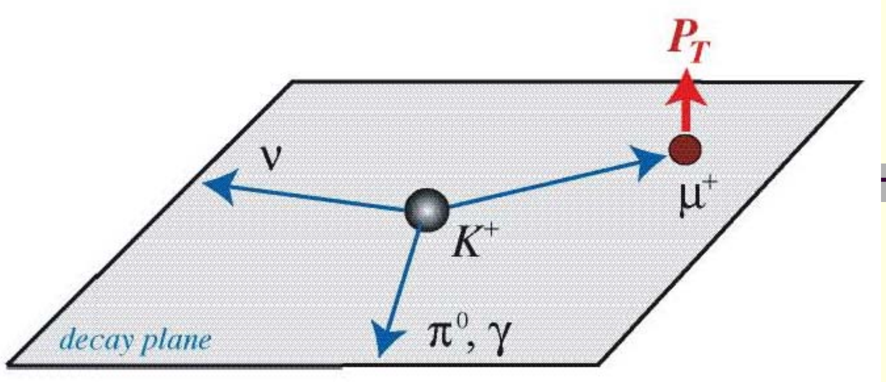
Charge asymmetry parameter (03+04 prelim. result):

$A_g^c = (-1.3 \pm 1.5_{stat.} \pm 1.7_{syst})\times 10^{-4} = (-1.3 \pm 2.3)\times 10^{-4}$

Transverse muon polarization

$K^+ \rightarrow \pi^0 \mu^+ \nu$ decay

$$P_T = \frac{\sigma_\mu \cdot (p_{\pi^0,\gamma} \times p_{\mu^+})}{|(p_{\pi^0,\gamma} \times p_{\mu^+})|}$$



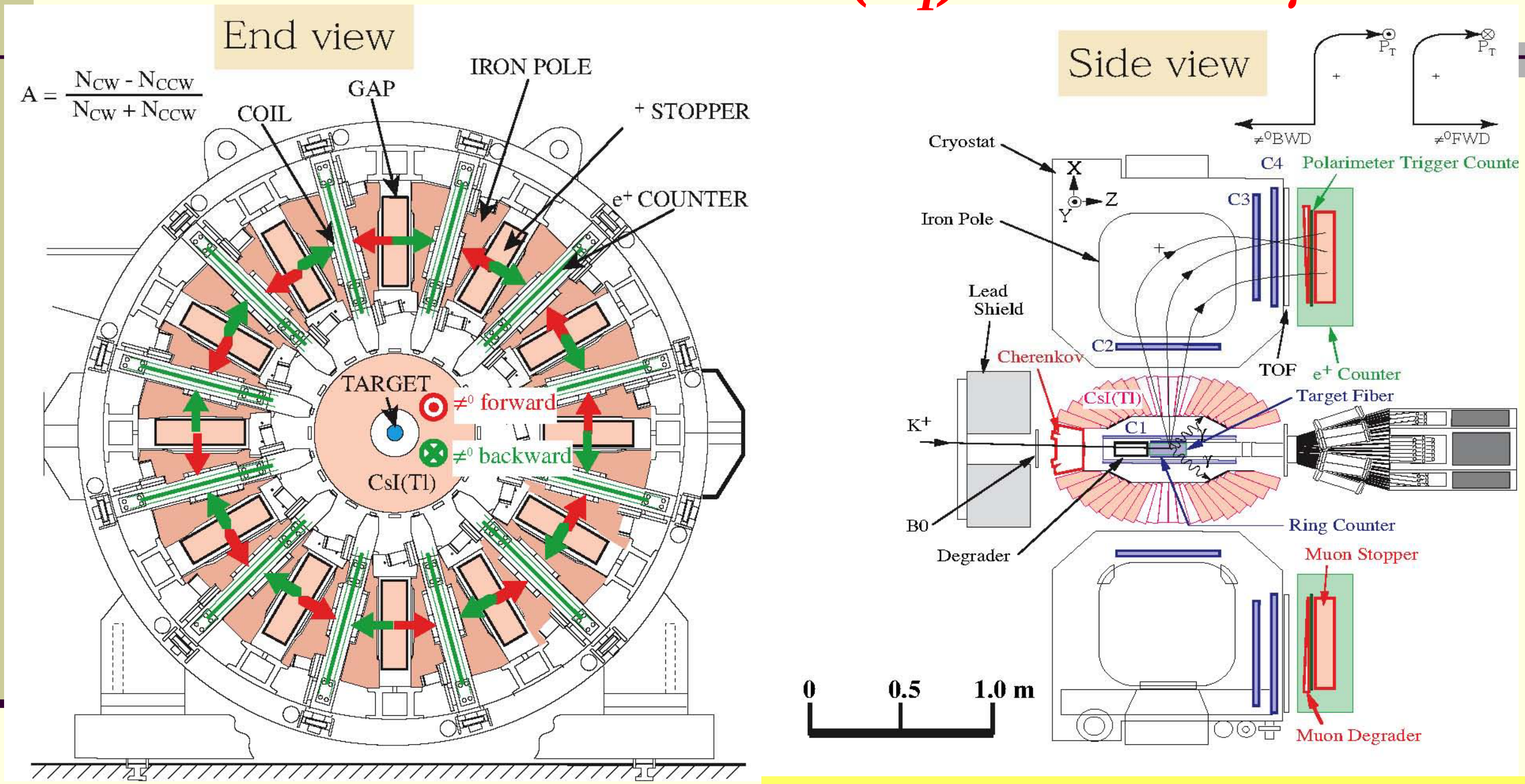
- P_T is T-odd and spurious effects from final state interaction are small.
  Non-zero P_T is a signature of T violation.
- Very clear channel to search for T violation. Long history of theoretical and experimental studies. (J.J. Sakurai, 1957)
- Powerful tool to study CP violation due to CTP theorem
- Standard Model contribution to P_T : $P_T(SM) < 10^{-7}$
- Effects from final state interactions (FSI): $P_T(FSI) < 10^{-5}$
- There is a large window for new physics in the region of

  $$P_T = 10^{-3} \sim 10^{-5}$$

- There are theoretical models which allow sizeable P_T without conflicting with other experimental constraints.

KEK-PS E246 experiment

Transverse Muon Polarization (P_T) in $K^+ \rightarrow \pi^0 \mu^+ \nu$ Decays



- Stopped K^+ decay
- SC toroidal spectrometer
- Measurement of e^+ emission *cw/ccw* asymmetry when π^0 in *fwd/bwd* directions

P_T = - 0.0017 ± 0.0023(*stat*) ± 0.0011(*syst*)
($|P_T|$ < 0.0050 : 90% *C.L.*)
Imξ = - 0.0053 ± 0.0071(*stat*) ± 0.0036(*syst*)
(|Imξ| <0.016 : 90% *C.L.*)

Phys. Rev. D73, 072005 (2006)

J-PARC E06 (TREK) experiment

Upgrade of the E246 detector, and adoption of active polarimeter

Statistical sensitivity

Standard analysis

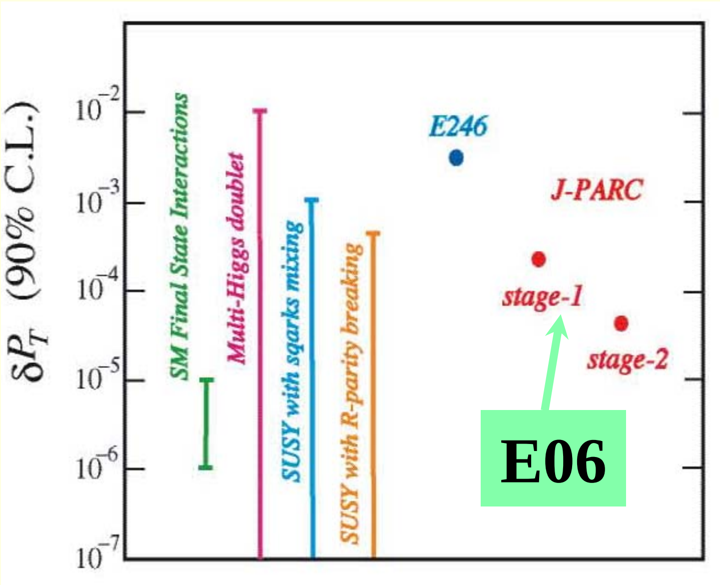
- Net run time 1.0 $\times 10^7$ s
  - 1/1.7 of E246
- Proton beam intensity 9μA on T1
- K^+ beam intensity 3×10^6 /s
  - ~30 times of E246
- Total number of good $K_{\mu 3}$ 2.4×10^9
  - Detector acceptance : ~8 times of E246
- Total number of *fwd/bwd* (*N*) 7.2×10^8
- Sensitivity coefficient $3.73 / \sqrt{N}$
  - Analyzing power : ~1.5 times of E246
- δP_T 1.35×10^{-4}

Including left/right regions

- δP_T 0.8×10^{-4}
  (*A careful systematic error study is necessary*)

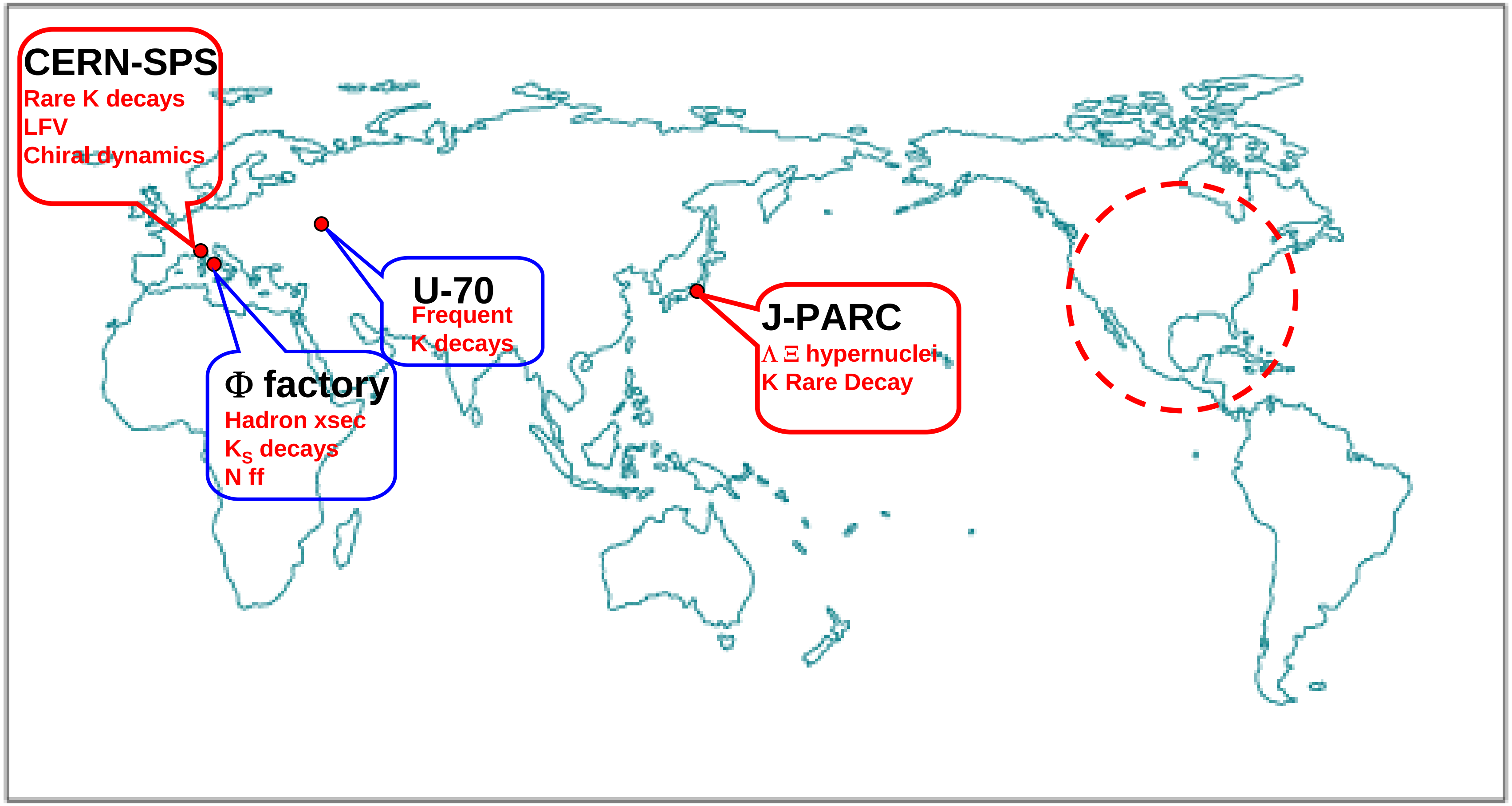
Systematic errors

Source		δP_T
δ_z	(field alignment)	$< 10^{-4}$
θ_z	(kinetic distortion)	$< 10^{-4}$
θ_e, E_e	(e^+ measurement)	$< 10^{-4}$
Total δP_T		$\sim 10^{-4}$

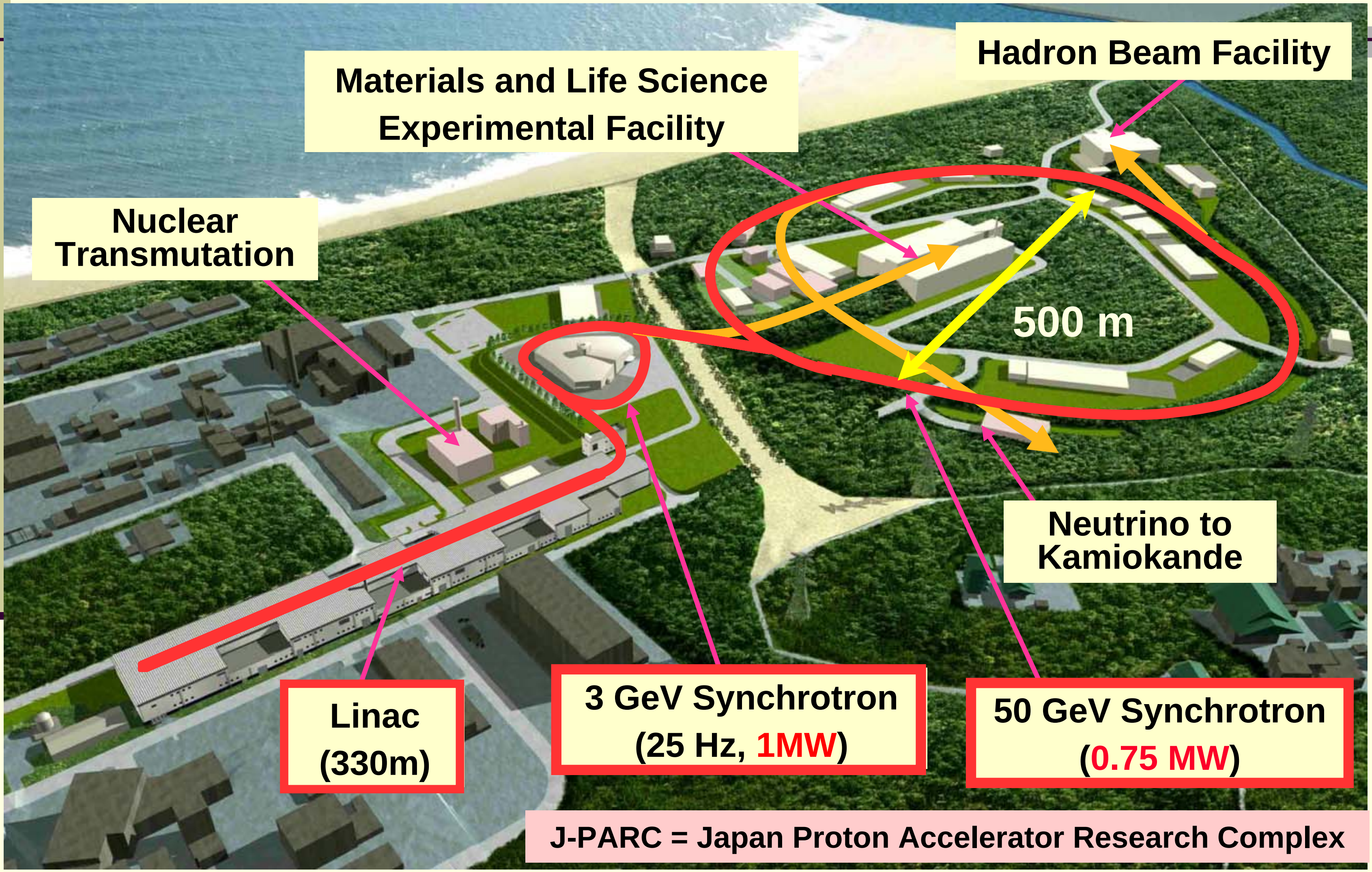


Kaon Facilities

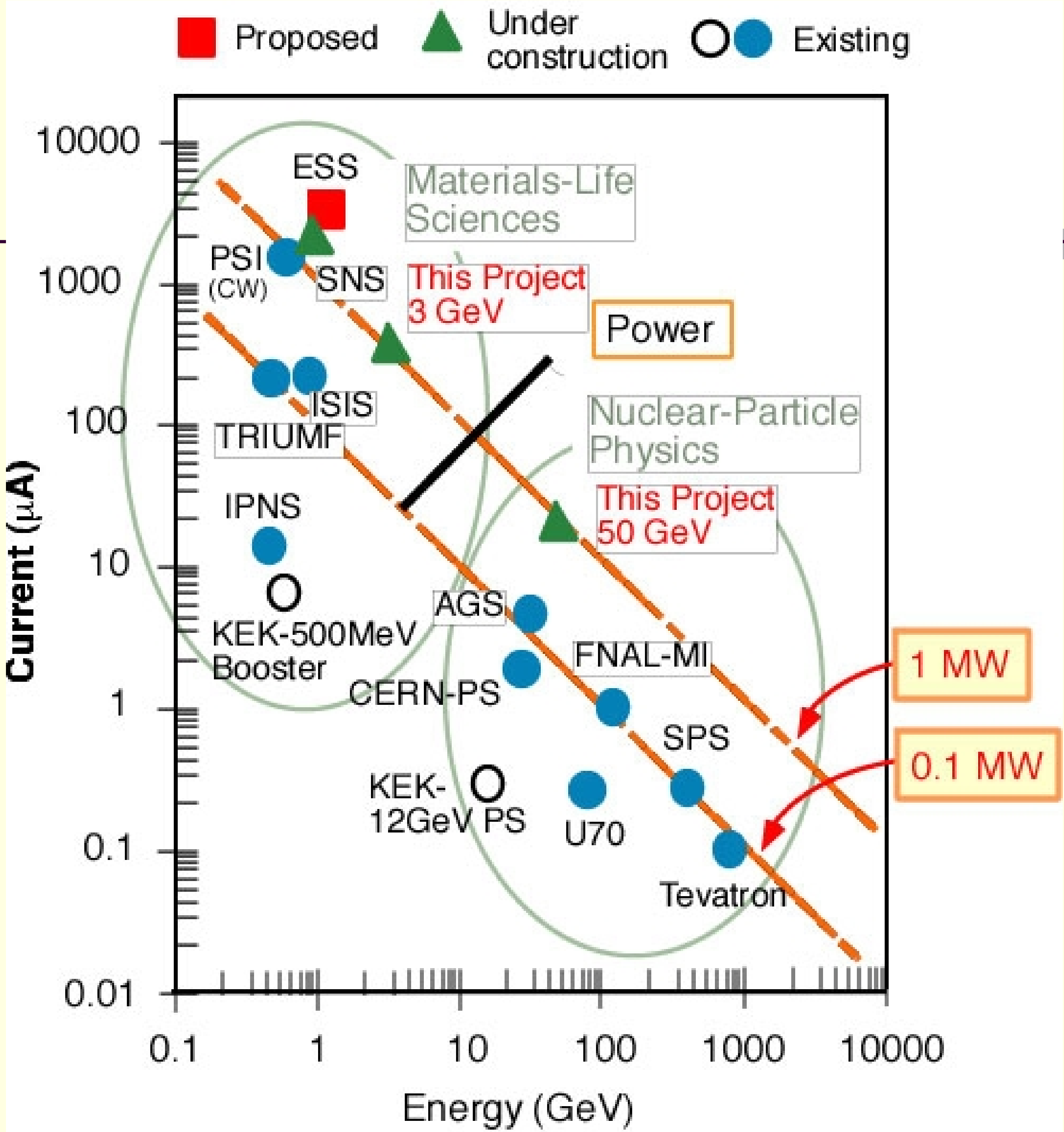
After many activities were cancelled in USA



J-PARC Facility

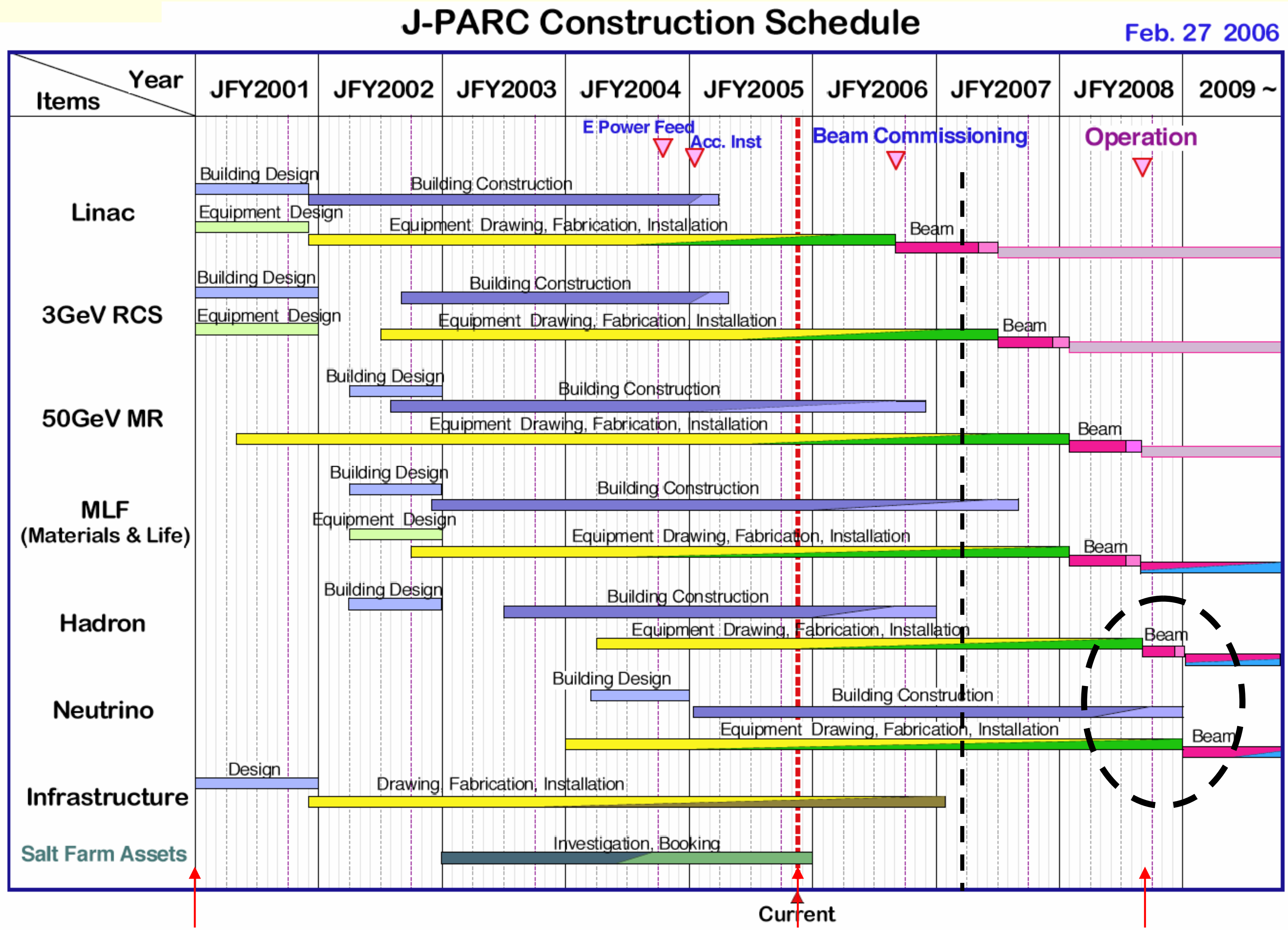


Joint Project between KEK and JAEA



Proposed
Under construction
Existing
ESS
Materials-Life Sciences
PSI (CW)
SNS
This Project 3 GeV
Power
ISIS
TRIUMF
Nuclear-Particle Physics
IPNS
This Project 50 GeV
KEK-500MeV Booster
AGS
FNAL-MI
CERN-PS
1 MW
SPS
0.1 MW
KEK-12GeV PS
U70
Tevatron
Current (μA)
Energy (GeV)
10000
1000
100
10
1
0.1
0.01
0.1
1
10
100
1000
10000


Hadron Experimental Hall
Materials & Life Experimental Hall
50 GeV Synchrotron
Neutrino Experimental Area
3 GeV Synchrotron
ADS Area
Linac
November, 2006



Construction Start

IAC Last Year

Facility Operation

$K \to \pi\ \nu\ \nu$ experiments

, which are interesting but challenging channels

- Two plans + one plan

  P326 at CERN-SPS for $K^+ \to \pi^+ \nu\ \nu$

  E391a at KEK-PS and E14 at JPARC-PS for $K_L^0 \to \pi^o \nu\ \nu$

  + at U-70 for $K_L^0 \to \pi^o \nu\ \nu$

- Two plans have similarities

  History: Surviving after cancellations of US competitors

  E949 at BNL and CKM at Fermilab for $K^+ \to \pi^+ \nu\ \nu$

  KOPIO at BNL and KAMI at Fermilab for $K_L^0 \to \pi^o \nu\ \nu$

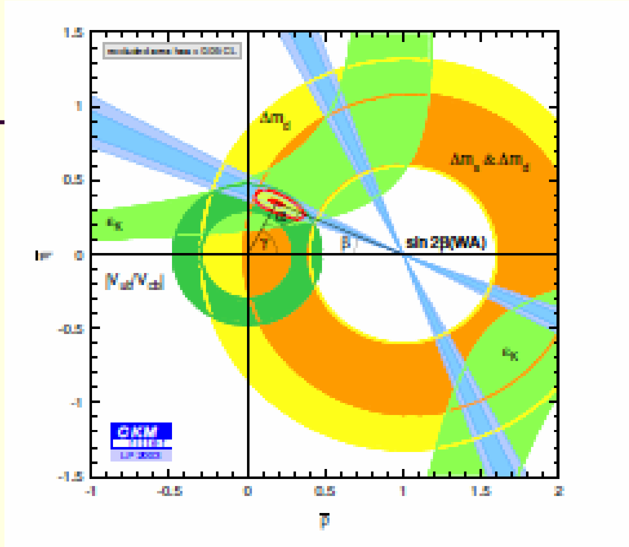
  Strategy: Utilizing recycles and experiences

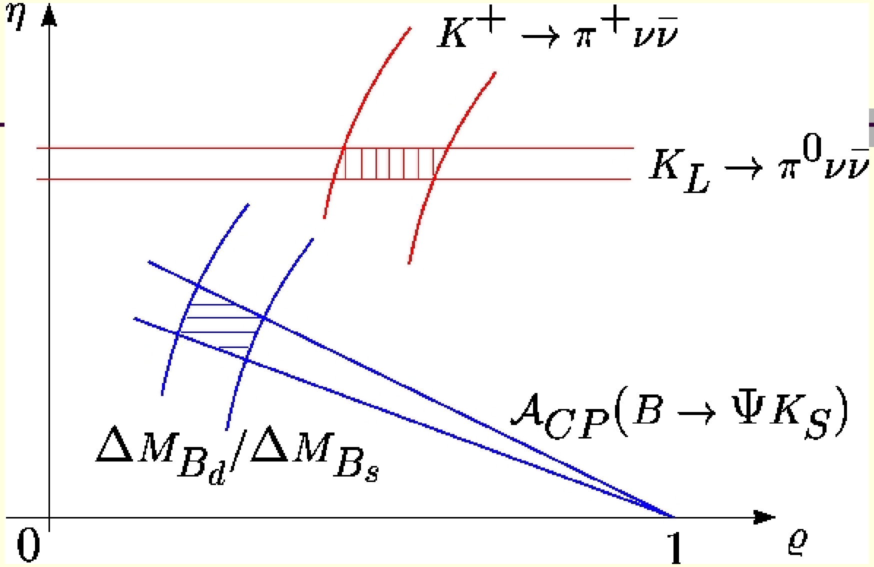
  P326 is a successor of NA48 called as NA48-3

  Step-by-step approach from E391a to E14

  The goal of both experiment is an observation of about 100 SM-events

Physics background





B has determined CKM very well

Precise predictions + small theoretical uncertainties

SM prediction	Buras et al hep-ph/0405132	accuracy	theoretical uncertainties
$K^+ \to \pi^+ \nu\bar{\nu}$	$(7.8 \pm 1.2) \times 10^{-11}$	±15%	±7%
$K_L^0 \to \pi^0 \nu\bar{\nu}$	$(3.0 \pm 0.6) \times 10^{-11}$	±20%	1-2%

Prospect of new physics,

in the case of $K_L \rightarrow \pi^o \nu\nu$ decay

How deeply can we seek for new physics?

<$3X10^{-13}$ ⇒ **>100 SM-events** ⇒ **>5σ for 1.75 X SM**

For $K_L \rightarrow \pi^o\nu\nu$, $|1+(M_W/\Lambda)^2/(A^2\lambda^5/(16\pi^2))|^2 \sim 1+r$

For $B \rightarrow X_S \mu^+\mu^-$ $B_S \rightarrow \mu^+\mu^-$, $|1+(M_W/\Lambda)^2/(A\lambda^2/(16\pi^2))|^2 \sim 1+r$

where Λ is energy scale.

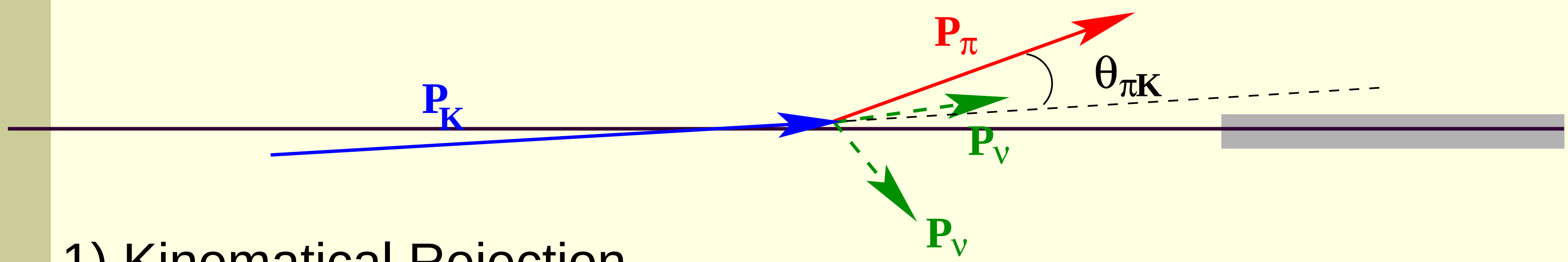
r=0.75 ⇒

Λ ($K_L \rightarrow \pi^o\nu\nu$) ~ 100 TeV,

Λ ($B \rightarrow X_S \mu^+\mu^-$ $B_S \rightarrow \mu^+\mu^-$) ~ 10 TeV

$K_L \rightarrow \pi^o\nu\nu$ decay is ideally perfect FCNC process, which Grinstein recommended in the Sunday's session.

Method to detect $K^+ \to \pi^+ \nu\nu$ decay



1) Kinematical Rejection

$$m^2_{miss} \approx m^2_K\left(1-\frac{|P_\pi|}{|P_K|}\right)+m^2_\pi\left(1-\frac{|P_K|}{|P_\pi|}\right)-|P_K||P_\pi|\vartheta^2_{\pi K}$$

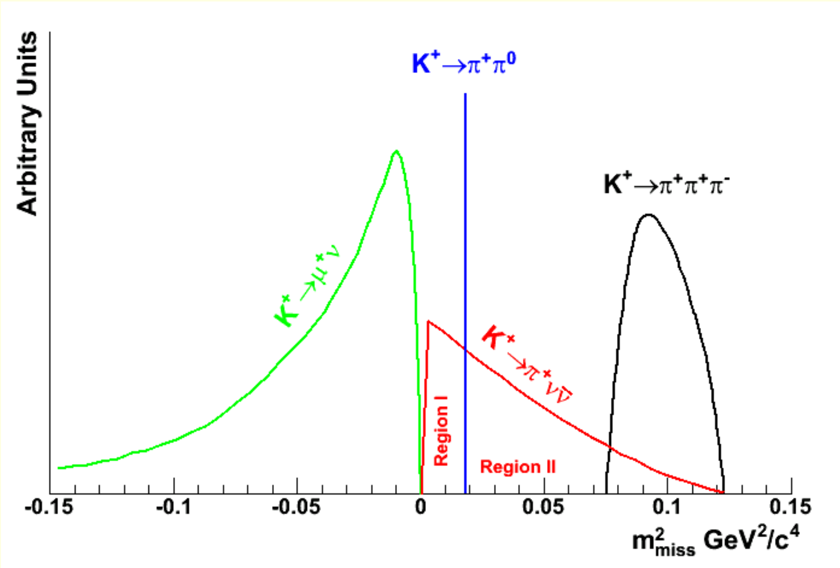
2) Photon vetoes to

reject $K^+\to\pi^+\pi^0$:

P(K^+) = 75 GeV/c

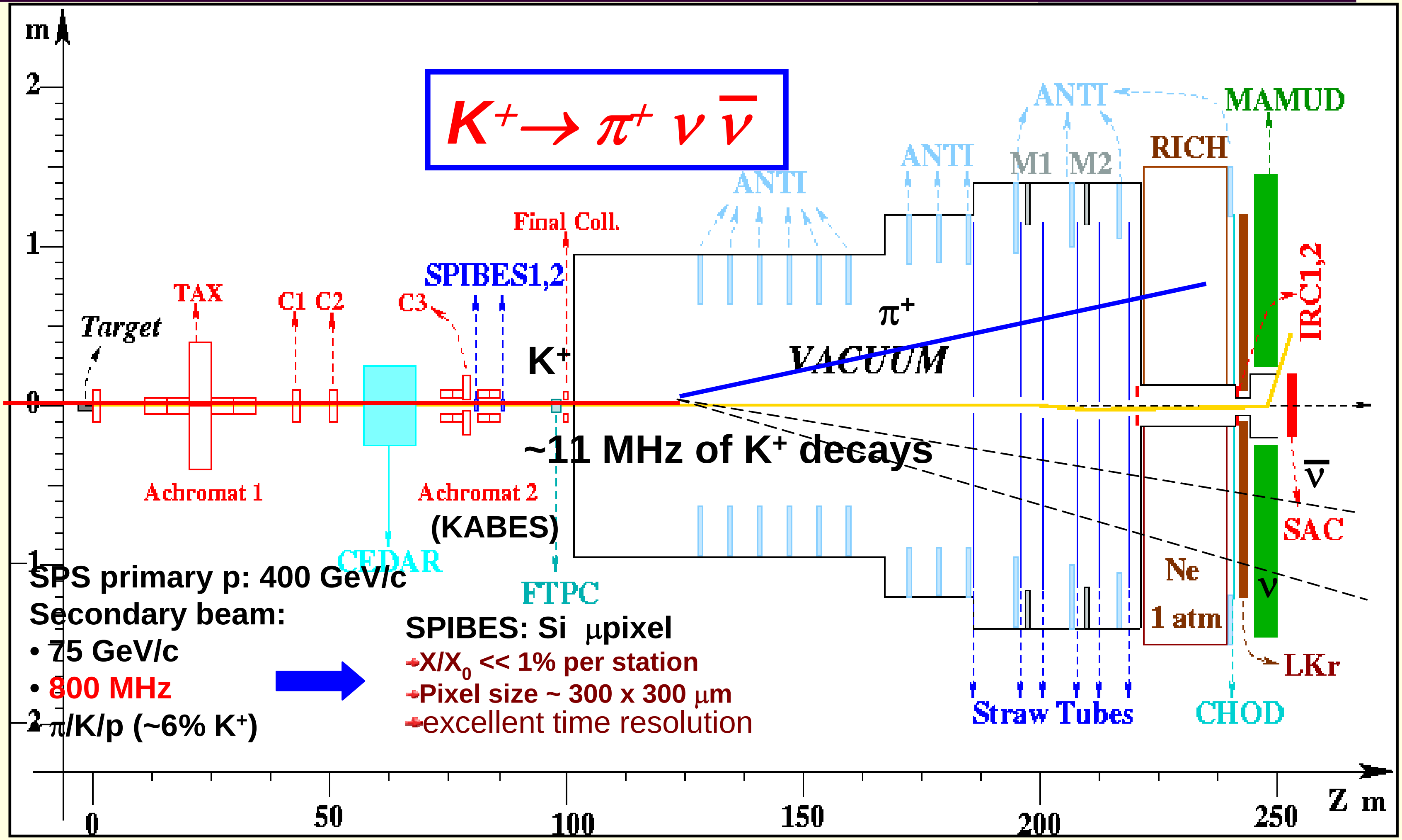
Requiring P(π^+) < 35 GeV/c

P(π^0) > 40 GeV/c It can be hardly missed in the calorimeters!!



3) PID (RICH) for $K^+\to\mu^+\nu$ rejection

P-326 Detector Layout



Signal and background rejection

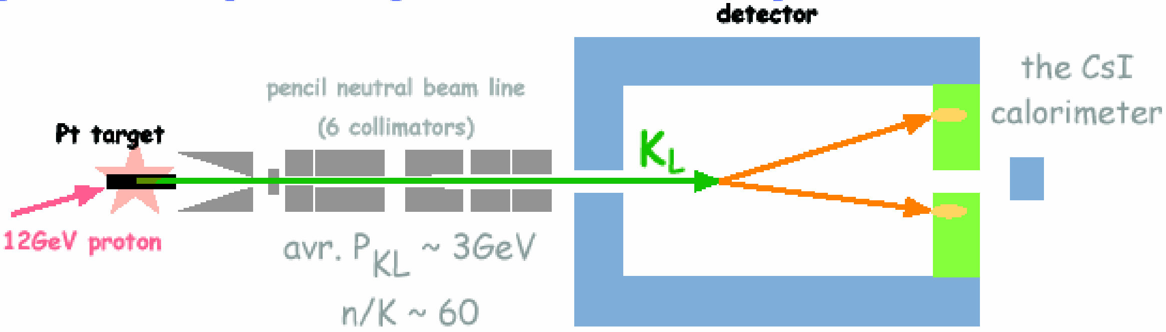
Events/year	Total	Region I	Region II
Signal *(acc=17%)*	65	16	49
$K^+\to\pi^+\pi^0$	2.7	1.7	1.0
$K^+\to\mu^+\nu$	1.2	1.1	<0.1
$K^+\to e^+\pi^+\pi^-\nu$	~2	negligible	~2
Other 3 – track decays	~1	negligible	~1
$K^+\to\pi^+\pi^0\gamma$	1.3	negligible	1.3
$K^+\to\mu^+\nu\gamma$	0.5	0.2	0.2
$K^+\to e^+(\mu^+)\ \pi^0\nu$, others	negligible	–	–
Total bckg.	9	3.0	6

➧ S/B ~ 8 (Region I ~5, Region II ~9)

Full five months run in 2007 for prototype-test and μ-e universality

Method to detect $K_L \rightarrow \pi^o \nu \bar{\nu}$

- ***detect 2g from pi0 decay + require no other particles***



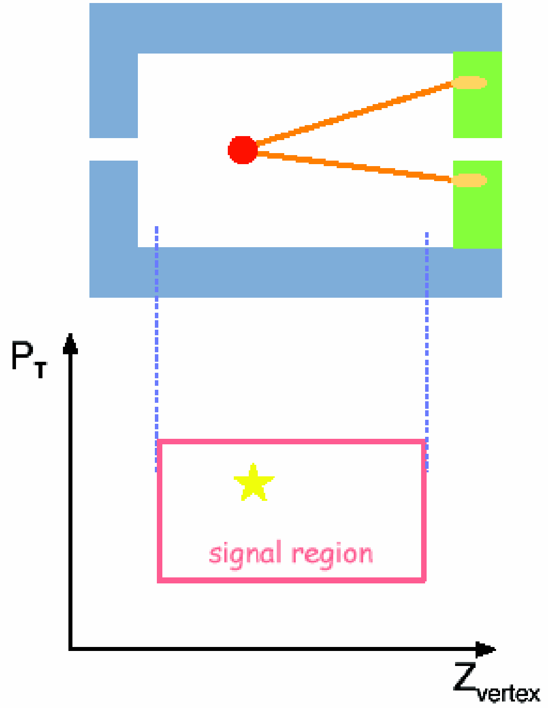
(1) measure gamma hit position and energy

↓

(2) reconstruct decay vertex asuuming M_{2g}=M_{pi0} **(along the beam axis)**

↓

(3) require missing Pt and decay vertex in the fiducial region

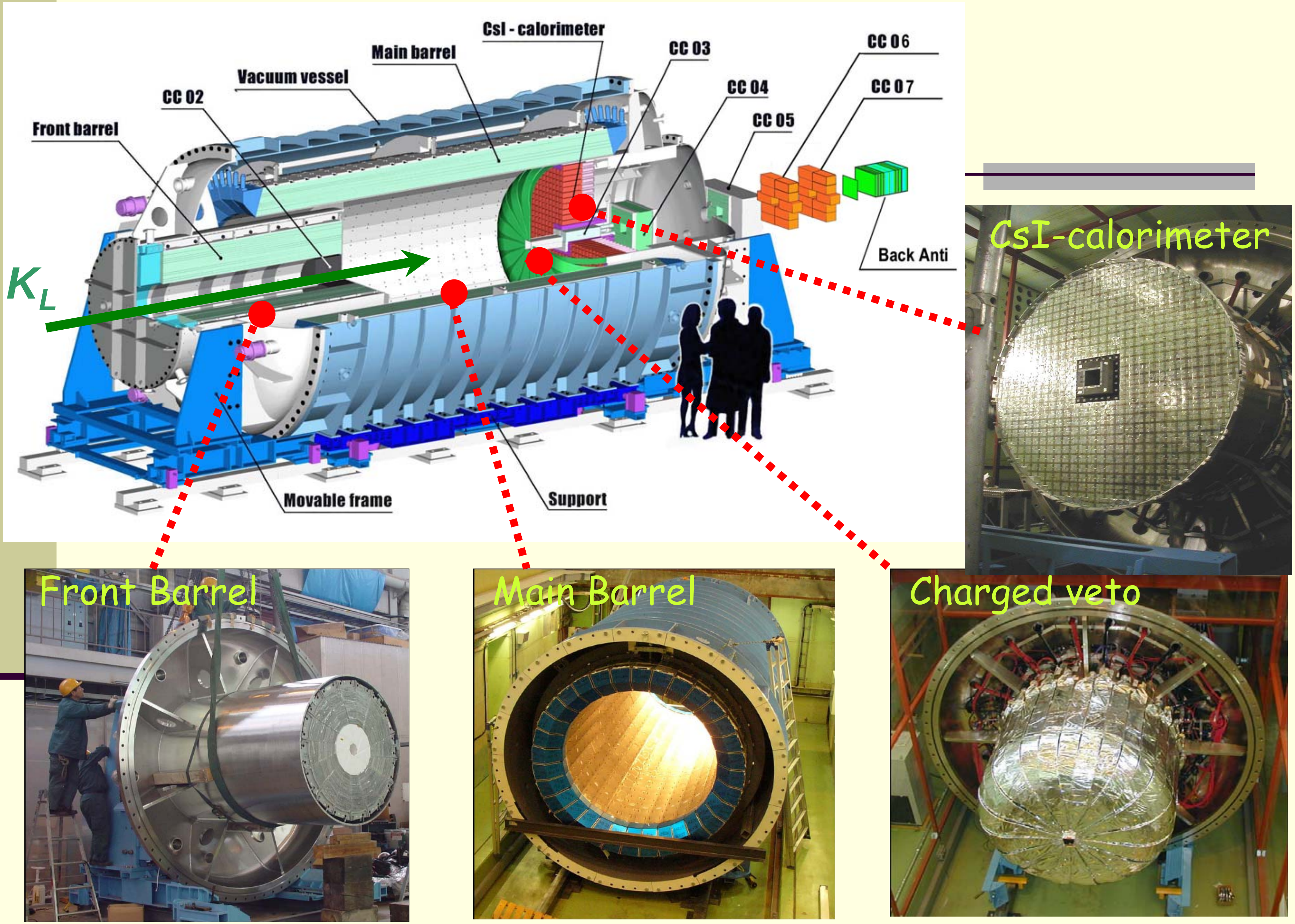


Extremely challenging

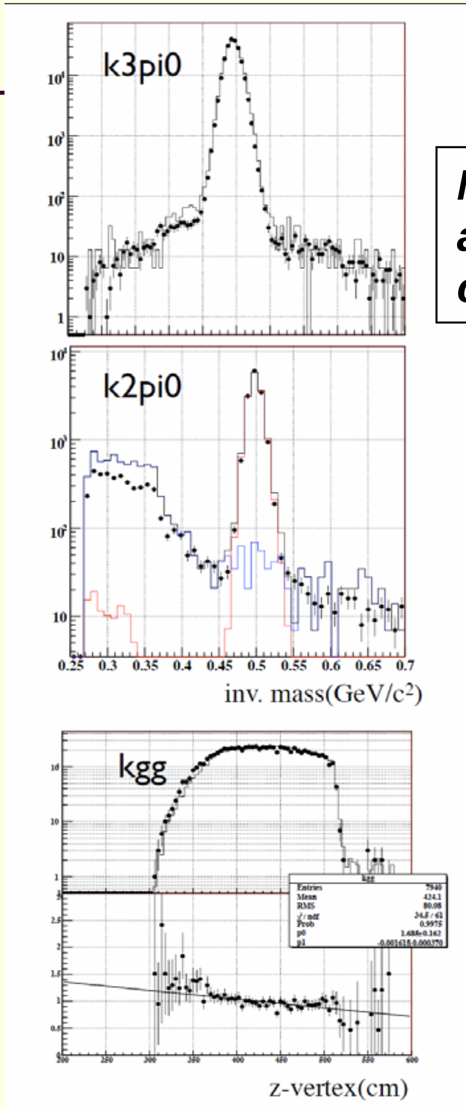
- Very rare decay (10^{-11})
  ⇒**Many complicate sources of background**
- Three body decay of all neutrals with two neutrinos
  ⇒**No distinct signature**
- n/KL～60 (～10 at E14)
  ⇒**KL decays +Another source of backgrounds**

- **Pencil beam (halo/core～10^{-5})**
- **Differential Pumping (10^{-5} Pa with little material in front of the detectors)**
- **Tight veto (down to 1 MeV)**
- **Several R&D**
  - Six stages of collimation with a GdO_2 section
  - Double decay chambers
  - Calibration in situ using cosmic muons and gammas from Al-target and $K\pi 3$
  - Temperature stability for CsI within 0.1℃
  - Techniques of wlsf readout, new scintillator (MS resin) and new PMT(EGP)
  - Fabrication, assembling and installation of large detectors
  - Reproduction of spectra down to sub-MeV energy-deposit by simulation

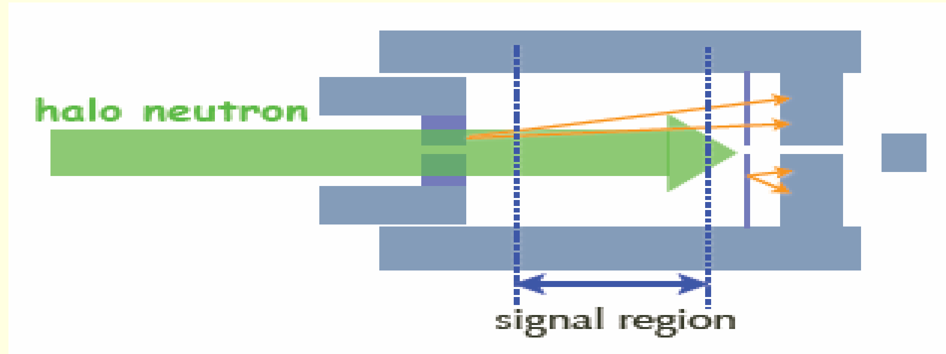
Step-by step approach

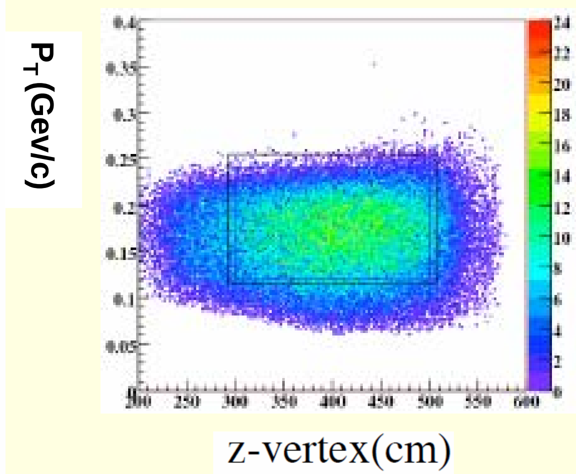

CsI - calorimeter
Main barrel
Vacuum vessel
CC 02
Front barrel
CC 03
CC 04
CC 05
CC 06
CC 07
Back Anti
K_L
Movable frame
Support
CsI-calorimeter
Front Barrel
Main Barrel
Charged veto

Tentative final-plot of one-third of Run-2

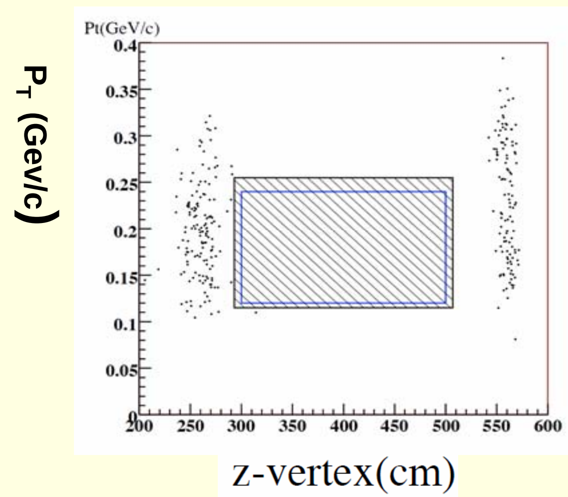


Normalization and monitor channels





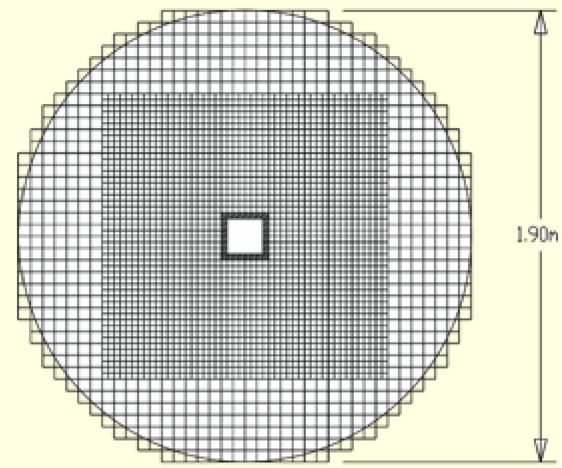
Signal MC

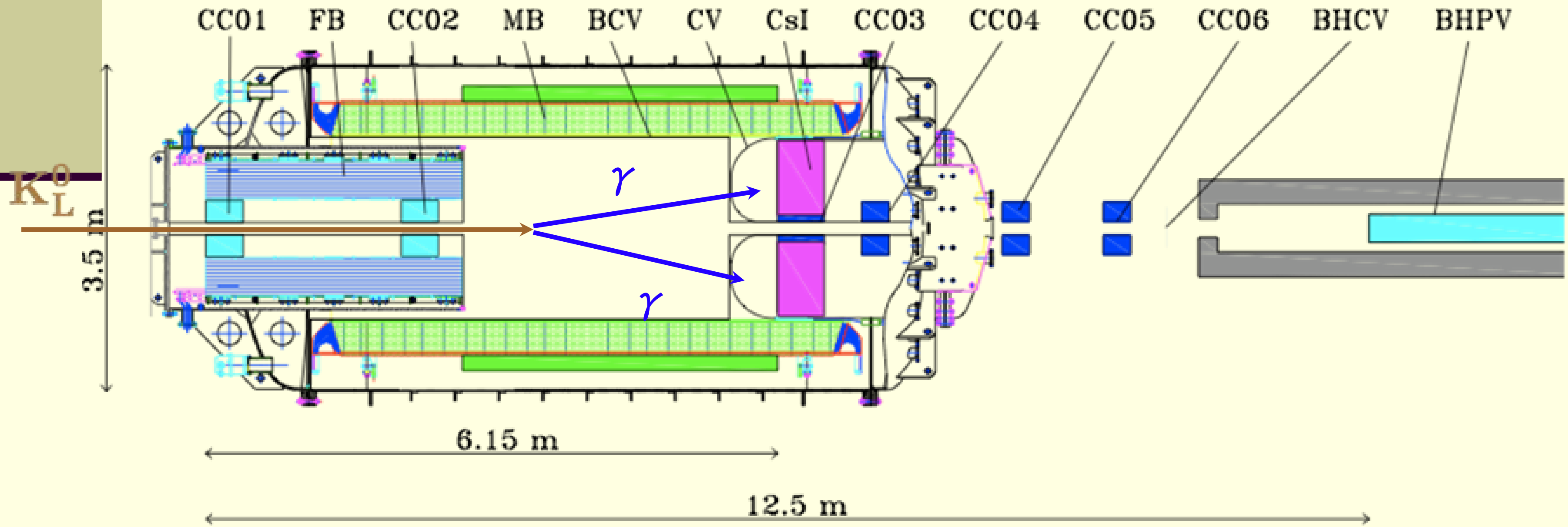


final plot

J-Parc Step 1 Experiment, E14

- New beam line
- Upgrade the E391a detector
  - CsI calorimeter
  - Readout: wave form digitizer
  - Photon vetoes along the beam

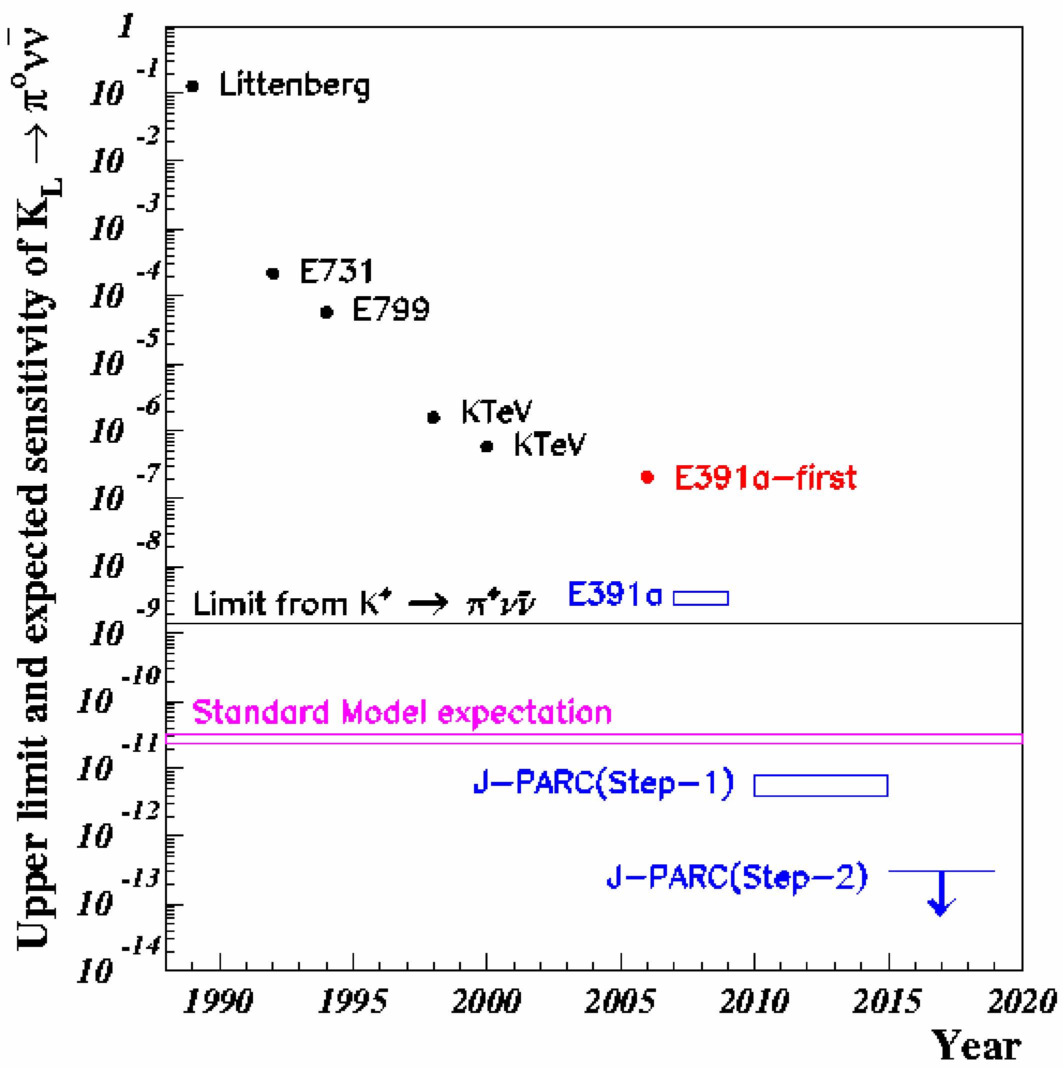




Goal and time-table of E391a and E14

Step-by-step approach with continuous improvement

- E391a-first
  - 2006: 2.1×10^{-7} (E391a, Run1 one-week)
- Prospect
  - SES ~ 3×10^{-9} (E391a full sample)
  - SES ~ 8×10^{-12} (E14, Step1)
  - SES ~ 10^{-13} (E14, Step2)



Summary

- K-decay activity was greatly affected by the terminations of the US facilities.
- But, K-decays are still performing interesting measurements in the field of flavor physics.
- Programs at J-Parc will join soon.

Backup slides

NA48 pi-pi scattering

Conclusions

Ke4

Using partial data samples recorded in 2003-2004, Na48/2 has improved measurements of the Ke4 form factors in the charged and neutral modes (5 to 30% stat. precision). Non zero fp term observed

$BR(Ke4^{00}) = (2.587 \pm 0.026_{stat} \pm 0.019_{syst} \pm 0.029_{theo}) \cdot 10^{-5}$

(10 times better than current PDG value)

Using a conservative theoretical approach, a preliminary value of a_0^0 is obtained with 3% precision (both stat. and syst.). More constrained result in progress with help from theorists.

$a_0^0 = 0.256 \pm 0.008_{stat} \pm 0.007_{syst} \pm 0.018_{theo}$ (Universal Band width)

New measurements of Matrix element and $\pi\pi$ scattering length in K3pi decays

Cusp

$a_0^0 - a_0^2 = 0.268 \pm 0.010_{stat} \pm 0.004_{syst} \pm 0.013_{theo}$

First evidence for a non-zero k' term

$k' = 0.0097 \pm 0.0003_{stat} \pm 0.0008_{syst}$

More stringent constrains in the (a_0^0, a_0^2) plane to be expected soon