

One question that we cannot skip:



Based on the talks given at the Flavor Physics session of the Alghero Dafne2 Workshop

Fernando Ferroni  
Roma “La Sapienza”  
& INFN Roma

Try to stick to facts

# The wildest dream

	$b \rightarrow s$	$b \rightarrow d$	$s \rightarrow d$
$\Delta F=2$ box	$\Delta M_{B_s}$ $A_{CP}(B_s \rightarrow \psi\phi)$	$\Delta M_{B_d}$ $A_{CP}(B_d \rightarrow \psi K)$	$\Delta M_K, \epsilon_K$
$\Delta F=1$ 4-quark box	$B_d \rightarrow \phi K, B_d \rightarrow K\pi, \dots$	$B_d \rightarrow \pi\pi, B_d \rightarrow \rho\pi, \dots$	$\epsilon'/\epsilon, K \rightarrow 3\pi, \dots$
gluon penguin	$B_d \rightarrow X_s \gamma, B_d \rightarrow \phi K,$ $B_d \rightarrow K\pi, \dots$	$B_d \rightarrow X_d \gamma, B_d \rightarrow \pi\pi, \dots$	$\epsilon'/\epsilon, K_L \rightarrow \pi^0 \ell\ell, \dots$
$\gamma$ penguin	$B_d \rightarrow X_s \ell\ell, B_d \rightarrow X_s \gamma$ $B_d \rightarrow \phi K, B_d \rightarrow K\pi, \dots$	$B_d \rightarrow X_d \ell\ell, B_d \rightarrow X_d \gamma$ $B_d \rightarrow \pi\pi, \dots$	$\epsilon'/\epsilon, K_L \rightarrow \pi^0 \ell\ell, \dots$
$Z^0$ penguin	$B_d \rightarrow X_s \ell\ell, B_s \rightarrow \mu\mu$ $B_d \rightarrow \phi K, B_d \rightarrow K\pi, \dots$	$B_d \rightarrow X_d \ell\ell, B_d \rightarrow \mu\mu$ $B_d \rightarrow \pi\pi, \dots$	$\epsilon'/\epsilon, K_L \rightarrow \pi^0 \ell\ell,$ $K \rightarrow \pi\nu\nu, K \rightarrow \mu\mu, \dots$
$H^0$ penguin	$B_s \rightarrow \mu\mu$	$B_d \rightarrow \mu\mu$	$K_{L,S} \rightarrow \mu\mu$

# Even theory has its limitations

decreasing SM contrib.

	$b \rightarrow s (\sim\lambda^2)$	$b \rightarrow d (\sim\lambda^3)$	$s \rightarrow d (\sim\lambda^5)$
$\Delta F=2$ box	$\Delta M_{B_s}$ $A_{CP}(B_s \rightarrow \psi\phi)$	$\Delta M_{B_d}$ $A_{CP}(B_d \rightarrow \psi K)$	$\Delta M_K, \epsilon_K$
$\Delta F=1$ 4-quark box	$B_d \rightarrow \phi K, B_d \rightarrow K\pi, \dots$	$B_d \rightarrow \pi\pi, B_d \rightarrow \rho\pi, \dots$	$\epsilon'/\epsilon, K \rightarrow 3\pi, \dots$
gluon penguin	$B_d \rightarrow X_s \gamma, B_d \rightarrow \phi K,$ $B_d \rightarrow K\pi, \dots$	$B_d \rightarrow X_d \gamma, B_d \rightarrow \pi\pi, \dots$	$\epsilon'/\epsilon, K_L \rightarrow \pi^0 \Gamma\Gamma, \dots$
$\gamma$ penguin	$B_d \rightarrow X_s \Gamma\Gamma, B_d \rightarrow X_s \gamma$ $B_d \rightarrow \phi K, B_d \rightarrow K\pi, \dots$	$B_d \rightarrow X_d \Gamma\Gamma, B_d \rightarrow X_d \gamma$ $B_d \rightarrow \pi\pi, \dots$	$\epsilon'/\epsilon, K_L \rightarrow \pi^0 \Gamma\Gamma, \dots$
$Z^0$ penguin	$B_d \rightarrow X_s \Gamma\Gamma, B_s \rightarrow \mu\mu$ $B_d \rightarrow \phi K, B_d \rightarrow K\pi, \dots$	$B_d \rightarrow X_d \Gamma\Gamma, B_d \rightarrow \mu\mu$ $B_d \rightarrow \pi\pi, \dots$	$\epsilon'/\epsilon, K_L \rightarrow \pi^0 \Gamma\Gamma,$ $K \rightarrow \pi\nu\nu, K \rightarrow \mu\mu, \dots$
$H^0$ penguin	$B_s \rightarrow \mu\mu$	$B_d \rightarrow \mu\mu$	$K_{L,S} \rightarrow \mu\mu$

decreasing  
SM  
contrib.


Theoretical errors  $\lesssim 10\%$


# And experiments have no less

decreasing SM contrib. 

	$b \rightarrow s (\sim \lambda^2)$	$b \rightarrow d (\sim \lambda^3)$	$s \rightarrow d (\sim \lambda^5)$
$\Delta F=2$ box	$\Delta M_{B_s}$ $A_{CP}(B_s \rightarrow \psi\phi)$	$\Delta M_{B_d}$ $A_{CP}(B_d \rightarrow \psi K)$	$\Delta M_K, \epsilon_K$
$\Delta F=1$ 4-quark box	$B_d \rightarrow \phi K, B_d \rightarrow K\pi, \dots$	$B_d \rightarrow \pi\pi, B_d \rightarrow \rho\pi, \dots$	$\epsilon'/\epsilon, K \rightarrow 3\pi, \dots$
gluon penguin	$B_d \rightarrow X_s \gamma, B_d \rightarrow \phi K$ $B_d \rightarrow K\pi, \dots$	$B_d \rightarrow X_d \gamma, B_d \rightarrow \pi\pi, \dots$	$\epsilon'/\epsilon, K_L \rightarrow \pi^0 \Gamma\Gamma, \dots$
$\gamma$ penguin	$B_d \rightarrow X_s \Gamma\Gamma, B_d \rightarrow X_s \gamma$ $B_d \rightarrow \phi K, B_d \rightarrow K\pi, \dots$	$B_d \rightarrow X_d \Gamma\Gamma, B_d \rightarrow X_d \gamma$ $B_d \rightarrow \pi\pi, \dots$	$\epsilon'/\epsilon, K_L \rightarrow \pi^0 \Gamma\Gamma, \dots$
$Z^0$ penguin	$B_d \rightarrow X_s \Gamma\Gamma, B_s \rightarrow \mu\mu$ $B_d \rightarrow \phi K, B_d \rightarrow K\pi, \dots$	$B_d \rightarrow X_d \Gamma\Gamma, B_d \rightarrow \mu\mu$ $B_d \rightarrow \pi\pi, \dots$	$\epsilon'/\epsilon, K_L \rightarrow \pi^0 \Gamma\Gamma,$ $K \rightarrow \pi\nu\nu, K \rightarrow \mu\mu, \dots$
$H^0$ penguin	$B_s \rightarrow \mu\mu$	$B_d \rightarrow \mu\mu$	$K_{L,S} \rightarrow \mu\mu$

decreasing  
SM  
contrib.

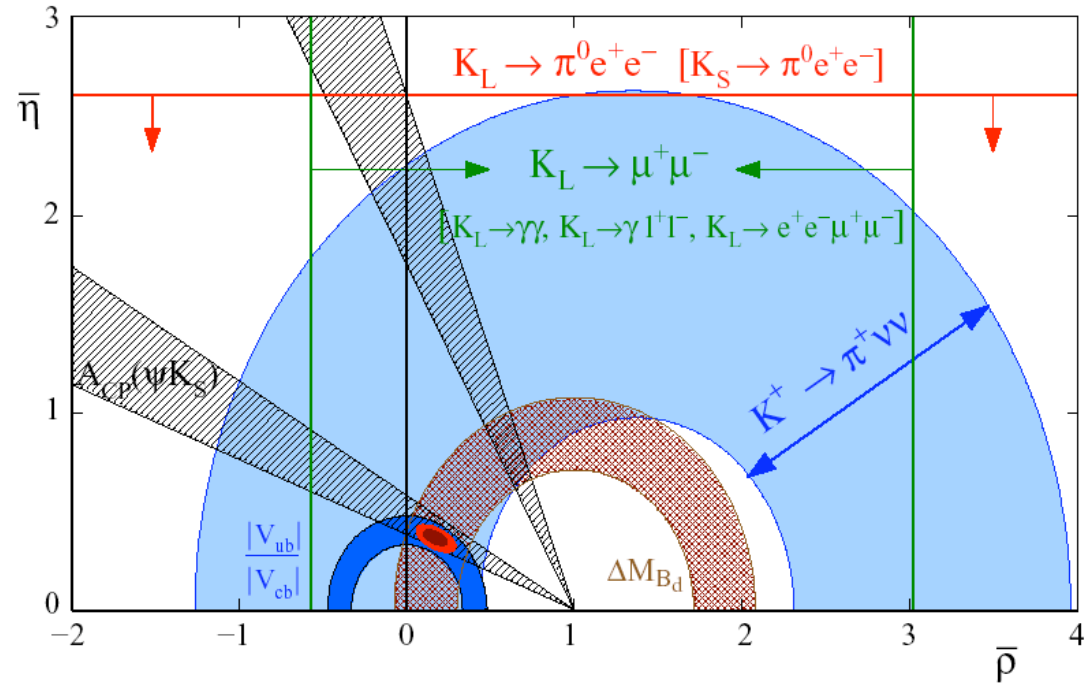
 = exp. error  $\sim 10\%$

 = exp. error  $\sim 100\%$

where are we ?

$$K^+ \rightarrow \pi^+ \nu \bar{\nu}$$

$$K_L \rightarrow \pi^0 \nu \nu$$



$$K_L \rightarrow \pi^0 e^+ e^- \quad [K_S \rightarrow \pi^0 e^+ e^-]$$

# K → πνν̄ at Hadron Machines

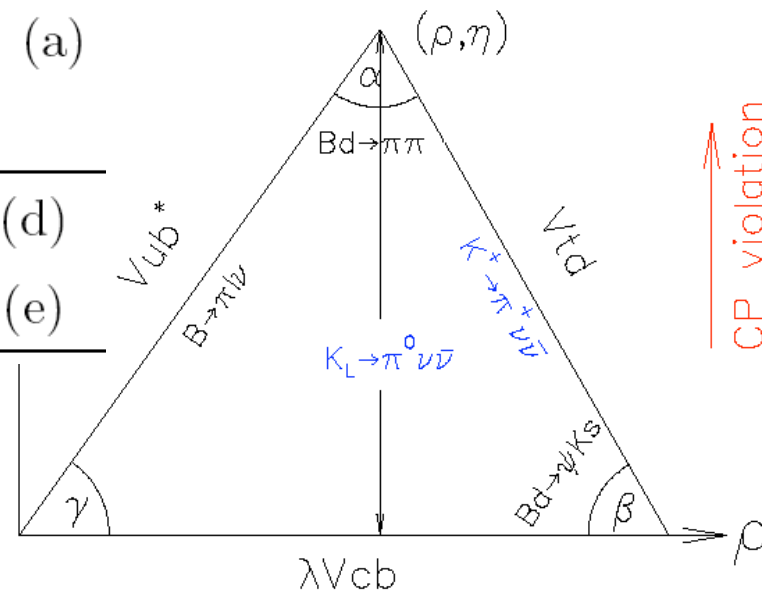
David E. Jaffe, BNL

## Overview

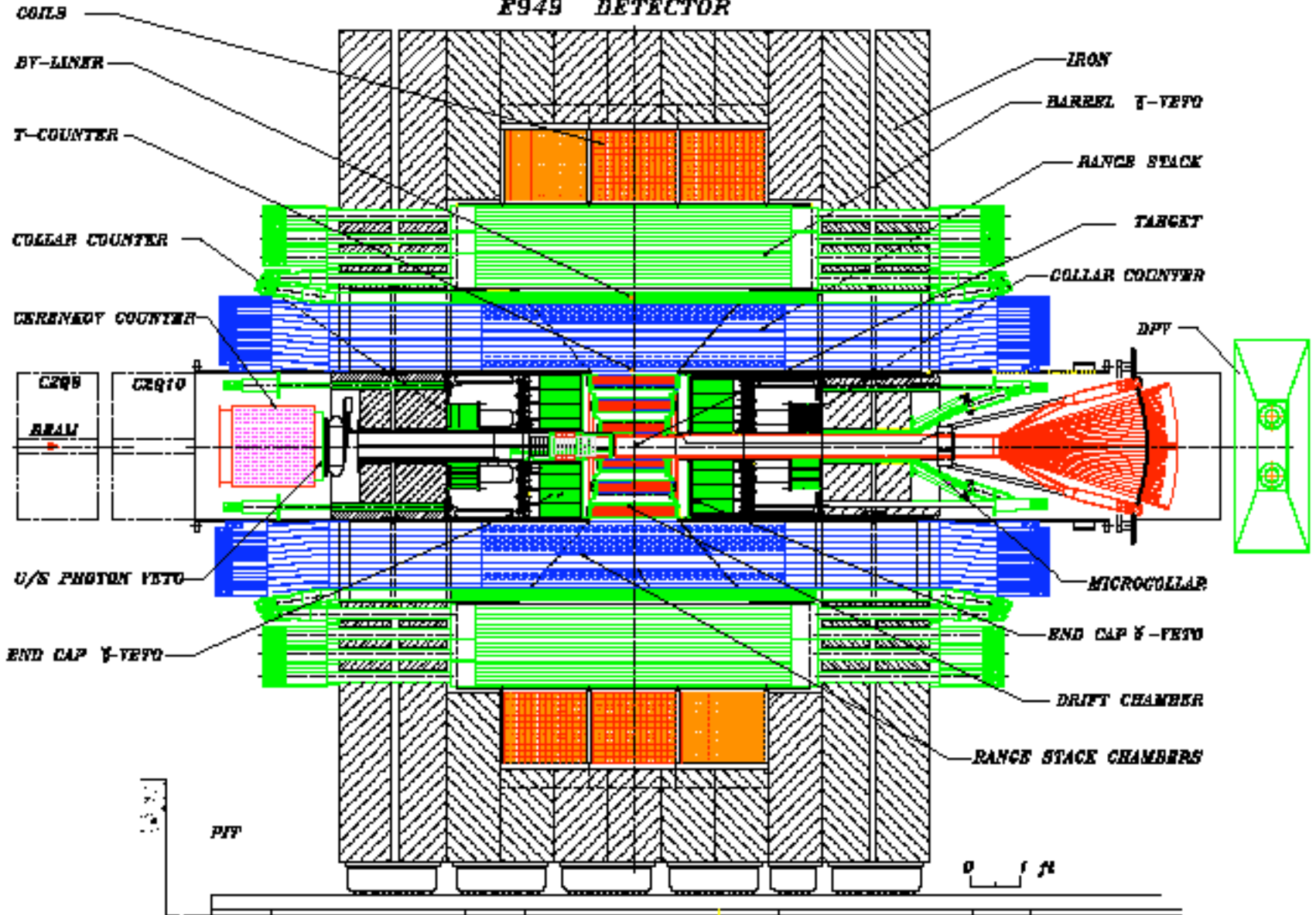
Expt	Mode	Results or Goal
E787	$K^+ \rightarrow \pi^+ \nu \bar{\nu}$	Completed. 2 candidates.
E949	$K^+ \rightarrow \pi^+ \nu \bar{\nu}$	1/5 completed. $\mathcal{O}(10)$ SM events

$$\mathcal{B}(K^+ \rightarrow \pi^+ \nu \bar{\nu})$$

Measurement	$(1.57^{+1.75}_{-0.82}) \times 10^{-10}$ (a)
Expectation	$(0.7 \pm 0.2) \times 10^{-10}$ (d)
	$(0.7 \pm 0.1) \times 10^{-10}$ (e)



**F949 DETECTOR**



## E949 status

### Upgrades to E787:

Improved photon veto hermeticity

Improved tracking resolution

Higher rate and duty factor

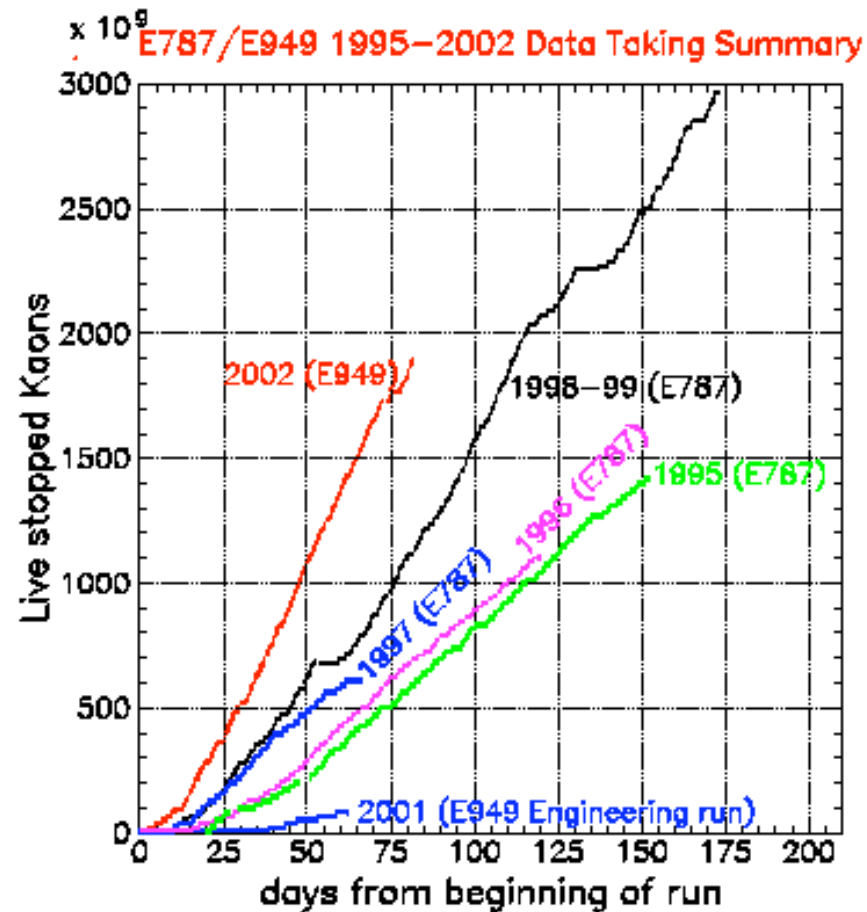
2002 run  $\leq$  E787 sensitivity,

$\sim 20\%$  of E949 sensitivity goal of  $< 10^{-11}$ .

pnn1 results: fall 2003.

### Not optimal in 2002:

1. Spill duty factor.
2. Proton beam momentum.
3. K/ $\pi$  electrostatic separators.



Clouds on future: cross the fingers

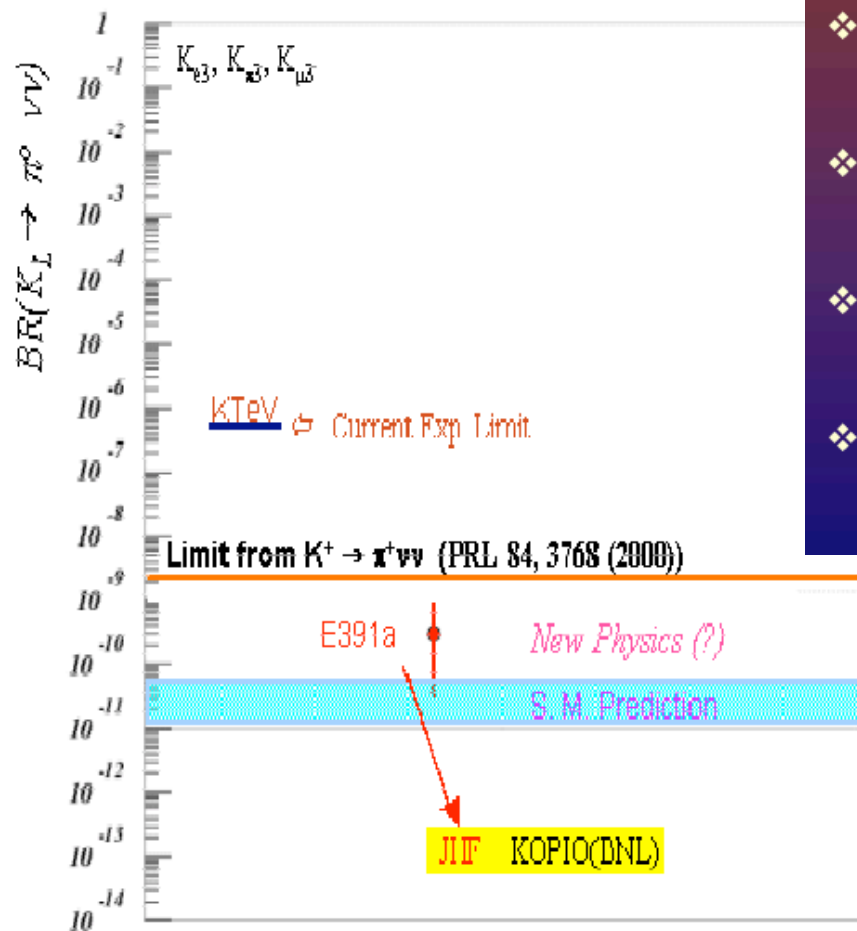
# Status of KEK-E391a and Future Prospects on $K_L \rightarrow \pi^0 \nu \bar{\nu}$ at KEK

GeiYoub Lim

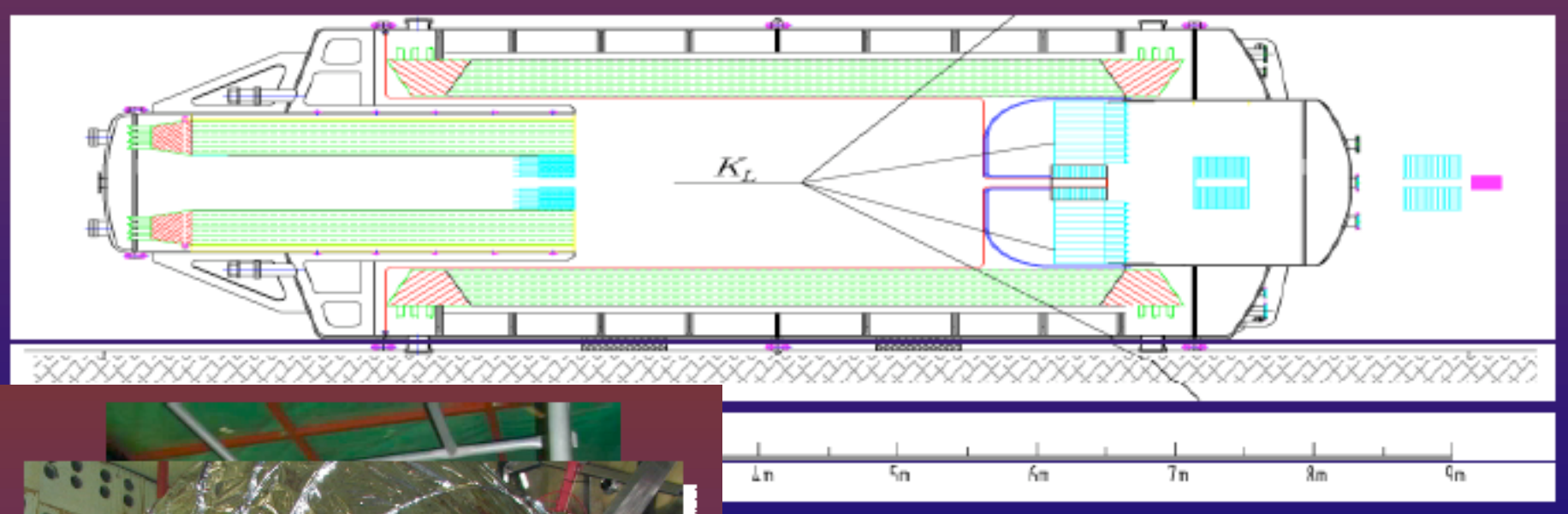
IPNS, KEK

## What shall we do ?

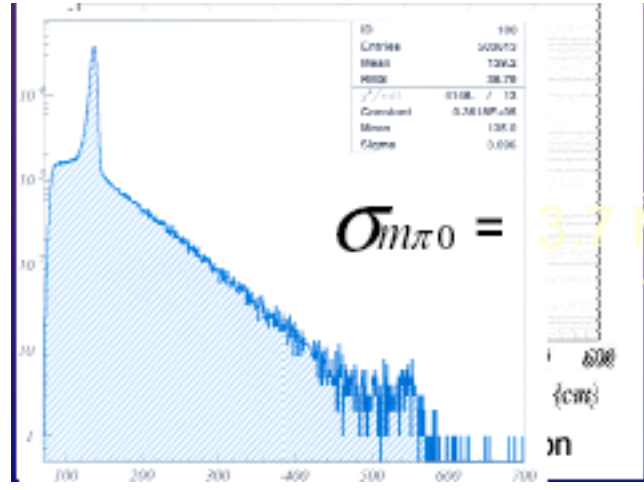
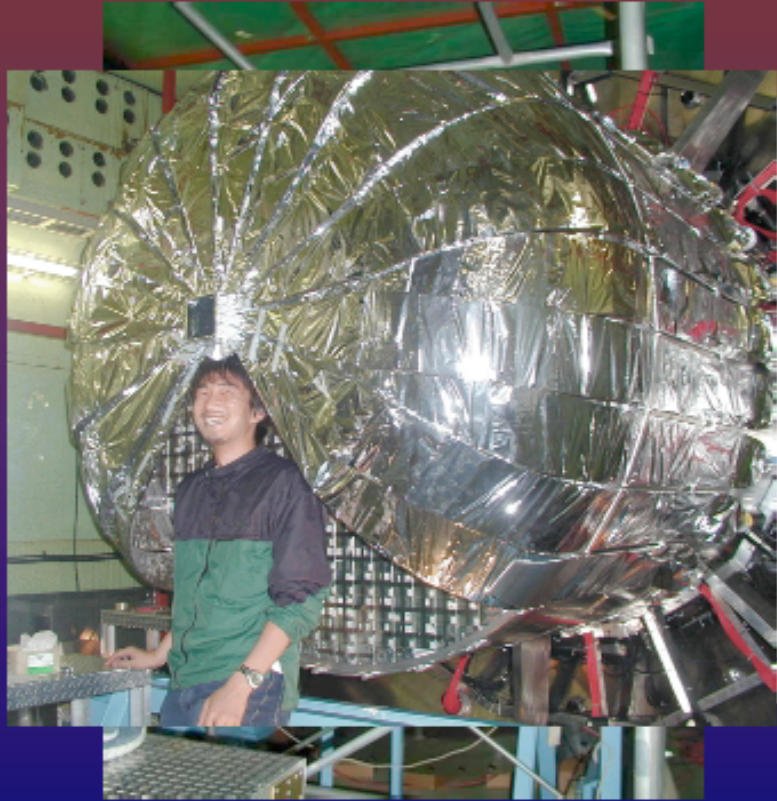
- ❖ Clear single  $\pi^0$ 
  - ❖  $\pi^0 \rightarrow \gamma\gamma$  for high sensitive measurement
- ❖ Confirm no other accompanying particle
  - ❖ Perfect veto system
- ❖ Complete understand of background
  - ❖ Based on data with help of M.C.
- ❖ A huge amount  $K_L$  decays
  - ❖ High intensity  $K_L$  beam line, Large acceptance



# E391a detector



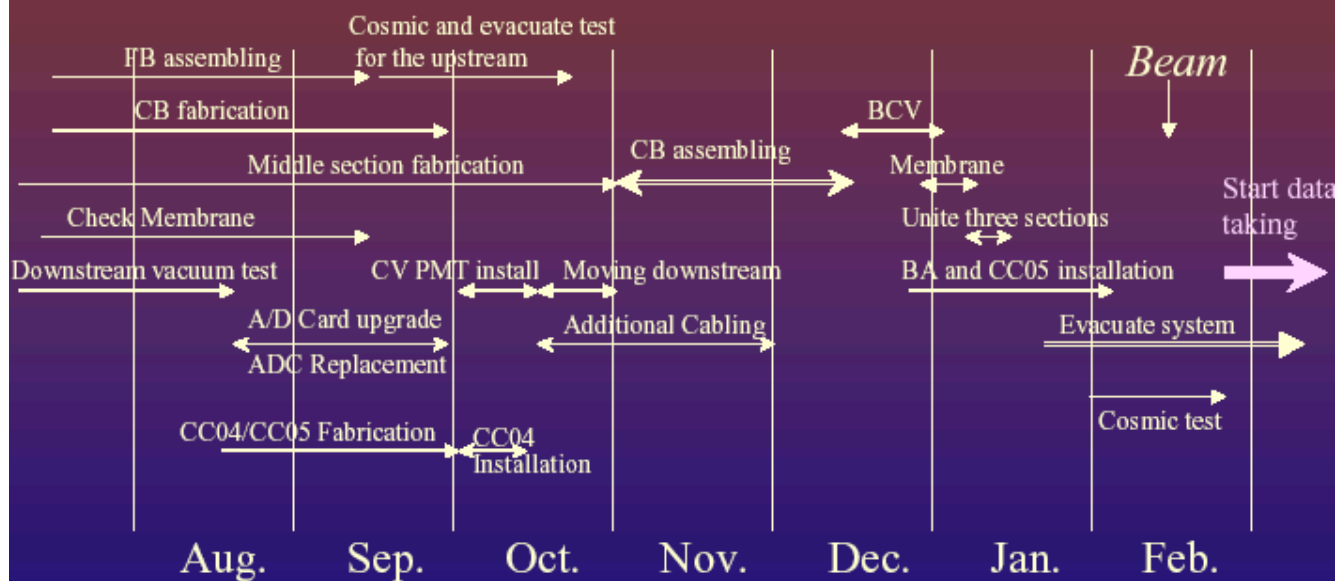
## Engineering run



# Summary

- ❖ KEK-PS E391a
  - ❖ The first dedicated experiment for the  $K_L \rightarrow \pi^0 \nu \nu$
  - ❖ Detector is constructed on schedule for Feb. 2004
  - ❖ Aiming to  $3 \times 10^{-10}$  S.E.S.
  - ❖ Significant step to the precise measurement

## Schedule



# Rare $K_L$ Decays Recent Results from KTeV

Marj Corcoran

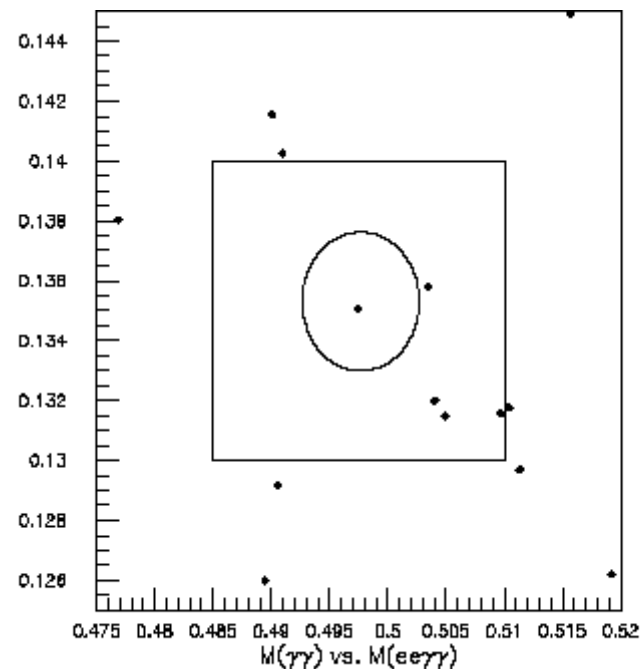
Rice University  
for the KTeV collaboration

- Best limits on modes with possible direct CP-violating contributions

- $K_L \rightarrow \pi^0 ee$

- $K_L \rightarrow \pi^0 \mu\mu$

- $K_L \rightarrow \pi^0 \nu\nu$



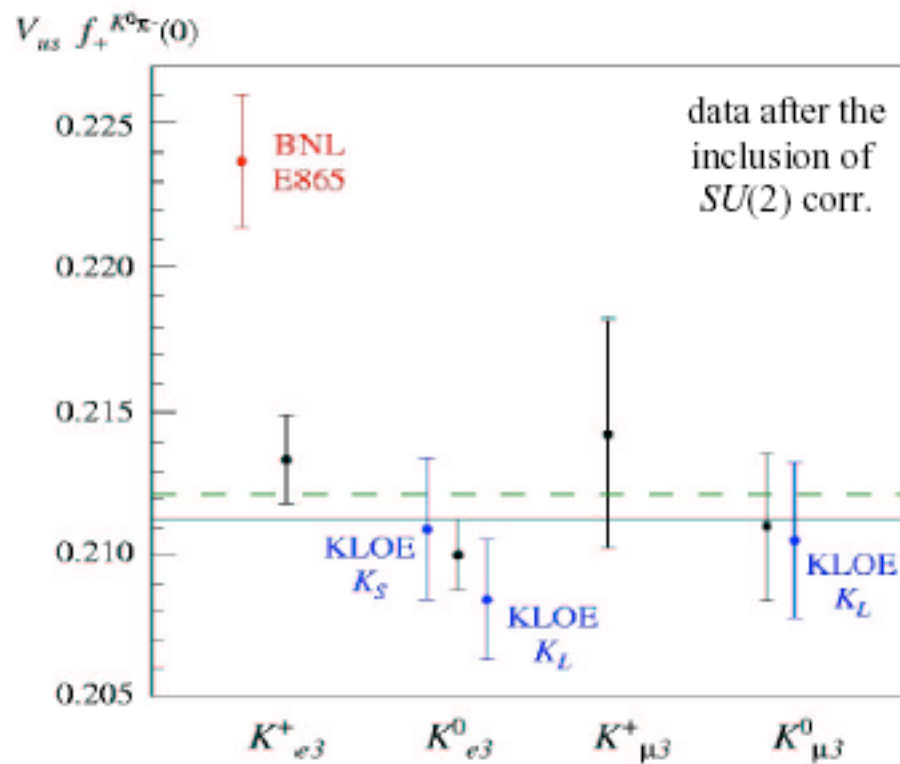
# Experiment: $K_L \rightarrow \pi^0 ee$ ( $\mu\mu$ )

E799-II (KTeV)

Mode	Upper Limit 90% CL	Ref.
$K_L \rightarrow \pi^0 ee$	$< 5.1 \times 10^{-10}$	PRL86 (2001) 97 data
$K_L \rightarrow \pi^0 \mu\mu$	$< 2.8 \times 10^{-10}$	Preliminary 97+99
	$< 3.8 \times 10^{-10}$	PRL84 (2000)

A tiny (!!??) factor 10 away

BTW looking at very rare we shall not overlook some duty we have



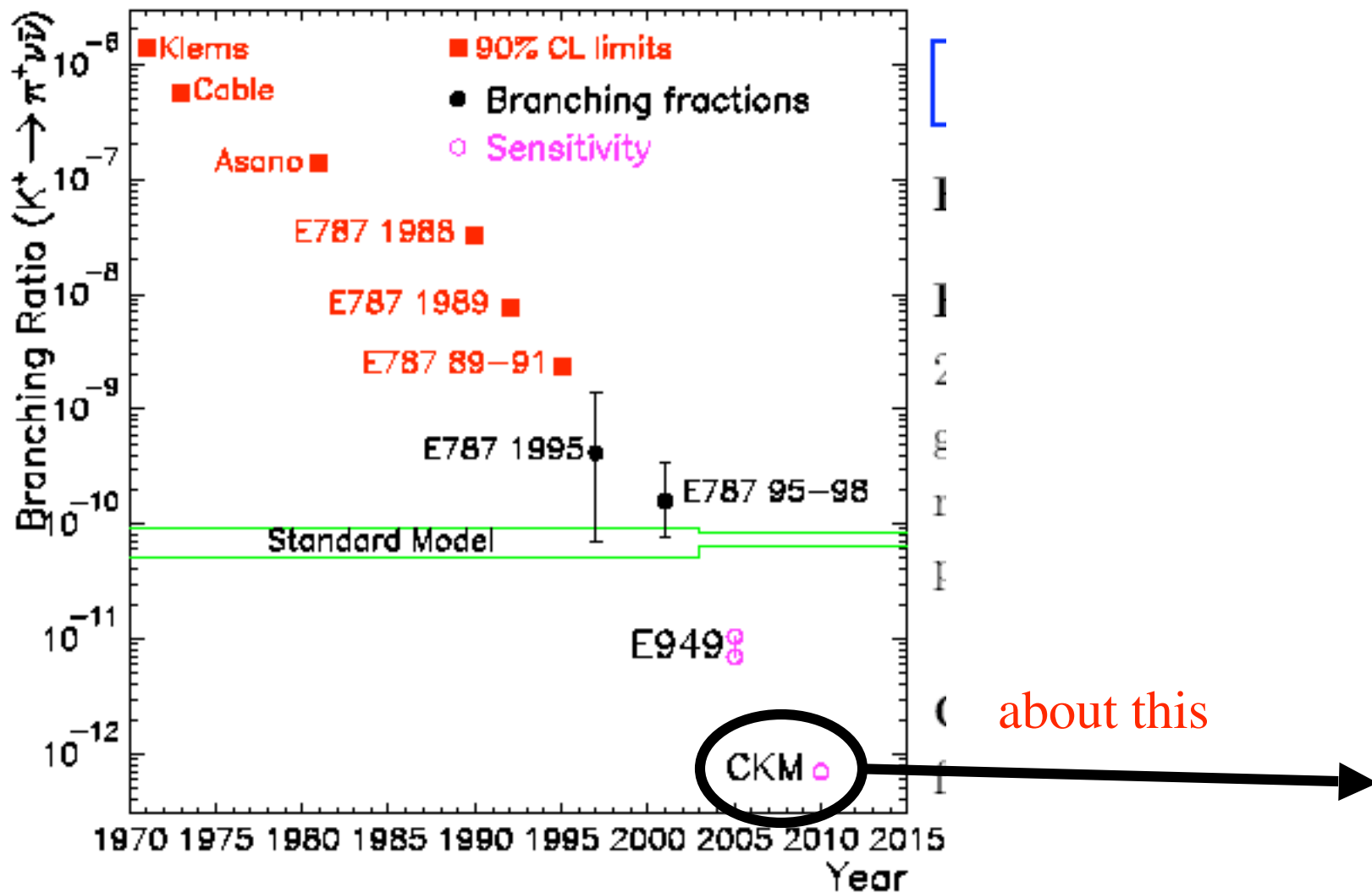
The present situation is rather confused [large  $SU(2)$  breaking = wrong th. corrections, or bad data?]

...but in a short-time, [with the help of KLOE data on both modes], we should be able to clarify it.



uncertainty dominated by the th. error on  $f(0)$ ?

# Future (semi-solid or rather liquid) in $K^+ \rightarrow \pi^+ \nu \bar{\nu}$



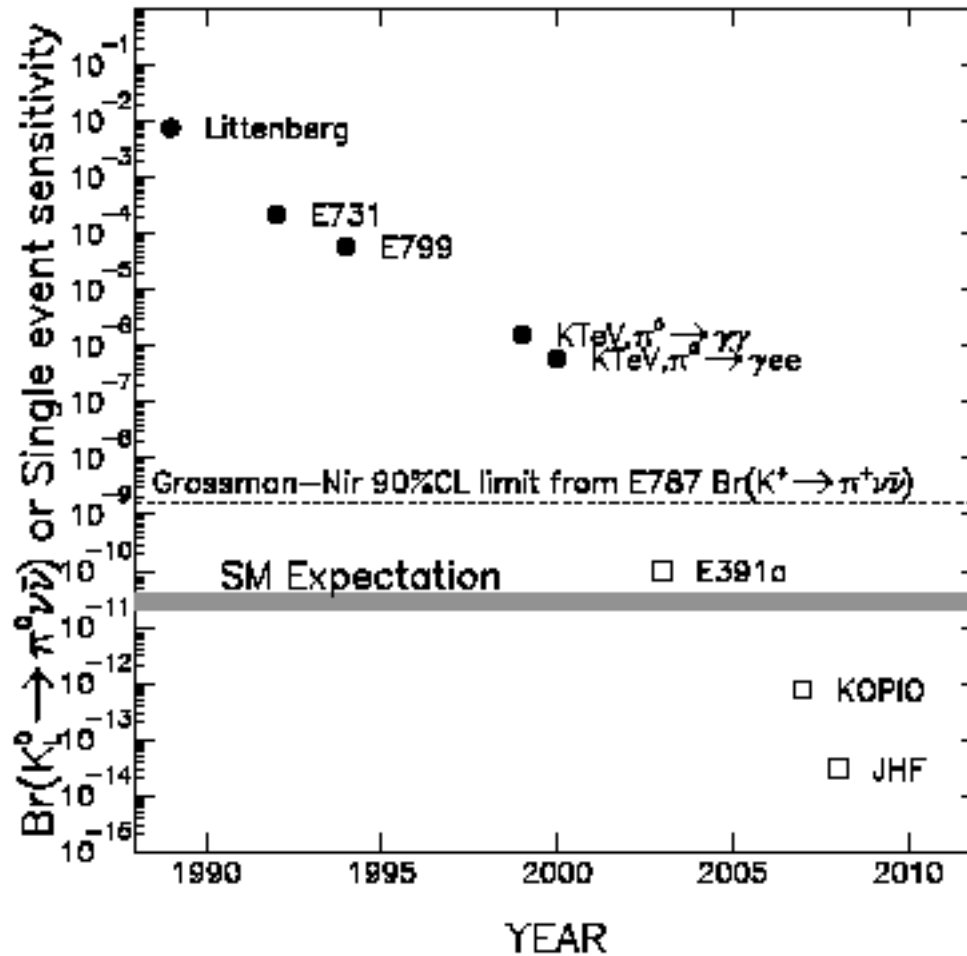
# Status as of today

Dear Fred:

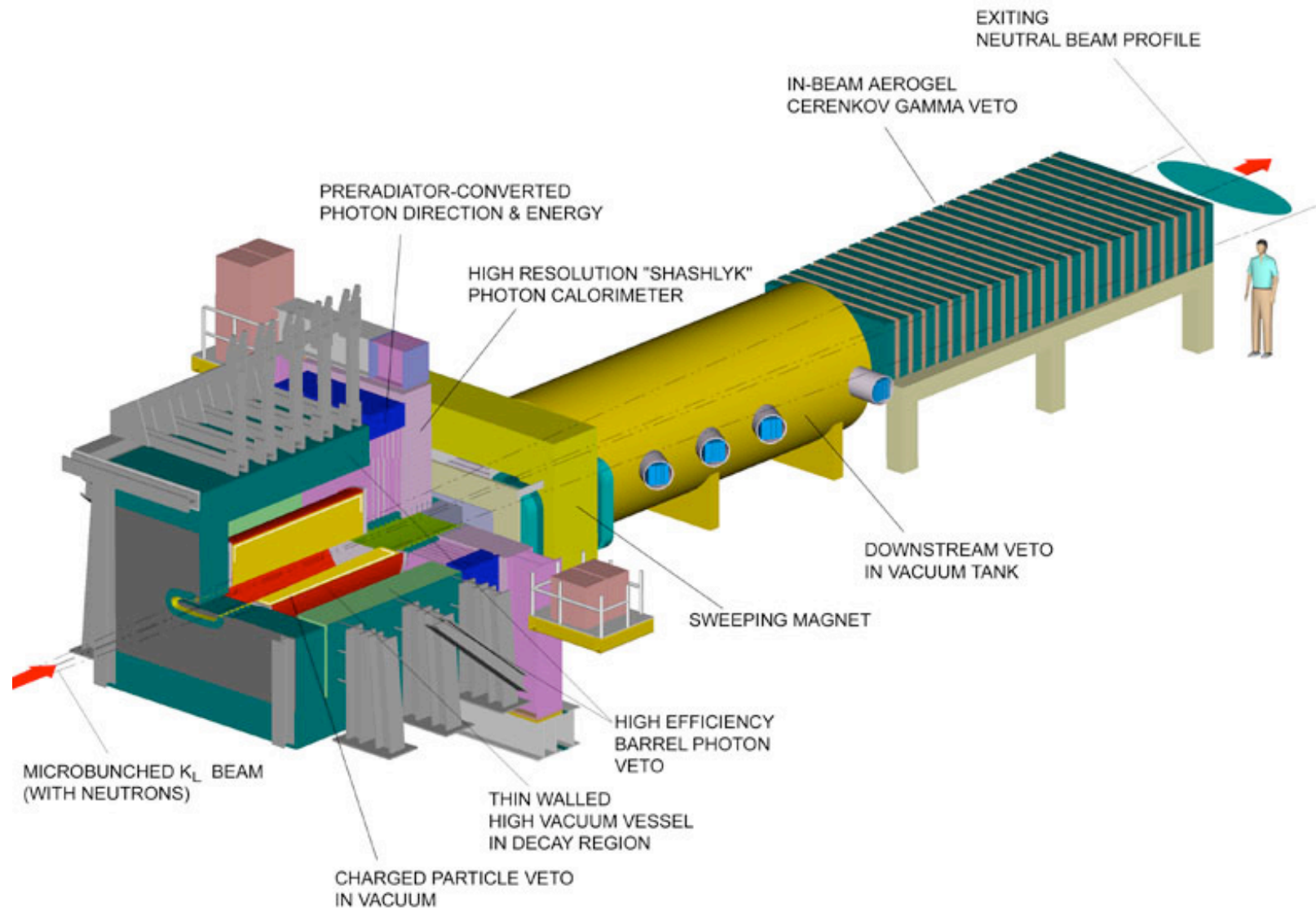
I am submitting the first report of the Particle Physics Project Prioritization Panel (P5) to HEPAP for consideration and forwarding to the DOE and the NSF. The P5 Subpanel of HEPAP was formed based on the November 6,

**Suggestions Based on Prioritization** – The present Fermilab plan calls for a similar funding profile and time-line for BTeV and CKM construction, with both starting to take data around 2009. The P5 Subpanel believes that this plan is likely to be too ambitious given the need to optimize the physics from the Tevatron Collider, as well as the desire to have BTeV completed promptly. Based on current budgetary models, P5 does not recommend proceeding with CKM.

# Future (same state of condensation) in $K_L^0 \rightarrow \pi^0 \nu \bar{\nu}$



# KOPIO: myth or reality ?



# $K_L \rightarrow \pi^0 \nu \nu$ at the J-PARC

- ❖ Large Number of  $K_L$  Decay
  - ❖ Three orders larger  $K_L$  flux
- ❖ Experience at KEK-PS
- ❖ Fast Electronics
  - ❖ High counting rates
- ❖ Optimization of beam line
  - ❖  $K_L/n/\gamma$  ratio,  $\Lambda$  production
- ❖ Detector Up-grade
  - ❖ Calorimeter
    - ❖ fast response
    - ❖ Granularity
  - ❖ Veto system
    - ❖ Detection efficiency
    - ❖ Become thicker (?)

	BNL	Fermilab		KEK	
	KOPIO	KTeV-99	KAMI-near	E391A	JHF
Proton energy	24 GeV	800 GeV	120 GeV	12 GeV	50 GeV
Protons/pulse	$5 \times 10^{13}$	$1 \times 10^{13}$	$3 \times 10^{13}$	$2 \times 10^{12}$	$2 \times 10^{14}$
Cycle time	3.6 sec	80 sec	2.9 sec	2.5 sec	3.42 sec
Flat-Top	1.6 sec	40 sec	1.0 sec	0.5 sec	0.75 sec
Ext.angle	45°	4.8 mr	24 mr	4°	10°
Beam profile	4mm×125mm	0.22mm×0.22mm	0.6mm×0.6mm	4 mm <sup>2</sup>	2.6 mm <sup>2</sup>
Solid Angle	500 μstr	0.048 μstr	1 μstr	12.6 μstr	5.5 μstr
$Y_{K_L^0}/p/\mu\text{str}$	$4.8 \times 10^{-3}$	$4.8 \times 10^2$	3.7	$5.9 \times 10^{-2}$	0.96
Av $K_L^0$ mom.	0.7 GeV/c	70 GeV/c	10 GeV/c	2 GeV/c	2 GeV/c
Decay region	3.5 m	38 m	34 m	2.7 m	2.7 m
Decay prob.	16 %	2.1 %	10 %	4.3 %	4.3 %
$K_L^0$ /pulse	$1.2 \times 10^6$	$2.3 \times 10^7$	$1.1 \times 10^6$	$1.5 \times 10^6$	$1.1 \times 10^6$
$K_L^0$ -decay/pulse	$1.9 \times 10^7$	$4.8 \times 10^8$	$1.1 \times 10^7$	$6.5 \times 10^4$	$4.7 \times 10^7$
Av $K_L^0$ -decay/sec	$5.3 \times 10^6$	$6 \times 10^8$	$3.8 \times 10^6$	$2.6 \times 10^4$	$1.4 \times 10^7$
Inst. decay-rate	12 MHz	12 kHz	11 MHz	130 kHz	63 MHz
Acceptance	1.6 %	5 %	7.4 %	8 %	16 %
Run Time	$3 \times 10^7$ sec	$6 \times 10^6$ sec	$3 \times 10^7$ sec	$1 \times 10^7$ sec	$3 \times 10^7$ sec
Running Eff.	50 %	50 %	50 %	50 %	50 %
Sensitivity	$7.8 \times 10^{-13}$	$1.1 \times 10^{-8}$	$2.3 \times 10^{-10}$	$1.0 \times 10^{-10}$	$3.0 \times 10^{-14}$
Events ( $1 \times 10^{-11}$ )	38 events		130 events		1000 events

T.Inagaki CP Violation in K (1998)

# Future (gaseous) in $K_L \rightarrow \pi^0 ee(\mu\mu)$ Perspectives

**\*Admittedly aggressive Road Map\***

- **Detector  $\sigma(\gamma\gamma)$   $\times 2$** 
  - Very ambitious, KTeV/NA48 already state of the art
- **$K_S$ - $K_L$  time dependent interference  $\times 2$** 
  - Position experiment between 9 and 16  $K_S$  lifetimes (hep-ph/0107046)
- **$K_S$ - $K_L$  time independent interference  $\times 3$** 
  - **Assume** constructive interference (theoretically preferred)
- **Data Taking  $\times 5$** 
  - Run in “**factory mode**”. After all E799-II run only for a few months to collect  $\sim 7 \times 10^{11}$   $K_L$  decays
- **Beam intensity  $\times 4$** 
  - Need  $\sim 10^{12}$  **protons/sec**, slowly extracted, high energy, DC
- **Tot  $\sim \times 240 \rightarrow$  **sens  $\sim \times 15$****
- close the gap between current upper limit and SM
- **Where? When?**

## **NA48/3 ??**

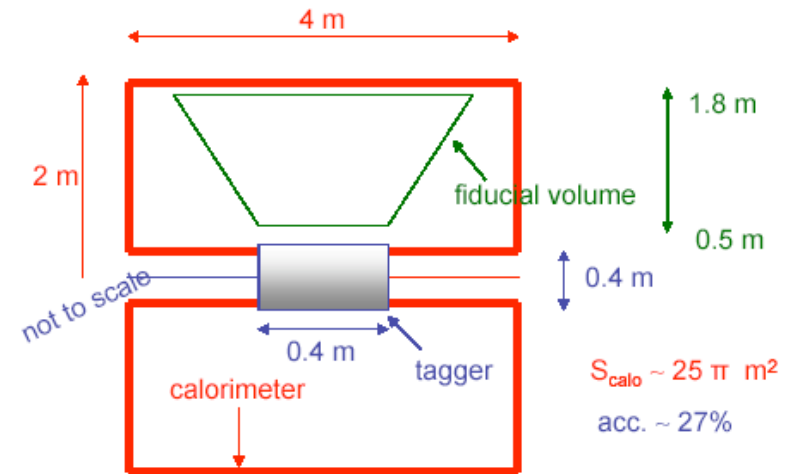
- CERN is currently the only place where high energy kaon beams could be employed

# Future (unknown state of matter)

$K_L \Rightarrow \pi^0 \nu \bar{\nu}$  at a  $\Phi$  factory? **F. Bossi**  
LNF-INFN

- Production rate:  $10^6$   $K_S$ - $K_L$  pairs / pb $^{-1}$
- 1 year @  $10^{35}$  cm $^{-2}$ s $^{-1}$ :  $10^{12}$   $K_L$  produced
- observed decays:  $30 * \epsilon_{\text{tot}}$  / year (SM)

**must be  $\epsilon_{\text{tot}} \geq \sim 10\%$**



The search for  $K_L \rightarrow \pi^0 \nu \bar{\nu}$  is probably the most exciting goal and solid motivation for the high luminosity option of DAΦNE 2 (see Gino's talk yesterday)

It requires however luminosities of order  $10^{35}$  cm $^{-2}$ s $^{-1}$

# Future (unknown state of matter)

$$1 \text{ year @ } 10^{32} = 1 \text{ fb}^{-1} \approx 3 \cdot 10^9 \Phi \approx 3 \cdot 10^9 K^\pm$$

→ Allows few per mil measurement of O(1%) BRs  
→  $V_{us}$  @ / below 1% (theor. error...?)  
→  $\delta_g(K^\pm \rightarrow \pi^\pm 2\pi^0)$  below 1 %

$$1 \text{ year @ } 5 \cdot 10^{33} = 50 \text{ fb}^{-1} \approx 1.5 \cdot 10^{11} \Phi \approx 1.5 \cdot 10^{11} K^\pm$$

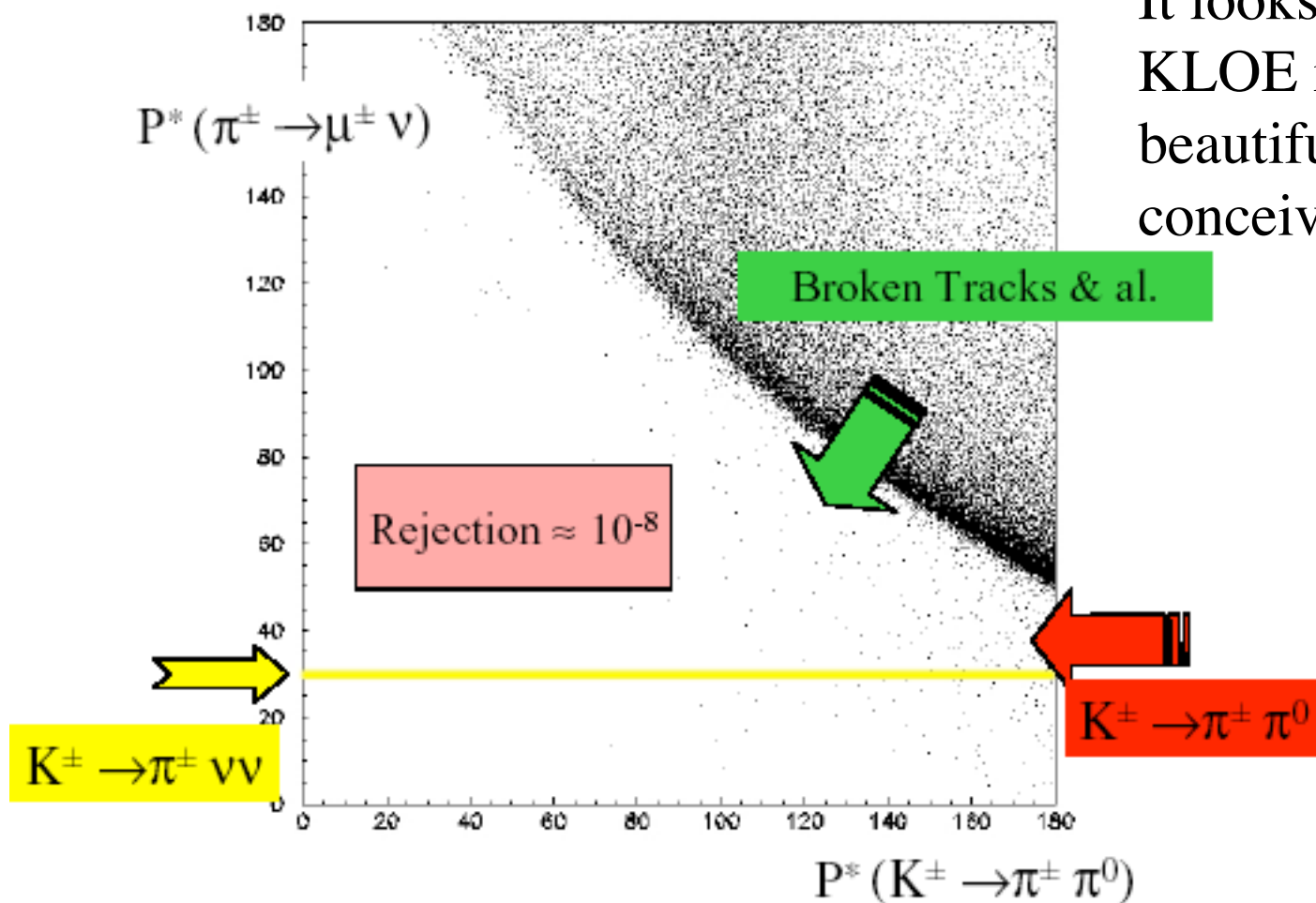
→  $\approx 2 \cdot 10^6 K^\pm \rightarrow e^\pm \nu$  produced  
→  $\approx 15 K^\pm \rightarrow \pi^\pm \nu \nu$  produced

$$1 \text{ year @ } 10^{35} = 10^3 \text{ fb}^{-1} \approx 3 \cdot 10^{12} \Phi \approx 3 \cdot 10^{12} K^\pm$$

→  $\approx 300 K^\pm \rightarrow \pi^\pm \nu \nu$  produced

# Future (unknown state of matter)

It looks like that KLOE is the most beautiful MC ever conceived



L. Passalacqua / LNF-INFN  
& the KLOE  $K^\pm$  group.

$$\epsilon_{\text{START}} = (2\epsilon_a) \cdot 0.85 \cdot (2\epsilon_a) \cdot 0.3 \sim 9\%$$

$$K \rightarrow \pi\nu\bar{\nu}/\text{year} @ \mathcal{L}=10^{35} \text{ cm}^{-2}\text{s}^{-1}$$

$\mathcal{L}$ $\mu\text{b}^{-1}/\text{s}$	$\int \mathcal{L} dt$ $\mu\text{b}^{-1}$	$N(K_L)$	$N(K^\pm)$
$10^5$	$10^{12}$	$10^{12}$	$3 \times 10^{12}$

$N(K_L)$	BR	$\epsilon$	$N(\pi\nu\bar{\nu})$
$10^{12}$	$2.7 \times 10^{-11}$	0.03	0.8

$N(K^\pm)$	BR	$\epsilon$	$N(\pi\nu\bar{\nu})$
$3 \times 10^{12}$	$7.7 \times 10^{-11}$	0.09	21

kindly provided by Paolo F.

# A contribute to discussion

- A realistic Luminosity plan for Dafne2 might allow the observation (not the measurement) of  $K^+ \rightarrow \pi^+$  and likely not even so for  $K_L \rightarrow \pi^0$
- However the physics potential of a machine should not be a single although V.I.Measurement (see Paolo F. talk)

# We are talking of ~2010

- A) SUSY does not exist
- B) SUSY will be discovered next year by LHC
- C) SUSY has been already discovered

## A) SUSY does not exist

- Then I could not care less about yet another constrain on an already over-constrained unitary triangle

## B) SUSY will be discovered next year by LHC

- Then we expect a BR for both  $K \rightarrow \pi$  channels  
Enhanced wrt. SM
- Observation might be more than enough
- Together the deviations most likely already  
observed in B decays ( $\pi K_s$  et al.) it will a great thing  
for the experimenters locally and world-wide

## C) SUSY has been already discovered

- Then DaΦne2 as well as SuperB(elle) will, for a long time, be the only places to work on the characterization of the SUSY
- A drop of water in the sea compared to NLC but they might exist while...