CP and CPT Studies with Kaons

or Kaons Are Still Interesting

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OUTLINE

1. In the beginning there were kaons
2. CP violation
3. Still to be done
4. Fixed Target and ϕ–factory
5. CPT tests

What did we learn from kaons

1. Flavor
2. $\not{P}$
3. $\Delta S = \Delta Q$
4. Dominance of $\Delta I = 1/2$

   still embarassing
5. Mixing ($\sin\theta_C$)
6. Quarks
7. $\not{C}\not{P}$

Some history

1. 1964 $\not{C}\not{P}$ in $|\Delta S| = 2$
2. '67-'73 $\mathcal{A}_\ell^L \sim \sqrt{2}\Re\epsilon$
3. . . . -'01 Direct $\not{C}\not{P}$ in $|\Delta S| = 1$
4. '01 $\not{C}\not{P}$ in $|\Delta B| = 2$

What's missing

1. Origin of $\not{C}\not{P}$ still unknown
2. $\Re(\epsilon'/\epsilon)\neq 0$ rules out Superweak theory, but
3. CKM$\Leftrightarrow\Re(\epsilon'/\epsilon)$ evades us

Other $\not{C}\not{P}$ Kaon Physics

1. $K_S \to \pi^0\pi^0\pi^0$, BR$\sim 2 \times 10^{-9}$ — NA48/1, KLOE 2004
2. Odd pion slopes from K^+ - K^- — NA48/2, KLOE 2004
3. $K^\pm \to \pi^\pm\pi^0\gamma$ — NA48/2, KLOE 2004
4. $\Gamma(++-) \Leftrightarrow \Gamma(--+)$ etc. — KLOE 2004
5. $K_S \to \pi^0 e^+ e^-$ — NA48/1, KLOE 2004
6. $K_L \to \pi^0 \nu\bar{\nu}$, BR$\sim 3 \times 10^{-11}$ — KOPIO?

In order of difficulty, BR!

Expected signals are quite predictable for 1. and 6.

5. Needed for understanding $K_L \to \pi^0 e^+ e^-$

The situation is different for 2., 3. and 4.

1. $K_S \to \pi^0\pi^0\pi^0$

From K_S impurity:

BR=1.89×10^{-9}, uncertainty $\sim$1.3%, a must!!

It has been said that finding a different answer would be proof that QM is no good (JE).

2. $K^{\pm} \to 3\pi$

Let $\Gamma(K^+ \to \pi^+\pi^+\pi^-) \equiv \Gamma^+_{++-}$

then $\Gamma^+_{++-} - \Gamma^-_{--+} \neq 0 \Rightarrow \not{C}\not{P}$, etc.

3. Odd pion slope

$A = (g_+ - g_-)/(g_+ + g_-) \neq 0 \Rightarrow \not{C}\not{P}$

η_i, BR and all that

Let: $K_S = K_1 + \epsilon K_2$; $K_L = K_2 + \epsilon K_1$; $\eta_i = \langle i|\,K_L\,\rangle / \langle i|\,K_S\,\rangle$

$\epsilon = (2\eta_{+-} + \eta_{00})/3$; $\arg\epsilon = 4\phi_{+-}/3 - \phi_{00}/3$.

$$\eta_{000} = \frac{\langle 3\pi^0|\,K_L\,\rangle}{\langle 3\pi^0|\,K_S\,\rangle} = \epsilon + \epsilon'_{000}; \qquad |\epsilon'_{000}/\epsilon| \ll 1$$

$$\mathrm{BR}_S(3\pi^0) = |\eta_{000}|^2 \times \mathrm{BR}_L(3\pi^0) \times \frac{\Gamma_L}{\Gamma_S}$$

$$= |\epsilon|^2 \times \mathrm{BR}_L(3\pi^0) \times \frac{\tau_S}{\tau_L} = 1.9 \times 10^{-9}$$

From $\delta\Re\,\eta_{000} \sim 2.2 \times 10^{-2}$ and $\delta\Im\,\eta_{000} \sim 2.8 \times 10^{-2}$ it follows $\delta\mathrm{BR}_S(3\pi^0) \sim 4.6 \times 10^{-7}$ or BR $< 0.8 \times 10^{-6}$ at 90% cl.

$K_S \to \pi \ell \nu$

Learn about

1. $\Delta S = \Delta Q$
2. TCP

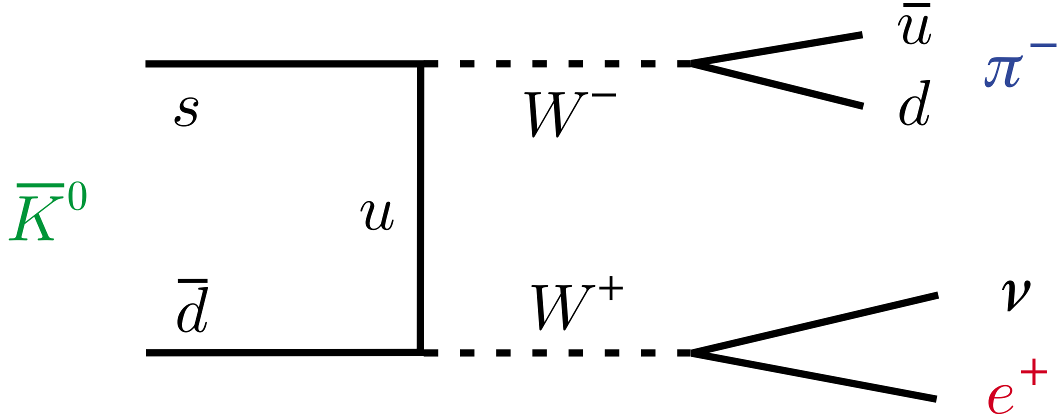
by measuring

3. $\Gamma(K_S \to \pi \ell \nu)$
4. $\mathcal{A}_\ell^S$

$\Delta S = \Delta Q$

There is no $\Delta S = -\Delta Q$ in the SM: $s \to W^- u$, $\bar{s} \to W^+ \bar{u}$

Fake $\Delta S = -\Delta Q$



$$x = \frac{A(\bar{K} \to \ell^+ \pi^- \nu)}{A(\bar{K} \to \ell^- \pi^+ \bar{\nu})} \sim G m^2 \sim 10^{-6}$$

Exp: $x < 10^{-2}$ @90% CL

NOT $x = \dfrac{A(\Delta S = -\Delta Q)}{A(\Delta S = \Delta Q)}$

TCP and $\Delta S = \Delta Q$

Decay Rates

$$\Gamma(K_S \to \pi\ell\nu) = \Gamma(K_L \to \pi\ell\nu)$$

Leptonic Asymmetry

$$\mathcal{A}_\ell^S = \mathcal{A}_\ell^L$$

It is not possible to disentangle both within the K_S-K_L system.

It is necessary to combine with K^0 (or $\bar{K}^0$) states tagged by SI.

Need *eg*, $e^+e^-\to\phi\to K^+K^-$. One K tags the other. Charge exchange in any material gives K^0(or $\overline{K^0}$).

If $c = d = 0$, then

$$\mathcal{A}_\ell^S - \mathcal{A}_\ell^L = 4\Re\delta$$

A limit from the above improves the determination of $\left(M(K^0) - M(\overline{K^0})\right)/M$

Need $n \times 10^{10}$ K's, tens of fb^{-1}

TCP can be violated in mass-matrix and/or decay amplitudes: 5 complex parameters for $K\to\pi\ell\nu$.

$$2\delta = \epsilon_S - \epsilon_L$$

$$a = A(TCP\text{-even},\ \Delta S = \Delta Q)$$

$$b = A(TCP\text{-odd},\ \Delta S = \Delta Q)$$

$$c = A(TCP\text{-even},\ \Delta S = -\Delta Q)$$

$$d = A(TCP\text{-odd},\ \Delta S = -\Delta Q)$$

$K^{\pm}\!\to\!3\pi$ Decays

There are four $\not{C}\not{P}$ asymmetries:

$$\mathcal{A}_\Gamma = \frac{\Delta\Gamma}{2\Gamma} = \frac{\Gamma(K^+ \to 3\pi) - \Gamma(K^- \to 3\pi)}{\Gamma(K^+ \to 3\pi) + \Gamma(K^- \to 3\pi)}$$

$$\mathcal{A}_g = \frac{\Delta g}{2g} = \frac{g(K^+ \to 3\pi) - g(K^- \to 3\pi)}{g(K^+ \to 3\pi) + g(K^- \to 3\pi)}$$

for both τ *i.e.* $\pi^\pm\pi^\pm\pi^\mp$ and τ' or $\pi^\pm\pi^0\pi^0$.

Asymmetry due to interference of two $\Delta I = 1/2$ amplitudes a, b

No $\Delta I = 3/2$ suppression. $\Im a/\Re a{\sim}\Im b/\Re b{\sim}10^{-4}$. But to lowest order in chiral perturbation $\arg a = \arg b$. Asymmetries in SM are therefore very small.

Example:

$$\mathcal{A}_g = \left(\frac{\Im b}{\Re b} - \frac{\Im a}{\Re a}\right) \sin(\alpha_0 - \beta_0) = \mathcal{O}(10^{-6})$$

$\alpha_0 - \beta_0$ small rescattering phases, sin(..)$\sim$0.1.

From Maiani and Paver:

$$\mathcal{A}_g, \tau = (-2.3 \pm 0.6) \times 10^{-6}$$

$$\mathcal{A}_g, \tau' = (1.3 \pm 0.4) \times 10^{-6}$$

$$\mathcal{A}_\Gamma, \tau = (-6 \pm 2) \times 10^{-8}$$

$$\mathcal{A}_\Gamma, \tau' = (2.4 \pm 0.8) \times 10^{-8}$$

But where things are small big surprises might hide.

D'Ambrosio, Isidori, Martinelli:

Large $\not{C}\not{P}$ effects, A_g of $\mathcal{O}(10^{-4})$, could be triggered by a misalignment of quark and squark mass matrices through the chromomagnetic operator - CMO:

possible only if several conditions. . . conspire in the same direction.

Fine tuning becomes then necessary for explaining $\Re(\epsilon'/\epsilon)$.

CP, Unitarity and Triangles

The price of $\not{C}\not{P}$: $J = A^2\lambda^6\eta$=(2.7$\pm$1.1)$\times$10^{-5}, *i.e.* poorly known.

J is also (2$\times$)area of all unitary triangles.

Check closing of all triangles and compare their areas.

Still many measurements needed for B's, one for K's

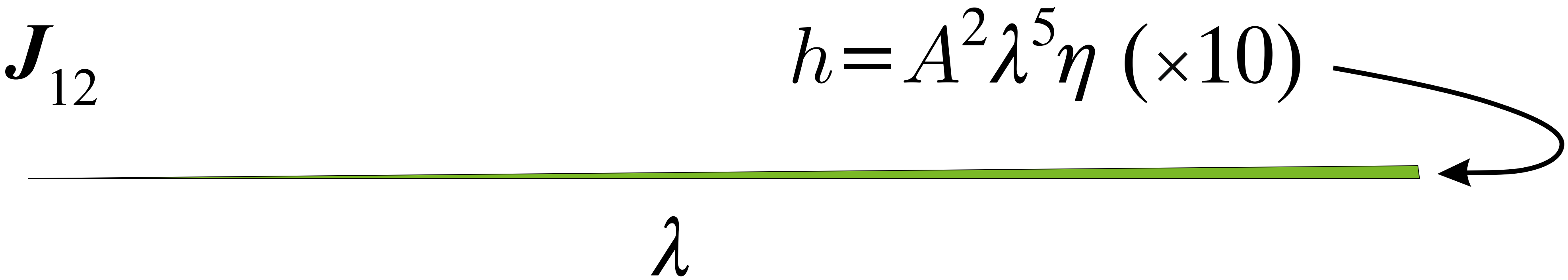
Notation

Wolfenstein

$$\mathbf{V} = \begin{pmatrix} 1-\frac{1}{2}\lambda^2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{1}{2}\lambda^2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}.$$

λ=0.22 to ∼1%, A∼0.84±0.09, $|\rho - i\eta| \sim$ 0.3±50%.

The K Triangle

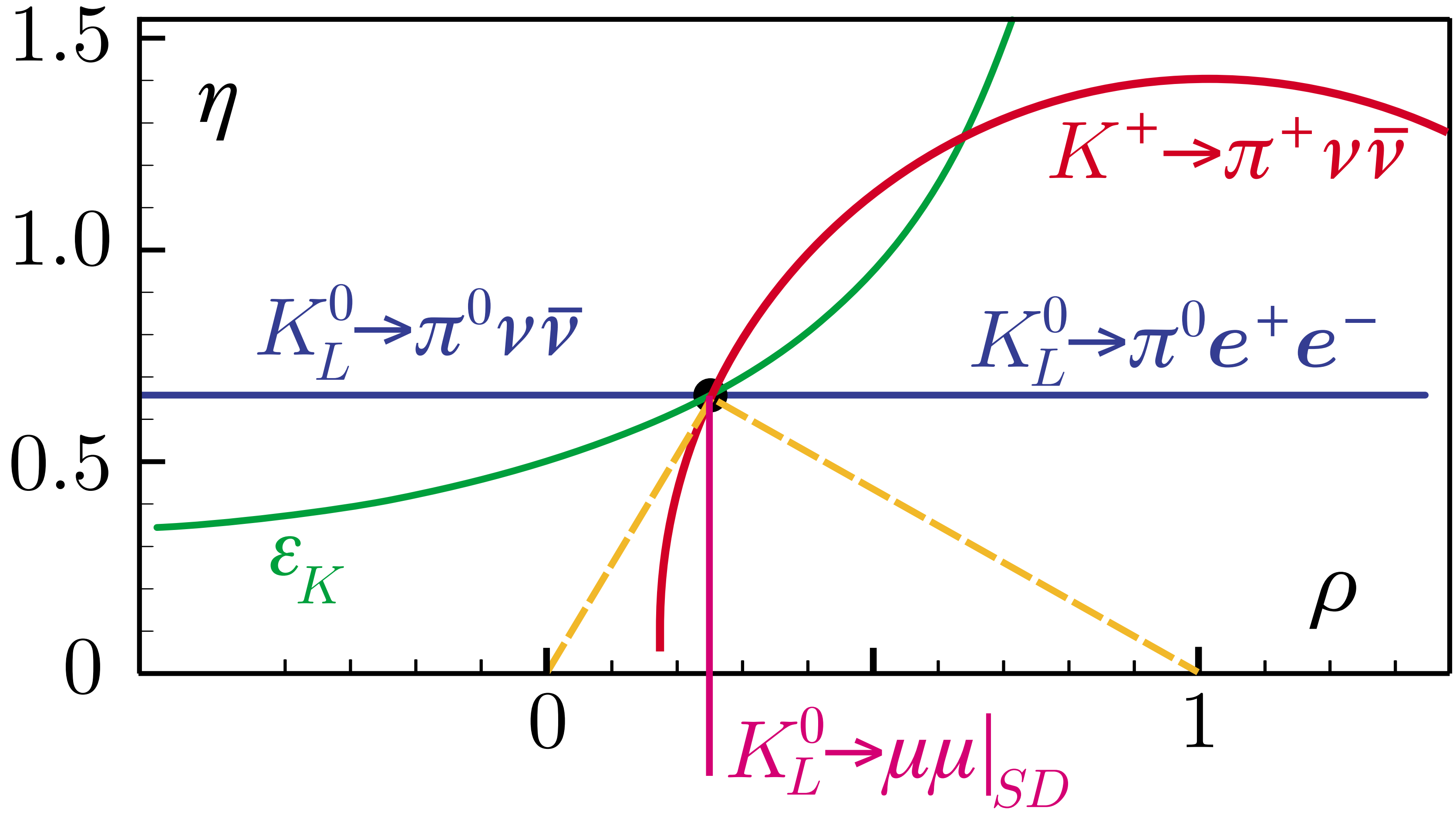


$$\frac{\delta J_{12}}{J_{12}} = 6\% \oplus \frac{\delta\eta}{\eta}$$

$$\Gamma(K_L \to \pi^0\nu\bar{\nu}) \propto \eta^2; \qquad \mathrm{BR}{\sim}3 \times 10^{-11}$$

$$J_{12} = \lambda(1 - \lambda^2/2)\Im(V_{td}V_{ts}^*) \approx 5.6[B(K_L \to \pi^0\nu\bar{\nu})]^{1/2}$$

100 events determine $\delta\eta/\eta$ to 5% and J_{12} to $\sim$8%.



$K^+ \to \pi^+ \nu\bar{\nu}$: 2 events, BR$\sim 1.5 \times 10^{-10}$

Unitarity

The most stringent proof so far is the extended GIM cancellation in $M(K_L) - M(K_S)$ and $K^0 \to \mu\mu$

Additional testing should not be limited to the closing of a triangle, but of all triangles.

AND must verify the equality of the areas of all triangles.

NA48/1

NA48/1: Unique Opportunity for $K_S \rightarrow \pi^0 e^+ e^-$ ($\mu^+\mu^-$)

- Use NA48 Detectors and beam-line
  - Exploits the NA48 collimator technique and 400 GeV SPS p beam
  - Intensity can be increased several hundred times wrt to double beam
- $K_S \rightarrow \pi^0 l^+ l^-$, $l=e,\mu$
- Search for CPV in K_S decays $K_S \rightarrow 3\pi^0$, $K_S \rightarrow \pi^+\pi^-\pi^0$
- 1999: 40h test run
  - BR($K_S \rightarrow \gamma\gamma$) = $(2.6 \pm 0.4 \pm 0.2)\ 10^{-6}$ PL B493 (2000) 29
  - BR($K_S \rightarrow \pi^0 e^+ e^-$) < 1.4×10^{-7} 90% CL PL B514 (2001) 253

  $\Rightarrow$ BR$(K_L \rightarrow \pi^0 e^+ e^-)_{mixing}$ < 4.2×10^{-10} 90% CL
- 2002:
  - Scheduled to run for about 80 days: it aims to reach SES ~3 10^{-10} for $K_S \rightarrow \pi^0 ee$ (Cut of beam time by 25% due to CERN budget crisis)

$K_L \to \pi^0 e^+e^-$ and $K_L \to \pi^0\mu^+\mu^-$

•SM prediction: BR(Direct CPV)~$(\mathrm{Im}V_{td})^2 \times 3\ 10^{-4}$

•Mixing contamination:

- BR(CP-Violation mixing)~1/300 BR($K_S \to \pi^0 e^+e^-$)

•CP-Conserving Component

- To be bound by studying $K_L \to \pi^0\gamma\gamma$

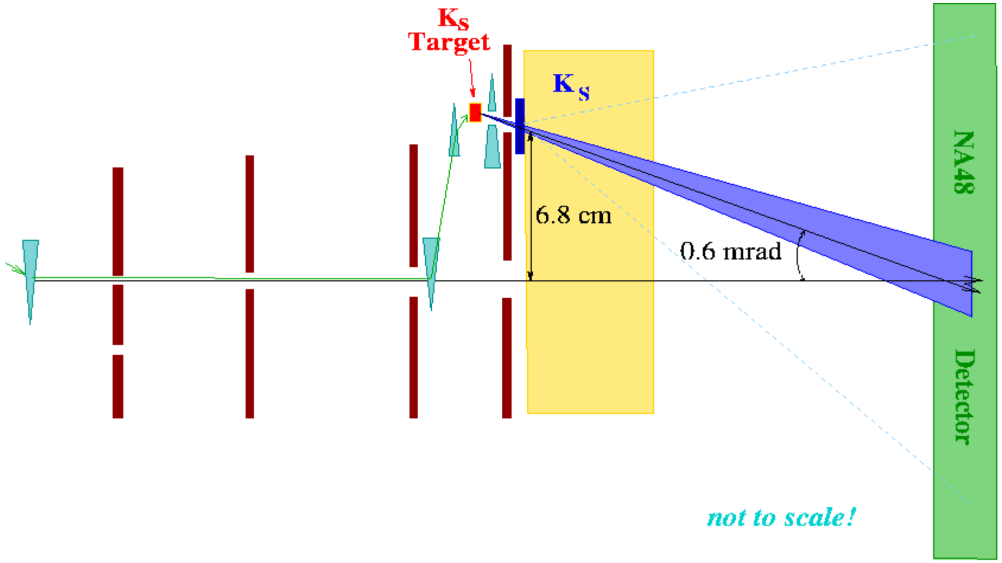
• Background from $K_L \to ee\gamma\gamma$ (Greenle, 1990) starts to be seen

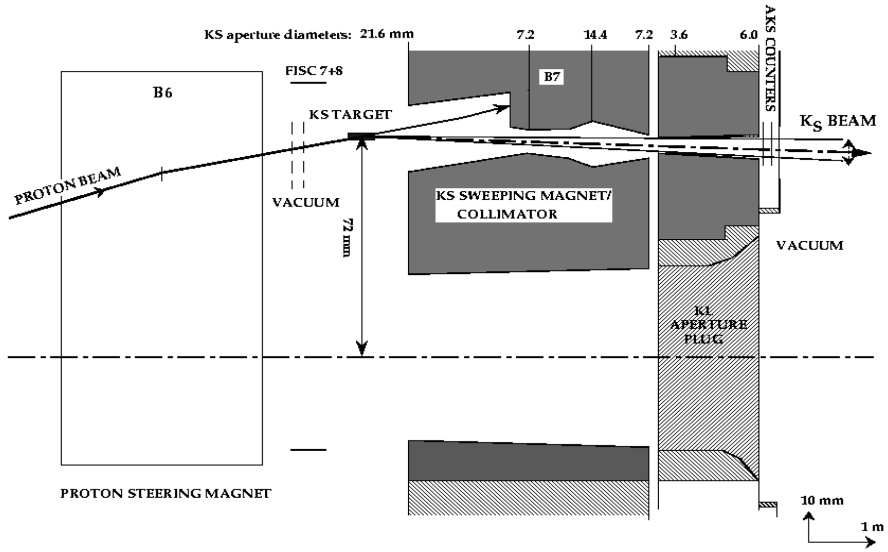
Mode	Upper Limit (90% CL)	Exp.	Ref.
$BR(K_L \to \pi^0 e^+ e^-)$	<5.1 10^{-10}	KTeV	PRL86 (2001)
$BR(K_L \to \pi^0 \mu^+ \mu^-)$	<3.8 10^{-10}	KTeV	PRL84 (2000)

New approach: measure muon polarization in $K_L \to \pi^0\mu^+\mu^-$ (Diwan, Ma, Trueman, hep-ex/0112350). Very large asymmetries are expected

NA48/1: Unique Opportunity

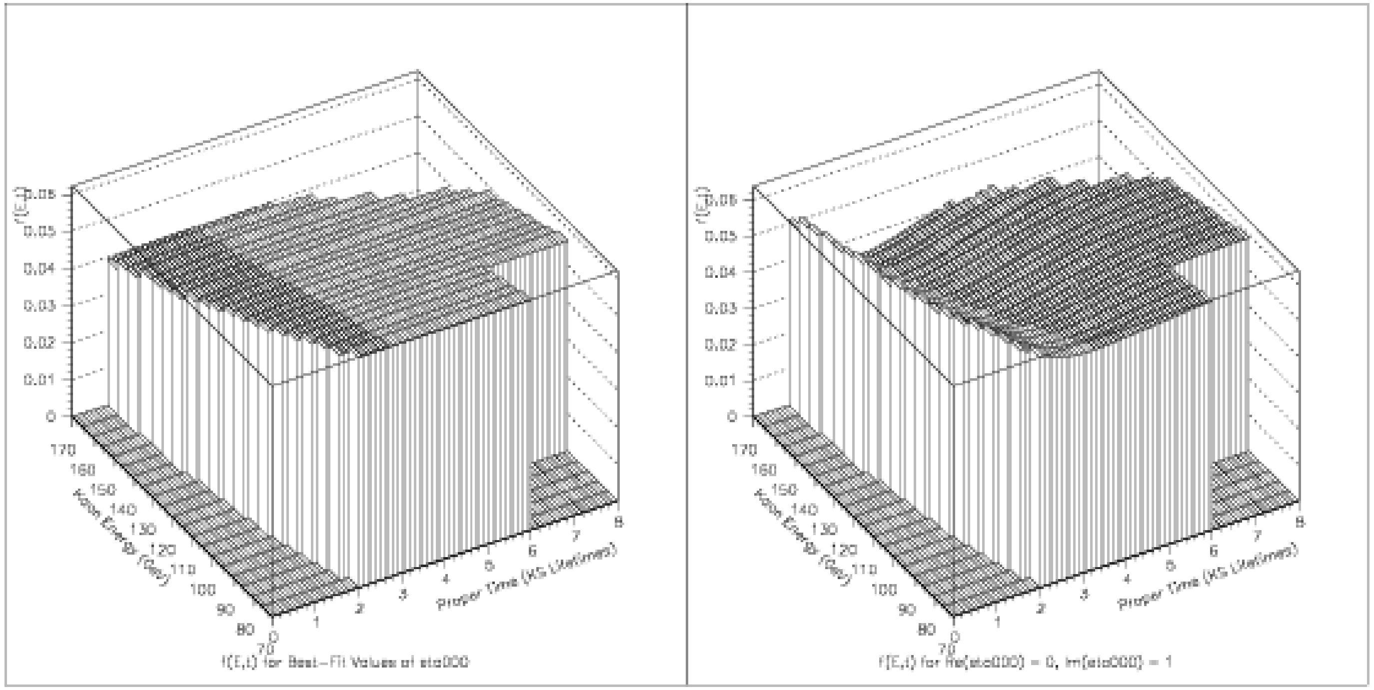
- Use NA48 Detectors and beam-line
- Sensitivity better than a factor of 10 or more over the competition
  - Exploits the NA48 collimator technique
  - Intensity can be increased hundred times wrt to double beam





$K_{S,L} \rightarrow 3\pi^0$ (45 days, 2000 Preliminary)

- Search for interference at small proper time
- The analysis of 10% of the data is quite advanced:
  - Statistical error: $Im(\eta_{000})$ =2.8% $Re(\eta_{000})$ = 2.2%
  - Systematic errors under evaluation



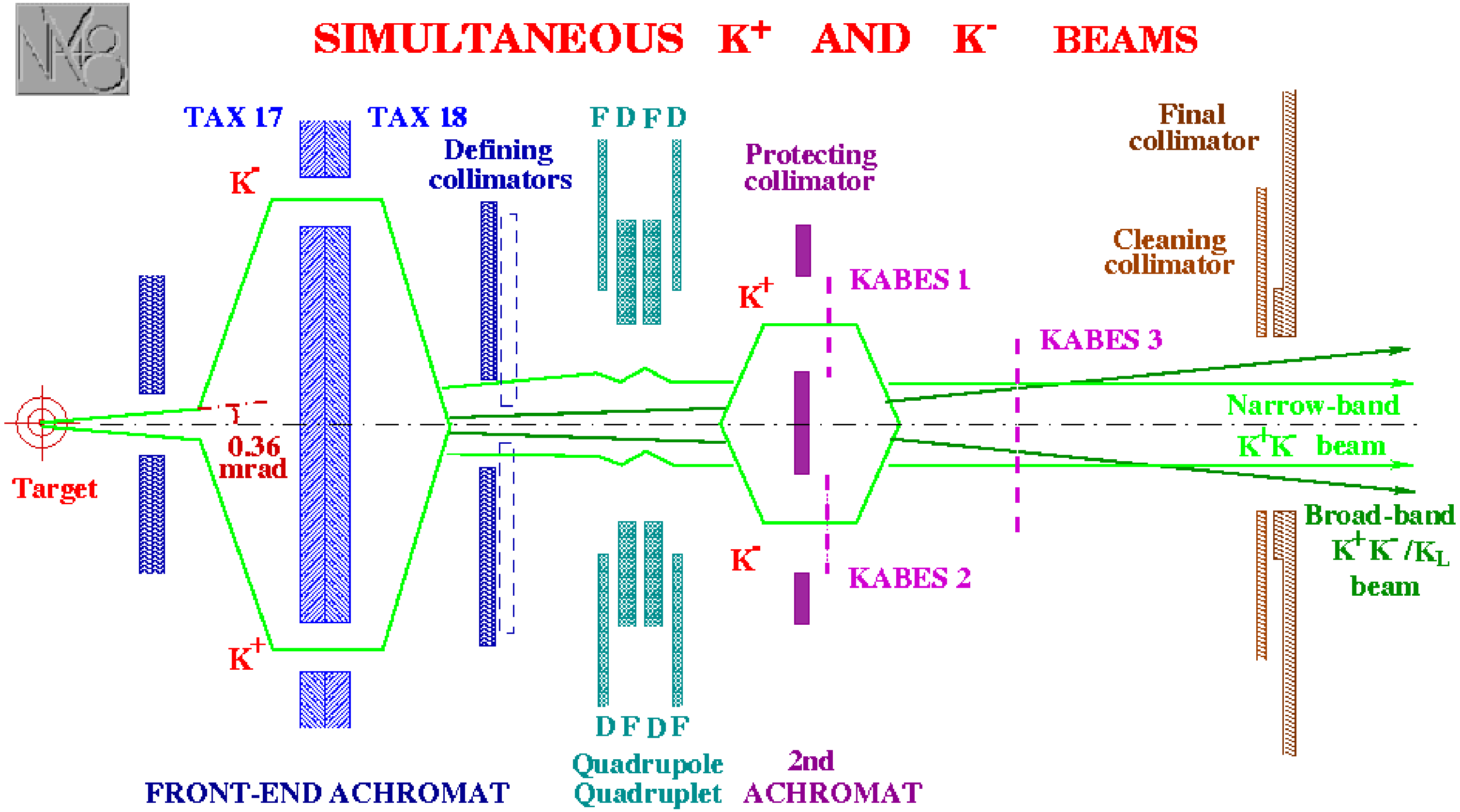
30/10/2001 SPSC 27

Preparations for 2002

- Modification of the KS target station
  - Installation of sweeping magnet
  - Provision for a photon converter
- Improvement to Drift Chamber front end
  - Better noise immunity →lower Drift Chamber High Voltage
- Upgrade of the Drift Chamber read-out
  - Remove loss due to overflows (30% in 1999 test run)
- New readout procedure for LKr and Upgrade of the online PC farm
  - Increase Level II bandwidth (currently limited by LKr)
  - Up to 1 Gbyte/burst

NA48/2

New technique: Simultaneous, unseparated K^+/K^- beams
60 GeV; narrow band ($\Delta P/P \sim 10\%$ R.M.S.)
5.5 (3.1) 10^{10} $K^+(K^-)$ decays/year (foreseen 2003)
$\Rightarrow$Push the measurement of A_g to 10^{-4}



21-26 January, 2002 WIN02 Christchurch, NZ 34

Direct CP Violation in $K^{\pm} \rightarrow \pi^{\pm} \pi^{+}\pi^{-}$

- Important to gather other $|\Delta S|=1$ CP violating effects

- Effects are predicted to be small: SM ($O \sim 10^{-5}$), SUSY ($O \sim 10^{-4}$)

D'Ambrosio, Isidori, Martinelli, PLB480(2000)

$$|M(u,v)|^2 \propto 1 + gu + hu^2 + kv^2 + \ldots \qquad u = (s_3 - s_0)/m_\pi^2 \qquad v = (s_1 - s_2)/m_\pi^2$$

$$S_0 = \frac{1}{3}(s_1 + s_2 + s_3) \qquad S_i = (P_K - P_i)^2 \qquad P_K, P_i = \text{momenta of kaon and pions (i=3 odd pion)}$$

$$A_g = \frac{(g_+ - g_-)}{(g_+ + g_-)}$$

- PDG: $A_g = (-7.0 \pm 5.3) \times 10^{-3}$ W.T. Ford et. al. 1970

- New data FNAL-HyperCP, 5% -preliminary!-

→No CP-Violation seen at a few per mill level

FERMILAB-CONF-01-321-E

KAon BEam Spectrometer

To resolve:

- *twofold ambiguity in K_{e4} reconstruction*
- *reconstruction of 2π events in $K^{\pm} \to (3\pi)^{\pm}$*

  (one π escaped detection)

- **Requirements:**

  $\delta P/P \approx 1\%$; $\theta_{X,Y} \leq 2$ *mrad*; *beam flux ~40 MHz*

- **Solution:**

  beam **measurement** in achromat **II** & downstream

  $\delta_{X,Y} \approx 0.25$ *mm*; $\delta t \approx 1$ *ns*; $\Delta X / X_0 \approx 10^{-3}$

KABES proposal

- **3 double stations of projection chambers with *MicroMegas* type amplification stage**

- **Two prototypes**:

  50 & 100 μm gaps; strips < 1mm; 60mm drift

- **Are tested now at SPS:**

  high intensity beam ($< 2\cdot10^7$ p/p)

- **Ongoing optimisation:**

  gas mixtures, electronics, position, ...

V.Kekelidze

Asymmetry

- **Obtained in few hours test run (*preliminary*):**

$$A_g = (-2 \pm 7) \cdot 10^{-3}$$

in accordance with $\approx 3.7 \cdot (1/N^{+} + 1/N^{-})^{1/2}$

- **The best direct measurement (*BNL*):**

$$(-7 \pm 5) \cdot 10^{-3}$$

ϕ–factory Yields

Parameter	Design	2001	2004
Bunches	120	45	
Current (A)	5	1.2	
$\mathcal{L}$ (μb^{-1} s^{-1})	5×10^{32}	5×10^{31}	5×10^{33}
Beam τ (m)	$\gg$100	$<$20	
$\int_{1y} \mathcal{L}dt$ pb^{-1}	5000	$\sim$190	50,000

The uniqueness of $e^+e^- \to \phi \to K_S K_L$

$$| \, i \, \rangle = \frac{| \, K^0, \mathbf{p} \, \rangle | \, \overline{K}^0, -\mathbf{p} \, \rangle - | \, \overline{K}^0, \mathbf{p} \, \rangle | \, K^0, -\mathbf{p} \, \rangle}{\sqrt{2}}$$

$$| \, K_S \, \rangle \equiv p' | \, K^0 \, \rangle + q' | \, \overline{K}^0 \, \rangle \qquad |p'|^2 + |q'|^2 = 1$$

$$| \, K_L \, \rangle \equiv p | \, K^0 \, \rangle - q | \, \overline{K}^0 \, \rangle \qquad |p|^2 + |q|^2 = 1$$

$$| \, i \, \rangle = \frac{| \, K_S, \mathbf{p} \, \rangle | \, K_L, -\mathbf{p} \, \rangle - | \, K_L, \mathbf{p} \, \rangle | \, K_S, -\mathbf{p} \, \rangle}{\sqrt{2(qp' + q'p)}}$$

CPT invariance requires $p' = p$ and $q' = q$

1. Pure, K_L, K_S, K^0, $\overline{K}^0$ beams

2. Kaon interferometry

From unitarity and $\sigma(\gamma\gamma \to K^0\overline{K}^0, J^P = 0^+)$

$$\frac{e^+e^- \to K_S K_S \text{ or } K_L K_L}{e^+e^- \to \phi \to K_S K_L} \sim \text{few} \times 10^{-10}$$

Unique opportunity to study:

K_S BR's to high accuracy

K_S Rare decays: K_S semileptonic... $K_S \to \pi^0\pi^0\pi^0$, $K_S \to \pi^0 \nu\bar{\nu}$

in addition to CP and CPT, the original mission of KLOE.

Things to do

1. Measure V_{ij}
2. Verify unitarity
3. Find $K_S \rightarrow \pi^0 \pi^0 \pi^0$
4. Study $K_S \rightarrow \pi \ell \nu$
5. Verify $\Delta S = \Delta Q$
6. Keep an eye on TCP
7. Hopefully peek beyond the SM

Mode	BR	Acc.	Events	Acc	Events	Note
		KLOE		NA48		
$K_S \to \pi^+\pi^-$	0.67	0.15	5×10^9			
$K_S \to \pi^0\pi^0$	0.31	0.15	2.5×10^9			
$K_S \to \pi e \nu$	7.4×10^{-4}	0.05	2×10^6			
$K_S \to \pi^0 e^+ e^-$	5.2×10^{-9}	0.05	13	0.05	7	Ind $\not{C}\not{P}$
$K_S \to 3\pi^0$	2×10^{-9}	0.17	16	0.05	4	η_{000}
$K_S \to \pi^0\gamma\gamma$	4×10^{-8}	0.15	300	0.1	114	
$K_S \to \pi^+\pi^-\gamma$	1.8×10^{-3}	0.15	1.35×10^7			
$K_S \to \pi^+\pi^-\pi^0$	3.2×10^{-7}	0.17	2500			
$K_L \to \pi^+\pi^-\pi^0$	0.12	0.16	1×10^9			
$K_L \to \pi^+\pi^-$	0.002	0.11	1.1×10^7			
$K_L \to \pi^0\pi^0$	0.001	0.1	4×10^6			
$K_L \to \pi^+\pi^-\gamma$	4.6×10^{-5}	0.16	3.7×10^5			

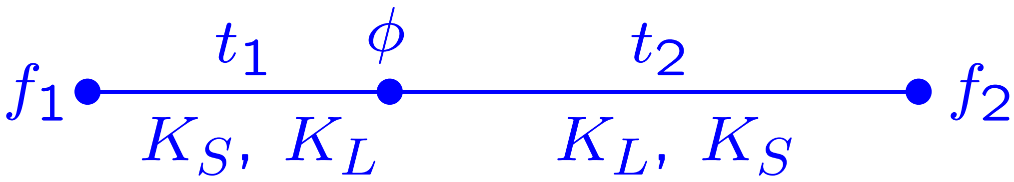
Mode	BR	Acc.	Events	Acc,	Events	Note
		KLOE		NA48		
$K^{\pm}\to\pi^{+}\pi^{-}\pi^{\pm}$	0.056	0.03	1.26×10^{8}		2×10^{9}	(1)
$K^{\pm}\to\pi^{0}\pi^{0}\pi^{\pm}$	0.017	0.09	1.22×10^{8}		1.2×10^{8}	(2)
$K^{\pm}\to\pi^{\pm}\pi^{0}\gamma$	2.8×10^{-4}	0.1	2×10^{6}	0.1	1×10^{6}	(3)
$K^{\pm}\to\pi^{\pm}\gamma\gamma$	5×10^{-7}	0.15	3750			

Notes:

(1). KLOE: $\delta A_g=4\times10^{-4}$, $\delta A_\Gamma=10^{-4}$. NA48/2: $\delta A_g=2\times10^{-4}$.

(2). KLOE: $\delta A_g=2\times10^{-4}$, $\delta A_\Gamma=10^{-4}$. NA48/2: $\delta A_g=3.5\times10^{-4}$.

(3). KLOE: $\delta A_\Gamma=10^{-3}$. NA48/2 $\delta A_\Gamma=10^{-2}$.



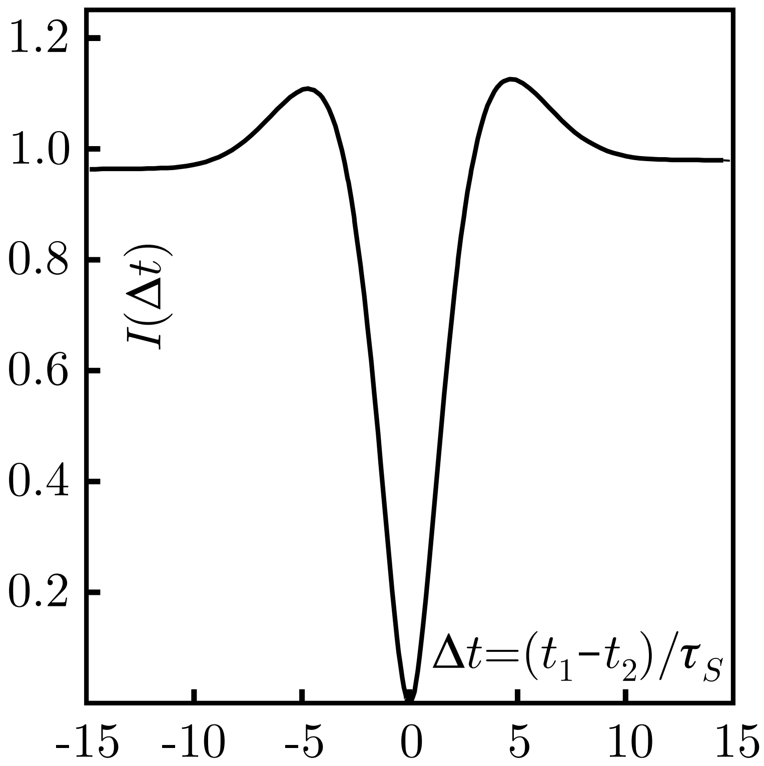
$$I(f_1,f_2,t_1,t_2) = |\langle\, f_1|\, K_S\,\rangle|^2 |\langle\, f_2|\, K_S\,\rangle|^2 e^{-\Gamma_S t/2} \times$$
$$[|\eta_1|^2 e^{\Gamma_S \Delta t/2} + |\eta_2|^2 e^{-\Gamma_S \Delta t/2} - 2|\eta_1||\eta_2| \cos(\Delta m\, t + \phi_1 - \phi_2)]$$

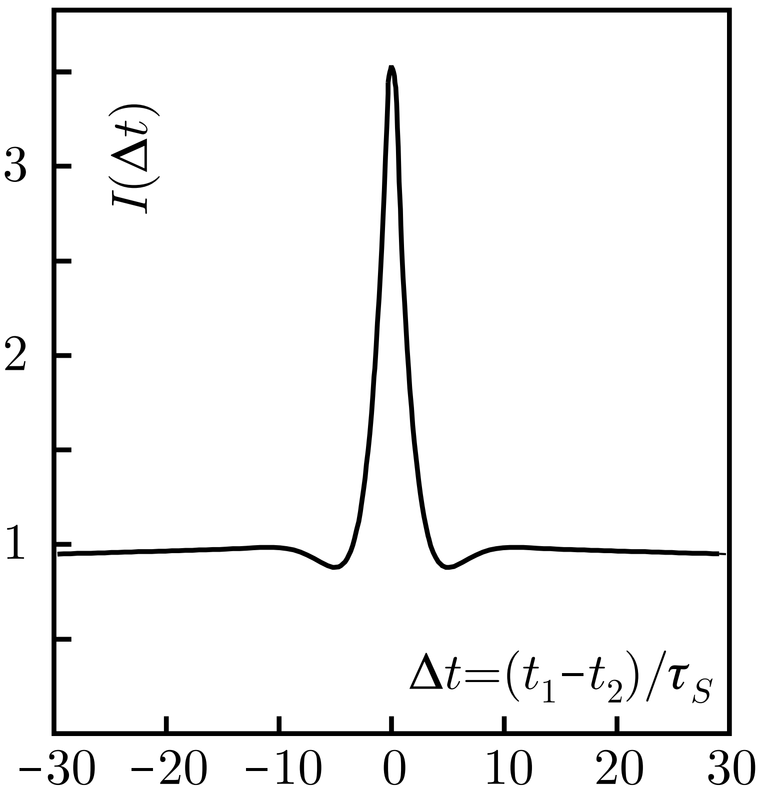
$$I(f_1,\ f_2;\ \Delta t) = \frac{1}{2\Gamma} |\langle f_1|\, K_S\,\rangle\langle f_2|\, K_S\,\rangle|^2 \times [|\eta_1|^2 e^{-\Gamma_L \Delta t} +$$
$$|\eta_2|^2 e^{-\Gamma_S \Delta t} - 2|\eta_1||\eta_2| e^{-\Gamma \Delta t/2} \cos(\Delta m \Delta t + \phi_1 - \phi_2)]$$

Measure ΔM, Γ, η_i – including phases.

$$\eta_i = \frac{A(K_L \to i)}{A(K_S \to i)},\ \ \arg(\eta) = \phi$$

Interference examples





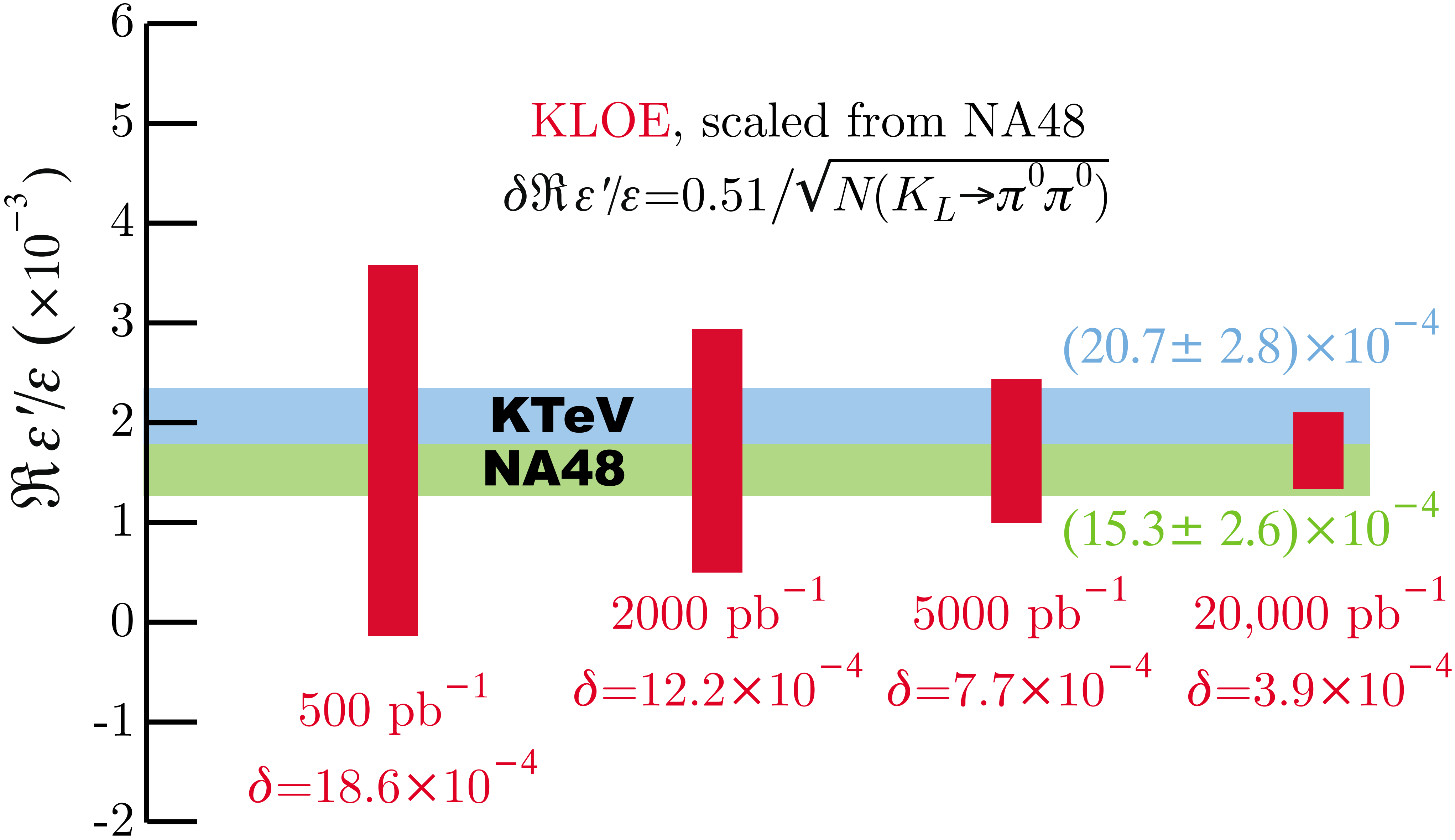
$f_{1,2}=\pi^+\pi^-,\ \pi^0\pi^0$

$\Re(\epsilon'/\epsilon),\ \Im(\epsilon'/\epsilon)$

$f_{1,2}=\ell^-,\ell^+$

$\Re$ and $\Im$ of $A_{\ell^\pm}$

KLOE vs NA48 and KTeV



K_S-decays

$\Delta I = 1/2$

Chiral expansion parameters

Calculation of $\Re(\epsilon'/\epsilon)$

BR's for K_S decays (and K_L)

$R = \Gamma(K_S \to \pi^+\pi^-)/\Gamma(K_S \to \pi^0\pi^0)$, not well known, few%

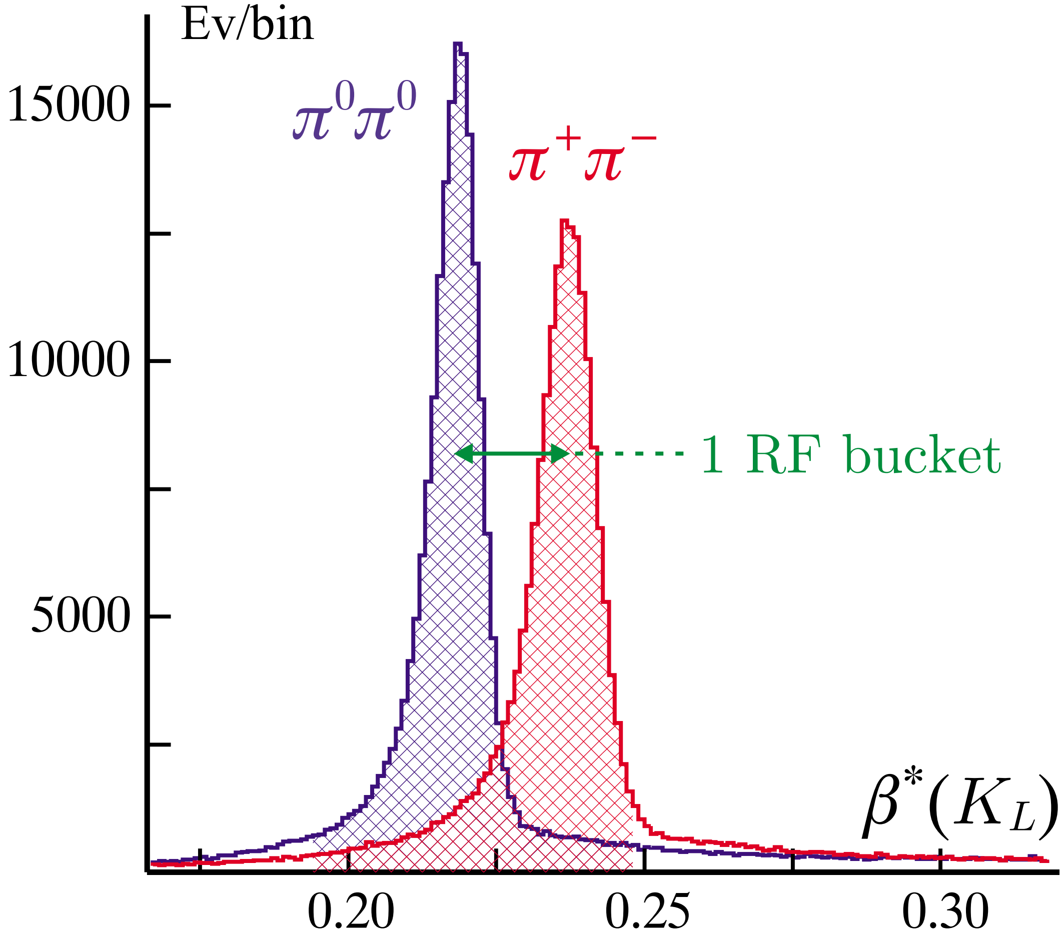
$(L \to +- /L \to 00)/(S \to +- /S \to 00)$ known to ~0.1%

Would like to reach 0.1% on former.

Corrections are background sensitive.

K_S decays

$\Gamma(K_S \to \pi^+\pi^-)/\Gamma(K_S \to \pi^0\pi^0)$

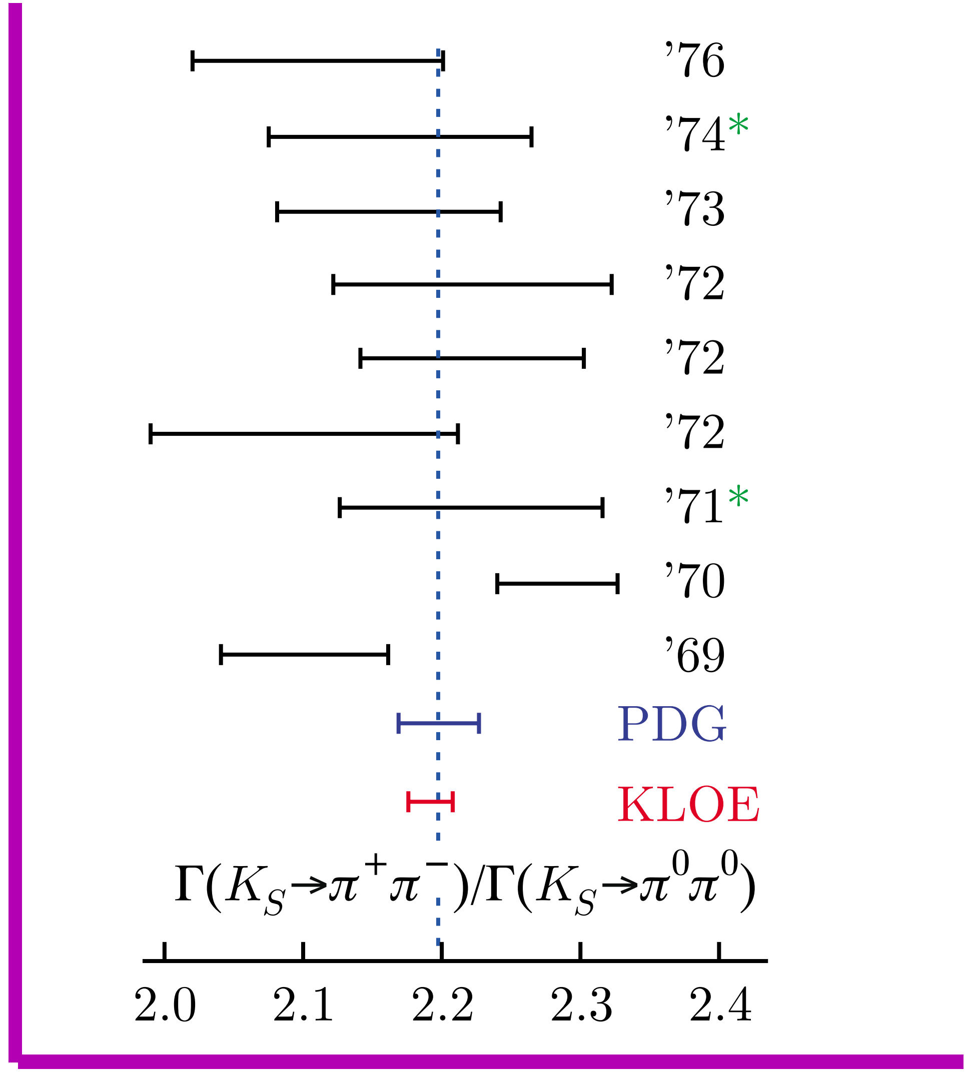


K_L interacting in the calorimeter gives an ideal K_S tag, almost independent of K_S decay mode

$K_S \to \pi\pi$

Trigger eff >96.5%
Overall accept. ∼57%
ALL FROM DATA ⇓
Systematic errors

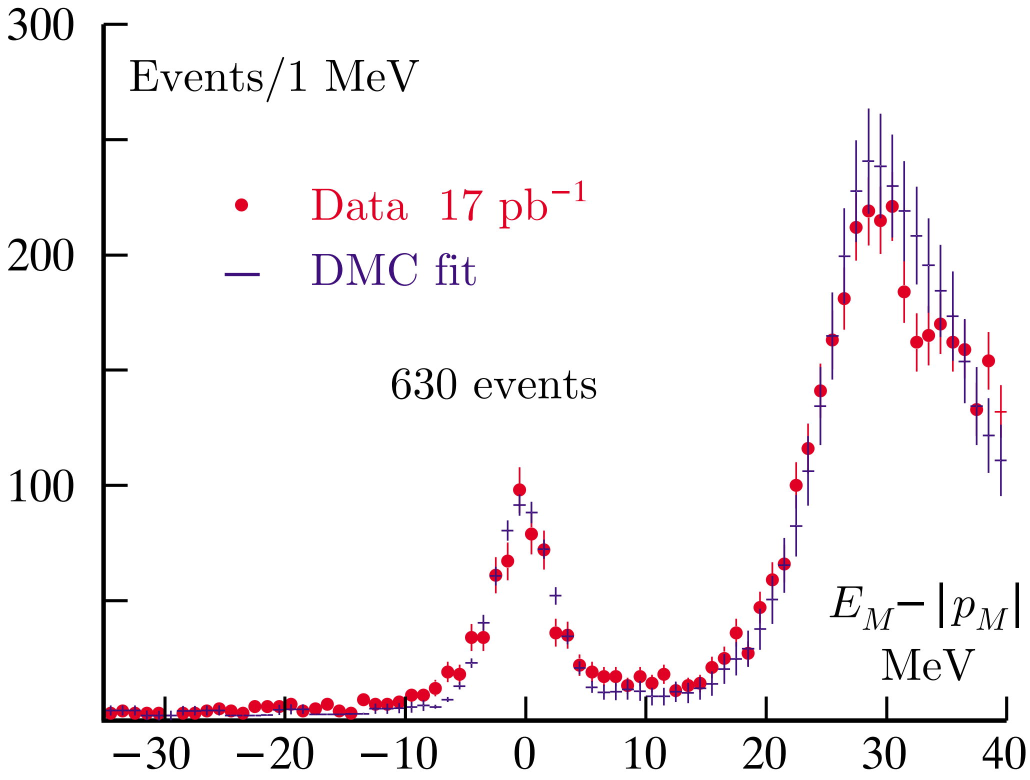
Source	Error, %
Tracking	0.2
Cluster count	0.5
Trigger	0.06
Cosmic-r. veto	0.35
Tagging	0.4
Total	0.76



$R = 2.239 \pm 0.003$(stat.)± 0.015(syst.) PLB 538, 21, June 2002

KLOE includes all $K_S \to \pi^+\pi^-\gamma$, others inc. unknown fraction.

$K_S \to \pi e \nu$ KLOE '01



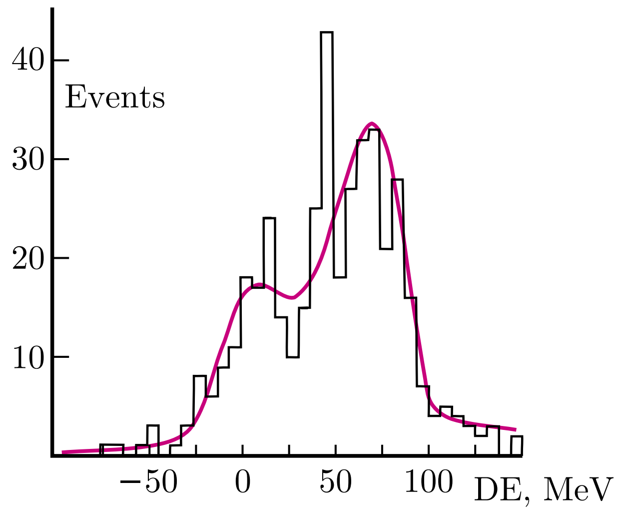
BR=$(6.91 \pm 0.37) \times 10^{-4}$

PLB 535, 37, May 2002

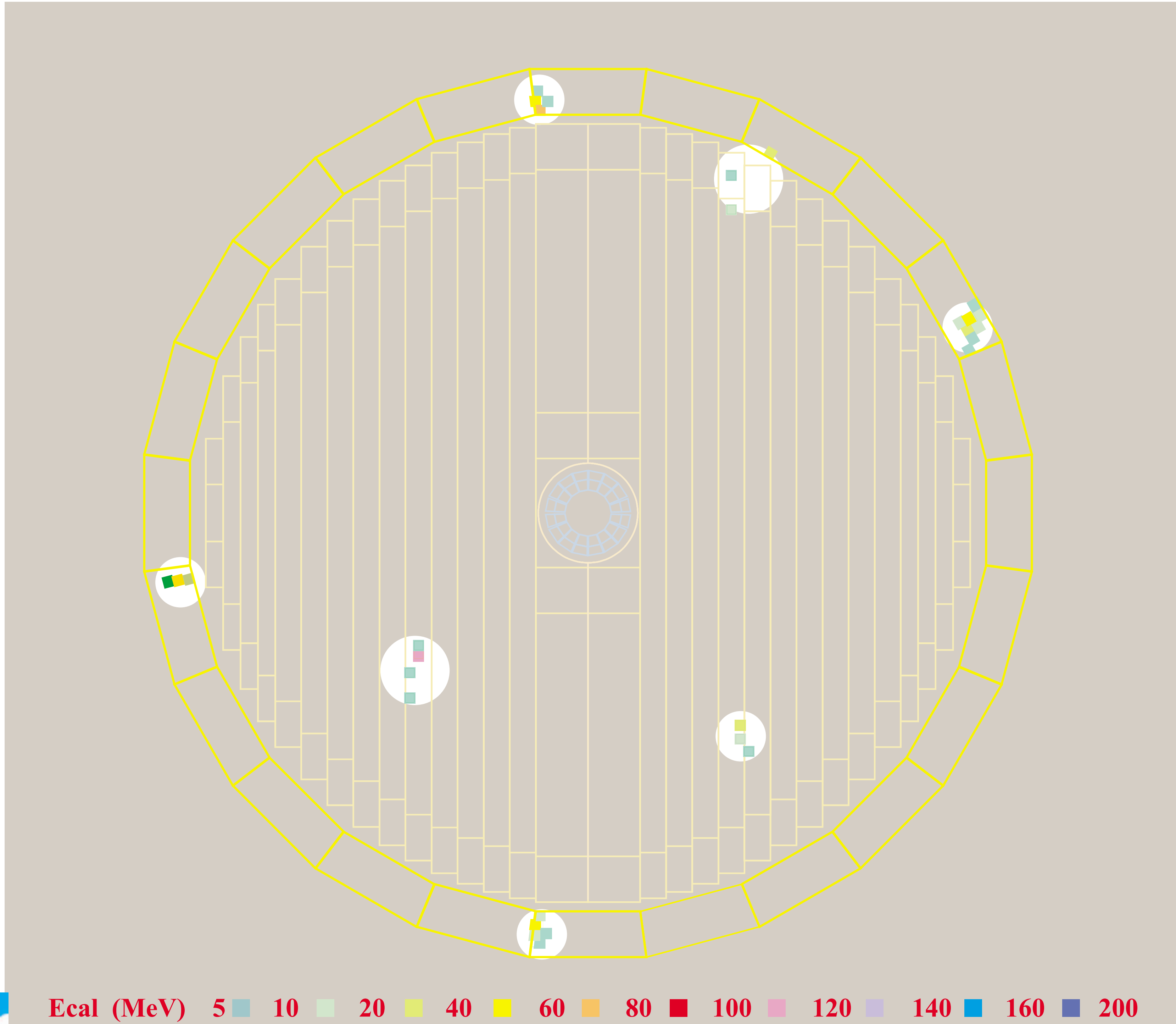
Use only non spiraling tracks. TOF for electron ID

Compare E_{miss} with $|p_{miss}|$

Almost complete rejection of $\pi^+\pi^-$ background



CMD-2 1998



Ecal (MeV) 5 10 20 40 60 80 100 120 140 160 200

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

$K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\pi^{0}$ form factors

PRELIMINARY RESULTS

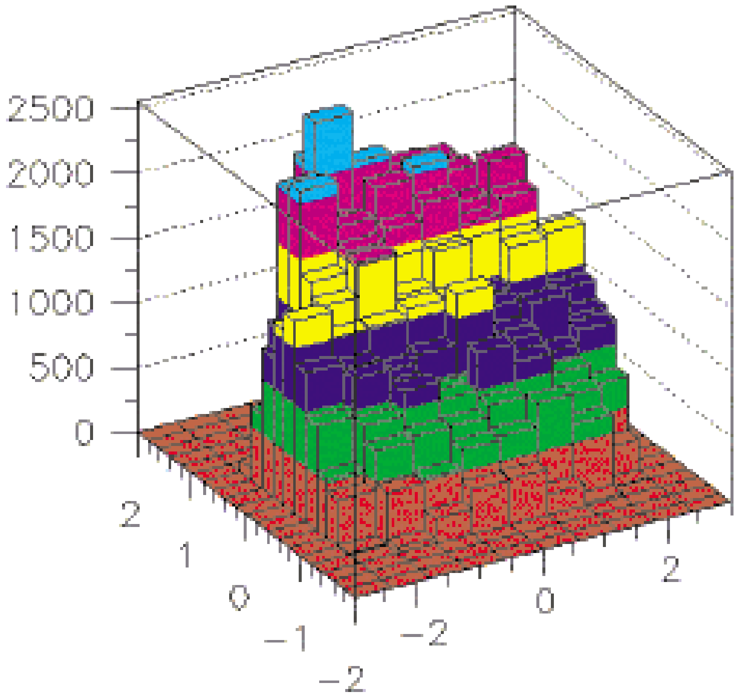
$s_i = (P_K - P_i)^2 \qquad i = 1,2,3$

$s_0 = \Sigma_i s_{i/3} = (m_K^2 + m_\pi^2 + 2m_{\pi^0}^2)_{/3}$

$$F(X,Y;g,h,k) = 1 + \mathbf{g}Y + \mathbf{h}Y^2 + \mathbf{k}X^2$$

$X = (s_1 - s_2)/m_\pi^2$

$Y = (s_3 - s_0)/m_\pi^2$



6.33 pb^{-1}
$\Rightarrow$ ~15500 $K_{\pi\pi^0\pi^0}$
(ε_{MC} normalized)

Form factor	KLOE 6.33 pb^{-1}	PDG
g	0.607±0.026	0.652±0.031
h	0.026±0.027	0.057±0.018
k	0.0080±0.0037	0.0197±0.0054

Conclusions

NA48/1 and NA48/2 will (presumably) have results by 2004.

KLOE Will begin taking data in 2004.

Thereafter one needs more intense kaon sources to attack the golden processes $K_L \rightarrow \pi^0 \nu \bar{\nu}$, $\rightarrow \pi^0 e^+ e^-$.

We have studied $\not{C}\not{P}$ for 39 years, we still have quite a few to go.