XXVIII IMFP
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17 Feb 2000

Physics @ a Φ Factory
(Mainly KLOE)

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Outline

- ✔ Introduction
- ✔ Status of DAΦNE
- ✔ Physics program at DAΦNE
- ✔ Digression on CP and CPT violation
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Introduction

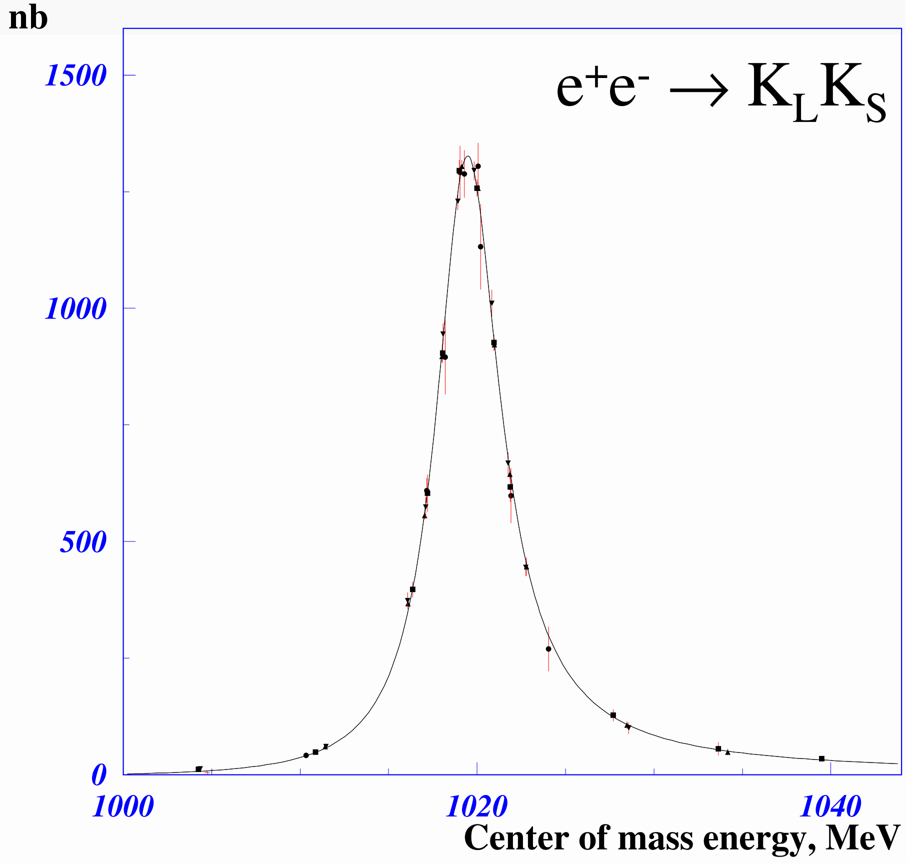
- ✔ A Φ-factory is a e^+e^- collider with $\sqrt{S} \cong M_\Phi \cong 1020$ MeV.
- ✔ Presently there are two Φ-factories: VEPP-2M & DAΦNE.
- ✔ VEPP-2M (Novosibirsk) is “standard” luminosity collider devoted to the study of hadron production from threshold to a c.m. energy of 1.4 GeV. It is in operation since 1992 and has collected 2.37 pb^{-1} @ $\sqrt{S} \cong M_\Phi$, i.e. $\sim 3 \cdot 10^5$ $K_S K_L$.
- ✔ DAΦNE (Frascati) is a high luminosity collider, mainly devoted to CP and CPT measurements. It has entered in operation in 1999 and should reach $\mathcal{L}$ **= 5 $\cdot$ 10^{32} $cm^{-2}s^{-1}$**, i.e. $\sim 2.2 \cdot 10^{10}$ ϕ mesons/year.

A Φ-factory is a Kaon factory

✔ $\sigma(\sqrt{S} \cong M_{\Phi}) \sim 4.4\ \mu b.$

Φ Decays

K^+K^-	49.1%
K_LK_S	34.3%
$\rho\pi$	12.9%
3π	2.5%
$\eta\gamma$	1.3%



Physics @ the Φ

- ✔ **KAON physics** :
  - CP/CPT violation studies (**double ratio+interferometry**)
  - rare K_S decays ($\mathbf{K_S \rightarrow \pi l\nu, \pi ee, \pi\mu\mu, \pi\nu\nu}$)
  - CPT limits $\mathbf{K_S \rightarrow \pi^+e^-\nu\ /\ \pi^-e^+\nu}$ vs $\mathbf{K_L \rightarrow \pi^+e^-\nu\ /\ \pi^-e^+\nu}$
  - kaon form factors ($\mathbf{K_L \rightarrow \pi l\nu}$, $\mathbf{K^+ \rightarrow \pi^0 l^+\nu}$)
  - ...
- ✔ **NON KAON physics** :
  - radiative ϕ decays ($\phi \rightarrow \eta\gamma$, $\eta'\gamma$, $f^0\gamma$, $a^0\gamma$, ...)
  - σ_{HAD} vs $\sqrt{s}$ ($\mathbf{e^+e^- \rightarrow \pi^+\pi^-}$ after ISR) for g-2 predictions
  - regeneration measurements at low momenta
  - ...

DAΦNE design

$\angle_{\mathrm{DA\Phi NE}} = 5\times10^{32}\ cm^{-2}\ s^{-1}$

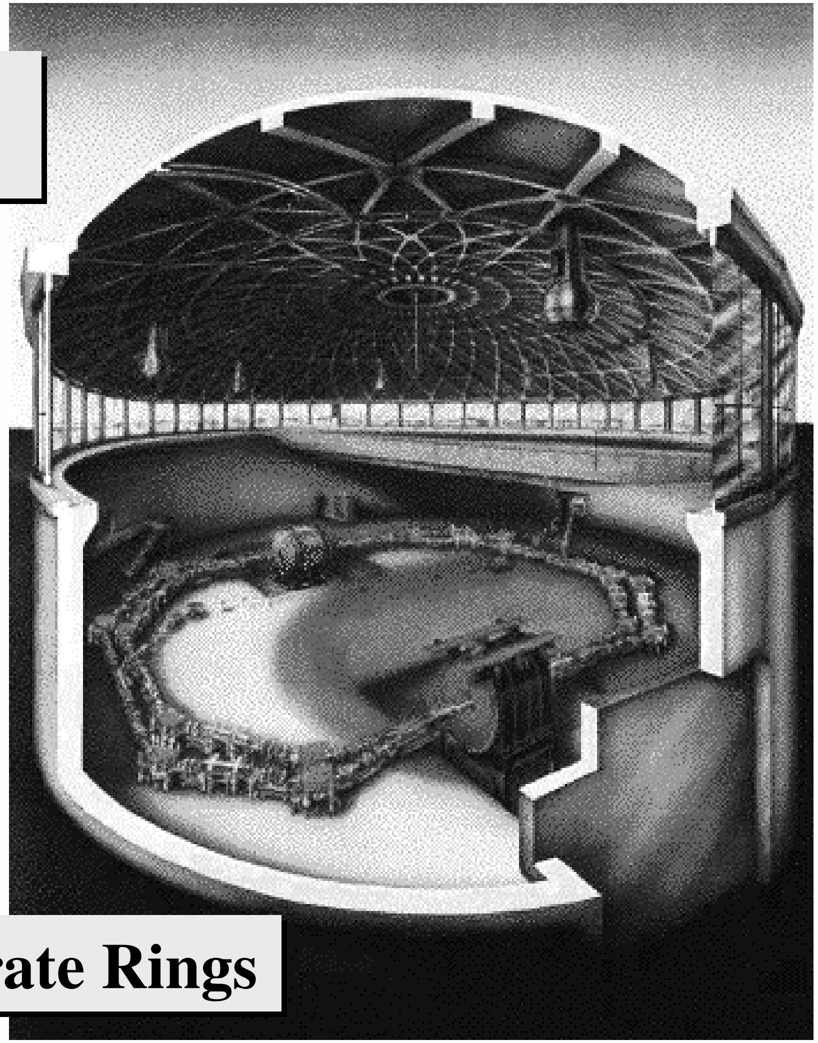
$\angle_{\mathrm{VEPP\text{-}2M}} = 5\times10^{30}\ cm^{-2}\ s^{-1}$

"conservative" single bunch approach:

$\angle_0$ (single bunch) ~ $\angle_{\mathrm{VEPP\text{-}2M}}$

<u>but</u> large number of bunches

$\angle_{\mathrm{DA\Phi NE}} = n_{\mathrm{bunches}} \times \angle_0$



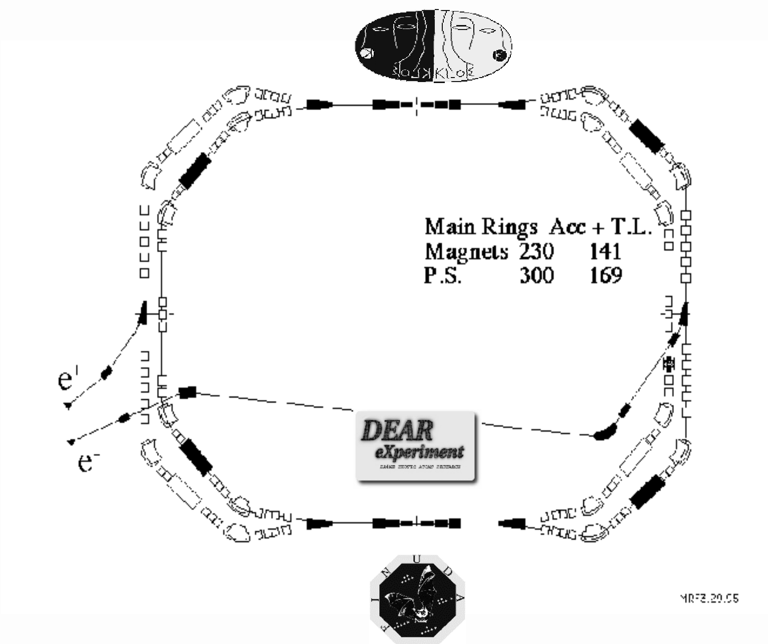
$n_{\mathrm{bunches}} \rightarrow 120 \ \Rightarrow$ **Two Separate Rings**

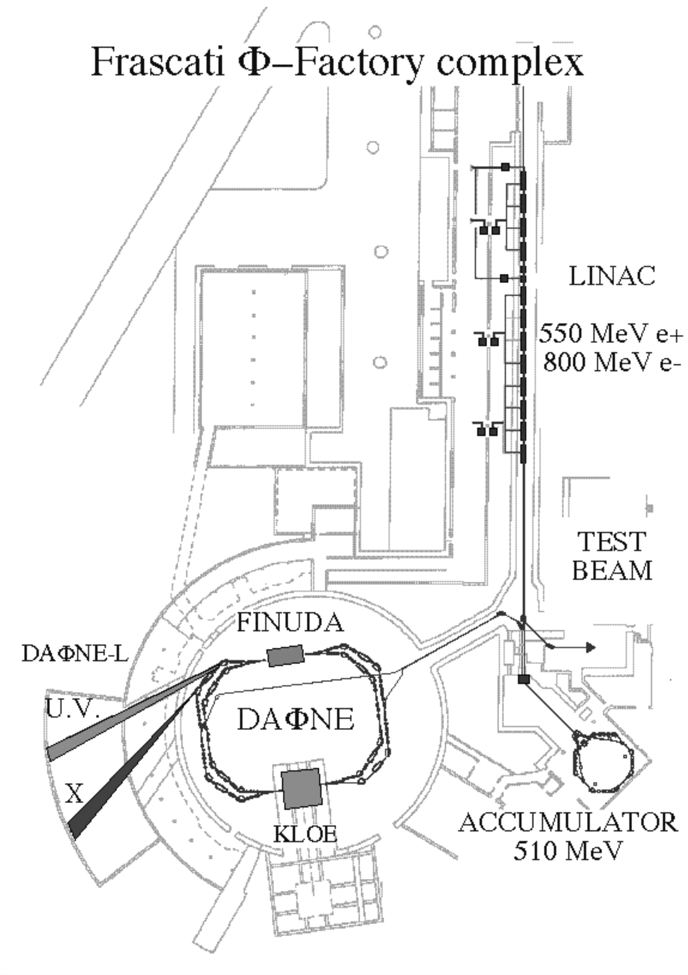
Φ-factory vs B-factories

	DAΦNE	**KEK-B**	**PEP-II**
Energy [*GeV*]	0.51	3.5/8.0	3.1/9.0
Beam-Beam Tune Shift	0.04/0.04	0.04/0.05	0.03/0.03
Trajectory [*m*]	98	3015	2200
Number of bunches	120	5120	1658
Bunch separation [*cm*]	81	59	126
Particles/bunch [10^{10}]	8.9	3.3/1.4	5.9/2.7
Crossing Angle [*mrad*]	12.5	11.0	0
Bunch lenght σ_z [*cm*]	3.0	0.4	1.0/1.1
Bunch size σ_x / σ_y [μm]	2000/20	80/2	200/6
Single Bunch ∟ [$cm^{-2}s^{-1}$]	$4.4 \cdot 10^{30}$	$1.95 \cdot 10^{30}$	$1.8 \cdot 10^{30}$

DAΦNE Layout

The DAΦNE Hall hosts three detectors: KLOE, DEAR and FINUDA.





DAΦNE physics program

KLOE
(K Long Experiment)
K mesons physics

DEAR
(DAFNE Exotic Atom Research)
Spectroscopy of kaonic Atoms (H,D)

FINUDA
(Fisica Nucleare a DAΦNE)
Spectroscopy of Hypernuclei

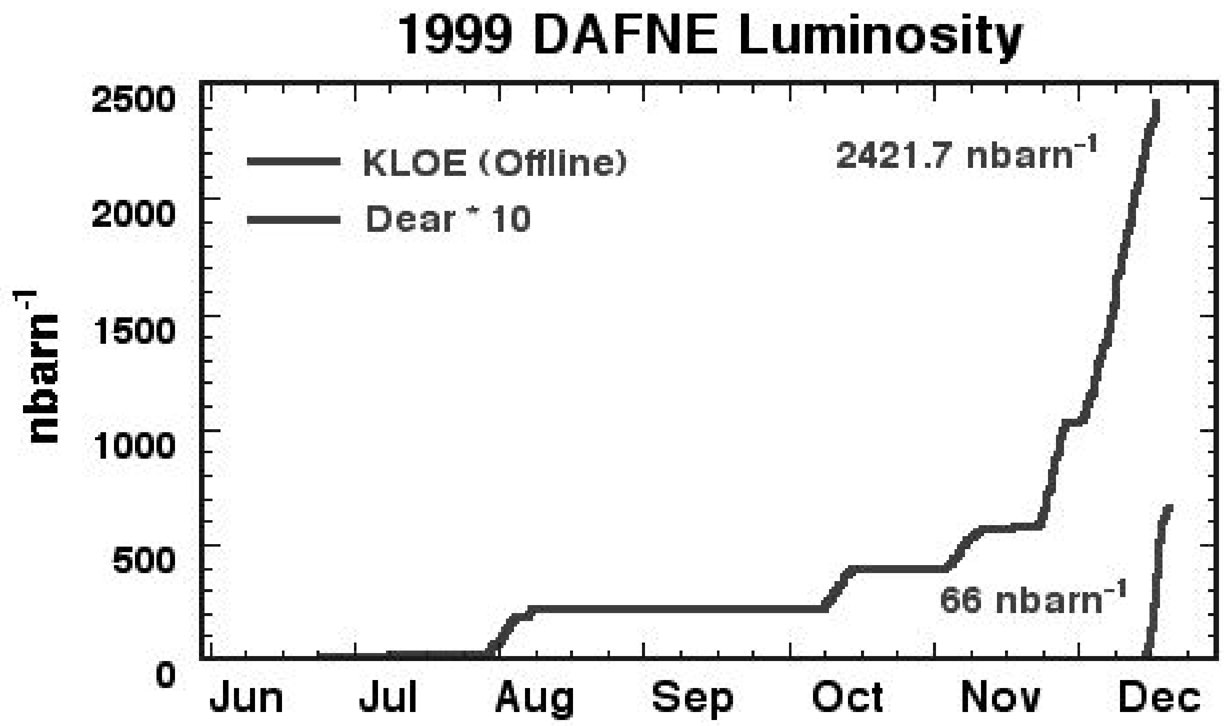
Rates

1 day @ $\mathcal{L}$ = 10^{31} cm^{-2}s^{-1} $\cong$ 1 pb^{-1} $\cong$ 10^{6} K$_L$

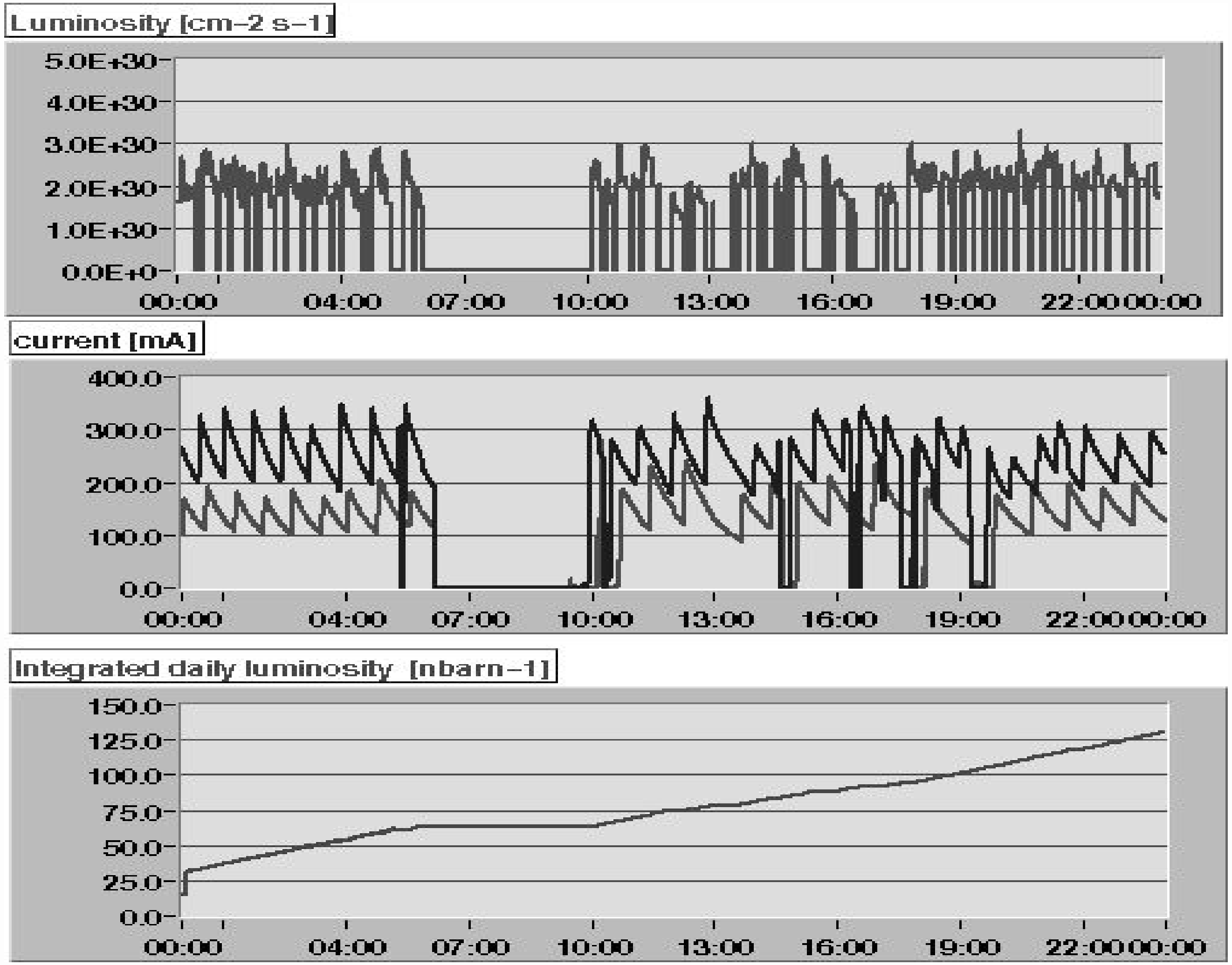
In one year @ $\mathcal{L}$ = **10^{31} cm^{-2}s^{-1}** DAΦNE could provide to KLOE 100 pb^{-1} of data (10^{8} K$_L$), which should have allowed the following physics results:

✓ Measurement of $\Re$ (ε'/ε) to 10^{-3} statistical accuracy;
✓ Measurement of $K_{\ell 3}$ form factors;
✓ First measurement of BR($\phi \rightarrow f_0\gamma \rightarrow \pi^+\pi^-\gamma$);
✓ Measurement of BR($\phi \rightarrow f_0\gamma \rightarrow \pi^0\pi^0\gamma$) to $\times$30 better accuracy;
✓ Measurement of BR($\phi \rightarrow a_0\gamma \rightarrow \eta\pi^0\gamma$) to $\times$ 30 better accuracy.

Beginning of data taking



A typically good day



Kaon production at a Φ-factory

$K_S K_L$ pairs are produced in a pure quantum state (**$J^{PC}=1^{--}$**):

$$|i\rangle = \frac{1}{\sqrt{2}}\left(\left|K^0,\vec{p}\right\rangle\left|\overline{K}^0,-\vec{p}\right\rangle - \left|\overline{K}^0,\vec{p}\right\rangle\left|K^0,-\vec{p}\right\rangle\right)$$
$$\cong \frac{1}{\sqrt{2}}\left(\left|K_S,\vec{p}\right\rangle\left|K_L,-\vec{p}\right\rangle - \left|K_S,\vec{p}\right\rangle\left|K_L,-\vec{p}\right\rangle\right)$$

✔ K_S/K_L have a momentum of ~110 MeV (p_Φ ~13MeV), with to a mean decay path of:

- λ_S = 0.56 cm
- λ_L = 354 cm

➨ Choosing different fiducial volumes it is very easy to get a pure **K_S** and **K_L** ***tagging.***

Digression on CP/CPT

$$\left| K_S, K_L \right\rangle = \text{mass eigens.}$$

$$\left| K^0, \overline{K}^0 \right\rangle = \mathrm{H}_s \ \text{ eigens.}$$

$$\left| K_1, K_2 \right\rangle = \mathrm{C}P \quad \text{eigens.}$$

$$\left| \pi^+ \pi^- \right\rangle = \sqrt{\frac{1}{3}} \left| 2,0 \right\rangle + \sqrt{\frac{2}{3}} \left| 0,0 \right\rangle$$

$$\left| \pi^0 \pi^0 \right\rangle = \sqrt{\frac{2}{3}} \left| 2,0 \right\rangle - \sqrt{\frac{1}{3}} \left| 0,0 \right\rangle$$

$$\eta_I = \frac{\left\langle f, I \,|\, H \,|\, K_L^0 \right\rangle}{\left\langle f, I \,|\, H \,|\, K_S^0 \right\rangle}$$

"Anyone who has played with these invariances knows that it is an orgy of relative phases"

A. Pais, Inward Bound

$$CP\,|\mathrm{i}\rangle = e^{i\xi_i}\,|\bar{\mathrm{i}}\rangle \quad \text{and} \quad CP\,|\bar{\mathrm{i}}\rangle = e^{-\xi_i}\,|\mathrm{i}\rangle$$

$$|\mathrm{i}\rangle \longrightarrow |\mathrm{f}\rangle(|\mathrm{g}\rangle)| \ \text{ vs } \quad |\bar{\mathrm{i}}\rangle \longrightarrow |\bar{\mathrm{f}}\rangle(|\bar{\mathrm{g}}\rangle)$$

$$\langle f\,|H|\,\mathrm{i}\rangle = Ae^{i\phi_i}e^{i\delta_i}$$

$$\langle \bar{f}\,|H|\,\bar{\mathrm{i}}\rangle = Ae^{-\phi_i}e^{i\delta_i}$$

Φ_i="weak" phases (complex coupling, phases in CKM,etc.)
δ_i="strong" phases (interaction after decay)
ξ_i="spurious" Quantum Mechanics arbitrary phases

Since T is a complex operator we can already imagine that CP violation is a matter of phases...

Mixing

$$|\mathrm{K_S}\rangle = q_s|\mathrm{K}^0\rangle + p_s|\overline{\mathrm{K}}^0\rangle = Q_1|\mathrm{K}_1\rangle + P_1|\mathrm{K}_2\rangle$$

$$|\mathrm{K_L}\rangle = q_L|\mathrm{K}^0\rangle - p_L|\overline{\mathrm{K}}^0\rangle = Q_2|\mathrm{K}_1\rangle - P_2|\mathrm{K}_2\rangle$$

$$|\mathrm{K_S}\rangle = \frac{(1+\varepsilon_K+\delta_K)|\mathrm{K}^0\rangle + (1-\varepsilon_K-\delta_K)|\overline{\mathrm{K}}^0\rangle}{\sqrt{2(1+|\varepsilon_K+\delta_K|^2)}}$$

$$|\mathrm{K_L}\rangle = \frac{(1+\varepsilon_K-\delta_K)|\mathrm{K}^0\rangle - (1-\varepsilon_K+\delta_K)|\overline{\mathrm{K}}^0\rangle}{\sqrt{2(1+|\varepsilon_K-\delta_K|^2)}}$$

$$\delta_K \xrightarrow[CPT]{} 0$$

$$\varepsilon_K \xrightarrow[CP]{} 0$$

Decay with one final state

$$i \to f \qquad \text{vs} \qquad \bar{i} \to \bar{f}$$

$$\langle f \mid H \mid \mathrm{i} \rangle = \sum_j^n (A_j + B_j) e^{i\delta_j} \xrightarrow[CPT]{} \sum_j^n \left|A_j\right| e^{i\phi_j} e^{i\delta_j}$$

$$\langle \bar{f} \mid H \mid \bar{\mathrm{i}} \rangle = \sum_j^n (A_j^* - B_j^*) e^{i\delta_j} \xrightarrow[CPT]{} \sum_j^n \left|A_j\right| e^{-i\phi_j} e^{i\delta_j}$$

$$\alpha = \frac{|\langle f \mid H \mid \mathrm{i} \rangle|^2 - |\langle \bar{f} \mid H \mid \bar{\mathrm{i}} \rangle|^2}{|\langle f \mid H \mid \mathrm{i} \rangle|^2 + |\langle \bar{f} \mid H \mid \bar{\mathrm{i}} \rangle|^2}$$

$$\alpha_{CPT}^{n=1} = 0$$

$$\alpha_{CPT}^{n=2} = \frac{-2A_1 A_2 sin(\delta_1 - \delta_2) sin(\phi_1 - \phi_2)}{A_1^2 + A_2^2 + 2A_1 A_2 \cos(\delta_1 - \delta_2)\cos(\phi_1 - \phi_2)}$$

Desiderata: ① $\delta_1 - \delta_2 \approx \frac{\pi}{2}$ ② $\phi_1 - \phi_2 \approx \frac{\pi}{2}$ ③ $A_1 \approx A_2$

Decay with two final states

$$i \to f, g \quad \text{vs} \quad \bar{i} \to \bar{f}, \bar{g}$$

$$\textit{if}\ \ \text{CPT and} \quad n = 1 \quad \text{and} \quad f = \bar{f}, g = \bar{g}$$

$$\langle f \mid H \mid \mathrm{i} \rangle = |A_1| e^{i\phi_1} e^{i\delta_1} \qquad \langle g \mid H \mid \mathrm{i} \rangle = |A_2| e^{i\phi_2} e^{i\delta_2}$$

$$\langle f \mid H \mid \bar{\mathrm{i}} \rangle = |A_1| e^{-i\phi_1} e^{i\delta_1} \mathrm{e}^{i\xi} \qquad \langle g \mid H \mid \bar{\mathrm{i}} \rangle = |A_2| e^{-i\phi_2} e^{i\delta_2} \mathrm{e}^{i\xi}$$

$$\beta = \langle f \mid H \mid \mathrm{i} \rangle \langle g \mid H \mid \bar{\mathrm{i}} \rangle - \langle g \mid H \mid \bar{\mathrm{i}} \rangle \langle g \mid H \mid \bar{\mathrm{i}} \rangle$$

$$\beta = 2iA_1 A_2 e^{i(\delta_1 - \delta_2 + \xi)} sin(\phi_1 - \phi_2)$$

Desiderata: ① $\delta_1 - \delta_2 \approx any$ ② $\phi_1 - \phi_2 \approx \frac{\pi}{2}$ ③ $A_1 \approx A_2$

Different kinds of CP Violation

(1) $\left|\frac{q}{q}\right| \neq 1$ CP Violation in *mixing*

(2) $\left|\frac{\overline{\mathrm{A}}}{\mathrm{A}}\right| \neq 1$ CP Violation in *decay*

(3) $\lambda = \frac{\mathrm{q}}{\mathrm{p}} \frac{\overline{A}_{f=CP}}{A_{f=CP}} \neq 1$ CP Violation in the *interference* between mixing and decay

CP Violation: Where to look

	Mixing	Decay	
$K^0 \to \pi^0\pi^0, \pi^+\pi^-$	ϑ	K	A_2 small
$K^0 \to \pi^0\pi^0\pi^0, \pi^+\pi^-\pi^0$	K	Λ	low BR
$K^0 \to \ell^{\pm}\nu\pi^{\mp}$	ϑ	Λ	W dominant
$K^+ \to \pi^+\pi^0$	-	Λ	n=1
$K^+ \to \ell^+\nu, \ell^+\nu\pi^0$	-	Λ	W dominant
$K^+ \to \pi^+\pi^-\pi^+, \pi^0\pi^0\pi^+$	-	KΛ	low BR

Hadronic Decays

$$\eta_{+-} = \frac{\left\langle \pi^+\pi^- \,|\, H \,|\, K_L^0 \right\rangle}{\left\langle \pi^+\pi^- \,|\, H \,|\, K_S^0 \right\rangle} \approx \varepsilon + \varepsilon' \quad \eta_{00} = \frac{\left\langle \pi^0\pi^0 \,|\, H \,|\, K_L^0 \right\rangle}{\left\langle \pi^0\pi^0 \,|\, H \,|\, K_S^0 \right\rangle} \approx \varepsilon - 2\varepsilon'$$

$$\varepsilon = \left[\varepsilon_k + i\frac{\Im(A_0)}{\Re(A_0)}\right] + \left[\frac{\Re(B_0)}{\Re(A_0)} - \delta_k\right]$$

$$\varepsilon' = \frac{e^{i(\delta_2-\delta_0)}}{\sqrt{2}}\frac{\Re(A_2)}{\Re(A_0)}\left\{i\left[\frac{\Im(A_2)}{\Re(A_2)} - \frac{\Im(A_0)}{\Re(A_2)}\right] + \left[\frac{\Re(B_2)}{\Re(A_2)} - \frac{\Im(B_0)}{\Re(A_0)}\right]\right\}$$

$$\varepsilon \xrightarrow[CPT\,\&\,\Im(A_0)=0]{} \varepsilon_k$$

$$\varepsilon \xrightarrow[CPT]{} |\varepsilon| e^{i\phi_w} \qquad \phi_w = arc\tan\left(\frac{2(m_L - m_S)}{(\Gamma_S - \Gamma_L)}\right)$$

Is $\Re(\varepsilon'/\varepsilon)$ a direct-CP test ?

$$\varepsilon' = \frac{e^{i(\delta_2-\delta_0)}}{\sqrt{2}} \frac{\Re(A_2)}{\Re(A_0)} \left\{ i\left[\frac{\Im(A_2)}{\Re(A_2)} - \frac{\Im(A_0)}{\Re(A_2)}\right] + \left[\frac{\Re(B_2)}{\Re(A_2)} - \frac{\Im(B_0)}{\Re(A_0)}\right]\right\}$$

$$\varepsilon' \xrightarrow[CPT\,\&(\delta_2-\delta_0)=0]{} i\,\frac{\Re(A_2)}{\Re(A_0)}\left[\frac{\Im(A_2)}{\Re(A_2)} - \frac{\Im(A_0)}{\Re(A_2)}\right]$$

$\Re(\varepsilon') \neq 0 \rightarrow$ Establish direct CP Violation

$|\varepsilon'| \neq 0 \rightarrow$ Does not necessarly imply direct CP Violation

However (experimentally)

$$(\delta_2 - \delta_0) \approx -\frac{\pi}{2} \rightarrow \Im(\varepsilon') \cong 0 \rightarrow |\varepsilon'| \approx \Re(\varepsilon')$$

The phase of ε is a CPT test

$$\varepsilon = \left[\varepsilon_k + i\frac{\Im(A_0)}{\Re(A_0)}\right] + \left[\frac{\Re(B_0)}{\Re(A_0)} - \delta_k\right] = \varepsilon_{CP} + \varepsilon_{CPT}$$

$$\varepsilon_{CP} = |\varepsilon_{CP}| e^{i\phi_w} \quad \text{and} \quad \varepsilon_{CPT} = -i|\varepsilon_{CPT}| e^{i\phi_w}$$

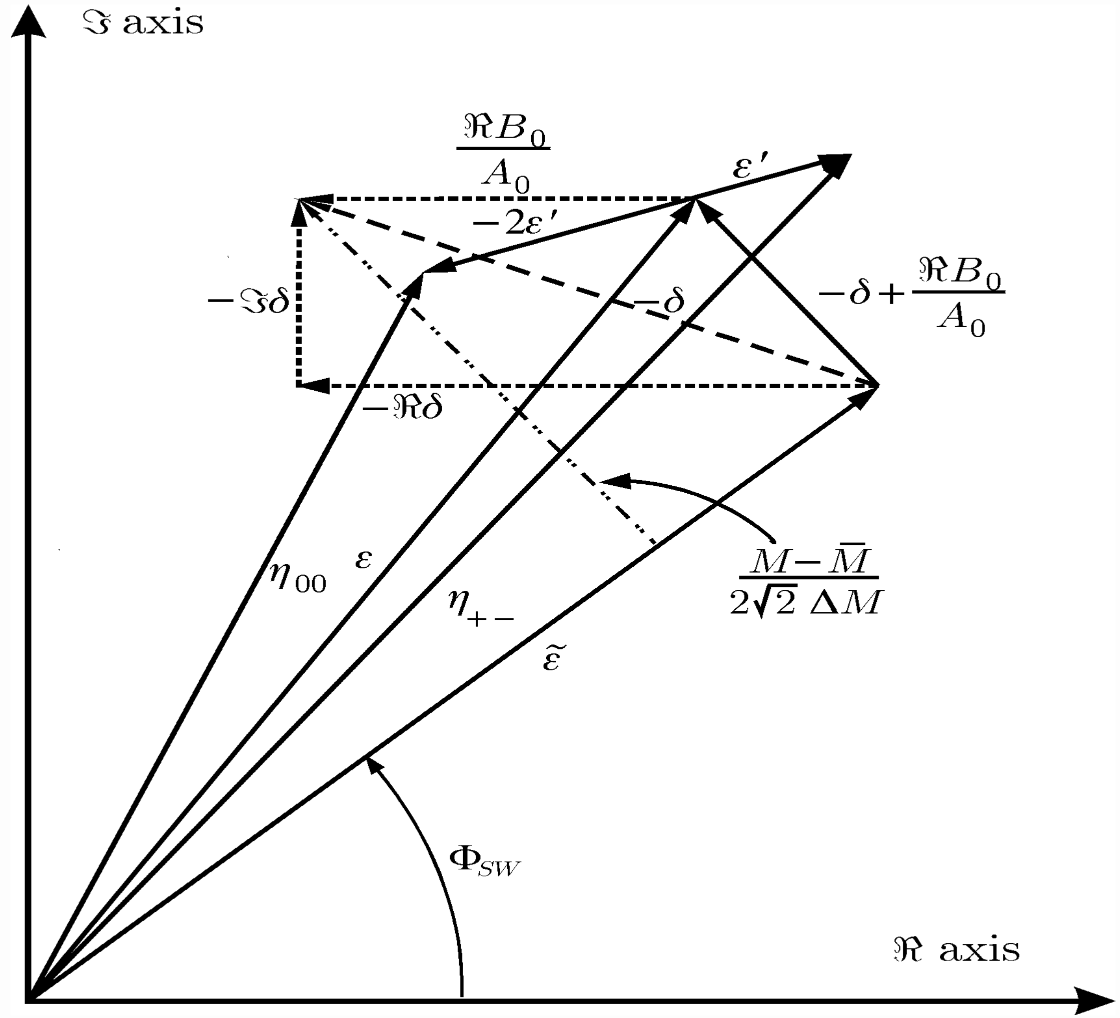
$$\phi_w = arc\tan\left(\frac{2(m_L - m_S)}{(\Gamma_S - \Gamma_L)}\right)$$

$$|\varepsilon_{CPT}| = \left|\frac{\Re(B_0)}{\Re(A_0)} - \delta_k\right| \cong |\varepsilon| \tan(\phi_\varepsilon - \phi_w)$$

$$\frac{\Re(B_0)}{\Re(A_0)} - \Re(\delta_k) \cong |\varepsilon_{CPT}| \cos(\phi_w)$$

$$\Im(\delta_k) \cong |\varepsilon_{CPT}| sin(\phi_w)$$

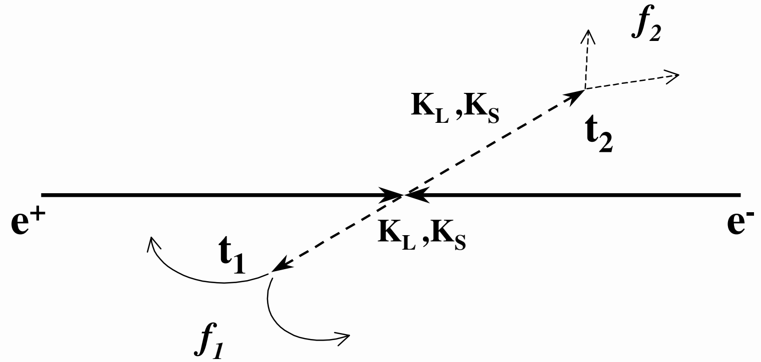
In other words...



CP/CPT unique to a Φ factory

Since K_S and K_L are produced in a pure quantum state, several tests of CP/CPT can be performed using the *interference patterns*.

The probability of finding



states f_1, f_2 at $\mathbf{\Delta t = t_1 - t_2}$ is:

$$I(f_1, f_2; \Delta t > 0) = \Gamma_{S,1}\Gamma_{S,2}/2\Gamma \times$$

$$\left[|\eta_1|^2 e^{-\Gamma_L|\Delta t|} + |\eta_2|^2 e^{-\Gamma_S|\Delta t|} - 2|\eta_1||\eta_2| e^{-\Gamma|\Delta t|/2} \cos(\Delta m|\Delta t| + \varphi_1 - \varphi_2)\right]$$

$$I(f_1, f_2; \Delta t < 0) \rightarrow 1 \leftrightarrow 2$$

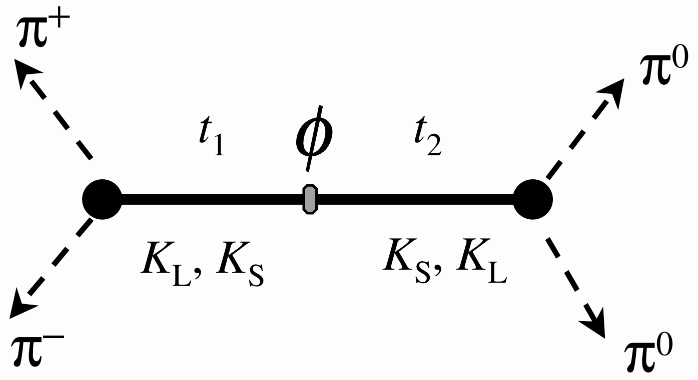
Interferometry: $f_1 = f_2 \equiv f$

$$I(f;\Delta t) = \Gamma_{S,f}\Gamma_{L,f}/2\Gamma \times \left[e^{-\Gamma_L|\Delta t|} + e^{-\Gamma_S|\Delta t|} - 2e^{-\Gamma|\Delta t|/2}\cos(\Delta m\,\Delta t)\right]$$

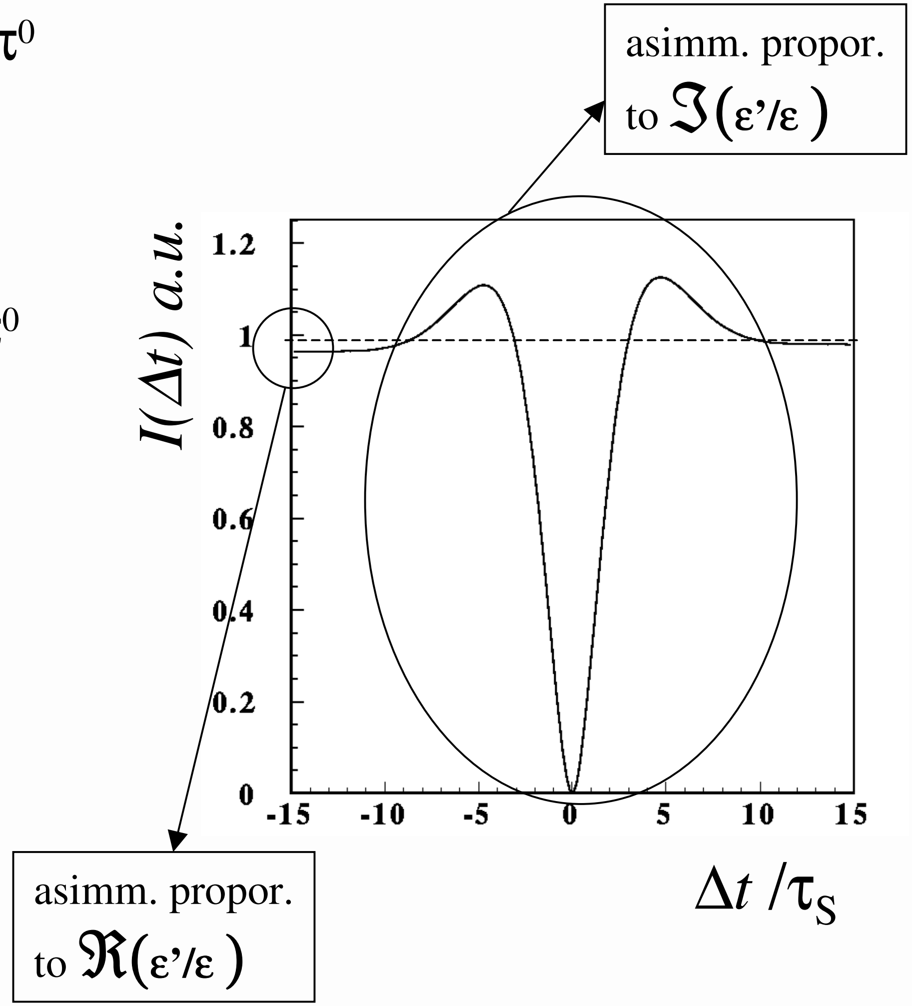
☞

Γ_L	σ_{Γ_L}	$= 0.0015\cdot 10^8\,\hbar s^{-1}$	**PDG98**
		$= 0.0001\cdot 10^8\,\hbar s^{-1}$	**KLOE**
Δm	$\sigma_{\Delta m}$	$= 0.14\cdot 10^8\,\hbar s^{-1}$	**PDG98**
		$= 0.12\cdot 10^8\,\hbar s^{-1}$	**KLOE**

Interferometry: $f_1 \approx f_2$ $\quad \pi^+\pi^-$ vs $\pi^0\pi^0$



$$\eta_1 = \eta_{+-} \approx \varepsilon + \varepsilon'$$
$$\eta_2 = \eta_{00} \approx \varepsilon - 2\varepsilon'$$
$$\delta_\phi = 3\Im(\varepsilon'/\varepsilon)$$



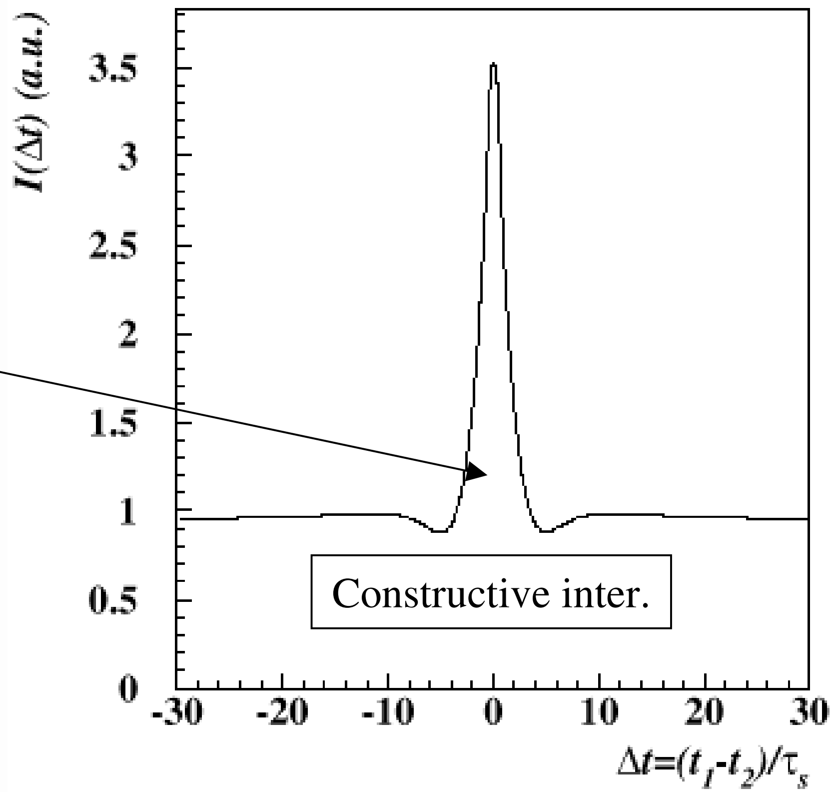
Interferometry: $f_1 \approx f_2$ $\ell^+\nu\pi^-$ vs $\ell\nu\pi^+$

$$\begin{cases} I(\Delta t > 0) \approx e^{-\Gamma_S|\Delta t|}(1 - 4\Re\delta_K) + 2e^{-\Gamma_S|\Delta t|/2}(\cos\Delta m\Delta t - 4\Im\delta_K \cos\Delta m\Delta t) \\ I(\Delta t < 0) \approx e^{-\Gamma_S|\Delta t|}(1 + 4\Re\delta_K) + 2e^{-\Gamma_S|\Delta t|/2}(\cos\Delta m\Delta t + 4\Im\delta_K \cos\Delta m\Delta t) \end{cases}$$

$\eta_1 = \eta_{\ell^+} = +1 - 2\delta_K$

$\eta_2 = \eta_{\ell^-} = -1 - 2\delta_K$

$\delta_\Phi = \pi - \Im\delta_K$



for $\Delta t \sim (1 \div 5)\tau_S$ $\Im\delta_K$

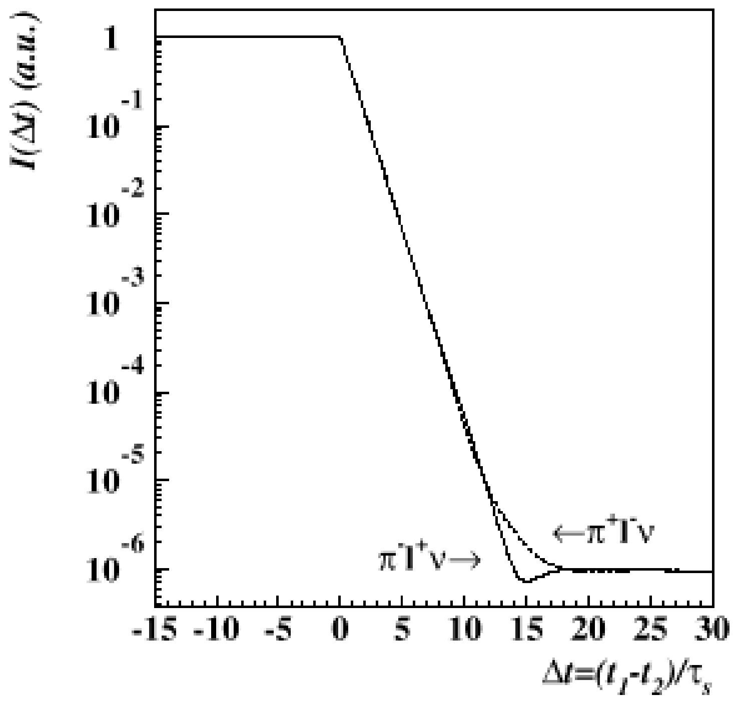
for $\Delta t >> \tau_S$ $\Re\delta_K$

Interferometry: $\pi\pi$ vs $\ell^{\pm}\nu\pi^{\mp}$

$$\eta_2 = \eta_{\ell^{\mp}} = -1 \mp 2\delta_K$$

$$\eta_1 = \eta_{+-} \approx \varepsilon + \varepsilon'$$

$$\eta_1 = \eta_{00} \approx \varepsilon - 2\varepsilon'$$



➥**Δm**, $|\eta_{\pi\pi}|$, $\phi_{\pi\pi}$ for *$\Delta t \sim (1 \div 5)\tau_S$*

➥ **A_L**(leptonic asymmetry) for *$\Delta t << -\tau_S < 0$ (poor stat.)*

Interferometry

✓ ***Inclusive decays***:

f_1 , t f_2

❶ $\pi^+\pi^-$ everything $\Rightarrow$ Γ_S , $|\eta_{+-}|$

❷ $\pi^0\pi^0$ everything $\Rightarrow$ $|\eta_{00}|$

❸ $\ell^\pm\nu\pi^\mp$ everything $\Rightarrow$ Γ_S , $\mathbf{A_L}$, $\Re\varepsilon_K$, $\Im\delta_K$

Leptonic Asymmetries

$$\langle \ell^+ \nu \pi^- | H | \mathrm{K}^0 \rangle = a + b \qquad \langle \ell^- \overline{\nu} \pi^+ | H | \mathrm{K}^0 \rangle = c + d$$

$$\langle \ell^- \overline{\nu} \pi^+ | H | \overline{\mathrm{K}}^0 \rangle = a^* - b^* \qquad \langle \ell^+ \nu \pi^- | H | \overline{\mathrm{K}}^0 \rangle = c^* - d^*$$

$$\delta_{\mathrm{L}} = \frac{|\langle \ell^- \overline{\nu} \pi^+ | H | \mathrm{K_L} \rangle|^2 - |\langle \ell^+ \nu \pi^- | H | \mathrm{K_L} \rangle|^2}{|\langle \ell^- \overline{\nu} \pi^+ | H | \mathrm{K_L} \rangle|^2 + |\langle \ell^+ \nu \pi^- | H | \mathrm{K_L} \rangle|^2} =$$

$$= 2\Re(\varepsilon_k) - 2\Re(\delta_k) + 2\frac{\Re(b)}{\Re(a)} + 2\frac{\Re(d)}{\Re(a)}$$

$$\delta_{\mathrm{S}} = \frac{|\langle \ell^- \overline{\nu} \pi^+ | H | \mathrm{K_S} \rangle|^2 - |\langle \ell^+ \nu \pi^- | H | \mathrm{K_S} \rangle|^2}{|\langle \ell^- \overline{\nu} \pi^+ | H | \mathrm{K_S} \rangle|^2 + |\langle \ell^+ \nu \pi^- | H | \mathrm{K_S} \rangle|^2} =$$

$$= 2\Re(\varepsilon_k) + 2\Re(\delta_k) + 2\frac{\Re(b)}{\Re(a)} - 2\frac{\Re(d)}{\Re(a)}$$

$$\delta_{\mathrm{S}} - \delta_{\mathrm{L}} = 4\Re(\delta_k) - 4\frac{\Re(d)}{\Re(a)} \qquad \delta_{\mathrm{S}} + \delta_{\mathrm{L}} = 4\Re(\varepsilon_k) - 4\frac{\Re(b)}{\Re(a)}$$

Statistical sensitivity at KLOE

Quantity	**Last exp.(stat.+syst.)**	**KLOE(stat. only)**
$\Re(\varepsilon'/\varepsilon)$	$(18.5 \pm 7.3) \cdot \mathbf{10^{-4}}$ **(NA48)**	$\pm\ 2 \cdot \mathbf{10^{-4}}$
	$(28.0 \pm 4.1) \cdot \mathbf{10^{-4}}$ **(KTEV)**	
$\Im(\varepsilon'/\varepsilon)$	$(-1.2 \pm 1.7) \cdot \mathbf{10^{-4}}$ **(NA31)**	$\pm 12 \cdot \mathbf{10^{-4}}$
	$(+4.7 \pm 3.5) \cdot \mathbf{10^{-4}}$ **(E731)**	
$\lvert\eta_{+-}\rvert$	$(227.5 \pm 1.9) \cdot \mathbf{10^{-5}}$ **(PDG 98)**	$\pm 0.06 \cdot \mathbf{10^{-5}}$
$\lvert\eta_{00}\rvert$	$(228.5 \pm 1.9) \cdot \mathbf{10^{-5}}$ **(PDG 98)**	$\pm 0.09 \cdot \mathbf{10^{-5}}$
Φ_{+-}	$(43.5 \pm 0.6)^{o}$ **(PDG 98)**	$\pm 1.2^{o}$
$\Phi_{+-} - \Phi_{00}$	$(-0.1 \pm 0.8)^{o}$ **(PDG 98)**	$\pm 0.2^{o}$
$\Re\delta_K$	$(2.4 \pm 2.7) \cdot \mathbf{10^{-4}}$ **(CPLEAR)**	$\pm 3 \cdot \mathbf{10^{-4}}$
$\Im\delta_K$	$(2.4 \pm 5.0) \cdot \mathbf{10^{-5}}$ **(CPLEAR)**	$\pm 6 \cdot \mathbf{10^{-3}}$

First KLOE results: radiative decays

$\phi \to f_0\gamma, a_0\gamma, \eta'\gamma$ radiative decays ($E_\gamma \approx 30 \div 60$ MeV)

$f_0(980)$ $I^G(J^{PC}) = 0^+(0^{++})$ $\pi\pi$ decay

$a_0(980)$ $I^G(J^{PC}) = 1^-(0^{++})$ $\eta\pi$ decay

$\eta'(958)$ $I^G(J^{PC}) = 0^+(0^{-+})$ $\eta\pi\pi$ decay

$\to$ the qq nature of f_0, a_0 is controversial;
(possible alternatives $qqqq$ states or KK molecule)

$\to$ the gluonic content of η' and
the value of η - η' are controversial;

First KLOE results

BR($\phi \to$)	Other Experiments	KLOE (Very Preliminary)
$\pi^0\pi^0\gamma$	$(1.14 \pm 0.10 \pm 0.12) \cdot \mathbf{10^{-4}}$ (SND) $(1.06 \pm 0.09 \pm 0.06) \cdot \mathbf{10^{-4}}$ (CMD2)	$(0.80 \pm 0.10 \pm 0.08) \cdot \mathbf{10^{-4}}$
$\eta'\gamma$	$(0.67 \pm 0.32 \pm$? $) \cdot \mathbf{10^{-4}}$ (SND) $(0.82 \pm 0.20 \pm 0.11) \cdot \mathbf{10^{-4}}$ (CMD2)	$(0.84 \pm 0.21 \pm 0.05) \cdot \mathbf{10^{-4}}$
$\eta\, \pi^0\gamma$	$(0.89 \pm 0.14 \pm 0.06) \cdot \mathbf{10^{-4}}$ (SND) $(0.83 \pm 0.23 \pm 0.11) \cdot \mathbf{10^{-4}}$ (CMD2)	$(0.91 \pm 0.24 \pm ?) \cdot \mathbf{10^{-4}}$

The kaonic hydrogen puzzle

$\varepsilon(\Gamma) =$ Energy shift(width) of $2p \to 1s$

$$\boxed{\varepsilon + i\Gamma = 2\alpha^2\mu^3 a(K^- p)}$$

$\alpha =$ fine structure constant

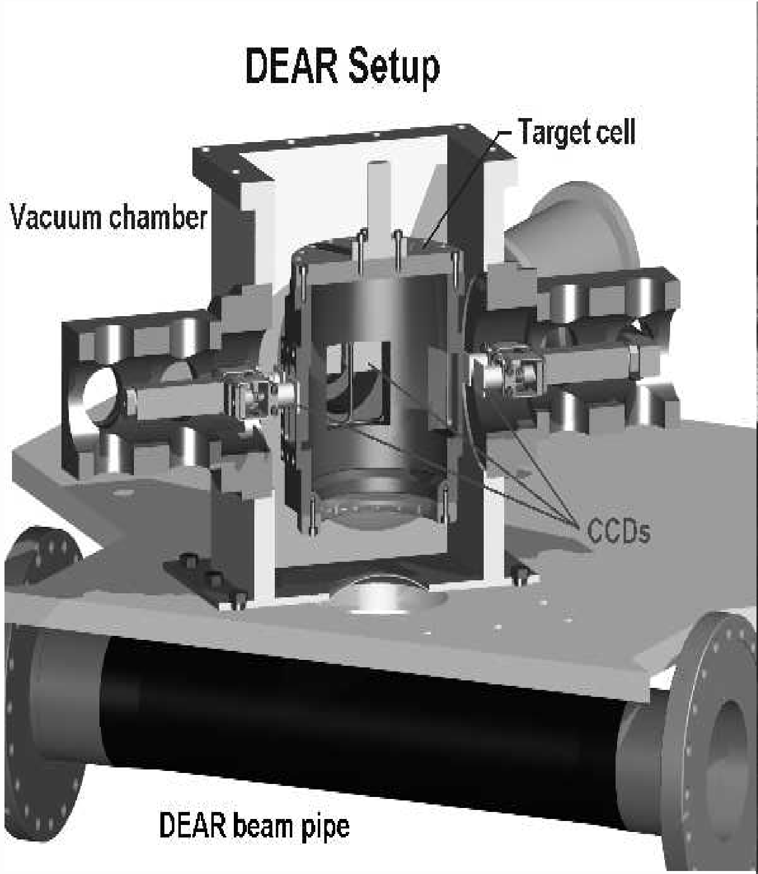
$\mu =$ reduced mass

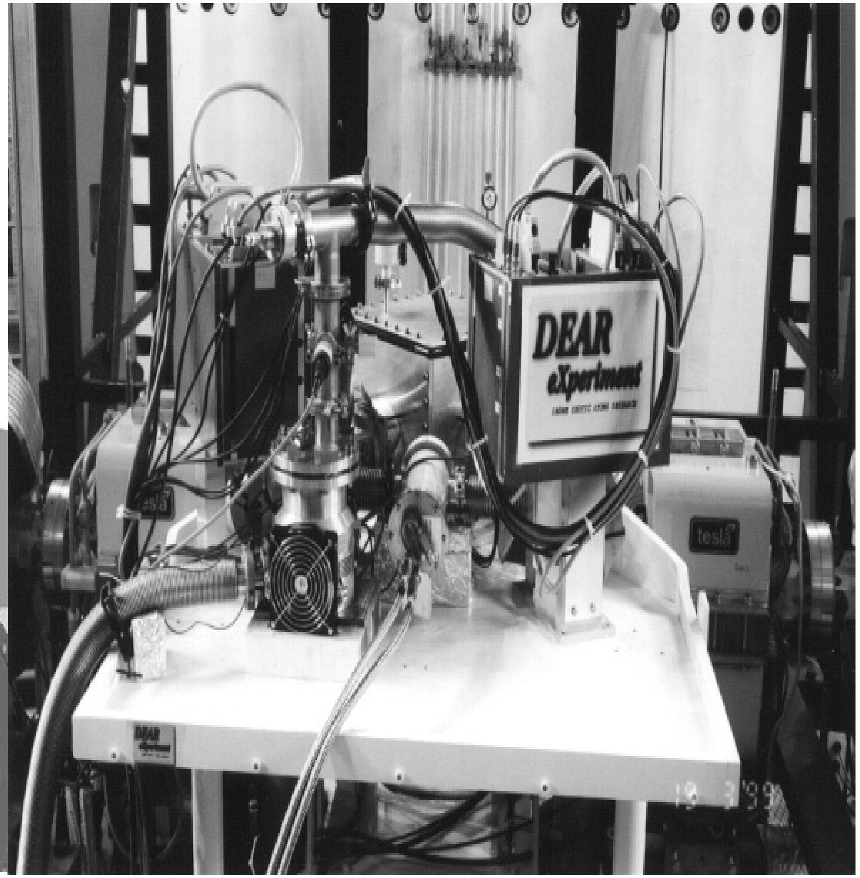
$a(K^- p) = K^- p$ scattering length

$$a(K^- p)(fm)$$

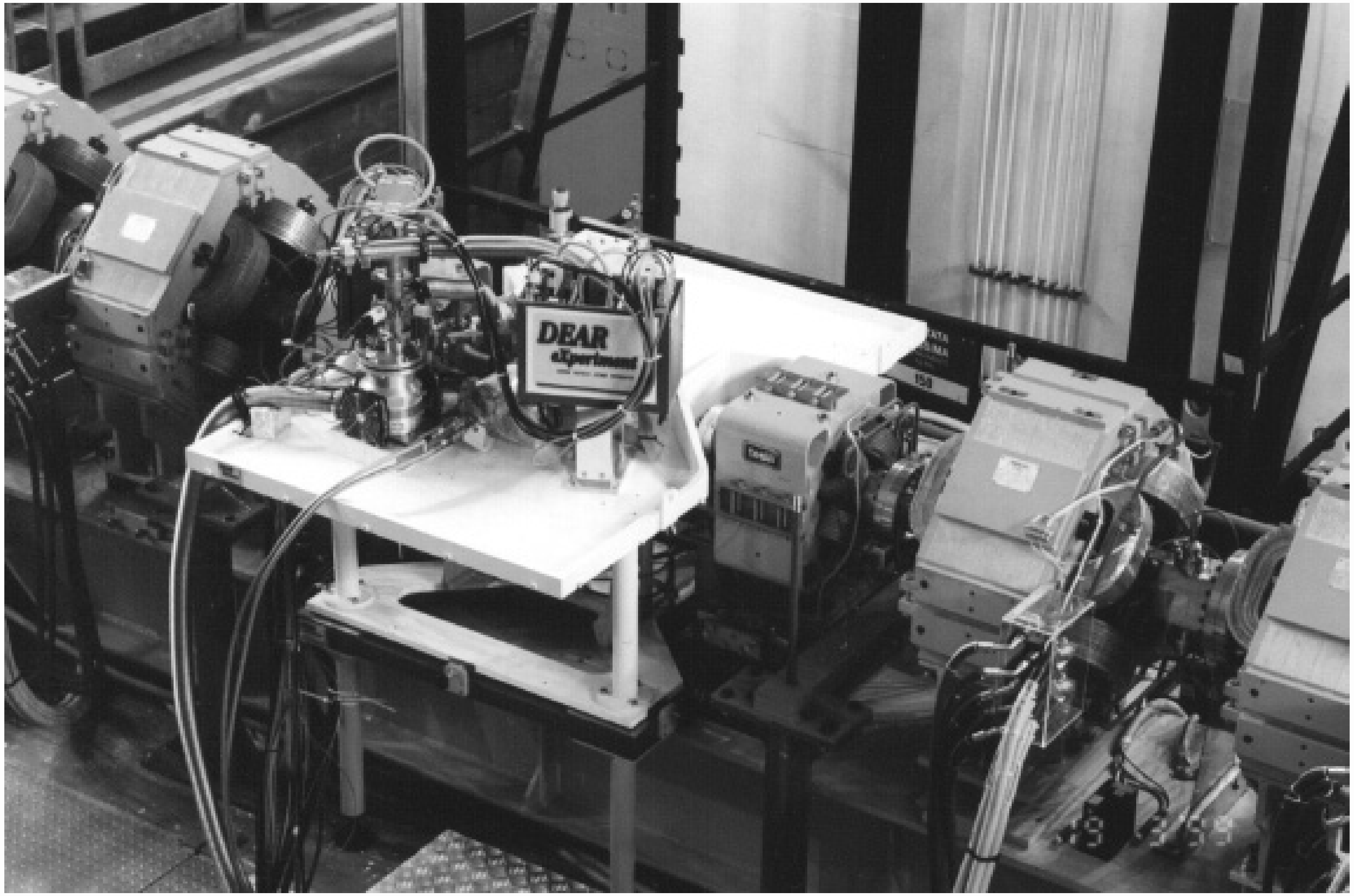
from Kaonic Hydrogen	from scattering analysis
$(0.10 \pm 0.14) + i\,(0.00^{+0.28}_{-0.00})$	$(-0.91 \pm 0.05) + i\,(0.48 \pm 0.03)$
$(0.65 \pm 0.19) + i\,(0.68 \pm 0.31)$	$(-0.87 \pm 0.04) + i\,(0.69 \pm 0.03)$
$(0.47 \pm 0.14) + i\,(0.10^{+0.27}_{-0.10})$	$(-0.89 \pm 0.02) + i\,(0.62 \pm 0.02)$
	$(-0.89 \pm 0.03) + i\,(0.66 \pm 0.03)$
	$(-0.66 \pm 0.05) + i\,(0.64 \pm 0.04)$

The DEAR detector

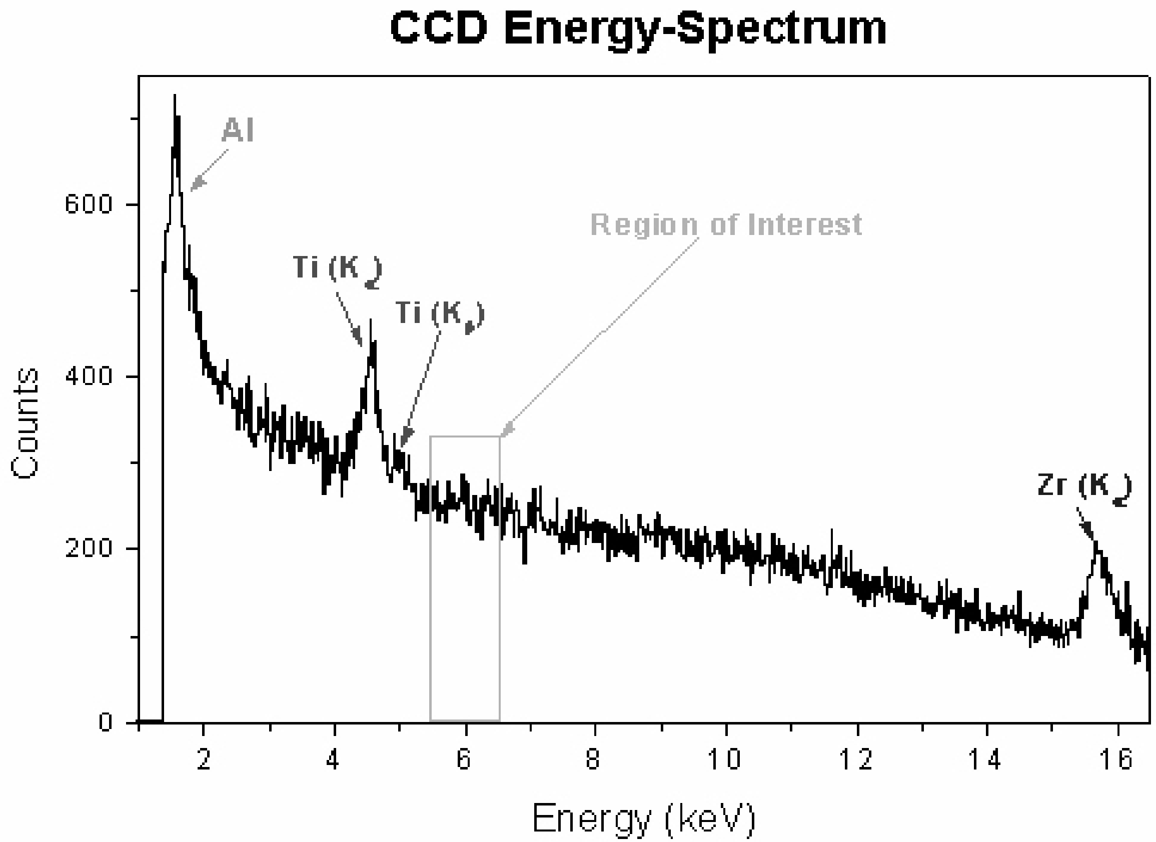




DEAR in the DAΦNE hall



DEAR Calibration



Hypernuclei with FINUDA

$$K^- + {}^A Z \rightarrow {}^A_Y Z + \pi^- \qquad Y = \Lambda, \Sigma, \ldots$$

- Study the validity of ΔI=1/2 in bound systems

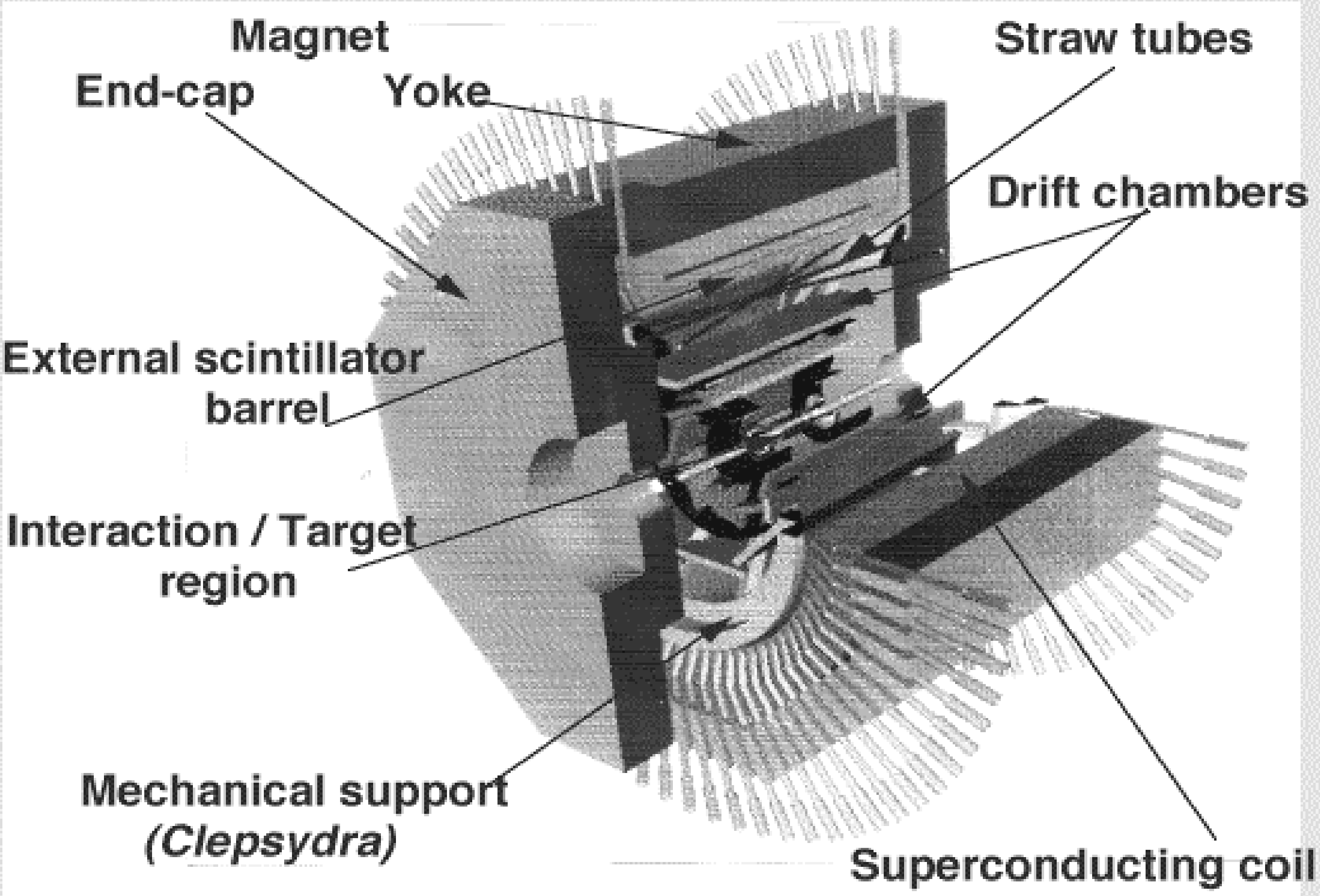
$${}^A_\Lambda Z \rightarrow {}^{A-2}Z + n + n \qquad \Lambda + n \rightarrow n + n$$

$${}^A_\Lambda Z \rightarrow {}^{A-2}(Z-1) + n + p \qquad \Lambda + p \rightarrow n + p$$

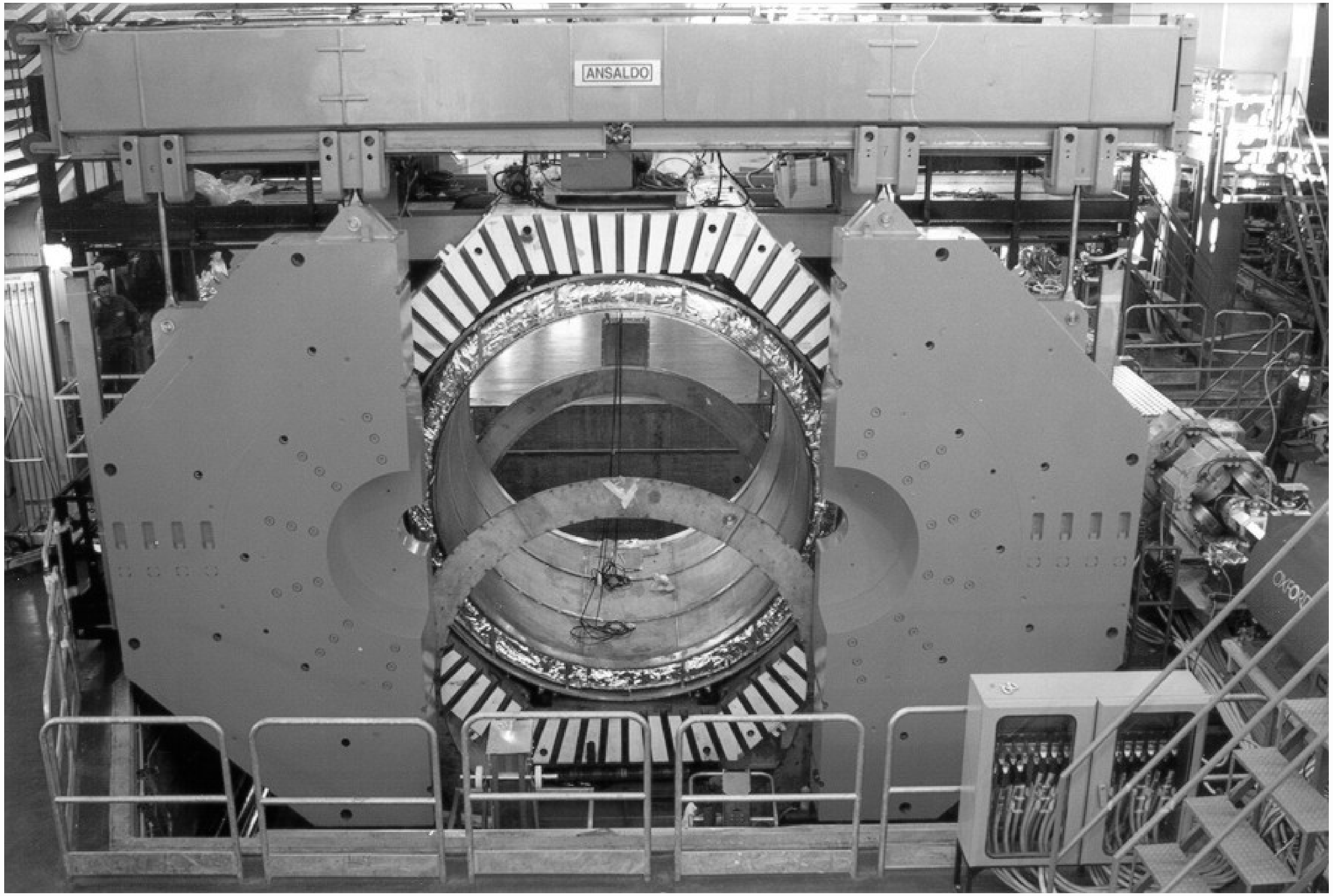
- Study models of quark deconfinement

With $\mathcal{L}$ **= 10^{32} cm^{-2}s^{-1}** FINUDA could reconstruct about 100 events/hr.

The FINUDA detector



FINUDA in the DAΦNE Hall



Conclusions and outlook

- ✓ DAΦNE has started operations and has delivered about 2.5 pb^{-1} to KLOE in 1999.
- ✓ Operations will be resumed in spring 2000 with new kickers.
- ✓ The KLOE and DEAR detectors are working very well and waiting for more data.
- ✓ First KLOE results on radiative decays are already competitive with results from VEPP-2M experiments.
- ✓ By the end of 2000 -with ~ 100 pb^{-1}- KLOE could reach 10^{-3} statistical accuracy on $\Re(\varepsilon'/\varepsilon)$.