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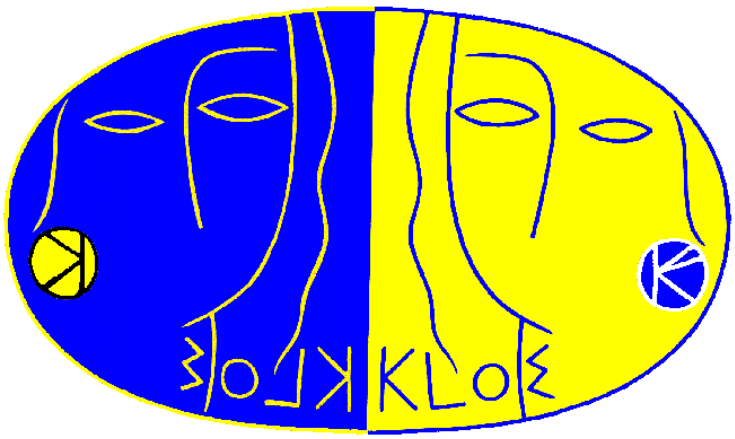

Messung hadronischer Wirkungsquerschnitte ($e^+e^- \to \pi^+\pi^-$) mit KLOE und ihr Bezug zum magnetischen Moment des Muons

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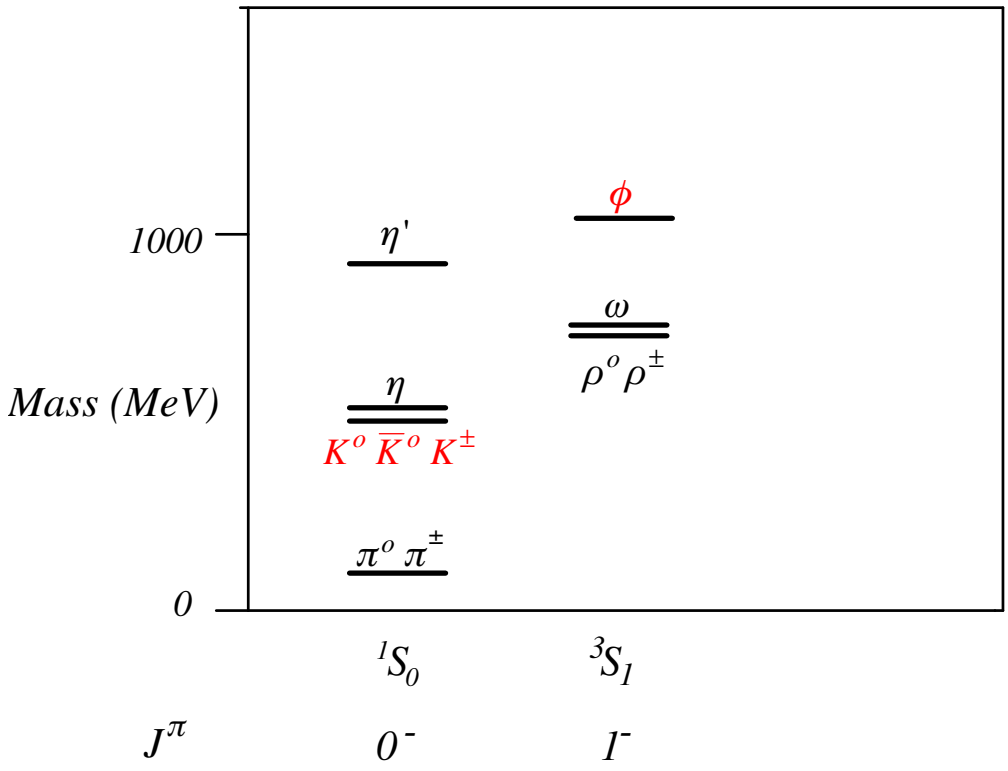
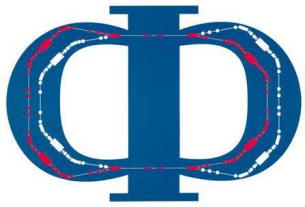
1. *DAΦNE*? A 'strangeness' ϕ-factory!

DAΦNE physics?



Lightest mesons

$DA\Phi NE\ \phi$ factory @ LNF



e^+e^- collider $\quad T_{e^+} = T_{e^-} = 510\ MeV$

$\phi(1020)$ with $J^{PC} = 1^{--}$ $\qquad (\mathcal{P} = C = -1 \Rightarrow C\mathcal{P} = +1)$

Luminosity : $\qquad L \approx 5 \cdot 10^{32}\ cm^{-2}\ s^{-1}$

Integrated luminosity: $\qquad \int_{1\,year} Ldt = 10^7\ s \cdot 5 \cdot 10^{32}\ cm^{-2}\ s^{-1} = 5 \cdot 10^3\ pb^{-1}$

Single bunch luminosity * large number of bunches

$5 \cdot 10^{30}$ (*VEPP-2M*) * *120* bunches, *2.7 ns* spacing

$$e^+e^- \rightarrow \gamma^* \rightarrow \phi(1020)$$

decay $\phi(1020)$	*BR*	events / year $2 \cdot 10^{10}$
$K^+ K^-$	49.5 %	$9.8 \cdot 10^9$
$K_S K_L$	34.4 %	$6.9 \cdot 10^9$
$\rho\pi,\ \pi^+\pi^-\pi^o$	14.8 %	$3.0 \cdot 10^9$
$\eta\gamma$	1.3 %	$2.6 \cdot 10^8$
$f_o\gamma, a_o\gamma, \eta'\gamma$	$\approx 10^{-4}$	20 000

Backgroundfree low energy monochromatic
tagged charged and neutral (coherent) kaons

Absolutely unique is the interferometry of neutral kaons (tagged K_S)

Mean decay path (K_L at *110 MeV/c*): $\ell_L = 3500$ *mm* $\tau_L = 51.70$ *ns*

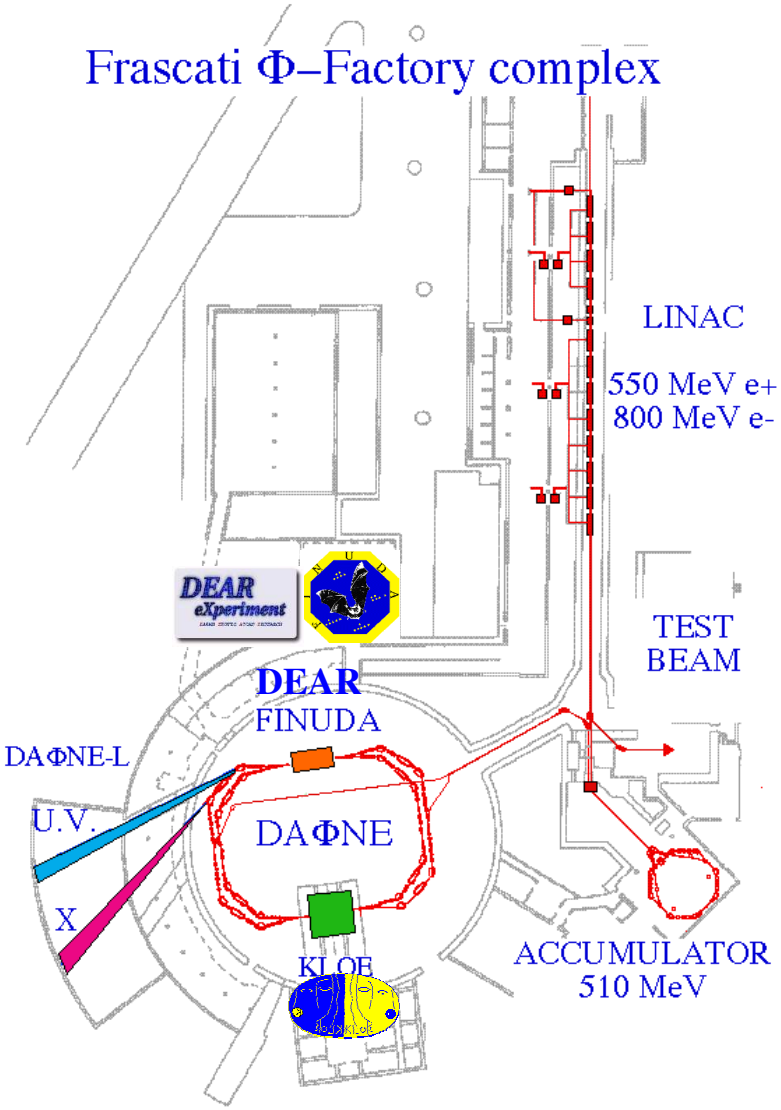
Mean decay path (K_S at *110 MeV/c*): $\ell_S = 6$ *mm* $\tau_S = 0.09$ *ns*

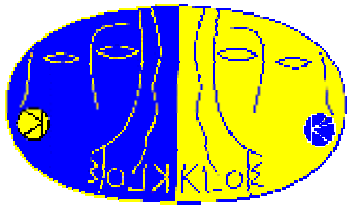
Mean decay path ($K^{\pm}$ at *127 MeV/c*): $\ell_{\pm} = 950$ *mm* $\tau_{\pm} = 12.40$ *ns*

Experiments @ *DAΦNE*

Detectors:

0. DEAR	nuclear physics	kaonic hydrogen
1. KLOE	particle physics	kaon physics, hadronic cross sections
2. FINUDA	nuclear physics	hypernuclei, *KN*, *K*-atoms





KLOE physics program

KAON PHYSICS

$\mathcal{CP}$ violation studies ε'/ε

- double ratio
- interference

$\mathcal{CPT}$ violation studies (limits ?)

- semileptonic asymmetry

$K_S \to \pi^+ e^- \nu \,/\, \pi^- e^+ \nu$

$K_L \to \pi^+ e^- \nu \,/\, \pi^- e^+ \nu$

$\delta_L \neq \delta_S$

- interference

rare K_S decays

kaon form factors

$K_L \to \pi^\pm \ell^\mp \nu\,, \quad K^\pm \to \pi^o \ell^\pm \nu$

kaon regeneration at low energies

NON - KAON PHYSICS

radiative ϕ decays

$\to f_o(980)\ \gamma$

$\to a_o(980)\ \gamma$

$\to \eta\,\gamma,\ \eta'\,\gamma$

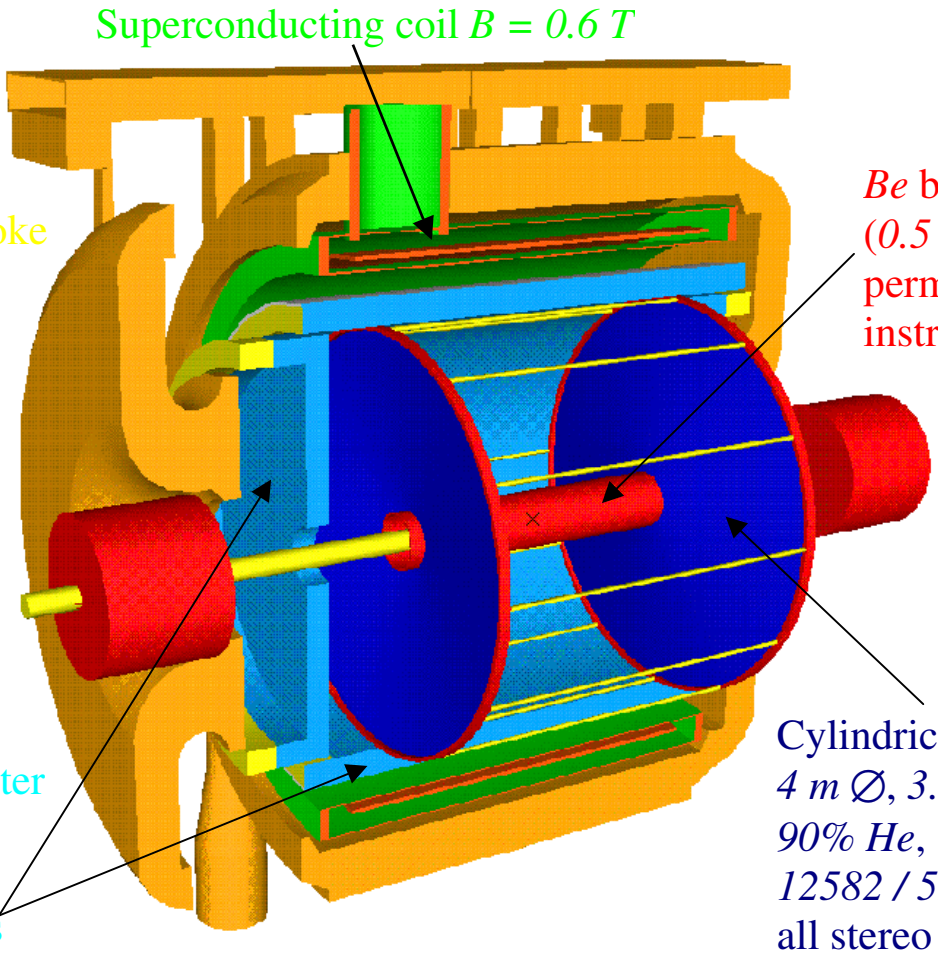
$\phi \to \rho\pi,\ \pi^+\,\pi^-\,\pi^o$ *etc.*

hadronic cross sections $e^+e^- \to hadrons$

(anomalous magnetic moment of the muon, running fine structure constant)

2. The Detector *KLOE*

Design: measurement of events like $K_L \to \pi^+ \pi^-$ $K_S \to \pi^o \pi^o$

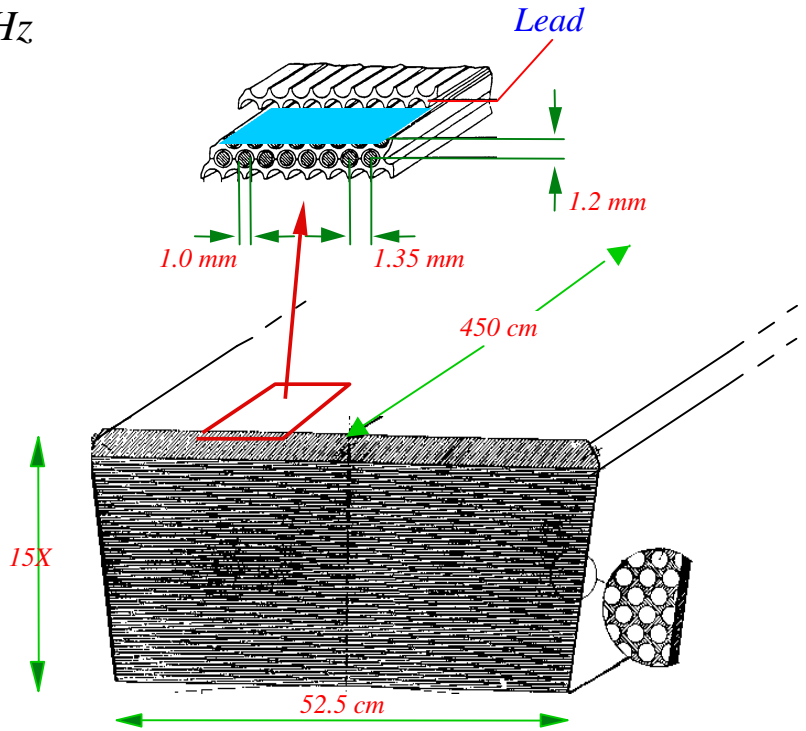


Electromagnetic calorimeter

Efficient detection of photons $> 20\ MeV$

- Barrel + endcap = 98% hermetic coverage
- Discrimination of $K_L \to \pi^o \pi^o$ against $K_L \to \pi^o \pi^o \pi^o$
- Reconstruction of decay vertex of $K_L \to \pi^o \pi^o$ within *1 cm*
- 1^{st} level trigger, scales *Bhabha* events down to *20 kHz*

Pb + scintillating fibres



design:
energy resolution $\sigma_E / E = 5\% / \sqrt{E(GeV)}$
time resolution $\sigma_t = 70\ ps / \sqrt{E(GeV)}$

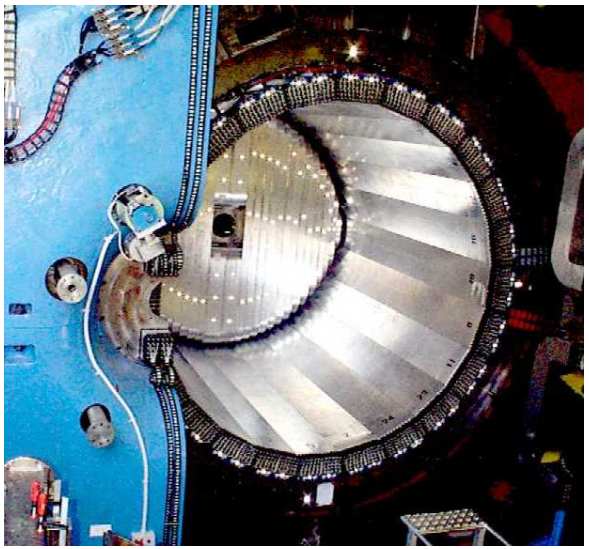
measured (*Bhabhas* …):

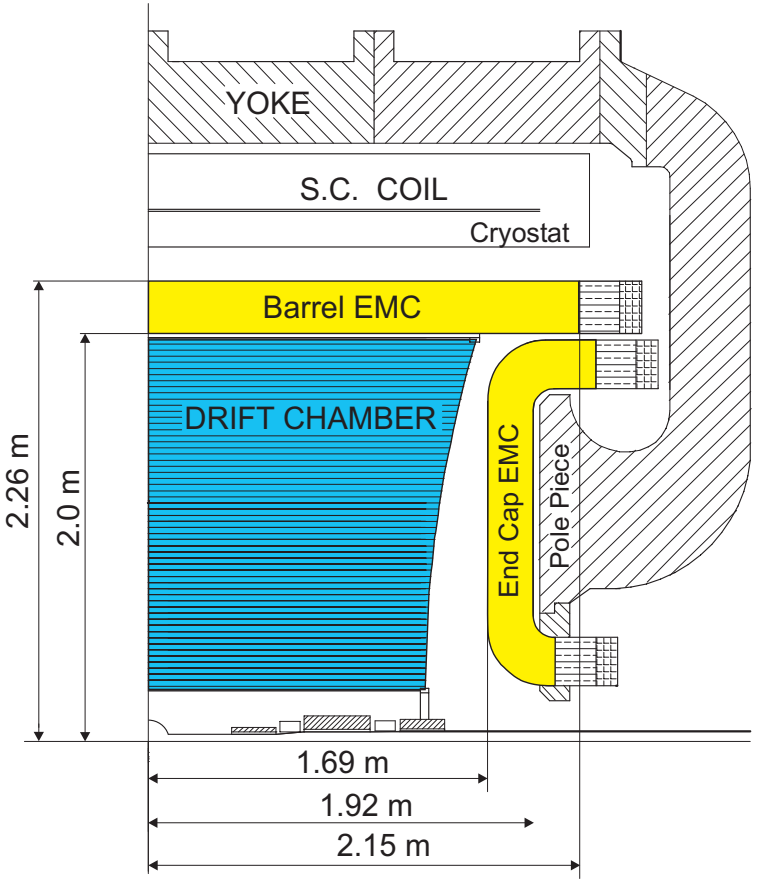
$\sigma_E / E = 5.7\% / \sqrt{E(GeV)}$

$\sigma_t = 57\ ps / \sqrt{E(GeV)} + 167\ ps$

Electromagnetic calorimeter

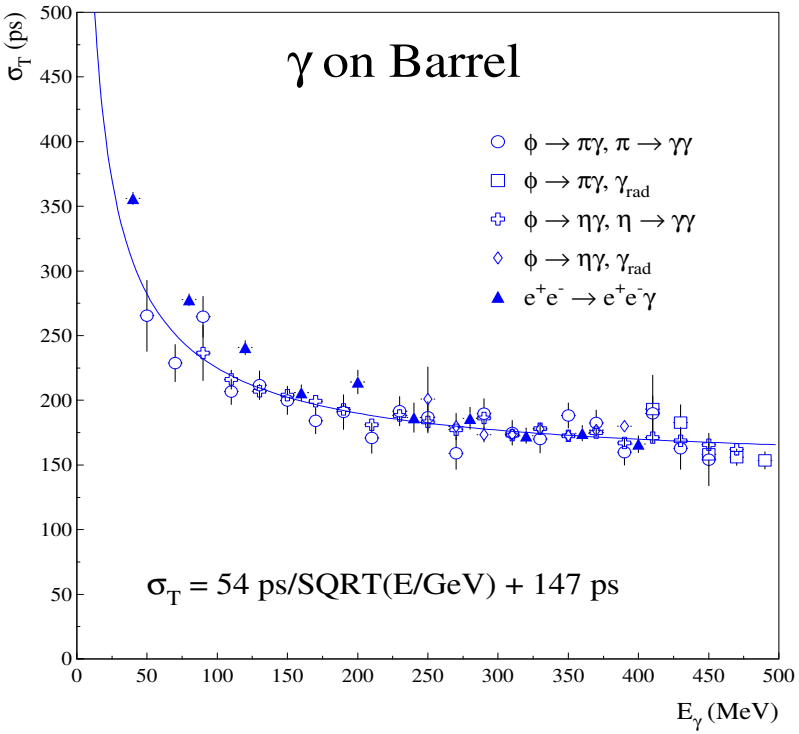
24 barrel modules
60 cells (*5* layers)
4.3 m length





2 × *32* endcap modules
10/15/30 cells

EmC: time and energy



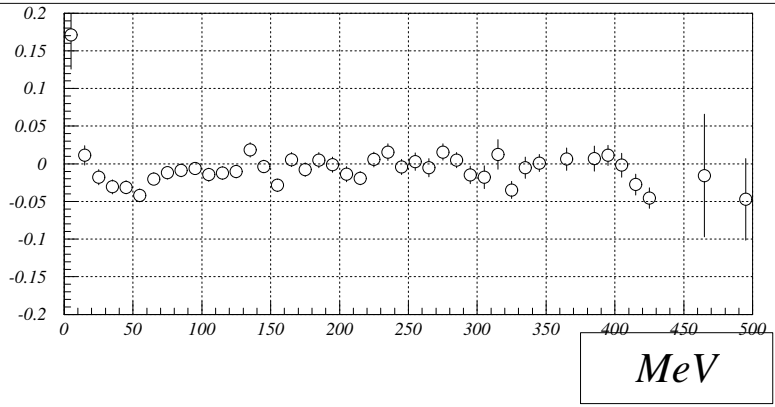
$$\sigma_t = \frac{57\ ps}{\sqrt{E(GeV)}} + 120\ ps + 40\ ps$$

bunch structure

miscalibration term

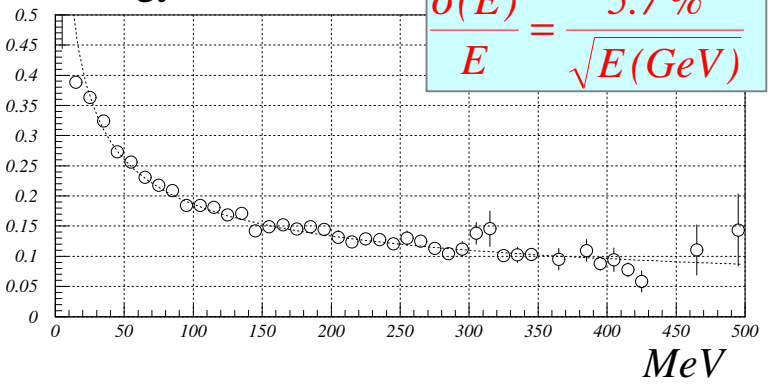
$e^+ e^- \to e^+ e^- \gamma$ E_γ from *DC*

residuals = meas. energy (*EmC*) - calc.e^+e^-(*DC*)



energy resolution

$$\frac{\sigma(E)}{E} = \frac{5.7\,\%}{\sqrt{E(GeV)}}$$



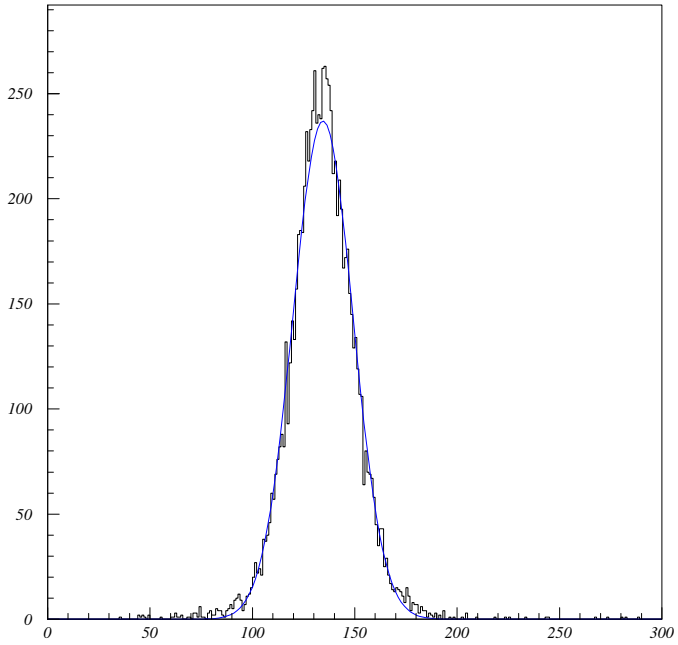
EmC: mass reconstruction (π^o, η)

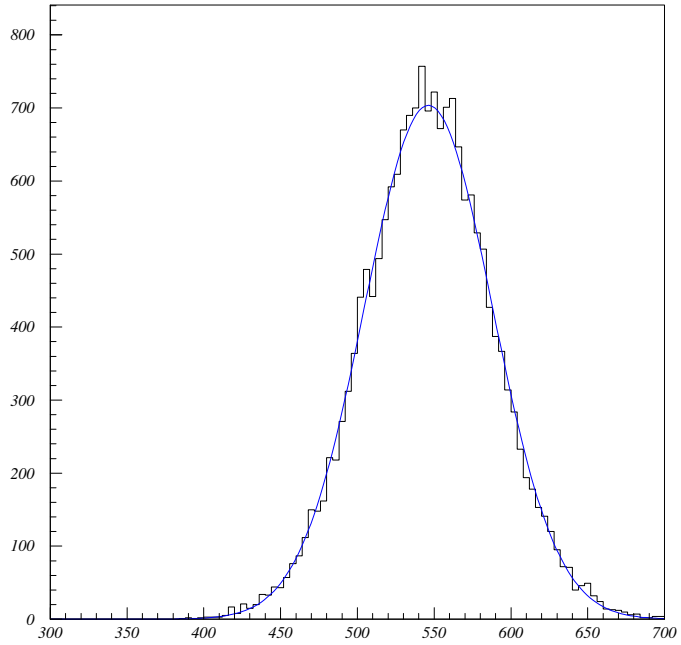
$\phi \rightarrow \pi^+\pi^-\pi^o$

$m\,(\pi^o \rightarrow \gamma\,\gamma)$ $m = 134.5\ MeV$, $\sigma_m = 14.7\ MeV$

$\phi \rightarrow \eta\,\gamma$

$m\,(\eta \rightarrow \gamma\,\gamma\,)$ $m = 546.3\ MeV$, $\sigma_m = 41.8\ MeV$



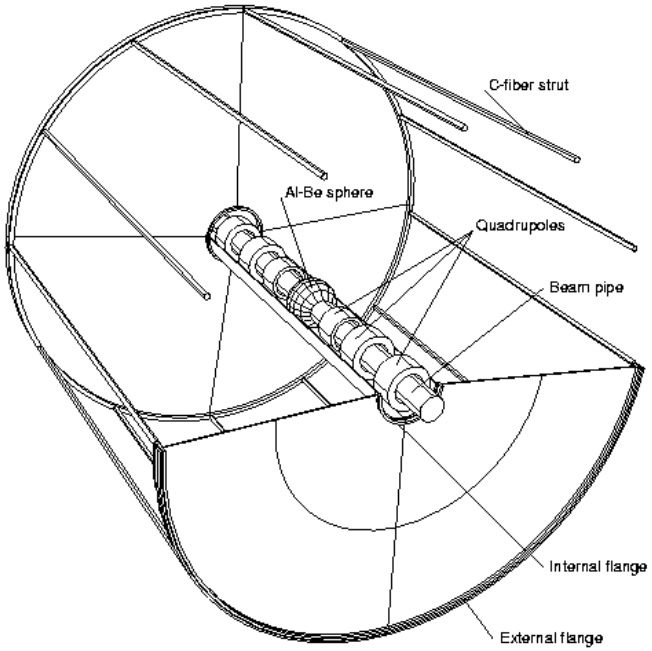


in agreement with *PDG* < *1%*

Cylindrical drift chamber

High momentum resolution for low energetic π, μ, e tracks

(e.g. $K_L \to \pi^+ \pi^-$ *vs.* $K_L \to \pi \mu \nu$)



- Size is dictated by decay length τ (K_L) $\Rightarrow$ *340 cm;*
  4 m ϕ, *3.3 m* length

- Transparent for low energetic photons,
  reduced multiple scattering and regeneration
  low mass gas mixture *90% He, 10%* iC_4H_{10} (X_o = *900 m*)
  mechanical structure of carbon fibre (< *0.1* X_o)

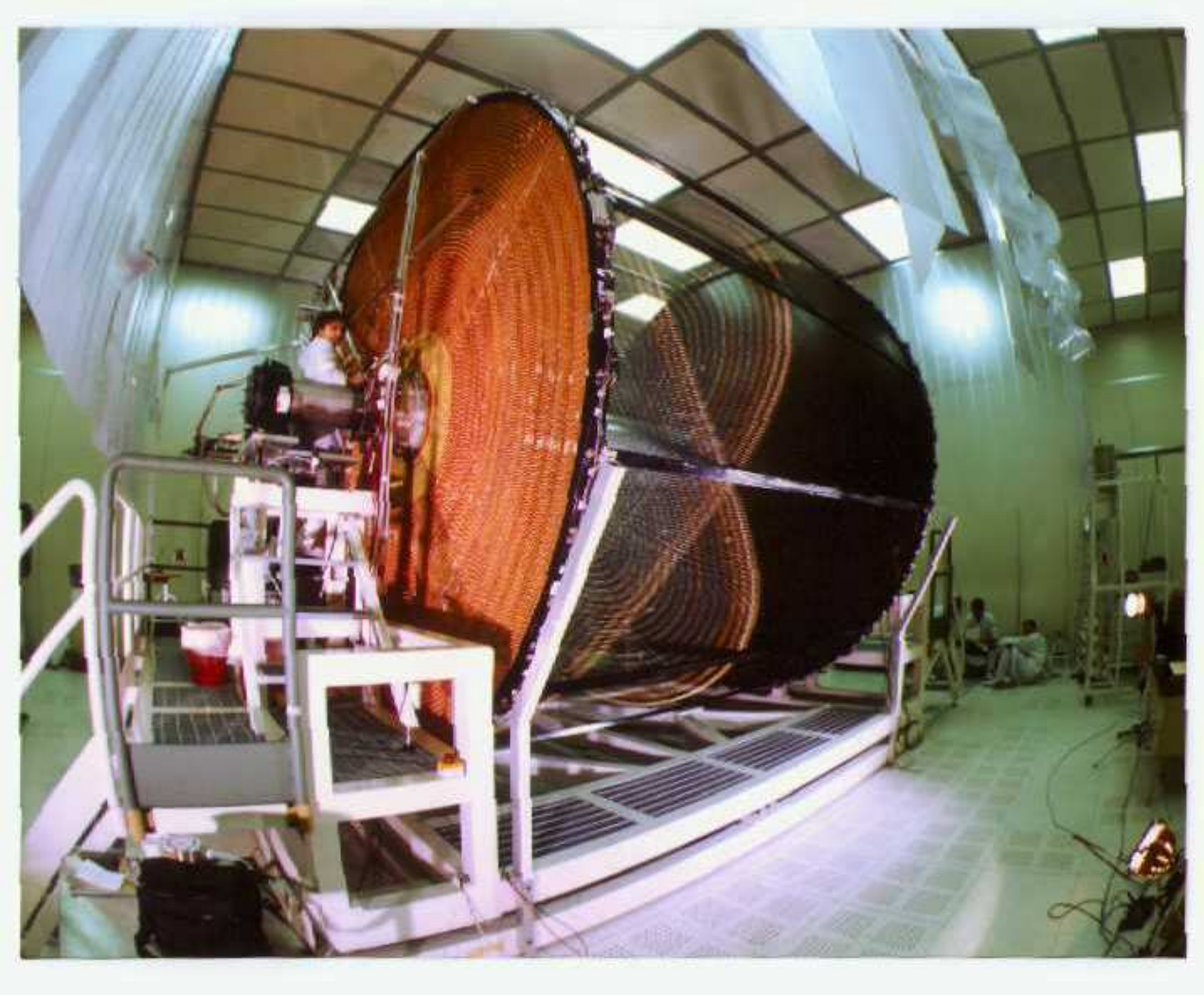
- uniform cell structure throughout the whole chamber
  square cells (*3:1* = field : sense wire)
  2 x 2 cm^2 inner *12* layers, *3 x 3* cm^2 outer *46* layers
  to achieve constant stereo drop
  the stereo angle varies between *60 … 150 mrad*

12582 / 52140 sense / total wires

$\sigma_{p_t} / p_t = 0.4\,\%$

$\sigma_{r\phi} = 200\ \mu m,\ \sigma_z = 2\ mm$

cell efficiency $\approx$ *99 %*

confirmed with data

Cylindrical Drift Chamber