The future NA48 programs at CERN

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New trends in high energy physics

On behalf of the NA48 Collaboration

The NA48 experimental program

MANY PHYSICS RESULTS ACHIEVED IN NA48:

⇒ MAIN GOAL: precise measurement of the direct CP violation parameter $\mathrm{Re}(\varepsilon'/\varepsilon)$ in the neutral kaon system: published results on 1997-1999 data, 2001 run in progress

⇒ IN PARALLEL: many studies of $\mathrm{K_S}$, $\mathrm{K_L}$ rare decays and neutral hyperon decays (concurrently with ϵ'/ϵ plus dedicated run)

⇒ FUTURE: 2 addenda to the NA48 proposal approved in 2000, data taking after the end of the ϵ'/ϵ program:

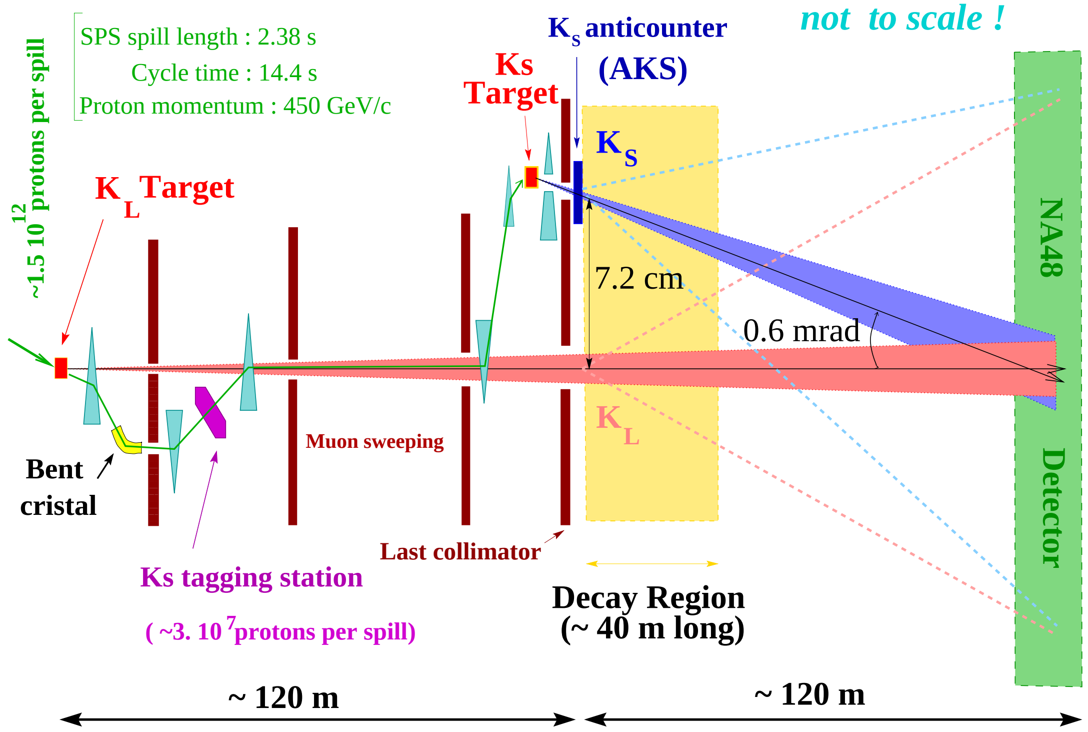
NA48/I: a high sensitivity investigation of $\mathrm{K_S}$ and neutral hyperon decays using a modified $\mathrm{K_S}$ beam (2002)

NA48/II: a precision measurement of charged kaon decay paramenters with an extended NA48 setup (2003)

The NA48 experiment at CERN

THE NA48 METHOD

- simultaneous $\mathrm{K_S}$ / $\mathrm{K_L}$ beams hitting the same detector region
- concurrent collection of $\mathrm{K_S}$, $\mathrm{K_L}$ $\rightarrow \pi^0\pi^0, \pi^+\pi^-$ $\rightarrow$ counting experiment
- double ratio techique for $\mathrm{Re}(\varepsilon'/\varepsilon)$ measurement
- $\mathrm{K_S}$ identification with proton tagging



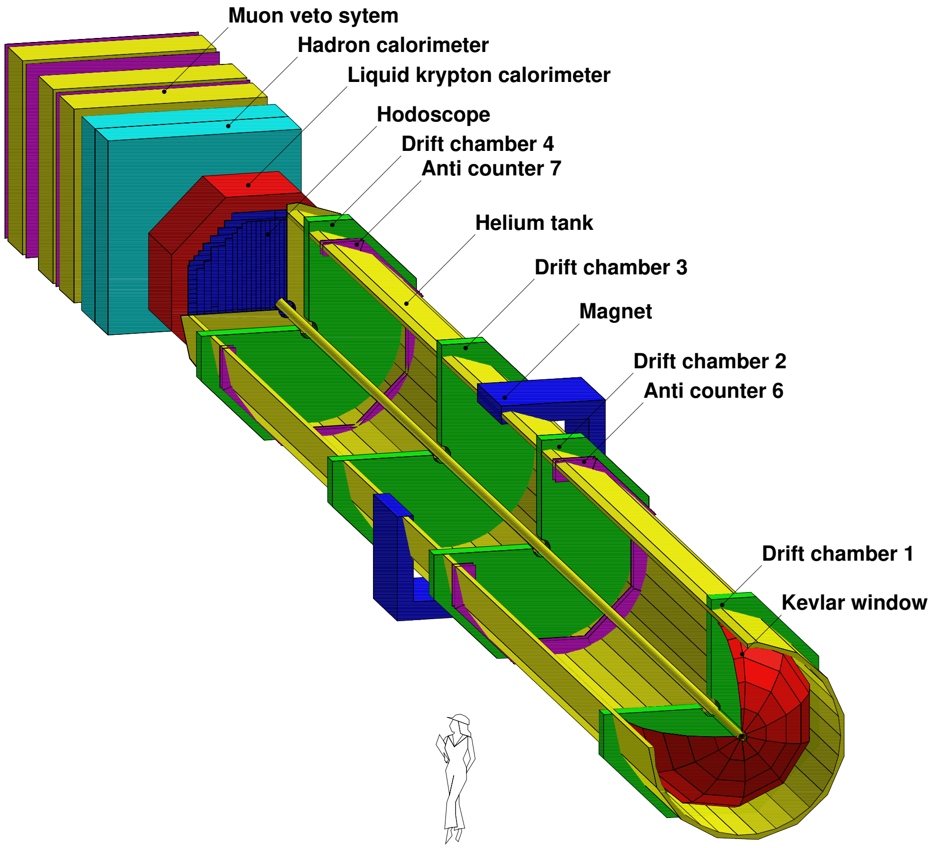
SCHEDULE OF THE FORTHCOMING ACTIVITY:

2001: end of ϵ'/ϵ program

2002: NA48/I: no $\mathrm{K_L}$, modified $\mathrm{K_S}$ beam, improved readout/daq capability

2003: NA48/II: new beam line for simultaneous K^+/K^-, upgraded detector

The NA48 detector



✧ CHARGED DECAYS:

magnetic spectrometer and scintillator hodoscope ($p_T^{kick} \simeq 265\ MeV/c$)

$$\frac{\sigma(p)}{p} \simeq 0.5\% \oplus 0.009\%\ p\ (GeV/c)$$

$$\sigma_{x,y}^{hit} \simeq 90\ \mu m$$

$$\sigma_{x,y}^{vtx} \simeq 2\ mm$$

$$\sigma_t \simeq\ 200\ ps$$

✧ NEUTRAL DECAYS:

LKr electromagnetic calorimeter

$$\frac{\sigma(E)}{E} = \frac{3.2\%}{\sqrt{E}} \oplus \frac{0.10}{E} \oplus 0.5\%\ (E\ in\ GeV/c)$$

$$\sigma_{m_{\pi^0}} \simeq 1\ MeV/c^2$$

$$\sigma_{x,y} <\ 1.3\ mm$$

$$\sigma_t <\ 300\ ps\ above\ 20\ GeV$$

Towards the High Intensity $\mathrm{K_S}$ proposal

RARE DECAYS IN NA48

- 1997-1999 $\mathrm{Re}(\varepsilon'/\varepsilon)$ data taking:
  - 450 GeV/c proton momentum
  - SPS pulse: $2.4s/14.4s$
  - 3.0×10^7 ppp on $\mathrm{K_S}$ target $\Rightarrow \sim 3 \times 10^2$ $\mathrm{K_S}$
  - 1.5×10^{12} ppp on $\mathrm{K_L}$ target $\Rightarrow \sim 2 \times 10^7$ $\mathrm{K_L}$
  - Decays per year (120 days, 50% efficiency):

    6.5×10^7 $\mathrm{K_S}$ /year $\Rightarrow$ SES: $\sim 1.5 \times 10^{-7}$

    3.6×10^{10} $\mathrm{K_L}$ /year $\Rightarrow$ SES: $\sim 3 \times 10^{-10}$

    (E_K: 70–170 GeV, 10% acceptance)
- 1999 High Intensity $\mathrm{K_S}$ run (48 hours)
  - no $\mathrm{K_L}$ beam
  - $\sim 6.0 \times 10^9$ ppp on $\mathrm{K_S}$ target ($\times 200$)
  - $\sim 2.3 \times 10^8$ $\mathrm{K_S}$ decays in E_K: 60–190 GeV

    $\Rightarrow$ SES: $\sim 4 \times 10^{-8}$ (10% acceptance)

    $\Rightarrow$ 48 hours $\simeq$ 3-4 years of ϵ'/ϵ operation
- 2000 High Intensity $\mathrm{K_S}$ run
  - no charged spectrometer
  - 400 GeV/c proton momentum
  - $\sim 9.0 \times 10^9$ ppp on $\mathrm{K_S}$ target
  - modified production angle
  - modified duty cycle ($3.2s/14.4s$)
  - $\sim 10^{10}$ $\mathrm{K_S}$ decays collected in $\sim$ 40 days

Rare decays physics in NA48

Summary of recent rare decays results in NA48

Decay	*NA48 (Preliminary)*		*Published result*	
K_L	*Evt.*	*BR*	*Evt.*	*BR*
$\pi^0\gamma\gamma$	2558	$(1.36 \pm 0.05)10^{-6}$	947	$(1.7 \pm 0.1)10^{-6}$ *(KTeV)*
$\pi^+\pi^- e^+e^-$	1337	$(3.1 \pm 0.2)10^{-7}$	50	$(3.5 \pm 0.6)10^{-7}$ *(KTeV)*
$e^+e^-e^+e^-$	132	$(3.7 \pm 0.4)10^{-8}$	441	$(3.7 \pm 0.3)10^{-8}$ *(KTeV)*
$e^+e^-\mu^+\mu^-$	19		1	$(2.9^{+6.7}_{-2.4})10^{-9}$ *(E799I)*
$e^+e^-\gamma\gamma$	492	$(6.3 \pm 0.5)10^{-7}$	1543	$(5.84 \pm 0.35)10^{-7}$ *(KTeV)*
$e^+e^-\gamma$			6864	$(1.06 \pm 0.05)10^{-5}$ *(NA48)*
K_S	*Evt.*	*BR*	*Evt.*	*BR*
$\pi^+\pi^- e^+e^-$	921	$(4.3 \pm 0.4)10^{-5}$	56	$(4.5 \pm 0.8)10^{-5}$ *(NA48)*
$\gamma\gamma$			149	$(2.6 \pm 0.4)10^{-6}$ *(NA48)*
$\pi^0 e^+e^-$	–	$< 1.4 \times 10^{-7}$	–	$< 1.1 \times 10^{-6}$ *(NA31)*
Ξ^0	*Evt.*	*BR*	*Evt.*	*BR*
$\Sigma^+ e^-\bar{\nu}$	60		176	$(2.7 \pm 0.4)10^{-4}$ *(KTeV)*
$\Lambda\gamma$			497	$(1.9 \pm 0.2)10^{-3}$ *(NA48)*
$\Sigma^0\gamma$			380	$(3.7 \pm 0.5)10^{-3}$ *(NA48)*

The NA48/I proposal

- A program for $\mathrm{K_S}$ rare decay and neutral hyperon search in the year 2002 has been approved by the CERN Research Board (CERN SPSC 2000-002)
- $\geq$ 120 days of data taking starting in april 2002
- IMPROVEMENTS OF THE NA48 SETUP
  - no $\mathrm{K_S}$ veto counter
  - vacuum along the passage of the beam
  - new drift chamber front end and read out electronics
  - optimized read out, data aquisition and trigger systems
  - optmized collimator design:
    - additional sweeping magnet $\rightarrow$ charged shower reduction
    - removable lead converter $\rightarrow$ photon conversions reduction
    - bronze absorber plug into $\mathrm{K_L}$ beam aperture $\rightarrow$ background reduction

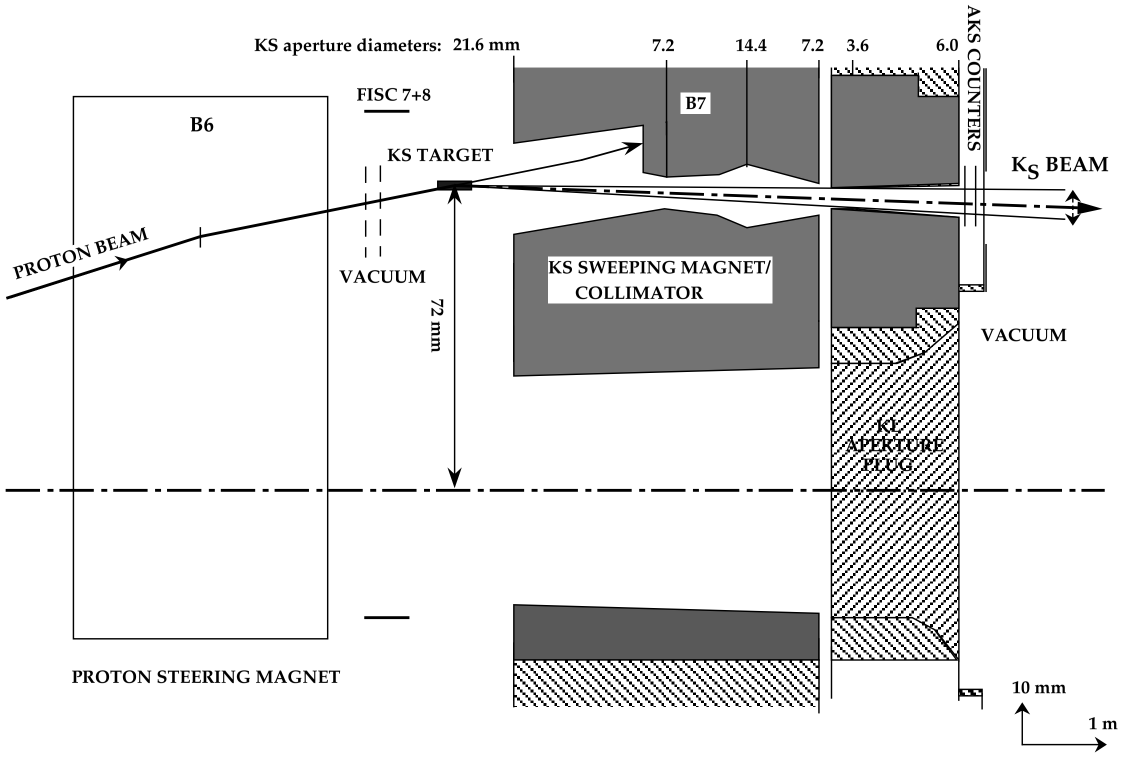
$\Rightarrow$ AIM: collect at least $\times 50$ the statistics of the 1999 data

$\Rightarrow$ proposal: $SES \sim 3 \times 10^{-11}/\alpha$ (α: acceptance for the decay after all cuts)

$\Rightarrow$ better sensitivity actually expected due to the upgrade of front end and read out electronics

The NA48/I beam characteristics

DETAIL OF THE K_S TARGET STATION



SPS proton momentum	400 GeV/c
Duty Cycle	5.2 s/16.8 s
Protons per pulse on target	1×10^{10}
Production angle	-2.5 $mrad$
Total kaon flux/pulse	$\sim 1.5\times10^{5}$
K-decays (40-240 GeV)/pulse	1.1×10^{5}
K-decays (40-240 GeV)/year	3.0×10^{10}
(50% efficiency × 120 days)	

- Features of the 2002 intense K_S beam (wrt 1999)
  - ⇒ lower proton momentum
  - ⇒ longer duty cycle
  - ⇒ modified production angle
  - ⇒ higher intensity

Physics case: $\mathrm{K_S} \to \pi^0 \mathrm{e^+e^-}$

The measurement of $\mathrm{K_S} \to \pi^0 \mathrm{e^+e^-}$ is essentially a measurement of $K_1 \to \pi^0 e^+ e^-$ with CP=+1 (CPC)

PHYSICS INTEREST:

- understand the chiral structure of the $K \to \pi\gamma^*$ vertex:
  - ⇒ $\mathrm{K_S} \to \pi^0 \mathrm{e^+e^-}$ is dominated by long–distance dynamics through one–photon exchange
  - ⇒ theoretical expectation from χPT ($a_s \sim O(1)$):

$$\mathrm{BR}(\mathrm{K_S} \to \pi^0 \mathrm{e^+e^-}) \sim 5.2 \times 10^{-9} |a_s|^2$$

- bound the indirect CPV component of the $\mathrm{K_L} \to \pi^0 \mathrm{e^+e^-}$ decay: 3 components contribute to the decay amplitude:
  - ⇒ CP conserving component

$$\mathrm{BR}(\mathrm{K_L} \to \pi^0 \mathrm{e^+e^-})_{CPC} \leq few \times 10^{-12}$$

dominated by the two-photon process (CP=-1) $K_2 \to \pi^0 \gamma^* \gamma^*$

  - ⇒ indirect CP violating component due to the fraction ϵ of K_1 in $\mathrm{K_L}$:

$$\mathrm{BR}(\mathrm{K_L} \to \pi^0 \mathrm{e^+e^-})_{ind} = |\epsilon|^2 \frac{\tau_L}{\tau_S} \mathrm{BR}(\mathrm{K_S} \to \pi^0 \mathrm{e^+e^-})$$

  - ⇒ direct CP violating component due to the K_2 decay in $\mathrm{K_L}$

Search for $\mathrm{K_S} \to \pi^0 e^+ e^-$

MEASUREMENT MOTIVATIONS:

⇒ direct and indirect CPV components of $\mathrm{K_L} \to \pi^0 e^+ e^-$ interfere, and the indirect contribution is linked to the χPT parameter a_s

⇒ Since the a_s parameter cannot be predicted, a high sensitivity search for $\mathrm{K_S} \to \pi^0 e^+ e^-$ is needed.

PRESENT STATUS:

⇒ Best result (NA48, 2001):

$$BR < 1.4 \times 10^{-7} (90\% CL)$$

(PDG: $BR < 1.1 \times 10^{-6}$ (90% CL) NA31, 1993)

⇒ NA48/I proposal: $SES \sim 6 \times 10^{-10}$
(1 year data taking, MC acceptance $\sim 5\%$)

⇒ expected signal in one year $\sim$ 7 events
for $BR(\mathrm{K_S} \to \pi^0 e^+ e^-) = 5 \times 10^{-9}$

⇒ main background due to $\mathrm{K_S} \to \pi^0 \pi^0_D$ estimated to be $<$ 0.3 events (MC simulation)

⇒ negligible background due to $\mathrm{K_S} \to \pi^0_D \pi^0_D$ and $K_{L,S} \to e^+ e^- \gamma\gamma$

Physics case: $\mathrm{K_S} \rightarrow \pi^0\pi^0\pi^0$

PHYSICS INTEREST: CP violation in $\mathrm{K_S} \rightarrow \pi^0\pi^0\pi^0$

$|\mathrm{K_S}> \simeq |\mathrm{K_1}> + \epsilon_S |\mathrm{K_2}>$

$CP(|\mathrm{K_1}>) = +1 \quad CP(|\mathrm{K_2}>) = -1 \quad CP(\pi^0\pi^0\pi^0) = -1$

$\Longrightarrow$ parametrized by $\eta_{000} = \frac{A(\mathrm{K_S}\rightarrow\pi^0\pi^0\pi^0)}{A(\mathrm{K_L}\rightarrow\pi^0\pi^0\pi^0)}$

- $\mathfrak{Re}(\eta_{000}) = \mathfrak{Re}(\epsilon) \sim 1.6 \times 10^{-3}$ is predicted by CPV in the K^0 -$\overline{\mathrm{K}}^0$ mixing

- $\mathfrak{Im}(\eta_{000})$ is sensitive to direct CPV in a decay amplitude.

- η_{000} is also important for CPT test through the Bell-Steinberger relation which couples the CPT violation parameter $\mathfrak{Im}(\delta)$ and $\mathrm{K_S}$ and $\mathrm{K_L}$ decay amplitudes into all final states:
  $\Rightarrow$ the uncertainty on $\mathfrak{Im}(\delta)$ is dominated by the error on η_{000}

$K_S \to \pi^0\pi^0\pi^0$ in NA48

THE MEASUREMENT OF η_{000} in NA48

The NA48 sensitivity to η_{000} comes from the $K_S - K_L$ interference term, which is superimposed on a very large, flat $K_L \to \pi^0\pi^0\pi^0$ component.

$$I_{3\pi^0} \sim e^{-t/\tau_L} + |\eta_{000}|^2 e^{-t/\tau_S} + 2D|\eta_{000}|e^{-t/2(1/\tau_S+1/\tau_L)}\cos(\Delta m t + \phi_{000})$$

D is the K^0 $\overline{K}^0$ dilution factor ($\sim$ 0.3 for NA48).

PRESENT EXPERIMENTAL SITUATION:

Experiment	$\mathfrak{Re}(\eta_{000})$	$\mathfrak{Im}(\eta_{000})$	BR($K_S \to \pi^0\pi^0\pi^0$)
Barmin et. al	-0.08 ± 0.27	-0.05 ± 0.27	$< 3.7 \times 10^{-5}$ 90 % CL
CPLEAR	0.18 ± 0.15	0.15 ± 0.20	$< 1.9 \times 10^{-5}$ 90% CL
SND			$< 1.4 \times 10^{-5}$ 95% CL

NA48 has collected about 10^6 $3\pi^0/c\tau_S$ in the 2000 run, which should allow to reach a new limit of few $\%$ on $\mathfrak{Re}(\eta_{000})$ and $\mathfrak{Im}(\eta_{000})$

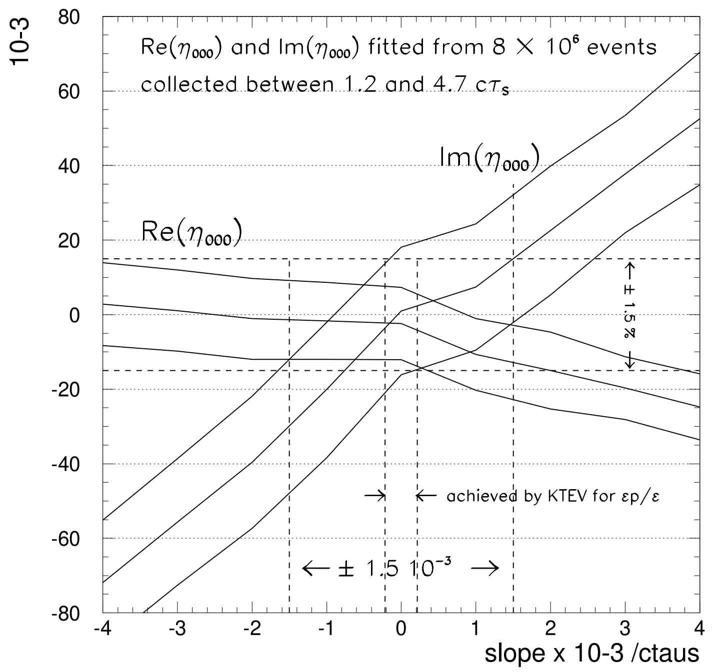
$\Longrightarrow$ NA48/I aims to reduce the error on $\mathfrak{Re}(\eta_{000})$ and $\mathfrak{Im}(\eta_{000})$ to $\sim 1\%$ measuring the K_S -K_L interference near the production target

The η_{000} measurement

Sensitivity to η_{000} in NA48/I

- Method: measure $\mathrm{K_S} - \mathrm{K_L}$ interference near the production target
  - $\Rightarrow$ maximum interference at the $\mathrm{K_S}$ target
  - $\Rightarrow$ most of the effect within few $\mathrm{K_S}$ lifetimes
- Sensitivity to $\mathfrak{Re}(\eta_{000})$ and $\mathfrak{Im}(\eta_{000})$ evaluated with $3\pi^0$ events (HI $\mathrm{K_S}$ run data and MC)
  - $\Rightarrow$ high $K^0 \to 3\pi^0$ statistics required to improve limits on $\mathfrak{Re}(\eta_{000})$ and $\mathfrak{Im}(\eta_{000})$
  - $\Rightarrow$ excellent knowledge of detector acceptance

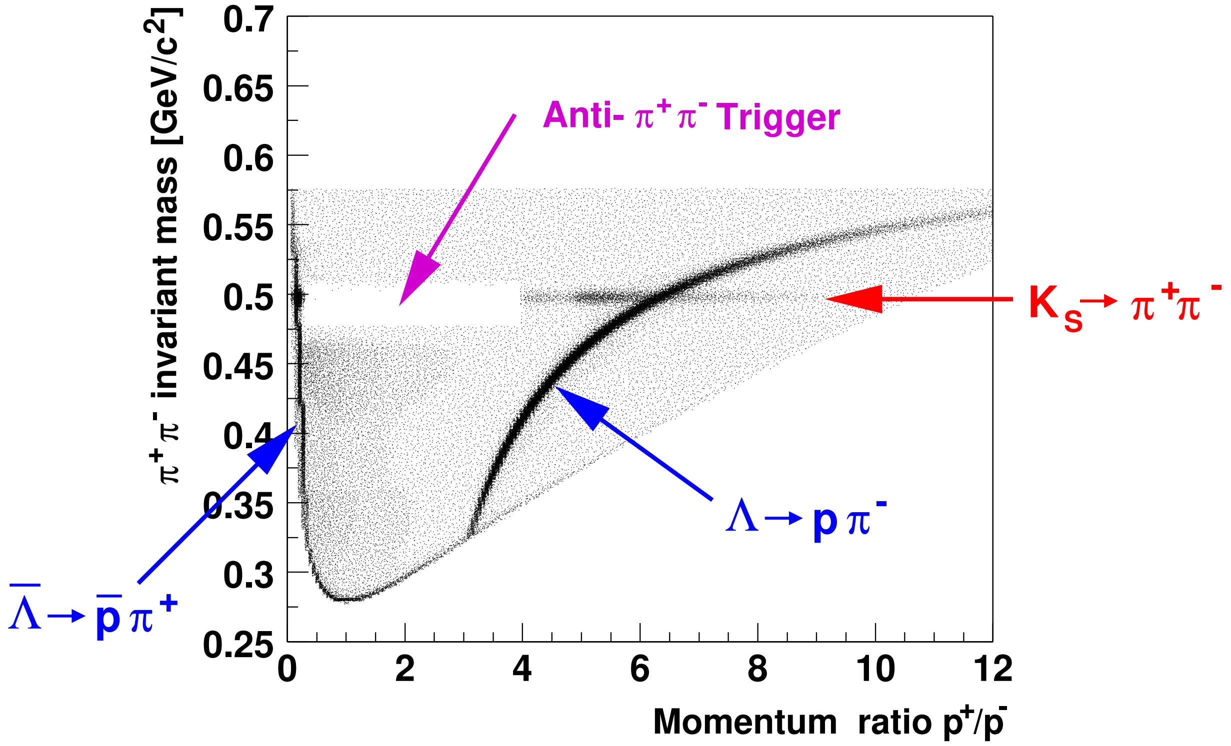
$\mathfrak{Re}(\eta_{000}), \mathfrak{Im}(\eta_{000})$: statistical and systematic error due to limited knowledge of the acceptance:



$\Longrightarrow$ NA48/I error on $\mathfrak{Re}(\eta_{000})$ and $\mathfrak{Im}(\eta_{000})$ within $\sim 1\%$ in one year of data taking

Hyperon decays in NA48

The $\mathrm{K_S}$ target is source of hyperons: the intense beam will be used to improve NA48 current results on neutral hyperon decays and start new studies.



HYPERON SAMPLE IN NA48 (1999 data): two tracks reconstructed under the $\pi^+\pi^-$ hypothesis ($\sim 41 \times 10^6$ 2–tracks events)

HYPERON TRIGGER IN NA48: apply cuts on anti–[$\mathrm{K_S} \to \pi^+\pi^-$] mass and p^+/p^- momenta ratio

Neutral hyperon physics

OUTLOOK AND MOTIVATION

- **precise measurement of $M(\Xi^0)$**
  - ⇒ check mass splitting among the SU(3) octect members related to radiative corrections
  - ⇒ test of theoretical approaches to mass calculation
  - ⇒ NA48: $M(\Xi^-) - M(\Xi^0) = 6.5 \pm 0.25\ MeV/c^2$
  - ⇒ NA48/I: improve error to 0.1 MeV/c^2
- **radiative decays** $\Xi^0 \to \Lambda^0\gamma/\Sigma^0\gamma$
  - ⇒ poor theoretical understanding: predictions of various models over an order of magnitude
  - ⇒ NA48 results (*preliminary*):

$$\mathrm{BR}(\Lambda\gamma) = (1.9 \pm 0.2) \times 10^{-3} \quad (497\ events)$$

$$\mathrm{BR}(\Sigma^0\gamma) = (3.7 \pm 0.5) \times 10^{-3} \quad (380\ events)$$

  - ⇒ NA48/I: increase samples by factor 100 and reduce systematics by factor 2: expect 5% accuracy on BR
- **hyperon β decay** $\Xi^0 \to \Sigma^+ e^- \bar{\nu}$
  - ⇒ direct analogue to $n \to p e^- \bar{\nu}$
  - ⇒ study flavor symmetry violation
  - ⇒ *PDG*: $\mathrm{BR}(\Sigma^+ e^- \bar{\nu}) = (2.7 \pm 0.4) \times 10^{-4}\ (KTeV)$
  - ⇒ NA48: observe $\sim$ 60 events
  - ⇒ NA48/I: expect up to 25000 events
- **search for $\Xi^0 \to p\pi^-$ ΔS=2 transitions**
  - ⇒ predicted $\mathrm{BR}(p\pi^-) \sim 10^{-17}$
  - ⇒ current limit: $\mathrm{BR}(p\pi^-) \leq 4 \times 10^{-4} \quad (90\%\ CL)$
  - ⇒ NA48/I: expect a factor 100 on existing limit

Competition to NA48/I

- RARE K_S DECAYS
  - competition from the KLOE experiment (Frascati – Italy)
  - complemetary experimental technique due to the K_S tagging in KLOE
  - at the full DAΦNE design luminosity of 5$\times$ 10^{32} cm^{-2}s^{-1}, however, the sensitivity per year for $K_S \to \pi^0 e^+ e^-$ is less than NA48/I proposal
- NEUTRAL HYPERON PHYSICS
  - competition from the KTEV experiment (FNAL – USA) which collects neutral hyperons from the vacuum beam
  - only hyperons with very high energy decay in KTEV fiducial region
  - capability of KTEV to track the leading baryon in the beam (no hole in tracking chambers)
  - NA48/I is up to one order of magnitude better than KTEV

Summary of NA48/I physics topics

$\mathrm{K_S}$ Physics program

Decay	Theory	Events in NA48/I
	Non-Leptonic decays (χPT)	
$\mathrm{K_S} \rightarrow \gamma\gamma$	2.1×10^{-6}	24000
$\mathrm{K_S} \rightarrow \pi^0\gamma\gamma$	3.8×10^{-8}	114
$\mathrm{K_S} \rightarrow \pi^0\pi^0\gamma\gamma$	5.6×10^{-9}	7
	Dalitz decays ($\gamma\gamma^*$)	
$\mathrm{K_S} \rightarrow \gamma e^+e^-$	3.4×10^{-8}	304
$\mathrm{K_S} \rightarrow \gamma\mu^+\mu^-$	8×10^{-10}	12
	$K \rightarrow \pi l^+l^-$	
$\mathrm{K_S} \rightarrow \pi^0 e^+e^-$	5×10^{-9}	7
$\mathrm{K_S} \rightarrow \pi^0\mu^+\mu^-$	1×10^{-9}	3
	$\mathrm{K_S} \rightarrow \pi^+\pi^-\gamma(\gamma^*)$	
$\mathrm{K_S} \rightarrow \pi^+\pi^-\gamma$	1.8×10^{-3}	5.3×10^6
$\mathrm{K_S} \rightarrow \pi^+\pi^-e^+e^-$	3.6×10^{-5}	5.4×10^4
	$K \rightarrow 3\pi$	
$K \rightarrow \pi^+\pi^-\pi^0$		$2.6 \times 10^6/\tau_\mathrm{S}$
$K \rightarrow \pi^0\pi^0\pi^0$		$1.5 \times 10^6/\tau_\mathrm{S}$

The NA48/II proposal

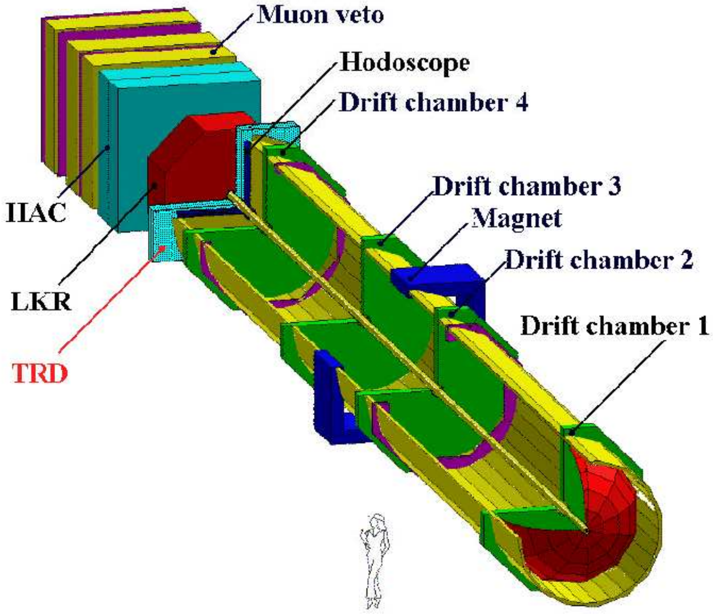
A new program has been approved by the CERN RB to study with high statistics specific properties of the decay of charged kaons (CERN SPSC 2000-003):

⇒ *direct CP violation in* $K \rightarrow 3\pi$

⇒ $q\bar{q}$ *condensate in QCD vacuum (*K_{e4}*)*

⇒ *possible deviations from V-A and Standard Model*

⇒ *measurement of rare charged kaon decays involving photons and/or* e^+e^- *pairs*



- use new simultaneous charged kaon beams
- upgrade the NA48 detector with a TRD for π/e rejection and with a small beam spectrometer for better K position and momentum measurement
- optimize trigger system
- data taking in the year 2003

Direct CP Violation in $\mathrm{K}^{\pm}$ decays

❖ High precision study of charged kaon decays:
⇒ important new possibility to search for direct CP violation additional to that of the neutral kaon sector without the complications induced by mixing
⇒ any difference in $\mathrm{K}^{\pm}$ decay matrix elements indicates direct CP violation

❖ NA48/II proposal: high statistics comparison of

$$\mathrm{K}^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-} \quad \mathrm{K}^{\pm} \to \pi^{\pm}\pi^{0}\pi^{0}$$

⇒ most promising processes

⇒ decay matrix element parametrized as:

$$|M(u,v)|^2 \sim 1 + gu + hu^2 + kv^2$$

$$u = (s_3 - s_0)/m_\pi^2 \quad v = (s_1 - s_2)/m_\pi^2$$

$$s_0 = (s_1 + s_2 + s_3)/3$$

$$s_i = (P_K - P_i)^2 \quad (\mathrm{i} = 3 \text{ for the odd pion})$$

⇒ direct CPV measured through the asymmetry :

$$A_g = \frac{g^+ - g^-}{g^+ + g^-}$$

⇒ observable quantity:

$$R(u) = \frac{\int dv |M^+(u,v)|^2}{\int dv |M^-(u,v)|^2} \approx 1 + u \cdot (g^+ - g^-) = \frac{N^+(u)}{N^-(u)}$$

⇒ any variation of $R(u)$ as a function of u is evidence of direct CPV.

The A_g measurement

PRINCIPLE OF A_g MEASUREMENT IN NA48/II

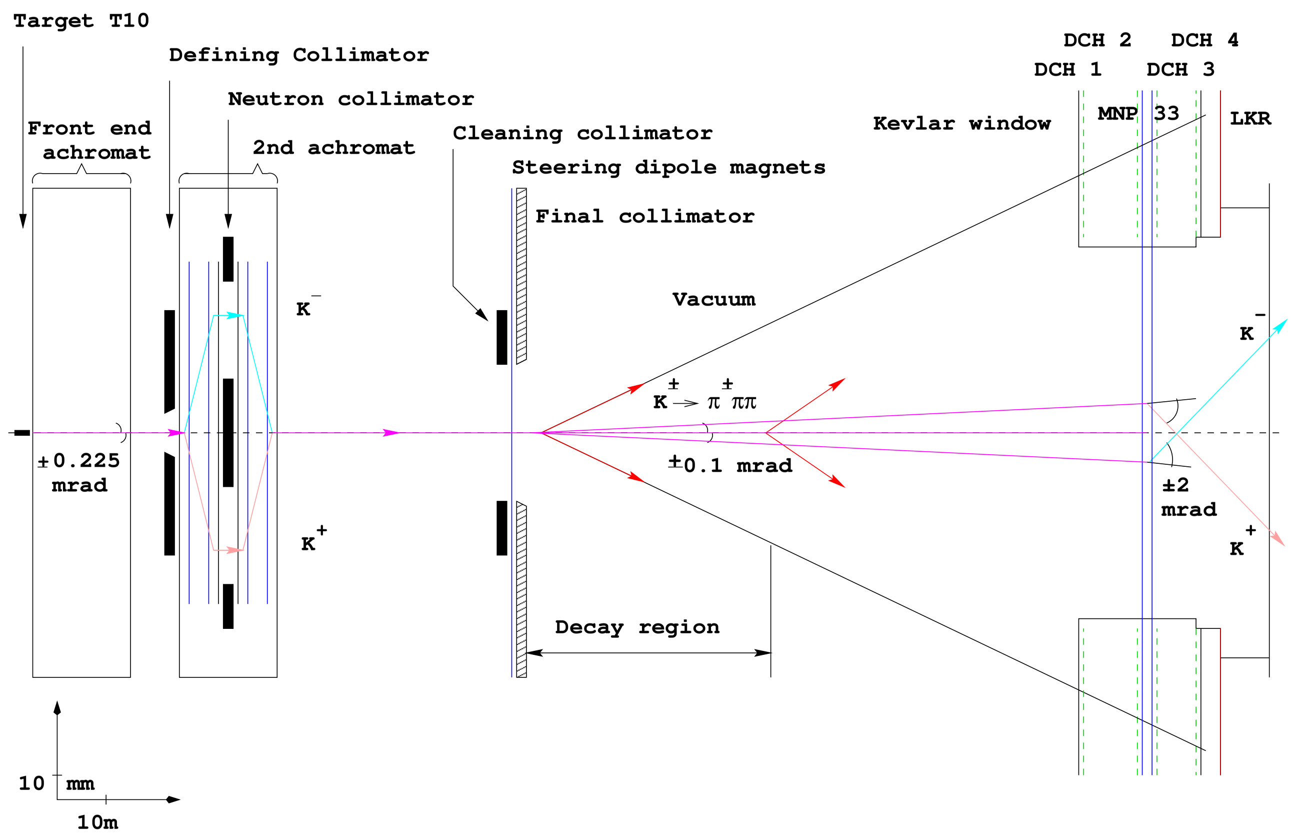
✥ Systematic uncertainties on A_g can create a slope different from zero (studied with MC):

- *different K^+ and K^- energy distributions*
- *local inefficiencies in drift chambers*
- *differences between the magnetic field in the two polarities*
- *relative offset of the two beams*
- *relative asymmetry in the profile of the two beams*
- *differences in the punch-through probabilities for positive and negative pions*
- *difference in the interaction probability in the spectrometer for positive and negative pions*

✥ Systematics could be kept at a level of $< 10^{-4}$ under the following conditions:

- use simultaneous K^+ and K^- beams overlapping in space and time, and within a narrow range of momentum such that K^+ and K^- decay in the same fiducial volume
- alternate the sign of the spectrometer field to equalize acceptances for K^+ and K^- decays in presence of localized imperfection in the detector
- bin data in kaon momentum and average $R(u)$ over different field orientations in each bin for a measurement independent of acceptance

The simultaneous K^+ and K^- beams



K^+ and K^- beam parameters

	K^+	K^-
Energy	400 GeV/c	
Duty cycle	5.2s/16.8s	
Proton per pulse	10^{12}	
Production angle, mrad	0.0	
Acceptance angle, mrad	± 0.36	
Momentum, GeV/c	60 ± 3	
proton flux/pulse (10^6)	8.6	0.9
pion flux/pulse (10^6)	33.2	24.6
kaon flux/pulse (10^6)	3.1	1.8
$K3\pi$(in 100m)/year (10^{10})	1.4	0.8

The precision of A_g measurement

RECONSTRUCTION OF $K^{\pm} \rightarrow 3\pi^{\pm}$ IN NA48/II

Decay	$\pi^{\pm}\pi^{+}\pi^{-}$	$\pi^{\pm}\pi^{0}\pi^{0}$
Acceptance (%)	45	6.5
K^{+}/K^{-} decays/pulse (10^4)	2.3/1.4	0.05/0.03
K^{+}/K^{-} decays/year (10^9)	7.3/4.4	0.15/0.09
M_K resolution (MeV/c^2)	1.6	1.2
P_K resolution (MeV/c)	460	360
z resolution (cm)	65	60
u resolution	0.035	0.02
STATISTICAL ERROR	0.7$\times$ 10^{-4}	$<$ $2.2\times$ 10^{-4}

SYSTEMATICS UNCERTAINTIES ON A$_g$

Source	Uncertainty on A$_g(10^{-5})$
Beam non collinearity	< 3.8 (MC stat.)
$P_{K^+} \neq P_{K^-}$	~ 1.0 (Kabes)
Accidentals in detector	< 2.0 (MC stat.)
π^{+}/π^{-} cross section difference	< 0.07 (MC stat.)
Pion punch-through effects	< 0.5 (K_e3 stat.)
Parasitic B, resolution on u,p...	negligible
TOTAL SYSTEMATICS	~ 5

$\Rightarrow$ the precision of A_g measurement in NA48/II is limited by statistics

$\Rightarrow$ total systematics $\sim 5 \times 10^{-5}$

$\Rightarrow$ with $\sim 10^{10}$ $K^{\pm} \rightarrow \pi^{\pm}\pi^{+}\pi^{-}$ decays/year NA48/II aims at a precision of $\sim 10^{-4}$ on A_g

Outlook on A_g measurement

- The precision of A_g measurement in NA48/II is limited by statistics
- Present experimental limit:

$$A_g = (-7 \pm 5) \times 10^{-3} \quad \textit{Ford et al.}\ (1970)$$

- Status of A_g measurement:

Experiment	$K^{\pm}$ decays	Statistics	δA_g
HyperCP	$\pi^{\pm}\pi^{+}\pi^{-}$	4.5×10^{8}	$\sim 6 \times 10^{-4}$
KLOE (1 year)	$\pi^{\pm}\pi^{+}\pi^{-}$	1.5×10^{8}	$\sim 4.4 \times 10^{-4}$
	$\pi^{\pm}\pi^{0}\pi^{0}$	0.6×10^{8}	$\sim 6.3 \times 10^{-4}$
NA48 (1 year)	$\pi^{\pm}\pi^{+}\pi^{-}$	1.17×10^{10}	$\sim 0.7 \times 10^{-4}$
	$\pi^{\pm}\pi^{0}\pi^{0}$	2.4×10^{8}	$< 2.2 \times 10^{-4}$

- Status of theoretical calculations:

Author	A_g prediction
A. Belkov et al.	$(2\text{-}4)\cdot10^{-4}$
E. Shabalin	$4\cdot10^{-4}$
D'Ambrosio	$4\cdot10^{-5}$
L.Maiani, N.Paver	$(2.3 \pm 0.6)\cdot 10^{-6}$
D'Ambrosio et al.	$\sim 10^{-4}$

- CP can also be investigated in NA48/II (limited statistics) in decays such as: $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$

CONCLUSIONS

- NA48 is concluding with the last data taking in 2001 a successful experimental program:
  - $\Rightarrow$ direct CP violation in the neutral kaon system has been clearly established
  - $\Rightarrow$ the rare decay program has provided very interesting physics results in the field of χPT and of CP violation in the neutral kaon sector and in the field of neutral hyperon physics

- two addenda to the NA48 proposal have been approved for further running after the end of $\mathrm{Re}(\varepsilon'/\varepsilon)$ program to get a deeper knowledge of kaon and hyperon physics:

NA48/I will take data in 2002 using the present beam line and detector with improved readout capability to probe the $\mathrm{K_S}$ and neutral hyperon decays physics with a beam intensity ~ 500 times the actual one.

NA48/II will take data in 2003 using an upgraded detector and simultaneous charged kaon beams to study direct CP violation in the decay $\mathrm{K}^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}$.

- The K sector has still great potentialities for exiting physics in the framework of direct CP violation investigation