Hyperon Rates 2002

Decay mode	Branching ratio ($\times 10^{-3}$)	Events 2002
$\Xi^0 \to \Sigma^+ e^- \bar{\nu}_e$	$0.254 \pm 0.011 \pm 0.016$	$(1-3) \cdot 10^4$
$\Xi^0 \to \Sigma^+ \mu^- \bar{\nu}_\mu$	???	$\sim 100 - 200$
$\Lambda \to p e^- \bar{\nu}_e$	0.832 ± 0.014	some $\sim 10^6$
$\Xi^0 \to \Lambda\gamma$	1.9 ± 0.16	some 10^5
$\Xi^0 \to \Sigma^0\gamma$	3.5 ± 0.4	some 10^5
$\Sigma^0 \to \Lambda e^+ e^-$		???
$\Sigma^0 \to \Lambda\gamma\gamma$		???
$\Xi^0 \to p\pi^-$		improve Limit $< 10^{-8}$

Trigger Rates (1999 High Intensity K_S Runs)

Decay mode	conditions	counts
(NUT)	$c\tau_S \leq 5.5$	7500
$K_S \to \pi^0\pi^0\pi^0$	NUT × (NPX>4 OR NPY>4)	1500
$K_S \to \gamma\gamma$	NUT × $Z < 9\ m$ NPX, Y $\leq 3 \times$ NPY, X < 2	2500
$K_S \to \pi^0 e^+ e^-$	NUT × 1/2 tracks	4000
$K_S \to \pi^+\pi^- e^+ e^-$	MBX 4 tracks	2000
hyperon trigger	$\overline{\text{MBX}}$	40000

L2 Trigger rates from September 1999 test run (5×10^9ppp). The Hyperon trigger needs to be improved (under work)

- The current Level II read out limit is 8 KHz, i.e. $\sim$ 20000 events/spill (2.4s).
- The Online PC farm can take twice as many triggers.

High Intensity KS: history and future

- Year 2000:

  We had 40 days of protons at 400 GeV/c

  $\rightsquigarrow$ collect data for K_S neutral decays ($K_S \to \gamma\gamma$ and η_{000})

  - No drift chambers, no beam-pipe and no kevlar window
  - Extend the vacuum into the Helium tank

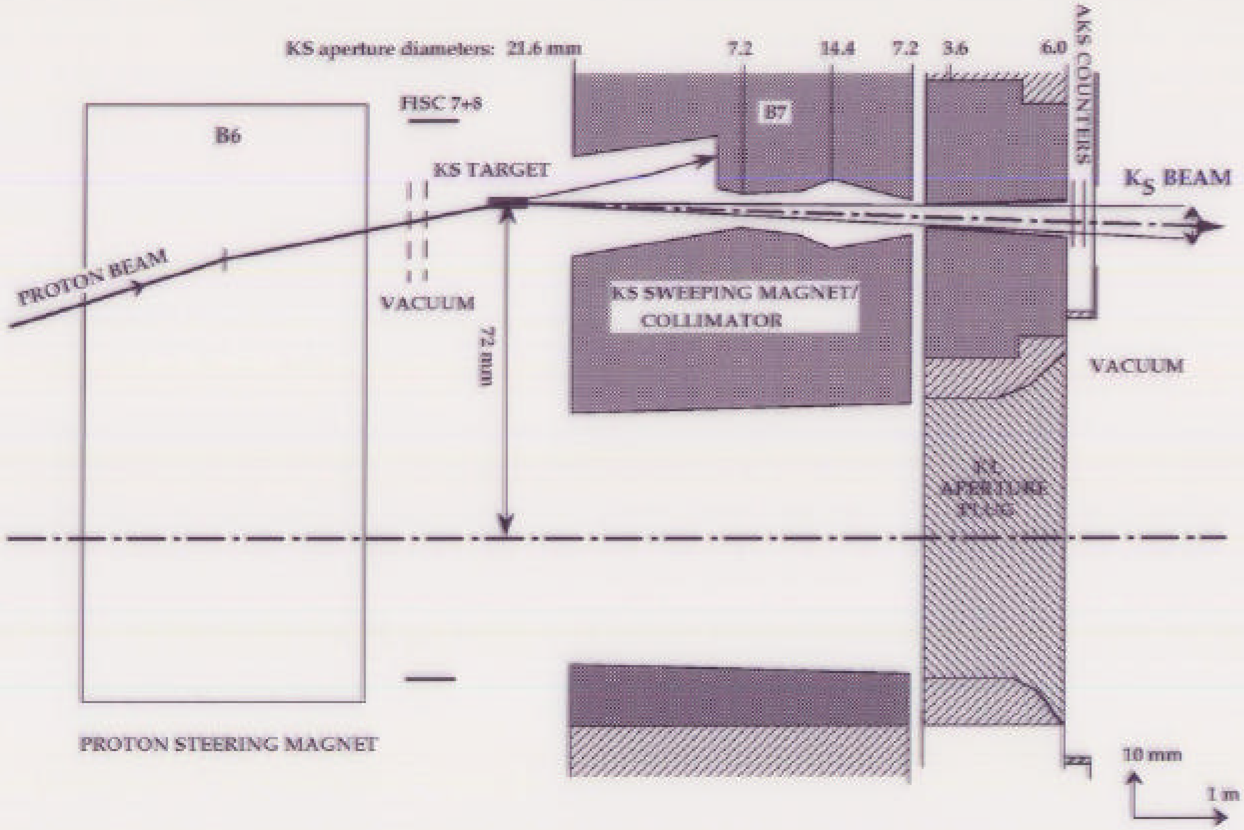
- Year 2002, after completion of $Re(\varepsilon'/\varepsilon)$ in 2001:

  120 days, 400 GeV/c protons, best possible duty cycle $\rightsquigarrow$ finish neutral K_S decays and achieve the proposed sensitivities for hyperon physics and for the rest of the K_S programme, notably $K_S \to \pi^0 e^+ e^-$.

Required Modifications for the K_S Run 2002

- Beam energy - The Proton energy will be reduced to 400GeV
- Duty cycle - 5s every 19.2s instead of 2.4s every 14.4s
- Beamline - The Protons will be sent straight to the K_S Target.
- Beamintensity - We will have $\sim 1 \times 10^{10}$ protons per Spill to the K_S target (to be compared with $\sim 3 \times 10^{7}$ protons per spill in the ϵ' data taking mode)
- small changes in the read out systems to deal with the longer duty cycle

The K_S target station



Detailed layout of the K_S target station and beam (vertical section)

K_S beam parameters

Beam	$K_L + K_S$ ($Re(\varepsilon'/\varepsilon)$)		Intense K_S beam	
Year	1999		2000	2002
SPS momentum (GeV/c)	450		400	400
Duty Cycle (s/s)	2.5/14.4		2.5/14.4	5.0/19.2
Protons per pulse on target	1.5×10^{12}	3×10^{7}	5×10^{9}	1×10^{10}
Production angle α (mrad)	+2.4	-4.2	-4.2	-2.5
Total beam flux K's/pulse	$\sim 2\times10^{7} + \sim 3\times10^{2}$		$\sim 5\times10^{4}$	$\sim 1.5\times10^{5}$
K-decays in Δp_K /pulse	$1.0\times10^{5} + 1.8\times10^{2}$		4.0×10^{4}	1.1×10^{5}
K-decays in Δp_K /year (0.5 × 120 days)	$3.6\times10^{10} + 6.5\times10^{7}$		1×10^{10}	3.0×10^{10}

Prospects of the High Intensity K_S Run 2002

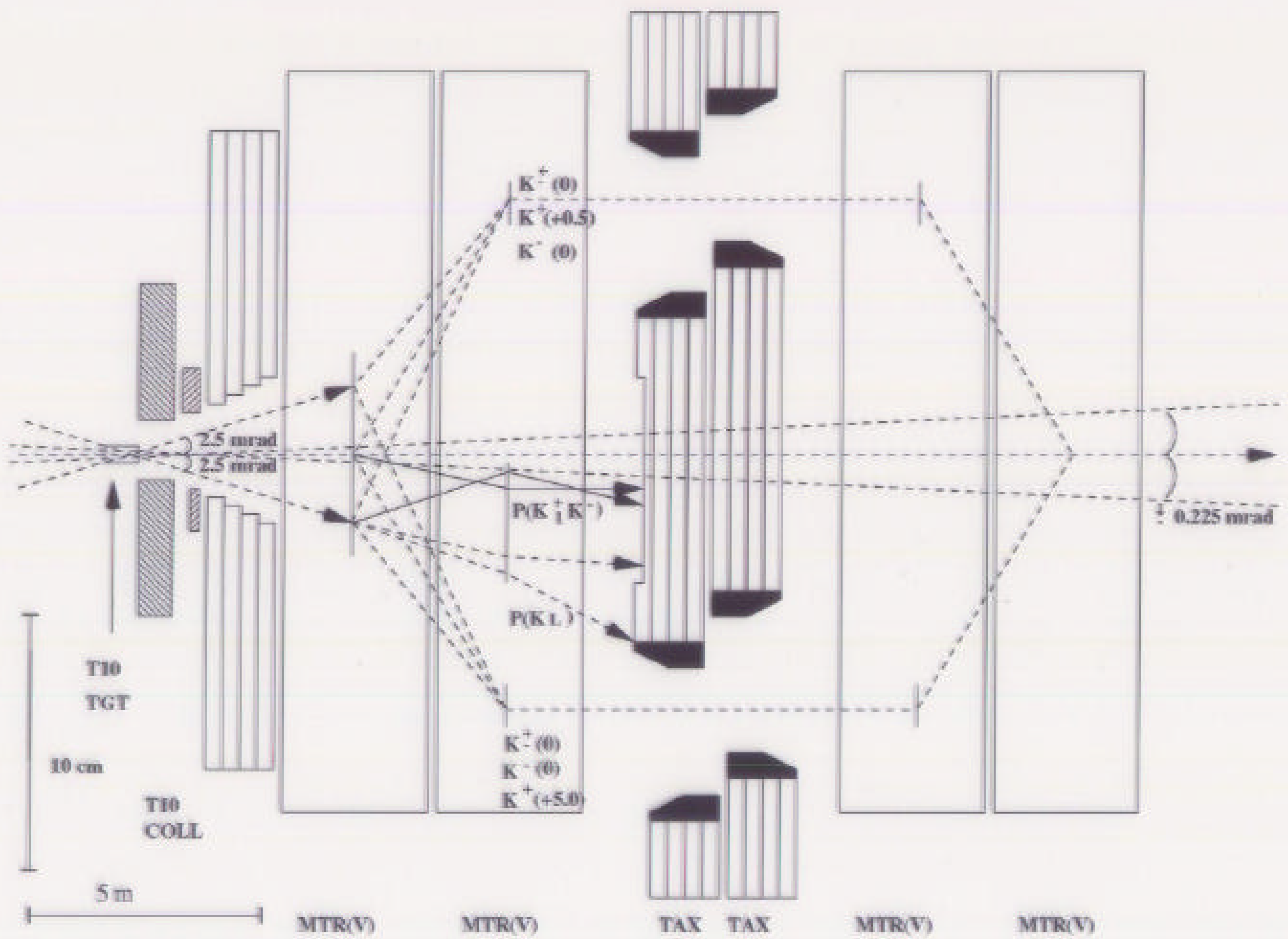
- 3×10^{10} K_S decays
- First observation of $\mathrm{K_S} \to \pi^0 \mathrm{e^+e^-}$ with ~ 7 events assuming BR of 5×10^9, main background ($K_S \to \pi^0 \pi^0_D$) expected to be < 0.3 other sources should be negligible.
- $\mathrm{K_S} \to \pi^0\pi^0\pi^0$: put a bound of 1% on η_{000}
- $\mathrm{K_S} \to \gamma\gamma$ High precision measurement of the branching ratio with $\sim 24,000$ events.
- $K_S \to \pi^+\pi^-\gamma$ and $K_S \to \pi^+\pi^- e^+e^-$: $\sim 5 \times 10^6$ and $\sim 5 \times 10^4$ events expected.
- First observation of various decay modes of the K_S, like $K_S \to e^+e^-\gamma, \mu^+\mu^-\gamma, \pi^0\gamma\gamma$...

The $K^{\pm}$ Program

After ending the K_S program in 2002 the break during the winter will be used to set up the charged Kaon Program. Some bigger modifications are required:

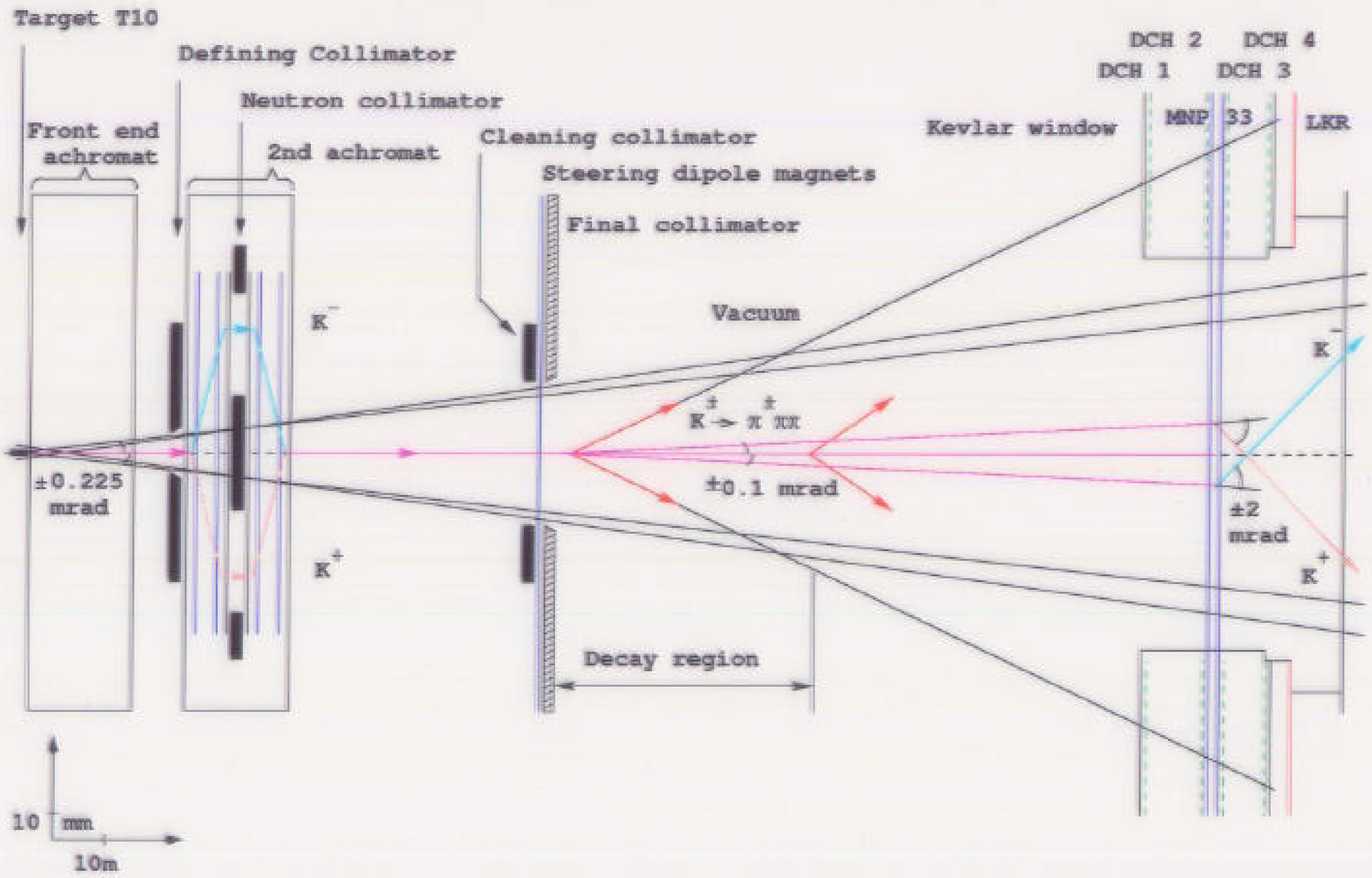
- New setup of the beamlines to obtain simultaneous $K^{\pm}$ beams
- Add Transition Radiation Detector (TRD) to the detector
- Beam spectrometer - measure parent kaon momentum

Beam Line Modification



Beam Line Modification II

Schematic layout of K^+ and K^- beams



Charged kaon beams

	K^+	K^-
Energy	400 Gev/c	
Duty cycle	5s/19.2s	
Proton per pulse	10^{12}	
Production angle, mrad	0.0	
Production angle, mrad	0.0	
Acceptance angle, mrad	±0.225	
Momentum, Gev/c	60±6	
proton flux/pulse (10^6)	7.5	-
pion flux/pulse (10^6)	29.0	17.3
kaon flux/pulse (10^6)	1.9	1.1
kaon decays/year (10^10)	5.5	3.1

Parameters of the beams

Source	Rate, Khz
$\pi^+ \rightarrow \mu^+$	240
$\pi^- \rightarrow \mu^-$	140
$K^+ \rightarrow$ all	110
$K^- \rightarrow$ all	60
Level 1 charged trigger	88
Level 1 neutral trigger	12

Rates in the detector

Upgrade of the detector

Transition Radiation Detector (TRD) to improve electron identification (for K_e4 decays)

π/e rejection >100 at $\epsilon_e=90\%$, $1<P<50$ Gev/c

Possibility: Use 7 modules of the NOMAD TRD in front of the LKr Calorimeter

Each module consists of 315 plastic foil radiator, 176 straw tubes and it is filled with a Xe/CH_4 mixture

Modifications required to open a beam hole

Study under way to integrate the TRD readout in the NA48 DAQ

$K^\pm \to \pi^\pm\pi^+\pi^-$, i.e. the main background to K_e4, the rejection factor is 345 at $\epsilon_e=90\%$ and 111 at $\epsilon_e=95\%$ (from simulation)

Upgrade of the detector, ctnd.

Add beam spectrometer in the second achromat $\rightsquigarrow$ good measurement of the parent kaon momentum (time of flight measurement to associate the kaon with the event, position measurement in the vertical plane to measure the kaon momentum and its direction $\rightsquigarrow$ resolve the ambiguity in the kinematic fit of the K_{e4} decay

Need for:

- High rate capability ($\approx 4 \times 10^7$ part/s)
- $\delta p/p \leq 1\%$
- $\sigma_{\theta x}, \sigma_{\theta y} \leq 1.5 \times 10^{-2}$
- Minimum material along the beam ($\leq 10^{-3} X_0$)

Use a Micromegas like detector (strips along the beam and drift orthogonal to the beam)

$\rightsquigarrow$ Time resolution $< 1ns$, momentum resolution of 1% angular resolution of better than 10^{-2}, with the recommended value for X_0 (from simulation).

Charged Kaon Physics

Study with high statistics specific properties of the decay of charged kaons:

- Direct CP violation in $K \rightarrow 3\pi$
- $q\bar{q}$ condensate in QCD vacuum (K_{e4})
- Detection of possible deviations from V-A and from the Standard Model
- Measurement of rare charged kaon decays involving photons and/or e^+e^- pairs

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

Results on $\mathrm{Re}(\varepsilon'/\varepsilon)$ higher than the average theoretical predictions.

⇝ Independent measure of direct CP violation required. Difference between K^{+} and K^{-} decays is an evidence for direct CP violation.

Direct CP violation induces asymmetry in Dalitz plot density of $K^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}$ and $K^{\pm} \to \pi^{\pm}\pi^{0}\pi^{0}$

The decay matrix element is parameterized as

$$|M(u,v)|^2 \propto 1 + g \cdot u + h \cdot u^2 + k \cdot v^2$$

where $u = (s_3 - s_0)/m_{\pi}^2, v = (s_1 - s_2)/m_{\pi}^2, s_0 = (s_1 + s_2 + s_3)/3, s_i = (P_K - P_i)^2$ and i=3 is the odd pion.

The asymmetry of the Dalitz plot density is defined as

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

Measure the ratio

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

A slope as a function of u is a measure of direct CP violation.
Theoretical Predictions:

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

Systematic Studies

Simulations done to look for induced A_g with

- Different spectra of K^+ and K^-
- 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-trough probabilities for positive and negative pions
- Difference in the interaction probability in the spectrometer for positive and negative pions

Those systematics could be kept at a level of less than 10^{-4} in the following conditions:

- Use simultaneous K^+ and K^- beams
- Maximize the overlap of the two beams by correcting dipoles
- Alternate the sign of the spectrometer field
- Bin in P_K and in u
- Circular acceptance cuts centered on the COG of the two beams

- In the described setup we expect
  - $\sim 2 \times 10^9$ $K^\pm \to \pi^\pm \pi^\pm \pi^\mp$ Decays
  - $\sim 1.2 \times 10^8$ $K^\pm \to \pi^\pm \pi^0 \pi^0$ Decays

  } (reconstructed)

- From that data sample A_g can be measured with an accuracy better than 2.2×10^{-4} (including systematics)

- upper limit for the asymmetry from $K^\pm \to \pi^\pm \pi^0 \gamma$ could be obtained at the level of 10^{-2}

Study of $K^{\pm} \to \pi^+\pi^-e^{\pm}\nu$ (Ke4)

Verify the dependence of the pion mass from the strong $q\bar{q}$ condensate in the QCD vacuum in the framework of Chiral Perturbation theory.

No experimental confirmation up to now for $q\bar{q}$ condensate

The most important parameter is a_0^0, the S-wave scattering length

Previous results and expectations:

Experiments	Statistics	$a_0^0 \pm \delta a_0^0$
Geneva-Saclay 1977	3.0×10^4	0.26 ± 0.05
BNL865 (data recorded)	0.4×10^6	$\approx \pm 0.015$
KLOE (1 year)	0.3×10^6	$\approx \pm 0.015$
NA48 (1 year)	1.0×10^6	$< \pm 0.010$

Other $K^{\pm}$ Decays

Decay	BR (PDG)	Ev. in 1 year	Parameters
$K^{\pm} \to \pi^{\pm}\gamma\gamma$	$(1.10 \pm 0.32) \times 10^{-6}$	10^{3}-10^{4}	ChPT, (c)
$K^{\pm} \to \pi^{\pm}\gamma\gamma\gamma$	$< 1.0 \times 10^{-4}$	$< 0.2 \times 10^{6}$	Branching ratio
$K^{\pm} \to \pi^{\pm}\pi^{0}\gamma$	$(1.80 \pm 0.40) \times 10^{-5}$	10^{4}-10^{5}	ChPT, CP viol.
$K^{\pm} \to \pi^{0}e^{\pm}\nu$	0.08	$> 2 \times 10^{8}$	f_S, f_V, f_T

- More than 2×10^9 $K^\pm \to \pi^\pm \pi^\pm \pi^\mp$ and 1.2×10^8 $K^\pm \to \pi^0 \pi^0 \pi^\pm$ fully reconstructed decays will be collected
  $\rightsquigarrow$ A_g can be measured with a precission better than 2.2×10^{-4}
- More than 10^6 K_{e4} decays will be collected
  $\rightsquigarrow$ Measure a_0^0 with an accuracy of 0.01
- $\sim 10^5$ $K^\pm \to \pi^\pm \pi^0 \gamma$ and $\sim 10^4$ $K^\pm \to \pi^\pm \gamma\gamma$ decays are to be expected
- Collect $\sim 10^8$ K_{e3} events (scalar and tensor form factors)