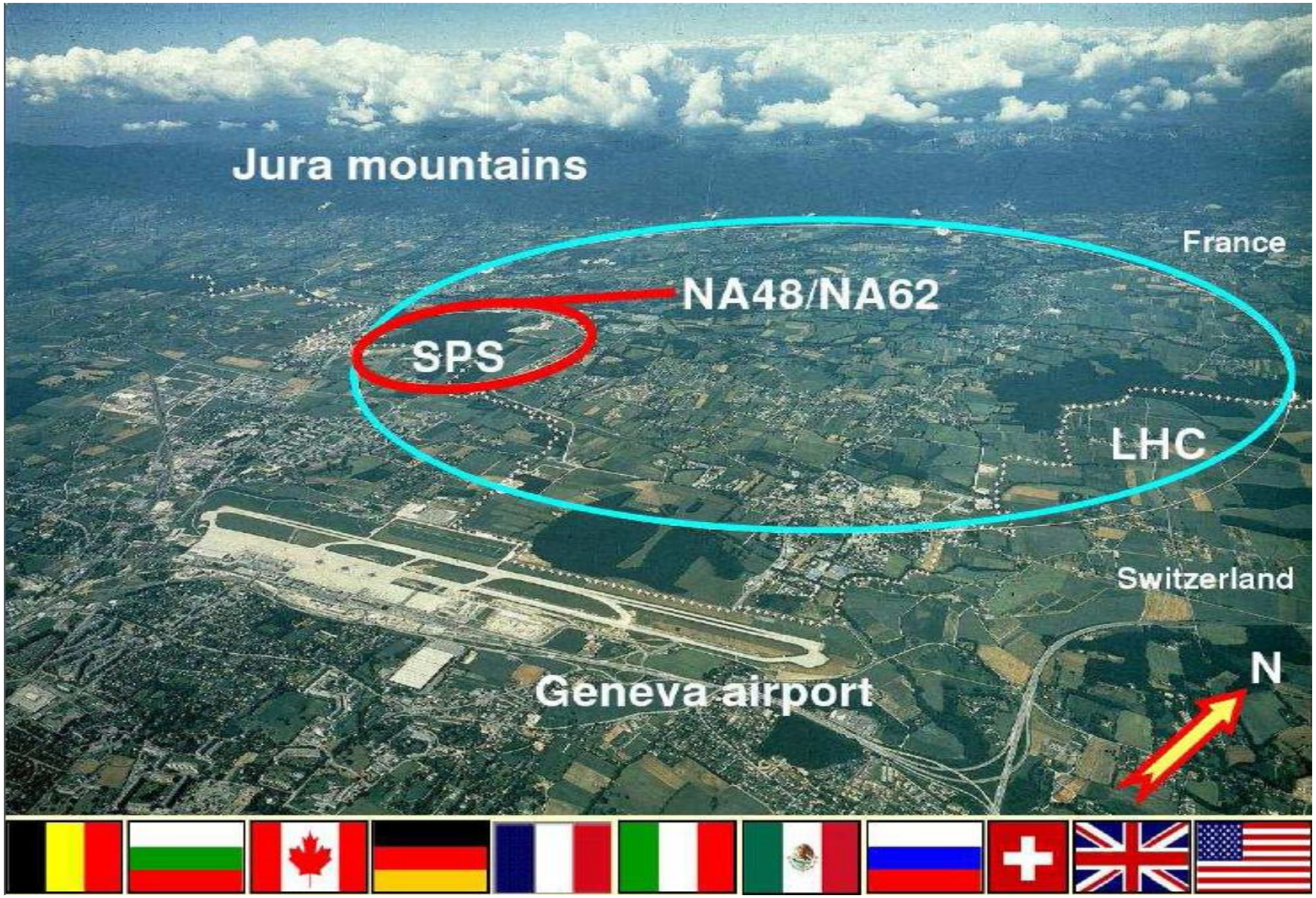
Searches for new physics at NA62

14th Lomonosov Conference on Elementary Particle Physics

Vito Palladino
On Behalf of NA62 Collaboration

NA62 @ CERN



NA62 Collaboration: Bern ITP, Birmingham, CERN, Dubna, Fairfax, Ferrara, Florence, Frascati, IHEP, INR, Louvain, Mainz, Merced, Naples, Perugia, Pisa, Rome I, Rome II, San Luis Potosí, SLAC, Sofia, Triumf, Turin

Overview

The Standard Model describes many phenomena in a very accurate way.

Any deviation from these predictions could be an alternative way (with respect to high energy experiments) to search for New Physics.

The NA62 experiment follows this approach and aims to search for New Physics using precise measurements of rare Kaon decays.

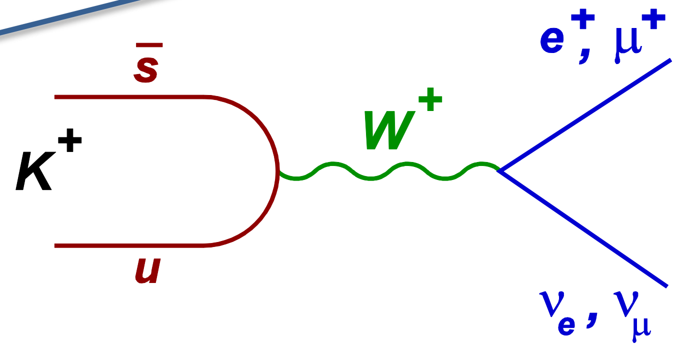
PhaseI
- 2007/2008 R_k

PhaseII
- 2008/2011 construction
- 2011 Start $K \to \pi\nu\nu$

R_k Standard Model

$$R_k^{SM} = \frac{\Gamma(K \to e\nu_e)}{\Gamma(K \to \mu\nu_\mu)} = \frac{m_e^2}{m_\mu^2} \cdot \left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2} \right) \cdot (1 + \delta R_K^{rad.corr})$$

Helicity Suppression
(V-A couplings)



Radiative correction (few%) due to IB part of the radiative K->evγ process, by definition INCLUDED in R_k

-> No direct use of $\Gamma(K \to l\nu_l)$ due to the hadronic uncertainties => R_k

-> Excellent sub-permill theoretical prediction

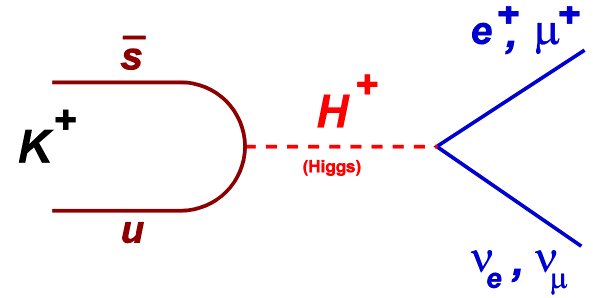
-> Strong helicity suppression of electronic channel enhance sensitivity to non-SM effects

$$R_K^{SM} = (2.477 \pm 0.001) \times 10^{-5}$$

V. Cirigliano and I. Rossell, Phys. Lett.99 (2007) 231801

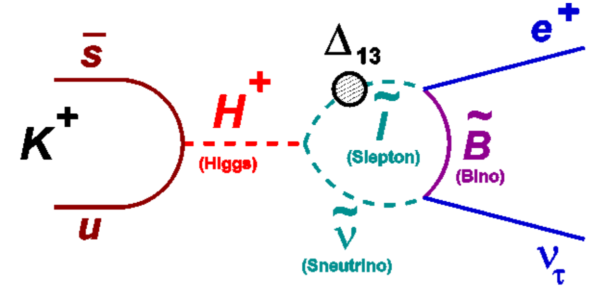
R_K *Beyond* Standard Model

In MSSM and large tanß scenario, a charged Higgs mediate a SUSY LFV contribution to the branching ratio with emission of ν_τ.



$$R_K^{LFV} = 2\frac{\Gamma_{SM}(K \to e\nu_e) + \Gamma_{LFV}(K \to e\nu_\tau)}{\Gamma_{SM}(K \to \mu\nu_\mu)} =$$

$$= R_K^{SM}\left[1 + \left(\frac{m_K}{m_H}\right)^4 \left(\frac{m_\tau}{m_e}\right)^4 |\Delta_{13}|^2 \tan^2\beta\right]$$



A.Masiero, P.Paradisi, R.Petronzio,

PRD76 (2006) 011701 and JHEP 0811(2008) 042

Sizeable effects are predicted for reasonable SUSY parameters.:

$\Delta_{13} = 5\cdot10^{-4}$, $\tan\beta = 40$, $m_H = 500$ GeV => $R_K^{LVF} \cong R_K^{SM}(1 + 0.013)$

Analogous effects in Pion decays are suppressed of a factor $(m_\pi/m_K)^4 \sim 6\cdot10^{-3}$

R_k Experimental Status

-> The PDG08 value is based on 3 measurements in 70s

$R_K = (2.45 \pm 0.11) \cdot 10^{-5}$ (4.5% error)

-> Preliminary results by KLOE and NA48/2

$R_K = (2.457 \pm 0.032) \cdot 10^{-5}$ (1.3% error)

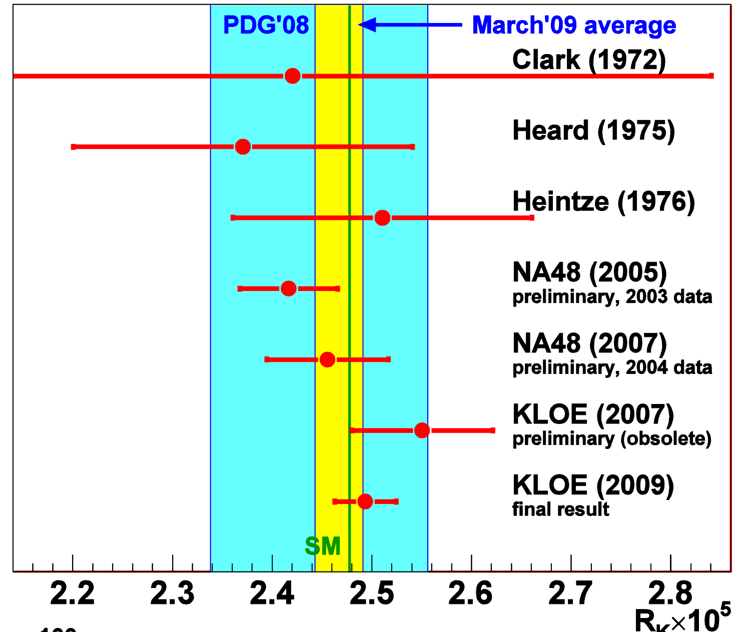
-> Final result by KLOE (LaThuile09)

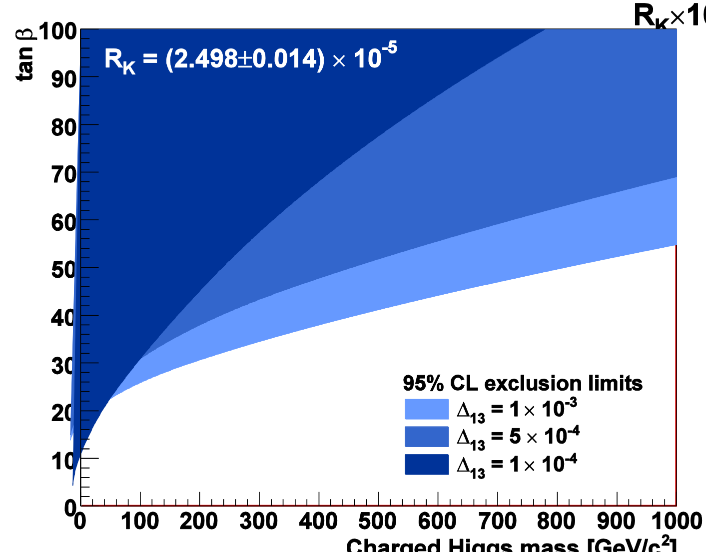
$R_K = (2.493 \pm 0.025 \pm 0.019) \cdot 10^{-5}$

(1.3% with ~13.8k K_{e2} candidates, 16% background)

World average

$R_K = (2.468 \pm 0.025) \cdot 10^{-5}$ (1% error)



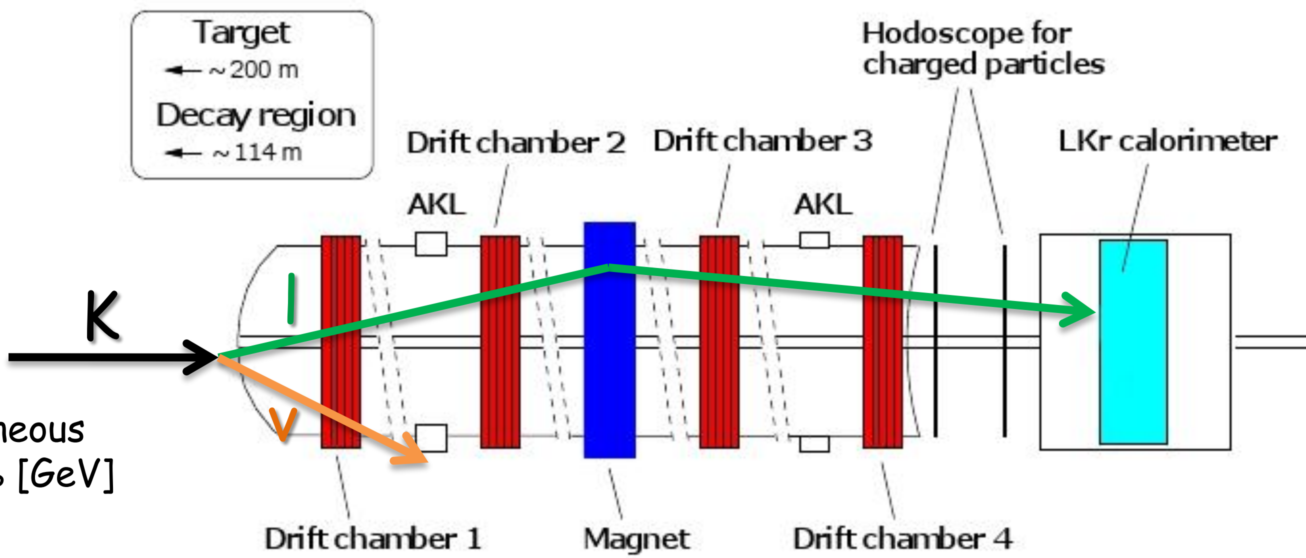


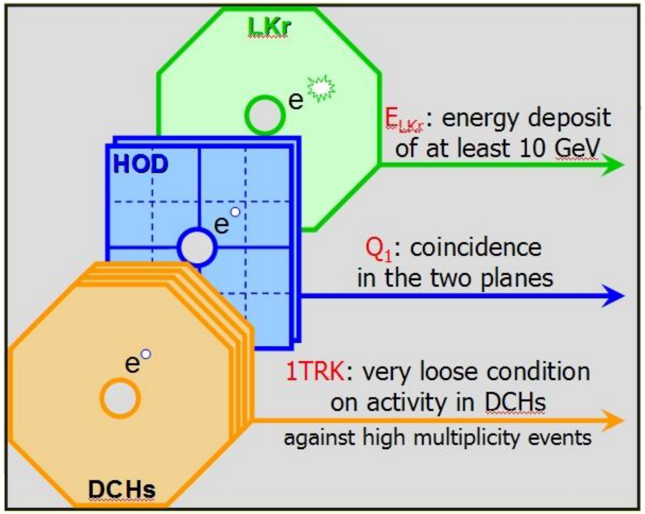
Apparatus and Trigger Logic

Magnetic spectrometer
-> 4 view / DCH -> high efficiency
-> σ_p/p = 1.0% + 0.044%·p [GeV/c]

Hodoscope
-> Fast trigger
-> σ_t = 150ps

Electromagnetic calorimeter
-> ~10 m^3 liquid krypton (~27 X_0)
-> High granularity, quasi-homogeneous
-> $\sigma_E/E = 3.2\%/\sqrt{E} + 9\%/E + 0.42\%$ [GeV]
-> $\sigma_{x,y}$ ~1 mm (@ 20 GeV)





Minimum Bias Hardware Trigger:
-> K_{e2} condition: 1TRK Q1 E_{LKr}
-> $K_{\mu 2}$ condition: 1TRK Q1

Software Trigger:
-> P_{DCH} < 90 GeV/c
-> E_{LKr}/P_{DCH} > 0.6 (K_{e2} only)

Measurement Strategy

K_{e2} and $K_{\mu 2}$ candidates collected simultaneously:

-> Many systematic effects reduced,

-> Measurement independent to the Kaon flux.

MC simulations used to limited extent:

-> Acceptance correction (only for geometry),

-> Simulation of "catastrophic" bremsstrahlung by muons.

Analysis in 10 track momentum bins.

Signal events — *Particle ID efficiency* — *Trigger Efficiency (>99.9%)*

$$R_K = \frac{1}{D} \, \frac{N(K_{e2}) - N_B(K_{e2})}{N(K_{m2}) - N_B(K_{m2})} \, \frac{f_m \cdot A(K_{\mu 2}) \cdot \varepsilon(K_{\mu 2})}{f_e \cdot A(K_{e2}) \cdot \varepsilon(K_{e2})} \, \frac{1}{f_{LKR}}$$

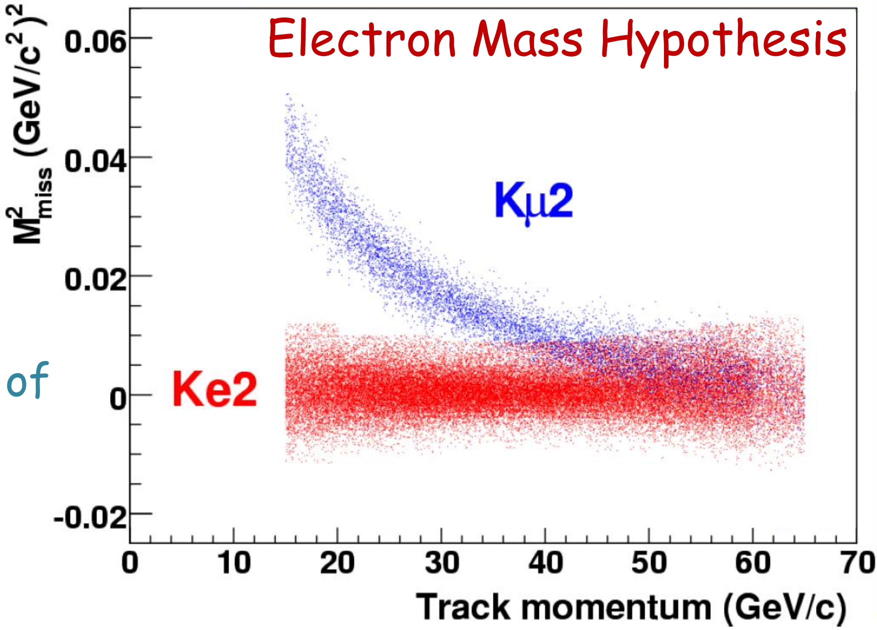
$K_{\mu 2}$ downscaling — *Background Events (Main source of systematic errors)* — *Geometrical acceptance* — *Global LKr readout eff (0.998)*

GOAL: Collect 150k K_{e2} events => measure R_K with a better than 0.5% accuracy

Signals Selection

Common reconstruction:

-> 1 Reconstructed Track,
-> Geometrical acceptance cuts,
-> Limit on LKr extra energy deposition,
-> Track momentum 15 GeV/c < p < 65 GeV/c
-> Decay vertex defined as closest approach of track & nominal Kaon axis.

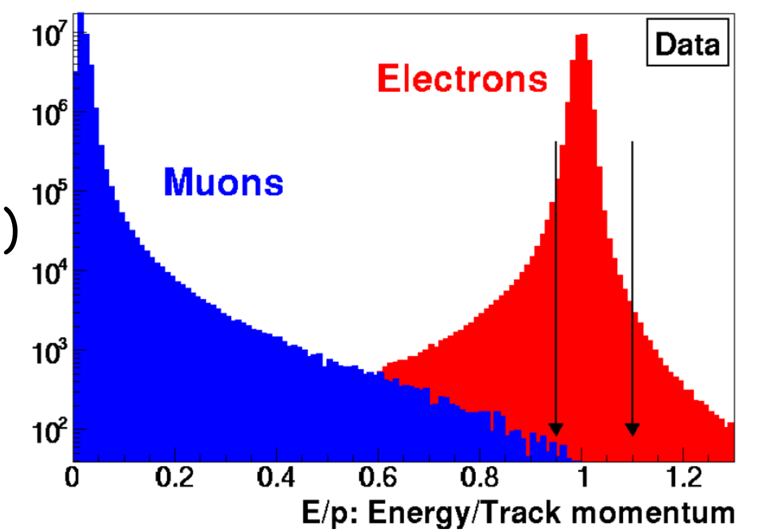


Kinematical separation => Excellent $K_{e2}/K_{\mu 2}$ separation at p<25 GeV/c:

-> Missing mass $M^2 = (p_K - p_l)^2$
-> P_K : Average measured with $K_{3\pi}$ decays

Particle Identification => Muon suppression $\sim 10^{-6}$

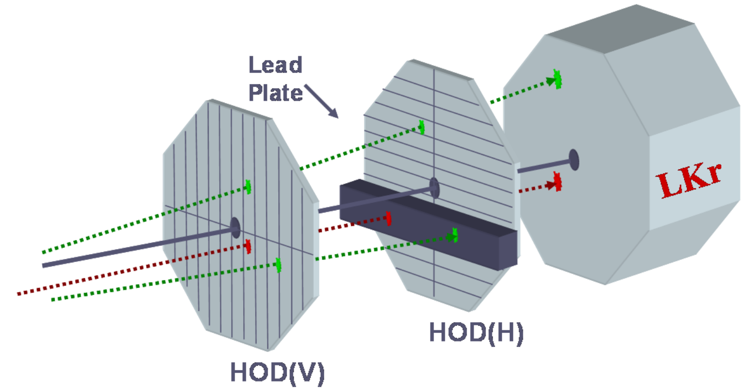
-> E/p = (LKr energy deposit/track momentum)
0.95<E/p<1.10 for electrons,
E/p<0.2 for muons.



Backgrounds (Muons)

The main background is due to "catastrophic" muon Bremsstrahlung events (E/p_{muon}>0.95) .
The expected probability is $P(\mu\text{->}e)\sim3\times10^{-6}$ (and momentum dependent), that corresponds to:

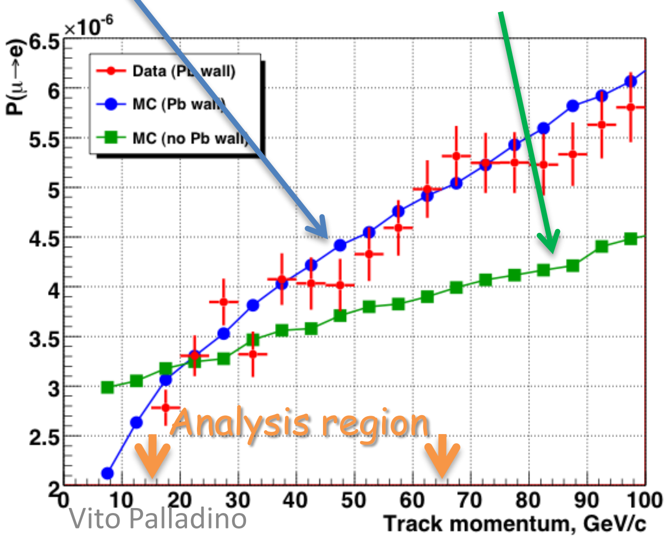
$$P(\mu\text{->}e)/R_K\sim10\%$$



This impose a direct $P(\mu\text{->}e)$ measure to validate theoretical models in a specific E_γ region.

MC validation

Used for Background subtraction

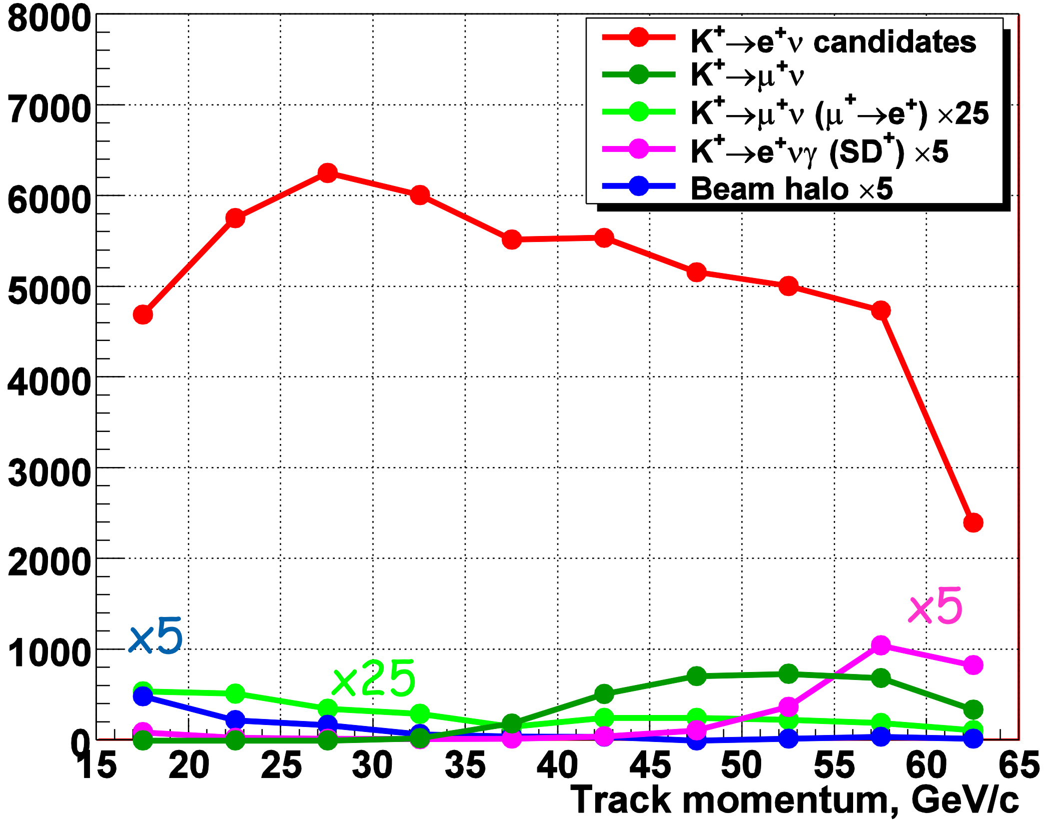


Solution: a ~$10X_0$ deep lead wall, in order to have a pure muon sample (electron contamination <10^{-7}), was installed for 50% of running time and on about 20% of HOD area.
This wall allowed to measure $P(\mu\text{->}e)$ and a very good Data/MC agreement has been found.

(6.28±0.17)%

A new special run has been scheduled in 2008 to collect a muon sample twice than 2007.

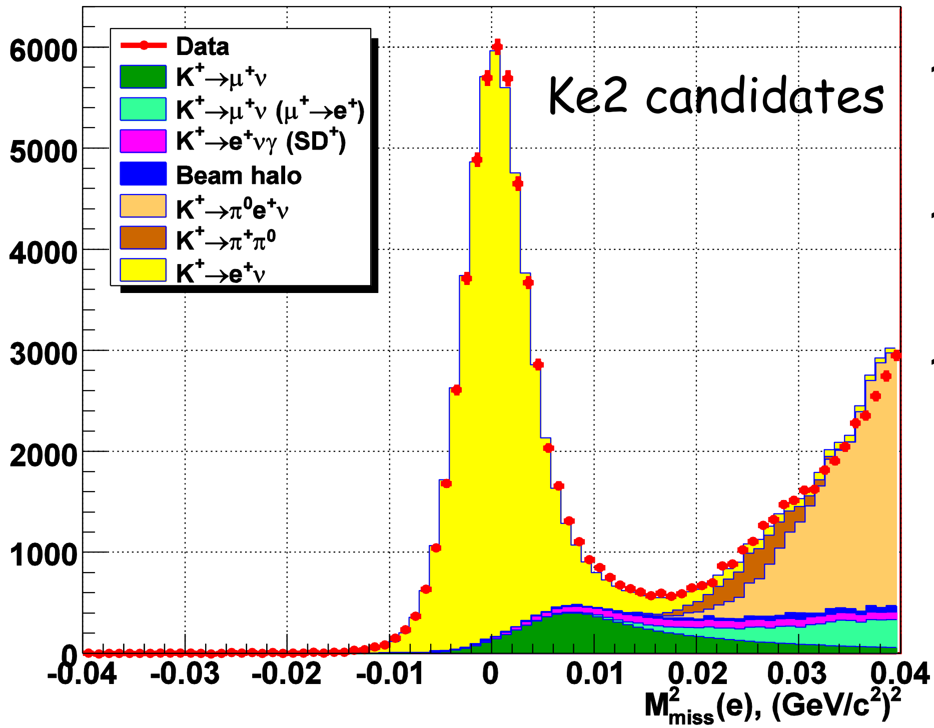
Backgrounds Summary

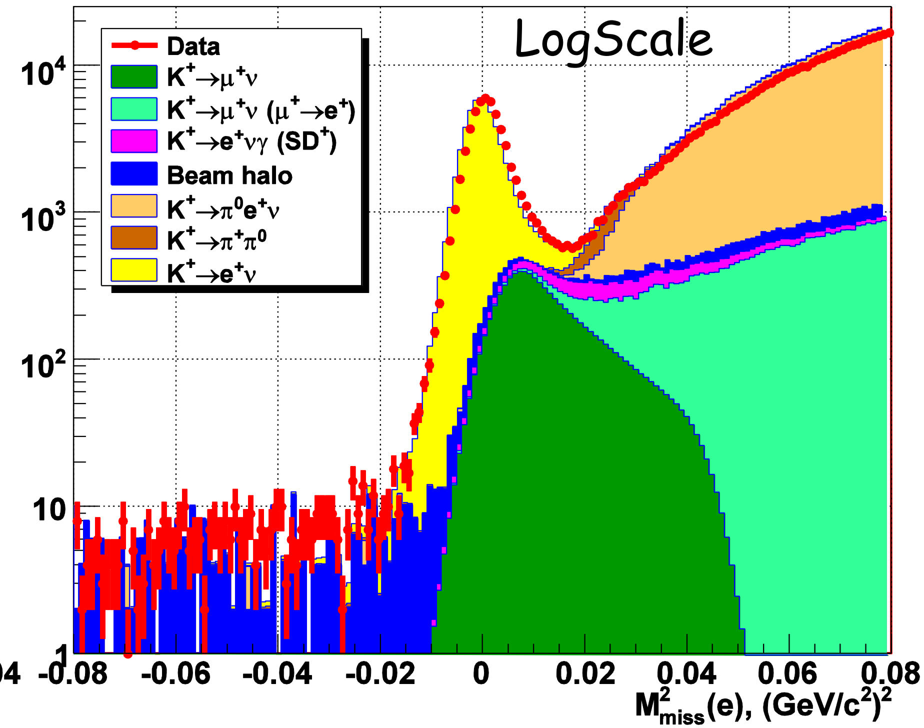


BKG Source	B/(S+B) (%)
$K_{\mu 2}$	6.28±0.17
$K_{\mu 2}$ (μ->e)	0.23±0.01
$K_{e2\gamma}$ (SD^+)	1.02±0.15
Beam Halo	0.45±0.04
K_{e3}	0.03
$K_{2\pi}$	0.03
Tot	*8.03±0.23*

Selection criteria has been optimized individually in each track momentum bin. (e.g. Z_{vertex} and M_{mis}^2)

K_{e2}: 40% of data set

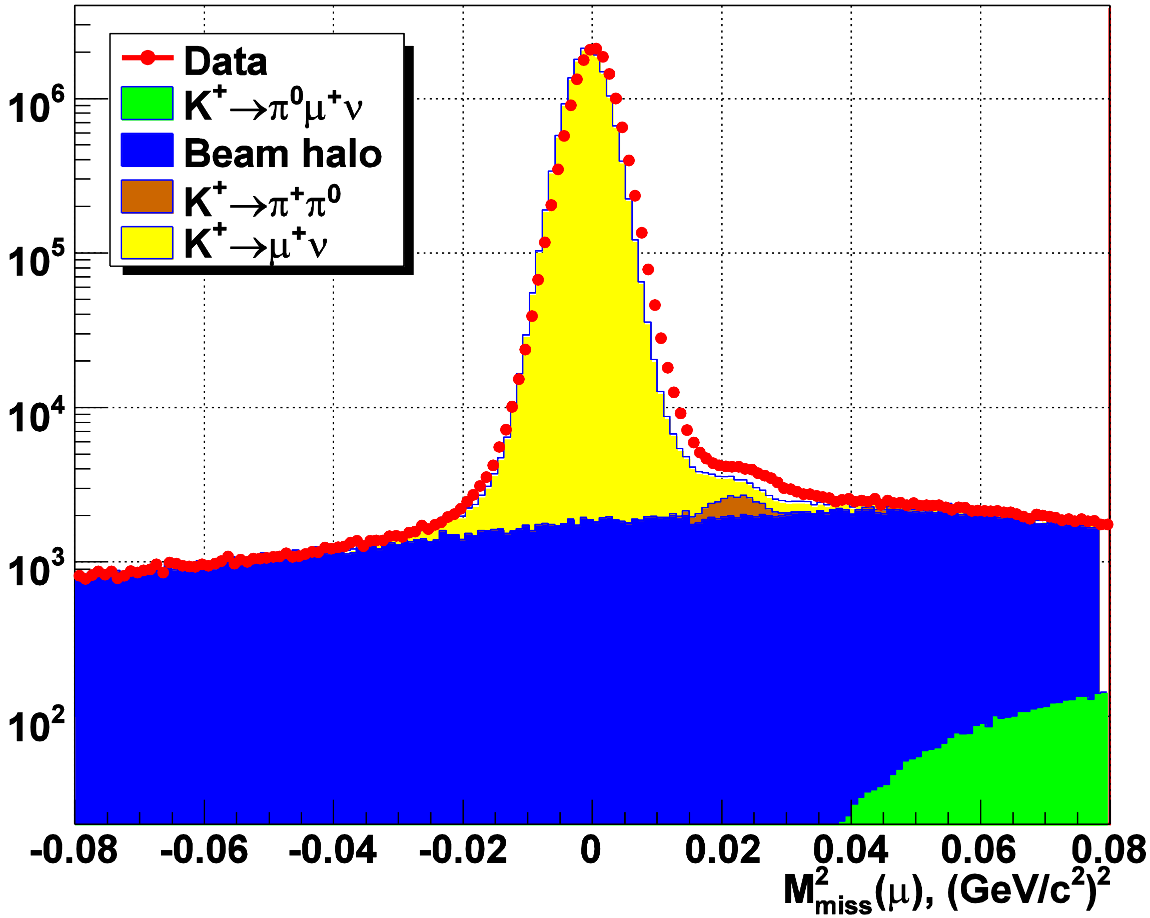




NA62 estimate total K_{e2} events: ~120k K+ & ~15k.
In NA62 proposal the goal was fixed at ~150k (CERN-SPSC-2006-033).

The present statistic gives 51 089 K_{e2} candidates events.
B/(S+B)=(8.0±0.2)%.

$K_{\mu 2}$: 40% of data set



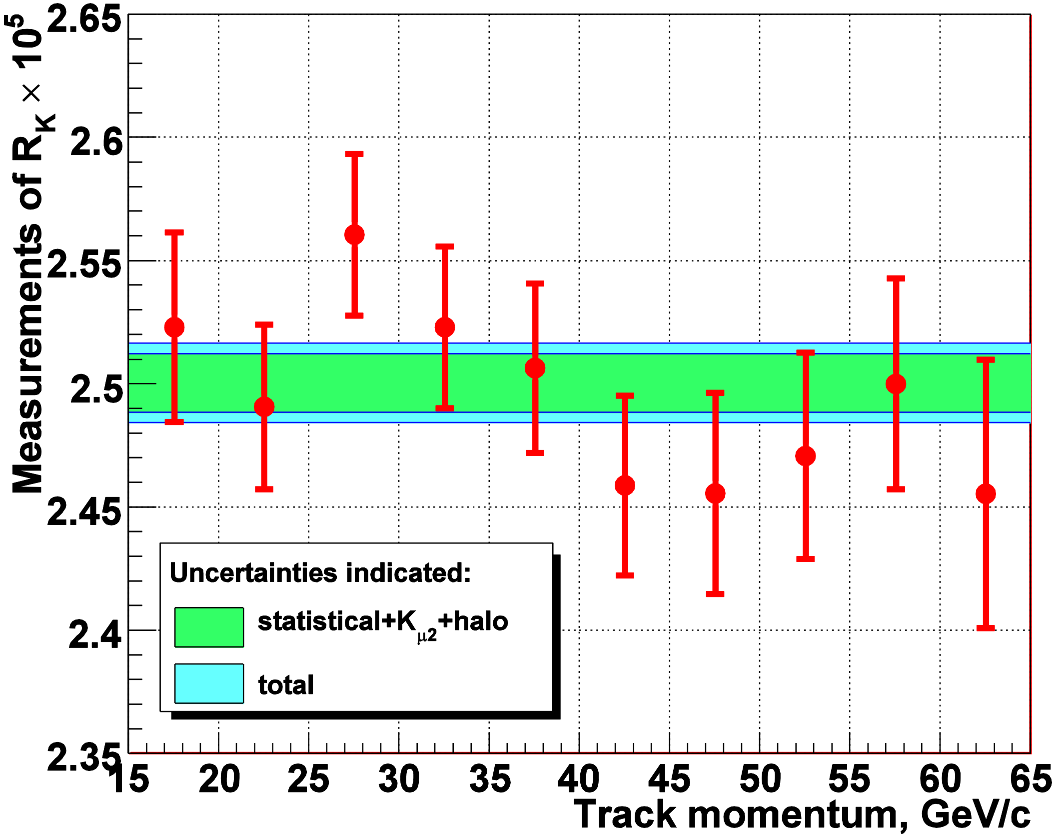
The $K_{\mu 2}$ is downscaled by a factor of 150

The $K_{\mu 2}$ main background is the Beam Halo.

15.56M are the $K_{\mu 2}$ candidates with low background B/(S+B)=0.25%

R_K Preliminary Result (40% data set)

$R_K = (2.500 \pm 0.012_{stat} \pm 0.011_{syst}) \times 10^{-5}$
$= (2.500 \pm 0.016) \times 10^{-5}$



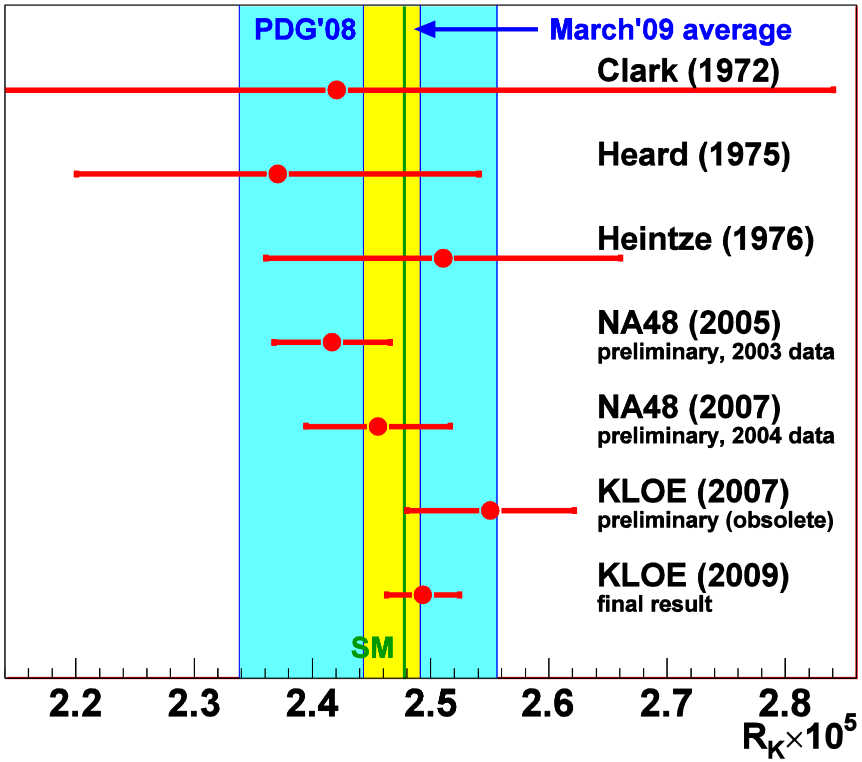
Source	$\delta R_K \times 10^{-5}$
Statistical	0.012
$K_{\mu2}$	0.004
Beam Halo	0.001
$K_{e2\gamma}$ (SD^+)	0.004
Electron ID	0.001
IB simulation	0.007
Acceptance	0.002
Trigger Timing	0.007
Tot	*0.016*

Precision 0.64%

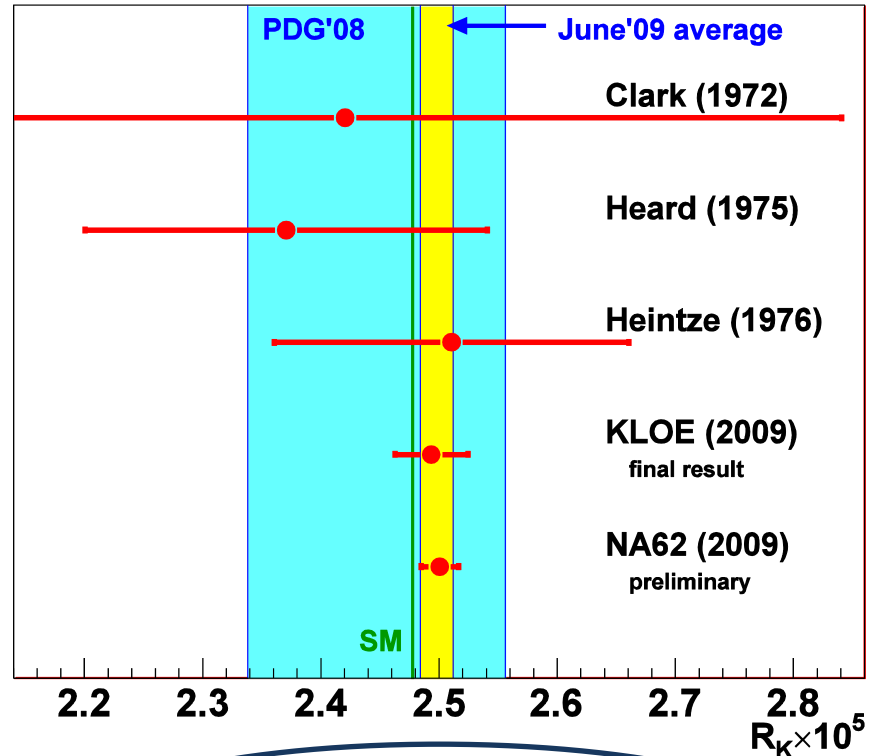
The whole sample will decrease the statistical uncertainty down to ~0.3% and a total uncertainty of 0.4-0.5%

World Comparison

March 2009



June 2009



$(2.467 \pm 0.024) \times 10^{-5}$
(precision 0.97%)

NA62 Preliminary →

$(2.498 \pm 0.014) \times 10^{-5}$
(precision 0.56%)

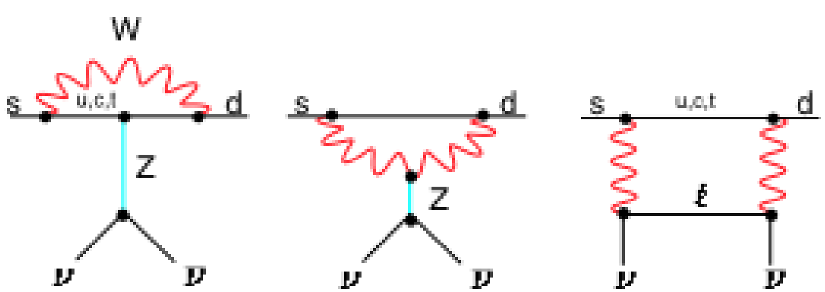
NA48/2 preliminary results excluded from new average: they are supersided by NA62

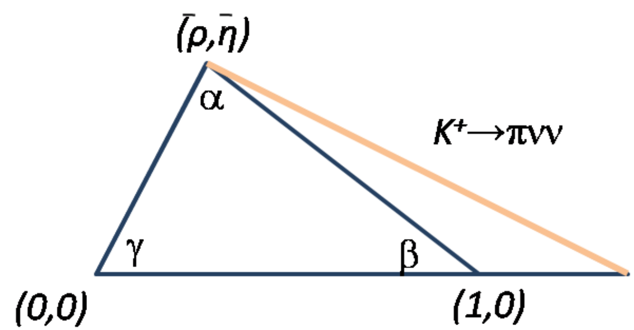
PhaseII: $K^+ \to \pi^+ \nu\nu$

The theoretical prediction within the SM is $(8.5 \pm 0.7) \times 10^{-11}$, thus a precise measurement will be sensitive to:

Precise Measurement of CKM matrix element V_{td}.

Evidence of Physics Beyond the SM if deviation to expectations.





Experimental status (E787/E949 experiment)
$(1.47^{+1.30}_{-1.05}) \times 10^{-10}$

Minimal SUSY Prediction
$BR(K^+ \to \pi\nu\nu)_{SM} / BR(K^+ \to \pi\nu\nu)_{SUSY} \in (0.65, 1.03)$

Apparatus and Measurement Strategy

Kaon decay in flight to avoid scattering and backgrounds induced by the stopping target (long decay region).

High momentum to improve background rejection (unseparated hadron beam).

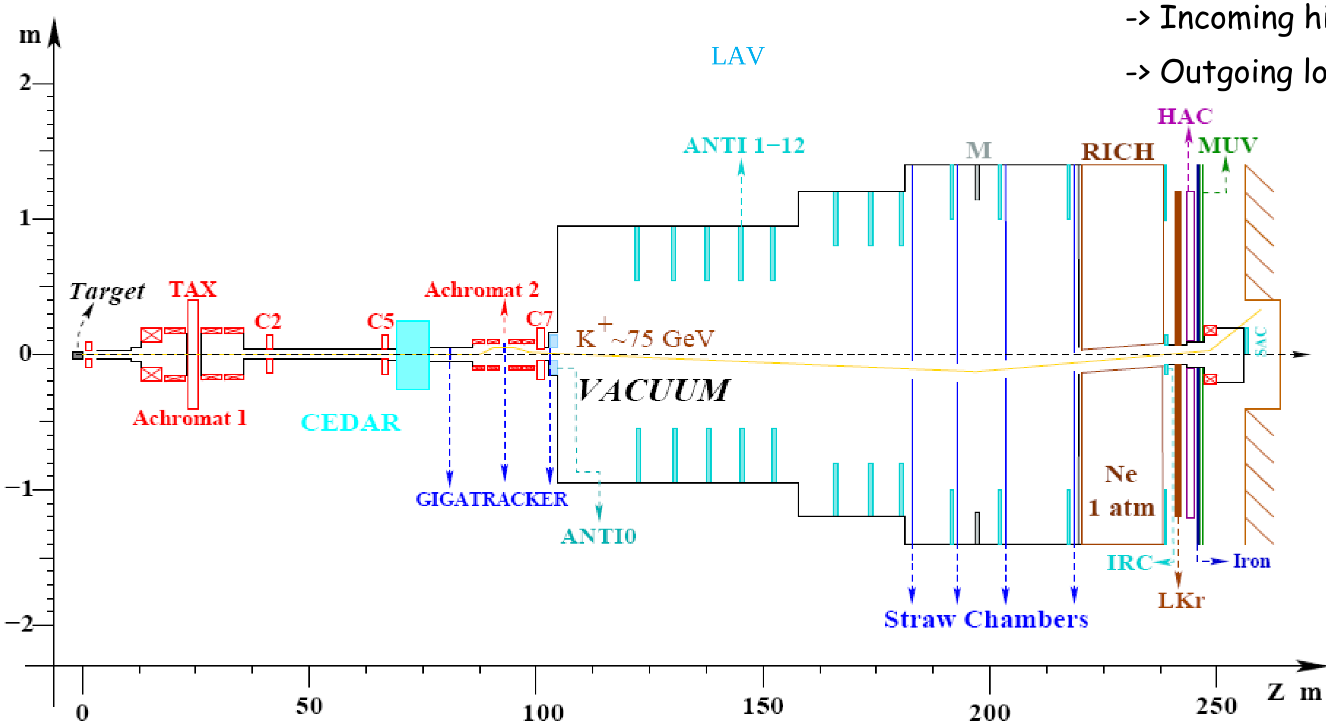
Precise timing to associate the decay to the correct incoming parent particle (K^+) in a ~800 MHz beam (beam tracker with σ_t ~ 100 ps).

High photon detection efficiency (10^{-4} 50MeV < E < 1GeV)

Signature

-> Incoming high momentum (75 GeV/c) K^+

-> Outgoing low momentum (< 35 GeV/c) p^+



Unseparated Beam:

-> Momentum 75GeV

-> Kaon beam percentage ~6%

-> Expected Signal 55 evs/y

-> # Kaons decays 4.8×10^{12}

-> S/B 10

Conclusions & future plans

-> R_k measurement is a SM stringent test because of his helicity suppression enhancement.

-> NA62 runs in 2007/2008 is optimized for R_k measurement provided a K_{e2} sample ~10 times larger than world integrated statistic up to now.

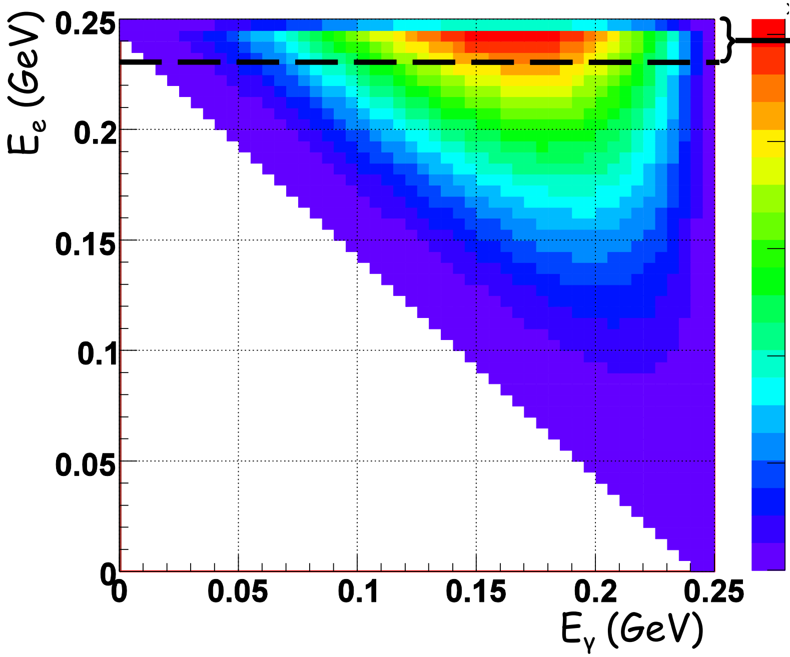
-> Preliminary results allow a 0.7% accuracy and no discrepancy from SM is observed.

-> With the whole NA62 2007/08 data sample, a precision better than 0.5% is expected.

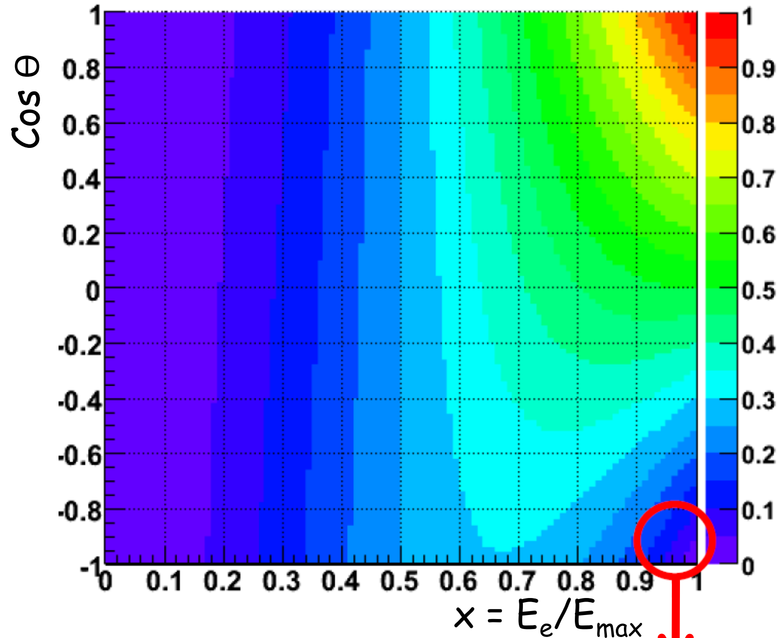
-> In parallel the works for NA62 PhaseII are ongoing, the development for many detectors is complete and the final construction has started.

Spares

Backgrounds



Only energetic (E > 230MeV) electrons are compatible to K_{e2} kinematic ID



$K_{e2\gamma}$ experimental knowledge is in 70s:

BR = $(1.52 \pm 0.23)\times10^{-5}$

Theoretically espec is model dependent:

BR = $(1.52 \pm 0.23)\times10^{-5}$

B/(S+B) = $(1.02 \pm 0.15)\%$

Uncertainty to be improved by KLOE and NA62

For BG due to in flight muons decays, according to Michel distribution in NA62 only energetic forward electrons are selected as K_{e2} candidate => Highly suppressed

B/(S+B) = $(0.23 \pm 0.01)\%$