EPS-HEP2009 Kraków, July 18th 2009

Search of New Physics with Kaon decays at the NA62 experiment at CERN

G.Collazuol, Scuola Normale Superiore and INFN - Pisa
on behalf of the NA62 collaboration:

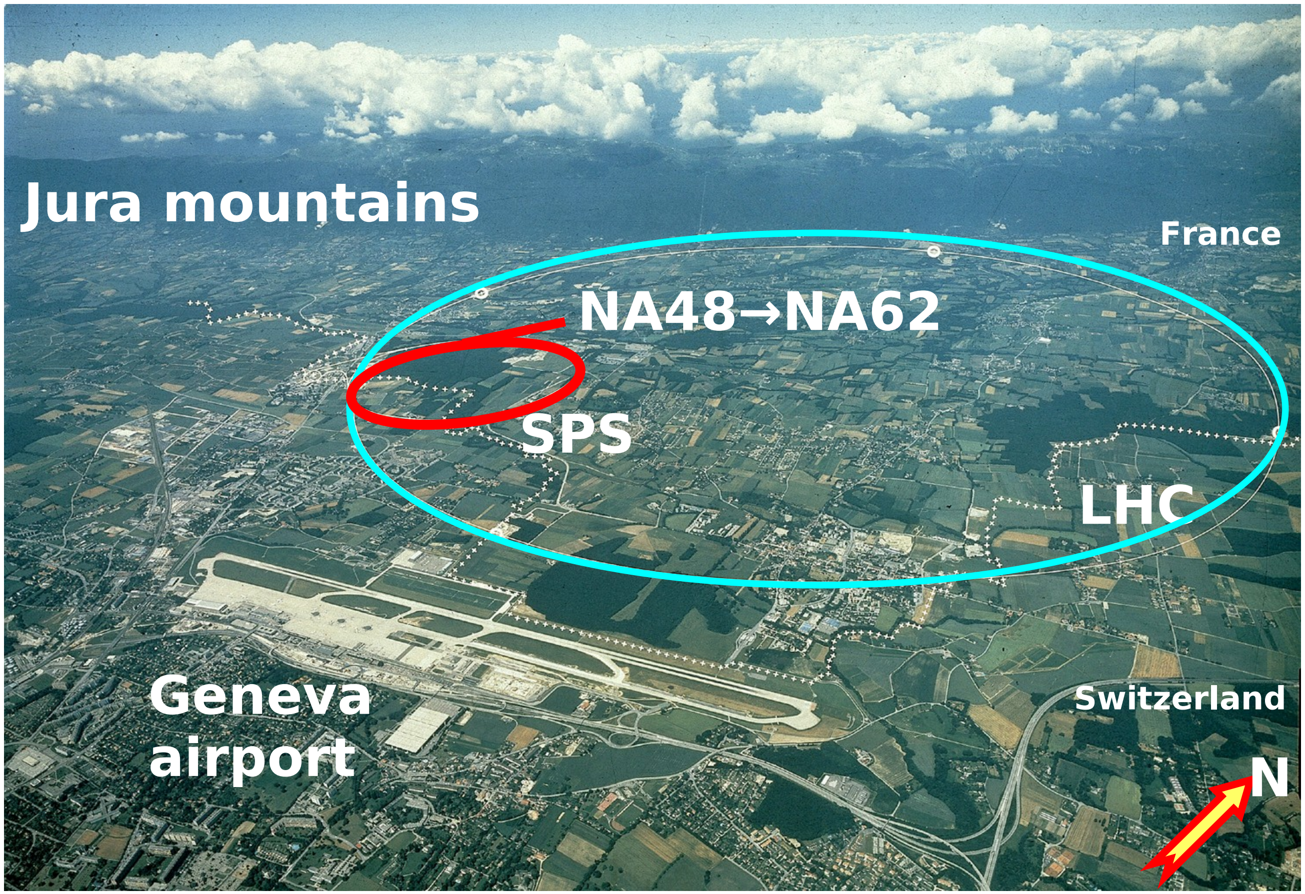
Bern ITP, Birmingham, CERN, Dubna, Fairfax, Ferrara, Florence, Frascati, Louvain, Mainz, Merced, Moscow, Naples, Perugia, Pisa, Protvino, Rome I, Rome II, Saclay, San Luis Potosí, Stanford, Sofia, Triumf, Turin

Overview

- NA62 phase 1: Lepton Universality with $K\ell 2$ decays
- Experimental principles
- Preliminary result (2009)
- NA62 phase 2: $K^+ \rightarrow \pi^+ \nu\nu$ experiment
- Experimental principles
- R&D status report

The NA62 experiment

A fixed target experiment
→ modern CERN kaon physics program



Test of Lepton Universality

Ultra rare K decays

past

NA48
- 1997 ε'/ε run $K_L + K_S$
- 1998 ε'/ε run $K_L + K_S$
- 1999 ε'/ε run $K_L + K_S$ | K_S Hi. Int.
- 2000 K_L only | K_S High Intensity | NO Spectrometer
- 2001 ε'/ε run $K_L + K_S$ | K_S High Int.

NA48/1
- 2002 K_S High Intensity

NA48/2
- 2003 $K^{\pm}$ High Intensity
- 2004 $K^{\pm}$ High Intensity

present

NA62 phase I

Dedicated 2007 run to measure:

$$R_K = \frac{\Gamma\left(K^{\pm} \to e^{\pm}\nu_e\right)}{\Gamma\left(K^{\pm} \to \mu^{\pm}\nu_{\mu}\right)}$$

future

NA62 phase II

measurement of the decay

$$K^{+} \to \pi^{+}\nu\bar{\nu}$$

(2008-2010 R&D
& construction
2011 start of data taking)

New Physics effects: promising roads

[G.Isidori Flavianet 2008]

MFV

Precision tests of **FCCC** and **FCNC** in **K** and **B**

Particularly interesting are helicity suppressed observables: sensitive to SUSY with large tanβ:

$B \to ll$, $B \to l\nu$, $K \to l\nu$

$K \to e\nu$ is favorite
(B decays are suppressed by Vus)

NA62 at CERN - phase 1
(data taking 2007/08)
Precision measurement of
$R_K = \Gamma(K \to e\nu)/\Gamma(K \to \mu\nu)$
Lepton Universality

Non -MFV / Generic

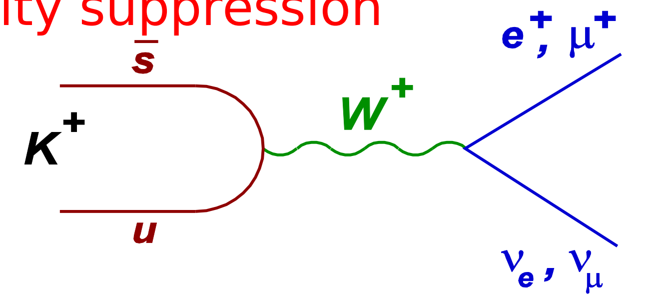
FCNC decays with
severe suppression in the SM
and clean theoretical prediction

$K \to \pi\nu\nu$ is λ^5 suppressed and can be very cleanly predicted by SM

NA62 at CERN - phase 2
(data taking starting in late 2011)
Measurement of
BR($K^+ \to \pi^+\nu\nu$)
Ultra rare K decay

K_{l2} and π_{l2} decays in the SM

Leptonic decays of mesons are interesting for helicity suppression enhances sensitivity to New Physics effects



Standard Model: accurate predictions of R_P due to cancellations of hadronic uncertainties in the ratio

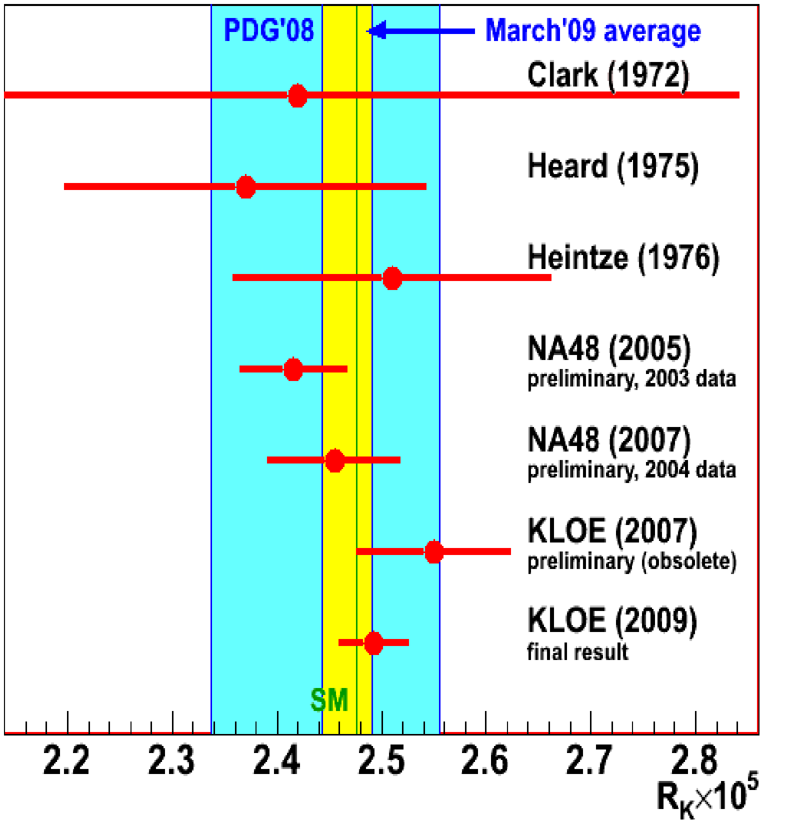
$$R_P = \frac{\Gamma(P\to e\nu(\gamma))}{\Gamma(P\to\mu\nu(\gamma))} = \underbrace{\left(\frac{m_e}{m_\mu}\right)^2}_{\text{helicity suppression (V-A couplings)}} \left(\frac{m_P^2-m_e^2}{m_P^2-m_\mu^2}\right)^2 \left(1+\underbrace{\delta R_{QED}}_{\text{radiative correction (~few \%)}}\right)$$

Theory: uncertainties well below 10^{-3}
→ latest SM predictions:

$R_\pi^{SM} = (12.352\pm0.001)\times10^{-5}$
$R_K^{SM} = (2.477\pm0.001)\times10^{-5}$

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

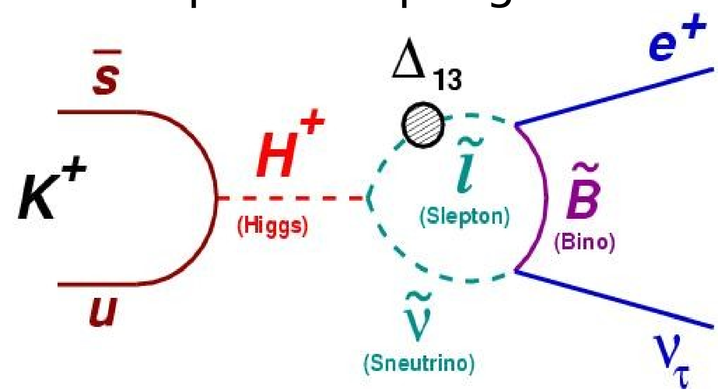
Experiment: challenging measurements
→ PDG'08 (world ave. 1990s experiments):
$R_\pi=(12.30\pm0.04)\times10^{-5}$ $(\delta R_\pi/R_\pi= 0.33\%)$
→ PDG'08 (based on 1970s experiments):
$R_K=(2.45\pm0.11)\times10^{-5}$ $(\delta R_K/R_K = 4.5\%)$
→ Significant improvements due to **NA48/2** and **KLOE** preliminary results:
$R_K^{avg}=(2.467\pm0.024)\times10^{-5}$ $(\delta R_K/R_K=0.97\%)$



K_{l2} decay beyond the SM

R_P ratio is a sensitive probe to all SM extensions that induce Pseudo-Scalar currents and non-universal corrections to lepton couplings

Effects from weak-scale New Physics are expected in the range $\delta R_P/R_P \sim 10^{-4} - 10^{-2}$



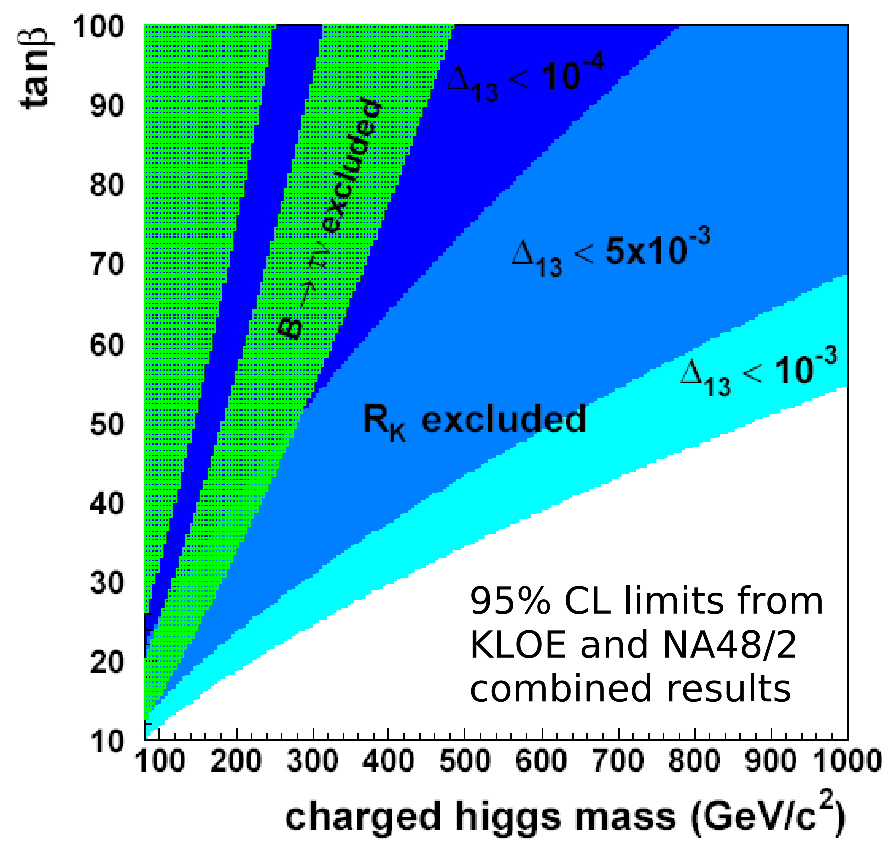
Example: R-parity violating SUSY (MSSM)
LFV contribution induced by RR $\tilde{\ell}$ mixing with emission of ν_τ might enhances the decay rate

A.Masiero, P.Paradisi, R.Petronzio PR D74 (2006) 011701

$$R_K^{LVF} = R_K^{SM}\left[1+\left(\frac{m_K}{m_H}\right)^4\left(\frac{m_\tau}{m_e}\right)^2|\Delta_{13}|^2\tan^6\beta\right]$$

A few percent effect in large $\tan\beta$ regime (not extreme) with massive charged Higgs

Example: $\Delta_{13}=5\times10^{-4}$, $\tan\beta=40$, $M_H=500\text{GeV}$
$\rightarrow R_K^{LVF} = R_K^{SM}(1+0.013)$



Note:
1) negative corrections possible (interference)
2) analogous SUSY effects in pion decay are suppressed by a factor $(m_\pi/m_K)^4 \approx 6\times10^{-3}$

Experimental principles of NA62 (phase I)

GOAL: Accuracy better than 0.5% for a stringent SM test

- Dedicated K_{e2} data taking strategy
- Very high statistics K_{e2} sample (160K) collected
- Low background (10%)

PRINCIPLES: (1) K_{e2} and $K_{\mu2}$ collected simultaneously:

- Result does not rely on K flux measurement
- Cancellation of many systematic effects at first order

(eg. reconstruction/trigger efficiencies, time dependent systematics)

(2) Counting events in track momentum bins:

$$R_K = \frac{N(K_{e2}) - N_{BKG}(K_{e2})}{N(K_{\mu2}) - N_{BKG}(K_{\mu2})} \cdot \frac{Acc(K_{\mu2}) \times \varepsilon^{ID}{}_{\mu} \times \varepsilon(K_{\mu2})}{Acc(K_{e2}) \times \varepsilon^{ID}{}_{e} \times \varepsilon(K_{e2})} \cdot \frac{1}{\varepsilon_{LKR}}$$

(3) Use of (data validated) MC simulations only for:

- Acceptance correction (geometry)
- Correction for Bkg (energetic bremsstrahlung by μ)

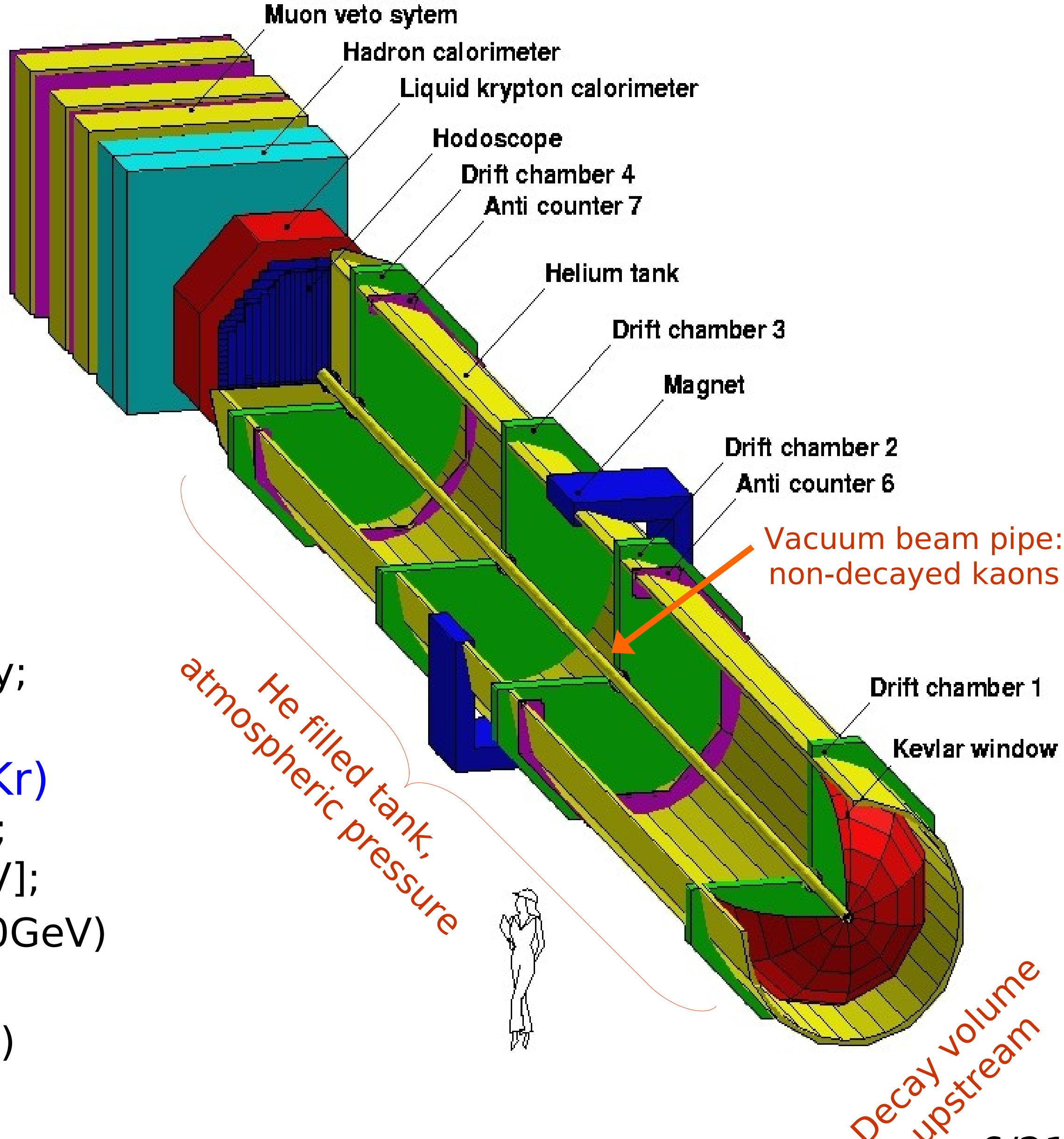
DATA TAKING Completed:

- Four months in 2007: ~400K spills, 300TB of raw data
- Two weeks in 2008 : special data sets for systematic uncertainties

Beam and detectors (NA48)

Beam

- high momentum (75GeV/c),
- narrow band ($\Delta p/p=2\%$)
- 90% data with K+ beam
- 10% data with K- beam
  (control sample for systematics)



Main detectors for R_K

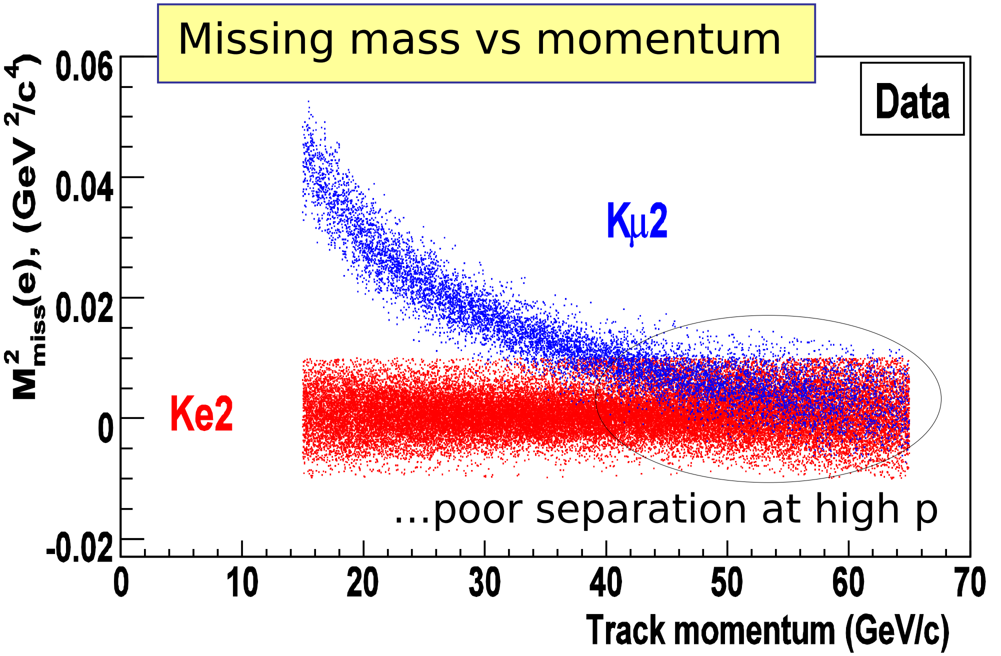
- Magnetic spectrometer (4 DCHs):
  4 views/DCH: redundancy → efficiency;
  $\sigma_p/p = 0.47\% + 0.02\%{*}p$ [GeV/c]
- Liquid Krypton EM calorimeter (LKr)
  High granularity, quasi-homogeneous;
  $\sigma_E/E = 3.2\%/E^{1/2} + 9\%/E + 0.42\%$ [GeV];
  $\sigma_x=\sigma_y=0.42/E^{1/2} + 0.6$mm (1.5mm@10GeV)
- Hodoscope
  fast trigger and track time ($\sigma_t \sim 200$ps)

K_{e2} / $K_{\mu 2}$ separation

1) kinematic identification with invariant missing mass

$M_{miss}^2(\ell)=(P_K-P_\ell)^2 \sim m^2_K(1-p_\ell/p_K)-p^2_t(p_K/p_\ell)$
With electron mass hypothesis
$|M_{miss}^2(l)|<0.01\ (GeV/c^2)^2$

- Excellent Ke2/Kμ2 separation at low p< 30GeV/c



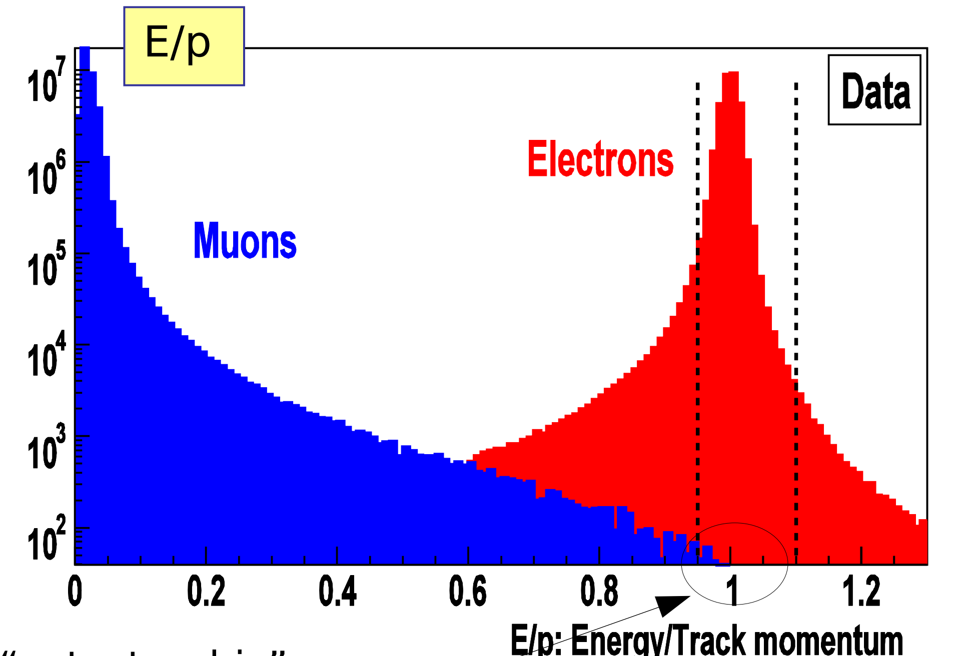
2) e/μ particle ID from E/p

Particle identification by E deposition in Calorimeter (E_{LKr}):

$0.95<E/p<1.10$ for electron

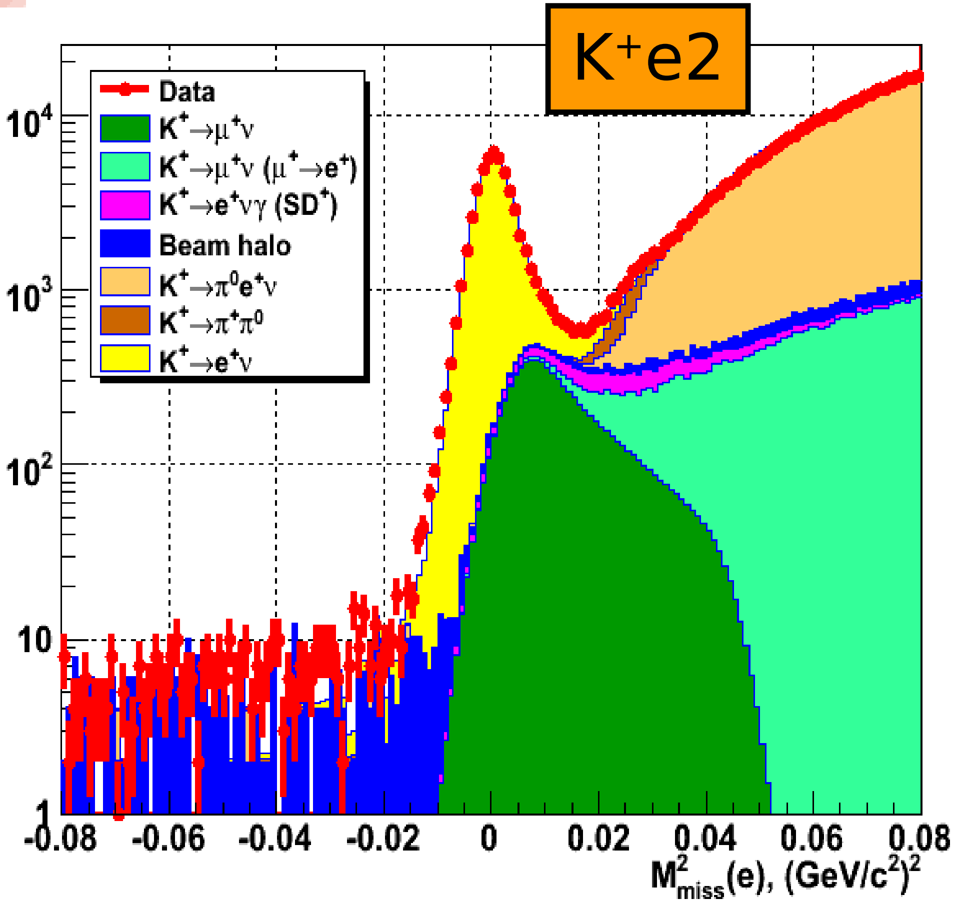
$E/p<0.2$ for muon

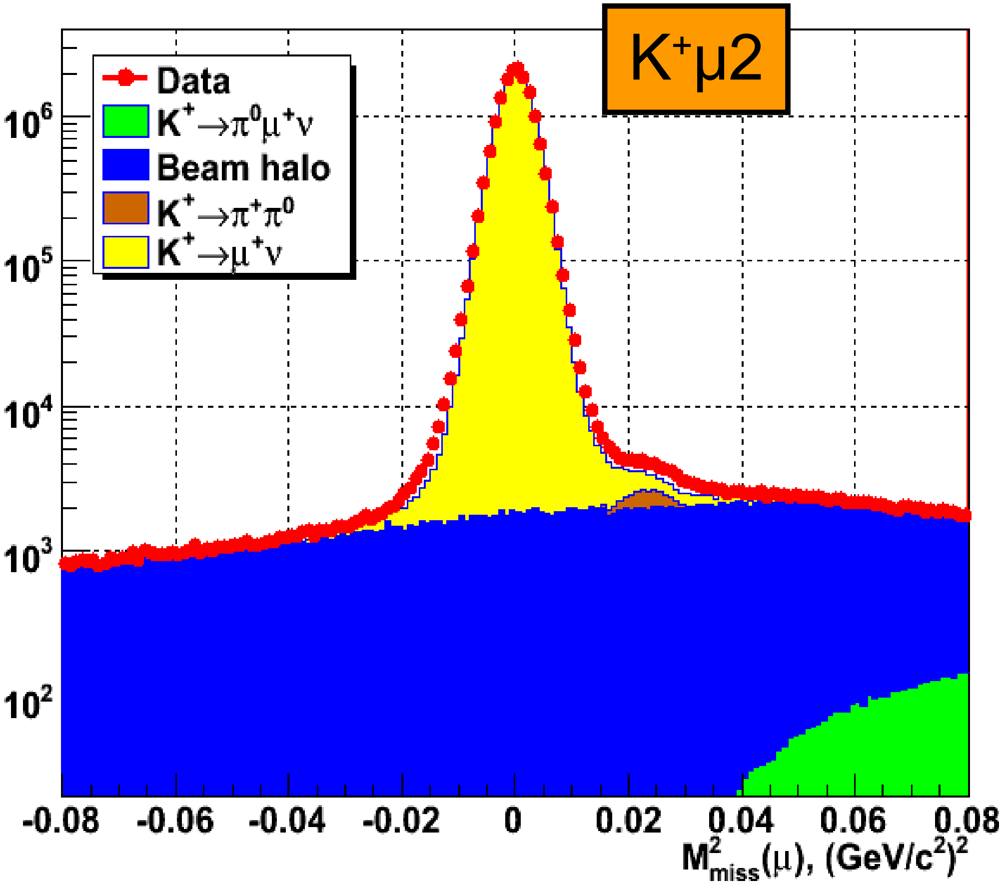
- Excellent μ rejection ~10^6
- High e and μ ID efficiency (>99%)



"catastrophic" energy loss by μ in LKr

Ke2 and Kμ2: DATA vs MC (40% data sample)





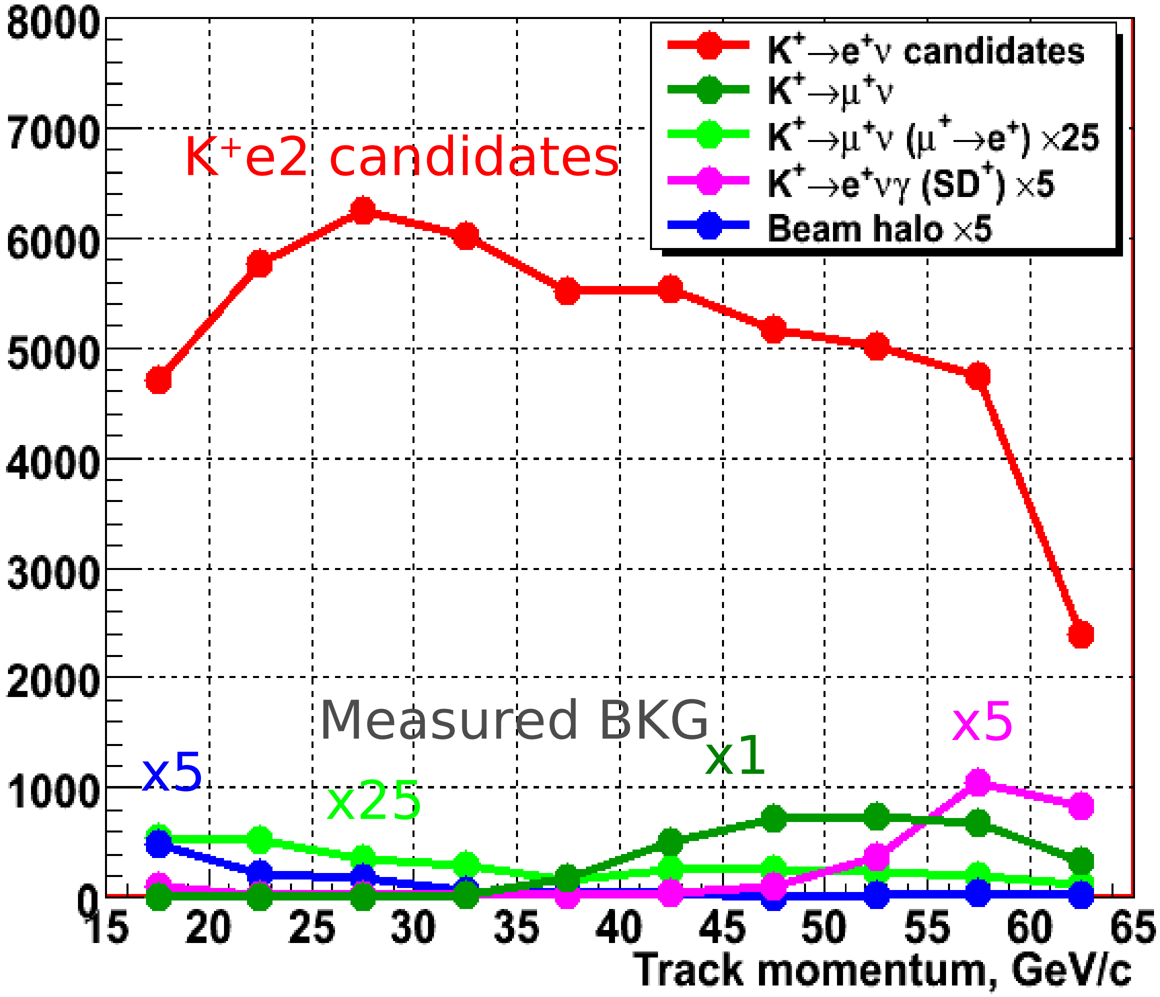
~51x10³ K⁺e2 candidates
Record World Ke2 sample
(KLOE: ~14x10³ candidates)

~16x 10⁶ K⁺μ2 candidates

BKG: (8.0±0.2)%
Main source: Kμ2 with "catastrophic" E loss by μ in LKr

BKG~0.25%
Only significant source:
μ beam halo

Background summary



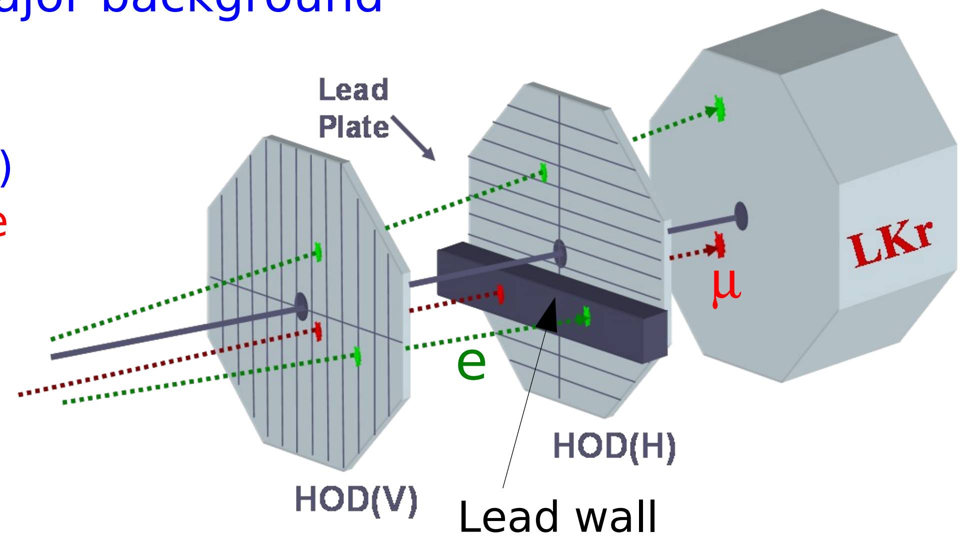
Source	B/(S+B)
$K\mu 2$ ($\mu \to e$ "catastrophic")	(6.28±0.17)%
$K\mu 2$ ($\mu \to e$ decay)	(0.23±0.01)%
$Ke2\gamma$ SD+ ($Ke2\gamma$ SD- negligible)	(1.02±0.15)%
beam halo (bgk to ke2 and $k\mu 2$)	(0.45±0.04)%
$K^+ \to e^+ \pi^0 \nu$	0.03%
$K^+ \to \pi^+ \pi^0$	0.03%
Total	(8.03±0.23)%

- Selection criteria optimized bin by bin
- Higher BKG at high momentum
  (no kinematic separation, more muon mis-ID due to bremsstrahlung)

BKG example: μ mis-identification as e

"Catastrophic" bremsstrahlung: P(μ→e) ~ 3×10^{-6} (and momentum dependent)
→ P(μ→e)/R_K ~ 10%: $K_{\mu2}$ decays are a major background

Note:
pure μ beam does not exsist (due to μ→e decay)
→ direct measurement of P(μ→e) is not possible
(e contamination in μ beam ~10^{-4})

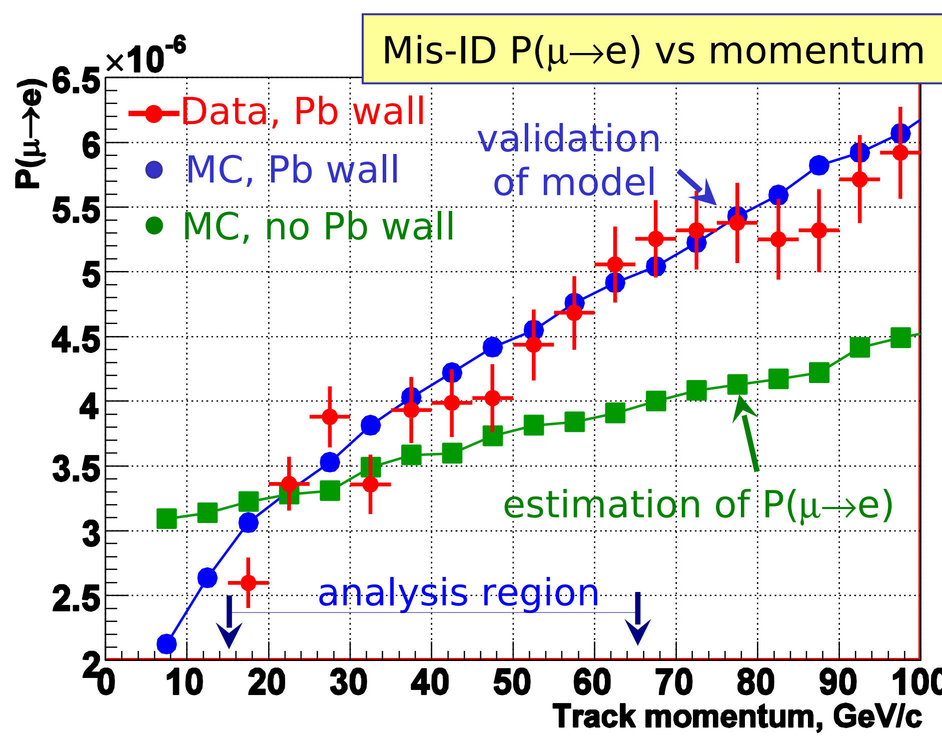


Strategy:

• Measure P(μ→e) with a pure muon sample in the calorimeter obtained by filtering muons with a Pb wall in front of the calorimeter: tracks traversing the wall and with E/p>0.95 are pure μ (contamination <10^{-7})

• Use this data for tuning and validating the MC simulation (description of high E_γ hard)

• Use data-validated MC simulation to determine P(μ→e) in absence of Pb wall



Preliminary result (40% data sample)

June 2009

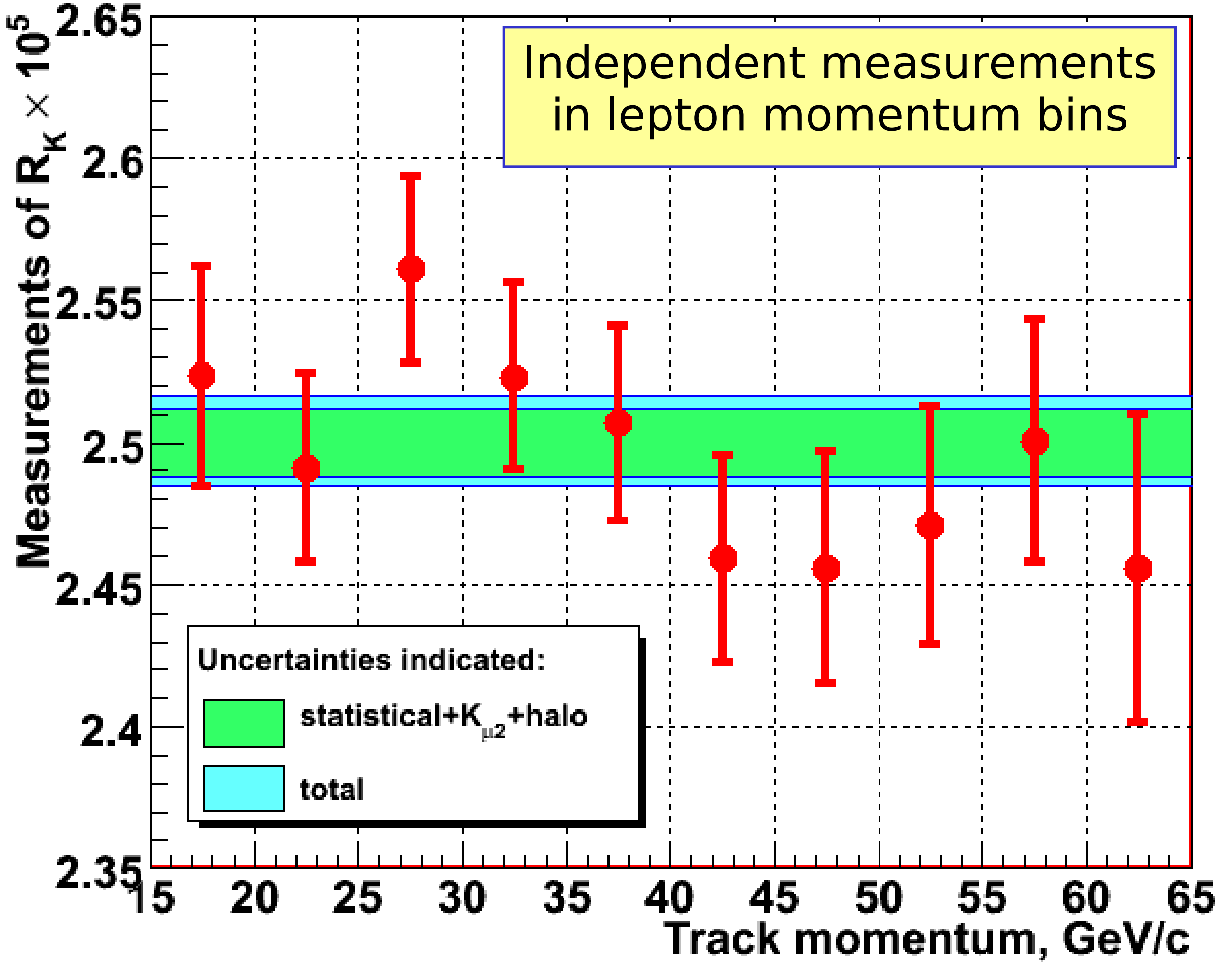
$R_K = (2.500 \pm 0.012_{stat} \pm 0.011_{syst}) \times 10^{-5}$
$= (2.500 \pm 0.016) \times 10^{-5}$

Compatible with SM !

Main uncertainties
(40% of the data sample)

Source	$\delta R_K x10^5$
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
Total	0.016

(0.64% precision)

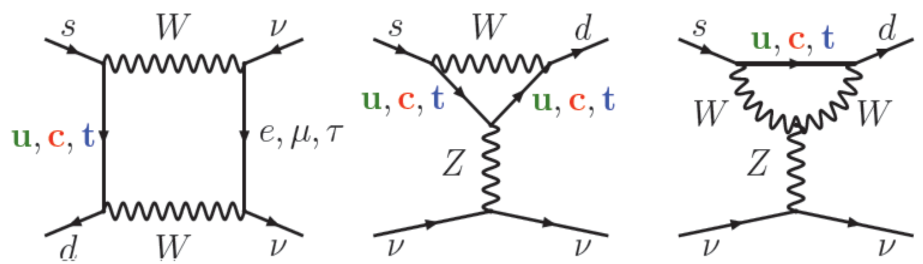


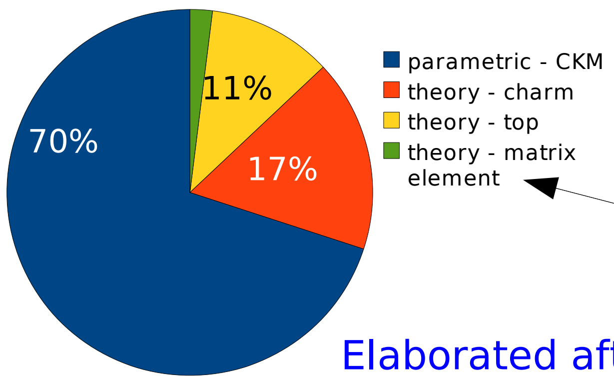
- Estimated total sample of **~120x10³ K⁺ + 15x10³ K⁻** candidates
- Final stat. uncertainty below 0.3% and **estimated total uncertainty of 0.4–0.5%**

$K\to\pi\bar{\nu}\nu$ in the Standard Model

$K\to\pi\nu\nu$ clean theoretical environment

FCNC loop processes:
top exchange dominating
→ severe Cabibbo suppression
in s→d transition



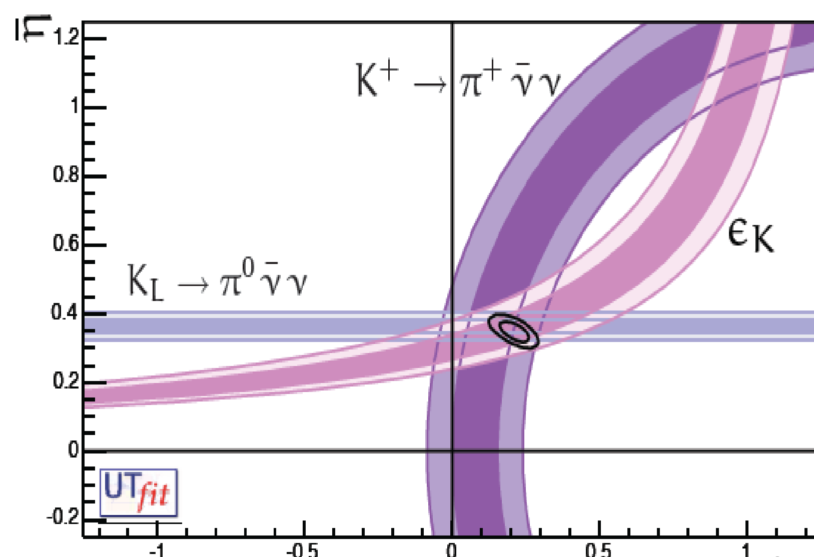


Elaborated after
M.Gorbahn - KAON09

$BR(K^+\to\pi\nu\nu)_{SM}=(0.85\pm0.07)\cdot10^{-10}$

Total error in SM prediction ~8%
Error budget: CKM parametric uncertainties dominate (6%). Theoretical contributions ≲ 3%

Future scenario [Buras, Gorbahn, Haisch, Nierste'06]



Cleanest way for extracting $\mathbf{V_{td}}$ and for giving independent determination of the unitarity triangle
[golden relation: $\sin(2\beta)_{\psi Ks}=\sin(2\beta)_{K\to\pi\nu\nu}$]

Enhanced sensitivity to generic new physics (NP degrees of freedom in loops)

New Physics and experimental status

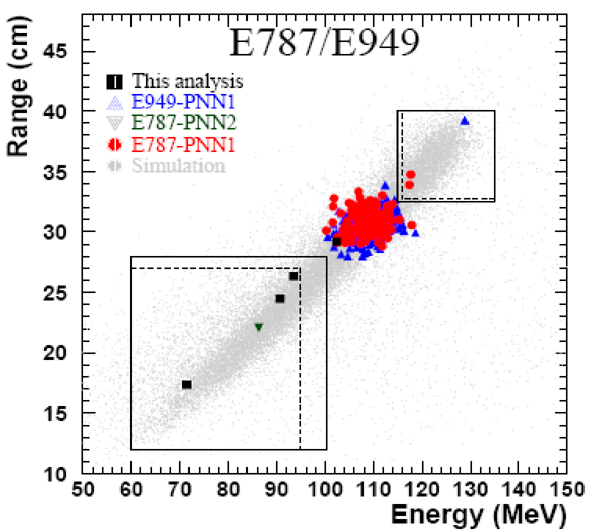
K→πνν decays give unique and clean information about the flavour structure of the s→d sector in any model with new degrees of freedom in the TeV range.
Sizable deviations from SM in a variety of models. Examples:
non-MFV in LR ũ mixing (MSSM), non-MFV in RR $\tilde{d}$ mixing (MSSM with large tanβ) or Little Higgs model with T-parity

If LHC will fix the energy scale of NP then K→πνν will be of help in discriminating between NP models

But in some specific scenarios NP effects could be seen in K→πνν decays
- even without any new particles seen at LHC
- even without significant signals in $B_{d,s}$ decays

Experimental status

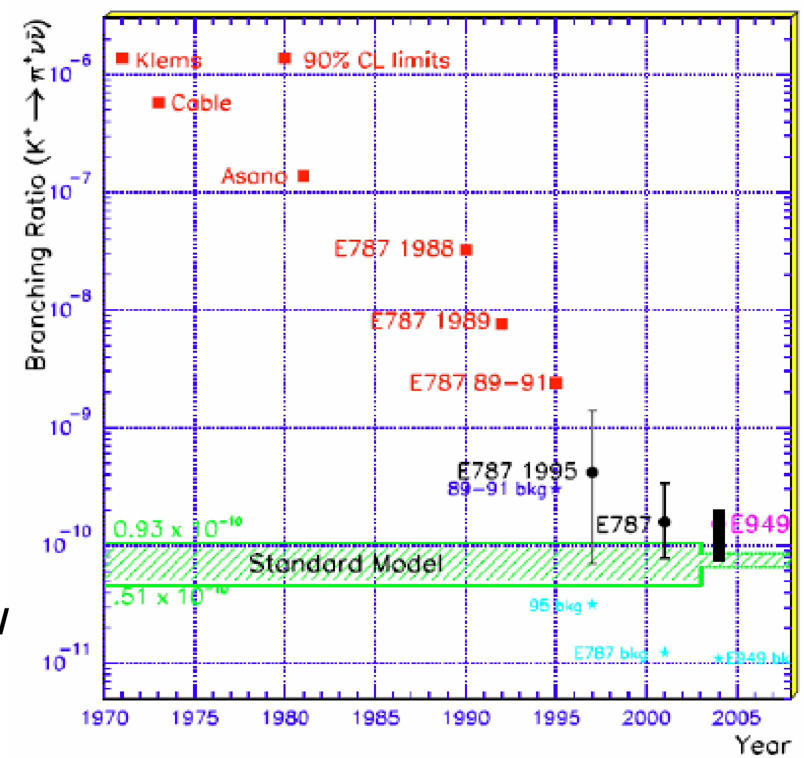
$BR(K^+\to\pi\nu\nu)_{EXP} = (1.73^{+1.15}_{-1.05}) \cdot 10^{-10}$



[E787, E959 (2008)]

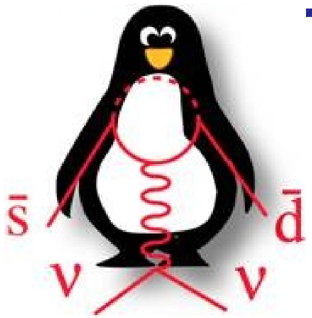
7 events observed

… need for a new technique…



NA62

$K^+ \rightarrow \pi^+\nu\bar{\nu}$ decays w/ NA62 (phase 2)



- Proposal 2005: CERN-SPSC-2005-013, SPSC-P-326
  Bern, Birmingham, CERN, Dubna, Ferrara, Fairfax, Firenze, Frascati, IHEP, INR, Louvain, Mainz, Merced, Napoli, Perugia, Pisa, Roma I+II, Saclay, SLAC, Sofia, Triumf, Torino

- Approval by CERN (Dec. 2008): “subject to the definition of resource sharing within the collaboration”

Main goal: to measure O(100) events ultra rare decays $K^+ \rightarrow \pi^+\nu\nu$ with low level of background (B/S < 10%) in 2 years (2012+)

Experimental principles:

Decay in-flight to avoid the scattering and the backgrounds introduced by the stopping target

High momentum K^+ beam to improve the rejection of the π^0 induced backgrounds

Kinematic rejection + Particle ID + Veto + Redundancy against backgrounds: $\pi^+\pi^0$, $\mu\nu$, 3-body, 4-body decays, ...
(BR several order of magnitude greater than signal)

Beam: High energy, monochromatic, high intensity
Sensitivity not limited by beam flux from SPS
(need ~10^{13} K decays ~same as NA48 measurement of $\varepsilon`/\varepsilon$)

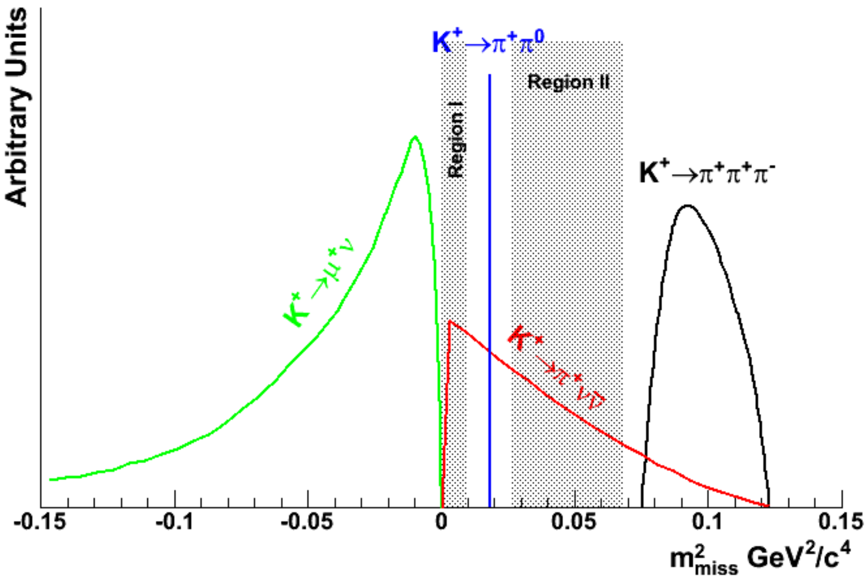
Note: reusing parts of the former NA48 apparatus and existing SPS protons

Signal and background

BR~10^{-10} at 10% (100 events) with acceptance ~10% and B/S<10%
→ 10^{13} K decays and rejection factor against background up to 10^{12}

NOTE:
- 1 particle in → 1 particle out
- Measurement based on the missing invariant mass

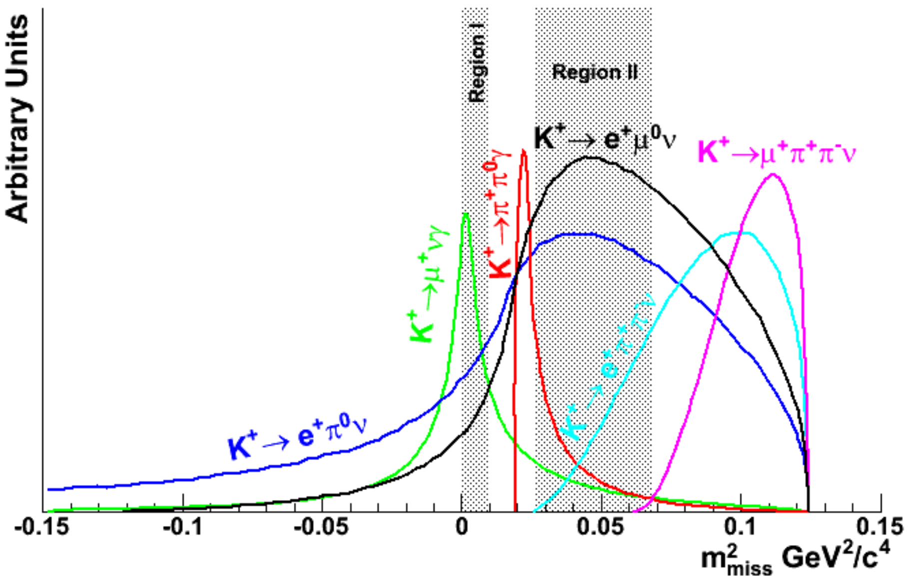
kinematically constrained



92% of K decays

- Definition of two signal regions
- Precise tracking with minimal material budget (multiple scattering)

NOT kinematically constrained



8% of K decays

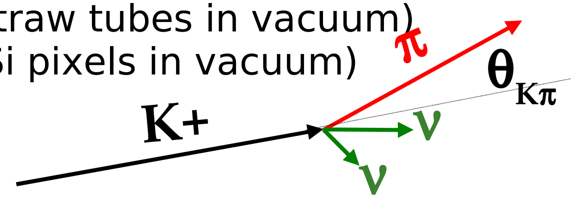
- Particle ID
- Photon Vetoes
- Redundancy

G.Collazuol - EPS-HEP2009

Experimental techniques and layout

Kinematics (rejection of 2 and 3 body decays)

- $K^+ \to \pi^+ \nu\nu$ is 1 track in (K) → 1 track out (π)
- Pion: Spectrometer (straw tubes in vacuum)
- Kaon: Beam Tracker (Si pixels in vacuum)



$$M^2_{miss} = (P_K - P_\pi)^2$$

Redundant Particle ID (K/π, π/μ)

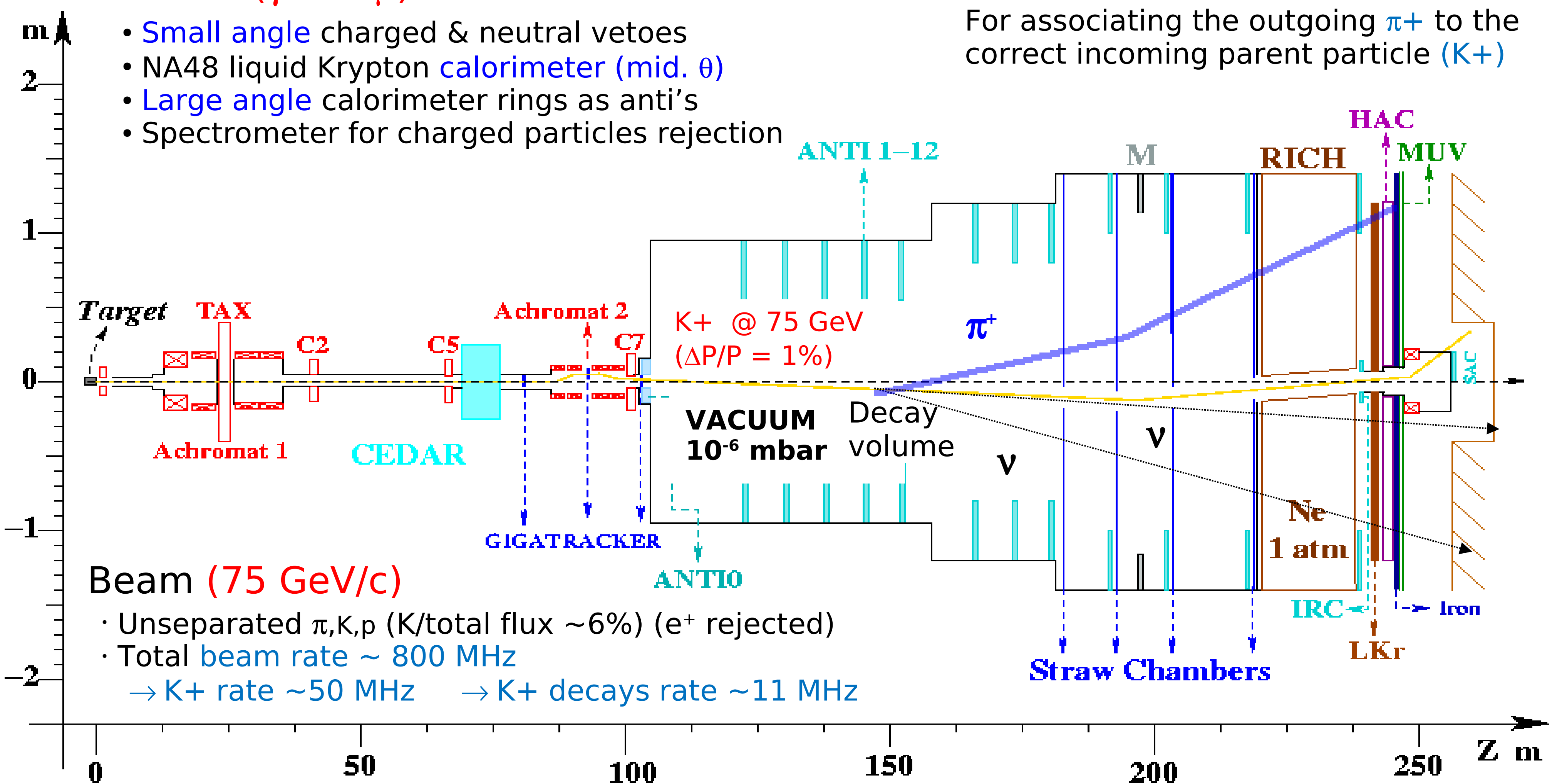
- Calorimeter (LKr) for e/$\gamma/\mu/\pi$ detection
- RICH for π/μ separation + TOF
- CEDAR for K identification + TOF
- Muon filter

Precise timing

For associating the outgoing π+ to the correct incoming parent particle (K+)

Vetoes (γ and μ)

- Small angle charged & neutral vetoes
- NA48 liquid Krypton calorimeter (mid. θ)
- Large angle calorimeter rings as anti's
- Spectrometer for charged particles rejection



Beam (75 GeV/c)

- Unseparated π,K,p (K/total flux ~6%) (e^+ rejected)
- Total beam rate ~ 800 MHz

  → K+ rate ~50 MHz → K+ decays rate ~11 MHz

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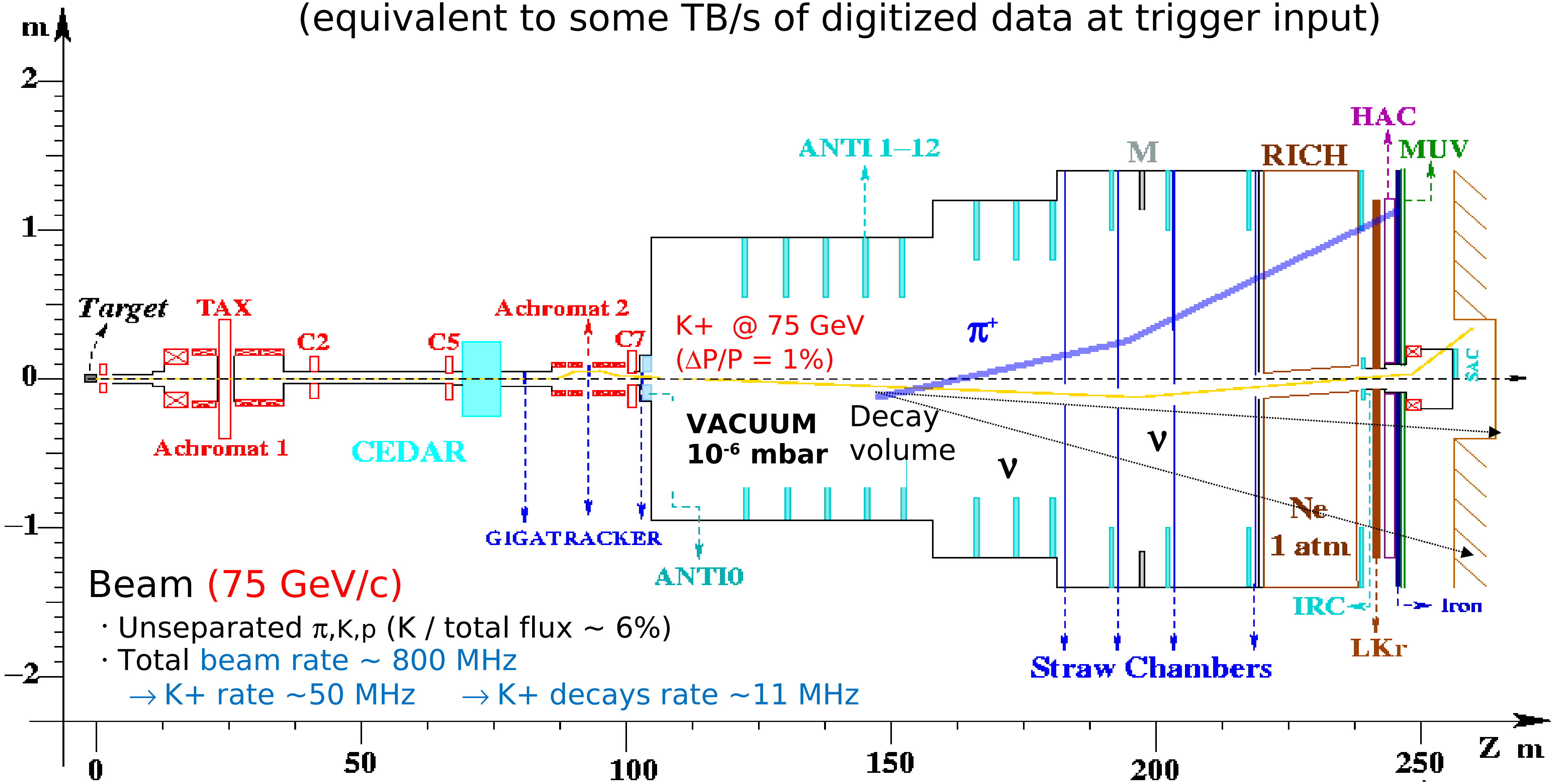
Several detector challenges

- Si beam tracker: timing @ 200 ps, rate ~1 GHz, 0.5% X_0/station
- Beam Cherenkov (CEDAR): photons @ 2MHz/mm2
- Spectrometer in high vacuum: P< 10^{-6} mbar
- RICH (18m long): μ/π separation at 10^{-3} level in range 15-35 GeV/c
- Vetoing with calorimeters: low inefficiency (<10^{-4})
- Triggering and fully efficient DAQ @ several MHz input rate (equivalent to some TB/s of digitized data at trigger input)



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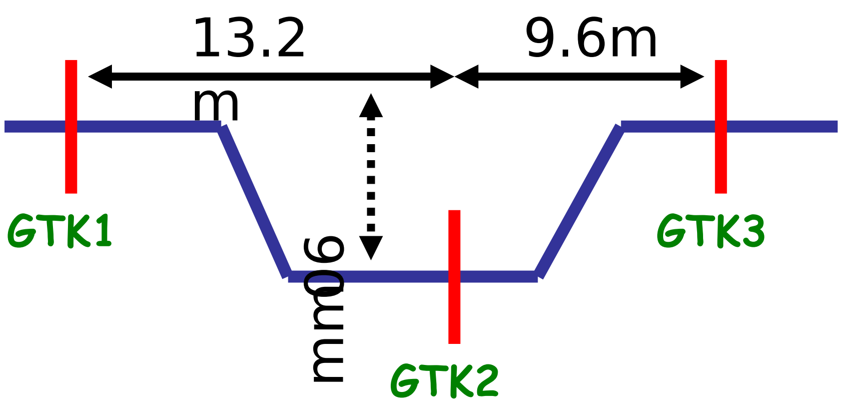
Example: Silicon pixel beam tracker

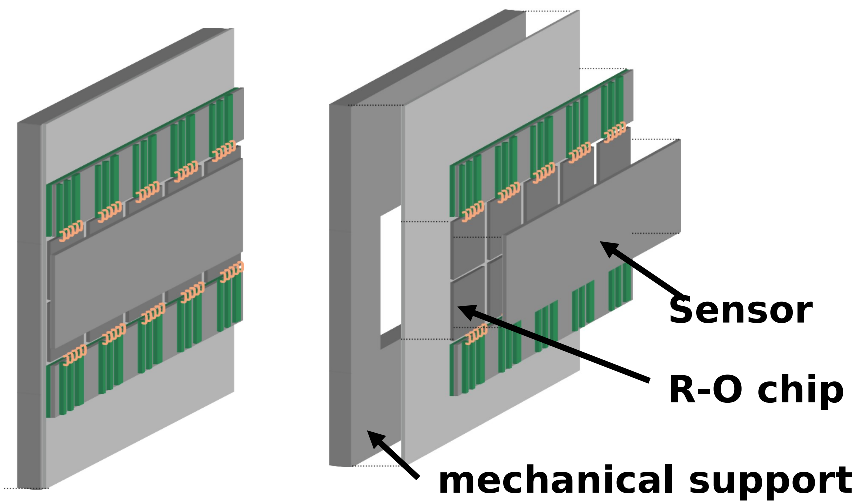
Requirements:

- Beam spectrometer: 3 stations
- Good space resolution
- Low material budget
- High intensity beam: **800 MHz**
- Excellent time resolution: **200 ps**



- Readout chip and sensor prototypes are ready
- Bumb bonding tests
- Test beam in late 2009

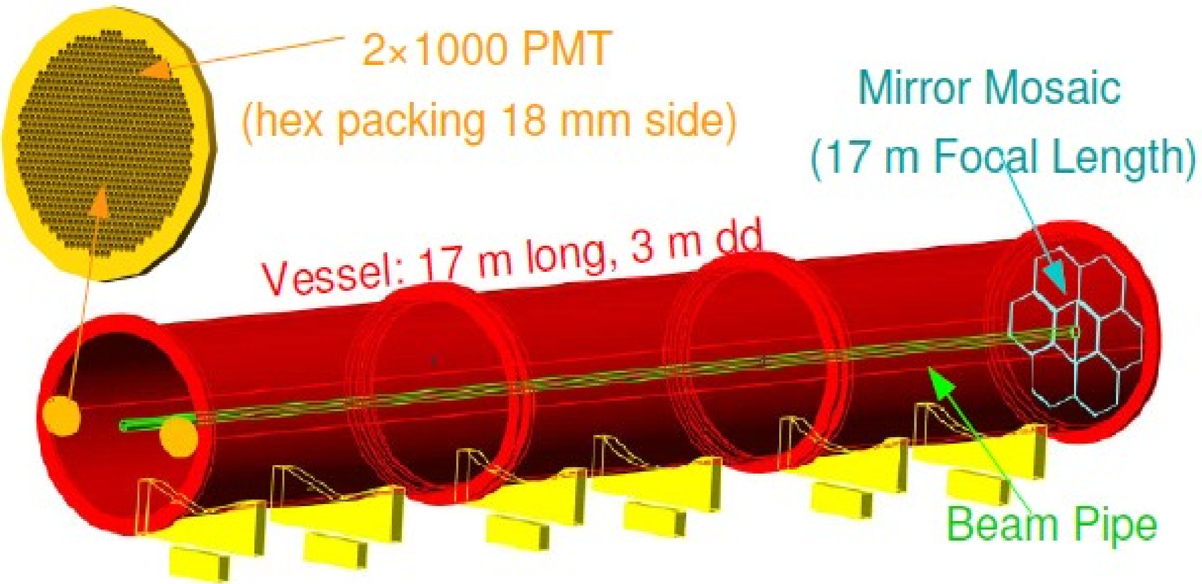
- 60X27 mm^2 per station
- 300 μmx300μm pixels
- Very thin silicon sensor + R-O chip (200+100 μm ~ 0.5X_0)
- **Radiation damages → cooling in vacuum w/ limited material bdg.**
- **Fast electronics: "on-pixel TDC"**
- time walk compensation (CFD)
- Bump bonded readout chip
- 0.13 μm CMOS technology



Example: RICH with Neon 18m long

Requirements:

- π/μ separation at 10^{-3} level with low inefficiency
- Timing of the event (better than 100ps)
- Low level trigger

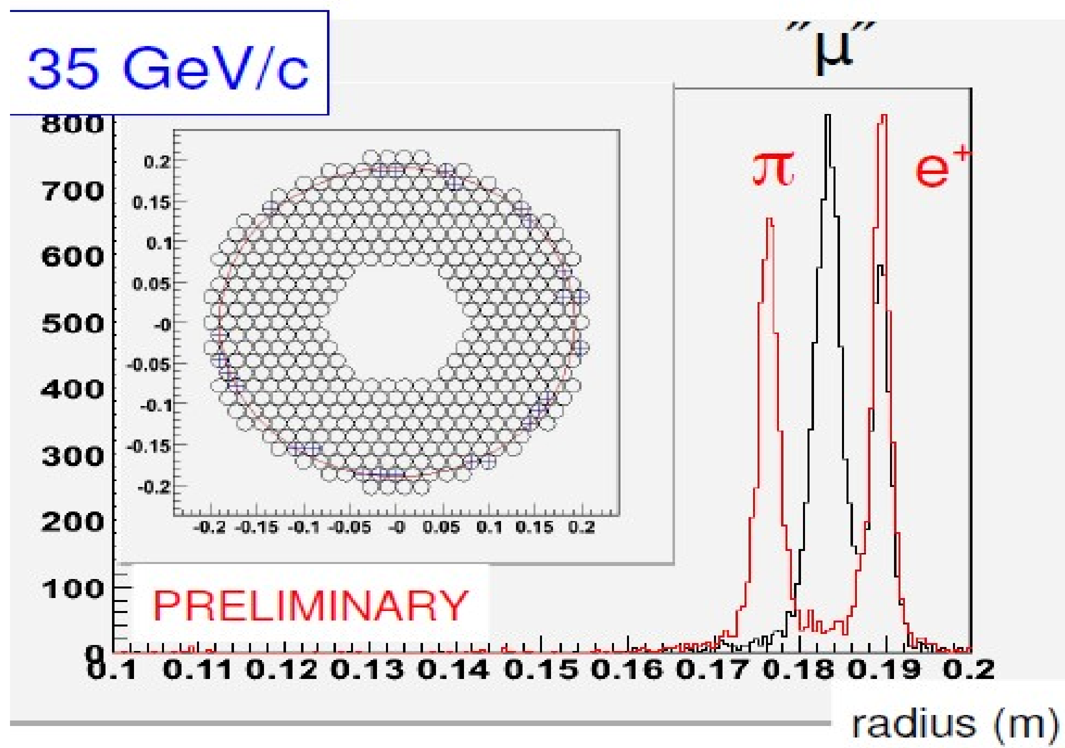


Test beam (june 2009)

- **Full length prototype** tested on beam at CERN SPS
- ~400 PMT installed
- ~17 photon/positron detected
- Timing requirements fulfilled

In addition

- test of the **new Trigger-DAQ** electronics based on HPTDC and TELL1 boards for fast triggering and readout



Schedule

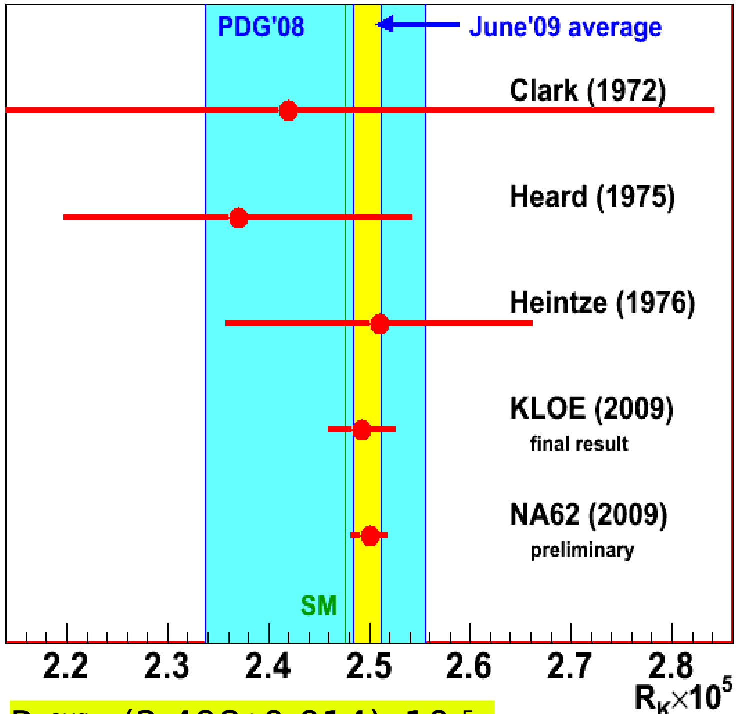
2007	First prototypes of RICH, STRAW on beam
2008	Tests of LAV, MUV, STRAW prototypes
2009	new fast LKr readout has been installed
	Test beams of prototype RICH+TDAQ system
	First prototype of GIGATRACKER
2010-11	Construction
2011-13	Data taking
… ? …	New NA62 phase for measuring $K_L \rightarrow \pi^o \nu\nu$

Conclusions

Kaons are still providing several and **unique opportunities in flavour physics** for searching New Physics effects and discriminating between NP models. Two golden opportunities come from testing Lepton Universality in $K_{\ell 2}$ decays and from measuring the ultra rare $K\to\pi\nu\nu$ decays

NA62 phase 1 data taking in 2007/08 was dedicated to a precision measurement of R_K (high statistics and powerful $K_{\mu 2}/K_{e2}$ separation)

- The analysis of a partial K_{e2} sample (~40%) reached the record accuracy of 0.7% and the preliminary result: $R_K = (2.500\pm0.016)\times10^{-5}$ is compatible to the SM prediction
- The analysis demonstrates that the overall uncertainty of 0.5% with the full data sample is within reach



$R_K^{avg} = (2.498\pm0.014)\times10^{-5}$
$(\delta R_K/R_K = 0.56\%)$

NA62 phase 2 is a challenging experiment aiming at measuring $K^+\to\pi^+\nu\nu$ decay by collecting O(100) events with B/S<10%

- It has been approved by CERN SPSC and Research Board
- Detectors R&D is on schedule and will be completed this year
- Data taking will start in late year 2011

Additional information

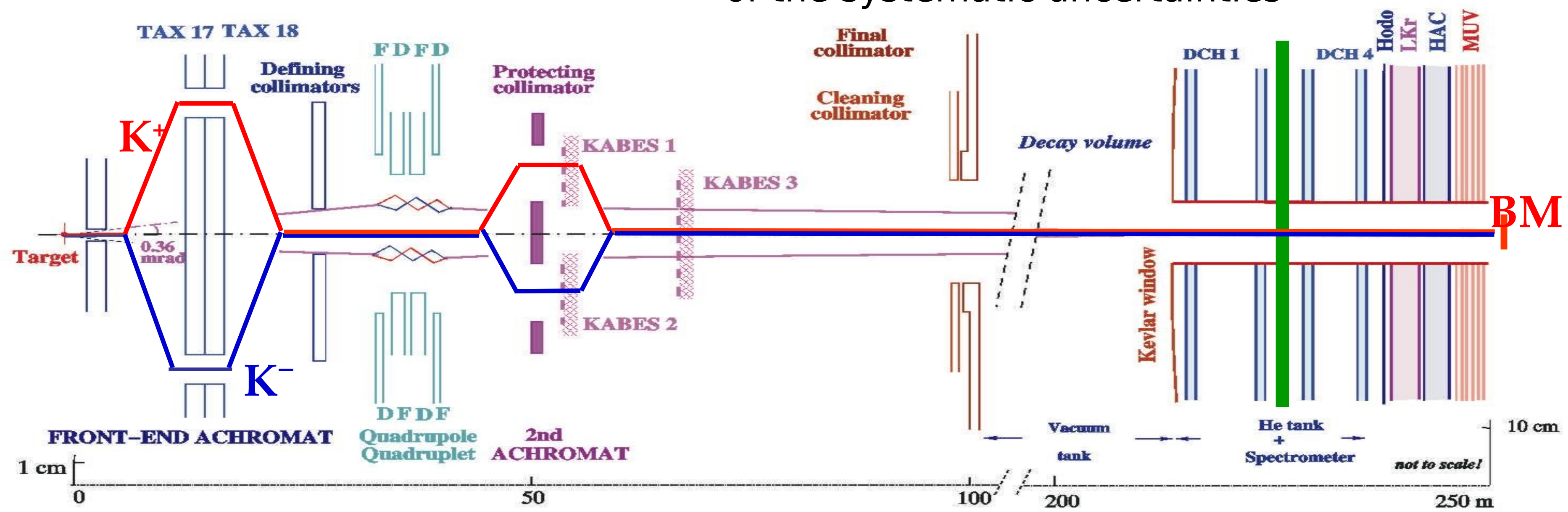
NA62 goal

Accuracy better than 0.5% to provide a stringent SM test

➡
- Dedicated K_{e2} data taking strategy
- Very high statistics K_{e2} sample (160K) collected
- Low background (10%)

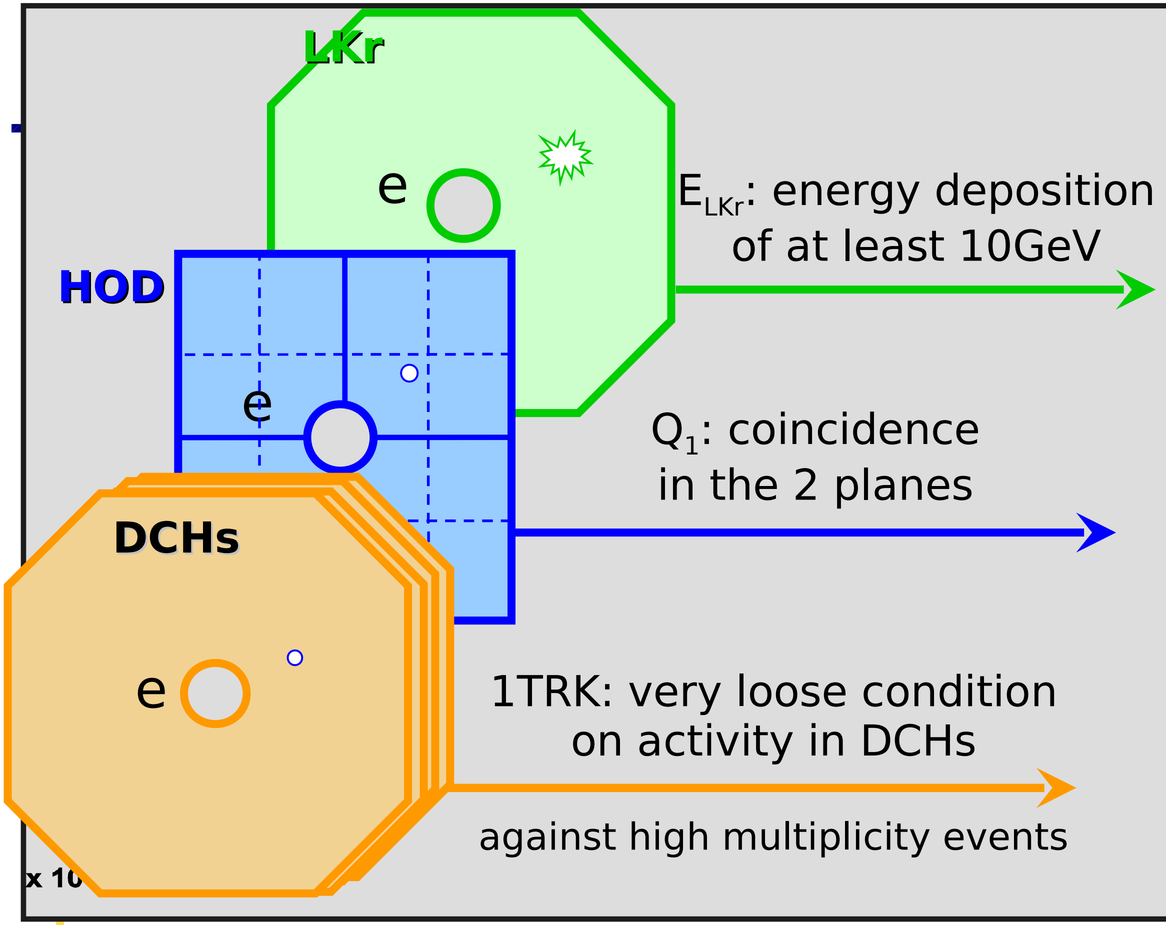
Data taking (completed): 2007 and 2008

- Four months in 2007 (23/06–22/10):
  ~400K spills, 300TB of raw data (90TB recorded)
- Two weeks in 2008 (11/09–24/09):
  special data sets allowing reduction of the systematic uncertainties



NA48-2 beams: simultaneous K^+/K^-, focused, high momentum, narrow band (designed for the search of direct CPV in $K^{\pm}\to3\pi$) **tuned for K_{e2}**

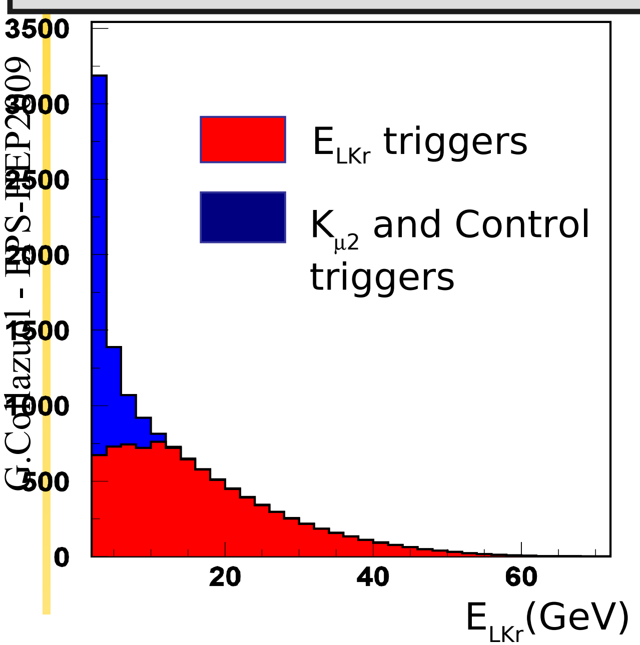
Trigger logic

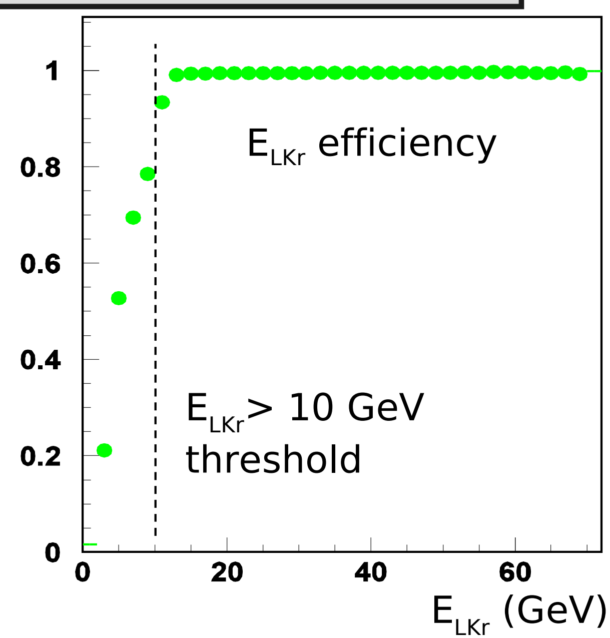


Minimum bias (high efficiency, but low purity) trigger configuration used

K_{e2} condition: $Q_1 \times E_{LKr} \times 1TRK$
Purity ~10^{-5}

$K_{\mu 2}$ condition: $Q_1 \times 1TRK/D$
Downscaling (D) =50 to 150
Purity ~2%





- $K_{\mu 2}$ & control triggers to monitor the efficiency of K_{e2} trigger
- E_{LKr} inefficiency is < 0.1% for p>15GeV/c

NA62 beam: K^+, high momentum, narrow band

K_{l2} candidates: kinematic identification

$$M_{miss}^2(l) = (P_K - P_l)^2$$
$$\approx m^2_K (1 - p_l/p_K) - p^2_t (p_K/p_l)$$

p_K is only measured on average (not on event by event basis)

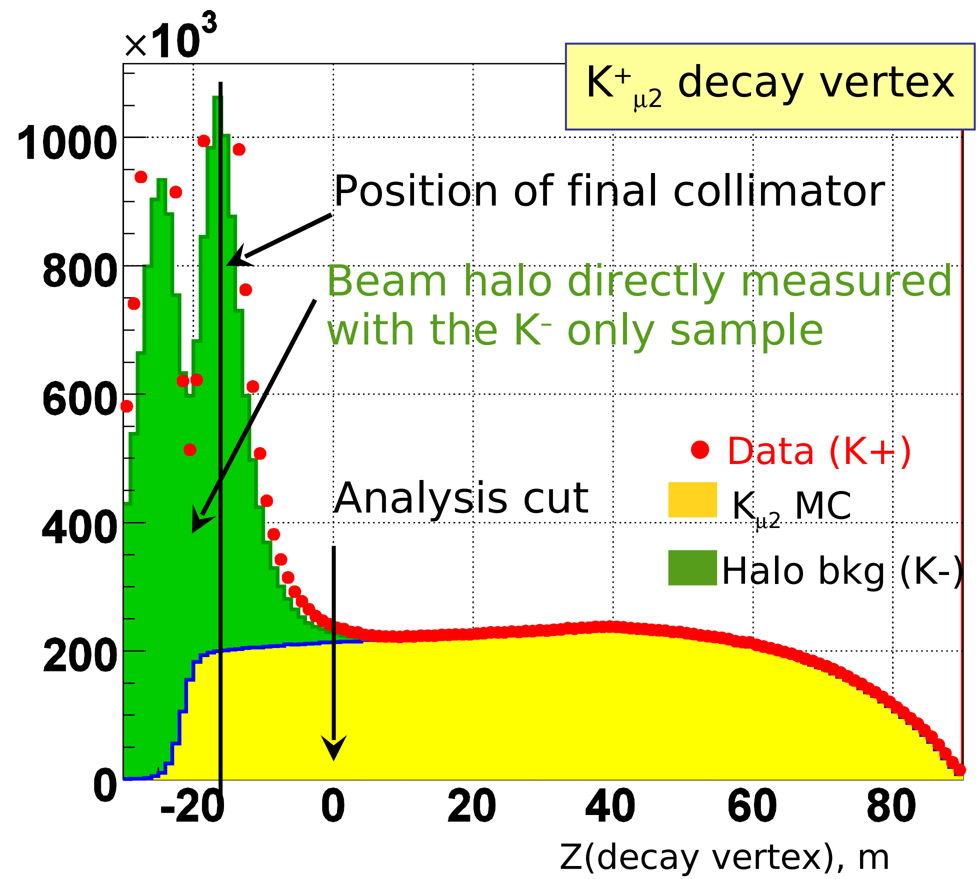
➡ Improvement of K_{e2} / $K_{\mu 2}$ separation by

1) high momentum beam (p=75 GeV/c)
2) narrow momentum band beam ($\Delta p_K^{RMS}/p_K$=2%) (optimization of M_{miss}^2 resolution)

Positive beam charge:
beam halo background (due to muon decays into electrons mimiking K_{e2} events) was much higher for K^-_{e2} (~20%) than for K^+_{e2} (~1%):

➡ ~90% of data sample: K^+ only beam
~10% of data sample: K^- only beam

Collection of "K^+ only" and "K^- only" data allows precision "cross-measurements" of beam halo background



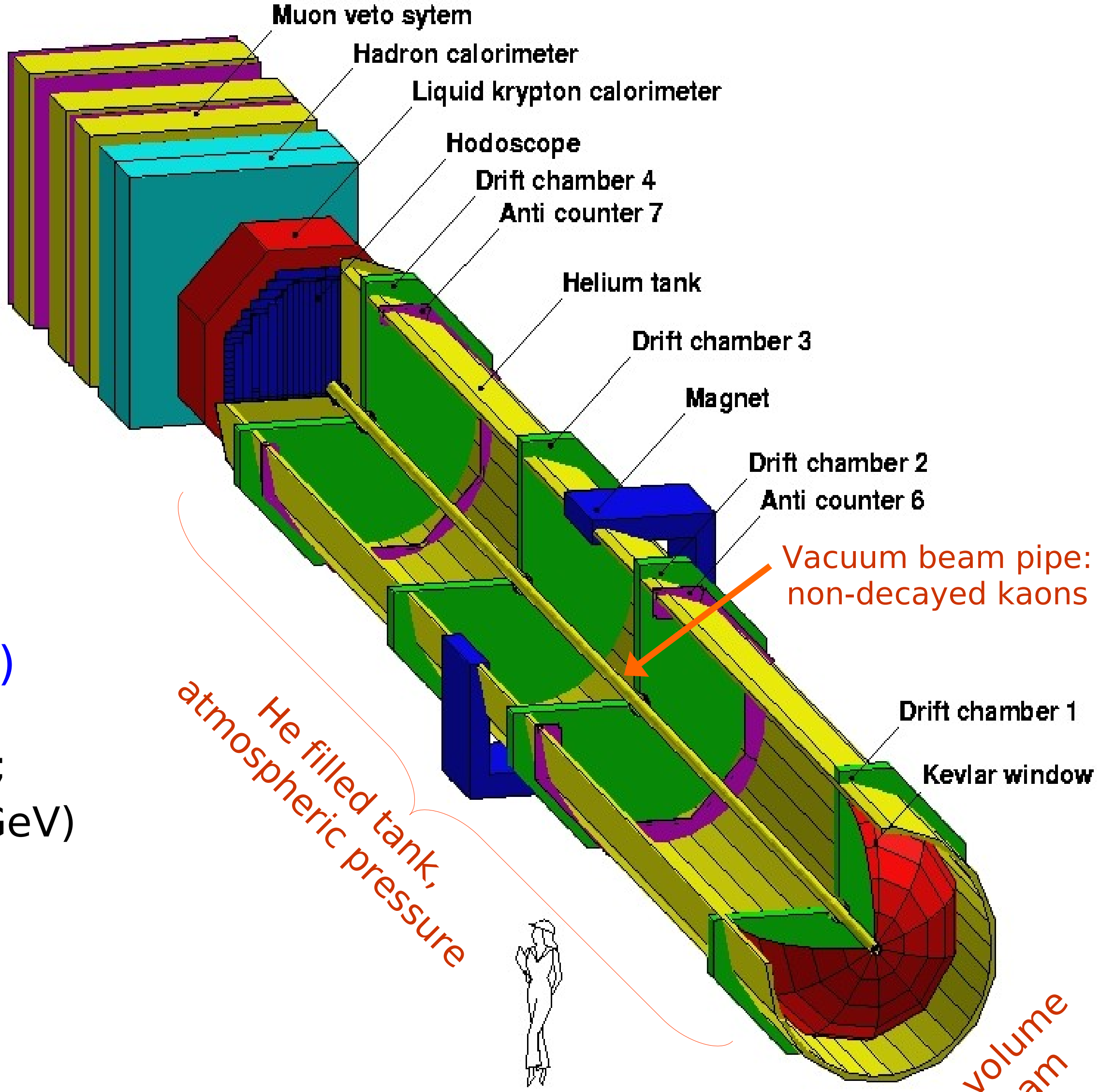
NA62 Main sub-detectors

K_{l2} candidates:
e/μ particle identification from E/p

- Magnetic spectrometer (4 DCHs):
  4 views/DCH: redundancy → efficiency;
  $\sigma_p/p = 0.47\% + 0.02\% * p$ [GeV/c]

- Liquid Krypton EM calorimeter (LKr)
  High granularity, quasi-homogeneous;
  $\sigma_E/E = 3.2\%/E^{1/2} + 9\%/E + 0.42\%$ [GeV];
  $\sigma_x=\sigma_y=0.42/E^{1/2} + 0.6\text{mm}$ (1.5mm@10GeV)

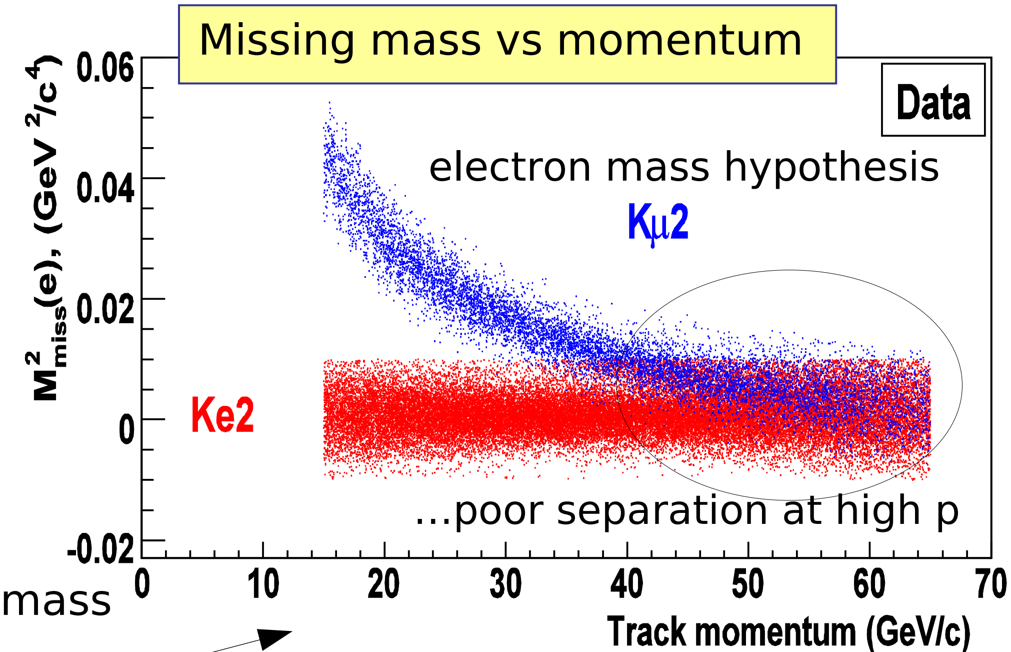
- Hodoscope
  fast trigger and track time ($\sigma_t \sim 200$ps)



K_{e2} and $K_{\mu2}$ selection

Common criteria for K_{e2} and $K_{\mu2}$

- One reconstructed charged track;
- Track in geometrical acceptance of the main sub-detectors;
- Upper limit on LKr energy deposition not associated to the track;
- Decay vertex: closest dist. approach (CDA) of track & kaon beam axis: CDA<2cm and $(Z_{vertex} - Z_{collimator})$>18m;
- Track momentum: 15GeV/c<p<65GeV/c



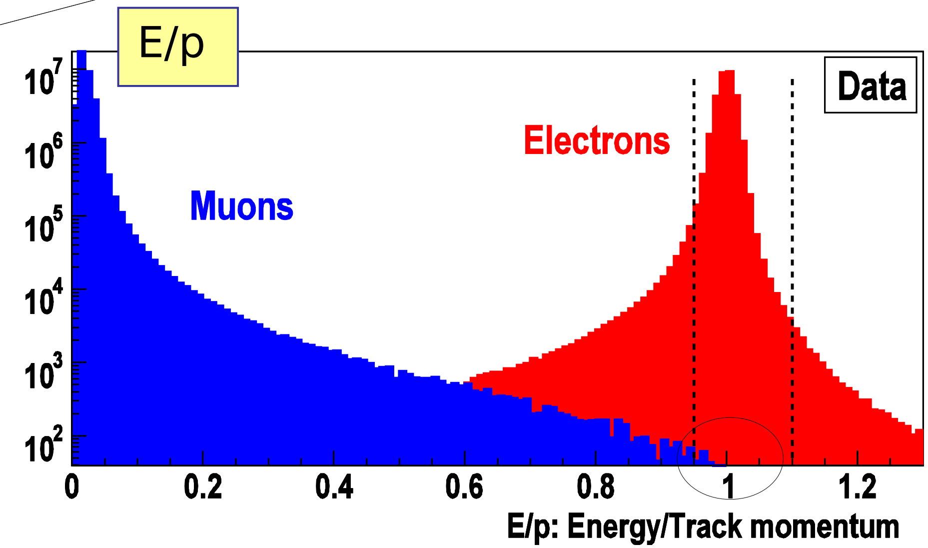
Criteria to discriminate K_{e2} from $K_{\mu2}$

- Kinematic identification by invariant missing mass $M_{miss}{}^2(l)=(P_K-P_l)^2 \sim m^2{}_K(1 - p_l/p_K) - p^2{}_t(p_K/p_l)$ (electron mass hypothesis):

  $|M_{miss}{}^2(l)|<0.01\ (GeV/c^2)^2$

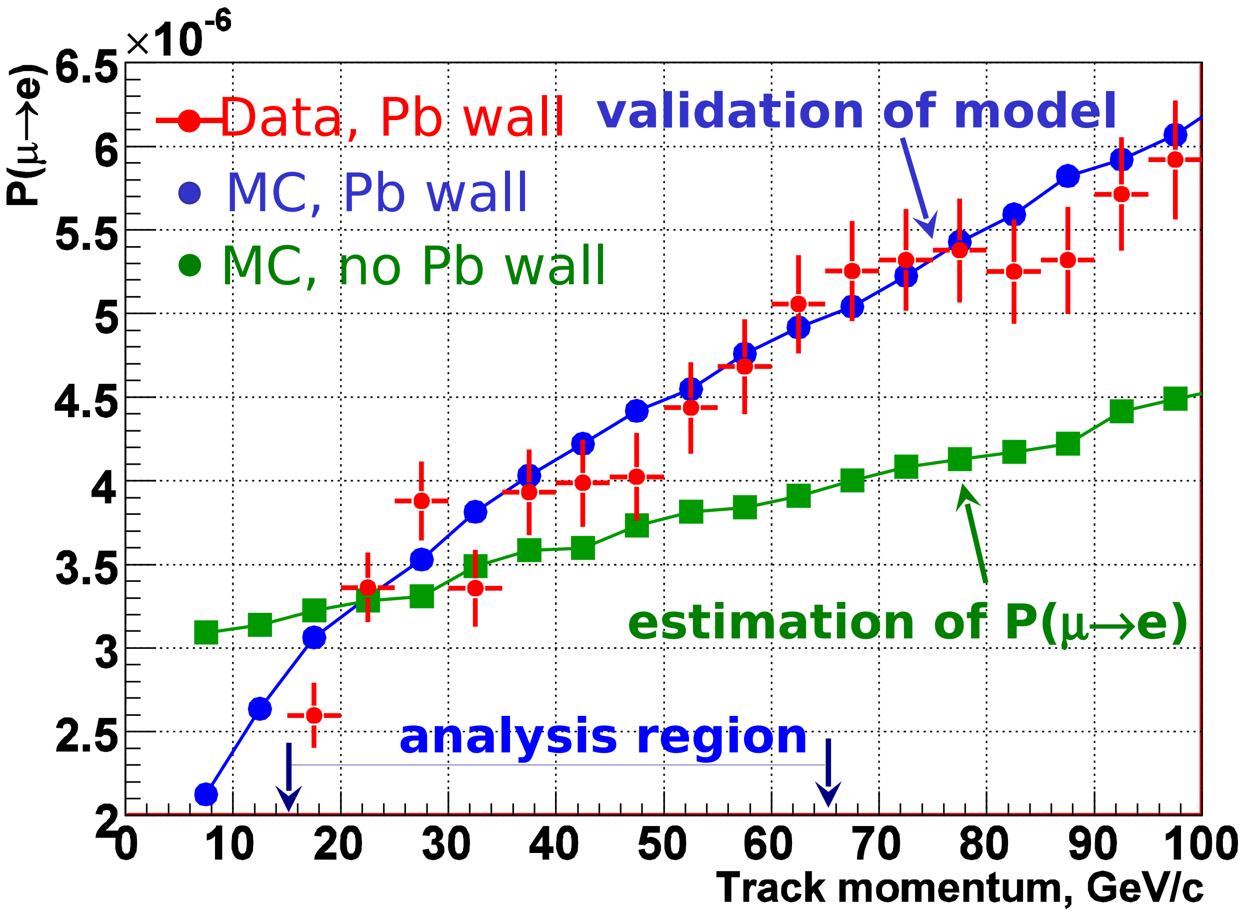
- Particle identification by energy deposition in Calorimeter (E_{LKr})

  - 0.95<E/p<1.10 for electron
  - E/p<0.2 for muon



Muonic background in K_{e2} sample (2)

Mis-identification probability $P(\mu \to e)$:
measurement (2007 muon sample) vs MC simulation (Geant4-improved)



The simulation was improved in collaboration with G4 developers

→ Data with Pb wall used for MC validation

$P(\mu \to e)$ is appreciably modified by the Pb wall, due to:
1) muon ionization losses (low p);
2) bremstrahlung in Pb (high p)

→ MC used to estimate the background in K_{e2}
Result: $B/S = (8.07 \pm 0.21)\%$

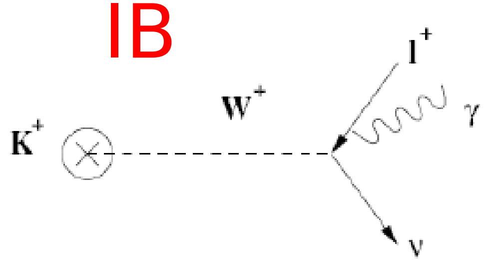
Uncertainty is due to the limited size of the data sample used to validate the simulation

Prospects:

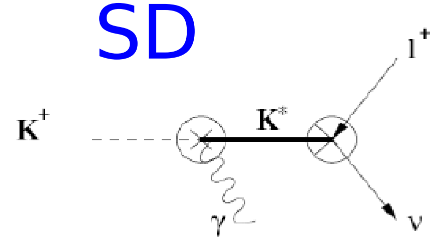
- The 2008 muon sample is twice as large as the 2007 one;
- Another tool: muons from $K_{\mu 2}$ decays in $K_{e2}/K_{\mu 2}$ separation region (p<25GeV/c)

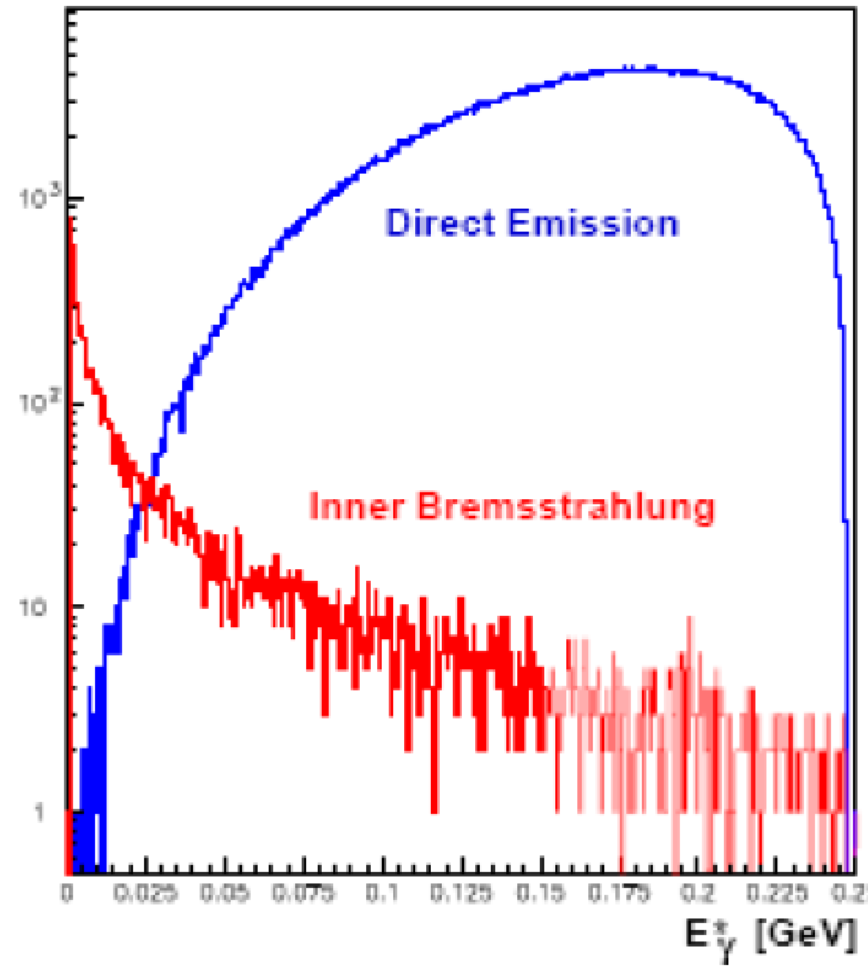
$K^{\pm} \rightarrow e^{\pm}\nu\gamma$ background

IB



SD





Radiative corrections in the theoretical-computation of R_K:

- Inner bremsstrahlung (IB) contribution is included
- Structure dependent direct emission (SD) contribution is not included

⬇

Ke2(γ) and Kμ2(γ) candidates are measured inclusively and then radiative SD contributions are subtracted (by accounting properly for acceptance)

Note: SD contribution is negligible in $K_{\mu 2}$, not in K_{e2}

$K^{\pm}\to e^{\pm}\nu\gamma$ background (2)

$K_{e2\gamma}$ structure dependent (SD^+):

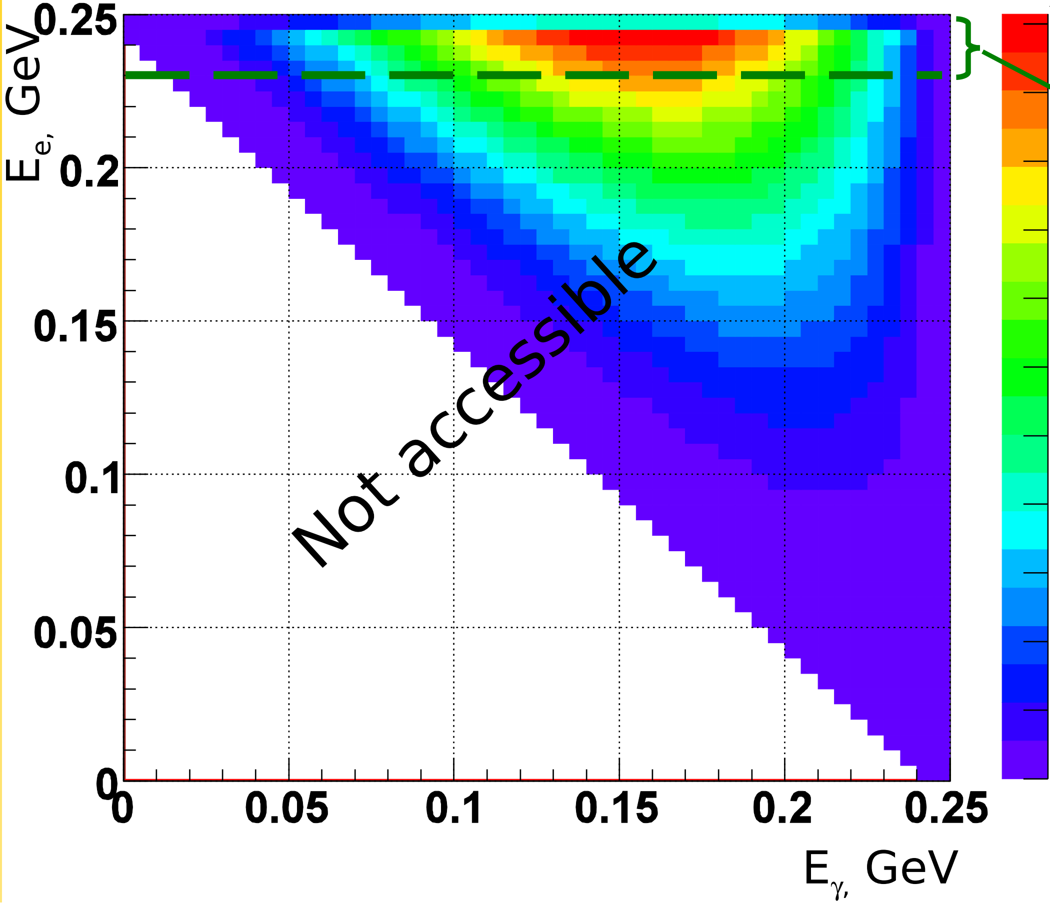
- Background (by definition of R_K)
- Rate similar to K_{e2}
- Known with very poor precision (~20%):

- Theory: $BR=(1.12–1.34)\times10^{-5}$ [model-dependent form-factor]
- Experiment: $BR=(1.52\pm0.23)\times10^{-5}$ [measurements in the 1970s]

Estimate: B/S = (1.29±0.32)%

Uncertainty is due to poor precision of theoretical and experimental knowledge

$K_{e2\gamma}$ (SD^+) Dalitz plot distribution



Only energetic electron events (E_e^*>230MeV) are compatible with K_{e2} kinematic ID

This part of phase space is accessible for a direct BR measurement, (being outside the area populated by the K_{e3} background (E_e^*<227 MeV)

Prospects:
Improve B/S estimate uncertainty by direct measurements by KLOE and NA62

G.Collazuol - EPS-HEP2009

Beam halo background

Background source in K_{e2} sample:
electrons produced by muons in beam halo via $\mu \rightarrow e$ decay, kinematically and geometrically compatible to a genuine K_{e2} decay

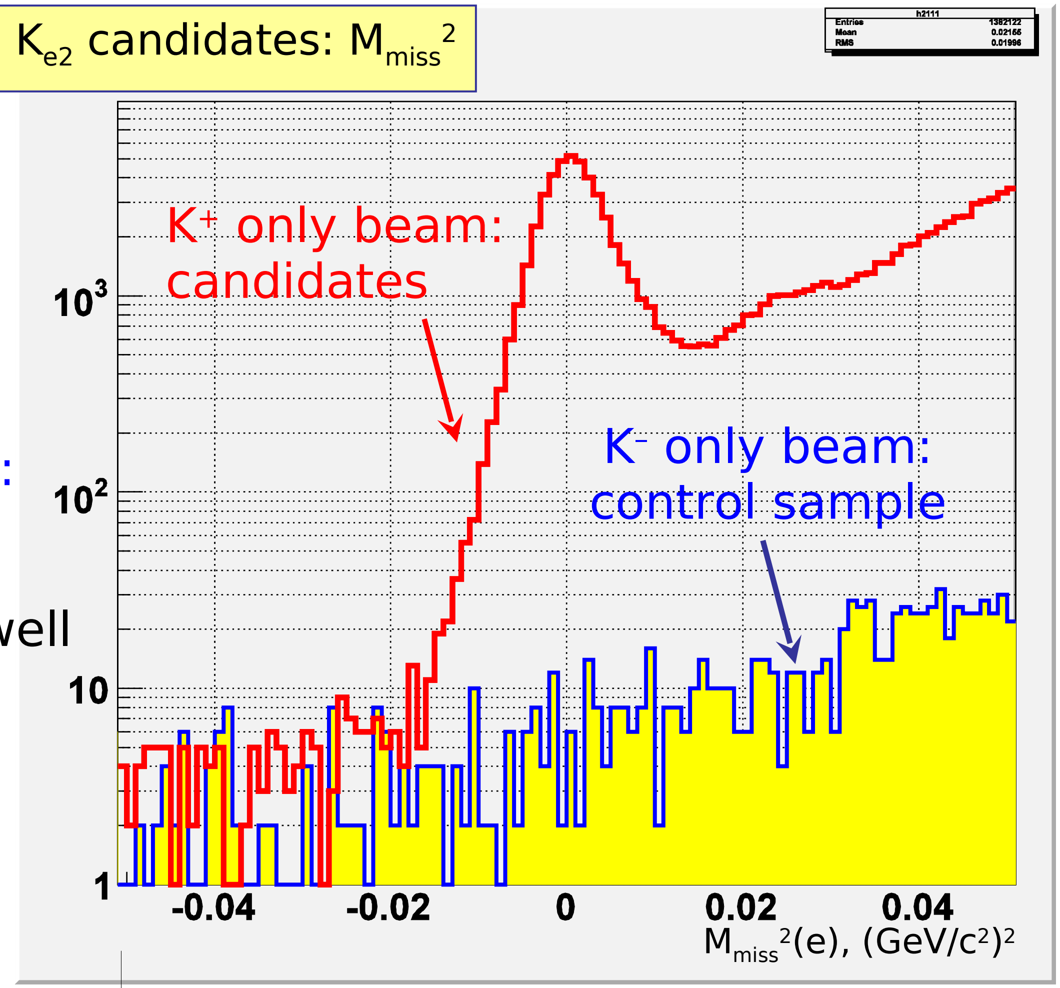
Directly measured with K^- only sample:
Result: $B/S=(1.23\pm0.07)\%$

Background rate and distribution are well reproduced with beam halo simulation

Uncertainty due to the limited size of control data sample

Prospects:

- 2008 K^- sample will improve precision;
- Smallness of uncertainty allows expanding the analysis fiducial volume further upstream and increase the data sample



Halo **background in $K_{\mu2}$ sample** measured with similar technique:

$B/S=0.14\%$
negligible uncertainty

Particle ID efficiencies

Electron ID efficiency f_e

directly measured by kinematic selection of electrons:

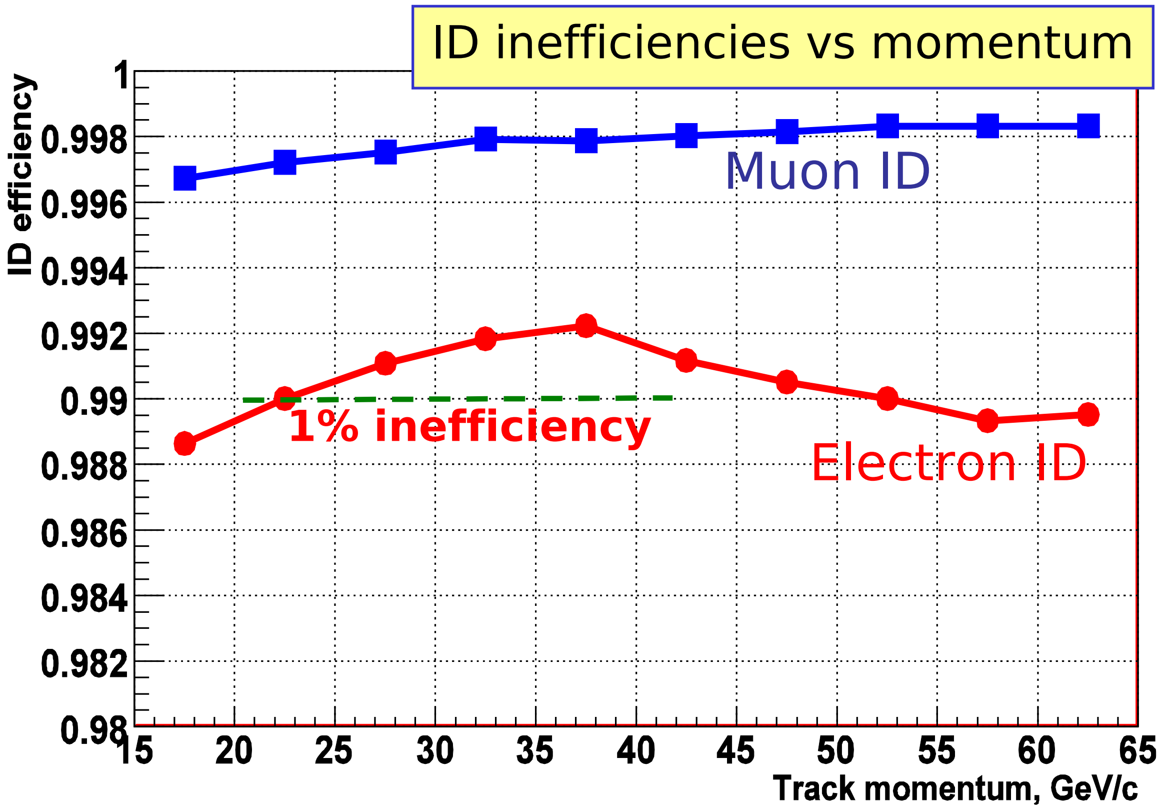
- from $K^{\pm}\rightarrow\pi^0 e^{\pm}\nu$ decays collected during main K data taking (limited momentum range p<50GeV/c);
- from $K_L\rightarrow\pi^{\pm}e^{\pm}\nu$ decays collected in a special 15h K_L run (whole track momentum range, due to broad K_L momentum spectrum).

→ f_e is measured (range: 0.988-0.992) with uncertainty below δf_e<0.1%

Muon ID efficiency f_μ

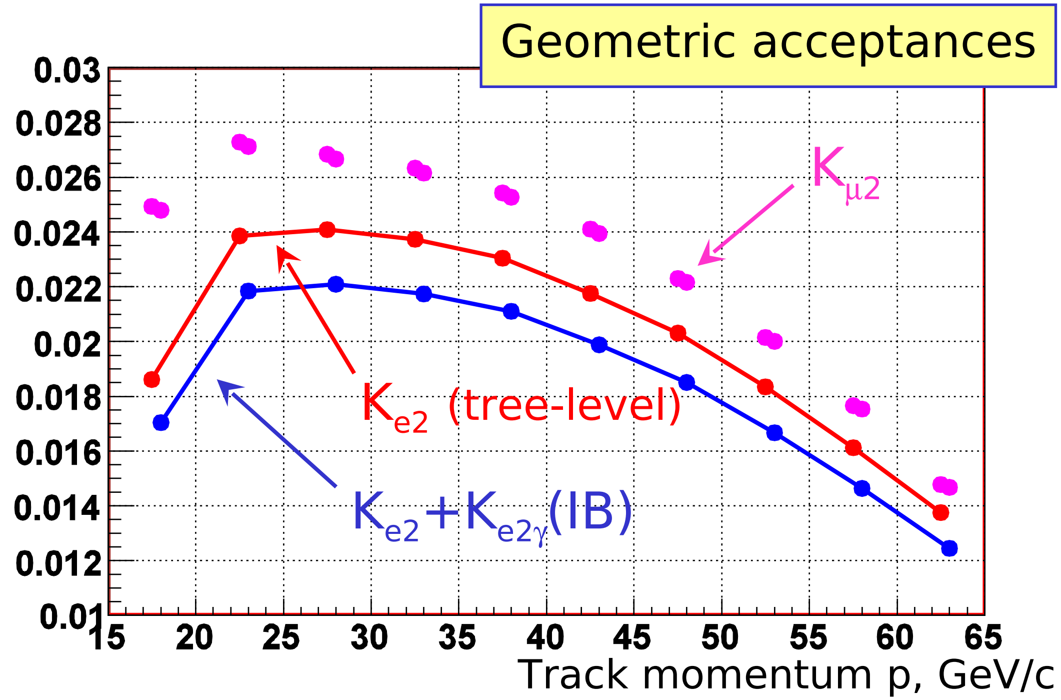
measurement is simple: electro-contamination is outside the muon ID region, and is neglibile wrt $1-f_\mu$

→ f_μ is measured directly (range: 0.996–0.999) with an uncertainty below δf_μ<0.1%



Other effects

Acceptance correction:
- Momentum dependent: $A(K_{\mu2})/A(K_{e2}) \sim 1.3$
- K_{e2} radiative (IB) corrections strongly affect the acceptance
- Preliminary conclusion: the correction can be evaluated with a 0.1% precision



Trigger efficiency correction:
- Efficiencies are monitored with control trigger samples;
- Q_1 efficiency mostly cancels in R_K, while E_{LKr} efficiency directly affects R_K
- E_{LKr} inefficiency measurement: $1-\varepsilon(E_{LKr}) \approx 1-\varepsilon(K_{e2})/\varepsilon(K_{\mu2}) < 0.1\%$

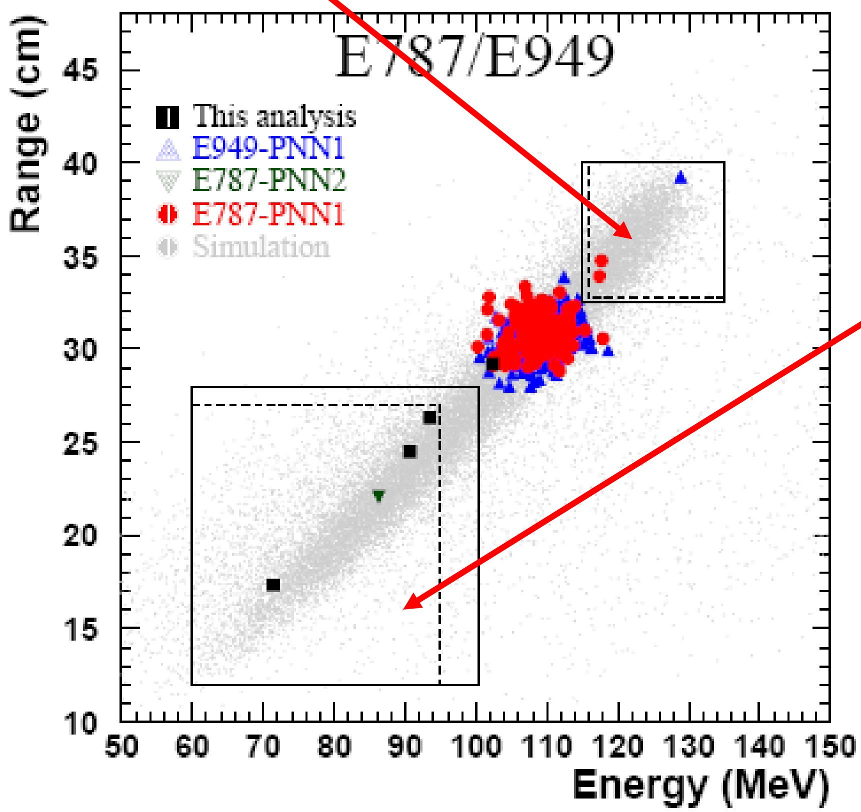
Other known sources of uncertainies (can be corrected for):
- Trigger after-pulses biasing the Q_1 downscaling factor;
- Global inefficiency of LKr calorimeter readout (measured: $1\text{-}f_{LKr} \approx 0.002$)

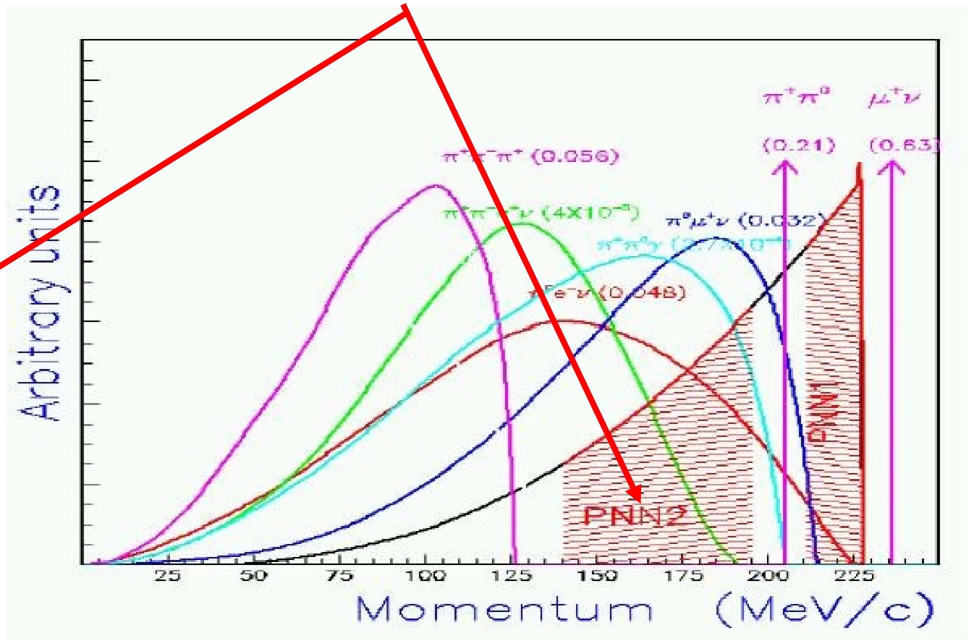
$K^+ \to \pi^+ \nu \bar{\nu}$ with E787-E949 @BNL

Stopped K: separated beam, high effective decay rate, kinematics

Region 1 between two 2-body peaks (lower background):

Study of region 2 below $\pi^+\pi^0$ peak: higher background (nuclear π int.) S/B is many times worse





E787+E949: 4 events
Bkg: 2.15 ± 0.43

E787+E949: 3 events
Bkg: 0.30 ± 0.03
(P=0.001)

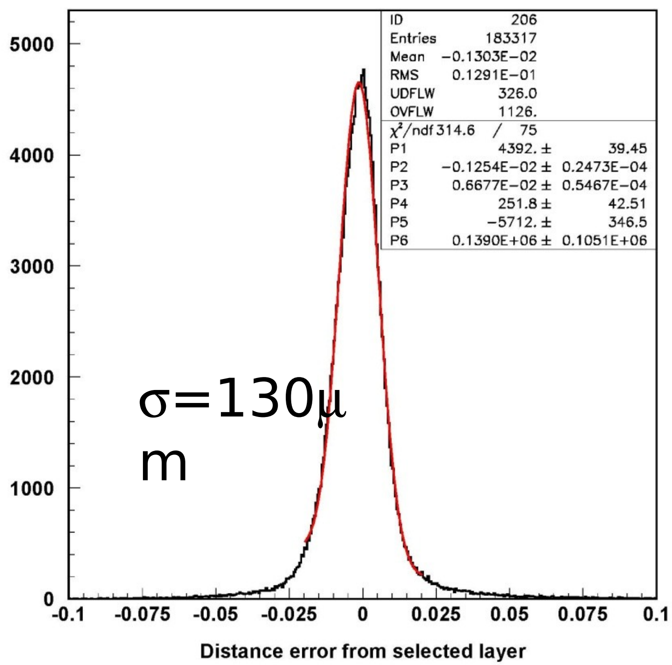
Combined result: BR = $(1.73^{+1.15}_{-1.05}) \cdot 10^{-10}$

Limits of this technique reached

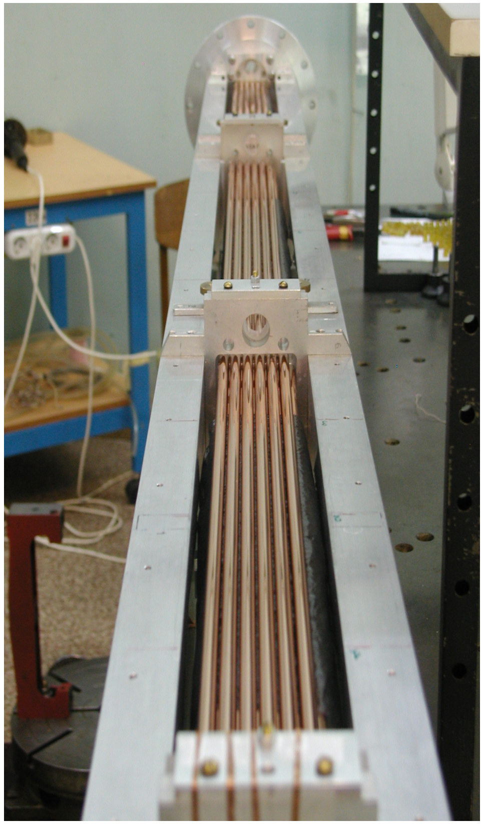
NA62-II: Straws

Requests:

- 4 chambers
- good space and momentum resolution
- Low material budget: $X/X_0 < 0.5\%$ per chamber
- operation in vacuum
- small inactive area around kaon beam



- 4 views with staggered planes
- Straw tubes in alluminium ultrasonic welded (no glue)
- measured resolution: 130μm per hit
- gap beetwen two straws: 1.2 cm (0.1 mm tollerance)

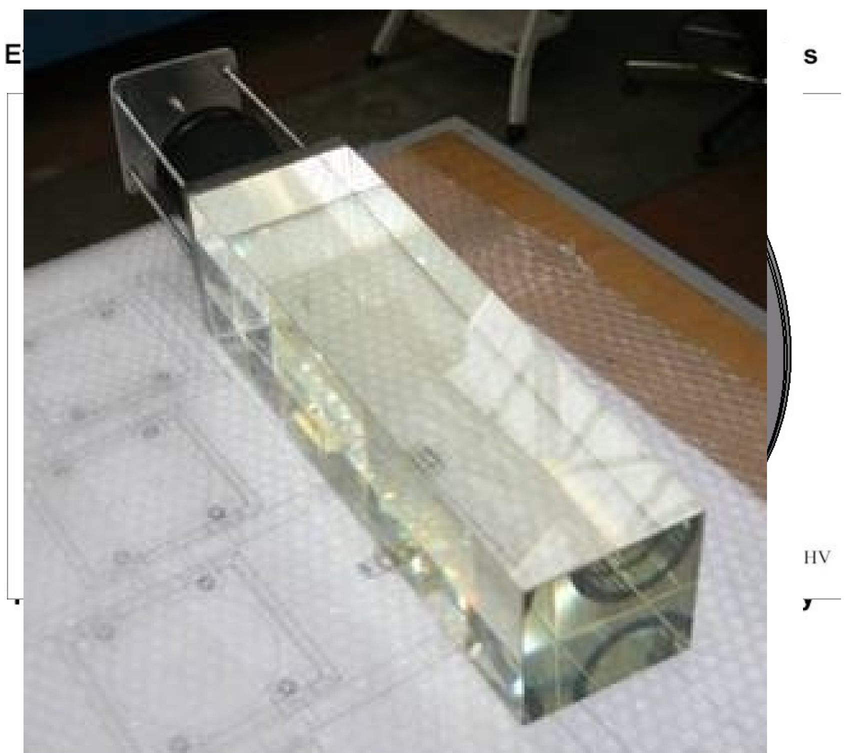


- Prototypes tested on vacuum with hadronic beam, muons and electrons
- Readout under definition
- Detector in construction

NA62-II: LAv

<u>Requests:</u>

- Vetos for gammas with large angle > 50 mrad
- Efficient covering along the decay region
- Inefficiency below 10^{-4} for E>200 GeV



- Three technology investigated (lead+scintillating fibers, lead+scintillator, lead glass)
- Opal lead glass solution
- Phototubes operating in vacuum
- 13 rings along the decay region

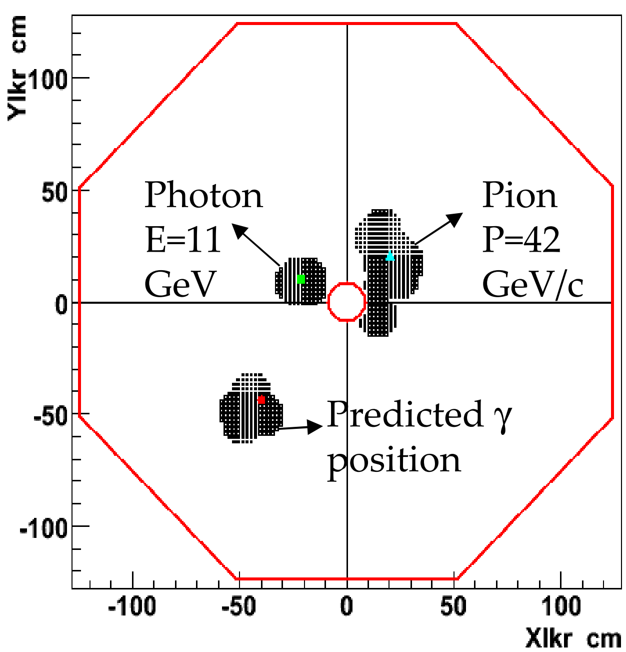
- Several test beam to chose the technology
- caracterization with hadrons and muons of a 4x5 blocks real scale protorypes
- Module 0 prototypes in construction for test beam next summer

NA62-II: LKr

Requests:

- Very high efficiency on forward photons (1<acceptance<10mrad)
- Good time resolution

- Na48 LKr calorimeter
- The efficiency has been measured with a special run in 2006
- $<10^{-6}$ for E>10 Gev, $<10^{-3}$ for 2.5<E<5.5 GeV



- New cryogenics system and new FE readout already done
- New electronics to allows faster triggering in construction

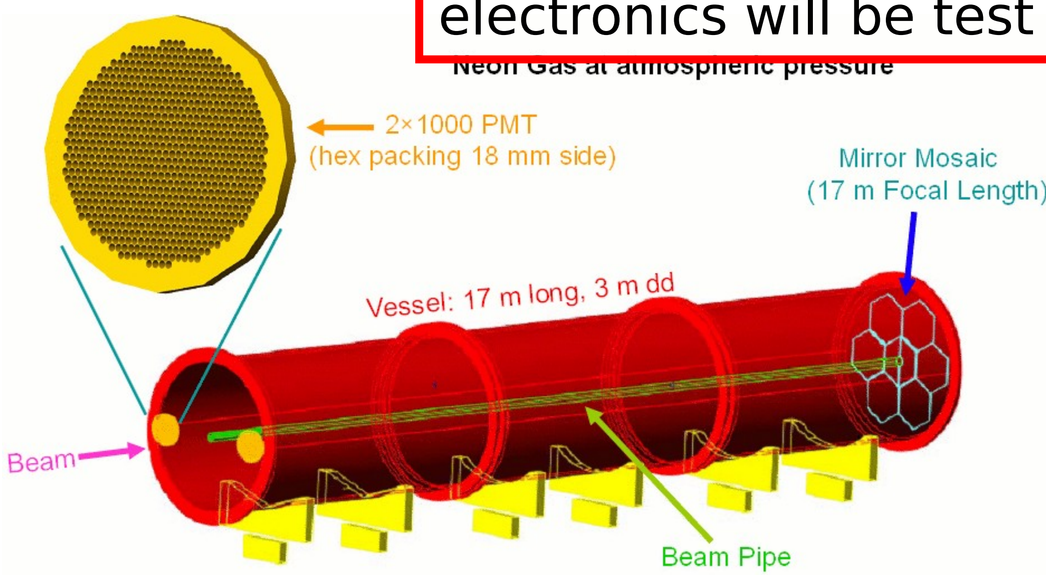
NA62-II: Rich

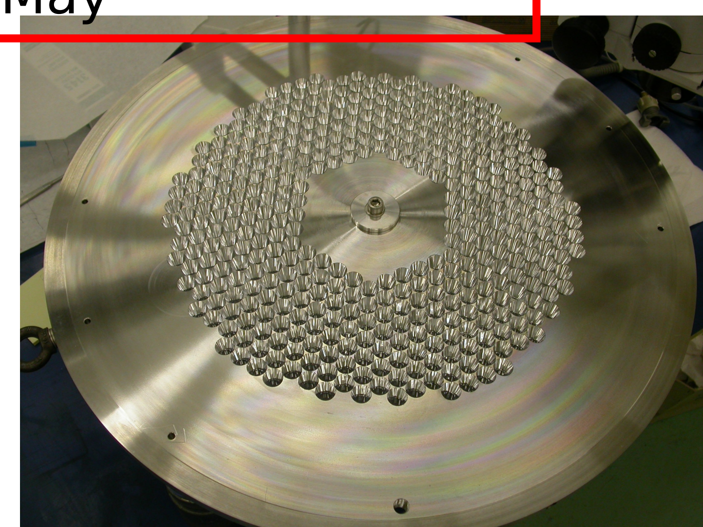
Requests:

- Provide π/μ separation at 5×10^{-3} in the range $15<p<35$ GeV/c
- Measure track time with 100 ps res
- Provide the main trigger for charged particle

- 18 m long tube filled with Neon
- Mirrors with f=17 m
- 2000 single anode PMTs, 1 cm in diameter
- 18mm "pixel" with Winston cones

- 100PMT full length prototype already tested
- 400PMT prototype with new readout electronics will be test in May





NA62-II: trigger & DAQ

- Quasi-triggerless paradigma: L0 hardware and L1 software
- High trigger efficency (>95%)
- Acquisition losses < 10^{-8}
- Fully monitored system: inefficiency, dead time and Xoff recording
- Low random veto probability: very high online time and double pulse resolution
- Integrated Trigger and DAQ fully digital system
- Readout without zero suppression for candidates
- Scalability in terms of bandwidth
- As uniform as possible for most detectors
- Exploit as much as possible existing and commercial solutions developed for existing or new experiments

detector	Rate (MHz)
CEDAR	50
GTK	800
LAV (total)	9.5
STRAW (each)	8
RICH	8.6
LKR	10.5
MUV	9.2
SAC	1.5

- L0 input rate: ~10MHz
- Conditions on LKr, MUV and RICH multiplicity can reduce the rate ~ 1 MHz