"Search of new physics with kaon decays at NA62"

Third Workshop on Theory, Phenomenology and Experiments in Heavy Flavour Physics
Capri 7/7/2010

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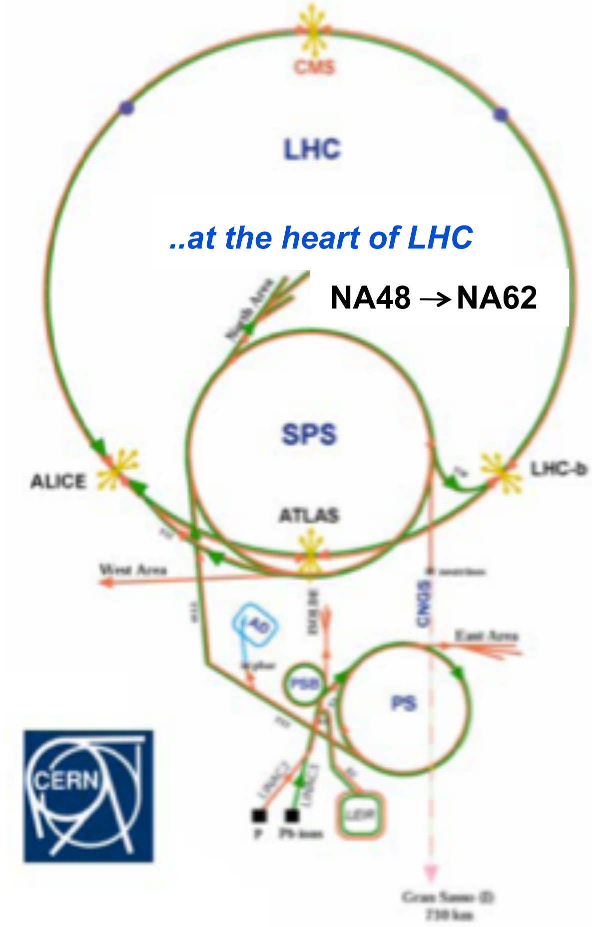
On behalf of the *NA62 collaboration*:
Bern ITP, Birmingham, CERN, Dubna, Ferrara, Fairfax, Florence, Frascati, IHEP, INR, Louvain, Mainz, Merced, Naples, Perugia, Pisa, Rome I, Rome II, San Luis Potosi, SLAC, Sofia, Triumf, Turin

Outline

- **NA62-I:** R_K with Kl2 decays
  - principle of the measurement
  - analysis status
- **NA62-II**: $K^+ \to \pi^+ \nu \bar{\nu}$ experiment
  - experimental methodology
  - main detectors description
- Conclusions



Kaon and Physics beyond the SM

New physics effects in Flavour Physics

[G.Isidori Capri, Flavianet 2008]

MFV: helicity suppressed observables are sensible to SUSY with large tanβ: ***B→ll, B→lν, K→lν***

The B decays are suppressed (Vub<<Vus) while the ***K***→***e***ν is $1.5 \cdot 10^{-5}$

Non-MFV: FCNC decays with high suppression in the standard model and clean theoretical prediction

The ***K***→πνν has a very clean SM prediction and has a λ^5 suppression

It's time for a precision measurement in K_{e2} and ***K***→πνν!!!

NA62-I (2007/08) → Lepton universality in Kaon decays

NA62-II (2011-12) → O(100) events measurement of ***BR*** ***(K***→πνν***)***

NA62-I

R_K with Kl2 decays

Ke2: R_K and LFV

- The hadronic uncertainties cancel in the ratio $K_{e2}/K_{\mu2}$ (no f_K)
- For this reason the SM prediction is very accurate dR_K/R_K~0.04%

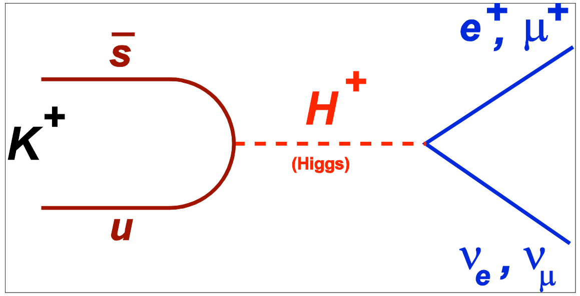
$$R_K = \frac{\Gamma(K^\pm \to e^\pm \nu)}{\Gamma(K^\pm \to \mu^\pm \nu)} = \frac{m_e^2}{m_\mu^2} \cdot \left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2}\right)^2 (1 + \delta R_K^{\mathrm{rad.corr.}})$$

$= (2.477 \pm 0.001) \cdot 10^{-5}$ [V.Cirigliano, I.Rosell JHEP 0710:005(2007)]

- The only difference between electron and muon channel is due to the V-A coupling
- A small correction has to be included due to the IB part of the radiative decay

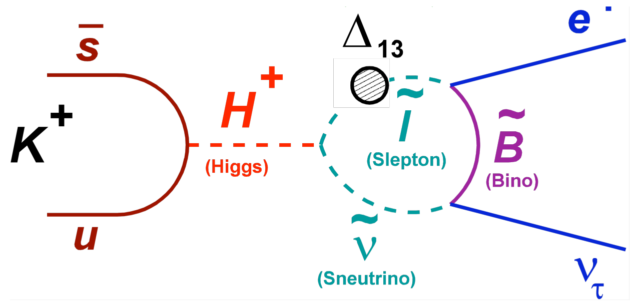
R_k *Beyond* Standard Model

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



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

$$R_K^{LFV} \approx R_K^{SM}\left[1 + \left(\frac{m_K^4}{M_{H^\pm}^4}\right)\left(\frac{m_\tau^2}{M_e^2}\right)|\Delta_{13}|^2 \tan^6\beta\right]$$



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)

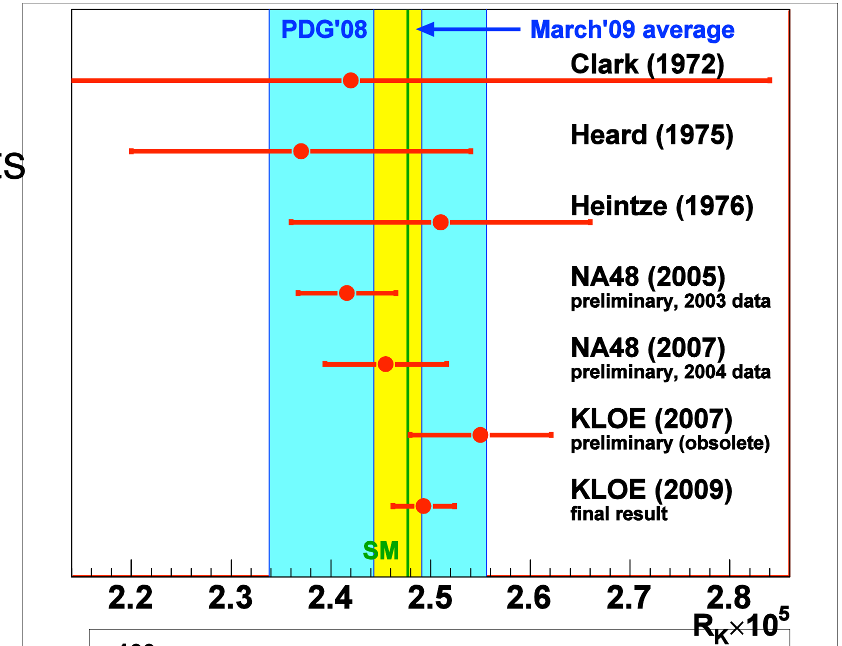
-> Final result by KLOE (LaThuile09)

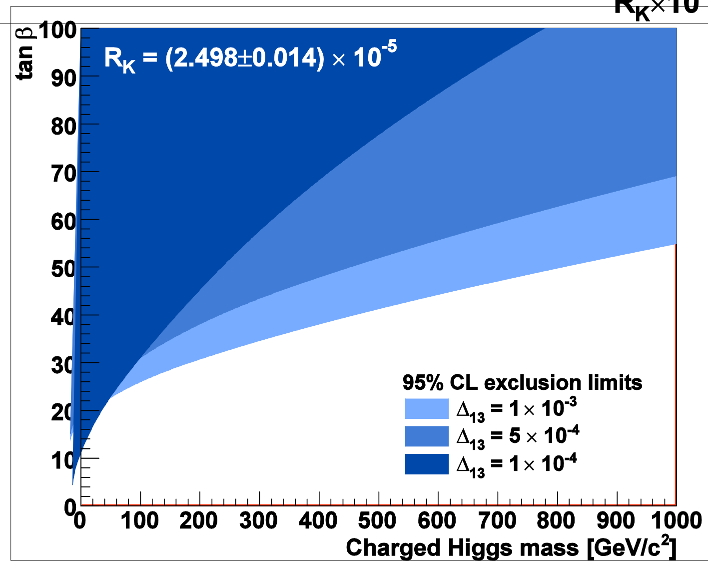
$R_K = (2.493 \pm 0.025 \pm 0.019) \cdot 10^{-5}$

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

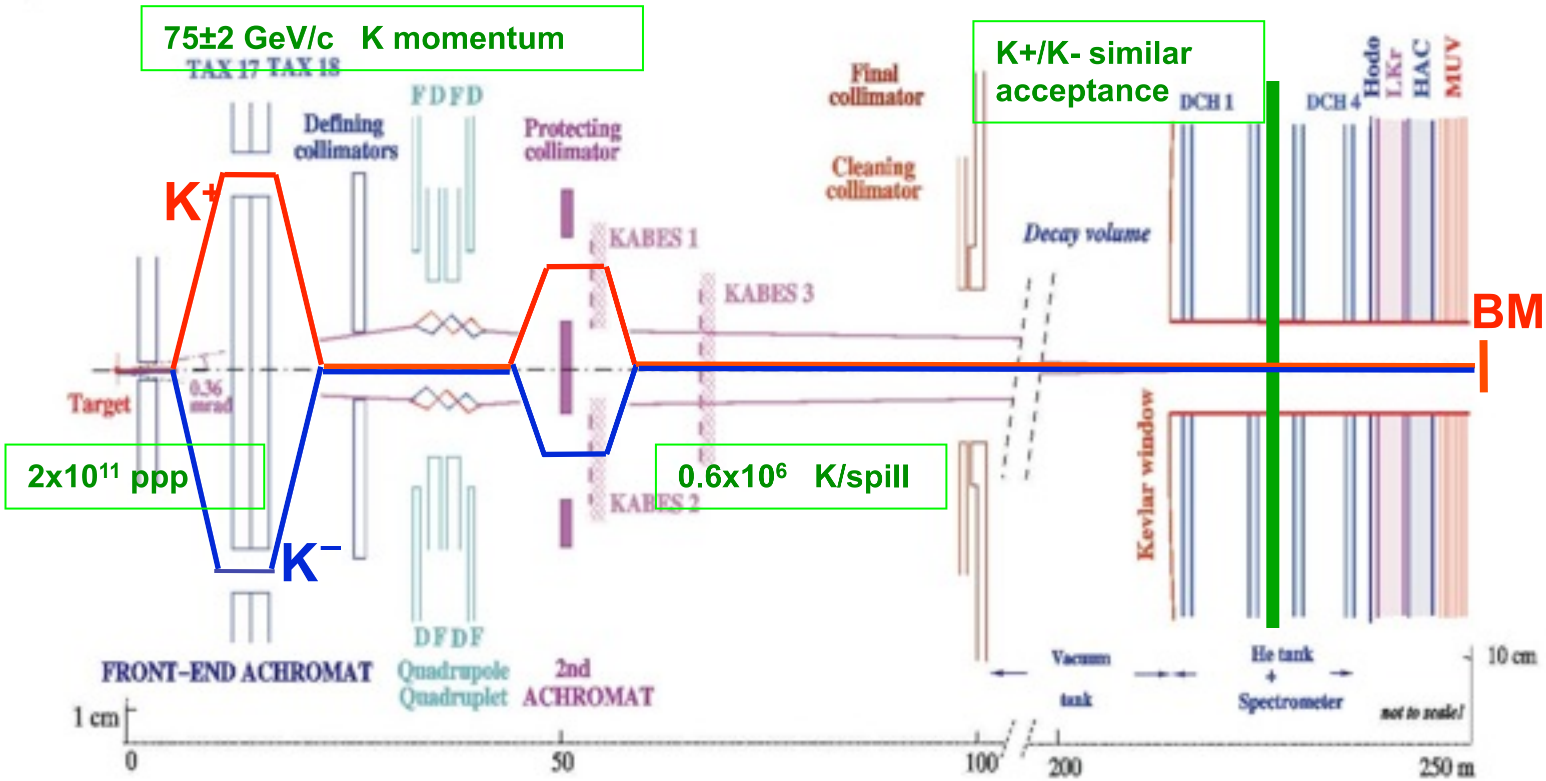
World average

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





Ke2 @ NA62-I (2007-2008)



- Goal: collect ~150000 signal events, below 0.5% precision on RK
- Higher beam momentum wrt NA48/2 runs (and higher momentum kick in the spectrometer magnet)
- Simultaneus K_{e2} and $K_{\mu2}$ collection (both for K+ and K-)
- about 80% K+ due to the fact that K- are affected by a larger halo background

NA62-I: Apparatus

Magnetic spectrometer

-> 4 view / DCH -> high efficiency

-> $\sigma_p/p = 1.0\% + 0.044\% \cdot p$ [GeV/c]

Hodoscope

-> Fast trigger

-> σ_t = 150ps

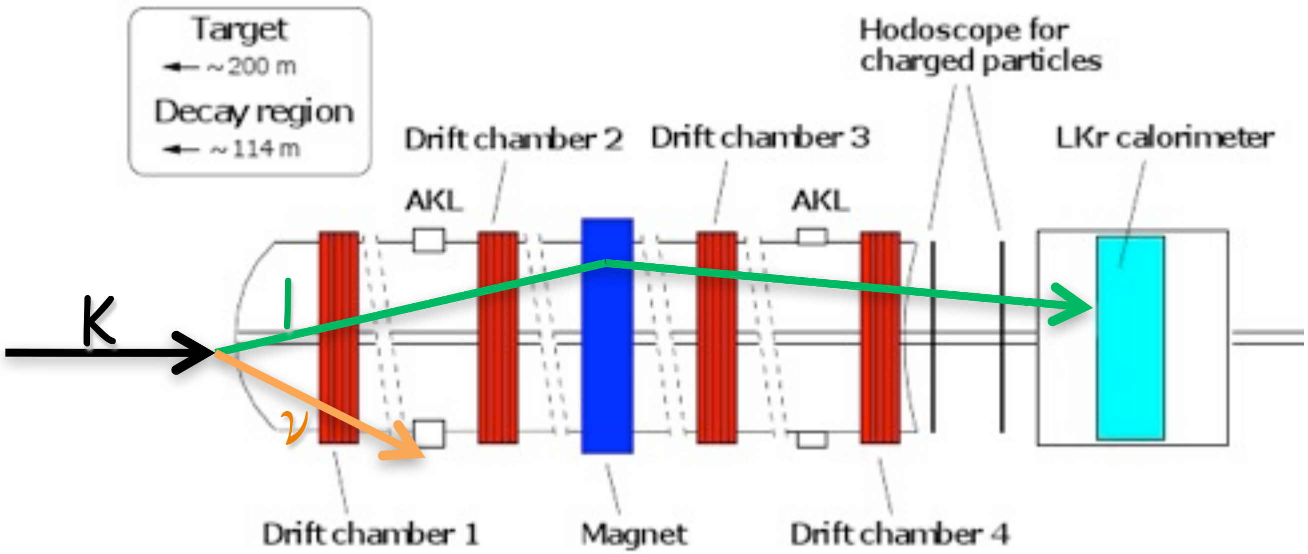
Electromagnetic calorimeter

-> ~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)



Measurement Strategy

K_{e2} and $K_{\mu2}$ candidates collected simultaneously:

-> Many systematic effects reduced,

-> Measurement independent to the Kaon flux.

Particle identification with E/p (LKr and spectrometer)

MC simulations used to limited extent:

-> Acceptance correction (only for geometry),

-> Simulation of "catastrophic" bremsstrahlung by muons.

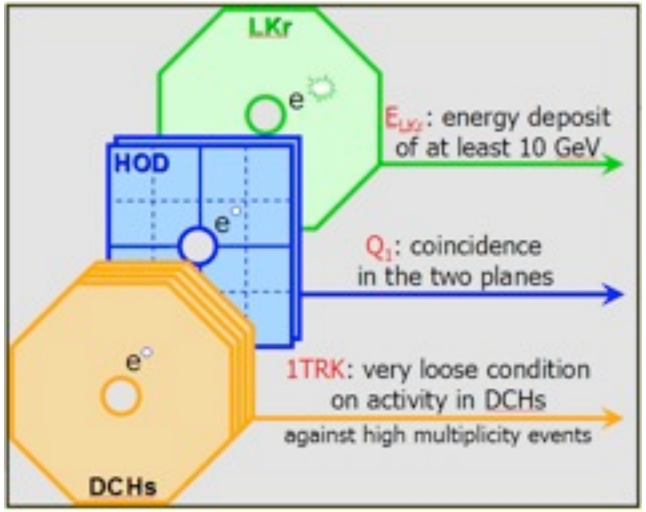
Analysis in 10 track momentum bins.

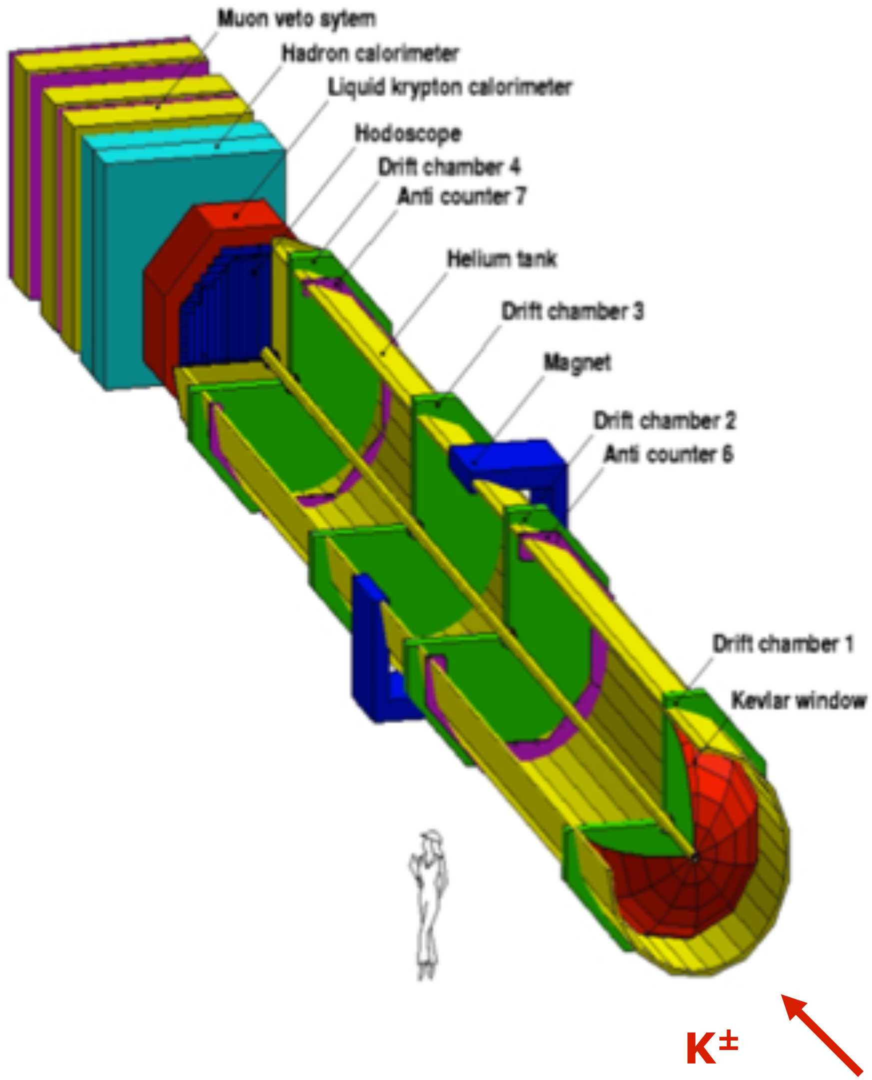
$$R_K = \underbrace{\frac{1}{D}}_{K_{\mu 2}\ \text{downscaling}} \cdot \frac{\overbrace{N(K_{e2})}^{\text{Signal events}} - \underbrace{N_B(K_{e2})}_{}}{N(K_{\mu2}) - N_B(K_{\mu2})} \cdot \frac{\overbrace{f_m}^{\text{Particle ID efficiency}} \cdot A(K_{\mu 2}) \cdot \overbrace{\varepsilon(K_{\mu 2})}^{\text{Trigger Efficiency (>99.9\%)}}}{f_e \cdot A(K_{e2}) \cdot \varepsilon(K_{e2})} \cdot \underbrace{\frac{1}{f_{LKR}}}_{\text{Global LKr readout eff (0.998)}}$$

N_B: Background Events (Main source of systematic errors)

A: Geometrical acceptance

NA62-I: Triggers





Minimum Bias Hardware Trigger:

-> $K_{\mu 2}$ condition: 1TRK Q1

-> K_{e2} condition: 1TRK Q1 ELKr

Software Trigger:

-> P_{DCH} < 90 GeV/c

-> E_{LKr}/P_{DCH} > 0.6 (K_{e2} only)

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 $K_{e2}/K_{\mu2}$ separation at p<25 GeV/c:

-> Missing mass $M^2 = (p_K - p_l)^2$

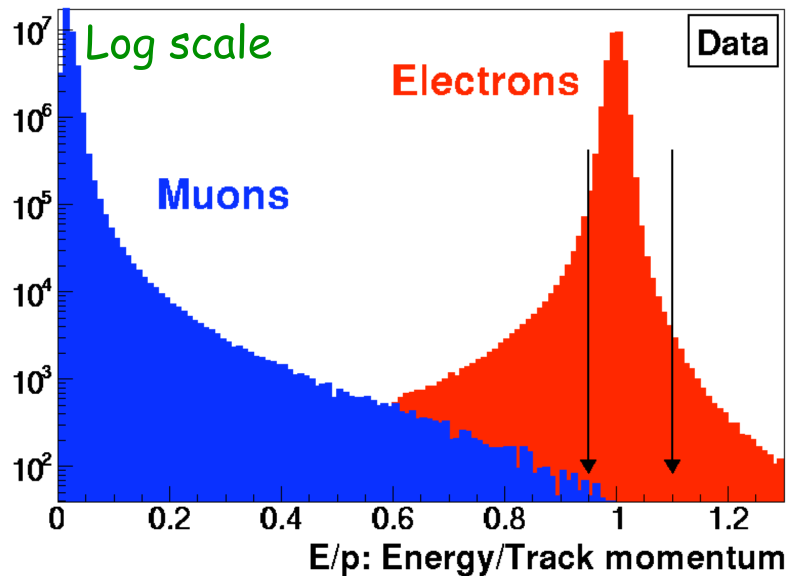
-> P_K : Average measured with $K_{3\pi}$ decays

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

-> E/p = (LKr energy deposit/track momentum)

0.95<E/p<1.10 for electrons,

E/p<0.85 for muons.



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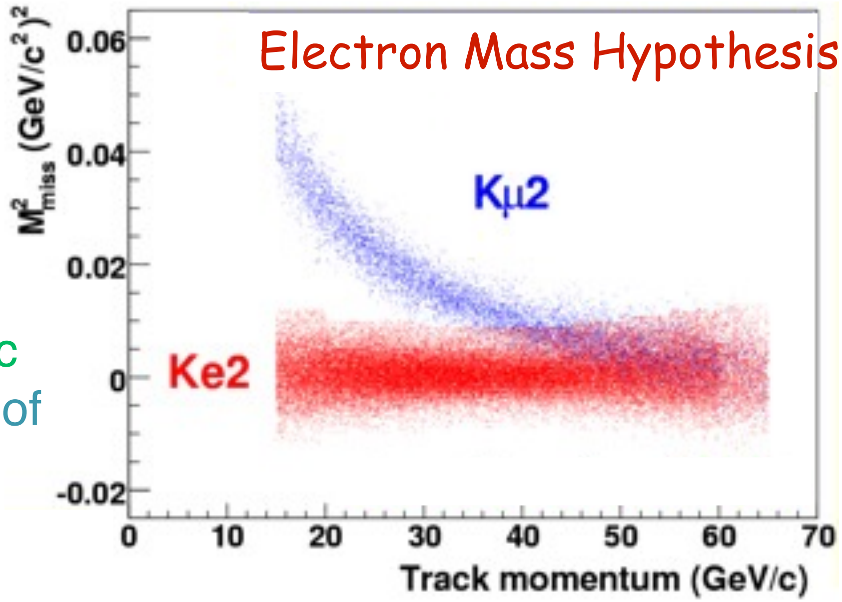

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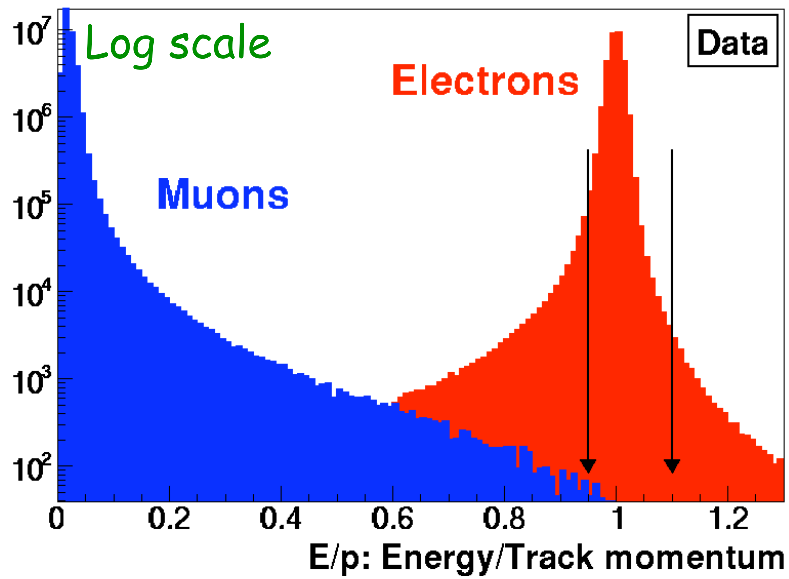

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Backgrounds (Muons)

The main background is due to "catastrophic" muon Bremsstrahlung events ($E/p_{muon}>0.95$) .

The expected probability is $P(\mu\text{->}e)\sim 3x10^{-6}$ (and momentum dependent), that corresponds to:

$$\boxed{P(\mu\text{->}e)/R_K \sim 10\%}$$

This impose a direct P(μ->e) measure to validate theoretical models in a specific E region.

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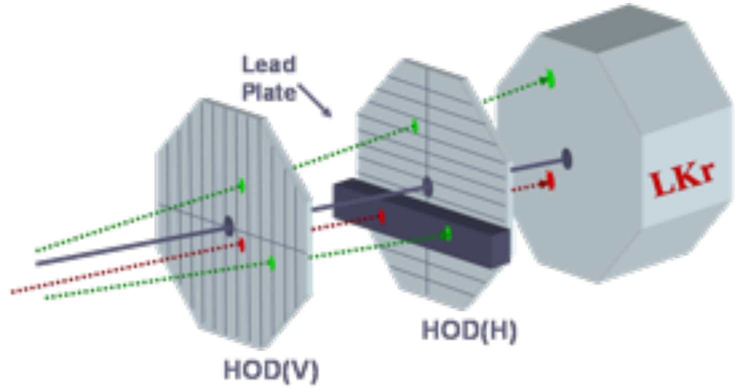

This impose a direct $P(\mu\text{->}e)$ measure to validate theoretical models in a specific E_γ region.

Solution: a $\sim10X_o$ 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.

$(6.28\pm0.17)\%$

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

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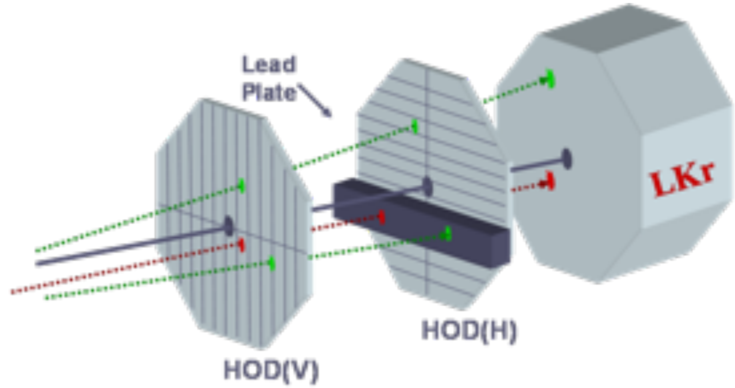

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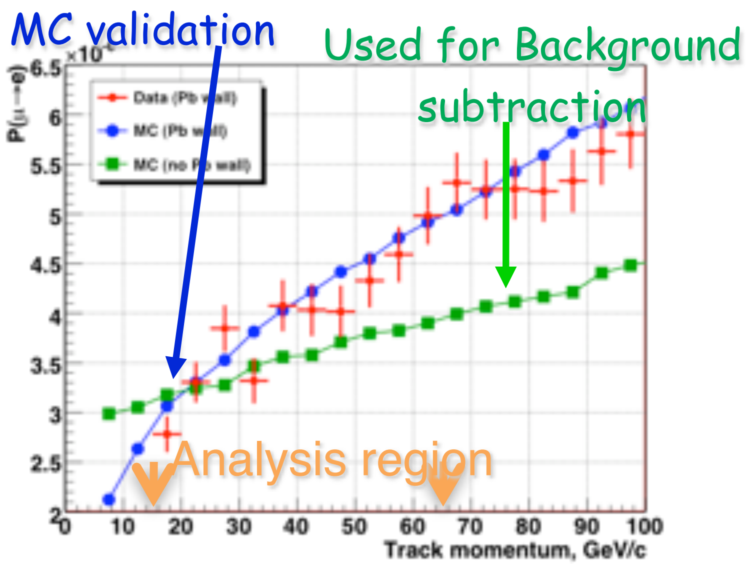

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(6.28±0.17)%

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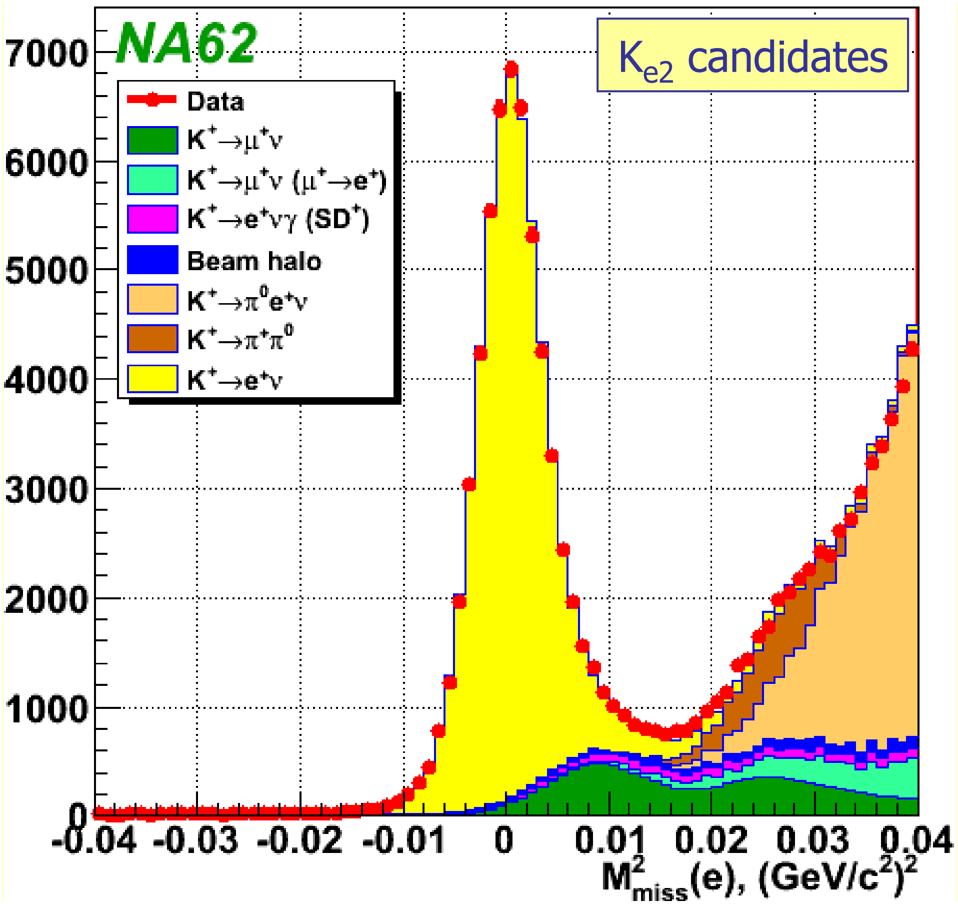
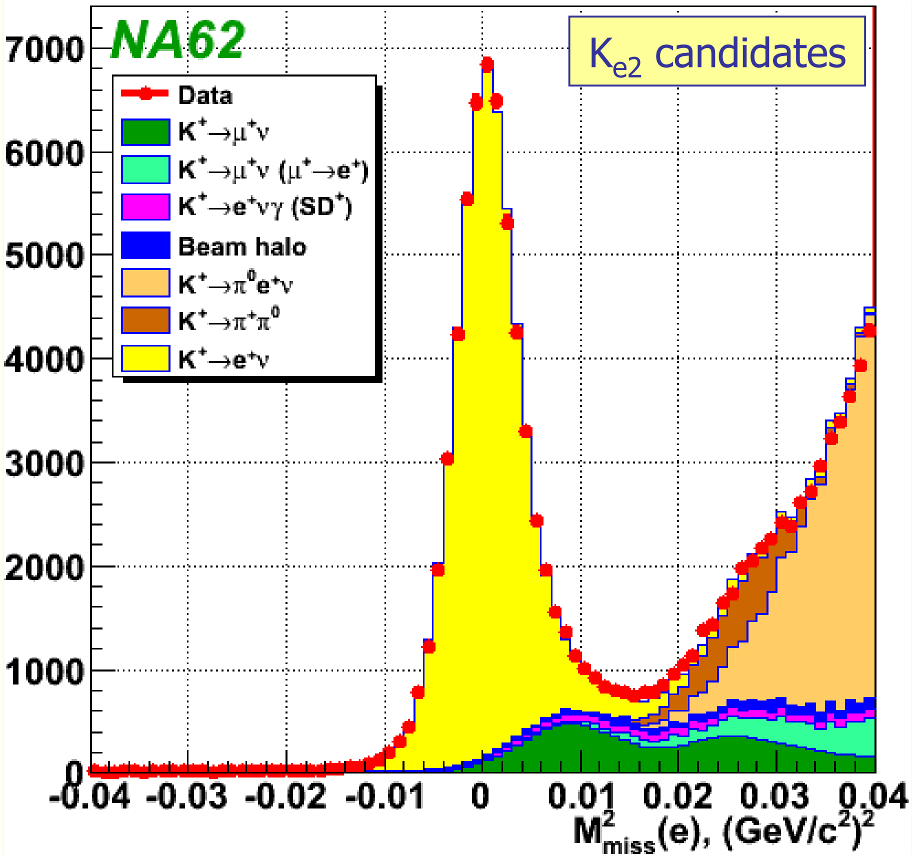
Other backgrounds

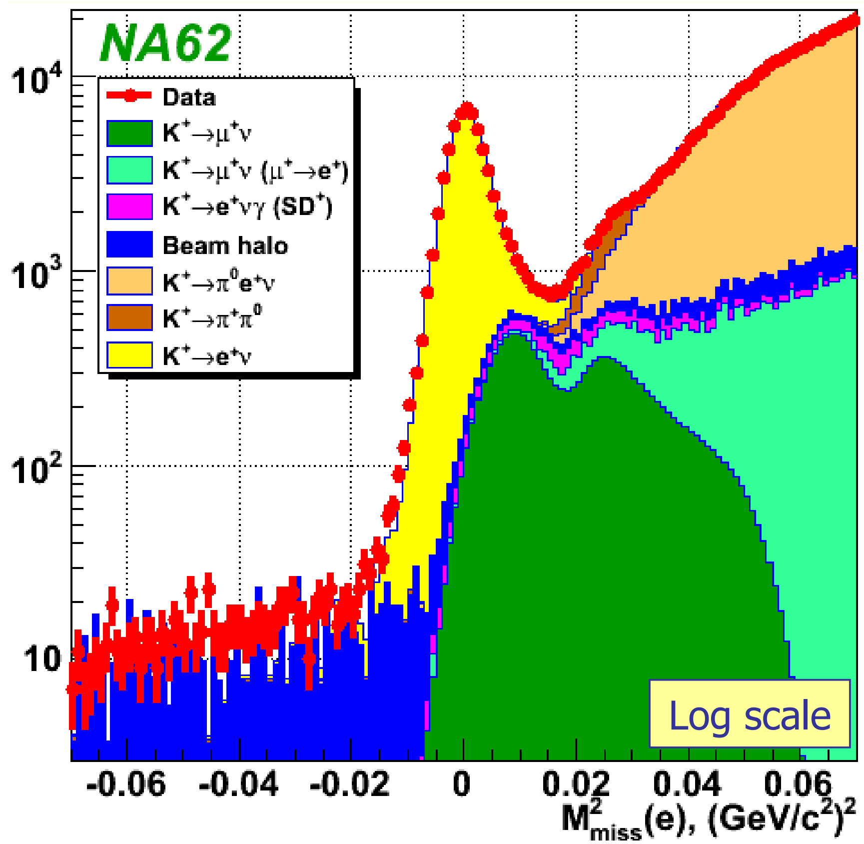
Backgrounds

Source	B/(S+B)
$K_{\mu 2}$	$(6.10 \pm 0.22)\%$
$K_{\mu 2}$ $(\mu \rightarrow e)$	$(0.27 \pm 0.04)\%$
$K_{e2\gamma}$ (SD^{+})	$(1.15 \pm 0.17)\%$
Beam halo	$(1.14 \pm 0.06)\%$
$K_{e3(D)}$	$(0.06 \pm 0.01)\%$
$K_{2\pi(D)}$	$(0.06 \pm 0.01)\%$
Total	$(8.78 \pm 0.29)\%$



K_{e2}: 40% of data set



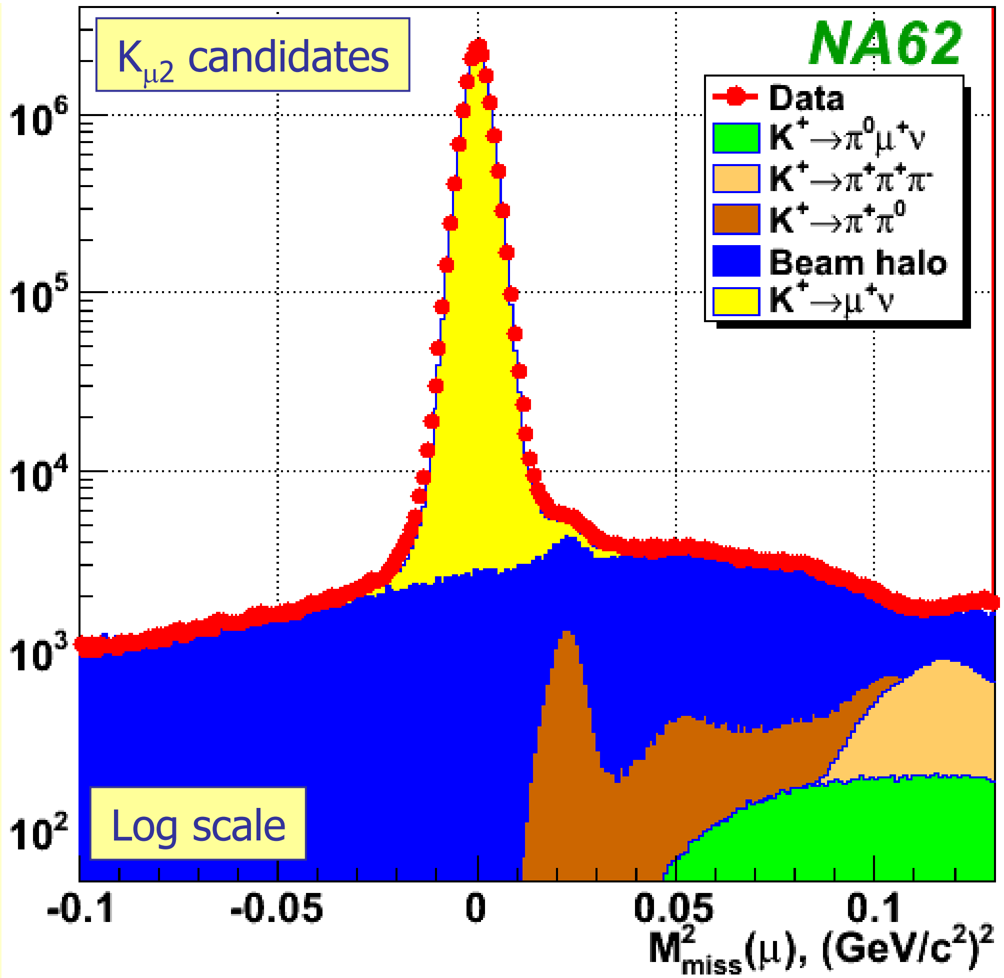


NA62 estimate total K_{e2} events: ~130k K+ & ~20k K-.

In NA62 proposal the goal was fixed at ~150k (CERN-SPSC-2006-033).

The present statistic gives 59963 K_{e2} candidates events and B/(S+B)=(8.8±0.3)%.

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



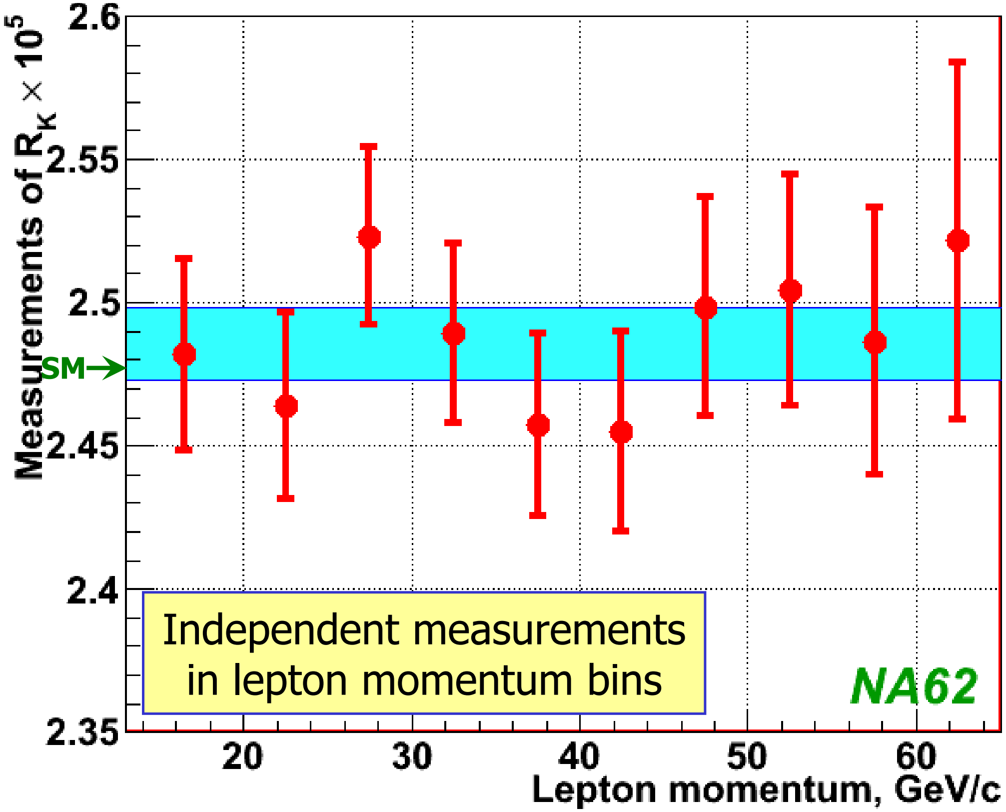
The $K_{\mu 2}$ is downscaled by a factor of 150

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

18,030 M are the $K_{\mu 2}$ candidates with low background B/(S+B) =0.38%

R_K Preliminary Result (40% data set)

$$R_K = (2.486 \pm 0.011_{stat} \pm 0.007_{syst}) \times 10^{-5}$$
$$= (2.486 \pm 0.013) \times 10^{-5}$$



Uncertainties

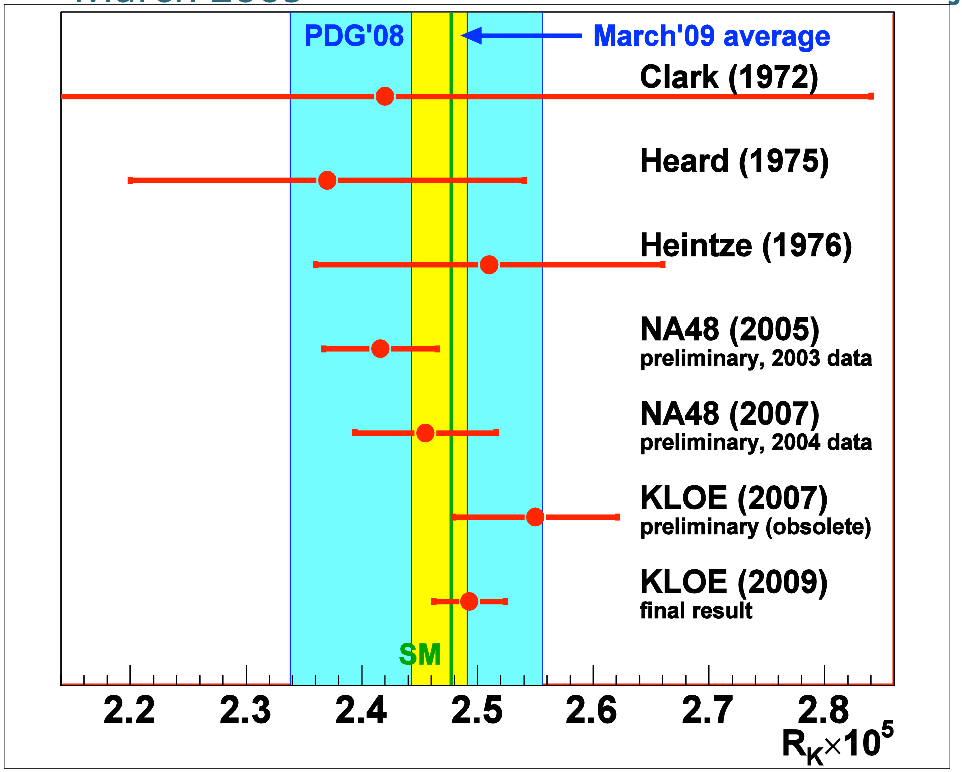
Source	$\delta R_K \times 10^5$
Statistical	0.011
$K_{\mu 2}$	0.005
BR($K_{e2\gamma}$ SD$^+$)	0.004
Beam halo	0.001
Acceptance corr.	0.002
DCH alignment	0.001
Positron ID	0.001
1-track trigger	0.002
Total	0.013

(0.52% precision)

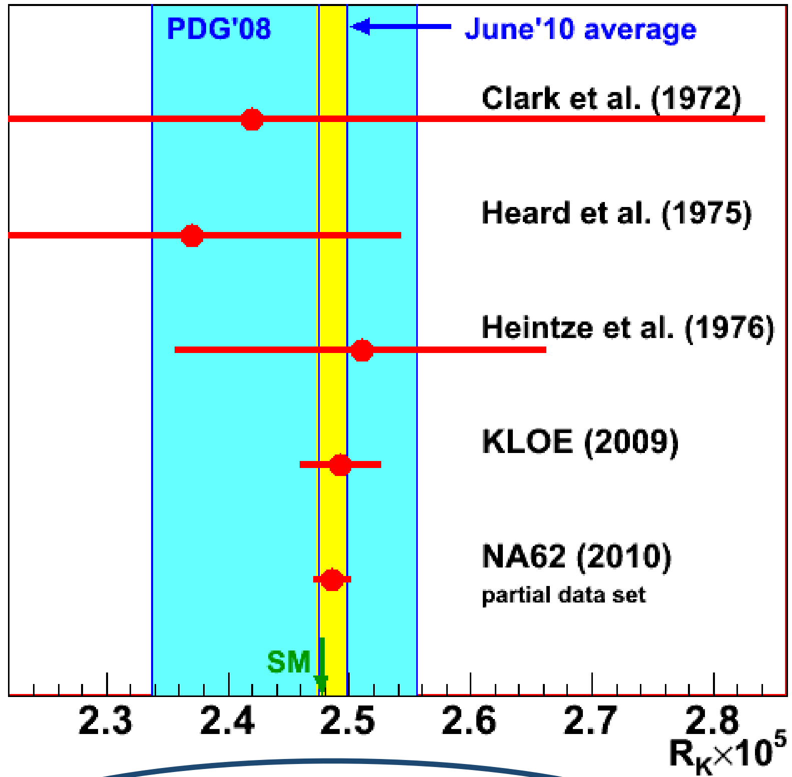
The whole sample will decrease the statistical uncertainty down to ~0.3% and a total uncertainty of 0.4-0.5%

World Comparison

March 2009



June 2010



NA62 Preliminary

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

(precision 0.56%)

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

(precision 0.97%)

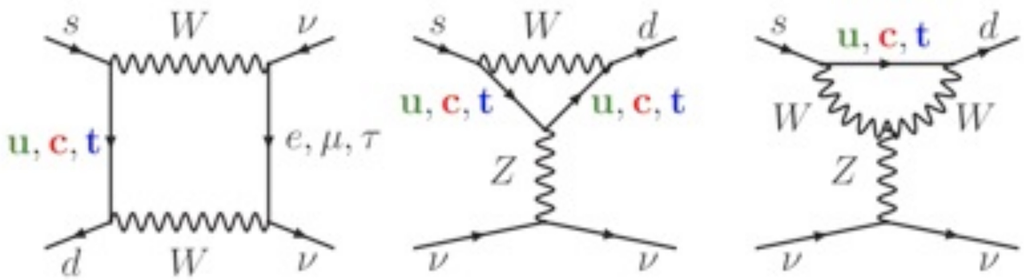
NA48/2 preliminary results excluded from new average: they are supersided by NA62

NA62-II

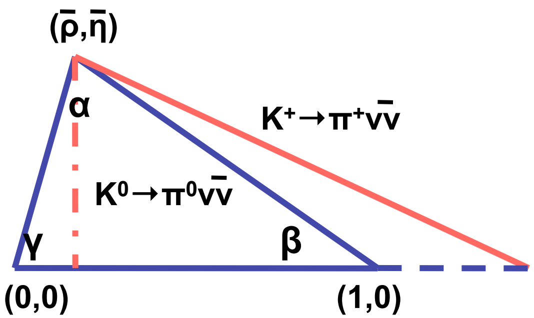
$K^+ \to \pi^+ \nu\bar{\nu}$ experiment

$K^+ \to \pi^+ \nu\bar{\nu}$: motivation (I)

- FCNC process forbidden at tree level
- Only one loop contributions: Boxes and Penguins



$$BR(K^+ \to \pi^+ \nu\nu) = (8.5 \pm 0.7) \times 10^{-11}$$ **8% error**



- Cleanest way to extract $\mathbf{V_{td}}$ and to give independent determination of the unitarity triangle
- Complementarity with B physics
- Very sensitive to New Physics

$K^+ \to \pi^+ \nu\bar{\nu}$: motivation (II)

1) Short distance contributions (Wilson coefficients i.e. perturbative QCD) are dominant (hard GIM mechanism): $A_q \sim (m_q)^2/(m_W)^2 \, \mathbf{V_{qs}V_{qd}}$

top quark is dominant, smaller contribution from charm negligible from up

2) The hadronic matrix element (LD) uncertainness benefits from the Isospin symmetry and well measured semileptonic $K^+ \to \pi^0 e^+ \nu_e$ decays:

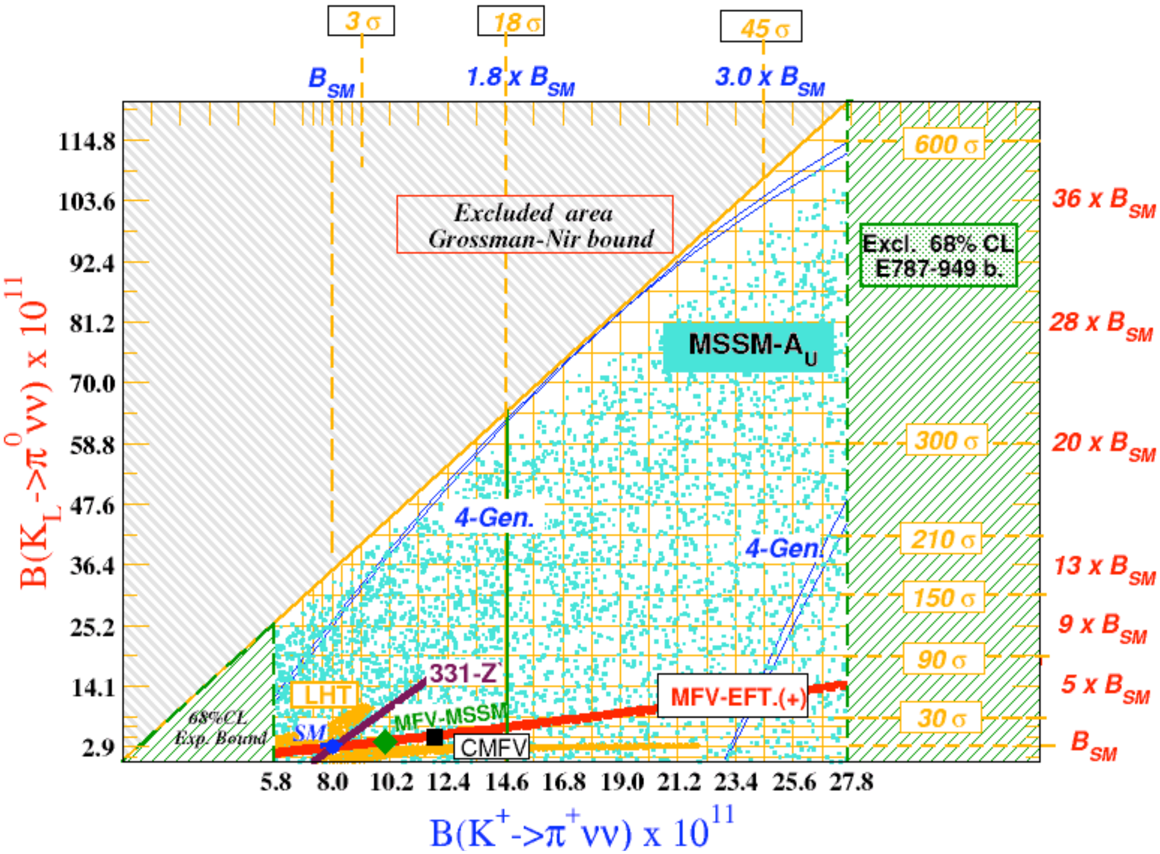
$$\left| \frac{\langle \pi^+ \nu\bar{\nu} | H_w | K^+ \rangle}{\langle \pi^0 e^+ \nu_e | H_w | K^+ \rangle} \right|^2 = \left| \frac{\langle \pi^+ | H_w | K^+ \rangle}{\langle \pi^0 | H_w | K^+ \rangle} \right|^2 = 2r_+$$

$$BR(K^+ \to \pi^+ \nu\bar{\nu}) = 6 r_{K^+} BR(K^+ \to \pi^0 e^+ \nu) \frac{|G_l|^2}{G_F^2 |V_{us}|^2}$$

$$G_l = \frac{\alpha G_F}{2\pi \sin\theta_W^2} (V_{ts}^* V_{td} X(x_t) + V_{cs}^* V_{cd} X_{NL}^l)$$

Effective coupling constant

$K^+ \to \pi^+ \nu\bar{\nu}$: motivation (III)



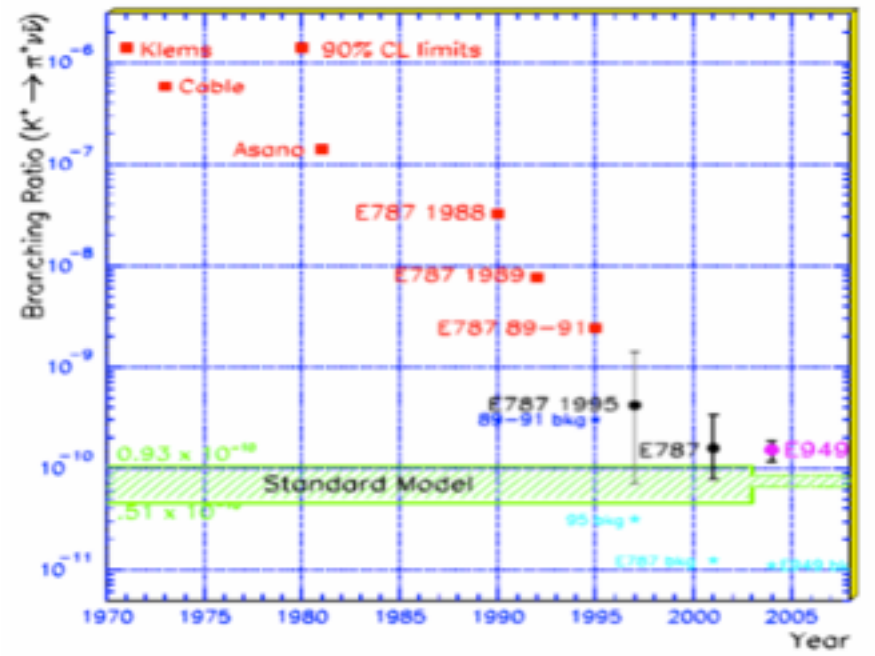
BR($K^+ \to \pi^+ \nu\nu$) $\times 10^{10}$: selected models	
SM	0.82±0.08
MFV (hep-ph/0310208)	1.91
EEWP (NPB697 (2004) 133, hep-ph/0402112)	0.75±0.21
EDSQ (PRD70 (2004) 093003, hep-ph/0407021)	up to 1.5
MSSM (NPB713 (2005) 103, hep-ph/0408142)	up to 4.0

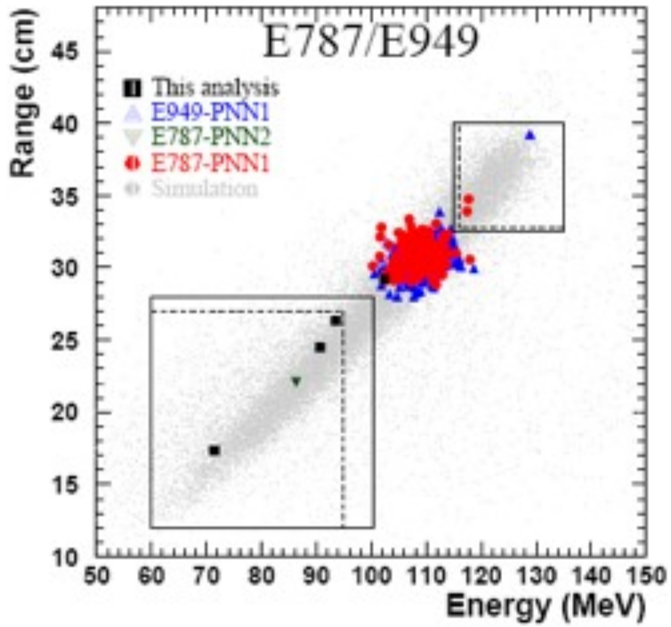
Large variation in prediction for new physics!

And experimental status

$BR(K^+ \rightarrow \pi^+\nu\nu)_{exp} = (1.73^{+1.15}_{-1.05}) \times 10^{-10}$

based on 7 candidates at BNL E787+E949





Probability that all 7 events are due to background: 10^{-3}

first experimental observation of $K^+ \rightarrow \pi^+\nu\nu$

they have shown that all physics background can be under control at 10^{-11} level !

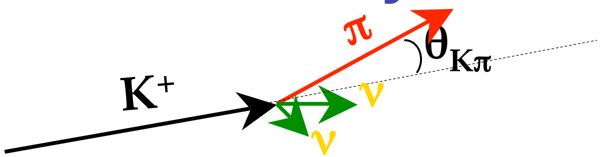
NA62 guidance principles

Our goal is to collect O(100) $K^+\rightarrow\pi^+\nu\nu$ events

N(K decays) ~10^{13}
Acceptance = 10%

- Kaon decay in flight technique;
- 400 GeV proton beam from SPS;
- Unseparated high energy K^+ beam (P_K=75 GeV/c);

Kinematical rejection



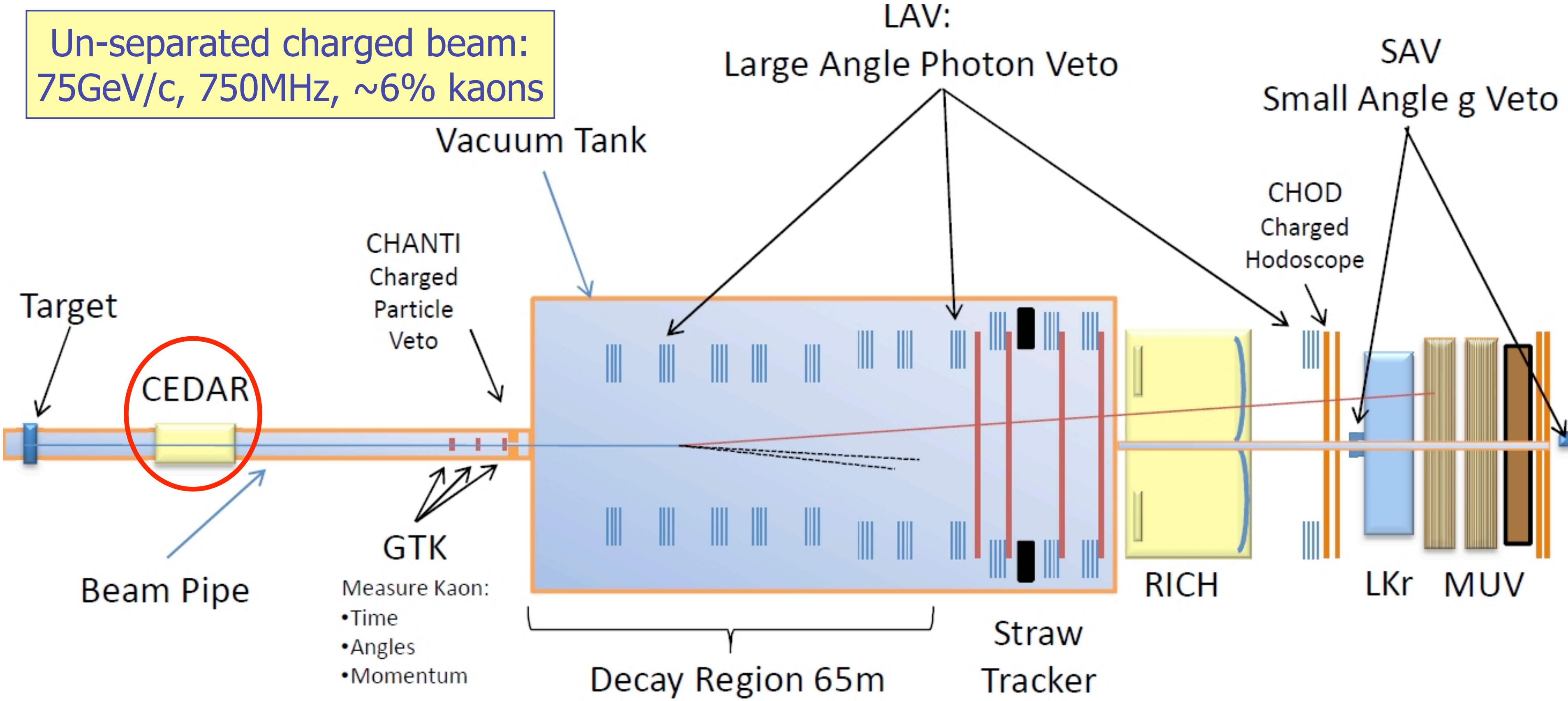
Single track signature: $m^2_{miss}=(P_K-P_\pi)^2$

- Kaon momentum: beam tracker;
- Pion momentum: spectrometer;

Particle ID and veto
in addition to kinematical rejection

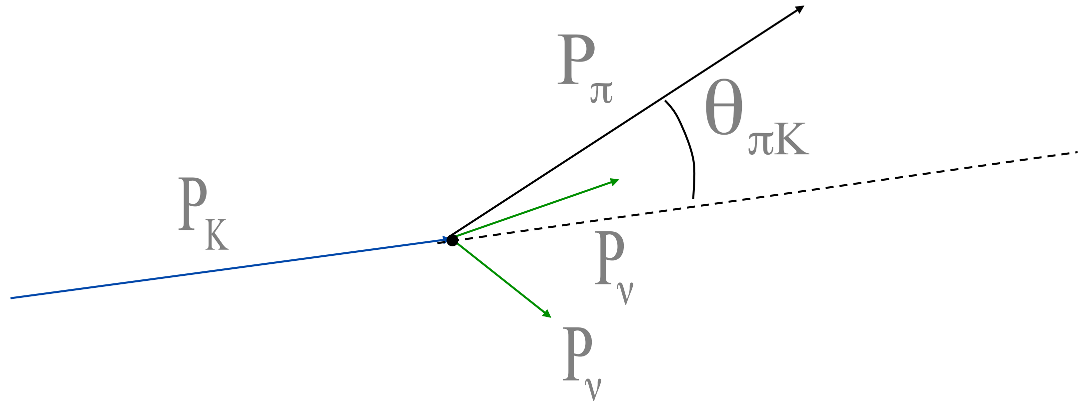
- Charged track veto: spectrometer;
- Photon veto: calorimeters;
- Beam kaon identification: CEDAR;
- $\pi/\mu/e$ separation: RICH;

$K^+ \to \pi^+ \nu \bar{\nu}$ @ NA62-II



- Decay in flight technique
- Goal: **O(100) events with S/B ~10**

Kinematic reconstruction



$$m_X^2 = m_K^2\left(1 - \frac{|\vec{P}_\pi|}{|\vec{P}_K|}\right) + m_\pi^2\left(1 - \frac{|\vec{P}_K|}{|\vec{P}_\pi|}\right) - |\vec{P}_K||\vec{P}_\pi|\theta_{\pi K}^2$$

Requirements:

- low mult. scattering

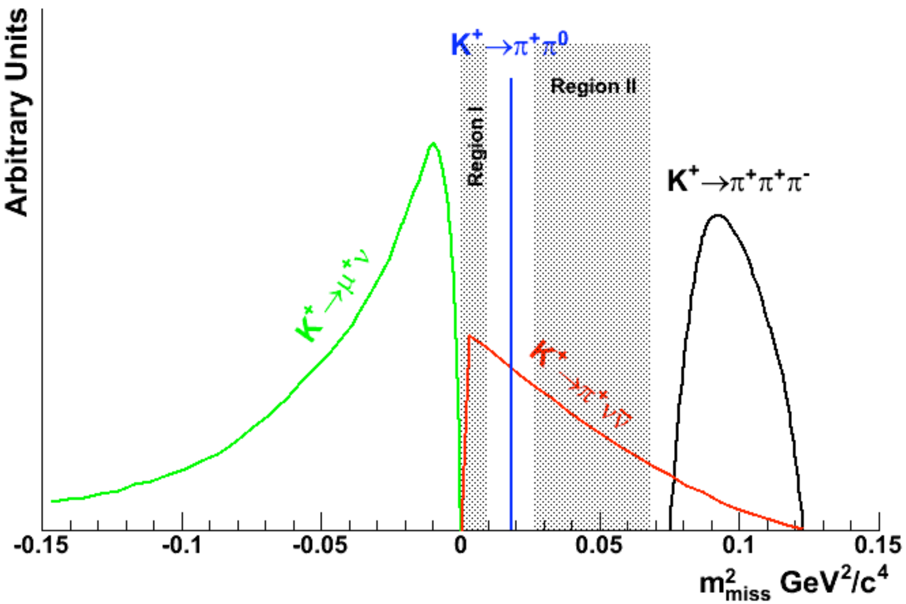
$\longrightarrow$ low mass tracker operating in vacuum

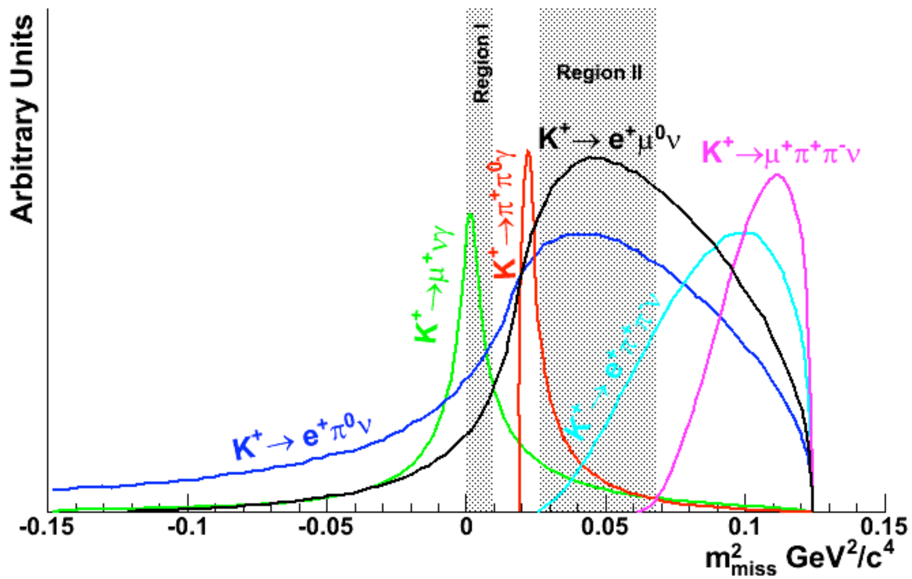
- good space resolution (~100 μm)

Detectors:

- GigaTracker
- Straw Chamber Spectrometer

Two allowed regions...



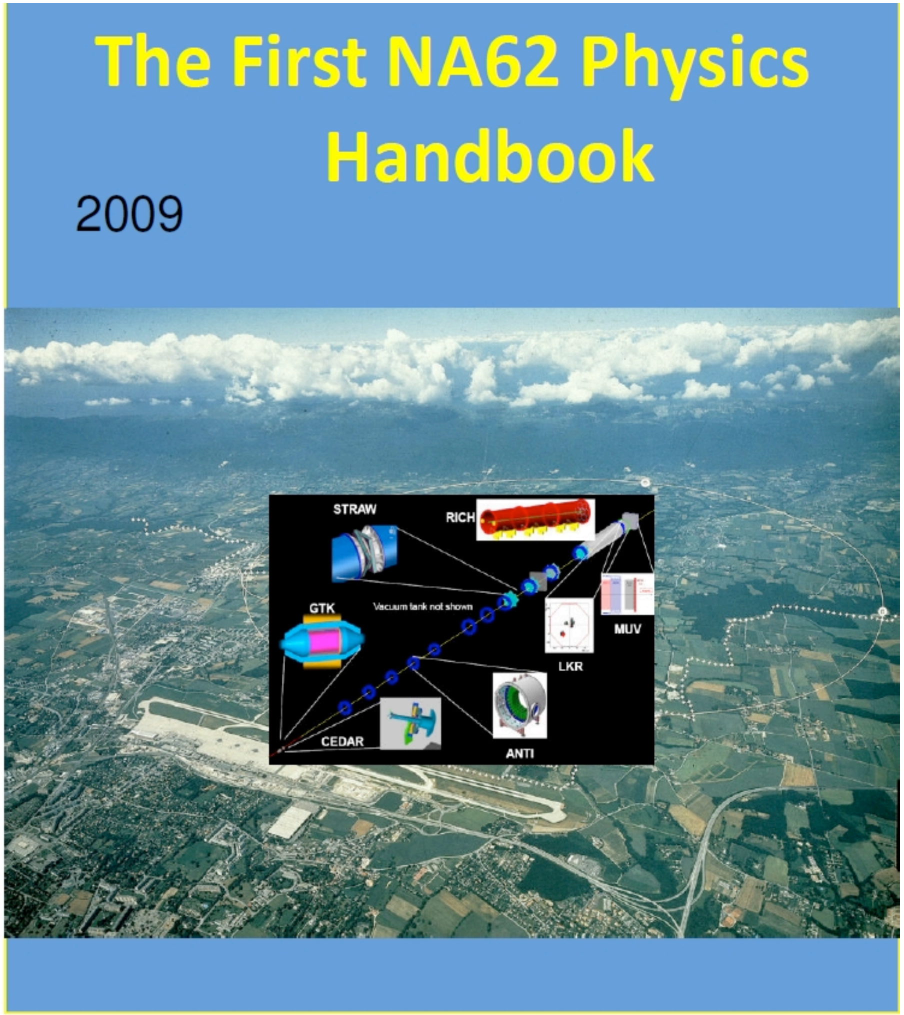


92% of background

We can define 2 signal regions

8% of background

Span across the signal region
We need vetos and PID



Other physics goals

- Lepton Flavour Violation: measurement of R_K to ~0.1% precision.
- LFV in forbidden decays: searches for $K^+ \to \pi^- l^+ l^+$, $K^+ \to \pi^+ l_1 l_2$.
- Heavy neutrinos (~100MeV), light sgoldstinos ($K^+ \to \pi^+ S$, $K^+ \to \pi^+ \pi^0 P$).
- Hadronic K decays and final-state $\pi\pi$ interactions in $K_{3\pi}$ and K_{e4} decays.
- ChPT tests with rare kaon/pion decays.

1st Physics Handbook workshop:
CERN, 10-11 December 2009
Handbook in preparation

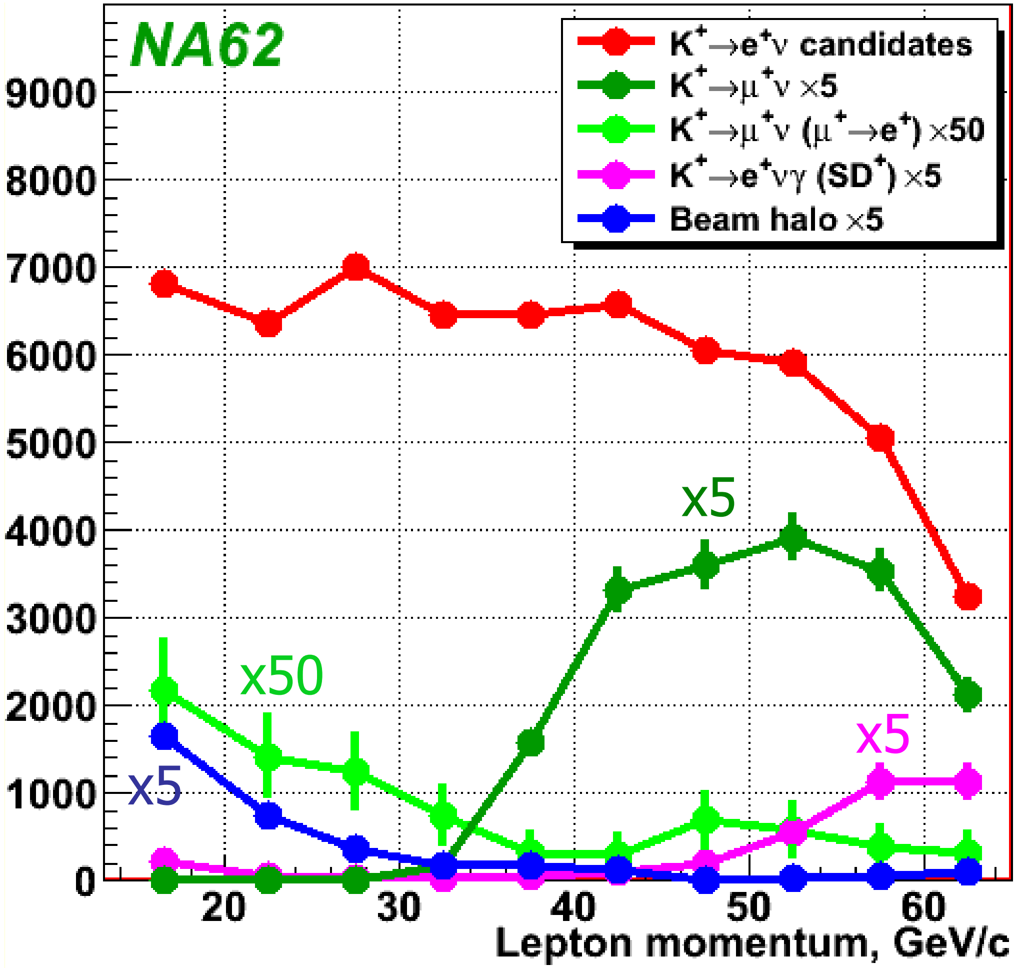
http://indico.cern.ch/conferenceDisplay.py?confId=65927

Conclusions

- In the flavour sector the new physics could appear both in MFV and in NON-MFV processes
- The R_K precise measurement in the Ke2 decay is a very powerful tool to constraints new physics parameters in case of presence of LFV mediators
- The NA62-I will reach a sensitivity of 0.4% exploiting the NA48/2 detectors in a dedicated run
- The 0(100) events measurement of the $K^+ \to \pi^+ \nu\nu$ decay could be a good opportunity to found NP and to distinguish among NP models
- The NA62-2 is a challenging experiments aiming at O(100) events with S/B=10
- The detectors R&D will be completed this year. <u>The data taking should start in the 2011-12</u>.

Spares

Backgrounds Summary

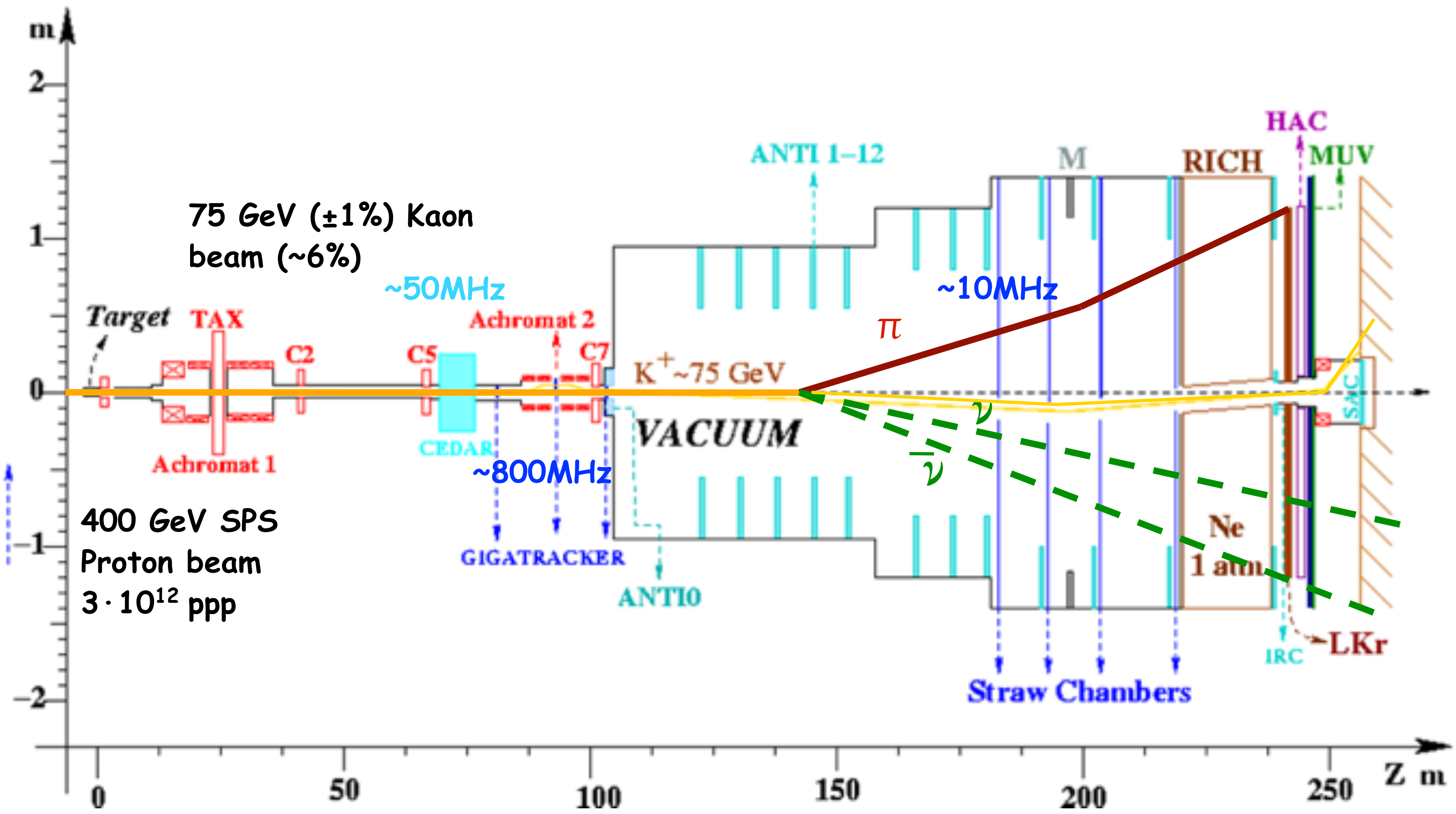


Backgrounds

Source	B/(S+B)
$K_{\mu 2}$	(6.10±0.22)%
$K_{\mu 2}$ ($\mu \to e$)	(0.27±0.04)%
$K_{e2\gamma}$ (SD^+)	(1.15±0.17)%
Beam halo	(1.14±0.06)%
$K_{e3(D)}$	(0.06±0.01)%
$K_{2\pi(D)}$	(0.06±0.01)%
Total	(8.78±0.29)%

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

$K^+ \to \pi^+ \nu \bar{\nu}$ @ NA62-II

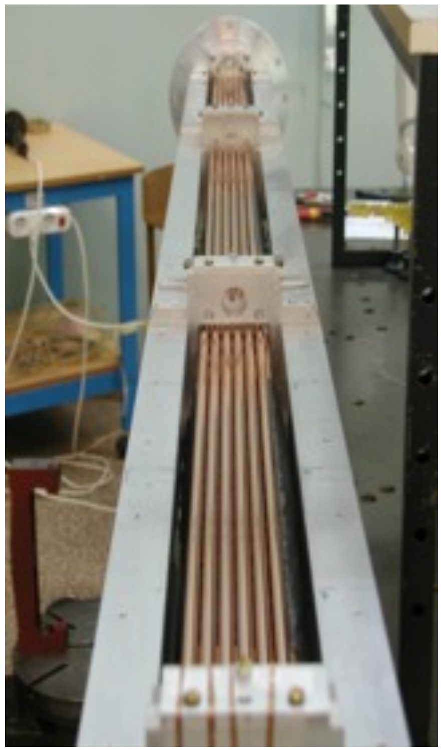


NA62-II: Straws

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



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

Particle Identification and photon VETO

Rejection factor needed: 10^{12}

Table of rejection factors for two body decays

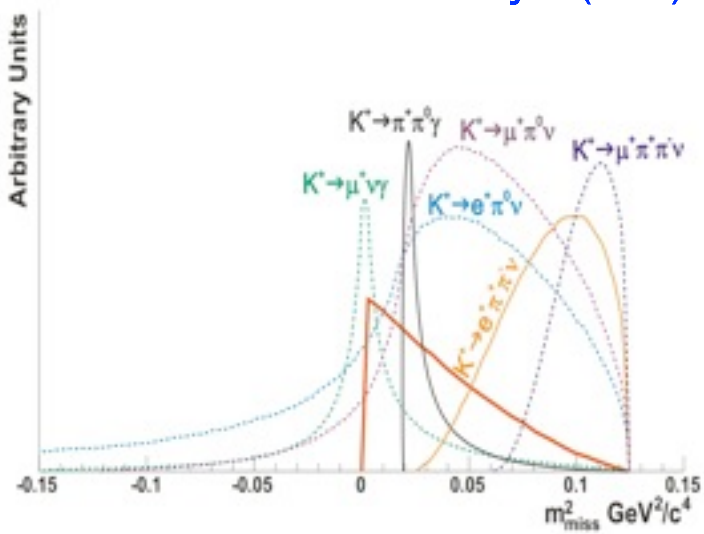
decay	R.F.
$K^+ \to \pi^+\pi^0$	10^4
$K^+ \to \mu^+\nu$	10^5

high efficiency detectors:

Photon veto: for **$K^+ \to \pi^+\pi^0$ supp**.

RICH and MUON VETO
for muon suppression

Not constrained decays (8%)



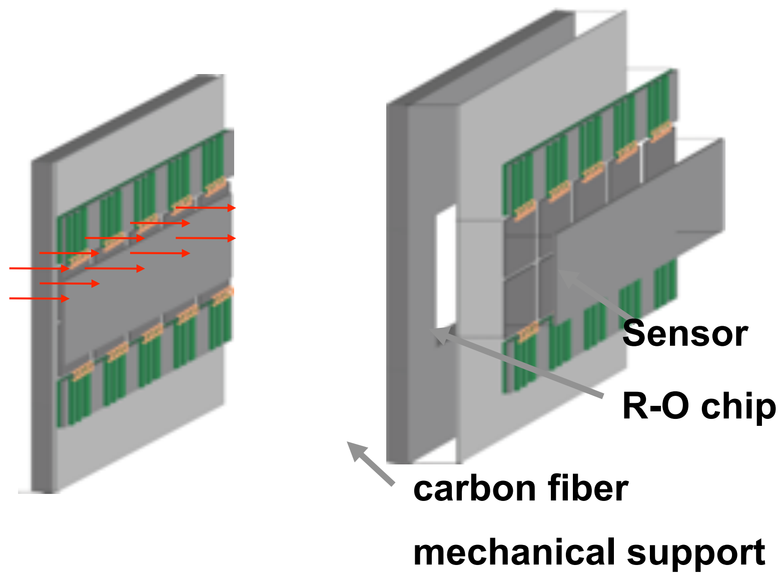
Gigatracker

Three tracking stations to provide a precise measurement of K^+ beam (momentum, direction and time)

main features
- low mass (multiple scattering),
- operating in vacuum
- severe environment: 1.5MHz/mm², 800 MHz total rate

Solution: silicon pixel stations
- 60x27 mm² area (beam profile)
- 300x300 μm² pixel size
- 200 μm thick sensor (15000 e^- for a MIP)
- 10 R-O chips 100 μm thick cmos
- 130 MHz rate/chip (max)
- 140 nm technology
- 0.5 X/X_0 /station material budget
- 200 ps /station time resolution
- ~14 μrad track resolution
- ~0.15 GeV/c momentum resolution

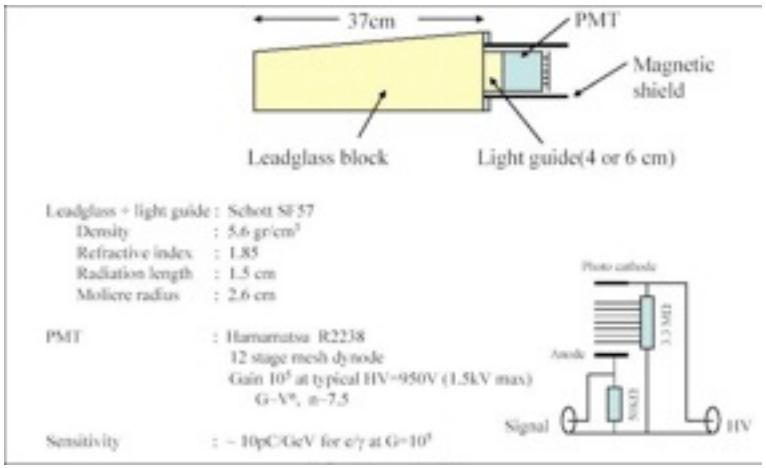
exploded view



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 MeV



- 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
- Module 1 is ready for test beam in august

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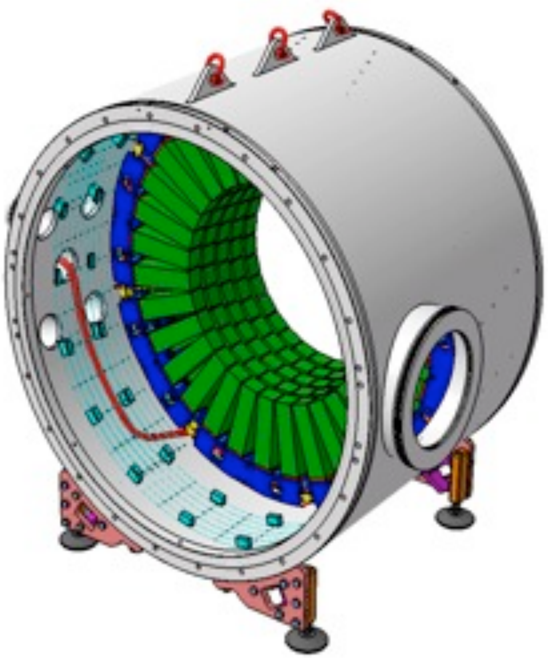

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- Phototubes operating in vacuum
- 13 rings along the decay region

- Several test beam to chose the technology
- Module 1 is ready for test beam in august

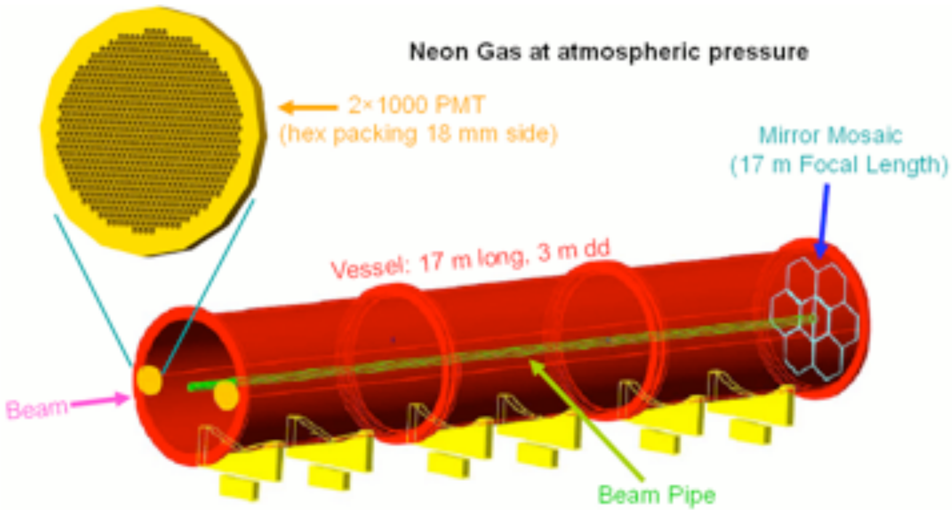
NA62-II: Rich

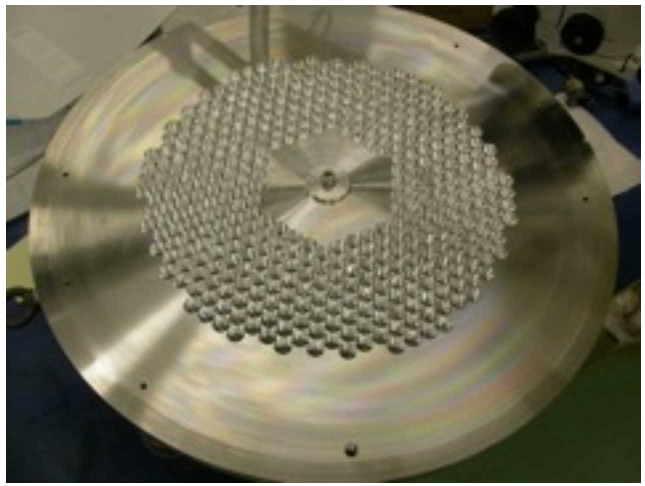
Requests:

- 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

- 400PMTs prototype with new readout electronics tested in May 2009





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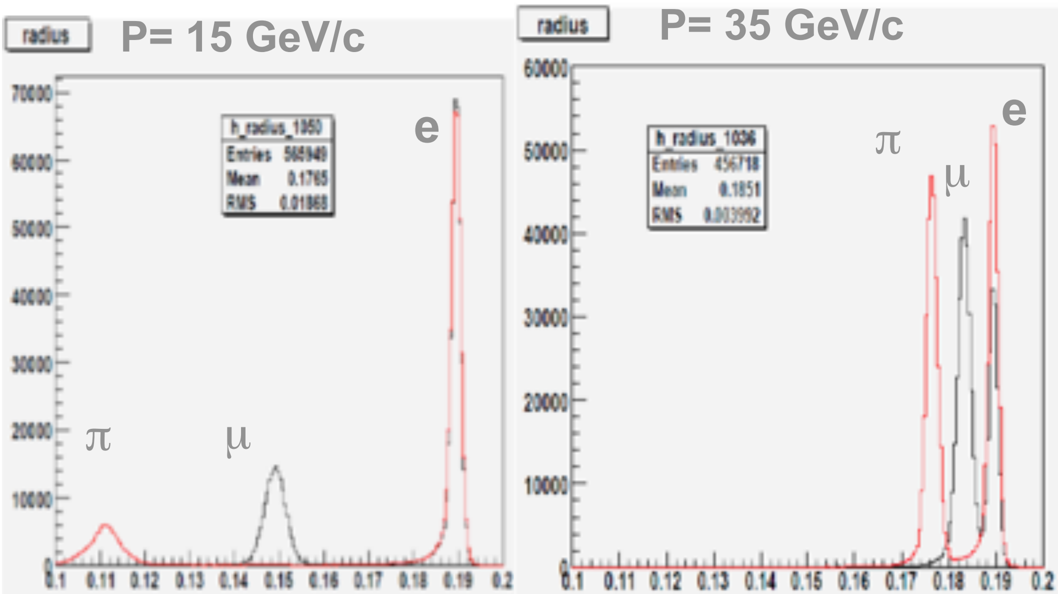
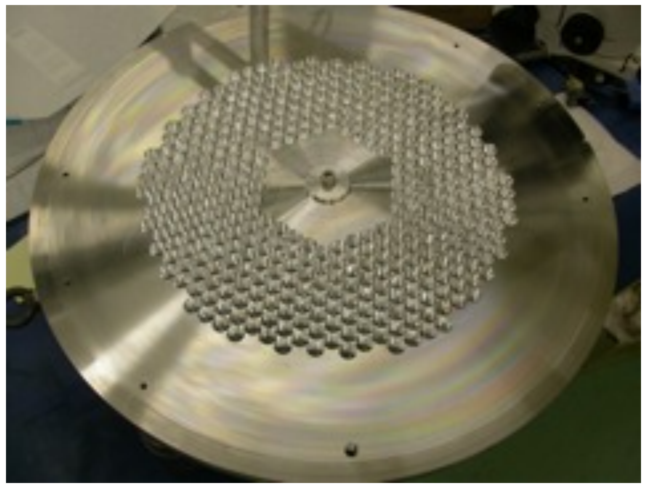
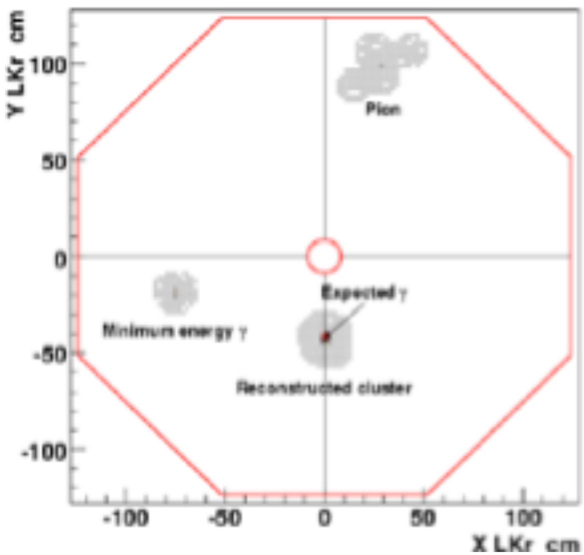




NA62-II: LKr



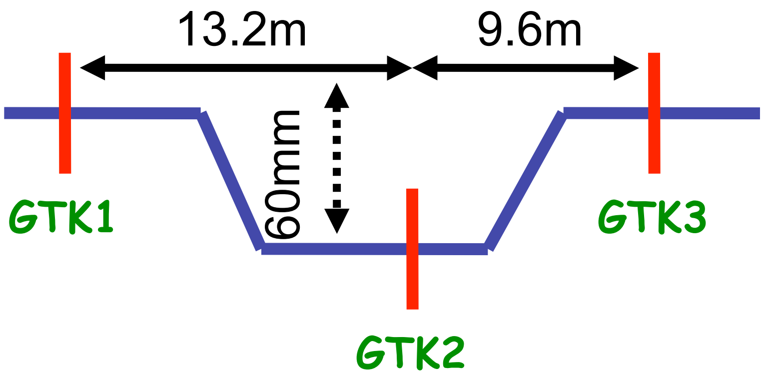
Requests:

- 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: Gigatracker

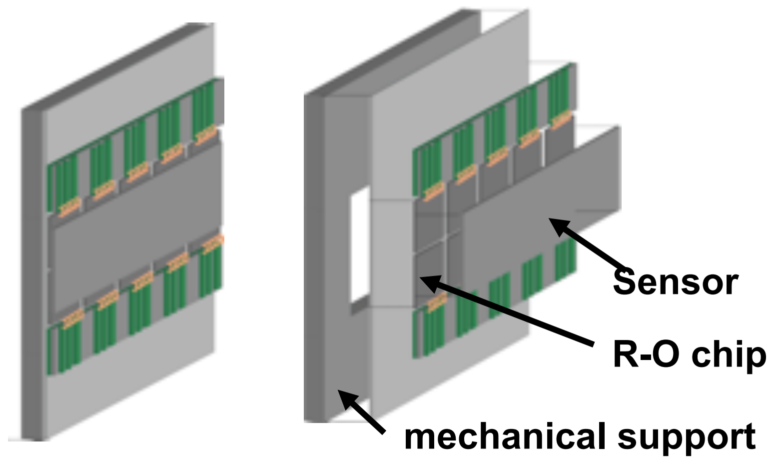


- Very thin silicon sensor and readout chip (200+100 μm ~ $0.5X_0$)
- On site bump bonded readout chip 0.13 μm CMOS tech
- 60x27 mm^2 per station
- 300μmx300μm pixels

- Readout chip and sensor Prototypes under construction
- Test beam in 2009

Requests:

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



Theoretical estimations

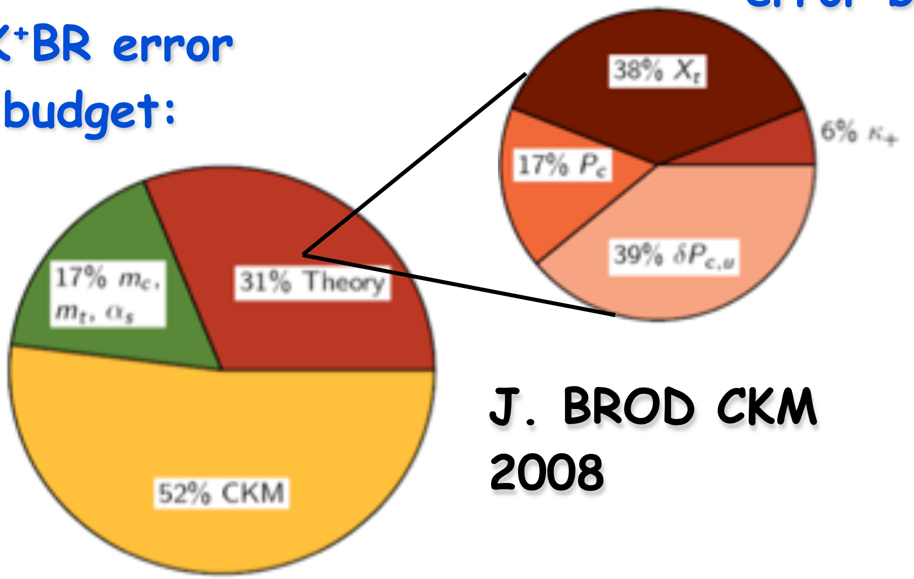
$BR(K^+ \to \pi^+ \nu\nu) = (8.5 \pm 0.7) \times 10^{-11}$ **8% error**

$BR(K_L \to \pi^0 \nu\nu) = (2.8 \pm 0.4) \times 10^{-11}$ 14% error

$m_c(m_c) = 1286 \pm 13$ MeV

K$^+$BR error budget:

K$^+$ theory error budget:



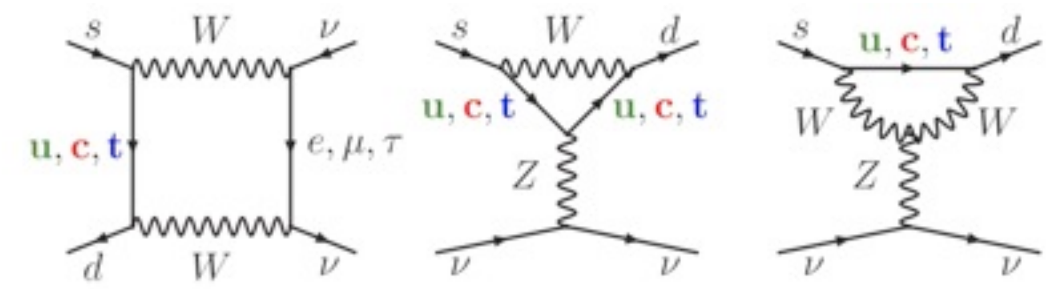
J. BROD CKM 2008

dominated by CKM elements

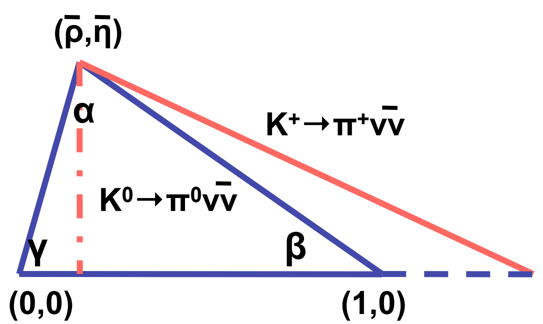
theory error can still be reduced

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

- FCNC process forbidden at tree level
- Only one loop contributions: Boxes and Penguins
- Top contribution is dominant: small coupling in CKM between t and d,s $\to \lambda^5$
  - Clean theoretical environment: small contribution by hadronic matrix element and long distance terms



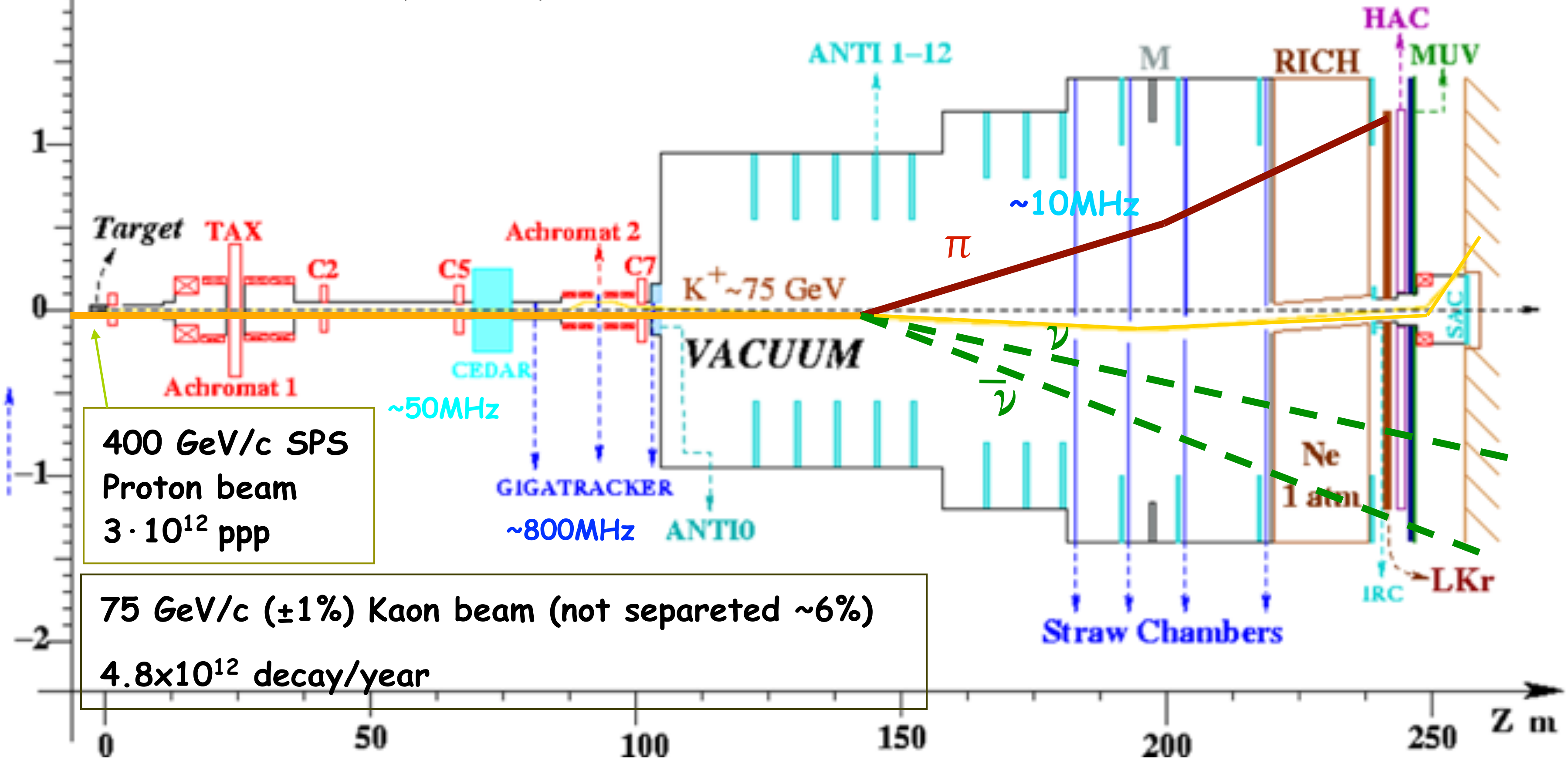
	Short distance	Irreducible error	BR_{SM}
$K_L \to \pi^0 \nu\nu$	>99%	1%	$3 \cdot 10^{-11}$
$K^+ \to \pi^+ \nu\nu$	88%	<3%	$8 \cdot 10^{-11}$
$K_L \to \pi^0 e^+ e^-$	38%	15%	$3.5 \cdot 10^{-11}$
$K_L \to \pi^0 \mu^+ \mu^-$	28%	30%	$1.5 \cdot 10^{-11}$



- Cleanest way to extract **Vtd** and to give independent determination of the unitarity triangle
- Complementarity with B physics
- Very sensitive to New Physics

Detector layout

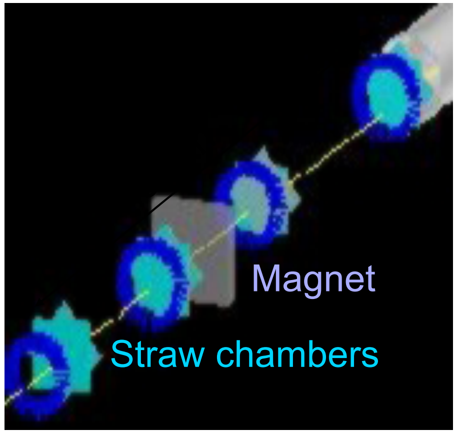
1. Kinematic rejection: GTracker, Straw Chambers Spectrometer
2. Precise Timing: Cedar, GTracker, Rich
3. Photon Vetos: ANTI 1-12,LKr cal.,SAC,IRC
4. Pid: Rich, Cedar, muon Veto

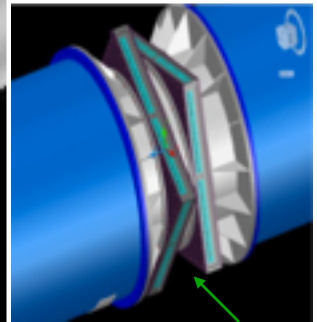


Straw chamber spectrometer (I)

To measure momentum and direction of K^+ decay

Requirements:
- low mass (multiple scattering),
- operating in vacuum
- good spatial and momentum resolution
- small inactive area around primary beam



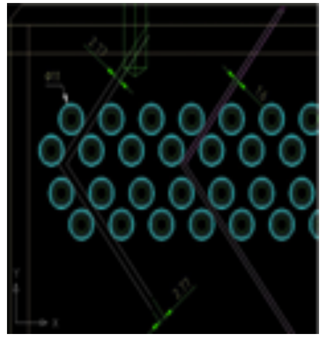


Two “cartesian” frames tilted of 45°

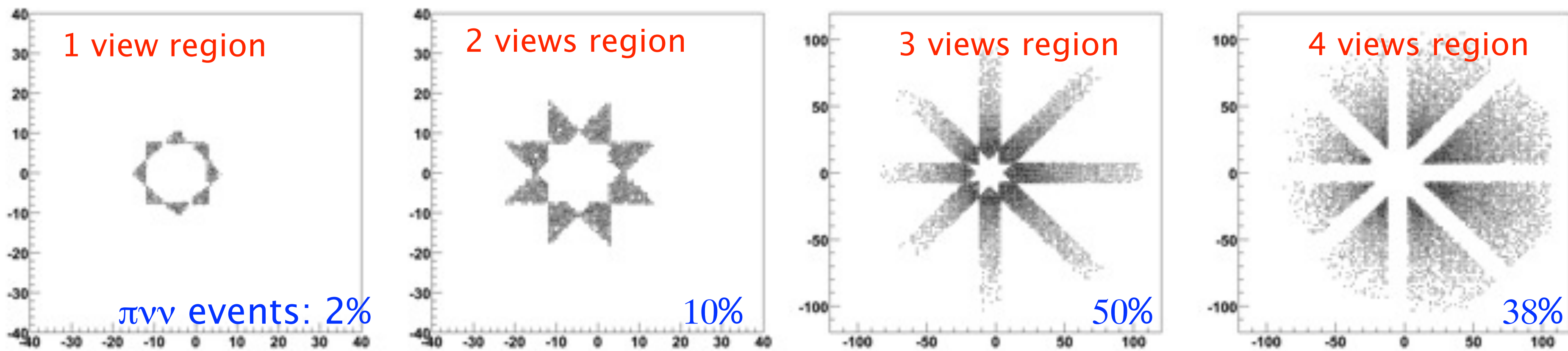
Solution:

four straw chambers and one magnet 256 MeV/c P_t
- 4 view/chamber XYUV
- 4 staggered layer/view (L/R ambiguity)
- 500 straws/view, 8000 grand total
- 9.6 mm radius mylar tube
- 2.1 m long
- X/X_0 ~0.1% per view

beam
hole



beam



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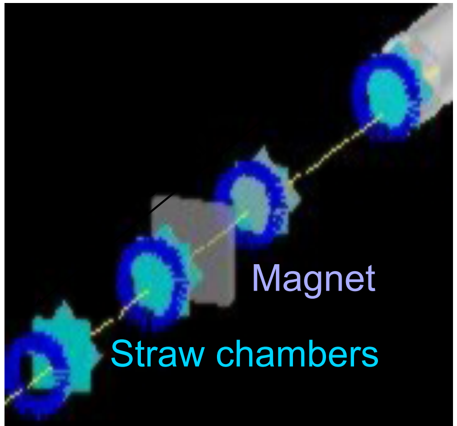

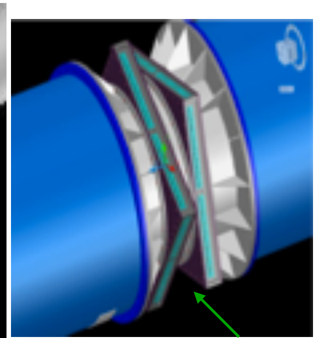

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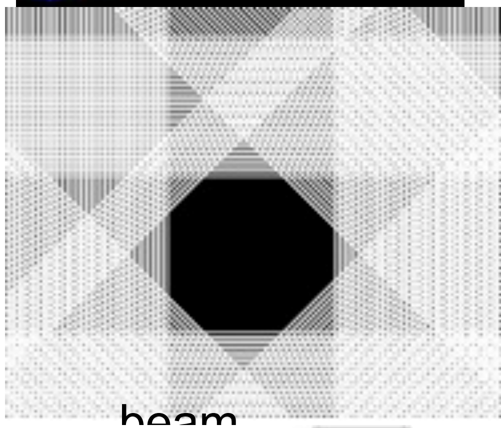
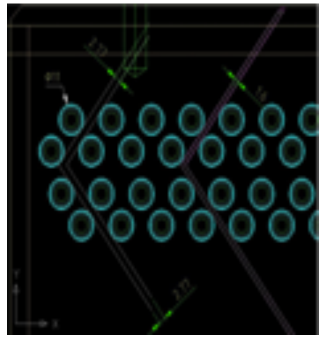
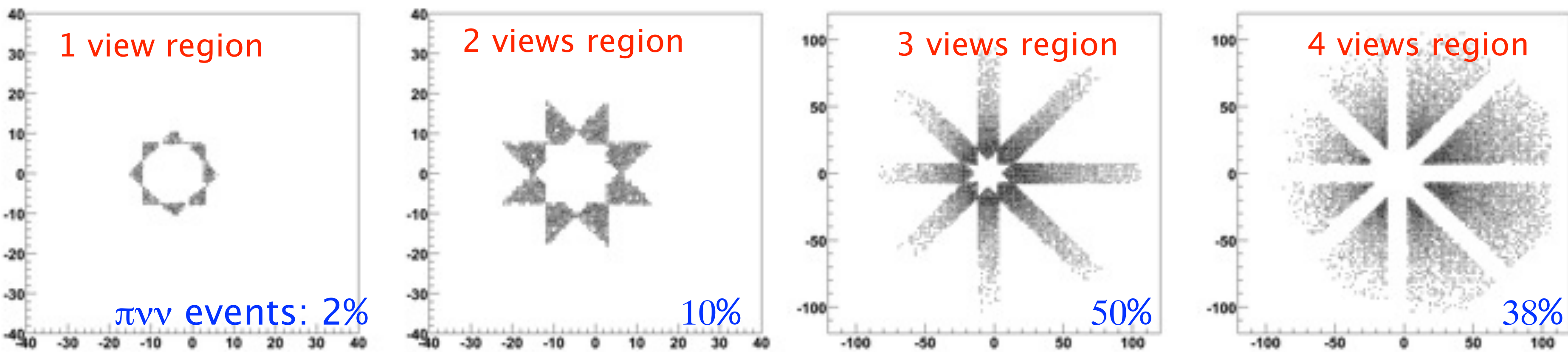
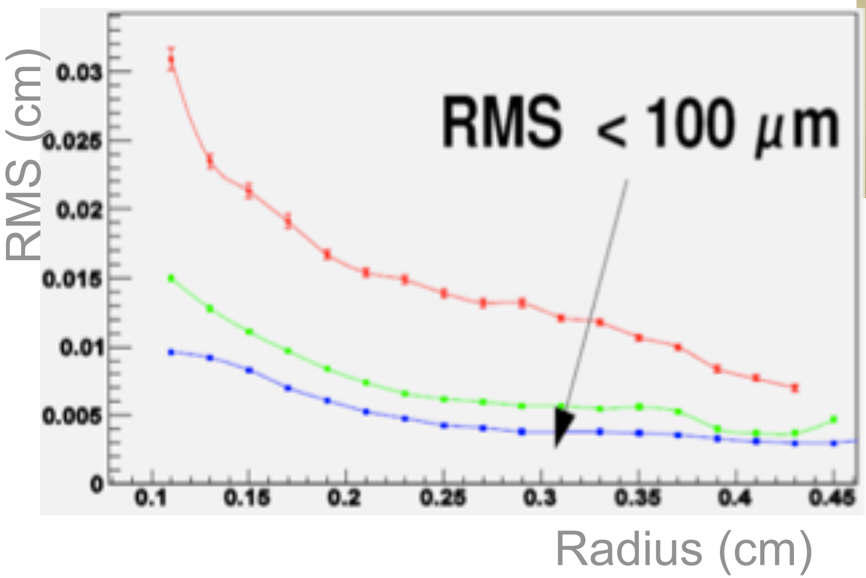


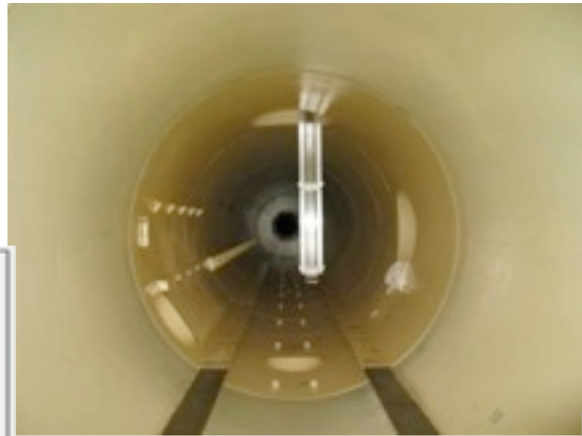




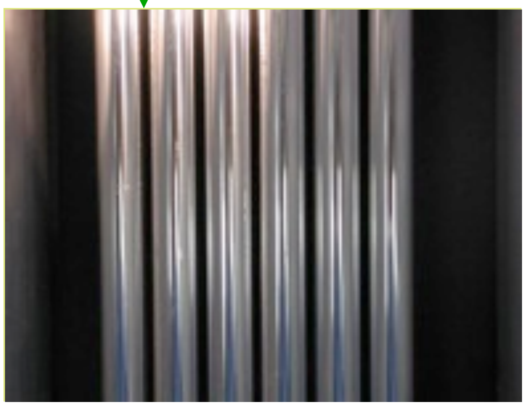
Straw chamber spectrometer (II)

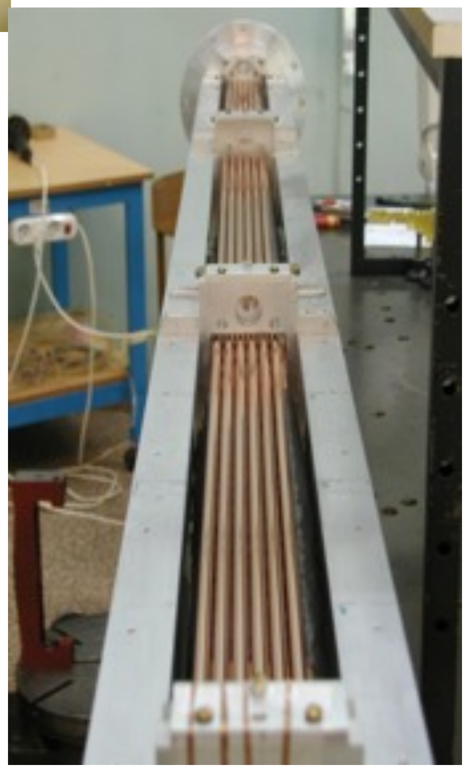
Prototype test beam in vacuum
muon tracks reconstruction





Small gap for diameter
expansion under vacuum





ultrasonic welded mylar
- no glue no out gassing
- better load and resistance

Impact of the kinematic reconstruction

The rejection factors estimated by a Geant4 Simulation

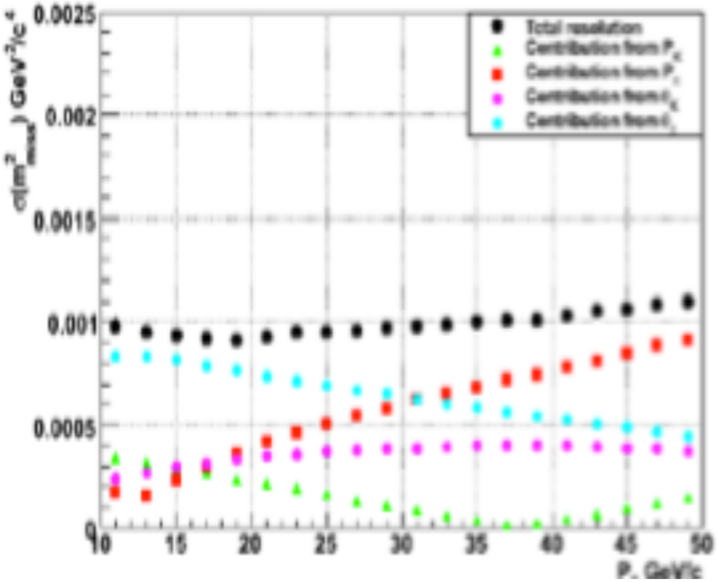
Table of resolutions

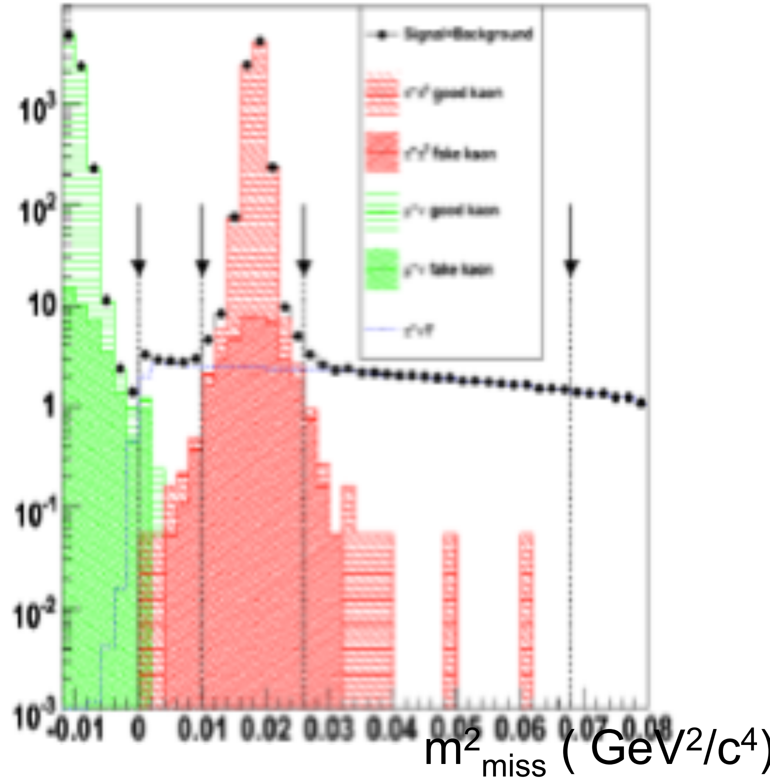
particle	P	direction
K^+	0.2%	17 μrad
π^+/μ^+	0.3%	15-45

Table of rejection factors for two body decays

decay	R.F.
$K^+\to\pi^+\pi^0$	10^4
$K^+\to\mu^+\nu$	10^5

Main sources of inefficiencies:





The Ring Image Cherencov detector (I)

Requirements:

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

RICH

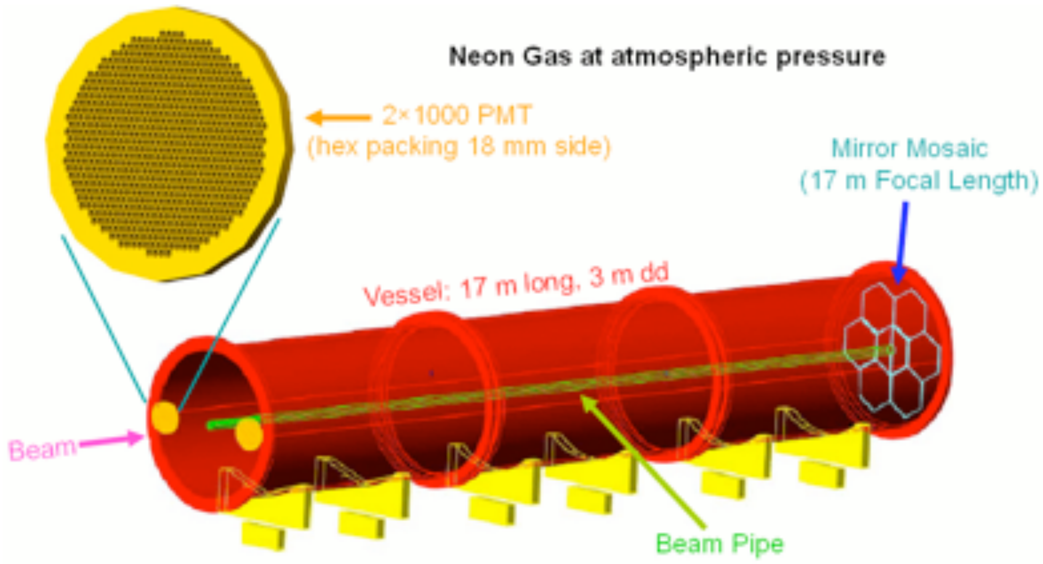
· 18 m long tube filled with Neon (1atm)

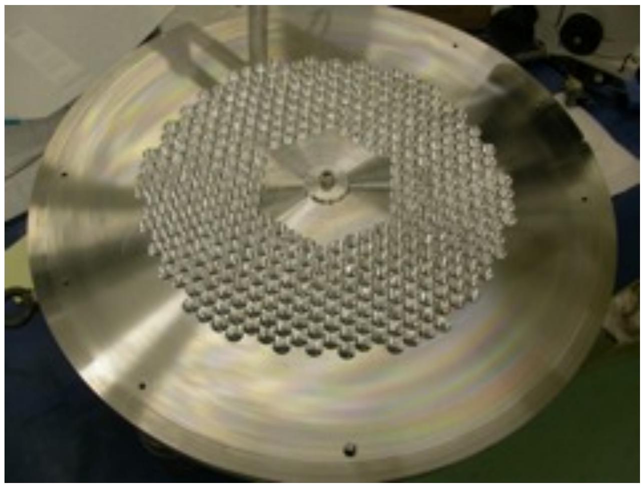
· 3 m diameter

· Mirrors with f=17 m

· 2000 single anode PMTs, 1 cm in diameter

18mm "pixel" with Winston cones



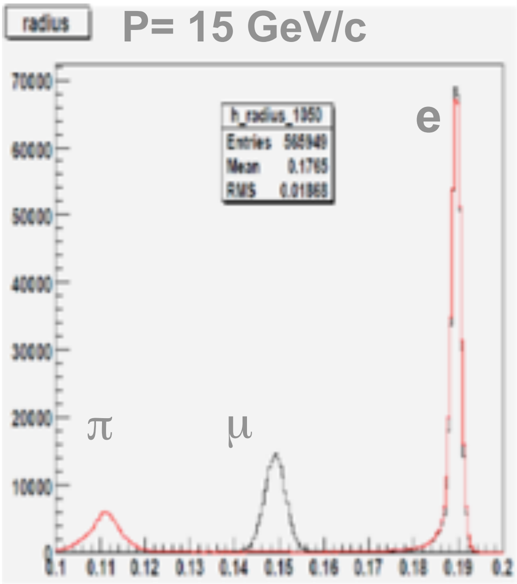


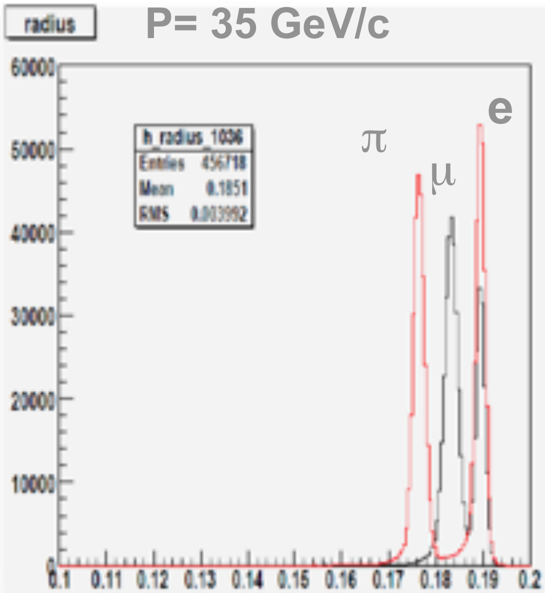
The Ring Image Cherencov detector (II)

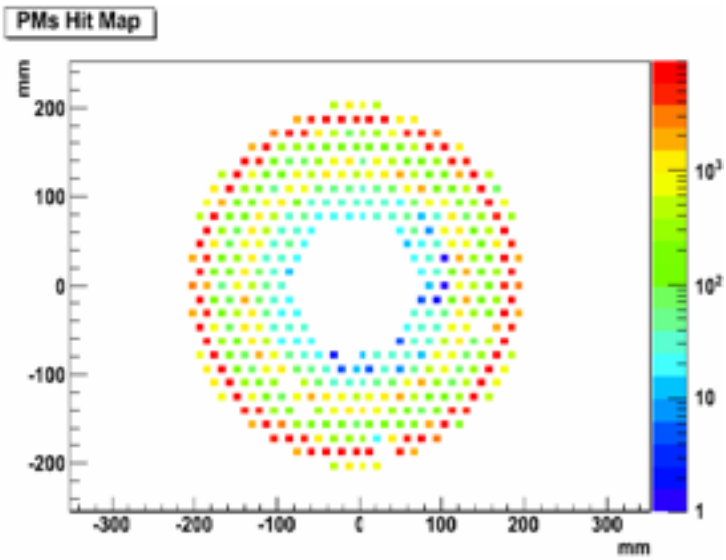
first prototype test beam results:

- N_{hits}/event ~ 17
- Δt_{event} ~ 70 ns
- ΔQ ~ 50 mrad (biased by PM geometry) NIM A 593, 2008

A full length prototype (0.5 m diameter) was tested in may
π,μ and **e** separation results (preliminary)







The Photon Veto System

To obtain the required rejection factor on **$K^+ \rightarrow \pi^+\pi^0$** a photon detectors system with **10^8 rejection factor on $\pi^0 \rightarrow \gamma\gamma$ is required**

Three different angular regions to be covered

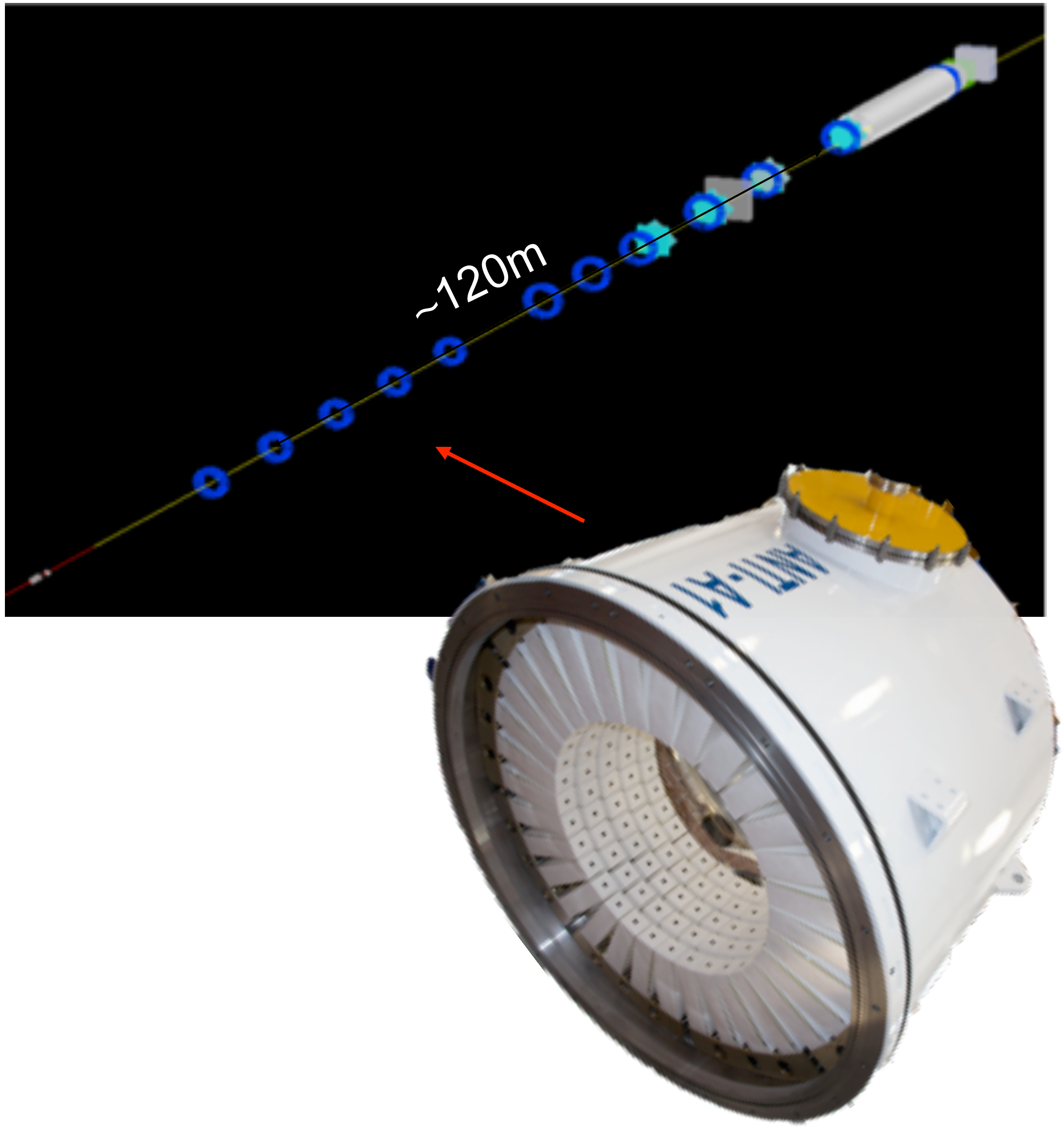
- LAV: Large Angle Veto: (10:50 mrad)
- LKr: Liquid Kripton calorimeter (1:10 mrad)
- IRC and SAC <1mrad

requiring P(**p$^+$**) < 35 GeV we get P(**p^0**)> 40GeV and high energy photons: photons > 1 GeV hit the LKr → high detection efficiency

Large Angle Veto (I)

12 rings to cover the large angle photons requirements:

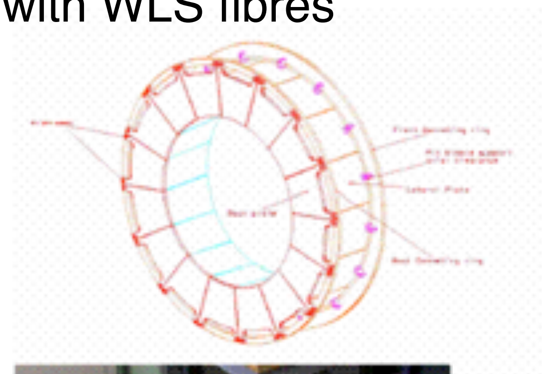
- Inner-outer radii: 60-96 to 90-140 cm
- Almost hermetic
- Large area: ~30 m^2
- Good efficiency down to "low" energy (200 MeV) photons
- Operating in vacuum

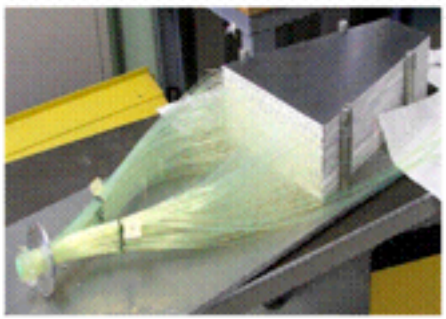


Large Angle Veto (II)

R&D three different technologies studied:

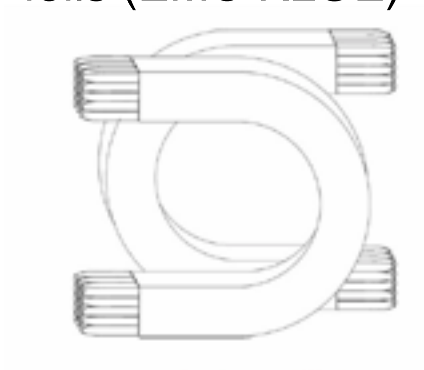
Tile calorimeter:
lead-plastic
scintillator foils
with WLS fibres

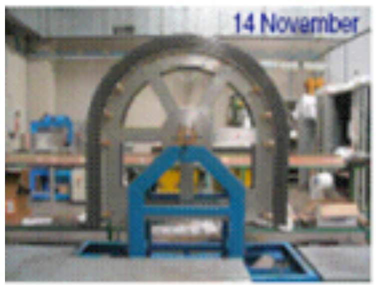


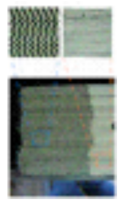


one sector prototype
borrowed by CKM
prop. exp. at FNAL

Scintillating fibres
embedded in lead
foils (EMC KLOE)

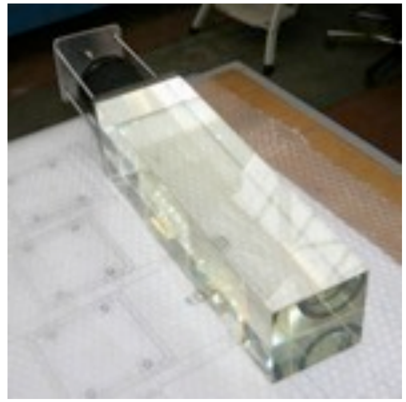






one U prototype
build at LNF

Lead-glass blocks
from the LEP OPAL
EMC



some blocks from
OPAL store at CERN

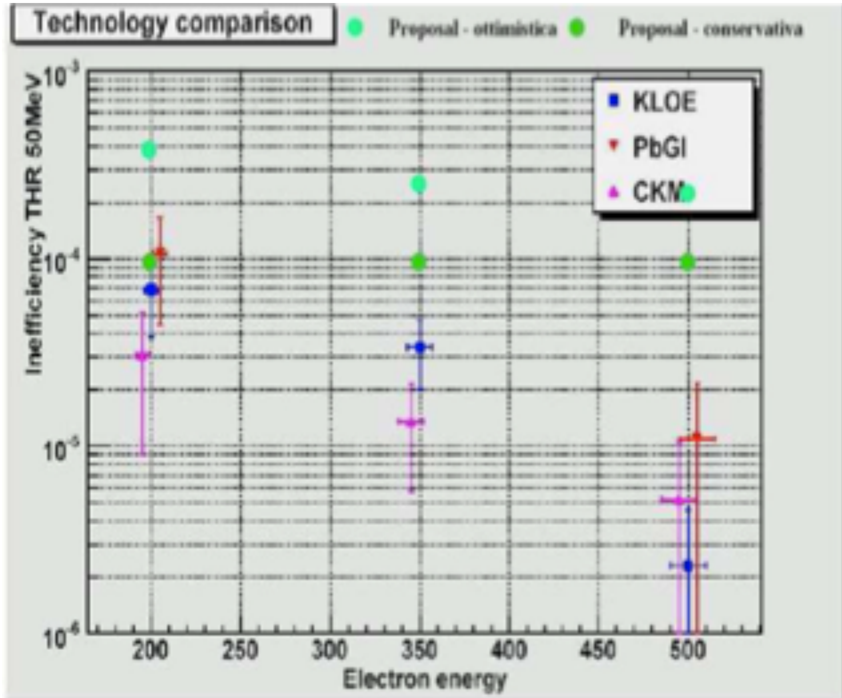
Large Angle Veto (III)

The three prototype tested at the BTF a LNF in Frascati:
50 Hz single e^+/e^- 200-500 MeV

all detectors fulfilled the requested efficiencies

OPAL LG choice for economic reasons

mechanic to hold the blocks was designed



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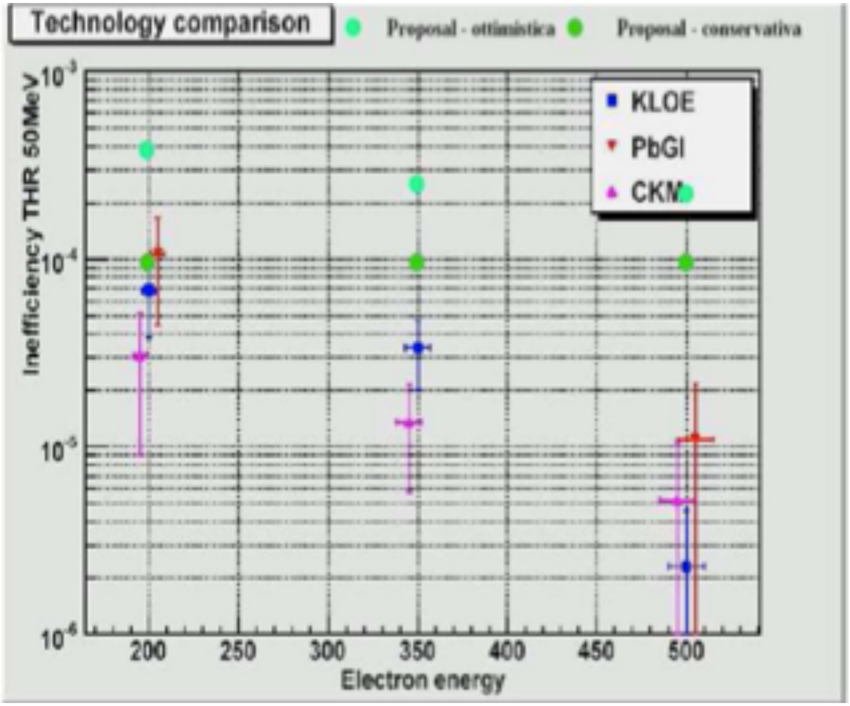
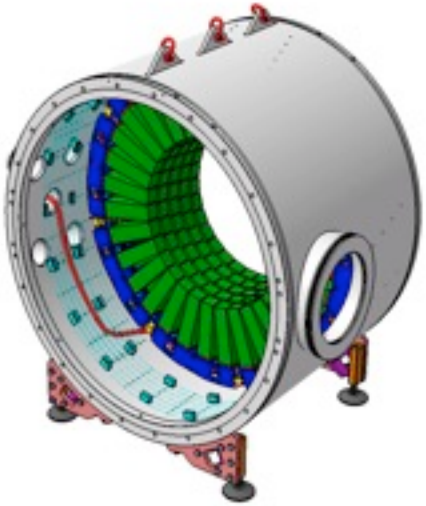


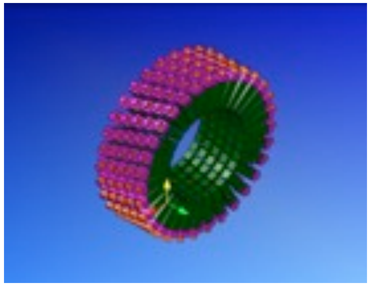


mercoledì 7 luglio 2010

Large Angle Veto (IV)

3606 blocks available (thanks to Tokyo-OPAL coll.)
2946 needed for the 12 stations
each station has 5 layer with a relative phase

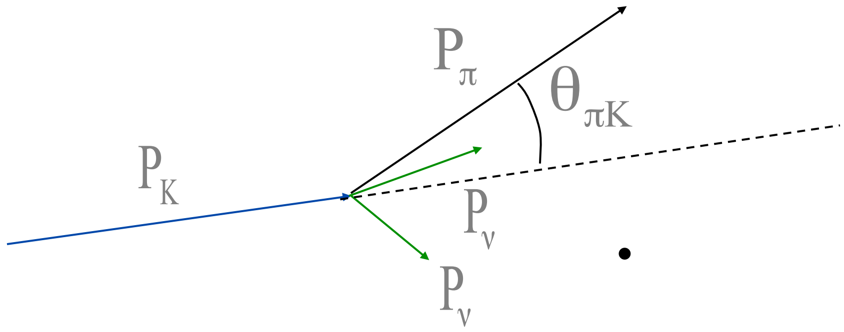
All the blocks have to be polished, tested, re-cabled, reinforced and wrapped again
Gain and PeY are measured by LED and Cosmic



A first station assembled at LNF (160 bloks) and arrived to CERN for the installation in the vacuum tube (22/709)

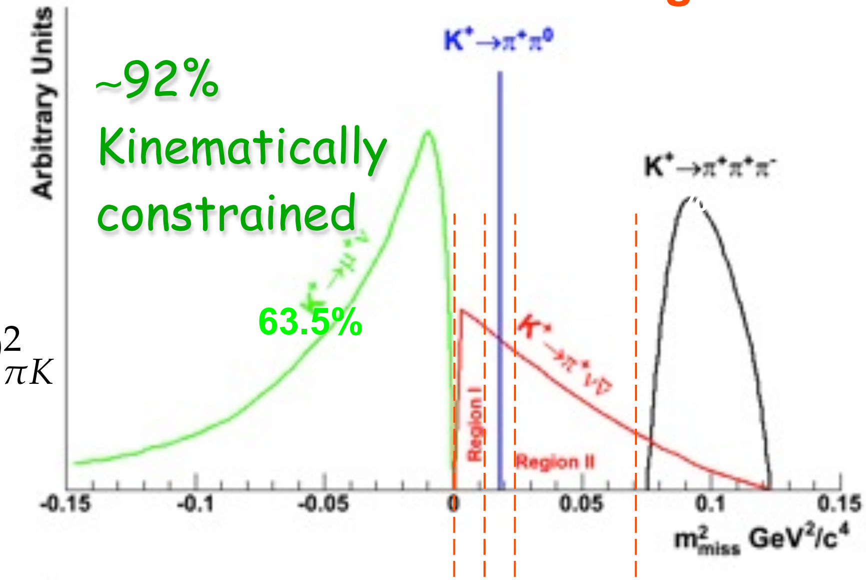
Large Angle Veto (pictures)

Kinematic reconstruction



$$m_X^2 = m_K^2\left(1-\frac{|\vec{P}_\pi|}{|\vec{P}_K|}\right) + m_\pi^2\left(1-\frac{|\vec{P}_K|}{|\vec{P}_\pi|}\right) - |\vec{P}_K||\vec{P}_\pi|\theta_{\pi K}^2$$

two bk free regions

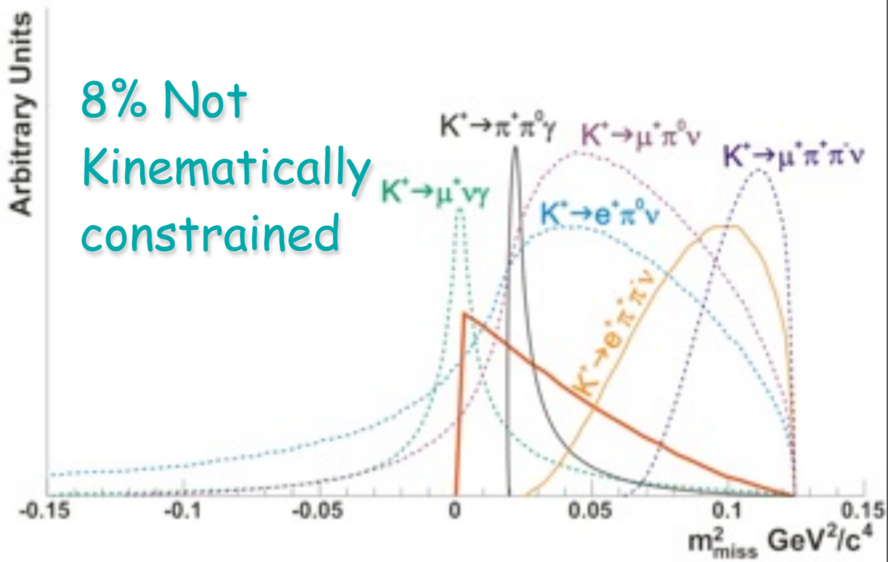


Requirements:

- low mult. scattering

$\rightarrow$ low mass tracker operating in vacuum

- good space resolution (~100 μm)



Detectors:

- GigaTracker
- Straw Chamber Spectrometer