Rare Kaon Decays: Opportunities at CERN

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Marseille, November 15, 2004

Why study Rare Kaon Decays

- Search for explicit violation of Standard Model
  - Lepton Flavour Violation
- Probe the flavour sector of the Standard Model
  - FCNC
- Test fundamental symmetries
  - CP,CPT
- Study the strong interactions at low energy
  - Chiral Perturbation Theory, Form Factors

CP-Violation in SM

A phase in the CKM matrix leads to CP-Violation

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

$N_g=2 \quad N_{phase}=0 \Rightarrow$ **No CP-Violation**

$N_g=3 \quad N_{phase}=1 \Rightarrow$ **CP-Violation Possible**

Predictions:

- **Direct-CP Violation: $\varepsilon' / \varepsilon \neq 0$ NA48, KTeV**
- **CP violation in the B meson sector: $A_{CP}(J/\psi\ K_s)$, BaBar, Belle**

Paradigm shift:

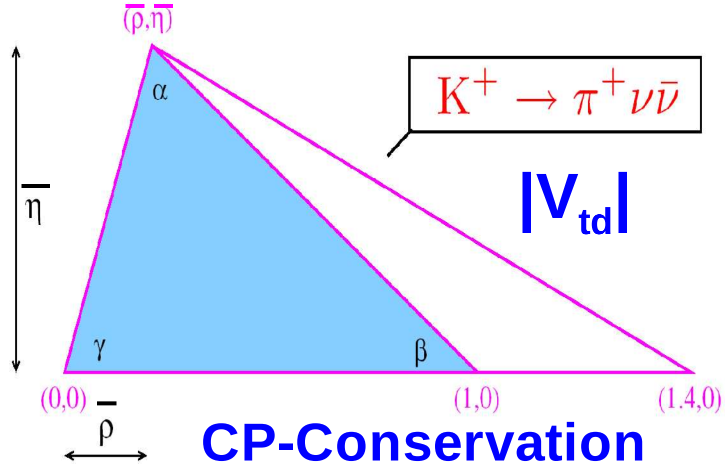
Look for inconsistencies (i.e. New Physics) in SM using observables with small theoretical errors

Kaon Rare Decays and the SM

CP-Violation

$K_L \to \pi^0 \nu\bar{\nu}$ **(holy grail)**

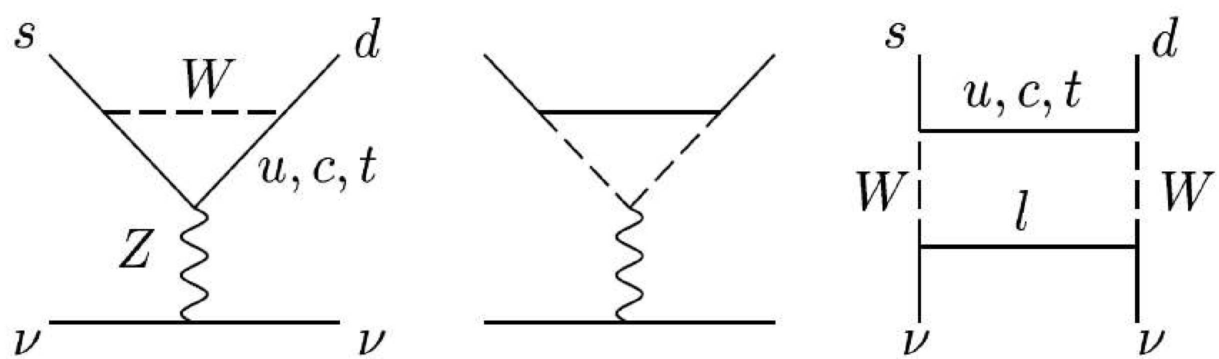
$$K_L \to \pi^0 e^+ e^- \begin{cases} K_S \to \pi^0 e^+ e^- \\ K_L \to \pi^0 \gamma\gamma \\ K_L \to ee\gamma\gamma \end{cases}$$



CP-Conservation

Kaons provide quantitative tests of SM independent from B mesons

$$K_L \to \mu^+\mu^- \begin{cases} K_L \to \gamma\gamma,\ K_L \to e^+e^-\gamma \\ K_L \to e^+e^-e^+e^-,\ e^+e^-\mu^+\mu^- \end{cases}$$



Th. error $\lesssim 10\%$ — decreasing SM contrib. →

	$b \to s$ $(\sim\lambda^2)$	$b \to d$ $(\sim\lambda^3)$	$s \to d$ $(\sim\lambda^5)$
$\Delta F=2$ box	ΔM_d $A_{CP}(B_s \to \psi K)$	ΔM_s $A_{CP}(B_s \to \psi\phi)$	ΔM_K ε_K
$\Delta F=1$ 4-quark box	$B_d \to \pi K$, $B_d \to \eta K$, $A_{CP}(B_d \to \phi K)$, ...	$B_d \to \pi\pi$, $B_d \to \rho\pi$, $A_{CP}(B_d \to \pi\pi)$, ...	ε'/ε, $A_{CP}(K \to 3\pi)$, ...
gluon penguin	$B_d \to X_s\gamma$, $B_d \to \pi K$, $A_{CP}(B_d \to \phi K)$, ...	$B_d \to X_d\gamma$, $B_d \to \pi\pi$, $A_{CP}(B_d \to \pi\pi)$, ...	$K_L \to \pi^0 l^+ l^-$, ε'/ε, ...
γ penguin	$B_d \to X_s l^+ l^-$, $B_d \to X_s\gamma$, $B_d \to \pi K$, $B_s \to KK$, ...	$B_d \to X_d l^+ l^-$, $B_d \to X_d\gamma$, $B_d \to \pi\pi$, $B_s \to \pi K$, ...	$K_L \to \pi^0 l^+ l^-$, ε'/ε, ...
Z^0 penguin	$B_d \to X_s l^+ l^-$, $B_s \to \mu^+\mu^-$, $B_d \to \pi K$, $B_s \to KK$, ...	$B_d \to X_d l^+ l^-$, $B_d \to \mu^+\mu^-$, $B_d \to \pi K$, $B_s \to KK$, ...	$K_L \to \pi^0 l^+ l^-$, $K_L \to \pi^0 \nu\nu$, $K^+ \to \pi^+ \nu\nu$, ε'/ε, ...
H^0 penguin	$B_s \to \mu^+\mu^-$	$B_d \to \mu^+\mu^-$	$K_{L,S} \to \mu^+\mu^-$

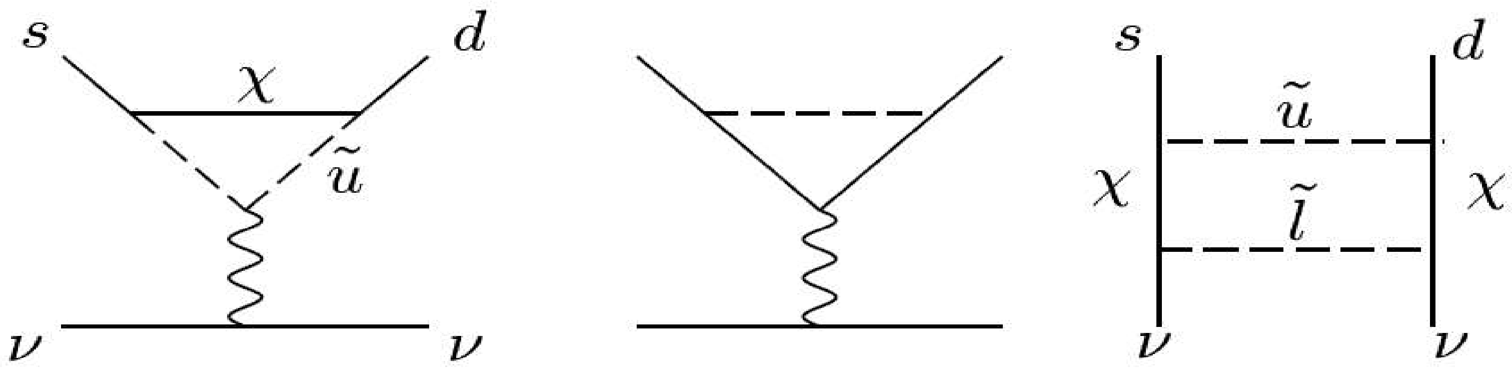
↓ decreasing SM contrib.

(filled circle) = exp. error $\lesssim 10\%$ (open circle) = exp. error $\sim$ 30-50%

Courtesy G. Isidori

Beyond SM

- These rare kaon decays are second order weak interactions mediated by Z pinguins that could be sensitive to new physics
- A deviation from the predicted rates of SM would be a clear indication of new physics
- When/if new physics will appear at the LHC, the rare decays may help to understand the nature of it



Kaons @ CERN

Past:

NA48: Direct CP Violation Established !

NA48/1: First Observations of K^0_S ? π^0 ee ($\mu\ \mu$)

- **Mixing CP-Violation in K^0_L ? π^0 ee ($\mu\ \mu$) measured !**

Present:

NA48/2: K^+ / K^- Taken data in 2003/2004

- **Search for Direct CP-Violation**
- **Inspiration to study K^+ ? $\pi^+ \nu\ \ \nu$ in flight**

Future Opportunities:

- **Short to medium term (? 2010)**

NA48/3 K^+ ? $\pi^+ \nu\ \ \nu$ TODAY MAIN FOCUS

- **Longer term**

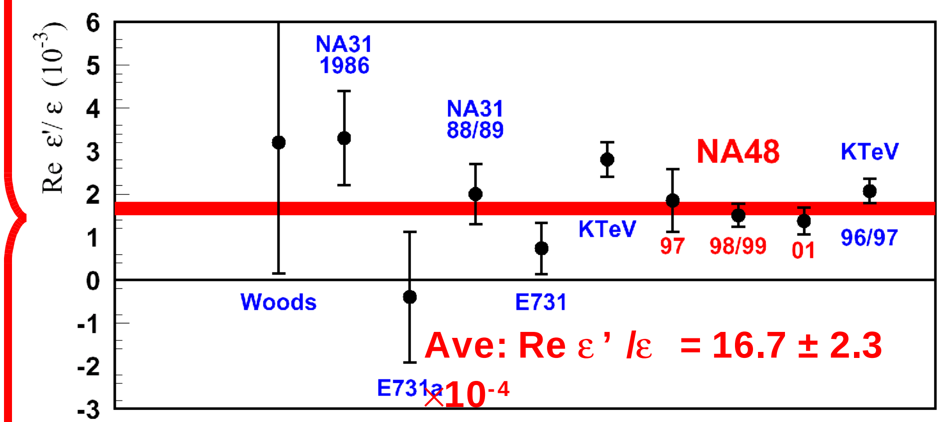
  NA48/4 K^0_L ? π^0 ee ($\mu\ \mu$)

NA48/5 K^0_L ? $\pi^0 \nu\ \ \nu$

NA48 Data Taking so far…

Direct CP-Violation established

Re ε' /ε = 14.7 ± 2.2 ×10^-4



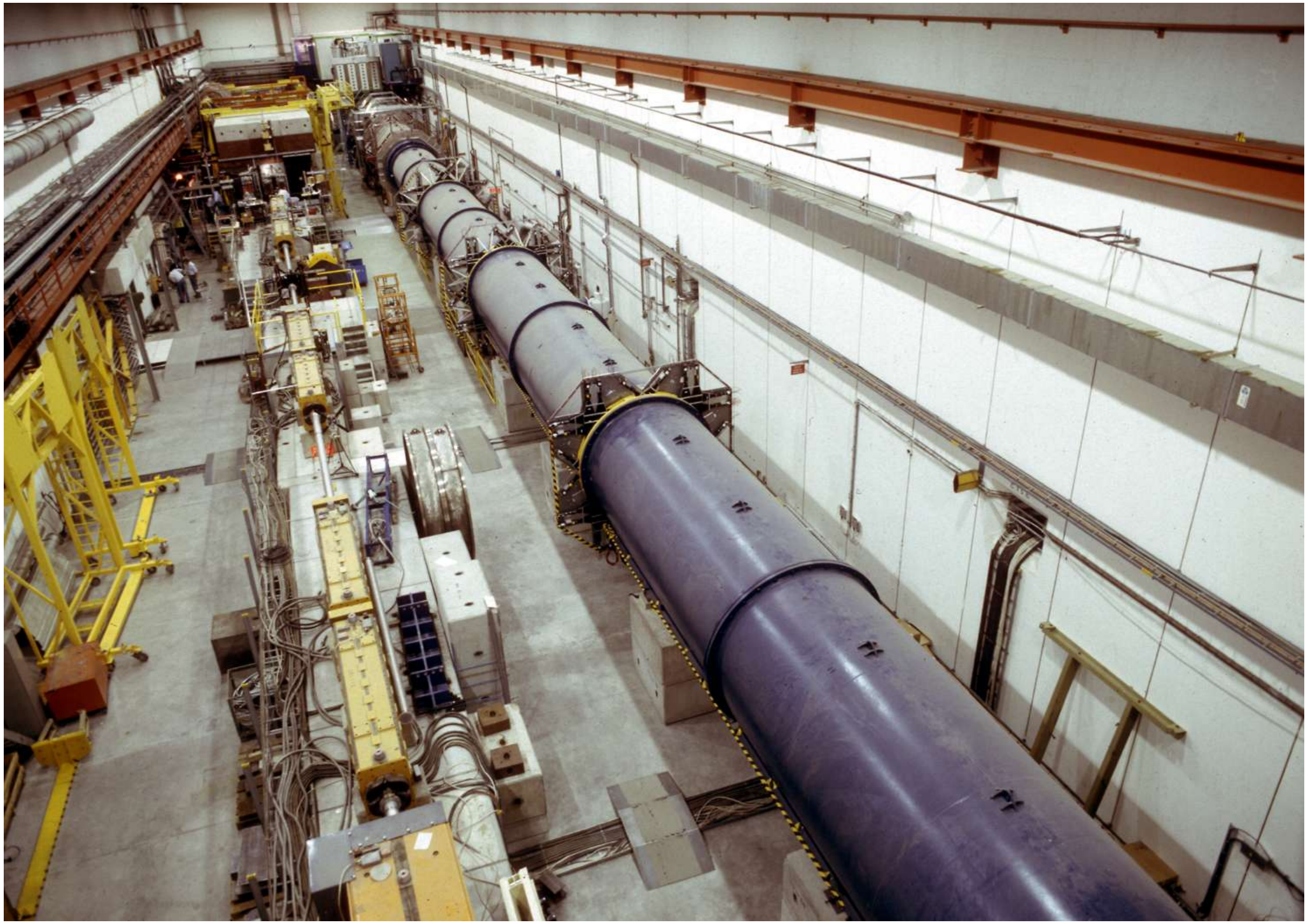
NA48: ε' /ε	1997
ε' /ε	1998
ε' /ε	1999
K_L no spectrometer ε / NA48/1 K_S	2000
ε' /ε lower inst. intensity	2001
NA48/1: K_S	2002
NA48/2: $K^{\pm}$	2003
	2004

+ K_L Rare Decays

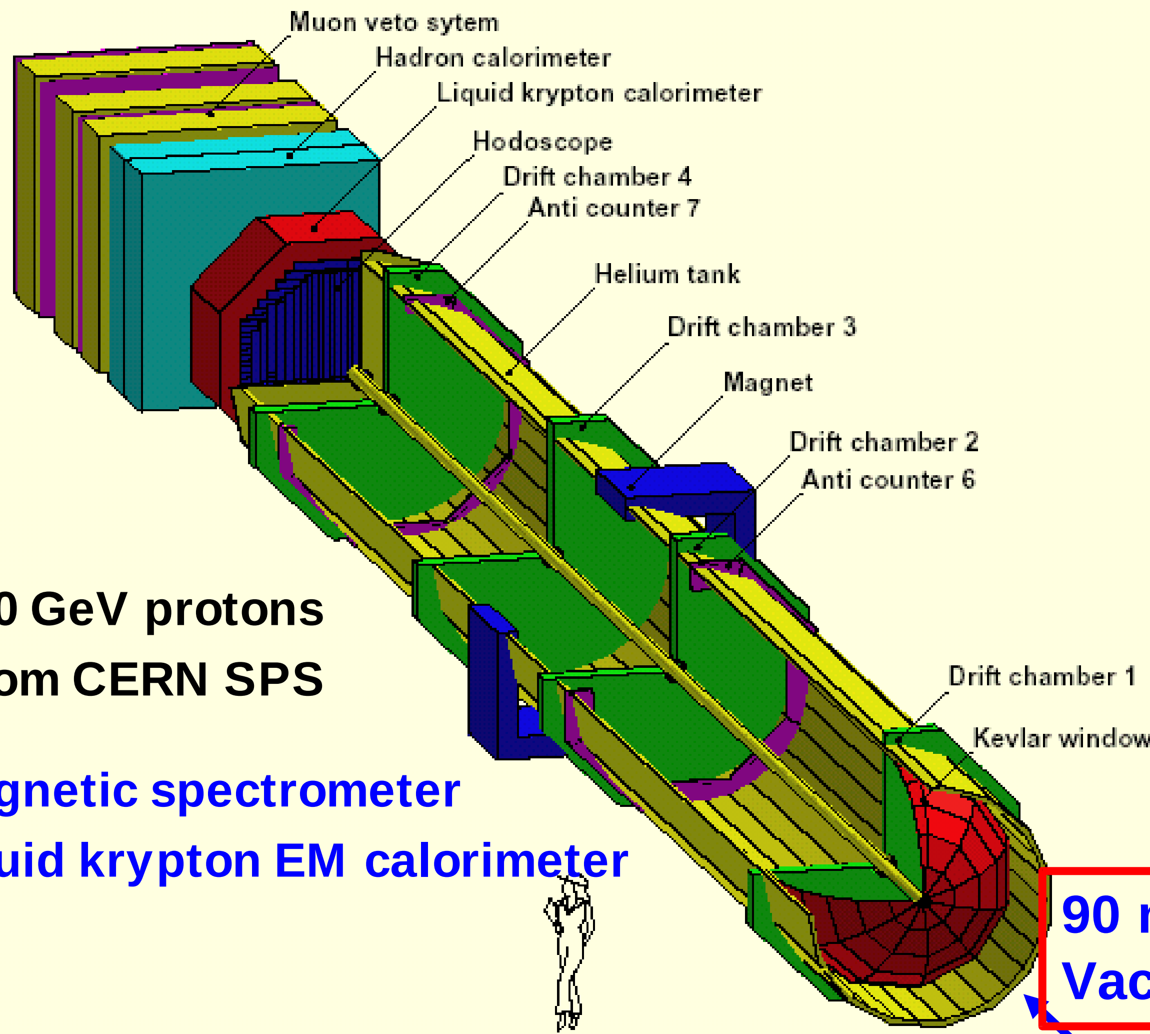
First observation of
K^0_S ?π^0 e^+e^- and K^0_S ?π^0 $\mu^+\mu^-$

Search for Direct CP-Violation in charged kaon decays

NA48 Vacuum Tank



NA48 Detector



400 GeV protons

From CERN SPS

Magnetic spectrometer

Liquid krypton EM calorimeter

90 m long Vacuum tank

NA48:Direct CP-Violation

$Re\ \varepsilon' / \varepsilon = 14.7 \pm 2.2 \times 10^{-4}$

Top "down-loaded" articles from Physics Letters B:

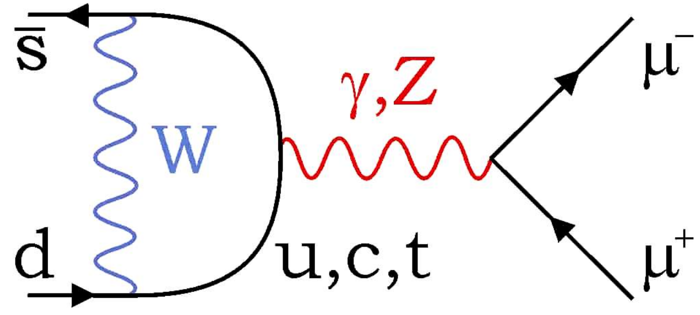
- 1. The hierarchy problem and new dimensions at a millimeter http://dx.doi.org/10.1016/S0370-2693(98)00466-3 Physics Letters B, Volume 429, Issues 3-4 , 18 June 1998, Pages 263-272 Nima Arkani-Hamed, Savas Dimopoulos and Gia Dvali
- **2. A precision measurement of direct CP violation in the decay of neutral kaons into two pions http://dx.doi.org/10.1016/S0370-2693(02)02476-0 Physics Letters B, Volume 544, Issues 1-2 , 19 September 2002, Pages 97-112 J. R. Batley et al. (NA48 Collaboration)**
- 3. Has the GZK suppression been discovered? http://dx.doi.org/10.1016/S0370-2693(03)00105-9 Physics Letters B, Volume 556, Issues 1-2 , 13 March 2003, Pages 1-6, John N. Bahcall and Eli Waxman
- 4. Testable scenario for relativity with minimum length http://dx.doi.org/10.1016/S0370-2693(01)00506-8 Physics Letters B, Volume 510, Issues 1-4 , 21 June 2001, Pages 255-263 Giovanni Amelino-Camelia
- 5. Role of effective interaction in nuclear disintegration processes http://dx.doi.org/10.1016/S0370-2693(03)00801-3 Physics Letters B, Volume 566, Issues 1-2 , 24 July 2003, Pages 90-97 D. N. Basu
- 6. Determination of solar neutrino oscillation parameters using 1496 days of Super-Kamiokande-I data http://dx.doi.org/10.1016/S0370-2693(02)02090-7 Physics Letters B, Volume 539, Issues 3-4 , 18 July 2002, Pages 179-187 S. Fukuda et al.

NA48/1

NA48/1: $K^0_S ? \pi^0 e^+ e^-$ and $K^0_S ? \pi^0 \mu^+ \mu^-$

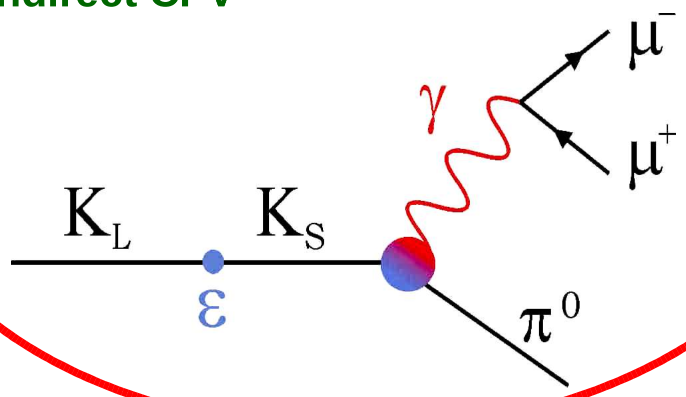
Principal aim of NA48/1:

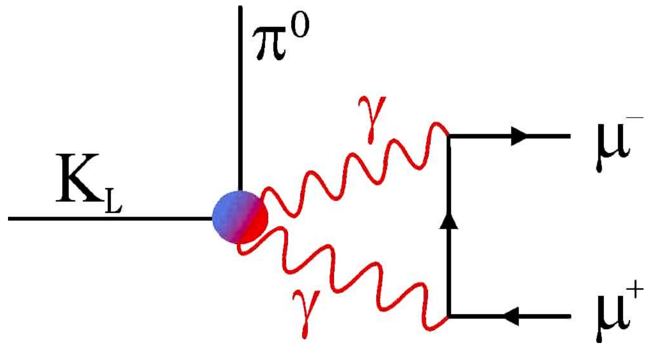
Measure the Indirect CP-Violating Contribution to $K^0_L ? \pi^0 e^+ e^-$ and $K^0_L ? \pi^0 \mu^+ \mu^-$



Direct CPV

Indirect CPV

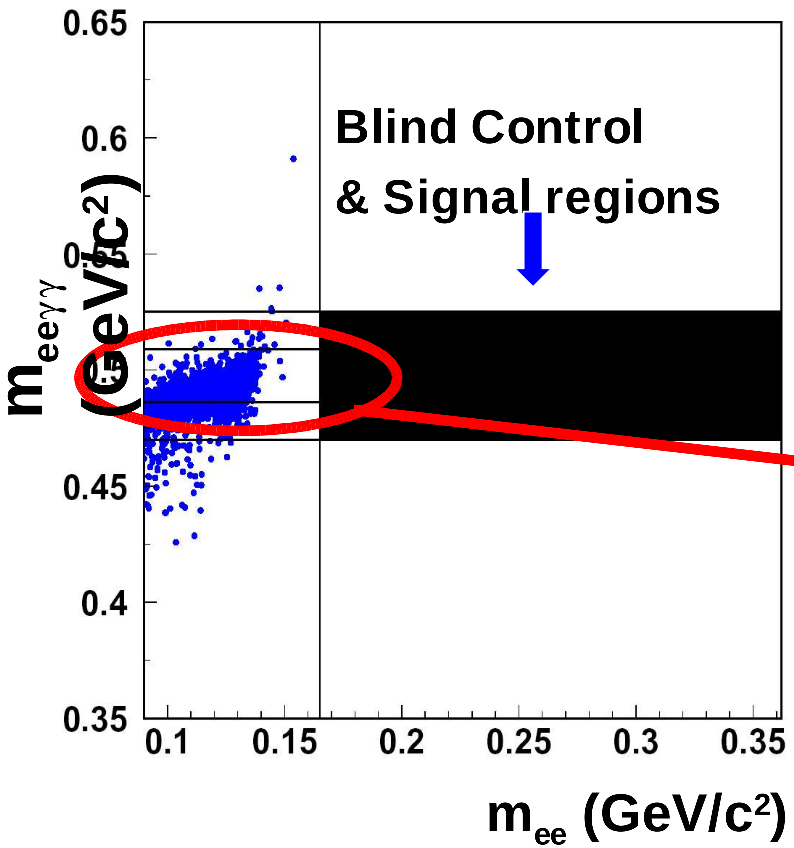




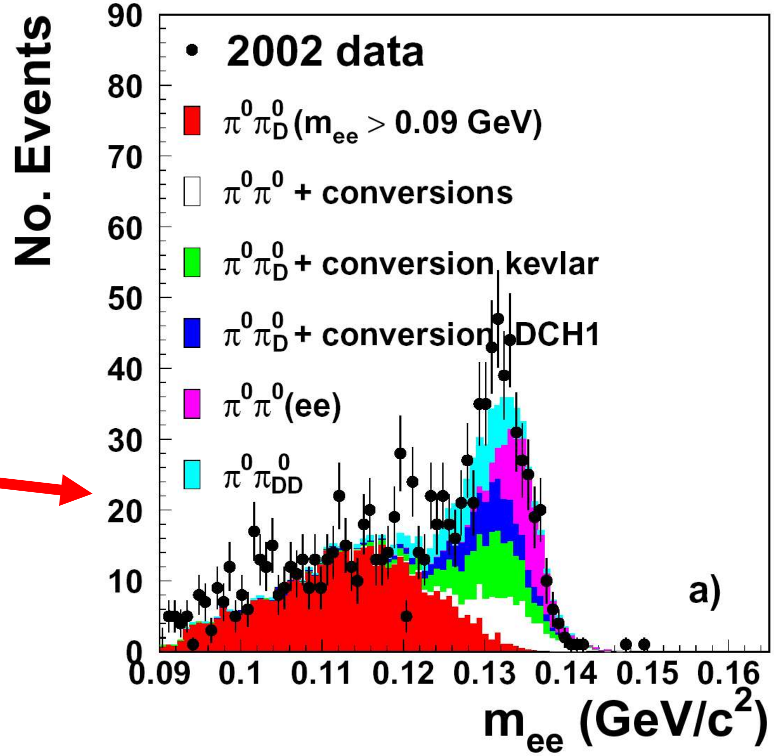
CPC

NA48/1: K_S ?π^0 ee

$e^{+-}e^{-+}$ (Odd Sign) DATA

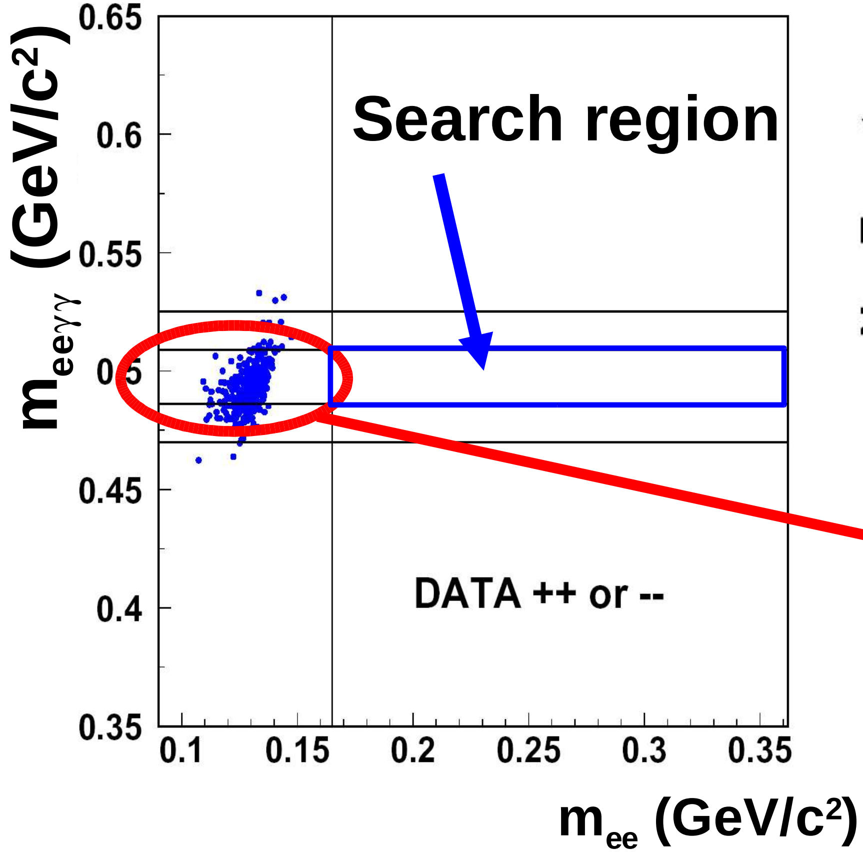


$e^{+-}e^{-+}$ DATA vs. MC

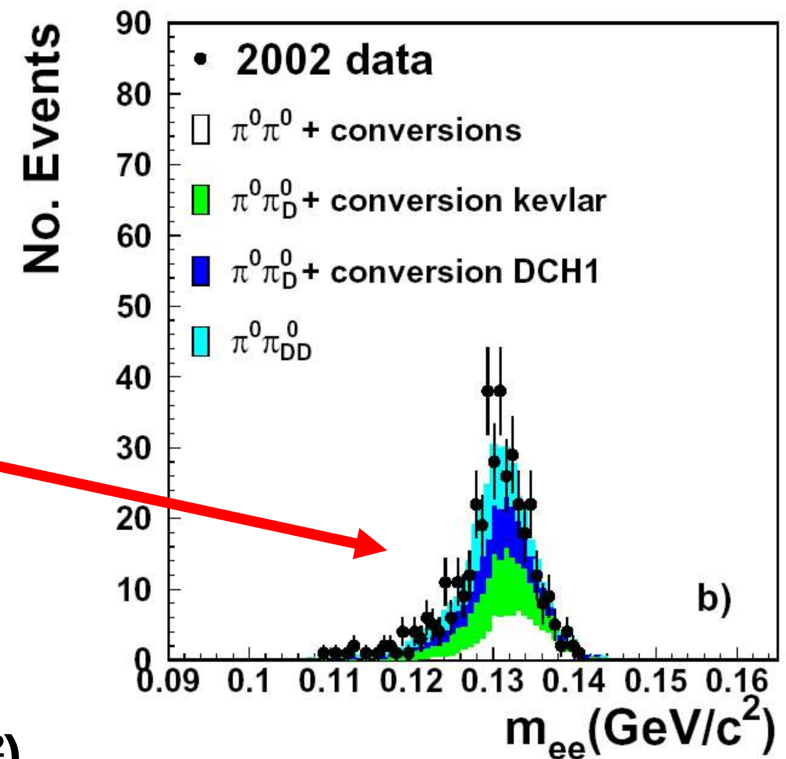


NA48/1: K_S ?π^0 *ee*

$e^{+-}e^{+-}$ (Same Sign) DATA



$e^{+-}e^{+-}$ DATA vs. MC



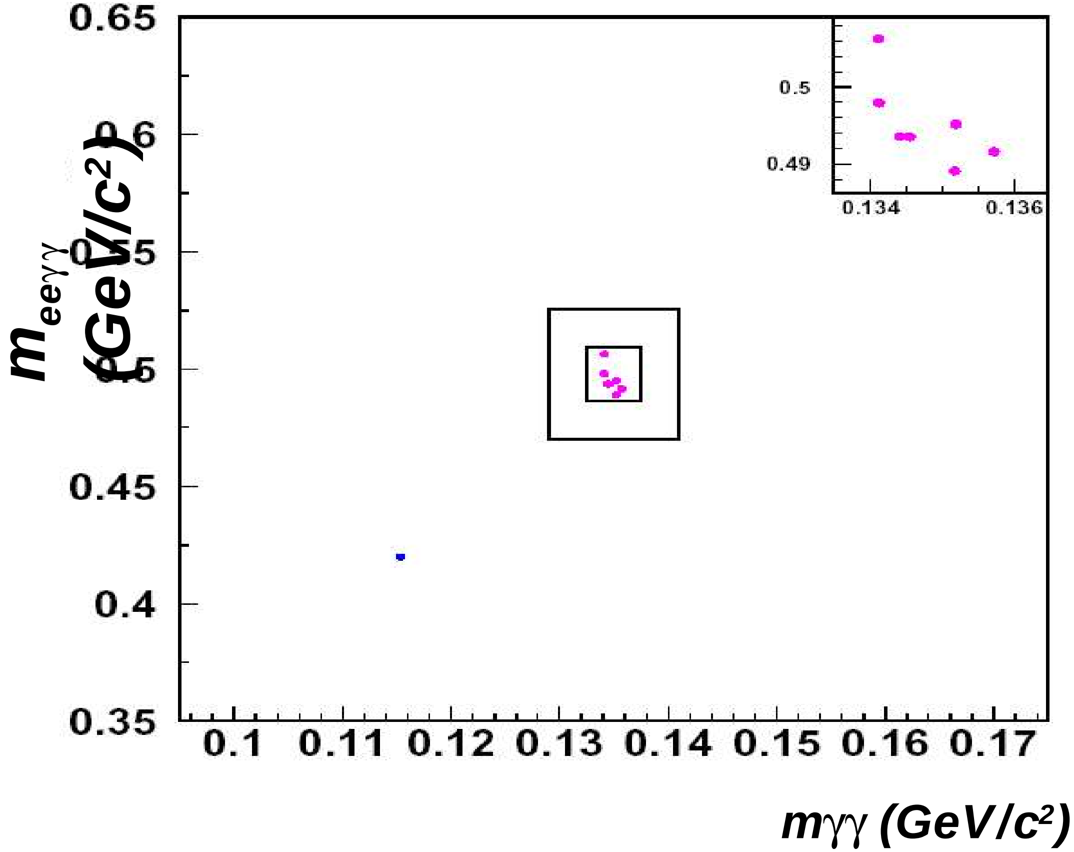
NA48/1: K_S ?π^0 *ee*

SUMMARY OF BACKGROUNDS:

Source	Control Region	Signal region
K_S ?$\pi^0_D \pi^0_D$	0.03	0.007
$K_{L,S}$? $ee\gamma\gamma$	0.11	0.075
$\pi e \nu + 2\pi^0(\pi^0)$	0.19	0.069
Total	$0.33^{+0.18}_{-0.11}$	$0.15^{+0.05}_{-0.04}$

- Many other sources investigated and found to be negligible (e,g neutral cascade decays)
- Blind analysis: Control and signal region remained masked until the study of the background was finished

NA48/1: K_S ?π^0 ee



- **7 candidates in the signal region**

- **0 in control region**
- **Background 0.15**

The probability that all 7 events are background is ~10^{-10}

→ **First observation of K_S ?π^0 ee**

NA48/1: K_S ?π^0 ee

PL B576 (2003); hep-ex/0309075

$BR(K_S ? \pi^0 ee, m_{ee} > 165\ MeV/c^2) = (3.0^{+1.5}_{-1.2}(stat) \pm 0.2(syst)) \times 10^{-9}$

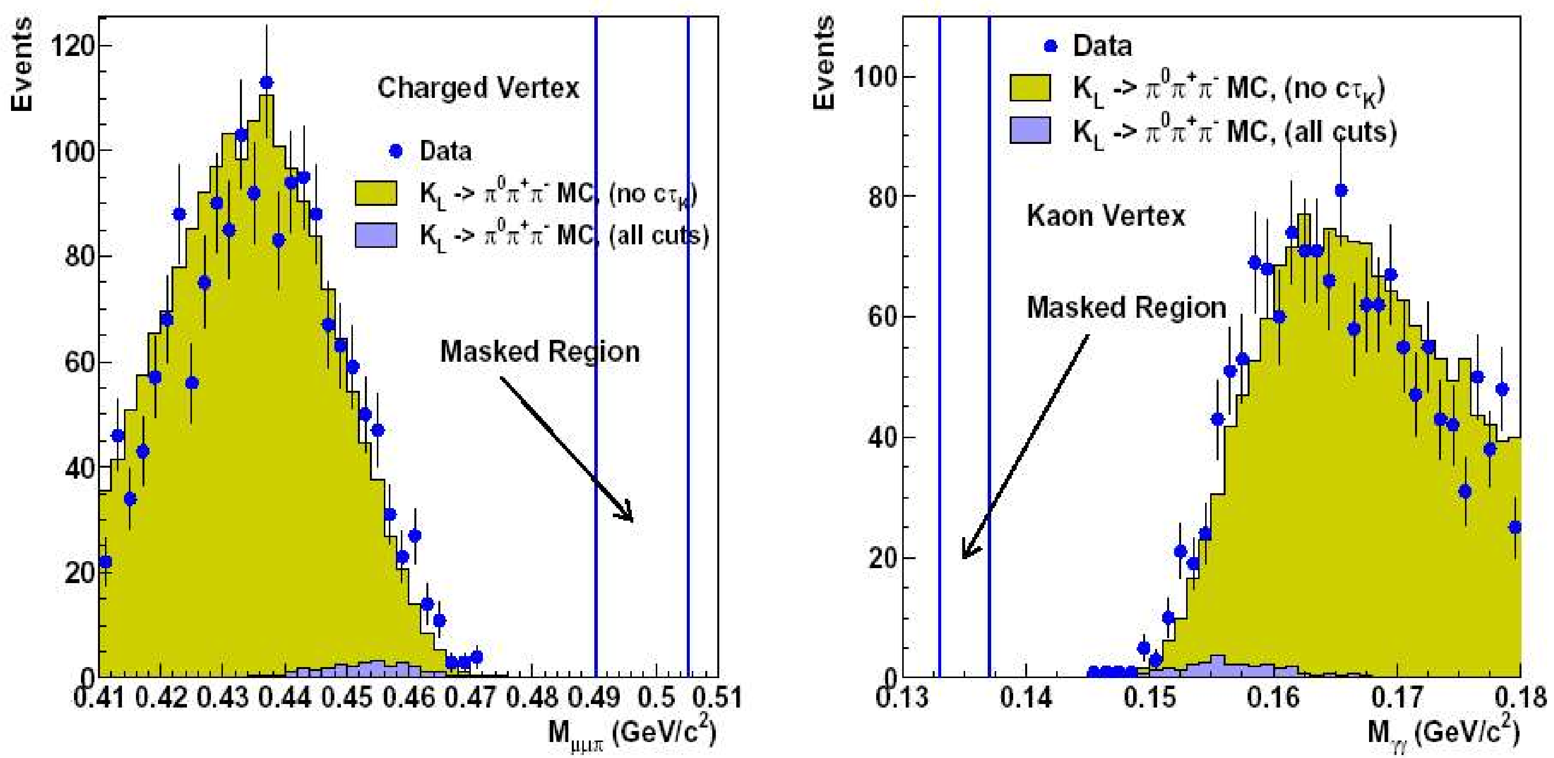
- Assuming vector interaction:

$BR(K_S ? \pi^0 ee) = (5.8^{+2.8}_{-2.3}(stat) \pm 0.8(syst)) \times 10^{-9}$

– See for the Theory:
  - Sehgal, NP B19 (1970)
  - Ecker, Pich, De Rafael, NP B 291 (1987)
  - Ecker, Pich, De Rafael, NP B 303 (1988)
  - Bruno, Prades ZP C57 (1993)

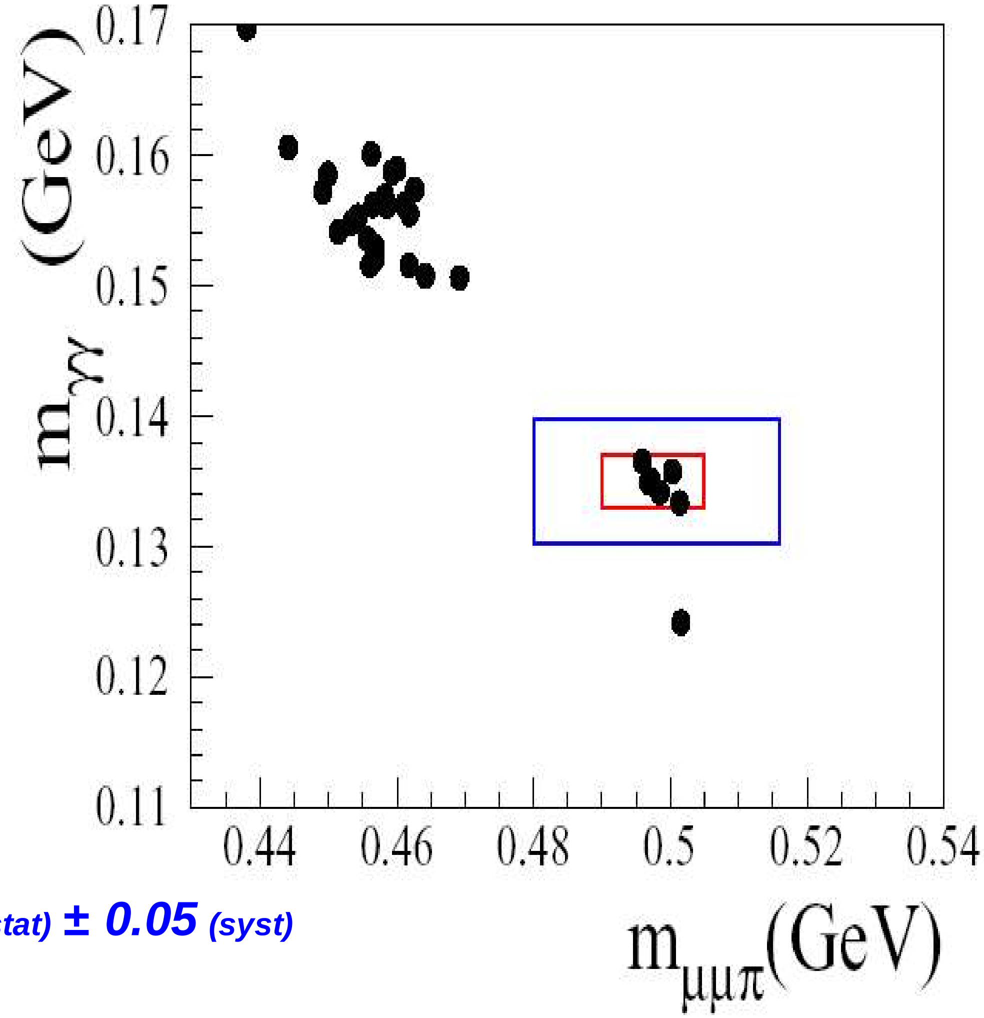
NA48/1: K_S ?$\pi^0 \mu \mu$

- Study of backgrounds from K_L? $\pi^0\pi^+\pi^-$? π^0 $(\mu\nu)(\mu\nu)$
- MC = 22 times the data



NA48/1: K_S ?$\pi^0 \mu \mu$

BR(K_S?$\pi^0\mu\mu$) × 10^9 = 2.9 $^{+1.4}_{-1.2}$(stat) ± 0.2(syst)



First Observation!

6 events

Expected back.

$0.22^{+019}_{-0.12}$

$|a_s|$=1.55$^{+0.38}_{-0.32}$ (stat) ± 0.05 (syst)

PLB 599 (2004)

Interference between K^0_L?π^0ee and K^0_s?π^0ee

Direct CP — Short Distance Contribution

Indirect CP — directly from $K_S \longrightarrow \pi^0 e^+ e^-$

Interference Term → Constructive / Destructive ?

Two independent theoretical analyses find that the interference term is constructive:

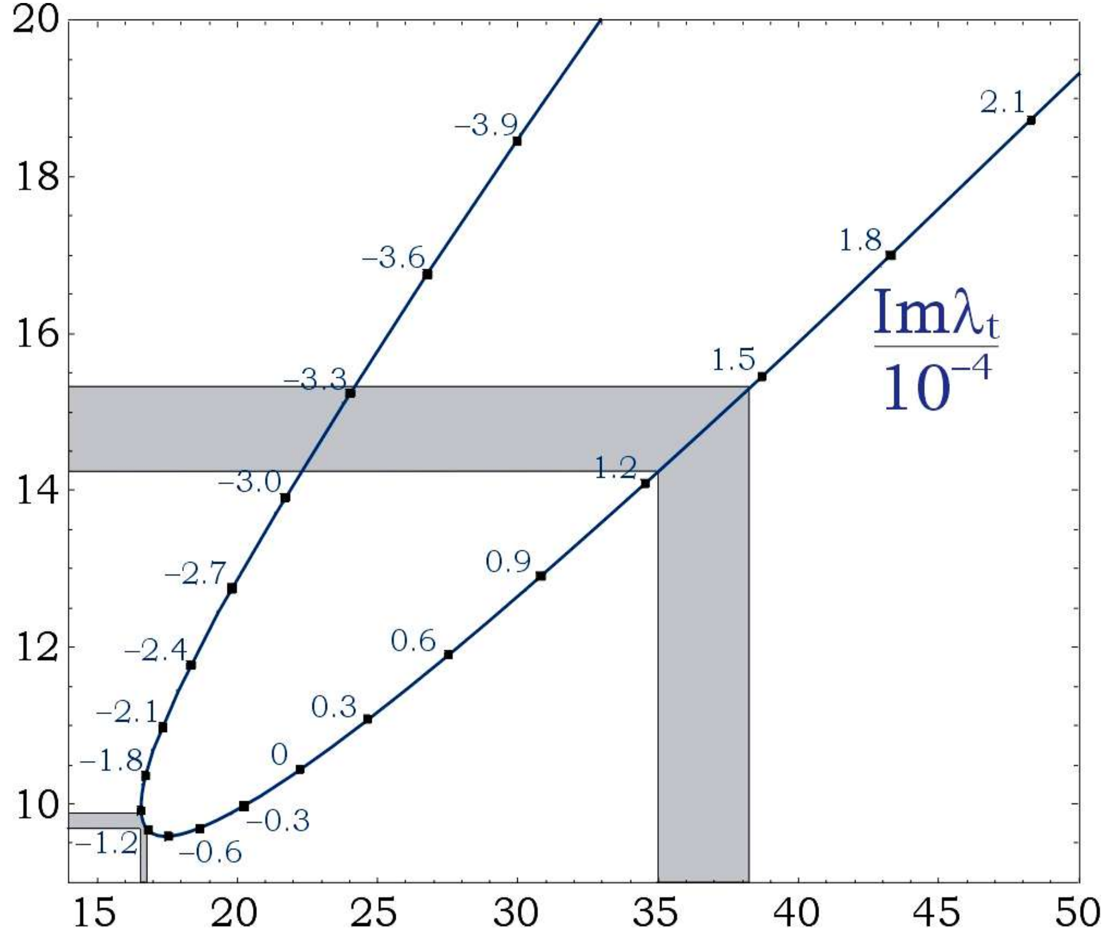
- **Buchalla,Isidori,D' Ambrosio: hep-ph/0308008, NP B 672 (2003)**
- **Friot, Greynat, de Rafael: hep-ph/0404136, PL B 595 (2004)**

K^0_L?π^0ee ($\mu\ \mu$): SM Branching Ratios

Thank to the NA48/1 measurements, the K_L BR can now be predicted

(Isidori, Unterdorfer, Smith, EPJC36 (2004))

$Br(K_L \to \pi^0\mu^+\mu^-)\quad (\times 10^{-12})$



$Br(K_L \to \pi^0 e^+e^-)\quad (\times 10^{-12})$

Constructive

$$B_{e^+e^-} = 3.7^{+1.1}_{-0.9}\times 10^{-11}$$

$$B_{\mu^+\mu^-} = 1.5^{+0.3}_{-0.3}\times 10^{-11}$$

now favored by two independent analyses*

Destructive

$$B_{e^+e^-} = 1.7^{+0.7}_{-0.6}\times 10^{-11}$$

$$B_{\mu^+\mu^-} = 1.0^{+0.2}_{-0.2}\times 10^{-11}$$

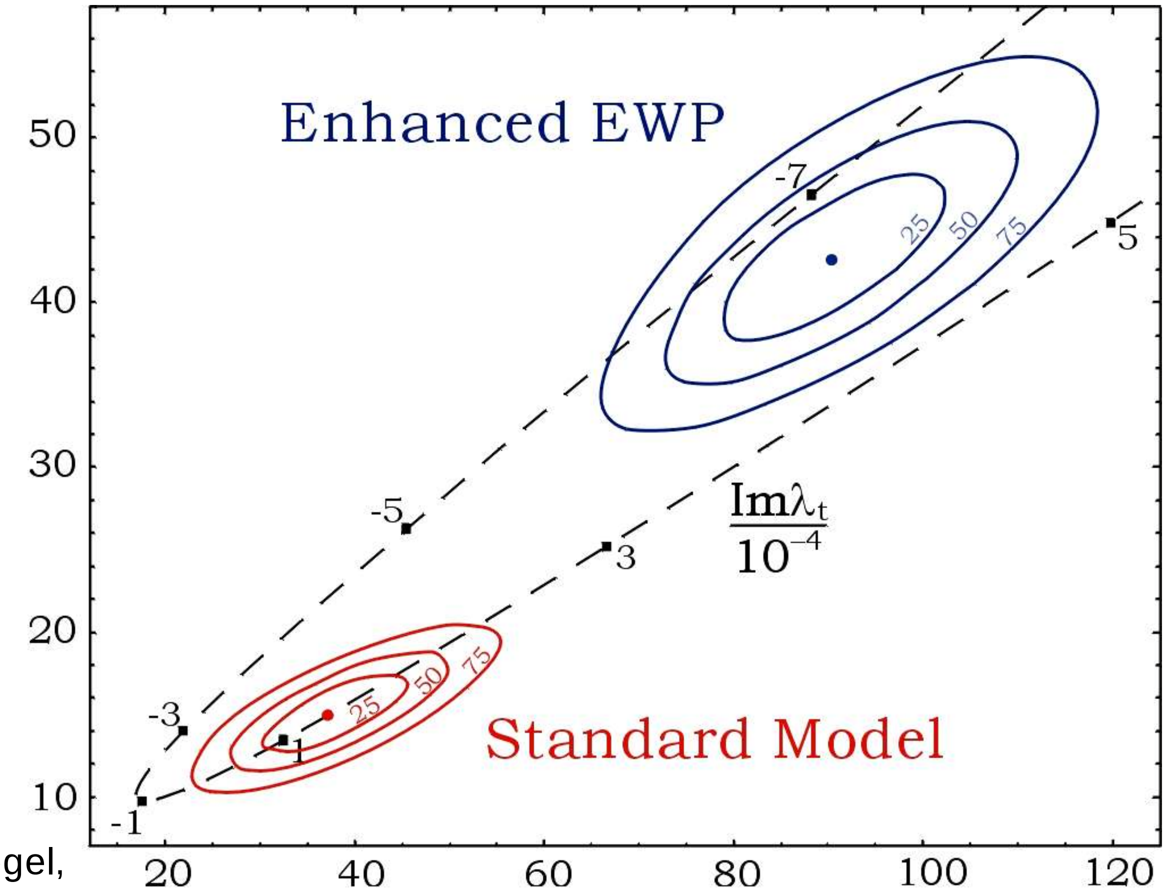
*G. Buchalla, G. D’ Ambrosio, G. Isidori, Nucl.Phys.B672,387 (2003)

*S. Friot, D. Greynat, E. de Rafael, hep-ph/0404136, PL B 595

K^0_L ?π ^{0}ee (μ μ): Sensitivity to New Physics

Isidori, Unterdorfer,Smith:

$Br(K_L \to \pi^0\mu^+\mu^-) \quad (\times 10^{-12})$



$Br(K_L \to \pi^0 e^+e^-) \quad (\times 10^{-12})$

Fleischer et al*:

Ratios of B_d ? Kπ modes could be explained by enhanced electroweak penguins which, in turn, would enhance the K_L BR's:

$$B^{NP}_{e^+e^-} = 9.0^{+1.6}_{-1.6} \times 10^{-11}$$

$$B^{NP}_{\mu^+\mu^-} = 4.3^{+0.7}_{-0.7} \times 10^{-11}$$

- A. J. Buras, R. Fleischer, S. Recksiegel, F. Schwab, hep-ph/0402112, NP B697 (2004)

NA48/2 : K^+/K^-

NA48/2: Aim

Direct CP violation

in $K^{\pm} \rightarrow \pi^{\pm} \pi^{\pm} \pi^{\mp}$, $K^{\pm} \rightarrow \pi^{\pm} \pi^{0} \pi^{0}$

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

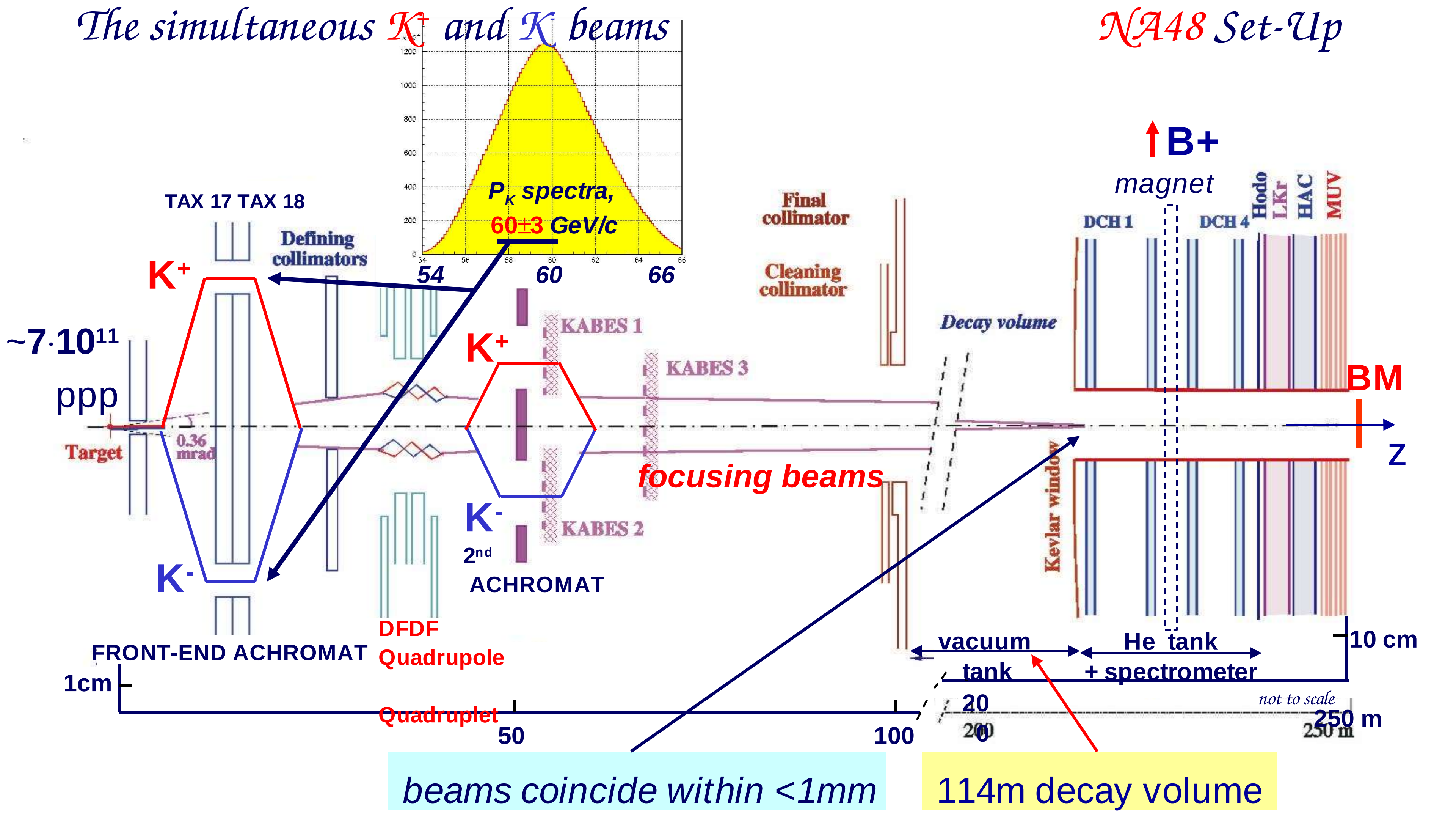
$$M(u) \propto 1 + g \cdot u, \quad u = f(E^{*}_{\pi-odd})$$

$$\delta(A_g) < 2 \cdot 10^{-4}$$

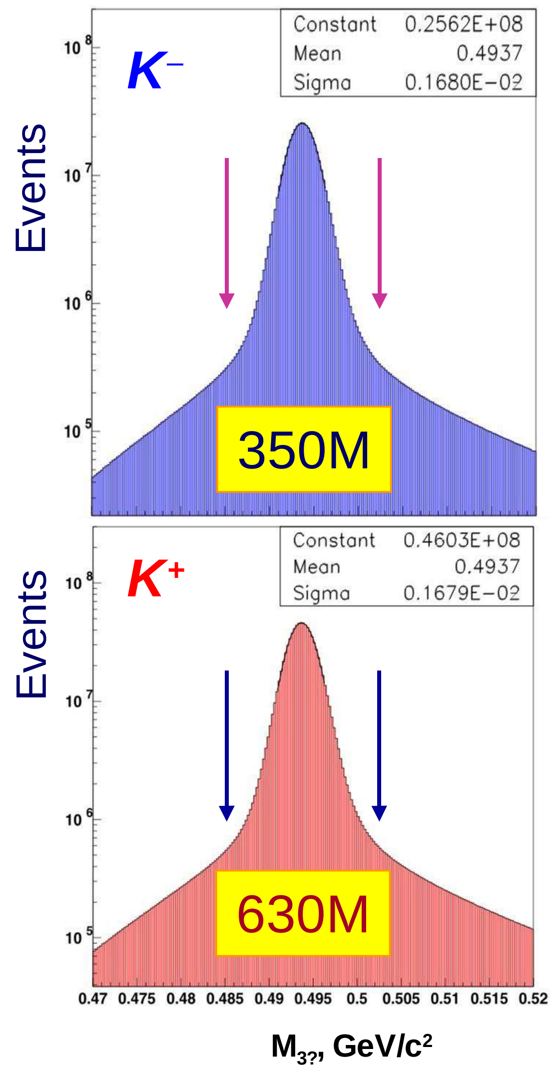
In addition:

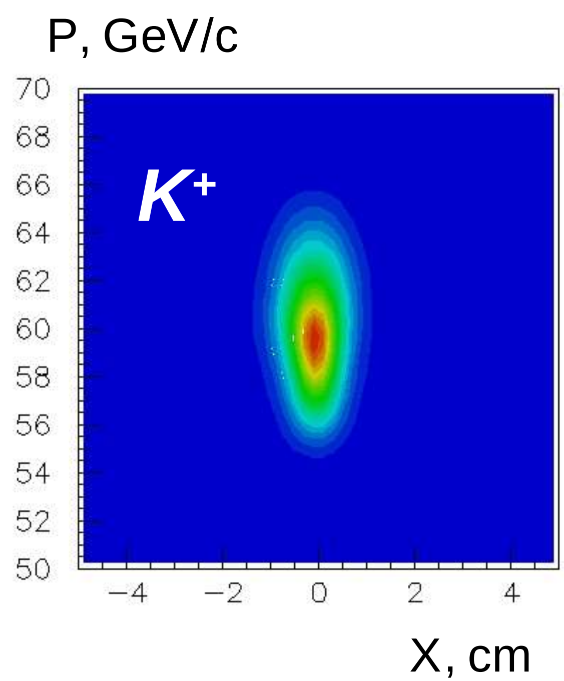
- **Study of $\pi\pi$ scattering using Ke4 (and $\pi^{\pm}\pi^{0}\pi^{0}$) events**
- **Study of medium-rare charged kaon decays**
- **Study of semi-leptonic decays**

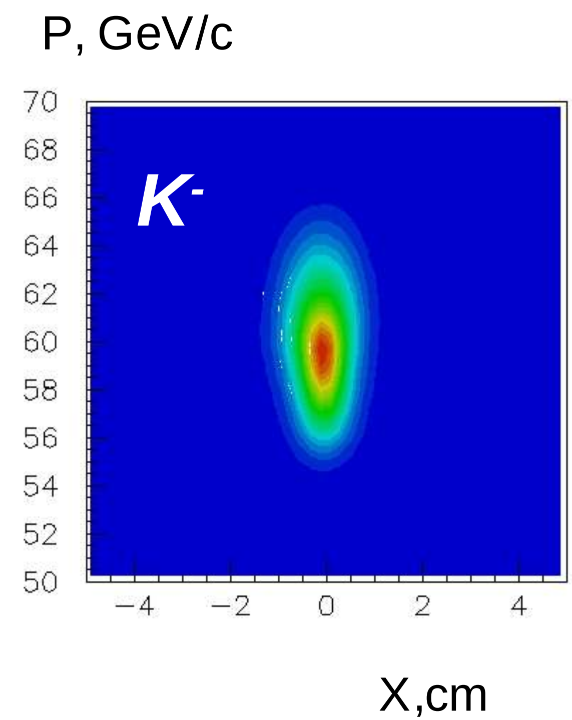
NA48/2 experiment configuration



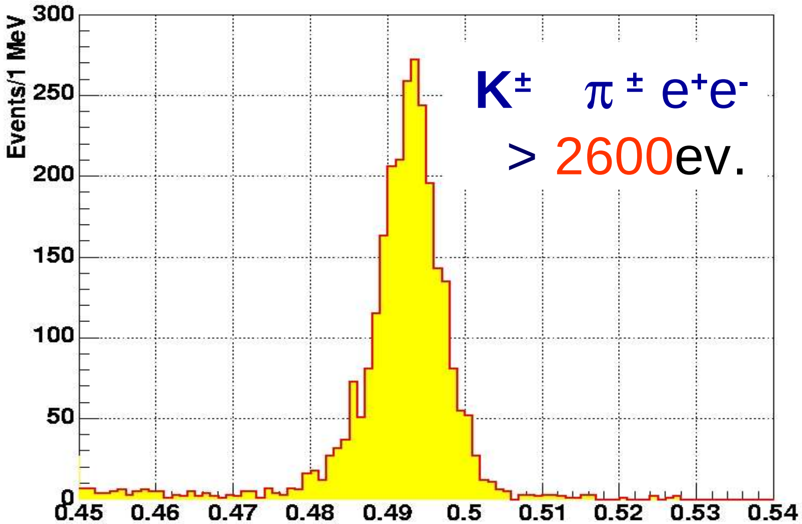
NA48/3: Subset of 2003 data



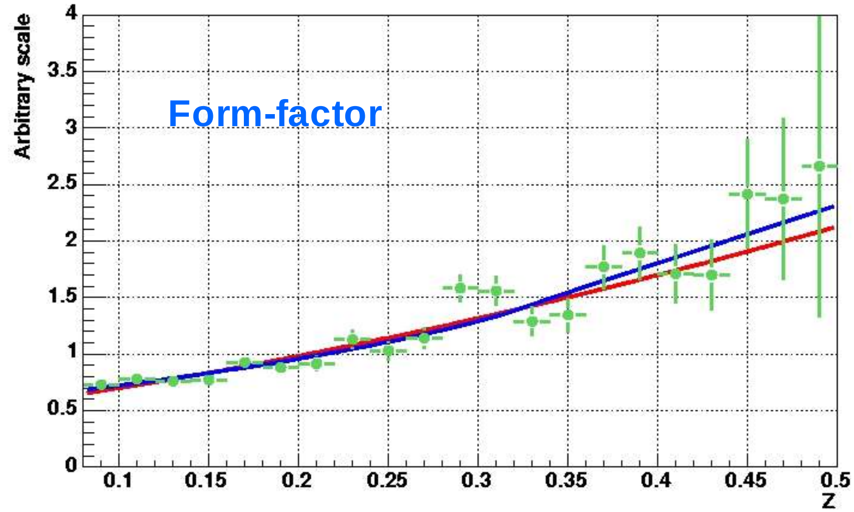




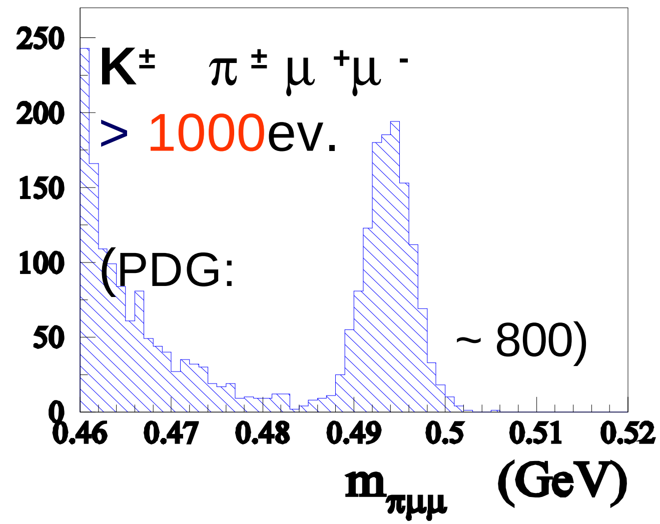
$K^{\pm}$ $\pi^{\pm}e^{+}e^{-}$ & $K^{\pm}$ $\pi^{\pm}\mu^{+}\mu^{-}$ selection *(preliminary)*



M($\pi^{\pm}$ $e^{+}e^{-}$), GeV/c^{2}

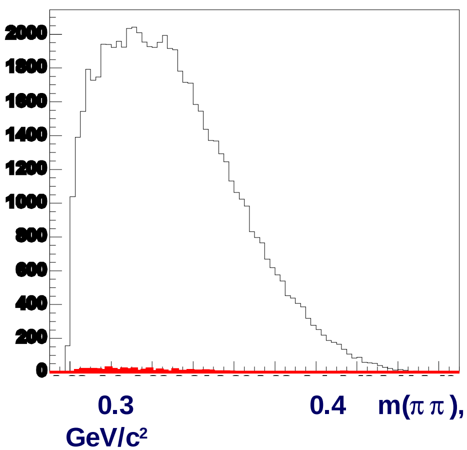


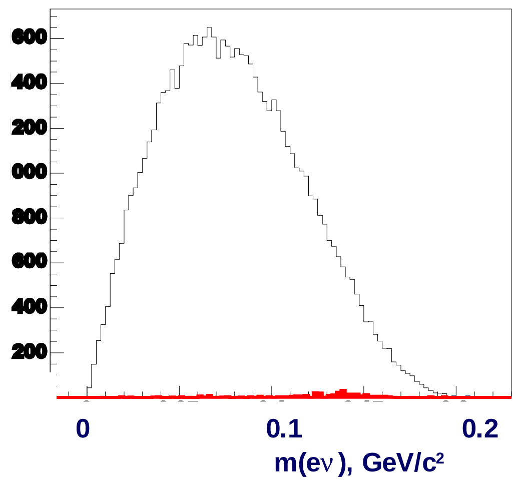
- low background (1-2%)
- expected data sample in 2003-2004 comparable to the World best sample

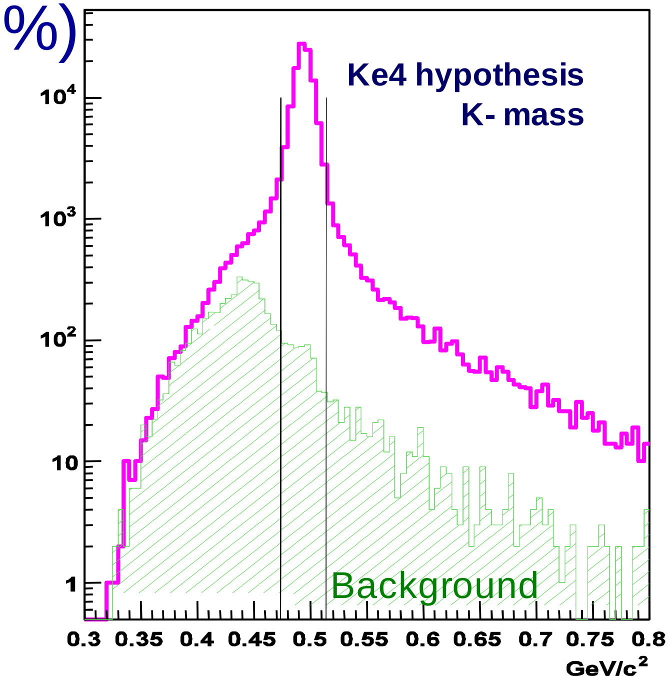


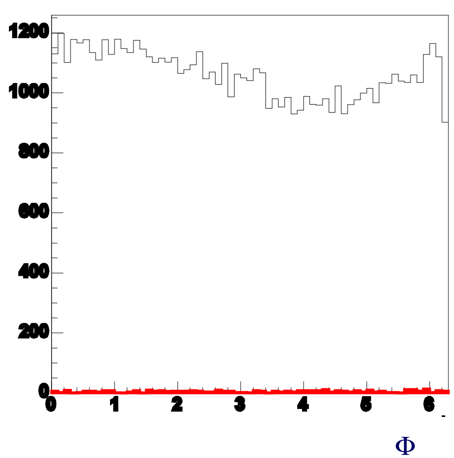
$K^{\pm}$ $\pi^{+}\pi^{-}e^{\pm}$? (K_{e4}) selection *(preliminary)*

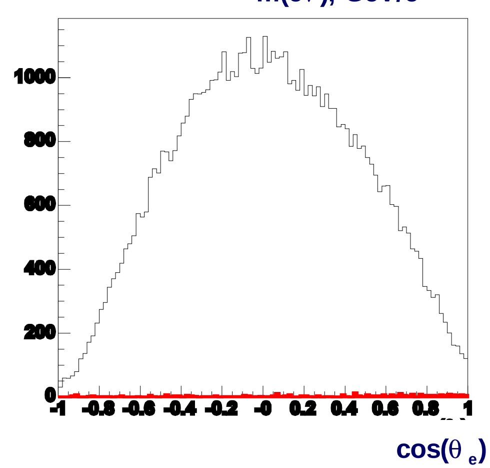
2003 data: > 500k (background ~0.6%)

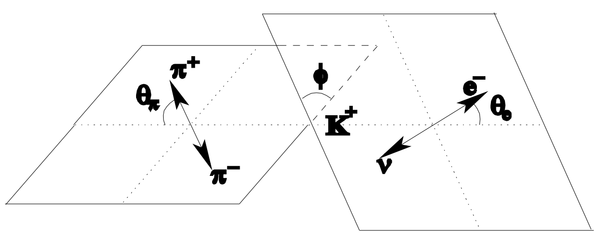










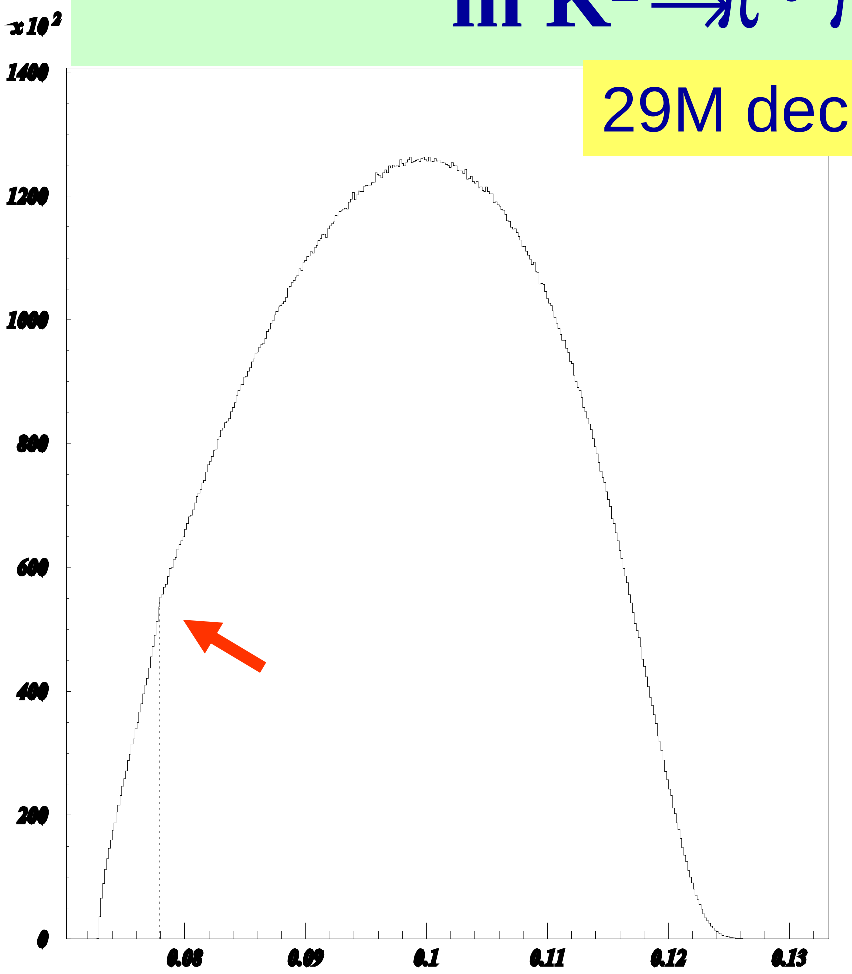


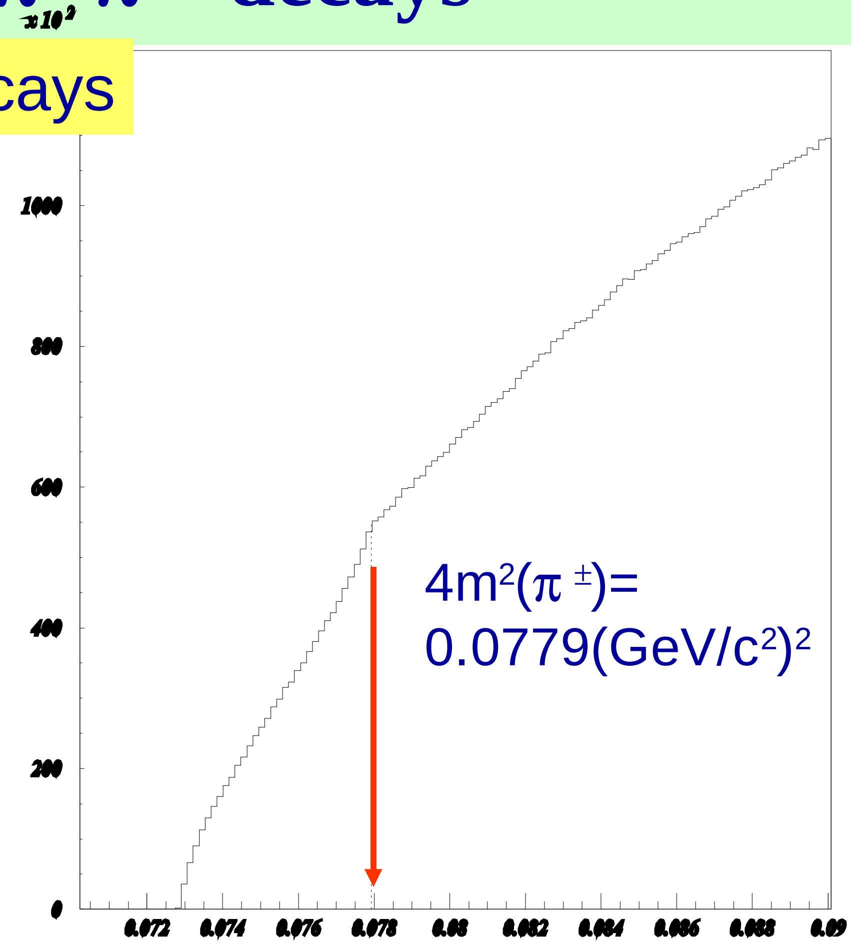
Cabibbo-Maksymowicz variables [backgr. in red]

2004 data: expected > 500k

First Observation of the $\pi^+\pi^-$ - rescattering in $K^\pm \to \pi^0\pi^0\pi^\pm$ decays

29M decays



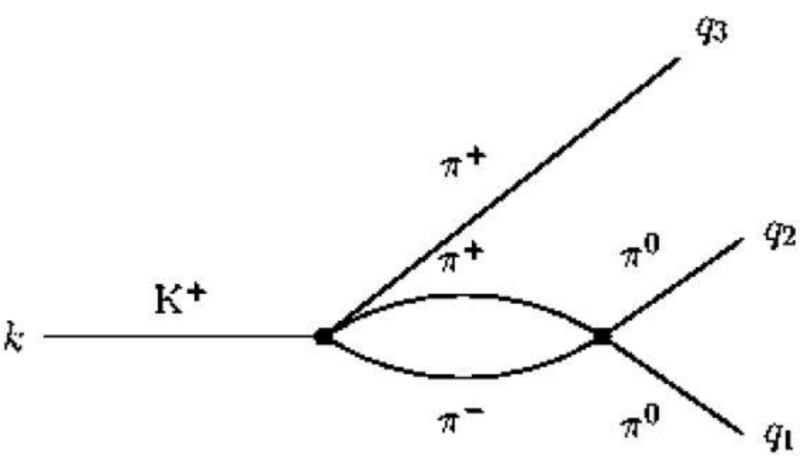


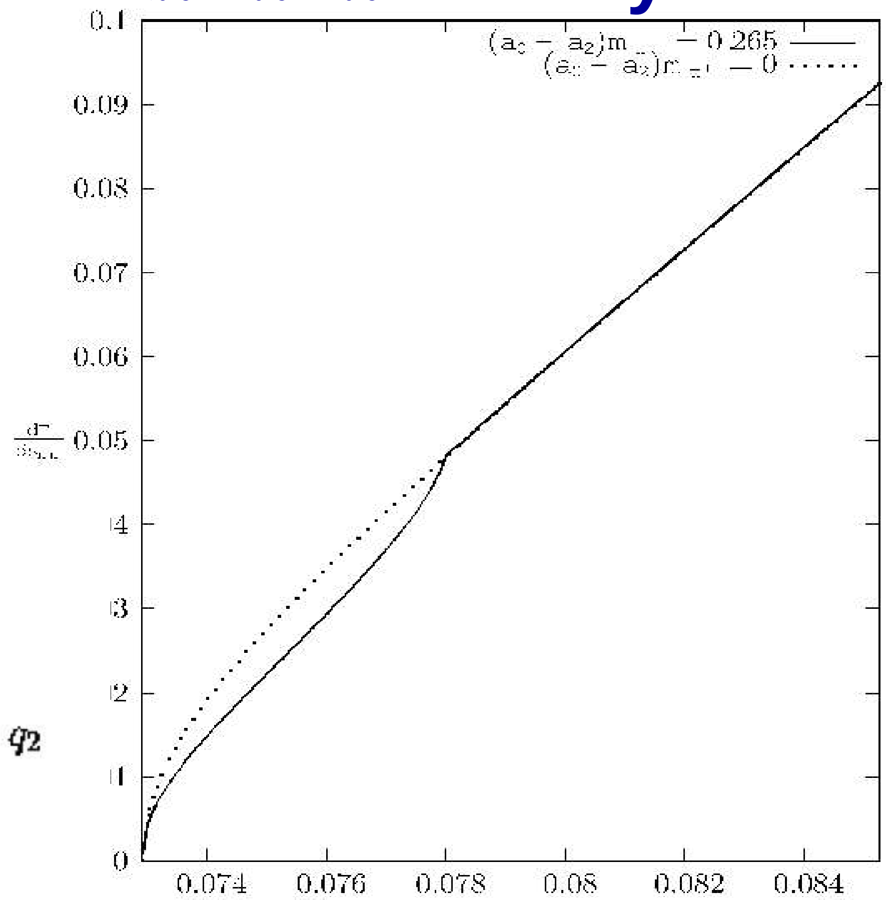
Determination of a_0-a_2 from $K^{\pm} \rightarrow \pi^0 \pi^0 \pi^{\pm}$ decays

a_0-a_2 = *0.265* (solid line)

= *0.* (dashed line)

N. Cabibbo
hep-ph 0405001, PRL93 (2004)





$M^2(\pi^0\pi^0)$, $(MeV/c^2)^2$

The Near Future: NA48/3
$K^+ ? \pi^+ \nu \nu$ at the CERN-SPS

SPSC-2004-029
SPSC-I229

Cambridge, CERN, Dubna, Ferrara,
Firenze, Mainz, Perugia,
Pisa, Saclay, Torino, + ??

Work inspired by:

- **High Quality NA48/2 charged Kaon beams and Beam Spectrometers**
- **Outstanding Progress by BNL E787/E949**
- **In flight technique with separated beam (FNAL CKM, not ratified by P5)**

“CERN Director General Outlines Seven-point Strategy for European Laboratory”

18.6.2004 Official CERN Press Release

Geneva 18 June 2004. “At the 128th session of CERN Council, held today under the chairmanship of Professor Enzo Iarocci, CERN Director General, Robert Aymar, outlined a <u>seven-point scientific strategy for the Organization</u>. Top of the list was completion of the Large Hadron Collider (LHC) project with start-up on schedule in 2007. This was followed by consolidation of existing infrastructure at CERN to guarantee reliable operation of the LHC, with the third priority being an examination of a possible future experimental programme apart from the LHC.”

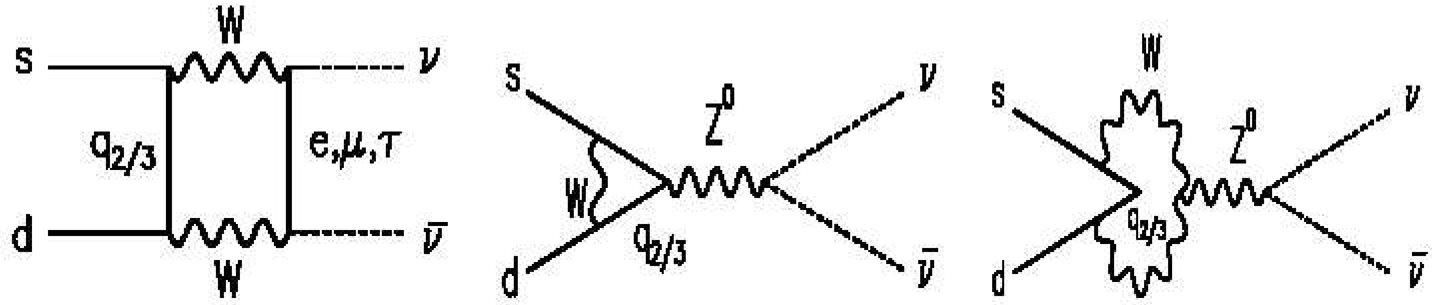
....

....

The possible Future Programme was reviewed in Villars

$K^+ ? \pi^+ \nu \nu$: Theory

- **The hadronic matrix element can be extracted from the well measured $K^+ ? \pi^0 e^+ \nu$**
- **No long distance contributions**



$$B_{SD}(K^+ \to \pi^+ \nu\bar{\nu}) = \frac{\kappa_+ \alpha^2 B(K_{e3})}{2\pi^2 \sin^4\theta_W |V_{us}|^2} \sum_l |X_t\lambda_t + X_c\lambda_c|^2 = 8.9\times 10^{-11} A^4\left[(\rho_0 - \bar{\rho})^2 + \bar{\eta}^2\right]$$

QCD NLO Buchalla, Buras 1999

Prediction (CKM Workshop): $BR(K^+ ? \pi^+ \nu \nu) = 8.0 \pm 1.1 \times 10^{-11}$

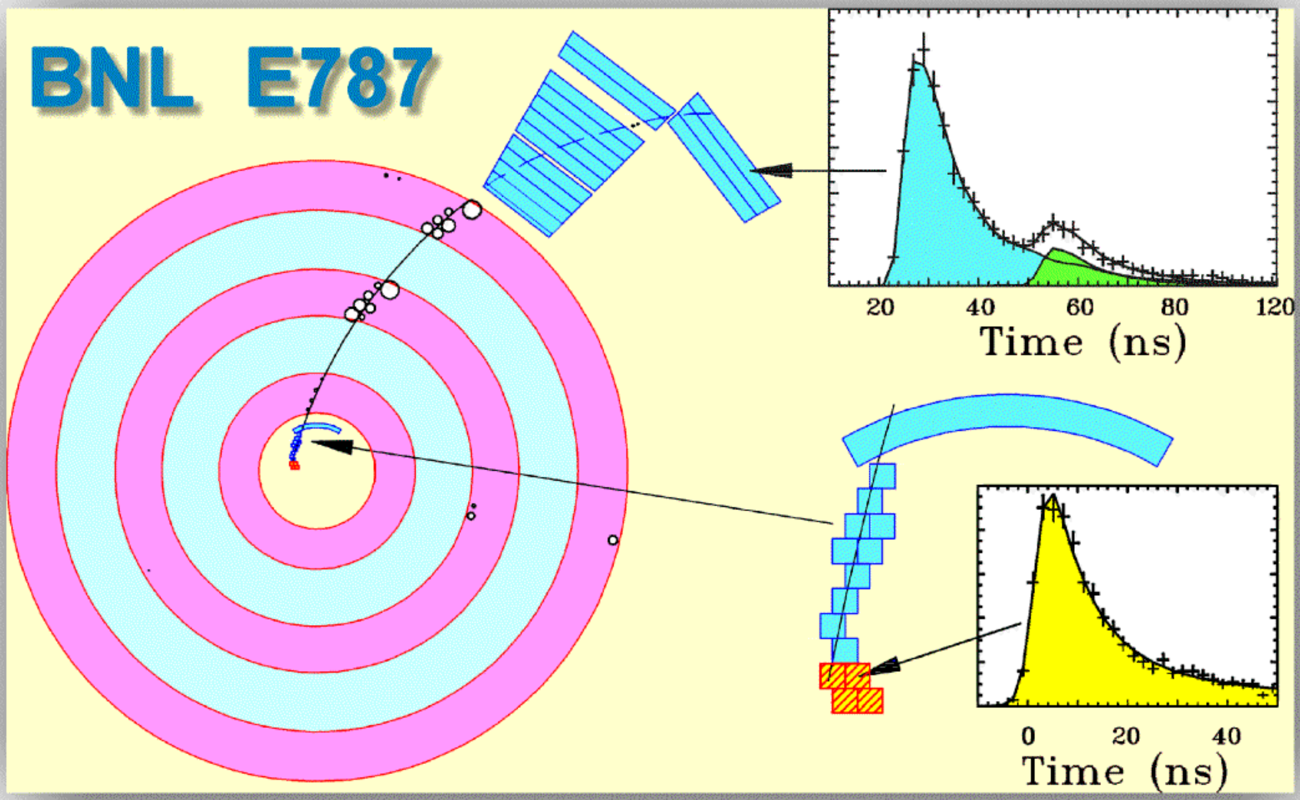
Expect improvements NNLO calculation + reduction parametric uncertainty 4 % error (Buras)

Main K^+ decay modes competing with $K^+ ? \pi^+ \nu \nu$

Decay	BR	Suppression:
$\mu^+\nu$	63 %	μ PID, kinematics
$\pi^+\pi^0$		γ veto, kinematics
$\pi^+\pi^+\pi^-$	21 %	CHV, kinematics
$\pi^+\pi^0\pi^0$	6 %	γ veto, kinematics
$\pi^0\mu^+\nu$	2 %	γ veto, μ PID
$\pi^0 e^+\nu$	3 % (called $K^+_{\mu 3}$)	γ veto, E/P
	5 % (called K^+_{e3})	

$BR(K^+ ? \pi^+ \nu \nu) \sim 10^{-10}$!!

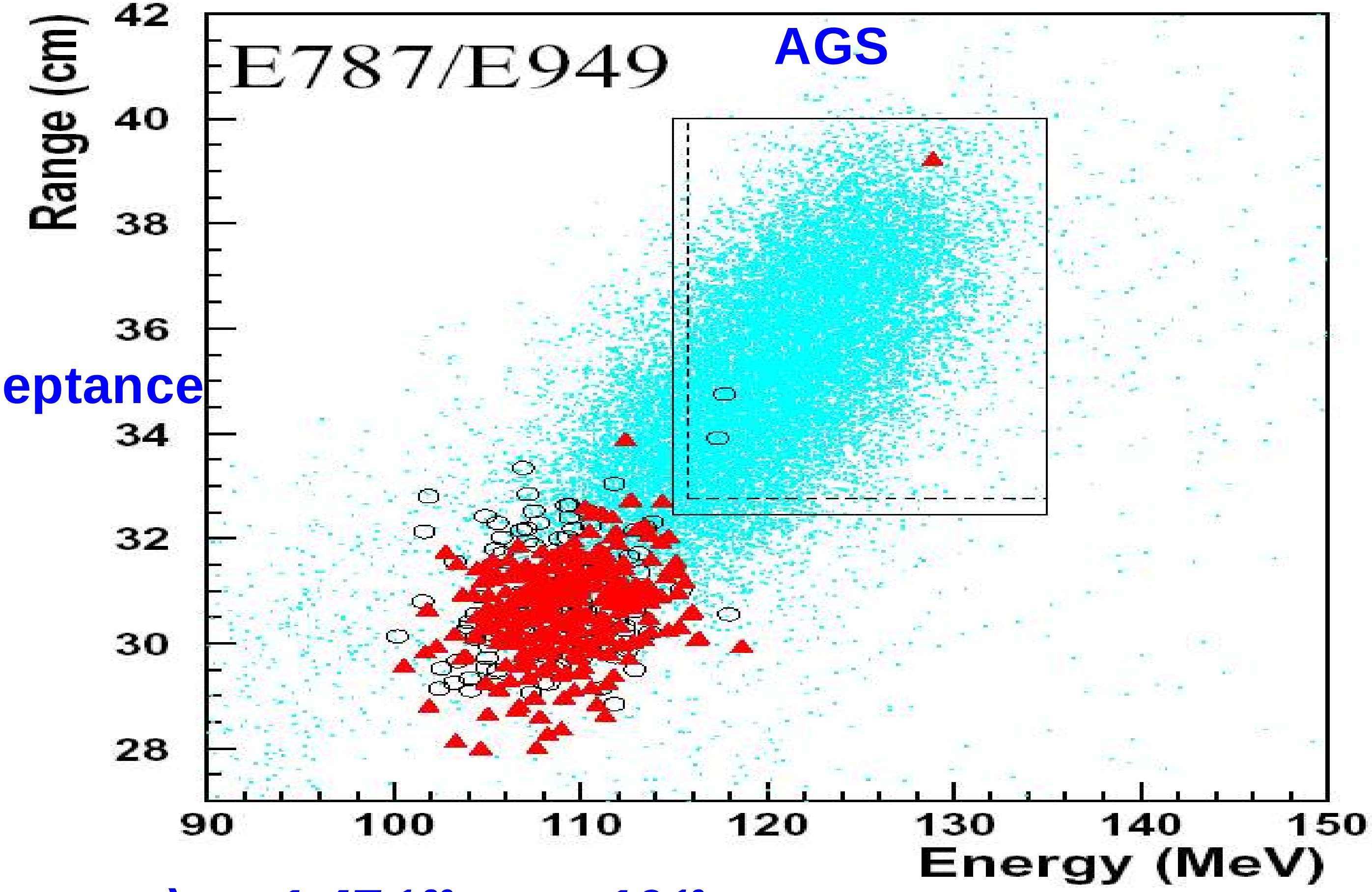
State of the art:
AGS-E787/E949 $K^+ ? \pi^+ \nu \nu$



K^{+}?$\pi^{+}\nu\nu$: State of the art

hep-ex/0403036

Stopped K
~0.1 % acceptance



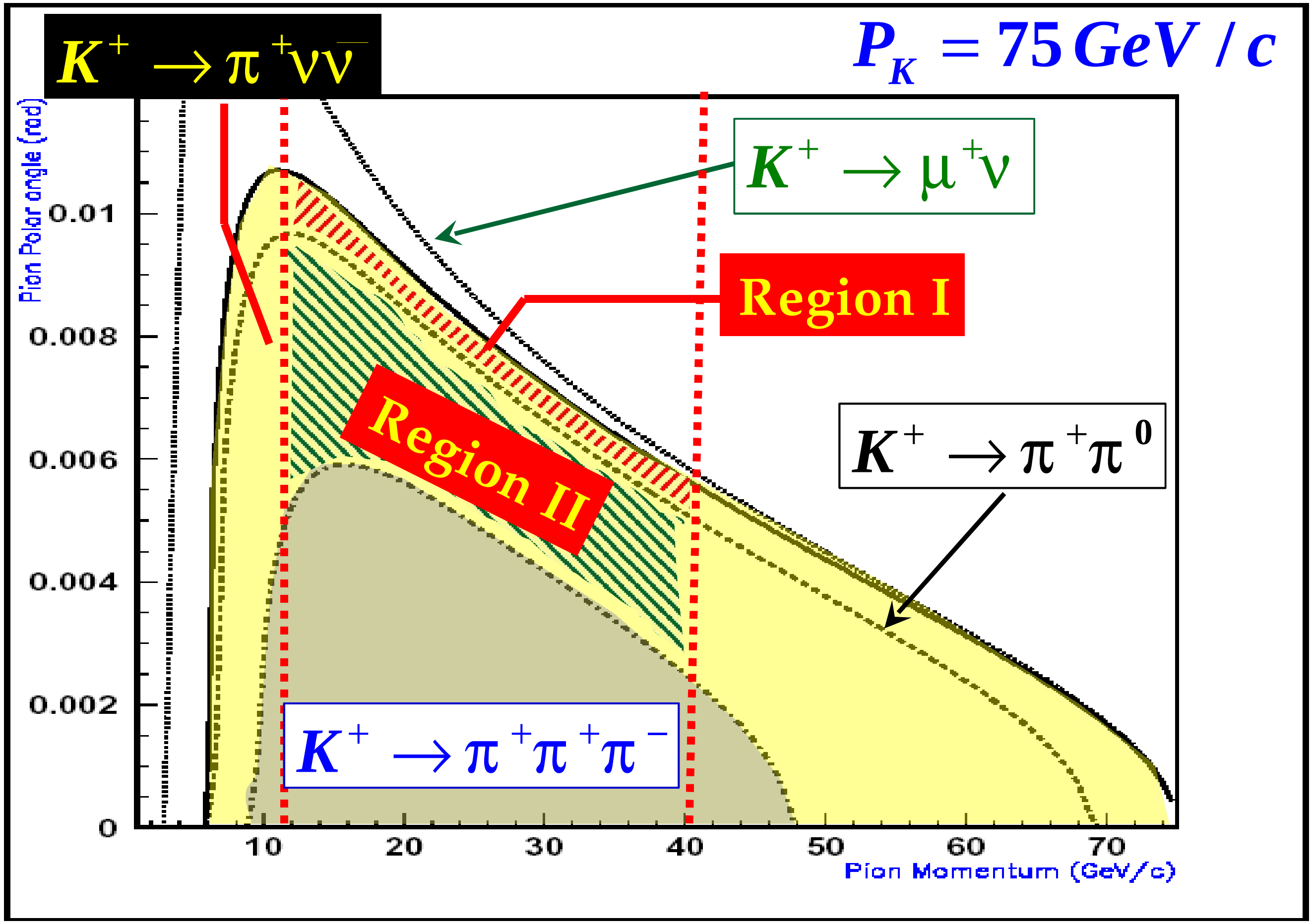
BR(K^{+} ? $\pi^{+}\nu\nu$) = $1.47^{+1.30}_{-0.89}$ × 10^{-10}

- **Twice the SM, but only based on 3 events…**

NA48/3: Framework

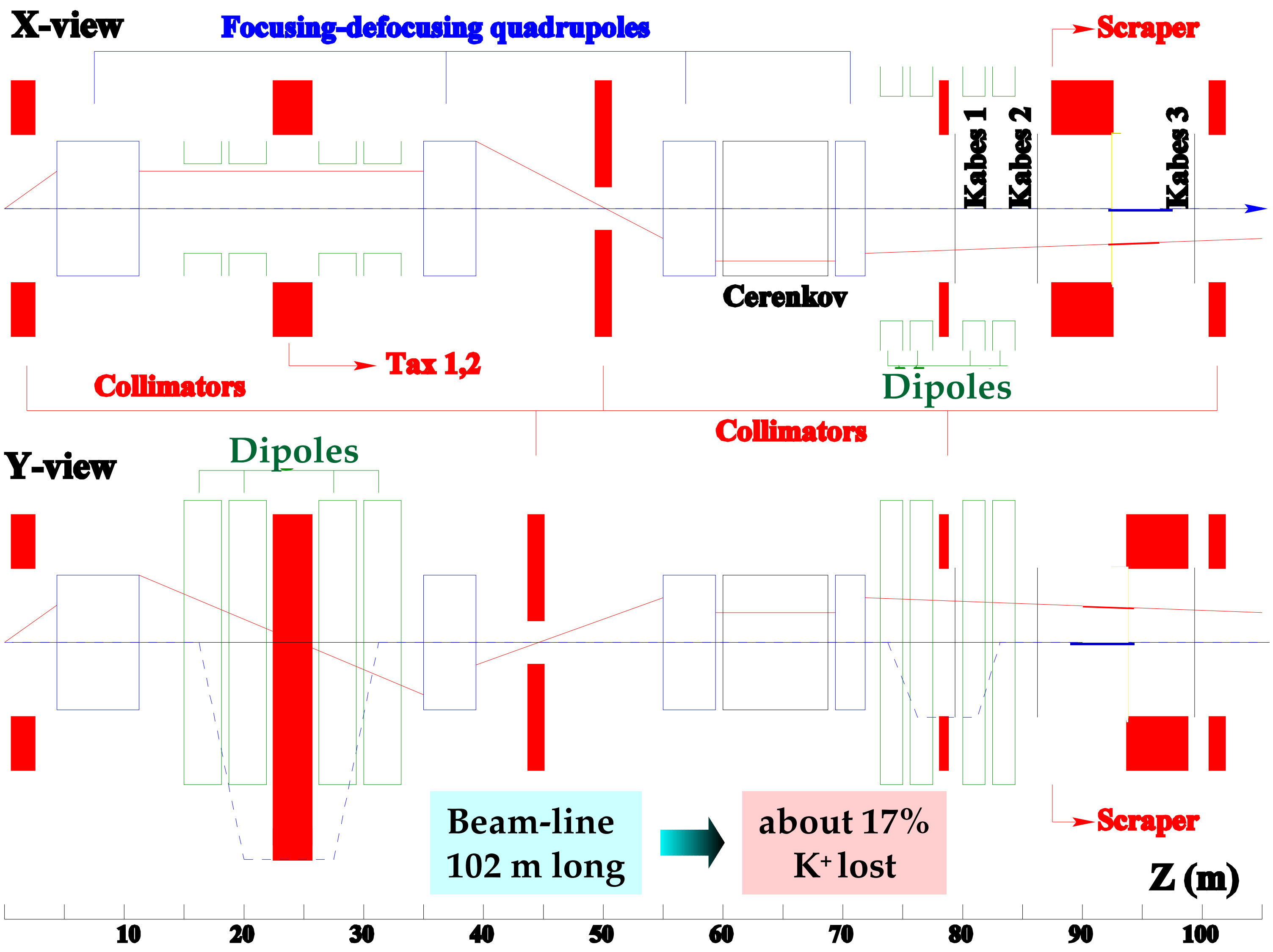
- So far $K^+ ? \pi^+ \nu \nu$ only studied with kaon decays at rest
  - This limits the statistics to a few events
- NA48/3 can collect ~100 events at the SPS by 2010
- Employ high energy kaons has the following advantages:
  - The larger cross section increases the kaon content in the beam
  - The rejection of backgrounds from $K^+ ? \pi^+ \pi^0$ is simplified
    - Tens of GeV of EM energy is deposited in the photon vetoes!
  - Accidental background are minimised (muons ~ 7 MHz)
    - The use of unseparated beam becomes a possibility
- 2/3 of the final state is invisible !!
  - The kaon and the pion must be redundantly measured to keep backgrounds under control
  - Muon and photon vetoes are essential

Kinematics

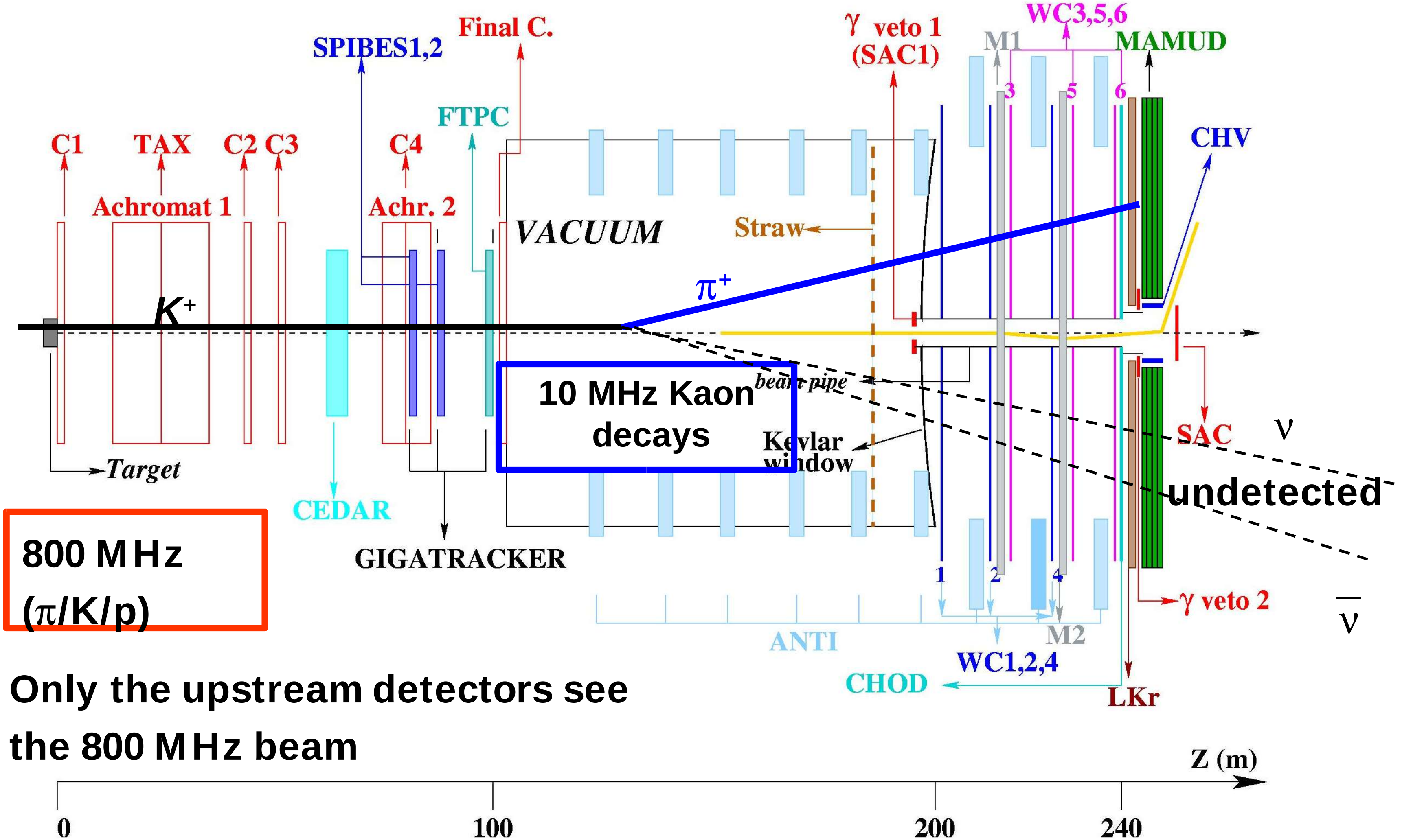


$K^+ \to \pi^+ \nu \bar{\nu}$
$P_K = 75\, GeV/c$
$K^+ \to \mu^+ \nu$
Region I
Region II
$K^+ \to \pi^+ \pi^0$
$K^+ \to \pi^+ \pi^+ \pi^-$
Pion Polar angle (rad)
0.01
0.008
0.006
0.004
0.002
0
10
20
30
40
50
60
70
Pion Momentum (GeV/c)

NA48/3: Beam Layout



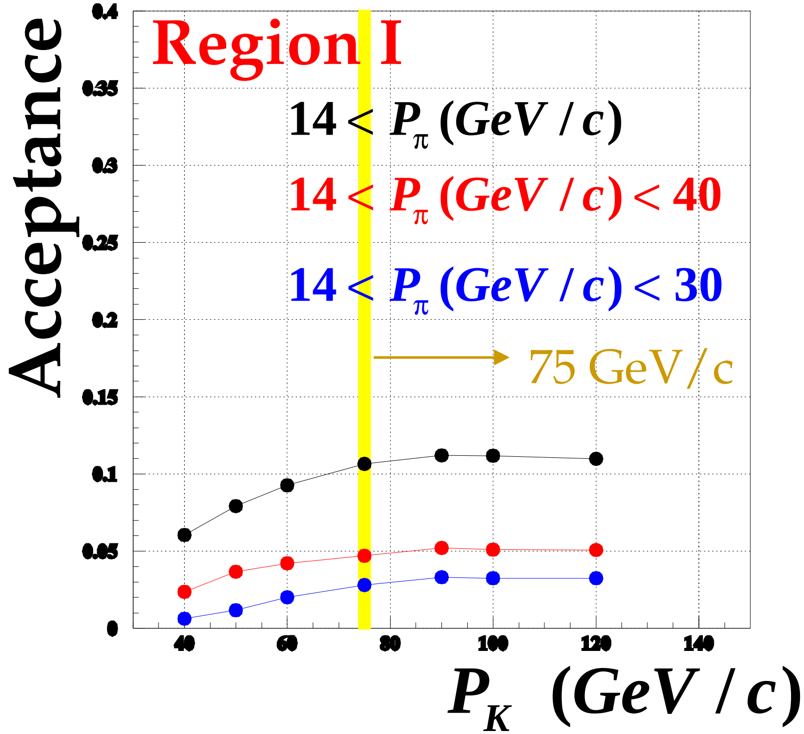
NA48/3 Detector Layout



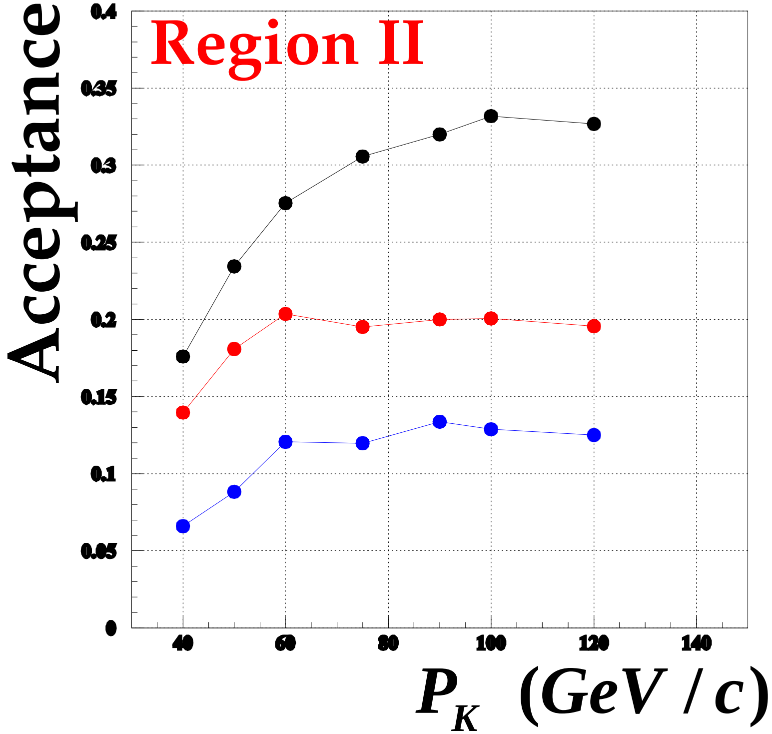
Only the upstream detectors see the 800 MHz beam

Acceptance

$0 < m^2_{miss} < 0.01 \ (GeV/c^2)^2$



$0.026 < m^2_{miss} < 0.068 \ (GeV/c^2)^2$



$P_K = 75 \, GeV/c \quad P_\pi < 40 \, GeV/c$

Assume Acceptance (Region I+II) ~ 10%

New high-intensity K^+ beam for NA48/3

Already Available

Beam:	Present K12 (NA48/2)	New HI K^+ > 2006	Factor wrt 2004
SPS protons per pulse on T10	1×10^{12}	3×10^{12}	3.0
Duty cycle (s./s.)	4.8 / 16.8		1.0
Solid angle (μ sterad)	≈ 0.40	≈ 16	40
Av. K^+ momentum $<p_K>$ (GeV/c)	60	75	Total : 1.35
Mom. band RMS: (Δp/p in %)	≈ 4	≈ 1	~0.25
Area at Gigatracker (cm^2)	≈ 7.0	≈ 20	≈ 2.8
Total beam per pulse ($\times 10^7$)	5.5	250	~45 (~27)
per Effective spill length (MHz)	18	800	~45 (~27)
/ … / cm^2 (KABES) (MHz)	2.5	40	~16 (~10)
Eff. running time / yr (pulses)	$3 * \times 10^5$	$3.1 * 10^5$	1.0
K^+ decays per year	1.0×10^{11}	4.0×10^{12}	≈ 40

NA48/3: Aim

- Collect 80 $K^+ ? \pi^+ \nu \nu$ events in about two years of data taking for:
  - 4×10^{12} Kaon decays/SPS year
  - BR($K^+ ? \pi^+ \nu \nu$) ~10^{-10}
  - Acceptance ~ 10%

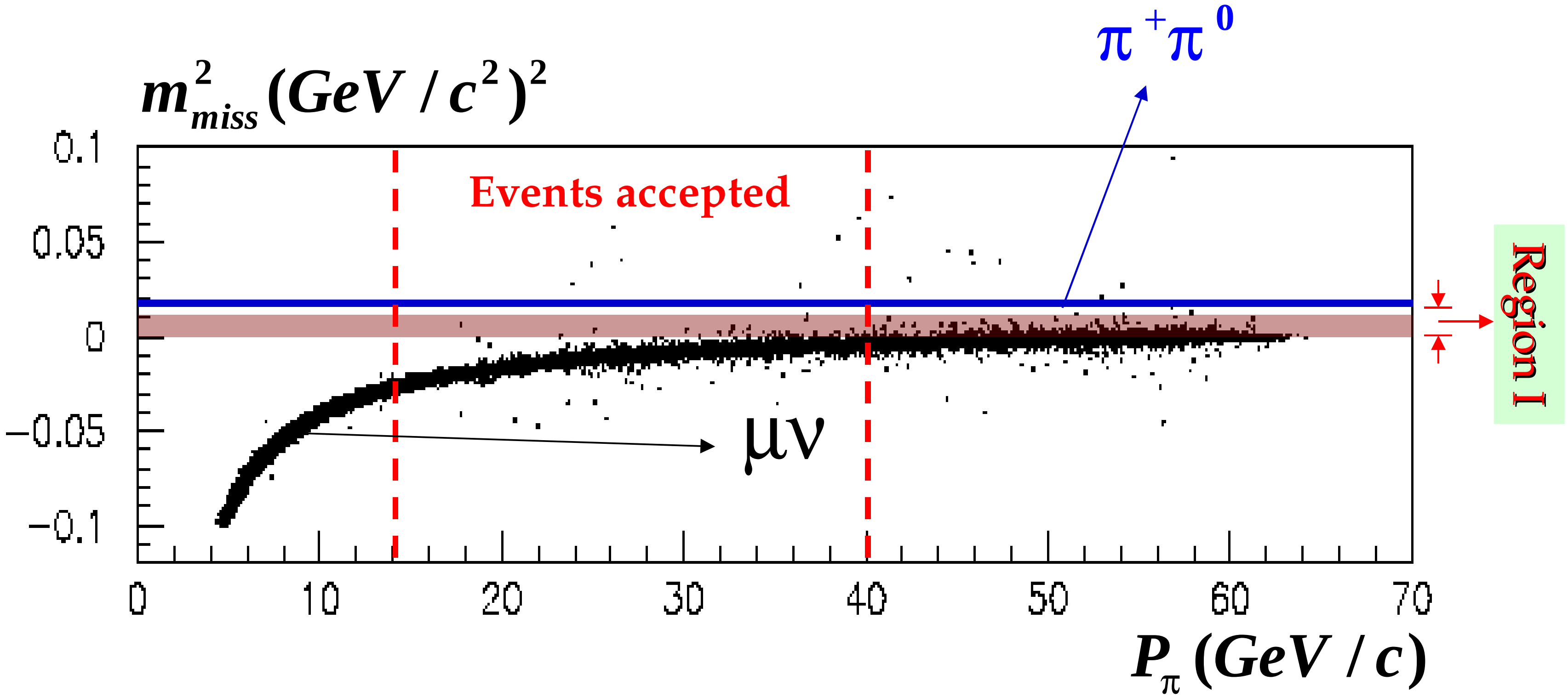
Detectors

- CEDAR
  - To tag positive kaon identification
- GIGATRACKER
  - To Track secondary beam before it enters the decay region
- ANTI
  - Photon vetoes surrounding the decay tank
- WC
  - Wire chambers to track the kaon decay products
- CHOD
  - Fast hodoscope to make a tight K-pi time coincidence
- LKR
  - Forward photon veto and e.m. calorimeter
- MAMUD
  - Hadron calorimeter, muon veto and sweeping magnet
- SAC and CHV
  - Small angle photon and charged particle vetoes

GIGATRACKER

- **Specifications:**
  - Momentum resolution to ~ 0.5 %
  - Angular resolution ~ 10 μ rad
  - Time resolution ~ 100 ps
  - Minimal material budget
  - Perform all of the above in
    - 800 MHz hadron beam, 40 MHz / cm^2
- **Hybrid Detector:**
  - SPIBES (Fast Si micro-pixels)
    - Momentum measurement
    - Facilitate pattern recognition in subsequent FTPC
    - Time coincidence with CHOD
  - FTPC (NA48/2 KABES technology with FADC r/o)
    - Track direction

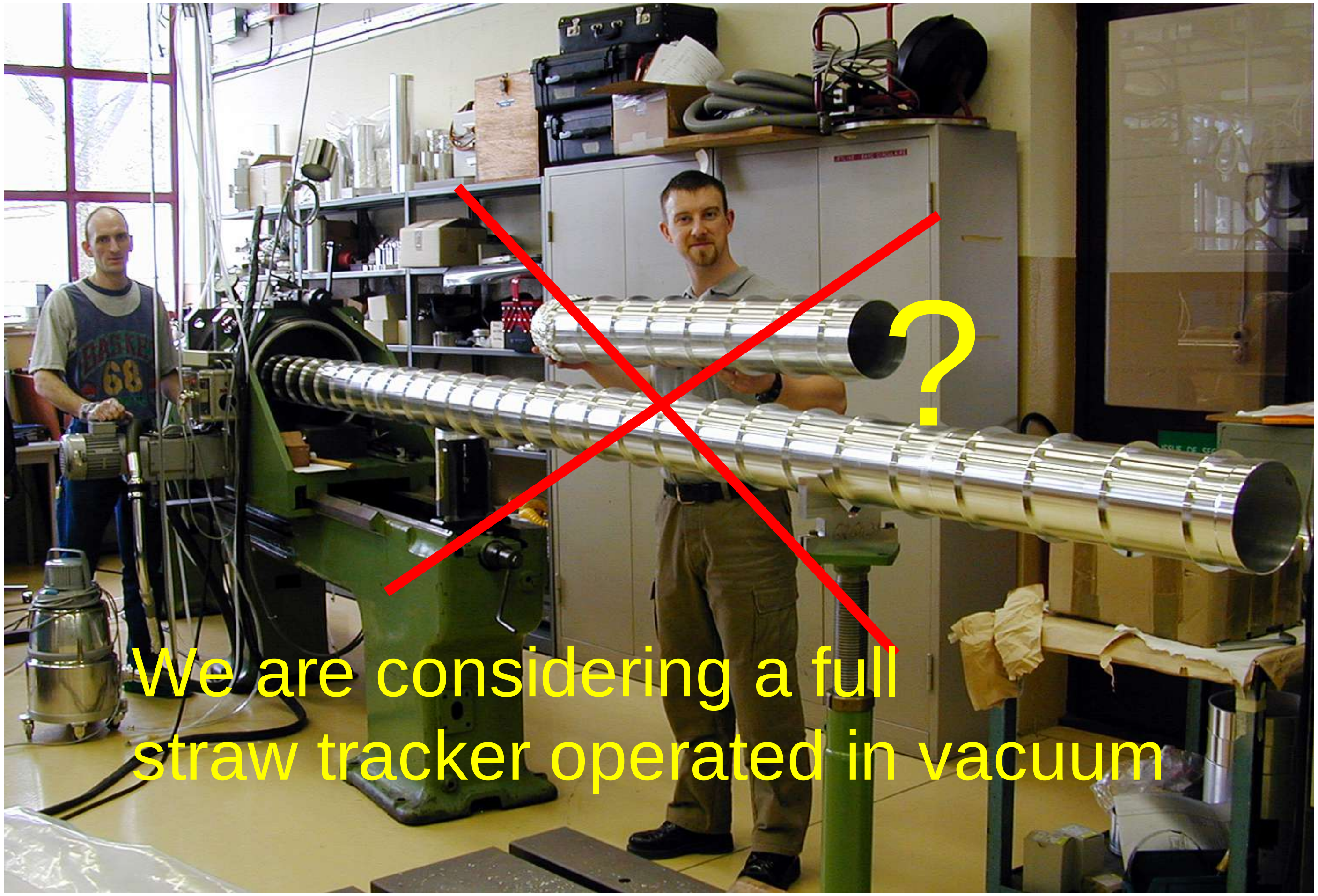
WC: Kinematical rejection



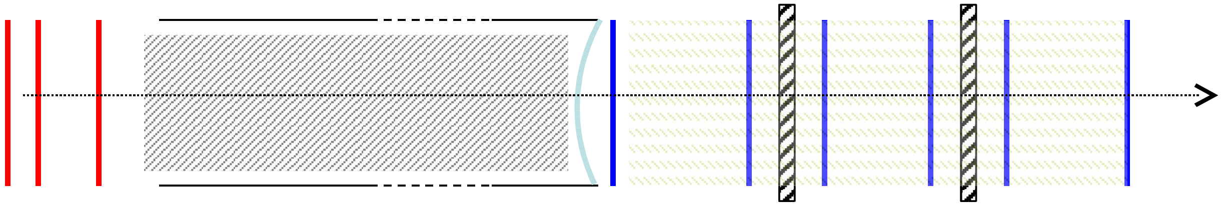
$$m^2_{miss} = m^2_K + m^2_\pi - 2(E_K E_\pi - p_K p_\pi \cos\theta_{K\pi})$$

Measured quantities

Can we do w/o beampipe?



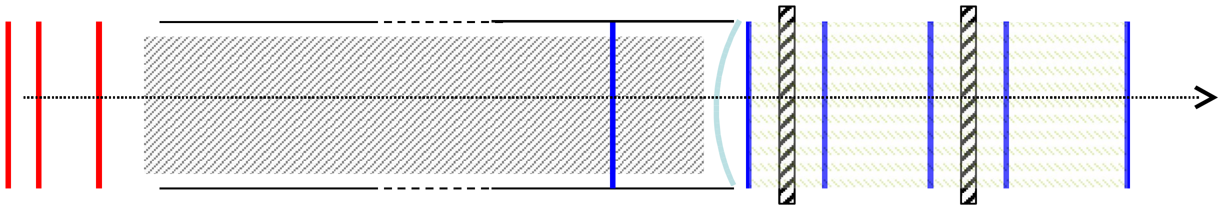
Simulation: Geometry



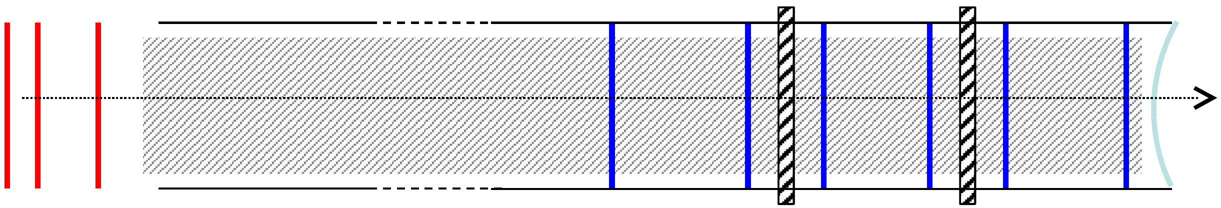
Standard

Testrun 2004 (beatch file)

NA48/3 (beatch file)

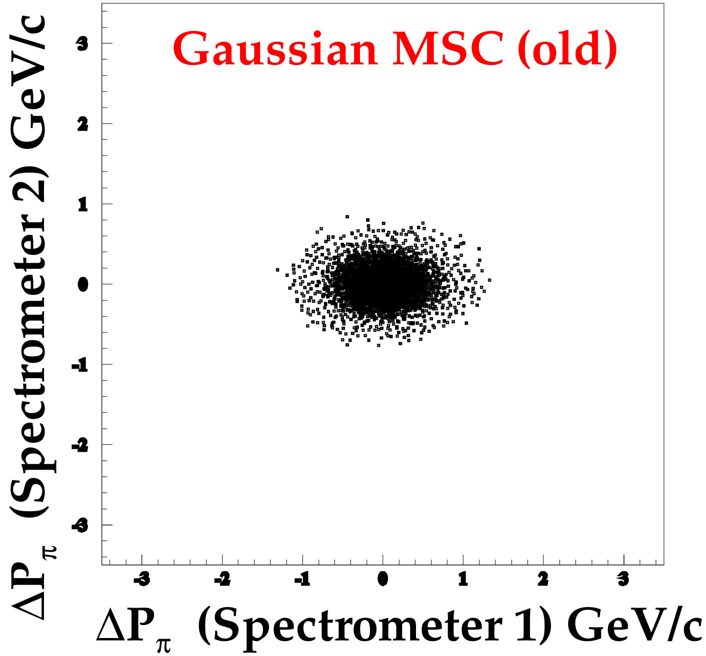


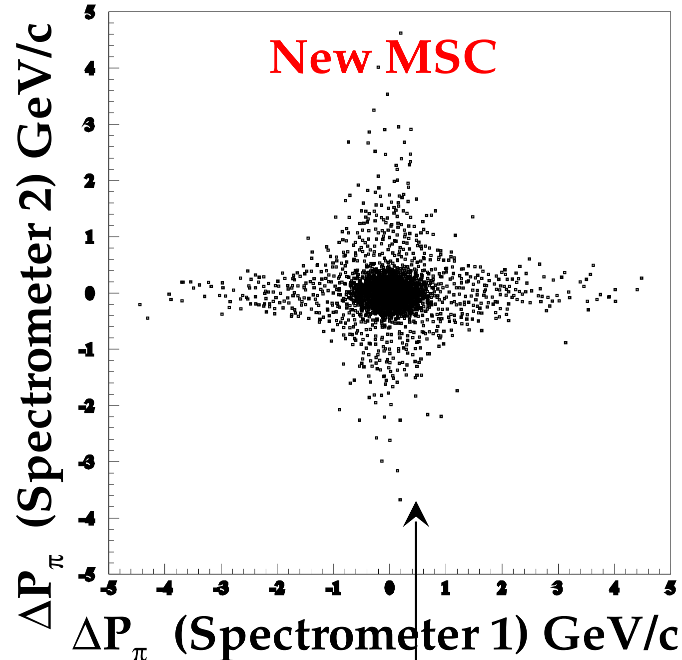
Upgrade1



Upgrade2

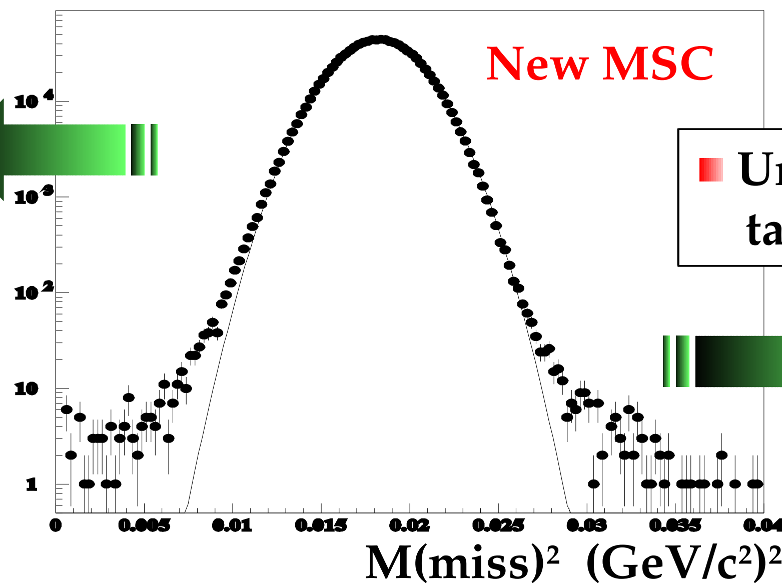
New NA48/3 simulation





- Uncorrelated non gaussian tails

REGION I



REGION II

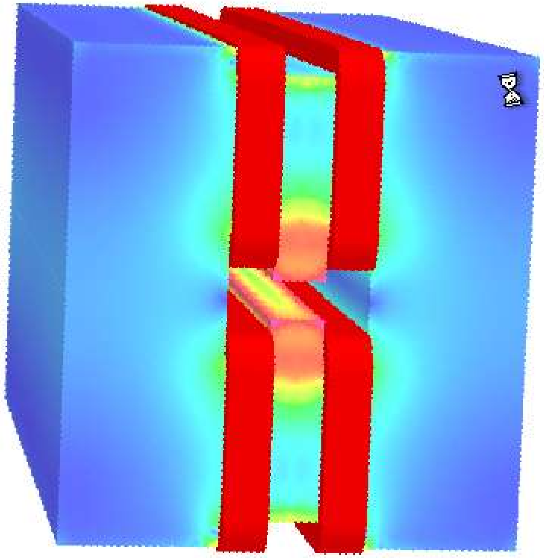
ANTI

- Set of ring-shaped photon vetoes surrounding the decay tank
- Specification: inefficiency to detect photons above 100 MeV $< 10^{-4}$
- The NA48 ANTI' s (AKL) need to be replaced
- Extensive R&D Performed by American and Japanese groups
- Claims that inefficiency as low as 10^{-5} can be achieved
- Baseline solution: Lead/ Plastic scintillator sandwich (1-2 mm lead / 5 mm plastic scintillator)
- Cost driver of NA48/3

LKR

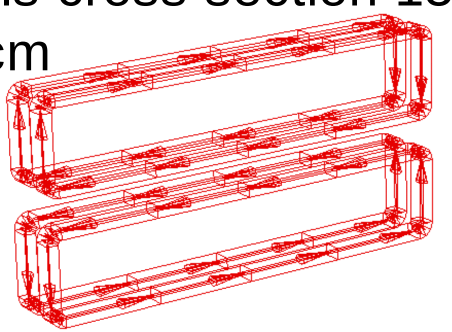
- **The NA48 Liquid Krypton Calorimeter**
- **Must achieve inefficiency $< 10^{-5}$ to detect photons above 1 GeV**
- **Advantages:**
  - **It exists**
  - **Homogeneous (not sampling) ionization calorimeter**
  - **Very good granularity (~2×2 cm^2)**
  - **Fast read-out (Initial current, FWHM~70 ns)**
  - **Very good energy (~1%, time ~ 300ps and position (~1 mm) resolution**
- **Disadvantages**
  - **0.5 % X_0 of passive material in front of active LKR**
  - **The cryogenic control system needs to be updated**

MAMUD



Pole gap is 11 cm V x 30 cm H

Coils cross section 15cm x 25cm



- To provide pion/muon separation and beam sweeping.
  - Iron is subdivided in 150 2 cm thick plates (260 $\times$ 260 cm^2)
- Four coils magnetise the iron plates to provide a 1.3 T dipole field in the beam region
- Active detector:
  - Strips of extruded polystyrene scintillator (1 x 4 x130 cm^3)
  - Light is collected by WLS fibres 1.2 mm diameter

Where are we?

- **September 26-27, 2004**
  - **Our presentations at Villars were well received**
- **October 7, 2004**
  - **John Dainton, SPSC Chairman reported the conclusions from Villars at CERN in a seminar at CERN**
  - **Verbally: "The SPSC looks forward to receive a proposal"**
- **October 18, 2004**
  - **Letter of Intent officially submitted.**

    SPSC-2004-029

    SPSC-I229
  - **We are establishing sub-working groups aiming to submit a proposal by mid 2005:**

    *****New Collaborators are welcome*****

From J. Dainton (SPSC Chair)

new rare decay frontier in K physics at CERN

new experiments planned for $K \to$ *important*

support R&D now for $K^+ \to {}^+$ *results* $\leq$ *2010*

- *no competition . .yet!*

longer term opportunity for $K^0 \to {}^0$

- *direct competition (decay at rest)*

synergy with energy frontier @ LHC . .@ CERN

- *B-physics*
- *LF violation*

2004 Test beam

- It was of the utmost importance to test in 2004 the performance of the NA48 detectors at intensities comparable to NA48/3 (no SPS in 2005!)
- This was a unique opportunity to collect data to validate our –simulated- understanding to quantify the necessary effort (technical and financial) to transform NA48 into an experiment capable to address $K^+ ? \pi^+ \nu \nu$.
- Thank to the extension granted by CERN we could test:
  - WC: raise intensity to about 30 times NA48/2
  - GIGATRACKER
    - Tested a state-of the-art ALICE SPD assembly in our beam
    - Use a thinner 25 micron MICROMEGAS amplification gap
    - Read out KABES with 480 MHz FADC (former NA48 tagger FADC)
    - Read KABES at ~14 times the NA48/2 rate
  - LKR: Complement the photon coverage with extra LKr electronics and a Small Angle Calorimeter SAC (CMS RCAL prototype)
  - CHOD test of prototypes

Time Schedule

- **2004**
  - Launch GIGATRACKER R&D
  - Vacuum tests
  - Evaluate straw tracker
  - Start realistic cost estimation
  - Complete analysis of beam-test data
- **2005**
  - Complete of the above
  - Complete Specifications
  - Submit proposal to SPSC
- **2006-2008**
  - Costruction, Installation and beam-tests
- **2009-2010**
  - Data Taking

Conclusions

- We have found a fortunate combination where a compelling physics case can be addressed with an existing accelerator, employing the infrastructure (i.e. civil engineering, hardware, some sub-systems) of an existing experiment
- We stress that this initiative in not a mere continuation of NA48
- We are seeking new Collaborators!