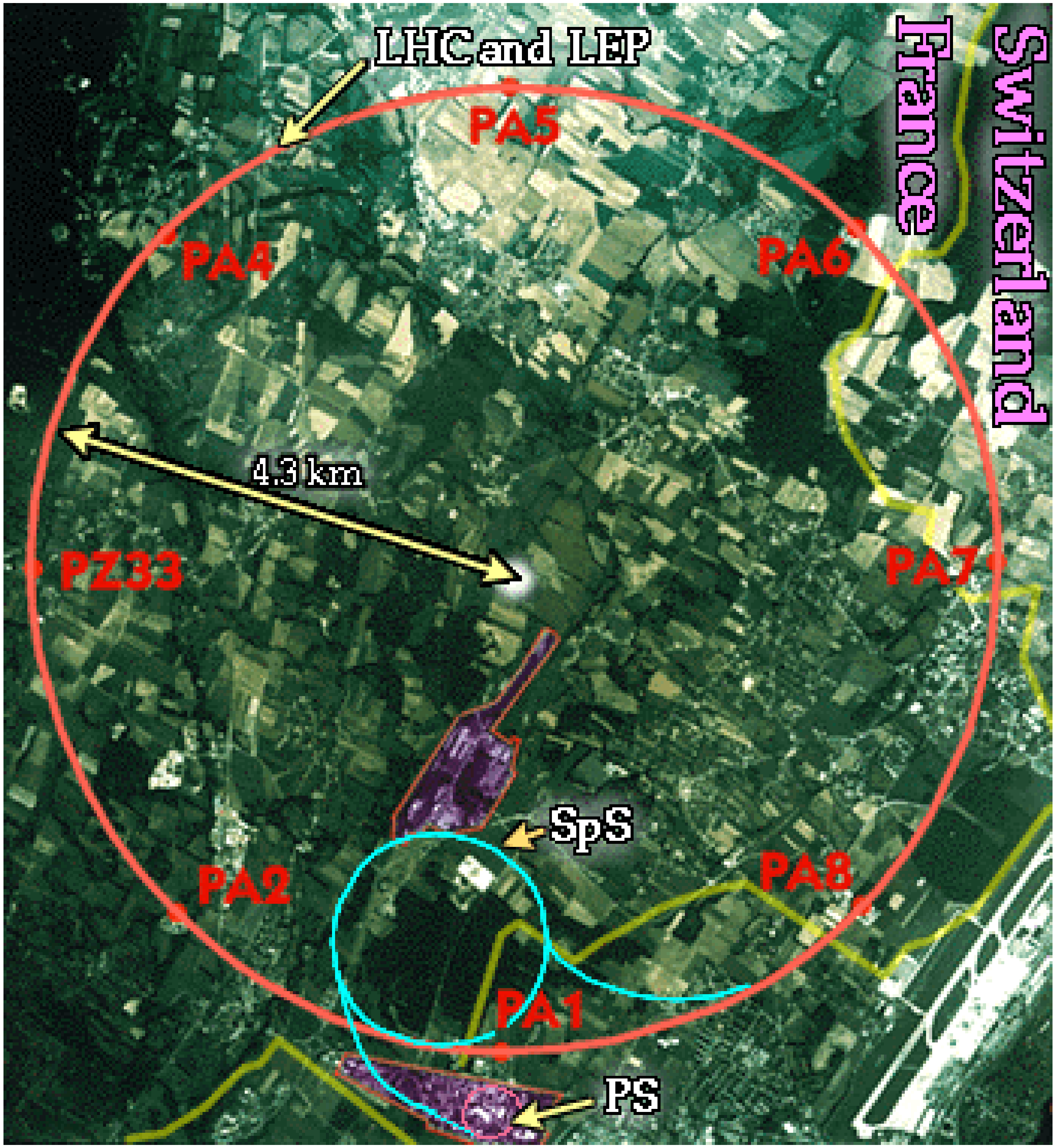
Recent Results
From the NA48 Experiment at CERN

26 February 2004

Phil Rubin
for the NA48 Collaboration

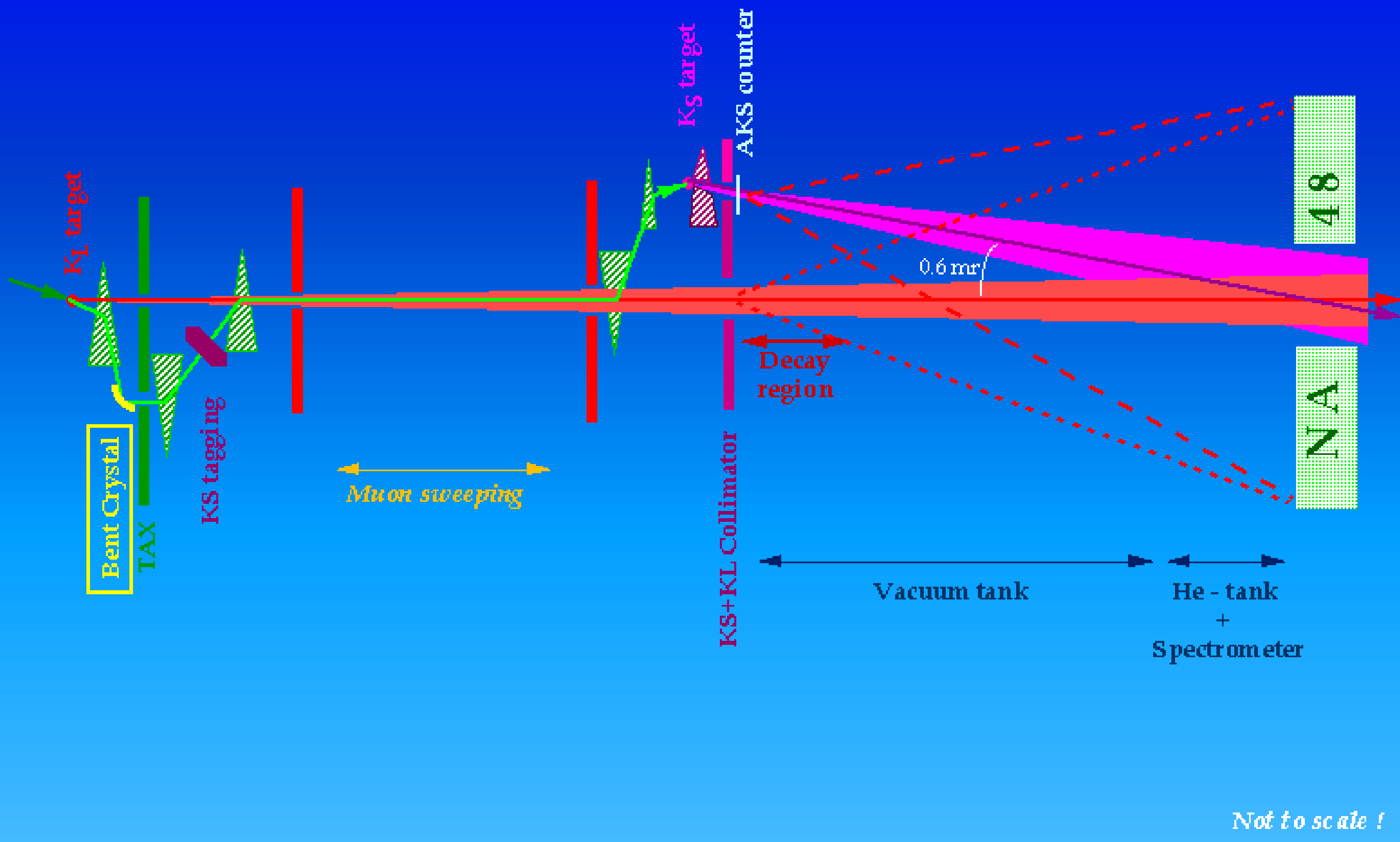
- CP-violation
- Rare Decays
- χ_{PT} Tests
- EW Tests

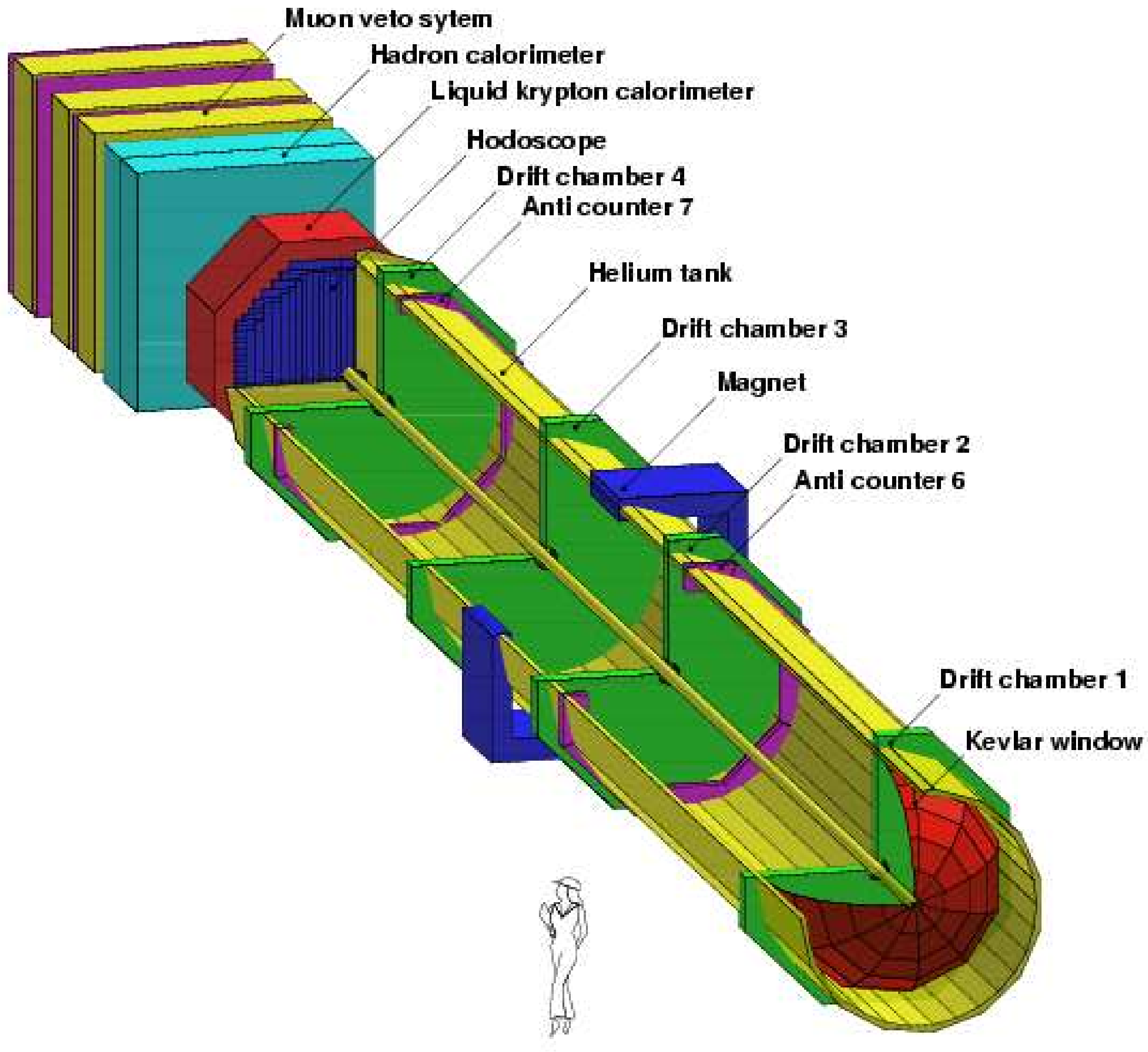
CERN



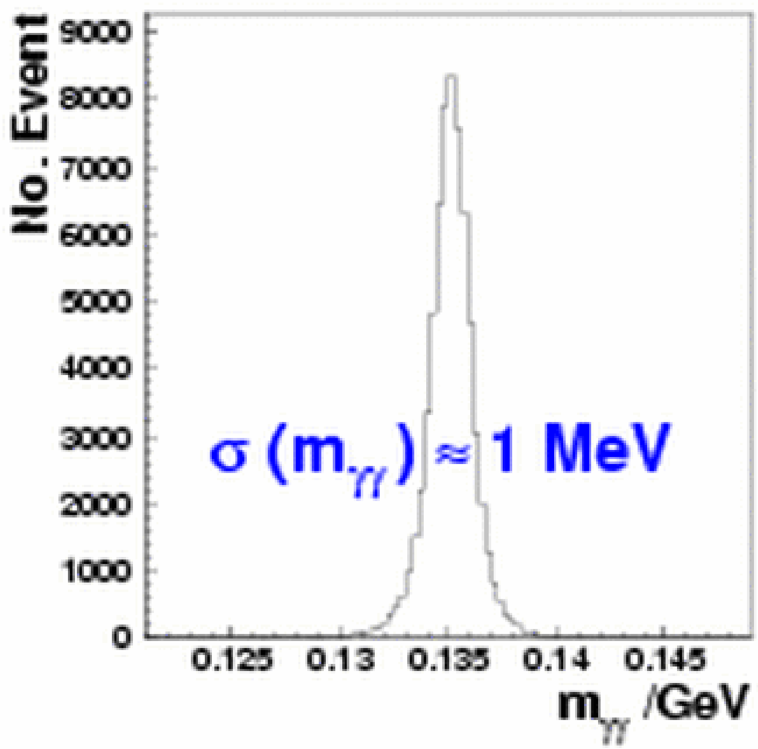
LHC and LEP
PA5
PA4
PA6
France
Switzerland
4.3 km
PZ33
PA7
SpS
PA2
PA8
PA1
PS

THE SIMULTANEOUS K_L AND K_S BEAMS

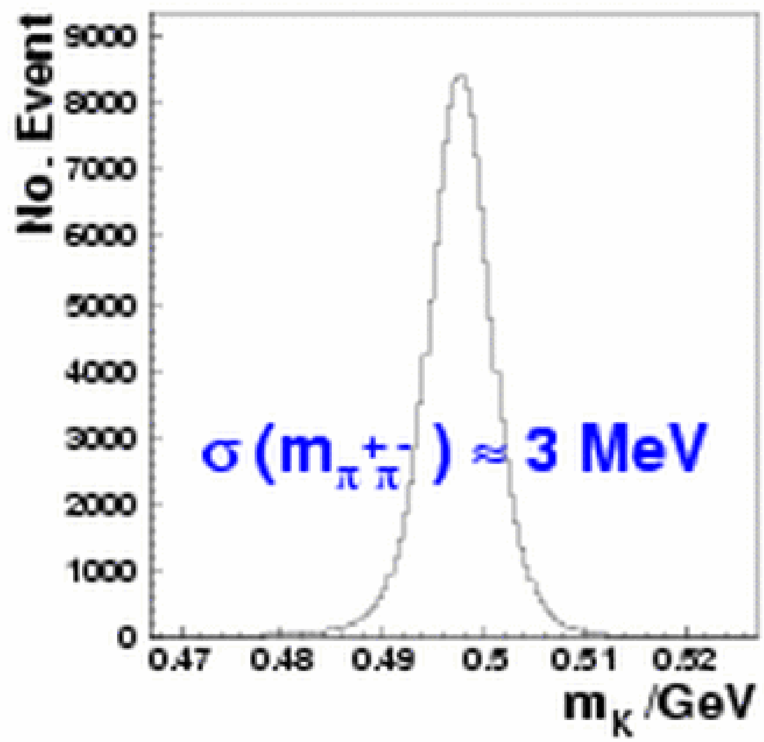



Muon veto sytem
Hadron calorimeter
Liquid krypton calorimeter
Hodoscope
Drift chamber 4
Anti counter 7
Helium tank
Drift chamber 3
Magnet
Drift chamber 2
Anti counter 6
Drift chamber 1
Kevlar window

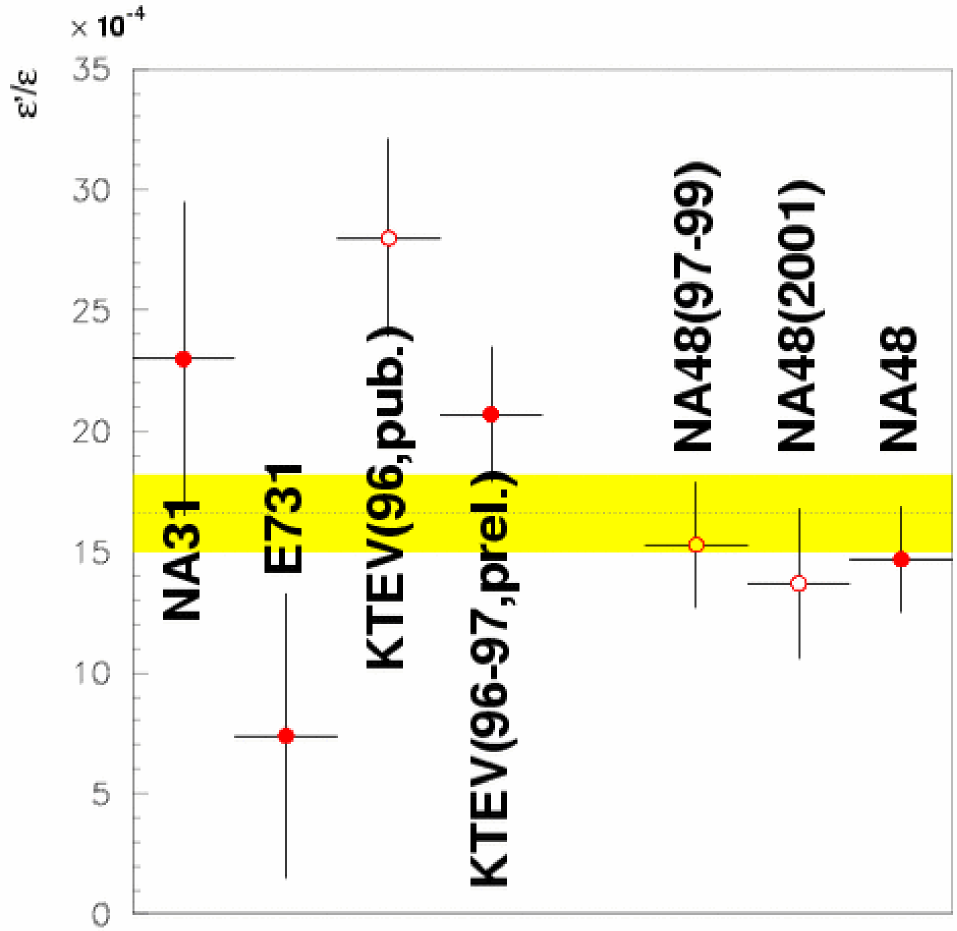
Detector Performance



Shower Detector



Tracking



World Average: $\mathrm{Re}(\epsilon'/\epsilon) = (16.6 \pm 1.6) \times 10^{-4}$

$[\chi^2/ndf = 6.3/3$ (10% probability)]

J.R.Batley et al. Physics Letters B 544, 92 (2002)

Data Taking Periods

Year	Designation	Beam	Physics Goals
1997	NA48	$K_L + K_S$	ϵ'/ϵ
1998	NA48	$K_L + K_S$	ϵ'/ϵ, Rare K_L Decays
1999	NA48	$K_L + K_S$	ϵ'/ϵ, Rare K_L Decays
	NA48	K_L	$K_{e3}/K_{\mu 3}$
	Test	HI K_S	K_s and Hyperon Decays
2000 (No Spectrometer)	NA48	K_L	ϵ'/ϵ Checks, K_L Decays
	NA48	η	ϵ'/ϵ Checks
	NA48/1	HI K_S	K_S Decays, η_{000}
2001	NA48	$K_L + K_S$	ϵ'/ϵ, $K_{e3}/K_{\mu 3}$
2002	NA48/1	HI K_S	Rare K_S, Hyperon Decays
2003	NA48/2	K^+/K^-	Direct CPV in $K^\pm \to (3\pi)^\pm$ Rare $K^\pm$ Decays, CKM Test
2004	NA48/2	K^+/K^-	

$$\eta_{000} \equiv \frac{A(K_S \to \pi^0\pi^0\pi^0)}{A(K_L \to \pi^0\pi^0\pi^0)}$$

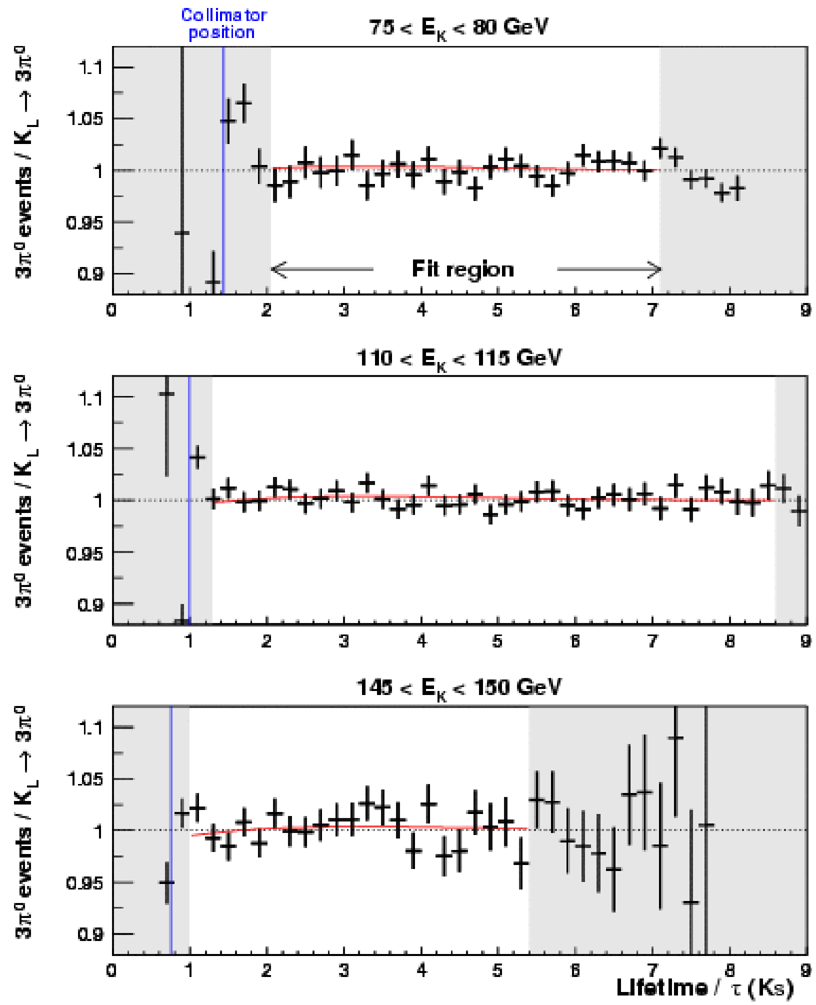
- In SM, $\eta_{000} \sim \epsilon$

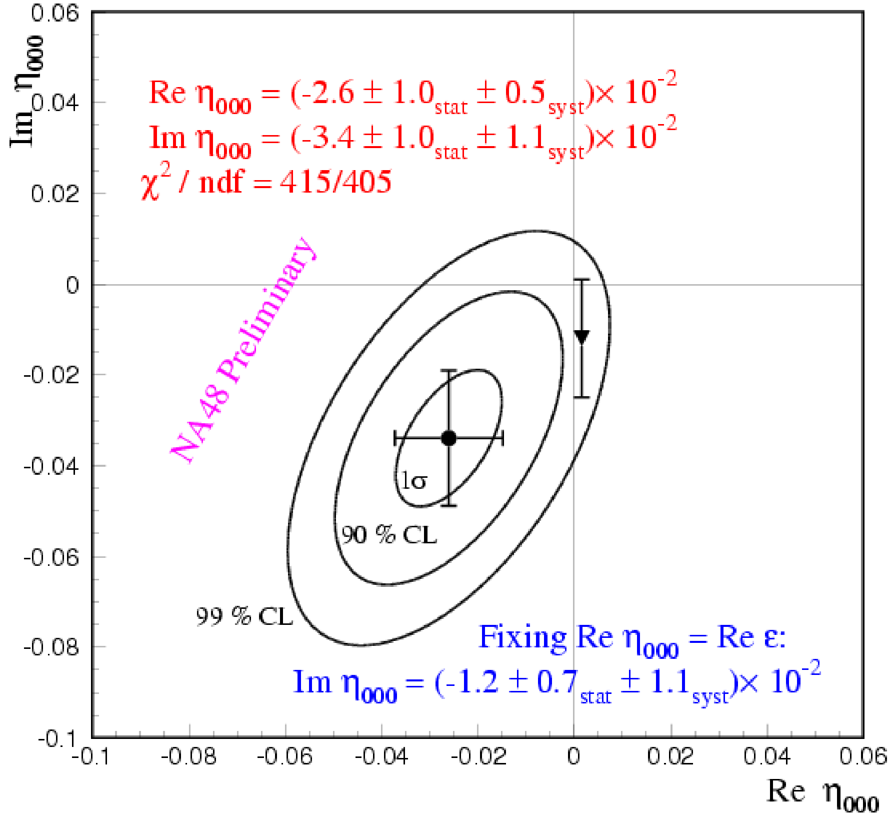
- $f(E,\, t) = \frac{N_{near\ target}}{N_{far\ target}} = A(E)[1+ \mid \eta_{000} \mid^2 e^{-(\Gamma_L - \Gamma_S)t} +$

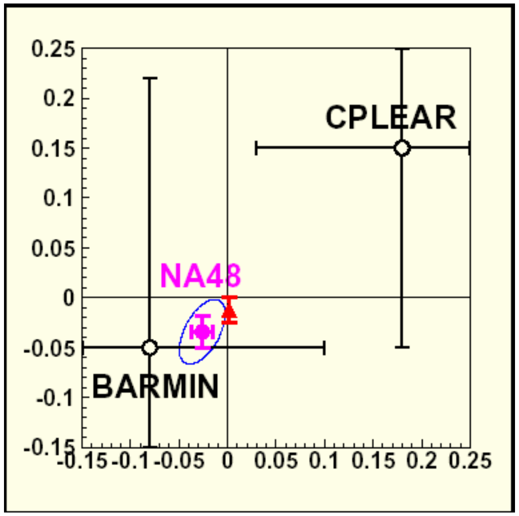
$$2D(E)e^{\frac{-(\Gamma_L-\Gamma_S)t}{2}}(\mathrm{Re}\eta_{000} \cos \Delta mt - \mathrm{Im}\eta_{000} \sin \Delta mt)]$$

- $\mathrm{BR}_{\mathrm{SM}}(K_S \to \pi^0\pi^0\pi^0) \sim 1.8 \times 10^{-9}$

In 2000, $\sim 10^7\ K_L$ and $6.5 \times 10^6\ K_S$

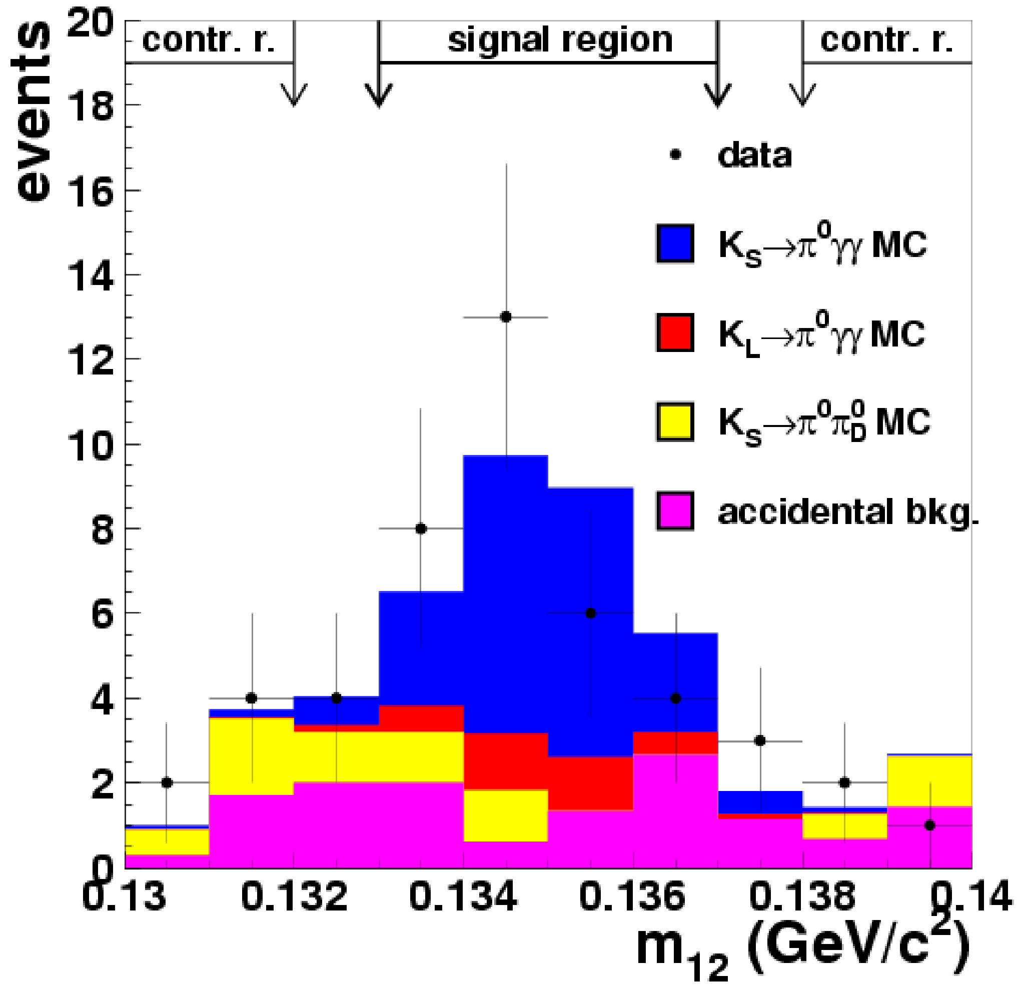






- 2-parameter fit and BS unitarity: $\mathrm{Im}\delta_{cpt} = (-1.7 \pm 3.4) \times 10^{-5}$
- 1-parameter fit: $\mathrm{BR}(K_S \to \pi^0\pi^0\pi^0) < 3.0 \times 10^{-7}$ 90% CL

First Observation of $K_S \to \pi^0\gamma\gamma$

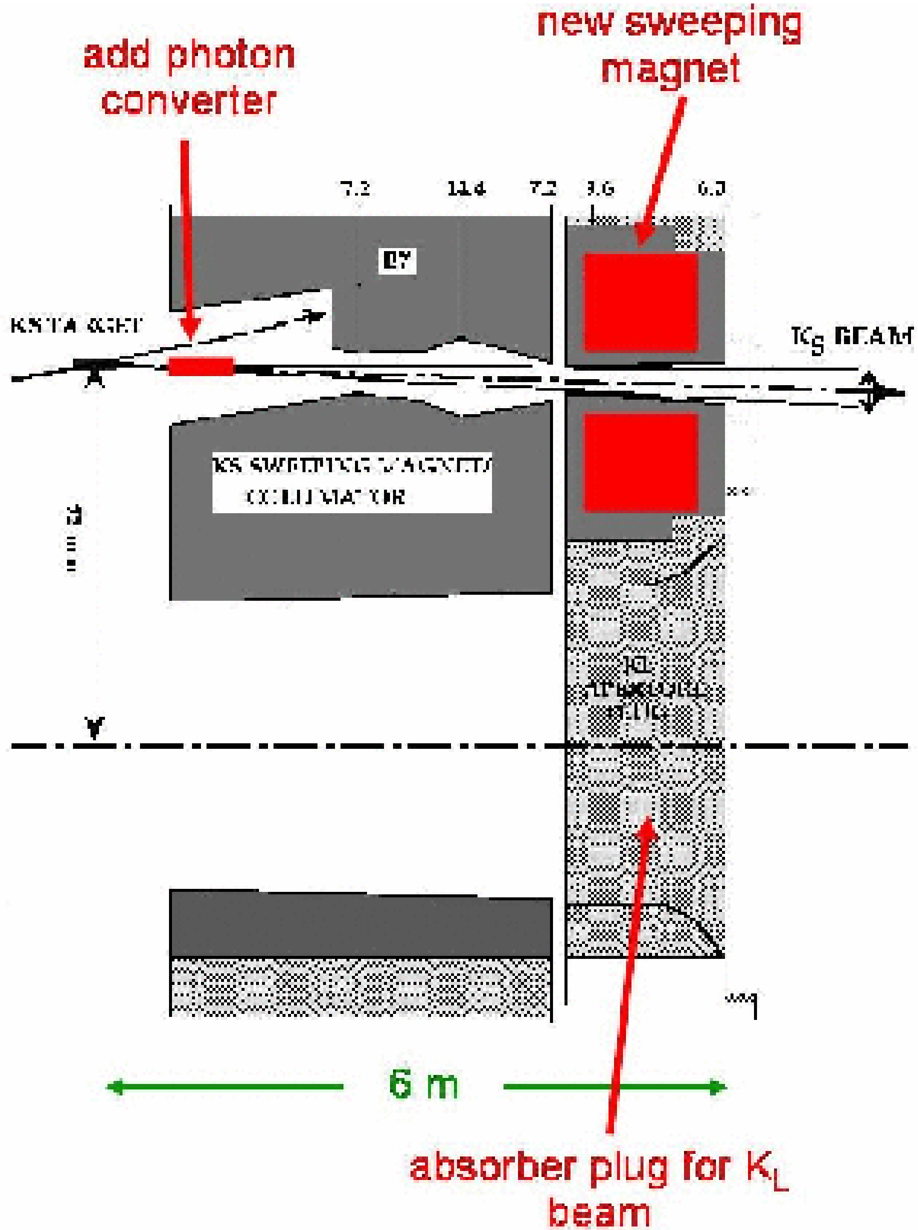


$$\mathrm{BR}(K_S \to \pi^0\gamma\gamma)_{q^2/M_k^2>0.2} = (4.9 \pm 1.8) \times 10^{-8}$$

χ_{PT} Prediction: $\mathrm{BR}(K_S \to \pi^0\gamma\gamma)_{q^2/M_k^2>0.2} = 3.8 \times 10^{-8}$

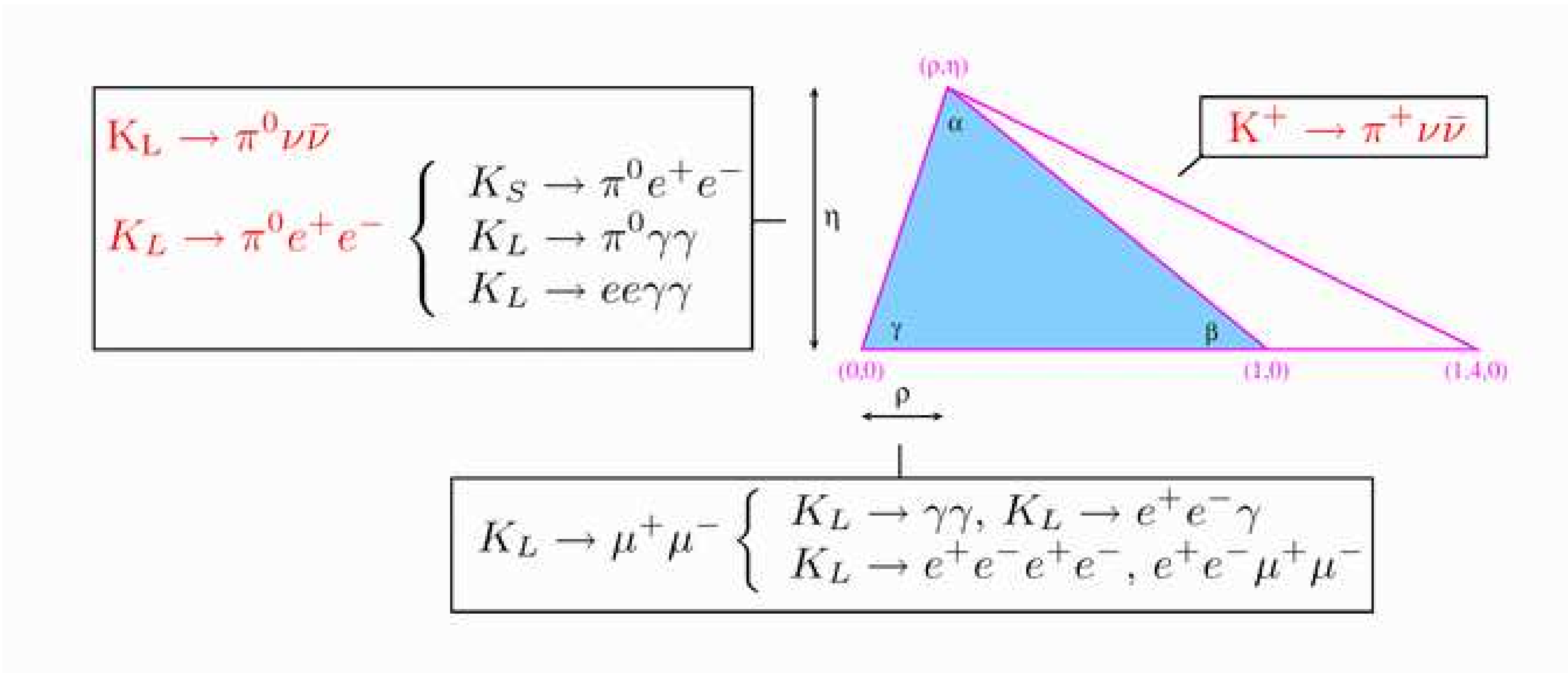
A. Lai et al. Phys. Lett. B 556 (2003) 105-113

NA48/1



add photon converter
new sweeping magnet
K_S BEAM
6 m
absorber plug for K_L beam

Measuring CP-Violation in the Standard Model

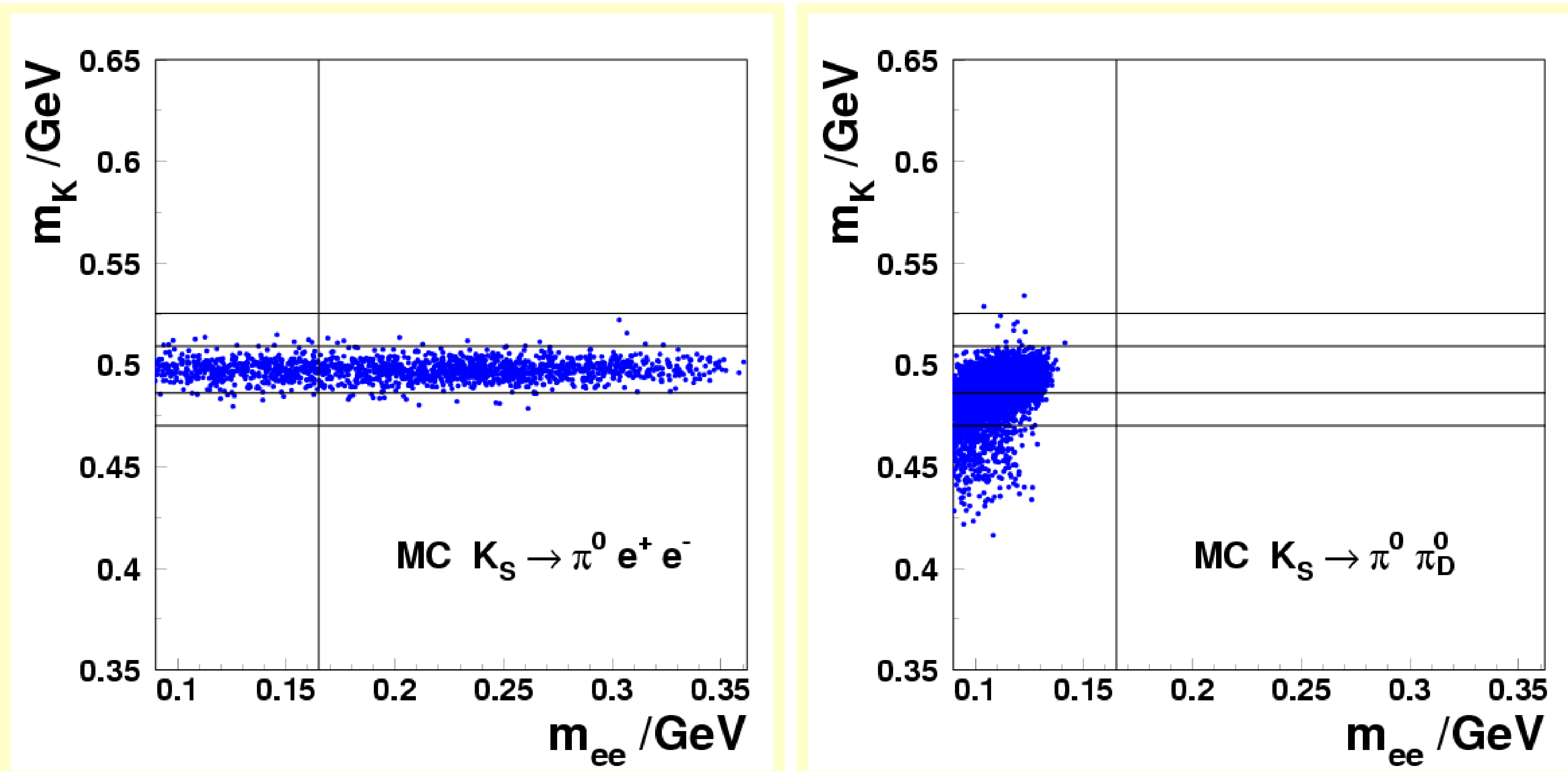


$$
\begin{aligned}
J_{CP} &= 2 \times \text{Area of triangle} \\
&= \text{Im}(V_{ud}^* V_{us} V_{ts}^* V_{td}) \sim \cos\theta_C \sin\theta_C \text{Im}\lambda_t
\end{aligned}
$$

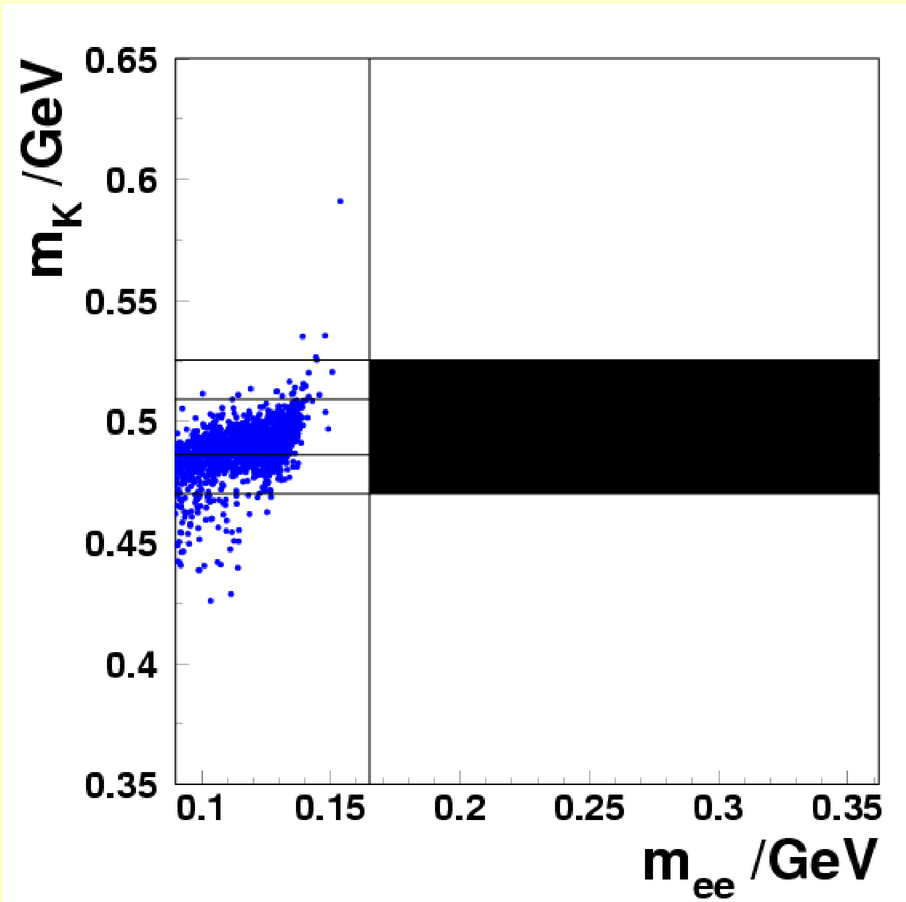
$$K_{L,\,S} \to \pi^0 e^+ e^- (\mu^+ \mu^-)$$

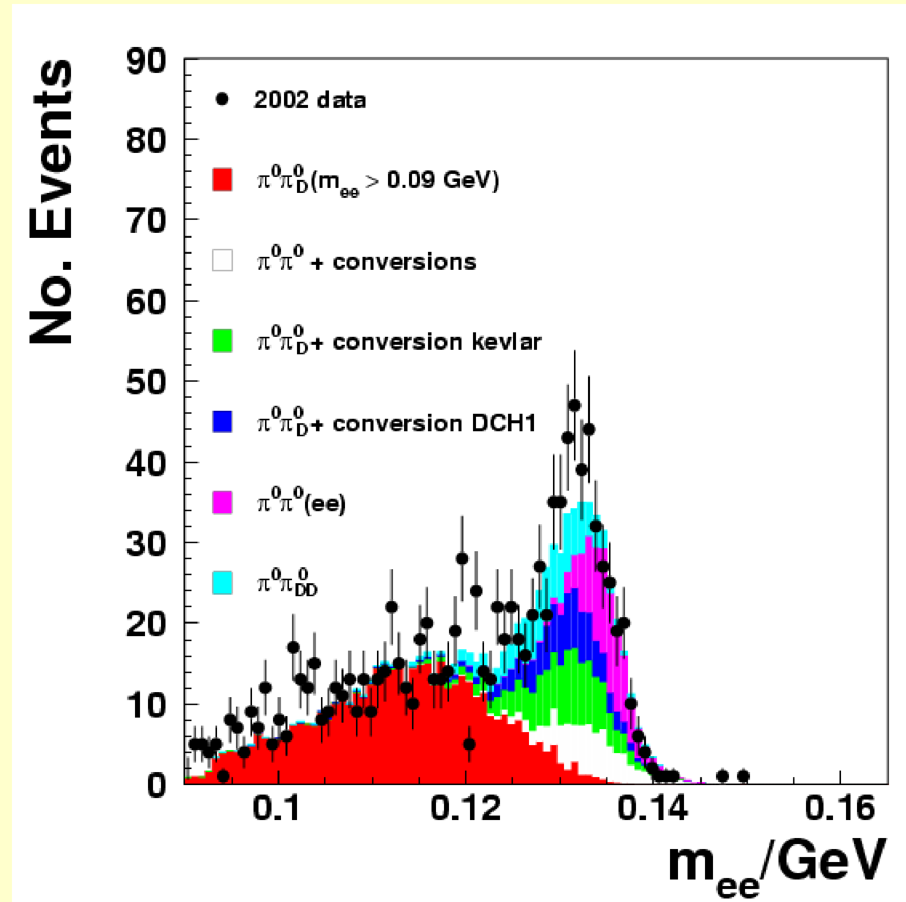
- Direct CP-Violating (Short-Distance)
  - SM Fit: $\mathrm{Im}\lambda_t (1.36 \pm 0.12) \times 10^{-4}$
  - $\mathrm{BR}(K_L \to \pi^0 ee)_{DirCPV} = (3.2 \pm 0.4) \times 10^{-12}$
- Indirect CP-Violating
  - $\mathrm{BR}(K_L \to \pi^0 ee)_{IndCPV} \approx \frac{1}{330} \mathrm{BR}(K_S \to \pi^0 ee)$
- CP-Conserving
  - $\mathrm{BR}(K_L \to \pi^0 ee)_{CPC} < 3 \times 10^{-12}$
    - Counter terms fixed from (NA48, NA48/1) results: $K_L \to \pi^0 \gamma\gamma$ and $K_S \to \gamma\gamma$

Search for $K_S \to \pi^0 e^+ e^-$



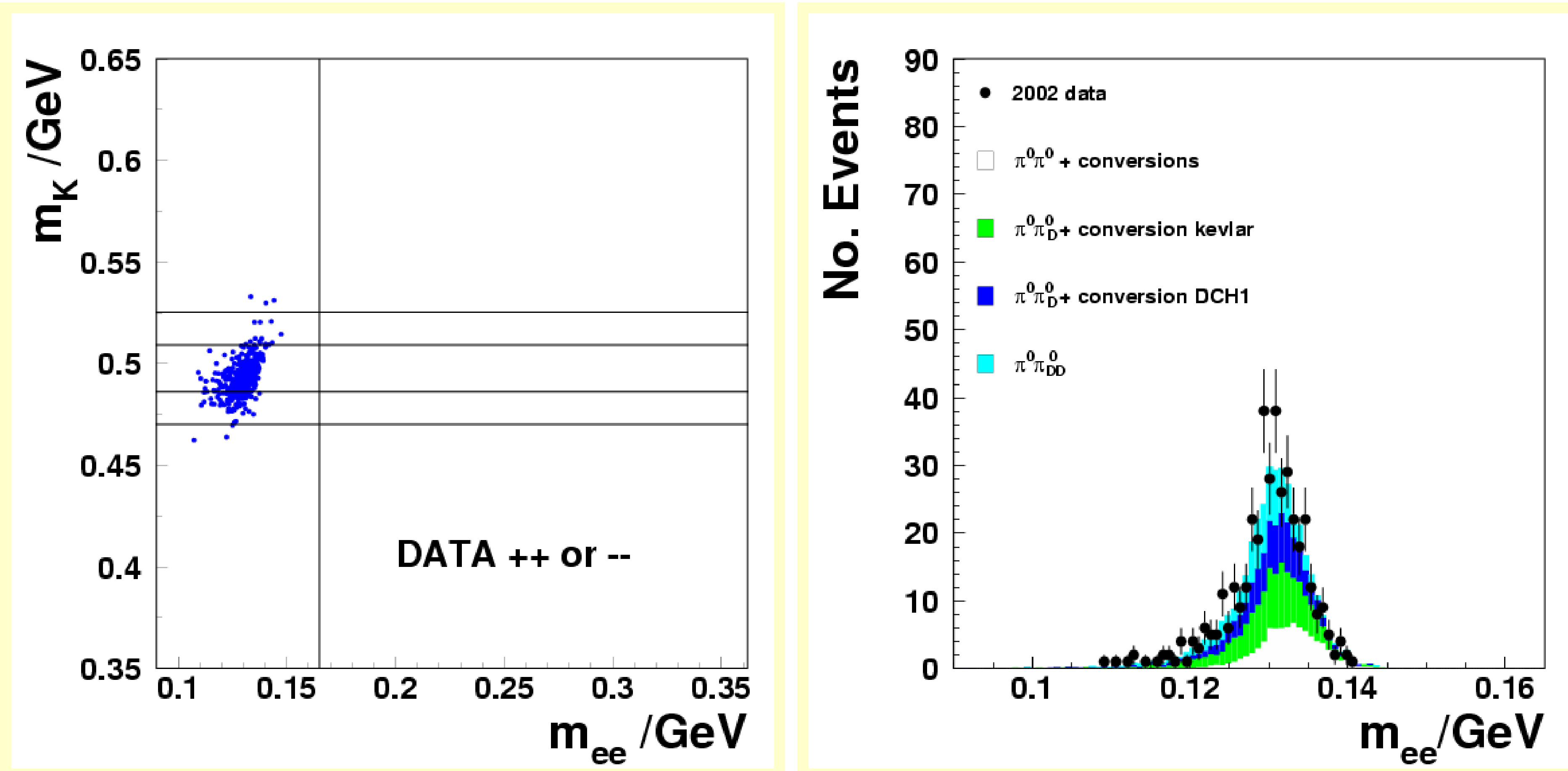
A “Blind” Analysis . . .





Backgrounds

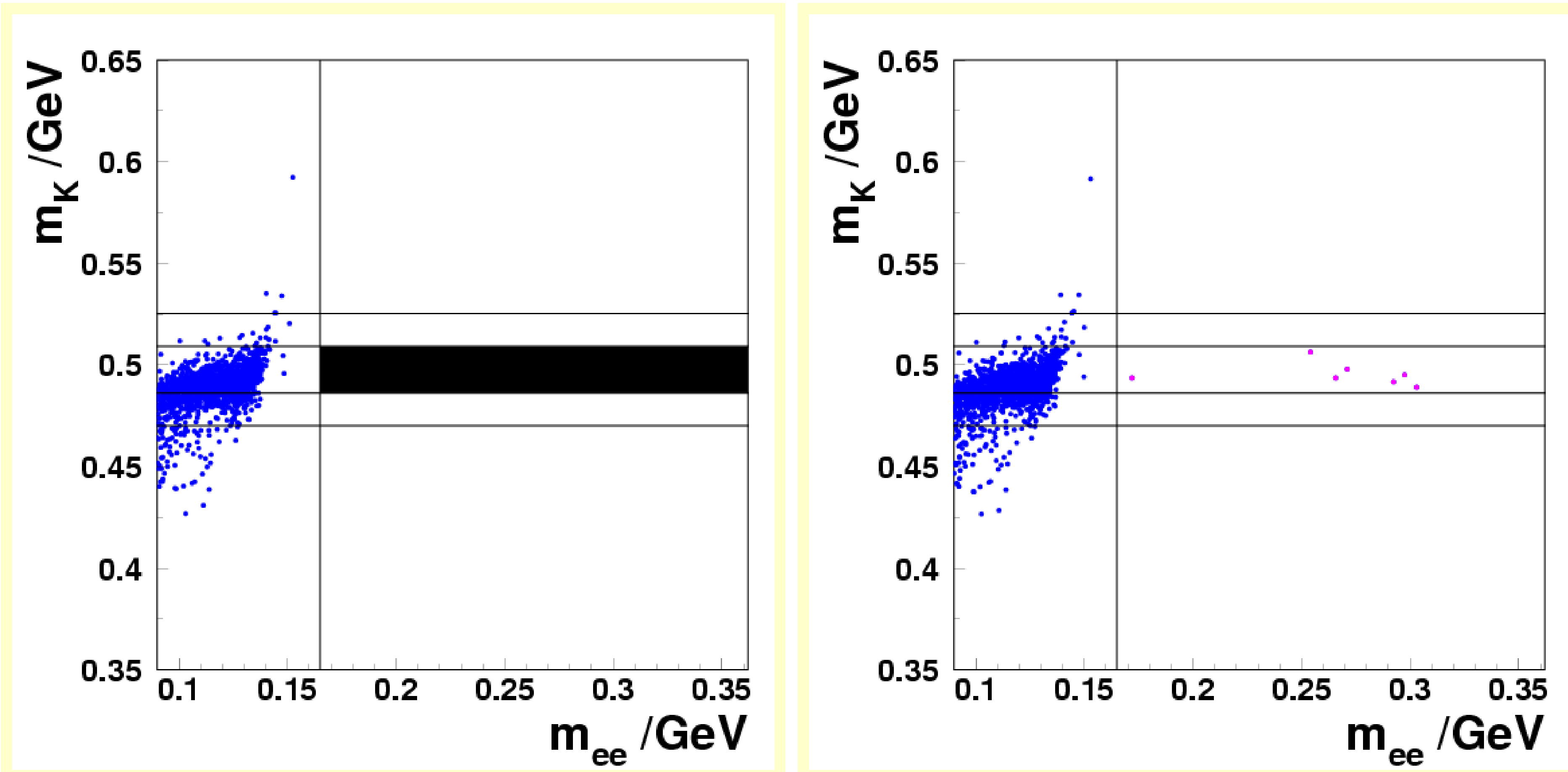
Same Sign Electrons



Background Summary

Source	Control Region	Signal Region
$K_S \to \pi^0_D \pi^0_D$	0.03	$<$0.01
$K_{L,\,S} \to ee\gamma\gamma$	0.11	0.08
$\pi e \nu + \pi^0(\pi^0)$	0.19	0.07
TOTAL	0.33	$0.15^{+0.10}_{-0.04}$

Opening the Box



7 Candidates in Signal Region

0 Events in Control Region

First Observation of $K_S \to \pi^0 e^+ e^-$

A. Lai et al., Phys Lett B (to be published) hep-ex/0309075

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

- Assuming VMD and a unity form factor:

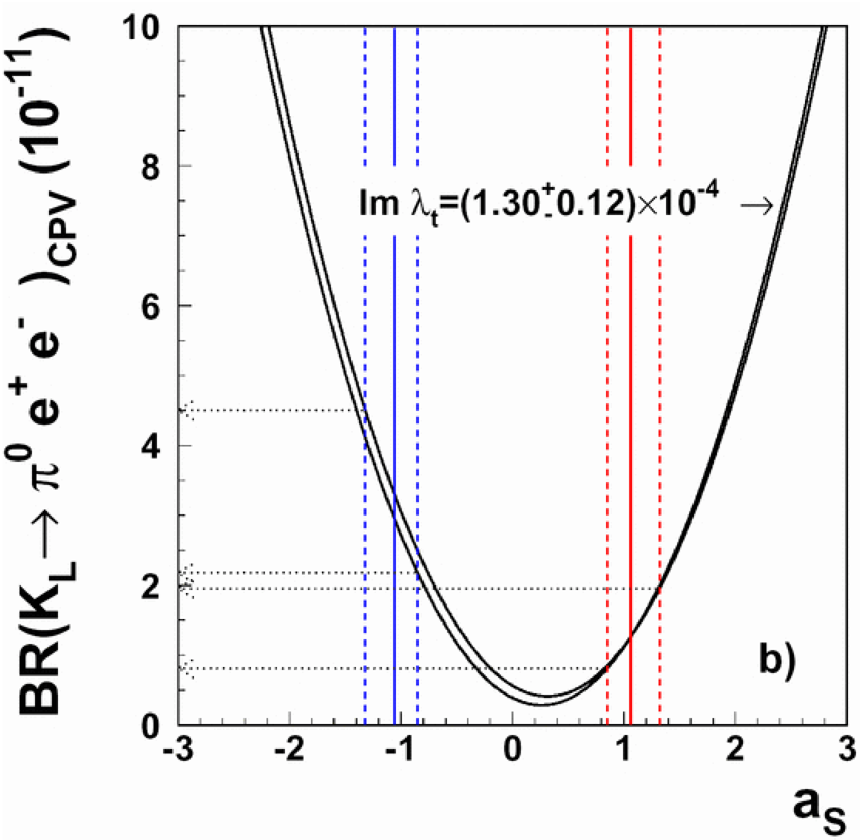
  $\mathrm{BR}(K_S \to \pi^0 ee) = [5.8\,^{+2.8}_{-2.3}(\mathrm{stat}) \pm 0.8(\mathrm{syst})] \times 10^{-9}$

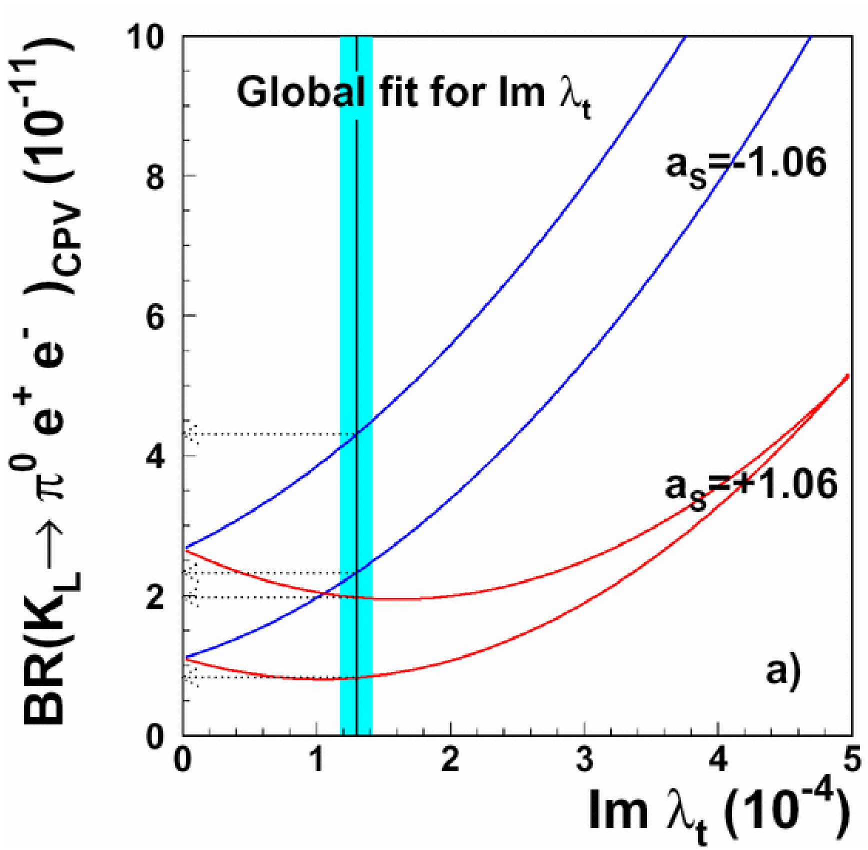
  - Indirect CP-Violation in $K_L \to \pi^0 ee$ is large
  - L. Seghal predicted [NP B19 (1970)]: $\approx 5.5 \times 10^{-9}$
  - D'Ambrosio, et al., [JHEP 08 (1998) 004] notation (χ_{PT}):

    $\mathrm{BR}(K_S \to \pi^0 ee) \approx 5 \mid a_s \mid^2 \times 10^{-9}$

    $\Rightarrow \mid a_s \mid = 1.06\,^{+0.26}_{-0.21}(\mathrm{stat}) \pm 0.05(\mathrm{syst})$

Sensitivity to Imλ_t?





$$\text{BR}(K_L \to \pi^0 ee)_{CPV} \approx \left[15.3 \mid a_s \mid^2 - 6.8 a_s \left(\frac{\text{Im}\lambda_t}{10^{-4}}\right) + 2.8 \left(\frac{\text{Im}\lambda_t}{10^{-4}}\right)^2\right] \times 10^{-12}$$

Perhaps, if interference is constructive.

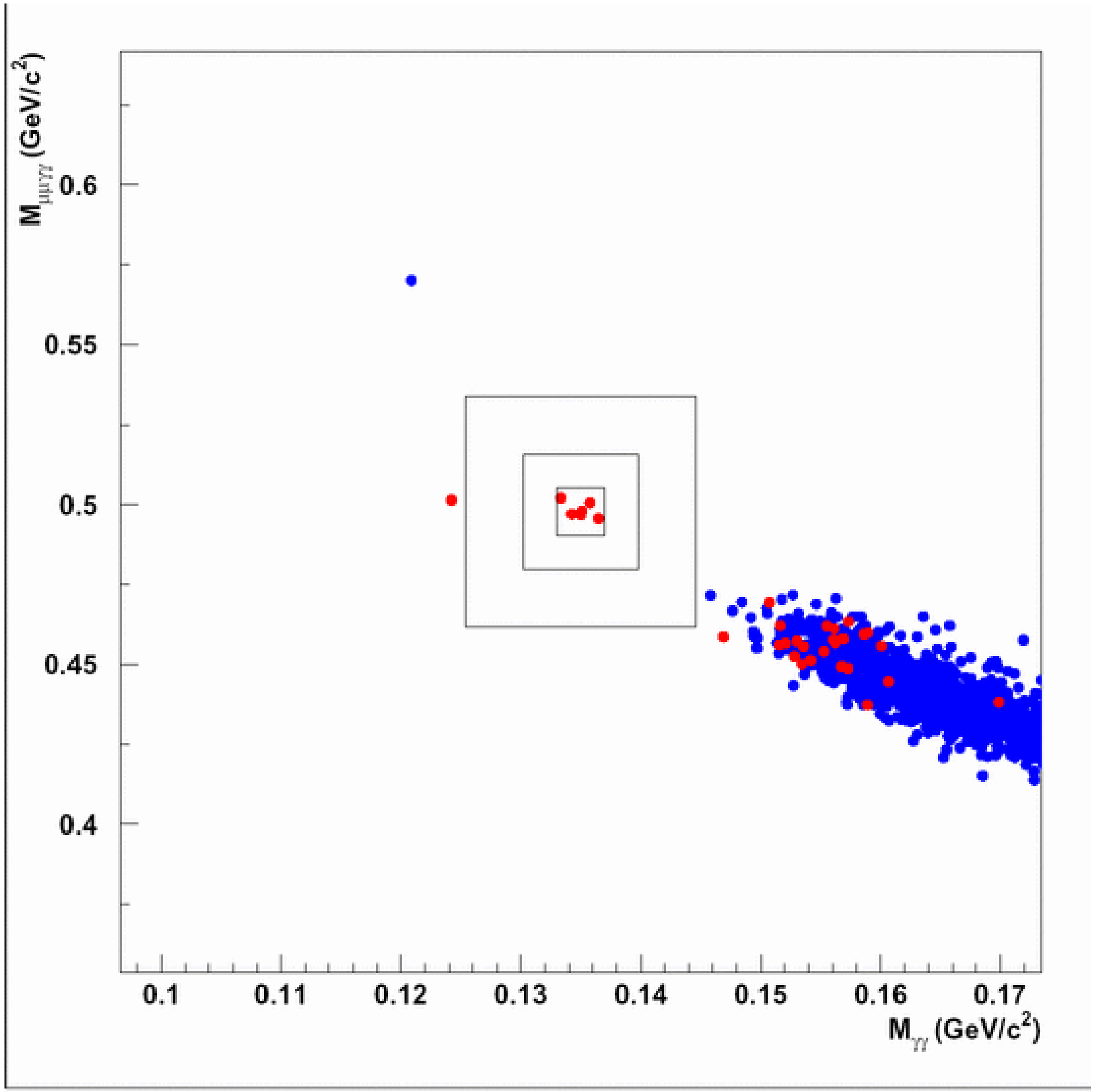
And $K_S \to \pi^0\mu^+\mu^-$?

- VMD predicts $\mathrm{BR}(K_S \to \pi^0\mu\mu) \approx \frac{1}{4}\mathrm{BR}(K_S \to \pi^0 ee)$

- Different backgrounds; larger acceptance

- Relation between two $K_S \to \pi^0 ll$ modes may permit form factor extraction

Preliminary



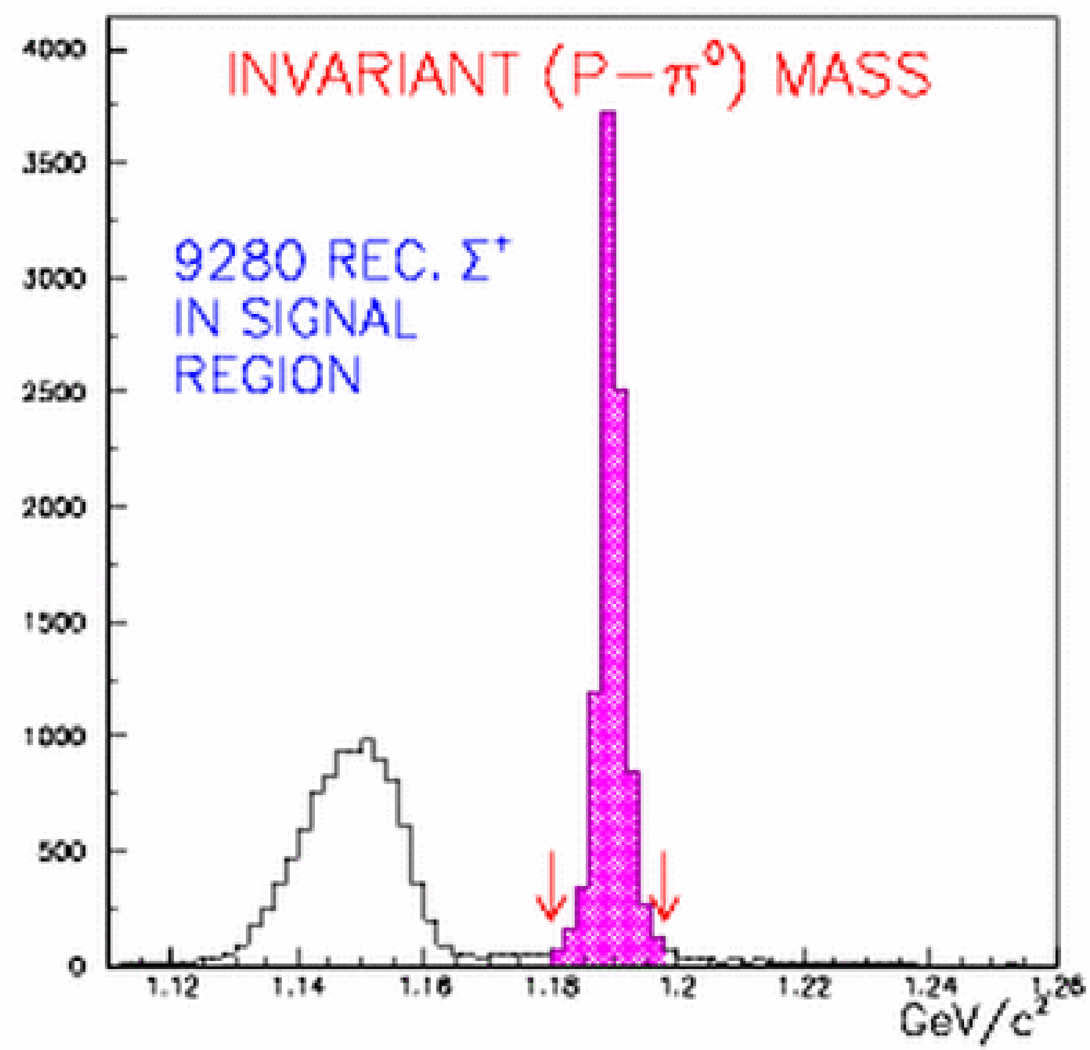
Six Candidates in Signal Region

0.24 expected from backgrounds: $K_{L,\,S} \rightarrow \mu\mu\gamma\gamma\ (0.04)$ and accidentals (0.20)

Neutral Hyperons

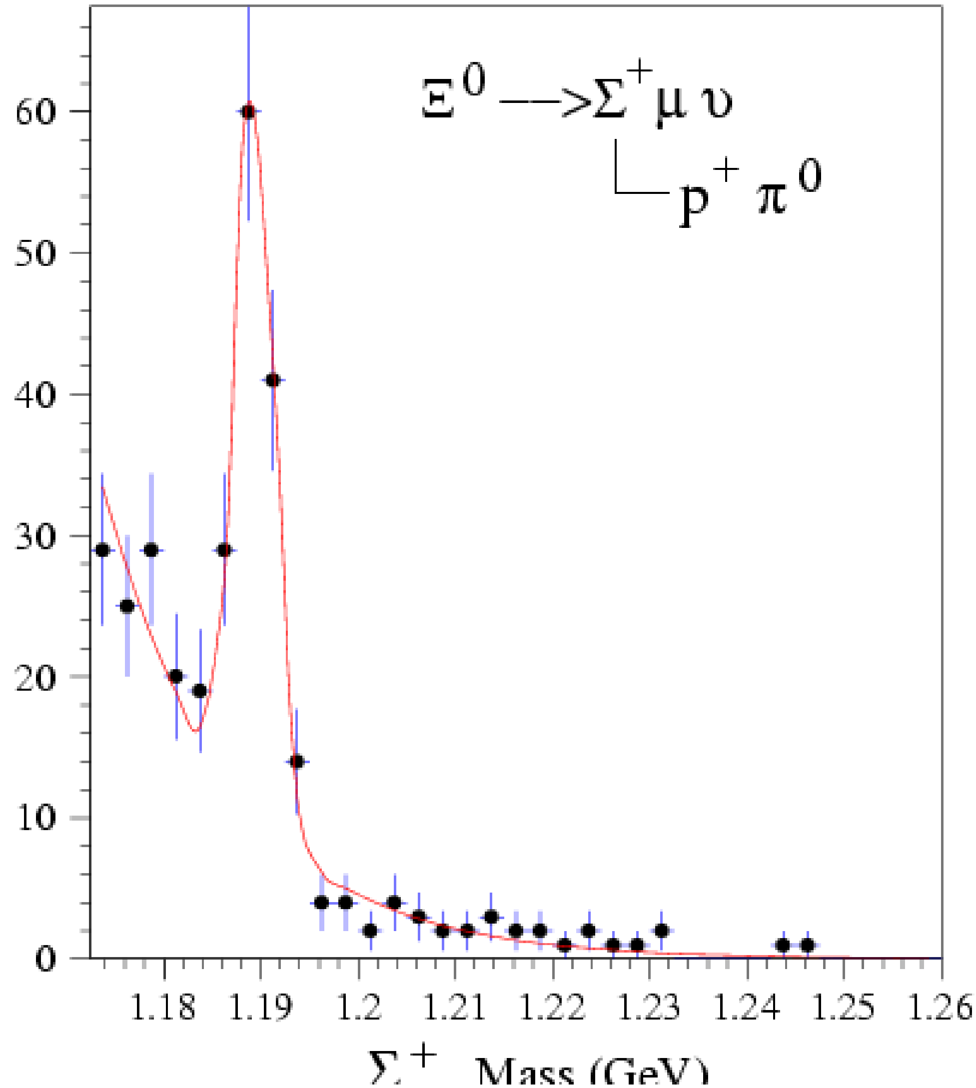
- Semileptonic branches and form factors
  - SU(3) symmetry breaking
  - V_{us} and CKM unitarity
- Asymmetries in radiative decays
  - Characterize weak radiative decays
- Rare/Forbidden decays

$$\Xi^0 \to \Sigma^+ e^- \overline{\nu_e}$$



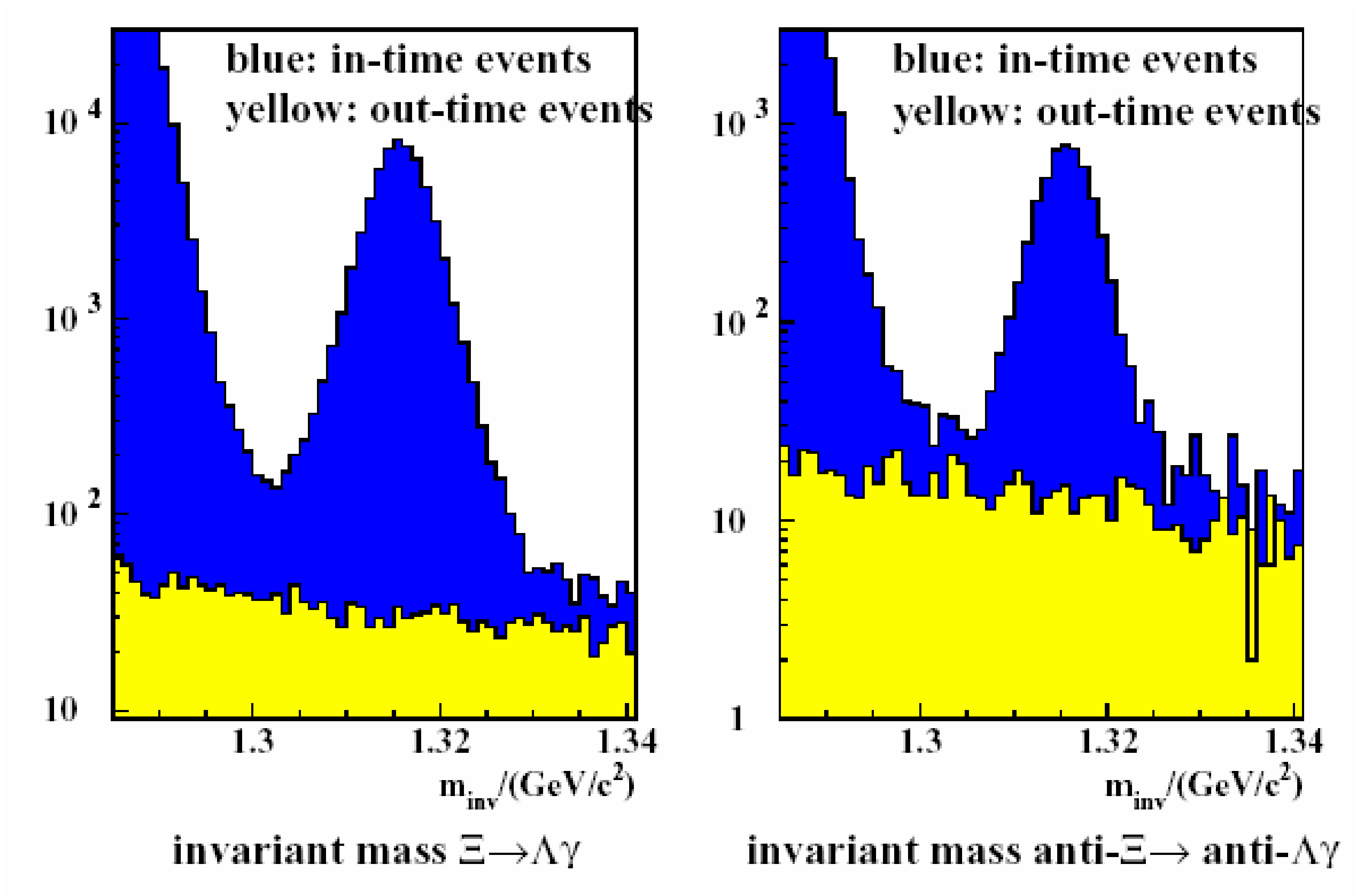
$\geq$ 4 times the world sample

First Clear Indication

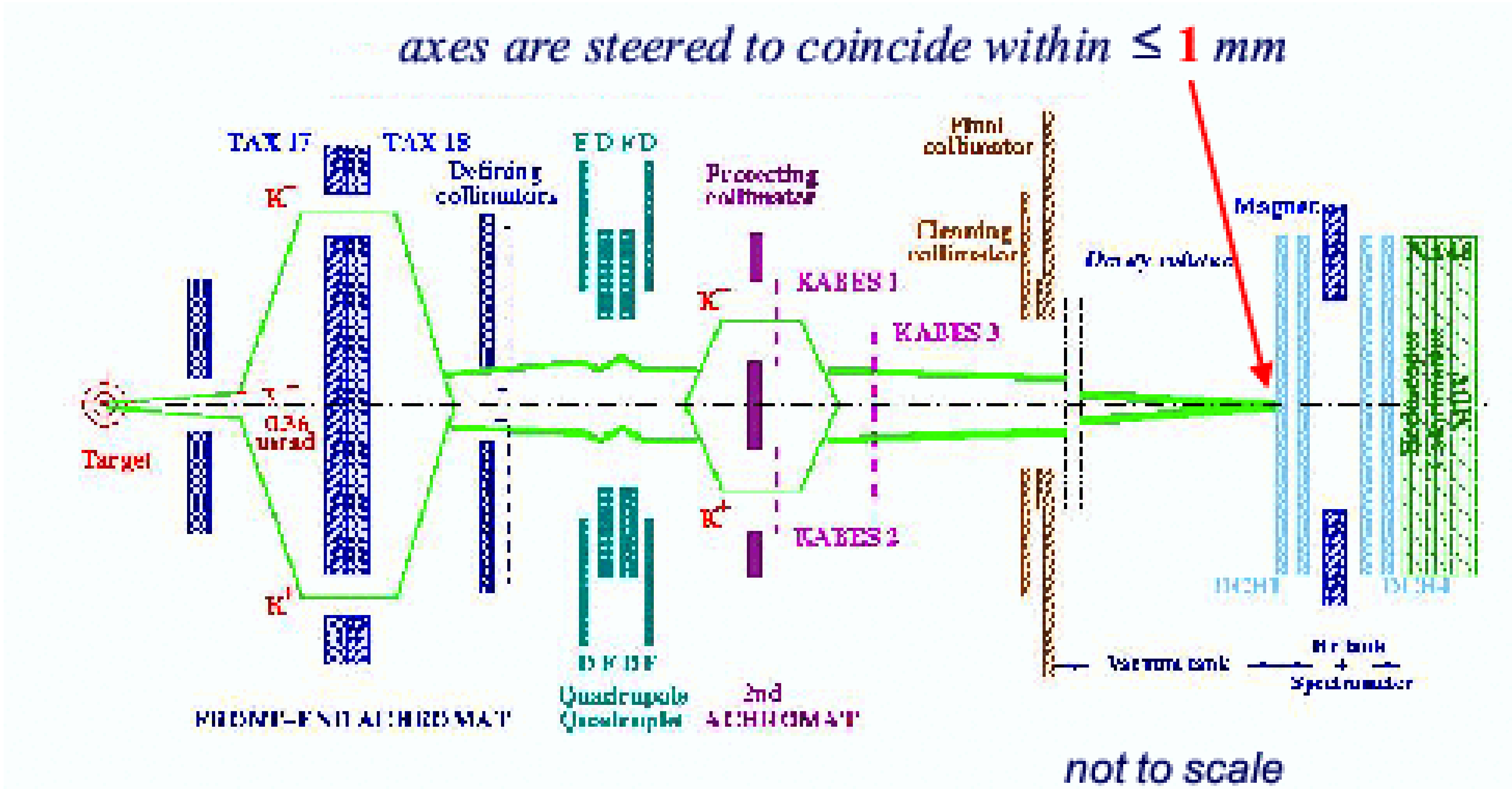


$M_{p\pi}$ when one muon identified

$\Xi^0/\overline{\Xi}^0 \to \Lambda/\overline{\Lambda}\gamma$



NA48/2

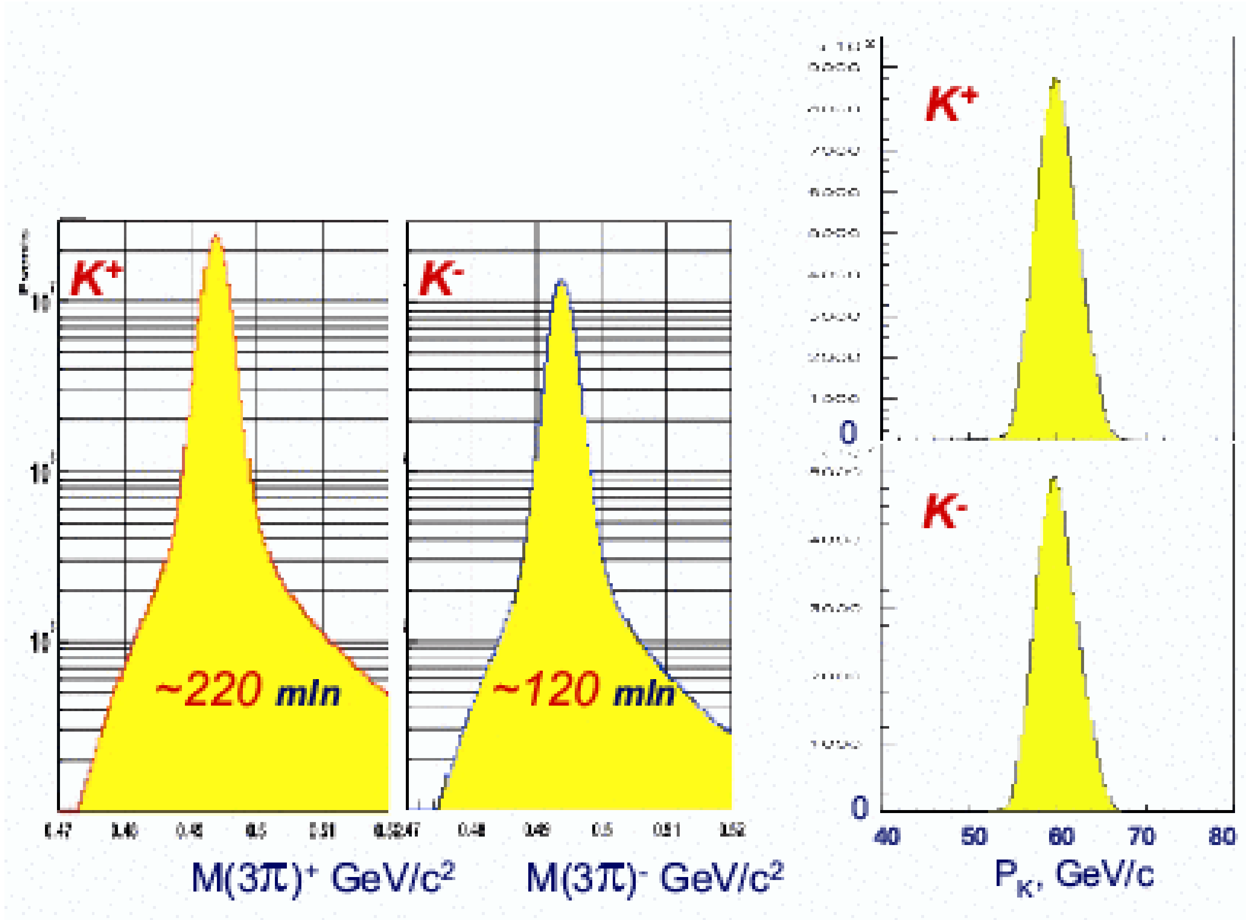

axes are steered to coincide within ≤ 1 mm
TAX 17
TAX 18
Defining collimators
Protecting collimator
Final collimator
Cleaning collimator
KABES 1
KABES 2
KABES 3
Magnet
Target
Quadrupole Quadruplet
2nd ACHROMAT
Vacuum tank
not to scale

NA48/2 Goals

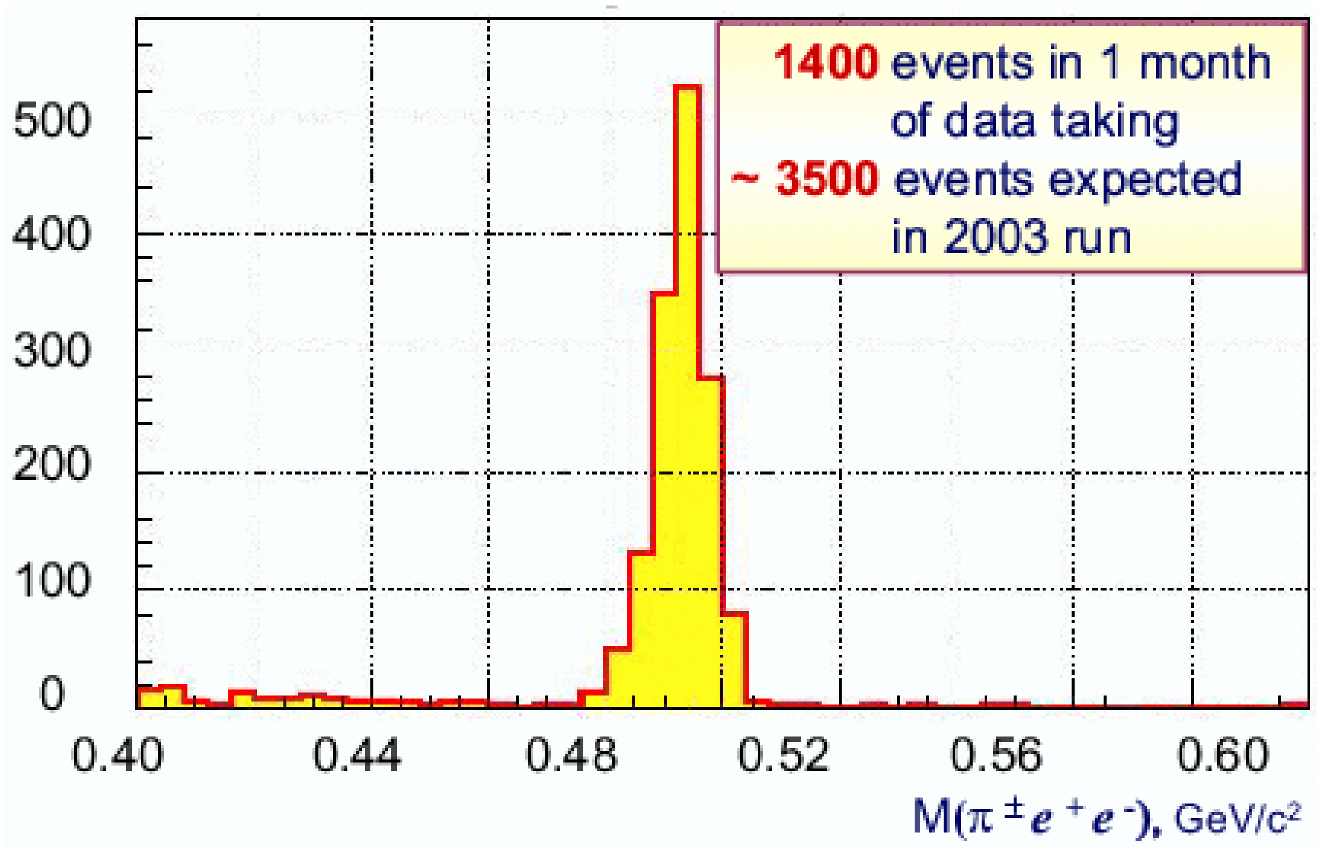
- Direct CP-Violation in $K^{\pm} \rightarrow \pi^{\pm}\pi^{+}\pi^{-}$ and $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\pi^{0}$ to $\delta(A) \sim 10^{-4}$
- K_{e4} to measure $\pi - \pi$ scattering length
- Rare decays to test χ_{PT}
- Semileptonics to measure V_{us} and CKM unitarity
- Leptonic decays to check universality.

From small subsets of the data…

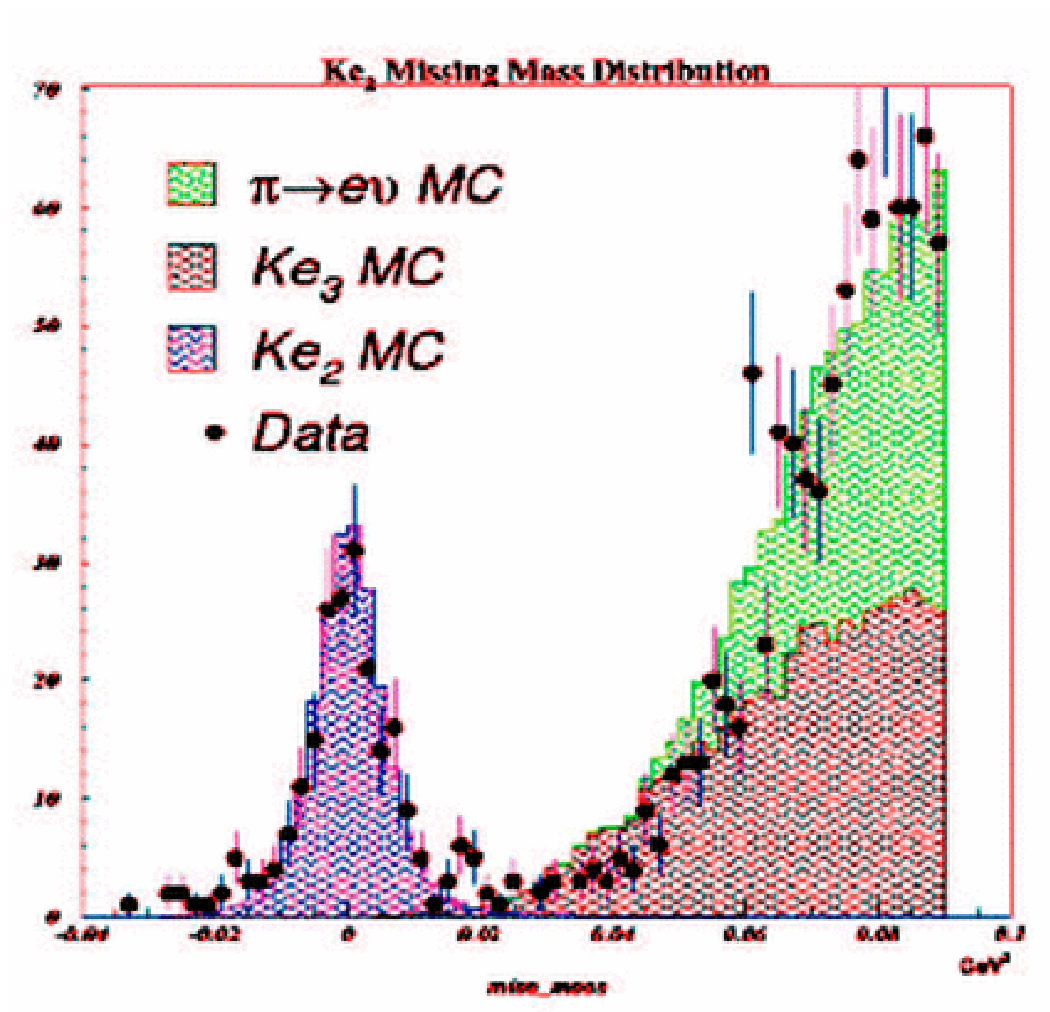
$$K^{\pm} \rightarrow \pi^{\pm}\pi^{+}\pi^{-}$$



$$K^{\pm} \rightarrow \pi^{\pm} e^{+} e^{-}$$



$$K^{\pm} \to e^{\pm}\nu$$



etc.