# Precision measurements of rare kaon decays

$K^{\pm} \rightarrow \pi^{\pm} \pi^{0} \gamma$

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

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

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on behalf of the **NA48/2** collaboration

**The 2009 Europhysics Conference on High Energy Physics**

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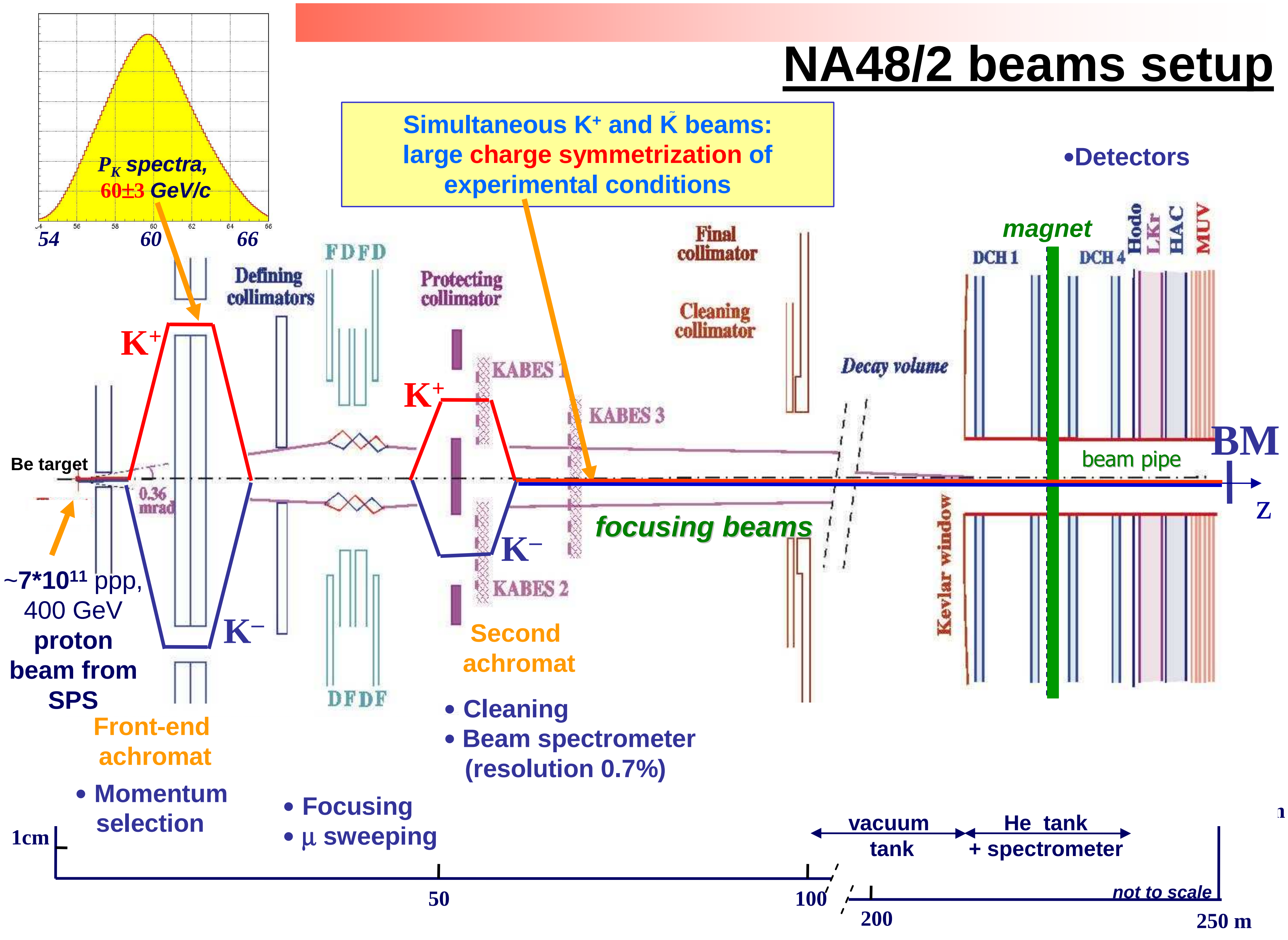


NA48/2 beams setup
Simultaneous K+ and K̃ beams: large charge symmetrization of experimental conditions
P_K spectra, 60±3 GeV/c
54
60
66
Be target
0.36 mrad
~7*10^11 ppp, 400 GeV proton beam from SPS
K+
K−
Defining collimators
FDFD
DFDF
Protecting collimator
KABES 1
KABES 2
KABES 3
Final collimator
Cleaning collimator
Decay volume
Kevlar window
focusing beams
magnet
DCH 1
DCH 4
Hodo
LKr
HAC
MUV
•Detectors
BM
beam pipe
Z
Front-end achromat
• Momentum selection
• Focusing
• μ sweeping
Second achromat
• Cleaning
• Beam spectrometer (resolution 0.7%)
vacuum tank
He tank + spectrometer
1cm
50
100
200
250 m
not to scale

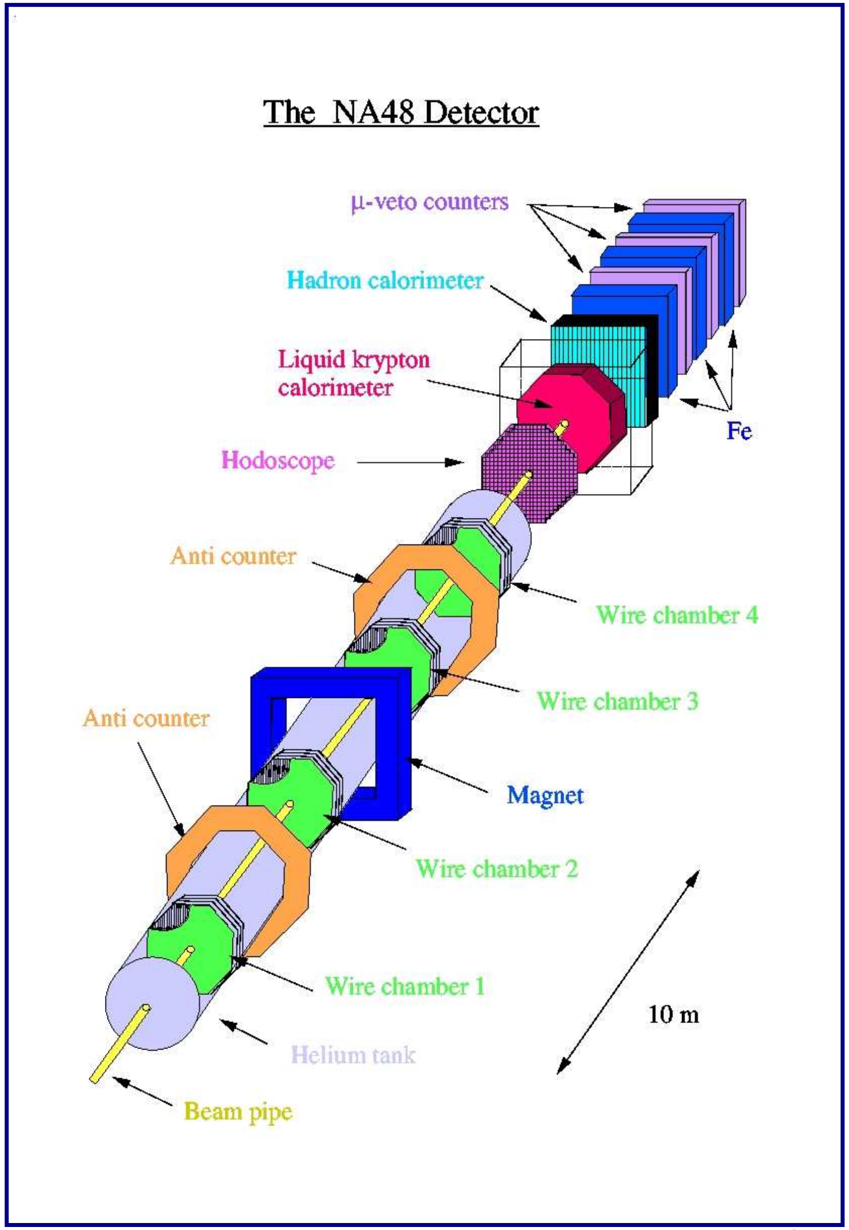
# NA48 detector

- ***Magnetic spectrometer (4 DCHs):***
  - **4 views : redundancy $\Rightarrow$ high efficiency;**
  - **$\Delta p/p = 1.0\% \oplus 0.044\% * p$ [GeV/c]**

- ***Hodoscope***
  - **fast trigger;**
  - **precise time measurement ($\sigma_t$ = 150 ps) .**

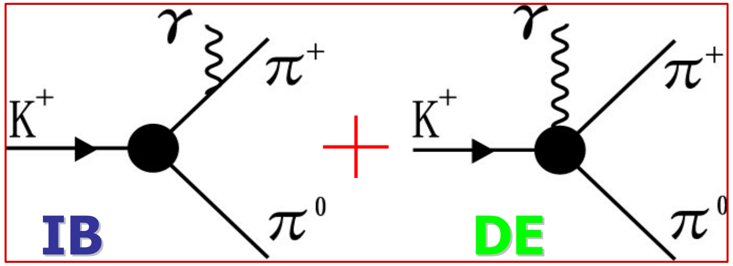
- ***Liquid Krypton EM calorimeter (LKr)***
  - **Quasi-homogeneous ionization chamber**
  - **27 electromagnetic radiation lengths long active volume**
  - **Segmented transversally 13248 cells, 2x2 cm2**
  - **Energy resolution (E in GeV):**

$$\frac{\sigma(E)}{E} = \frac{0.032}{\sqrt{E}} \oplus \frac{0.09}{E} \oplus 0.0042$$



$$K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$$

# $K^{\pm}\to\pi^{\pm}\pi^{0}\gamma$ - theoretical framework and motivation




**Lorentz invariant** $$W^2 = \frac{(P_K^* \cdot P_\gamma^*)(P_\pi^* \cdot P_\gamma^*)}{(m_k m_\pi)^2}$$

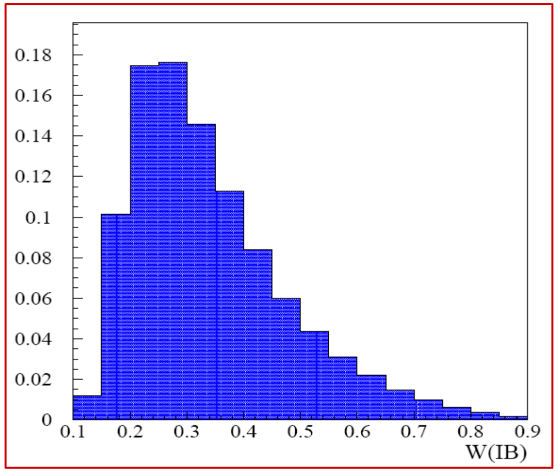
**DE can occur via electric and magnetic dipole transitions $X_E$ and $X_M$**

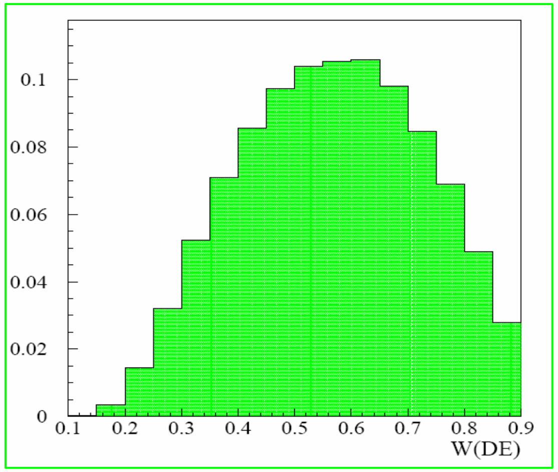
**Differential rate**

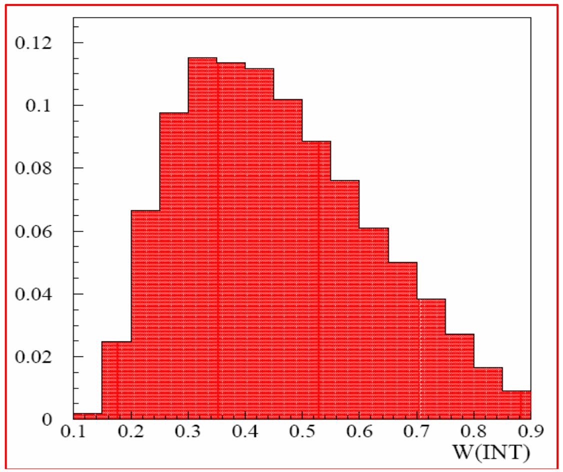
$$\frac{\partial \Gamma^{\pm}}{\partial W} = \underbrace{\frac{\partial \Gamma^{\pm}_{IB}}{\partial W}}_{\text{IB}} \Big[ 1 + \underbrace{2\cos(\pm\phi + \delta_1^1 - \delta_0^2)\, m_\pi^2 m_K^2 \,|X_E|\, W^2}_{\text{INT}} + \underbrace{m_\pi^4 m_K^4 (|X_E|^2 + |X_M|^2) W^4}_{\text{DE}} \Big]$$

| | |
|---|---|
| Inner Bremsstrahlung(IB) | : BR = $(2.75\pm0.15)\cdot10^{-4}$ PDG ($55<T^*_\pi<90$ MeV) |
| Direct Emission (DE) | : BR = $(4.3\pm0.7)\cdot10^{-6}$ PDG ($55<T^*_\pi<90$ MeV) |
| Interference (INT) | : not yet measured |

**Very different distributions!**



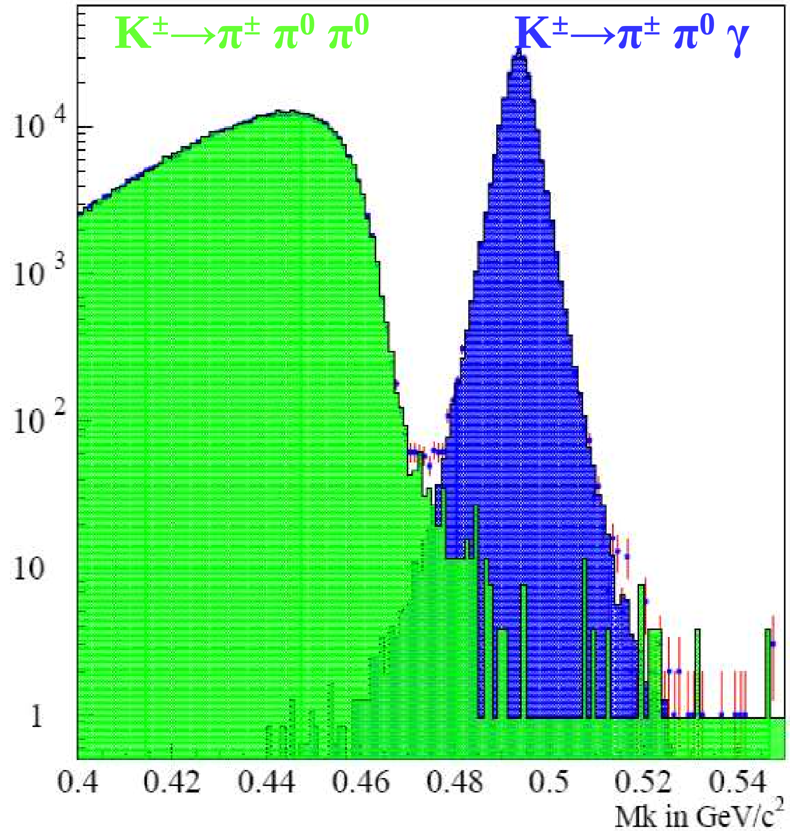



# $K^{\pm} \to \pi^{\pm} \pi^0 \gamma$ – event reconstruction and signal region

- NA48/2 measurement of $K^{\pm} \to \pi^{\pm} \pi^0 \gamma$ decay

  - $K^+$ and $K^-$ present in the beam:
    possibility to study CP violating effects
  - Enlarged $T^*_\pi$ region in the low energy part ($0<T^*_\pi<80$ MeV) wrt previous experiments
  - Background contribution <1% * DE, mainly $K^{\pm} \to \pi^{\pm}\pi^0\pi^0$
  - Order ‰ $\gamma$ mistagging probability for IB, DE and INT




- In total:

  - More than 1 M reconstructed events (the full number is used for the CPV measurements)
  - After a cut on W (0.2; 0.9) and on $E_\gamma$ (>5GeV), still 600 k events left for the measurement of the DE and INT fraction

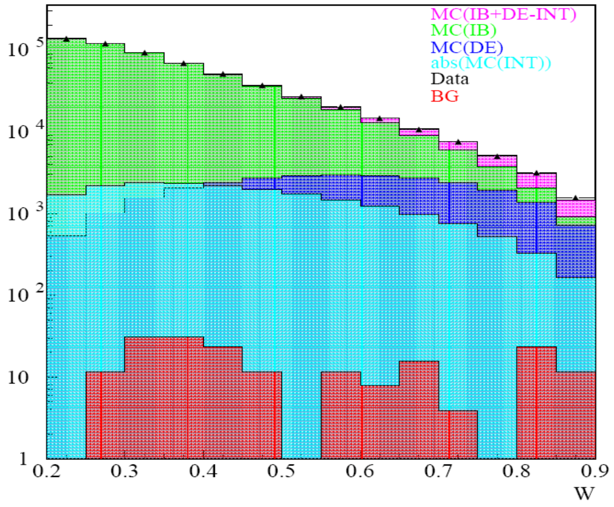
# $K^{\pm} \to \pi^{\pm} \pi^{0} \gamma$ – fitting techniques and fit results

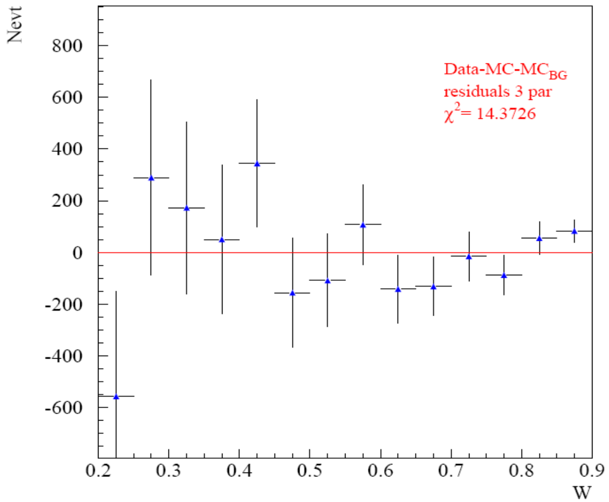
- **Extended Maximum Likelihood Fit *(main method)***
  - **An algorithm assigns weights to MC W distributions of the 3 components to reproduce data**

$$Data(i) = (1-\alpha-\beta)\cdot IB(i) + \alpha \cdot DE(i) + \beta \cdot INT(i)$$

  - **This algorithm relies on the very different W distributions**
- **Polynominal Fit *(used as cross-check)***
  - **The ratio W(Data)/W(IBMC) is fitted with polynomial function:** $F = c \cdot (1 + aW^2 + bW^4)$

| Systematics | DE x $10^{-2}$ | INT x $10^{-2}$ |
|---|---|---|
| Acceptance | 0.10 | 0.15 |
| L1trigger | 0.01 | 0.03 |
| L2 trigger | -- | 0.30 |
| Energy scale | 0.09 | 0.21 |
| Total | 0.14 | 0.39 |




**INT has never been observed before!**

**Final result ( 2003+2004 )**

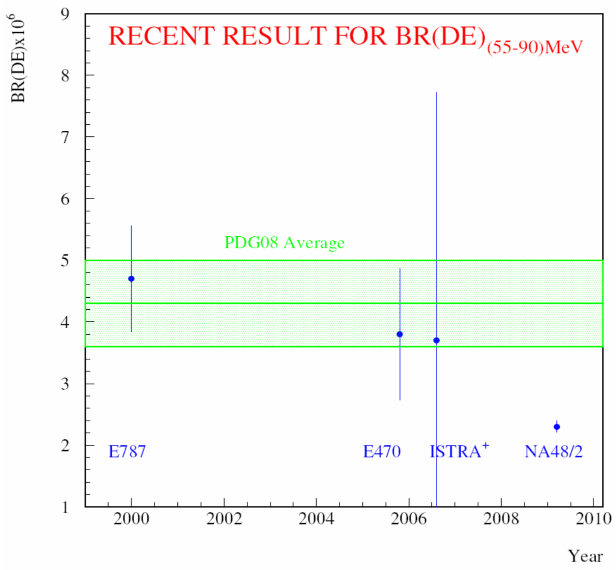
$Frac(DE)_{T^*\pi(0\text{-}80)MeV} = (3.32 \pm 0.15_{stat} \pm 0.14_{sys})*10^{-2}$

$Frac(INT)_{T^*\pi(0\text{-}80)MeV} = (-2.35 \pm 0.35_{stat} \pm 0.39_{sys})*10^{-2}$

## $K^{\pm}\to\pi^{\pm}\pi^{0}\gamma$ – comparison with previous experiments

**The BR(DE) assuming INT=0 ($T_{\pi}^{*}$= 55-90) MeV**
**polynomial fit technique**

- BR(DE) $_{T^*\pi(55-90)MeV}$= $(2.3\pm0.05_{stat}\pm0.077_{sys})\cdot10^{-6}$
- $PDG08_{avg} = (4.3 \pm 0.7)\cdot10^{-6}$
- Bad $\chi^2$ probability of the polynomial fit: indicates that INT=0 is a wrong assumption




## $K^{\pm}\to\pi^{\pm}\pi^{0}\gamma$ – first extraction of $X_E$ $X_M$

**Under following approximations:**

$\phi = 0$ and $\cos(\delta_1^1-\delta_0^2) = \cos(6.5°) \sim 1$

$X_E$ and $X_M$ can be extracted using the formulae:

$$X_E = \frac{Frac(INT)}{2\cdot(0.105\cdot m_K^2 m_\pi^2)}$$

$$X_M = \sqrt{\frac{Frac(DE) - m_K^4 m_\pi^4 \,|X_E|^2\, 2.27\cdot10^{-2}}{2.27\cdot10^{-2}\cdot m_K^4 m_\pi^4}}$$

**Magnetic and electric components**

$X_E=(-24 \pm 4_{stat} \pm 4_{sys})$ GeV$^{-4}$

$X_M = (254 \pm 11_{stat} \pm 11_{sys})$GeV$^{-4}$

## $K^{\pm}\to\pi^{\pm}\pi^{0}\gamma$ – CPV parameters measurements: asymmetry and $\phi$ angle: compatible with 0

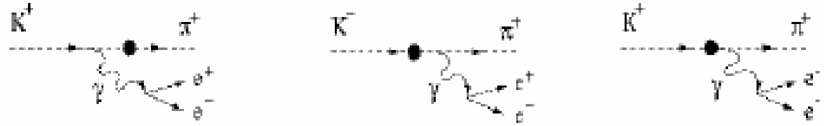
$$K^{\pm} \longrightarrow \pi^{\pm}\gamma^{*} \longrightarrow \pi^{\pm}l^{+}l^{-}$$

## $K^\pm \rightarrow \pi^\pm l^+ l^-$ - motivation and theory

$$d\Gamma_{\pi ee}/dz \sim \rho(z)\cdot|W(z)|^2$$

$z=(M_{ee}/M_K)^2$, $\rho(z)$ phase space factor

- suppressed FCNC processes
- one-photon exchange
- useful test for ChPT



Form-factor models:


(1) polynomial: $W(z) = G_F M_K^2 \cdot f_0 \cdot (1+\delta z)$

(2) ChPT $O(p^6)$: $W(z) = G_F M_K^2 \cdot (a_+, b_+, z) + W^{\pi\pi}(z)$

(3) ChPT, large-Nc QCD: $W(z) = W(w, \beta, z)$

(4) Mesonic ChPT: $W(z) = W(M_a, M_\rho, z)$

(2) D'Ambrosio et al. JHEP 8 (1998) 4
(3) S. Friot et al. PLB 595 (2004) 301
(4) Dubnickova et al. hep-ph/0611175

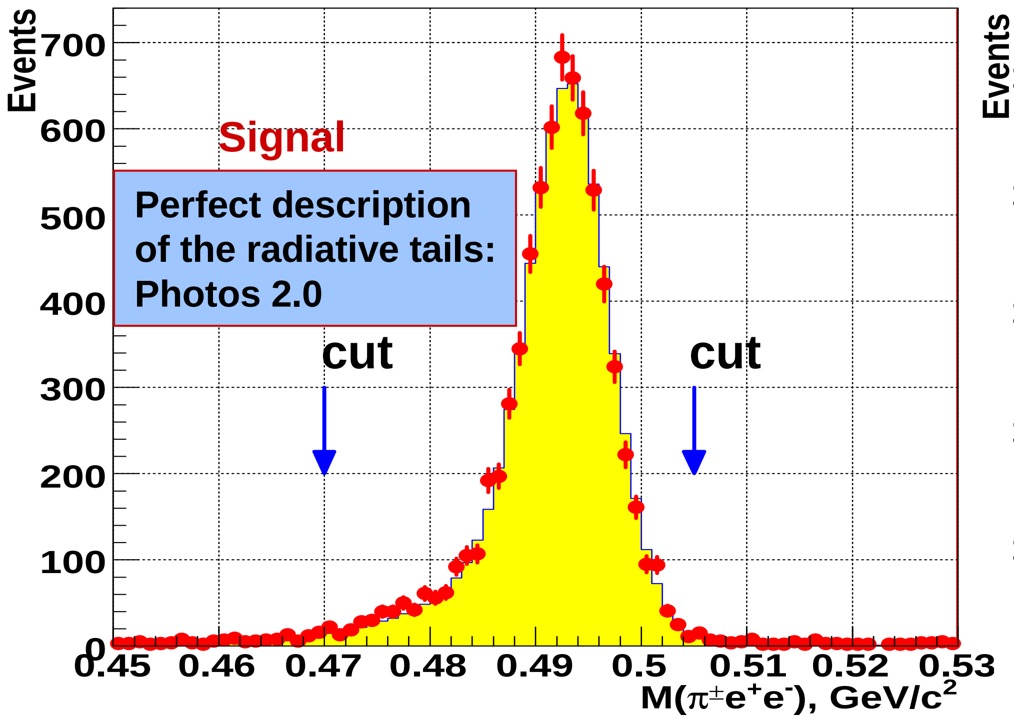
$(f_0, \delta)$ or $(a_+, b_+)$ or $(w, \beta)$ or $(M_a, M_\rho)$ determine a model-dependent BR

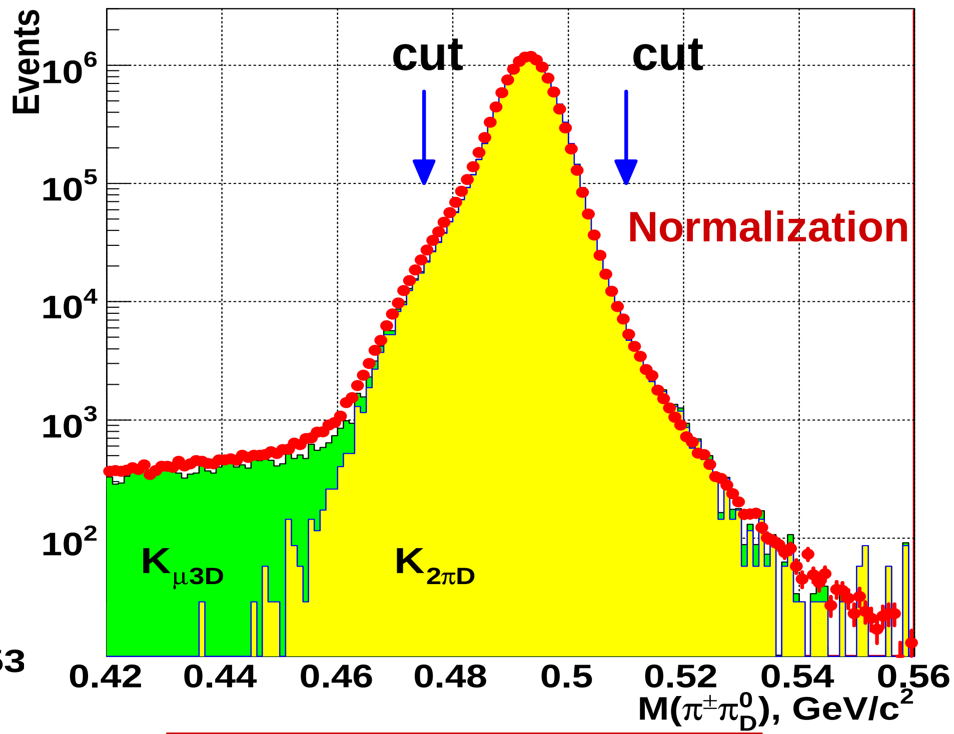
- Parameters of models and BR in full kinematical range
- Model-independent BR ($z > 0.08$) in visible kinematical range

# $K^{\pm} \rightarrow \pi^{\pm} e^{+} e^{-}$ - signal and normalization samples

**Selections of both channels based on very similar conditions: systematics (trigger, PID) in the BR ratio cancel particially**

- Mee > 140 MeV – cut for bg suppression
- Aditional $\gamma$ in the normalisation channel




**7253 candidates**
**BG: 71 events estimated with data BG/SIG. ~ 1.0%**

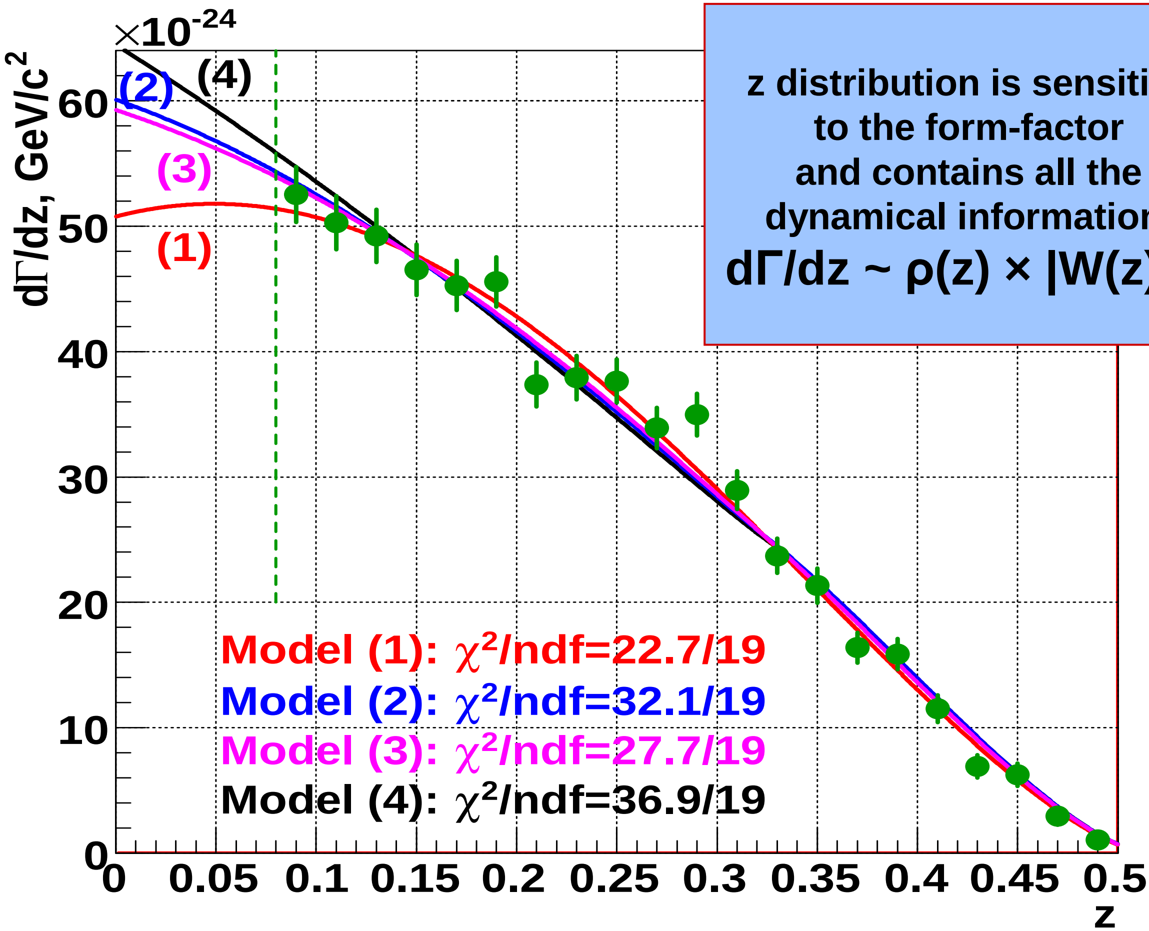
**12.12 M candidates**
**BG/Signal ~ 0.15%**
**BG subtracted with MC**

**Kaon decay flux (2003+2004): $\Phi_K = 1.70 \times 10^{11}$ with Flavianet'08 $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}$ BR**

# $K^{\pm} \to \pi^{\pm} e^{+} e^{-}$ - form factor measurement

GOALS

- Model-independent BR integrating $d\Gamma/dz$ in the observable z region
- Model dependent BRs using fit parameters.
- All models agree reasonably well with data




z distribution is sensitive to the form-factor and contains all the dynamical information:

$$d\Gamma/dz \sim \rho(z) \times |W(z)|^2$$

**Fit results**

$\delta = 2.32 \pm 0.18_{stat+syst}$

$|f_0| = 0.531 \pm 0.016_{stat+syst}$

$a_+ = -0.578 \pm 0.016_{stat+syst}$

$b_+ = -0.779 \pm 0.066_{stat+syst}$

$w = 0.057 \pm 0.007_{stat+syst}$

$\beta = 3.45 \pm 0.30_{stat+syst}$

$M_a = 0.974 \pm 0.035_{stat+syst}$ GeV

$M_\rho = 0.716 \pm 0.014_{stat+syst}$ GeV

# Results – comparison with previous experiments

**Model independent measurement**

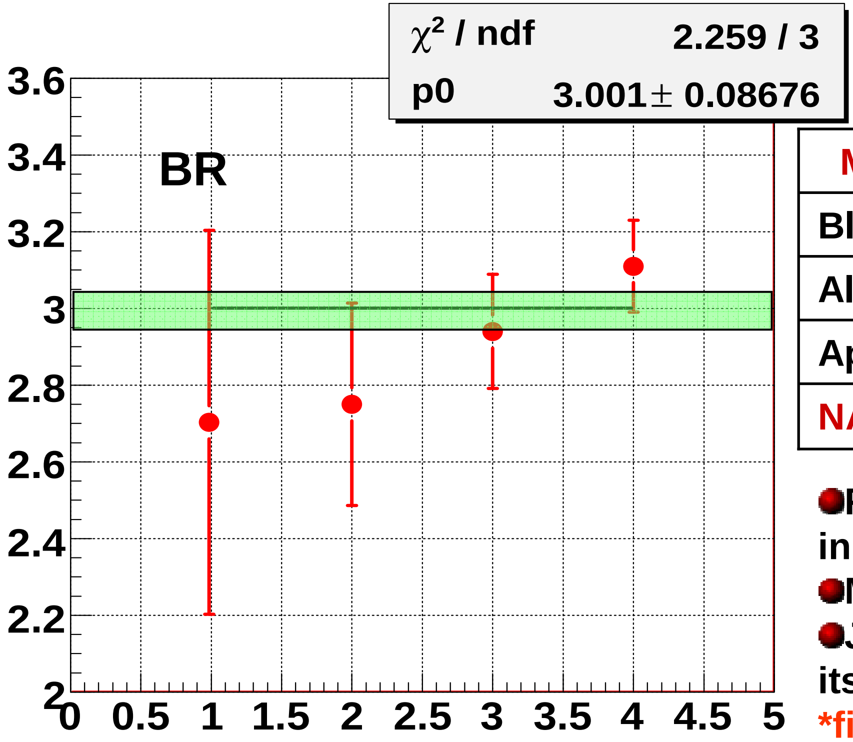
$$BR_{mi}\times10^{7}\ \ (M_{ee}>140\text{MeV}/c^{2}) = 2.28 \pm 0.03_{stat} \pm 0.04_{syst} \pm 0.06_{ext} = 2.28 \pm 0.08$$

**Combined result of the 4 models**

$$BR = (3.11\pm0.04_{stat}\pm0.05_{syst}\pm0.08_{ext}\pm 0.07_{model})\times10^{-7} = (3.11\pm0.12)\times10^{-7}$$

**CP violating asymmetry (first measurement! correlated $K^{+}/K^{-}$ uncertainties excluded):**

$$\Delta(K^{\pm}_{\pi ee}) = (BR^{+}-BR^{-}) / (BR^{+}+BR^{-}) = (-2.2\pm1.5_{stat}\pm0.6_{syst})\%$$

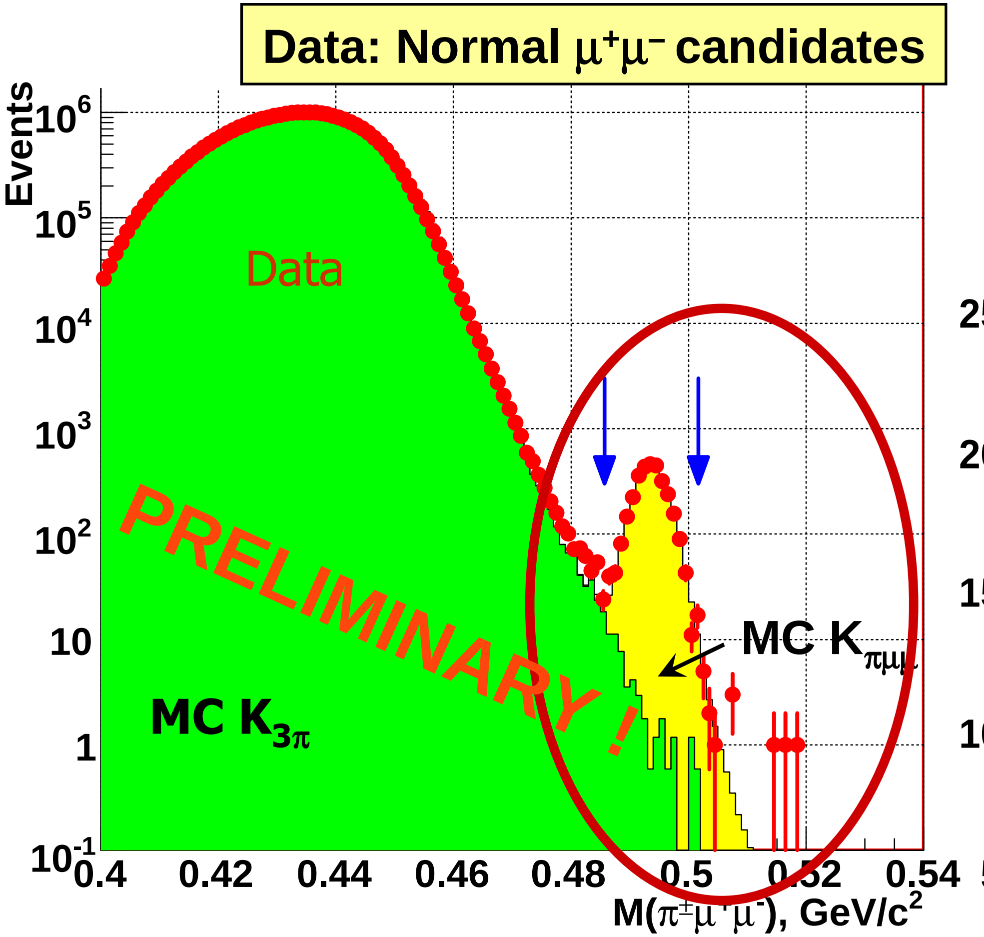



| Measurement | events | BR×10[7] |
|---|---|---|
| Bloch et al., PL 56 (1975) B201 | (41) | 2.70±0.50 |
| Alliegro et al.[E777], PRL 68 (1992) 278 | (500) | 2.75±0.26 |
| Appel et al. [E865], PRL 83 (1999) 4482 | (10000) | 2.94±0.15 |
| NA48/2 final (2009) | (7253) | 3.11±0.12 |

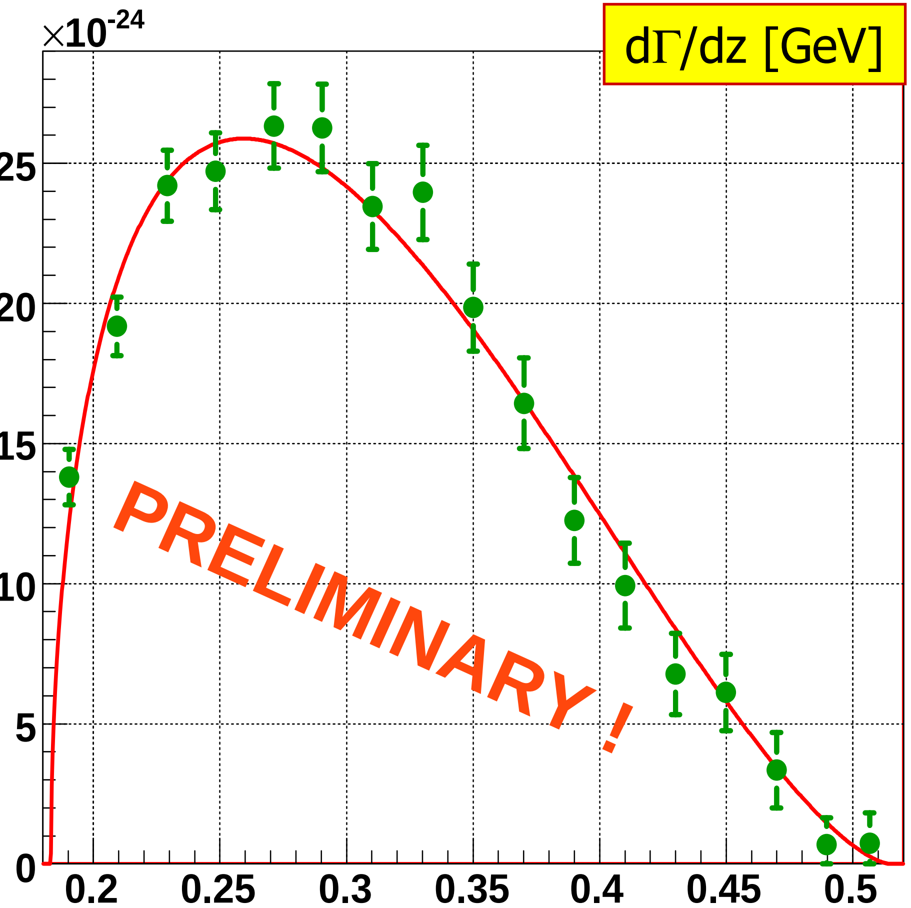
- Form factor measurements for Model 1, 2 and 3* in agreement with previous measurements
- Model 4 – never tested before
- J.Prades, e-Print: arXiv:0707.1789 [hep-ph], predicts (up to its sign) $a_{+} = -(0.6\ ^{+0.6}_{-0.23})$, in agreement with our result

*fit done by the authors of Model 3 using BNL E865 data

# $K^\pm \to \pi^\pm\mu^+\mu^-$ - signal region and fit




Fit to the linear form-factor




~**3100** reconstructed events in the signal region:
4 times larger sample than the existing world statistics!

# Conclusions

- **Precise measurement of $K^{\pm} \to \pi^{\pm} \pi^{0} \gamma$**
  - Precise measurement of DE contribution and first measurement of INT term
  - The values of $X_M$ and $X_E$ are extracted
  - The BR(DE) assuming INT=0 (55-90) MeV gave bad $\chi^2$ fit
  - CPV parameters measurements
  - Final result, paper in preparation

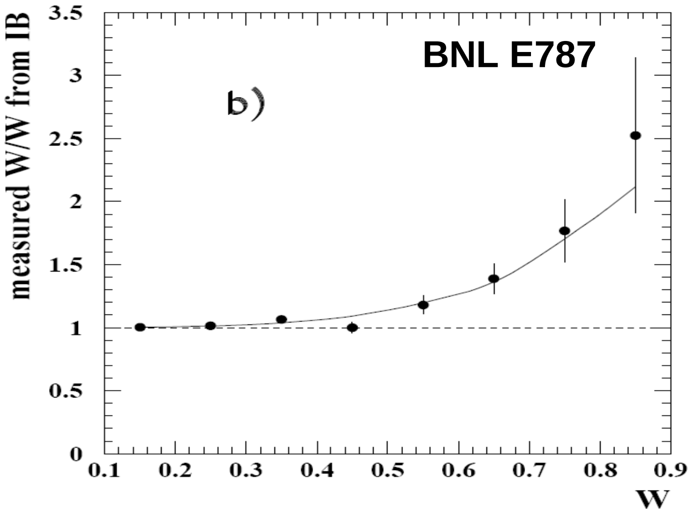
- **Precise measurement of $K^{\pm} \to \pi^{\pm} e^{+} e^{-}$**
  - Precision comparable with world's best;
  - BR and form factor measurements in agreement with ChPT and other measurements;
  - First limit on CPV asymmetry.
  - Paper published in PLB

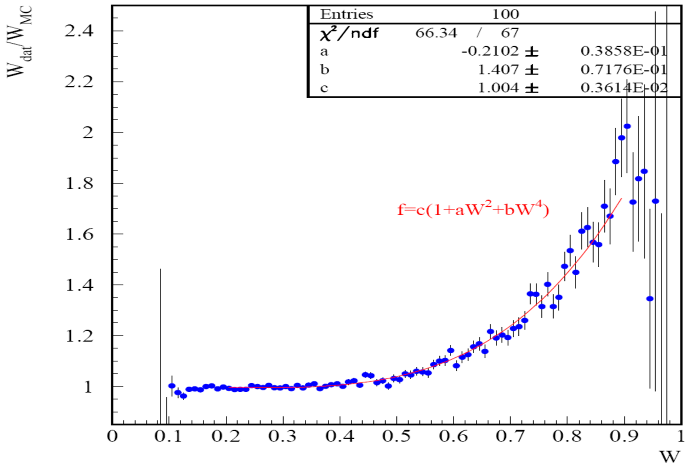
- **Precise measurement of $K^{\pm} \to \pi^{\pm} \mu^{+} \mu^{-}$**

  - Four times larger sample than the existing world statistics has been collected
  - Analysis is well advanced. Aim to bless preliminary results this year.

# SPARES

# $K^{\pm} \rightarrow \pi^{\pm} \pi^{0} \gamma$ – polynomial fit




**Polynomial fit**

**Frac(DE) = $(3.2 \pm 0.16) \cdot 10^{-2}$**

**Frac(INT) = $(-2.20 \pm 0.4) \cdot 10^{-2}$**

**The two results are in a very good agreement!**

# Fit function for W distribution

$$\frac{\partial\Gamma^{\pm}}{\partial W}=\frac{\partial\Gamma^{\pm}_{IB}}{\partial W}\left[1+\underbrace{2\cos(\pm\phi+\delta^1_1-\delta^2_0)m^2_\pi m^2_K\,|X_E|W^2}_{\textbf{INT}}+m^4_\pi m^4_K(|X_E|^2+|X_M|^2)W^4\right]$$

$$\frac{d\Gamma}{dW}=\frac{d\Gamma(IB)}{dW}\left(1+(X_E\cos\phi\cos\Delta^1_0\pm X_E\sin\phi\sin\Delta^1_0)\cdot W^2+cW^4\right)$$

$$\frac{d\Gamma}{dW}=\frac{d\Gamma(IB)}{dW}\left(1+(a\pm e)W^2+cW^4\right)$$

$$\frac{dAsym}{dW}=\frac{\Gamma^+-\Gamma^-}{\Gamma^++\Gamma^-}=\frac{e\cdot W^2}{1+a\cdot W^2+b\cdot W^4}$$

$$a=\frac{\cos\phi\cos(\Delta^1_0)X_E}{\int INT/IB}=\frac{Frac(INT)}{0.105}=-0.247$$

$$e=\frac{\sin\phi\sin(\Delta^1_0)X_E}{\int INT/IB}\Rightarrow Asym=e\int INT/IB$$

$$b=\frac{frac(DE)}{\int DE/IB}=\frac{0.032}{2.27\cdot10^{-2}}=1.463$$

# Extraction of the $\phi$ angle

$$\frac{\partial\Gamma^{\pm}}{\partial W} = \frac{\partial\Gamma^{\pm}_{IB}}{\partial W}\left[1 + 2\cos(\pm\phi + \delta_1^1 - \delta_0^2) m_\pi^2 m_K^2 \,|\, X_E \,|\, W^2 + m_\pi^4 m_K^4 (|\, X_E \,|^2 + |\, X_M \,|^2) W^4\right]$$

$$A_N = \frac{\Gamma^+ - \Gamma^-}{\Gamma^+ + \Gamma^-} \sim \frac{\Gamma^+ - \Gamma^-}{2\Gamma_{IB}} = 2(I_{INT}/I_{IB}) X_E m_K^2 m_\pi^2 sin(\phi) sin(\delta_1^1 - \delta_0^2)$$

$$sin(\phi) = \frac{A_N}{2(I_{INT}/I_{IB}) X_E m_K^2 m_\pi^2 sin(\delta_1^1 - \delta_0^2)}$$

**sin($\phi$) 2003+2004**

**sin($\phi$) = (-0.011 ± 0.43)     |sin($\phi$)|<0.56 CL 90%**

$\phi$

# $K^{\pm}\to\pi^{\pm}\pi^{0}\gamma$ - CP violation parameters

- **Asymmetry in the rates**

$$A_N = \frac{N_+ - RN_-}{N_+ + RN_-}$$

**where $R=N(K^+)/N(K^-)=1.7998\pm0.0004$ (using $K3\pi$ decays)**

**The NA48/2 result: $A_N = (0.03 \pm 1_{stat} \pm 0.6_{sys})\cdot10^{-3}$; limit -** $A_N < 1.5\cdot10^{-3}$ 90% C.L.

- **If $\phi \neq 0$ then $\Gamma(K^+\to\pi^+\pi^0\gamma) \neq \Gamma(K^-\to\pi^-\pi^0\gamma)$: clear sign for CP violation!**

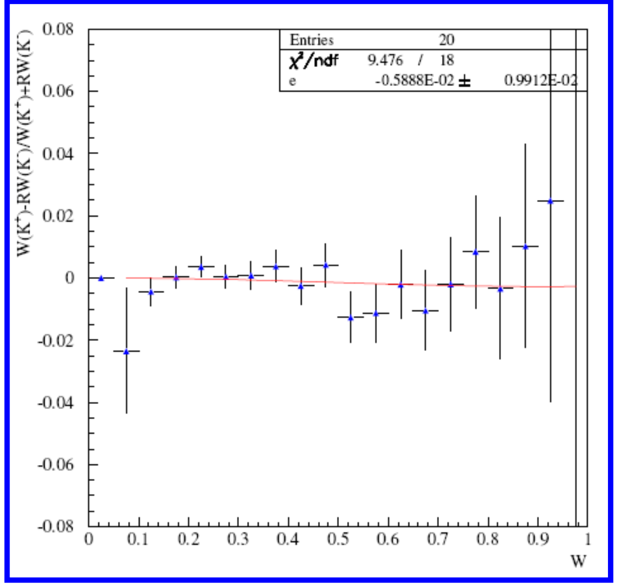
**NA48/2 result on $\sin(\phi)$: $\sin(\phi) = (-0.011 \pm 0.43)$, $|\sin(\phi)|<0.56$ CL 90%**

**Theoretical prediction (SM) :** Theoretical range $2\cdot10^{-6}$ to $1\cdot10^{-5}$ with $50<E_\gamma^*<170$ MeV

- **Asymmetry in the W spectrum**

$$\frac{dAsym}{dW} = \frac{e\cdot W^2}{1-0.247\cdot W^2+1.463\cdot W^4}$$

$$Asym = e\int INT/IB = (-0.6\pm1.)\cdot10^{-3}$$




**NA48/2 result: $A_W = (-0.6 \pm 1_{stat})\cdot10^{-3}$**

# CPV table of systematic

| **Effect** | **Value** |
|---|---|
| $P_K$ distribution correction | $3 \cdot 10^{-4}$ |
| + - Acceptance difference | $< 4 \cdot 10^{-5}$ |
| LVL1 trigger | $3 \cdot 10^{-4}$ |
| LVL2 trigger | $4 \cdot 10^{-4}$ |
| $\pi^+ \pi^-$ cross section difference | $\sim 4 \cdot 10^{-5}$ |
| R max variation | $3.5 \cdot 10^{-4}$ |
| **Total Systematic** | $\mathbf{6.1 \cdot 10^{-4}}$ |

# $K^{\pm} \to \pi^{\pm}e^{+}e^{-}$ - selection criteria

**BR ($K^{\pm} \to \pi^{\pm}e^{+}e^{-}$) is measured normalizing to $K^{\pm} \to \pi^{\pm}\pi^{0}_{D} \to \pi^{\pm}e^{+}e^{-}\gamma$**

**Common selection criteria**

- 3-track vertex concistent in space and time
- $E/p < 0.85$ ($\pi^{\pm}$), $E/p > 0.95$
- opposite sign electrons

## Selection cuts: signal

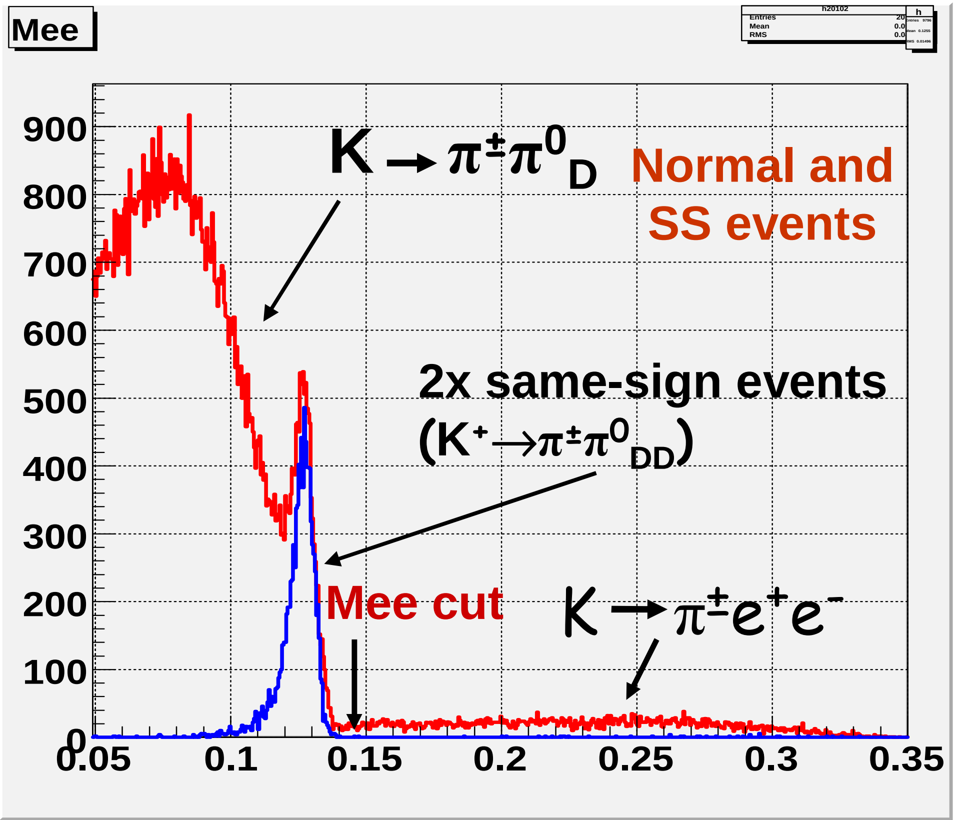
- $M_{ee} > 140$ MeV kinematical suppression of the bg from the normalization channel
- Cut on kaon ($\pi^{\pm}e^{+}e^{-}$) mass, total and transverse momentum

## Selection cuts: normalization ($K^{\pm} \to \pi^{\pm}\pi^{0}_{D}$)

- Selection of good $\gamma$
- Cut on kaon ($\pi^{\pm}e^{+}e^{-}\gamma$) mass, total and transverse momentum

**The use of a very similar channel cancels systematics (trigger, PID) in the BR ratio**

# $K^{\pm} \to \pi^{\pm}e^{+}e^{-}$ - background




$M_{ee}$ (all cuts applied except $M_{ee}$ > 140 MeV or z > 0.08)

**BG is identified with MC but BG is estimated from DATA with "same – sign" (SS) events.**

**The region $M_{ee}$ < 140 MeV is dominated by background**

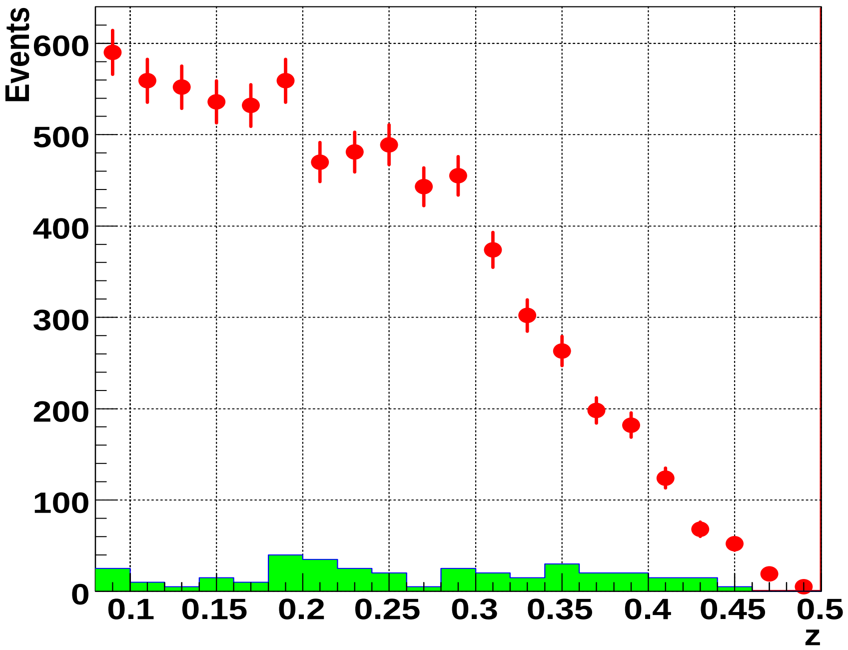
- $K^{\pm} \to \pi^{\pm}\pi^{0}_{D}$ with misid. $e^{\pm}$ and $\pi^{\pm}$
- $K^{\pm} \to e^{\pm}\nu\pi^{0}_{D}$ with misid. $e^{\pm}$
- $e^{+}e^{-}$ pairs (conversions and Dalitz)

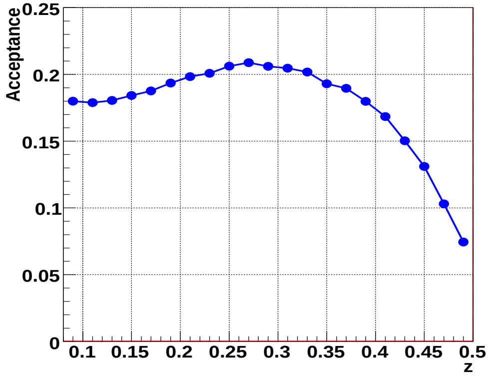
$$\left.\right\} \frac{SS}{BG} = 1$$

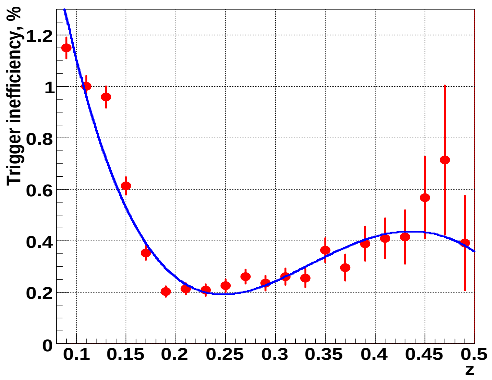
$$\left.\right\} \frac{SS}{BG} = \frac{1}{2}$$

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

acceptance




Background – scaled by factor 5 to be visible!

Trigger efficiency

# $K^{\pm} \to \pi^{\pm} e^{+} e^{-}$ - Final results on form factors, BR, asymmetry

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $BR_{mi} \times 10^{7}$ ($M_{ee}$>140MeV/$c^2$) | 2.26 | $\pm$ | $0.03_{stat}$ | $\pm$ | $0.03_{syst}$ | $\pm$ | $0.06_{ext}$ | = | $2.26 \pm 0.08$ |
| $\delta$ = | 2.32 | $\pm$ | $0.15_{stat}$ | $\pm$ | $0.09_{syst}$ | | | = | $2.32 \pm 0.18$ |
| $\lvert f_0 \rvert$ = | 0.531 | $\pm$ | $0.012_{stat}$ | $\pm$ | $0.008_{syst}$ | $\pm$ | $0.007_{ext}$ | = | $0.531 \pm 0.016$ |
| **$BR_1 \times 10^7$** = | 3.05 | $\pm$ | $0.04_{stat}$ | $\pm$ | $0.05_{syst}$ | $\pm$ | $0.08_{ext}$ | = | **$3.05 \pm 0.10$** |
| $a_+$ = | −0.578 | $\pm$ | $0.012_{stat}$ | $\pm$ | $0.008_{syst}$ | $\pm$ | $0.007_{ext}$ | = | $-0.578 \pm 0.016$ |
| $b_+$ = | −0.779 | $\pm$ | $0.053_{stat}$ | $\pm$ | $0.036_{syst}$ | $\pm$ | $0.017_{ext}$ | = | $-0.779 \pm 0.066$ |
| **$BR_2 \times 10^7$** = | 3.14 | $\pm$ | $0.04_{stat}$ | $\pm$ | $0.05_{syst}$ | $\pm$ | $0.08_{ext}$ | = | **$3.14 \pm 0.10$** |
| w = | 0.057 | $\pm$ | $0.005_{stat}$ | $\pm$ | $0.004_{syst}$ | $\pm$ | $0.001_{ext}$ | = | $0.057 \pm 0.007$ |
| $\beta$ = | 3.45 | $\pm$ | $0.24_{stat}$ | $\pm$ | $0.17_{syst}$ | $\pm$ | $0.05_{ext}$ | = | $3.45 \pm 0.30$ |
| **$BR_3 \times 10^7$** = | 3.13 | $\pm$ | $0.04_{stat}$ | $\pm$ | $0.05_{syst}$ | $\pm$ | $0.08_{ext}$ | = | **$3.13 \pm 0.10$** |
| $M_a$ = | 0.974 | $\pm$ | $0.030_{stat}$ | $\pm$ | $0.019_{syst}$ | $\pm$ | $0.002_{ext}$ | = | $0.974 \pm 0.035$ GeV |
| $M_\rho$ = | 0.716 | $\pm$ | $0.011_{stat}$ | $\pm$ | $0.007_{syst}$ | $\pm$ | $0.002_{ext}$ | = | $0.716 \pm 0.014$ GeV |
| **$BR_4 \times 10^7$** = | 3.18 | $\pm$ | $0.04_{stat}$ | $\pm$ | $0.05_{syst}$ | $\pm$ | $0.08_{ext}$ | = | **$3.18 \pm 0.10$** |

**Including uncertainty due to the model dependence:**

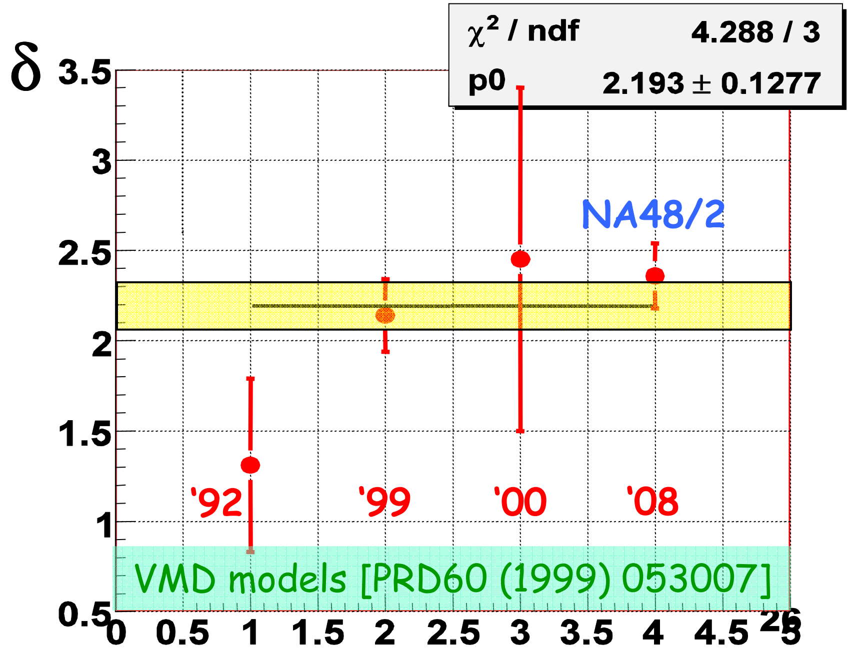
**$BR = (3.11 \pm 0.04_{stat} \pm 0.05_{syst} \pm 0.08_{ext} \pm 0.07_{model}) \times 10^{-7} = (3.11 \pm 0.12) \times 10^{-7}$**

**CP violating asymmetry (first measurement! correlated $K^+/K^-$ uncertainties excluded):**

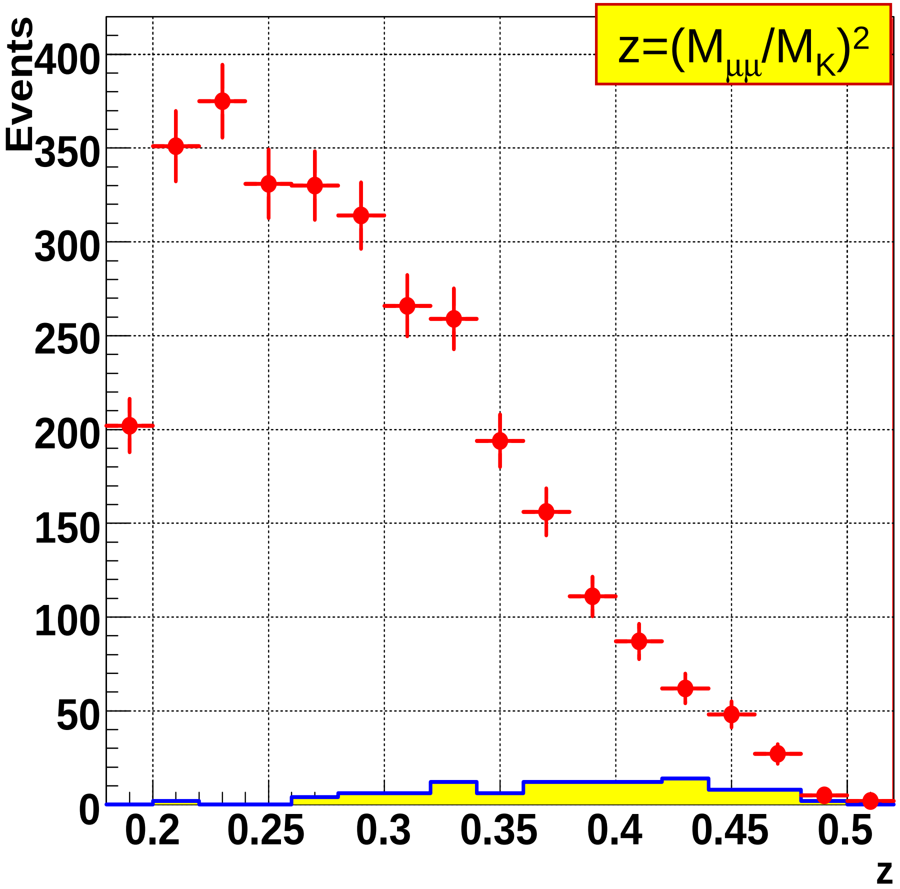
**$\Delta(K^{\pm}_{\pi ee}) = (BR^+ - BR^-) / (BR^+ + BR^-) = (-2.2 \pm 1.5_{stat} \pm 0.6_{syst})\%$**

# $K^{\pm} \to \pi^{\pm} e^{+} e^{-}$ : Linear fit – comparison with previous experiments

| Measurement | Process | Result |
|---|---|---|
| Alliegro et al.[E777], PRL 68 (1992) 278 | $K^{+} \to \pi^{+} e^{+} e^{-}$ | $1.31 \pm 0.48$ |
| Appel et al. [E865], PRL 83 (1999) 4482 | $K^{+} \to \pi^{+} e^{+} e^{-}$ | $2.14 \pm 0.20$ |
| Ma et al. [E865], PRL 84 (2000) 2580 | $K^{+} \to \pi^{+} \mu^{+} \mu^{-}$ | $2.45^{+1.30}_{-0.95}$ |
| NA48/2 final (2009) | $K^{\pm} \to \pi^{\pm} e^{+} e^{-}$ | $2.32 \pm 0.18$ |

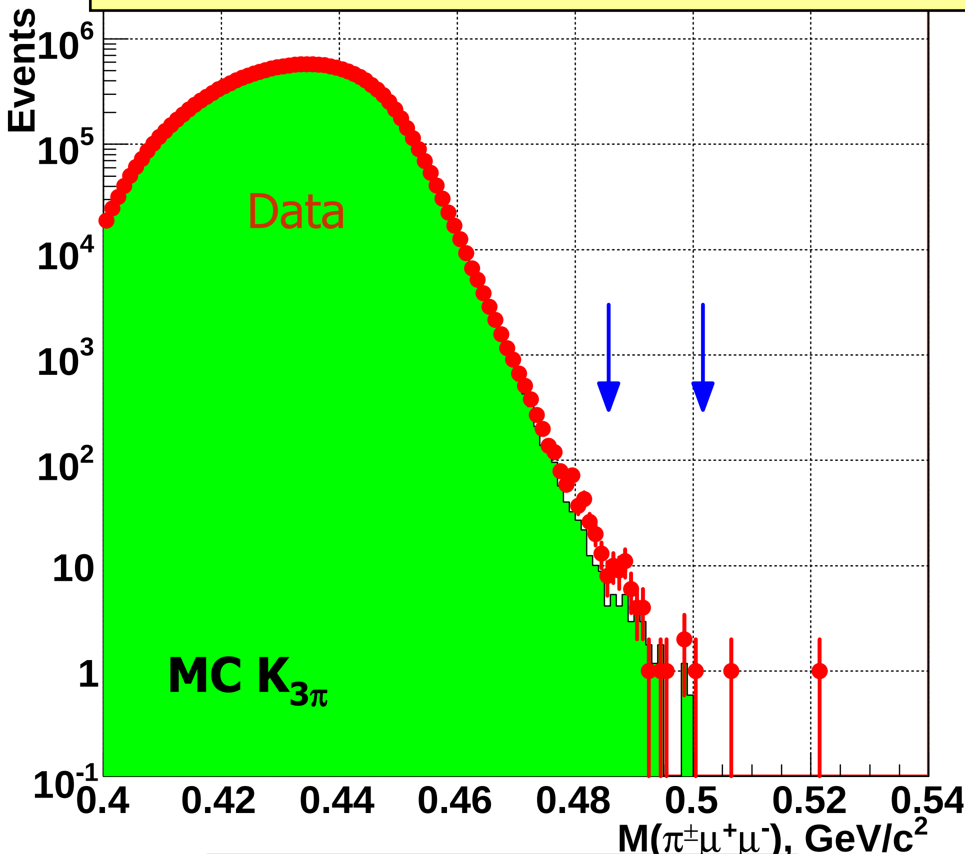


# $K^{\pm} \to \pi^{\pm}\mu^{+}\mu^{-}$ - background estimation




**Background estimated with same sign events**

**Data: 2 x Same-sign muon candidates**




**Consistent description of the background both with Monte Carlo simulation and data**