Measurements of radiative processes at NA48

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on behalf of the NA48/2 Collaboration

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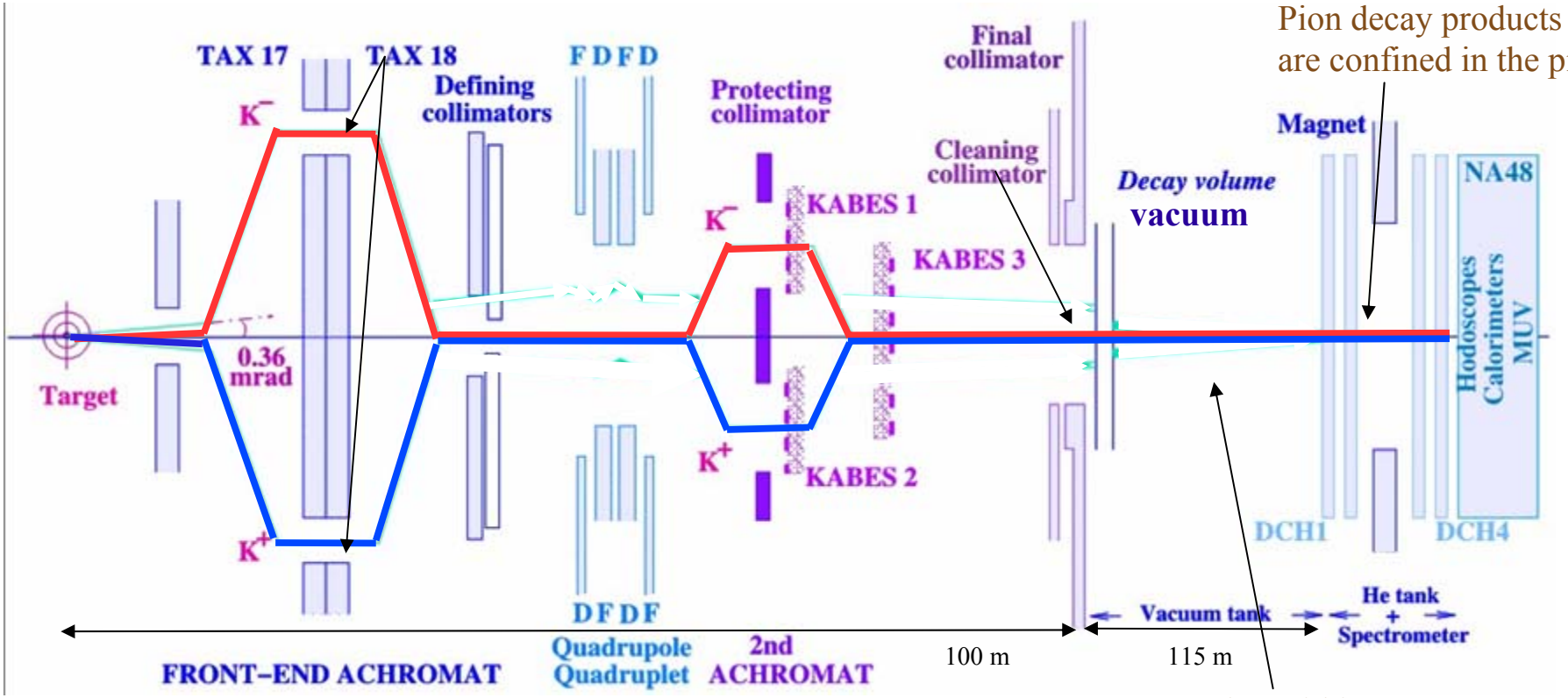
Outline

- $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$ decay
  - Formalism
  - Experimental status
  - NA48/2 measurement (preliminary)

- $K^{\pm} \rightarrow \pi^{\pm}e^{+}e^{-}\gamma$ decay
  - NA48/2 first evidence (preliminary)

- $\Xi^{0} \rightarrow \Lambda\,\gamma$ end $\Xi^{0} \rightarrow \Lambda^{0}e^{+}e^{-}$
  - NA48/1 measurement (final)

The NA48/2 beam line



Pion decay products are confined in the pipe

Beams overlap within ~1mm through the 115m long decay volume (vacuum 10^{-5} mbar)

- Split +/-
- Select P (60±3) Gev/c
- Recombine +/-

- Focusing
- Muon sweeping

- Cleaning
- Beam spectrometer (resolution 0.7 %)

The NA48 detector

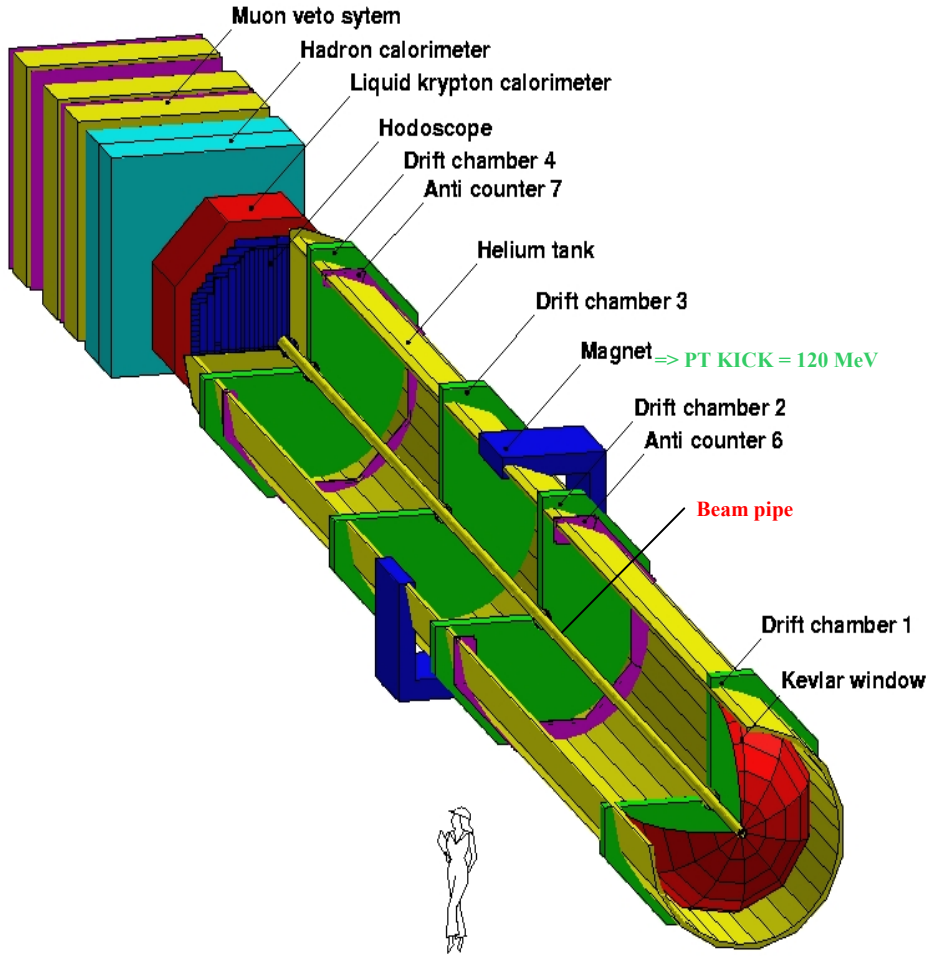
- Magnetic spectrometer (4 DCHs):
  $\Delta p/p = 1.0\% + 0.044\% * p$ [GeV/c]
  $\pi^+\pi^-\pi^\pm$ mass resolution about 1.7 Mev/c

- Liquid Krypton EM calorimeter (LKr)
  High granularity, quasi-homogenious;
  $\Delta E/E = 3.2\%/\sqrt{E} + 9\%/E + 0.42\%$[GeV]
  $\sigma_x, \sigma_y \sim 1.5$ mm
  $\pi^0\pi^0\pi^\pm$ mass resolution about 1.4 Mev/c

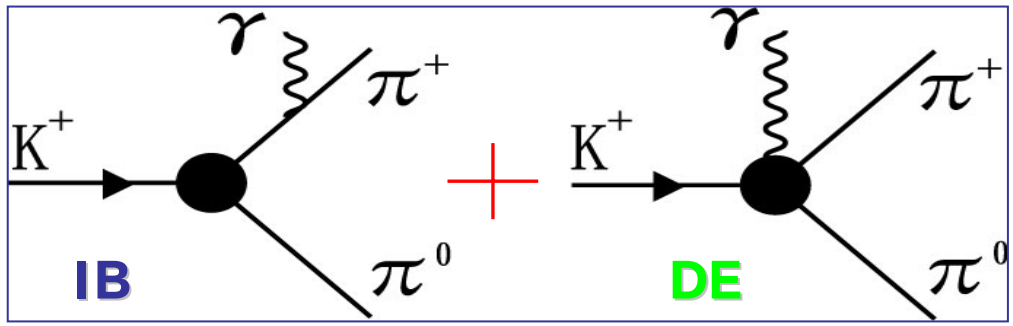
- Hodoscope
  fast trigger;
  precise time measurement (200ps).

- Hadron calorimeter, muon veto counters,
  photon vetoes.

LV1 trigger: hodoscope and DCH multiplicity
LV2 trigger: on-line data processing



$K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$ (decay formalism)



$$\frac{d\Gamma^{\pm}}{dW} \simeq \left(\frac{d\Gamma^{\pm}}{dW}\right)_{IB}\left[1 + 2\left(\frac{m_\pi}{m_K}\right)^2 W^2|E|cos((\delta_1-\delta_0)\pm\phi) + \left(\frac{m_\pi}{m_K}\right)^4 W^4(|E|^2+|M|^2)\right]$$

IB INT DE

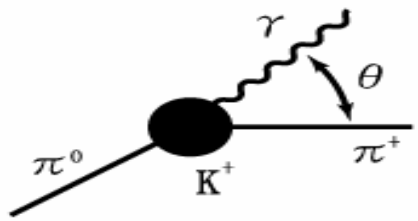
$\Gamma^{\pm}$ depends on 2 variables (T^*_π and **W**) that can be reduced to only one integrating over T^*_π

Sensitive variable:

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

$$W^2 = \frac{E_\gamma^2(E_\pi - P_\pi \cos\theta_{\pi\gamma})}{m_K m_\pi^2}$$

$\mathbf{P}^*_K$ = 4-momentum of the $K^{\pm}$
$\mathbf{P}^*_\pi$ = 4-momentum of the $\pi^{\pm}$
$\mathbf{P}^*_\gamma$ = 4-momentum of the γ



$K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$ (amplitudes)

Two types of contributions:

Electric (J=l±1) dipole (E)

Magnetic (J=l) dipole (M)

Electric contributions are dominated by the Inner Bremsstrahlung term

DE shows up only at order $O(p^4)$ in CHPT: is generated by both E and M contributions

INT term is sensitive to E only

Status of the art before NA48/II measurement:

Inner Bremsstrahlung(IB) : $(2.75\pm0.15)\cdot10^{-4}$ PDG (2006) ($55<T^{*}_{\pi}<90$ MeV)

Direct Emission (DE) : $(4.4\pm0.7)\cdot10^{-6}$ PDG (2006) ($55<T^{*}_{\pi}<90$ MeV)

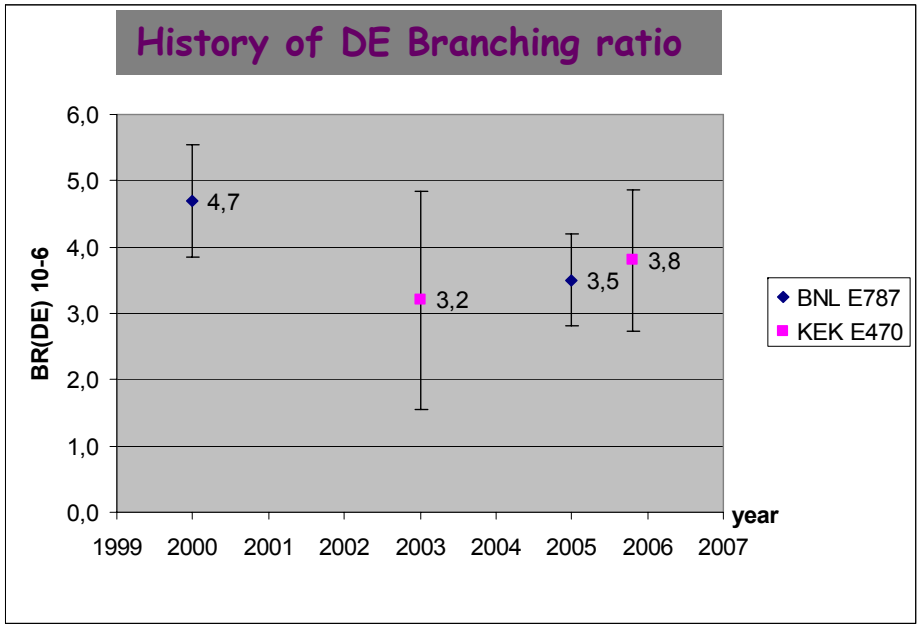
Interference (INT) : not yet measured

$K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$ (exp results for DE and INT)

Experiment	Year	# Events	BR(DE) × 10^6
E787 [20]	2000	19836	$4.7 \pm 0.8 \pm 0.3$
E470 [21]	2003	4434	$3.2 \pm 1.3 \pm 1.0$
E787 [22]	2005	20571	$3.5 \pm 0.6^{+0.3}_{-0.4}$
E470 [23]	2005	10154	$3.8 \pm 0.8 \pm 0.7$

All the measurements have been performed:

- ✓in the T^*_π region **55-90 MeV** to avoid $\pi^{\pm}\pi^0$ and $\pi^{\pm}\pi^0\pi^0$ background
- ✓assuming INT = 0



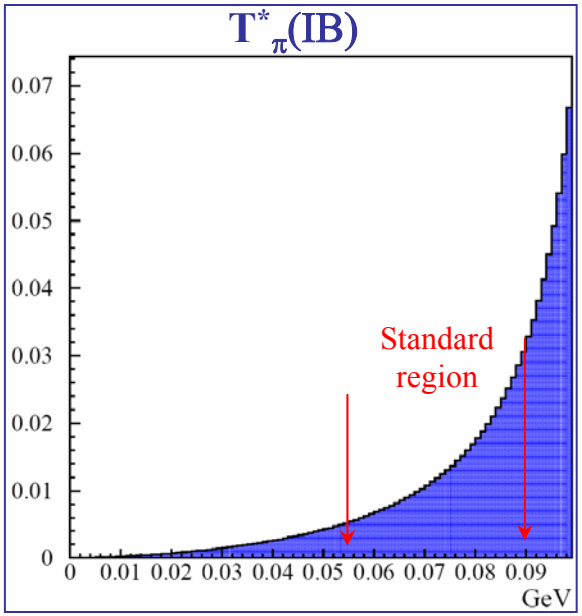
Interference estimations*:

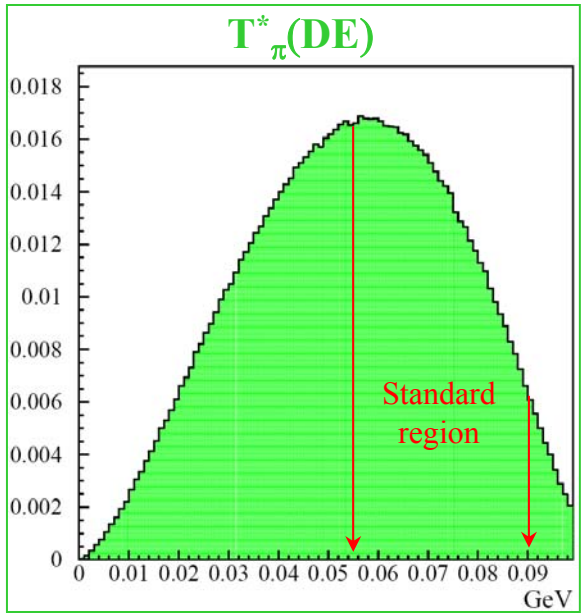
$$\mathrm{INT} = (-0.58^{+0.91}_{-0.83})\% \text{ of IB}$$ **BNL E787**

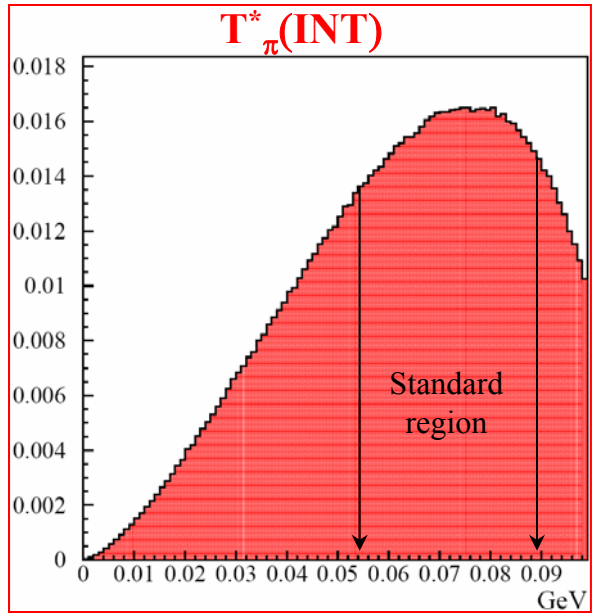
$$\mathrm{INT} = (-0.4 \pm 1.6)\% \text{ of IB}$$ **KEK E470**

*not quoted as measurements by authors

$K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$ (enlarged T^{*}_{π} region)







Use standard region **$55<T^{*}_{\pi}<90$ MeV** as safe choice for BG rejection

But…. region **<55 MeV** is the most interesting to measure **DE** and **INT**

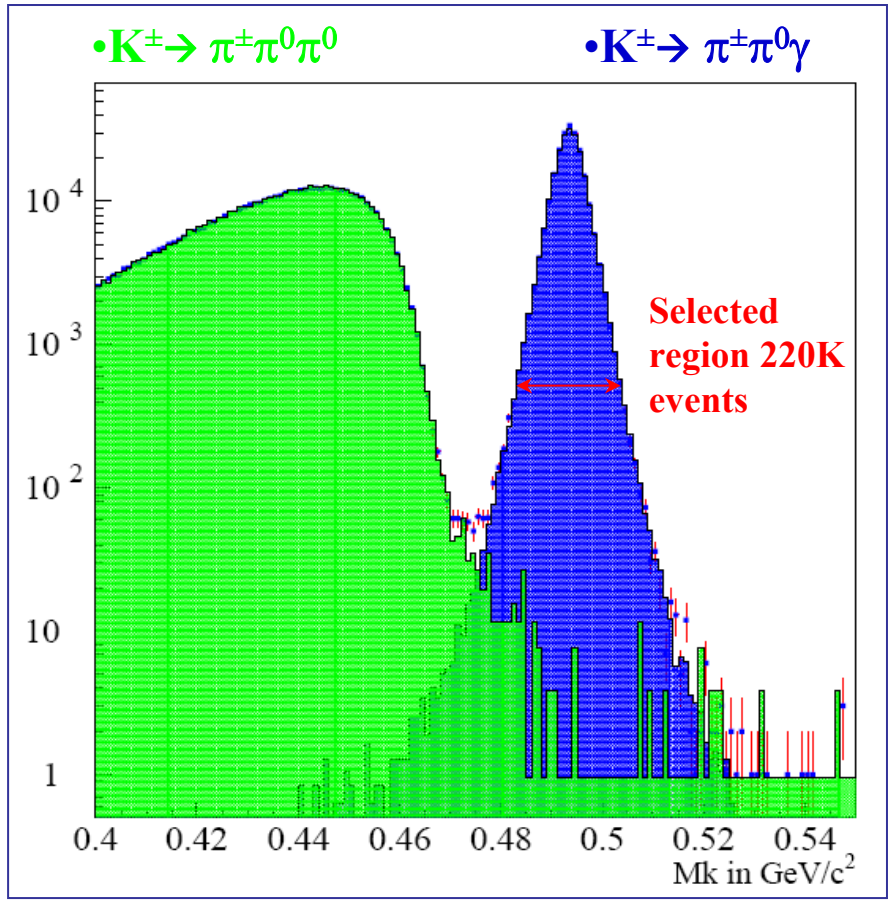
This measurement is performed in the region

$0 < T^{*}_{\pi} < 80$ MeV

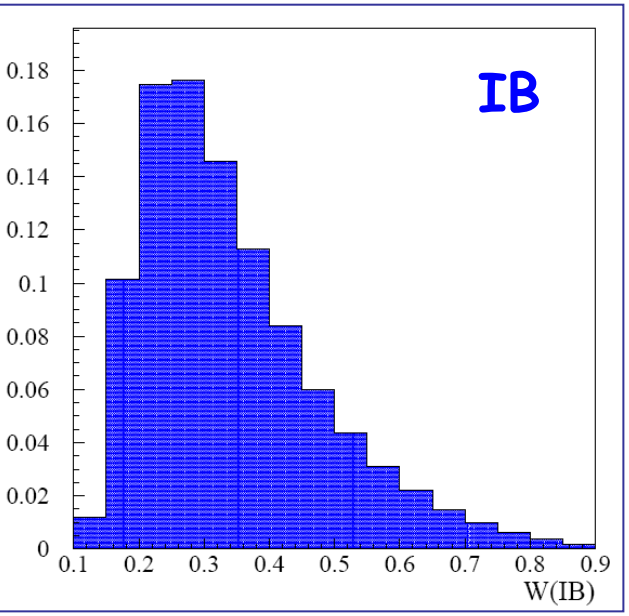
to improve statistics and sensitivity to **DE**

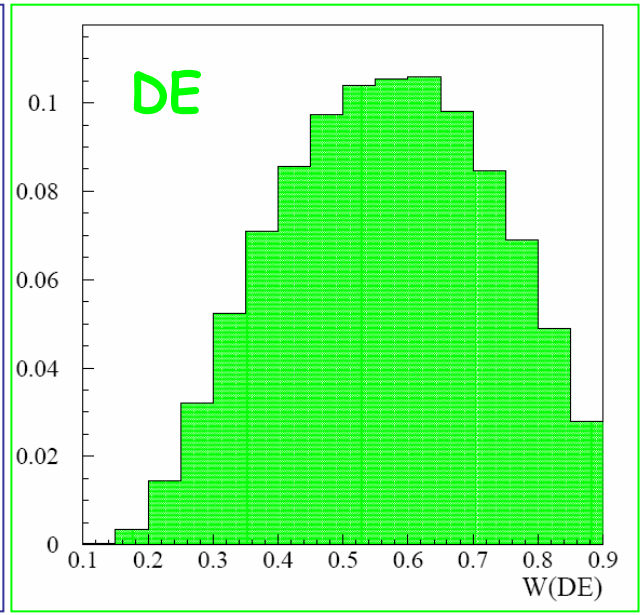
$K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$ (the selected data sample)

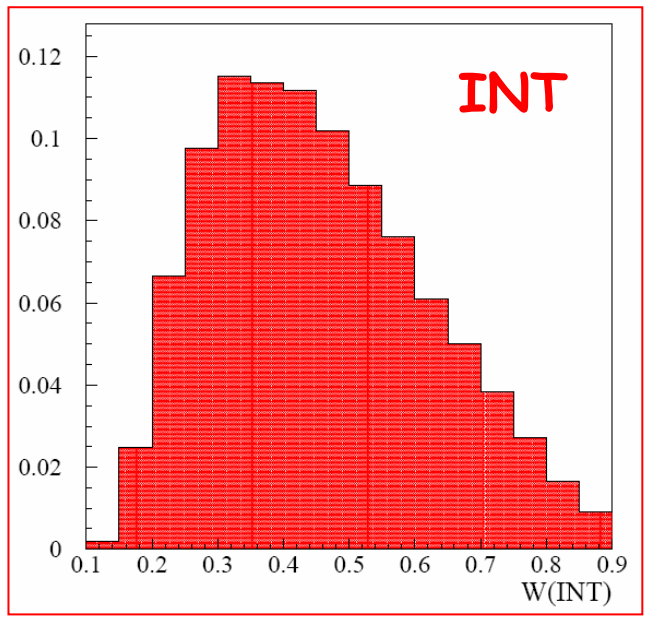
- Event selection
  - requirements on tracks
  - requirements on LKR clusters
  - effort into γs pairing
  - requirements on the event closure
- All **physical BG** can be explained in terms of $\pi^{\pm}\pi^{0}\pi^{0}$ events only
- Very small contribution from accidentals
- γ mistagging probability ("self background") is order of ‰



$K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$ (W shapes from MC)



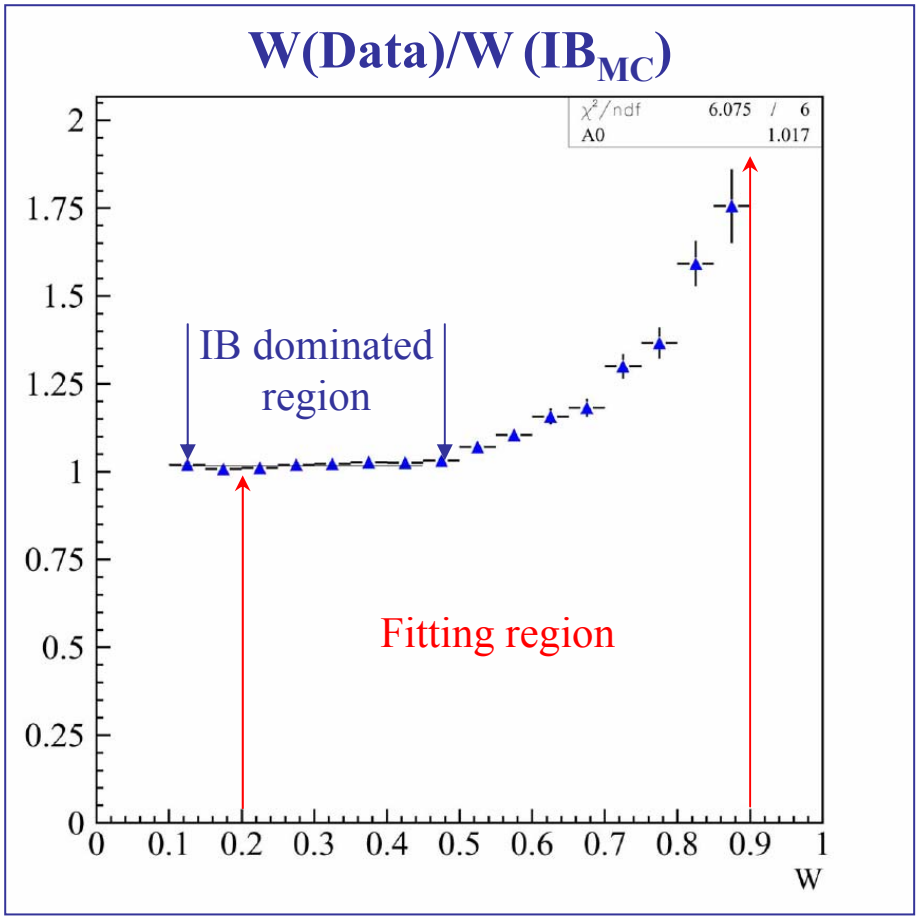




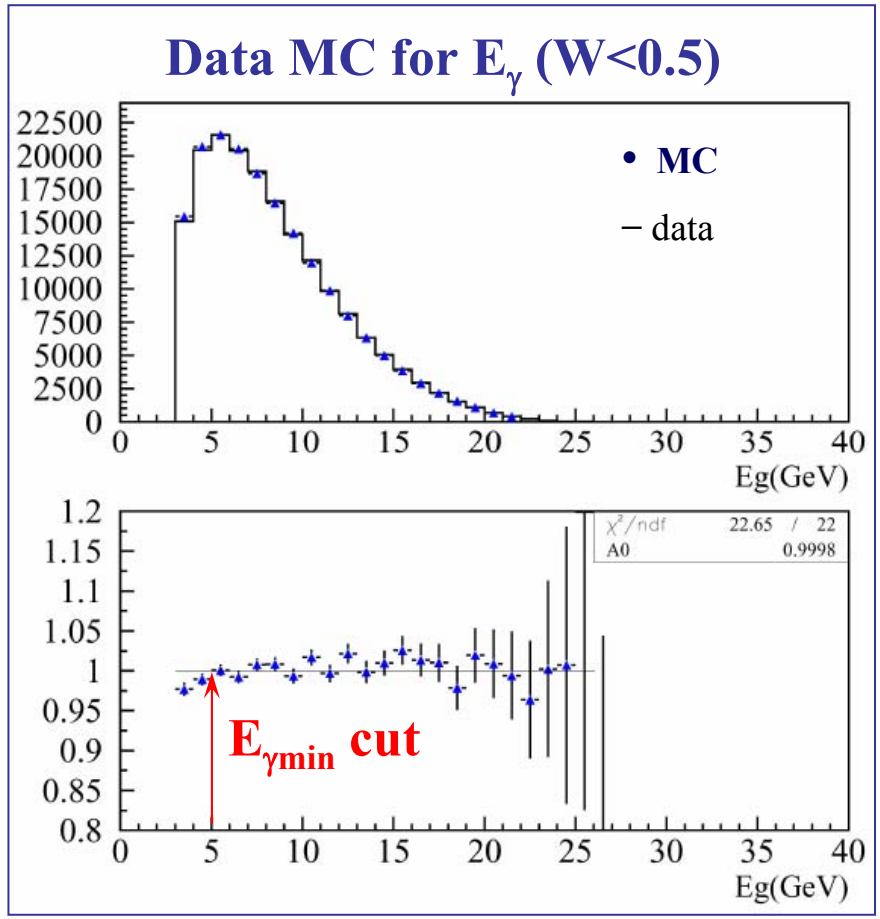
- 3 MC data samples for the 3 contributions to the decay

$K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$ (Data-MC comparison)

IB dominated part of the W spectrum



Radiated γ energy (**IB** dominated)



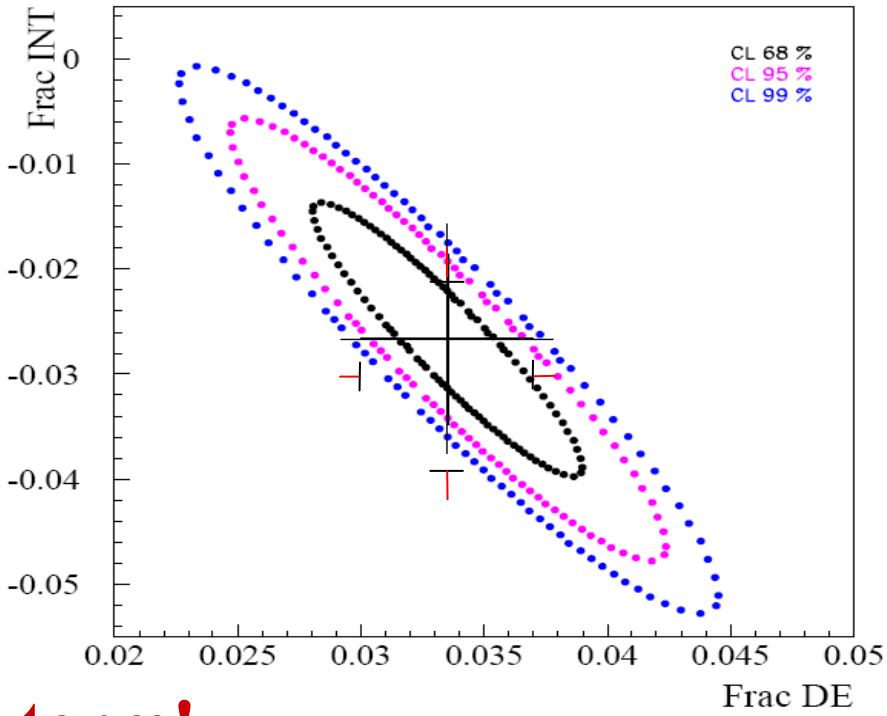
- IB contribution is very well reproduced by MC

$K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$ (fit results)

- fit the W data spectrum using MC shapes with the weights to be extracted:

$$W_{dat} = (1-\alpha-\beta)W_{IB} + \alpha W_{DE} + \beta W_{INT}$$

- systematic dominated by Trigger efficiency.
- parameters are highly correlated r=-0.92



First evidence of non zero INT term!

$$Frac(DE)_{0<T^*_\pi<80\ MeV} = (3.35 \pm 0.35 \pm 0.25)\%$$

$$Frac(INT)_{0<T^*_\pi<80\ MeV} = (-2.67 \pm 0.81 \pm 0.73)\%$$

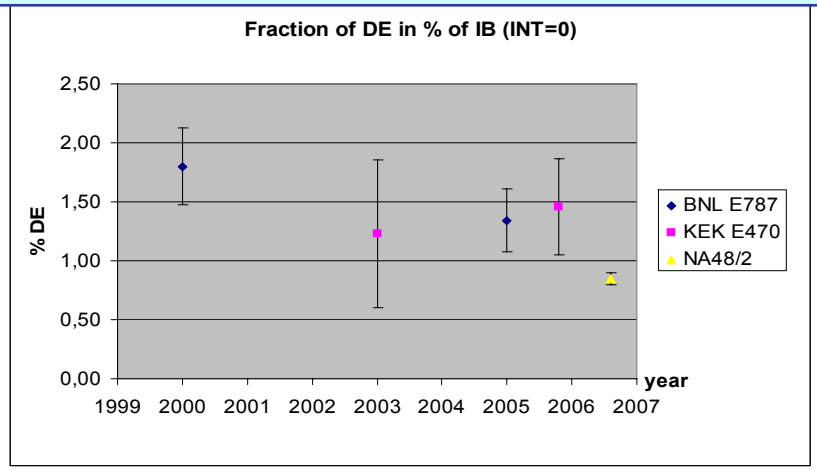
2004 data set: x4 # events and lower systematic due to trigger

$K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$ (comparison to others)

✓ For comparison with previous experiments the fraction of DE has been also measured, with:

- INT = 0
- $55<T^{*}_{\pi}<90$ MeV

$Frac(DE)_{55<T^{*}_{\pi}<90\ MeV} = (0.85 \pm 0.05 \pm 0.02)\%$



Consistent, although the analysis of fit's residuals shows a bad χ^2

Indication for a non-null INT term

$K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$ (final remark)

✓ from D'Ambrosio and Cappiello (**Phys.Rev.D75:094014,2007**)

new input to $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$ dynamics

- $d\Gamma^{\pm}/dW$ should include a form factor (dependent on W)

→ W shapes in MC samples need to be recomputed (DE shape only)

→ the fit as well

→ non negligible modifications are expected on DE and INT fractions

→ The form factor can induce a fake positive INT term

$K^{\pm} \to \pi^{\pm} e^{+} e^{-} \gamma$ (BR measurement)

Never observed before

Naïve estimation of the BR:

$BR(K^{\pm} \to \pi^{\pm} e^{+} e^{-} \gamma) = BR(K^{\pm} \to \pi^{\pm} \gamma\gamma) \cdot 2\alpha \sim 1.6 \cdot 10^{-8}$

Theoretical expectation (χPt based, Gabbiani 99):

$BR(K^{\pm} \to \pi^{\pm} e^{+} e^{-} \gamma) = (0.9\text{-}1.6) \cdot 10^{-8}$ depending from $\hat{c}$

Event sample:

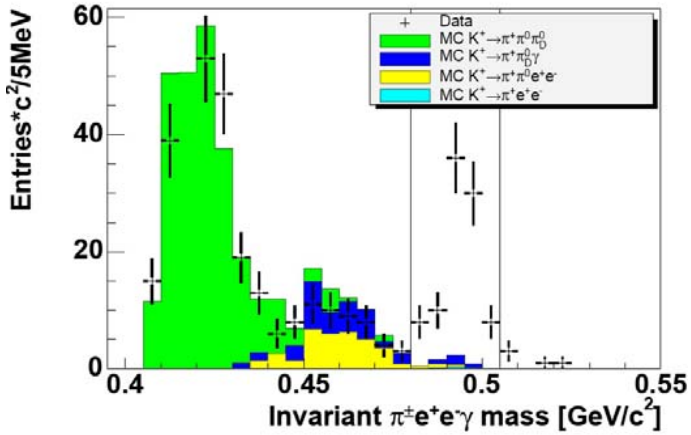
92 candidates events with

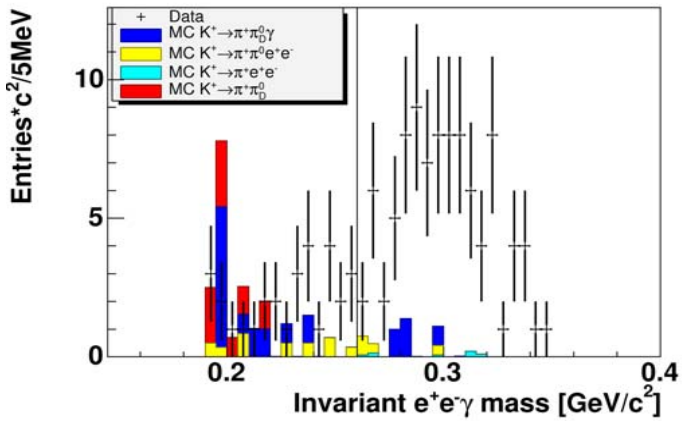
1±1 accidental background

5.1±1.7 physical background

Normalization channel:

$K^{\pm} \to \pi^{\pm} \pi^{0}_{D}$: 14M events



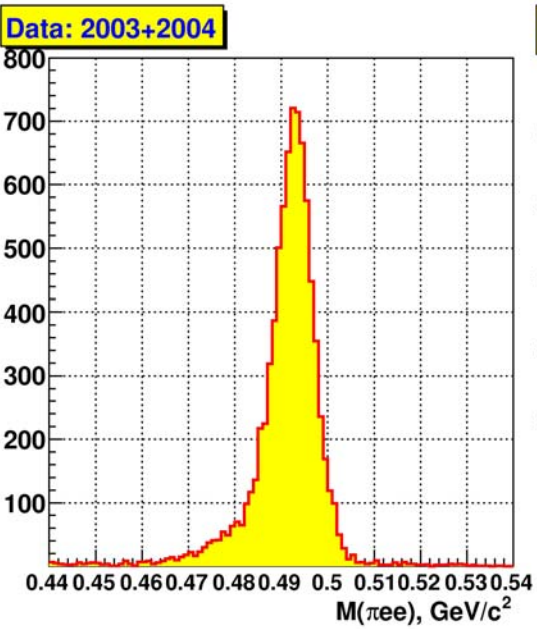


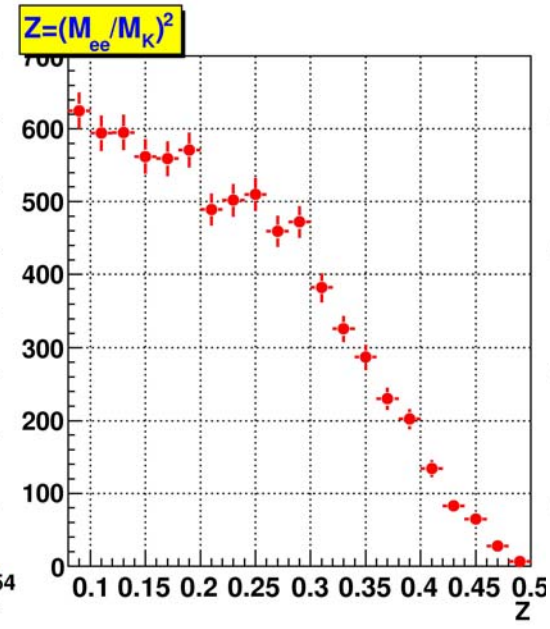
$$BR(K^{\pm} \to \pi^{\pm} e^{+} e^{-} \gamma) = (1.27 \pm 0.14_{stat} \pm 0.05_{sys}) \cdot 10^{-8}$$

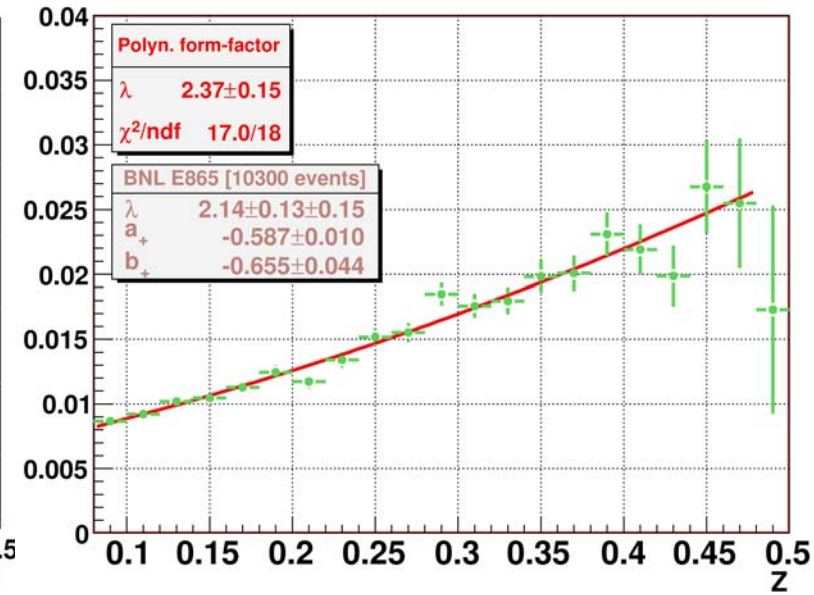
$K^{\pm} \to \pi^{\pm} e^{+} e^{-}$ (bkg to $K^{\pm} \to \pi^{\pm} e^{+} e^{-} \gamma$)

Flavor changing neutral current decay, $\Delta S=1$ (hep-ph/9808289)

7700 events with a background of 0.6% from 2003 and 2004 runs





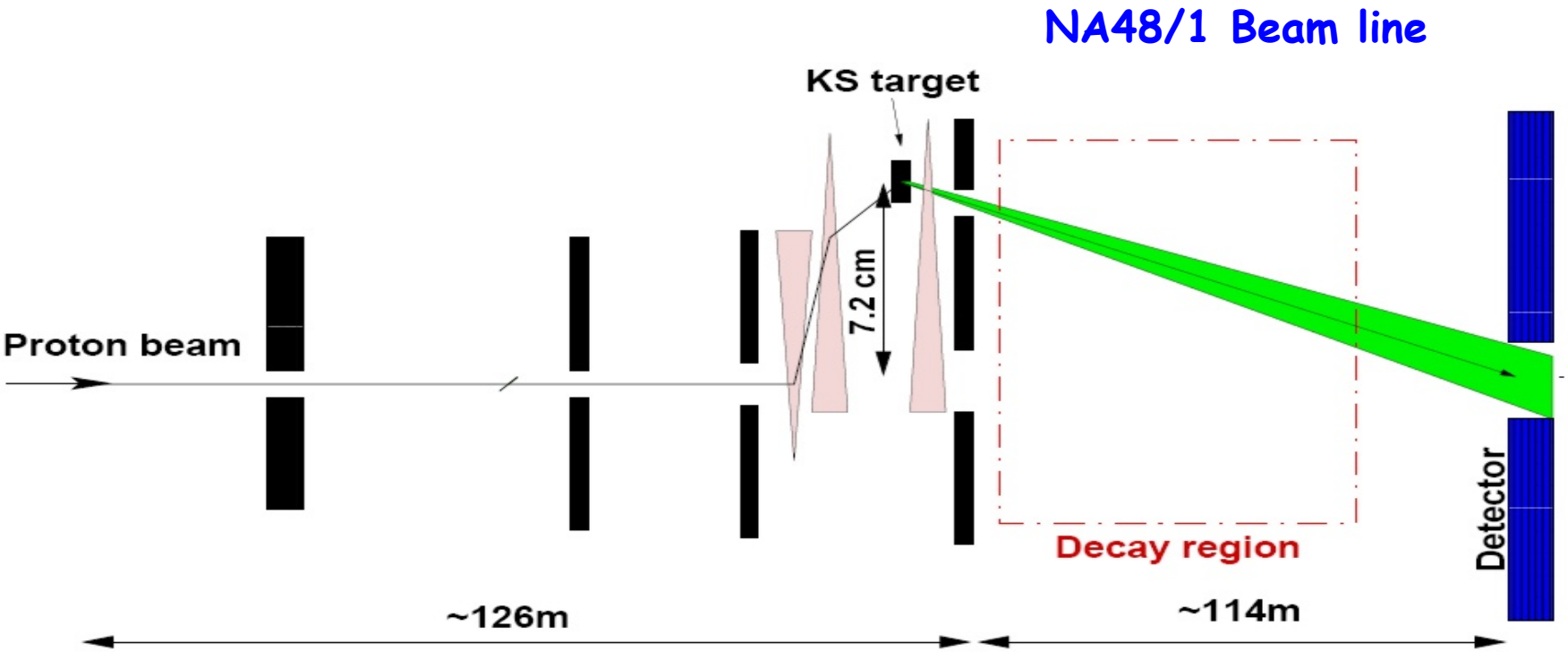


Measurement of the linear slope of the form factor:

$\lambda = 2.37 \pm 0.17$ (preliminary)

BR measurement is ongoing to extract both a_+ and b_+

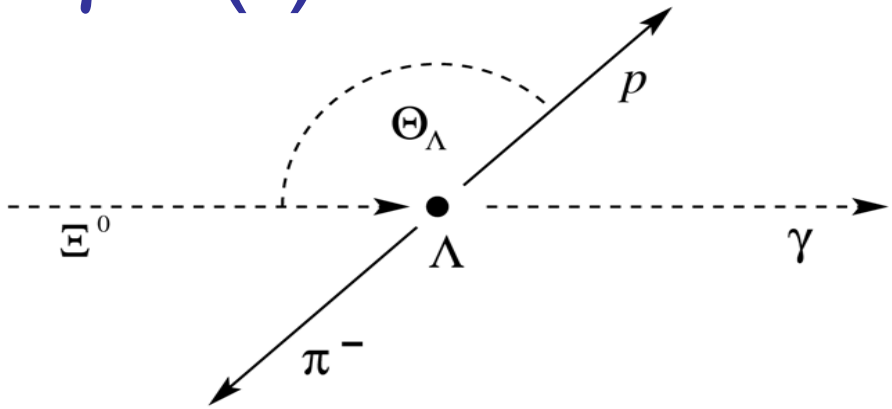
Radiative Hyperon decays from NA48/1



- same detector as NA48/2
- neutral beam: mainly K^0, Ξ^0, Λ, n, γ

$\Xi^0 \rightarrow \Lambda\,\gamma$ (I)

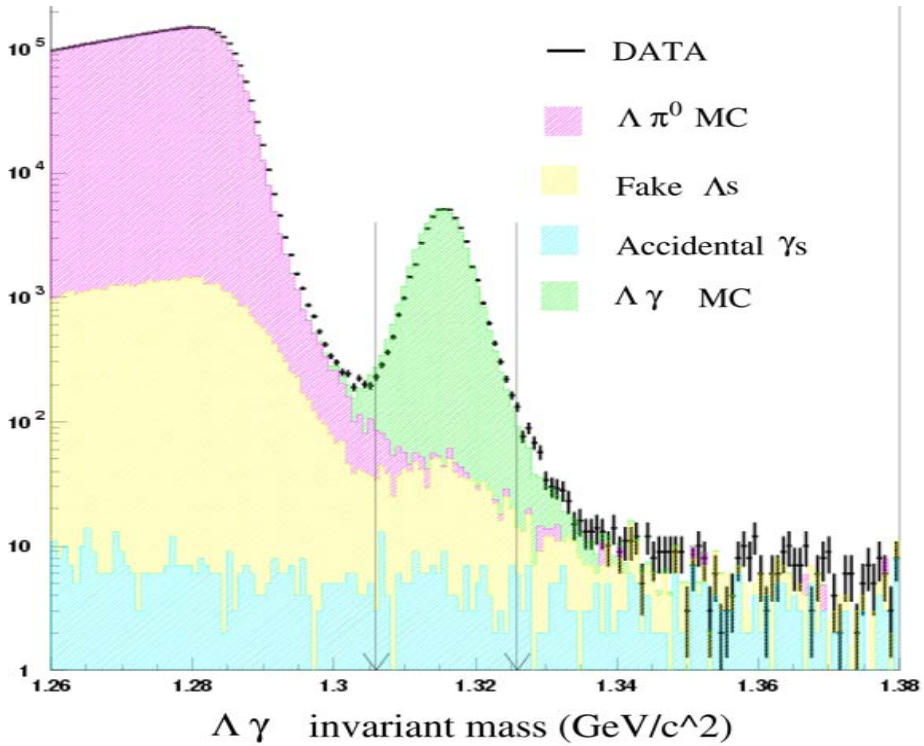
- Use the $\Lambda \rightarrow p\pi^-$ as analyser
- $dN/d\cos\Theta \propto 1 - \alpha_\Lambda \alpha_\Xi \cos\Theta$
- $\alpha_\Lambda = 0.642 \pm 0.013$ (PDG)



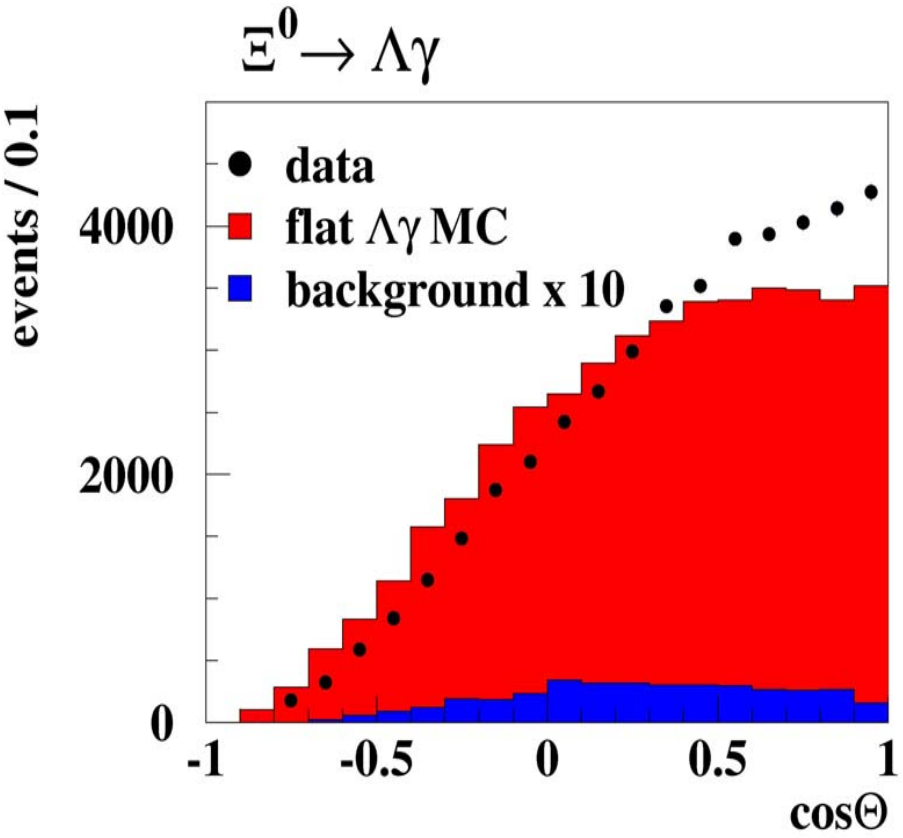
From 2002 run:

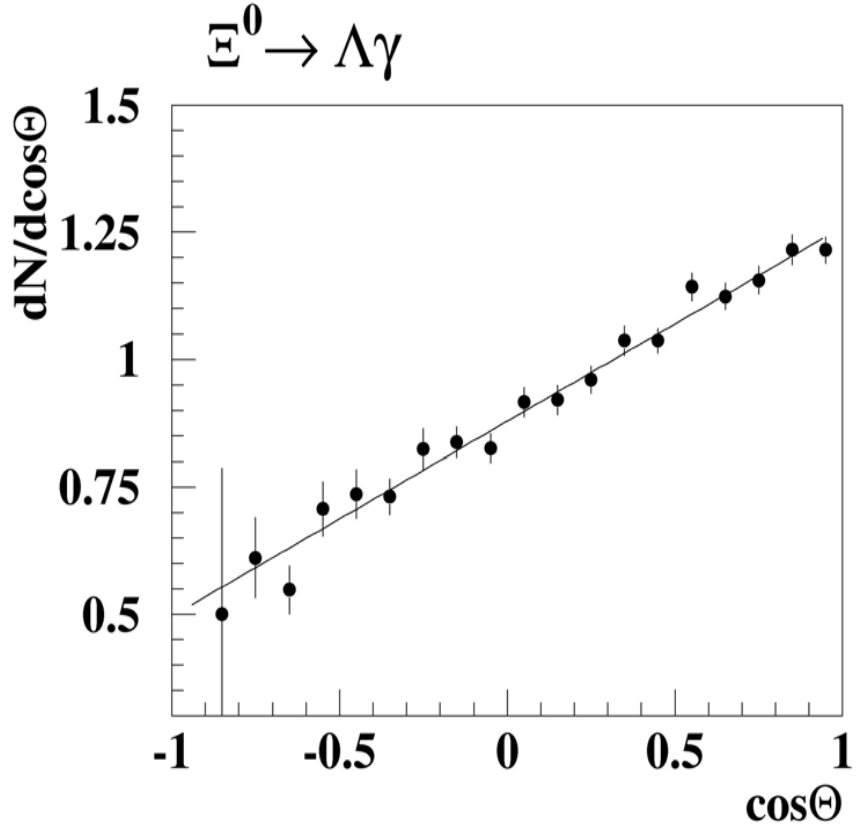
43814 $\Xi^0 \rightarrow \Lambda\,\gamma$ events selected

0.8 % background



$\Xi^0 \rightarrow \Lambda\,\gamma$ (II)





$\alpha(\Xi^0 \rightarrow \Lambda\,\gamma)$ = −0.68±0.02stat ±0.06syst

$\Xi^0 \rightarrow \Lambda^0 e^+ e^-$

Never observed before

Naïve estimation of the BR:

$BR(\Xi^0 \rightarrow \Lambda e^+ e^-) = BR(\Xi^0 \rightarrow \Lambda\gamma) \cdot \alpha \sim 8.8 \cdot 10^{-6}$

Theoretical expectation (QED based, Bernstein 65):

$BR(\Xi^0 \rightarrow \Lambda e^+ e^-) = (6.4\text{-}7.3) \cdot 10^{-6}$

Event sample:

412 candidates events with

7±5 accidental background

8±3 physical background

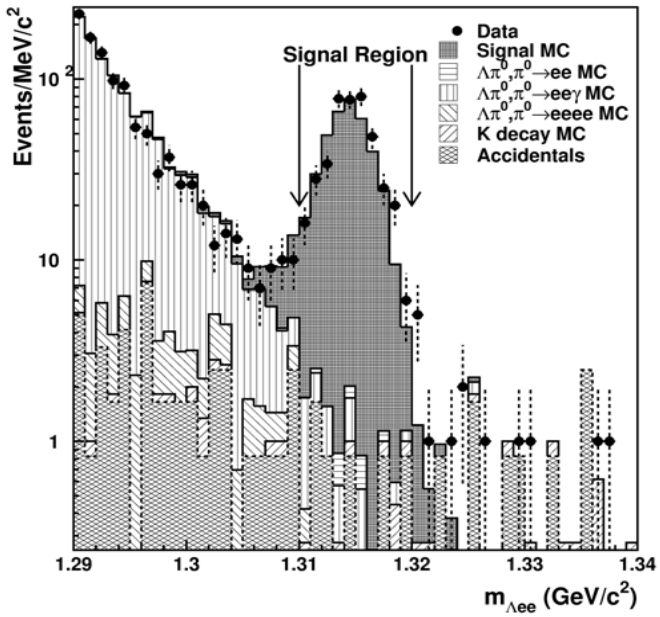
Normalization channel:

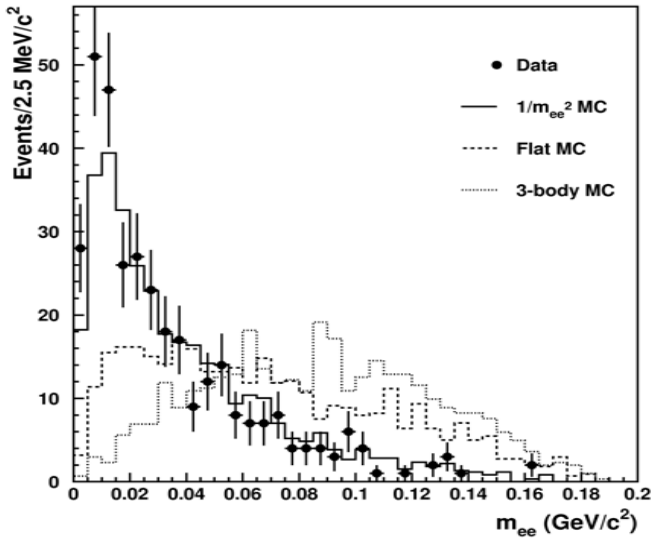
$\Xi^- \rightarrow \Lambda\pi^0_D$: **30K events**

$BR(\Xi \rightarrow \Lambda ee) = 7.7 \pm 0.5_{stat} \pm 0.4_{syst} \cdot 10^{-6}$

$\alpha(\Xi \rightarrow \Lambda ee) = -0.8 \pm 0.2$

Phys.Lett.B650:1-8,2007 (hep-ex/0703023)





Conclusion

- **NA48/2 recent results in charged radiative Kaon decays:**
  - **First evidence of non 0 INT term in $K^{\pm}\to\pi^{\pm}\pi^{0}\gamma$**
  - **First measurement of $K^{\pm}\to\pi^{\pm}e^{+}e^{-}\gamma$ BR**

- **NA48/1 results in radiative hyperon decays:**
  - **New measurement of $\Xi^{0}\to\Lambda\gamma$ decay asymmetry**
  - **First evidence of the decay $\Xi^{0}\to\Lambda e^{+}e^{-}$ measurement of BR and decay asymmetry**