Review of NA62 and NA48 physics results

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on behalf of the NA62 Collaboration

Birmingham, Bratislava, Bristol, Bucharest, CERN, Dubna (JINR), Fairfax, Ferrara, Florence, Frascati, Glasgow, Liverpool, Louvain-la-Neuve, Mainz, Merced, Moscow (INR), Naples, Perugia, Pisa, Prague, Protvino (IHEP), Rome I, Rome II, San Luis Potosi, Sofia, TRIUMF,Turin, Vancouver (UBC)
~200 participants

QCD@Work
Matera, June 24th-28th, 2018

Outline

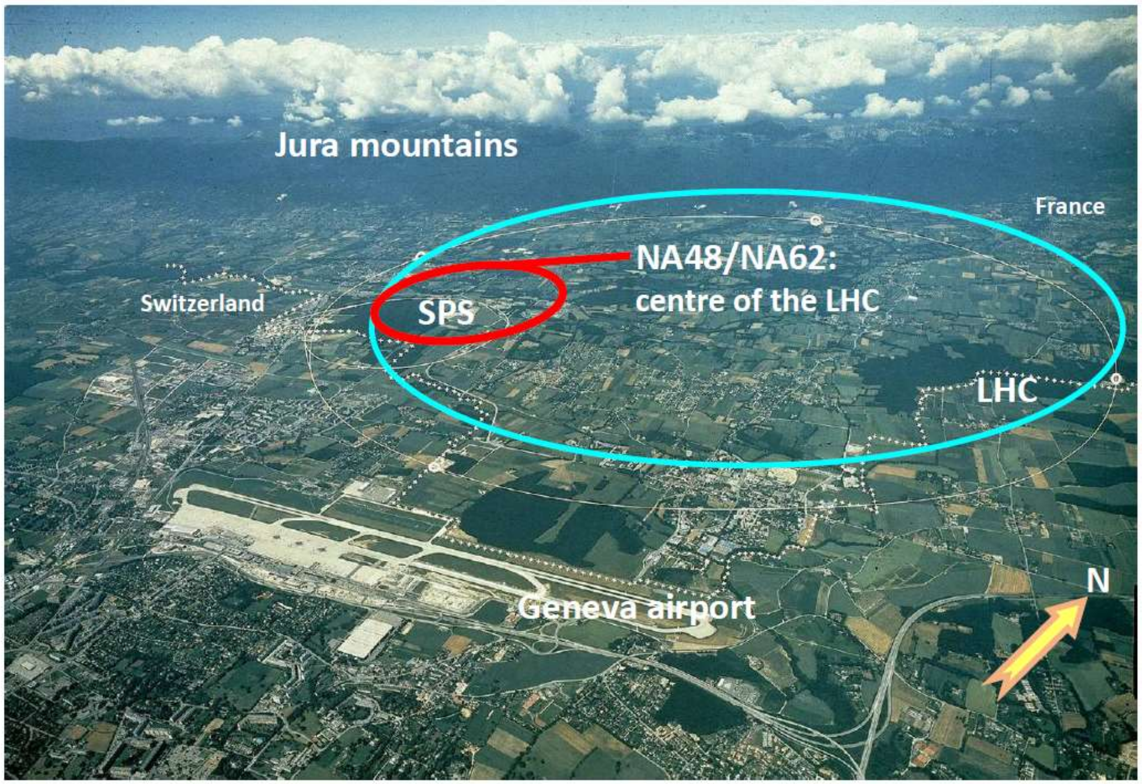
- Kaon decays at CERN

- NA62 results
  - $K^+ \to \pi^+ \nu\nu$ preliminary analysis
  - Prospects

- NA48 results
  - Form factors in $K^\pm \to \pi^0 \ell^\pm \nu_\ell$
  - First observation of $K^\pm \to \pi^+ \pi^0 e^+ e^-$

- Conclusions

Kaon decays at CERN



Earlier: NA31

NA48 (discovery of direct CPV)
- 1997: ε'/ε: K_L+K_S
- 1998: K_L+K_S
- 1999: K_L+K_S | K_S HI
- 2000: K_L only | K_S HI
- 2001: K_L+K_S | K_S HI

NA48/1
- 2002: K_S/hyperons

NA48/2
- 2003: K^+/K^-
- 2004: K^+/K^-

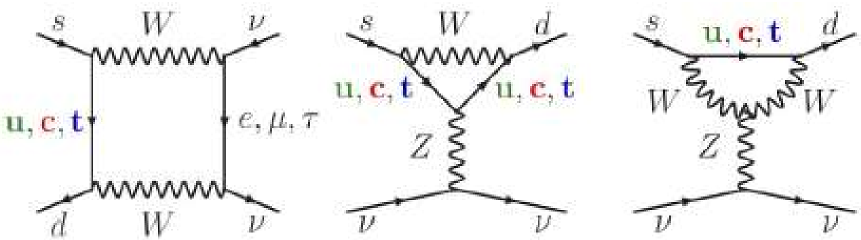
NA62 (R_K phase)
- 2007: $K^{\pm}_{e2}/K^{\pm}_{\mu 2}$ | tests
- 2008: $K^{\pm}_{e2}/K^{\pm}_{\mu 2}$ | tests

NA62
- 2014: pilot run
- 2015: commissioning run
- 2016 – : $K^+\rightarrow\pi^+\nu\nu$ run

This talk (2003, 2004, 2016 –)

NA62: $K \rightarrow \pi\nu\nu$

$K^+ \to \pi^+ \nu\bar{\nu}$: clean theoretical environment



FCNC loop processes:
s->d coupling
Highest CKM suppression

Very clean theoretically
No hadronic uncertainties
Hadronic matrix element related to the precisely measured BR ($K^+ \to \pi^0 e^+ \nu$)

SM predictions [Buras et al. JHEP 1511 (2015) 33]

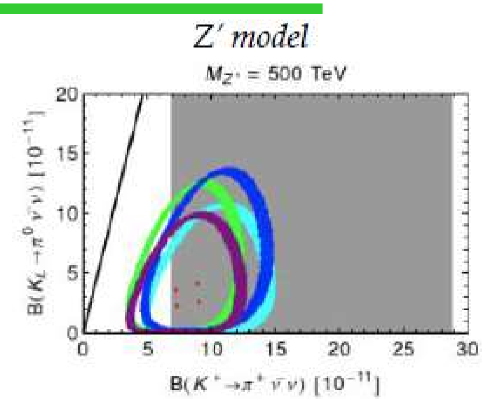
$$BR(K^+ \to \pi^+ \nu\bar{\nu}) = (8.39 \pm 0.30) \cdot 10^{-11} \cdot \left(\frac{V_{cb}}{0.0407}\right)^{2.8} \cdot \left(\frac{\gamma}{73.2^0}\right)^{0.74} = (0.84 \pm 0.10) \cdot 10^{-10}$$

$$BR(K^0 \to \pi^0 \nu\bar{\nu}) = (3.36 \pm 0.05) \cdot 10^{-11} \cdot \left(\frac{V_{ub}}{0.00388}\right)^{2} \cdot \left(\frac{V_{cb}}{0.0407}\right)^{2} \cdot \left(\frac{\sin\gamma}{\sin 73.2^0}\right)^{0.74} = (0.34 \pm 0.06) \cdot 10^{-10}$$

$K \to \pi\nu\nu$ are the most sensitive probes to NP models among B and K decays

The combined measurement of K^+ and K_L modes could shed light on the flavour structure of NP ($\Delta S=2$ / $\Delta S=1$ correlation)

$K \to \pi\nu\bar{\nu}$ NP sensitivity



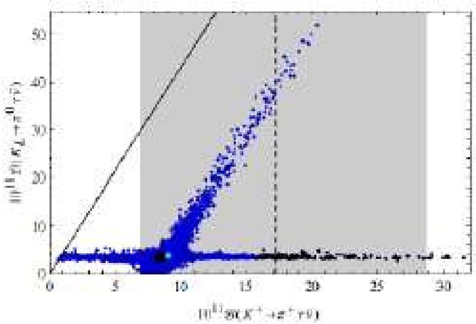
Simplified Z, Z′ models

A. J. Buras, D. Buttazzo, R. Knegiens, JHEP 1511 (2015) 166

More specific NP models

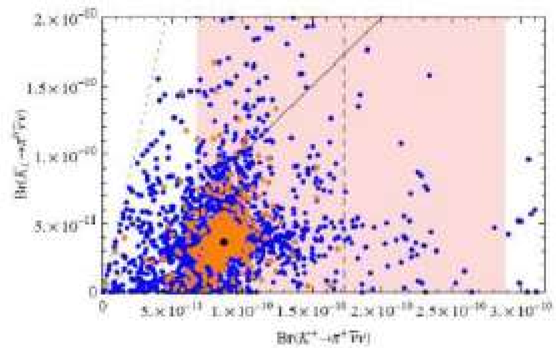
Littlest Higgs with T-parity

M. Blanke, A.J. Buras, S. Recksiegel, EPJ C76 (2016) 182



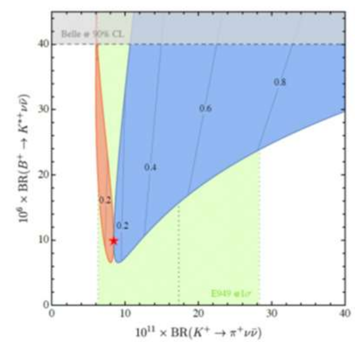
Custodial Randall-Sundrum

JHEP 0903 (2009) 108



LFU Violation

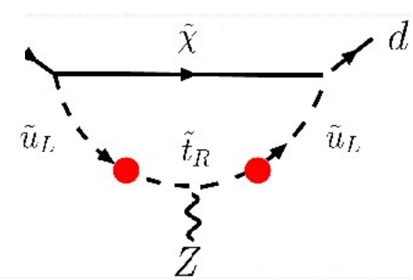
Isidori et al, EPJC (2017) 77



- Started to be probed at LHC, small effects in B physics.

Best probe of MSSM non-MFV [JHEP 0608 (2006) 064]

- E.g. non-MFV in up-squarks trilinear terms
- Still not excluded by the recent LHCb data.



Today status of K $\rightarrow \pi\nu\bar{\nu}$

E787/E949 @Brookhaven: 7 candidates $K^+ \rightarrow \pi^+\nu\bar{\nu}$

2 experiments, stopped kaon technique

- Separated K^+ beam(710 MeV/c, 1.6MHz)
- PID: range (entire π+→μ+→e+decay chain)
- Hermetic photon veto system

Probability of all events to be background ~ 10^{-3}

Expected background: 2.6 events

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

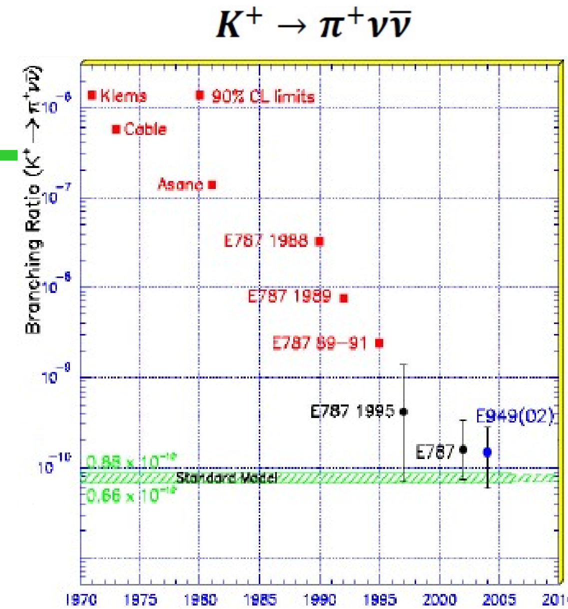
Phys. Rev. D77,052003 (2008), Phys. Rev. D79,092004 (2009)

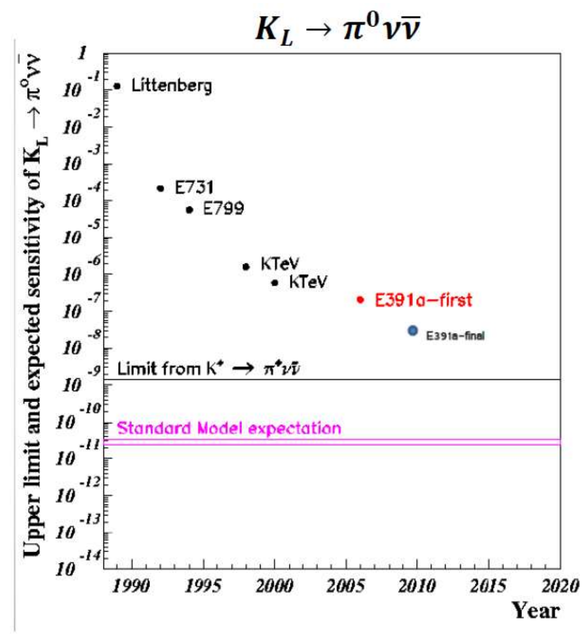
E391a @ KEK: Phys. Rev. D81,072004 (2010)

$$BR(K_L \rightarrow \pi^0\nu\bar{\nu}) < 2.6 \times 10^{-8} (90\%\ CL)$$

Preliminary from 2015 run of KOTO@JPARC:
arXiv 1609.03637

$$BR(K_L \rightarrow \pi^0\nu\bar{\nu}) < 5.1 \times 10^{-8} (90\%\ CL)$$





NA62 goals and challenges

- Measurement of the $K^+ \rightarrow \pi^+ \nu\bar{\nu}$ branching ratio
  - This requires at least 10^{13} Kaon decays
  - In-flight decay technique
  - 75 GeV beam helps in background rejection
    - Event selection with P_π<35 GeV/c
    - i.e. $K_{\pi 2}$ decays have around more than ~40 GeV of electromagnetic energy
    - $O(10^{12})$ rejection factor of common K decays

Good tracking devices

Accurate measurement of the kaon momentum
Accurate measurement of the pion momentum
Missing mass cut: $O(10^5)$ rejection on $K_{\mu 2}$, $O(10^4)$ on $K_{\pi 2}$

Veto detectors

Photons: to reduce the background by a factor of 10^8
Muons: add a rejection factor of $O(10^5)$

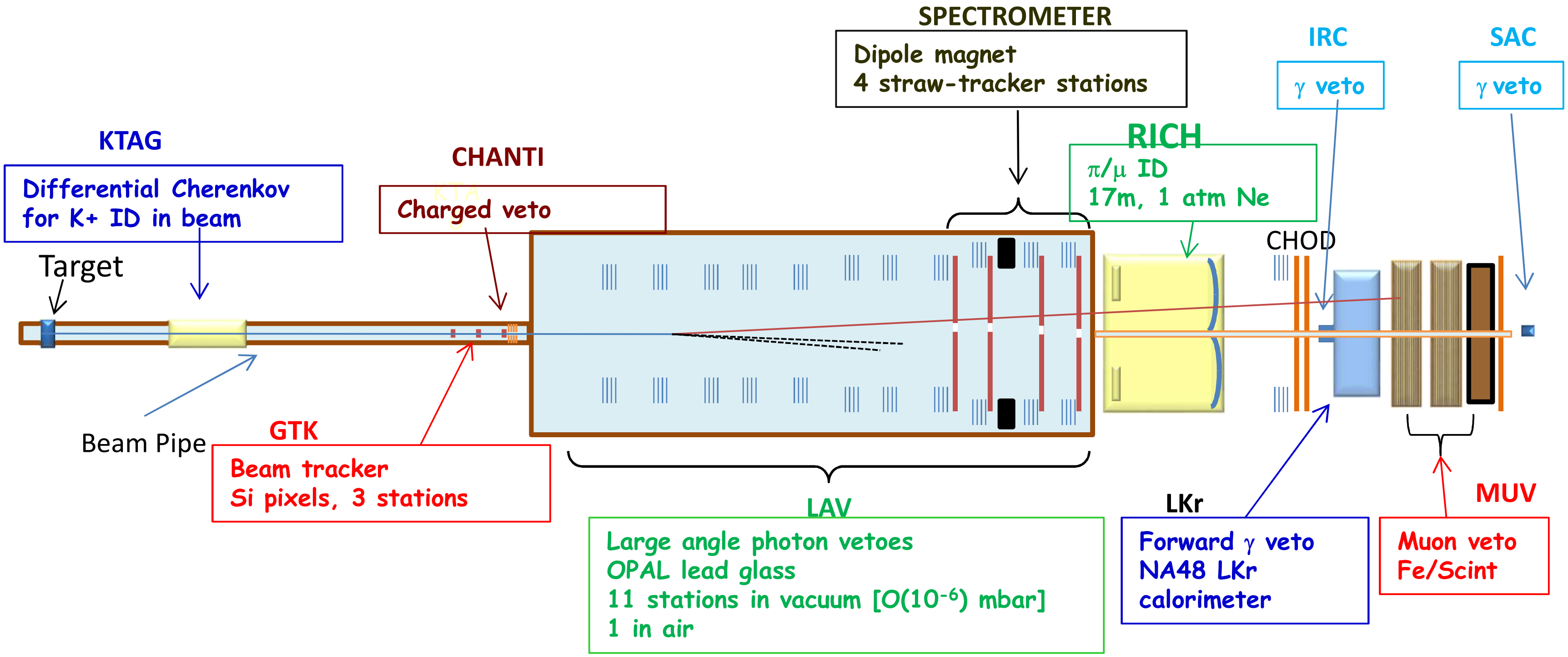
Particle identification

Identify kaons in the beam
Identify positrons
Additional π/μ rejection $[O(10^2)]$

Precise sub-ns timing

Kaon-pion time association
To reduce random veto

The NA62 detector



← Beam detectors →← Decay products detectors →

Beam	
Momentum	75 GeV/c, 1% bite
Divergence (RMS)	100 μrad
Transverse Size	$60 \times 30 mm^2$
Composition	K+ 6%, π+ 70%, p 24%
Nominal Intensity	33×10^{11} ppp (750 MHz at GTK3)

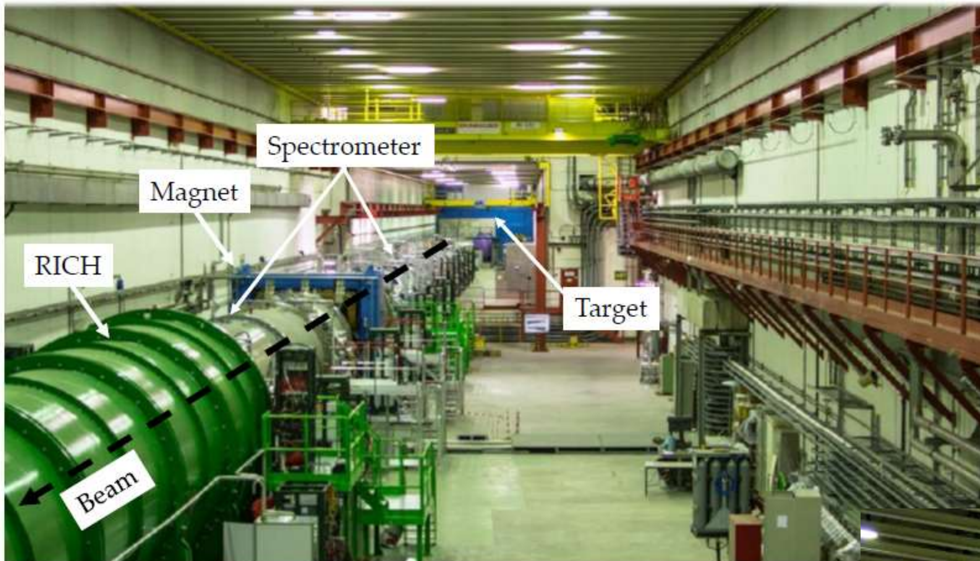
Fiducial region

60 m decay region

10^{-6} mbar vacuum

Downstream rate ~ 10 MHz

NA62 runs



2014: Pilot run

2015: Commissioning run

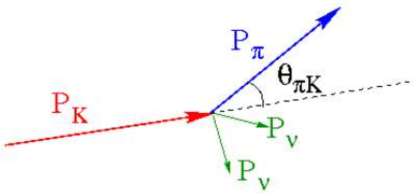
2016: Commissioning and physics run

2017: 160 days data taking

2018: Data taking ongoing (217 days)

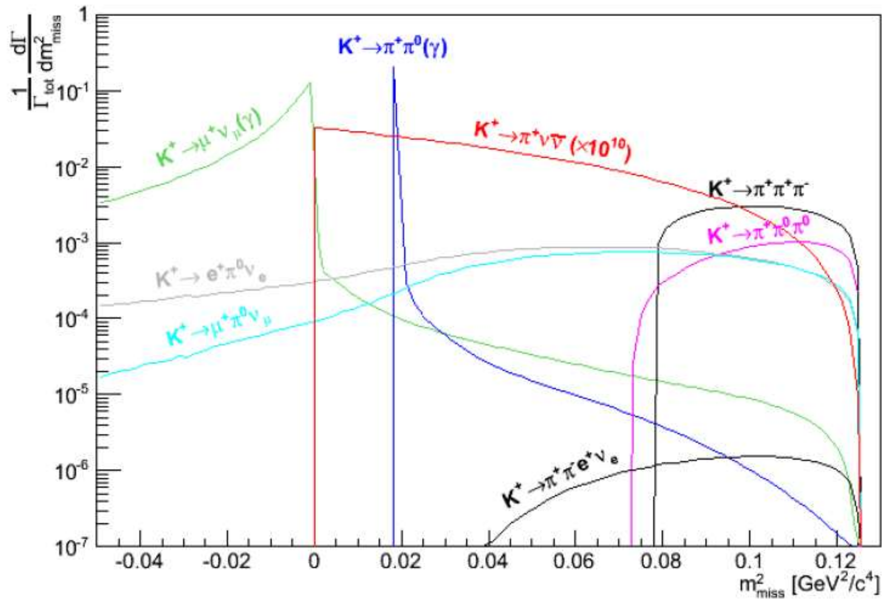
K^+ decay in-flight

- Signature: one incident kaon, 1 charged output track
- Missing mass distributions: $m^2_{miss} = (P_K - P_{track(hyp\ \pi^+)})^2$
- Define two regions in m^2_{miss} to accept candidate events
- 65 m long decay fiducial region, $15 < P\pi < 35$ GeV/c
- Particle ID (Cherenkov detectors, calorimeters)
- Photon Veto



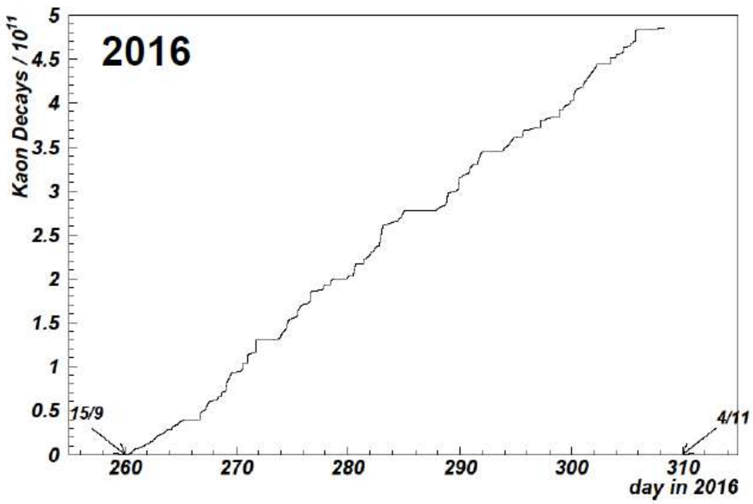
- Backgrounds:
  - Accidental beam activity
  - K+ decay modes:

$K^+ \to \pi^+\pi^0\ (\gamma)$ Br = 0.2067
$K^+ \to \mu^+\nu\ (\gamma)$ Br = 0.6356
$K^+ \to \pi^+\pi^+\pi^-$ Br = 0.0558
$K^+ \to \pi^+\pi^- e^+\nu$ Br = 4.25×10^{-5}



2016 data analysis

- $13 \cdot 10^{11}$ ppp on target
  - 40% of nominal intensity
- 10^{11} K^+ decays useful for $\pi\nu\nu$
- Blind analysis procedure
  - Signal and control region kept masked for the whole analysis
- Main trigger streams:
  - $\pi\nu\nu$, control
- Offline analysis
  - $\pi\nu\nu$ sample
  - Control samples
    - $K^+ \rightarrow \pi^+\pi^0$
    - $K^+ \rightarrow \mu^+\nu$
    - $K^+ \rightarrow \pi^+\pi^+\pi^-$

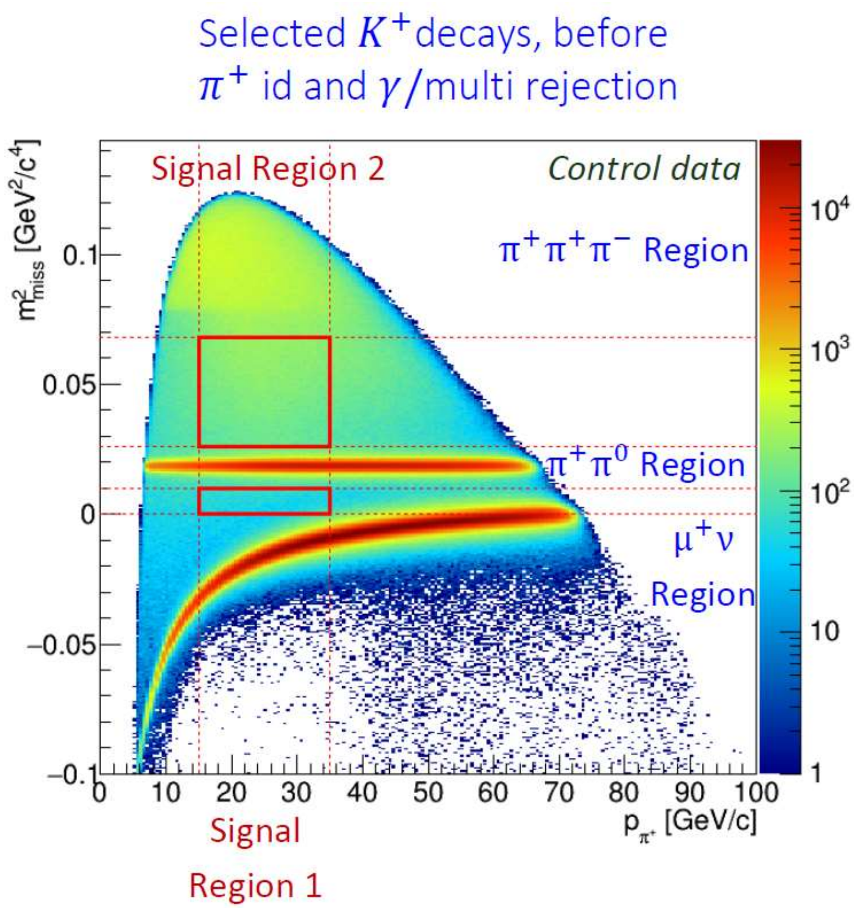


Analysis steps

- Selection
- Determination of single event sensitivity (SES)
- Estimation and validation of the expected background
- Un-blinding of the signal regions and results

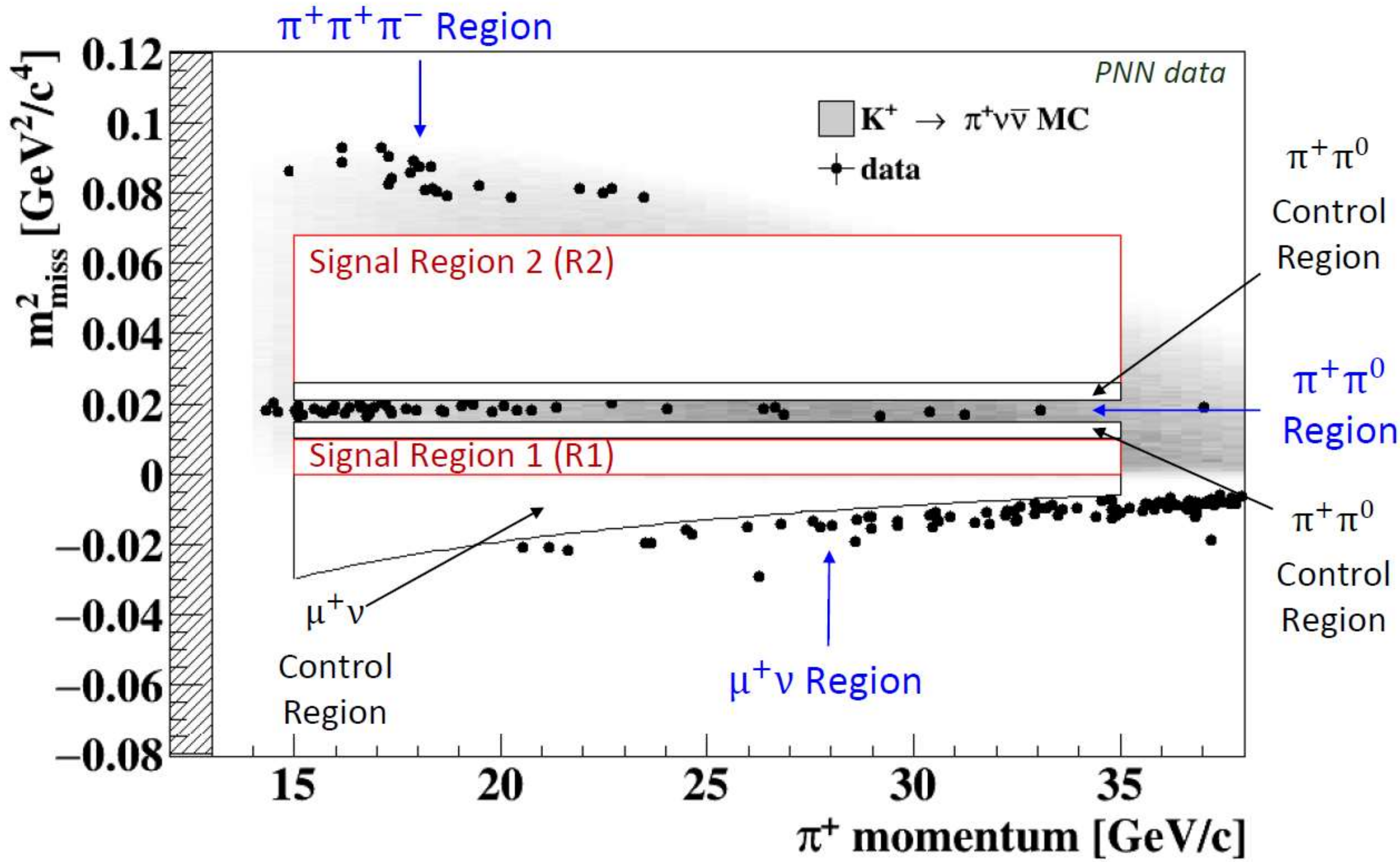
Kaon decay selection

- Selection
  - K^+ decay into one charged particle
  - π^+ identification
  - Photon rejection
  - Multi track rejection



- Performances
  - GTK-KTAG-RICH timing: O(100 ps)
  - π^+ ID: $\varepsilon_\mu = 10^{-8}$; $\varepsilon_{\pi+}$ ~64%
  - γ/multi rejection $\varepsilon_{\pi 0} = 3 \cdot 10^{-8}$
  - $\sigma(m^2_{miss})$ ~ 10^{-3} GeV^2/c^4

Data after selection



Single Event Sensitivity (SES)

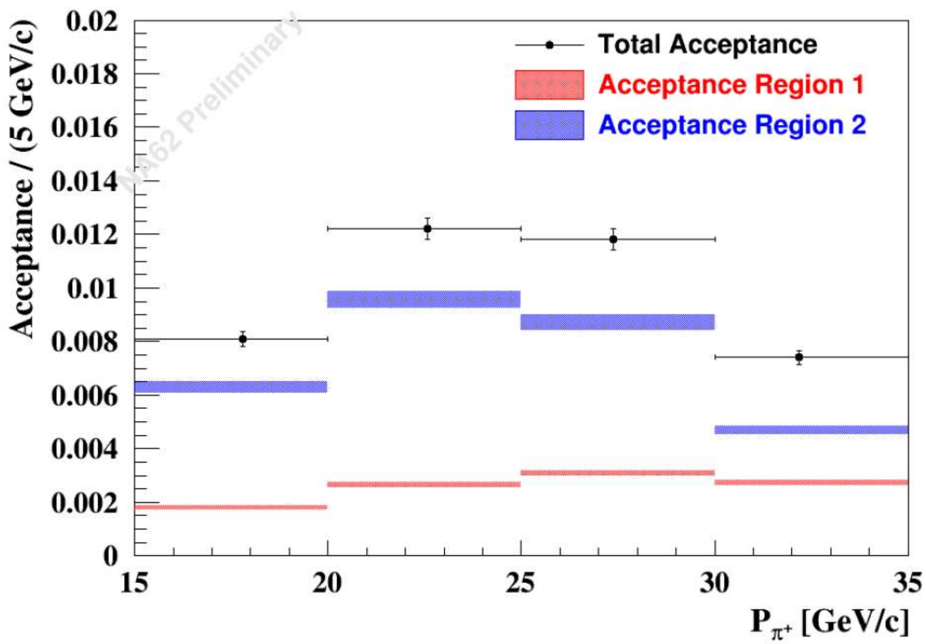
- Determine Kaon flux from $K^+ \to \pi^+\pi^0$ selected with control trigger (downscale 400)
- Use the same $\pi\nu\nu$ selection, but without photon and multiplicity rejection and with missing mass cut modified

$$SES = \frac{1}{N_K\left(A_{\pi nn}\,\epsilon_{RV}\,\epsilon_{trig}\right)} \qquad N_K = \frac{N_{\pi\pi}\,D}{A_{\pi\pi}\,BR_{\pi\pi}}$$

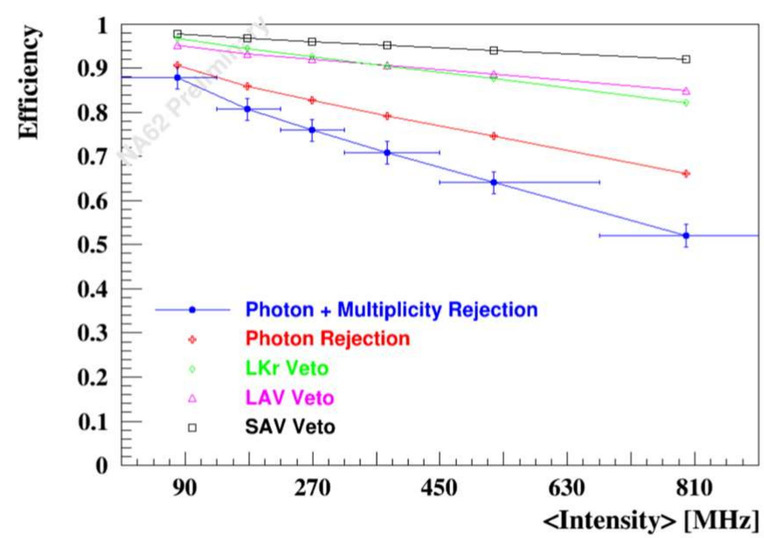
Number of K^+ decays	**$N_K = (1.21 \pm 0.02) \cdot 10^{11}$**
Acceptance for $K^+ \to \pi^+ \nu\nu$	$A_{\pi\nu\nu} = 0.040 \pm 0.001$
PNN trigger efficiency	$\varepsilon_{trig} = 0.87 \pm 0.02$
Random veto	$\varepsilon_{RV} = 0.76 \pm 0.04$
SES	$(3.15 \pm 0.01_{stat} \pm 0.24_{syst}) \cdot 10^{-10}$
Expected Standard Model $K^+ \to \pi^+ \nu\nu$	$0.267 \pm 0.001_{stat} \pm 0.020_{syst} \pm 0.032_{ext}$

SES: Signal acceptance and random veto

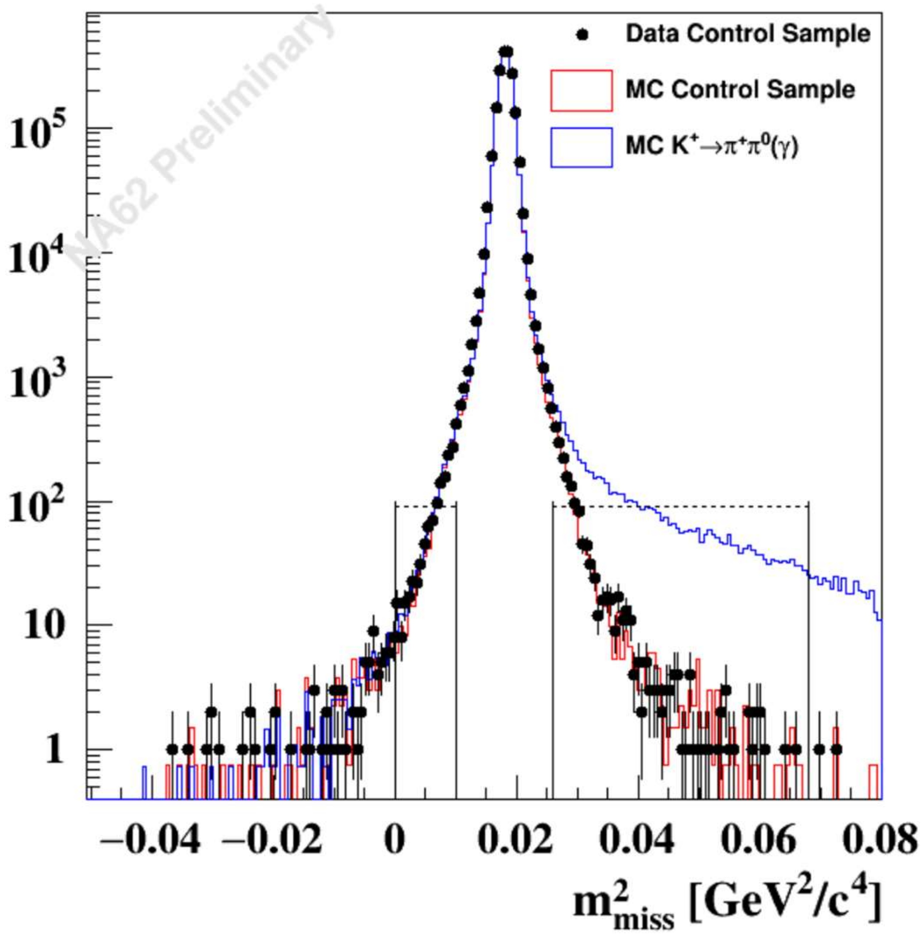
- Acceptance
  - Computed with MC
  - Particle ID, losses due to π^+ interaction included



- Random veto
  - Random losses due to gamma and multiplicity rejection measured with $K^+ \rightarrow \mu^+\nu$
  - $\varepsilon_{RV} = 0.76 \pm 0.04$
    - independent from $P_{\pi+}$
    - dependent on instantaneous intensity



$\pi^+ \pi^0 (\gamma)$ background

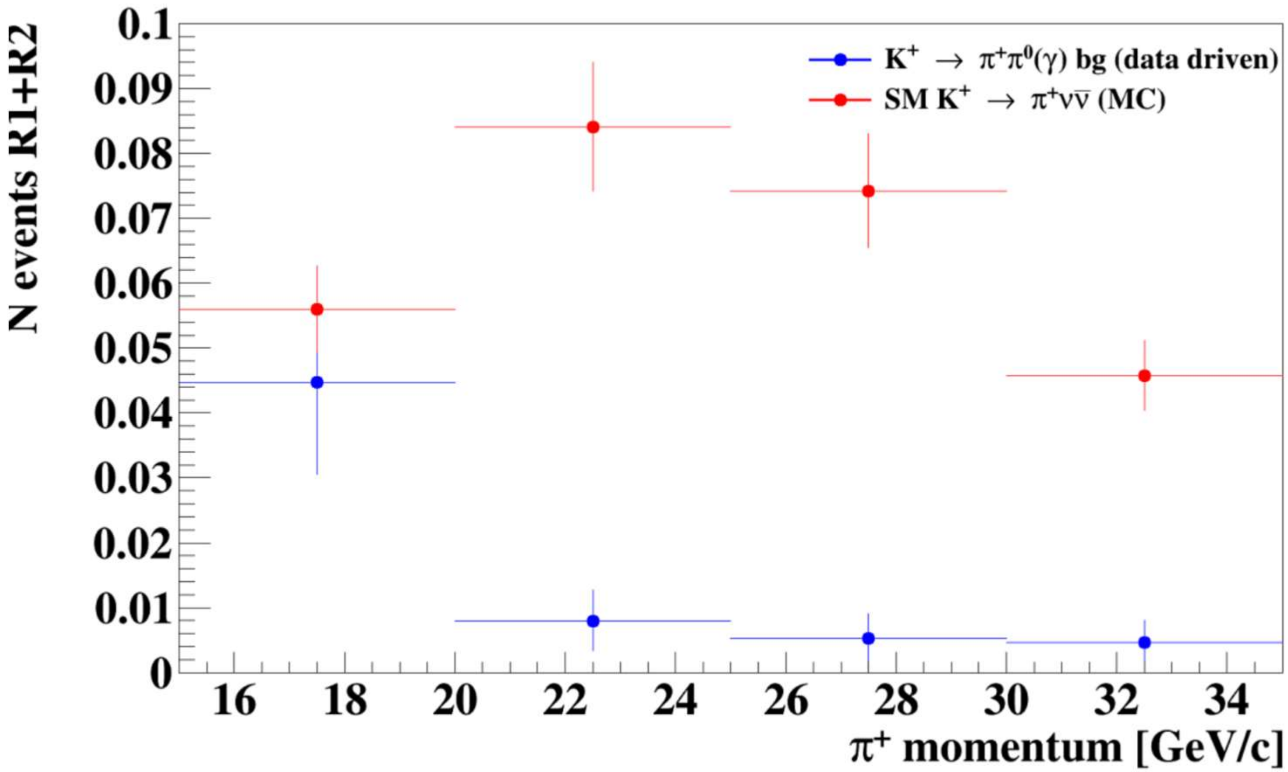


$$N_{\pi\pi}^{exp}(region) = N(\pi^+\pi^0) f^{kin}(region)$$

- Kinematic rejection independent from the photon one
- $N(\pi^+\pi^0)$: data events in $\pi^+\pi^0$ region after $\pi\nu\nu$ selection
- f^{kin} : tails, from $\pi^+\pi^0$ control sample selected on data tagging the π^0
- $f^{kin}(R1+R2) \sim 10^{-3}$ (not radiative)
- Radiative: $\pi^0 + \gamma \rightarrow$ x30 π^0 rejection in R2

$\pi^+ \pi^0 (\gamma)$ background

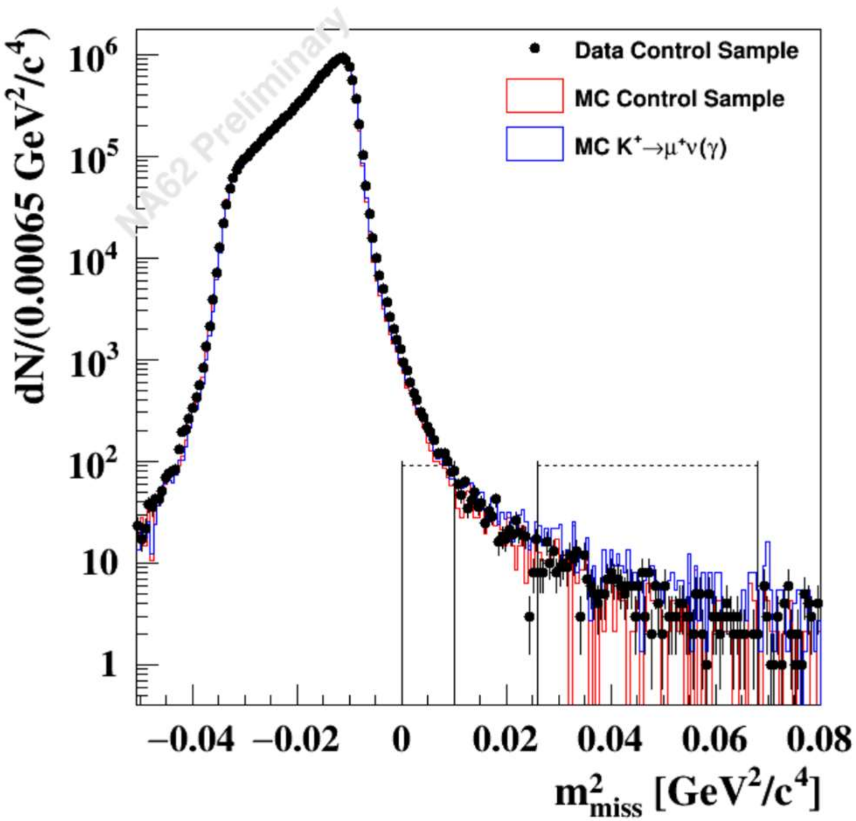
$$N_{\pi\pi(\gamma)}^{expected} = 0.064 \pm 0.007_{stat} \pm 0.006_{syst} \ (< 10\% \ radiative)$$



Expected control regions: 1.46 ± 0.17 → observed 1

$K^+ \to \mu^+\nu$ background

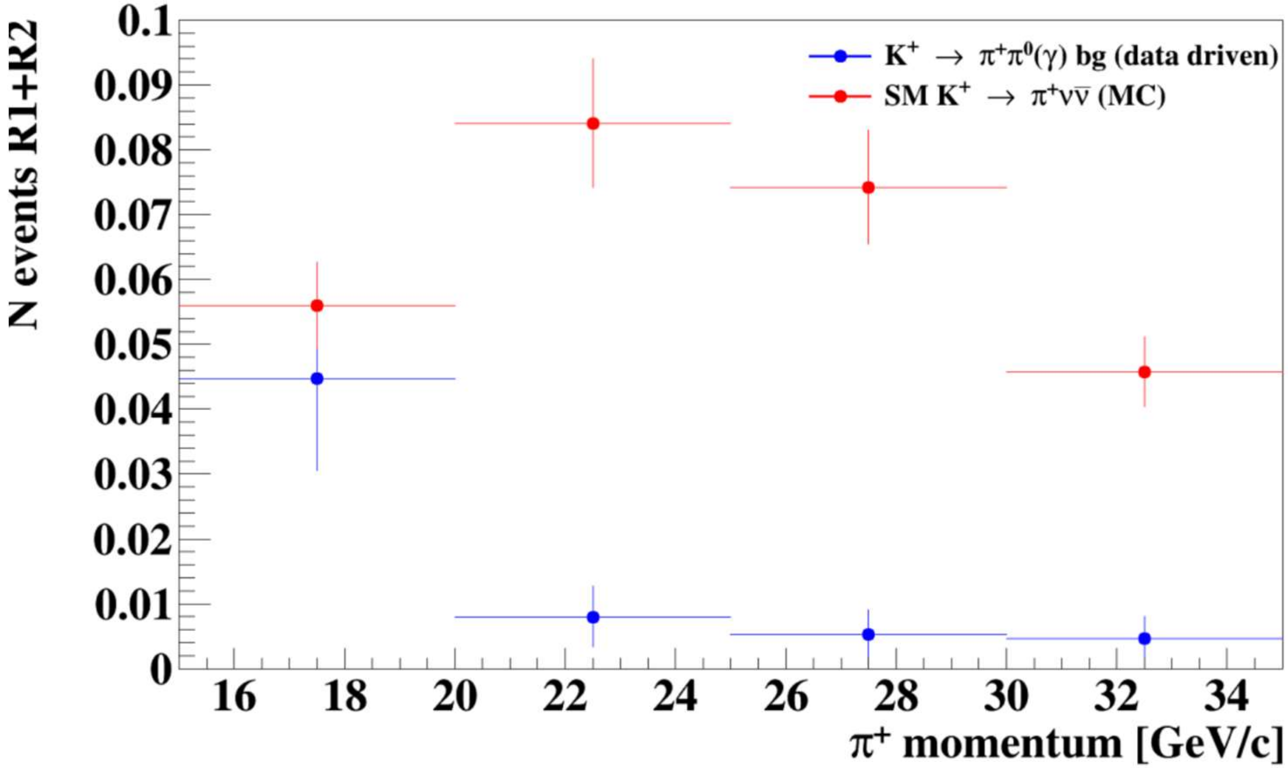
$$N_{\mu\nu}^{exp}(region) = N(\mu^+\nu) f^{kin}(region)$$



- Kinematic rejection independent from PID
- $N(\mu^+\nu)$: data events in $\mu^+\nu$ region after $\pi\nu\nu$ selection
- f^{kin} : tails, from $\mu^+\nu$ control sample selected on data with μ^+-ID in calorimeters
- $f^{kin}(R1) \sim 10^{-5} - 10^{-3}$ [15,35] GeV
- $f^{kin}(R2) \sim O(10^{-5})$
- Radiative included in f^{kin}

$K^+ \rightarrow \mu^+\nu$ background

$$N_{\mu\nu(\gamma)}^{expected} = 0.020 \pm 0.003_{stat} \pm 0.003_{syst}$$

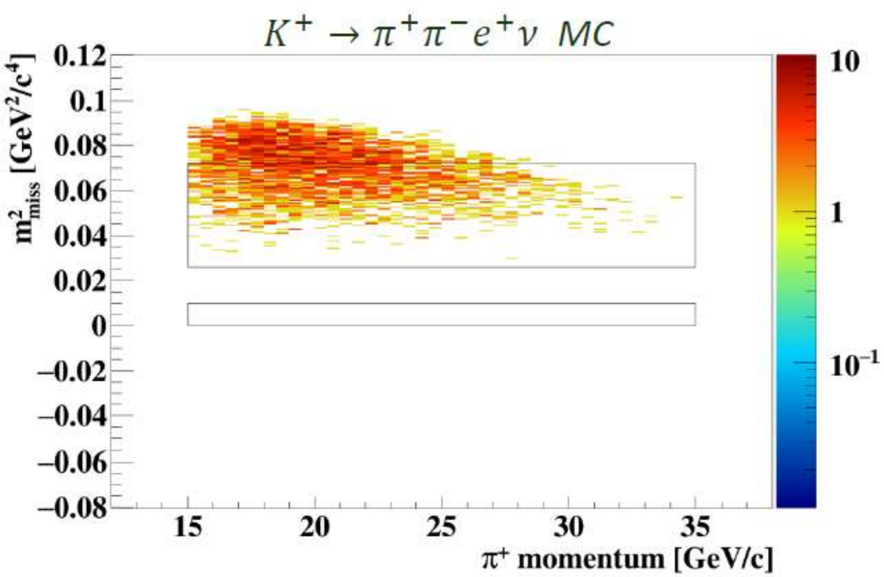


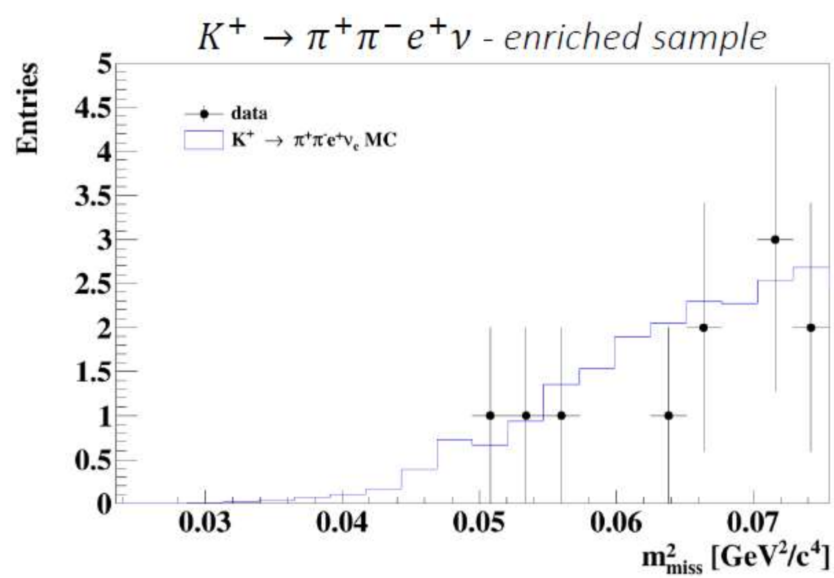
Expected control regions: 1.02 ± 0.16 → observed 2

$K^+ \to \pi^+\pi^- e^+\nu$ (K_{e4}) background

- Measured branching ratio: $4.247(24) \cdot 10^{-5}$
- Topology-correlated kinematics spanning Region 2
- MC-based background estimation, $4 \cdot 10^8$ events generated
- Validation of MC done with data using enriched $K^+ \to \pi^+\pi^- e^+\nu$ sample

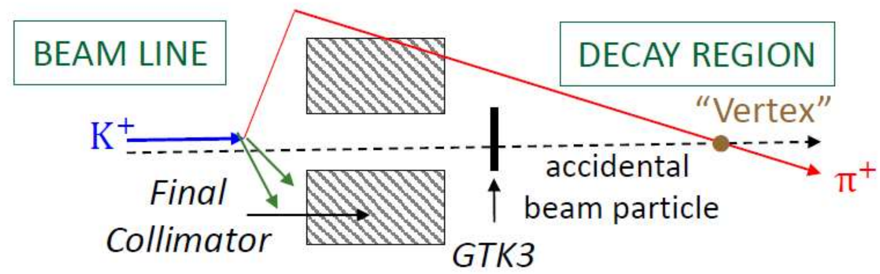
$$N_{\pi\pi e\nu}^{expected} = 0.018^{+0.024}_{-0.017}|_{stat} \pm 0.009_{syst}$$



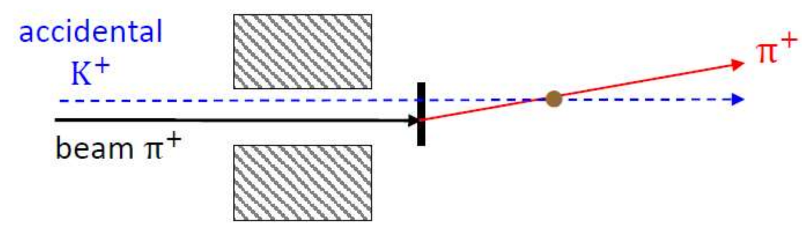


Upstream background

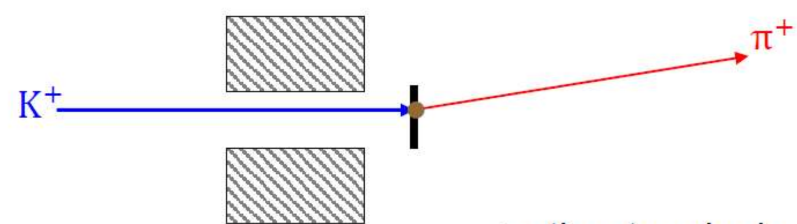
- K^+ decays along the beam line
  - Only π^+ going forward
  - Dependence on material along the beam, magnetic field
  - Match an accidental beam particle



- Beam π^+ interactions in the GTK station
  - π^+ production
  - Match accidental K^+

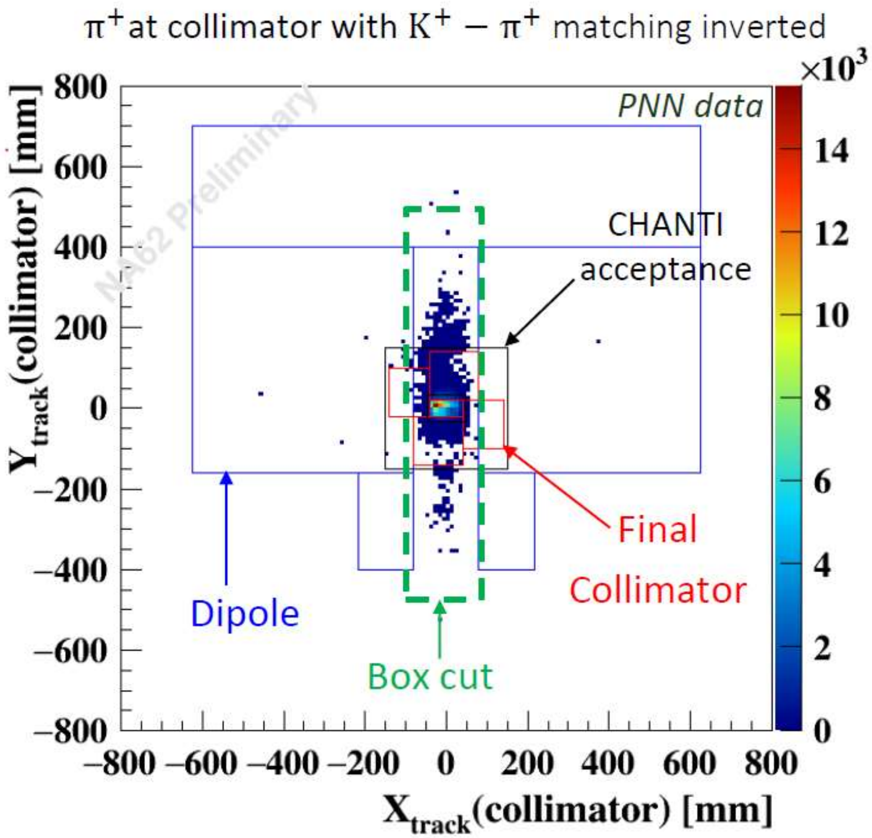


- K^+ interactions in GTK station
  - π^+ production
  - Vertex mis-reconstructed



+ other topologies

Upstream background



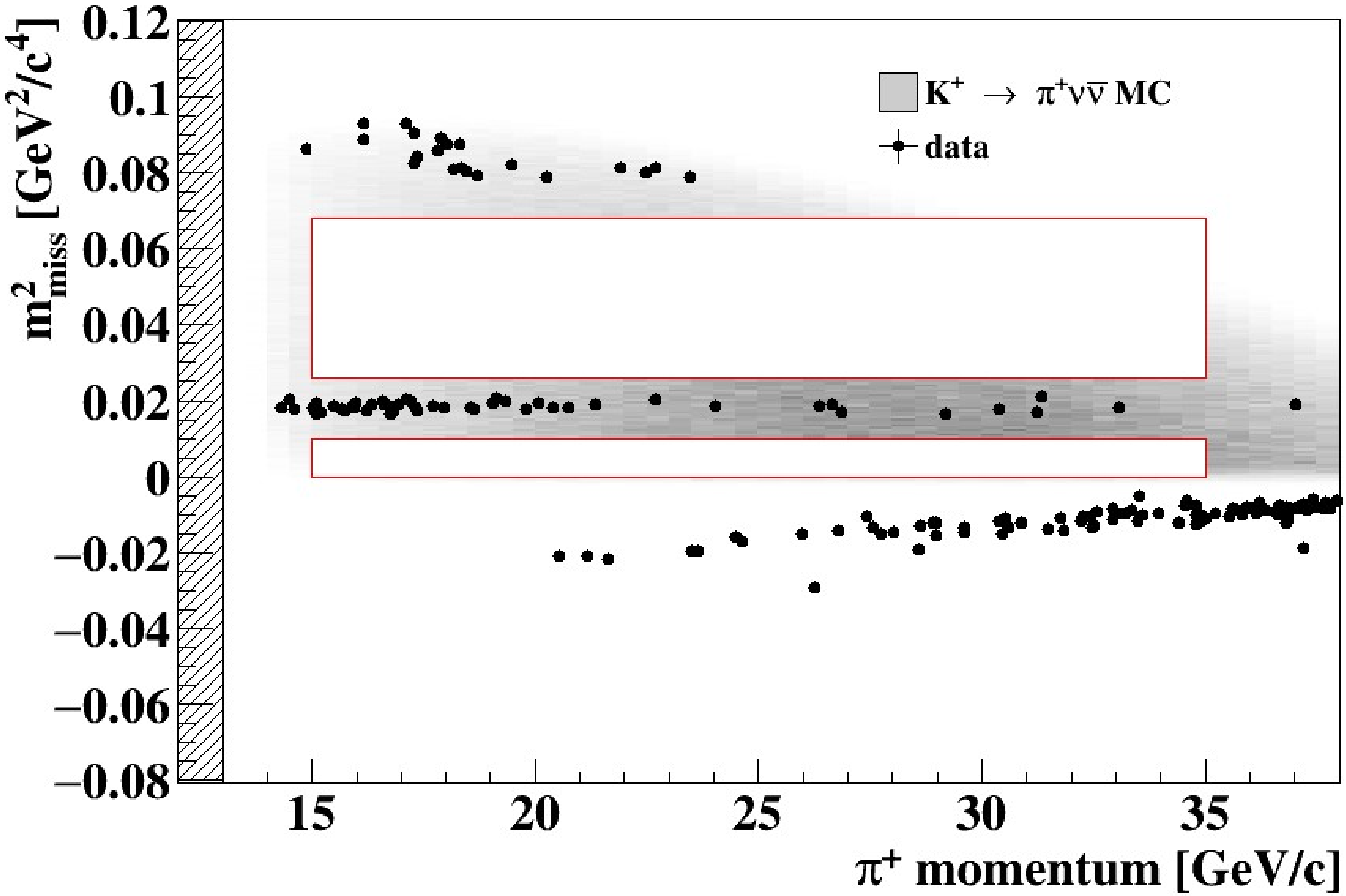
- Cuts to fight upstream background
  - $K^+ \pi^+$ matching
  - "Box cut" around π^+ position at collimator
  - Z_{vertex}, CHANTI
- Background estimation
  - Fully data driven
  - Cuts inversion
  - Statistics limited in 2016

$$N^{exp}_{upstream} = 0.050^{+0090}_{-0.030}|_{stat}$$

Background summary

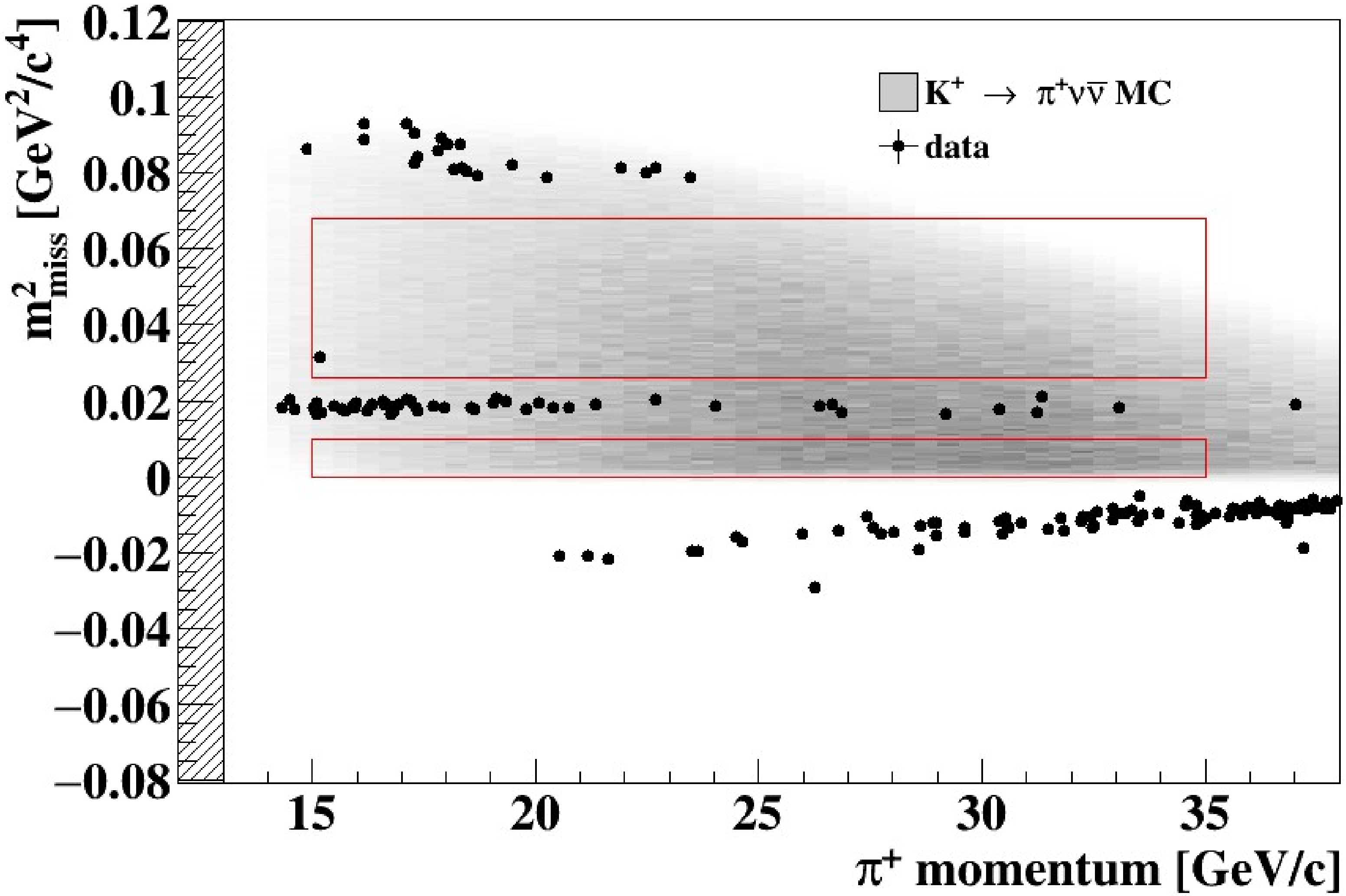
Process	Expected events in R1+R2
$K \to \pi\nu\nu$ (SM)	$0.267 \pm 0.001_{stat} \pm 0.020_{syst} \pm 0.032_{ext}$
Total Background	$0.15 \pm 0.09_{stat} \pm 0.01_{syst}$
$K^+ \to \pi^+\pi^0 (\gamma)$	$0.064 \pm 0.007_{stat} \pm 0.006_{syst}$
$K^+ \to \mu^+\nu (\gamma)$	$0.020 \pm 0.003_{stat} \pm 0.003_{syst}$
$K^+ \to \pi^+\pi^-e^+\nu$	$0.018^{+0.024}_{-0.017}\vert_{stat} \pm 0.009_{syst}$
$K^+ \to \pi^+\pi^+\pi^-$	$0.002 \pm 0.001_{stat} \pm 0.002_{syst}$
Upstream background	$0.050^{+0.090}_{-0.030}\vert_{stat}$

Result



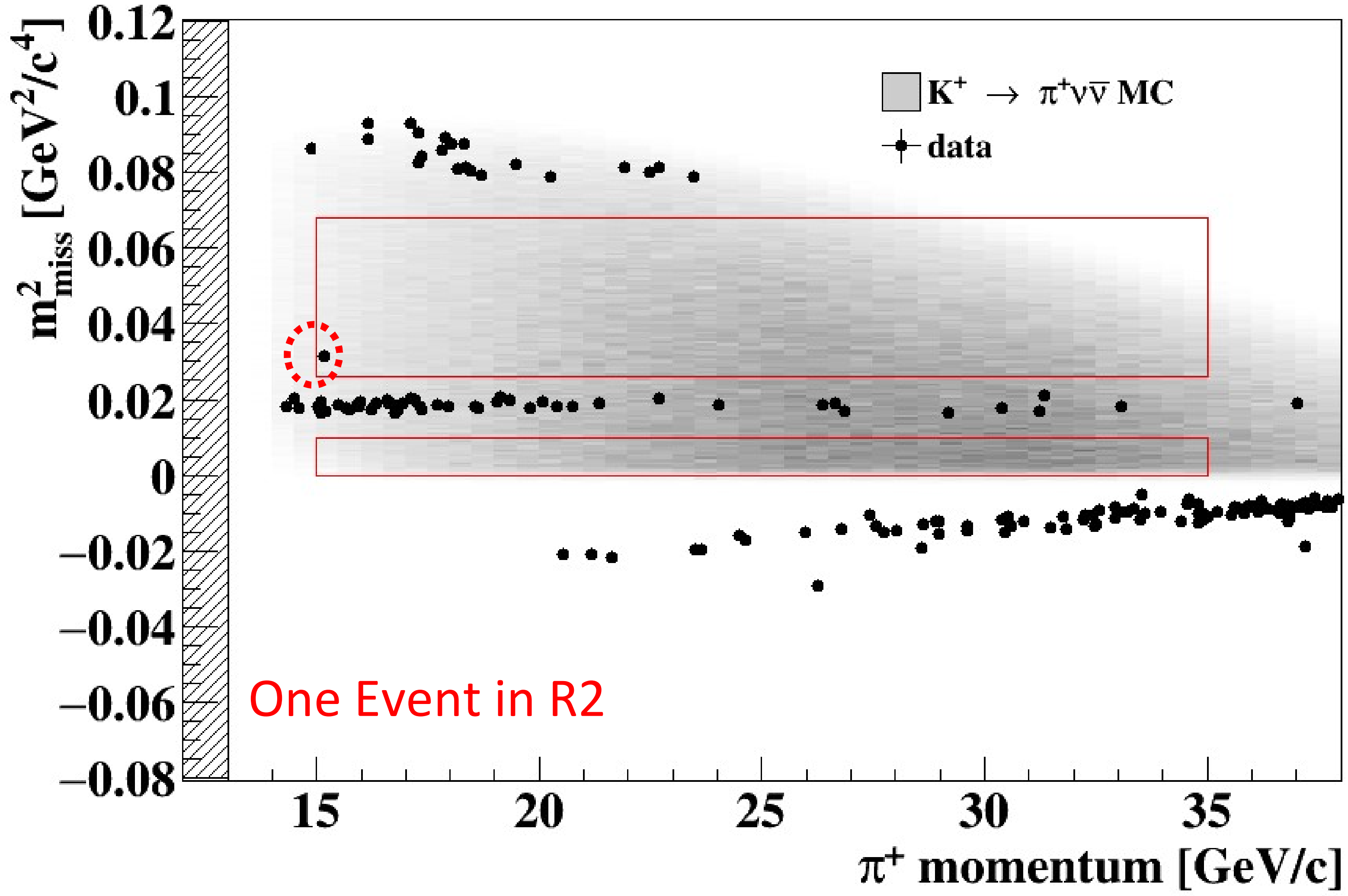
$K^+ \rightarrow \pi^+\nu\bar{\nu}$ MC
data
m^2_{miss} [GeV^2/c^4]
0.12
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
−0.08
15
20
25
30
35
π^+ momentum [GeV/c]

Result



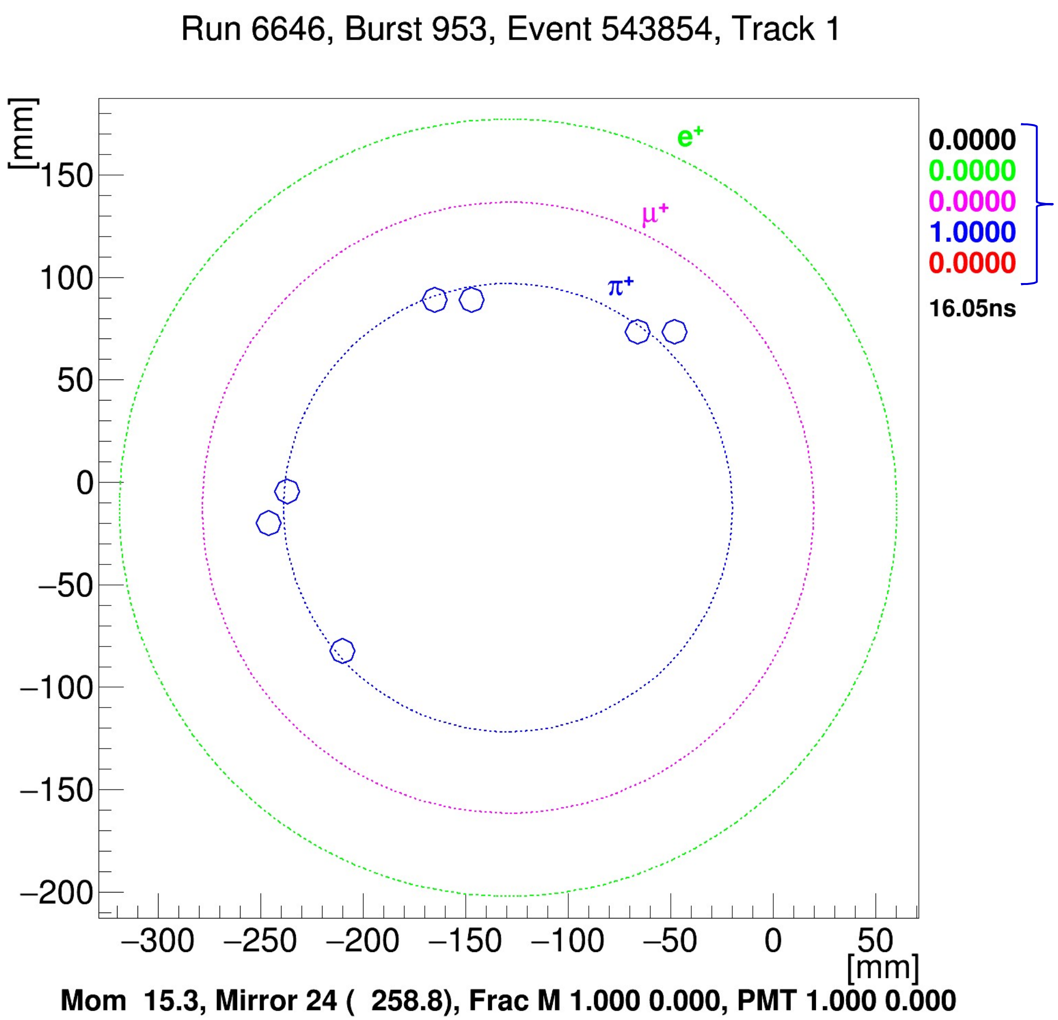
$K^+ \rightarrow \pi^+\nu\bar{\nu}$ MC
data
0.12
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
−0.08
m^2_{miss} [GeV^2/c^4]
15
20
25
30
35
π^+ momentum [GeV/c]

Result



$K^+ \to \pi^+\nu\bar{\nu}$ MC
data
One Event in R2
m^2_{miss} [GeV^2/c^4]
0.12
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
−0.08
15
20
25
30
35
π^+ momentum [GeV/c]

The candidate in the RICH



Value of the likelihood with different mass hypotheses

Preliminary result

- Events Observed: 1
- SES $(3.15 \pm 0.01_{stat} \pm 0.24_{syst}) * 10^{-10}$
- Expected background $0.15 \pm 0.09_{stat} \pm 0.01_{syst}$

- $BR(K \to \pi\nu\nu) < 11*10^{-10}$ @ 90% CL
- $BR(K \to \pi\nu\nu) < 14*10^{-10}$ @ 95% CL

- Expected limit: $BR(K \to \pi\nu\nu) < 10*10^{-10}$ @ 95% CL
- For comparison: $BR(K \to \pi\nu\nu) < 2.8^{+4.4}_{-2.3}*10^{-10}$ @ 68% CL

- $BR(K \to \pi\nu\nu)_{SM} = (0.84 \pm 0.10)*10^{-10}$ SM prediction
- $BR(K \to \pi\nu\nu) = (1.73^{+1.15}_{-1.05})*10^{-10}$ BNL E787/E949, kaons at rest

Prospects on $K \to \pi\nu\nu$

- 2017 Data Processing ongoing
  - 20 times the presented statistics
  - Expect to reduce upstream background
  - Methods to improve signal efficiency under study

- 2018 data
  - Run going on smoothly
  - Further mitigation of the upstream background is expected

- Expect about 20 SM events from 2017+2018 data

Not only $\pi\nu\bar{\nu}$

- Standard kaon physics
  - ChPT studies: $K^+ \to \pi^+ \gamma\gamma$, $K^+ \to \pi^+\pi^0 e^+ e^-$, $K_{\ell 4}$
  - Lepton universality: $R_K=\Gamma(K \to e\nu(\gamma))/ \Gamma(K \to \mu\nu(\gamma))$
- Searches for lepton-flavor or –number violating decays
  - $K^+ \to \pi^+\mu e$, $K^+ \to \pi^-\mu^+e^+$, $K^+ \to \pi^-\ell^+\ell^+$
- Search for heavy neutrinos
  - $K^+ \to \ell^+\nu_h$ (inclusive)
  - ν_h from upstream K, D decays with $\nu_h \to \pi\,\ell$
- Search for long-lived dark sector particles
  - Dark photon γ' produced in π/ρ decays in target with $\gamma' \to \ell^+\ell^+$
  - Axion-like particle A^0 produced in target/beam dump, with $A^0 \to \gamma\gamma$
- π^0 decays
  - $\pi^0 \to$ invisible; $\pi^0 \to 3\gamma$, 4γ ; $\pi^0 \to \gamma'\gamma$

NA48: $K^{\pm} \rightarrow \pi^0 \ell^{\pm} \nu_{\ell}$

$K^{\pm} \rightarrow \pi^0 \ell^{\pm} \nu_\ell$ form factors

$$\frac{d^2\Gamma}{dE_l\, dE_\pi} \propto A f_+^2(t) + B f_+(t) f_-(t) + C f_-^2(t)$$ (neglecting radiative effects), where:

$t = M_{l\nu}^2 = (P_K - P_\pi)^2 = m_K^2 + m_\pi^2 - 2m_K E_\pi$

E_π, E_l, E_ν = energies in the $K^\pm$ rest frame

$f_-(t) = (f_+(t) - f_0(t))\,(m_K^2 - m_\pi^2)\,/\,t$

$f_0(t), f_+(t)$ = "scalar" and "vector" FF

Ingredients for the determination of $|V_{us}|$

$A = M_K[2E_lE_\nu - m_K(E_\pi^{max} - E_\pi)] + M_l^2\,[\frac{1}{4}(E_\pi^{max} - E_\pi) - E_\nu]$

$B = M_l^2[E_\nu - \frac{1}{2}(E_\pi^{max} - E_\pi)]$ negligible for K_{e3}

$C = \frac{1}{4}M_l^2(E_\pi^{max} - E_\pi)4$ negligible for K_{e3}

Fit data to the Dalitz plot

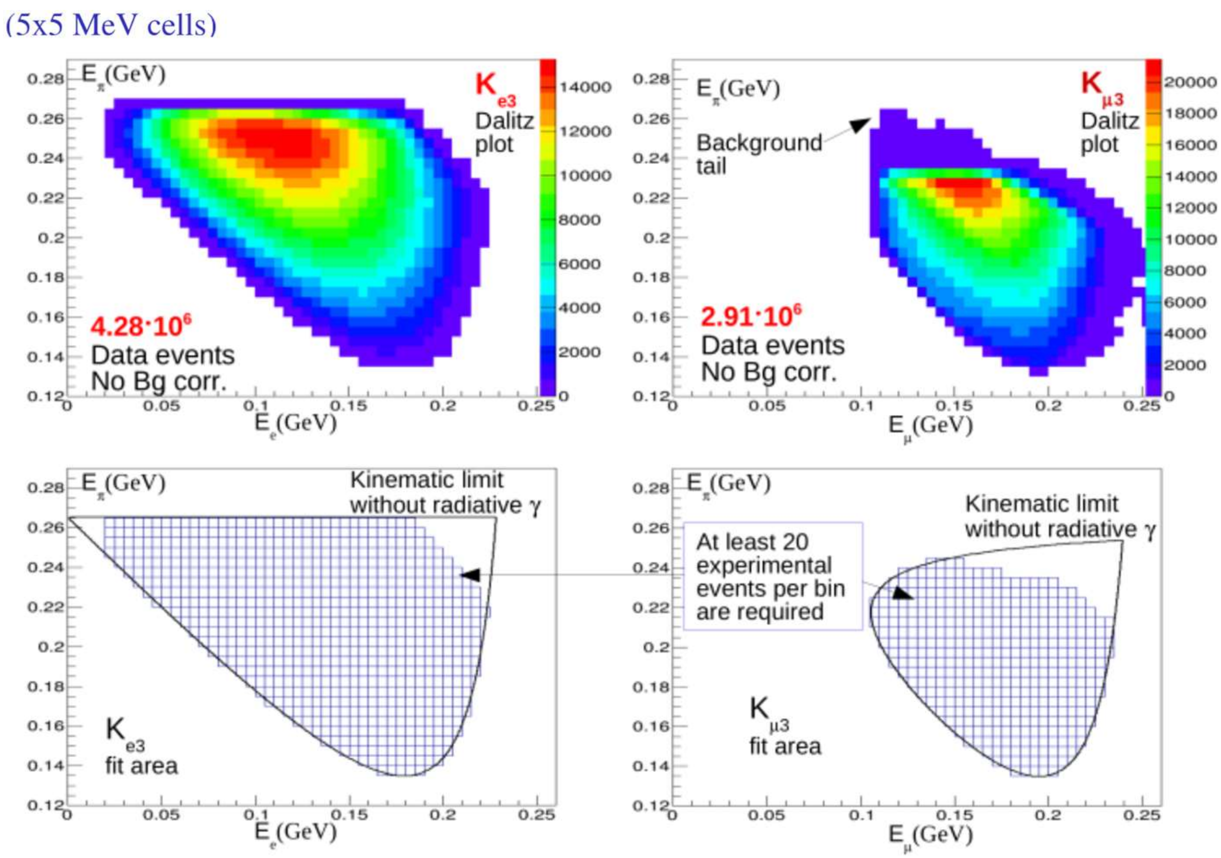
FF parametrization	$f_+(t, \text{parameters})$	$f_0(t, \text{parameters})$
Quadratic (linear for $f_0(t)$)	$1 + \lambda'_+ t/m_\pi^2 + \lambda''_+ (t/m_\pi)^2$	$1 + \lambda'_0 t/m_\pi^2$
Pole	$M_V{}^2/(M_V{}^2 - t)$	$M_S{}^2/(M_S{}^2 - t)$
Dispersive *	$\exp\left((\Lambda_+ + H(t))t/m_\pi^2\right)$	$\exp\left((\ln[C] - G(t))t/(m_K^2 - m_\pi^2)\right)$

* B. Bernard, M. Oertel, E. Passemar, J. Stern, Phys.Rev.D80(2009) 034034

We use MC radiative decay generator of C. Gatti [Eur.Phys.J. C45(2006) 417-420] provided by the KLOE collaboration. It includes $f_0 = f_+ = 1 + \lambda' t/m_\pi^2$

Measured Dalitz plot and fit areas

Data sample: 3 days of NA48/2 special run taken in 2004



Results for the joint $K_{\ell 3}$ analysis

Quadratic parametrization (10^{-3})

	λ'_+ (K_{l3})	λ''_+ (K_{l3})	λ_0 (K_{l3})
Central values	23.35	1.73	14.90
Stat. error	0.75	0.29	0.55
Syst. error	1.23	0.41	0.80
Total error	1.44	0.50	0.97

Correlation coefficients

	λ''_+ (K_{l3})	λ_0 (K_{l3})
λ'_+ (K_{l3})	-0.954	-0.076
λ''_+ (K_{l3})		0.035

Results of the combined $K_{\ell 3}$ analysis

Separate $K_{\mu 3}$ and K_{e3} analysis gave compatible results

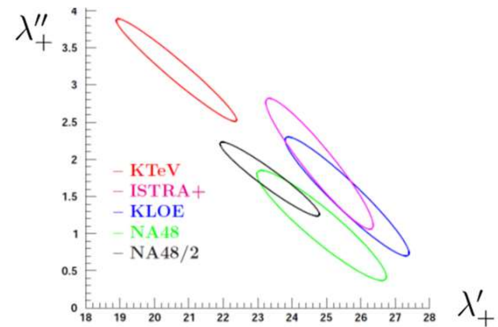
Most precise results in the world

Pole parametrization (MeV)

	m_V (K_{l3})	m_S (K_{l3})
Central values	894.3	1185.5
Stat. error	3.2	16.6
Syst. error	5.4	35.5
Total error	6.3	39.2

Correlation -0.278

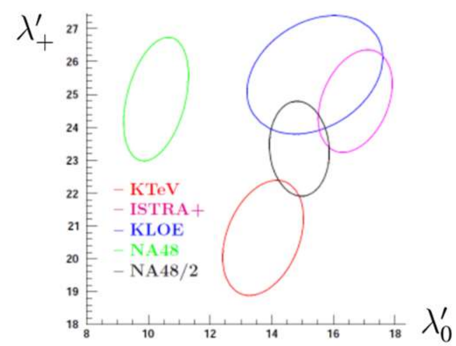
- Quadratic fit: $\rightarrow \lambda'_+, \lambda''_+, \lambda'_0$
- Parameter correlation (1σ ellipses)
- black ellipse = NA48/2
- comparison to other experiments

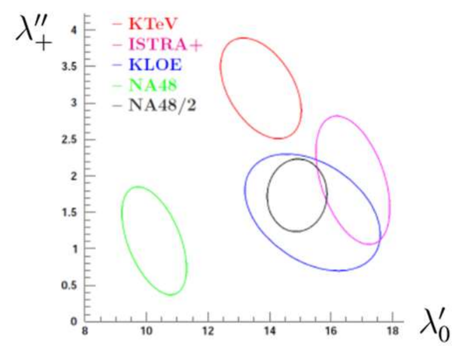


Dispersive parametrization (10^{-3})

	Λ_+ (K_{l3})	Ln[C] (K_{l3})
Central values	22.67	189.12
Stat. error	0.18	4.91
Syst. error	0.55	11.09
Total error	0.58	12.13

Correlation -0.035





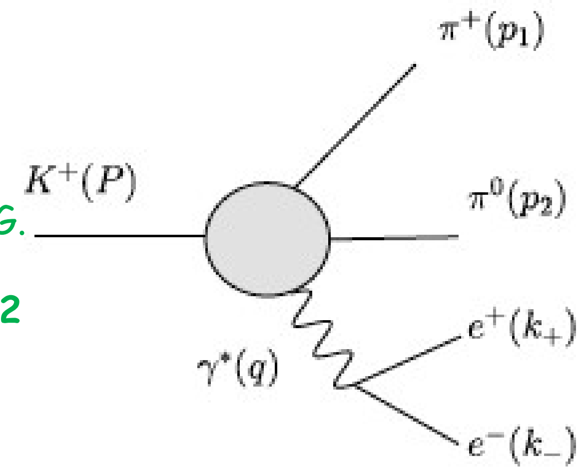
NA48: $K^{\pm} \longrightarrow \pi^{\pm}\pi^{0}\gamma^{*} \longrightarrow \pi^{\pm}\pi^{0}e^{+}e^{-}$

$K^{\pm} \to \pi^{\pm}\pi^{0}\gamma^{*} \to \pi^{\pm}\pi^{0}e^{+}e^{-}$ motivations

- Never observed
- Inner bremsstrahlung, direct emission (E,M) and interference components

$$\frac{d^3\Gamma}{dE^*_\gamma\, dT^*_c\, dq^2} = \frac{d^3\Gamma_B}{dE^*_\gamma\, dT^*_c\, dq^2} + \frac{d^3\Gamma_E}{dE^*_\gamma\, dT^*_c\, dq^2} + \frac{d^3\Gamma_M}{dE^*_\gamma\, dT^*_c\, dq^2} + \frac{d^3\Gamma_{\text{int}}}{dE^*_\gamma\, dT^*_c\, dq^2},$$

L. Cappiello, O. Catà, G. D'Ambrosio ,D.Gao
EPJ C72 (2012) 1872
H. Pichl
EPJ C20 (2001) 371



- Interference $\Gamma_B\ \Gamma_E$ can confirm the discrepancy in sign with the theoretical prediction observed by NA48/2 in $K^{\pm} \to \pi^{\pm}\pi^{0}\gamma$ EPJC 68 (2010) 75-87

- Magnetic interference is genuine $\pi\pi ee$ and can be used to extract the sign of the magnetic term Γ_M (impossible to extract in $\pi^{\pm}\pi^{0}\gamma$).

- P violating observables in the dilepton pair coupling can be used to access short distance physics using K^+ only (NA62)

- Charge asymmetry not contaminated by indirect CP violation (as in K^0)

NA48/2 data from 2003 and 2004 runs

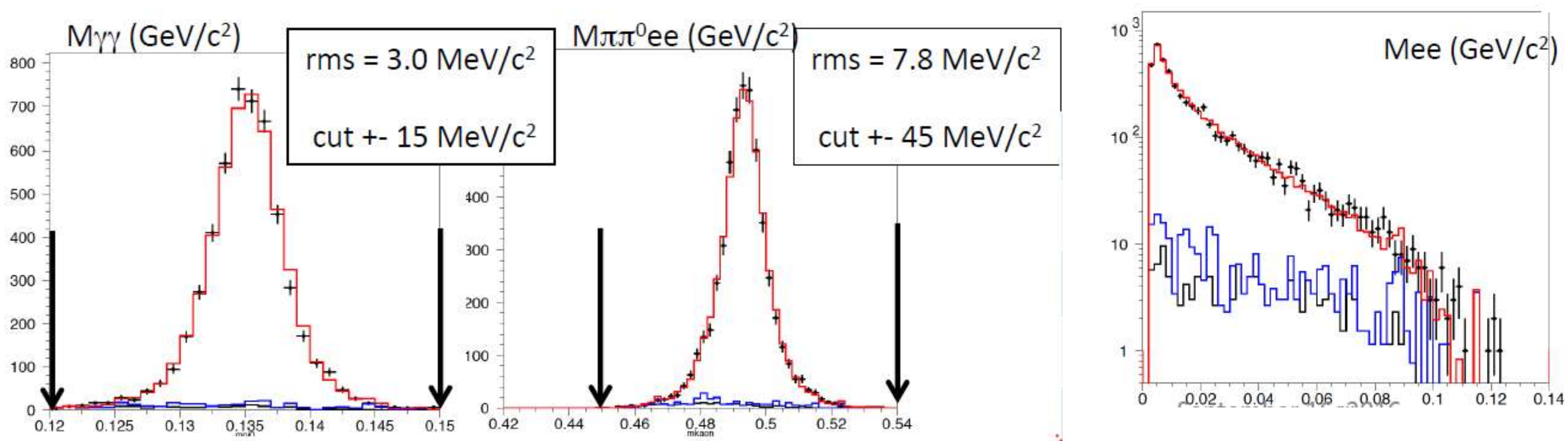
A clean signal sample

$K^{\pm} \longrightarrow \pi^{\pm}\pi^{0}e^{+}e^{-}$ signal dominated by

- IB, then DE (M) and INT(IB,E) : 4 independent generations (IB, M, INT>0 and INT <0) with different acceptances (A(M) and A(BE) ~ 3 x A(IB))
- Radiative corrections adding extra photon(s) emission using Photos

Backgrounds

$K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\pi^{0}_{D}$ ($K_{3\pi D}$): 159±8 events $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}_{D}$ (γ) ($K_{2\pi D}$): 130±24 events



M_{ee} > 3MeV/c², background dominates at large values

A large normalization sample

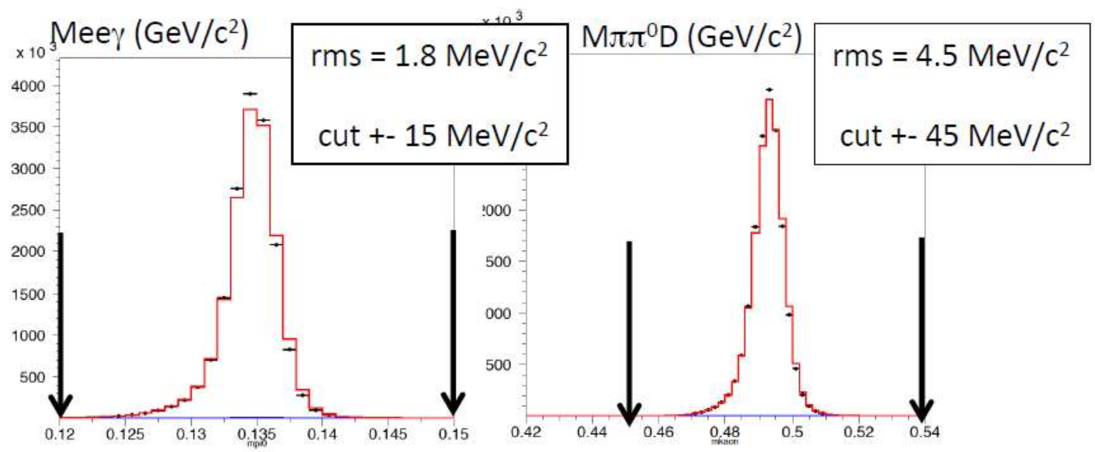
Normalization with $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}_{D}$;Several generators used

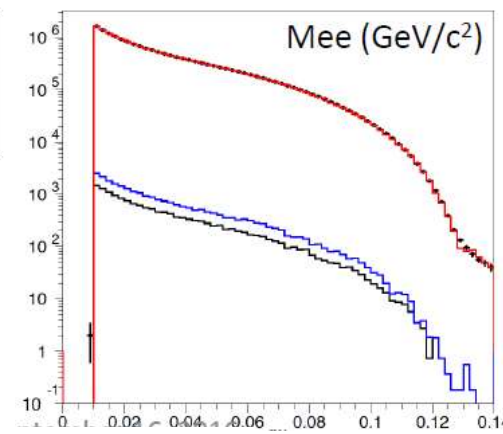
- $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}$ generator code including 1 real photon emission - Gao EPJ C 45 (2006)
- π^{0}_{D} decays including 1 extra photon emission - Husek, Kampf, Novotny PRD 92 (2015)
- also π^{0}_{D} decays including extra photon(s) emission (Photos) - Was et al CPC 79 (1994)

Backgrounds

$K_{\mu 3D}$: 15182 ± 173 events

K_{e3D}: 10334±140 events





M_{ee}> 10 MeV/c², low sensitivity to radiative correction modeling

Branching ratio measurement

$$BR(\pi\pi ee) = \frac{(N_S - N_{BS}) \cdot A_N \cdot \varepsilon_{L1N} \cdot \varepsilon_{L2N}}{(N_N - N_{BN}) \cdot A_S \cdot \varepsilon_{L1S} \cdot \varepsilon_{L2S}} \cdot BR_{Norm}$$

We have computed a model dependent branching ratio using a total acceptance in which the weights of the various components have been taken from Cappiello et al.

$$A_S = \frac{Acc(IB) + Frac(DE)_{Th} \cdot Acc(DE) + Frac(INT)_{Th} \cdot Acc(INT)}{1 + Frac(DE)_{Th} + Frac(INT)_{Th}}$$

Frac(DE)=1/71 and Frac(INT)=1/128 computed in Cappiello et al. using inputs from the NA48 measurement of $K^{\pm} \to \pi^{\pm}\pi^{0}\gamma$

N_S	5076
N_{BS}	289
Acceptance A_S	(0.666±0.001)%
L1 Trigger Efficiency (ε_{L1S})	(99.73±0.01)%
L2 Trigger efficiency (ε_{L2S})	(99.46±0.02)%

N_N	16774613
N_{NS}	25517
Acceptance A_N	(4.083±0.002)%
L1 Trigger Efficiency (ε_{L1N})	(99.767±0.003)%
L2 Trigger efficiency (ε_{L2N})	(98.548±0.007)%

Branching ratio measurement

Theoretical predictions:

No Radiative corrections, no isospin corrections BR= $4.29 \cdot 10^{-6}$ (*)

No Radiative corrections, with isospin corrections BR= $4.19 \cdot 10^{-6}$ (**)

$BR_{\pi\pi ee}^{NA48/2} = (4.22 \pm 0.06_{stat} \pm 0.04_{syst} \pm 0.13_{ext}) \cdot 10^{-6}$

Dominated by the external error on BR(π^0_D)

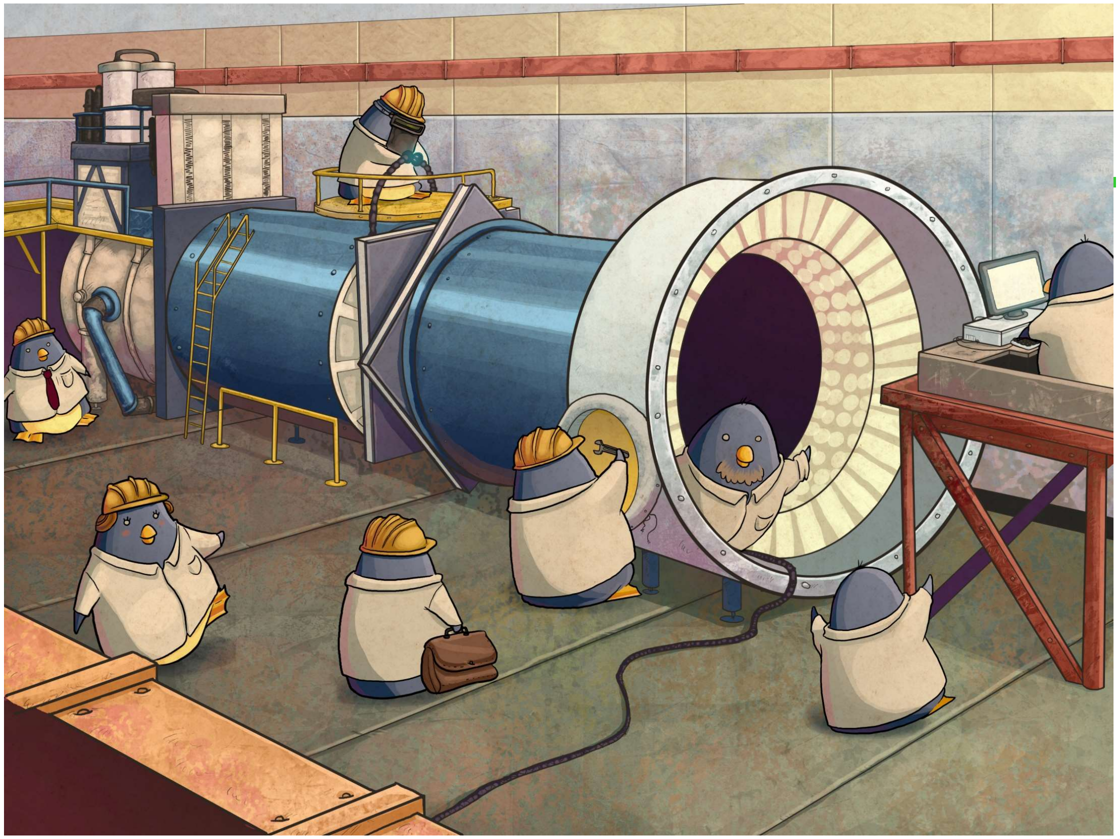
(*) EPC C72 (2012)
(**) private communications from the authors

Conclusions

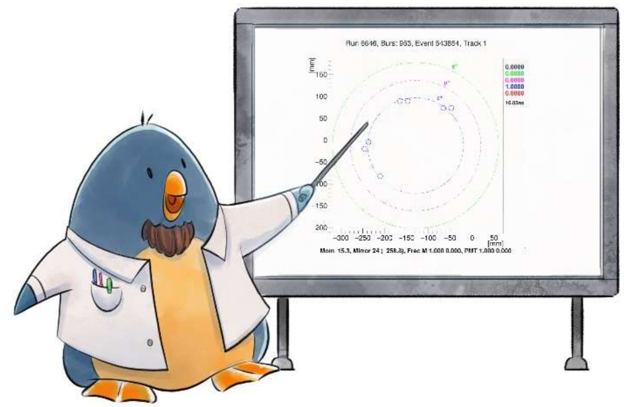
- NA62 is taking data with the complete detector since 2016
- A preliminary result from the 2016 data sample has been obtained
  - 1 event found with an expected background of 0.15
  - An upper limit to the branching ratio has been obtained

- Results about $K_{\ell 3}$ form factors from NA48/2 have been presented
  - Agreement with previous measurements and the most precise in the world

- First observation of $K^{\pm} \longrightarrow \pi^{\pm}\pi^{0}e^{+}e^{-}$ from NA48/2
  - Precise measurement of the branching ratio
  - Good agreement with the theoretical predictions
  - Close to the final results



Artist's view of the past installation activity…



Thank you!

… and of the current analysis work…