# Observation and measurement of $K^+ \to \pi^+\pi^0\pi^0\gamma$ Decay

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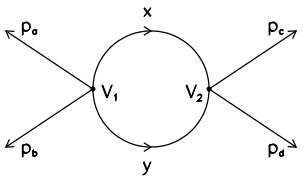
On behalf of OKA exprtiment, Preliminary

$21^{st}$ Lomonosov Conference on Elementary Particle Physics,
Moscow, August 24-30, 2023

## Motivation

- $BR(K^+ \to \pi^+\pi^0\pi^0\gamma) = (3.76 \pm 0.03) \times 10^{-6}$ $(E^*_\gamma > 10MeV)$
  D'Ambrosio et al., "$K \to \pi\pi\pi\gamma$ in Chiral Perturbation Theory", UWThPh-1996-55 LNF-96/070 (P) Dec. 1996

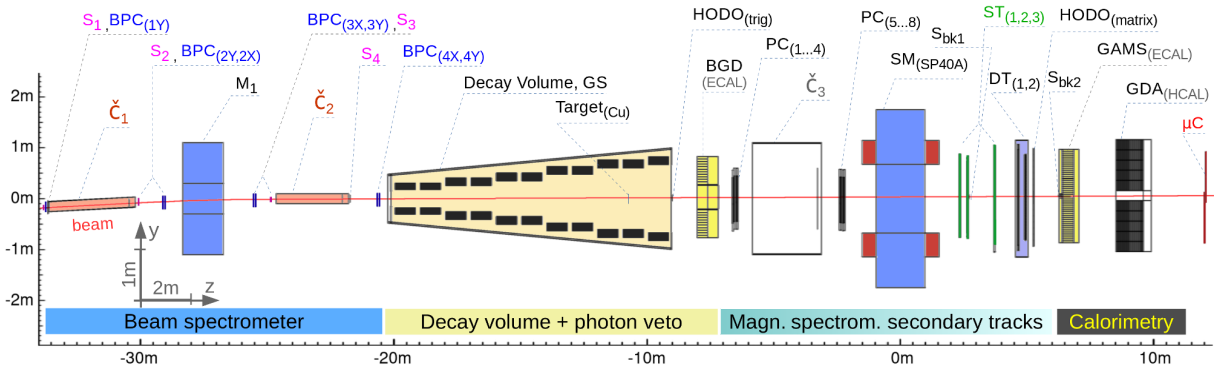



- Experiment: $7.6^{+6}_{-3} \times 10^{-6}$
  ISTRA, Protvino, 1985. Indirect observation 5 events.
  V.N.Bolotov et al., "Observation of the decay $K^- \to \pi^-\pi^0\pi^0\gamma$", Pisma Zh.Exp.Theor.Fiz 42(1985) 390-392

# OKA Setup

IHEP, Protvino

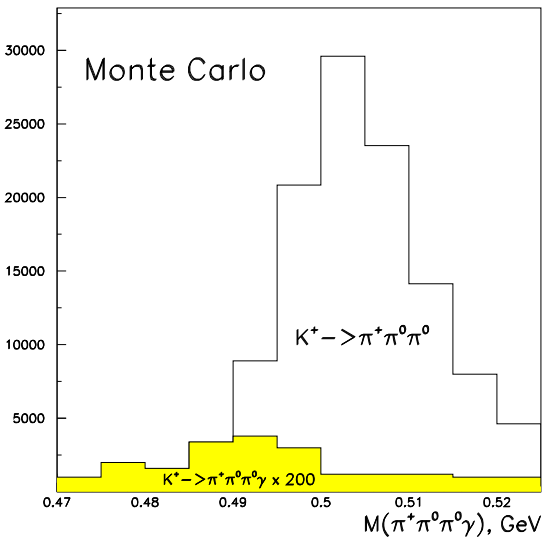
- Beam 17.6 GeV
- 12%$K^+$, 35%$\pi^+$, 53% p
- $2.5 \times 10^5 K^+/s$
- Data taking 2012,2013.



## Event Selection

First stage employed set of standard criteria:

- One beam and one secondary positive tracks
- One track segment downstream magnet
- Beam track momentum within beamline design limits
- Cherenkovs response matches $K^+$
- Angle between beam and secondary tracks $\Theta > 2mrad$
- Distance between beam and secondary tracks $< 1cm$
- Event vertex within decay volume
- 5 $\gamma$-quanta $E_\gamma > 0.5GeV$ detected
- 2 $\pi^0$'s found
- Only $\pi^+\pi^0\pi^0$ background survives

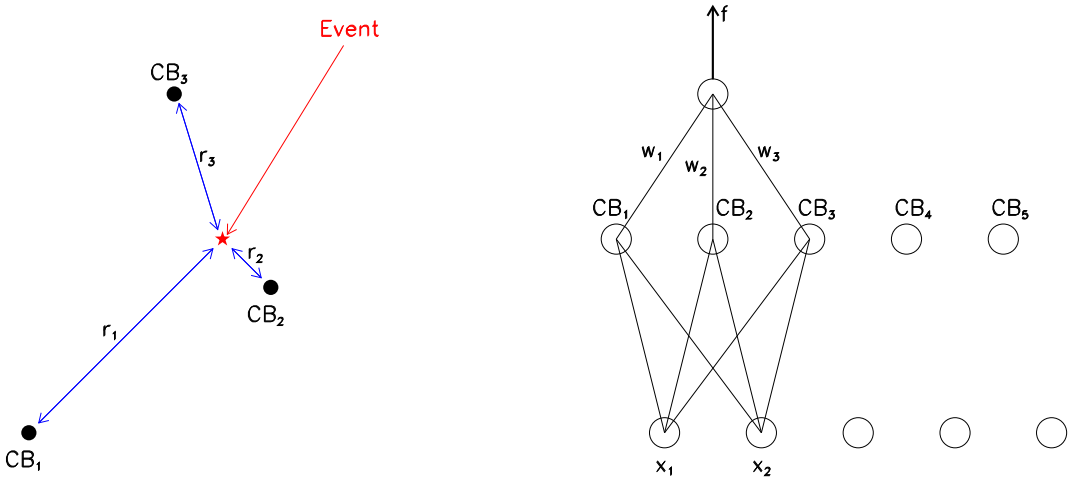


## Backgrounds

- Background: $K^+ \to \pi^+\pi^0\pi^0$
- $\frac{BR(K^+\to\pi^+\pi^0\pi^0)}{BR(K^+\to\pi^+\pi^0\pi^0\gamma)} = \frac{1.76\times10^{-2}}{3.76\times10^{-6}} \approx 4700$
- Fluctuations of $\pi^+$ shower in GAMS mimic extra $\gamma$
- 5 $\gamma$ final state $\to$ combinatorial background
- RBFN neural net trained on MC events employed for background suppression

## Neural Net

Radial Basis Function Neural Net trained on 100,000 $K^+ \to \pi^+\pi^0\pi^0\gamma$ and 100,000 $K^+ \to \pi^+\pi^0\pi^0$ MC events.

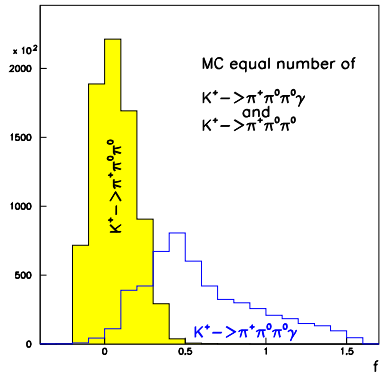


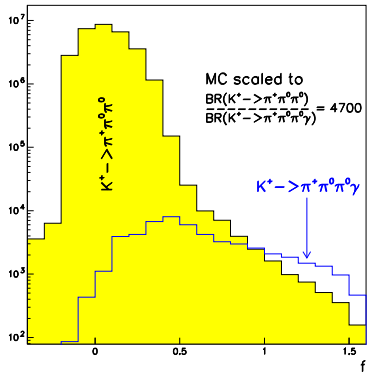

$$\text{Output: } f = \sum_i w_i \exp\left[-\frac{r_i^2}{\sigma_i^2}\right]$$

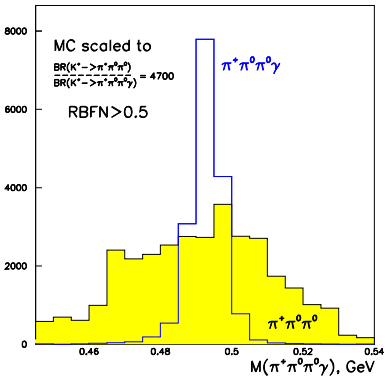
Input variables:

1. $\Delta E = E_{\pi^+} + \sum_{i=1}^{5} E_{\gamma_i} - E_{beam}$ - energy balance
2. $E_5$ - 5-th $\gamma$ energy
3. $dist_5$ - Distance from 5-th $\gamma$ to track
4. $CHI_5$ - 5-th $\gamma$ $\chi^2$
5. $FIT_5$ - $\chi^2$ of 3C-fit to $\pi^+\pi^0\pi^0\gamma$
6. $lg(FIT_5)$
7. $CFC = \frac{M_4 - 0.488}{0.111 - \frac{1}{R_{54}^2}}$, $\quad R_{54} = lg(Fit5/Fit4)$,
   $M_4 = m(\pi^+\pi^0\pi^0)$, 3C-fit

# Background suppression by RBFN



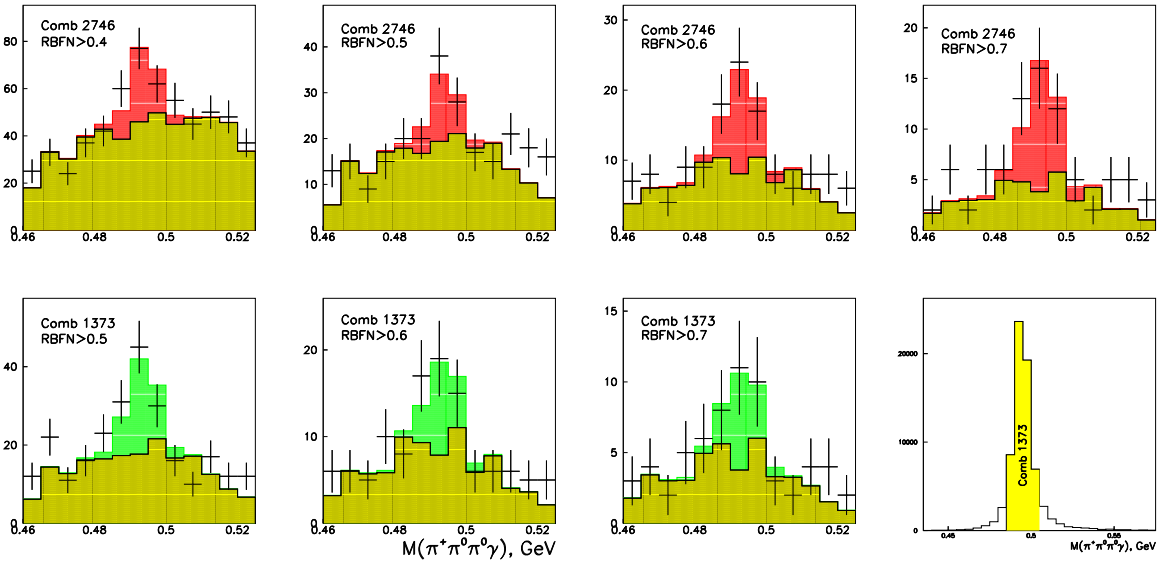




Numbers for $f > 0.5$

| | $\pi^+\pi^0\pi^0\gamma$ | $\pi^+\pi^0\pi^0$ | $\frac{\pi^+\pi^0\pi^0\gamma}{\pi^+\pi^0\pi^0}$ |
|---|---|---|---|
| Total events | 17015.6 | 33257.0 | 0.51 |
| 3 central bins $0.485 < m < 0.5$ | 15152.09 | 9056.13 | 1.67 |

**Fit** $Data = \alpha \times MC(K^+ \to \pi^+\pi^0\pi^0\gamma) + \beta \times MC(K^+ \to \pi^+\pi^0\pi^0)$

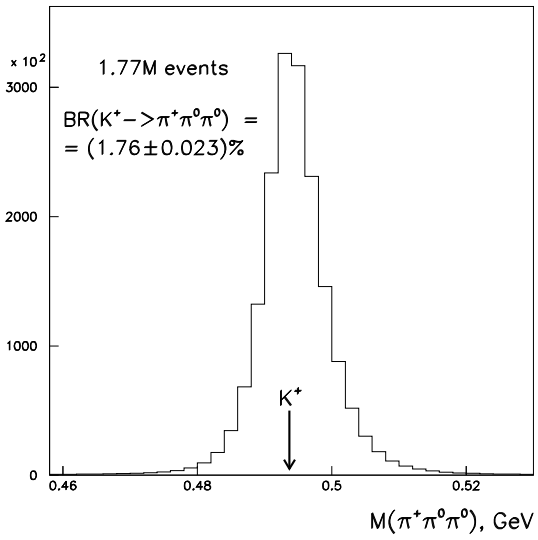
Preliminary

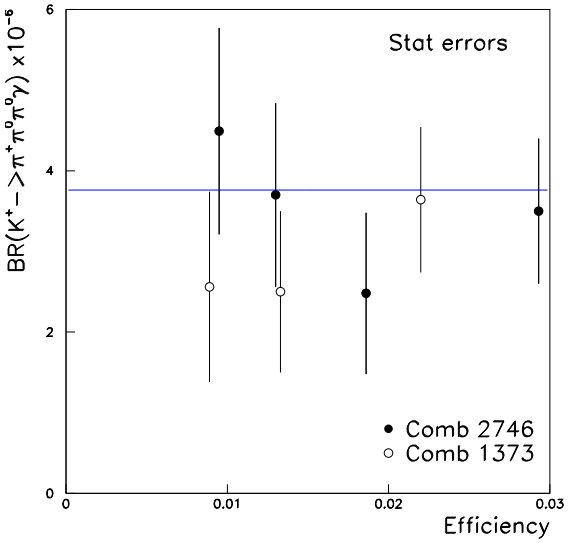



- Comb 2746 trained in full mass range
- Comb 1373 trained in narrow mass window $M = M_K \pm 10MeV$

# **BR** $(E^*_\gamma > 10MeV)$

Preliminary



## Conclusions

- $\approx 60$ events of $K^+ \to \pi^+\pi^0\pi^0\gamma$ decay observed
- Major background source $K^+ \to \pi^+\pi^0\pi^0$, $\frac{BR(K^+\to\pi^+\pi^0\pi^0)}{BR(K^+\to\pi^+\pi^0\pi^0\gamma)} \approx 5000$
- RBFN neural net employed for background suppression
- Signal:Background obtained $\approx 1$
- Preliminary $BR(K^+ \to \pi^+\pi^0\pi^0\gamma)$ measured $(3.2 \pm 1.0(stat)) \times 10^{-6}$
- Agrees with ChPT prediction $(3.76 \pm 0.03) \times 10^{-6}$
- Systematics under study