Study of rare decays of charged K-mesons in the NA62 experiment at SPS CERN

$K^+ \to \pi^+\pi^-\mu^+\nu$ (Kμ4)

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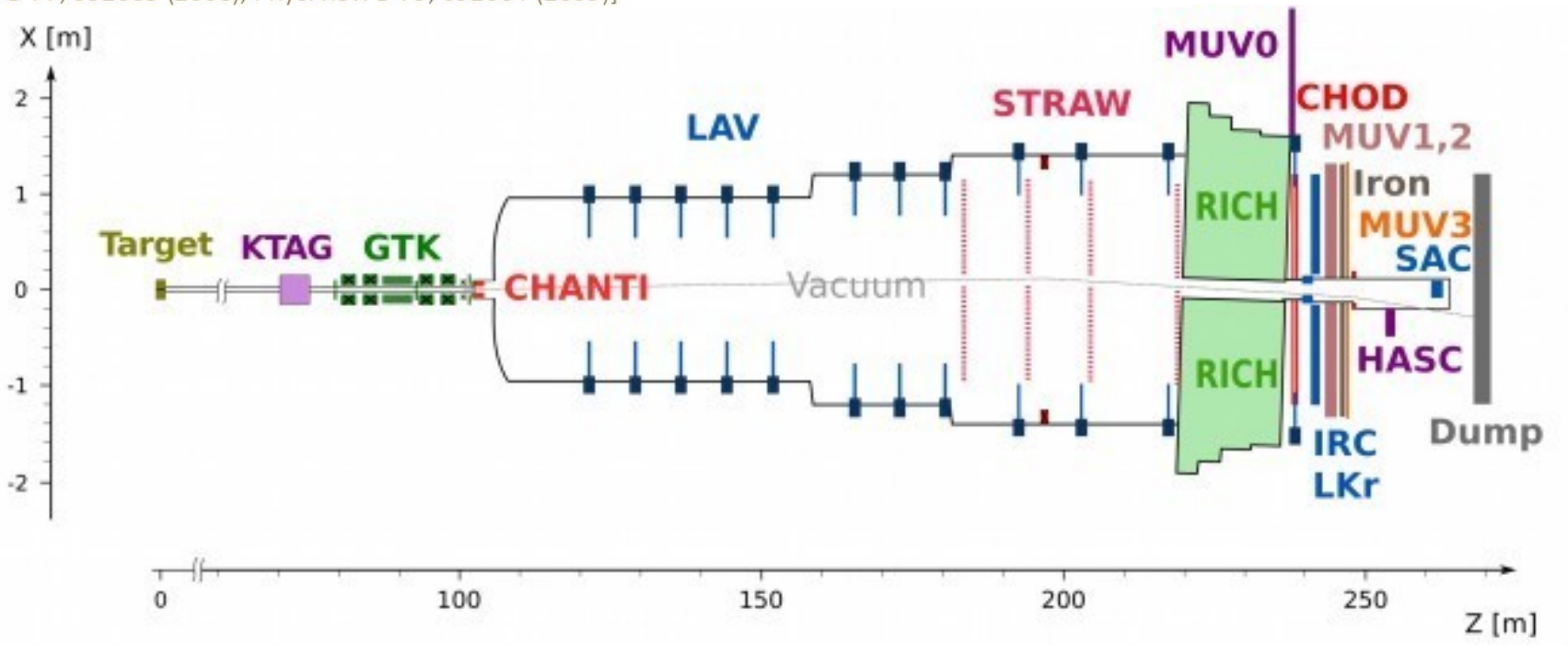
Kaon Physics in the NA62 Experiment

SM prediction [Buras et al. JHEP 1511 (2015) 33] $\mathrm{BR}(K^+ \to \pi^+ \nu\bar{\nu}) = (8.4 \pm 1.0) \cdot 10^{-11}$

Experimental status (E787, E949) $\mathrm{BR}(K^+ \to \pi^+ \nu\bar{\nu}) = \left(17.3^{+11.5}_{-10.5}\right) \times 10^{-11}$

[Phys. Rev. D 77, 052003 (2008), Phys. Rev. D 79, 092004 (2009)]



- SPS Beam:
  - 400 GeV/c protons
  - 2.10^{12} protons/spill
  - 3.5s spill
- Secondary positive Beam:
  - 75 GeV/c momentum, 1 % bite
  - 100 μrad divergence (RMS)
  - 60x30 mm^2 transverse size
  - $K^+(6\%)/\pi^+(70\%)/p(24\%)$
- Decay Region:
  - 60 m long fiducial region
  - ~ 5 MHz K^+ decay rate
  - Vacuum ~ $O(10^{-6})$ mbar

The new NA62 decay-in-flight technique

Kaon Physics in the NA62 Experiment

Motivation

In V-A theory of weak interactions, the hadronic part of the matrix element describing the $K_{\mu 4}$ decay can be represented as follows:

$$\langle \pi\pi | J_\lambda | K \rangle = 2^{-\frac{3}{2}} (K_o p_o q_o)^{-\frac{1}{2}} \times \left(F_1 (p+q)_\lambda + F_2 (p+q)_\lambda + F_3 (K - p - q)_\lambda + F_{4\lambda\mu\sigma\rho} p_\mu q_\sigma K_p \right)$$

where p_l, q_l are 4 - moment of two pions, and K_l is the momentum of the parent kaon. The third term, related to the ratio $\Gamma(K_{\mu 4}) / \Gamma(K_{e4})$, can only be studied in $K_{\mu 4}$ decays, which makes this decay an interesting possible source of information on the properties of semileptonic decays.

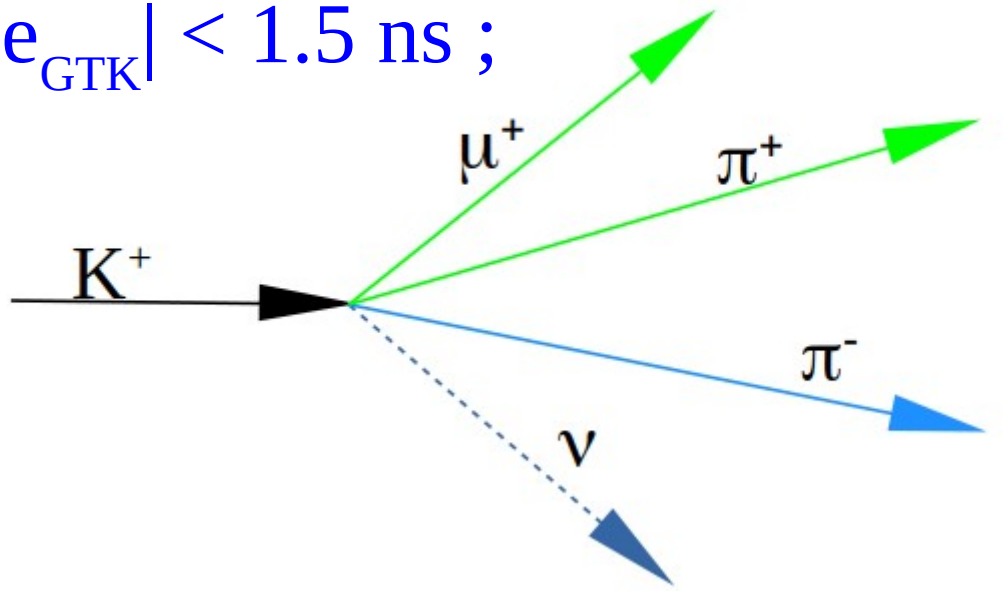
Earlier measurements in 1965 year:

- Best precision : **Br (Kμ4) = (1.4 ± 0.9)*10^{-5} (PDG)**
- D. Cline and W.F.Fry, Phys. Let 3(1965) 293.
- Douglas E. Greiner, W.Z. Osborne, and Walter H. Barkas, Phys. Rev. Letters 3(1964) 284.
- V. Bisi, R.Cester, A. Marzari Chiesa and M. Vigone, Phys. Let 10(1967) 572.

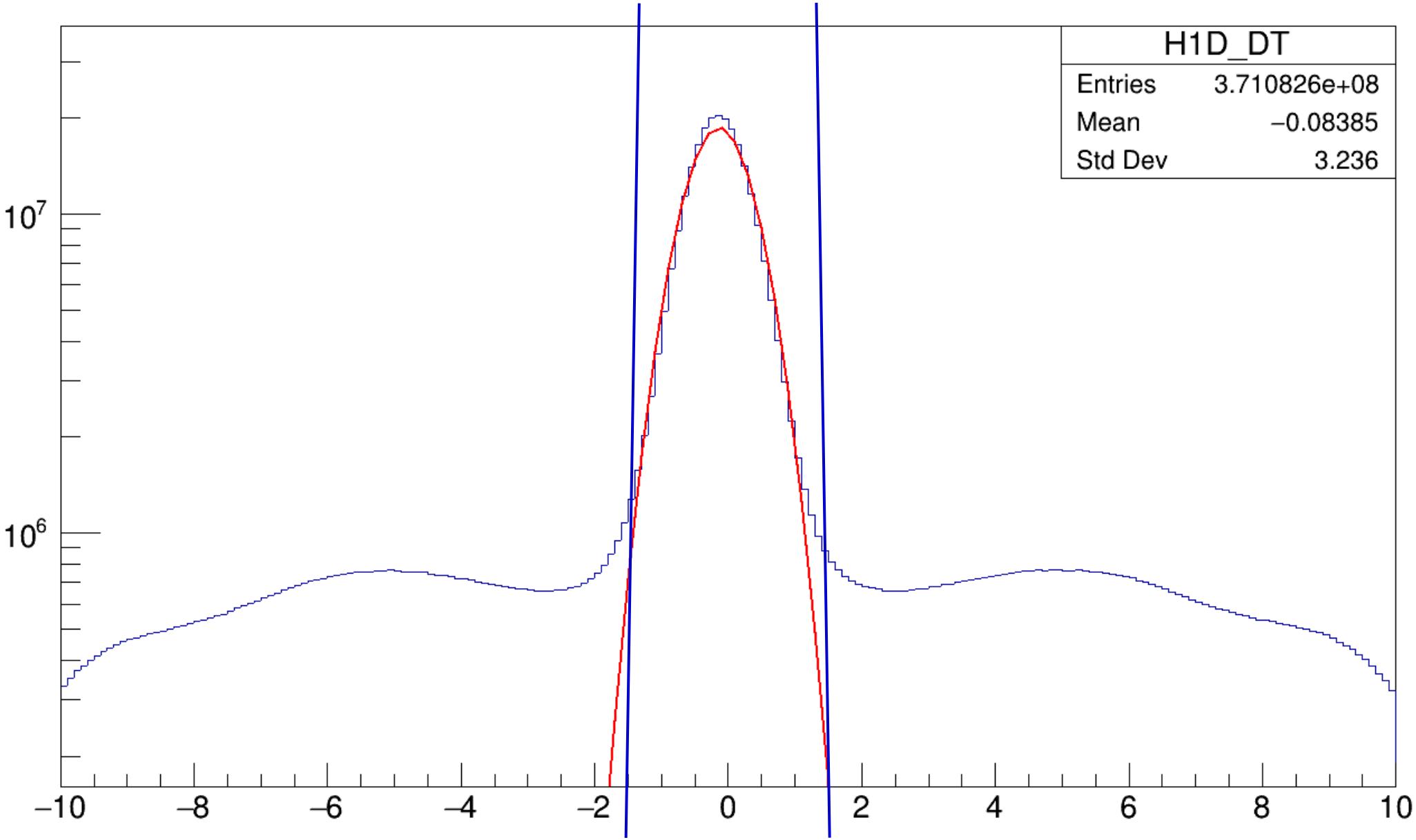
Conditions to selection of $K^+ \to \pi^+\pi^-\mu^+\nu$:

- $X^2_{\text{3tr-vtx}} \leq 20$;
- $106\ \text{m} \leq Z_{\text{3tr-vtx}} \leq 180\ \text{m}$
- $P_{\text{3tr-vtx}} < 71\ \text{GeV/c}$ (cut against $K^+ \to \pi^+\pi^+\pi^-$);
- VetrexTime: average of 3 tracks NewCHOD times;

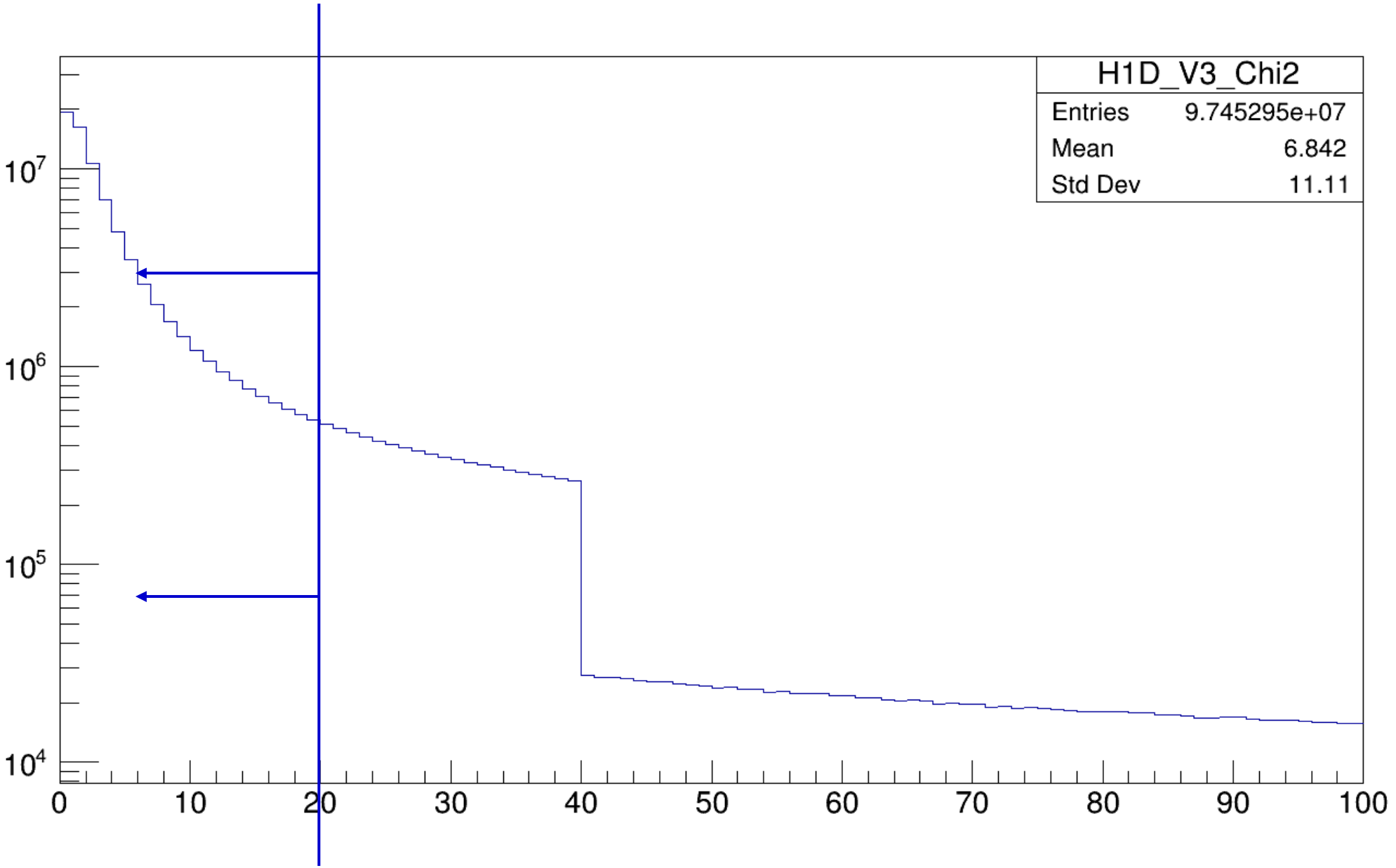
$|\text{Time}_{\text{3tr-vtx}} - \text{Time}_{\text{GTK}}| < 1.5\ \text{ns}$;



$|Time_{3tr\text{-}vtx} - Time_{GTK}| < 1.5$ ns

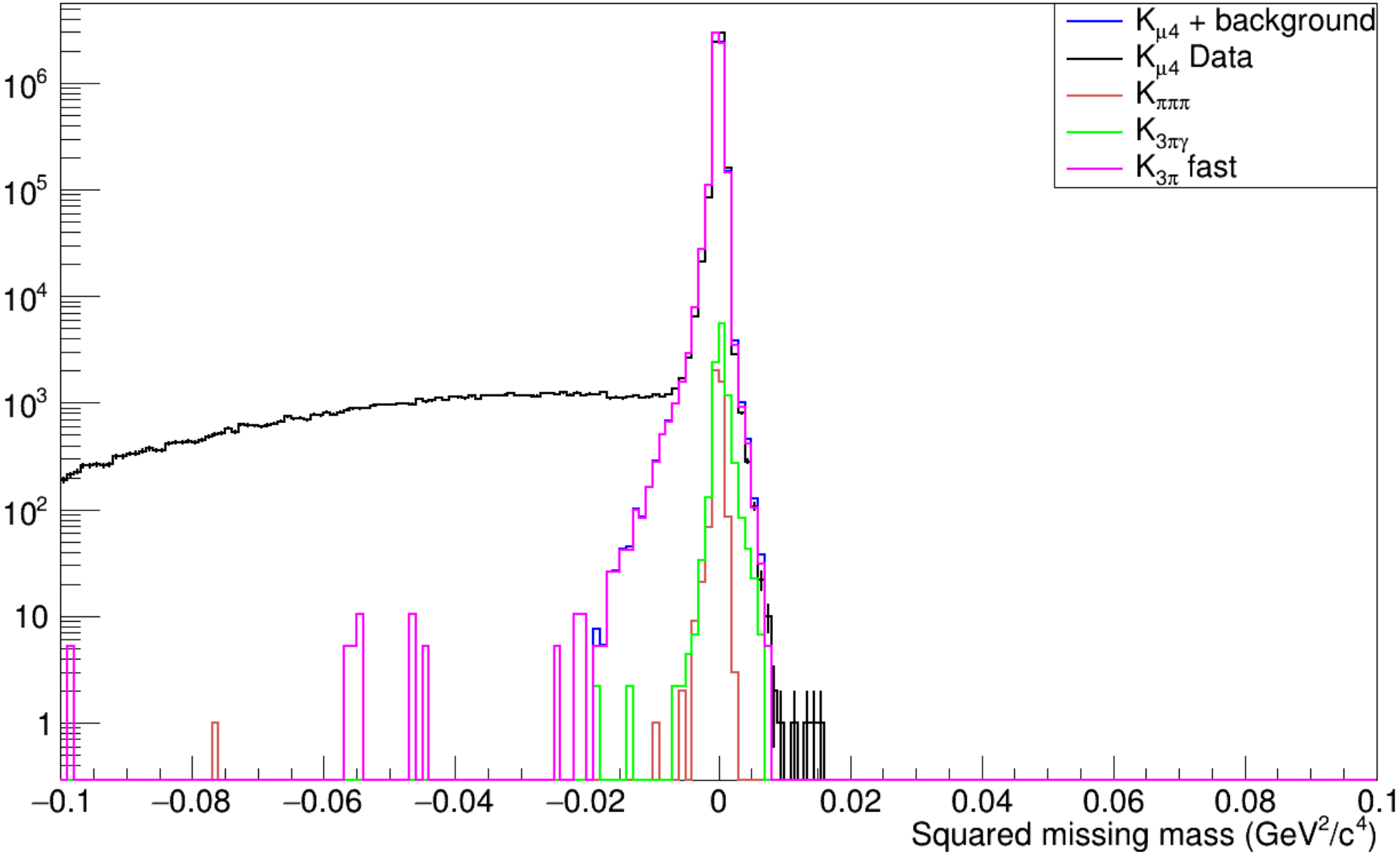


$\chi^2_{\text{3tr-vtx}} \leq 20$;

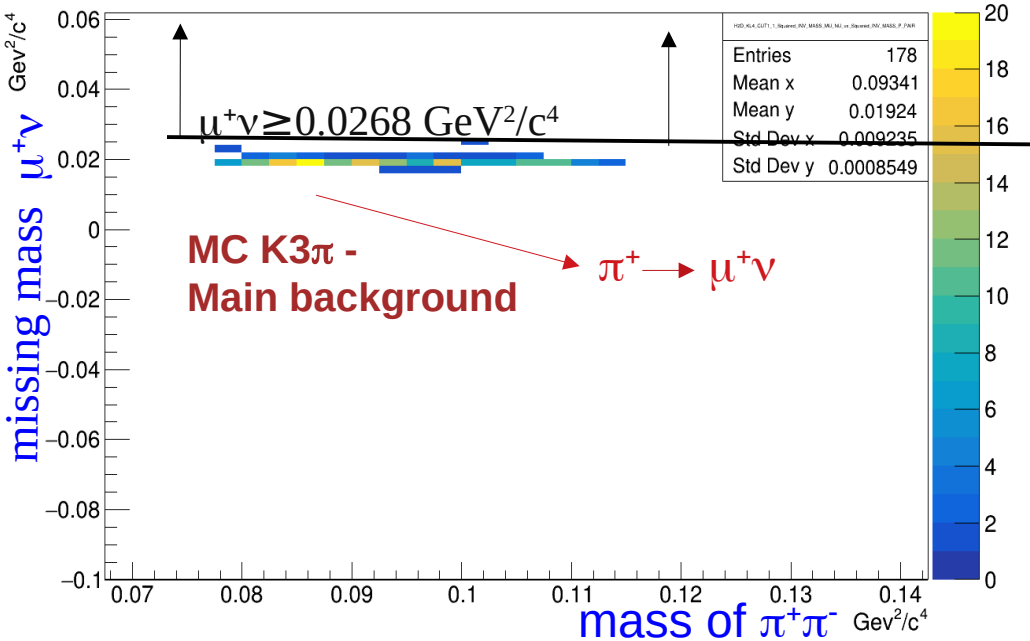


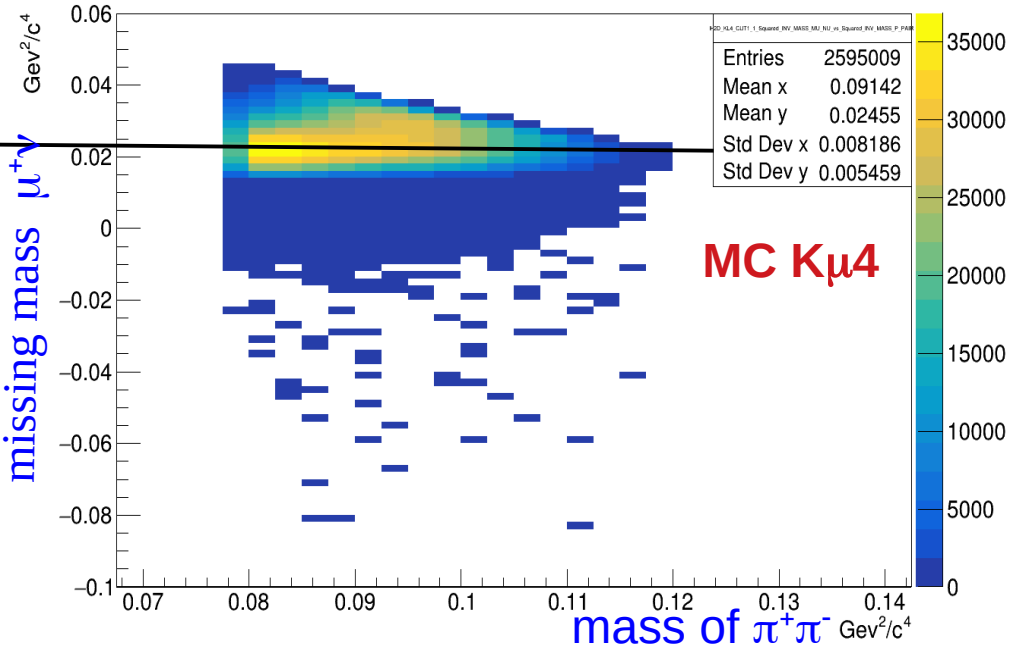
Squared missing mass without cuts

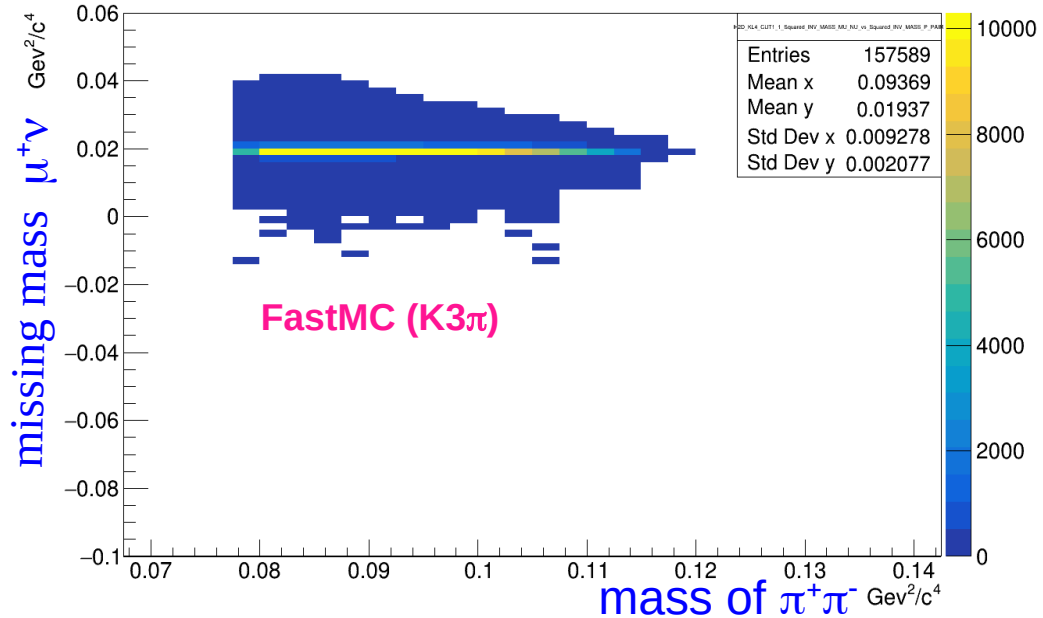
Decay in flight technique: $m^2_{miss} = (P_K - P_{\pi^-} - P_{\pi^+} - P_{\mu^+})^2$

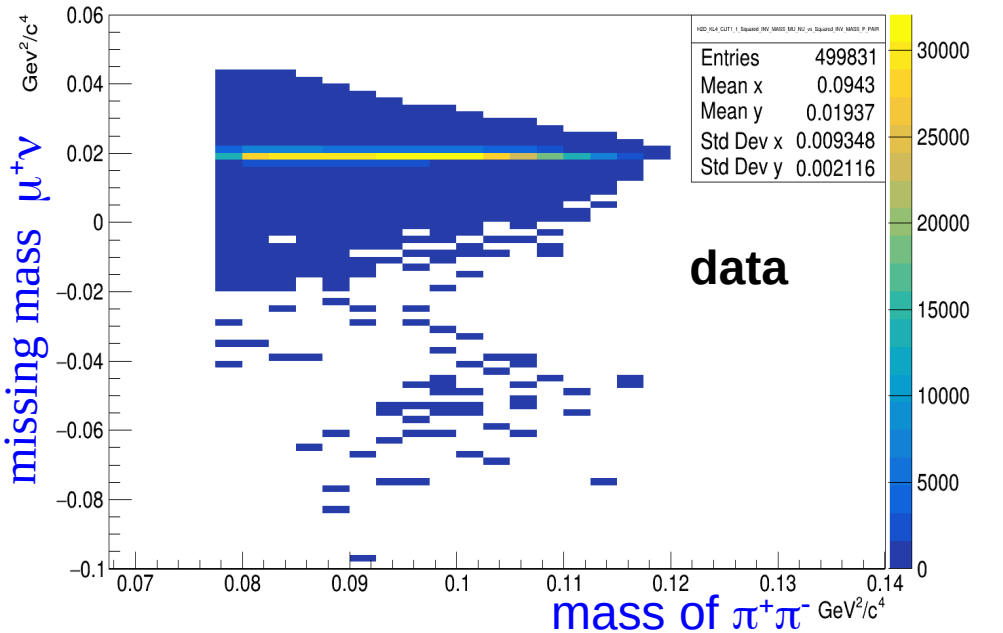


Squared missing mass of $\mu^+\nu$ vs Squared mass of $\pi^+\pi^-$

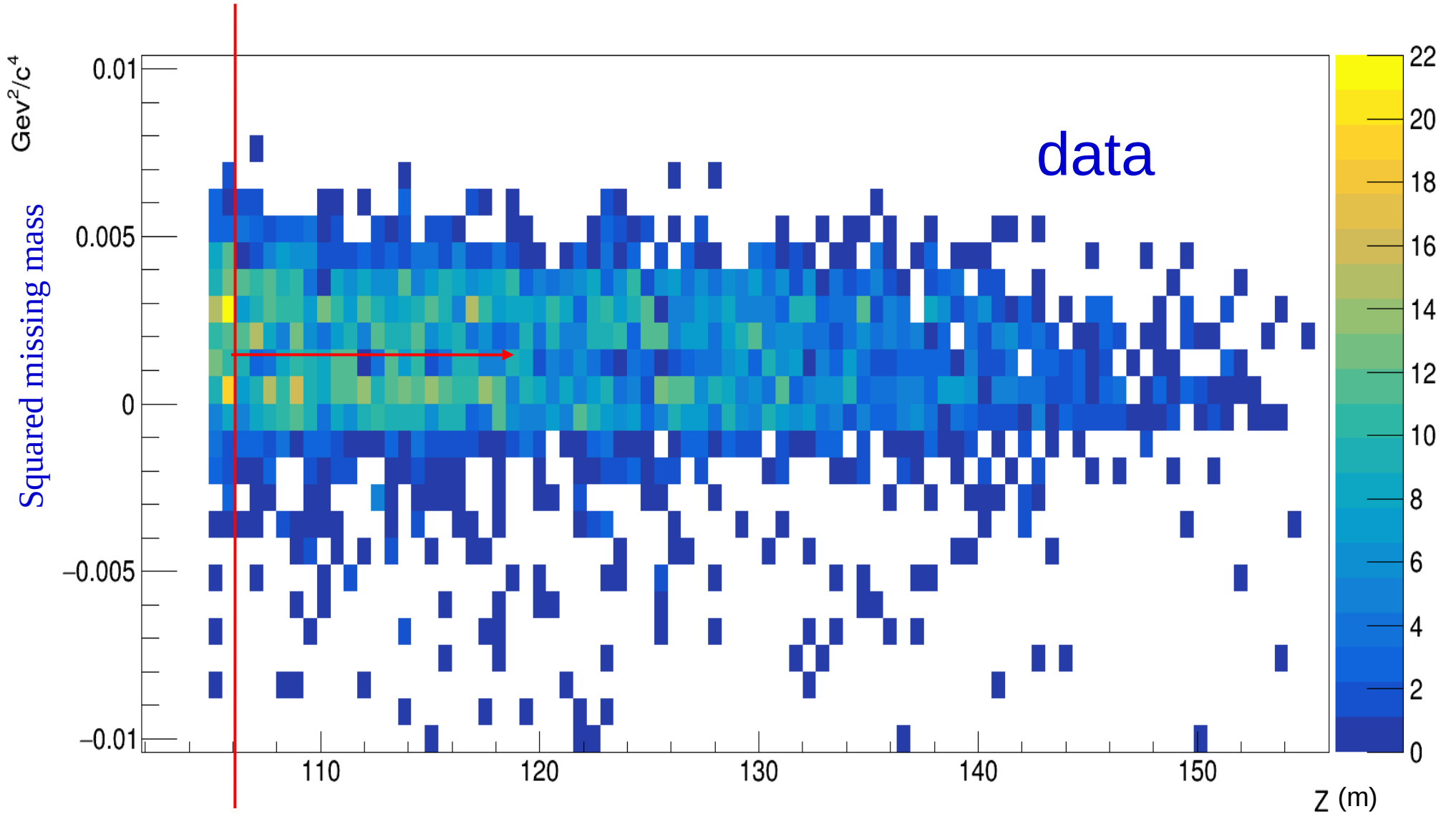




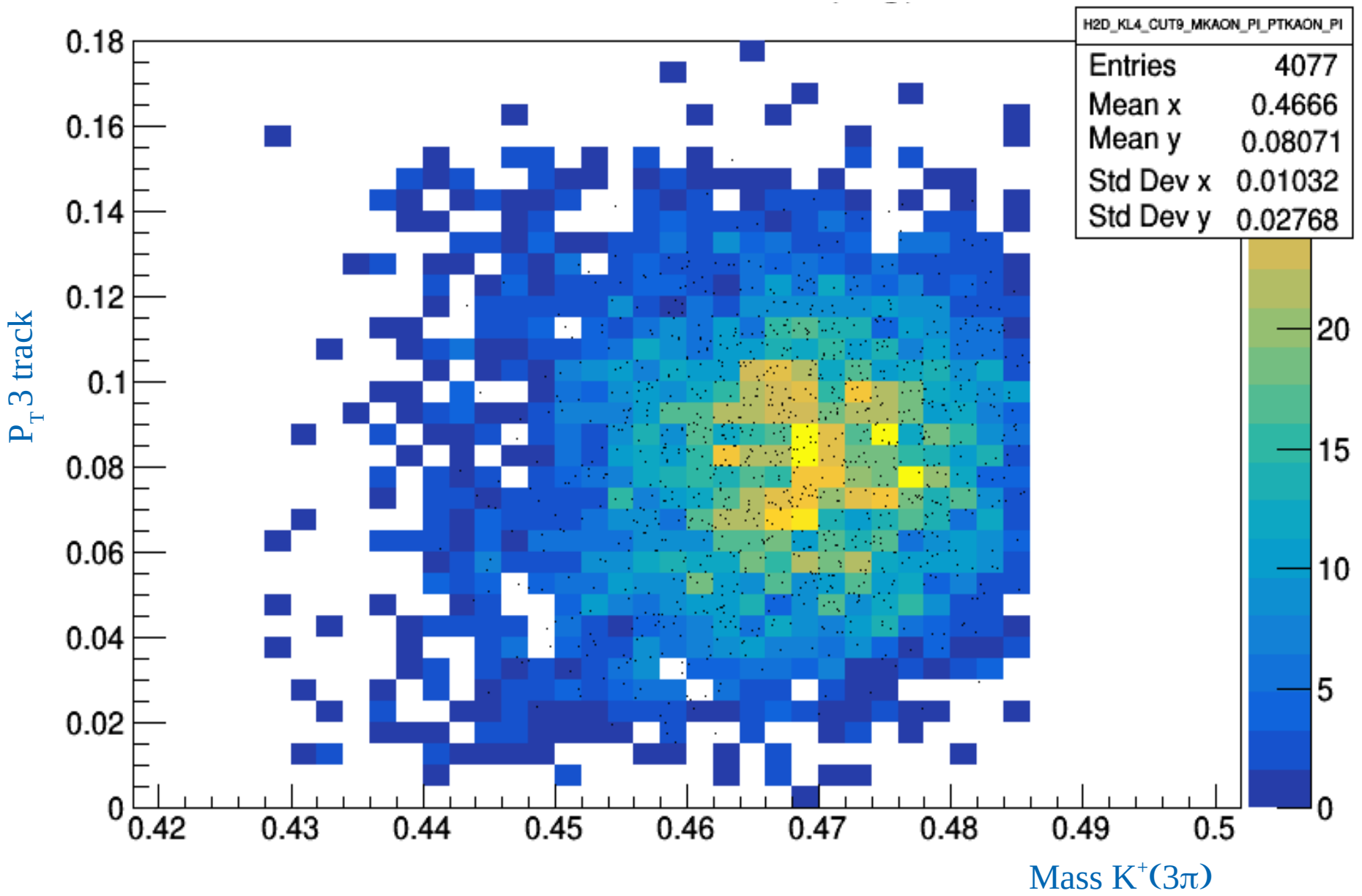




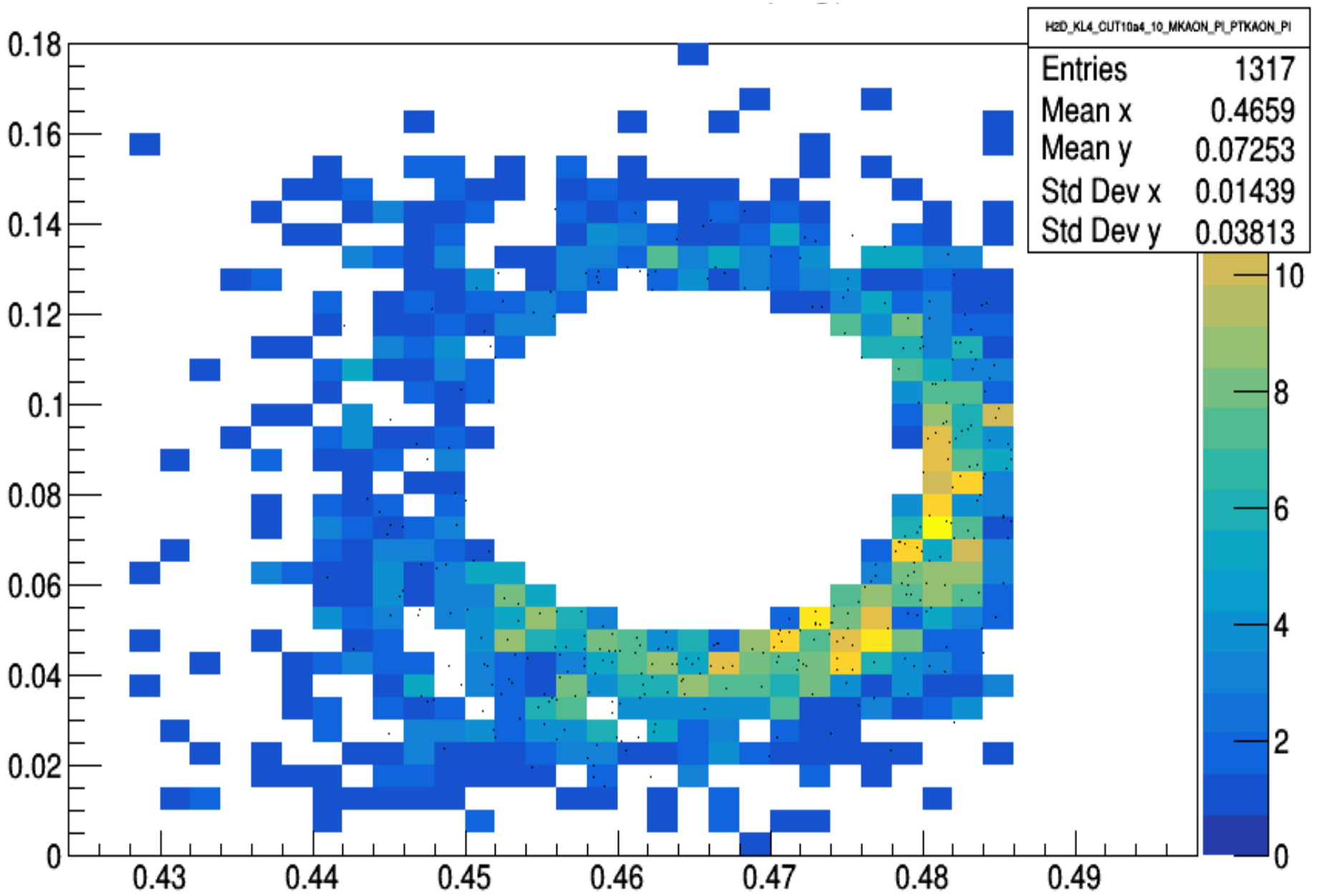
Squared missing mass vs Z



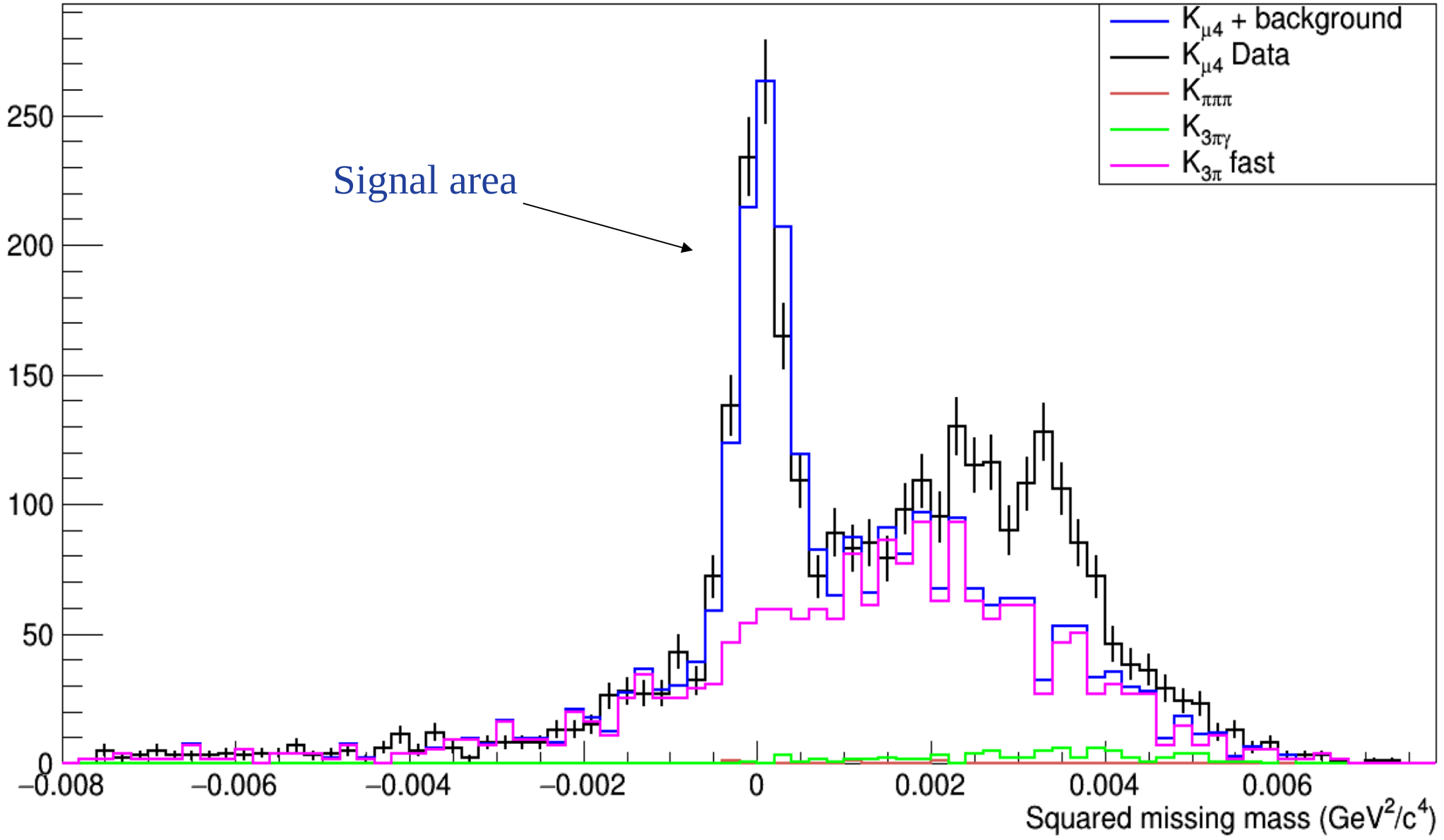
P_T 3 track vs Mass $K^+(3\pi)$



Pt 3 track vs Massa $K^{+}(3\pi)$



Squared missing mass (Sample 2017A)



Main results and next step

- The basic backgrounds to the decay of Km4 were studied.
- Cuts were set to suppress the background.

Next steps:

- Research on the effectiveness of triggers;
- It is necessary to calculate Br.