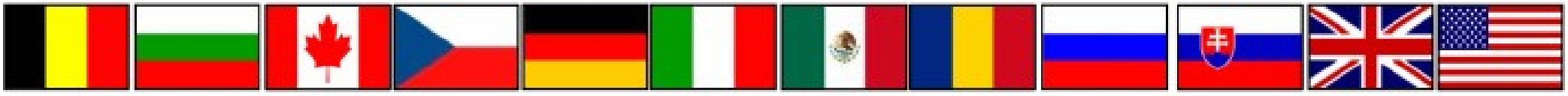
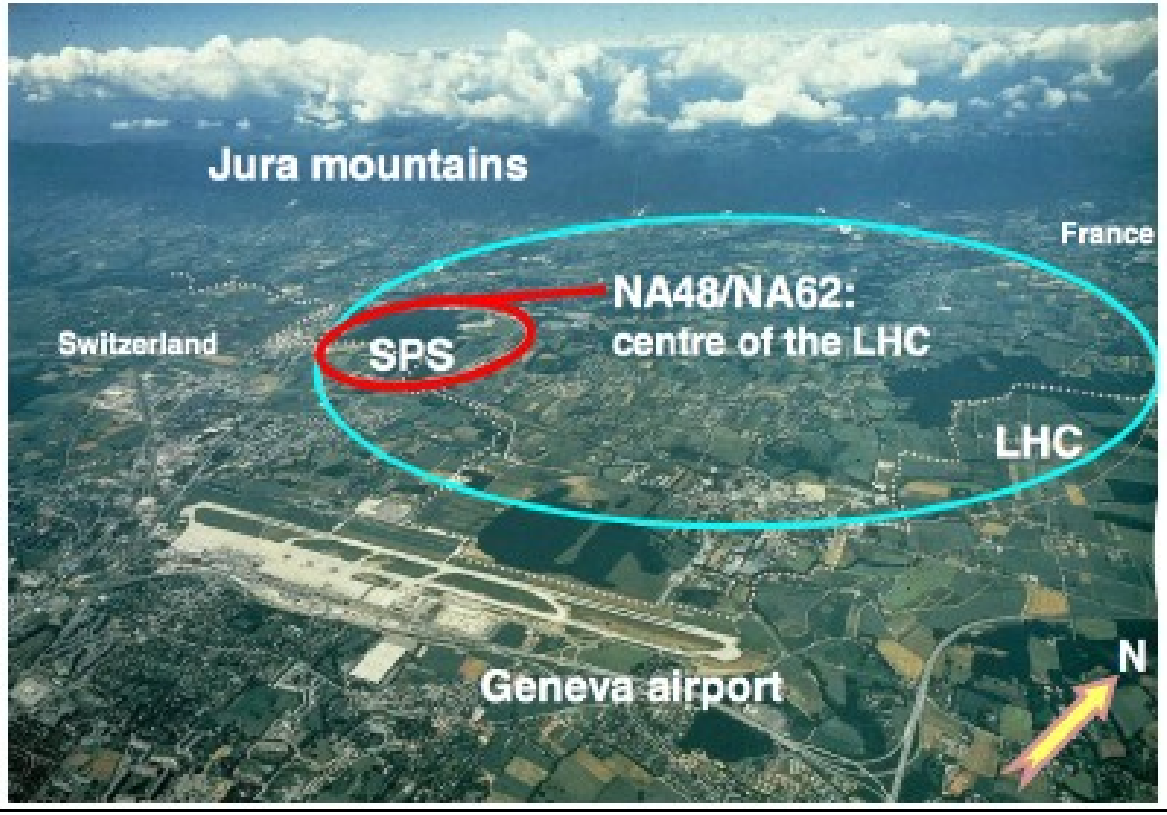
Analysis of the rare decay $K \to \mu \nu \mu \mu$

Aigul Baeva
JINR Dubna

NA62 experiment at CERN



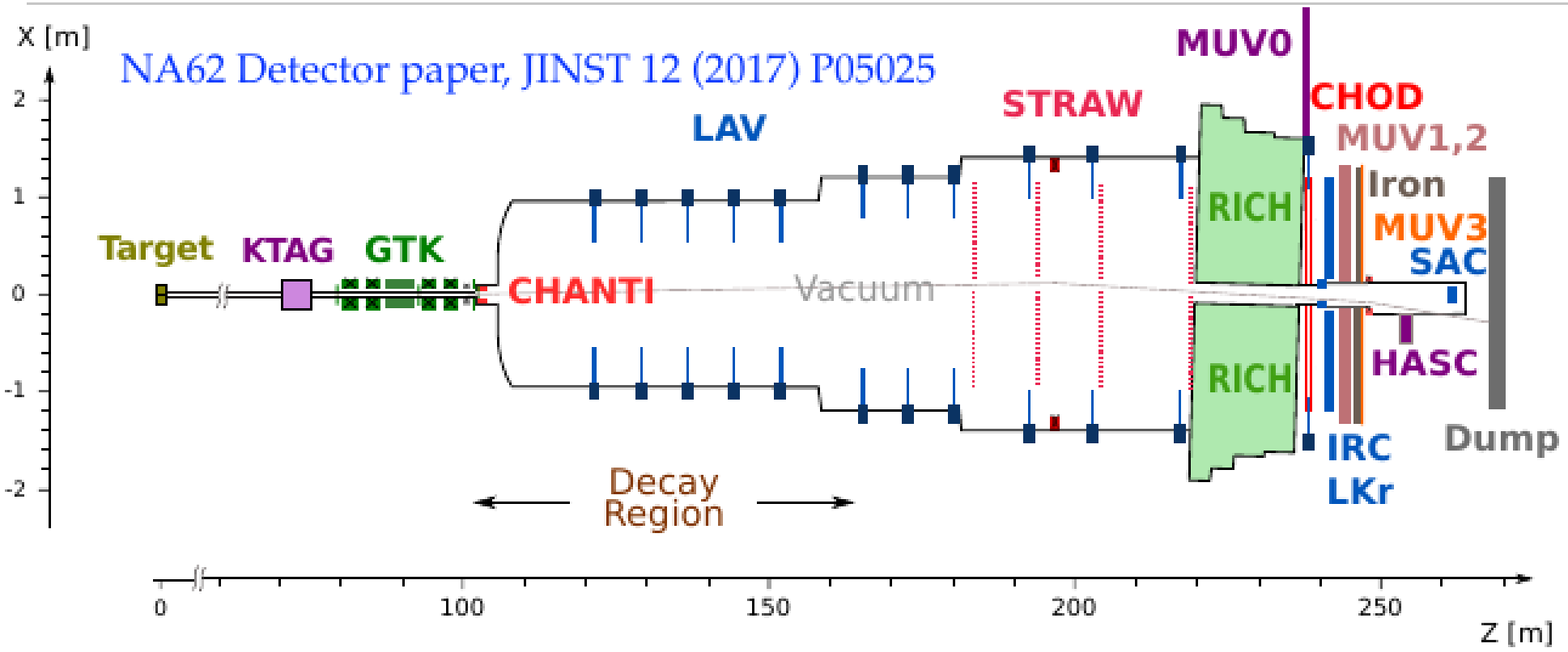
~30 institutes, ~200 participants form: Birmingham, Bratislava, Bristol, Bucharest, CERN, Dubna, Fairfax, Ferrara, Firenze, Frascati, Glasgow, Liverpool, Louvain, Mainz, Merced, Moscow, Napoli, Perugia, Pisa, Prague, Protvino, Roma I, Roma II, San Luis Potosi, Sofia, Torino, TRIUMF, Vancouver UBC



NA62 experiment is located at north area(NA) of CERN. Protons are extracted from the SPS with p=400 GeV/c producing a secondary beam of hadrons (~6% are kaons). Kaon decay-in-flight technique.

Main goal is to measure the $K^+ \to \pi^+ \nu\nu$ branching fraction with high precision

The NA62 detector



- Kaon ID and direction (KTAG, GTK, CHANTI)
- Pion ID and direction (STRAW, CHOD, RICH)
- Photon veto (LAV, LKr, IRC, SAC)
- Muon veto (MUV1,2,3)

Secondary beam

- Momentum 75 GeV/c
- Composition: K^+(6%), π^+(70%), p(24%)

Data collection

2014	2015	2016	2017	2018	2019-2020
Pilot Run	Commissioning	Commissioning + Physics Run	Physics Run	Physics Run	LS2 Long shutdown 2

2016: 40% of nominal intensity, ~5×10^{11} kaon decays recorded

2017+2018: 60% of nominal intensity, > 8×10^{12} kaon decays on the tape

— better data quality assessment

— higher data taking efficiency

Trigger streams:

- $\pi\nu\nu$ trigger: 1 track, γ / μ veto
- Control trigger: samples for normalization, background estimation

$K \to \mu \nu \mu \mu$

The collected statistics allows to analyse other rare decays, in particular, $K \to \mu \nu \mu \mu$. Rare decays make it possible to experimentally investigate one of the aspects of the Standard Model, the chiral perturbative theory (ChPT).

I'd like to present the first results of $K \to \mu \nu \mu \mu$ signal selection

- Theory Br($K \to \mu \nu \mu \mu$) = $1.35 \cdot 10^{-8}$
- $K \to \mu \nu \mu \mu$ was not experimentally observed
- There is only an upper limit Br($K \to \mu \nu \mu \mu$) < $4.1 \cdot 10^{-7}$ CL 90%

Backgrounds:

- $\pi \to \mu \nu$
- $K \to \pi \pi \pi$
- $K \to \pi \pi \mu \nu$
- $K \to \pi \mu \mu$

- Signal $K \to \mu \nu \mu \mu$ (mask 6) L0: (RICH x Q_x x MO2);
- Data: 2017A sample (8134-8198)
- Dimuon three track vertex - “2MU3TV” filter

- MC: $K \to \mu \nu \mu \mu$: v0.11.3

Track

- In STRAW, RICH, Lkr, MUV3 acceptance

Straw Track:

- $3\,GeV \le P_{STRAW}\,track \le 50\,GeV$
- $\left|Time_{RICH} - Time_{NewCHOD}\right| < 3\,ns$

RICH ID for positive particles

- d(e) < 0.9
- d(μ) < 0.9
- d(π) < 0.9

where

- d(e) = 1- L(e) + L(μ) + L(π),
- d(μ) = 1- L(μ) + L(e) + L(π),
- d(π) = 1- L(π) + L(μ) + L(e),

where **L** is RICH Likelihood

GTK Track

- NCedarCandidate > 0
- N_{CEDAR}sectors >= 4
- $|Time_{GTK} - Time_{CEDAR}| < 3$ ns

Electron Particle ID: EoPtotalForFilter > 0.8 and
RICH ID as e and
0.9 < EoP < 1.2
DDeadCell > 20 mm

Muon Particle ID: not an electron
Requare association with MUV3 (within 5 ns)
RICH ID as μ and
No association with LKr or
ELKr < 1.5 GeV

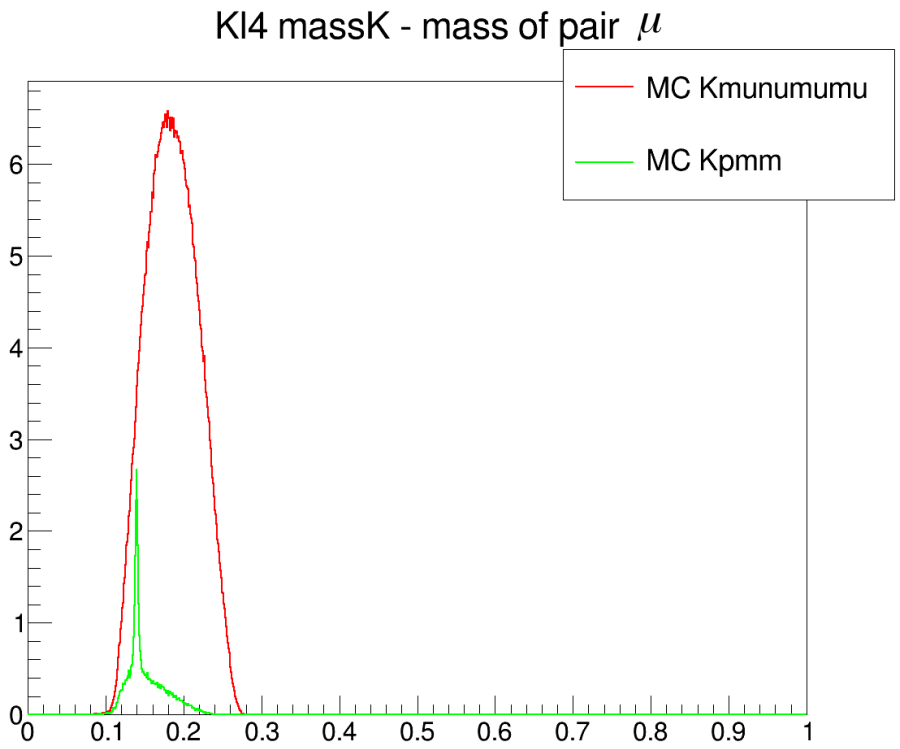
Pion Particle ID: not an electron and not a muon
RICH ID as π

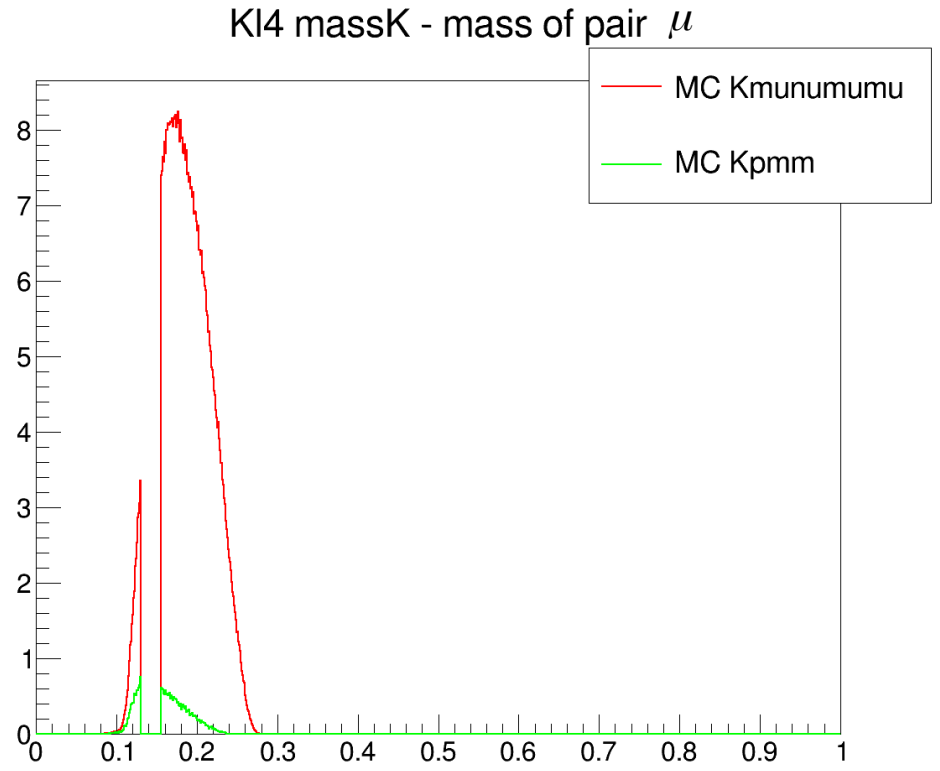
Vertex Selection

- Three-track vertex >= 1;
- 3 identified muons;
- $q_{3tr\_vtx} = +1$;
- $\chi^2_{3tr\_vtx} <= 40$;
- $102\ m <= Z_{vtx} <= 180\ m$;
- $P_{vtx} < 90\ GeV$;
- VertexTime: average of 3 tracks NewCHOD times;
- |VertexTime - GTKtime| < 2 ns ;
- Distance beetween GTK track and vertex in the vertex plane < 100 mm (initial relaxed cut)

Final cuts

Cut for $\pi\mu\mu$ background





$$P_\pi = P_K - P_\mu - P_\mu$$

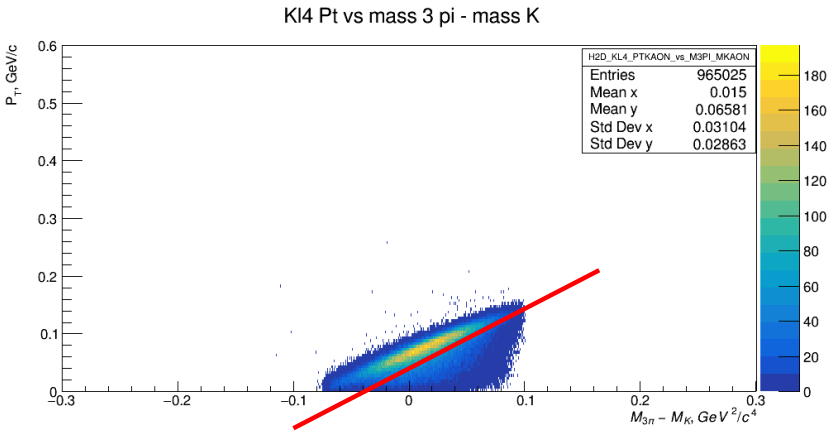
Cut $0.13 < M_\pi < 0.155$

Cut for Km4

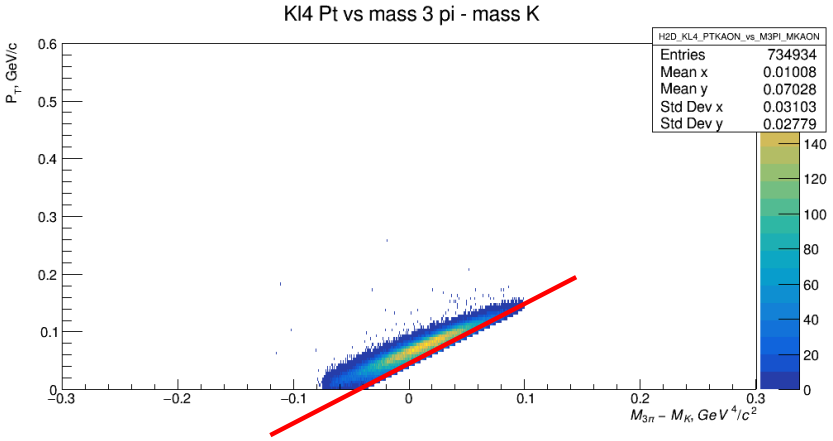
Mu mass is attributed to each track

$K \to \mu \nu \mu \mu$

before cut

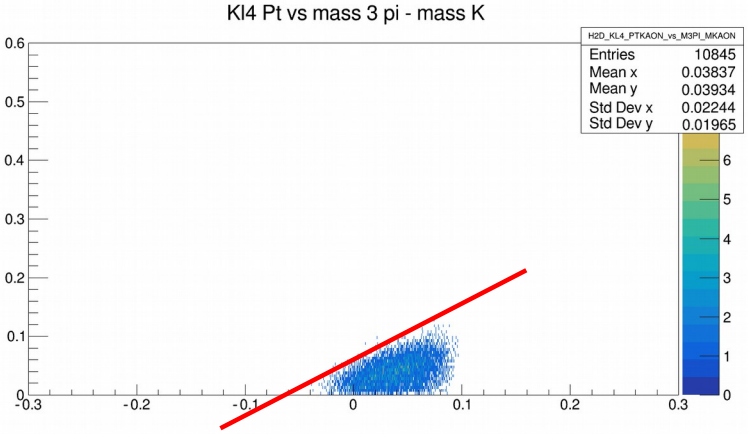


after cut

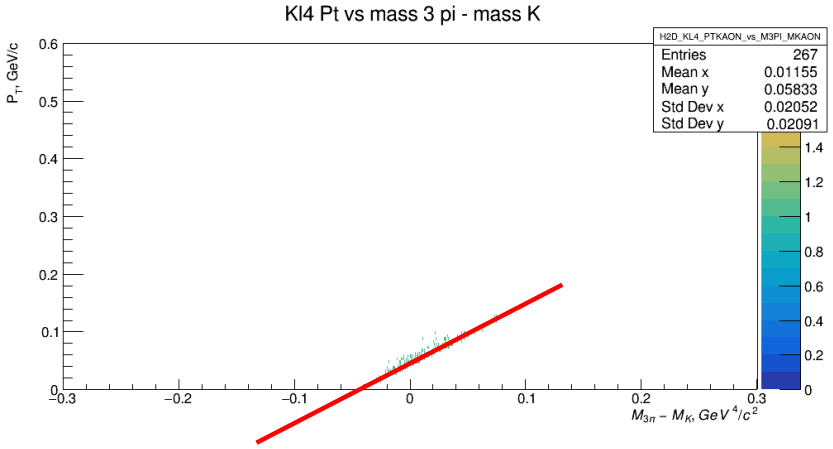


$Km4$

before cut

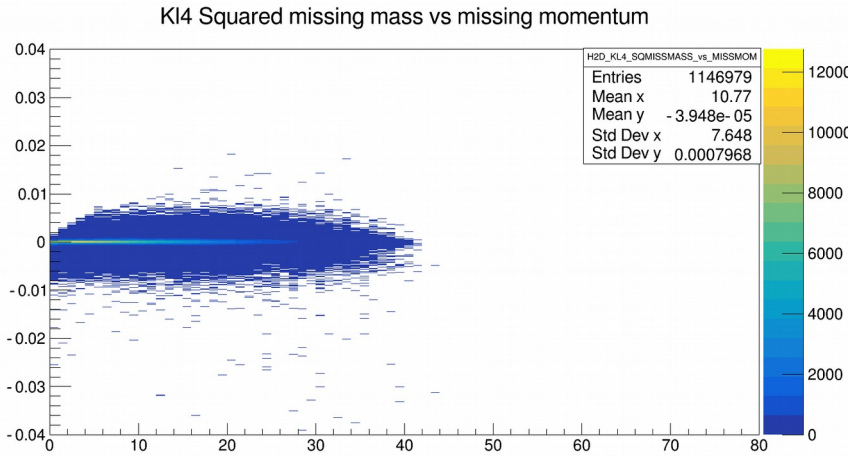


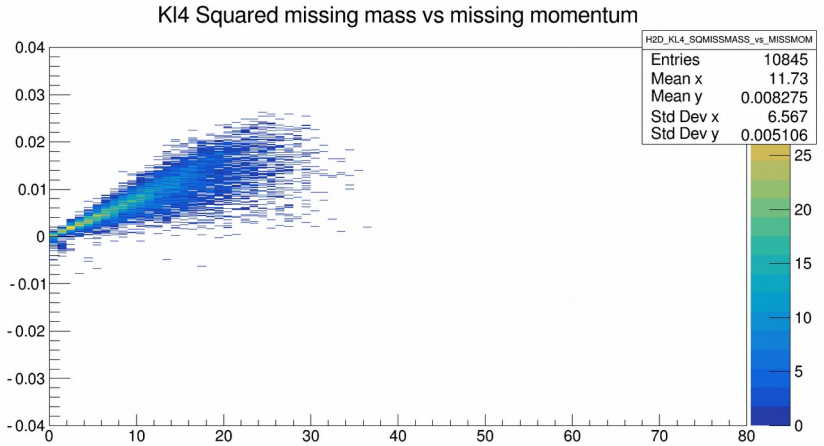
after cut



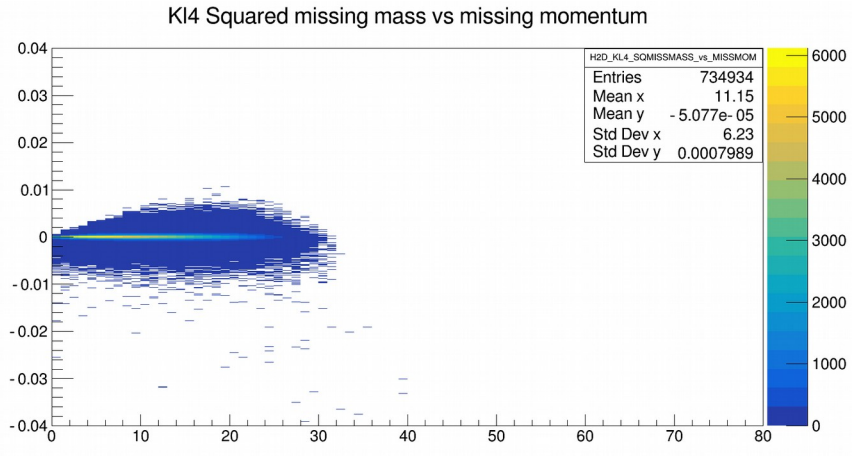
Squared Missing Mass vs Missing Momentum

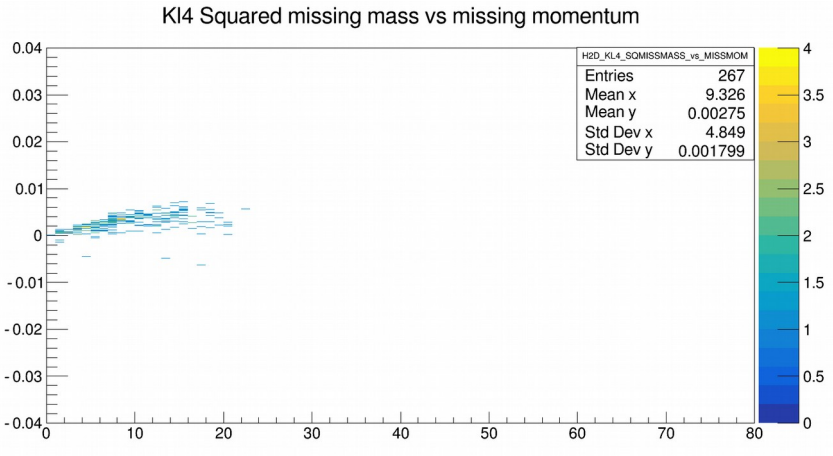
Squared missing mass





After two final cuts

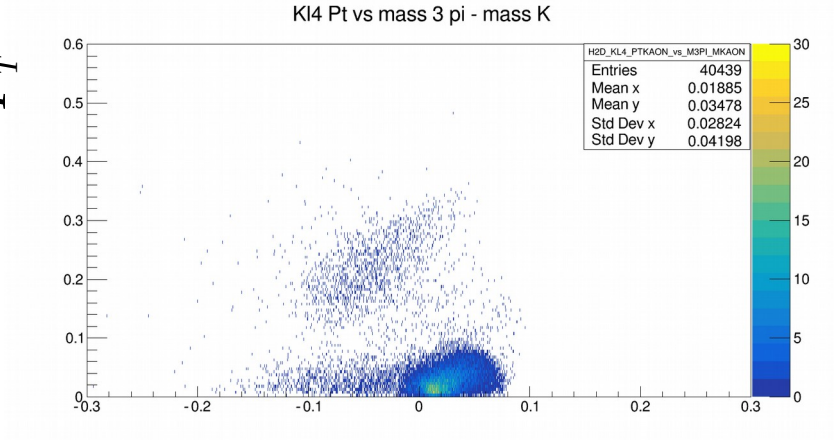




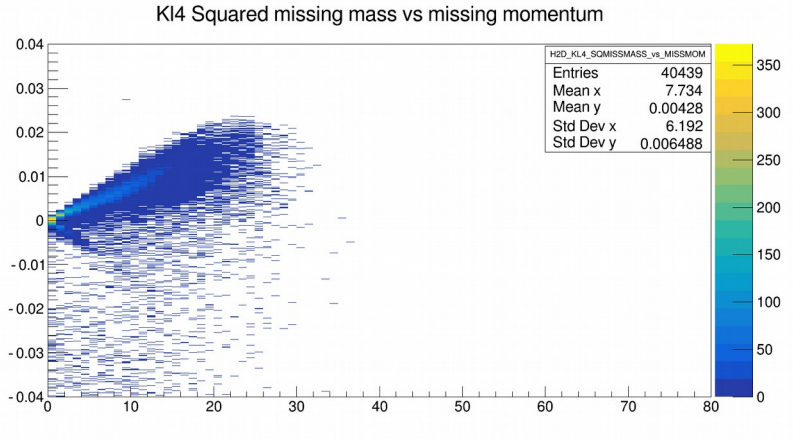
Missing momentum

Data

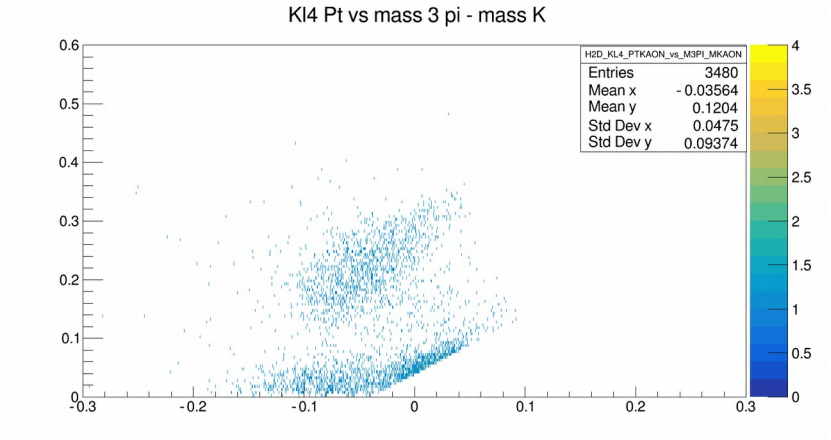
P_T



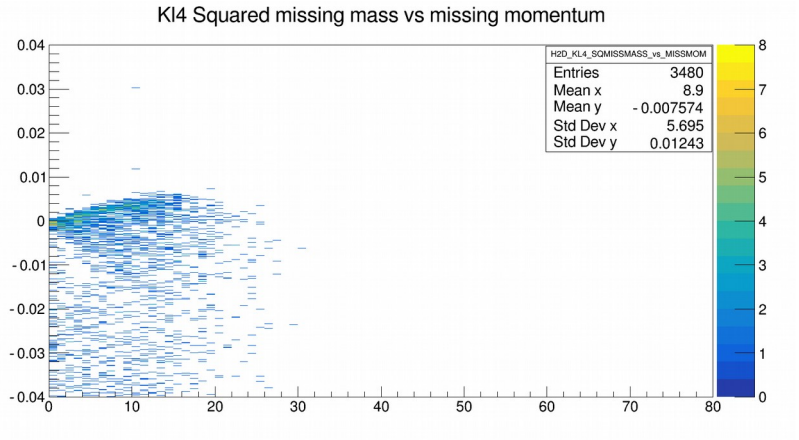
Squared missing mass



After cuts

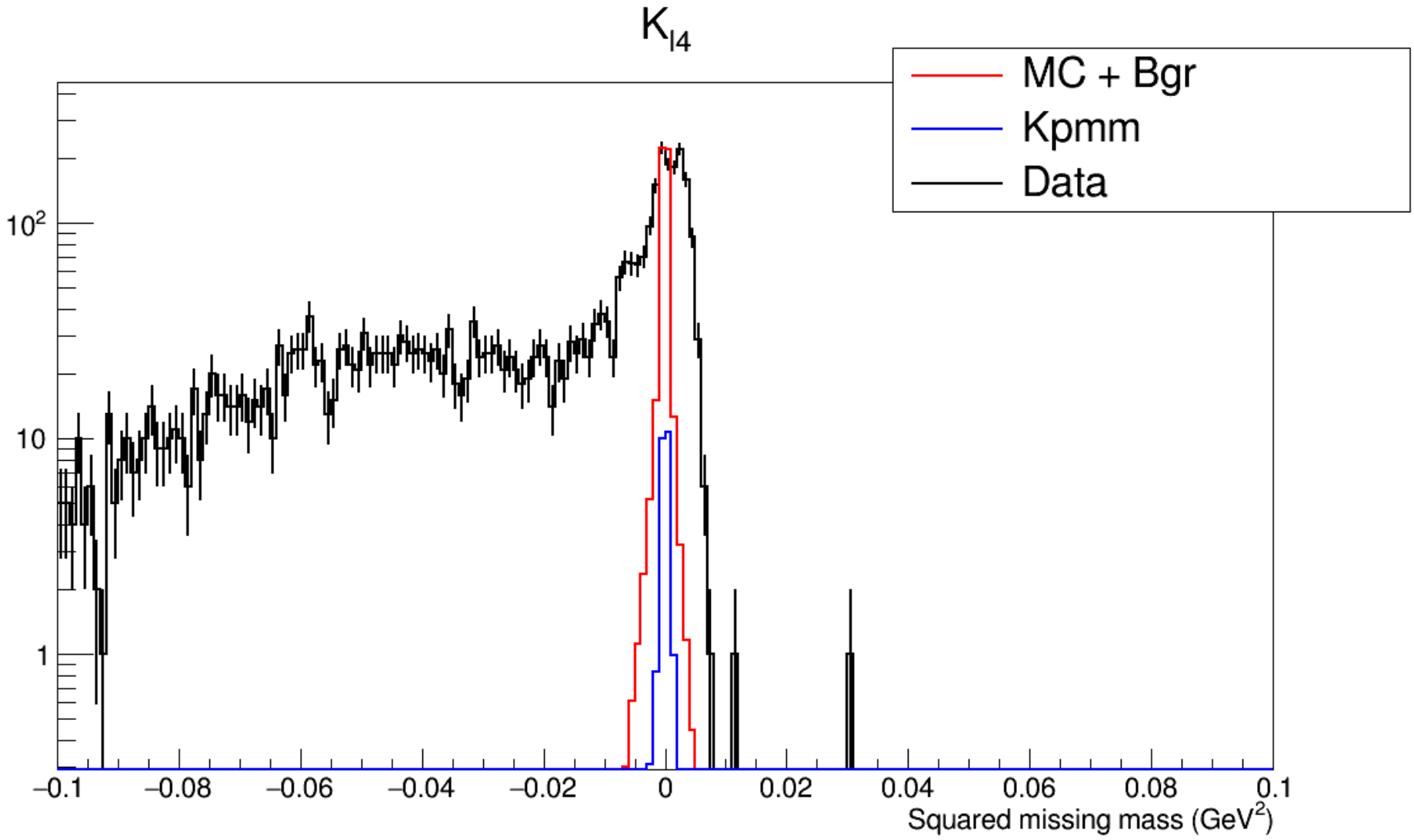


$M_{3\pi} - M_K$



Missing momentum

Squared Missing Mass of $K \rightarrow \mu \nu \mu \mu$



Conclusions

- Signal selection seems to work.
- Signal is visible.

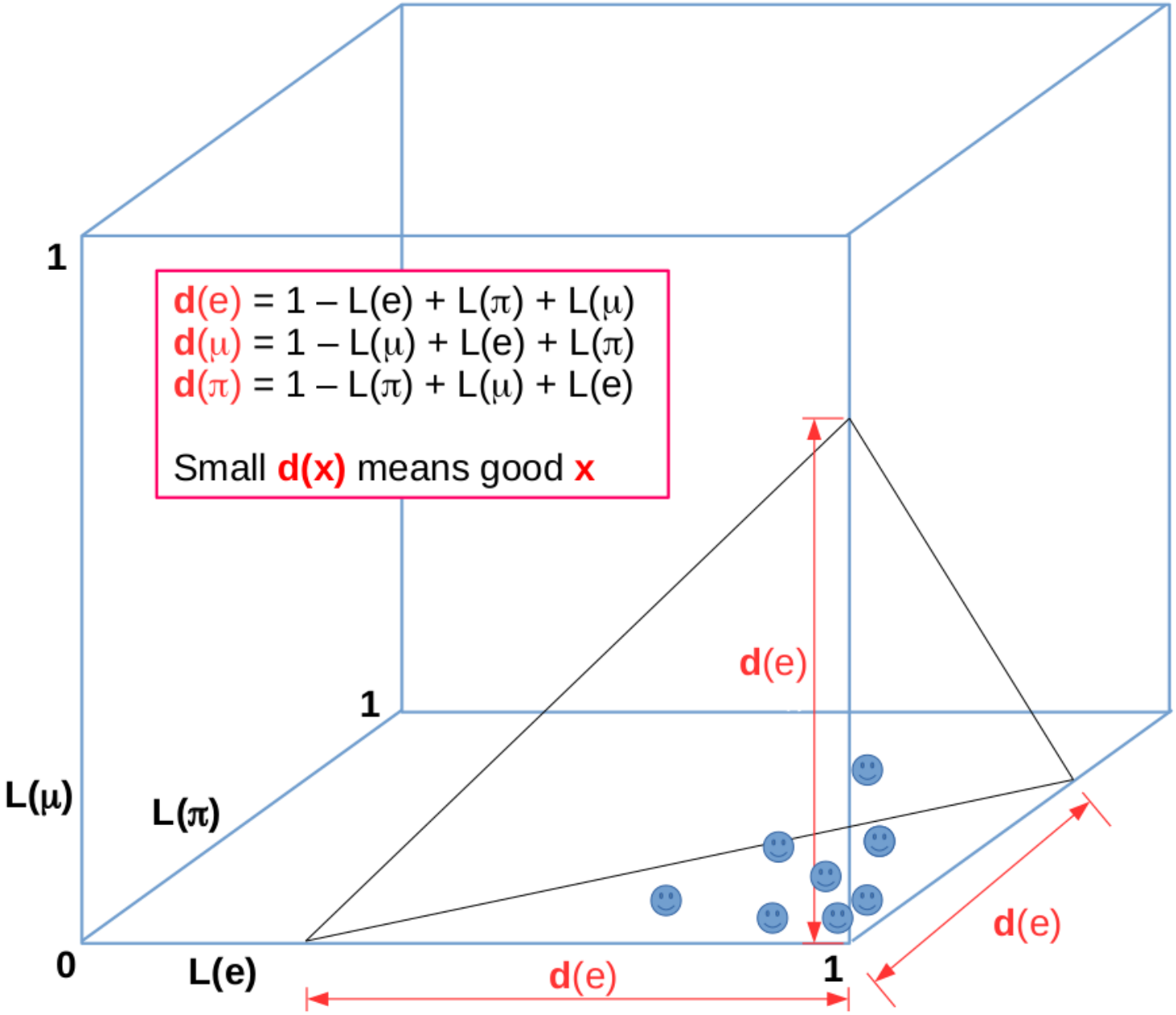
To do

- To use fastMC for describing background from K3π
- Normalization channel
- Other background channels

Backup

RICH linear discriminant **d**

L is RICH Likelihood



Unlike the L-ratio criteria, **d** also suppress the low-likelihood area, that is also uncertain for RICH.

One could invent some “radius” of ellipse, but 3D points here are not distributred elliptically.

So linear discriminant is just the simplest one.

Cuts on **d**(e), **d**(μ), **d**(π) may be different in various analyses.

Soft cut : **d** < 0.9 just exclude other corners