Going to Stockholm?

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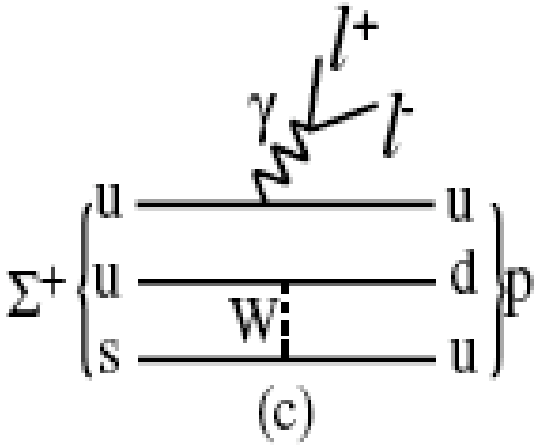
KTeV Collaboration Meeting
10 Sept 2005

Original sighting

In early 2005 (FNAL Wine & Cheese, 21 Jan 2005; PRL **94**, 021801, the same date) the *HyperCP* collaboration announced the observation of $\Sigma^+ \to p\mu^+\mu^-$ with three unusual events.

The process normally proceeds through an off-shell γ, and the dimuon system does not have a mass resonance.



However, all 3 of the *HyperCP* events had the same (214.3MeV) mass, to within the experimental resolution of ~0.5MeV; unlikely at the 0.8% C.L.

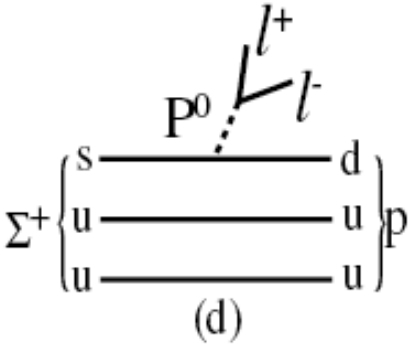
Using acceptance for S.M. diagrams and form factors consistent with limits on $Br(\Sigma^+ \to pe^+e^-)$, the observed $Br(\Sigma^+ \to p\mu^+\mu^-)$ was higher than expectation at about the 1σ level.

Original sighting

The *HyperCP* collaboration suggested that there could be a new physics contribution to $\Sigma^+ \to p\mu^+\mu^-$.

The acceptance seems quite different than for the γ^* process - they write

$$Br\left(\Sigma^+ \to pP^0, P^0 \to \mu^+\mu^-\right) = \left[3.1^{+2.4}_{-1.9} \pm 1.5\right] \times 10^{-8}$$



Recall also that NuTeV found 3 anomalous dimuon events albeit with transverse mass over 2.2GeV

This quark but not lepton flavor changing neutral current corresponds to a partial width of

$$\Gamma\left(\Sigma^+ \to pP^0, P^0 \to \mu^+\mu^-\right) = 2.5 \times 10^{-19}\ MeV$$

Counting quanta

- For on-shell pointlike P^0, the $\mu^+\mu^-$ pair must materialize with no orbital angular momentum; then (as fermion and antifermion have opposite parities) this new boson must have $J^{(P)}$ of either $0^{(-)}$ or $1^{(-)}$
- For the vector boson case, the new particle should appear in the $0^{(-)} \rightarrow 0^{(-)} \oplus 1^{(-)} \oplus 1^{(+)}$ process $K_L \rightarrow \pi^0 P^0$, followed by $P^0 \rightarrow \mu^+\mu^-$; in other words, the $J^{(P)} = 1^{(-)}$ case means that the new particle should contribute to $K_L \rightarrow \pi^0\mu^+\mu^-$
- The existing KTeV limit, $Br(K_L \rightarrow \pi^0\mu^+\mu^-) < 3.8 \times 10^{-10}$ corresponds to a partial width of 4.8×10^{-24} MeV. That is almost 5 orders of magnitude below the *HyperCP* result
- For the pseudoscalar case, the new particle should appear in the $0^{(-)} \rightarrow 0^{(-)} \oplus 0^{(-)} \oplus 0^{(-)}$ process $K_L \rightarrow \pi^0\pi^0 P^0$, followed by $P^0 \rightarrow \mu^+\mu^-$; in other words, the new particle should contribute to $K_L \rightarrow \pi^0\pi^0\mu^+\mu^-$ and also to $K_L \rightarrow \pi^+\pi^-\mu^+\mu^-$. I think it was Julie Whitmore who first pointed out that $\pi^0\pi^0\mu^+\mu^-$ was E-Z for KTeV.

Simulating the signal

I just analyzed the 1997 data in E799 trigger B05:
2V*DC12*2MU3*PHVBAR1*2HCY_LOOSE*HCC_GE1

For the MC, I modified the old kp0hdk deck, verifying first that I had a version with the fixed PIMUDK bug. It is a pair of two body zero spin decays, not really complicated

My accidental overlay files came from an old πee analysis - not quite right as that analysis requires TRDs to be working

I do not have a normalization analysis. I'll just take 2.68 x10^{11} K_L decays, from Sada's analysis

A few of my jobs died due to simple bugs; I decided to live with the loss of a few % of the dataset

No attempt to evaluate a systematic uncertainty on the acceptance has been made.

Looking for the signal

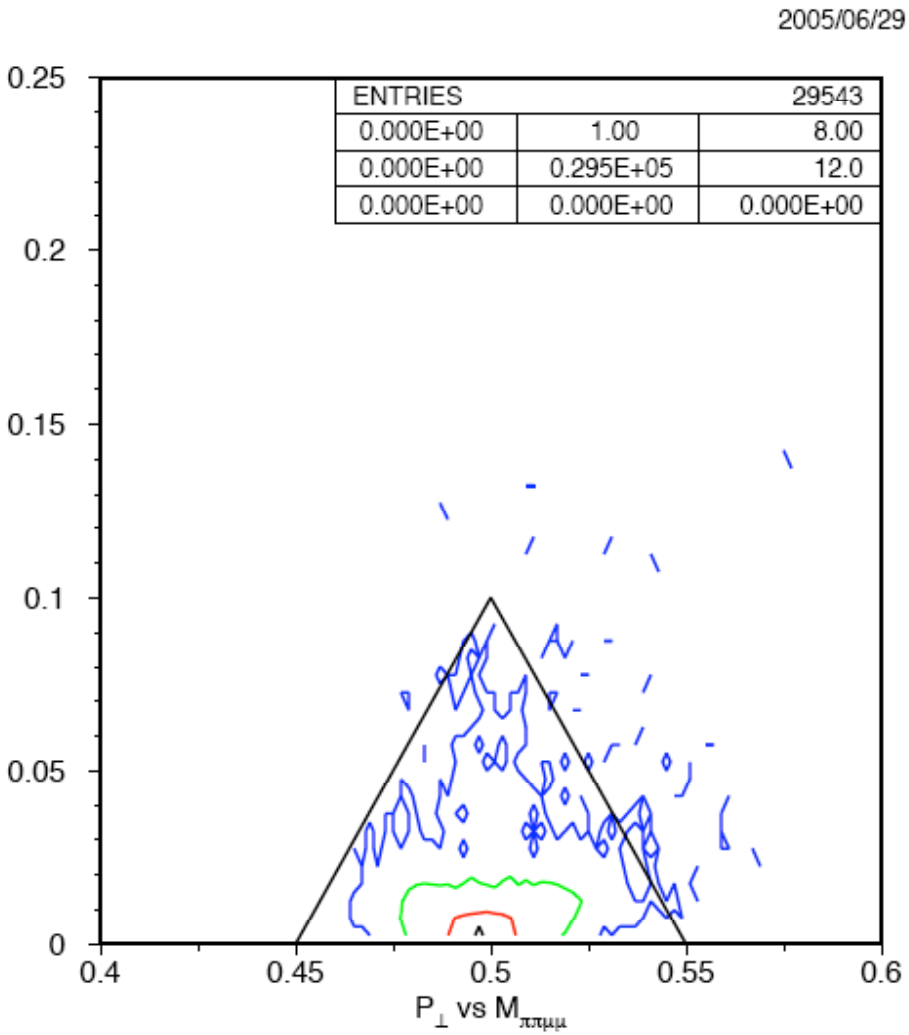
I took a lot of muon code from Julie - many thanks! The mod that mattered the most in the end was to change the thresholds in CSI799 so as to stifle false hard-clusters, that could look like muons in the early 1997 data

The results of Sada's ancient crunch were not usable; he had a P⊥ cut based on reconstructing $\pi^0\mu^+\mu^-$ exactly. So I ran off the split tapes to make my ntuple.

Ntuple cuts were straightforward:

Two vertexable tracks of 7GeV or more and associated hard or soft clusters below 2GeV, exactly 4 hardware clusters away from tracks, and these clusters should form a pair of π^0s that are within 15MeV of the nominal mass, using the charged vertex.

Defining the triangle

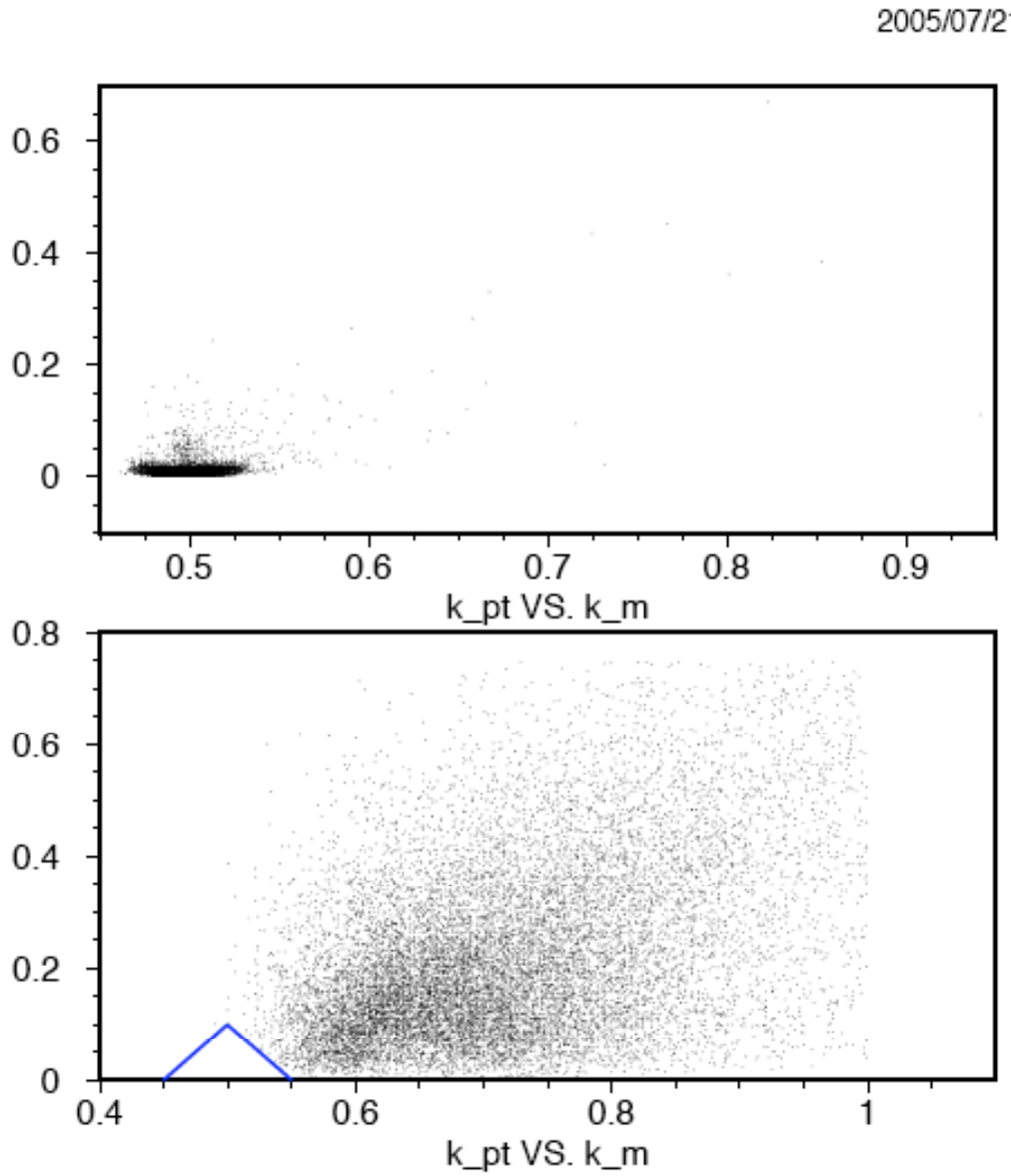


From the signal MC, a cut that is a bit more than 3σ of the signal

$$P_{\perp} < 0.1 - 2\,|M_{\pi\pi\mu\mu} - 0.5\text{GeV}|$$

Data outside this region constitutes my background sample

What is the background?

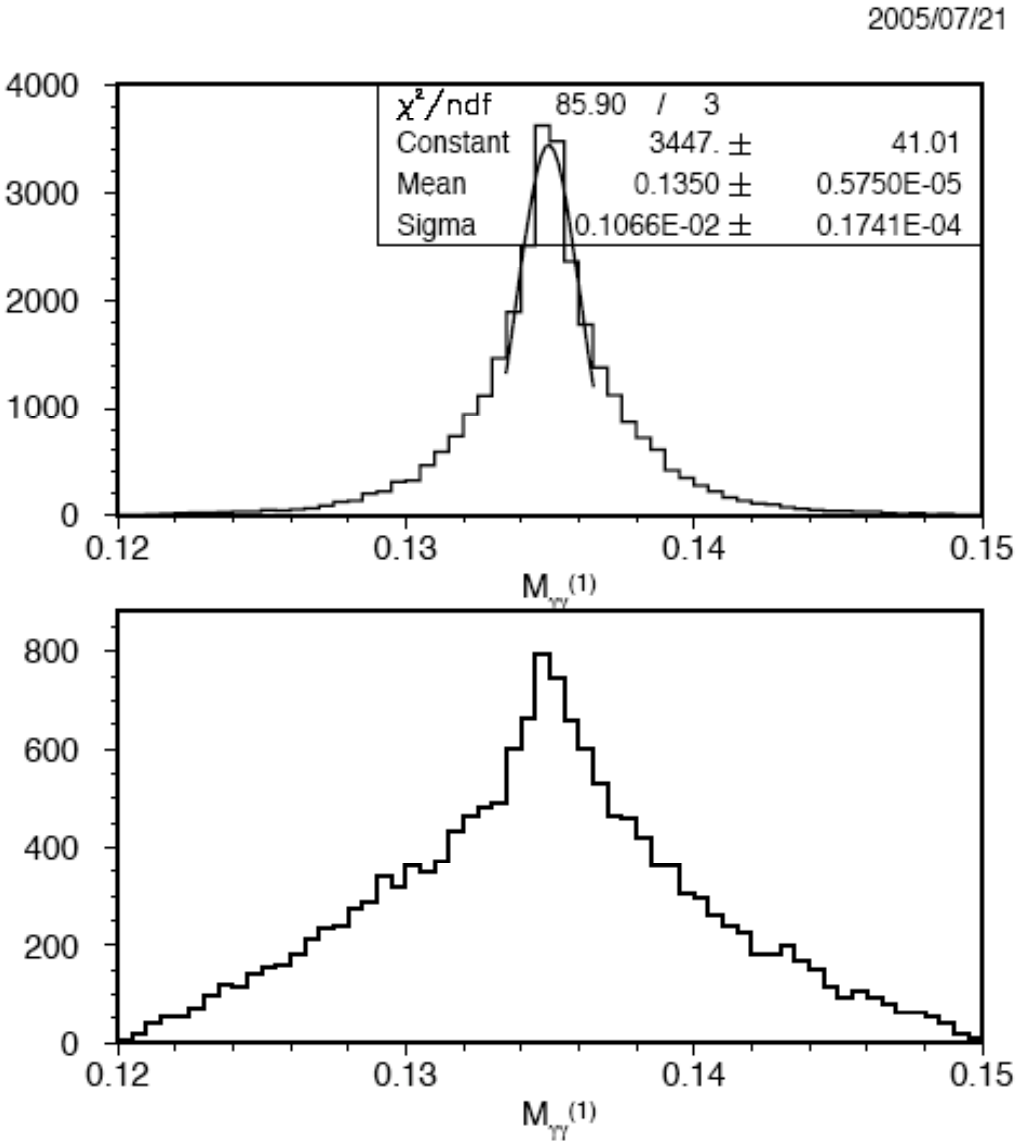


I don't know.

It obviously has a lot of accidental activity, and 2 muons, decays or punchthroughs. And a lot of missing $P\perp$

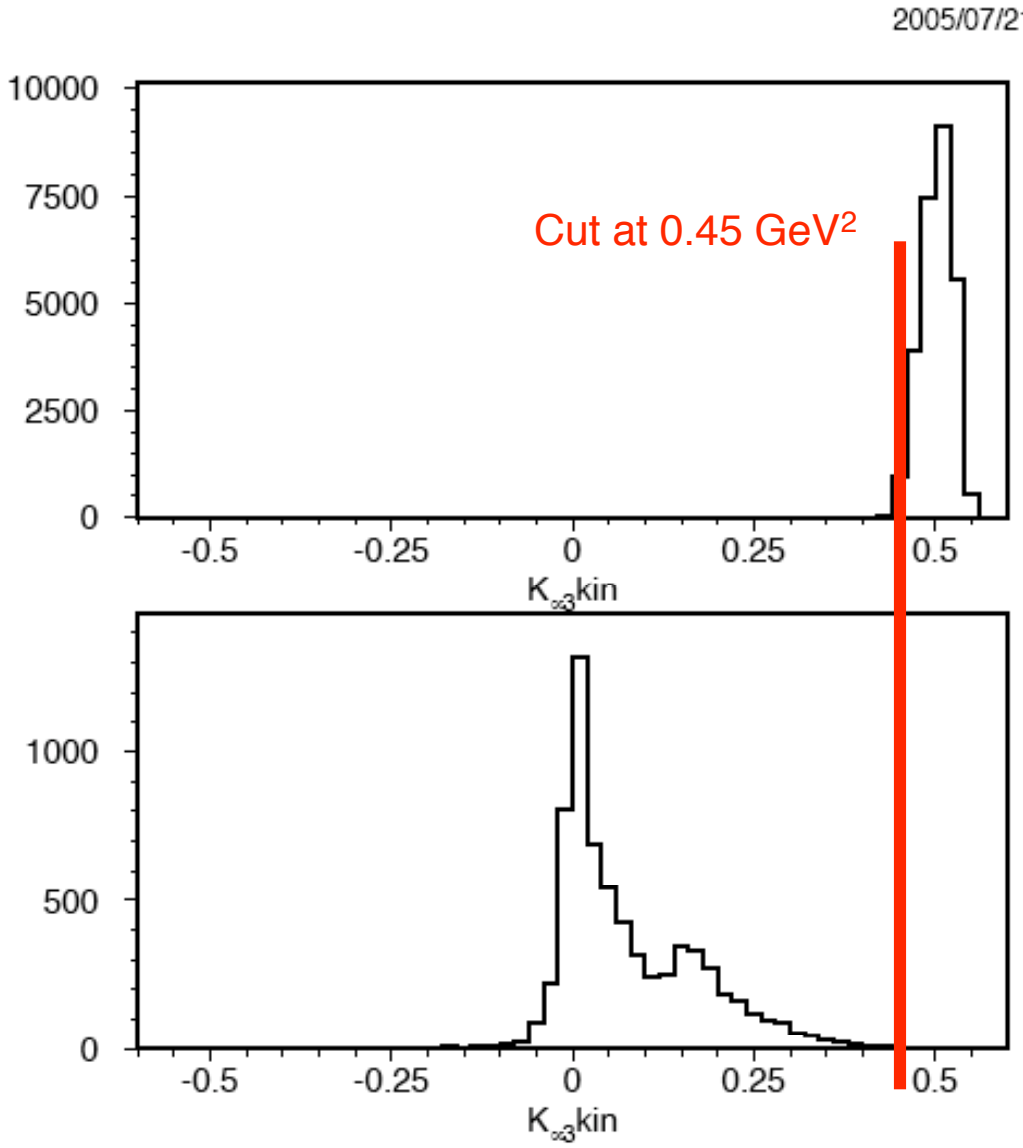
I'll guess it is pairs of overlapped $\pi^+\pi^-\pi^0$ with decays/PT & missing tracks

An incision here…



From the $M_{\gamma\gamma}$ distribution in the MC for the 1st π^0, that is the π^0 closest to 135MeV, I decided to cut at $|M_{\gamma\gamma}$-135MeV| < 9MeV for both reconstructed π^0 candidates.

An excursion there?

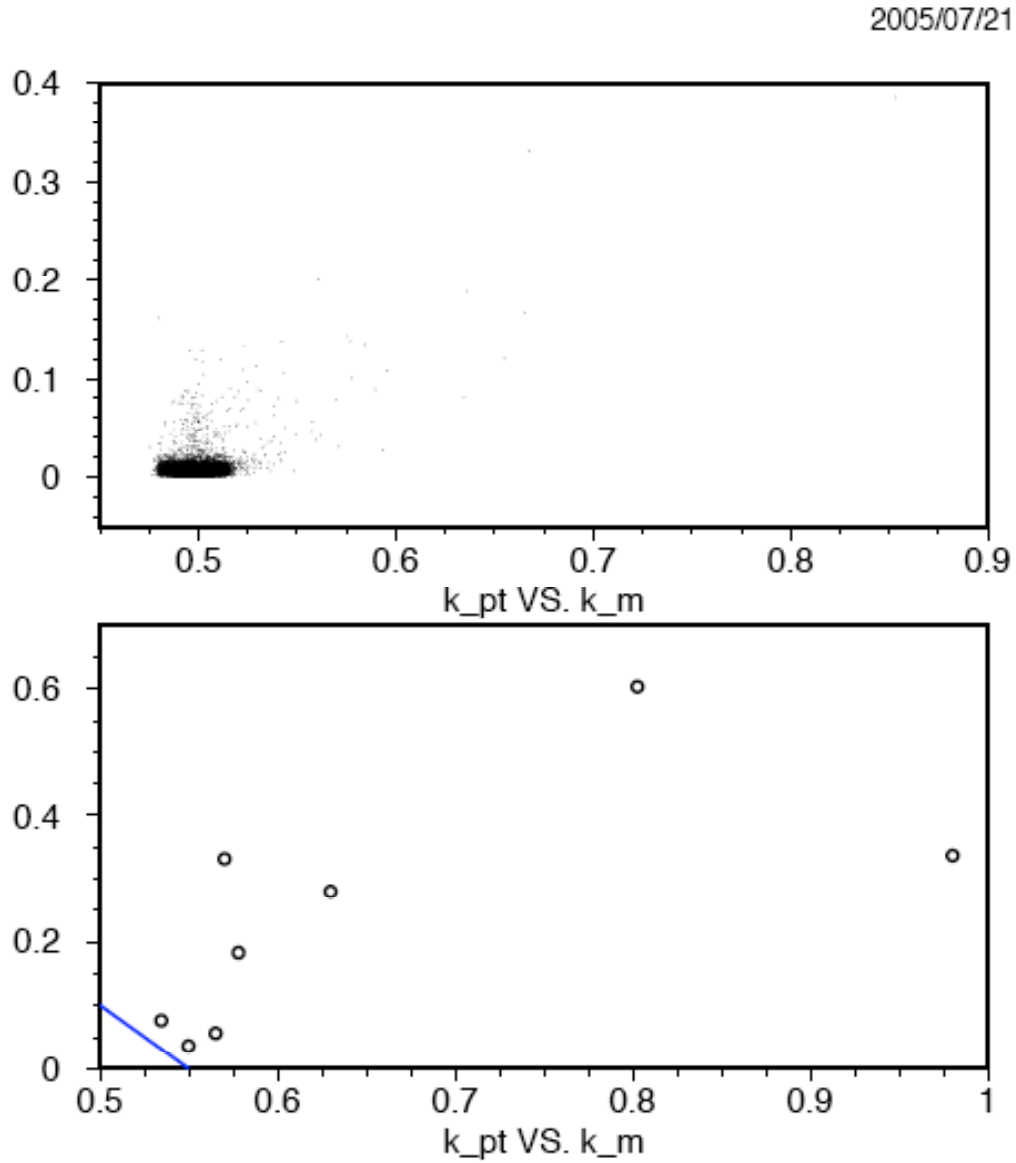


Thinking that there might be a lot of $K_{\mu 3}$ with accidental $K_L \rightarrow 2\pi^0 X$ background, I looked at `KM3KIN`, defined as

$$\frac{\left(M_K^2 - M_{\pi\mu}^2\right)^2 - 4 M_K^2 P_\perp^2}{P_\perp^2 + M_{\pi\mu}^2}$$

This is the square of the longitudinal momentum of the neutrino, under the hypothesis that the charged particles are from $K_{\mu 3}$, in the frame where $P_{//}$ of the charged particles is zero

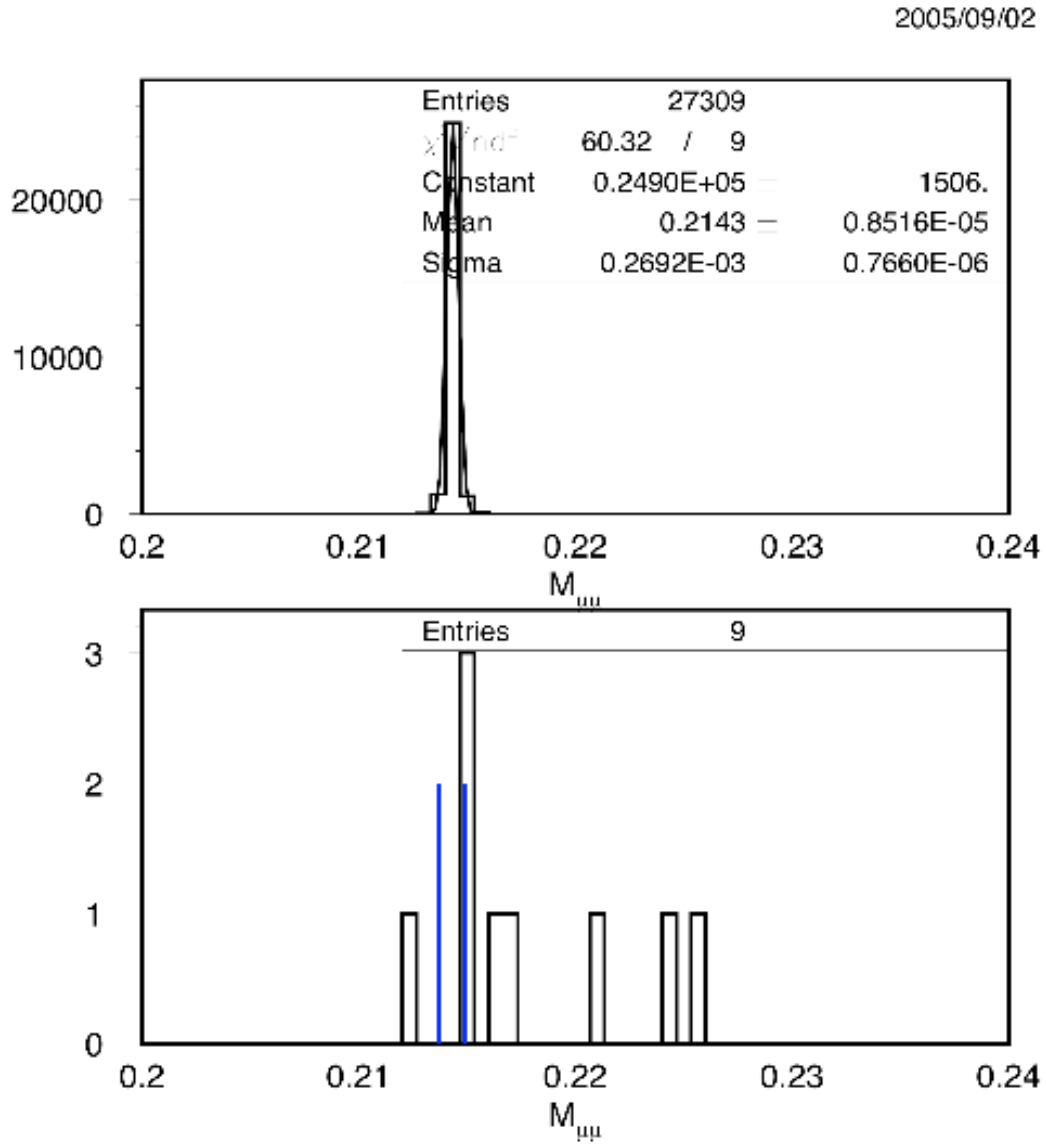
Not much left!



Actually, there are 9 background events left at this point.

I don't have a model of the shape of the background at this point in the ($M_{\pi\pi\mu\mu}$,$P_{\perp}$) plane - in such a case though it is not unreasonable to set it (conservatively) to zero.

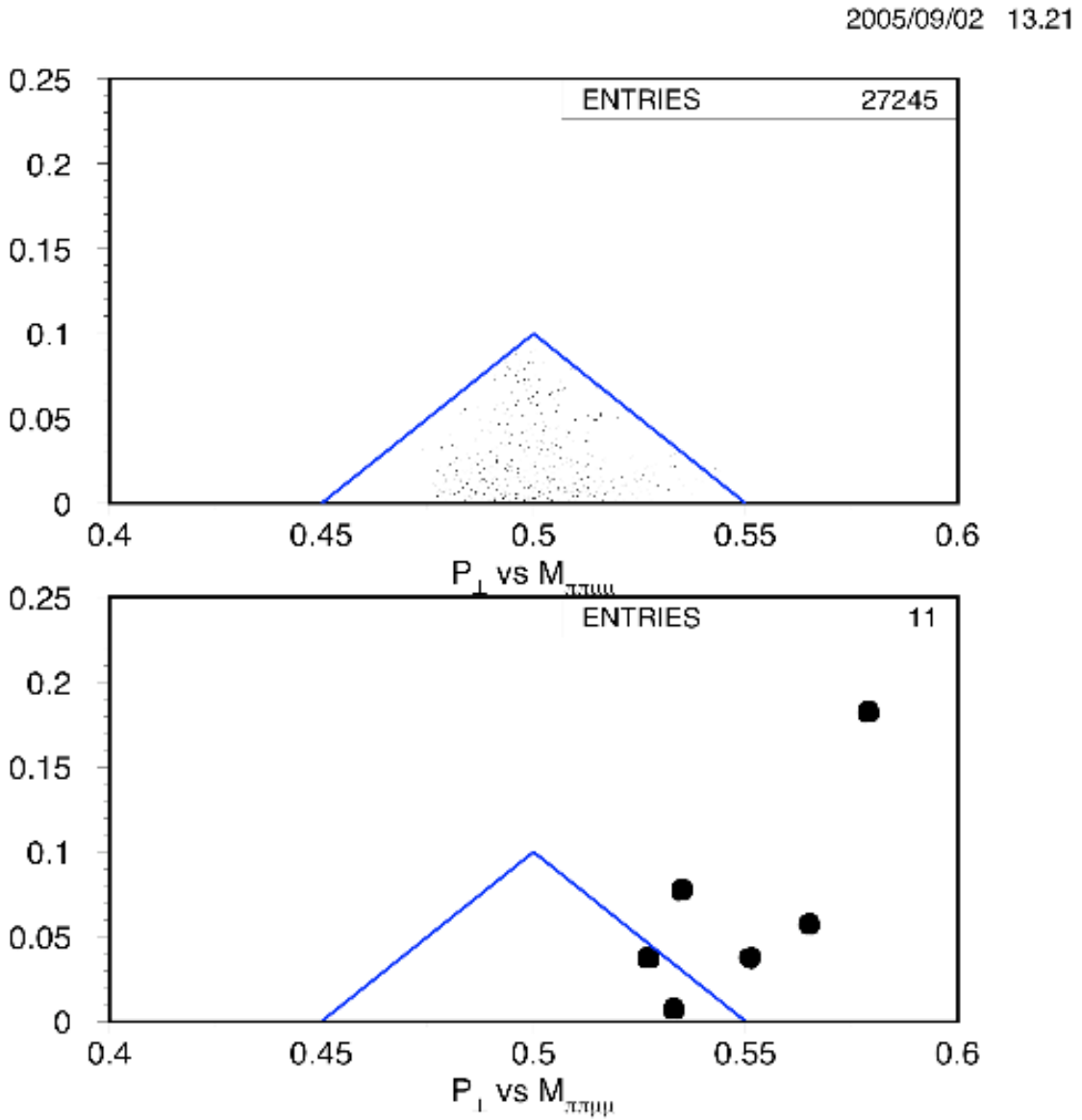
The dimuon mass spectrum



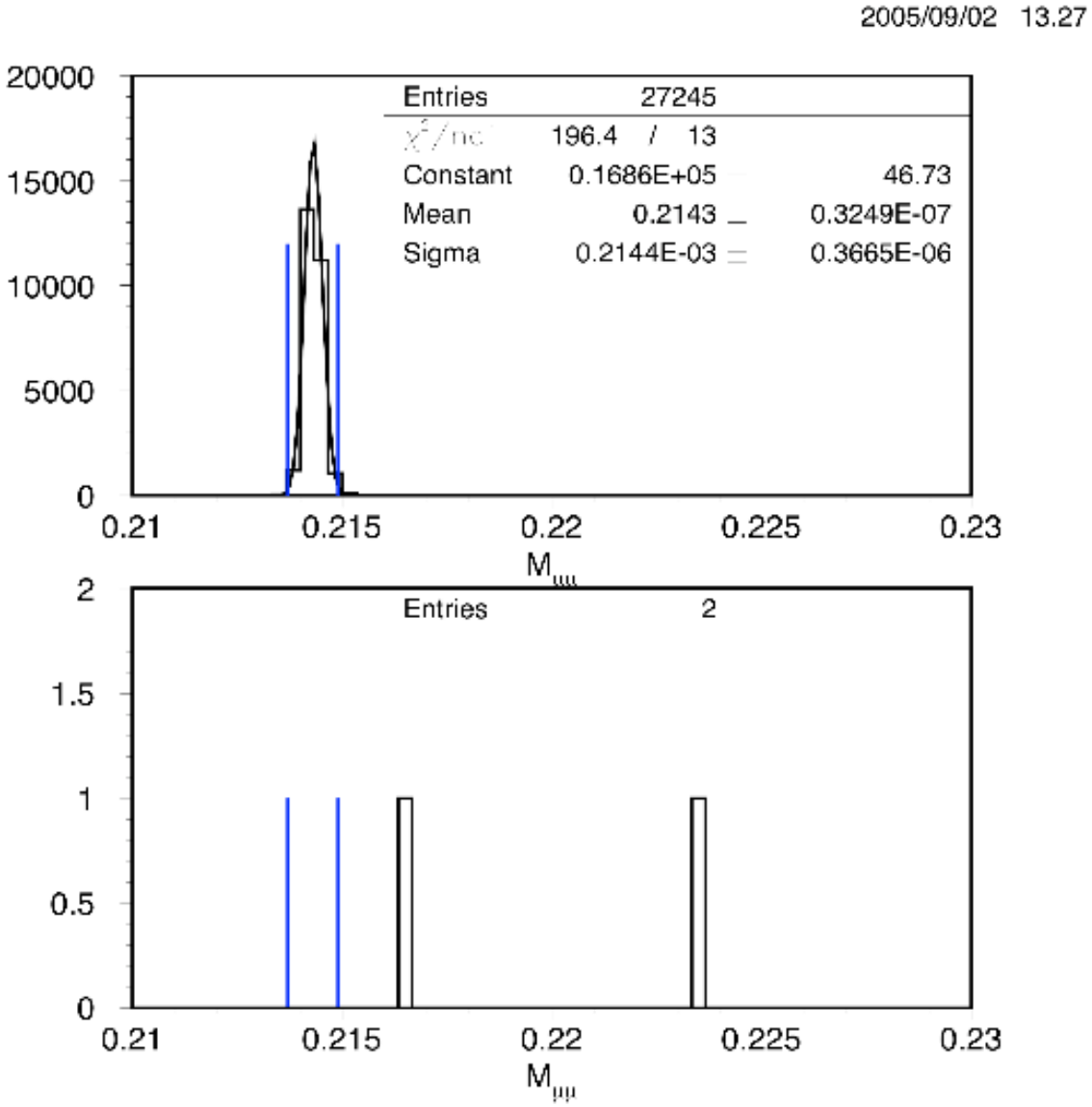
I decided to cut at ±0.6MeV, which is about ±3σ of the M.C. width before the KM3KINE cut.

Acceptance is about 2.73%, corresponding to a single event sensitivity of 1.4 x10^{-10} in branching ratio, or 1.8 x10^{-24}MeV in Γ. Compare that to the 2.5 x10^{-19}MeV level that is interesting, and realize that if the *HyperCP* result is right, there is a mountain in the triangle.

oh


2005/09/02 13.21
ENTRIES 27245
0.25
0.2
0.15
0.1
0.05
0
0.4
0.45
0.5
0.55
0.6
P⊥ vs Mππμμ
ENTRIES 11
P⊥ vs Mππμμ

well


2005/09/02 13.27
Entries 27245
χ²/nd 196.4 / 13
Constant 0.1686E+05 46.73
Mean 0.2143 0.3249E-07
Sigma 0.2144E-03 0.3665E-06
20000
15000
10000
5000
0
0.21
0.215
0.22
0.225
0.23
M_μμ
Entries 2
2
1.5
1
0.5
0
0.21
0.215
0.22
0.225
0.23
M_μμ

Therefore,

With no background and the estimated acceptance, the signal is less than 2.3 events, so at the 90% C.L., the partial width for a new pseudoscalar quark but not lepton flavor changing boson is less than 4.0 x10^{-24} MeV, which is almost 5 orders of magnitude below the *HyperCP* suggestion.

If the new boson has a spatial extent (the widths are too small for it be a strong interaction system probably) then there can be a unit of orbital momentum in the $\mu^+\mu^-$ system; the outgoing states could be $J^{(P)}$ = $0^{(+)}$, $1^{(+)}$ and $2^{(+)}$. All 3 should occur; however the $0^{(+)}$ and $2^{(+)}$ cases should appear in $K_L \rightarrow \pi^0\mu^+\mu^-$ (but do not) and the $1^{(+)}$ cases should contribute to $K_L \rightarrow \pi^0\pi^0\mu^+\mu^-$ (but does not).

Going to Stockholm…

…maybe next year.

NOW what?

If I were my advisor, and this were my thesis, I wouldn't sign it.

Lack of time has prevented:

1. Characterization of the background composition
2. Measurement of background level
3. Removal of errors in signal acceptance calculation
4. Introduction of uncertainties to acceptance calculation

Not withstanding, it is a result of some interest. I won't be able myself to spiff it up, but we probably should make some kind of public statement. In it's present state, I don't know that it really can or should be sent off to PRL. Unless there is a student interested in doing a better job, I'd propose to make a preliminary result at some conference that will publish citeable proceedings, put the proceedings preprint on the LANL/SPIRES archive and let it go at that.