Z' search at Belle @ 2017秋季日本物理学会

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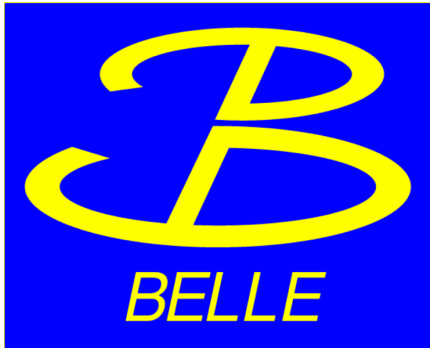
September 12^{th}, 2017



Outline

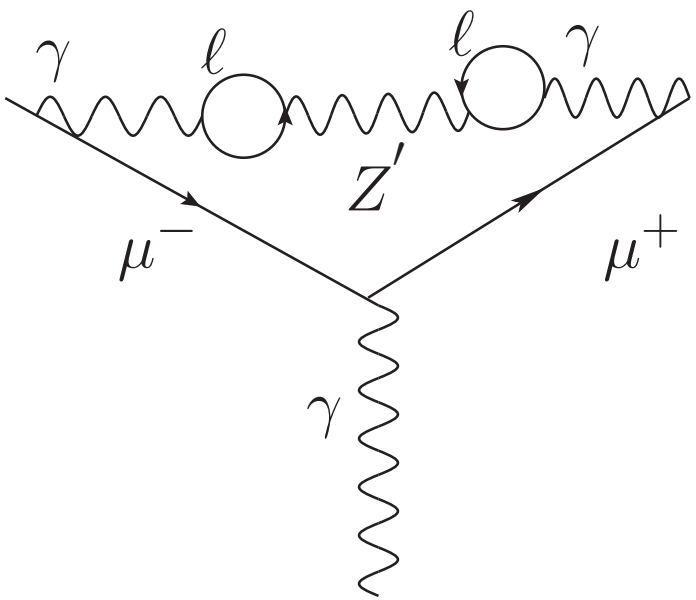
Muonic Dark Photon

Assuming MSM (Minimal SM) with the $L_\mu - L_\tau$ model

Xiao-Gang He, G. C. Joshi, H. Lew, and R. R. Volkas Phys.Rev.D 44, 2118 – Published 1 October 1991

$$\mathcal{L}_{Z_1'} = g_1' Z_1'^{\mu}(\bar{e}\gamma_\mu e - \bar{\mu}\gamma_\mu \mu) \quad \mathcal{L}_{Z_2'} = g_2' Z_2'^{\mu}(\bar{e}\gamma_\mu e - \bar{\tau}\gamma_\mu \tau)$$

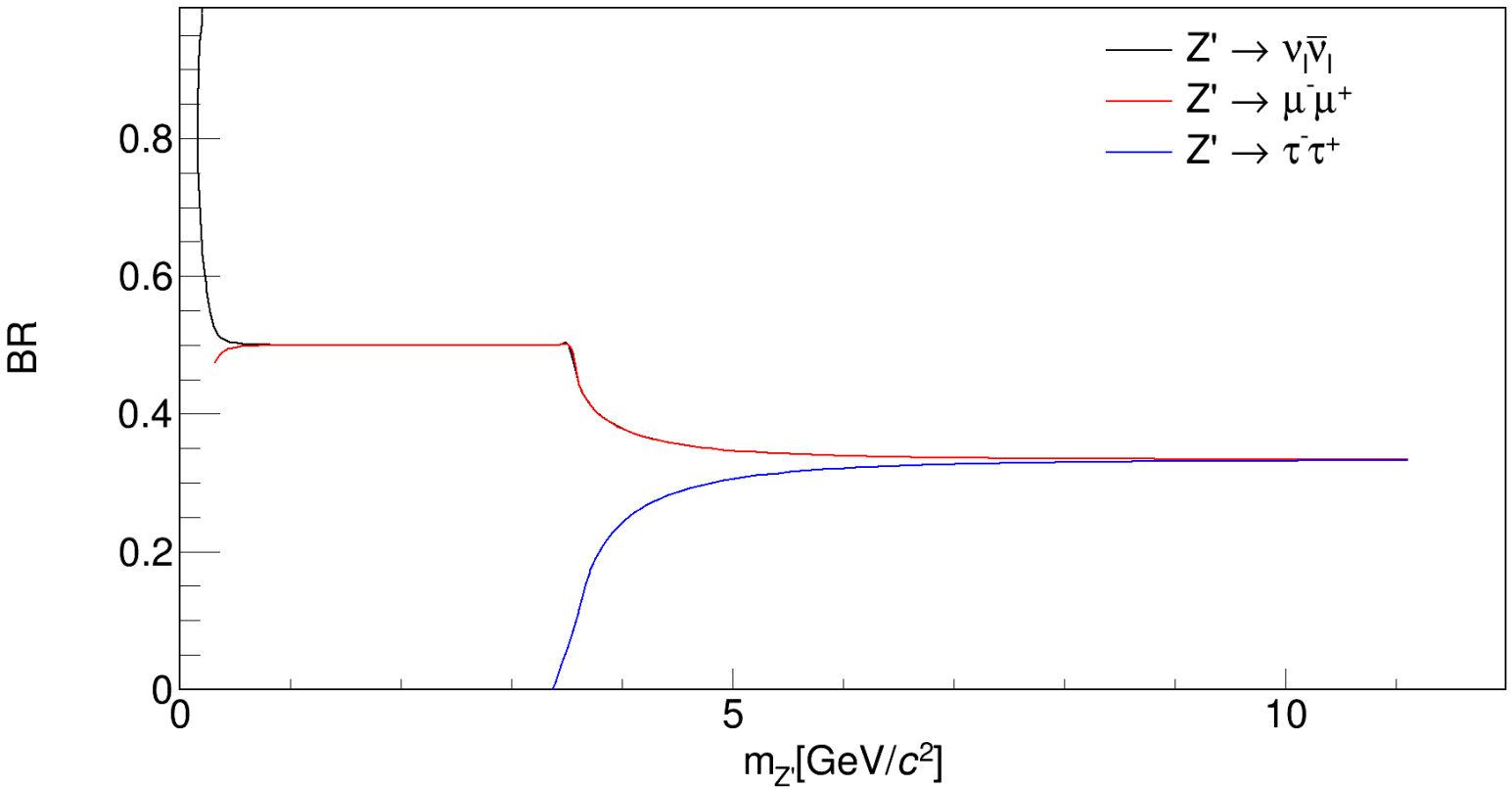
muon coupling term tau coupling term



- not the usual Dark Photon model
- A model motivated by the $g_\mu - 2$ problem
- Z' as cause for $g_\mu - 2$ excess may be *rejected* by BELLE analysis following results from NA64

Z' Branching Ratios

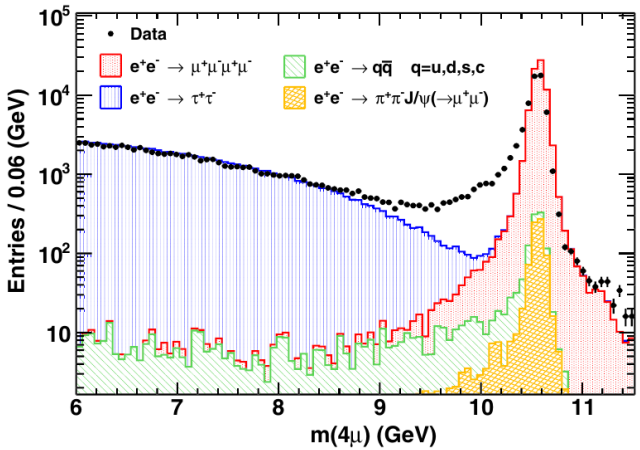
Model courtesy from Brian Shuve

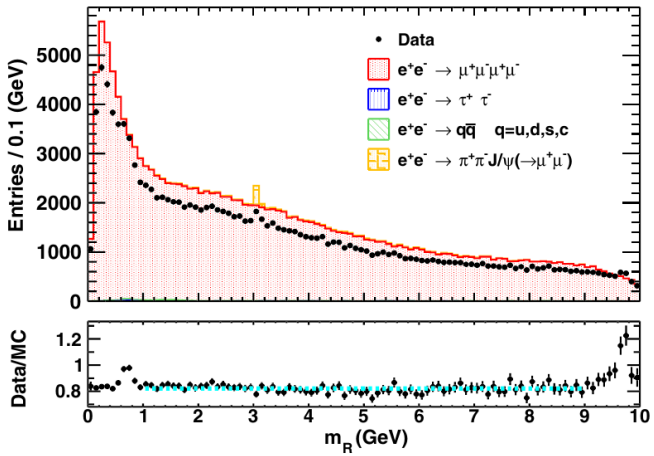


- $\nu_\ell \bar{\nu}_\ell$ might allow for sterile neutrino probes

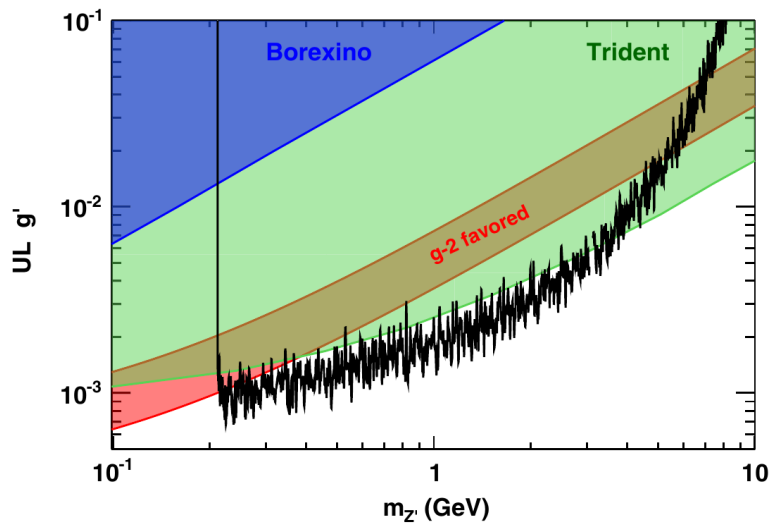
BaBar Leptophilic Dark Gauge Search

Search for a muonic dark force at BaBar Phys.Rev.D.94.011102 - 2016

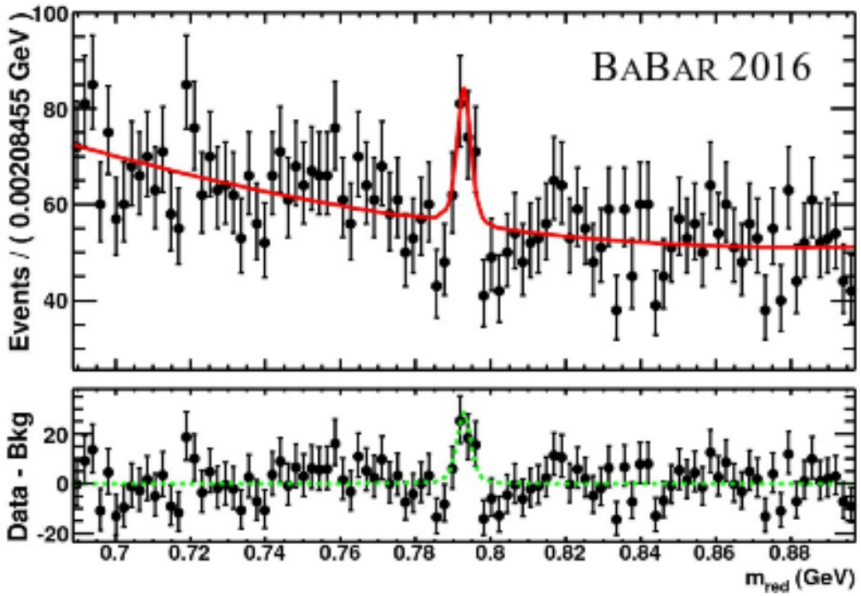




- $e^+e^- \to \mu^+\mu^- Z' \to \mu^+\mu^-\mu^+\mu^-$ search
- Z', μ coupled dark gauge
- $L_\mu - L_\tau$ model



Babar result for $e^+e^- \to \mu^+\mu^- Z'$

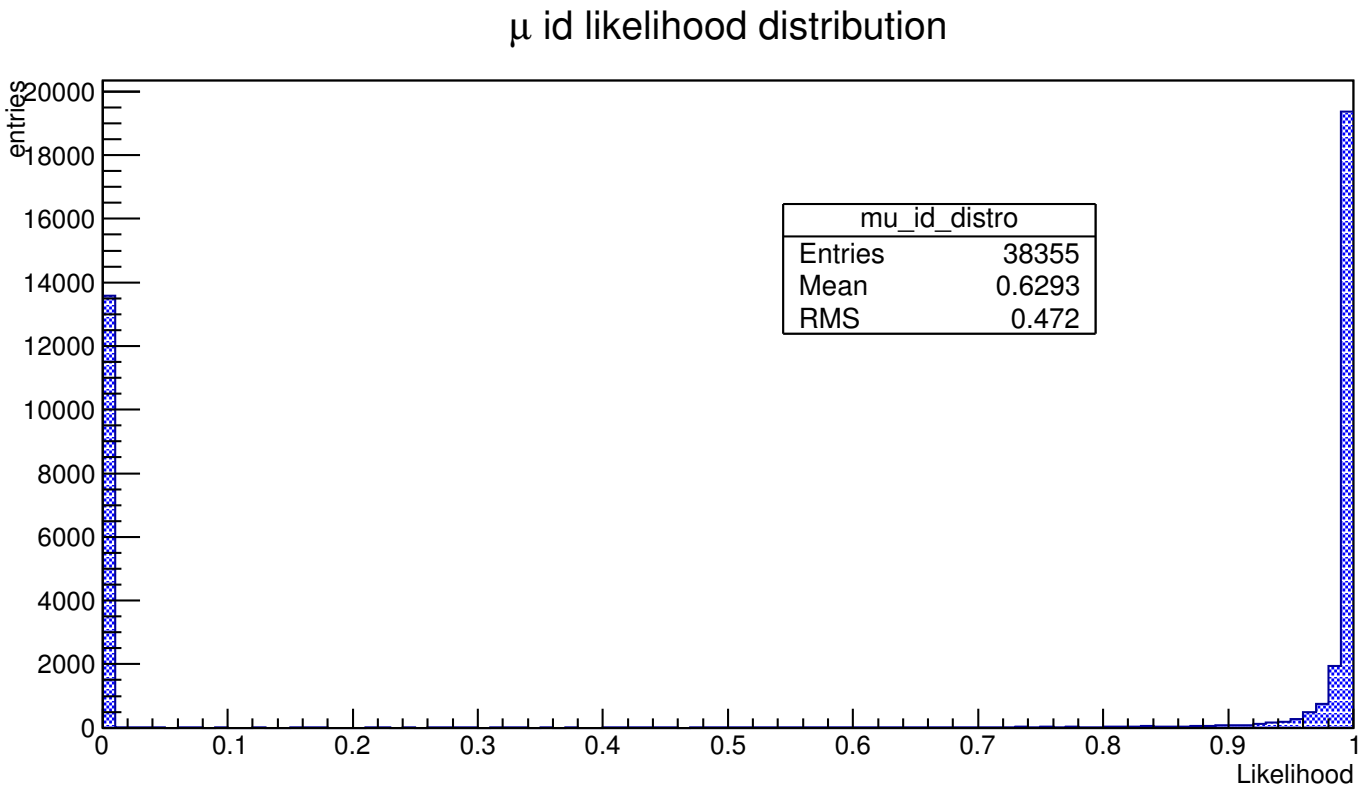


- **Highest significance at $m_{Z'} = 0.79$GeV, 4.9σ, locally**
- 1.6σ globally $\to$ **no signal**
- Belle larger data sample and better sensitivity could get a better result on the same channel analysis

Belle Z' Search - MC production parameters and cuts

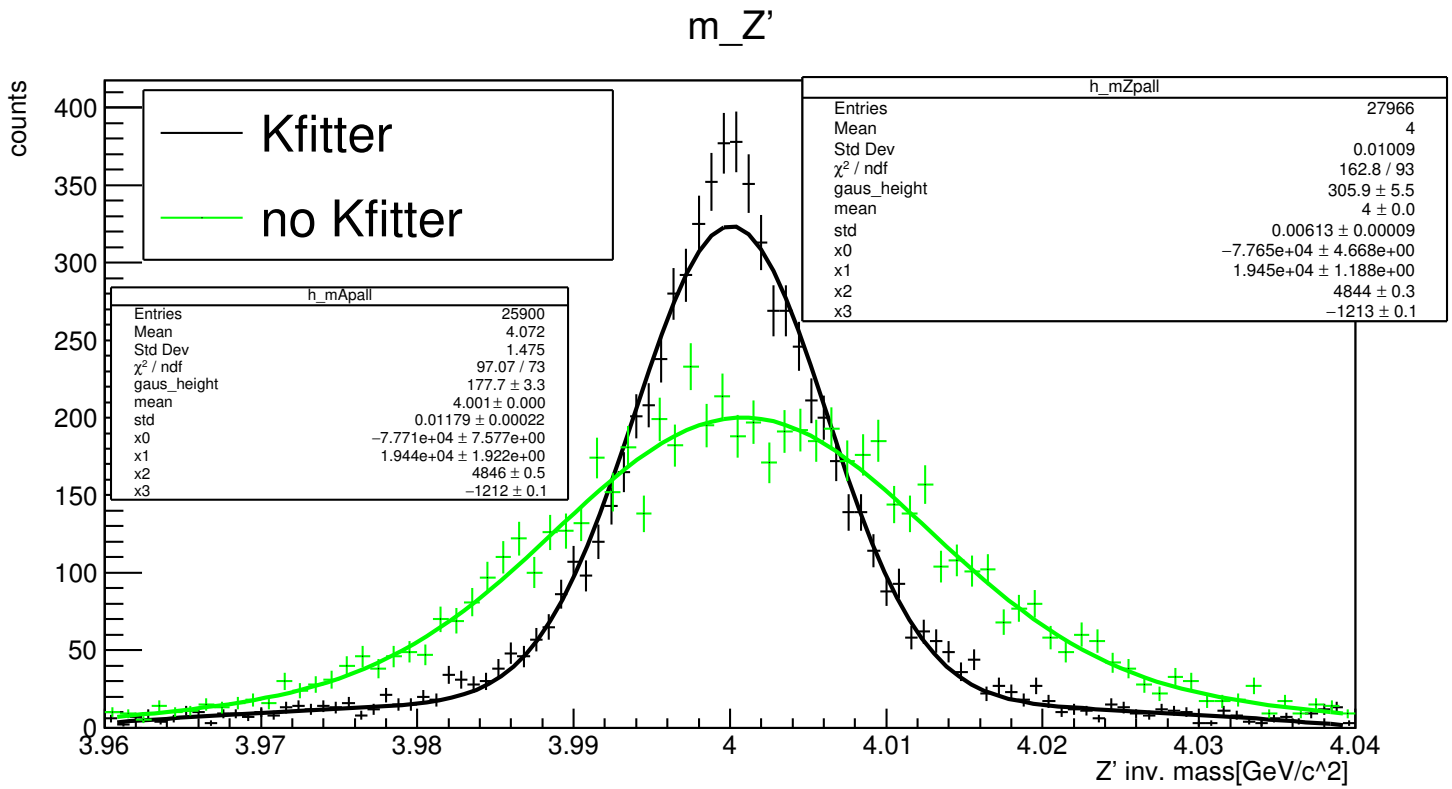
- $e^+ + e^- \rightarrow Z^{'} \mu^+ \mu^- \rightarrow \mu^+ \mu^- \mu^+ \mu^-$
- 10 000 events using MadGraph 5
- **0.25 GeV**$\sim$ 10GeV Dark Photon generation mass range
- Z' defined as oppositely charged promptly decayed $\mu^{\pm}$ pair, while two other charged tracks are another $\mu^{\pm}$ pair also promptly decayed from initial interaction
- Background is $e^+ e^- \rightarrow \mu^+ \mu^- \mu^+ \mu^-$
- 4 charged tracks requirement which reduces the yield by 61% assuming loose muon inclusion, but nullifies all most of the non leptonic background
- Kinematic fitter used to guarantee mass, momentum and energy conservation improved resolution of Z' invariant mass, constraining the initial state with the final state

μ id likelihood distribution



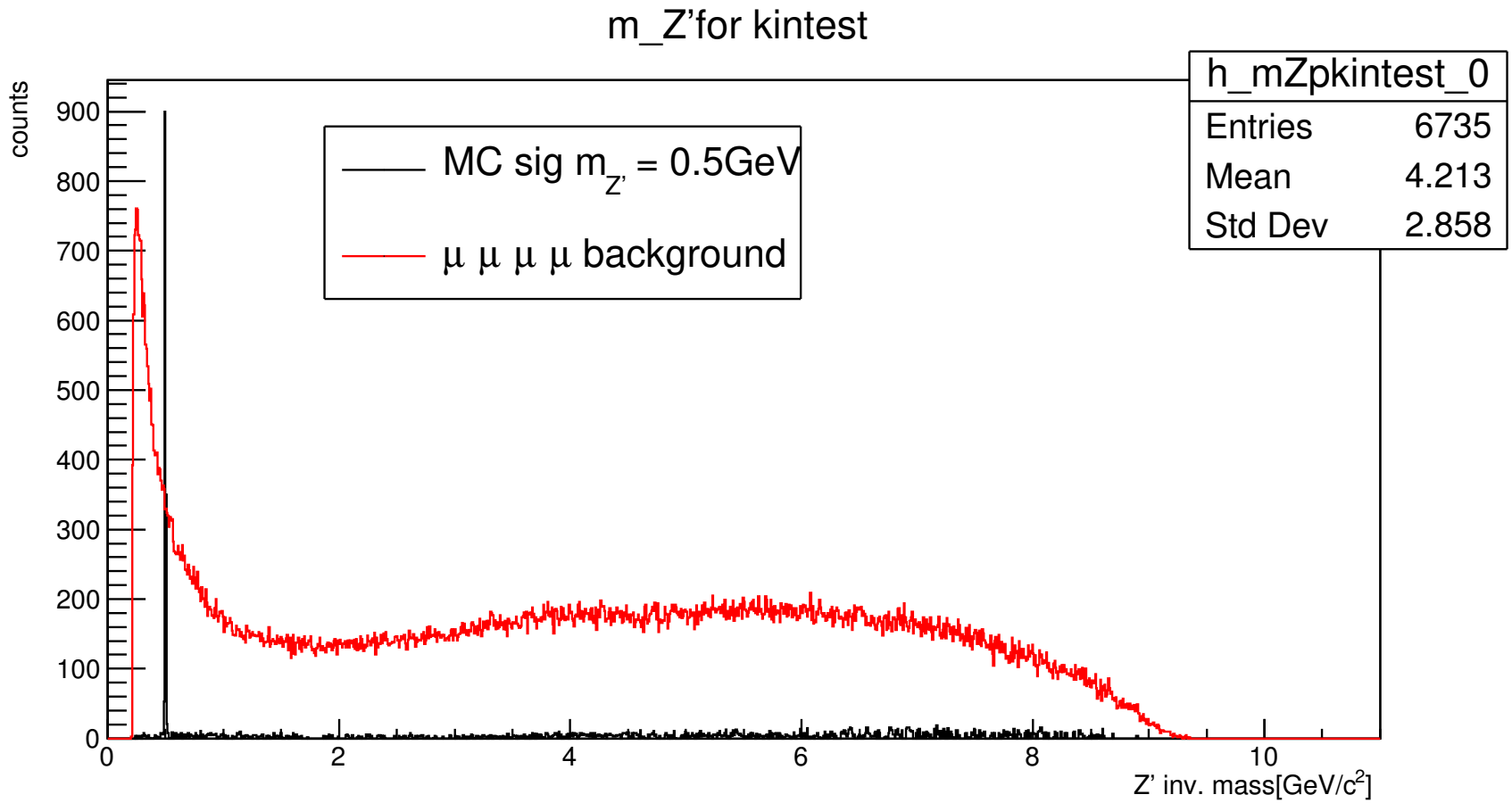
- Looking at the peak over 1, it is clear that most of the signal comes from tight muons, but the signal could be boosted by adding the lower likelihood ones as well

Comparison for the Z' inv mass with and without the use of the Kinematic Fitter



- the Kfitter $\sigma = 0.006$ while the no Kfitter σ=0.01

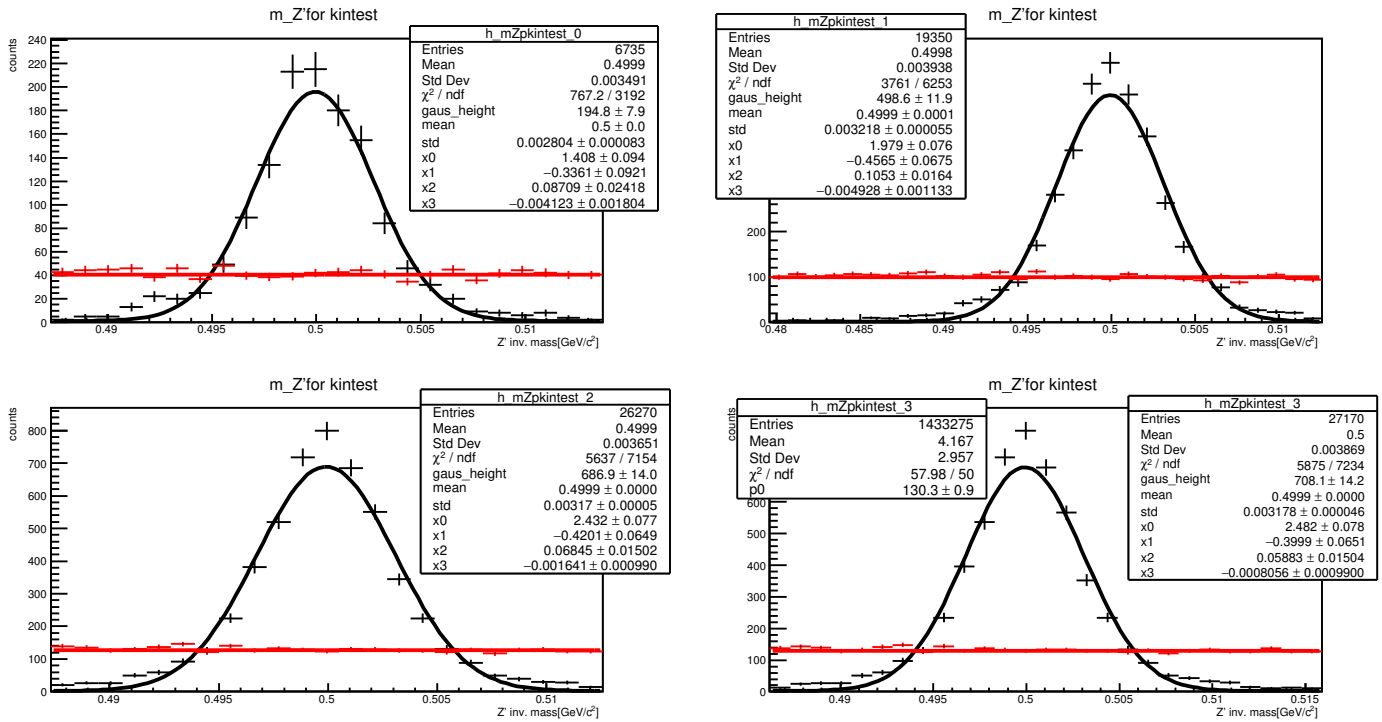
4μ final state background distribution with 0.5GeV signal



- This background is scaled by $\frac{1}{3}$ due to its luminosity compared to Belle's.

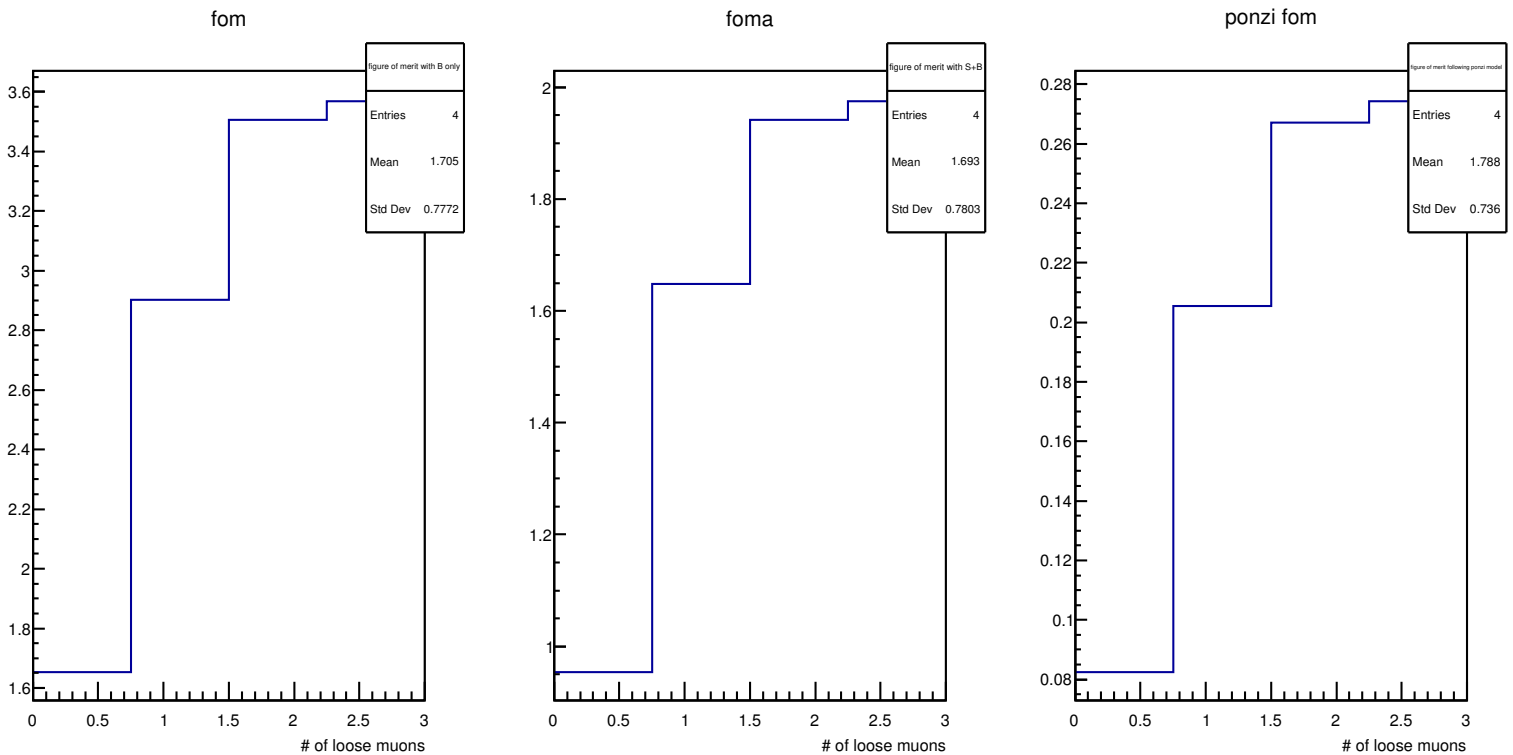
Z' inv mass fit to extract signal efficiency

Evaluation of inclusion of different amounts of loose muons, from left to right, top to bottom: 0,1,2,3



- From top left (up to 0 loose muons) to bottom right (up to 3 loose muons), the yield increases from 6735, 19350, 26270 to 27170 events

FOM for different loose muons



- The Figure of Merit is highest for up to 3 loose muon inclusion in the signal

Visible Cross Section Evaluation

$\sigma^{\text{visible}} = \frac{N_{\text{obs}} - N_{\text{bkg}}}{\mathcal{L} \cdot \mathcal{B} \cdot \epsilon}$

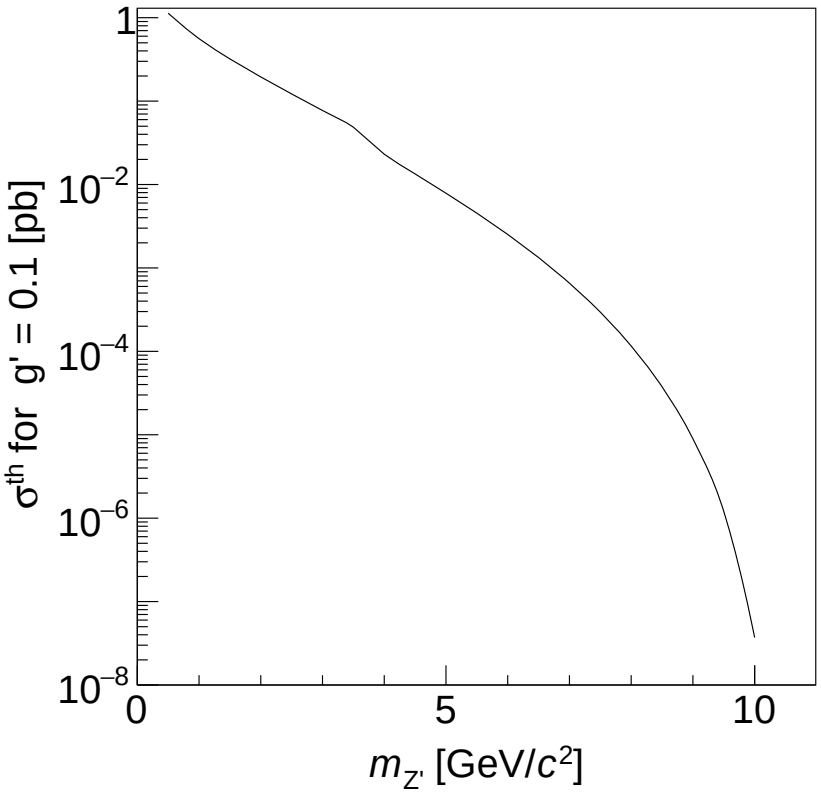
where:

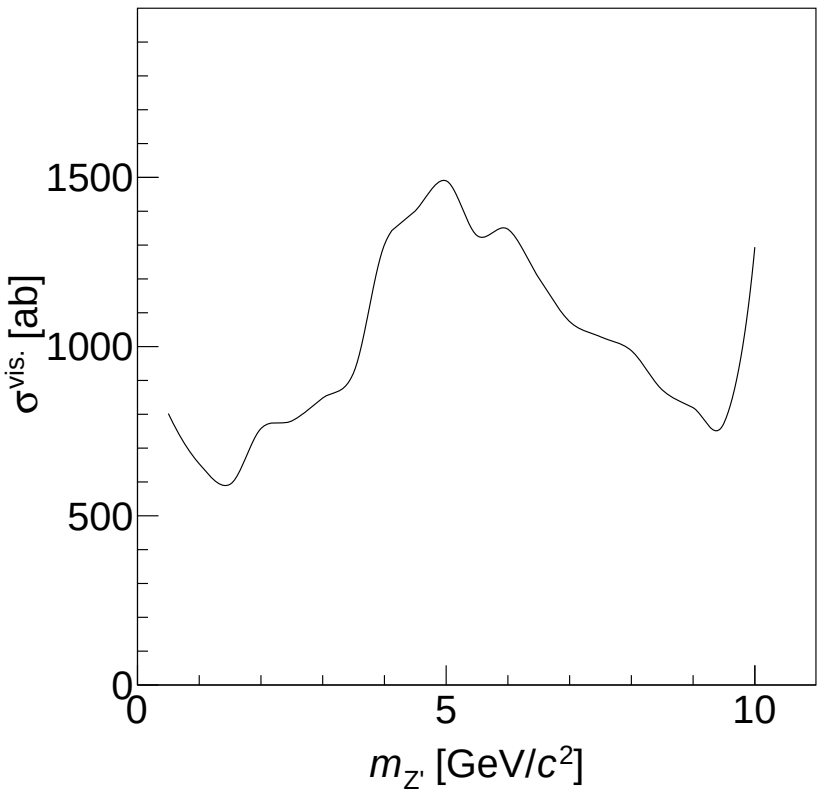
- N_{obs} is the number of observed events
- σ^{visible} is the visible cross section
- $\mathcal{L}$ is the luminosity
- $\mathcal{B}$ is the Branching Ratio
- ϵ is the detection efficiency

Find the maximum coupling at a particular mass for which the data does not allow a distinction between Z' or *no* Z', null hypothesis $N_{\text{obs}} = N_{\text{bkg}}$

Assuming null hypothesis is a good description of the data

Theoretical cross section and 90% CL on mc Z' visible cross section up to 10GeV by Mass

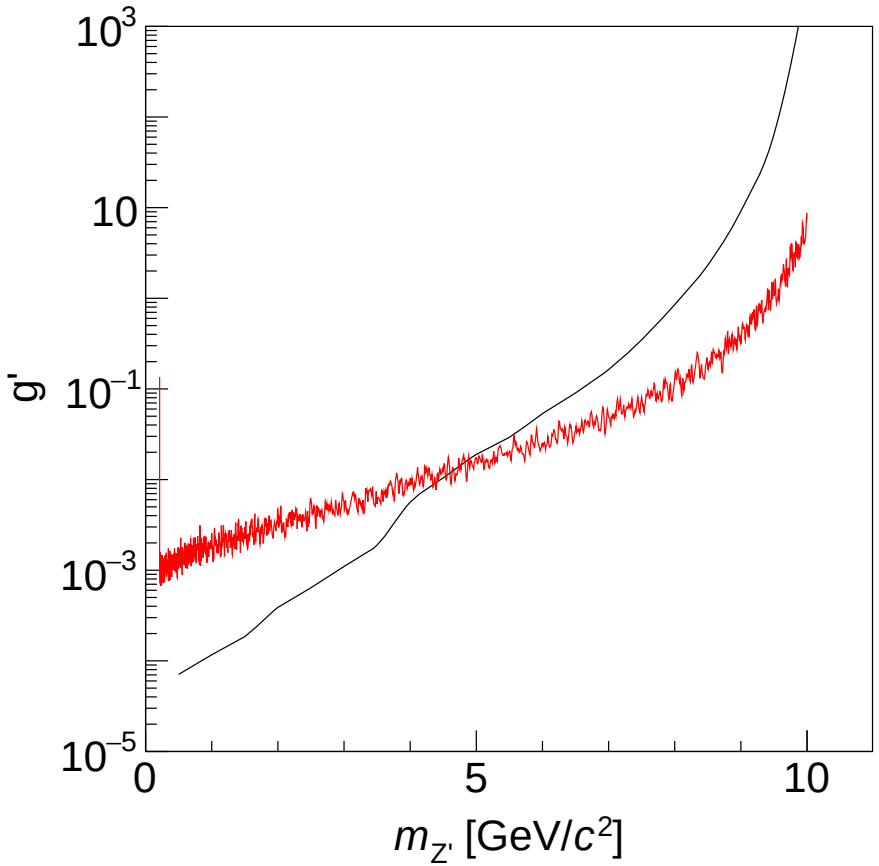




$e^+e^- \to \mu^+\mu^- Z', Z' \to \mu^+\mu^-$

- Mc background $e^+e^- \to \mu^+\mu^-\mu^+\mu^-$

Mc g' coupling with BaBar 2016 up to 10GeV



- Still no obvious reason why Belle results should be worse than BaBar for masses higher than 4.5GeV.

Summary

- There are still ways to reduce the background, KLM acceptance angle cut, dimuon pairs difference cut, any other suggestions?
- Other sources of background to be included, $\pi\pi\pi\pi$, KK, and others
- Not clear why g' for higher energies worse than BaBar's
- No analytical cross section yet