MC Generators for τ Decays (Experiment)

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Outline

1. General
2. Recent data from BaBar and Belle
3. Lepton Flavor Violation (LFV)
4. Conclusions

General

TAUOLA, KORALB(Z), KKMC, PHOKHARA, PHOTOS – very important tools for experiments at LEP, CLEO, BaBar, Belle, LHC

S.Jadach, Z.Wąs, Comp. Phys. Commun. 36, 191 (1985);
S.Jadach, J.H.Kühn,Z.Wąs, Comp. Phys. Commun. 64, 275 (1990);
M.Jeżabek, Z.Wąs, S.Jadach, J.H.Kühn, Comp. Phys. Commun. 70, 69 (1992)

Hadronic form factors from the group of J. Kühn in 90-ies,
$V - A$ structure of $J_{\rm weak}$ plus phase space production in $J_{\rm hadr}$

High-statistics experiments $\Rightarrow$ more precise description:

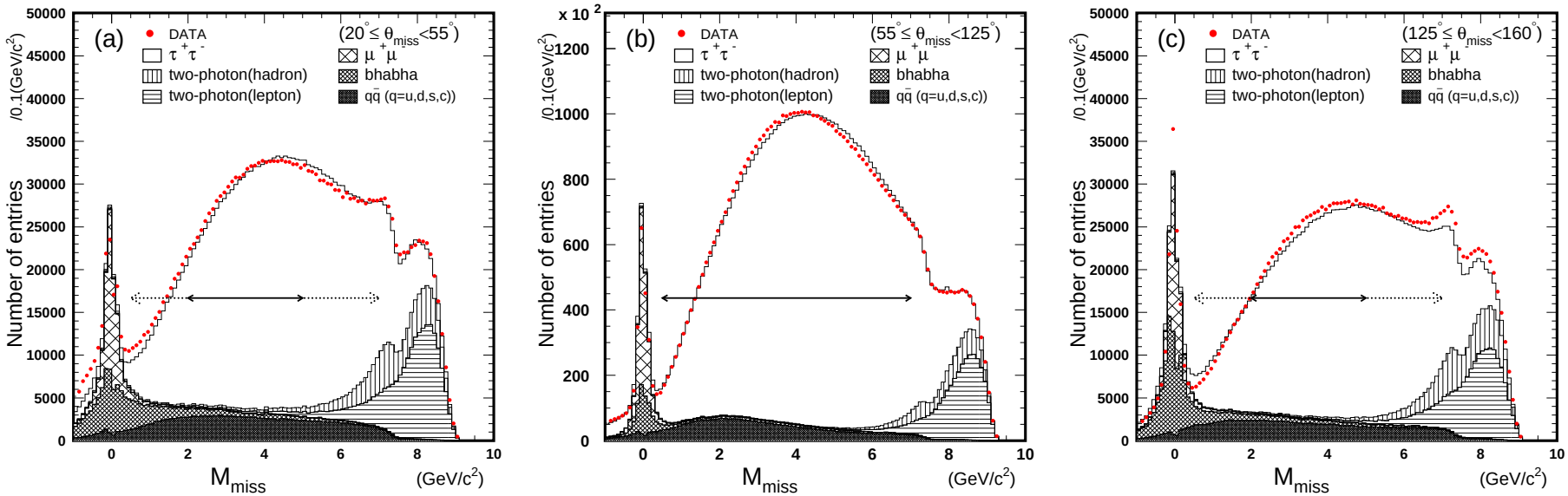
- CLEO package
- Novosibirsk e^+e^- data for hadronic currents in $\tau \to 4\pi\nu_\tau$
  A.Bondar, SE, ..., Z.Wąs, M.Worek, Comp. Phys. Commun. 146, 139 (2002)
- Improvement for $\tau \to 5h\nu_\tau$ by
  J.H.Kühn, Z.Wąs, Acta Phys. Polon. B 39, 147 (2008)

Why Important?

- Signal MC is used to calculate acceptance ϵ and various distributions for selection and comparison to data
- From background MC we estimate $N_{\rm ev}^{\rm BG}$ and BG shape, in addition to $\tau^+\tau^-$ there is $q\bar{q}$, $\gamma\gamma$ etc.
- ϵ is small (a few %) and depends on the model, detectors claim uniform acceptance
- Observed distributions should be unfolded to get rid of detector effects, again ϵ is needed; important while extracting resonance parameters
- Analysis of publications shows that effects of MC signal modeling are neglected

$\tau^- \to \pi^- \pi^0 \nu_\tau$ at Belle – I

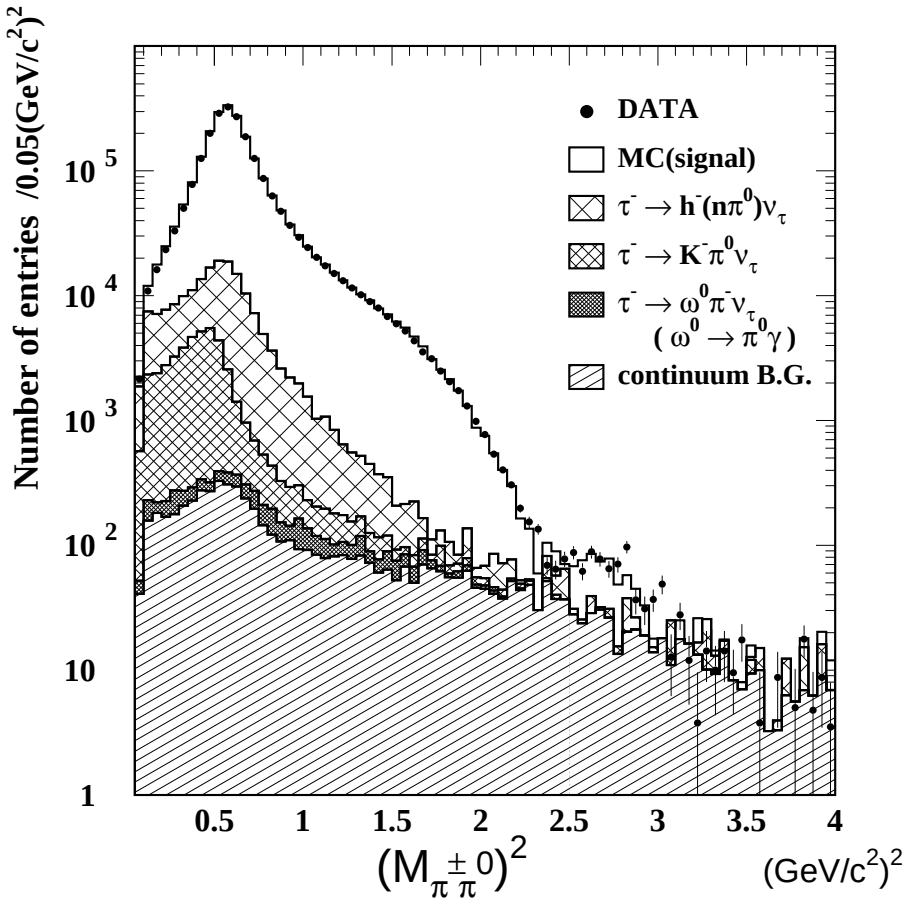
From less than 10% of data 5.4M events selected!

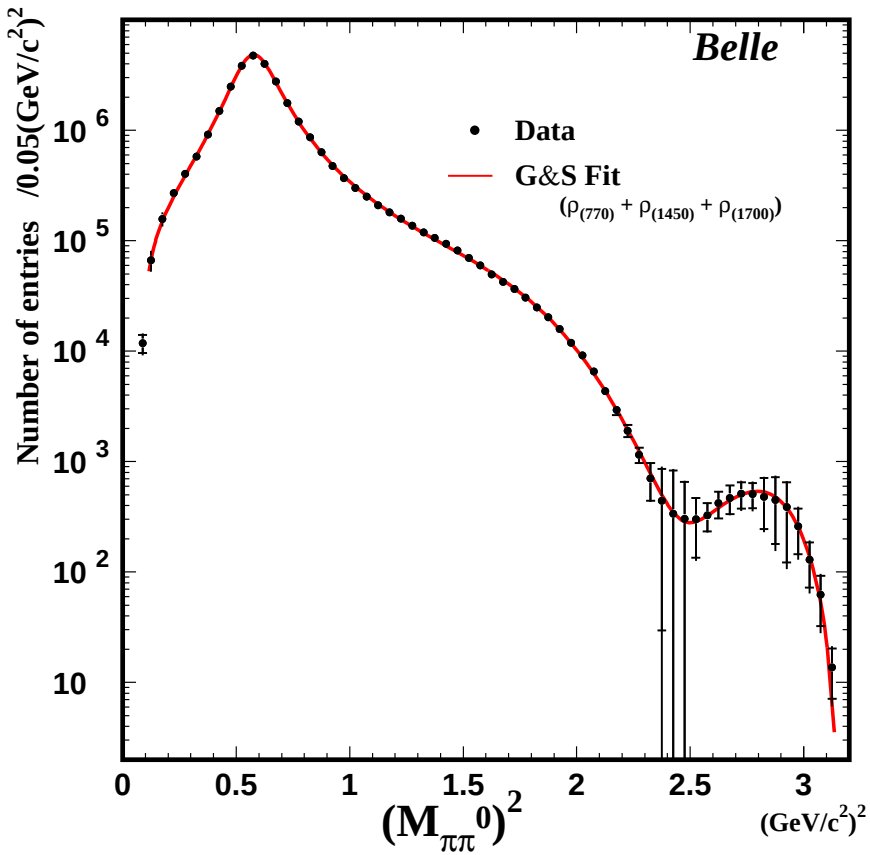


Small discrepancies observed between MC and data

M. Fujikawa et al., Phys.Rev. D 78, 072006 (2008)

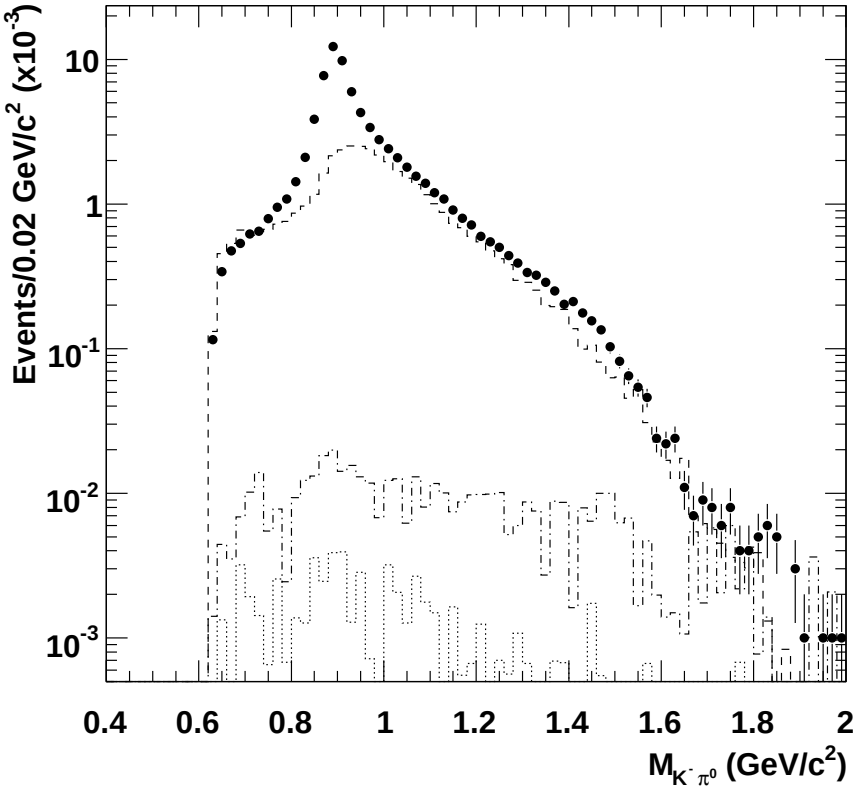
$\tau^- \to \pi^-\pi^0\nu_\tau$ at Belle – II

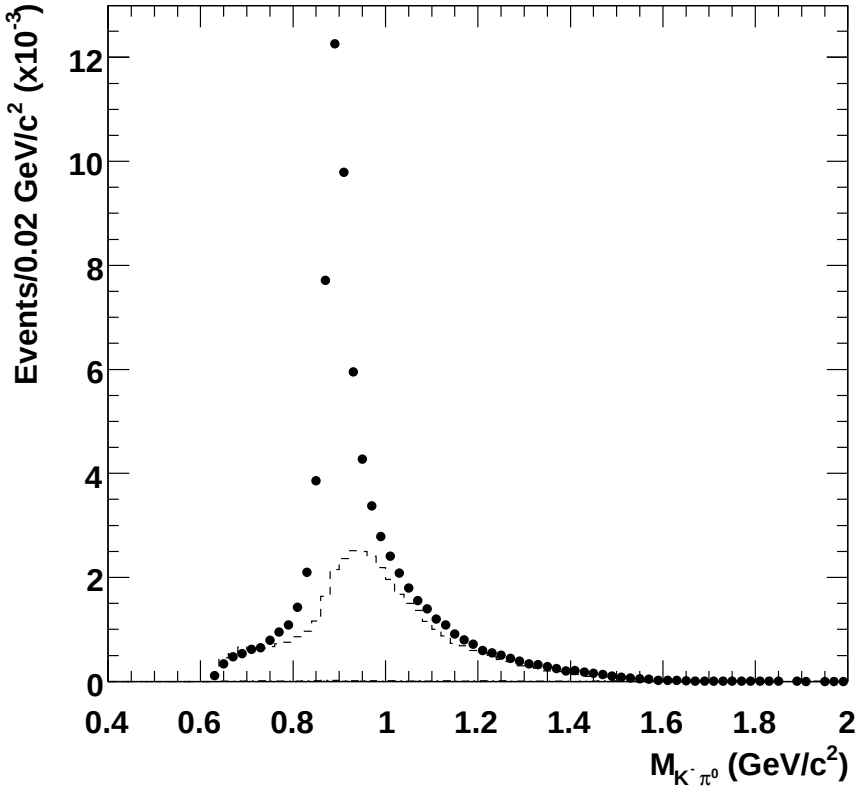




Non-trivial dynamics: interference of the ρ and ρ''s

$\tau^- \to K^-\pi^0\nu_\tau$ at BaBar



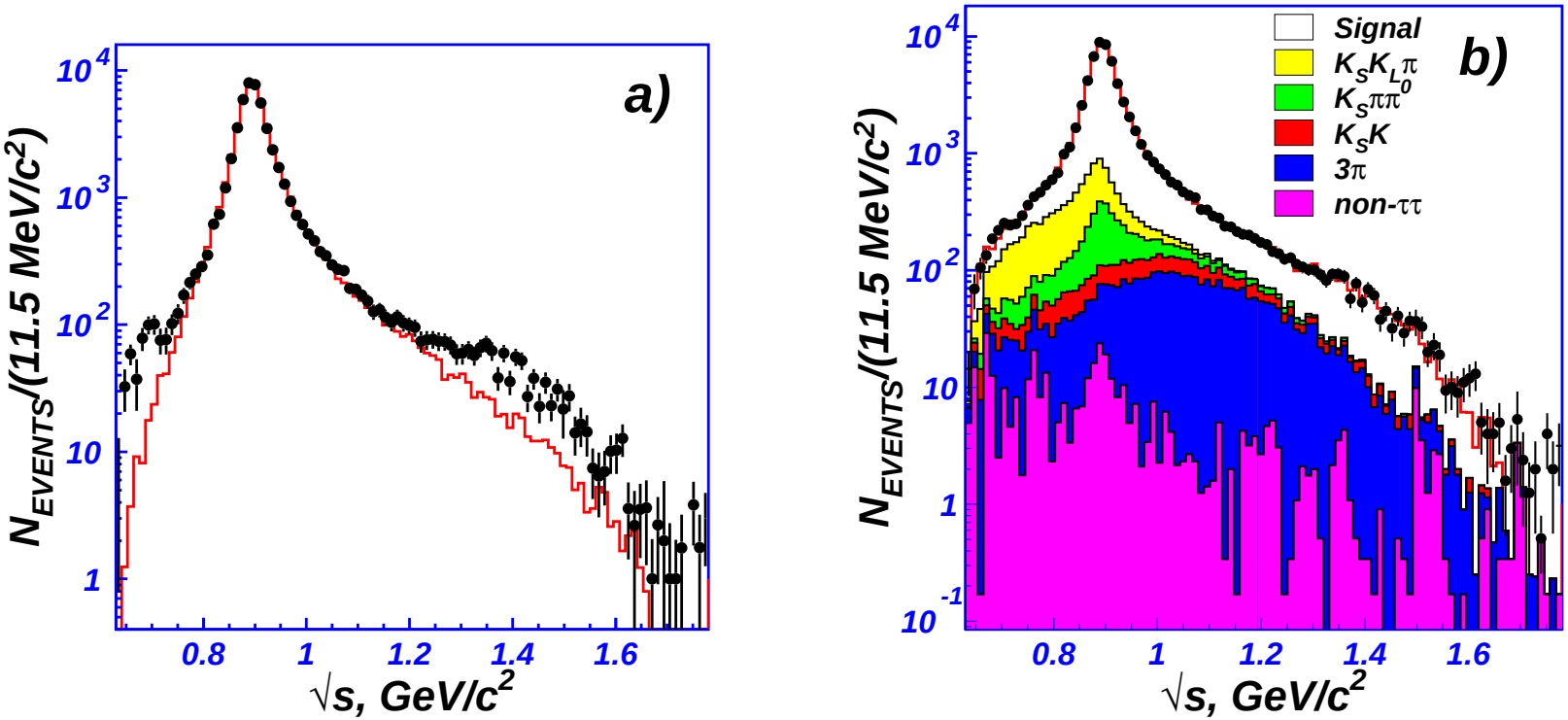


Dynamics differs from pure $K^*(892)$

Proper MC of the background from $\tau^- \to \pi^-\pi^0\nu_\tau$

B. Aubert et al., Phys. Rev. D 76, 051104 (2007)

$\tau^- \to K_S^0 \pi^- \nu_\tau$ at Belle

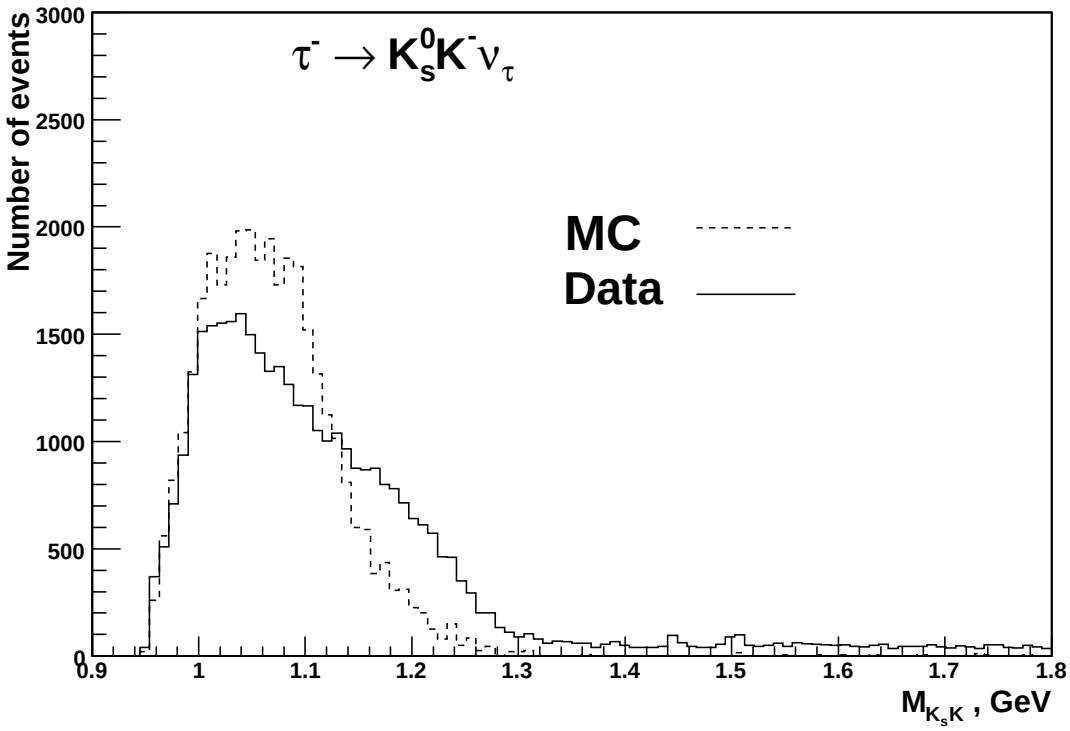


Dynamics differs from pure $K^*(892)$:

the best fit includes $K_0^*(800) + K^*(892) + K^*(1410)/K_0^*(1430)$

D. Epifanov et al., Phys. Lett. B 654, 65 (2007)

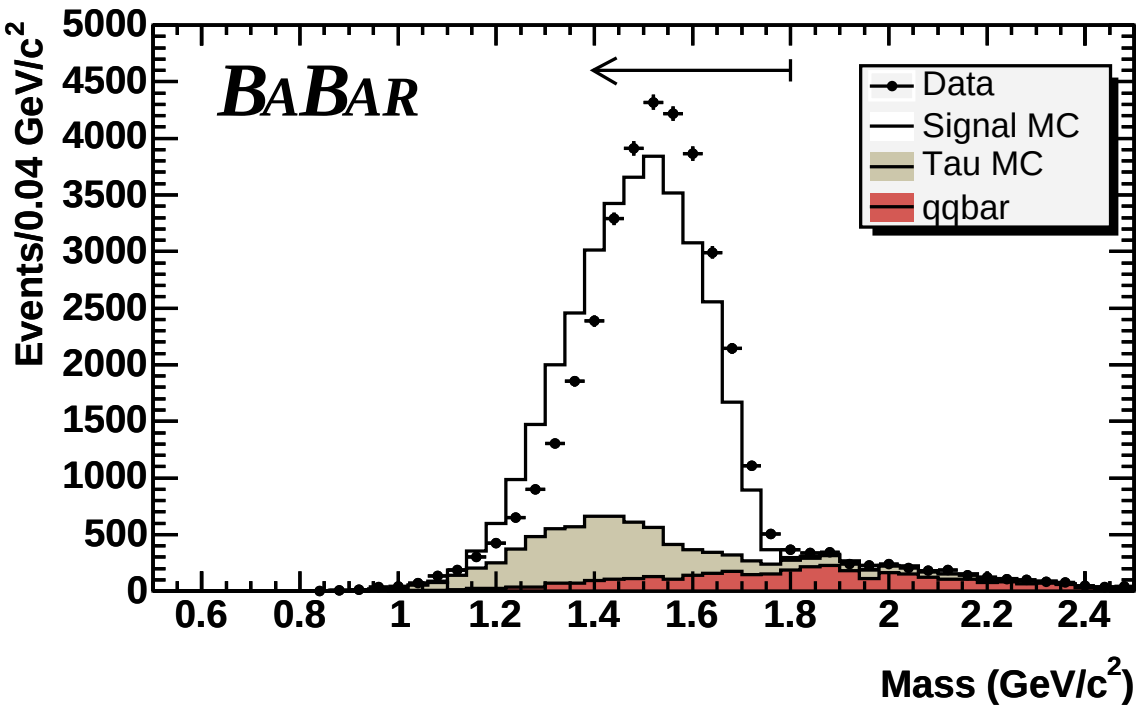
$\tau^- \to K_S^0 K^- \nu_\tau$



MC obviously prefers not as broad mass range as in data

Belle – preliminary

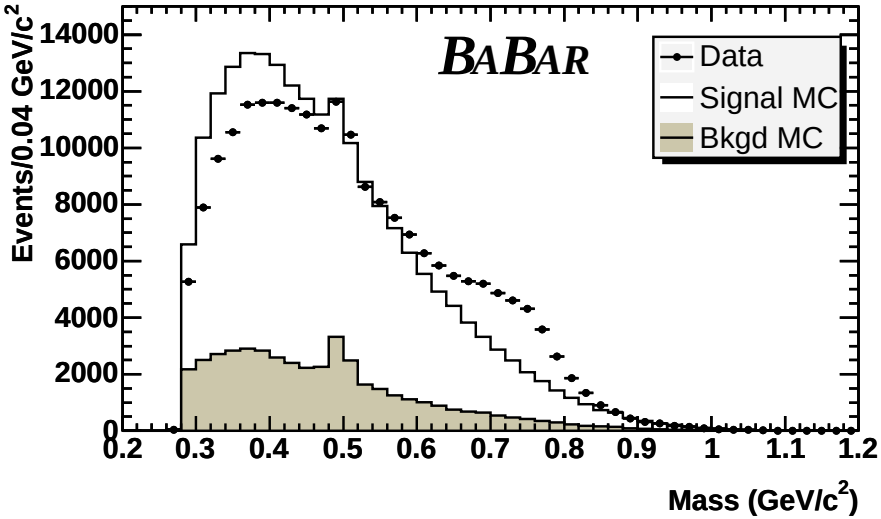
$\tau^- \to 3h^- 2h^+ \nu_\tau$ at BaBar – I

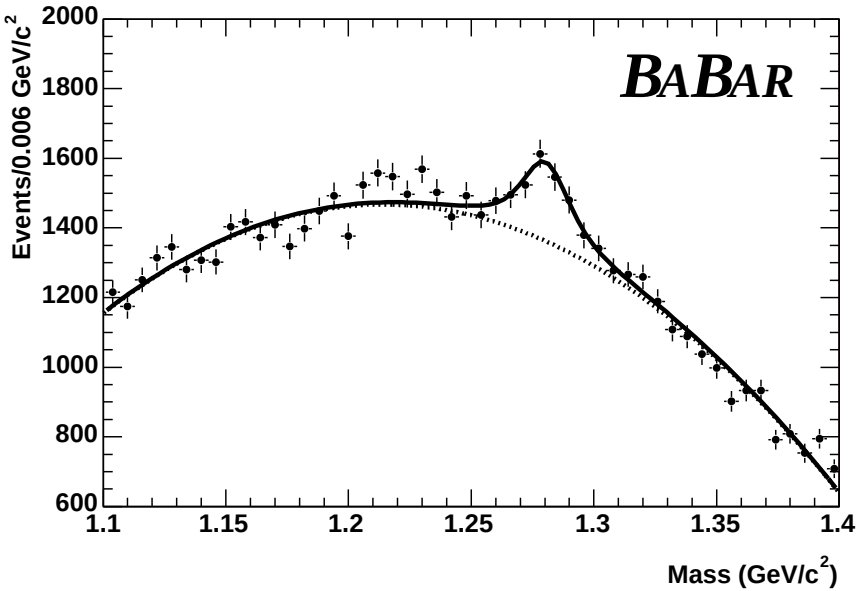


Clear discrepancy between MC for τ decays and data

B. Aubert et al., Phys. Rev. D 72, 072001 (2005)

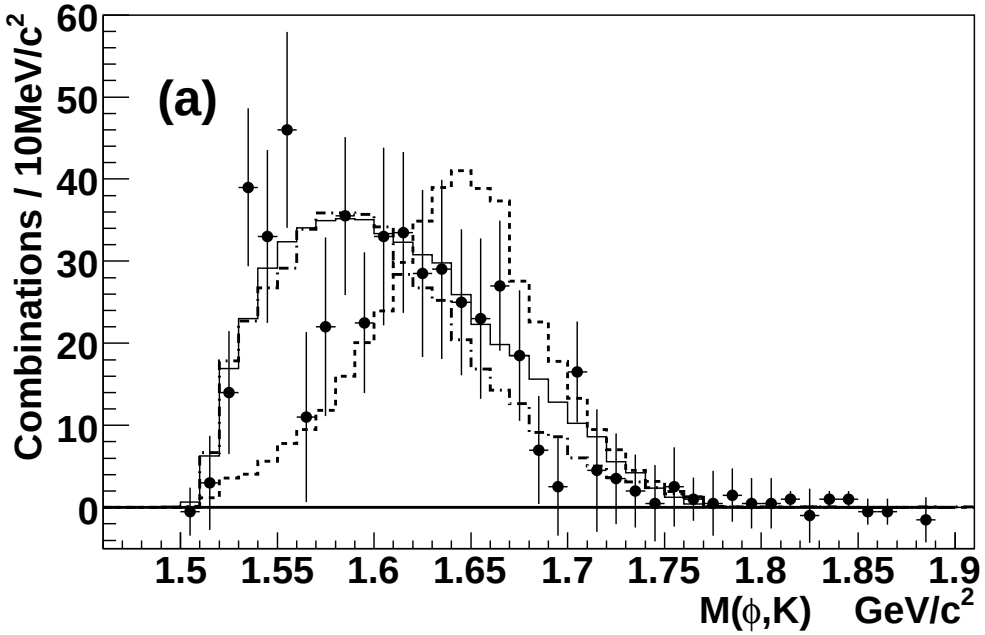
$\tau^- \to 3h^- 2h^+ \nu_\tau$ at BaBar – II





Dynamics strongly differs from phase space:
obvious ρ^0 signal, presence of $f_1(1285)\pi^-$ etc.

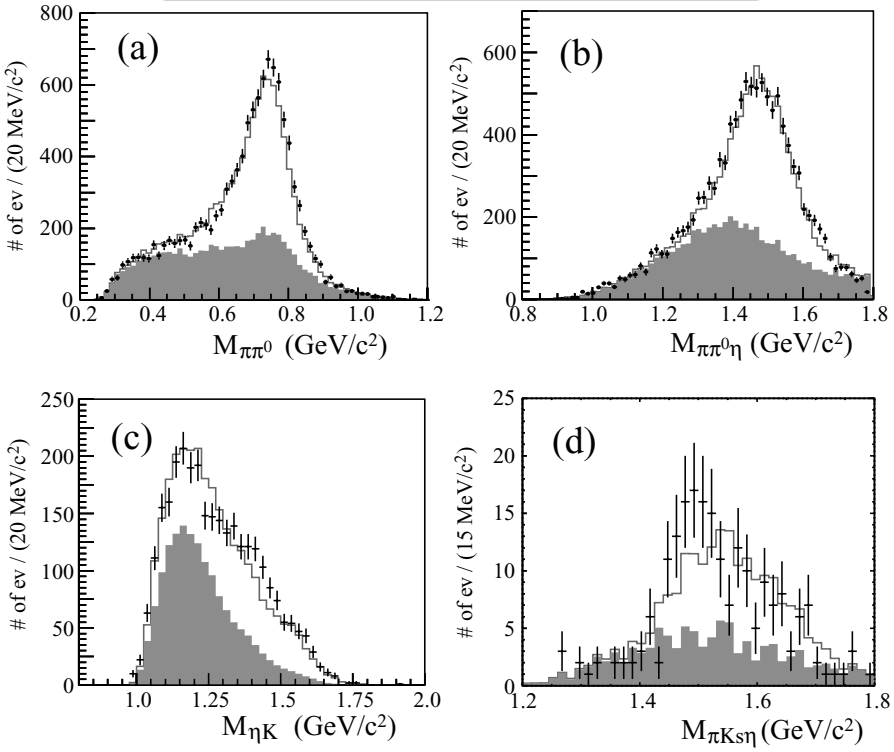
$\tau^- \to \phi K^- \nu_\tau$ at Belle



ϕK dynamics: a possible state at ~ 1.6 GeV

K. Inami et al., Phys. Lett. B 643, 5 (2006)

$\tau^- \to \eta X \nu_\tau$ at Belle



Reasonable agreement for $\eta\pi^-\pi^0\nu_\tau$ (a, b),
worse for $\eta K^-\nu_\tau$ (c) and $\eta K^{*-}\nu_\tau$ (d)

K. Inami et al., Phys. Lett. B 672, 209 (2009)

LFV Decays

- In most of the cases (ALWAYS) phase space production is assumed
- LFV assumes New Physics $\Rightarrow$ matrix elements are no longer separated into weak and hadronic parts
- Theoretical papers suggesting LFV in new models rarely provide differential cross sections
- Angular correlations for $\tau^- \to \mu^-\gamma,\ \mu^-\mu^+\mu^-,\ \mu^-e^+e^-$, R. Kitano and T. Okada, Phys. Rev. D 63, 113003 (2001)
- Model-independent analysis of $\tau \to l_1 l_2 l_3$ decays, B.M. Dassinger et al., JHEP 0710:039 (2007)
- There are purely phenomenological attempts: Belle papers mention comparison of $V - A$ and $V + A$

Conclusions

- High-statistics and high-precision experiments as well as searches for rare processes result in a new challenge: adequate description of energy and angular distributions
- Spectral functions (shape) are important in various applications: m_τ, m_{ν_τ}, CVC tests, $(g_\mu - 2)/2$, QCD parameters (α_s, condensates, m_s)
- There are suggestions to use semi-automatic, adaptive methods combining direct experimental data with theoretical currents (Z. Wąs)
- An alternative: construct theoretical currents from first principles: chiral theory, gauge invariance, isospin symmetry, CVC and phenomenology – vector dominance (P. Roig)
- In reality a combination of both approaches should be used
- About 200 various τ decays, more than 50 LFV modes