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$\tau^{\pm} \rightarrow \pi^{\pm}\pi^{+}\pi^{-}\pi^{0}\nu_{\tau}$ decays at BaBar

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Outline

- Motivation and aims:
  - Branching fractions of interest
  - G-parity violation
- Analysis plan and method:
  - Tau reconstruction
  - Cuts and optimisation
- Monte-Carlo mass plots
- Current status and future plans.

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Study Motivation and Aims

- Measure the branching fraction for the decay $\tau^- \rightarrow \pi^-\pi^+\pi^-\pi^0\nu_\tau$
- Obtain inclusive branching fraction measurements for decays involving ω, η and ρ (and any other) resonances.
- Look for second class currents:
  - Such decays which do not conserve G-parity: $G = C(-1)^I$
  - Second class current suppression factor w.r.t. first class currents is proportional to $|m_u - m_d| / (m_u + m_d)$ (Berger and Lipkin 1987).
  - The decays of particular interest for this are:
    - $\tau^- \rightarrow b_1(1235)\nu_\tau \rightarrow \omega\pi^-\nu_\tau \rightarrow \pi^-\pi^+\pi^-\pi^0\nu_\tau$
    - $\tau^- \rightarrow a_0(980)\nu_\tau \rightarrow \eta\,\pi^-\nu_\tau \rightarrow \pi^-\pi^+\pi^-\pi^0\nu_\tau$
  - The decay $\tau^- \rightarrow \omega\pi^-\nu_\tau$ is allowed as a first class (p-wave) current, which makes finding the second class (s/d-wave) current harder.
  - The decay $\tau^- \rightarrow \eta\,\pi^-\nu_\tau$ is unambiguously second class, into either a s or p-wave state.

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Study Motivation and Aims

- Plan to use the same framework to look at decays with one or more charged pions replaced with charged kaons.
- Current BF values are
  - $\tau^- \rightarrow \pi^-\pi^+\pi^-\pi^0\nu_\tau$ - (4.37±0.09) %
  - $\tau^- \rightarrow \pi^-\pi^+\pi^-\pi^0\nu_\tau$ (ex. K^0) - (4.25±0.09) %
  - $\tau^- \rightarrow \pi^-\pi^+\pi^-\pi^0\nu_\tau$ (ex. K^0, ω) - (2.51±0.09) %
- Previous claim of detection of $\tau^- \rightarrow \eta\,\pi^-\nu_\tau$ by HRS was later refuted by CLEO; current upper limit is <0.014%; theory expects them to be in the range 0.5% - 10^{-4} .

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Plan

- Event selection and tau reconstruction is split over a number of stages:
  - For initial event selection we use a standard BaBar ‘skim’ of the dataset; this skim consists of events containing charged tracks with a 1-on-N topology (using the event thrust to define the two hemispheres) along with a number of requirements on event quality.
  - Run over the skim selecting events with a 1-3 topology of the charged tracks with at least one π^0 in the 3-prong hemisphere, reconstructing all possible $h^-h^+h^-\pi^0$ combinations for each event into τ candidates.
  - Then impose further restrictions based on particle identification and number and quality of π^0s.

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Plan

- Optimise cuts on a number of quantities to obtain a cleaner event sample.
- After applying cuts, measure inclusive branching fraction for the decay $\tau^- \rightarrow \pi^-\pi^+\pi^-\pi^0\nu_\tau$.
- Look for resonances and measure their:
  - branching fractions,
  - masses,
  - widths,
  - angular distributions.

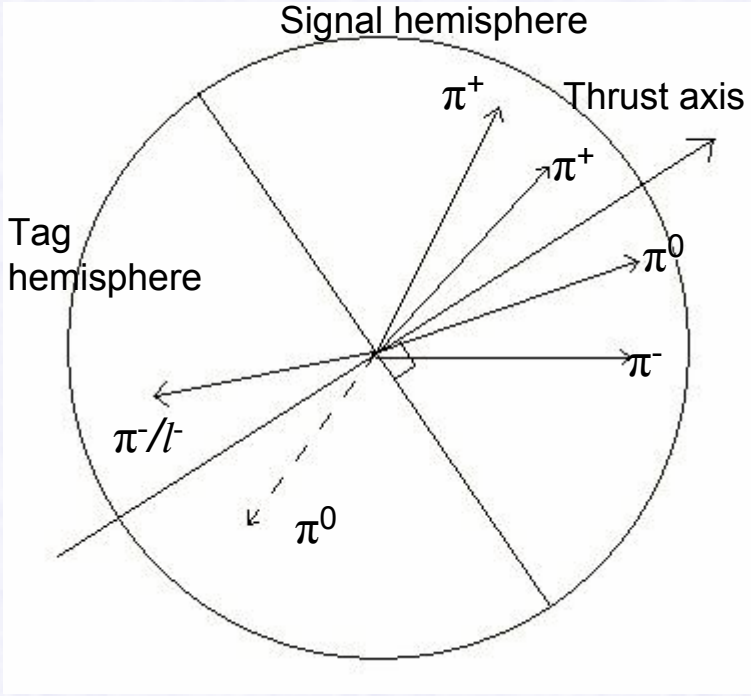
Tau Reconstruction

All possible τ candidates in the event are reconstructed.

- Requirements on charged tracks are:
  - p<10 GeV
  - p_T>0.1 GeV
  - At least 12 drift chamber hits
  - Closest approach to IP is within 1.5cm in the *x-y* plane and 10cm in the *z* plane.
- Requirements on the π^0 are:
  - Lateral moment between 0.001 and 0.5
  - E_γ>50 MeV
  - $E_{\pi 0}$>200 MeV
  - Each photon deposits energy in at least two crystals.
  - Split off energy cut 110 MeV, distance 25 cm.
  - χ^2 < 5.0 for vertexing the photons.
  - No merged π^0 .

Tau Reconstruction

- We then select candidates where:
  - All four daughter particles lie in the same hemisphere,
  - The charged daughters are not tagged as leptons, kaons or protons.
  - There is only one π^0 in the signal hemisphere.
  - No π^0 in the tag hemisphere for lepton tags, one for ρ tags.
  - For ρ tags require the ρ candidate mass to be between 0.67 GeV and 0.87 GeV.



Optimisation and cuts

- Optimise cuts to maximise the value of $S^2/(S+B)$.
- Have optimised for lepton tags and ρ tags separately and combined; plan to optimise with leptons separated into *e* and *μ* tags.
- Variables that are optimised on:
  - Total event energy (E_{total})
  - Thrust magnitude
  - Angle between thrust axis and beam axis (θ_{thrust})
  - Dipion mass under electron mass hypothesis.
  - Unassociated energy; this is all clusters:
    - Not associated with a charged track or π^0,
    - At least 50 MeV and 3 crystals,
    - Lateral moment less than 0.6,
    - At least 25 cm from nearest track,
    - $0.32<\theta<2.44$.

Optimisation and cuts

- After applying cuts the majority of background is from other τ decays, with roughly equal contributions from:
  - $\tau^- \rightarrow \pi^-\pi^+\pi^-\pi^0\pi^0\nu_\tau$
  - $\tau^- \rightarrow \pi^-\pi^+\pi^-\nu_\tau$
- Cuts may need some adjustment when data is looked at due to un-modeled backgrounds.

Tag	lepton	ρ	Combined
E_{total}/GeV	<11.75	<11.8	<11.6
Thrust	>0.8425	>0.88	>0.8725
cos θ_{thrust}	<0.95	<0.935	<0.995
m_{ee}^2/GeV^{2}c^{-4}	>0	>0	>0
Unassociated energy/GeV	<0.25	<0.25	<0.25

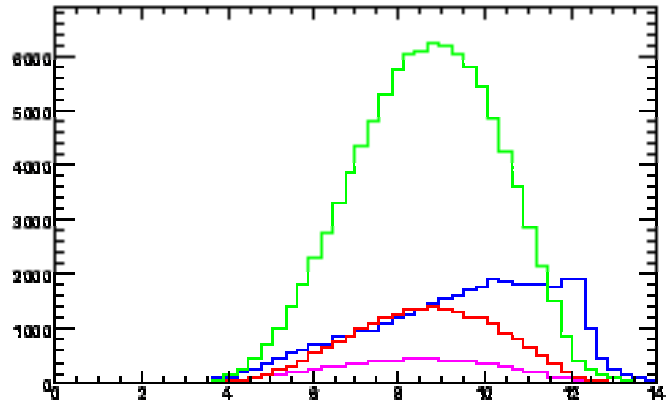
- Following plots are for lepton tag only and are scaled to 99.7fb^{-1} of on peak (centre of mass energy=10.58GeV) data.

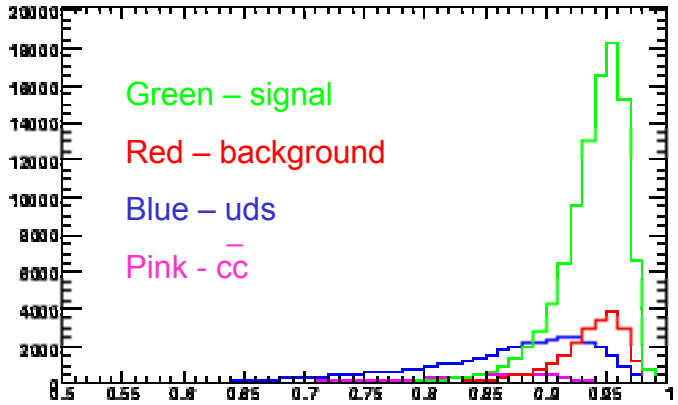
Optimisation and cuts

Event energy

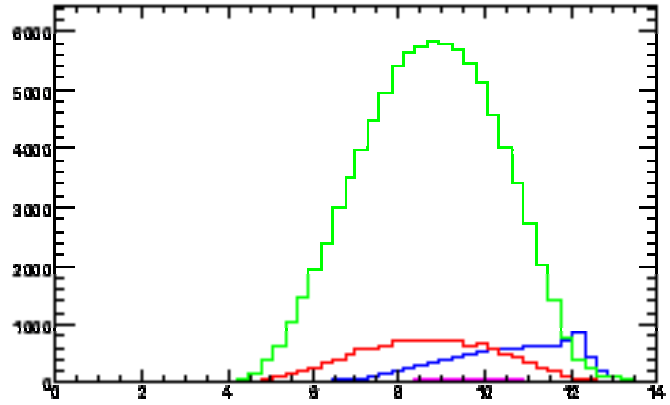
Thrust magnitude

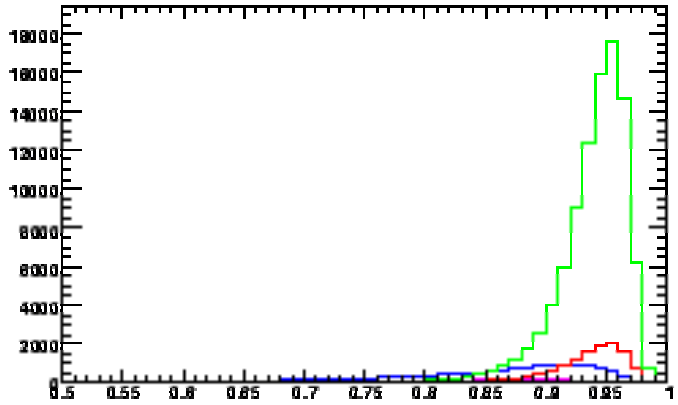
Before cuts





After cuts





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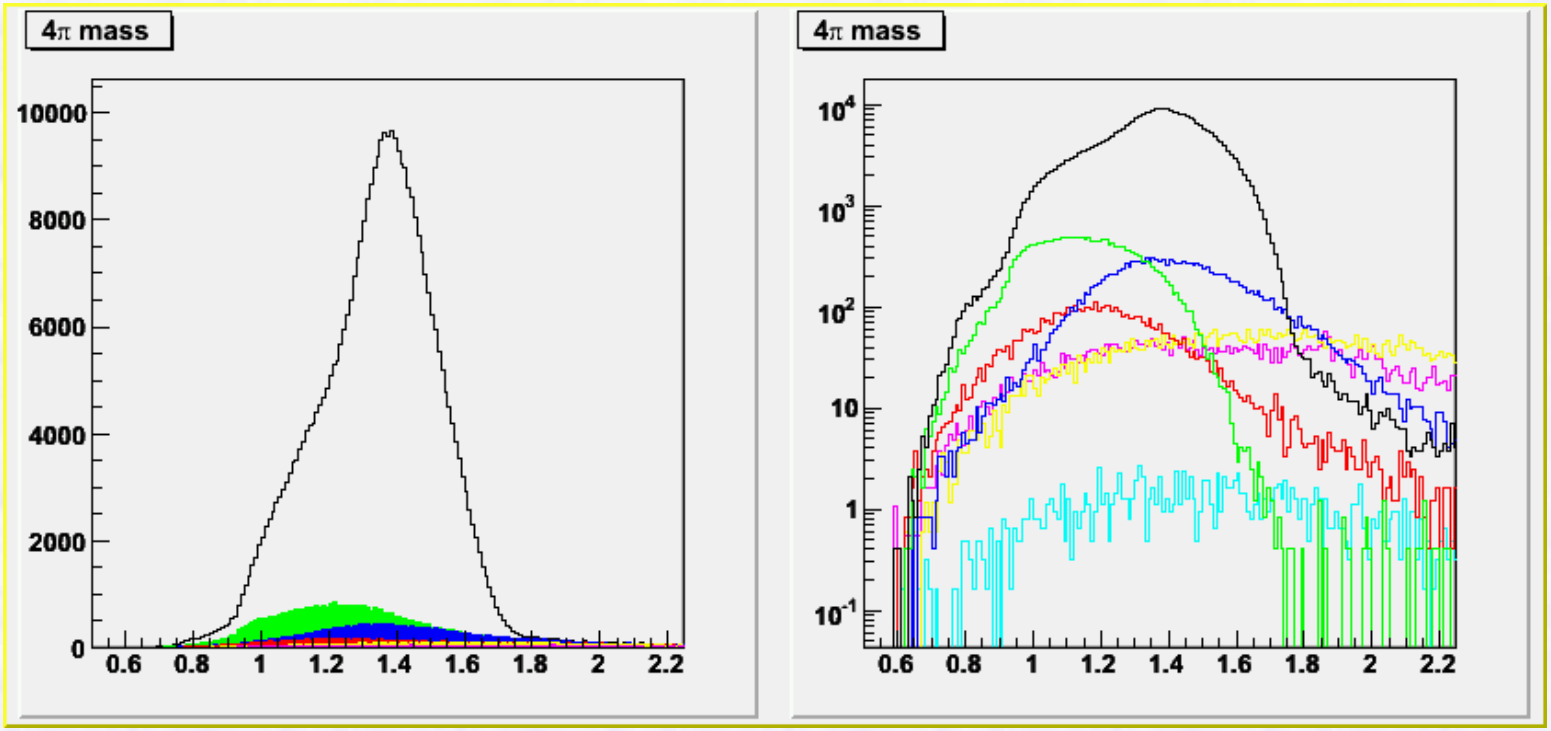
Monte-Carlo Mass spectra



Left plot is cumulative, right is not.

- –Black is signal
- –Green is $\tau^- \rightarrow \pi^-\pi^+\pi^-\pi^0\pi^0\nu_\tau$
- –Dark blue is $\tau^- \rightarrow \pi^-\pi^+\pi^-\nu_\tau$
- –Red is other τ background
- –Yellow is uds
- –Pink is ccbar
- –Light blue is BBbar

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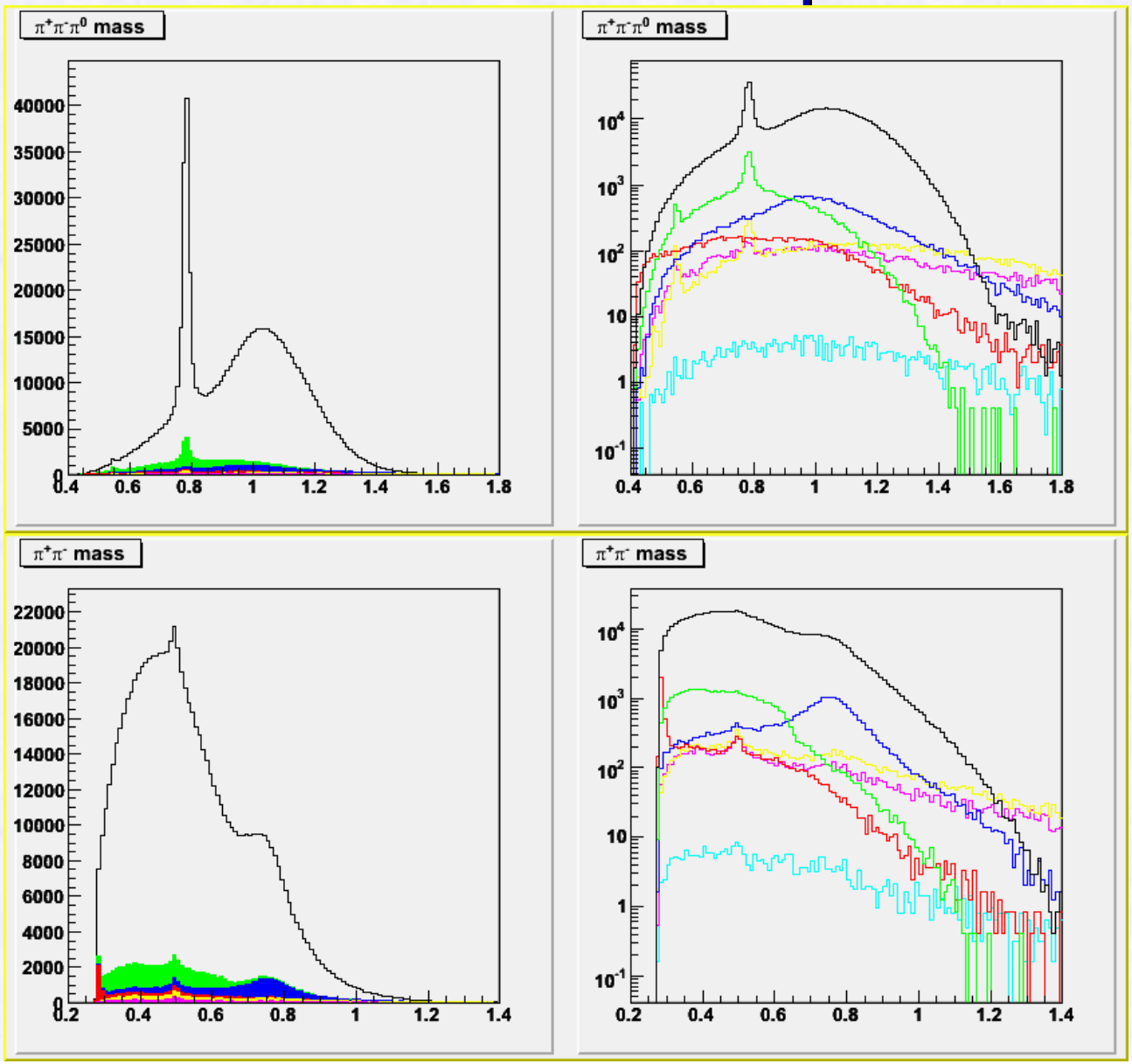
Monte-Carlo Mass spectra



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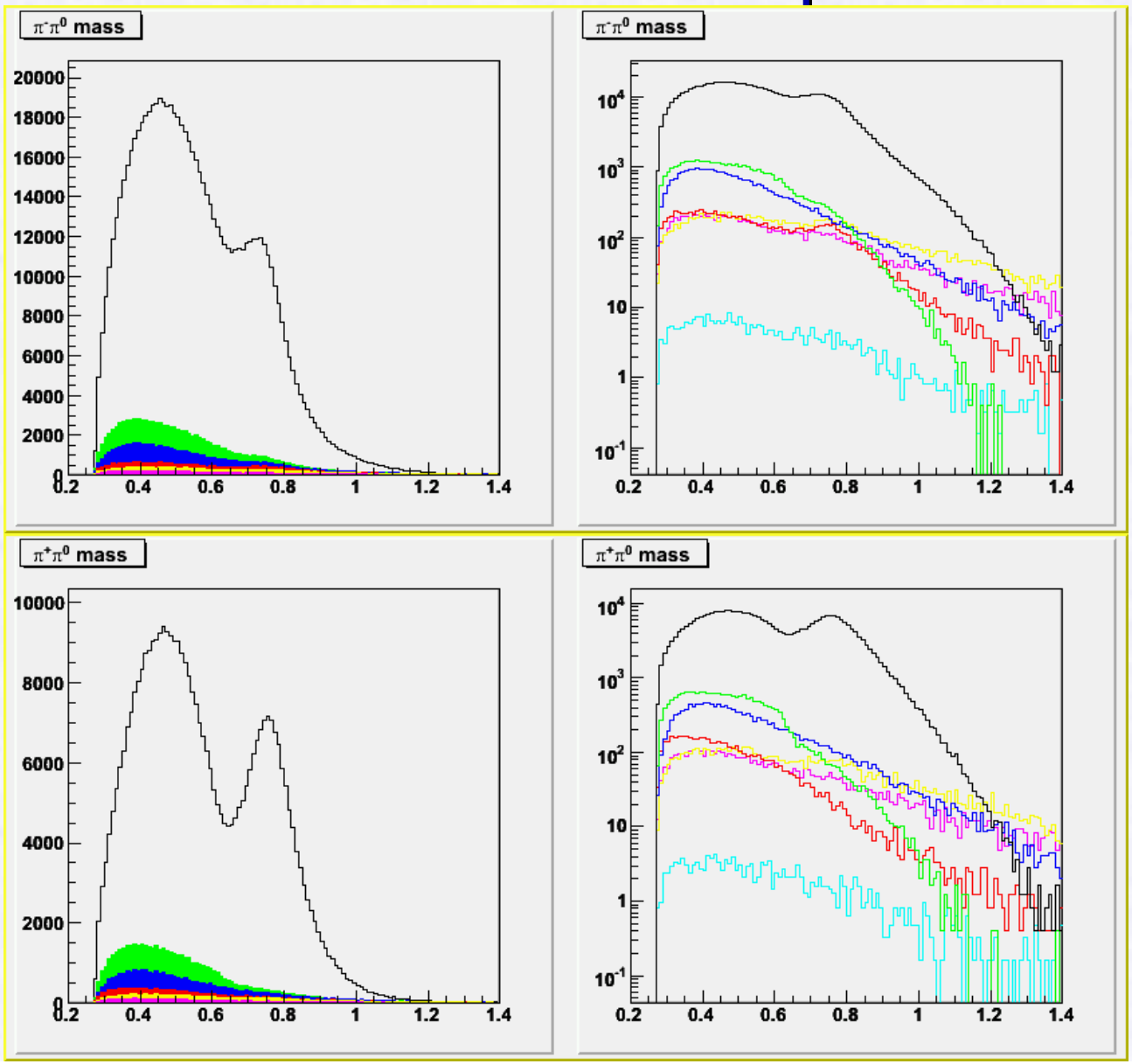
Monte-Carlo Mass spectra



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Current status and future plans

- Optimisation done, just need to do a couple of small tweaks before looking at data.
- Aiming to send branching fraction measurements/limits to Tau ’06 (September).
- Then plan to submit for publication.
- Intend to look at modes with charged kaons replacing pions.