Sensitivity improvements with hadronic energy fraction binning

NuMu group, Oct. 2016

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Version details

- Running in **S16-09-13**

- Using FD and ND NuMu decafs found here: /pnfs/nova/persistent/production/concat/R16-03-03-prod2reco.d/

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Outline

- All Sensitivities shown:
  - made with the SA NuMu (non max mixing) oscillation parameters
  - Include all NuMu systematics but not the cosmic background

- Sensitivity with cvn-remid hybrid selection & finer neutrino energy binning & Ehad frac binning

- Tune of cvn-remid hybrid selection
  - for contour area
  - for max mixing rejection

- Sensitivity with varying number of neutrino energy bins and 4 Ehad frac bins.

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Oscillation parameters

SetL(810);
SetRho(0); // No matter effects
SetDmsq21(7.59e-5);
SetDmsq32(2.6746e-3);
SetTh12(.601);
SetTh13(.1567);
SetdCP(0);
SetTh23(0.68696); // non max (ssqth23 = 0.4022)

CVN and ReMId hybrid selection

Kirk introduced a hybrid remid and cvn FD cut designed for efficiency studies in the FD:

```cpp
const Cut kKirkSATuneFD(
    {"sel.cosrej.anglekal", "sel.remid.pid","sel.cvn.numuid",
    "slc.nhit", "sel.nuecosrej.pngptp","sel.cosrej.numucontpid"},
    [](const caf::StandardRecord* sr)
      { return (sr->sel.remid.pid > 0.5
                && sr->sel.cvn.numuid > 0.5
                && sr->sel.cosrej.anglekal > 0.4
                && sr->slc.nhit < 400
                && sr->sel.nuecosrej.pngptp < 0.9
                && sr->sel.cosrej.numucontpid > 0.51);
      }
    );
```

I created a similar cut for the ND omitting the cosmic rejection and nhit cuts.

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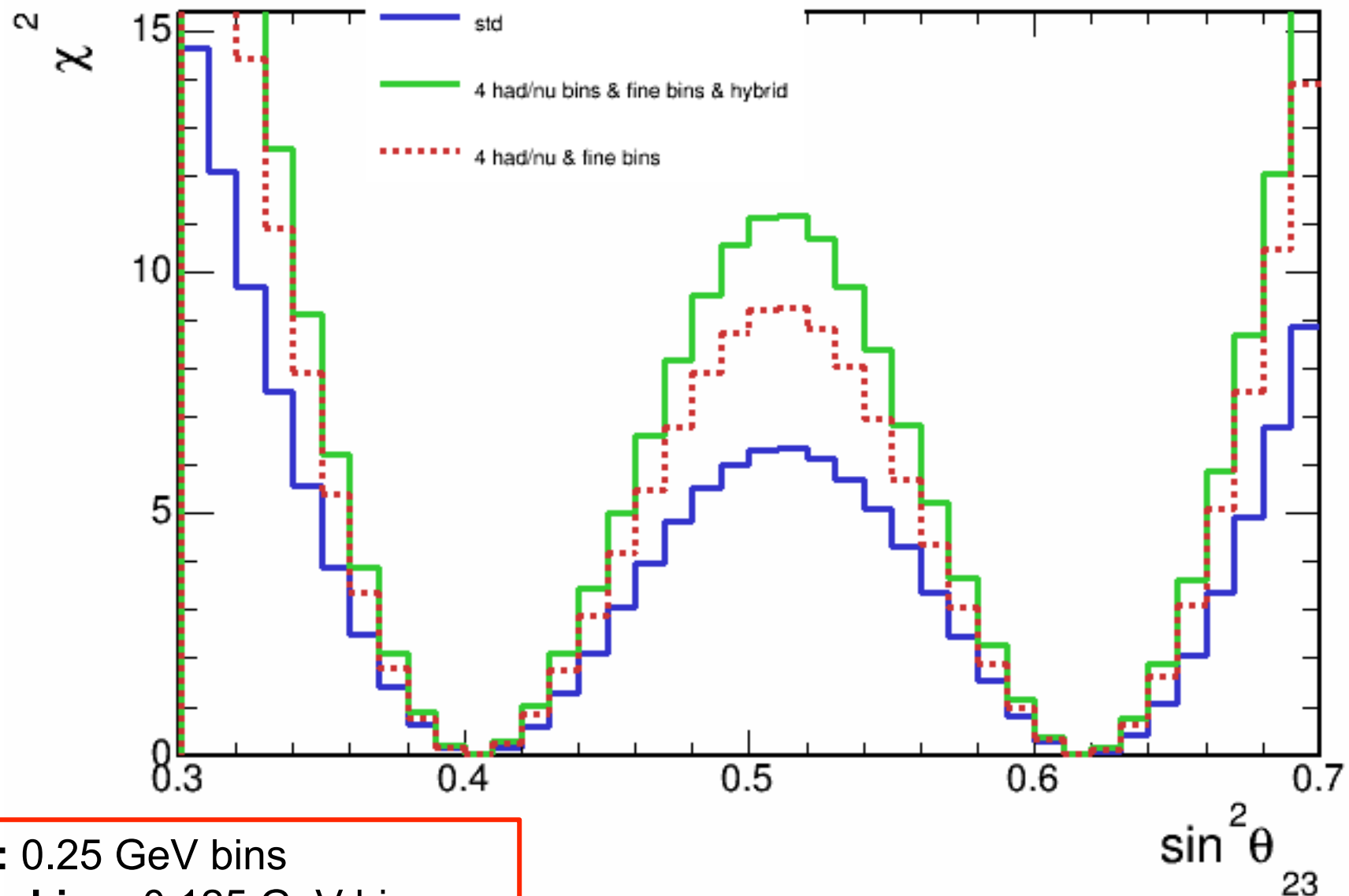
Contours with and without cosmic bkg
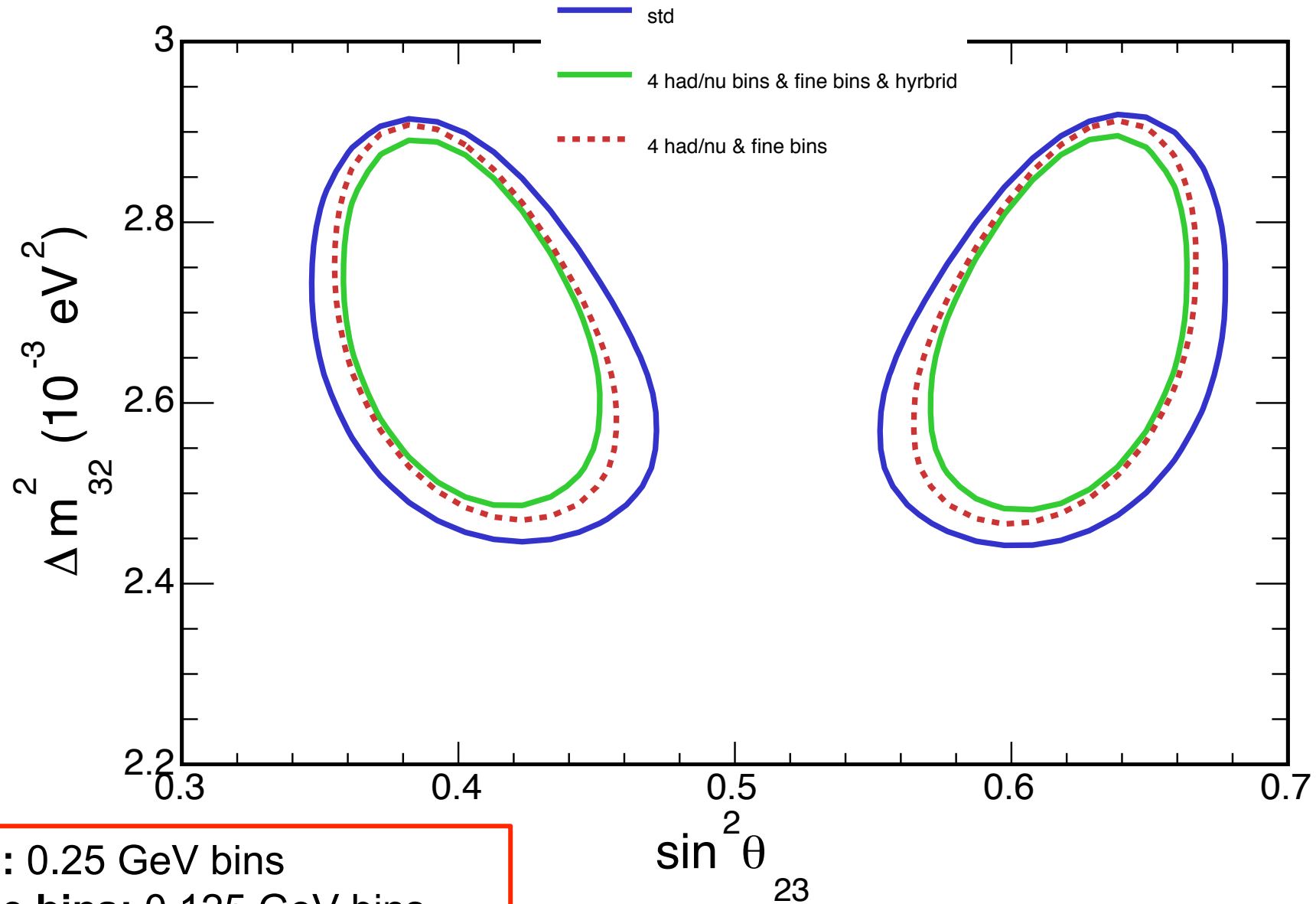
std: 0.25 GeV bins
Fine bins: 0.125 GeV bins
hybrid: remid & cvn selection

Contours with and without cosmic bkg

Rejection of max. mixing increased to **3.3** σ with combination of hybrid selection, finer energy binning and hybrid selection

std: 0.25 GeV bins
Fine bins: 0.125 GeV bins
**hybrid:** remid & cvn selection

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Optimising CVN and ReMId hybrid selection

Following plots are the result of making a std (no had. energy fraction binning) non-max mixing full-syst. sensitivity contour for each value of the remid and cvn cuts.

First, number of bins within the contour shows a approximation of the contour size.

Second, the rejection of maximal mixing is shown for each value of the remid and cvn cut.
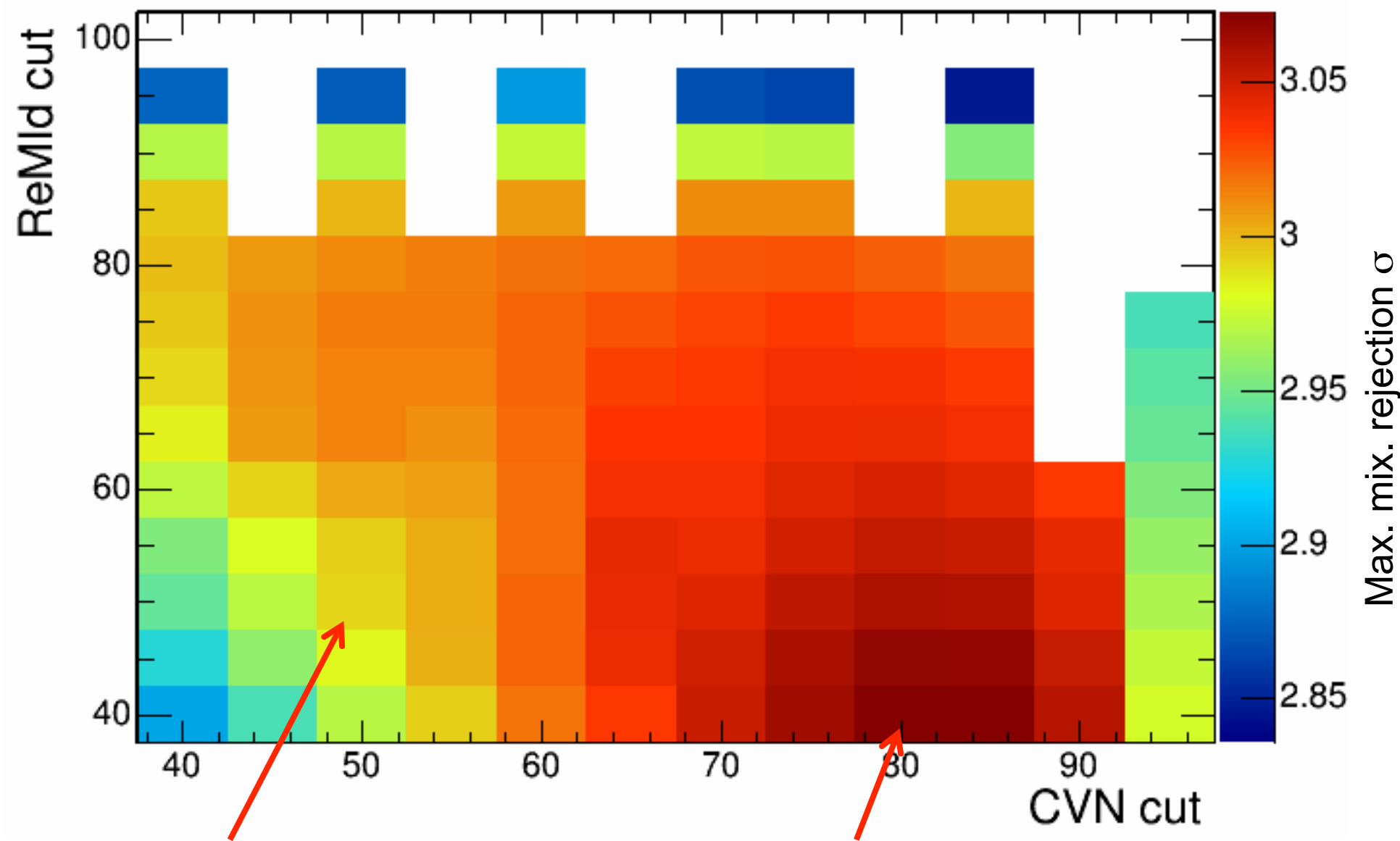
Number of bins within 90% C.L.
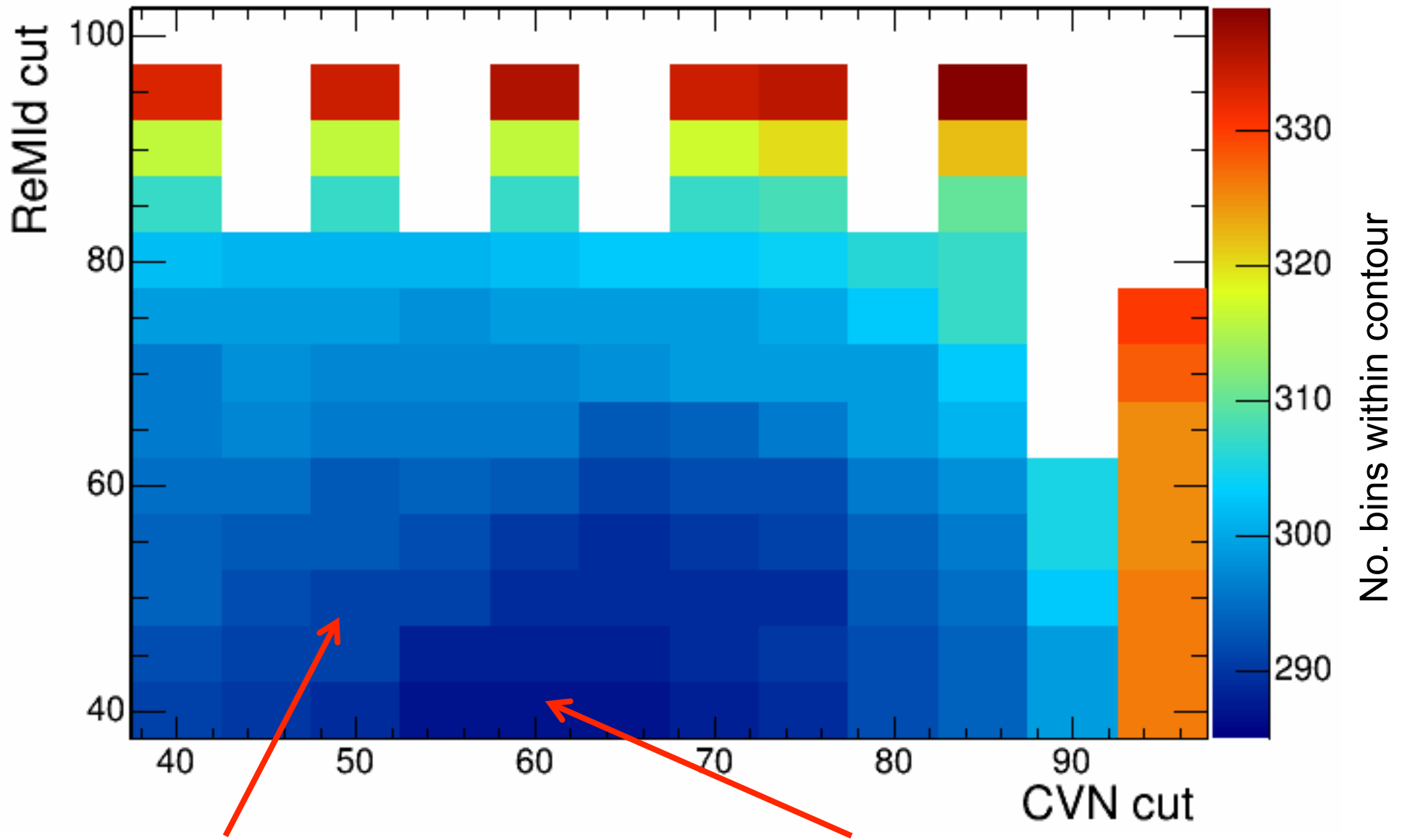
Current parameters used in tuned hybrid cut (291 bins)

Least number of bins within contour (287 bins)

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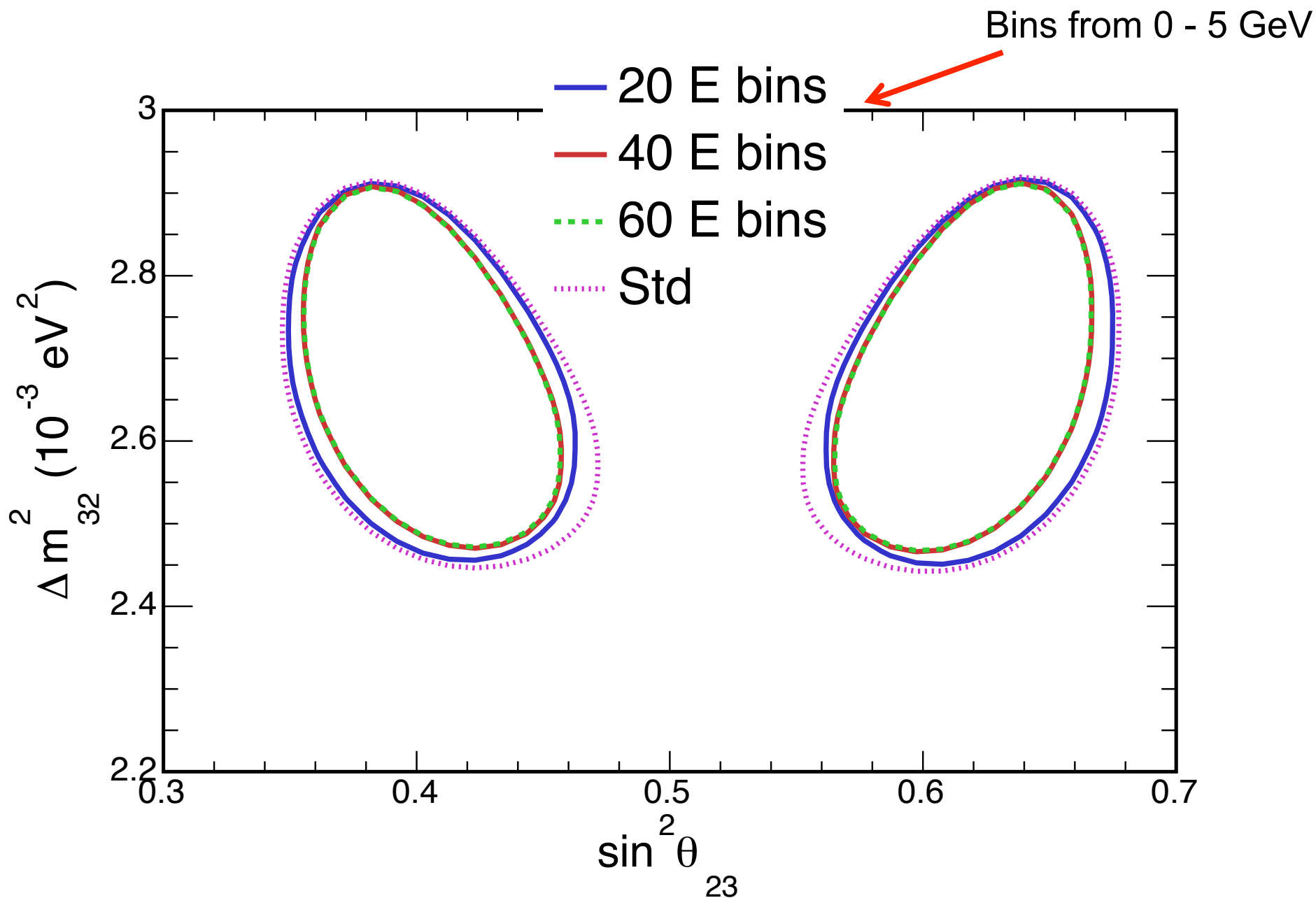
Sensitivity to reject maximal mixing

Current parameters used in tuned hybrid cut (2.992 σ)
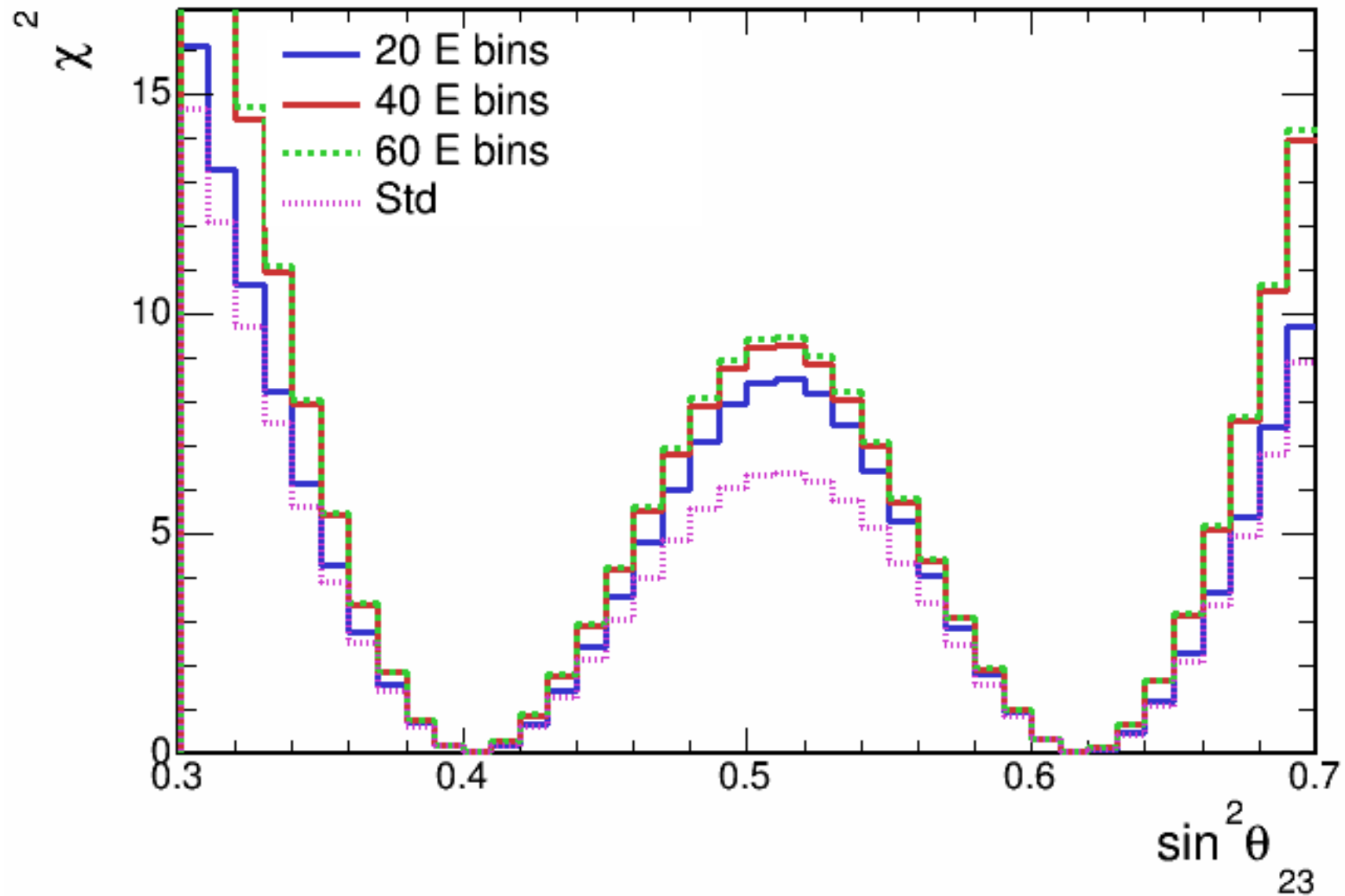
Largest maximal mixing rejection sensitivity (3.073 σ)

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4 had frac. bins
and
vary number neutrino energy bins
{20,40,60,80,120,160}

- We can use Ehad/Enu to divide our better and worse resolved events

- A finer binning would take advantage of the well resolved portion of events
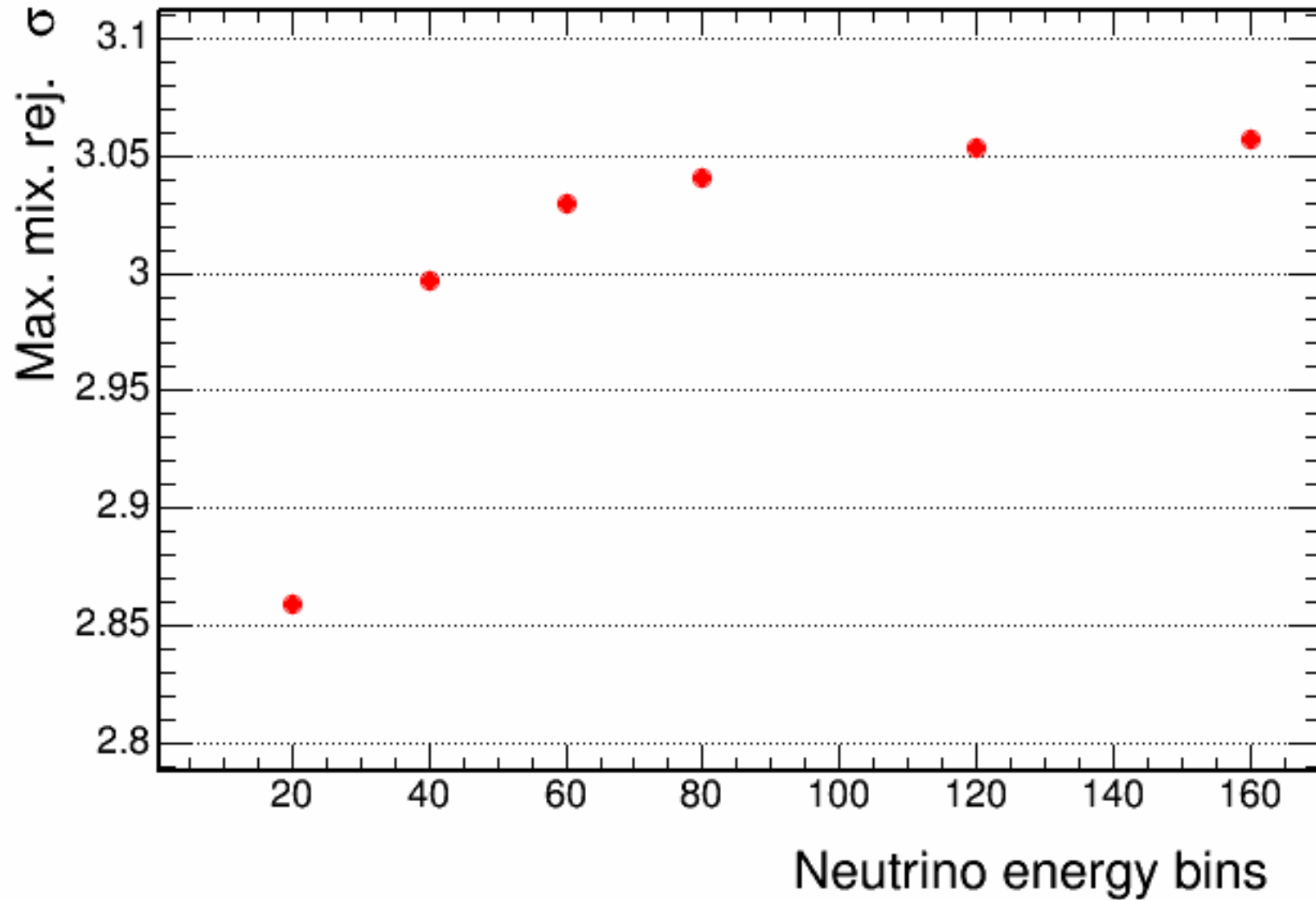
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Non-max mixing contours, 4 had frac bins

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Non-max mixing contours, 4 had frac bins

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# Non-max mixing contours, 4 had frac bins

Summary

- Using hybrid selection along with finer neutrino energy binning and had. frac binning increases sensitivity (at SA NuMu parameters) to reject maximal mixing to **3.3** σ
- Sensitivity to rejection of maximal mixing is fairly flat vs. the hybrid selection values
    - but would be slightly increased with adjustment (increase in max. mixing rejection of 0.08 σ)
    - "Optimal" value of cuts probably not shown, need to assess lower region of remid and cvn
- Rejection vs. number of neutrino energy bins shows that 50 or 60 neutrino energy bins is about optimal for rejection and computing time

Future plan

- Use variable neutrino energy binning and reduce number of bins
    - finer in most statistically powerful region
    - coarser in less powerful regions
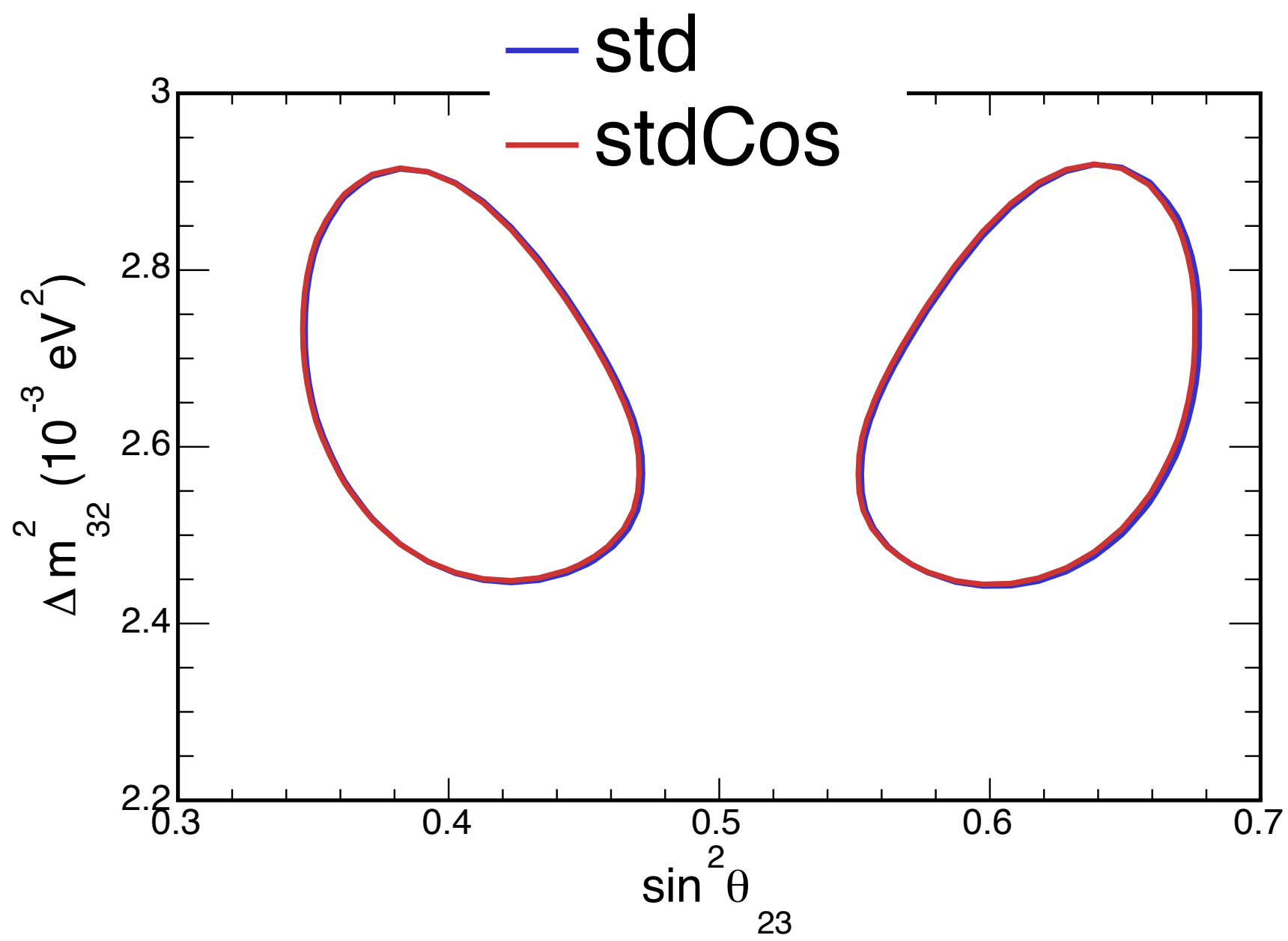   - optimise for 4 had frac divisions

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Backup

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Hadronic energy fraction vs. reco. energy

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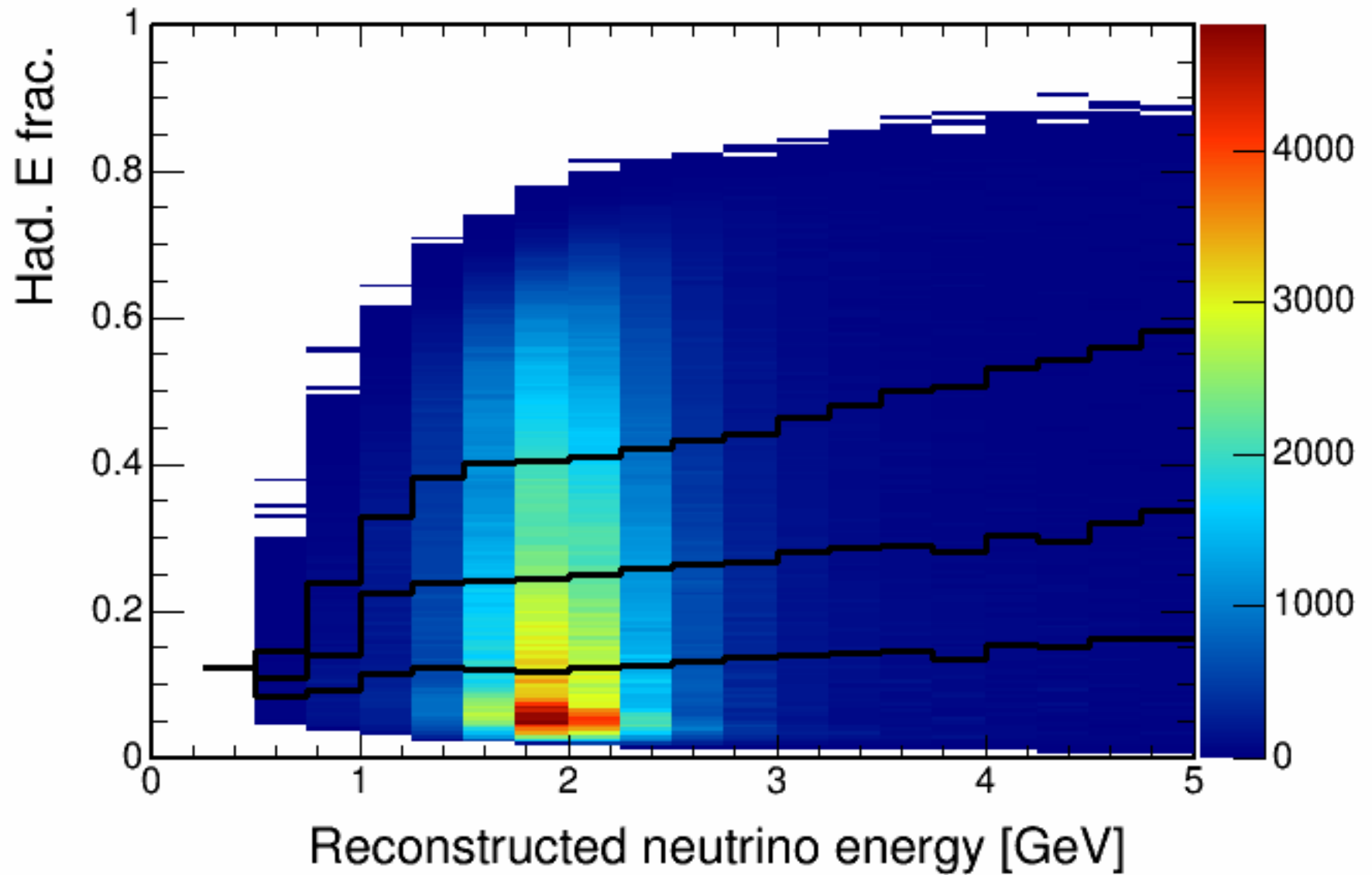
Cosmic background

Contours with and without cosmic bkg

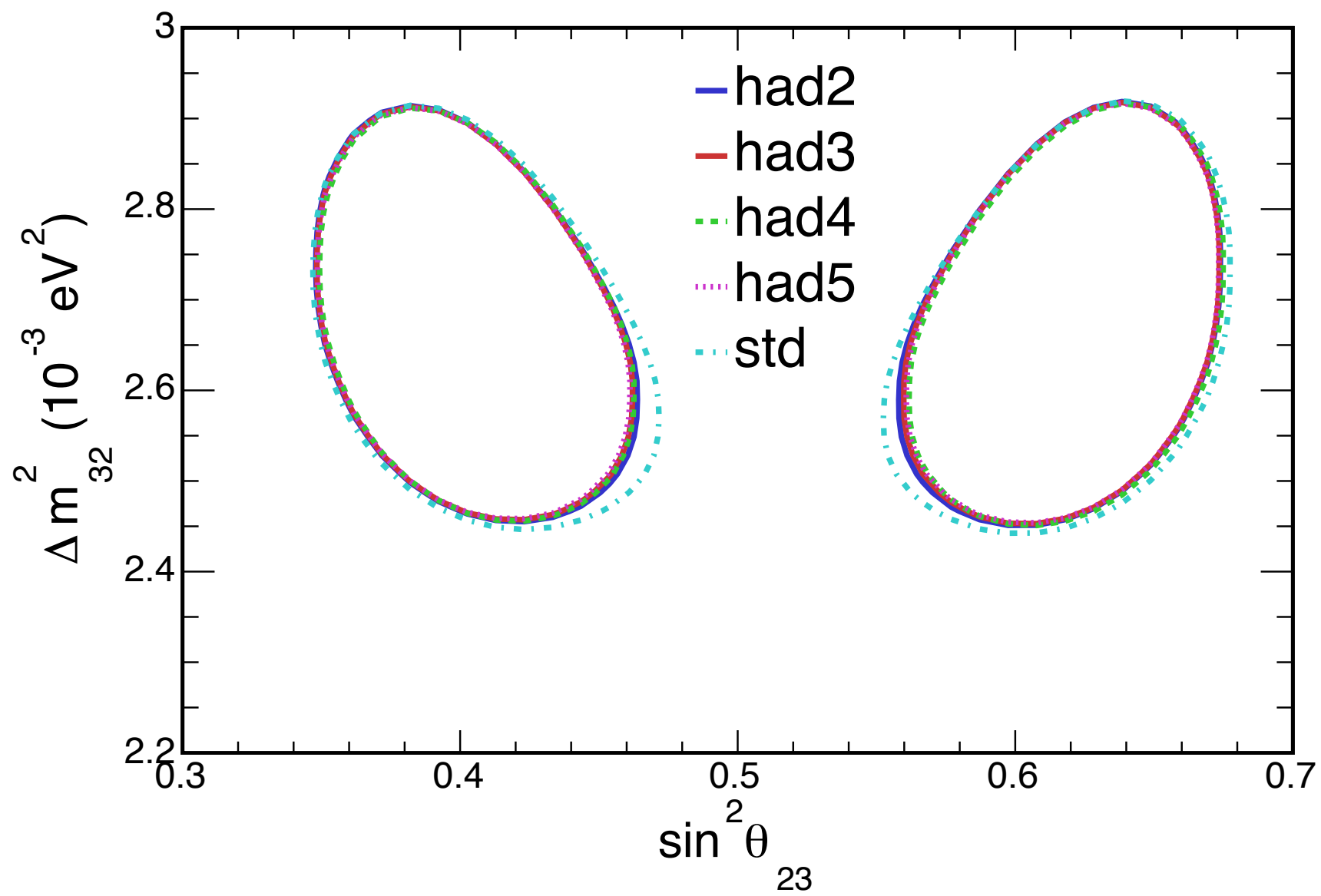# Contours with and without cosmic bkg

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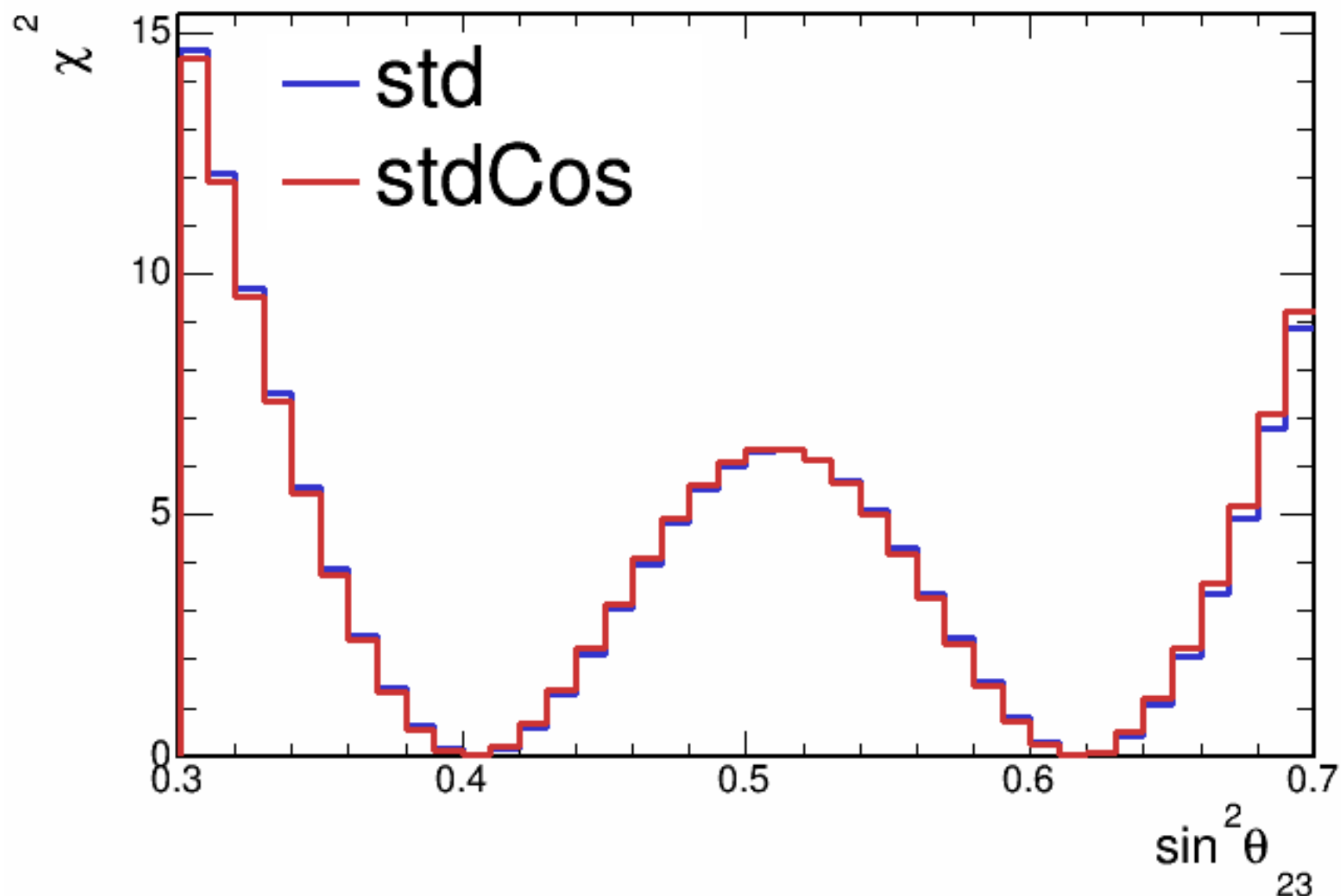
Hadronic energy fraction binning

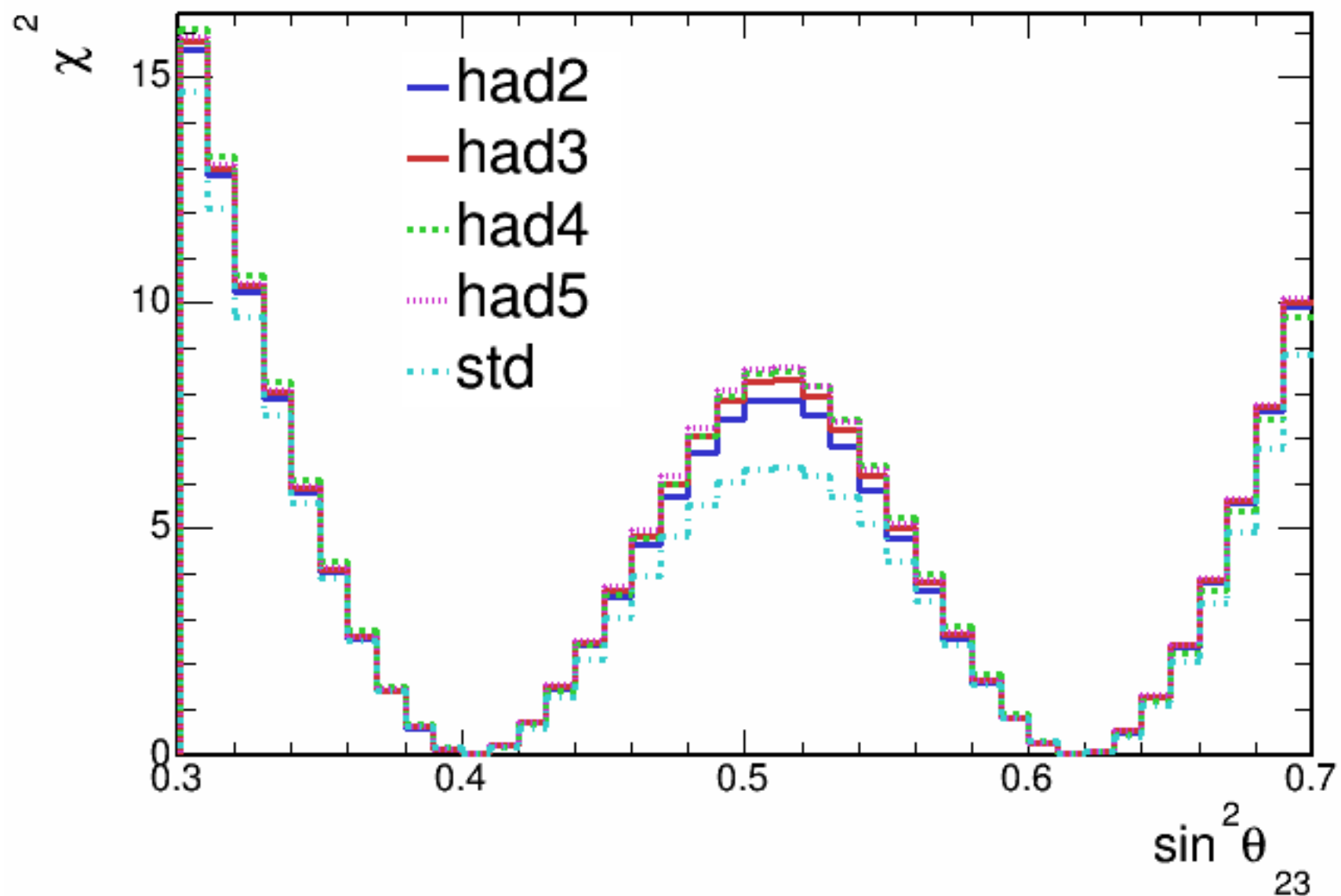Split events into hadronic energy quantiles

Quantiles made for each bin of reconstructed neutrino energy

Up next, sensitivities with events split into 2,3,4 and 5 hadronic energy fraction quantiles

Sensitivity with hadronic energy fraction binning

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Sensitivity with hadronic energy fraction binning

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Sensitivity with hadronic energy fraction binning

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