

Joint T2K and reactor experiments analysis within VALOR

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Overview

- Motivation
- Study with Double Chooz inputs
 - $\sin^2 \theta_{13}$ 1D fit study
 - δ_{CP} 1D fit study
- Study with Daya Bay inputs
 - $|\Delta m_{32}^2| \times \sin^2 \theta_{13}$ 2D fit study
- Future plans
- Summary
- Comments on the talk

Motivation

What is used now:

- The penalty term used in current analysis is gaussian (i.e. “symmetric”)

Proposed idea:

- Combine likelihood surface from T2K and reactor experiment
 - More accurate analysis
(reactor likelihood is not exactly symmetric)
- Take advantage of reactor experiments being sensitive to $|\Delta m_{32}^2|$

Double Chooz (DC): Fit features

- Two ways of taking into account reactor constraint:
 - Penalty term using mean and sigma from reactor experiment best fit (same as current analysis, but using DC instead of PDG average)

- $L_{T2K} + L_{Reactor}$

i.e. get χ^2 directly from reactor experiment likelihood surface and sum with T2K one

- 1D likelihood surface ($L_{Reactor}(\theta_{13})$)
- 2D likelihood surface ($L_{Reactor}(\theta_{13}, \Delta m_{32}^2)$)

- Converting $\Delta m_{ee}^2 \rightarrow \Delta m_{32}^2$

$$\Delta m_{ee}^2 \simeq \cos^2 \theta_{12} |\Delta m_{31}^2| + \sin^2 \theta_{12} |\Delta m_{32}^2|$$

$$|\Delta m_{32}^2| \simeq |\Delta m_{ee}^2| \mp 5.2 \times 10^{-5} eV^2$$

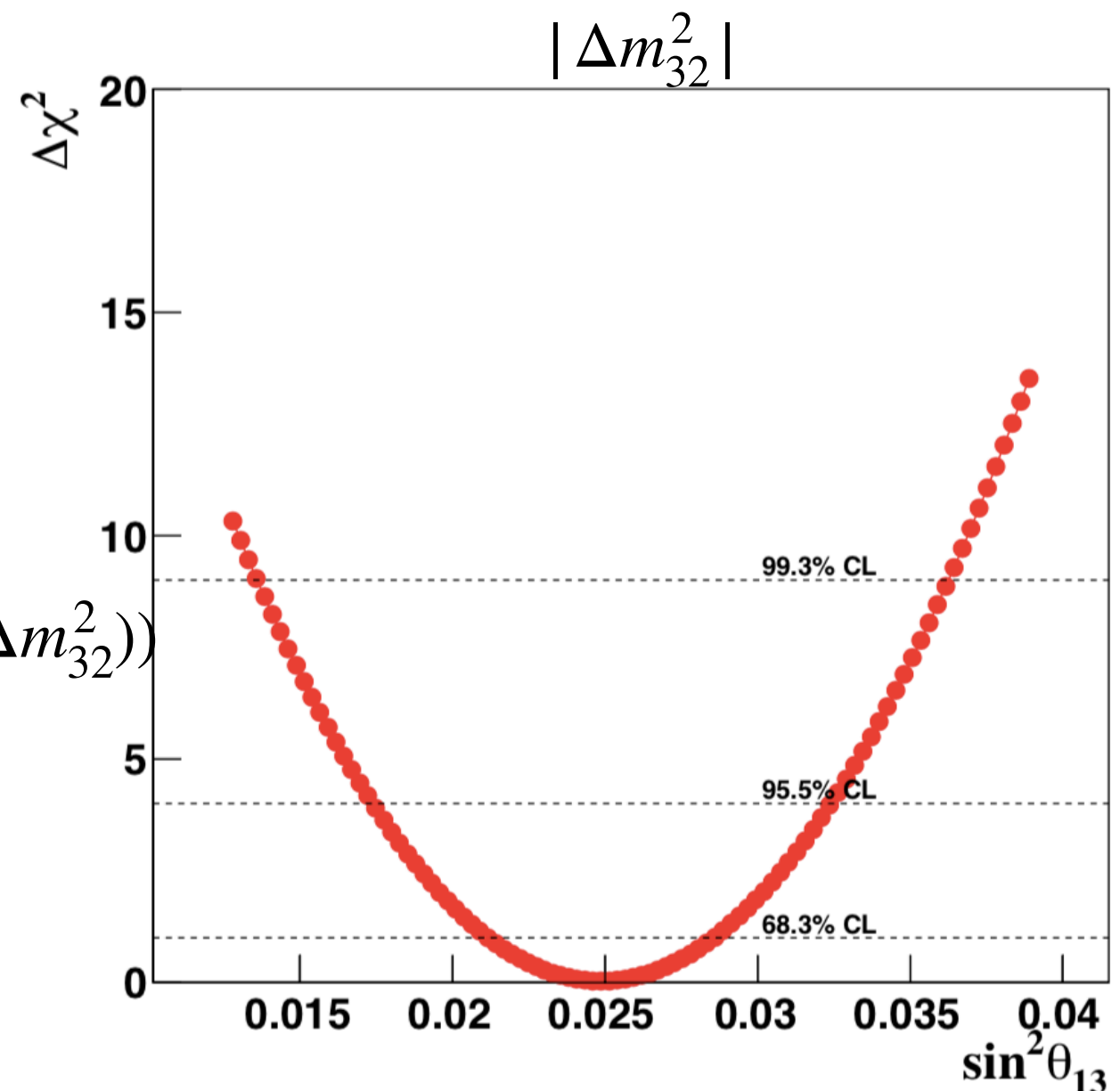
assuming NH (upper sign) or IH (lower sign)

DC best-fit values:

$$\sin^2 \theta_{13} = 0.025 \pm 0.005$$

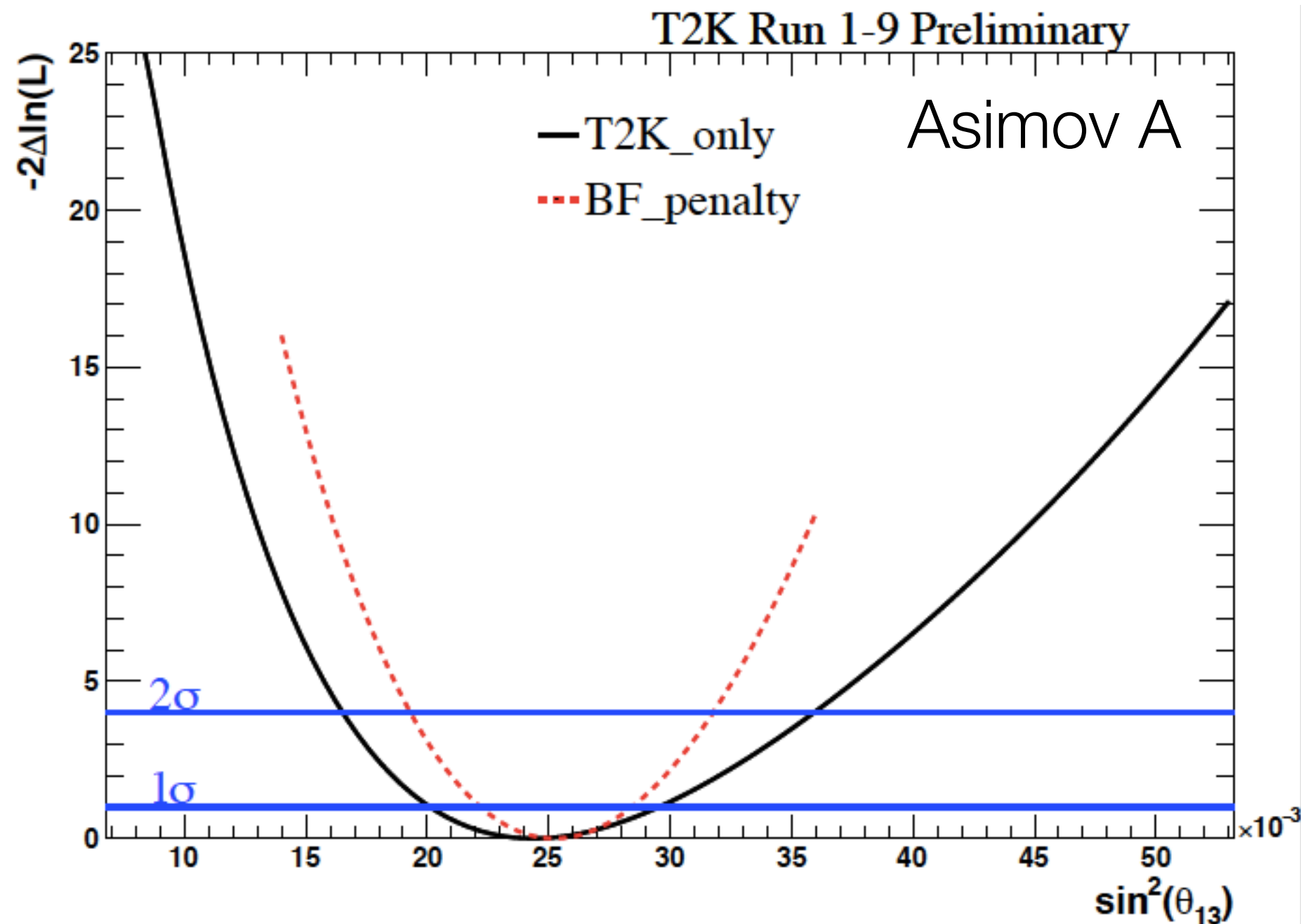
$$|\Delta m_{32}^2| = (2.58 \pm 0.46) \times 10^{-3} eV^2$$

Used DC likelihood surface with fixed



T2K only vs. T2K+ DC BF

- T2K-only fit :
 - μ 0.024
 - 1σ interval
[0.021;0.029]
- T2K + DC BF
penalty fit
 - μ 0.025
 - 1σ interval
[0.022;0.028]



T2K only vs. T2K+DC 1D

- T2K-only fit :

- μ 0.024

- 1σ interval

[0.021;0.029]

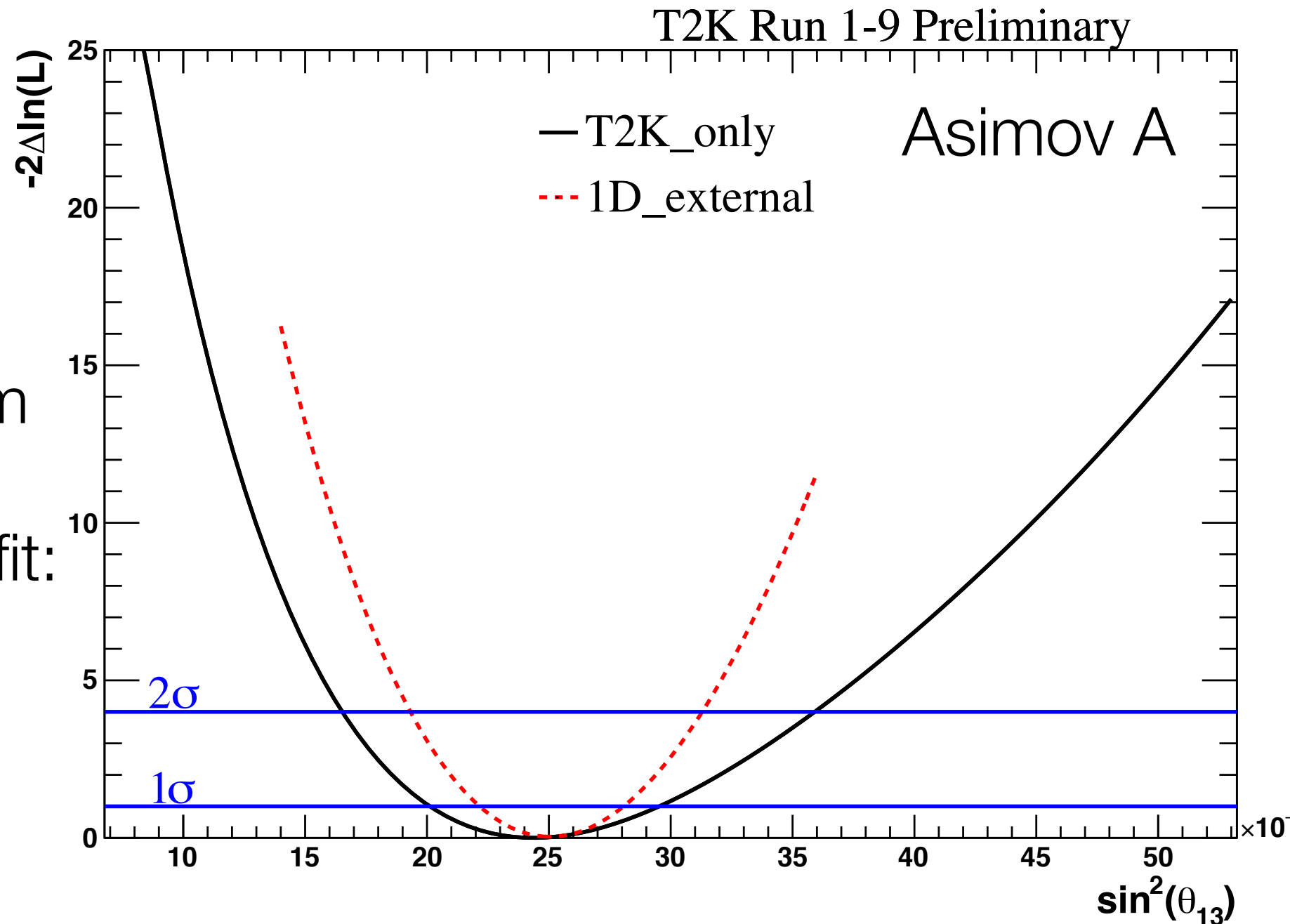
- T2K + penalty term
from DC 1D
likelihood surface fit:

- μ 0.025

- 1σ interval

[0.022;0.028]

- Denoted : 1D_external



T2K+DC 1D vs. T2K+ DC BF

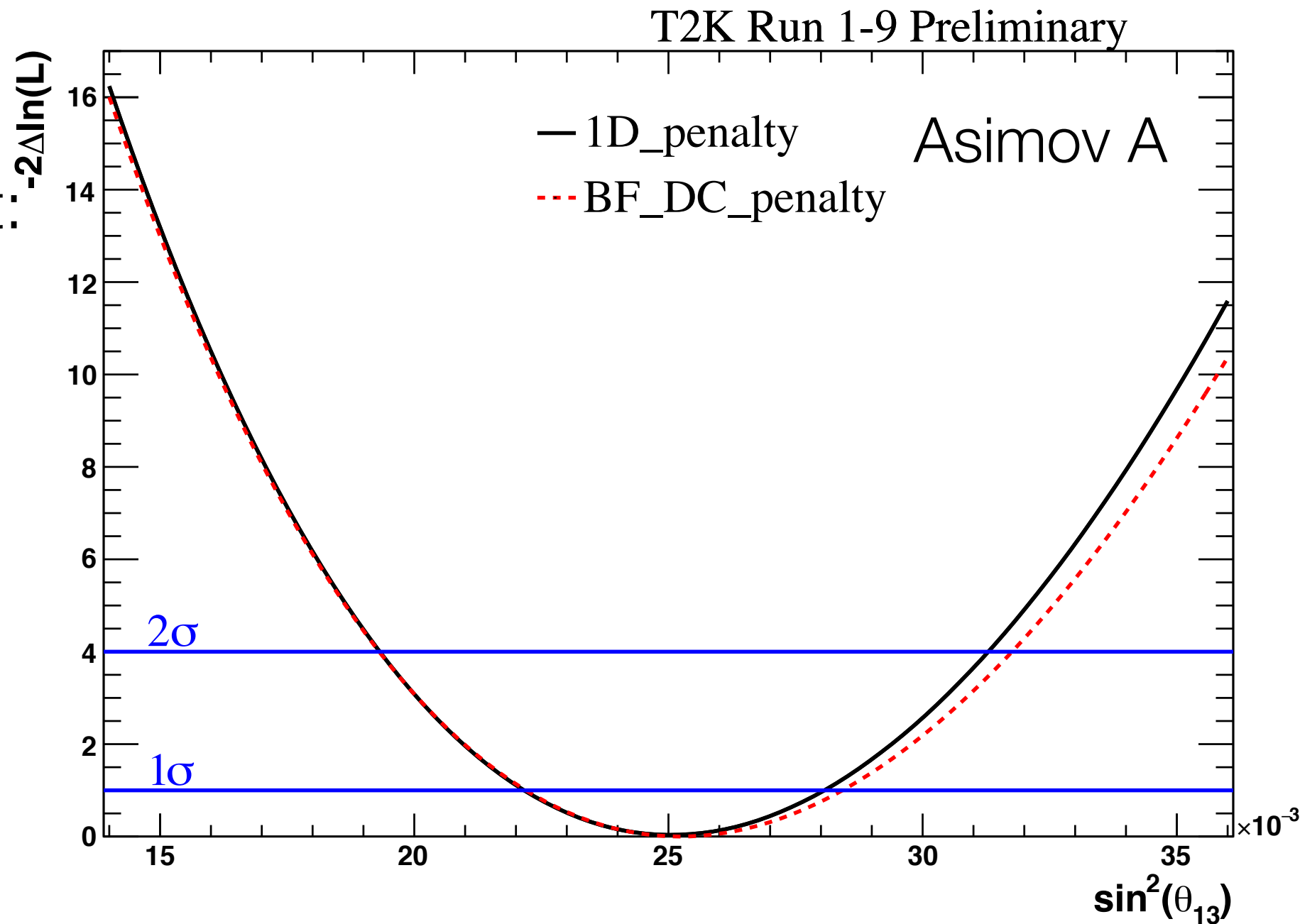
- T2K + penalty term from DC 1D likelihood surface fit:

- μ 0.025
- 1σ interval [0.022;0.028]
- Denoted: 1D penalty

- T2K + DC BF penalty fit:

- μ 0.025
- 1σ interval [0.022;0.028]

- Denoted : BF_DC_penalty

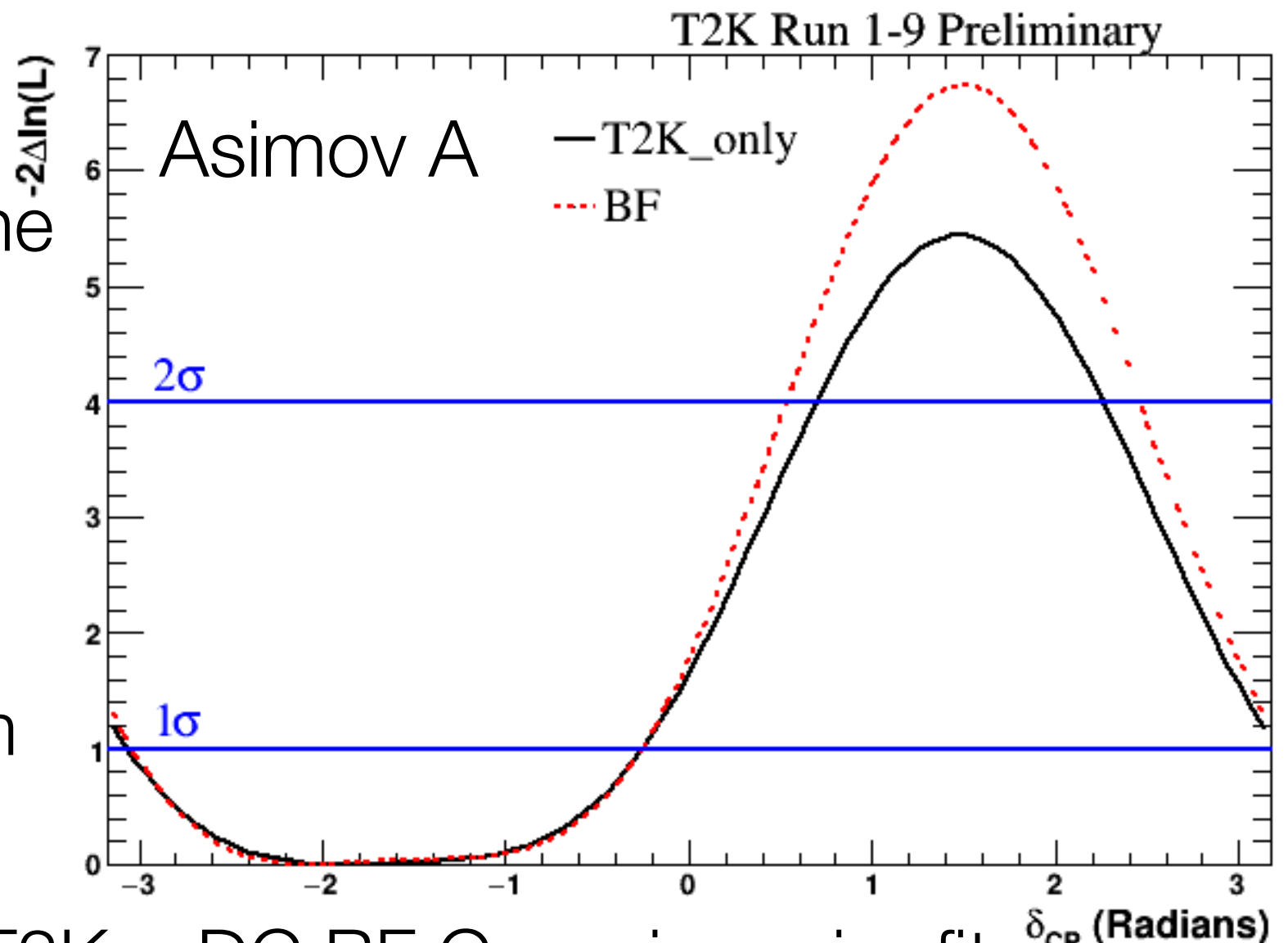


T2K only vs. T2K + DC BF based prior

δ_{CP} study:

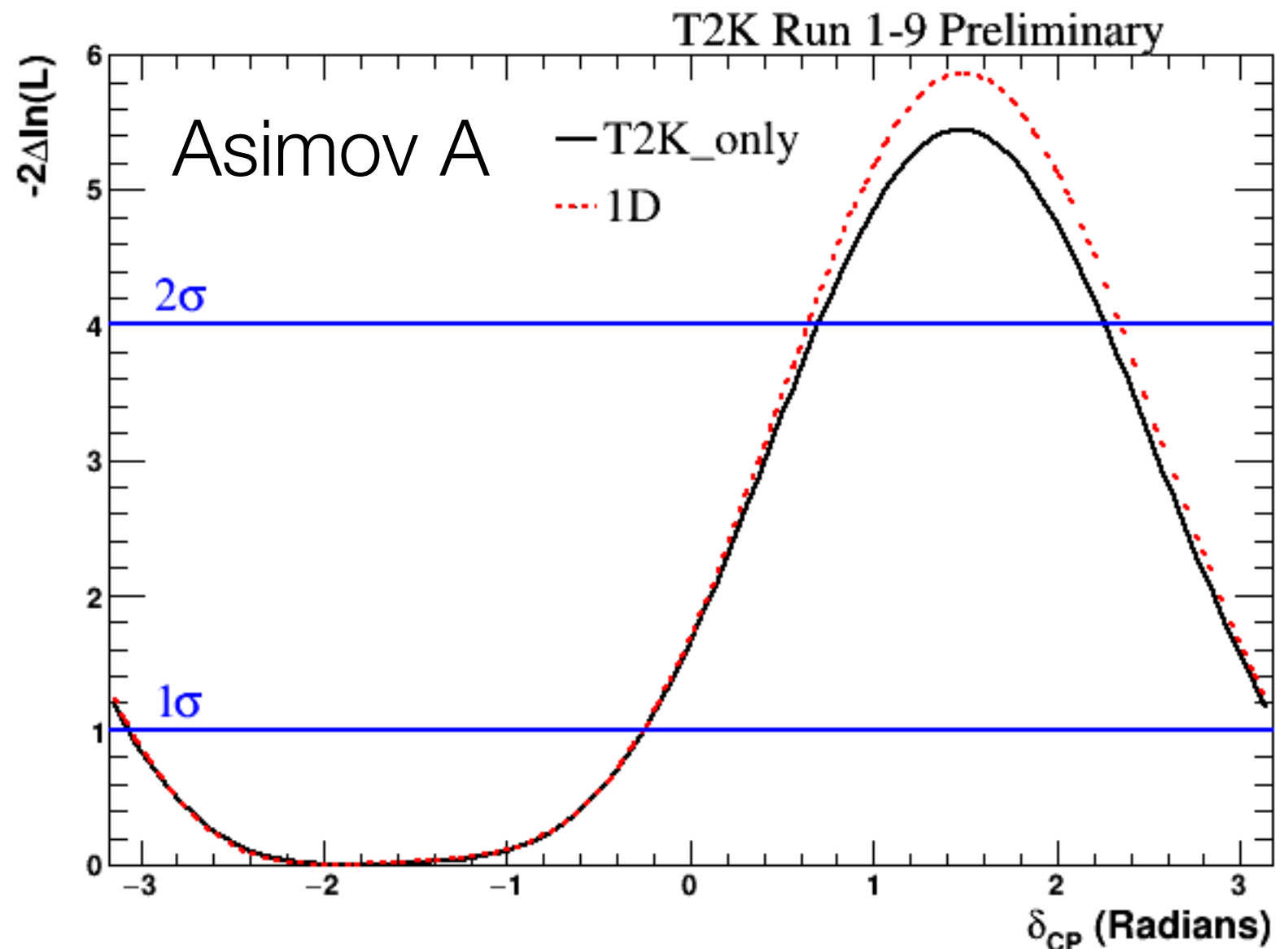
- Use different priors for the Theta 13:
 - Gaussian prior based on BF value from reactor experiment
 - Non-Gaussian prior - likelihood surface from reactor experiment
- T2K-only fit:
 - μ -1.88
 - 1σ interval [-3.10;-0.25]

- T2K + DC BF Gaussian prior fit:
 - μ -2.07
 - 1σ interval [-3.10;-0.25]



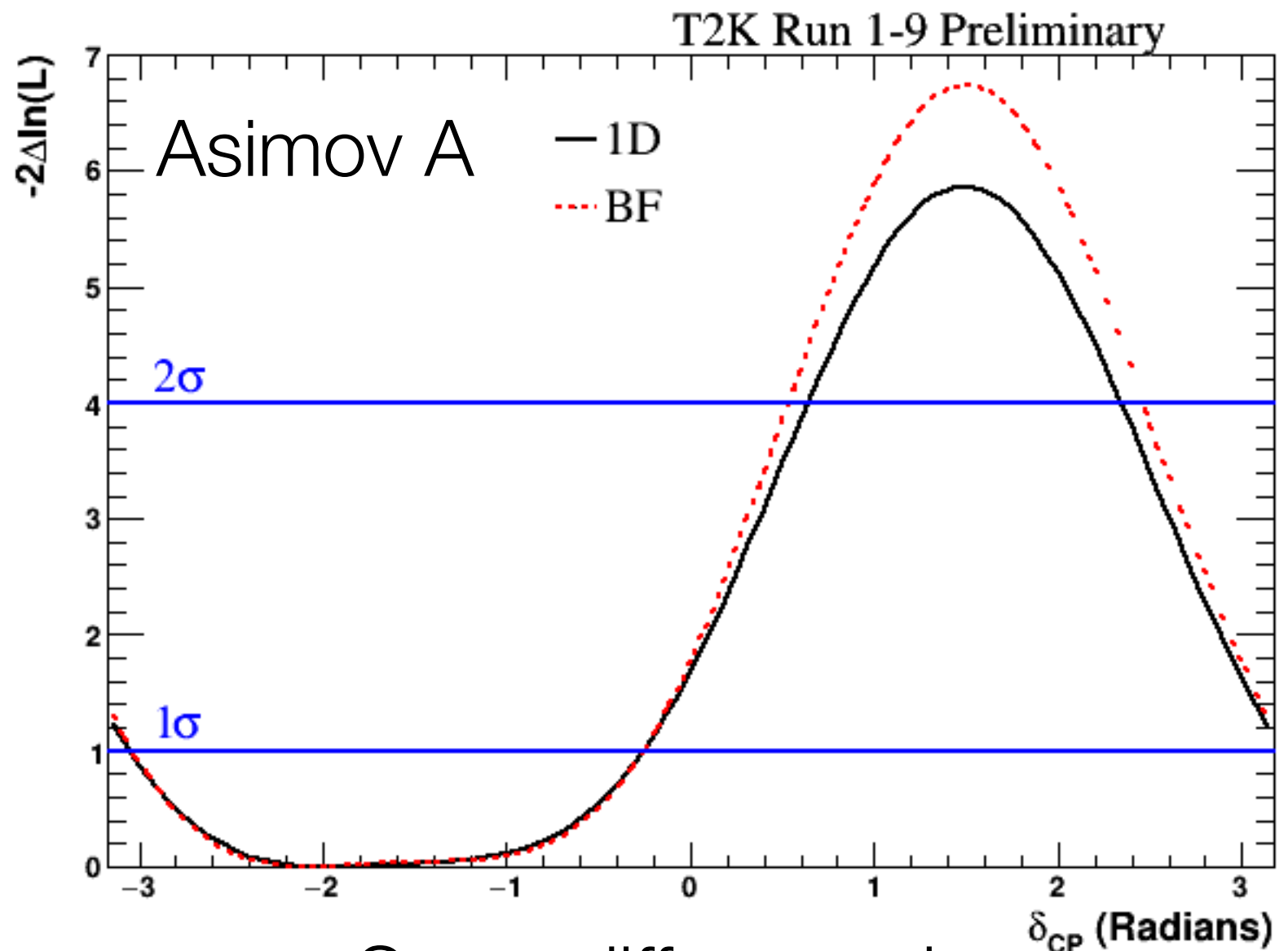
T2K only vs. T2K +DC 1D based prior

- T2K-only fit::
 - μ -1.88
 - 1σ interval
[-3.10;-0.25]
- T2K + DC 1D likelihood surface as a prior fit:
 - μ -1.94
 - 1σ interval
[-3.11;-0.26]



T2K + DC 1D based prior vs. T2K + DC BF based prior

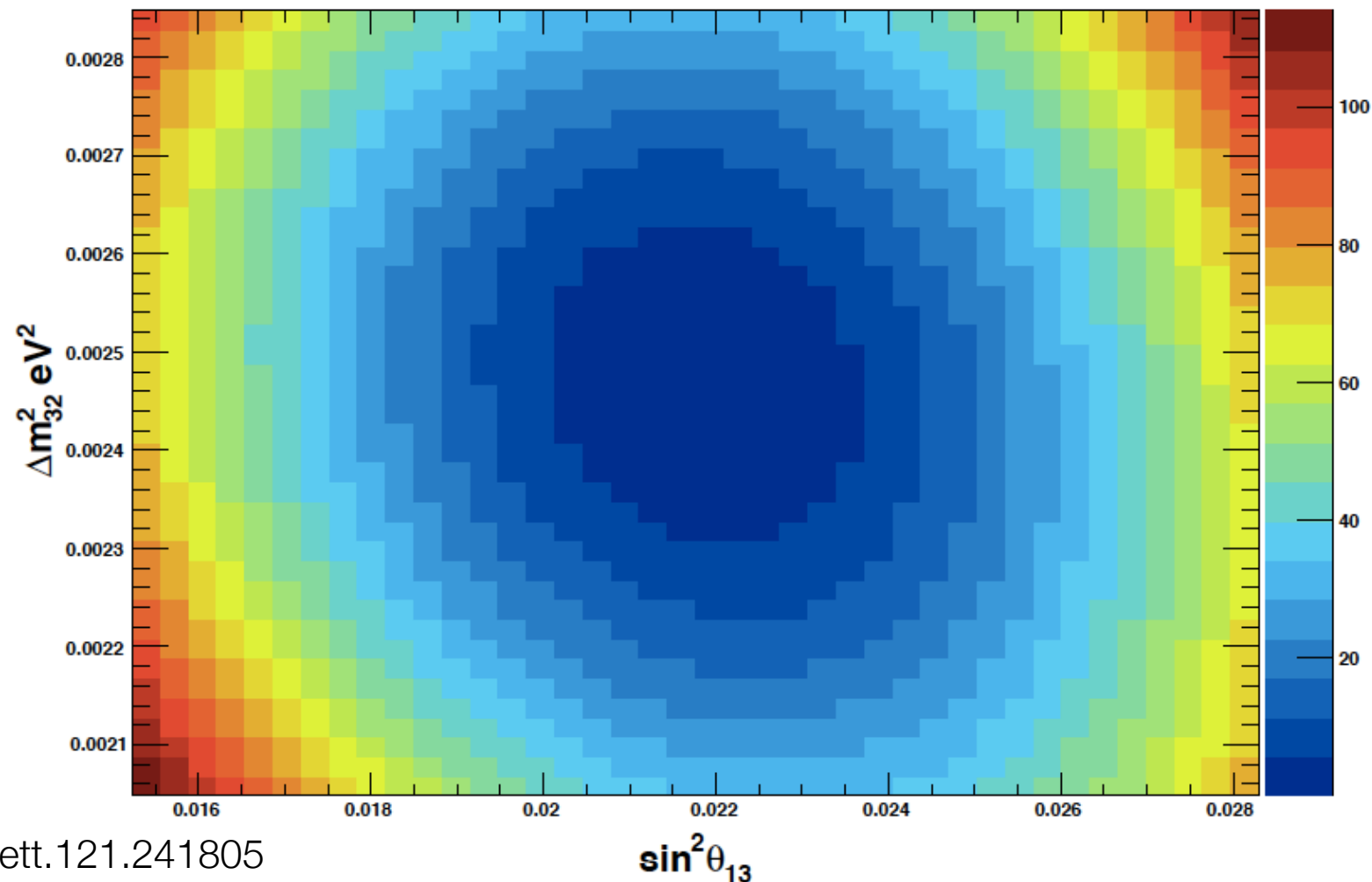
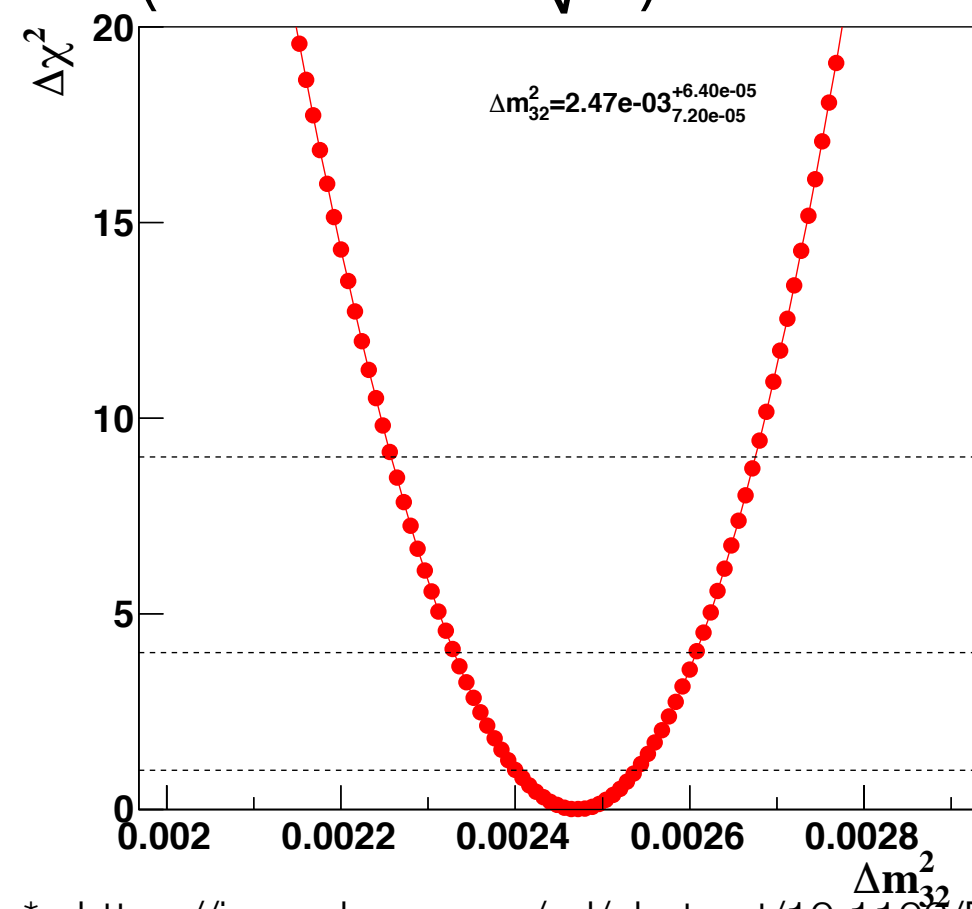
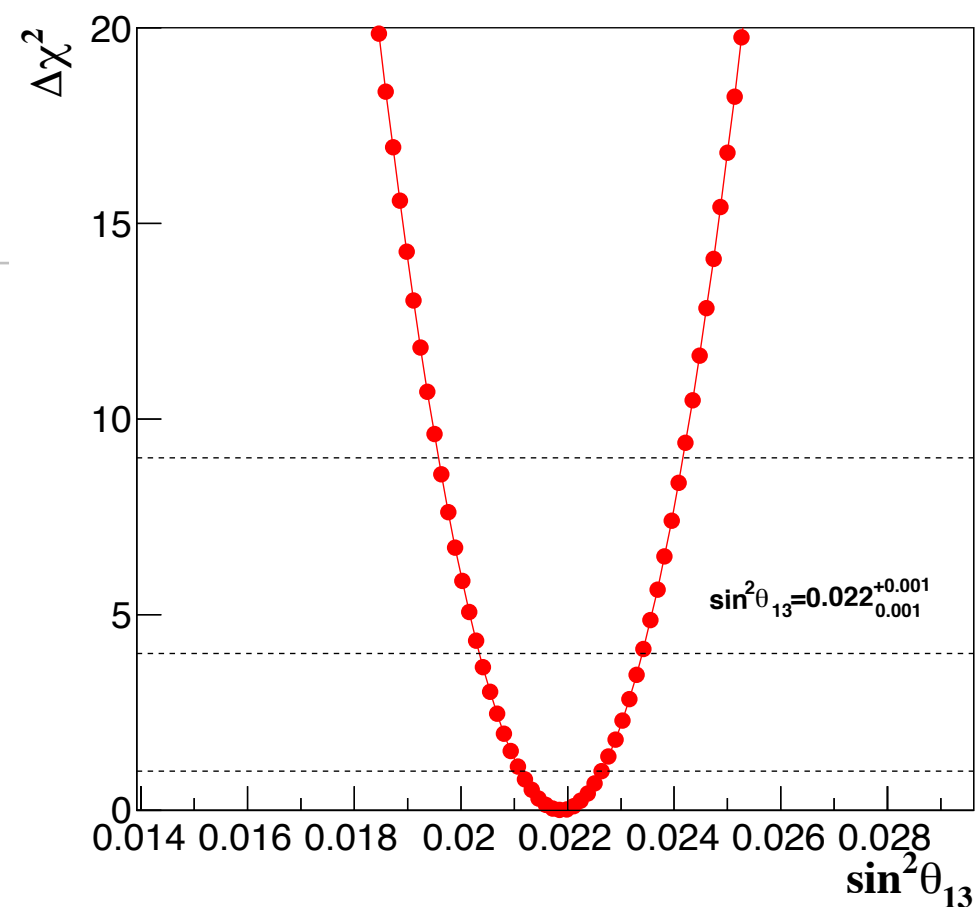
- T2K + DC 1D likelihood surface as a prior fit:
 - μ -1.94
 - 1σ interval
[-3.11;-0.26]
- T2K + DC BF Gaussian prior fit:
 - μ -2.07
 - 1σ interval
[-3.10;-0.25]



Same difference in
behaviour as for the
fits $\sin^2 \theta_{13}$

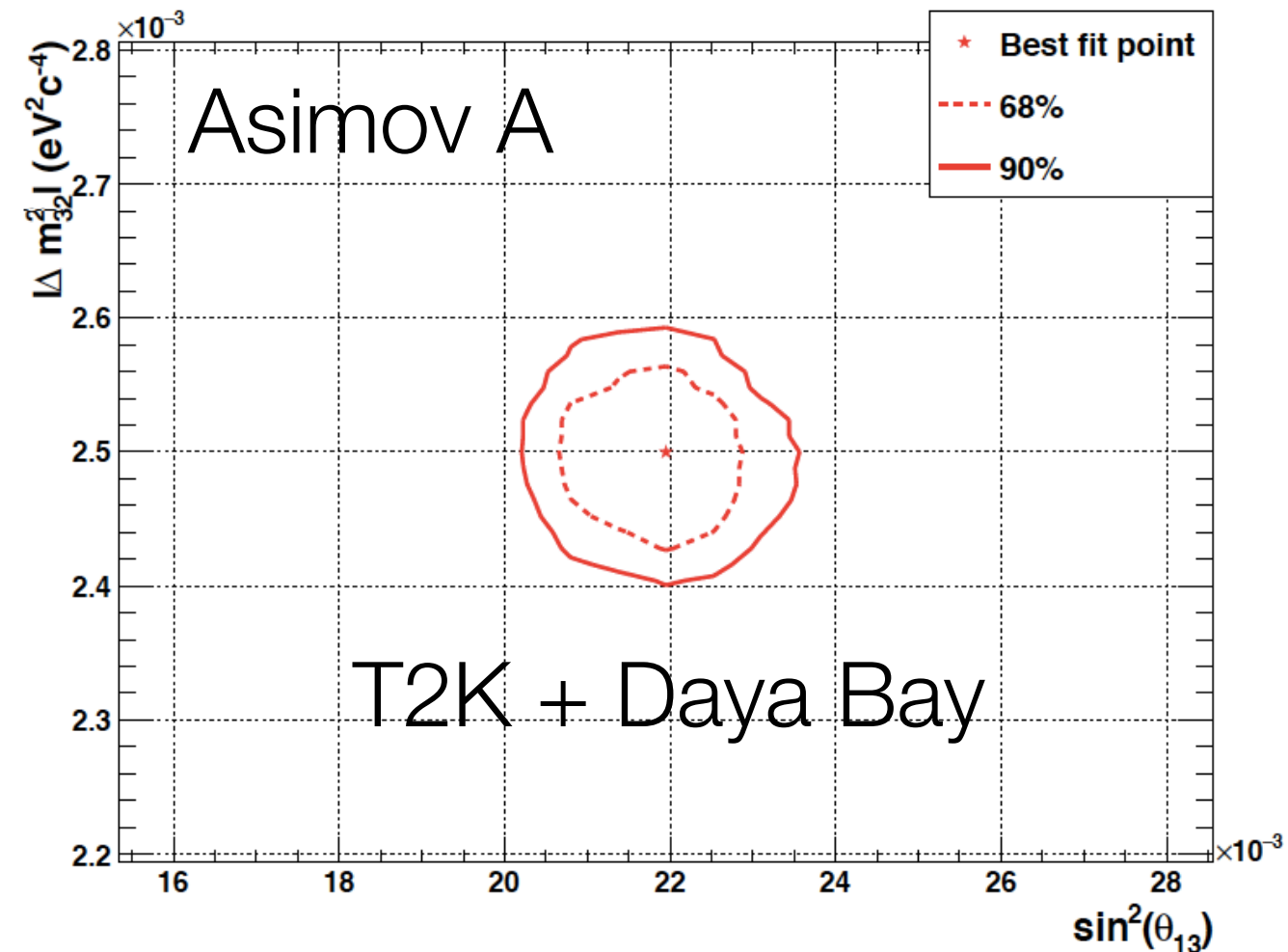
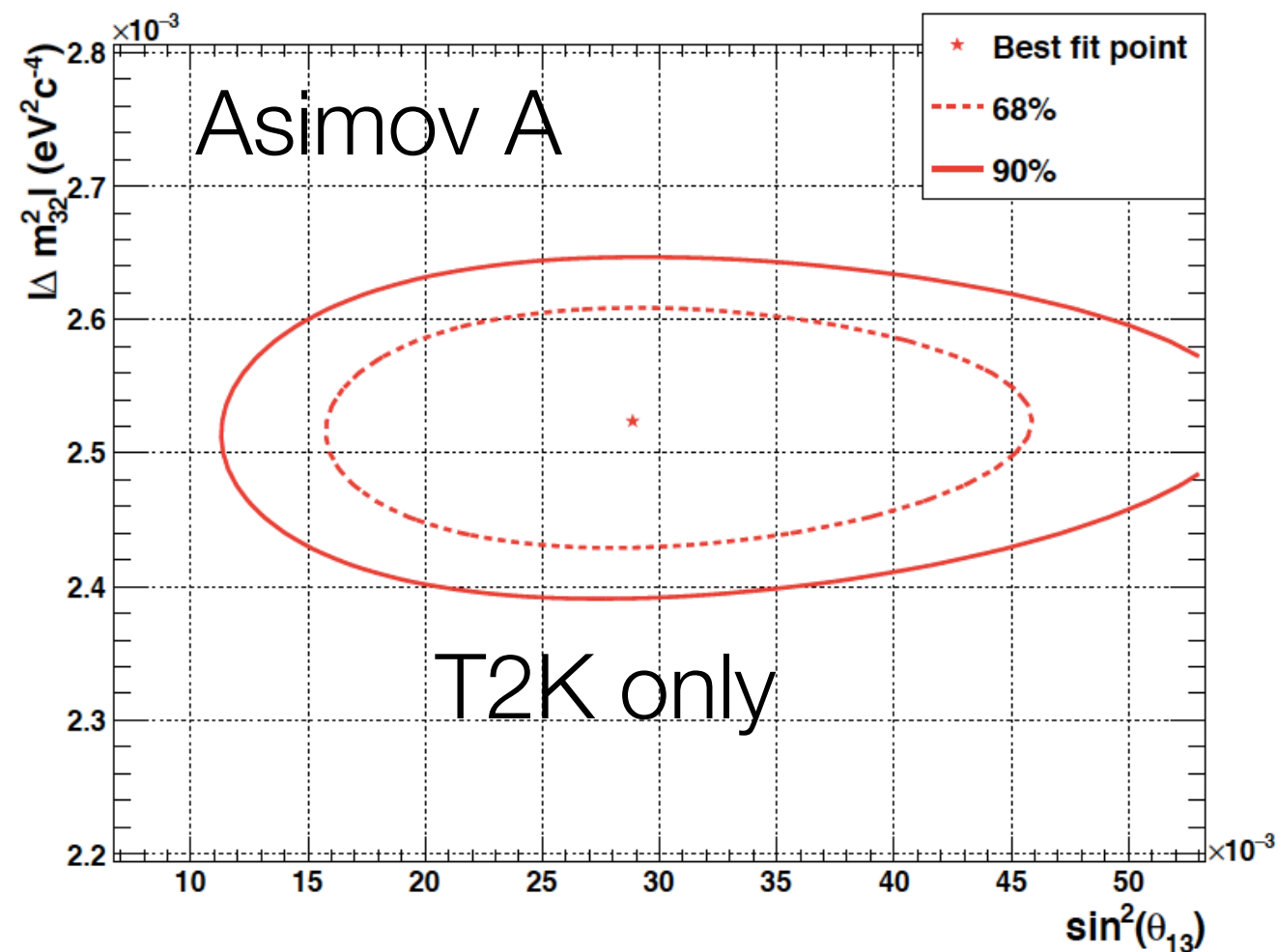
Daya Bay 2D fit

- χ^2 surface based on official Daya Bay data release *
- Better precision on $\sin^2 \theta_{13}$
- Improving accuracy for $|\Delta m_{32}^2|$ (at least $\sim \sqrt{2}$)



* <https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.121.241805>

T2K only vs T2K + DB 2D likelihood surface



- Improvement in the BF value
- Will do comparison with gaussian priors (to be shown at next OA meeting)
- Here may be a problem in T2K only fit -> to be investigated

- T2K-only fit :
 $\sin^2 \theta_{13} = 0.028$
 $\Delta m_{32}^2 = 2.52 \times 10^{-3} \text{eV}^2$
- T2K + DB penalty fit :
 $\sin^2 \theta_{13} = 0.022$
 $\Delta m_{32}^2 = 2.5 \times 10^{-3} \text{eV}^2$

Further steps

- Check the impact on δ_{CP} using Daya Bay inputs
- Repeat T2K + Daya Bay analysis for IH
- Focus on the validating new VALOR framework
- Try to implement Daya Bay analysis based on released data within that framework

Summary

- A combined T2K+Reactor-experiments fit implemented within VALOR
- Rather than applying a gaussian penalty term (official approach), likelihoods are combined
- This new approach accounts for the fact that reactor likelihoods are not symmetric (unlike gaussian penalty term)
- It also takes advantage of the sensitivity to $|\Delta m_{32}^2|$ in reactor experiments:
$$L_{Reactor} = L(\theta_{13}, \Delta m_{32}^2)$$
- The implementation has been validated with Double Chooz likelihood (comparison of different approaches)
- A combined T2K + Daya Bay analysis is currently being performed (preliminary results presented)
 - results on θ_{13} consistent with official approach (expected)
 - significant improvement in $|\Delta m_{32}^2|$ precision (as expected, $\sim \sqrt{2}$)
 - impact on δ_{CP} ?

Comments on the talk

- Suggest fits:
 - 1D and 2D fits comparison for T2K+PDG vs. T2K+DB
- P-theta and MaCH3 are interested in performing the same study
- Nakajima-san used to work in DayaBay -> willing to answer any of our question related on DB analysis procedure