Double Chooz results at the double detector phase

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on behalf of the Double Chooz Collaboration

Neutrino Oscillation Workshop 2018
Rosa Marina, Ostuni / Italy

HIGHLIGHTS

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-> Double Chooz Near+Far results

(as presented at Neutrino 2018)

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-> First ND measurement of MCSpF (world-best to date)

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-> Spectral bump discussion

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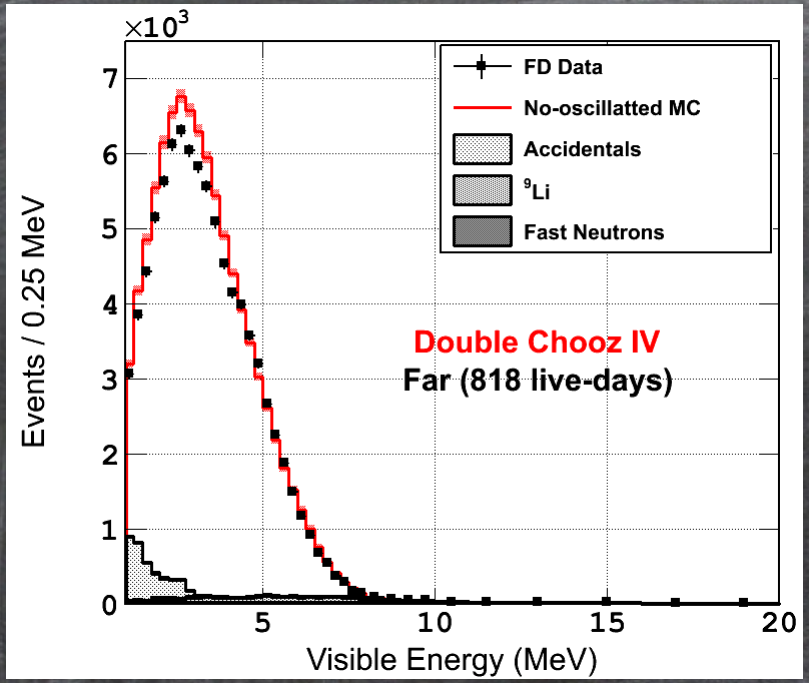
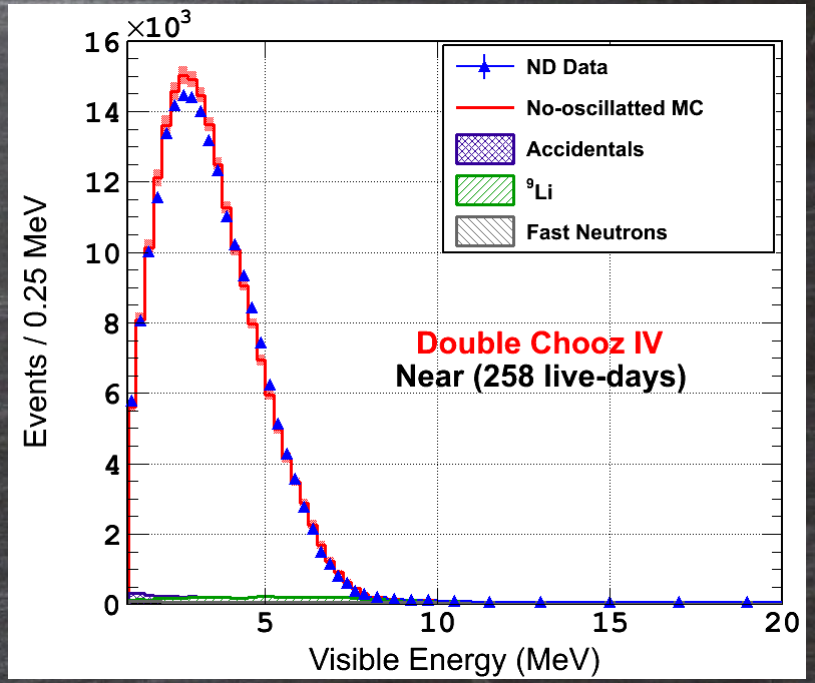
-> First ND measurement of MCSpF (world-best to date)

-> Spectral ~~bump~~ discussion
distortion

DC-IV FIT RESULTS





Data-MC fit including Bugey 4 normalization

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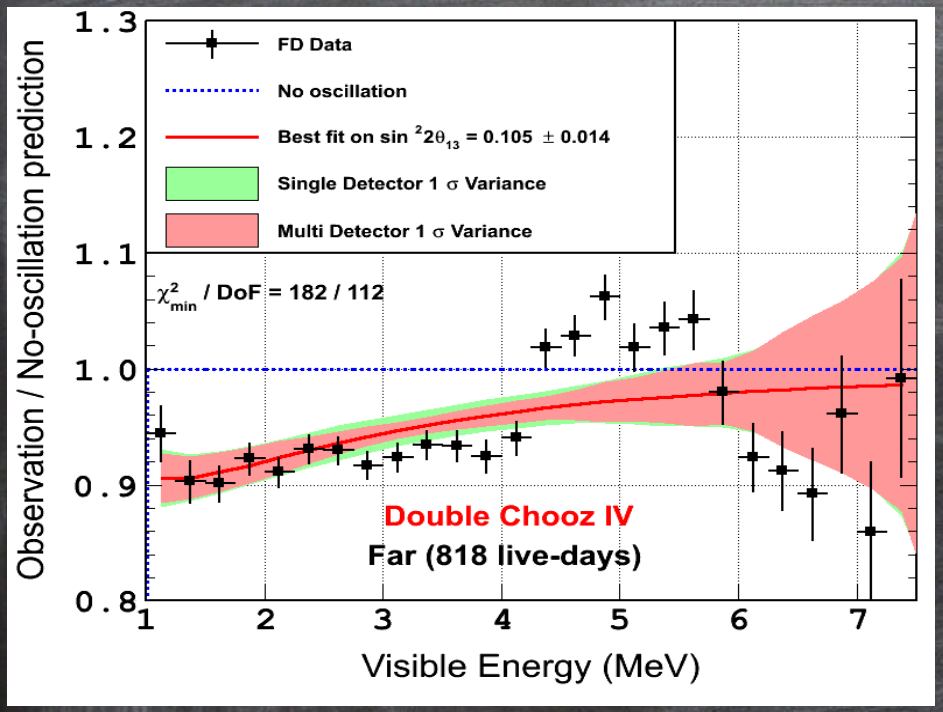
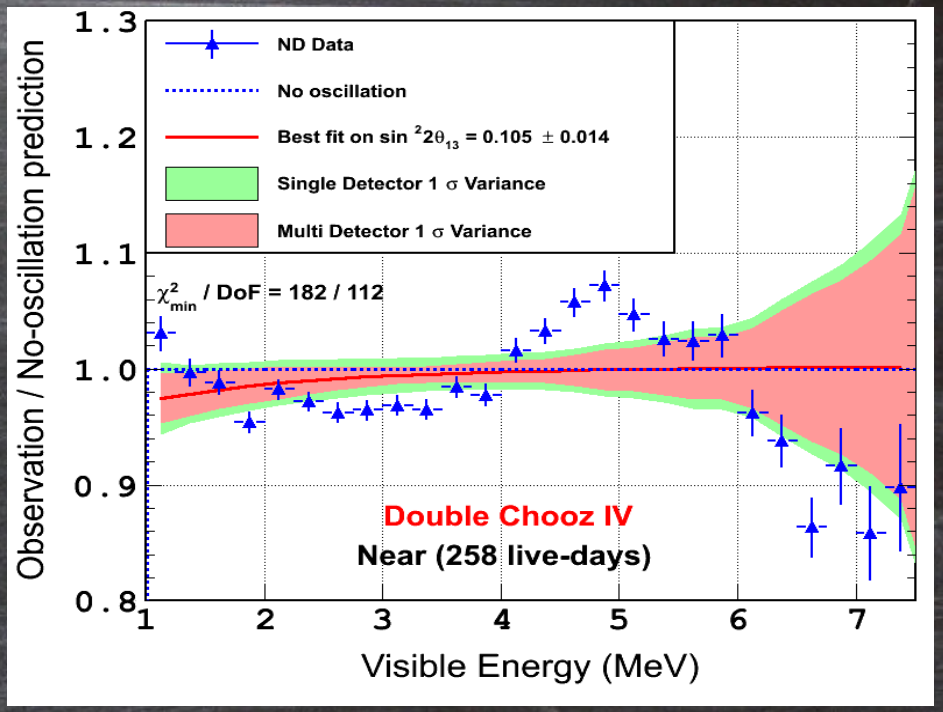


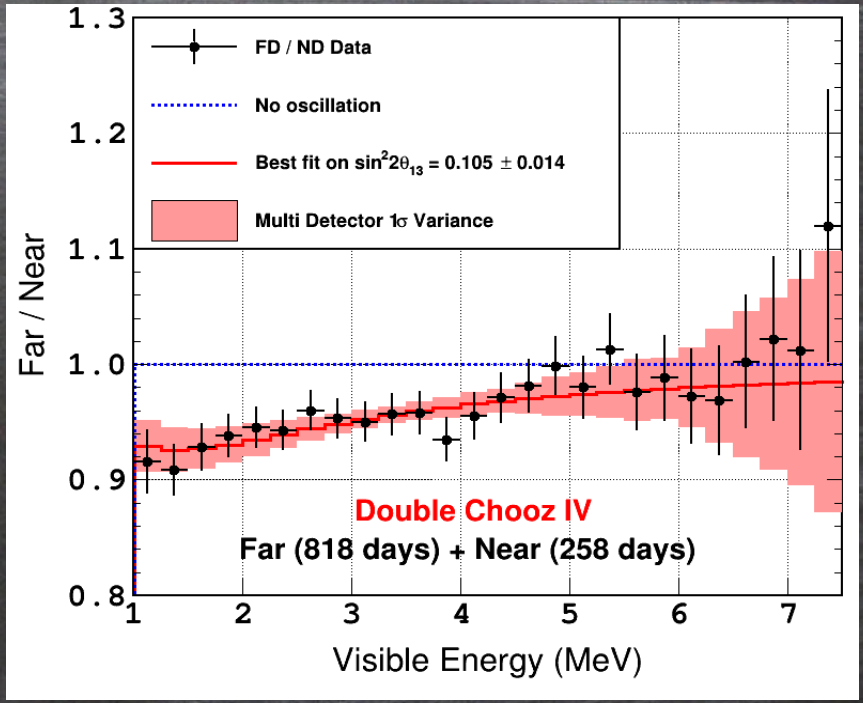


Data-MC fit including Bugey 4 normalization

$\sin^2 2\theta_{13} = 0.105 \pm 0.014$ (stat.+syst.)

Neutrino2018

DC-IV Fit Results



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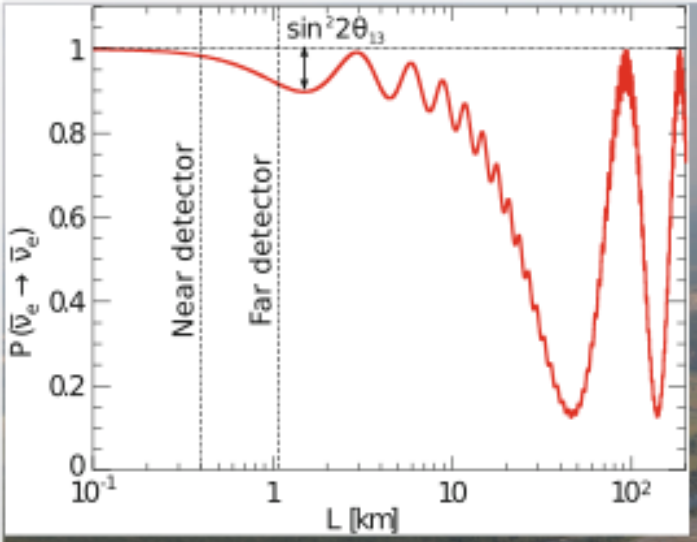
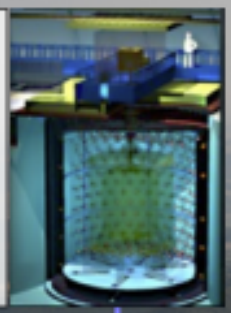
Neutrino2018

Multi detector fit robust against spectral distortion

„THE" SLIDE ON REACTOR NEUTRINOS



Far
< L > 1050m
~100 $\bar{\nu}_e$/ day
300 m.w.e.
2011



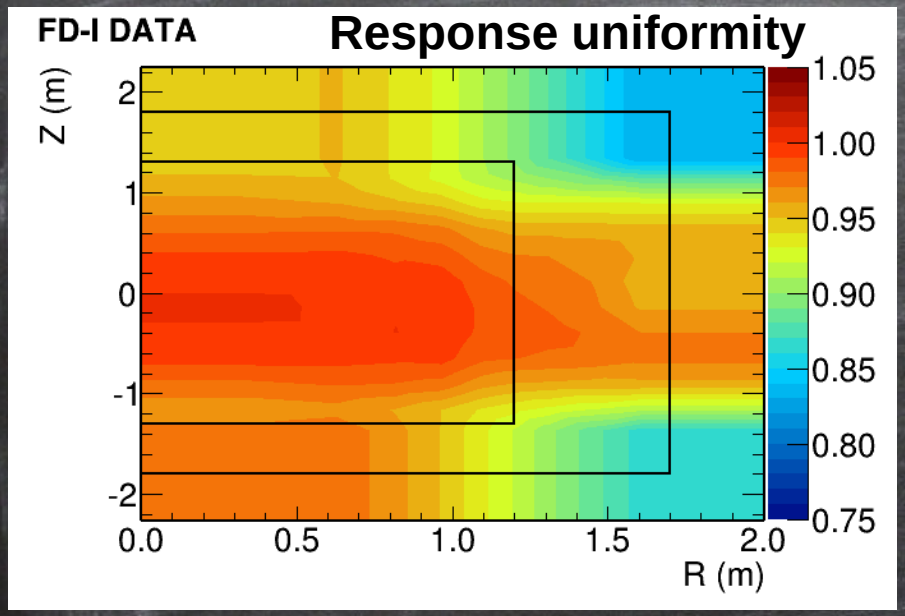
Near
< L > 400m
~800 $\bar{\nu}_e$/ day
120 m.w.e.
2015

2 reactors
$2 \times 4.25\,GW_{th}$
$\sim 10^{21}\,\bar{\nu}_e/s$

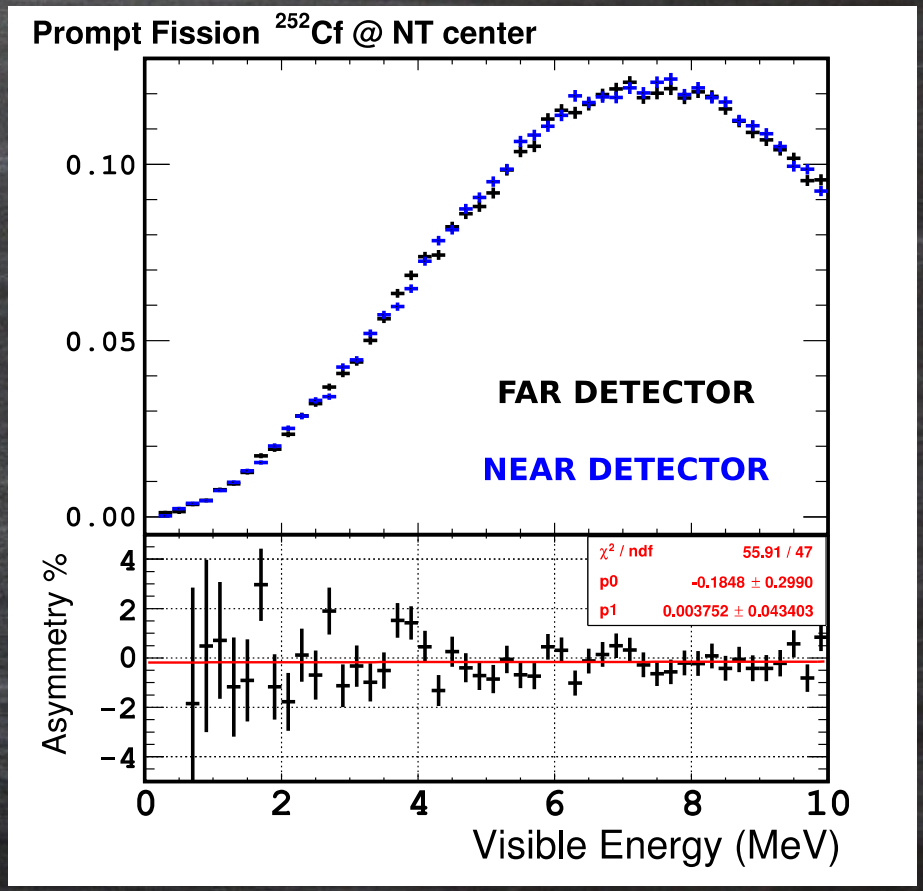
Near Detector: to suppress systematics

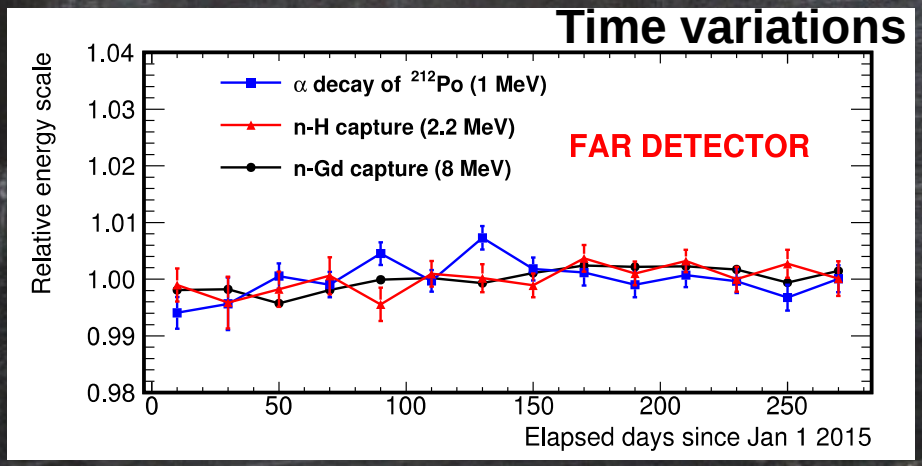
$\bar{\nu}_e$ Disappearance between Near and Far detectors → θ_{13}

ENERGY RECONSTRUCTION



VERY GOOD NEAR - FAR AGREEMENT

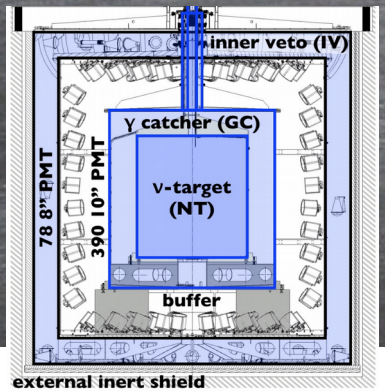




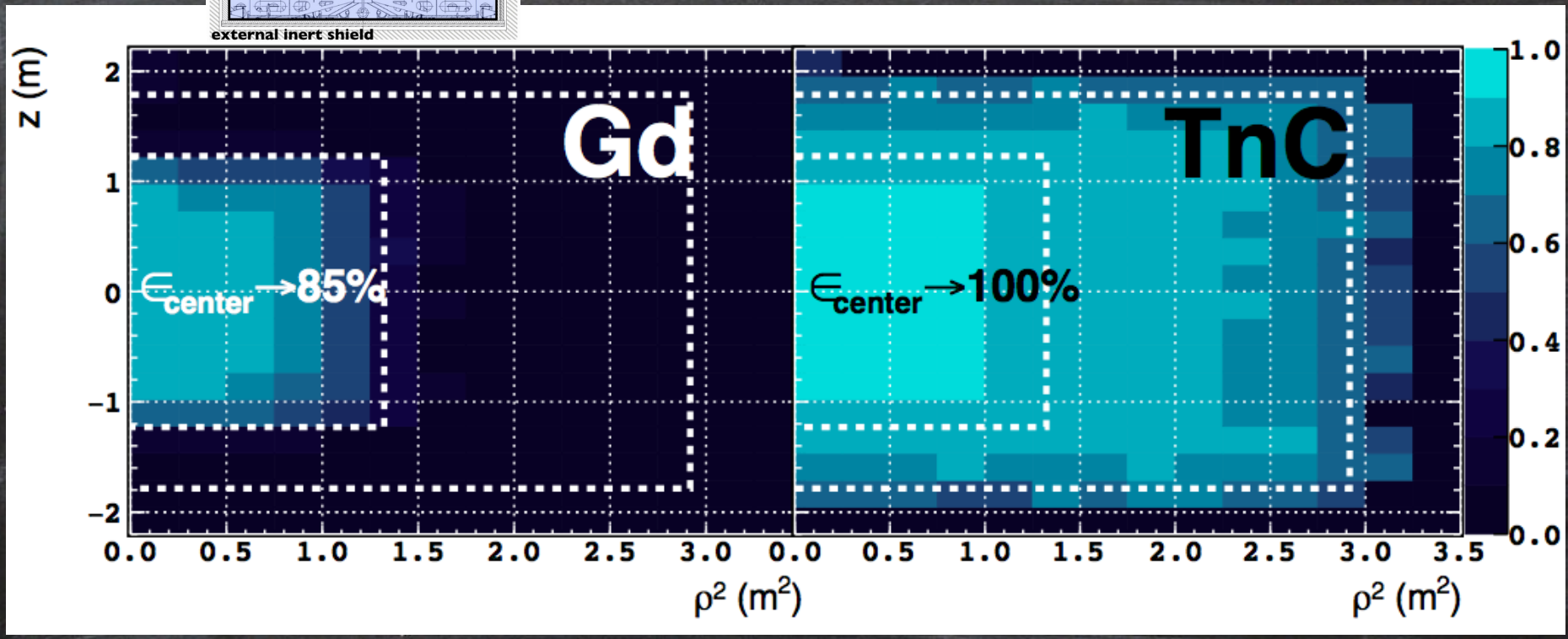
No Near-to-Far slope!

σ = 0.04

DC STATISTICS / EFFICIENCY

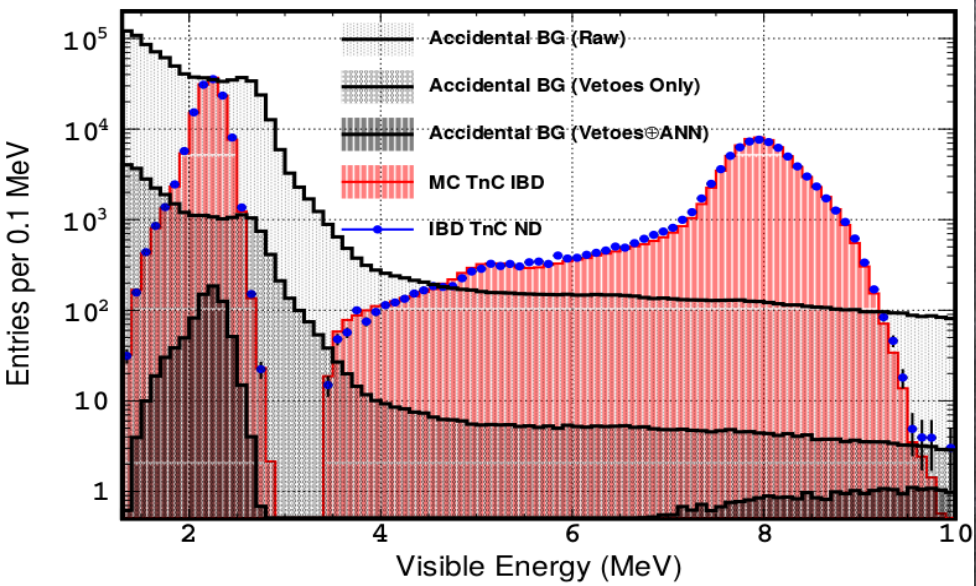


„Small" Gd-target (8.3 t)
and „only" two reactors



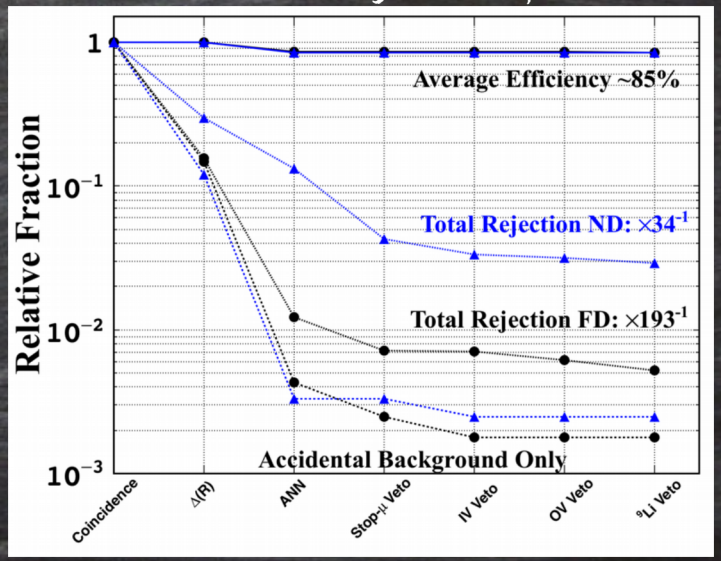
„Total n-Capture" (TnC) improves statistics factor 2.5!
(captures on Gd+H+C -> leak immune!)

BACKGROUND REDUCTION



Delayed E spectrum (data and MC) before and after cuts

Cumulative rejection per cut

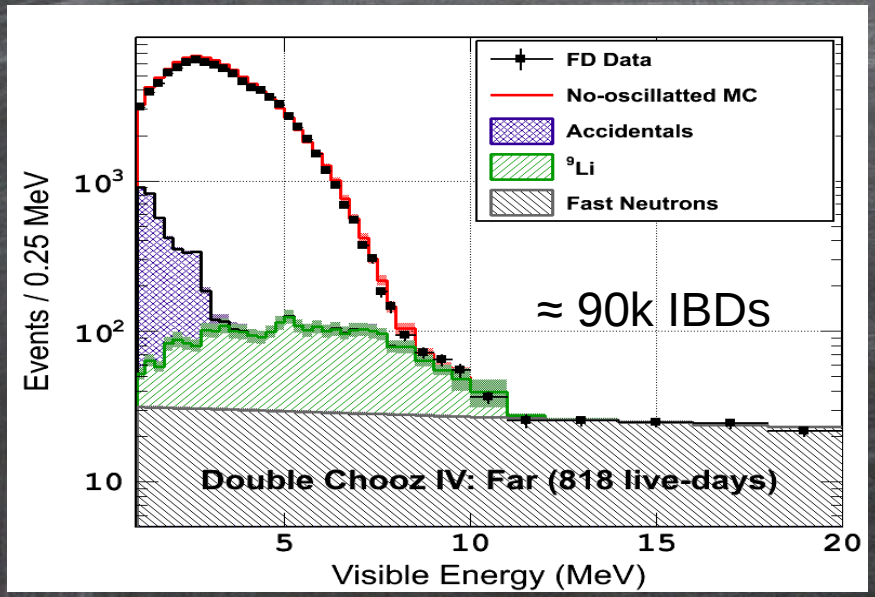


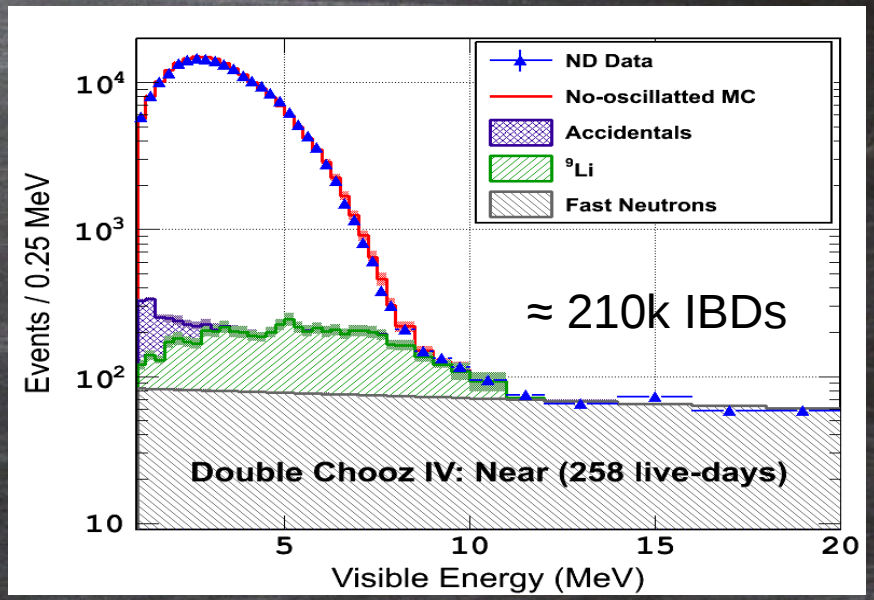
-> Good data/MC agreement for IBD candidates

-> Efficient background supression with cuts/vetoes

IBD efficiency and background rejection

SIGNAL AND BACKGROUNDS

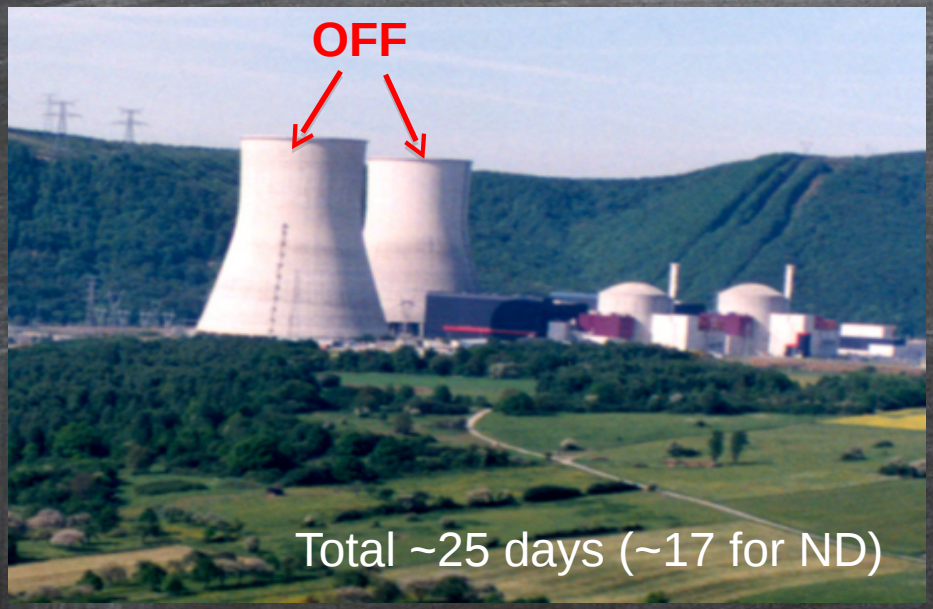


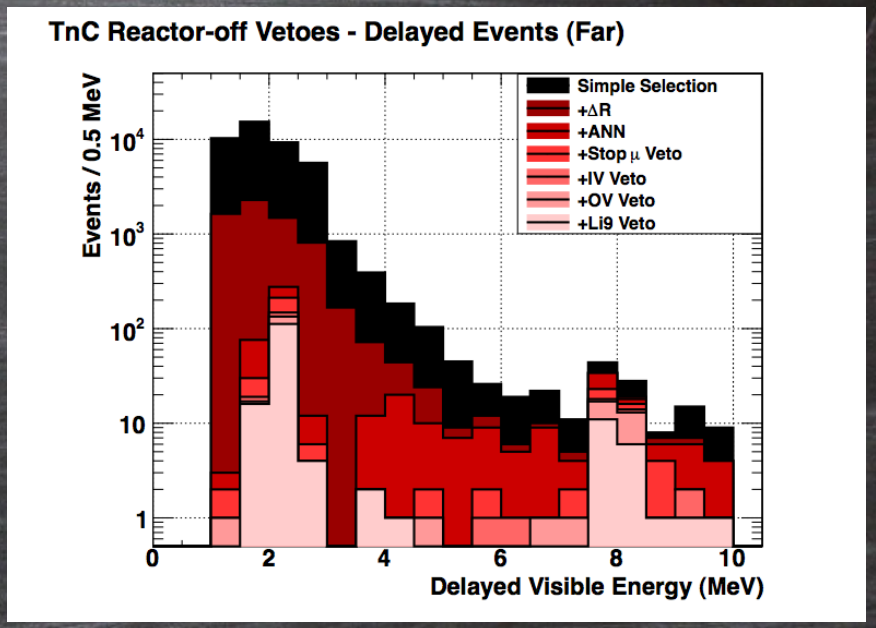


	Ev./day FD	Ev./day ND
IBD candidates	112	816
Cosmogenic BG (^{9}Li)	2.62 ± 0.27	14.52 ± 1.48
Fast n	2.50 ± 0.05	**20.85 ± 0.31**
Accidental BG	**4.13 ± 0.02**	3.11 ± 0.01

S/B>10!

BOTH REACTORS OFF DATA



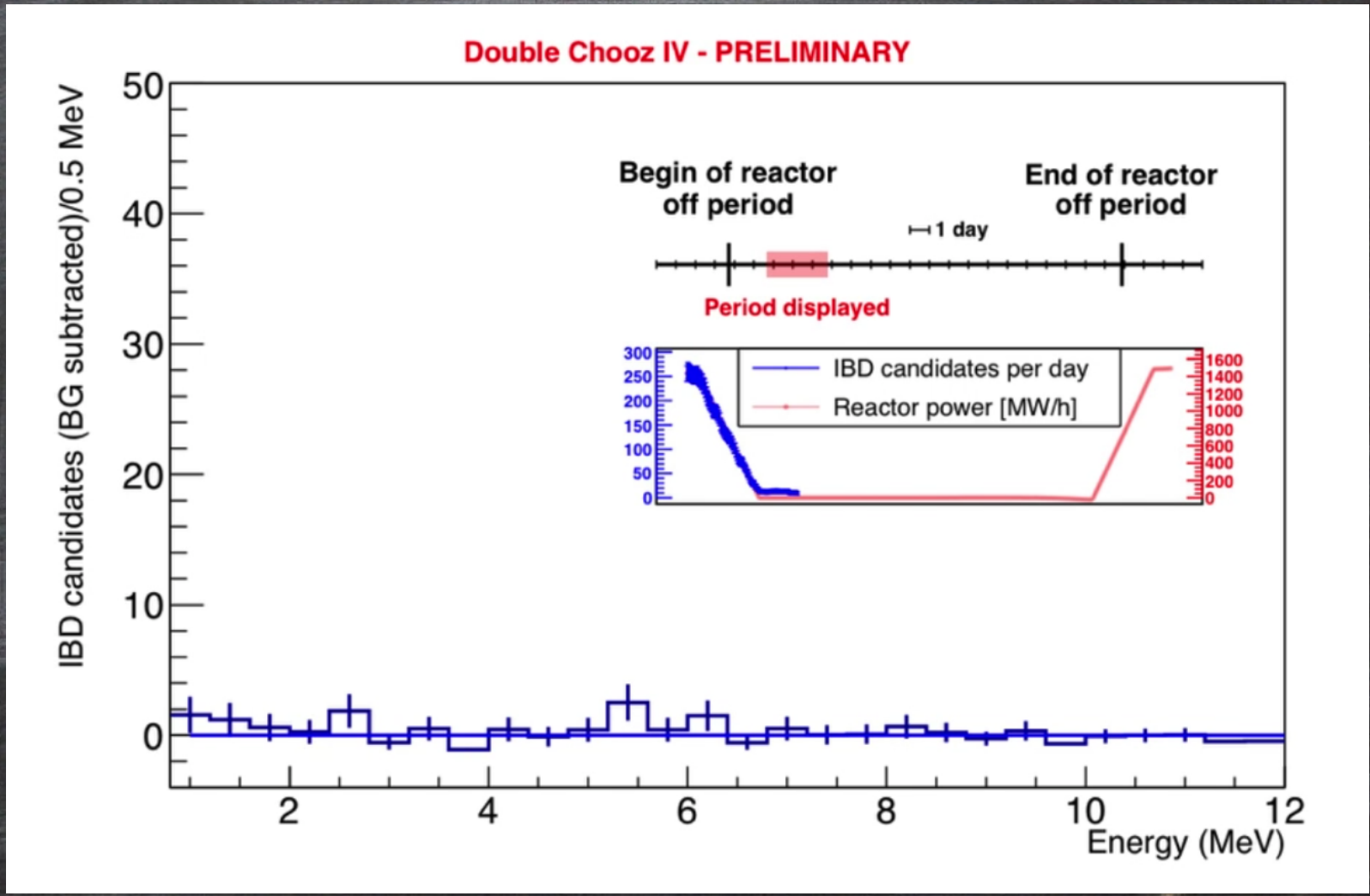


	ND (ev./day)	FD (ev./day)
OFF-OFF I (2012)	---	8.9 ± 1.2
OFF-OFF II (2017)	39.6 ± 2.5	9.8 ± 0.9
Rate+Shape values	38.5 ± 1.5	9.3 ± 0.3

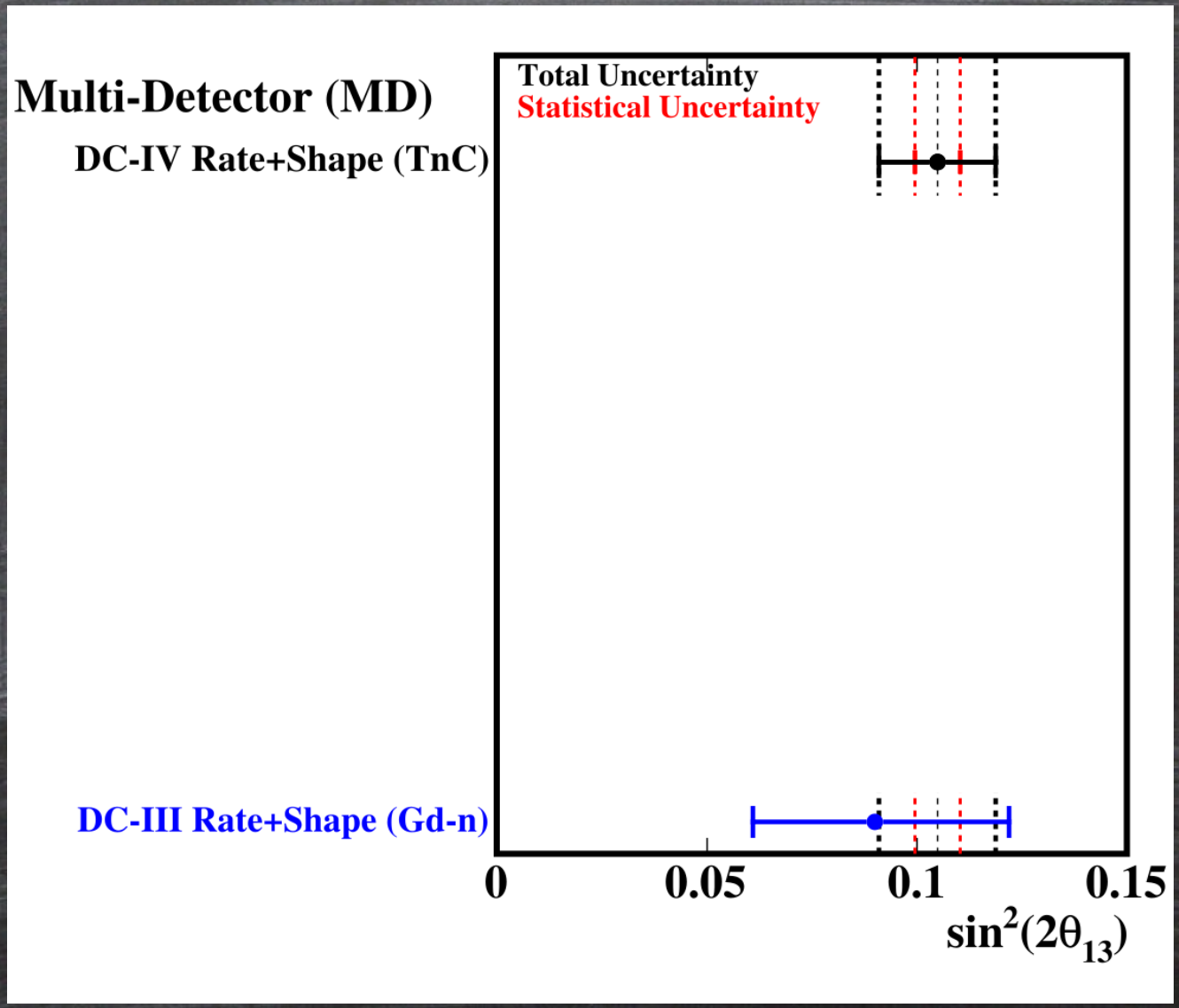
Background understanding

All numbers within 1σ

VALIDATION OF BACKGROUND MODEL



MORE DC θ_{13} FITS



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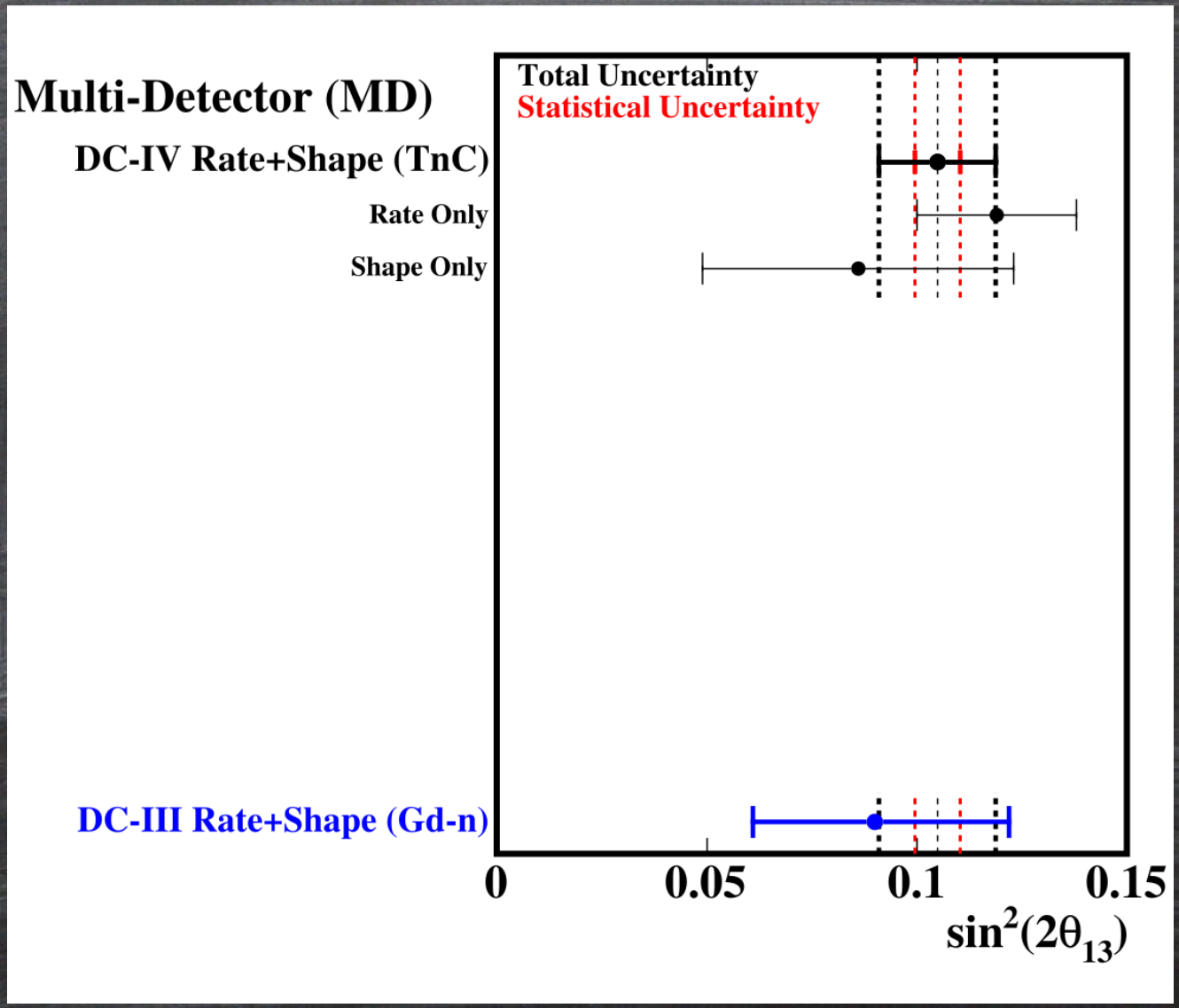
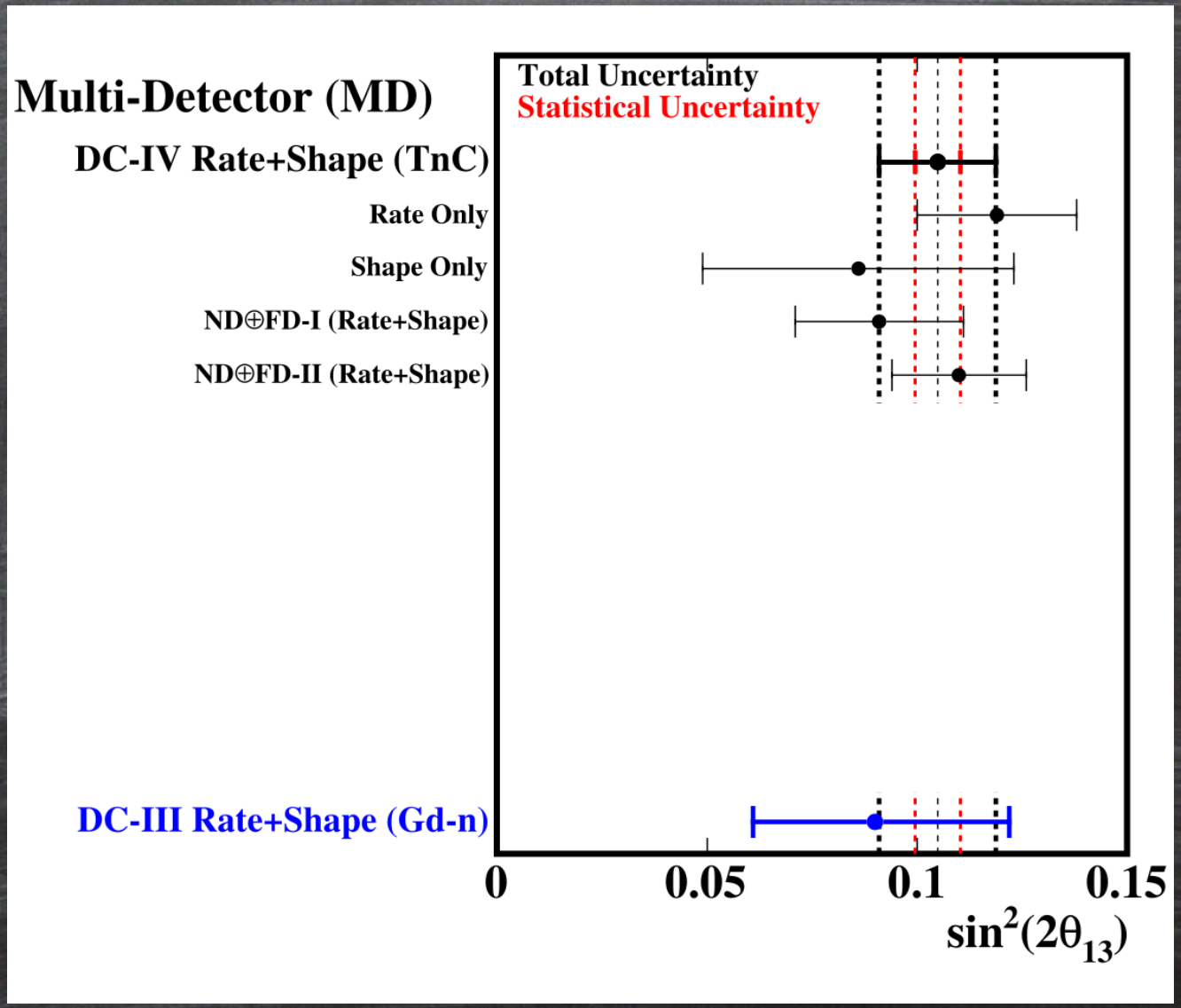


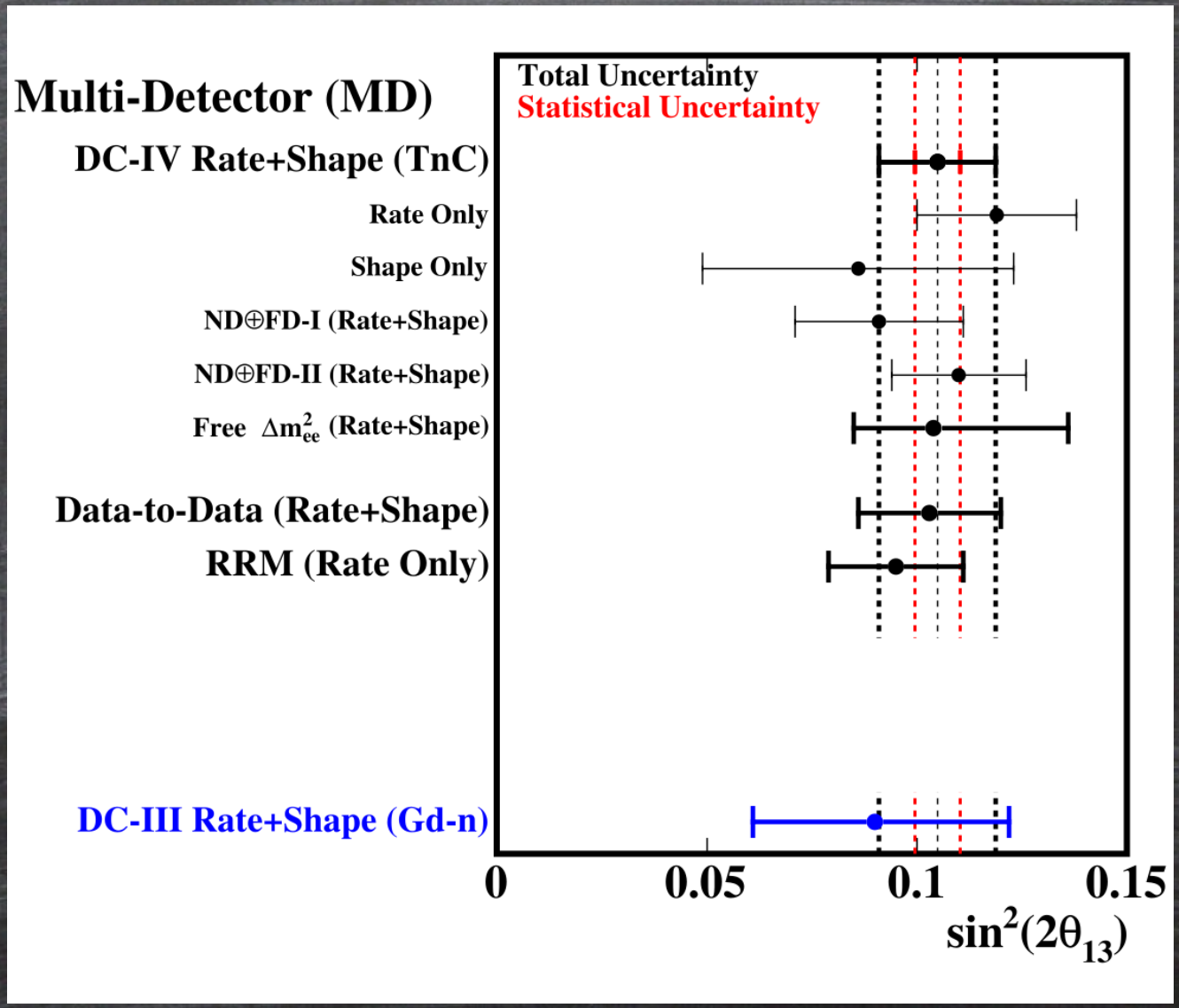
Norm. Pushes up

MORE DC θ_{13} FITS



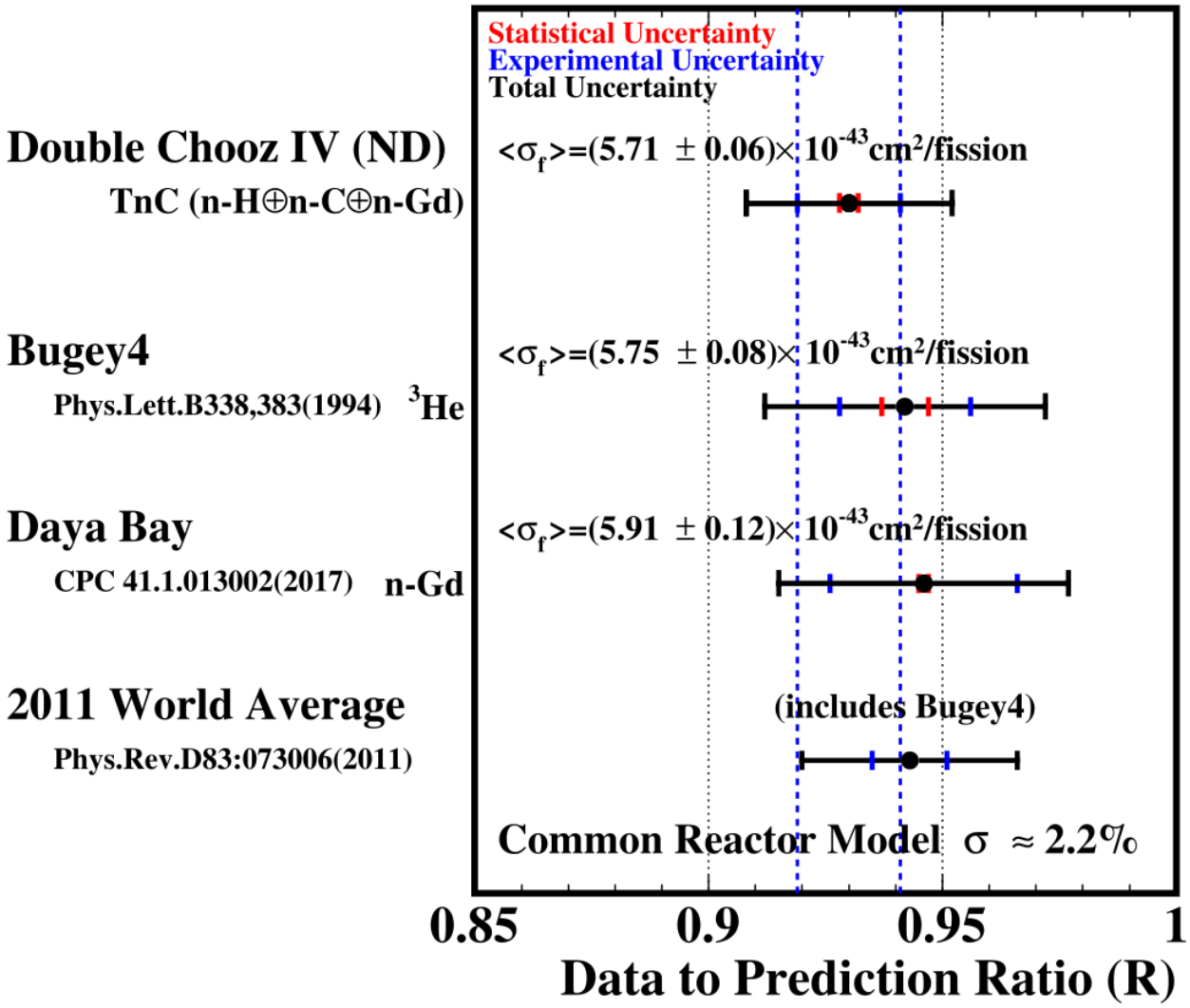
FD-II (Flux Cancelation)
Pushes up

MORE DC θ_{13} FITS



Complementary Fits

NORMALIZATION - ND VS BUGEY4



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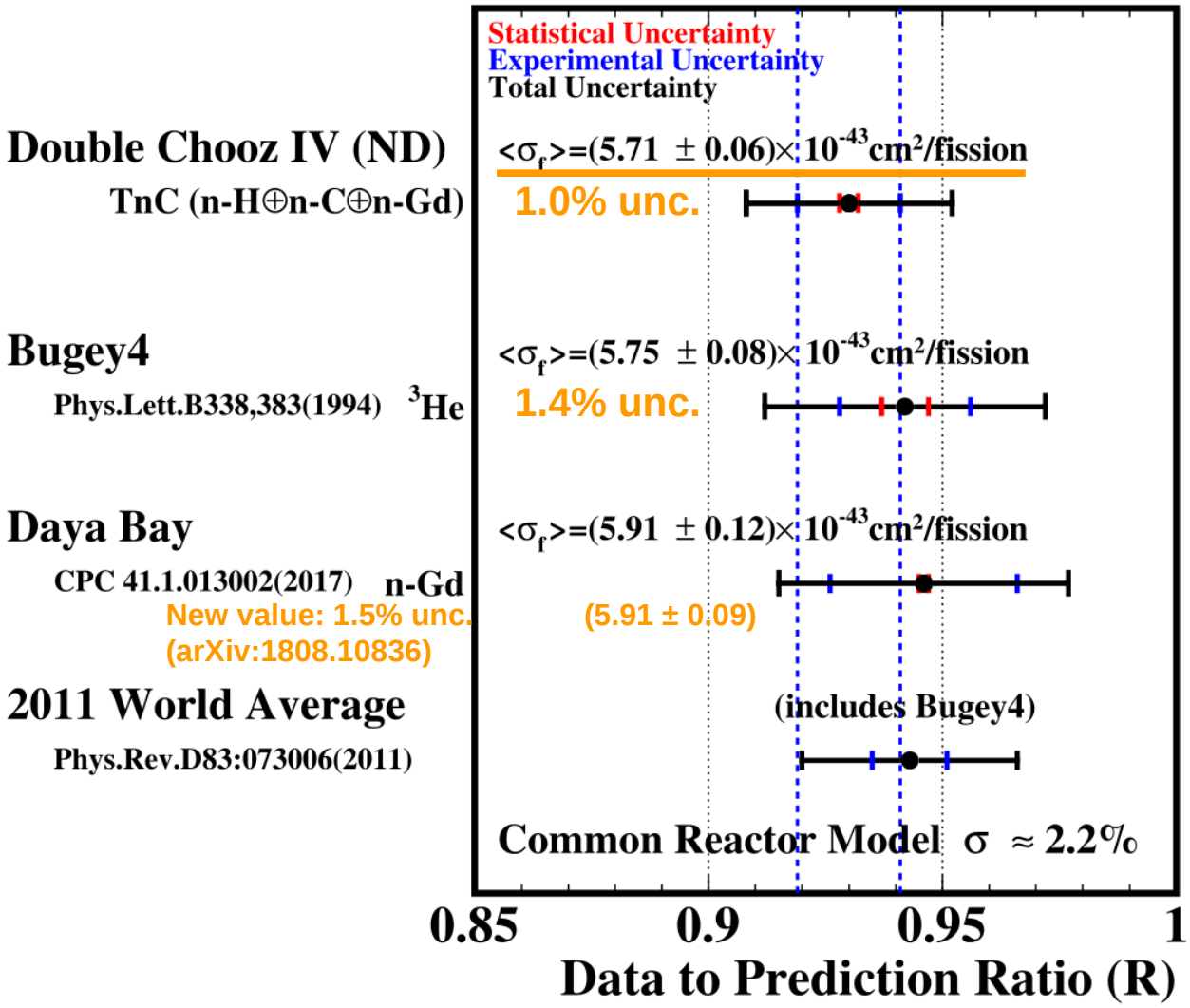
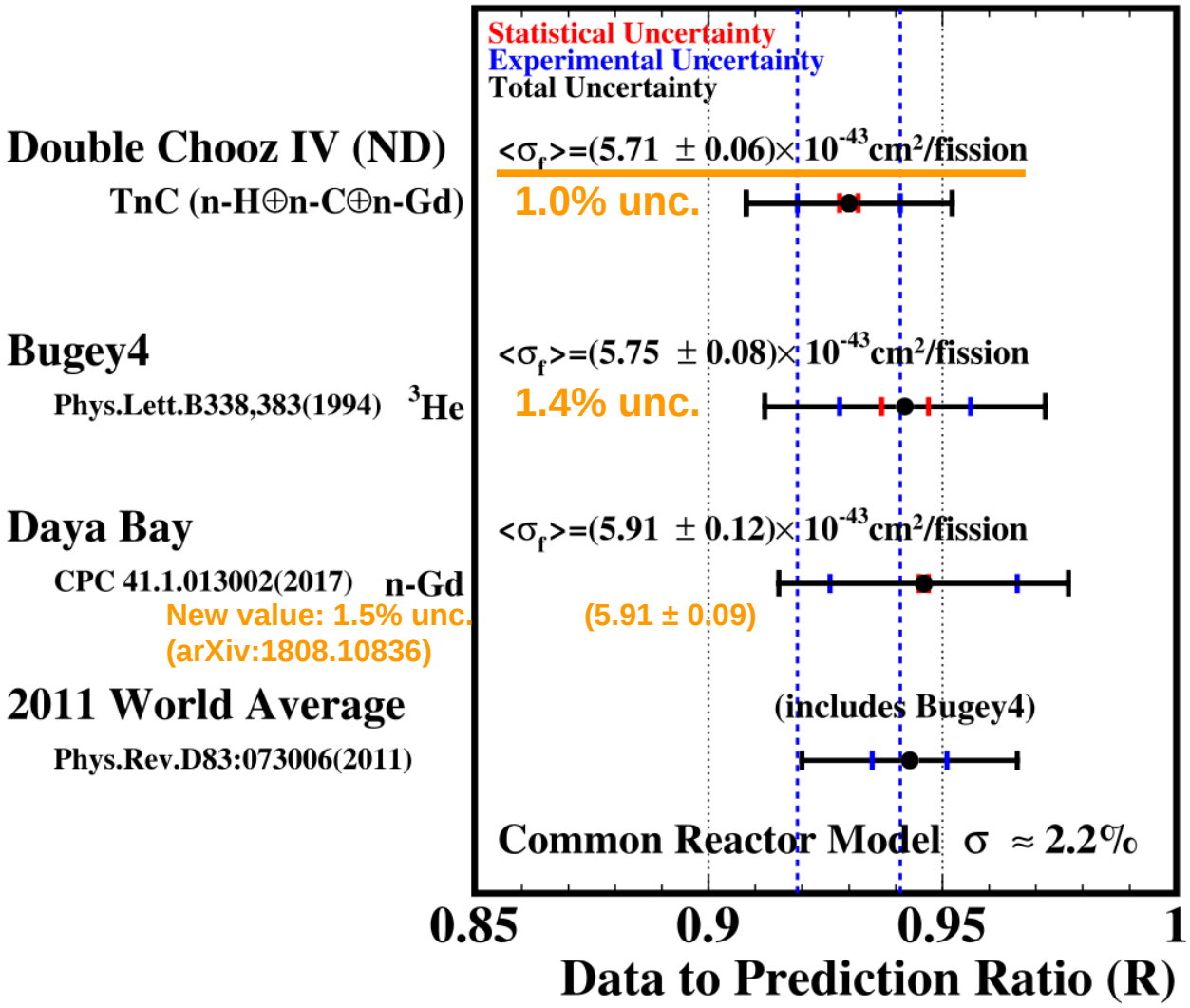


NEW!

NORMALIZATION - ND VS BUGEY4



NEW!

DC ND Fission Fraction
(2 reactors weighted)

235U -> 0.520

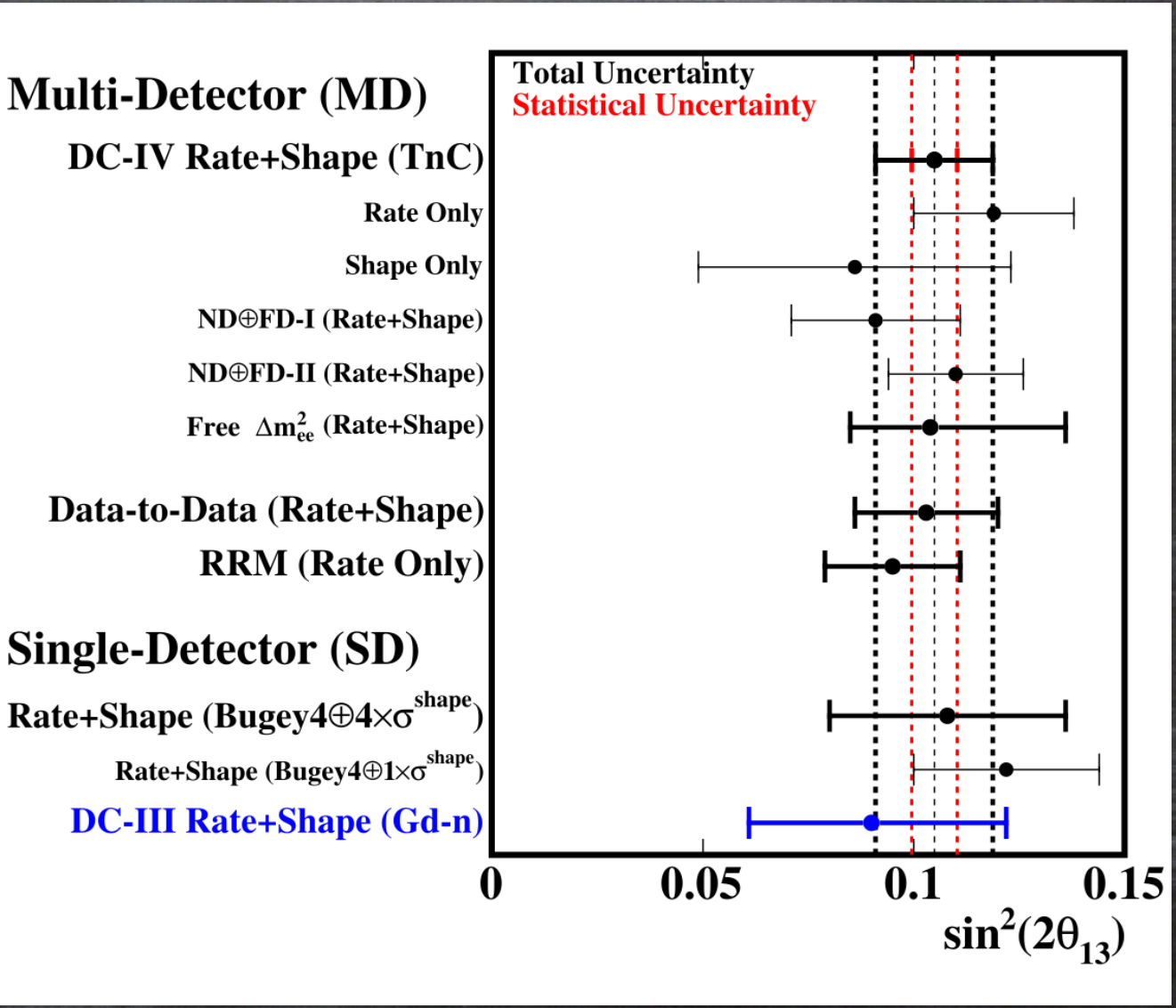
238U -> 0.087

239Pu -> 0.333

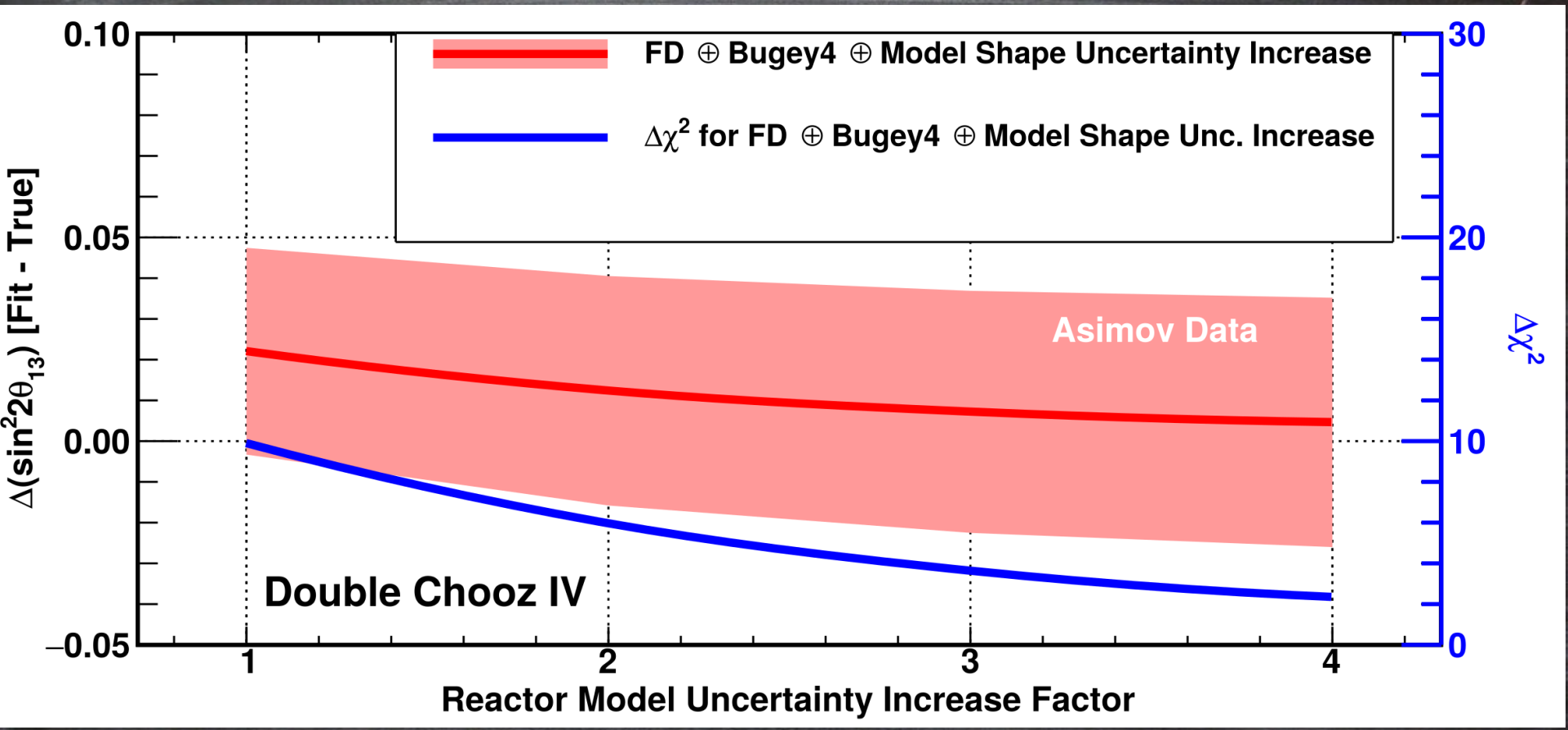
241Pu -> 0.060

B4 (DC fuel corrected) = (5.77 ± 0.08) x 10^{-43} cm^2/fission

MORE DC θ_{13} FITS



FLUX ERROR BUDGET & SINGLE DETECTOR FIT



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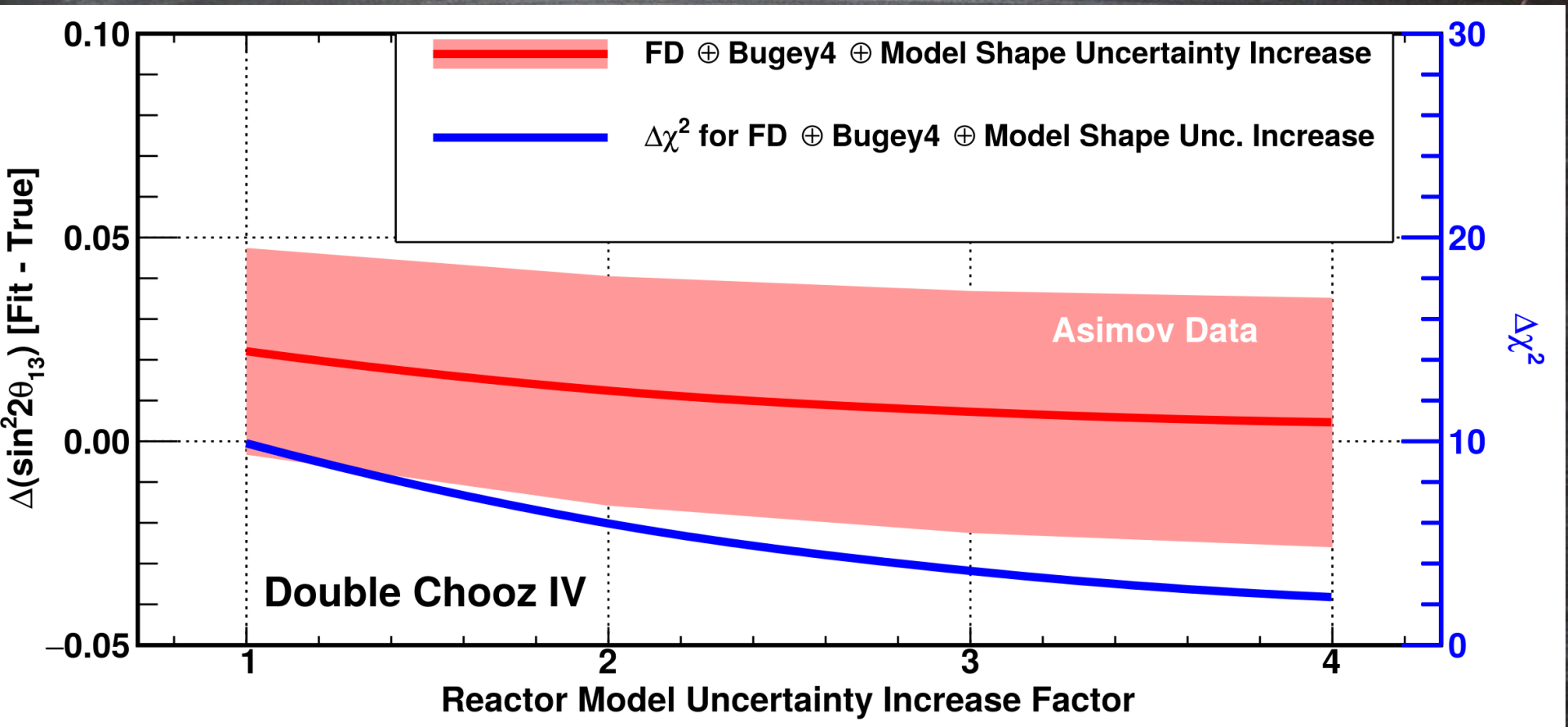

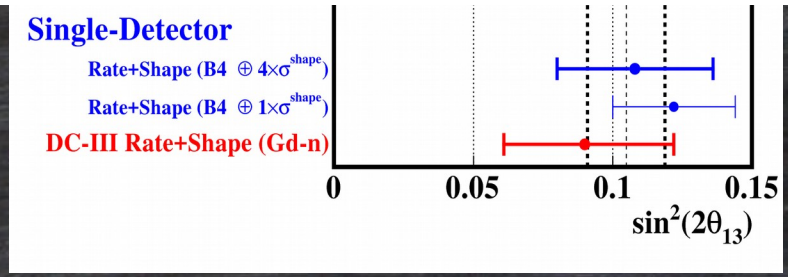

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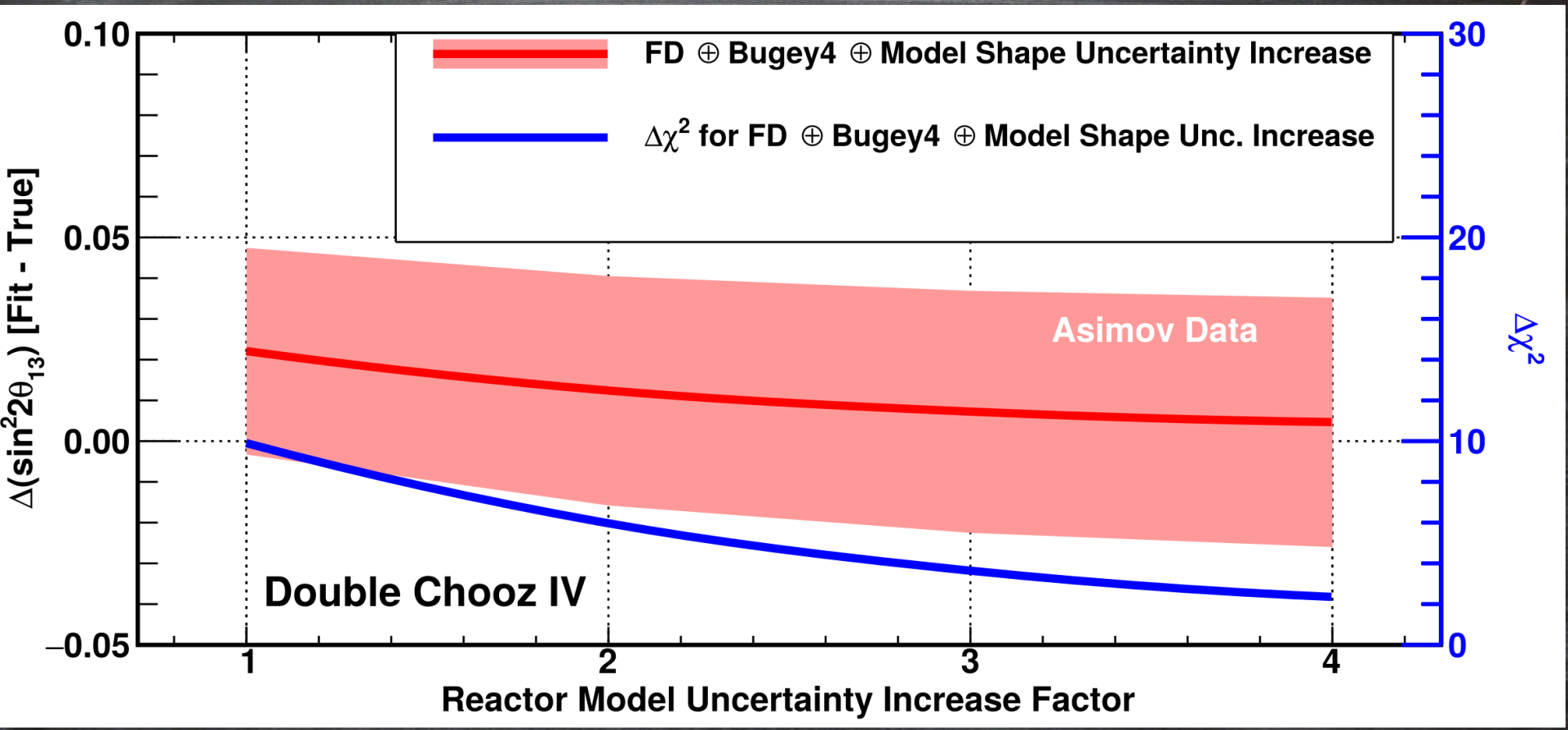

-> Distortion causes χ^2 to blow up

χ^2 (x1 -> x4 error) w/ Data:
FD+B4 = 105 -> 53 (74 DoF)

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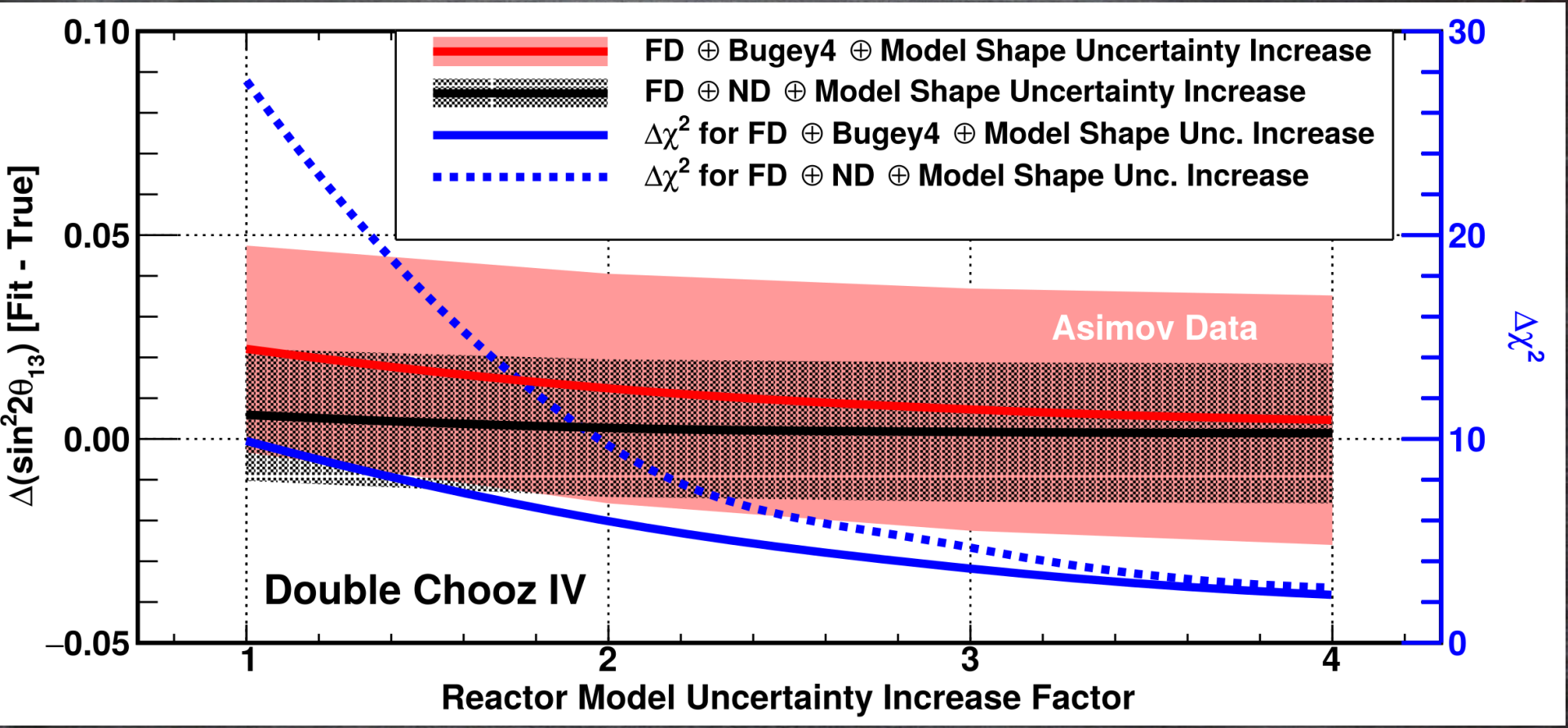

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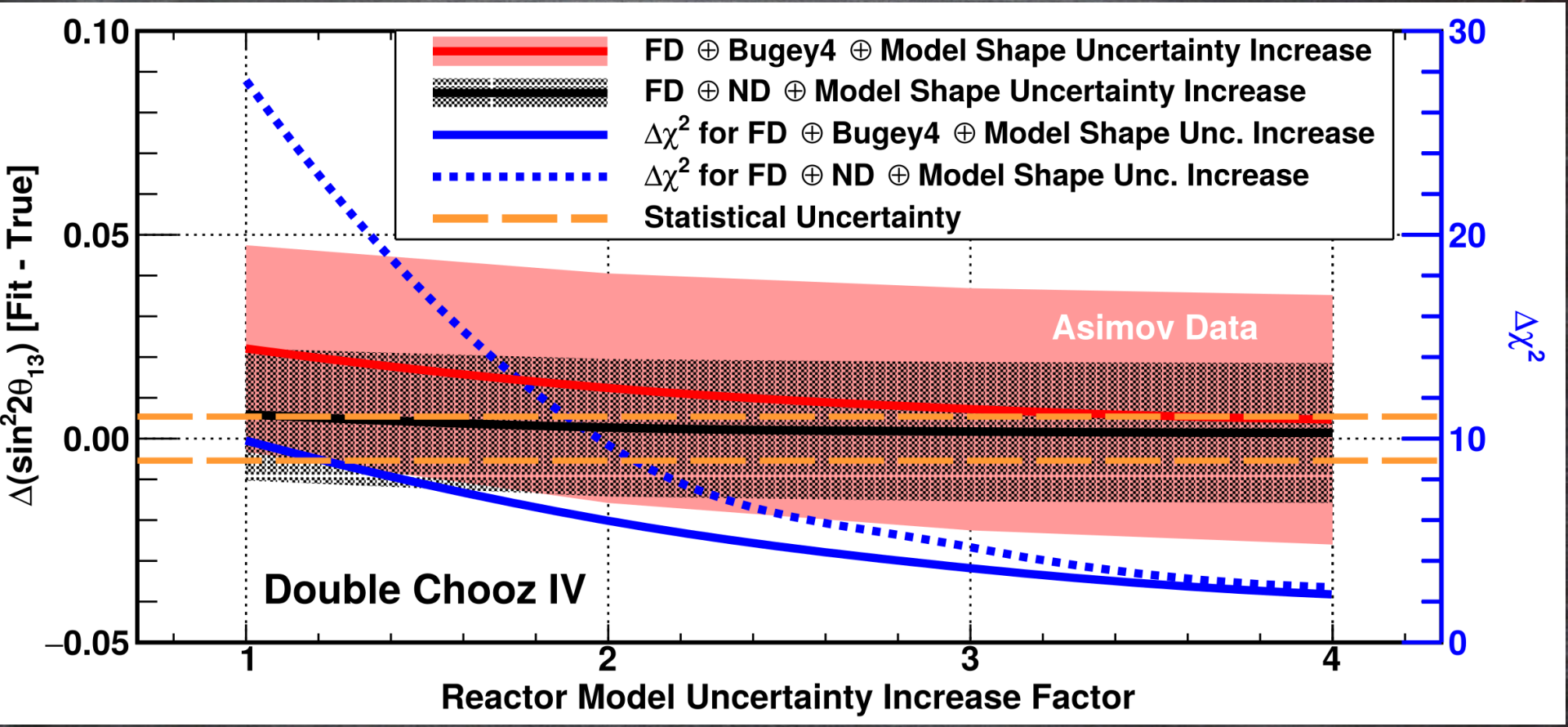
χ^2 (x1 -> x4 error) w/ Data:
FD+B4 = 105 -> 53 (74 DoF)
FD+ND = 182 -> 93 (112 DoF)

FLUX ERROR BUDGET & SINGLE DETECTOR FIT



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-> Corroborated with Data

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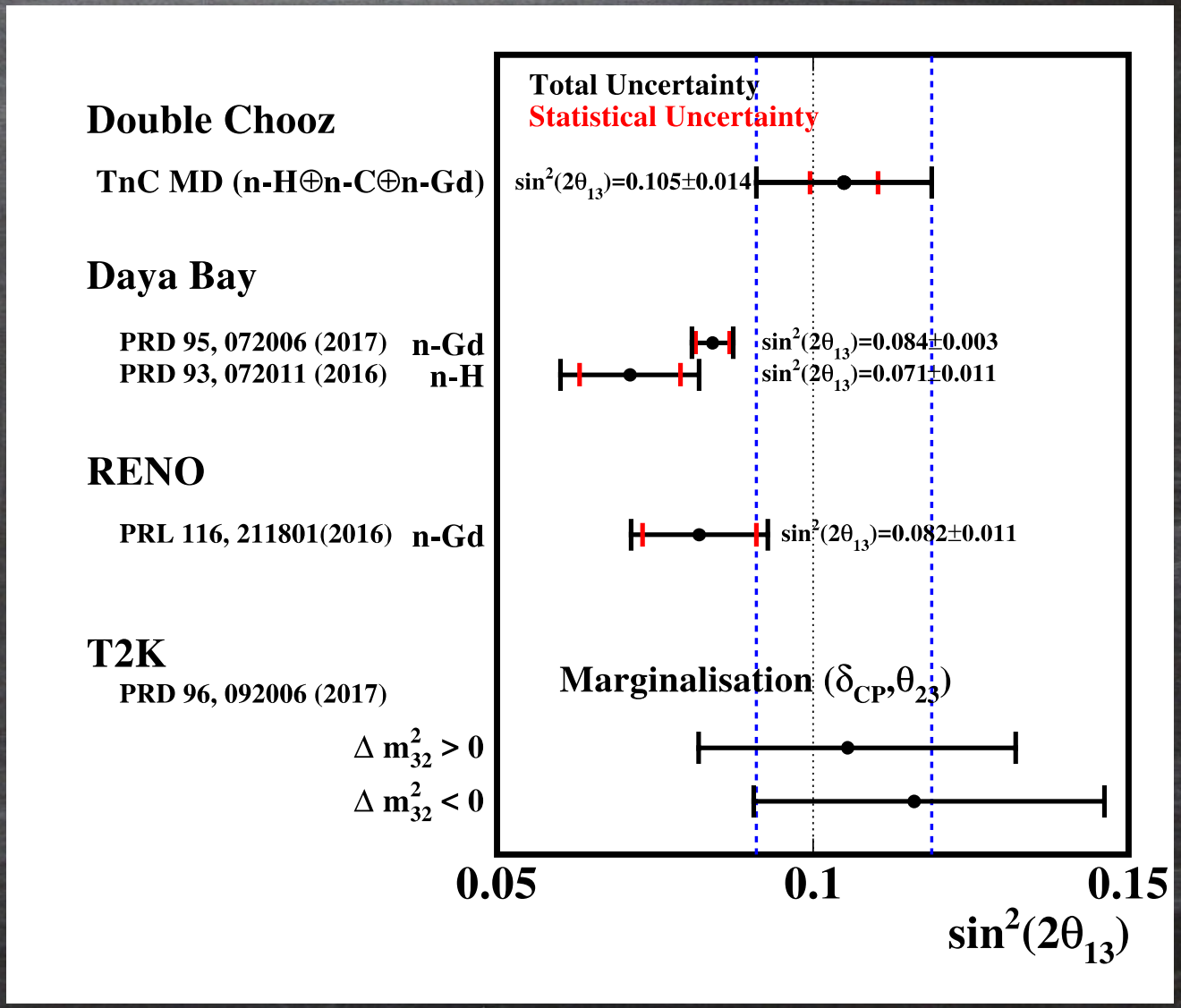

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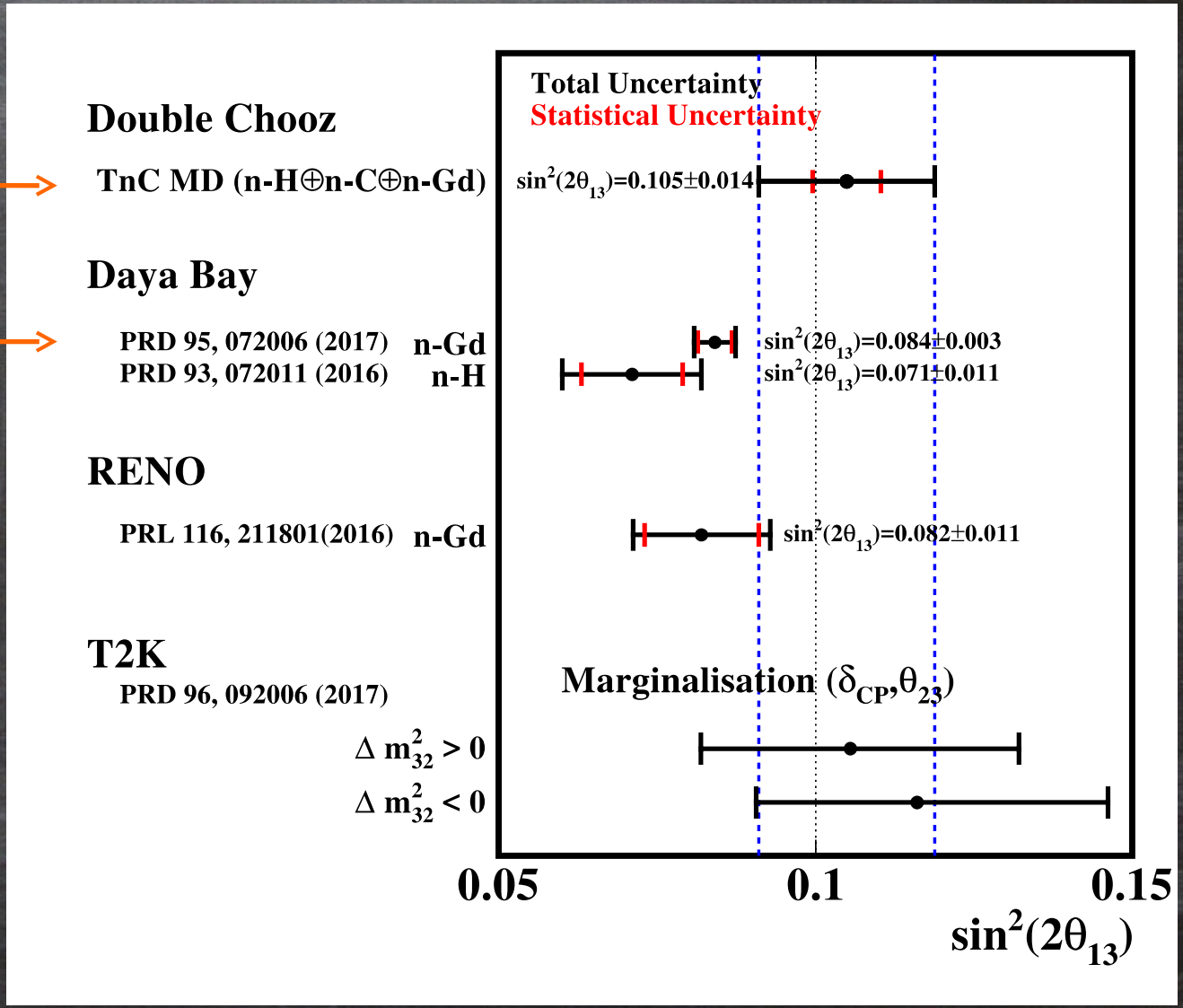
<~2σ difference (systematics!)



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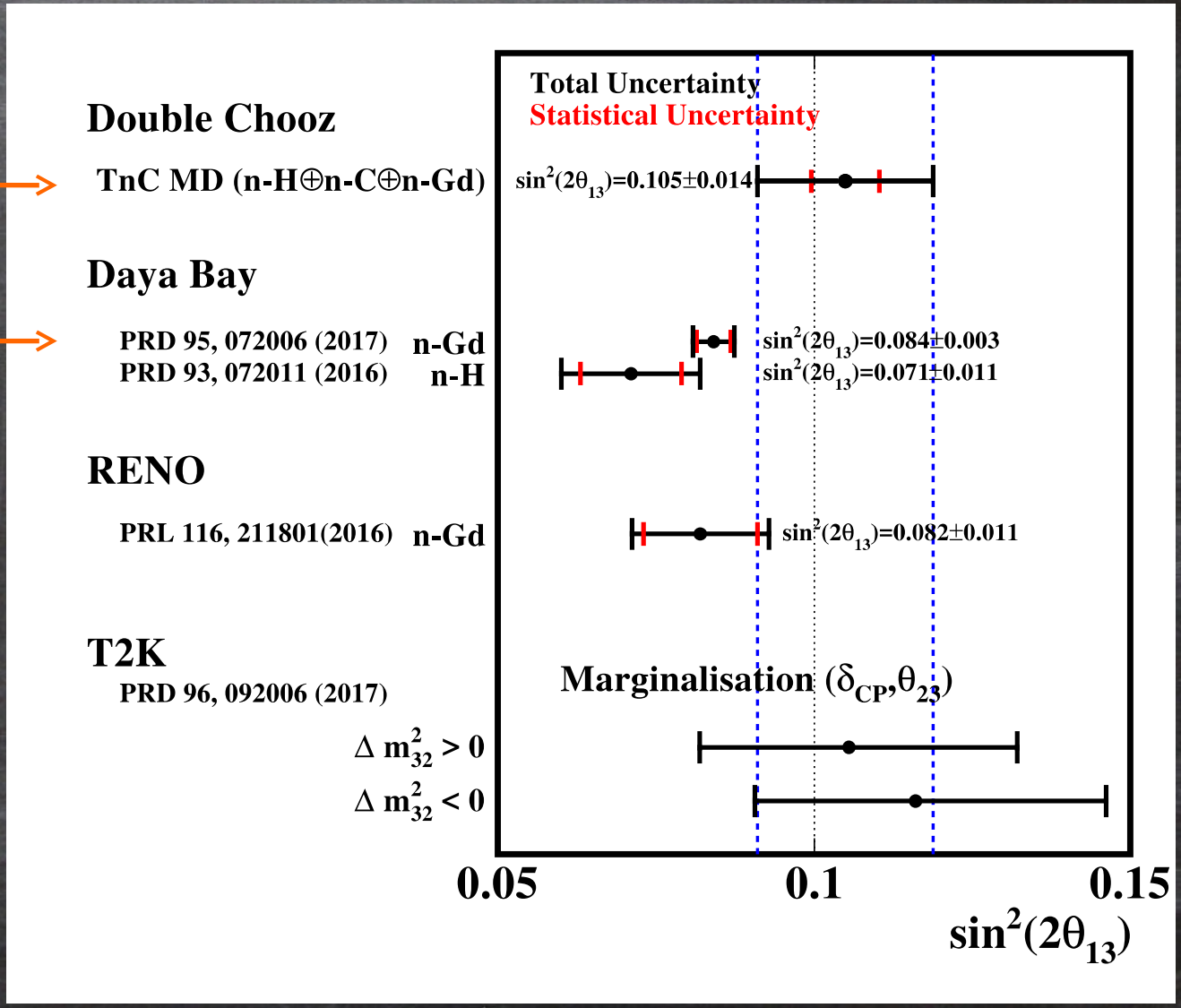
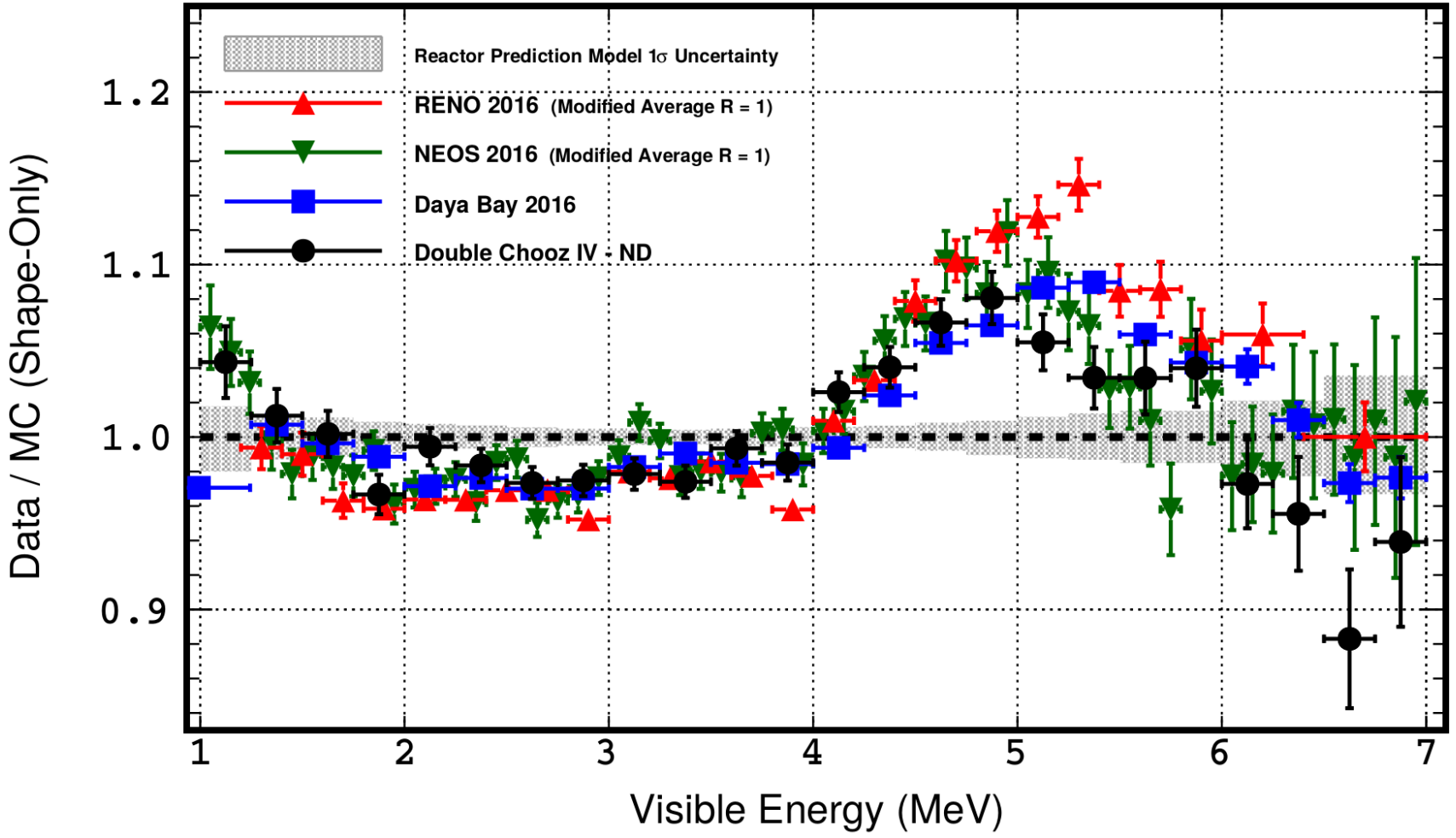


Intl. Reactor-θ_{13} Workshops: Combined (DC/DYB/RENO) effort to understand systematics

SPECTRAL DISTORTION COMPARISON (SHAPE ONLY)



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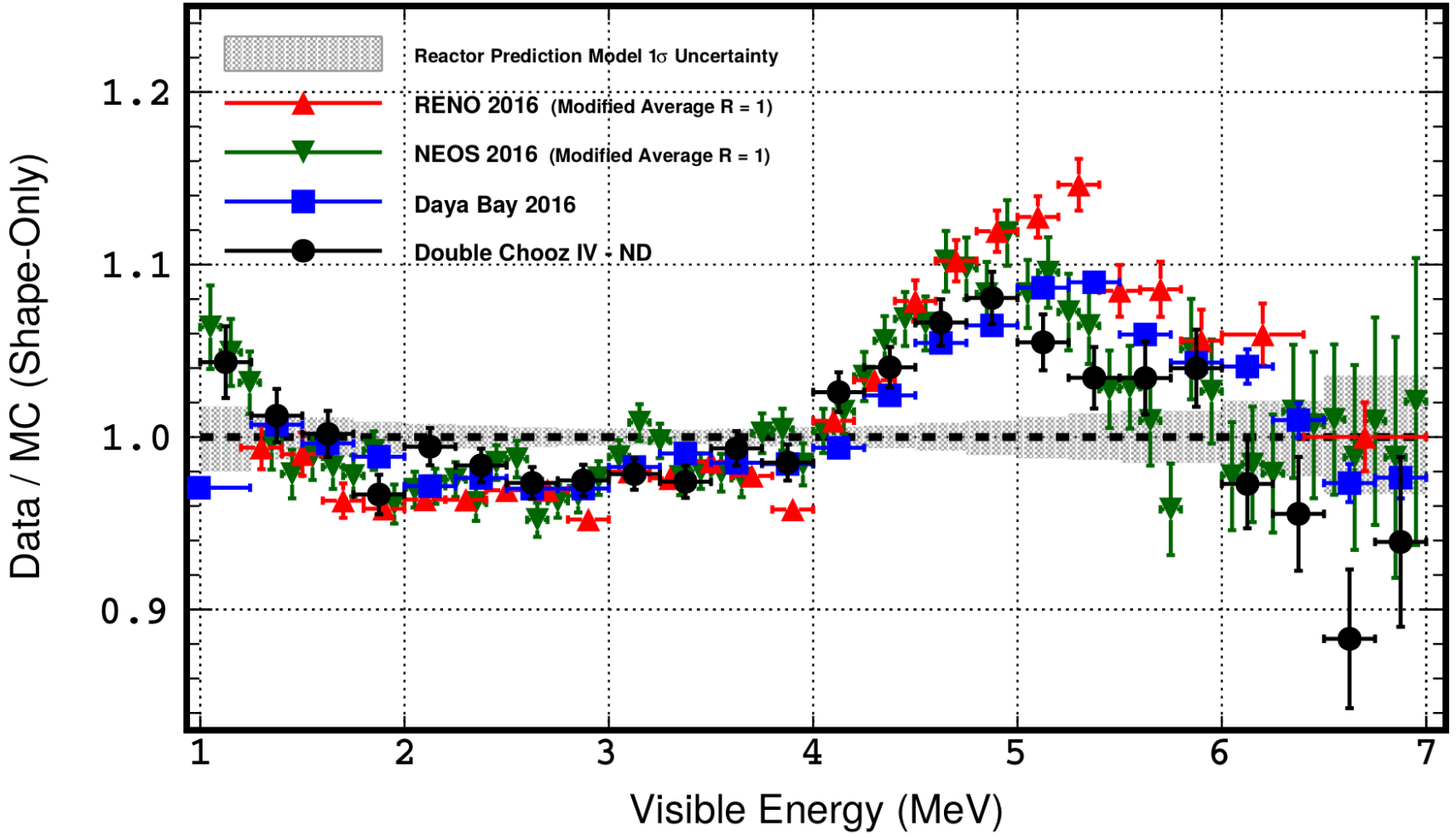
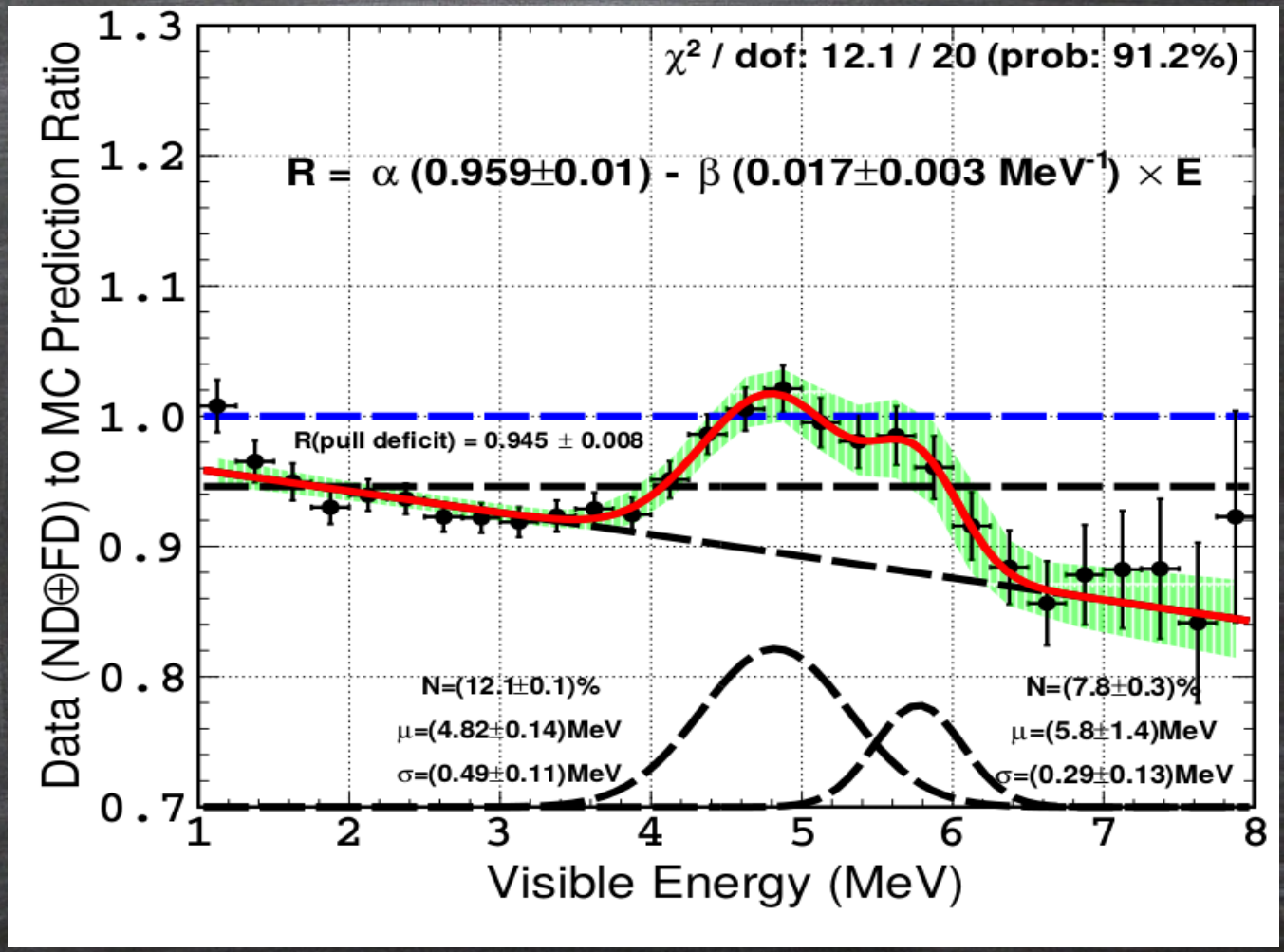


Good agreement to first order

SPECTRAL DISTORTION COMPARISON (SHAPE & RATE)



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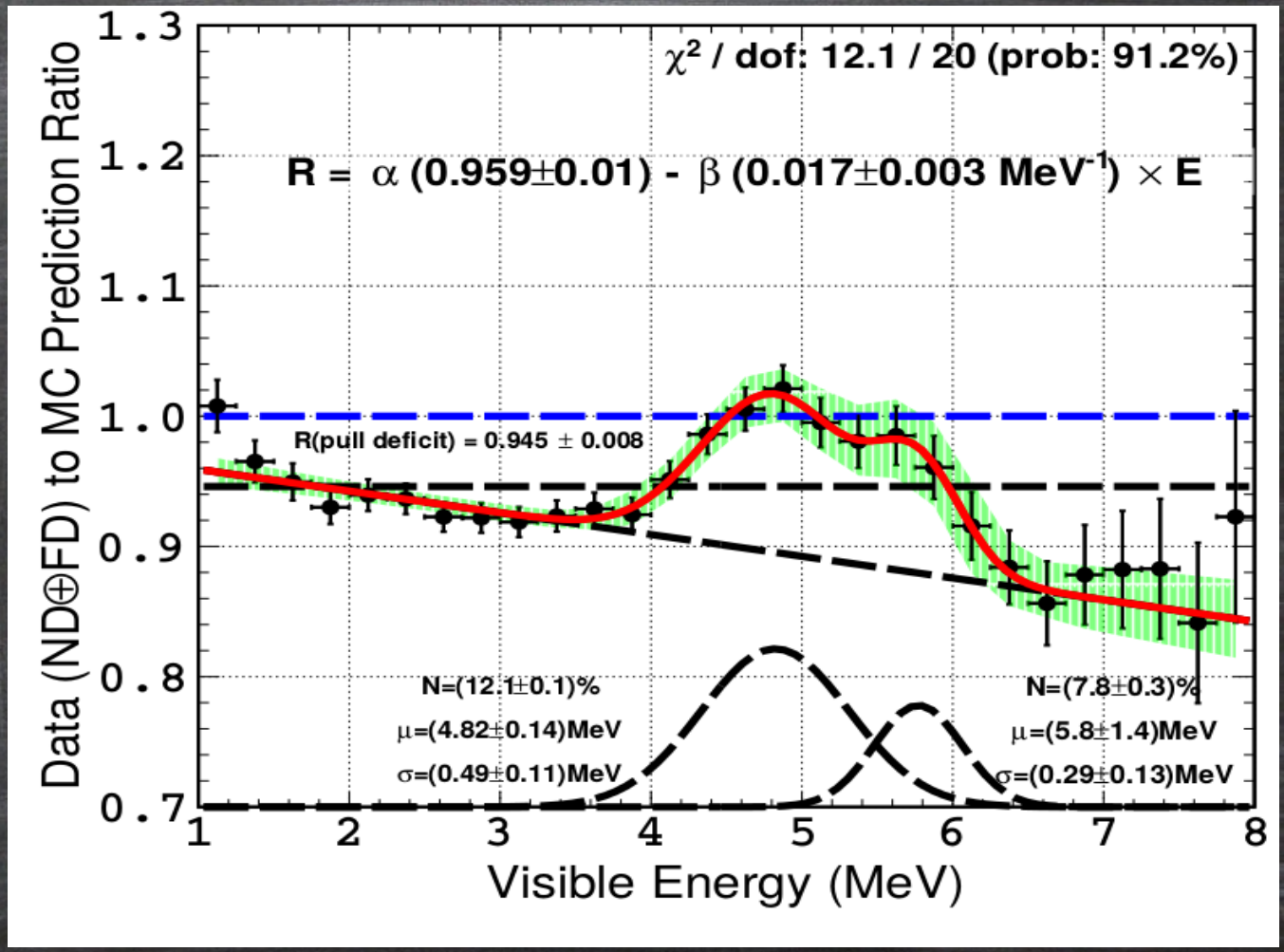

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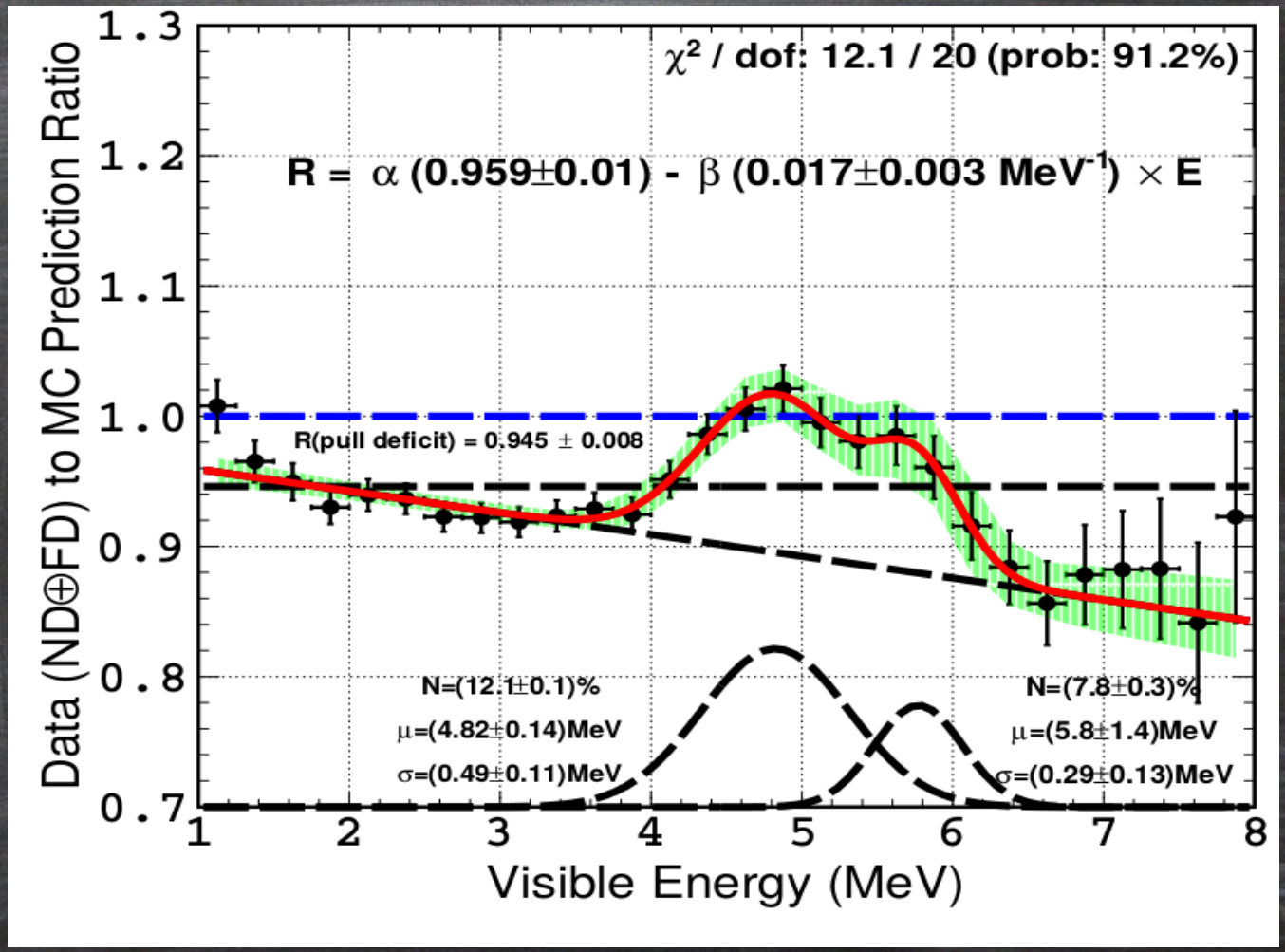

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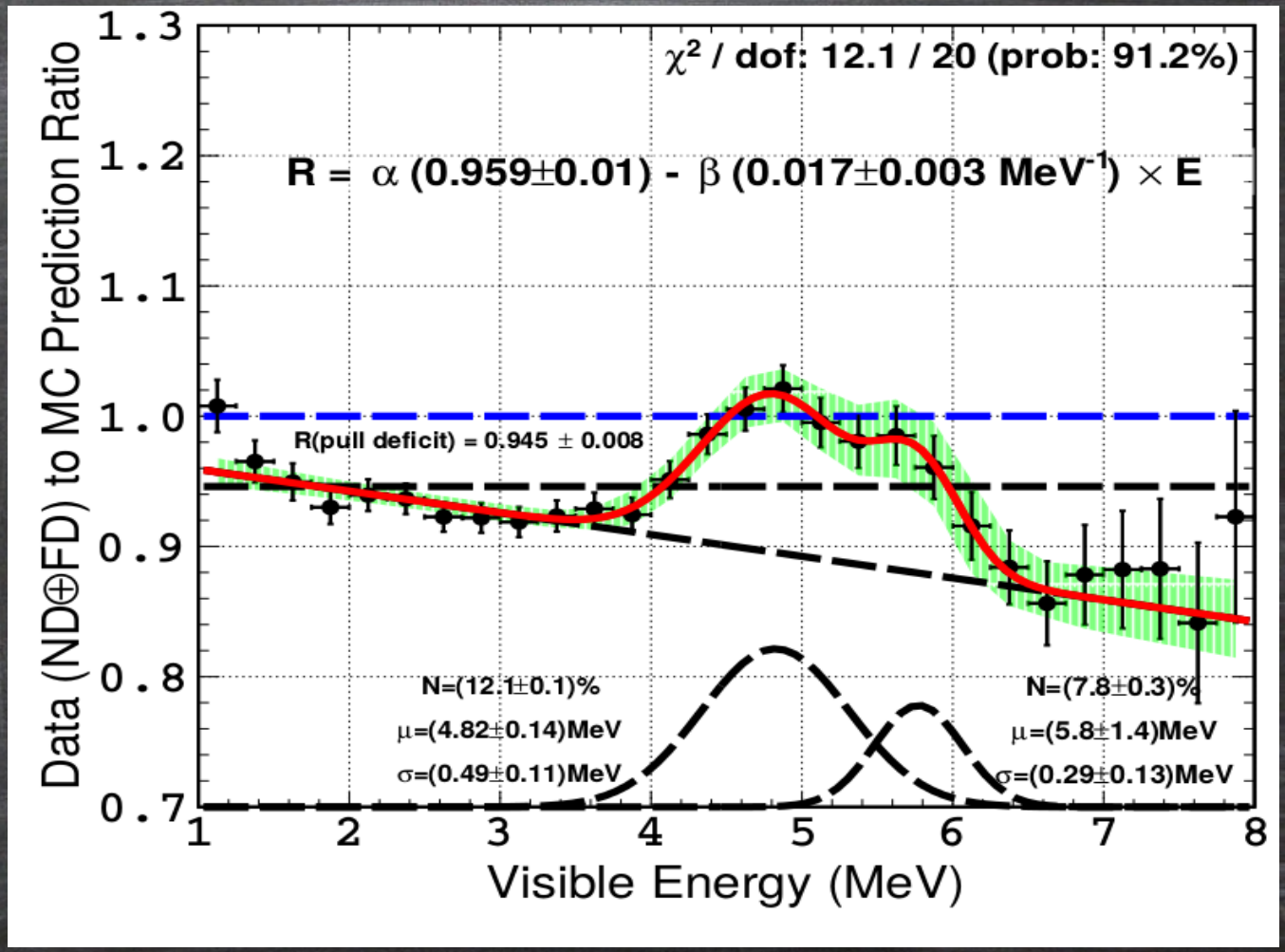

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-> $\sin^2 2\theta_{13}$ sensitivity improvement: extra data and better proton number measurement under consideration -> ~< 0.01

IN MEMORY OF ...

Herve de Kerret
(Spokesperson 2004 – 2017)

THANK YOU !

DOUBLE CHOOZ COLLABORATION

Brazil

CBPF
UNICAMP

France

APC (IN2P3)
CEA/IRFU:
- SPP
- SPhN
- SEDI
- SIS
- SENAC

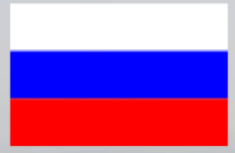
CENBG (IN2P3)
LNCA (IN2P3/CEA)
Subatech (IN2P3)

Germany

EKU Tübingen
MPIK Heidelberg
RWTH Aachen
TU München

Japan

Tohoku U.
Tokyo Inst. Tech.
Tokyo Metro. U.
Tokyo U. Science
Kitasato U.
Kobe U.



Russia

INR RAS
RRC Kurchatov

Spain

CIEMAT-Madrid

USA

Alabama U.
ANL
Chicago U.
Drexel U.
Hawaii U.
Notre Dame U.
Virginia Tech.

Spokesperson:
A. Cabrera (IN2P3/CNRS)

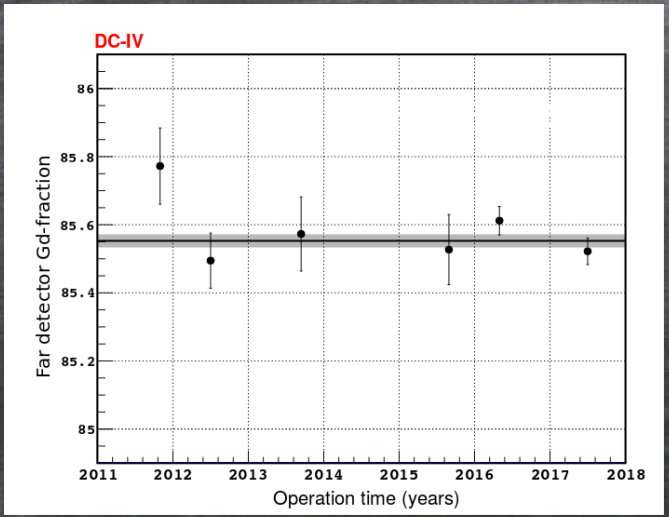
Project Manager:
Ch. Veyssière (CEA)

97 scientists 25 institutions (Americas, Asia, Europe)

doublechooz.in2p3.fr

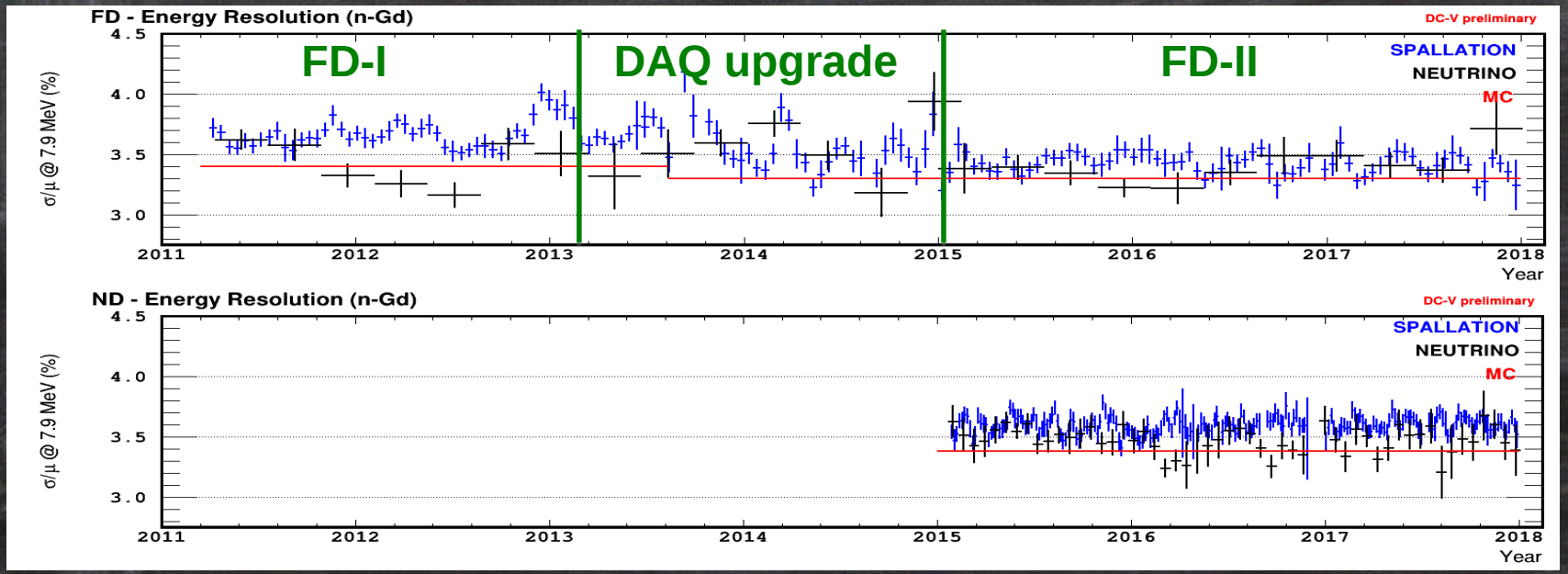

BACKUPS

SCINTILLATOR STABILITY



-> Optical and chemical stability of Gd-scintillator (7 years)

-> Gd fraction (center) stable on < 0.1% level

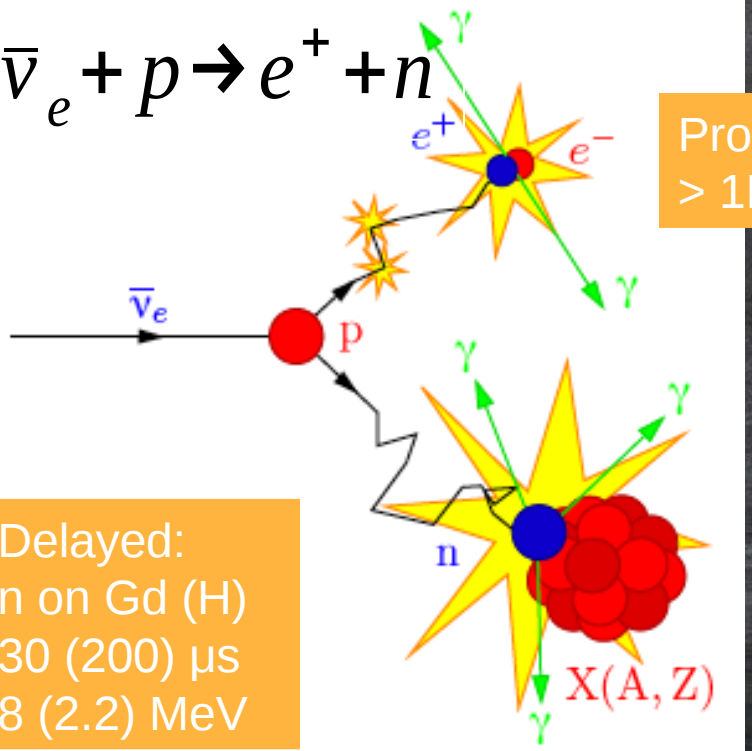


NEUTRINO PRODUCTION / DETECTION

$$N_\nu^{\exp}(t) = \frac{\varepsilon N_p}{4\pi L^2} \times \frac{P_{th}(t)}{\langle E_f \rangle} \times \langle \sigma_f \rangle$$

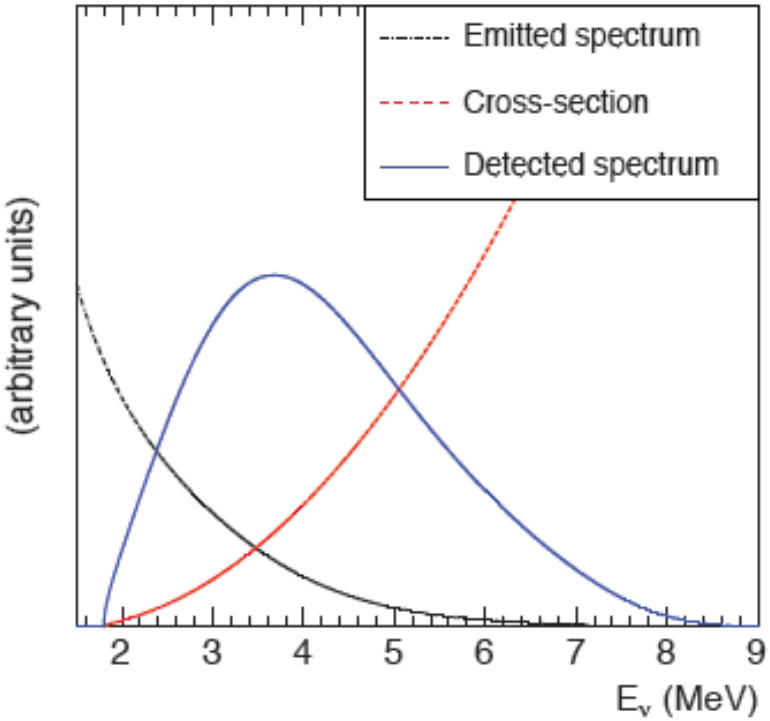
→ Mean cross section per fission (Near detector!)

$$\bar{\nu}_e + p \rightarrow e^+ + n$$



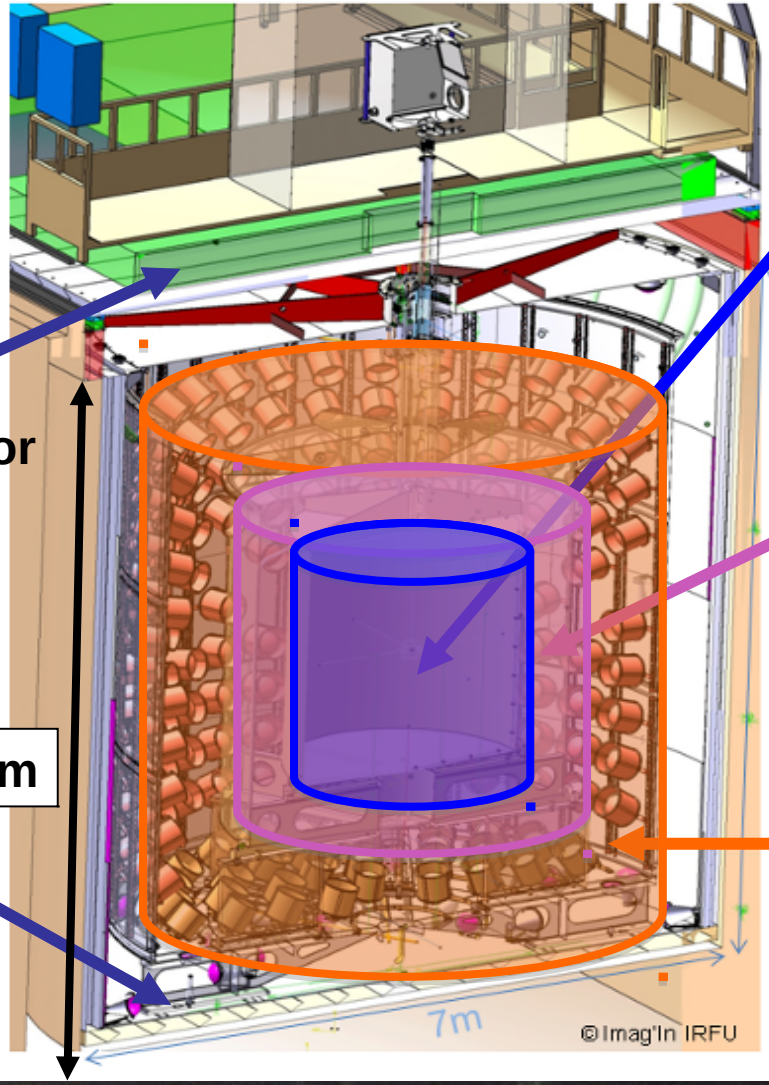
Prompt:
> 1MeV

Delayed:
n on Gd (H)
30 (200) μs
8 (2.2) MeV



$$E_{vis} = E_\nu - 0.8\,MeV$$

DETECTOR DESIGN



Outer Veto:
Plastic scintillator

Inner Veto:
- **Steel**
- **70 t LS**
- **78 PMTs (8”)**

Inner detector:

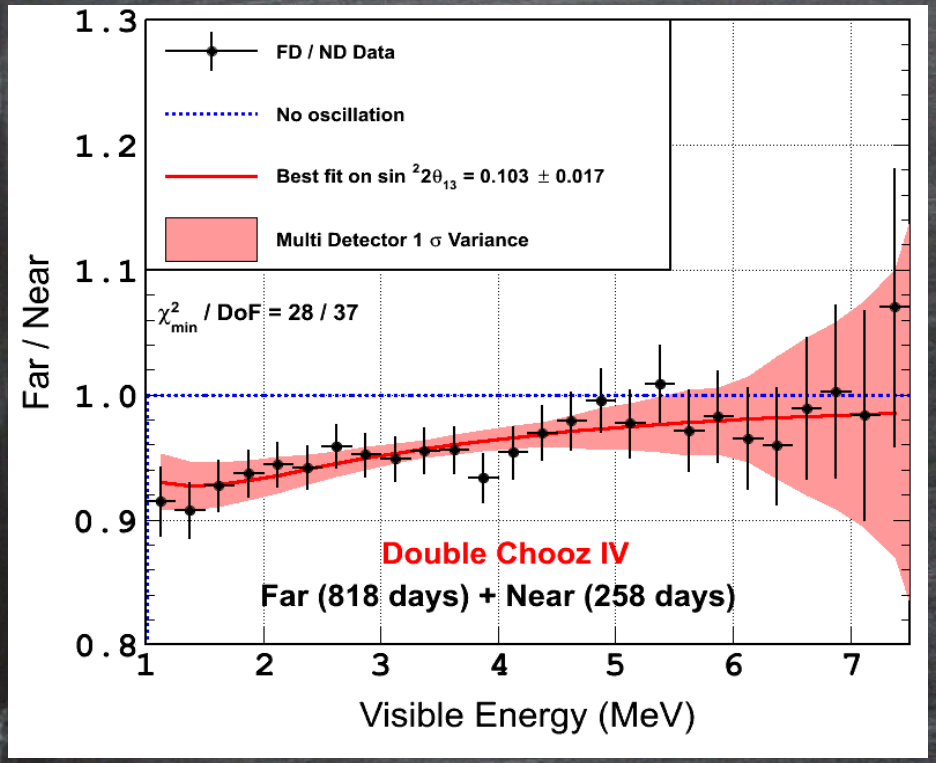
Target (r = 1.2 m):
- Acrylic vessel
- 8.3 t Gd-scintillator (1 g/l Gd)

Gamma Catcher (0.55 m):
- Acrylic vessel
- 18 t liquid scintillator

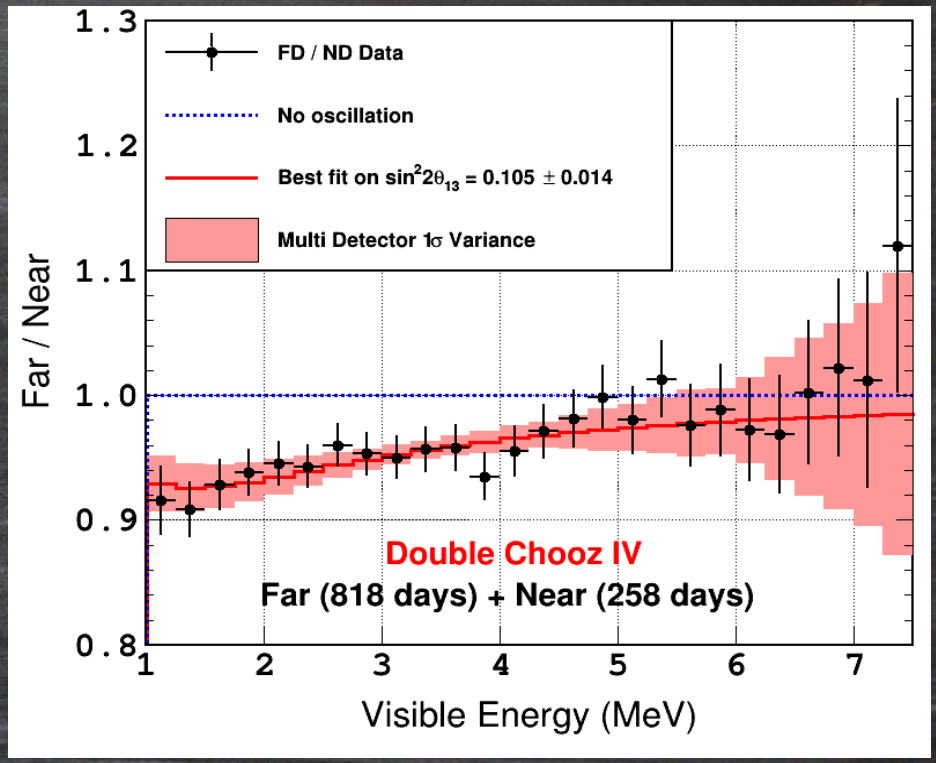
Buffer (1.05 m):
- Steel vessel
- 80 t “oil”
- 390 PMTs (10”)

NEAR TO FAR RATIO

Data-to-Data Fit Output

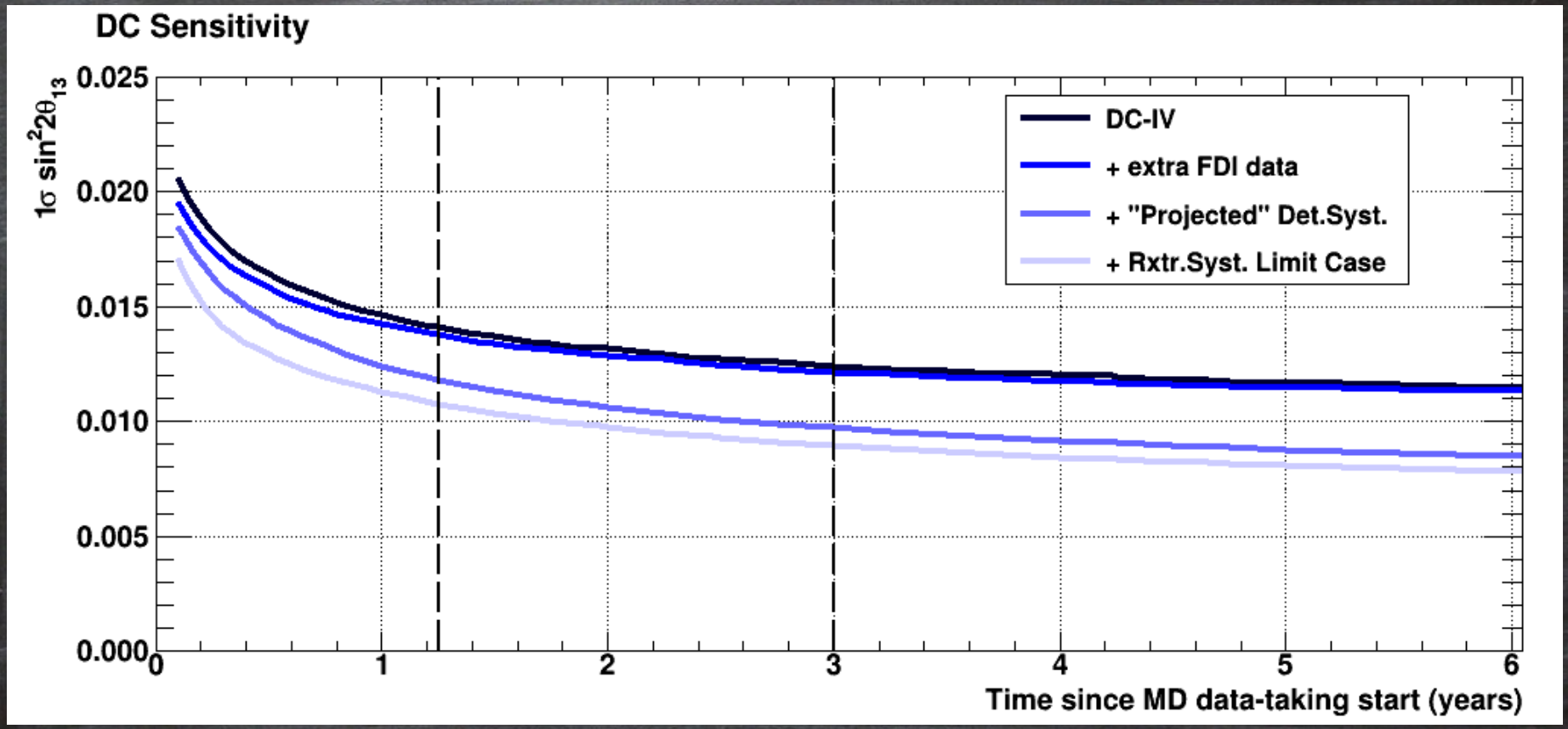


Data-to-MC Fit Output



Data to data result: $\sin^2 2\theta_{13} = 0.103 \pm 0.017$

SENSITIVITY PROJECTION



-> Double Chooz final sensitivity: 0.009~0.010 !