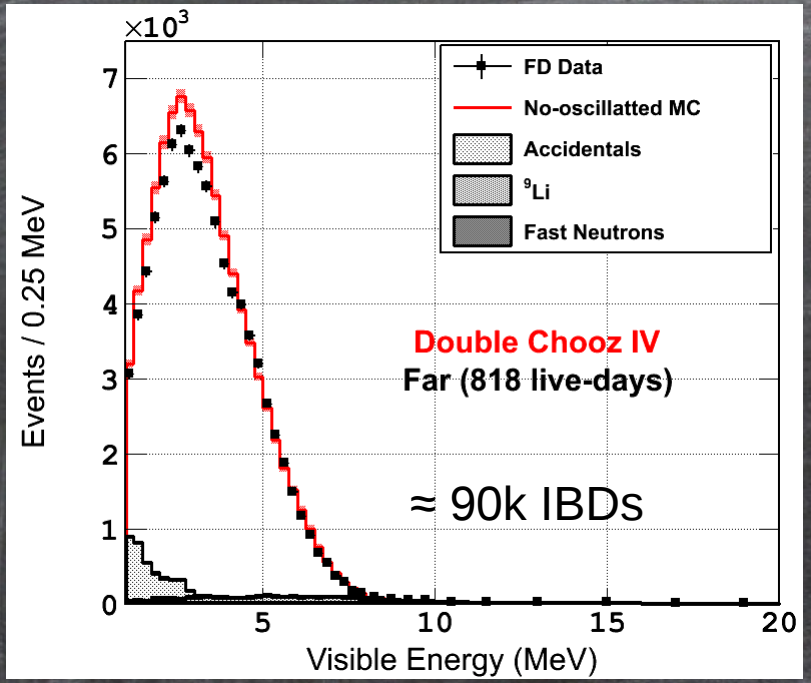
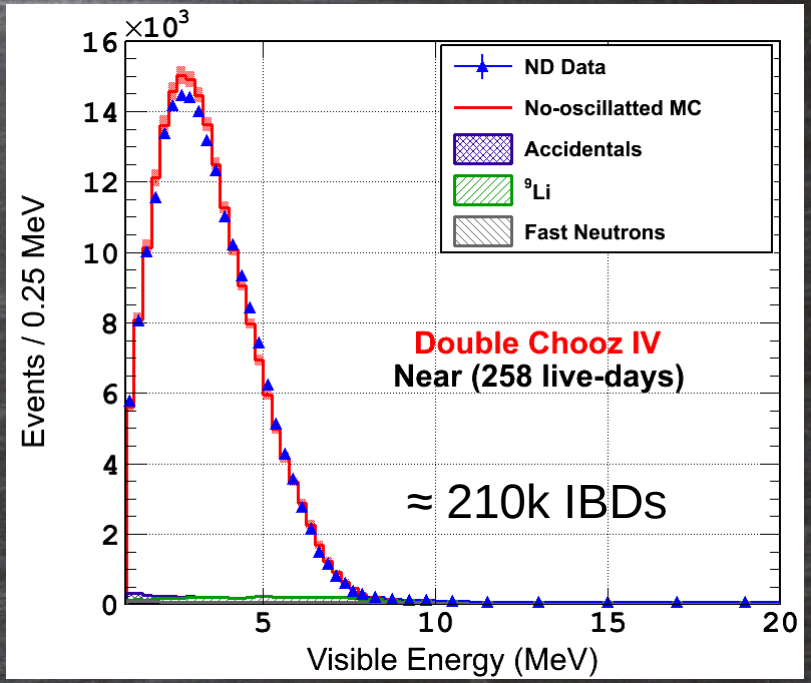
New Results from the Double Chooz Experiment

Thiago Bezerra (SUBATECH – IN2P3/CNRS, Nantes)
on behalf of the Double Chooz Collaboration

GDR Neutrino Meeting @ APC, 12/06/2018

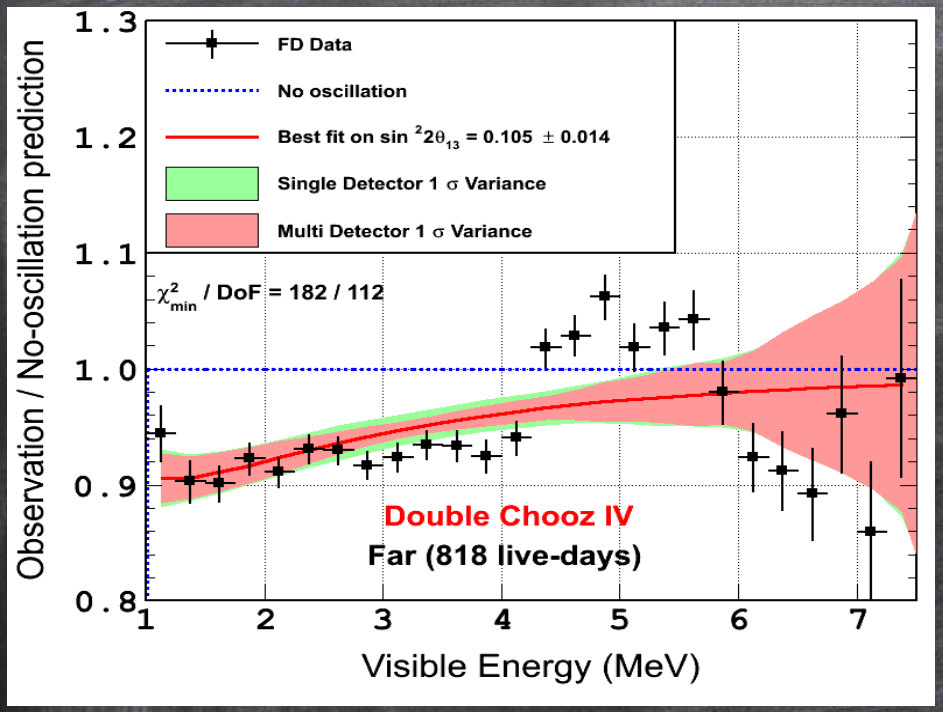
DC-IV FIT RESULTS

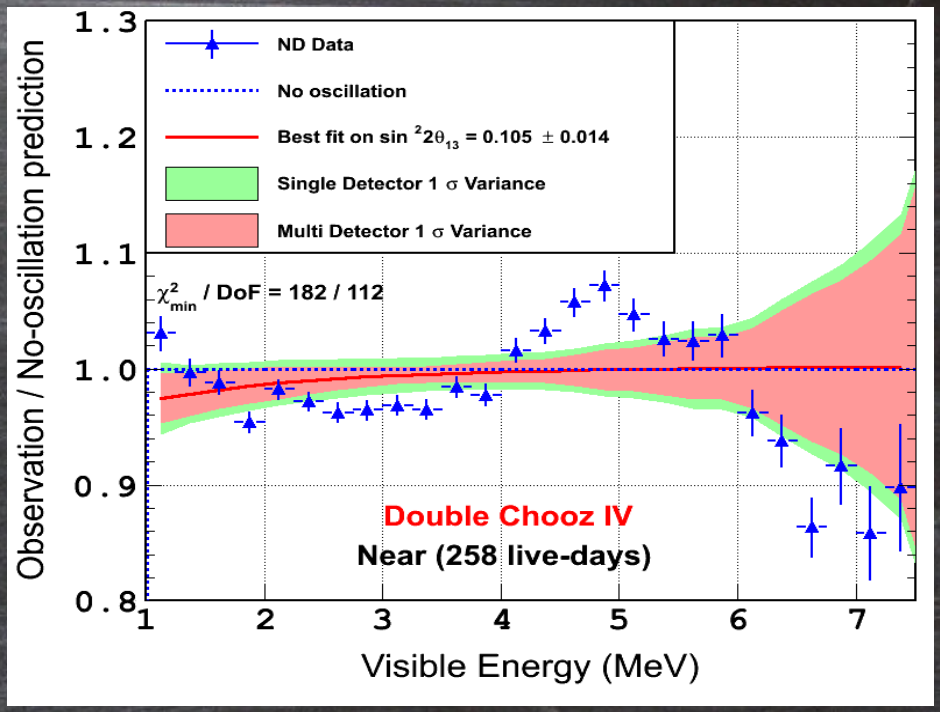




Data-MC fit including Bugey 4 normalization

DC-IV FIT RESULTS



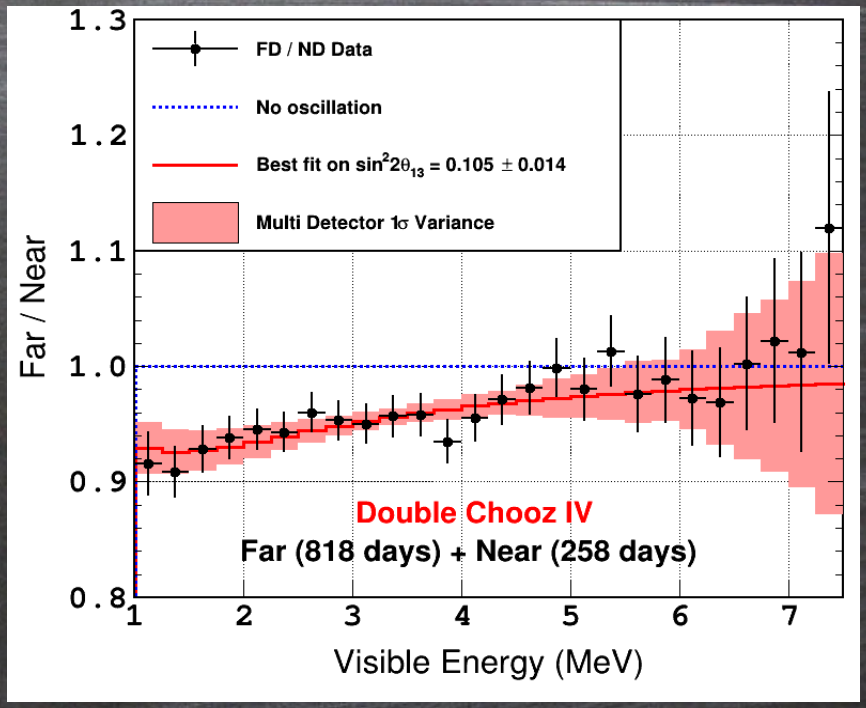


Data-MC fit including Bugey 4 normalization

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

NEW!

DC-IV Fit Results



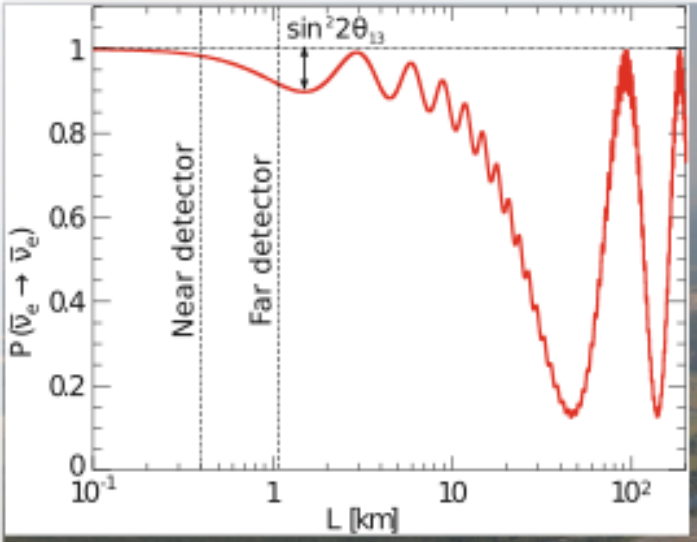
Data-MC fit including Bugey 4 normalization

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

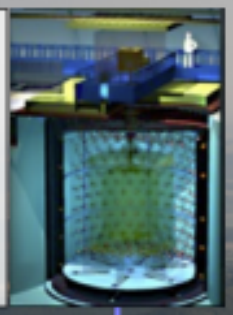
NEW!

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



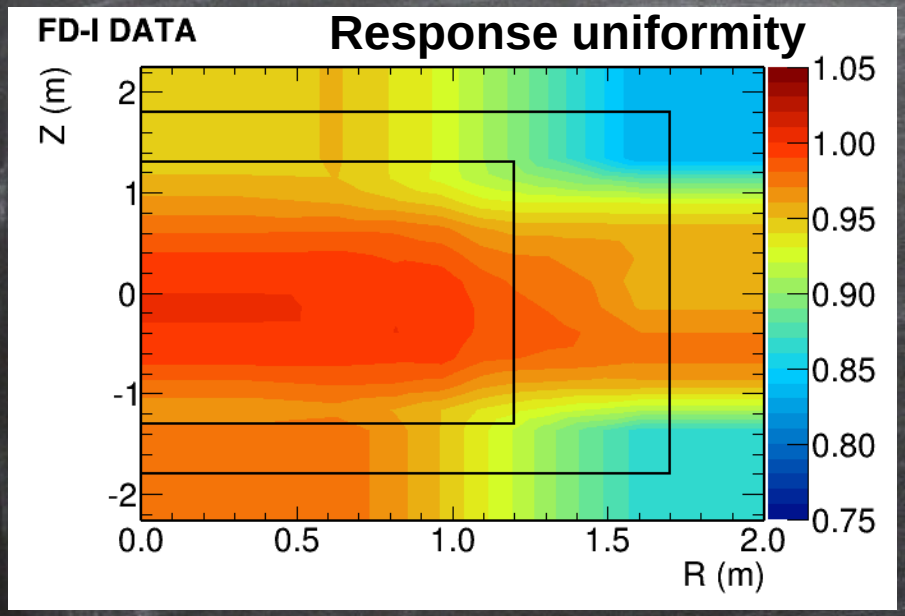
Near
< L > 400m
~800 $\bar{\nu}_e$/ day
120 m.w.e.
2015

2 reactors
2 × 4.25 GW_{th}
~ 10^{21} $\bar{\nu}_e$/ s

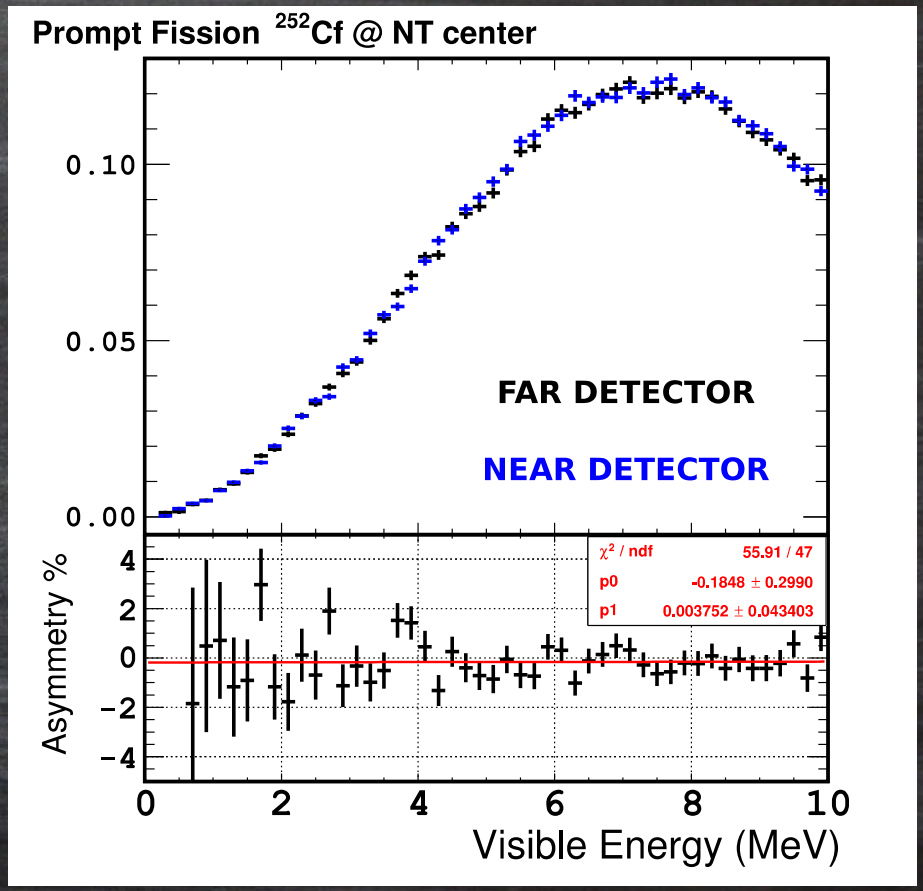
Near Detector: to suppress systematics

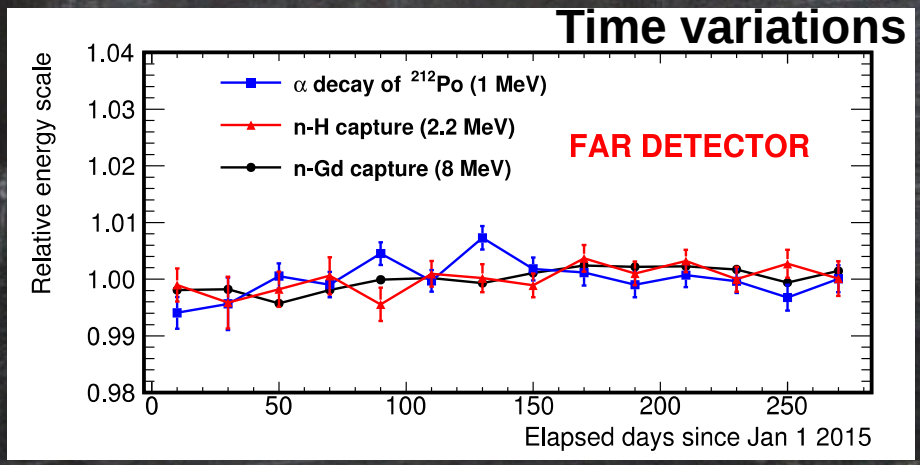
$\bar{\nu}_e$ Disappearance between Near and Far detectors → θ_{13}

ENERGY RECONSTRUCTION



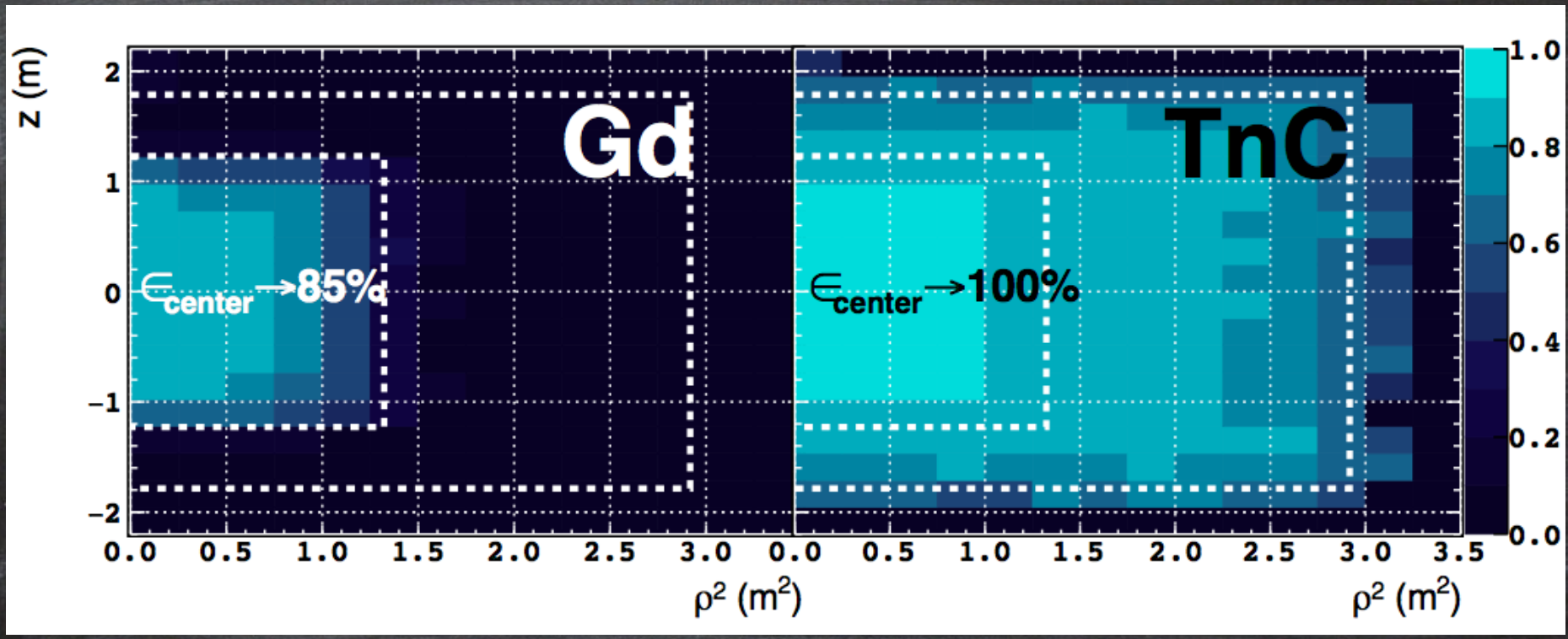
VERY GOOD NEAR - FAR AGREEMENT





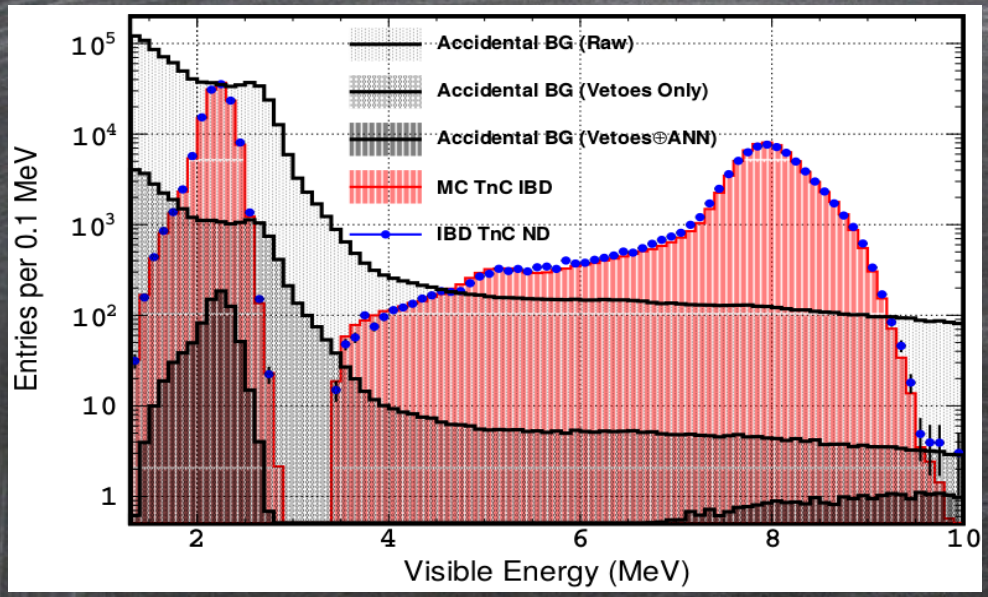
DC STATISTICS / EFFICIENCY

„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



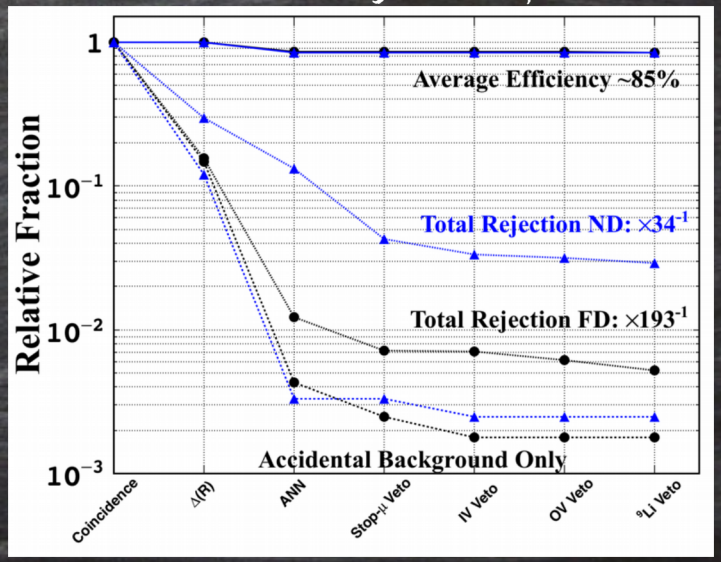
Delayed E spectrum (data and MC) before and after cuts

-> Good data/MC agreement for IBD candidates

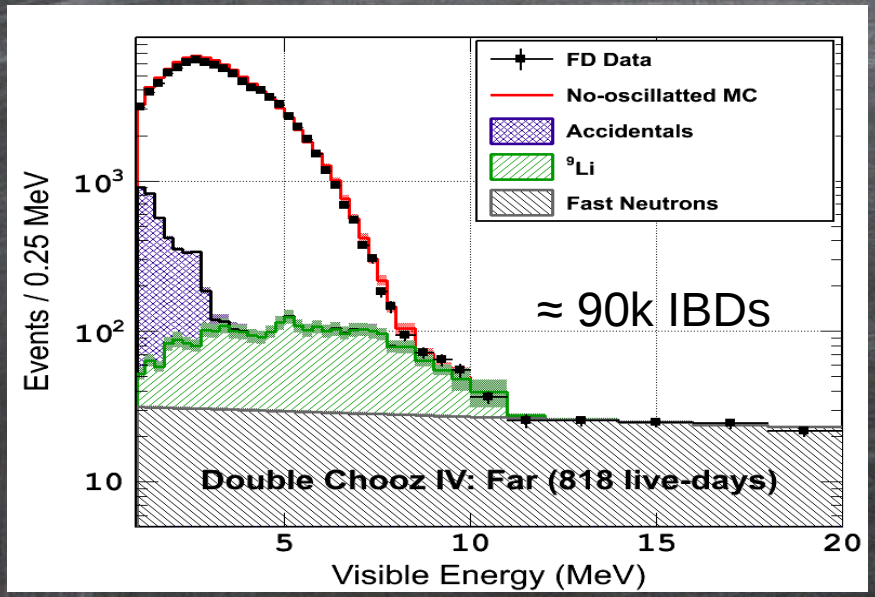
-> Efficient background supression with cuts/vetoes

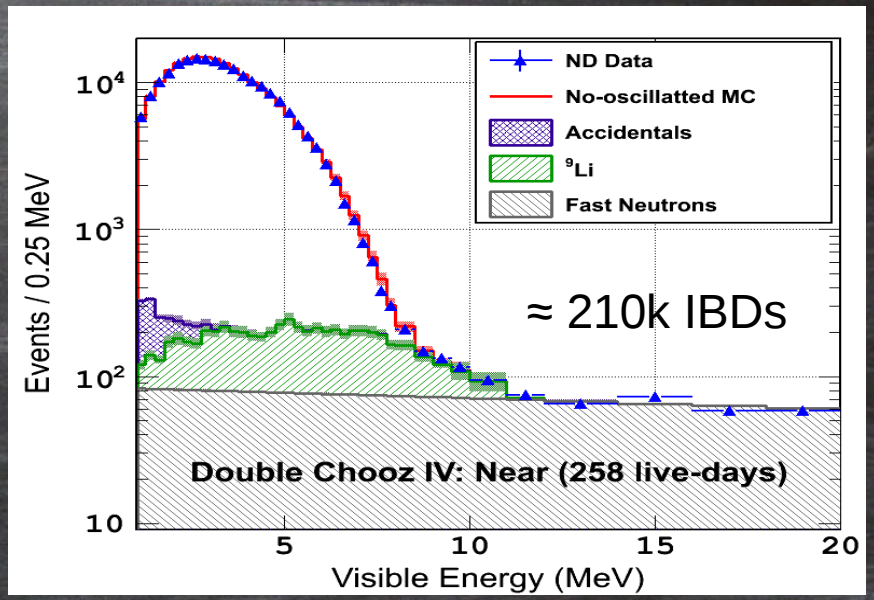
IBD efficiency and background rejection

Cumulative rejection per cut



SIGNAL AND BACKGROUNDS

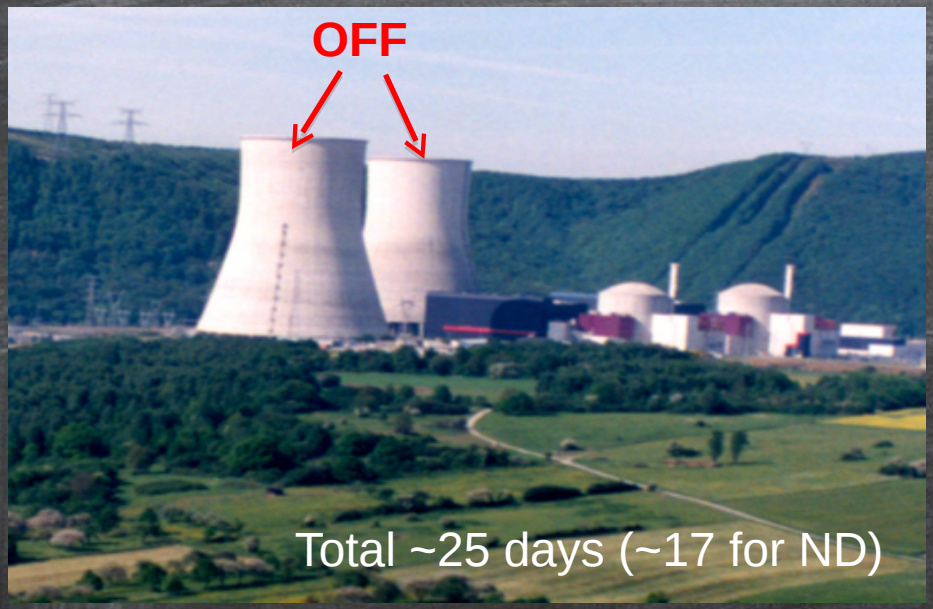


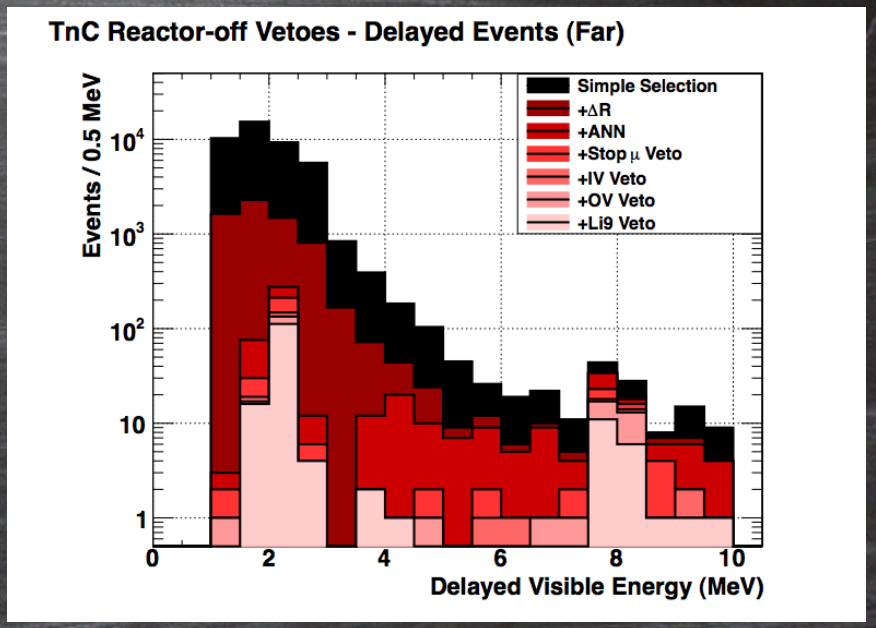


	Ev./day FD	Ev./day ND
IBD candidates	112	816
Cosmogenic BG (^{9}Li)	2.62 ± 0.27	14.52 ± 1.48
Fast n	2.50 ± 0.05	**20.85 ± 0.31**
Accidental BG	**4.13 ± 0.02**	3.11 ± 0.01

S/B>10!

BOTH REACTORS OFF DATA



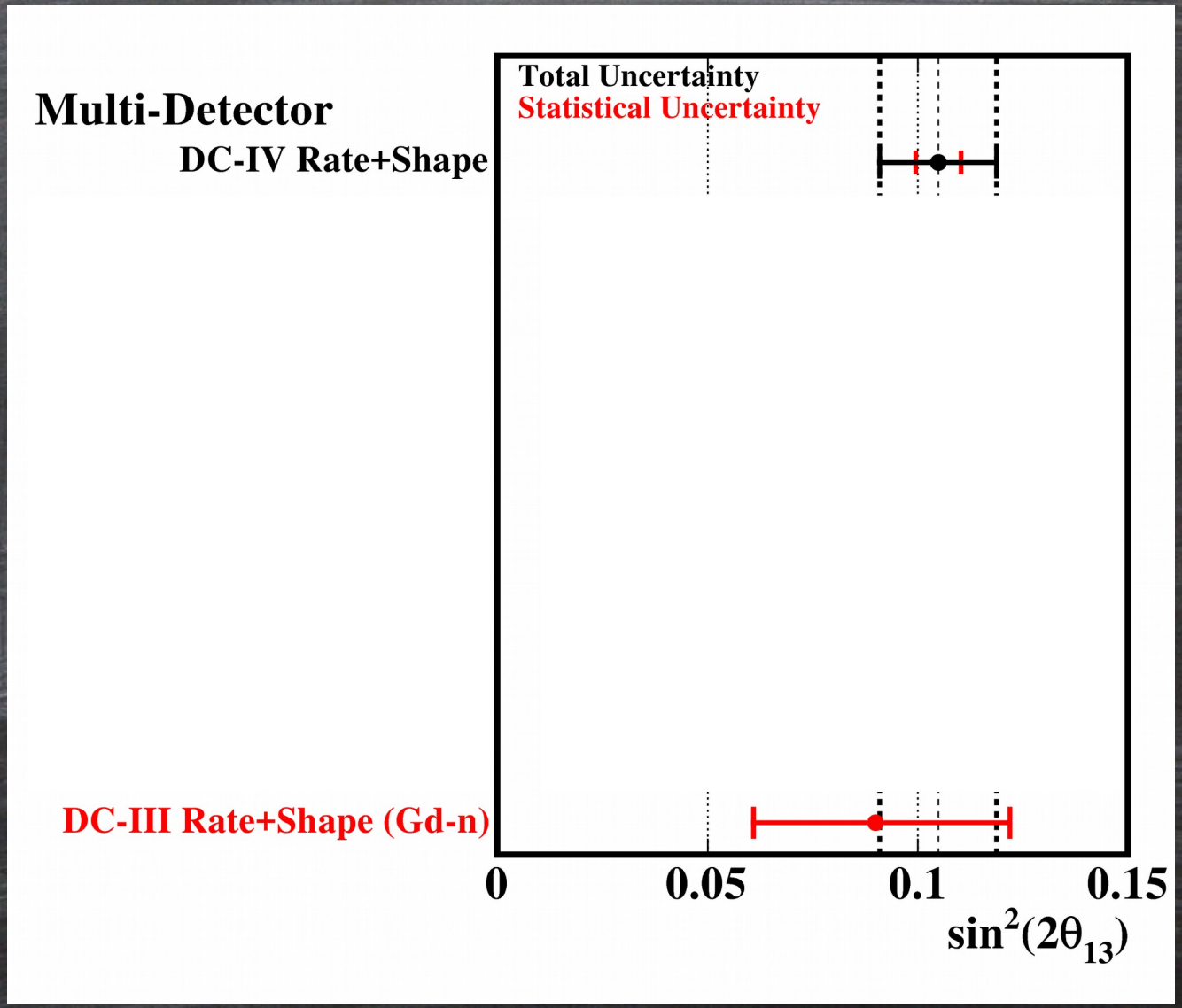


	ND (ev./day)	FD (ev./day)
OFF-OFF I (2012)	---	8.9 ± 1.2
OFF-OFF II (2017)	39.6 ± 2.5	9.8 ± 0.9
Rate+Shape values	38.5 ± 1.5	9.3 ± 0.3

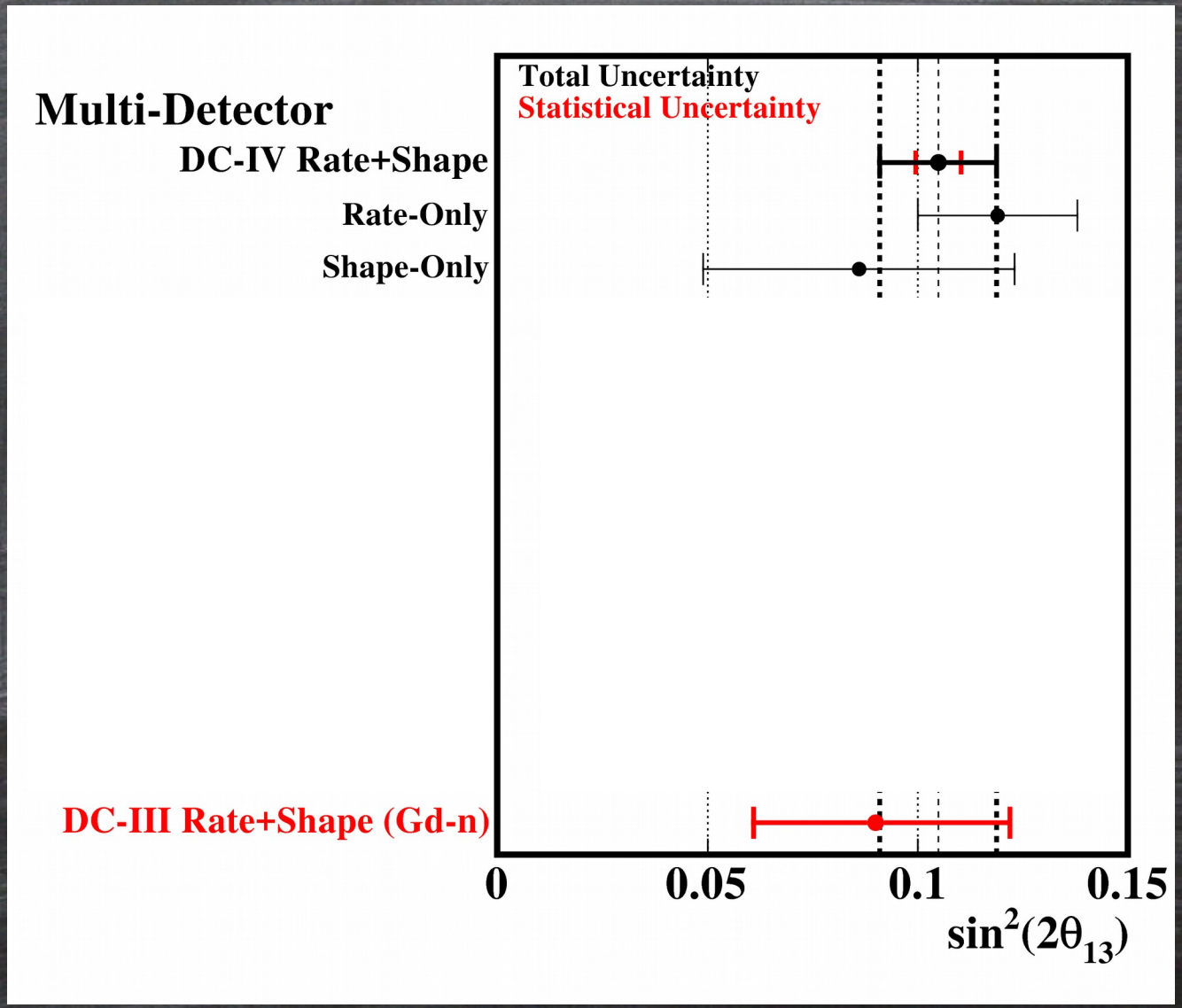
Background understanding

All numbers within 1σ!

MORE DC θ_{13} FITS

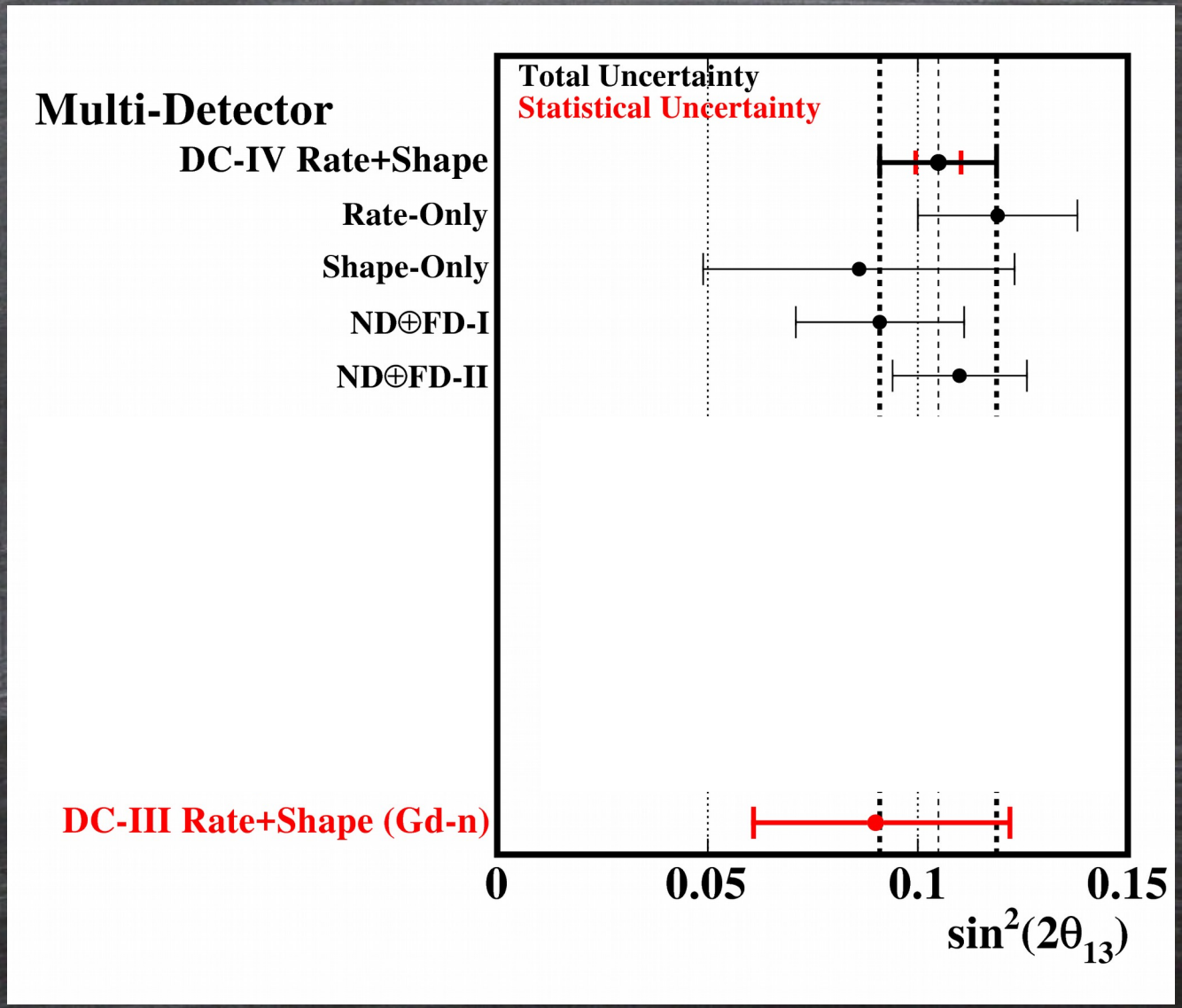


MORE DC θ_{13} FITS



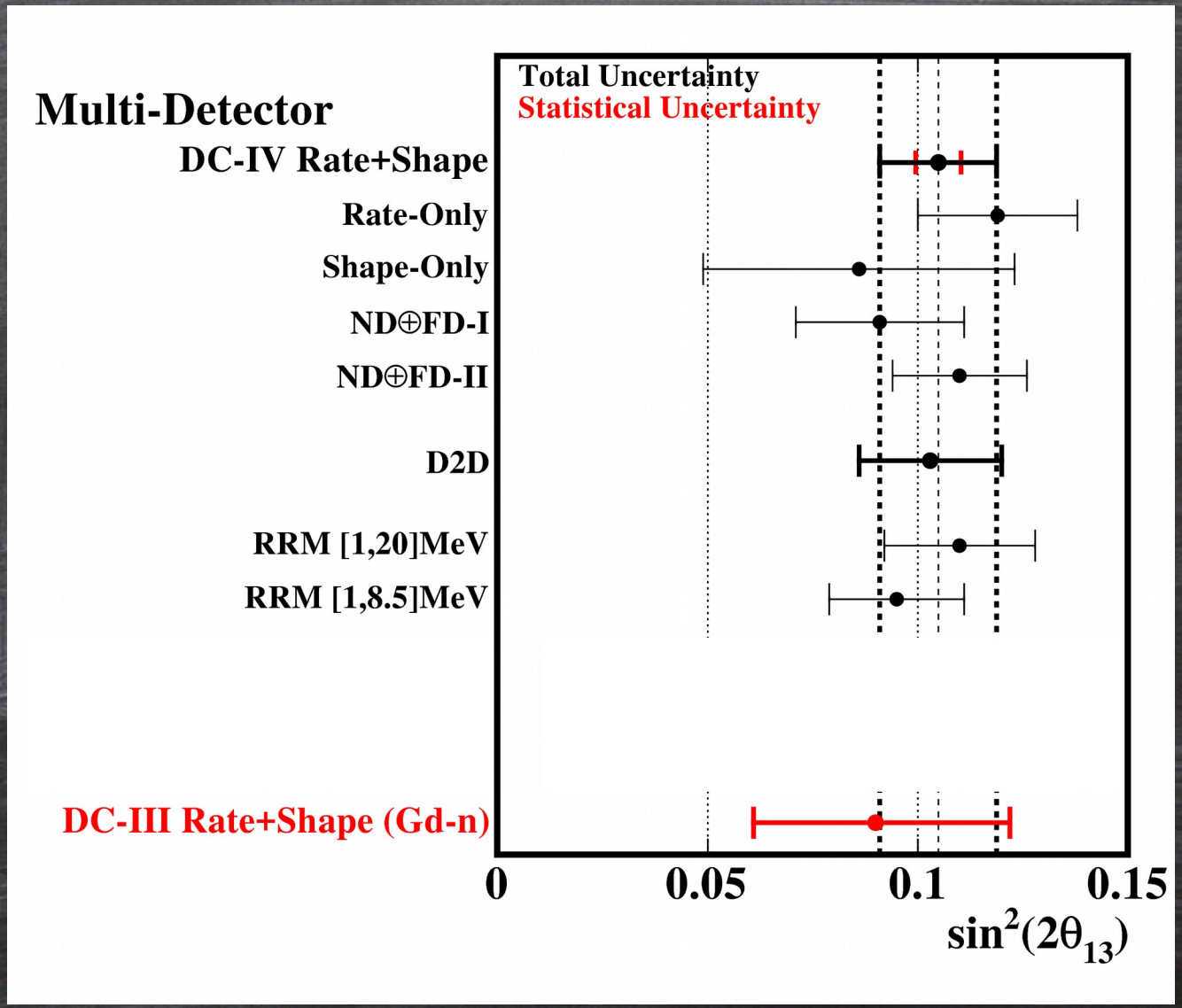
Norm. Pushes up

MORE DC θ_{13} FITS



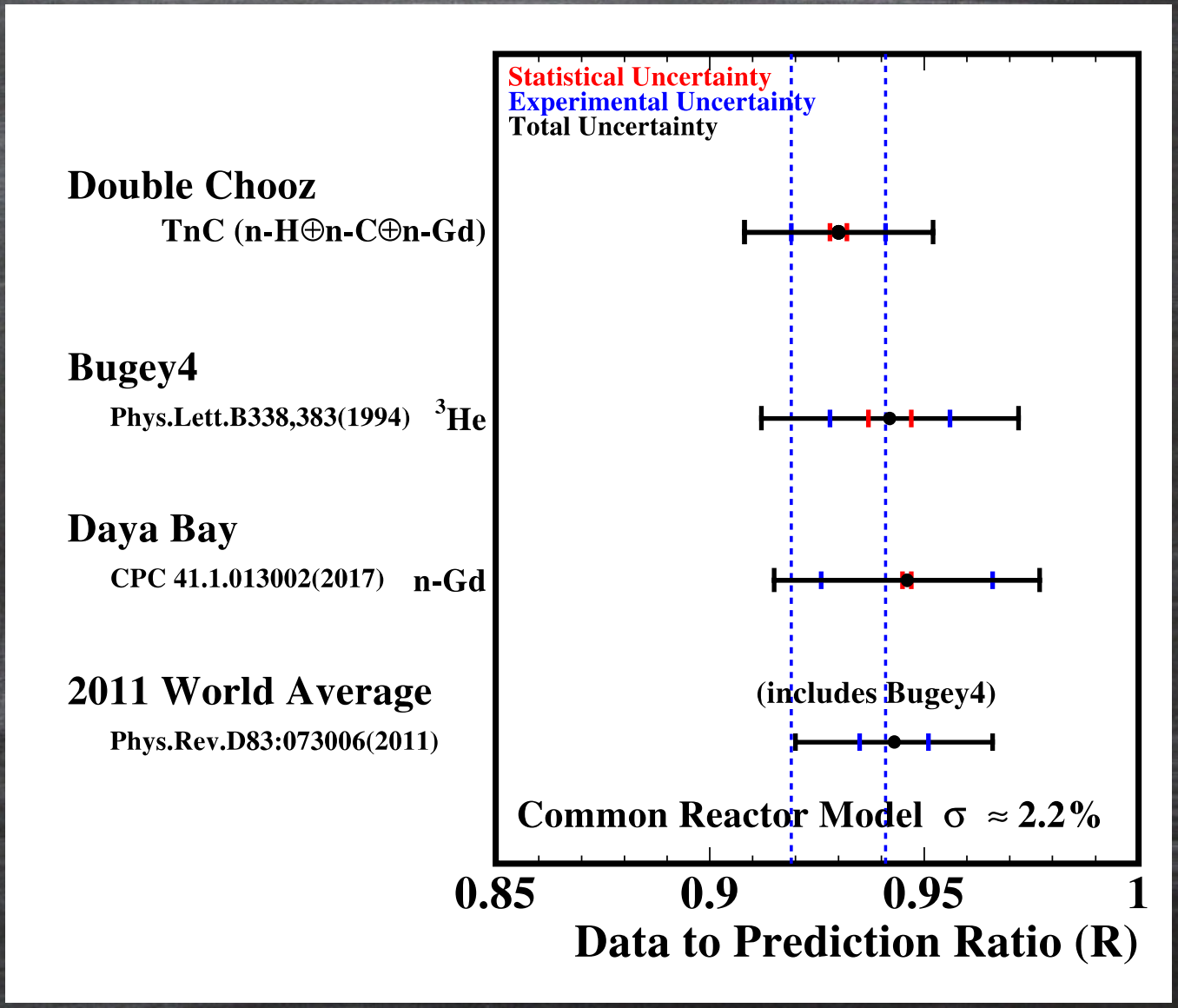
FD-II (Flux Cancelation)
Pushes up

MORE DC θ_{13} FITS

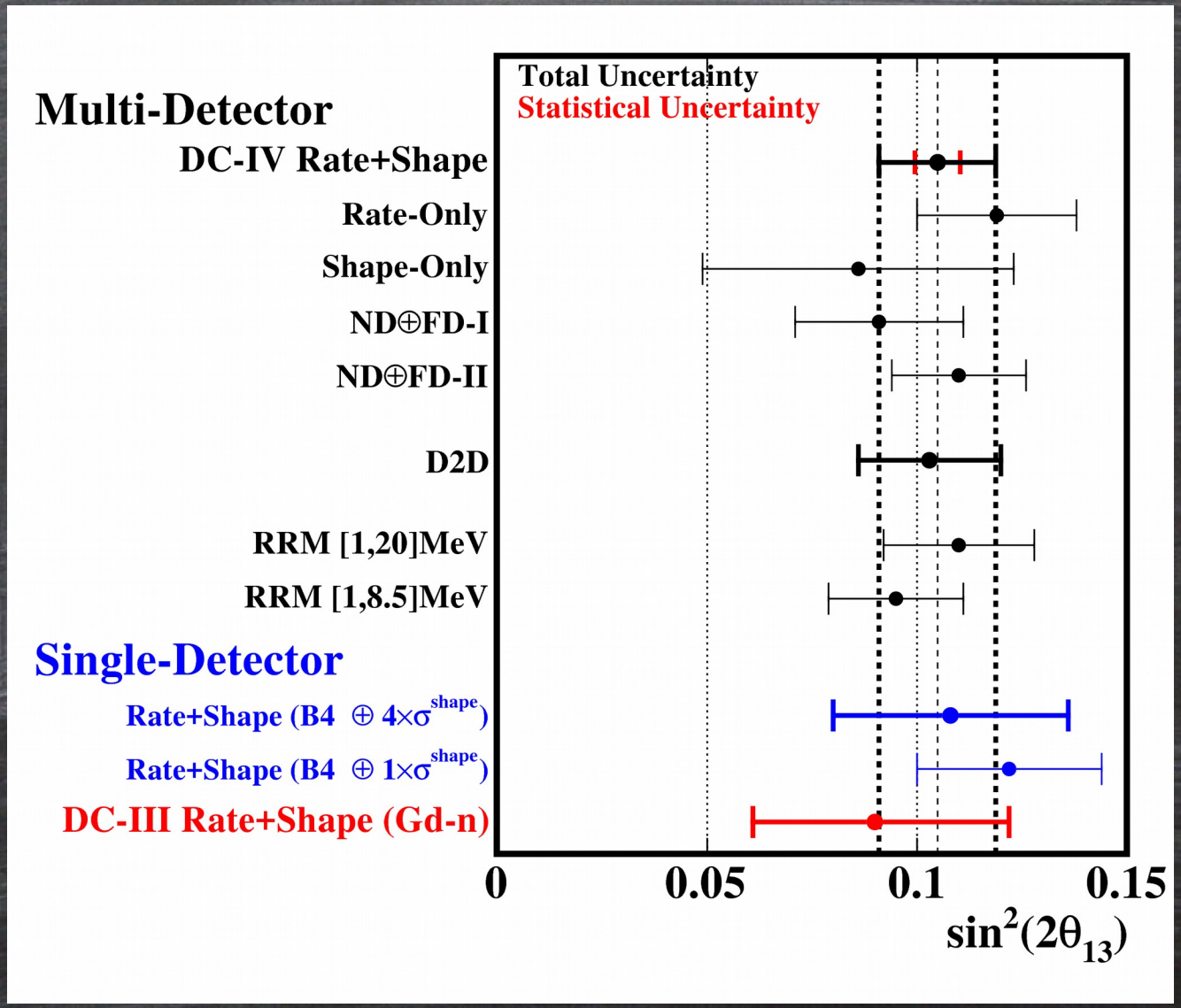


Complementary Fits

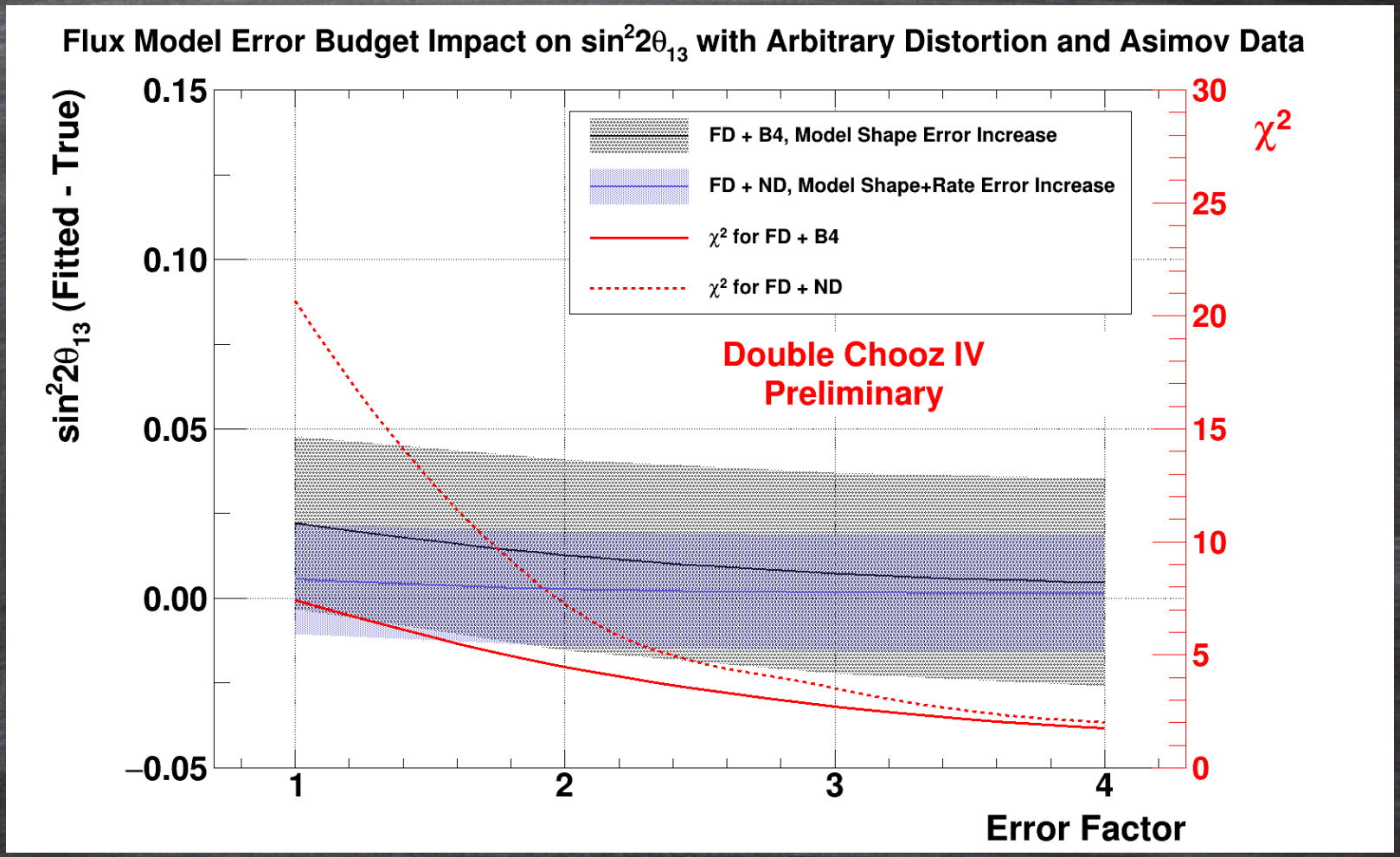
NORMALIZATION ND VS B4



MORE DC θ_{13} FITS



FLUX ERROR BUDGET & SINGLE DETECTOR FIT



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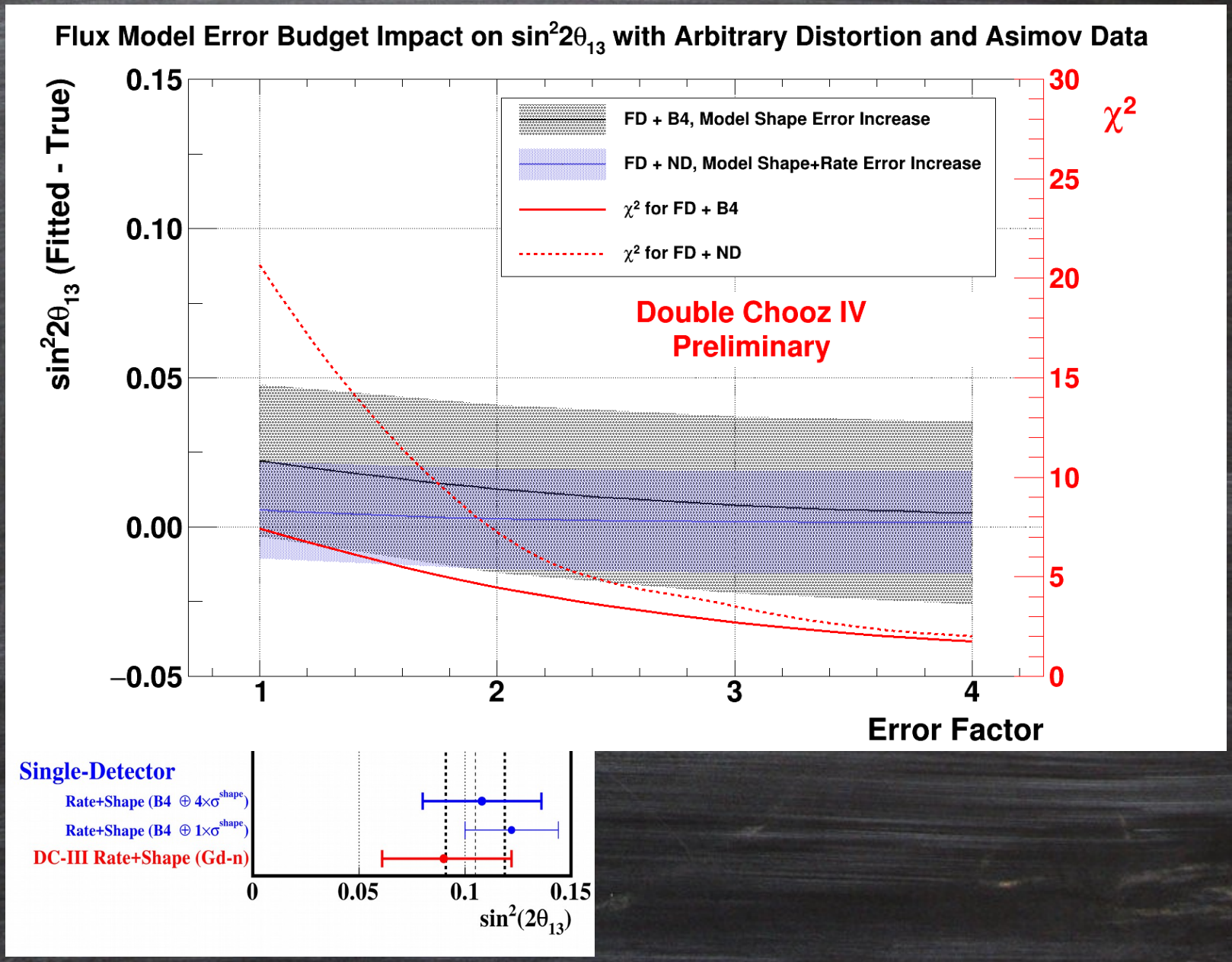

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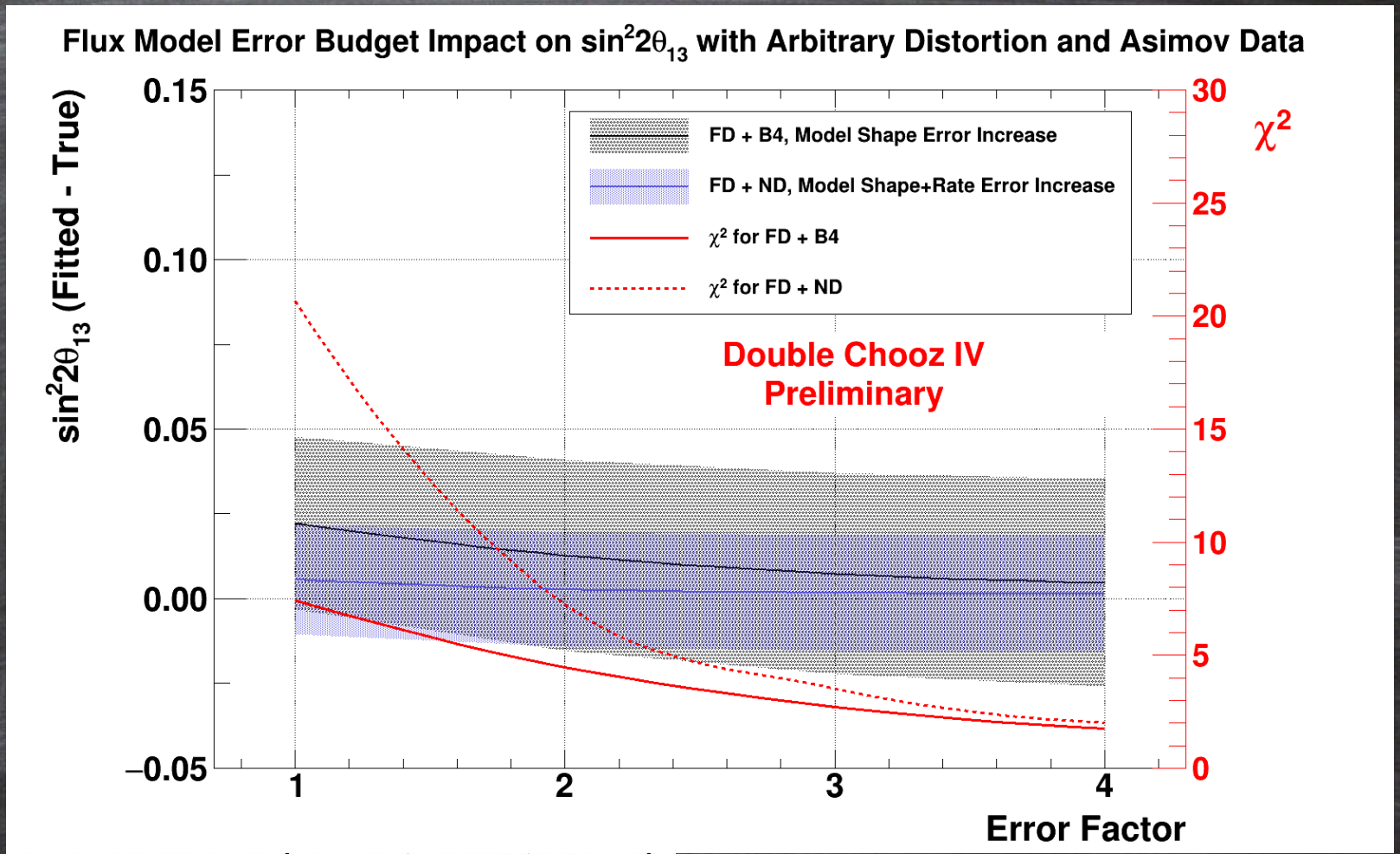
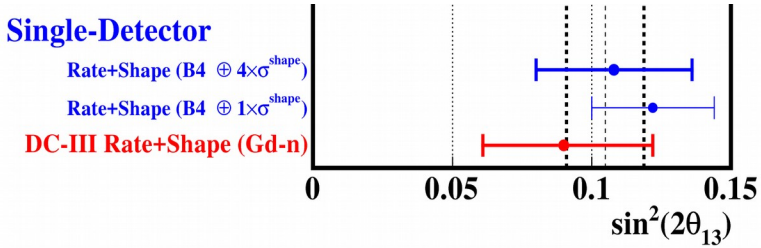


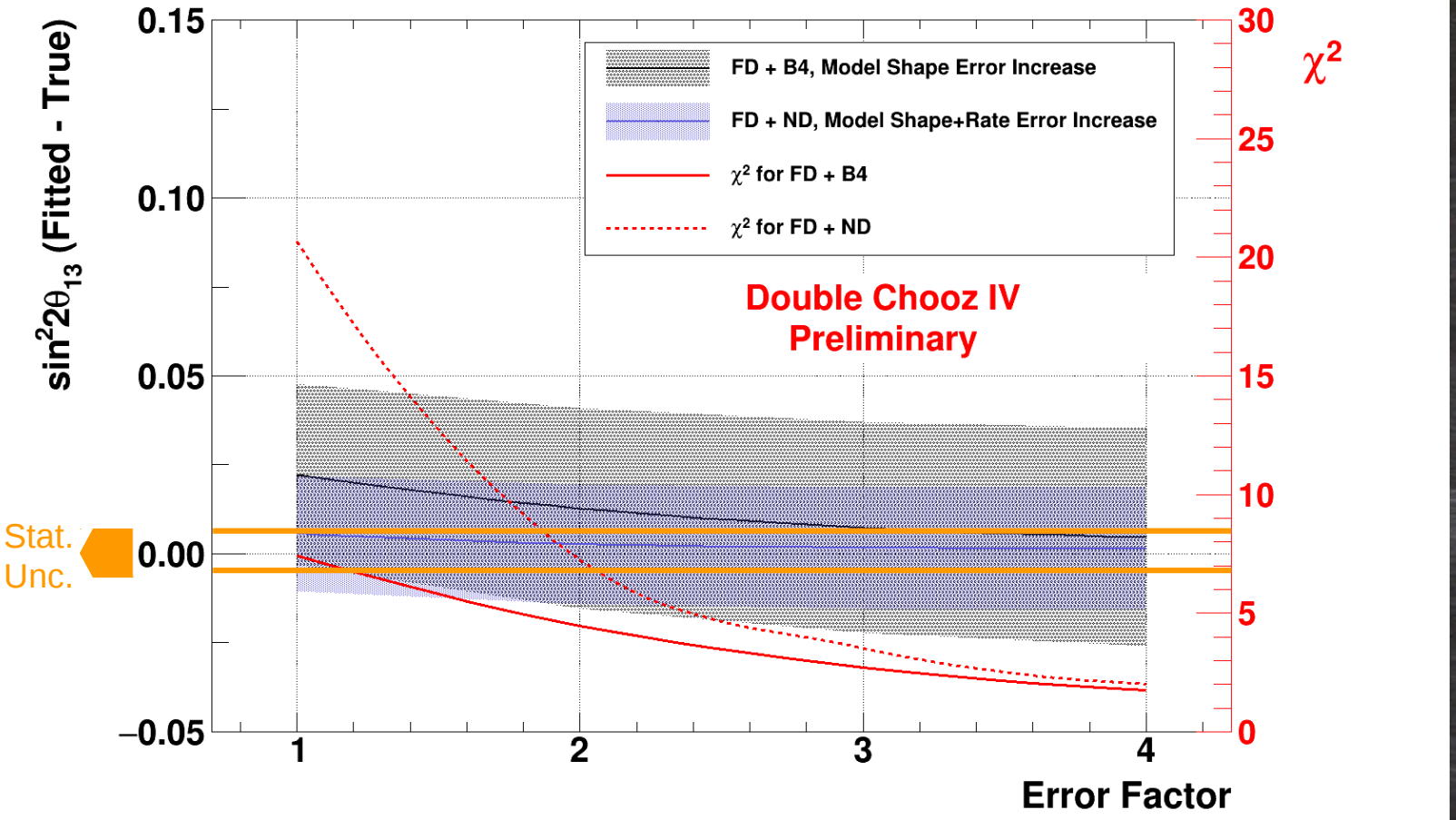


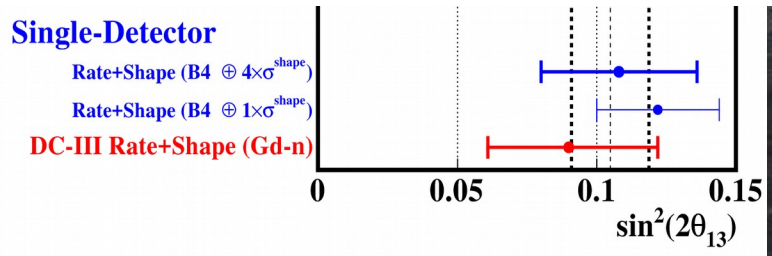
χ^2 (x1 -> x4 error) w/ Data:

FD+B4 = 105 -> 53 (74 DoF)

FD+ND = 182 -> 93 (112 DoF)

FLUX ERROR BUDGET & SINGLE DETECTOR FIT





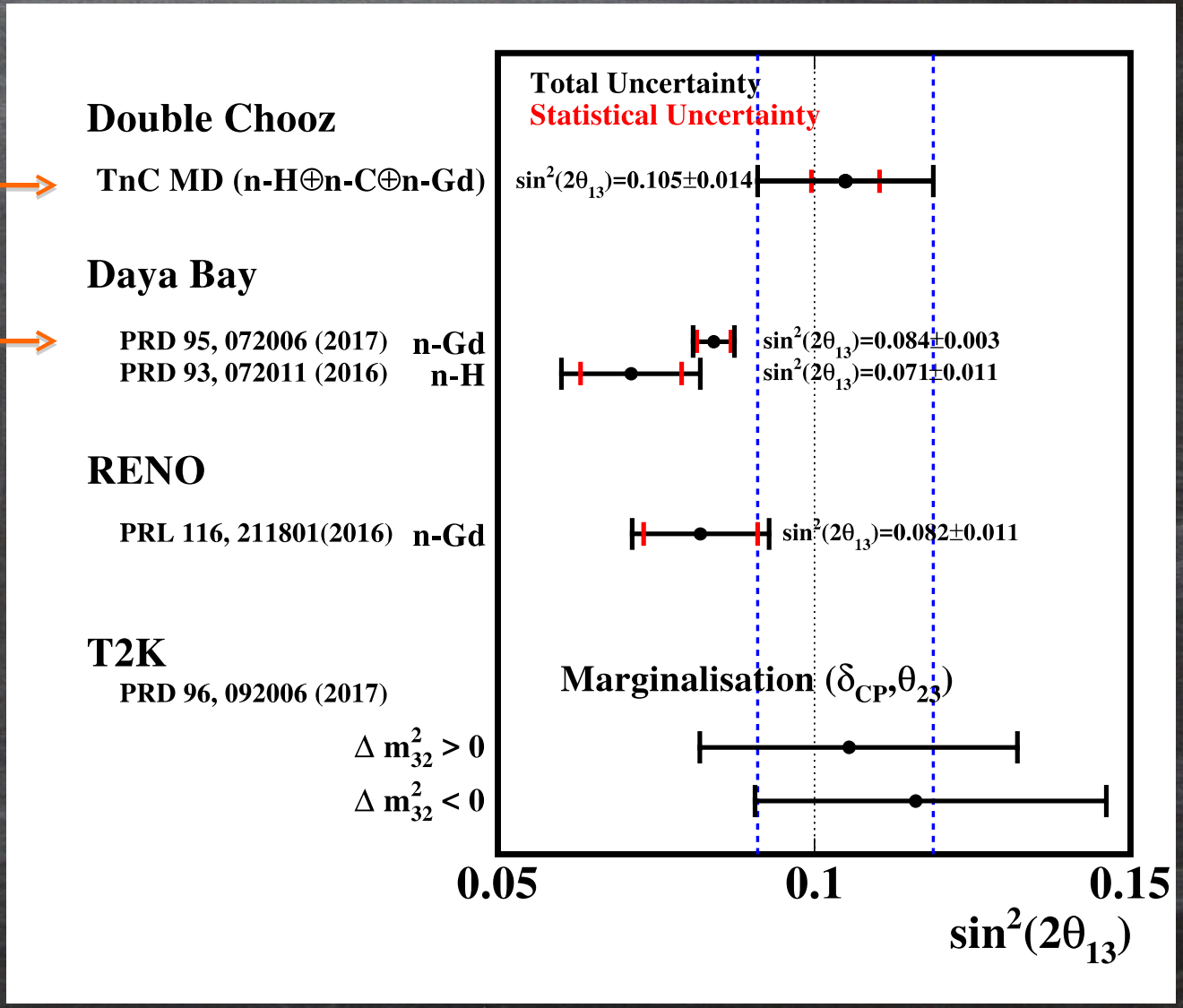
χ^2 (x1 -> x4 error) w/ Data:

FD+B4 = 105 -> 53 (74 DoF)

FD+ND = 182 -> 93 (112 DoF)

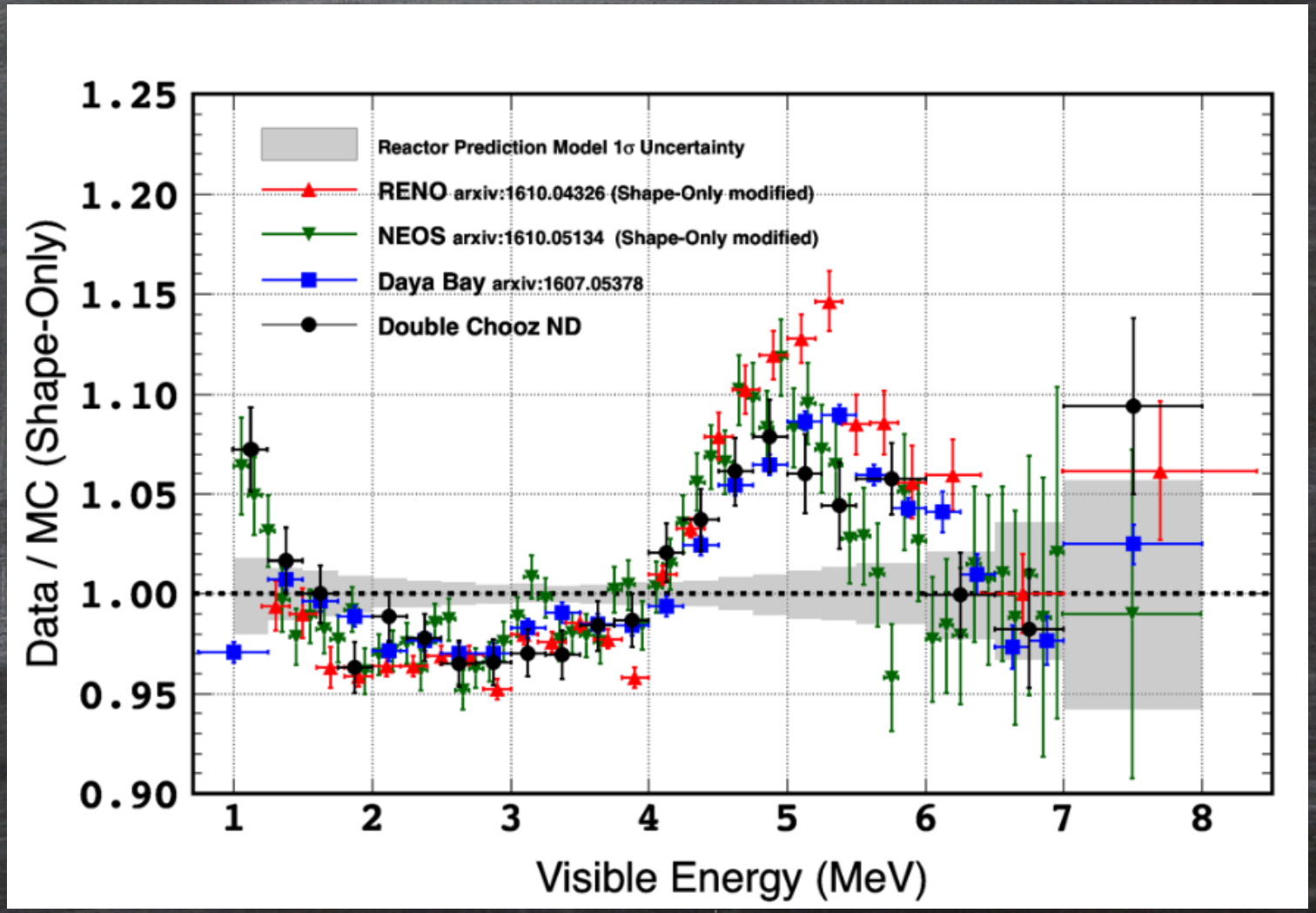
RESULT COMPARISON WORLDWIDE

<~2σ difference (systematics!)



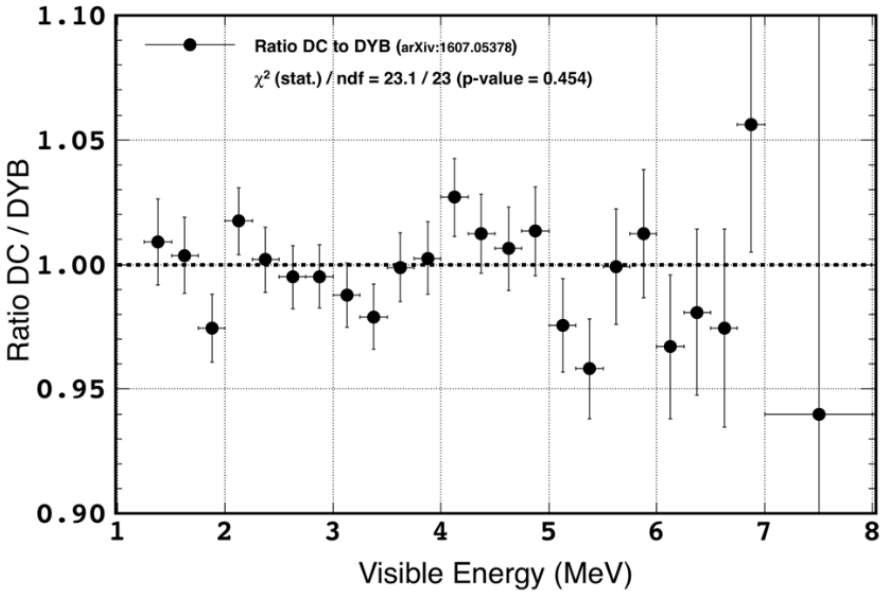
Intl. Reactor-θ_{13} Workshops: Combined (DC/DYB/RENO) effort to understand systematics

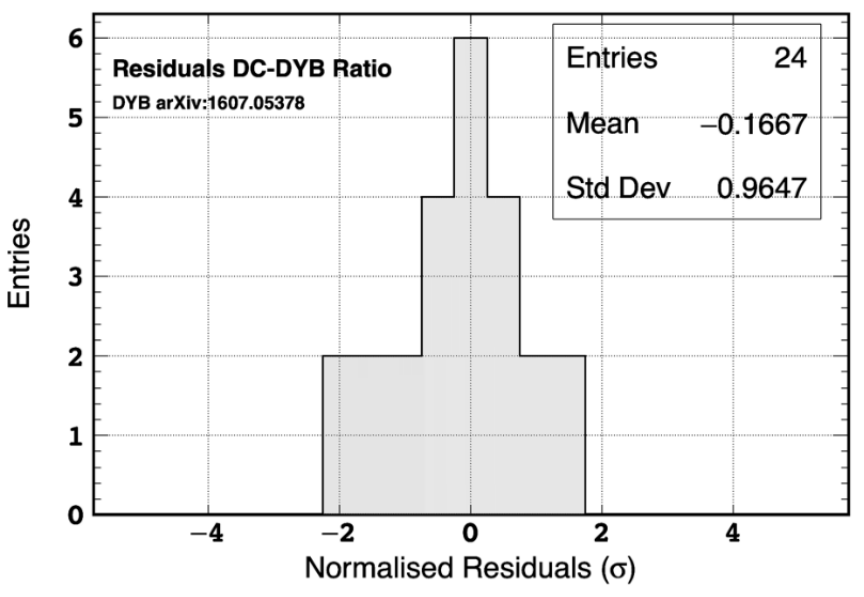
SPECTRAL DISTORTION COMPARISON (SHAPE ONLY)



Excellent agreement to first order

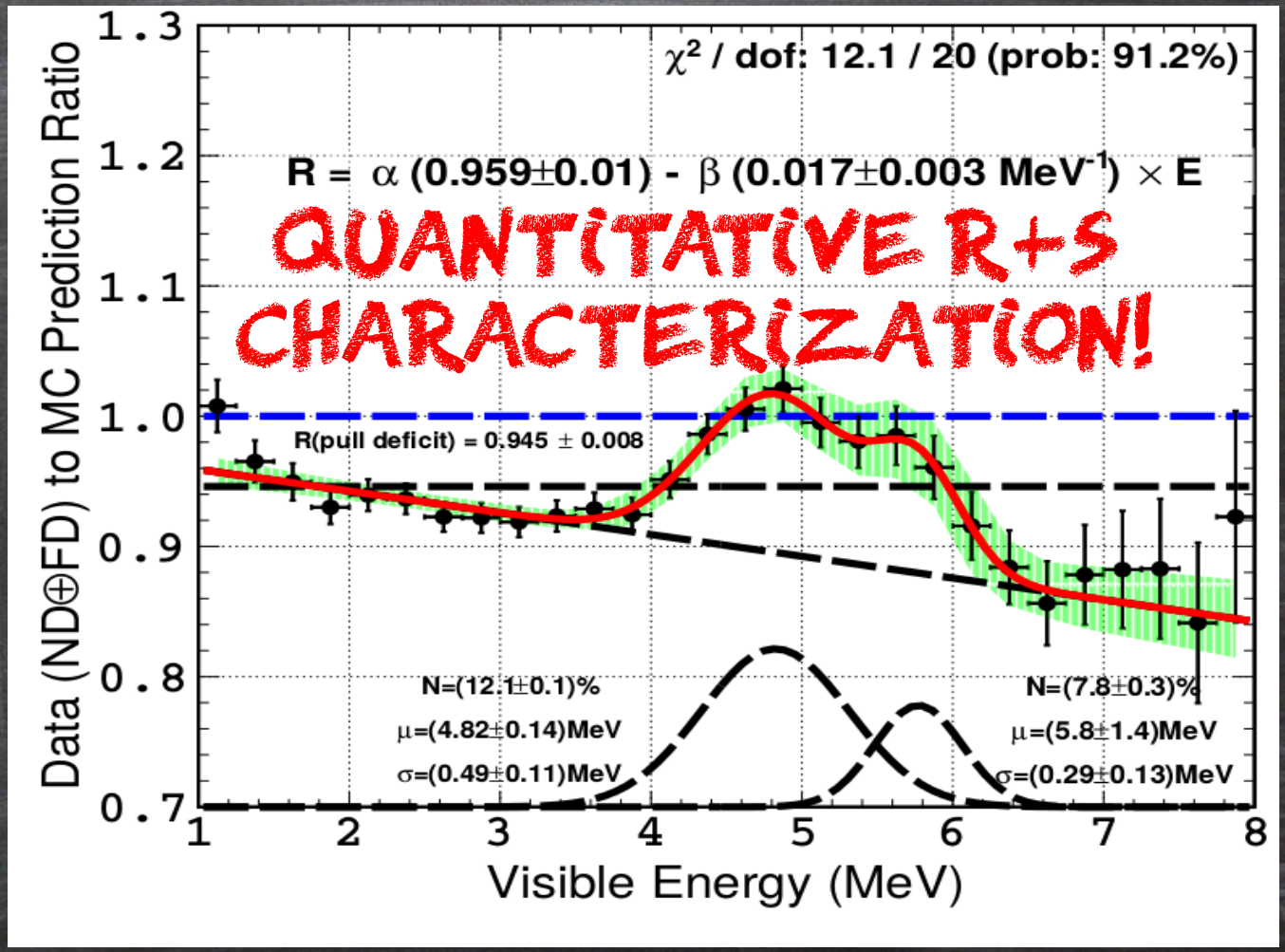
SPECTRAL DISTORTION COMPARISON (SHAPE ONLY)





Agreement within statistics

SPECTRAL DISTORTION COMPARISON (SHAPE & RATE)



-> "Excess" in agreement with Flux model

-> Empirical fit: negative slope and empirical double peak
-> Width significant larger than energy resolution
-> Slope not compatible with E.S. model

SUMMARY

-> Three Years of Double Chooz 2 detectors data: 2015 - 2017

-> Novel IBD detection : Total Neutron Capture

-> Improved statistics & systematics

-> Good background control (S/B > 10) → Confirmed background model with Reactor-off Data!

-> New result: $\sin^2 2\theta_{13}$ = 0.105 ± 0.014 (w/ 15 months of data)

-> Single Detector Fit protected with a new Flux error budget

-> Spectral distortion: slope + 4-6 MeV structure

-> Currently finalizing publication

-> Sensitivity improvement: extra data and new measurement of target proton mass -> ~< 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

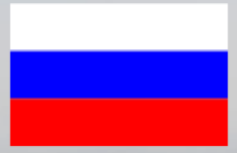
CENBG (IN2P3)
LNCA (IN2P3/CEA)
Subatech (IN2P3)

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)

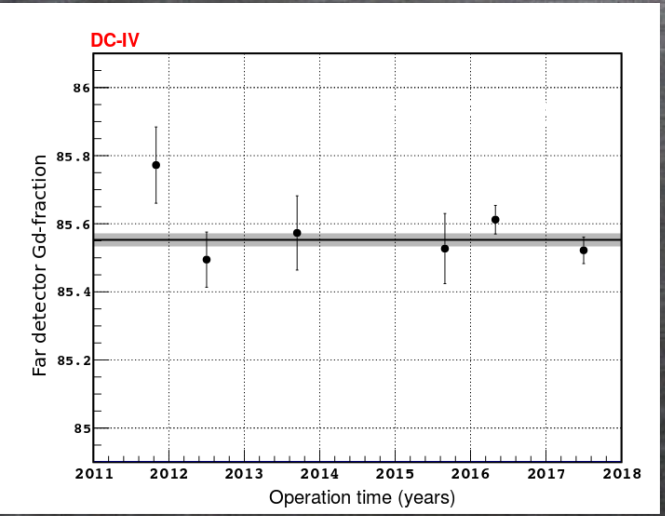
Project Manager:
Ch. Veyssière (CEA)

97 scientists 25 institutions (Americas, Asia, Europe)

doublechooz.in2p3.fr

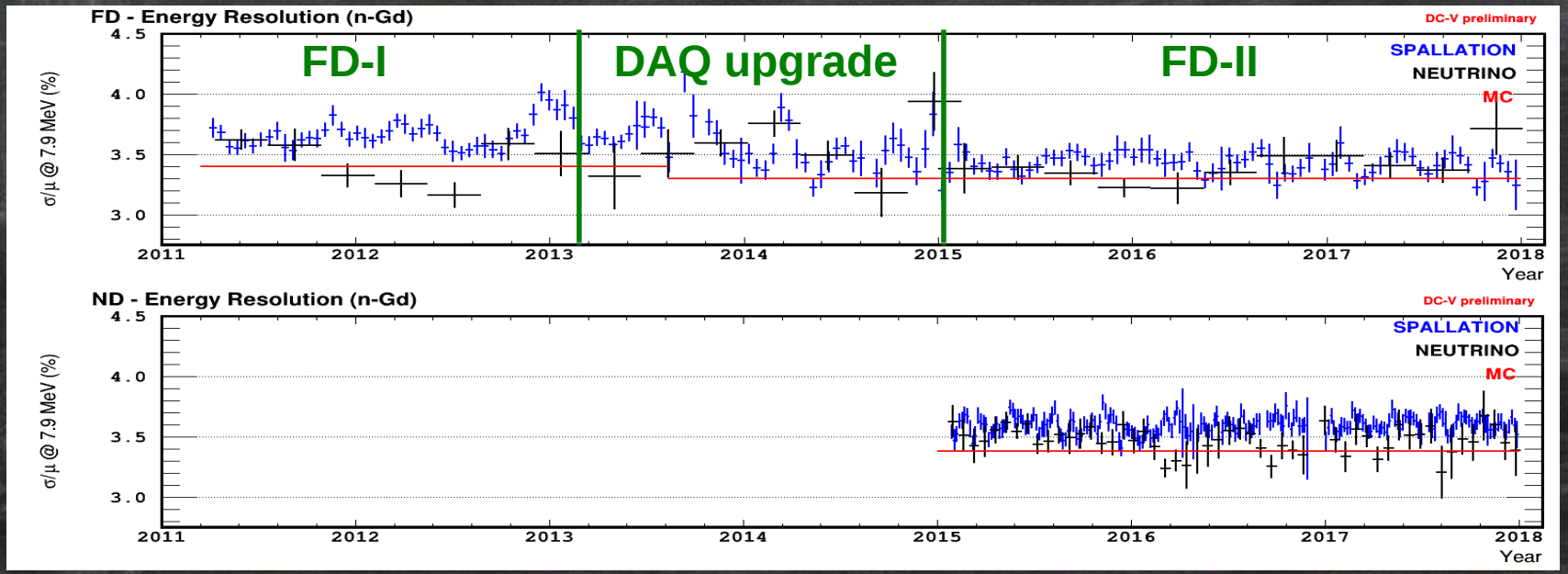
BACKUPS

SCINTILLATOR STABILITY



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

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

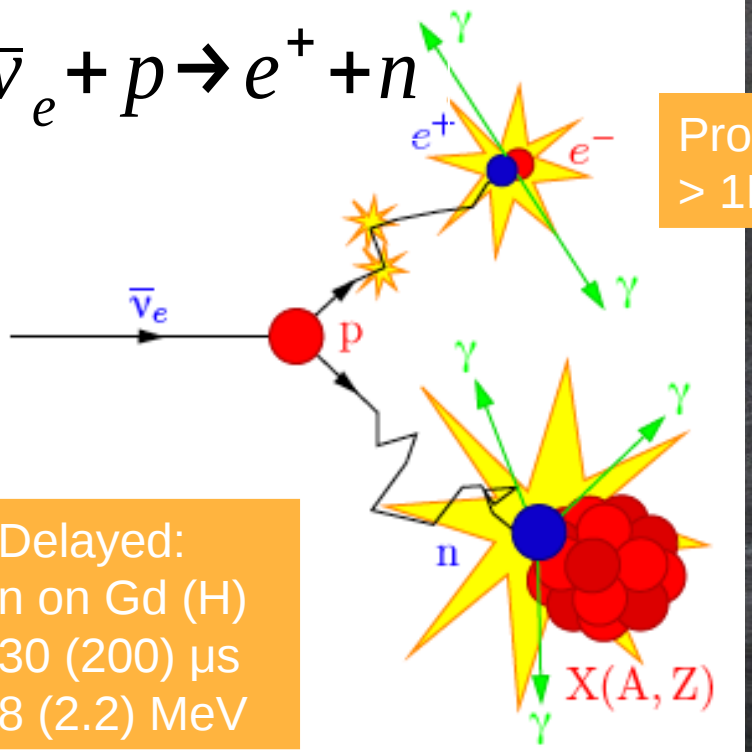


NEUTRINO PRODUCTION / DETECTION

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

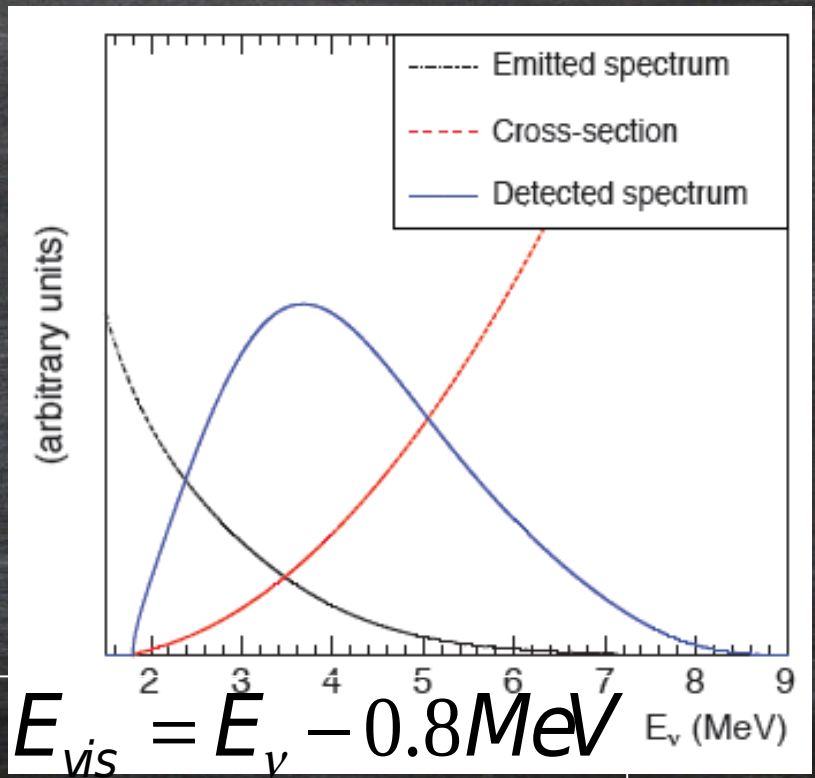
→ Mean cross section per fission (Near detector!)

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



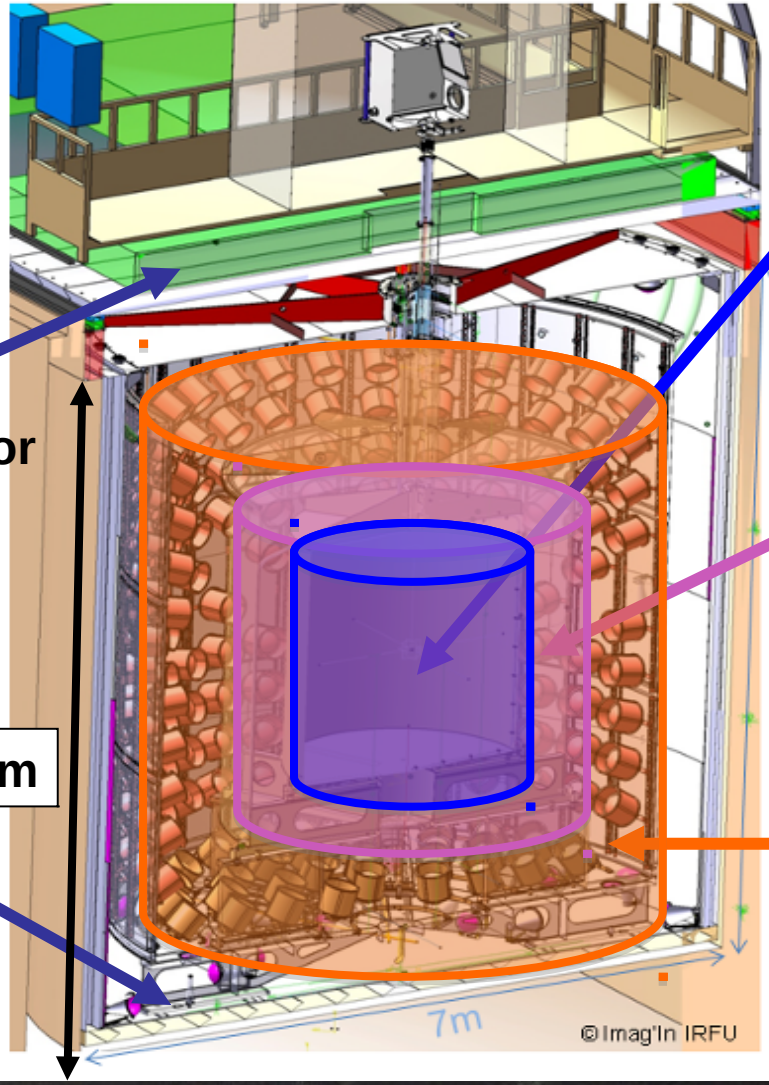
Prompt:
> 1MeV

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”)**

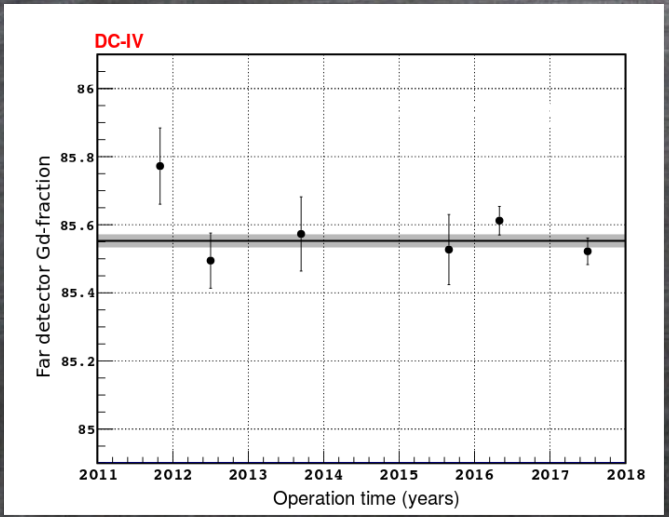
Inner detector:

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”)

SCINTILLATOR STABILITY



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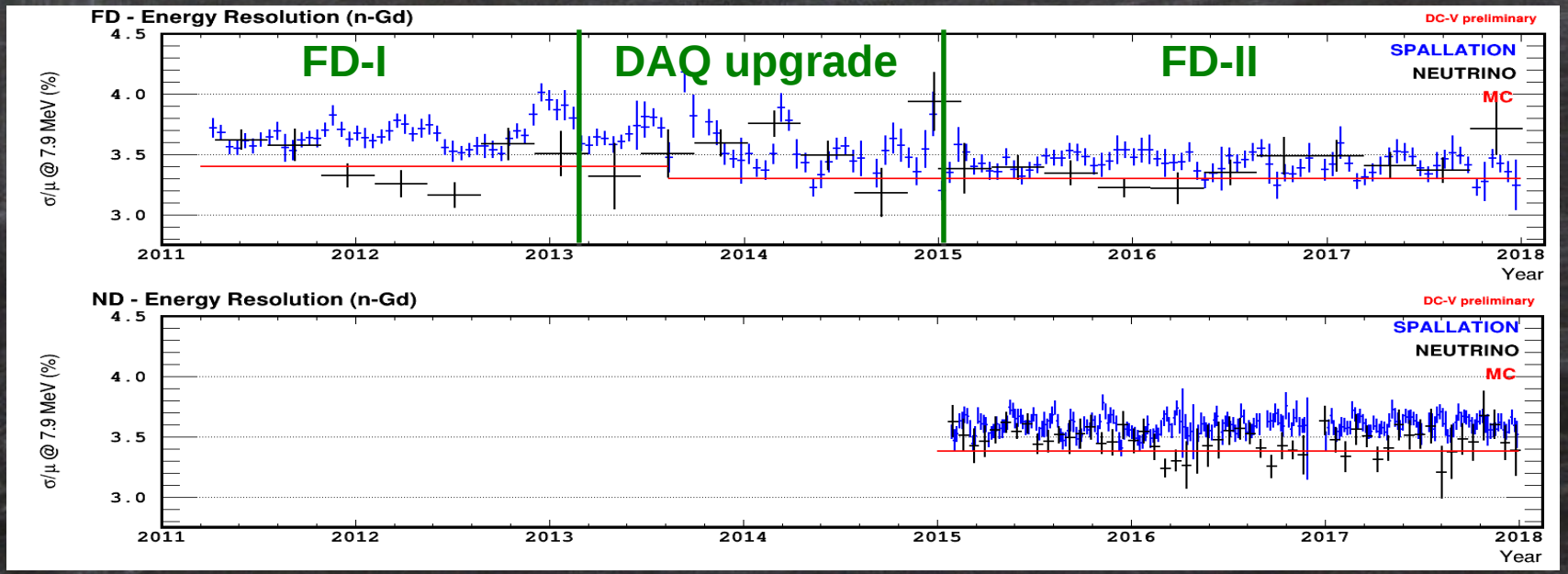
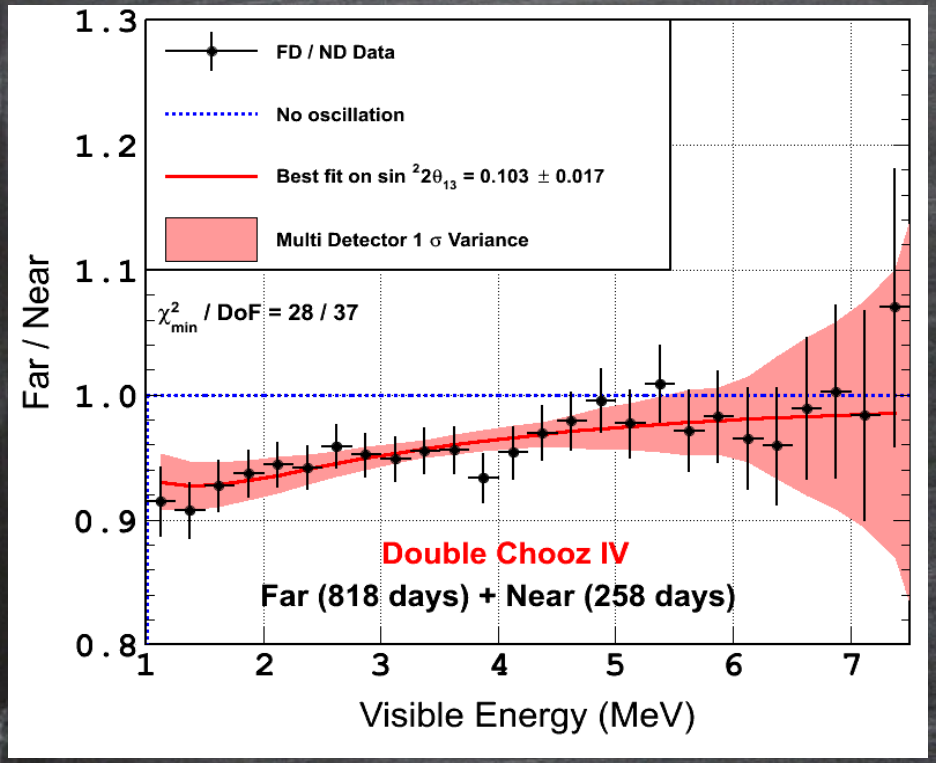
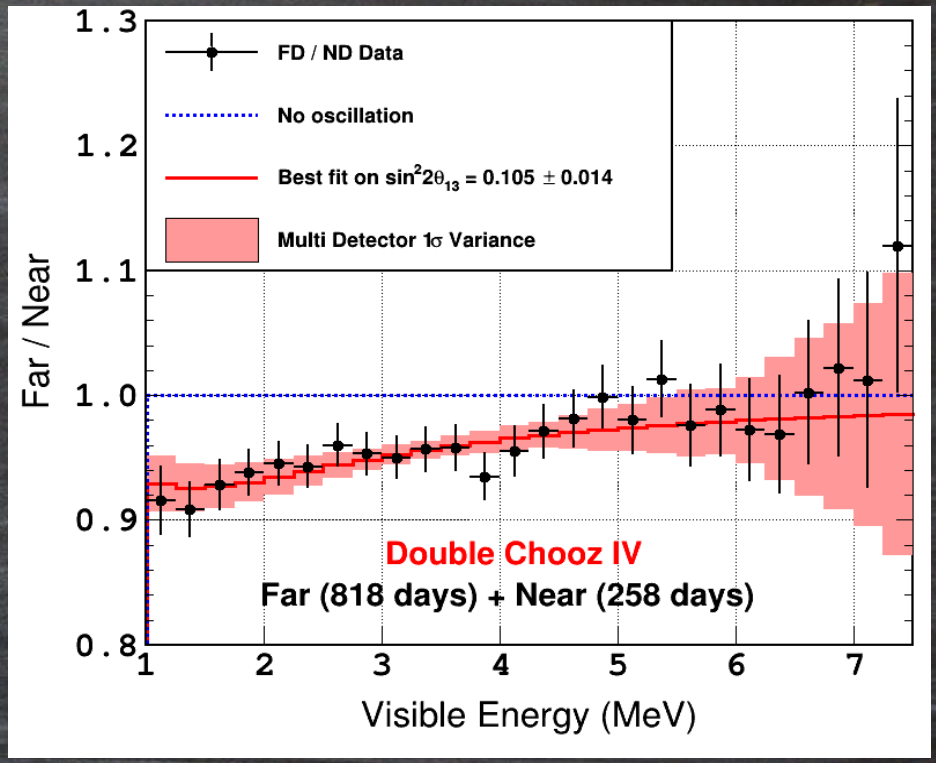


NEAR TO FAR RATIO

Data / data

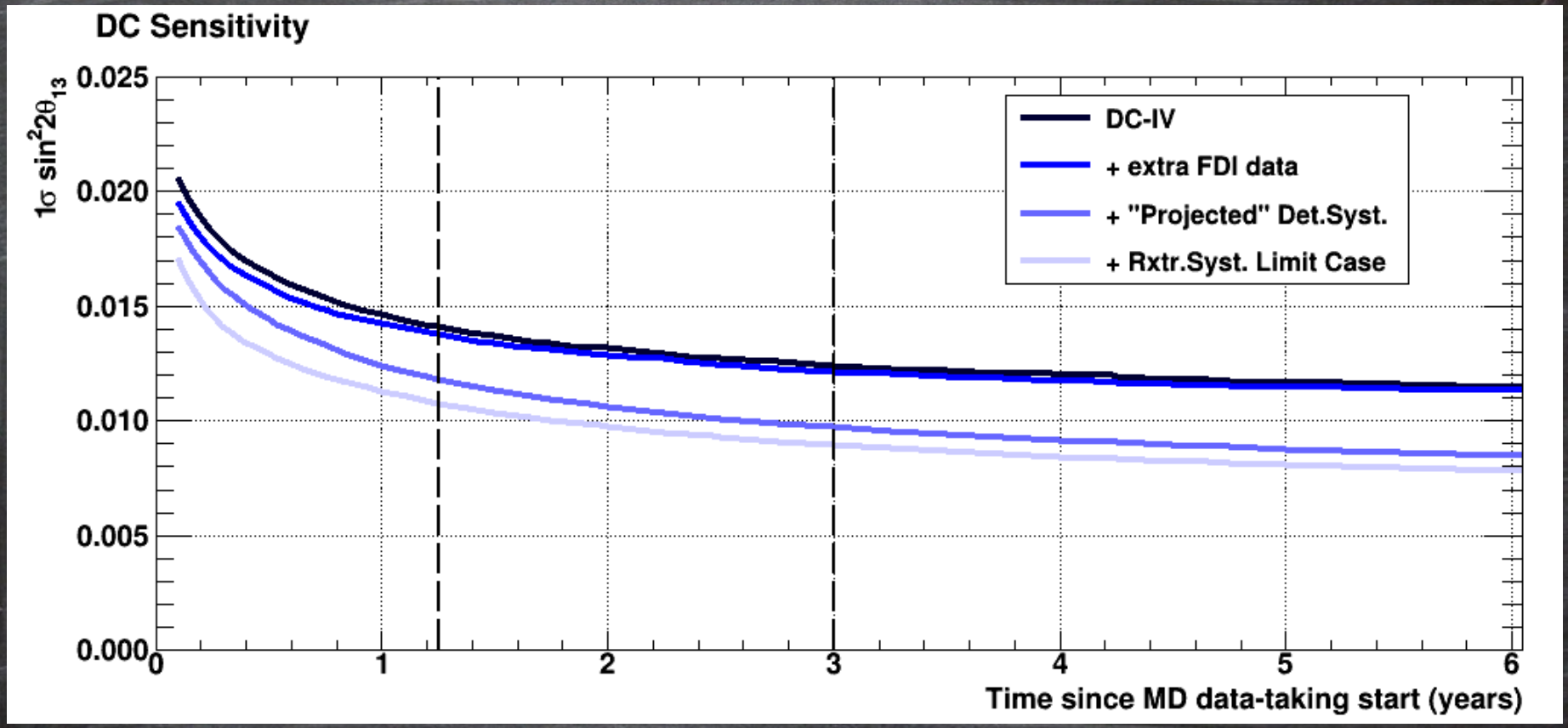


Data / MC ratio plot



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

SENSITIVITY PROJECTION



-> Double Chooz final sensitivity: 0.009~0.010 !

-> Proposal (2006): ~0.025