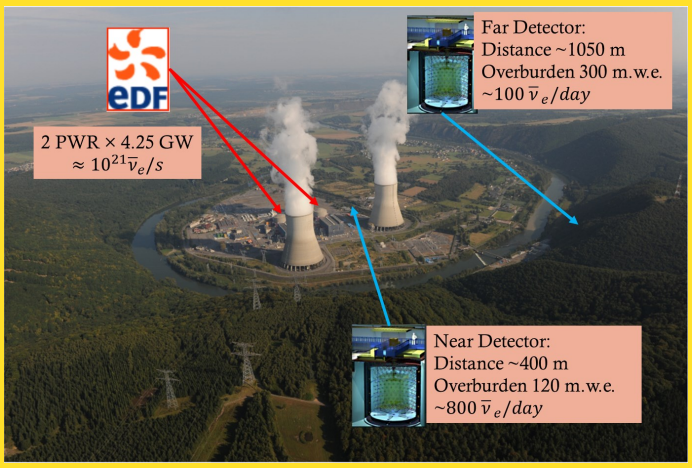
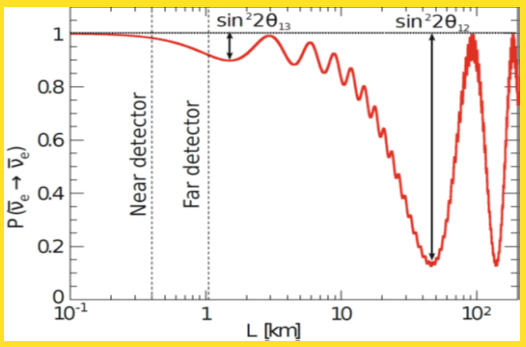
New Double Chooz θ_{13} via Total Neutron Capture Detection

Aldiyar Oralbaev[1] on behalf of the Double Chooz Collaboration
[1]NRC "Kurchatov institute", Moscow, Russia (*Oralbaev_AY@ncrki.ru*),

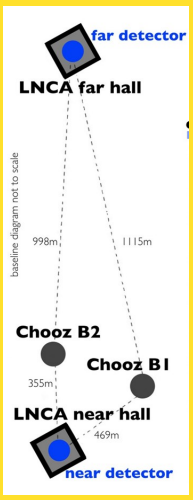
5th International Conference
on Particle Physics and Astrophysics,
October 5-9, 2020, ICPPA-2020

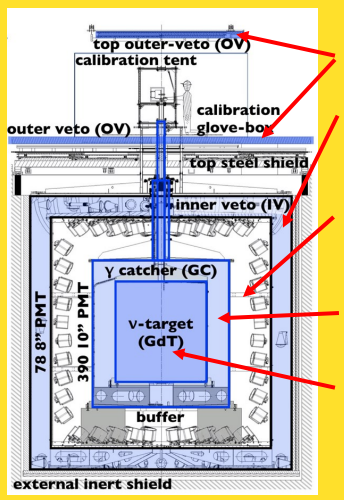
The Double Chooz Experiment





- The θ_{13} determination is based on the electron antineutrino survival probability:
  $P(\nu_e \to \nu_e) \approx 1 - \sin^2 2\theta_{13} \sin^2(1.267 \Delta m^2_{ee} L/E_\nu)$
- Almost iso-flux positioning
  $(L_{ND\text{-}B1}/L_{FD\text{-}B1} \approx L_{ND\text{-}B2}/L_{FD\text{-}B2})$ thus almost full cancellation of reactor flux systematics.





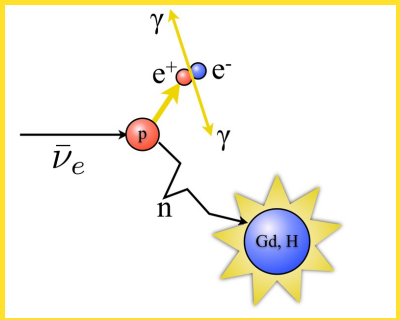
Outer Veto:
Plastic scintillator
Inner Veto:
- Steel
- 80 m³ LS
- 78 PMTs (8")

Buffer (1.05 m):
- Steel vessel
- 93 m³ "oil"
- 390 PMTs (10")

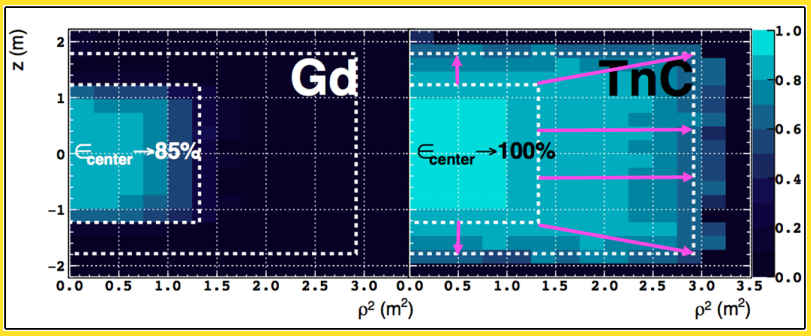
Gamma Catcher (0.55 m):
- Acrylic vessel
- 23 m³ liquid scintillator

Gd-target (r = 1.2 m):
- Acrylic vessel
- 10 m³ Gd-scintillator
- (1 g/l Gd)

Total Neutron Capture detection technique - TnC

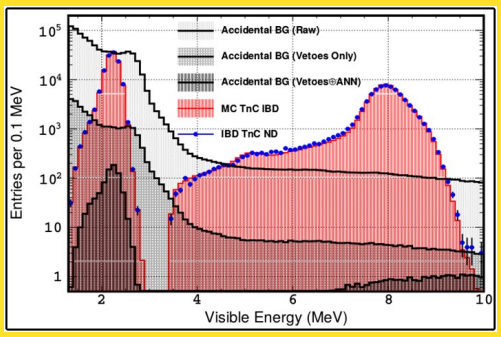


The inverse beta-decay reaction (IBD) is the corner stone in reactor neutrino physics.
The IBD reaction provides specific coincidence signature:
- Prompt event - positron annihilation $E_e \approx E_\nu$ - 0.78 MeV
- Delayed event – neutron capture on all available nuclei (Gd, H ,C) TnC special feature.



- The TnC technique improves statistics by a factor of 2.5 thanks to the expansion of the detection volume.
- Detection systematics understood at 0.2% level (except Proton # in the GC)
  Cf Multiplicity allows validation to 0.1 %.
- Spill-in/-out effect and Gd/H-fraction became irrelevant.

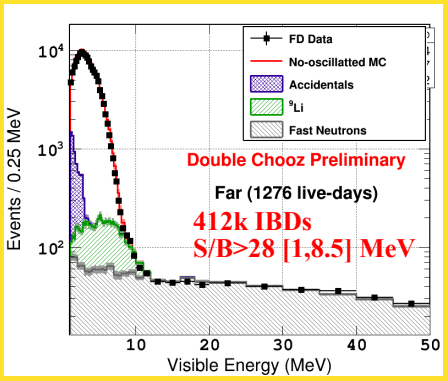
Background rejection

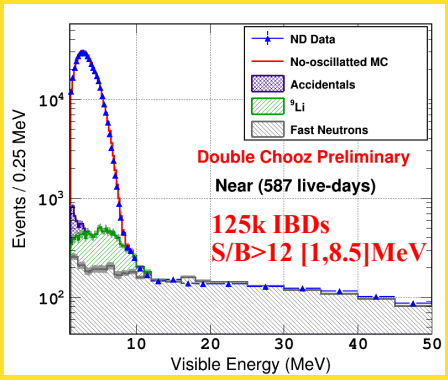


Delayed energy spectrum (Data & MC) before and after applying selection cuts.

The IBD space-time coincidence relies on a multivariable ANN thus rejecting large amount of the accidental BG (>2 orders of magnitude), while keeping high the selection efficiency averaged over the prompt energy spectra:

ND:86.78±0.21%
(MC: 86.75±0.01%) ;
FD:85.47±0.08%
(MC: 85.54±0.02%) .



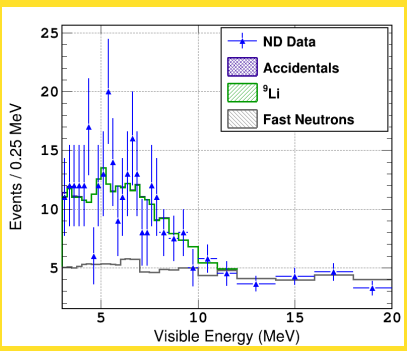


- Differences in the accidental rate observed between FD and ND come from the fact that there is no Light Noise (LN) in ND. LN is caused by spontaneous light emission from the bases of the PMTs installed in ID.
- Due to less overburden the cosmic muon induced BG rate is higher for ND.

Detector (ev./day) [1,50] MeV	FD 1276 live-days	ND 587 live-days
IBD candidates	112	765
Accidental BG	4.36 ± 0.01	3.07 ± 0.01
Cosmogenic BG (^{9}Li)	2.74 ± 0.22	12.97 ± 0.97
Fast-Neutron	5.85 ± 0.08	45.49 ± 0.36

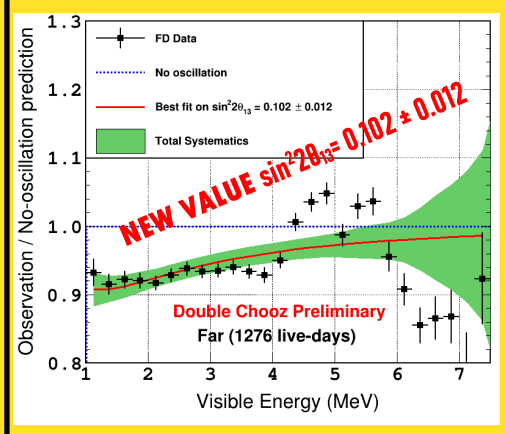
Reactor Off-Off Data

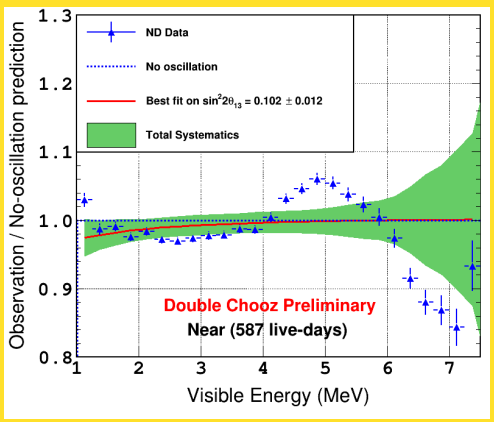
Detector (ev./day)	FD	ND
IBD cand.	210	710
IBD cand. -∑BG	25±15	101±35



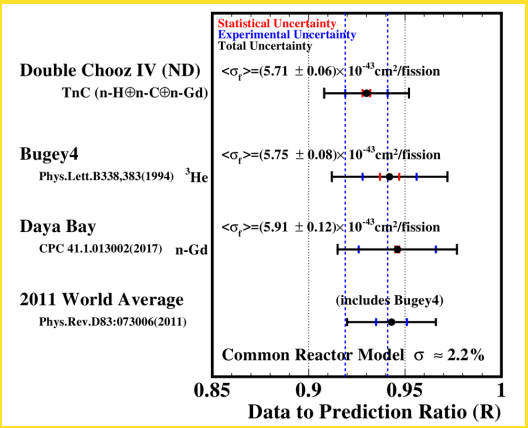
Due to unique situation when both reactors were off the background model has been scrutinized and no systematic bias or tension (<1σ) has been found. We can conclude that the BG model is complete and independent.
Reactor-off data gives extra constrain on BG above 3 MeV.

Fit results

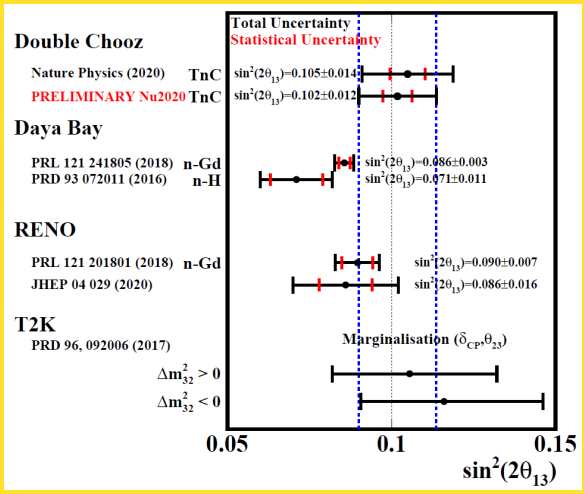




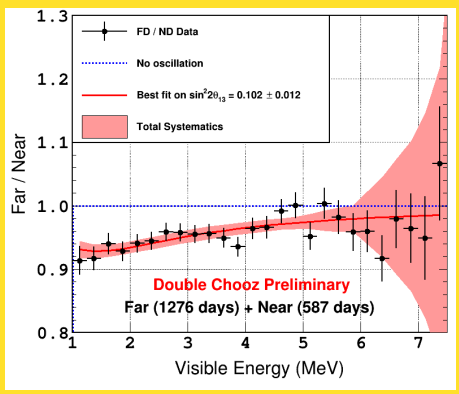
The ratios of the observed spectra to the non-oscillated predictions for FD and ND.



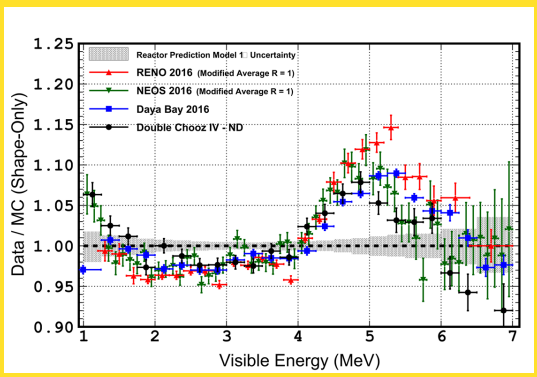
Mean cross section per fission.
Absolute normalization is compatible within experimental uncertain-



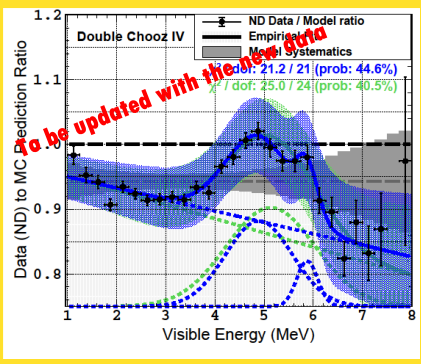
The DC $\sin^2(2\theta_{13})$ is compatible with other experiments within 2 σ range.



Inter-detector ratio doesn't show any spectral distortion in the 5 MeV region, thus ensuring the θ_{13} accuracy.



Observed spectral distortions are in good shape agreement between RENO, Daya Bay, DC and NEOS.



This distortion can be characterized as a sort of a slope with one or two gaussians peaks.

Summary:
1) $\sin^2 2\theta_{13} = 0.102 \pm 0.012$(stat.+syst.)
2) $\langle\sigma_f\rangle = (5.71 \pm 0.06) \times 10^{-43}$ cm²/fission – Best value up to date
3) Still room for $\sin^2 2\theta_{13}$ improvement (1σ less than or equivalent to 0.01)

NATIONAL RESEARCH CENTER
"KURCHATOV INSTITUTE"