Double Chooz reaches its proposal's goal with only one detector !!!

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LAL Orsay
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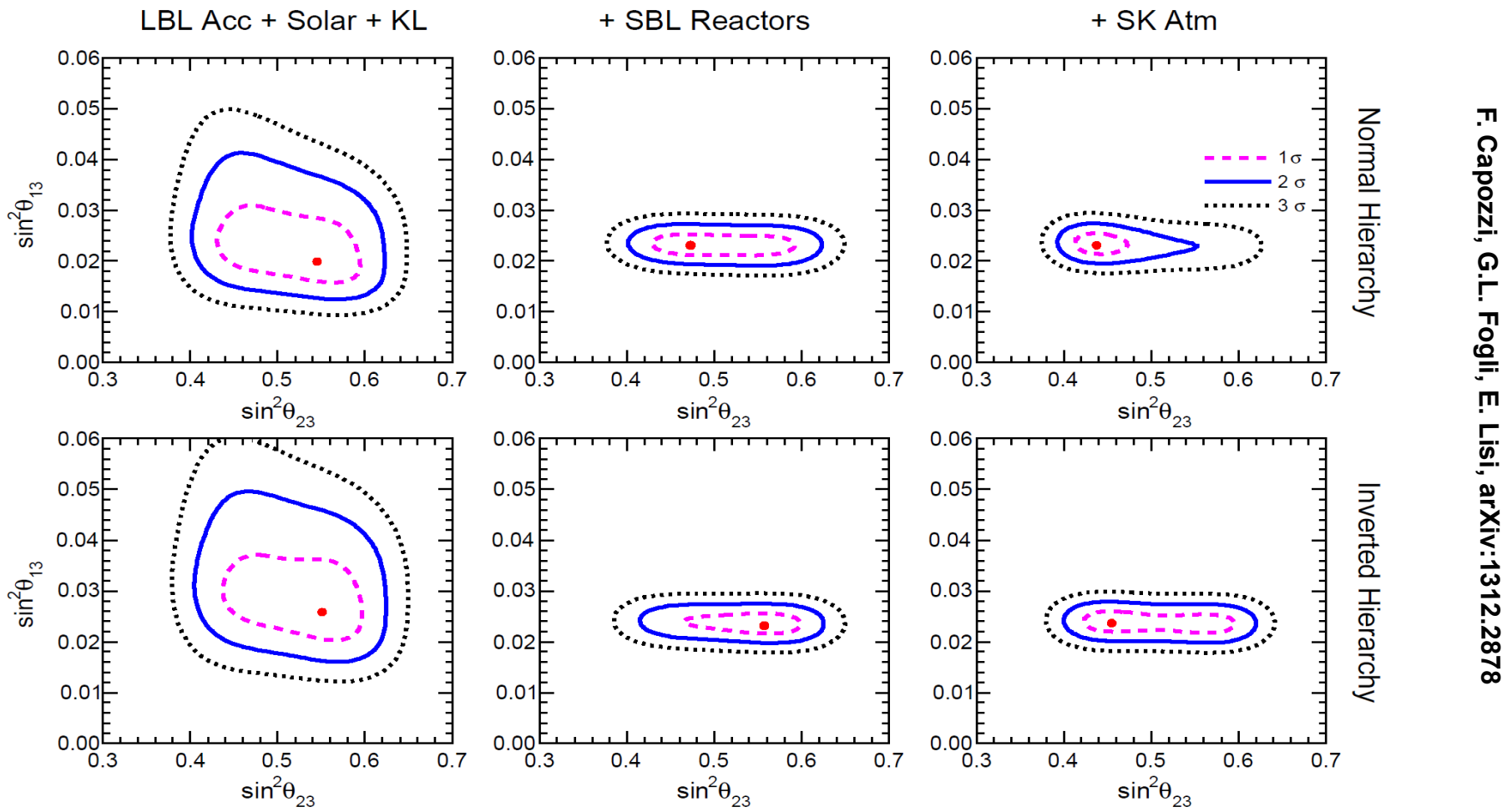
Θ13 : The contribution of the Reactor Experiments



F. Capozzi, G.L. Fogli, E. Lisi, arXiv:1312.2878

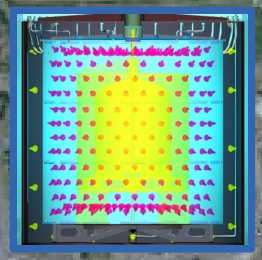
$\sin^2\Theta_{13}$ is known @8.5% (±3σ/6) **in principal due to the reactor experiments.**

Even so, it's one of the worst known oscillation parameters. For comparison:

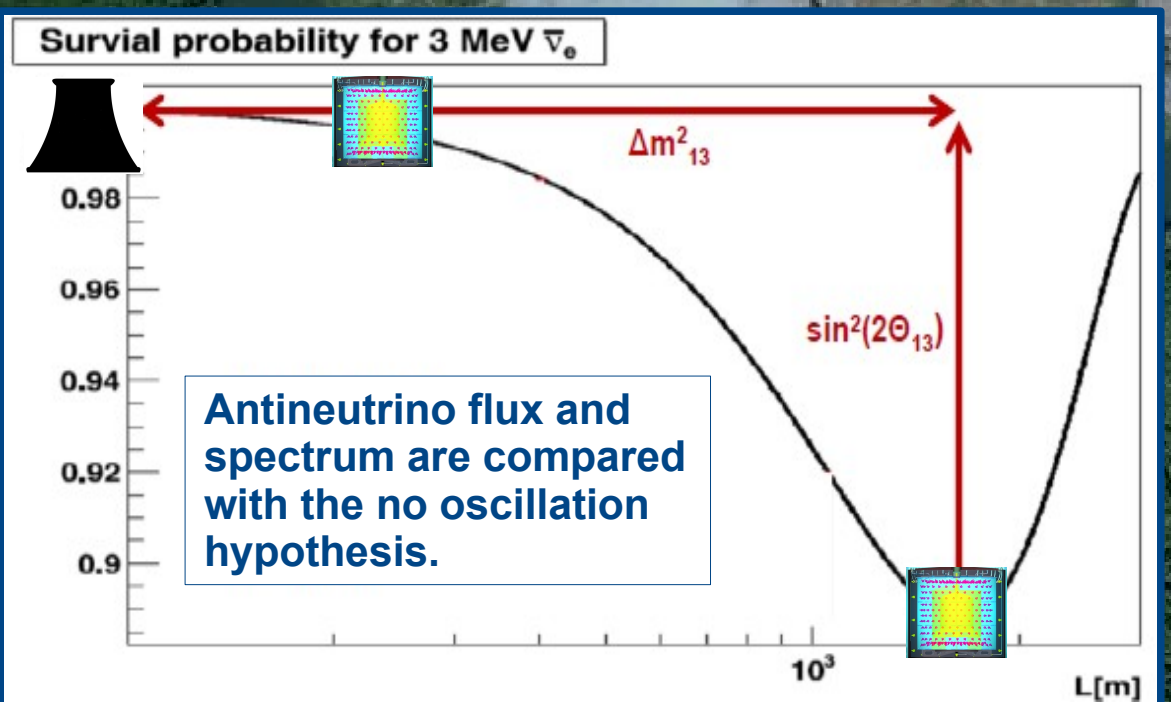
Δm^2_{21}= 2.6% $\sin^2\theta_{12}$= 5.4% $|\Delta m^2_{32}|$ = 2.6% $\sin^2\theta_{23}$= 9.6%

Double Chooz

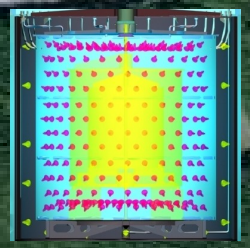
Two N4-REP reactors ($2*4.27GW_{th}$)



Near detector @400m
Overburden 120mwe
Will start summer 2014

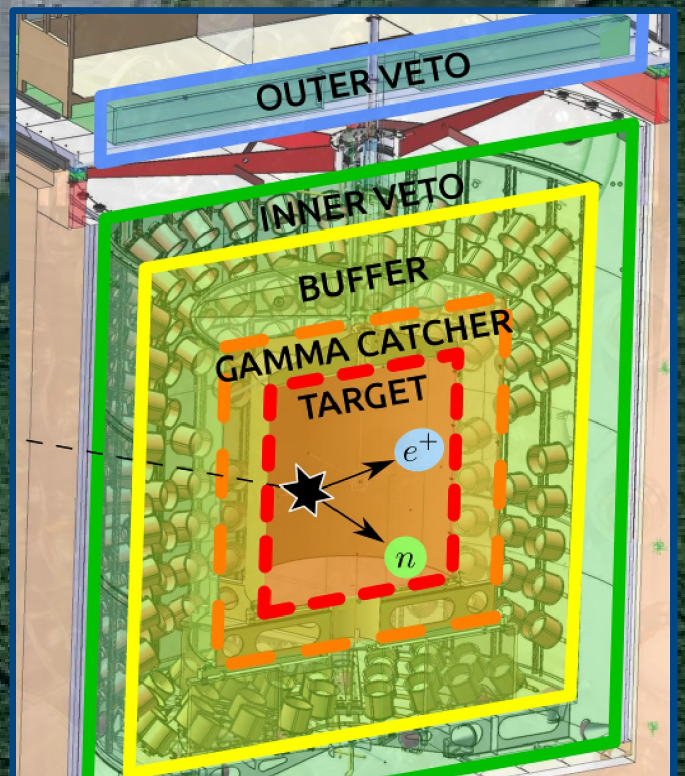


Antineutrino flux and spectrum are compared with the no oscillation hypothesis.



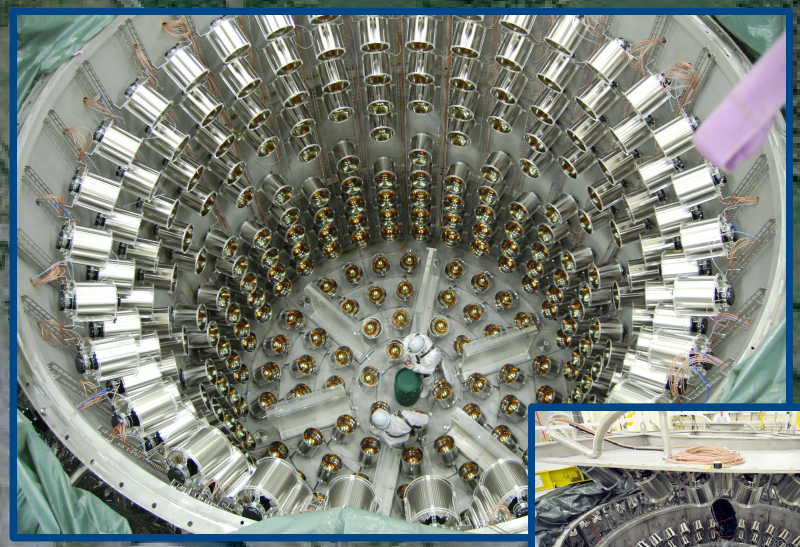
Far detector @1050m
Overburden 300 mwe
Running since 2011

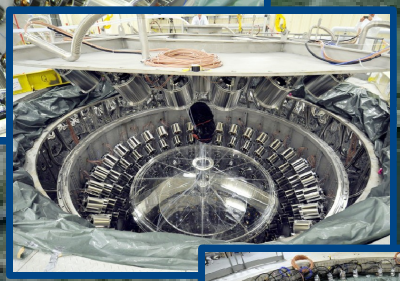
Double Chooz



“Onion like detector”:
Concentric volumes for antineutrino detection (target, gamma catcher) decreasing background (buffer) and background tagging (inner and outer veto).

Double Chooz

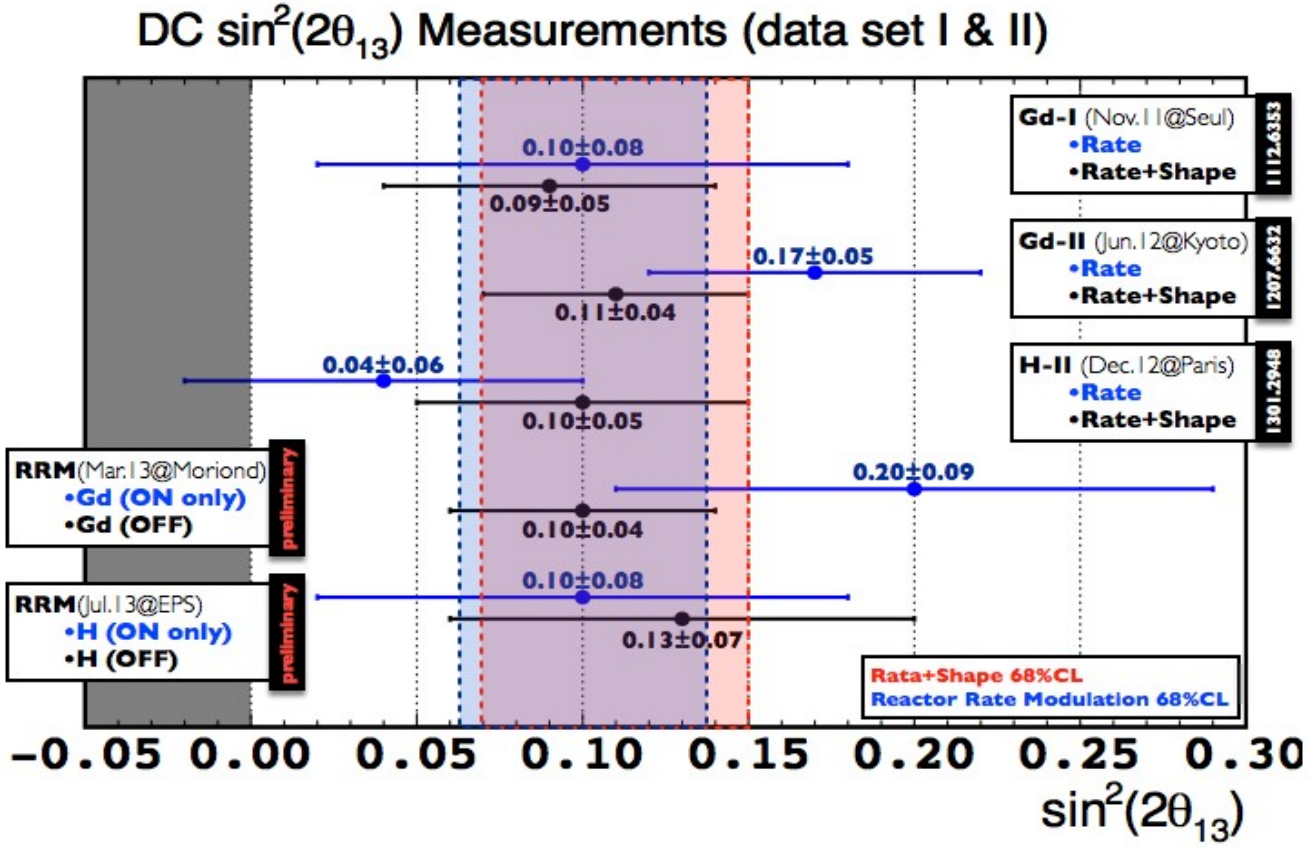




Near detector status

Closure →	done
Chimney →	ongoing
Filling →	summer
Shielding →	summer
DAQ commiss.→	Sep.~Oct.

Θ13 measurements with Double Chooz: **Several Analyses**

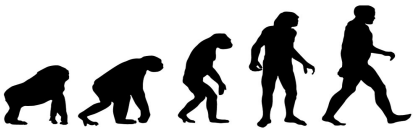


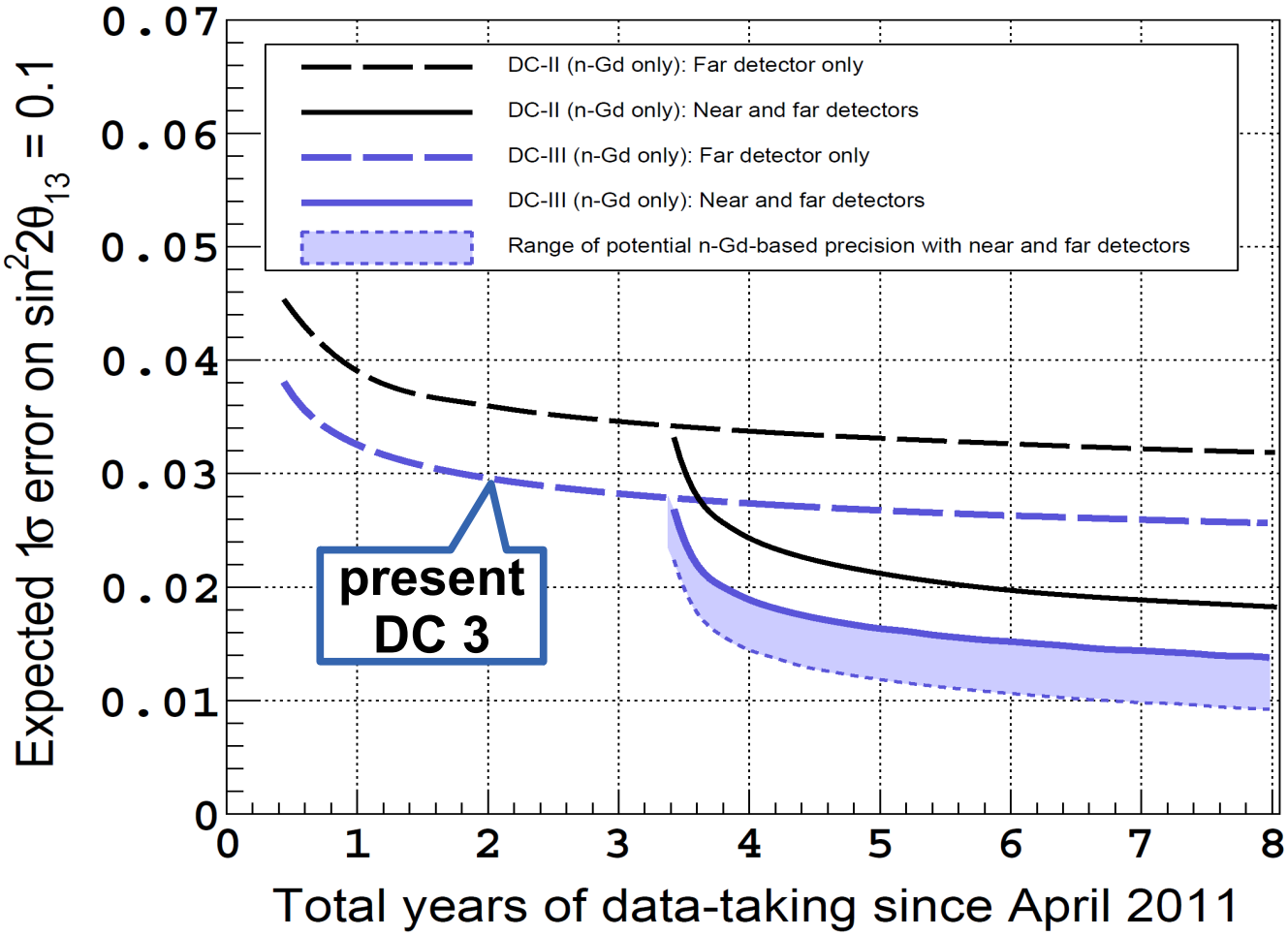
Rate+Shape (R+S) Analysis: Exploit full spectra and E/L signature of θ13 (oscillations)
The most precise measurement of θ13

Reactor Rate Modulation (RRM) Analysis: θ13 and Background fitted in the same time
(Unique DC) remarkable cross-check of θ13

Analyses with neutron captures on Gd or/and H: different background, statistics, etc.

The evolution of the Θ13 measurement

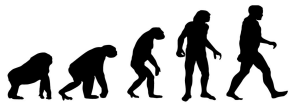




Important gain in sensitivity between previous (DC 2) and present (DC3) analyses.

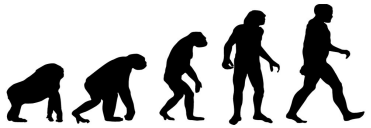
Final (1σ) err. of near/far phase can reach ~0.01 (DC proposal: 0.03 !!!)

The evolution of the ev. Selection: Gd Analyses

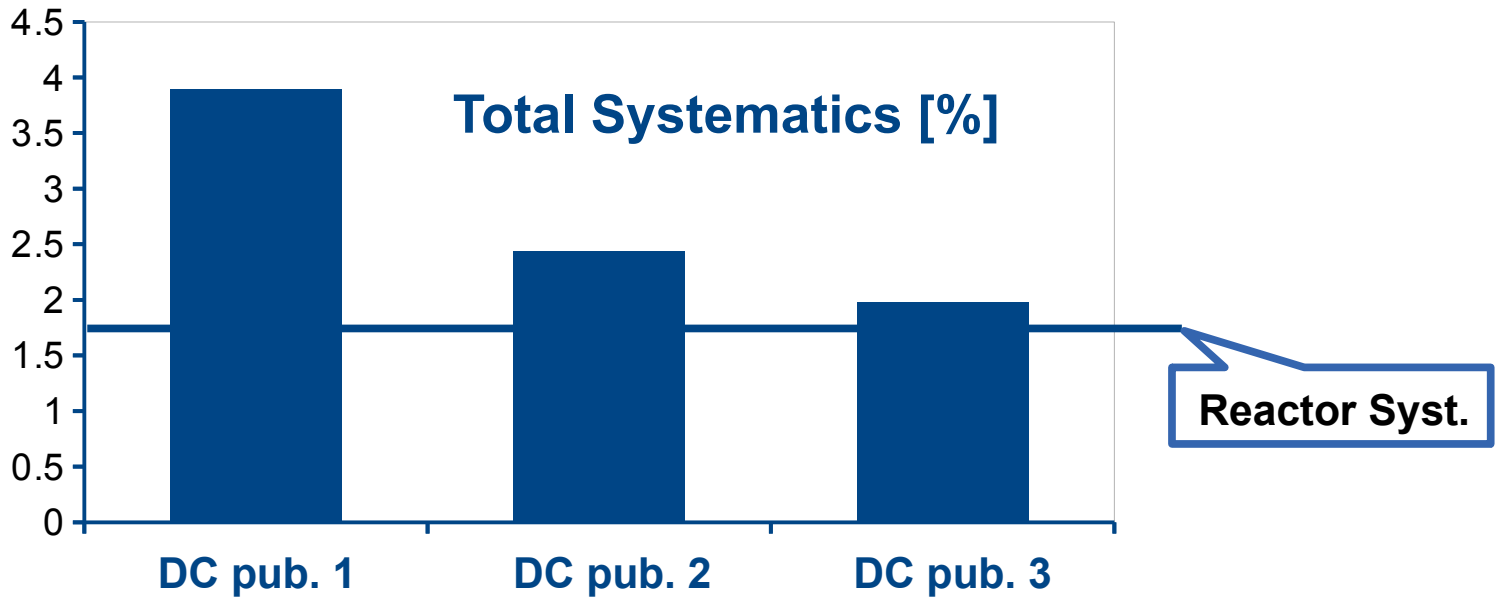


	DCpub.1 (PRL 108, 131801)	DCpub.2 (PRD 56, 052008)	DC III Analysis
μ-Veto	Δt(μ) > 1ms		
			E(ID) ≥ 20MeV & Q(IV) ≥ 30k(a.u.)
Light Noise	Qm/Qt < 0.09 & RMS(t) > 40ns		Qm/Qt < 0.12
			2D cut RMS(t,Q) ΔQ < 30k(a.u.)
Inverse Beta Decay	Epr = [0.7, 12.2] MeV Edl = [6, 12] MeV ΔT(pr, dl) = [2, 100] μs		Epr = [0.5, 20] MeV Edl = [4, 10] MeV ΔT(pr, dl) = [0.5, 150] μs
			L(pr, dl) < 1m
	Multipl. (pr, dl): [-0.1, 0.4] ms		Multipl. (pr, dl): [-0.2, 0.6] ms
Bkg. Reject.		No OV hit	
		Δtμ (Eμ > 600 MeV) > 0.5 s	Likelihood Li+He veto
			No IV hit cond (PMT mult, Q(IV), Δd(ID-IV), Δt(ID-IV)) FV veto

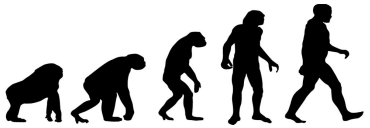
The evolution of systematics

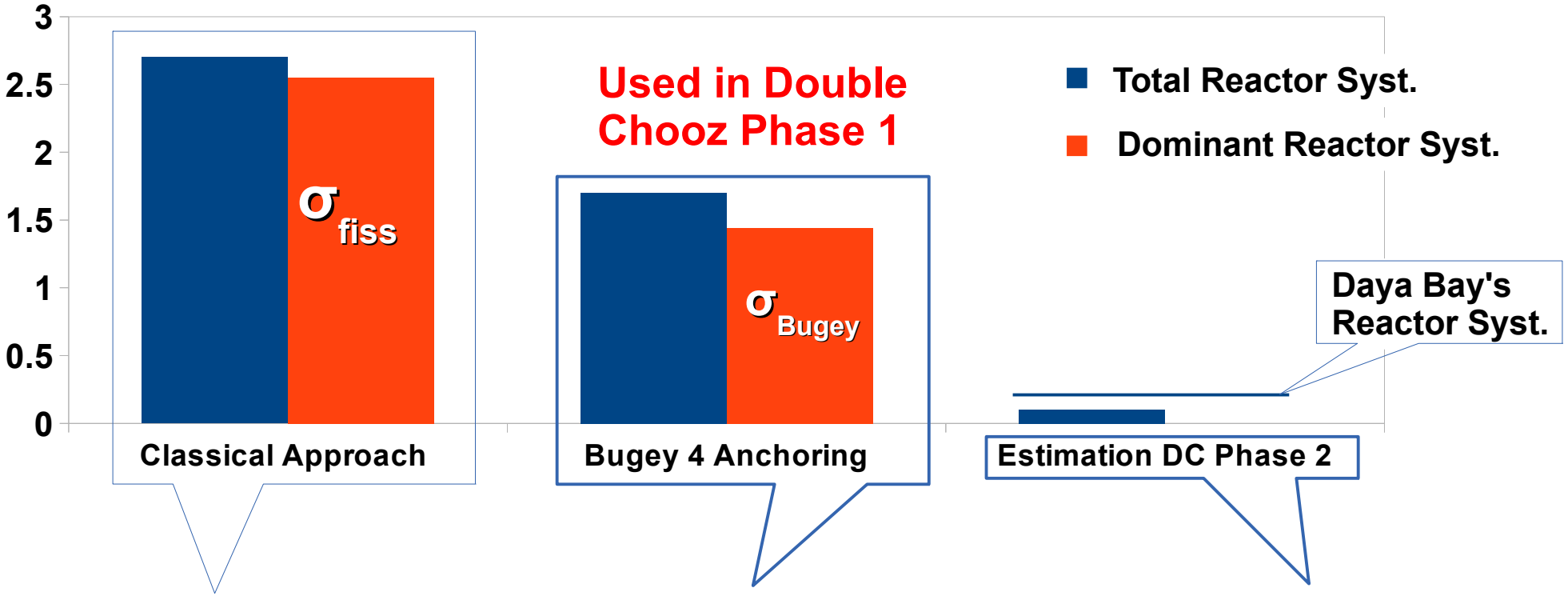


	DC 1	DC 2	DC 3	Foreseen for DC Near/Far
Reactors		1.7		~ 0.1
Detection	2.0	1.0	0.6	~ 0.2
Background	2.9	1.5	0.8	~ 0.3
Total syst.	3.9	2.4	1.9	All errors are in percent.
Statistics	1.6	1.1	0.8	



The evolution of the reactor systematics





Estimation dominated by the error of the mean IBD X-section per fission

The mean IBD X-section per fission anchored to the Bugey 4 measurement

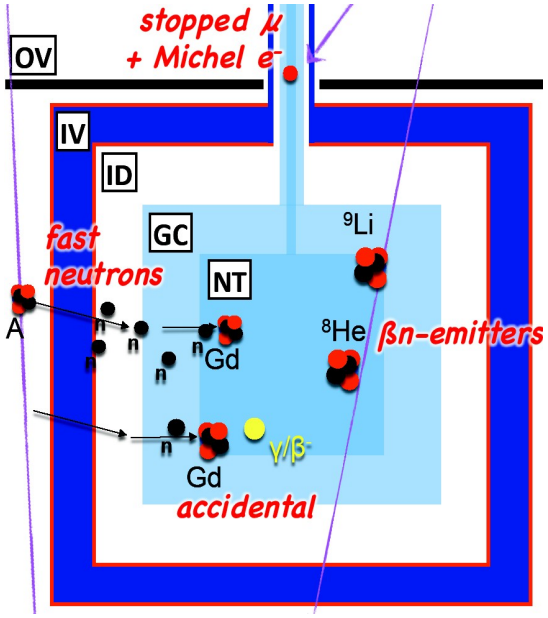
Residual reactor error for the Near-Far phase

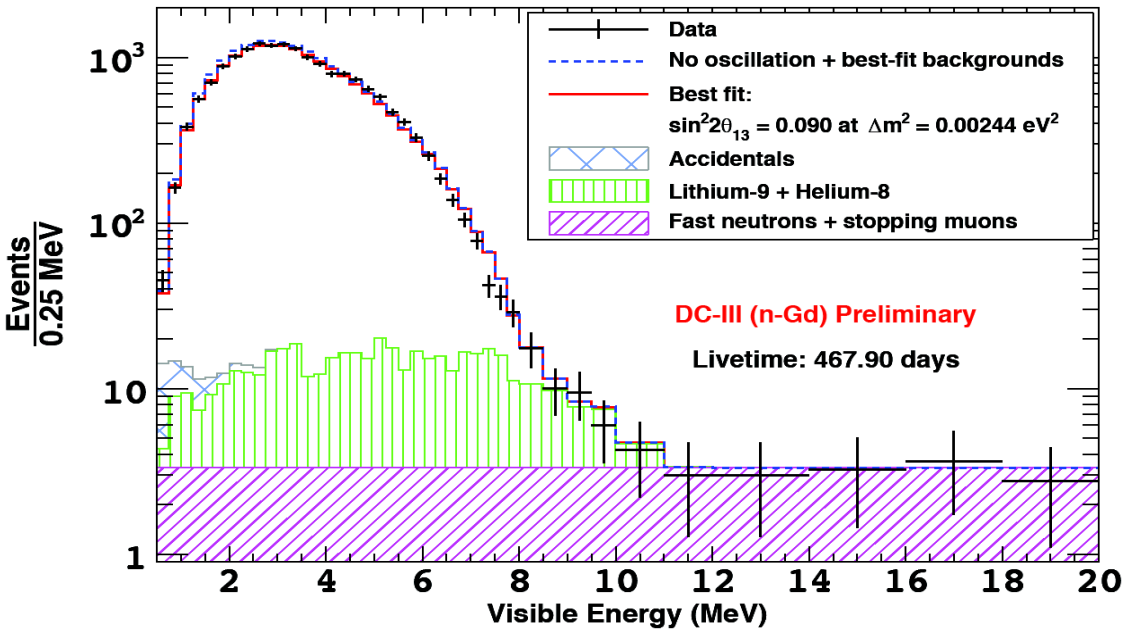
Bugey4 measurement acts as effective Near detector for phase 1.

For Phase 2, the reactor induced systematics will not be dominant.

Background Related Strategies

Rates and uncertainties are determined:
Exclusively → **using regular data sample**
Inclusively → **Reactors Off-Off period** → **account for unknown contributions**



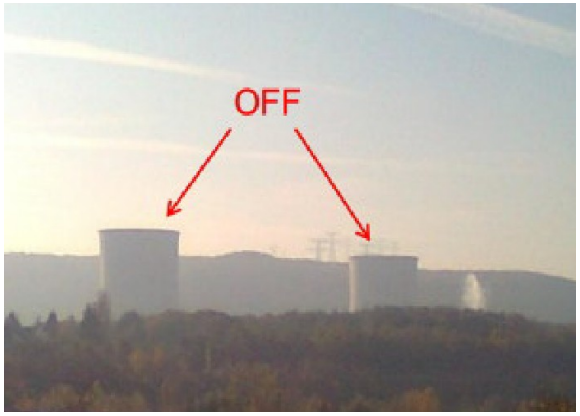


Dominating background uncertainty in DC3 → βn emitters: 9Li + 8He

βn-rate → based on fit to the Δt-distribution of IBD candidates close (<1m) to muon tracks.

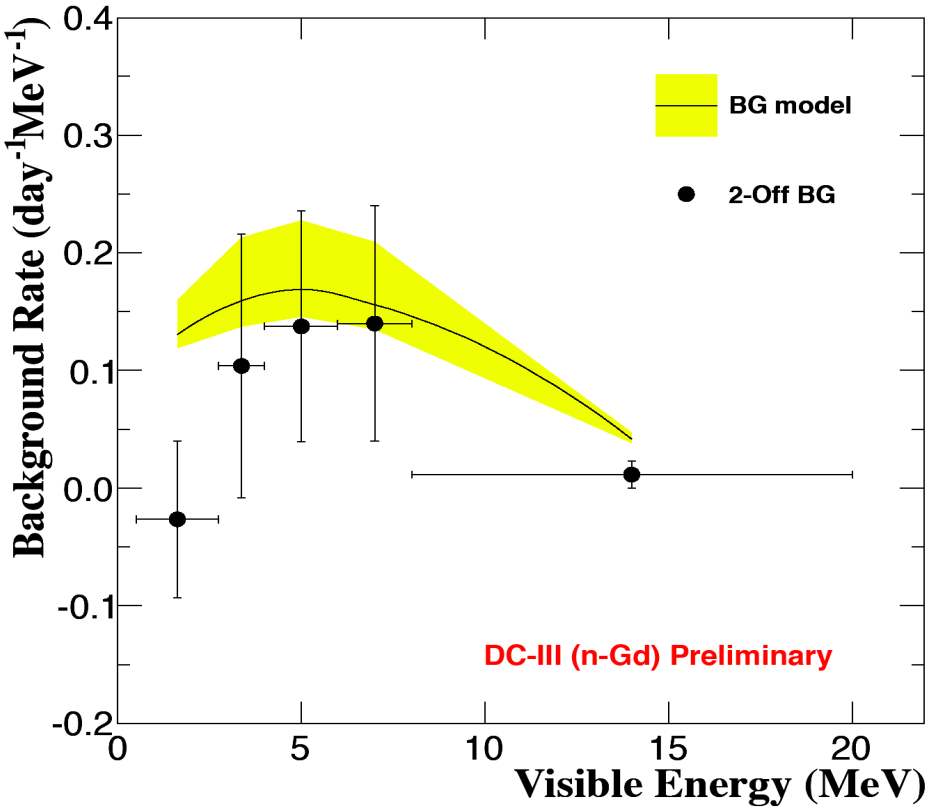
βn-spectrum → Selected IBD candidates with likelihood tag:
L(n multiplicity, d to muon, time to muon)

Reactors OFF measurement



Double Chooz: only Θ13 experiment which can take OFF data.

Important measurement to anchor/X-check background.

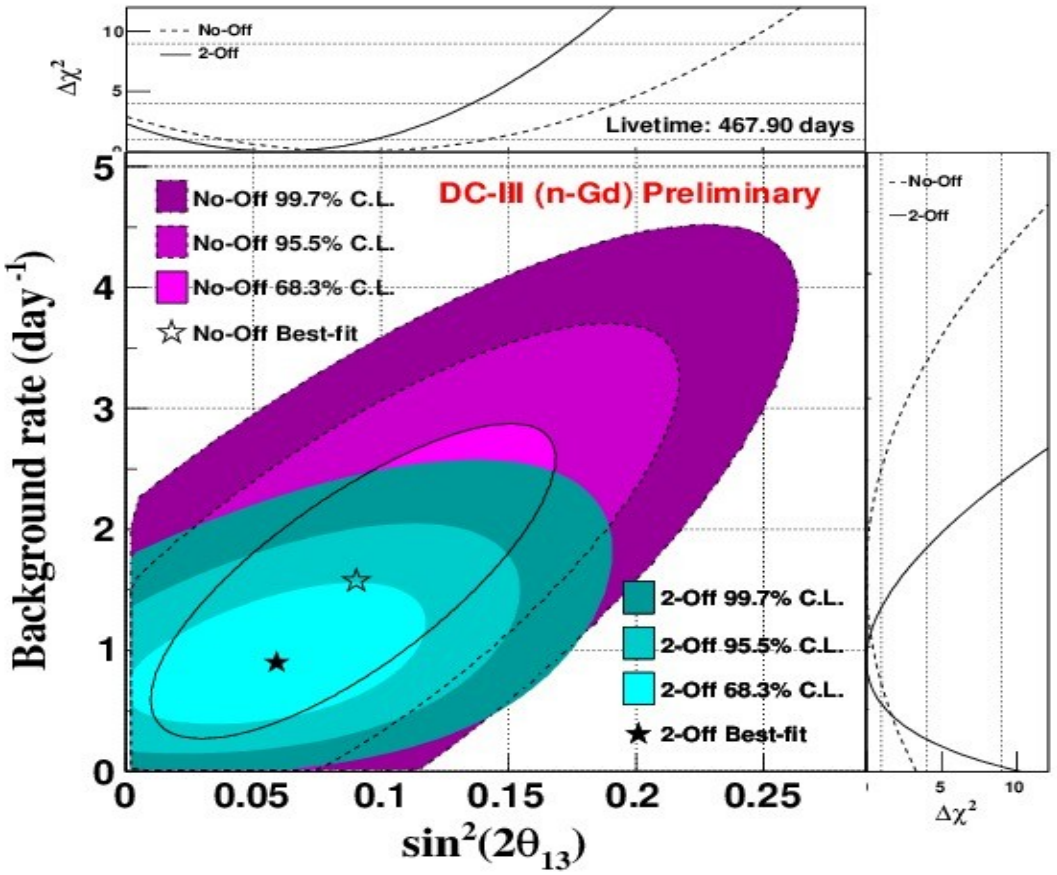


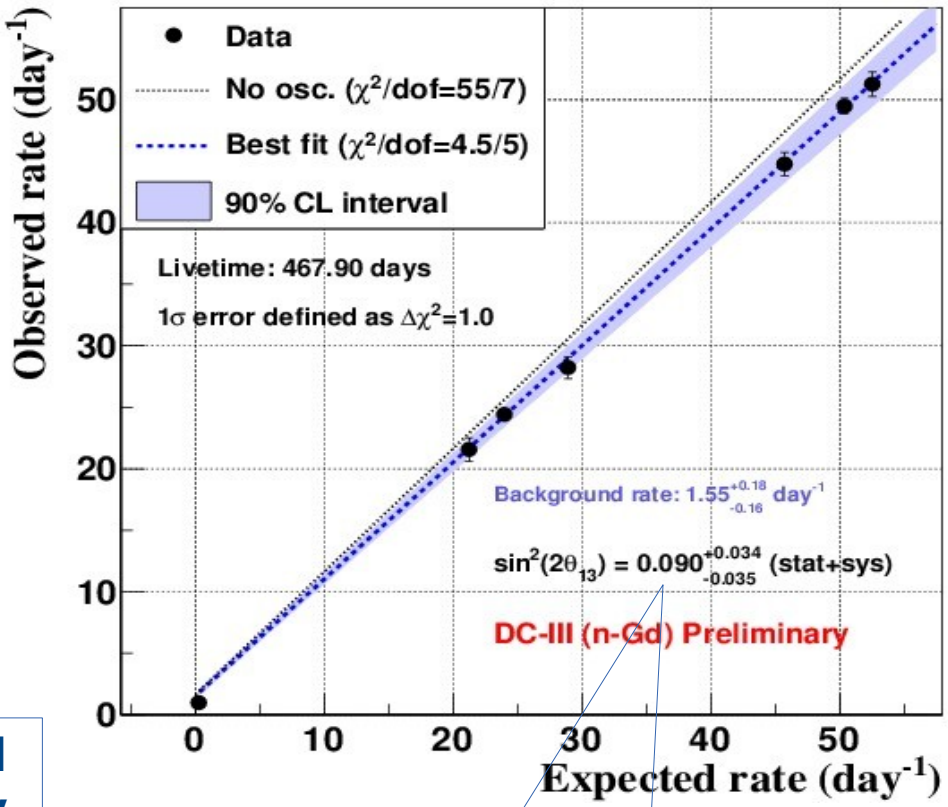
In 7.23 live days reactors-off, 7 candidates passed the analysis cuts. → 0.76 ± 0.37 /d

Expected from background model → 1.57 +0.42/-0.18 /d

Tension between bkg model and OFF data @2σ → no room for unknown bkg.

Reactor Rate Modulation (RRM) analysis





Exploiting reactors power variations, Θ13 and the background are measured simultaneously.

Linear fit:
intercept = background
slope = $\sin^2(2\Theta 13)$

Improve fit precision by OFF data, bkg. model.

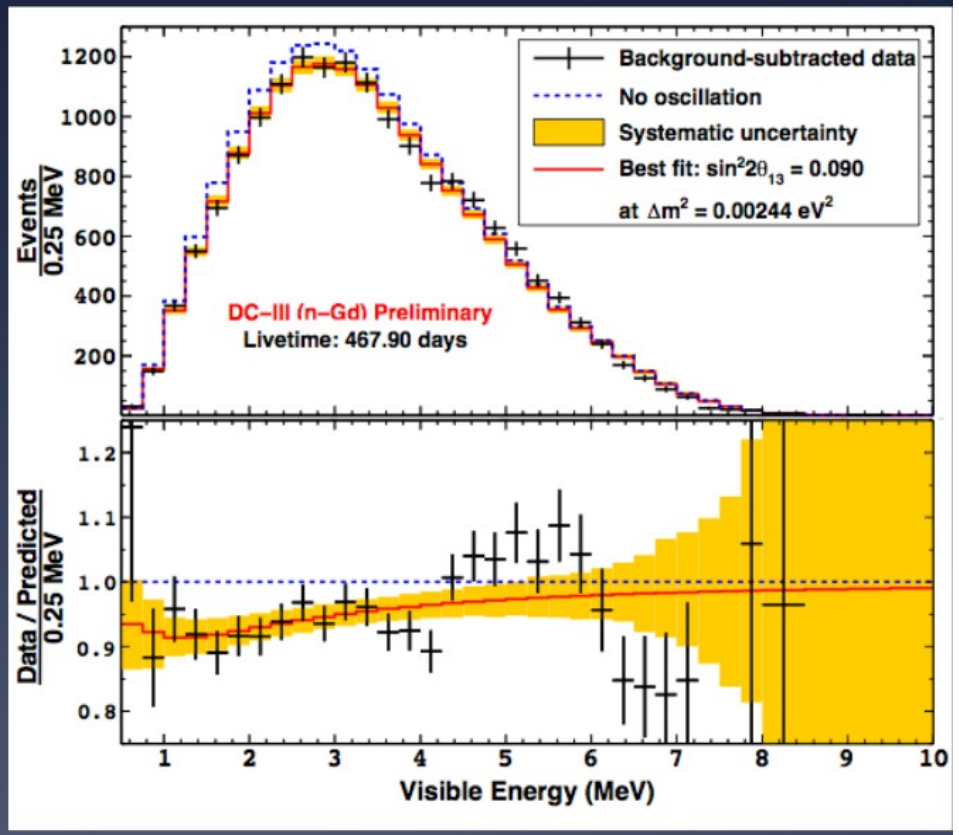
DC3 Θ13 RRM result for ON + OFF + BKG model

New Θ13 result by DC3 R+S analysis

H. de Kerret @ Neutrino 2014 Conf.

Rate+Shape results

- **many improvements…**
  - NEW!! •250keV binning and [0.5,20]MeV
  - NEW!! •**BG fully data driven** (first time)
- **signal treatment…**
  - NEW!! •new spectrum with ^{238}U (low energy)
  - •Δm^2 from MINOS (confirmed T2K)
- **BG treatment…**
  - NEW!! •**full** OFF data constraint (extra bin)
  - •**accidental pull term**
    - NEW!! •**rate:** syst. dominated
    - •**shape:** data measured
  - •**fast-n pull term** (~no stopping μs) NEW!!
    - •**rate:** stats dominated
    - •**shape:** data measured
  - •**Li+He pull term**
    - NEW!! •**rate:** statistics driven
    - NEW!! •**shape:** data measured (no MC**!!!**)
  - •negligible ^{12}B and BiPo
- **energy treatment…**
  - •e+ energy model (via tuned MC) NEW!!
  - •scintillator non-linearity NEW!!



$\sin^2(2\Theta_{13})=(0.09\pm0.03)$

(χ^2/n.d.f. = 51.4/40)

background subtracted

(BG systematic 3x smaller than previous results)

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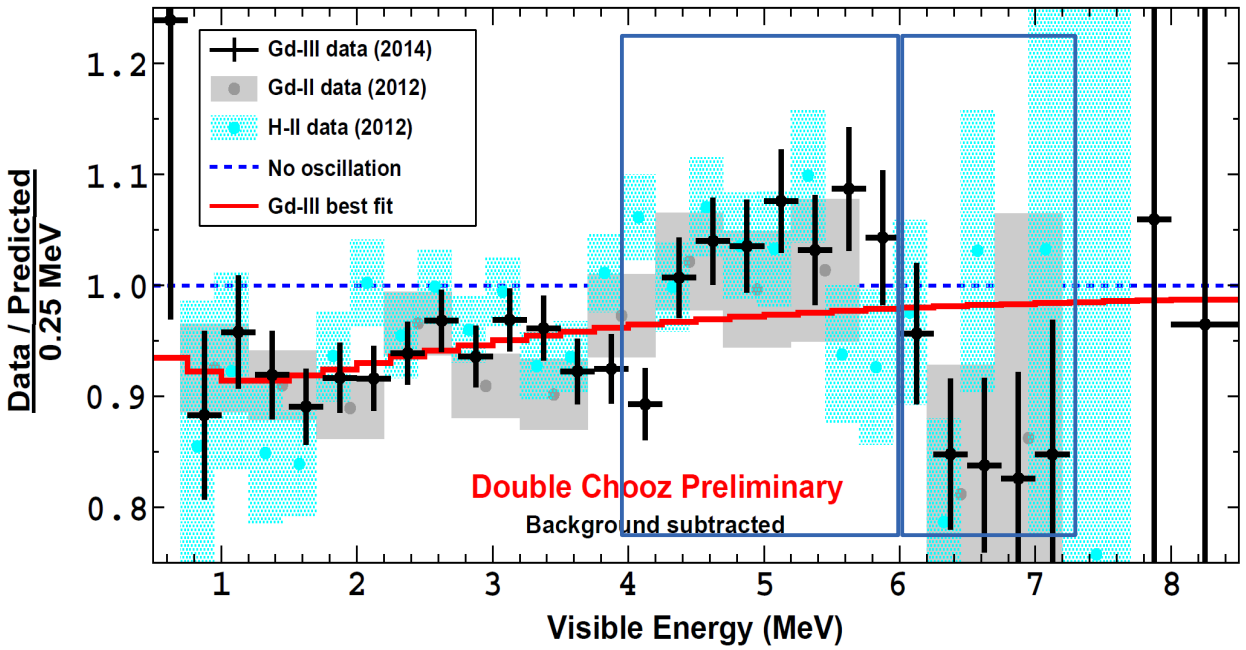
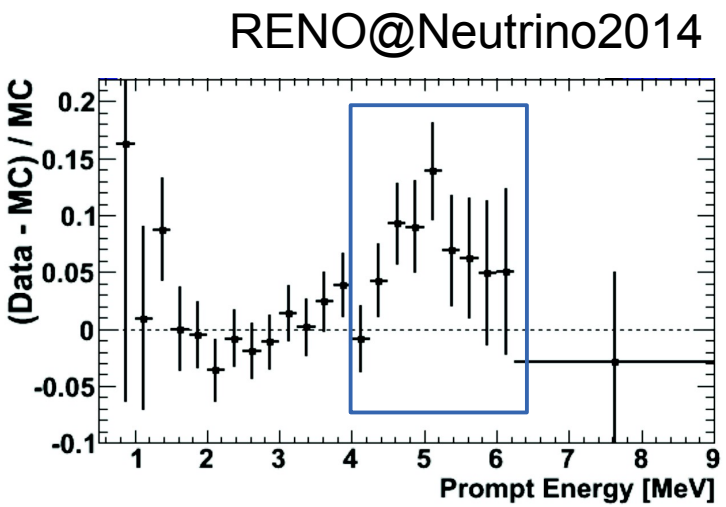
The pattern at high E



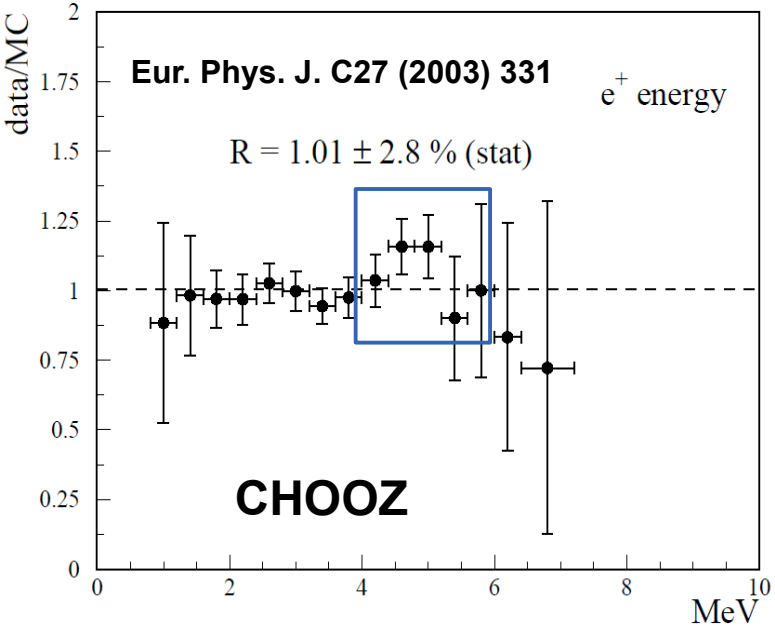


Observed ~[4,8) MeV Data/MC structure @1.5σ:
~[4,6] MeV excess + ~[6,8] MeV deficit

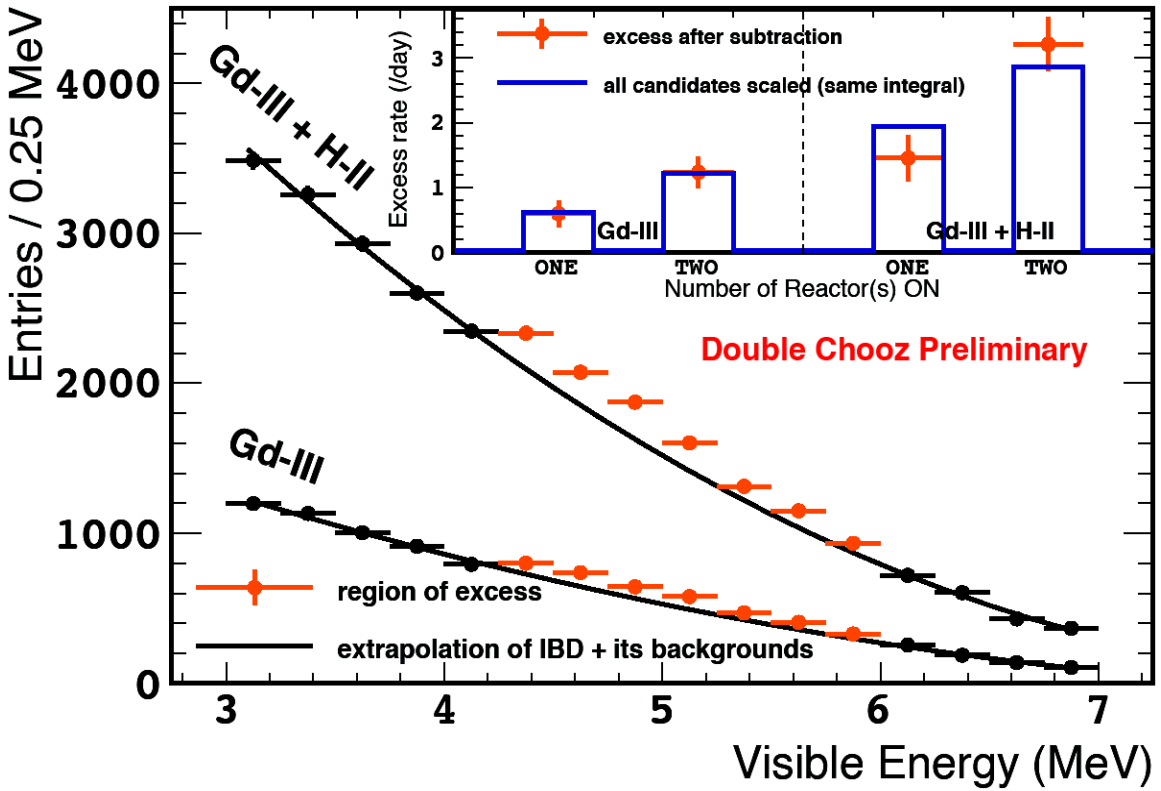
The pattern appears in all the analyses, for different detector volume cuts, different background, systematics, etc.

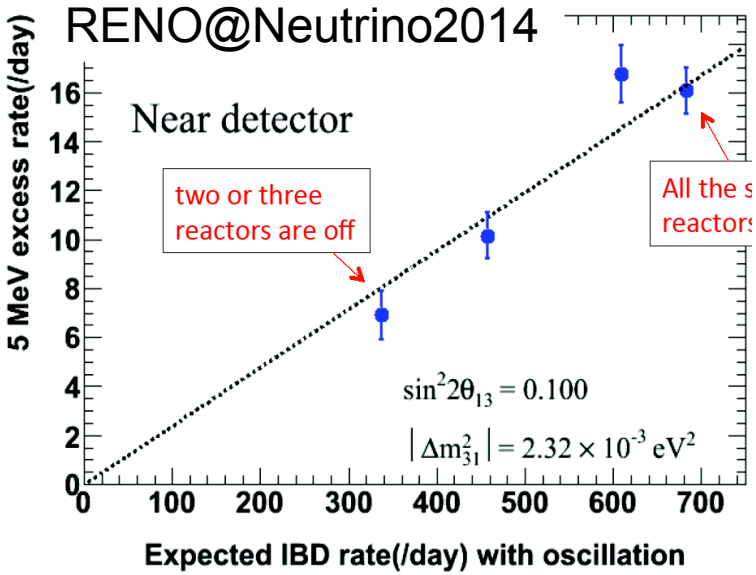
More statistics increases the clarity.

Seen also in RENO (and perhaps in CHOOZ ?).



The pattern at high E





The observed pattern in Data/MC over [4,6]MeV is not yet understood, but NO impact on the θ13 measurement (many tests→ very robust).

Correlations with background and energy are disfavored by dedicated analyses.

Strong correlation with reactor power (and with statistics).

Considering only IBD neutrinos, the pattern is consistent with an unaccounted reactor neutrino flux effect @ ~1.5σ

To remember

DC3 analysis shows big improvements with respect to the last published analysis (PRD86 052008):

Statistics (2X), Detection syst. (2X), Background syst. (3X)

Θ13 and the background are measured with several different analyses.

DC3's precision of Θ13 is the same with the one assumed in the Proposal (hep-ex/0606025) for two detectors !!

More physics with DC: Lorenz violation (PRD86 112009), neutrino directionality (next), reactor physics (next).

Near detector will be operational at the end of this summer !!

Major improvements in analysis already in preparation !!