BASELINE MIND

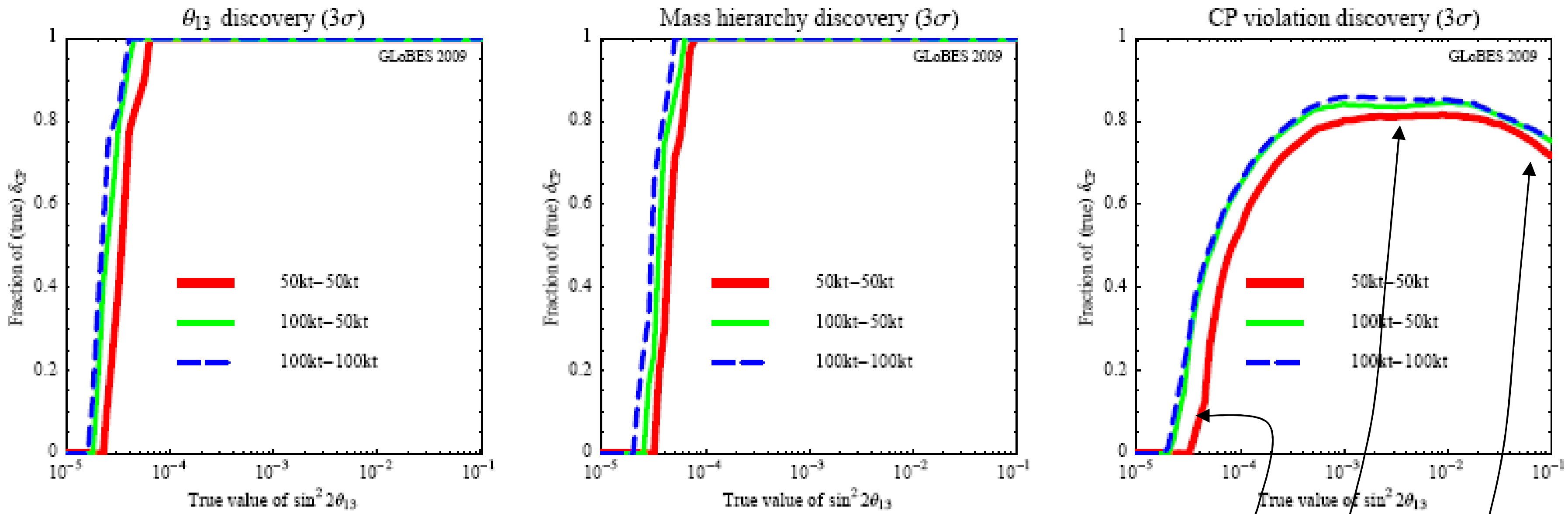
1. Assume two detectors, first in the CP sensitive region 2000-4000km 'CP detector', one at magic baseline
2. To bear in mind: oscillation maximum is 500km/GeV thus
   -- 4-8 GeV for the "CP" detector
   -- 15 GeV for the "magic" detector
   they don't have to be the same.
3. With a EU-centric view, INO is an example of the Magic detector
4. What are the characteristics of CP and Magic?

Aim: make as large as possible to remain affordable and make good statistical use of the facility.

beam folks maximize the flux within boundary conditions and detector people maximize the number of events

THE STUDY

Walter Winter has revisited the relative importance of the CP and Magic detectors in the note IDS-NF-007.



These plots include systematics as follows:

1.	**Background uncertainties**	**± 20%**
2.	**Normalization near/far uncertainty**	**± 2.5%**
3.	**Matter uncertainty**	**± 2%**

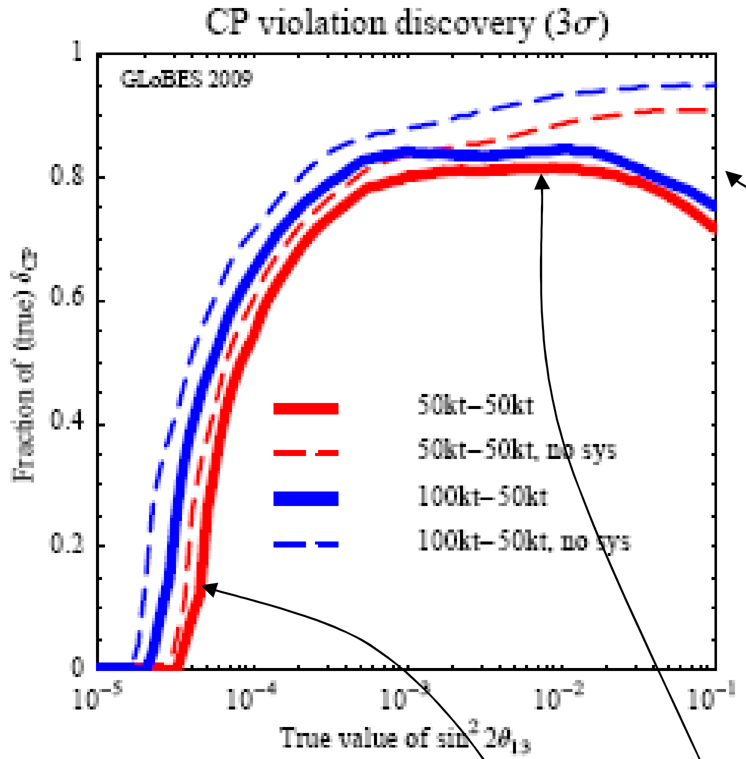
On this basis alone I would consider that there is a good case for

-- increasing the mass of the CP detector to 100kton
(this is the detector that was deemed 'well feasible' by J. Nelson in the ISS study)

-- studying which mass is sufficient for the magic detector to do its job
hypothesis to be tested: the INO detector as proposed today is good enough

-- the case would become even stronger if one can reduce systematic errors

MORE on SYSTEMATICS



These plots include systematics as follows:

1. Background uncertainties ± 20%
2. Normalization near/far uncertainty ± 2.5%
3. Matter uncertainty ± 2%

NB this was not so easy to trace back in the ISS physics report

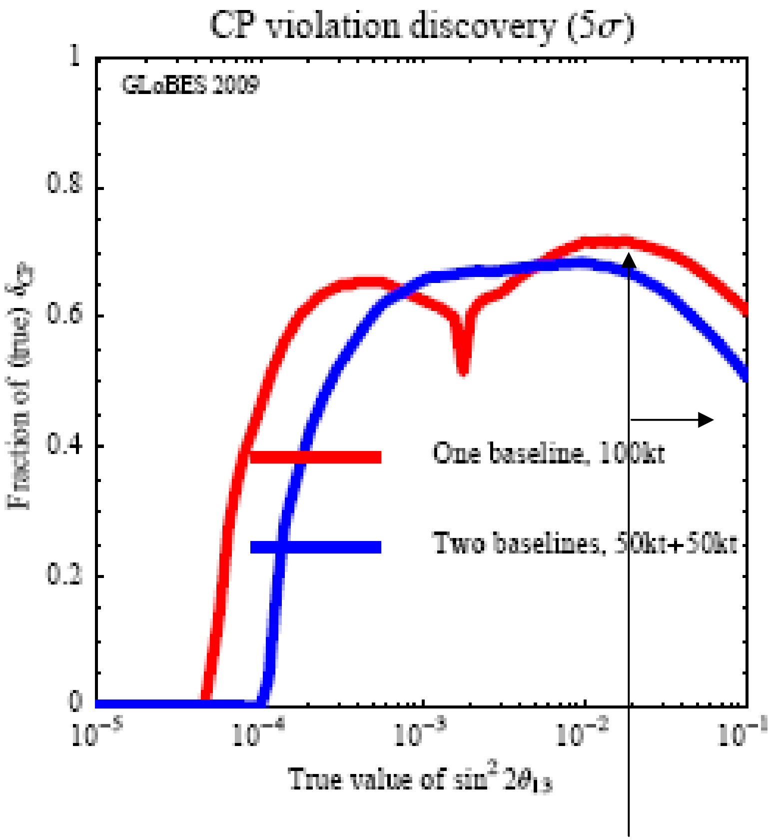
SYSTEMATICS

It is obvious that if we are systematics limited there is no point in increasing the mass.

The matter effect uncertainty was taken to be 2% as interpretation of the work of J. Peltoniemi (see ISS detector report) on the CERN-> Pyhasalmi baseline which has been studied in the framework of a European Geological survey. It is not clear that it should be so small for an arbitrary baseline of 4000km.

If the value of θ_{13} is large ($\sin^2 2\theta_{13}$ >0.02) this error is the dominant one. One should then decrease this systematic error by reducing the distance and picking a baseline with very well known matter profile.

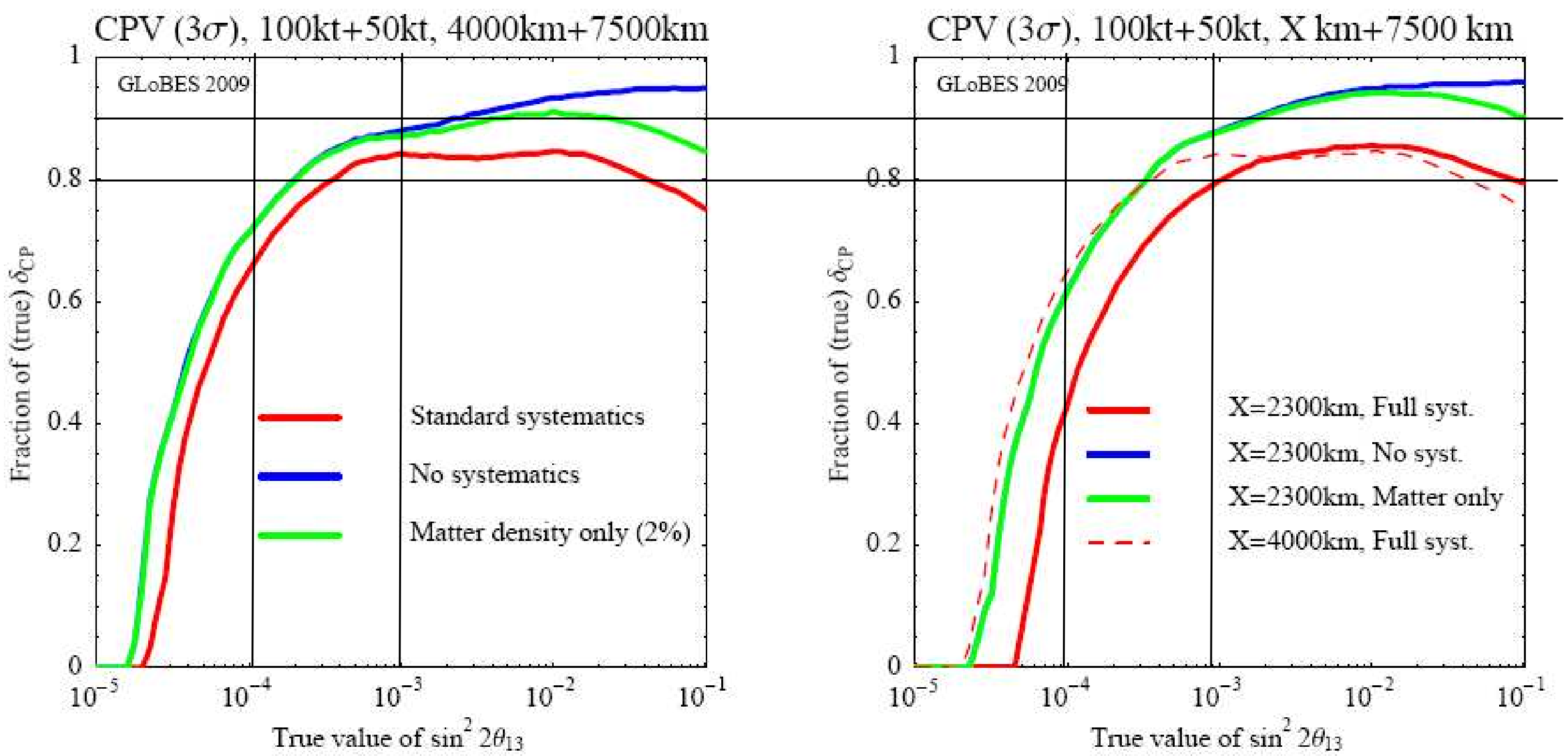
Here, the "magic" detector may not be critical, the additional resources made available could be used for a magnetized TASD or tau detector. (à la LENF – but tau detection requires E_μ > 15 GeV)



If you know you are here…

Walter Winter, private communication

NB 95% at 3sigma means
$\Delta\delta$= 360*0.05/12= 1.5° !
(near δ=0)



NB here X=2285 km i.e. CERN-Pyhasalmi

SYSTEMATICS

The background uncertainty

This is the dominant error for small values of θ_{13} ($\sin^2 2\theta_{13} < 0.001$)

Today we cannot predict the level of background to wrong sign muons with a precision better than 20%, … but…

This number will be known much more precisely at the neutrino factory thanks to the near detector.

1. The dominant intrinsic background consists of very inelastic production of charm by (mostly) ν_e and will be measured precisely by the near detector. Because θ_{13} is small the flux of ν_e hardly changes between near and far detector!
2. The next one is inelastic ν_μ events and should be re-normalized to the oscillated ν_μ's observed in the far detector or to di-muons.
3. The wrong sign tau (followed by decay to wrong sign muons) is a signal and should be analyzed accordingly.
4. Muon charge assignment is the main issue at low muon momentum, but should be well determined in the near detector (the MINOS near detector is a 1kton detector which contains muons up to 5 GeV – at the NUFACT one can test presence of wrong sign muons in the near detector with high accuracy)

At this point I would believe that the background should be considered *'statistical only'* although its level can be taken conservatively as 20% higher than estimated.

SYSTEMATICS

Near/far normalization

We have discussed the flux normalization in the ISS detector report (and earlier in the CERN yellow report). Flux can be determined to 10^{-3} using a combination of

-- muon polarization measurement

-- divergence measurement

-- absolute normalization using the $\nu e \rightarrow \mu\nu$ purely leptonic process in the near detector. This requires that the energy is significantly above 11 GeV (and so does the use of the magic detector).

The mass of detector in a segmented magnetic detector is known to a precision that can be a few 10^{-3} (slabs can be weighted and thickness homogeneity measured) NB the fiducial volume is 80% of the total mass.

The fiducial volume can be determined with a precision of a few mm in each direction for events with a muon

(see CDHS paper CDHS Collaboration, Z. Phys. C45, 361 (1990))

which is commensurate with a near detector: 1.4m radius and 20m long (a 1.15kton near detector) leads to systematic error of the order of 0.5%. (less if the detector is wider and shorter)

➔ The near/far extrapolation uncertainty should be ~0.5% for MIND

CONCLUSIONS of THE STUDY

Main conclusions:

1. There is much more to gain at increasing the mass of the CP detector
2. The loss in decreasing the mass of the Magic detector is not so great
3. The magic detector is very useful at lifting degeneracies for small values of theta_13

My interpretation: the real precision comes from the CP detector and the Magic is there to avoid that ambiguities spoil it.

Once the information is 'good enough' there is little gained in increasing the Magic mass.

Is 100 kton MIND 'reasonable'?

NOvA detector 15.7X15.7X63m of liquid scintillator in plastic extrusion. Detectors are 4cm wide 15m long and 6cm along the beam.

Assume (like for TASD studies) that the width of scintillator can be reduced to 17mm*33mm (triangles)

assume an octogonal design 8m in radius (16m in diameter)

70m of magnetized iron in plates of 2.5cm interspaced with planes of scintillator 17mm thick -- total length is 115 m.

take fiducial volume 40cm away from edges (like CDHS)

Total mass	119.4kton			
Fiducial mass	100kton			
Iron mass	110kton	----------	220M$	(2$/kg)
Scintillator mass	9.4 kton	-----------	47-188M$	(5-20$/kg) ←
number of channels	2.2M	-------------	11-66M$	(5-30$/ch) ←
Various (akin NovA)		------------	30M$	
		total	300M$-600M$	

This is not a cost estimate! Work is needed to understand margin of error and margin of progress especially in the active elements

PROPOSAL

Given that the 100 kton MIND is

1. Not unreasonable size
2. Not unreasonable cost (compared to rest of facility)
3. Quite feasible according to experts (J. Nelson)

And given the physics that

1. There is much gain in increasing the detector size at the CP sensitive location
2. There is much less gain in increasing the detector size at the Magic location
3. The systematic errors should be worked on further but if anything, what has been assumed so far is very (too) conservative (except for the matter uncertainty)

➔ establish the MIND-100 as baseline detector for the CP-sensitive location