Summary of discussion session II: the inter-experiment coincidence

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Abstract

This is a summary of the main conclusions from discussion session II of the supernova early alert network workshop.

1 Introduction

During this discussion session, we went through the list of discussion questions (see `http://hep.bu.edu/~schol/workshop/topics.txt`). We answered many of them easily, but others will require further discussion and experience. Here are some of the conclusions, and some of the questions that were identified for further discussion. Many details were relegated to a working group to be formed from experimental collaborators. **Skip to Section 5 at the end for a brief overall summary.**

2 Experimental capabilites

What are the capabilities of the currently online (and soon-to-be-online) experiments?

These were well covered in the detector talks [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]

Detector	Type	Mass (kton)	Location	No. of events @8.5 kpc	Status
Super-K	water Čeren.	32	Japan	5000	running
SNO	H_2O, D_2O	1.7 1	Canada	300 400	running
MACRO	scint.	0.6	Italy	150	running
LVD	scint.	0.7	Italy	170	running
KamLAND	scint.	1	Japan	300	2001
Borexino	scint.	0.3	Italy	100	2000
AMANDA	long string	Meff $\sim$ 2/pmt	Antarctic		running
OMNIS	high Z Fe, Pb, or NaCl	5-10	USA	$\sim$1000	2000+
LAND	high Z Pb	1	Canada	450	2000+

Table 1: Summary of SN neutrino signal capabilities for current and future experiments.

Table 1 gives a summary of the expected signals from the various neutrino experiments represented at this workshop.[1] Other experiments (not present at the workshop) are Baksan and Icarus. LIGO and other gravitational experiments will eventually be able to provide gravitational collapse signals. Table 2 gives a summary of the supernova neutrino online monitoring capabilities of the current or very-soon-to-be-current experiments.

Here "Estimated response time" time is the estimated time between the actual occurrence of the burst and the time the alarm would be sent out to the international coincidence machine. "Alarm interval" is the approximate interval between background supernova alarms that are issued by the monitoring software. This rate is usually tunable: by changing multiplicity thresholds, alarm rates can be increased or decreased (and SN distance sensitivity correspondingly increased or decreased). "Network connectivity"

[1] Note that AMANDA's supernova detection capabilities are based on coincident increase of PMT single count rates, so that some columns in this table do not really apply.

Detector	Online monitor status	Alarm inter-val	Est. resp. time	Network connection	Time stamp	Timescale for int'l connect
Super-K	running	1-2 wk	40 min	good	$<$ms	online now
MACRO	running	2-3 wk	20 min	good	$<$ms	online now
SNO	prototype running		short	good	$<$ms	$\sim$6 months
LVD	running	10 d	short	good	$<$ms	few months
AMANDA	running		short	50% coverage	0.5 s	few months

Table 2: Summary of experimental monitoring capabilities for currently running experiments

gives some idea of what fraction of time the experiment's signal would be able to reach an international coincidence server machine. For most experiments, this should be most of the time ("good"); however AMANDA at the South Pole has incomplete satellite coverage. The South Pole coverage is expected to improve [6] over the next several years. "Time stamp resolution" indicates the absolute time accuracy of the time stamps of the individual neutrino events. Most experiments have UT clock or GPS based time seconds and can do much better than milliseconds. However AMANDA's integration of PMTs count rates over 0.5 second intervals give it a lower time resolution; this is expected to improve [6] to ms intervals by the year 2001.

Experiments which are under construction presumably will install SN neutrino monitoring software as soon as they are running.

3 The Inter-experiment coincidence

This section is divided into "Coincidence configuration" and "Information exchange" subsections, but they are inter-connected issues.

3.1 Coincidence configuration

References [11, 12] give some background information about coincidence configuration issues.

What false alarm rate per experiment is acceptable for the coinci-

dence?

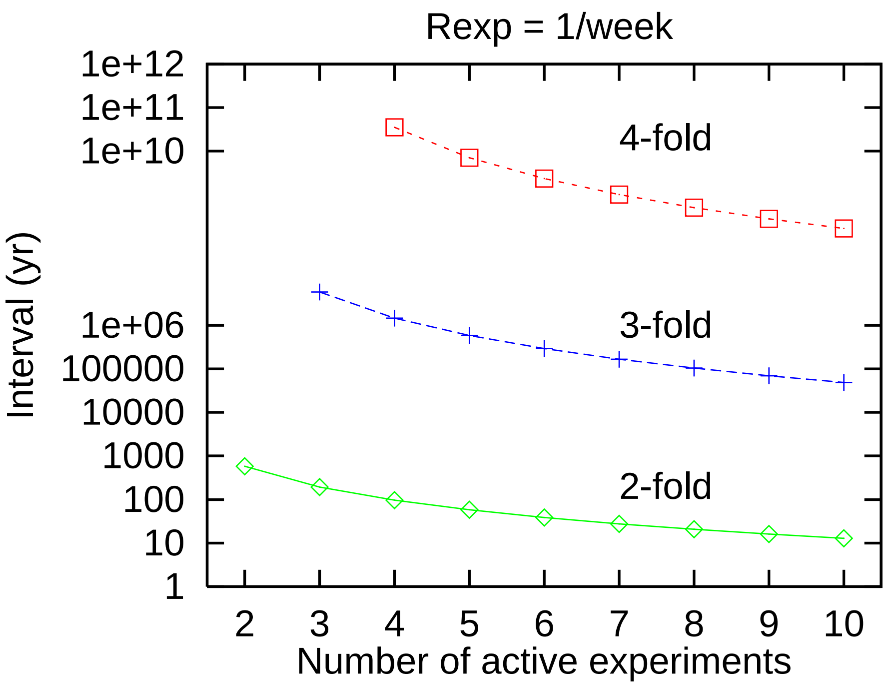

Figure 1: Interval between accidental coincidences as a function of number of experiments, for a 1 per week individual experiment rate and a coincidence time window of 10 seconds.

Figure 1 [11, 12] shows the average time between coincidences as a function of number of running experiments, for 2-fold, 3-fold and 4-fold coincidence requirements, for an assumed rate of alarms per experiment of 1/week. A 10 second coincidence window is assumed here. We will assume that an acceptable average rate for alarms to the astronomical community is 1 per 100 years.[2]

For a 2-fold coincidence, Figure 1 shows that the individual experiment rate should be $<$ 1/week if the accidental coincidence rate is to be $<$ 1

[2]This is approximately the same as the expected rate of supernovae. This gives a Poisson probability of an alarm in a 10 year period of $\sim$10%. Is this conservative enough? For the moment, we are assuming yes.

per 100 years. We will adopt the nominal requirement that a participating experiment's false alarm rate must be < 1 per week.

How shall we set up the coincidence? 2-fold, 3-fold, "silver" and/or "gold" queues?

The assumptions for Figure 1 are that the experiment alarms are Poissonian and uncorrelated. However, one can imagine some kind of correlated event trigger bursts that could fire all experiments at once. For instance, there could be some shared power line noise for experiments at the same laboratory. Perhaps a solar storm could cause correlated electrical noise. Another possibility for correlated "noise" is fraud – a malicious hacker could be trying to simulate an alarm condition.

The message from astronomers is that false alarms are fatal (see the summary from discussion group III). Therefore, in order to suppress possibly correlated coincidences between experiments at the same laboratory (e.g. MACRO and LVD, or Super-K and KamLAND), we decided to require either a *remote* 2-fold coincidence, or else a 3-fold coincidence (assuming a 1 per week individual experiment rate).

The "gold-" and "silver-plated" queue idea ([11]), for sending high and low rate alarms to astronomers with different false alarm tolerances, was rejected. The message from the astronomers is that "silver-plated" alarms will not be taken seriously. Only "gold-plated" (a fake only every 100 years) alarms should be sent to astronomers, regardless of the astronomer false alarm tolerance.

However silver-plated alarms would be OK for a "test queue" (since we need some rate of alarms for tests), for the purpose of exercising the system.

How many coincidence server machines do we want to have, and where?

Everyone agreed that redundant servers are desirable.

Note that the redundancy of the servers does not mean that the alarm is not "blind": each server is still individually implementing a blind coincidence. There must be no supernova burst searches based on received alarms from other experiments, and burst information received must be kept strictly confidential. Security is also an issue for ensuring each experiment's privacy, which will limit the practical number of servers online.

Some experimental sites are fairly remote and have non-ideal Internet access, so we may prefer to have more centrally-located coincidence server machines.

For now, we will retain the `kaboom` test machine at the Mozumi Super-K site. Next, we will add one at LNGS, and when SNO is online we will add one at a SNO collaborating institution.

The details of the setup are left to the working group.

3.2 Information exchange

Do we want to include "EXPERIMENT DEAD" or "NO SIGNAL" information in the coincidence, to lower false alarm rates and possibly increase sensitivity? How could we implement this?

The essential answer to this question was "YES". Most collaborations seem uncomfortable with the idea of sending out continual alive-or-dead ping information; however this may not be necessary. The generally accepted proposal was to query the individual experiments after a coincidence is found: i.e. if a 2 or more -fold coincidence is found, each experiment will be polled: *Are you online? If so, did you see anything?* Then a coincidence would be required between all experiments which should have seen something.

Some kind of time-out would be needed. Technically, this is not difficult to implement. Again, details of implementation are left to the working group.

What information do we exchange?

This question ties in with the previous question and the discussion of correlated alarms.

It may be possible to suppress correlated alarms (due to solar activity or whatever unthought-of strange phenomenon) by requiring some sort of consistency between the neutrino signals of the different experiments. Presumably, an electrical storm would cause bursts of events which look unlike a true neutrino pulse, and the strange burst would look different in different experiments.

The following was proposed: when a coincidence is found, the individual experiments will be queried for *some signal information* (for the case of a signal) not just simple alive-or-dead, signal-or-no-signal data.

So, what consistency criteria can we use? The query and consistency check should be completely automated, so the information exchanged should be simple. Here are several ideas for the signal information to exchange:

- Events/kton (equivalently, a distance estimate to a standard SN, but that was discarded as being confusing.)
- Some sort of "significance" criterion. This could be based on some sort of position uniformity criterion. However a believability criterion is pretty hard to quantify in a detector-independent way (since it depends on detector configuration, background, etc. and may even be time-dependent for a given detector.) We decided that each experiment is responsible for sending out only "significant" alarms. Each experiment should be responsible for suppressing bizarre alarms as much as possible, of course.
- Possibly, a direction, for those experiments capable of measuring one (from elastic scattering, probably).

Events/kton is probably the most robust and straightforward piece of information to exchange.

Some disagreed with the consistency requirement, arguing that in real life experiments are fallible, i.e. the probability is not small that experiments will mess up and the signals won't look perfect. In this view, if we have a strong consistency requirement on numbers of events, a perfectly real supernova signal could be rejected. For instance, the HV might be off on some phototubes, or discriminator thresholds might not be set right, or something could be wrong with the reconstruction code, or... This sort of thing is impossible to predict. A stringent signal consistency requirement could appreciably cut off our supernova signal sensitivity.

This argument boils down to trade-off between trying to maximize sensitivity while minimizing danger of a false alarm. Unfortunately for this case, it's nearly impossible to optimize cuts in a quantitative way, because we have *no idea* of the nature of the non-Poissonian conditions that may drive the correlated coincident alarm rate. We also have no idea of what human errors could cause flawed measurements. We can only use judgment.

The general feeling after discussion of this question was that this argument is a good one for making the consistency cuts *loose ones*– say, require a factor of two consistency in events/kton – but our fear of bogus alarms outweighs our fear of missing a signal enough to require some sort of automated consistency check before sending out the alarm.

How can we best deal with the different experiments' sensitivities?

If an inter-experiment coincidence is required, obviously the sensitivity of the entire network is limited to that of the least sensitive experiment.

To first order, this is not a problem, because each experiment can issue its own alarm independent of the network. For instance, Super-K's sensitivity is $\sim$ 100 kpc. Super-K can simply issue an independent alarm if it sees a distant supernova. Second, all of the experiments participating are essentially sensitive to all of the stars in the Galaxy. The number of SN candidate stars as a function of distance from Earth levels off rapidly beyond the far edge of the Galaxy [13]. Therefore all experiments are sensitive to approximately the same stellar collapse candidates.

So, for the initial network setup we will make no attempt to deal with varying sensitivities. In the future, we could improve the situation by doing the following [11]: after a coincidence is found, each experiment is queried for its distance sensitivity information (which depends on the current active mass and background rate). Then we require a coincidence between all experiments which *should* have seen a signal.

Do we want to exchange event-by-event information?

For the moment, the answer to this question is "NO" – event by event information should not be necessary for a prompt alarm and rough consistency check. However we may eventually want to expand the information exchange if we want to do triangulation. AMANDA in particular may need external information to extract good information. It's still unclear if triangulation is possible, and if so, how much information it will be necessary to exchange. We must wait for answers from triangulation studies before deciding this.

Do we want to allow retraction of alarms by experiments?

Here, the simple answer is "YES". If any alarm is found to be pathological, humans at each experiment ought to be able to retract the alarm (there may be enough time to do this since some experiments can take up to 40 minutes). A utility to allow deletion of alarms from the queue can be written.

Do we want to have a second level of non-automated, human-checked alarms?

Yes, in addition to the automated information query if a coincidence happens, we can have an exchange of human-checked information. Of course this will happen with some delay.

3.3 More issues

Should we try to coordinate calibrations to minimize collective down-time?

Yes, for major periods of down-time (longer than a day or so). It would probably be too troublesome to try to arrange non-overlapping down-time for short periods.

We discussed SN sensitivity during calibrations: many experiments, such as MACRO and Super-K are actually sensitive to SN neutrinos during calibrations in the sense that events would be recorded although the burst would not be picked out by online monitor software.

Is it necessary or desirable to use dedicated phone lines?

There is no firm answer to this question yet; a dedicated phone line is probably not necessary at the moment. If we have redundant servers, the Internet may be reliable enough. A possible setup is to have a phone line ready in case the standard socket connection fails. A testing period will show us the answer to this one.

What's the best way to deal with security?

The implementation details are left to the working group, although everyone agreed that security is something definitely worth worrying about. Our primary source of "non-Poissonian" coincidences on a 100 year timescale may be hackers clever enough to simulate an alarm!

How can we connect the output to the astronomers?

The astronomers' answer to this question is quite simple: send email to a mailing list of interested parties, including the Astronomical Bulletin. The word will spread itself after that. See the astronomy discussion group summary for more on this.

How shall we do tests?

It was agreed that we should have a reasonably long testing period. Details will be decided by the working group.

We can set up a the "silver (or bronze...)-plated" queue as a test queue with tagged test alarms.

4 Remaining issues

Triangulation issues are still unresolved – we need more input from theorists on predictions for the rising edge of the neutrino pulse before we really know whether pulse registration is possible.

We left a number of the technical details to be decided by the inter-experiment working group. Here are some of these:

- Where shall we set up more servers?
- How do we implement security measures?
- How do we do tests?
- How can we make sure clocks are synched?
- What data format do we use for information exchange?
- etc.

5 Overall summary

Here is a summary of the main conclusions from discussion group II:

- A 1/100 year accidental coincidence rate is acceptable for "gold" alarms. This corresponds to an individual experiment rate of < 1 per week.
- The message from the astronomers is that only "gold" alarms are to be sent out (although "silver" alarms are OK for internal testing purposes).
- We should try to suppress possibly correlated inter-experiment alarms (e.g. electrical noise from solar flares) by requiring rough consistency in the neutrino signals, e.g. require roughly consistent events/kton. In addition, "remote" 2-fold coincidence will be required.
- Information will be exchanged by all experiments AFTER a coincidence between at least 2 experiments is detected. This information will include: experiment dead or alive $\rightarrow$ if alive: signal or no signal $\rightarrow$ if signal: some signal information for consistency check such as events/kton.
- More detailed information exchange issues are not decided yet, e.g. shall we exchange event-by-event information to attempt triangulation? This needs more study.
- Non-overlapping downtime should be coordinated between experiments for major ($>$ day) scheduled outages and calibrations.
- We can have several servers, each implementing the alarm for redundancy (but all still "blind"). All information sent to each server will be kept private.
- We need to worry about security (hackers).
- There will be a fairly long testing period before sending out any alarms to the astronomers (6 months to 1 year)
- A inter-experiment working group with representatives from each experiment will decide technical details. They will also act as liaisons to their experimental collaborations for data exchange issues. See the `http://www-ussk.icrr.u-tokyo.ac.jp/~kate/snnet/wg/working_group.html` page for working group member list and information.

References

[1] Y. Fukuda, Workshop transparencies, p. 47

[2] A. McDonald, Workshop transparencies, p. 59

[3] J. Heise, Workshop transparencies, p. 65

[4] W. Fulgione, Workshop transparencies, p. 77

[5] K. Scholberg, Workshop transparencies, p. 85

[6] A. Bouchta, Workshop transparencies, p. 99

[7] M. Chen, Workshop transparencies, p. 107

[8] C. Hargrove, Workshop transparencies, p. 115

[9] A. Murphy, Workshop transparencies, p. 129

[10] L. de Braeckeleer, Workshop transparencies, p. 265

[11] K. Scholberg, Workshop transparencies, p. 137

[12] A. Habig and K. Scholberg, document available at `http://www-ussk.icrr.u-tokyo.ac.jp/~kate/snnet/gcnet.ps`

[13] J. Bahcall, *Neutrino Astrophysics*