The IceCube data acquisition system for galactic core collapse supernova searches

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for IceCube-Collaboration

6th of August 2013

Outline

1. Data Acquisition - Hardware
2. Data Acquisition - Software & Physics Capabilities
3. Data Acquisition - Automating
4. Conclusion

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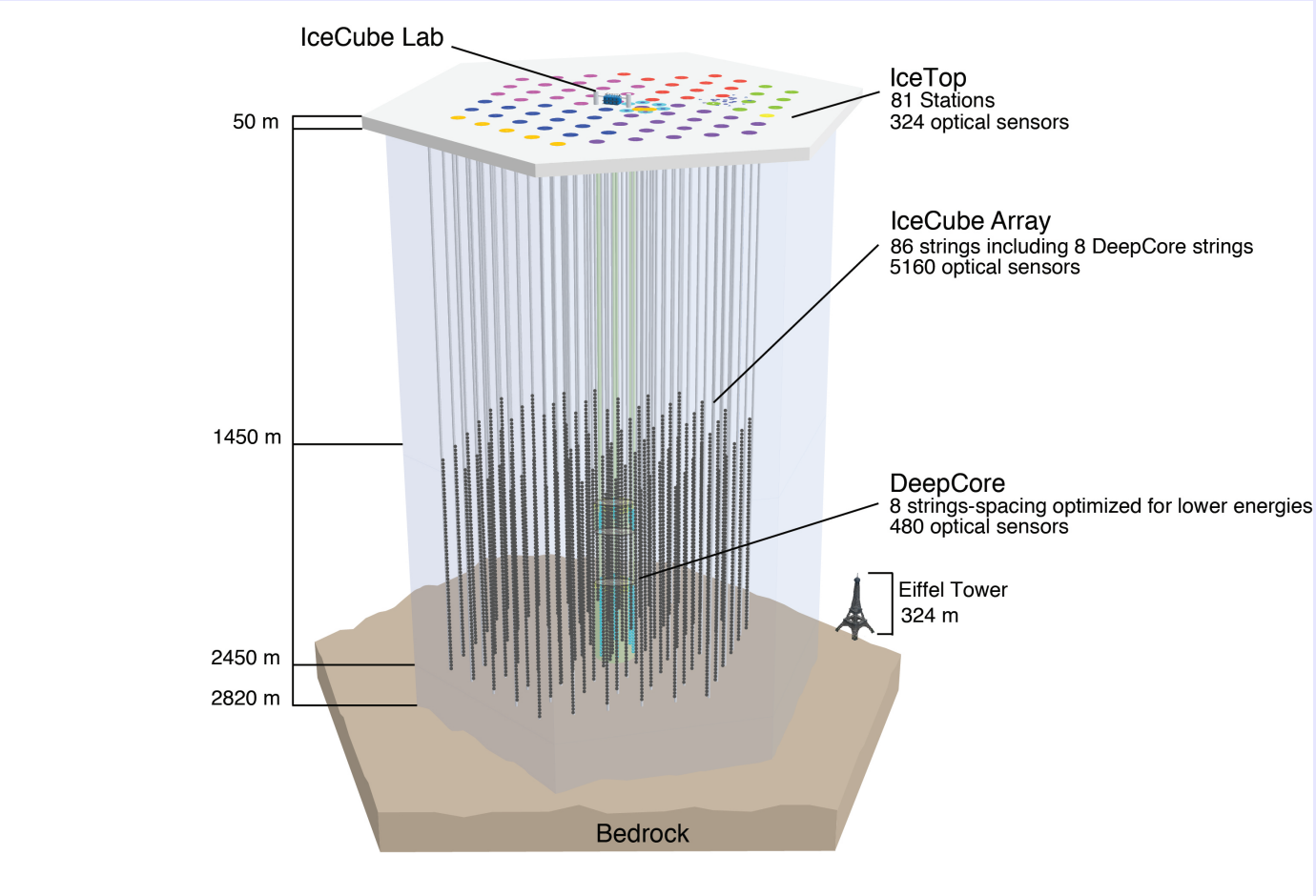
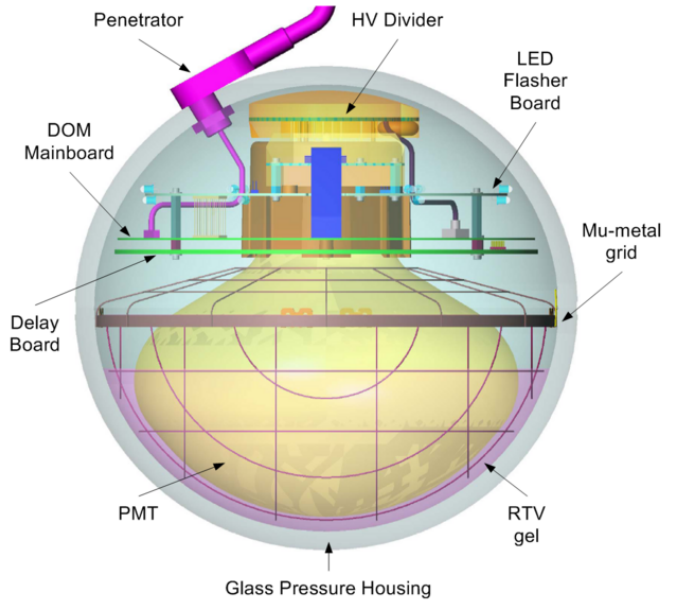
The detector



- Configurations before completion: IC40, IC59, IC79
- Configurations after completion: IC86-I, IC86-II

The Digital Optical Module (DOM)



- Supernova data acquisition hardware
- Scalers count every hit exceeding discriminator threshold of $\approx 0.25\,\mathrm{SPE}$
- Hits are binned by scaler in $1.6384\,\mathrm{ms}$ units (asynchronously between DOMs)

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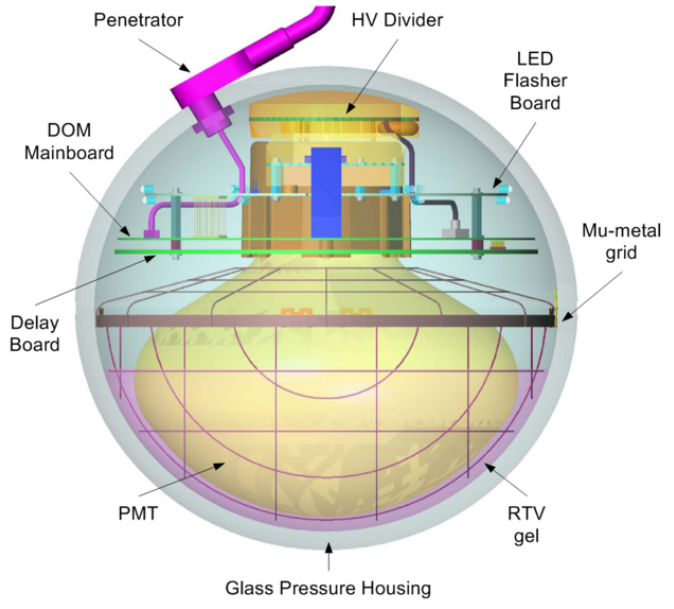

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- Average dark noise rate $\approx 540\,\mathrm{Hz}$ (atm. muons, radioactivity, ...)
  Artificial deadtime of $250\,\mu\mathrm{s} \rightarrow 285 \pm 26\,\mathrm{Hz}$
- Very stable in time and only slightly varying with depth

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3 Data Acquisition - Automating

4 Conclusion

SNDAQ

- Search for MeV-$\bar{\nu}_e$'s from core collapse SN by measuring collective dark noise rate deviation $\Delta\mu$

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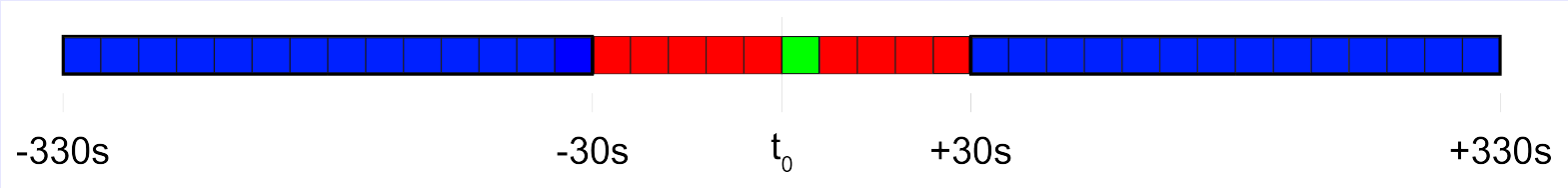
  - rebins and synchronises scaler bins to $500\,\mathrm{ms}$
  - calculating $\Delta\mu$ which depends on:
    - the rate distribution in the $2 \cdot 5\,\mathrm{min}$ sidebands (blue)
    - number of noise hits in the analysis window (green)



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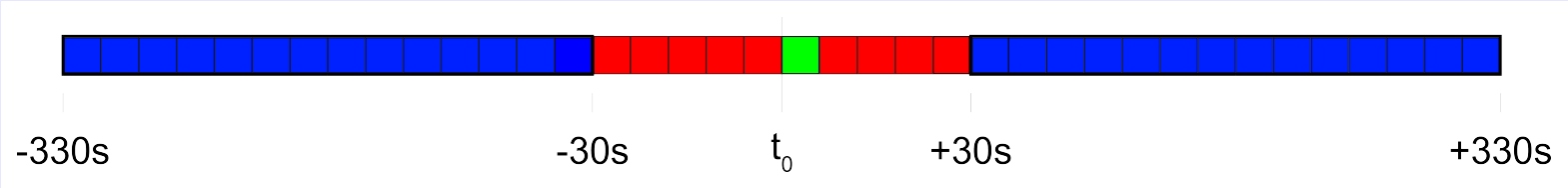


  - in total 4 analysis: $0.5\,\mathrm{s}, 1.5\,\mathrm{s}, 4\,\mathrm{s}$ & $10\,\mathrm{s}$

- Significance ξ is defined as:

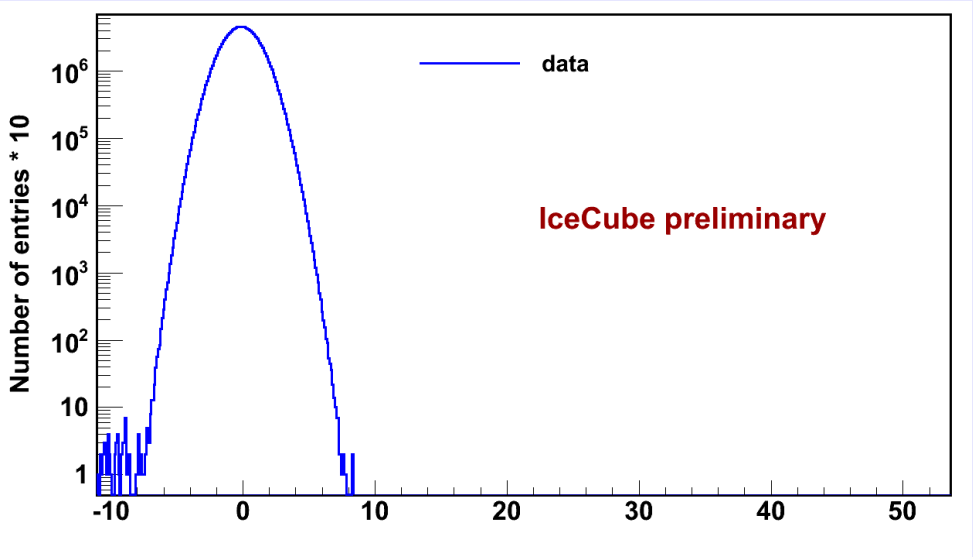
$$\xi = \Delta\mu / \sigma_{\Delta\mu}$$

ξ is only „true“ significance if no correlated noise

SNDAQ analysis

- ξ-distribution widened:

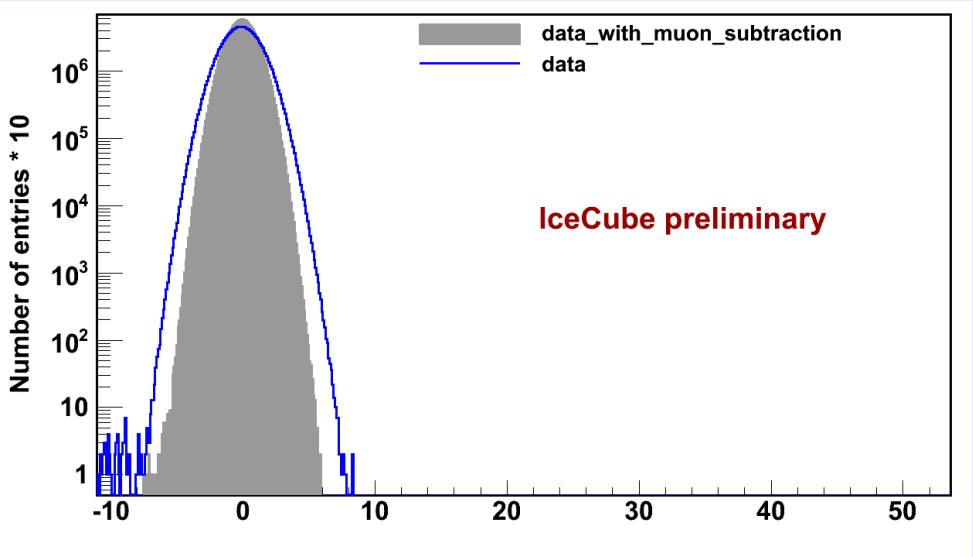
  $\sigma_\xi \approx 1.26(\text{IC40}), 1.46(\text{IC79})$



SNDAQ analysis

- ξ-distribution widened:
  $\sigma_\xi \approx 1.26$(IC40), 1.46(IC79)

- Offline subtraction using filter rates: $\sigma_\xi \rightarrow 1.03$
  Online subtraction planned



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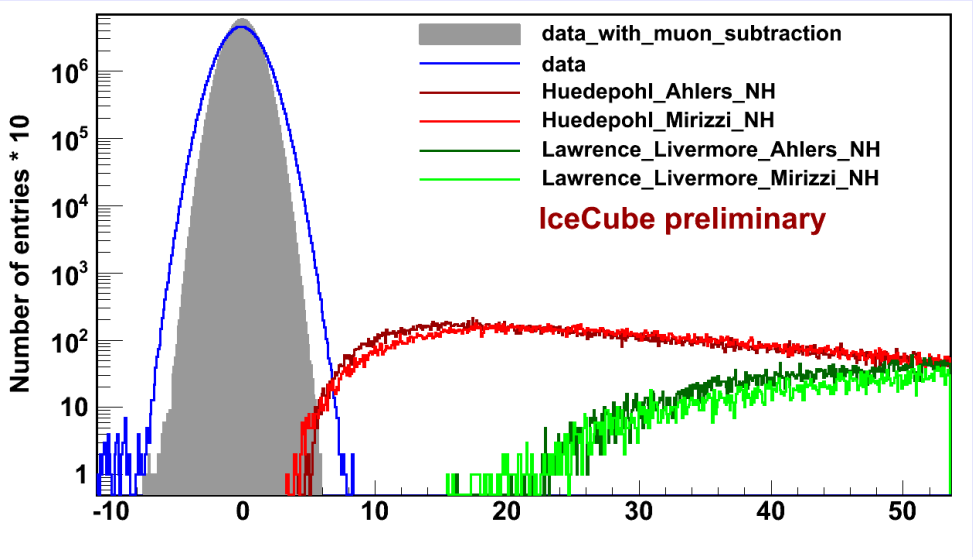

- Very good signal to noise discrimination for different SN models (Hüdepohl/Lawrence-Livermore) & star distributions (Ahlers/Mirrizi)

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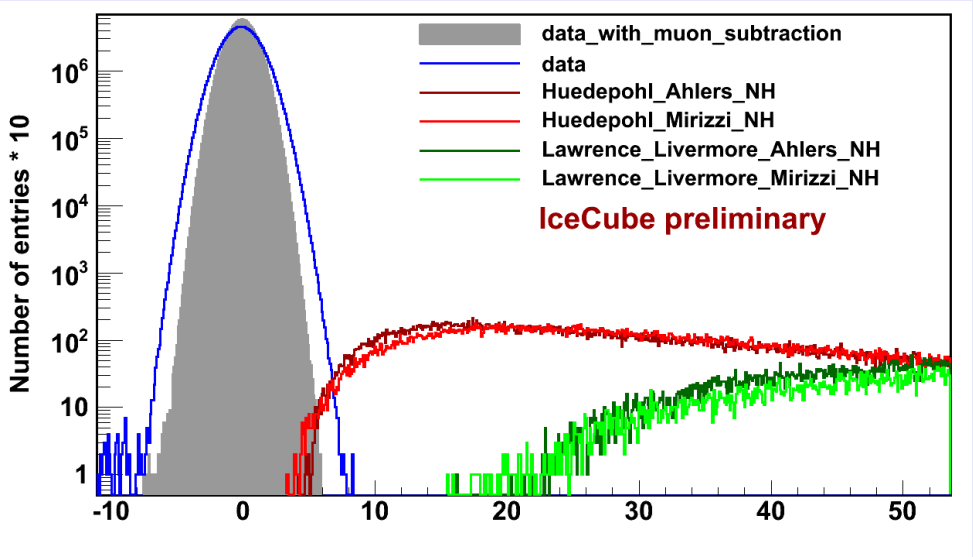
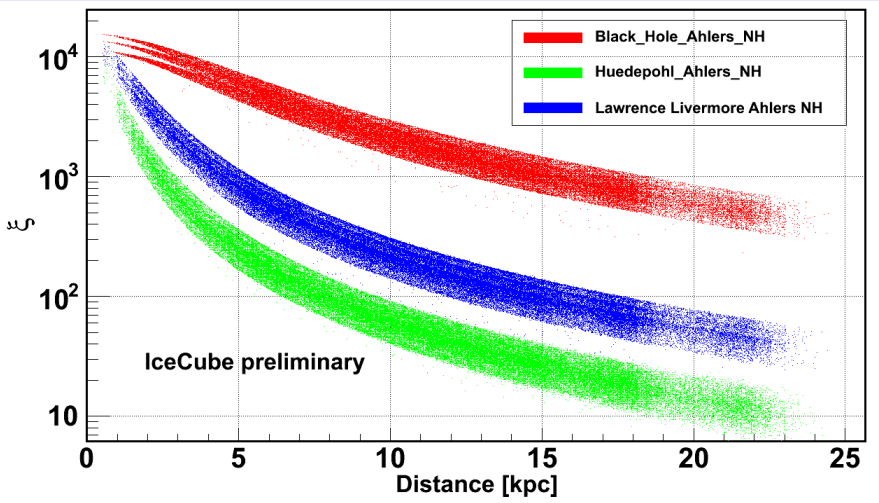


- Very good signal to noise discrimination for different SN models (Hüdepohl/Lawrence-Livermore) & star distributions (Ahlers/Mirrizi)

- IceCube will provide the world's highest statistic for core collapse supernova in our galaxy

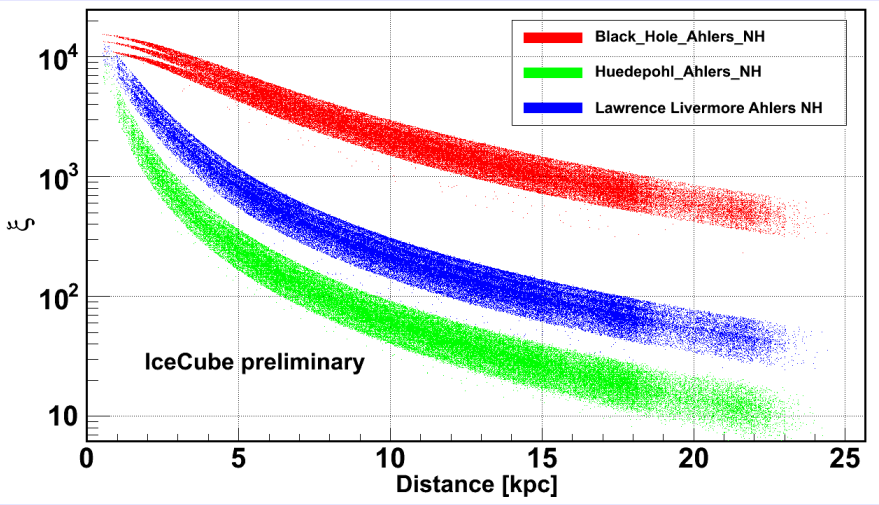
Physics capabilities

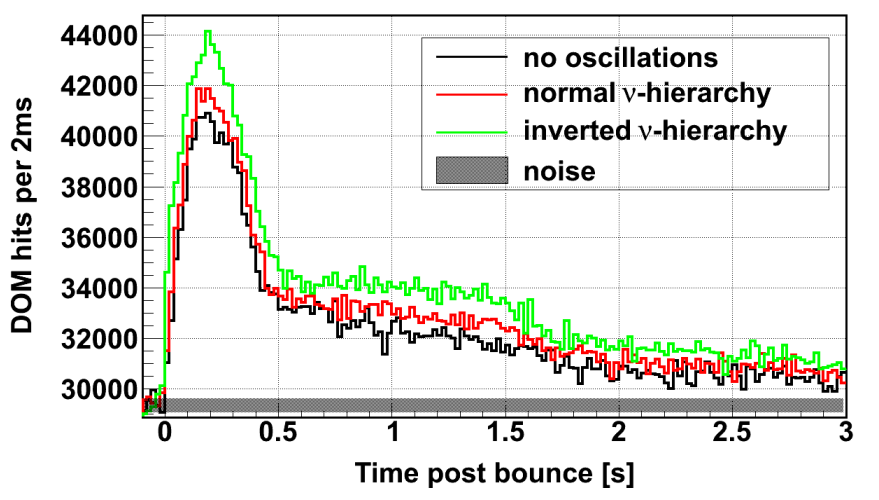


- Separation of different SN models in the galaxy

  shown for IC40 - IC79 and most recent star distribution (Ahlers)

Physics capabilities





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- Separation of inverted and normal ν-hierarchy for Lawrence-Livermore model at $10\,\mathrm{kpc}$

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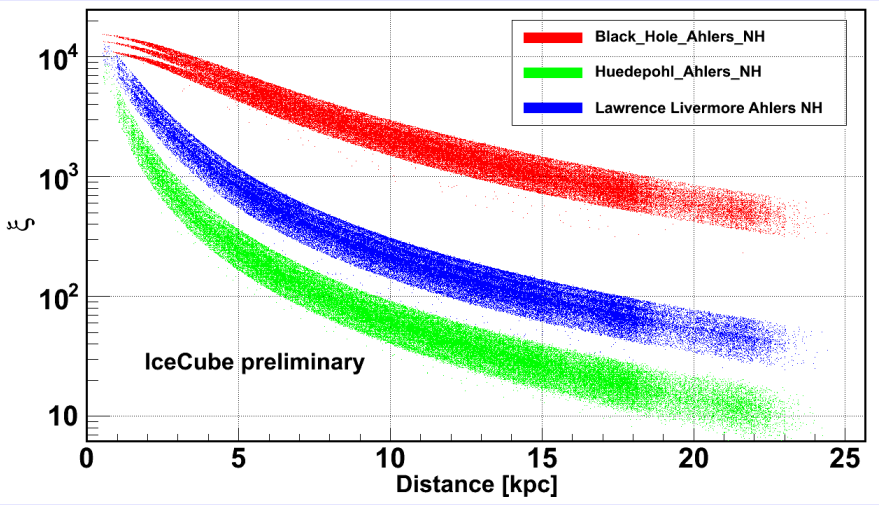

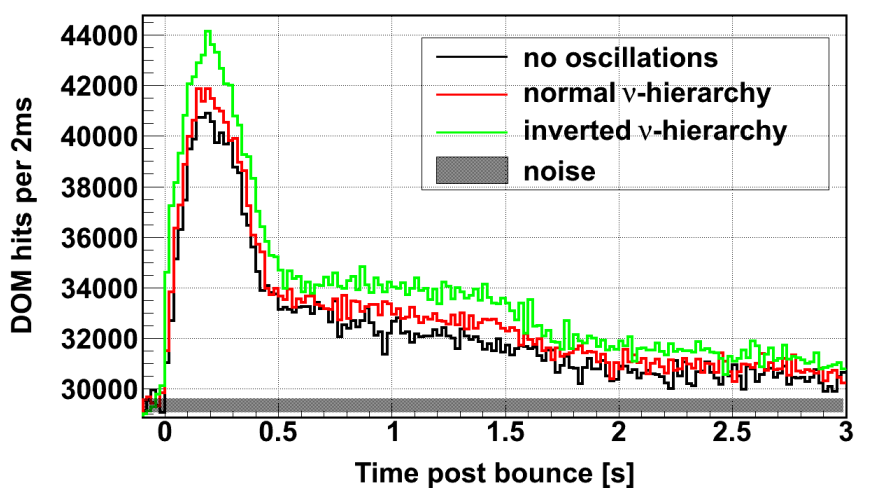

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- To do: Energy estimation

HitSpooling

- HitSpooling $\hat{=}$ buffering of timestamped hits at SNDAQ trigger
- Improving muon subtraction by using single hits
- Pinpointing SN start time thanks to nanoseconds resolution
- Search for frequency modulations (e.g. due to grav. waves $\approx 600\,\mathrm{Hz}$)

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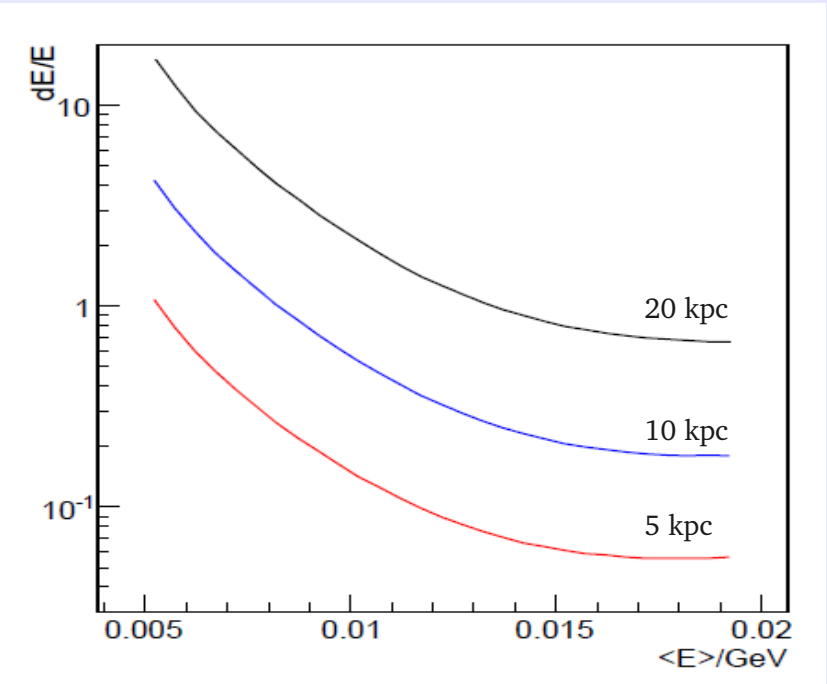
- Pinpointing SN start time thanks to nanoseconds resolution
- Search for frequency modulations (e.g. due to grav. waves $\approx 600\,\mathrm{Hz}$)
- Estimation of mean ν-energy:
  - Ratio of the number of nearest-neighbour hits to single DOM hits is energy dependent
  - 30 % energy resolution at $10\,\mathrm{kpc}$ for most conservative model



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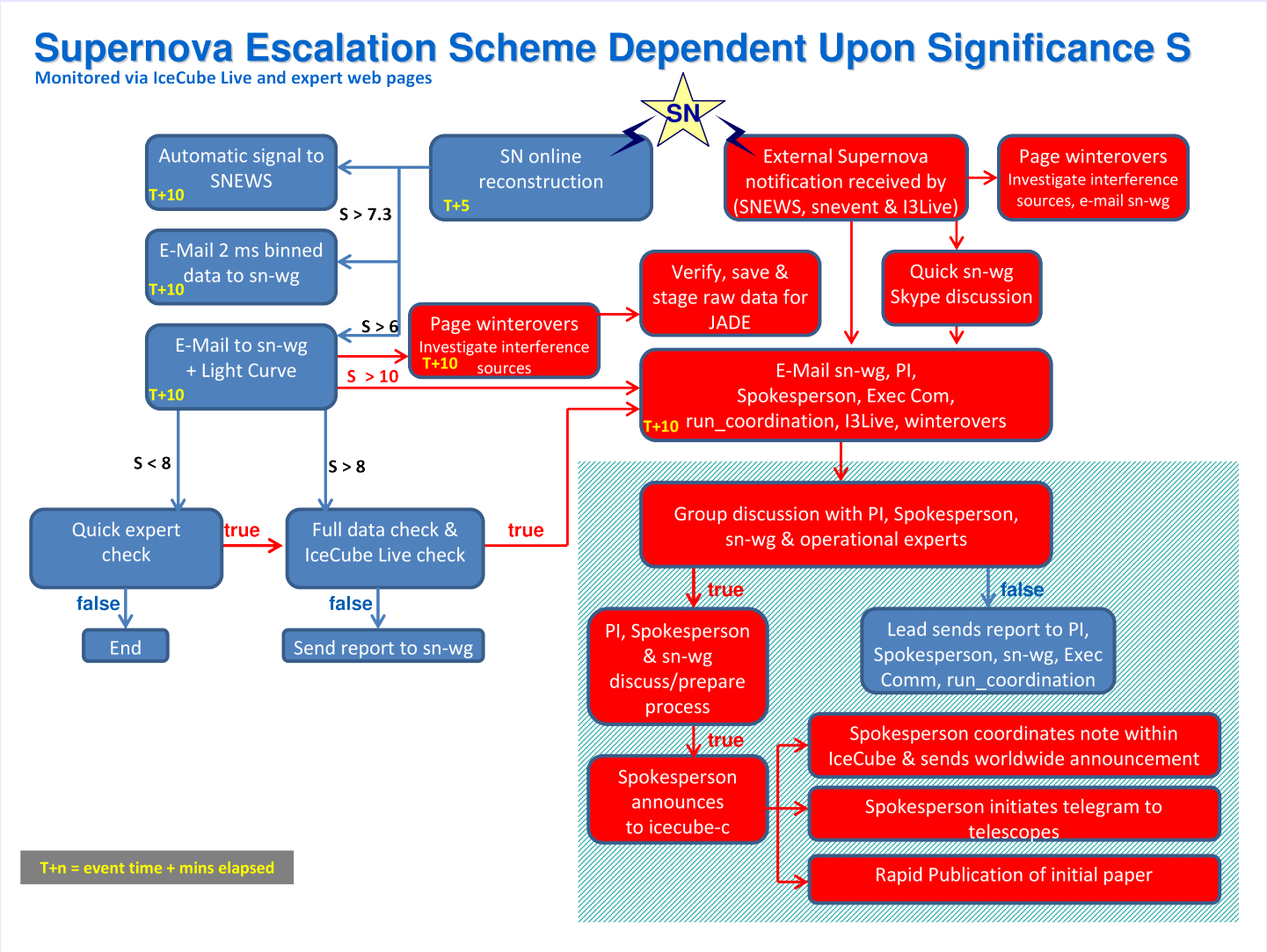
SN escalation scheme



Alert Emails and fast analysis

- Alert emails send to working group at $\xi > 6$
- Example: highest candidate triggered by SNDAQ at 2013-02-05

```
trigger timestamp                    = 2013-02-05 UTC 23:46:40
run number                           = 121833
significance                         = 9.09 = 3.30/0.36
chi-square                           = 5133 (chi2 probability p is 56.68%, (1-p) is 43.32%)
active channels                      = 5069
bin width                            = 1500 ms
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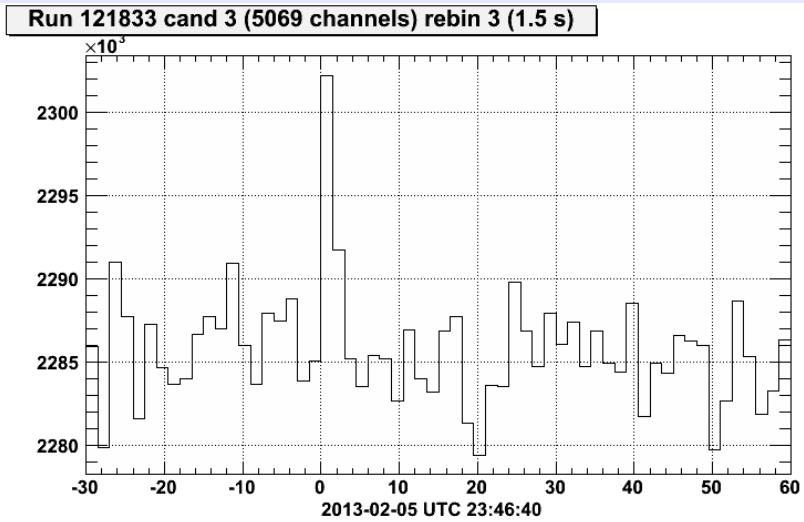
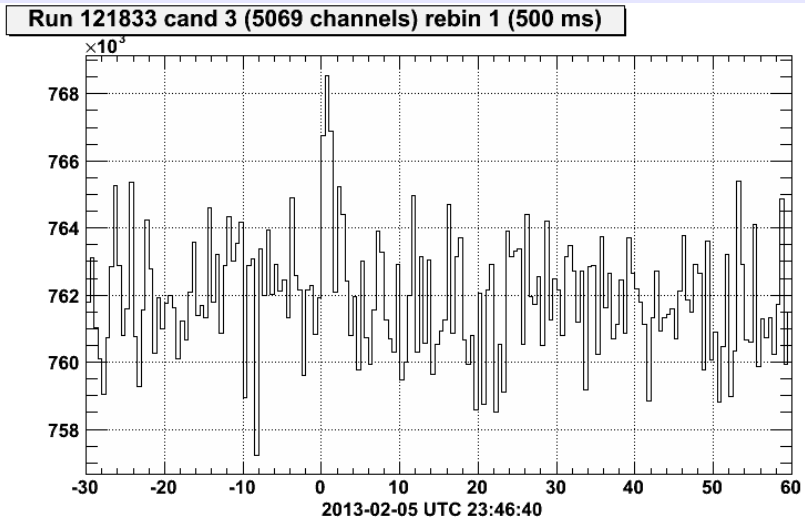
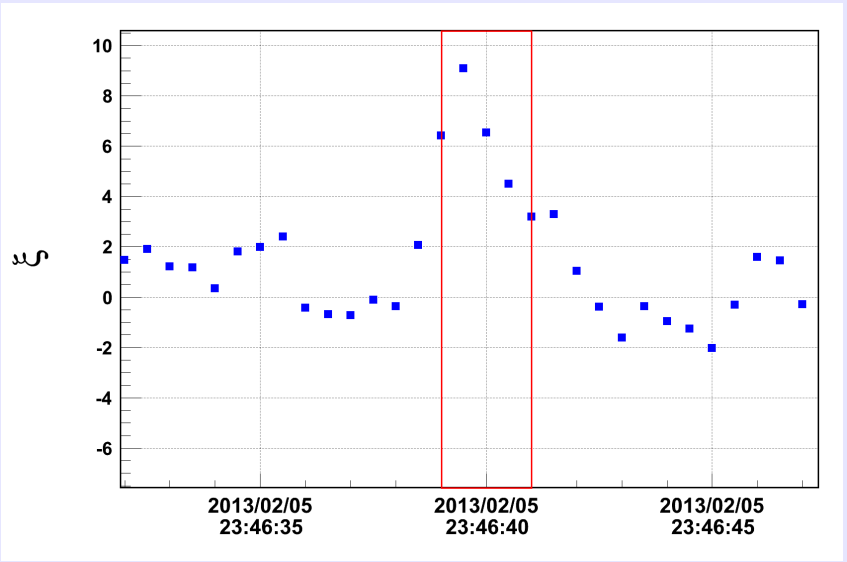
- Fast ($\mathcal{O}(\mathrm{min})$) analysis plots available:





Investigation on atmospheric muons



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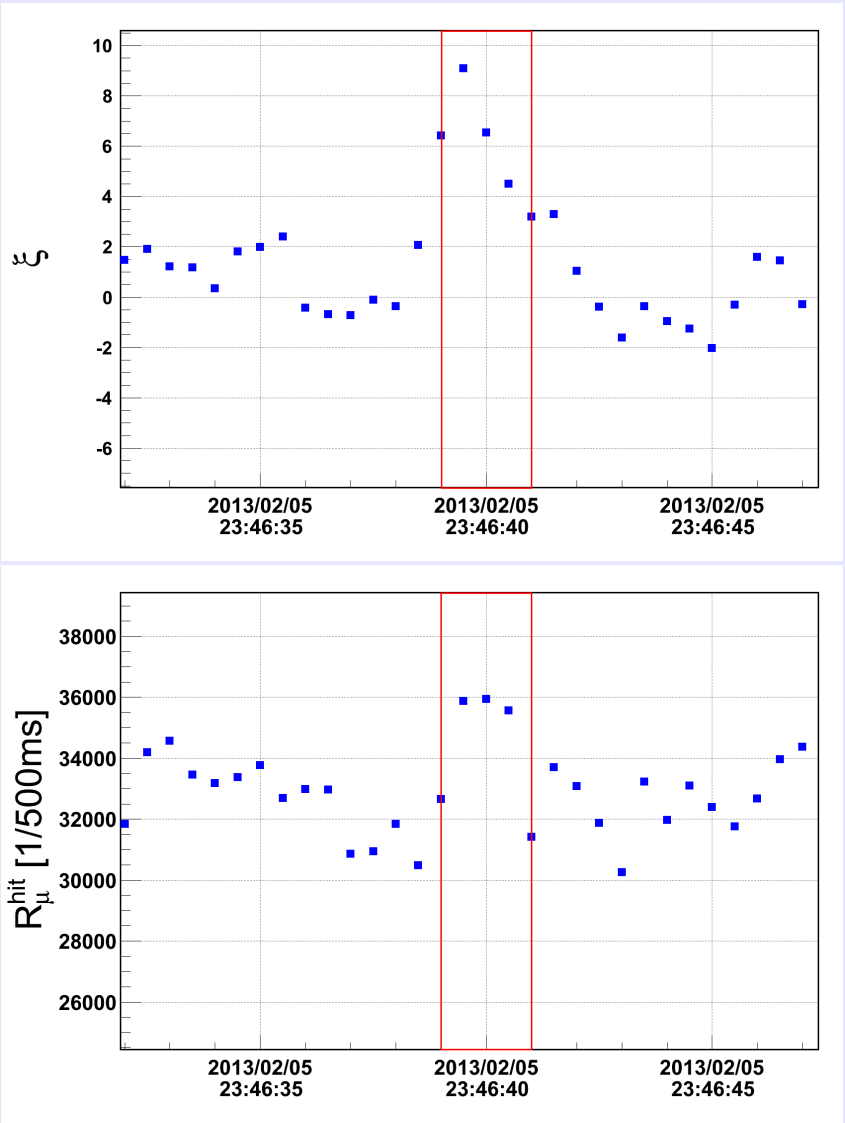


- For an interval of 1.5 s R_μ^{hit} is risen but not to uncommon levels
- Rise in R_μ^{hit} clearly correlates to and explains rise in ξ

$\Rightarrow$ Online subtraction of atmospheric muons needed & planned !

Physics monitoring I

- Provides important information about the datasets (runs)

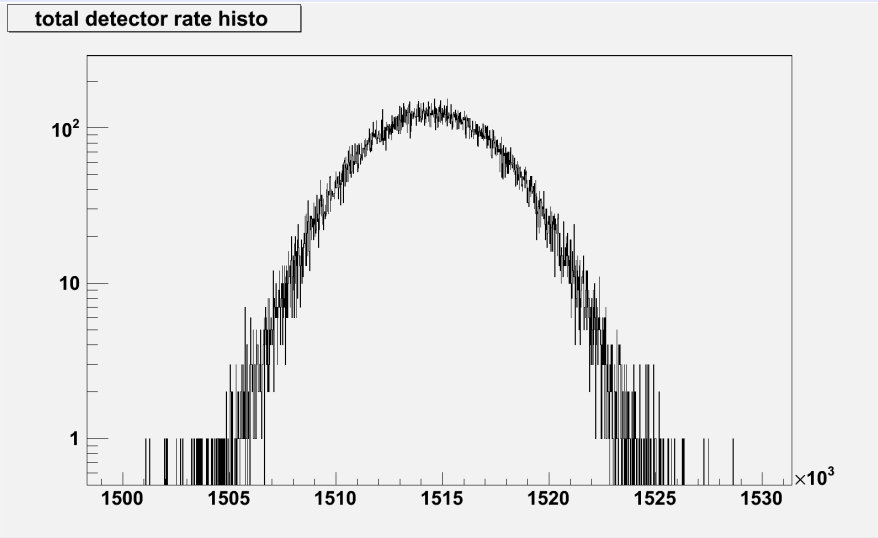
SNDAQ Run Summary

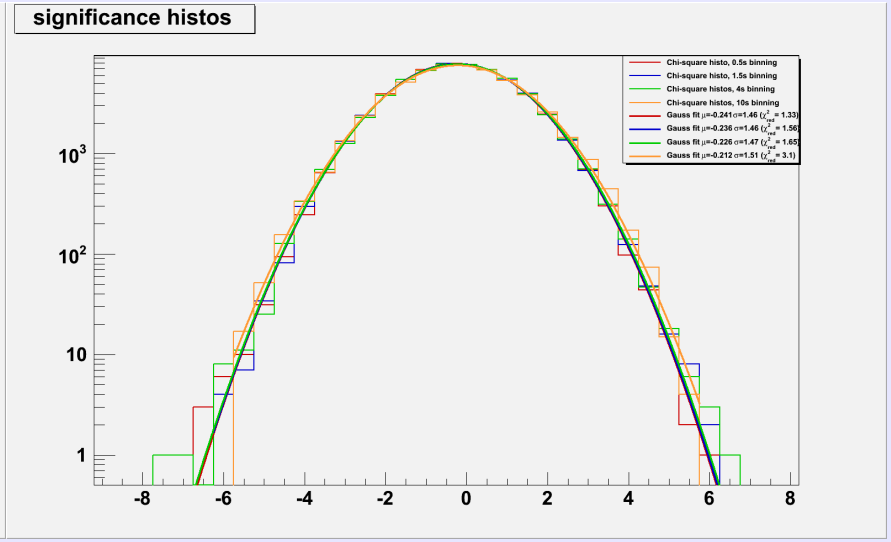
< 2013 >

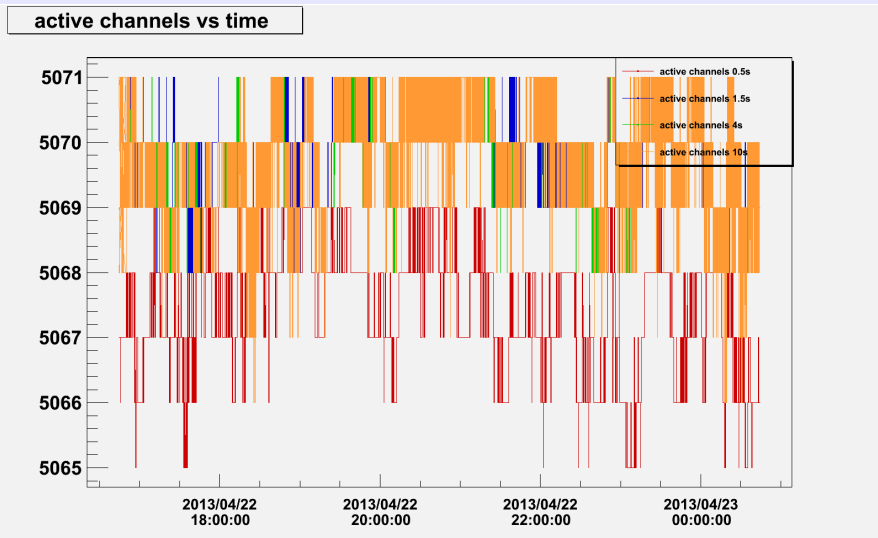
Run	Start Time	Stop Time	Duration (s)	Gap (s)	Deadtime (µs)	Booked DOMs	Dead DOMs	Candidates	Files[1]	Status
122699	2013-07-21 23:18:11	2013-07-22 07:18:14	28803.0	last run	250.0	5153	82	3	1	ok
122698	2013-07-21 15:16:44	2013-07-21 23:16:47	28803.5	84	250.0	5153	83	1	1	ok
122697	2013-07-21 07:15:13	2013-07-21 15:15:16	28802.5	88	250.0	5153	83	2	1	ok
122696	2013-07-20 23:13:45	2013-07-21 07:13:48	28803.0	86	250.0	5153	82	2	1	ok
122695	2013-07-20 15:12:20	2013-07-20 23:12:23	28802.5	82	250.0	5153	81	5	1	ok
122694	2013-07-20 07:10:53	2013-07-20 15:10:55	28802.0	85	250.0	5153	82	3	1	ok
122693	2013-07-19 23:09:29	2013-07-20 07:09:31	28802.0	82	250.0	5153	82	4	1	ok
122692	2013-07-19 23:06:31	2013-07-19 23:08:04	92.5	85	250.0	5153	0	0	1	partially bad
122691	2013-07-19 15:04:35	2013-07-19 23:04:38	28802.5	113	250.0	5153	83	2	1	ok
122690	2013-07-19 07:03:05	2013-07-19 15:03:08	28803.0	88	250.0	5153	83	1	1	ok
122689	2013-07-18 23:01:34	2013-07-19 07:01:36	28802.5	88	250.0	5153	83	6	1	ok
122688	2013-07-18 15:00:08	2013-07-18 23:00:10	28802.5	84	250.0	5153	85	3	1	ok
122687	2013-07-18 06:58:43	2013-07-18 14:58:46	28803.0	81	250.0	5153	83	3	1	ok
122686	2013-07-17 22:57:19	2013-07-18 06:57:23	28803.5	81	250.0	5153	83	3	1	ok
122685	2013-07-17 22:52:18	2013-07-17 22:54:53	155.0	147	250.0	5153	0	0	1	partially bad
122684	2013-07-17 22:49:22	2013-07-17 22:49:25	3.0	173	250.0	5153	0	0	1	partially bad
122683	2013-07-17 14:47:45	2013-07-17 22:47:48	28803.0	94	250.0	5153	83	2	1	ok
122682	2013-07-17 06:46:14	2013-07-17 14:46:17	28802.5	88	250.0	5153	83	4	1	ok
122681	2013-07-16 22:44:47	2013-07-17 06:44:50	28803.5	84	250.0	5153	83	5	1	ok
122680	2013-07-16 14:43:15	2013-07-16 22:43:18	28802.5	89	250.0	5153	83	6	1	ok
122679	2013-07-16 06:41:40	2013-07-16 14:41:43	28803.0	92	250.0	5153	85	2	1	ok
122678	2013-07-15 22:40:09	2013-07-16 06:40:12	28802.5	88	250.0	5153	83	5	1	ok
122677	2013-07-15 14:38:33	2013-07-15 22:38:36	28803.0	94	250.0	5153	82	4	1	ok
122676	2013-07-15 06:37:11	2013-07-15 14:37:13	28802.5	79	250.0	5153	82	1	1	ok

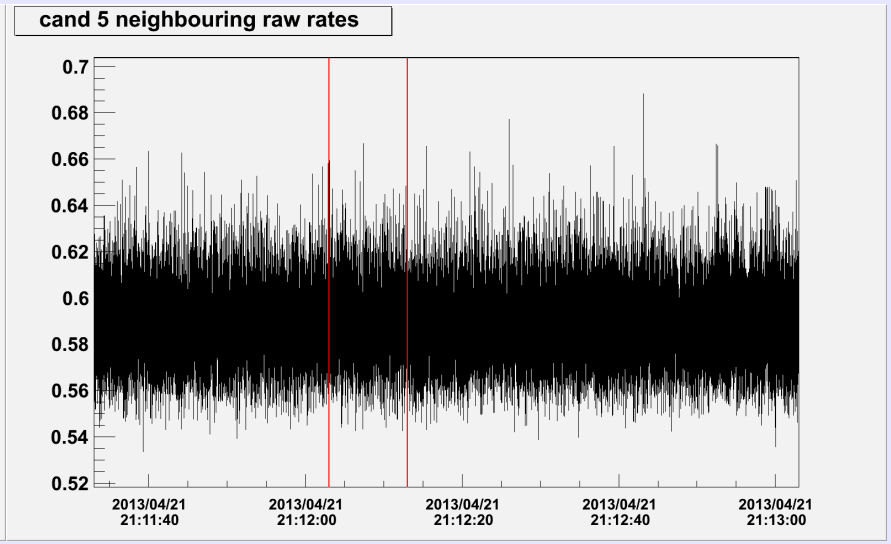
Physics monitoring II

- Examples for run and candidate related physics plots:

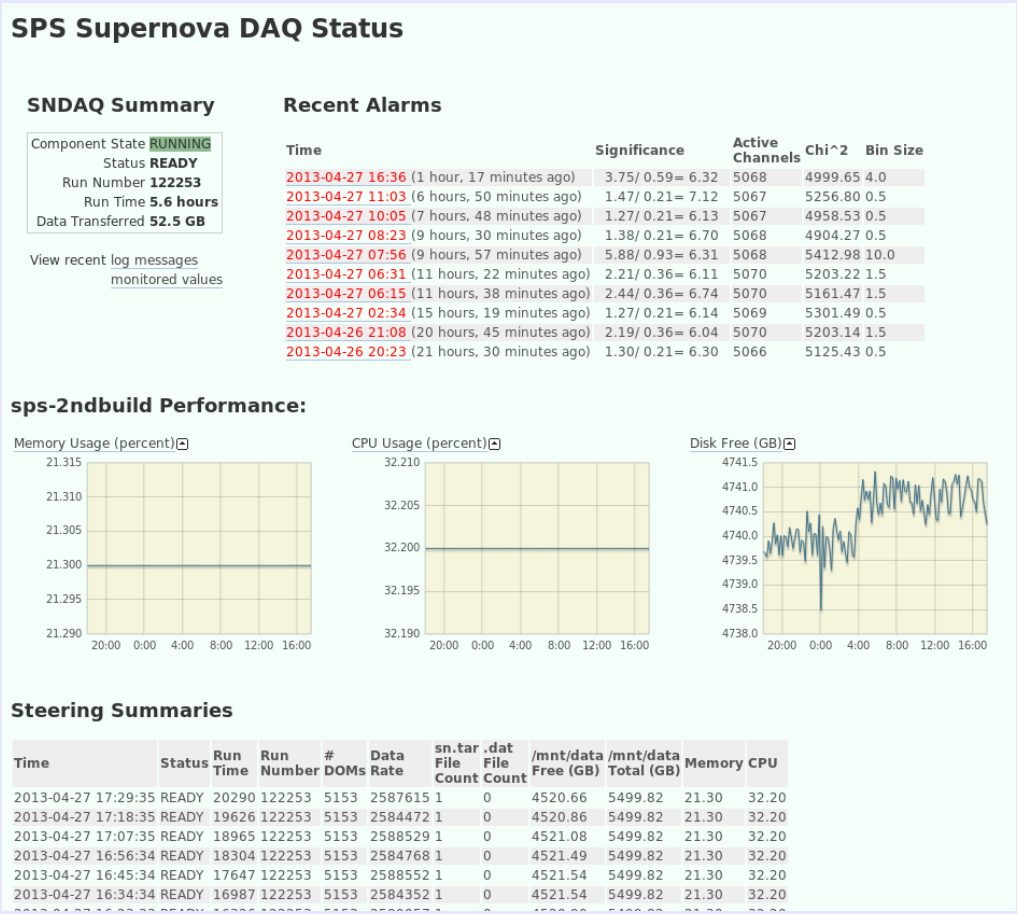








Technical monitoring



SPS Supernova DAQ Status

SNDAQ Summary

Component State RUNNING
Status **READY**
Run Number **122253**
Run Time **5.6 hours**
Data Transferred **52.5 GB**

View recent log messages
monitored values

Recent Alarms

Time	Significance	Active Channels	Chi^2	Bin Size
2013-04-27 16:36 (1 hour, 17 minutes ago)	3.75/ 0.59= 6.32	5068	4999.65	4.0
2013-04-27 11:03 (6 hours, 50 minutes ago)	1.47/ 0.21= 7.12	5067	5256.80	0.5
2013-04-27 10:05 (7 hours, 48 minutes ago)	1.27/ 0.21= 6.13	5067	4958.53	0.5
2013-04-27 08:23 (9 hours, 30 minutes ago)	1.38/ 0.21= 6.70	5068	4904.27	0.5
2013-04-27 07:56 (9 hours, 57 minutes ago)	5.88/ 0.93= 6.31	5068	5412.98	10.0
2013-04-27 06:31 (11 hours, 22 minutes ago)	2.21/ 0.36= 6.11	5070	5203.22	1.5
2013-04-27 06:15 (11 hours, 38 minutes ago)	2.44/ 0.36= 6.74	5070	5161.47	1.5
2013-04-27 02:34 (15 hours, 19 minutes ago)	1.27/ 0.21= 6.14	5069	5301.49	0.5
2013-04-26 21:08 (20 hours, 45 minutes ago)	2.19/ 0.36= 6.04	5070	5203.14	1.5
2013-04-26 20:23 (21 hours, 30 minutes ago)	1.30/ 0.21= 6.30	5066	5125.43	0.5

sps-2ndbuild Performance:

Memory Usage (percent)
21.315
21.310
21.305
21.300
21.295
21.290
20:00 0:00 4:00 8:00 12:00 16:00

CPU Usage (percent)
32.210
32.205
32.200
32.195
32.190
20:00 0:00 4:00 8:00 12:00 16:00

Disk Free (GB)
4741.5
4741.0
4740.5
4740.0
4739.5
4739.0
4738.5
4738.0
20:00 0:00 4:00 8:00 12:00 16:00

Steering Summaries

Time	Status	Run Time	Run Number	# DOMs	Data Rate	sn.tar File Count	.dat File Count	/mnt/data Free (GB)	/mnt/data Total (GB)	Memory	CPU
2013-04-27 17:29:35	READY	20290	122253	5153	2587615	1	0	4520.66	5499.82	21.30	32.20
2013-04-27 17:18:35	READY	19626	122253	5153	2584472	1	0	4520.86	5499.82	21.30	32.20
2013-04-27 17:07:35	READY	18965	122253	5153	2588529	1	0	4521.08	5499.82	21.30	32.20
2013-04-27 16:56:34	READY	18304	122253	5153	2584768	1	0	4521.49	5499.82	21.30	32.20
2013-04-27 16:45:34	READY	17647	122253	5153	2588552	1	0	4521.54	5499.82	21.30	32.20
2013-04-27 16:34:34	READY	16987	122253	5153	2584352	1	0	4521.54	5499.82	21.30	32.20

- Technical information:
  - details about the SNDAQ machine: CPU/memory usage, disk space, #files accumulating
  - history of recent alerts
  - log files of SNDAQ control scripts

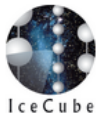
- Even more quantities to be displayed soon

Supernova early warning system SNEWS

- Members Super-K, KamLAND, IceCube, LVD, Borexino, SNO(+), ... send candidates to SNEWS looking for coincidences
- Limited directional information $\Rightarrow$ amateur astronomers
  „If you receive a SNEWS alert, get out there and look!“

(`http://snews.bnl.gov/amateur.html`)

- SNEWS monitoring (trigger threshold: 7.3 $\hat{=}$ $1\,\mathrm{alert}/10\,\mathrm{d}$):



SNEWS Monitoring @ Mainz
Datagrams | Tests

Type	Trigger Time (UTC)	Delay (s)	Signal Strength (Hz)	Significance	Timebase (s)	Active Channels	χ^2	Datagram
sn	2013-02-06 16:31:15	586	6.00 ± 0.93	6.44	10	5069	5388.76	held
sn	2013-02-06 15:56:50	551	1.30 ± 0.21	6.26	0.5	5067	5079.38	held
sn	2013-02-06 15:48:16	585	1.29 ± 0.21	6.23	0.5	5067	5071.82	held
sn	2013-02-06 14:14:57	544	3.62 ± 0.59	6.11	4	5071	5364.10	held
sn	2013-02-06 13:04:49	552	4.16 ± 0.59	6.99	4	5069	5063.49	held
sn	2013-02-06 09:12:30	571	3.60 ± 0.59	6.05	4	5069	5413.90	held
sn	2013-02-06 06:47:09	532	2.22 ± 0.36	6.12	1.5	5069	5140.19	held
sn	2013-02-06 06:08:16	706	3.75 ± 0.59	6.31	4	5069	5168.33	held
sn	2013-02-06 06:02:45	556	1.33 ± 0.21	6.44	0.5	5069	5127.87	held
sn	2013-02-06 03:30:05	536	1.25 ± 0.21	6.03	0.5	5068	5343.11	held
sn	2013-02-05 23:46:40	1401	3.30 ± 0.36	9.09	1.5	5069	5132.65	sent
sn	2013-02-05 22:18:16	585	5.68 ± 0.93	6.09	10	5068	5281.16	held

Outline

1 Data Acquisition - Hardware

2 Data Acquisition - Software & Physics Capabilities

3 Data Acquisition - Automating

4 Conclusion

Conclusion

- IceCube will provide world's highest statistic for core collapse SN inside the galaxy and has capability to distinguish between different SN models and ν-hierarchies
- HitSpooling will provide the energy estimation, improve muon subtraction and overcome the 1.6384 ms binning
- Automating:

  Automated high significance alerts for working group, SNEWS, etc ...

  Automated fast analysis

  Automated technical and physics monitoring

  Automated control scripts for SNDAQ

Thank You!