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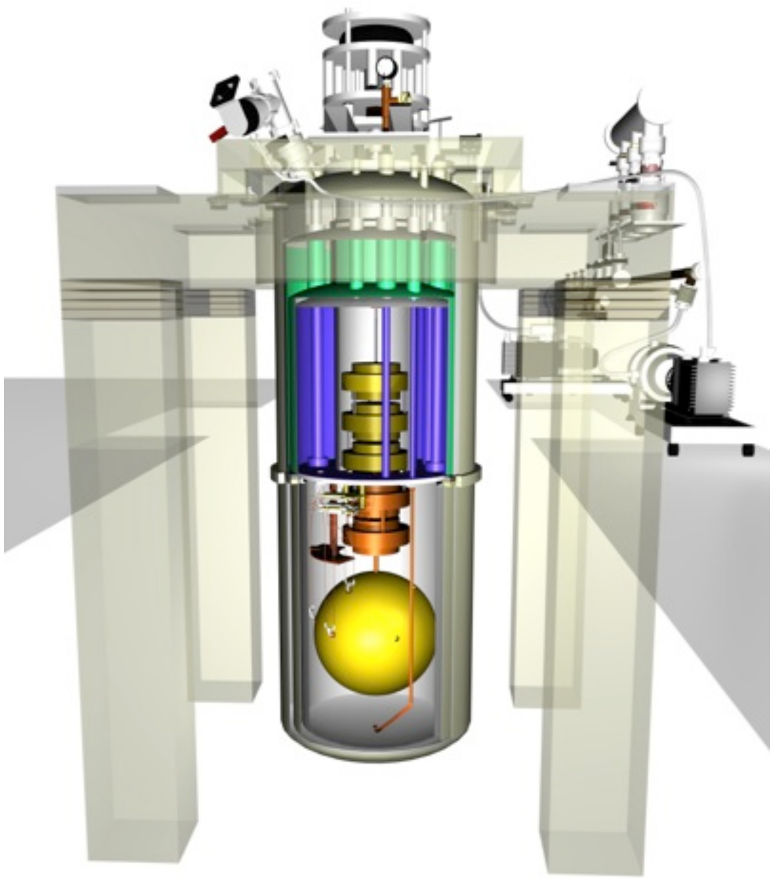
# Mario Schenberg Detector

INPE/DAS, 9th April 2014

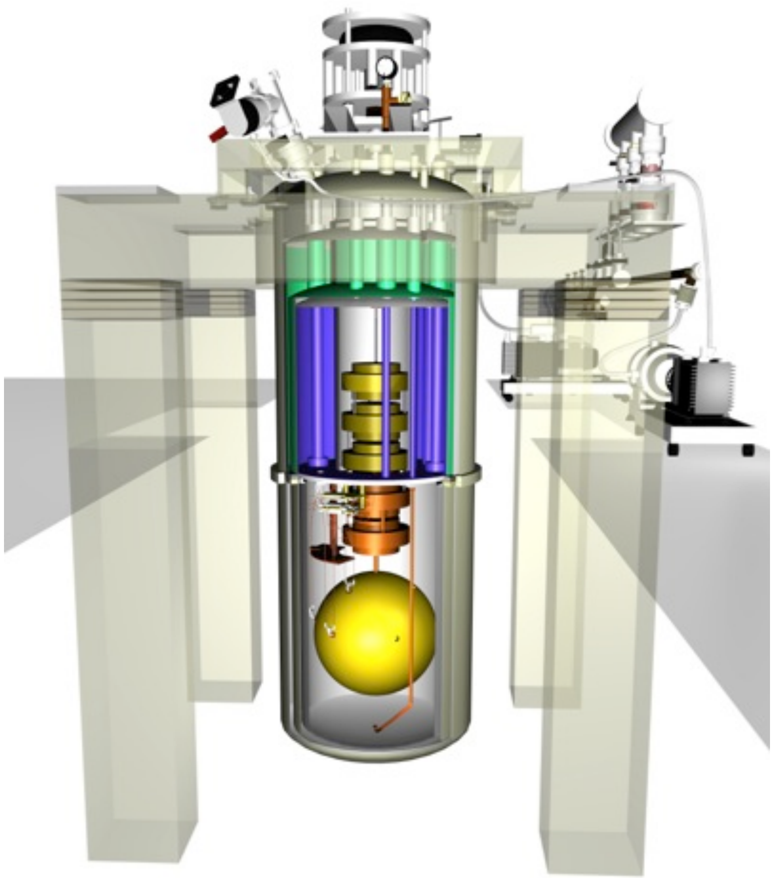
Schema of the Mario Schenberg detector



Carlos Filipe Da Silva Costa
Data analysis of the GW detector M. Schenberg
(Post-doc, scholarship PCI)

# Plan

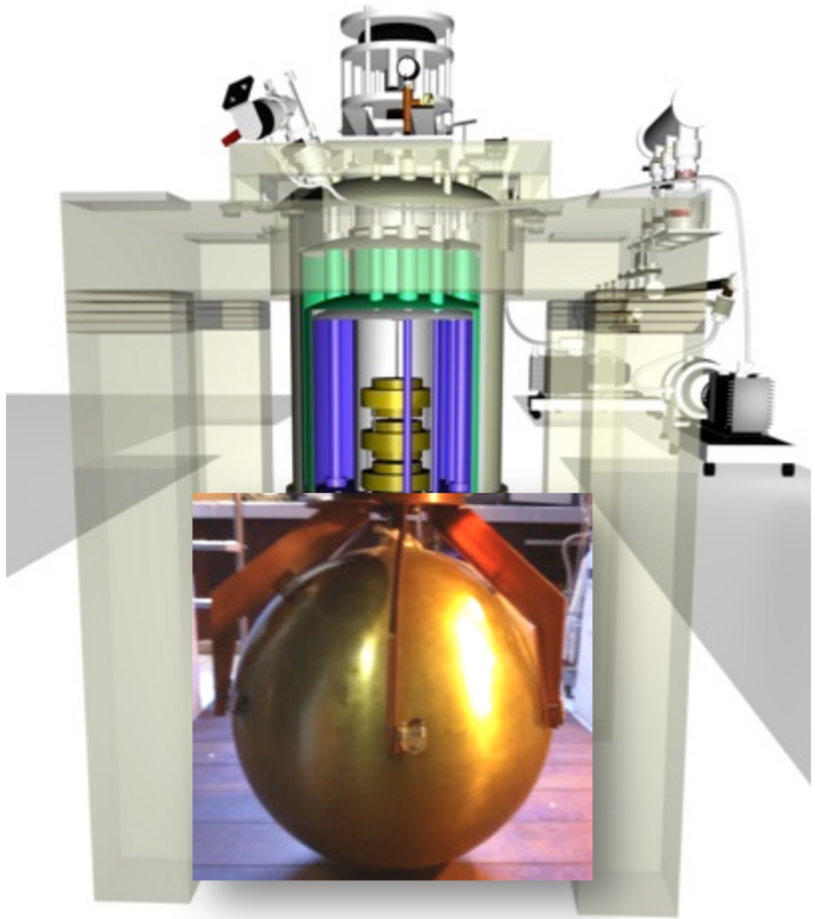
Schema of the Mario Schenberg detector



- Mario Schenberg Detector
- Low latency analysis
- Cosmic rays veto
- Next steps
- Conclusions

# Mario Schenberg/ Working principle

Schema of the Mario Schenberg detector

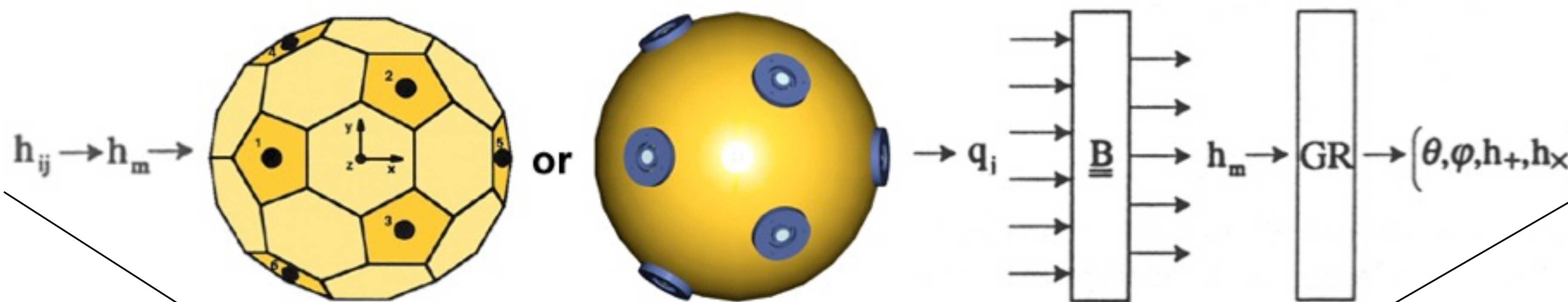


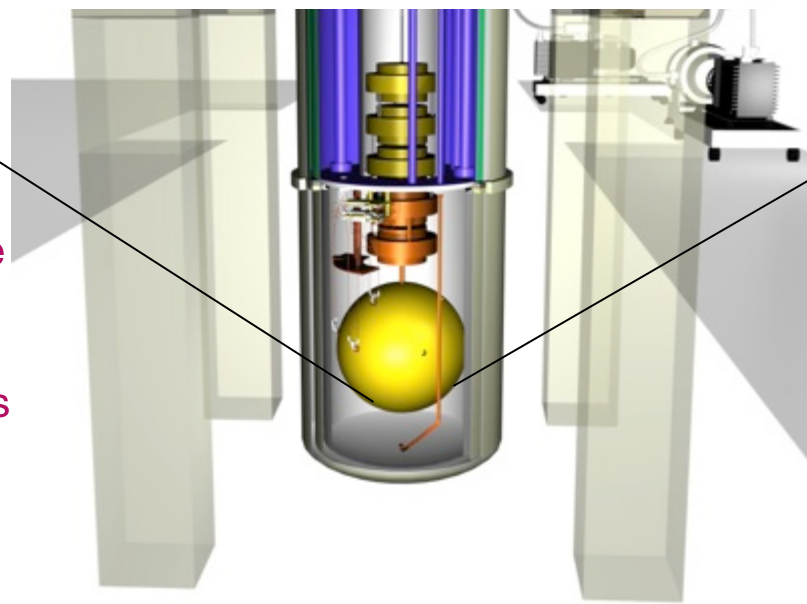
The Mario Schenberg sphere is made of a high mechanical Q alloy: CuAl(6%).

The sphere weights 1150kg and measures 65cm diameter.

# Mario Schenberg/ Working principle

TIGA configuration Schema with transducers Converting transducer oscillations into $h_m$



GWs ($h_{ij}$) couple with the 5 quadrupolar mode of the sphere.

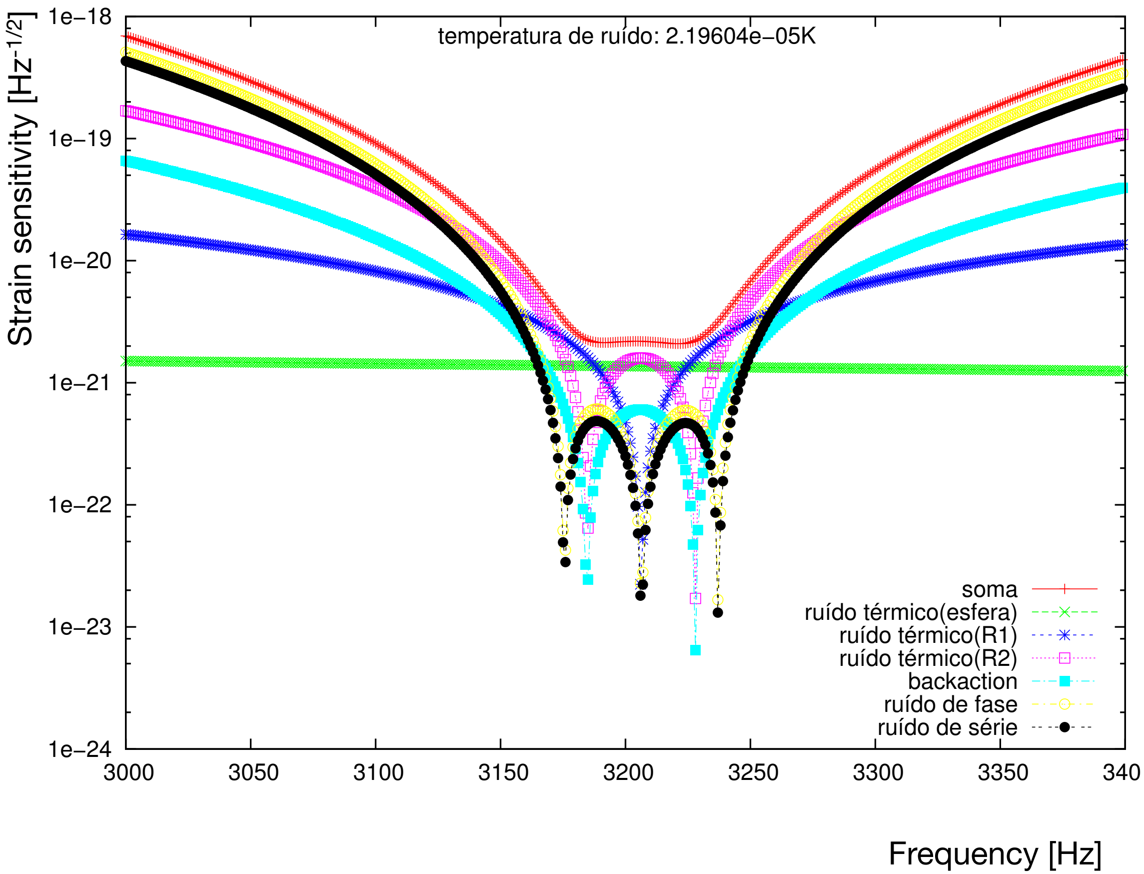
We have six transducers monitoring these five quadrupolar modes. (TIGA configuration)

The main advantages:
-The sphere is isotropic.
- We have GW arrival direction and polarisation.

-> A sphere is well designed for GW astronomy.

# Mario Schenberg/ Strain sensitivities

Theoretical strain sensitivity of Mario Schenberg




The strain sensitivity is the sum of all noises.

Bandwidth: ~80Hz around 3.2kHz
Strain sensitivity: ~$10^{-21}$ Hz$^{-1/2}$

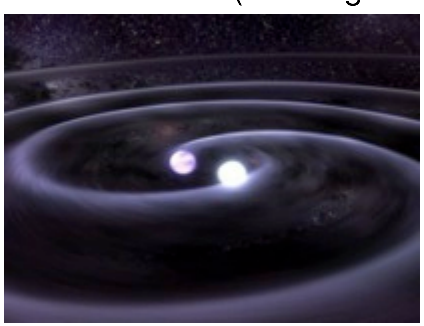
We are not competitive with interferometers: larger band and better sensitivity.

We are better for fast GW source localisations!

# Mario Schenberg/ Sources

Burst (supernovae)

Coalescences (last stage only)



We have a short frequency band 80Hz thus we can detect principally burst signals.

The detection of coalescence is seen as burst. The Mario Schenberg detector could follow only the last moment of the coalescence.

Where can we detect the sources?
The distance of detection depends on the amplitude of the source and the detector sensitivity. E.g. for burst:

$$h_{rss} \cong 10^{-19} \left( \frac{E}{10^{-2} M_{\odot} c^2} \right)^{1/2} \left( \frac{7kpc}{r} \right) \left( \frac{1kHz}{f_{gw}} \right) \mathrm{Hz}^{-1/2}$$

We expect one supernovae each 50 years in one galaxy the Milky Way size .
Thus we need a better sensitivity to “see” farther.

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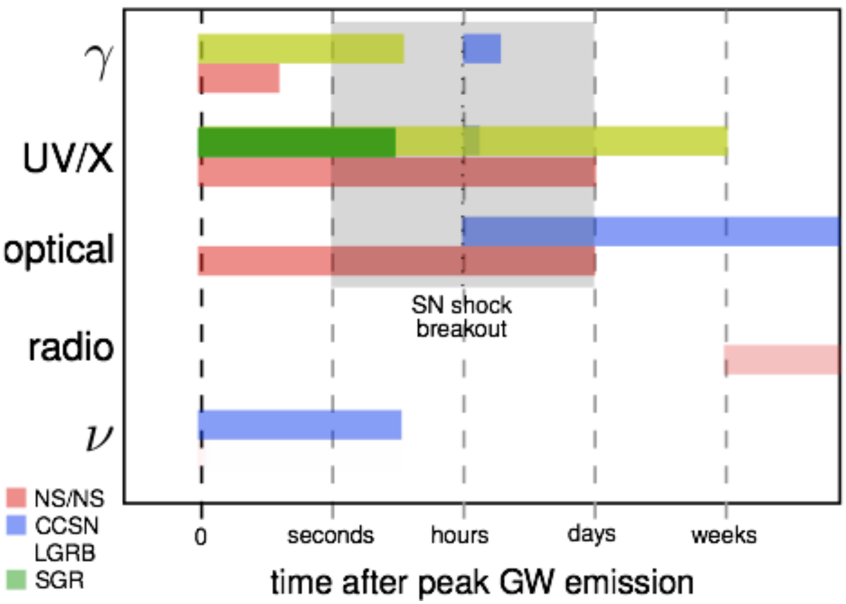
# Low latency analysis/ Why?

Event messenger accompanying GW emissions




To confirm a gravitational wave detection:
-We can cross check the event with other GW detectors.

-Or we can confront possible gravitational waves with other astrophysical messengers. In this case, we need to tell astrophysicists where they should point their telescope.

-> The analysis should be done within a few second with a good confidence.

# Low latency analysis/ Who participate?

Square Kilometer Array Pathfinder (Australia)

**Neutrinos:**
Antares, Ice Cube, Kamiokande

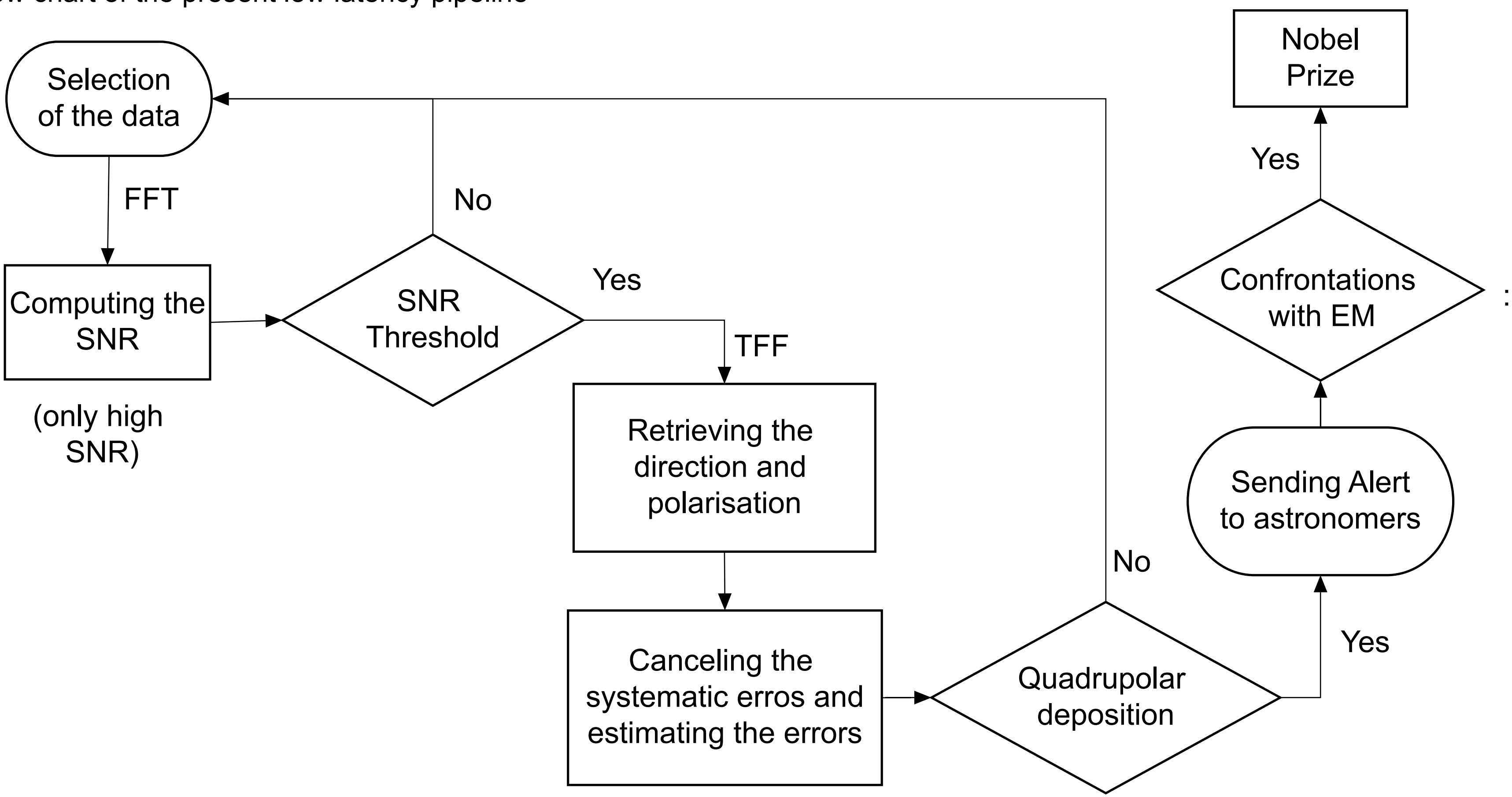
E.g. in SuperNovae (Iron core collapse) $10^{53}$ ergs liberated in
-Electromagnetic Wave (<1%)
-Neutrinos (~99%)
-Gravitational Waves (<$10^{-6}$%)

**Gamma-ray burst:**
Swift, Fermi, MAXI, HETE-2, (SVOM) part of a GRB Alert Network

**Radio Transients:**
Square Kilometer Array (SKA)

# Low latency analysis/ The pipeline

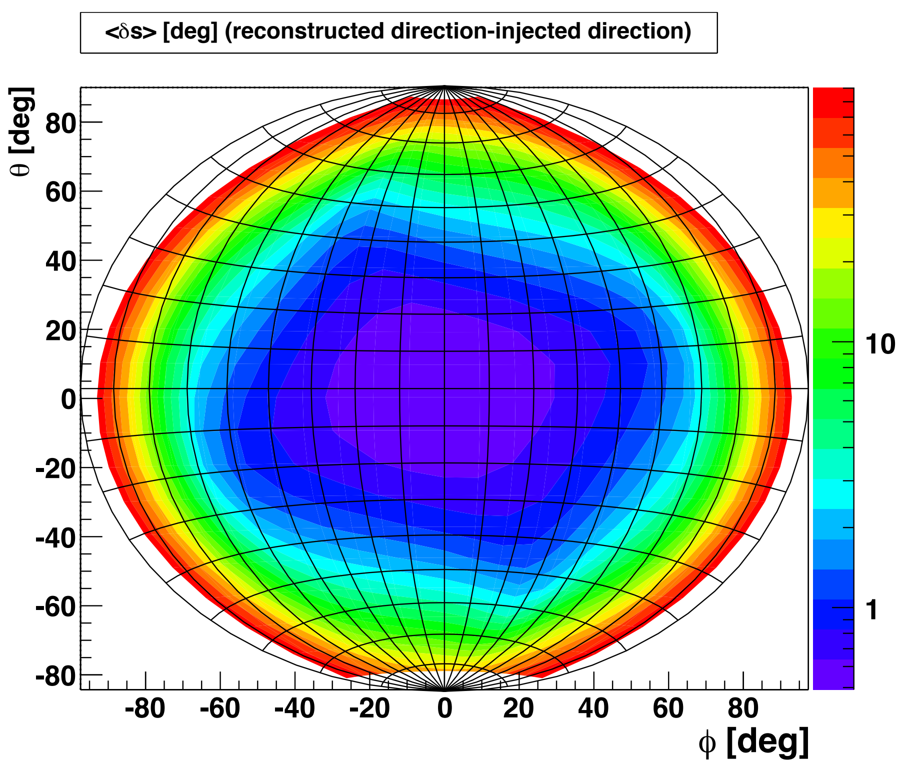
Flow chart of the present low latency pipeline

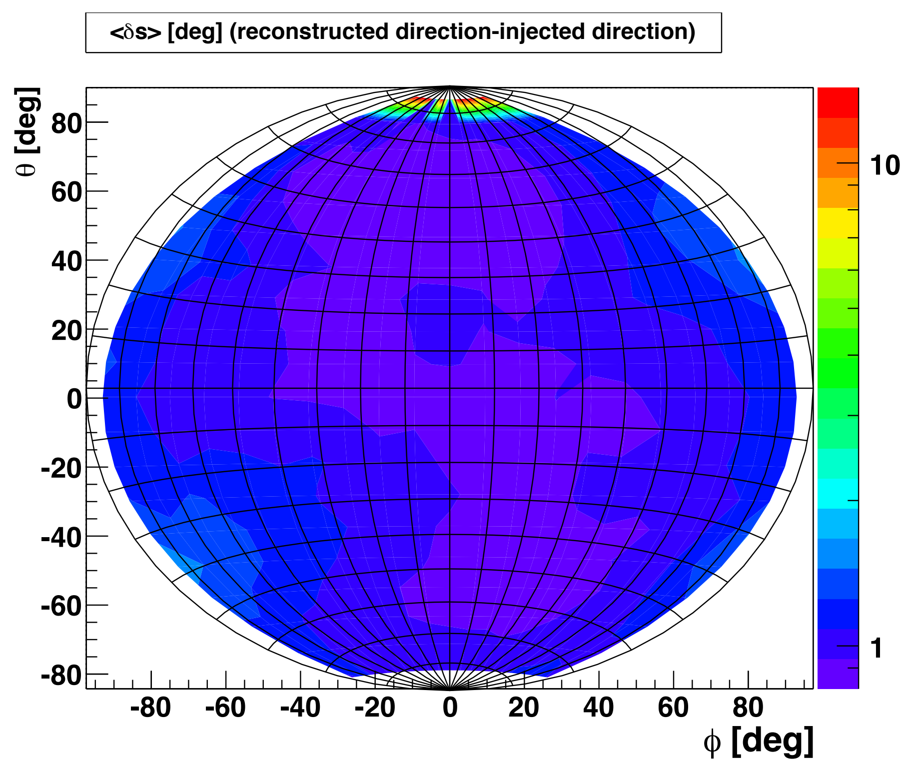


# Low latency analysis/ Main results/

## Direction:

Implementations not straightforward but solved.



# Low latency analysis/ Main results

## Resolution:

| SNR | $\langle\sigma(\delta s)\rangle$ | $\sigma\left(\sigma(\delta s)\right)$ |
|---|---|---|
| 180 | 0.23 | 0.05 |
| 130 | 0.32 | 0.06 |
| 80 | 0.55 | 0.12 |
| 50 | 0.82 | 0.18 |
| 40 | 1.09 | 0.24 |
| 25 | 1.63 | 0.35 |
| 22 | 1.82 | 0.39 |
| 17 | 2.77 | 3.37 |
| 12 | 5.50 | 7.93 |
| 9 | 8.42 | 11.21 |

**Table 2.** For each SNR level, we report here the average, standard deviation, the minimal value and the maximal value of direction resolution $\sigma(\delta s)$. Each SNR level contains 420 direction tested. Values are expressed in degrees.

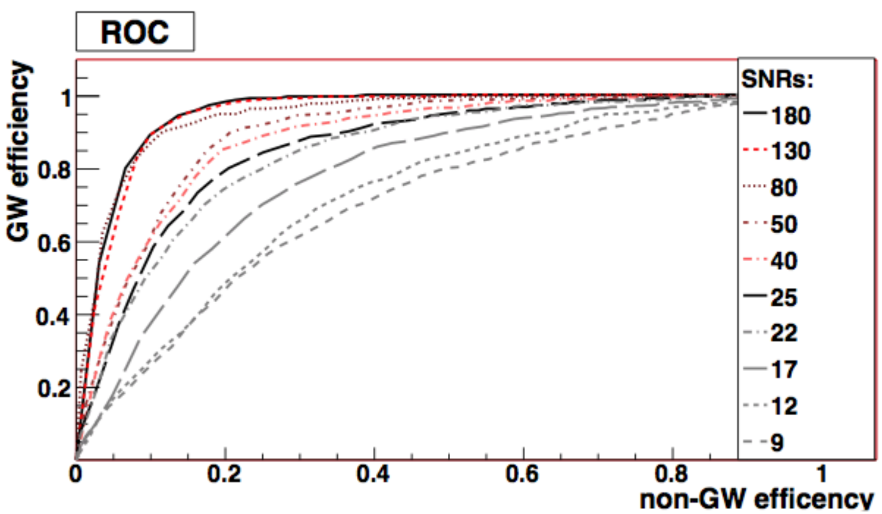
The error seams high but they are compatible with the theoretical prediction of the sphere resolution.

Methods to improve it should be developped.

# Low latency analysis/ Main results

## Vetoing

Suppression of false alarm, an important step. We should not send any false alarm to astronomers.
I tested a new veto using the GW properties (quadrupolar energy deposition into the sphere).



# Low latency analysis/ Main results

## Execution time

1 minute of data in 0.85s.
The execution is relative good.

$$t_{execution} = 0.16 \ln(t_{data}) + 0.19 \,.$$

# Mario Schenberg/ Veto of cosmic rays

Photo of the astroparticle shower setup

Astroparticle showers are also a source of noise. They deposit energy in the sphere that could be confounded with GW events.

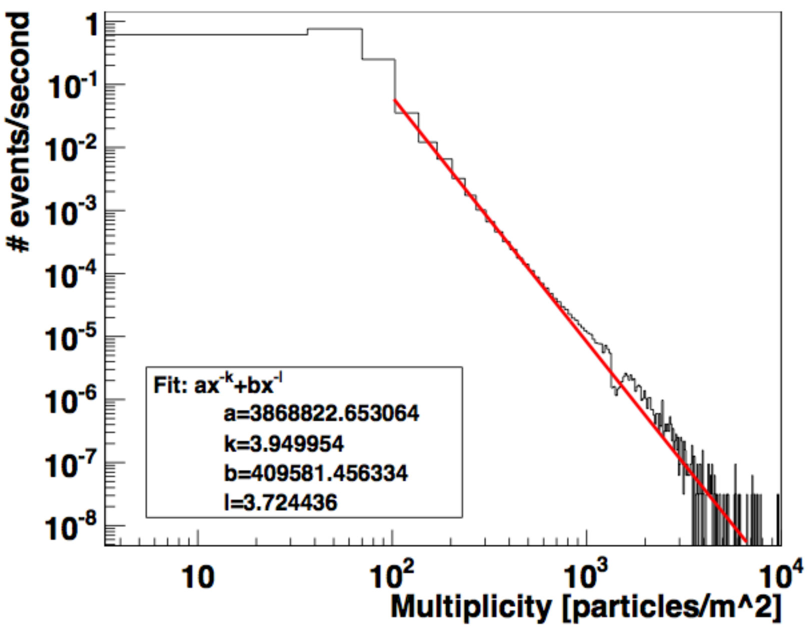
In November 2011, an astroparticle shower veto composed of three scintillators was added to the DAQ system of Mario Schenberg. Since then the veto is acquiring data.

We register all shower triggers and will confront them with potential GW triggers.

See: - Thesis Denis Borgareli
- R. Marinho, N. Magalhães, O. Auguiar and C. Frajuca (2001)

# Mario Schenberg/ Veto of cosmic rays

Measured multiplicity after one year and an half




We are able to determine the local multiplicity (particles/m^2), but we don't know at which multiplicity level the detector will be sensitive.

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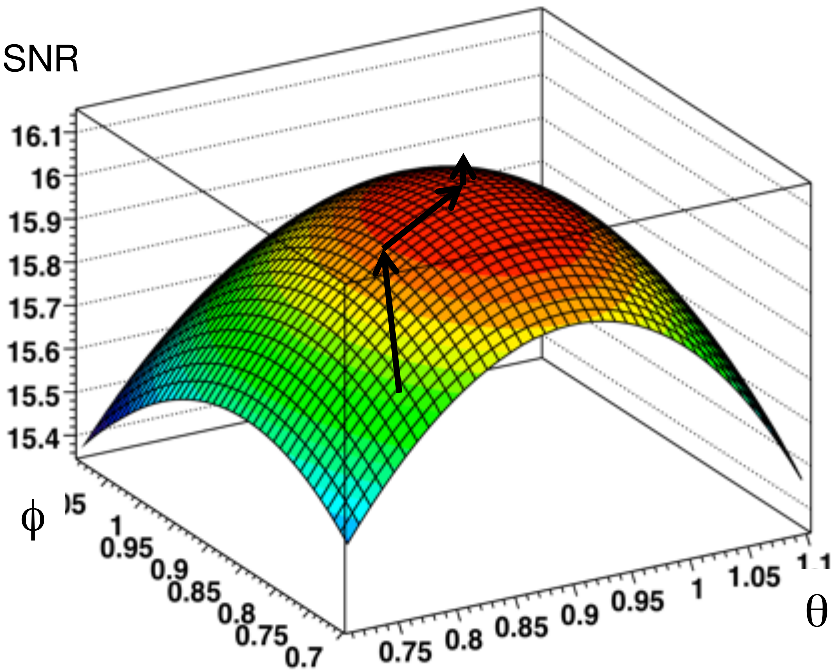
# Low latency analysis/ Next steps/ MF and second direction reconstruction

SNR direction determination




By using a SNR maximization technique, we can reconstruct an second independent direction.

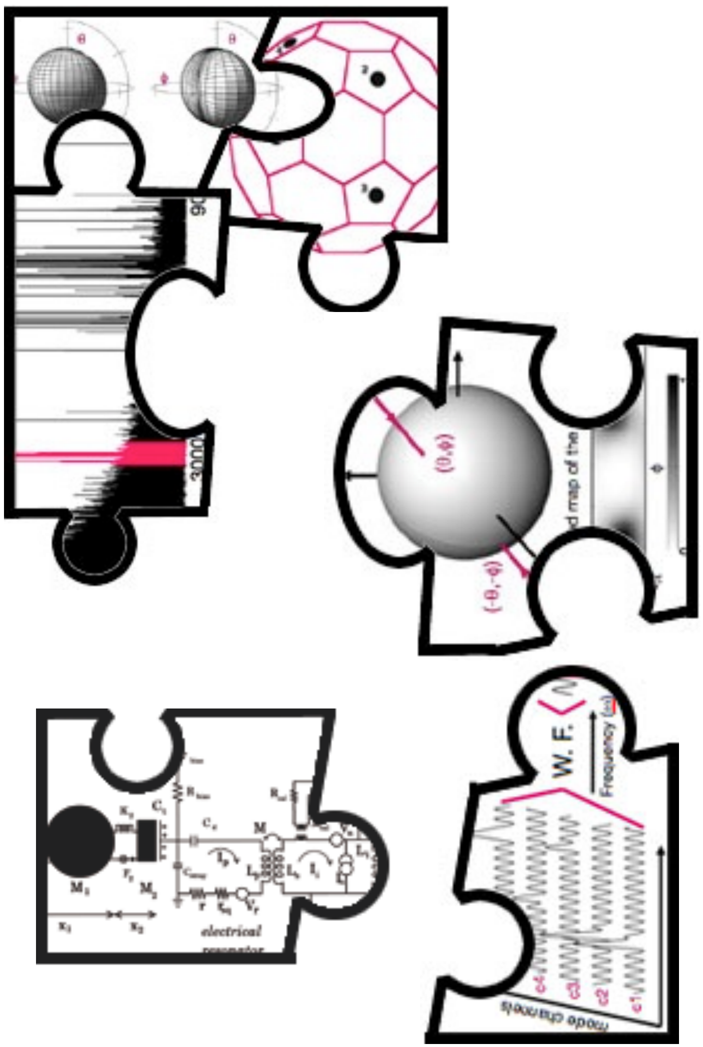
The search for the direction is based on a Hessian method:

$$\vec{P}_1(\theta,\phi) = \vec{P}_0 + H_0^{-1}\nabla SNR(\theta,\phi)$$

The direction is given by the gradient of the SNR. The Hessian of the SNR gives the distance to the next point.

This method takes a few seconds as function of the signal form complexity.

# Conclusion/




A spherical detector like Mario Schenberg is well designed for GW astronomy

We implemented the first the low latency analysis pipeline for a spherical detector.
It will be improved by the addition a MF technique.

The cosmic ray veto is operational. When Schenberg will be working we will proceed at coincidence search.

Many works to do…