Search for neutrinos from transient sources with the ANTARES telescope and optical follow-up observations (TAToO)

CPPM IRFU LAM TAROT

Imen Al Samarai
CPPM-ANTARES

Plan

- Transient sources: GRBs and Core collapse SNe
- Research methods for GRBs
- TAToO
- Perspectives

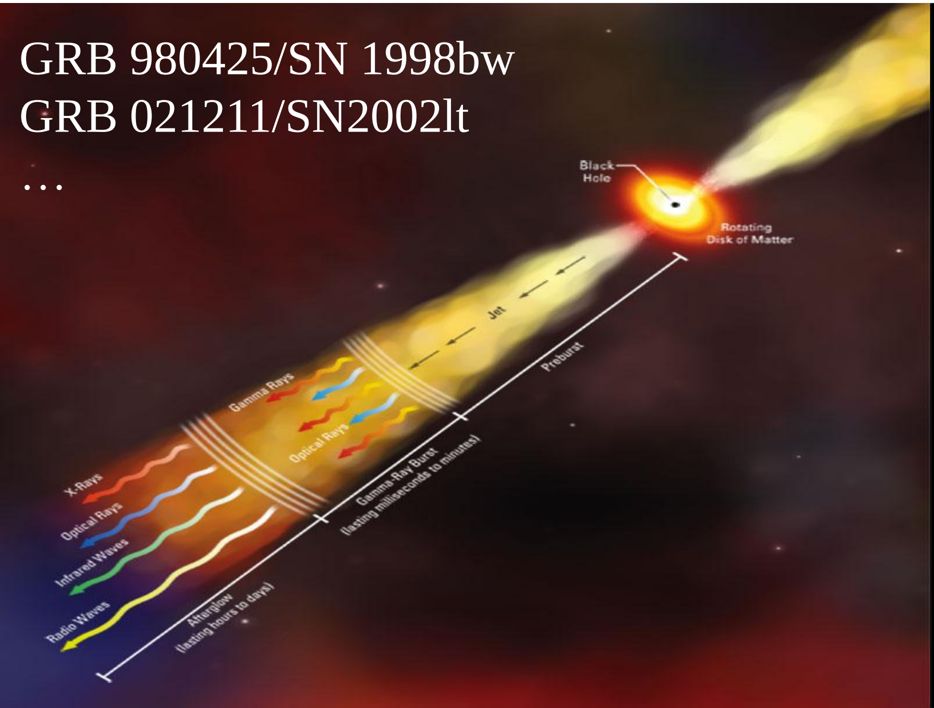
Introduction

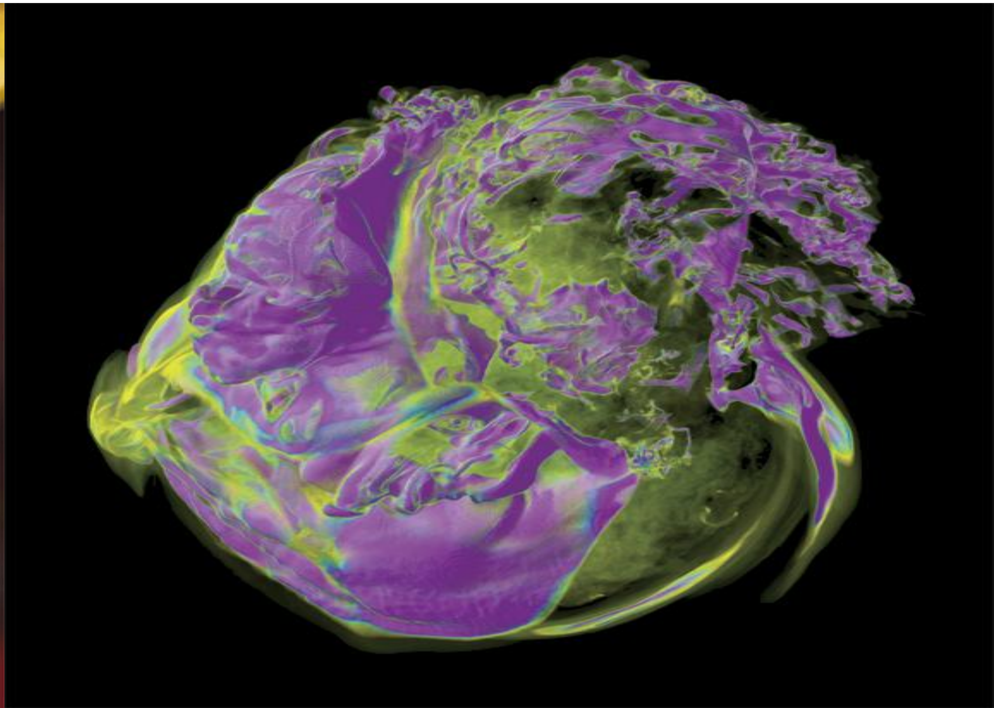
GRBs

- Core collapse of massive supernovae($\Gamma \approx 100$)
- Prompt emission of neutrinos(100 TeV)
- Prompt emission of gammas
- Afterglows (X, V, Radio…)
- 1 CCSN with HR jets /1000

Core collapse SN

- Core collapse of massive SNe($\Gamma \approx$few)
- HE neutrino emission (100 GeV -TeV)
- No gamma emission (choked gammas)
- Afterglows (X, V, Radio…)





Technics for GRB search

Triggered search

Neutrino Detection triggered by external sources (SWIFT, INTEGRAL, FERMI…) providing timing and position information

Rolling Search

Search for HE neutrino events or multiplets (n>=2) within the same direction and temporal window.

Technics for GRB search

Triggered search

Neutrino Detection triggered by external sources (SWIFT, INTEGRAL, FERMI…) providing timing and position information

Advantages:

Nature and location of the sources are known

Very low background

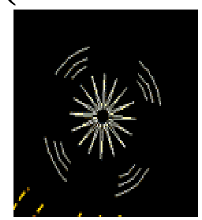
Disadvantages:

Dependance on external sources

SWIFT (1.4 sr fov) → Only ~1 / 9 GRB is detected

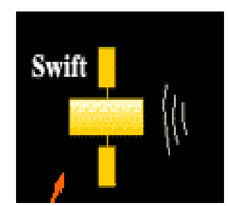
(no external trigger for choked GRBs)

Look for neutrinos in dT and (Ra, Dec)
(Off-line analysis)



Gamma
signal

alert



dT
and (Ra,
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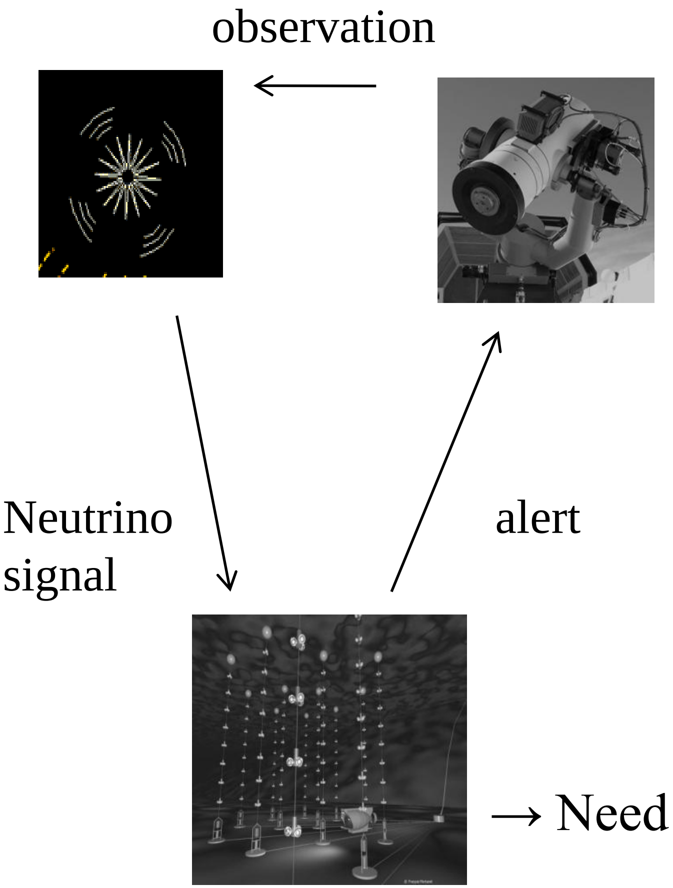
Technics for GRB search



Rolling Search

Search for HE neutrino events or multiplets (n>=2) within the same direction and temporal window.

<u>Avantages:</u>

- Covers full hemisphere
- No external triggers

<u>Disadvantages:</u>

- The nature of the source is unknown

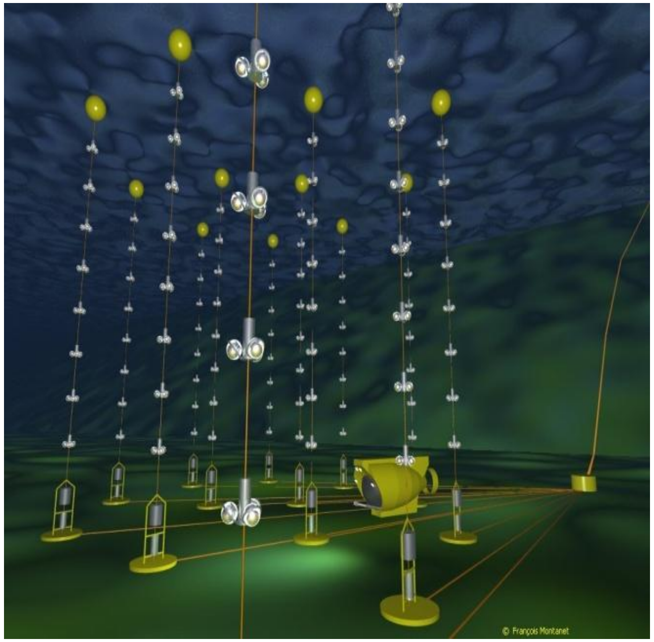
→ Need follow up to confirm detection(nature, redshift…)

→ need fast analysis and good angular resolution

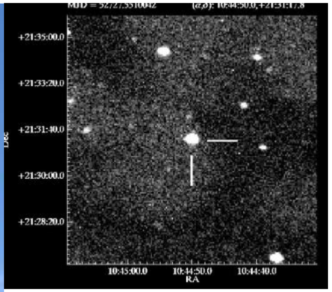
The TAToO Project

Principle

***T**arot **A**ntares **T**arget **o**f **O**ppotunity*



ANTARES: 3D net of 900 PMs



- *TAROT Sud (chili)*

- *FOV :2° x 2°*
- *Fast repositioning (10s)*
- *Good sensitivity(*V<19 in 300s)

The TAToO Project

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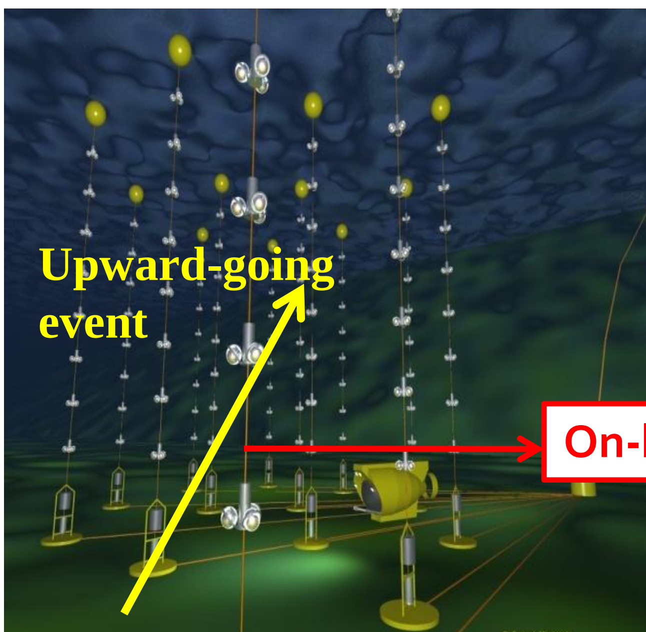
Triggers:
Multiplet (>=2)neutrinos
Single HE neutrino **Alert**

Keys of success:
1. High performance of the online reconstruction
2. Good event selection



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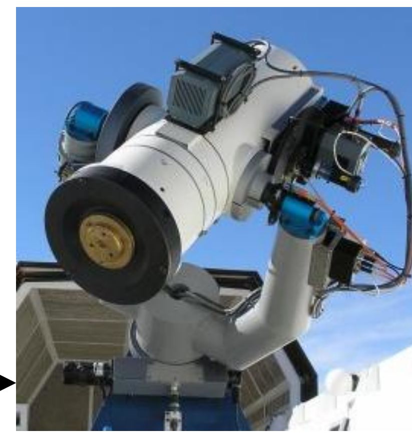
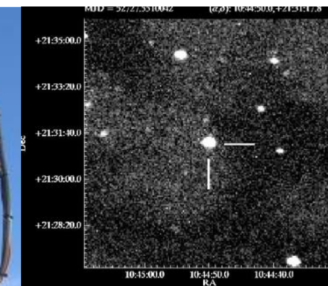
On-line reconst.





GCN alert

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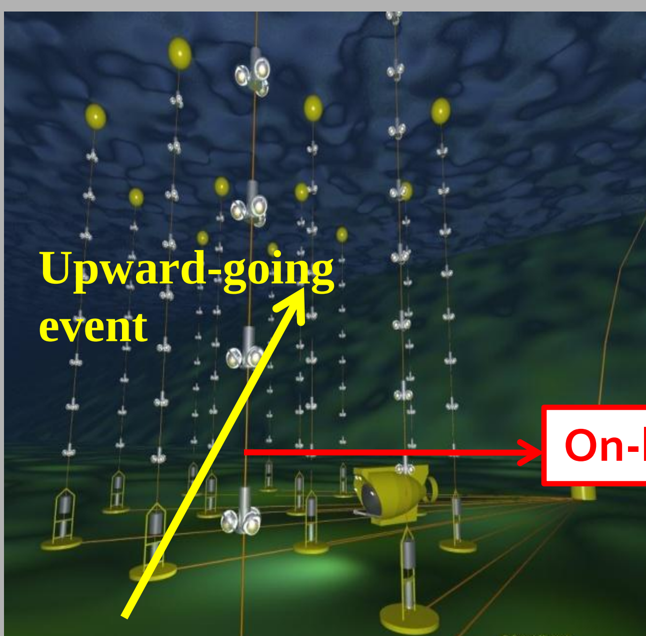
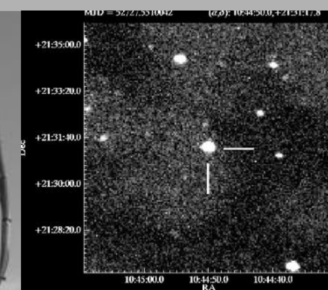


On-line reconst.

ANTARES: *Réseau tridimensionnel de 900 PMs*



GCN alert

- *TAROT Sud (chili)*
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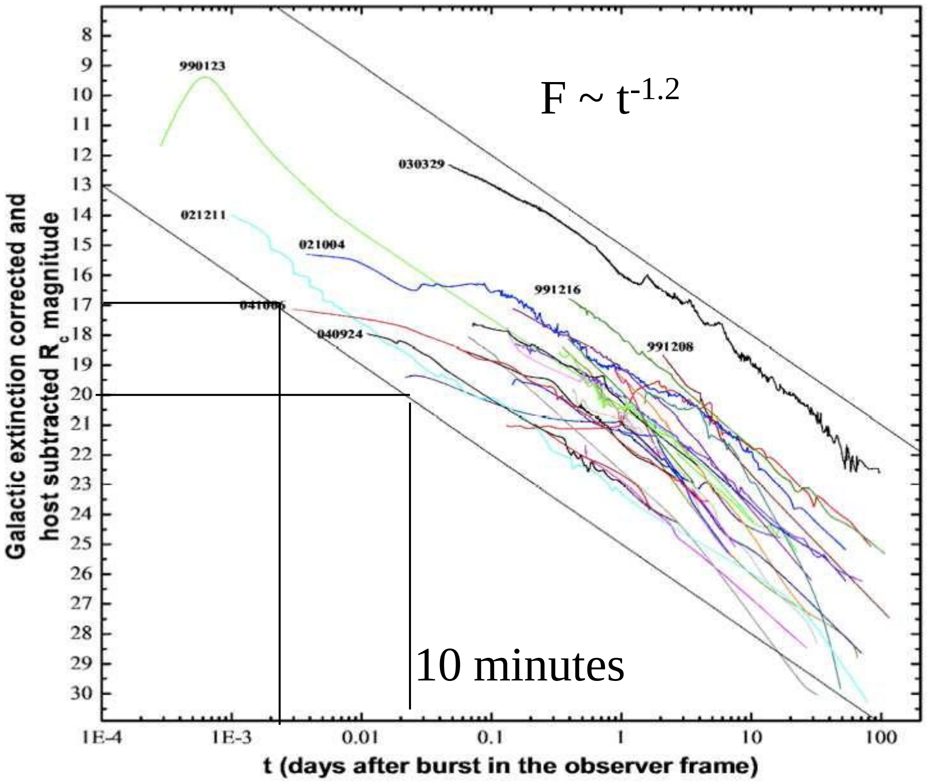
- *Bonne sensibilité (V<19)*

The TAToO Project

Keys of success(1/2):

The On-line reconstruction performance in ANTARES



→ A **very fast reconstruction algorithm** is needed

The TAToO Project

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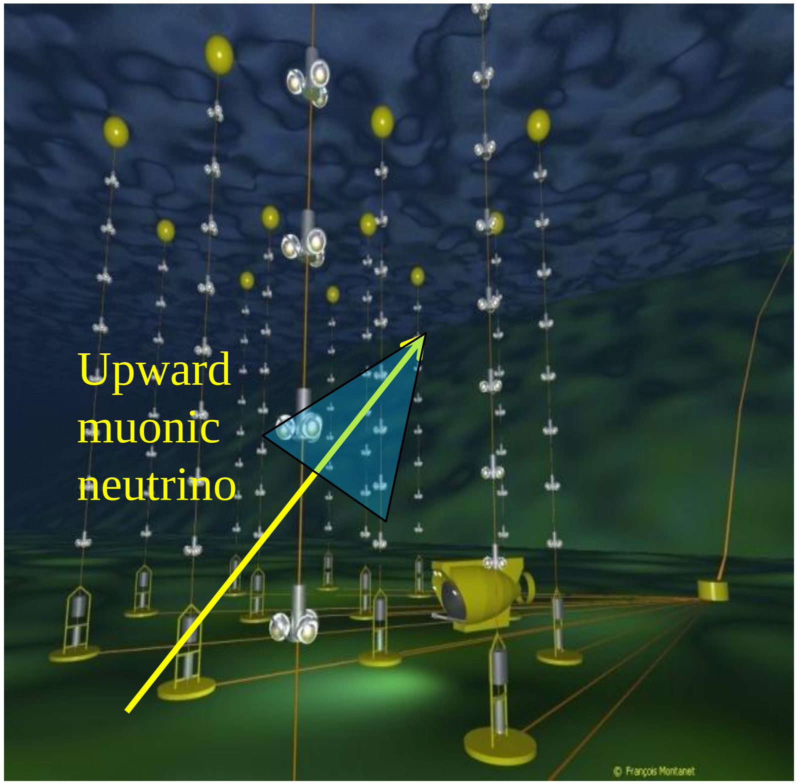
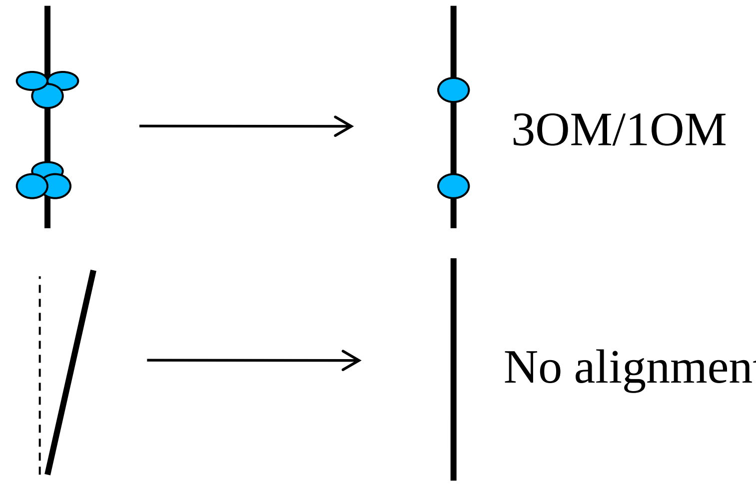
The On-line reconstruction performance in ANTARES



On- line reconstruction assumptions



→ Reconstr. taking **10ms / event** is implemented

The TAToO Project

Keys of success(1/2):

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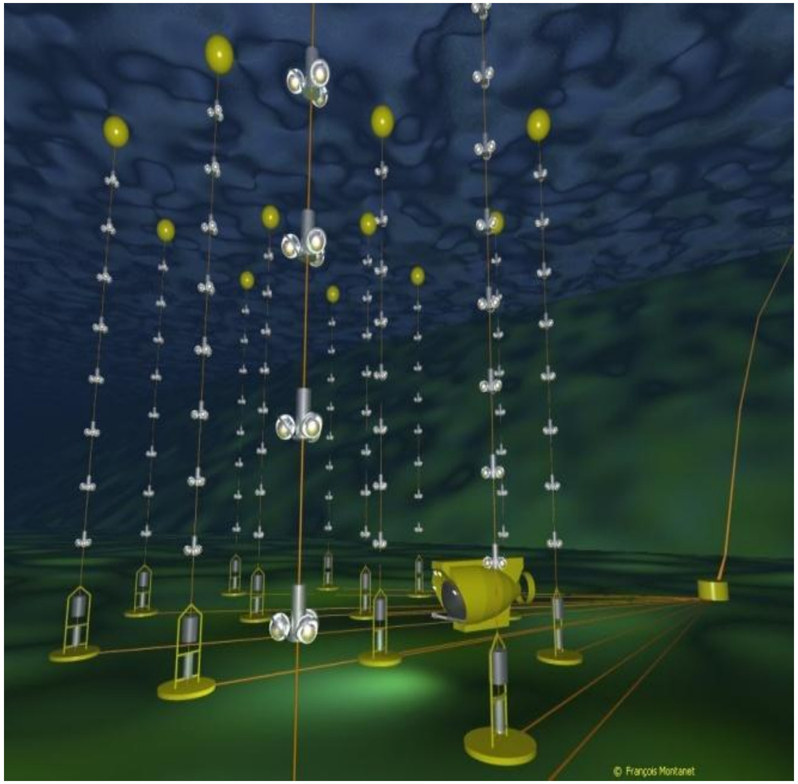
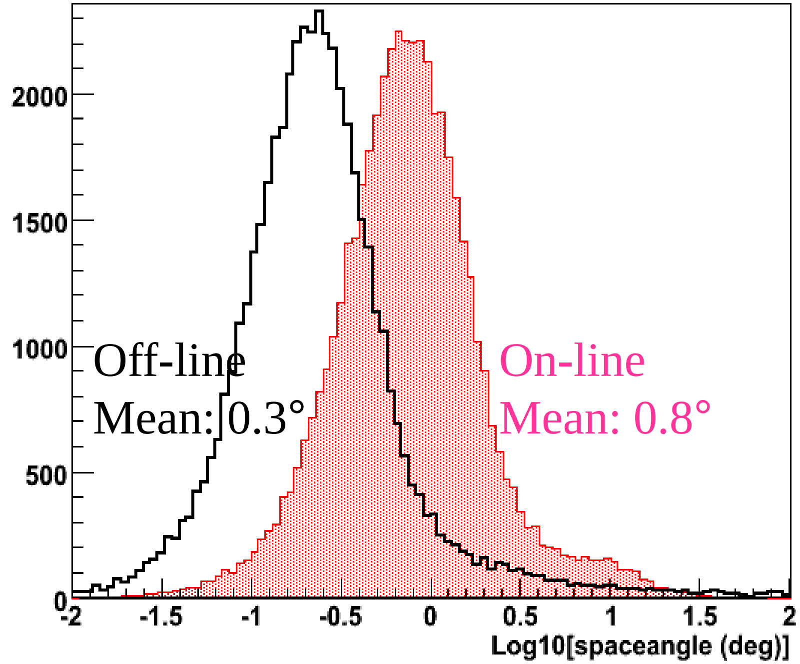


Angular resolution distribution



→ Reconstr. taking **10ms / event** is implemented

→On-line reconstruction enlarges the angular resolution
→ Need to send a refined position after off-line reconstruction

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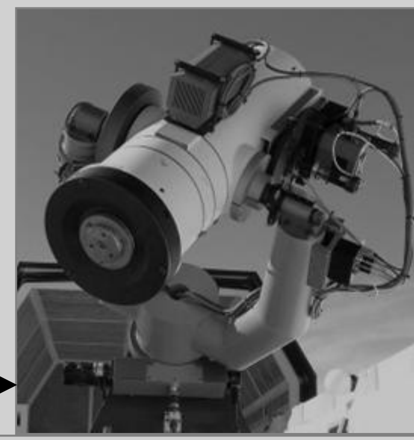
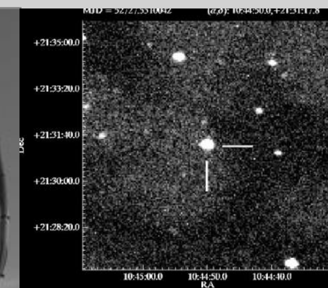
ANTARES: *Réseau tridimensionnel de 900 PMs*

On-line reconst.





GCN alert

- *TAROT Sud (chili)*
- *FOV : 2° x 2°*
- *Repositionnement rapide (10s)*
- *Bonne sensibilité (V<19)*

The TAToO Project

Keys of success (2/2):

The event selection

- **Multiplet of neutrinos (n>=2) background**

$R_{1\,atm}$ = 300 yr^{-1} in ANTARES (upward going events, fitted on more than 2 lines)

For a doublet:

$\Delta\Omega = 3^\circ \times 3^\circ$

$\Delta t = 15$ min

$$R_2^{atm} \approx 2\left(\frac{\Delta\Omega}{2\pi}\Delta t\right)\left(R_1^{atm}\right)^2$$

Lower for a triplet, ….

→ **$R_{2\,atm}$ ~0.007 yr^{-1}**

→ **A detection would be almost significant**

→ **The trigger is now implemented**

The TAToO Project

Keys of success (2/2):

The event selection

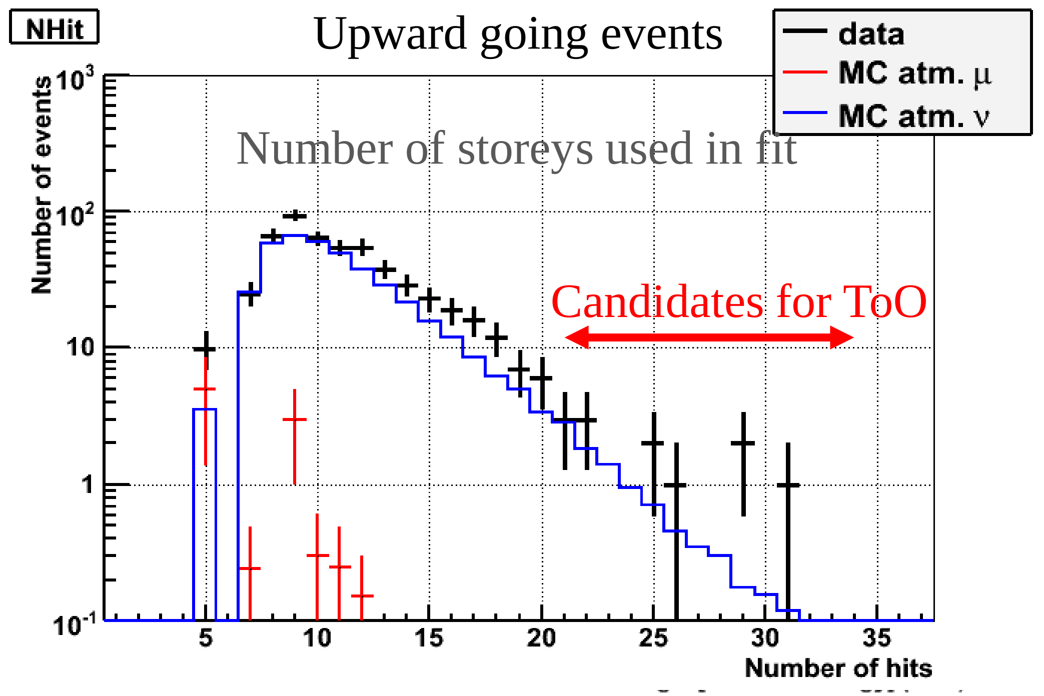
- **High energy events**

→Selection by cuts on energy estimators so that : **1 to 2 alerts sent / month**

Energy estimators are:

- Number of touched storeys used in the fit

- Signal amplitude in the PMs (p.e.)



The TAToO Project

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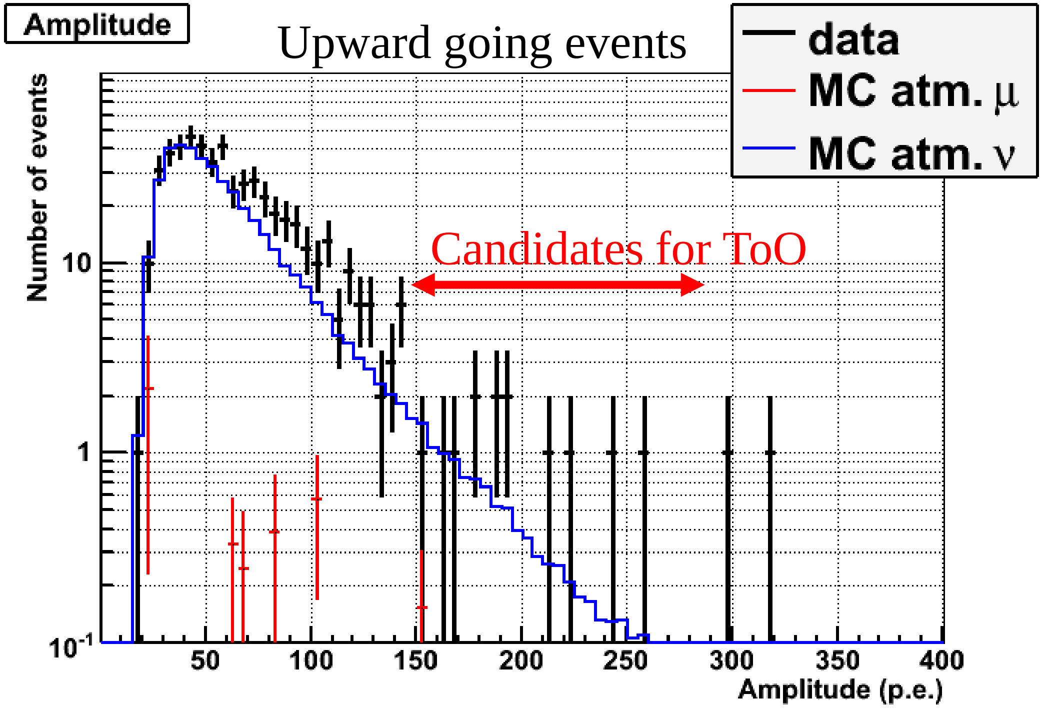


→ Cuts are optimized for **12 lines configuration**
→ Trigger is **now implemented**

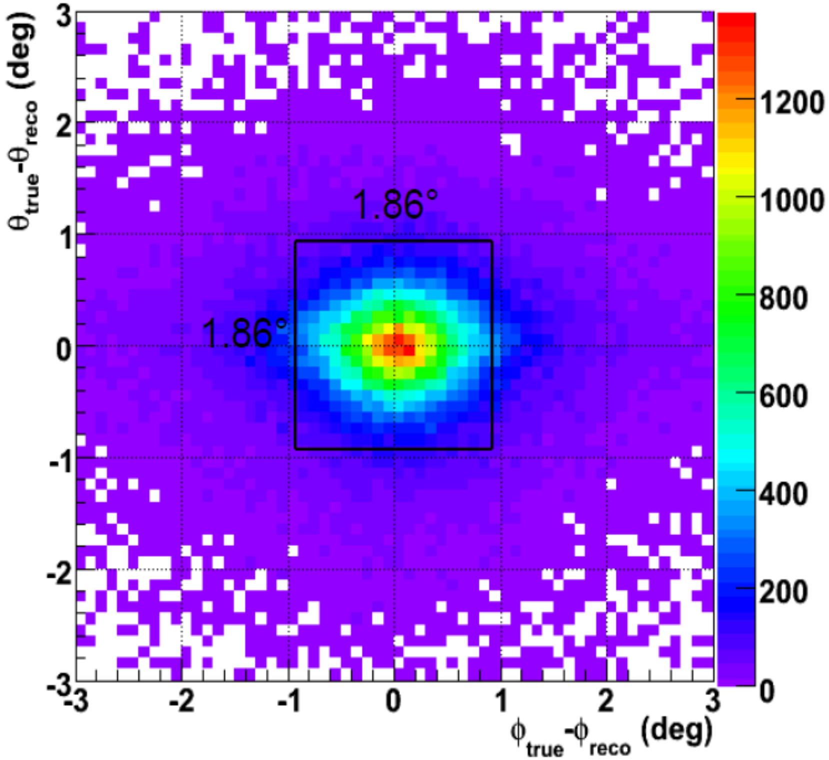
The TAToO Project

Keys of success (2/2):

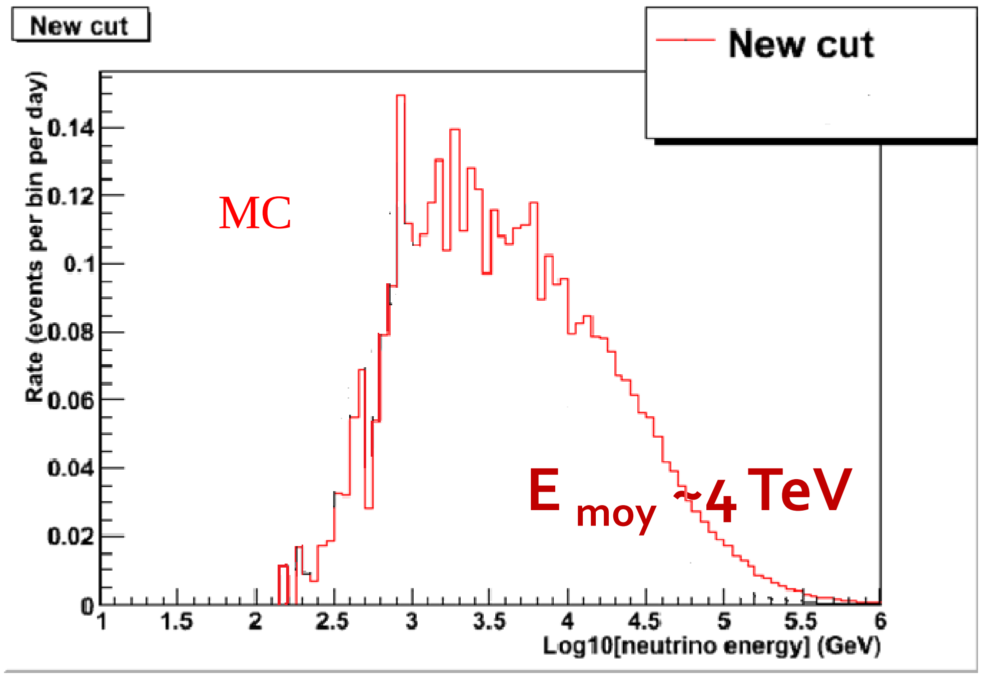
The event selection

- **High energy events**

Angular resolution after cuts



Energy distribution after cuts



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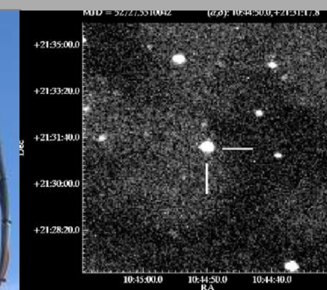

GCN alert

- *TAROT Sud (chili)*
- *FOV :2° x 2°*
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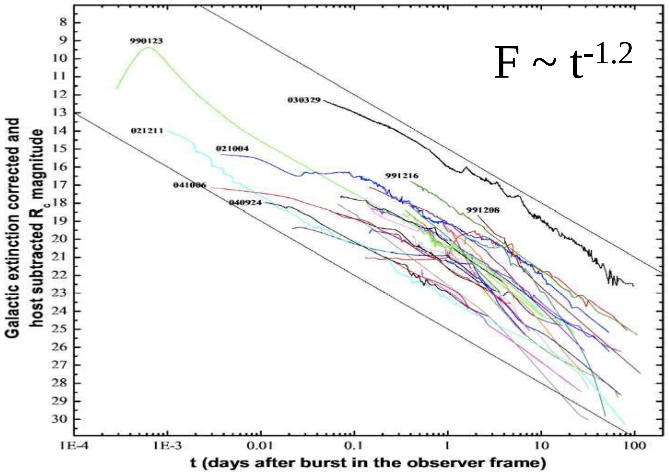
Observation strategy

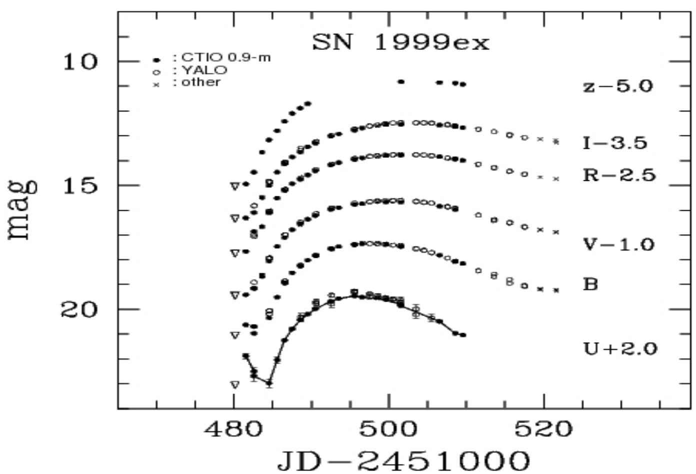
Real Time:



6 images of 3 minutes

(T0, T0+3min, T0+6min, T0+9min, T0+12min and T0+15min)

Delayed:



T0+1 day: 6 images of 3 min

T0+3 days: ________________

T0+9 days: ________________

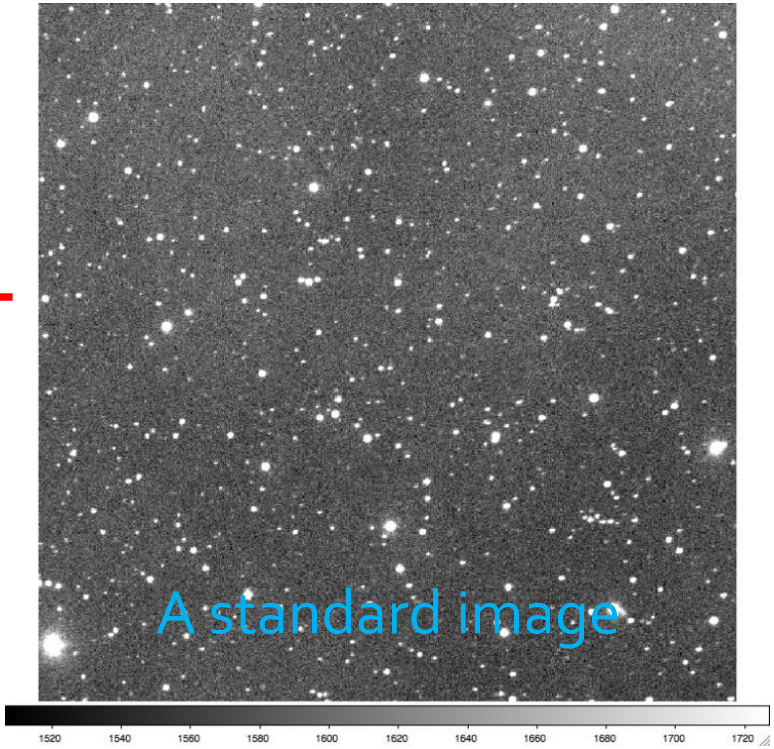
T0+27 days: ________________

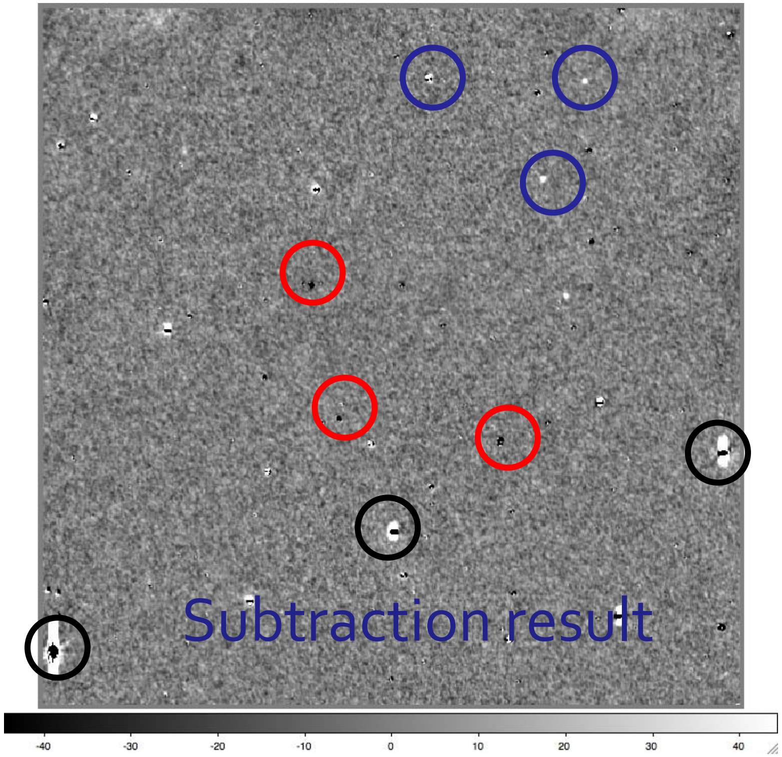
Image Analysis

Image substraction tool

Tuning an image substraction program originally used for SNe Search

Example





Increasing luminosity

Decreasing luminosity

Badly substracted

Conclusion et perspectives

- TAToO is a research using **« special »neutrino events as a trigger for other detections**
- **8 alerts** in total have been sent to TAROT→ **6 were followed** (images taken)
- The system is now **fully operational !**

I was involved in :

- Setting up the **neutrino triggers** for different ANTARES lines configuration
- Evaluating the **optical background** for GRBs/ CCSN detection
- Comparing **trigger efficiencies** for GRB/CCSN detection
- Being a « permanent » shifter…

To come next:

- **First analysis** of the images
- Include it **automatically in the chain**
- Call for **other telescopes** (ROTSE, ZATCO…)
- Extend to **other detections** (X, Radio..)

BACK UP

Expected neutrino signal from CCSN (slow jet model)

The model (***Ando & Beacom*** *(PRL 95,061103(2005))*

- Extension of RMW model

Low Γ, high baryon density

p-p colllisions

Pions

Neutrinos

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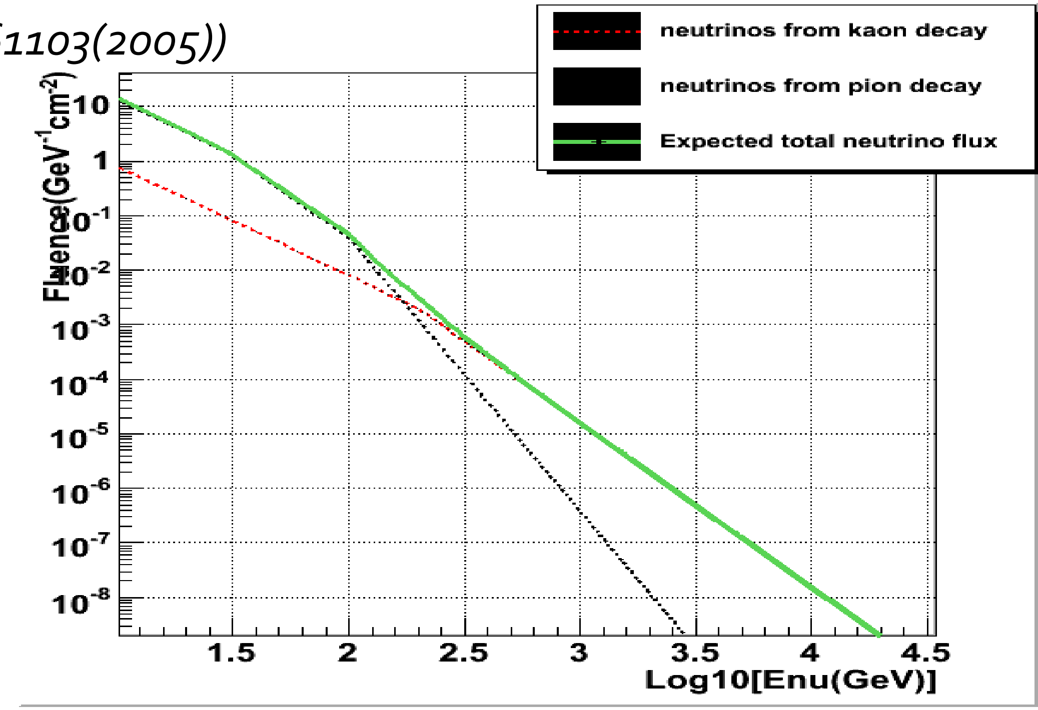
Pions

Kaons

Neutrinos

Neutrinos



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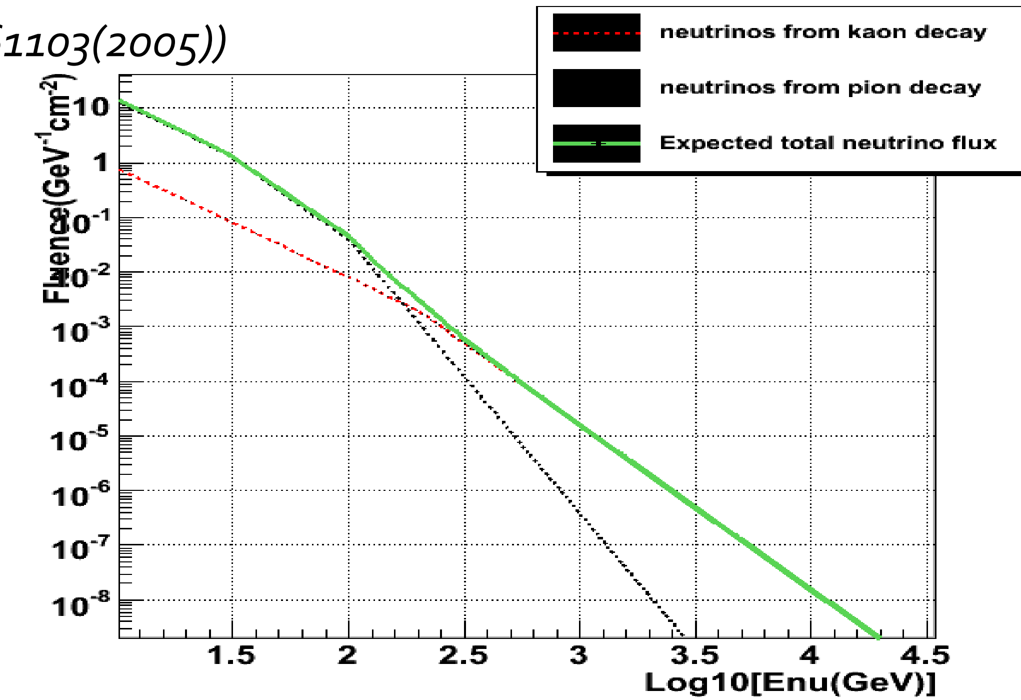


Low Γ, high baryon density

p-p colllisions

Pions

Kaons

Neutrinos

Neutrinos

Undergo less energy loss before decay

Responsible for higher energy Neutrino emission

Expected neutrino signal from CCSN (slow jet model)

- For a jet with the following parameters:

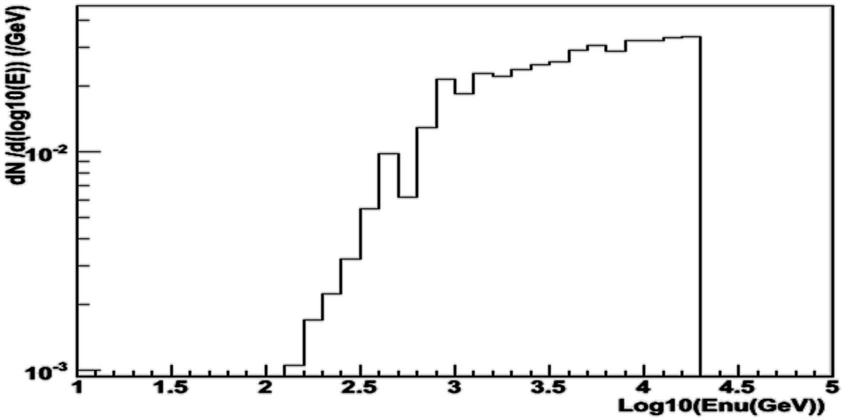
- Ejet = 3. 10^{51} ergs
- Bulk Lorentz factor = 3
- Jet duration : 10 s

- **For our usual alerts (HE (12/yr))**

HE cuts set (pure sample, 5TeV mean energy(MC)):

0.4 HE from SN(10 Mpc)

HE neutrino spectrum (kaons + pions decay contributions) from a CCSN at 10 Mpc



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- **For our usual alerts (HE (12/yr))**

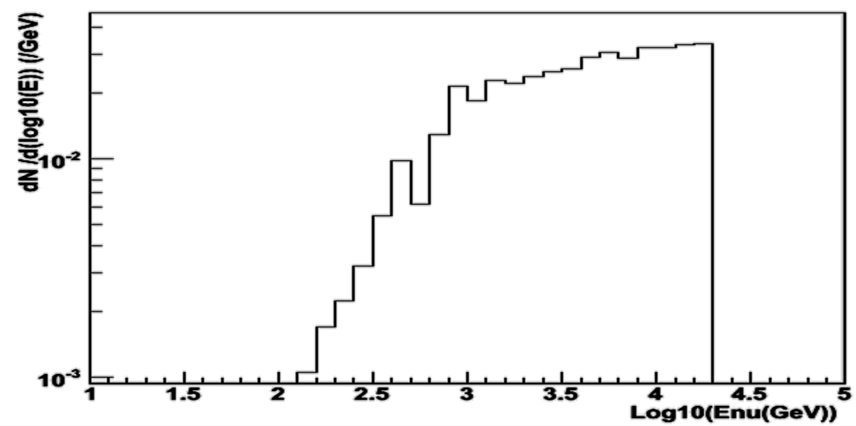
HE cuts set (pure sample, 5TeV mean energy(MC)):

0.4 HE from SN(10 Mpc)

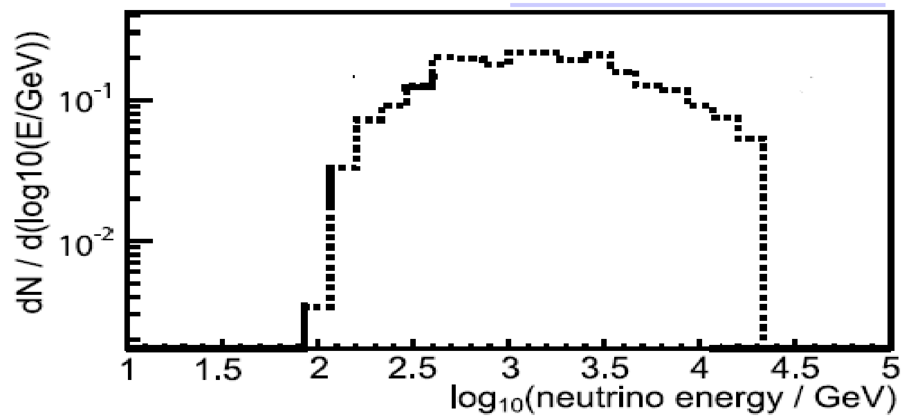
- **For IC usual alerts (doublets (25 /yr))**

1.5 doublets from SN (at 10 Mpc)

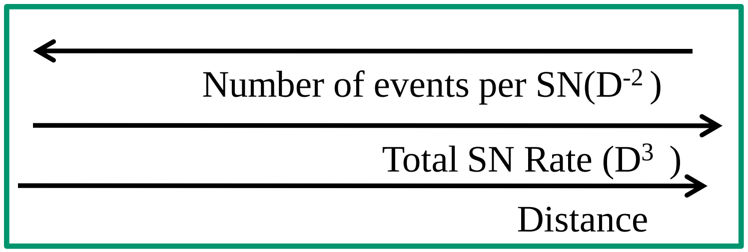
HE neutrino spectrum (kaons + pions decay contributions) from a CCSN at 10 Mpc



arXiv:0909.0631v1

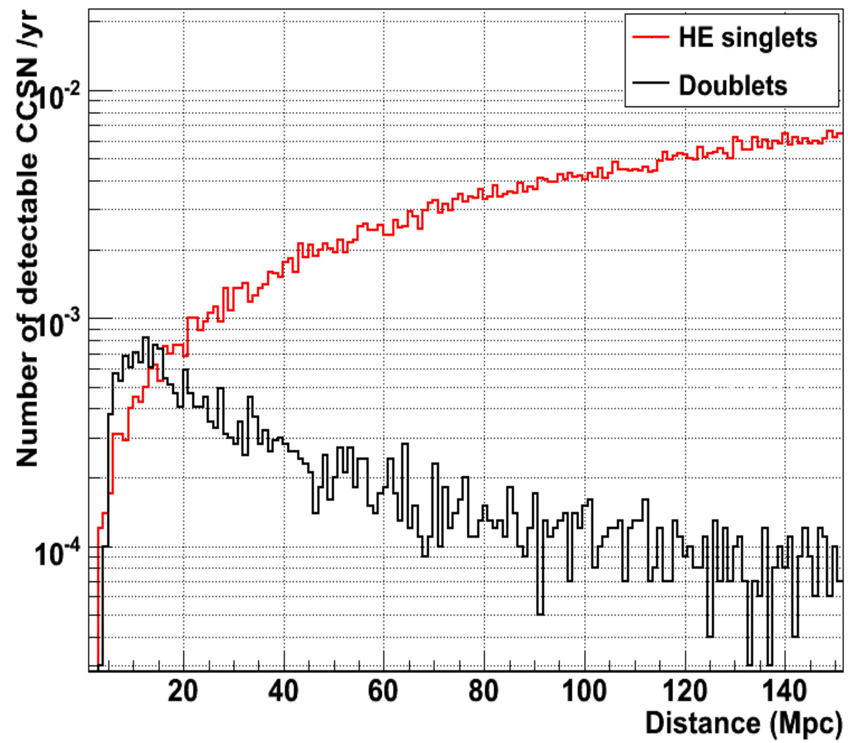


Triggers sensitivity for CCSNe



Total CCSN rate : 1/ yr/ $10Mpc^{3}$

For (R= 1% Total rate; Ej = 3. 10^{51} ergs)



- Poisson fluctuations included:

HE: 2/yr
Doublet: 4 10^{-2} /yr

- Within 20Mpc (local supercluster), trigger sensitivities are comparable .

- HE trigger dominant within 300 Mpc (Tarot sensitivity)

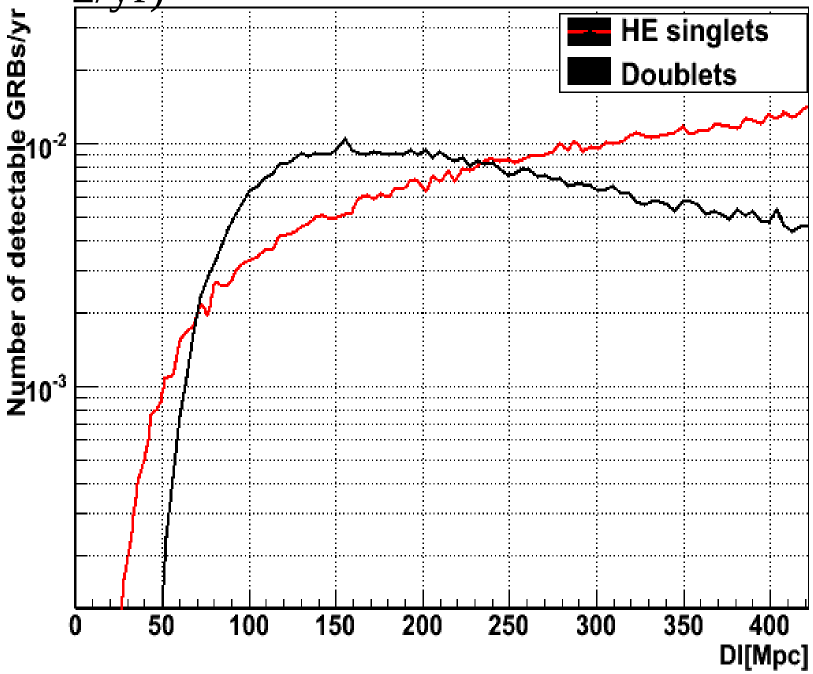
Triggers sensitivity for GRBs

- Waxman-Bahcall Flux (Average BATSE burst)
- Same calculation as for CCSN considering :
  - Average luminosity 10^{53} ergs/s
  - GRB local rate : 2/year (non –linear rate extension)

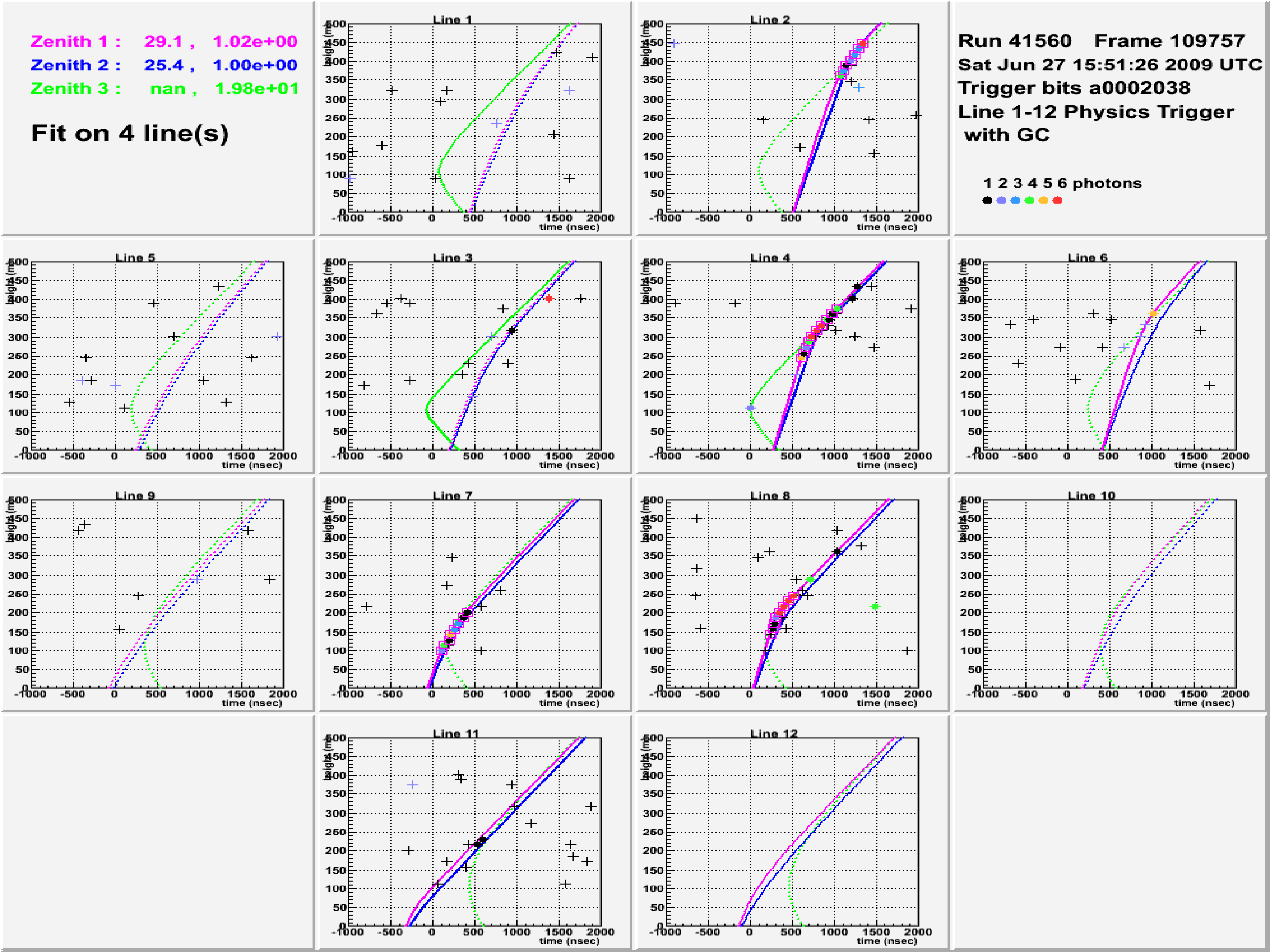
Triggers are comparable within 400 Mpc
HE 0.7 /yr
doublets 0.6/yr

Example

For (Ej $=10^{53}$ ergs ; R = local rate 2/yr)

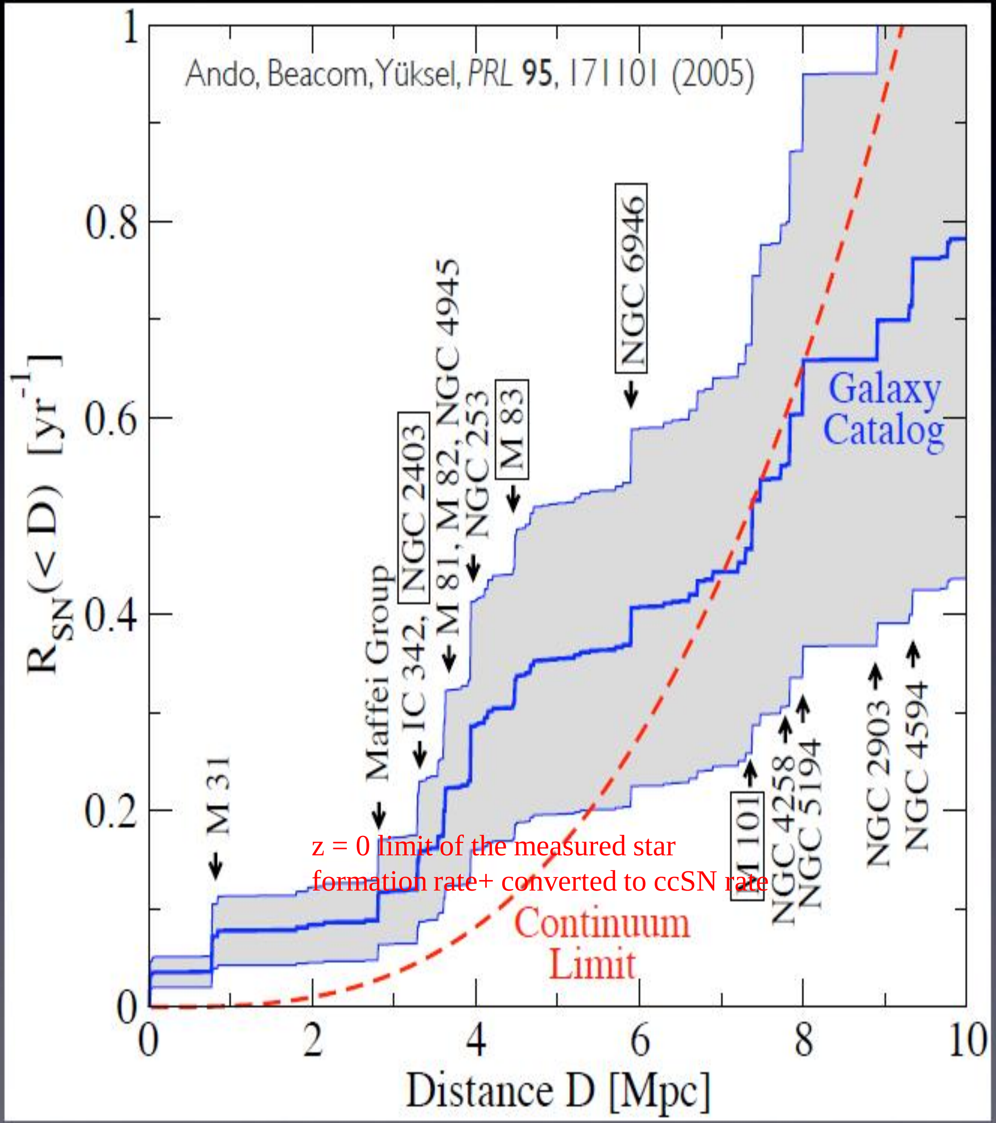


GRBs rate has to studied as a function of their luminosities



Zenith 1 : 29.1 , 1.02e+00
Zenith 2 : 25.4 , 1.00e+00
Zenith 3 : nan , 1.98e+01
Fit on 4 line(s)
Run 41560 Frame 109757
Sat Jun 27 15:51:26 2009 UTC
Trigger bits a0002038
Line 1-12 Physics Trigger
with GC
1 2 3 4 5 6 photons
Line 1
Line 2
Line 5
Line 3
Line 4
Line 6
Line 9
Line 7
Line 8
Line 10
Line 11
Line 12
height (m)
time (nsec)

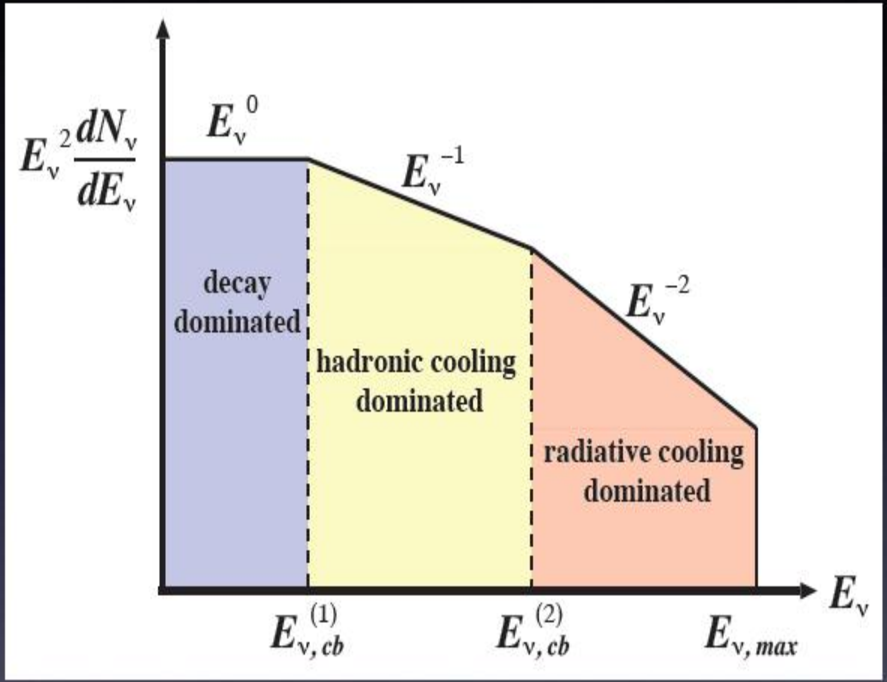
Supernova rate with galaxy catalog



- Galaxy catalog (name, distance, morphology, luminosity, etc.) by Karachentsev et al. (2004)
- Conversion to SN rate with calibration by Cappellaro et al. (1999)
  - Underestimating starbursts?
- R_{SN} ~ 1 / yr within 10 Mpc

Neutrino spectrum

Ando & Beacom, *Phys. Rev. Lett.* **95**, 061103 (2005)



	$E_{cb}^{(1)}$ [GeV]	$E_{cb}^{(2)}$ [GeV]
π	30	100
K	200	20,000

- K-decay neutrinos have higher break energies because
  - Lifetime is twice shorter
  - 4 times massive, significantly less radiative loss ($t_{rc} \sim m^4$)
  - Neutrino carries larger fraction of meson energy