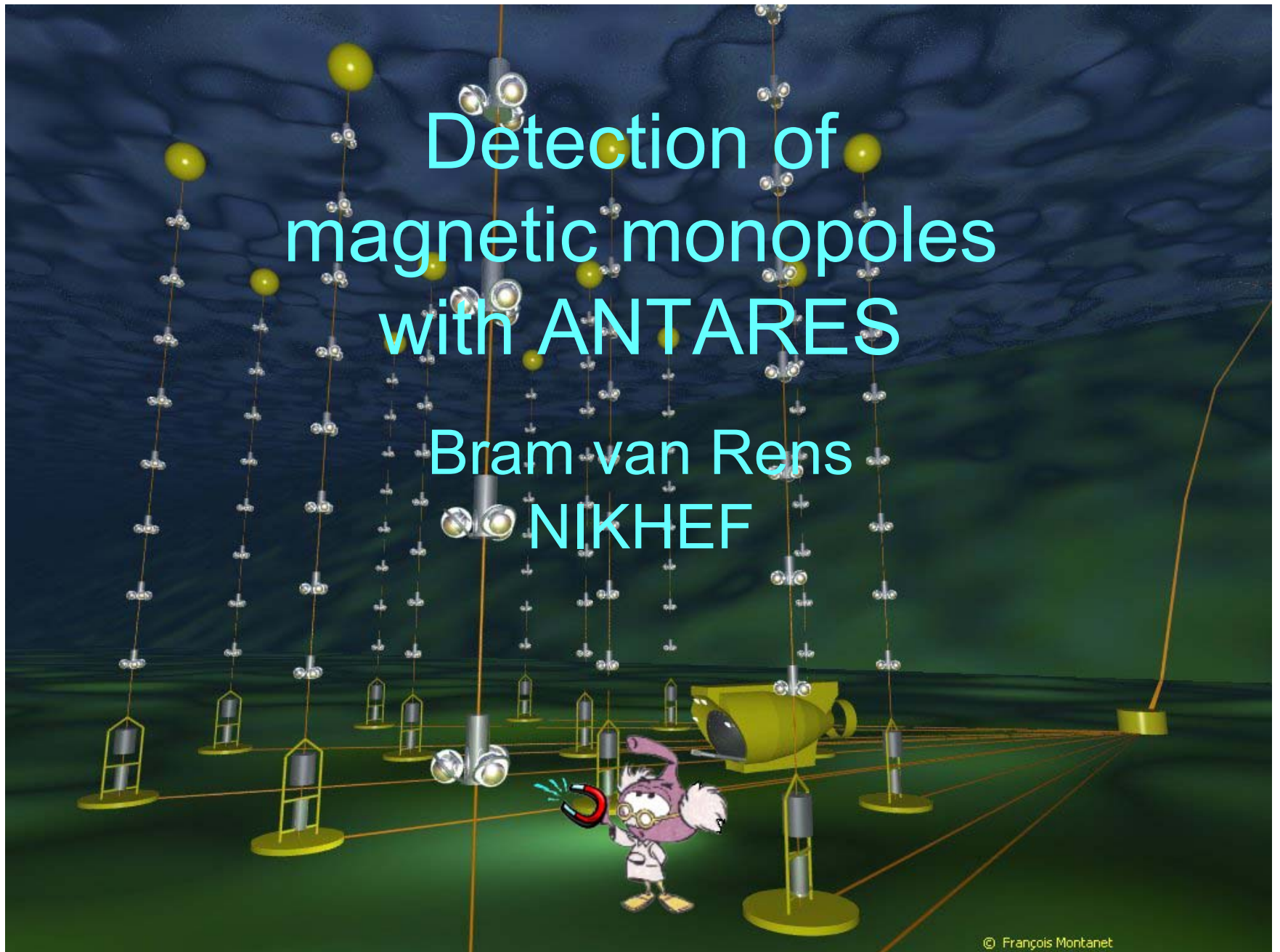


Detection of magnetic monopoles with ANTARES

Bram van Rens
NIKHEF

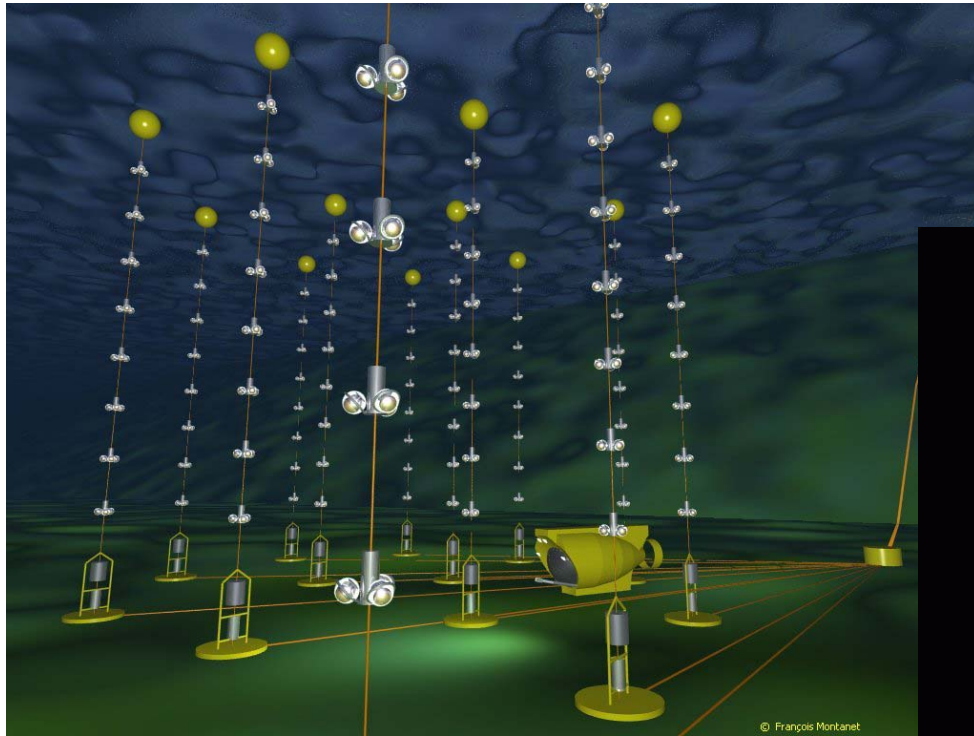


Contents



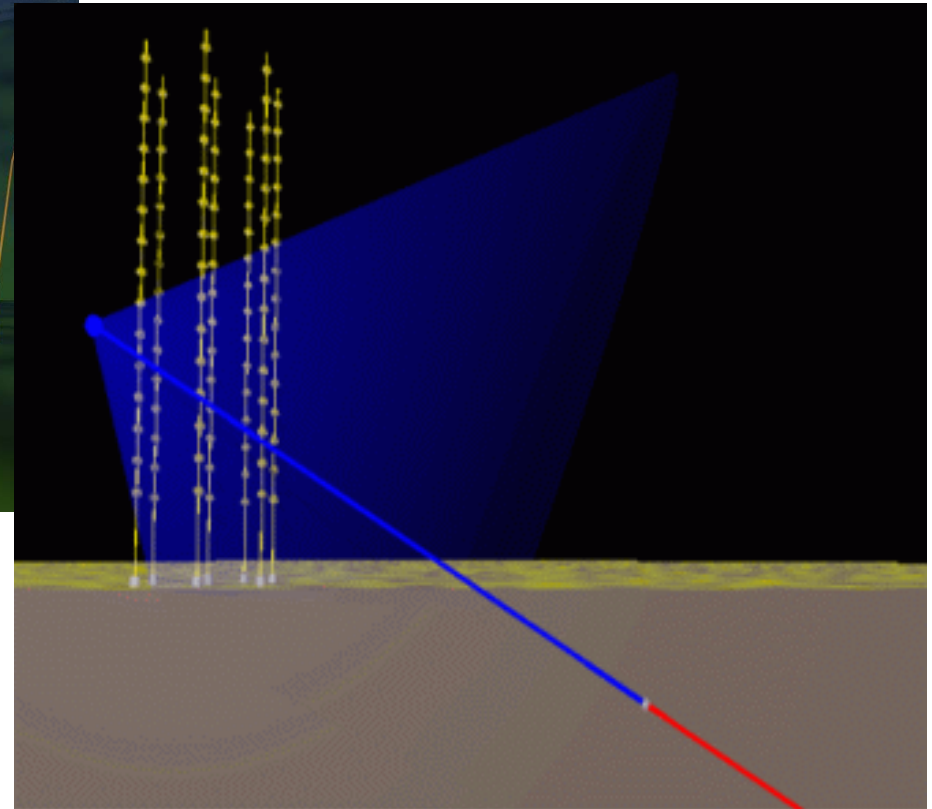
- ANTARES
- Data acquisition and triggering
- Simulation of monopole events
- Monopole trigger
- Conclusions and plans

ANTARES: astronomy with a neutrino telescope



900 PMTs

ν induced μ



Data acquisition and triggering



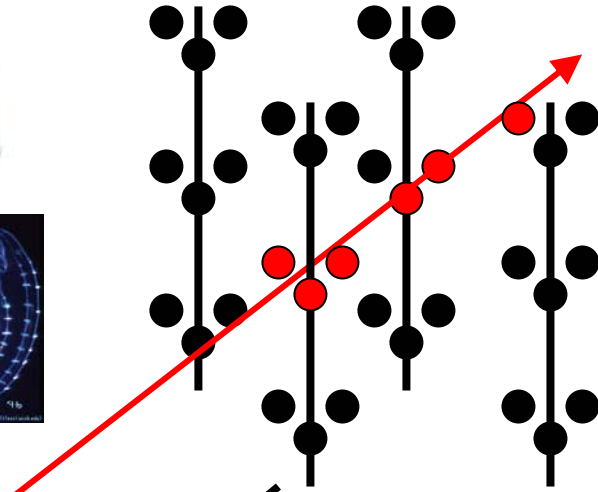
offshore | on-shore

Detector

~ 100 kHz/PMT

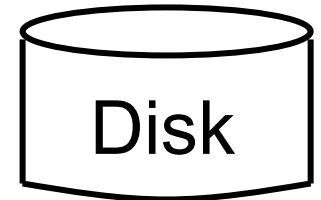
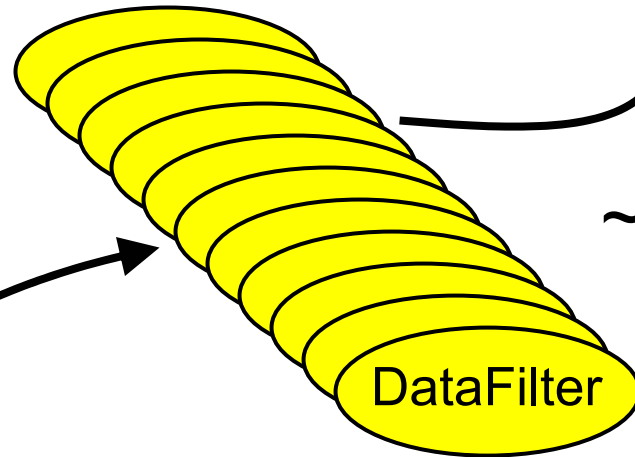


μ



“ADTS”
~ 1 GB/s

Trigger farm



events
~ 1 MB/s

Simulation of monopole events



Which monopoles?

- GUT monopoles (cosmic)
- Unit Dirac charge

$$g_D = \frac{\hbar c}{2e} = \frac{e}{2\alpha} = 68.5e$$

- Relativistic: $\beta_m > 0.1$
- Ionisation loss regime: $\gamma_m \leq 1000$ ($\gamma_c \sim 10^4$)
- Upward going



Do monopoles cross Earth?

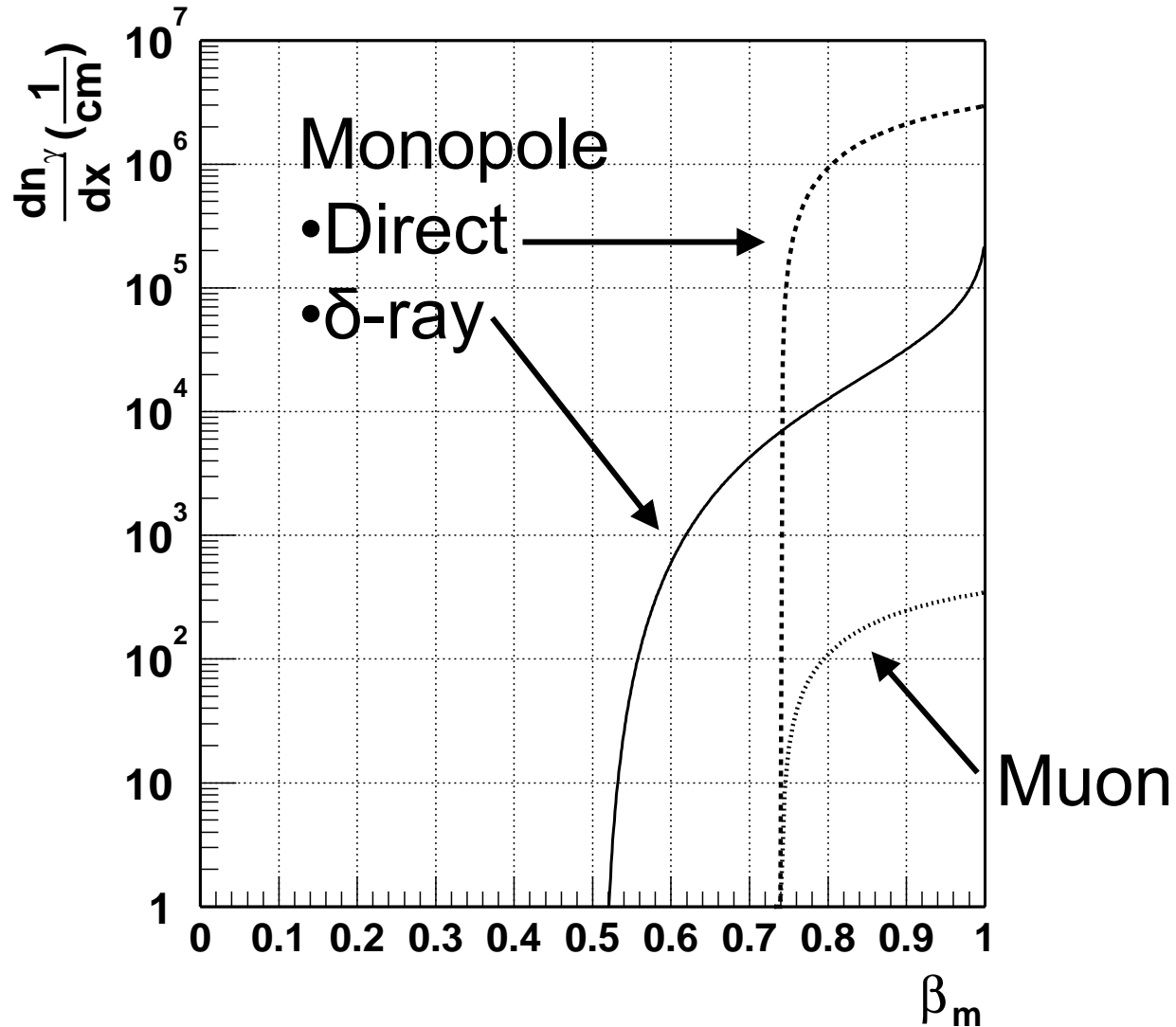
- Total ionisation loss in Earth: $\sim 10^{11}$ GeV
- Acceleration in (extra)galactic magnetic fields: $\leq 10^{16}$ GeV
- Predicted mass of monopoles:
 $10^6 - 10^{17}$ GeV
- Monopole with mass $> 10^8$ GeV could cross Earth



Interesting signals:

- Direct Cherenkov emission for $\beta_m > 1/n$
($n = 1.35 \rightarrow \beta_m > 0.74$)
 - Cherenkov emission enhanced by factor
~ 8500 w.r.t. muon
- Production of δ -rays (knock-on electrons)
 - δ -rays emit Cherenkov for $\beta_m > 0.51$

Total number Cherenkov photons $300 < \lambda < 600 \text{ nm}$

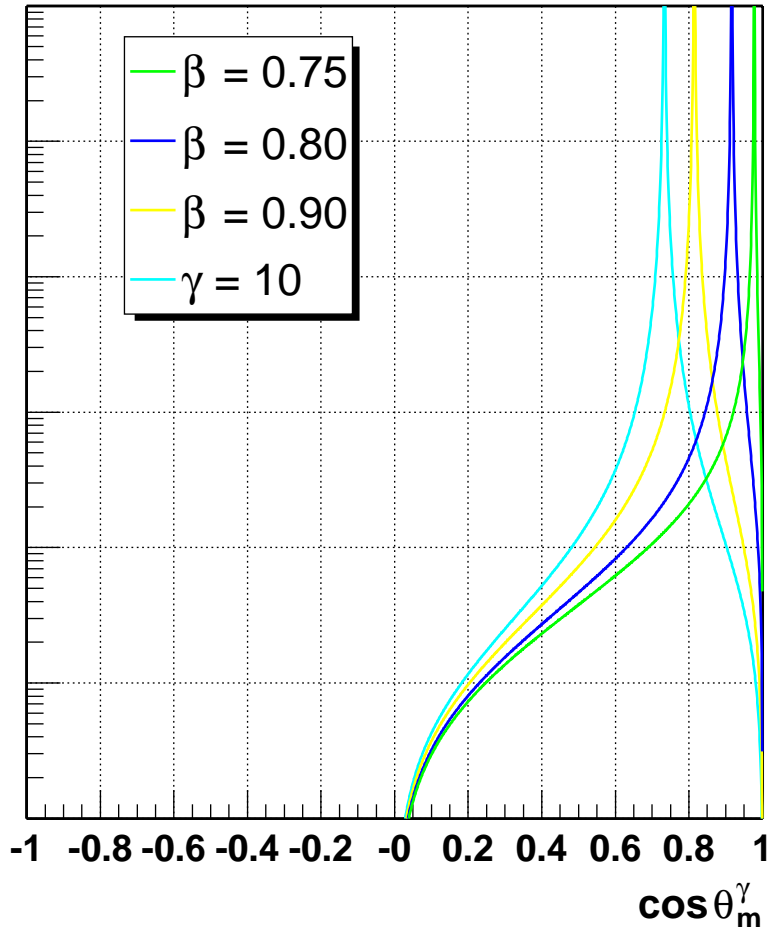


Angular distribution Cherenkov photons

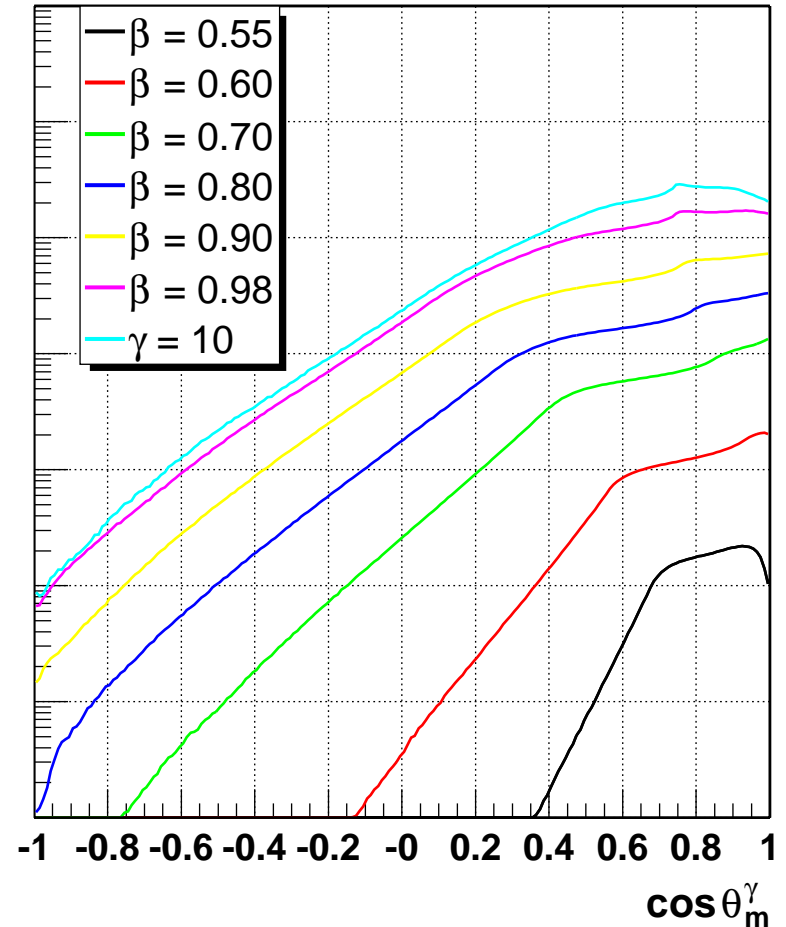
$300 < \lambda < 600 \text{ nm}$



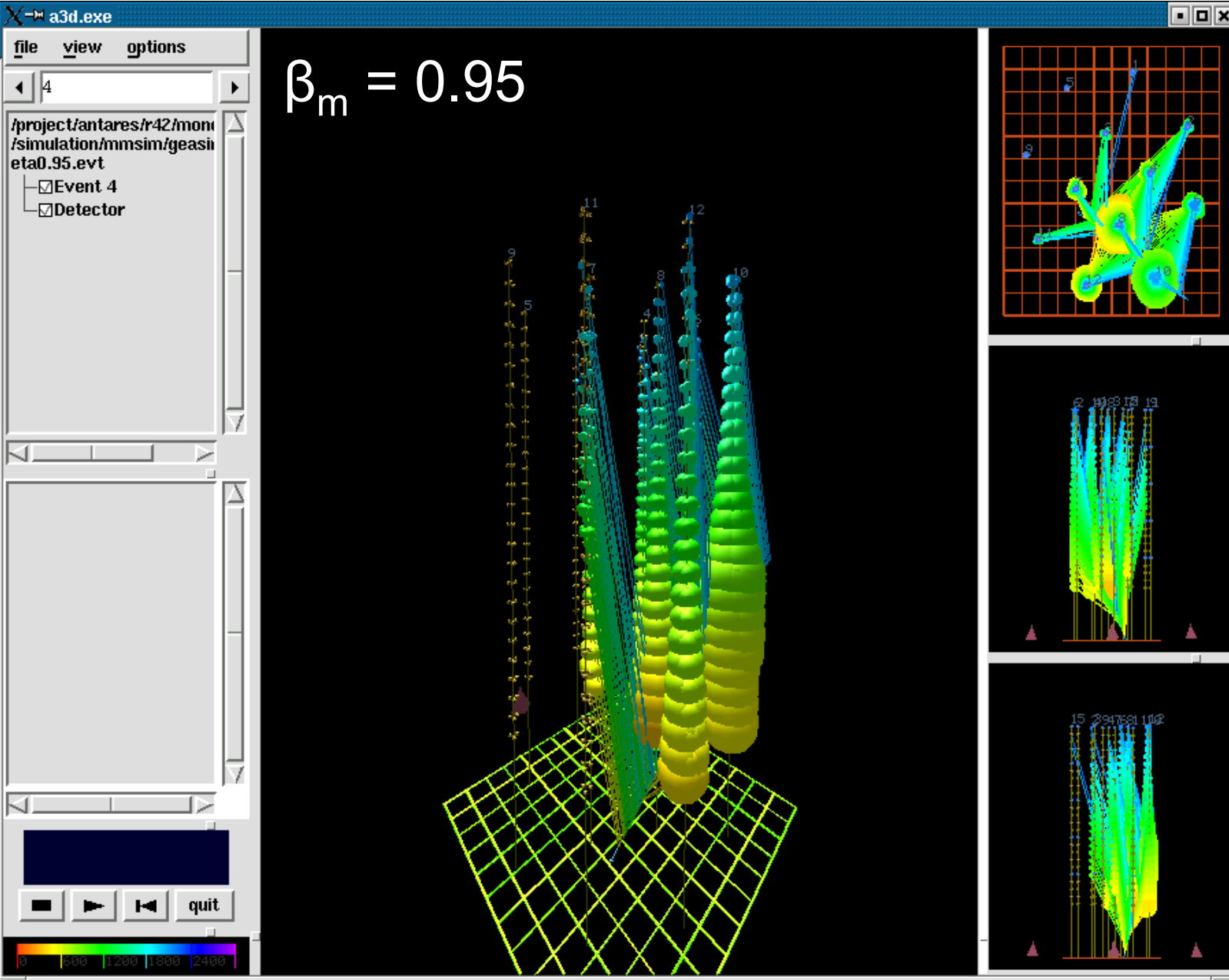
Direct Cherenkov



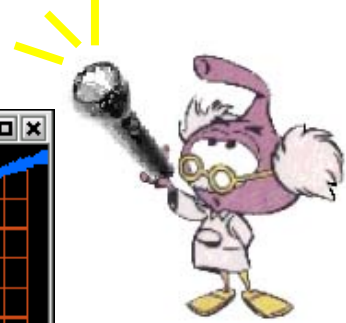
δ -ray Cherenkov



Direct Cherenkov



δ -ray Cherenkov



a3d.exe

file view options

202

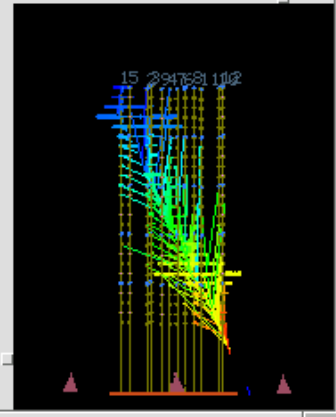
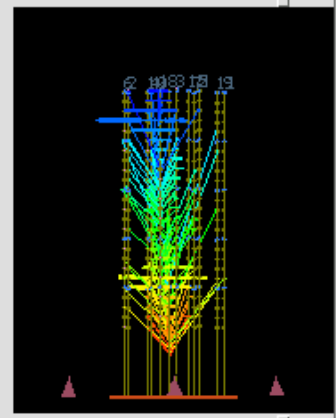
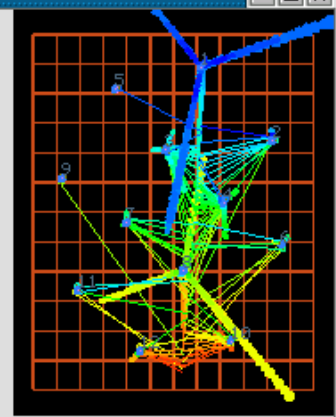
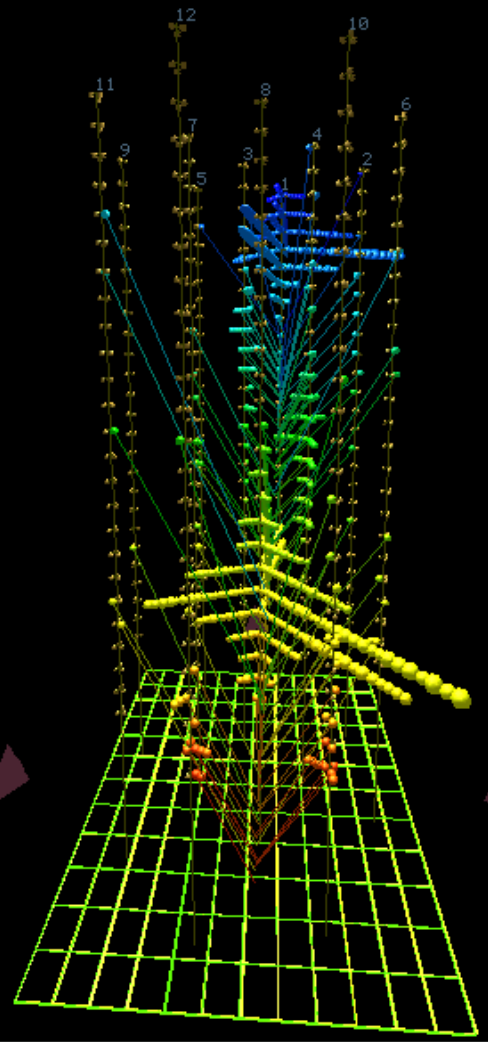
/project/antares/r42/mon
/simulation/mmsim/geas
only/data/evt/gea.beta0.f

- Event 202
- Detector

quit

500 1100 1700 2300 2900

$$\beta_m = 0.60$$



Intermezzo: muon trigger



Offshore

- L0: amplitude hit > 0.3 p.e.

On-shore

- L1: - Coincidence of 2 L0 on 2 different PMTs in same floor, $|\Delta t| < 20$ ns
 - 1 L0 with amplitude > 3.0 p.e.
- L2: 3D space-time correlation of L1 within maximum event time $\sim 2 \mu\text{s}$
- Minimum correlation speed c/n

$$|\Delta t| \leq \frac{n}{c} |\Delta x| = \frac{|\Delta x|}{0.74c}$$

Monopole trigger



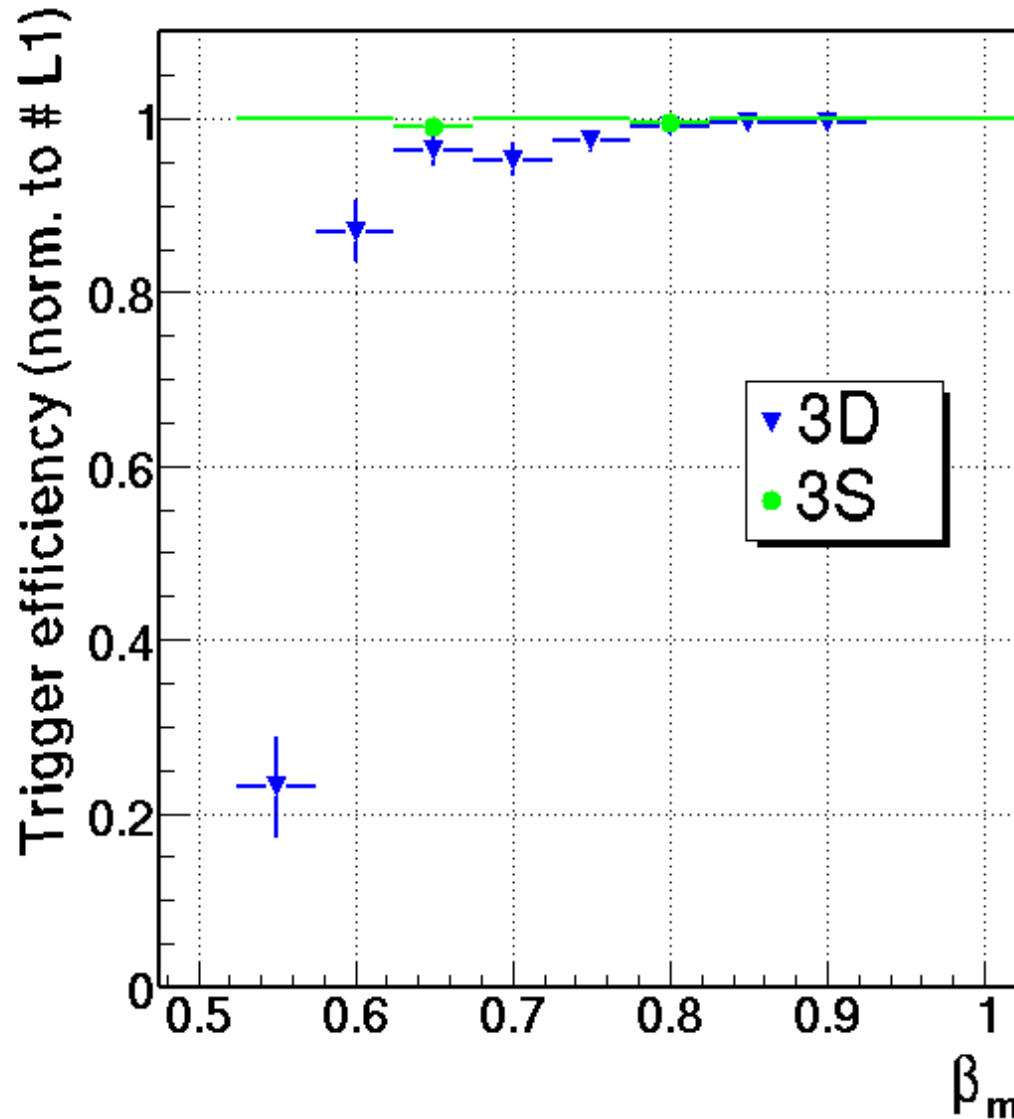
- Adapt 3D trigger:
3S(low) trigger, minimum correlation
speed $\beta_{\min} c = 0.5c$,

$$|\Delta t| \leq \frac{|\Delta x|}{\beta_{\min} c} = \frac{|\Delta x|}{0.5c}$$

- Maximum event time $\sim 3 \mu\text{s}$

Trigger efficiency (norm. to # L1)

At least 5 correlated L1





- For 3S trigger:
 - Larger causality time window
 - Larger maximum event time

Results in larger random background event rate:

Rate (kHz)	Trigger	Time/slice* (ms)	Trigger rate (Hz)
100	5L1:3D	176	45
100	5L1:3S: $\beta 0.5$	191	173

* 2.2 GHz Intel Pentium 4 processor
gcc version 2.96



- Standard 3N trigger:
 - Cluster 3D
 - Loop over n directions
 - Cluster 1D in each direction
- Standard 1D trigger:

$$-\frac{R}{c} \tan \theta_c + \frac{\Delta z}{c} \leq \Delta t \leq \frac{\Delta z}{c} + \frac{R}{c} \tan \theta_c$$

- Background event rate reduction in standard case factor ~ 100
(without loss of efficiency!)

- 3S trigger:
 - Introduce scan of directions
 - Adapt 1D trigger:



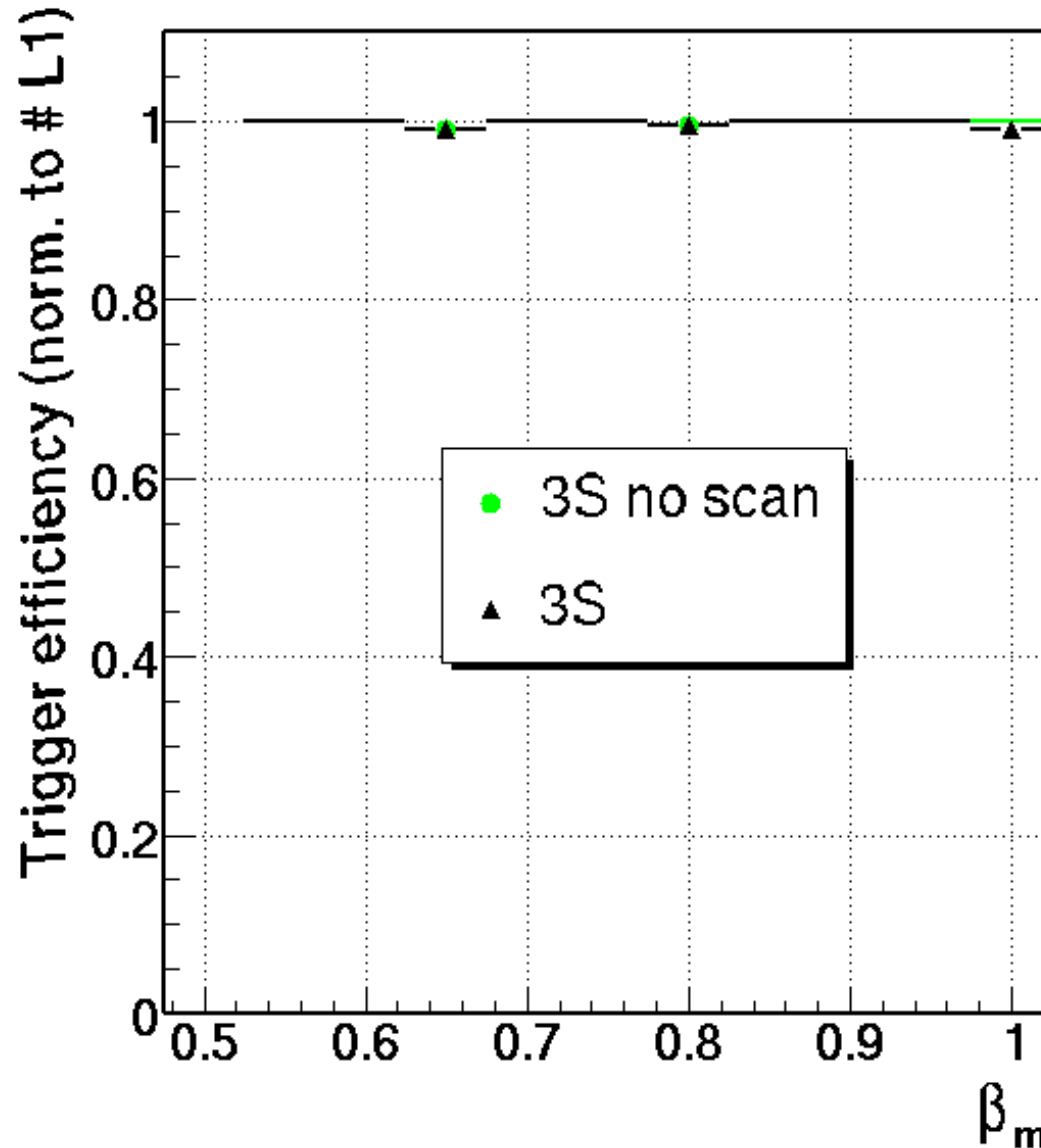
$$-\frac{L}{c}(\beta_{\min}^{-1} - n) - \frac{Rn}{c} + \frac{\Delta z}{\beta_m c} \leq \Delta t \leq \frac{\Delta z}{\beta_m c} + \frac{Rn}{c} + \frac{L}{c}(\beta_{\min}^{-1} - n)$$

- R = transverse distance
- L = order of λ_{abs}
- $\beta_m c$ = speed of monopole

- Depending on sign of Δz choose β_m to be $\beta_{\min} = 0.5$ or $\beta_{\max} = 1$ to optimise time window

Trigger efficiency (norm. to # L1)

At least 5 correlated L1



$$R_{\max} = 90 \text{ m}$$

$$L = 24 \text{ m}$$

$$\beta_{\min} = 0.5$$



Random background event rate

Rate (kHz)	Trigger	Time/slice (ms)	Trigger rate (Hz)
100	5L1:3D	176	45
100	5L1:3S: β 0.5:n.s.	191	173
100	5L1:3S: β 0.5:R90	192	1
100	5L1:3S: β 0.1:R90	330	325



Conclusions

- ADTS: can trigger on any time-position correlation
- Dedicated monopole triggering possible for $\beta_m > 0.51$
- Monopole trigger more efficient for $\beta_m < 0.80$
- Random background manageable for $\beta_m > 0.5$

Plans

- Extend to $\beta_m \sim 0.1$:
 - Investigate detectable signals of monopoles for $\beta_m < 0.5$ (nucleon decay?)
 - For $\beta_m < 0.5$ large random background: working on prefit for further background suppression
- Reconstruction of monopole events
 - Effective area of ANTARES for monopoles