- String-18 Analysis -
presentation of the NIM paper on the
IceCube prototype string

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Hardware/Software changes at Pole
Timing Performance
A look at ice effects
Down going muon analysis/reconstruction
Feedback to paper

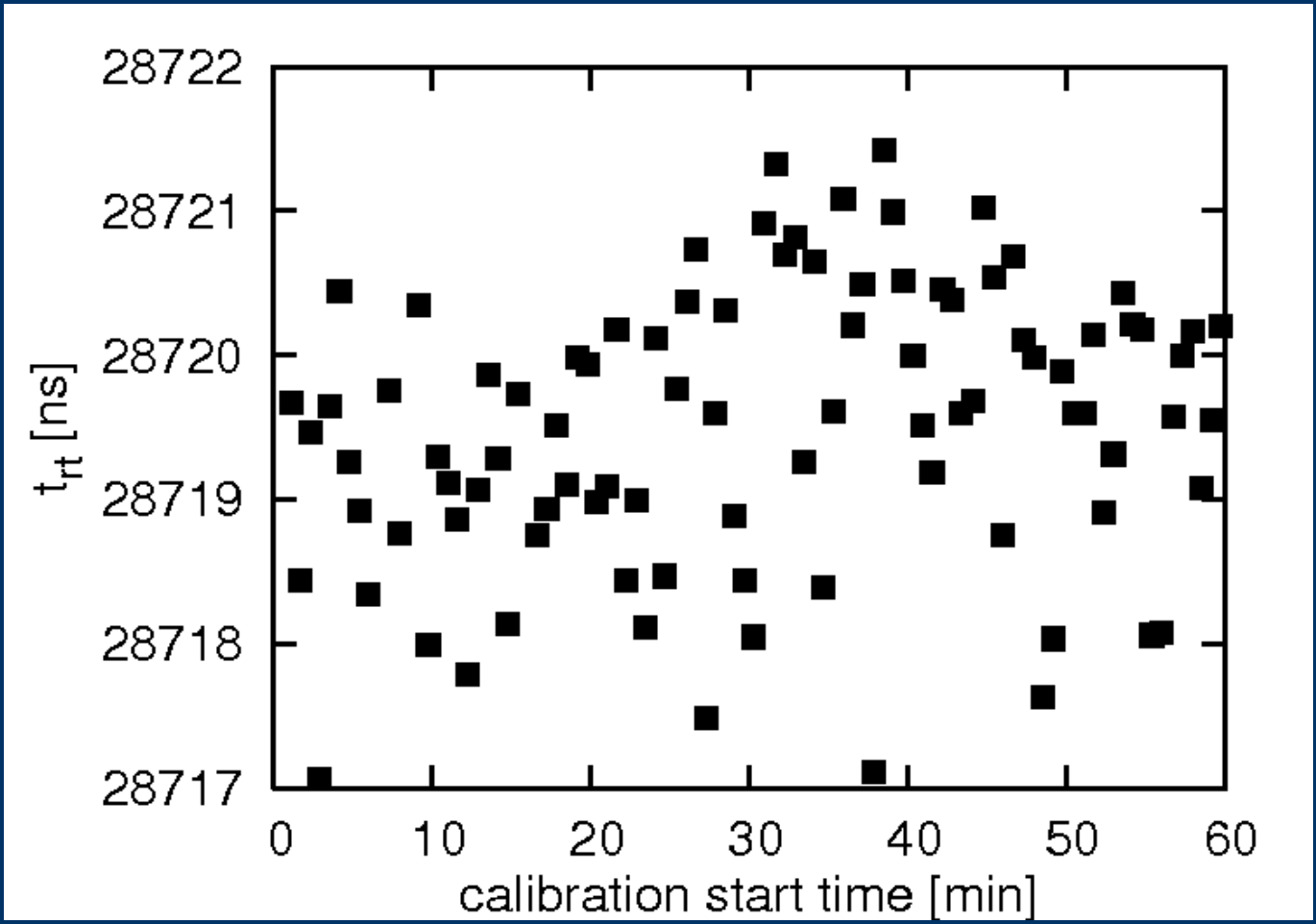
Changes in 2003-04 season

- **Upgrade readout for taking muon data**
  - **Load new FPGAs to all DOMs and DOMCOMs (Fast communication, RAPCal)**
  - **Optimization of HVs for digital read out**
  - **New surface software → improved DAQ speed**
  - **New InIce software → reduced overhead**
  - **Waveform compression in ice (zero suppression, run-length, Hufman-lite encoding)**
- **30% duty cycle** (up from 1%)
- **21 perfect DOMs** (incl. RAPCal, FastComm)

- Muon data: free running, no local coincidence, data compression in CPU, offline trigger

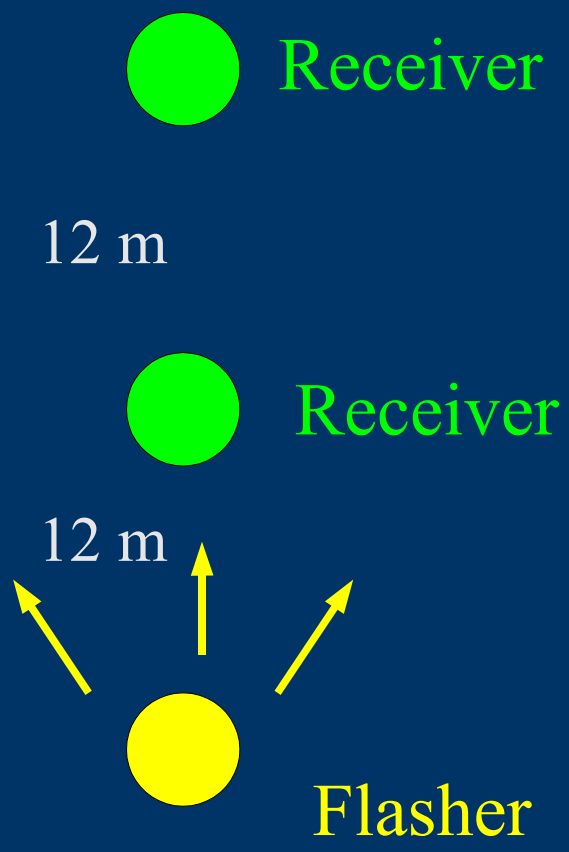
- Systematic flasher data taking

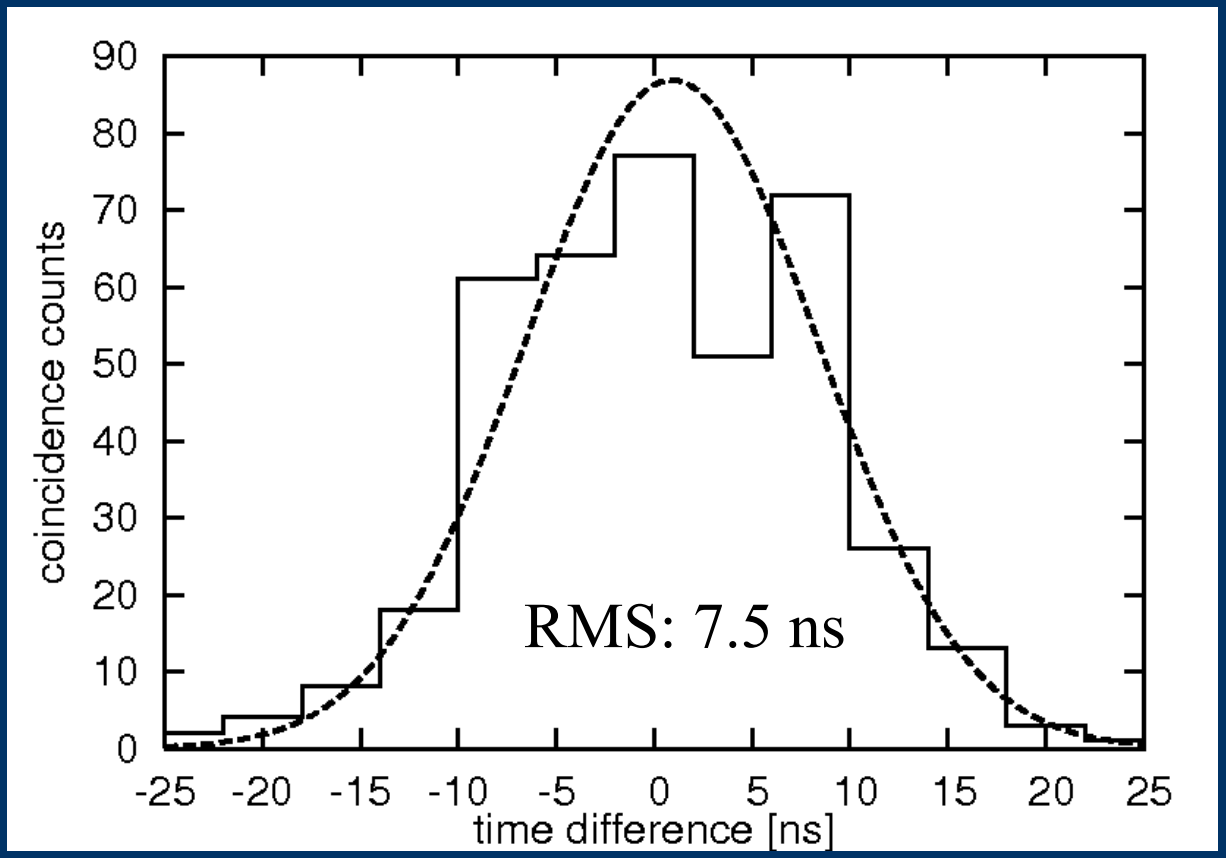
RAPCal round trip time stability



Jitter: 1.1 ns → relative accuracy: $4 \cdot 10^{-5}$

Timing accuracy

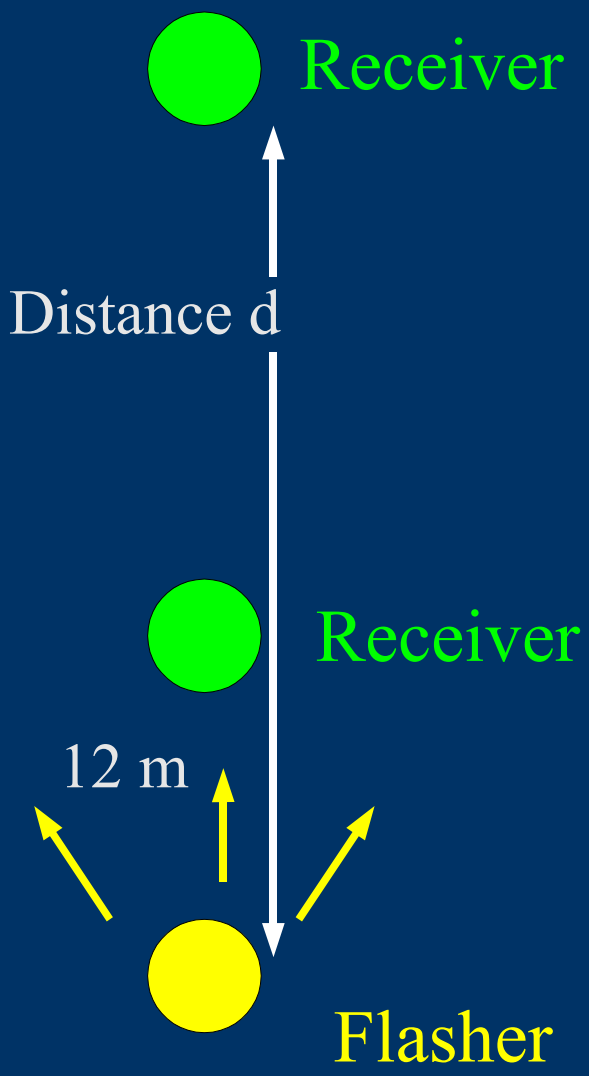


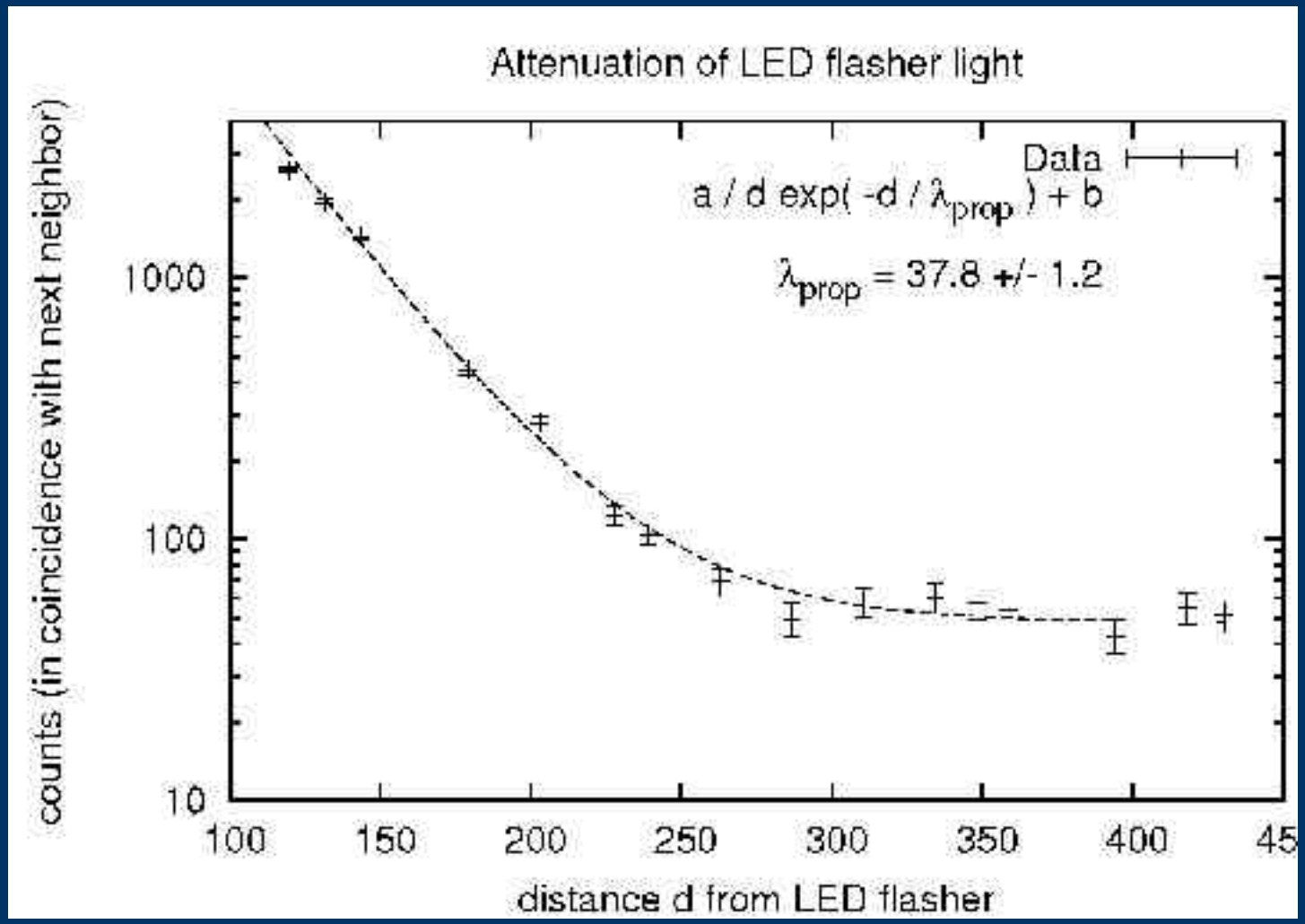


Flasher operated at very bright intensity

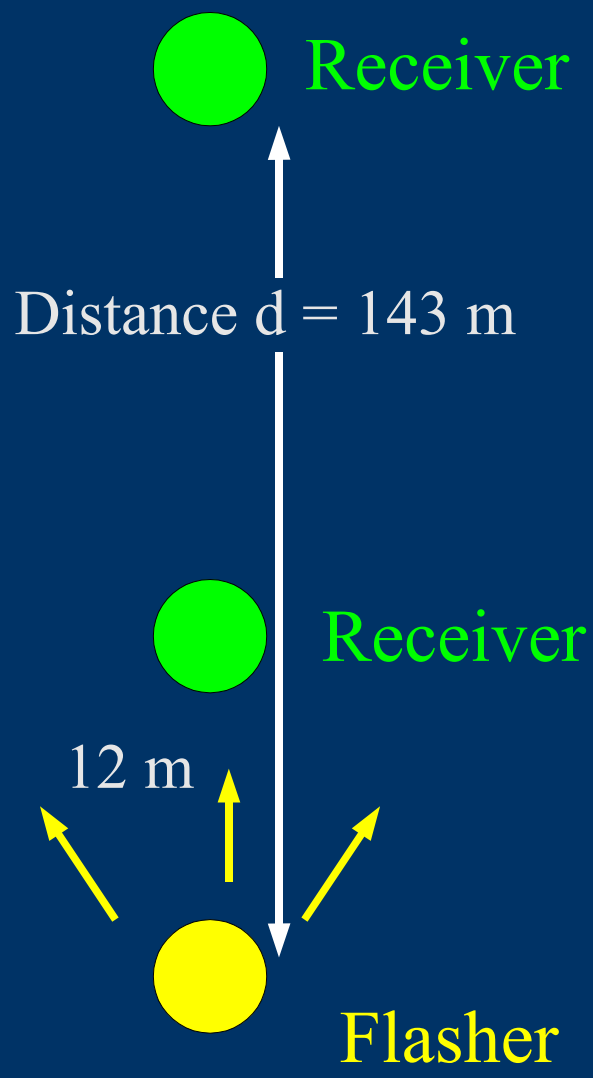
→ leading edge at receiver unaffected by scattering in ice

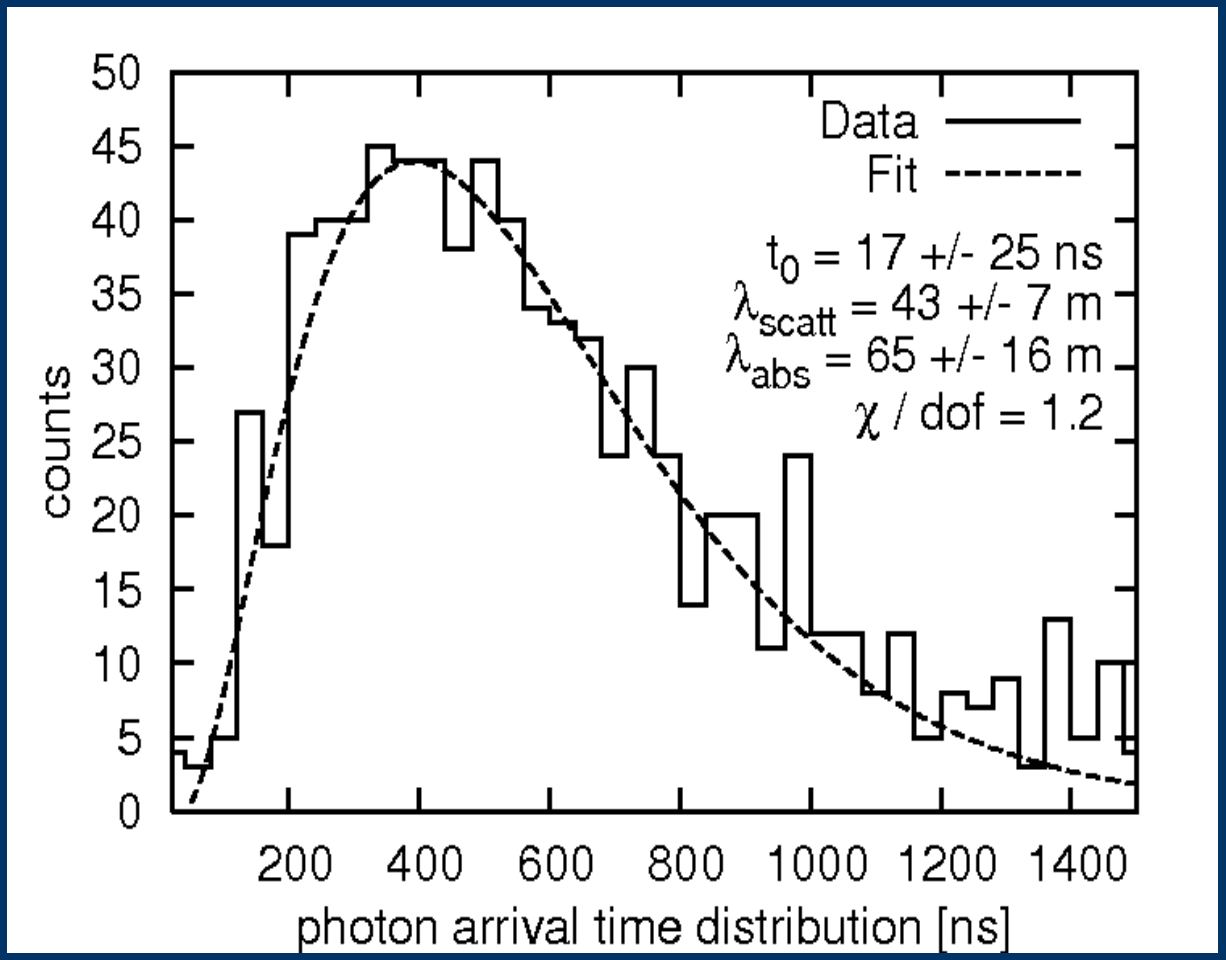
LED light attenuation through ice



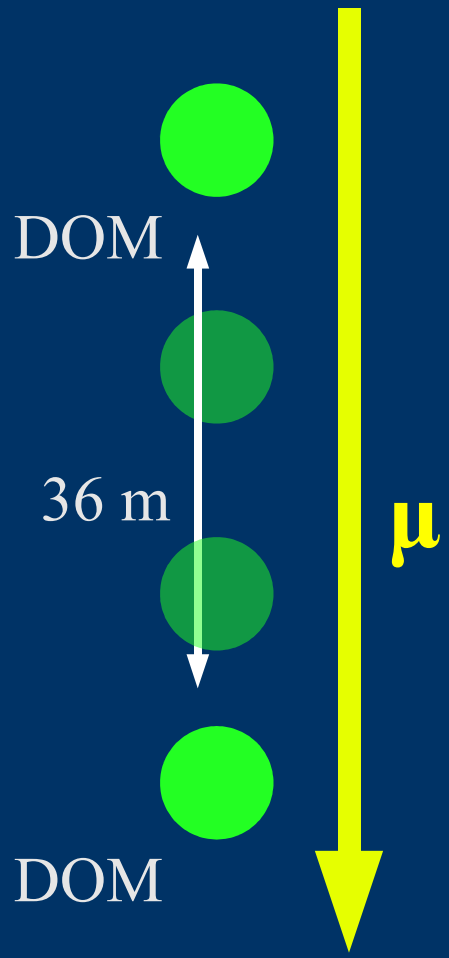


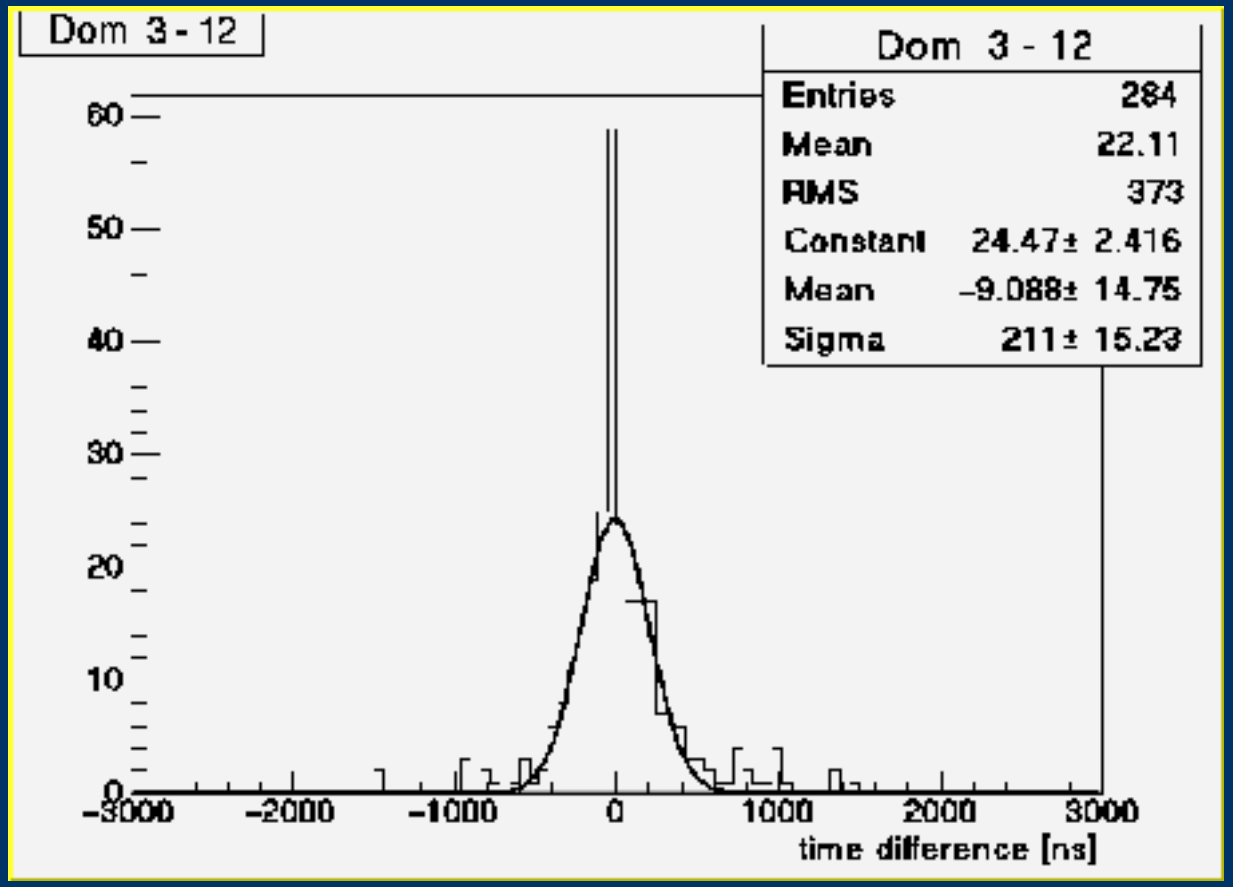
Arrival time distribution





Coincidences between 2 DOMs

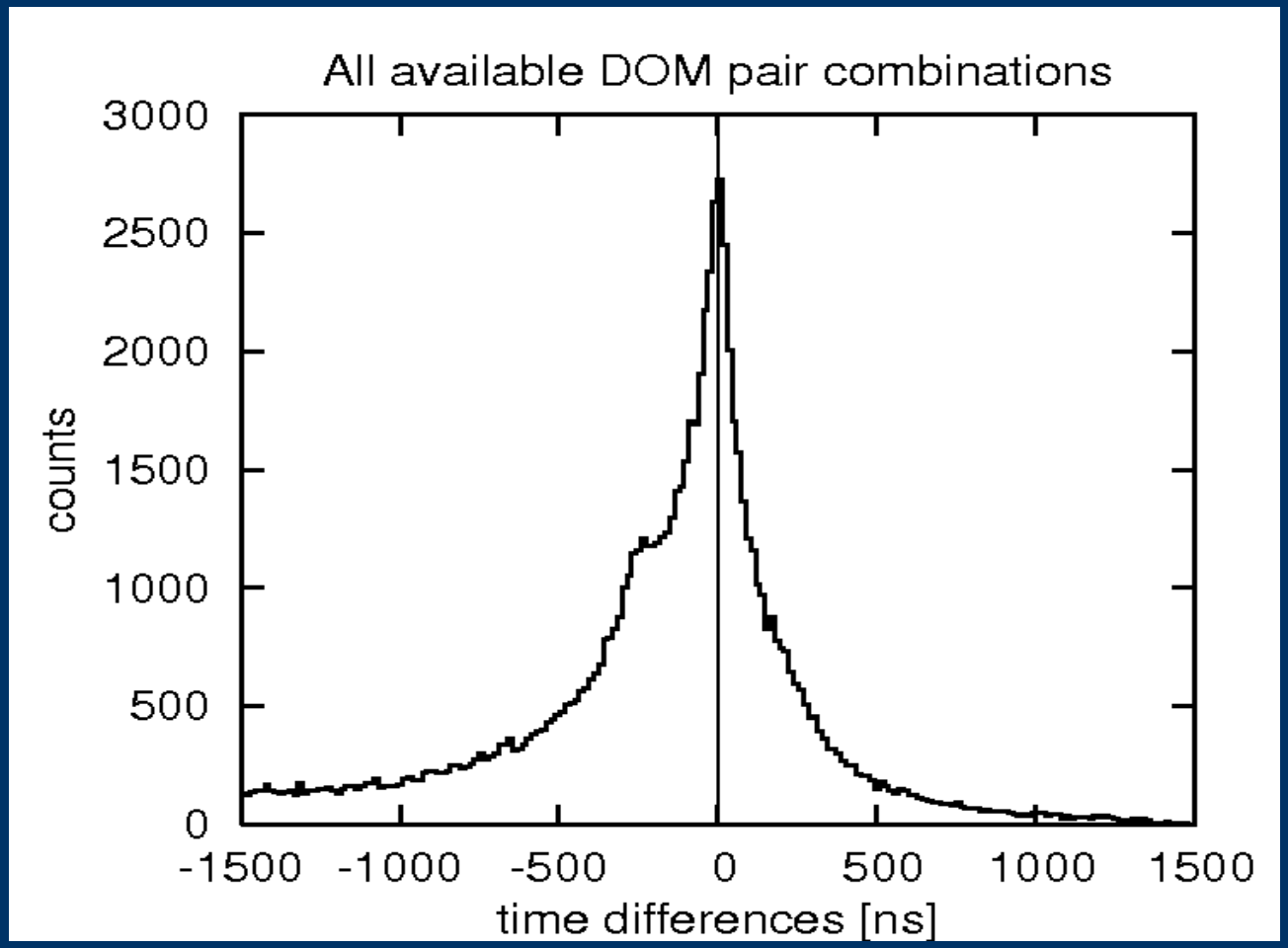


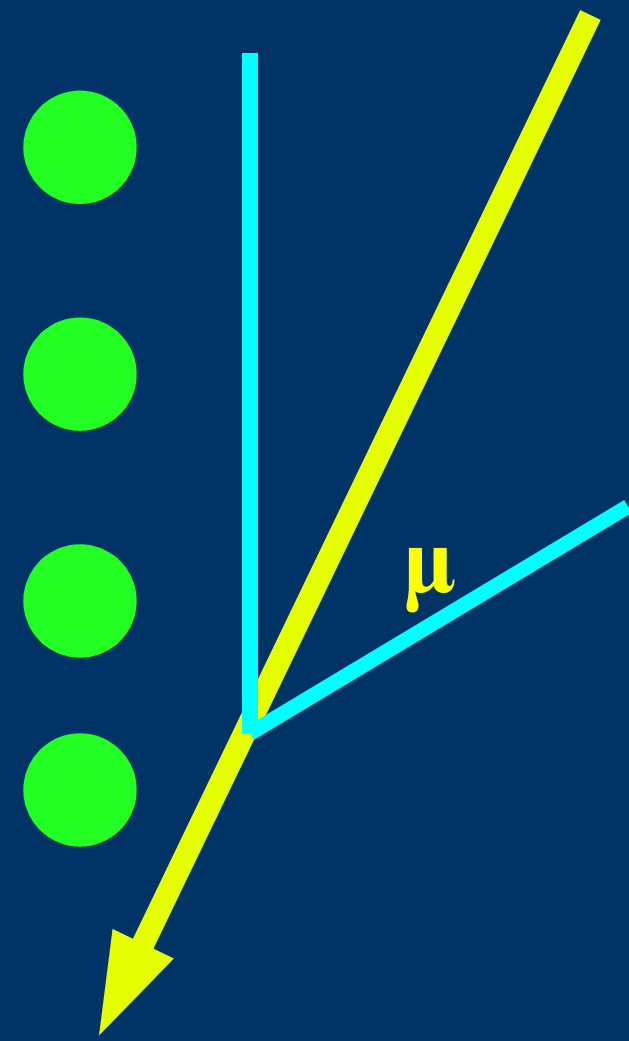


3rd next neighboring DOMs
time difference shifted with hypothesis of down going muons

RMS includes effects of light scattering in ice

All DOM pairs accumulated



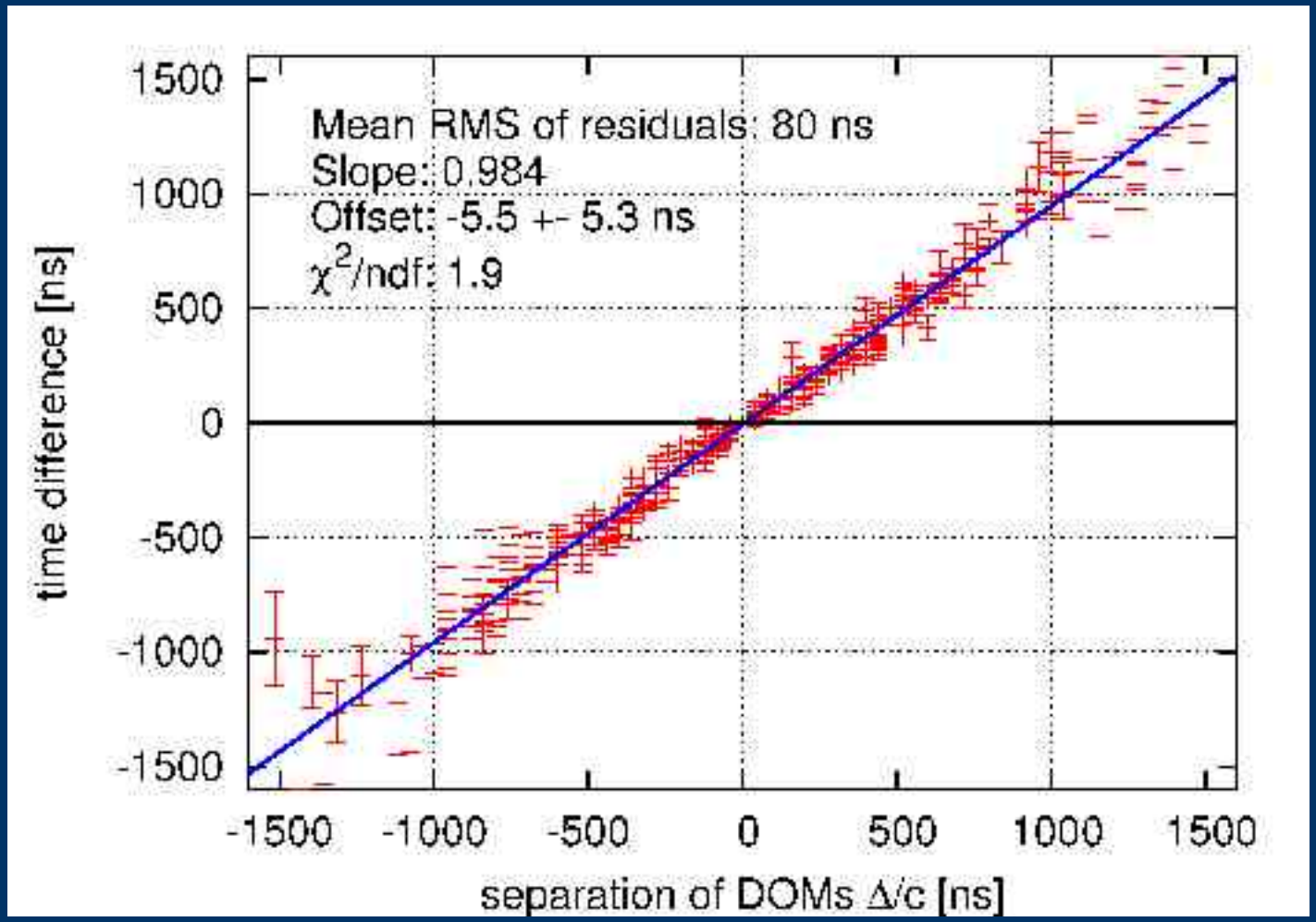


Maximum at 0± 2 ns : ***consistent with down going muon hypothesis***

Asymmetry due to angular distribution of muons

Possible source of "shoulder": ang. dist of muons peaks at ~15 deg

DOM combinations vs separation



Multiplicity => 8

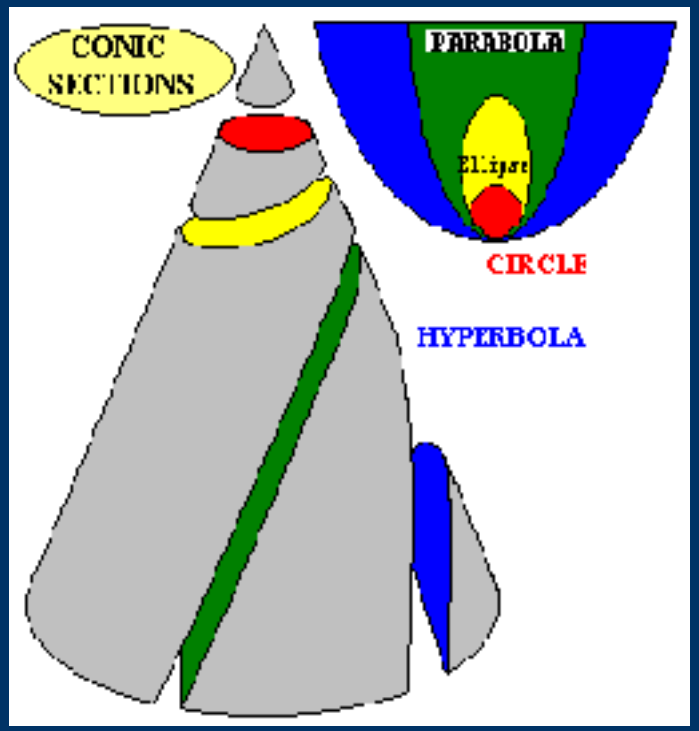
! Clearly down going muons !

Independent cross check of Amanda geometry calibration

Muon reconstruction with a single string

Hyperbola:

$$t = t_0 + \frac{1}{c}\left[(z - z_0)\cos\theta + \sqrt{n^2 - 1}\sqrt{d^2 + (z - z_0)^2 \sin^2\theta}\right]$$



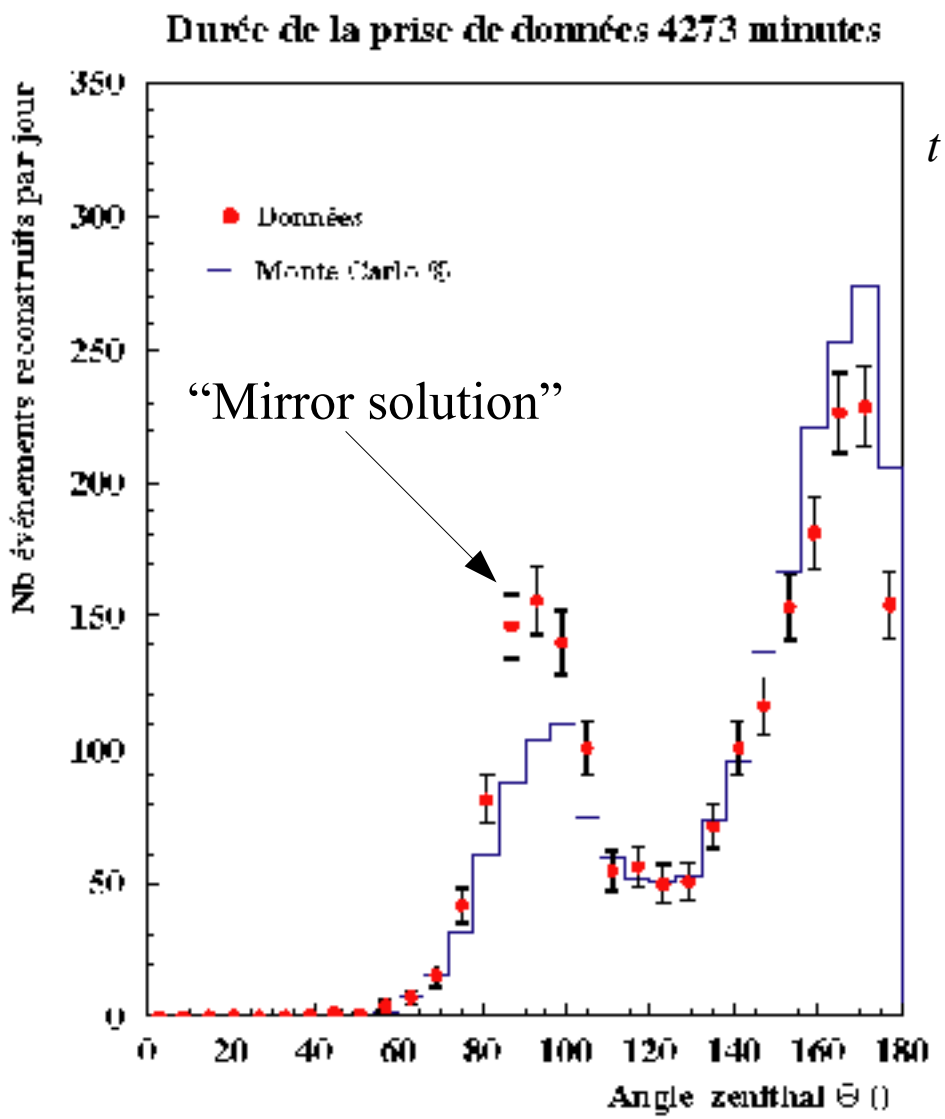
Special case:
section is parallel to symmetry axis:

$$z = \frac{1}{a}\sqrt{d^2 + y^2},\ a = 1/\sqrt{n^2 - 1}$$

$$z \Rightarrow (t - t_0)c - (z - z_0)\cos\theta$$

$$y \Rightarrow (z - z_0)\sin\theta$$

Antares result



$$t = t_0 + \frac{1}{c}\left[(z - z_0)\cos\theta + \sqrt{n^2 - 1}\sqrt{d^2 + (z - z_0)^2 \sin^2\theta}\right]$$

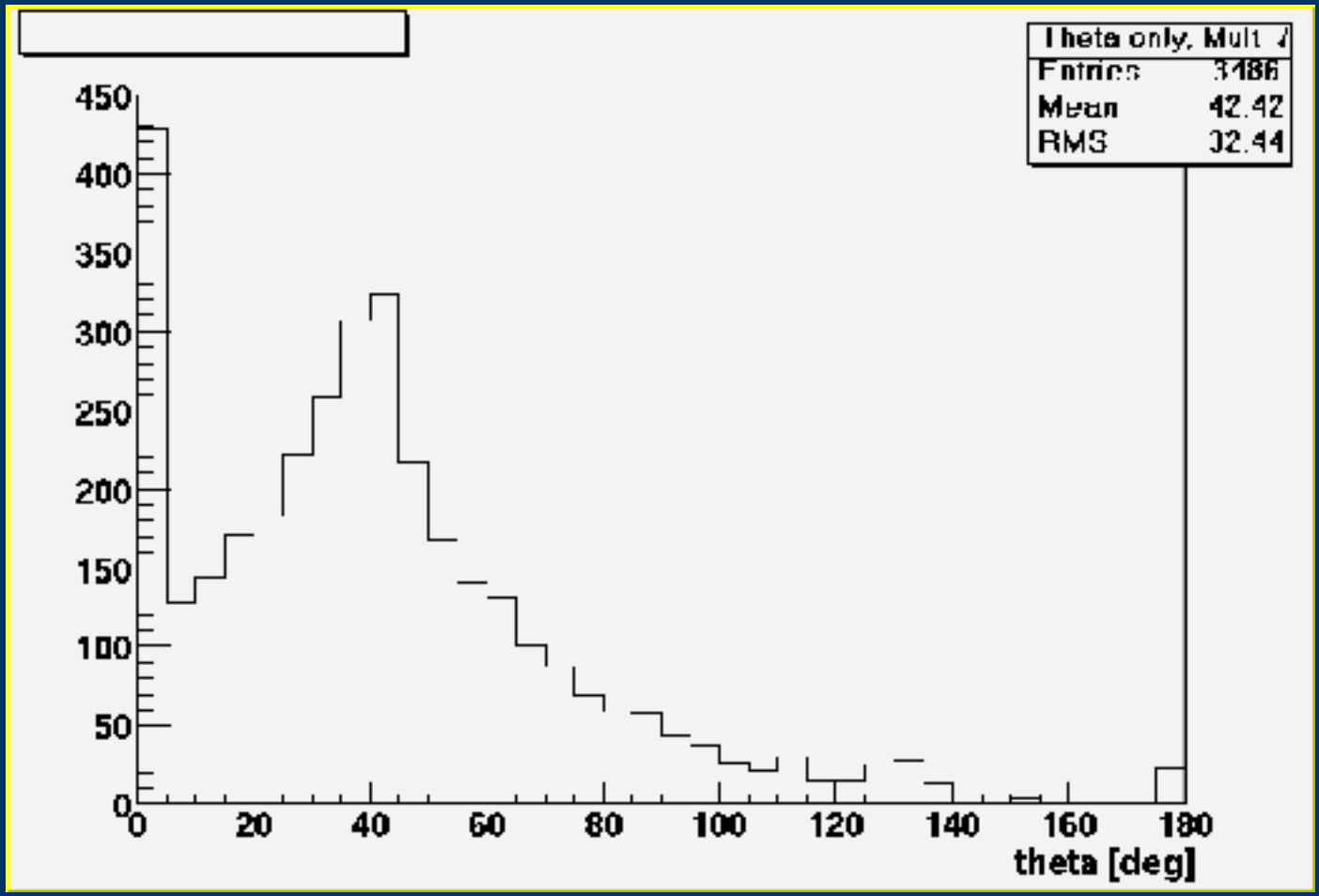
"Starting point" for fit:
$d = 0$

$$c(t_i - t_0) = (z_i - z_0)(\cos\theta + \sqrt{n^2 - 1}\sin\theta)$$

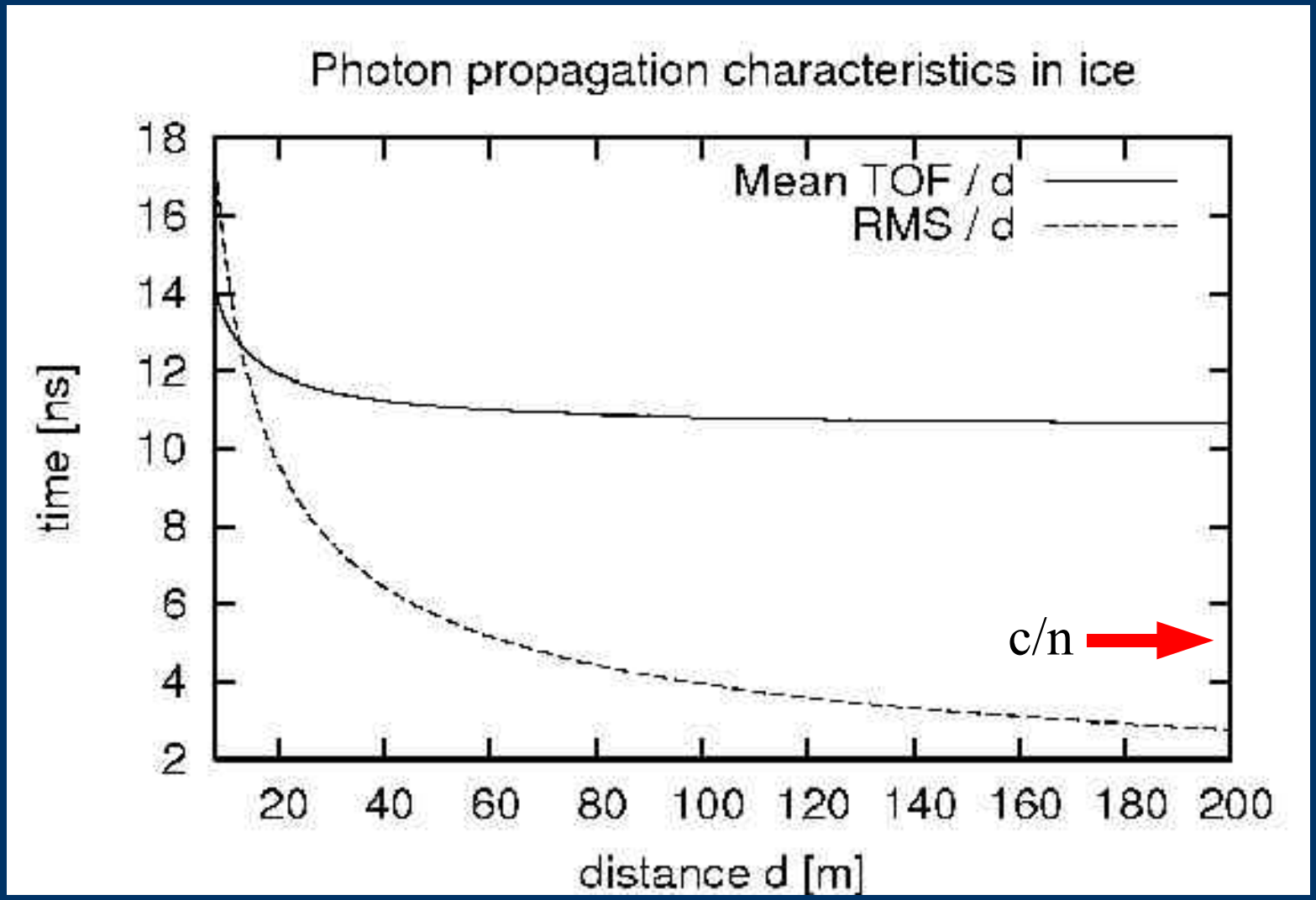
Math is wrong!

But also: Antares only sees light from below (less scattering)
→ only part of track visible

My first attempt

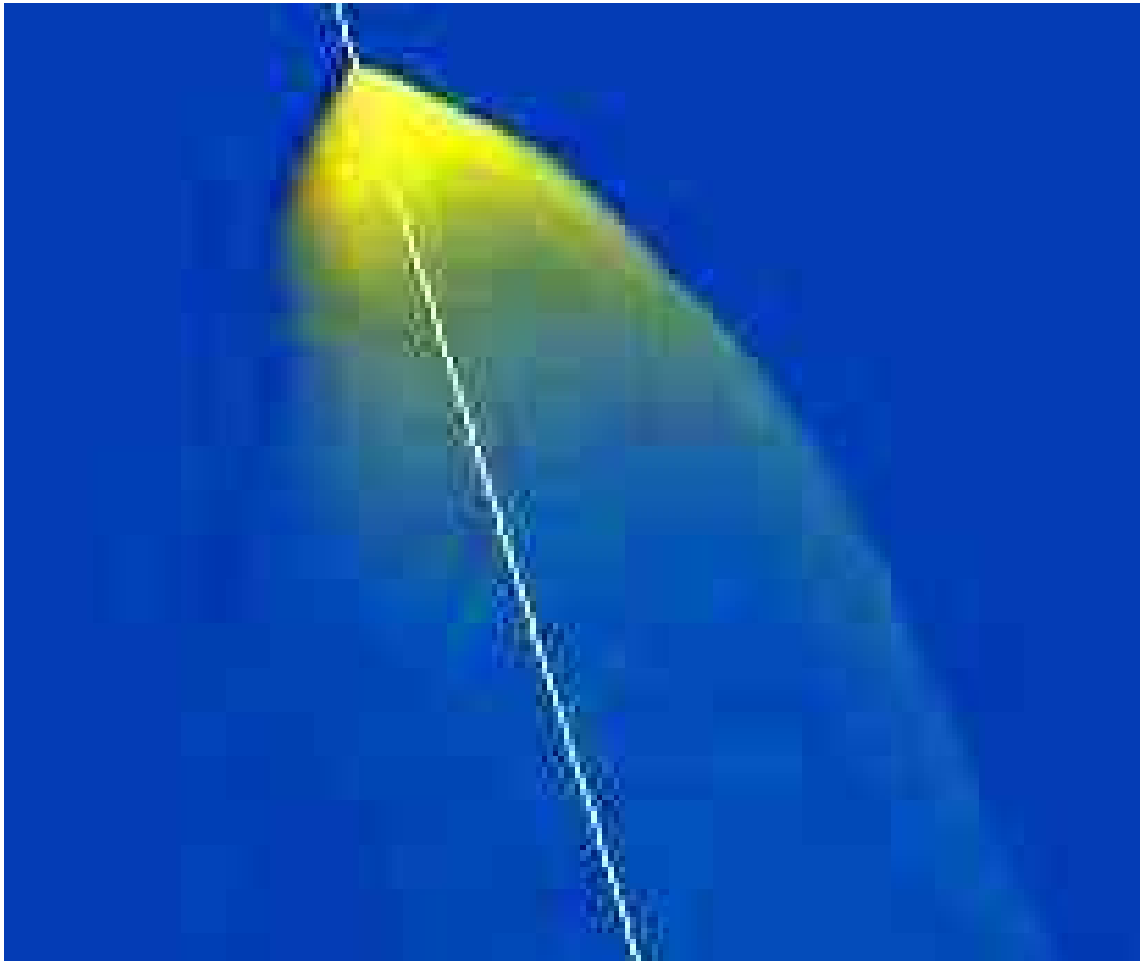


The effective speed of light in ice

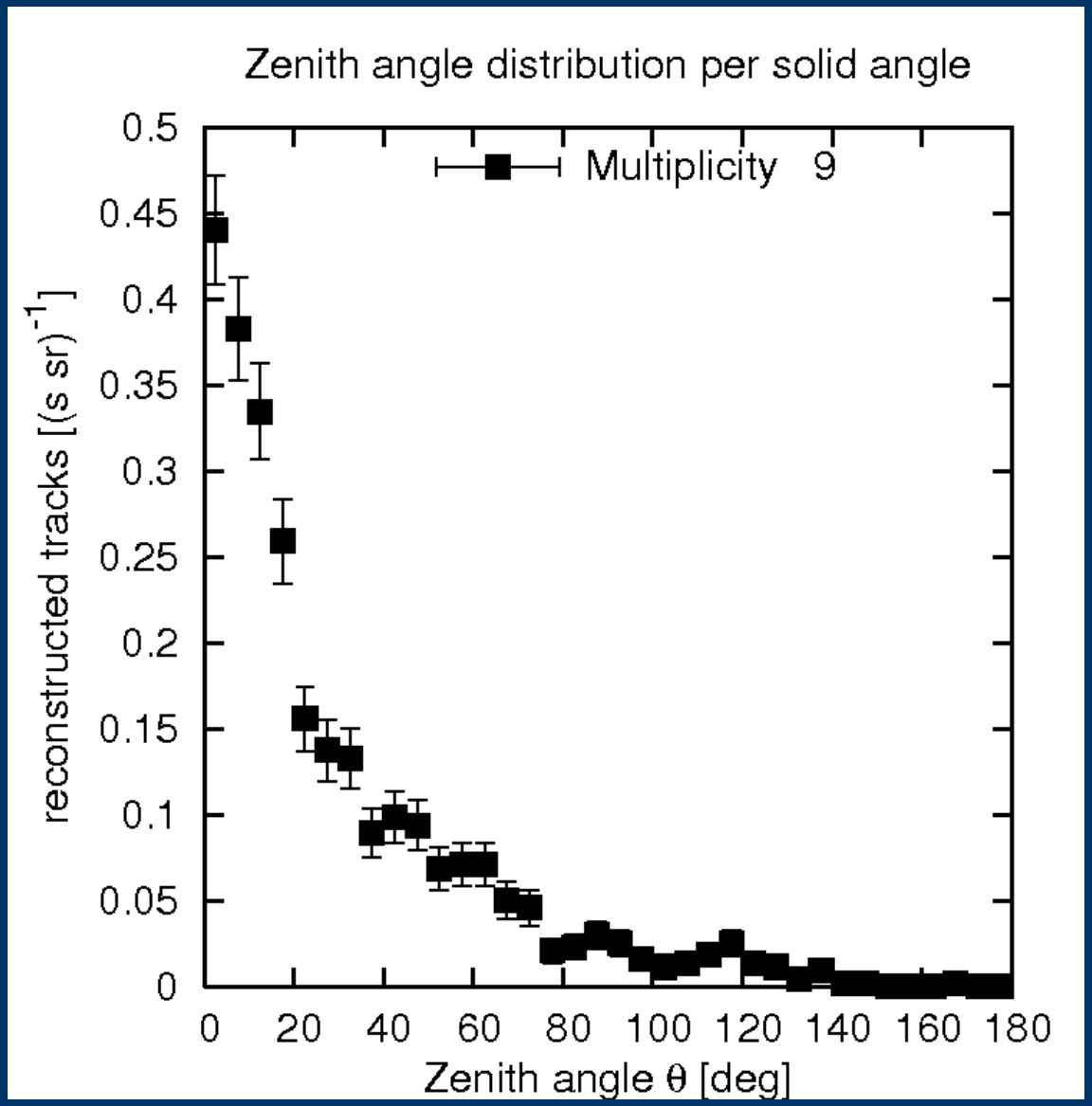


Replace n = 1.32 with n = 3.16 to mimic mean speed

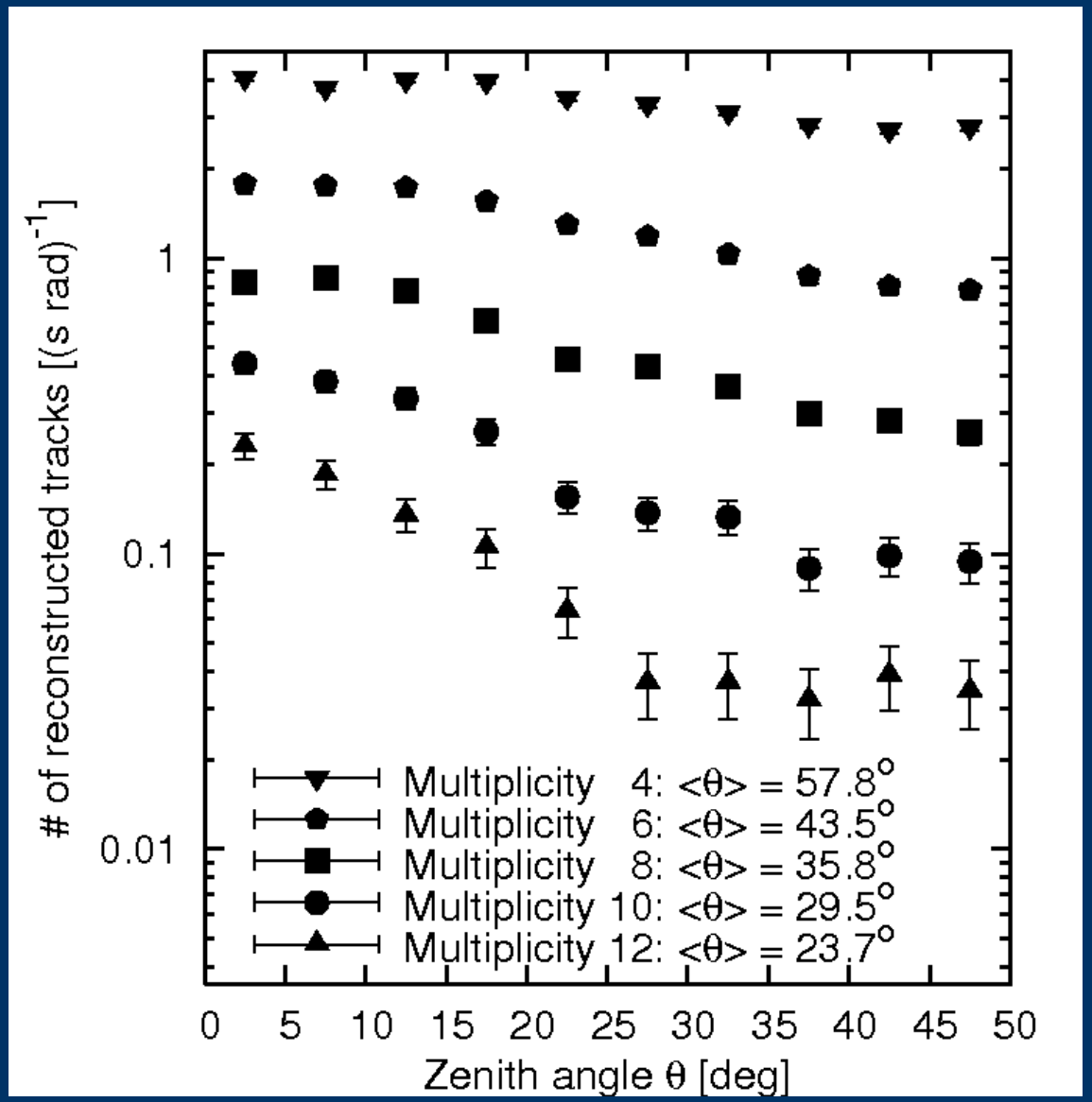
Effect of ice on Cherenkov cone



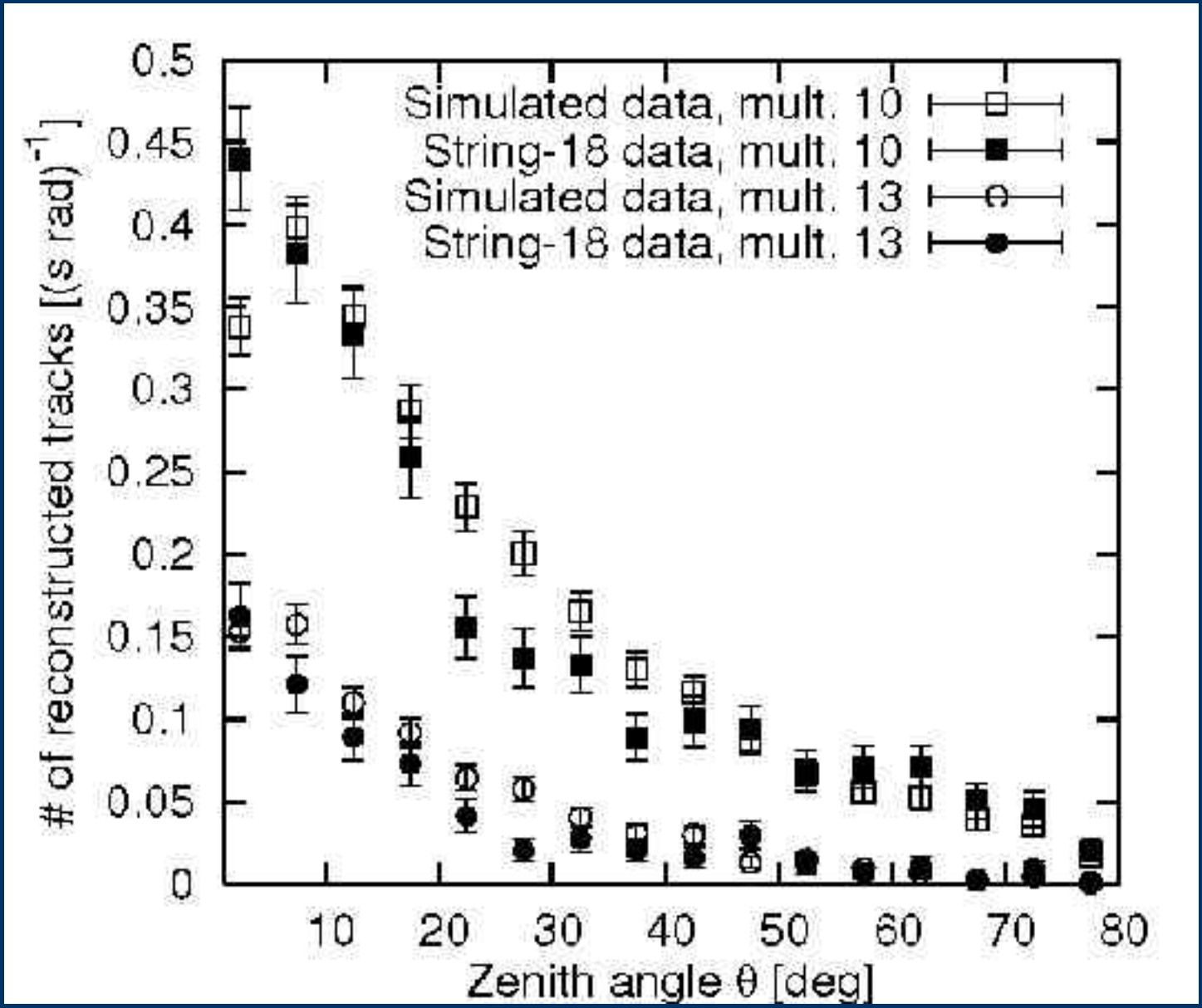
Reconstruction with String-18



Reconstruction: Effect of multiplicity



Comparison with Simulation

Simulation:
- COSIKA
- MMC (Dima)
- AMASIM (reduced to String-18)

Shape and **absolute** rate in excellent agreement!