Calibration of the ANTARES neutrino telescope

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ERLANGEN CENTRE
FOR ASTROPARTICLE
PHYSICS

Outline

- ANTARES neutrino telescope
- Time calibration
- K40 calibration
- Position calibration / Alignment
- Summary

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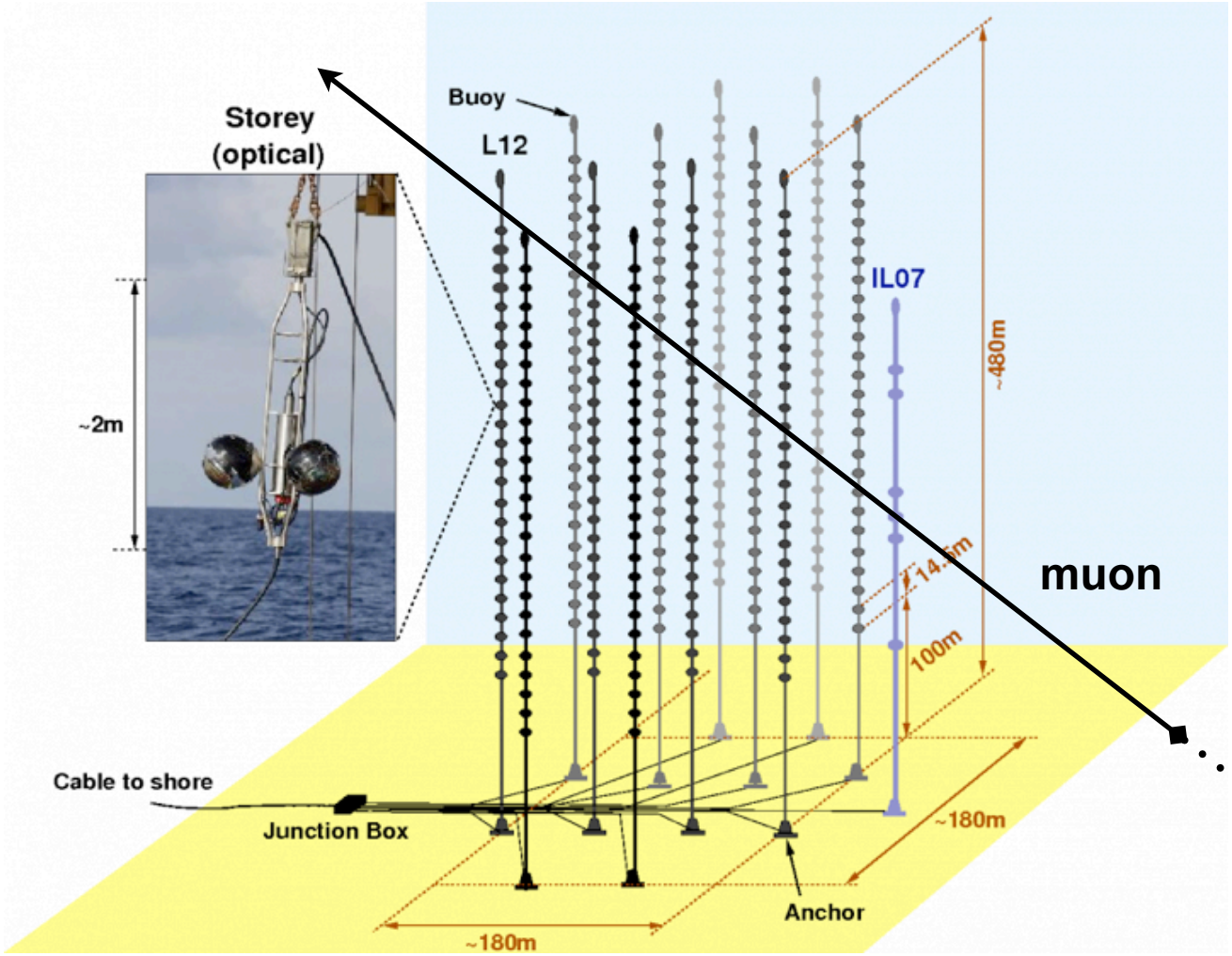
The ANTARES neutrino telescope



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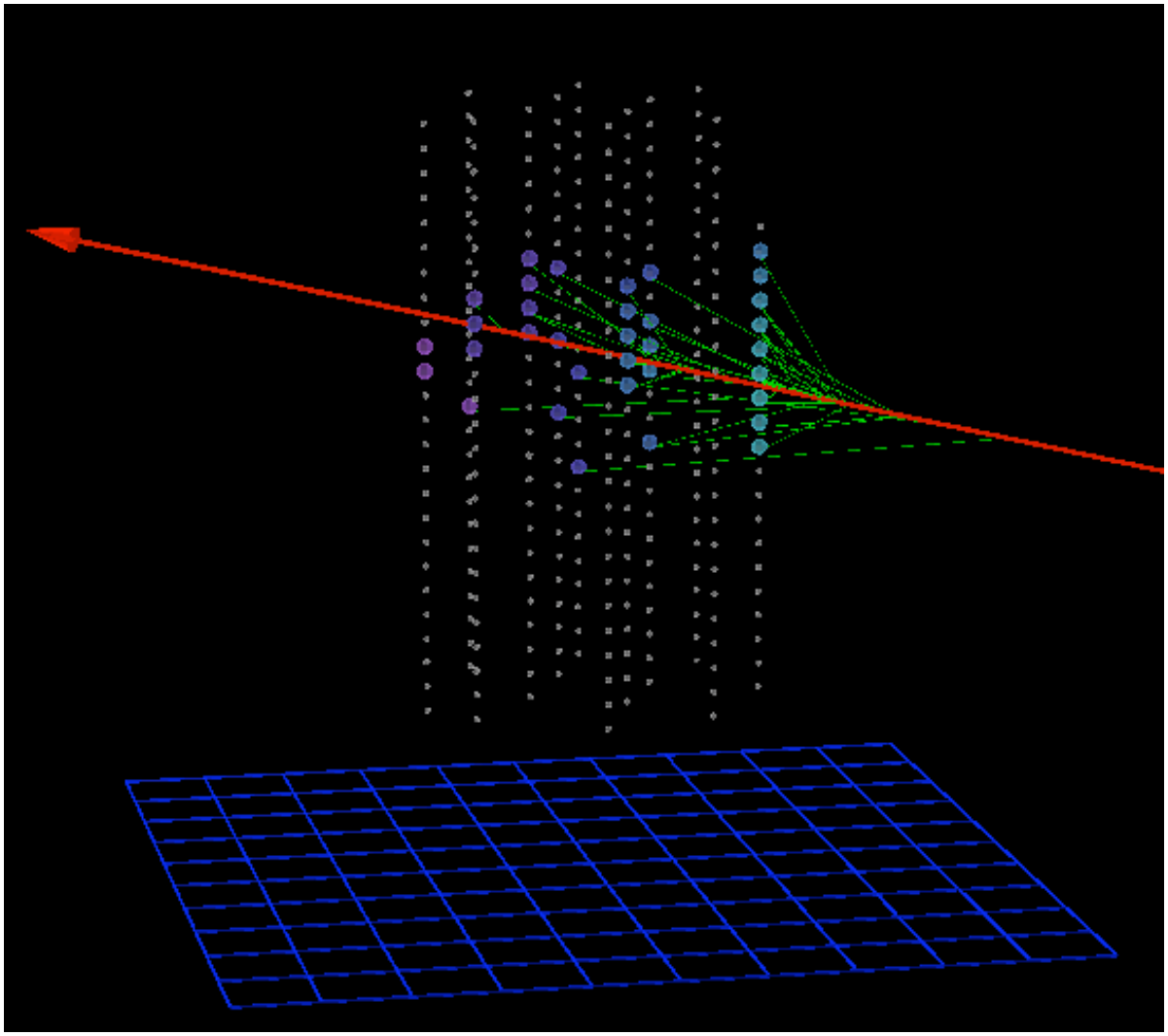
Upgoing live event



Time calibration

need precise relative timing of light arrivals at Photomulitplier tubes

- individual PMT transit time spread

  $\sigma \approx 1.3$ ns

- optical properties of sea water: e.g. scattering

  $\sigma \approx 1.5$ ns for 40m light propagation

- read-out electronics

  $\sigma \approx 0.5$ ns

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Time calibration - Hardware

- Internal clock
- Internal OM LED

transit time evolution for individual PMTs

Agilent HLMP-CB15 LED (blue)

- LED optical beacon (LOB)

36-LEDs on a hexagonal structure

4 LOBs per line (storey 2, 9, 15 and 21)

Hamamatsu H6780-03 PMT inside

- Laser beacon

2 NdYAG lasers with 1ns (FWHM) pulse duration on line 7 and 8

Time calibration - Internal clock

- measure time offsets of each storey
  20 MHz on-shore clock generator
  clock transceiver board in each LCM

  storey answers through same optical fiber
  in situ measurements every 4 h show a stable resolution of 100 ps

- address absolute event time (from GPS) with 100 µs accuracy

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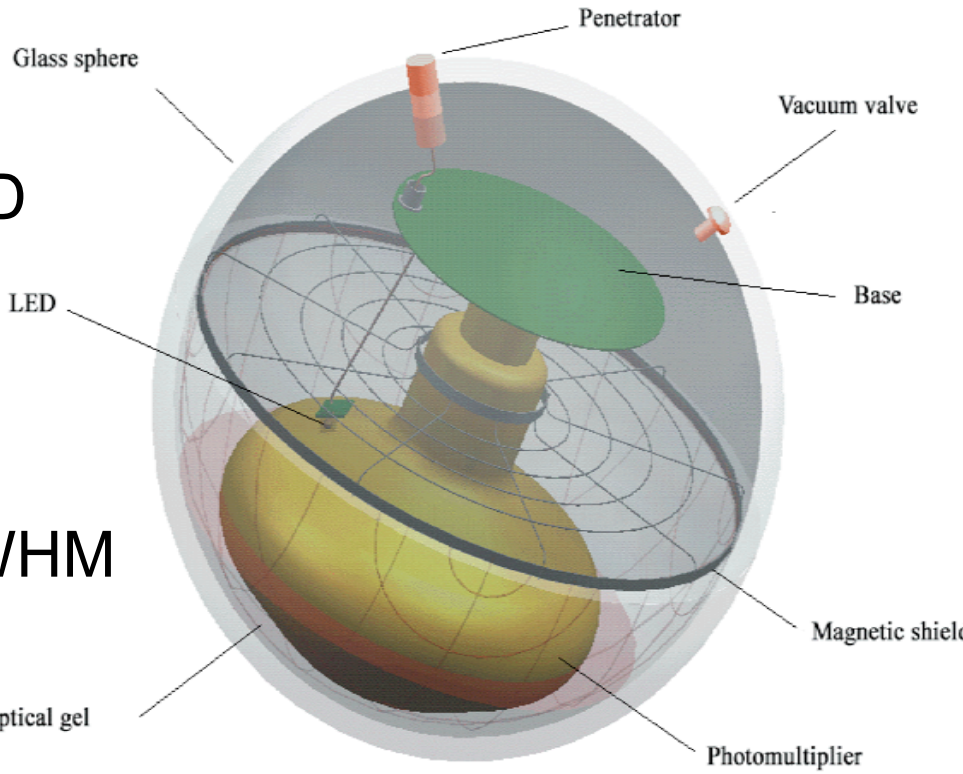
Time calibration - Internal OM LED

- monitor transit time spread/stability for individual PMT
- Agilent HLMP-CB15 LED illuminating the back of the photocathode
- peak 470 nm, 15 nm FWHM



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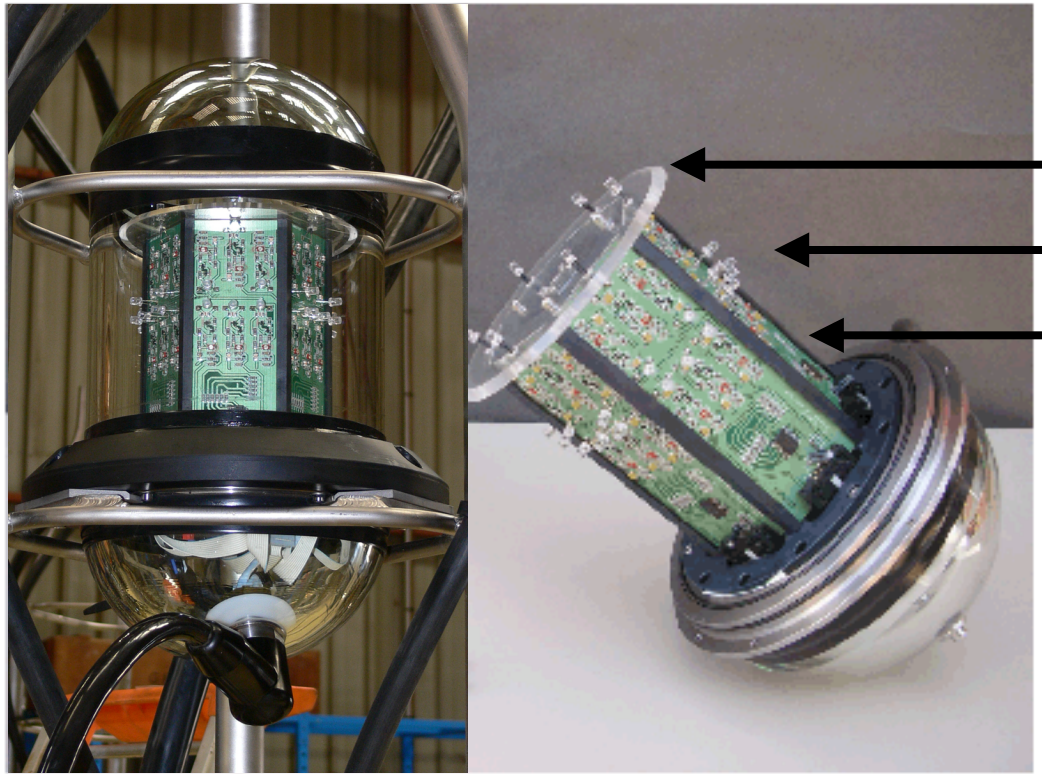
Time calibration - LED optical beacon (LOB)



- 36 LEDs per beacon (synchronised to better than 0.1 ns)
- 4 LOBs per ANTARES line (2, 9, 15, 21)
- Hamamatsu H6780-03 PMT inside

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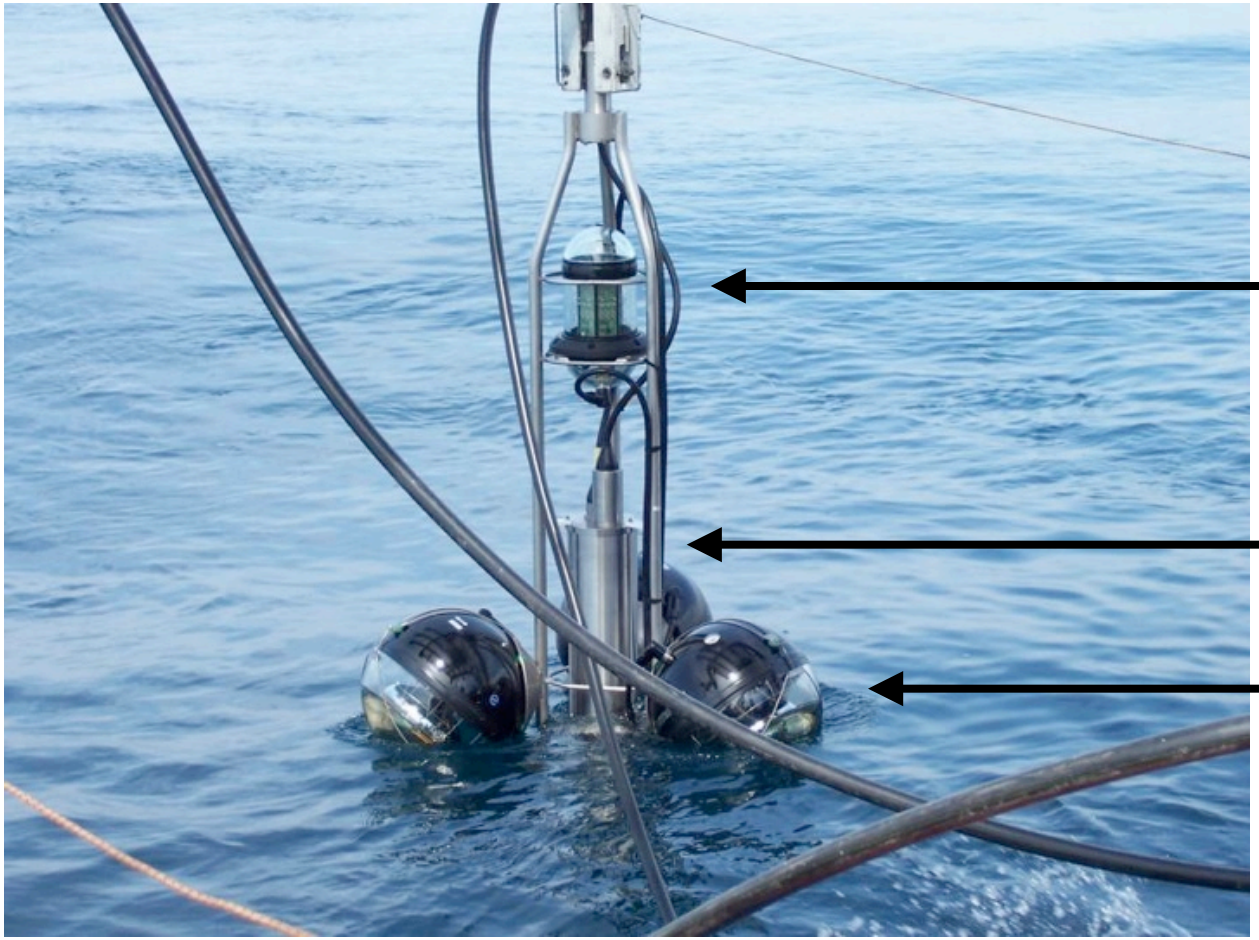
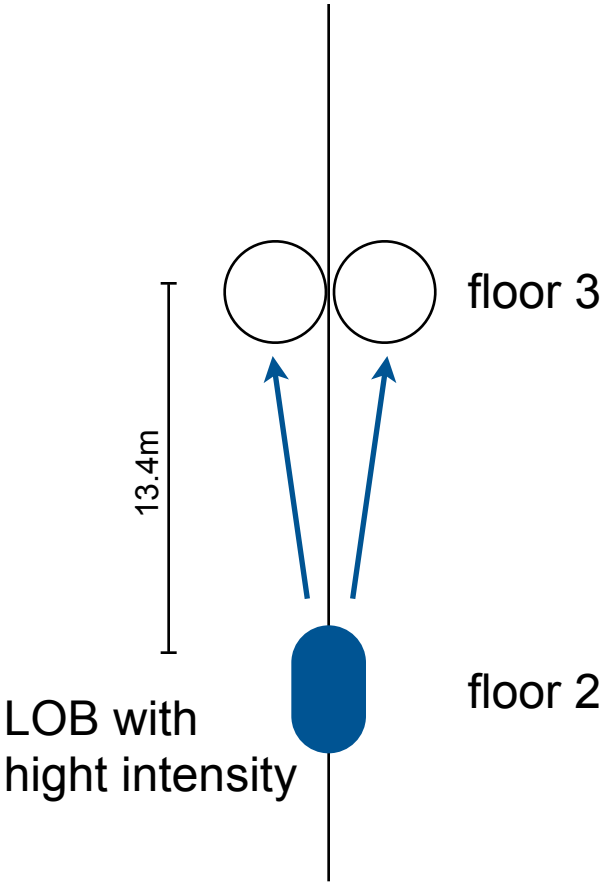
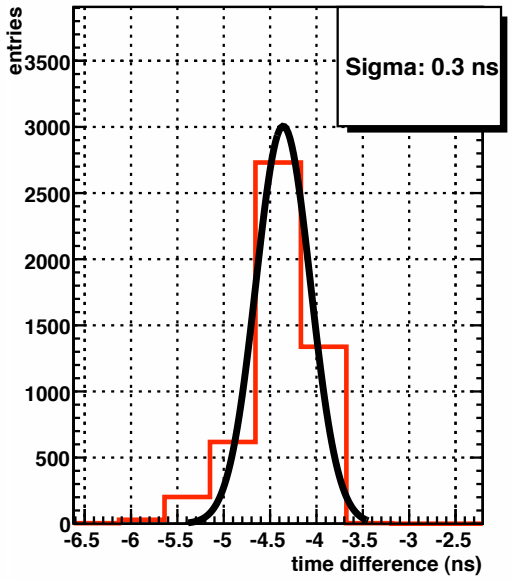
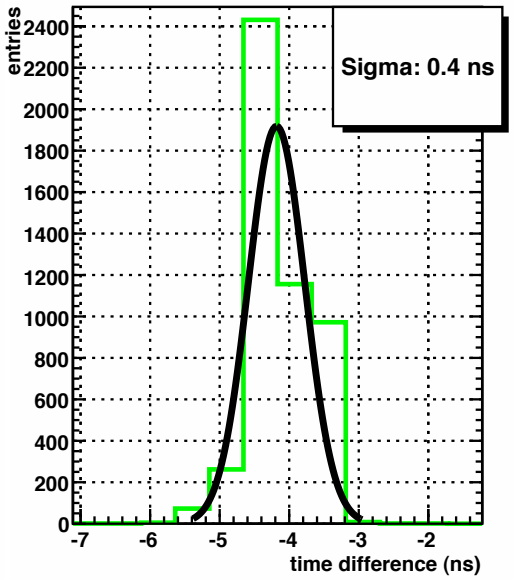
Time calibration - LED optical beacon (LOB)



Arrival time distribution after LOB flashing







neglect geometry, light scattering, pulse walk, transit time

$\sigma^2 = \sigma^2_{TTS}/N_{pe} + \sigma^2_{water}/N_{pe} + \sigma^2_{electronics}$

read-out electronics contributes with 0.4 ns

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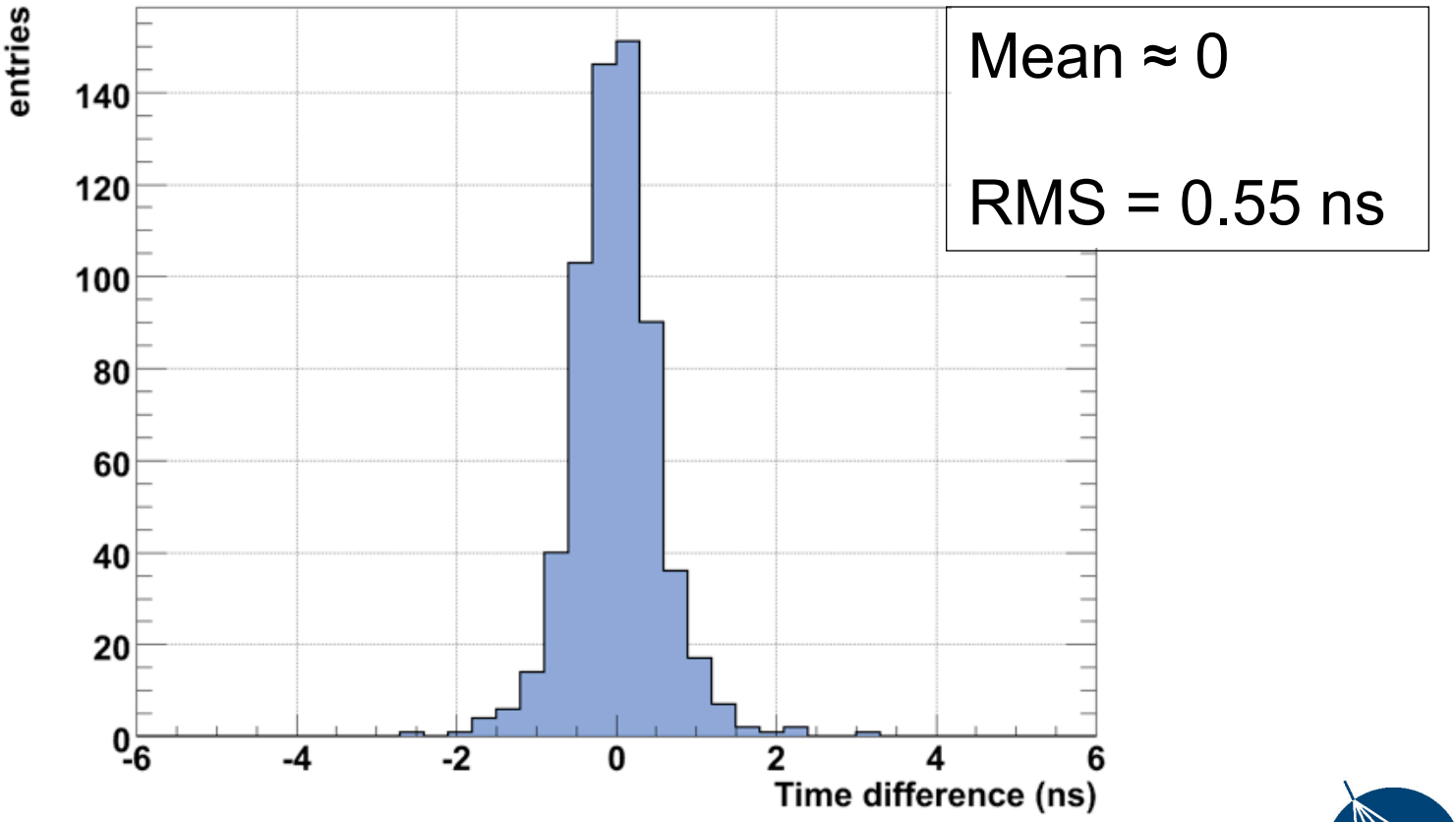
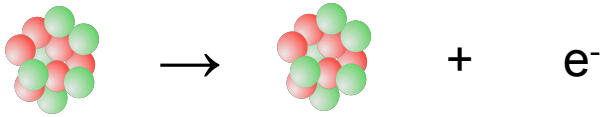
ARS T0 correction

Line 1 - 12 interstorey OM-OM time difference



K40 calibration



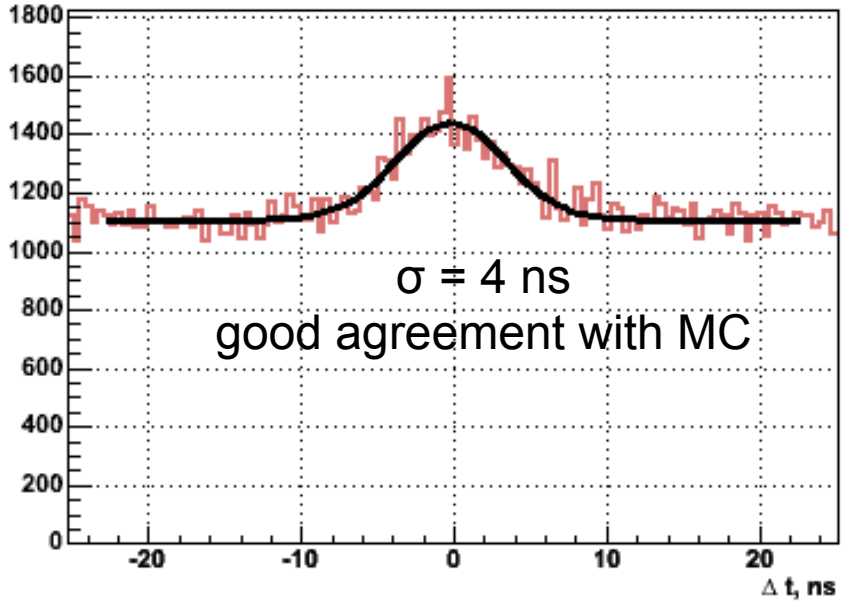
K-40 → Ca + e^-

K-40 stable concentration

Ca

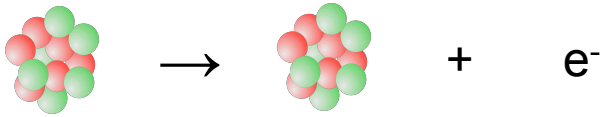
150 Cherenkov photons

OM-OM time difference



- special local trigger (20 min of data, once a week)
- coincidence rate from integral of events using Gaussian fit → monitor OM efficiencies
- check ARS T0 calibration from monitoring peak offset

K40 calibration



K-40 stable concentration

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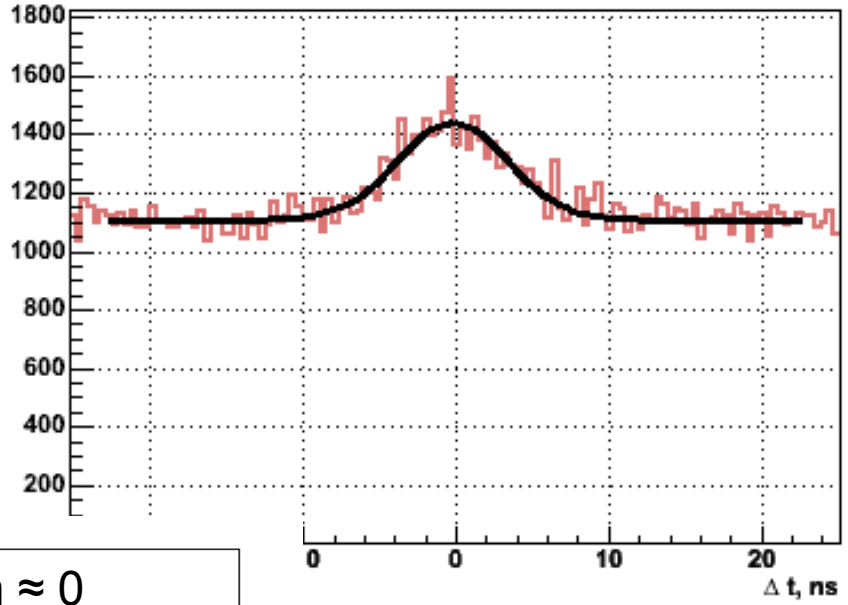

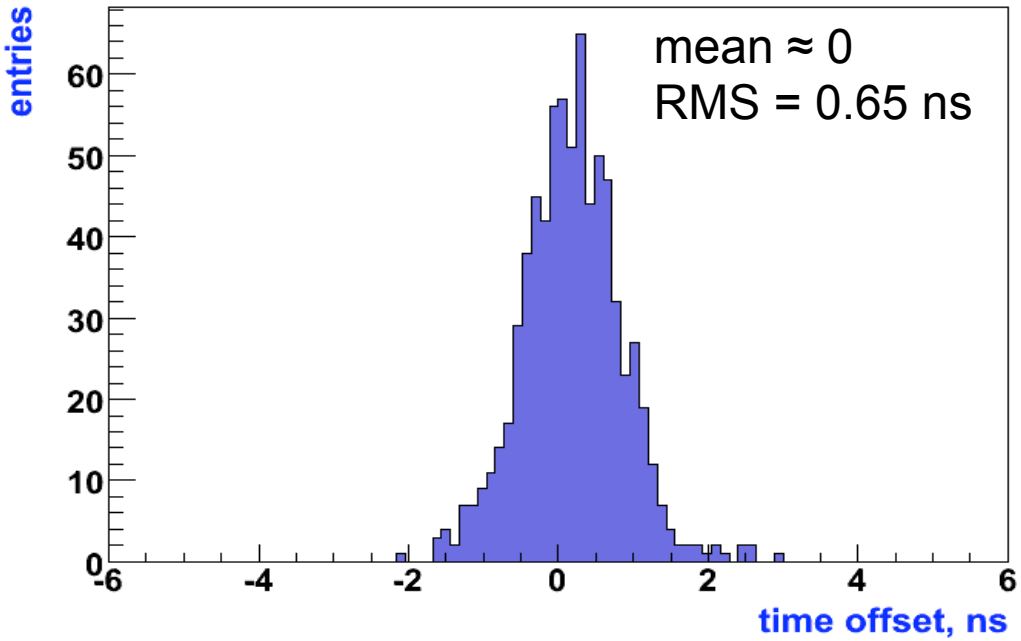

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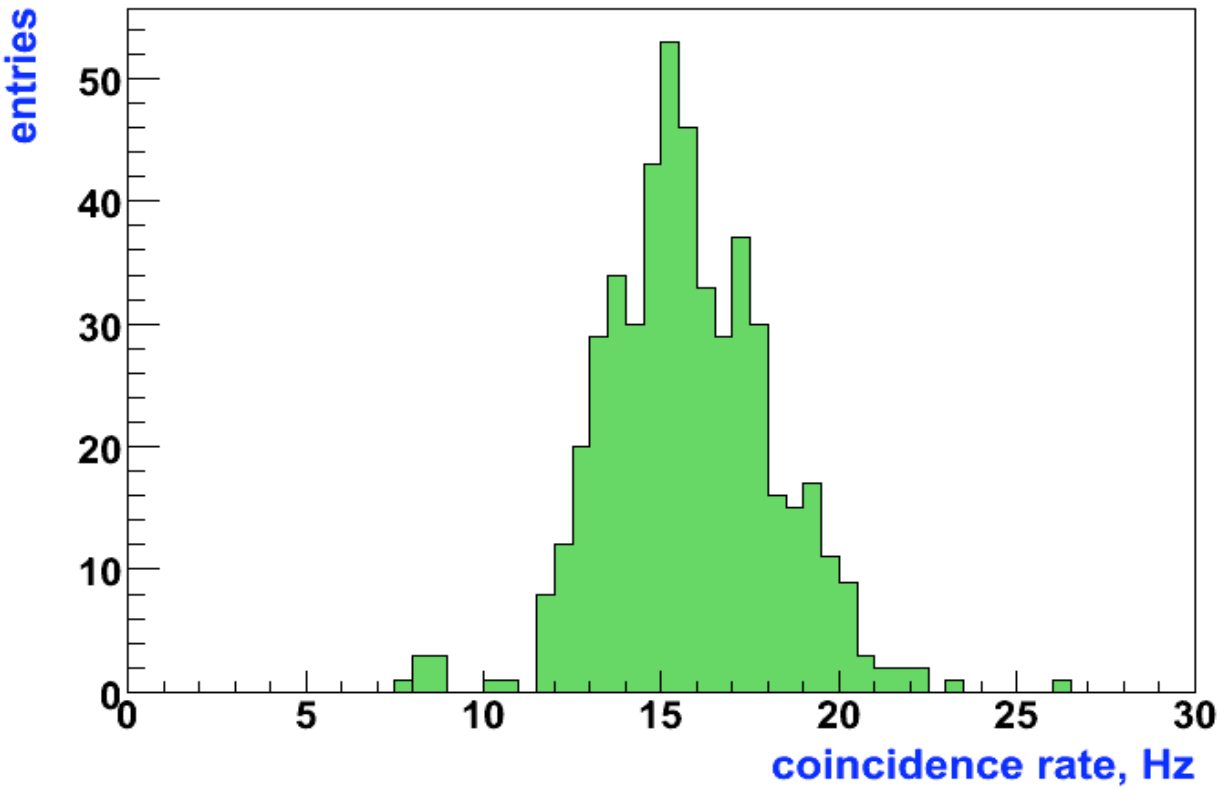
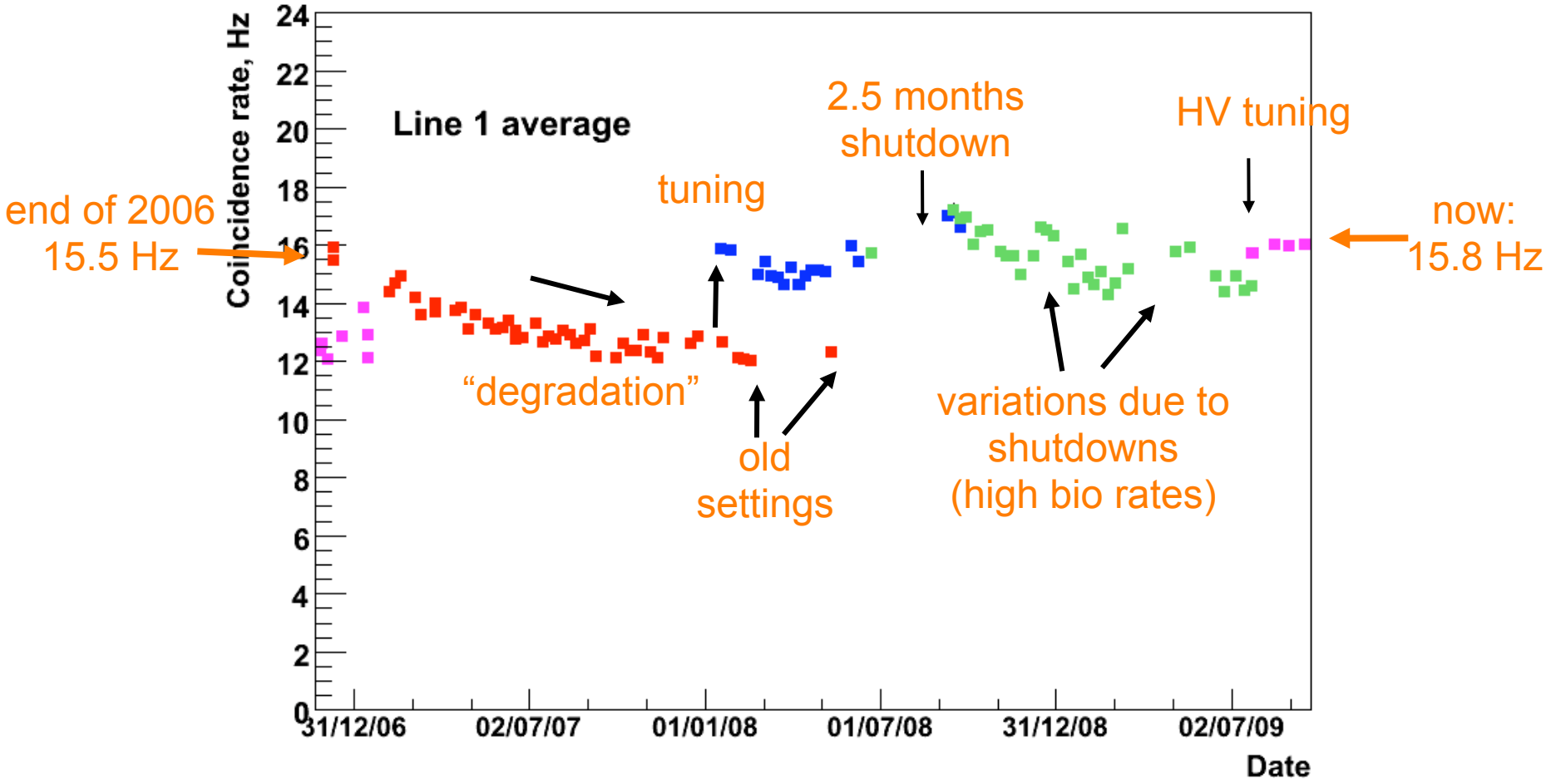
K40 coincidence rate



- mean 15.8 Hz, RMS 2.4 Hz
- no dependence on bioluminescense
- corresponding to 10% OM efficiency spread

K40 coincidence rate - time dependence



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Position calibration - Hardware

per line

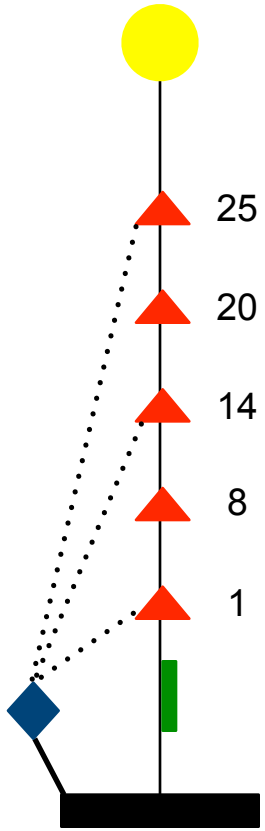
- 5 receiver hydrophones
- 1 receiver/emitter hydrophone
  40-60 kHz, attenuation length 0.7-1 km

2 sound velocimeters

- connected to conductivity,
  temperature and pressure probes

per storey

- compass ↔ heading
- tiltmeter ↔ 2 local tilts



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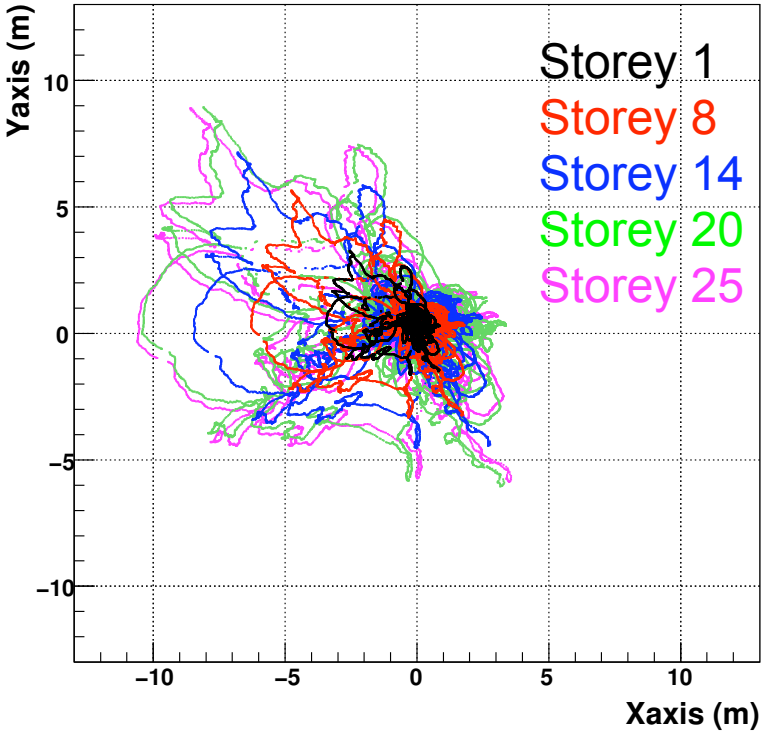
Relative positioning

- triangulation of hydrophone positions (5 storeys) every 2 minutes
- perform a fit on line shape to obtain positions of remaining storeys

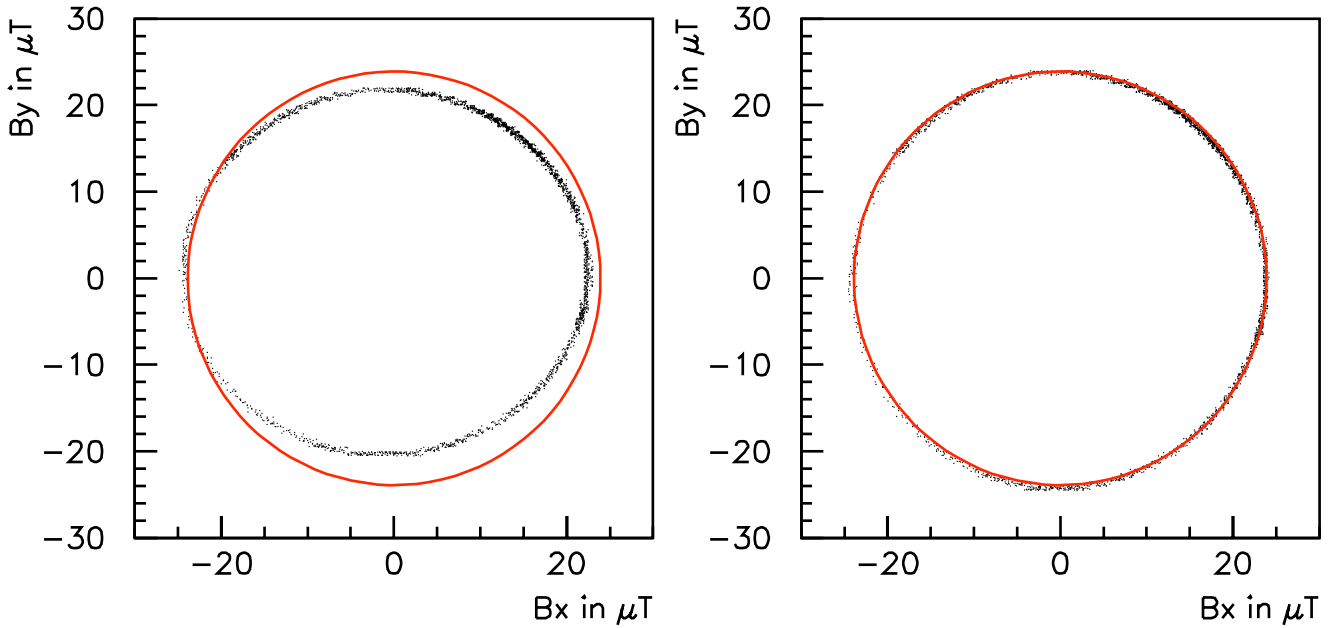


Tiltmeter/Compass system (TCS)

- TCM 2 and TCM 2.5 cards from PNI Sensor Corporation on each storey
- measurement of 2-axis tilt with 0.2° accuracy and 0.1° resolution for pitch and roll
- measurement of heading with 0.8° accuracy
- measurement of B-Field with 0.05 μT accuracy

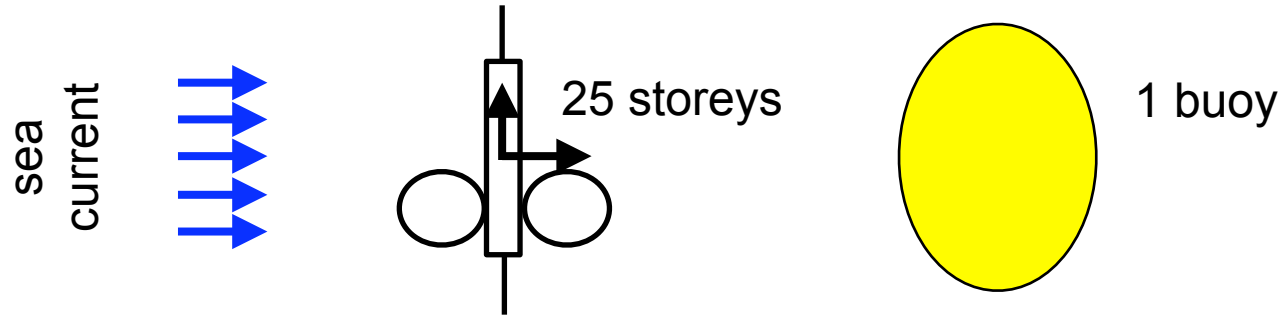
Calibration of TCS

- B-field at the ANTARES site B_x = 0,06 µT, B_y = 24 µT
- B-fields from electronic container, miscalibration in lab



Line shape model

- buoyancy, drag forces of detector elements



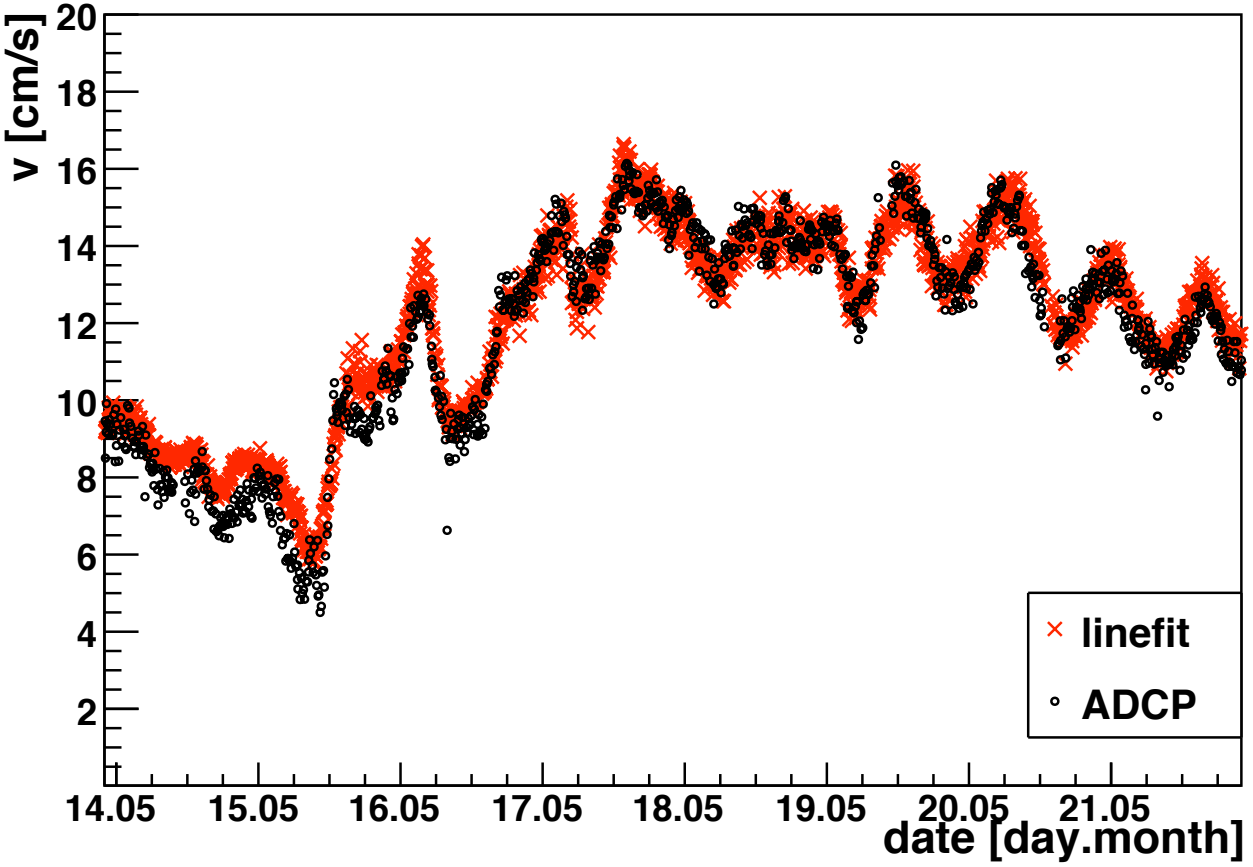
- radial displacement at height z, current velocity v

$R(z,v) = c_1 z v^2 + c_2 v^2 \ln(1 - c_3 z)$

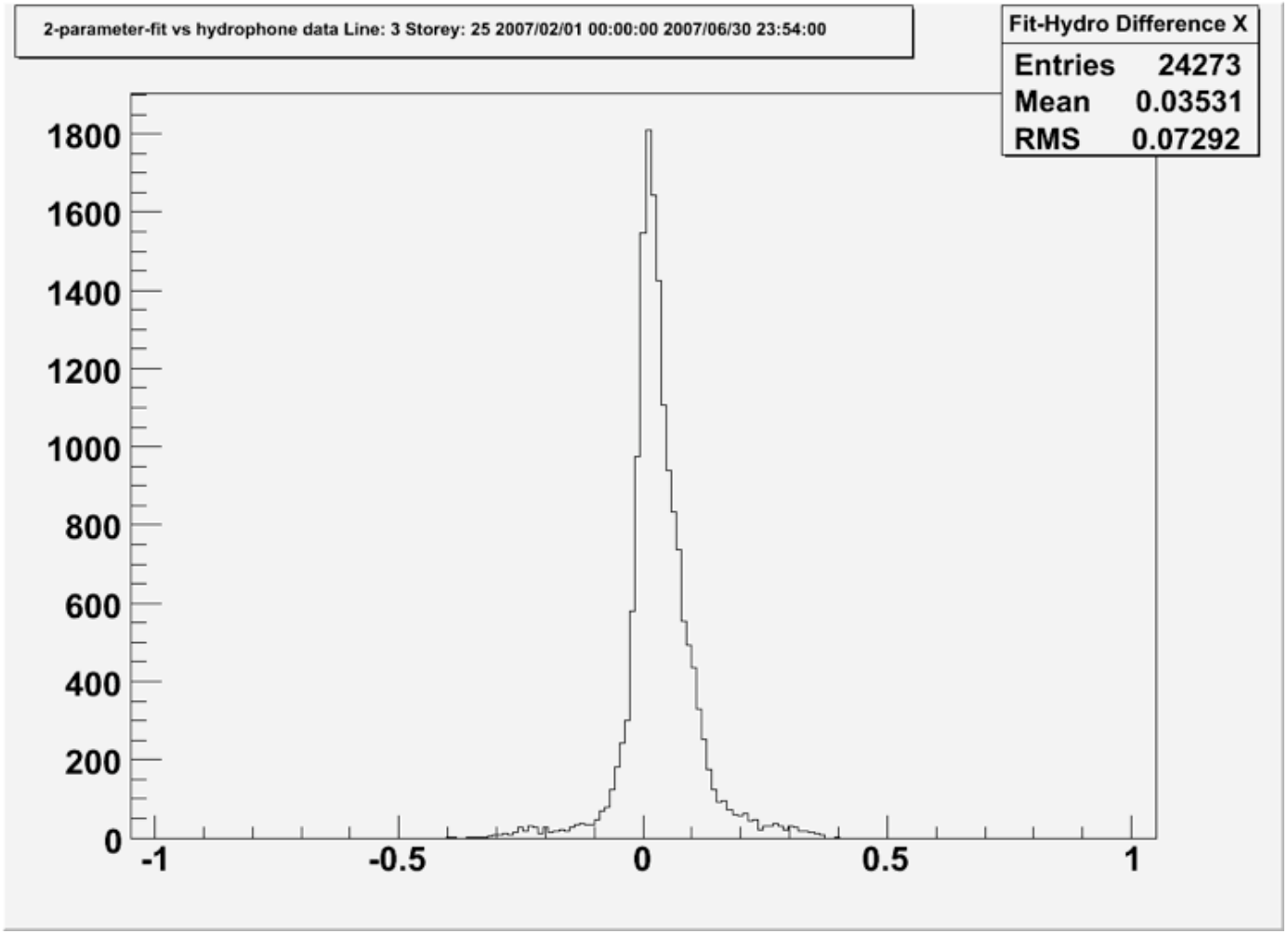
5 cm/s → 1 m, 12 cm/s → 5 m, 30 cm/s → 30 m

- performing χ^2 fit and obtain v_x and v_y from fit

Comparison with Acoustic Doppler Current Profiler (ADCP)



Accuracy



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Summary

- Time calibration done monthly with a set of Optical Beacons is in good agreement with the K40 analysis.
- Desired precision of electronics (< 0.5 ns) to the overall time resolution is achieved.
- Detector homogeneity: 10% spread in OM efficiency.
- Positioning (every 2 min): Alignment is able to reconstruct positions within 10-20 cm.

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Thank you very much!

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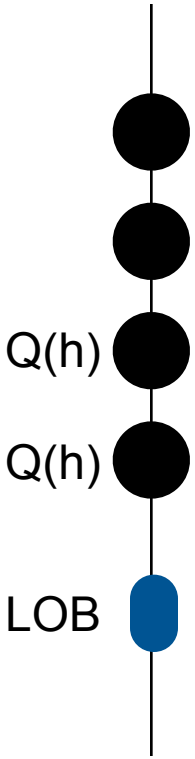
Backup

Attenuation length

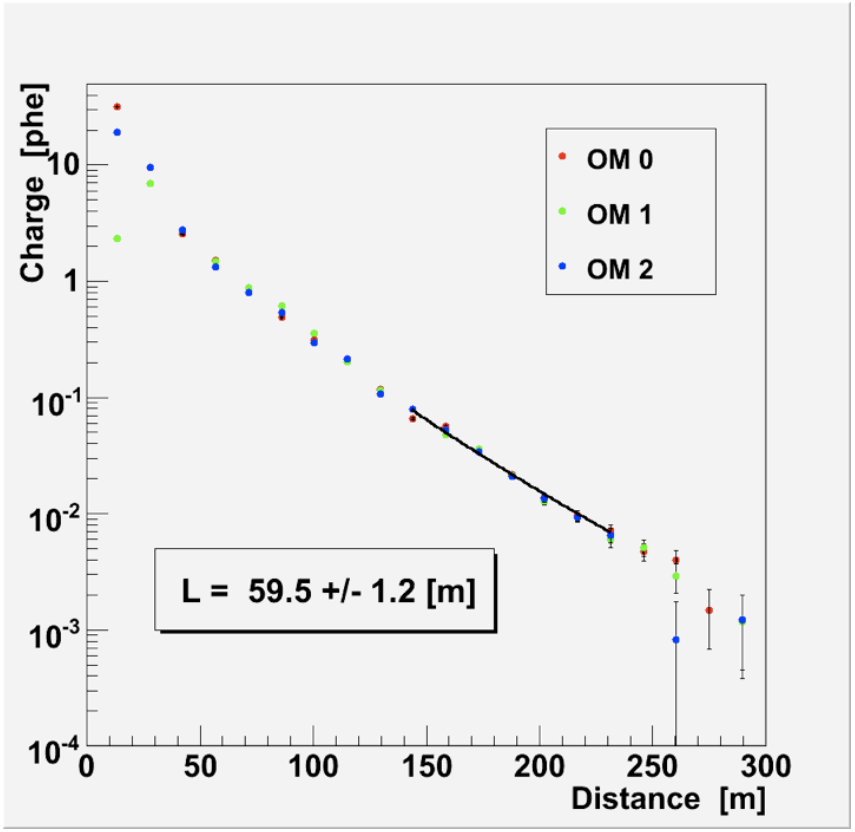
Measure Q(h) and fit with $Q(h) = Q_0/R^2 \exp(-R/L)$



Choose range

R_{min}:
to avoid ARS dead time

R_{max}:
hits are compatible
with noise fluctuations



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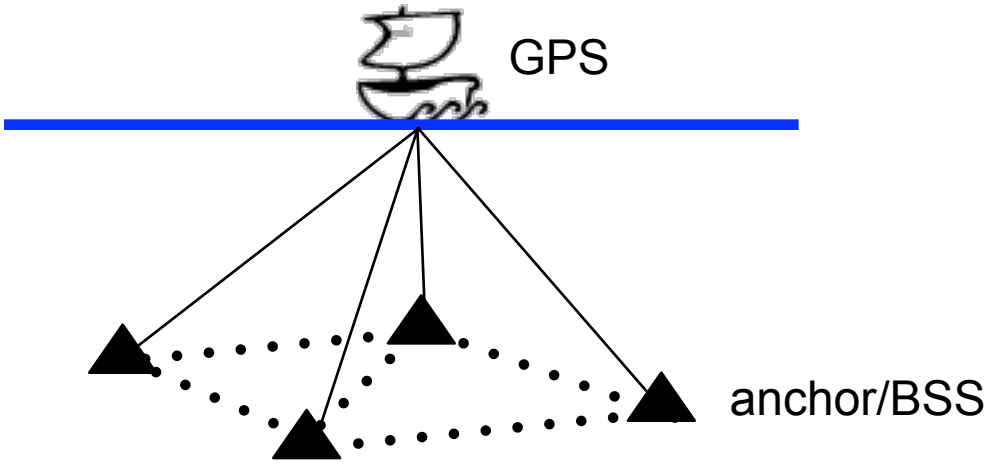
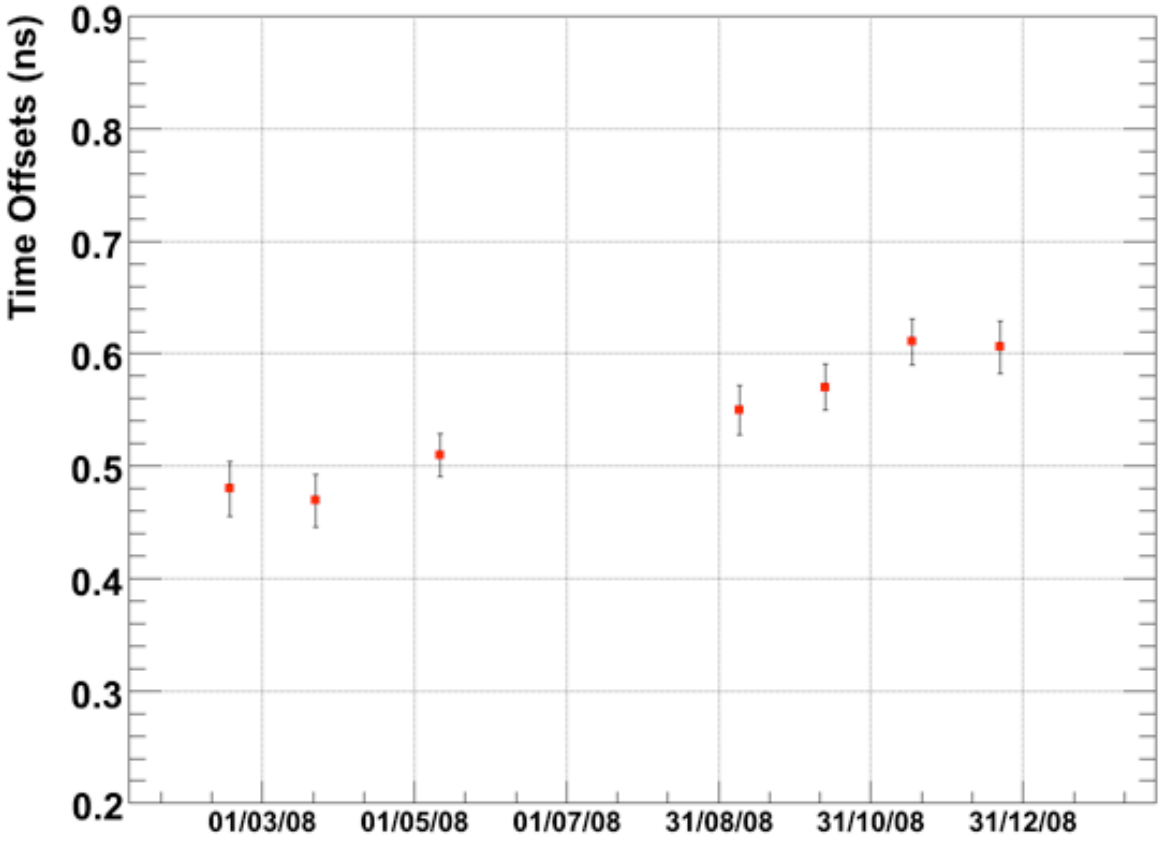
Absolute positioning

- anchor positions obtained by LFLBL measurement within 1m accuracy after deployment.



- using HFLBL measurements positions are recalculated within 1cm accuracy.

Stability of ARS T0



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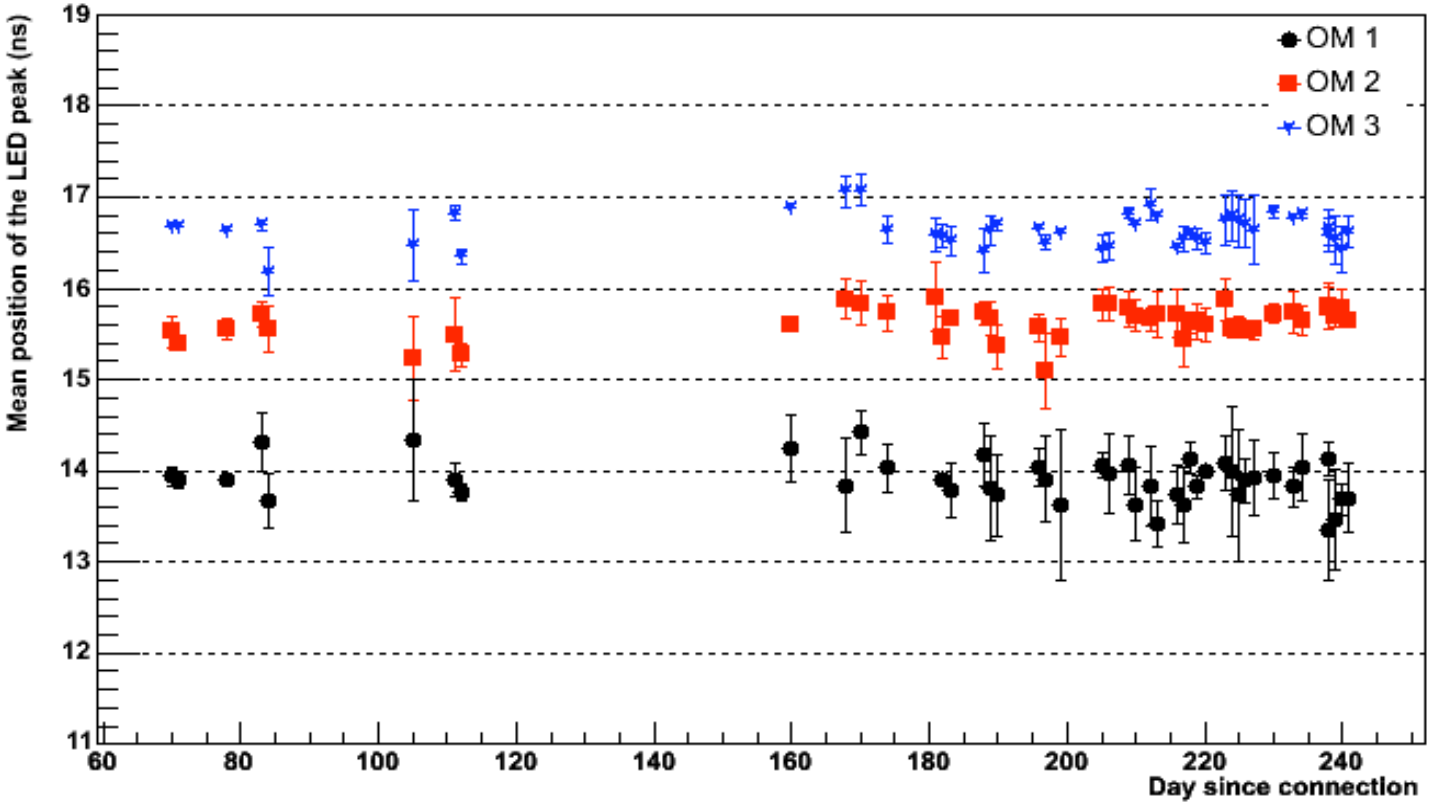
Time calibration - Internal OM LED



stable within 0.5 ns

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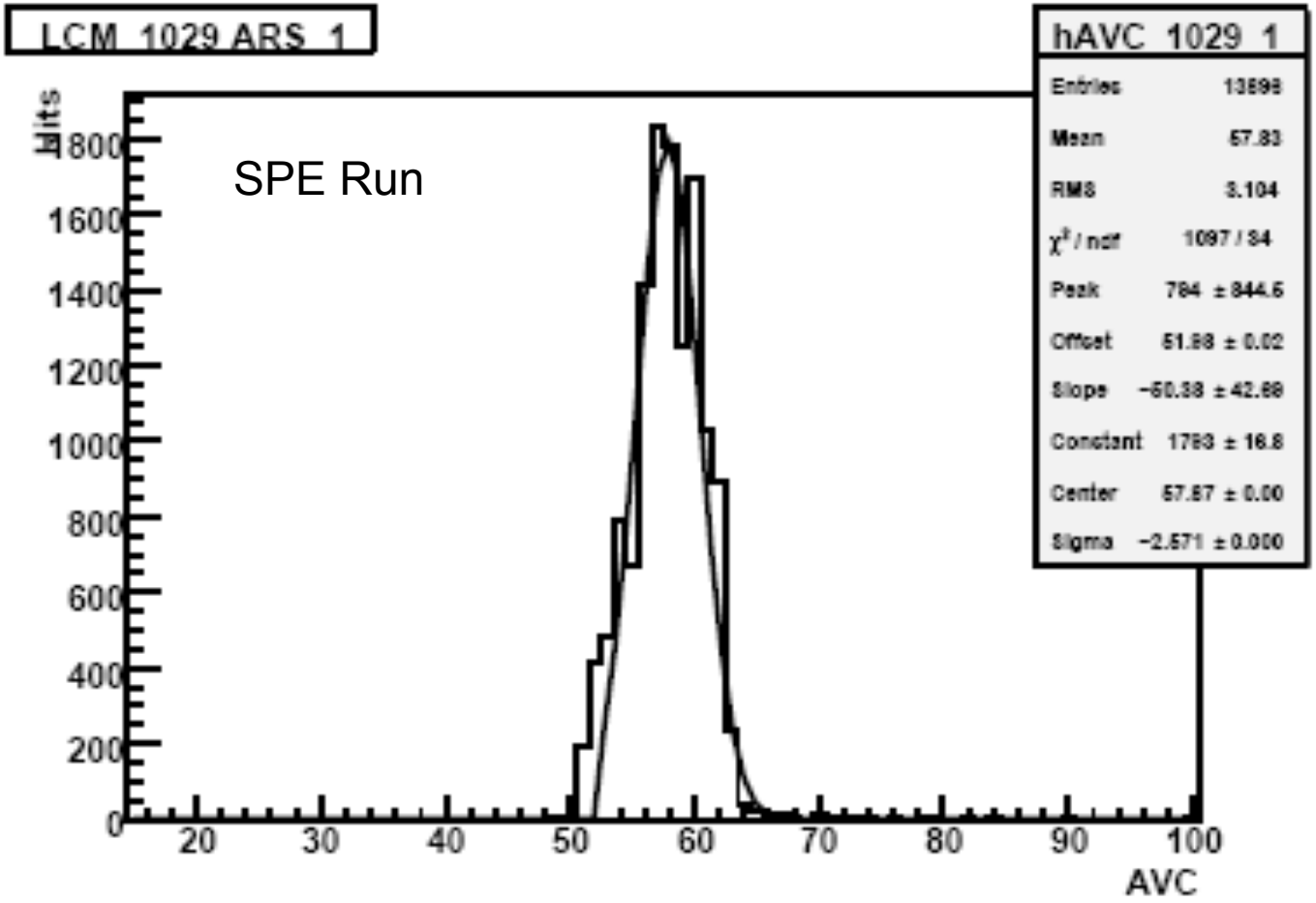
Charge calibration



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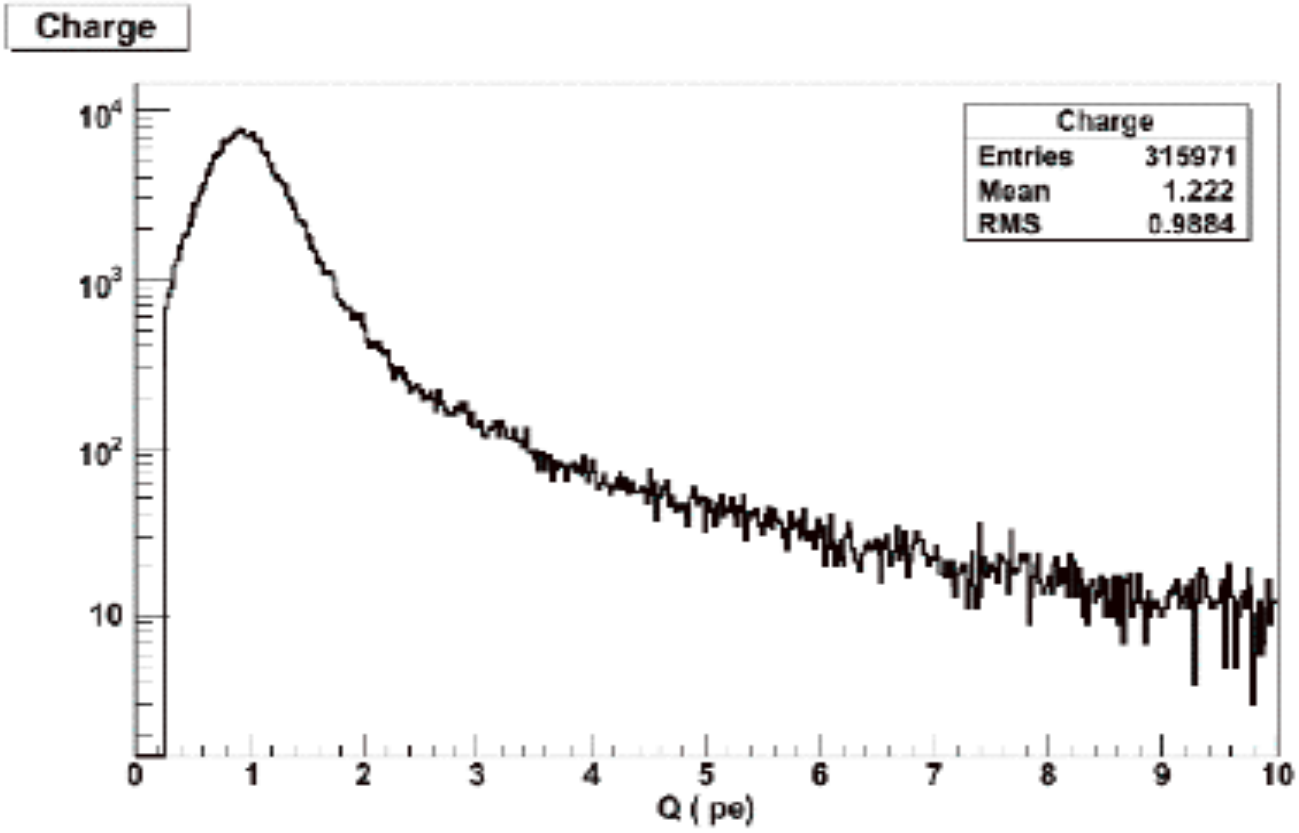

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