PSF and pointing accuracy

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Overview

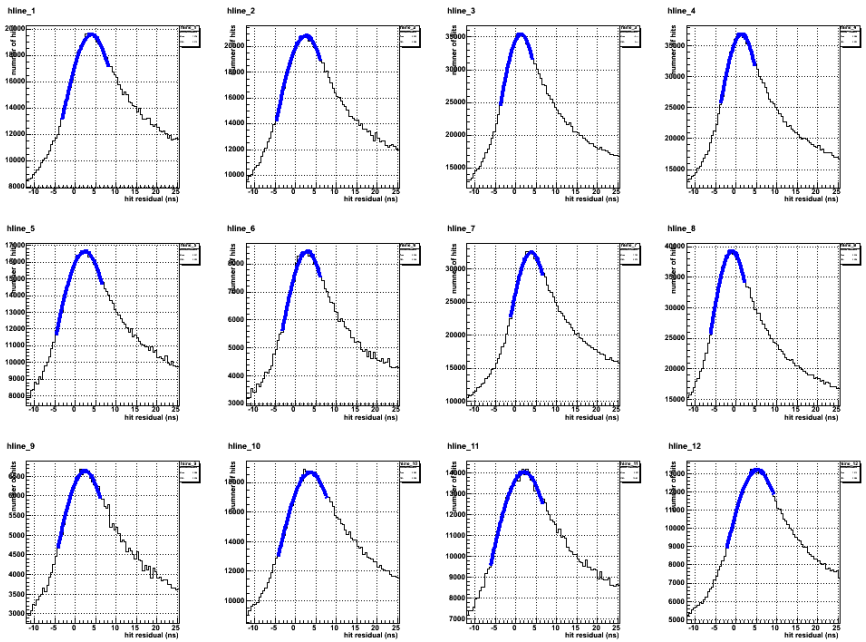
- Timing
- Absolute positioning
- Sea current
- Detector alignment
- Moon shadow
- Surface array
- Split event
- 2ns smearing

PSF

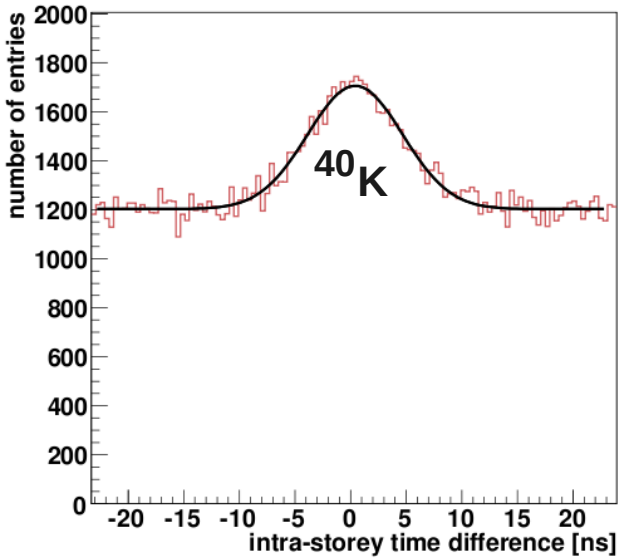
Timing

LCM to shore	intra storey	intra line	intra line	inter line	inter line	**Overall**
clock phase	40K	dark room testbench	LED becons	multi line events	LASER beacon	
0.1ns	0.6ns	0.6ns	0.3ns	0.5ns	0.5ns	**1ns**
				analysis ongoing (~1ns now)		**1.5ns**

Time residuals for each line

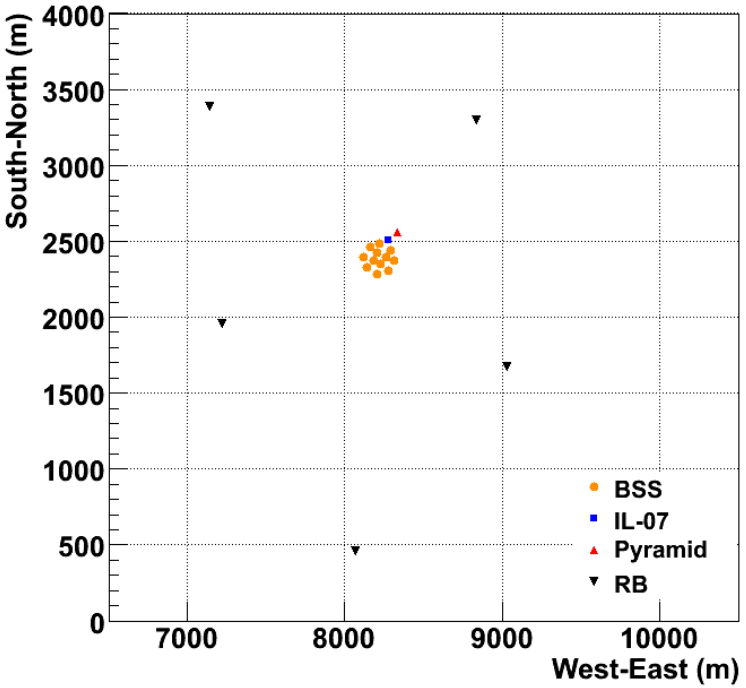


TTS	chromatic dispersion	**Overall**
1.3ns	1.5ns @ 40m	**2ns**



Absolute detector orientation

- **5 reference transponders** (RT): AGPS + low frequency acoustic positioning (LFLBL)
  - 8-16 kHz, **8 km range, <meter absolute precision**
- **Line Anchors**: Boat+RB, LFBF
- **Detector geometry** (when low current): high frequency acoustic positioning (HFLBL)
  - 40-65 kHz, **700 m range, 3cm precision**
- + **relative z measurement** (with pressure **10cm precision**, with detector geometry when low current)

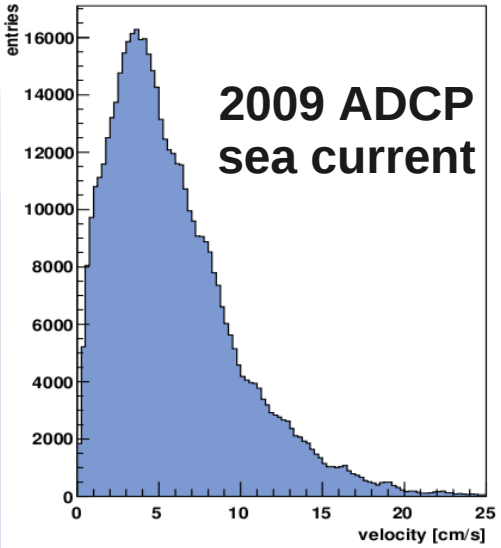


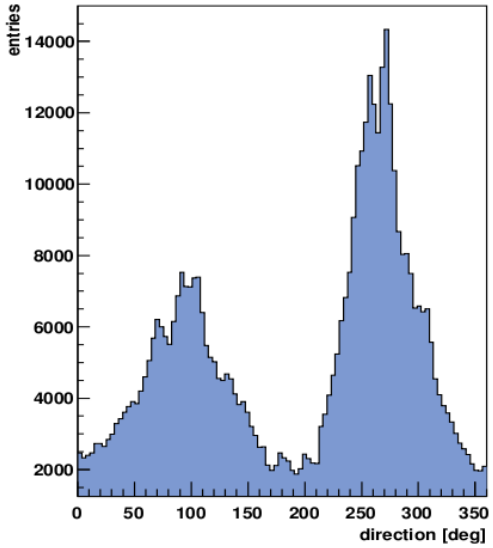
Result:

$$\sigma_{horizontal} = 0.127 \pm 0.002$$

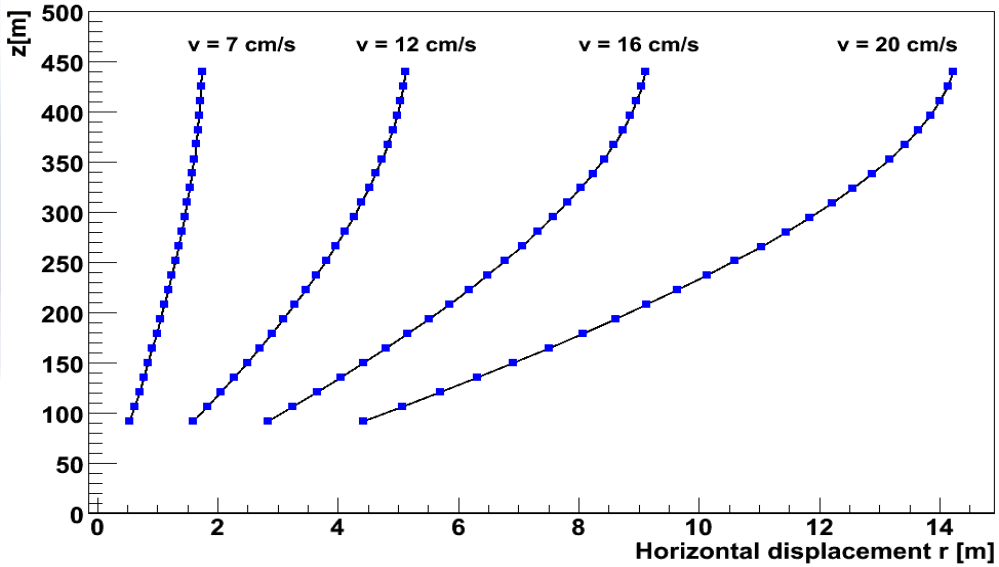
$$\sigma_{vertical} = 0.035 \pm 0.02$$

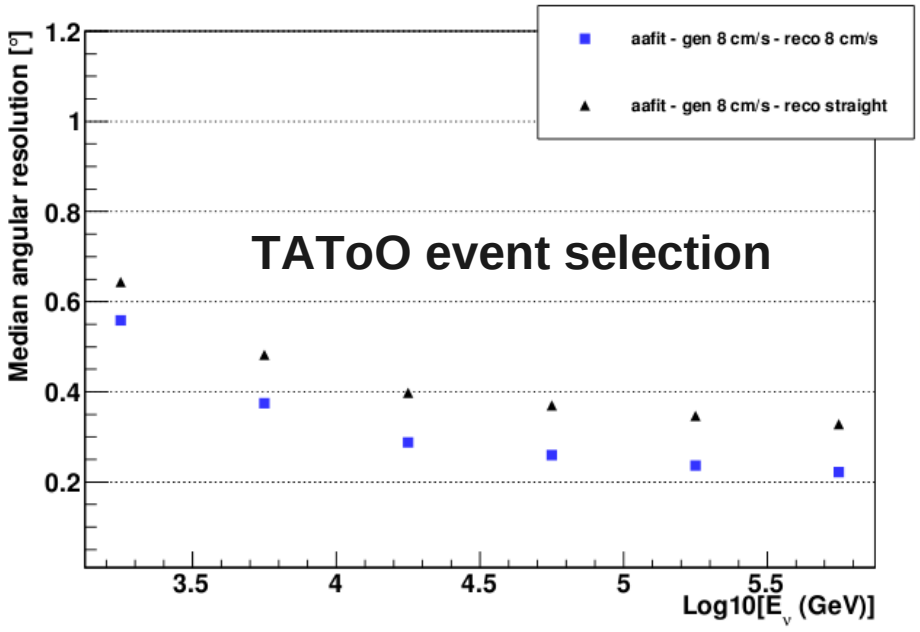
Sea current





- Sea current usually bellow 7cm/sec:
  - <2m lateral displacement
  - <0.3° effect (later corrected)
  - slight improvement thanks to non linear geometry! (but usually more background hits)



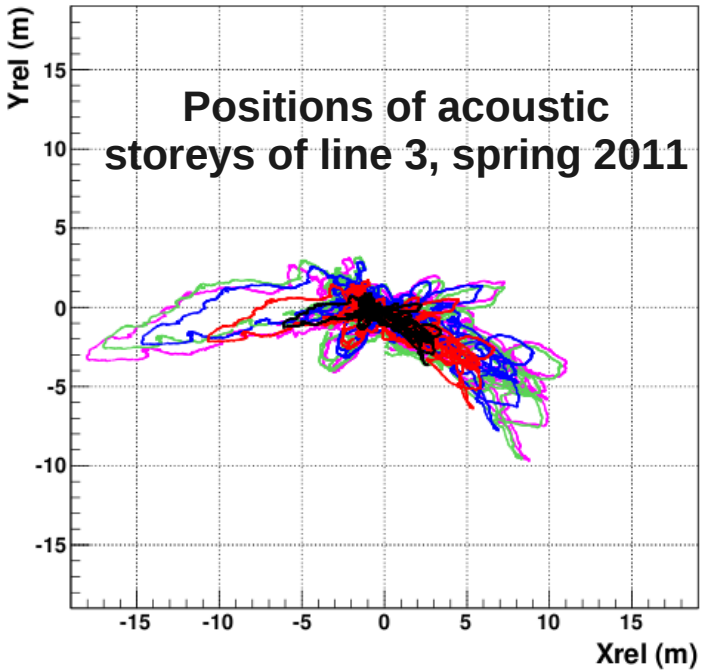


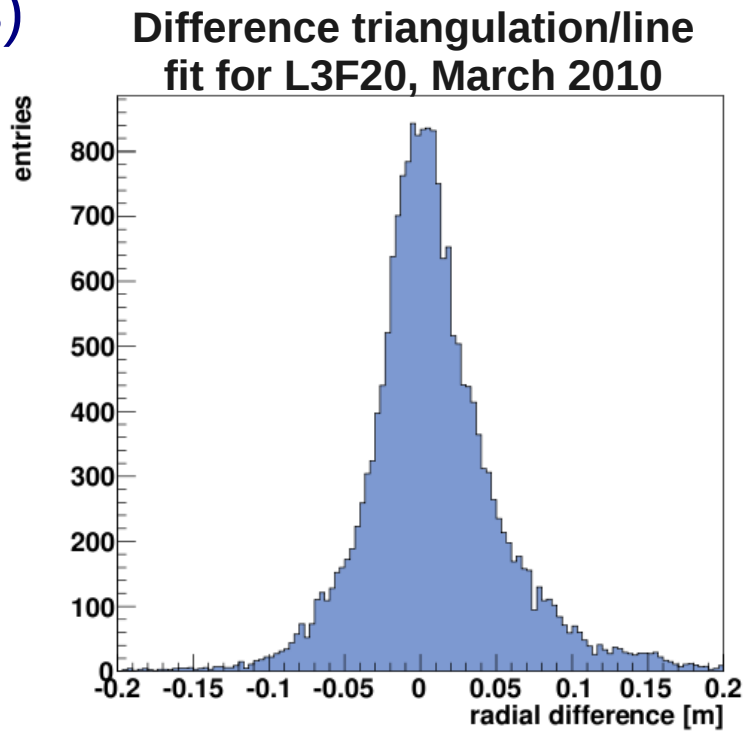
Detector alignment: Relative geometry

- Measurements every **2 minutes**:

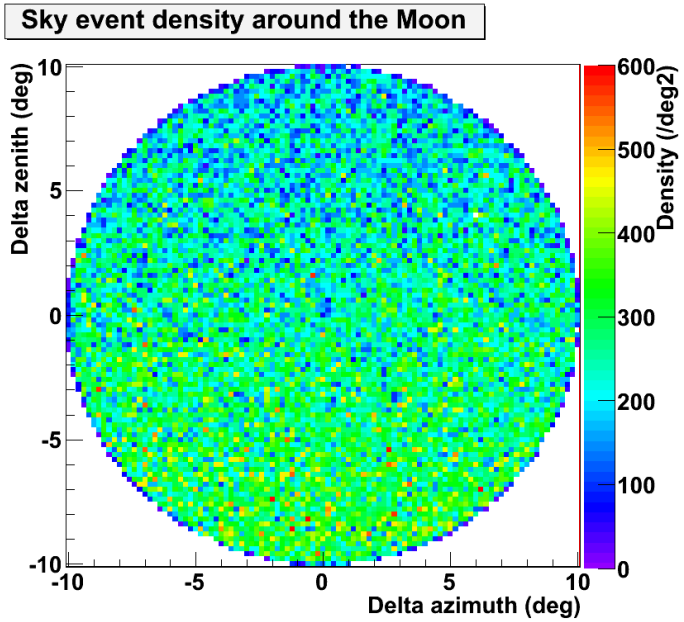
HFLBL	pitch/roll	compass	total
3cm	0.2°	1°	<10cm
5/line	1/storey	1/storey	OM

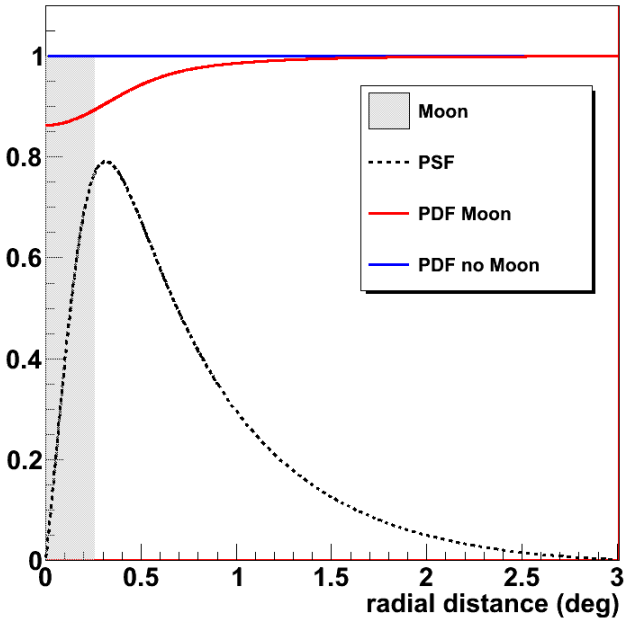
- Current inferred, position of all OMs computed
- Result: **<10 cm precision** (**<0.5 ns**)





Moon shadow

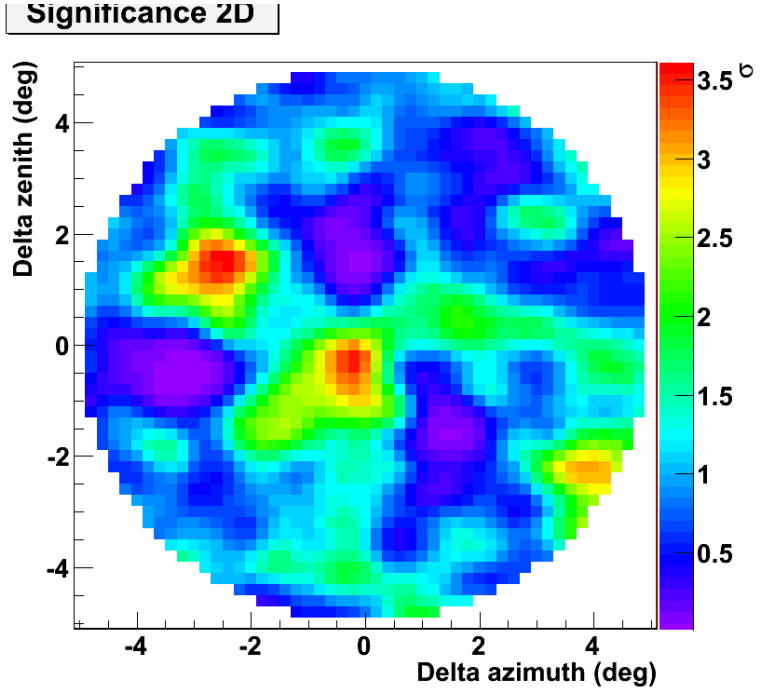




- Likelihood analysis based on PSF (Λ>-5.5, median resolution 0.75°):

$$PDF(x|H_0) \propto 1$$

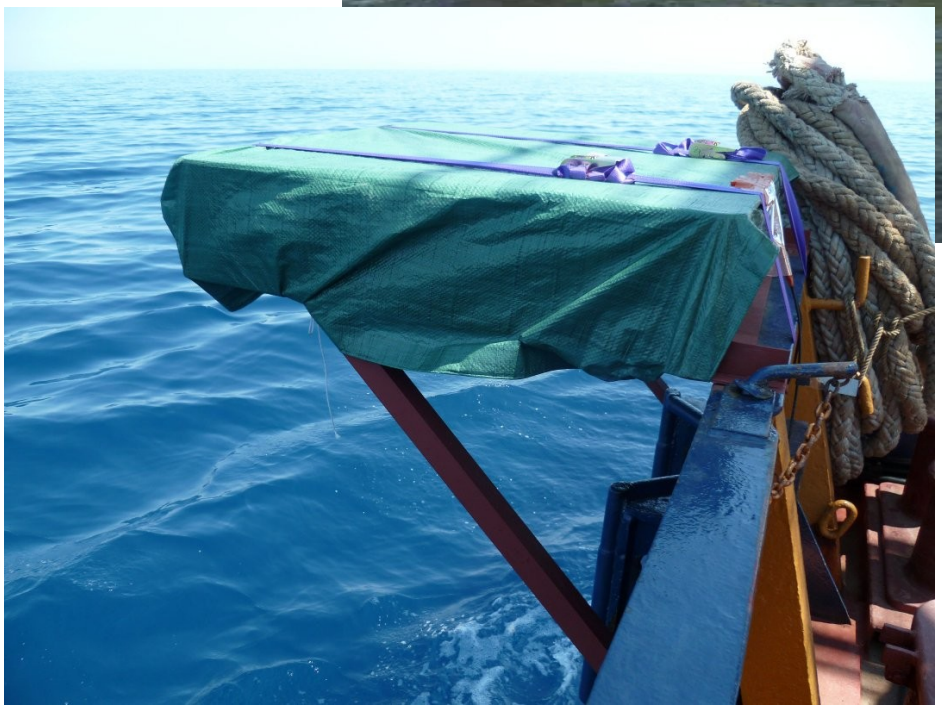
$$PDF(x|H_1) \propto (1 - PSF \otimes \delta_{Moon})(x)$$

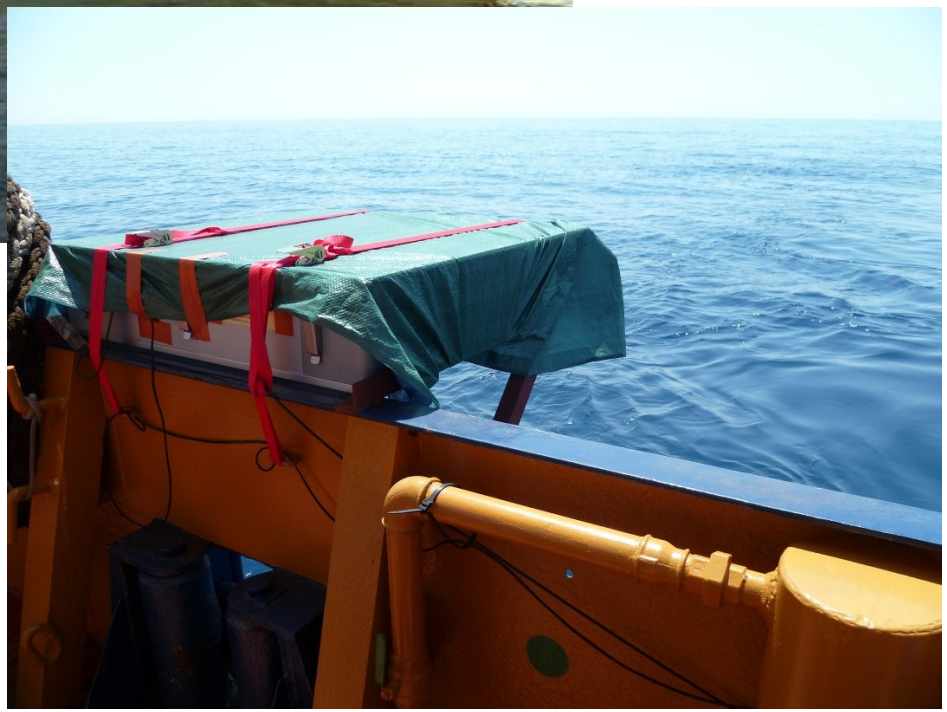


Current analysis, 2007-2010: **2.7σ** (expected 2.1±0.9σ)

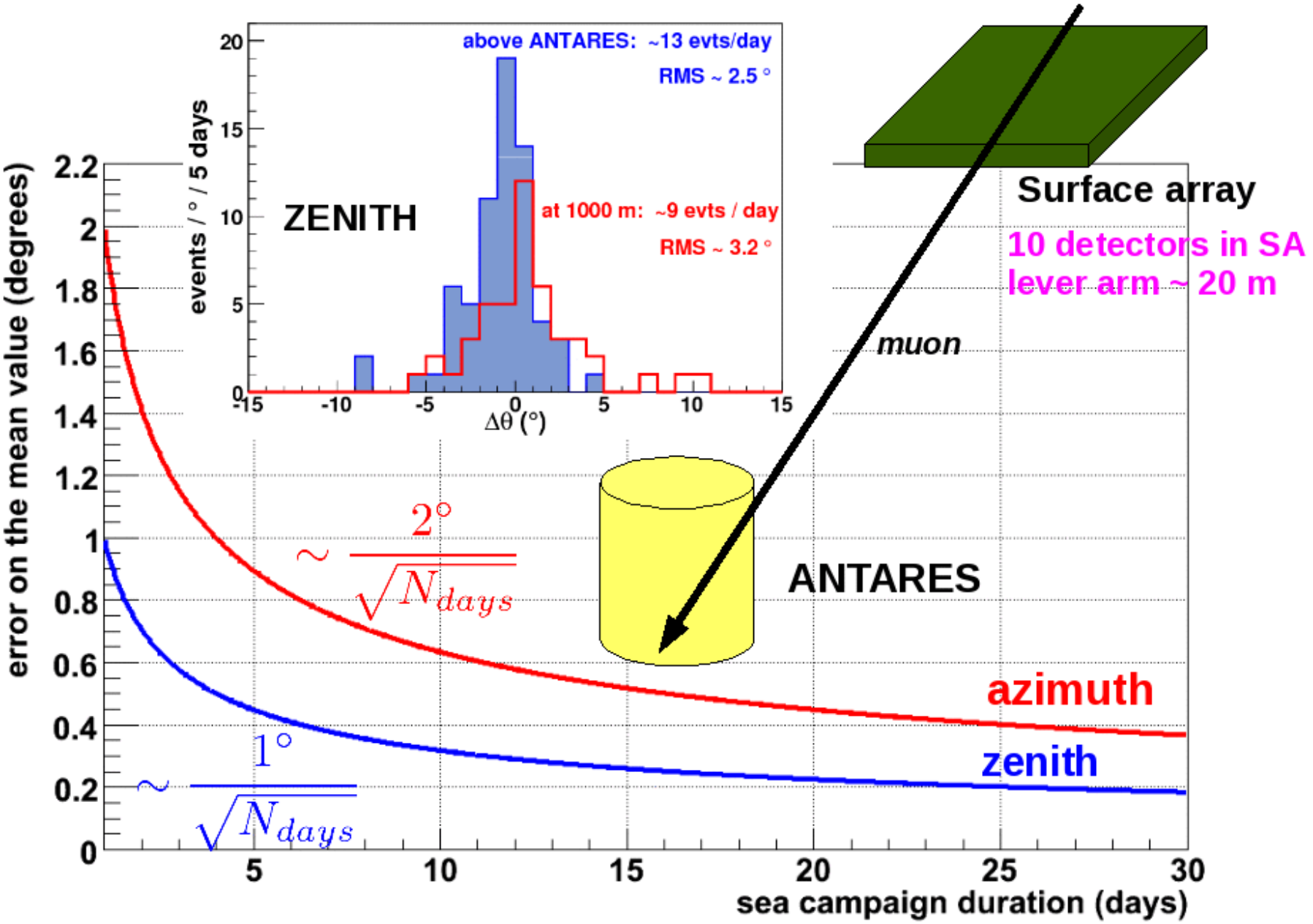
Stat *2, *5, *10: 2.8σ, 4.2σ, 5.9σ

Surface array

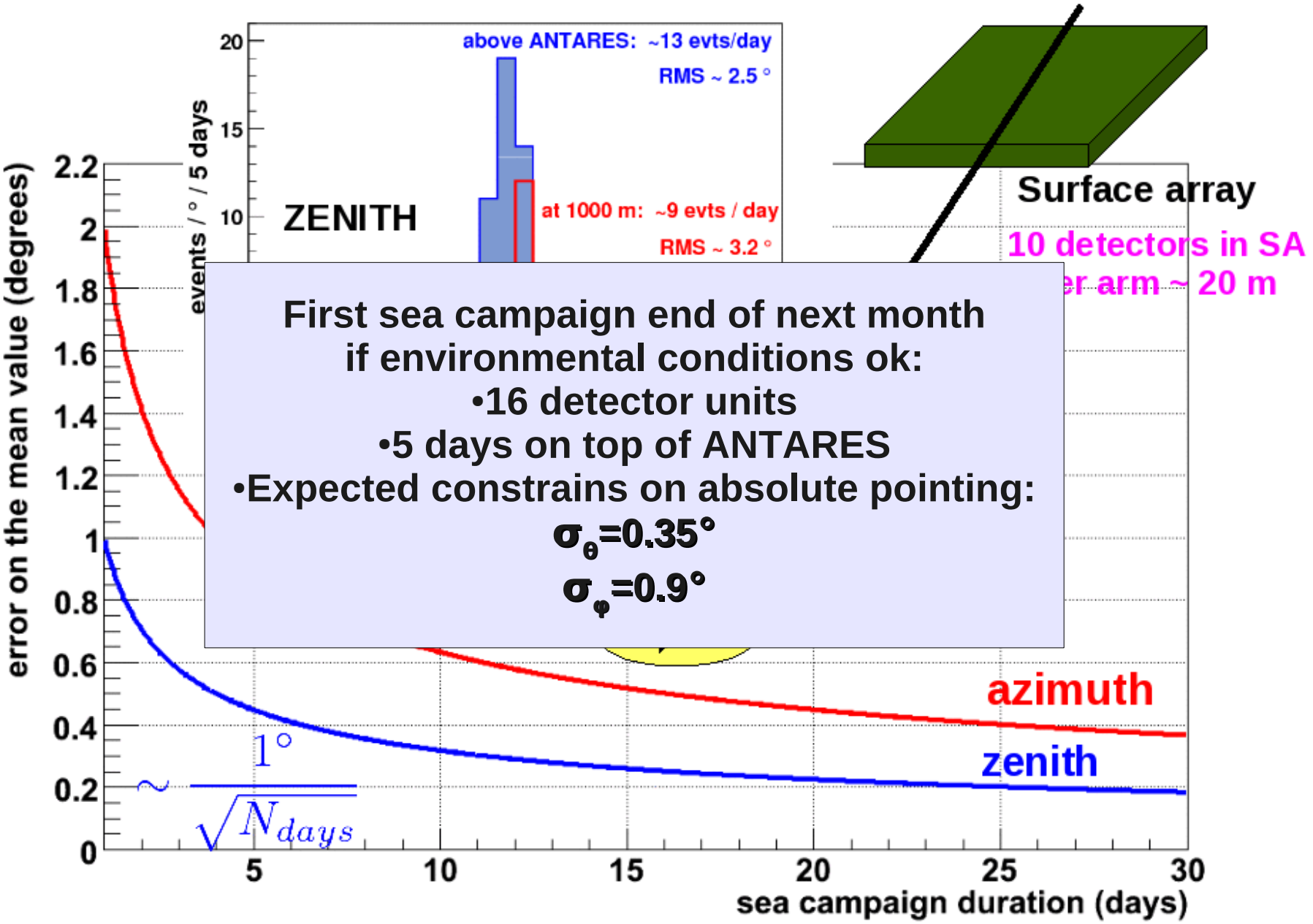




Surface array

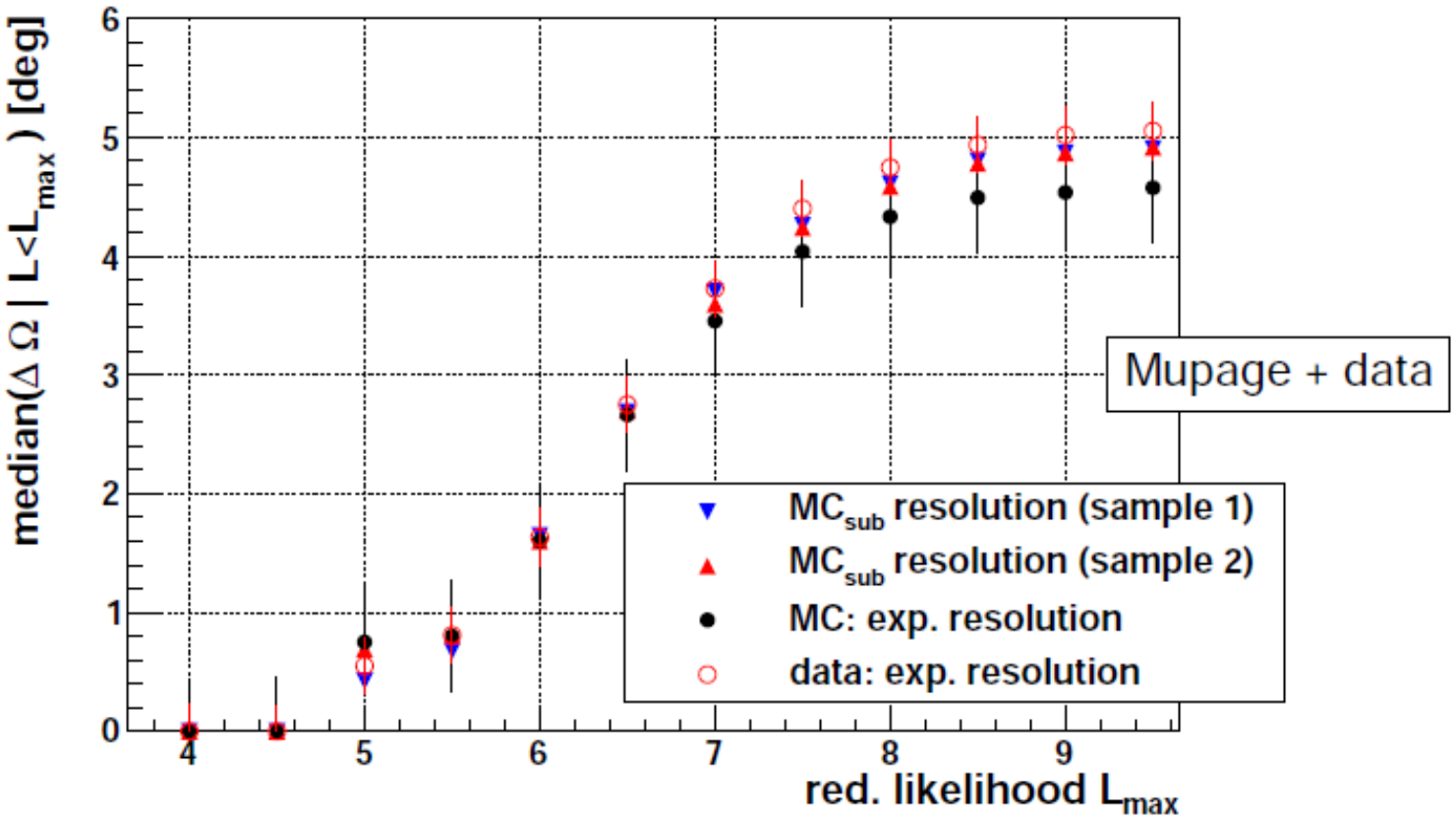


Surface array



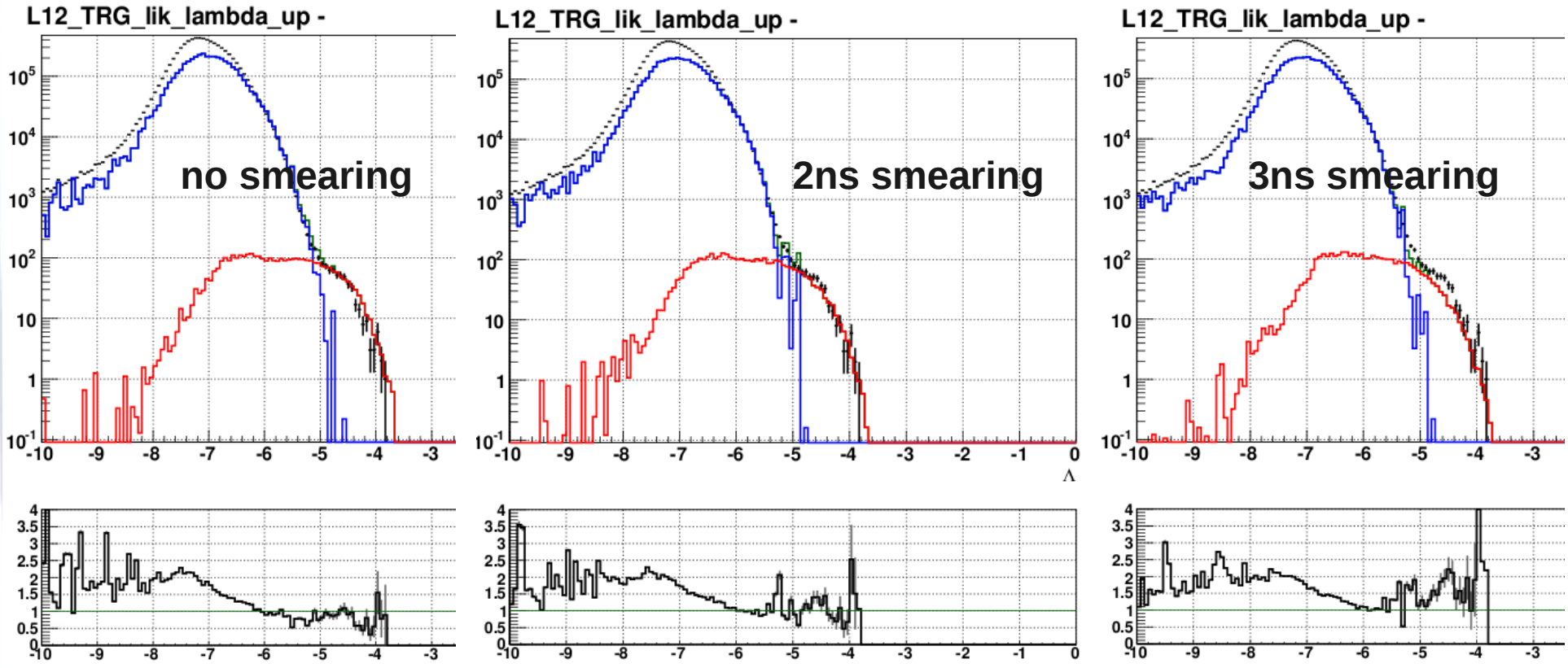
Crosscheck PSF with data: Split events

- Split each event into 2 sub-events containing half the hits
- Compare the directions of the 2 reconstructed sub-events ("experimental resolution")
- Prelim (only a few runs), but **data & MC exp. resolution agree**



2ns smearing

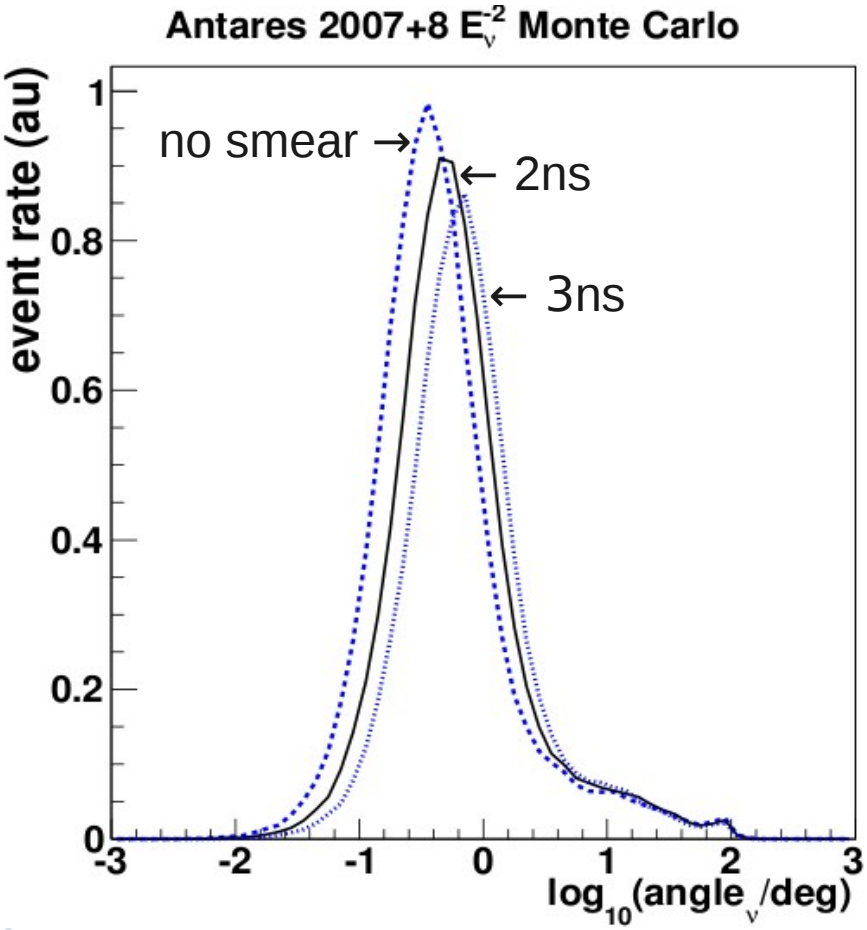
- Better quality in MC tracks than in data:
  - reduce OM acceptance?
  - degrade time resolution?
- Best fit (quality parameter shape, up-going neutrinos) with **2ns smearing**
  - **3ns rejected at 2σ**
  - 0 & 1ns disfavored

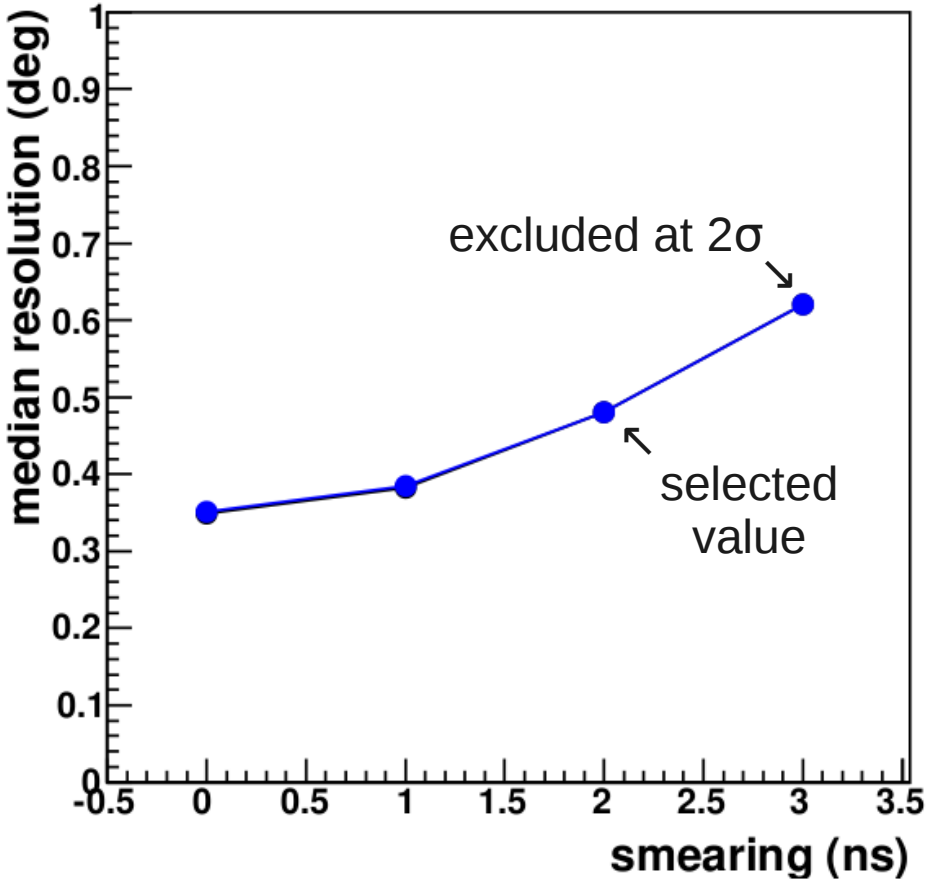


2ns smearing

=> Conservative approach, use 2ns smearing

Median angular resolution **increased by ~0.1°** with Λ>-5.4 cut (0.36° => 0.48°)





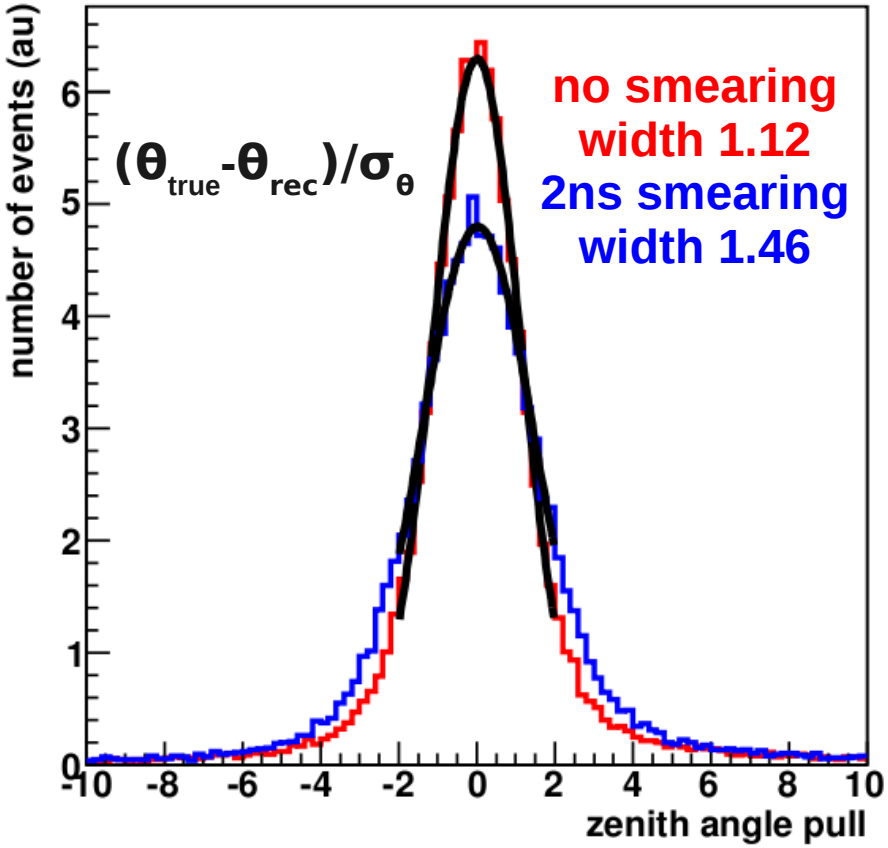
How to get rid of them

- **Reduce uncertainties** on calibration (eg. interline offset)
- **Refine MC**, cutting down systematics:
  - run by run
  - OM response (TTS, pre/afterpulses)
  - water properties (chromatic dispersion, diffusion, absorption)
- Then **update PDF** in track reconstruction algorithms

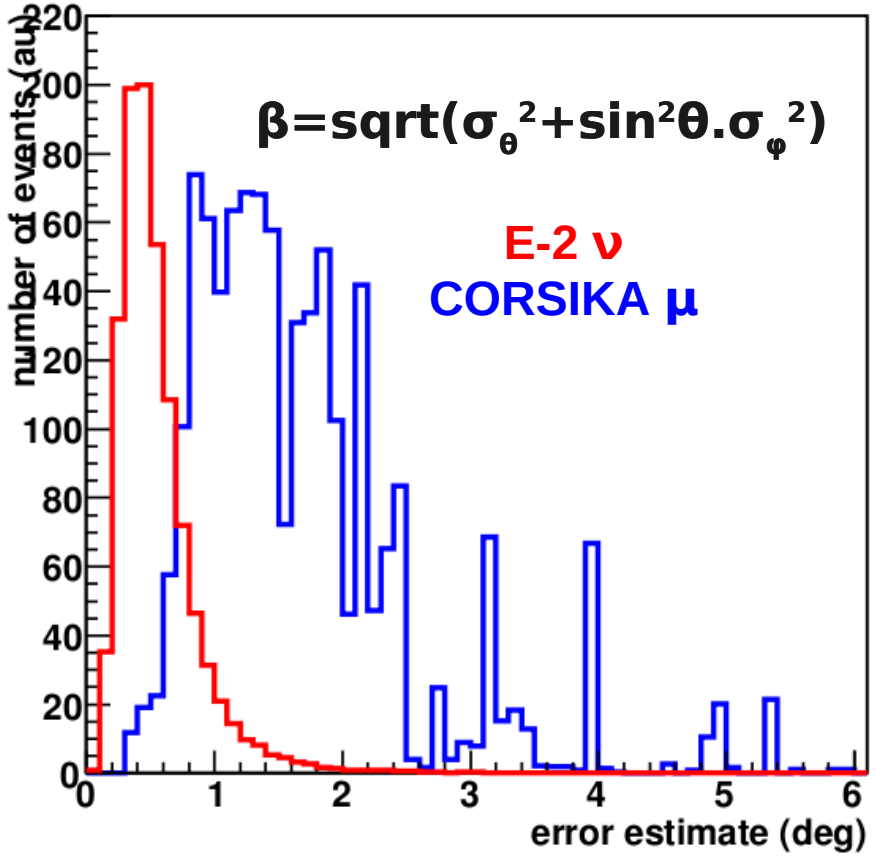
Many efforts ongoing, so hopefully we will get rid of some of this extra 0.1° soon

Error estimate β

- Uncertainty from the second derivative of the log likelihood function



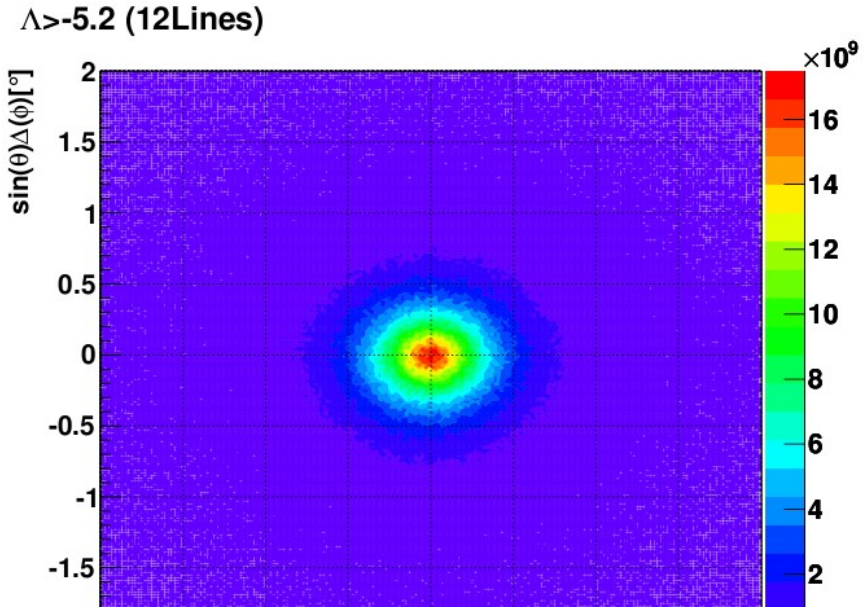
Pull distribution of the zenith angle



Error estimate for up-going reconstructed events

used as a cut so far

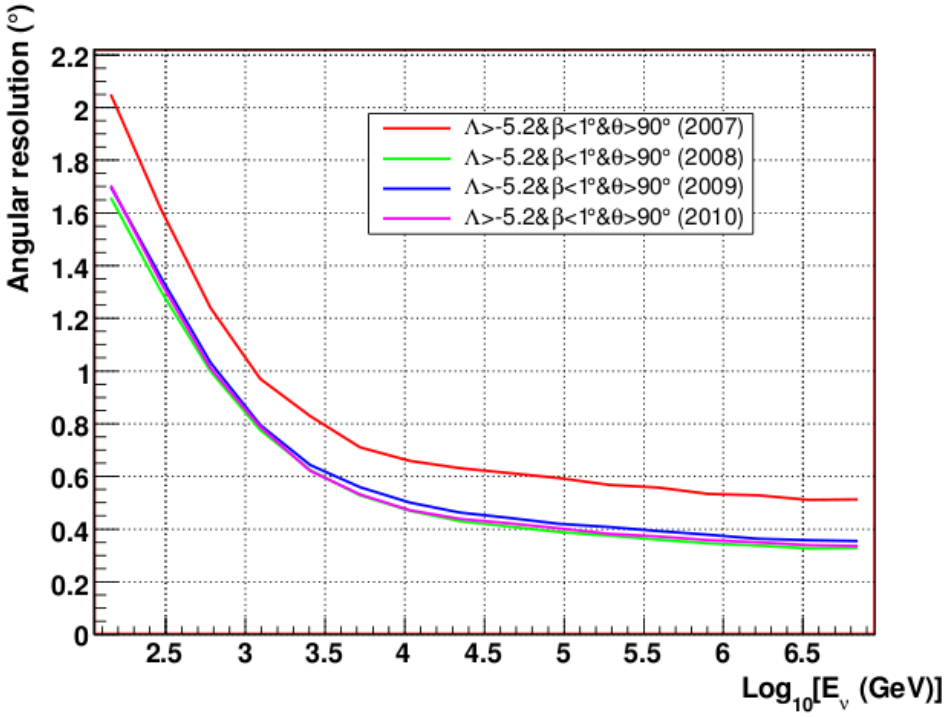
Results

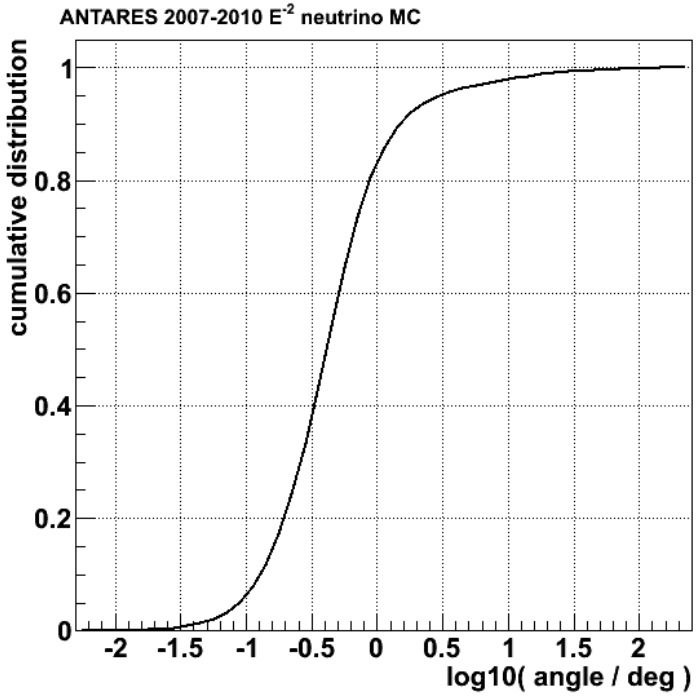


Here, cuts Λ>-5.2 & β<1°

Median resolution (including 2ns smearing):

- high energy 12 lines: 0.37°
- **2007-2010, E^{-2} ν: 0.46°**





Summary

- Absolute detector orientation: $\sigma_{horizontal}$=0.13° $\sigma_{vertical}$=0.04°
- Moon Shadow, Surface array:
  - check correct ANTARES operation
  - no strong constrains on absolute pointing / PSF expected
- Most parameters measured well enough for optimal performance:
  - detector geometry
  - intraline timing
- Interline timing to ~1ns now, should be ~0.5ns soon
- 2ns extra smearing to reproduce data → +0.1° to median res.
- Ongoing improvements to cut it down (chrom. disp., TTS, interline)

Median resolution 0.46° for 2007-2010 data, PS cuts