Muon track reconstruction for multi-PMT in KM3NeT

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Outline

- Reconstruction strategy for detectors made of strings equipped with multi-PMT
- Trigger included in the reconstruction code
- 2 version of the code:
  - recov4r6scan-str10.exe → used for high energy
  - recov4r6scan-str19h.exe → used for low energy
  - The general code description refers to both version, differences are highlighted

Trigger

All hits are analyzed to look for the following patterns:

- L1: simple coincidence between 2 PMT on the same OM in a time window $\Delta t = \pm 5$ ns
- T0: coincidence between an L1 hit and a simple hit on adjacent or next-to-adjacent OMs on the same line in $\Delta t = \pm(5\text{ ns} + \Delta d/v)$
- T1: like T0 but between 2L1 hits
- L2: multiple (>2) coincidence between PMTS on the same OM in $\Delta t = \pm 5$ ns
- N1: coincidence between 2 L1 hits on OMs on the nearby string but at the same z

Event accepted if

- **Version "10" : L2≥1 or T1≥1 or N1≥1**
- **Version "19h": L1≥3 or L2≥1 or T1≥1 or N1≥1**

Each type of coincidence gives to the correspondent hit a "score" that is used during the reconstruction phase for the hit selection

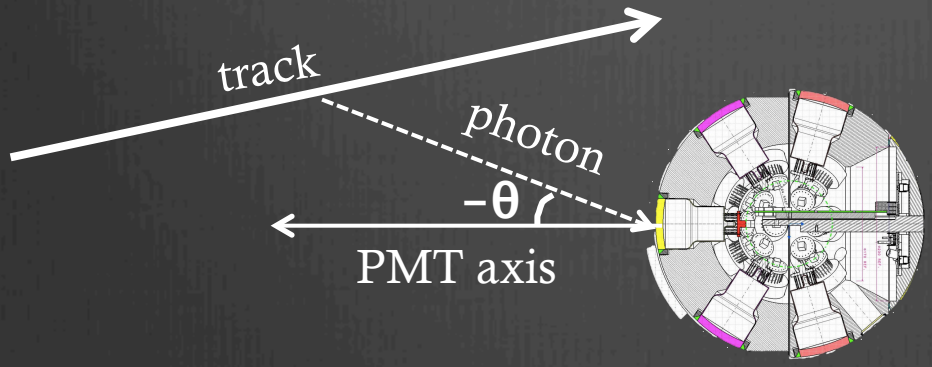
Reconstruction code

"AartStrategy" reconstruction algorithm modified to exploit the multi-PMT peculiarities

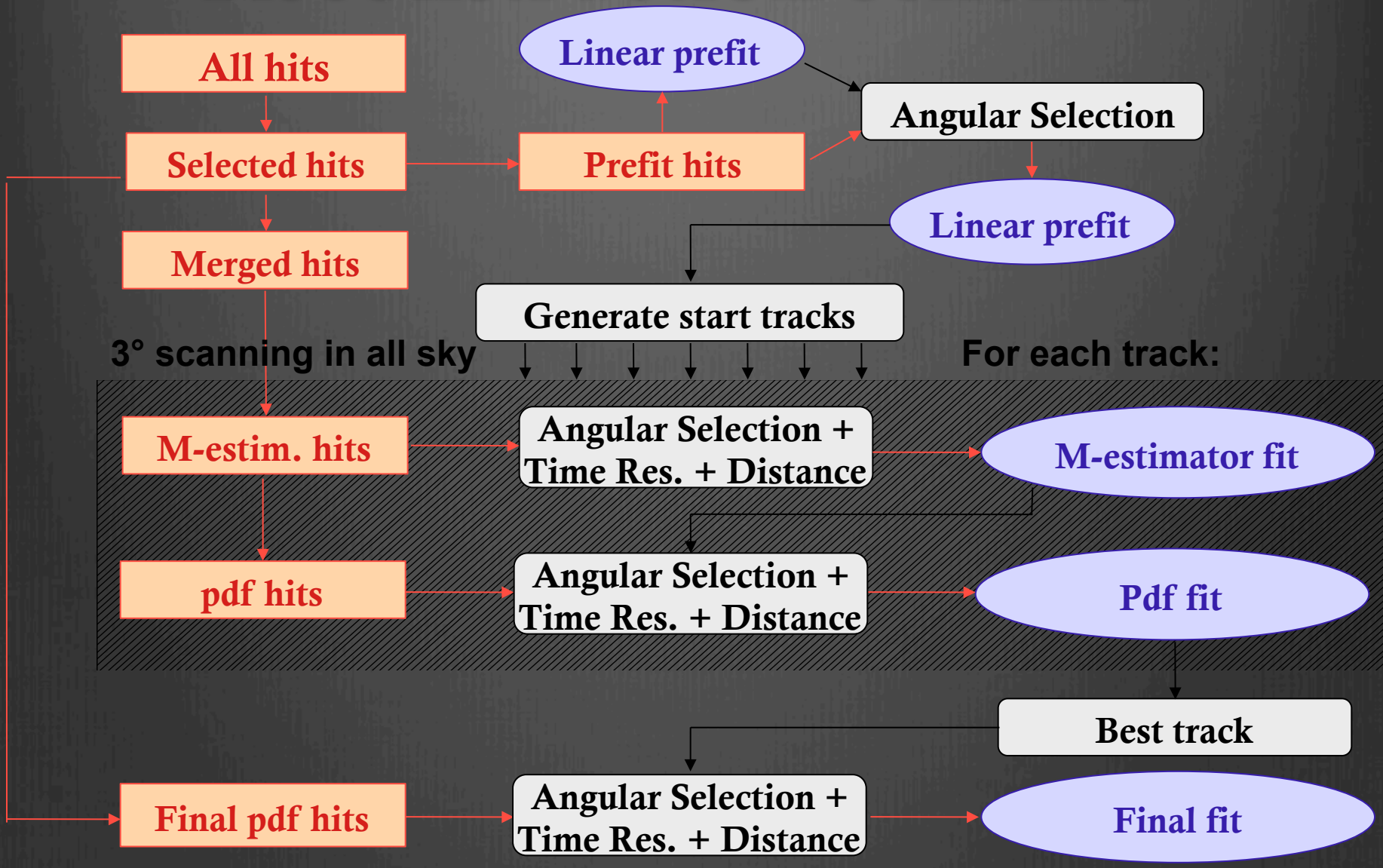
Trigger based on coincidence between PMT on the same OM, nearby OMs on the same line and OMs on nearby strings

Dependence on the hit amplitude neglected. Instead, each hit have a "score" depending on the type of coincidence

Angular Selection: hit accepted in PMT field of view $\cos\theta < -0.5$ (where θ is the angle between the incident photon from a starting track and the axis of the PMT)



Reconstruction scheme



Causality filter

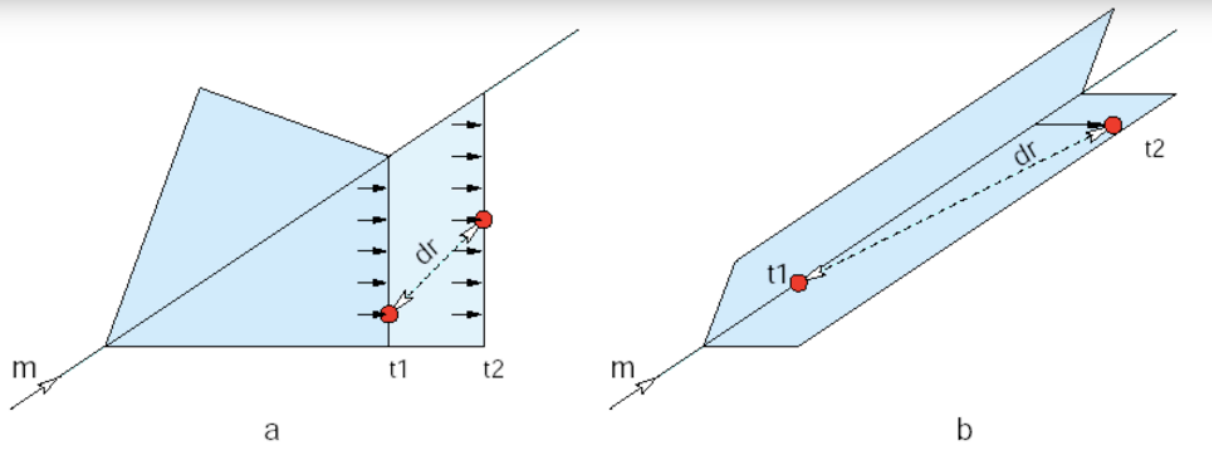
All hits

↓

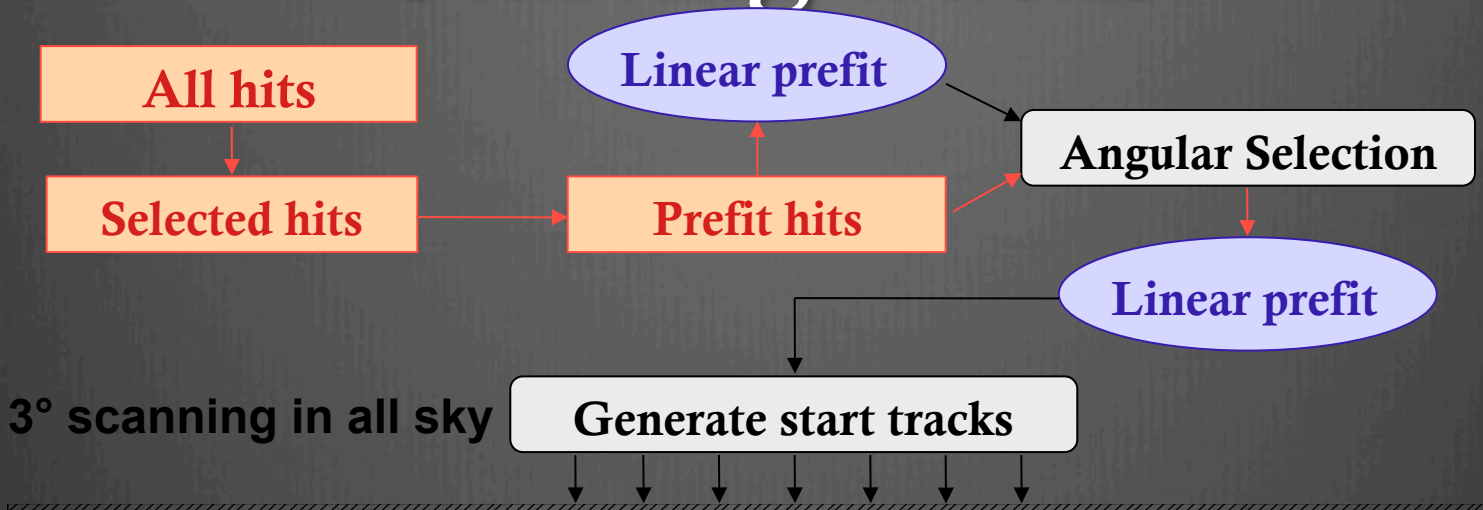
Selected hits

- ✓ Selection based on the causality filter w.r.t. the hit with high score
- ✓ version "str19h" : if there are only L1 hits, the reference hits is chosen as the one that have the major number of hits in a causality relation

$$|\Delta t| - \frac{\Delta r}{c/n} < 20ns \quad \&\& \quad \left| |\Delta t| - \frac{\Delta r}{c} \right| < 500ns$$



Starting tracks

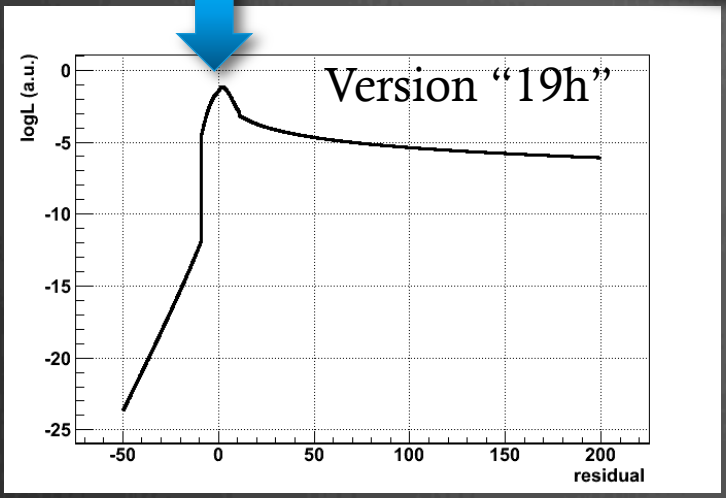


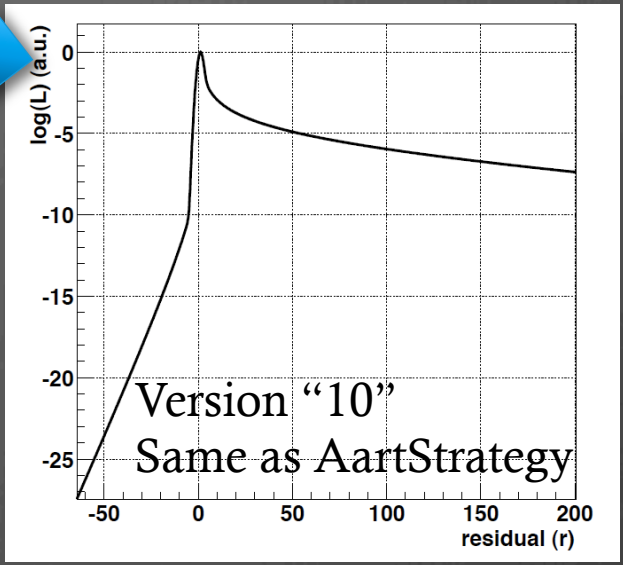
Starting from the prefit track, a scanning of all sky is performed by step of 3° (7200 tracks)

- Version "10": all tracks are processed
- Version "19h": to speed the algorithm only the first 100 tracks that have the major number of hits in time-spatial relation are considered

Fit

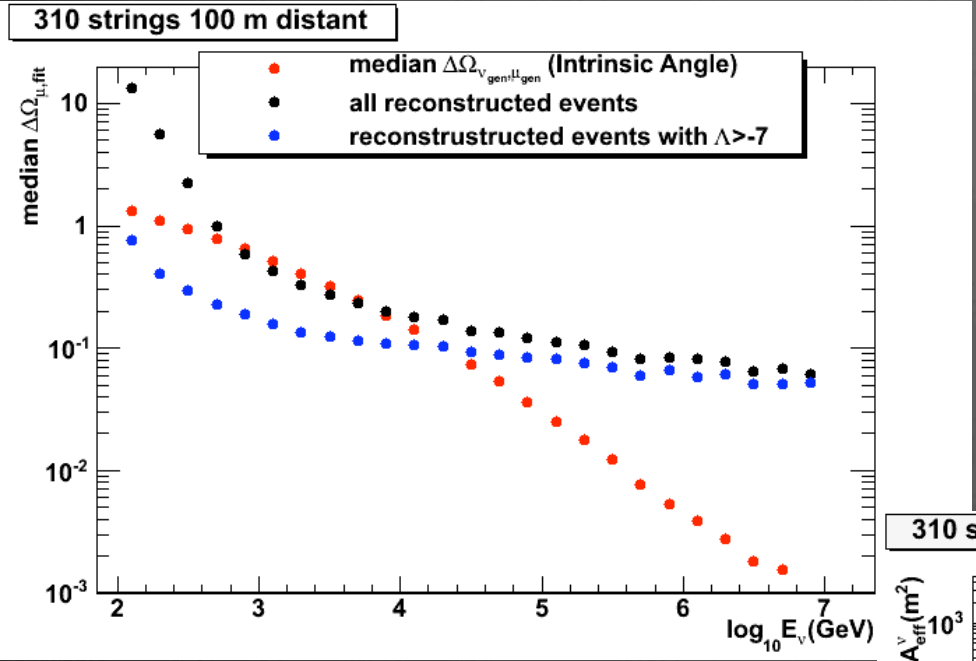
- For each track:
  - M-estimator fit ➔ same as Aartstrategy
  - PDF fit





- A best track is chosen according to the higher value of Q=Nhit – Chi2/(Nhit-5)
- Final fit ➔ same as Aartstrategy
- Each fit use the result of the previous procedure as a starting point and are used only hits selected with the "angular selection" and with limits on the time residual and on the orthogonal distance from the reference track. Hits with the highest score are always added.

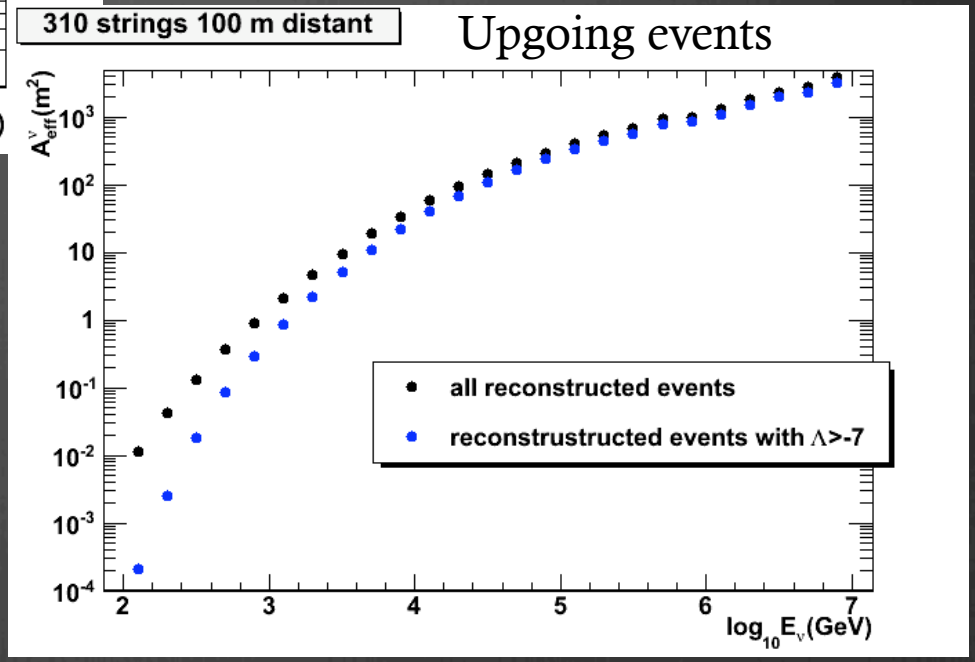
High E - reconstruction results



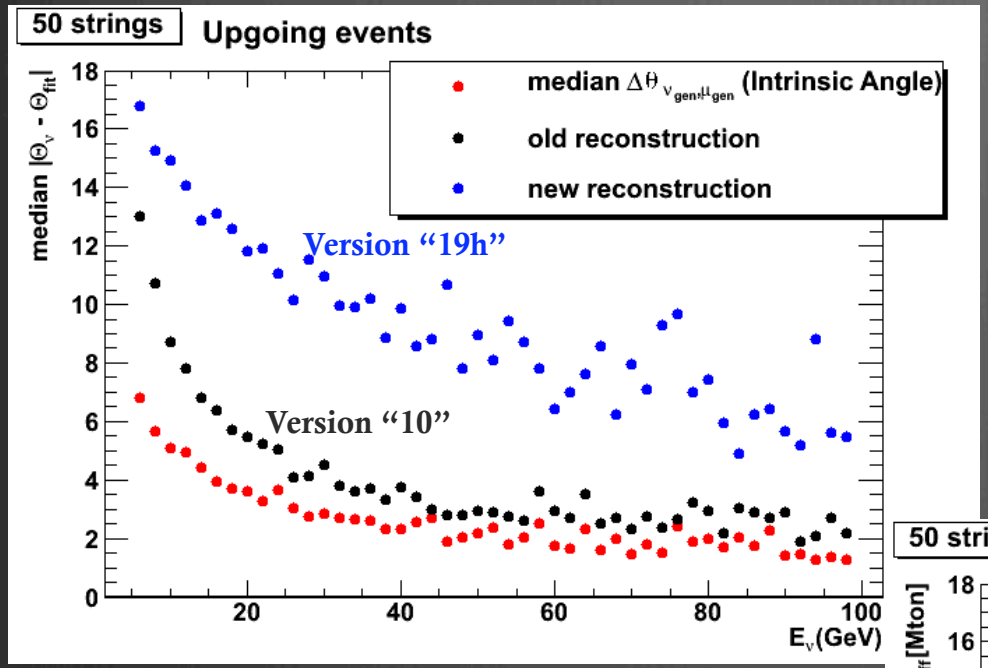
Standard KM3NeT detector:

- 2 blocks of 310 strings
- 100m average distance between strings
- 20 multi-PMT OMs in each string
- 40m vertical spacing between OMs in the string

Reconstruction strategy version "10"

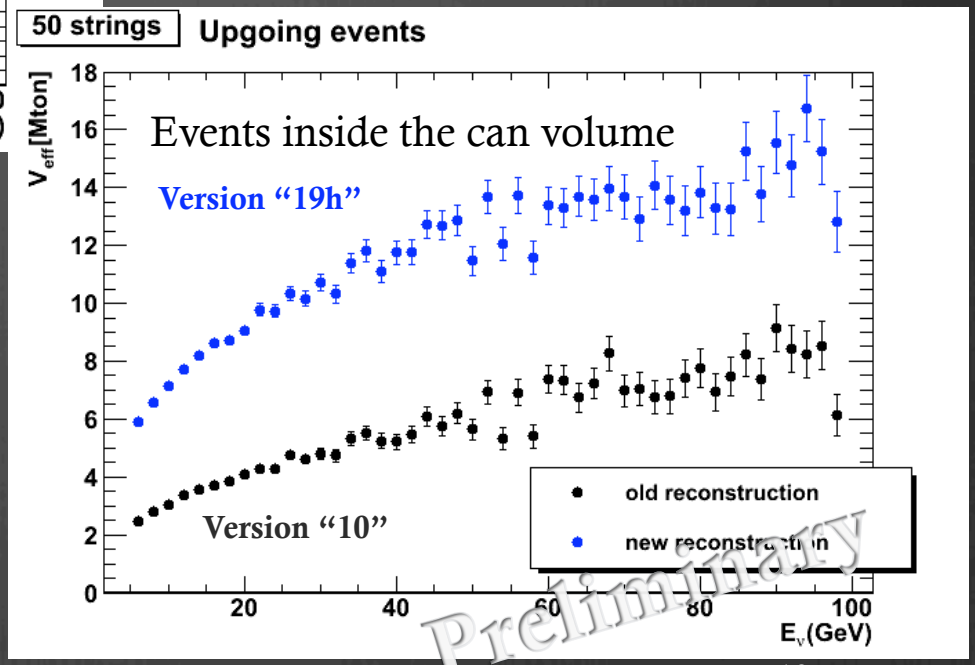


Low E - reconstruction results



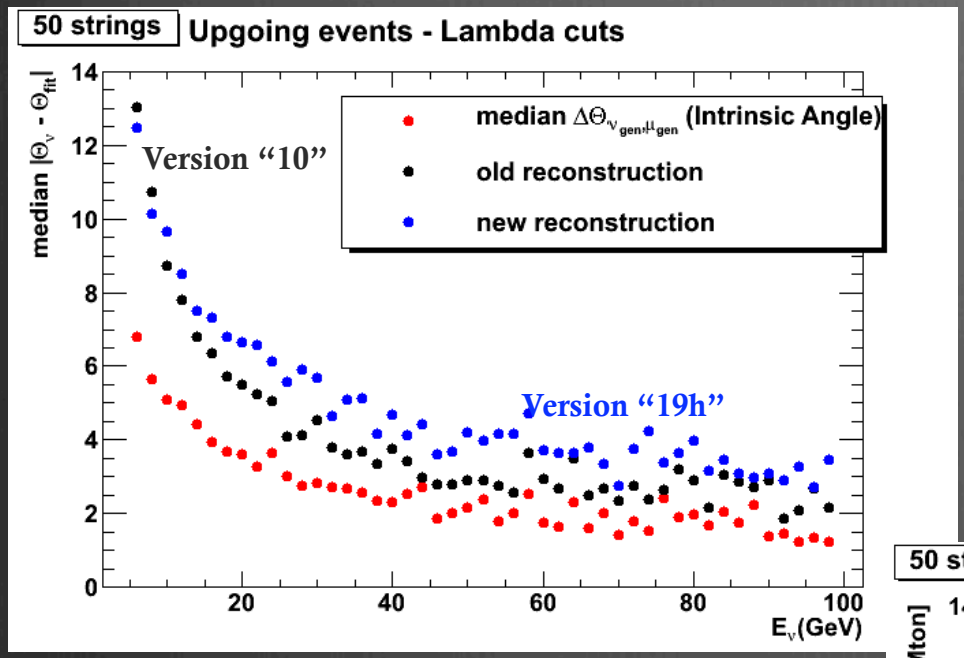
Standard ORCA detector:

- 50 strings
- 20m average distance between strings
- 20 multi-PMT OMs in each string
- 6m vertical spacing between OMs in the string

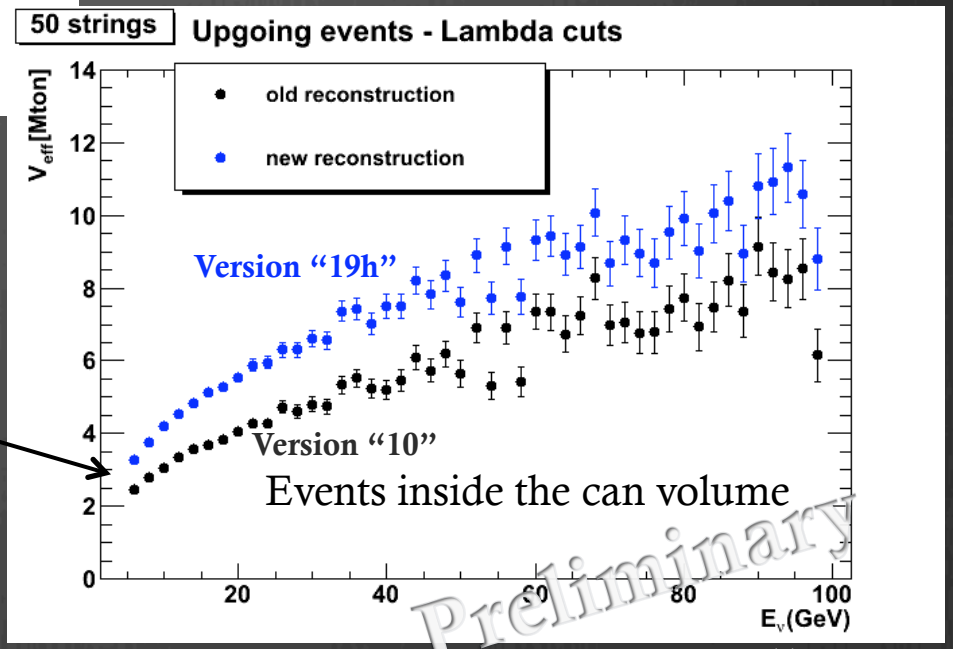


Both the effective volume and the angular error increase but…

Low E - reconstruction results



Quality cuts applied to get the same angular resolution at low energy



Effective volumes increase of about 25%-30% at E_ν <50 GeV

Backup

λ	QE	QE'
260	0	0
270	0	0
280	0.5	0
290	3.1	0
300	9.8	0
310	17.5	0.5
320	23.2	4.3
330	26.5	12.2
340	28.1	19.5
350	28.1	23.6
360	29.1	26.8
370	30.1	28.5
380	30.4	28.1
390	30.1	29.3
400	29.9	29.4
410	29.3	28.7
420	28.6	27.9
430	27.5	27.0
440	26.5	25.9
450	25.0	24.5

λ	QE	QE'
460	23.2	22.8
470	21.1	20.8
480	19.6	19.3
490	18.5	18.3
500	17.2	17.0
510	15.4	15.3
520	12.1	12.0
530	9.3	9.2
540	7.2	7.1
550	6.2	6.1
560	4.6	4.6
570	3.6	3.6
580	2.8	2.8
590	2.1	2.0
600	1.3	1.3
610	0.8	0.8
620	0.5	0
630	0.3	0
640	0	0
650	0	0

$\cos\theta$	ε
-1.0	1.56
-0.95	1.17
-0.9	1.06
-0.85	0.96
-0.8	0.91
-0.75	0.85
-0.7	0.77
-0.65	0.72
-0.6	0.67
-0.55	0.61
-0.5	0.58
-0.45	0.52
-0.4	0.49
-0.35	0.45
-0.3	0.39
-0.25	0.35
-0.2	0.31
-0.15	0.29
-0.1	0.19
-0.05	0.10
-0.0	0.0

Table 2: Left: The QE (unit %) a function of the wavelength of the photon (unit nm). (QE' includes the optical transmitivity of the glass sphere and the gel). Right: The angular acceptance of the PMT, ε, including the effect of the optical ring (θ is the angle between the incident photon and the axis of the PMT, where $\cos\theta = -1$ corresponds to a head-on angle of incidence).