Algorithm for muon bremsstrahlung shower reconstruction

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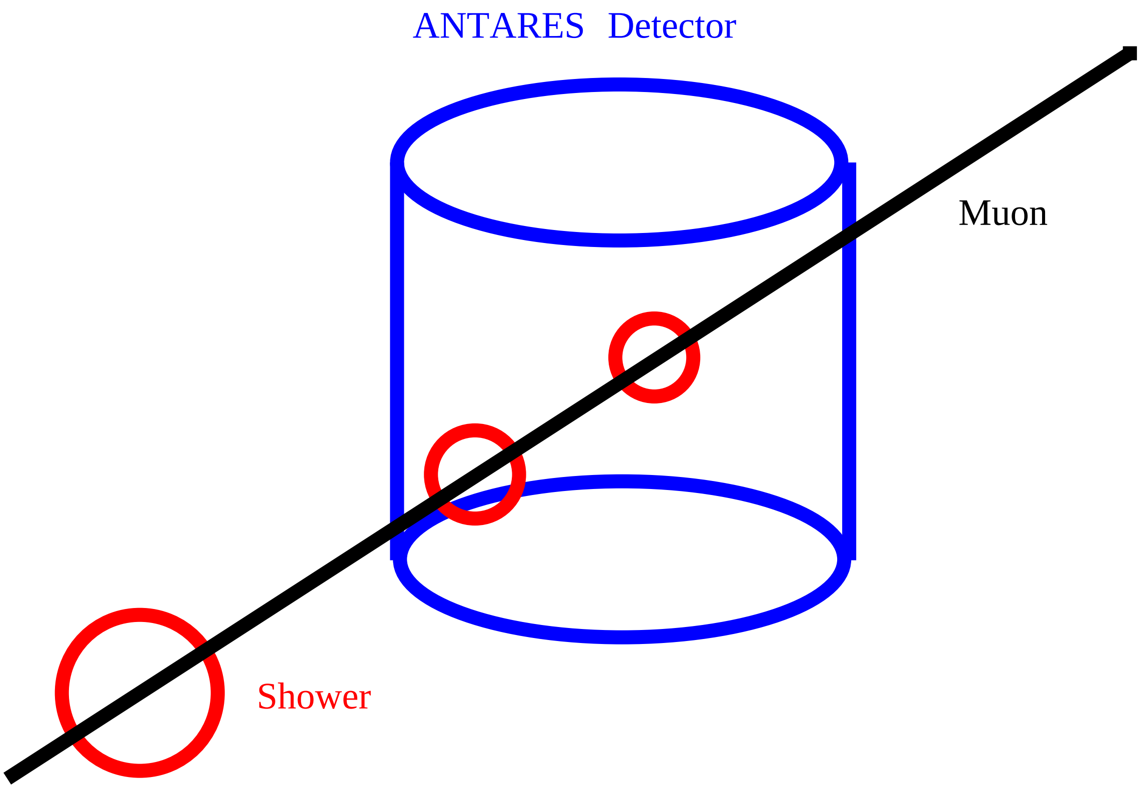
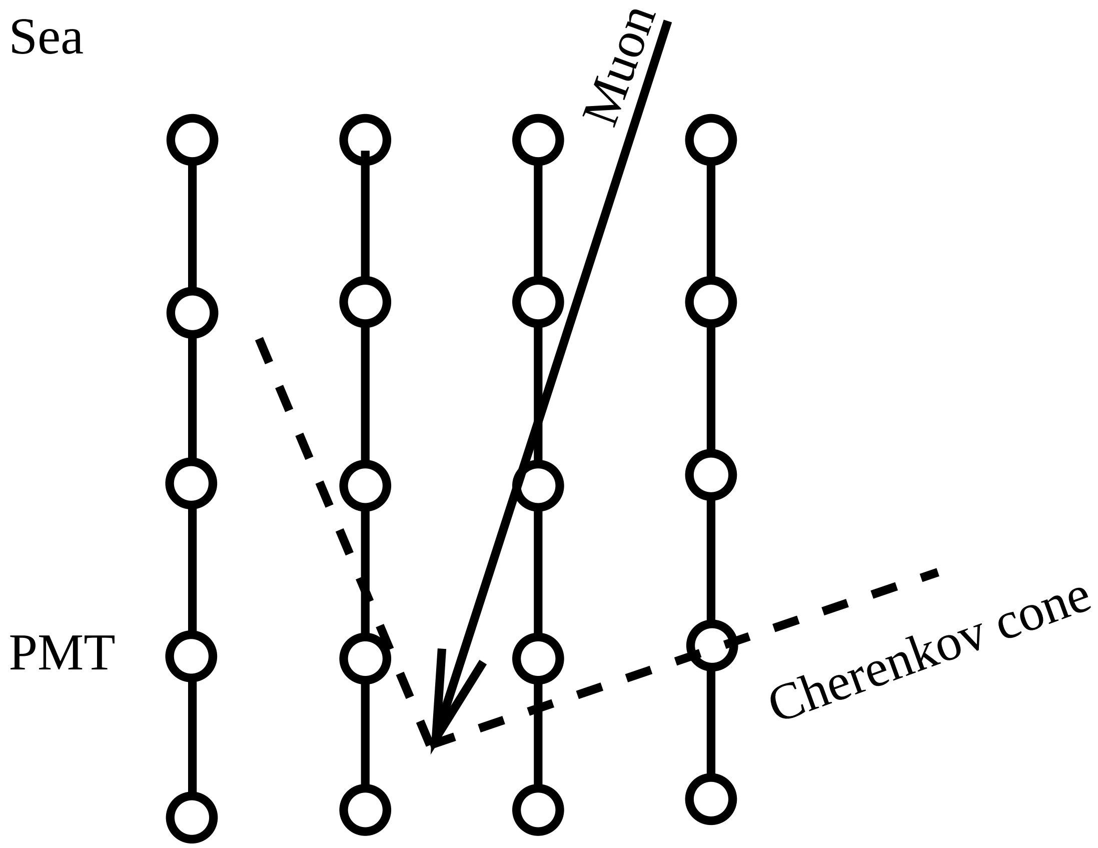
- Motivation
- Method
- Event Display
- Results



ANTARES detector

- underwater cherenkov detector
- Mediterranean sea at 2500 m depth
- array of photomultiplier tubes
  $\Rightarrow$ reconstruction muon trajectory



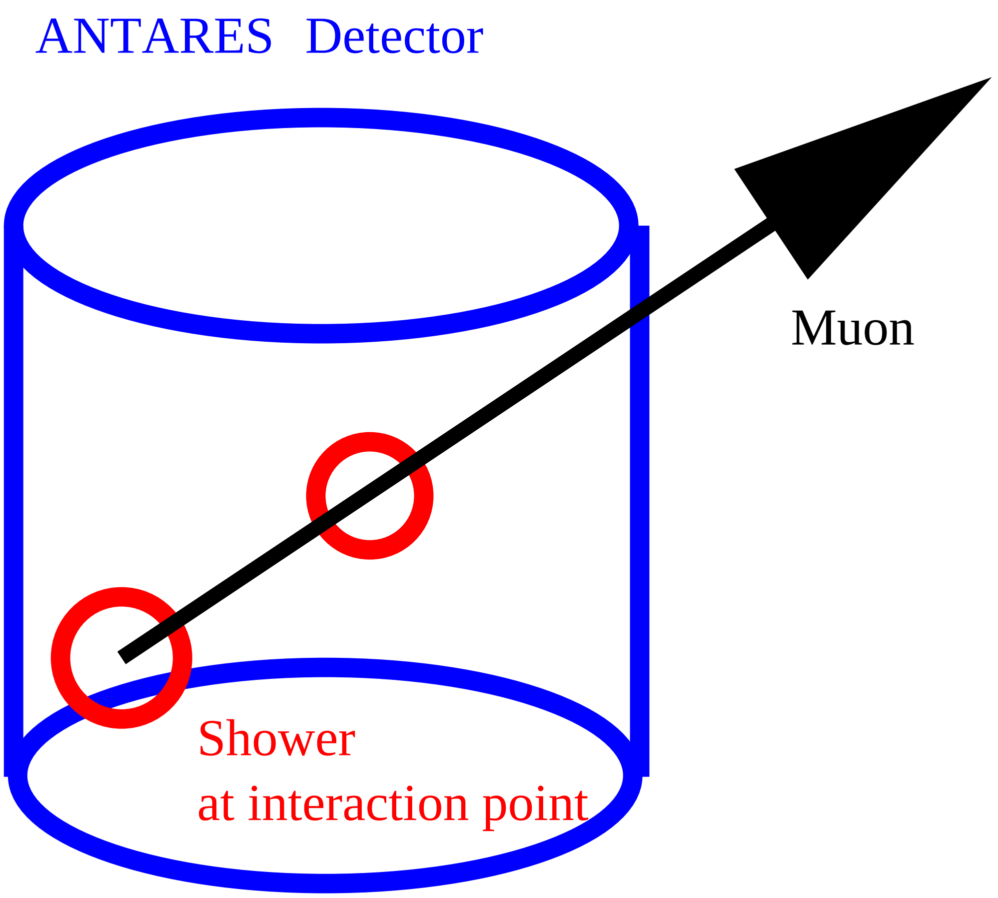
This talk:

bremsstrahlung showers from muons

Motivation

- Extract more information:
  - many μ's have showers
  - additional variables (shower multiplicity)

- Not explored yet
  - number of showers per track length
    $\Rightarrow$ energy estimator
  - distinguish event topologies



Identify showers in three analysis steps

1. $\boxed{\text{Basic selection}}$

   muon candidates

2. $\boxed{\text{1-dimensional pre-selection}}$

   select hits with associated shower(s)

   ⇒ shower candidates

3. $\boxed{\text{Final selection}}$

   3-dimensional fit of pre-selected hits

   ⇒ shower candidates with 3D position

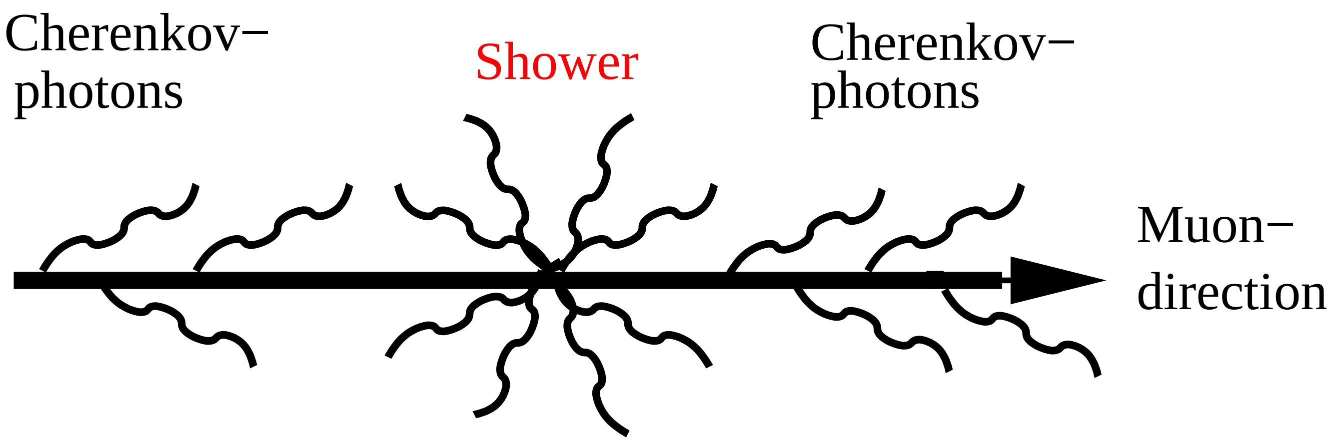
Analysis Idea

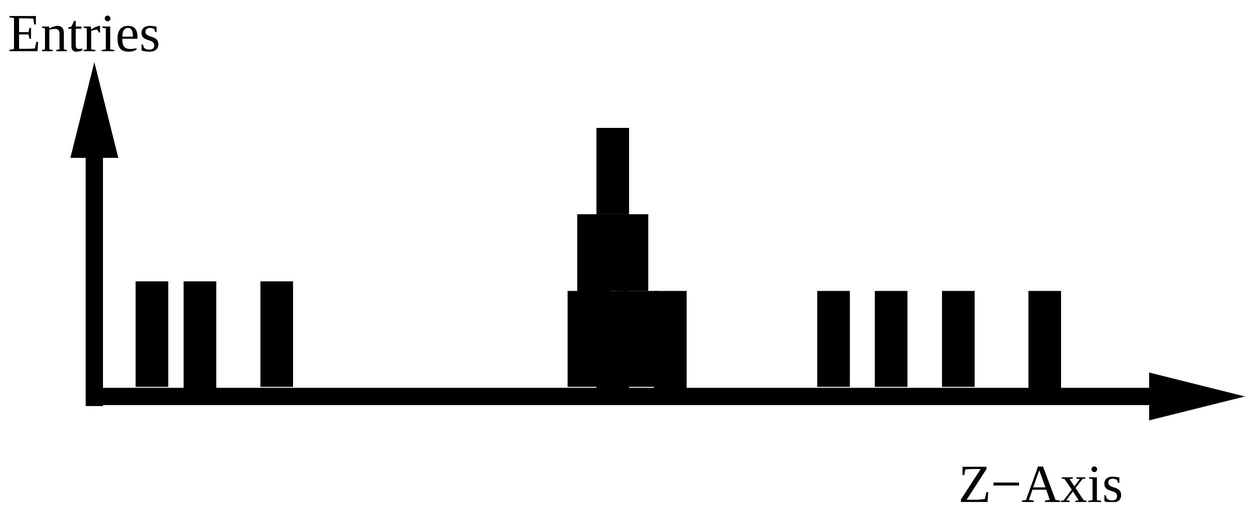
Hit information (3D position and time)

$\downarrow$

reduce to one dimensional problem

by projection on muon direction



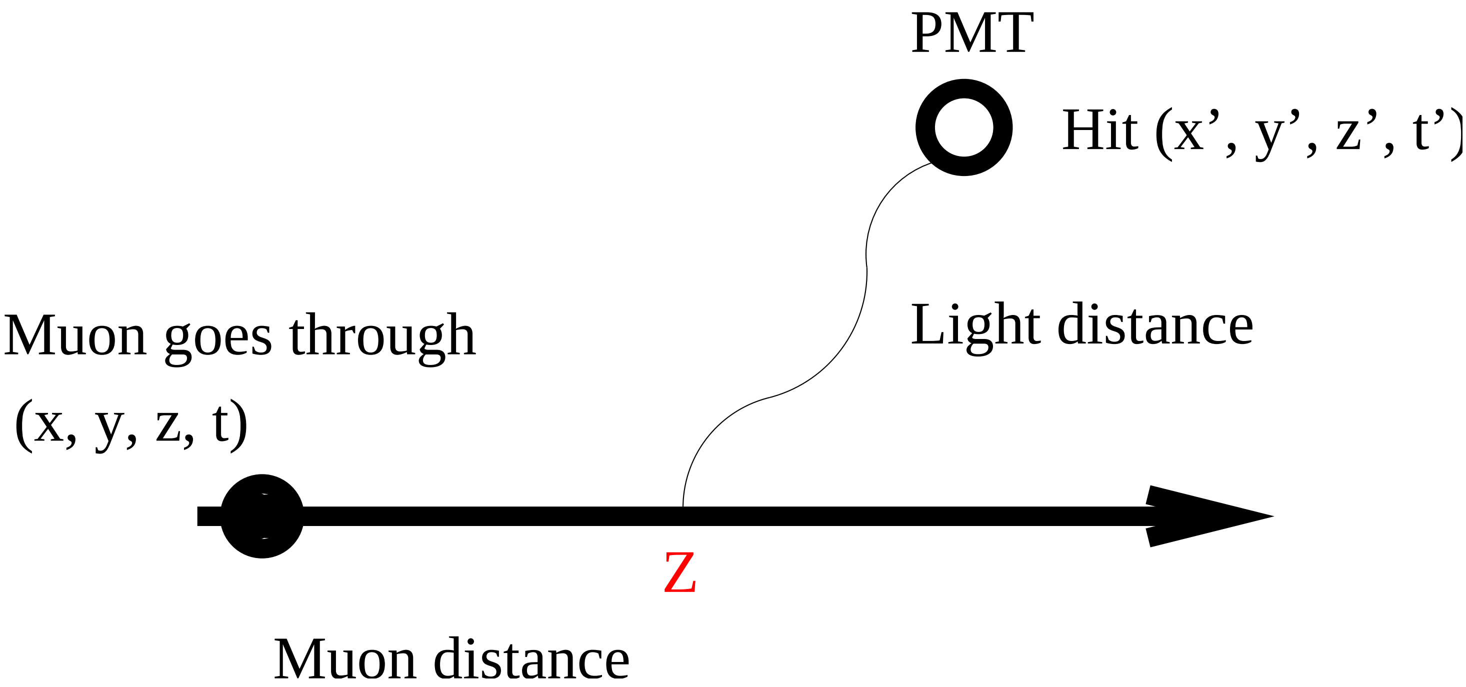


use peak finder $\Longrightarrow$ shower Z-position

From hit information to Z position

Z-calculation in rotated system:

$$t' = t + \underbrace{\frac{Z - z}{c}}_{\mu\ \text{time}} + \underbrace{\frac{n}{c}\sqrt{(x'-x)^2 + (y'-y)^2 + (z'-Z)^2}}_{\text{time for light in water}}$$



Rewrite to quadratic equation $aZ^2 + bZ + c = 0$

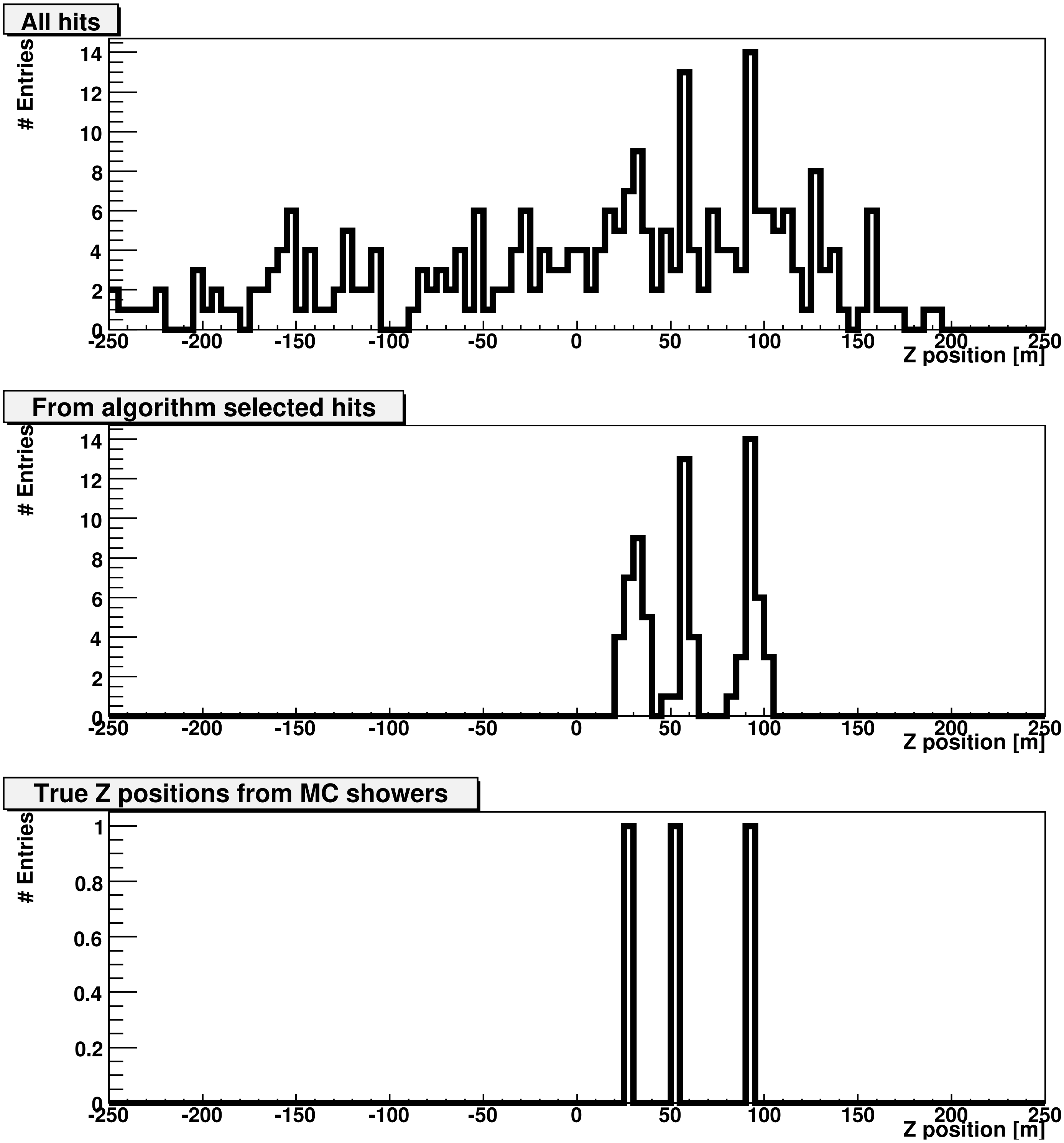
Algorithm to find showers

- Algorithm
  1. take direction of muon
  2. calculate Z-positions
  3. search shower candidates
  4. eliminate background
  5. fit 3-dimensional position

  $\Rightarrow$ muon with at least one shower

- Simple algorithm with few parameters
  - width and significance of the peak
  - Z selection
  - fit probability

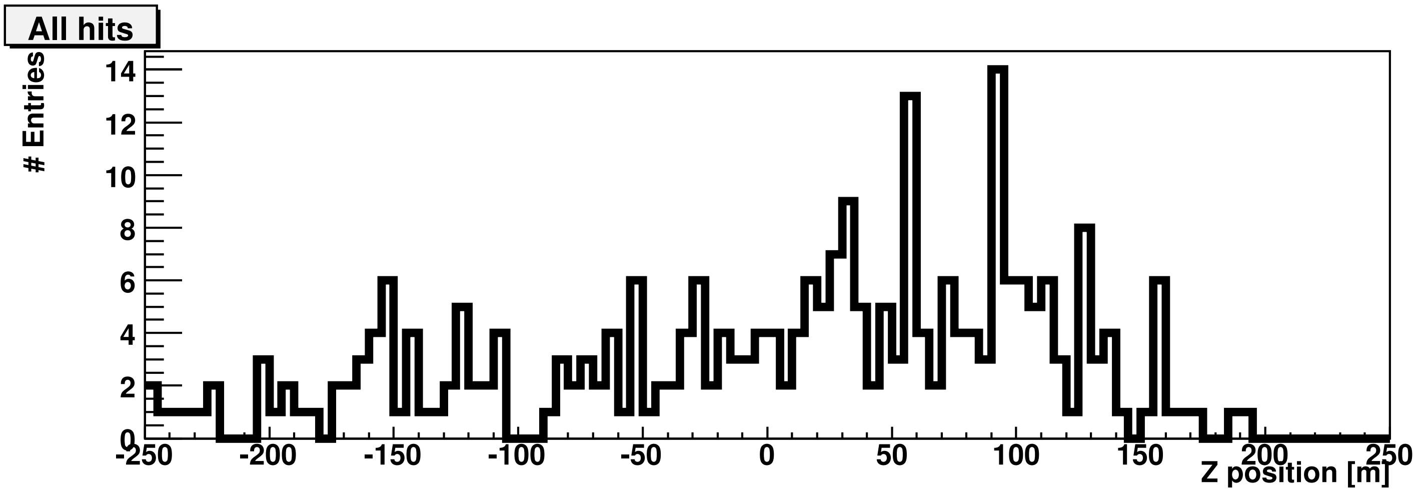
Z-Display for one MC event

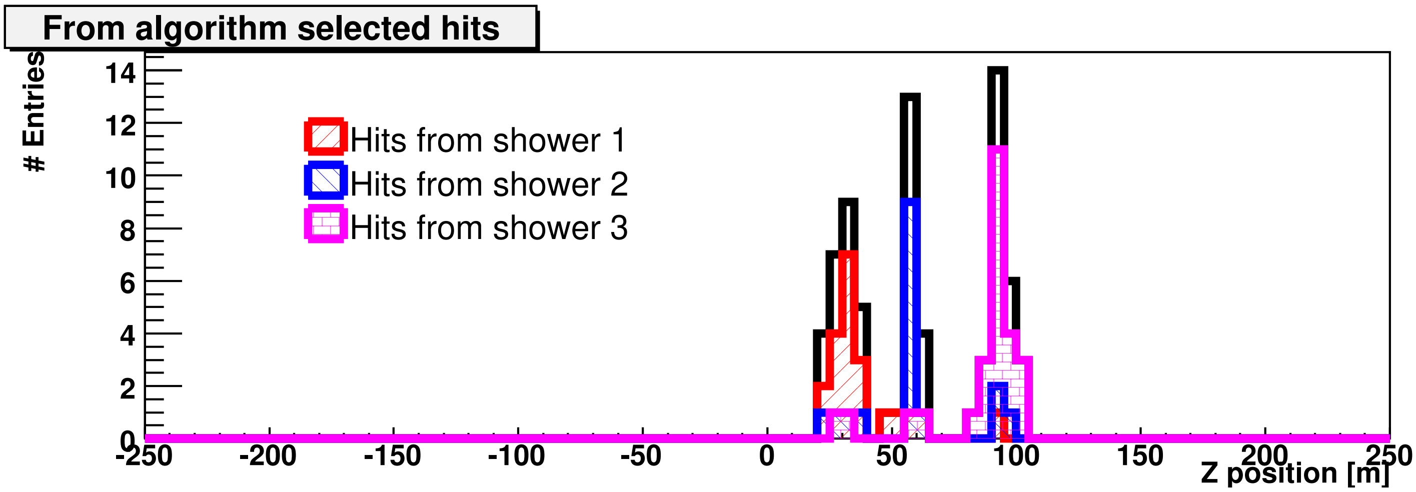


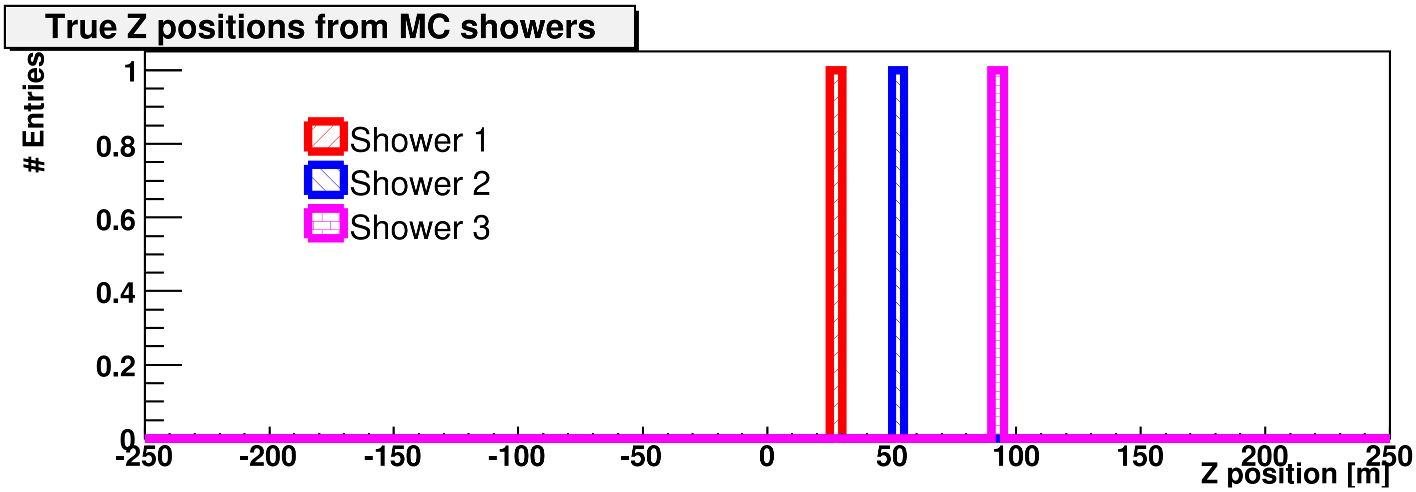
atmospheric muon MC including background

reconstruction: peak width 20 m and $>$ 10 hits

Same Z-Display with hit information







$\Rightarrow$ high hit purity for each shower

MC Event Display

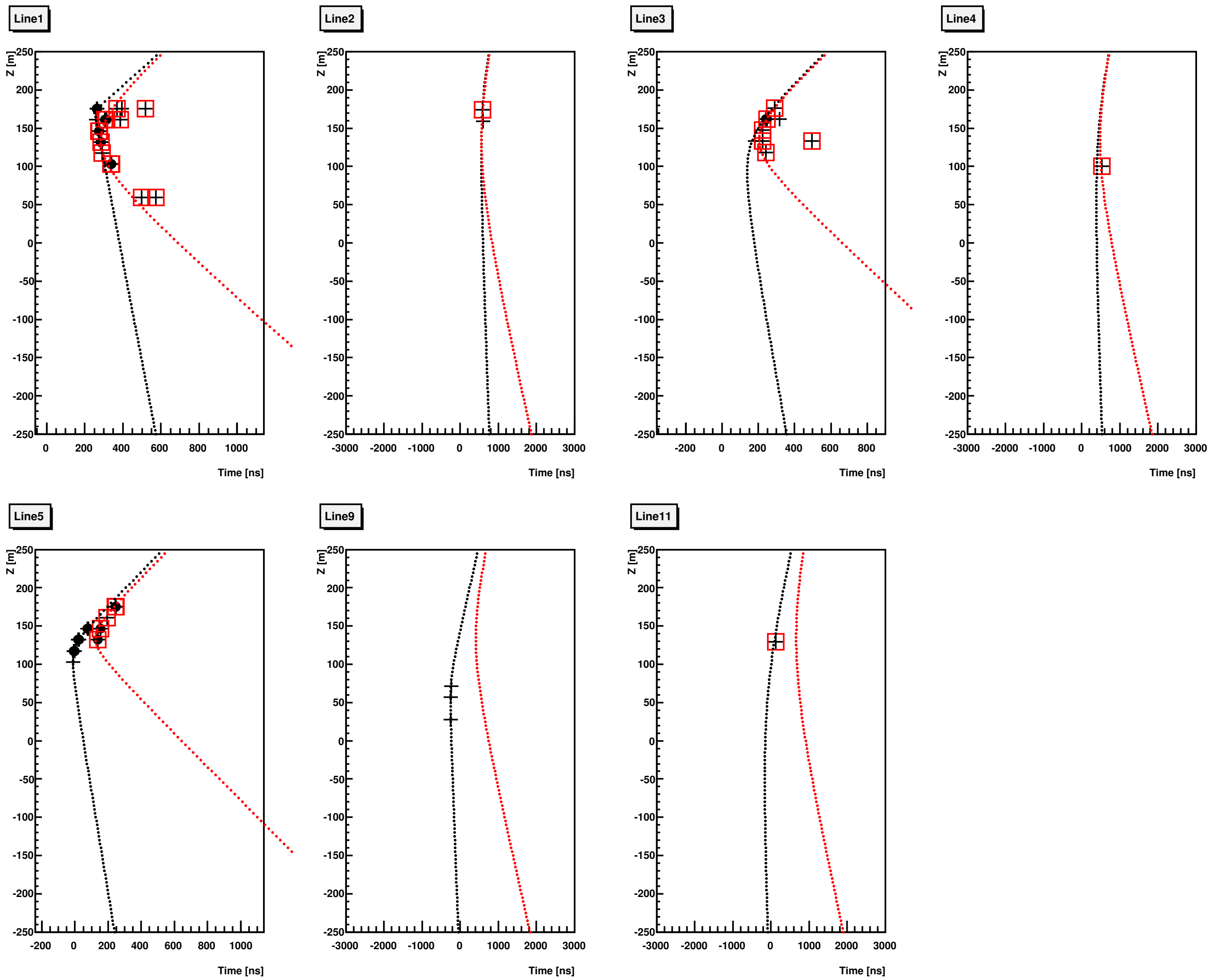
dots = two photon hits

crosses = one photon hits

black Line = Cherenkov light $\longleftrightarrow$ red Line = shower light

red box for hits from shower

Run : 1234 Event : 2263 FrameTarget : 0 FrameIndex : 51029



Data Event Display

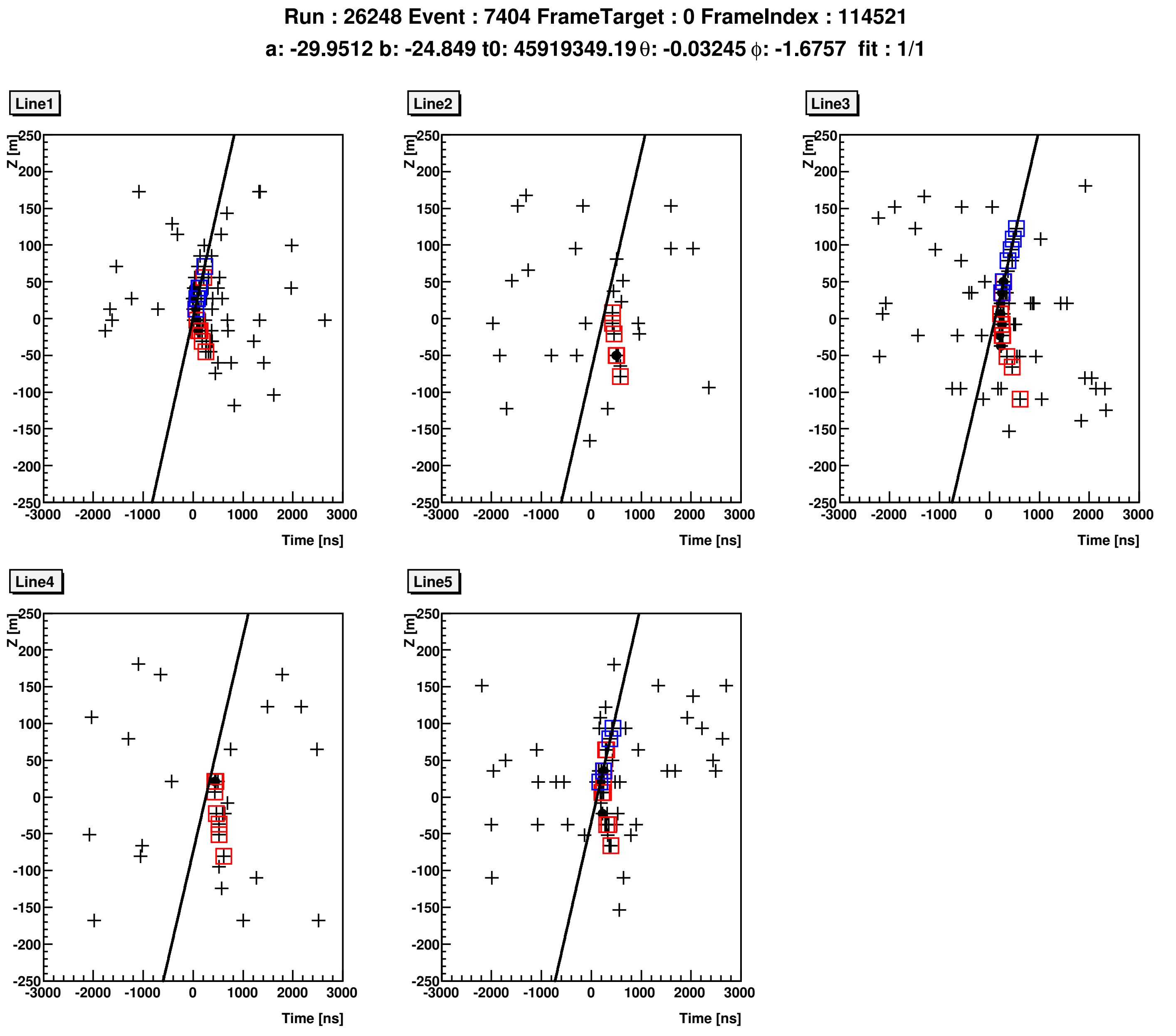
dots = two photon hits

crosses = one photon hits

black Line = result of μ-reconstruction

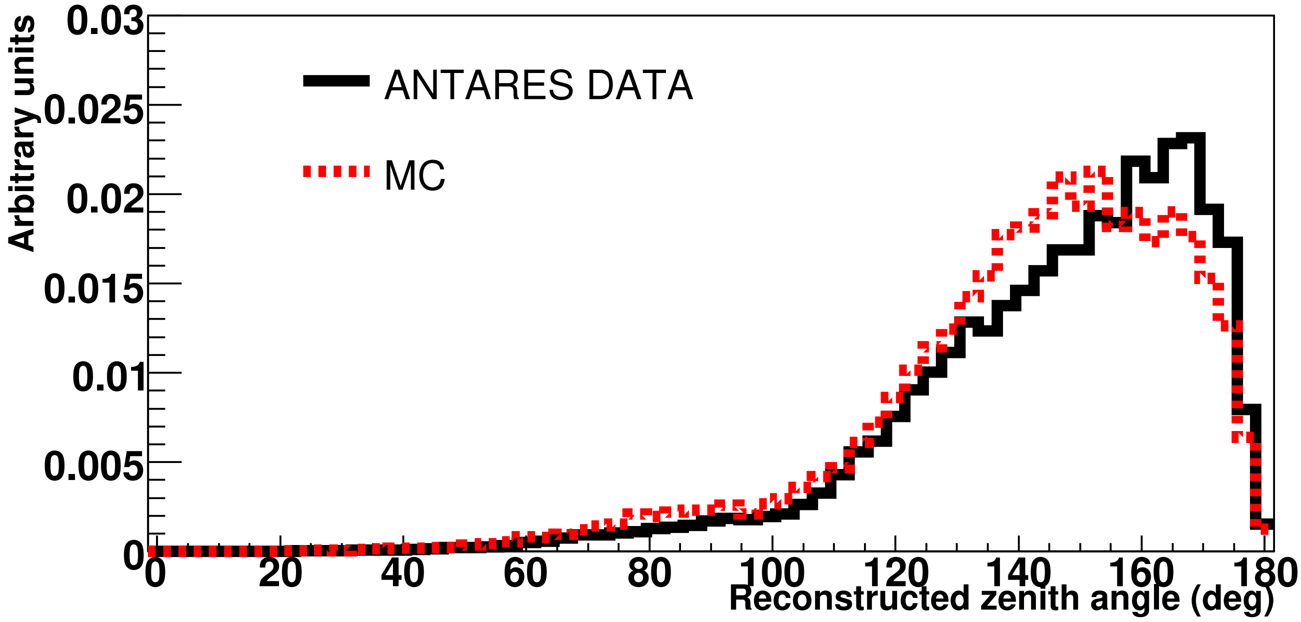
blue box for hits used in μ-reconstruction

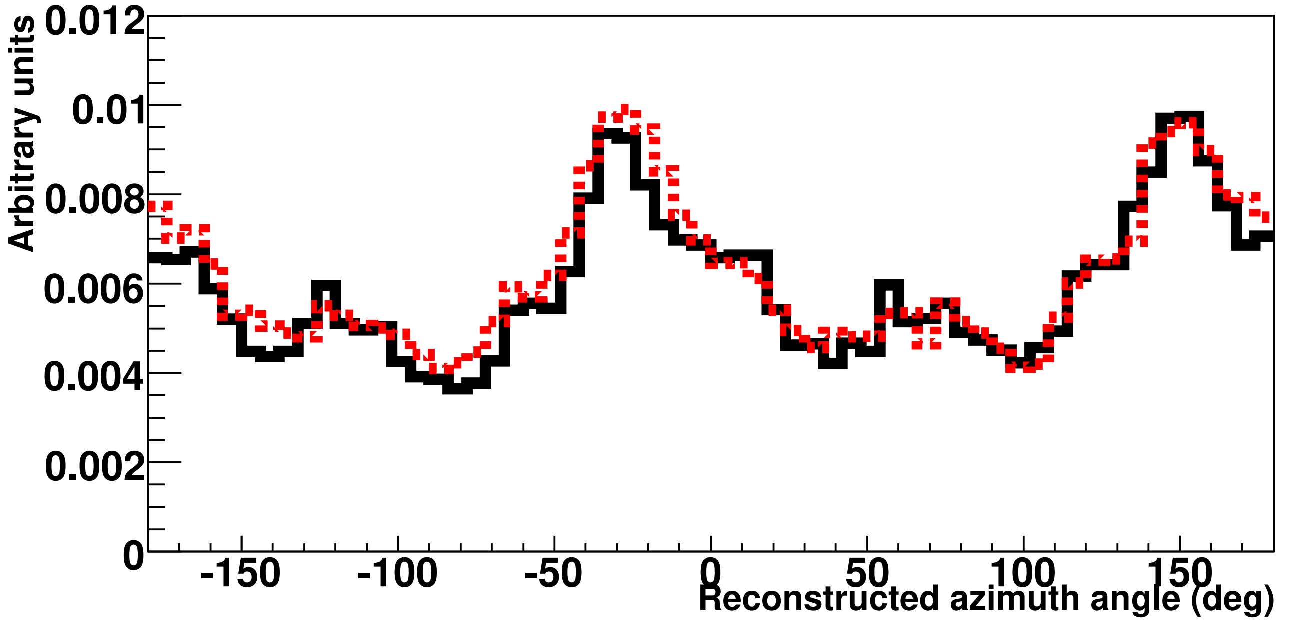
red box for hits in peak



Muon candidates: DATA-MC comparison

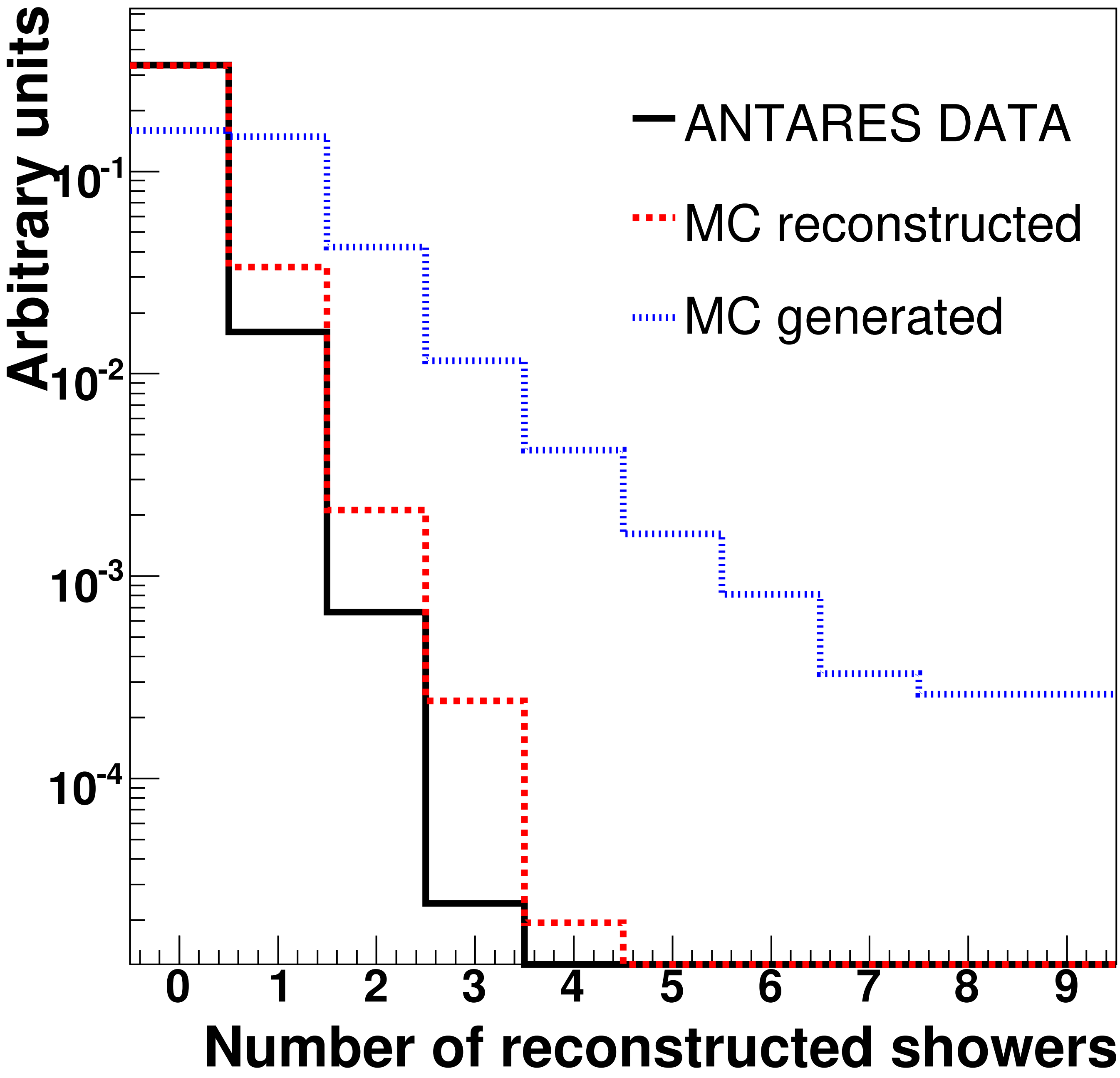
multiple atmospheric muon event generator





reconstructed zenith and azimuth angle of muons

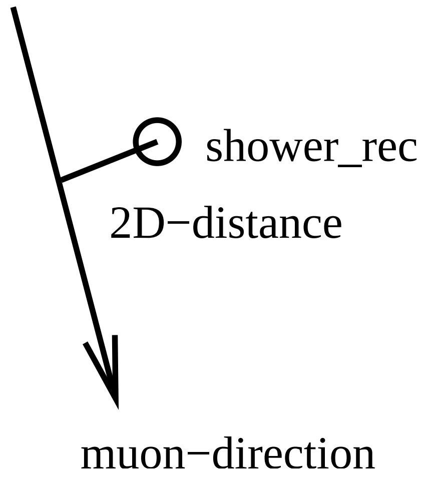
Number of showers per muon

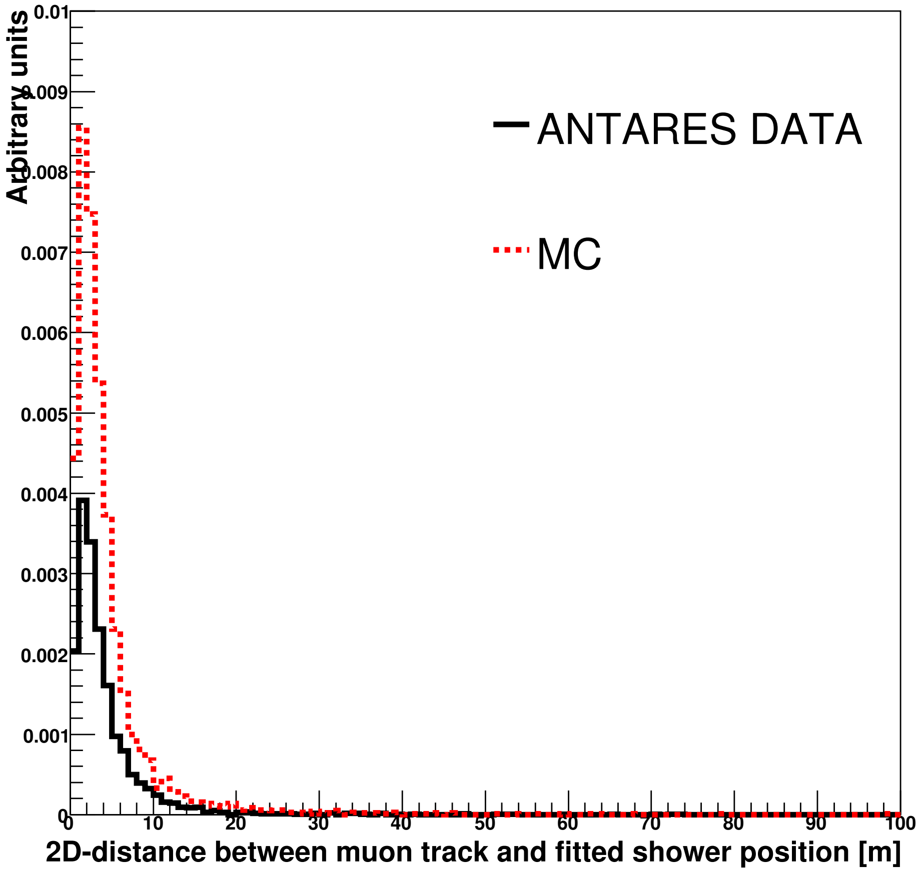


MC close to DATA

$\sim$ 5% (0.5%) of muons have one (two) rec. showers

Showerfitresult: 2D-distance per shower





This variable tells that shower comes from the right track!

Conclusions

- Analysis Idea:
  - project hit information to μ-axis
  - search significant peaks
  - make 3-dimensional fit

  $\Rightarrow$ identification of μ's with showers

- ANTARES sees bremsstrahlung showers from μ's: shower multiplicity fairly well reproduced by MC

- Outlook: use shower information for energy and event topology