Processing of 3D volume data from new reconstruction method applied to LENA

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Outline

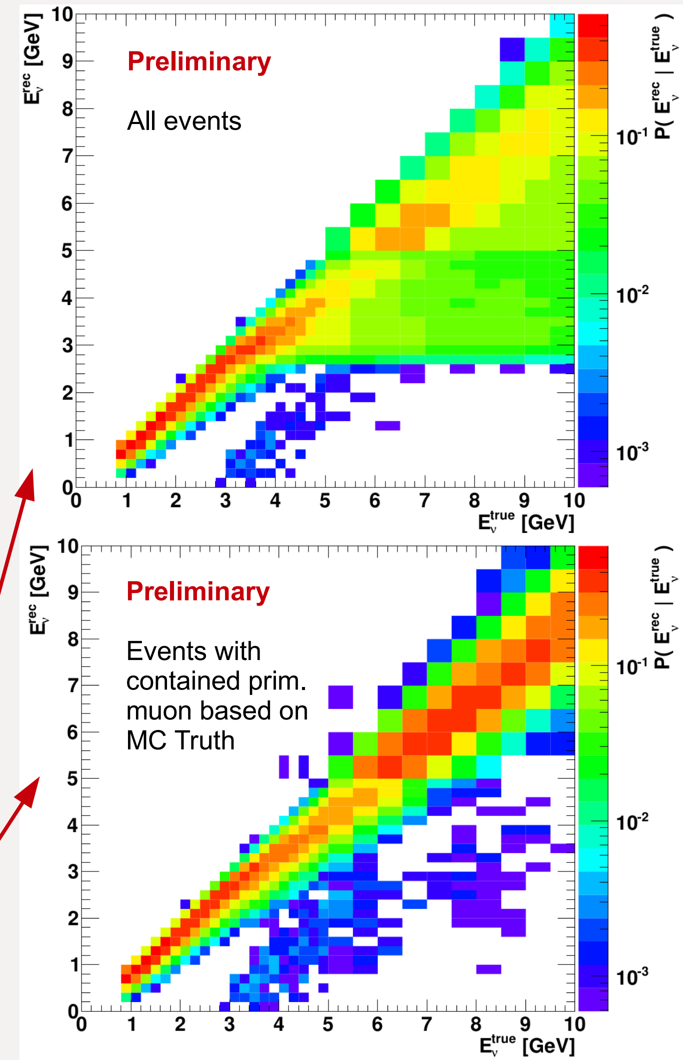
- The LENA detector
- Motivation for reconstruction algorithms in liquid scintillator
- Processing of the output from the spatial reconstruction method of B. Wonsak
- Outlook and conclusion

The LENA Detector

- Design for an unsegmented large volume liquid scintillator (LSc) detector of the next generation
- Cylindrical target volume of 96 m height and 28 m diameter
→ target mass : 50 kt of LAB
- Photon detection with PMTs + light concentrators (Winston-cones)
→ ~30% optical coverage
→ **~30k PMTs (12")**
- Primarily designed for high statistic measurements of low-energy (LE) neutrinos from terrestrial and astrophysical sources

Motivation for Reconstruction Algorithms in LSc

- Event reconstruction algorithms in LSc required for
  - suppression of muon-induced backgrounds in LE applications,
  - high-energy (HE) applications with atmospheric and beam neutrinos.
- At HE, events are not point-like anymore and have more complex toplogies. Therefore, one needs to
  - discriminate different neutrino interaction types based on similar event signatures,
  - take the spatial extension of the energy deposition into account when reconstructing the energy,
  - identify contained events (calorimetric energy measurement!).

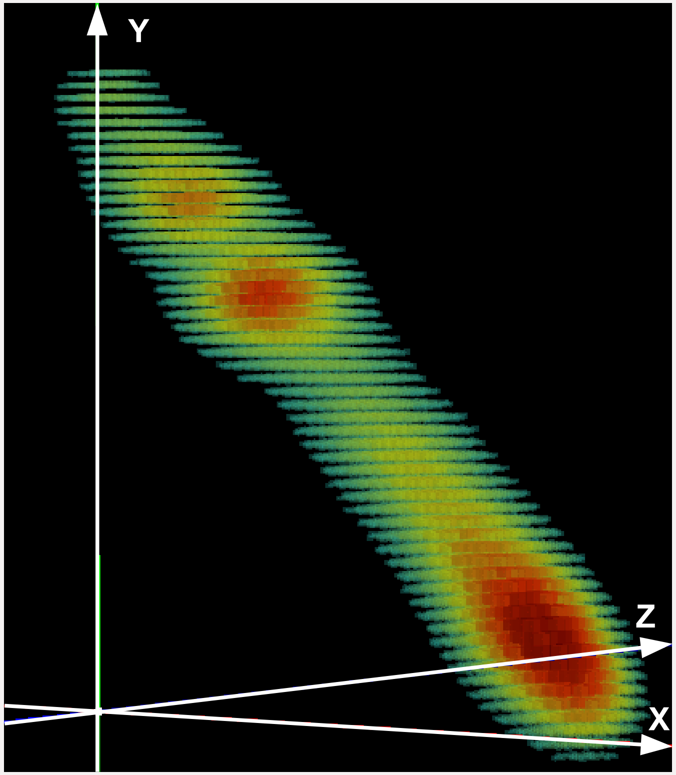


Energy migration matrices for simulated ν_μ CC events starting from the center of LENA. [D. Hellgartner – TU Munich]

The Output of the Spatial Reconstruction Algorithm

- Reconstruction procedure was described in previous talk by B. Wonsak.
- For each bin j at position $\mathbf{x}_j$ in a regular 3D grid a value $\Phi_j = \Phi(\mathbf{x}_j)$ is calculated.
- If Φ_j is correctly normalized,
  → correlation with the number of **detected** scintillation photons emitted from that point in space

  → To do: translate to number of **emitted** scintillation photons
- Process the distribution $\Phi(\mathbf{x})$ to access information on the event's topology, dE/dx, ...



Reconstruction data display for a 3 GeV muon starting at (0,10,0) m with direction (1,-1,0) in LENA.
Data correspond to > 40% of relative bin content.

Binarization of Volume Data

- Additional processing of the reconstruction data is required to extract relevant information for physics analyses.
  → **pave the way for pattern recognition**

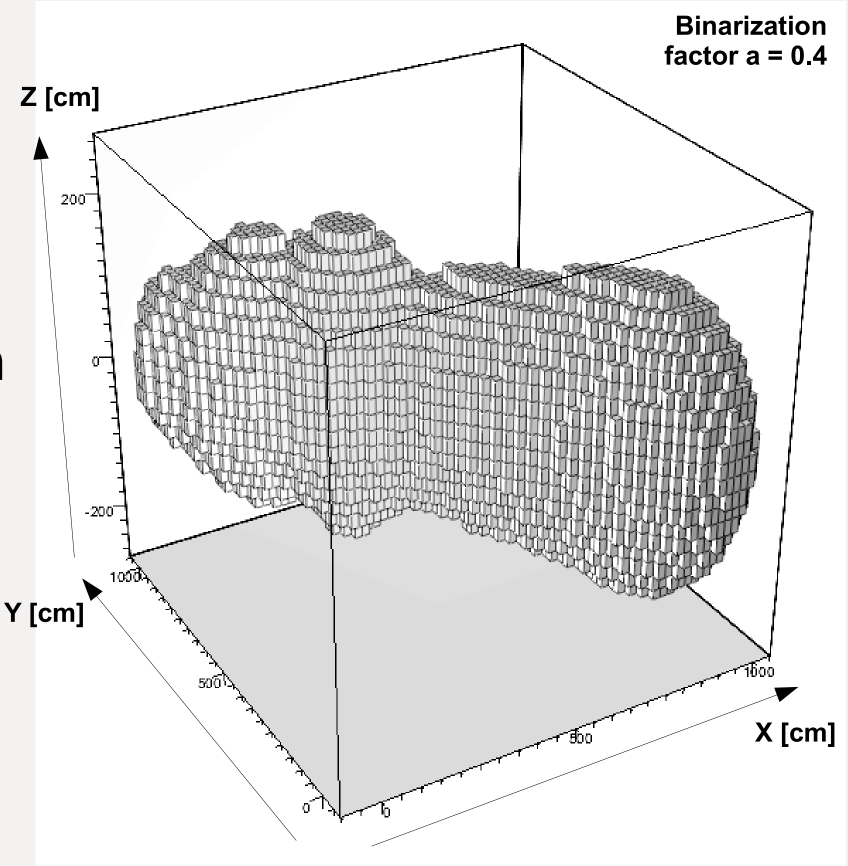
- Study of volume data is a common task, e.g. analysis of tomopgraphic images in medical science.

- Standard algorithms can be found in literature on computational science.

- Starting point: binarize the data using a relative threshold

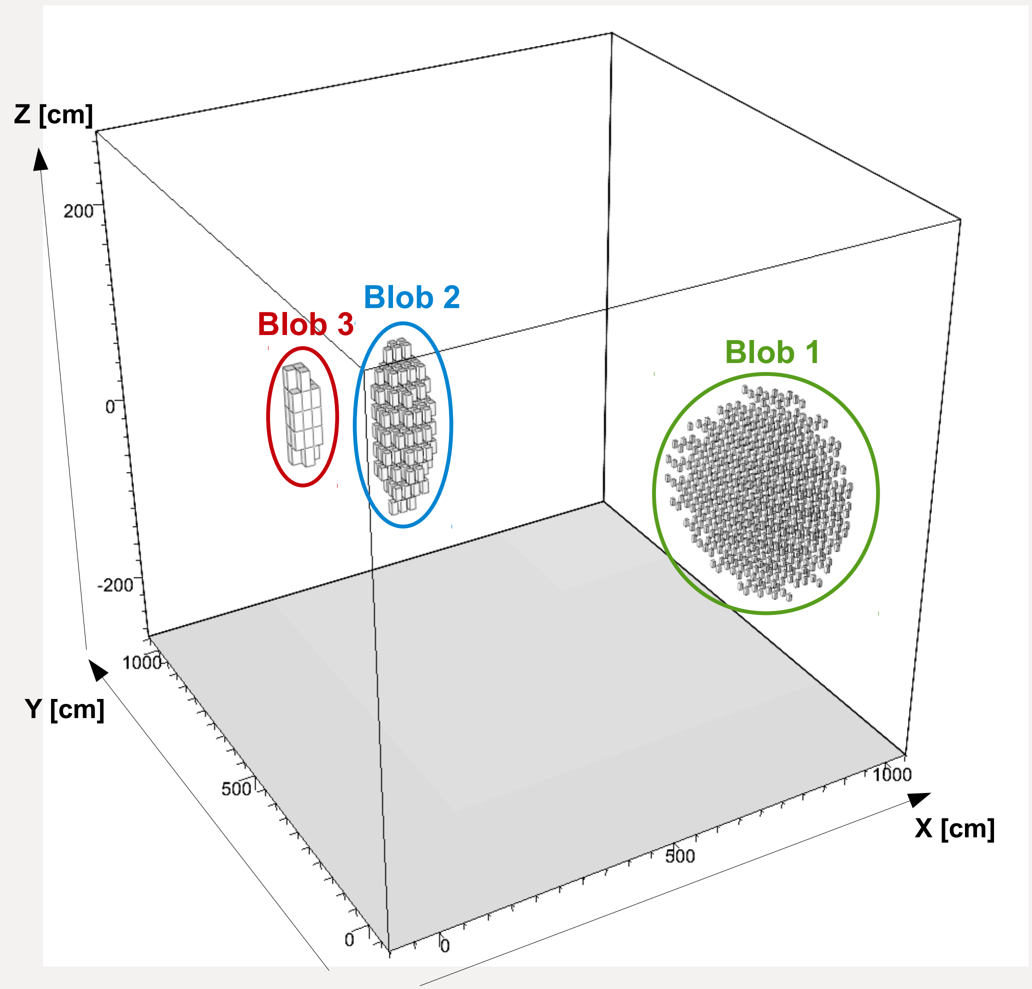
$$T(a) = a \cdot \Phi_{max}$$

with $\Phi_{max} = \mathit{max}\{\Phi_j\}$, $a \in [0,\ldots,1]$



“Blob“ Finding

- Identify spatially separated “blobs“, e.g. from converted gammas.
- Identify “sub-blobs“, by changing the binarization threshold .
- Process the found “blobs“ individually, e.g. determine number of associated bins and corresponding energy deposition.

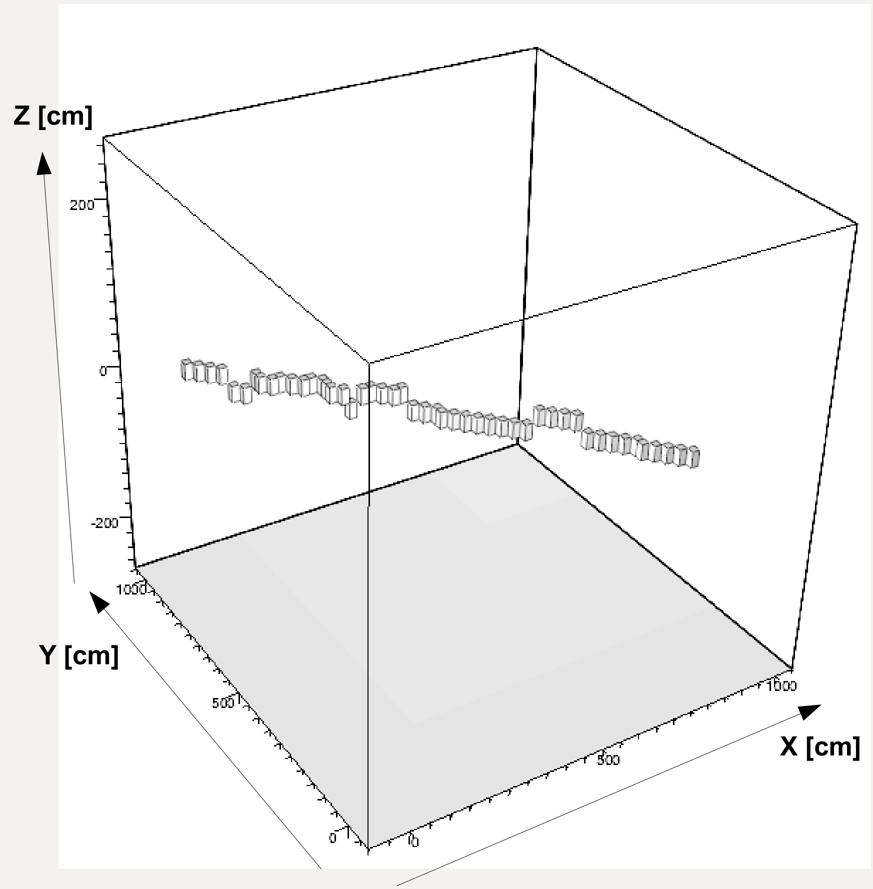


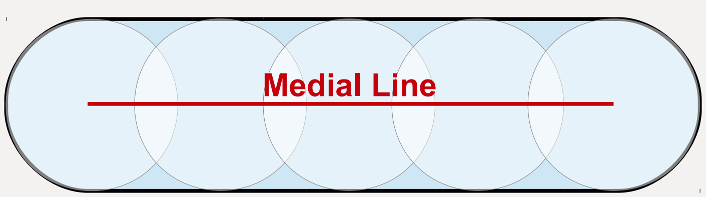
Medial Line Extraction

- Idea : the track of a particle is smearded in all directions due to the intrinsic and extrinsic degradation of the scintillation photon timing information.
- 1D track becomes a 3D object in the reconstruction data.
- Task : compute back from the solid object to the track

  → find the **“medial line“** of the object

- Medial line : *Locus of circles with radii such that they are tangent to the object's surface in at least two points.*



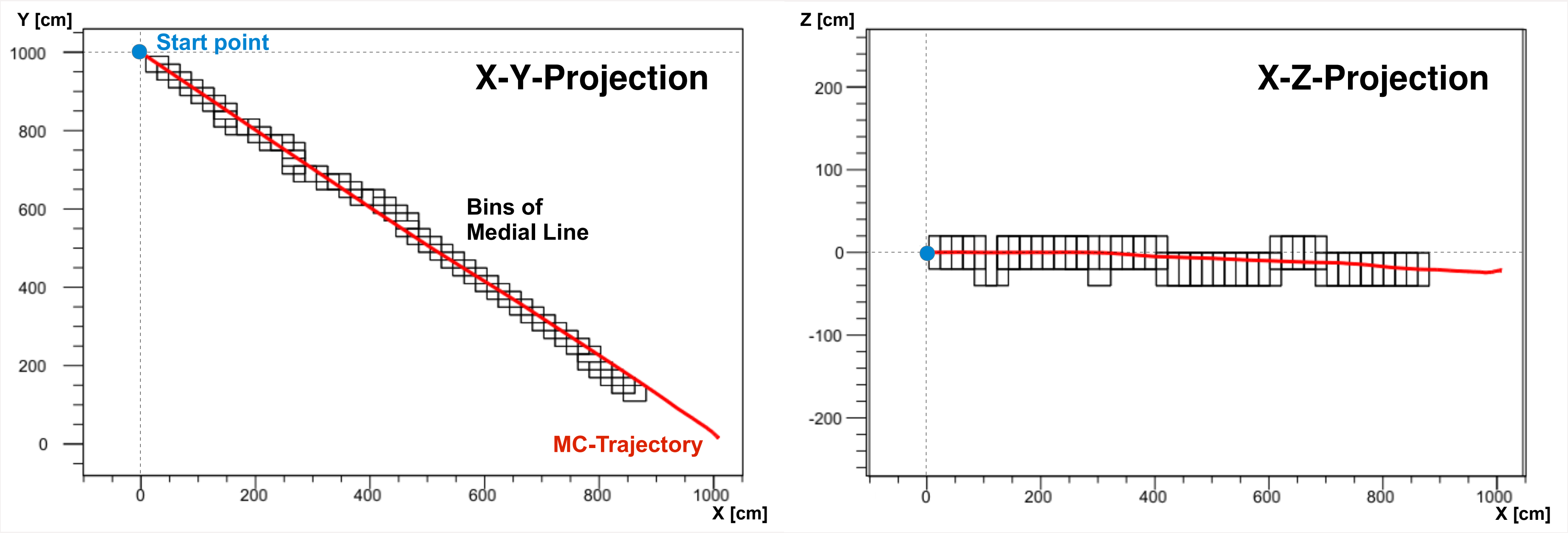


Medial Line Extraction

- Use an iterative thinning procedure with iteration-by-iteration smoothing to extract the medial line from the reconstruction data.
- Thinning : Peel off layers from the solid object according to templated rules to obtain the medial line.

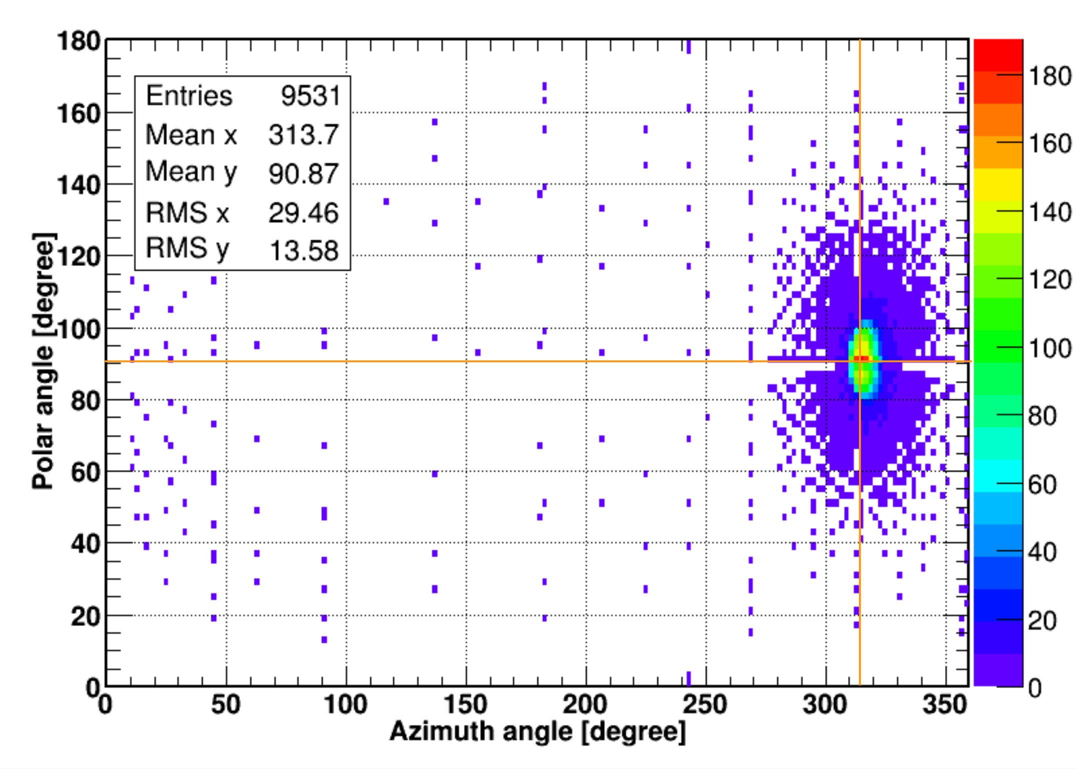
"A 3D 6-subiteration thinning algorithm for extracting medial lines"
[Pattern Recognition Letters 19 (1998) 613-627]

"Thinning combined with iteration-by-iteration smoothing for 3D binary images"
[Graphical Models (2011) 335-345]



Azimuth and Polar Angle

- Determine the polar and azimuth angle for each binary-1 bin
  wrt. the reconstructed vertex
  → cluster of angle combinations in the direction of the track



Data	Azimuth angle [deg]	Polar angle [deg]
MC (Vertex)	315	90
MC (End-Start)	315.7	90.9
Reco data *(2D Gauss fit)*	316.8 +/- 4.1	91.0 +/- 6.7

Outlook

- Reconstruction and post-processing need to be applied to larger event samples.
- Extension of the reconstruction and post-processing chain to allow the extraction of strong parameters for event discrimination via a multivariate analysis.
- Use the bin weight information from the reconstruction data which is currently not respected due to binarization.
- Obtain start values for a likelihood-based fit from the reconstruction data.

We are just at the beginning...

Conclusion

- Event reconstruction in a liquid scintillator detector like LENA seems feasible and is required for HE applications and improved background suppression in the LE regime.
- The reconstruction algorithm developed by B. Wonsak produces volume data from which relevant event information needs to be extracted in a post-processing step.
- Based on the binarized reconstruction data, (spatially separated) “blobs“ can be identified and the medial line can be determined for succeeding purposes.
- The goal is to extend the reconstruction chain towards the extraction of parameters from the reconstruction data, which then can be used in a multivariate analyis or as start values for a likelihood-based fit.

Thank you for your kind attention!