Topological Reconstruction in Liquid Scintillator

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on behalf of

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FroST – Topical Workshop for THEIA

Mainz, 22nd October 2016

Outline

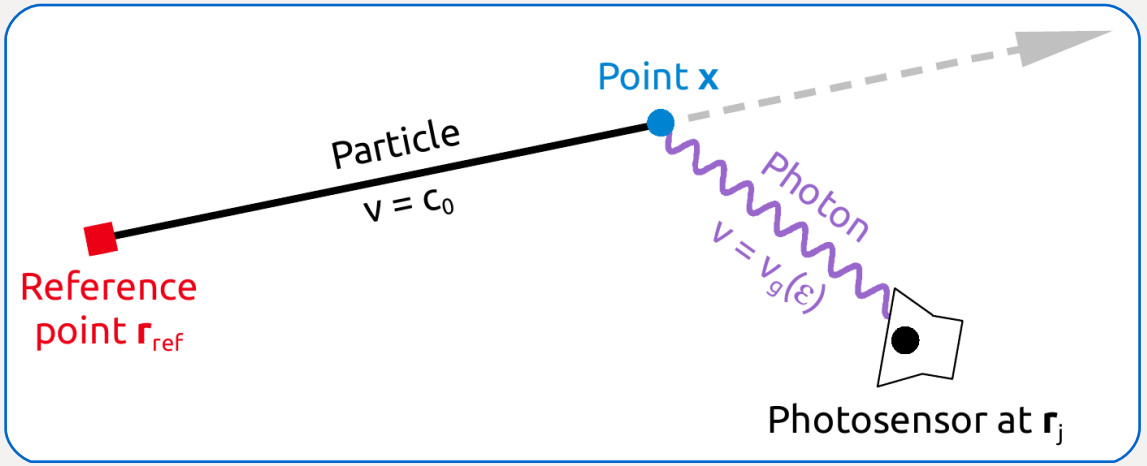
- *History / Motivation*
- *Working Principle of the Topological Reconstruction (in LSc)*
- *Current Status*
- *Prospects*
- *Outlook for THEIA*
- *Summary & Conclusion*

History / Motivation

- Original motivation: 50 kt LSc detector LENA as far-detector in an LBNO experiment with GeV neutrino energies
  - → requires detailed reconstructions of complex event toplogies
- Reconstruction method based on a concrete event hypothesis was developed for LENA at TU Munich around 2010
- We also wanted something independent of a concrete hypothesis
  - → Development of the topological reconstruction method by Björn Wonsak (Universität Hamburg) since 2013
- Today‘s motivation: 20 kt LSc detector JUNO
  - Muon track reconstruction for improved cosmogenic background vetoes
  - Improve energy reconstruction of MeV neutrino events

Working Principle of the Topological Reconstruction (Scintillation only)

- *Goal*: Reconstruction of the spatial number density distribution of isotropic, optical photon emissions
- For each detected photon answer the question: Where did it come from?
- Only a few basic assumptions:

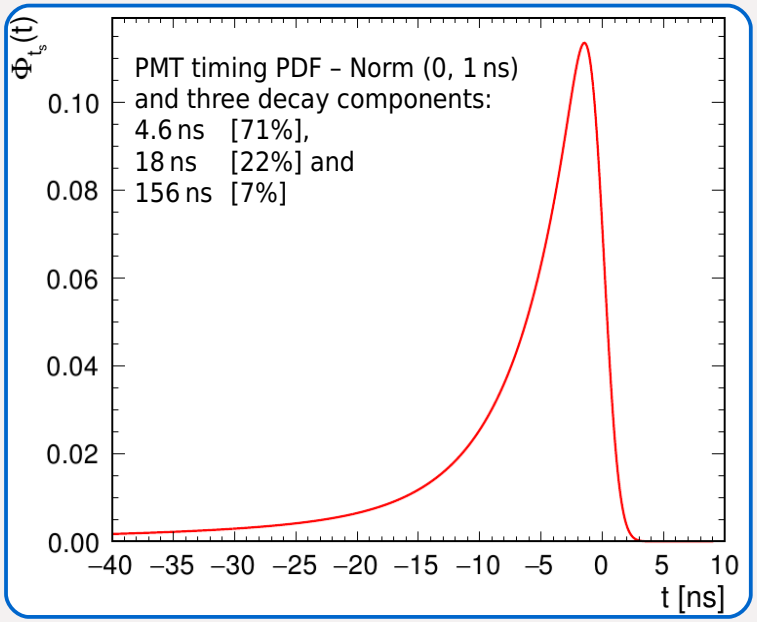


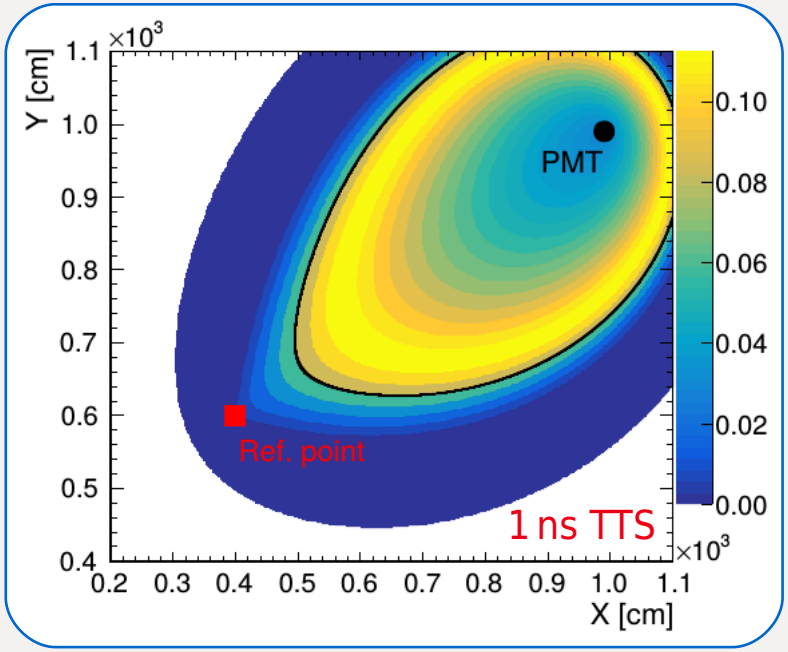
$$t(\mathbf{x}) = t_{\mathrm{ref}} \pm \underbrace{\frac{|\mathbf{x} - \mathbf{r}_{\mathrm{ref}}|}{c_0}}_{\text{particle}} + \underbrace{\frac{|\mathbf{r}_j - \mathbf{x}|}{v_g(\epsilon)}}_{\text{photon}}$$

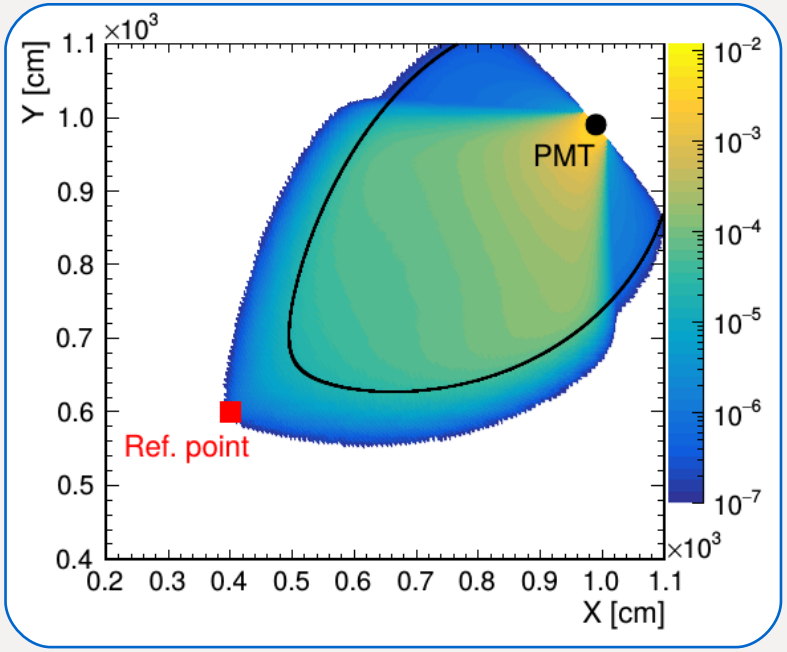
Working Principle of the Topological Reconstruction (Scintillation only)

- Photon emission, propagation and detection are random processes
- Take **temporal** (scintillation, PMT timing) and **spatial constraints** (acceptance, optical properties, light concentrator, ...) for photon emission points into account

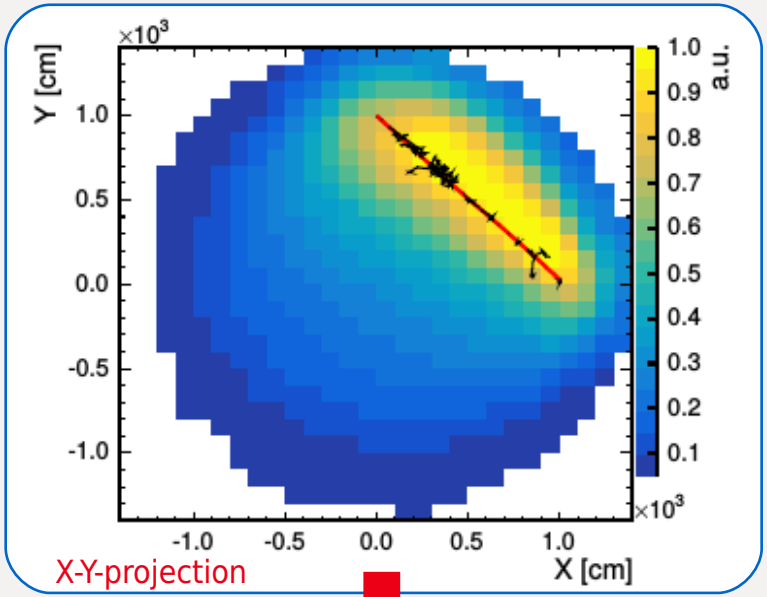
  → spatial p.d.f. for photon emission point







Working Principle of the Topological Reconstruction



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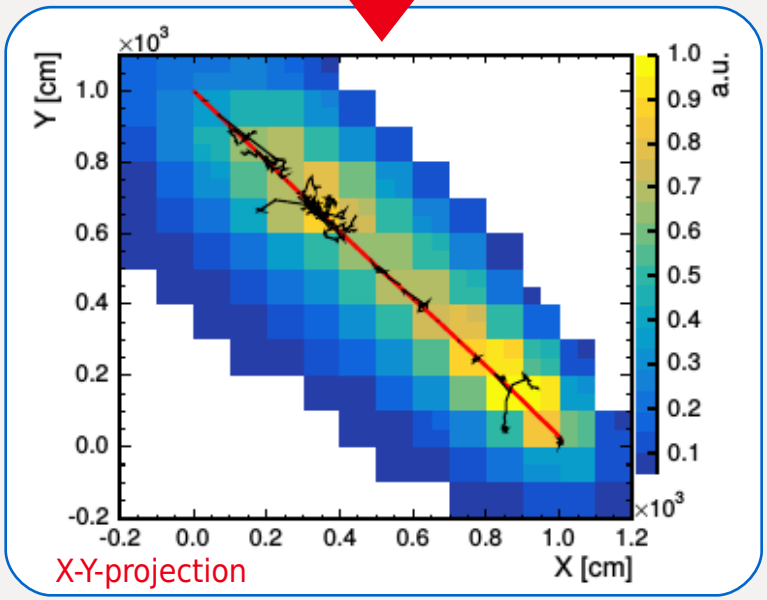

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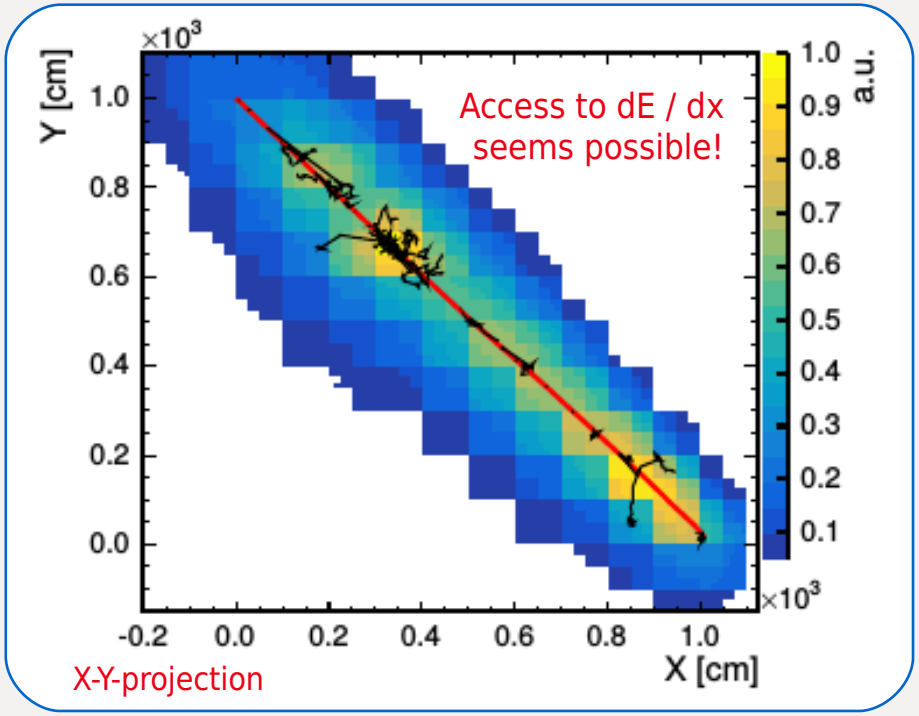
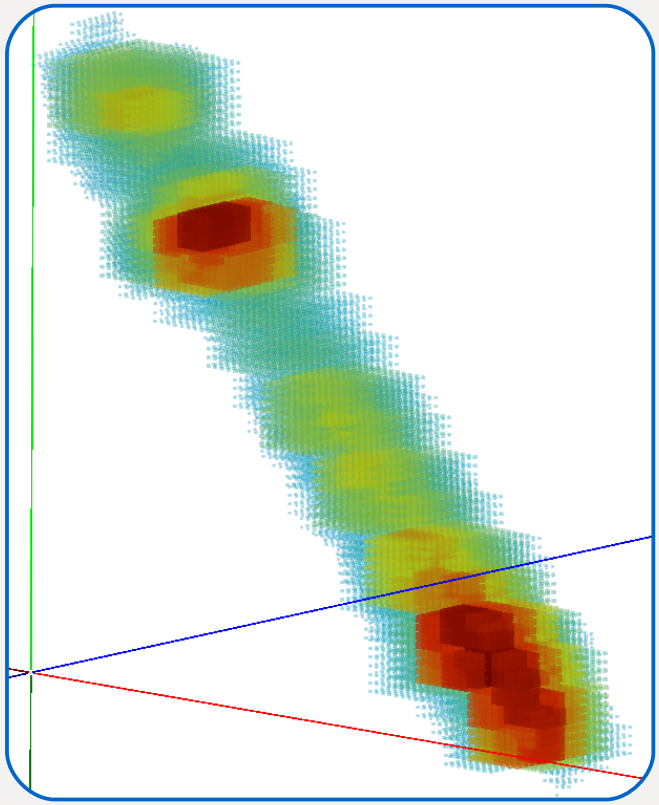


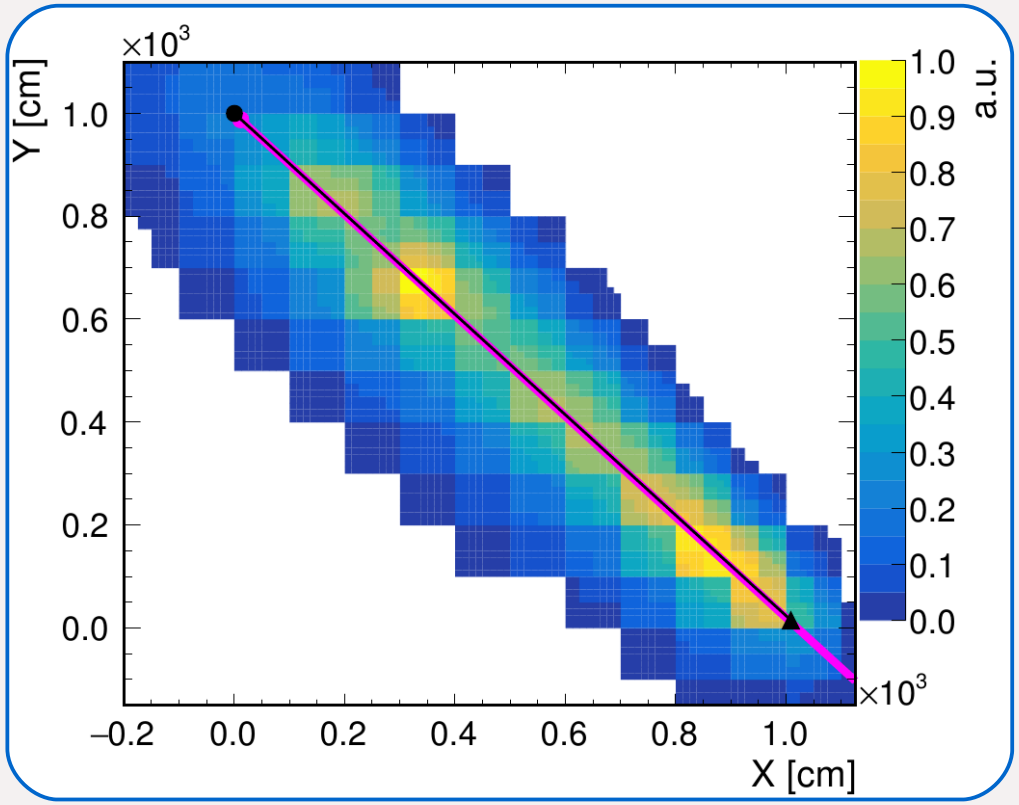
3 GeV muon simulated in LENA

- Use all photon hits from all PMTs
- Divide result by local detection efficiency
  - → Number density of emitted photons
- "Connect information" in multiple iterations
  - → Use prior result as "prior information" in next iteration

Working Principle of the Topological Reconstruction

- Finally, extract event topology and descriptive physics parameters from the 3D output data → highly nontrivial!
- Application of “standard“ 3D data analysis / image processing techniques

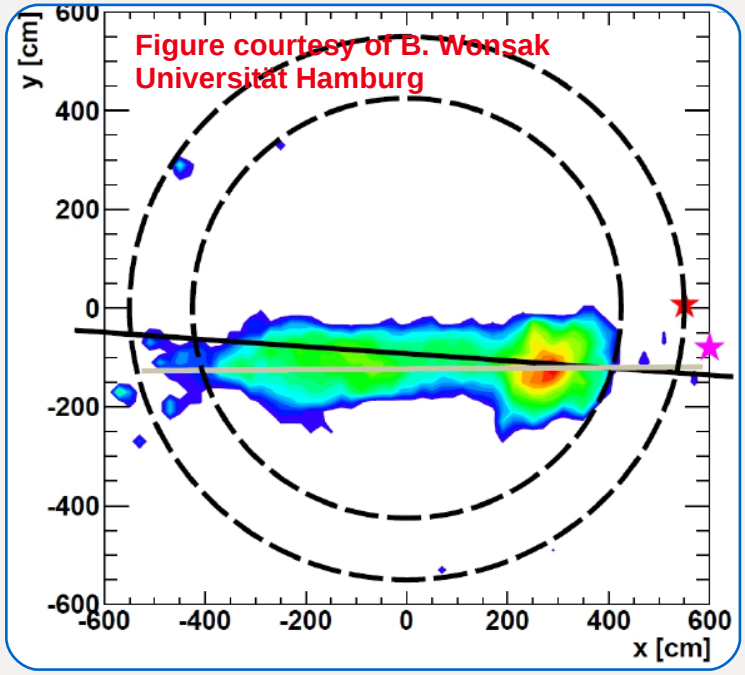


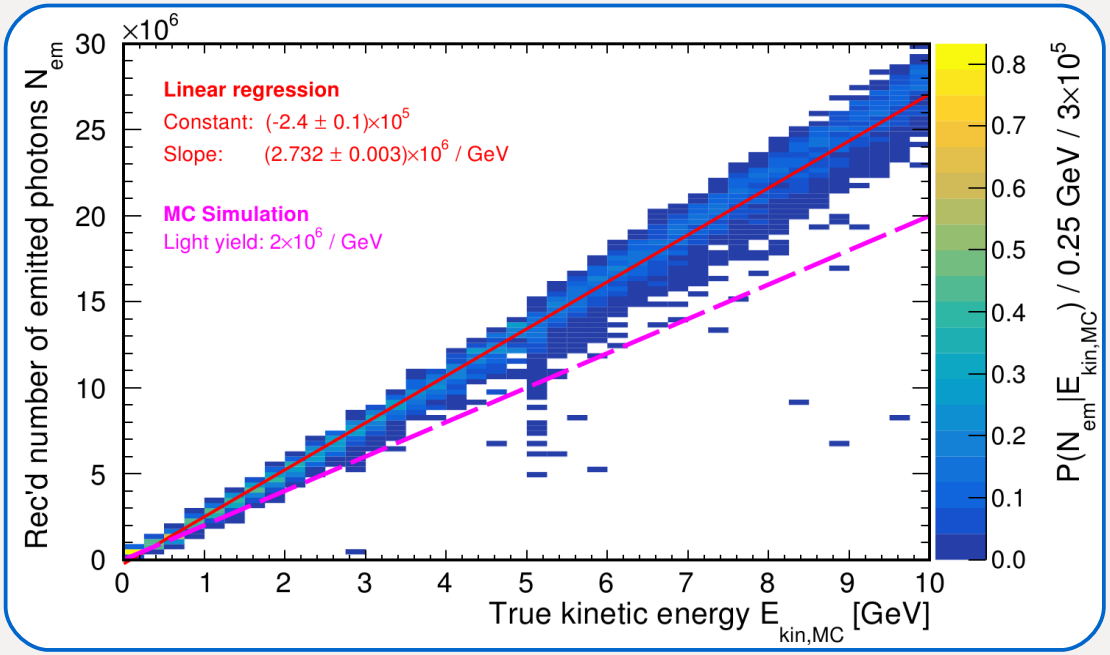


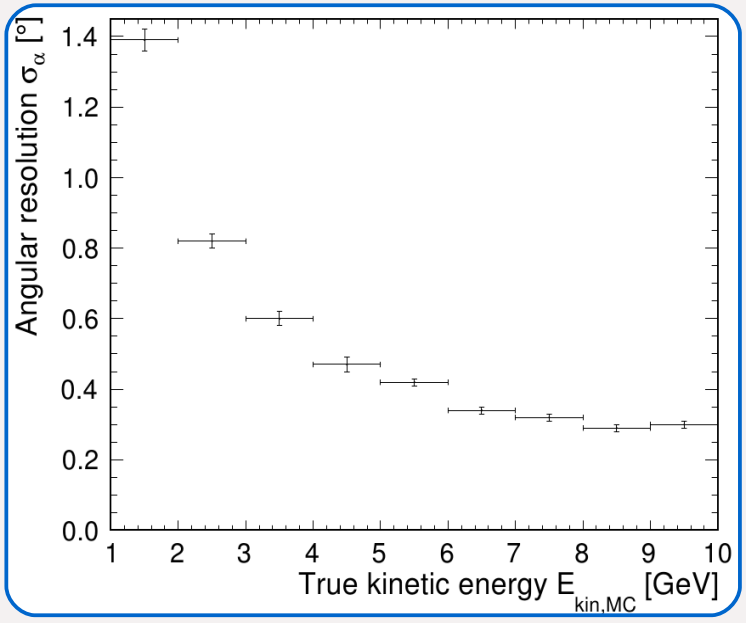
3GeV muon simulated in LENA

Current Status

- Early version tested with real Borexino data
- Developed C++ reconstruction framework
  - LENA implemented
  - JUNO implementation ongoing
    (more complicated optical model)
  - Borexino implementation ongoing
    (real data!)
- First performance evaluation with fully-contained MC muon events in LENA

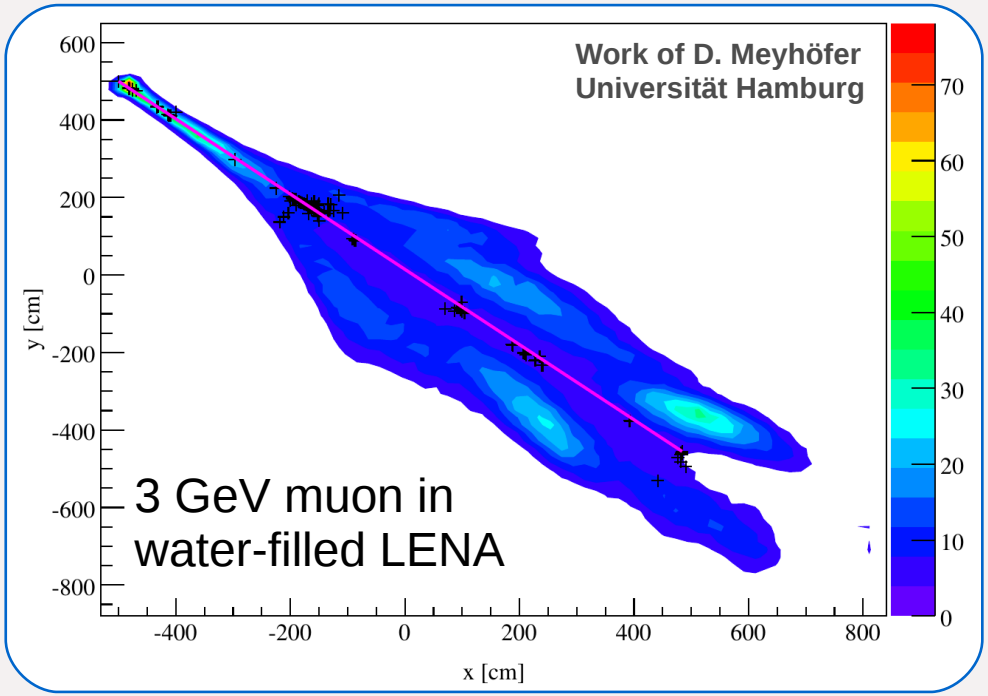






Prospects

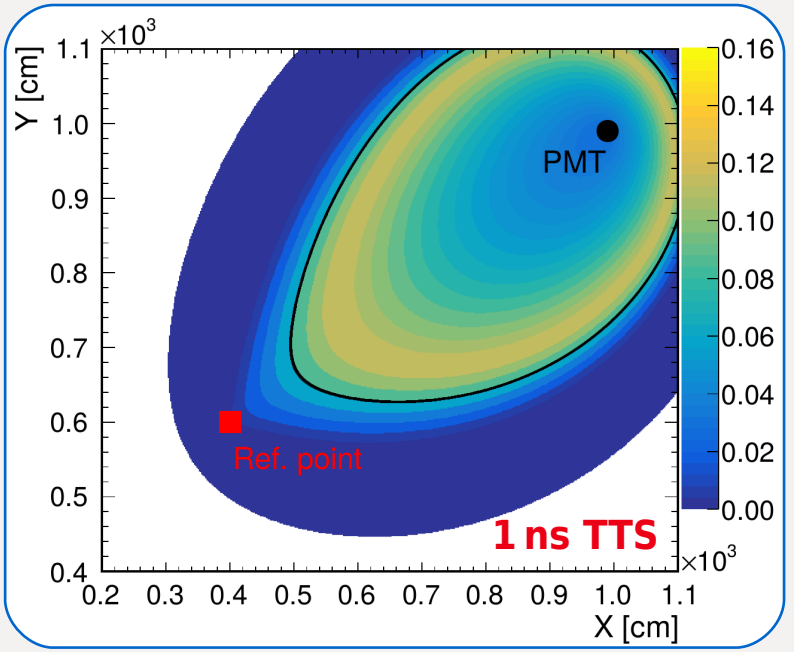
- Improve computation speed
  - Hardware level (parallelization)
  - Software level (data structures,...)
  - Algorithm level (scattered photons,...)
- Enhance analysis of 3D output data (access dE/dx)
- Implement Cherenkov light (already some experience)
- Study low-energy events (already some experience)
- Reconstruction of more complex event topologies

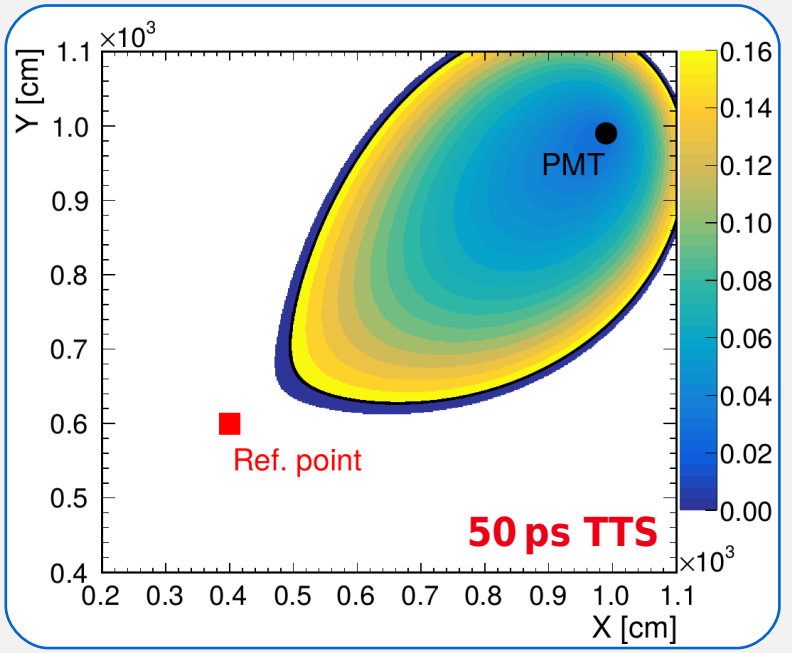


Outlook for THEIA

Impacts of WbLSc and LAPPDs:

- Scintillation + Cherenkov light
  - Dedicated reconstruction modes important
  - Energy and direction (momentum) reco → good PID?
- Large attenuation (scattering) lengths
  - Less scattered light → well-contoured 3D structures
- Better time resolution of photon hits
  - Well-contoured 3D structures
  - Smaller cell sizes justified → resolve finer structures
  - Efficient “removal“ of scattered photons
- Better spatial resolution of photon hits
  - Reduce / remove artifacts at detector edge





Summary & Conclusion

- A new topological reconstruction method for high- and low-energy events in LSc is in development
- Access to dE/dx seems possible; tracking of GeV neutrino interactions in WbLSc and ObLSc appears to be within reach
- The method was evaluated with MC muon events in LENA; results from real Borexino muon data also look promising
- First tests with Cherenkov light gave valuable input for further development
- WbLSc and LAPPDs would greatly enhance the performance / capablities of the topological reconstruction method

Thank you for your kind attention!