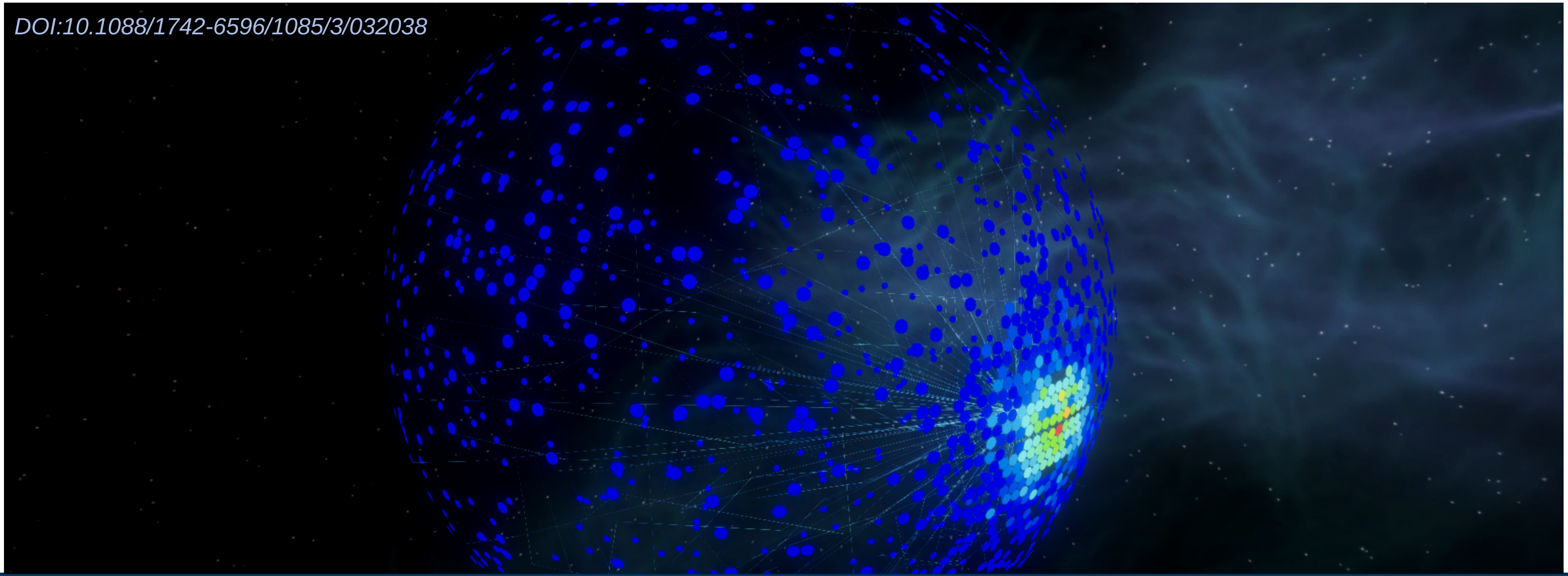


EVENT RECONSTRUCTION IN JUNO

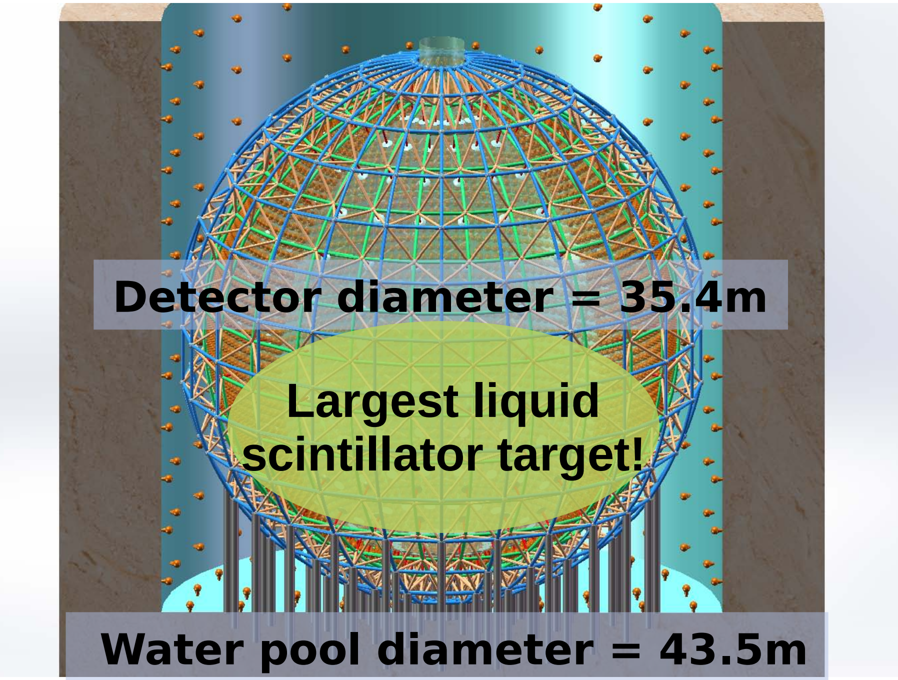
XIX International Workshop on Neutrino Telescopes

26.02.21 I PHILIPP KAMPMANN

ON BEHALF OF THE JUNO COLLABORATION

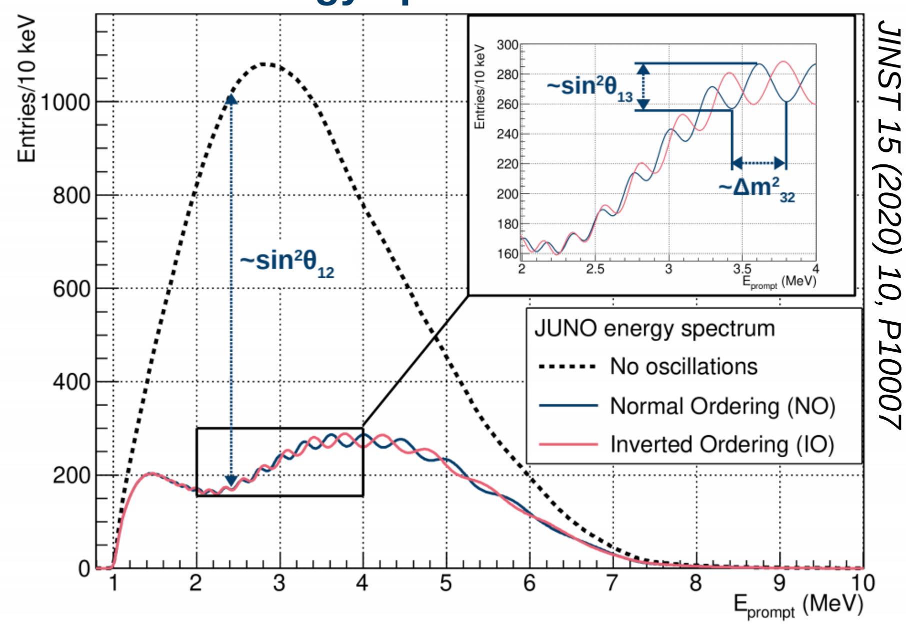
The JUNO experiment

Aiming to resolve the Neutrino Mass Ordering



- 17,612 large 20''-PMT's
- 25,600 small 3''-PMT's
  - High optical coverage (~78%)
- 20 ktons of liquid scintillator
  - Recipe optimized for high light yield and transparency
- **About 1,300 p.e./MeV expected!**
  - Borexino: ~500 p.e./MeV
  - KamLAND: ~250 p.e./MeV

Energy spectrum of JUNO



JINST 15 (2020) 10, P10007

- Oscillated reactor $\bar{\nu}_e$ spectrum with 53 km baseline
- Neutrino Mass Ordering hypotheses can be distinguished via fast Δm^2_{32} pattern
- Challenging requirement of an energy resolution **better than 3% at 1 MeV**

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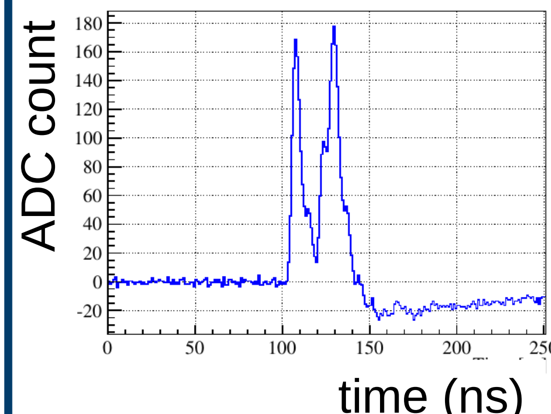
Workflow of reconstruction

Waveform reconstruction

Reconstruction of
- **amplitudes** and
- **times**

of photon hits from the readout signals

Reconstruction of each channel

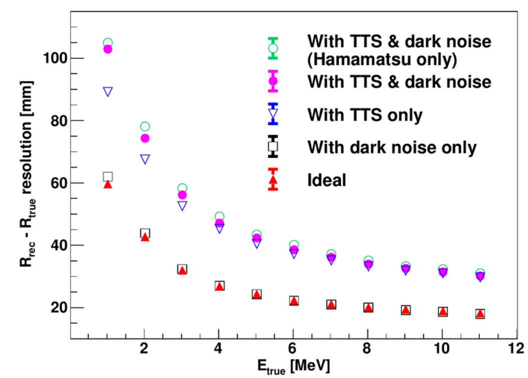


Event reconstruction

Reconstruction of
- **Energy**
- **Vertex + time**
- **Particle type**

from all reconstructed PMT signals

Reconstruction of global event characterization

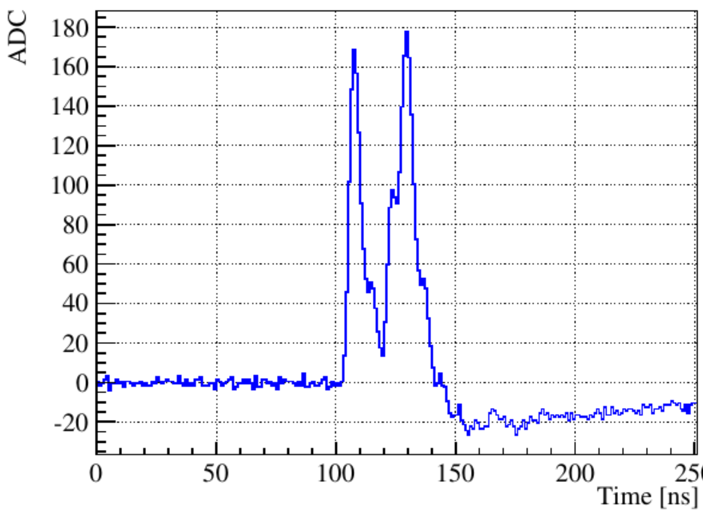


Waveform reconstruction

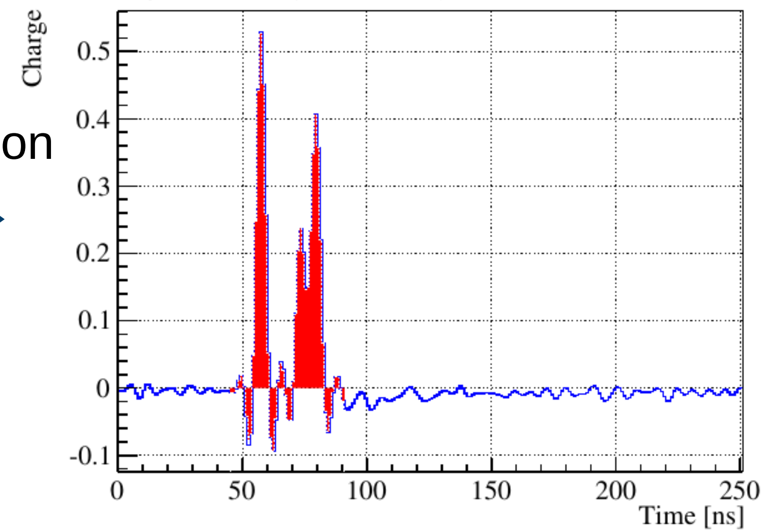
- **Waveform = electronic signal from PMT readout**
- Need to reconstruct time and charge (=amplitude)
- Strategy: **Deconvolution**
  - Fourier-transformation of the signal to frequency domain
  - Multiply with (low-pass) filter function
    - Obtained from single p.e. response
  - FFT back to time domain -> Integrate to obtain charge

$$\text{Filter} = \frac{\text{Signal}^2 - \text{Noise}^2}{\text{Signal}^2}$$

https://doi.org/10.1016/j.nima.2018.03.061



Deconvolution



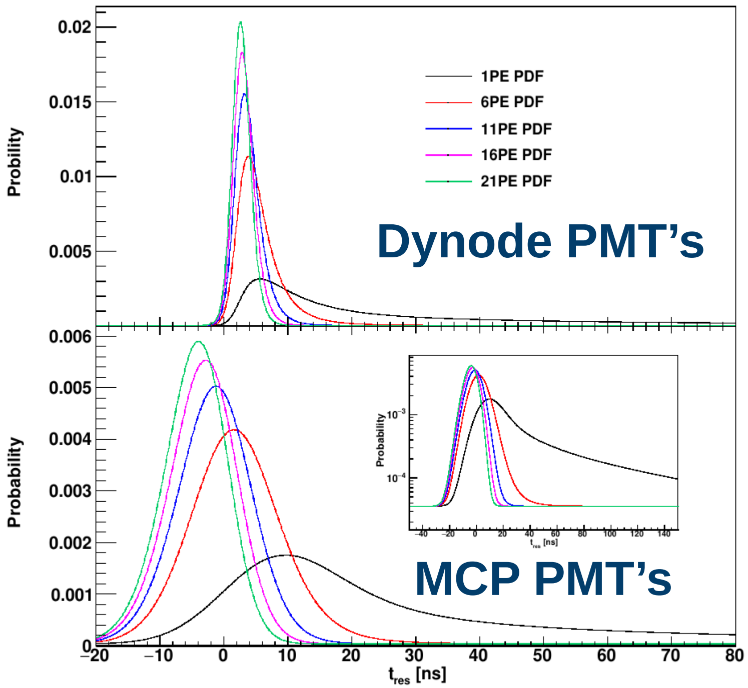
Other methods: waveform fitting, simple charge integration, etc.

Vertex reconstruction

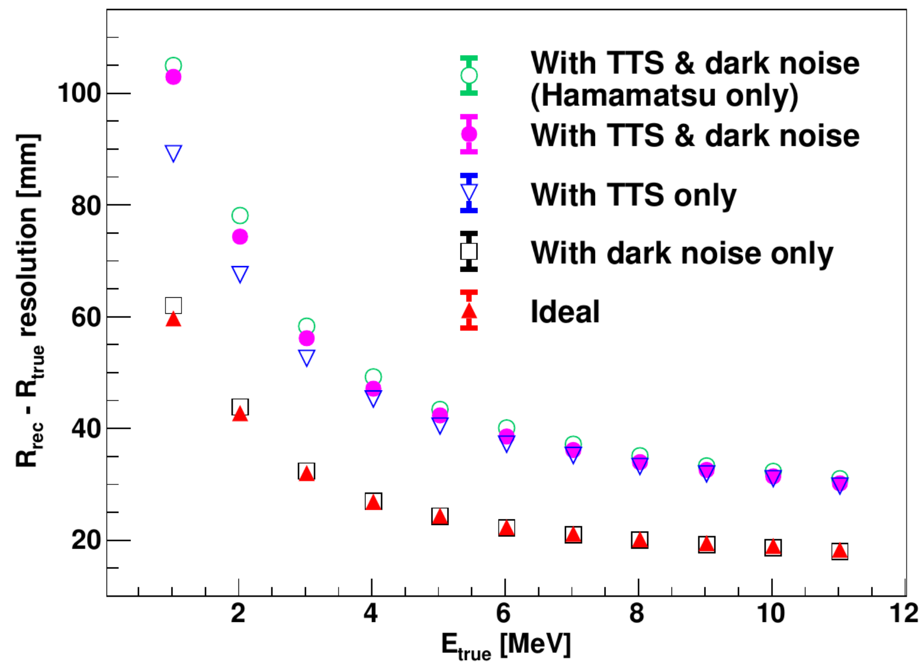
arXiv:2101.08901

- The vertex reconstruction uses the reconstructed time information to estimate the **position and time of light emission**
- **Procedure:**
  - Select first hit times for each fired channel
  - Correct time of flight and event time: $t^i_{res}(\vec{r}_0, t_0) = t_i - tof_i - t_0$
  - Compare to PDF and minimize LLH function to estimate light emission vertex

First hit time PDF functions



Radial resolution



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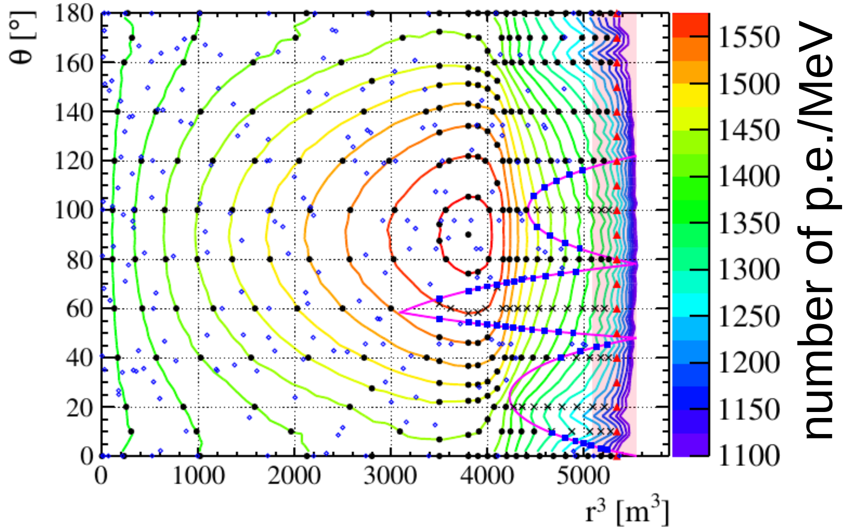
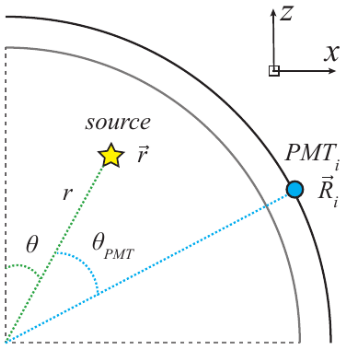
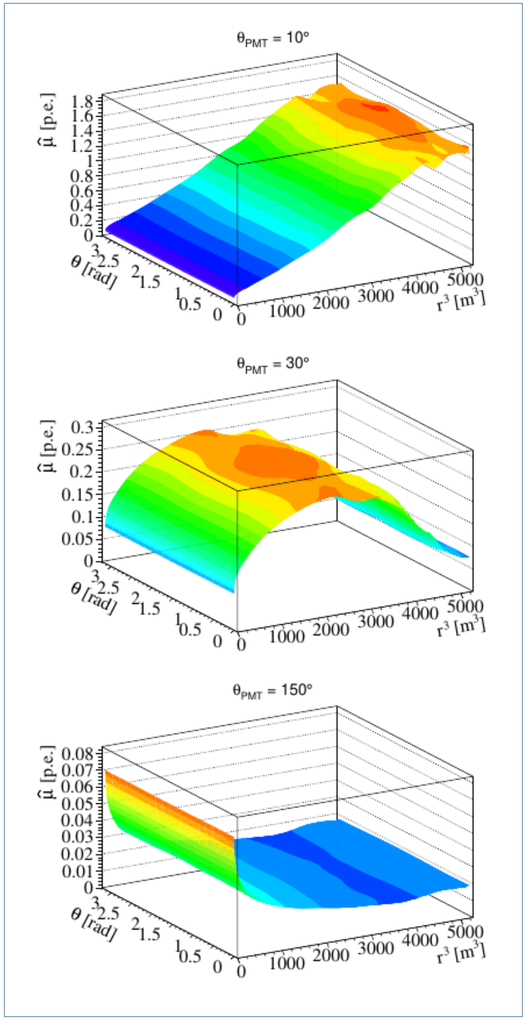
Energy reconstruction

arXiv:2102.03736

Map of optimized calibration points







- Use of (simulated) calibration data to create maps for
  - $\mu(r,\theta,\theta_{PMT})$ - expected charge at each PMT
  - timing profile for each PMT depending on the emission position
- Obtain the best estimate of the reconstructed energy via combined Likelihood fit
- Light propagation model independent!
- **Challenge:** Achieve 3% resolution at 1 MeV with ~2.8% stat. uncertainty

Summary & some missing topics

- **(Very) brief introduction to reconstruction algorithms in JUNO**
  - Waveform reconstruction - deconvolution algorithm
  - Vertex reconstruction - (fast) time likelihood
  - Energy reconstruction - combined time-charge likelihood
  - **Only a snippet of the ongoing work is presented!**

- **Many reconstruction efforts are not presented!**
  - Machine learning reconstructions: ← e.g. *arXiv:2101.04839*
    - Many approaches followed: From basic BDT's to complex Graph-NN
  - Efforts in particle identification ← e.g. *DOI:10.1088/1748-0221/16/01/p01016*
    - Conventional: Reconstruction of photon emission topologies
    - Neural network approaches
    - Separation of positrons and electrons seems feasible!
  - High energy reconstructions
    - High charge waveform reconstruction algorithms
    - Muon track reconstruction algorithms (Conventional and NN)