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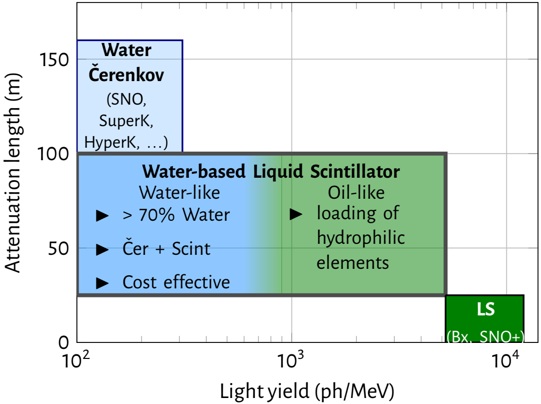
Water-based Liquid Scintillator TestCell Status

Why a WbLS TestCell

Water Čerenkov Detector + Liquid Scintillator Experiments → **WbLS** are **candidate** for the **next generation** of optical neutrino detectors



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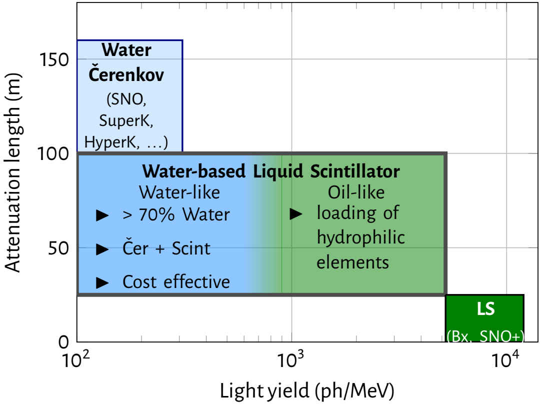


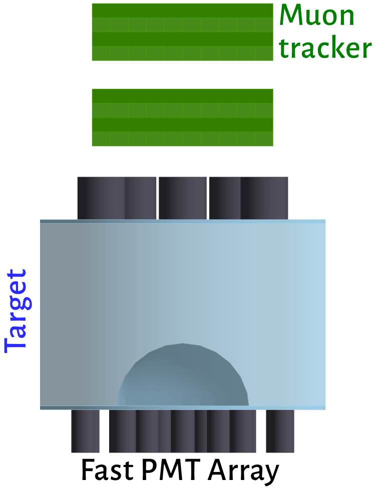
The Mainz WbLS TestCell

GOAL: Study Čerenkov/Scintillation light separation

HOW:

- Conceptual design
  - Target geometry
  - WbLS optical properties
  - Photodetection system
- Monte Carlo simulation
  - Analysis pipeline
  - Preliminary results
- Next

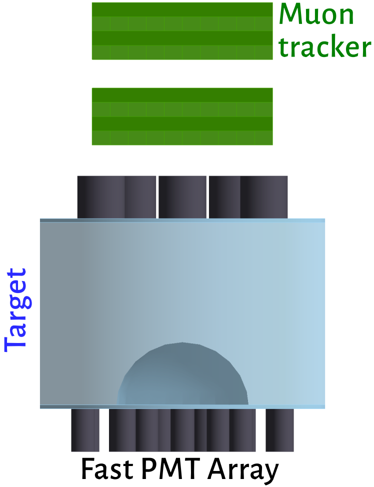
TestCell concept



Features

- Lab-scale
- Versatile: cosmic rays, calibration sources, low-energy e^{-}, ...
- Flexible geometry and easy readout access
  benchmark for new photodetection system (LAPPD, SiPM array, ...)

TestCell concept



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Muon tracker

Trigger + independent μ tracking

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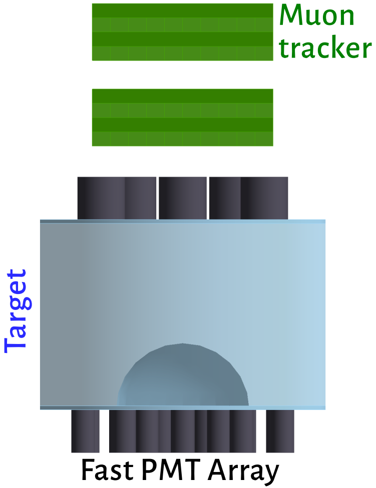

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Target

$\approx$ 20 l, designed to enhance Čerenkov ring pattern

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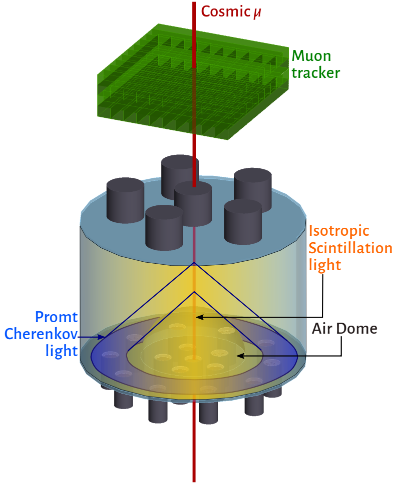

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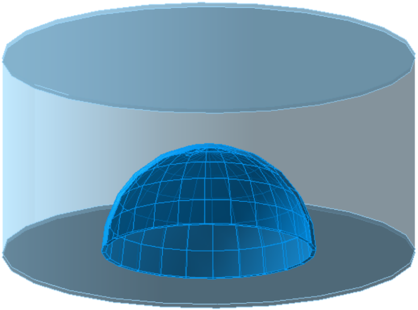
Fast PMTs

Čerenkov/Scintillation separation (time + pattern)
WbLS characterization (LY, time profile, ...)

WbLS Target



The Tank

- Diameter $\approx$ 30 cm
- Acrylic endcaps + black barrel
- (Removable) Air Gap Dome
  stop production of Čerenkov light

WbLS Properties

Water + (1%)LAB+(2.5 g/l)PPO

Preliminary model:

- Emission spectrum of PPO
- LY = 100 ph/MeV (i.e. 1% of pure LAB+PPO)
- Water refractive index
- Double exponential scintillation time profile
  ($\tau_{\text{fast}} = 2.5$ ns, $\tau_{\text{slow}} = 12.7$ ns)

$N_{\text{ph}}^{\text{Čer}}$/cm [250, 620 nm] $\approx$ 500
$N_{\text{ph]}}^{\text{Scnt}}$/cm [PPO] $\approx$ 150

BUT important effect of **absorption/re-emission** of Čerenkov photons on PPO molecules

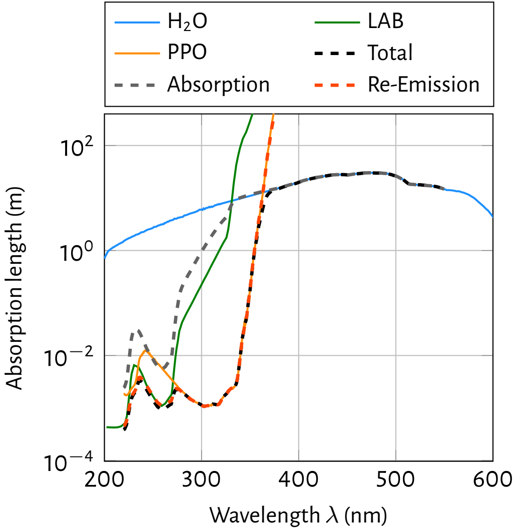
WbLS optical properties

Beer-Lambert law for composition of optical properties

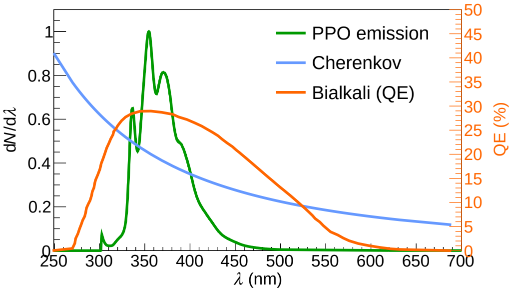
Two distinct absorption length

- **Real absorption** photon absorbed and lost forever
- **Re-emission absorption** photon is absorbed, WLS and re-emitted (isotropically) with $\tau_{PPO} \approx 1.6$ ns

A significant fraction of Čerenkov photons are absorbed and re-emitted in this way



Photodetection system



Requirements

- High granularity (hit pattern)
- Fast response
- Excellent time resolution (time separation)

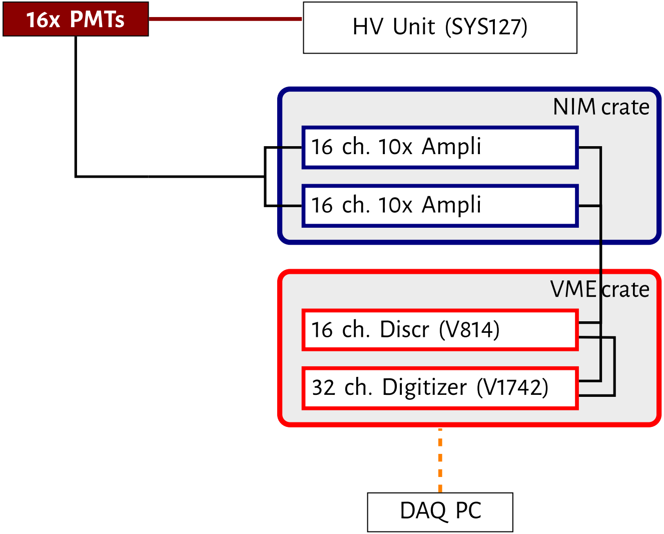
16 fast 1 inch PMTs

Shortlisted candidates TTS 160–290 ps (FWHM)

Full assembly + mu-metal shield for accurate timing

Possible top array for measurement of WLS + Scintillation light

Data Acquisition Chain

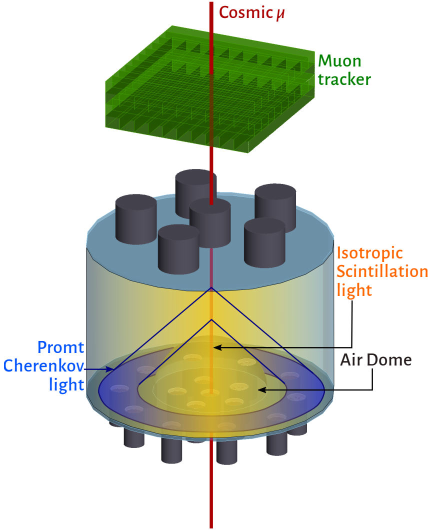


- PMT signal will (likely) require **amplification stage**
- Amplified signals feed a 16 ch. **fast discriminator** which triggers the digitizer
- Record **digitized waveform** with high sampling rate (5 GS/s) to exploit every possible information in the signal

↓

Offline Waveform Analysis

MC Simulation of the test cell



Full analysis pipeline

1. Geant4 simulation

TestCell core components implemented in Geant4
Simulation of vertical cosmic muons

2. Syntetic Waveform Production

For each PMT a waveform is produced based on the recorded hits

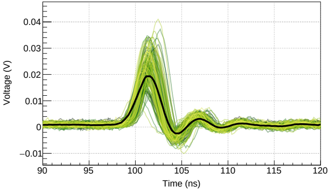
3. Offline Waveform Analysis

Automatic pulse detection and waveform fit

Electronic response simulation

Waveform samples

Adit L25D19 1" PMT
+ 10x NIM amplifier
+ DRS4 Evaluation board



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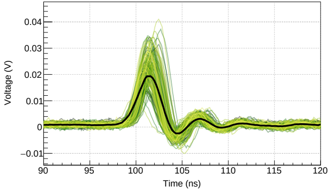
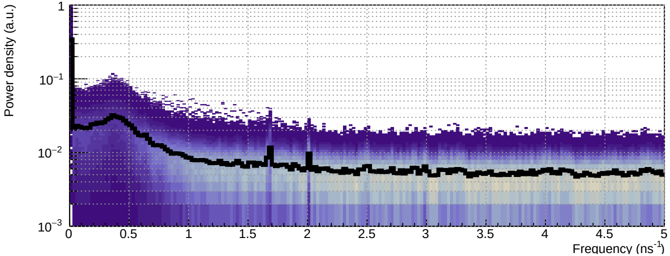


Noise power spectrum



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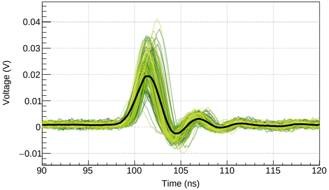

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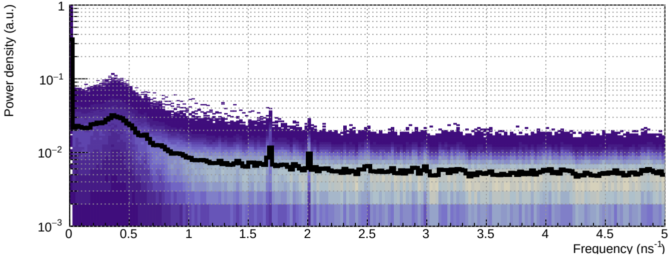
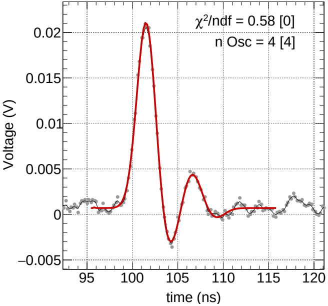


Pulse modelling

Pulse + afterpulse swing heuristic model

$$f(t) = \sum_n A_n \times G(t; t_0 + n\Delta t, \sigma)$$

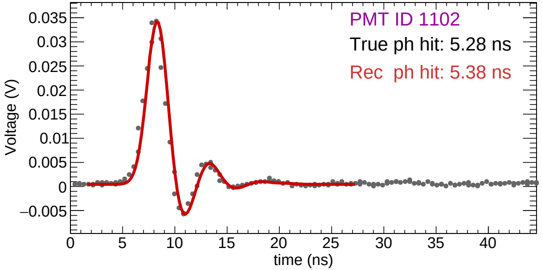


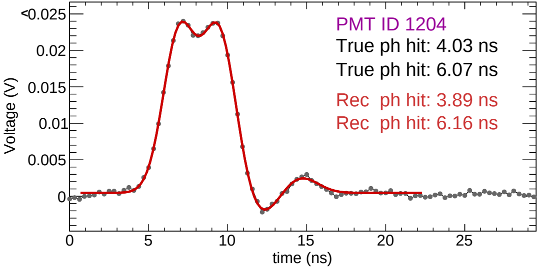
Offline waveform analysis

Concept

Scan waveform $w(t)$ and its derivatives $\dot{w}(t)$, $\ddot{w}(t)$ to identify region with pulse(s)

$\hookrightarrow$ **Fit** waveform with pulse model





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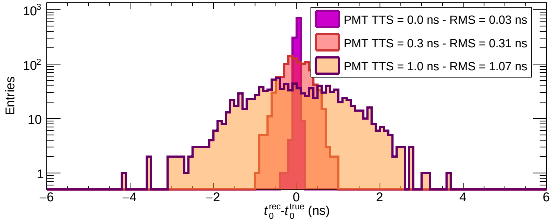
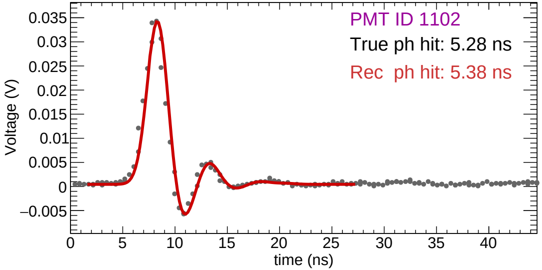
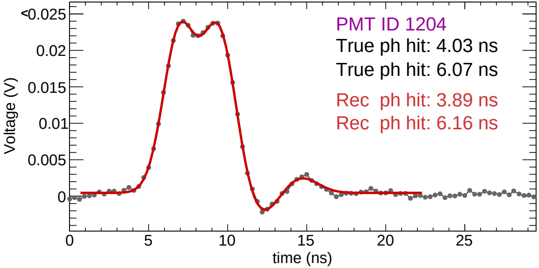
Contribution to time resolution negligible compared to intrinsic PMT TTS



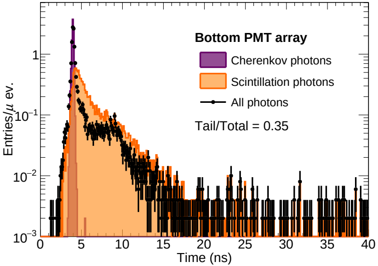




Preliminary MC Results

Hit time distribution

Clear prompt Čerenkov peak
(Note effect of unresolved pile-up)



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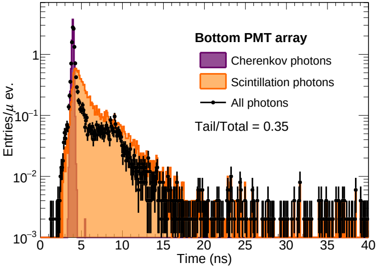
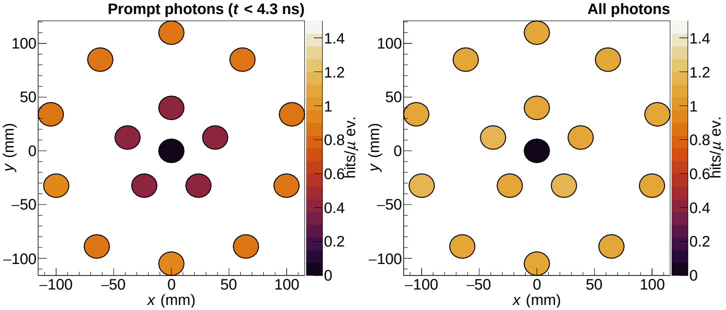


Hit pattern

Čerenkov ring visible in prompt events



Excellent prospect for Čerenkov/Scintillation separation studies

Status

Conceptual design (✔)

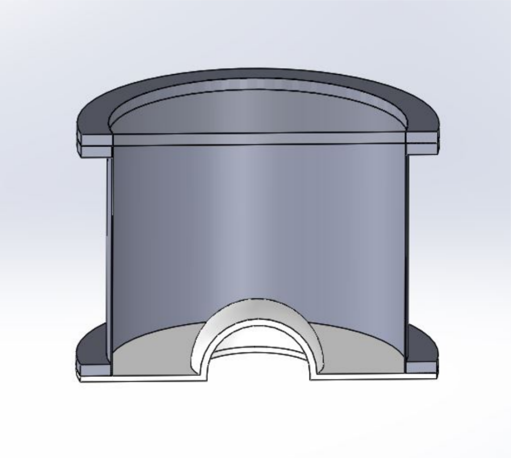
- Preliminary Monte Carlo simulation
- Analysis pipeline in place

Procurement, technical design, DAQ setup ($\longrightarrow$)

- Electronics and PMT procurement in progress
- Setup technical drawing about to start
- DAQ software
- Event reconstruction (MiniBooNE concept)

Commissioning ($\twoheadrightarrow$)

- Expected after Summer



Next step: Beam test setup

Concept

- ton-scale setup for PS/SPS extracted beamline
- “back” photodetectors optimized for Č/S separation
- “side” photodetectors for scintillation studies

Physics

- Further characterization of WbLS
- Test of reconstruction algorithm
- Test particle ID (μ/e)