DUNE ND-GAr ECAL Concepts

by Sebastian Ritter
on behalf of Peter Bernhard, Andrea Brogna, Volker Büscher, Karl-Heinz Geib, Asma Hadef, Antoine Laudrain, Lucia Masetti, Marisol Robles Manzano, Anna Rosmanitz, Christian Schmitt, Alfons Weber, Quirin Weitzel

PRISMA+ DETECTOR LAB

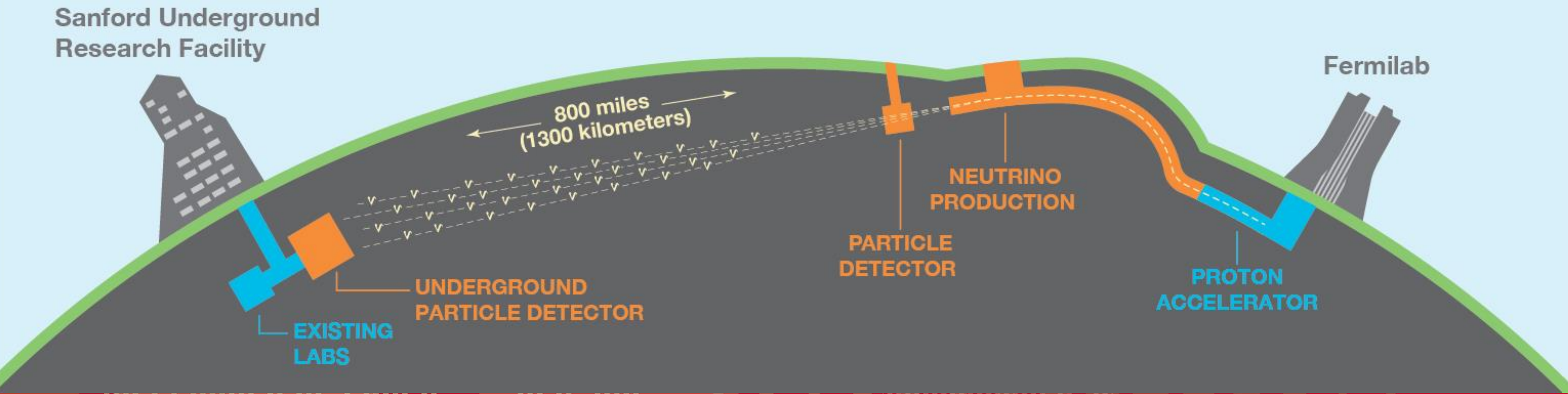
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

AGENDA

- Introduction
- ECAL Module Design
- Neutron-Photon PSD
- Outlook

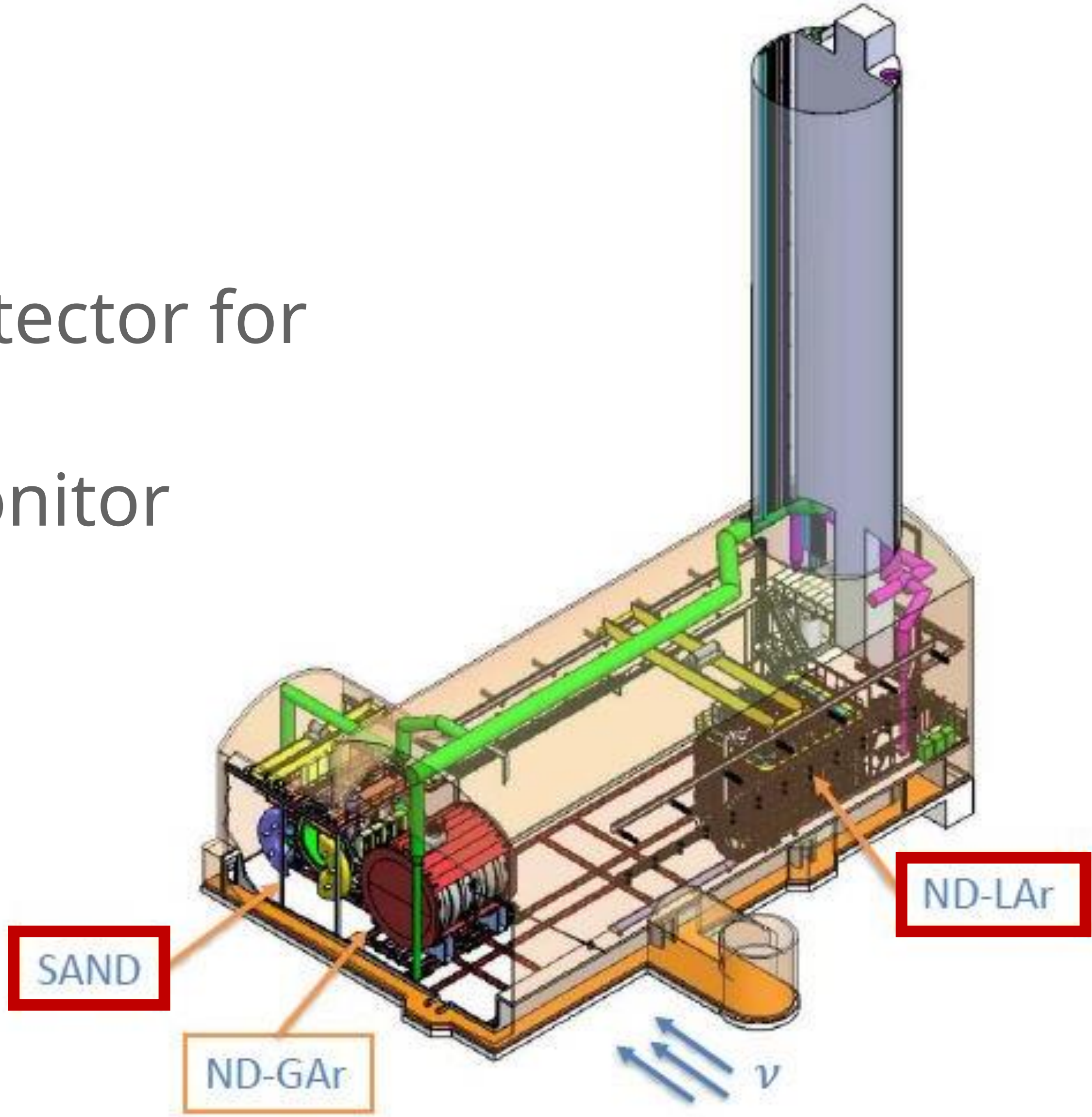
INTRODUCTION

- **D**eep **U**nderground **N**eutrino **E**xperiment
- 1.2 MW neutrino beam
- Near detector (ND) site 0.5km from production target



NEAR DETECTOR SITE

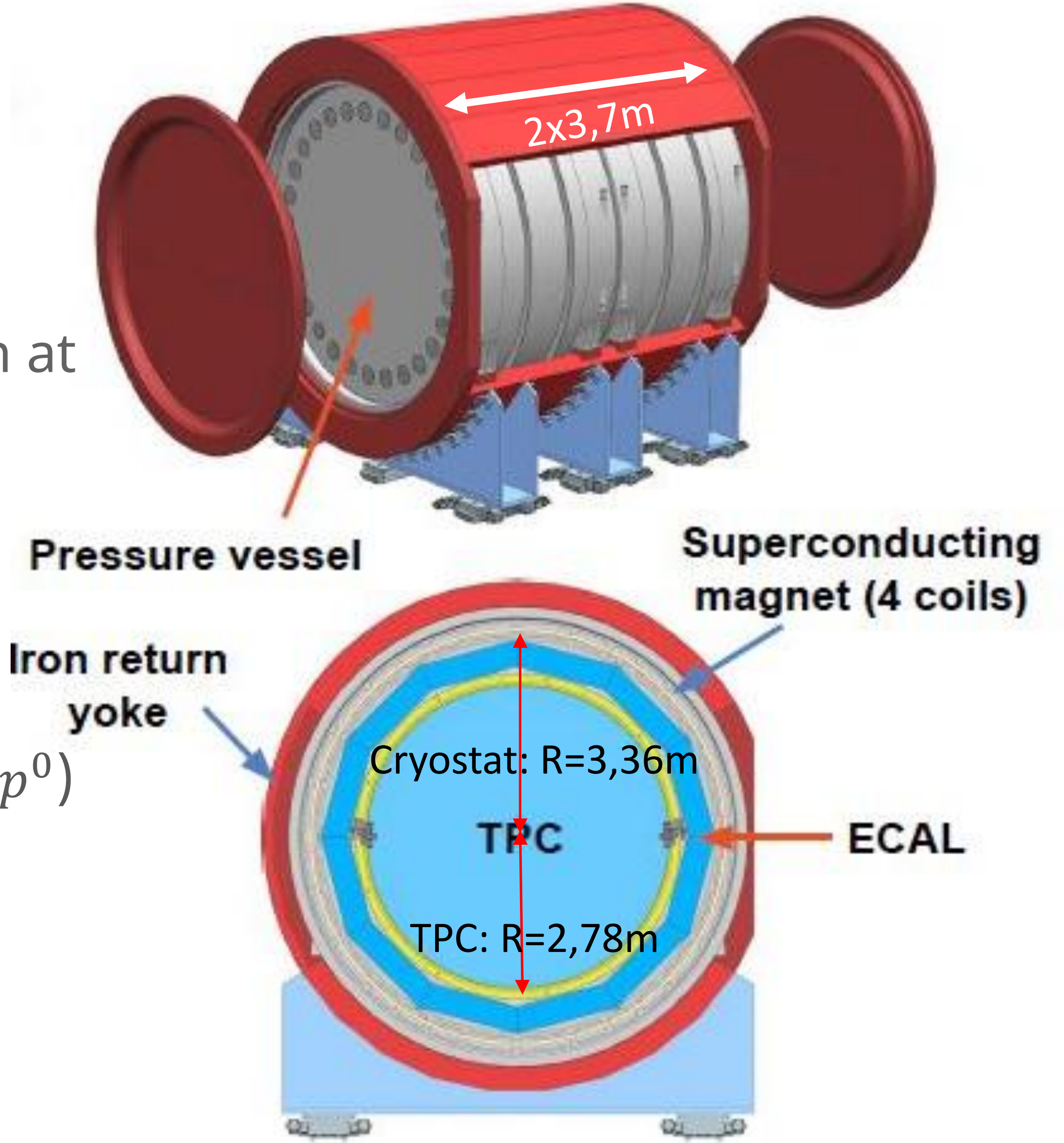
- **ND-LAr**: LArTPC similar to the far detector for comparability
- **SAND**: on-axis magnetized beam monitor



NEAR DETECTOR SITE

- **ND-GAr**:
  - High Pressure Gas TPC based on ALICE, run at 10atm
  - Surrounded by ECAL (ca. 45cm thick)
  - 0.5T superconducting magnet
  - Objective: improve ν-nucleus interaction models

  - **ECAL:** measuring neutral particles $(\gamma + n + p^0)$
  - **Restrictions:** TPC and cryostat sizes fixed
  - **Size:** around 45 cm total thickness
  - Few high granular tile layers + mayor part crossed strip layers

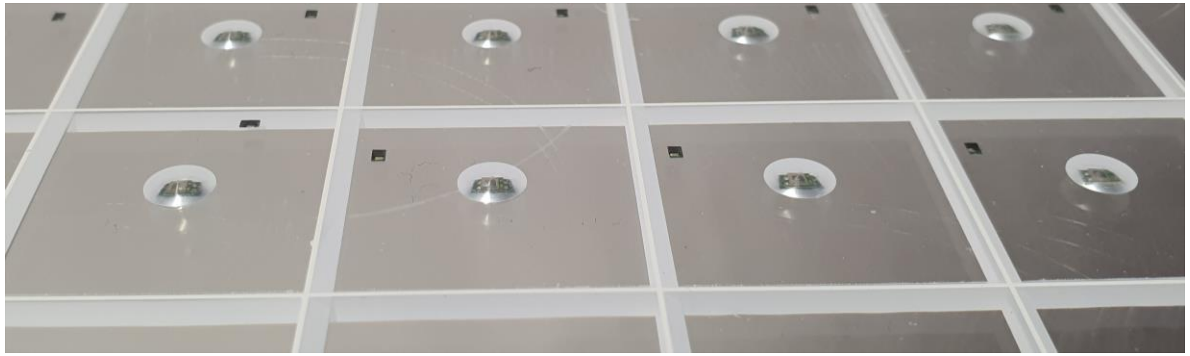


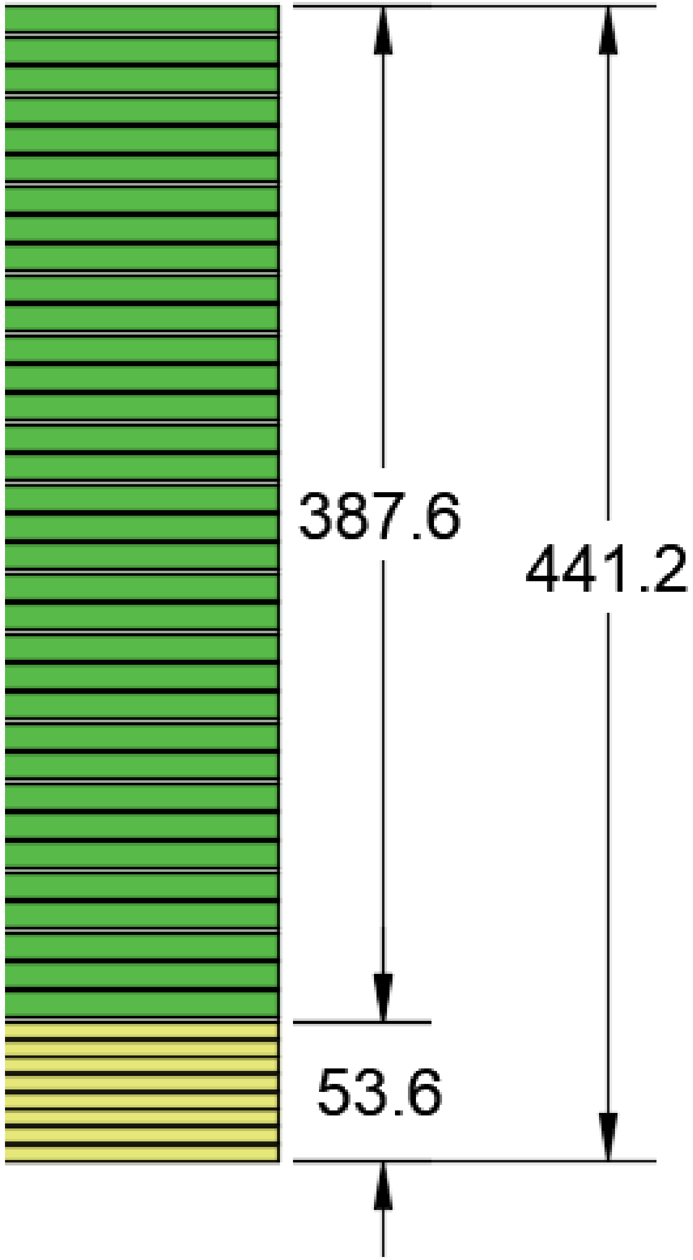
EVERYTHING BEYOND THIS POINT IS CONCEPTUAL WORK IN PROGRESS!

ECAL MODULE DESIGN

ECAL COMPOSITION

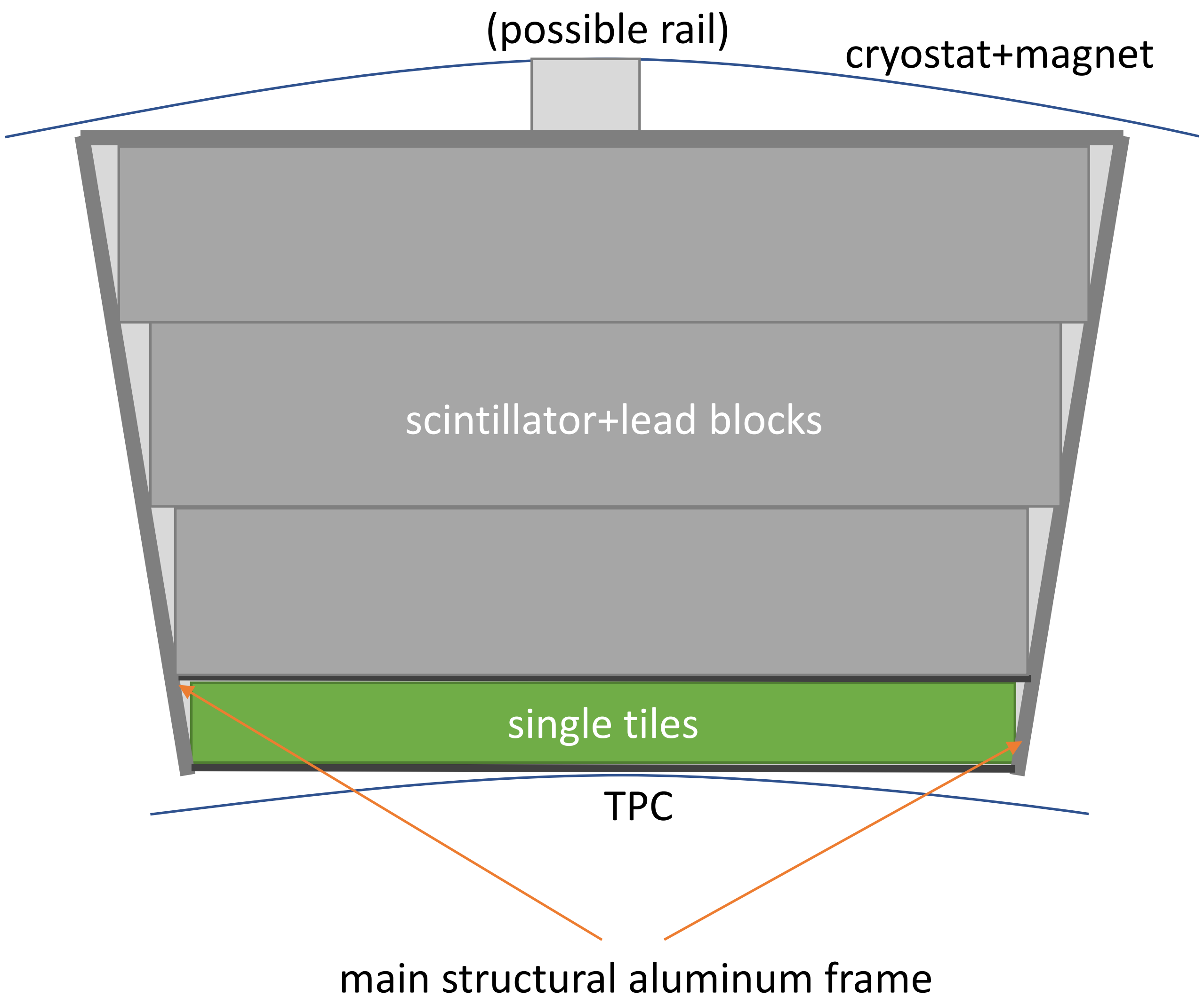
- Sampling calorimeter
- Total ECAL thickness around 450mm
- 8 high granular CALICE-like tile layers
  - 0.7mm lead + 6mm scintillator
- 34 crossed strip layers
  - 1.4mm lead + 10mm scintillator





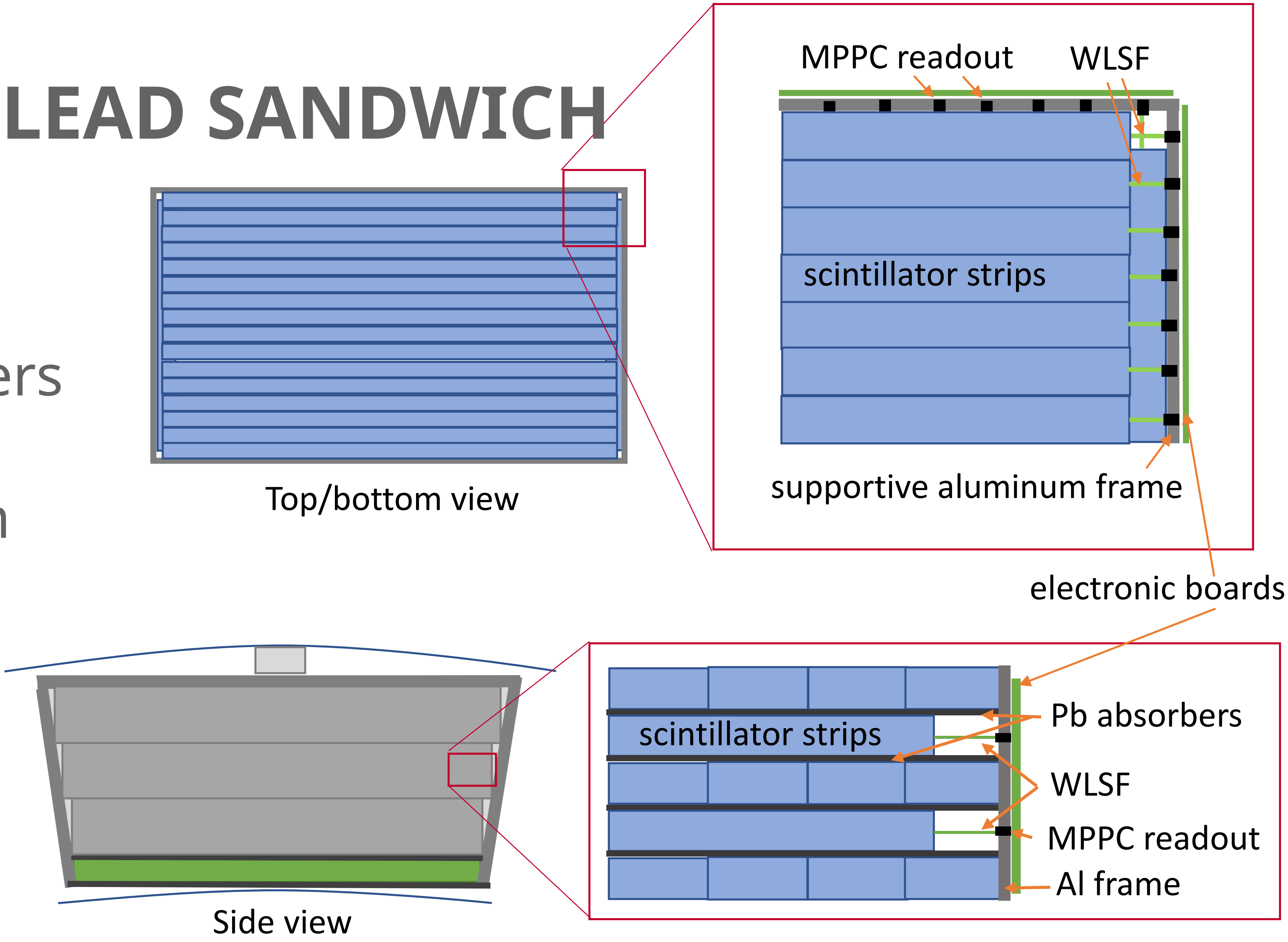
MODULE STRUCTURE

- Main frame made of aluminum
- Supports towards TPC made of carbon fiber
- Big blocks of strip layers and lead absorbers glued together
- Minimal uninstrumented area between active elements
- Module internals separated in different segments
  - Tile layers
  - 10-15cm thick strip segments



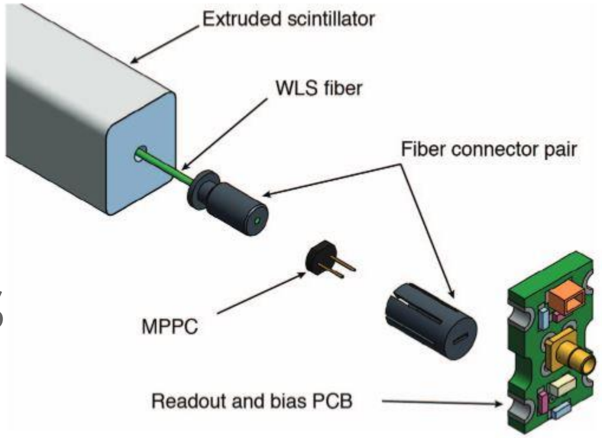
SCINTILLATOR+LEAD SANDWICH

- Very robust extruded scintillator bars
- Scintillator + lead layers glued together
- Supportive aluminum frame
- Each layer supported by frame in X **or** Y direction

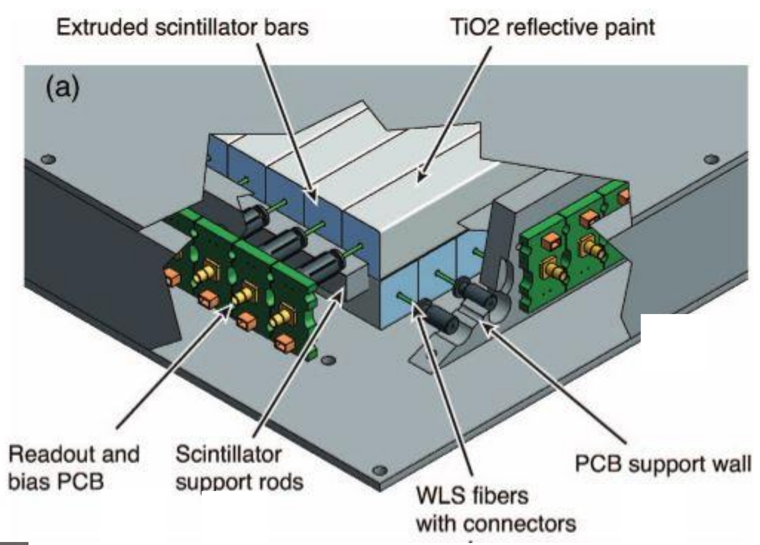


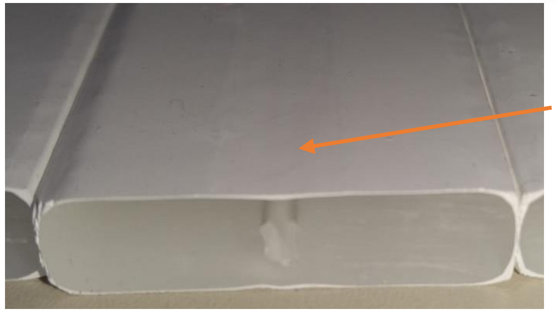
STRIP READOUT

- CALICE-like electronic boards with surface mount MPPCs and KLAUS-ASICs for readout
- Hope for experienced German groups to join efforts (e.g. DESY 😜)
- Current focus on SiPM/fiber coupling R&D

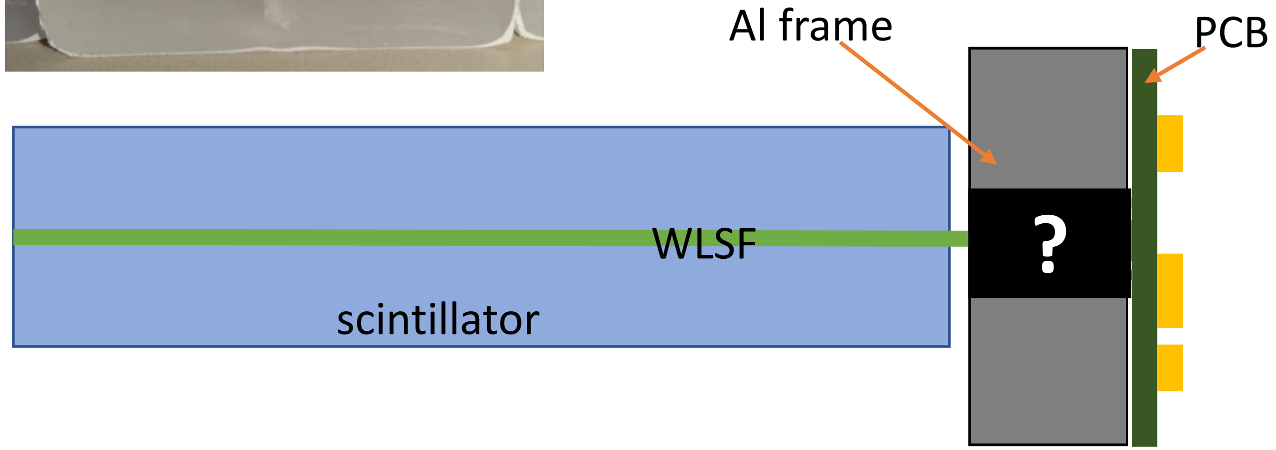


T2K experiment





extruded scintillator

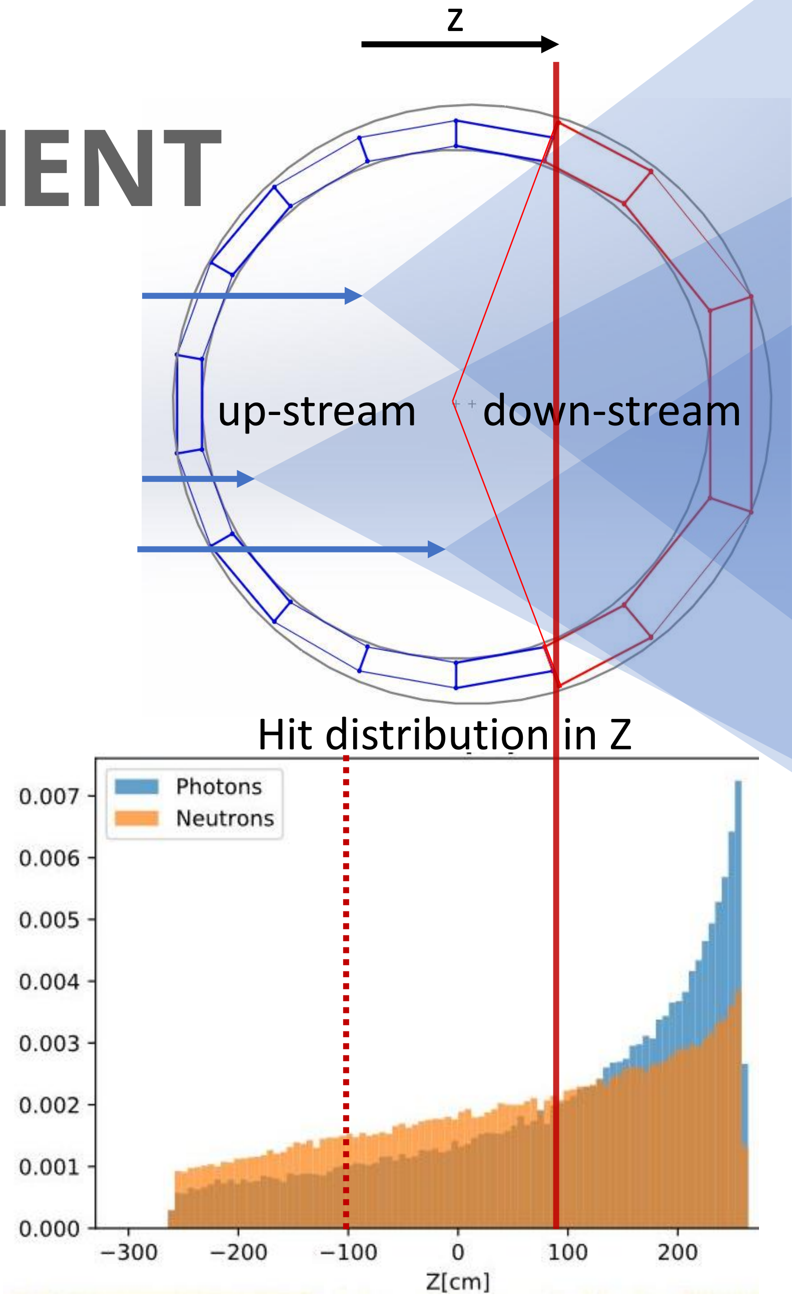


SPECIAL CASE: TARGET EXPERIMENT

- Main energy deposition in experiment in down stream direction
- Use of resources should be focused on down stream detector
- Idea: off-center TPC, less ECAL up-stream

- Important variables for design considerations:
  - Uninstrumented area in forward direction
  - Cost / # of channels (double sided strip readout)
  - Outer radius / clearance (next slide)

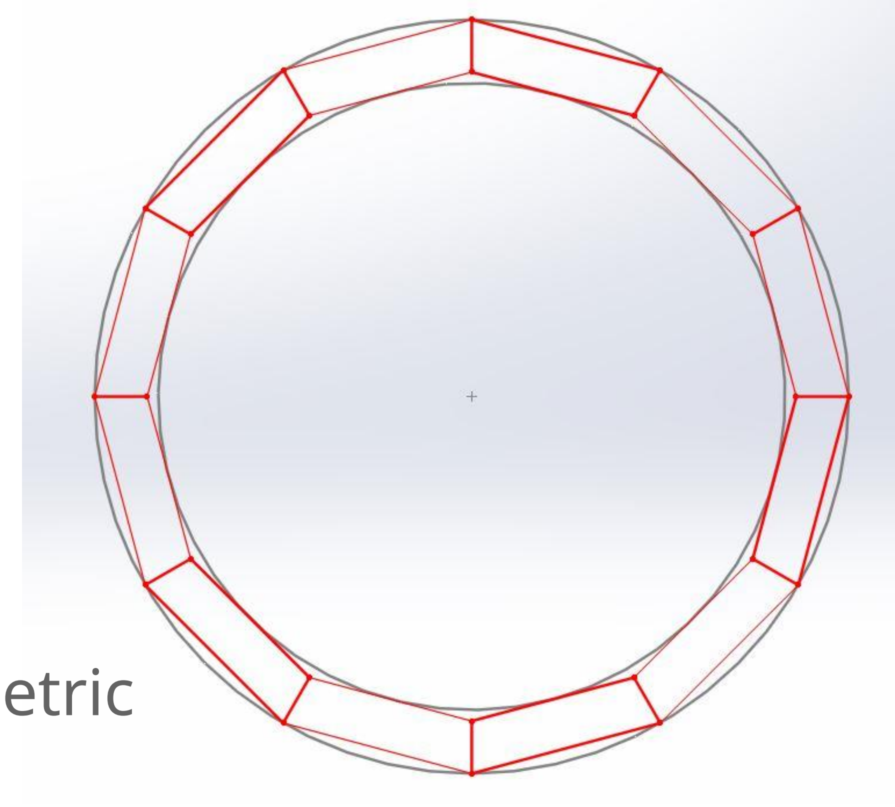
- Big thanks to Lorenz Emberger from MPI for physics simulations!



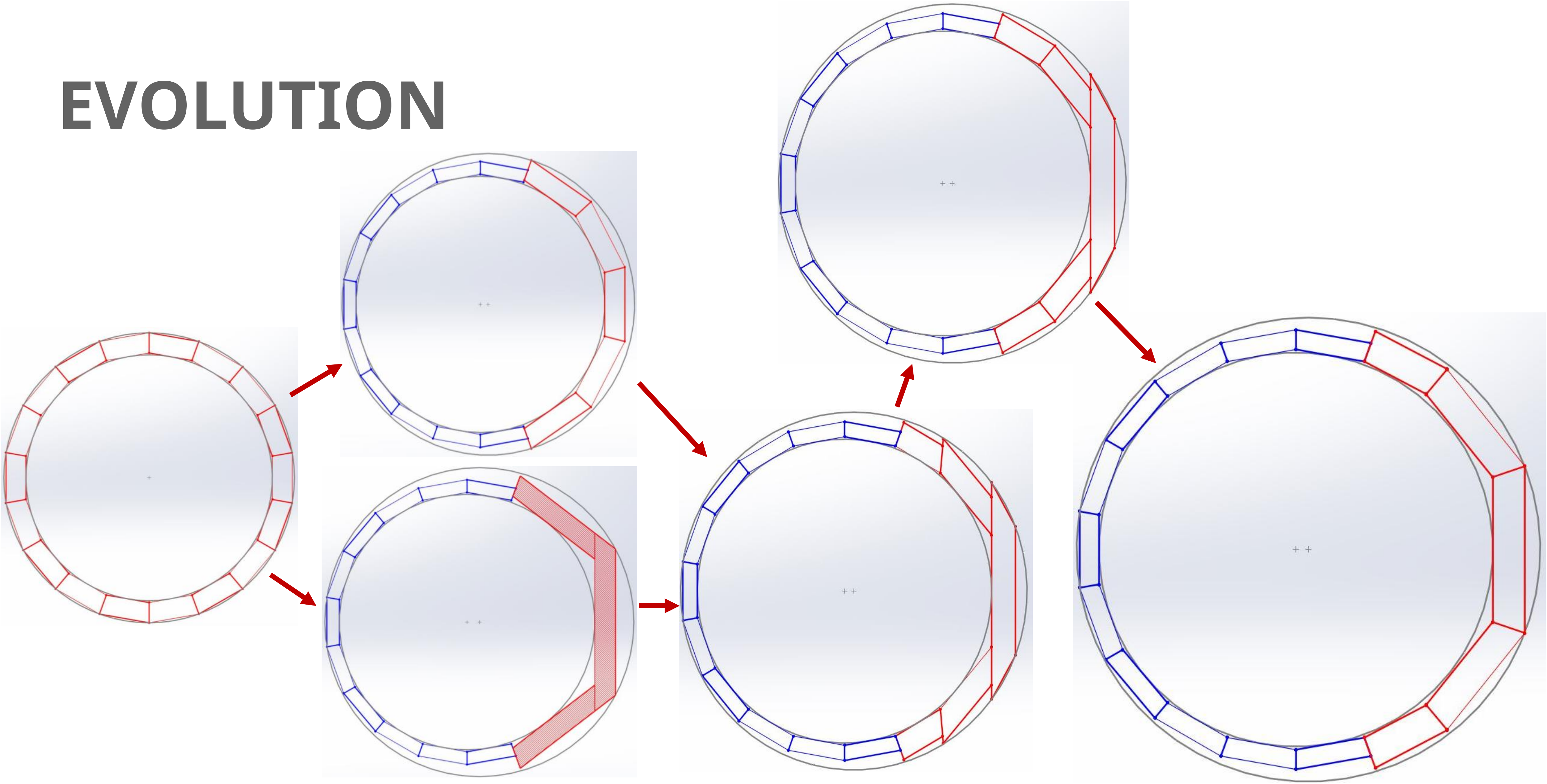
ECAL INTRODUCTION

- Baseline design: 12-sided symmetric barrel
  - Inefficient use of space
  - Problem: too big in diameter

- Alternatives considered :
  - Symmetric barrel with higher module number
  - Asymmetric ECAL designs motivated by asymmetric energy deposition (140° forward direction)

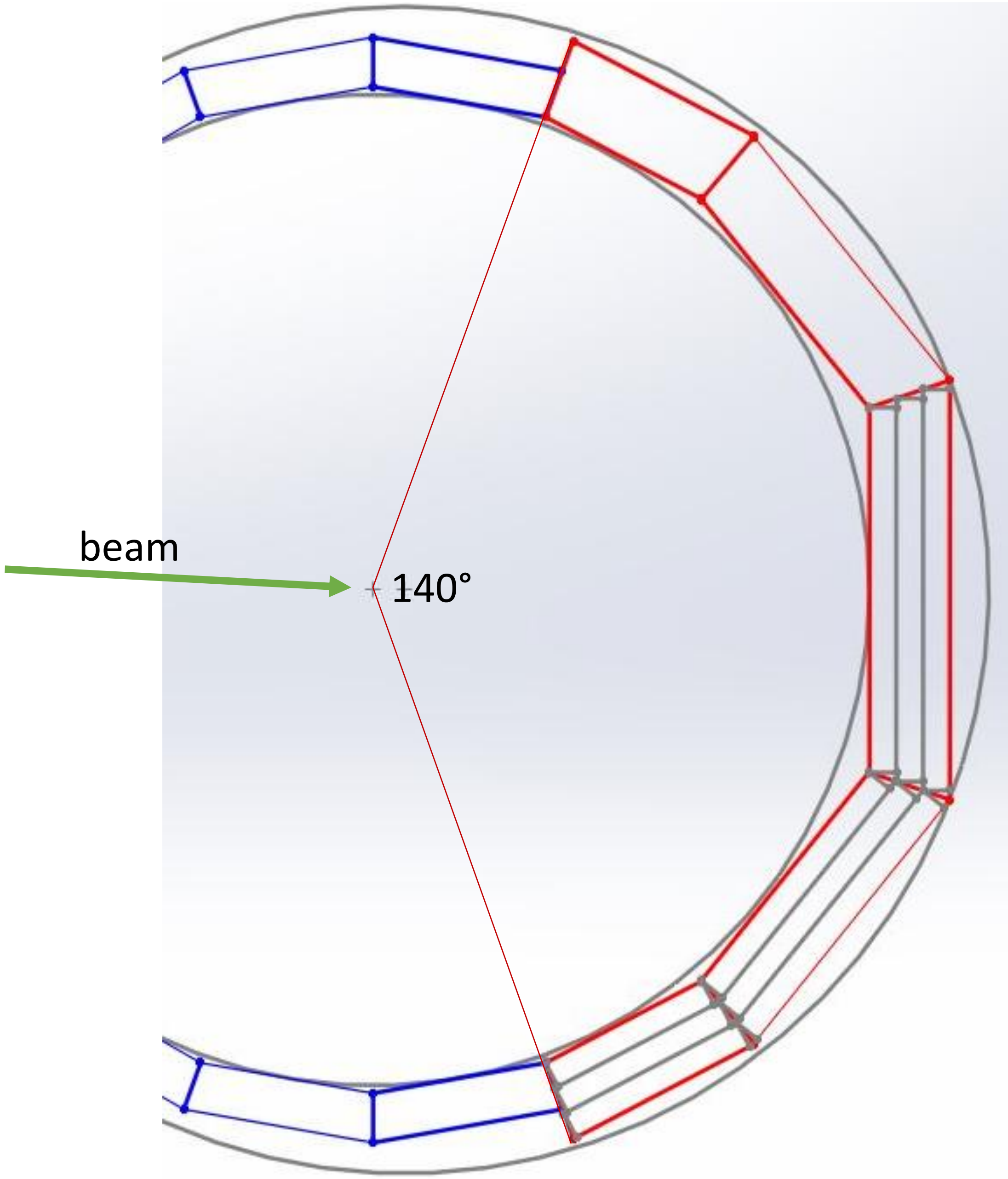


EVOLUTION



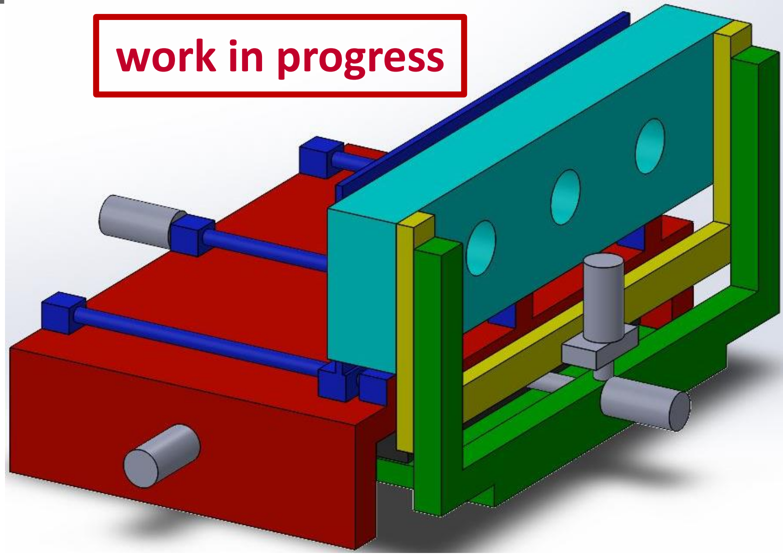
CURRENT BASELINE

- Best coverage with instrumentation
  - Center facing module edges
  - Biggest module on down-stream beam axis
- Outer dimensions reduced by over 17cm in diameter
- Reduced cost from up-stream channel reduction (>55%)
- Under current conditions most promising design
- Detailed simulations needed to determine physics performance!



PROTOTYPING

- Ongoing design for performance focused prototype
- Fiber readout optimization in cooperation with other Mainz groups
- Main focus:
  - WLS/SiPM coupling
  - Readout integration in structural frame to reduce dead area
  - Measuring light yield
  - Testing of different components



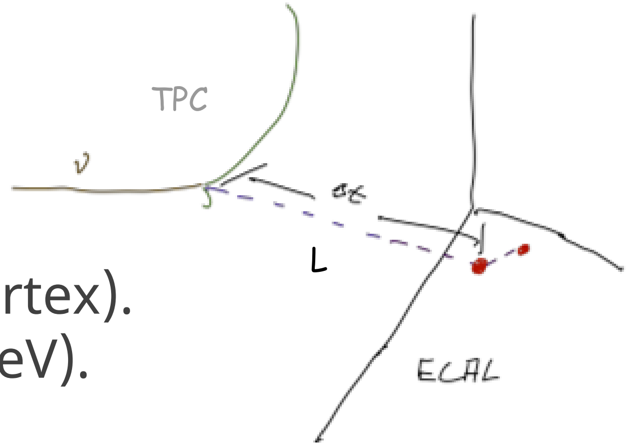
CONCLUSION

- Module design seems to converge (based on what we know atm)
- To be validated by physics simulation

- Start of conceptual prototype design
- Hopefully start constructing in the coming weeks

NEUTRON-PHOTON PSD

ECAL @ DUNE ND

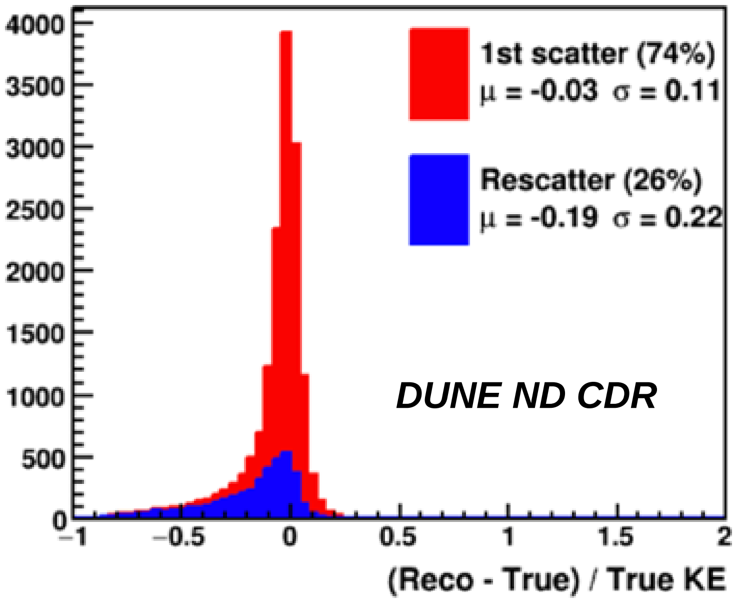


- Fast Neutrons with energies <100 MeV>:
  - created @TPC: from the interaction of incident neutrino beam (vertex).
  - detected @ ECAL: scattering → energy transfer to protons (<10 MeV).

- Reconstruct kinetic energy from **time of flight (TOF).**

TOF = Δt = time (detected @ ECAL) - time (created @TPC)

$E = 1/2\ m\ v^2 \iff E = 1/2\ m\ L^2/\Delta t^2$



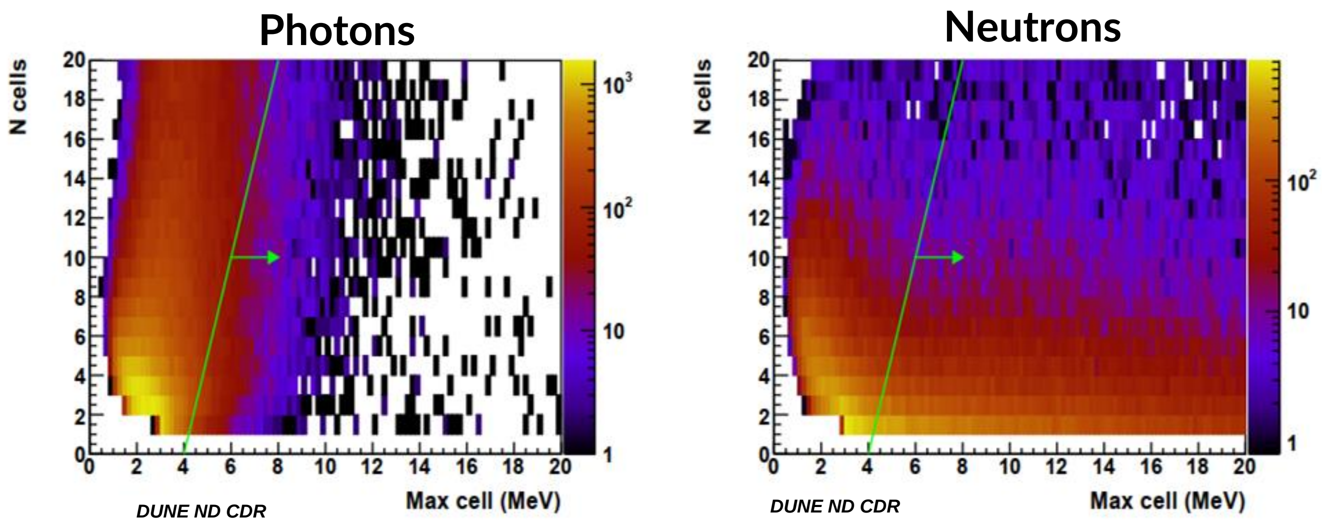
Requirements:
- Precise timing: 100 ps – 1 ns…
- … and position: high granularity calorimeter => CALICE-like design.

Issues:
- distinguish between neutrons and photons (from neutral pion decay).
- Neutron detection efficiency ~ 40%.

ECAL @ DUNE ND

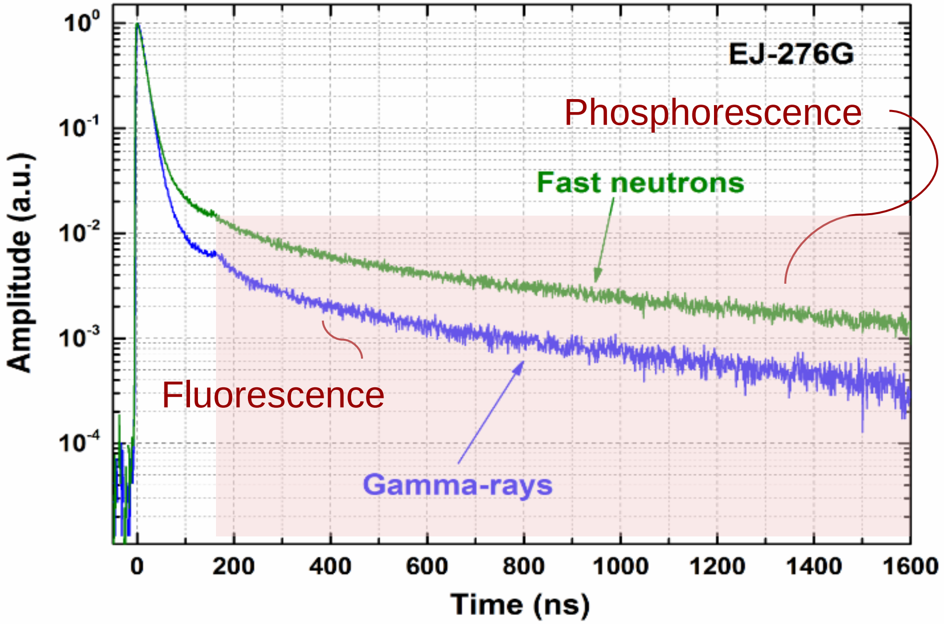
Our project

Distinguish between photons from π^0 and neutrons.



Neutron and photon-induced clusters are separated based on:

- Total number of hits in the cluster.
- Total energy of the cluster.
- Maximum hit energy.

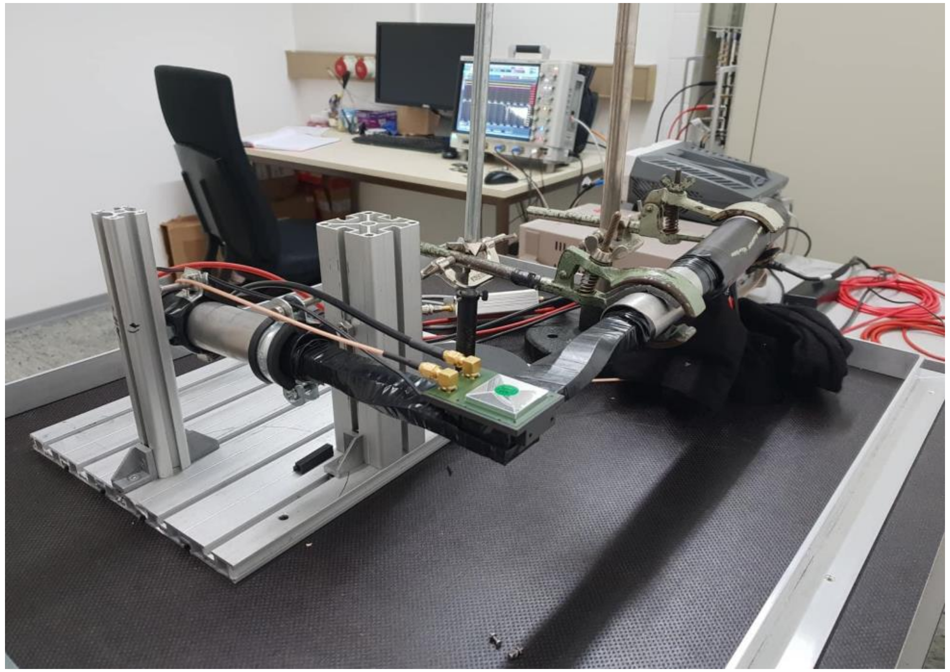


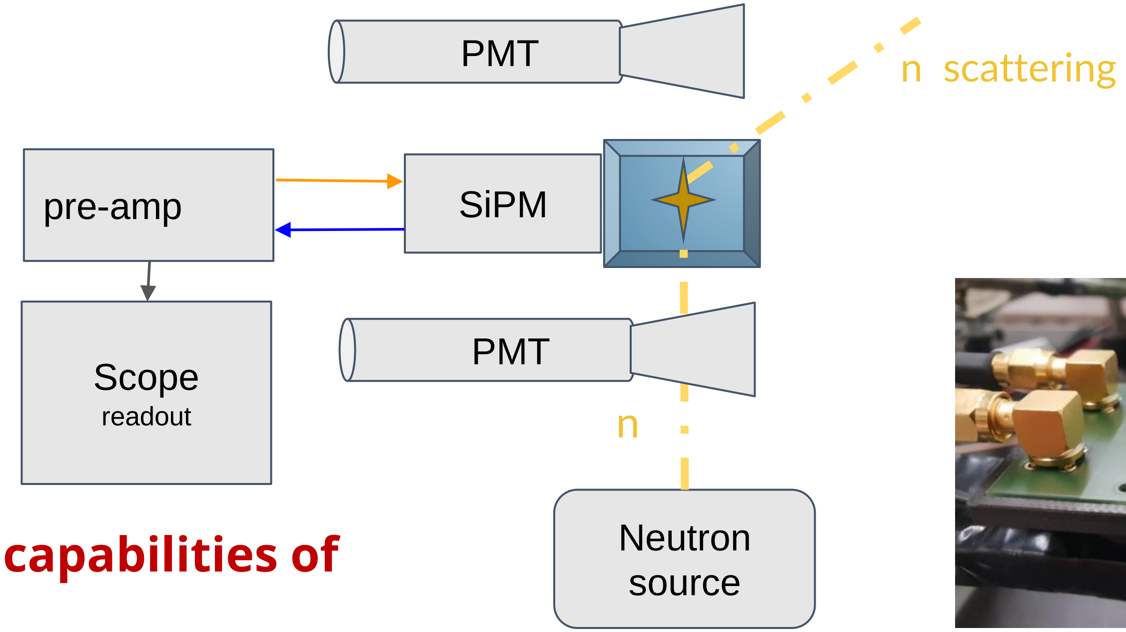
Use difference in scintillation profiles to bring additional information:

Pulse Shape Discrimination (PSD)

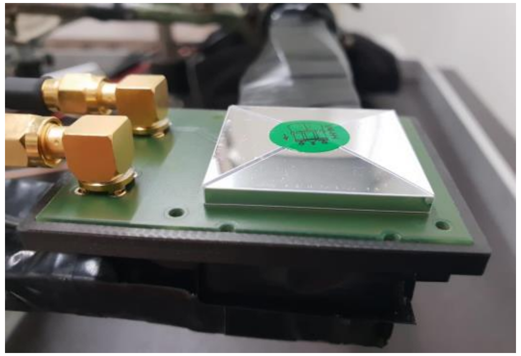
PSD techniques based on the difference in the long decay constants: compare total charge to charge in the tail.

Experimental Setup @ Mainz





Test sample
(3x3 cm2
Scintillator Tile)



Experimental study neutron/gamma PSD capabilities of various plastic scintillator candidates.

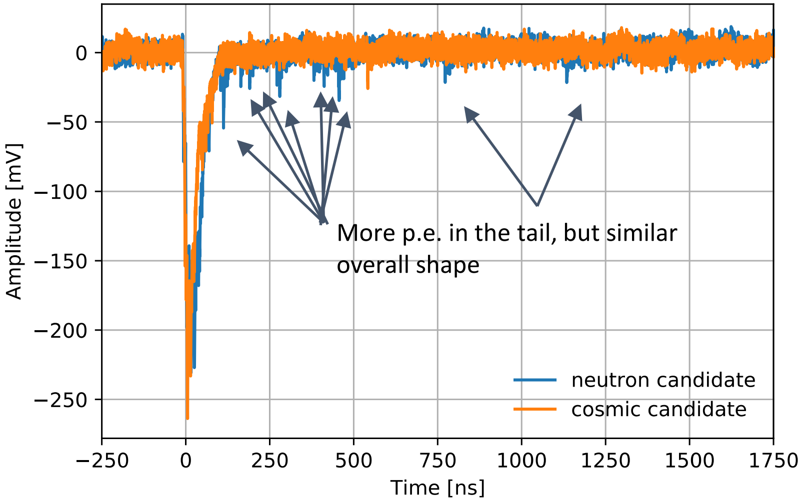
- Gamma/neutron from an AmBe source (15 MBq => a few neutrons/min detected).
- Test setup of small plastic scintillator samples with (SiPM) read-out.
  CALICE tile (well known)
  Eljen EJ-208 (generic plastic)
  Eljen EJ-276G (PSD-optimized)
- Cosmic veto/trigger using two PMTs.

Ongoing work and lessons learnt so far

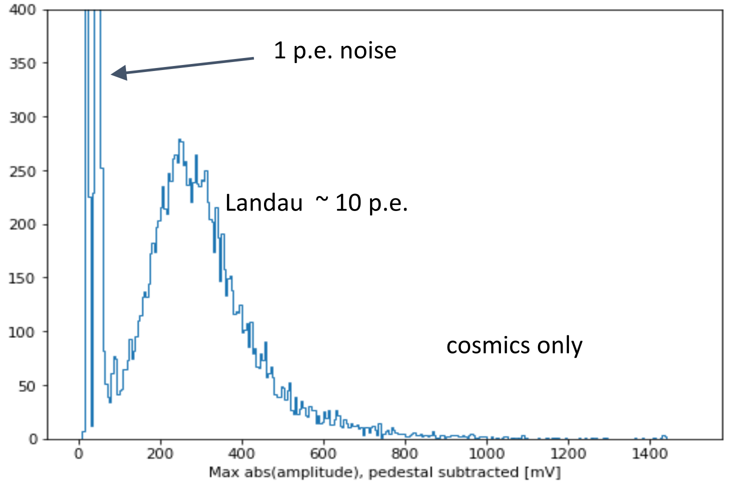
Signal from cosmics, gamma, and neutrons can be seen, **but not easily distinguished**.

- **Preamplifier** (CAEN A1423B) **shapes the signal into a bipolar waveform**.
- **Using this preamplifier, signal tail too deformed for effective PSD using tail integration**.
- Try counting the number of individual p.e. pulses in the tail instead (method under development).

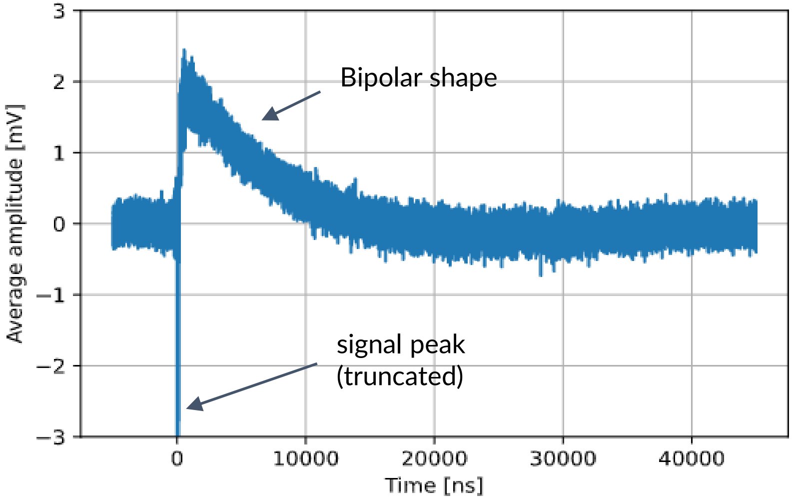
A few waveforms example



MIP distribution



Bipolar shape illustration



- **CALICE-like LED calibration procedure being developed** ("SPS scan").
- **Simulation work ongoing**:
  - Validate setup results.
  - Extrapolation to higher energies (neutrons from AmBe ~ 10 MeV, neutrons in DUNE ~100-1000 MeV).

OUTLOOK

- Next step: build first prototype (mini) module
- Ideally with new KLAUS-HBU adapted to strip geometry
- Including connected readout chain ("wink" to Wuppertal)

- Good chance to continue our common work in CALICE in a new Germany centered ECAL development

THANK YOU FOR YOUR ATTENTION!