Baby MIND: last results from beam test at CERN

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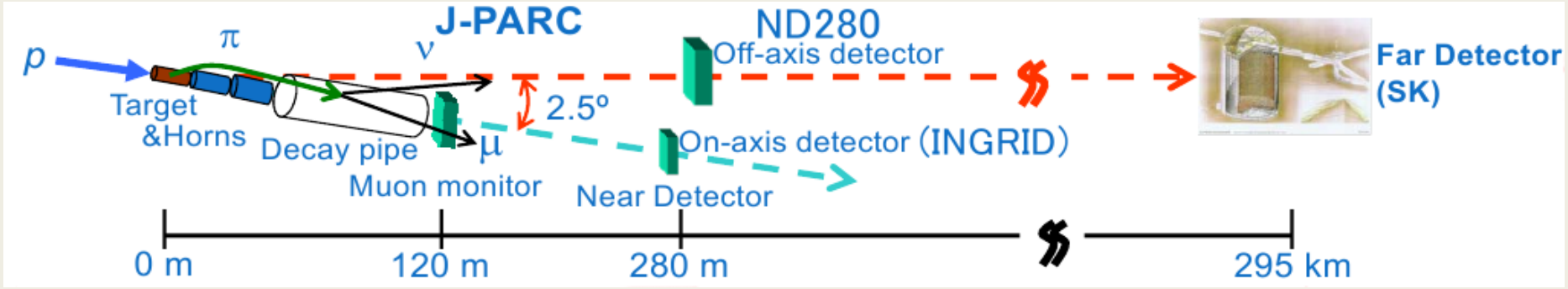
4 - National Research Nuclear University “MEPhI”,Moscow Russia

Motivation (T2K Experiment)

- LBL experiment to study neutrino oscillations with J-PARC *v* beam
- Near detectors (ND280) and Super-Kamiokande as a far-detector
- ND280 data used to constrain flux and XSec parameters for oscillation analysis



The largest systematic uncertainty due to:

- Difference in the target material between the far (H_2O) and near (CH) detectors
- Limited acceptance of near detector w.r.t. to Super-Kamiokande (= 4π)

Systematic	ν_μ	ν_e
Flux	3.6 %	3.6 %
Non-canceling XSEC	4. 1 %	5.1 %
Super-K detector etc.	3.9 %	2.4 %
FSI+SI	1.5 %	2.5 %
Total	5.0 %	5.4 %

WAGASCI (WAter-Grid-SCIintilator-Detector)

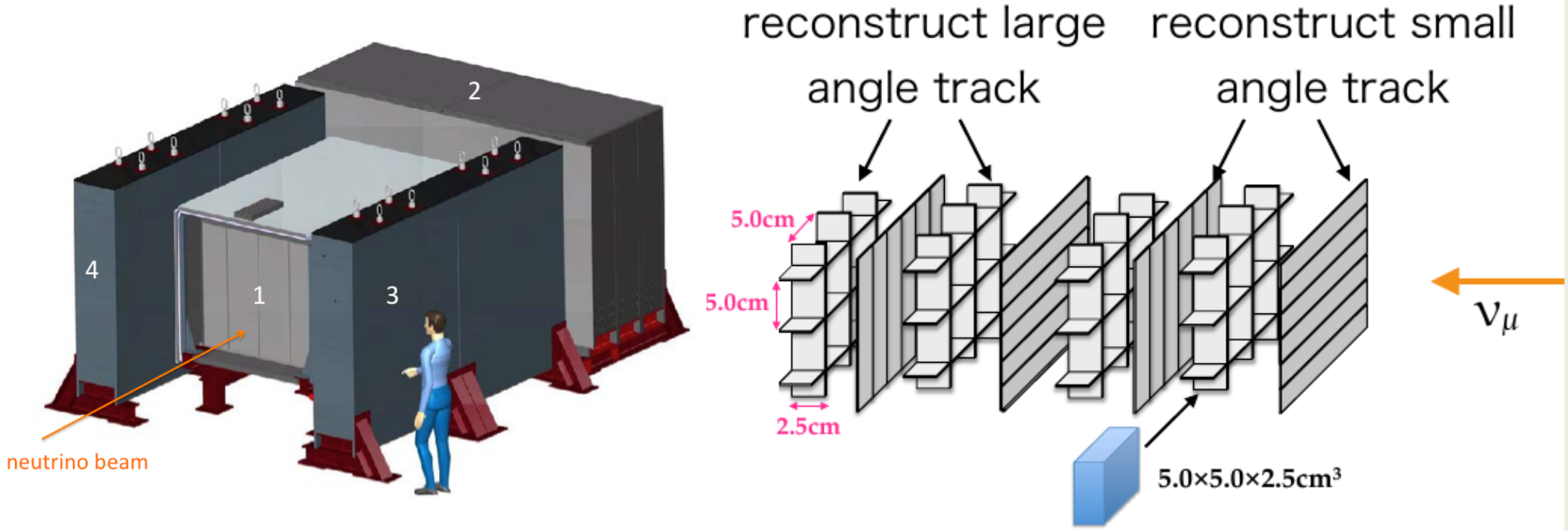
Water scintillator detector WAGASCI to take data with J-PARC (ν_μ, anti-ν_μ) beam at ~1 GeV

Main goals:

- Measure the CC cross section ratio between water and scintillator with 3% accuracy
  - High angular acceptance measurement
  - ND280 43 : 56 H_2O:CH fraction vs WAGASCI 79 : 21 H_2O:CH
- Measure different CC neutrino interaction channels with high-precision
  - Test models of nuclear target-dependence in neutrino interactions
- Strategy already proved with T2K on-axis INGRID detector

WAGASCI Design

- Target: 3D grid structure filled with H_2O/CH
- Side muon range detectors MRDs : iron + scintillator
- Downstream detector – Baby MIND (ν_μ/anti-ν_μ) event separation



Baby MIND motivation

- Demonstration of a Magnetized Iron Neutrino Detector (MIND) for neutrino physics.
- Ability to measure muon momentum, charge identification and particle identification.
- Ability to measure appearance and disappearance oscillation channels at the same time
- Baby-MIND will be used used for WAGASCI experiment at J-PARC to measure neutrino cross-sections.
- Possible reconstruction efficiency:

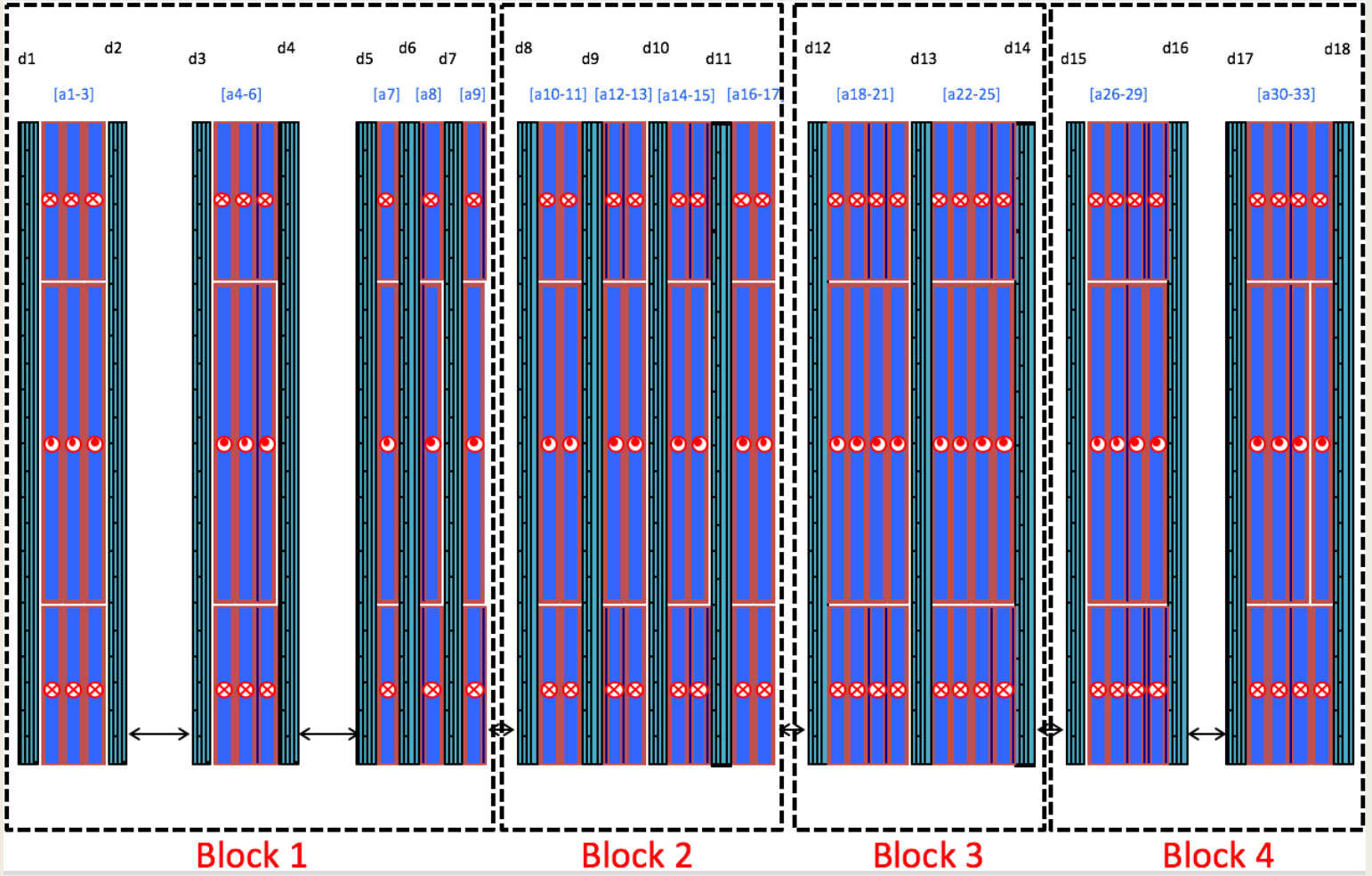
– *muon detection efficiency > 95% for full range (0.4-6 GeV/c),*

– *charge identification efficiency > 90% for full range (0.4-6 GeV/c)*

Baby MIND Design

- 18 Scintillator modules;
  Each module composed of 4 layers:
  - 2 horizontal planes (95 bars);
  - 2 vertical planes (8 bars)

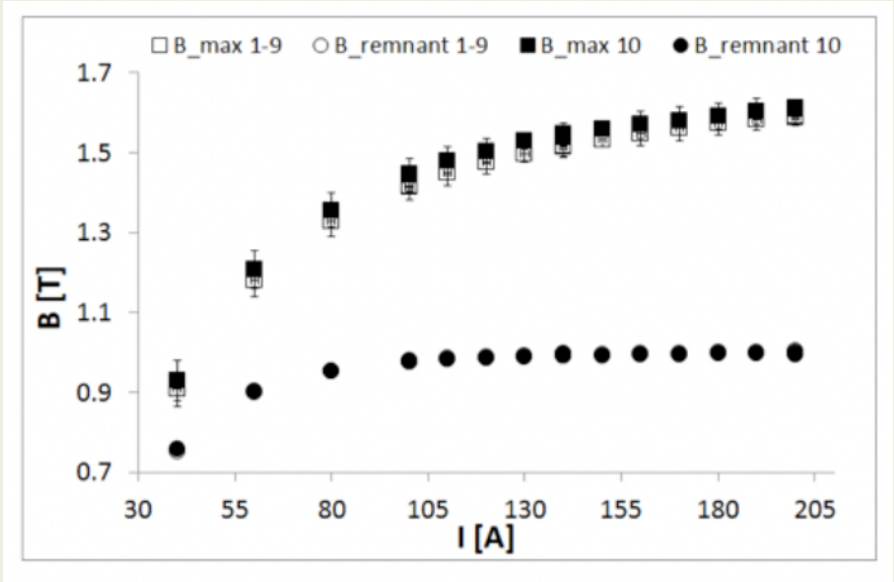
  Bars are overlapped to ensure 100% hit efficiency for minimum ionising muons. The improved spatial resolution is a consequence of the overlap.
- 33 Magnet modules;
- Scintillators held together mechanically (no glue) within aluminium support frame.

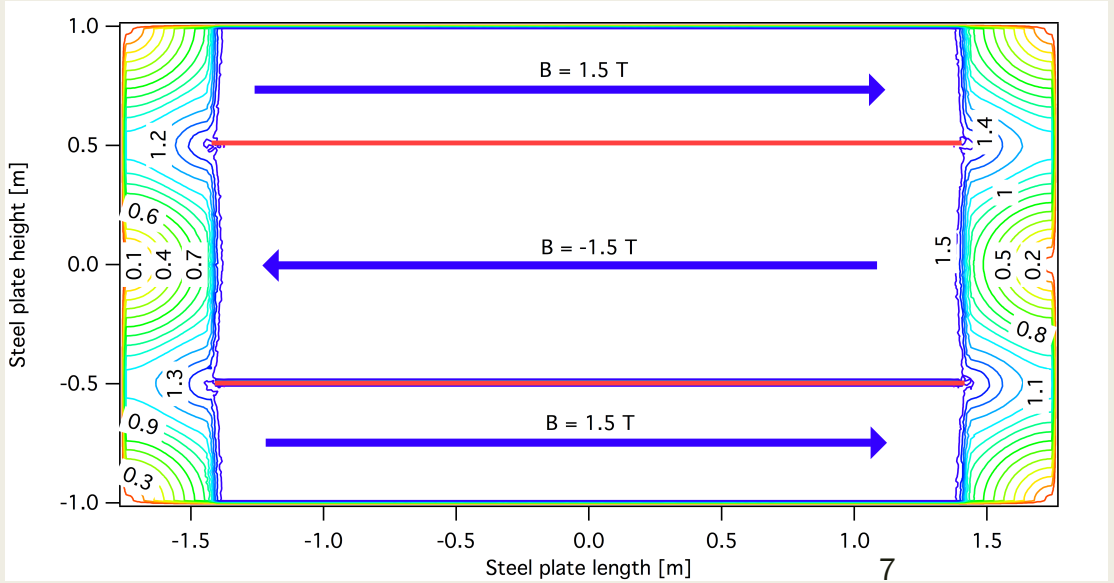


Magnet module concept

Design principles:

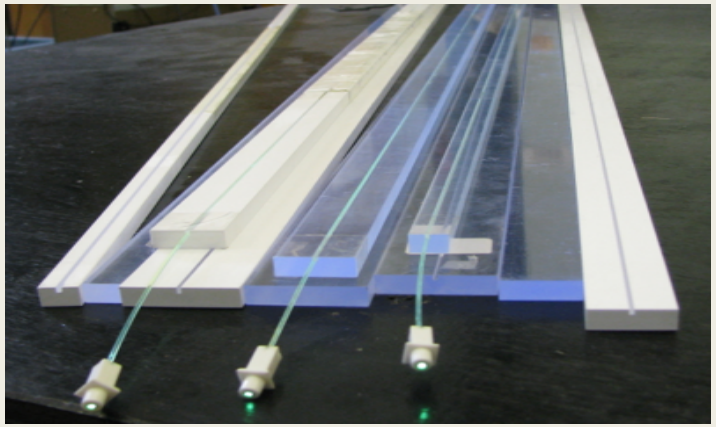
- Dimensions: 3500 × 2000 × 30mm^3;
- Individually magnetized iron (ARMCO) plates;
- Two-slit design;
- Well defined B-field lines in central zone: B = B_x ;
- Contained stray fields;
- Modularity and flexibility;
- Field > 1.5 T for coil current ~ 140 A;
- Power for all 33 modules: 12 kW.

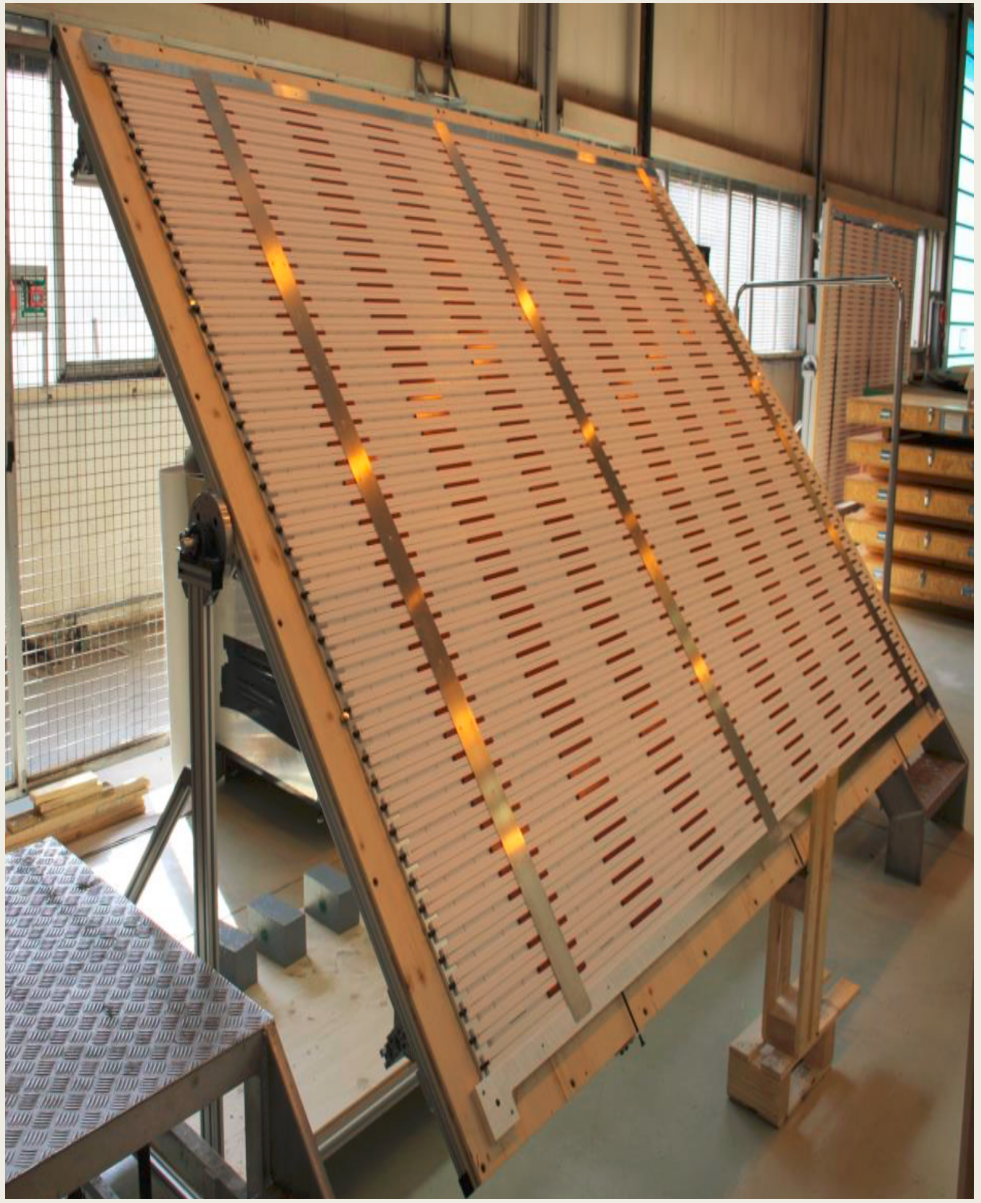




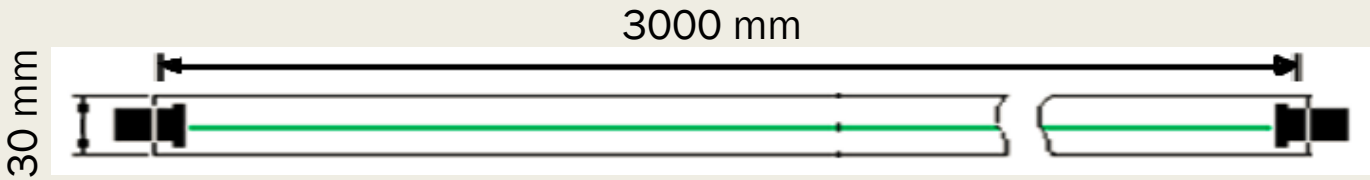
Scintillator bars

- Polysterene based, 1.5 % PTP, 0.01% POPOP.
- Reflective coating 30 to 100 μm from chemical etching of surface.
- Kuraray WLS fiber (200 ppm, S-type), dia 1.0 mm.
- Eljen EJ-500 optical cement.
- Custom optical connector.

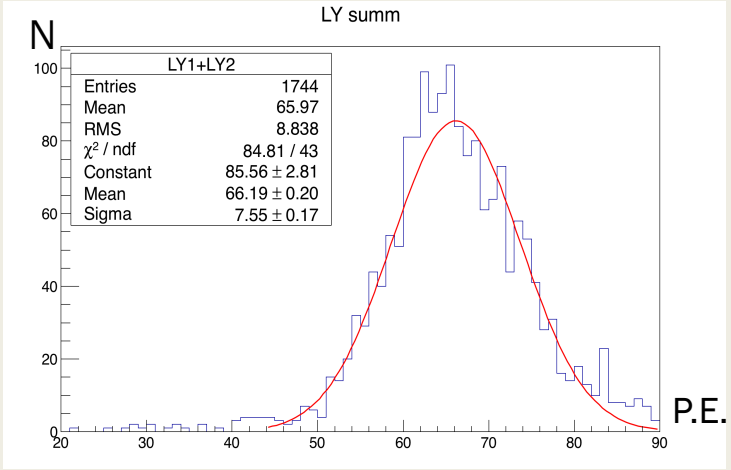


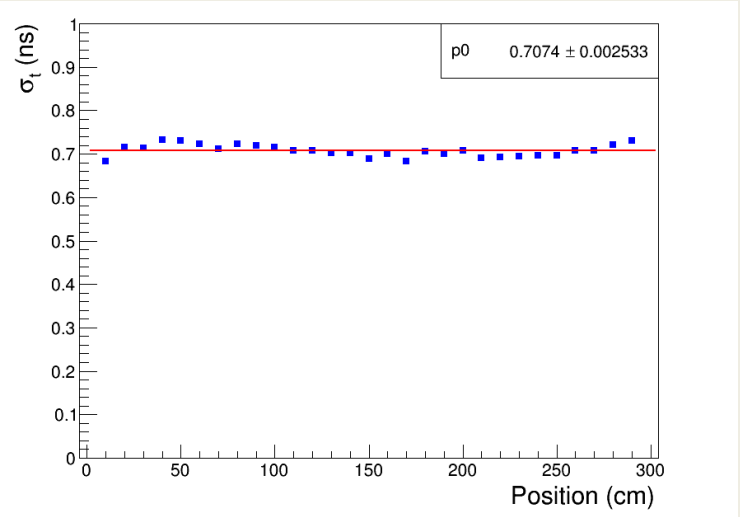


Horizontal bars



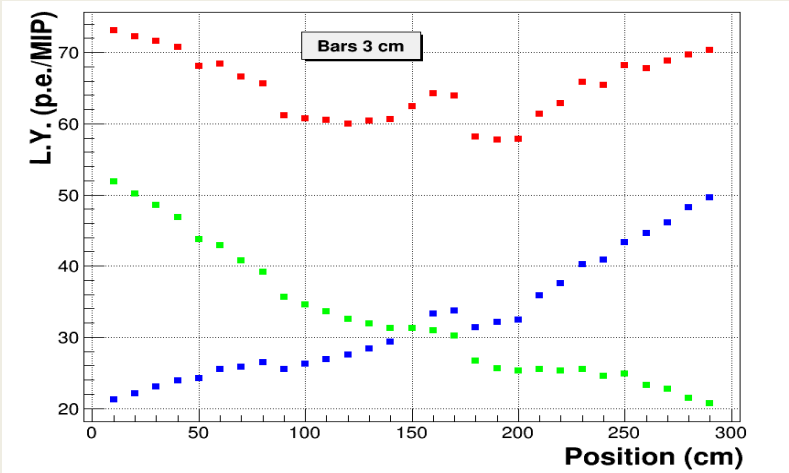
Light Yield of horizontal scintillator bars:

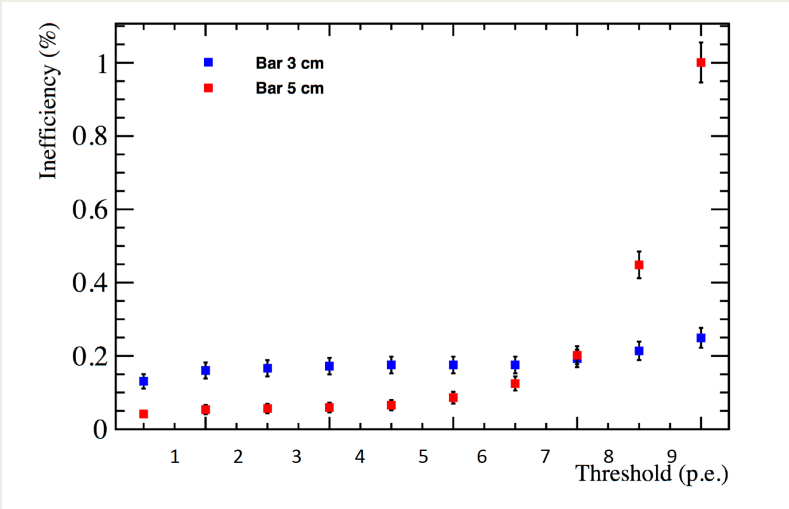




Time resolution (constant fraction method)
Average σ_t=707ps

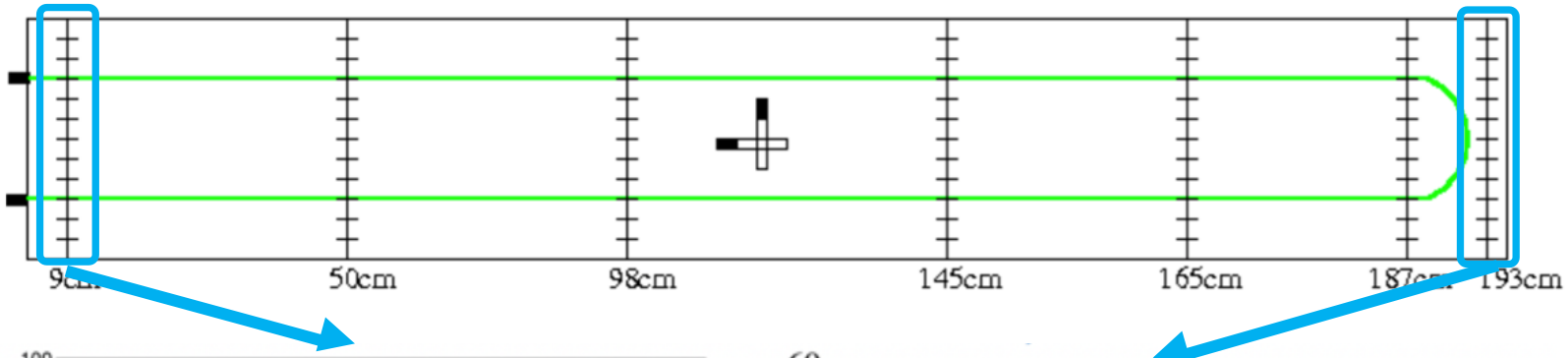
Light Yeld depending of event position (Green – LY from one end; Blue – LY from another end; Red – LY sum):

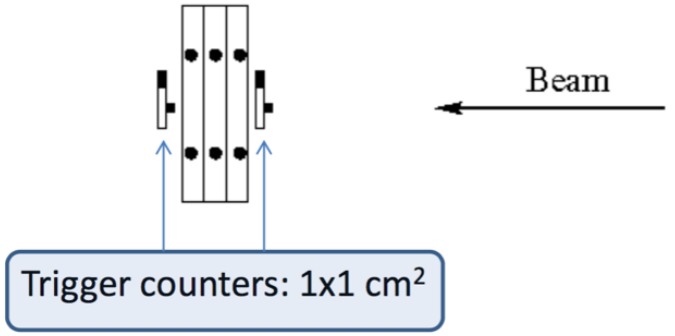


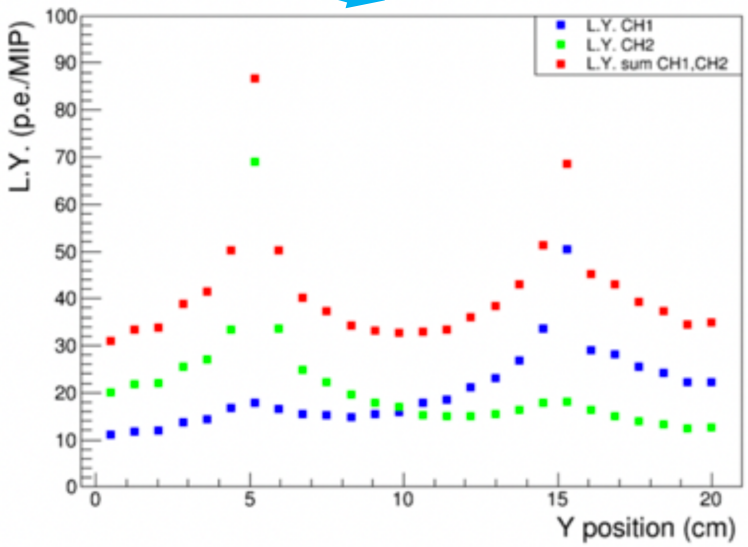


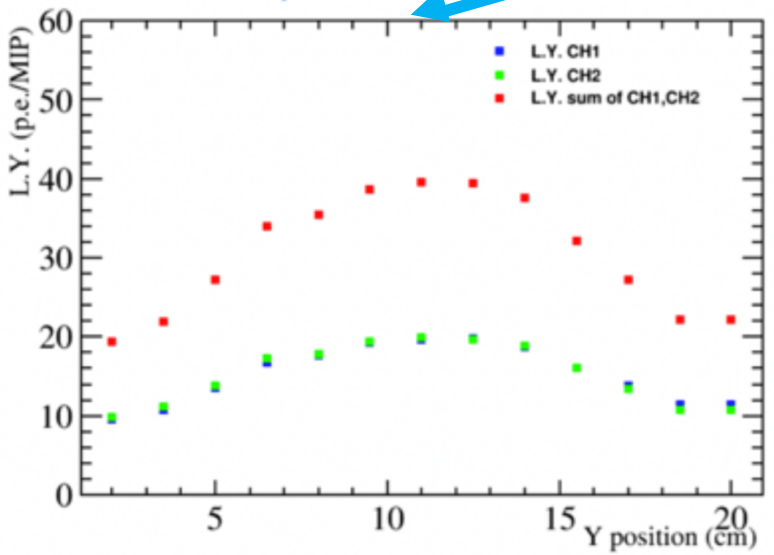
Horizontal bars inefficiency in %:

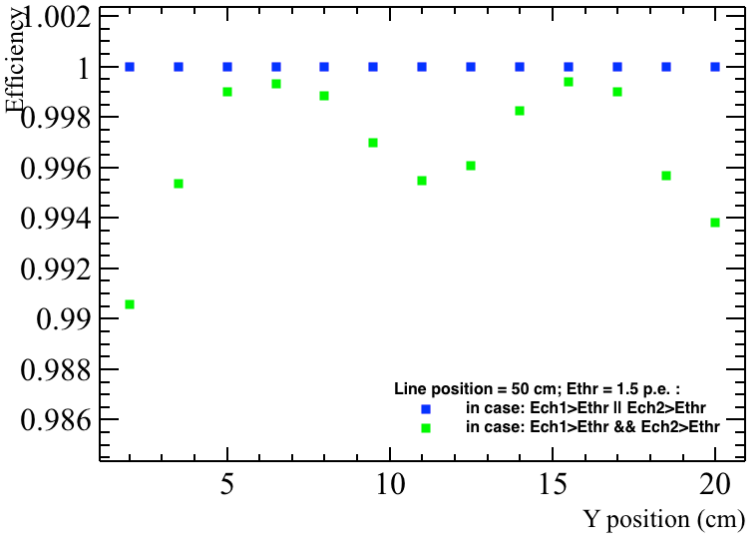
Vertical bars







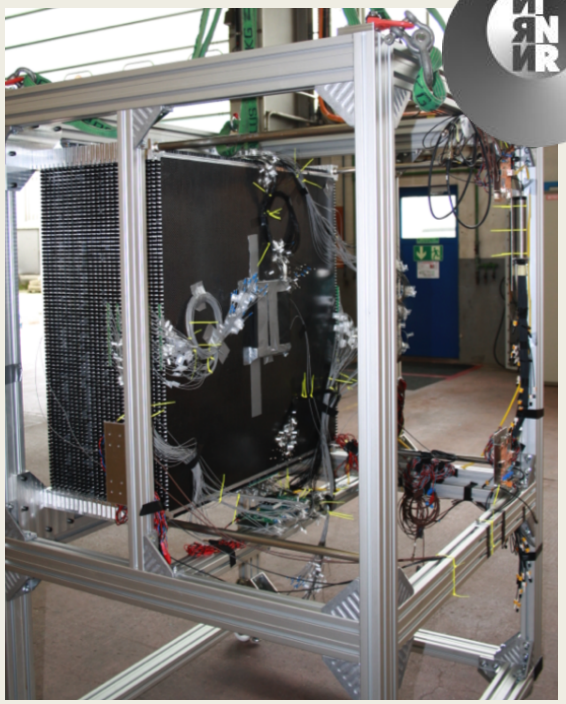




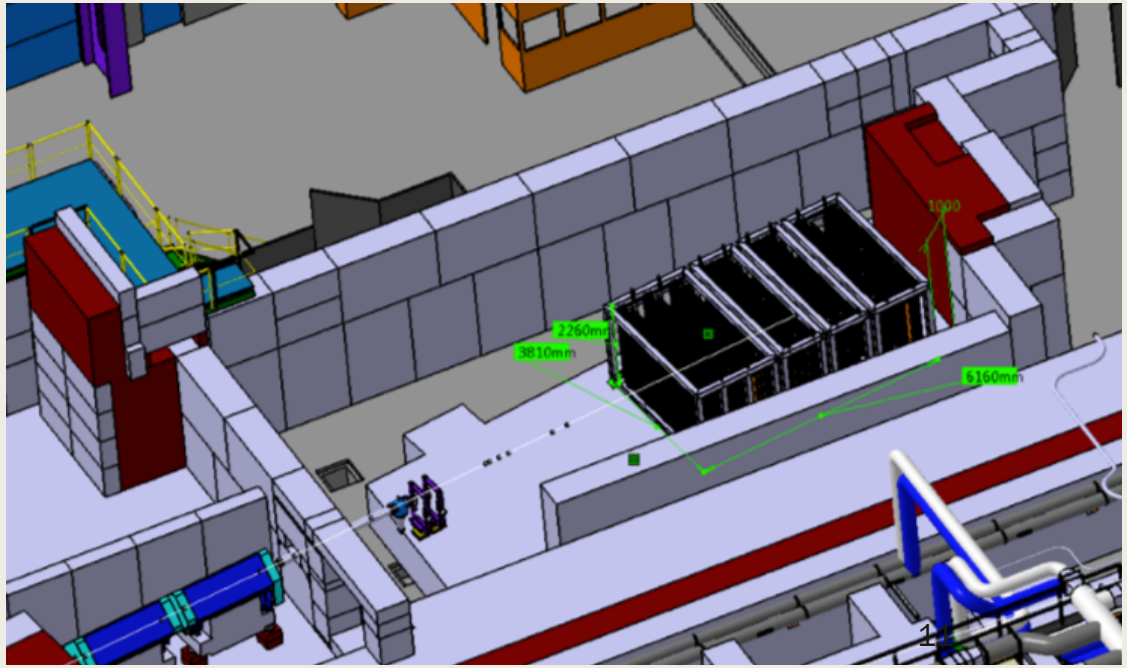
Beam tests at CERN T9 beam line

- Beam tests 2016: 3 weeks in summer 2016 on T9 beamline at the PS in the East Area. Electronics, vertical sci. bars.
- Beam tests 2017: 1 week: 1st to 8th May. Block 1 (of 4 blocks), with 9 magnet modules, 7 scintillator modules. 5 weeks: 7th June to 12th July. Tests of full detector: 33 magnet modules, 18 scintillator modules.

Beam tests 2016: TASD (Totally Active Scintillator Detector)



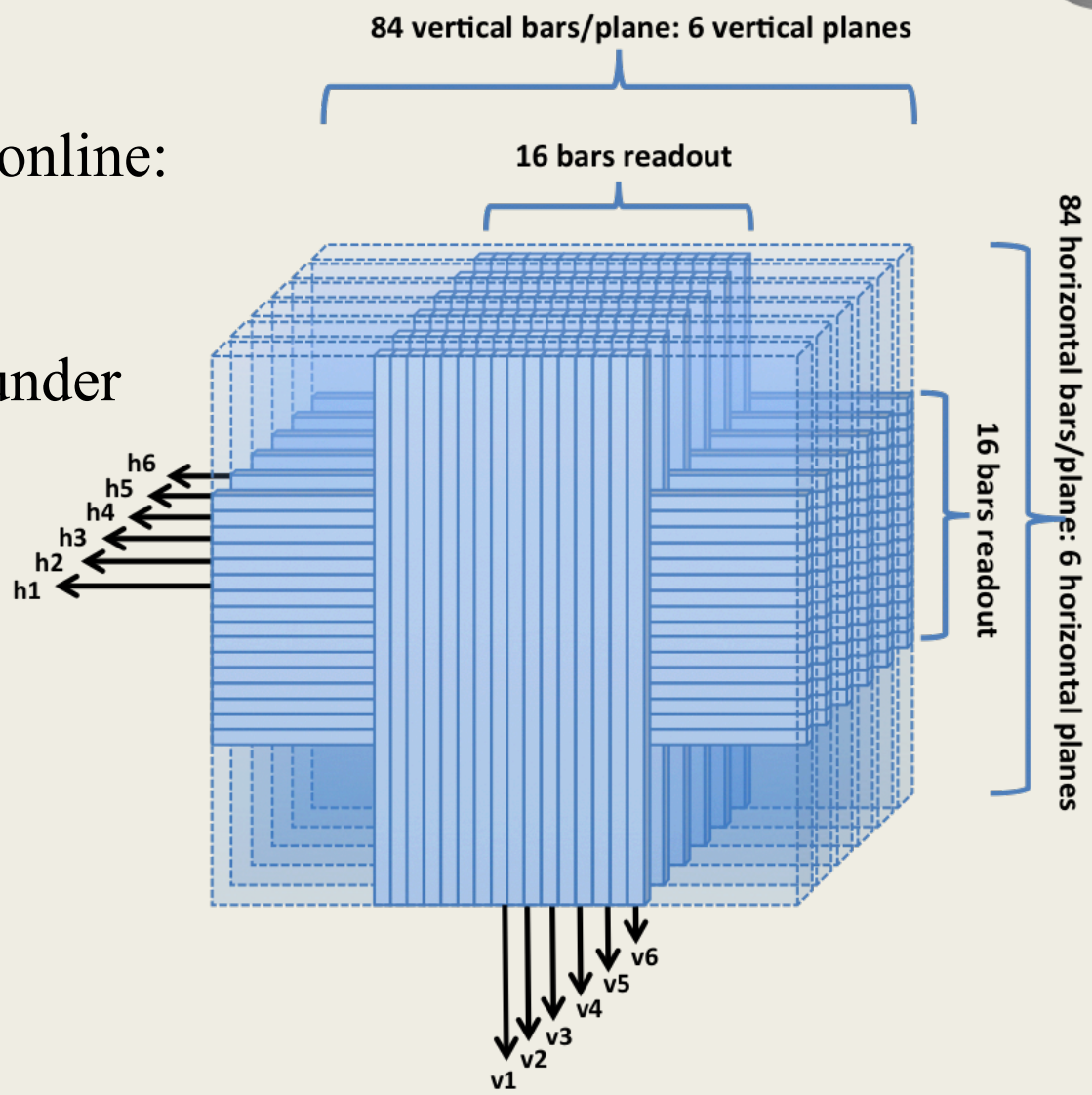
Beam tests 2017: Baby MIND



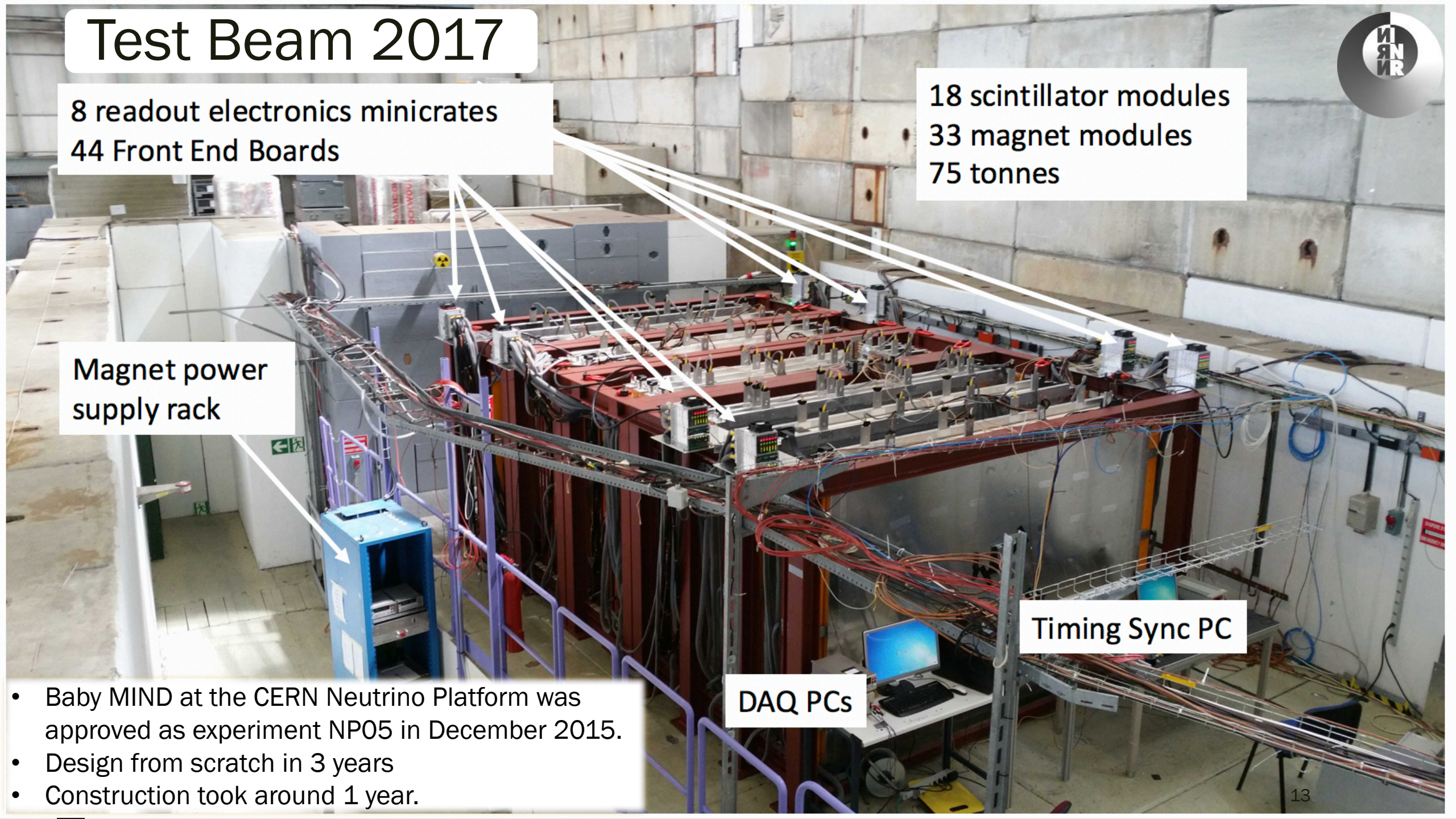
Test Beam 2016

- Electronics FEBv1 characterization online:
  - 4 FEBs.
  - 384 MPPCs.
  - Scintillator modules developed under AIDA project.

- Tests of FEB functionality:
  - Calibration.
  - Analogue readout.
  - Time-over-threshold.



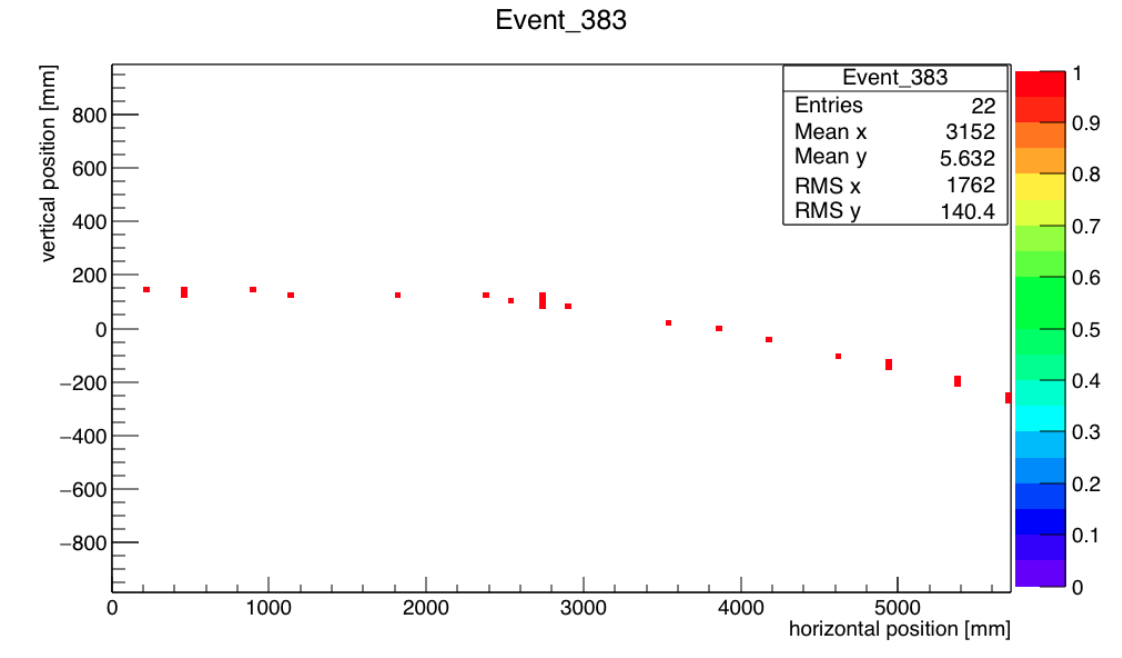
Test Beam 2017



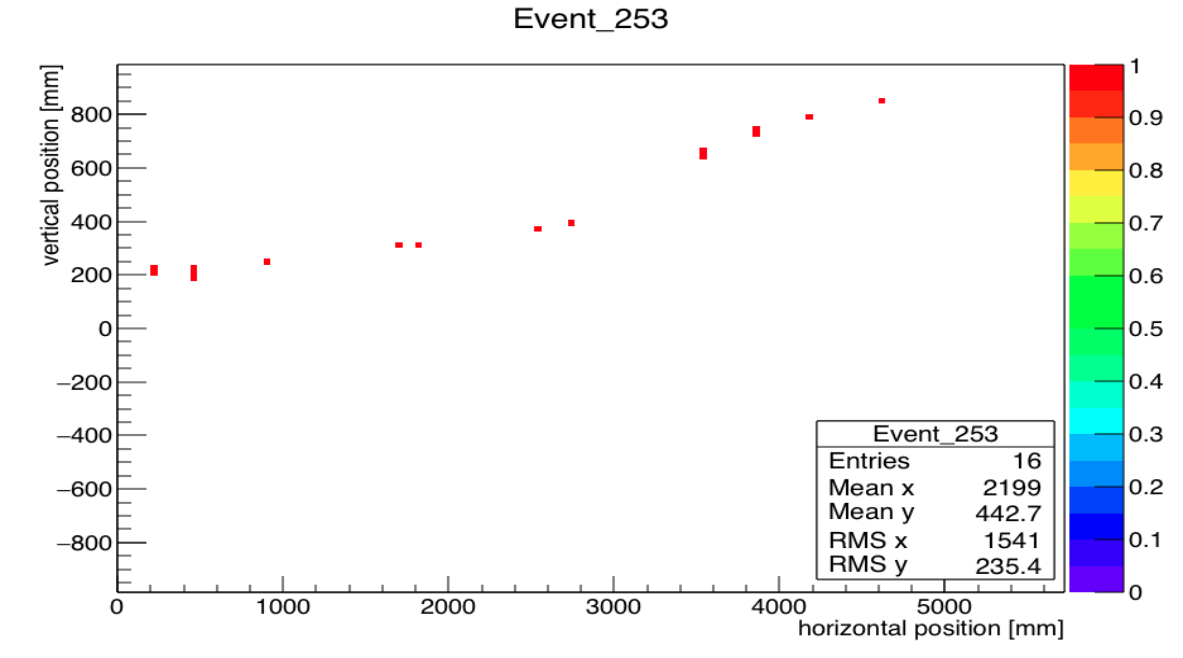
- Baby MIND at the CERN Neutrino Platform was approved as experiment NP05 in December 2015.
- Design from scratch in 3 years
- Construction took around 1 year.

Event displays (Y-Z)

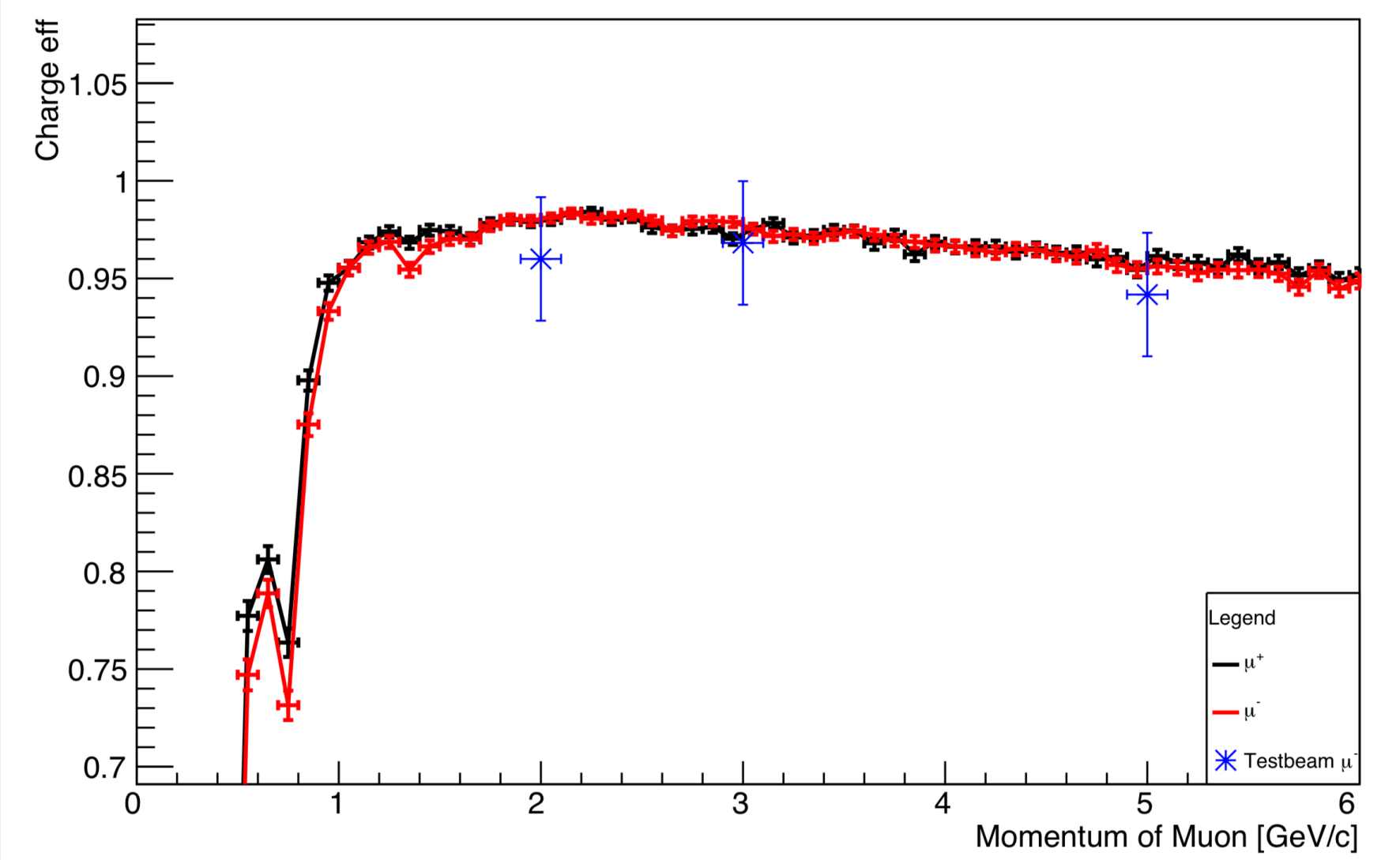
+3 GeV/c muon



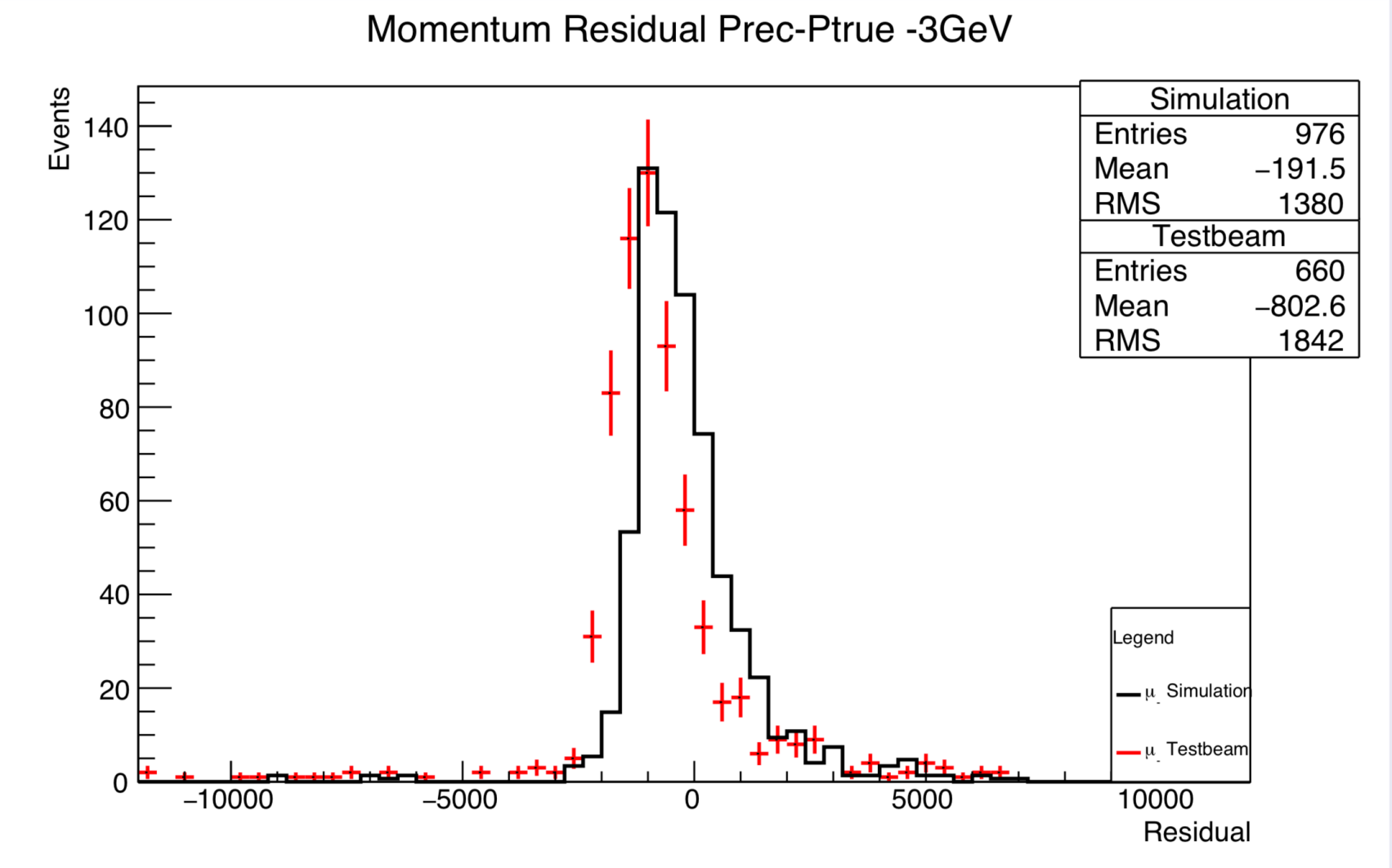
-3 GeV/c muon



Charge reconstruction efficiency



Momentum Residual P_{rec}-P_{true} -3GeV



Conclusion

- NP05 Baby MIND project status Project approved in December 2015 as a Neutrino Platform project. Construction finished at June 2017.
- Magnet modules: the novel design, enables far greater flexibility in detector layout compared with previous designs for this type of detector.
- Scintillator modules: All 18 modules extensively tested and qualified with test beam.
- Baby MIND can measure particle momenta in an interval of 0.3-10.0 GeV/c
- Muon charge efficiency above 80% layout for full range, above 95% at 800 MeV/c for both layouts
- Japan shipping in November 2017.
- Installation starts in January 2018 at J-PARC.

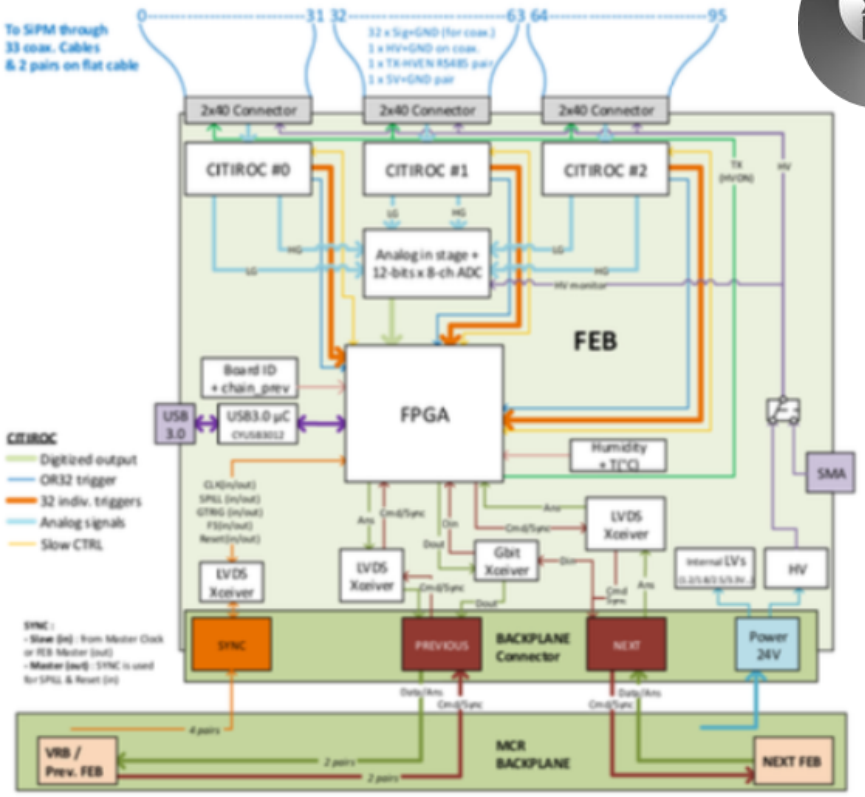
Current publications

- 2017-02-03 New and Optimized Magnetization Scheme for the Baby Magnetized Iron Neutrino Detector at J-PARC http://ieeexplore.ieee.org/document/7842530
- 2017-04-26 Baby MIND: A magnetised spectrometer for the WAGASCI experiment https://arxiv.org/abs/1704.08079
- 2017-04-28 Baby MIND Experiment Construction Status https://arxiv.org/abs/1704.08917 2017-05-29
- Baby MIND: A magnetized segmented neutrino detector for the WAGASCI experiment https://arxiv.org/abs/1705.10406

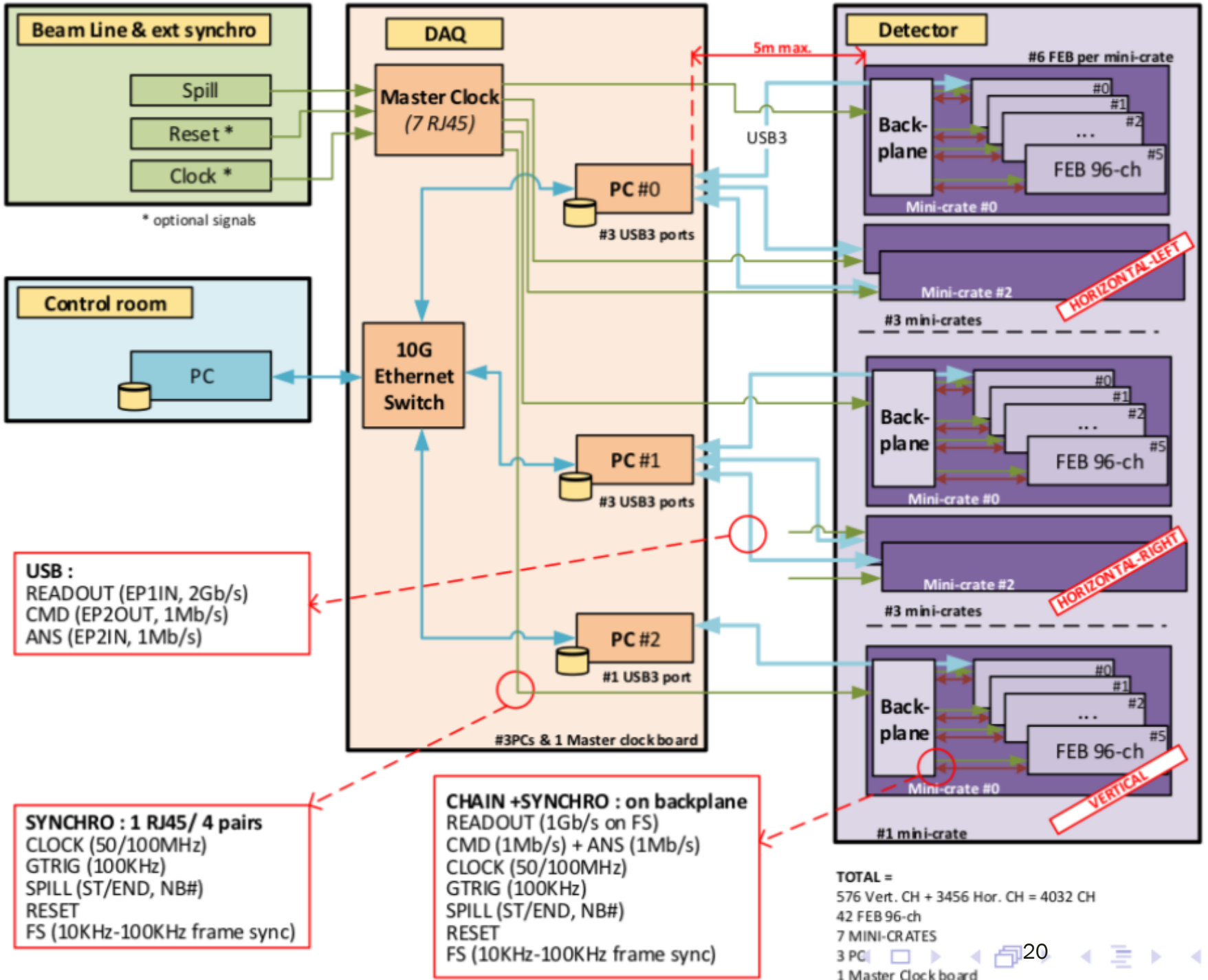
Electronics

Custom made FEB

- Designed by Geneva University
- Rack mounted.
- x3 32-ch connectors, 3 CITIROC ASICs 32-ch.
- 12-bits 8-ch 40 MS/s/ch ADC.
- Altera ARIA5 FPGA.
- Timing: 400 MHz sampling.
- Analog readout: 8µs for 96-ch L-Gain and H-Gain.
- Readout/Slow control on USB3 and/or Gigabit RJ45 chain.
- Power supplies (HV/LV).
  Platform independent readout, Windows/Linux.
- CITIROC made by Weeroc, a spin-off company from Omega laboratory (IN2P3/CNRS)



Electronics readout scheme



Photosensors and connectivity

Photosensor characteristics:

- *Hamamatsu MPPC S12571-025C*
- *1 × 1 mm^2 (65% fill factor).*
- *25 μm cell size. Operating voltage ~ 67.5 V.*
- *PDE ~ 35%.*
- *Gain 5×105.*
- *Dark counts 100 kcps typ.*

Custom connectors.

- *Designed by INR.*
- *Alignment of MPPC andcoupling to WLS fiber.*
- *Small pcb with UFL connector.*
- *Coax cable: I-PEX 0.5 mlength to cable bundle*