T59 experiment: Plan of installation of the Baby MIND muon spectrometer *

T59 collaboration†

November 27, 2017

Abstract

T59 is a test experiment to develop a 3D grid-like neutrino detector with a water target to study the neutrino-nucleus interaction at the near detector hall of the J-PARC neutrino beamline. The downstream muon range detector, which is the final missing element of T59, was build as the Baby MIND detector, in which each of the iron plates is wound by a coil and can be magnetized. It will provide the charge identification capability in addition to the function as a muon range detector. T59 is planing to install Baby MIND in January to March, 2018 and to do commissioning with a neutrino beam in April and May, 2018. The magnetization requires a new 400 V tri-phase power line at the experimental site and will be tested when the power line becomes available, desirably in March. Once the Baby MIND is commissioned, the original aim of T59 will be completed.

Contents

---

[*] This work is supported by the Baby MIND collaboration, whose member list is attached at the end of this document.

[†] The member list is attached at the end of this document.

1 Motivation

1.1 Introduction

T59 is a test experiment to develop a 3D grid-like neutrino detector with a water target to study the neutrino-nucleus interaction at the near detector hall of the J-PARC neutrino beamline. It was proposed and has been conducted by the WAGASCI collaboration. The proposed experimental setup contained side and downstream muon range detectors (MRD) with iron plates and scintillators in addition to the 3D grid-like scintillator-water detector. However, so far those detectors have not been installed yet. In October 2017, we have submitted a document describing the current status of T59, the data taking plan from October 2017 to May 2018 and the plan of the installation of the side MRD's in January-March, 2018. The downstream MRD was build as a CERN Neutrino Platform project NP05 and called the Baby MIND detector. Each of the iron plates of the Baby MIND is wound by a coil and can be magnetized. Therefore, it provides the charge identification capability in addition to the function as a muon range detector. The charge identification is essentially important to select antineutrino events in the antineutrino beam because contamination of the neutrino events is as high as 30%. In this document, we describe the Baby MIND detector and the plan of the installation and commissioning of the Baby MIND in 2018. Once the Baby MIND is commissioned, the original aim of the T59 will be completed and T59 will be terminated. The plan for the future cross section measurement using the completed setup, that is, the grid-type detector, side MRD and the Baby MIND will be described and proposed to J-PARC in a separate document by the WAGASCI collaboration.

1.2 The Baby MIND project

The Baby MIND is the baseline downstream Muon Range Detector (dMRD) for the approved WAGASCI [1] experiment (T-59) at J-PARC, Figure 1. The novel WAGASCI 3-D grid-like arrays of small cubic cells whose walls are made from plastic scintillators with wavelength shifting fibers readout by silicon photomultipliers provide better acceptance compared to a more classical layout of successive X and Y plane scintillator bars. They also have higher mass ratio of water to scintillator bars compared with the ND280 detector.

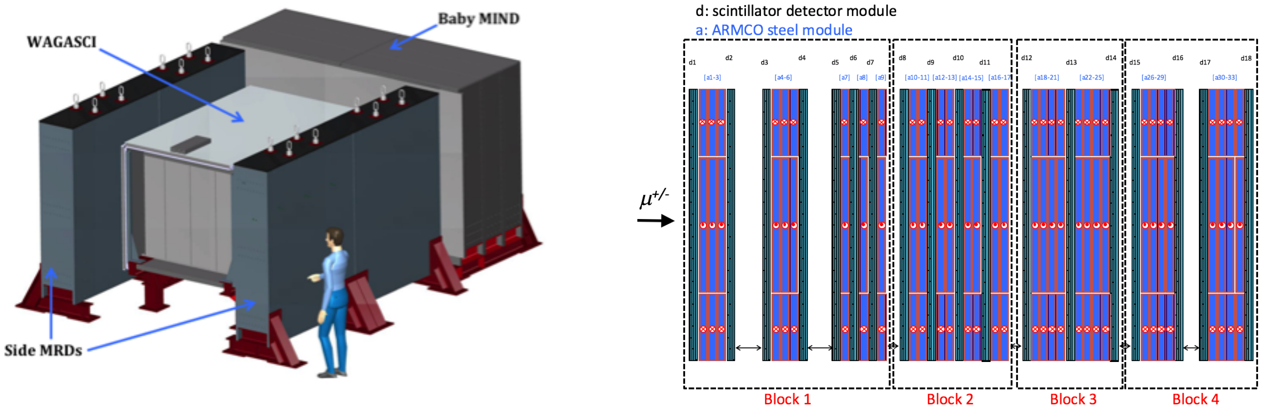

Figure 1: Left) WAGASCI modules: flanked by 2 side muon range detectors (sMRD) and one downstream muon detector (Baby MIND). Right) side view layout of the Baby MIND during beam tests at CERN.

The Baby MIND collaboration [1] submitted a proposal to the SPSC at CERN, SPSC-P-353 [2], written to outline project plans with a focus on construction and testing activities at CERN. The project was approved by the CERN research board as Neutrino Platform project NP05. The detector consists of 33 magnet modules,

---

[1] Contact person: E. Noah, Spokesperson: A. Blondel, Deputy spokesperson: Y. Kudenko

each 3500 mm × 2000 mm× 50 mm (30 mm steel) with a mass of approximately 2 tonnes. Of these magnet modules, 18 are instrumented with plastic scintillator modules.

A total of 3996 silicon photomultipliers are read out by custom electronics Front End Boards that can process up to 96 channels each, sending charge and timing information of hits in the detector to dedicated data acquisition computers.

One challenge to be addressed by the Baby MIND collaboration is that of obtaining high charge identification efficiencies for μ^+/μ^- down to 500 MeV/c and below. Magnetized iron neutrino detectors are limited by multiple scattering in the iron, and their use is overlooked for applications requiring good charge ID efficiencies below 1 GeV/c. By optimizing the distance between the first magnet modules, rendered possible by the magnet design, our simulations show improved charge identification efficiencies down to 400 MeV/c.

The size of the Baby MIND matches with that proposed in the T59 proposal providing excellent acceptance for forward secondaries from interactions in the upstream WAGASCI water and carbon targets. The Baby MIND construction was completed in June 2017, and it was then tested in June and July 2017 at the Proton Synchrotron experimental hall at CERN with a mixed particle beam comprising mostly muons whose momenta could be selected between 0.5 and 5 GeV/c. An event display from the summer 2017 tests is shown in Figure 2.

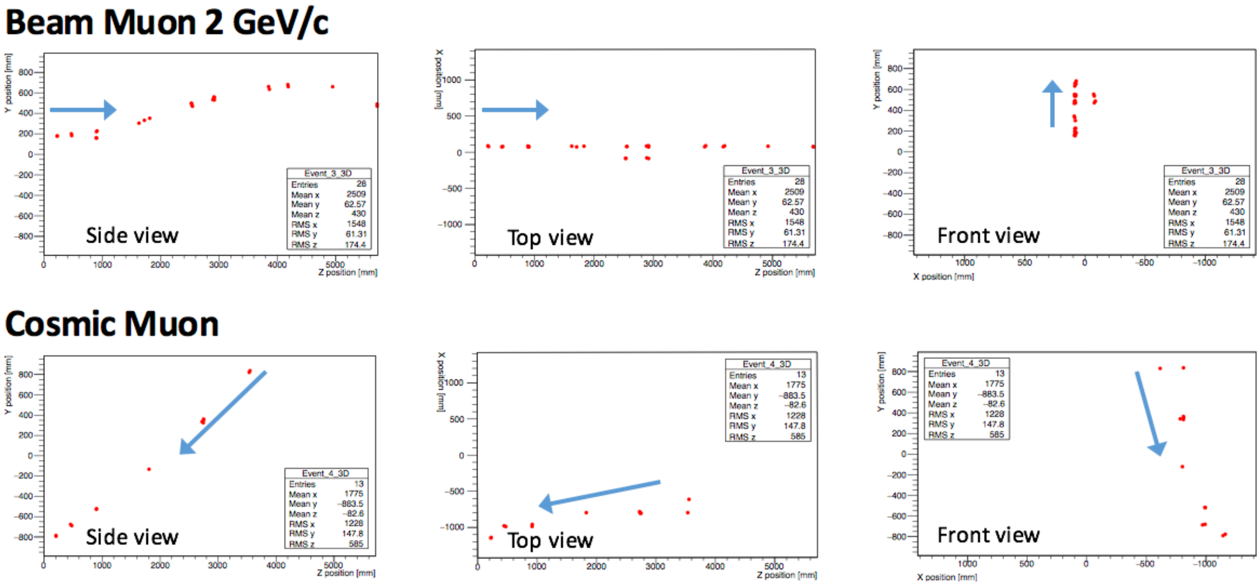

Figure 2: Comparison of a beam muon and cosmic muon in the three different geometrical projections of the detector. The beam impinges on the detector from the left. The arrows indicate the direction of travel of these muons. The direction of the cosmic muon is inferred from timing information.

This document describes the logistics for shipment (briefly, Q4/2017) and installation (Q1/2018) of the detector at J-PARC and outlines plans to commission and test (Q1 and Q2/2018) the detector.

2 Baby MIND detector description

The main Baby MIND systems are the magnet, scintillator and electronics modules [3].

2.1 Magnet modules

Project constraints for the design, construction and testing of the Baby MIND come from the need to operate the detector both at CERN and J-PARC on a relatively short timescale. The installation at J-PARC in particular has driven the overall geometry of the detector. For example, the magnetization scheme for the Baby MIND is a direct result of the requirement to lower segments of detector elements through the narrow shaft down to the lowest floor of the ND280 building pit at J-PARC [4]. Indeed the Baby MIND is built from sheets of iron interleaved with scintillator detector modules but unlike traditional layouts for magnetized iron neutrino detectors (e.g. MINOS) which tend to be monolithic blocks with a unique pitch between consecutive steel segments and large conductor coils threaded around the whole magnet volume, the Baby MIND iron segments are all individually magnetized, allowing for far greater flexibility in the setting of the pitch between segments, and in the allowable geometries that these detectors can take.

The key design outcome is a highly optimized magnetic field map. A double-slit configuration for coil winding was adopted to increase the area over which the magnetic flux lines are homogeneous in B_x across the central tracking region. Simulations show the magnet field map to be very uniform over this central tracking region covering an area of 2800 × 2000 mm^2, Figure 3. The B_x component dominates in this region, with negligible B_y and B_z. This was confirmed by measuring the field with 9 pick-up coils wound around the first ARMCO module. Subsequent modules were equipped with one pick-up coil. Test results on the 33 modules show all to achieve the required field of 1.5 T for a current of 140 A, with a total power consumption of 11.5 kW. The polarity of the field map shown in Figure 3 (middle) can be reversed by changing the power supply configuration.

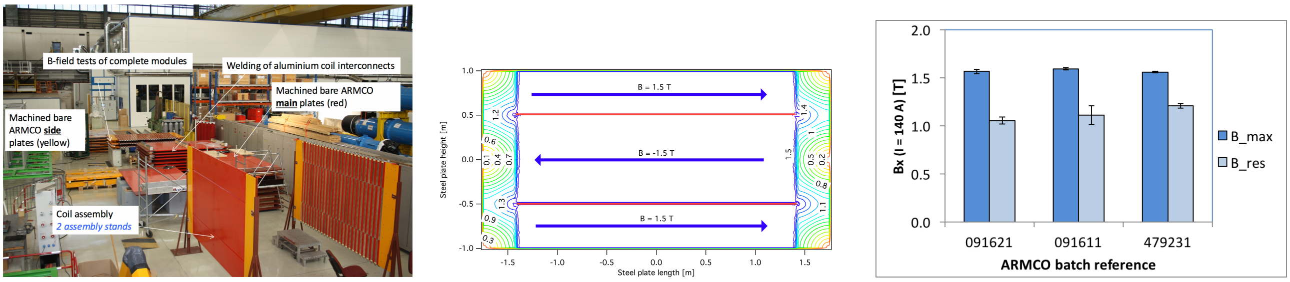

Figure 3: Left) Magnet assembly zone at CERN. Middle) Magnetic field map with a coil along 280 cm of the length of the plate. Right) Measured B field for 33 modules.

2.2 Scintillator modules

Each of the 18 scintillator modules is constructed from 2 planes of horizontal counters (95 counters in total) and 2 planes of vertical counters (16 counters in total) [5], arranged with an overlap between planes to achieve close to 100% hit efficiency for minimum ionizing muons. The arrangement of planes within a module is vertical-horizontal-horizontal-vertical, with construction of each module carried out in two separate phases, one front half-module constructed with two planes vertical/horizontal, and one back half-module constructed with two further planes horizontal/vertical. The scintillator bars are held in place using structural ladders that align and maintain the counters, Figure 4. No glue is used in the process, so counters can be replaced. Aluminum sheets front and back provide light tightness.

The plastic scintillator counters were made from 220 mm-wide slabs, consisting of extruded polystyrene doped with 1.5% paraterphenyl (PTP) and 0.01% POPOP. They were cut to size then covered with a 30-100 μm thick diffuse reflector resulting from etching of the surface with a chemical agent [6, 7]. The horizontal counter size is 2880 × 31 × 7.5 mm^3, with one groove along the length of the bar in which sits a wavelength shifting fiber from Kuraray. The vertical counter size is 1950 × 210 × 7.5 mm^3, with one U-shaped groove along

Figure 4: Scintillator modules assembly. Left) top of front half-module showing vertical counters, and the spacers-ladders that set the pitch between horizontal counters and hold them in place. Middle) rear half-module showing horizontal counters on their ladders. Right) Assembled rear half-module, the front half-module can be seen in the background.

the bar. On each counter, two custom connectors house silicon photomultipliers, MPPC type S12571-025C from Hamamatsu, either side of the horizontal counter, and both connectors at the top for the vertical counter. This geometrical configuration for vertical counters was chosen for ease of connectivity to the electronics, and maintenance operations.

A total of 1744 horizontal counters and 315 vertical counters (including spares) were produced at the Uniplast company (Vladimir, Russia). All counters were measured at INR Moscow with a cosmic ray setup using the same type S12571-025C MPPCs and CAEN DT5742 digitizer [8]. The average light yield (sum from both ends) was measured to be 37.5 photo-electrons (p.e.) per minimum ionizing particle (MIP) and 65 p.e./MIP for vertical and horizontal counters, respectively. After shipment to CERN, all counters were tested once more individually with an LED test setup [9]. 0.1% of counters failed the LED tests and were therefore not used during the assembly of modules.

3 Electronics

The Baby MIND electronic readout scheme includes several custom-designed boards [10]. The revised version is shown in Figure 5. At the heart of the system is the electronics Front End Board (FEB), developed by the University of Geneva, Figure 6. The readout system includes two ancillary boards, the Backplane, and the Master Clock Board (MCB) whose development has been managed by INRNE (Bulgarian Academy of Sciences) collaborators.

One critical element in the photosensor readout path is the cable bundle, a 5 m extension coaxial cable RG174U that connects the photosensor to the FEB. Each bundle connects up to 32 photosensors. The purpose is to decouple the FEBs from the scintillator modules, which improves accessibility to FEBs and their long term maintainability. The module end of the bundle hosts some electronics that manages the application of the high voltage to the SiPMs, enabling faulty SiPMs to be switched off at that level. This feature was added after the summer 2016 beam tests, where a short circuit on a single channel would disable a bank of 96 channels.

The FEBv2 hosts 3 CITIROC chips that can each read in signals from 32 SiPMs [11]. Each signal input is processed by a high gain, and a separate low gain, signal path. Both paths comprise independent pre-amplification and "slow" shaping stages with tunable gain and shaping time constant, respectively. The outputs from the slow shapers can be sampled using one of two modes: a mode with an externally applied delay, and a peak detector mode. A faster shaper can be switched to either HG or LG paths, followed by discriminators with adjustable thresholds providing 32 individual trigger outputs and one OR32 trigger output. An Altera ARIA5 FPGA on the FEBv2 samples these trigger outputs at 400 MHz, recording rising and falling times for the individual triggers and assigning time stamps to these. Time-over-threshold from the difference between falling and rising times gives some measure of signal amplitude, used in addition to charge information and

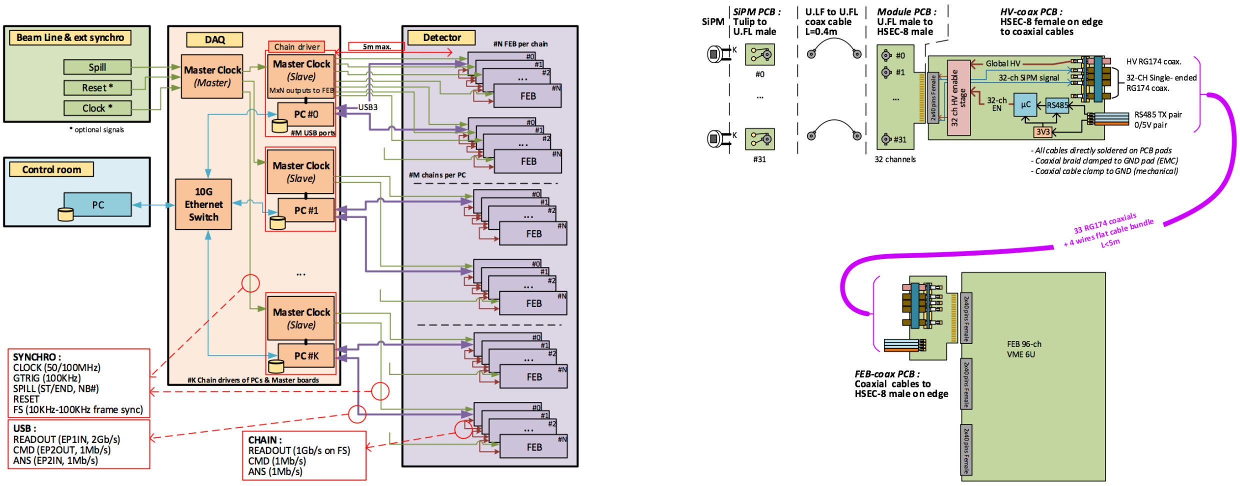

Figure 5: Left) Baby MIND electronics readout scheme. Right) SiPM-to-FEB connectivity.

useful if there is more than one hit per bar within the deadtime due to the readout of the multiplexed charge output of $\sim 9\ \mu$s. The ARIA5 also manages the digitization of the sampled CITIROC multiplexed HG and LG outputs via a 12-bit 8-ch ADC.

The FEBv2 is designed to fit into a slot in a minicrate as shown in Figure 6. The front face receives the SiPMs cable bundles, the rear end plugs into the backplane. Up to 6 FEBv2 can be housed in each minicrate. Eight minicrates are distributed either side of the Baby MIND.

The internal 400 MHz clock on the FEBv2 can be synchronized to a common 100 MHz clock. The synchronization subsystem combines input signals from the beam line into a digital synchronization signal (SYNC) and produces a common detector clock (CLK) which can eventually be synchronised to an external experiment clock [12]. Both SYNC and CLK signals are distributed to the FEBs. Tests show the FEB-to-FEB CLK(SYNC) delay difference to be 50 ps (70 ps). Signals from the beam line at WAGASCI include two separate timing signals, arriving 100 ms and 30 μs before the neutrino beam at the near detectors [13]. The spill number is available as a 16-bit signal.

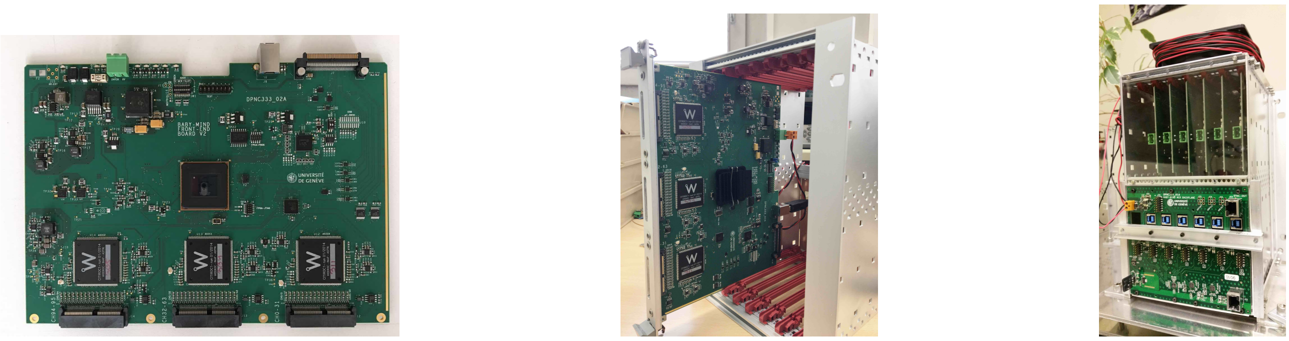

Figure 6: Left) Second version of the electronics readout Front End Board (FEBv2), received at the University of Geneva in March 2017. Middle) FEBv2 in minicrate. Right) rear of minicrate with 6 FEBs connected through a Backplane PCB on the lower half of the minicrate.

Several connection options are possible between the FEBv2 and a DAQ PC. The FEBv2 can be operated as a standalone device, connected directly to a DAQ PC via USB3. This is useful for laboratory measurements on the FEB itself, its maintenance and calibration, and qualification tests on other components such as MPPCs or cable bundles. It is also possible to daisy chain several FEBs via the backplane PCB in experiment data taking mode, with the first FEB in the chain connected directly to the DAQ PC via a USB3 link. In this mode the USB3 bandwidth is shared with the potential 6 FEBs in the chain thanks to a Time Division Multiplexing (TDM) protocol, each FEB having 1/6th of the data throughput. For enhanced measurements or calibration a dedicated option of the chaining is also possible where 1 single FEB in the chain can use the full bandwidth of the single USB3 connection. The DAQ software is platform independent. The data protocol encodes information such as spill number, FEB ID, hit channel number, time and charge, as well as tags to match the TDM data stream to the correct minicrate slot ID.

4 Experiment layout

The candidate location of the Baby MIND on the B2 floor is downstream of the WAGASCI neutrino detector modules at an off-axis angle of 1.5°, Figure 7. The actual location will be further optimized by taking neutrino spectrum difference and floor boundary conditions into account. The arrangement of detectors upstream of the Baby MIND, WAGASCI, INGRID (1 module), Proton and sideMRD modules may change.

The overall footprint of the Baby MIND is contained within an area of 3700 × 4600 mm^2. Two possible layouts are presented here for the Baby MIND, Figures 8 and 9:

- Layout 1: The Baby MIND in this layout is further upstream, 800 mm into the space between the two large concrete blocks. One concern is replacing a faulty horizontal MPPC cable in the first block on the RIGHT side., period during which Baby MIND will be installed.
- Layout 2: The Baby MIND in this layout is further downstream, 357 mm into the space between the two large concrete blocks. Replacing a faulty horizontal MPPC cable in the first block on the RIGHT side is less of a concern. Replacing faulty horizontal cables at the rear LEFT is a concern. The assumption is that the support frame can be moved to the right if necessary.

Note the position is asymmetric LEFT RIGHT. Distance between support frame and concrete block is 200 mm LEFT and 110 mm RIGHT, in this view. This is to ensure the support frame is installed away from the drain at floor level at the rear of the building.

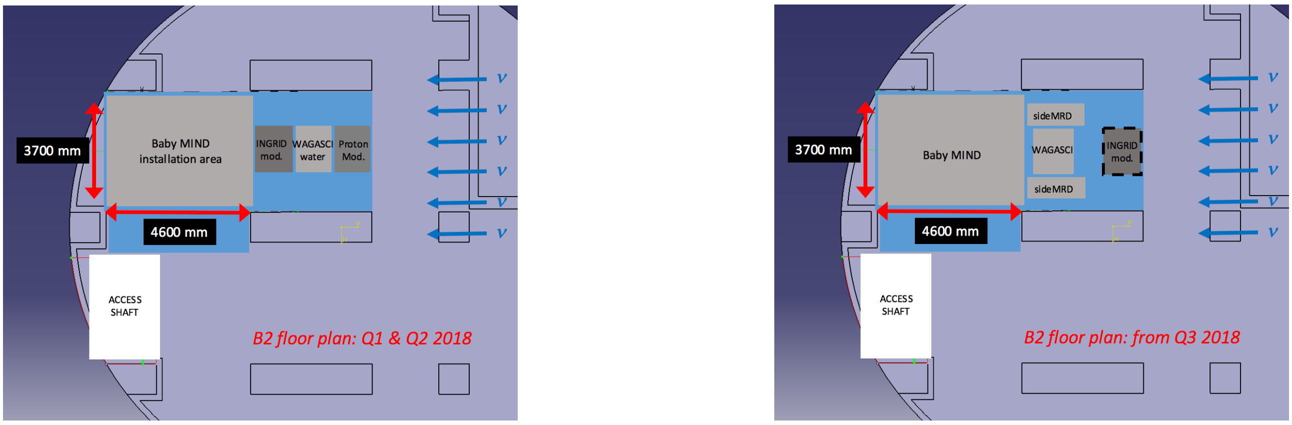

Figure 7: Left: Floor plan at B2 floor for Q1 and Q2 2018, period during which Baby MIND will be installed. Right: Floor plan at B2 floor from Q3 2018.

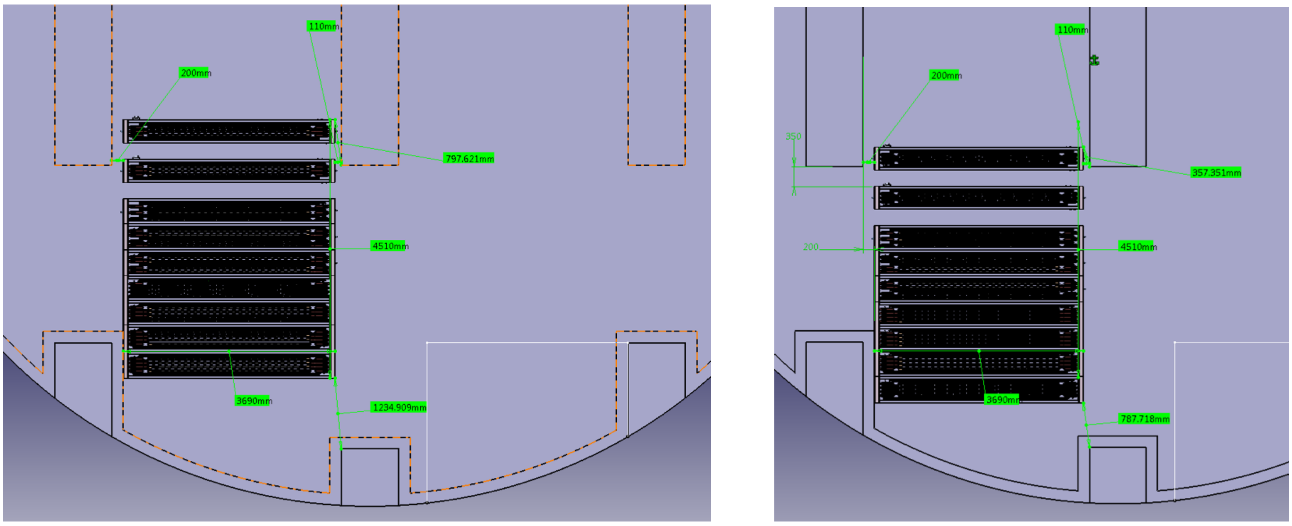

Figure 8: Both layouts shown here are top views, rotated by 90^o with respect to the previous figure. Left: Layout 1: The Baby MIND in this layout is further upstream, 800 mm into the space between the two large concrete blocks. Right: Layout 2: The Baby MIND in this layout is further downstream, 357 mm into the space between the two large concrete blocks.

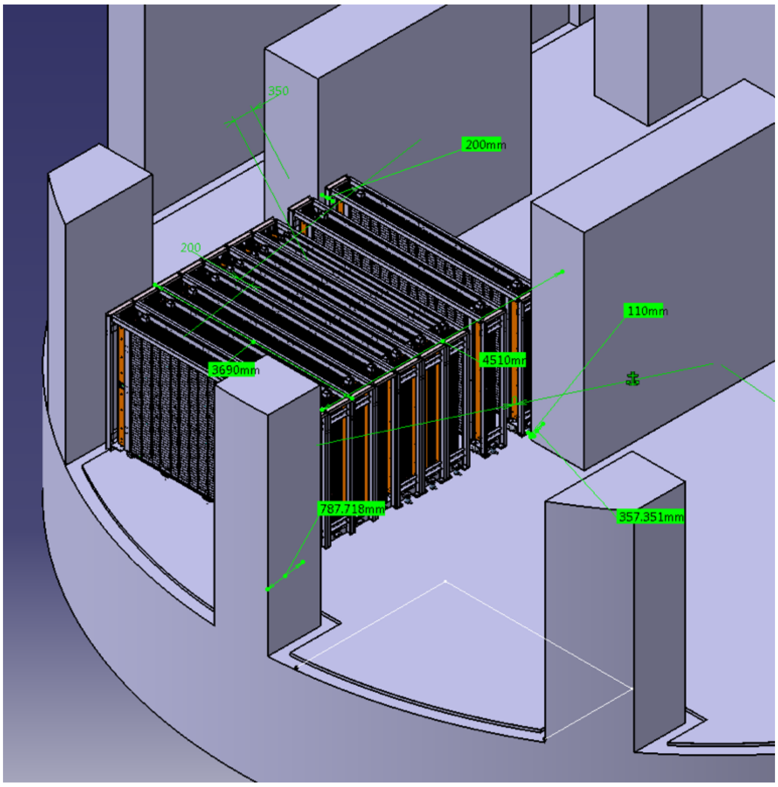

Figure 9: Isometric view of the Baby MIND on the B2 floor.

5 Plan at J-PARC

5.1 Installation

The Baby MIND collaboration will install the detector once it arrives at J-PARC. The installation phase involves assembling the various systems into one coherent hardware set:

- mechanics support systems.
- magnet modules.
- scintillator detector modules.
- cable bundles.
- front end electronics modules.
- daq modules.

The general approach of the collaboration is to ensure documentation and traceability of components and systems. A construction database stores parameters relevant to the detector hardware such as detector geometrical configurations, serial numbers of components and test data. The majority of systems have undergone prototype validation before launching the production phases. Assembly and qualification procedures were drafted for the CERN beam test phase. Integration procedures will be used to ensure the detector is re-constructed appropriately at J-PARC.

5.2 Basic performance assesssment

Several tests will be carried out to assess the performance of the scintillator detector modules, more specifically to determine that their basic functionality has remained unchanged after shipping. These assessments will therefore focus on demonstrating that all photosensors are functional. Tests of the magnet modules will be carried out to validate their basic functionality after shipping. The level of testing will be decided depending on the equipment available, for example if a power supply is not available, simple electrical connectivity tests of the coils will be performed.

5.3 Synchronization

Tests of the synchronization of all electronics modules will be carried out, with external signals from the T2K beamline, Figure 10.

5.4 Magnetization

Tests of the magnetization of all magnet modules will be carried out, with a power supply connected to a 400 v tri-phase power supply and pick-up coils wound around each magnet module.

6 Logistics J-PARC installation

The shipping and reception of Baby MIND parts was addressed in a separate document, issued by the T59 collaboration towards the end of September 2017 as a request for support for reception and storage of the Baby MIND.

A brief description of the offloading of the 4 Baby MIND transport structures (referred to as chassis) holding the magnet and scintillator modules upon arrival at J-PARC is given here. The 10 t capacity of the crane in

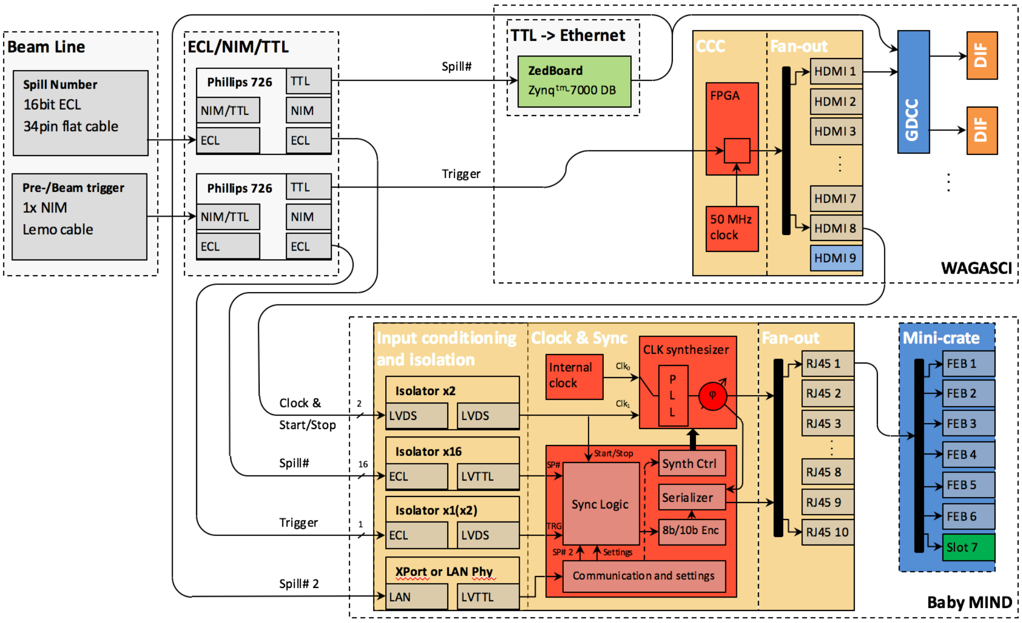

Figure 10: Synchronization scheme for Baby MIND within T59 experiment.

the pit building and the low height of this crane exclude offloading inside the building. It will therefore occur outside the building, with the requirement to rent a crane lorry. The 4 chassis will each be fitted with a set of 4 rollers as they are lifted out of the containers. They can then be pushed into the building for storage. Once in the building, the chassis will be lifted with jacks, and the rollers will be removed. The chassis will then be lowered onto the floor for the storage period. If the chassis need to be moved (for example to move other T2K equipment), the rollers have to be fitted back on.

A detailed report of the installation work plan will be submitted to the J-PARC neutrino section for approval prior to the installation work. It will be also notified to T2K and be confimed that the work would not interfere the T2K ND activity.

6.1 Note on the shaft in the pit building

Baby MIND components are designed to fit through the shaft, Figure 11. Although their length extends beyond 3500 mm, they are characteristically thin, < 100 mm. Taking all fixed objects in the shaft (pipes, cables etc...), components fit through the diagonal of the shaft.

Some preparations for usage of the shaft are assumed, such as the removal of the metallic structure that currently occupies the footprint of the shaft, Figure 11.

6.2 Assembly on B2 floor

The first structures to be assembled on the B2 floor are the 9 support frames. Their design takes into account seismic loads.

6.2.1 Assembly of B2 support frames

Each one of the 9 B2 support frames will be shipped to J-PARC as a collection of parts. The assembly of the B2 support frames will be done one-by-one. For any given support frame, its parts are first lowered down the

Figure 11: Left: Position and dimensions of the shaft through which components will be lowered from the ground floor to the B2 floor. Right: The structure shown in the photo which occupies the footprint of the shaft on the B2 floor must be removed.

shaft. It is then assembled, directly under the shaft, since the 10 t crane can be used. Once the frame is built, it can be lifted up by 50 cm or so, and rollers can be fixed to the four feet. It is then lowered back to the floor, and is moved to a temporary storage area until the next phase.

6.2.2 Lowering modules down the shaft

Throughout these operations, the driving consideration is safety, the modules must at all times be secure. Risks of personal injury or damage to the equipment must be minimized. We assume:

- The transport chassis is in the pit building, ground floor.
- The B2 support frame is assembled and positioned underneath the shaft, B2 floor.

Given the height that can be reached by the 10t crane is not sufficient for removal of modules vertically out of the transport chassis, they will be removed through the side, horizontally out of the chassis. All transport chassis are designed such as to allow for this horizontal removal. Although most of the chassis is welded, one of the top horizontal beams is bolted, so can be removed. The module to be moved is attached to the 10 t crane, lifted out of the chassis, then lowered down the shaft. It is then guided into the B2 floor support frame.

6.2.3 Moving the B2 floor support structures into place

Once a given B2 support structure has received its full complement of magnet and detector modules, it is ready to be moved into position. At this stage, it is equipped with temporary support bars to ensure it does not topple over.

The B2 support structure is rolled into position. Jacks are then used to lift the support structure. Linking pieces are then inserted between the support structure feet and the floor, to raise the height of the support structure and ensure the support structure does not rest on the rollers. The rollers will however remain on the support structures for any future and as yet unplanned displacement of the structures.

6.2.4 Locking all 9 support frames together

As a B2 frame is moved from the shaft to its intended position, it is locked into the frame previously installed.

6.2.5 Fitting interconnect cables to the magnet

The interconnects between magnet modules can only be done once the full detector layout is confirmed.

6.2.6 Cabling the scintillator modules

The scintillator modules will be cabled once all 9 support structures are in place. This stage includes fixing the electronics modules to the frames. It also includes connecting the modules to DAQ PCs.

7 Schedule

The planned schedule assumes the major hardware parts have arrived at J-PARC. These are/will be shipped in several phases. The magnet and scintillator modules were sent by ship, leaving Europe on the 2nd November on the vessel NYK Arcadia. The support structures for the B2 floor and electronics will be sent by air.

Installation work for the Baby MIND detector will be carried out when T2K is not taking data in early 2018. It is therefore dependent on the T2K beam schedule. Taking this schedule into account, our plan is to install in Q1 2018, sometime between January and March.

Planned major dates for this proposal, all items are estimated with day 1 of the installation as the start date, which depends on the T2K beam schedule:

- Baby MIND installation B2 floor [**Q1 2018, between January and March. Duration 1 month. Most likely split in 2 phases**].
- Testing and commissioning standalone mode with cosmics. [+ **1 month, duration 2 weeks**].
- Testing and commissioning standalone mode with beam. **Wish for magnet power line to be installed by beginning of March 2018**. [+ **1.5 month, duration 2 weeks, aim to start these beginning of March 2018**].
- Systems integration tests as WAGASCI sub-detector with beam. [+ **2 months, duration 2 weeks**].

Assuming there is no T2K beam in January 2018, and planning for a potential allocation of additional beam time at the beginning of March (planned return of beam is end March), the plan is for the Baby MIND to be ready to start tests in standalone mode with beam at the beginning of March 2018.

Our desire is to magnetize the detector in the same period. However, if the 400 V tri-phase power line is only available after the April-May 2018 beam time, the test of magnet operation will be conducted after the power line becomes available.

8 Requests

We request several items, some being focused on support or provisions of specific equipments, others being studies such as power supply options. The significant request is the installation of a 400 V 3-phase electrical power line for the magnet, for beginning of March 2018. Given the T2K beam is on from March to May 2018, then off until 2019. It is crucial for us to acquire some data with all WAGASCI systems and a functioning magnet in 2018.

8.1 Neutrino beam

The test experiment can run independently of, and parasitically with T2K and T59 WAGASCI. There are therefore no specific request for beam time. We would however request the test experiment site to be on the B2 floor of the near detector hall at the J-PARC neutrino beamline.

8.2 Equipment request including power line

We request the following in terms of equipment on the B2 floor:

- Site for the Baby MIND detector and its electronics systems on the B2 floor of the near detector hall.
- Anchor points (holes) on the B2 floor to secure the 9 support frames, of order 4 holes per frame, detailed floor plans to be communicated in a separate document.
- Power line for the magnet: 400 V tri-phase 48-to-62 Hz, capable of delivering 12 kW. We have a wish for the magnet power line to be installed and available to us by beginning of March 2018.
- Electricity for electronics, 1 kW, standard Japanese electrical sockets.
- Beam timing signal and spill information
- Network connection

The infrastructure for much of the above exists already, and will be shared in part with the WAGASCI experiment. Exceptions are the power line for the magnet and holes in the B2 floor to anchor the detector support structures.

8.3 Study of power supply and power extraction options for magnet

We request a study of provision of electrical power for the Baby MIND magnet, via a 3-phase 400 V power line, with an outcome end January 2018.

8.4 Study of Baby MIND installation plan

The installation phase will start in January 2018. We will submit a detailed installation plan. We request a study of this installation plan, with an outcome (comments, recommendations) by end 2017.

9 Handling archive

A few photographs of the installation at CERN are reported in this section, since they are of relevance to the installation at J-PARC.

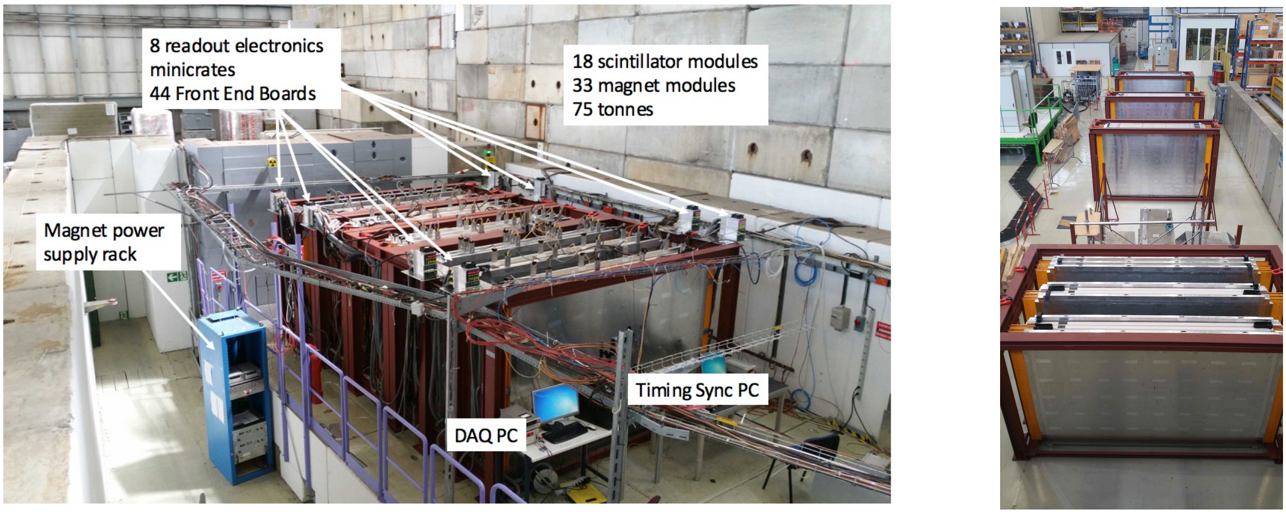

Figure 12: Left: Baby MIND detector installed in the experimental hall of the PS. Right: Temporary storage at CERN after summer 2017 beam tests.

Figure 13: Left: Loading Baby MIND chassis 1 onto a lorry. Middle: Chassis 1 approaching the Proton Synchrotron (PS) experimental hall. Right: Chassis 2 approaching the PS hall.

Figure 14: Left: Lifting Baby MIND chassis 1 to the beamline at the PS. Middle: Chassis 1 approaching the Proton Synchrotron (PS) experimental hall. Right: Chassis 2 approaching the PS hall.

References

[1] E. Noah *et al.* , The WAGASCI experiment at J-PARC to measure neutrino cross-sections on water, PoS EPS-HEP2015 (2015).

[2] M. Antonova *et al.* CERN-SPSC-2015-031, SPSC-P-353.

[3] E. Noah *et al.*, PoS EPS **-HEP2017** (2017) 508.

[4] G. Rolando, P. Benoit, A. Blondel, A. Dudarev, E. Noah, H. Pais Da Silva, M. Rayner and H. H. J. t. Kate, IEEE Trans. Magnetics **53** (2017) no.5, 8000706. doi:10.1109/TMAG.2017.2664053

[5] M. Antonova *et al.* [Baby MIND Collaboration], arXiv:1704.08917 [physics.ins-det].

[6] Y. G. Kudenko, L. S. Littenberg, V. A. Mayatsky, O. V. Mineev and N. V. Ershov, Nucl. Instrum. Meth. A **469** (2001) 340. doi:10.1016/S0168-9002(01)00780-X

[7] O. Mineev, Y. Kudenko, Y. Musienko, I. Polyansky and N. Yershov, JINST **6** (2011) P12004 doi:10.1088/1748-0221/6/12/P12004 [arXiv:1110.2651 [physics.ins-det]].

[8] M. Antonova *et al.* [Baby MIND Collaboration], JINST **12** (2017) no.07, C07028 doi:10.1088/1748-0221/12/07/C07028 [arXiv:1705.10406 [physics.ins-det]].

[9] G. Mitev *et al.*, "Light Pulse Generator for testing Multi-Element scintillation detectors", Proc. XXVI International Scientific Conference Electronics - ET2016, Sozopol, Bulgaria, 2016.

[10] E. Noah *et al.*, PoS PhotoDet **2015** (2016) 031.

[11] J. Fleury, S. Callier, C. de La Taille, N. Seguin, D. Thienpont, F. Dulucq, S. Ahmad and G. Martin, JINST **9** (2014) C01049. doi:10.1088/1748-0221/9/01/C01049

[12] G. Mitev, Y. Favre *et al.*, "Synchronization of the distributed readout frontend electronics of the Baby MIND detector", Proc. XXVI International Scientific Conference Electronics - ET2017, Sozopol, Bulgaria, 2017.

[13] N. Chikuma *et al.*, "Development of electronics and data acquisition system for the J-PARC T59 (WAGASCI) experiment", PoS EPS-HEP2017 (2017).

J-PARC T59 experiment collaboration

A. Bonnemaison, R. Cornat, L. Domine, O. Drapier, O. Ferreira, F. Gastaldi,

M. Gonin, J. Imber, M. Licciardi, F. Magniette, T. Mueller, L. Vignoli, and O. Volcy

Ecole Polytechnique, IN2P3-CNRS, Laboratoire Leprince-Ringuet, Palaiseau, France

S. Cao, T. Kobayashi

High Energy Accelerator Research Organization (KEK), Tsukuba, Ibaraki, Japan

M. Khabibullin, A. Khotjantsev, A. Kostin, Y. Kudenko, A. Mefodiev, O. Mineev,

S. Suvorov, and N. Yershov

Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia

B. Quilain

Kavli Institute for the Physics and Mathematics of the Universe (WPI), The University of Tokyo

Institutes for Advanced Study, University of Tokyo, Kashiwa, Chiba, Japan

T. Hayashino, A. Hiramoto, A. K. Ichikawa, K. Nakamura, T. Nakaya, K. Yasutome,

and K. Yoshida

Kyoto University, Department of Physics, Kyoto, Japan

Y. Azuma, J. Harada, T. Inoue, K. Kin, N. Kukita, S. Tanaka, Y. Seiya,

K. Wakamatsu, and K. Yamamoto

Osaka City University, Department of Physics, Osaka, Japan

A. Blondel, F. Cadoux, Y. Karadzhov, Y. Favre, E. Noah, L. Nicola, S. Parsa,

and M. Rayner

University of Geneva, Section de Physique, DPNC, Geneva, Switzerland

N. Chikuma, F. Hosomi, T. Koga, R. Tamura, and M. Yokoyama

University of Tokyo, Department of Physics, Tokyo, Japan

Y. Hayato

University of Tokyo, Institute for Cosmic Ray Research, Kamioka Observatory, Kamioka, Japan

Y. Asada, K. Matsushita, A. Minamino, K. Okamoto, D. Yamaguchi

Yokohama National University, Faculty of Engineering, Yokohama, Japan

November, 2017

Baby MIND collaboration

M. Antonova[a], R. Asfandiyarov[b], R. Bayes[c], P. Benoit[d], A. Blondel[*][b], M. Bogomilov[e], A. Bross[f], F. Cadoux[b], A. Cervera[g], N. Chikuma[h], A. Dudarev[d], T. Ekelöf[i], Y. Favre[b], S. Fedotov[a], S-P. Hallsjö[c], A.K. Ichikawa[j], A. Izmaylov[a], Y. Karadzhov[b], M. Khabibullin[a], A. Khotyantsev[a], A. Kleymenova[a], T. Koga[h], A. Kostin[a], Y. Kudenko[†][a], V. Likhacheva[a], B. Martinez[b], R. Matev[e], M. Medvedeva[a], A. Mefodiev[a], A. Minamino[k], O. Mineev[a], G. Mitev[l], M. Nessi[d], L. Nicola[b], E. Noah[‡][b], T. Ovsiannikova[a], H. Pais Da Silva[d], S. Parsa[b], M. Rayner[b], G. Rolando[d], A. Shaykhiev[a], P. Simion[i], P. Soler[c], S. Suvorov[a], R. Tsenov[e], H. Ten Kate[d], G. Vankova-Kirilova[e], K. Yasutome[j] and N. Yershov[a]

[a]Institute of Nuclear Research, Russian Academy of Sciences, Moscow, Russia
[b]University of Geneva, Section de Physique, DPNC, Geneva, Switzerland
[c]University of Glasgow, School of Physics and Astronomy, Glasgow, UK
[d]European Organization for Nuclear Research, CERN, Geneva, Switzerland
[e]University of Sofia, Department of Physics, Sofia, Bulgaria
[f]Fermi National Accelerator Laboratory, Batavia, Illinois, USA
[g]IFIC (CSIC & University of Valencia), Valencia, Spain
[h]University of Tokyo, Tokyo, Japan
[i]Uppsala University, Uppsala, Sweden
[j]Kyoto University, Kyoto, Japan
[k]Yokohama National University, Yokohama, Japan
[l]Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria

November 24, 2017

---

[*] Spokesperson
[†] Deputy Spokesperson
[‡] Contact person