Baby-MIND commissionning

Alain Blondel, University of Geneva

The WAGASCI Baby-MIND collaboration (JPARC-E69)

Technical Design Report (TDR):
Study of neutrino-nucleus interaction at around 1 GeV using cuboid lattice neutrino detector, WAGASCI, muon range detectors and magnetized spectrometer, Baby-MIND, at J-PARC neutrino monitor hall
(E69, WAGASCI/Baby-MIND)

N. Truong

The University of DaNang, University of Science and Technology, Vietnam

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 and 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

L. Eklund, S-P. Hallsjö, J. Nugent, and F.J.P. Soler

University of Glasgow, School of Physics and Astronomy, Glasgow, UK

N. Van

IFRISE, Quy Nhon, Vietnam

T. Hayashino, A. Hiramoto, A.K. Ichikawa, T. Kikawa, 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. Favre, E. Noah, L. Nicola, and S. Parsa

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

N. Chikuma, F. Hosomi, T. Koga, K. Matsushita, 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, A. Minamino, K. Okamoto, and D. Yamaguchi

Yokohama National University, Faculty of Engineering, Yokohama, Japan

May 18, 2018

1

Baby-MIND is CERN Neutrino Platform project NP05

Baby MIND: A magnetized segmented neutrino detector for the WAGASCI experiment

M. Antonova,[a,k] 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. Izmaylov,[a] Y. Karadzhov,[b] M. Khabibullin,[a] A. Khotyantsev,[a] A. Kleymenova,[a] T. Koga,[h] A. Kostin,[a] Y. Kudenko,[a,j,k] V. Likhacheva,[a] B. Martinez,[b] R. Matev,[e] M. Medvedeva,[a] A. Mefodiev,[a,j,1] A. Minamino,[l] O. Mineev,[a] M. Nessi,[d] L. Nicola,[b] E. Noah,[b] T. Ovsiannikova,[a] H. Pais Da Silva,[d] S. Parsa,[b] M. Rayner,[d] G. Rolando,[d] A. Shaykhiev,[a] P. Simion,[i] F.J.P. Soler,[c] S. Suvorov,[a] R. Tsenov,[e] H. Ten Kate,[d] G. Vankova-Kirilova[e] and N. Yershov.[a]

[a] *Institute for Nuclear Research of the Russian Academy of Sciences, 60 October Revolution Pr 7a, Moscow, Russia*

[b] *Dept. de Phys. Nucl. et Corpuscul. (DPNC), University of Geneva, Quai Ernest-Ansermet 24, Geneva, Switzerland*

[c] *School of Physics and Astronomy, University of Glasgow, Kelvin Building, Glasgow, UK*

[d] *European Organization for Nuclear Research, CERN, CH-1211 Geneva 23, Switzerland*

[e] *Department of Physics, University of Sofia, James Bourchier Blvd. 5, Sofia, Bulgaria*

[f] *Fermi National Accelerator Laboratory, Kirk Road and Pine Street Batavia IL 60510-5011, Illinois, USA*

[g] *IFIC (CSIC & University of Valencia), Calle Catedràtico Josè Beltran, 2, Valencia, Spain*

[h] *International Center for Elementary Particle Physics, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan*

[i] *University of Uppsala, 752 36, Uppsala, Sweden*

[j] *Moscow Institute of Physics and Technology, 9 Institutskiy per., Dolgoprudny, Moscow Region, Russia*

[k] *Moscow Engineering Physics Institute, Kashirskoe shosse 31, Moscow, Russia*

[l] *Yokohama National University, 79-8 Tokiwadai, Hodogaya, Yokohama, Japan*

INR Moscow
Geneva
Glasgow
CERN
Sofia
Fermilab
Valencia
Tokyo
Uppsala
Yokohama
+ A. Ichikawa, K. Yasutome - Kyoto

filiation: neutrino factory DS → AIDA→ LBNO→ WA105→ CERN NP05→ WAGASCI@B2

Baby MIND

Magnetized Iron Neutrino Detector

Design goals

-- adaptable to rectangular geometries (LBNO)
-- efficient to low energy muons (>300 MeV)
-- magnetic charge separation
-- momentum by range
-- as high field as possible
-- low power consumption
-- low cost

Collaboration

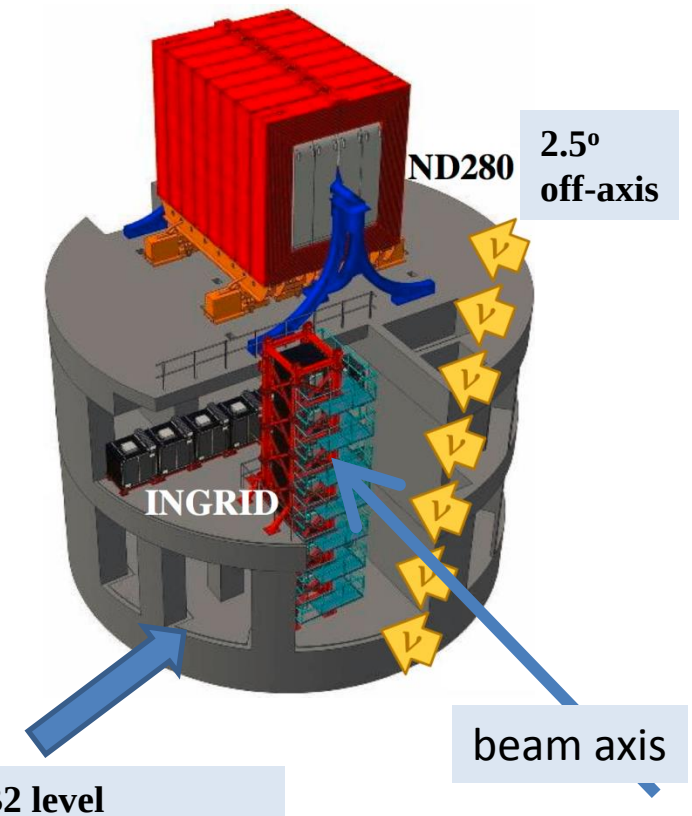
initially in Neutrino Factory (-> 100 kton!) AIDA
then LBNO … not needed for DUNE
→ spectrometer for WAGASCI in T2K ND280
2015: CERN NP05 project
spokes Blondel, Kudenko, PM: Etam Noah
2018 taking data in T2K
First ν events in NP experiment!

Physics goals
-- Water cross-sections at different off-axis angles
➔ access «neutrino energy response function»

-- an important step in the T2K campaign against systematic errors!

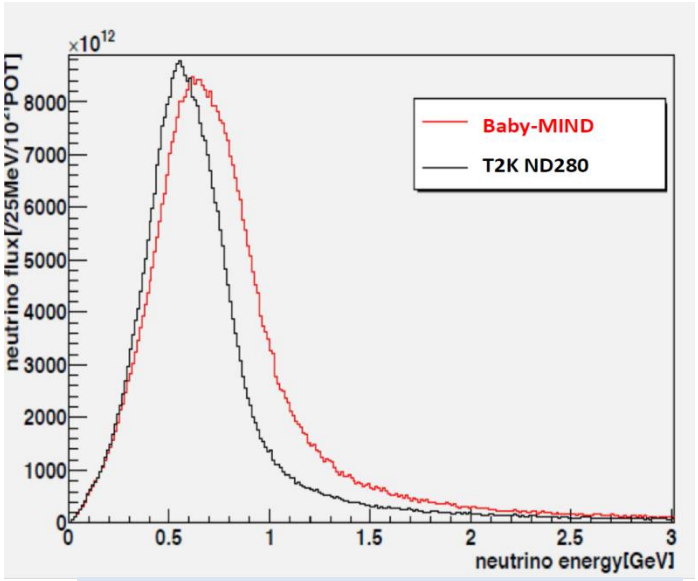
-- joint T2K/Wagasci-baby-MIND analysis
-- integration in T2K collaboration

WAGASCI-Baby-MIND Location

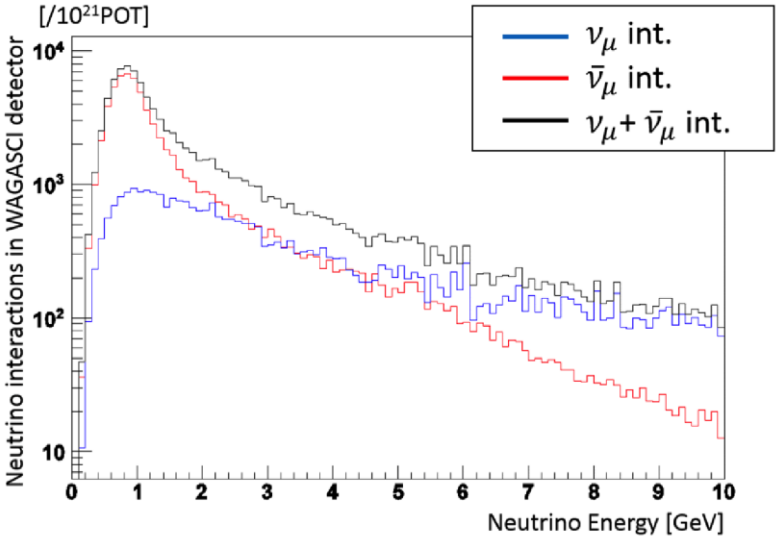


2.5° off-axis

B2 level
in T2K ND280 pit
1.6° off-axis



Good location to study events ~200 MeV above T2K



Magnetic detector essential for antineutrino run

combined T2K ND280 and WAGASCI analysis

➔ allows to isolate neutrino fluxes with sharp edges to study the **energy response function, relationship between true energy and reconstructed energy.**

Neutrinos oscillate according to true energy!

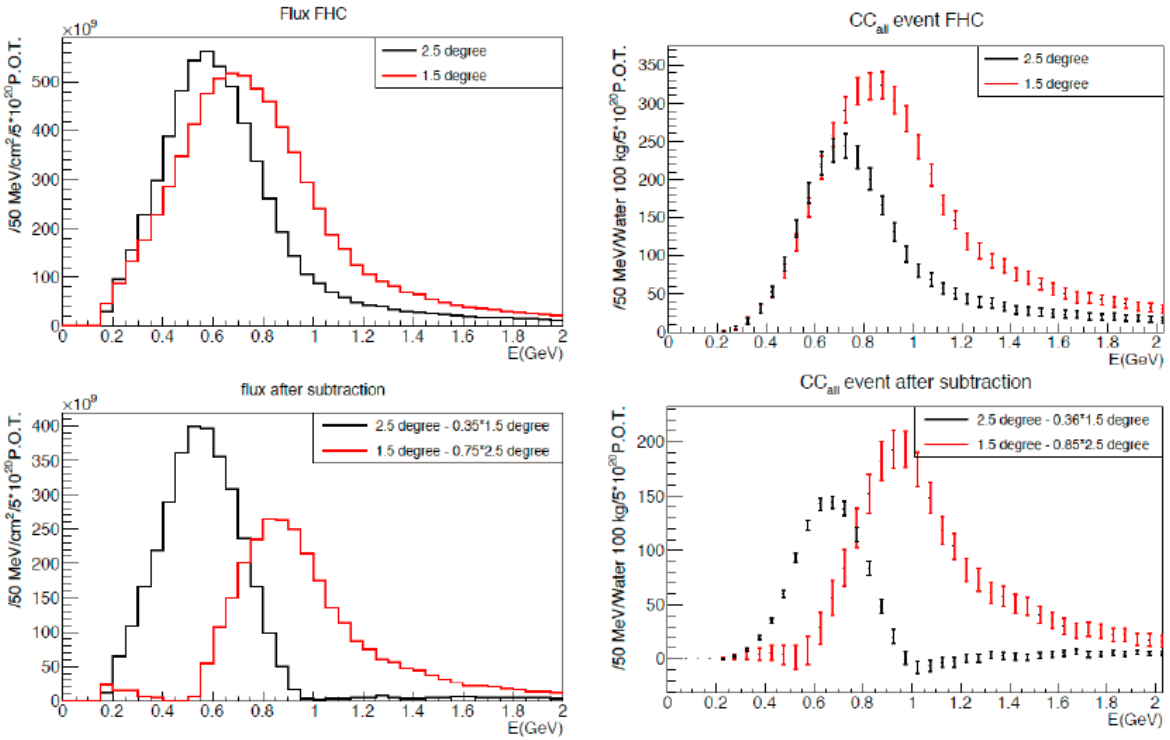
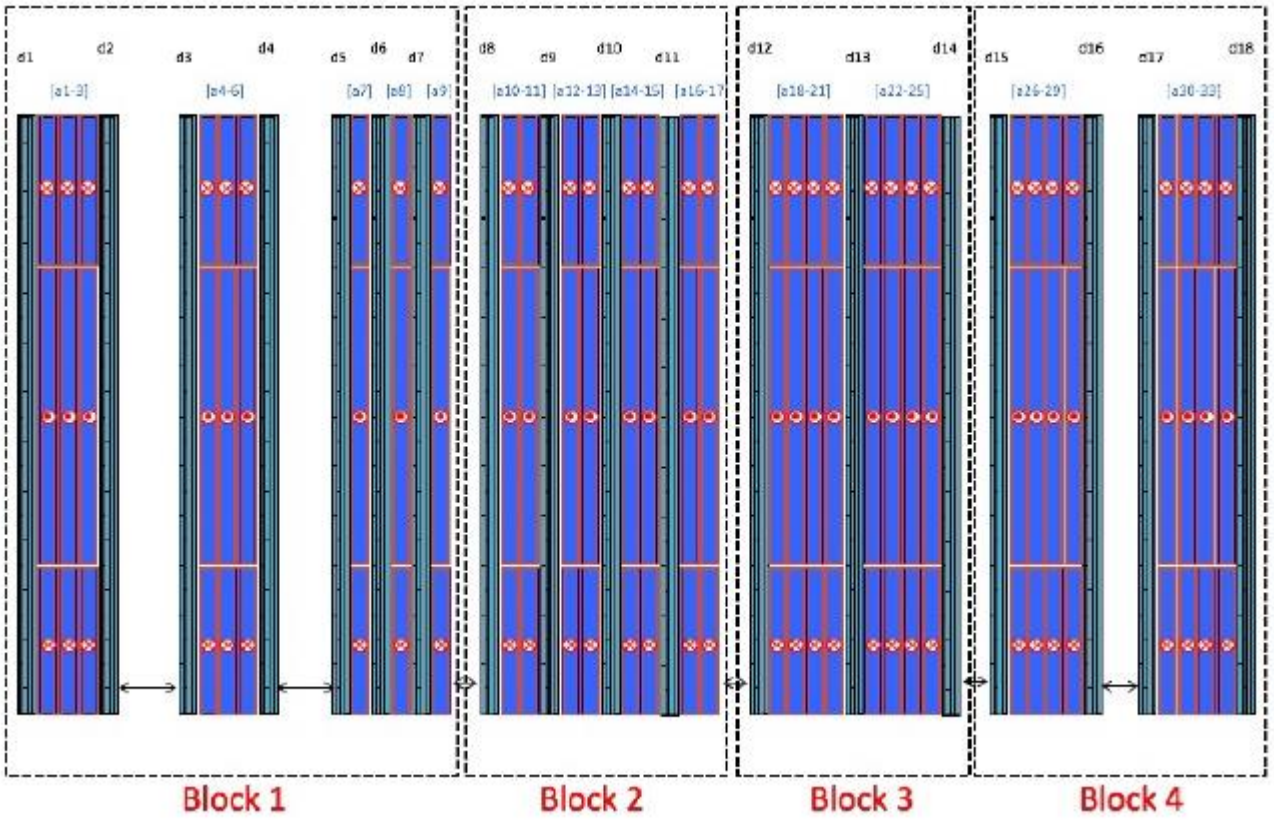


Figure 1: Energy spectra obtained by using different off-axis angle fluxes. The top two plots show the energy distribution of the fluxes (left) and interactions (right) for ND280 (off-axis 2.5 degree) and WAGASCI (off-axis 1.5 degree). The bottom two plots show the fluxes (left) and spectra of interaction events (right) obtained by subtraction of fluxes at ND280 and WAGASCI. The error bars represent the statistical error and those in the bottom right plot assume the statistical error for ND280 measurements are much smaller than those of the WAGASCI experiment.

Baby-MIND LAYOUT



ν

Scintillator planes with 1cm pitch in bending direction 10cm in horizontal direction.
Air gap after 9cm of iron for measurement of bending angle (charge sep. down to ~300 MeV)
total iron thickness 1m.

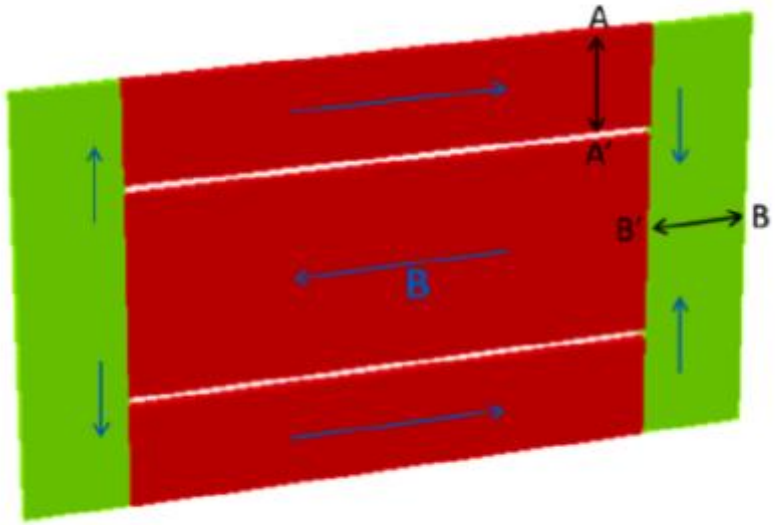
$\Delta\theta_{MS} = (0.015/P)\ \sqrt{L/X_0} = 0.034/P$ for 9cm of iron

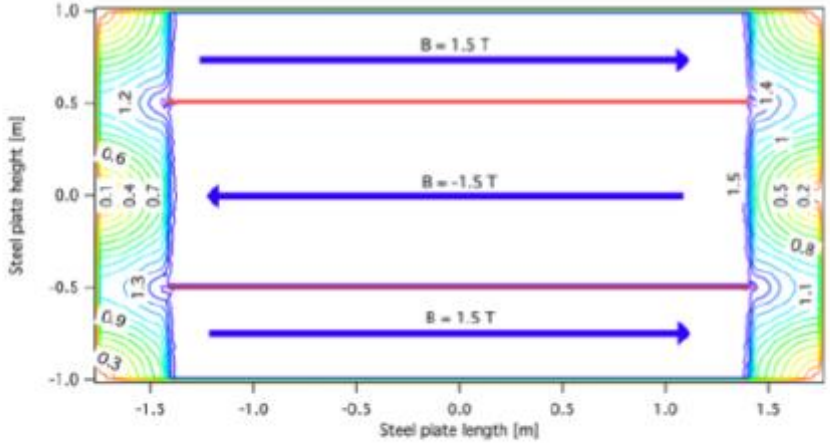
$\theta_B = 0.3\ BL\ /P = 0.040/P$ for 9cm of 1.5T magnetized iron

Layout for illustration, the actual layout inND280 is slightly different

CERN contribution

- Individually magnetised iron (ARMCO) plates
- Two slit design, simple dipoles.
- Well contained and defined field lines.
- Very uniform in area of interest.
- Modular and flexible.
- Field $\approx$ 1.5 T for coil current $\approx$ 140 A
- Stray fields insignificant $<$ 15 mT.
- Power required for all 33 modules: 12 kW.
- ... and much more (logistics, handling, assembly space through the CERN Neutrino Platform)





low power consumption and modularity well adapted to B2 pit installation.

Baby MIND systems: [S. Parsa *et al.*, arXiv:1704.08917]

Novel magnet design — *x 33 modules*

Custom scintillator modules — *x 18 modules*

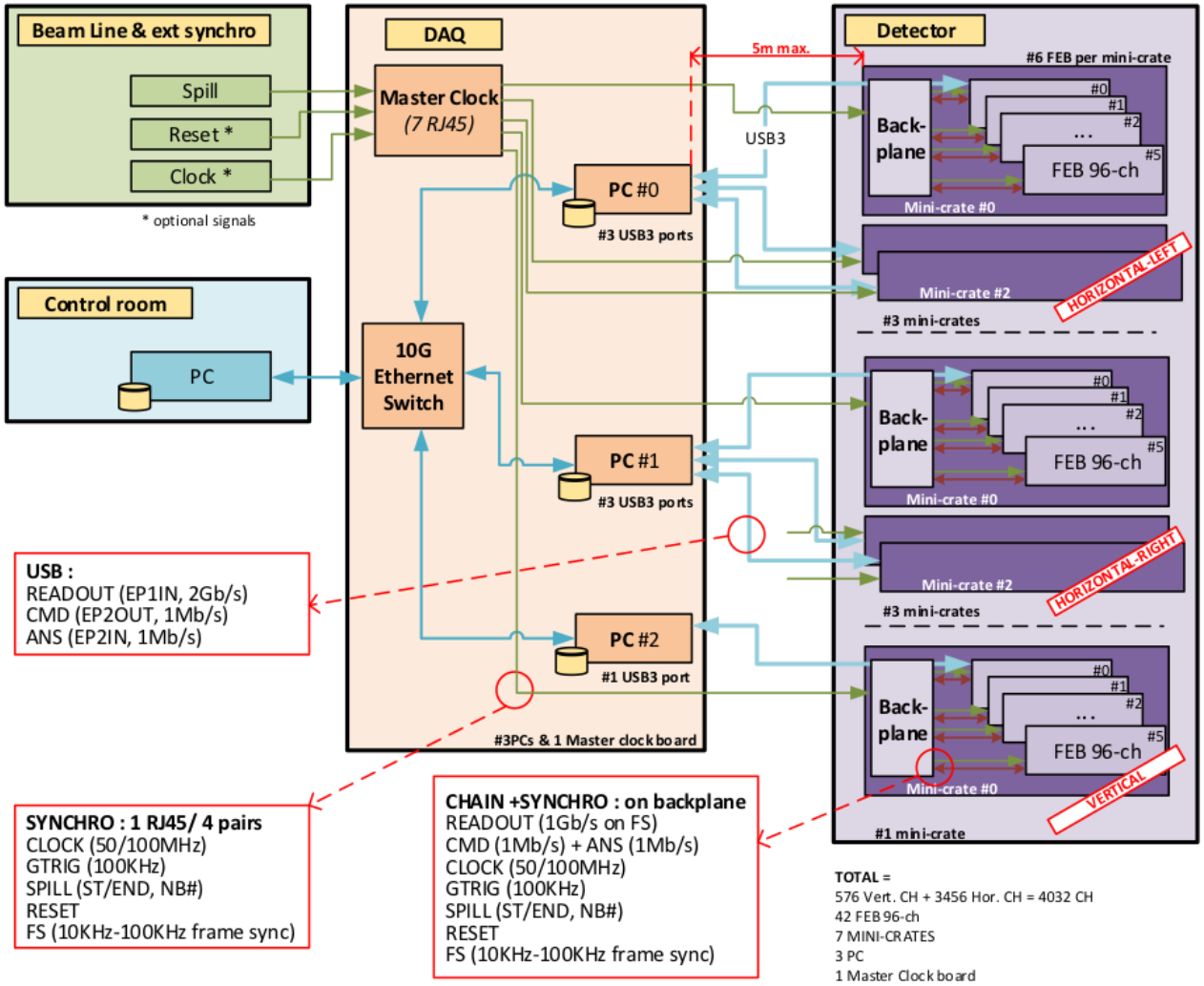
Support mechanics for transport to Japan

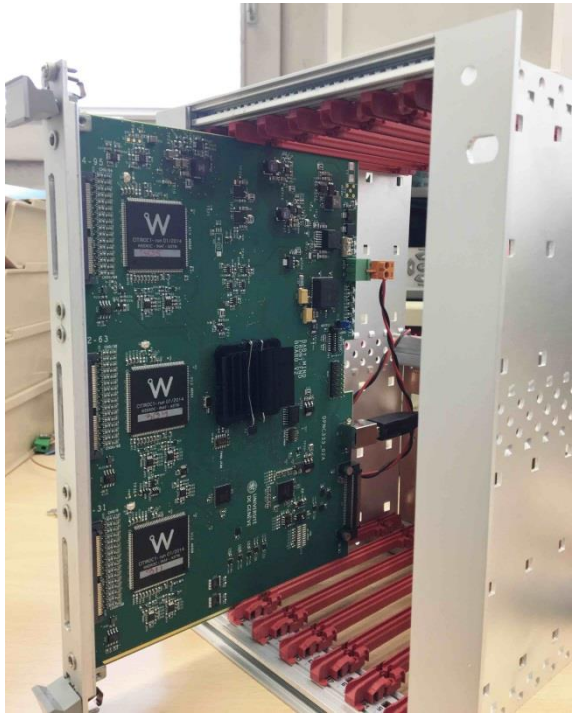
Cable bundles (scintillator-to-electronics)

Custom readout electronics (USB3)

Readout electronics

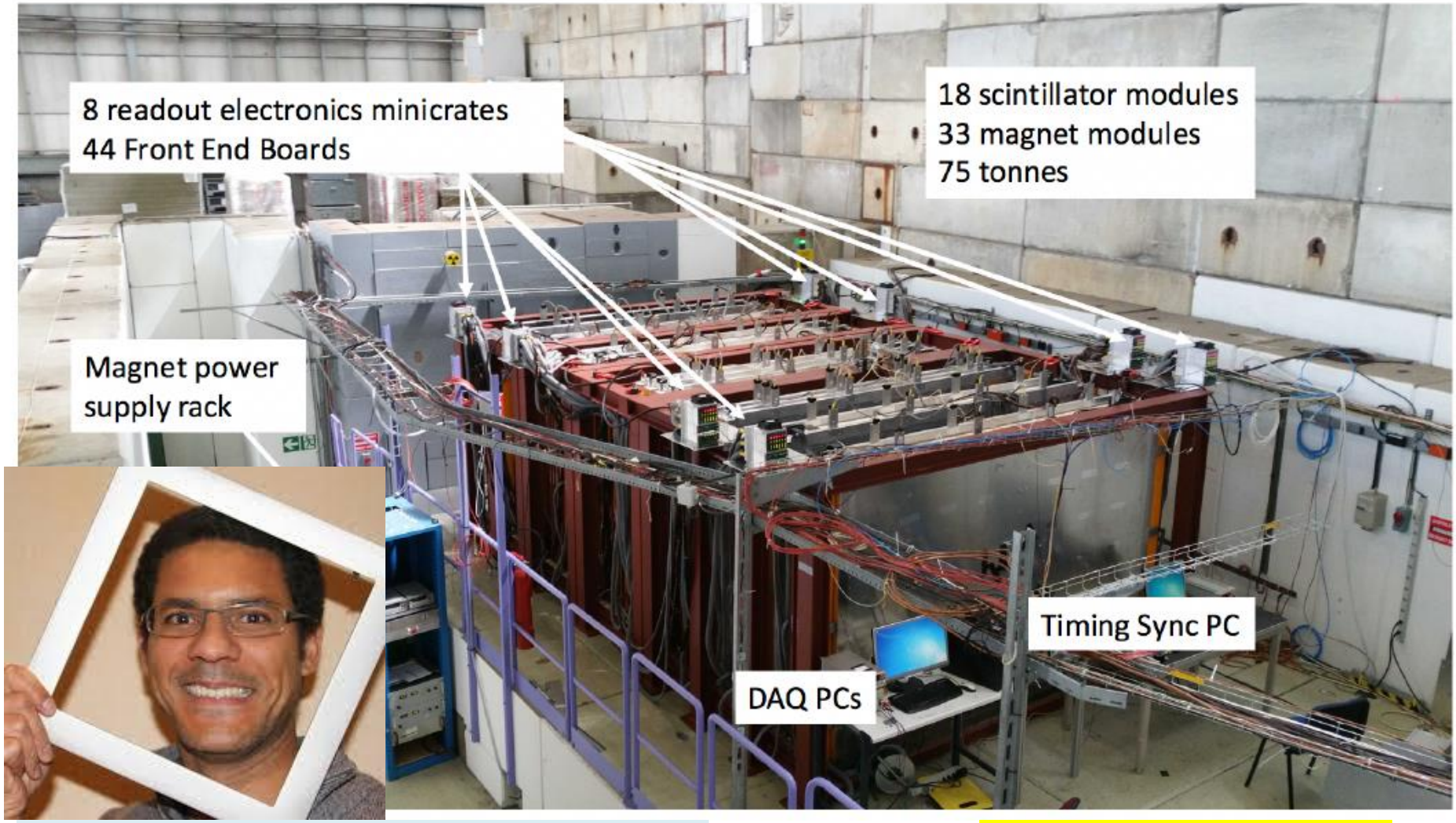
[E. Noah et al., PoS PhotoDet 2015]





Custom readout board designed for Baby MIND (UNIGE)

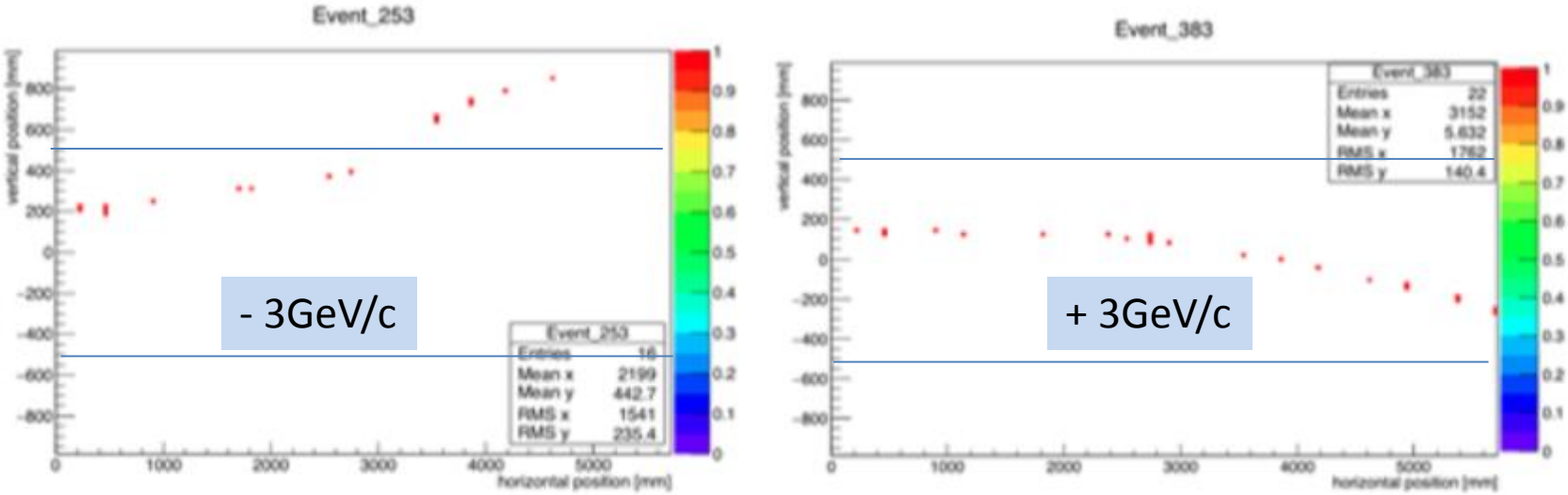
Baby MIND at PS-CERN experimental hall (T9 beam line): July 2017



Etam Noah, NP05 Baby-MIND coordinator

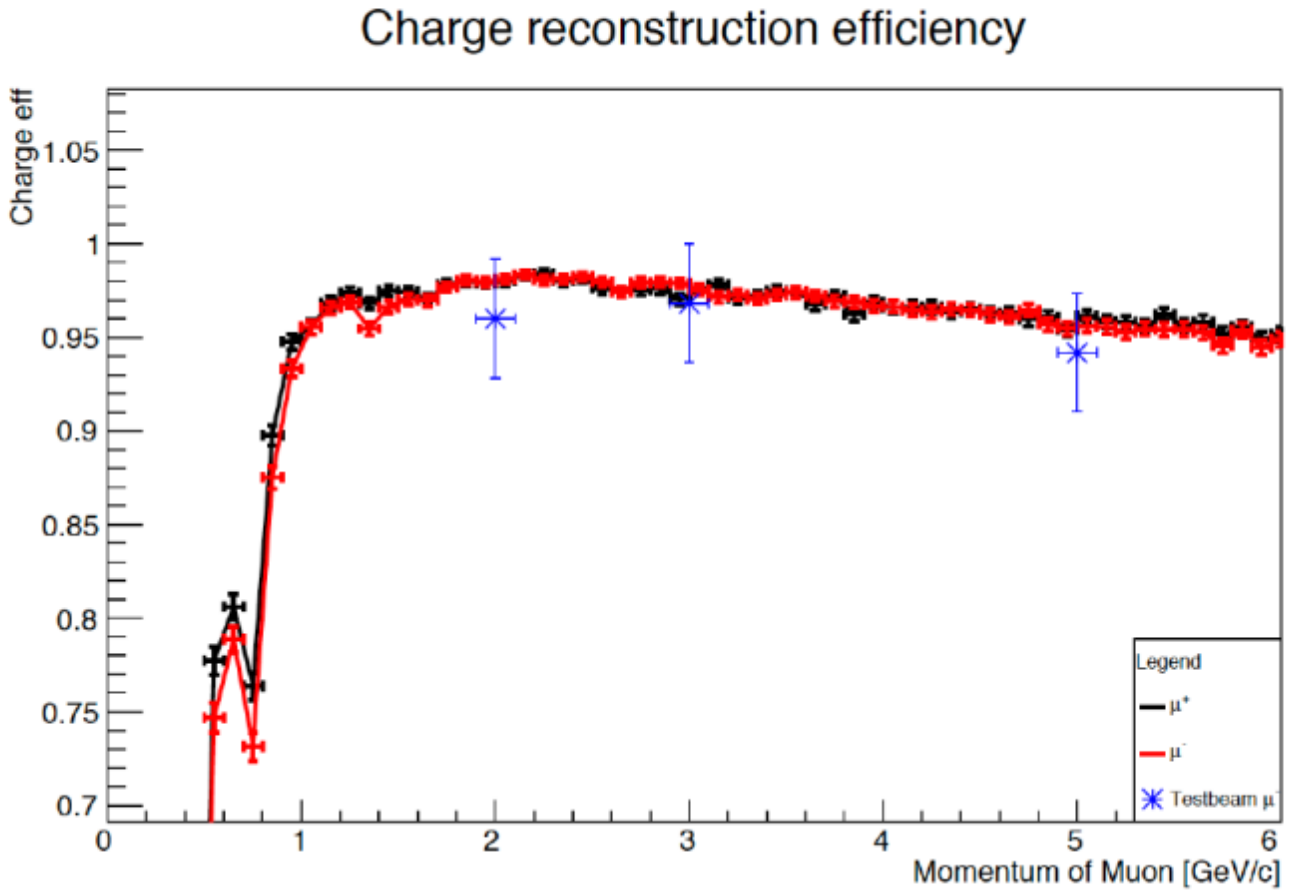
Baby-MIND ready to go!

Muon events

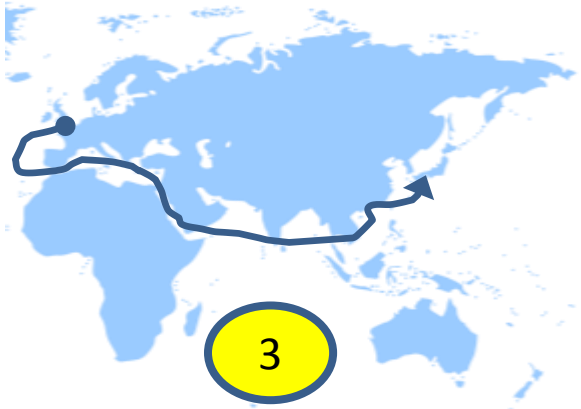


Event displays, side view of the Baby MIND, -3 GeV/c muon on the left and +3 GeV/c muon on the right.

Preliminary: Charge ID efficiencies: [S-P. Hallsjö *et al.*, Proc. NuFACT 2017]



Also time resolution is ~1ns (Mefodev)



CERN NEUTRINO PLATFORM

Neutrino detectors on the move

On 12 June, a 120 tonne cuboidal particle detector measuring 18 m long was loaded onto a lorry at CERN to begin a six-week journey to Fermilab in the US. Called ICARUS, the detector will form part of Fermilab's short-baseline neutrino programme, which aims to make detailed measurements of neutrino oscillations and search for eV-scale sterile neutrinos (*CERN Courier* June 2017 p25).

ICARUS, which is based on advanced liquid-argon time projection technology, began its life under a mountain at the Gran Sasso National Laboratory in Italy in 2010, recording data from neutrino beams sent from CERN. Since 2014, it has been at CERN undergoing an upgrade and refurbishment at the CERN Neutrino Platform (*CERN Courier* July/August 2016 p21). It left CERN by road and boarded a boat on the Rhine to a port in Antwerp, Belgium, where it was loaded in two identical pieces onto a ship. As the *Courier* went to press, ICARUS was already heading across the Atlantic to Indiana, equipped with a GPS unit that allows its progress to be tracked in real time.

N Gonzalez and J Ordan, Julien Marius

A Blondel

ICARUS (above) on its departure day, and a section of BabyMIND (left) being moved to the test-beam area.

Just two days after ICARUS left CERN, another key component of the CERN Neutrino Platform was on the move, albeit on a smaller lorry. BabyMIND, a 75 tonne prototype for a magnetised iron neutrino detector that will precisely identify and track muons, was moved from its construction site in building 157 to the east experimental hall of the Proton Synchrotron. Following testing and characterisation in a high-energy beam, at the end of July BabyMIND will be transported to Japan to be part of the WAGASCI experiment, where it will contribute to a better understanding of the T2K neutrino-oscillation experiment.


lowering of iron plate in the ND280 pit


arriving in the B2 floor with its scintillator module
→tight!←

total of 75 tons were pushed by hand…

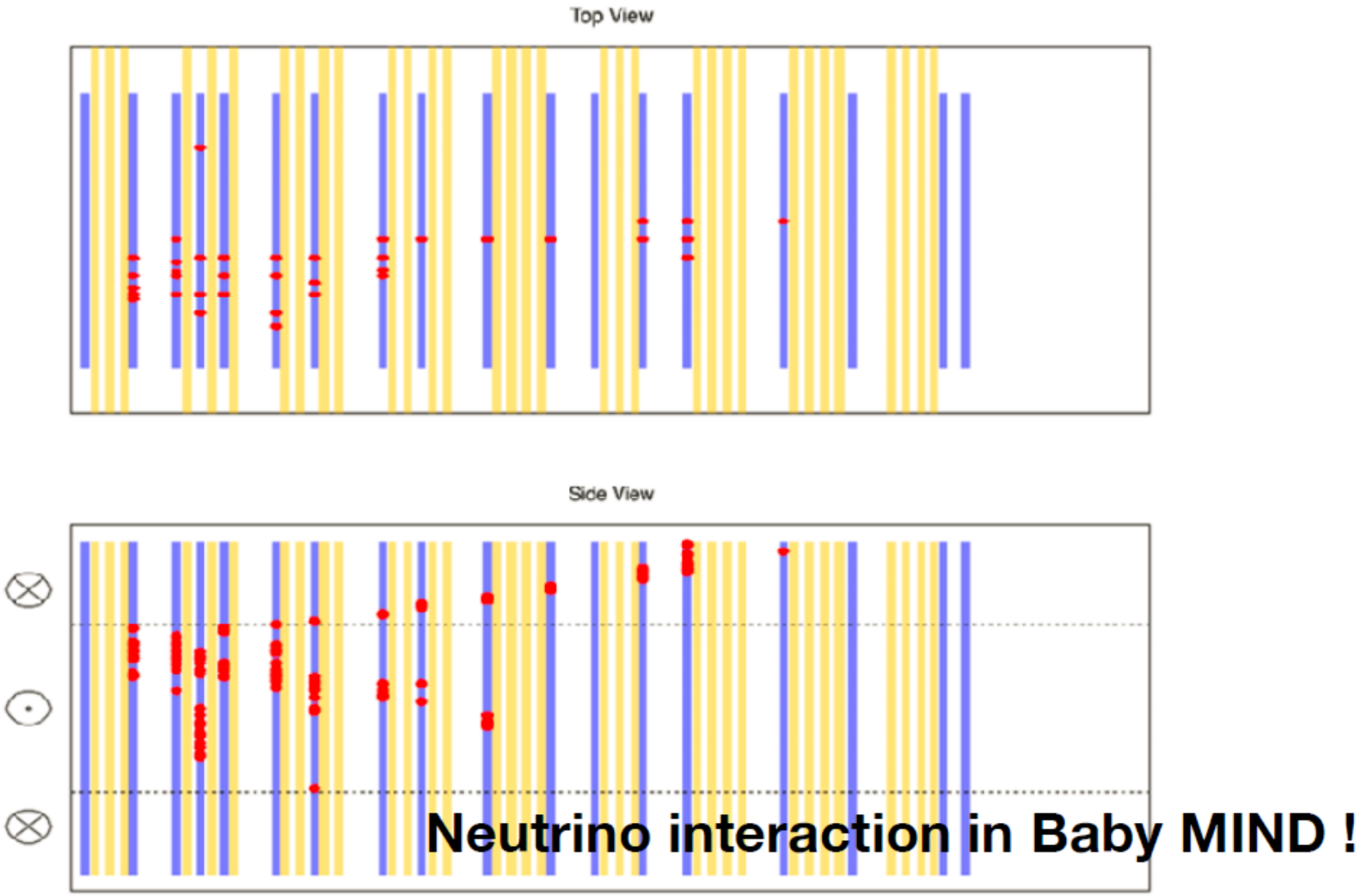
Baby-MIND is in place!

Overview of Electronics Installation (2/26 - 3/2)

Sasha, Saba, Andrey, Kenji

Detector Performance 3

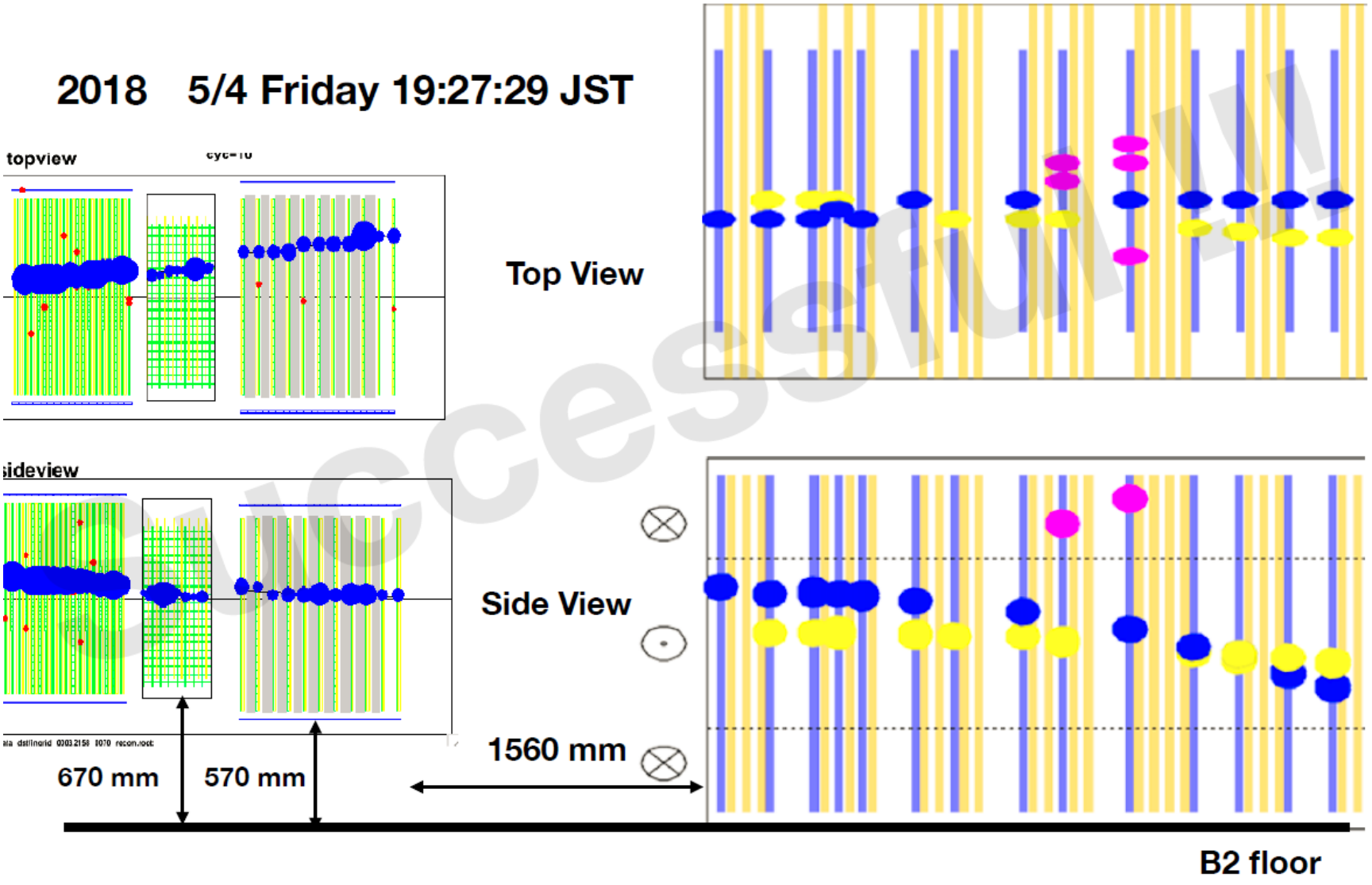
Event Display



Neutrino interaction in Baby MIND !

Matching with Wagasci

Detector performance and Analysis



NB Color of hits indicates timing; all blue points are on time.

Conclusion and next steps

The baby-MIND detector is a modern version of the well known magnetized iron detector
-- use of air gaps allows to lower the treshold of charge identification for sub-GeV muons
-- this development found a natural use in the T2K experiment as muon spectrometer for the WAGASCI water(80%)-scintillator detector.

The project would have never been concluded without inclusion in the neutrino platform, then without the JPARC neutrino group!

Now the WAGASCI-Baby-MIND (approved as JPARC E69) is included in the T2K collaboration

Data taking will resume in Q1 2019 in final configuration for ~3 years…

→ physics and cross-sections to be included in the T2K oscillation analysis!