Tests of TASD and MIND prototypes at CERN

Proposal for characterization of muon spectrometers for neutrino beam lines with the Baby MIND*

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], Y. Favre[b], S. Fedotov[a], S-P. Hallsjo[c], A. Izmaylov[a], A. Kleymenova[a], Y. Karadzhov[b], M. Khabibullin[a], A. Khotyantsev[a], T. Koga[h], Y. Kudenko[a], V. Likhacheva[a], B. Martinez[b], R. Matev[e], A. Mefodiev[a], A. Minamino[i], 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[b], G. Rolando[d], A. Shaykhiev[a], P. Soler[c], S. Suvorov[a], R. Tsenov[e], H. Ten Kate[d], G. Vankova-Kirilova[e] 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]Kyoto University, Kyoto, Japan

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

Motivation

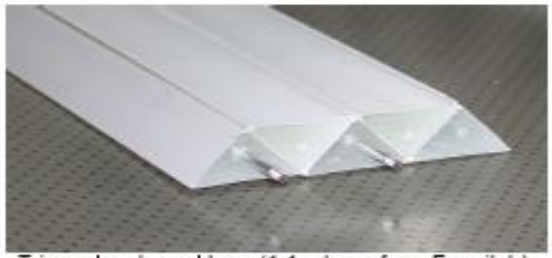
AIDA integrated infrastructure program for neutrinos: beyond the state of the art 'study of lepton identification and **charge discrimination**' in view of neutrino factory with a a ~1m deep Totally Active Scintillator Detector (TASD).
and a 50 ton prototype of a Magnetized Iron Neutrino Detector (Baby-MIND)

The experimental program at CERN main aims are:
1. test of electron/positron charge separation vs momentum in TASD immersed in magnetic field.
➔ a 0.9x0.9x0.9/ρ m^3 prototype with variable density ρ has been built to be inserted in the Morpurgo Magnet in the H8 beam line.

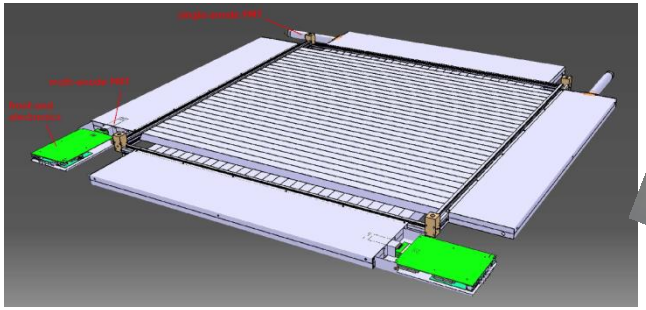
2. test of muon charge separation as function of momentum down to 10^{-4} separation above 1 GeV/c in a suitable test beam.
➔ a 2x3x1 m^3 Baby-MIND is under construction with 3cm iron plates magnetized at 1.5 T.

Following this, further opportunities will be offered to use the Baby-MIND
-- in the T2K beam line, the WAGASCI project has expressed strong interest to use baby-MIND for precision measurement of water to scintillator ratio of anti-neutrino cross-sections. We are planning to do this, which gives unique opportunity within a real neutrino beam.

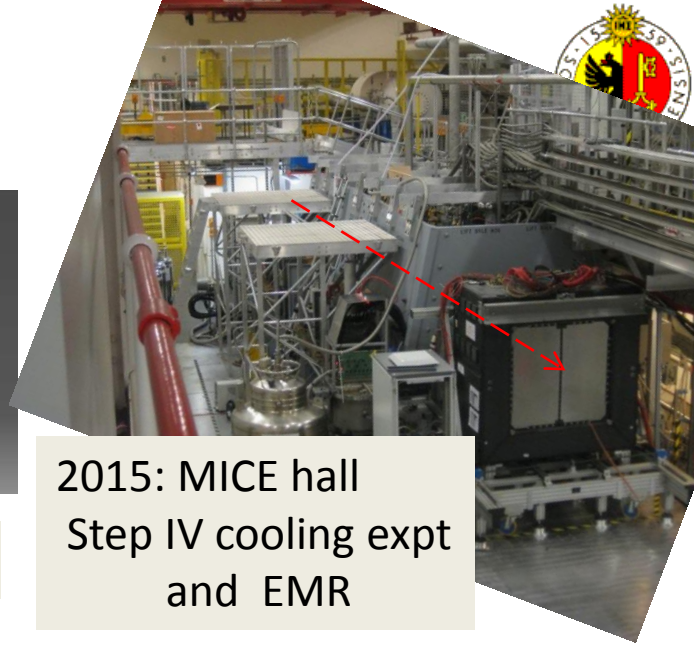
PREAMBLE: EMR detector for MICE at RAL 100-400 MeV/c


Triangular shaped bars (1.1m long, from Fermilab)

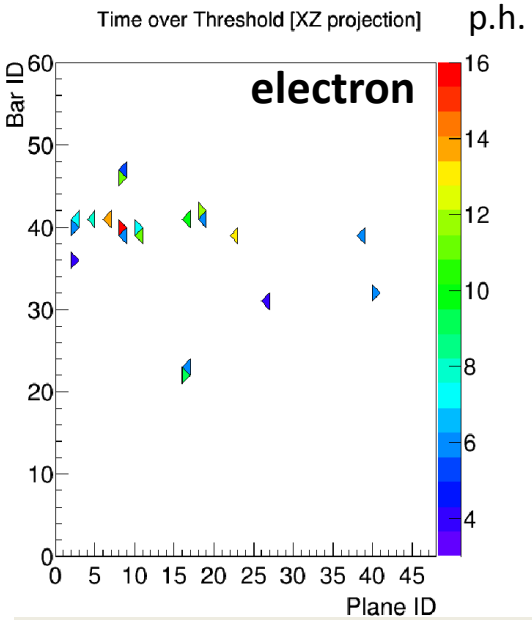
Same batch as MINERvA at Fermilab -- 98% active

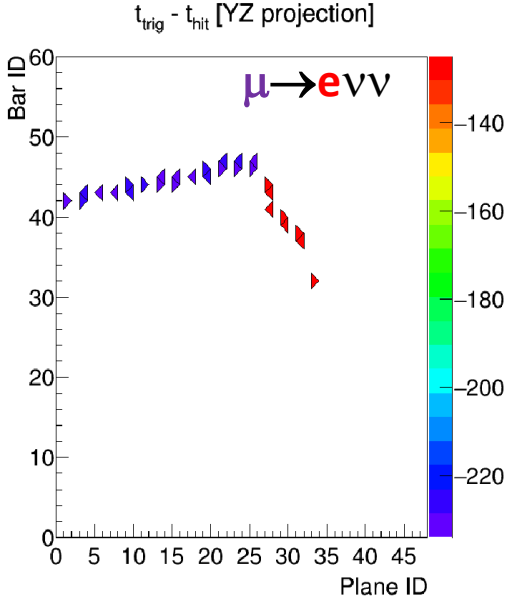


24 x-y modules (48 planes)

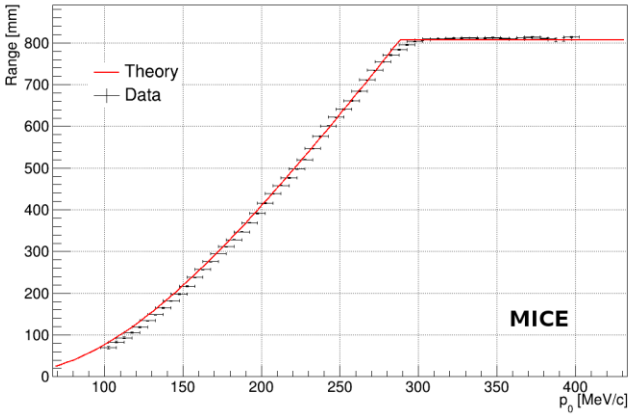


2015: MICE hall
Step IV cooling expt and EMR





range vs momentum meast.



➔Δp/p ~3% at 200 MeV/c from range measurement

at 200 MeV/c : 99% muon eff. with 2% e-> mu prob.

MICE note 466, to appear in JINST

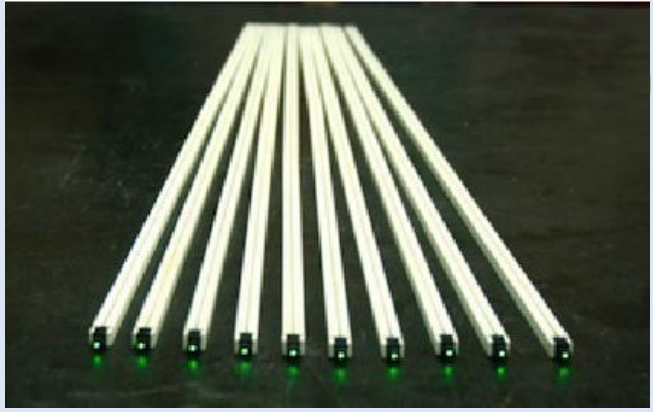
TASD detector

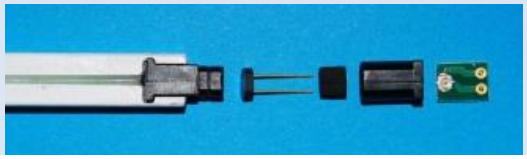
9000 bars of 0.7 x 1.0 x 900 mm^3 manufactured & tested at INR with WLS (Kurarai Y11) fiber and custom designed connectors to MPPCs

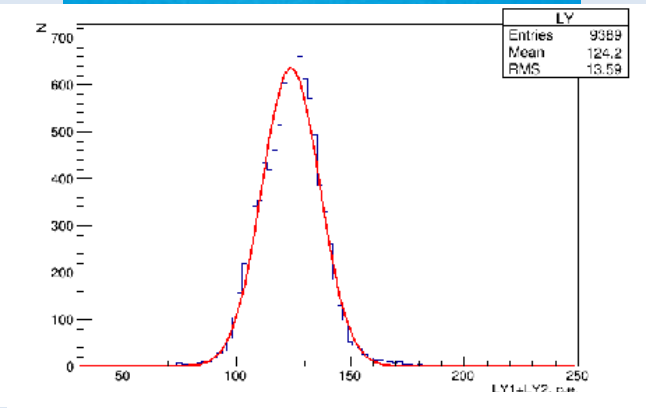
Assembled in 50 alternating x and y planes
readout by 3000 Hammamatsu S12571-025C MPPC
Will read out part of the detector (on beam path)

Mechanical assembly allows for extensible design with air gaps between planes
-- a cheap way to increase radiation length!

These modules will also serve for 1st test of Baby-MIND

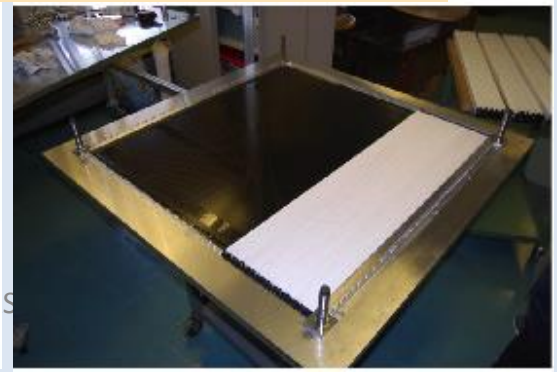


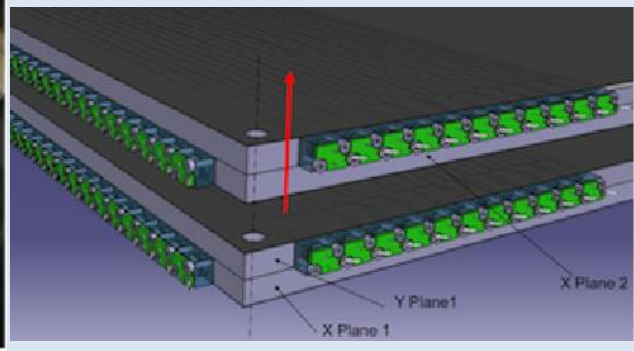




Light yield at INR (70 p.e. /mip)

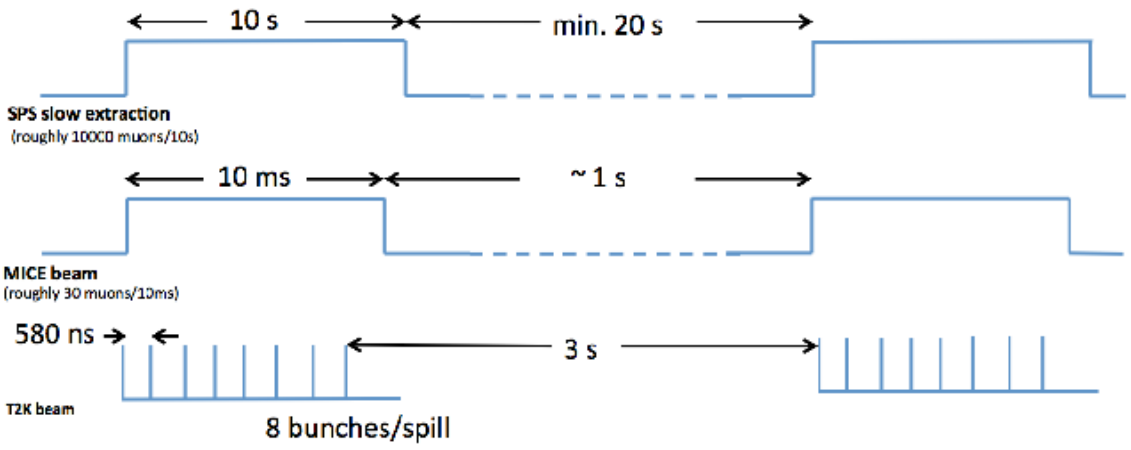
construction ~ complete
← 50 modules in bdg 595



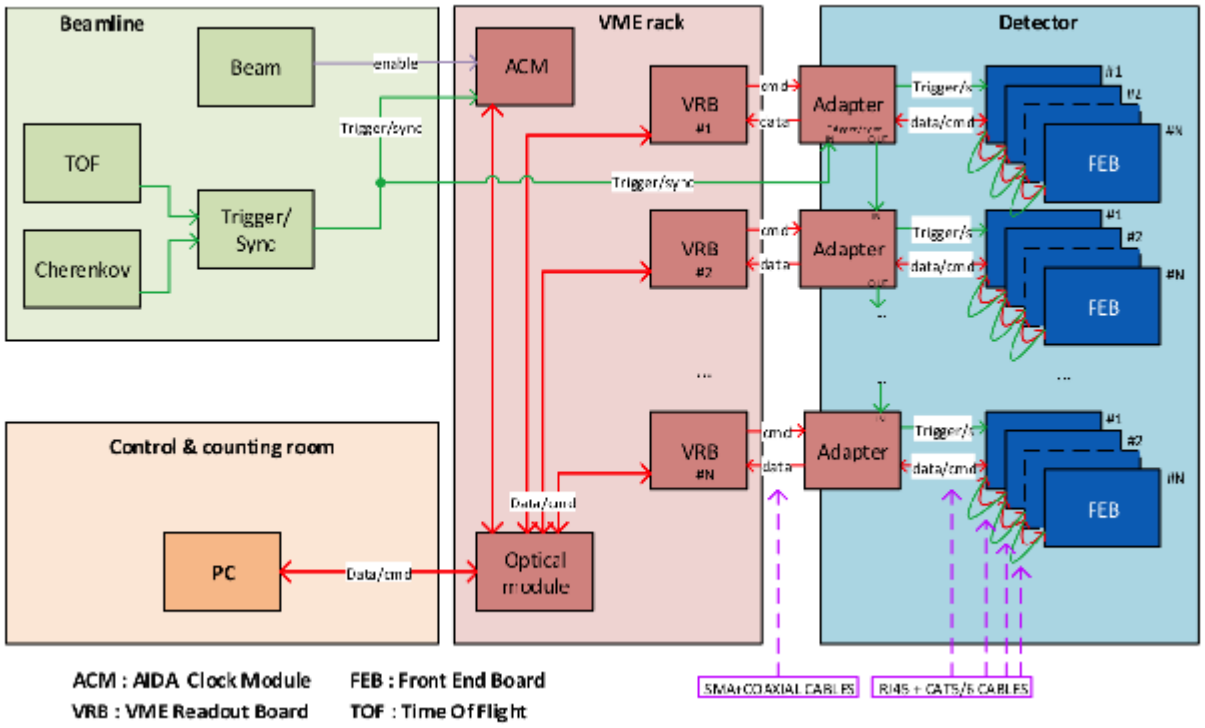


Electronics

The electronics is designed to adapt to the time structures of
-- SPS test beam (typically 10 second slow spill every 0.5 to 1 minute)
-- MICE beam (2 ms every 1 to 2.6 second)
-- T2K fast extraction with 8 bunches separated by 580 ns every 2.6 to 1 seconds.



In test beam mode, can record up to 10^4 events per spill -- or ~10^7 on a good day.
In MICE or T2K mode, can record all data without dead time.



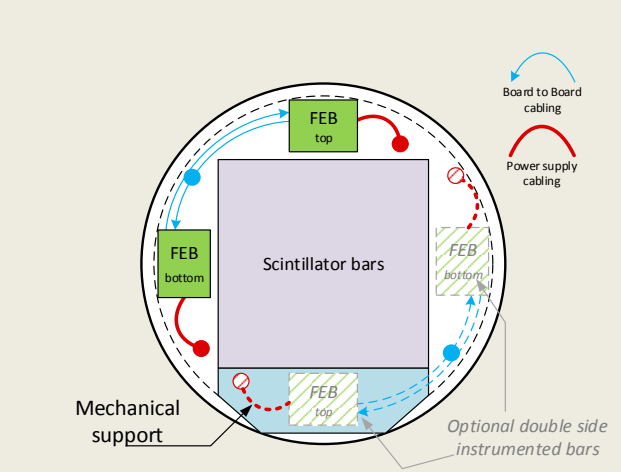
MPPCs

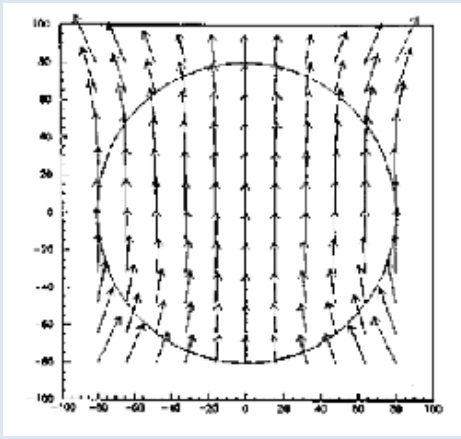
Front-end board

e and tests at
2015

These electronics are proposed as common tool for neutrino platform experiments (ref. Y. Favre, Neutrino platform, 3-09-2015)

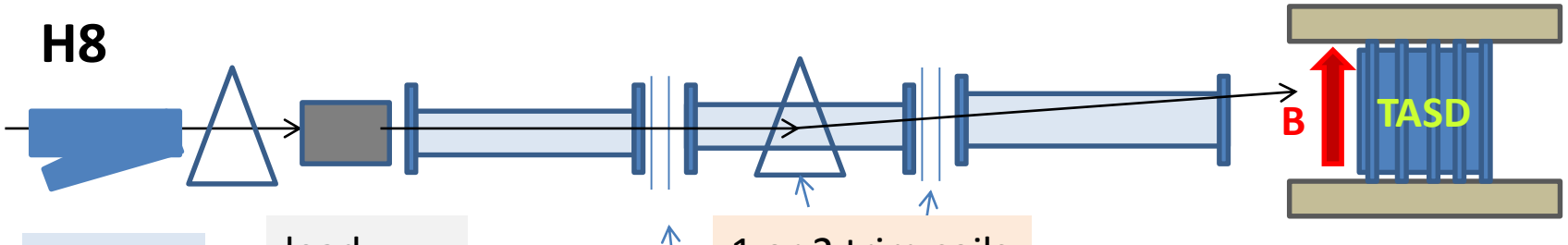
TASD tests





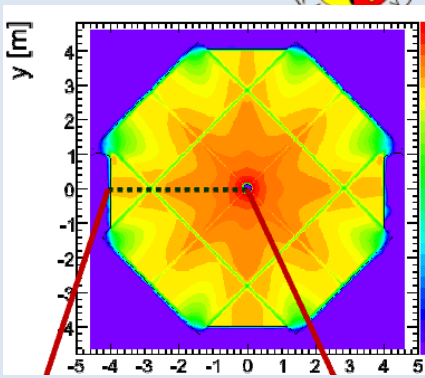
Field map
0.7 T OK.

Will expose TASD to electron or muon beam of 0.5 to 10 GeV
For momenta lower than ~4 GeV this requires a degrader.



+ beam halo veto and trigger, not indicated

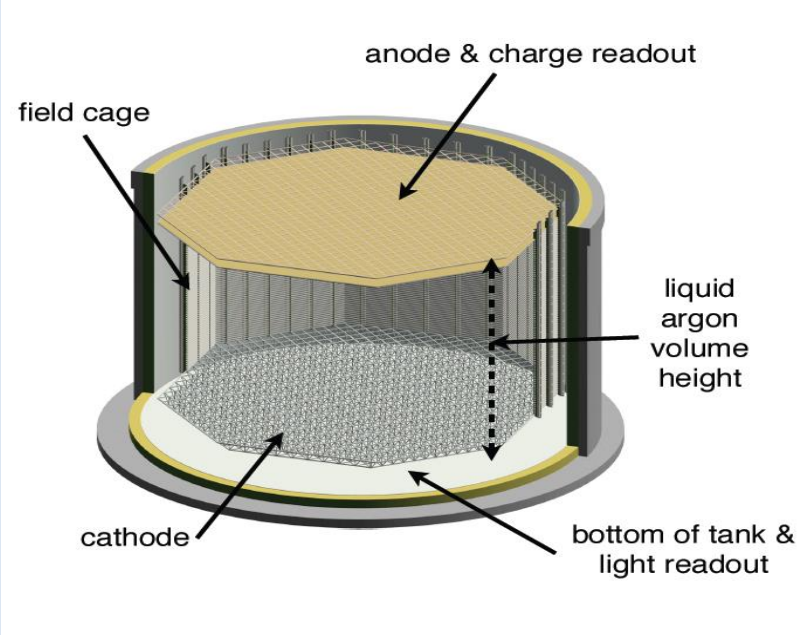
Baby-MIND

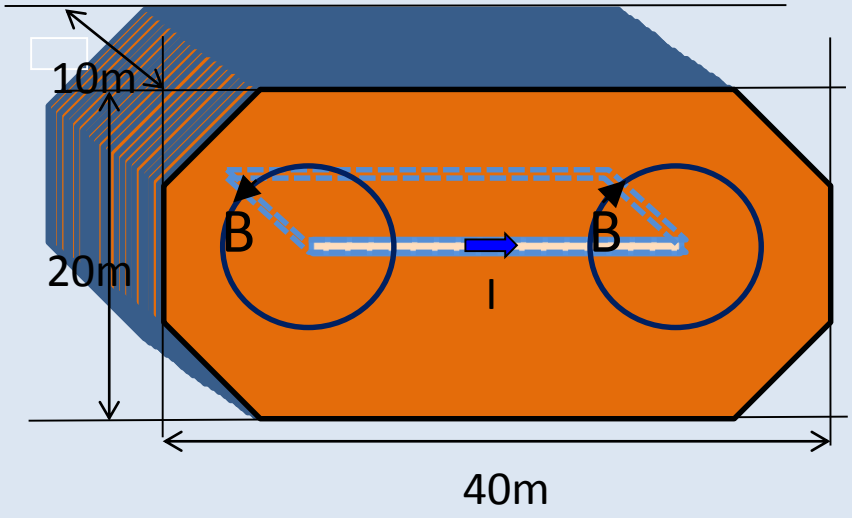


charge separation for MINOS was not measured to better than ~1%
due to anti-neutrino contamination and uncertainties in magnetic field close to the central coil.

➔ requirement for test beam and a more homogeneous magnetic field

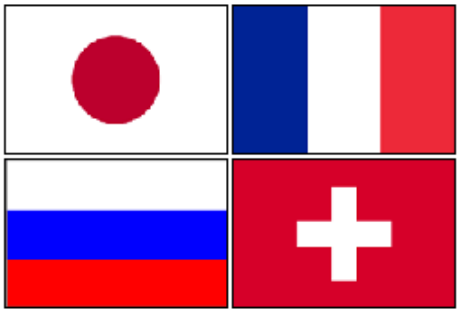
Pure toroidal geometry is inadequate for e.g. muon filter behind LBNO Liquid Argon detector





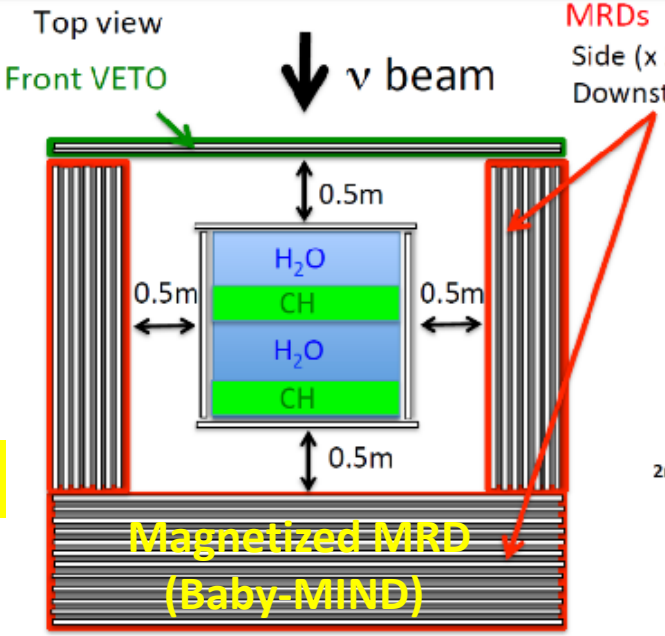
We settled on the requirements related to the WAGASCI experiment.

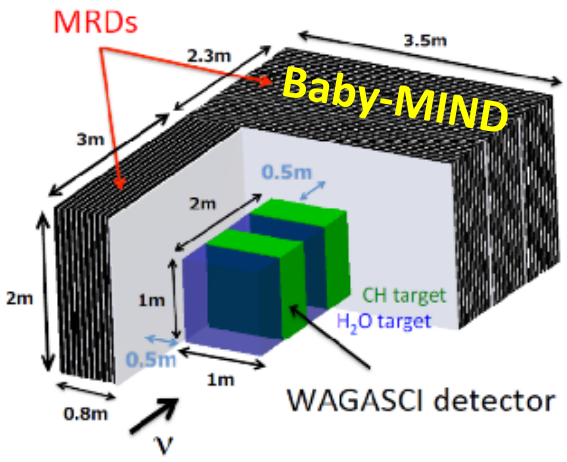
WAGASCI experiment



+ more

>2 ton target

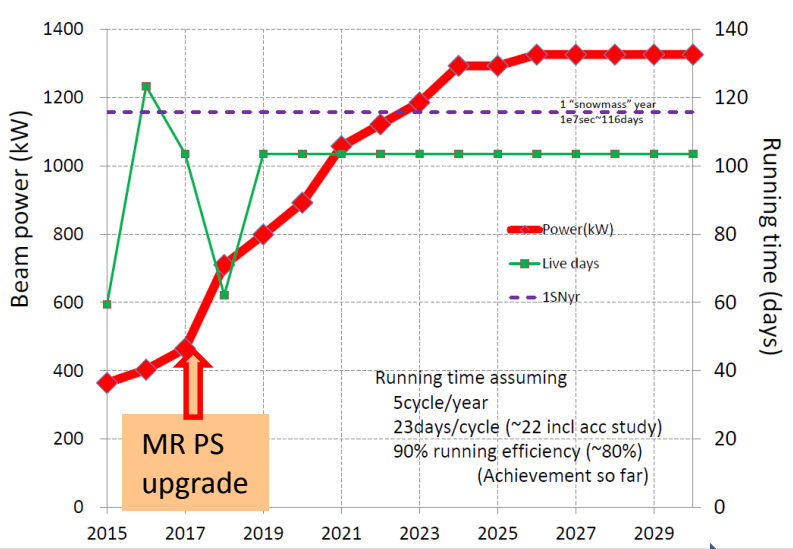




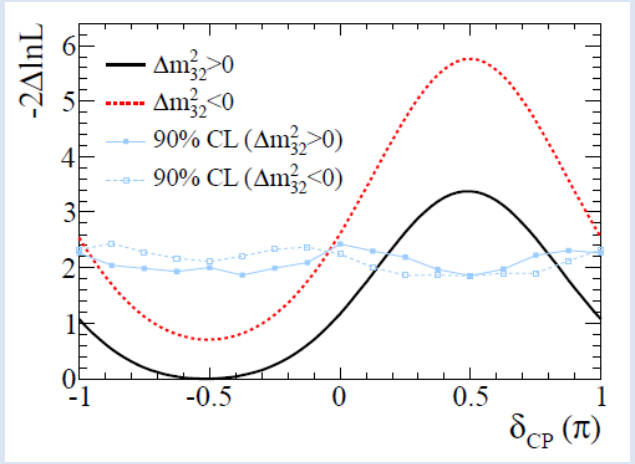
- Goal
  1. Measure the cross section ratio of charged current neutrino interaction on nucleus between H_2O/CH with 3% accuracy.
  2. Measure the differential cross section(T_μ, θ_μ) with large phase space acceptance.
- Location
  - J-Parc neutrino near detector hall. (at B2 floor)
  - Use the **similar off-axis angle to T2K ND280 and SK**. ($\sim 1.6^\circ$)
- Design
  - Little difference in flux and detection efficiency between H2O/CH targets.
    ⇒ Taking cross section ratio **cancels systematic error in beam flux**.
  - Background is rejected by time information and veto planes.

Workshop for Neutrino Programs with facilities in Japan (4-8 Aug-2015)

https://kds.kek.jp/indico/event/19079/



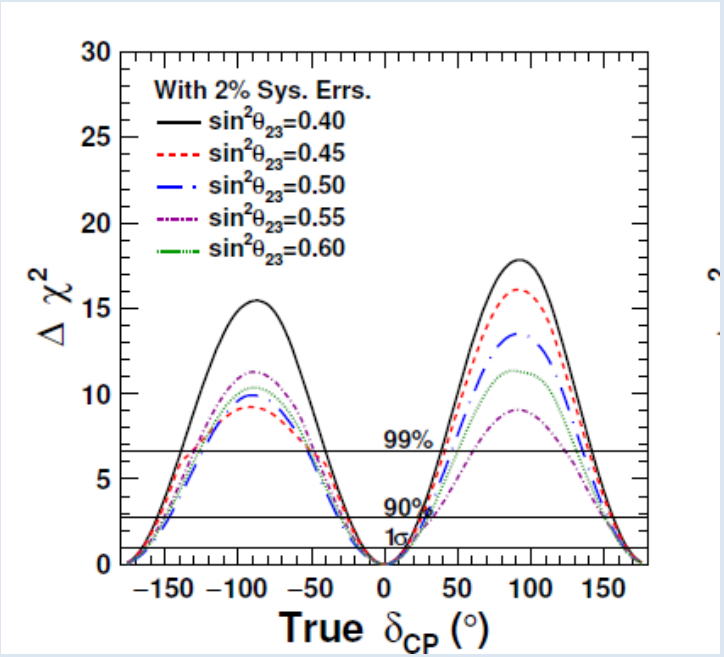
T2K → **T2HK (proposed)**

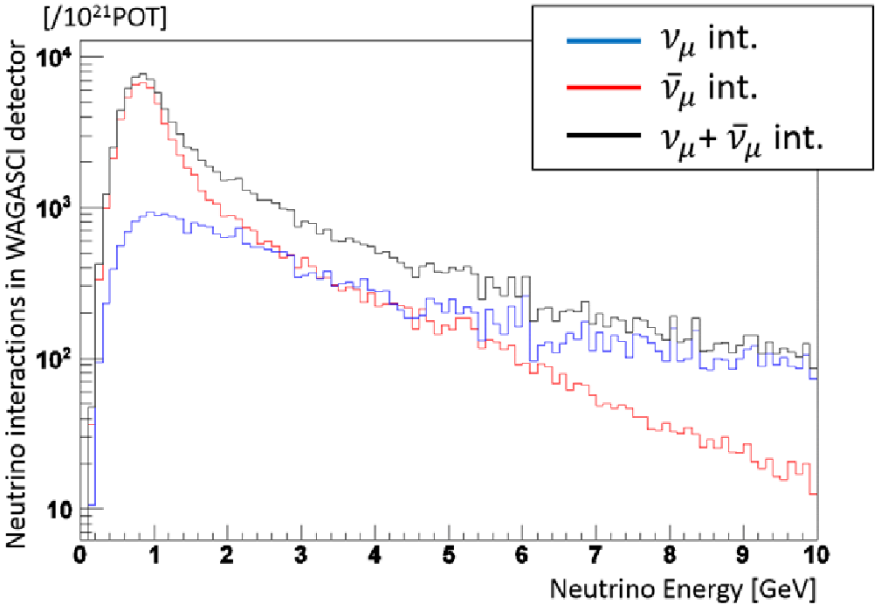


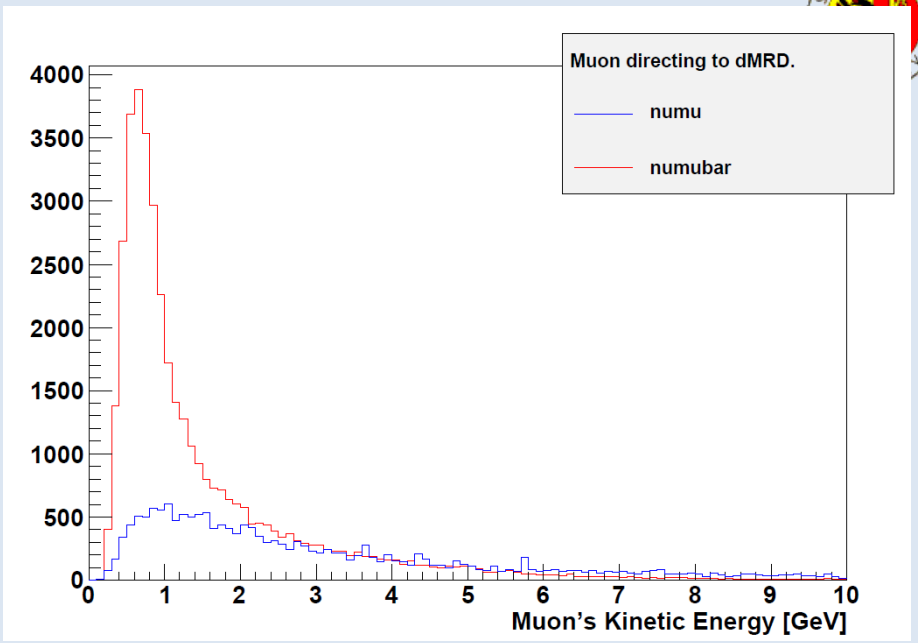
T2K, PRL 112 (2014) 061802

T2K is proposing to run until 2025 with beam power progressively increasing up to 1.3 MW

➔ 3-4 s.d. evidence for CP violation is possible if the presently preferred point is correct.
This requires systematic errors at 3% level.



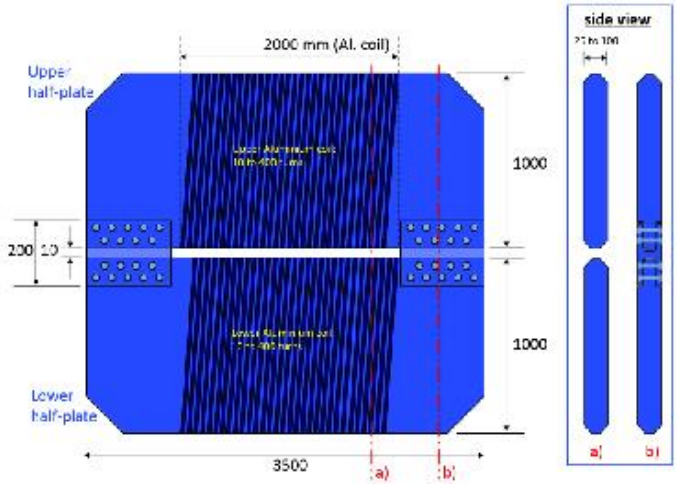


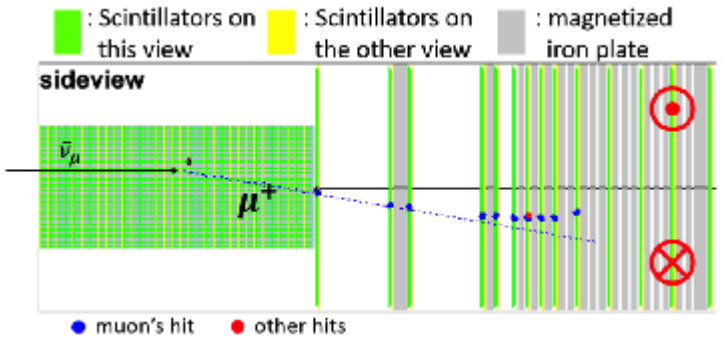


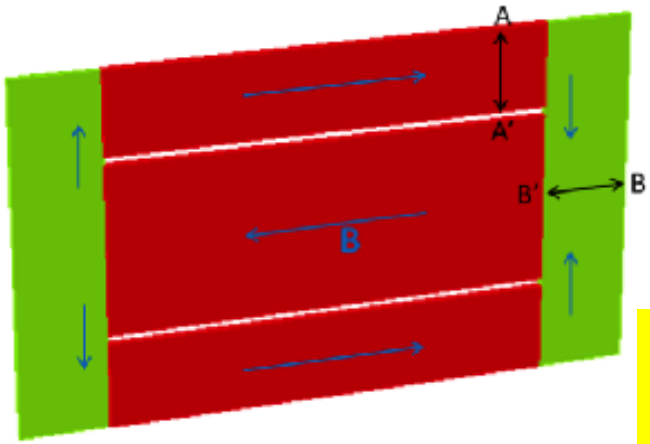
Since the main emphasis of T2K is now to measure the CP asymmetry, it is essential to be able to predict $\nu_\mu \rightarrow \nu_e$ **and** $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ **appearance** events for any set of osc. parameters. One of the dominant systematics : ND280 is mainly C_nH_{2n} while far detector (SK) is Water.

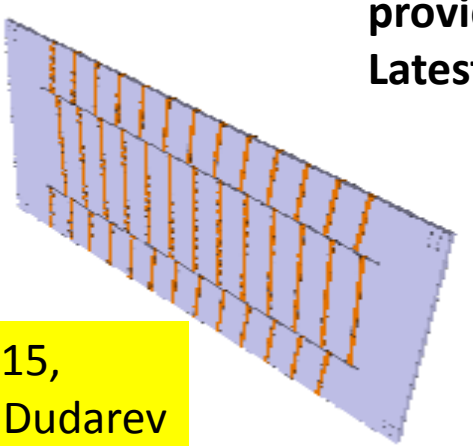
The large fraction of neutrino events (integrated 30%) in the antineutrino running requires charge separation of -- mostly high energy & forward -- muons.

The magnetic design has been elaborated in collaboration with CERN (A. Dudarev);
Requirements in magnetic field (1.5 T), space and power consumption.









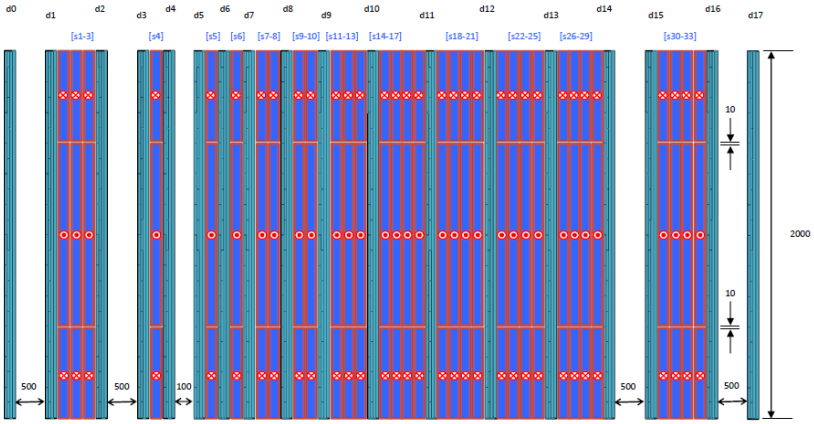
2015,
A. Dudarev

Both layouts are power efficient and provide homogeneous field.
Latest one improves
-- dead space in end plates
-- sign symmetry between μ^+ and μ^-

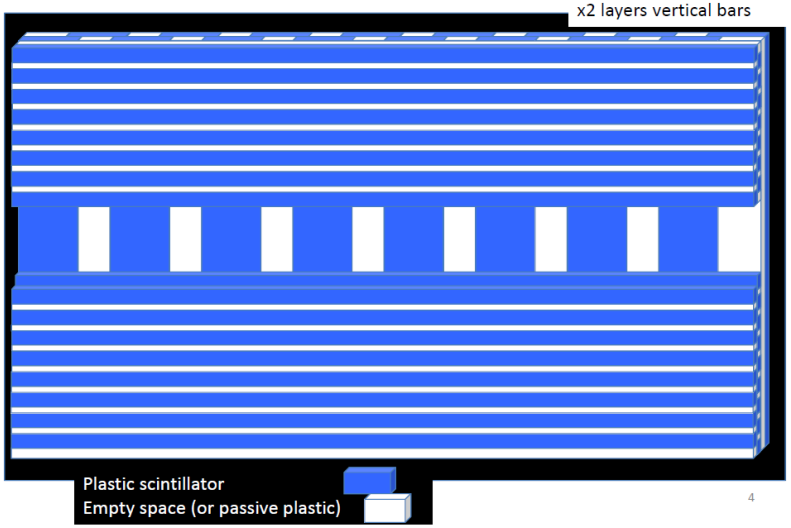
89% sign separation for muons entering front face of Baby-MIND
(will improve further by fiducial cuts

Layout ii): high momentum measurement

d: detector module
s: steel module



WAGASCI dMRD modules



dedicated scintillators will be built

first part:
measure direction before and after 9cm thick plate
(maximizes low momentum resolution)
another direction measurement in the back
ensures good measurement for
high momentum muons.

reduced transverse size allows
installation in ND280 pit.

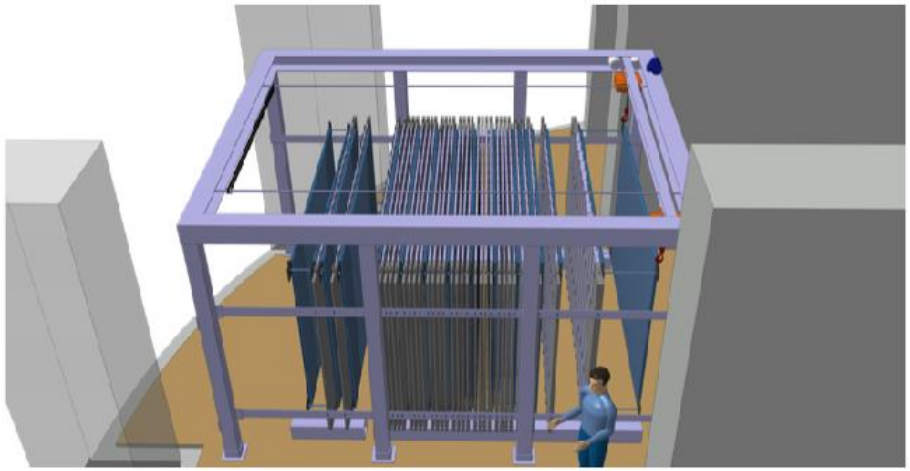
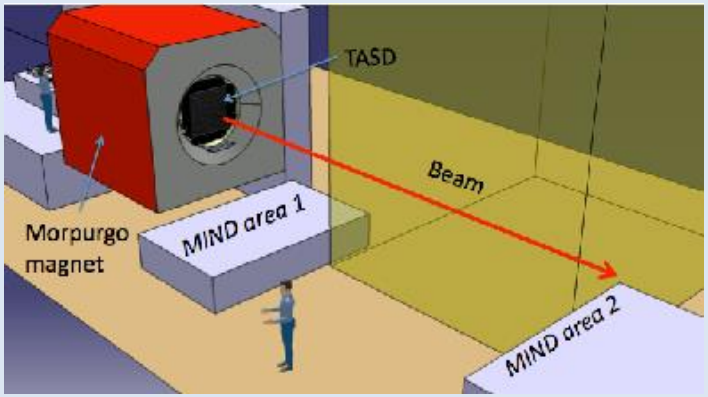


Figure 6: Sketch of the Magnetised Iron Neutrino Detector (Baby MIND) prototype planned for tests at the SPS, and operation at J-PARC in Japan.

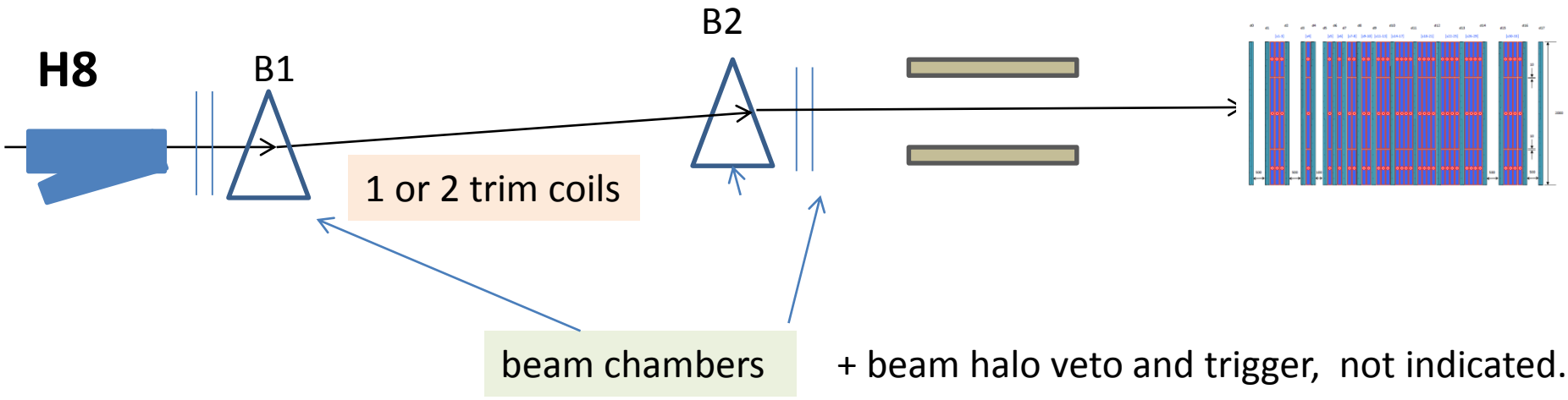
Baby-MIND tests

Phase 1. will use the scintillators MPPCs, cables and electronics from TASD

Phase 2. will use dedicated scintillators+ TASD MPPCs, cables and electronics

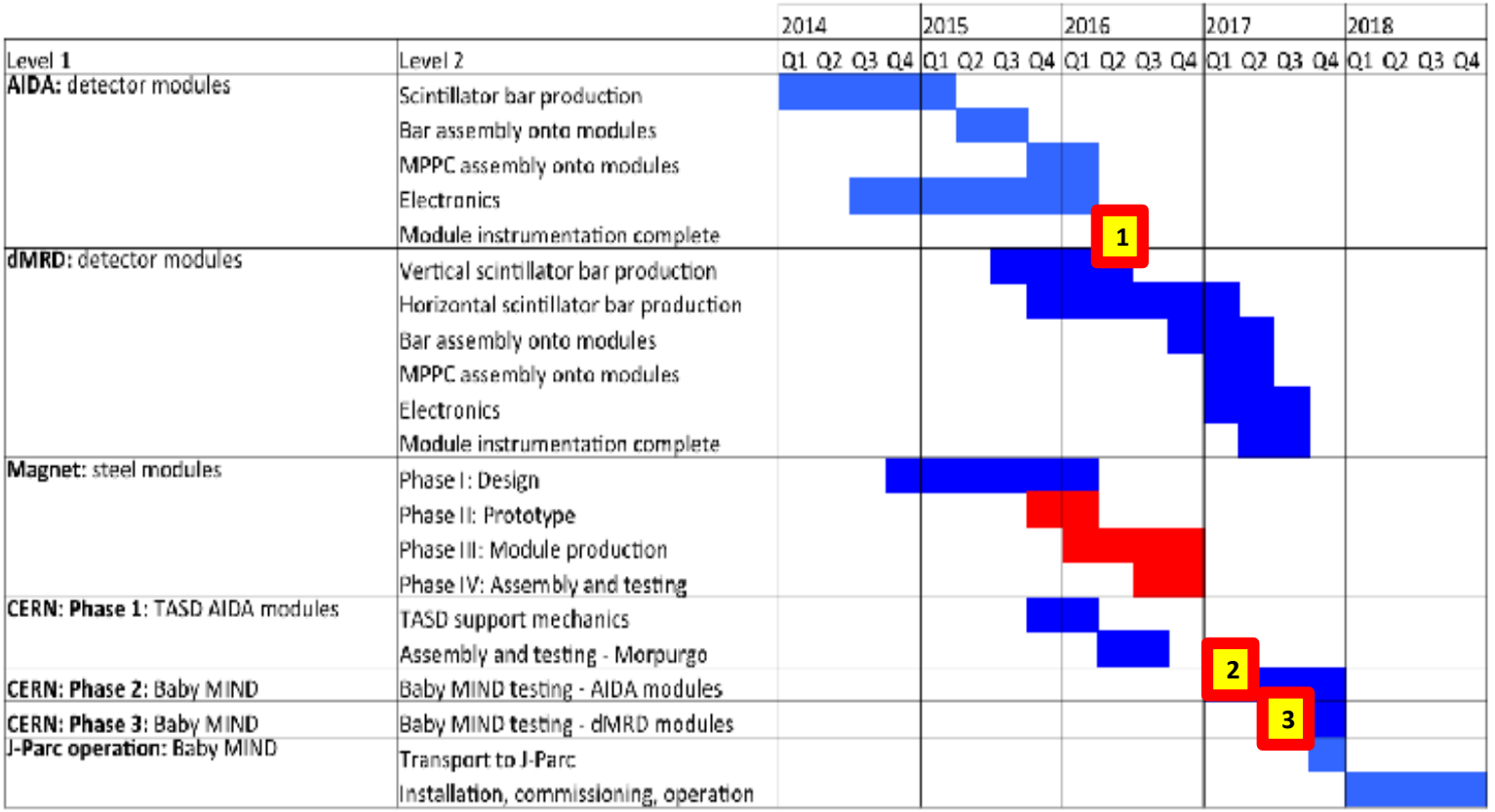


Will expose Baby-MIND to pion/muon beam of 0.5 to 10 GeV



Requested beam test periods

Phase	Installation & commissioning	Operation with beam
TASD + AIDA modules	2 weeks	4 weeks
Baby MIND + AIDA modules	4 weeks	4 weeks
Baby MIND + dMRD modules	4 weeks	4 weeks



Conclusions

We have built a 9000 channel extensible TASD to test the electron charge reconstruction of electrons in dense medium and magnetic field

A Baby-MIND (60 tons) detector has been designed to test the muon charge separation with high precision and to extend it below 1 GeV, and construction has begun.

This Baby-MIND is part of a measurement of water to scintillator cross-section ratio in the neutrino and antineutrino beam at T2K within the WAGASCI experiment in view of a reduction of systematic errors for T2K CP asymmetry measurements.

Tests of these detectors in beams are requested at CERN in several steps

-- 1 -- TASD tests in the MORPURGO magnet using dedicated TASD scintillators and a set of MPPCs, connectors, and electronics

-- 2 -- Baby-MIND tests using the magnetized iron plates with the same detectors and electronics as the TASD tests above.

-- 3 -- Baby-MIND tests using the final scintillator configuration to calibrate the charge separation and momentum measurement performance of the final detector.