NP05 (Baby MIND) status report

Etam NOAH (UniGe) - Baby MIND Collaboration

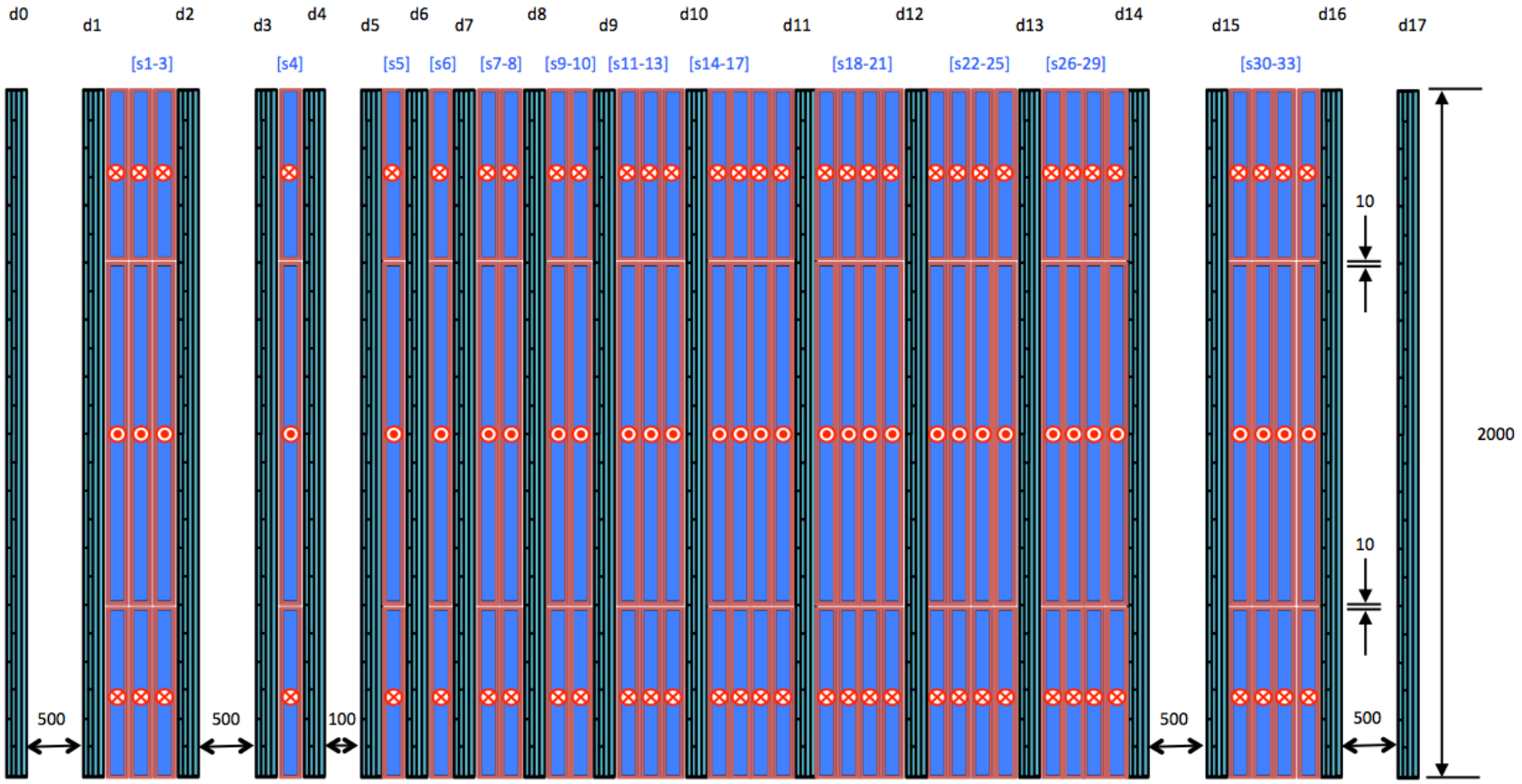
April 19, 2016

Motivation for Baby MIND at WAGASCI

- Current T2K setup:
  - Far detector (SK) is H_2O with 4π acceptance.
  - Near detector (ND280) is plastic (CH), its acceptance is forward scattering.
  - Systematic error sources are dominated by ν flux and cross-section non-constrained by the ND280.
- Hence motivation for measurement of H_2O/CH ratio with large polar angle at WAGASCI (approved experiment T59 at J-PARC).
- Magnetized muon spectrometer required to tell the charge of muons, especially in anti-neutrino beam mode where wrong-sign contamination in the beam is up to 30%.

Baby MIND layout

- Magnet module thickness: 50 mm (30 mm Fe) (envelope: 60 mm).
- Detector module thickness: 38 mm (31 mm CH).
- Finalization of the layout will be done with T9 and simulation info.



SPSC recommendations 22 October 2015:

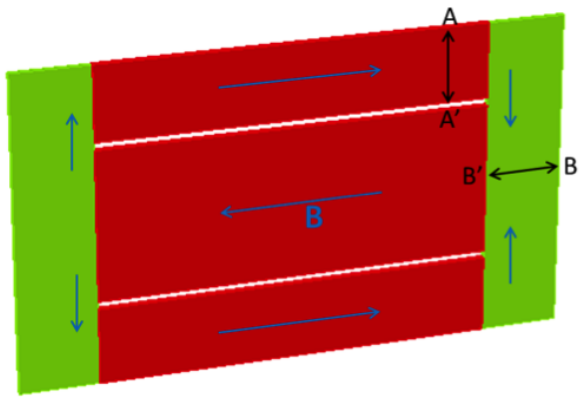
- The Committee **received** with interest the proposal to test a Totally Active Scintillator Detector (TASD) and to test a prototype of a Magnetised Iron Neutrino Detector (Baby MIND) at the SPS H8 beam line in period 2016-2018 (SPSC-P-353).
- The SPSC **recognises** the interest to tag muon charges and the potential of a magnetised iron detector and their foreseen application in the WAGASCI experiment at J-PARC, Japan.
- **The SPSC recommends the collaboration to focus on the Baby MIND part of the proposed test beam programme. The Committee also recommends the test of the Baby MIND detector as a part of the neutrino platform project at CERN.**
- The SPSC **notes** that the H8 beamline foreseen is not optimal for low energy particles and requests to revise the planning towards using an existing low-energy optimised beamline at CERN, e.g. at the PS.
- The SPSC **notes** that the schedule for Baby MIND tests at CERN is late compared to the overall WAGASCI schedule. **The Committee asks the collaboration to take all actions to meet the WAGASCI schedule.** Moreover, the SPSC asks for a common schedule of the project including details on the production of the detector modules for the WAGASCI experiment.
- The proposed tests of a TASD in a magnet **will be further reviewed** once the Baby MIND project is well defined.

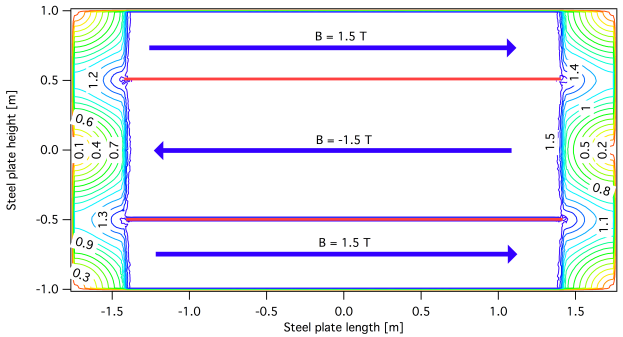
Project status at CERN Neutrino Platform

- The Baby MIND was approved by the CERN Research Board at a meeting on 9 December 2015 as NP05, a Neutrino Platform experiment.
- The addendum #5 to the MoU for Collaboration in the Neutrino Program that concerns the NP05 Baby MIND experiment was signed by the CERN Director of Research and Scientific Computing on 15 December 2015. Of the 6 signatures required from Collaborating Institutes, 5 have been submitted, the 6th is on its way.
- NP05 is now listed in the CERN Grey Book database as one of the Neutrino Platform experiments: Grey Book database link.

Magnet module concept

- Design now frozen.
- Individually magnetized iron plates.
- Two-slit design.
- Well defined B-field lines in central zone: $B = B_x$.
- Contained stray fields.
- Modularity and flexibility.
- Low power (< 200 W/module).
- Low cost.



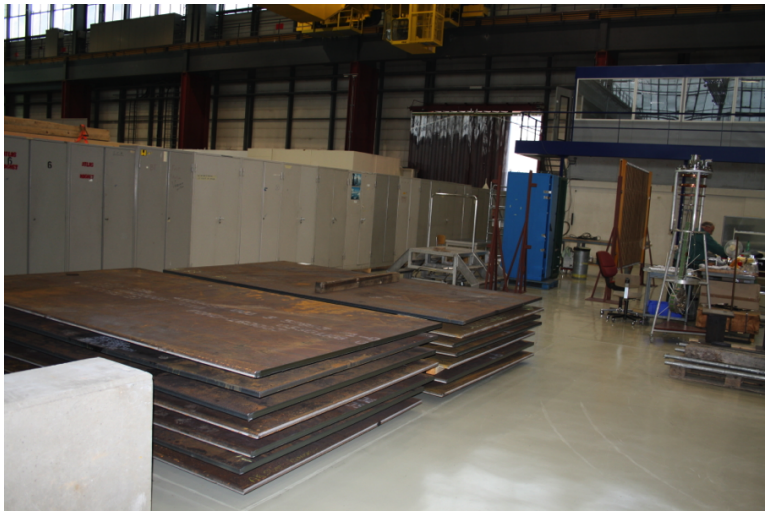


Magnet module prototype

- Full size prototype $3500 \times 2000 \times 30\text{mm}^3$.
- 10 mm wide slits (water jet).
- 10 mm-thick flux return plates $\times 4$.
- Aluminium coil: 50 mm wide $\times$ 4 mm thick: half-turns.
- Fiber glass insulation sheath.
- Coil tested to 400 A: R = 17 mΩ.
- $B_x = 1.56$ T.

Magnet material procurement

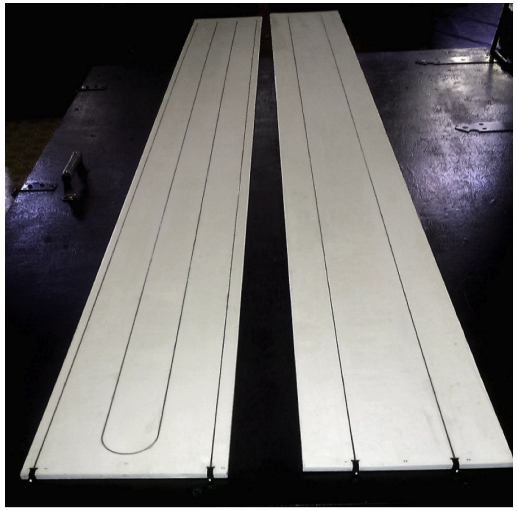
- ARMCO 30 mm: 14 of 33 plates delivered 5 April 2016.
- ARMCO 10 mm: delivered March 2016.
- Aluminium coil: delivered 8 April 2016.

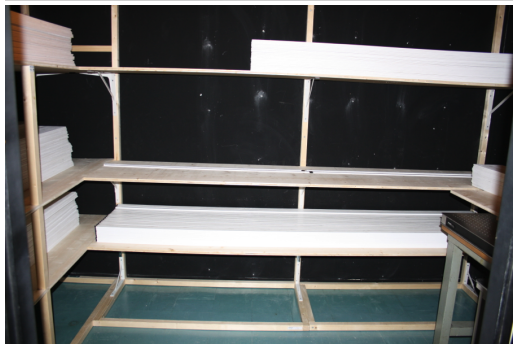


Scintillator bar production

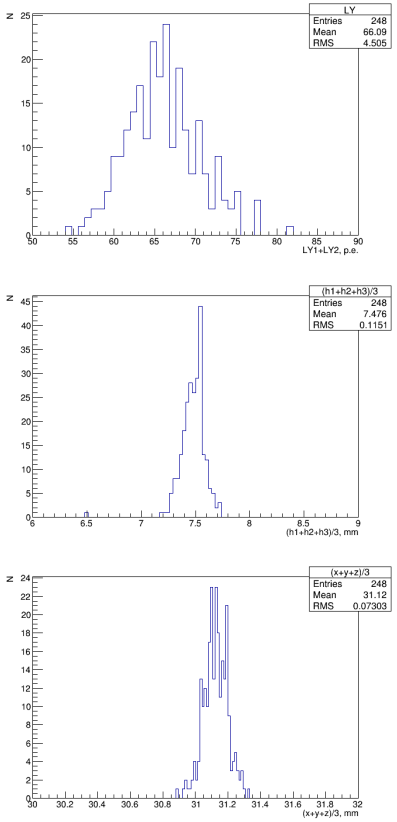
- Responsibility of INR.
- Polysterene based, 1.5 % PTP, 0.01% POPOP.
- Reflective coating 30 to 100 μm from chemical etching of surface.
- Kuraray WLS fiber (200 ppm, S-type), dia 1.0 mm.
- Eljen EJ-500 optical cement.
- Custom optical connector.
- **First batch** delivered **March 2016** - Good for 2 modules.
- **Second batch** expected **October 2016**.

Vertical bars (U vs W groove)



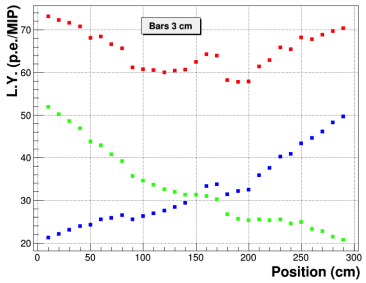


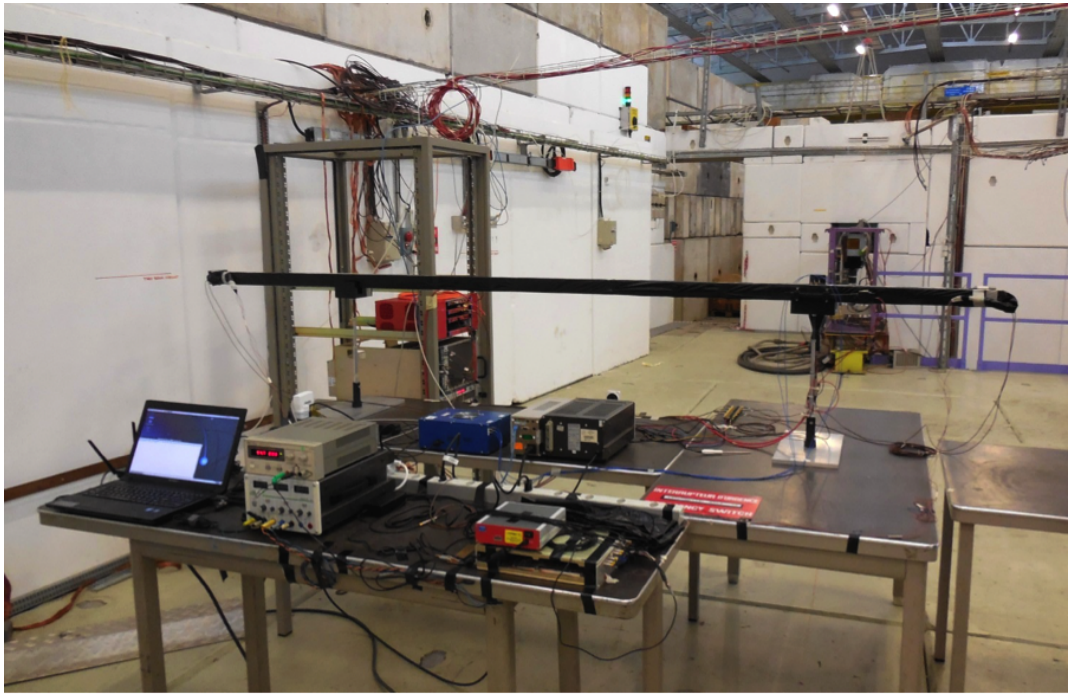
Horizontal bars light yield (top) & dimensions (middle/bottom)



Horizontal bar tests at T9 in October 2015

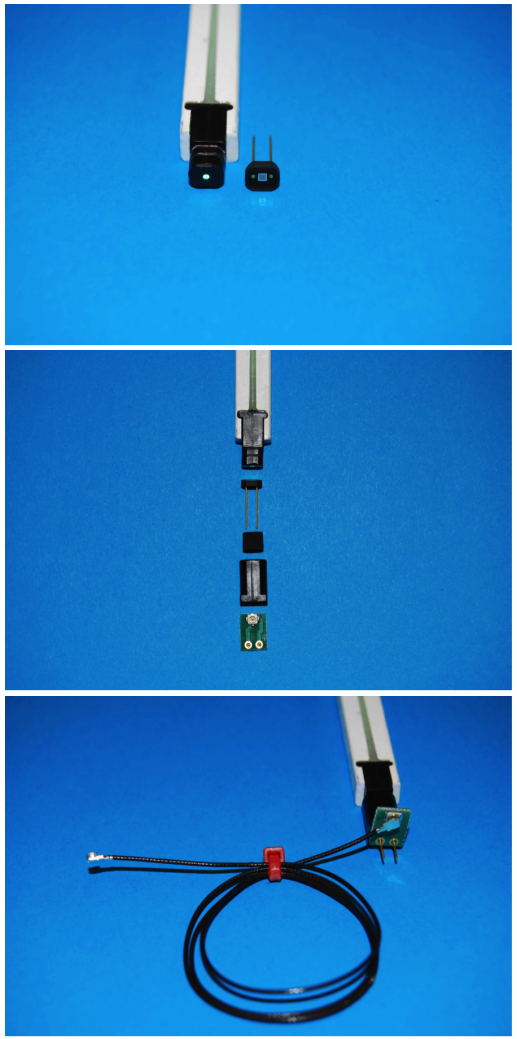
- Beam test for SHiP experiment with bar similar to Baby MIND horizontal bars: 3000 x 30 x 7.5 mm^3.
- CAEN DT5742 digitizer.
- 10 GeV/c muons.
- Light yield: 60 photo-electrons.
- Light propagation: 1.7×10^8 $m.s^{-1}$.



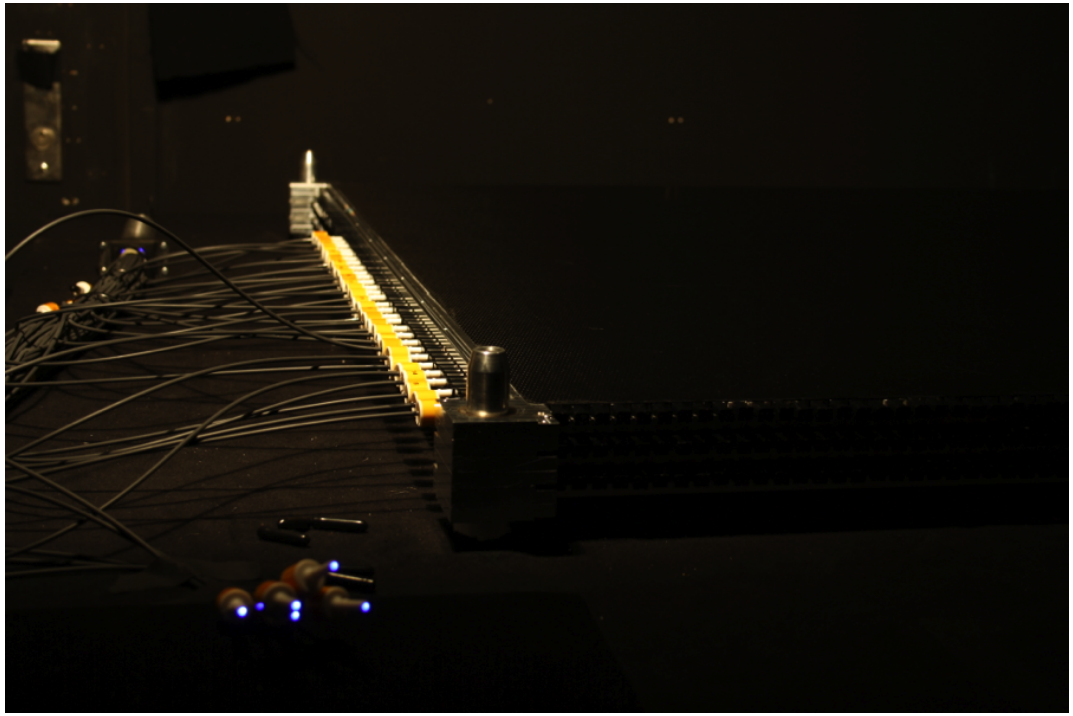


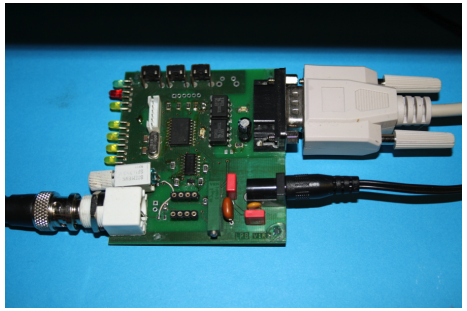
Photosensors and connectivity

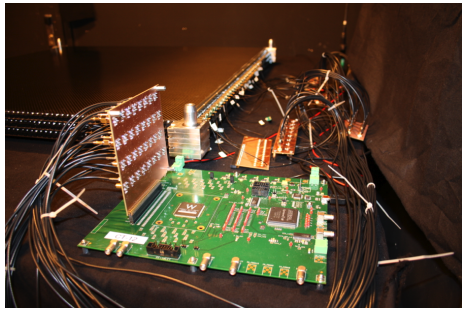
- Photosensor characteristics:
  - Hamamatsu MPPC S12571-025C.
  - 1×1 mm^2 (65% fill factor).
  - 25 μm cell size.
  - Operating voltage $\sim$ 67.5 V.
  - PDE $\sim$ 35%.
  - Gain 5×10^5.
  - Dark counts 100 kcps typ.
- Custom connectors.
  - Designed by INR.
  - Alignment of MPPC and coupling to WLS fiber.
  - Small pcb with UFL connector.
  - Coax cable: HIROSE 1 m length to FEB.

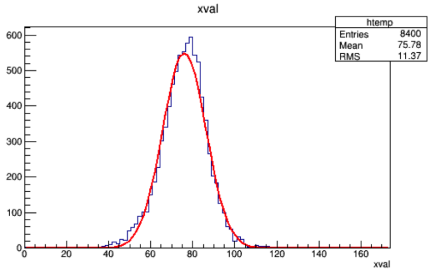


Test system with LED driver from Sofia



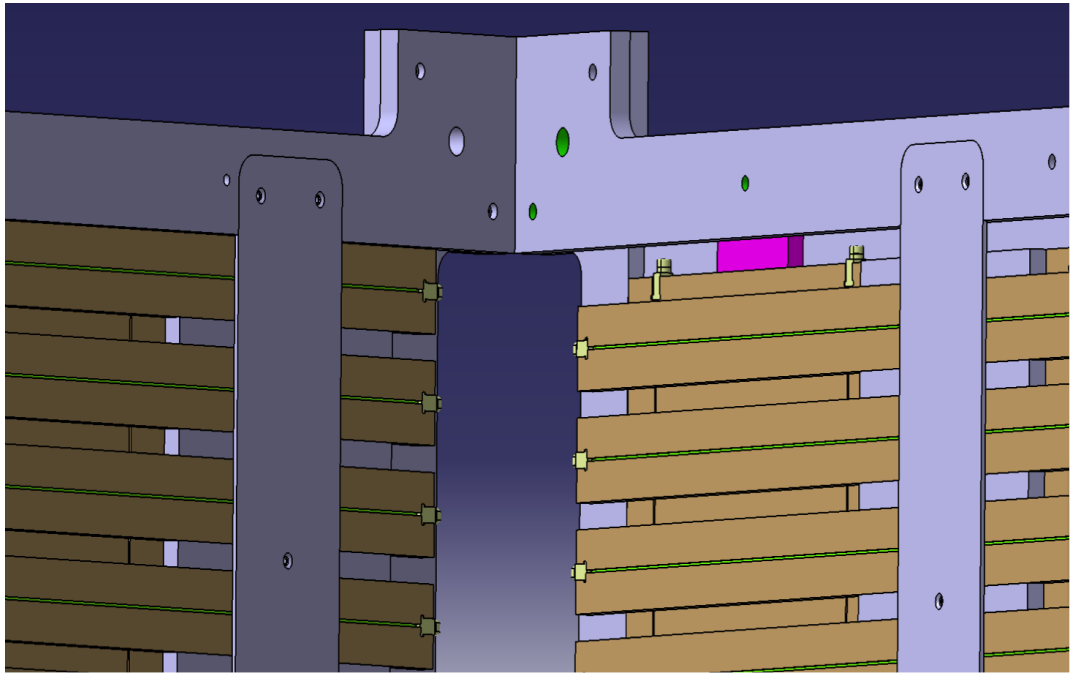


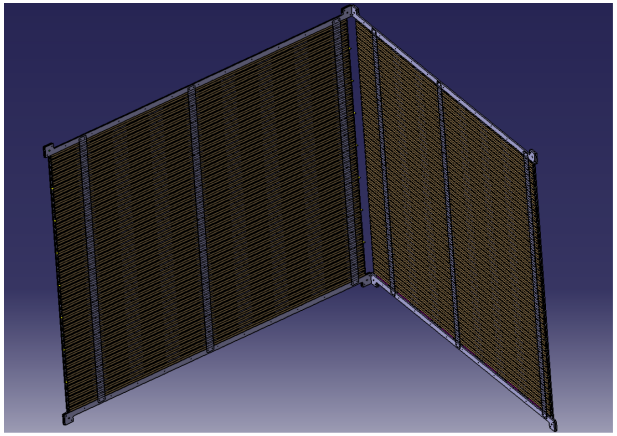


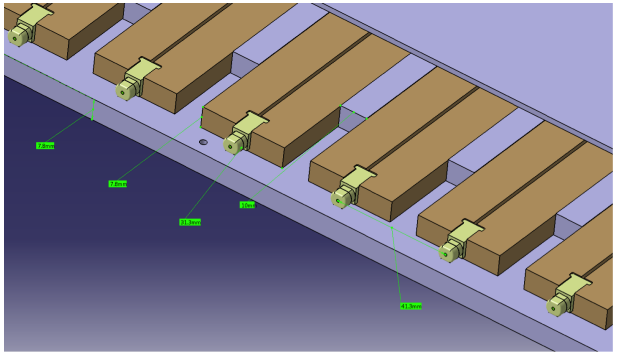


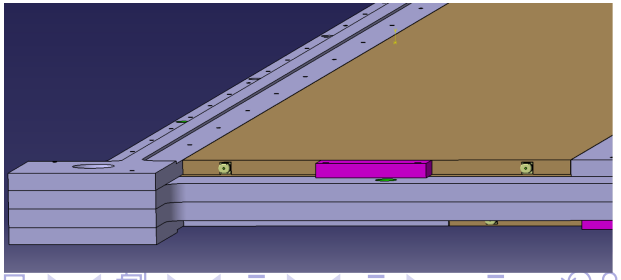
Module mechanics

- Two half-modules assembled separately.
- Each half-module: 1 horizontal + 1 vertical plane:
  - 95 horizontal bars: 3000 mm x 31 mm x 7.5 mm
  - 8 vertical bars: 1950 mm x 210 mm x 7.5 mm
- Scintillators held together mechanically (no glue) within aluminium support frame.



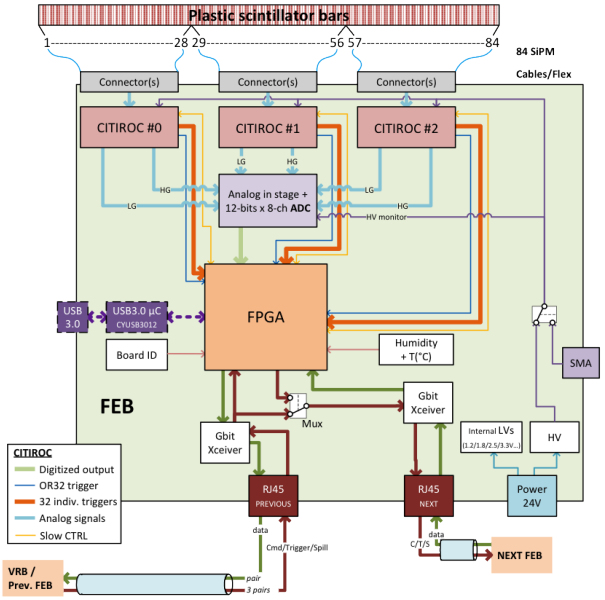


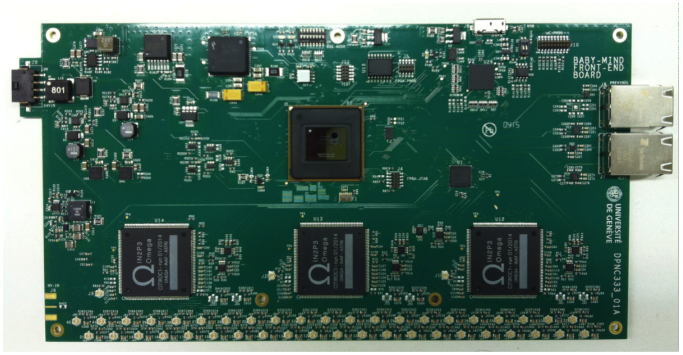




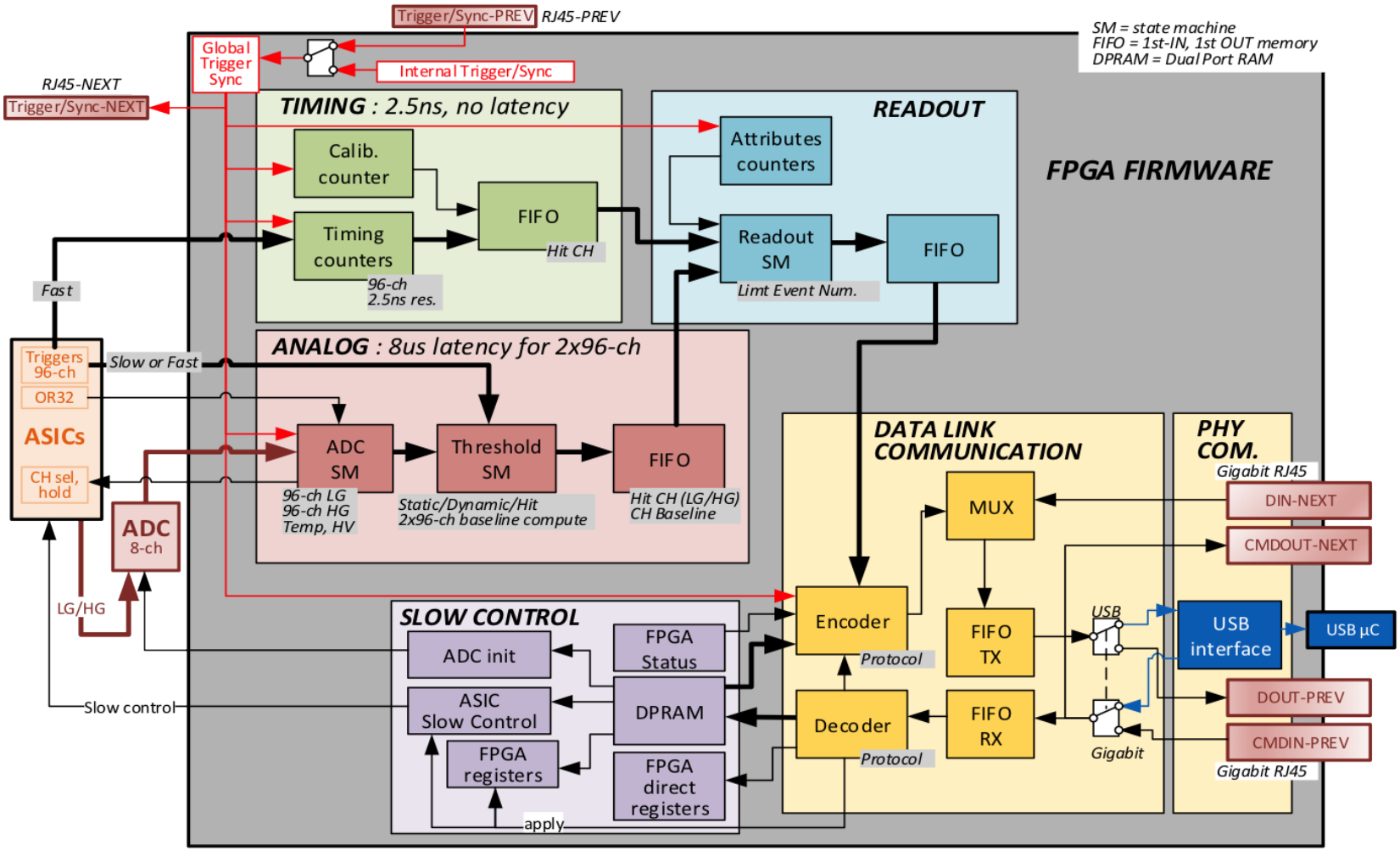
Custom electronics Front End Board

- Features of the Front End Board:
  - 96 coax. connectors.
  - 3 CITIROC ASICs 32-ch.
  - 12-bits 8-ch 40MS/s/ch ADC.
  - Altera ARIA5 FPGA.
    - Timing: 2.5 ns resolution.
    - Analog readout: 8μs for 96c-ch LGain and HGain.
    - HV, ASIC T + board T + RH%.
  - Readout/Slow control on USB3 and /or Gigabit RJ45 chain.
  - External propagated Trig/sync. signal.
  - Power supplies (HV/LV).
- Firmware and software:
  - FPGA firmware: Analog readout + slow control on USB done.
  - Software engineer hired for low level software.



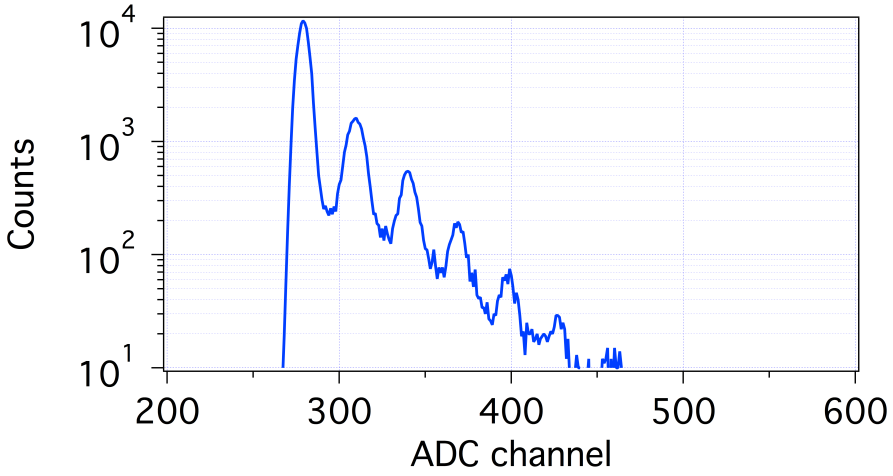


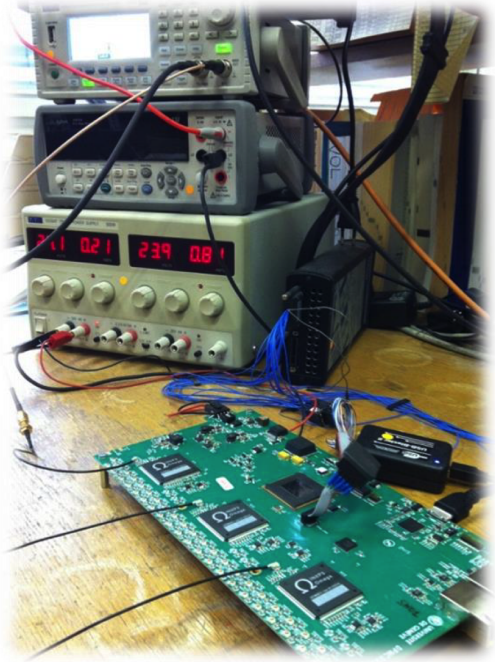
FEB FPGA firmware



Prototype FEB testing and optimization

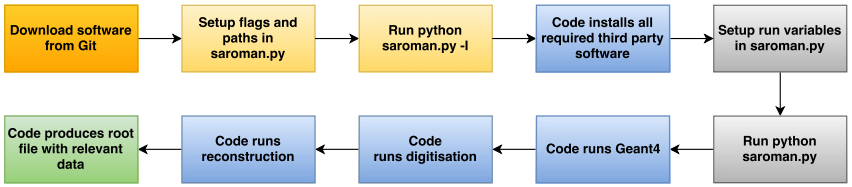
- 5 boards fully tested:
  - Hardware, firmware blocks, USB3 link.
- Next version of FEB:
  - ASIC analog signals conditioning & ASIC input stage protection.
  - Trigger and timing chains.
  - FPGA remote FW update.

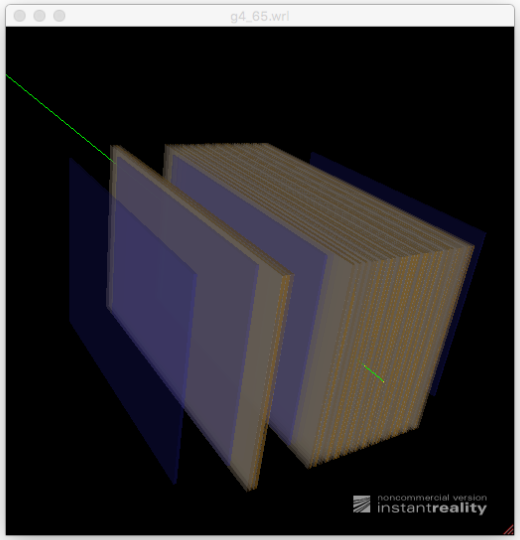




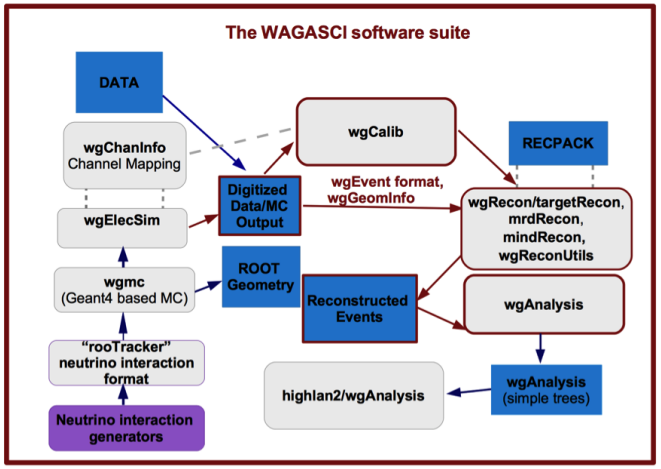
Two software environments to be merged into one

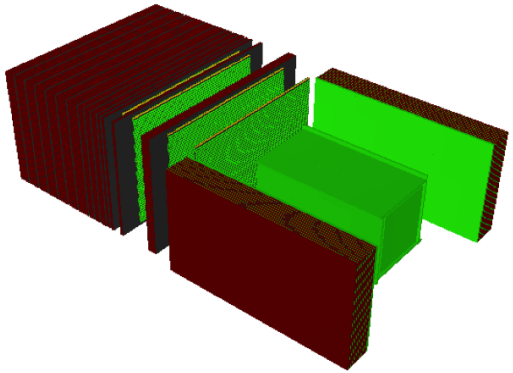
- The SaRoMan (Simulation And Reconstruction Of Muons And Neutrinos) package, derived from Neutrino Factory and nuSTORM studies.





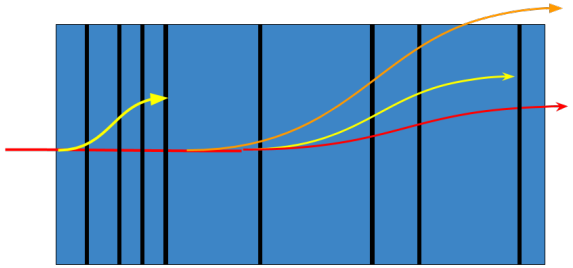
- The WAGASCI-Baby MIND package, derived from the T2K ND280 software suite.





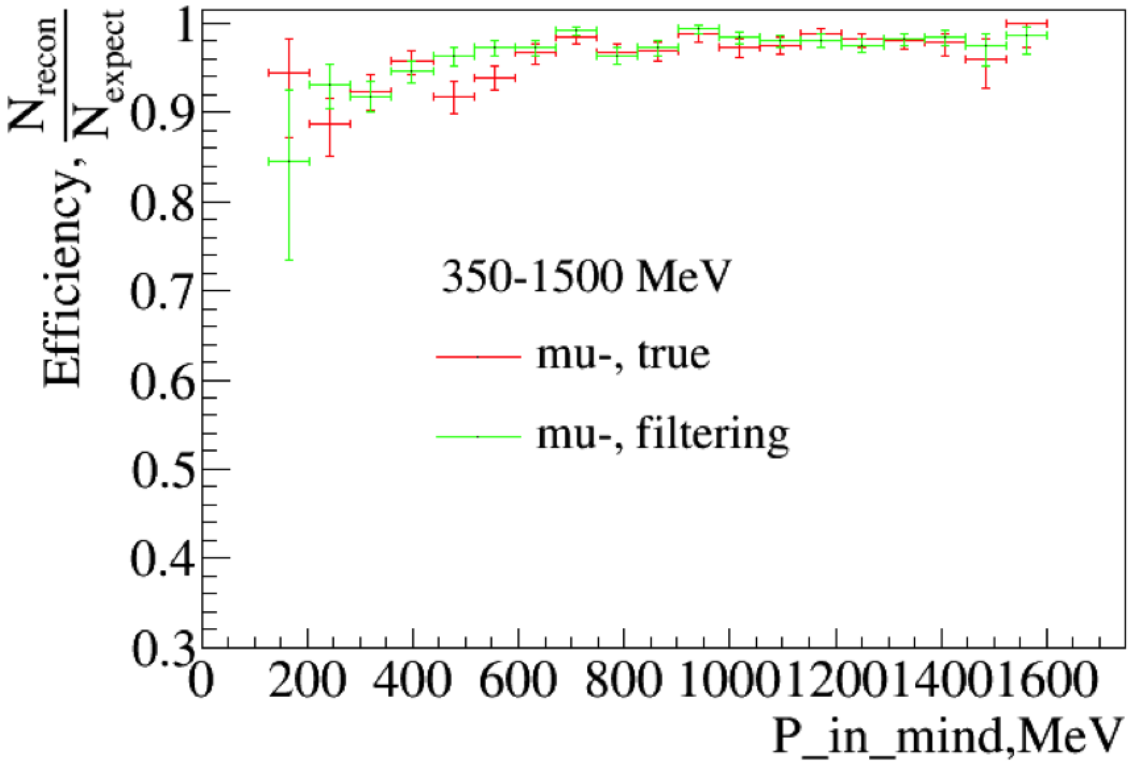
Reconstruction in SaRoMan

- 4-10 hits, use the lever arm, momentum from range and charge from a quadratic fit.
- $>$ 10 hits calculate a seed with momentum and charge and then feed this seed into a kalman fitter.
- If the track stops in the detector use a range momentum calculation and charge from a quadratic fit, if not estimate the momentum from the curvature.



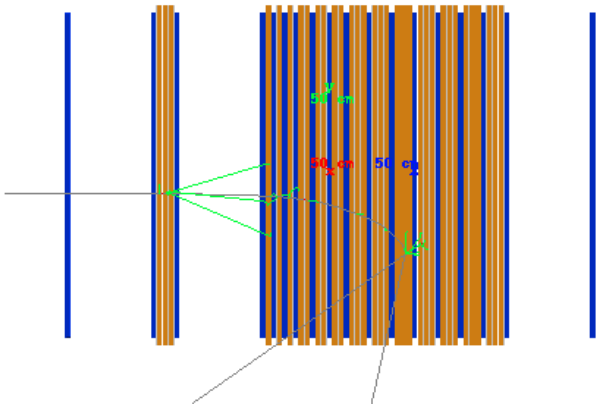
Charge ID with WAGASCI-Baby MIND

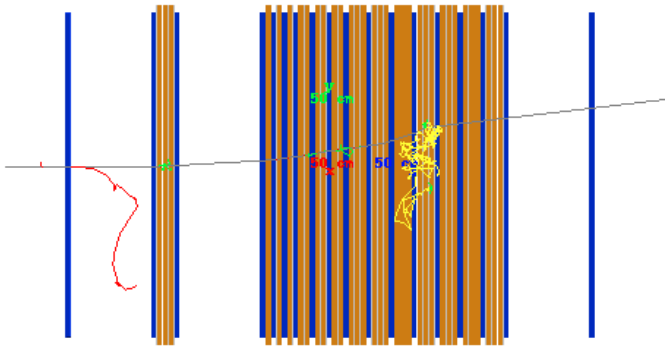
- $>$ 90% at 300 MeV/c.
- 95% at 600 MeV/c.
- 99% at 1 GeV/c.

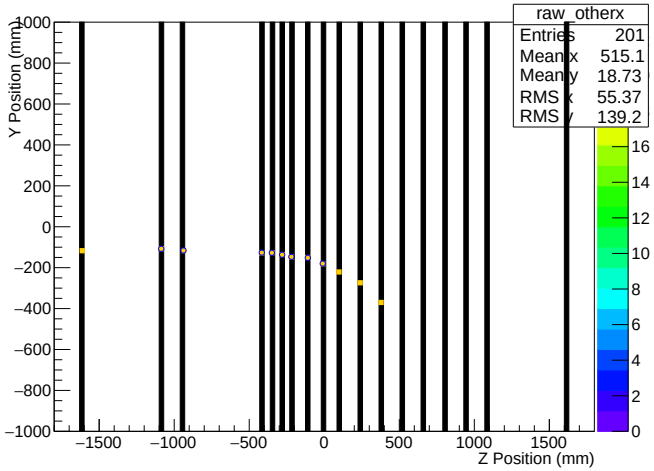


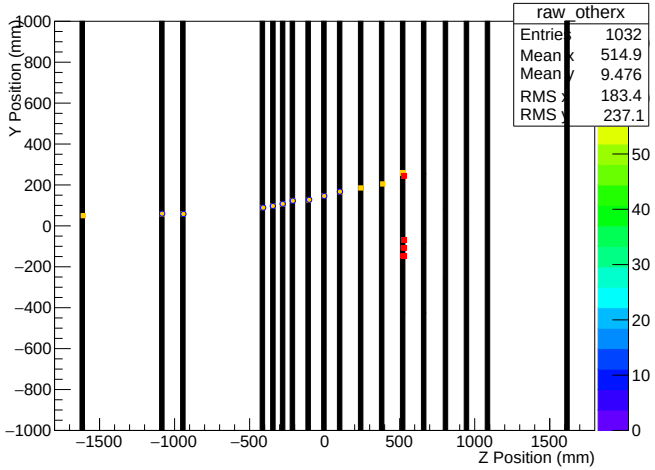
SaRoMan event topologies: 1 GeV μ^+ & 1 GeV μ^-

Green: γ; Red: e^-; Yellow: neutron; Grey: Other (incl. muon)

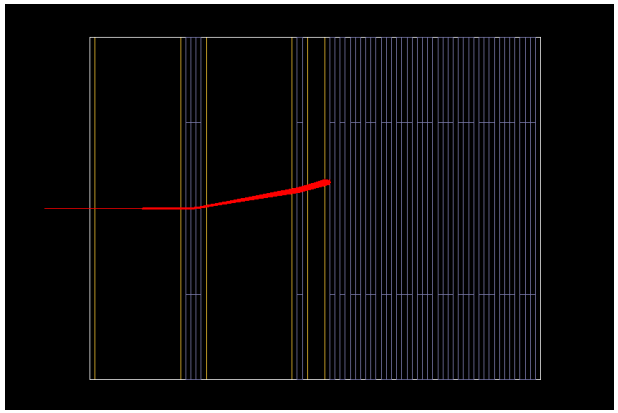


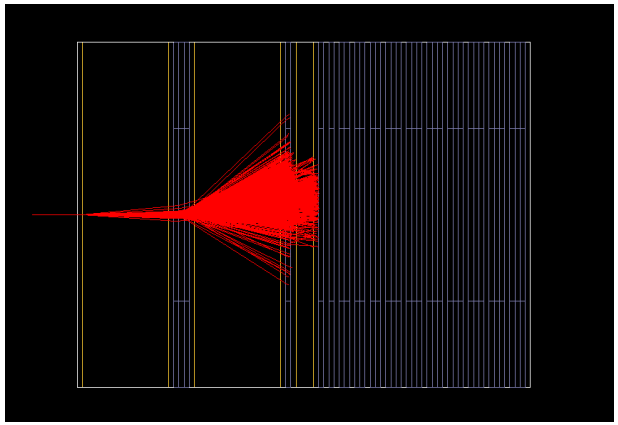


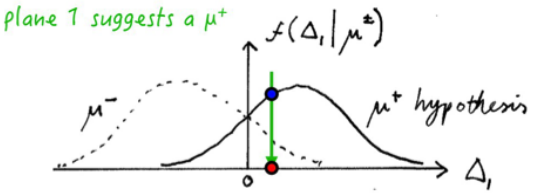


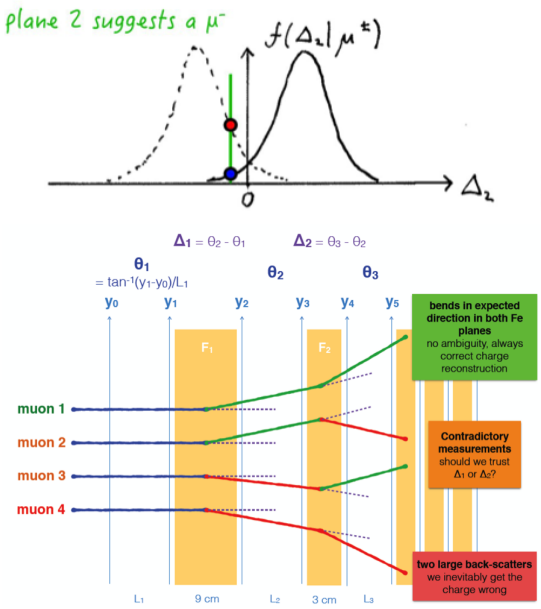


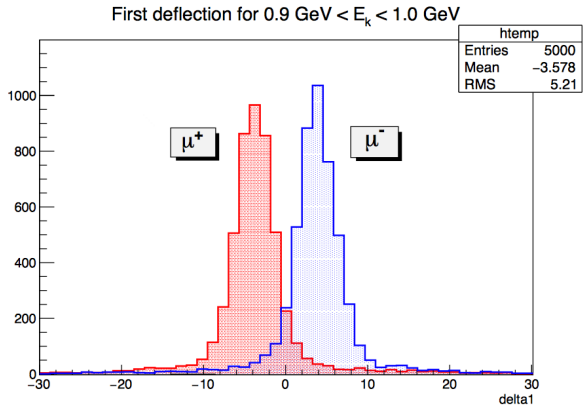
Low momenta: Lever Arm vs Multiple Scattering











$$Rec\ as\ \mu^- \ if\ \frac{f_{\mu^-}(\Delta_1)}{f_{\mu^+}(\Delta_1)} > \frac{f_{\mu^+}(\Delta_2)}{f_{\mu^-}(\Delta_2)}$$

$$Rec\ as\ \mu^+ \ if\ \frac{f_{\mu^+}(\Delta_1)}{f_{\mu^-}(\Delta_1)} > \frac{f_{\mu^-}(\Delta_2)}{f_{\mu^+}(\Delta_2)}$$

Collaboration members

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]

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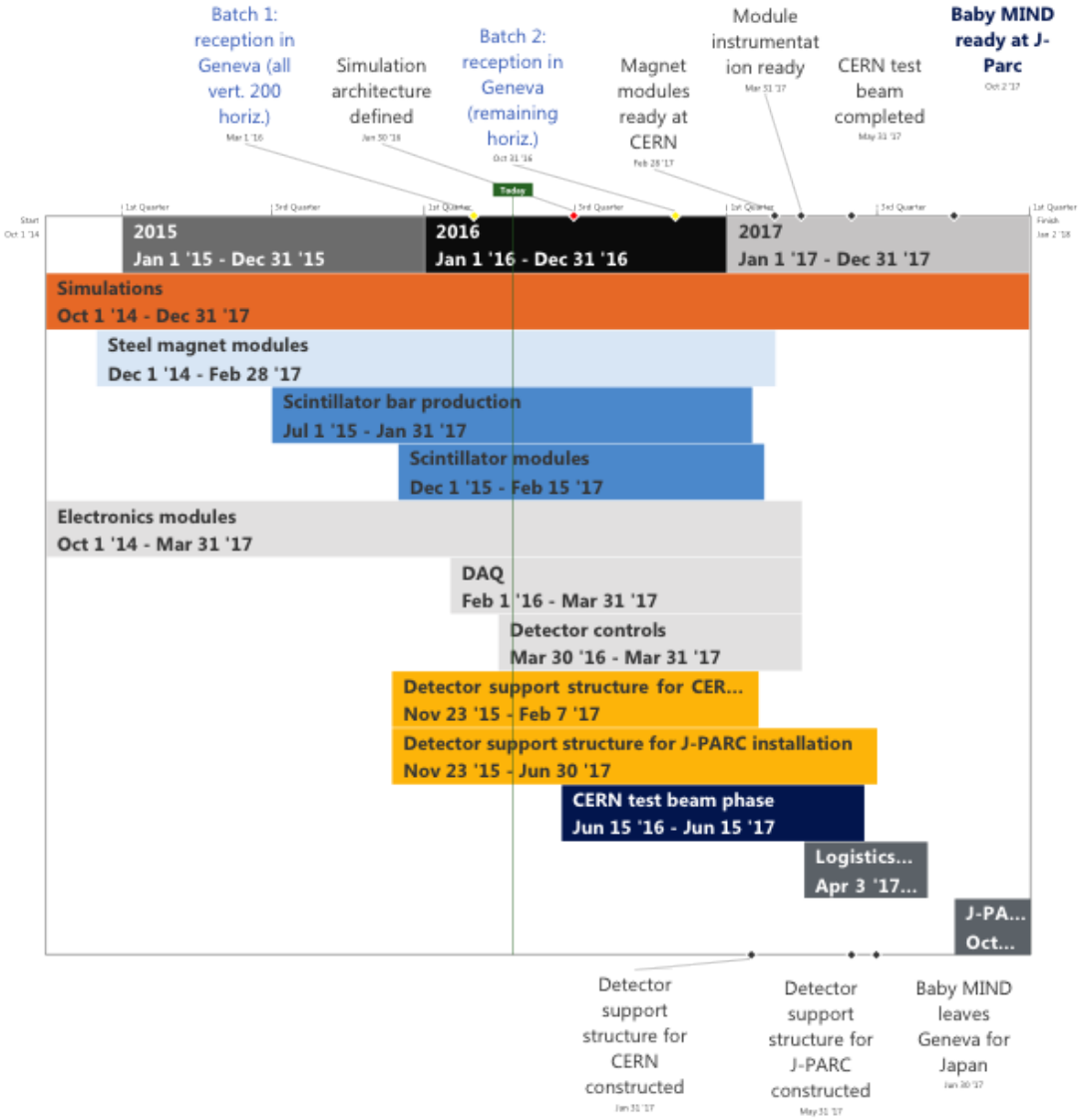
Spoke: A. Blondel, Co-spoke: Y. Kudenko, Contact: E. Noah

Working within CERN Neutrino Platform Framework

- NP funding for magnet design and construction.
- Access to NP manpower for technical, administrative assistance.
- Use of everyday working tools within NP framework:
  - bMIND website
  - bMIND edms
  - bMIND indico


Batch 1: reception in Geneva (all vert. 200 horiz.)
Simulation architecture defined
Batch 2: reception in Geneva (remaining horiz.)
Magnet modules ready at CERN
Module instrumentation ready
CERN test beam completed
Baby MIND ready at J-Parc
Today
2015
Jan 1 '15 - Dec 31 '15
2016
Jan 1 '16 - Dec 31 '16
2017
Jan 1 '17 - Dec 31 '17
Simulations
Oct 1 '14 - Dec 31 '17
Steel magnet modules
Dec 1 '14 - Feb 28 '17
Scintillator bar production
Jul 1 '15 - Jan 31 '17
Scintillator modules
Dec 1 '15 - Feb 15 '17
Electronics modules
Oct 1 '14 - Mar 31 '17
DAQ
Feb 1 '16 - Mar 31 '17
Detector controls
Mar 30 '16 - Mar 31 '17
Detector support structure for CER...
Nov 23 '15 - Feb 7 '17
Detector support structure for J-PARC installation
Nov 23 '15 - Jun 30 '17
CERN test beam phase
Jun 15 '16 - Jun 15 '17
Logistics...
Apr 3 '17...
J-PA...
Oct...
Detector support structure for CERN constructed
Detector support structure for J-PARC constructed
Baby MIND leaves Geneva for Japan

Project milestones

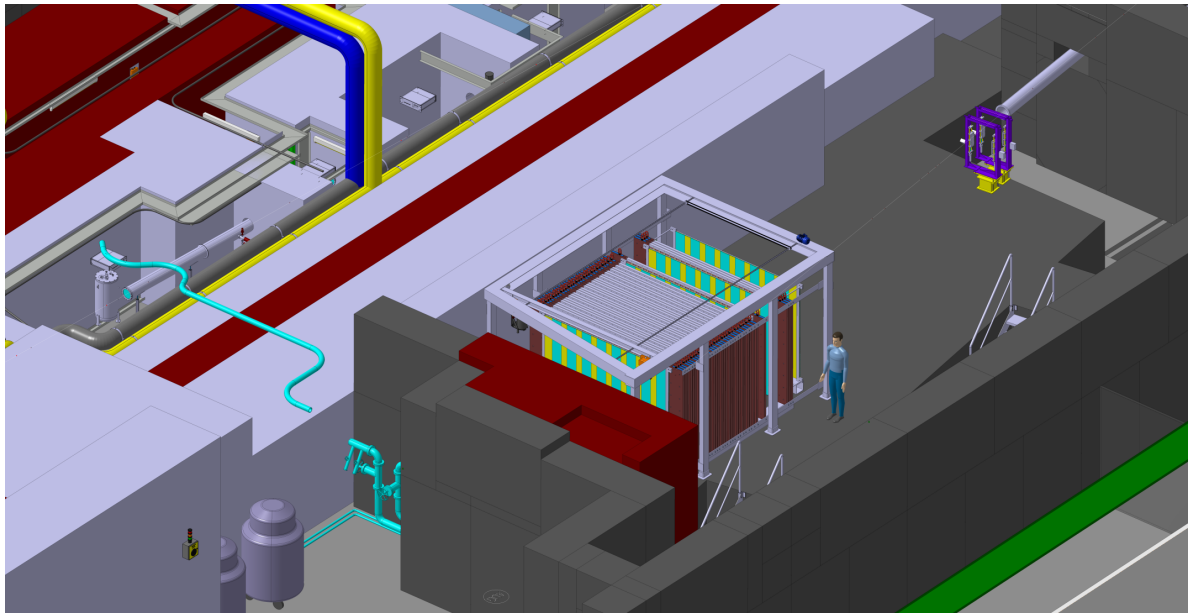
- **Electronics Front End Board** beam test at T9 in **June 2016**.
- **First** complete **Baby-MIND module** in **August 2016**.
- **Delivery** of remaining **scintillators** in **October 2016**.
  - *Was end Q1 2017 in October 2015 schedule*
- **Magnet modules** ready on the **T9** platform end of **February 2017**.
- **Detector modules** ready on the **T9** platform end of **March 2017**.
- **Beam tests** characterization at T9 in **May 2017**.
- **Shipment** to **Japan** in **July 2017**.
- **Installation** in Japan **ND280 pit** in September for operation in **October 2017**.

Beam requests Our beam requests center around activities in 2016 and 2017 as follows:

- **Beam request 2016**: We submitted a beam request for 2016 on the T9 beam line at the PS in the East Area, asking for two separate slots, one in the summer and if possible one towards the end of the 2016 run. We were allocated two runs in the summer, one week in June, one week in July. These will allow us to carry out the detailed characterization of our electronics. The first few magnet and Baby MIND scintillator modules will be ready in August. Should a slot be made available for the end of the run in October, we would very much appreciate usage of the beam in T9 then.
- **Installation at T9 request**: we are requesting full access to the T9 platform from November 2016. This would enable us to start installation of the Baby MIND support structure and magnet modules.
- **Beam request 2017**: we plan to file a beam request for 2017 at T9 for the beginning of the run in May 2017, for a duration of 4 weeks, in order to fully characterize the Baby MIND. The Baby MIND will be installed as far downstream as possible at the T9 experimental area. This may enable some degree of flexibility in scheduling the use of the beam by other experiments.
- **Dismounting at T9**: we plan to dismount the Baby MIND and pack it for transport to Japan in June 2017.

Installation, running and dismounting in the East Area at T9

- Availability of T9 platform in October/November 2016 should allow us to understand transport and assembly issues of the magnet and detector modules.
- By end 2016/January 2017 we will have a clear appreciation of where we stand concerning logistics for the full detector, dismounting and packing for shipment to Japan.
- Running with cosmics from February 2017.



- 4 weeks of data taking in May 2017.
- 4 weeks of dismounting at T9 and packing in June 2017.

Summary

- **NP05 Baby MIND project status** The Baby MIND was approved by the CERN Research Board at its meeting of 9 December 2015 as a Neutrino Platform project and is now listed as NP05 in the CERN Grey Book database.
- **Magnet modules**: the design of the magnet modules is complete. A functional prototype has been assembled. Procurement of all components is underway and on schedule to meet milestone.
- **Scintillator modules**: the design of the scintillator modules is complete. Production of scintillator bars under the responsibility of INR is proceeding well and on schedule.
- **Electronics**: the design of a new Front End Board is complete. The first prototype is undergoing extensive tests.
- **Support mechanics and logistics**: A concept for support mechanics for the Japan implementation has been drafted. Detailed design and costing is planned for late 2016.
- **Physics simulations**: We are merging two simulation environments: one developed by the WAGASCI collaboration derived from the T2K ND280 software and another developed by collaboration members in Glasgow, the SaRoMan package, derived from Neutrino Factory and nuSTORM studies.