AIDA2020 Task 8.6 Status Report

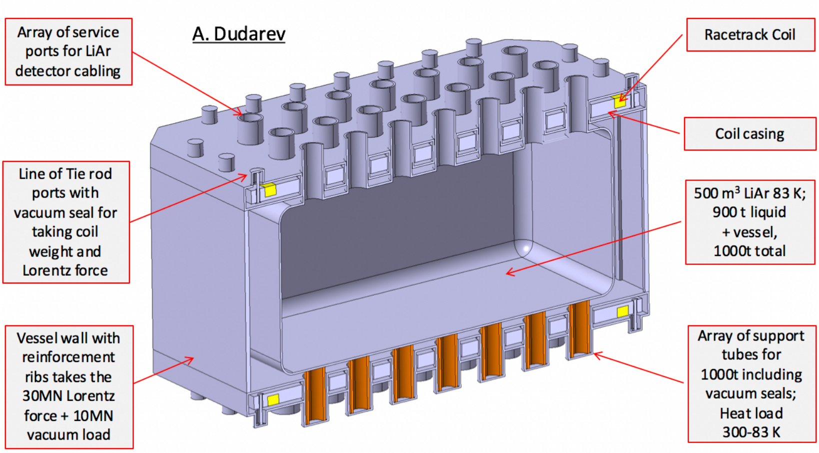
Etam NOAH (UniGe) - Baby MIND Collaboration

April 5, 2017

Task 8.6 Magnetization: definition

- Definition of Task 8.6 in AIDA-2020 Proposal 654168.
  - **Magnetization** of **large scale cryogenic liquid argon** detectors - **study** of magnetisation based on **Superconducting Transmission Lines (STL)** and of magnetisation based on **High temperature Superconducting (HTS) lines**.
  - **Tests** of **novel magnetization** schemes on **iron** - using hardware at CERN developed in previous AIDA project.
- Participation
  - University of Geneva **(UniGe)**: 1 PhD student: Saba Parsa: since **1st September 2016**.
  - University of Glasgow **(UniGla)**: 1 PhD student: Patrik Hallsjo: since **1st October 2015**.

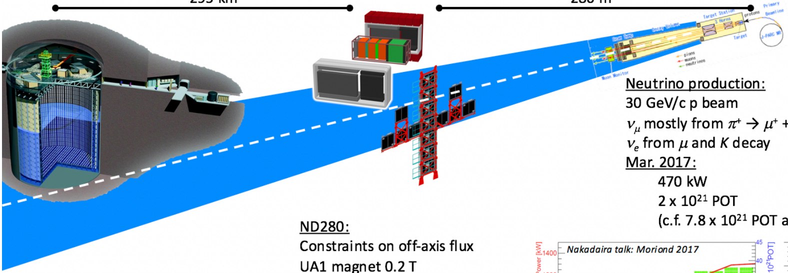
Magnetizing large scale cryogenic liquid detectors



Baby MIND project

- Magnetized Iron Neutrino Detectors
  - ... as **main detectors** (CDHS, MINOS, Neutrino Factory, NuSTORM)
  - ... **downstream/surrounding** LAr, Water Cherenkov, totally active scintillator detector etc...
- Backgrounds with conventional ν beams
  - ... experiments must handle **wrong sign neutrinos**.
- Baby MIND at WAGASCI
  - Initial motivation for Baby MIND was study of **charge identification** of muons on a **charged particle beamline** at CERN.
  - Baby MIND was then found to be a **good match** for the downstream muon spectrometer at the **WAGASCI** experiment (T59) at J-PARC, using neutrinos from the T2K beamline.
- Baby MIND at the CERN Neutrino Plaltform
  - was **approved** as experiment **NP05** in **December 2015**.

T2K experiment overview



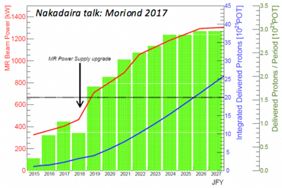
Neutrino production:
30 GeV/c p beam
ν_μ mostly from $\pi^+ \rightarrow \mu^+ + \nu_\mu$
ν_e from μ and K decay

Mar. 2017:
470 kW
2 x 10^{21} POT
(c.f. 7.8 x 10^{21} POT app.)

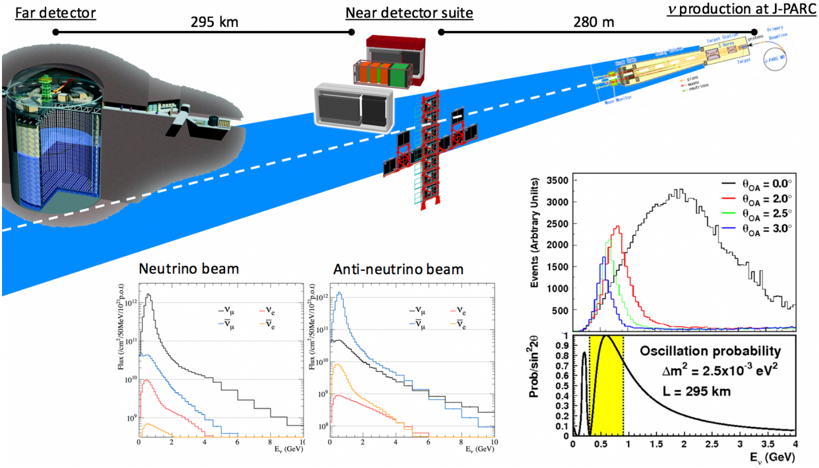
ND280:
Constraints on off-axis flux
UA1 magnet 0.2 T

Ingrid:
Flux characterization
Beam profile

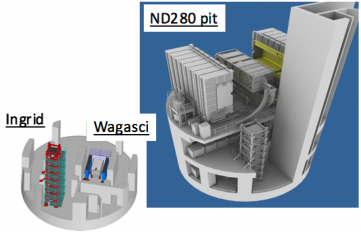
Super Kamiokande:
Neutrino oscillation measurements
Atmospheric, solar, K2K, T2K
Proton lifetime
50 kton Water Cherenkov
(22.5 kton fiducial volume)

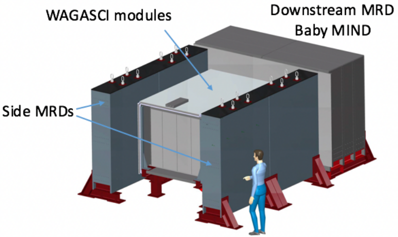


T2K off-axis beam

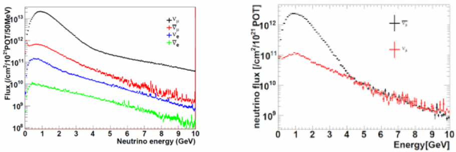


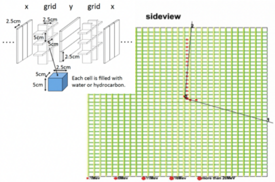
WAGASCI (T59 experiment) at J-PARC





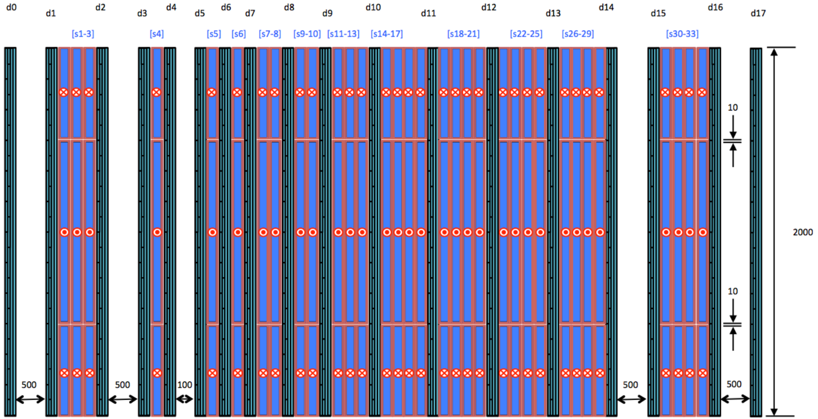
Neutrino flux at WAGASCI (1.6° off-axis)





Baby MIND layout

- Magnet module thickness: 50 mm (30 mm Fe) (envelope: 60 mm).
- Detector module thickness: 38 mm (31 mm CH).

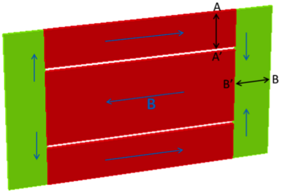


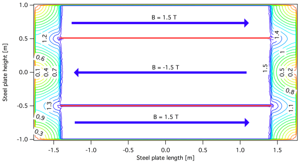
Baby MIND hardware status

	Design		Prototyping		Production	
	04/2016	04/2017	04/2016	04/2017	04/2016	04/2017
Magnet modules						
Standard steel plates	✓	N/A	✓	N/A	N/A	N/A
ARMCO plate machining	×	✓	×	✓	×	✓
Coil engineering	✓	✓	✓	✓	×	✓
Magnet module assembly	✓	✓	✓	✓	×	✓
Scintillator modules						
Scintillator bars	✓	✓	✓	✓	✓	✓
Scintillator module mechanics	×	✓	×	✓	×	✓
Scintillator module assembly	×	✓	×	✓	×	✓
Cable bundles						
Cable selection	×	✓	×	✓	×	✓
HV Coax PCB	×	✓	×	✓	×	✓
FEB Coax PCB	×	✓	×	✓	×	✓
Cable bundle assembly	×	✓	×	✓	×	✓
Electronics modules						
FEBv1	✓	✓	✓	✓	×	×
FEBv2	×	✓	×	✓	×	✓
Backplane	×	✓	×	✓	×	✓
Master Clock Board	×	✓	×	×	×	×
Minicrate mechanics	×	✓	×	✓	×	✓
Mechanics						
Support frame #1	×	✓	×	✓	×	✓
Support frame #2	×	✓	×	✓	×	✓
Support frame #3	×	✓	×	✓	×	✓
Support frame #4	×	✓	×	✓	×	✓

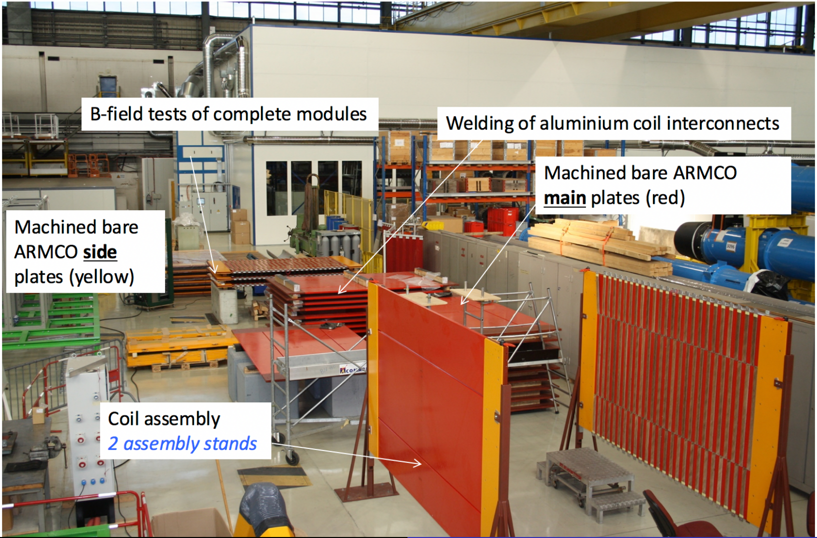
Magnet module concept

- Design principles:
  - 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.
- Dimensions:
  - $3500 \times 2000 \times 30\text{mm}^3$.
  - 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.
- Test measurements.
  - Field > 1.5 T for coil current ~ 140 A
  - Power for all 33 modules: 12 kW





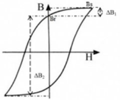
Magnet module assembly: all 33 modules complete

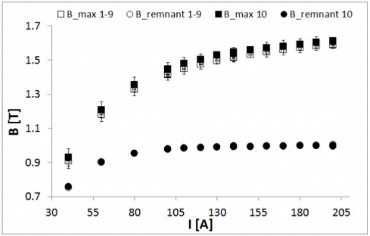


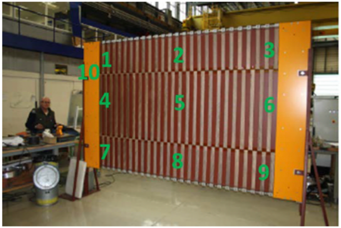
Magnet module B-field measurements

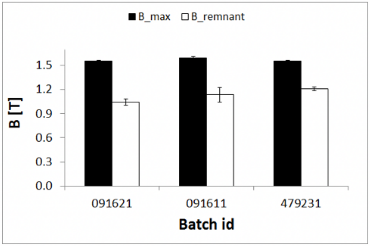
- First measurements were performed with 9 pick-up coils on one module.
- All 33 plates each have one pick-up coil for B-field measurements.

$$\int_{t_{start}}^{t_{end}} V(t)dt = \int_{t_{start}}^{t_{end}} N_{pc} \cdot \frac{d\phi}{dt} dt = N_{pc} \cdot S \cdot \Delta B$$



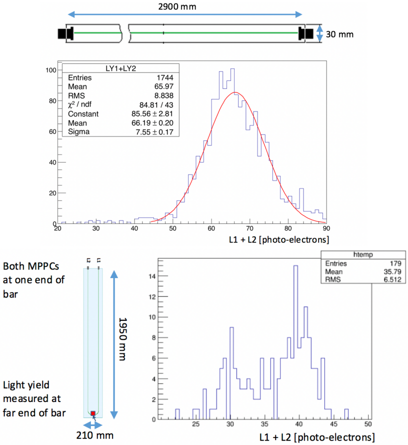






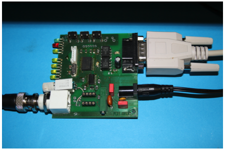
Scintillator bar production

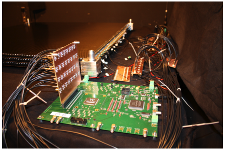
- Design and production by INR:
  - Polysterene based, 1.5 % PTP, 0.01% POPOP.
  - Reflective coating 30 to 100 μm from chemical etching of surface.
  - Kuraray WLS fiber (200 ppm, S-type), dia 1.0 mm.
  - Eljen EJ-500 optical cement.
  - Custom optical connector.
- Delivery schedule INR-CERN:
  - **First batch** delivered **March 2016**.
  - **Second batch** delivered **November 2016**.

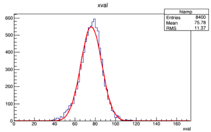


Test system with LED driver from Sofia

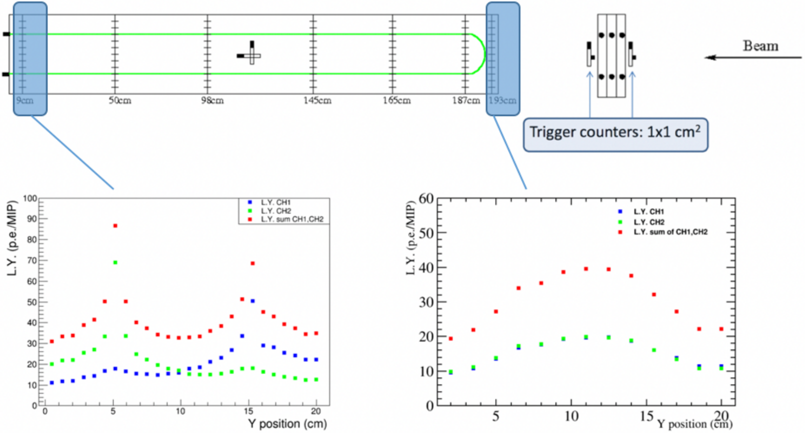
- Every sci. bar is tested at INR before shipping with cosmic ray setup.
- Every sci. bar is tested at CERN after shipping with LED setup.





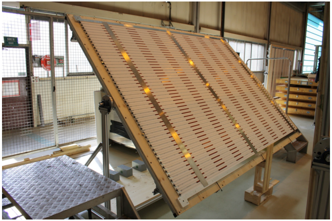


Beam tests at T9 summer 2016: vertical bars



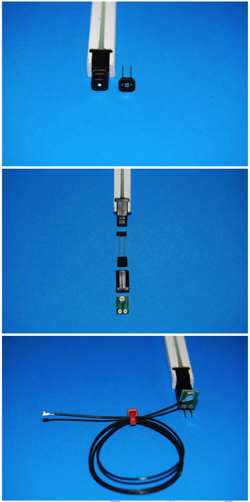
Scintillator module assembly

- Two half-modules assembled separately.
- Each half-module: 1 horizontal + 1 vertical plane:
  - 95 horizontal bars: 3000 x 31 x 7.5 mm^3
  - 8 vertical bars: 1950 x 210 x 7.5 mm^3
- Scintillators held together mechanically (no glue) within aluminium support frame.



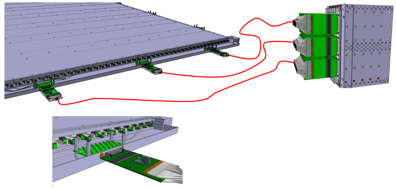
Photosensors and connectivity

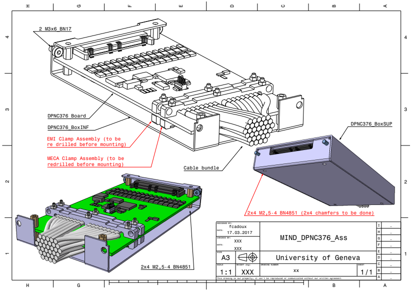
- Photosensor characteristics:
  - Hamamatsu MPPC S12571-025C (and derived S10943-5796).
  - 1×1 mm^2 (65% fill factor).
  - 25 μm cell size.
  - Operating voltage $\sim$ 67.5 V.
  - PDE $\sim$ 35%.
  - Gain 5×10^5.
  - Dark counts 100 kcps typ.
- Custom connectors.
  - Designed by INR.
  - Alignment of MPPC and coupling to WLS fiber.
  - Small pcb with UFL connector.
  - Coax cable: I-PEX 0.5 m length to cable bundle.



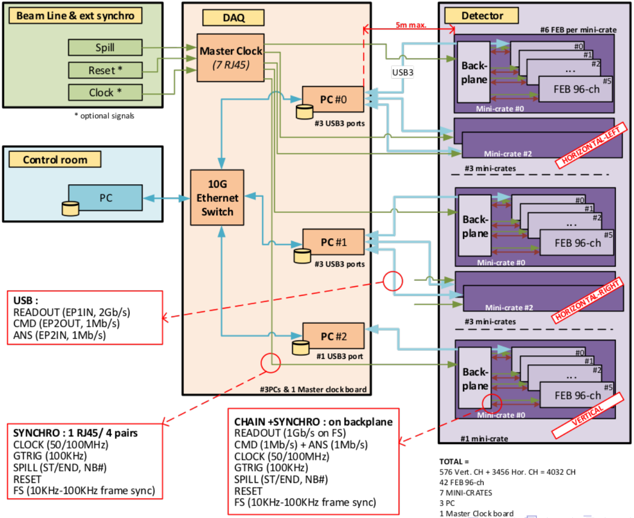
Cable bundles

- Design principle:
  - Decouple electronics Front End Boards from scint. modules.
  - Better accessibility and maintainability.
  - 5 m extension between photosensors and FEB.
  - No amplification before FEB.
  - Control of MPPC HV ch-by-ch on bundle PCB close to scint. module.
- Production Timeline:
  - Option chosen October 2016.
  - Validation December 2016.
  - Production April 2017.





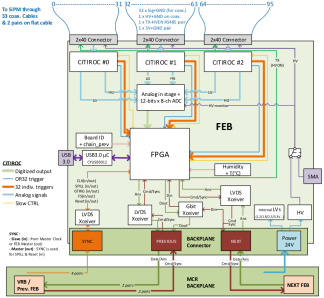
Electronics readout scheme

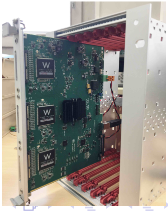


TOTAL =
576 Vert. CH + 3456 Hor. CH = 4032 CH
42 FEB 96-ch
7 MINI-CRATES
3 PC
1 Master Clock board

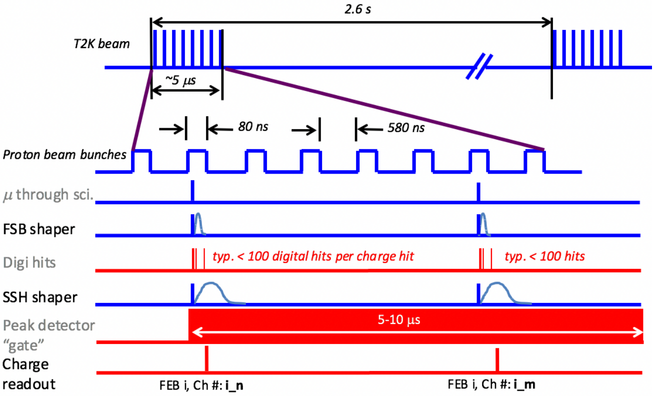
Custom electronics Front End Board

- Features of the Front End Board:
  - Rack mounted.
  - $\times$3 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.
    - 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 DAQ:
  - Analog readout + slow control on USB.
  - Platform independent readout. Windows/Linux.



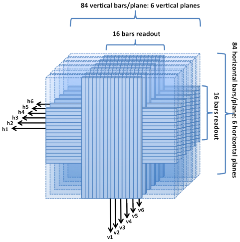


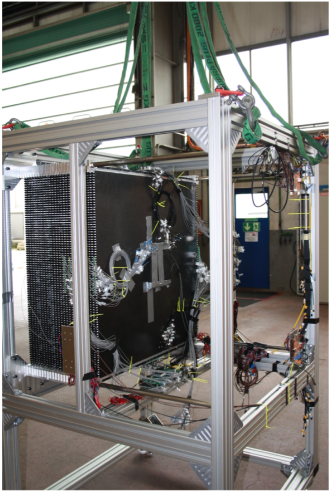
CITIROC peak detector gate



Beam tests at T9 summer 2016

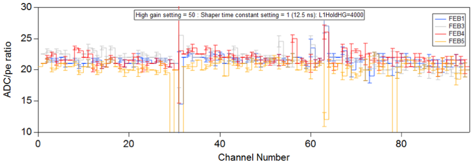
- FEB characterization online:
  - 4 FEBs.
  - 384 MPPCs.
  - Scintillator modules developed under AIDA project.
- Tests of FEB functionality:
  - Calibration.
  - Analogue readout.
  - Time-over-threshold.

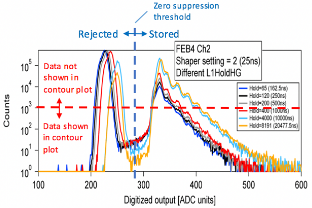


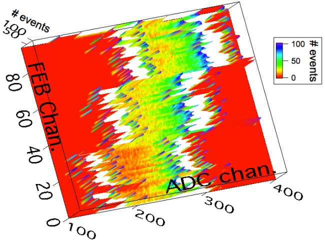


FEBv1 at T9 summer 2016: calibration

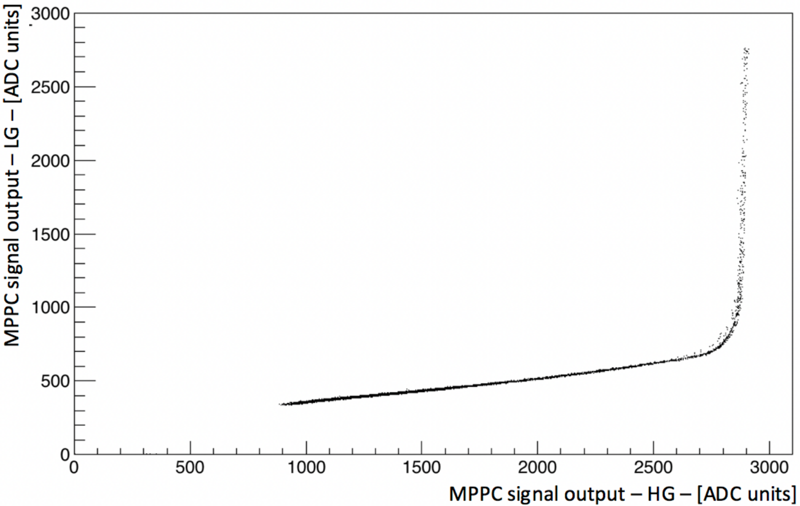
- MPPC signal calibration:
  - Pre-selection of MPPCs with Vop = nominal $\pm$ 100 mV.
  - Gain $\sim$ 20 ADC/p.e.
  - FEBv1 dynamic range HG $\sim$ 120 p.e.
- Zero suppression:
  - 3 ASICs on each FEB require different thresholds.
  - Localization of true baseline.







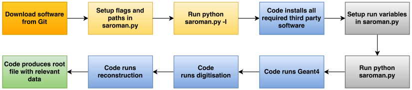
FEBv1 at T9 summer 2016: Low Gain calibration

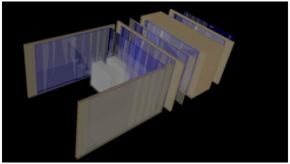


Block 1 (of 4) load tests: March 2017: 20 t

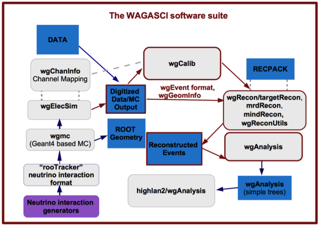
Two software environments

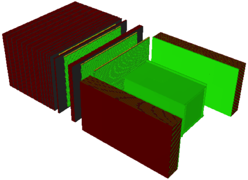
- The SaRoMan (Simulation And Reconstruction Of Muons And Neutrinos) package, derived from Neutrino Factory and nuSTORM studies.



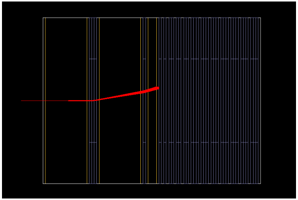


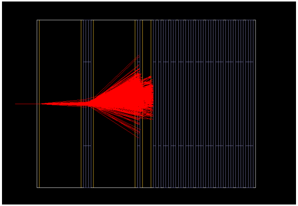
- The WAGASCI-Baby MIND package, derived from the T2K ND280 software suite.

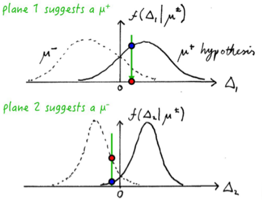


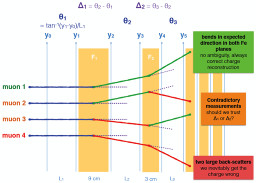


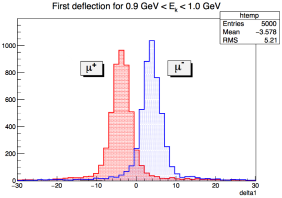
Low momenta: Lever Arm vs Multiple Scattering









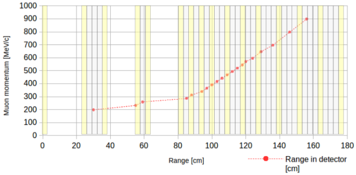


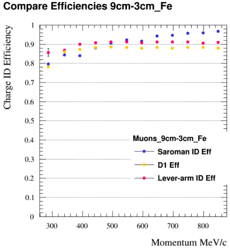
$$Rec\ as\ \mu^-\ if\ \frac{f_{\mu^-}(\Delta_1)}{f_{\mu^+}(\Delta_1)} > \frac{f_{\mu^+}(\Delta_2)}{f_{\mu^-}(\Delta_2)}$$

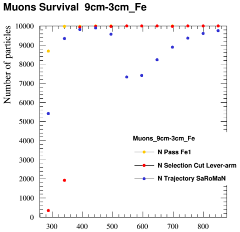
$$Rec\ as\ \mu^+\ if\ \frac{f_{\mu^+}(\Delta_1)}{f_{\mu^-}(\Delta_1)} > \frac{f_{\mu^-}(\Delta_2)}{f_{\mu^+}(\Delta_2)}$$

Lever Arm charge identification

- 300 MeV/c to 450 MeV/c: use the deflection angle after the first magnet stack only.
- 450 MeV/c to 1 GeV/c: use the Lever-Arm algorithm.
- Above 1 GeV/c: use RecPack.

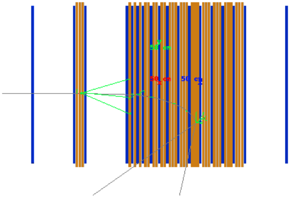


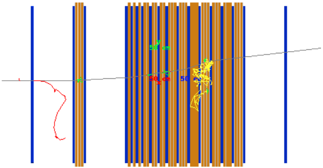


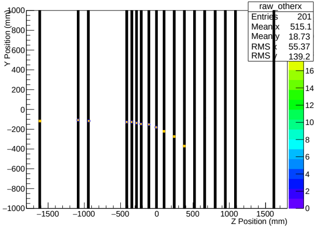


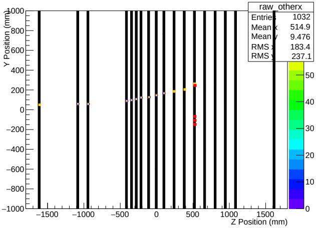
SaRoMan event topologies: 1 GeV μ^+ & 1 GeV μ^-

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







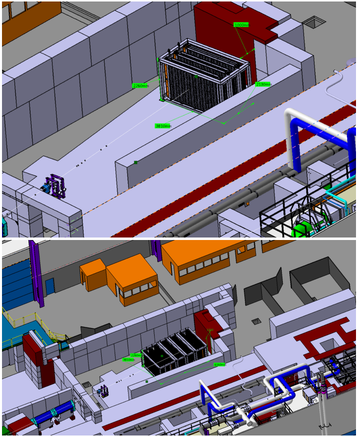


Project milestones

- **Electronics Front End Board** beam test at T9 in **June 2016**.
- **First** complete **Baby-MIND module** in **October 2016**.
- **Delivery** of all **scintillators** by **November 2016**.
  - *Was end Q1 2017 in October 2015 schedule*
- **Magnet modules** ready end of **February 2017**.
- **Detector modules** ready end of **April 2017**.
- **Beam tests** characterization at T9 in **May 2017 - Block 1**.
- **Beam tests** full detector at T9 in **June 2017**.
- **Shipment** to **Japan** in **July 2017**.
- **Installation** in Japan **ND280 pit** in September for operation in **October 2017**.

Beam tests at CERN

- **Beam tests 2016**: 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. 3 weeks: 31st May to 21st June. Tests of full detector: 33 magnet modules, 18 scintillator modules.
- **Removal from T9**: we plan to dismount the Baby MIND and pack it for transport to Japan over $\sim$ 3 days around 21st June 2017.



Summary

- **AIDA-2020: 2 PhD students active on Task 8.6 on magnetization.**
- **NP05 Baby MIND project status** Novel magnetization scheme applied to the construction of the Baby MIND magnet modules. The Baby MIND is a CERN Neutrino Platform project. It will be tested on a beamline at the PS at CERN before taking physics data on the T2K beamline in Japan.
- **Magnet modules**: the novel design, with each having its own coil, enables far greater flexibility in detector layout compared with previous designs for this type of detector. 33/33 magnet modules constructed.
- **Scintillator modules**: Scintillator bars by INR. 9/18 modules assembled.
- **Electronics**: Front End Board redesigned, integrating feedback from 2016 T9 beam tests, and new cabling scheme. Production of $\sim$ 50 FEBs underway.
- **Cable bundles**: Photosensors connected to FEBs via 5 m, 32-ch extension cable bundles. Production of $\sim$ 150 bundles underway.
- **Support mechanics and logistics**: Support frames for beam tests at T9 CERN, and for transport J-PARC. Reduction of installation and removal times at T9.
- **Installation in Japan**: Support mechanics concept takes into account access constraints due to the pit shaft. Discussion ongoing with Japanese colleagues.
- **Physics simulations**: Active updates of SaRoMan package, its track reconstruction module was tested partially with 2016 beam test data.