Commissioning of the Baby MIND detector

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Speaker

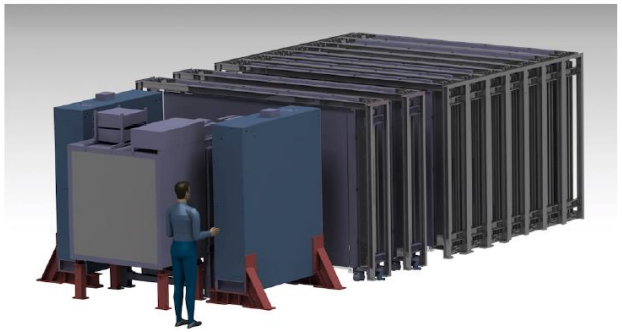
Prof. Alain Blondel (University of Geneva)

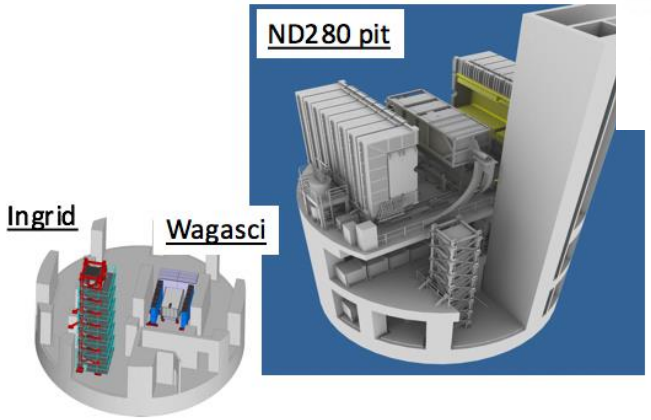
Description

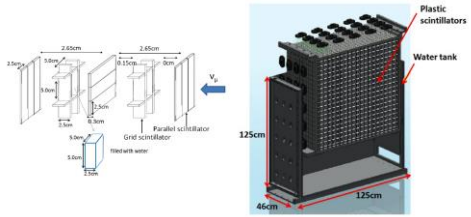
The Baby MIND (Magentized Iron Neutrino Detector) is characterized by its original magentization design, as well as by the presence of air gaps allowing muons to be reconstructed down to 300 MeV/c and their charge identified. The detector was completed, assembled and tested at the neutrino platform at CERN, and delivered to the T2K ND280 pit in December 2017. First results from test beam at CERN and commissionning in the neutrino beam at T2K will be presented.

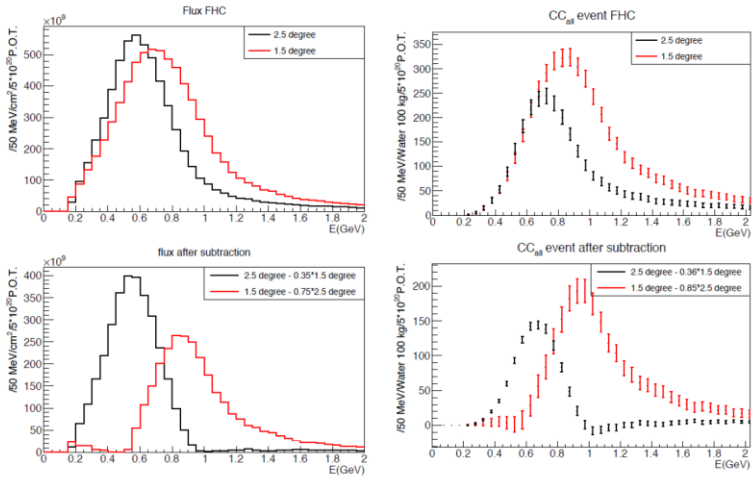
Motivation for WAGASCI/Baby MIND

- Measurement of differential cross-sections for charged-current interactions on H_2O and CH.
- Water-scintillator mass ratio is 4:1
  - high purity measurement of σ on H_2O.
  - Water removed from one module enables high purity measurement on CH with low momentum threshold for protons, also subtraction of CH background from water-in data.
- Addition of T2K proton module provides high statistics comparison of σ between H2O and CH.
- Comparison with ND280 measurements enables model-independent extraction of σ for a narrow energy spread.





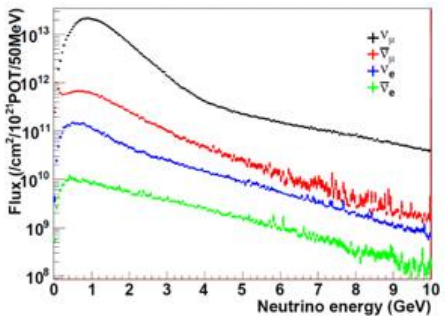


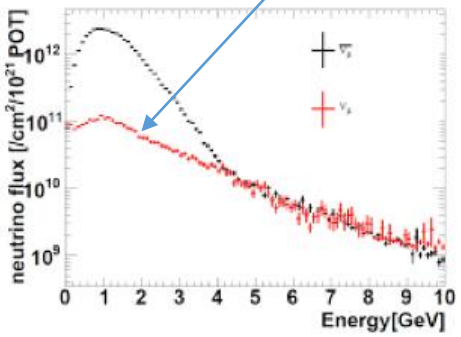


Wrong-sign background estimated from charge identification in Baby MIND

$$\sigma_{CC} = \frac{N_{sel} - N_{BG}}{\phi T \epsilon}$$

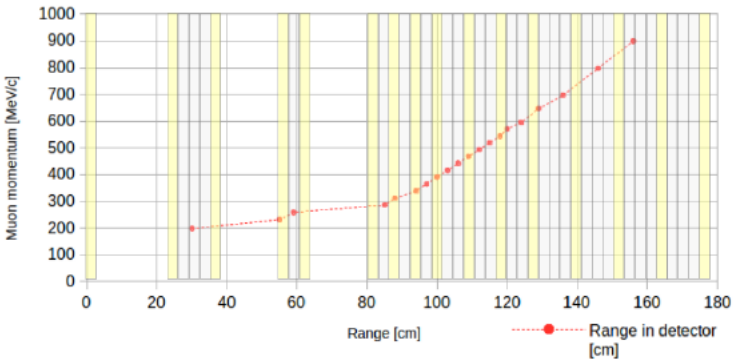
Neutrino flux at WAGASCI (1.6° off-axis)





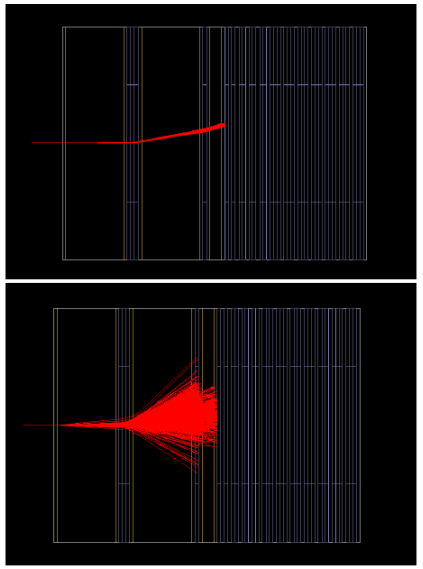
Charge identification

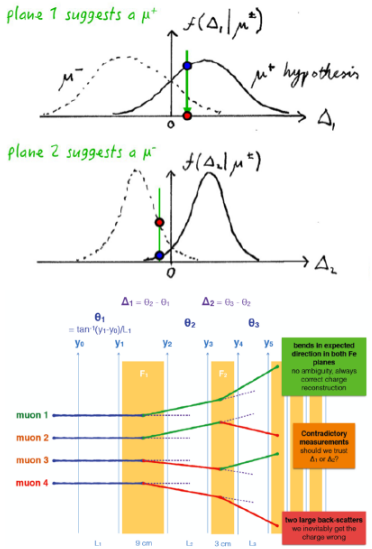
- Depending on muon momentum, use different algorithms to identify charge:
  - 300 MeV/c to 450 MeV/c: Use deflection angle after the first steel stack.
  - 450 MeV/c to 1 GeV/c: Use lever arm algorithm.
  - Above 1 GeV/c use RecPack or custom algorithm.

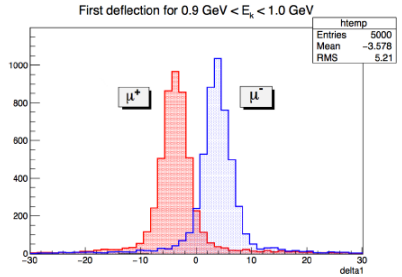


Older layout for illustration

Low momenta: Lever Arm vs Multiple Scattering







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

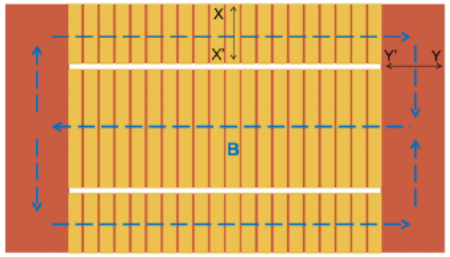
$$\text{Rec as } \mu^+ \text{ if } \frac{f_{\mu^+}(\Delta_1)}{f_{\mu^-}(\Delta_1)} > \frac{f_{\mu^-}(\Delta_2)}{f_{\mu^+}(\Delta_2)}$$

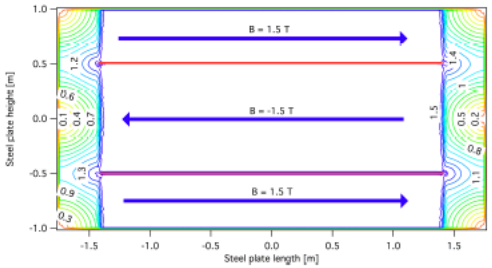
Magnet design

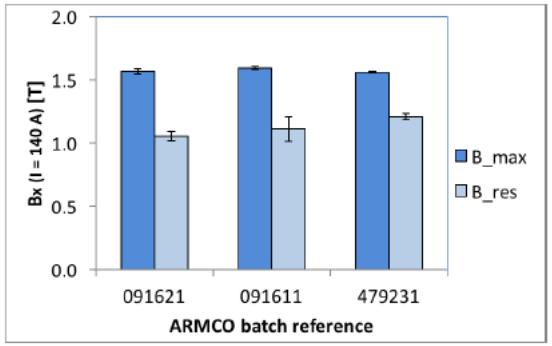
[G. Rolando et al., IEEE Trans. Mag. (53) 2017, 5]

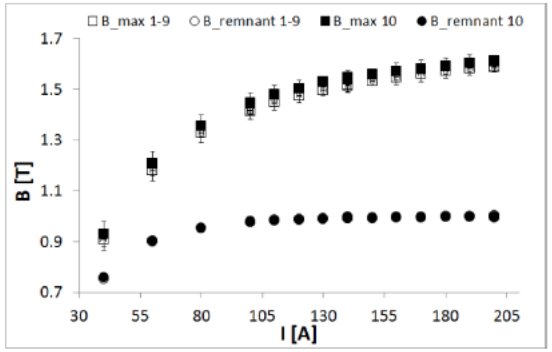
- Design principles (modular approach):
  - Individually magnetized iron (ARMCO) plates.
  - Homogeneity of B-field in central zone: B = Bx.
  - Dimensions:
  - 3500 × 2000 × 50 mm^3 (30 mm steel).
  - 10 mm-wide slits (water jet).
  - 10 mm-thick flux return plates × 4.
  - Aluminium coil: 50 mm wide × 4 mm thick

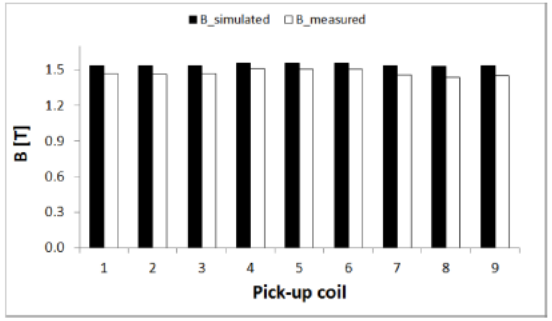
- Test measurements:
  - Field > 1.5 T for nominal current 140 A.
  - Power for all modules: 10 kW.
  - Stray fields < 10 mT on surface of steel.







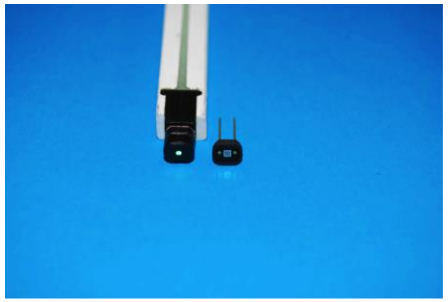


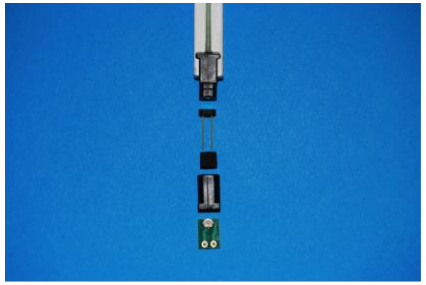


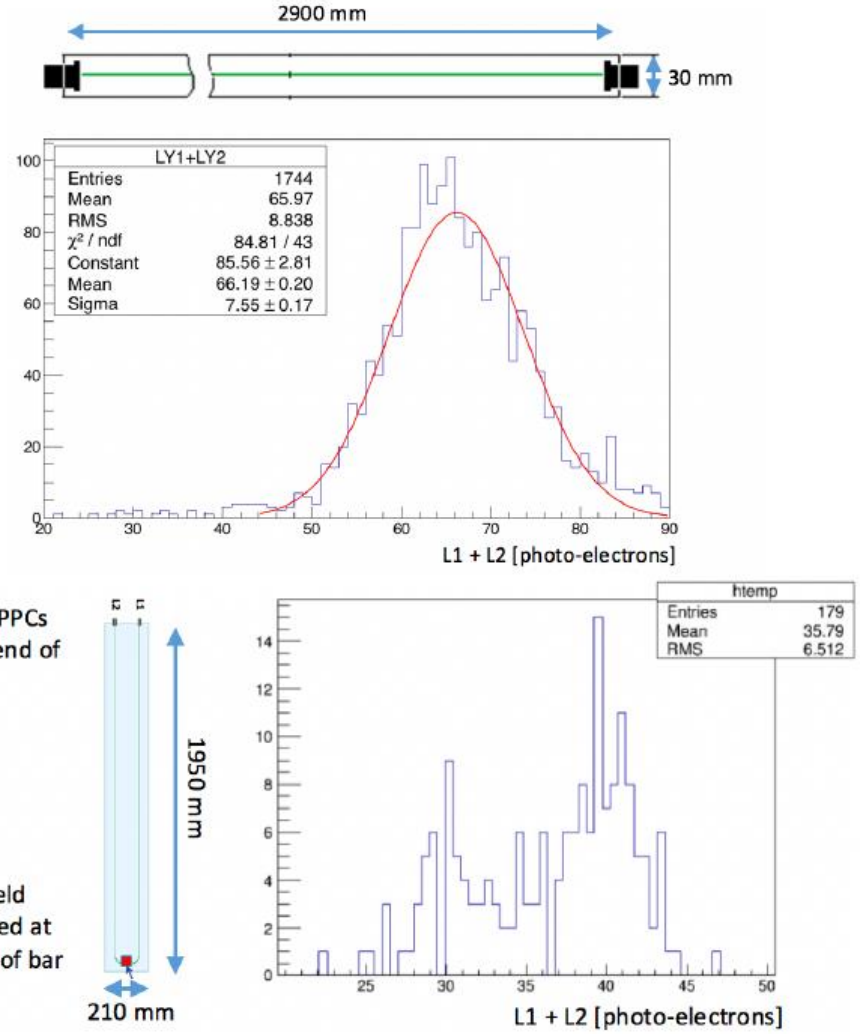
Scintillator bars and optical connectivity

[A. Mefodiev et al., arXiv:1705.10406v3]

- Bars 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.
- Photosensor characteristics:
  - Hamamatsu MPPC S12571-025C.
  - 1 × 1 mm^2 (65 % fill factor).
  - 25 mm cell size.
  - Operating voltage ~ 67.5 V.
  - PDE ~ 35 %.
  - Gain 5 × 10^5.
  - Dark counts 100 kcps.

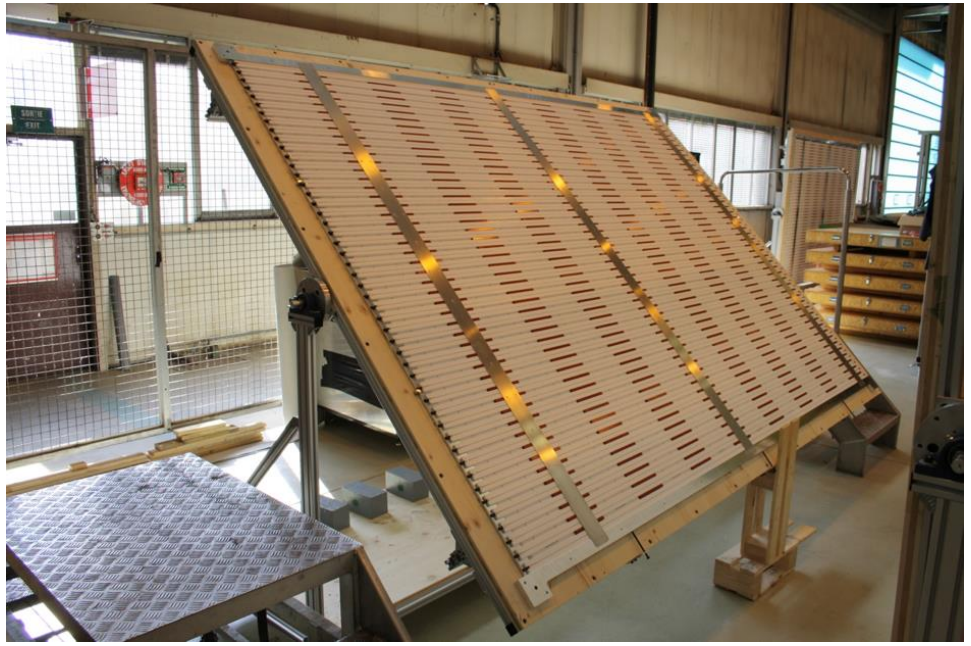






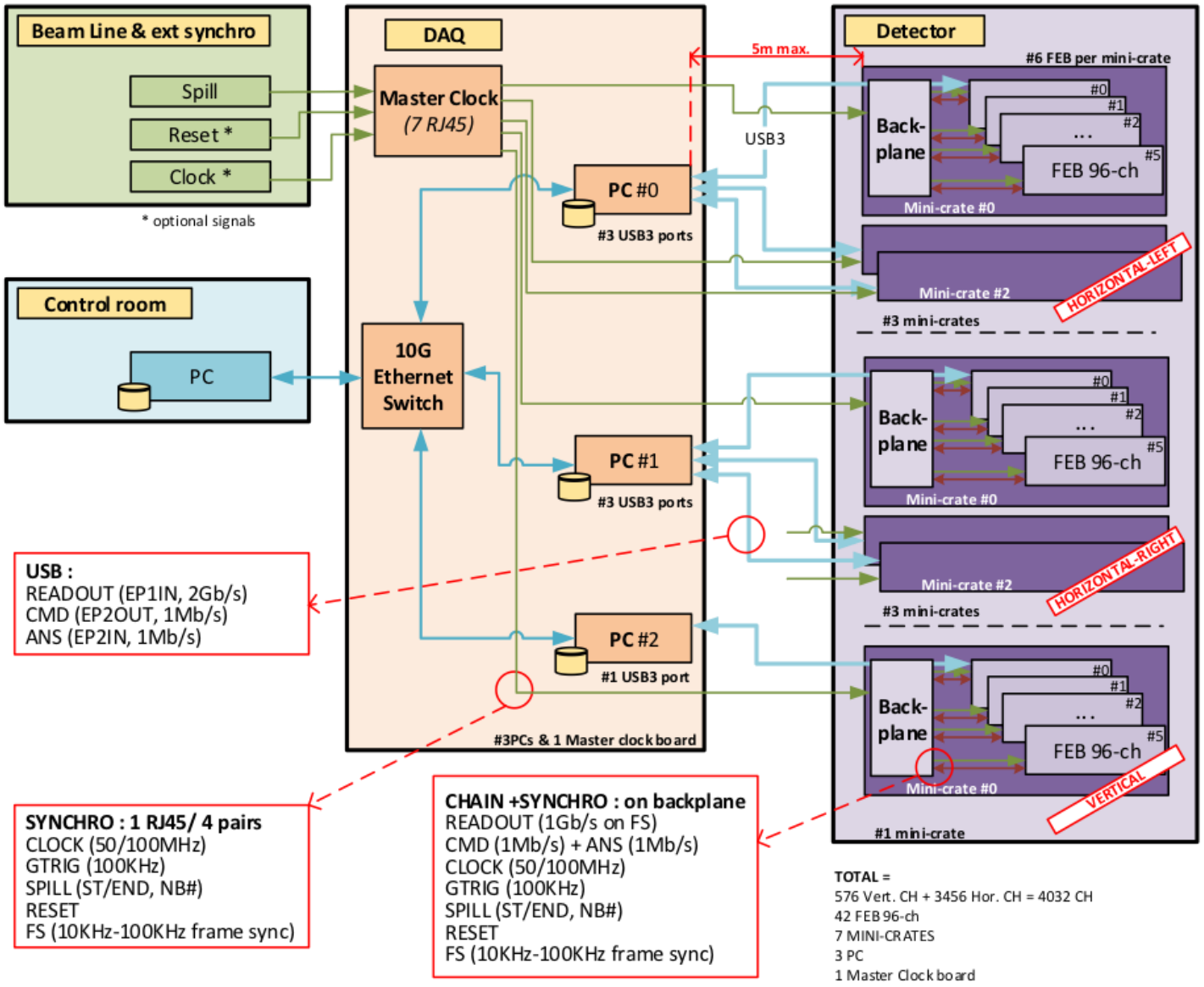
Scintillator modules

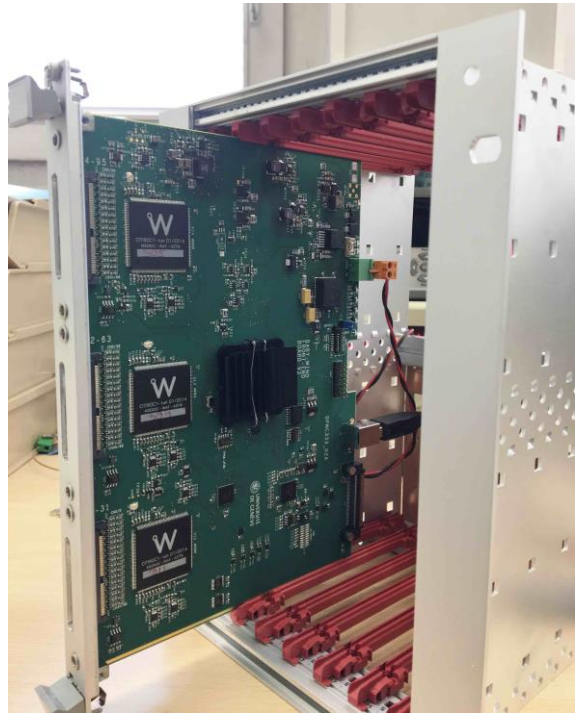
- Scintillator module assembly:
  - 18 scintillator modules.
  - Two half-modules assembled separately.
  - Each half-module: 1 horizontal + 1 vertical plane.
  - Bars per modules:
    - 95 horizontal bars: 3000 × 31 × 7.5 mm^3.
    - 16 vertical bars: 1950 × 210 × 7.5 mm^3.
  - Scintillators held together mechanically (no glue) within aluminium support frame.



Readout electronics

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





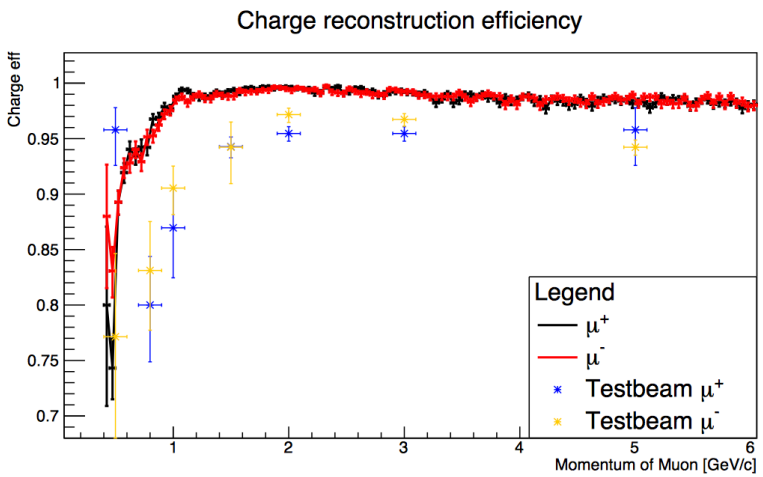
Custom readout board designed for Baby MIND

Beam tests at CERN: summer 2017

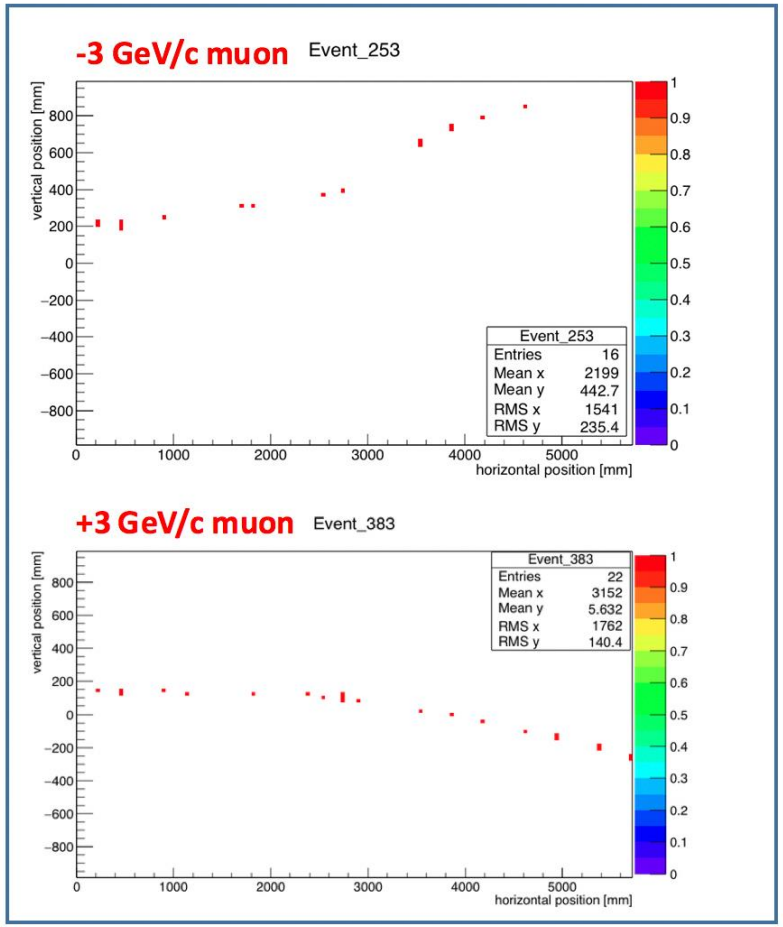
[E. Noah et al., PoS EPS-HEP2017]

Particle type: $\mu^{+/-}$, $\pi^{+/-}$, $e^{+/-}$, p.
Momentum selection: 0.5 to 5 GeV/c.

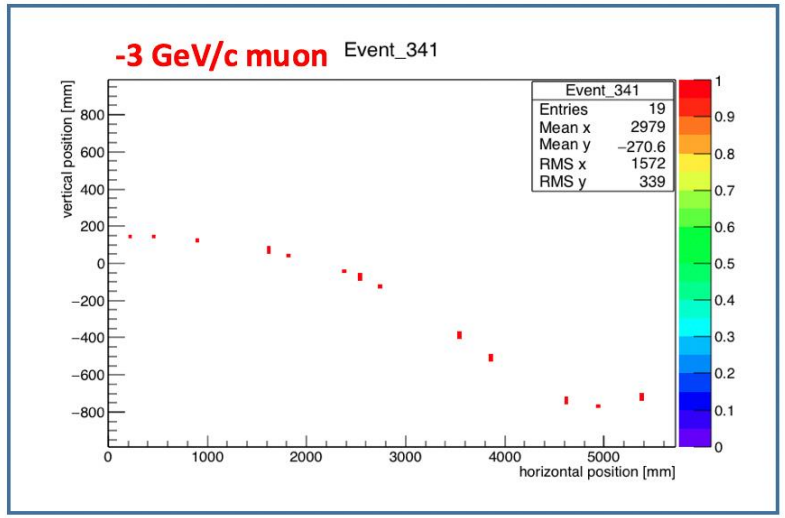
[S-P. Hallsjö et al., Proc. NuFACT 2017]

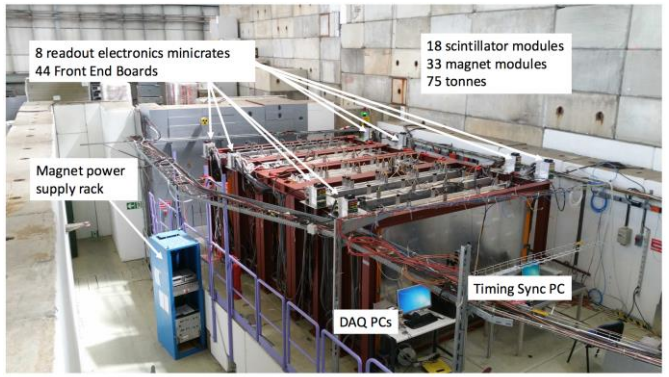


Magnet in forward current mode

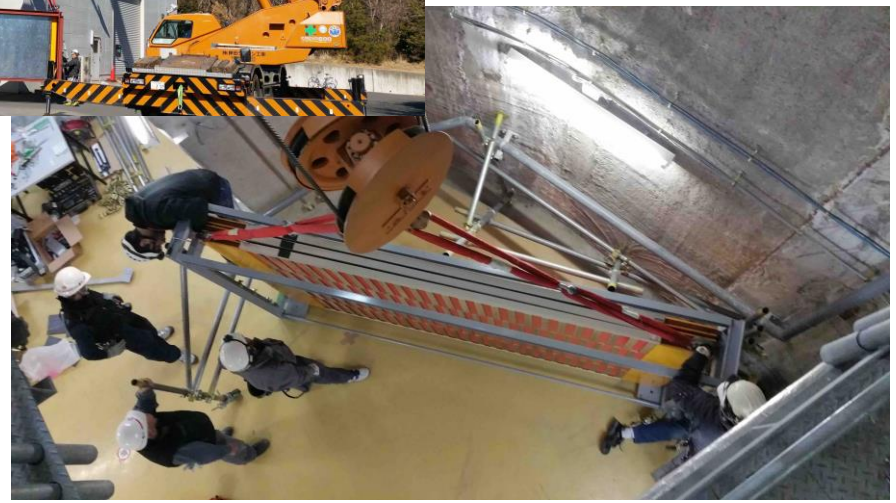


Magnet in reverse current mode

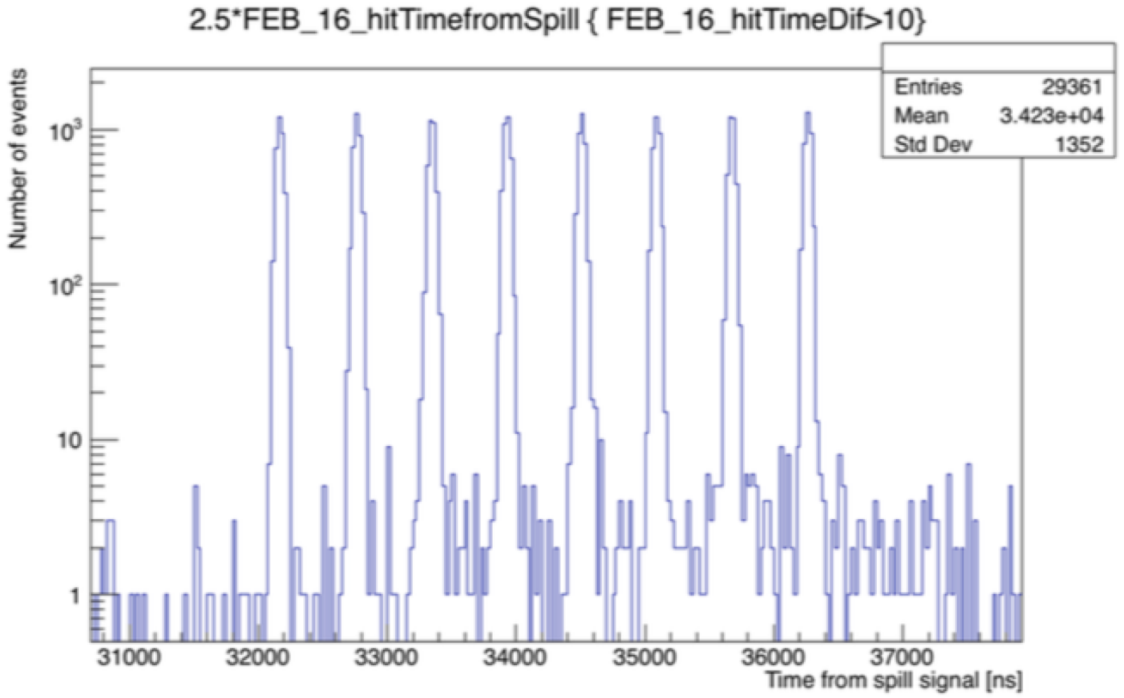




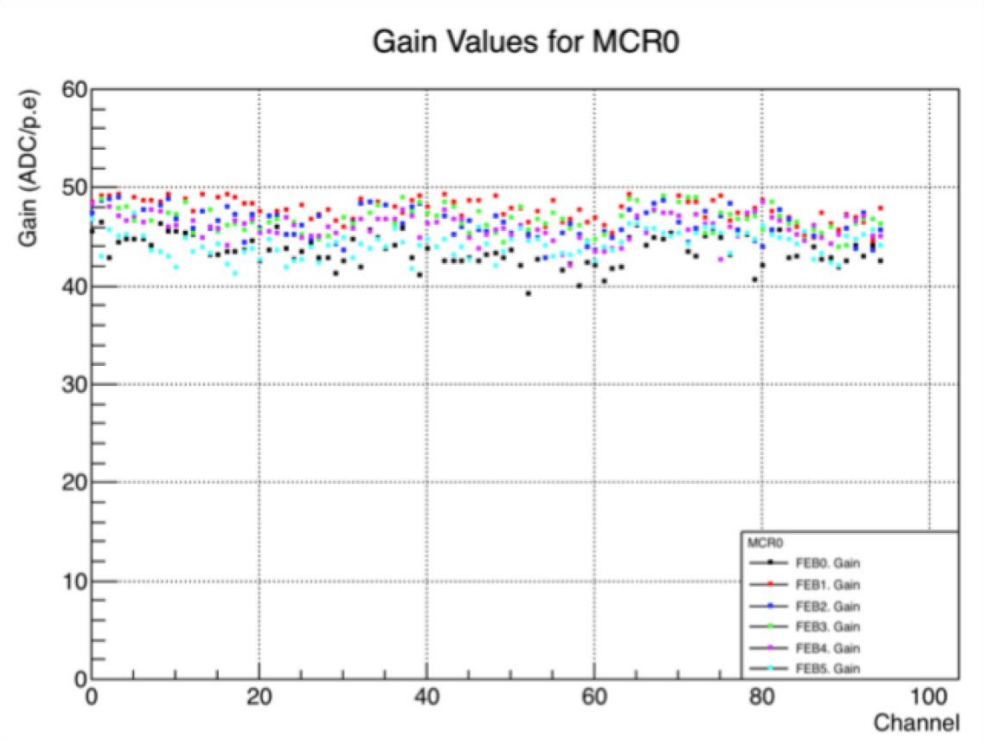
Transport and installation at J-PARC



Electronics performance



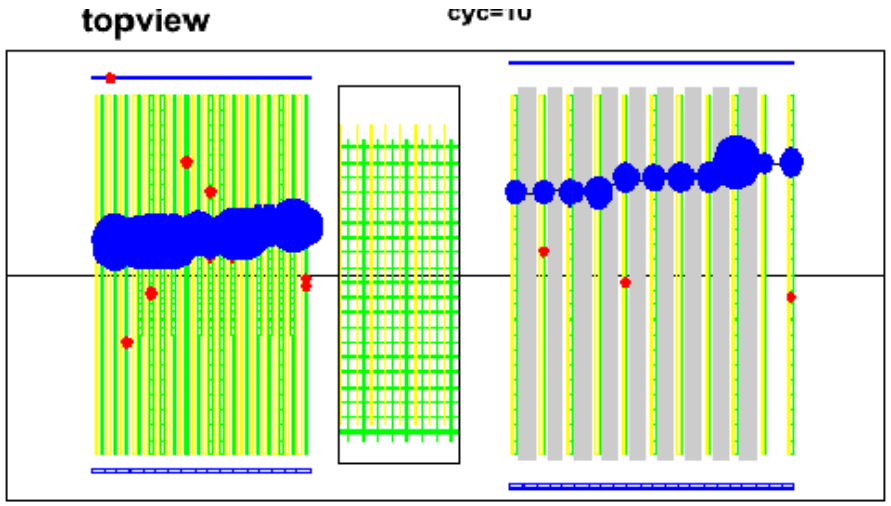
Hit timing information reproduces T2K beam spill time structure:
Good synchronisation of the Baby MIND readout electronics with the T2K beam.

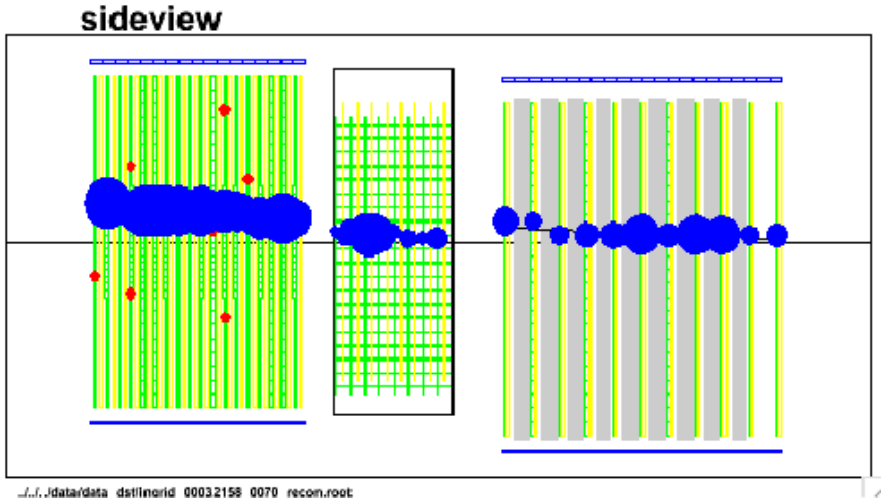


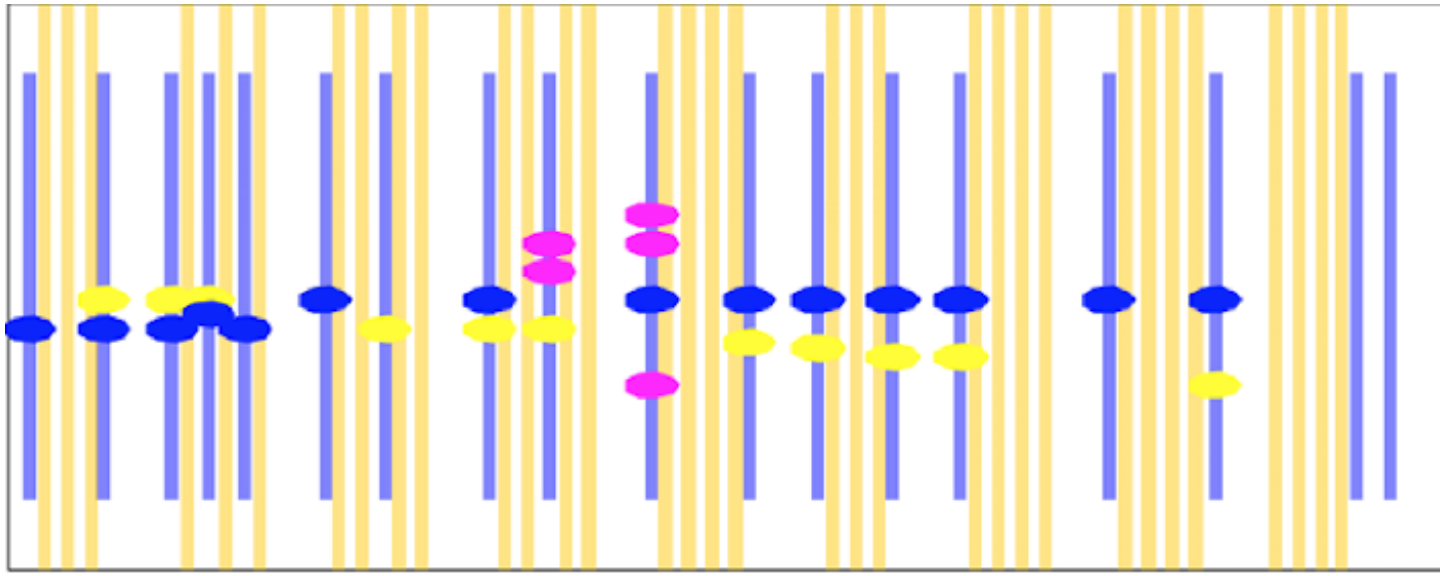
Calibration measurements straightforward.
Gain spread could be improved.

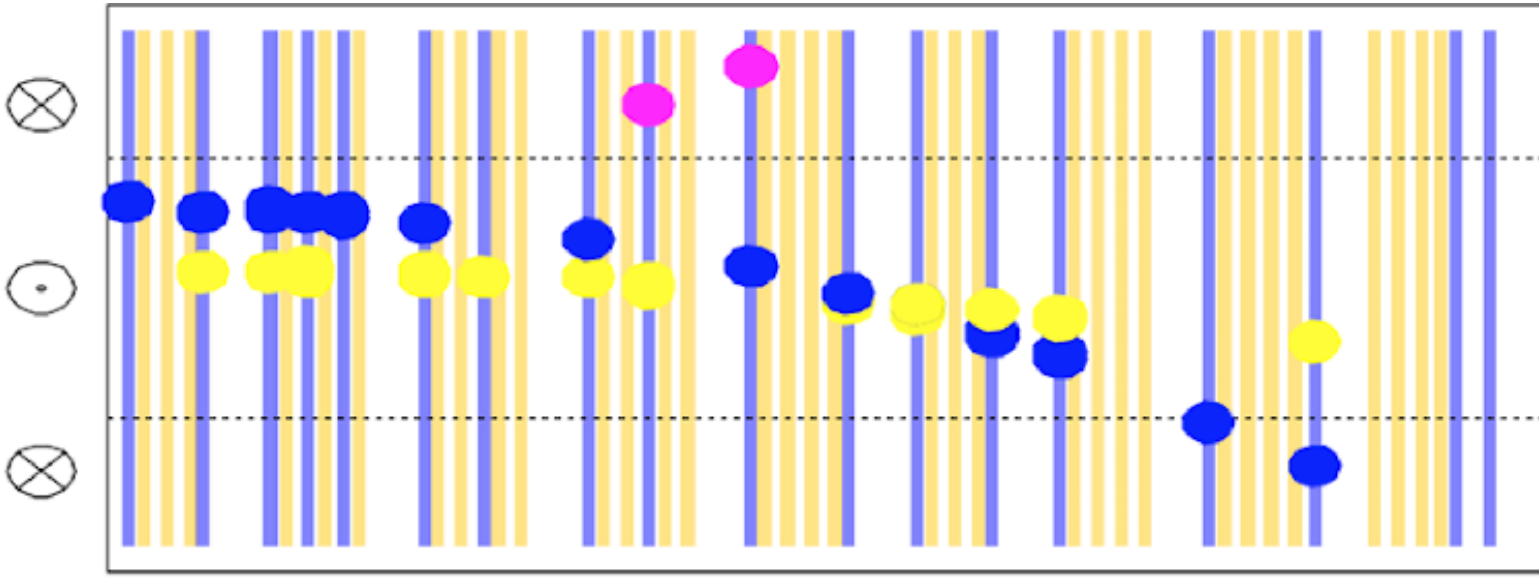
Track matching

Friday 4th May 2018 19:27 JST









Proton module

WAGASCI

INGRID

Baby MIND