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A test experiment to measure sub-GeV flux in the on-axis direction at the J-PARC neutrino beam

Presented by Takaaki Kajita,
for the Bern-Lyon-Tokyo group

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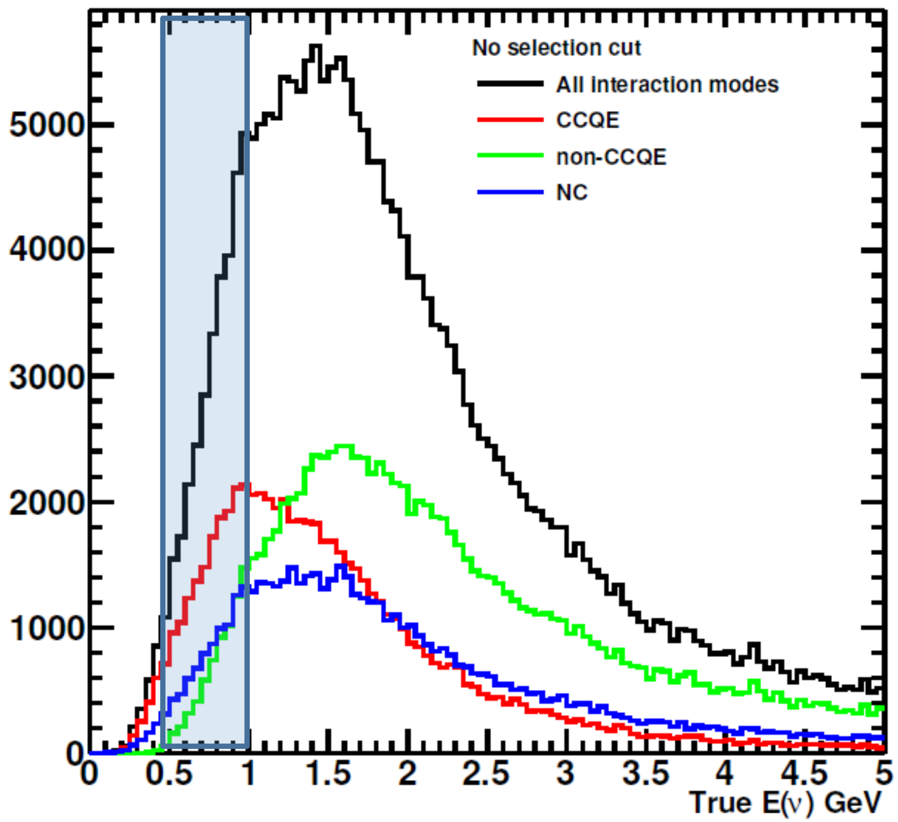
Motivation

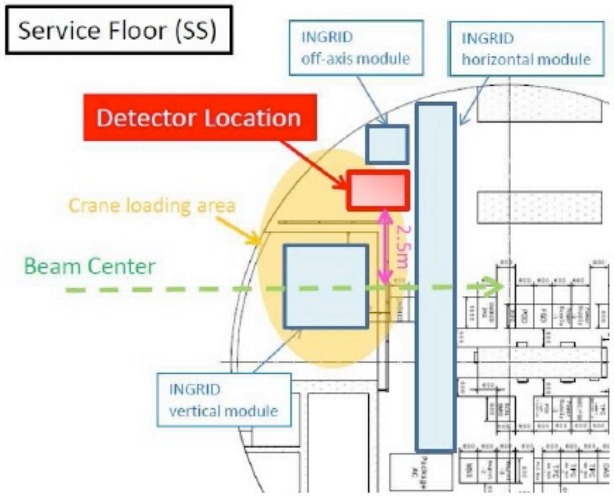
- Test experiment to measure Sub-GeV neutrino flux with a simple detector system
- Provide information on sub-GeV, on-axis neutrino flux
  - No other existing detector covers this energy region.
- Flux information should be useful for T2K and other future experiments with the J-PARC neutrino beam.

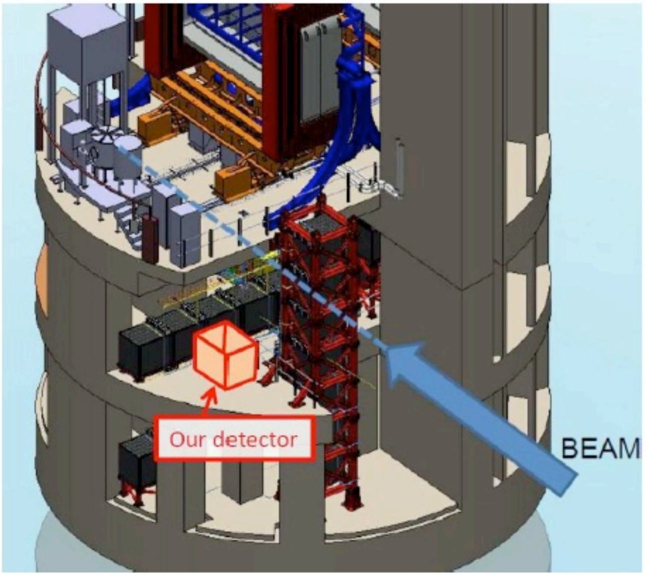


(The on-axis sub-GeV flux contributes more than 50% of the 2.5 degree off-axis sub-GeV flux.)

Location of the detector

ND280 hall, service stage:





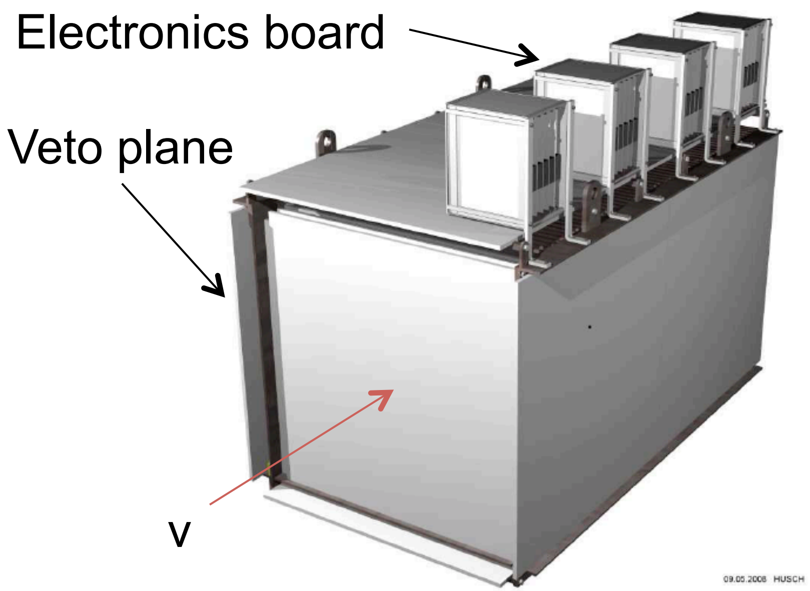
- Candidate location is in front of INGRID.
- The off-axis angle is 0.5 degree.
- The detector can be installed easily with the 10 ton crane of the hall.

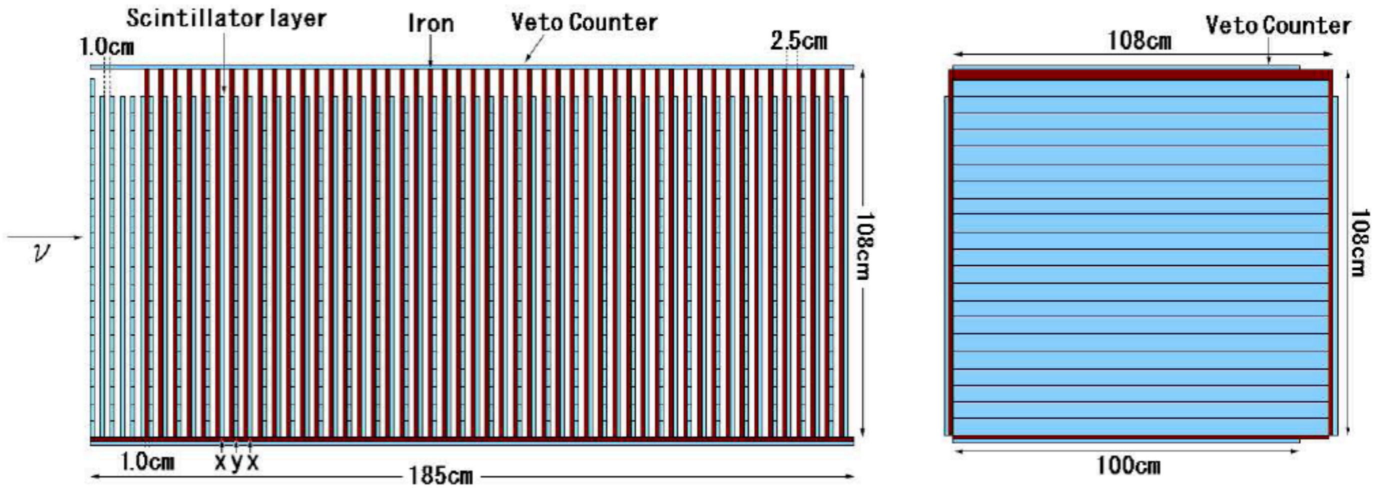
INGRID
- T2K on-axis ν detector
- Sensitive to beam direction
- Covers higher energy region

Detector design

Tracking detector with scintillator bars

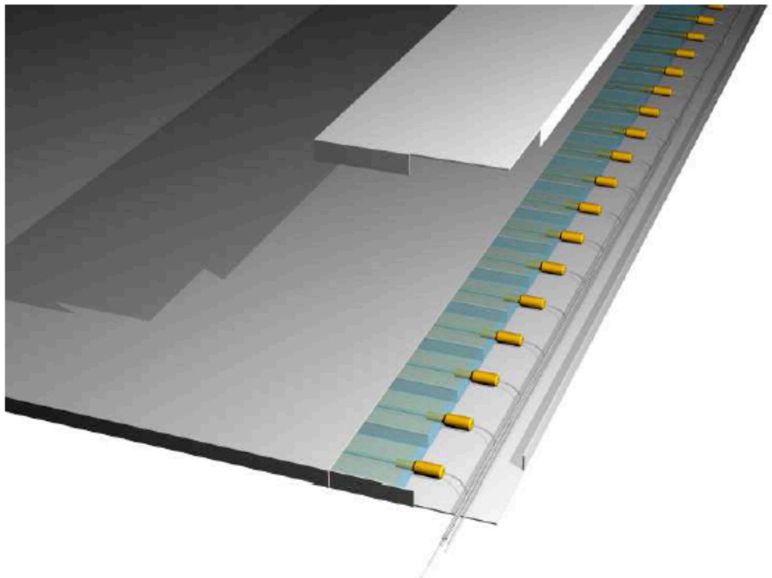
- Designed to detect muons induced by ν_μ CC interaction
- 108cm×108cm×185cm
- 56 scintillator layers and 50 iron plates (1cm thick)
- Surrounded by 6 veto planes

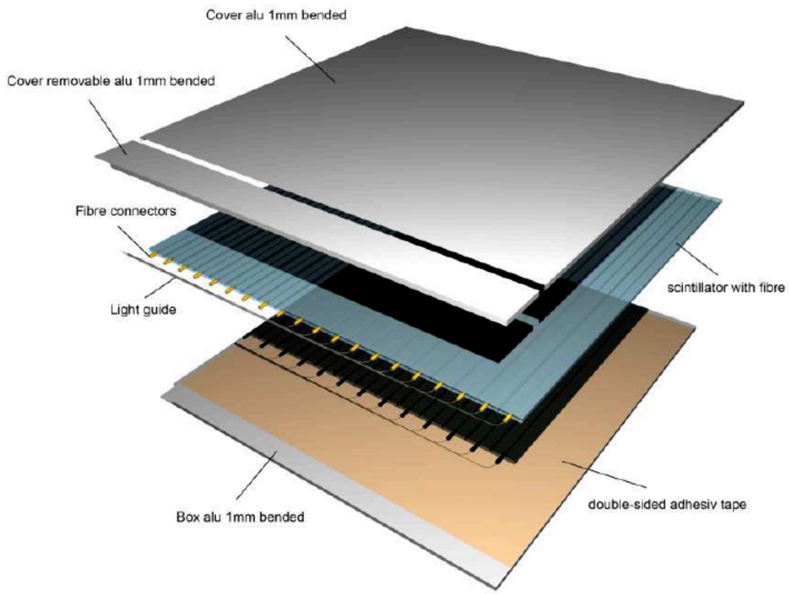




Counter plane

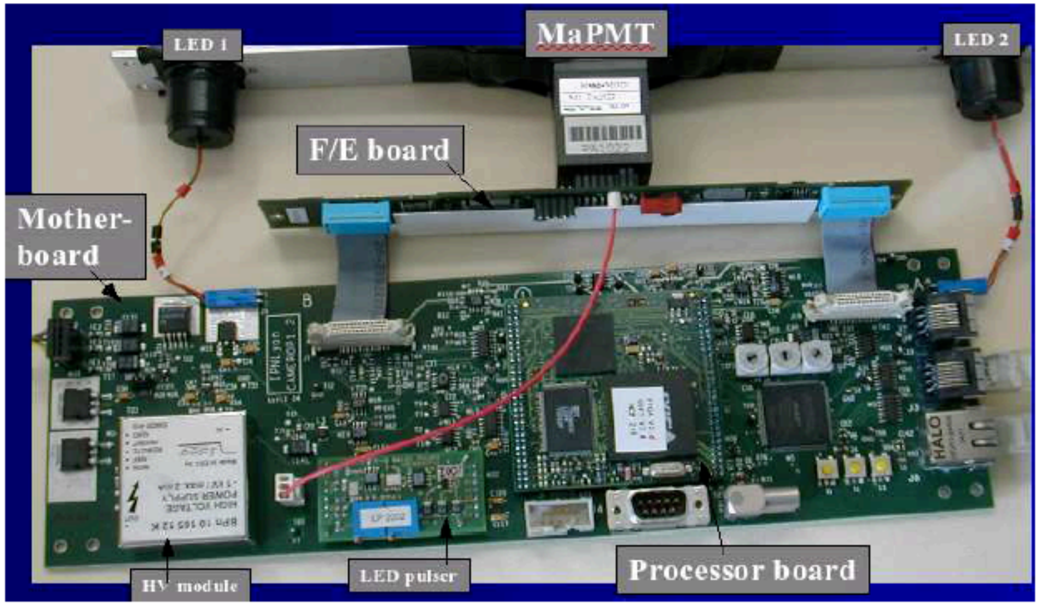
- Consists of 20 scintillator bars ($5\times1\times100cm^3$)
- Scintillation light is guided to PMTs by WLS and clear fibers.
- light tightness and mechanical rigidity are provided by double sided scotch strips and aluminum sheets.





DAQ system

- 64 channel multi-anode PMT (H8804MOD-1) is used for photo sensor.
- Followed read-out system (consists of two 32-channel ASICs)
  - Fast ADC with timing resolution of ~10ns
  - LED pulse generator for self-calibration
  - Ether-net connection with the DAQ machine
- This system is used in the OPERA experiment (@Gran Sasso), and well established with their long term operation.



Event selection

- Monte Carlo (Geant 4) simulation is performed to understand the detector response.
  - We generated neutrino interaction data using the on-axis beam flux.
- Following cuts are used to select CC (QE) events:
  - Nhitlayer >=5
  - No VETO hit
  - In fiducial volume
  - Reject single proton track by dE/dx
  - Reject multiple track events
  - P(μ-assumption) > 250 MeV/c

No VETO hit, In fiducial volume: Reject muons from outside

Reject single proton track by dE/dx ← Reject NC interactions

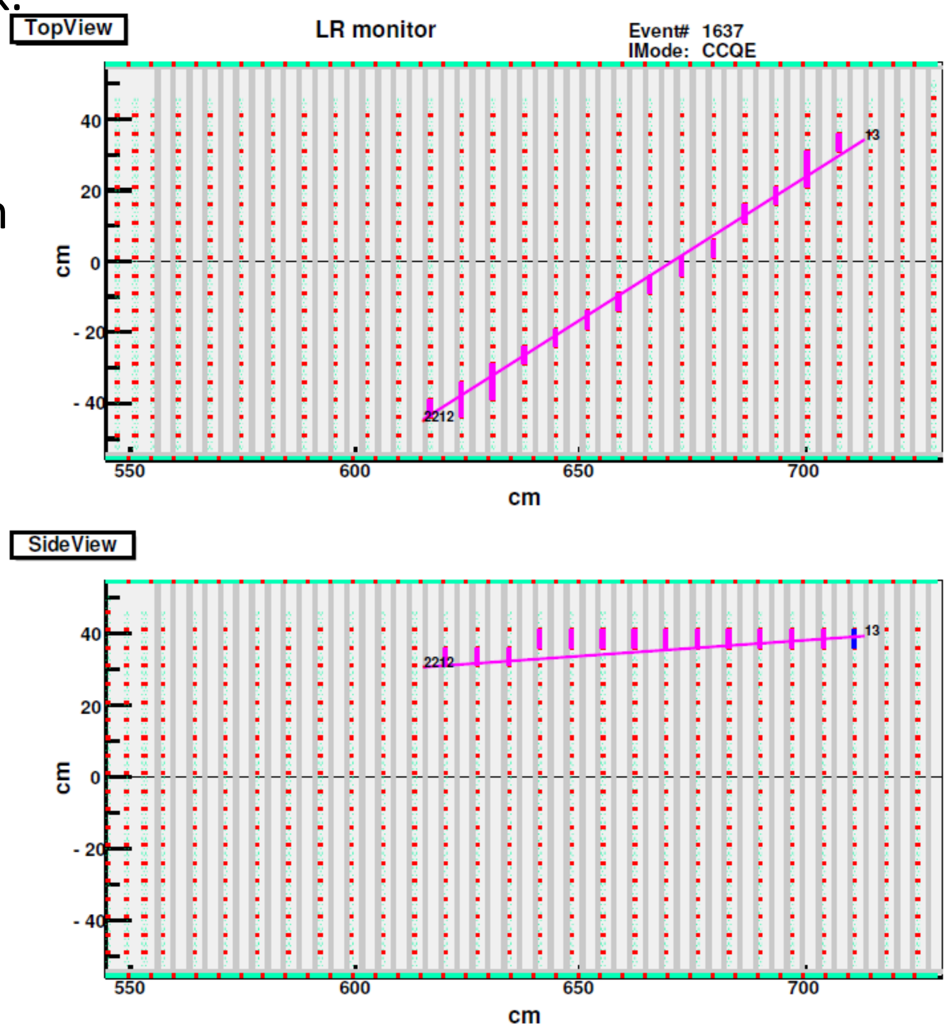
Reject multiple track events ← Rejects CC non-QE interactions

P(μ-assumption) > 250 MeV/c ← Reject NC interactions

Typical CCQE event

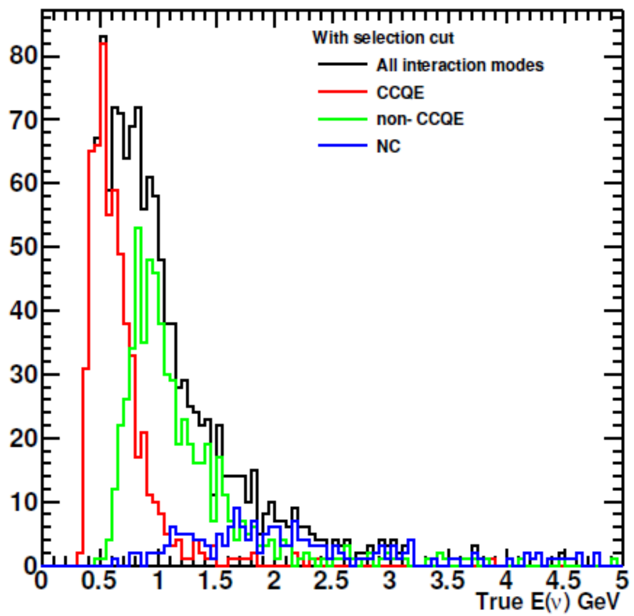
- Typical CCQE has only one long track.
    - Muon track is shown by pink line.
- Muon momentum is estimated from the number of hit layers.
- Initial neutrino energy, E_ν, is determined by the following formula:

$$E_\nu = \frac{1}{2} \cdot \frac{2M_p E_\mu - M_\mu^2}{M_p - E_\mu + \sqrt{E_\mu^2 - M_\mu^2} \cdot \cos\theta_\mu}$$

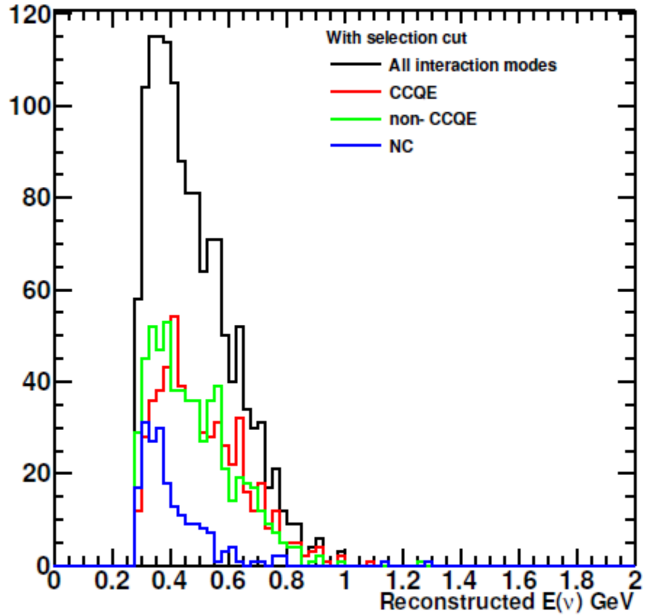


ν energy distribution

True neutrino energy

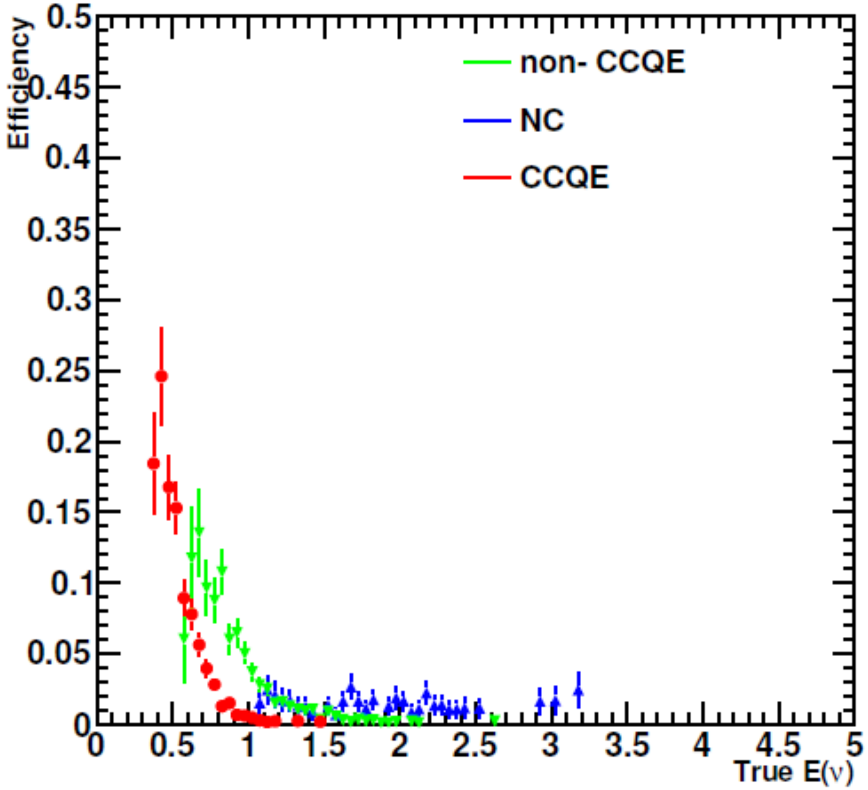


Reconstructed neutrino energy



- The distributions assume 100kW of beam power and 10^7 s of beam time.
- NC interactions from high energy neutrinos produce relatively long proton tracks. They are sometimes mis-identified as muons. However, reconstructed neutrino energies (assuming they are muons) are small in that case.
- In the reconstructed energy greater than 0.4 GeV region, most events are CC interaction and CC QE/non-QE ratio is ~ 1.

Energy acceptance



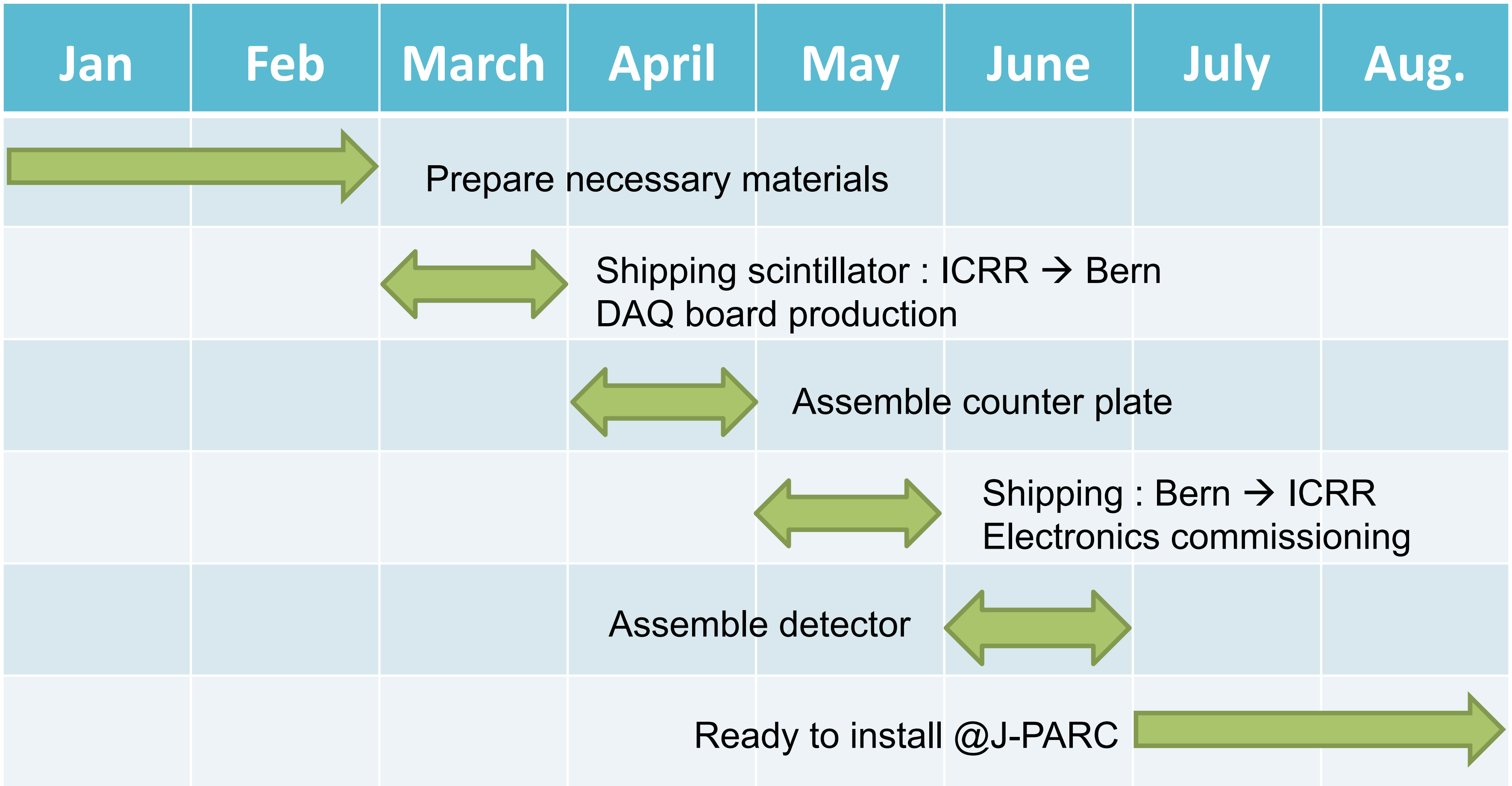
- Reasonable acceptance for CC QE events below 1 GeV and significant reduction for CC non-QE and NC events above 1 GeV

Expected number of events

	All	CC	CCQE	non-CCQE	NC
No cut	629900	471610	166446	305164	158290
$N_{HitLayer} \geq 5$	418758	365722	125709	240013	53036
No veto hit	57107	36505	11237	25268	20602
In FV	17614	10521	3191	7330	7093
Proton track	7144	5416	2054	3363	1728
Multi track	4127	3348	1578	1770	779
$P_{\mu} > 250\text{MeV}$	3412	2929	1431	1497	483
Efficiency	0.0081	0.0080	0.0114	0.0062	0.0091
Fraction	1.	0.8584	0.4194	0.4387	0.1416

- About 3400 events expected after reduction with 100 kW proton beam and 10^7 seconds of the running time
- Sufficient statistics (~ 2 % accuracy, statistical) will be obtained to measure the low energy neutrino events
- CC purity : 86 %

Schedule


Jan
Feb
March
April
May
June
July
Aug.
Prepare necessary materials
Shipping scintillator : ICRR → Bern
DAQ board production
Assemble counter plate
Shipping : Bern → ICRR
Electronics commissioning
Assemble detector
Ready to install @J-PARC

Beam time request

- We request 10^7 seconds of beam time under the assumption of 100 kW beam power.
- Obviously, if the beam power would be higher, the exposure time will be reduced accordingly.

Conclusion

- We propose a test experiment to measure low energy neutrino events with the J-PARC neutrino beam with a rather simple detector.
- The requested beam time is 10^7 seconds for the 100 kW beam power.
- The detector can be ready to installed in the summer 2010 in the ND280 pit.