Scintillating Tracker
Design overview

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DUNE ND Workshop
23 Oct 2019

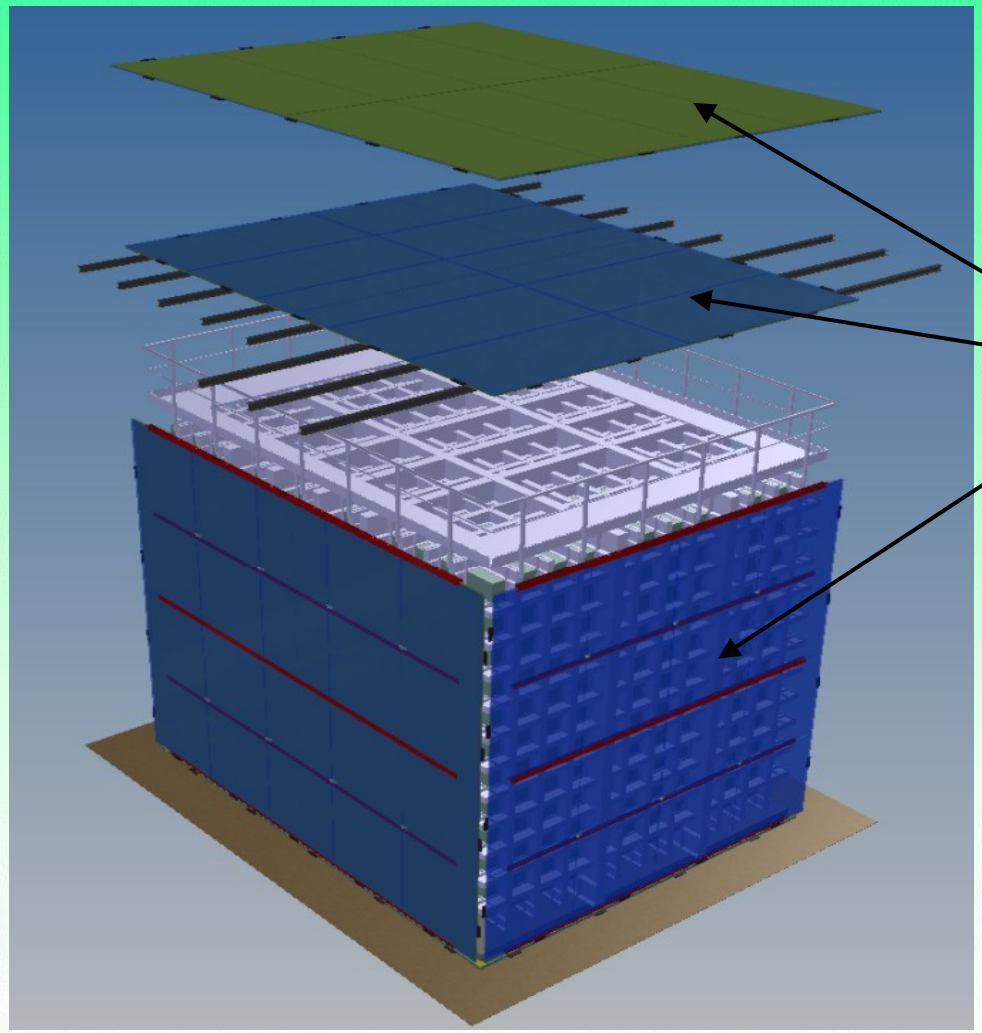
Reference documents:

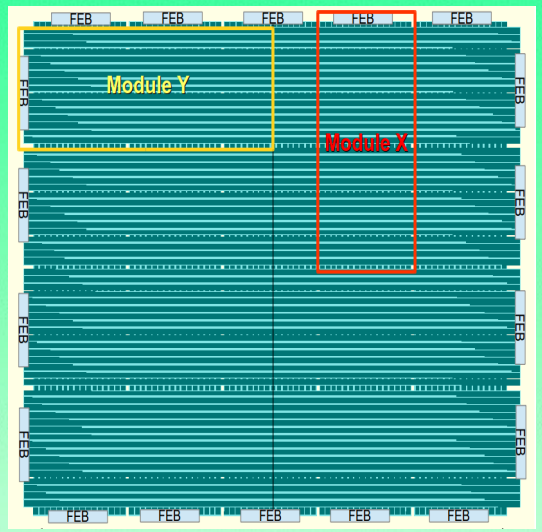
1. ***Design and construction of the MicroBooNE Cosmic Ray Tagger system***
MicroBooNE Collaboration (C. Adams (Harvard U.) et al.). JINST 14 (2019) no.04, P04004; arXiv:1901.02862

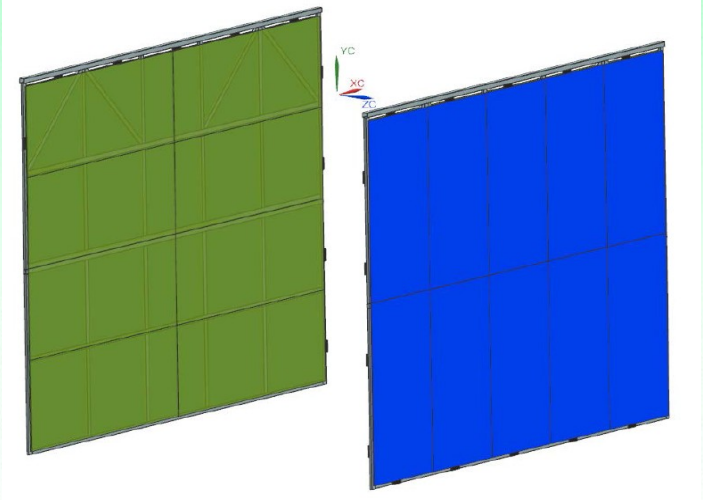
2. ***A Novel Cosmic Ray Tagger System for Liquid Argon TPC Neutrino Detectors***
M. Auger et al., (U. Bern, AEC & Bern U., LHEP) et al., Instruments 1 (2017) no.1, 2; arXiv:1612.04614

3. ***Multi-channel front-end board for SiPM readout***
M. Auger et al., (Bern U., LHEP & U. Bern, AEC). JINST 11 (2016) no.10, P10005; arXiv:1606.02290

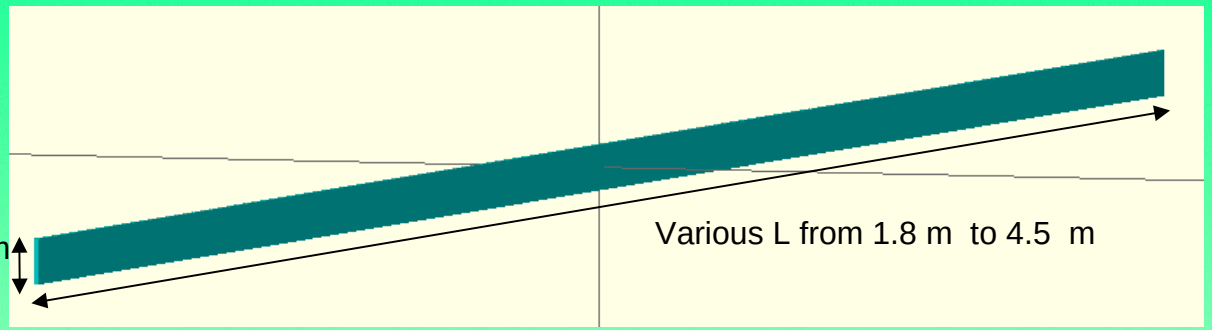
Designed as Cosmic Ray Tagger (CRT) for MicroBooNE and SBN-ND detectors

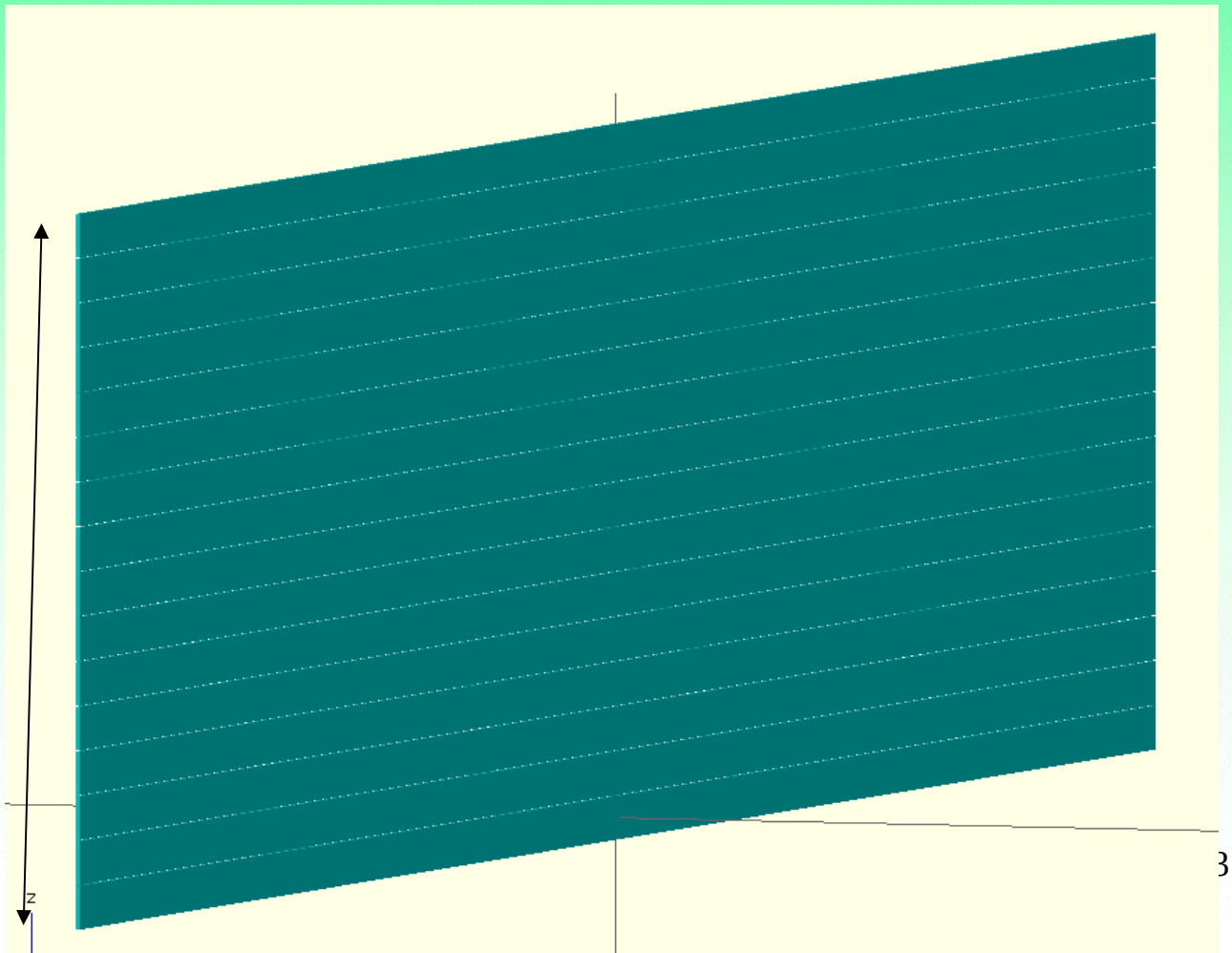




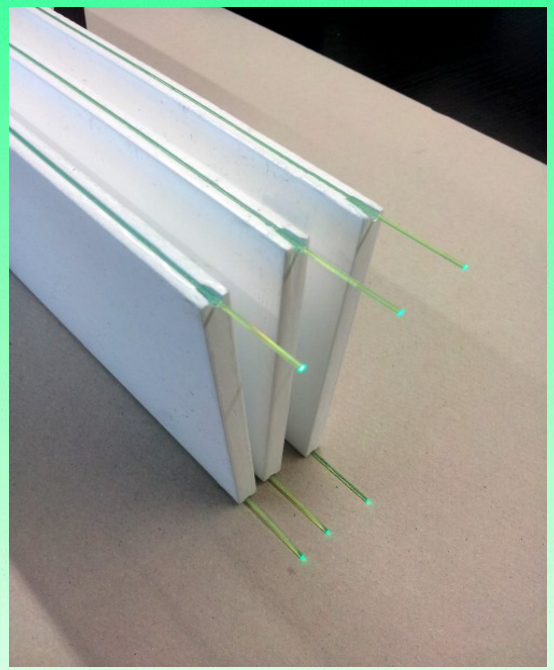


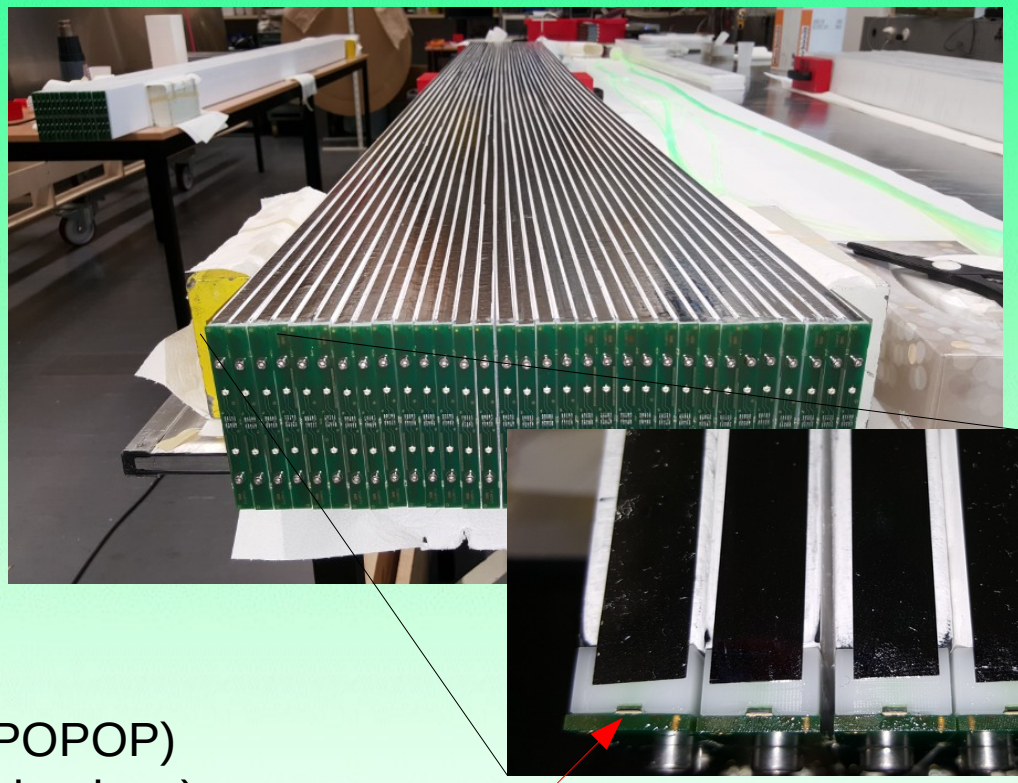
Tracker module assembly concept





Tracker strip structure





Scintillator: USMS-03 (PS+PTP+POPOP)
Reflective surface (UNIPLAST technology)
WLS fibers: Kuraray Y11(200)MS, 1mm diameter
Optical glue: ESA 7250 polysiloxane compound
SiPM: Hamamatsu S12825-050P

2 SiPMs per strip

Tracker module structure

16 strips per module

Module length:
1.8m to 4.5m

Module width:
0.96m & 1.8m

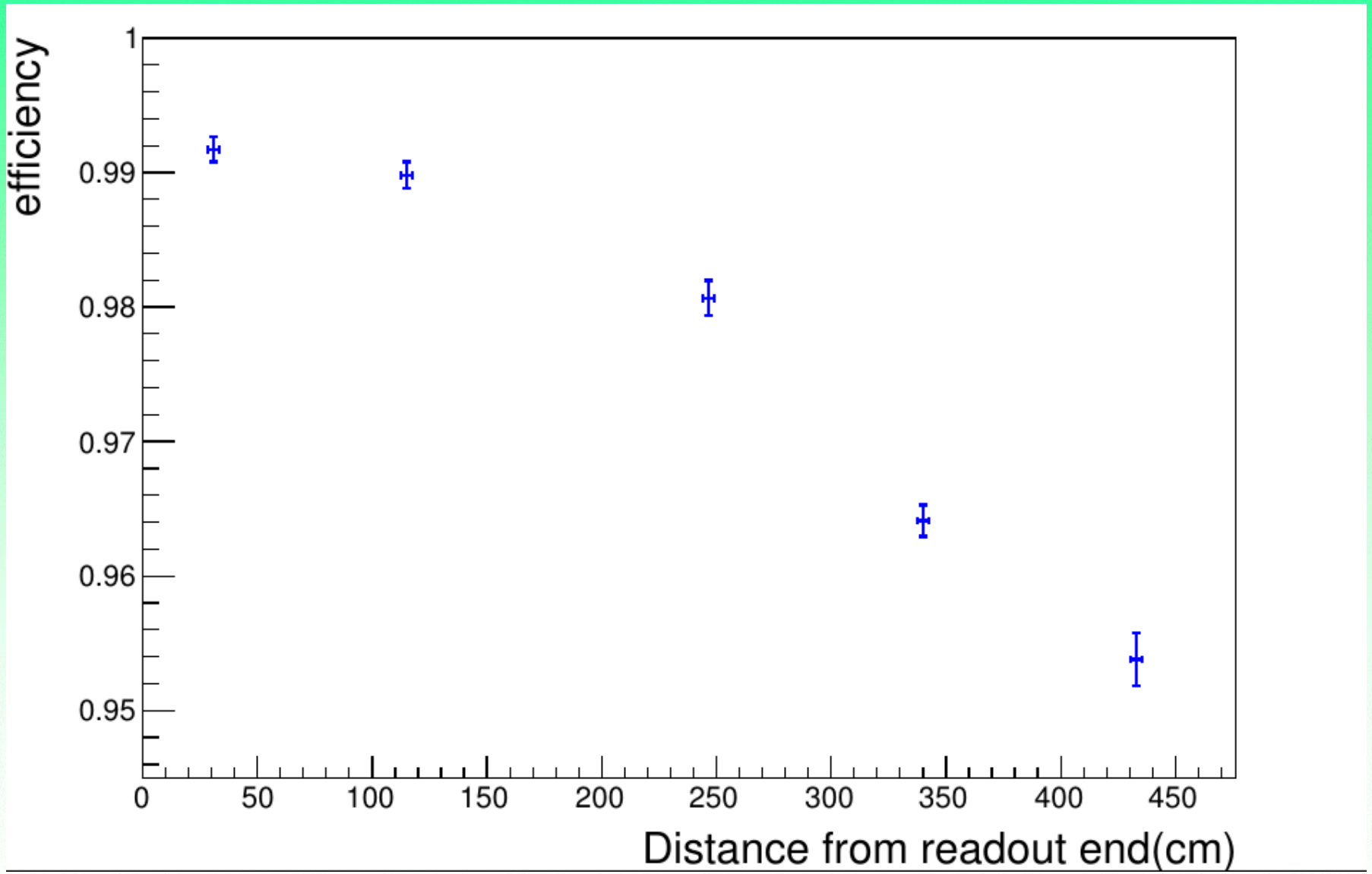
Module thickness:
20 mm

Aluminum case
(2 mm thick covers)

Robust, self-supporting

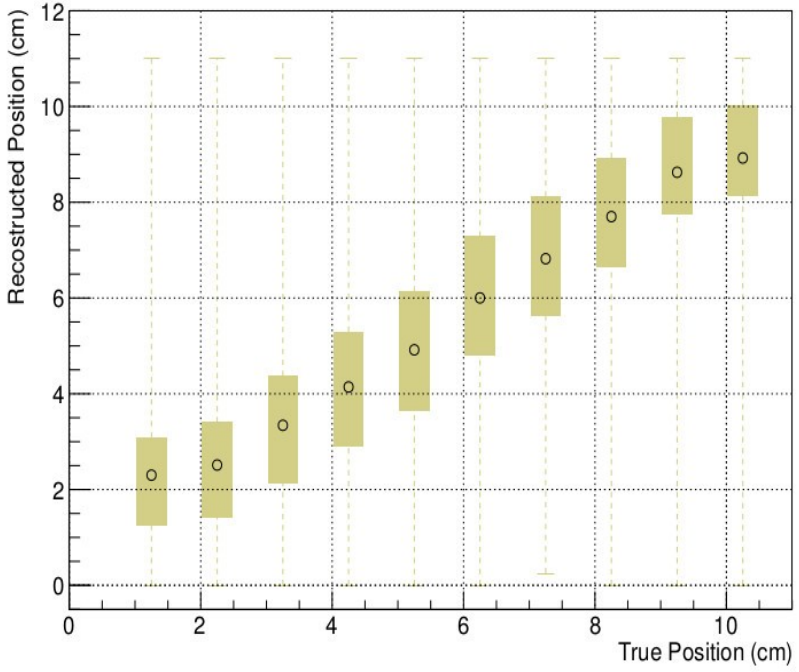
Tracker modules ready for Bern — FNAL trip

Tracker module measured detection efficiency for muons

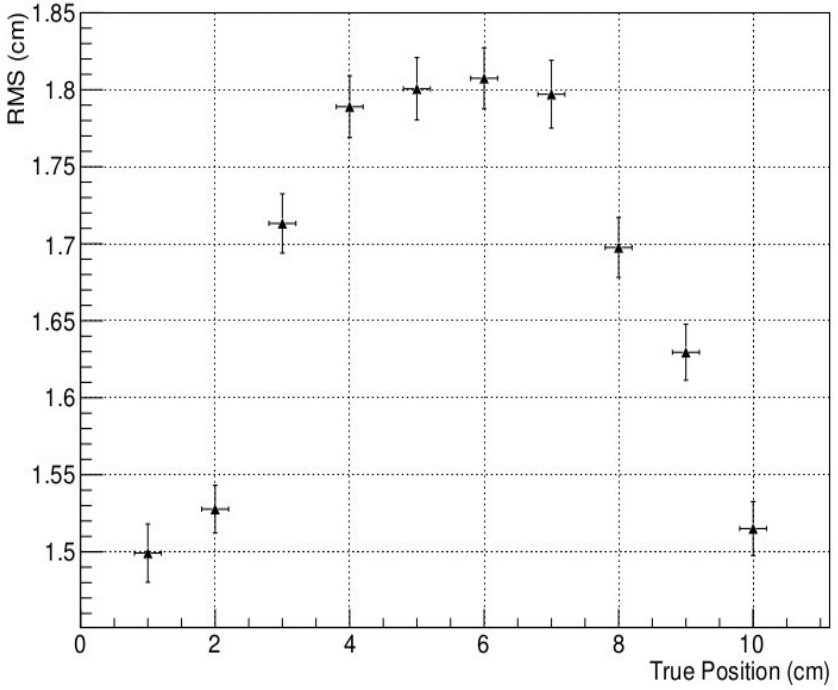


Tracker module measured coordinate resolution (left-right weighting method)

Reco vs True track coordinate



Coordinate resolution



Front-end electronic board (FEB)

Bias voltage 40-90 V, individually adjustable for each of the 32MPPCs

Amplifying and shaping of the MPPC output pulse on each of the 32 channels

Discriminating the shaped signal at a configurable level from 0 to 50 photo-electrons

Signal coincidence from each pair of WLS fibers => trigger

External event validation from other FEB(s) (allows X-Y coincidence)

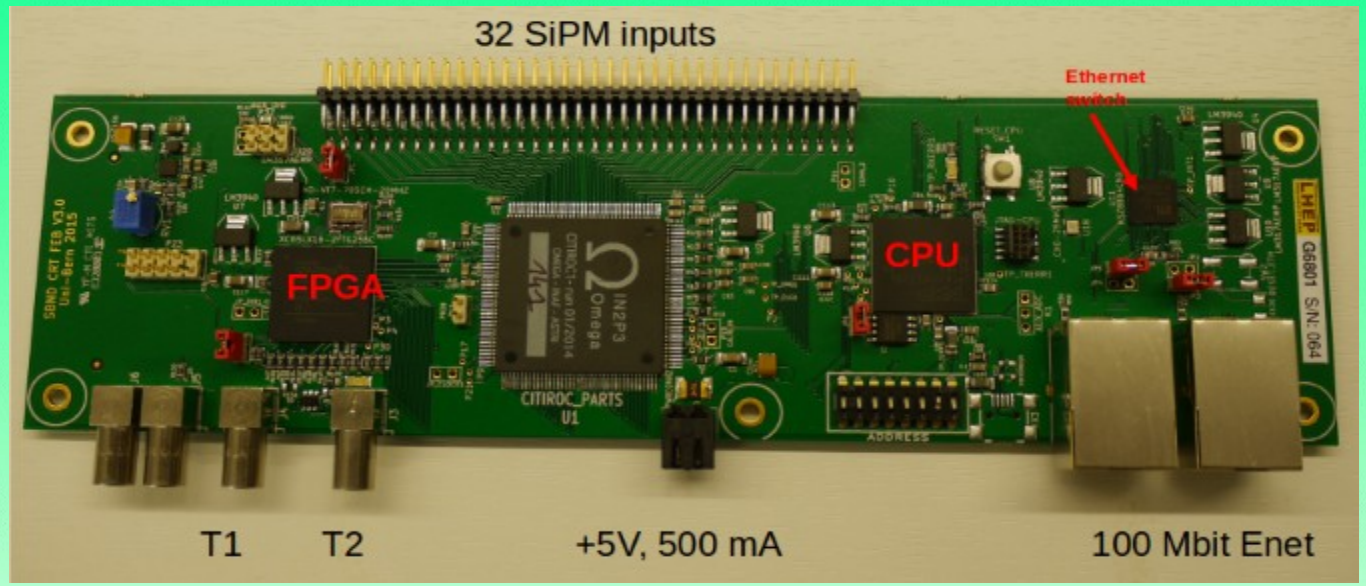
Time stamp w.r.t. external reference (GPS PPS and BNB RWM), accuracy 1.3 ns RMS

Data buffer for 1024 events

Efficient Ethernet-based back-end communication

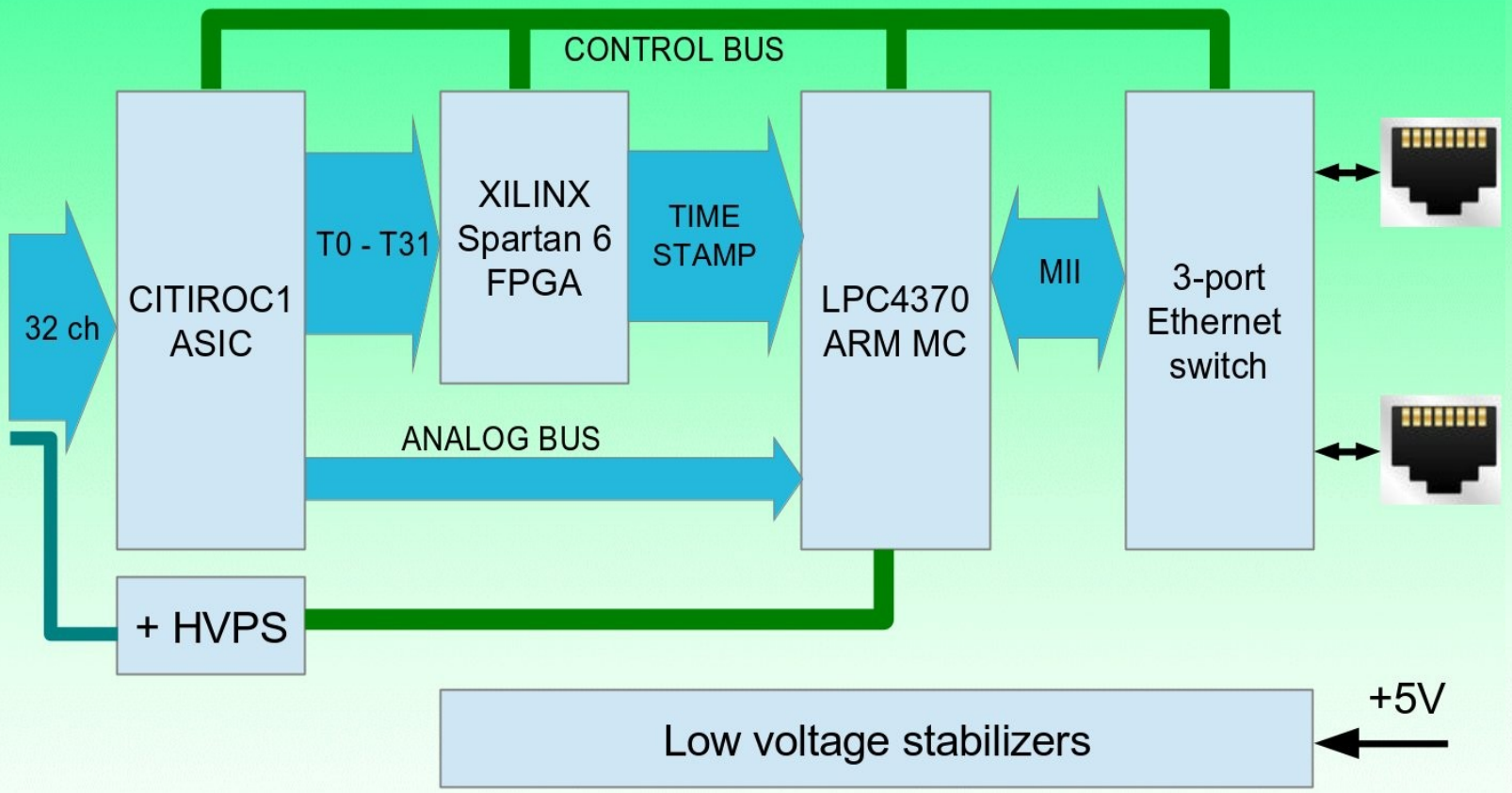
Firmware update over Ethernet

Front-End Board Rev3

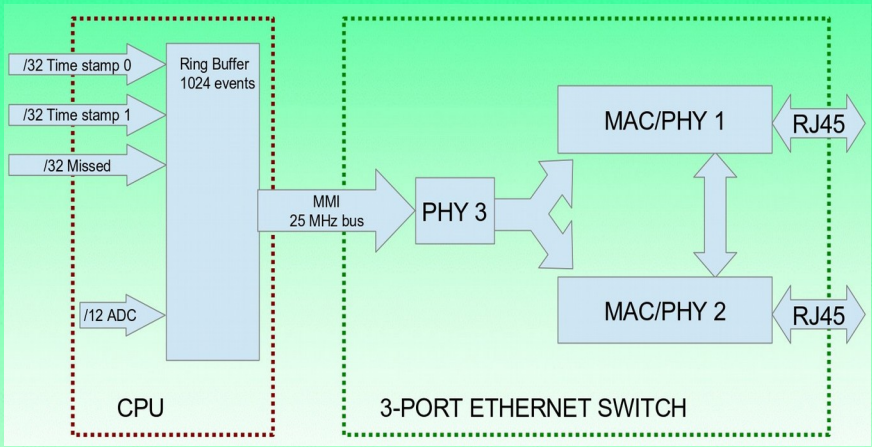


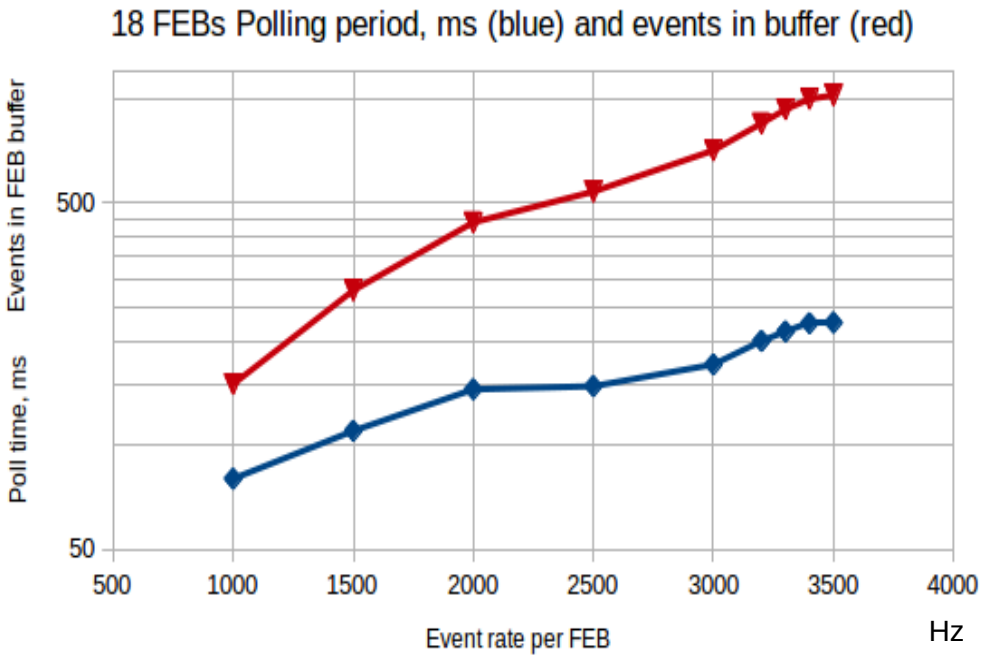
All required FEBs for existing panels are produced and tested.

Front-End Module (Board)



Front-End Module (Board)
Rate capability

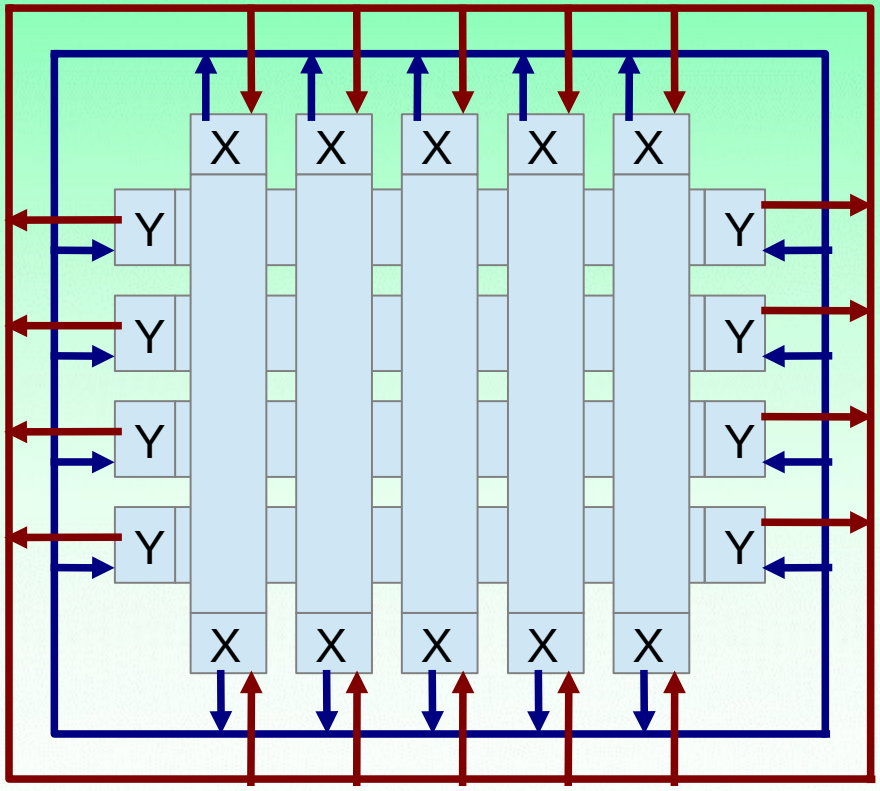


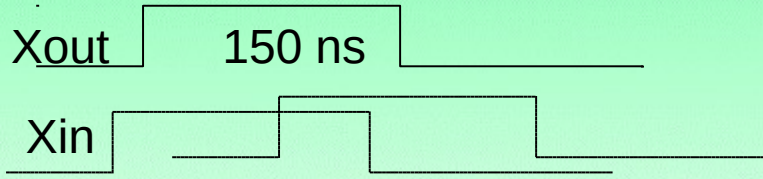


Front-End Board
Analog readout performance
Local X-Y coincidence

Data rate can be reduced by factor of 5 with local coincidence

Ring cables, no termination, driven by 3-state buffers

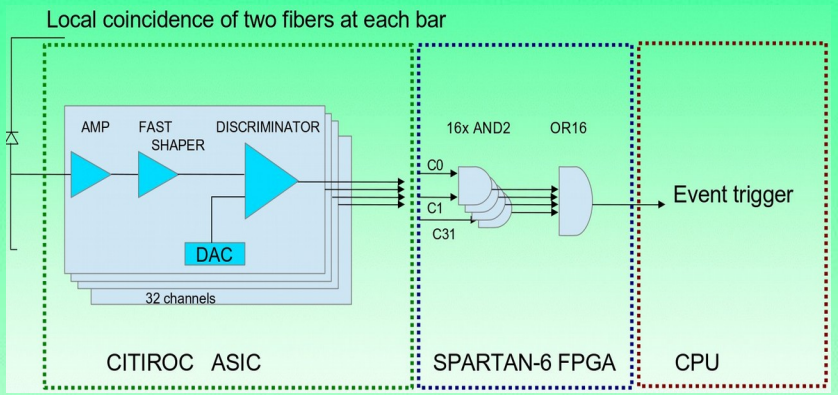


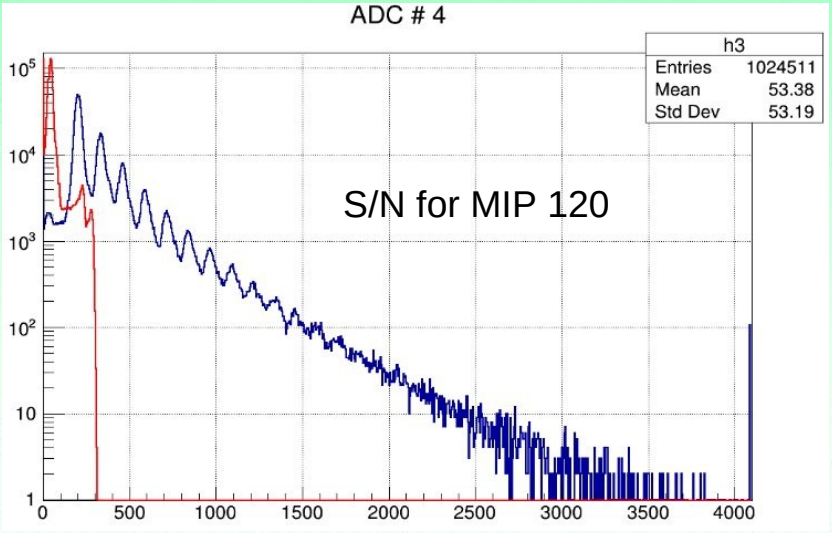


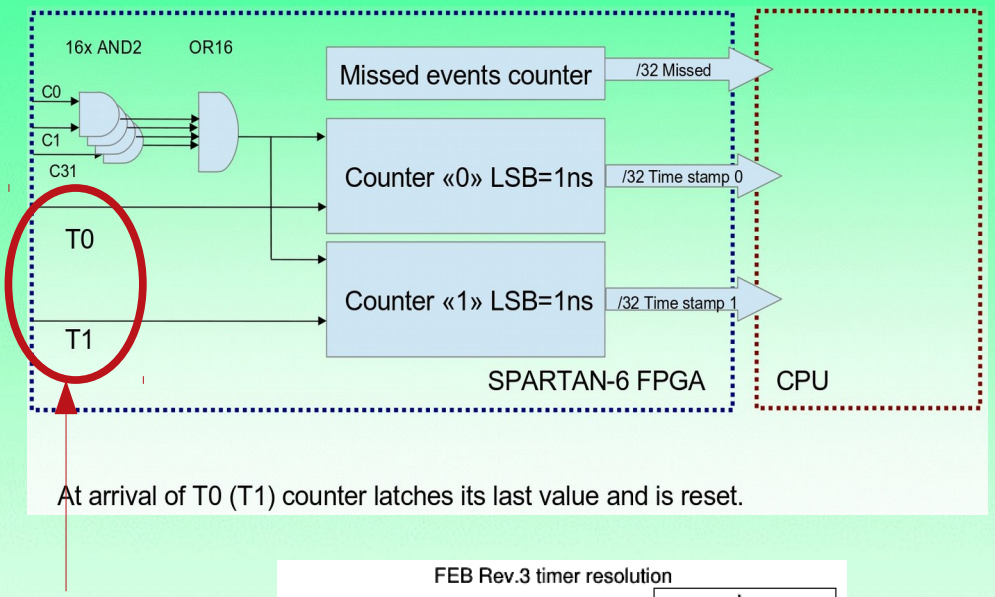
Every local trigger:
if there is input during 160 ns:
    Trigger readout
else:
    Reset and start over

Dead time reduced by factor >10

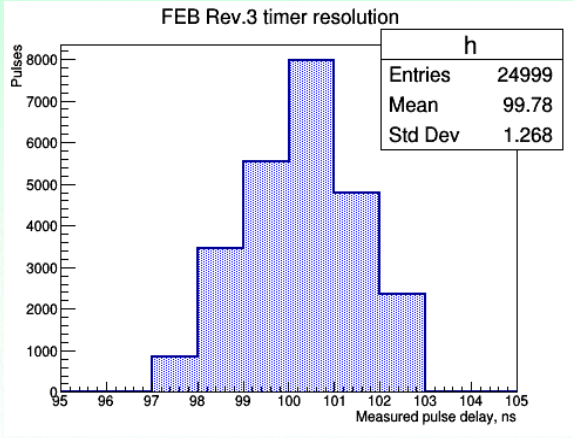
Front-End Module (Board)
Analog, trigger and timers





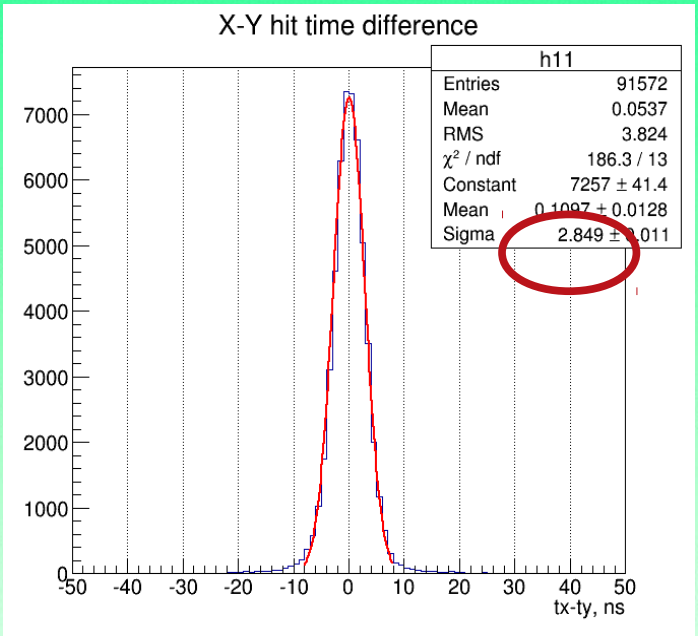


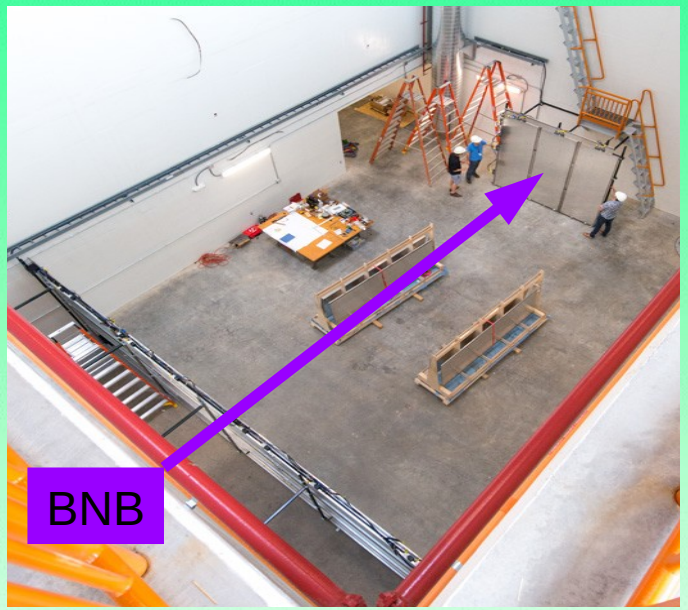
Two timers with separate reference inputs

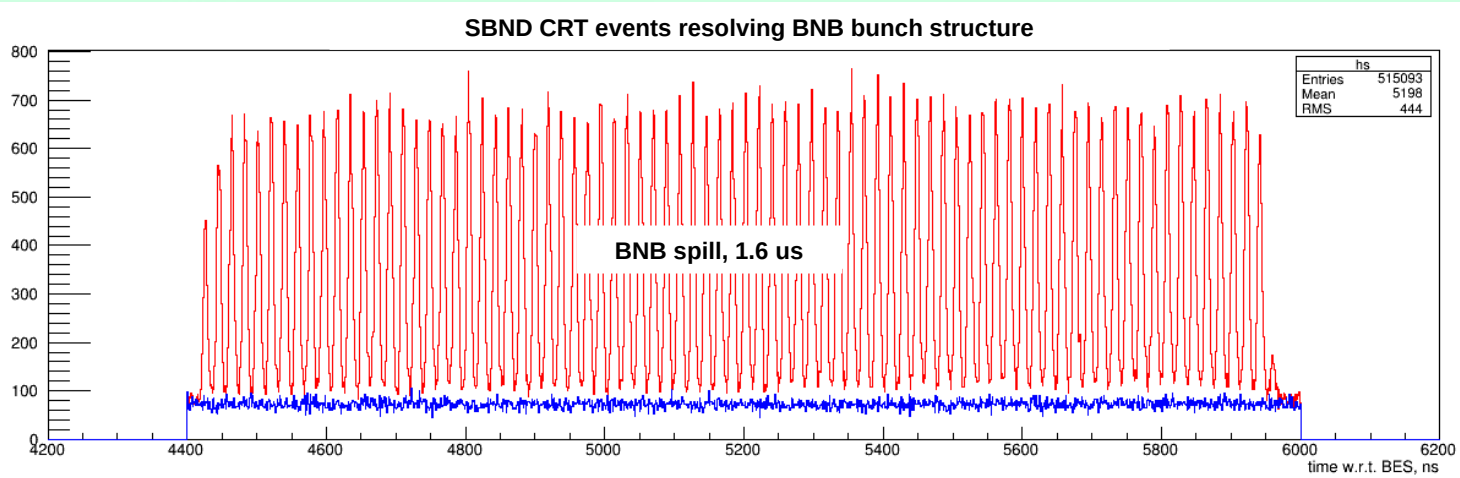


1.3 ns time stamp accuracy

Time resolution: beam hits seen by SBN-ND







Tracker module
Performance summary

Muon detection efficiency	95% to 99%
Coordinate resolution	< 2 cm (2D)
Time tag accuracy	2.8 ns RMS (electronics: 1.3 ns)
Trigger latency	22 us
Amplitude dynamic range	100 p.e. => 3 x MIP Optional: 500 p.e. => 15 x MIP
S/N ratio for MIP	Up to 120
Practical threshold	400 keV

Tracker module manipulation and tools required

Vacuum suction jig: < 0.2 bar working pressure

Module weight 50 to 180 kg

Tracker modules packing and transport

Not too fragile, withstands standard transport (car, ship, train)

Manufactured modules

uBooNE

L ,m x W,m	
1.85 x 1.8	8 pc
2.3 x 1.8	12 pc
2.6 x 1.8	18 pc
3.5 x 1.8	10 pc
3.65 x 1.8	16 pc
4.0 x 1.8	3 pc
4.1 x 1.8	6 pc

Total: 73 modules

Area : 395 m^2
(1-d coverage)

SBND

L,m x W,m	
1.8 x 1.8	2 pc
2.8 x 0.94	34 pc
3.6 x 1.8	51 pc
4.5 x 1.8	*56 pc*

Total: 143 modules

Area : 880 m^2
(1-d coverage)

ProtoDUNE 3x1x1

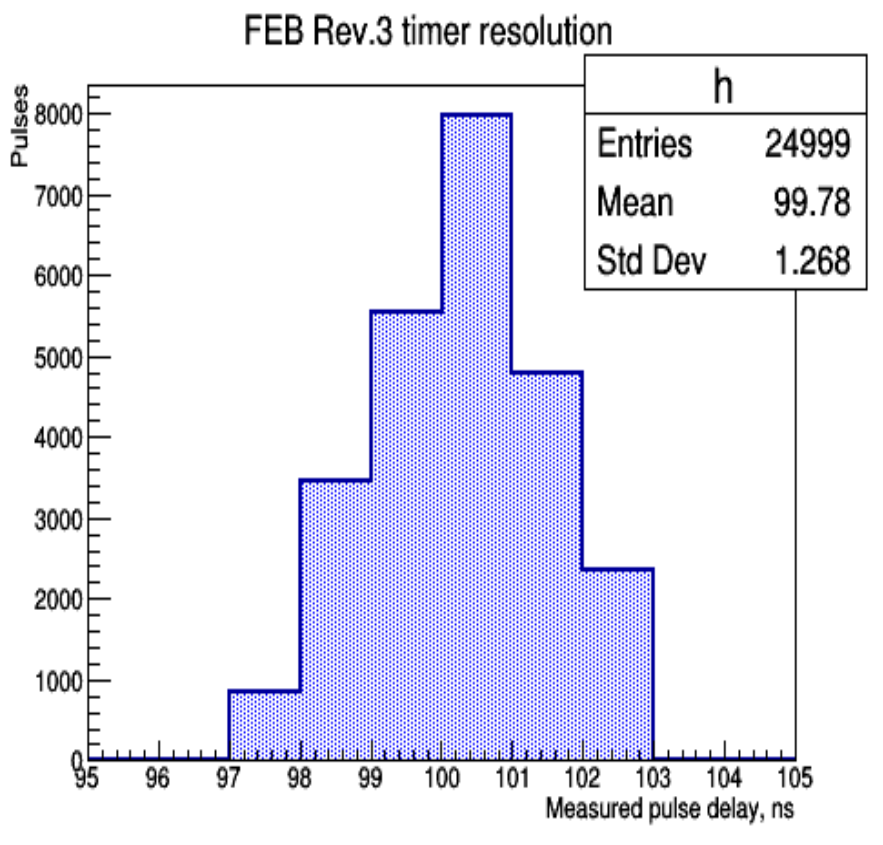
L,m x W,m	
1.8 x 1.8	4 pc

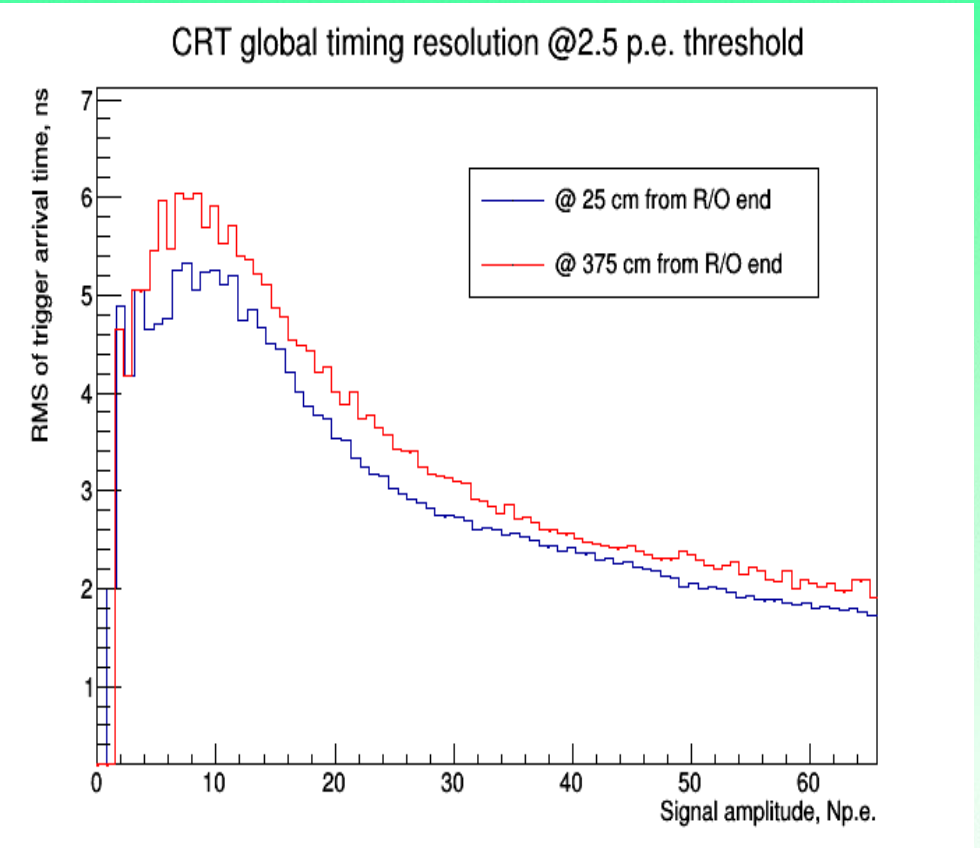
Total : 4 modules

Area : 13 m^2
(1-d coverage)

Backup slides

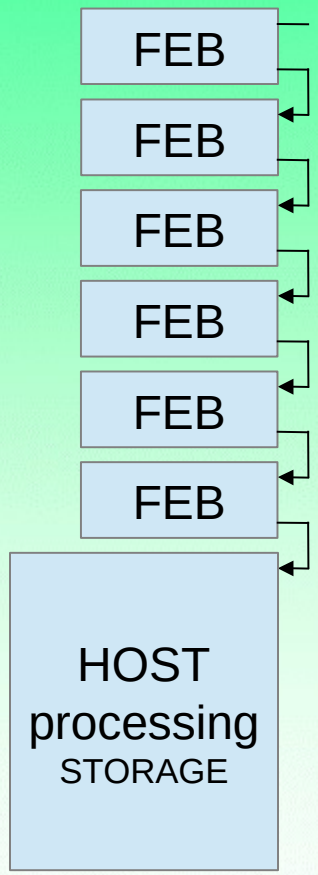
Timing resolution of the 4-m long scintillating bar
Measured with 60-ps 400-nm laser pulse





Event time resolution ranges from 1.7 ns (near end) to 6 ns (far end)

Front-End Board concept
Multiple FEB readout



Communication: L2 Ethernet (minimum overhead)

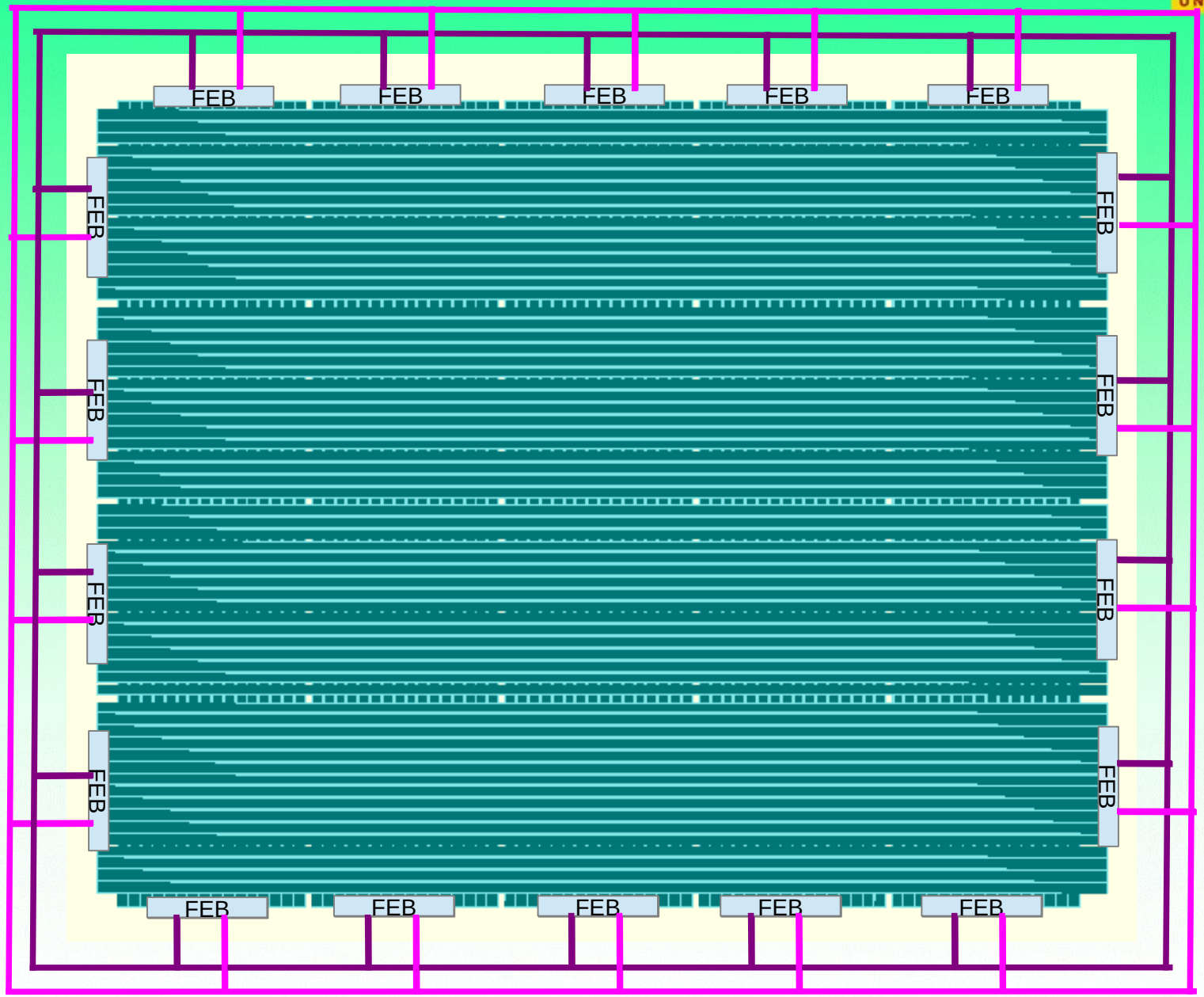
No Collision Detection => deterministic!

Host interrogates — FEB answers every 100 ms

Proprietary protocol FEBDTP:

Configuration
Health check
Data transfer

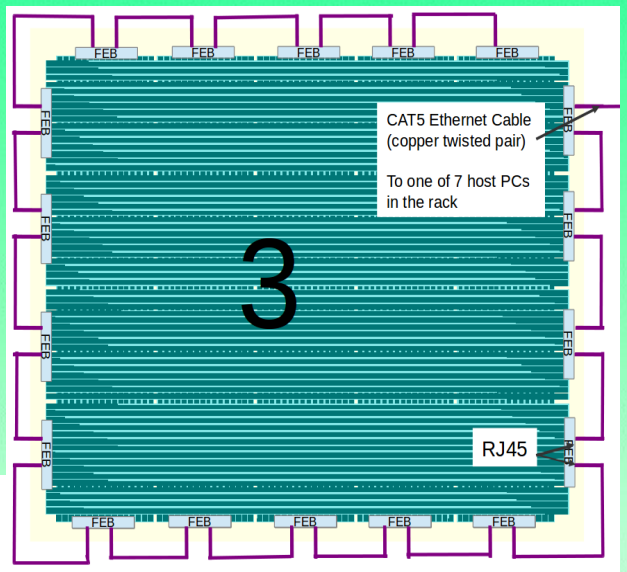
Example tracker wall structure: X-Y coincidence (local)

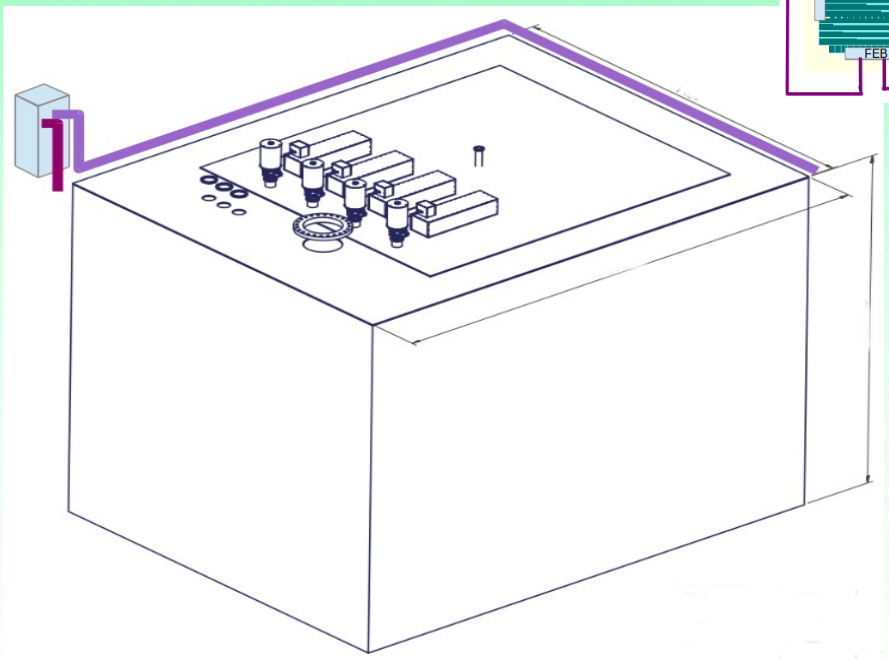


2 x 50 Ohm coax cables, 3mm OD, connection to FEB via LEMO

Example tracker: Signal distribution

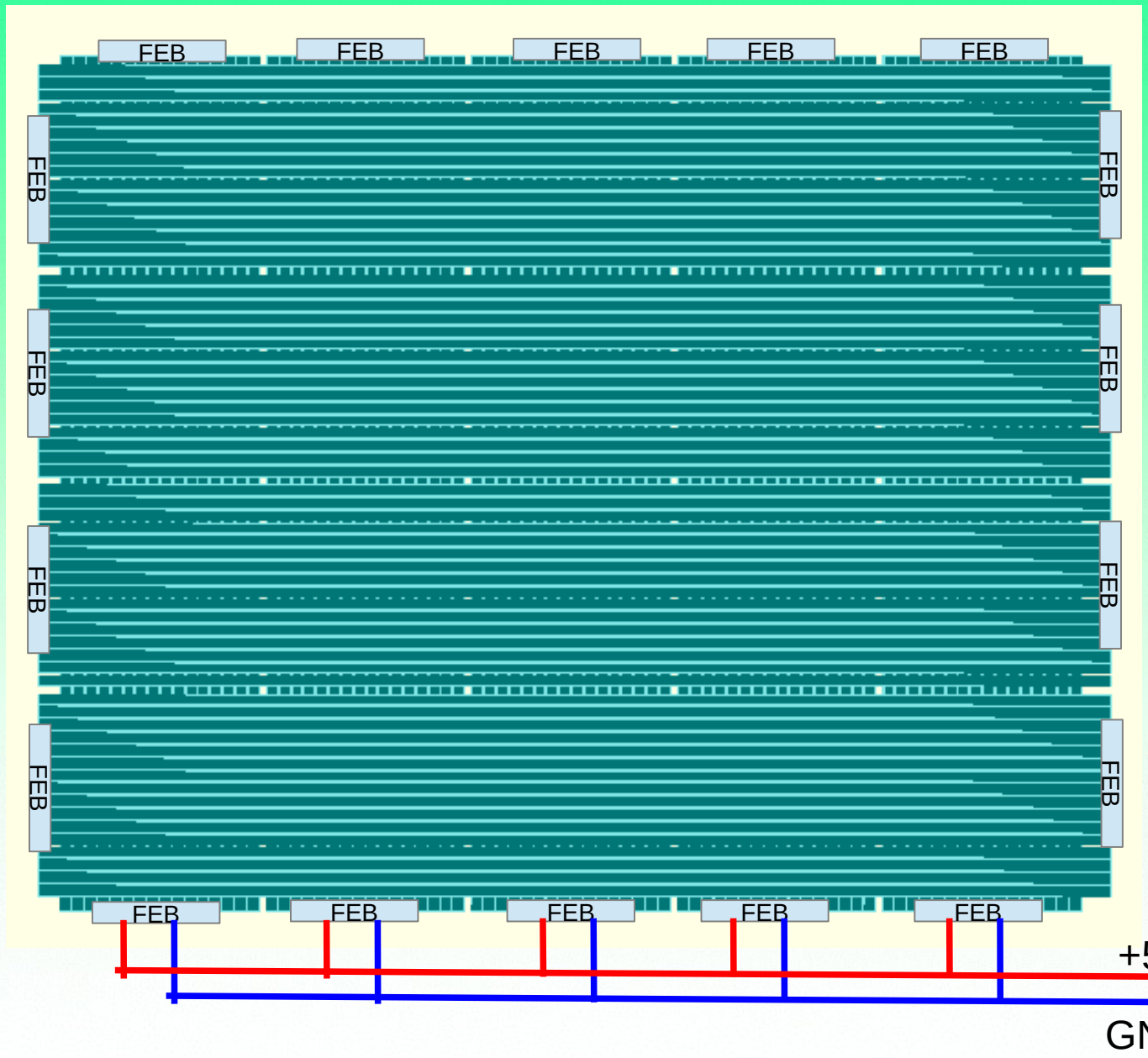
Equipment is distributed over standard 19" racks





44U Rack

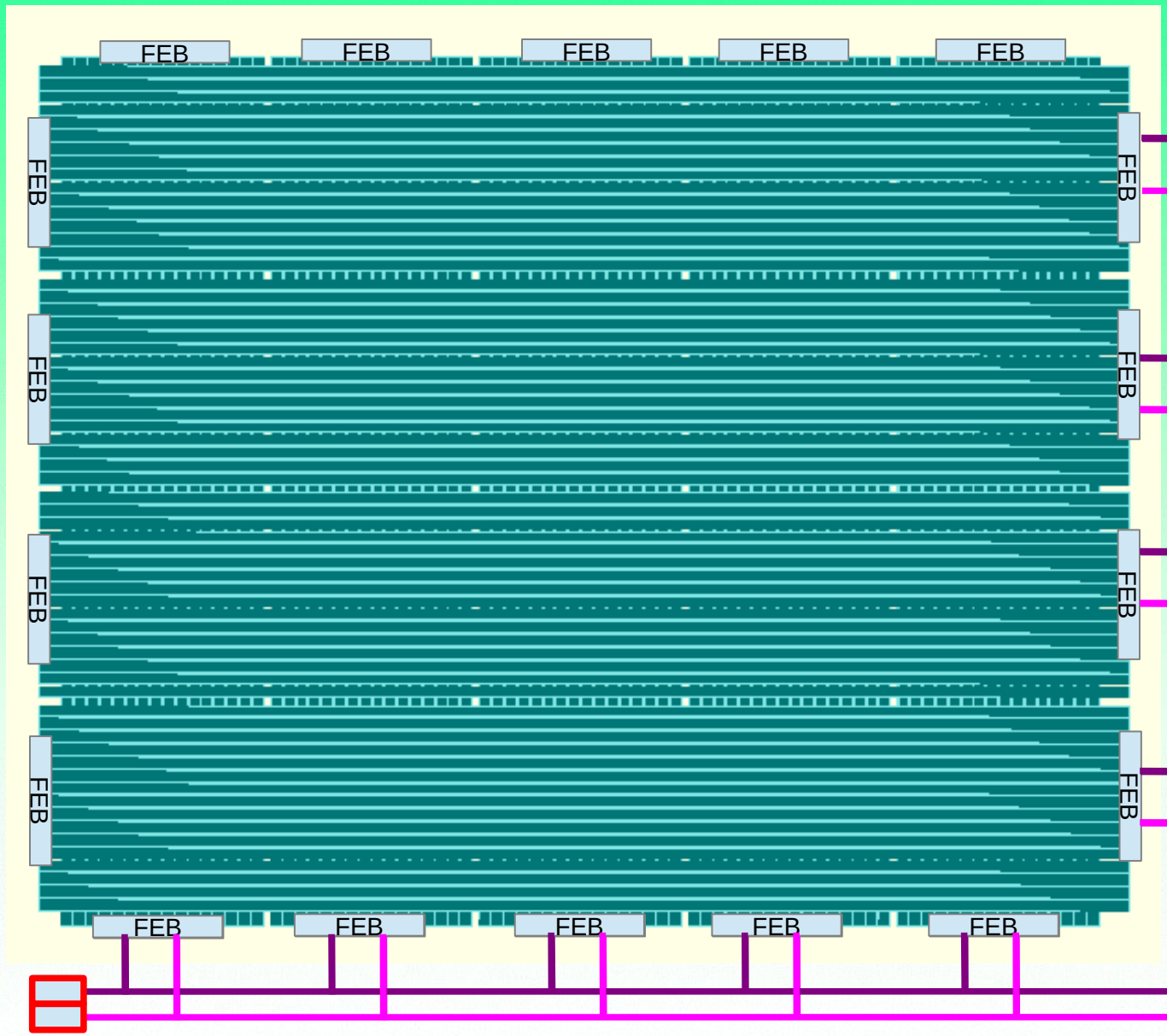
Example tracker wall structure: power distribution



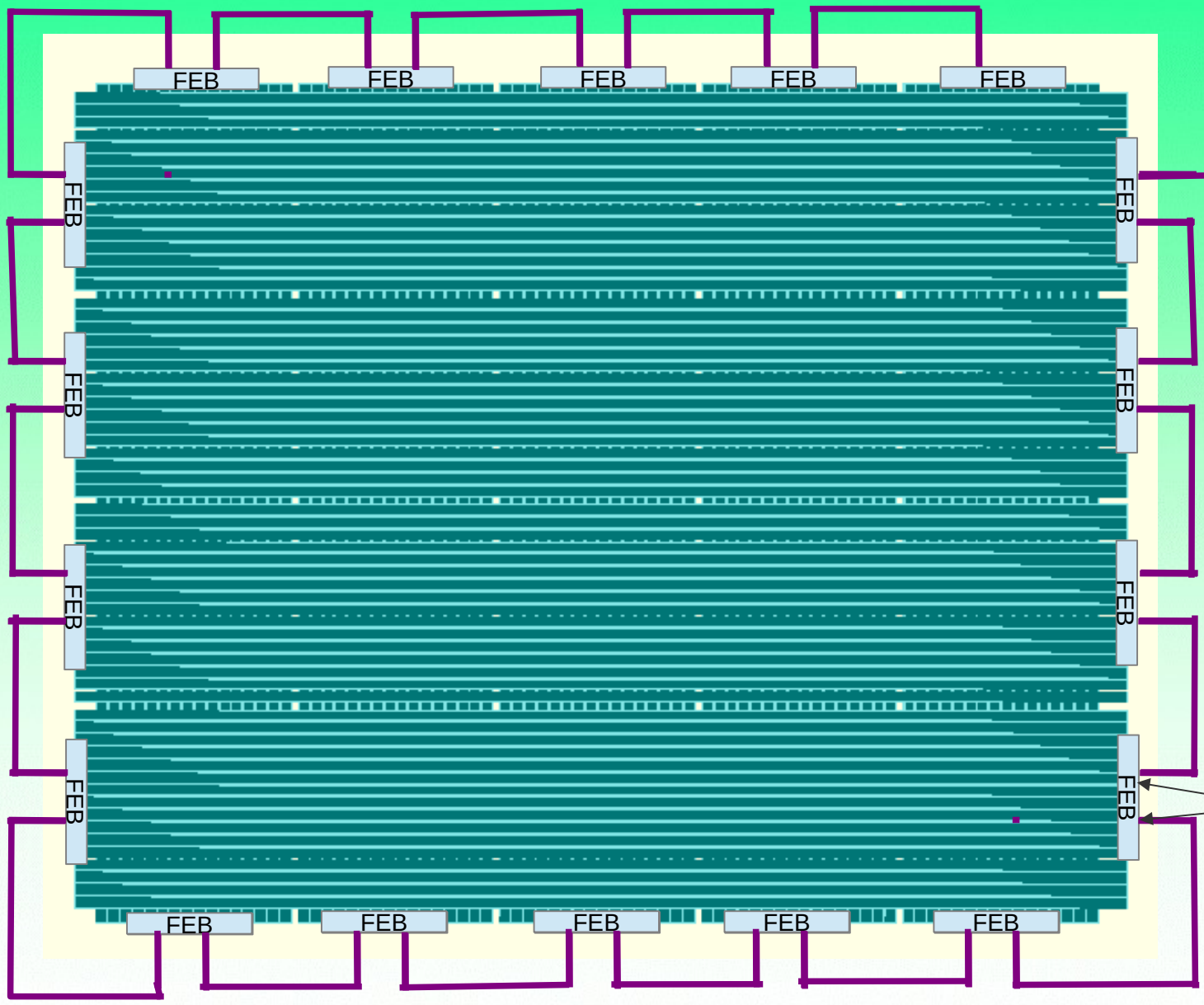
Consumption:

0.5A per FEB
2.5A per cable
10A per 5x7m wall

Example tracker wall structure: Reference signals distribution



Example tracker wall structure: Data R/O distribution



CAT5 Ethernet Cable
(copper twisted pair)

To one of host PCs
in the rack

RJ45