SBN Far Detector CRT System Update

Bob Wilson

for the SBN Far Detector CRT Group

CERN, **Colorado State,** Dubna, **FNAL,**
LIP (Lisbon), INFN Bologna, INFN Frascati, INFN Milano,
Houston, Pittsburgh, UTEF (Prague)

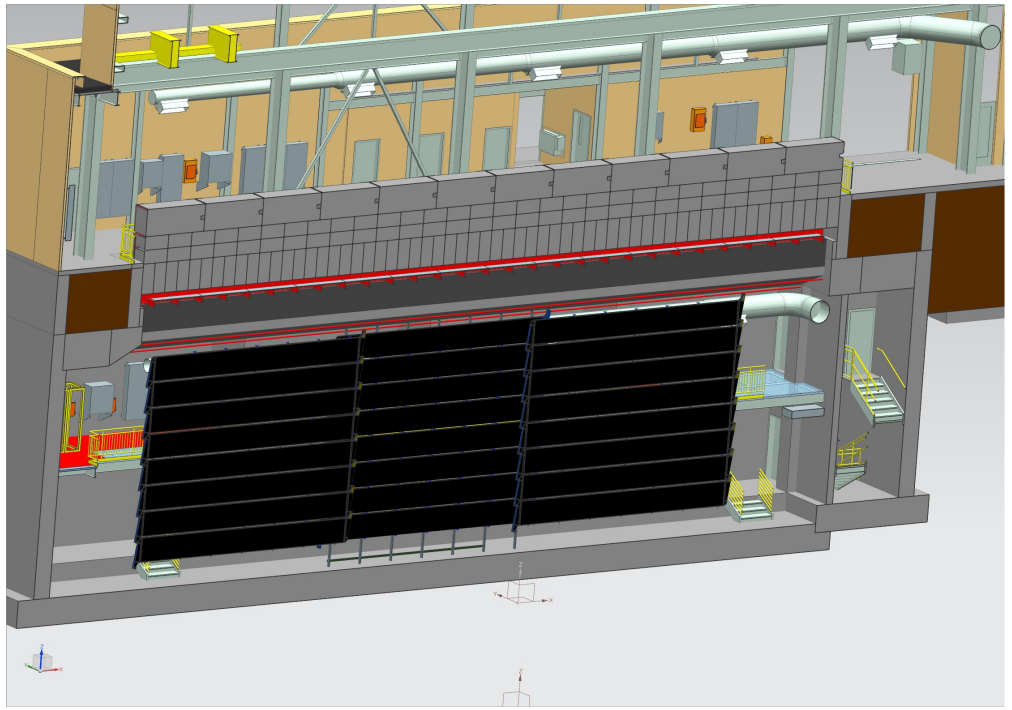
19 September 2018
ICARUS Collaboration Meeting

SBN Far Detector CRT Group

- Collaborative effort to provide ~4-pi coverage Cosmic Ray Tagger for ICARUS
  - Chaired by Umut Kose (CERN) also Top-CRT Coordinator
- Side/Bottom-CRT Group (ICARUS) led by Anne Schukraft (FNAL)
  - Other essential contributors: Simone Marcocci (FNAL post doc), Chris Hilgenberg (CSU student), Dave Warner (CSU engineer)
  - Support structure design: John Belle -> Cat James + Justin Tilman (all FNAL)
  - New addition: Biswaranjan Behera (CSU post doc)
- Joint SBN CRT Working Group
  - Conveners: Umut Kose (chair), Igor Kreslo (MicroBooNE/SBND), Bob Wilson
  - Coordination and cooperation between all SBN CRT groups
- Most slides for this presentation provided by Umut and Anne – thanks!
- Will move through quickly – more time for discussion in Friday SBN WG meeting

Side/Bottom CRT

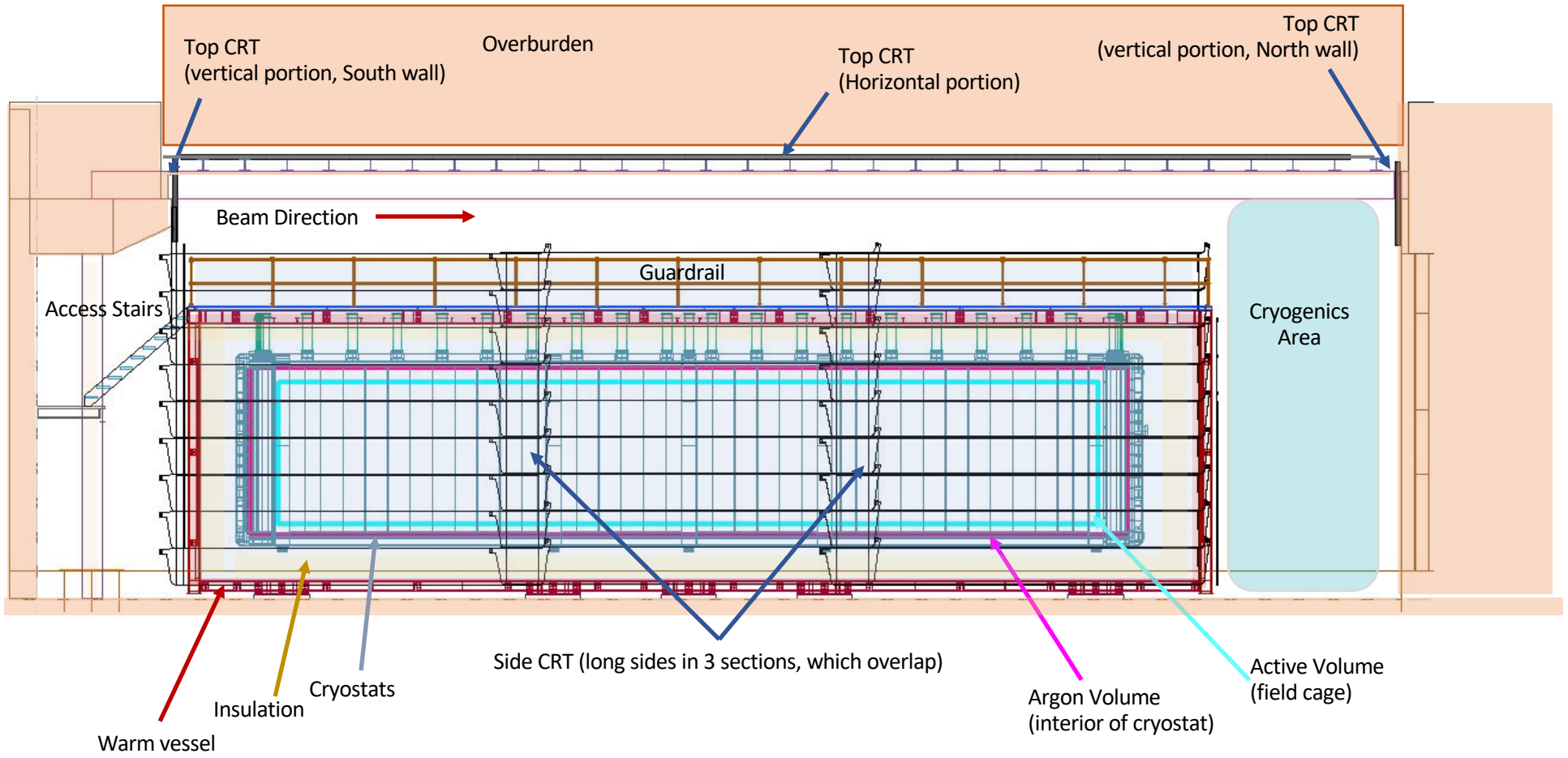
Side CRT system overview



- ICARUS side system includes coverage of four sides of the detector: East, West, South, North
- Re-use of MINOS scintillator modules from far detector cosmic veto. Dimensions: 8 m x 80 cm
- 172 good modules (tested) - enough for a double-layer coverage on all four sides

- Configuration
  - **East and West**: three wall segments of two layers of parallel (1/2 strip width offset) modules
  - **South**: one wall segment, horizontal and vertical layer
  - **North**: Conceptual design layout: patch of reduced length modules around cryogenics (cutting and resealing has been tested)

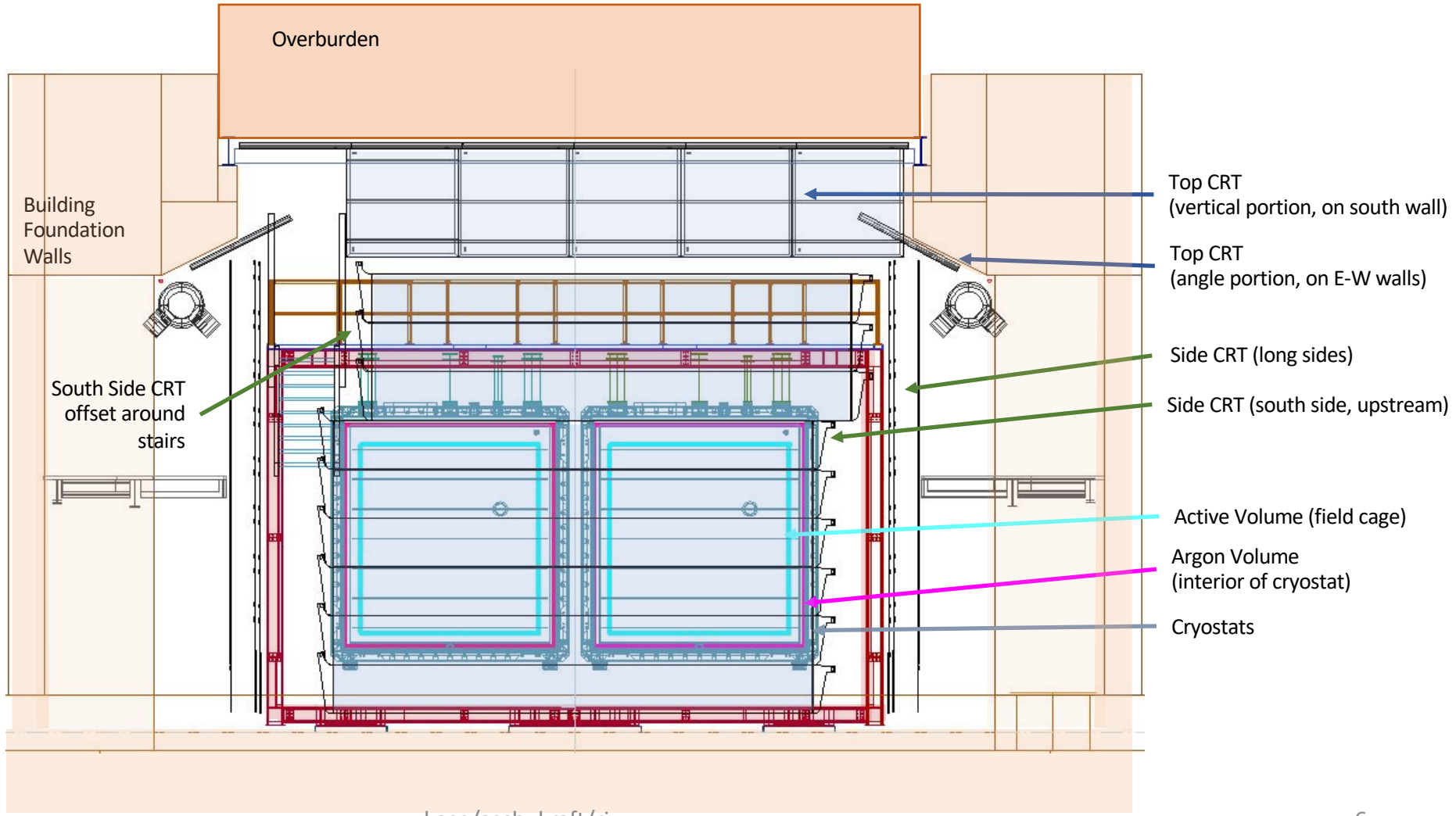
East/West Wall



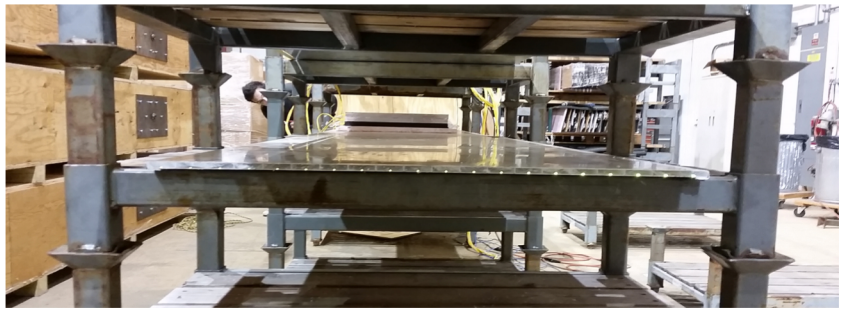
- SiPM sensors and FEBs can be attached after the modules have been installed
- Procurement of mounting parts has started. Installation will be stretched over longer time period.

South Wall

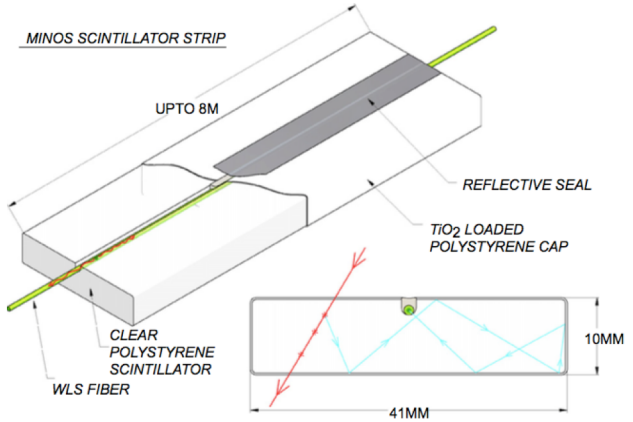
- South wall will also have two layers of modules.
- Second layer final layout TBD.
- Need to leave space for access stairs to warm vessel top



Re-use of MINOS scintillator modules



MINOS module snout



- 20 strips per module (each 4 cm wide)
- The strips are glued to and wrapped in a light-tight aluminum skin
- One fiber per strip, readout on both ends -> 40 channels per module (40 * 172 = 6880 channels total)

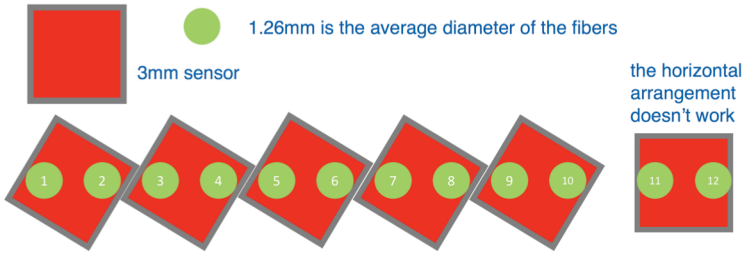
Main difference to other CRT systems (top, SBND, MicroBooNE):

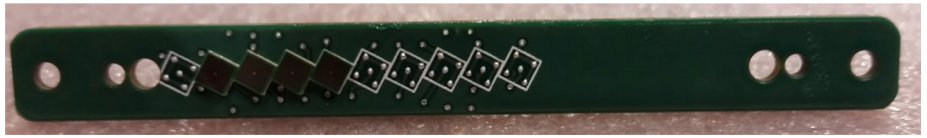
- Only 1 fiber per strip instead of 2 – cannot require coincidence between SiPMs for noise reduction
- Fibers read out on both ends

Readout design

Photosensors:

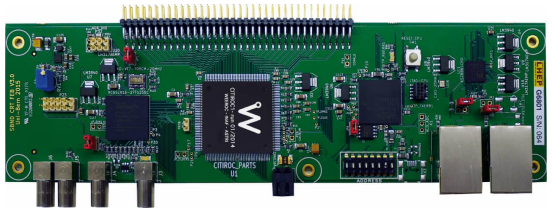
- MINOS modules were originally read out by multi-pixel PMTs – replaced with compact, low voltage SiPMs
- Some geometrical challenges finding best commercial solution to optimize SiPM and fiber matching
- Chosen solution: 3mmx3mm SiPMs, optically ganging two channels (4 cm granularity -> 8 cm granularity)
- SiPMs have been ordered after technical review of the readout design
  (documentation: https://sbn-docdb.fnal.gov/cgi-bin/private/DisplayMeeting?conferenceid=2612)





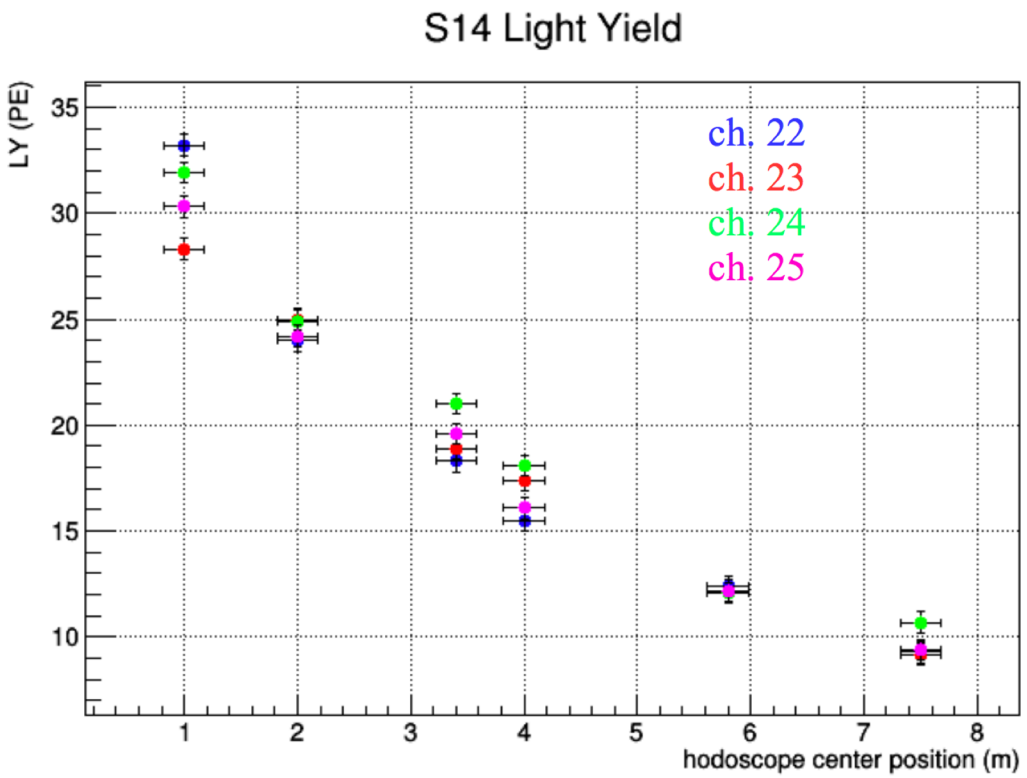
Electronics:

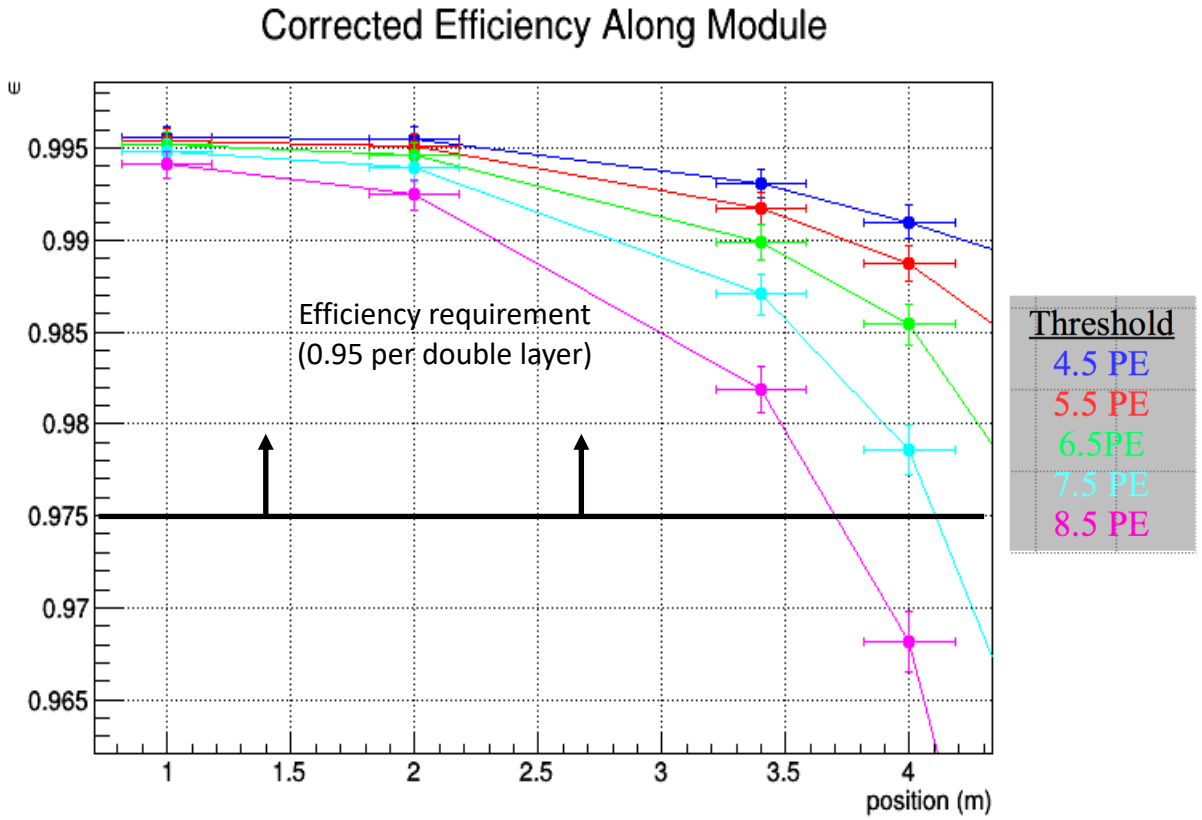
- Front end readout board is CAEN A1702 (developed by University of Bern for use in SBND and MicroBooNE)
- Same readout board as used in the top CRT and SBND and MicroBooNE.
  Will simplify common DAQ and analysis.



Results: Module and sensor testing

- 3mmx3mm SiPM solution was prototyped and tested for a mini-version of 4 (of 10) SiPMs (= 8 of 20 strips). Results: https://sbn-docdb.fnal.gov/cgi-bin/private/DisplayMeeting?conferenceid=2612
- Light-output and efficiency measurement using external hodoscope to trigger

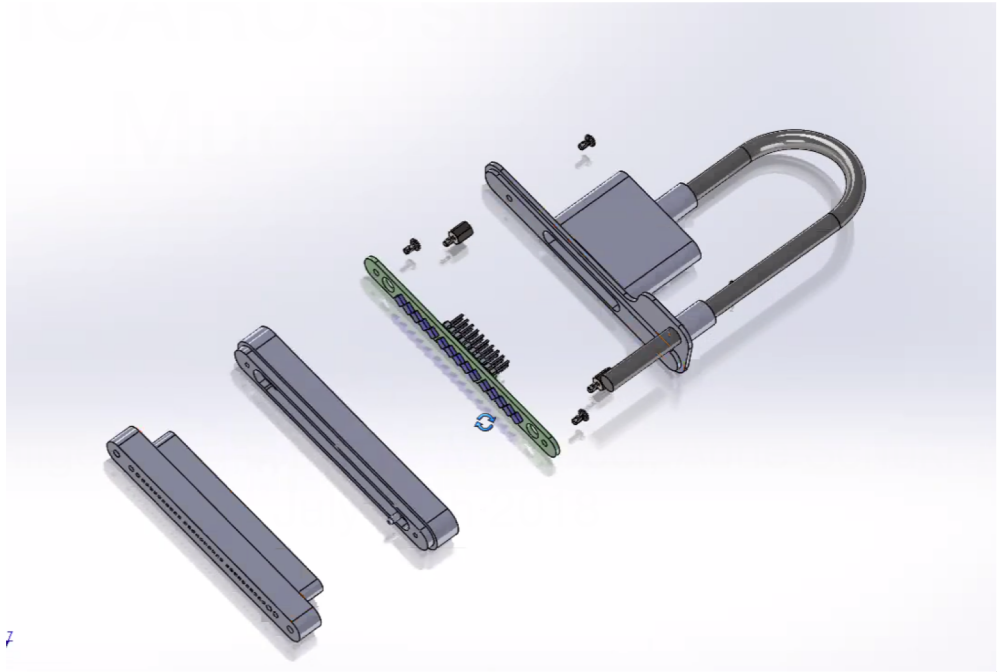


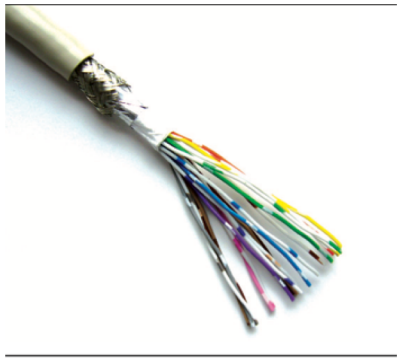


- **95% efficiency per double-layer can be reached**

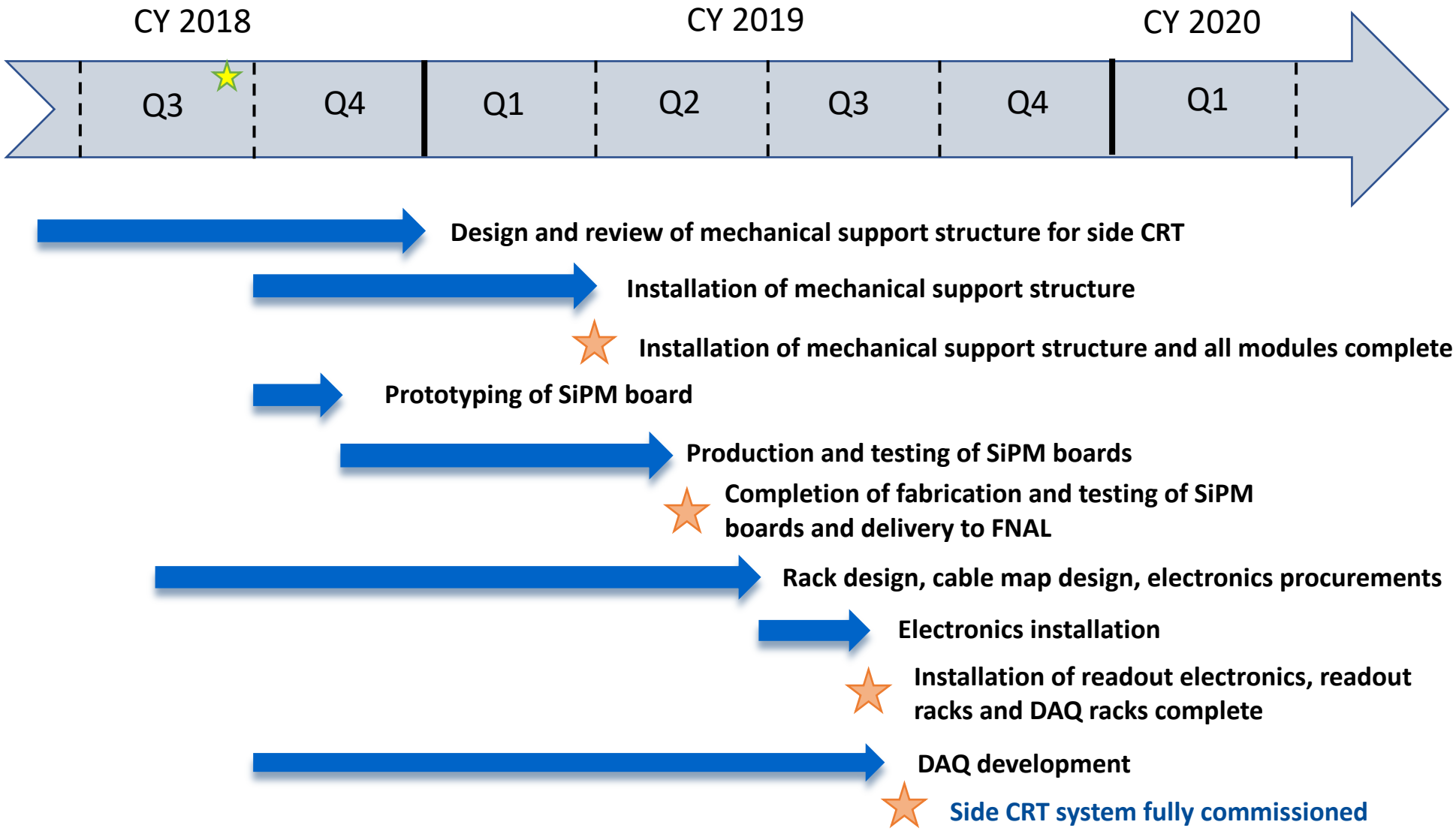
Design production housing and cable

- Sensor board and housing being designed by CSU
  - 150 SiPMs purchased for prototype sensor boards
  - FNAL currently comparing cables (twisted pair, shielded) between sensor boards and front end boards
  - Prototype boards and 3D-printed prototype housings will be produced by CSU and tested at FNAL
  - Design technical review before the end of the year
- Production of boards and housings at CSU
  - Detailed schedule developed
  - Pre-production prototypes and testing phase at CSU ~4 months
  - Ready for production review late October
  - Production January-April 2019
  - CSU providing funds for the photosensor housing production





Tentative schedule (slightly updated since Director's Review)



Bottom CRT

14 Double Chooz modules were installed in 2017 underneath the warm vessel

Remaining tasks

Rack

- Move equipment from test rack into production rack w/ rack protection and slow control
- Add system to slow controls
- Proper cable routing in the pit (can only be done once installation of side CRT and cryogenics has progressed further)

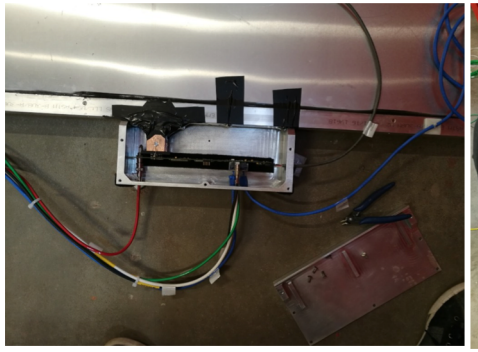
DAQ

- Currently using standalone test DAQ. Needs integration into experiment DAQ.
- Same modules are being used by ProtoDUNE. Can re-use DAQ work from ProtoDUNE.

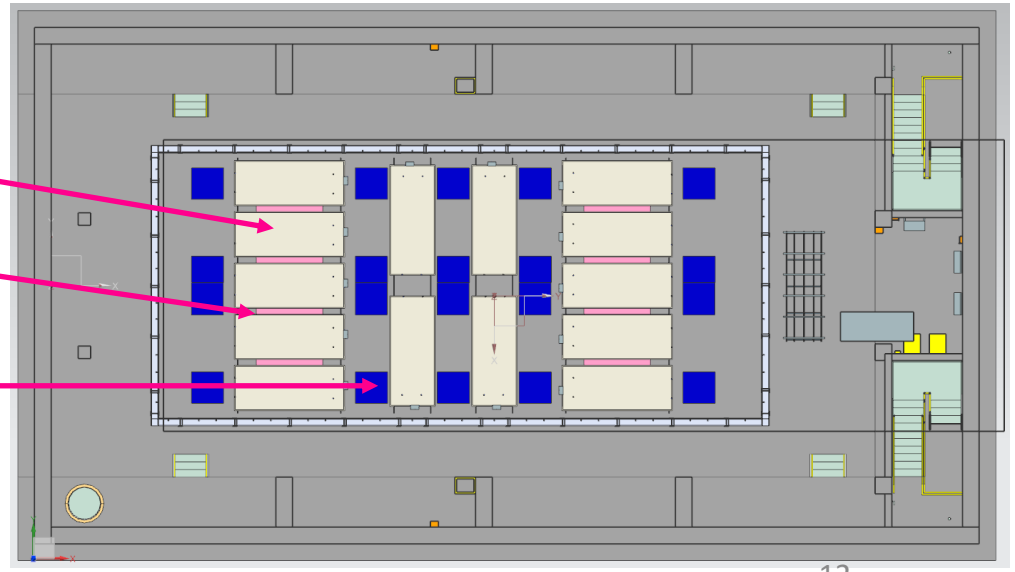
Needs additional effort.







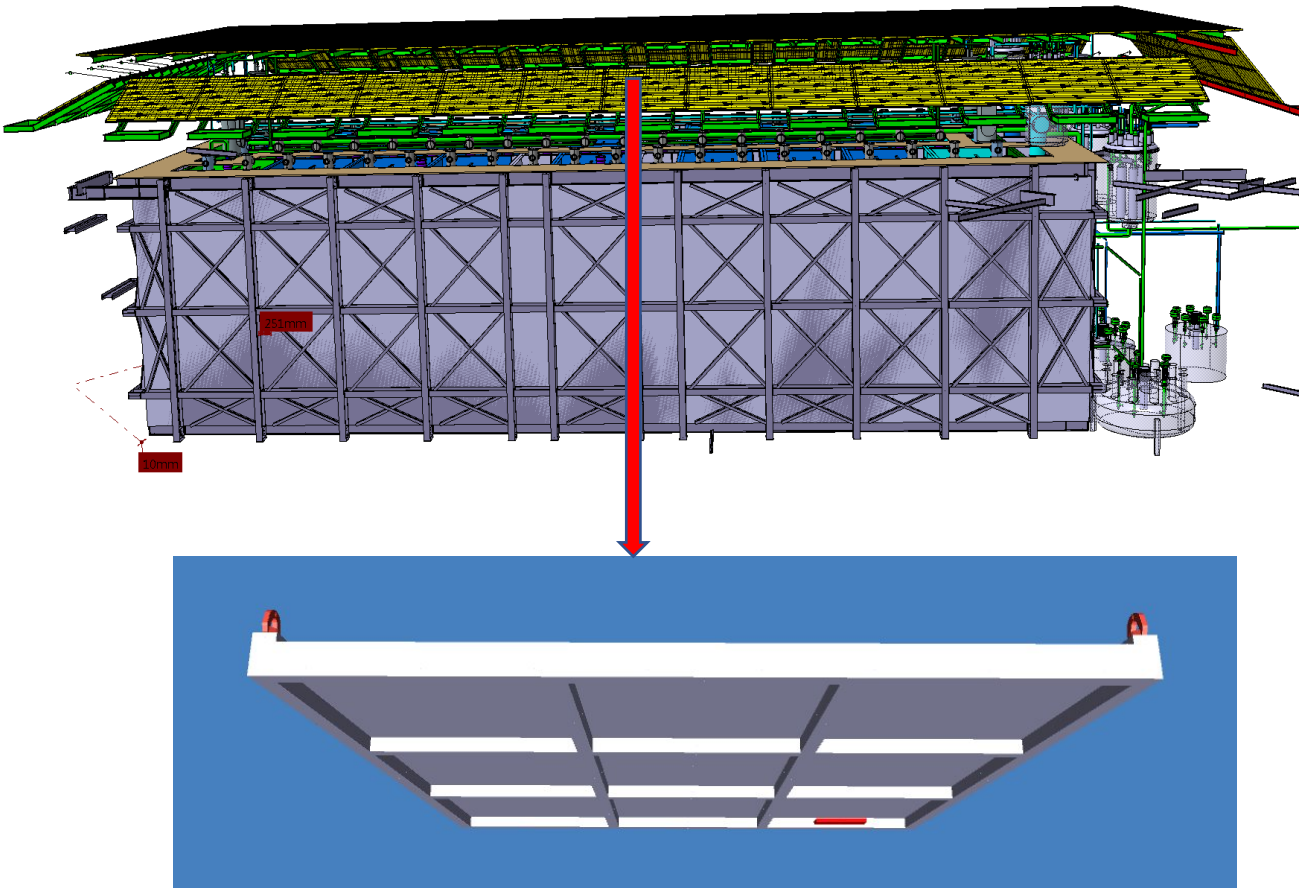

Bottom CRT layout



SBN Far Detector TOP CRT System

Slides from Umut Kose

Top CRT System:



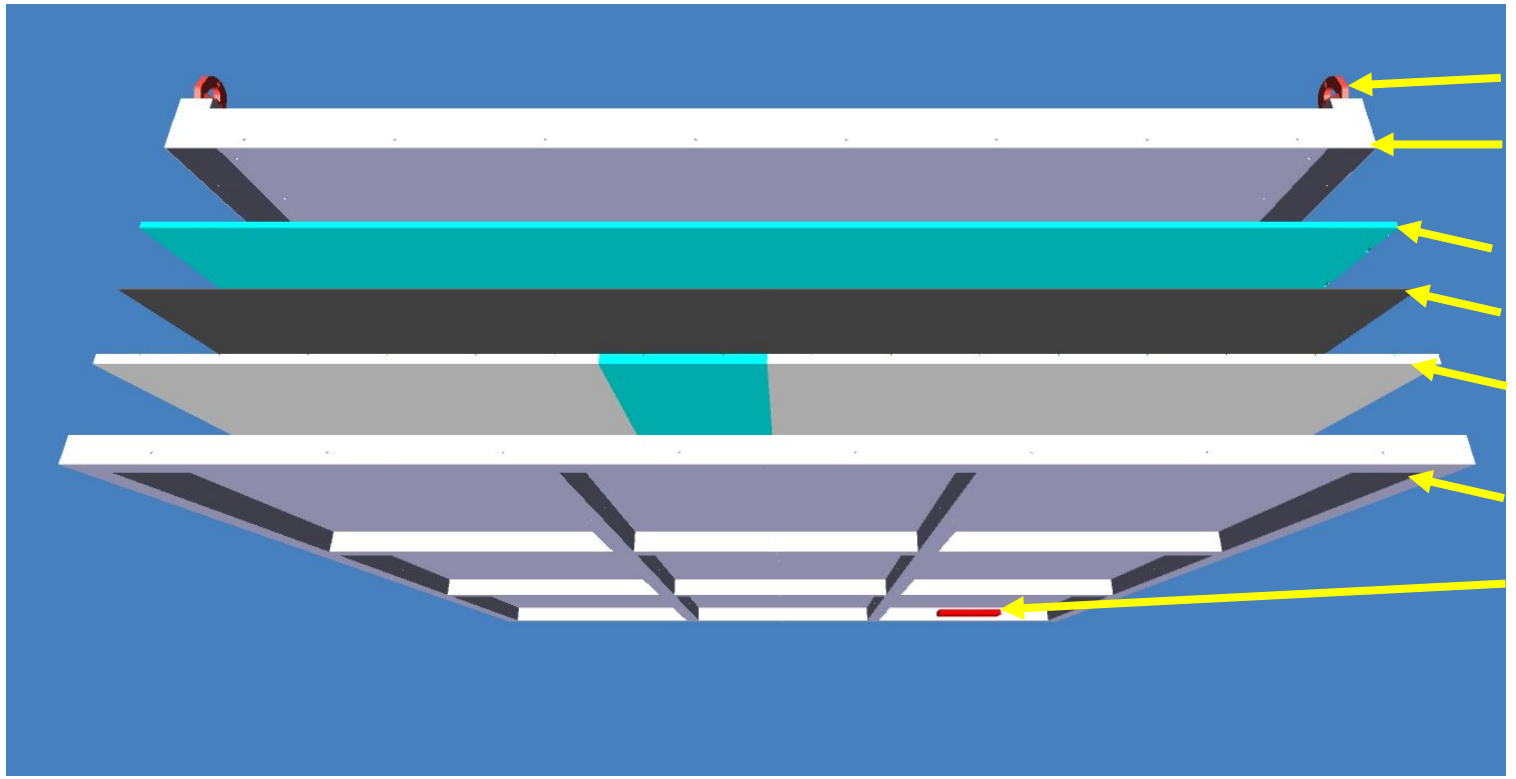
Single CRT module

- Top Cosmic Ray Tagger (CRT) system deployed above the ICARUS detector to tag cosmic ray events
- Composed of 5 scintillating planes:
  - an array of 1.9 x 1.9 m^2 of modules: 84 modules below concrete plug, 38 modules on sloping parts and some spares
- Expected rate of cosmic events → 28 kHz
- Tagging of 80% of the muons

Modular Design:

- independent square modules placed each one contiguous to the next one
- Each module contains both X and Y oriented scintillator bars (8 bars/layer).

CRT Module



The weight of single module is about 160 kg.
In total 125 modules including spares to be constructed for CRT Top units.

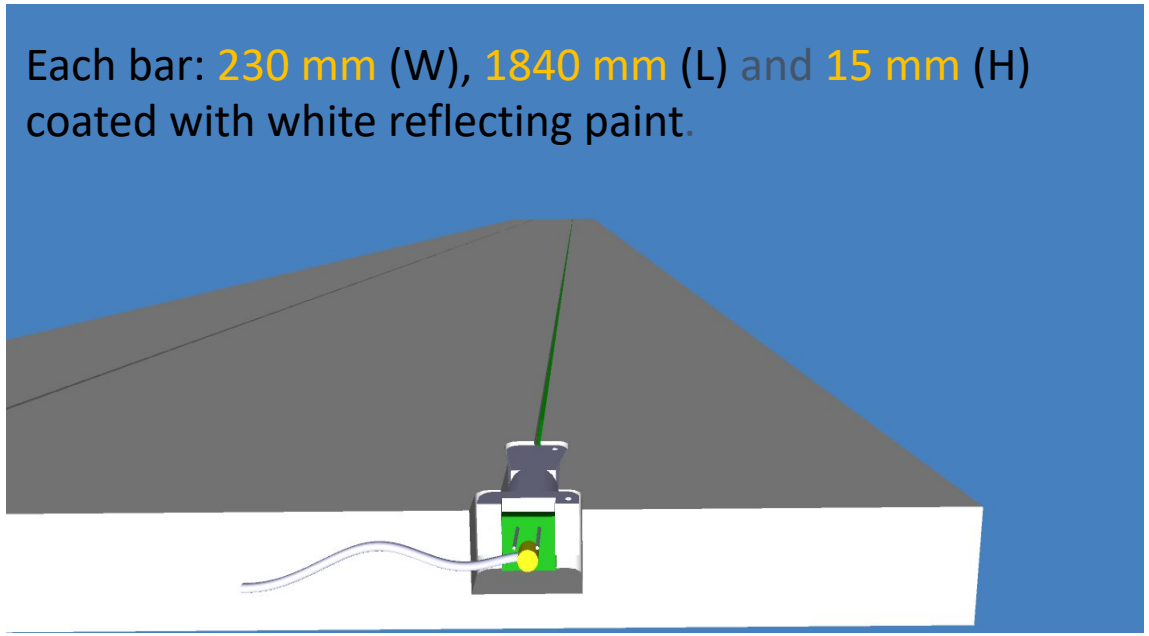
Scintillator production companies:

- **10 mm thick bars from NUVIA, Kralupy, Czech**
- **15 mm thick bars from ISMA, Ukraine**
- **60% of the scintillator bars received.**

Two scintillator quality check stations: Prague and Dubna

[1] Attenuation length using Sr90 source

[2] Light yield using cosmic muons

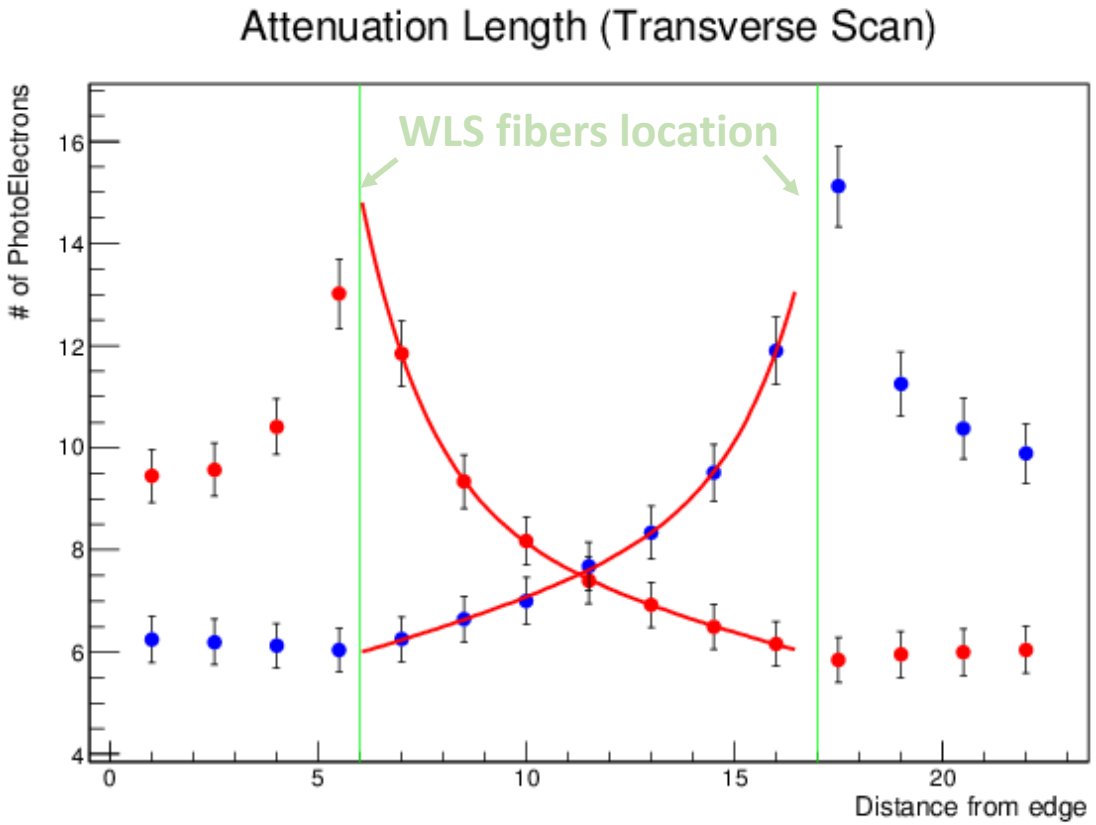


- **Multiclad WLS fibers: Kuraray Y11(200) 1 mm diameter. Cutting, polishing two ends, aluminization of one end by magnetron sputtering technique and quality control have been done in LIP, Lisbon, Portugal.**
- **Photosensor: Hamamatsu S13360-1350CS SiPM with an active area of 1.3 × 1.3 mm^2 - procured**
- **PCBs: SiPM holder and Adapters designed and produced**
- **Module Readout: 32 channels CAEN FEB (Bern design, as SBND) Logical OR of 16-paired channels + coincidence between layers - procured**

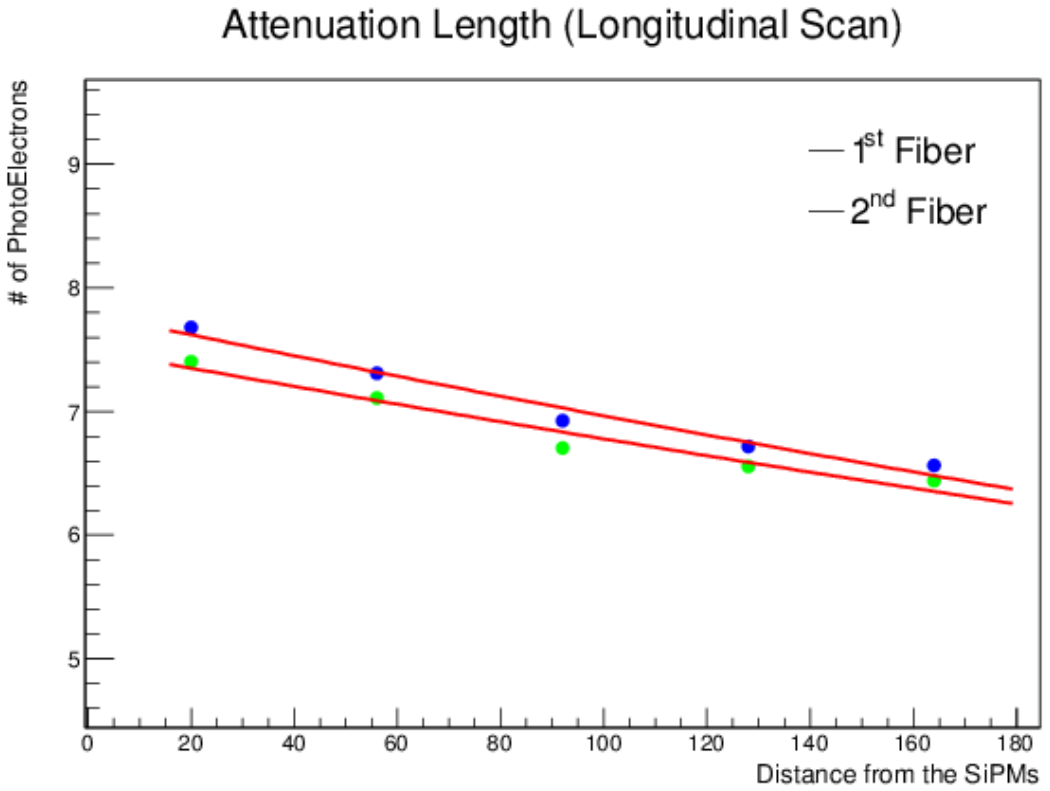
Scintillator quality check

Cosmic muons (calibration with Sr90 source)

Across the scintillator bar



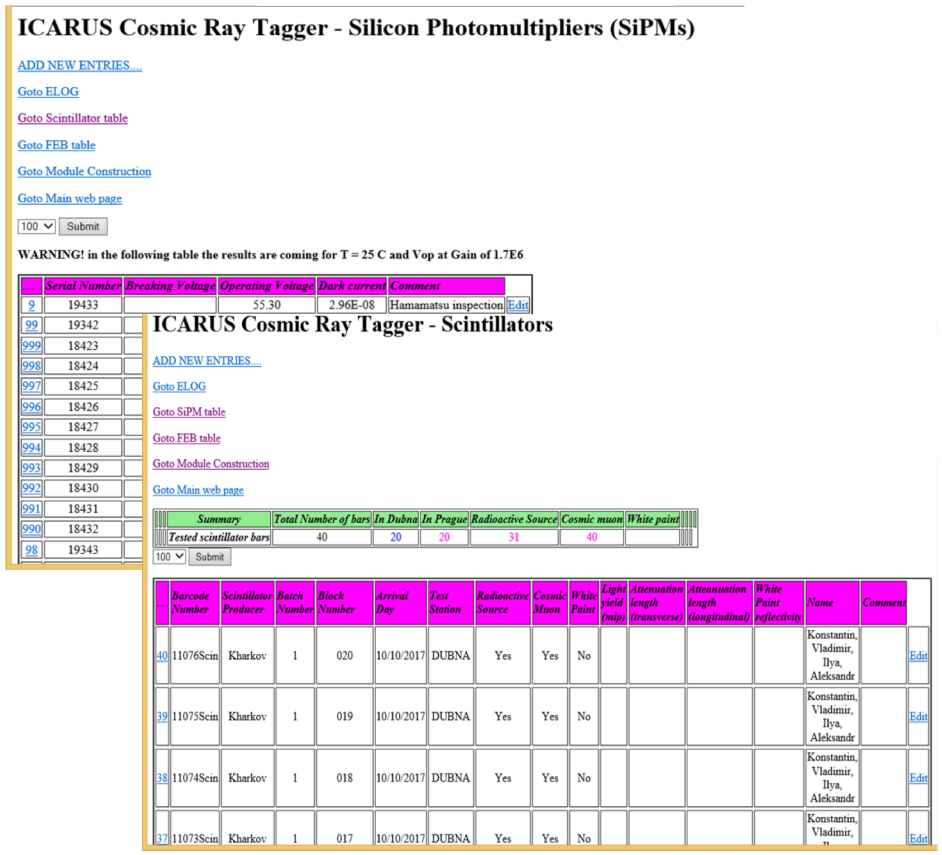
Along the scintillator bar



Quality requirement: # Ph. E. > 15 for 10 mm thick and > 18 for 15 mm thick ; scintillator attenuation > 30 cm

Database of module measurements

Barcode system used to know within CRT module the history/configuration of each single piece: scintillator production batch, characteristics of SiPMs connected to FEB channels, FEBs configurations etc.



ICARUS Cosmic Ray Tagger - Silicon Photomultipliers (SiPMs)

ADD NEW ENTRIES....
Goto ELOG
Goto Scintillator table
Goto FEB table
Goto Module Construction
Goto Main web page
100 Submit

WARNING! in the following table the results are coming for T = 25 C and Vop at Gain of 1.7E6

...	Serial Number	Breaking Voltage	Operating Voltage	Dark current	Comment	
9	19433		55.30	2.96E-08	Hamamatsu inspection	Edit
99	19342					
999	18423					
998	18424					
997	18425					
996	18426					
995	18427					
994	18428					
993	18429					
992	18430					
991	18431					
990	18432					
98	19343					

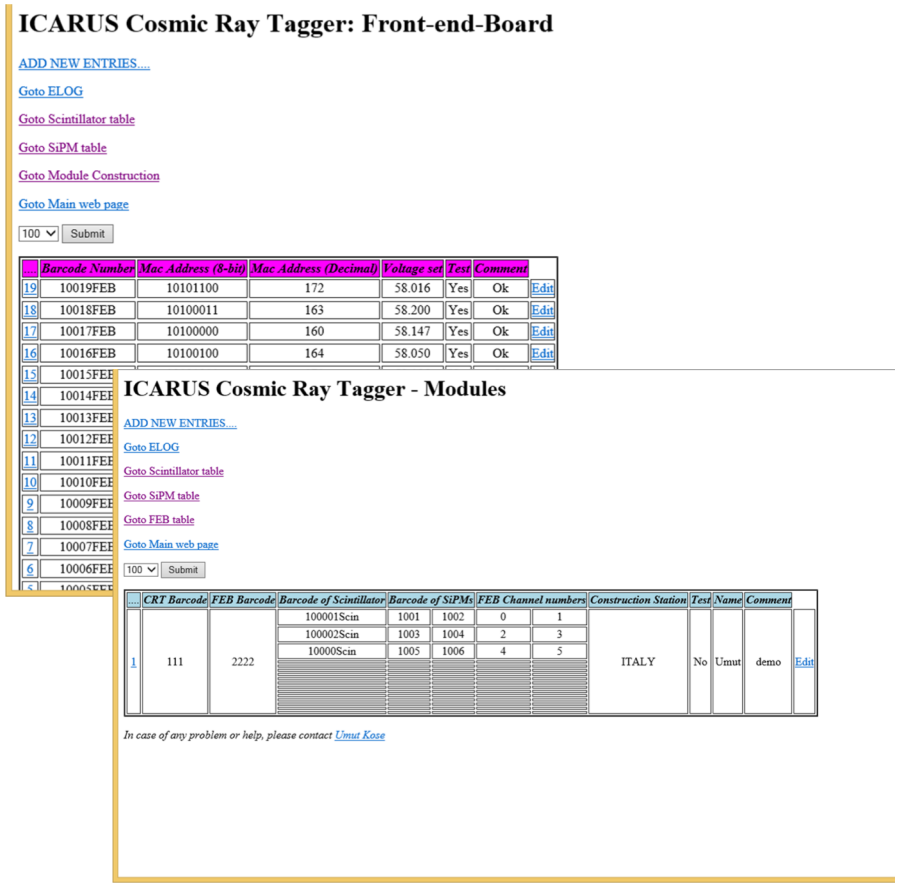
ICARUS Cosmic Ray Tagger - Scintillators

ADD NEW ENTRIES....
Goto ELOG
Goto SiPM table
Goto FEB table
Goto Module Construction
Goto Main web page

Summary	Total Number of bars	In Dubna	In Prague	Radioactive Source	Cosmic muon	White paint
Tested scintillator bars	40	20	20	31	40	

100 Submit

	Barcode Number	Scintillator Producer	Batch Number	Block Number	Arrival Day	Test Station	Radioactive Source	Cosmic Muon	White Paint	Light yield (mip)	Attenuation length (transverse)	Atteanuation length (longitudinal)	White Paint reflectivity	Name	Comment	
40	11076Scin	Kharkov	1	020	10/10/2017	DUBNA	Yes	Yes	No					Konstantin, Vladimir, Ilya, Aleksandr		Edit
39	11075Scin	Kharkov	1	019	10/10/2017	DUBNA	Yes	Yes	No					Konstantin, Vladimir, Ilya, Aleksandr		Edit
38	11074Scin	Kharkov	1	018	10/10/2017	DUBNA	Yes	Yes	No					Konstantin, Vladimir, Ilya, Aleksandr		Edit
37	11073Scin	Kharkov	1	017	10/10/2017	DUBNA	Yes	Yes	No					Konstantin, Vladimir,		Edit



ICARUS Cosmic Ray Tagger: Front-end-Board

ADD NEW ENTRIES....
Goto ELOG
Goto Scintillator table
Goto SiPM table
Goto Module Construction
Goto Main web page
100 Submit

...	Barcode Number	Mac Address (8-bit)	Mac Address (Decimal)	Voltage set	Test	Comment	
19	10019FEB	10101100	172	58.016	Yes	Ok	Edit
18	10018FEB	10100011	163	58.200	Yes	Ok	Edit
17	10017FEB	10100000	160	58.147	Yes	Ok	Edit
16	10016FEB	10100100	164	58.050	Yes	Ok	Edit
15	10015FEB						
14	10014FEB						
13	10013FEB						
12	10012FEB						
11	10011FEB						
10	10010FEB						
9	10009FEB						
8	10008FEB						
7	10007FEB						
6	10006FEB						

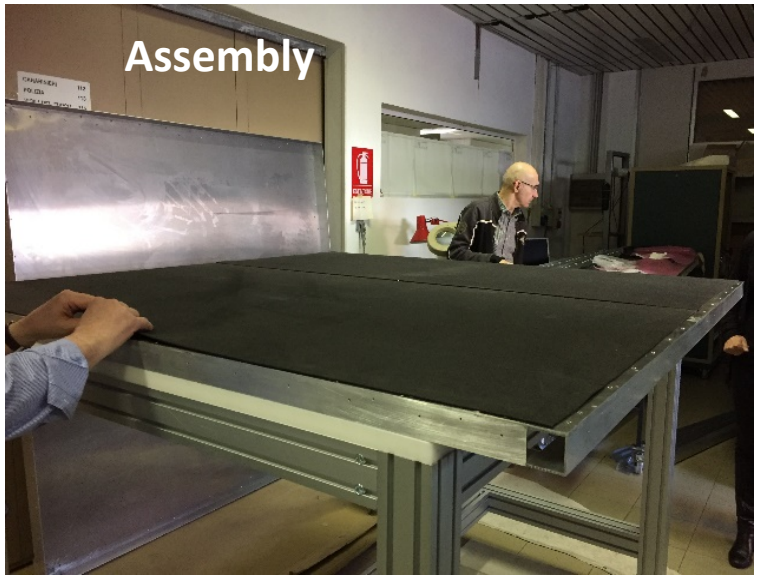
ICARUS Cosmic Ray Tagger - Modules

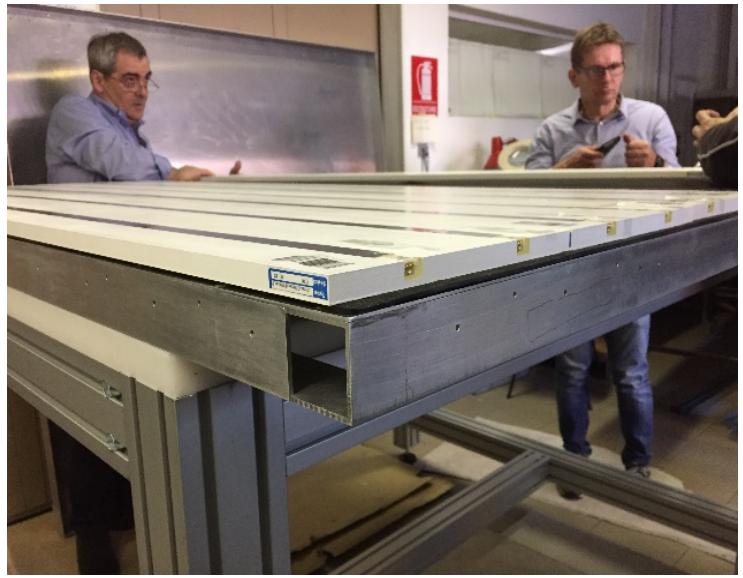
ADD NEW ENTRIES....
Goto ELOG
Goto Scintillator table
Goto SiPM table
Goto FEB table
Goto Main web page
100 Submit

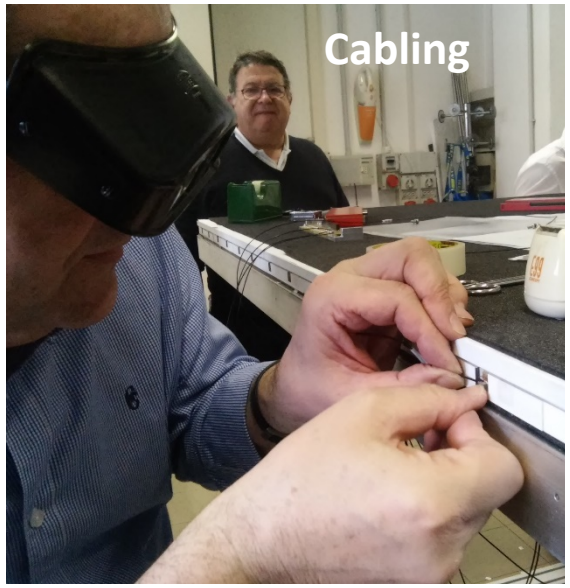
...	CRT Barcode	FEB Barcode	Barcode of Scintillator	Barcode of SiPMs		FEB Channel numbers		Construction Station	Test	Name	Comment	
1	111	2222	100001Scin	1001	1002	0	1	ITALY	No	Umut	demo	Edit
			100002Scin	1003	1004	2	3					
			10000Scin	1005	1006	4	5					

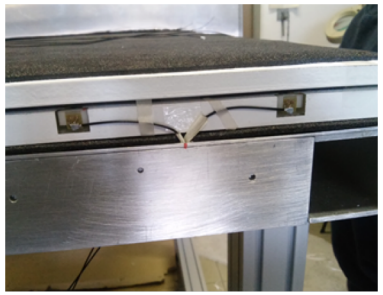
In case of any problem or help, please contact Umut Kose

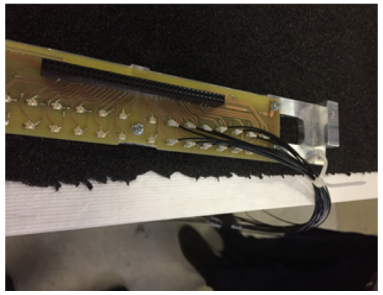
CRT Module Prototype in Bologna: I

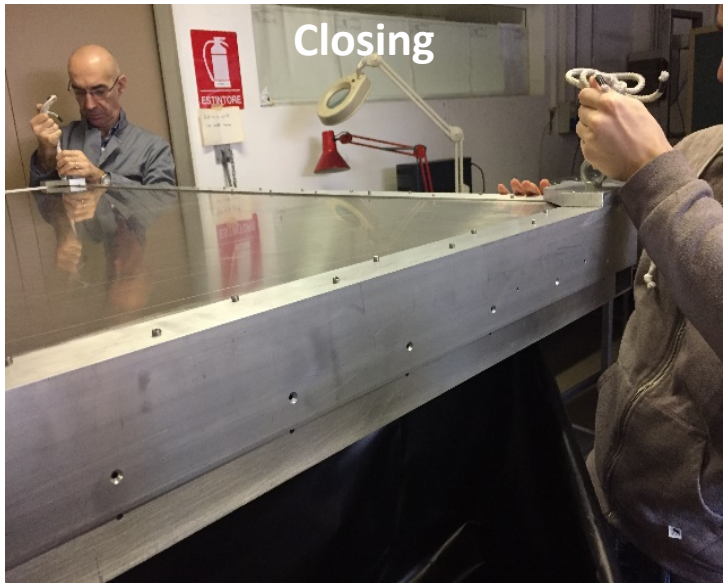




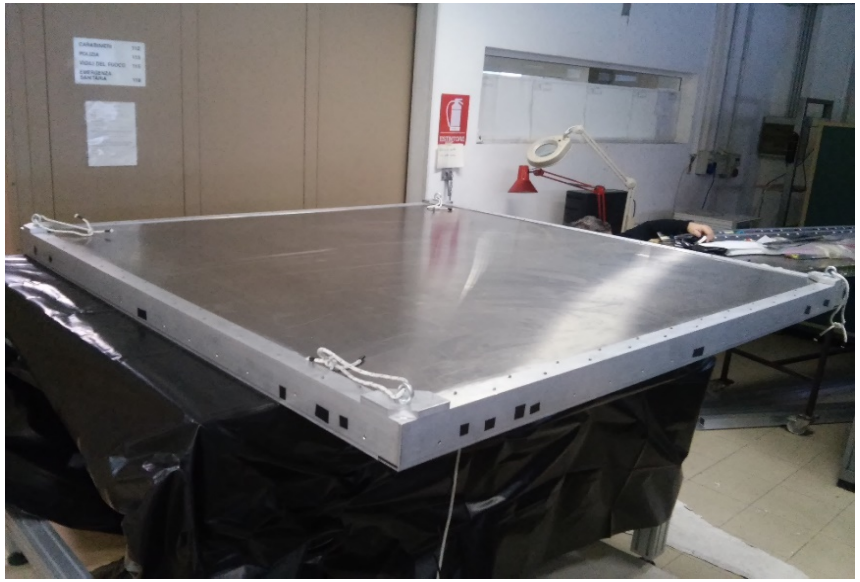


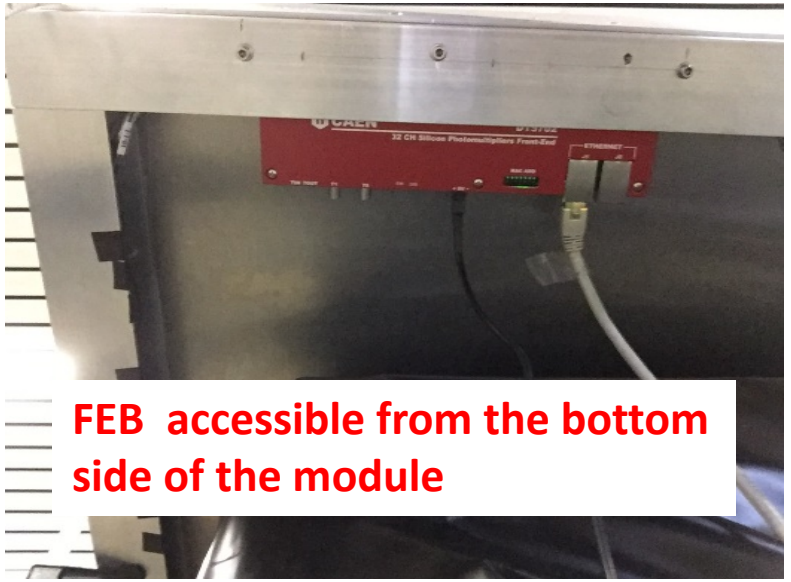




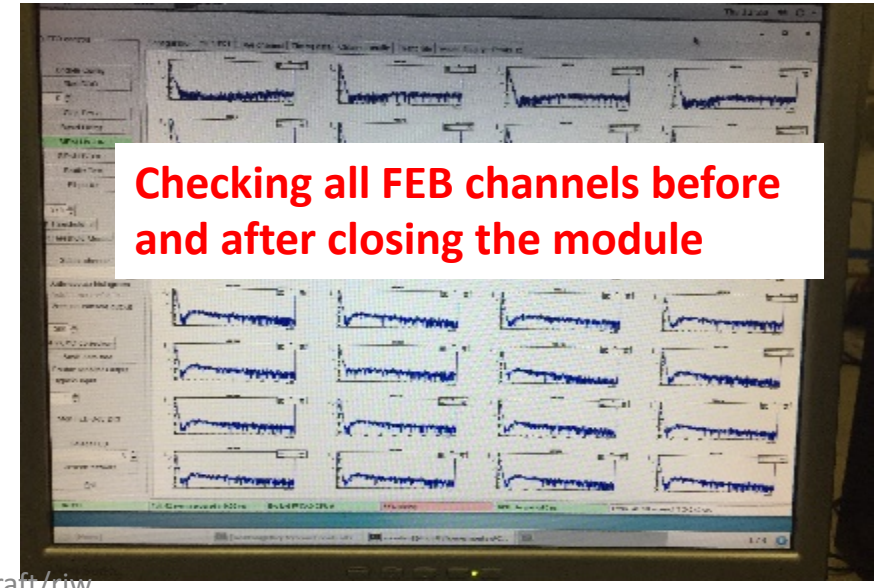


CRT Module Prototype in Bologna: II





FEB accessible from the bottom side of the module



Checking all FEB channels before and after closing the module

CRT Module assembly in Frascati

Gluing started mid of July and is ongoing

Assembly will start at the end of October 2018.
(Machining of Al profiles finishing within 4 weeks)
Goal to assemble two modules per day.

Top CRT Schedule:

- Module Design finalized – February 2018 ✓
- Prototyping completed – March-April 2018 ✓
- Full test of 10% of scintillator bars for each batch: ✓ following production
- Database of all parts and their performances: implemented, being filled
- Material Procurement :
  - Scintillators: 60% produced, last delivery expected November 2018
  - WLS+SiPM, Micro-coax cable - received ✓
  - Connectors 50% 3-D printed
  - Aluminum box in progress
  - CAEN FEB received (firmware and quality testing underway) ✓
- Assembly Lab + construction tools - ready ✓
- Module Test Stand (Cosmic Rays) in progress (~ 2 months)
- First production module complete - end of October 2018
- First modules for inclined TOP CRT parts delivered to Fermilab - depends when we have 38 modules ready to be transported!
- The rest of the modules delivered to Fermilab - July 2019
- Module installation complete – Summer 2019

CRT DAQ

- Work being done as part of the SBN DAQ joint Working Group led by Wes Ketchum
  - He will report in the SBN meeting on Friday
- Other ICARUS collaborators: Bill Badgett (FNAL), Tyler Boone (CSU student)
- Test facility being set up at FNAL
- New addition: University of Houston (Dan Cherdack)
  - Will purchase readout electronics and computers
  - Set up a test station at UH
  - Will add postdoc and students

Summary

- Side-CRT
  - Modules testing and waiting installation
  - Photosensors selected and purchase order placed
  - Photosensors housing designed – prototypes under construction
    - Production schedule developed
  - Cable candidates tested – selection imminent
  - Modules to be installed in ICARUS Hall ~April 2019
  - Electronics installation and commissioning ~July 2019
- Top CRT
  - Scintillator selected and 60% procured
  - All SiPMs and readout electronics procured
  - Prototype modules constructed and tested
  - Production facility is ready
  - Complete delivery to Fermilab ~July 2019
- CRT support structure designed, parts under procurement

- **Far Detector CRT system complete ~ late summer 2019**