Cosmic RayTagger :, new geometry, timing

Update to
https://edms.cern.ch/document/1512005/1

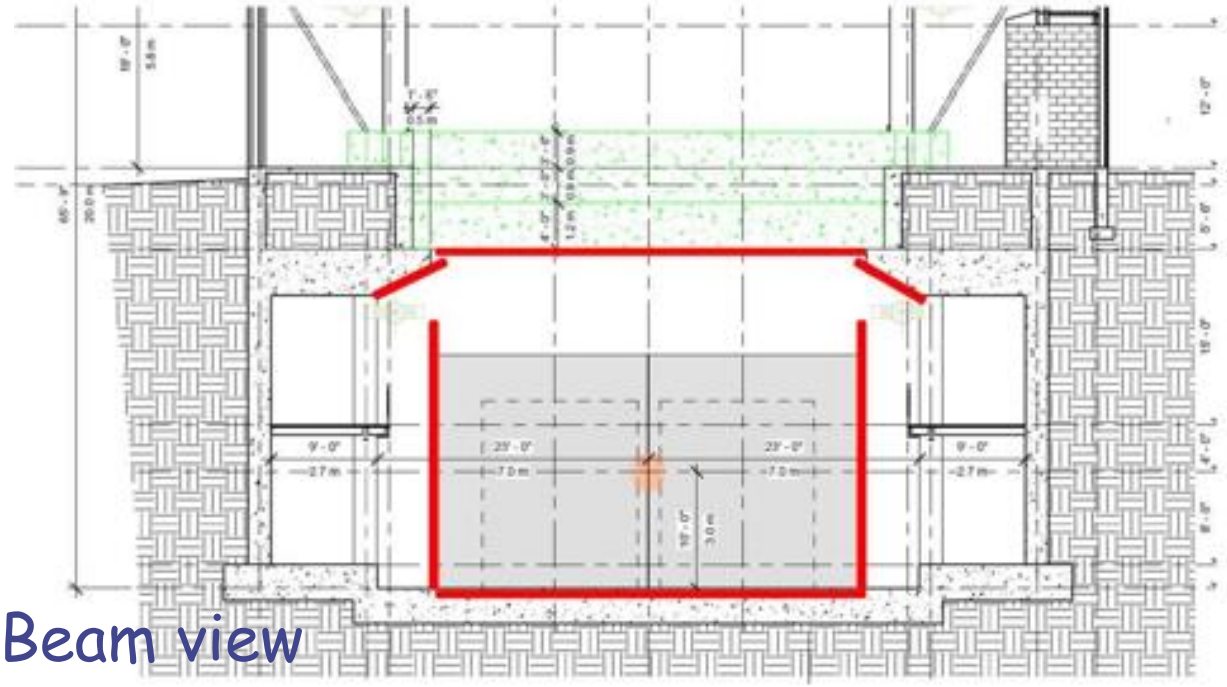
Summary of previous work

- CRT == cosmic ray tagger , for SBN at FNAL
- Aim : mitigate background from cosmics, in particular high energy γ mimicking a ν_e CC interaction.
- Note that software tools and internal PMT system can also be used to discriminate the background (see SBN proposal arXiv:1503.01520)

- Basic layout: scintillator layers surrounding the detectors

- Possible drawback: auto-veto of non contained neutrino events

A possible full coverage CRT (4π CRT)



Beam view

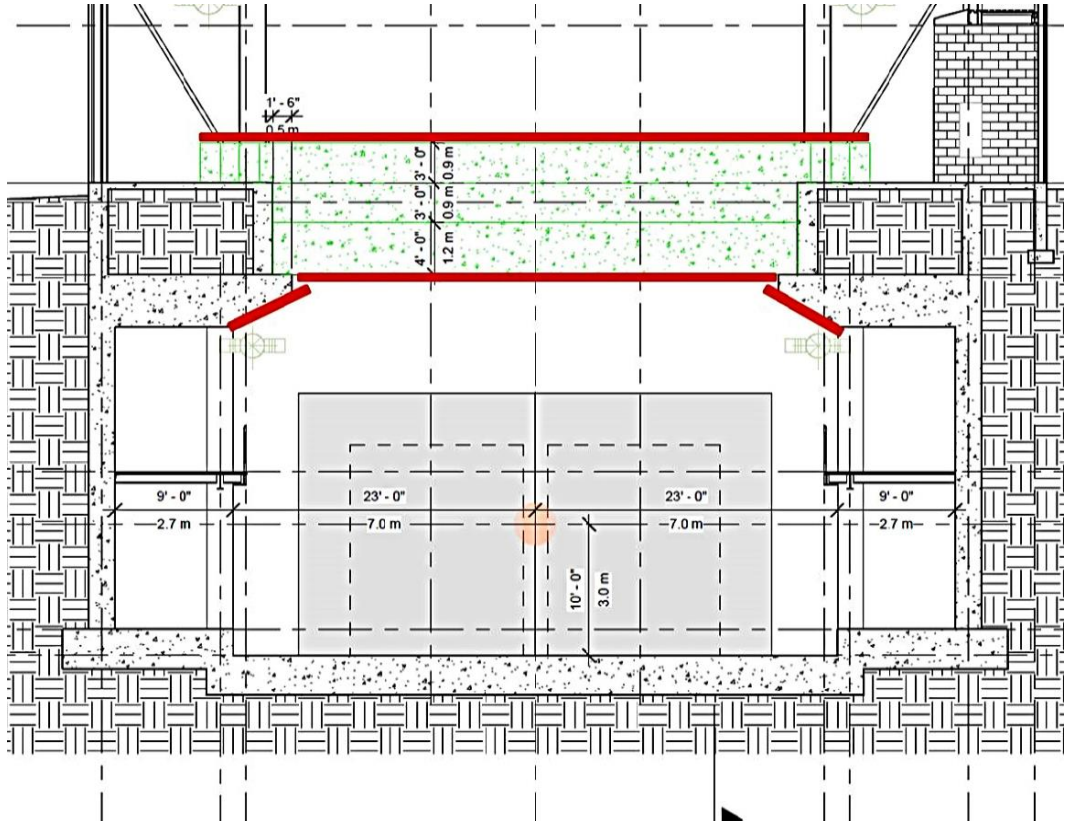
Possible configuration:
Scintillator units (in red)
Each units composed by two layers
Each layer composed by stripes, oriented at 90^0 between layers

Total surface: ~1000 m^2
Option: with or without bottom unit

Geometrical efficiency : 99.9%

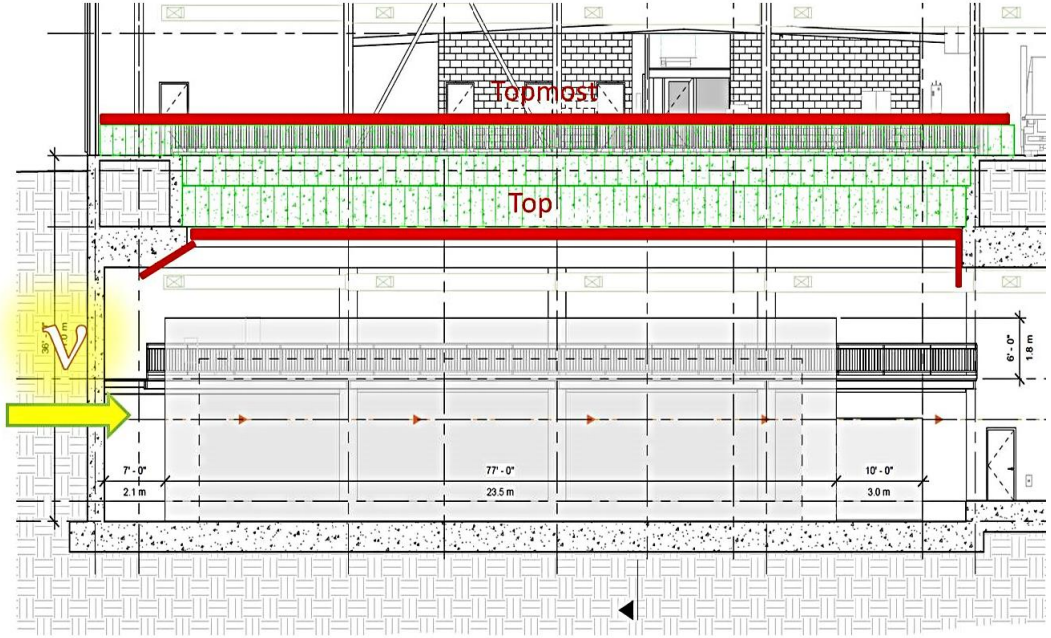
Side view

A possible Telescope CRT



Beam view

Possible configuration:
Scintillator units (in red) above and below the concrete ceiling
Each unit composed by two layers
Each layer composed by stripes, oriented at 90^0 between layers



Side view

Total surface: ~800 m^2

Geometrical efficiency : 80%

Residual backgrounds/fakes status may 2015

	Background in 211 sec						auto-veto %	
	Before cuts			After cuts			ν_μ CC	ν_e CC
	Timing A	Timing B	Total	Timing A	Timing B	Total		
no CRT	32600	225000	258000	21	179	200	0	0
4π CRT								
Signal in at least one unit	33	225	**258**	0	0.2	**0.2**	32	12
Vector	7200	49500	**56700**	5	39	44	3	1
Vector if no bottom unit	28000	191000	**219000**	18	152	**170**	1.8	0.6
CRT Telescope								
Signal in at least one unit	6200	43700	**49000**	4	34	**38**	8	3.5
Vector	10000	69000	**79000**	6	55	**61**	0	0

1000 m^2

400 m^2

Intrinsic ν_e CC from beam 1500

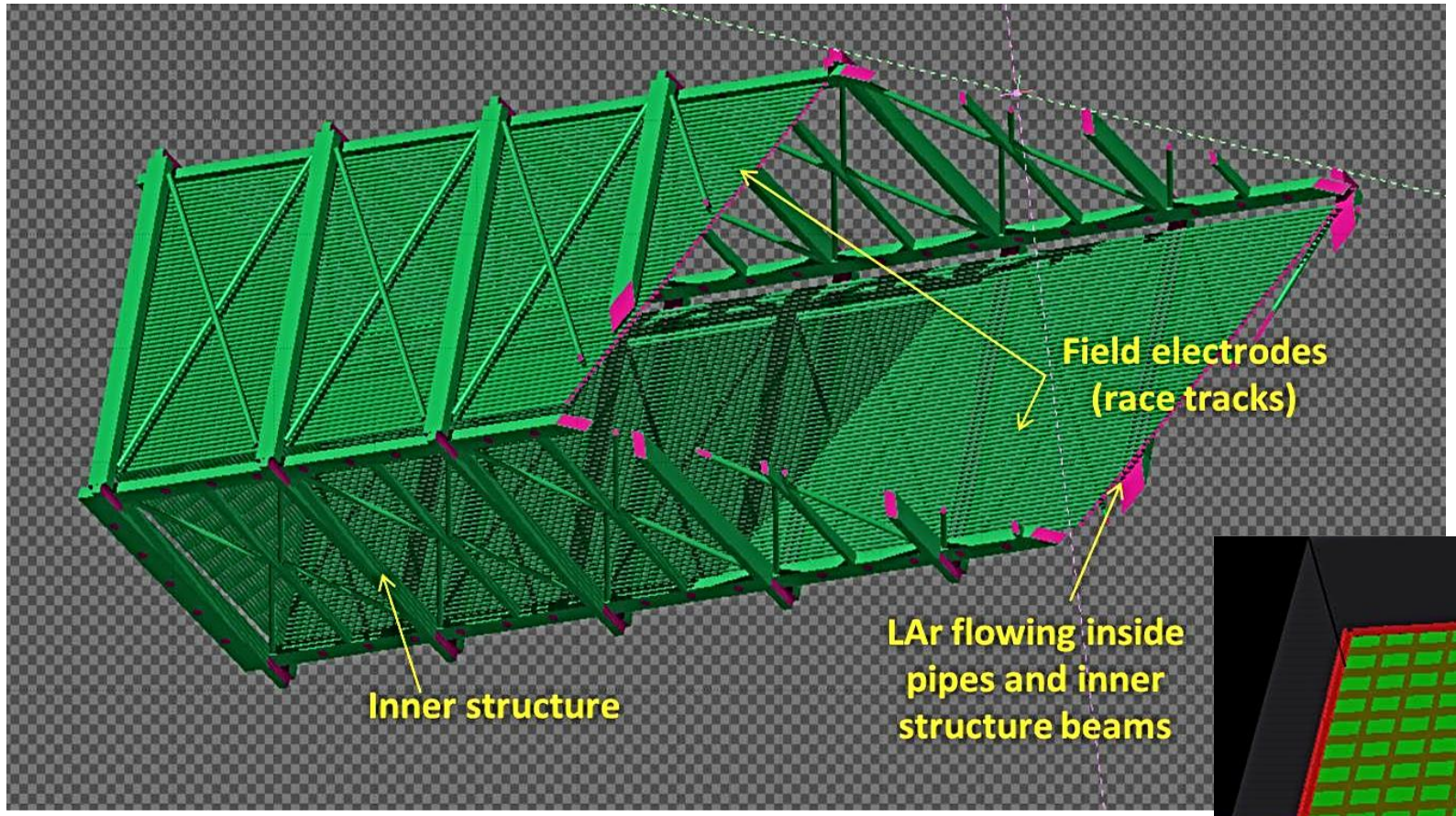
Way to go

- Staged approach (top first, bottom last)
- Consider timing as a discriminant between cosmic and internal events (ns resolution needed)
- Consider using single-layer scintillators bars, reading at both ends gives timing and position..

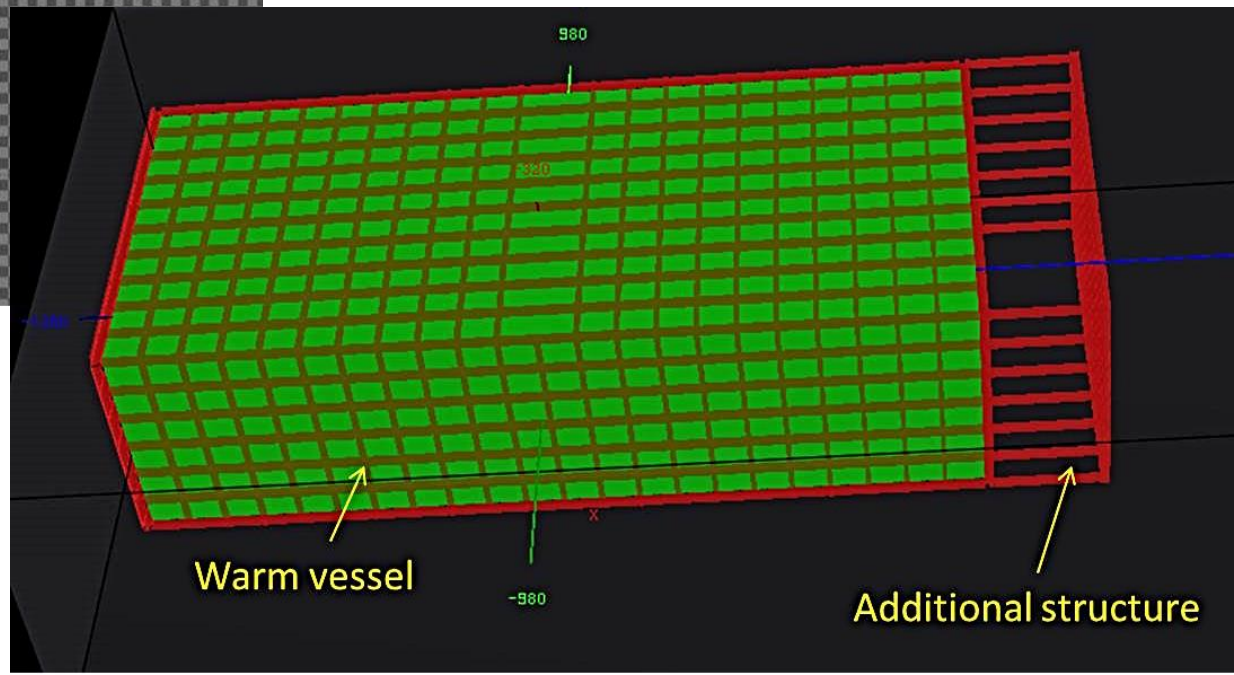
Today's update :

- Improved geometry description
- Timing of beam events
- Auto-veto with timing, and with single layer

New geometry



- Thanks to Umut, we have a full and detailed description of
  - Inner structure, field cage
  - Cold Cryostat
  - Warm vessel
  - Building



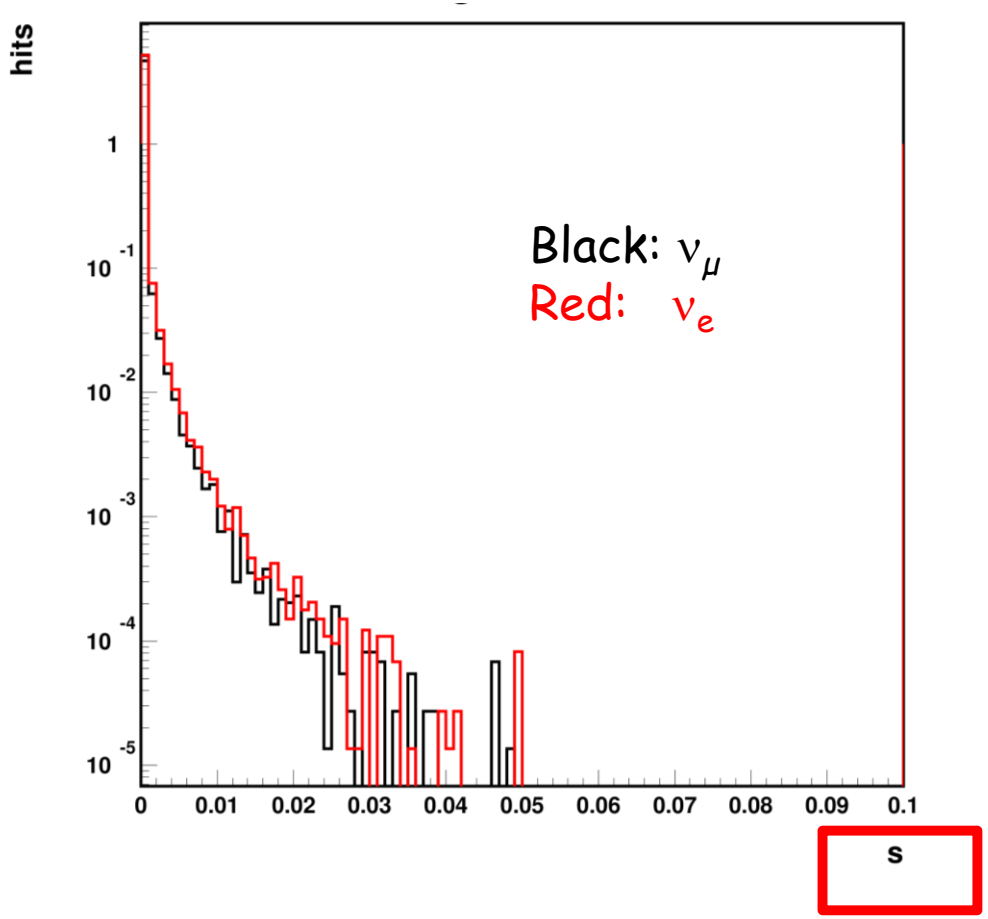
Option on "back" panel : before or after additional structure

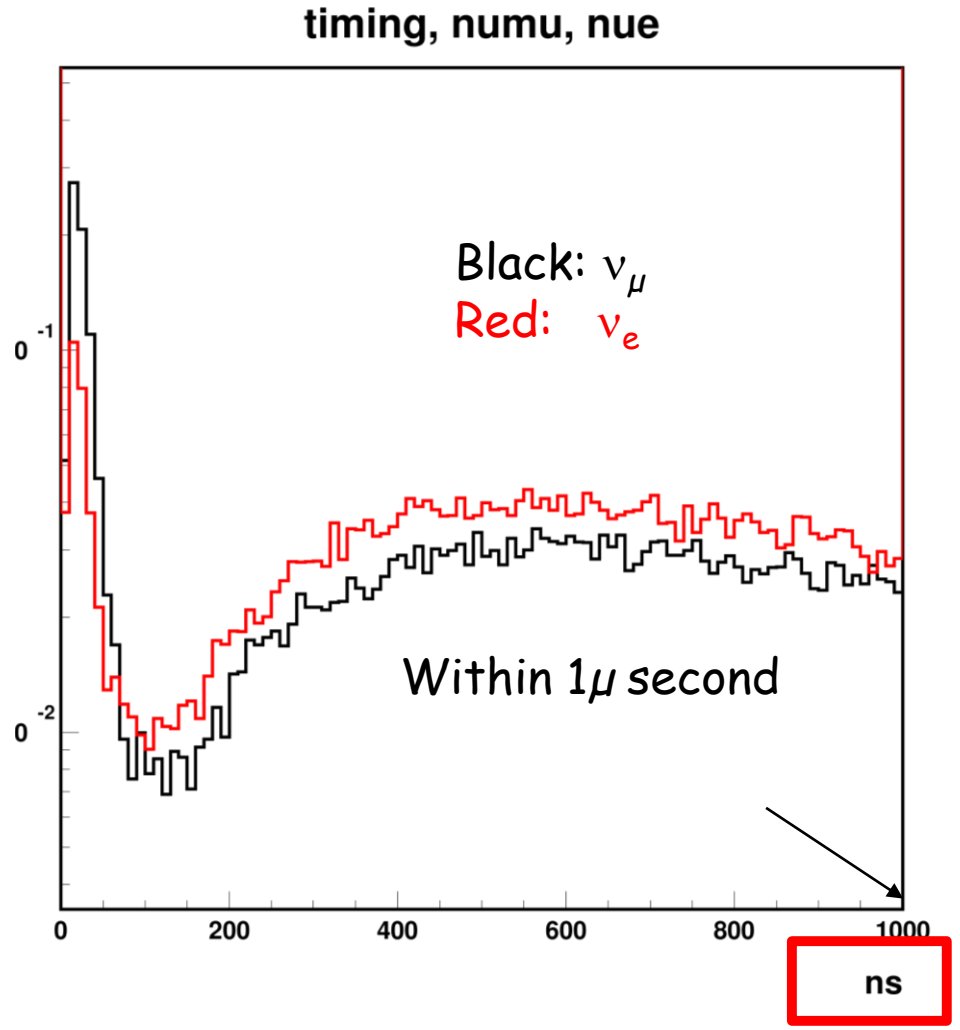
New runs

- For cosmics: no change wrt previous numbers.

- For Internal Neutrino events:
  - added dump of time of arrival and
  - added quenching of light in the scintillator (to be checked with real one)

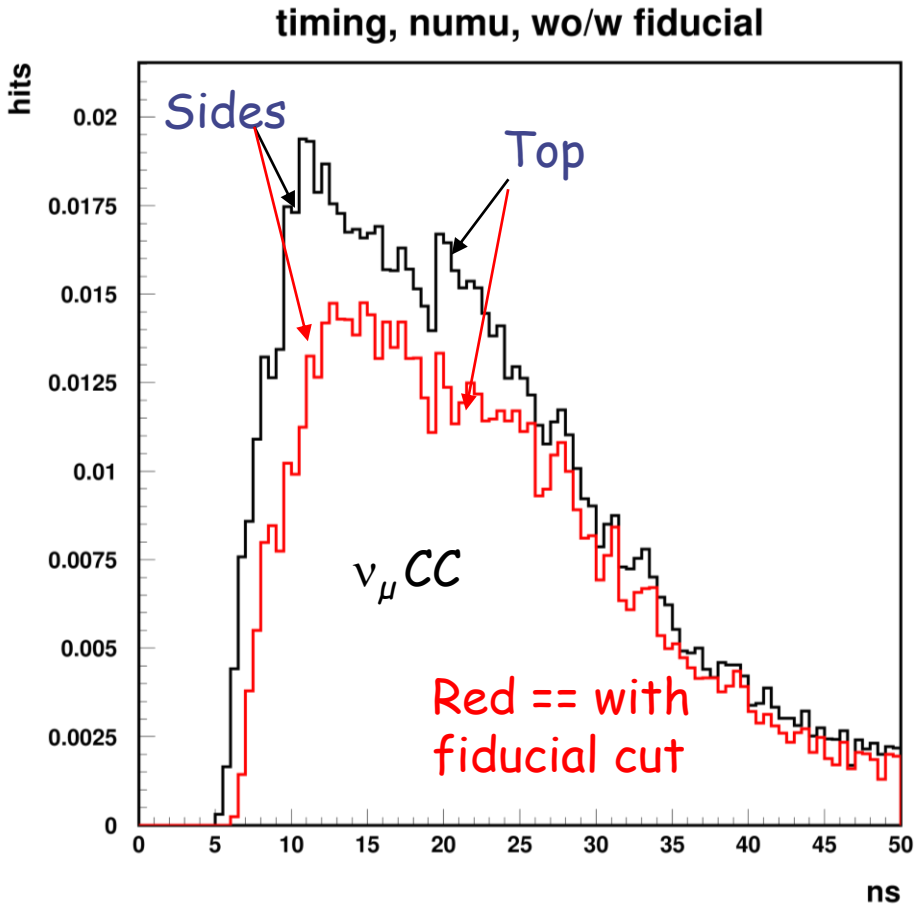
Time of arrival 4π CRT



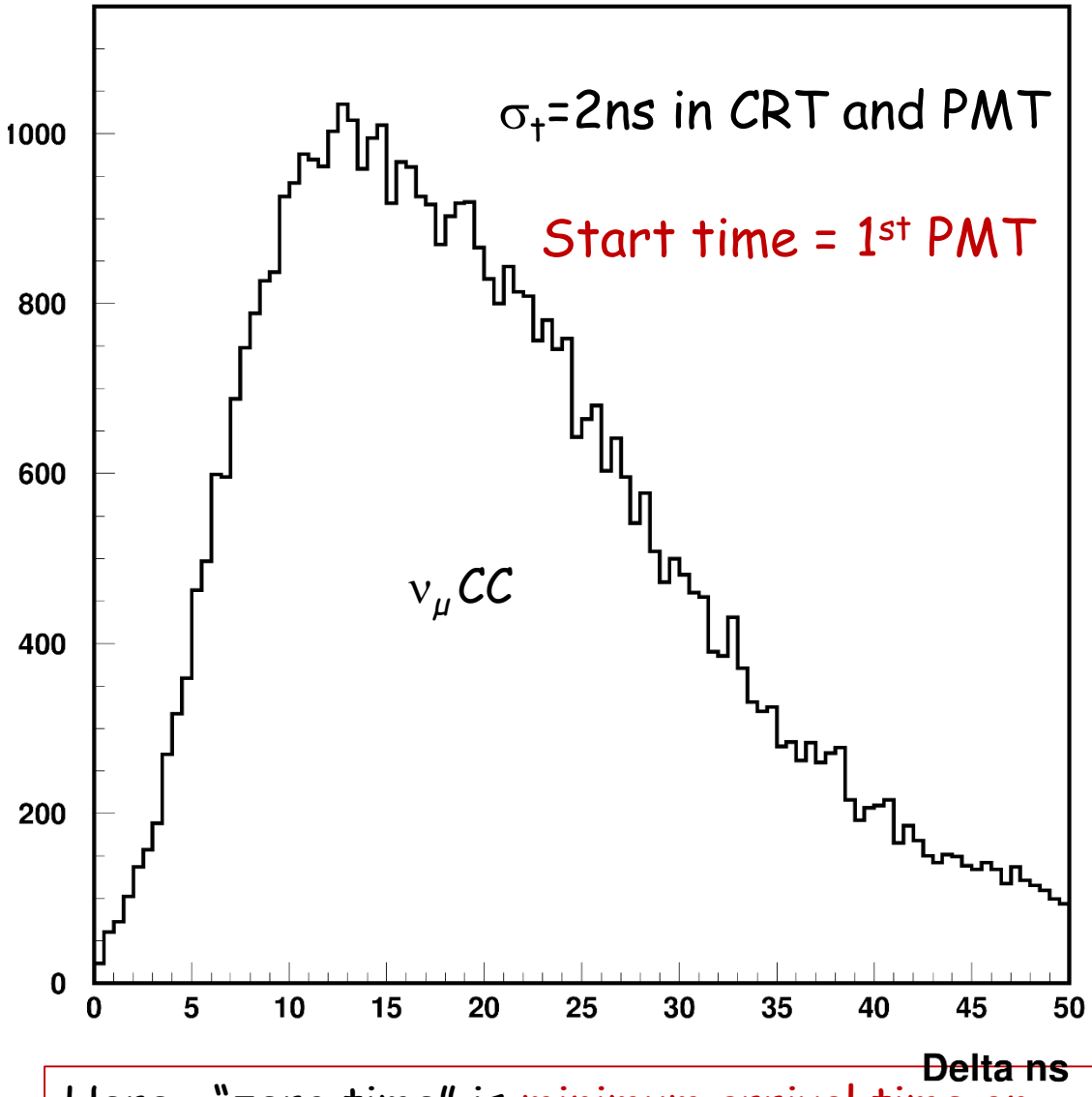


Time distribution for every energy deposition in the CRT scintillators.
Start time is given by neutrino interaction
Only events in fiducial volume
Only events with at least a signal above 0.5MeV in one scintillator layer

Time of arrival- 4π CRT zoom

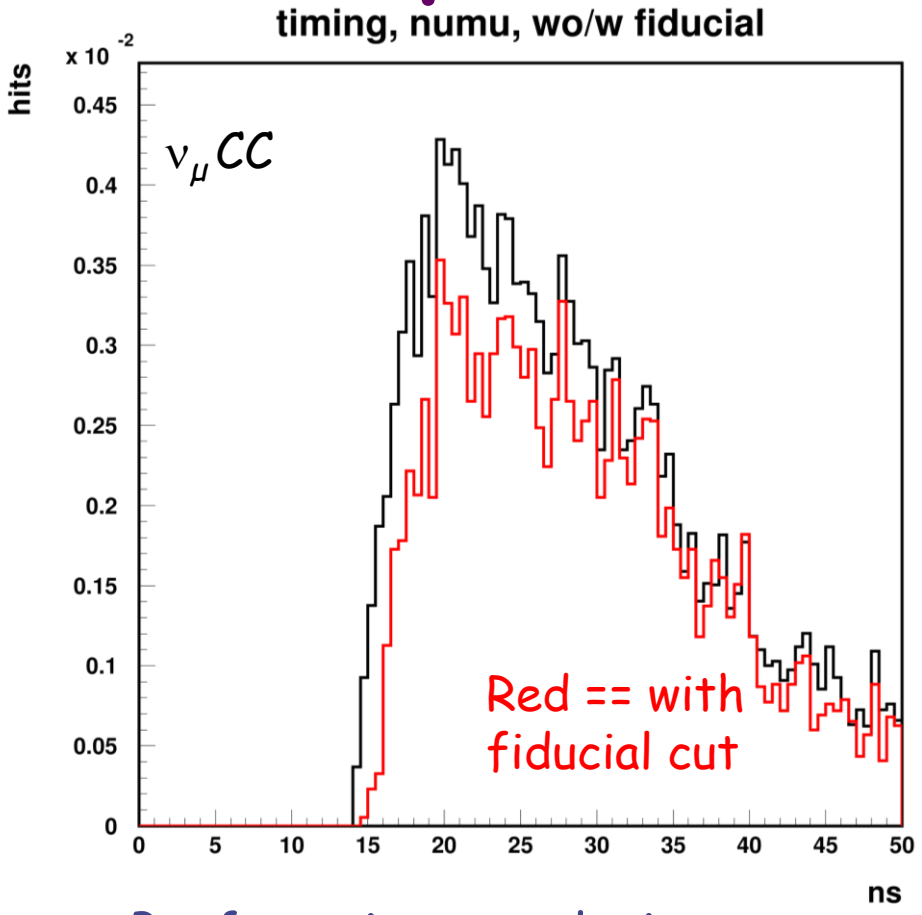


- Perfect time resolution assumed
- Only events with CRT signal
- T depends on CRT module.
- Minimum approx. 5ns

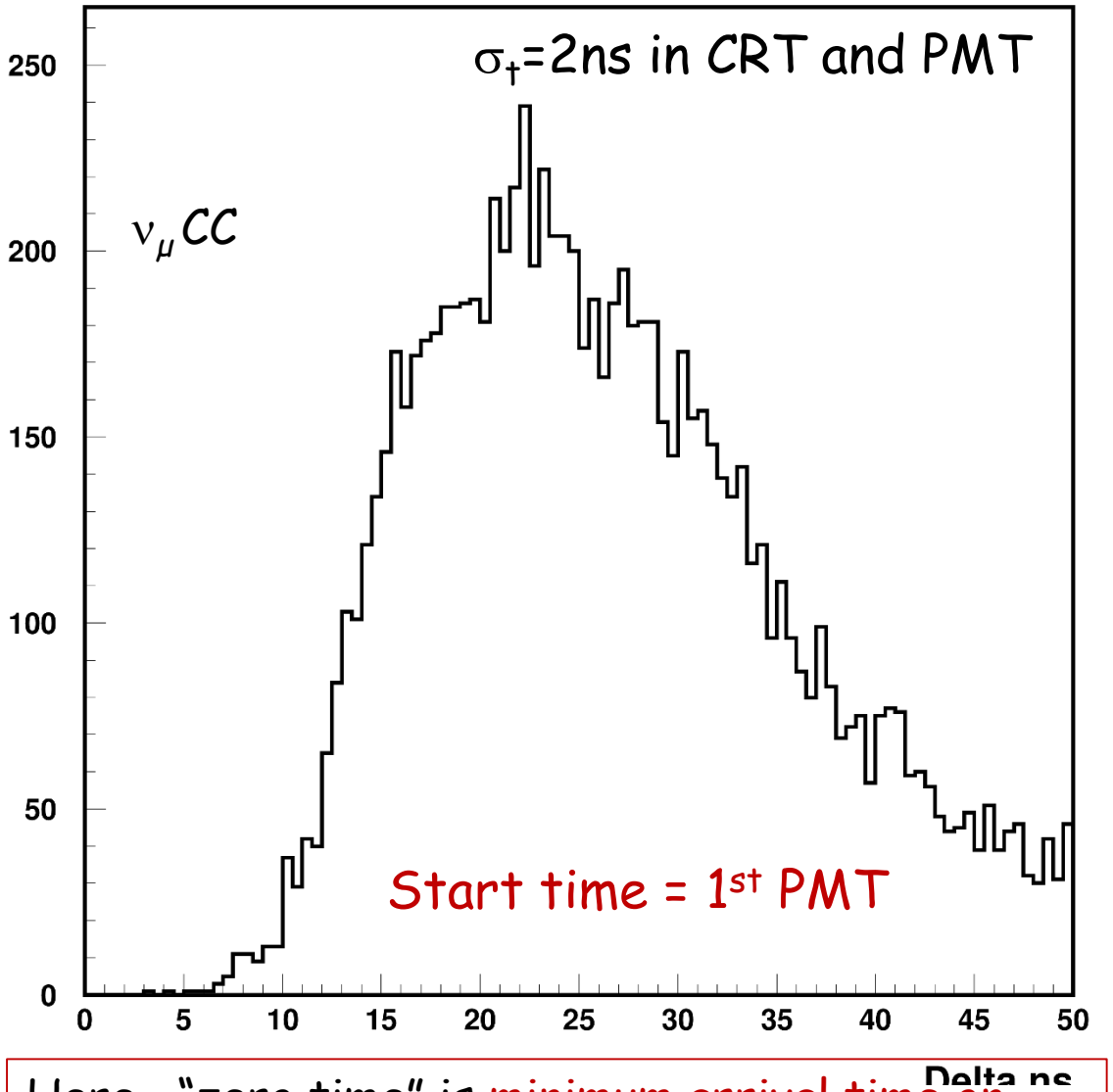


Here , "zero time" is minimum arrival time on internal PMT system. (Rough estimate from vertex position).
Time resolution added (2⊕2 ns)

Time of arrival- Telescope

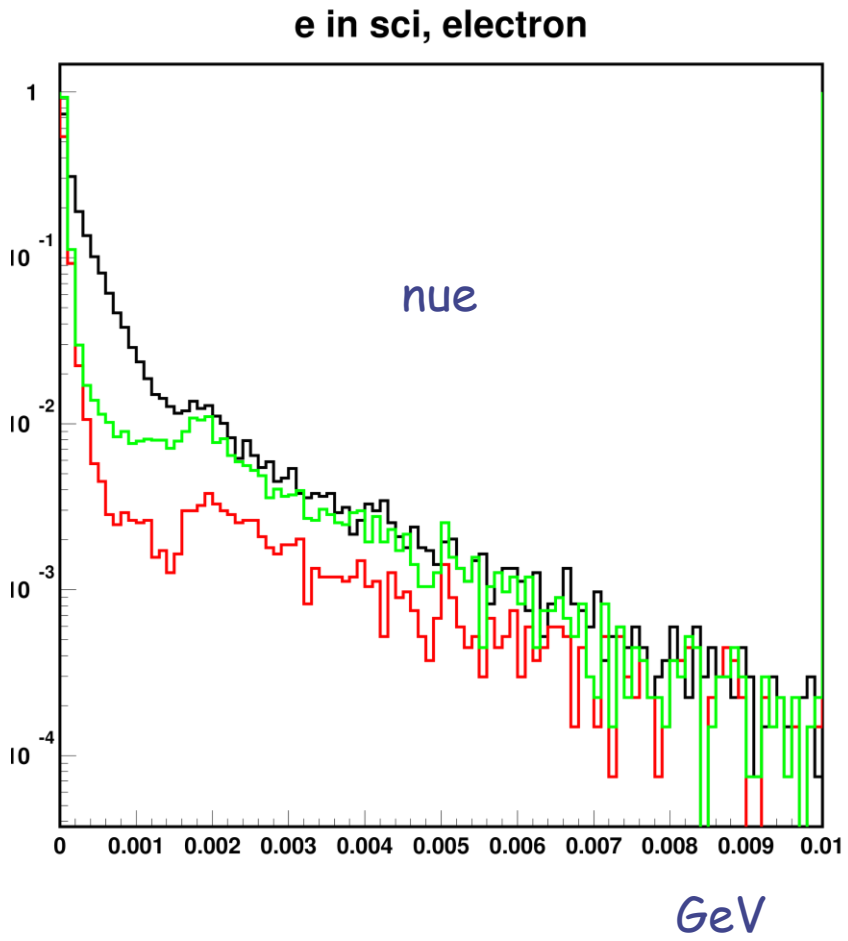


- Perfect time resolution assumed
- Only events with CRT signal
- Only TOP
- Min 15nsec



Here , "zero time" is minimum arrival time on internal PMT system. (Rough estimate from vertex position).
Time resolution added (2⊕2 ns)

Time-gated auto-veto

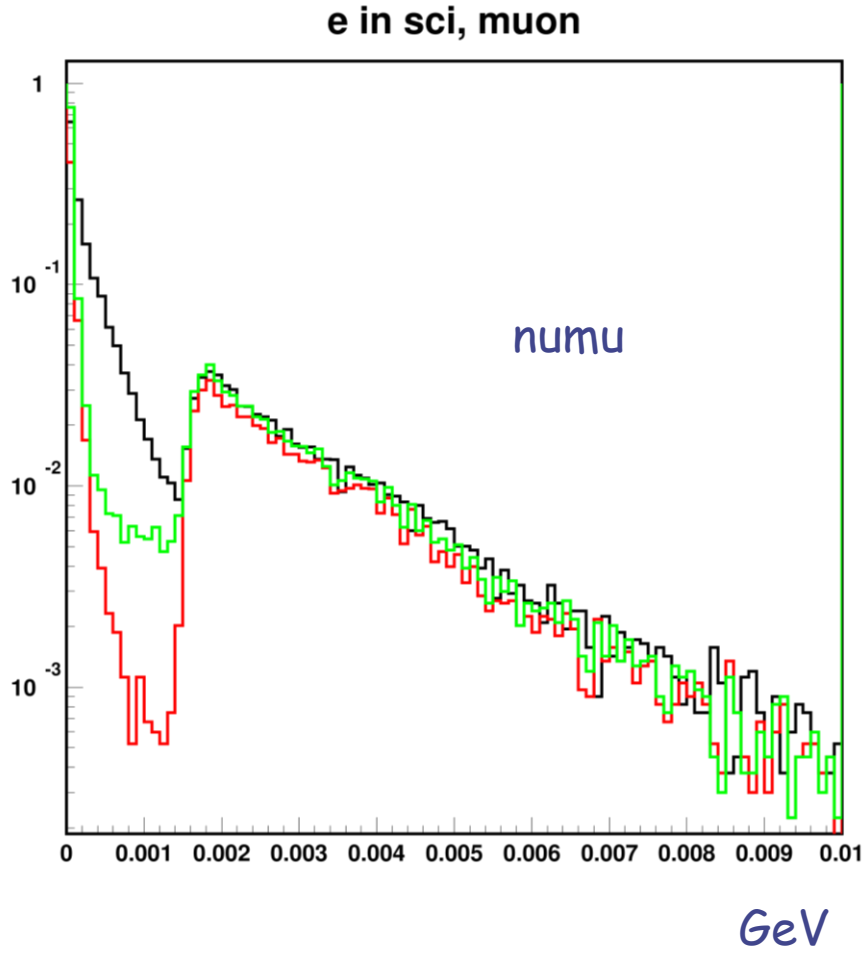


Energy deposited in one CRT layer (1 cm scint)

Black=all hits

Red = time cut at 1μs

Green: signal quenching (Birks)



Muon component clearly visible. Time cutoff affect strongly the auto-veto rate, especially for nue. Signal quenching in scintillator can also affect.
Note: all auto-veto calculations consider a CRT signal only if Edep > 0.5 MeV

Auto-veto from non contained neutrino events

4 π	ν_e CC bckg	ν_μ CC	ν_e CC osc	ν NC	C.R. eff.
single unit, 1 layer	34 /24	45 /36	27 /19	32 /22	
single unit, double layer	9/ 6	26/ 24	6 / 4	6 /3	99.9%
vector	1 / 0.4	2/ 1.2	0.5 / 0.2	0.4 /0.1	

Threshold: 0.5 MeV in one layer Red: time -cut at 1μ sec

Telescope	ν_e CC bckg	ν_μ CC	ν_e CC osc	ν NC	C.R. eff.
single unit, 1 layer	14 / 9	15 / 11	11 / 7	32 / 8	
single unit, double layer	4/ 2	7 / 6	2 / 2	2 / 1	80%
vector	0 / 0	0 / 0	0 / 0	0 / 0	

Conclusion and next

- Geometry updated to latest vessel design → more material, less auto-veto
- First look at timing for neutrino events
- Time cut-off also reduces auto-veto
- Still non-negligible, especially for ν_μ and for single-layer CRT modules
- PMT-CRT time difference few ns
- All figures are "better" for the TOP CRT module, suggesting again a staged approach (my personal view)

- "Dirt" events being processed
- Update of the EDMS note ongoing
- More analysis will be done by our ICAR-US colleagues – will send data asap