Summary of the 8^{th} SND@LHC Collaboration Meeting

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Emulsion Production

Slavich Company

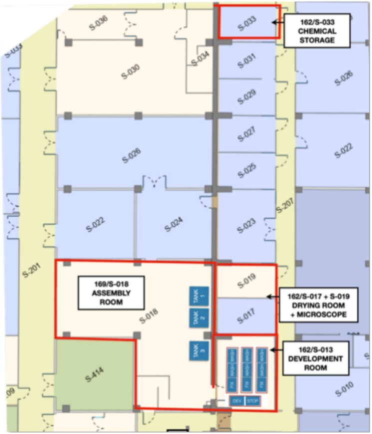
Was the planned main provider for 2022
Problems with the transport of the emulsions
Will be transported via Finland
Will not have the planned upgrade to the production facilities

Nagoya University

Automated production is now possible
Production for 2022 cannot be increased (other commitments)
Production for 2023 will be increased

Emulsion Target

- Current Tungsten sheets have bad roughness
- Waiting for Slavich emulsions to complete the target
- Development facilities have been prepared
- Still no equipment installed

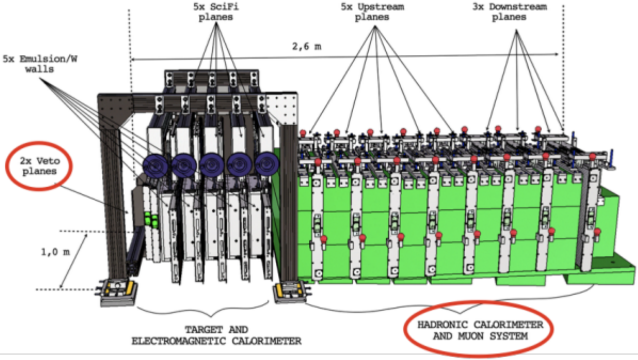


Development Facilities

Development+drying rooms: wall removal, door opening, asbestos removal, wall painting

SND@LHC Layout

Veto System
2 Planes of 7 bars, with 8 SiPMs per bar end
Scintillating Fiber Trackers
5 Planes with X and Y measurements done by 1536 SiPMs per side
Muon System
Upstream System : 5 planes of 10 bars, with 8 SiPMs (6 big + 2 small) per side
Downstream : 3 double planes of 60 bars, with 2 SiPMs for Horizontal bars and 1 per Vertical bar (extra vertical plane at the end)



Monitoring System

Is already **INSTALLED**

Controls :

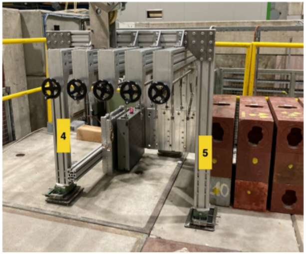
- Temperature
- Humidity
- Smoke
- Cooling System

3 Alarm Levels :

- Low → system remains on state One sensor triggers, one smoke detector triggers or cooling system turns off
- Medium → hardware kill command sent until alarm is cleared Two or more sensors trigger or cooling system stays off for a prolonged time
- High → hardware kill command sent until alarm is cleared Two or more smoke sensors are triggered

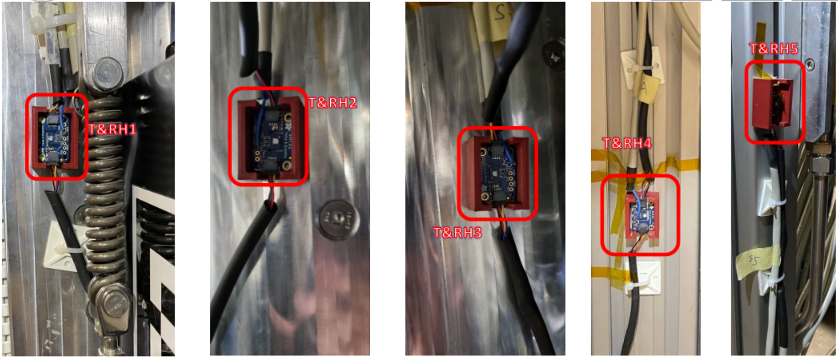
Monitoring System

T/H position
on SND



Monitoring System

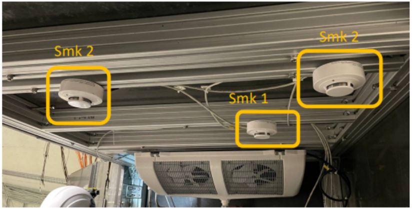
Installation at SND: T&RH sensors



Monitoring System

Installation at SND

Smoke sensors



Main board box

Veto Status

Installed

2 out of 4 PCBs were removed for repairs before being installed in TI18

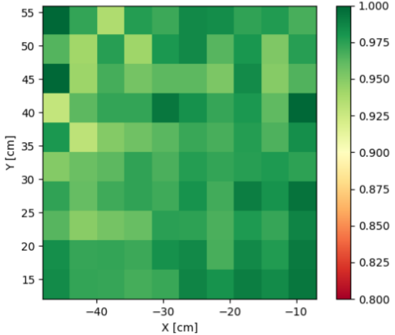
Data taken during last week (7 days of cosmic muons) is now being analyzed

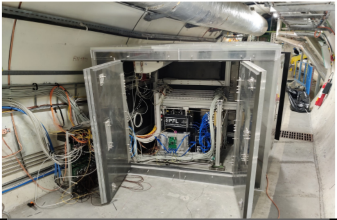
Preliminary results :

- Only 3 out of 224 channels for 1 plane are faulty. Other plane is fully functional
- This pattern was seen in H6, but seems to be on different planes now **Need to verify plane switch !**

SciFi Target Tracker Status

- Installed inside the coldbox
- Time Resolution ($\approx$ 550ps -> should be $\approx$ 250ps)
- Timestamp correction $\approx$ 40ps
- **Coincidence between mats to follow**
- Efficiency > 95% on average
- Not completely homogeneous
- Can be improved with better thresholds





Muon System

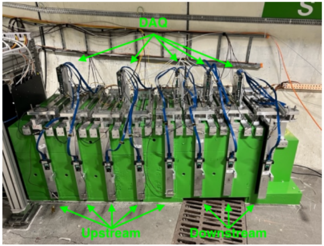
First fully assembled subsystem of SND@LHC

Already installed in TI18

Fully aligned apart from US5 (alignment done by survey) : shows overlap conflict with iron blocks in simulation

10 Missing channels in H6 data (8 in US1R, 1 in US1L, 1 in DS4V) $\rightarrow>$ **99% channels functional**

Cosmic data from last week shows different missing channels!!!



Testbeam in September 2022

Plans to have a testbeam at the North Area in September/October are undergoing

There is a need/want to produce 20% spares for the detector. This includes scintillating bars, frames, SiPMs and PCBs, which would amount to :

- 1 extra US
- 1 extra DS

To perform the testbeam additional money and man-power is required → Call on interested institutes has been made

Cold Box

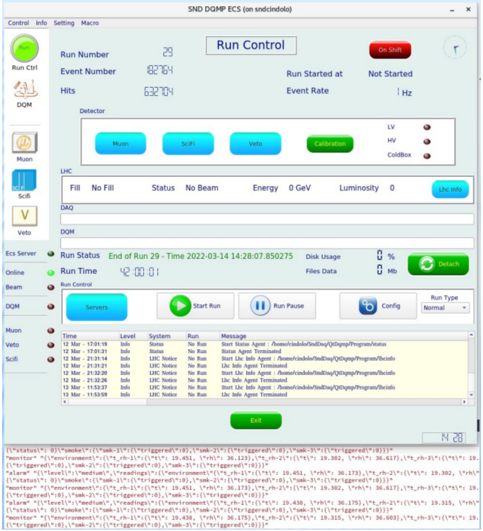
16th March state of Cold Box

Online System

Consists of :

- **Experiment Control System (ECS)** - Controls the activities of the online agents
- **Data Acquisition (DAQ)** - Realize dataflow from the detector to the data storage
- **Detector Control System (DCS)** - Oversees, monitors and controls the detector services : power-supplies, coldbox and detector safety system
- **Data Quality Monitor (DQM) and Real Time Analysis** - Software packages to monitor data quality, detector performance and real time light-analysis
- **LHC Communication**
- **Logging and Databases** - Based on Elog

ECS Graphical User Interface



Data Quality Monitor

Still very primitive

Data is recorded to a server that transmits it to a separate client. This client allows the several agents to access and process it in order to present results in the ECS.

Only parts implemented so far are the Server and Client, and their connection.

No useful functions have been implemented yet.

There is no data streaming program yet

My understanding is that data is being transferred offline through the .root files that are saved periodically - Every 10^6 events creates a new file in order to prevent size issues.

Priority is being put on the Detector, Readout, Run Control, DCS, Logging and Communication with the LHC.

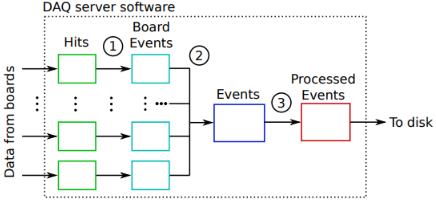
Online Commissioning Summary

DAQ	DQM	DCS	OS-VM
DAQ_Server	DQM_Client	CAEN_Monitor	Elog (sndlogbook.cern.ch)
VME_Server	DQM_Agents	ColdBox_Monitor	Run DB
ECS_Server	RT_Hist_Producer	DCS_Presenter	Calibration DB
DQM_Server	Presenter_Server	DCS_Server	
EPM_Server	Web Presenter		
LHC_Server			

Data Acquisition

Event Builder

- Performed by the DAQ server
- Can cope with 10^3kHz
- Expected $\approx$ 400kHz muons
- Triggerless event building
- Bunches hits within 25 ns



Hardware Calibration

- Hardware threshold algorithm based on Dark Count Rates being developed
- Bugs being ironed out

SND Software

Detector data and software data are written in different formats.

Detector data is converted to offline format in order to make use of the tools already developed.

No conversion of online data available yet :

- Convert streaming data
- Keep track of incoming data files and convert them as they are produced

Independent of the online DQM software.

Tracking : Hough Transform

Already implemented, and tuned for muons from neutrino interactions

Has some ambiguity problems in order to perform 3D reconstructions

Internal Alignment of Tracking Stations

Needs to be redone with beam

SND Software

Monte Carlo has no updates

Waiting on better understanding of the SiPM QDC and timing responses from the testbeam and TI18 data

Detector/Raw Data Calibration

Mostly applies to Veto and US detectors. Ongoing activities include :

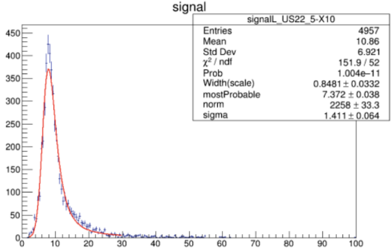
- QDC calibration for large and small SiPMs
- TDC calibration - need for internal alignment per bar side
- TDC calibration - need station to station alignment, bar by bar

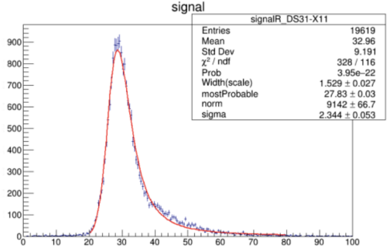
QDC is for the charge measurements and TDC for the timing.

Improvement of the signal velocity per bar/fibre is necessary ("See the Update on time walk studies" from the 22/03 SND@LHC SoftPhys Meeting)

Need inventory of good and bad channels (I am currently working on this)

Veto and Muon System - SiPM Signal





Data from H8 Test Beam

- 4 Energies : 140, 180, 240, 300 GeV π
- Rate : 200 - 2 $\times$ 10^3 Hz
- Beam spot : $\approx$1 cm

SiPM Signal

- Landau$*$Gaussian shape
- For US, relatively uniform in same bar side
- DS signal is bigger (area coverage % is bigger)

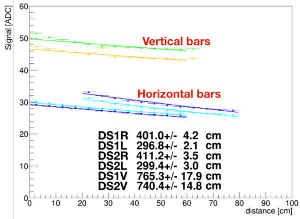
Veto and Muon System - Light Propagation

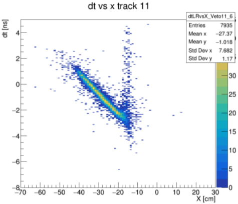
Atenuation Length :

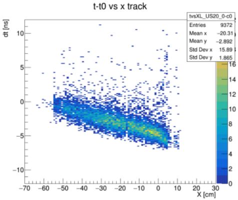
- Close to manufacturers ≈ 3.8m (3.6 ± 0.1m for Horizontal)
- Vertical bars have ≈ 7m (bottom end is reflective)

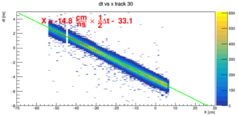
Propagation Speed :

- Veto ≈ 13.5 cm/ns
- Upstream ≈ 13.1 cm/ns
- Downstream ≈ 14.8 cm/ns
- SHiP Prototype ≈ 15.5cm/ns









Veto and Muon System - Time Resolution

Time Resolution :

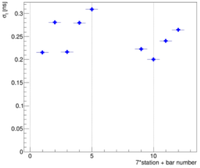
Expected from SHiP Prototype :

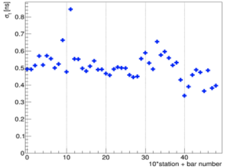
- Timing Detector ≈ 85 ps
- Single SiPM ≈ 75 ps

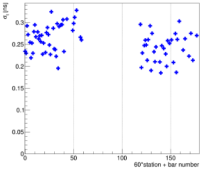
Current Commissioning Measurements

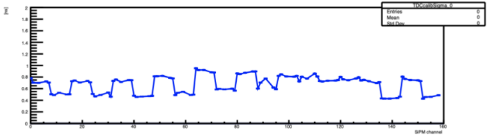
- Veto ≈ 170 ps
- Upstream ≈ 300 – 500 ps
- Downstream ≈ 170 ps
- Single SiPM ≈ 250 ps - 1 ns

Should be seeing resolutions close to ≈ 160 ps per channel.
Current channel to channel resolutions are of ≈ 400 ps → ≈ 150 ps resolution for bar side (pending ongoing internal calibration).









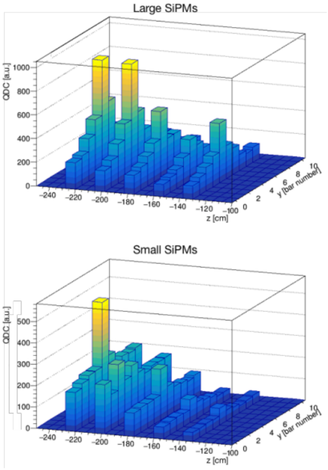
Veto and Muon System - Shower Response and Efficiency

Shower Response

Shower mainly contained in first 3 US layers
There is spillover to first two DS layers
Small SiPMs are needed due to saturation of bigger SiPMs
No real energy calibration yet

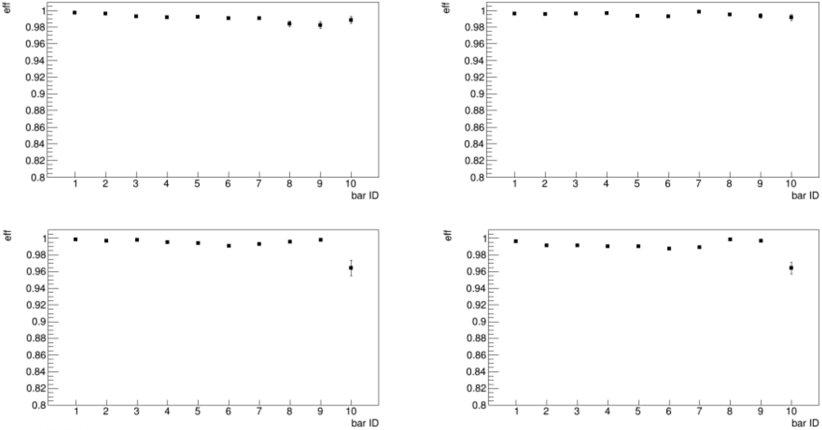
Detector Efficiency

Measurements from the H8 Test Beam data
Events with tracks fitted from 2 hits on DS (also on both projections)
Extrapolated back to 1st US within a radius of 2 cm
Efficiency $> 98\%$ for π^+ beam
Not as good for cosmics and muons
Criteria for track selection should be revisited
Further energies will be explored



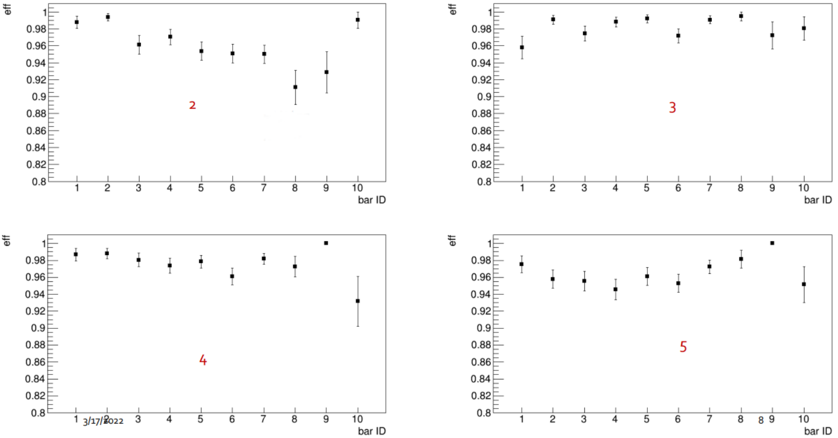
Veto and Muon System - Bar Efficiency Plots

Run 46 : 180 GeV π^+



Veto and Muon System - Bar Efficiency Plots

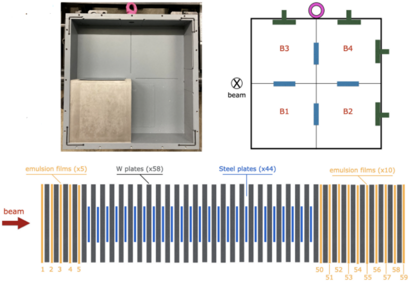
Run 55 : $\mu^{\pm}$ from blocked pion beam



Emulsion Commissioning

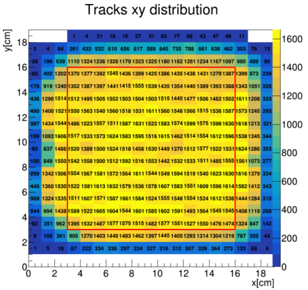
Test Run for Naples LAB

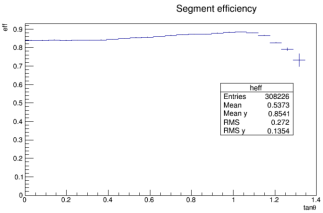
- Emulsion Cloud Chamber with 192mm $\times$ 192mm
- Exposure to cosmics from 16 Nov to 18 Nov
- Only 15 films (full ECC has 59)
- Upstream : 5 films
- Downstream : 10 films
- Inbetween : Steel Plates
- Tungsten Plates with 1 mm
- Emulsions scanned at Naples in December
- CPU processing scan took 2 days
- GPU processing scan took 1 day



Emulsion Commissioning

- Tracks reconstructed for Upstream
- Required 4 planes out of 5 to participate
- In red square average of $(1.5 \pm 0.1) \times 10^3$ tracks/cm^2
- Yields 0.52 ± 0.03 muonscm^{-2}s^{-1}
- Expected cosmic flux 0.73 muonscm^{-2}s^{-1}
- Does **NOT** take into account minimum cosmic energy nor tracking efficiency

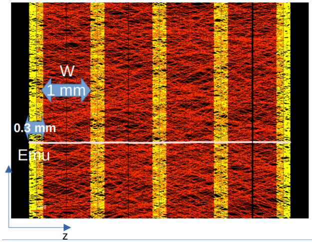




Emmulsion Commissioning

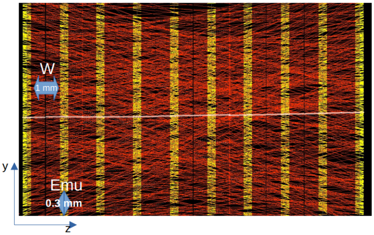
Upstream section of B1

5 emulsion films



Downstream section of B1

10 emulsion films



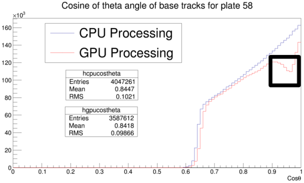
Emmulsion Commissioning

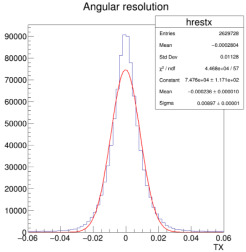
Track Resolution :

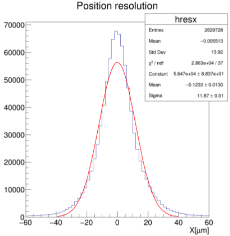
- Comparison with linear fits
- At least 7 segments per track (Downstream)
- **Angular Resolution :** $\approx$ 8 mrad
- **Position Resolution :** $\approx 12\mu$m

GPU vs CPU Processing

- GPU 2$\times$ as fast as CPU
- GPU shows clear loss of efficiency for big angles







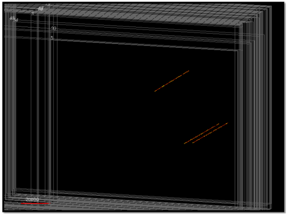
Muon Background in Emulsions

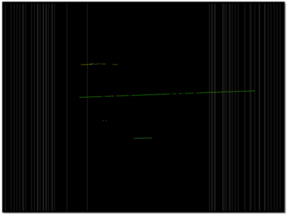
Studies presented at the 7^{th} Collaboration Meeting already showed a background of 3.7×10^4

Muon Background on the Emulsions

Simulated muon densities from 10^3 μ/cm^2 to 10^5 μ/cm^2
Muons simulated with FLUKA, transported to a 1×1 ^{2} in the center of a ECC brick
Propagated with GEANT4, and translated to FEDRA (framework for reconstruction)
85% emulsion segment efficiency artificially inserted

Muon tracks usually appear as **split tracks**





Muon Background in Emulsions

Muon Track Optimization

- Tracks per simulated muon
- Segments per reconstructed track
- Plates crossed by reconstructed muon
- Muon track purity $\left(1 - \frac{foreign\ segments}{muon\ segments}\right)$

Muon Background Vertices

Mostly due to bremsstrahlung
Dangerous when right after missing segments due to inefficiencies
$10^3\ \mu\ fb^{-1} cm^2$: Expected 1.8×10^4 $\mu vertices per \nu vertex$
$10^4\ \mu\ fb^{-1} cm^2$: Expected 1.9×10^5 $\mu vertices per \nu vertex$
Results per wall in 25 fb^{-1}.

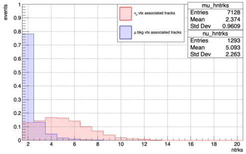
Possible criteria for separation :

- Multiplicity of tracks in vertex
- Vertex probability of FEDRA vertexing algo.
- Angular distance between tracks in vertex
- Mean impact parameter of tracks at vertex
- Maximum impact parameter
- Fill factor of tracks at vertex

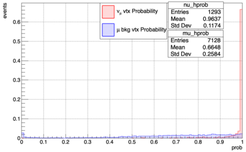
Analysis was done separately on background and signal, and compared, but no selection criteria was actually applied

Muon Background in Emulsions

Multiplicity of tracks building up the vertex

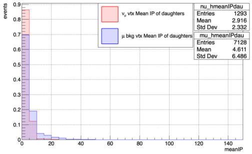


Vertex probability, as provided by the FEDRA vertexing procedure

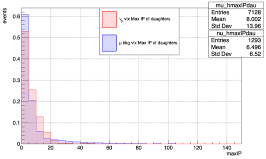


Angular distance

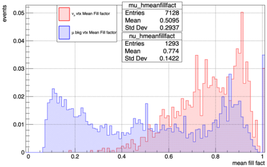
Mean Impact Parameter of tracks at the vertex



Max Impact Parameter of tracks at the vertex



Fill factor of tracks at the vertex



NC and ν_e CC Interaction Separation

Muon ID with Hough Transform already implemented.

ν_μ CC shows good separation from NC and ν_e CC interactions (7^{th} SND@LHC Collaboration Meeting)
Goal was to inspect separation between NC and ν_e CC interactions using only electronic detectors
Conservative approach with just hit patterns (no faithful electronic response for Veto and Muon Systems yet).

Strategy

Find distribution of hits for each event as a function of the station
Establish first station where cumulative distribution > 1%
Calculate total number of hits in vertical and horizontal planes
Check range of channels containing 68.3% of the hits (measure of width)
For each starting station :

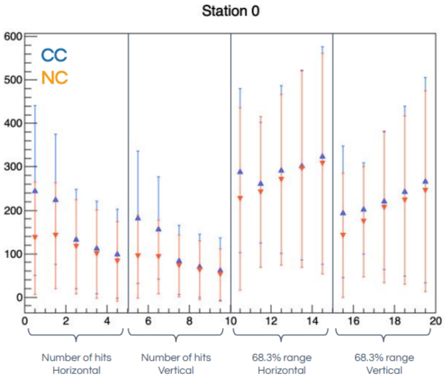
- Compute the mean μ for the previous statistics
- Compute covariance S
- Compute Mahalanobis distances of the previous statistics to classify events

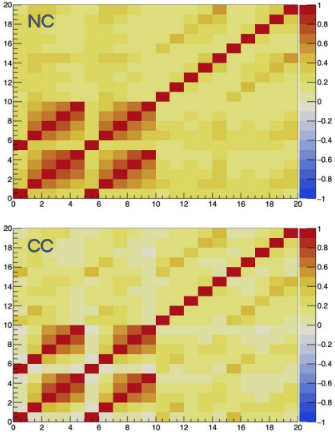
$$d_{NC} = \sqrt{(\vec{x} - \vec{\mu}_{NC})\, \boldsymbol{S}_{\boldsymbol{NC}}^{-1}\, (\vec{x} - \vec{\mu}_{NC})}$$

$$d_{CC} = \sqrt{(\vec{x} - \vec{\mu}_{CC})\, \boldsymbol{S}_{\boldsymbol{CC}}^{-1}\, (\vec{x} - \vec{\mu}_{CC})}$$

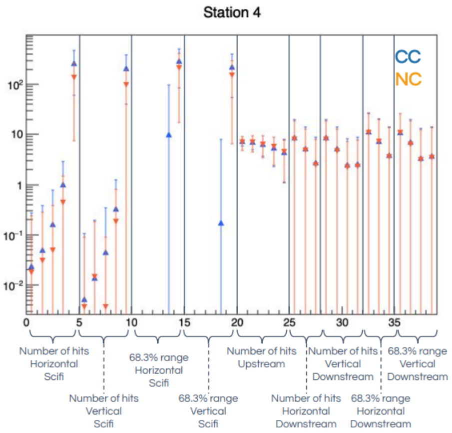
$$\text{Classifier} = d_{NC} - d_{CC}$$

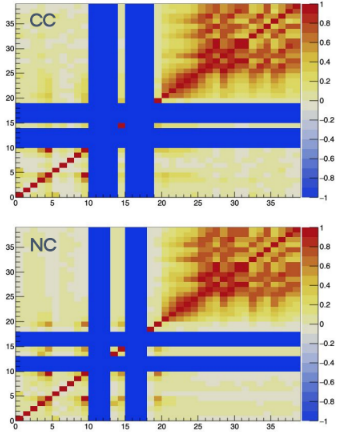
NC and ν_e CC Interaction Separation





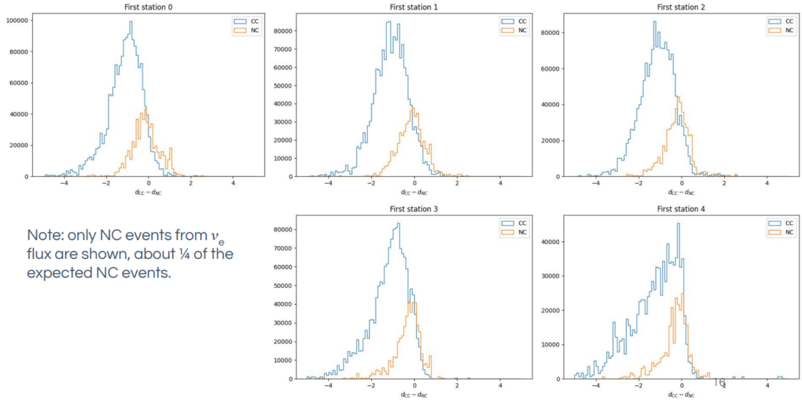
NC and ν_e CC Interaction Separation





NC and ν_e CC Interaction Separation

ν_eCC/NC separation



Note: only NC events from ν_e flux are shown, about ¼ of the expected NC events.

Schedule

- **Week 12 :** 24 March - Closure of caverns
- **Week 14 :**
  - 3 Day Access Period
  - 8 April - First Beam for Commissioning
- **Week 19 :** Collisions at injection energy for commissioning (not part of planned luminosity)
- **Week 21-24 :** Electron cloud scrubbing 1.2×10^{11}ppb
  - 2-4 days at a time
- **Week 23 :** 8 June - First stable beam
- **Week 24 :** 16 June - Media backup date
- **Week 24 :** SND@LHC Collaboration Meeting at Anacapri
- **Week 25-28 :** Intensity ramp-up to 1200 bunches
- **Week 29 :** Installation of fully instrumented Emulsion walls

Also on the to do list :

- Shifters : 1 week at CERN on call - 28 for 2022
- Emulsion Related Personnel : 1-2 weeks at CERN - 32 weeks*person power (6 experts for brick replacement)
- Total 60 weeks*person power
- Shifters might become remote eventually