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What Physics Can We Learn about in SBND from its "Prehistoric Era"?

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On behalf of the SBND Collaboration

New Perspective 2023

Fermilab

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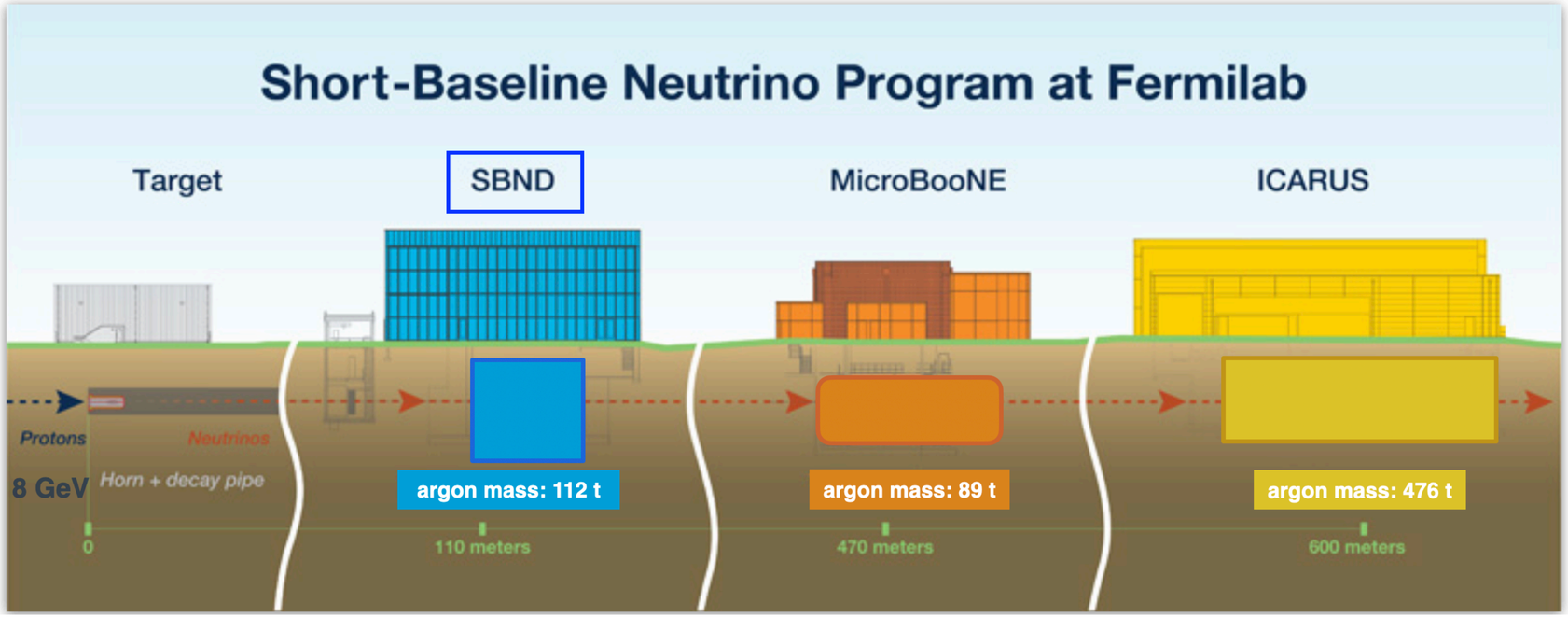
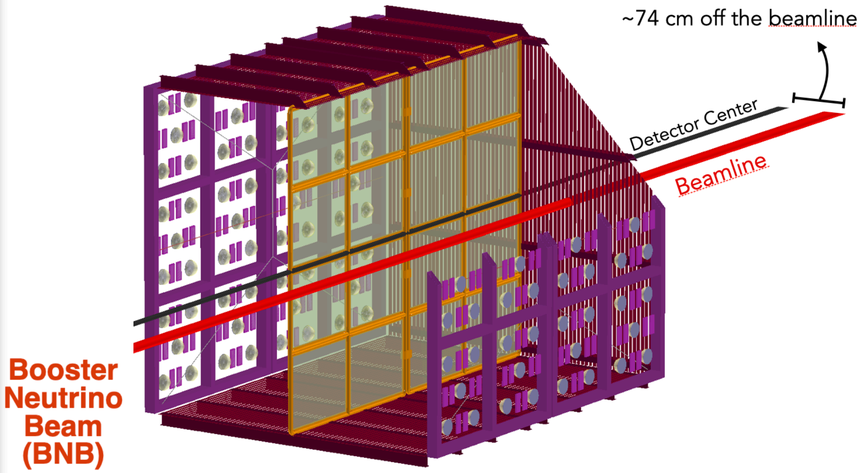
Short-Baseline Neutrino Program and the Near Detector

All nice details about SBN and SBND are covered by **Henry Lay's** talk!





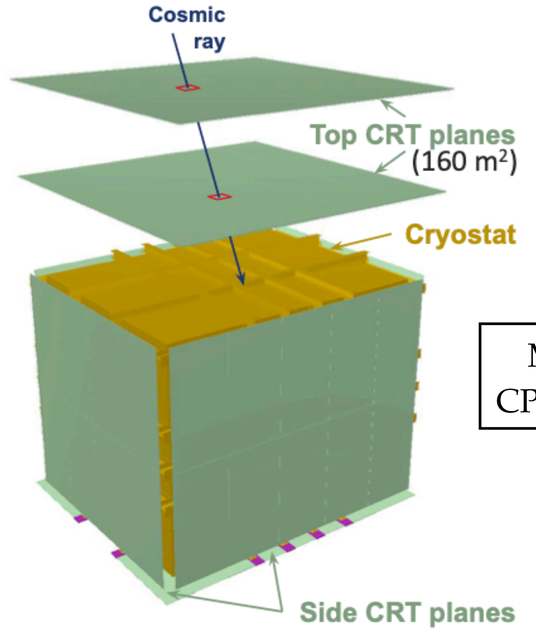
Beam composition:

- ν_μ **(93.6%)**
- $\bar{\nu}_\mu$ (5.9%)
- $\nu_e+\bar{\nu}_e$ (0.5%)

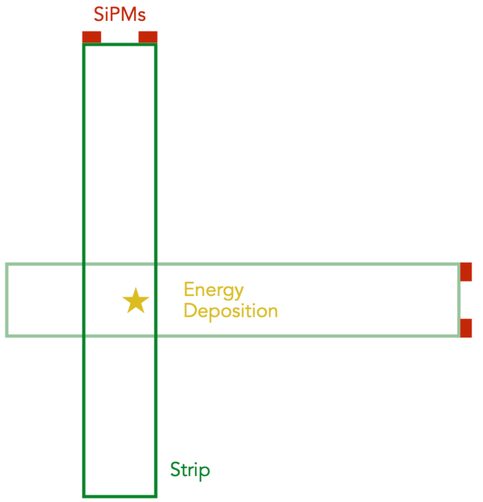
SBND is an **on-surface** detector, **located closely** (110 m) to the neutrino source

Cosmic Ray Tagger (CRT) system in SBND

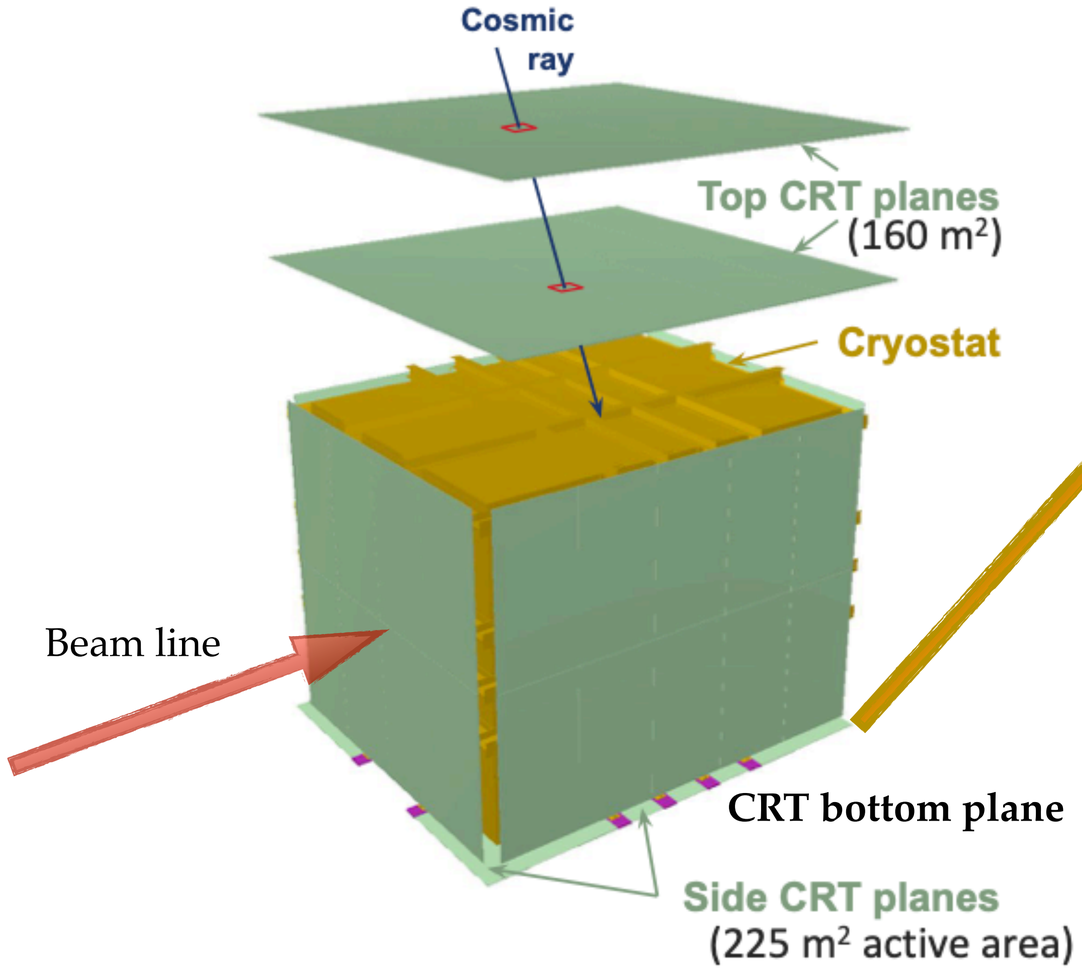
- SBND is an on-surface detector:
  - CRT is designed to tag muons to veto the cosmic ray backgrounds
    - surrounds SBND for a 4π coverage
- CRT system:
  - the tracker planes are made of strips, each strip is made of:
    - plastic scintillator
    - wavelength shifting fibres
    - silicon photomultipliers (SiPMs)
  - each CRT plane will have two perpendicular layers overlapping
- Tag muons **>95% efficiency, O(cm) tracking resolution, O(ns) timing resolution**

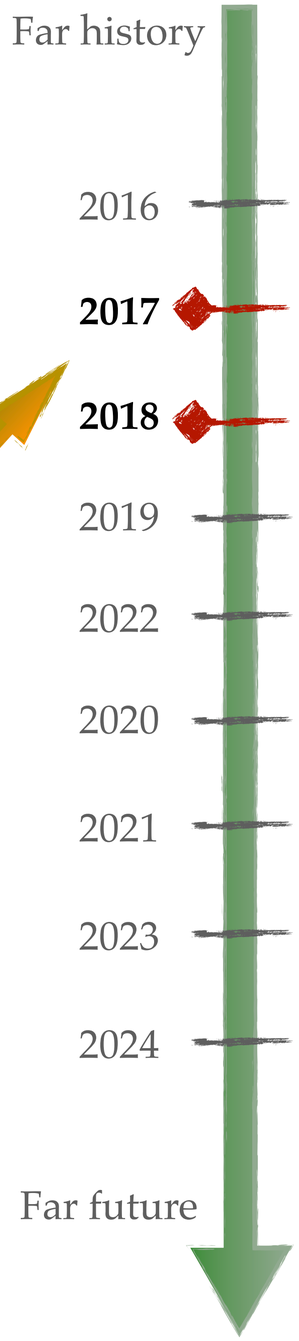


Michelle Stancari, CPAD workshop 2022



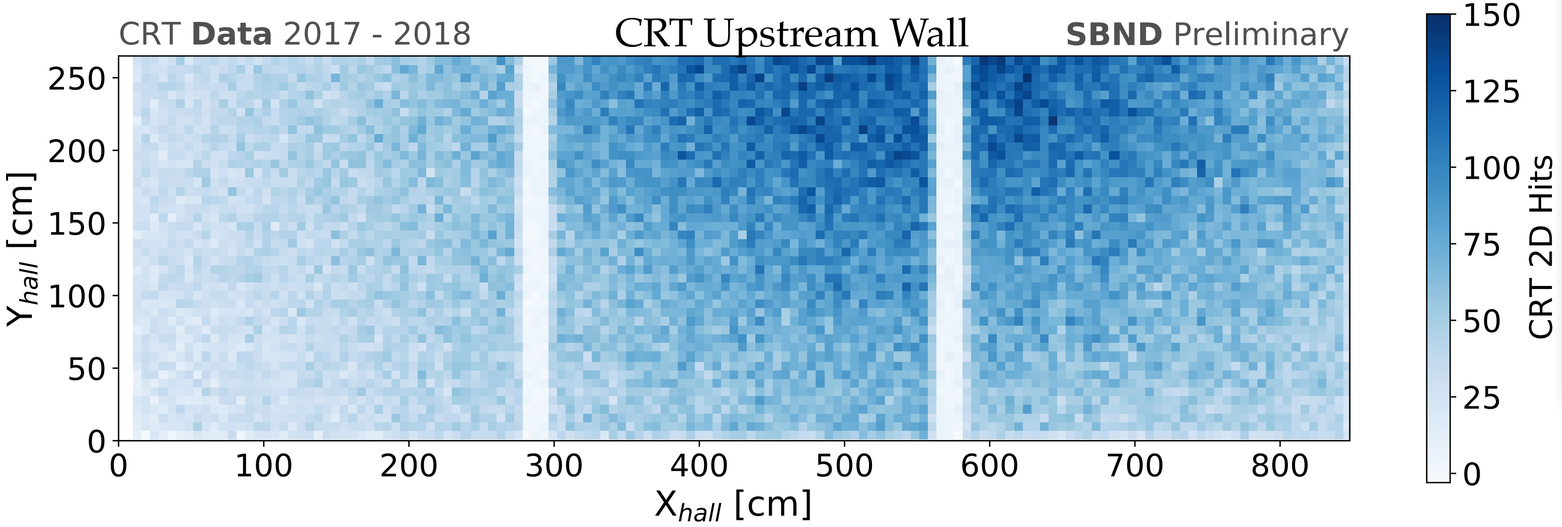
Let’s jump back to the history first!

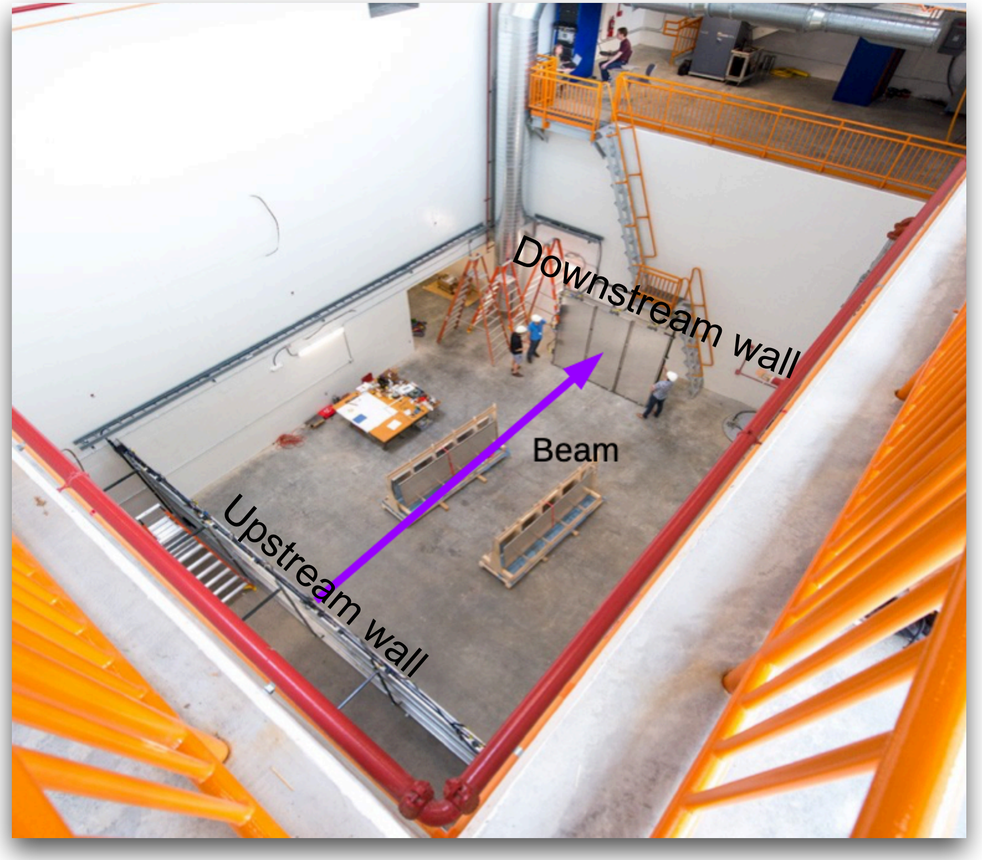

Cosmic ray
Top CRT planes (160 m²)
Cryostat
Beam line
CRT bottom plane
Side CRT planes (225 m² active area)


Far history
2016
2017
2018
2019
2022
2020
2021
2023
2024
Far future

CRT Beam Telescope

- In 2017-2018, the beam telescope was set up to test the bottom plane of the CRT system
- Data taken with BNB in the SBND detector hall
  - beam structure is seen with the hit in the CRT upstream wall





Q1: Can we learn something else and cool from the existing CRT data?

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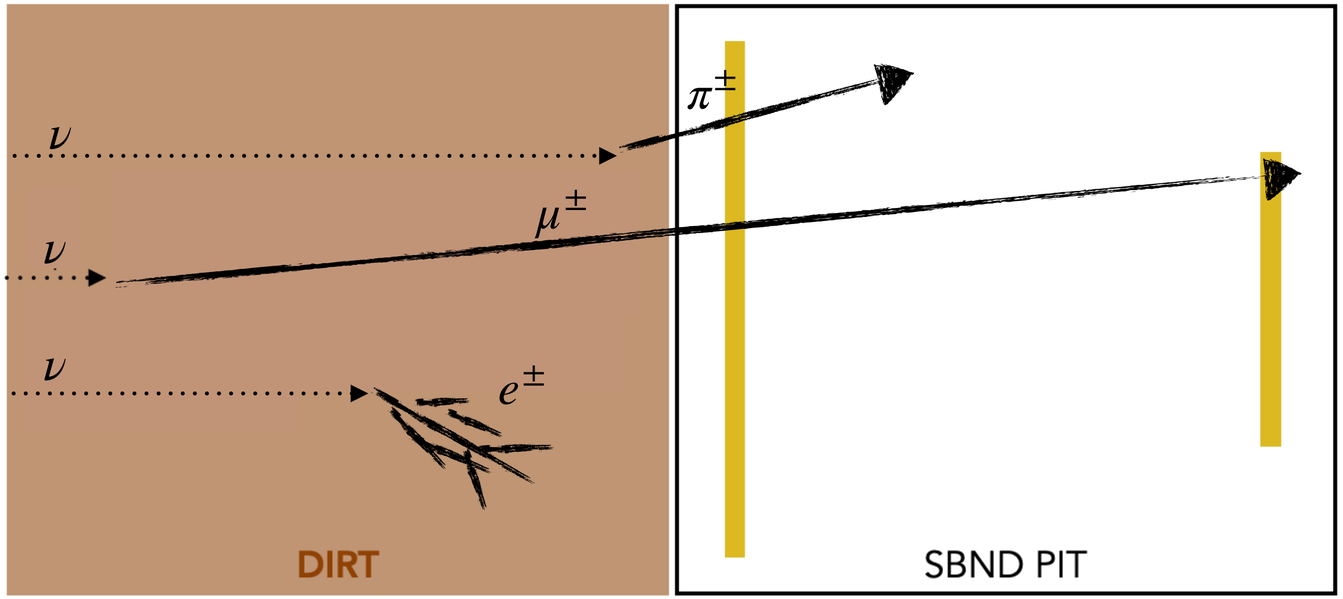
A1: yes, we can

How well do we simulate our dirt neutrino?

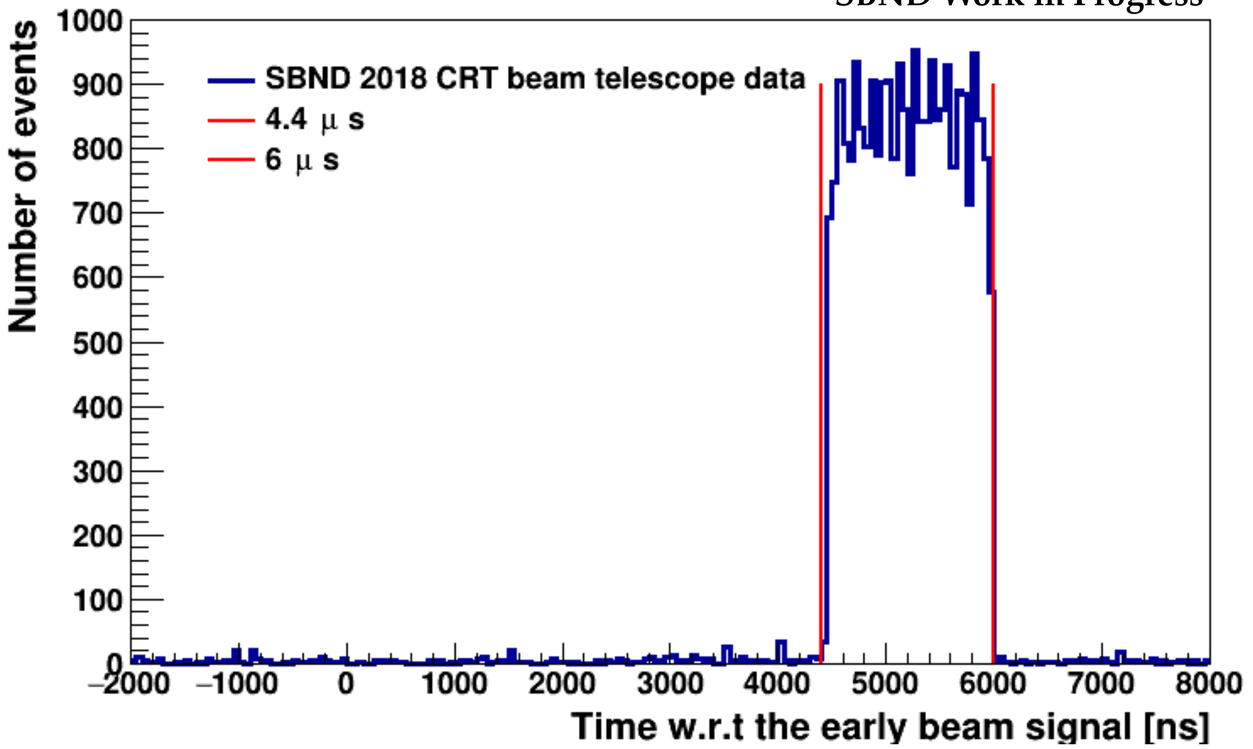
- One of major backgrounds for many analysis is so-called dirt neutrinos
  - if neutrinos interact between the source and the CRT panels, the products can make it into the detector and cause false positives
- The beam-telescope data can be used for the validation of our dirt simulation



Data: Cosmic Background Subtraction

- In the data: **dirt + cosmic**
- Select dirt dominate data to compare with our dirt simulation:
  - use **time of flight**: [20, 50] ns to select the forward-going muons along the beam direction
  - select the beam window
  - use the same length of timing window to estimate the cosmic background
  - subtract the cosmic-background data from the beam-window data

SBND Work in Progress



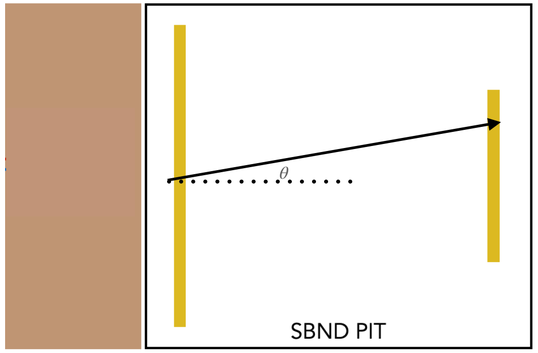
Data in beam spill, all	Data in beam spill, estimated cosmic	**Data in beam spill, after subtraction**	Dirt simulation
26000	142	**25858**	1828

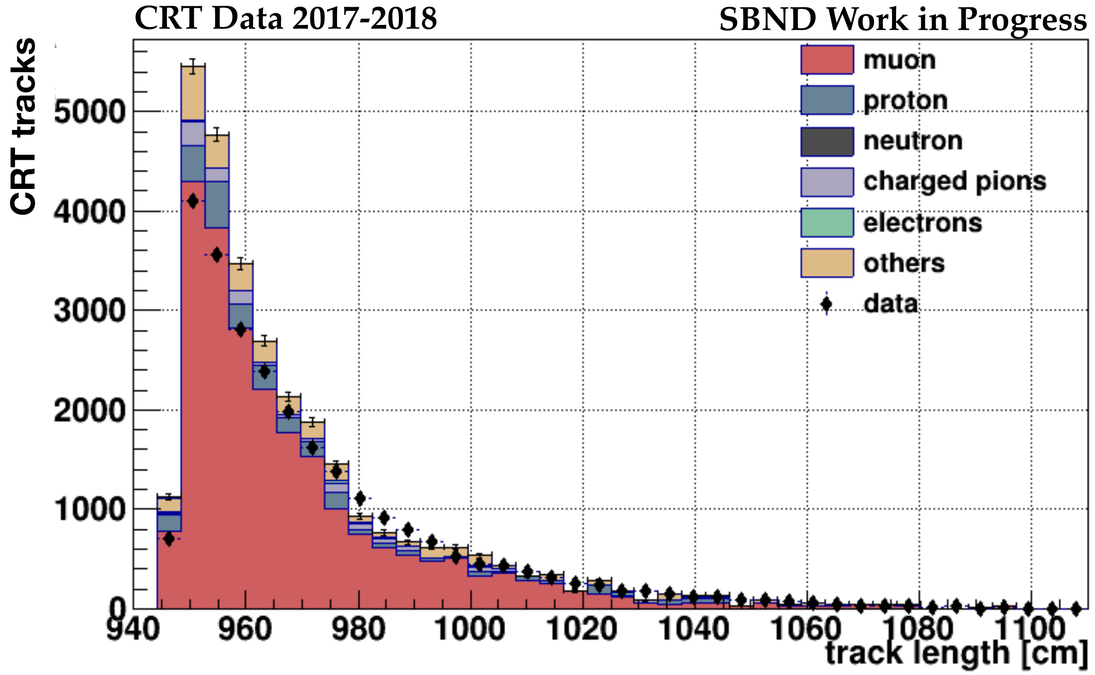
The cosmic background is almost negligible (142/25858 ~0.5%)!

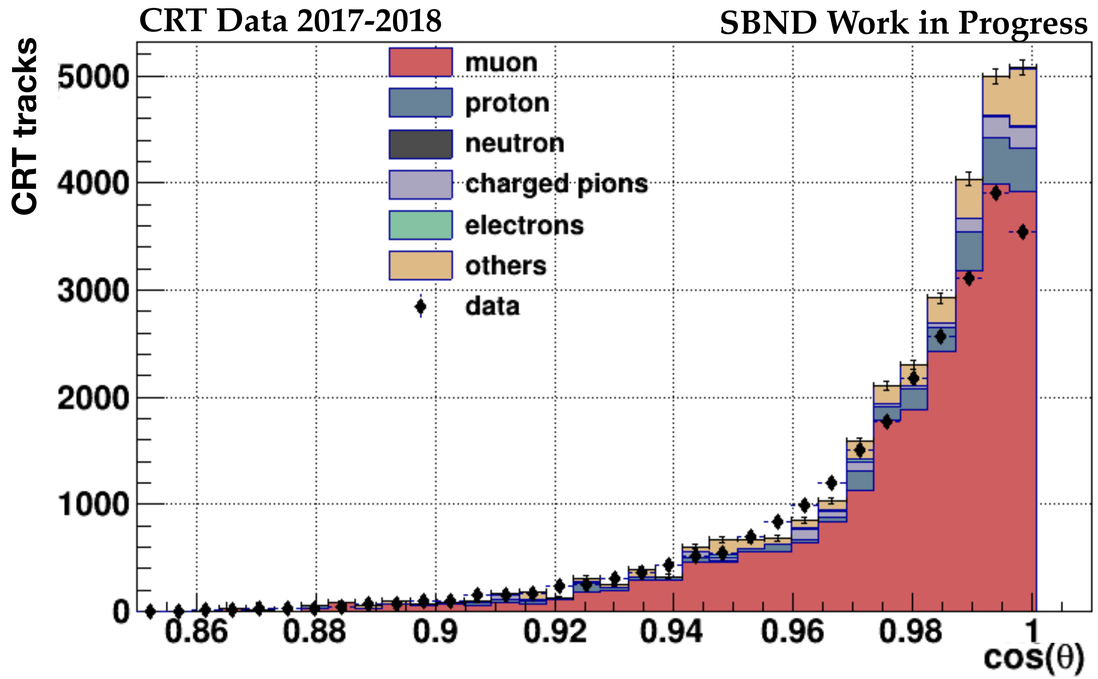
Needs more dirt sample for sure!

CRT tracks

- The cut-off in the track length is due to the distance between two panels in the CRT beam telescope
- The dirt simulation:
  - dominated by muons, which is expected
  - have a small fractions of protons, charged pions and electrons, no neutrons
- MC have a good agreement with the data
- The MC shows an over-prediction to data with the short track length, small angle w.r.t the beam direction

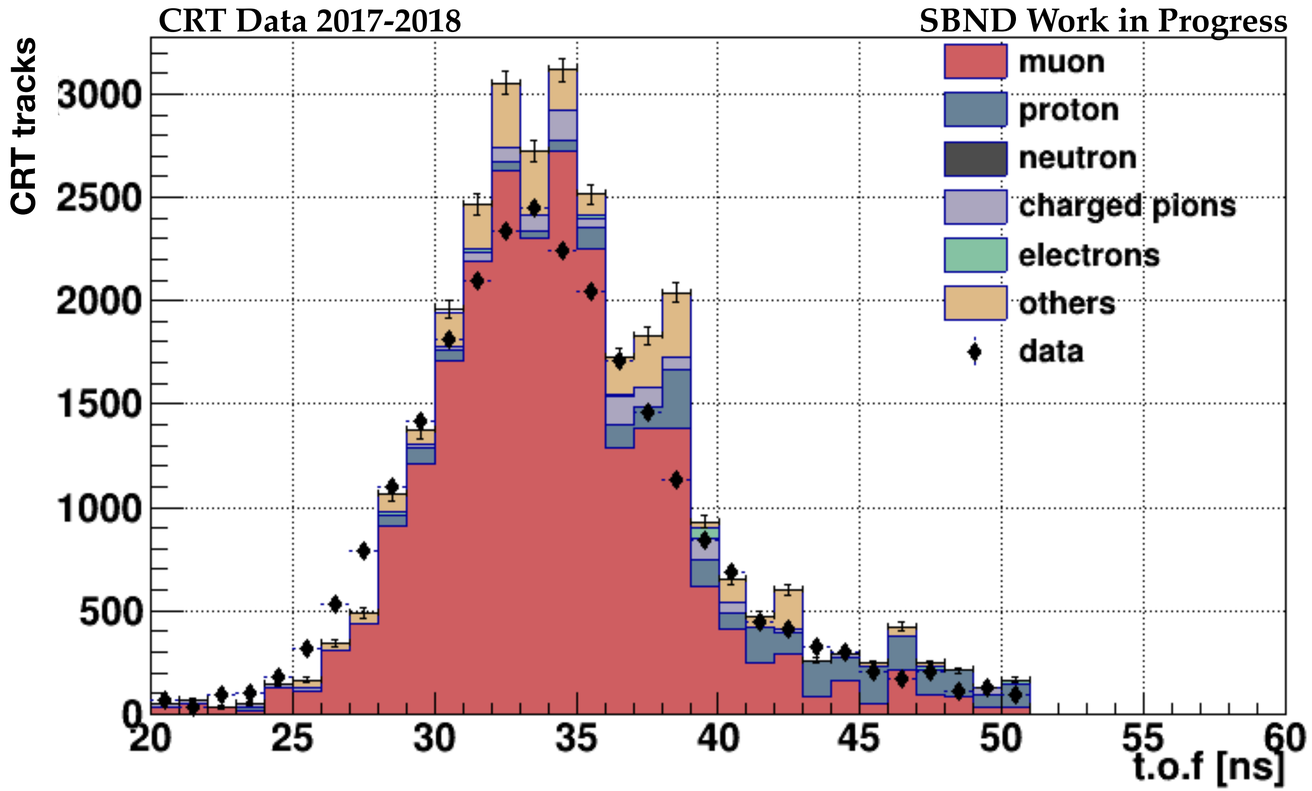




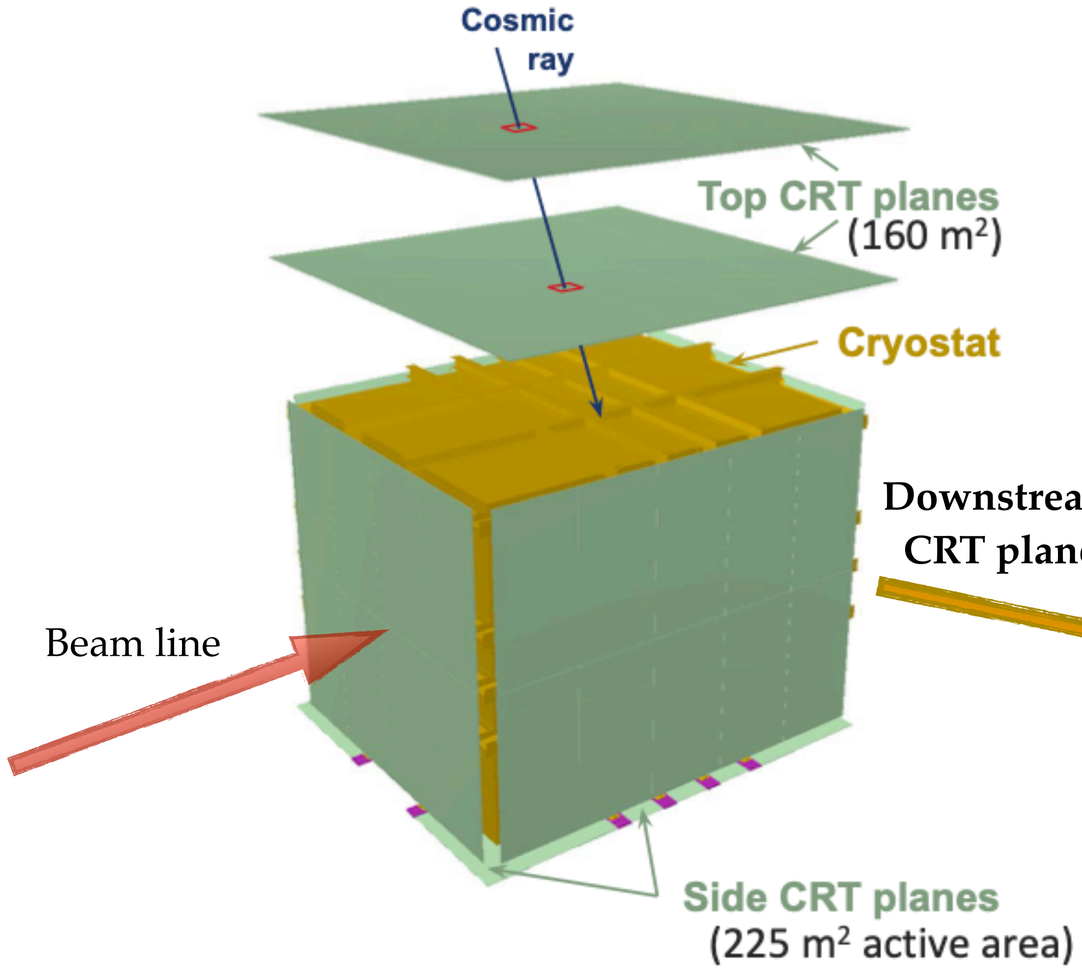


CRT tracks - time of flight (t.o.f)

- The non-smooth shape of dirt MC is due to the statistics
  - a bigger sample for dirt simulation will be generated
- T.O.F distribution shows decent data/MC agreement, but somewhat worse than for the track-length and cos(θ)
  - we are working on corrections, and once it is done we can use the corrected t.o.f to reconstruct the momentum



What is happening for the CRT right now?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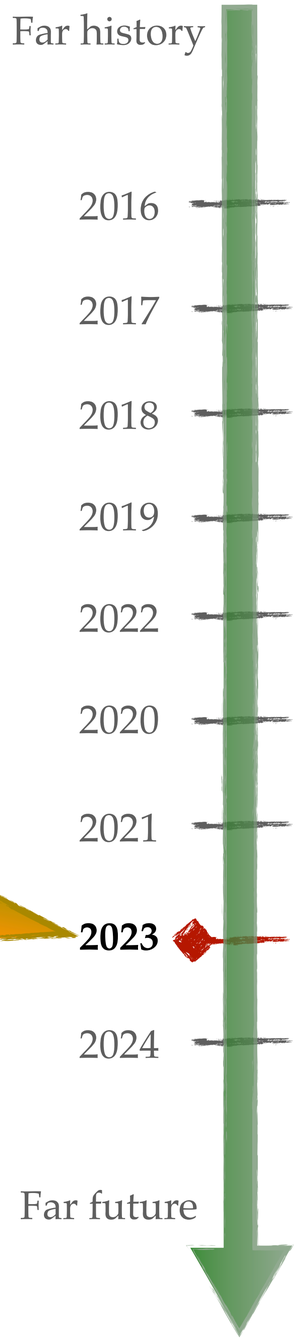
Side CRT planes (225 m² active area)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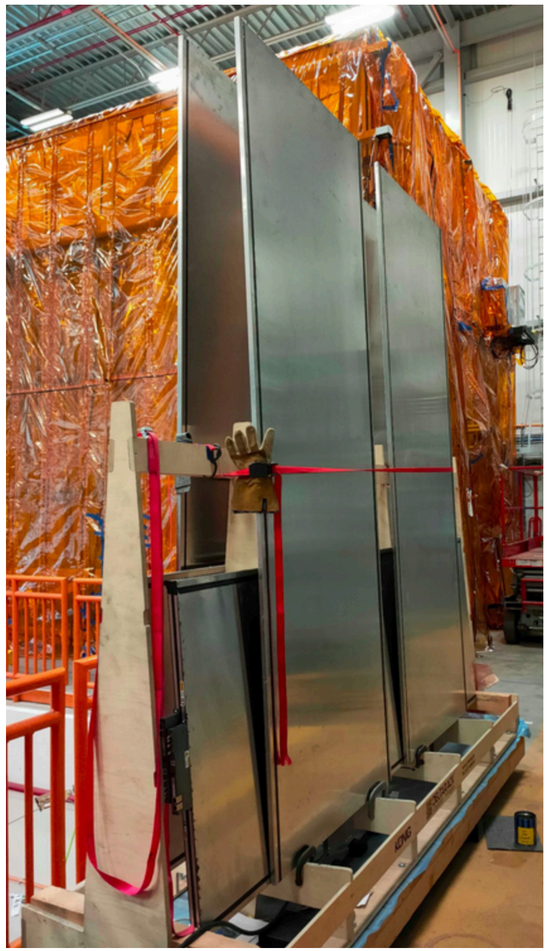
Far future

The installation of other CRT walls

- CRT commissioning is ongoing!
  - we are installing other CRT walls now
  - using special CRT A-frame to test all modules prior to installation
    - perform the “are-you-alive” test after 6 years since the production
    - equalise the module response for MIP muons
      - require us to understand **SiPM responses to photon electrons (PEs)**

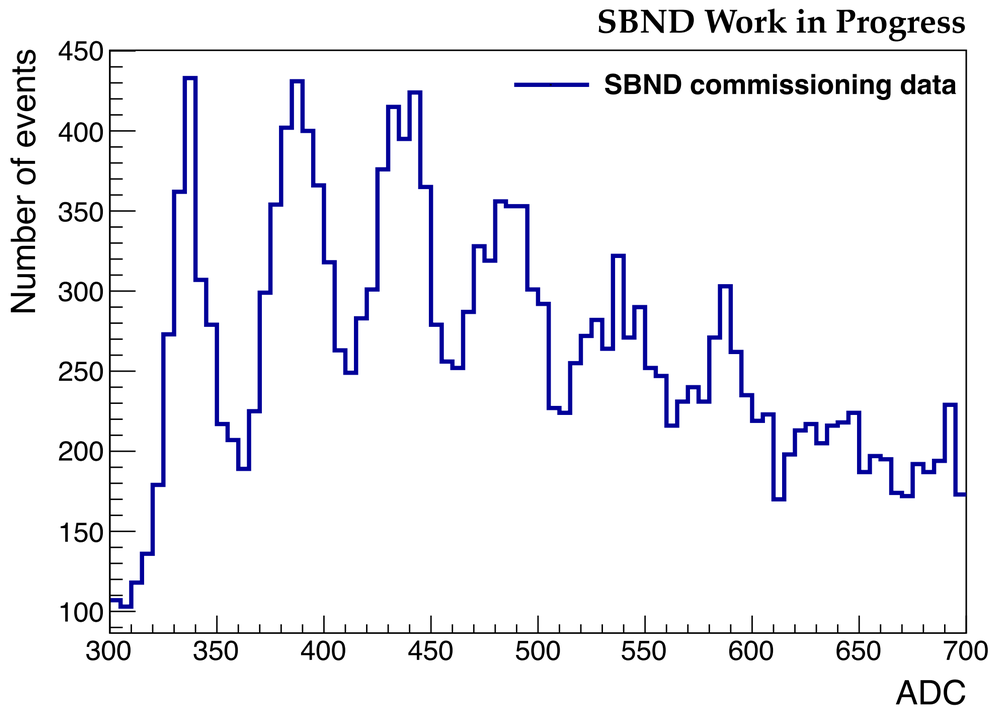


SBND CRT A-frame test stand

Q2: How are SiPM responses to PEs?

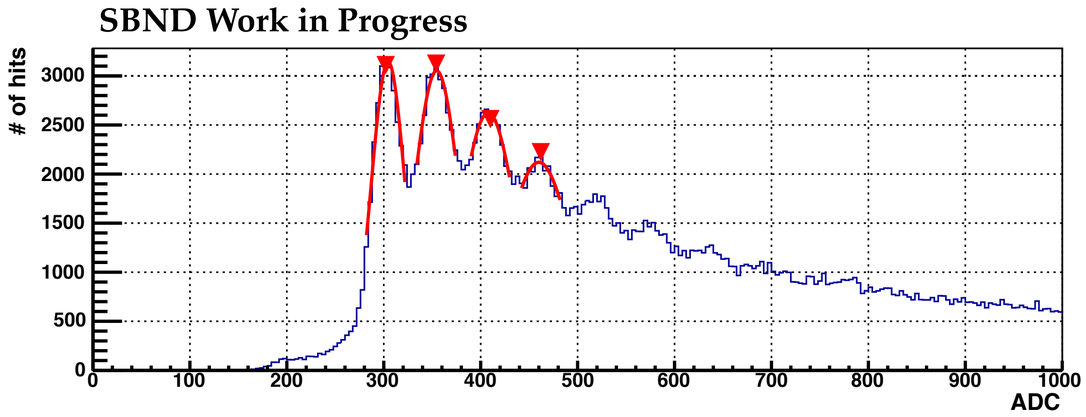
Methodology

- The approach to measure the SiPM response:
  - use radiogenics to find single PE ADC response for each SiPM —> the so-called “finger” plot



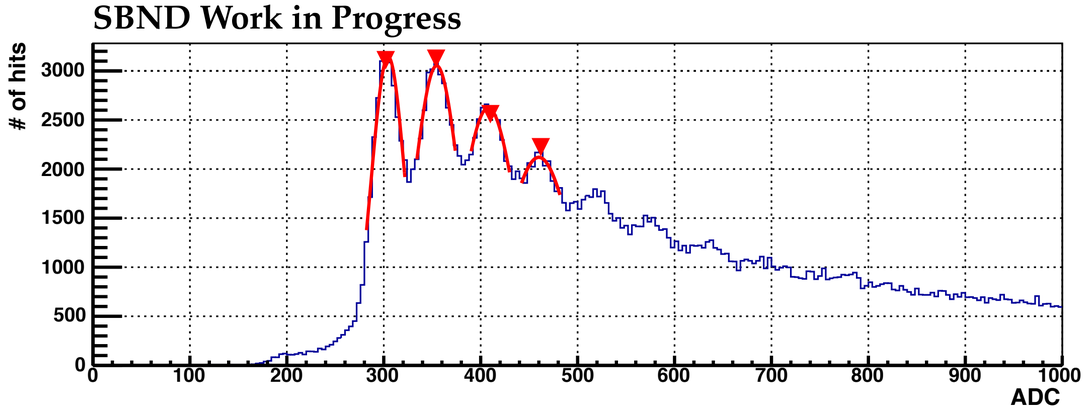
Methodology

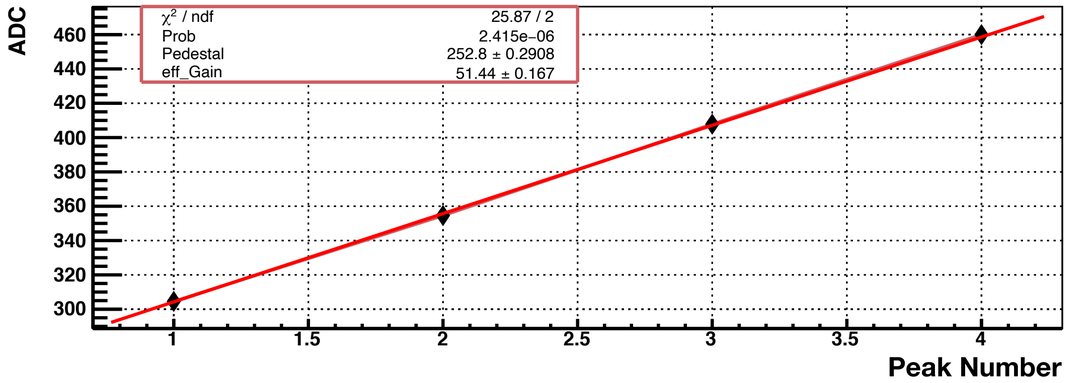
- The approach to measure the SiPM response:
  - use radiogenics to find single PE ADC response for each SiPM —> the so-called “finger” plot
  - extract the effective gain value (the ADC response to PEs) by:
    - fit the “finger” plot with multiple Gaussian peaks



Methodology

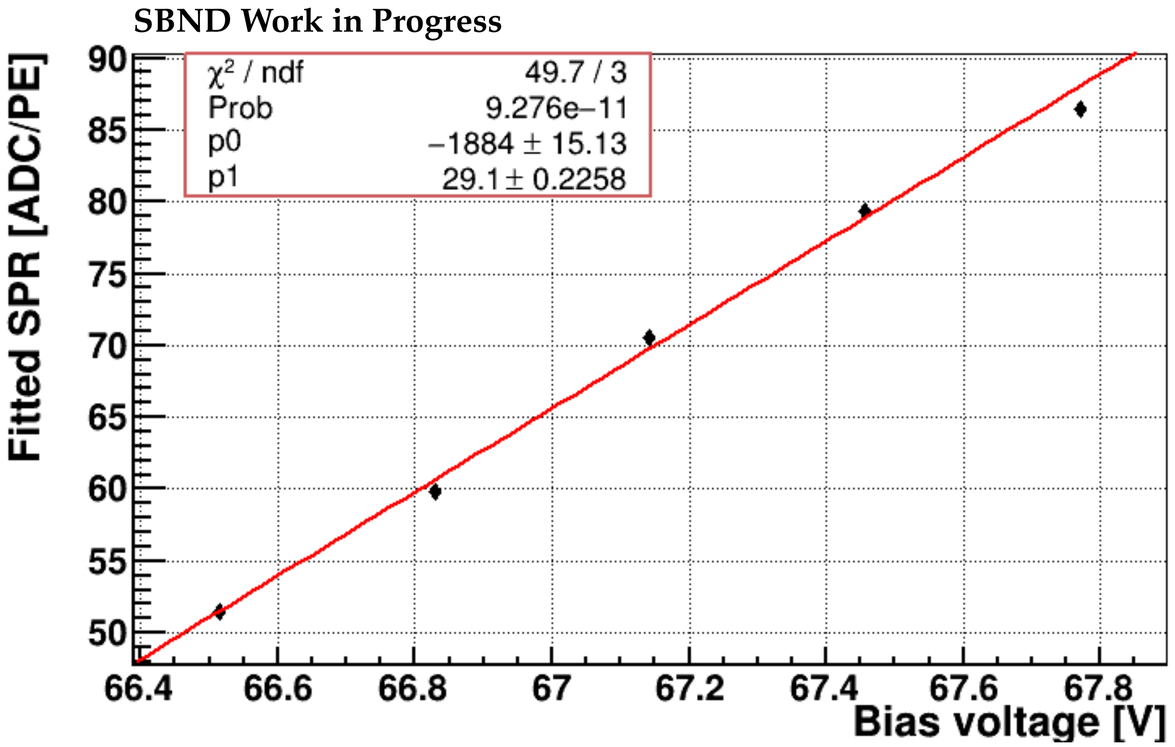
- The approach to measure the SiPM response:
  - use radiogenics to find single PE ADC response for each SiPM —> the so-called “finger” plot
  - extract the **Single Photon-electron Response (SPR)** value (the ADC response to PEs) by:
    - fit the “finger” plot with multiple Gaussian peaks
    - extract and plot the ADC values of peaks from the fit and the number of peak (ADC value vs. peak number)
    - linear fit the ADC value vs. peak number plot —> extract the **SPR**





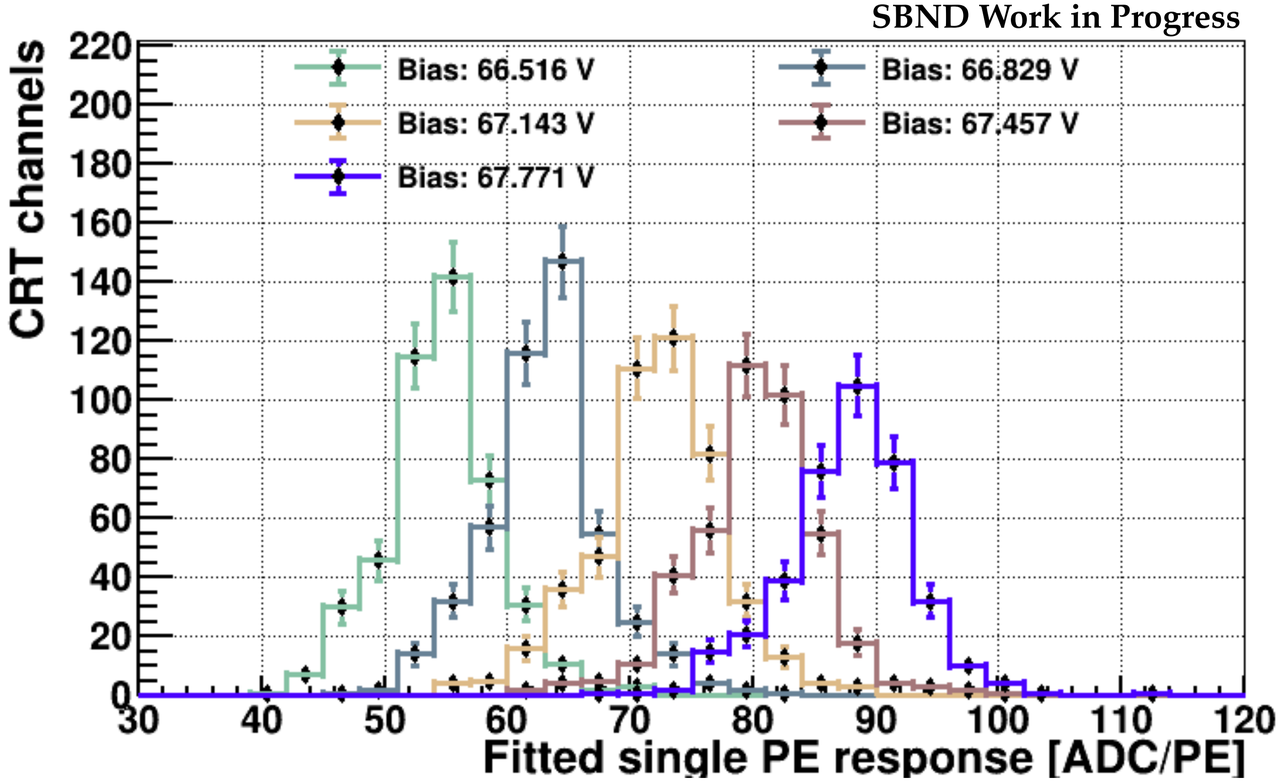
Methodology

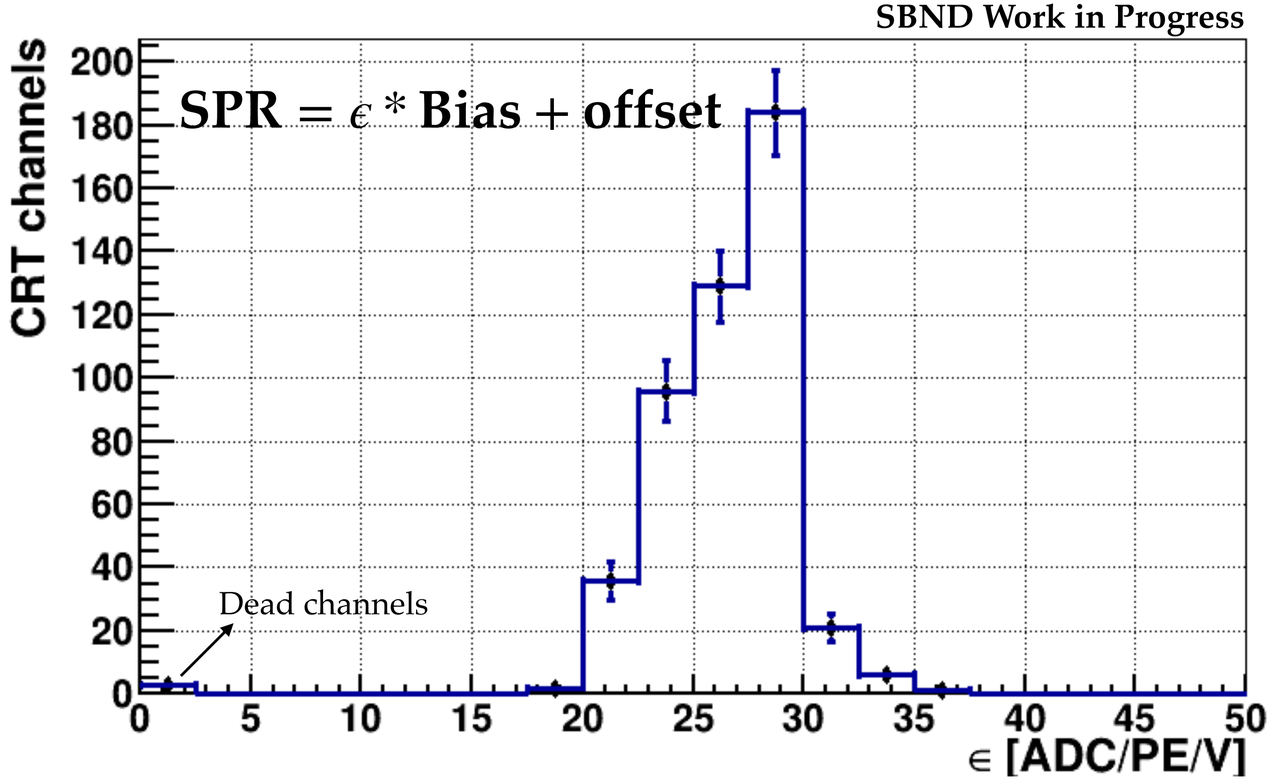
- The approach to measure the SiPM response:
  - use radiogenics to find single PE ADC response for each SiPM —> the so-called “finger” plot
  - extract the Single Photon-electron Response (SPR)
  - SPR = ϵ * Bias + offset
    - scan with different bias voltages
    - linear fit the fitted SPR value vs. bias plot —> extract the value of ϵ and **offset**



Results from modules from downstream CRT wall

- For each individual bias voltage, the shape of effective gain value is Gaussian-like
- The effective gain increases with the increment of bias voltages
- The slope ϵ calculated from different bias voltage is mostly around 20 to 35
- Most channels are alive! only 2 out of 544 channels are dead.





Summary

- SBND is in a very exciting stage right now, is about to switch on!
- Even in the SBND “prehistoric era”, there are many interesting studies that we can do

- The CRT beam telescope data are useful for physics study!
  - we see our dirt simulation in general are doing a good job compared to our data
  - we are also using this dataset to do other cool physics studies, stay tuned! ;-)
- We are building our CRT system and commissioning is on-going right now
  - for the downstream wall: we see most our channels of modules are **alive** and have **decent and similar behaviours** across different SiPMs

SBND moving: Dec. 2022

SBND CRT downstream installation: April. 2023

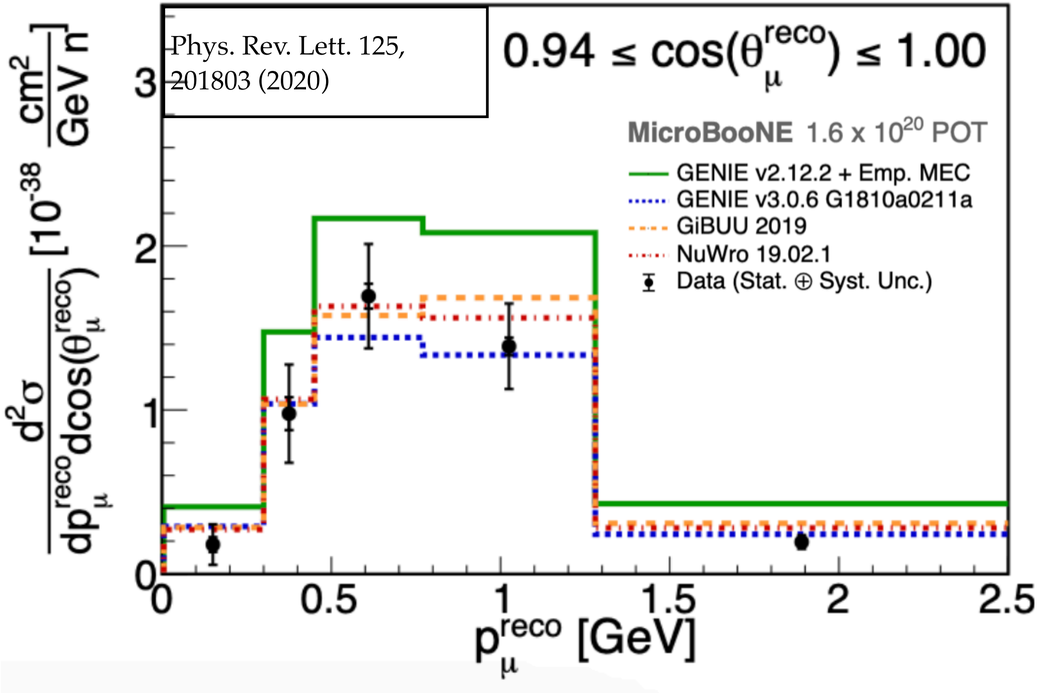
Stay tuned for SBND!!! ;-)

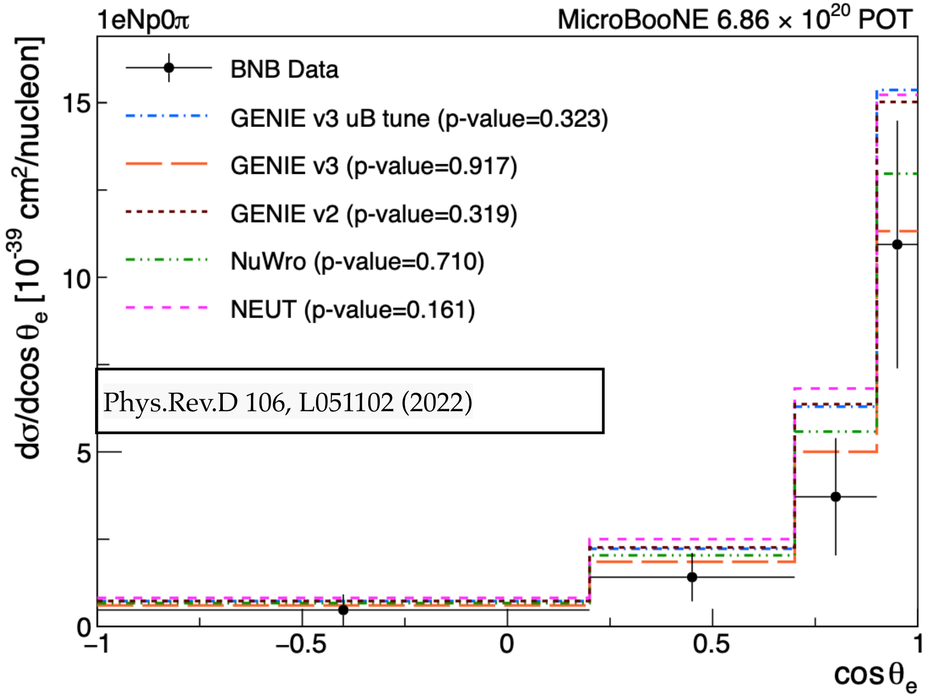
Thank you very much! :))
非常感谢！

SBND TPC and cryostat reunion day: April. 2023

Backup

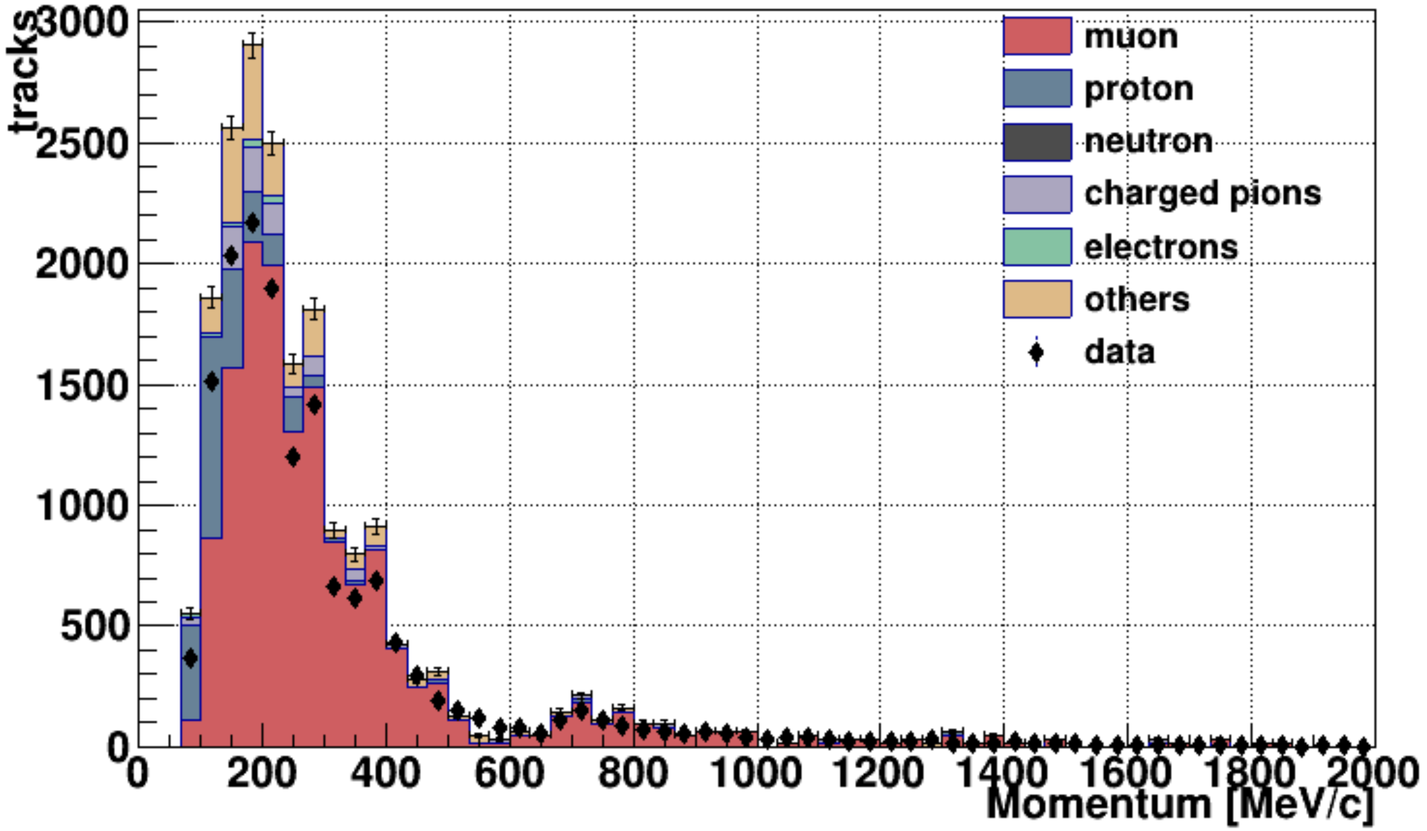
Results from LArTPC





(a)

CRT tracks - reconstructed momentum



Angle vs. Track length