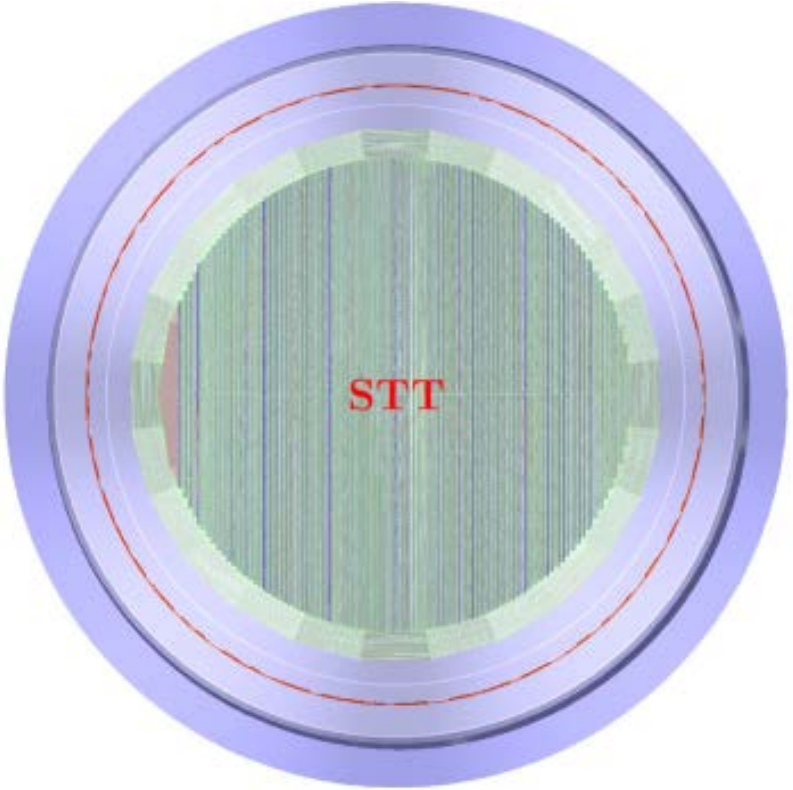
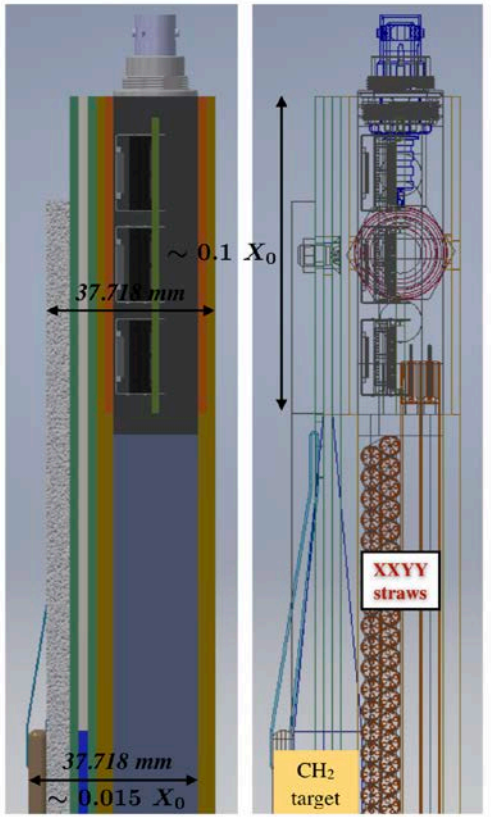
Detection of (anti)neutrino Interactions with a Low-Density Target/Tracker



Nibir Talukdar

Oct 22, 2021



A brief introduction about neutrinos

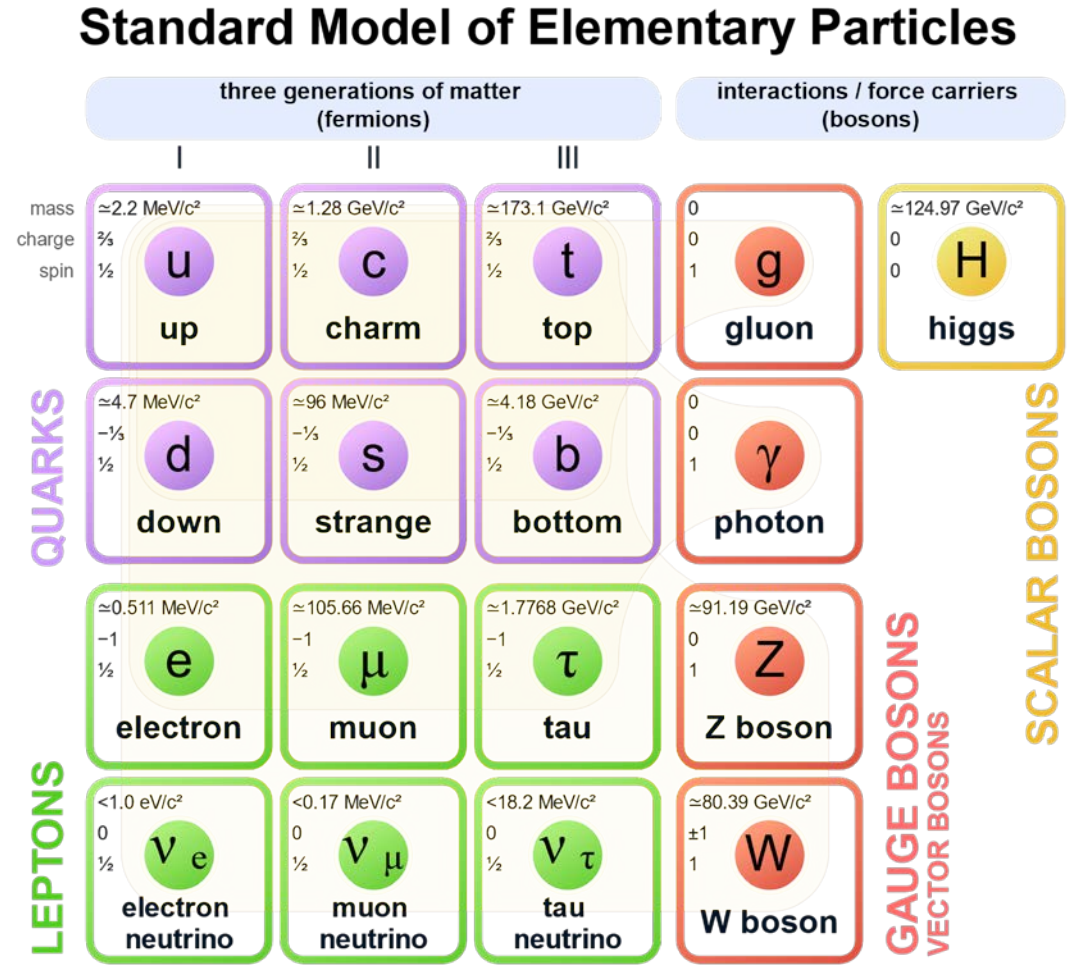
- Chargeless
- Spin half particle (fermion)
- Weakly interacting (by exchange of Z/W+-)
- Difficult to detect
- Neutrinos generated from

Natural sources

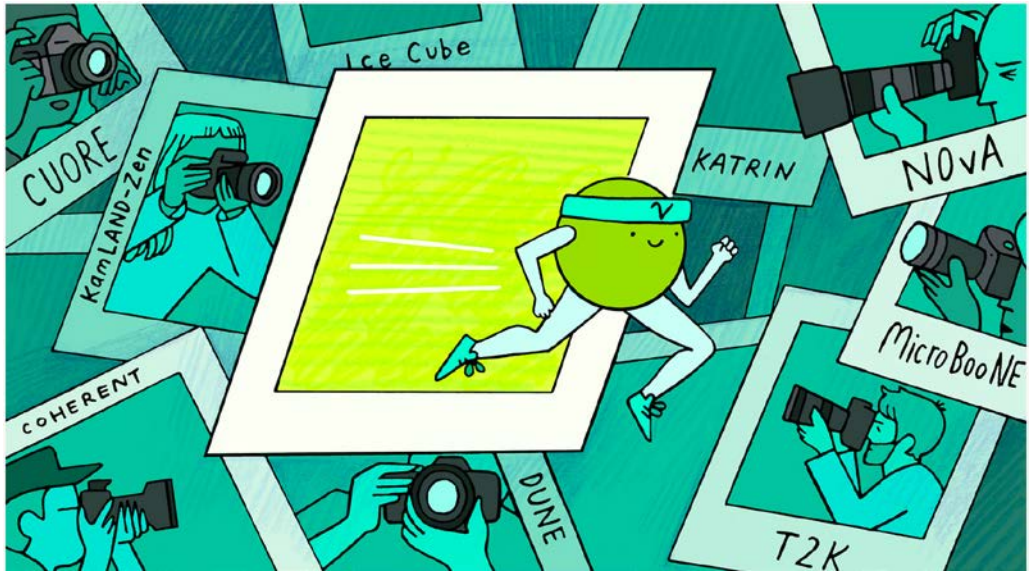
1. sun
2. cosmic ray air showers
3. supernovae

Artificial sources

4. *nuclear reactors and* ***particle accelerator***



Abundance of neurtrinos : About 60 billion neutrinos from the sun cross 1cm^2 of your body every second



Neutrino Oscillations

- During the late 1990s, oscillations among different flavors of neutrinos were established; physics beyond the S.M.
- Mass eigenstates and flavor eigenstates are not the same:

Neutrino Mixing Matrix

neutrino flavor states participate in weak interactions

$$\begin{pmatrix} \nu_e \\ \nu_m \\ \nu_t \end{pmatrix} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{m1} & U_{m2} & U_{m3} \\ U_{t1} & U_{t2} & U_{t3} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

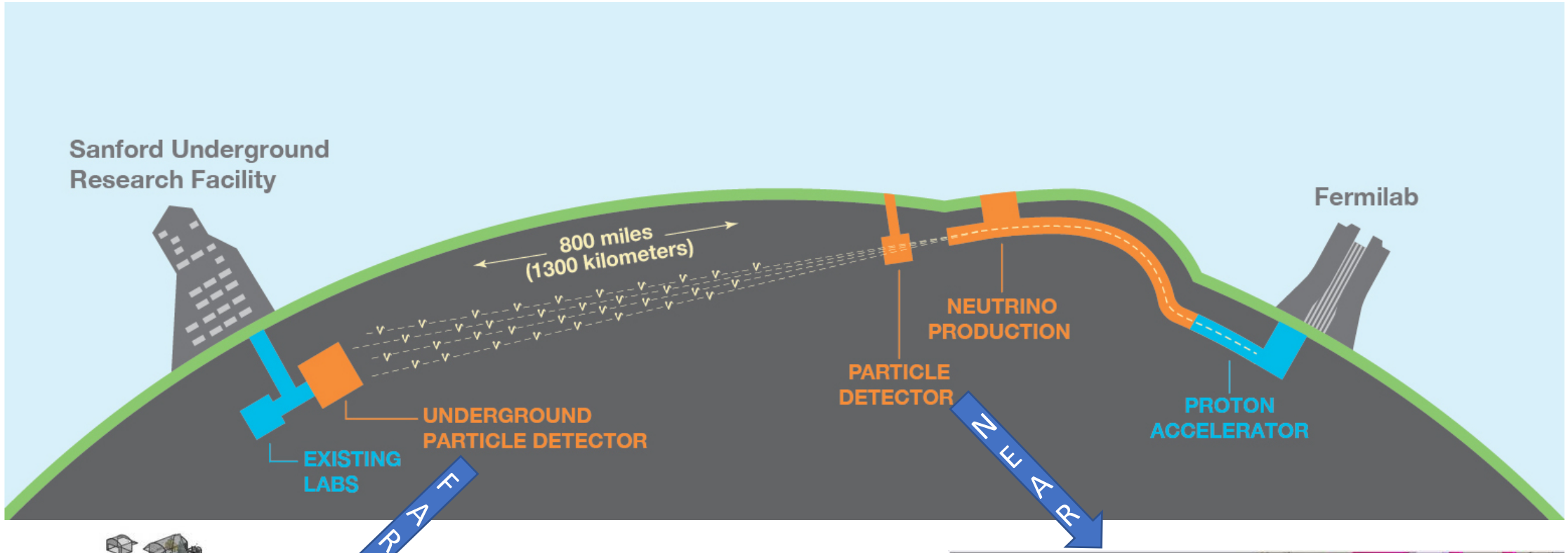
Mass eigenstates

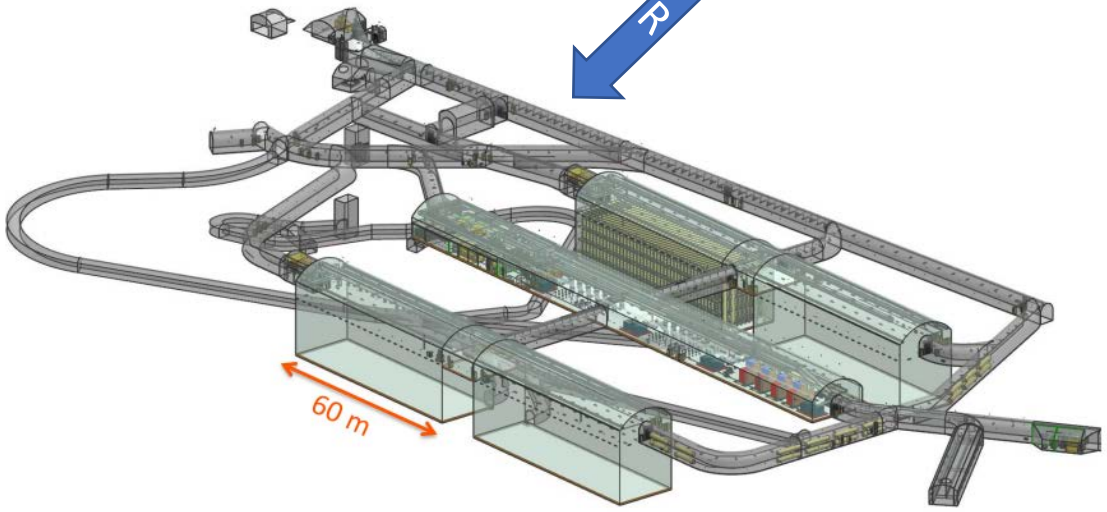
- Raises many interesting questions including possibility of CP violation in neutrino oscillations $(e.g.,\ P(\nu_\mu \to \nu_e) \neq P(\bar{\nu}_\mu \to \bar{\nu}_e))$
- CP violation in neutrino sector could be responsible for the matter-antimatter asymmetry (leptogenesis)

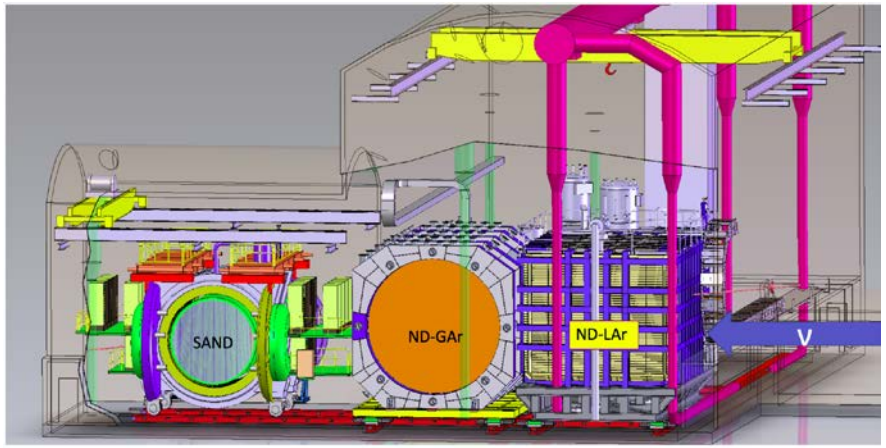
$$\Gamma(N \to \ell^+ + H^-) > \Gamma(N \to \ell^- + H^+)$$

The antilepton excess is converted to a baryon excess through nonperturbative S.M. B+L violating, but B-L conserving processes.

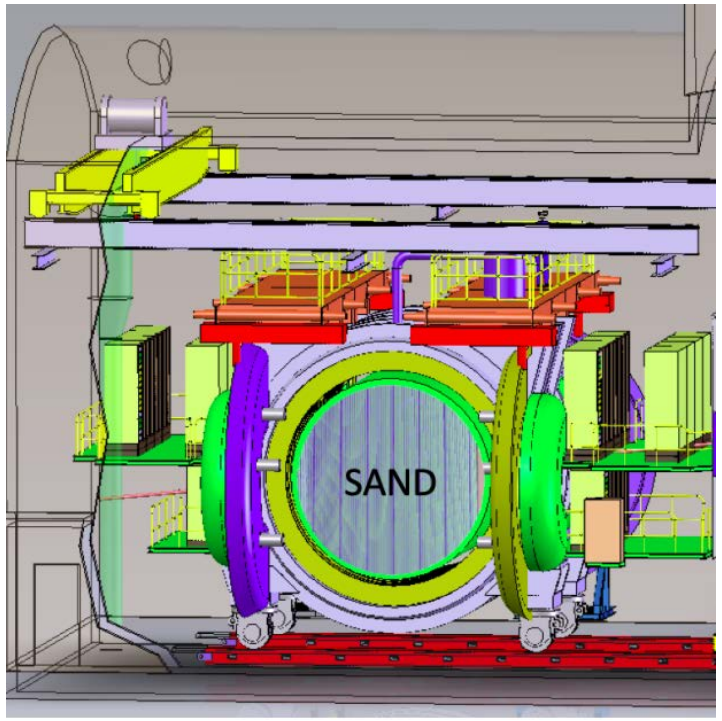
Deep Underground Neutrino Experiment





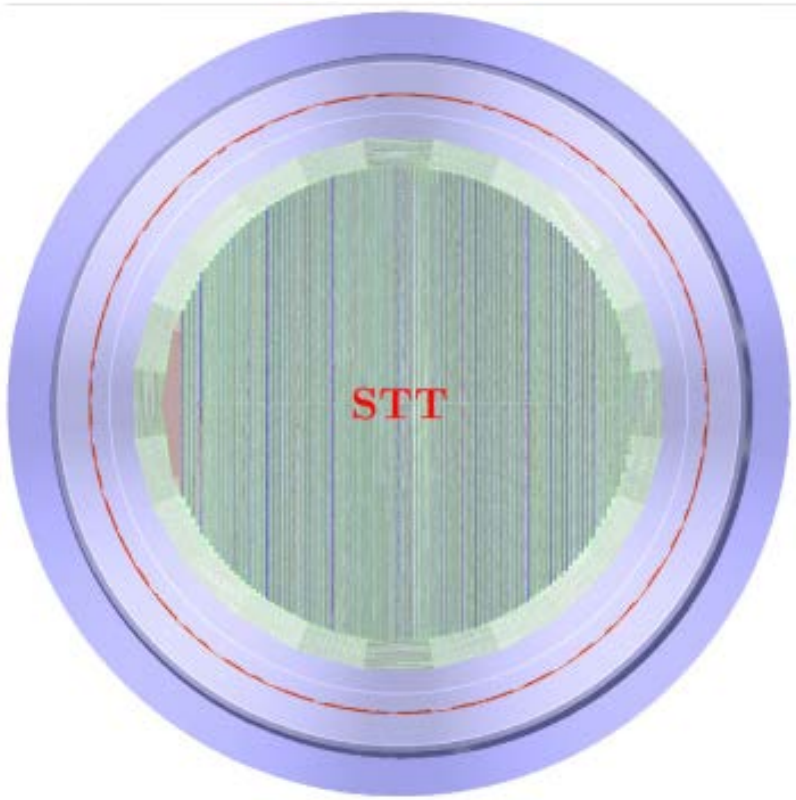


System for On-Axis Neutrino Detection



SAND will be permanently on-axis in a dedicated alcove It will consist of:

* a superconducting solenoid magnet
* an Electromagnetic Calorimeter (ECAL)
* a thin active Lar target
* **low density target/tracker (STT)**

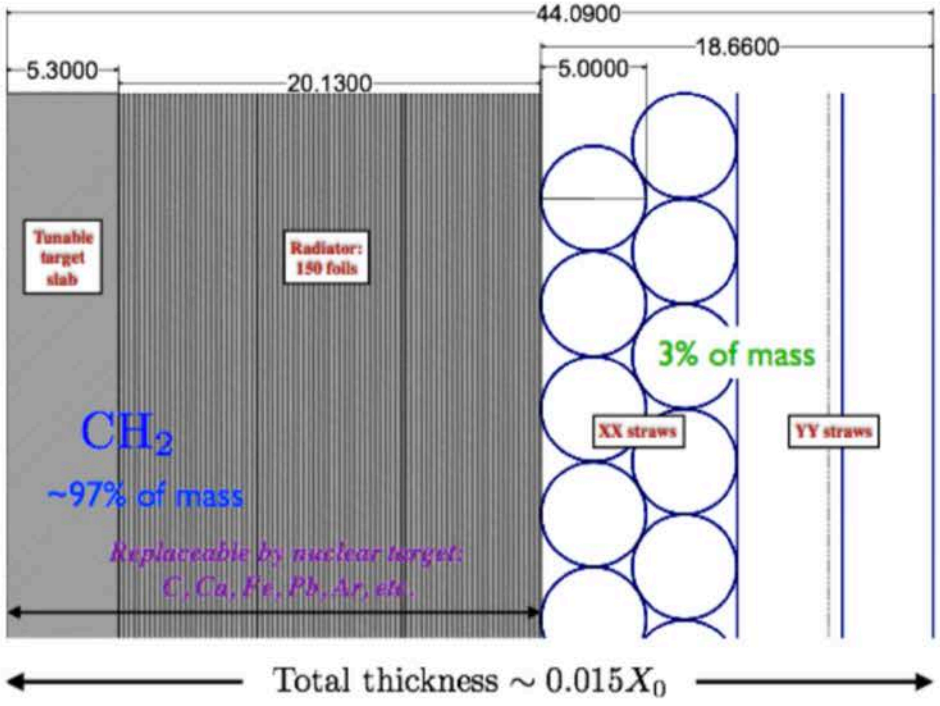


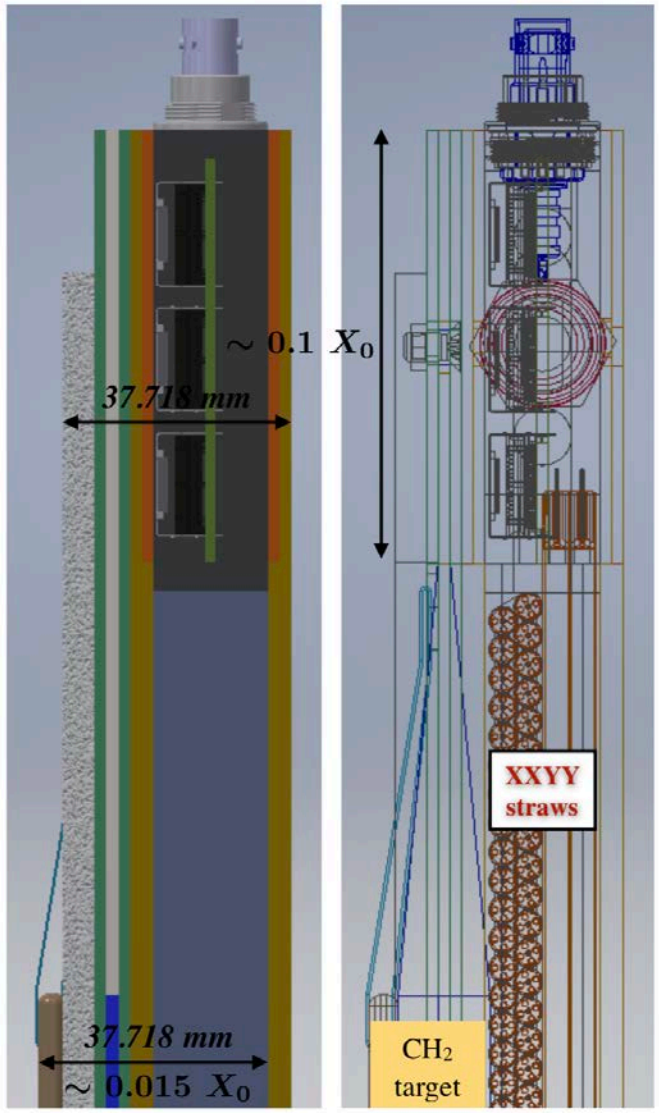
Purpose of SAND

- **Monitoring of the beam stability on a few-days basis**
- **Precision in-situ flux measurements of ν_μ , a-ν_μ , ν_e , a-ν_e**
- **Constraining systematics from nuclear effects and related smearing**

Straw Tube Tracker

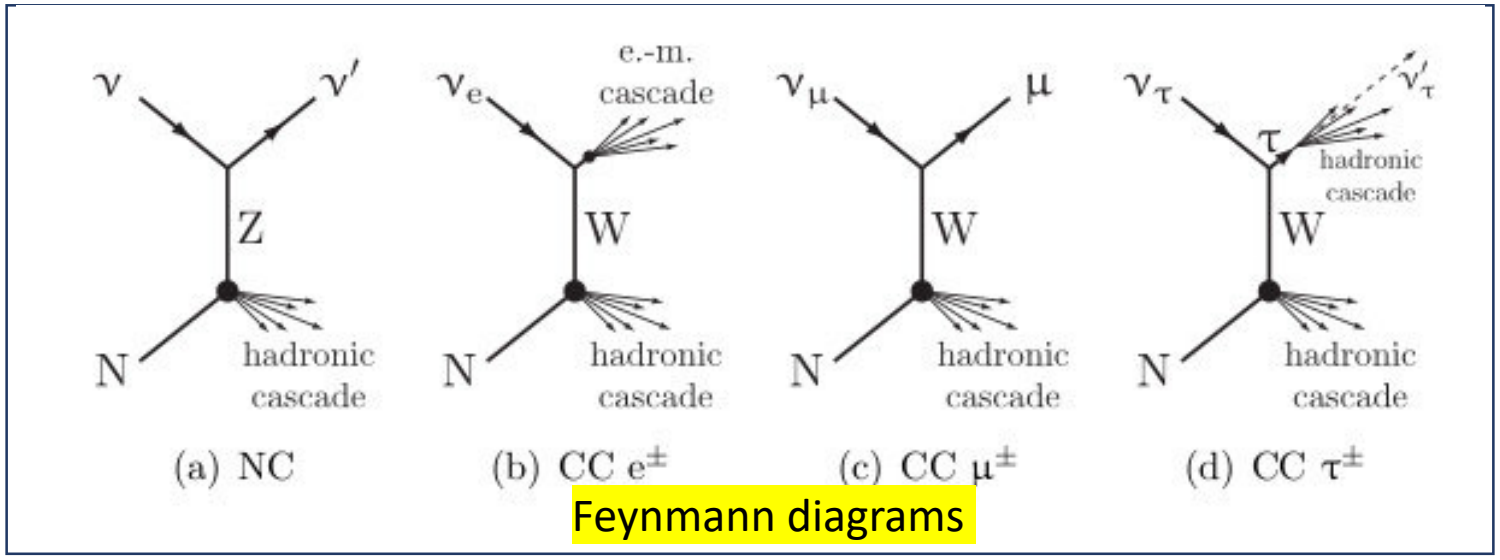
- Thin passive targets (100% purity) physically separated from active tracker (straws ~3% of total mass)
- Tunable target mass & density by varying thin targets (~97% of total mass) with average density 0.005<= rho <=0.18 g/cm^3
- A variety of thin (<0.1 X_0) nuclear targets can be installed & replaced during data taking: C, Ca, Fe, Pb,etc



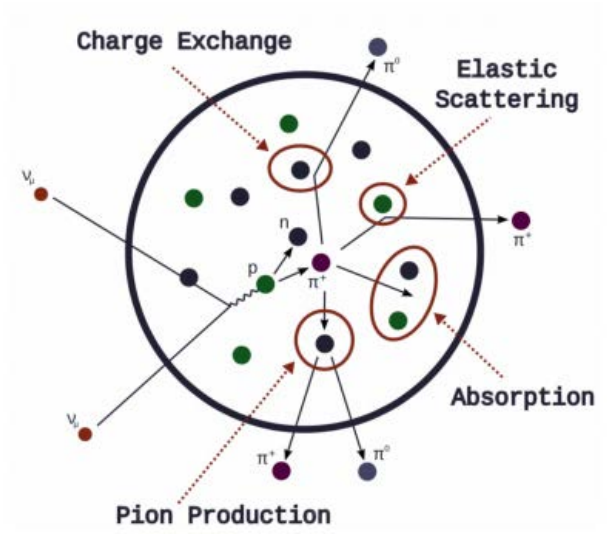


Modular design (flexible) offering a control of the configuration, chemical composition, and mass of targets comparable to e-scattering experiments

Neutrino-nucleus interaction

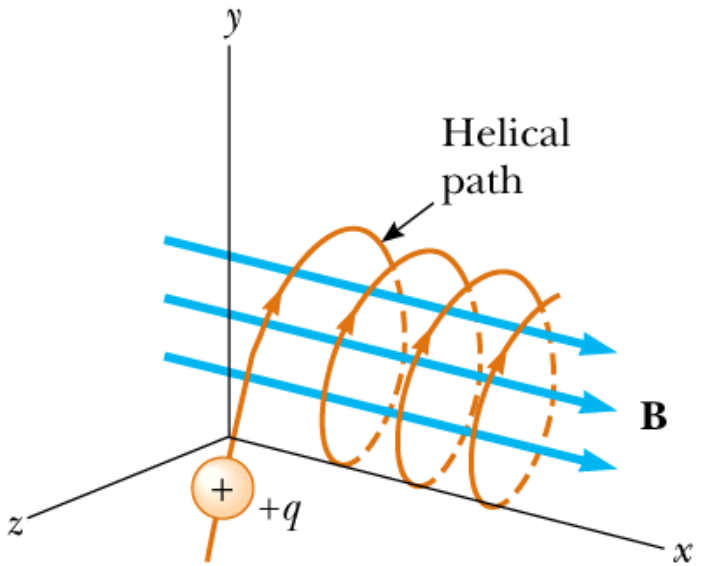


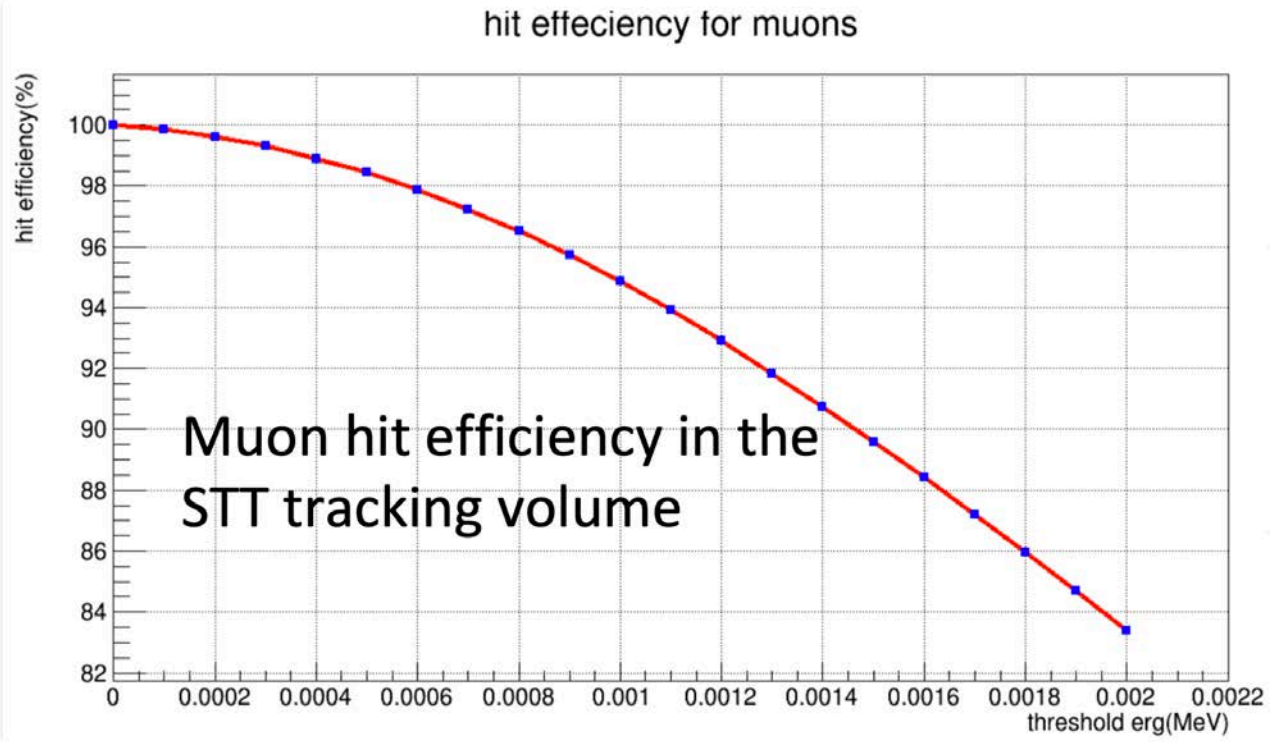
Feynmann diagrams

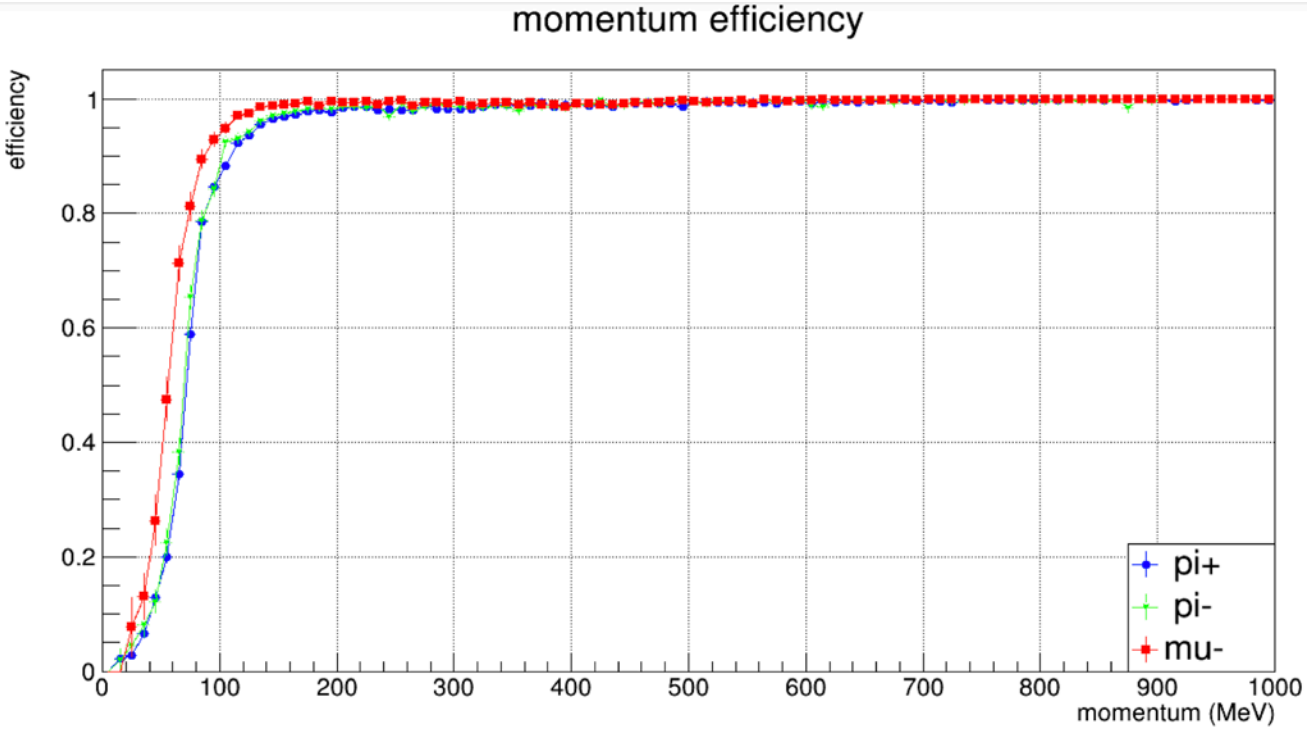


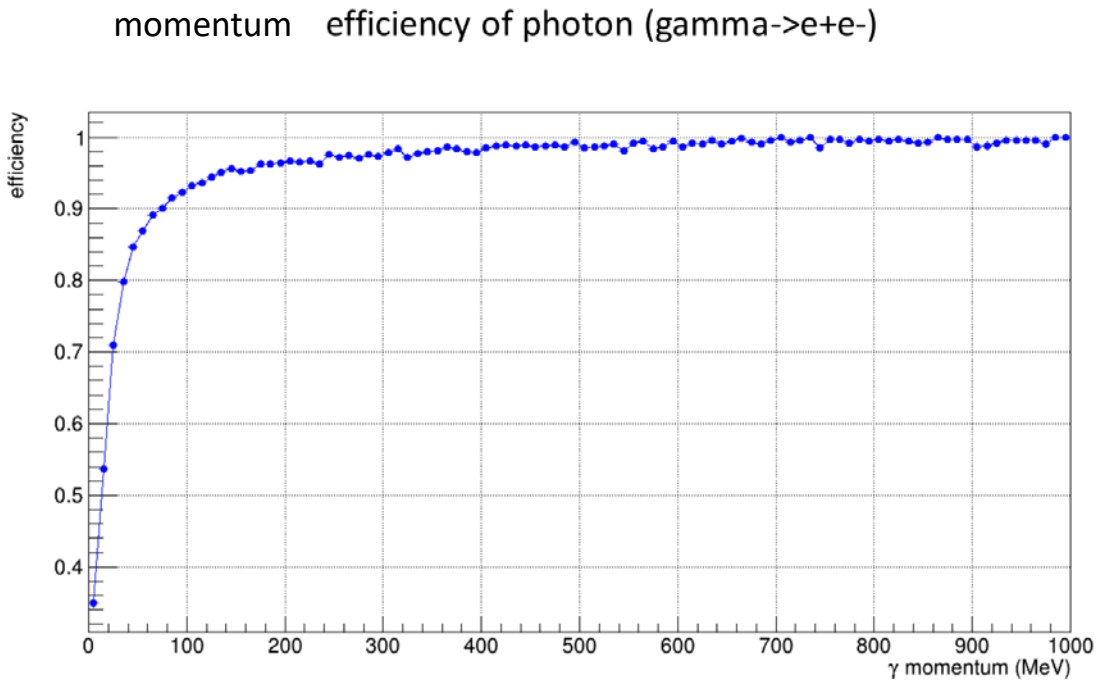
Purpose of STT

- Charged particle (from neutrino nucleus interaction) tracking. Basically reconstructing the momentum of the particle.







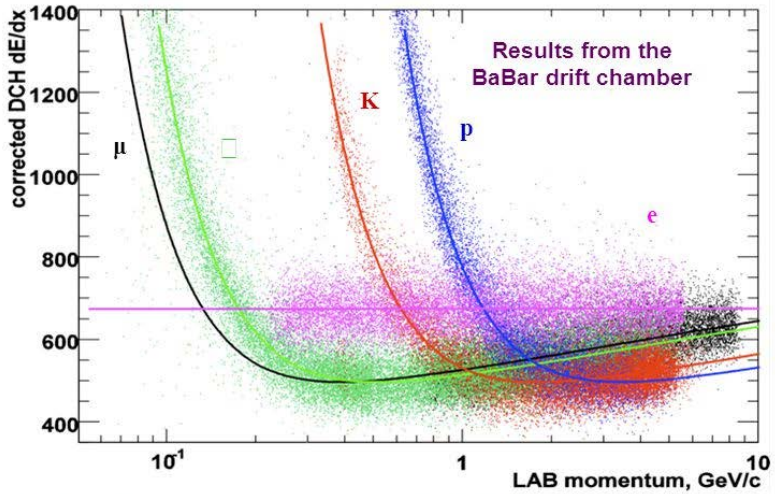


Momentum efficiency = reconstruction efficiency as a function of the momentum of the particle.

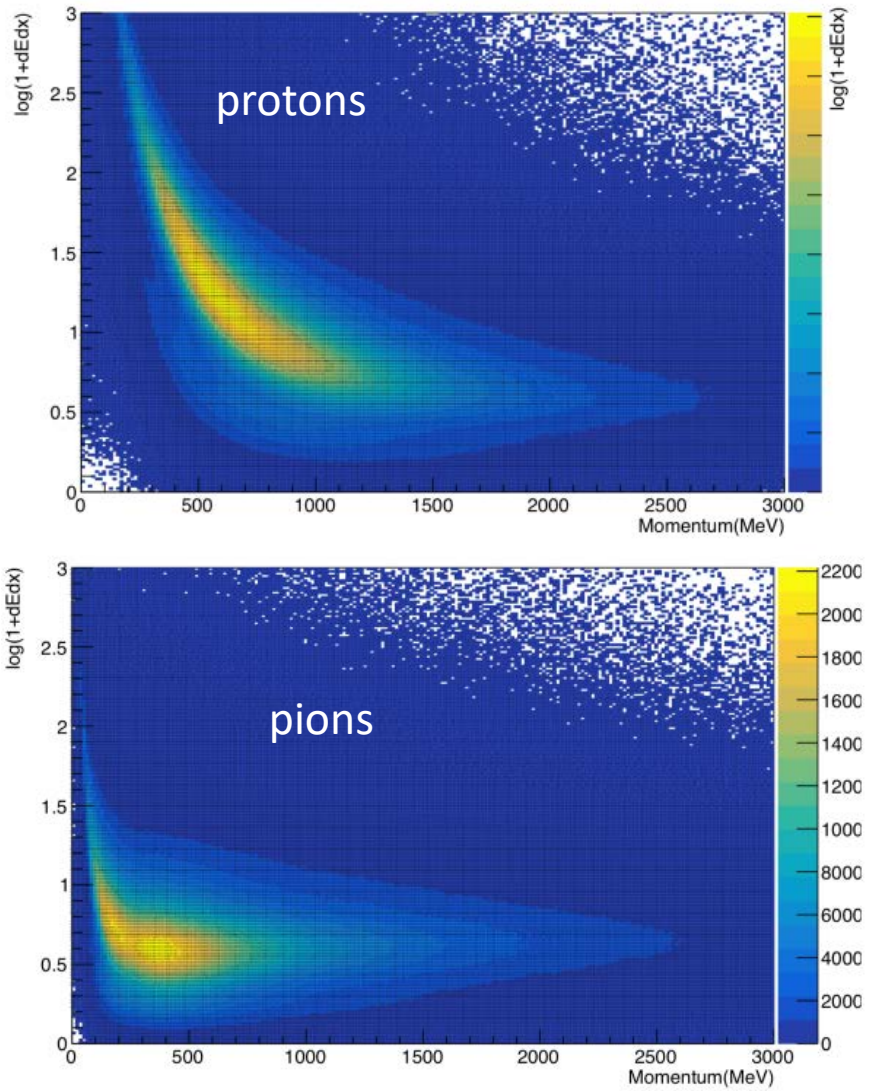
It can be seen that high energy particles can be reconstructed easilly

Particle identification in STT

Particle identification from dE/dx and p measurements



A simultaneous measurement of dE/dx and momentum can provide particle identification.

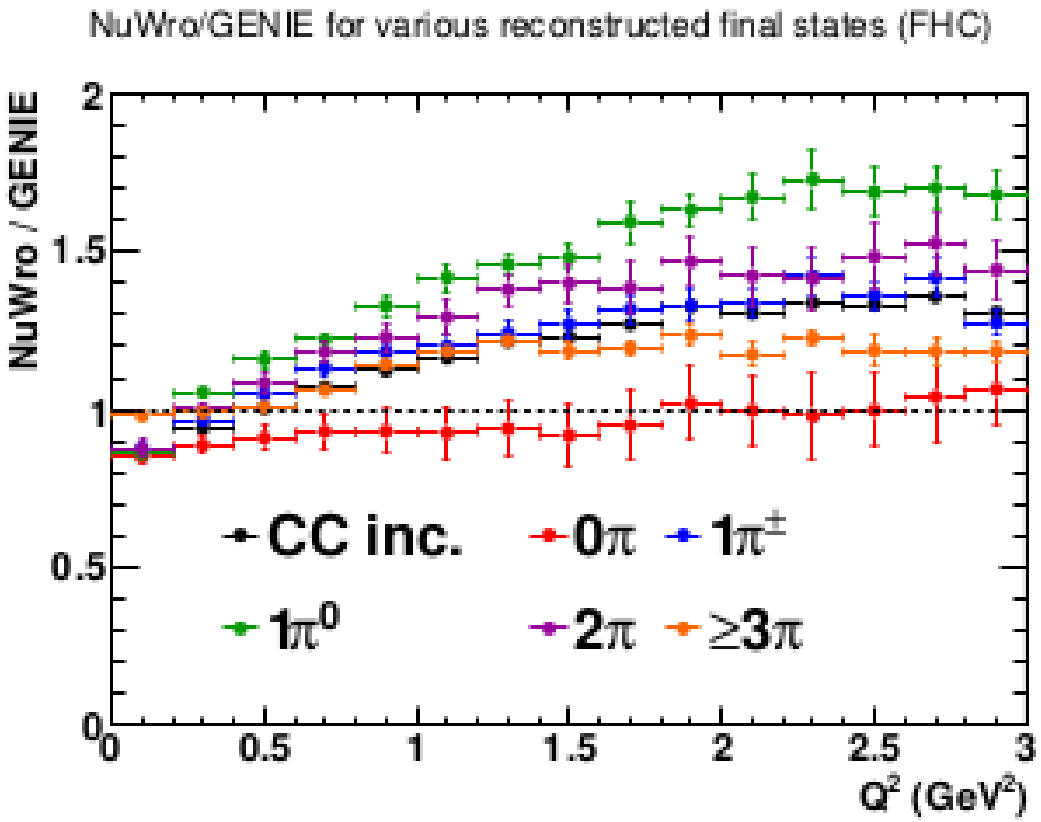


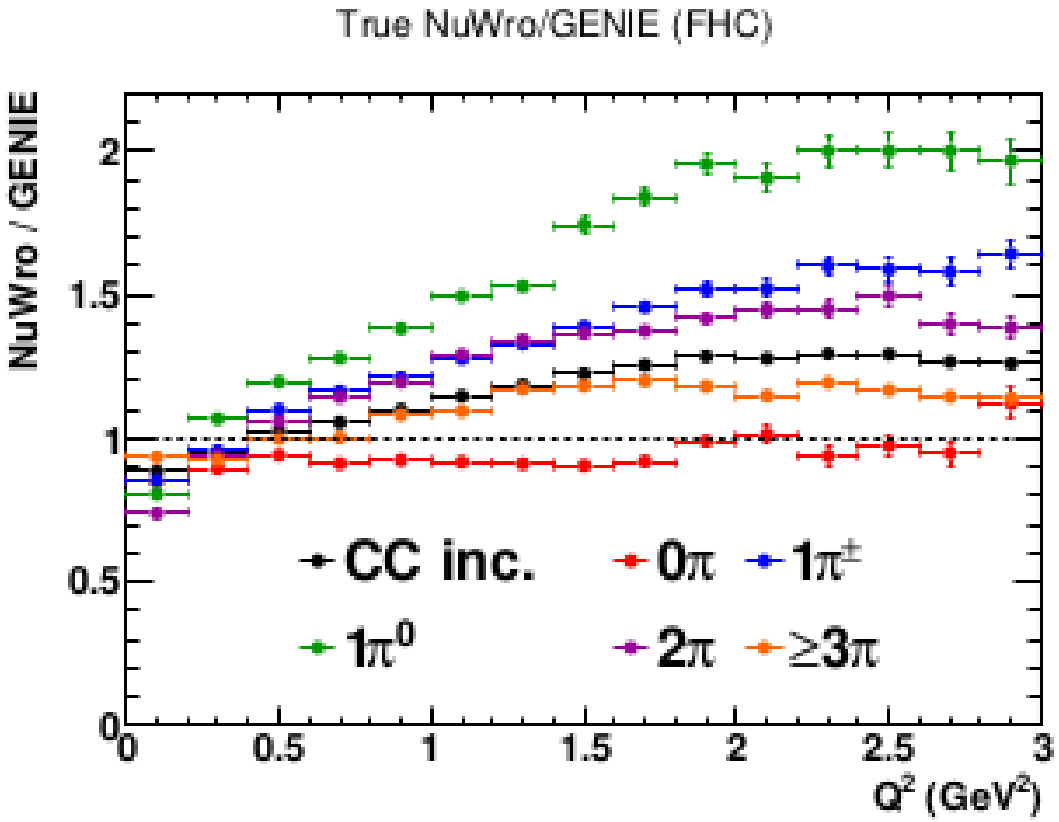
Distribution of log(1 + dE/dx) as a function of the momentum for protons (left plot) and pions (right plot) in STT. The energy deposition in the gas mixture Xe/CO 2 (or Ar/CO 2 for modules with graphite targets) of each straw crossed by the particle is used. Reconstruction effects are taken into account in the plots.

How do we analyse the events before the experiment?

- Using monte-carlo generators.
- Popular Neutrino generators = GENIE, NuWro, GiBUU
- The plots which I did were based on GENIE generated events.

Study of NuWro Vs GENIE events





Q = momentum transfer

Thank you for listening !!!!

Sources :

- https://arxiv.org/pdf/2002.03010.pdf
- https://inspirehep.net/files/c993b249124af552c33ba3ce833de863
- https://arxiv.org/pdf/2103.13910.pdf
- https://indico.cern.ch/event/857610/contributions/3654731/attachments/1957937/3252993/LBNC_Dec_6th_2019_SB.pdf