Neutron beam test with 3D-projection scintillator tracker prototypes for long-baseline neutrino oscillation experiments at Los Alamos National Laboratory

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on behalf of the Joint T2K-DUNE 3D Scintillator R&D Group

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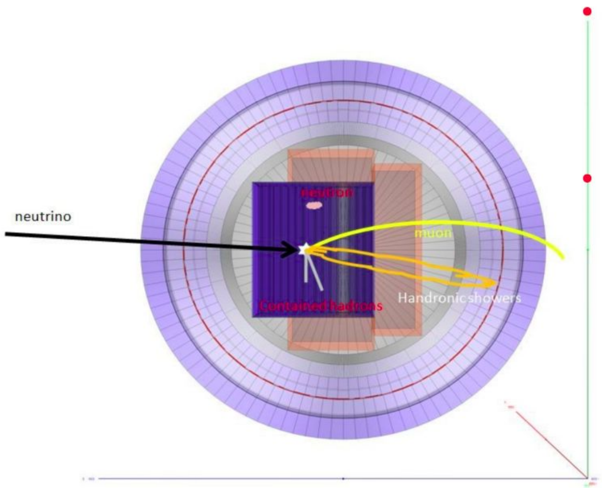
Introduction

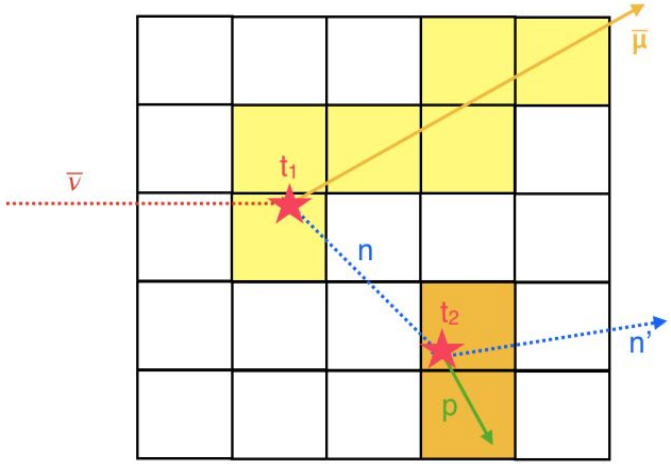
- One of the major systematic uncertainties in the model of neutrino interaction in the long-baseline neutrino oscillation experiments comes from the blindness of the detector to neutrons in the final state.
- A three-dimensional projection scintillator tracker, which is capable of neutron detection, as part of a Near Detector system has been proposed.
- SuperFGD for T2K being built and 3DST design for DUNE is being finalized



3DST for SAND for the Near Detector in DUNE

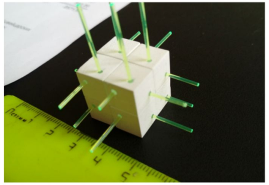
Introduction

- SuperFGD and 3DST are able to measure neutron kinetic energy on an event-by-event basis.
- The neutron kinetic energy can be found by using time-of-flight and the distance between the neutrino interaction vertex and neutron induced hit.
- In order to fully demonstrate the neutron detection capability, in December 2019 and in December 2020, 2 prototype detectors have been exposed to the neutron beam test in Los Alamos National Laboratory.



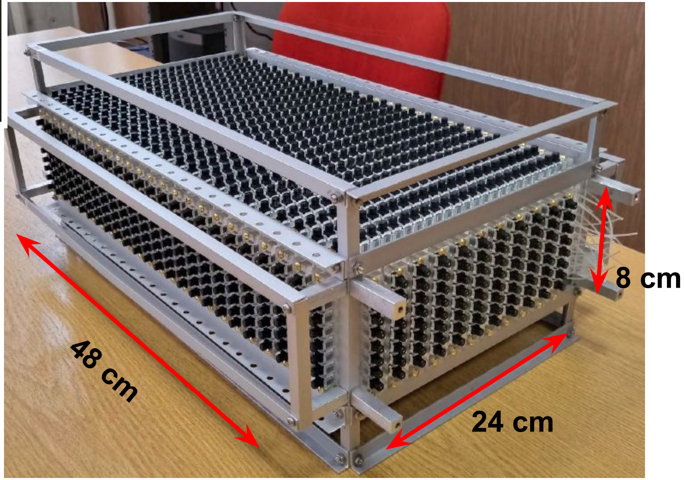
time-of-flight technique

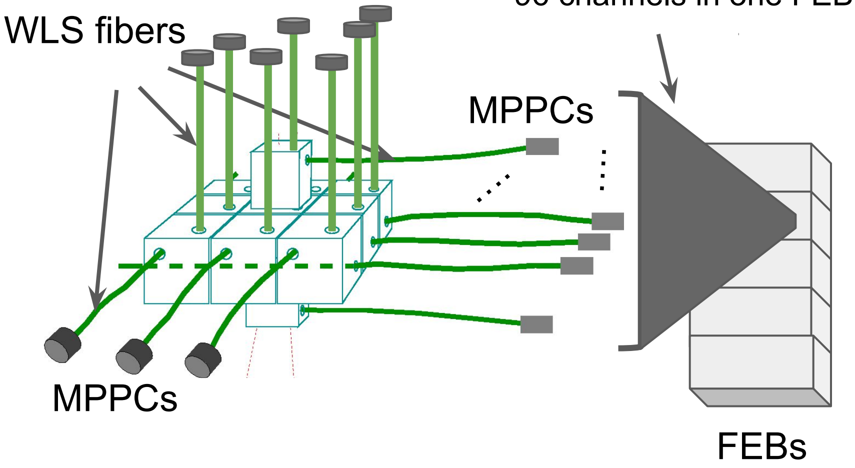
The prototype detectors



- Both detectors are composed by 1cm x 1cm x 1cm scintillator cubes with wavelength shifting fibers perpendicular in 3 directions.
- The size of the SuperFGD prototype is 24cm x 8cm x 48cm
- The size of the US-Japan prototype is 8cm x 8cm x 32cm
- The US-Japan prototype is closer to the final design of the SuperFGD

SuperFGD prototype





US-Japan prototype

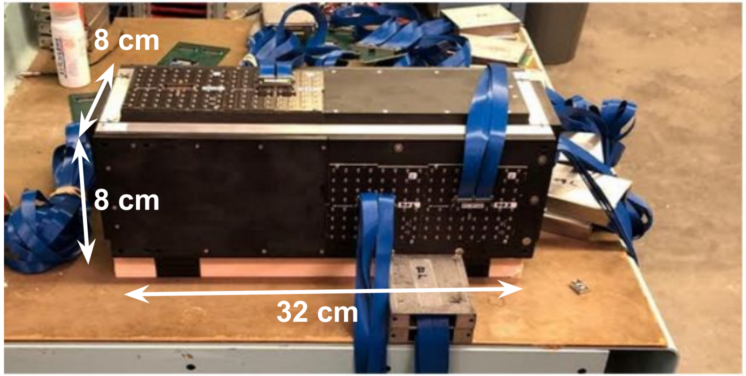
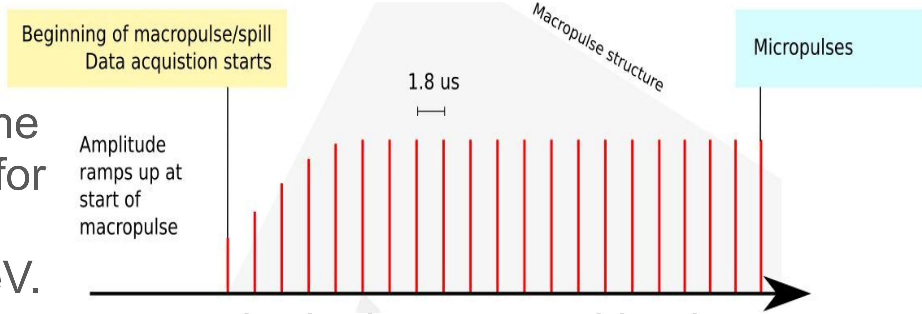
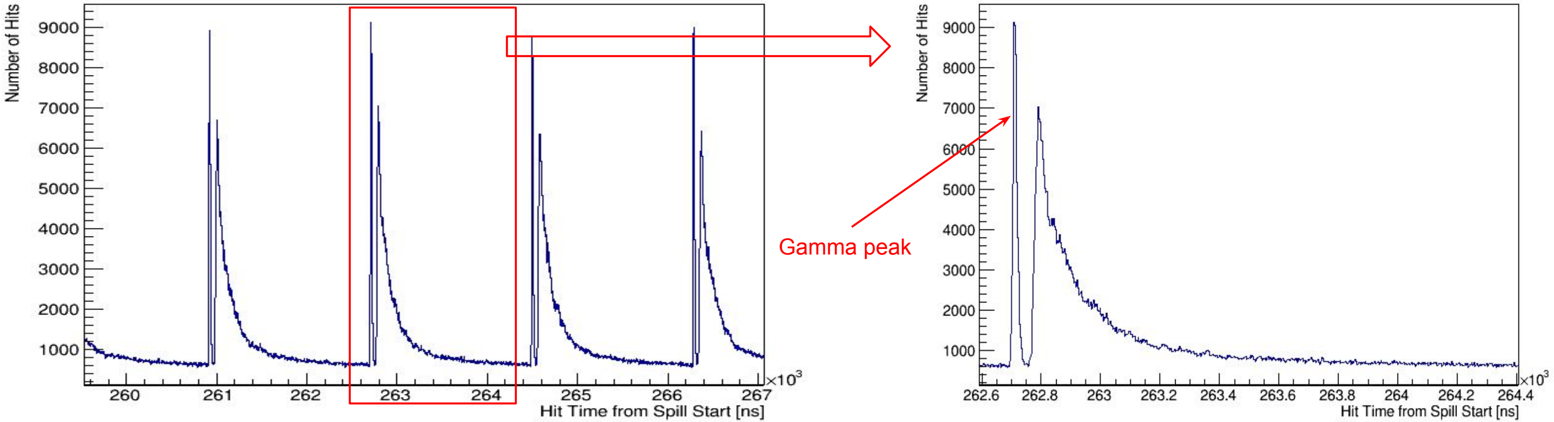


Image from https://arxiv.org/pdf/2103.13910.pdf

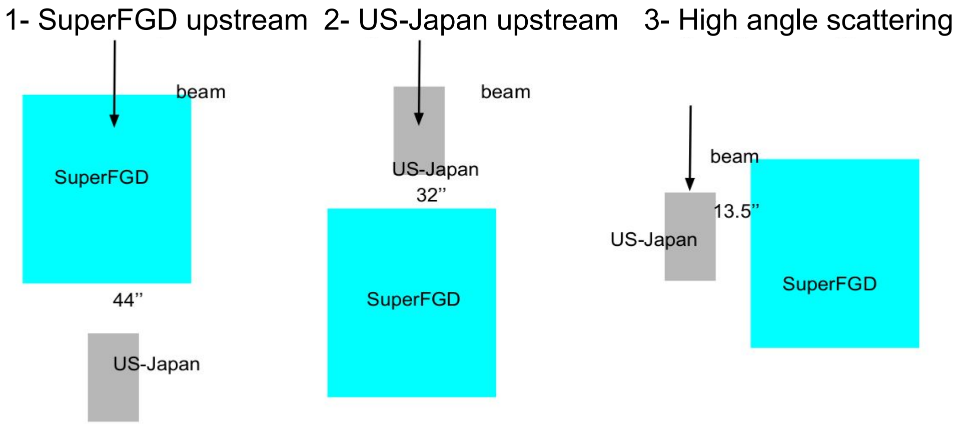
The neutron beam



- We exposed the two prototype detectors to the neutron beam at the LANL LANSCE Facility for 2 weeks for both 2019 and 2020.
- The neutron beam energy range is 0-800 MeV.
- The neutron pulse time is narrow enough to allow us to obtain the neutron kinetic energy by using the ToF method which will use the time between the beam pulse and the neutron detection in the detector
- Wrap-around neutrons appear in the 1.8μs pulse spacing , and the neutron wrap-around is up to 13Mev.

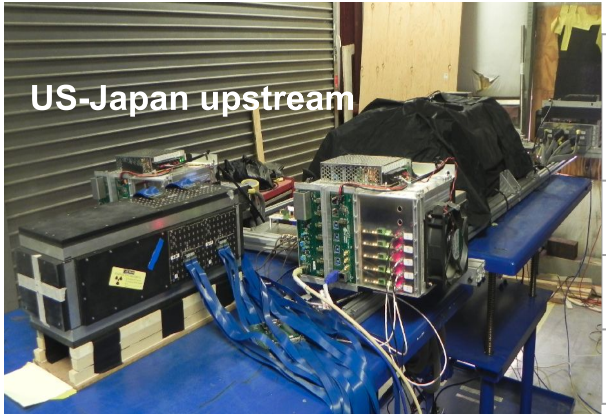


Different configuration : 2020



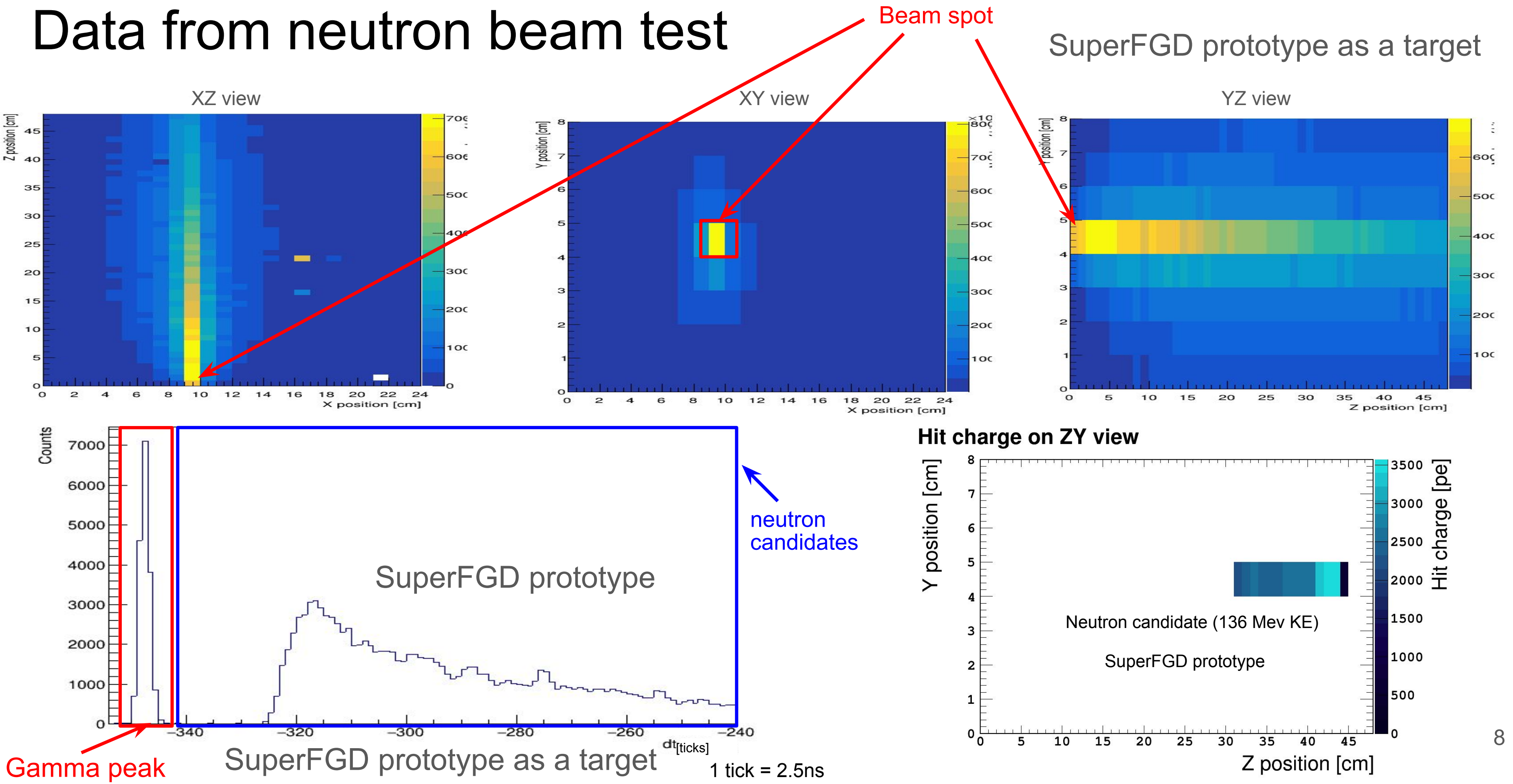
1. An individual detector exposing to the beam to achieve our primary physics goals.
2. Seek for an extended scenario, which may effectively enlarge the detector.
3. Study the scattering angle.

We had 2 micropulse spacing for the beam: 1.8μs and 3.6μs.



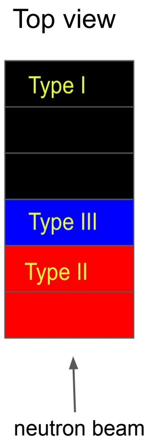
Collimator size + micropulse spacing	1 cm + 1.8 μs	1 cm + 3.6 μs	1 mm + 1.8μs	1 mm + 3.6 μs
SFGD upstream	2.1×10^{8} neutrons	1.2×10^{8} neutrons	1.8×10^{6} neutrons	5.1×10^{5} neutrons
USJ upstream	2.6×10^{8} neutrons	NA	6.7×10^{6} neutrons	NA
High angle sct.	2.2×10^{8} neutrons	3.2×10^{7} neutrons	NA	NA

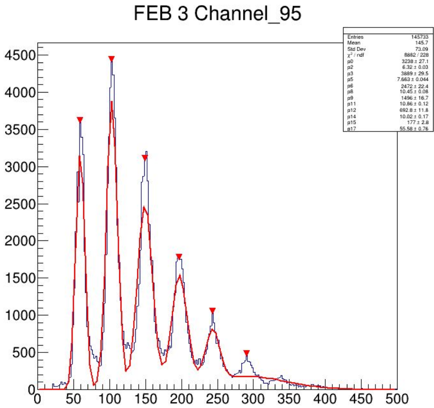
Data from neutron beam test



Gain Calibration

- A LED scanning channel-by-channel has been performed on the prototype. Every LED data was taken with a fixed temperature.
- Based on those LED data we can extract the gain of channel corresponding to each FEB, by looking at the “finger plot” of the ADC distribution.
- We have 3 type of MPPCs for the prototype.
- Temperature dependence can be observed on the gain.
- MPPCs type III can always observe the finger plots (because of the high dark count), so that indicate a temperature measurement. And MPPCs type III helps us to get the temperature difference that will be used to include the temperature effect on type I and II for all physics runs.

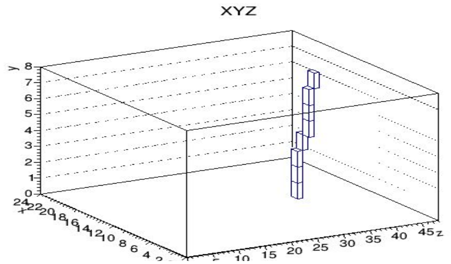


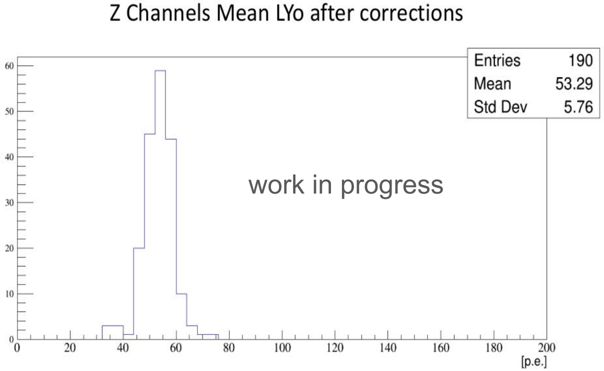


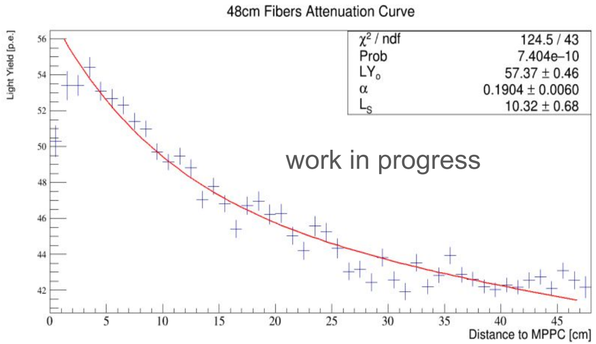
Description	Type I	Type II	Type III
Manufacturer ref.	S13360-1325CS	S13081-050CS	S12571-025C
No. in Prototype	1152	384	192
Pixel pitch [µm]	25	50	25
Number of pixels	2668	667	1600
Active area [mm^2]	1.3×1.3	1.3×1.3	1.0×1.0
Operating voltage [V]	56–58	53–55	67–68
Photon detection eff. [%]	25	35	35
Dark count rate [kHz]	70	90	100
Gain	7×10^5	1.5×10^6	5.15×10^5
Crosstalk probability [%]	1	1	10

Calibration - Cosmics

- In 2020 , cosmics data has been taken in LANL with the SuperFGD prototype.
- A scintillator pad (22cm x 18 cm) on top of the detector has been used during the cosmic data run taking to trigger a time window that covers the muons.
- The event selection for the cosmic required a linear track that has hits on the top and the bottom layers of the detector.
- The cosmics provide light yield calibration for each cube and attenuation information of the fiber.







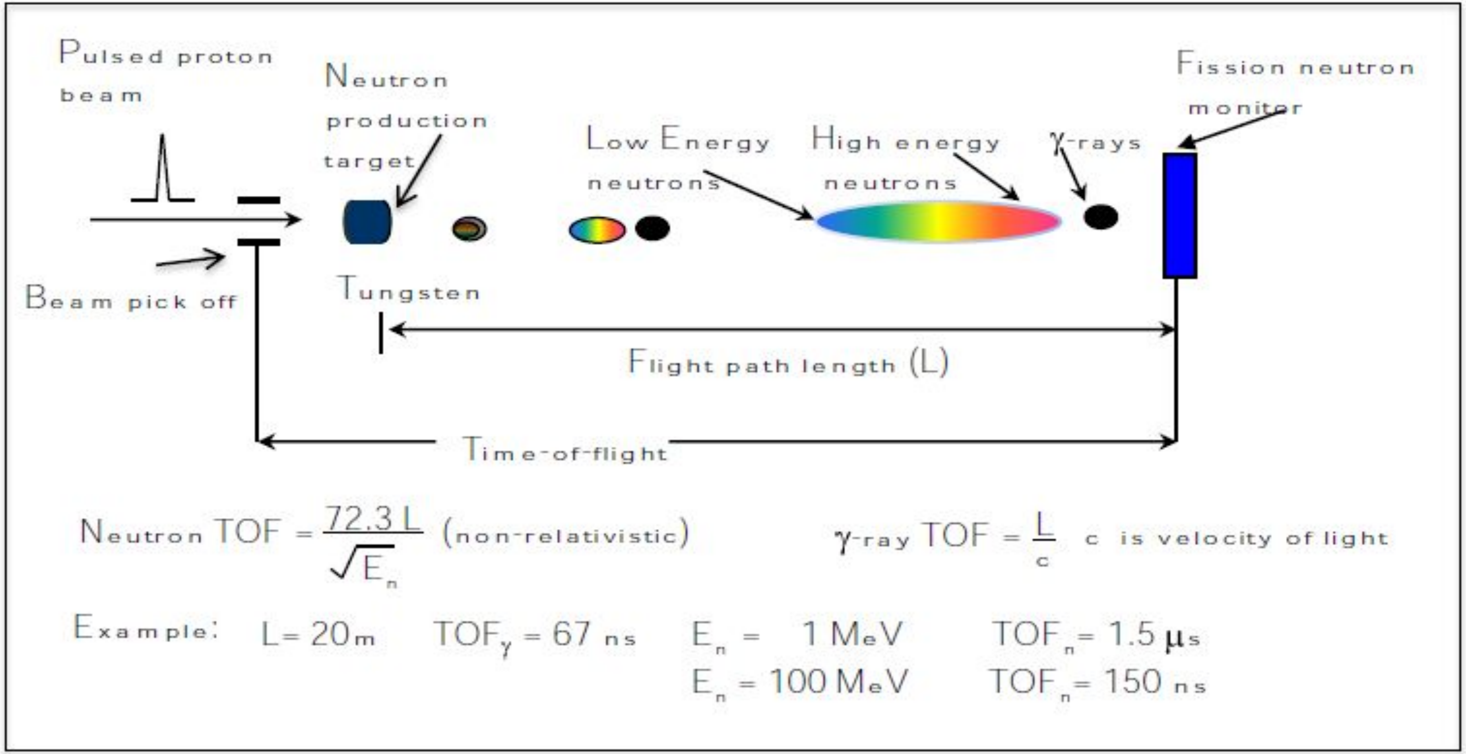
Conclusion

- The beam test helps to study the capacity of the prototypes detectors to reconstruct neutron events.
- We aim at measuring the response of the detector to n,p scattering and pion and gamma-ray production as a function of primary neutron kinetic energy. An example is the measurement of the total neutron cross section as a function of neutron kinetic energy (See Eric Chong from University of Pennsylvania will talk about).
- The data can be used to tune the simulation and optimize the detector design.
- A number of publications are expected.

Thank you

BACKUP

Time of flight method



The beam structure