T2K & SuperK Group Update

Ka Ming Tsui
Particle Physics Annual Meeting, May 2022

UNIVERSITY OF LIVERPOOL

Members

- Neil McCauley
- Christos Touramanis
- Costas Andreopoulos
- Kostas Mavrokoridis
- Jon Coleman

- Ka Ming Tsui
- Pablo Fernandez Menendez → Sam Jenkins
- David Payne
- Andy Carrol
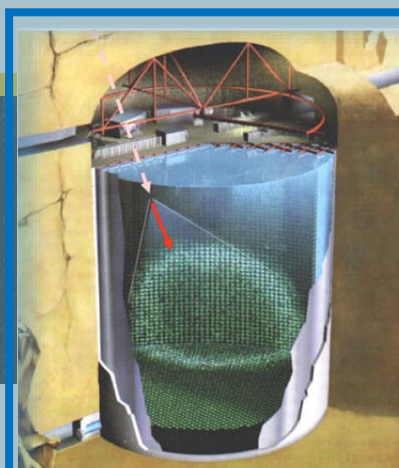
- Balint Bogdan
- Ashley Greenall
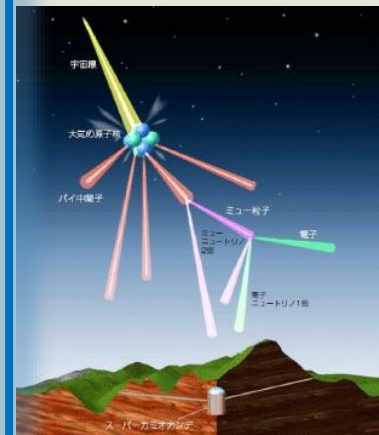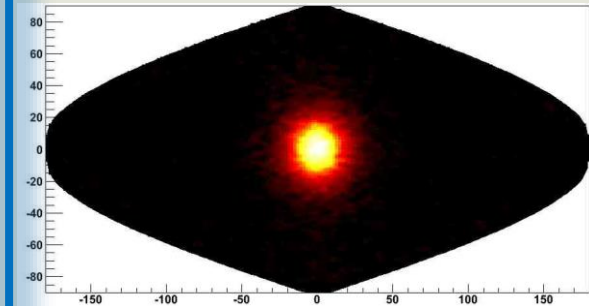- Carl Metelko

- Francis Bench
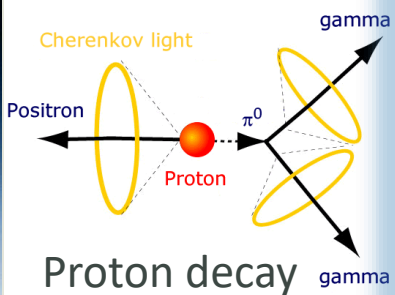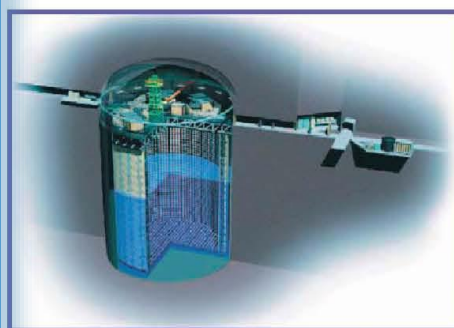- Gabriel Penn
- Pruthvi Mehta
- Jaiden Parlone
- Adam Tarrant

Solar neutrino

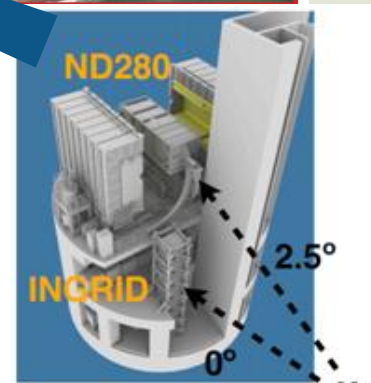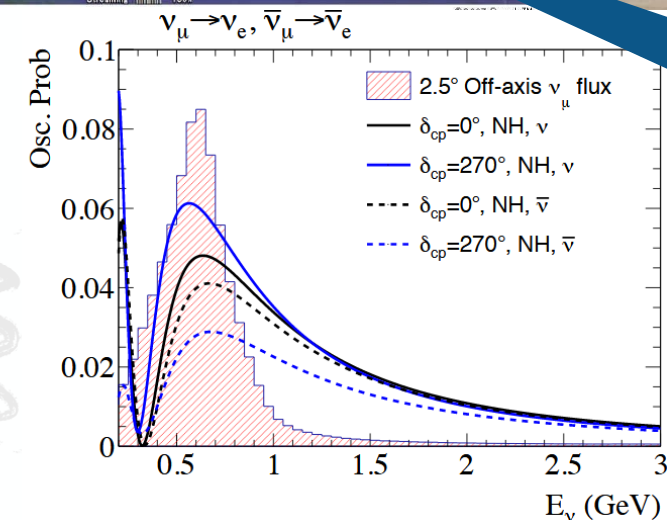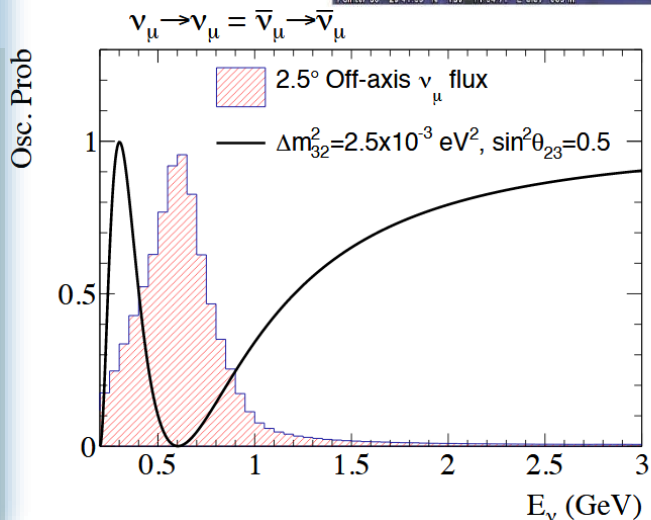Atmospheric neutrino

Proton decay

Super-Kamiokande
(ICRR, Univ. Tokyo)

T2K

295km

J-PARC Main Ring
(KEK-JAEA, Tokai)

KAMIOKA — TOKAI

ND280

INGRID

2.5°

0°

ν_μ

INGRID (on-axis) and
ND280 (off-axis)

$\nu_\mu \rightarrow \nu_\mu = \bar{\nu}_\mu \rightarrow \bar{\nu}_\mu$

2.5° Off-axis ν_μ flux

$\Delta m^2_{32}=2.5\times10^{-3}$ eV^2, sin$^2\theta_{23}=0.5$

Osc. Prob

E_ν (GeV)

$\nu_\mu \rightarrow \nu_e, \bar{\nu}_\mu \rightarrow \bar{\nu}_e$

2.5° Off-axis ν_μ flux

$\delta_{cp}=0°$, NH, ν
$\delta_{cp}=270°$, NH, ν
$\delta_{cp}=0°$, NH, $\bar{\nu}$
$\delta_{cp}=270°$, NH, $\bar{\nu}$

Osc. Prob

E_ν (GeV)

Cherenkov light
gamma
Positron
Proton
π^0
gamma

Oscillation Analysis

Nature 580 (2020) 7803, 339-344
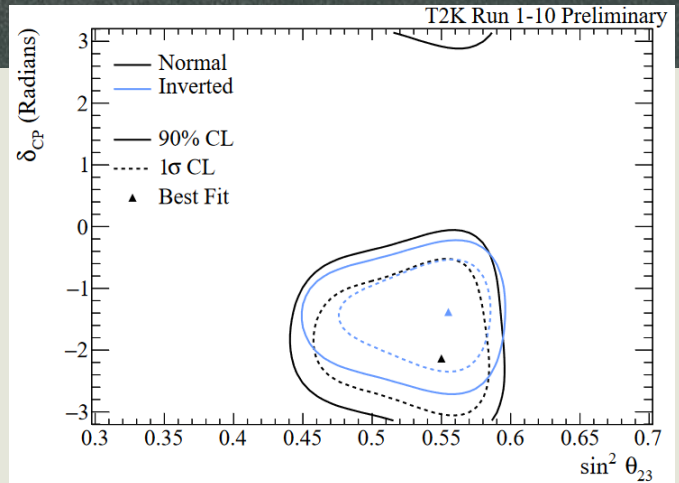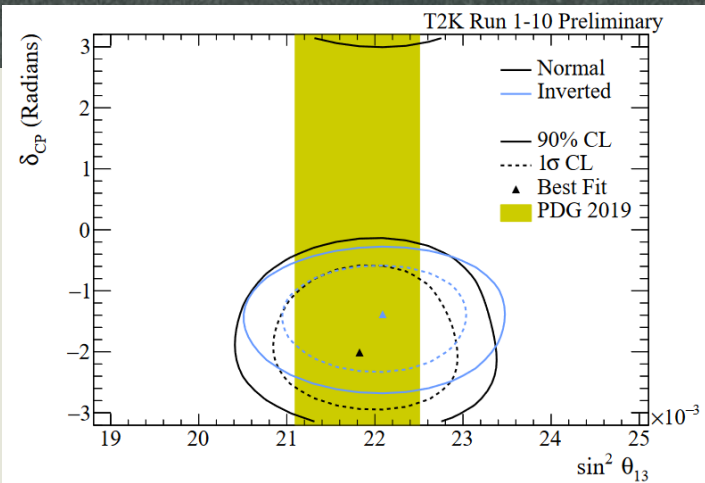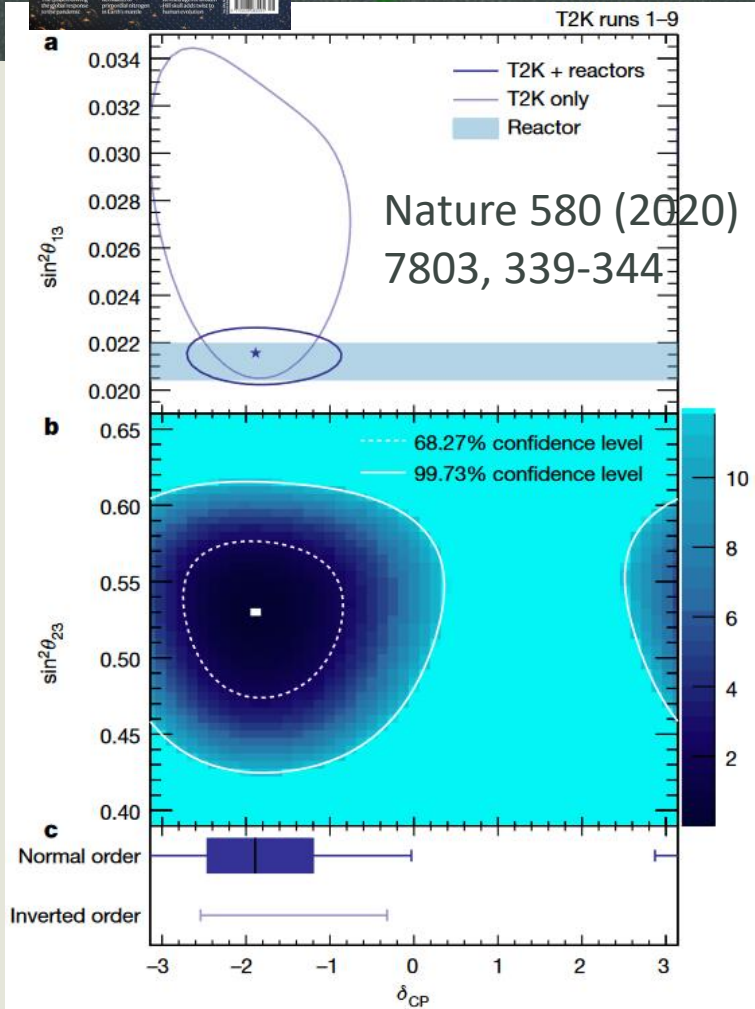
(mostly) statistical update with 30% more data in neutrino mode

Work by Jaiden

FHC MR ν_μ CC1π^+
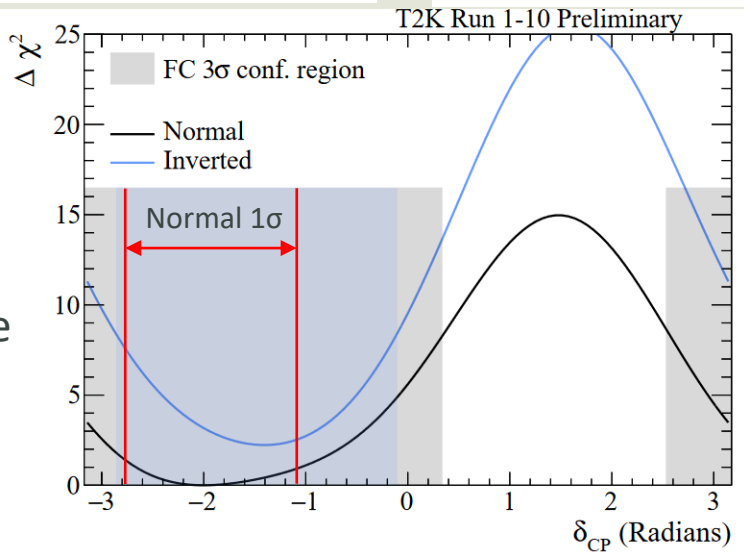
- New muon neutrino multi-ring (pion) sample

- Excess in pion production?
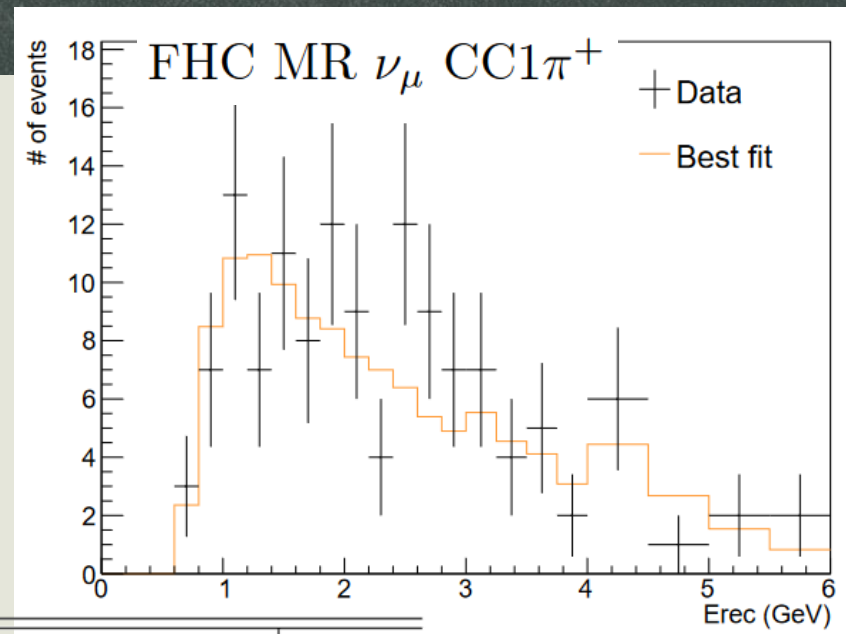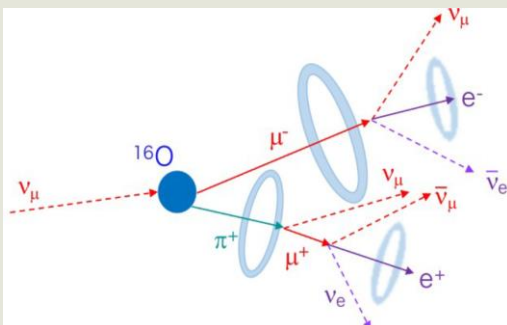
	$\delta_{CP} = -\pi/2$	$\delta_{CP} = 0$	$\delta_{CP} = \pi/2$	$\delta_{CP} = \pi$	$\delta_{CP} = -2.18$	Data
FHC 1Rμ	376.863	376.164	376.822	377.644	377.303	318
RHC 1Rμ	144.292	143.945	144.294	144.668	144.503	137
FHC 1Re	102.279	86.2003	70.7227	86.8013	99.6123	94
RHC 1Re	17.286	19.6316	21.7309	19.3853	17.6153	16
FHC 1R ν_e CC1π^+	10.0223	8.72417	7.1075	8.4057	9.669	14
FHC MR ν_μ CC1π^+	115.994	115.489	115.968	116.482	116.278	134

- Transverse kinematic imbalance to characterize nuclear model in $\nu_\mu\ CC1\pi^+$ interaction

$\nu_\mu + \text{p} \to \mu^- + \pi^+ + \text{p}$

(a) $\delta p_{TT} = p_{TT}^\pi + p_{TT}^{\text{p}}$.
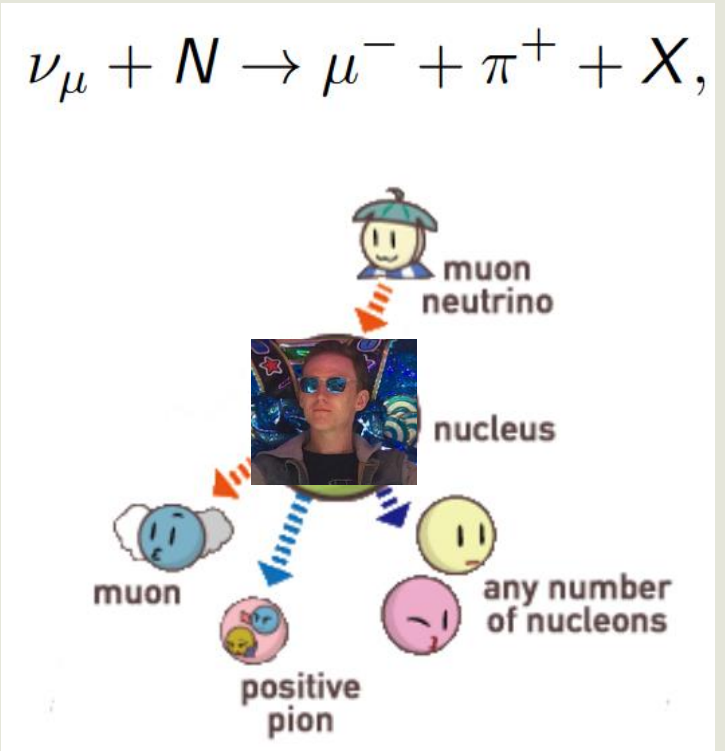
Phys.Rev.D 103 (2021) 11, 112009
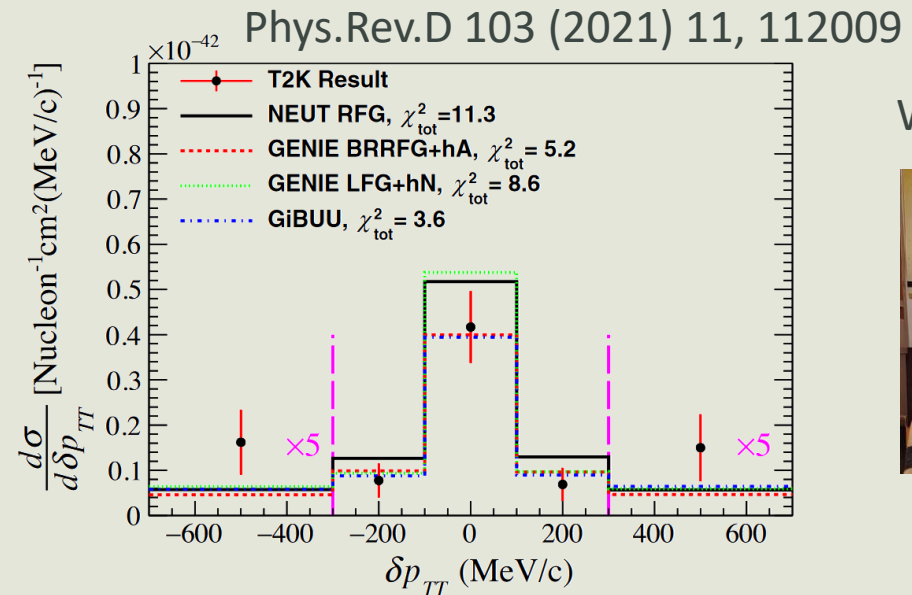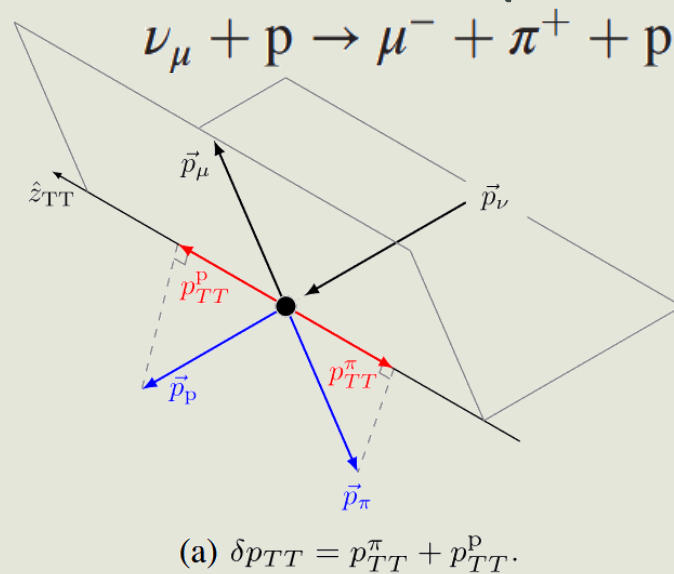
Work by me =]

- Show great potential with limited statistics

Cross-section measurement

- Sam's $\nu_\mu \ CC1\pi^+$ measurement on water

$$\nu_\mu + N \rightarrow \mu^- + \pi^+ + X,$$

Global particle ID tools in ND280

- Combine information from each subdetector crossed

- Use particle gun MC (uniform kinematic phase space) in training to avoid neutrino interaction model dependencies

- BDT-based PID significantly outperforms existing ND280 PID methods

ND280

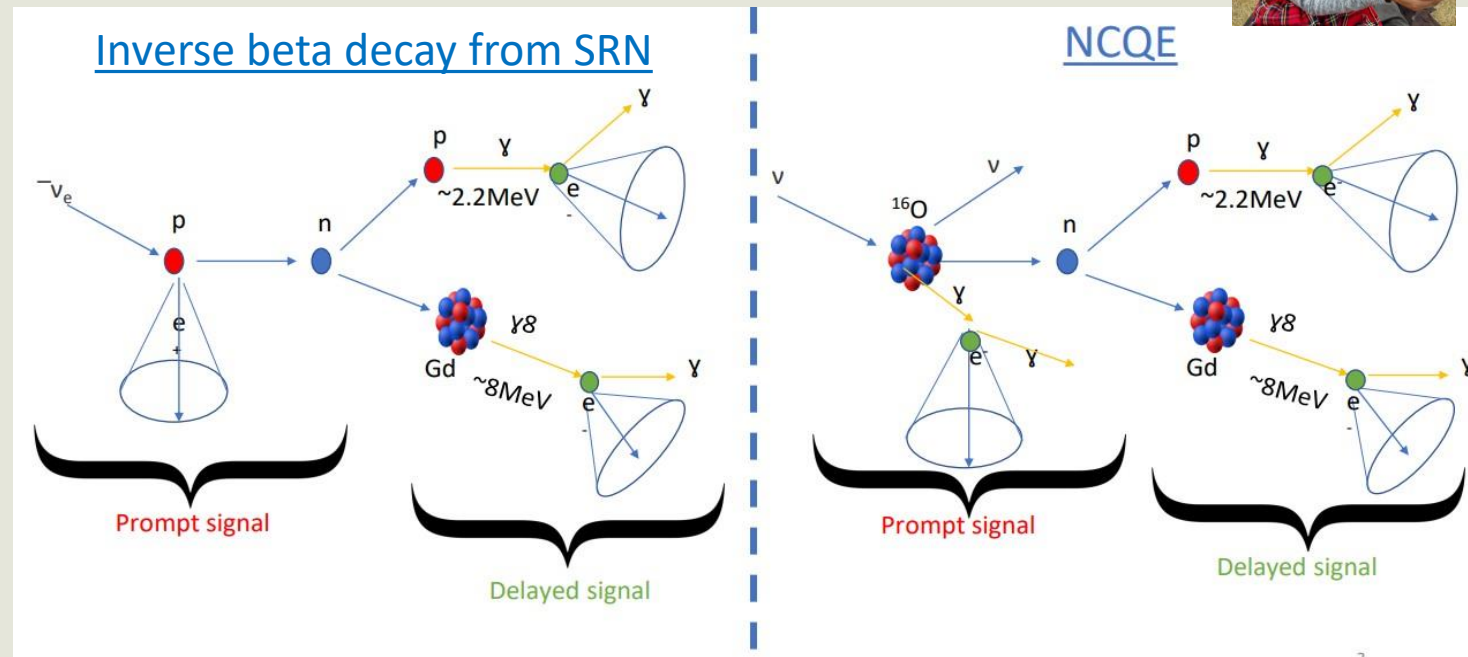Work by Gabriel

Existing PID (mostly TPC)

Signal purity

BDT PID (extra info from FGDs, ECal, SMRD)
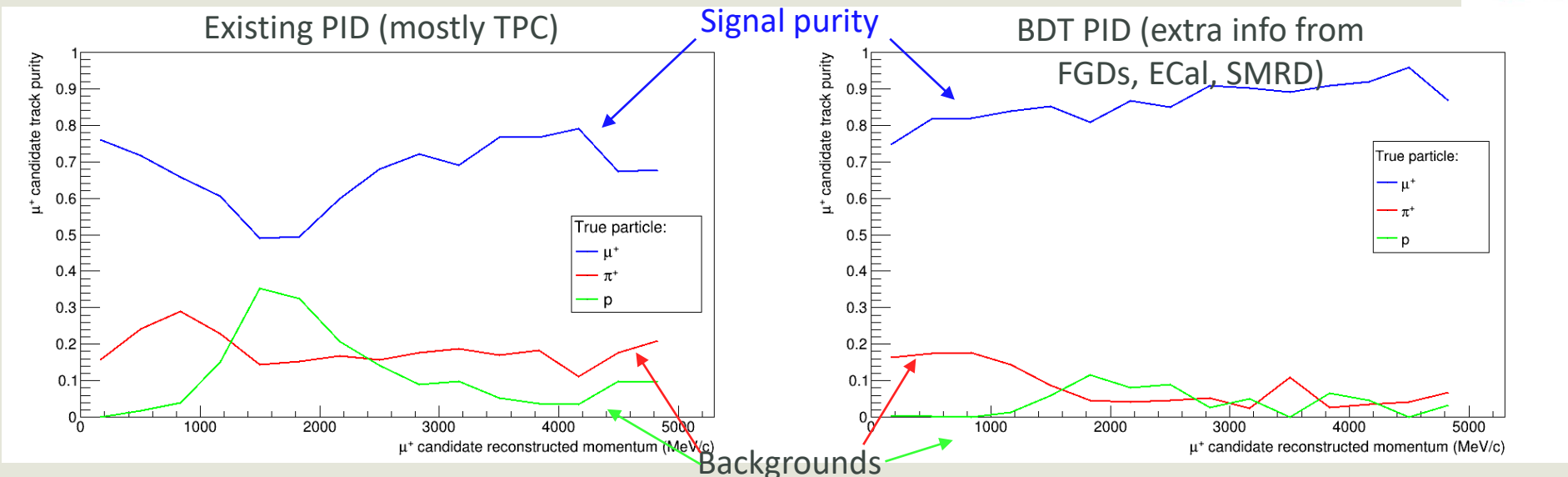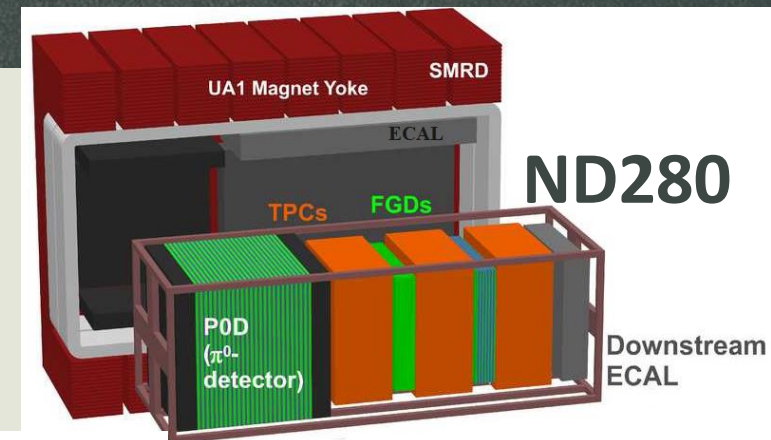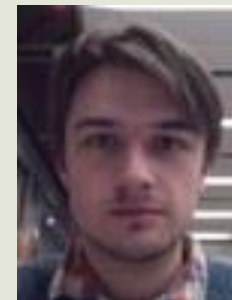
Backgrounds

T2K-SK NCQE interaction with neutron tagging

Work by
Pruthvi

- Neutral current quasielastic interaction: major background in supernova relic neutrino (SRN) searches

- Use T2K beam to evaluate NCQE cross sections close to atmospheric peak

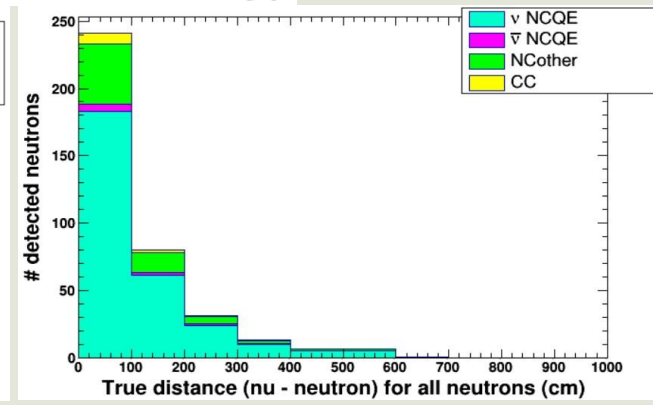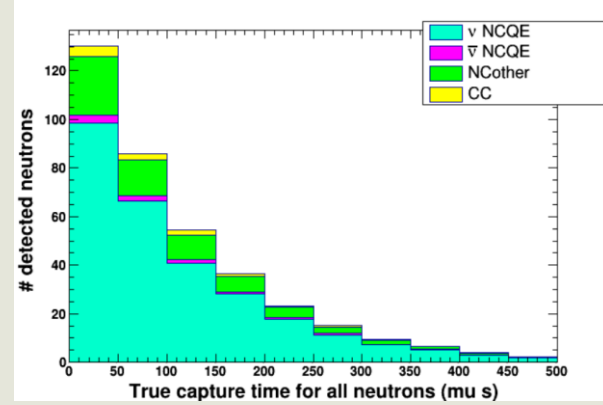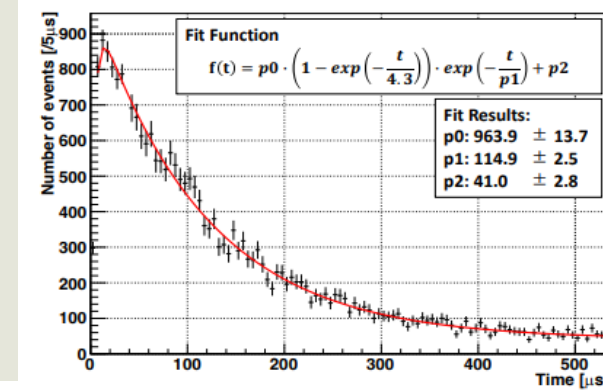- Gadolinium loading enables efficient neutron tagging → characterization of neutron properties and nuclear effects

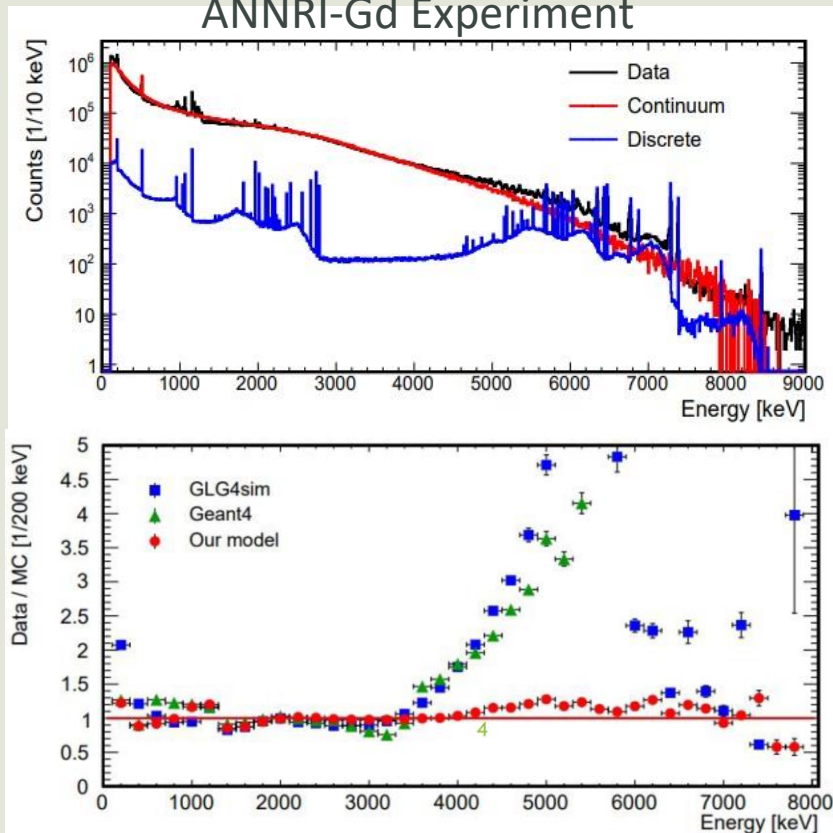Inverse beta decay from SRN

NCQE

- More accurate Gd-deexcitation model

  ANNRI-Gd Experiment

- Neural network-based selection to tag neutrons in NCQE interaction sample

  $$f(t) = p0 \cdot \left(1 - exp\left(-\frac{t}{4.3}\right)\right) \cdot exp\left(-\frac{t}{p1}\right) + p2$$

  Fit Results:
  p0: 963.9 ± 13.7
 p1: 114.9 ± 2.5
  p2: 41.0 ± 2.8

Looking forward

- Beam upgrade
  - Increased power
  - New horns ready for installation
  - First operation this year
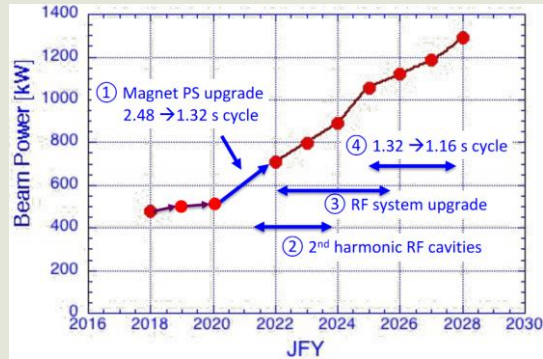
|	FY2020	FY2021	FY2022	FY2023	FY2024	FY2025	FY2026
Operation		MR PS upgrade					
Primary beamline & Beam Monitor	FF upgrade, Beam monitor						
Horn PS,Trans etc.							
Horn magnets	Cooling cap. up	New Horn production for 1.3MW					
Target	Heat Ex. Upgrade	1.3MW target & Cooling capability up.					
TS/NU3 Cooling capability							
Radiation safety	For >750kW	For 1.3MW					
Control/DAQ							
Remote Handling							
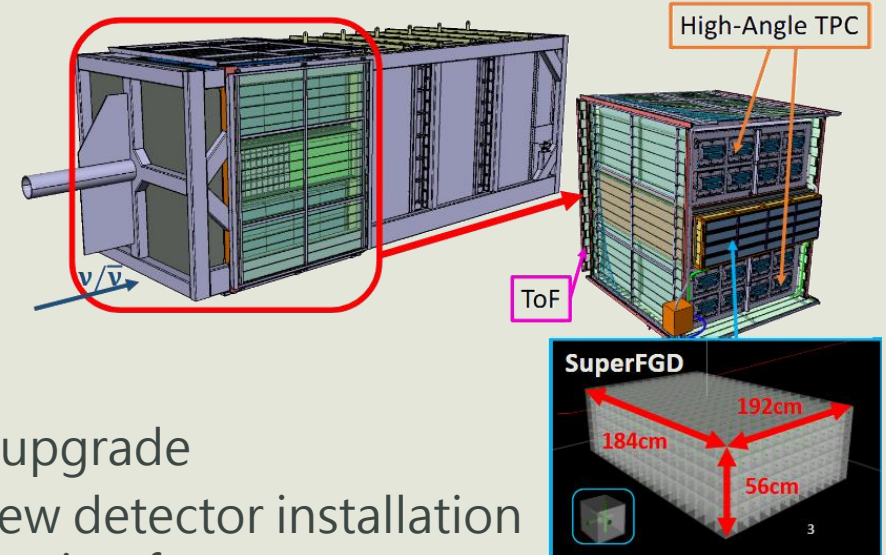
- ND280 upgrade
  - New detector installation starting from summer
  - Ready for operation by March 2023
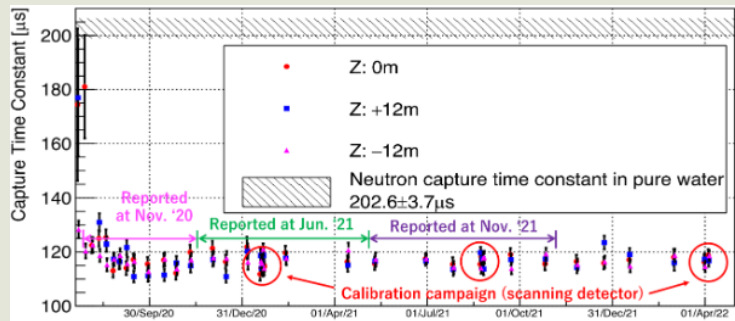 - Working on reconstruction/sample selection in SuperFGD

Looking forward
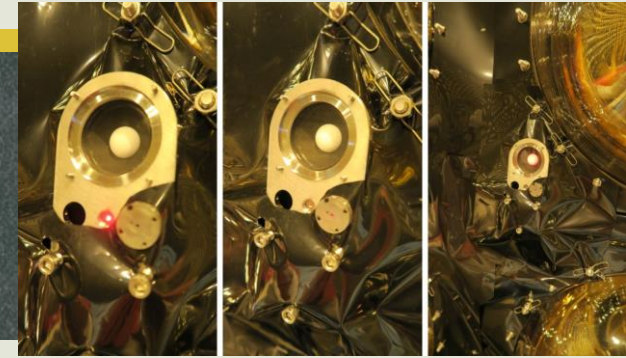
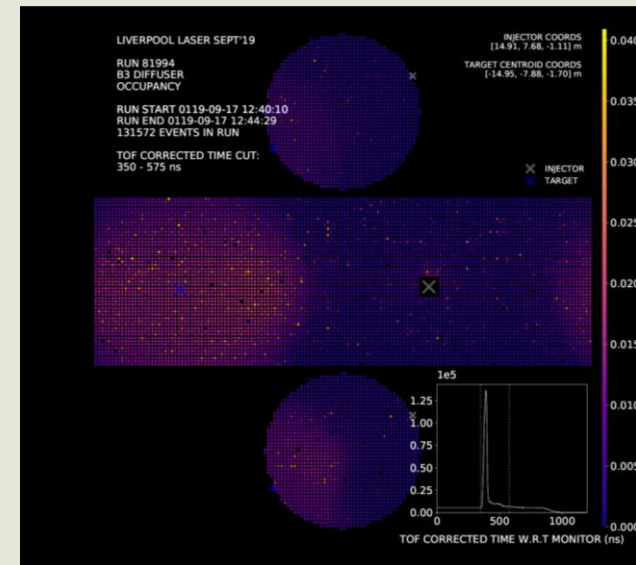- Gadolinium loading
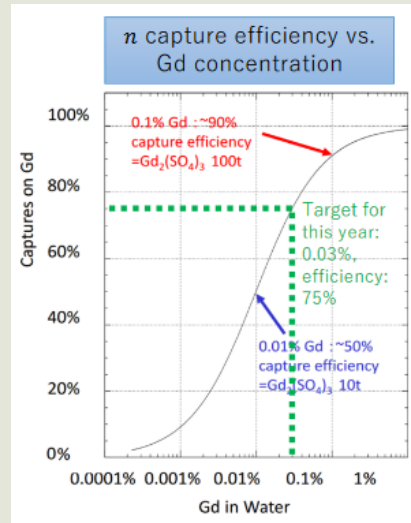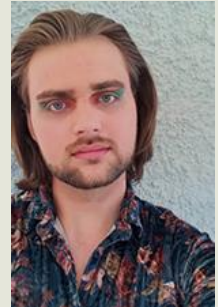 - Good water transparency after loading
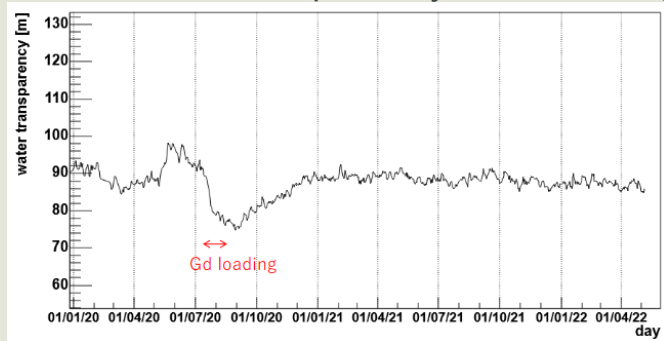
  - Am/Be neutron calibration gives stable capture time constant

  - Next loading starts in May

- Liverpool light injector calibration system
  - New laser (440nm$\rightarrow$368nm) to monitor Gd deployment
  - Possibly a first trip since 2019 for upgrades/fixes (~September)
  - Analyze diffuser data by Adam

First in-person T2K meeting since COVID!!!

Tokai, Japan

(K)CERN