Imperial College London

Recent results from High Pressure TPC (HPTPC) R&D efforts

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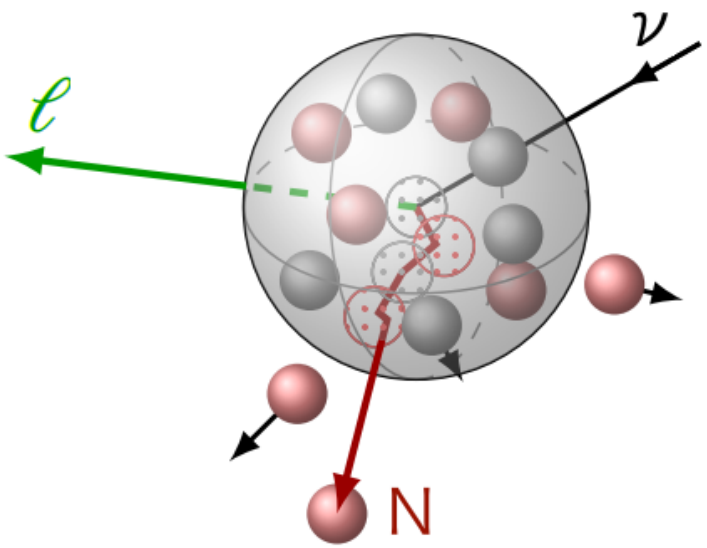
Overview

- Why would an HPTPC be helpful for T2K?
- Transverse variables
- What R&D is being done into HPTPCs?
- Some early sensitivity studies
- Things to work on and what's next

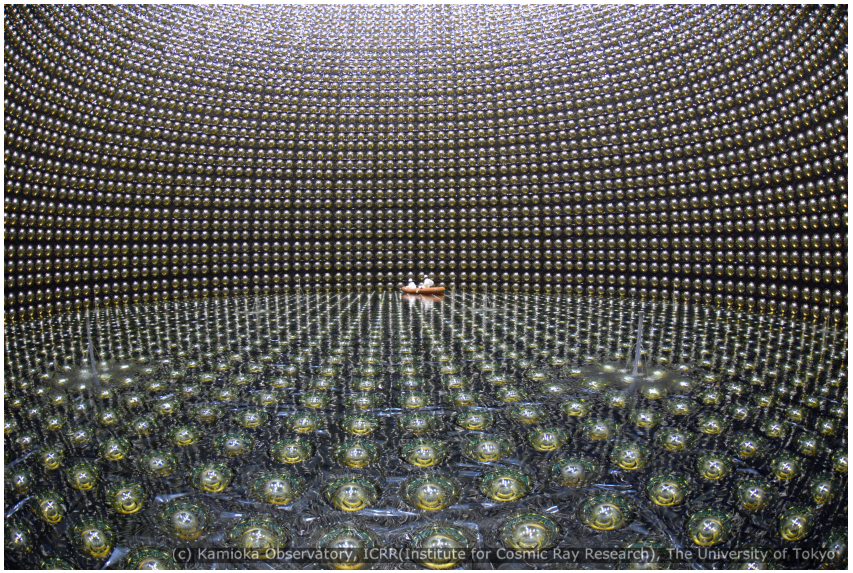
T2K neutrino interaction model

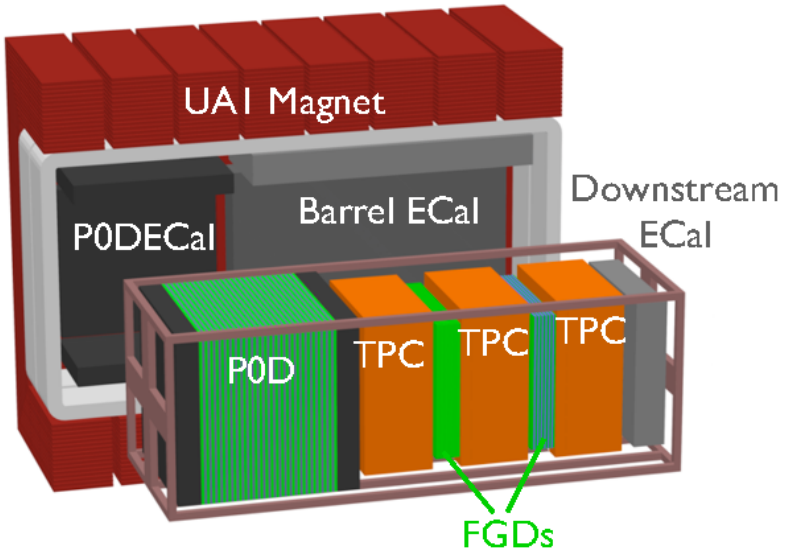
- Several elements convoluted:
  - Neutrino nucleon interaction
  - Nucleon kinematics
  - Secondary interactions etc.
- Even if your model correctly describes lepton kinematics in one target can't tell if it's right



What problems could we have?

- Different nuclei at near and far detector

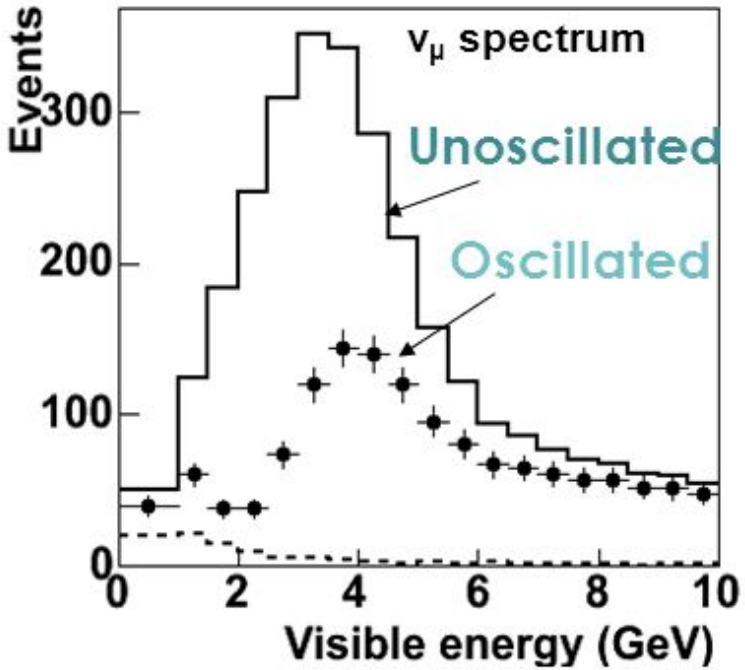




- Could use a water near detector like Nu-Prism/Titus

What problems could we have?

- Different energy spectrum at near and far detector



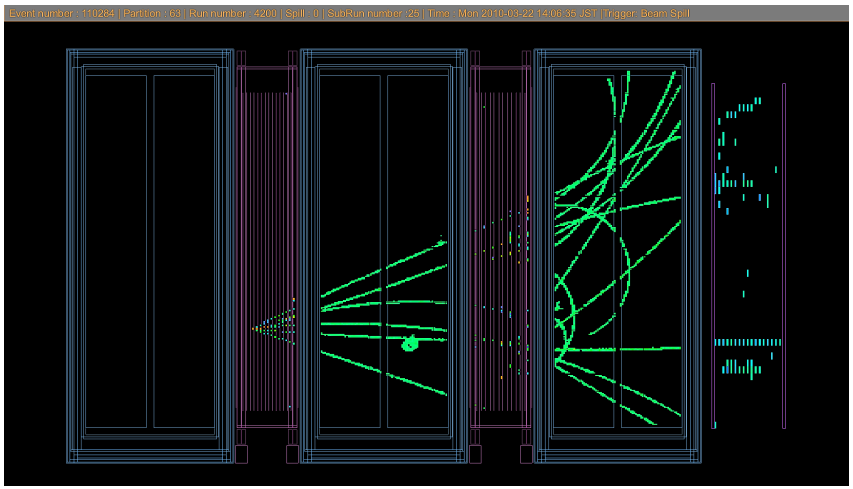
- Even if same nucleus this can be problematic

What can we do about it?

- Great work already being done by xsec/external fitting groups
- Need to do more to test if $\nu/\bar{\nu}$ difference is from CP violation
  - Must look at more variables including hadronic ones
  - Must look at as many nuclei as possible
- Can use an HPTPC to do this

What is an HPTPC?

- Has the fine resolution and low thresholds of a TPC
- High pressure gives enough density to use as a target
- Can look at different nuclei by altering gas mix



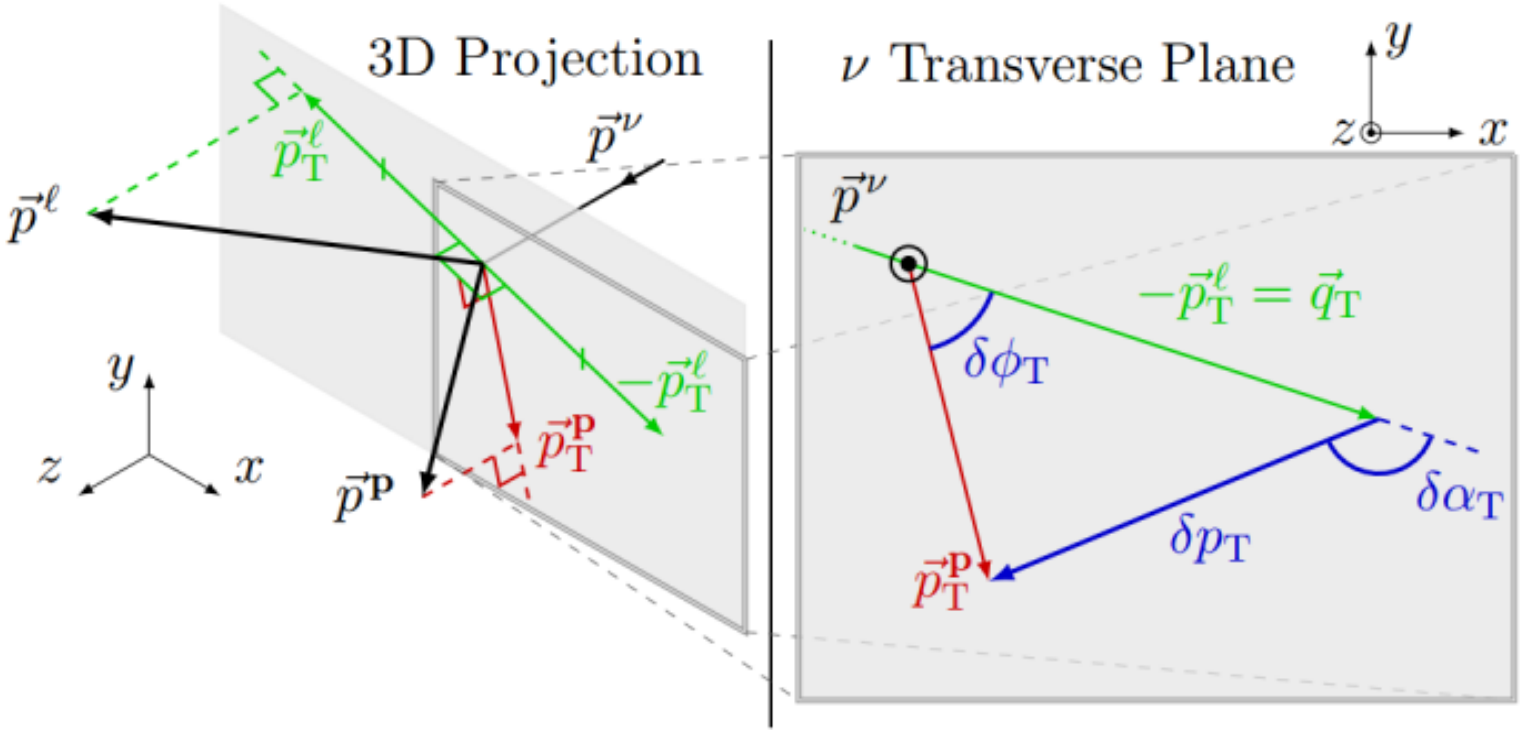
Sensitivity studies with HPTPC

- Aim to include an ∼600kg HPTPC as an HK near detector
- Have taken ND280 truth MC and applied HPTPC like efficiencies and thresholds
  - Assumes same target nuclei as ND280
- Calculate event variables and compare detectors
- Low hadronic thresholds allow for use of hadron kinematics

Particle	ND280 Threshold/MeV	HPTPC Threshold/MeV
μ	100	15
π	120	16
p	450	60
e	100	1

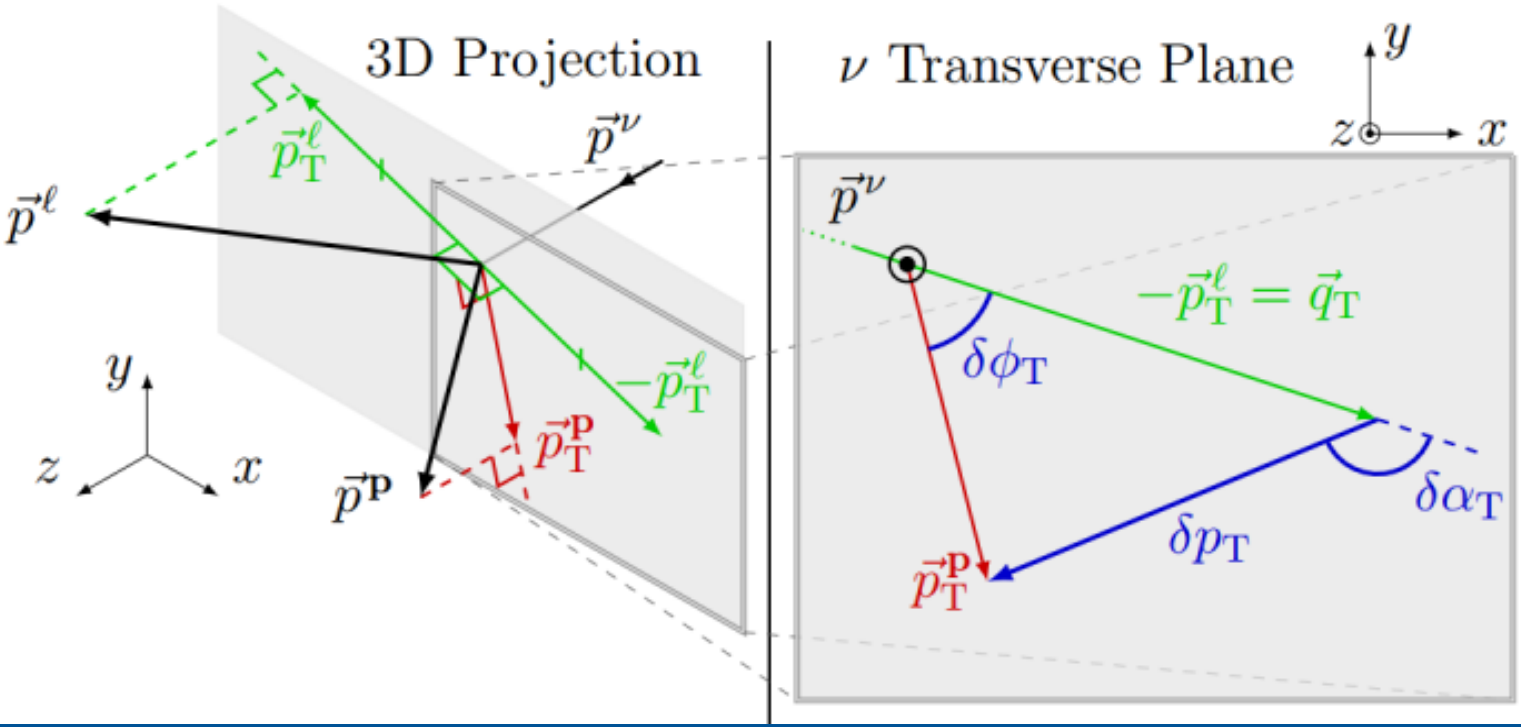
Single Transverse Variables

- Use hadronic information to estimate nuclear effects
- Any imbalance perpendicular to neutrino direction should come from nuclei/unseen particles
  - Details in Xianguo's talk
- Variables widely used in other areas of particle physics



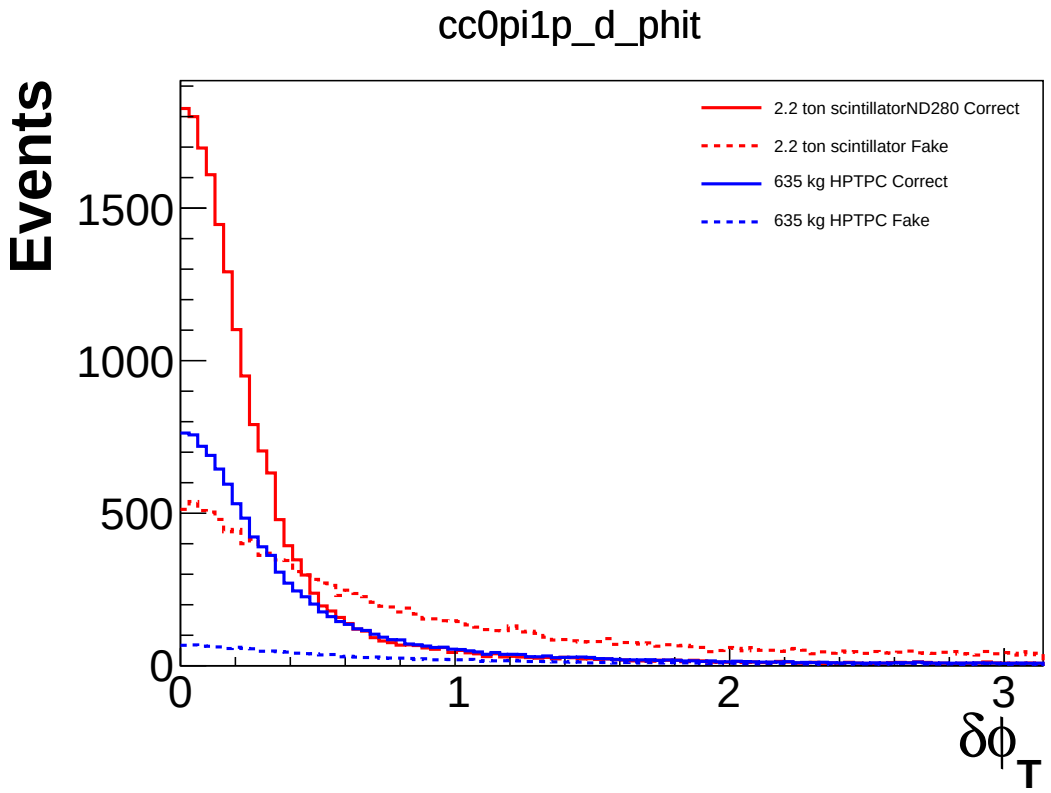
Aside on naming for STV

- Naming that is emerging in neutrino physics is different from other areas: e.g. hadron colliders
  - $\delta p_T = p_T^{miss}$, $\delta\phi_T = \pi - \Delta\phi(lep, had)$, $\delta\alpha_T = \pi - \Delta\phi(lep, p_T^{miss})$
- Personally find hadron collider naming more intuitive
- Worth considering whether we want to standardise



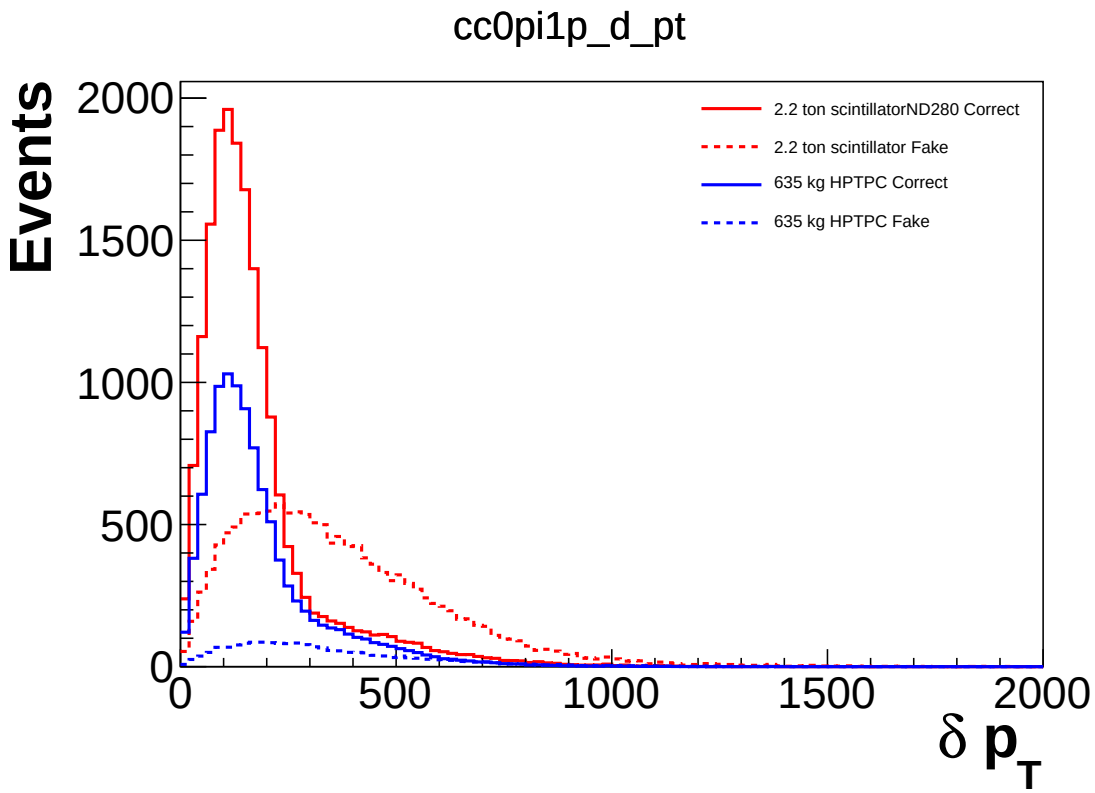
1D distributions for CC0π1p

- Use truth information to separate correctly identified real CC0π1p events from fakes
- HPTPC event rates are lower but purity is much better



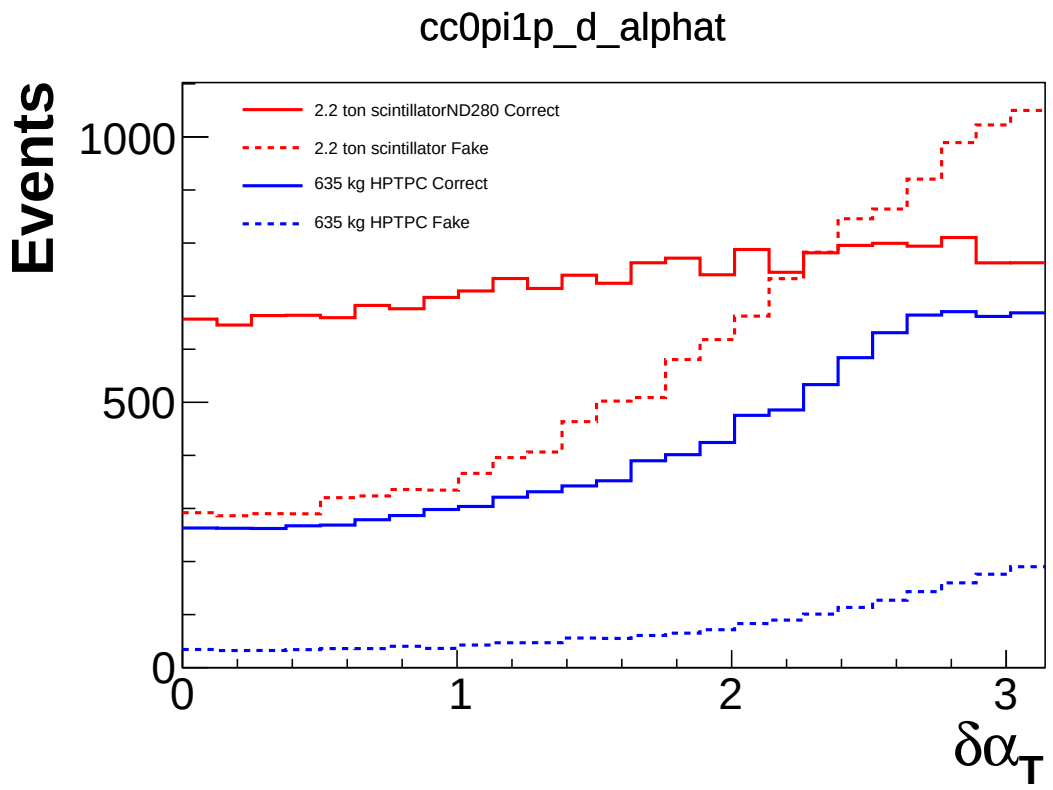
1D distributions for CC0π1P

- Shape differences with nominal model aren't that great
- But aim is not just to add samples to BANFF fit



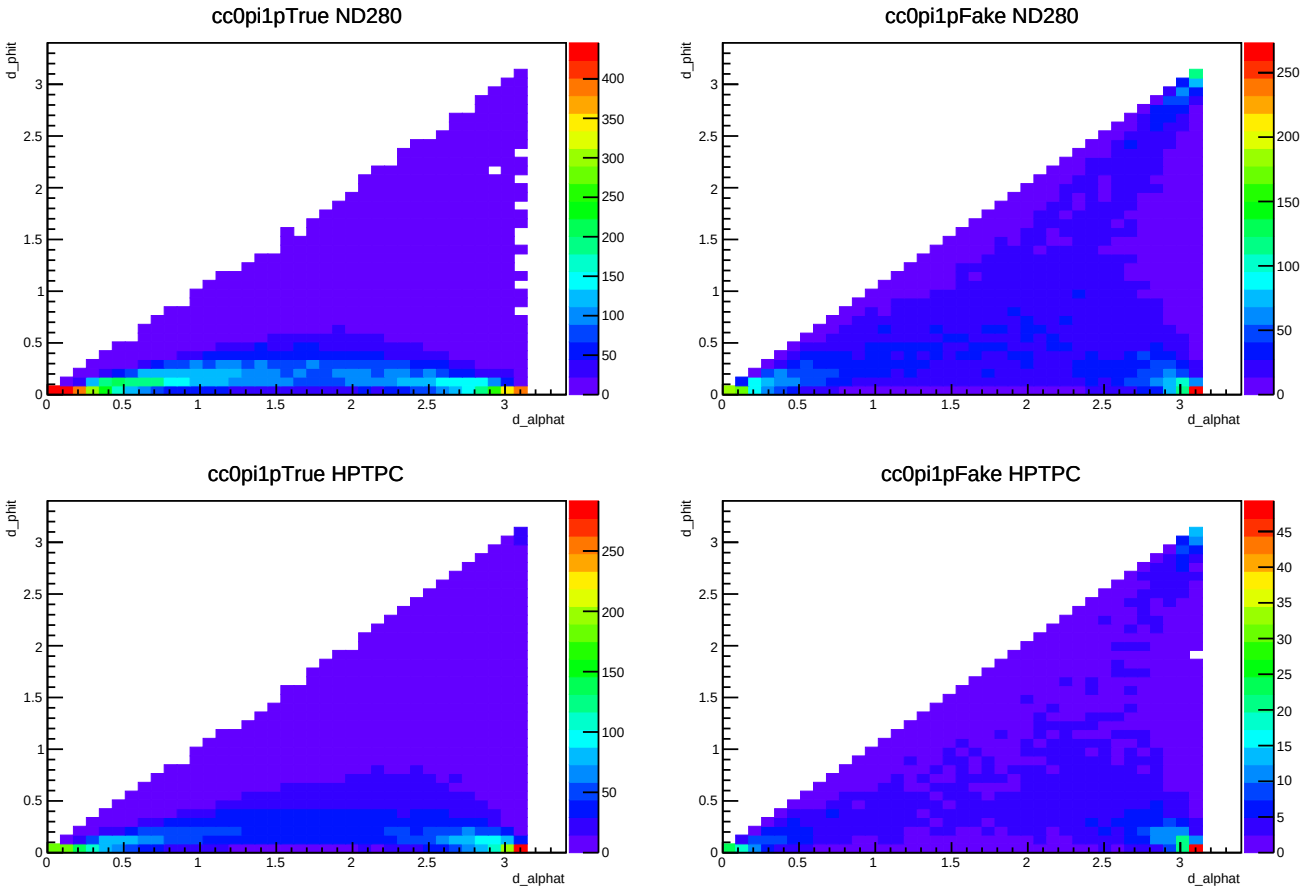
1D distributions for CC0π1P

- Hope to use HPTPC for model selection
- High purity sample can be reliably compared to MC



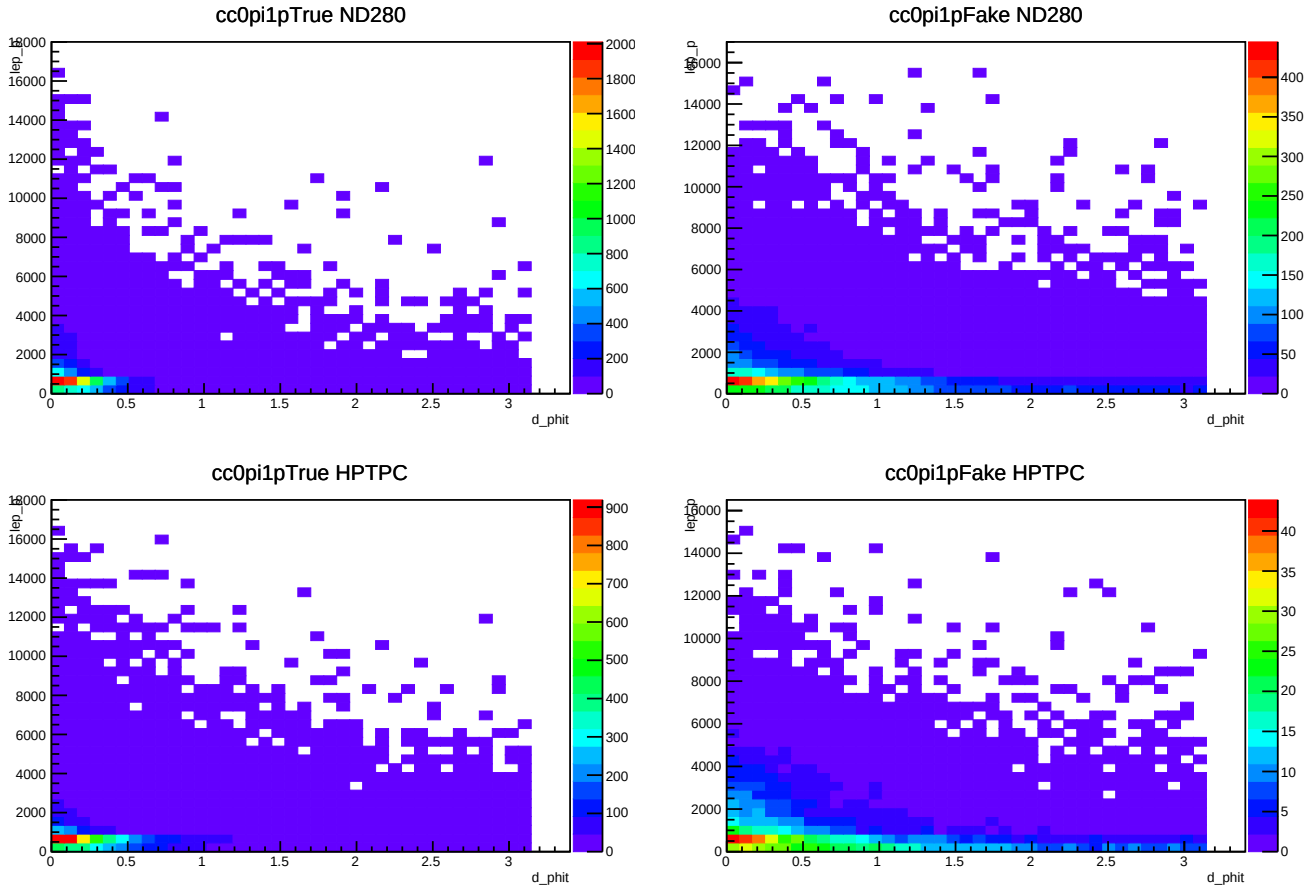
2D distributions for CC0π1P

- Also look at 2D distributions



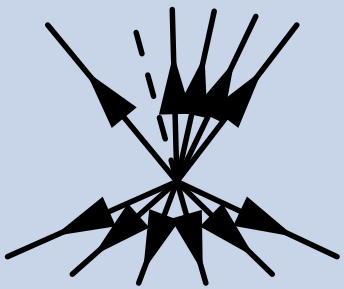
2D distributions for CC0π1P

- And compare lepton and hadron variables

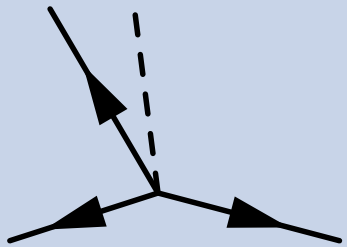


Other Transverse Variables - Reminder

- Particularly for p_T^{miss} context is important



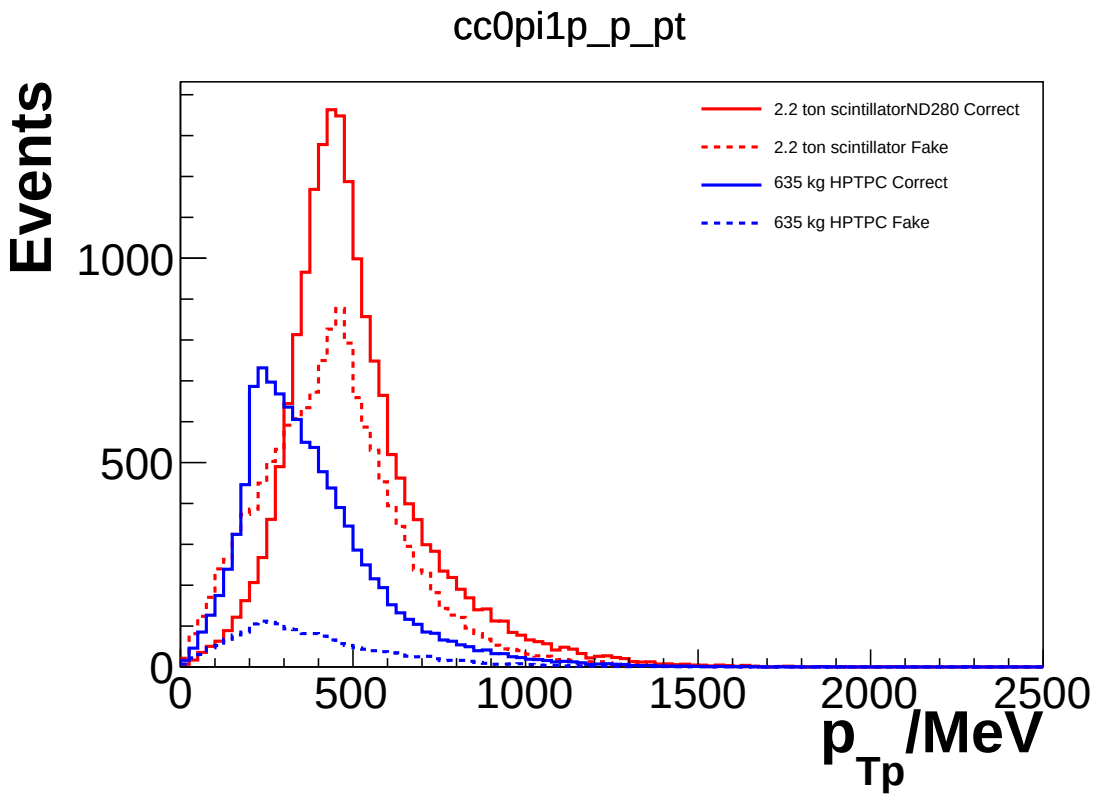
VS



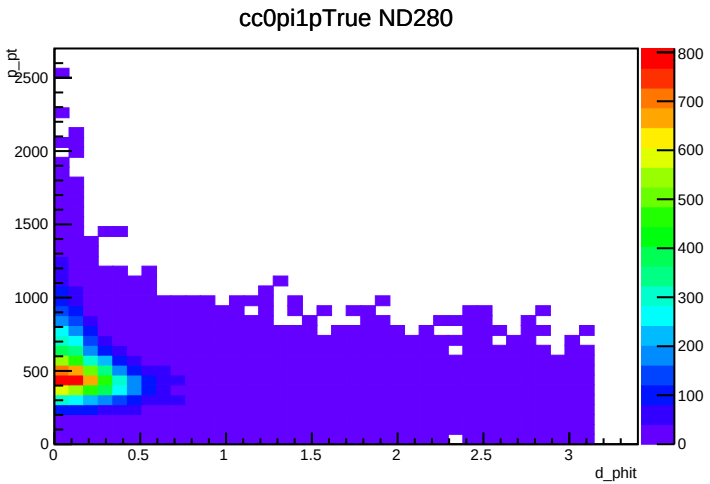
- Both events have the same $p_T^{miss}/\delta p_T$ but on the right this is clearly more significant compared to uncertainties on visible object momenta

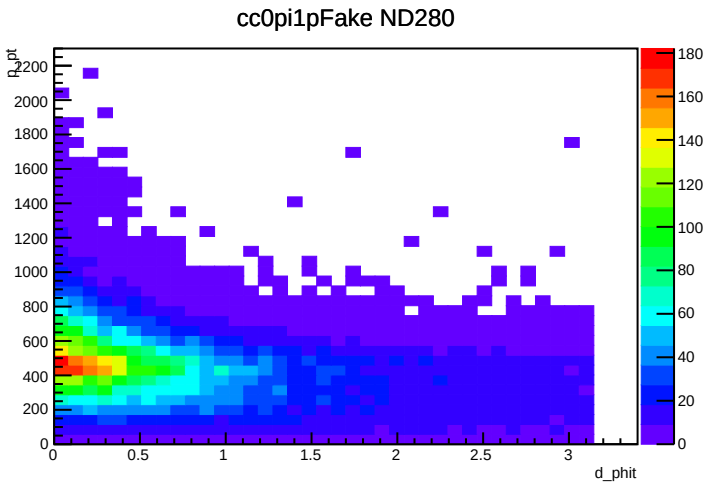
Additional information

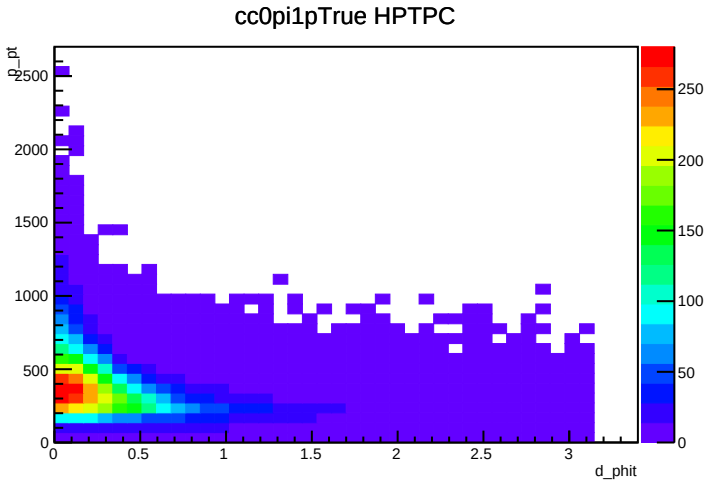
- Look at component of proton momentum in transverse plane

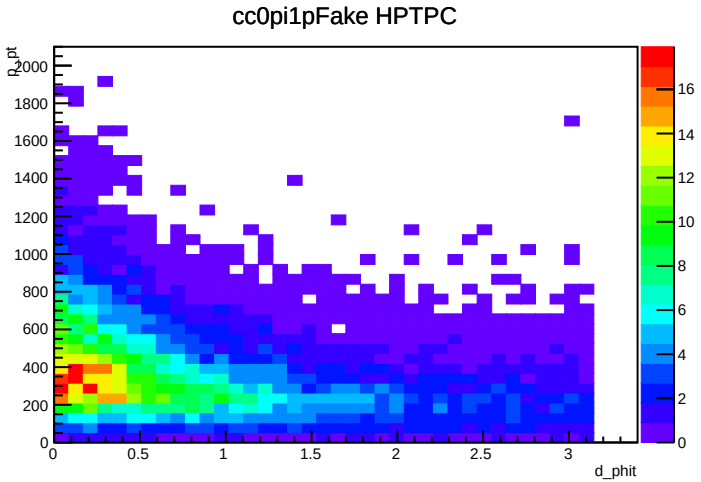


2D distribution highlights for CC0π1P









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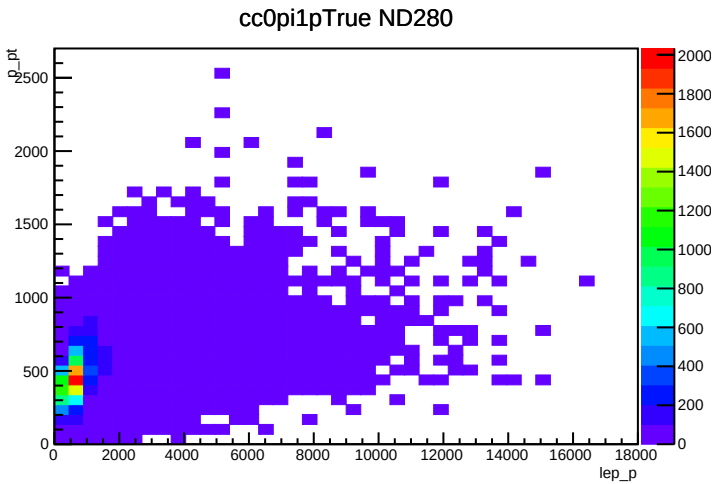
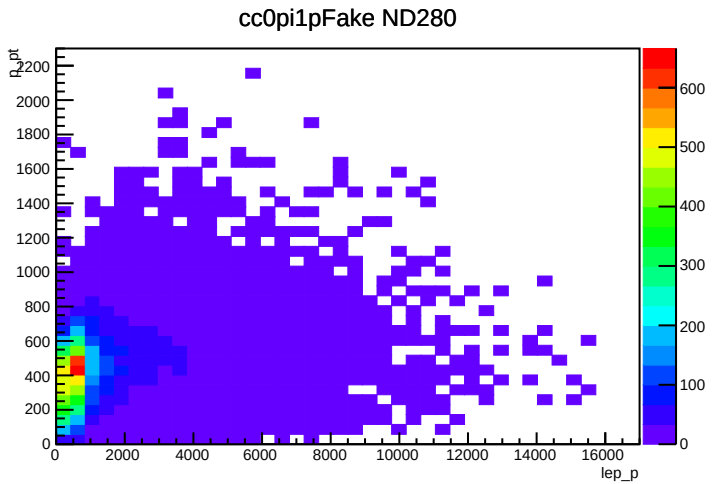
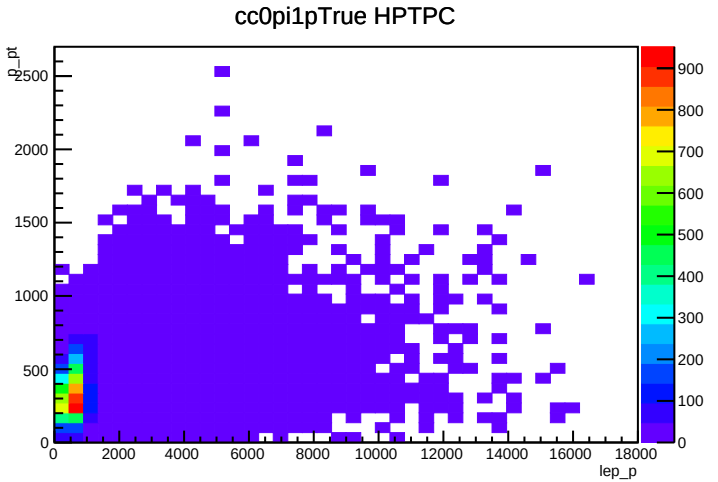
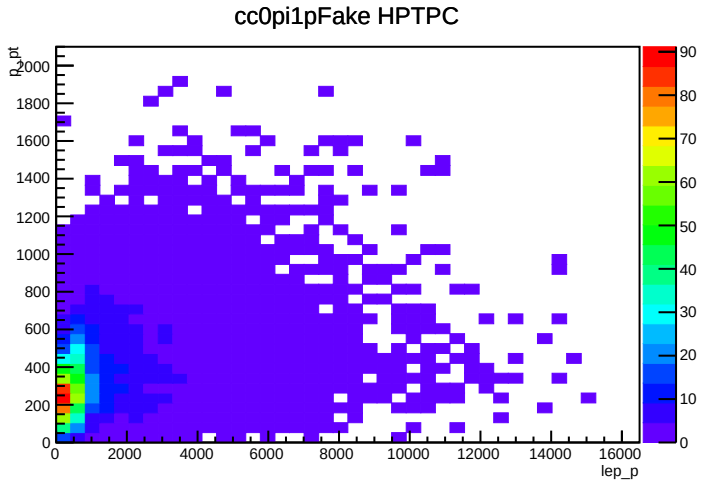






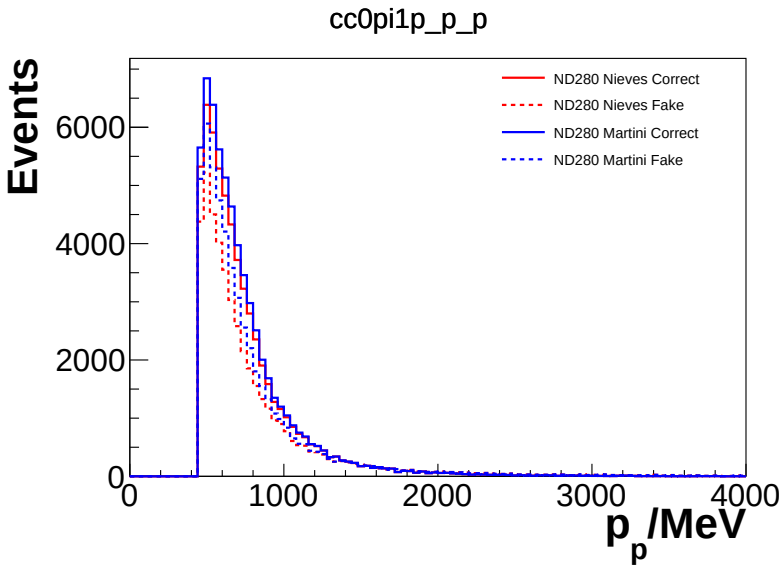


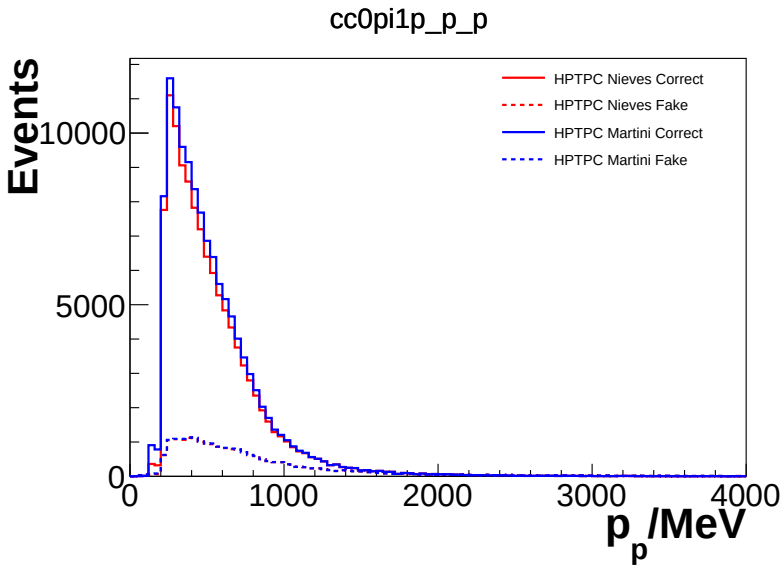
Model selection

- Have studied HPTPC ability to discriminate between 2p2h models
- 2p2h Describes interactions between neutrino and 2 nucleons
- MC is generated with Nieves model
- Existing fake data studies use reweighting to study Martini model

CC0π1p - Martini/Nieves

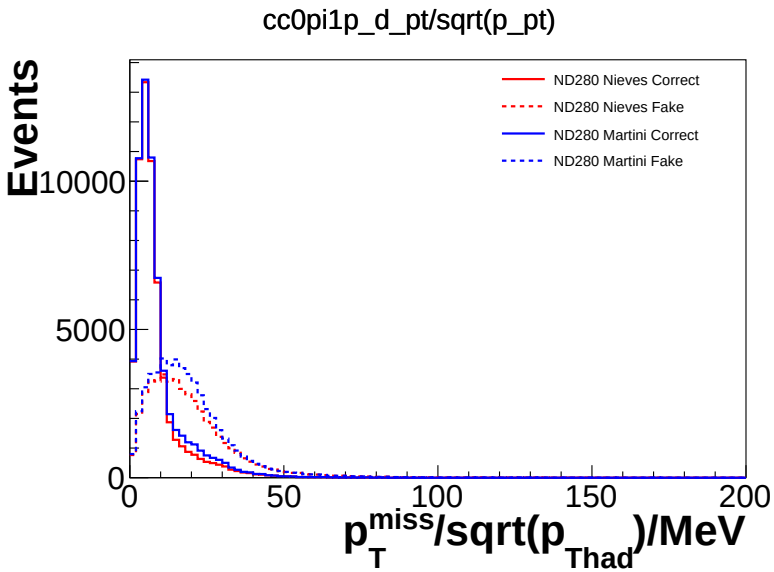
- Don't see that much sensitivity when looking at proton momentum

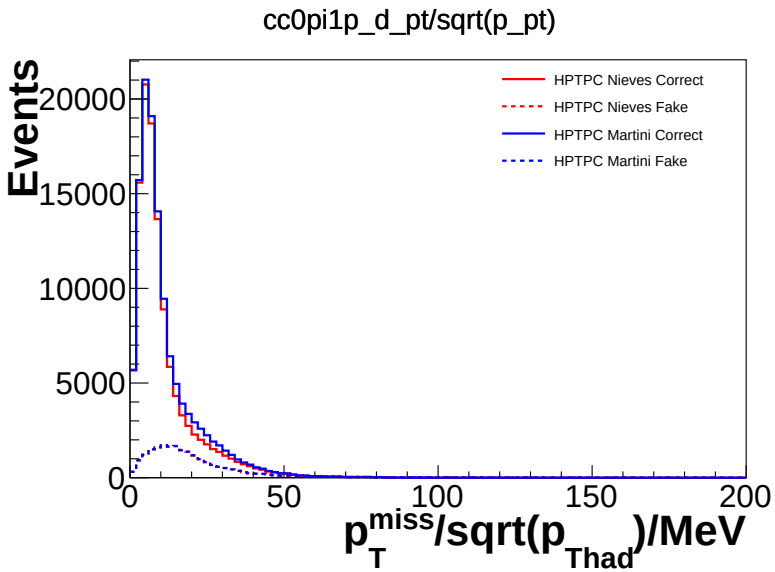




CC0π1p - Martini/Nieves

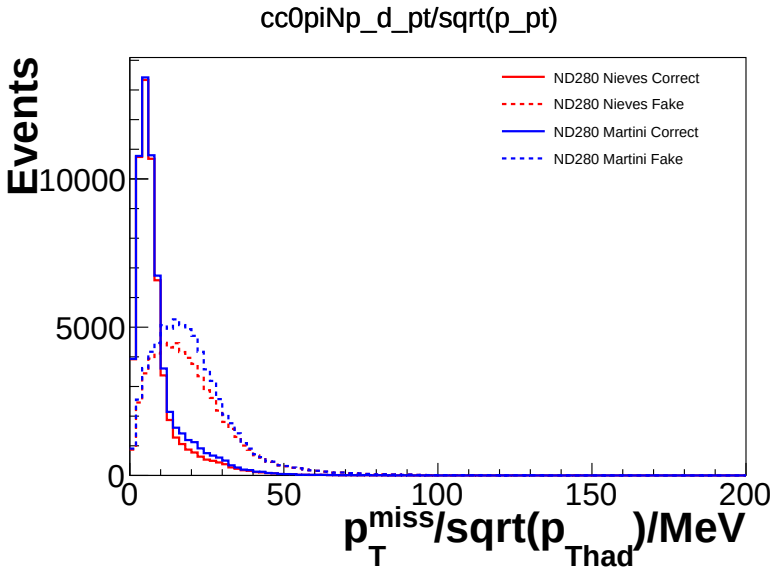
- Try 'p_T^{miss} significance' variable
- Divide p_T^{miss} by $\sqrt{p_{Tp}}$
- Provides good fake/correct discrimination
- Still not much model sensitivity

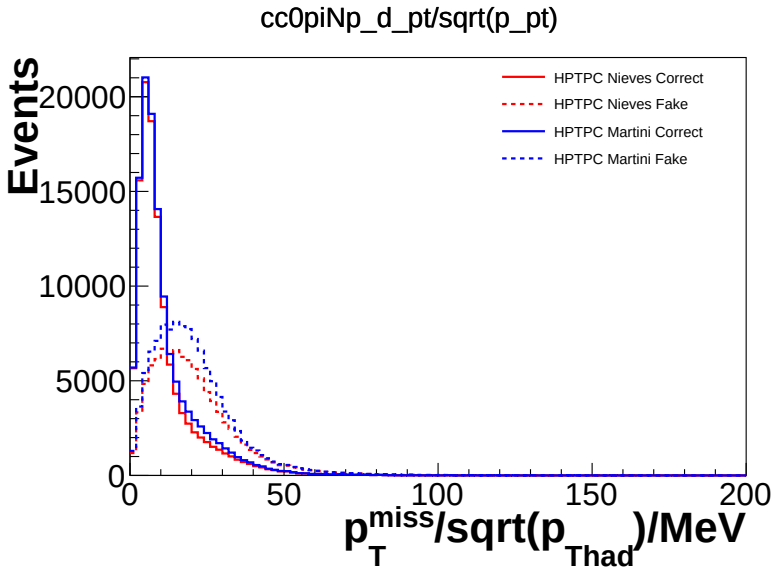




CC0πNp

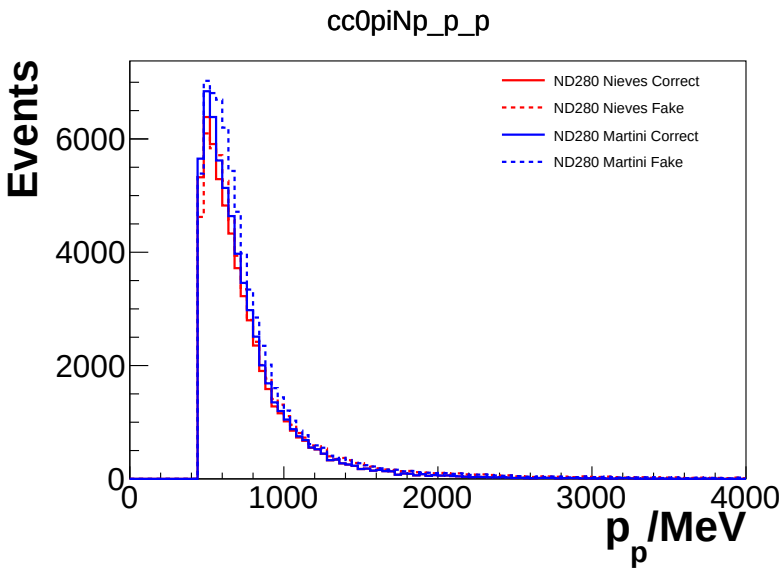
- Look at sample with >=1 proton and no pions
- Expect there may be more power in CC0πNp because Martini and Nieves predict different proton multiplicities

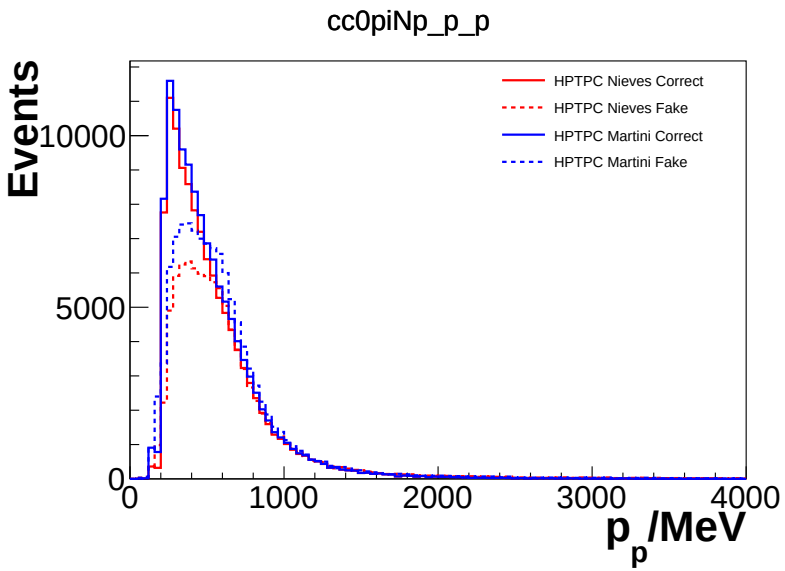




CC0πNp

- Slightly better than CC0π0p but still not great



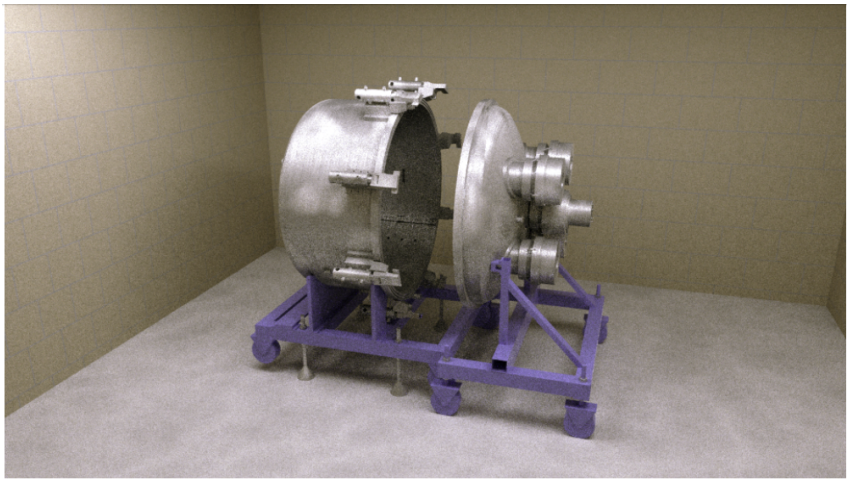


Why don't we see much model difference?

- Martini reweighting is done in 1D as a function of E_ν
- Would not expect this to give a good description of hadronic variables
- Solutions:
  1) Generate Martini events
     - Computationally prohibitive
  2) Come up with a better reweighting scheme
     - Open to suggestions/help from experts

HPTPC Hardware R&D

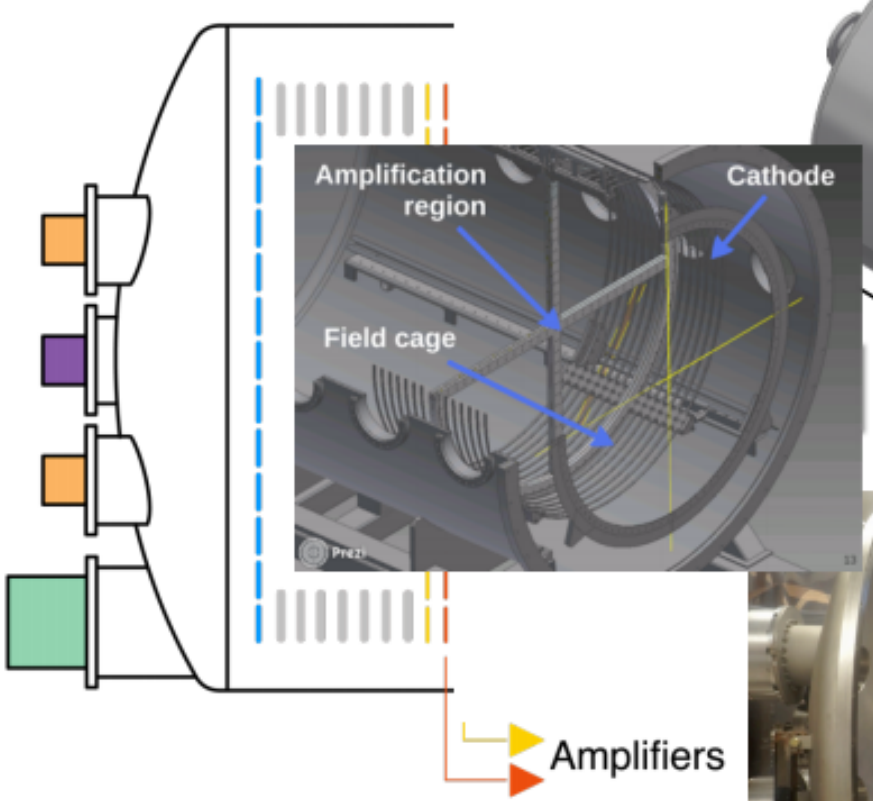
- Building 5 Bar, $1m^3$ prototype HPTPC in UK
- Will be being tested in the next year in CERN beam line
- Several T2K collaborators involved
- Developing full simulation
- Looking at reconstruction using T-Rex

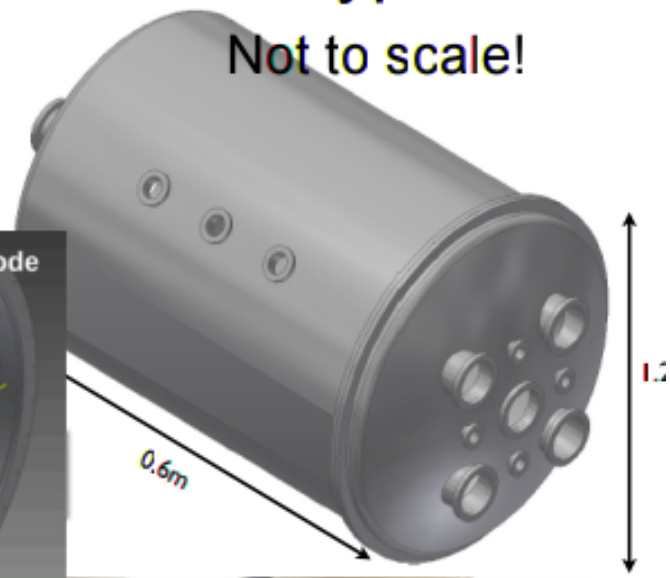


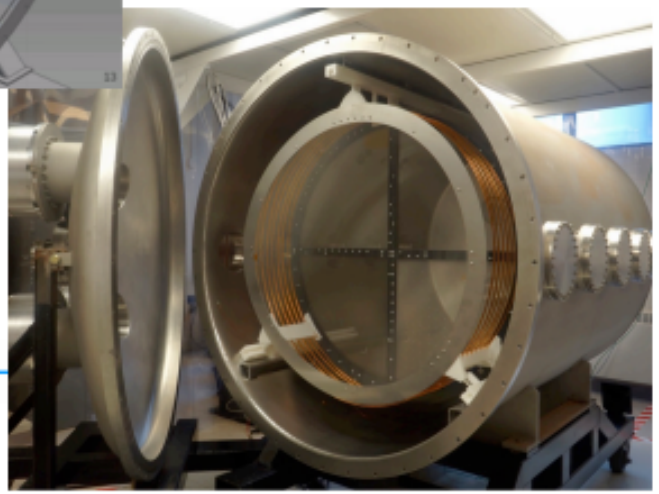
UK STFC PRD: HPTPC Prototype

Draws on DMTPC 1m3 detector.

Not to scale!







Conclusions

- HPTPC will have very good hadronic and leptonic momentum thresholds and efficiencies
- Will give high purity samples of events to test models with
  - Full exploitation of this data will need development of model comparison tools
- Hardware development well underway with beam tests in the near future
- In conjunction with other HK near and intermediate detectors will give much more confidence in our interaction model