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Study of single π^+ production in ν_μ NC interactions in the T2K experiment and the upgrade of its near detector ND280

A comprehensive summary

Part 1:

Measuring NC1π^+

Introduction and motivations

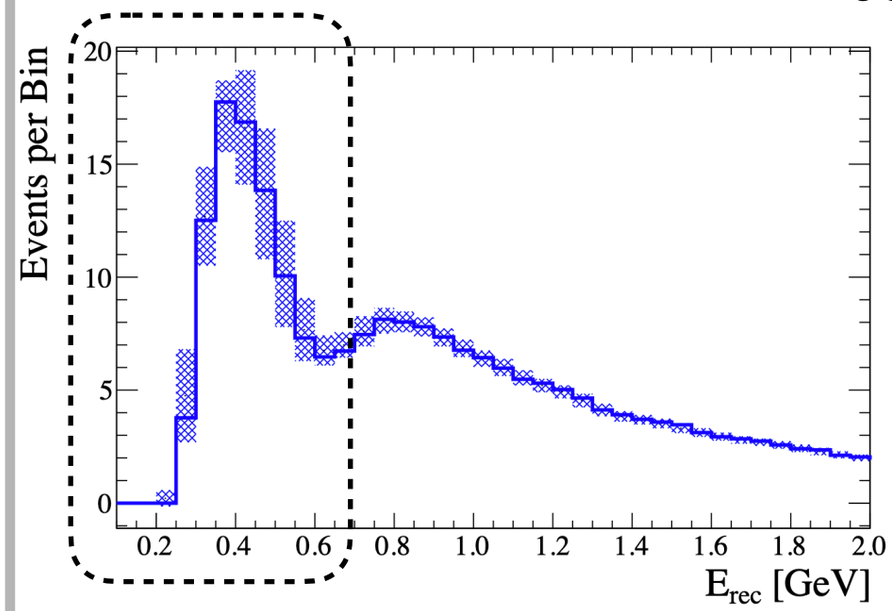
Why do we care about NC1π?

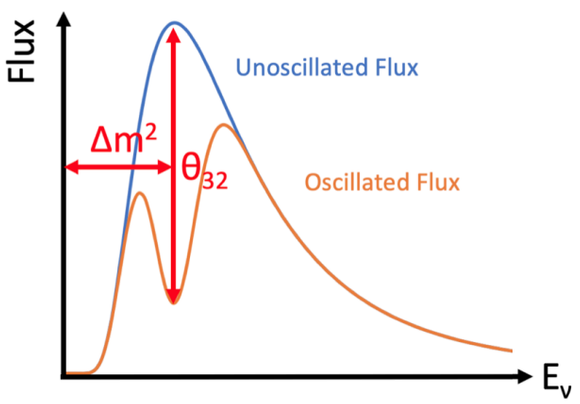
https://arxiv.org/pdf/2101.03779.pdf

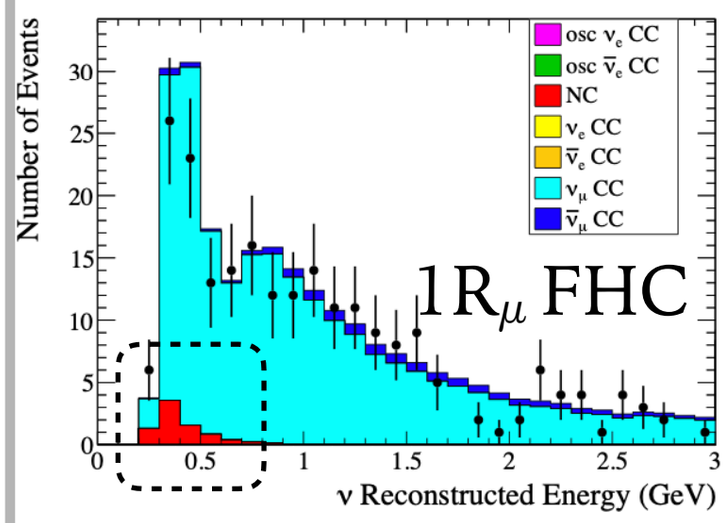
The NC1π+ 59% syst. compared to 5% for CC0π

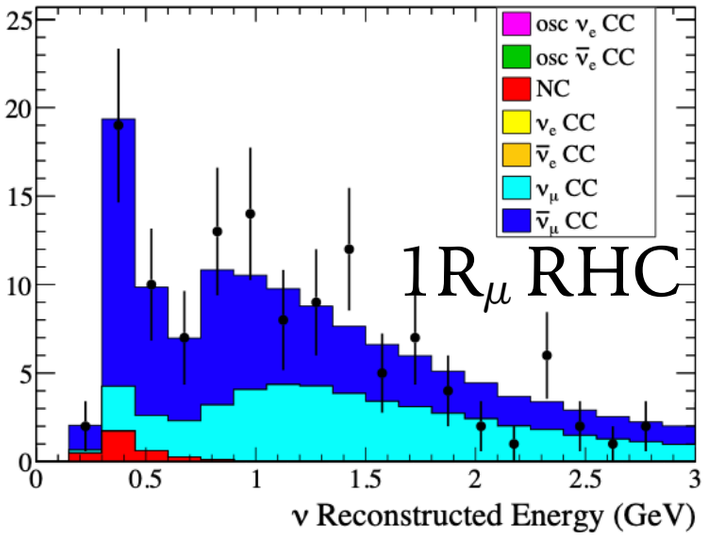
5% 110 → ± 5.5 events

60% 10 → ± 6 events



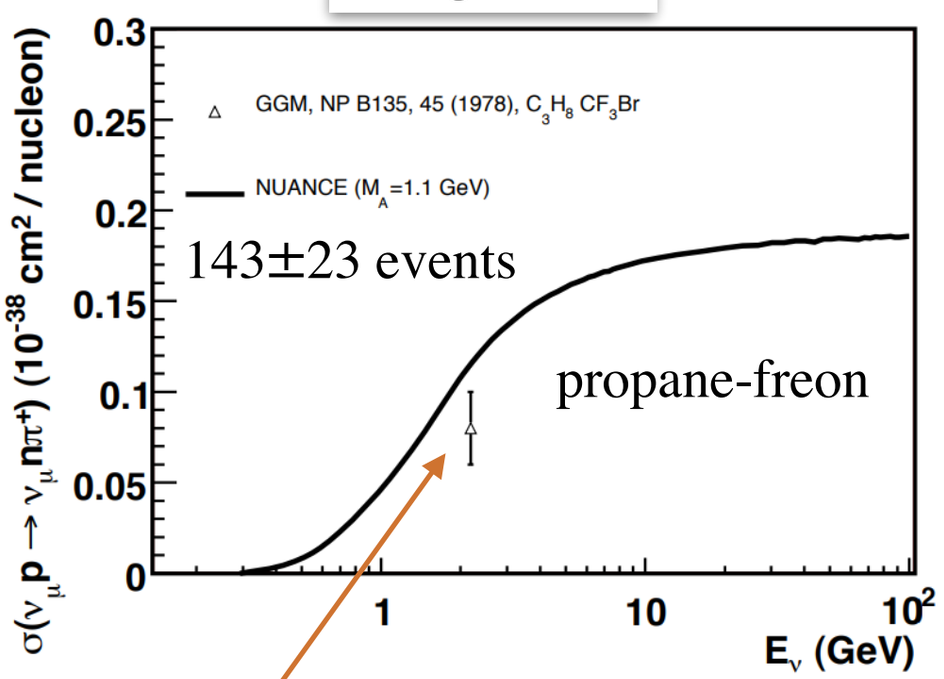






Existing published data

Gargamelle



$$\sigma_{nuc}^{GGM} = 0.056 \pm 0.011 \times 10^{-38}\,\mathrm{cm}^2\,,$$

$$\sigma_{cor}^{GGM} = 0.08 \pm 0.02 \times 10^{-38}\,\mathrm{cm}^2\,.$$

Argonne National Laboratory

$$\sigma(\nu_\mu p \to \nu_\mu n\pi^+)/\sigma(\nu_\mu p \to \mu^- p\pi^+) = 0.17 \pm 0.08$$

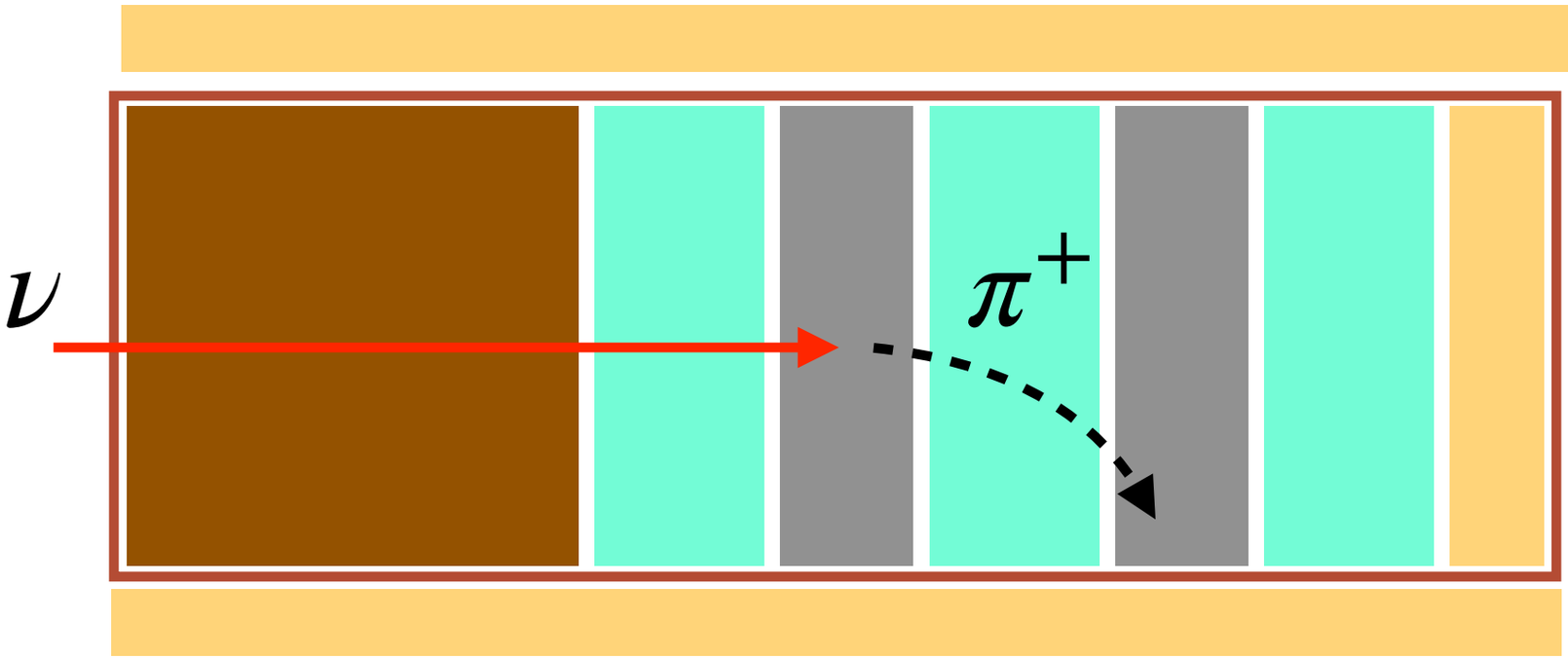
$$\sigma(\nu_\mu p \to \nu_\mu n\pi^+)/\sigma(\nu_\mu p \to \mu^- p\pi^+) = 0.12 \pm 0.04$$

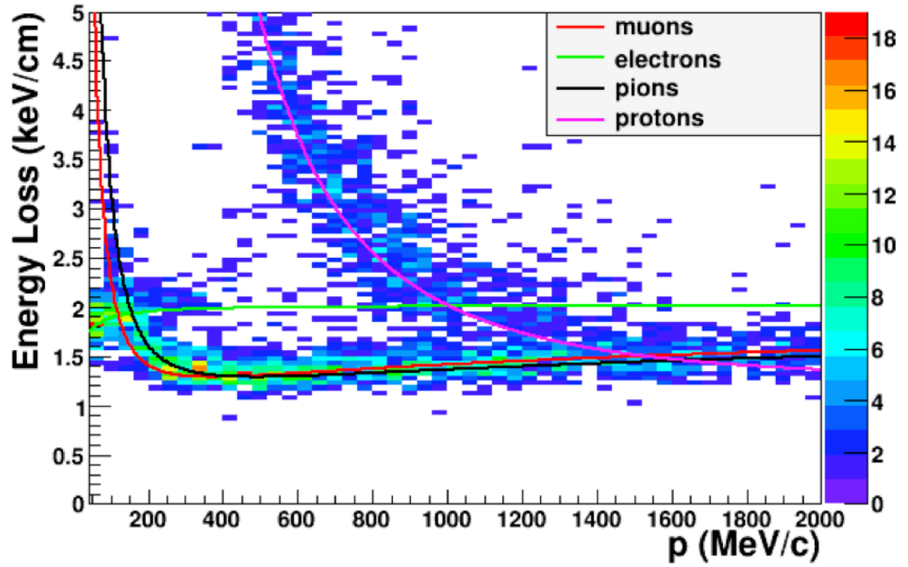
H_2, energy peak ~0.5 GeV long tail.

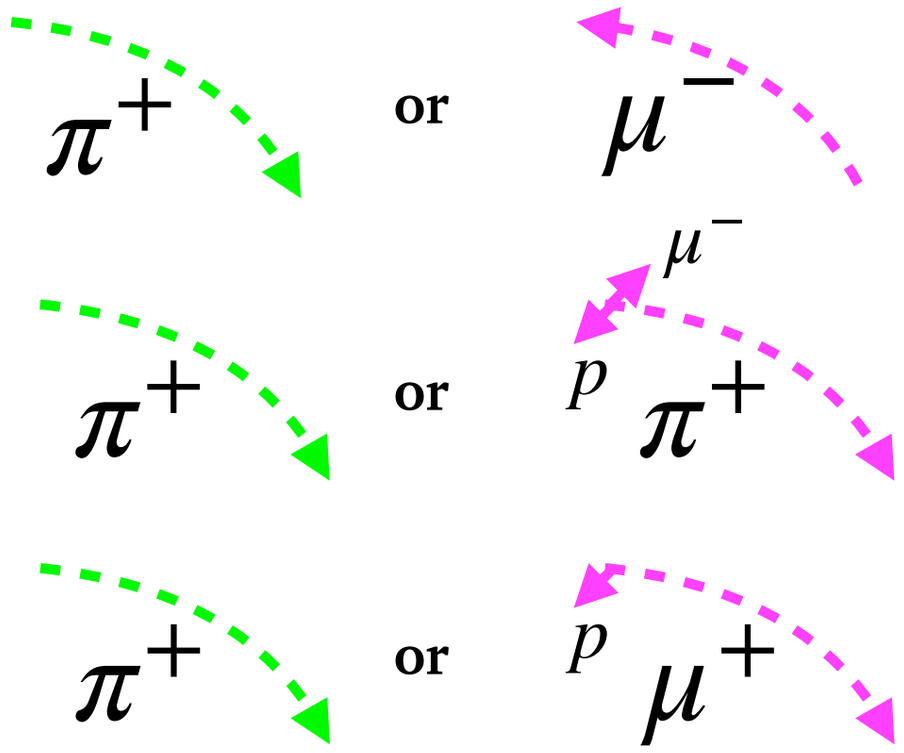
The selection

Signal definition: $1\pi^+$ + 0/N neutrons

Look for a single positive pion starting in FGD1 and nothing else.







ν_μ CC0π signals with backward going muon are more numerous than NC1π⁺ and difficult to reject.

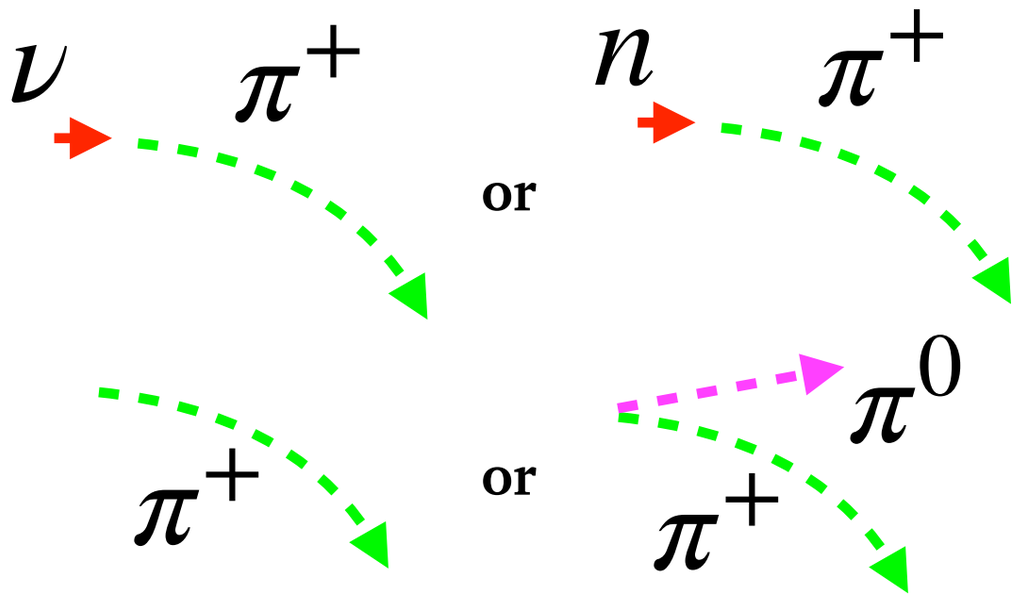
ν_μ CC1π signals with a low momentum μ^- (absorbed, not tracked) + low momentum proton (not tracked)

$\bar{\nu}_\mu$ CC0π signals with μ^+ looking like π^+ and low momentum proton (not tracked)

The selection

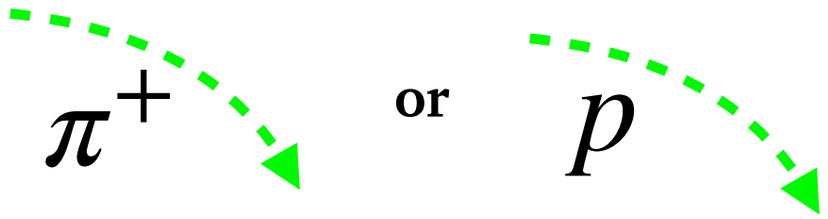
Signal definition: $1\pi^+$ + 0/N neutrons

Additional backgrounds



OOFV Interactions created by neutrons

NCother interactions created with additional mesons which are not tracked, typically π^0.



NC0π interactions with a proton miss-identified as a π^+.

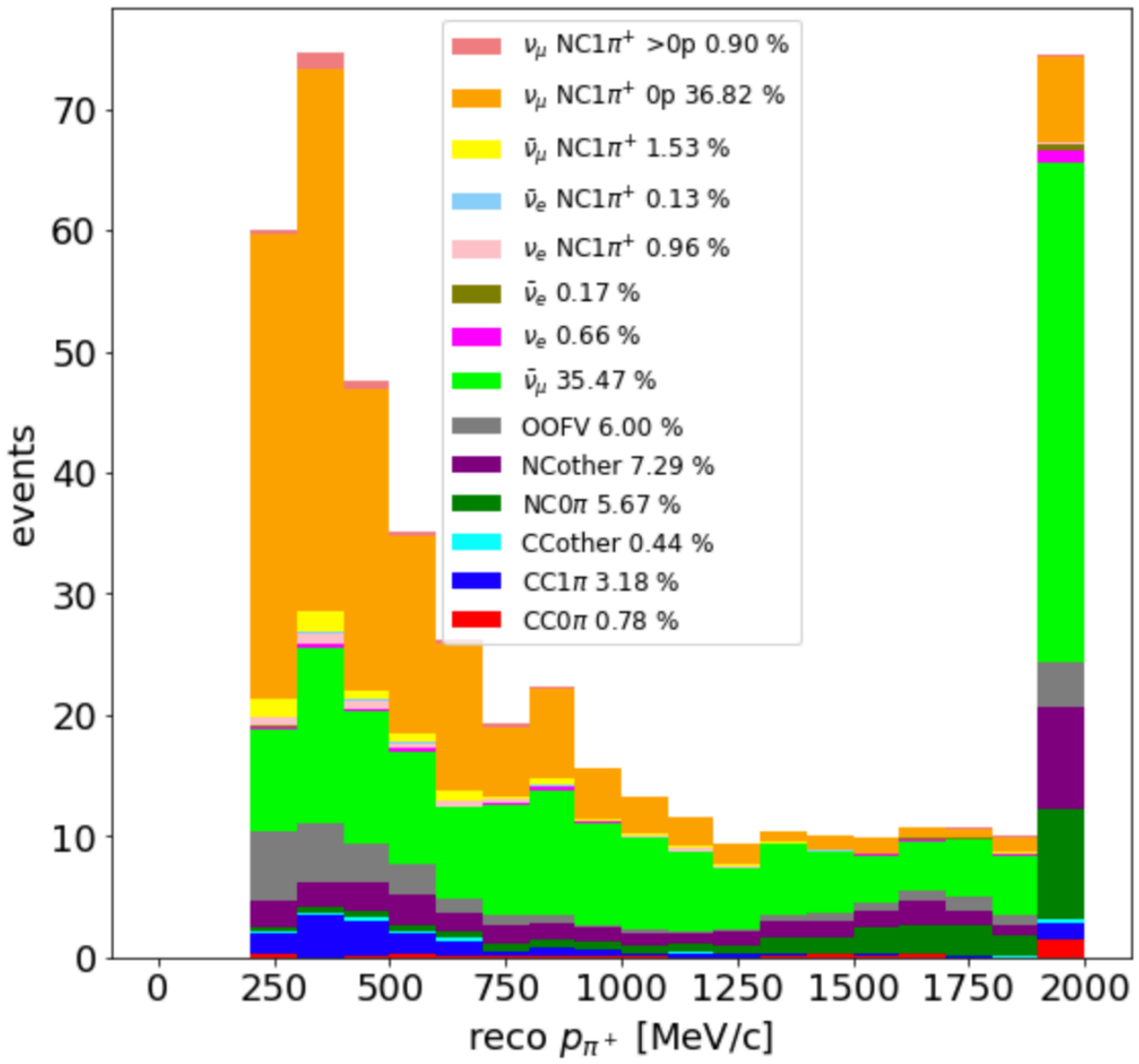
Selection strategy in a nutshell:

- Select positive tracks starting in FGD1 consistent with π^+ ionization in TPC.
- Veto events with upstream activity.
- Rely on FGD1 ionization to reject additional short tracks and discriminate stopping backward muons from outgoing forward pions.
- Add control regions for $\bar{\nu}_\mu$ CC0π and NC0π.
- Possibly limit the measurement to low momentum.

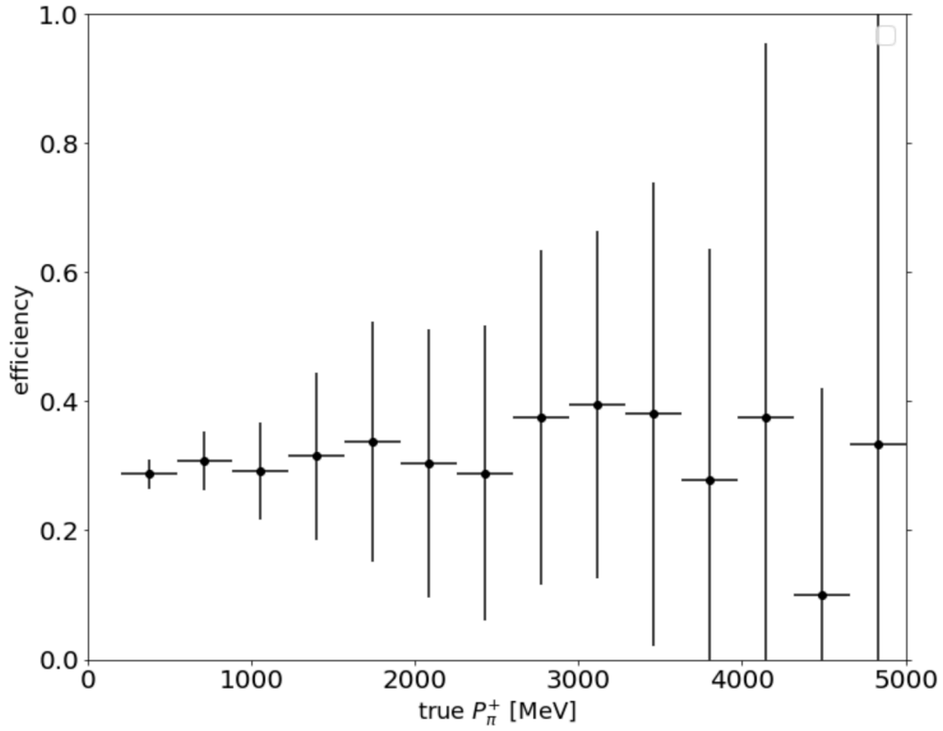
Preliminary results

Signal definition: $1\pi^+$ + 0/N neutrons

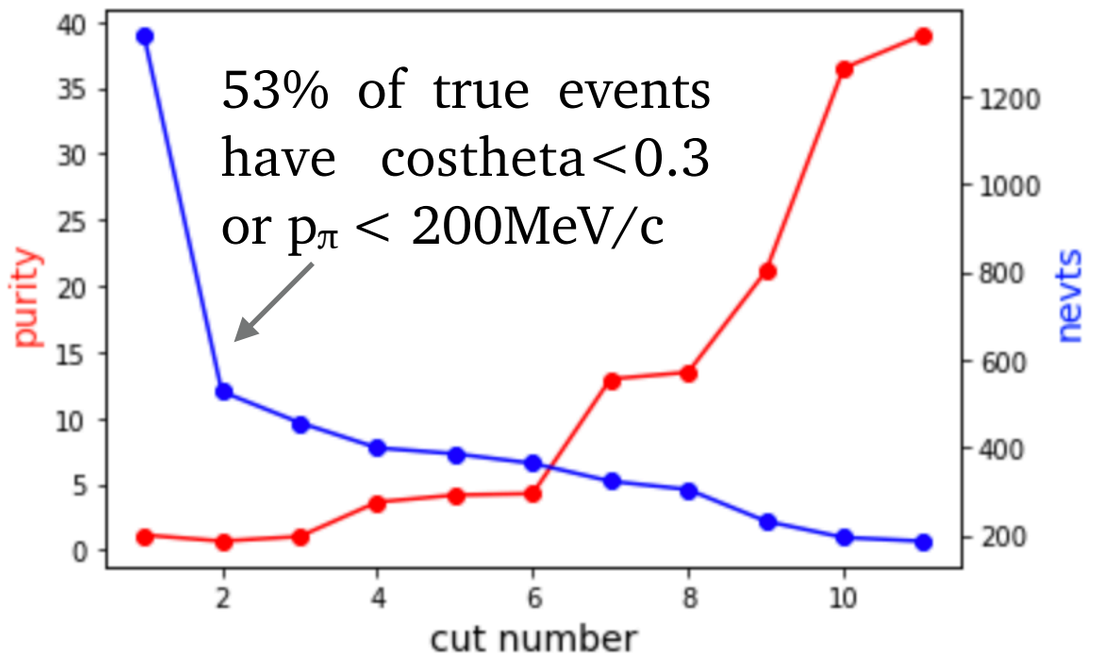
preliminary signal:



efficiency is quite flat in momentum:



Dependence on the cuts:



if $p_\pi \in$ [0.2,2] GeV/c

183 signal events with 45% pur & 34% eff

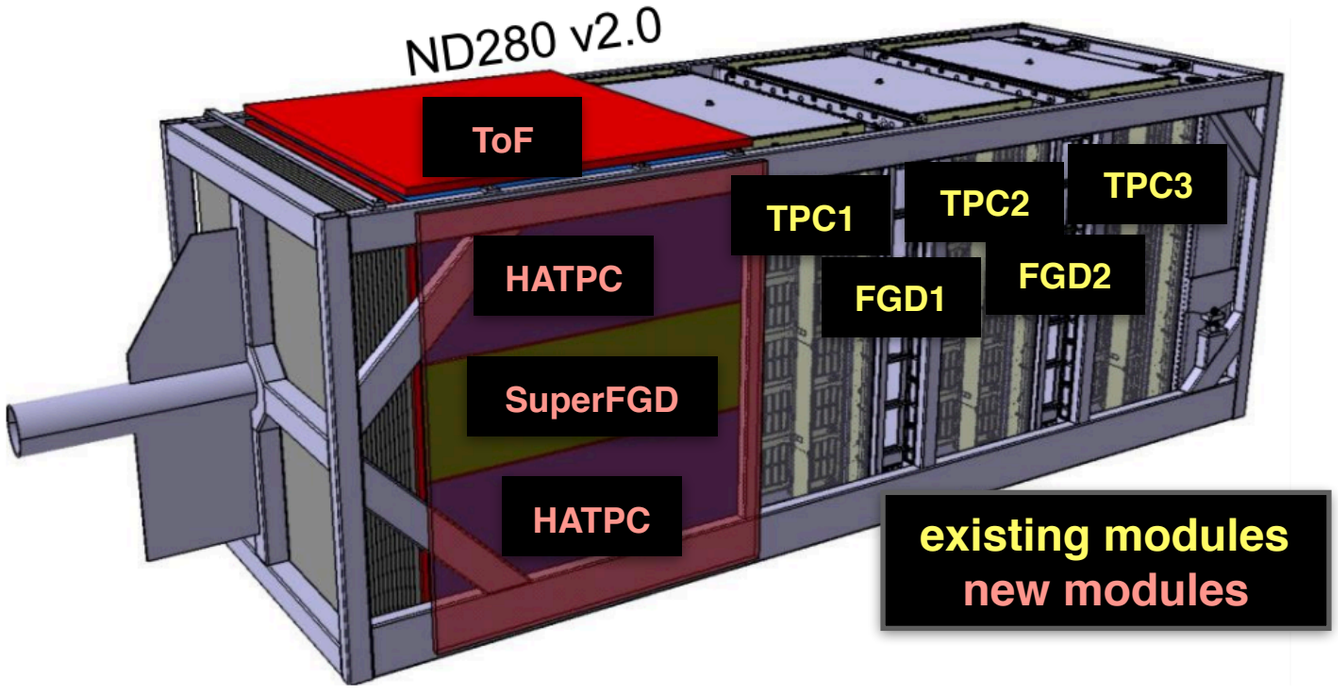
if $p_\pi \in$ [0.2,1] GeV/c

168 signal events with 56% pur & 36% eff

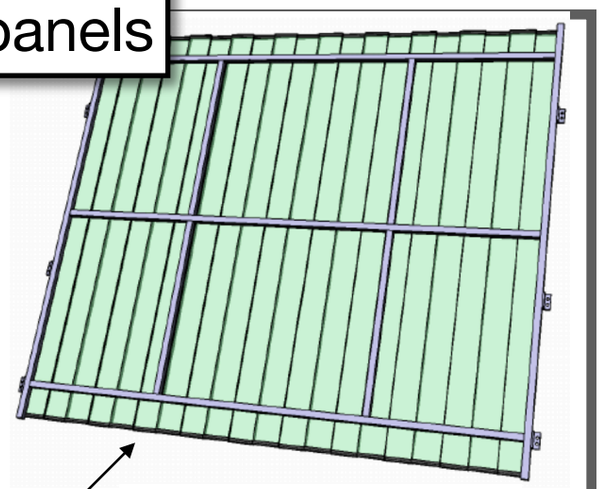
Part 2:
ND280 upgrade

The ND280 upgrade

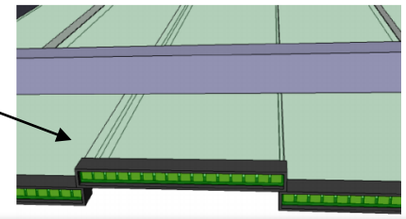
arXiv: 1901.03750



6 ToF panels

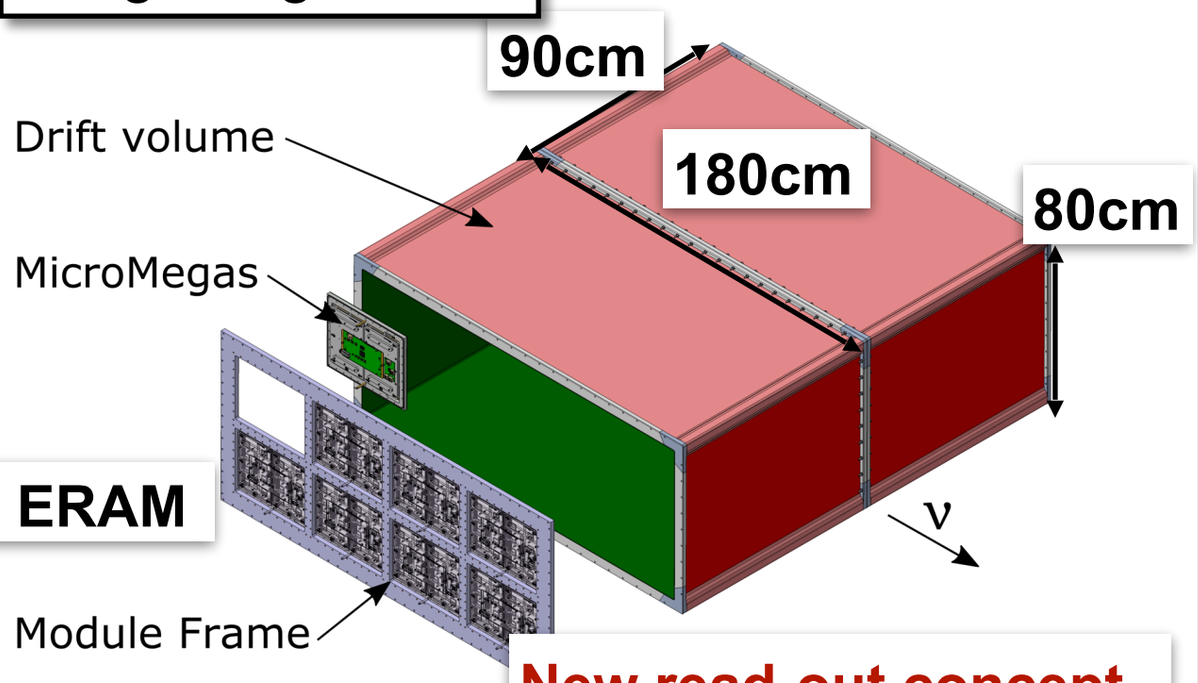


ToF bars



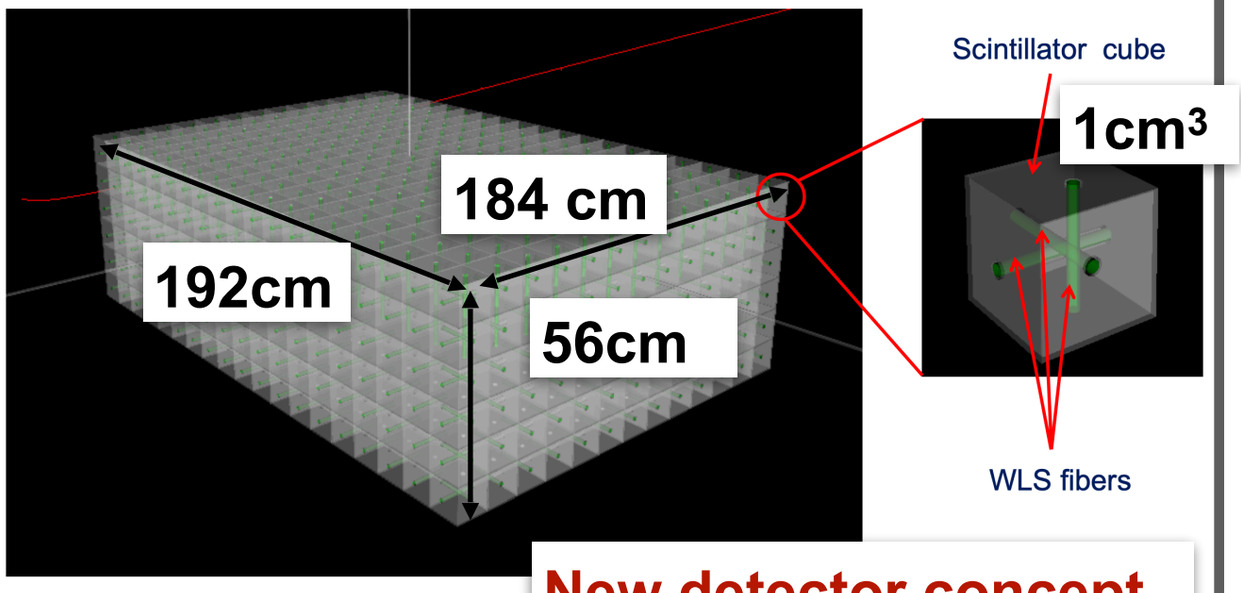
150 ps resolution

2 High Angle TPCs



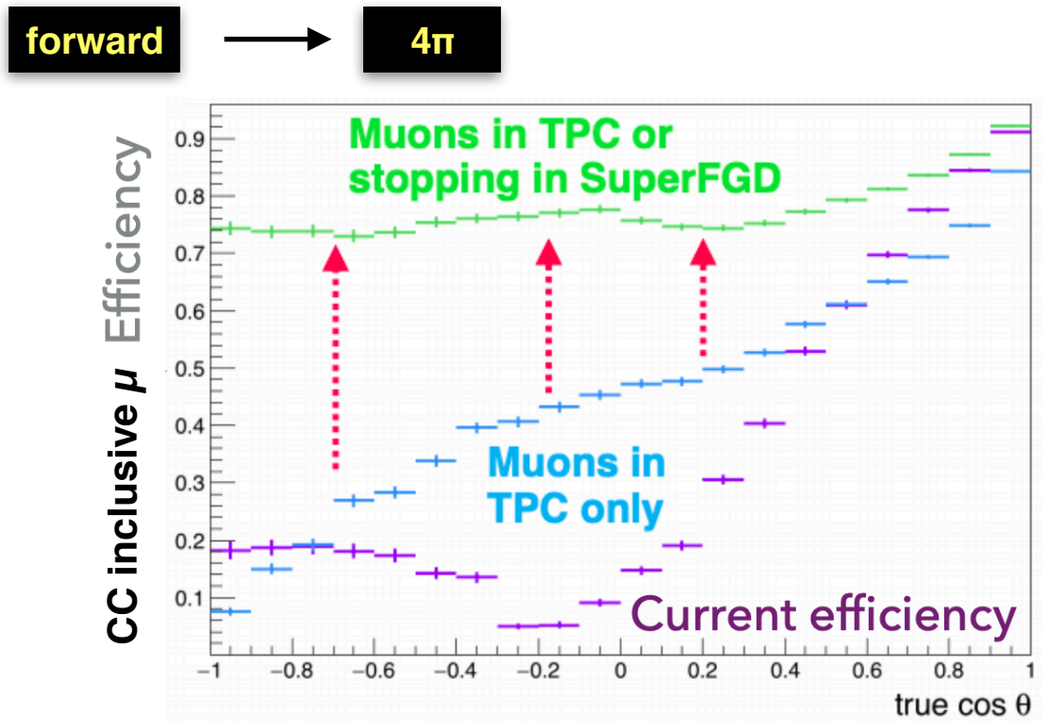
New read-out concept

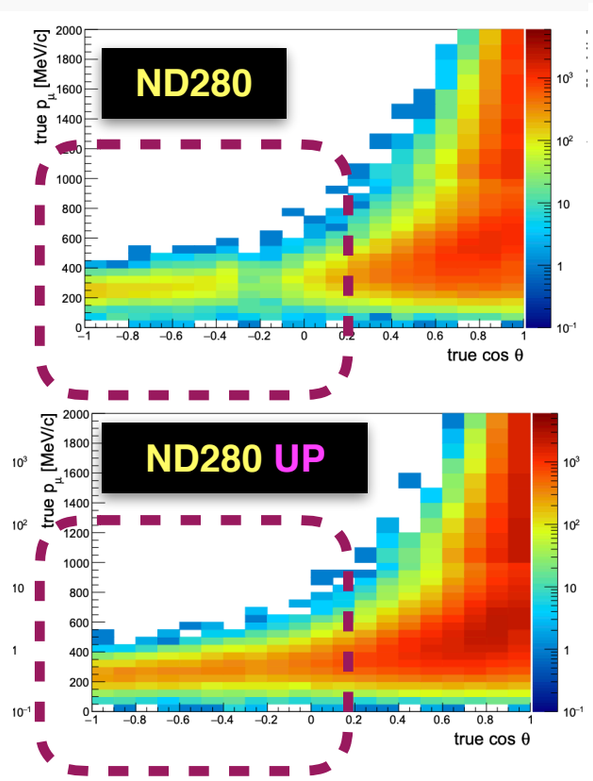
1 SuperFGD

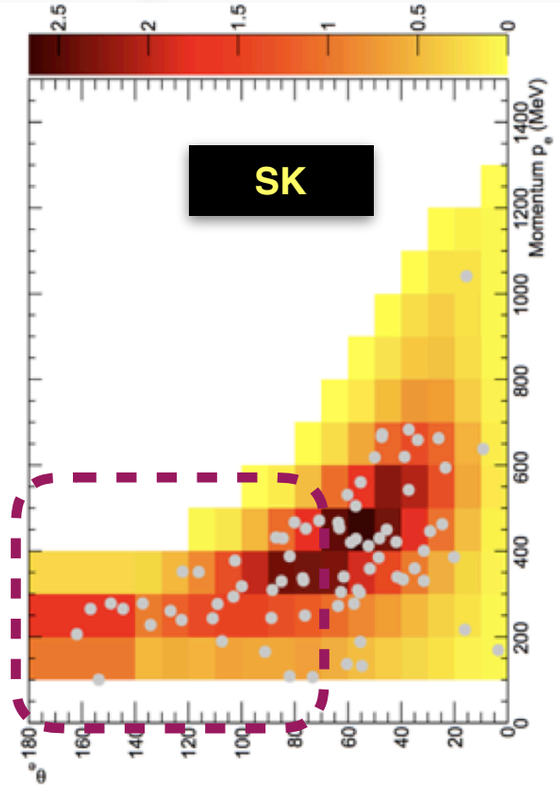


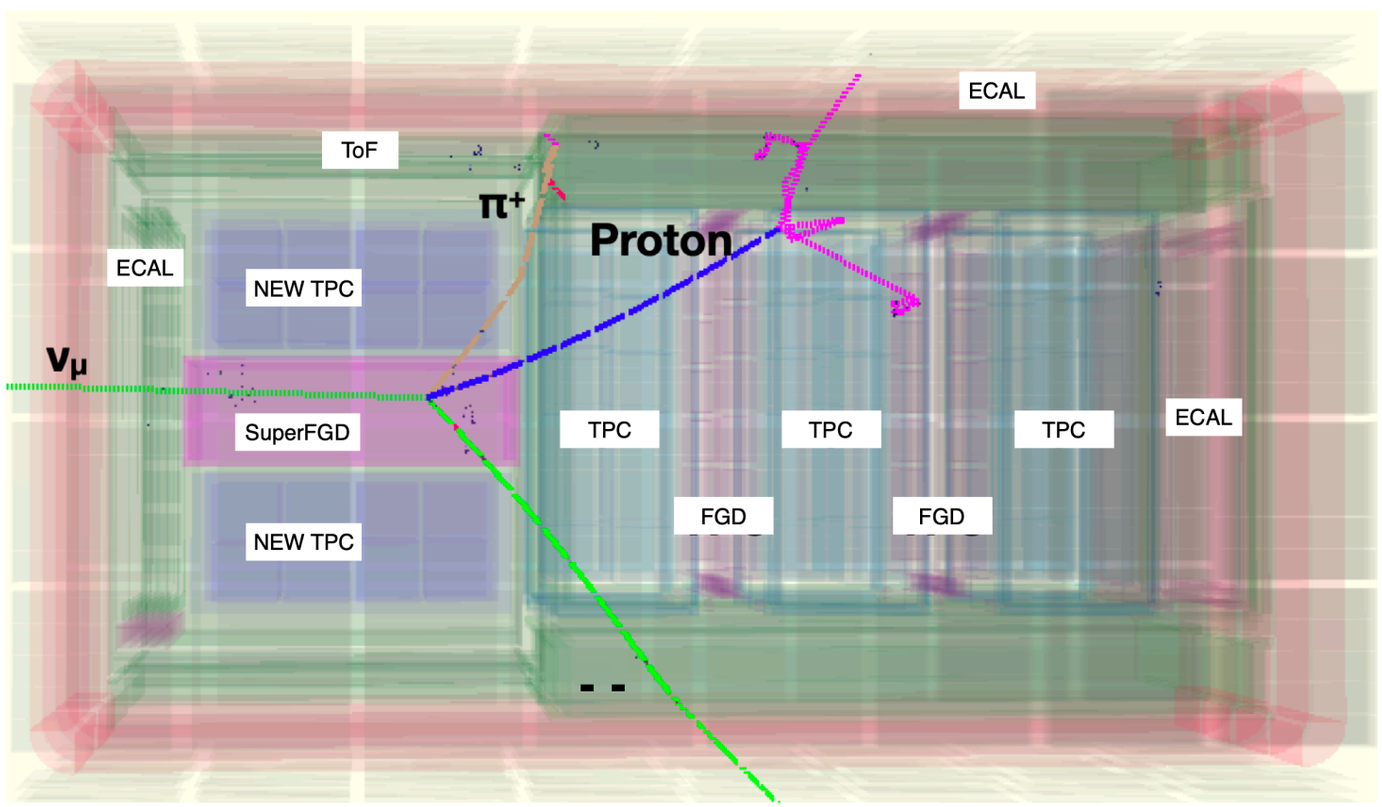
New detector concept

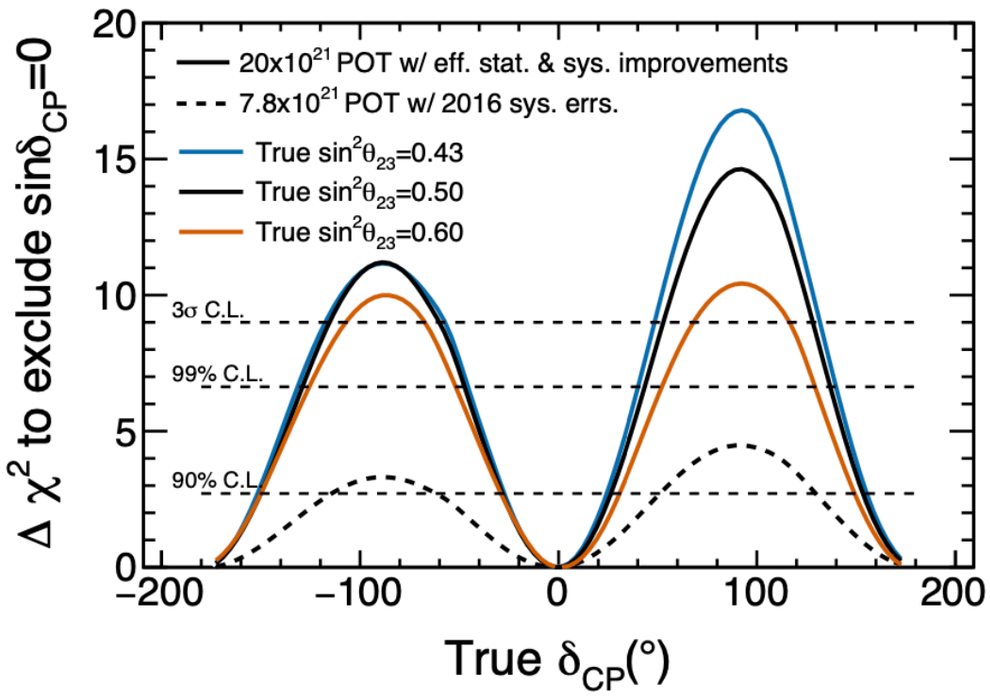
Direct benefits for the OA





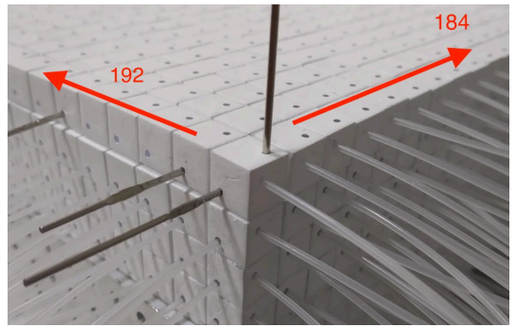




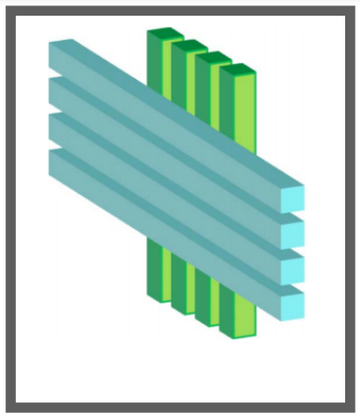


SFGD concept

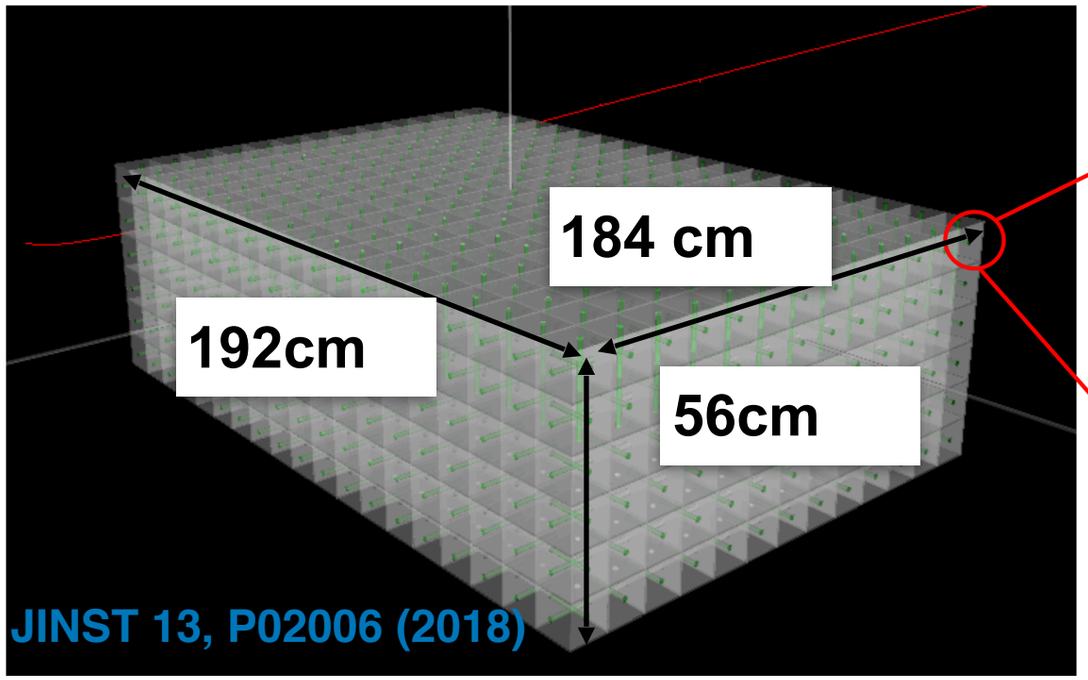
To improve the granularity the new active target will be a novel 3D tracking

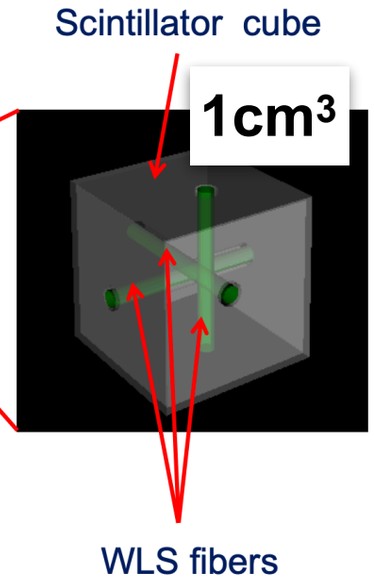


FGD concept



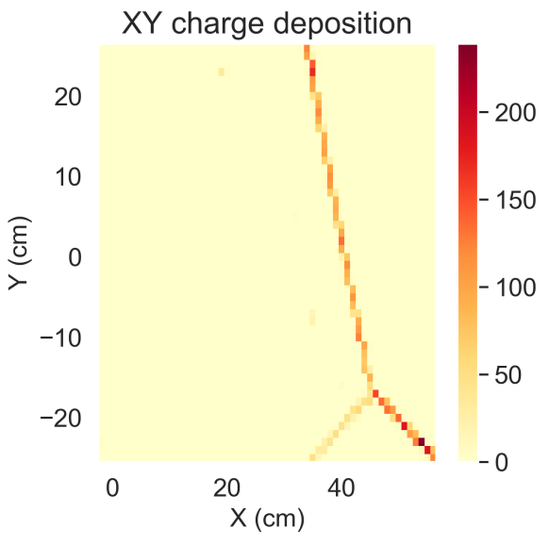
SuperFGD concept

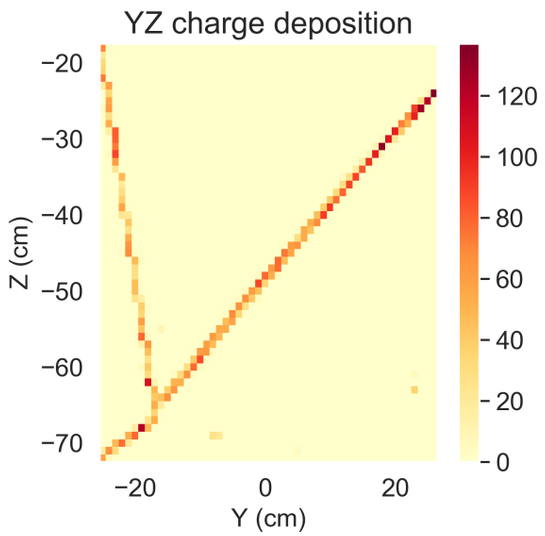


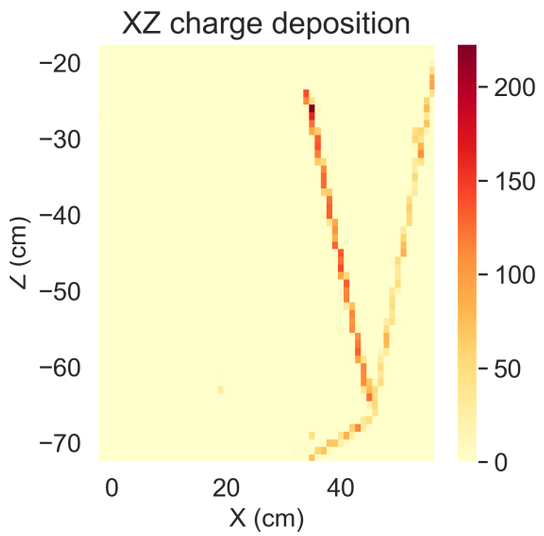


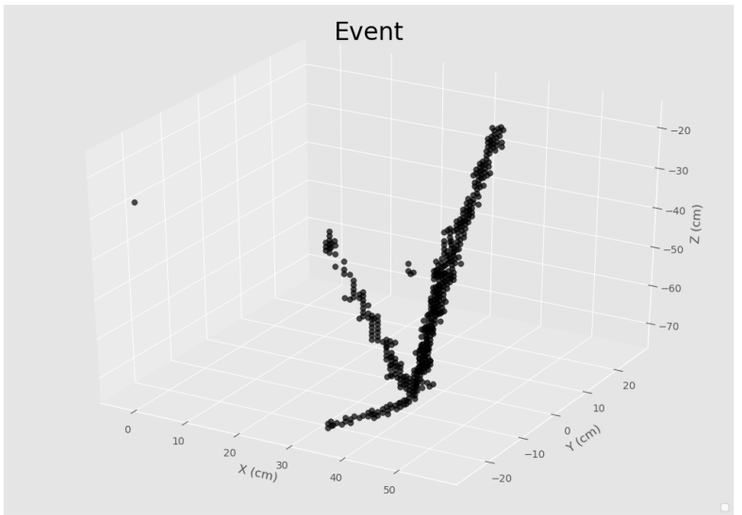
+ new electronics

CITIROC ASIC









Characterizing SFGD prototpye

Improvements in tracking

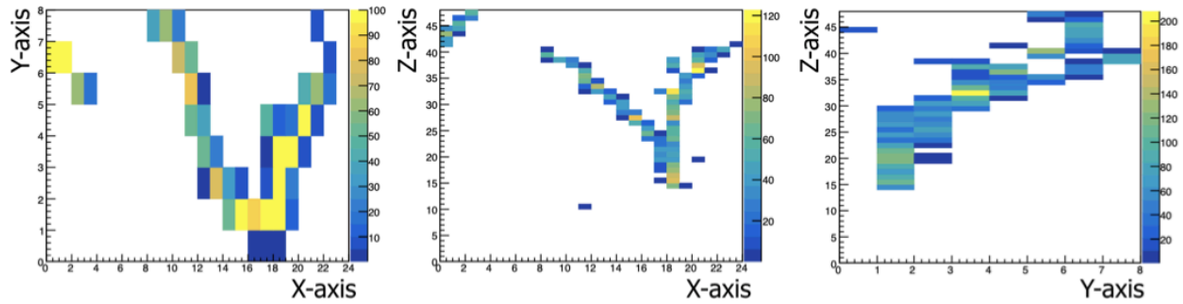
Current FGDs PID is much worse than TPCs

Charge particles beamtest @CERN (2018)

The SuperFGD Prototype charged particle beam tests

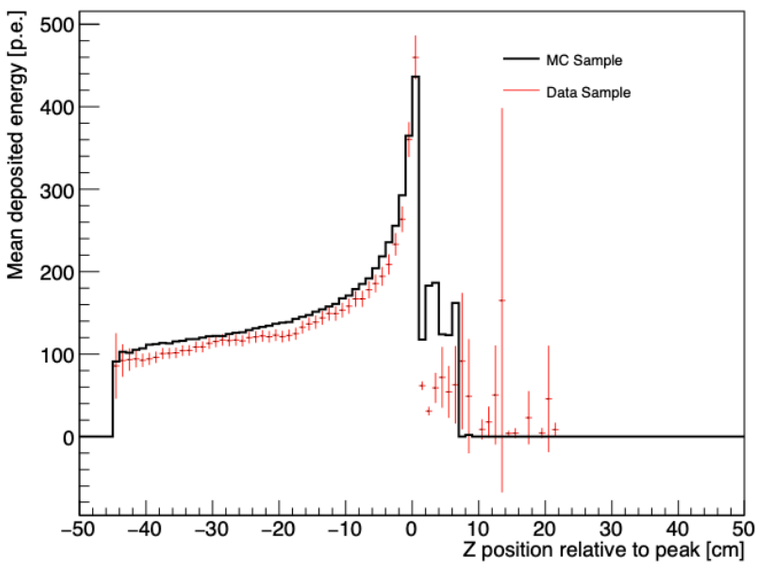
JINST 15 P12003

24x8x48

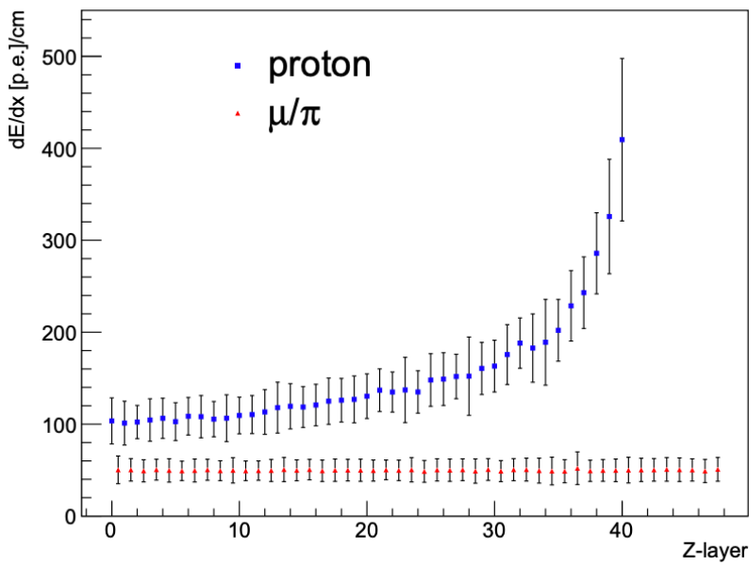


We can see gamma conversions in SuperFGD: important to tag $\pi^0 \rightarrow \gamma\gamma$

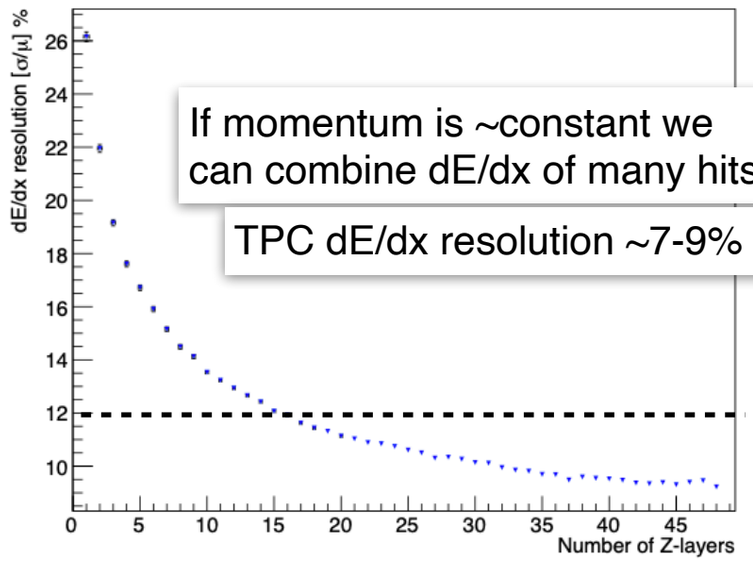
ν_e background reduction



We can see bragg peak



Great μ/proton discrimination by dE/dx



If momentum is ~constant we can combine dE/dx of many hits

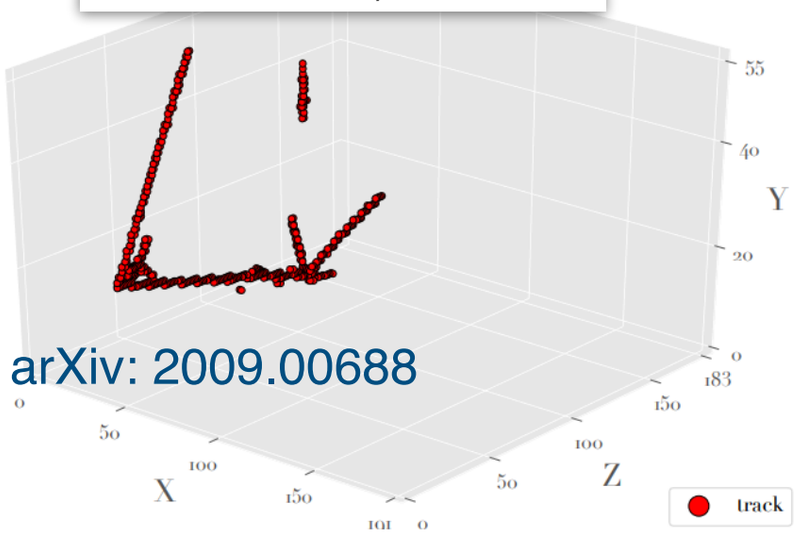
TPC dE/dx resolution ~7-9%

Complement to TPC PID

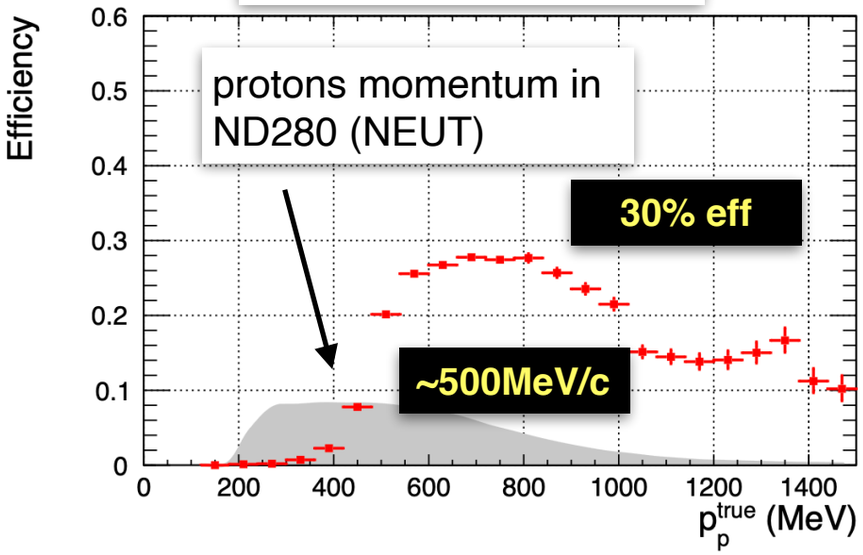
Studying other possibilities with SFGD

Improvements in tracking for low momentum tracks

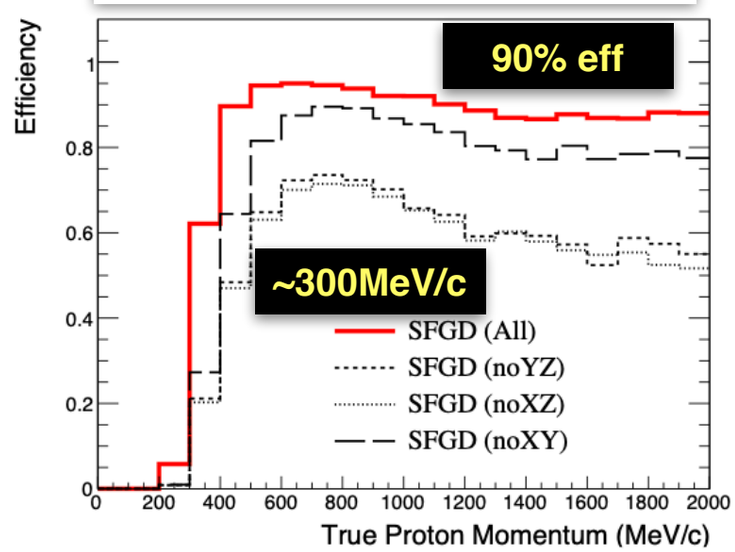
SuperFGD 3D ν_μ MC event



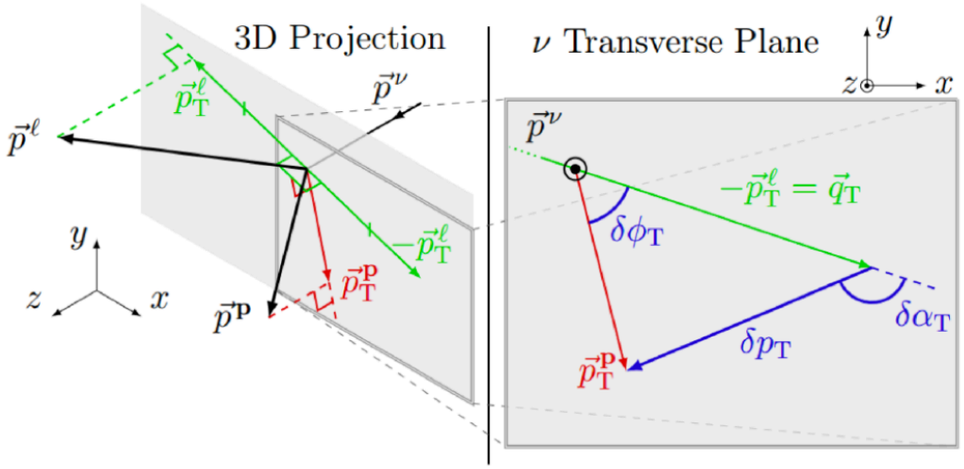
Current ND280 (FGD1)



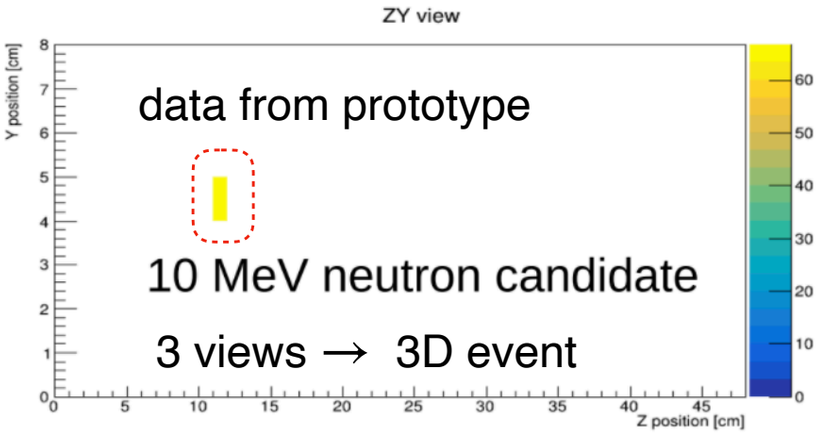
Upgraded ND280 (SuperFGD)

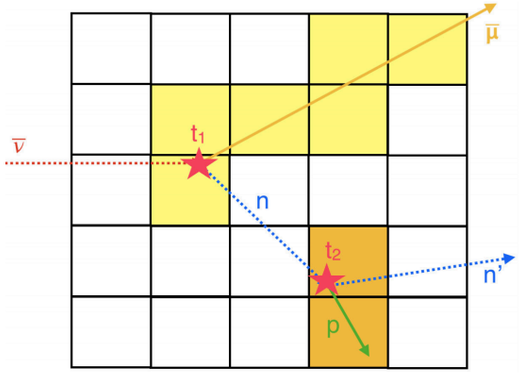


We can study kinematic imbalances using better proton information



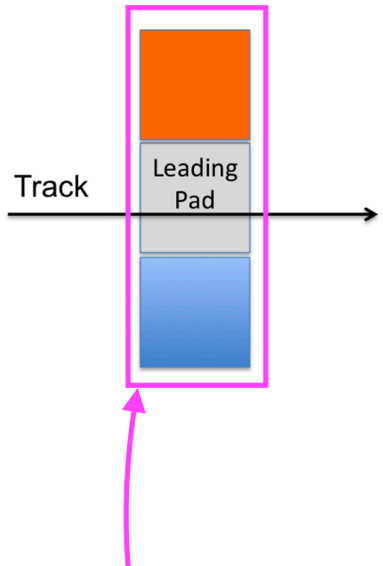
Also for neutrons!

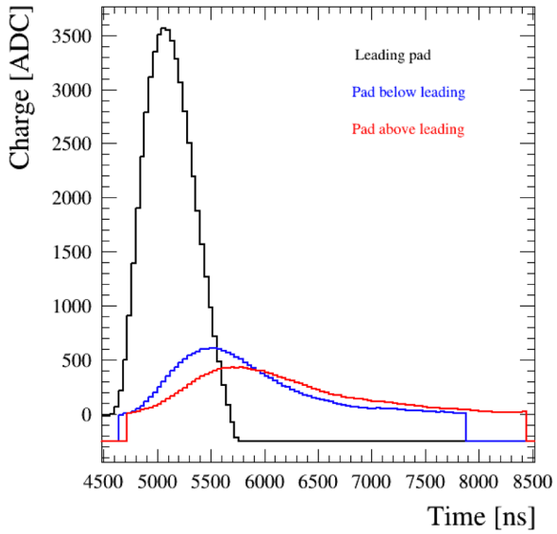




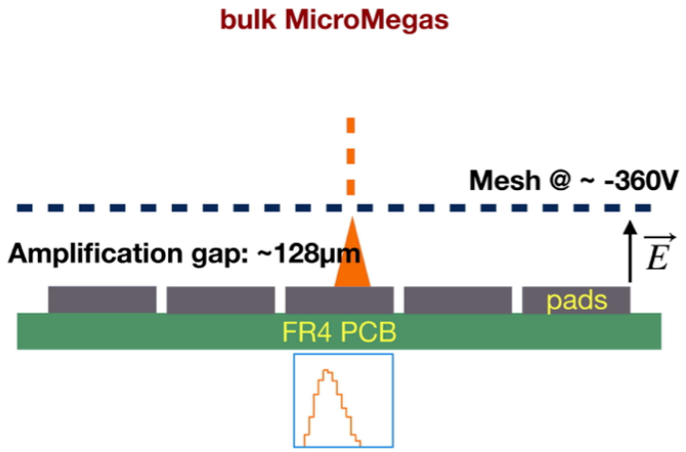
We can better understand multi-nucleon knockout processes.

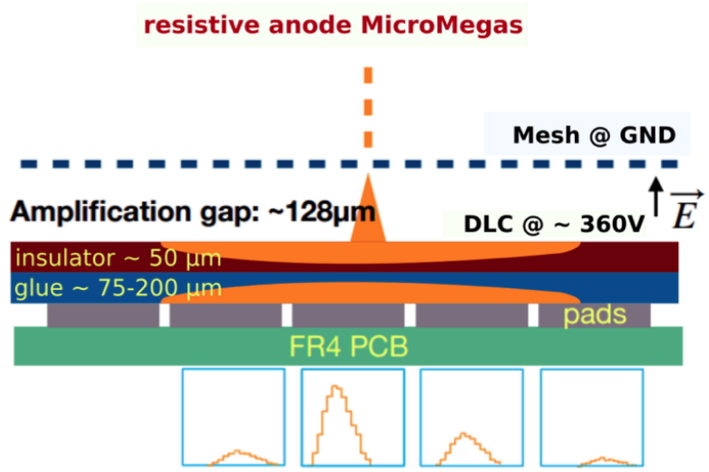
HA-TPC characterisation



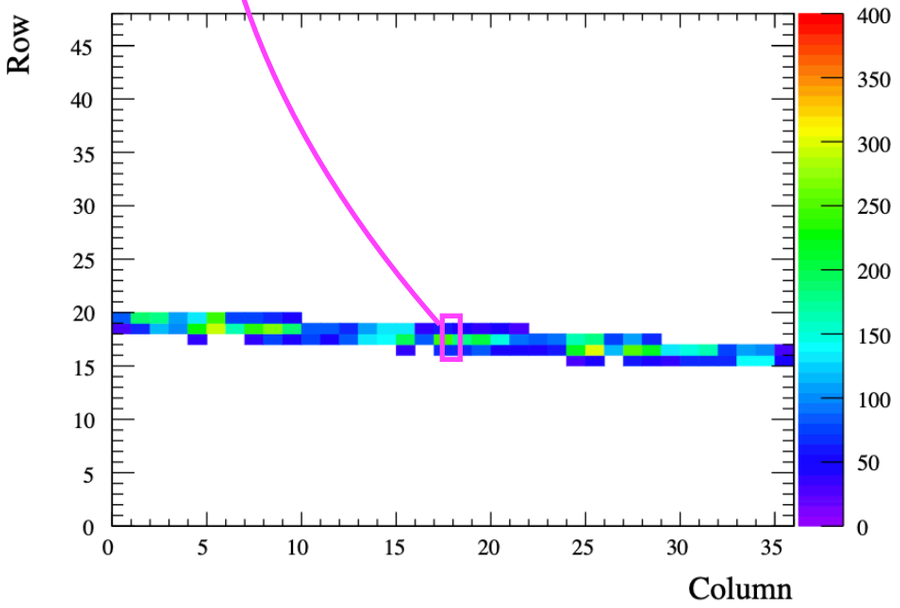


Waveform

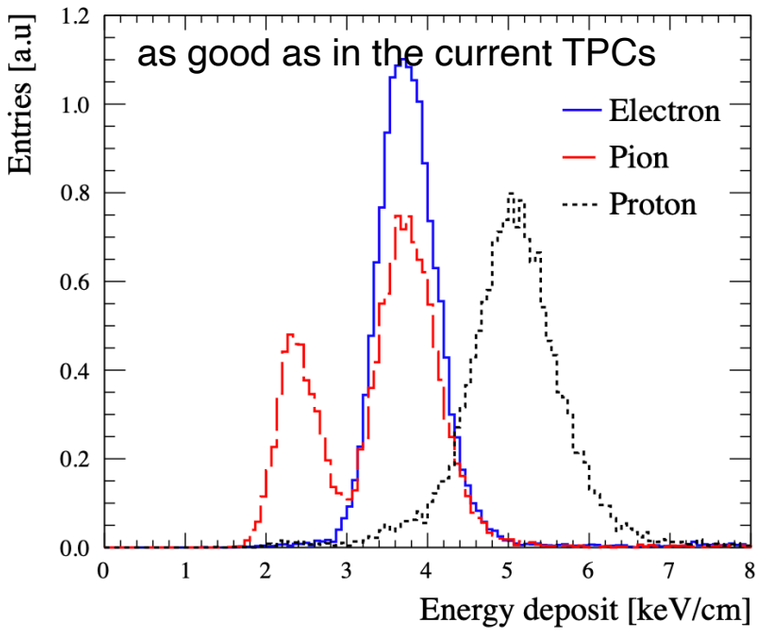




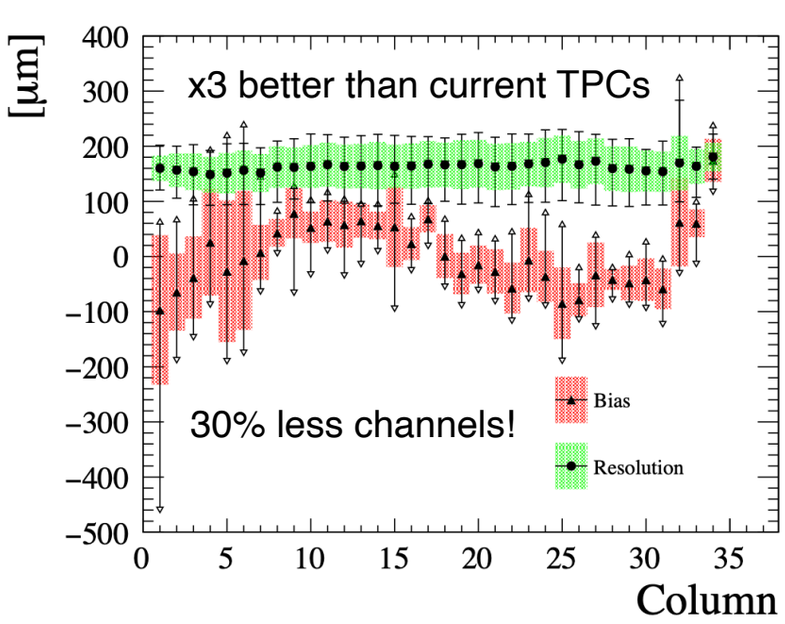
Event display



Ionization for different particle triggers

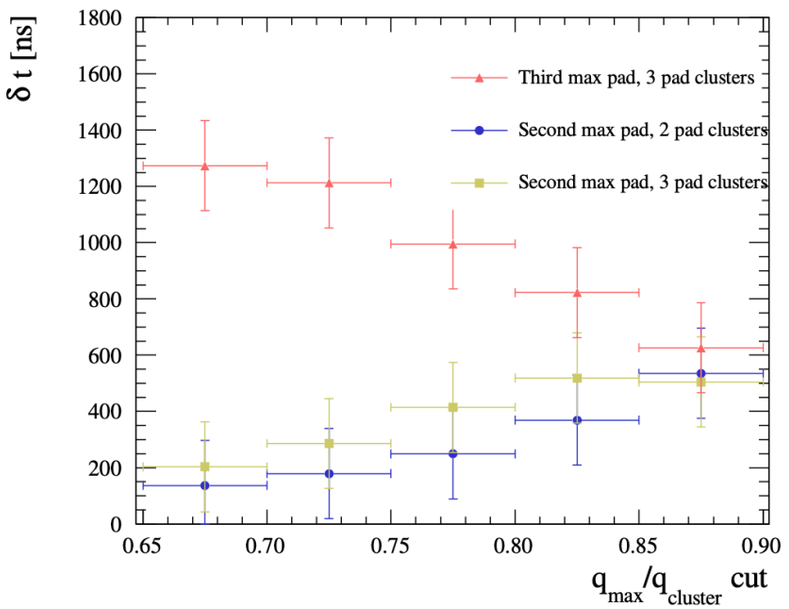


Excellent position resolution

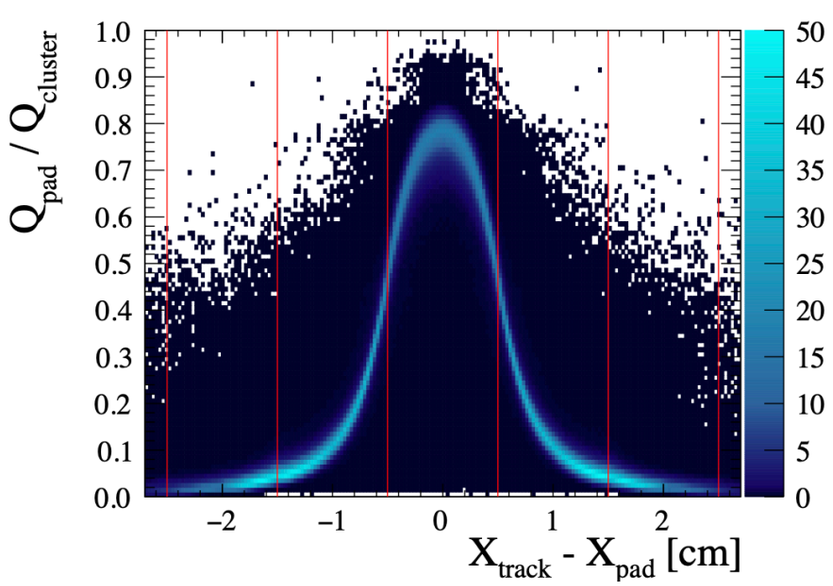


HA-TPC characterisation

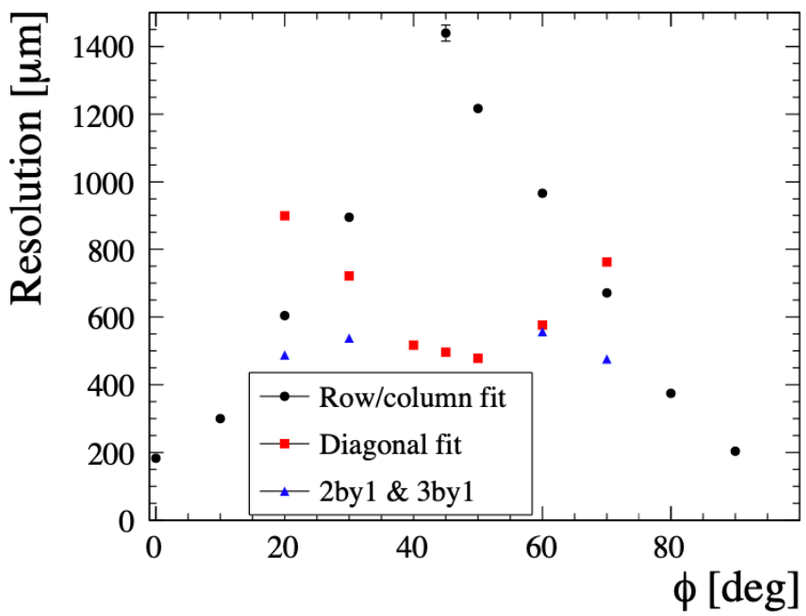
Measurement of the charge spread velocity



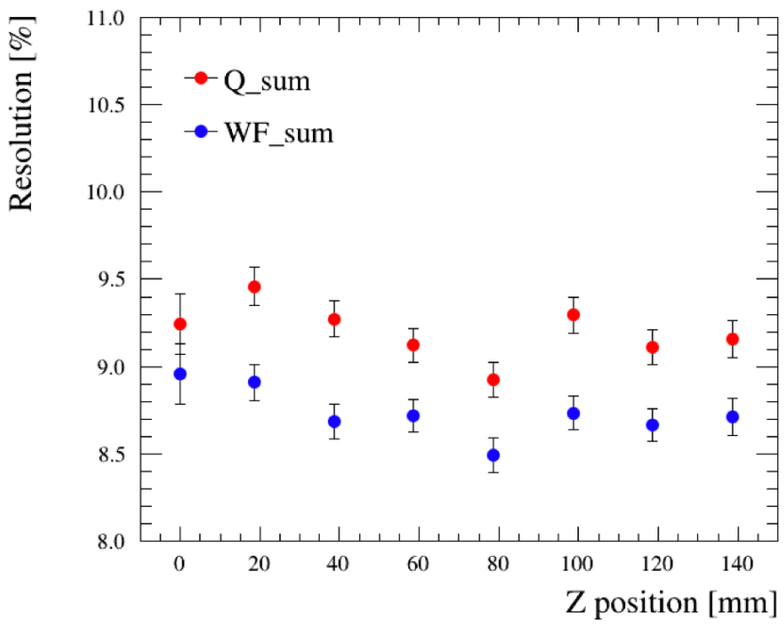
Measurement of the charge spread profile



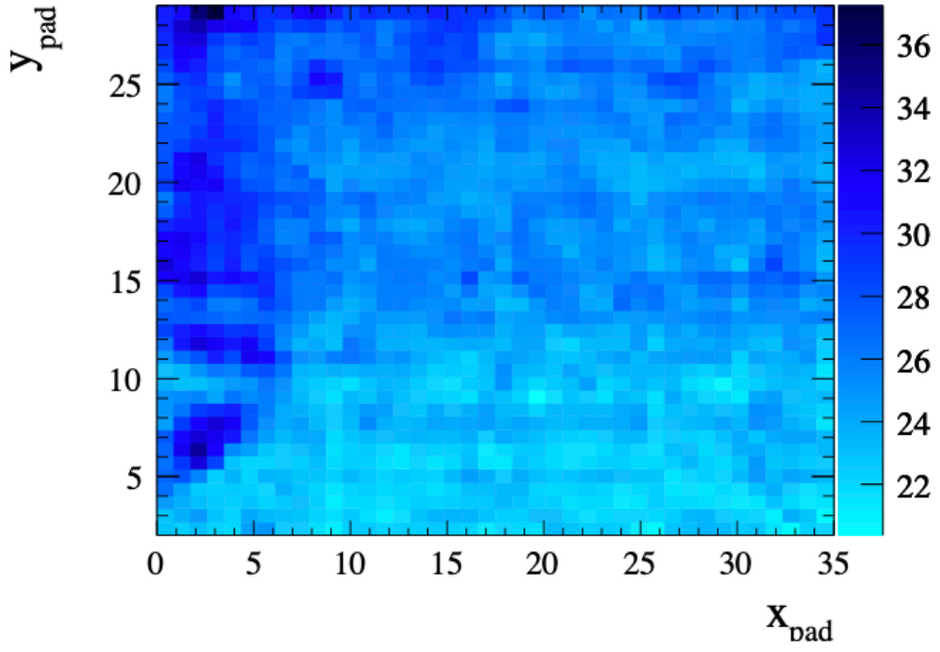
Position resolution vs angle of the track



Energy resolution



Measurement of the resistive foil uniformity



Conclusions

~1 year ahead to finish PhD:

- Upgrade activities ‘done’ (SuperFGD + TPC studies), prototypes look good, upgrade in 2023
- NC1π analysis ongoing!

Back Up