WP4:
High Pressure TPC

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Outline

- Motivation & Physics goals.
- Simulations
  - Event statistics
  - Track detection thresholds.
- Final remarks

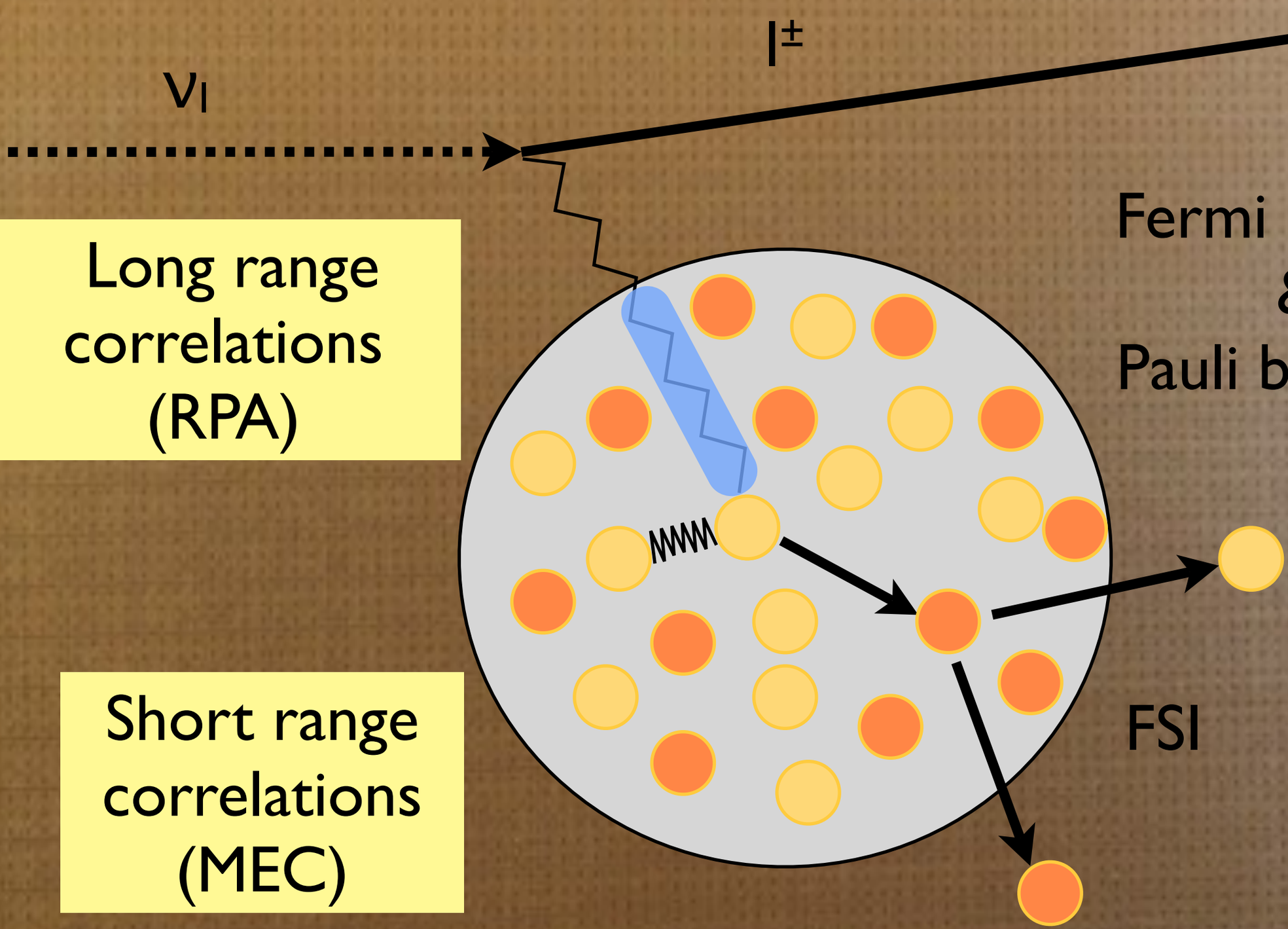
Motivation

Future T2K & HK challenges

- Protons on target!.
- Balancing anti-neutrino / neutrino runs.
- Neutrino flux shape: NA61 (and a little of near detector data)
- Neutrino cross-sections (also for ν flux)

Can we improve ND280 to optimize cross-section measurements?

Cross-section



Long range correlations (RPA)

Short range correlations (MEC)

Cross-sections

- The uncertainties in cross-sections affect:
  - neutrino energy reconstruction.
  - background calculation (Resonant into QE feed down).
  - Acceptance correction near-far (high angle and backward tracks).
- Actual unknowns:
  - 2p-2h
  - FSI and Pion re-interactions at detector.
  - 1π and high mass resonances.
  - Spectral functions.

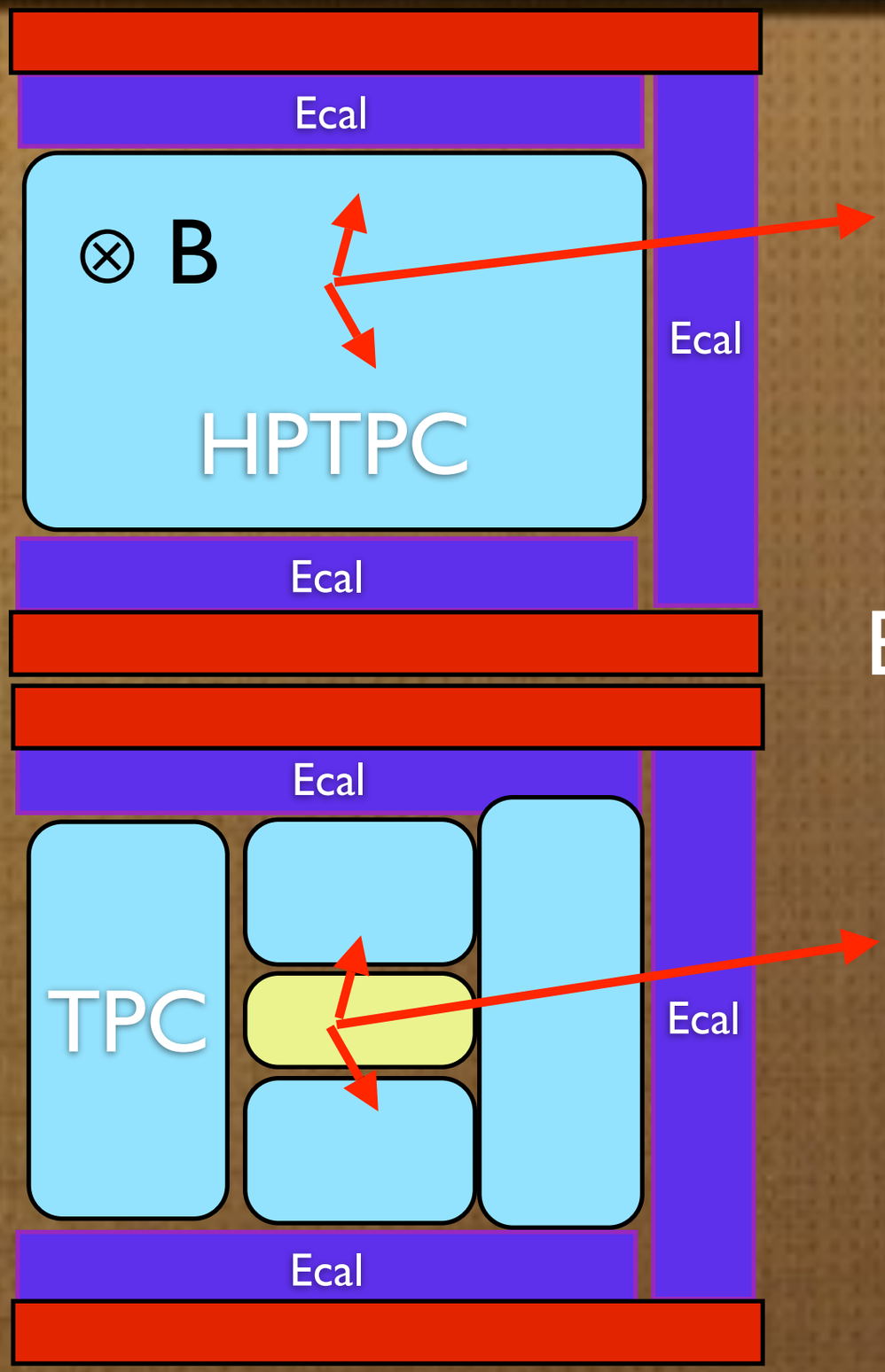
} Most of these unknowns can be adressed with low threshold detectors.

why a TPC ?

A time projection chamber is a good candidate for these studies:

+ Target = detector.
+ 3D reconstruction capabilities.
+ Possibility to exchange targets.
+ low density → low thresholds
+ excellent PID capabilities.
+ Almost uniform 4π acceptance.
- low number of interactions → requires high pressure and large volume.
- requires in addition a magnet or range detectors to measure momentum.

HPTPC concept



Cross-section experiment

- Target = detector. Low momentum detected inside the TPC.

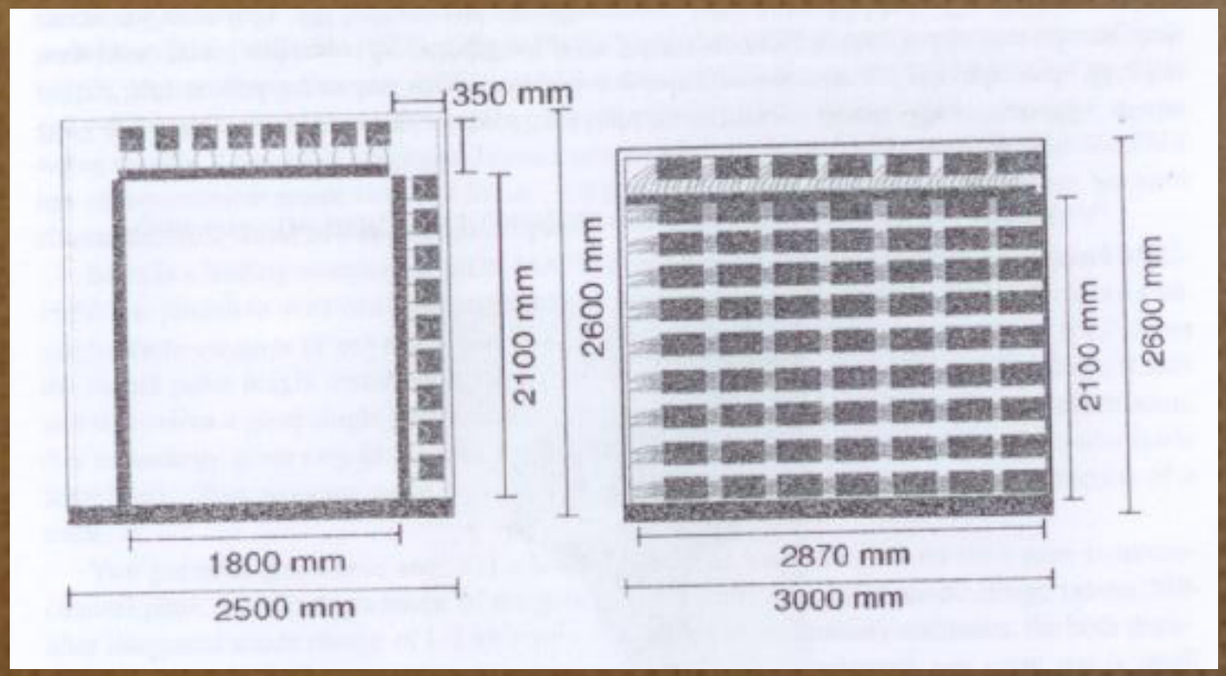
Basic technology common to both!

T2K HK near detector

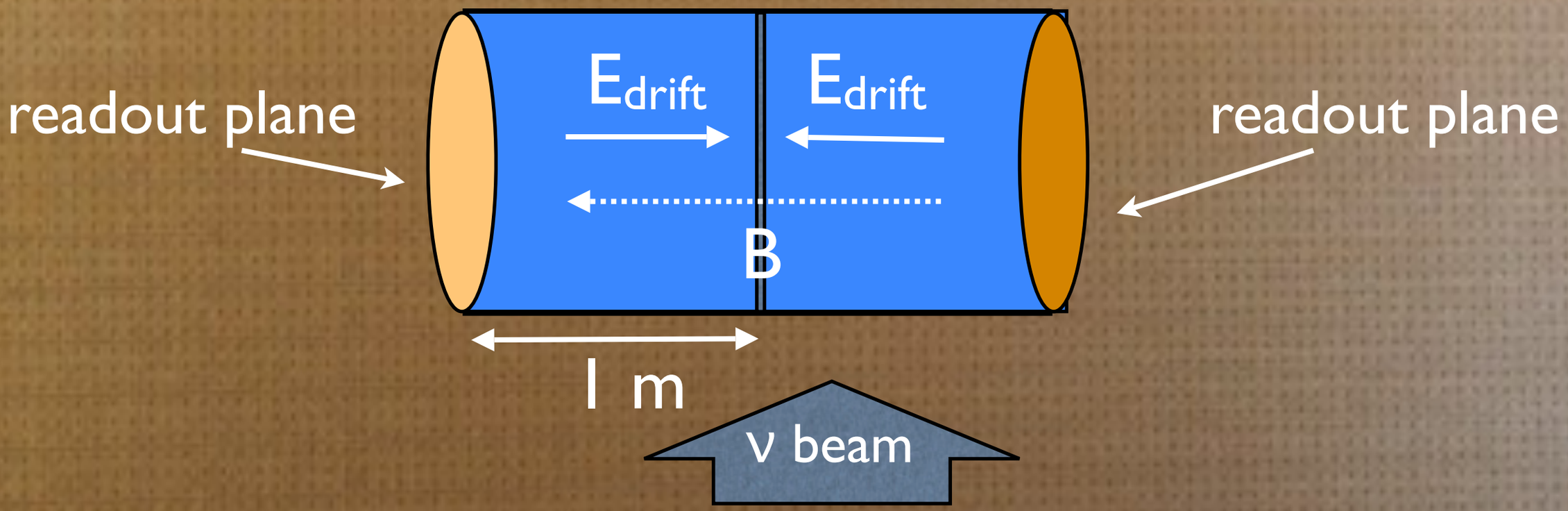
- Target is not the TPC so we can use H_20 as target.
- High Pressure is not needed in this case.

HPTPC concept

- Let's assume that we want to reuse the ND280 magnet.
- The drift has to be along the B field (⊥ to the ν beam).
- The inner basket size is (2.5x2.5 m^2)
- If we leave space for vessel + equipment → ~2 m drift.



HPTPC concept



In the hypothesis of central cathode plane and contained in ND280 magnet, we will have ~1m of drift distance

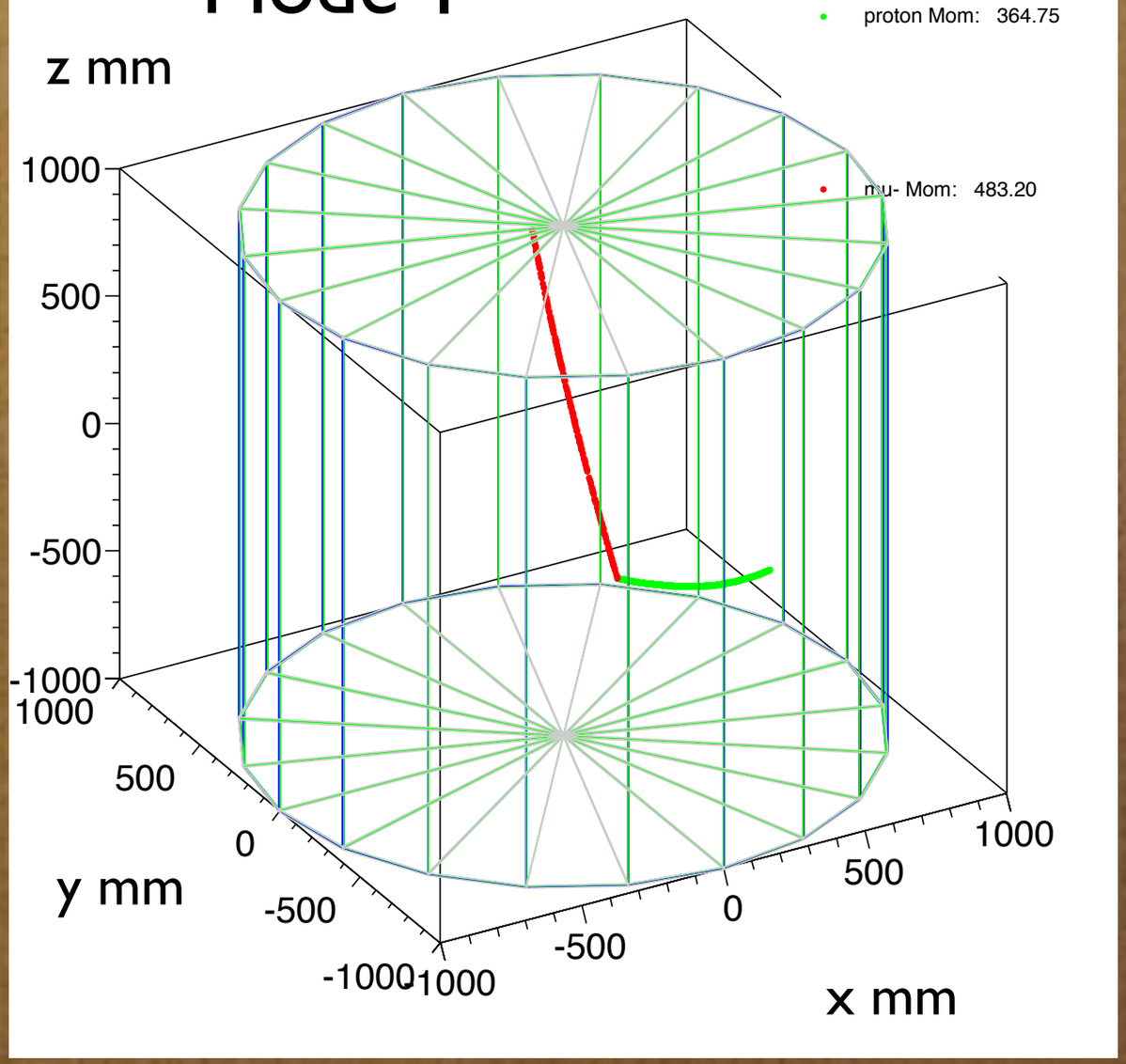
Number of Events

CC events assuming a 8m^3 detector & full FV.

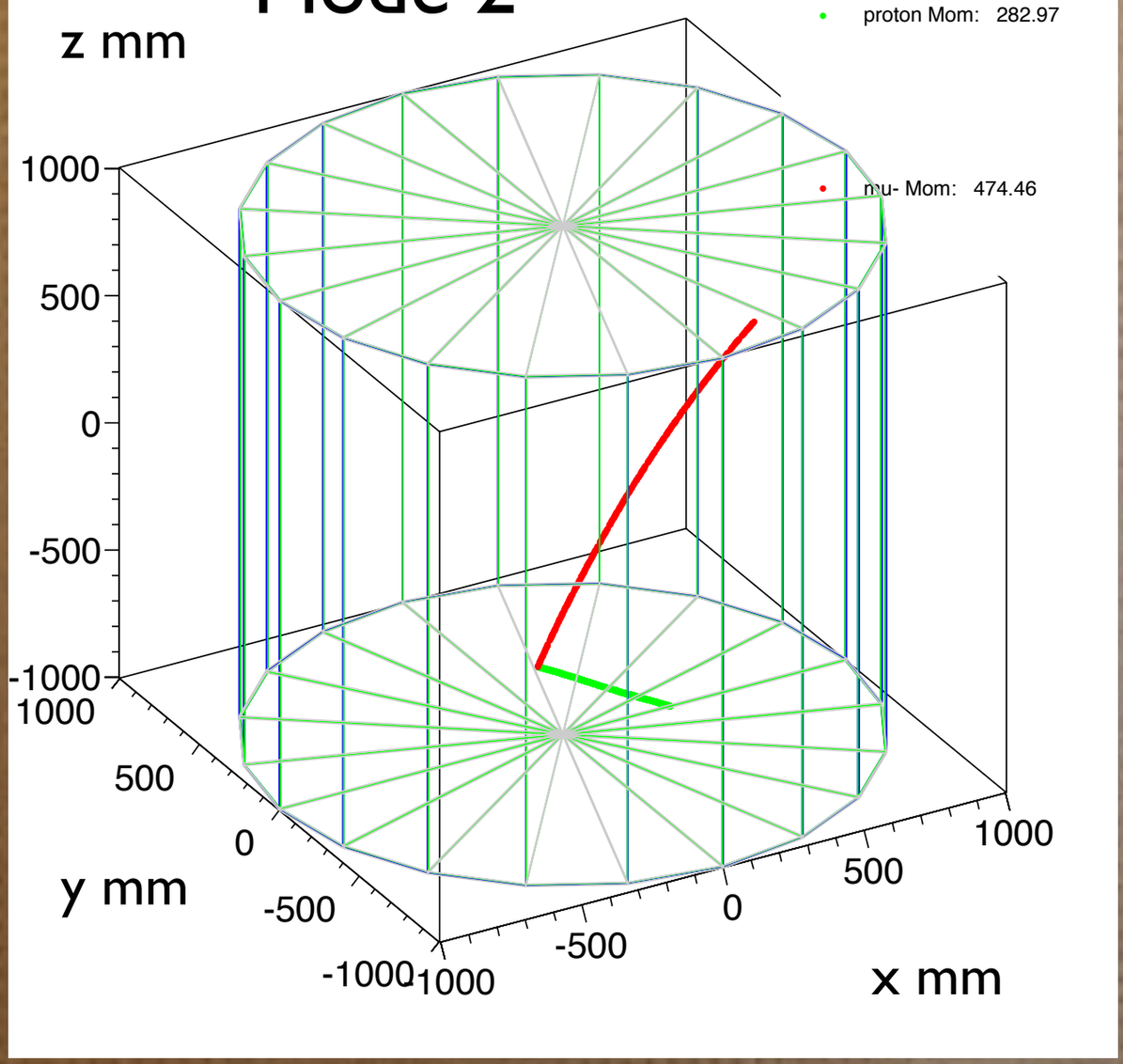
2x2x2 m^3 20°C	5 bars	10 bars
He	6.65 kg	13.3 kg
	520 evt/10^{21}pot	1040 evt/10^{21}pot
Ne	32.5 kg	67.1 kg
	2543 evt/10^{21}pot	5086 evt/10^{21}pot
Ar	66.5 kg	133 kg
	5203 evt/10^{21}pot	10406 evt/10^{21}pot
CF_4	146.3 kg	293 kg
	11450 evt/10^{21}pot	22893 evt/10^{21}pot

Event display

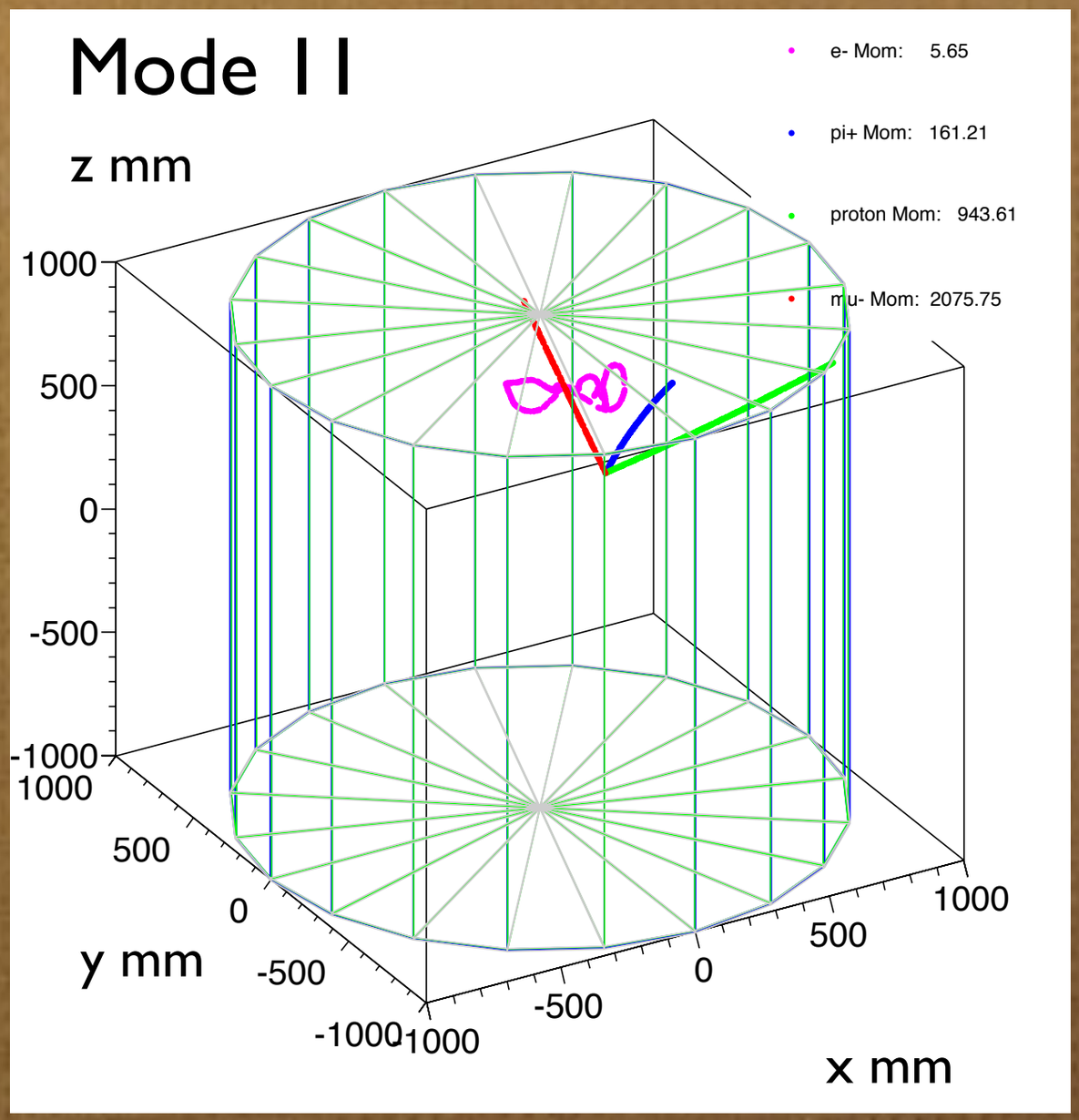
Mode 1

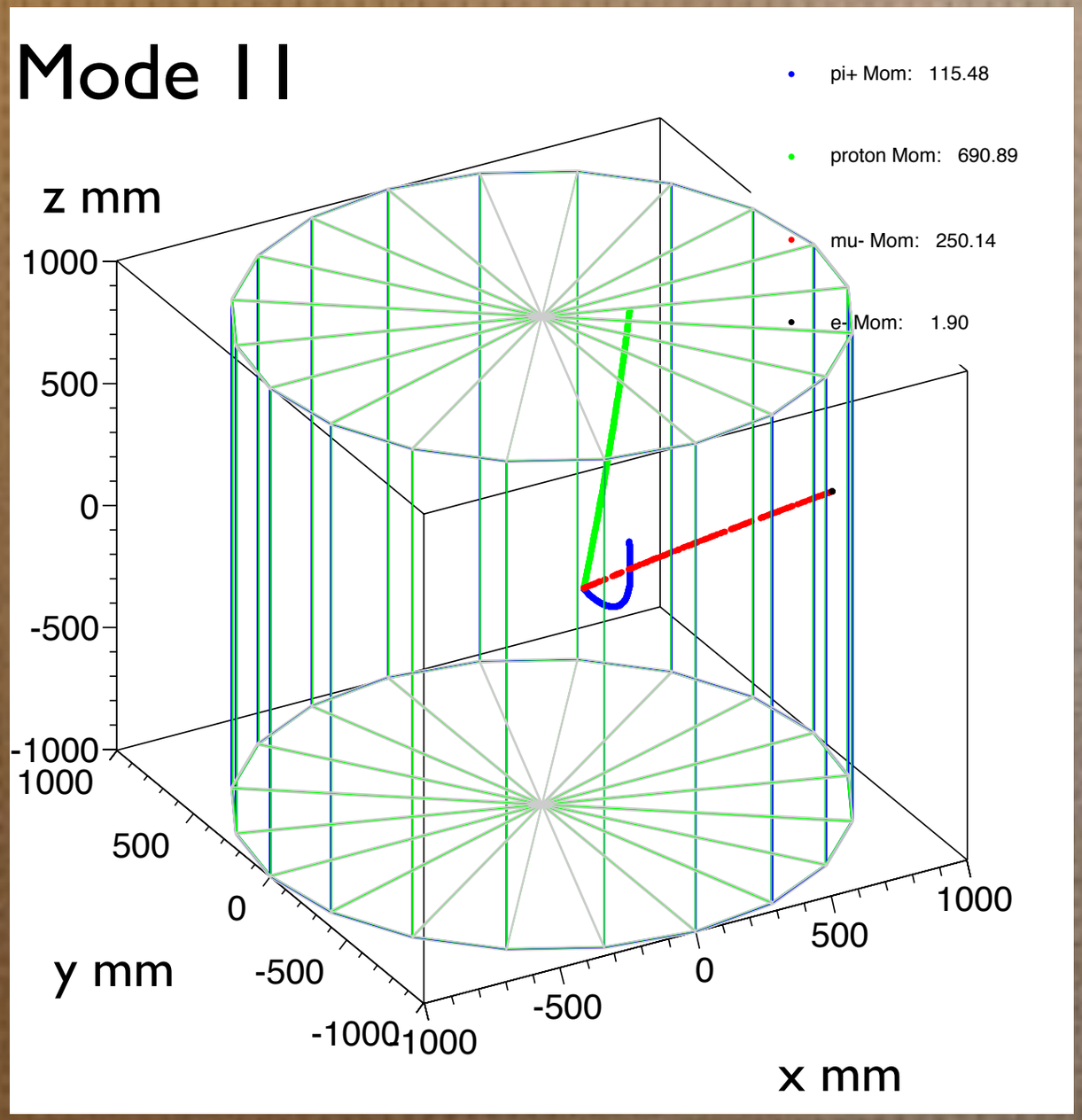


Mode 2



Event displays



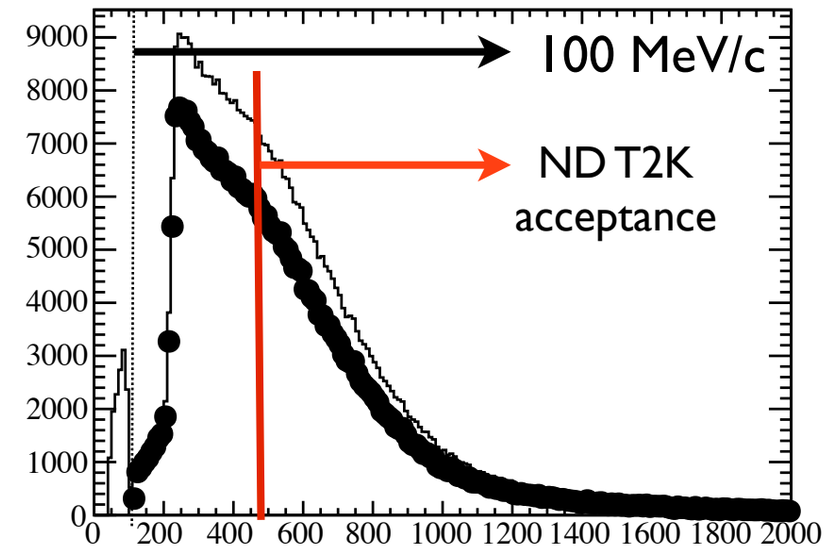


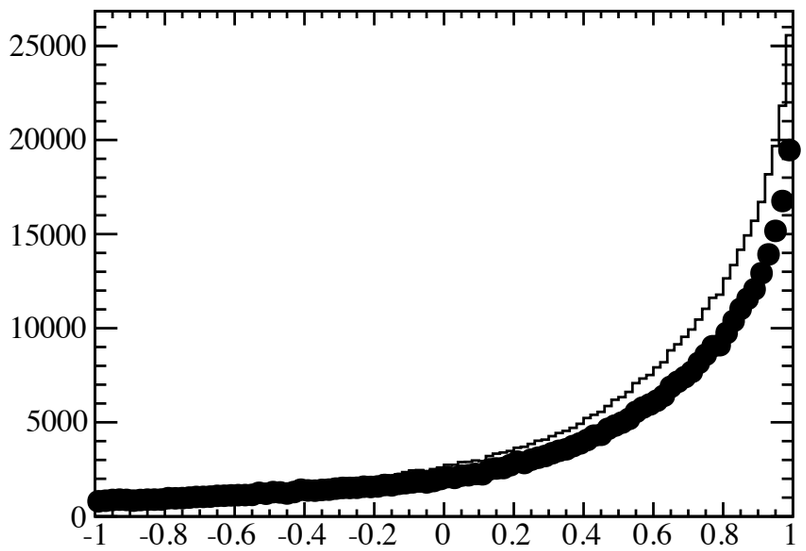
Selection criteria

- An event is detected if all protons and pions emitted by the nucleus are detected.
- A particle is detected if fullfils one of the two conditions:
  - If the particle starts and stops inside the gas, the length should be larger than 50mm (~ 5 detector pads).
  - If the particle leaves the TPC, the lenght transverse to the B field should be such that the error in the p_t is smaller than 20%.

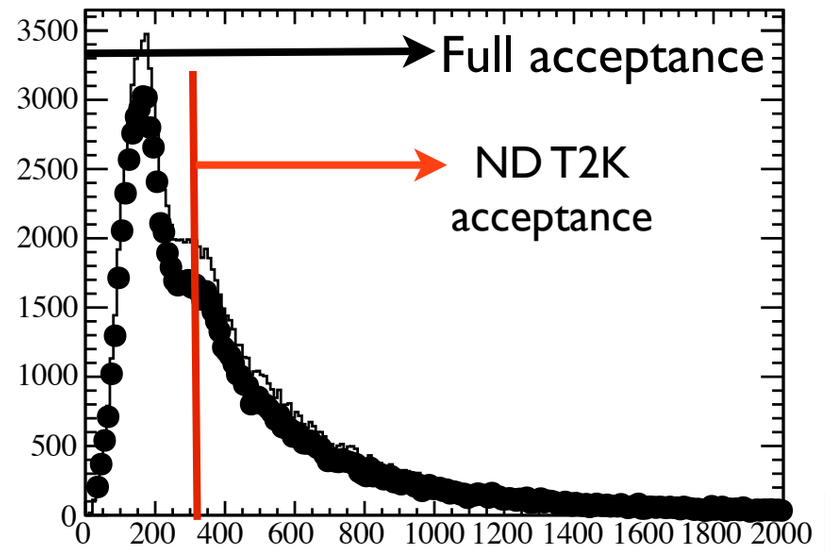
Particle acceptance

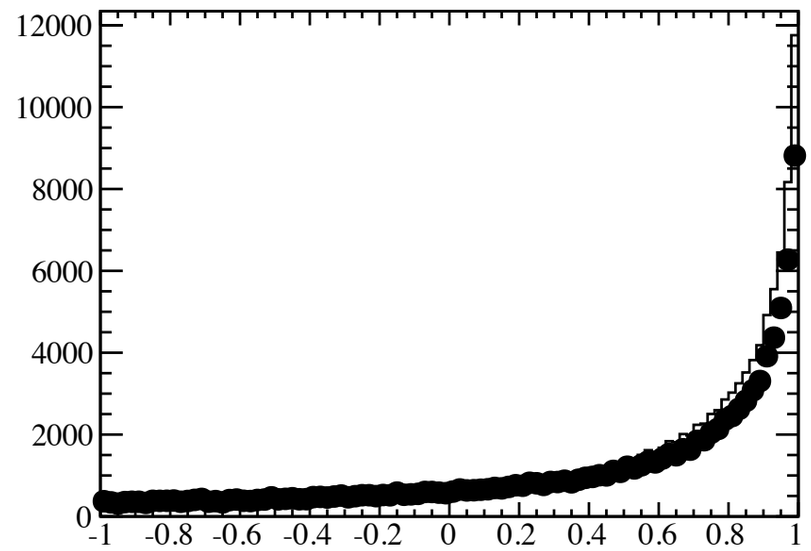
Protons





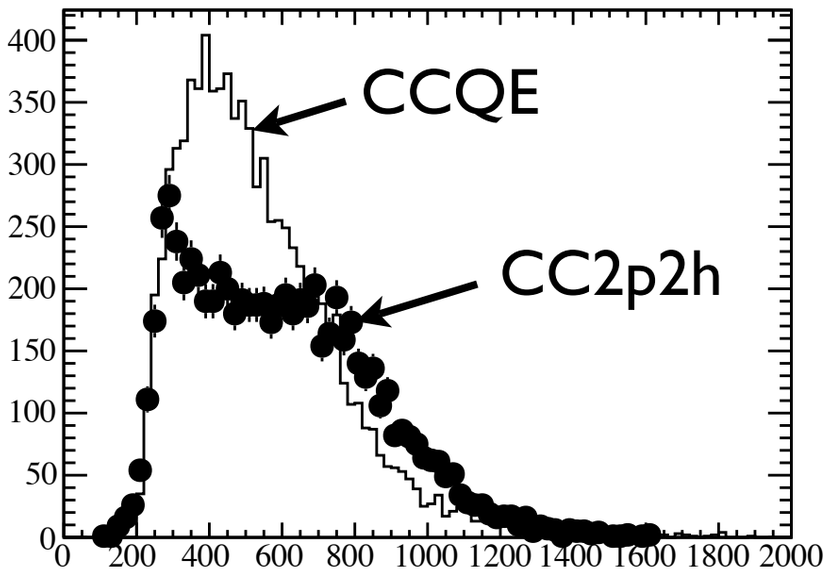
Pions



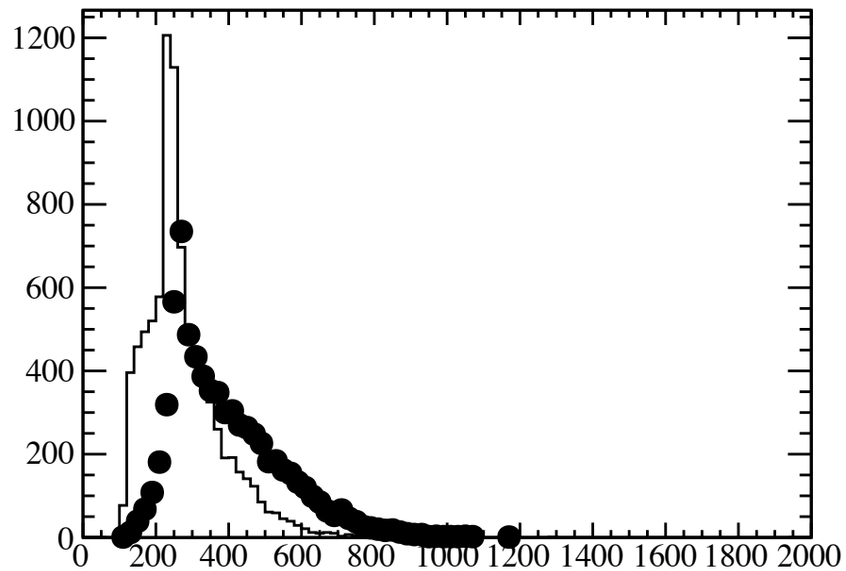


CC2p2h vs CCQE

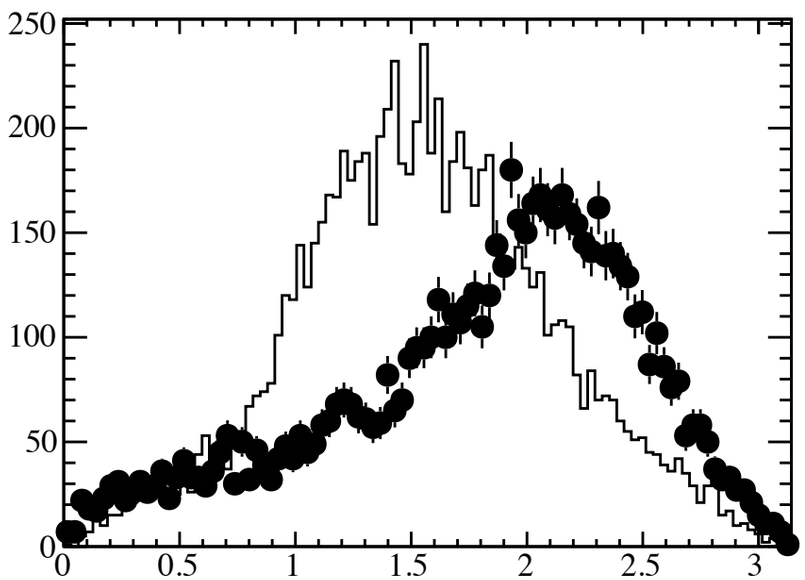
Simulation 500 kEvt



p_{max}



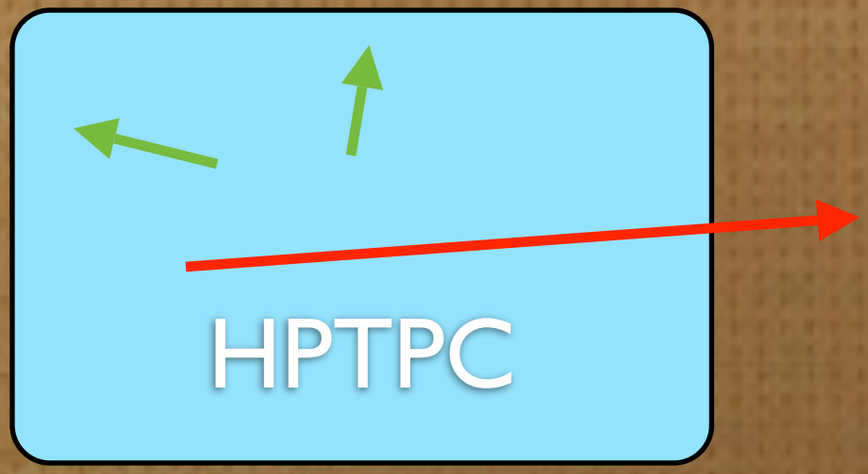
p_{min}



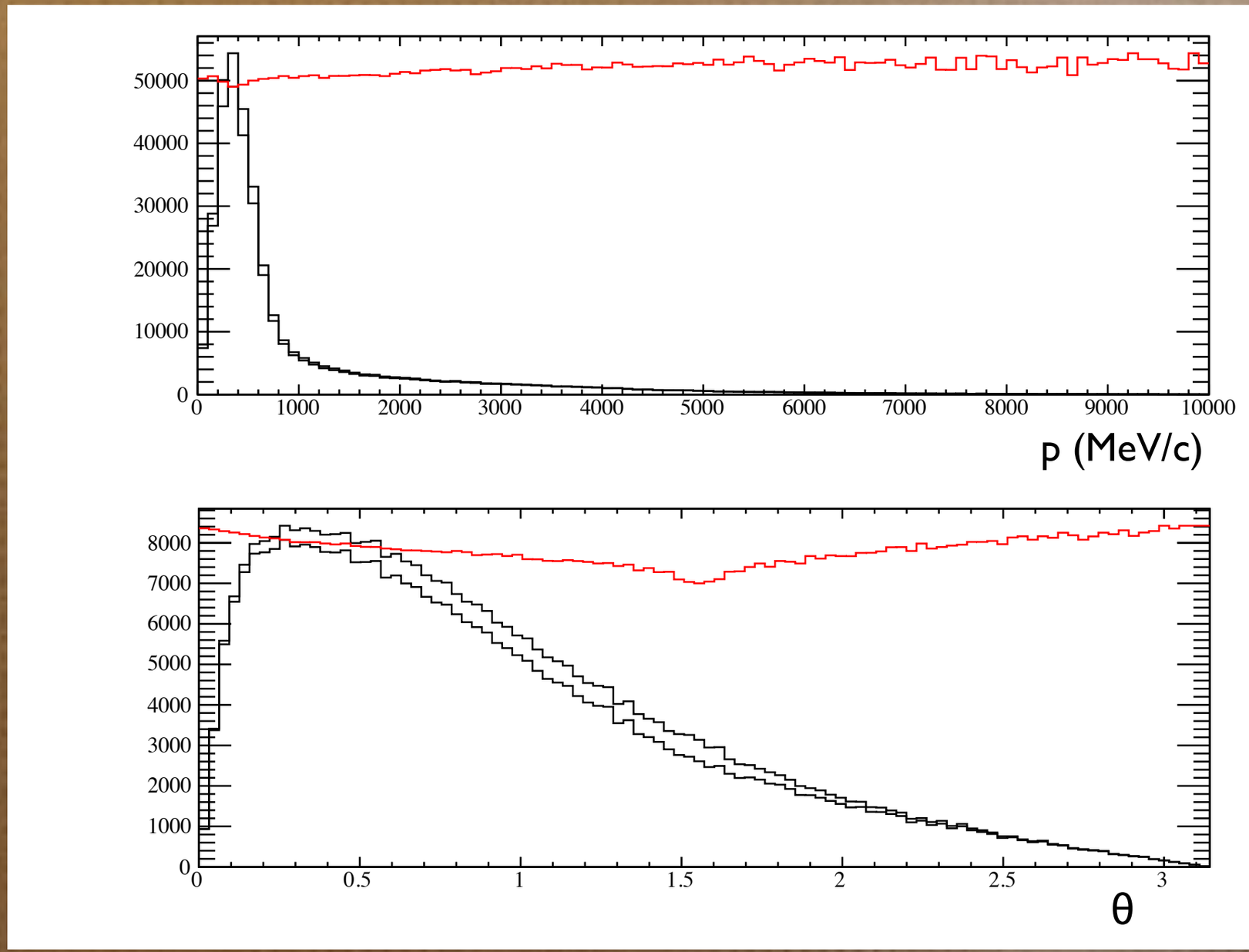
θ_{pp}

- fully reconstructed events with (only) 2 protons in final state.
- $N_{CCQE+FSI} \sim N_{2p2h}$
- Observables are sensitive to differences.

Muon acceptance



- The muon is accepted when:
  - leaving the detector in the forward direction.
  - lateral/backward direction the muon is fully contained or has a momentum resolution of at least 20%.



Potential interests

- The following groups have shown interest in this development:
  - Univ. Geneve
  - Imperial College (London)
  - INFN Bari (Jennifer)
  - Saclay (Paris) (Jennifer)
  - IFAE (Barcelona) (Jennifer)
  - Queen Mary College (London) (Jennifer)
  - KEK (Jennifer)

Conclusions

- HPTPC is considered in two scenarios:
  - Near detector upgrade of T2K and near detector of HK.
  - Cross-section experiment to improve T2K and HK physics.
- A high pressure TPC will allow to access the low energy nuclear debris and help in the study for neutrino-nucleus interactions.

HPTPC & Jennifer

- There are many Jennifer groups interested in this development including the KEK group.
  - Jennifer funds will help in keeping the activities linked with the Japanese group.
- This is an important development for T2K, T2HK and also potentially for future DUNE project.
- Working on an EU proposal that allows to finance personnel and R&D including EU, EEUU and Japan groups.
- Deliverables (depending on additional funding):
  - Proposal for a near detector upgrade (EDM:24)
  - Proposal for a new experiment (EDM:48)
  - Proposal for a near detector detector for HK (EDM:48)

Backup

Reconstruction criteria

$$\delta k_{\rm res} = \frac{\epsilon}{L'^2}\sqrt{\frac{720}{N+4}}, \qquad \epsilon = 0.6 \text{ mm}$$

(From ND280 TPC)

$$p\cos\lambda = 0.3\, z\, B\, R\ ,$$

$\delta k_{\rm res}$ = curvature error due to finite measurement

L' = the projected length of the track onto the bending plane

ϵ = measurement error for each point, perpendicular to the trajectory

N = number of points measured along track

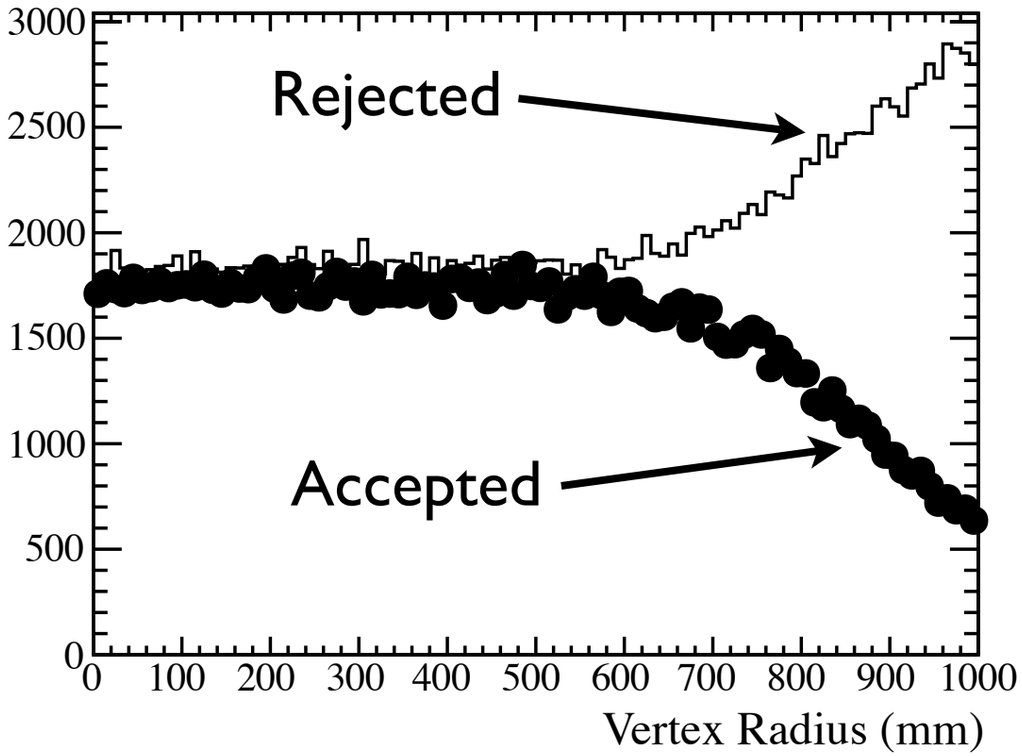
k = curvature of the track

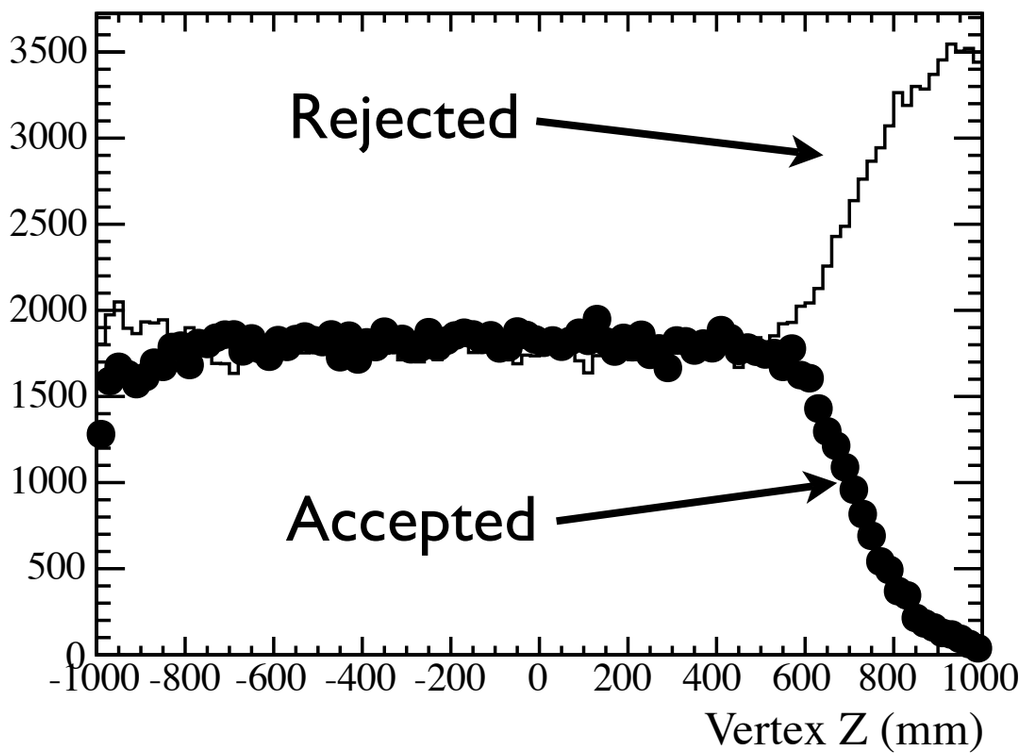
p_t = transverse momentum

B = magnetic field

$$\delta k_{\rm res}/k < 20\%, \qquad k = 0.3B/p_t$$

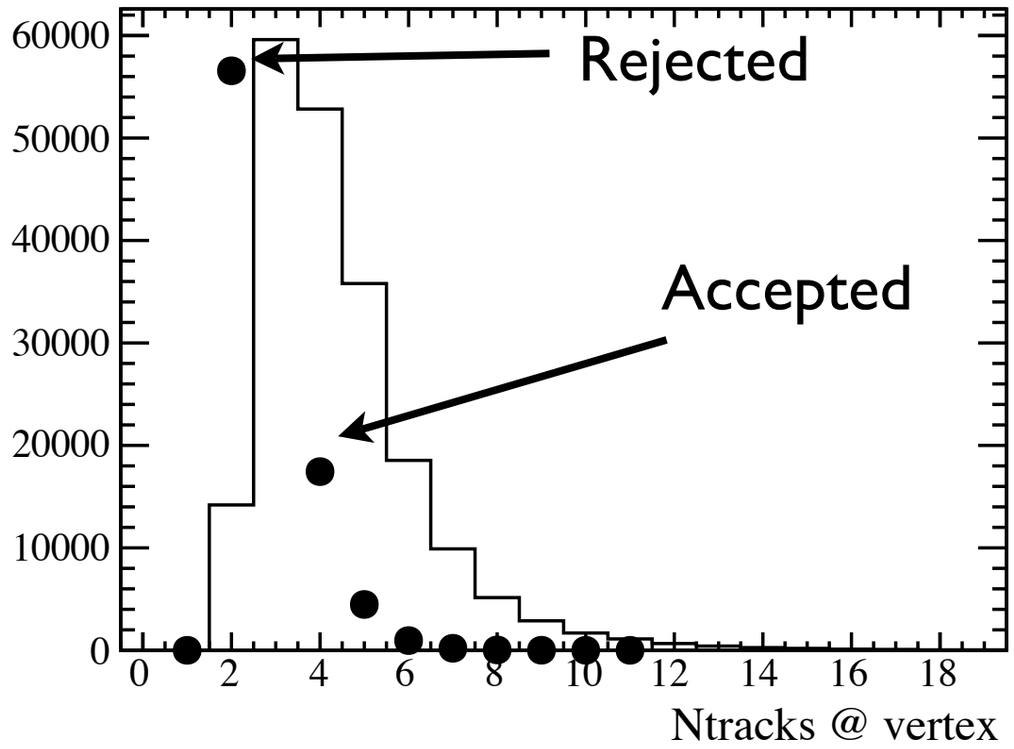
Acceptance

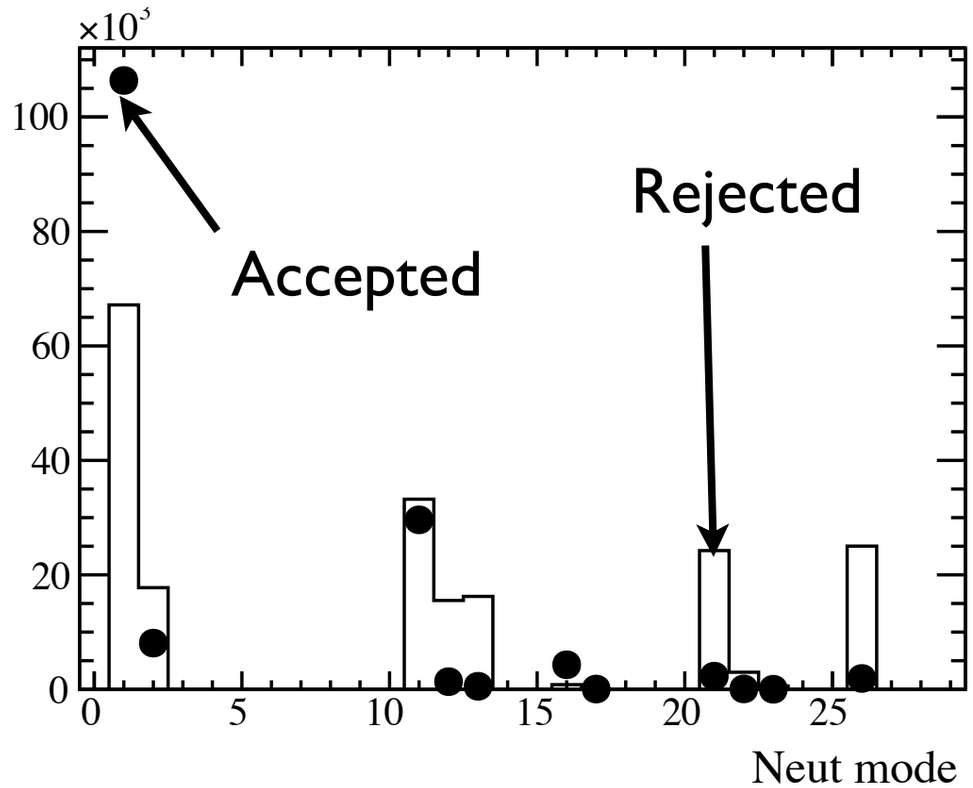




- Total acceptance: ~44%

Acceptance





- The acceptance penalize large multiplicities. Mainly pions!
- Many of these pions can be detected with external detectors. The detector surroundings are critical !