WP4: High Pressure TPC

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Outline

- Motivation & Physics goals
- Atmospheric TPC
- High Pressure TPC
- Conclusions

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?

News!

- T2K has submitted a proposal for a T2K-phase II.
- This proposal contains:
  - Increase of statistics (20 x 10^{21}) (actual 7.8x10^{21})
  - Potential upgrades of the near detector.

arXiv:1609.04111v1 [hep-ex] 14 Sep 2016

Proposal for an Extended Run of T2K to 20×10^{21} POT

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M. Hartz,[19,48] T. Hasegawa,[10,*] N.C. Hastings,[35] T. Hayashino,[21] Y. Hayato,[44,19]
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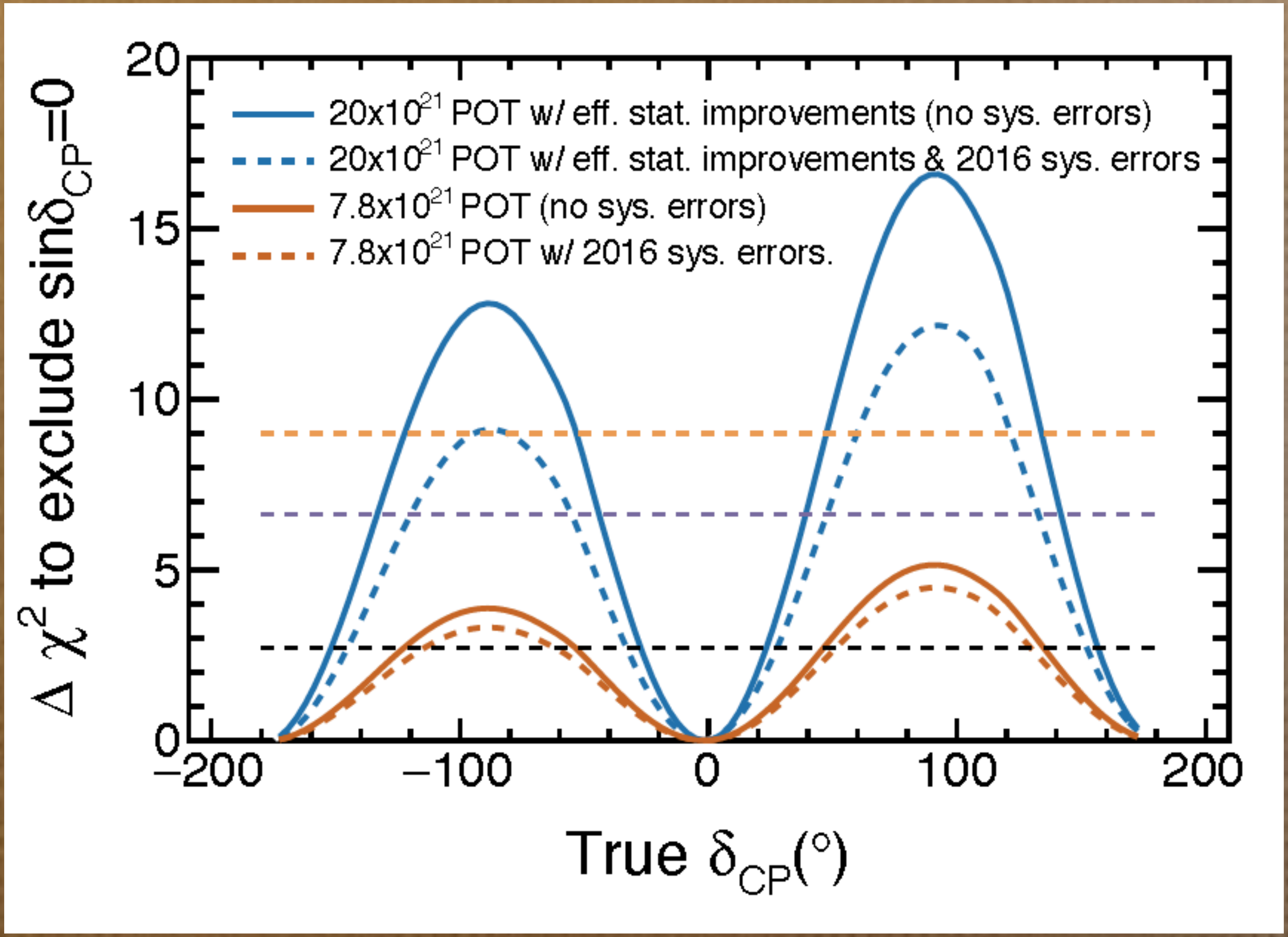
Sensitivity & systematics



News!

- Very agresive program to reduce the systematic error.
- Predictions for the flux estimations:

	Current Uncertainty (%)		Projected Uncertainty (%)	
Neutrino species	Absolute	Extrapolation	Absolute	Extrapolation
ν−mode, ν_μ	9.1	0.17	5.6	0.12
ν−mode, $\bar{\nu}_\mu$	7.6	0.62	6.6	0.38
ν−mode, ν_e	8.8	0.37	5.2	0.27
ν−mode, $\bar{\nu}_e$	7.2	0.50	5.0	0.41
$\bar{\nu}$−mode, ν_μ	7.3	0.61	6.3	0.31
$\bar{\nu}$−mode, $\bar{\nu}_\mu$	9.1	0.28	5.5	0.27
$\bar{\nu}$−mode, ν_e	6.7	0.73	4.8	0.33
$\bar{\nu}$−mode, $\bar{\nu}_e$	8.7	0.43	5.3	0.16

The oscillations

- The number of events depends on the cross-section:

$$N_{events}(E_\nu) = \sigma_\nu(E_\nu)\Phi(E_\nu)$$

- This is not so critical if we can determine the energy of the neutrino, since at the far detector

$$N^{far}_{events}(E_\nu) = \sigma_\nu(E_\nu)\Phi(E_\nu)P_{osc}(E_\nu)$$

- and it cancels out in the ratio as function of energy:

$$\frac{N^{far}_{events}(E_\nu)}{N_{events}(E_\nu)} = P_{osc}(E_\nu)$$

The oscillations

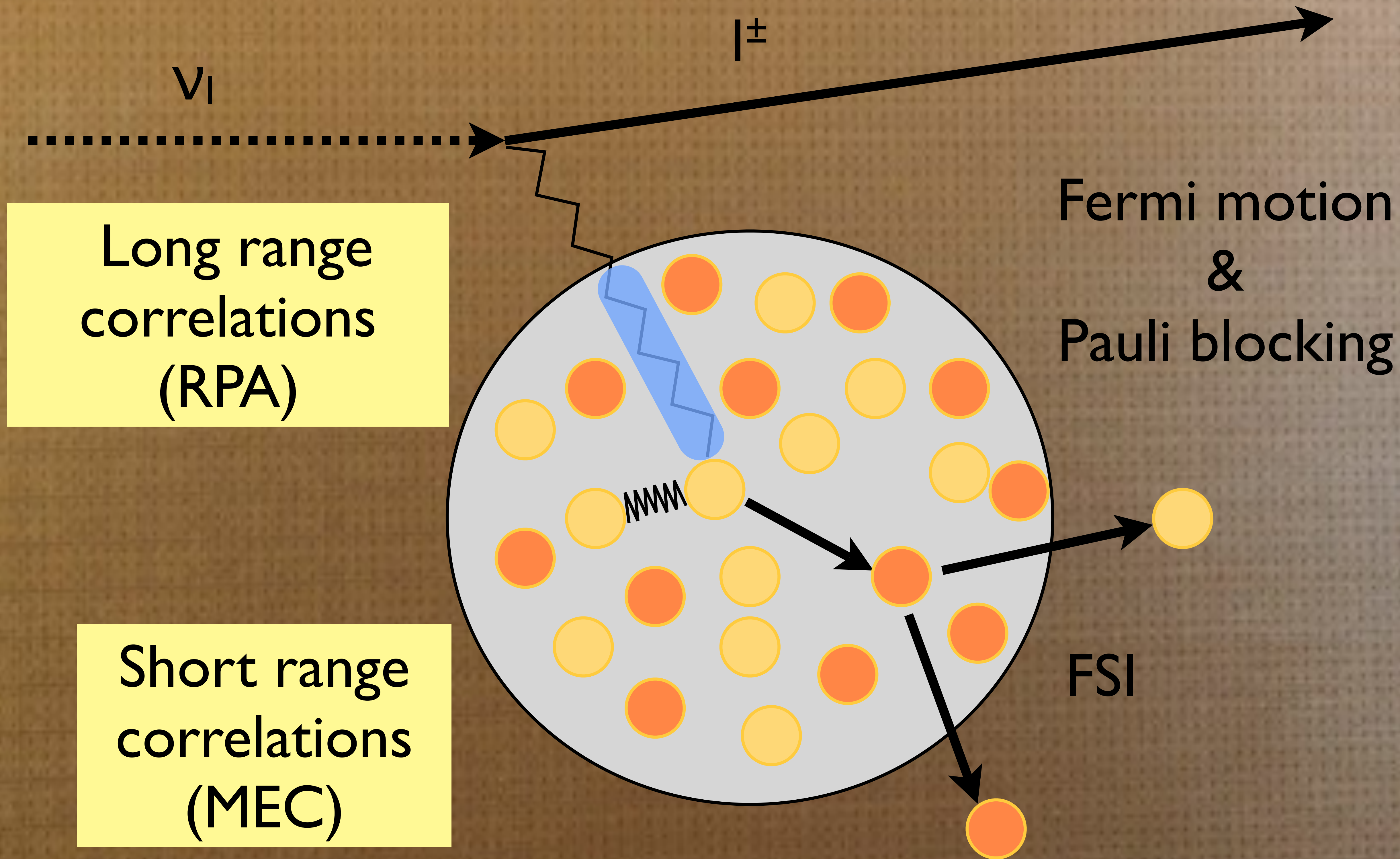
- Since the neutrino energy is not monochromatic, we need to determine event by event the energy of the neutrino.
- This estimation is not perfect, we have the problem that the cross-section does not cancels out in the ratio.

$$\frac{N^{far}_{events}(E_\nu)}{N_{events}(E_\nu)} = \frac{\int \sigma(E'_\nu)\Phi(E'_\nu)P(E_\nu|E'_\nu)P_{osc}(E'_\nu)dE'_\nu}{\int \sigma(E'_\nu)\Phi(E'_\nu)P(E_\nu|E'_\nu)dE'_\nu}$$

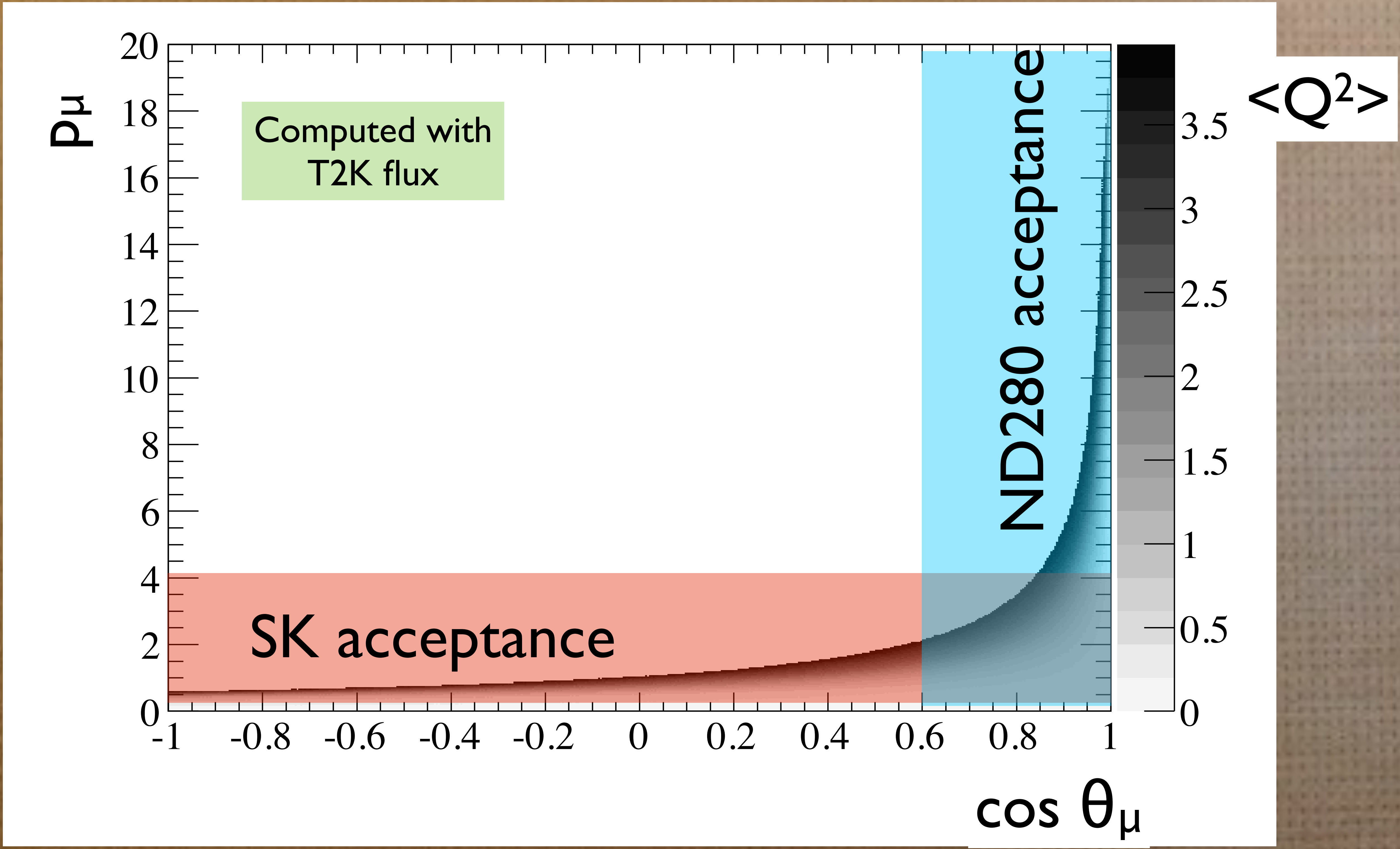
- The neutrino oscillations introduce differences in the flux spectrum and the ratio does not cancel the cross-sections.

Oscillation experiments require to know $\Phi(E_\nu)$, $\sigma(E_\nu)$ & $P(E_\nu|E'_\nu)$

Cross-section



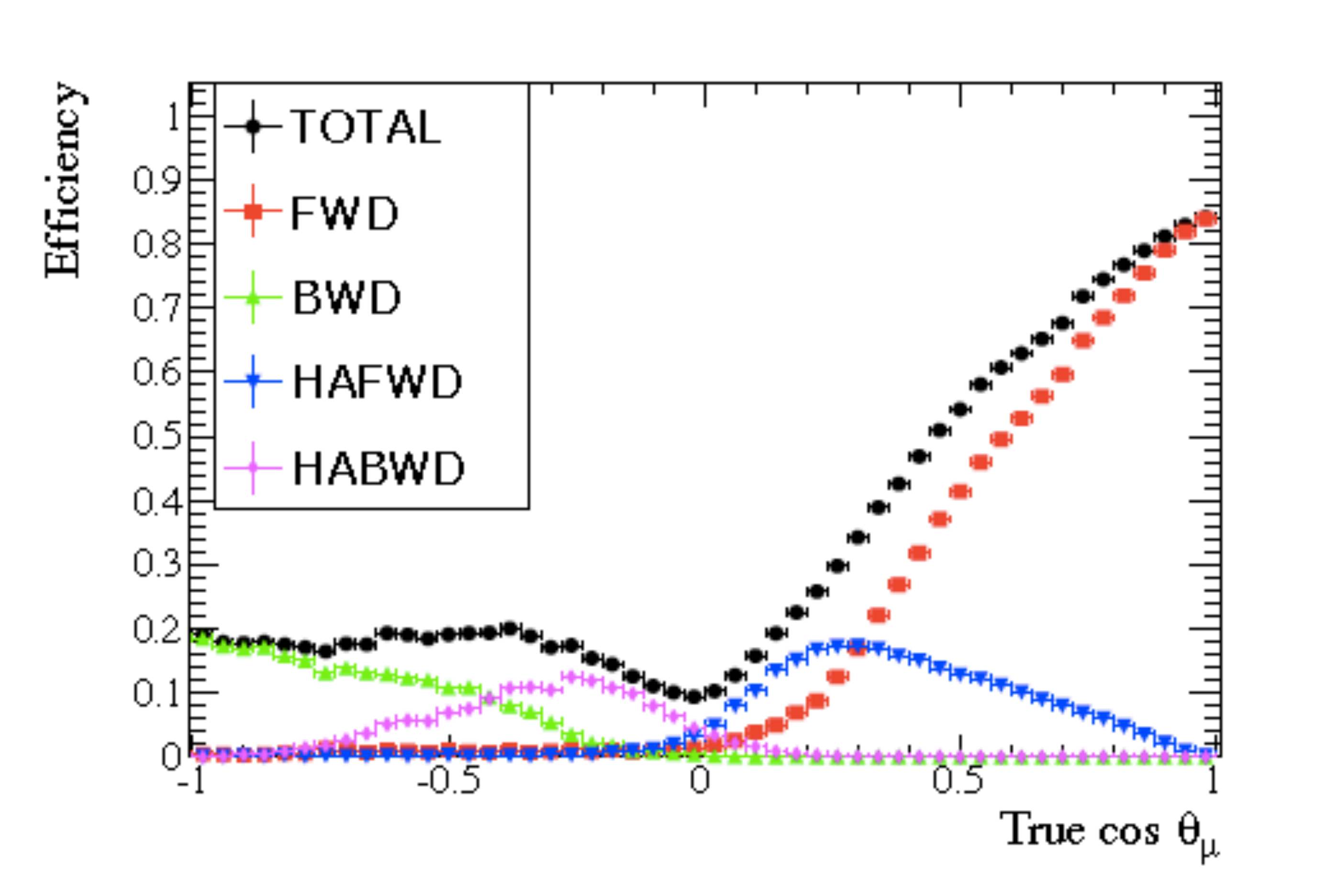
Acceptance



Computed with T2K flux
ND280 acceptance
SK acceptance
p_μ
$\cos\theta_\mu$
$<Q^2>$
20
18
16
14
12
10
8
6
4
2
0
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
3.5
3
2.5
2
1.5
1
0.5
0

The main issue

- The near detector acceptance does not match the far detector:
  - high angle and low momentum has low efficiency.



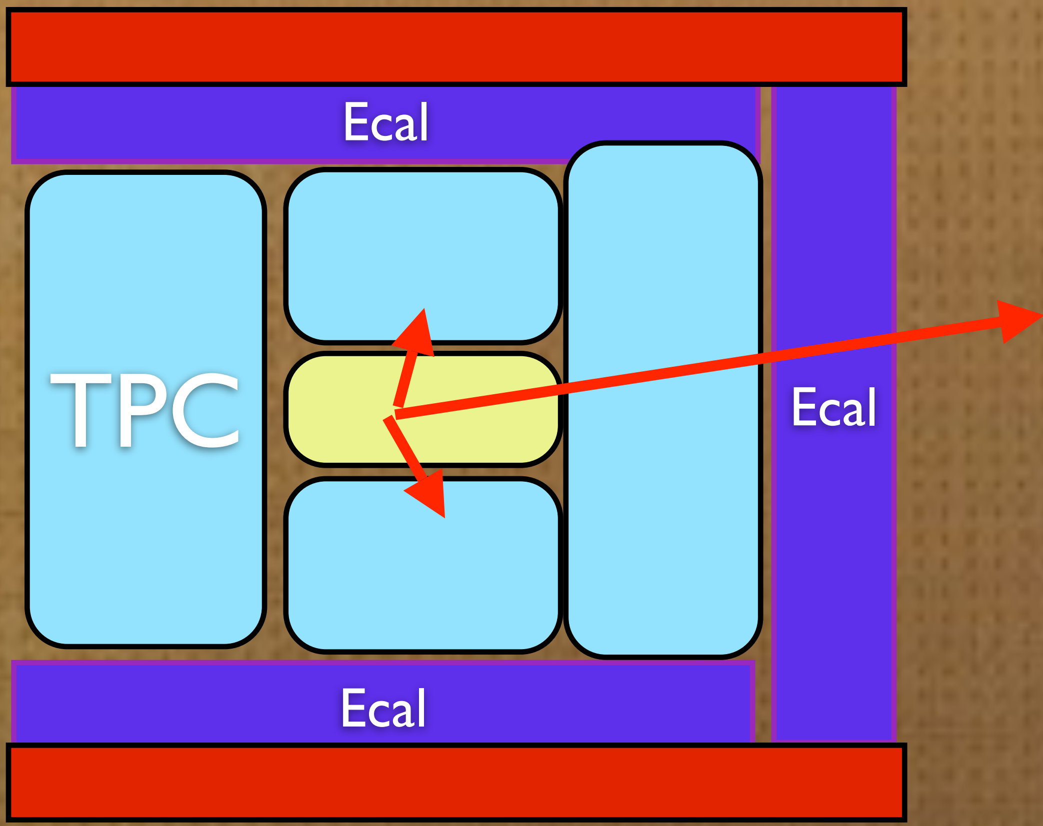
Red is used until now, new analysis will cover high angles.

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 ?
  - bind energy ?

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

TPC upgrade concept



T2K phase II near detector

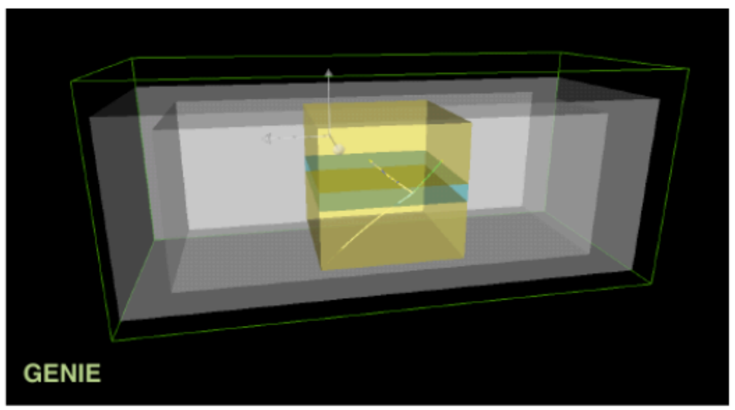
- Target is not the TPC so we can use H_20 as target.
- High Pressure is not needed in this case.

- Minimal upgrade pointing to acceptance matching!
- Interest from several institutions (all WP4 from Jennifer + many more)
- workshop being organised at CERN the 7th and 8th November 2016:
  - https://indico.cern.ch/event/569777/

TPC upgrade

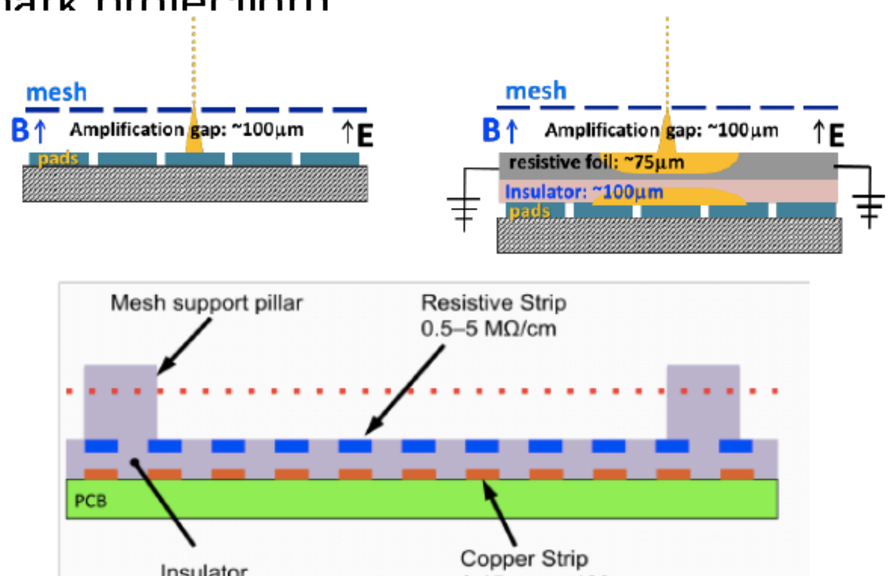
Geant4 framework

- Framework developed to study acceptance and efficiencies issues with a parameterized detector response



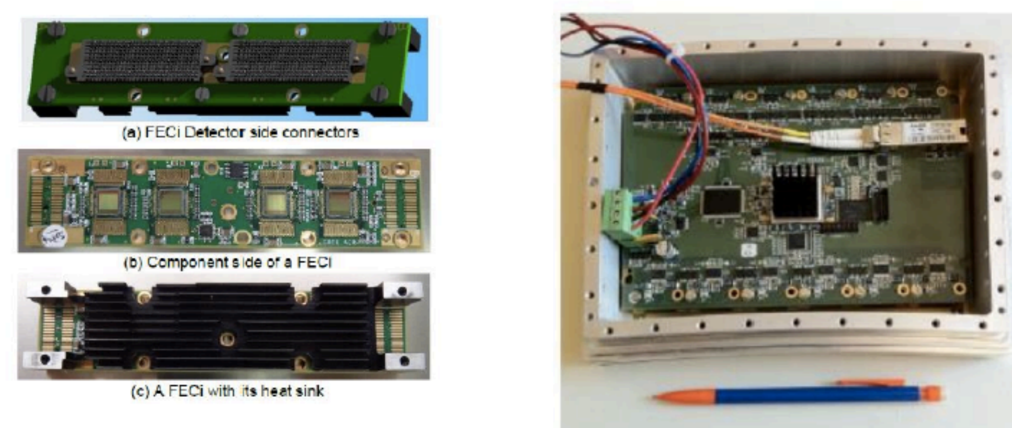
Resistive Bulk Micromegas

- Several advantages (charge spread, intrinsic spark protection)
-



- Activities and R&D already starting.

ILC TPC R/O electronics



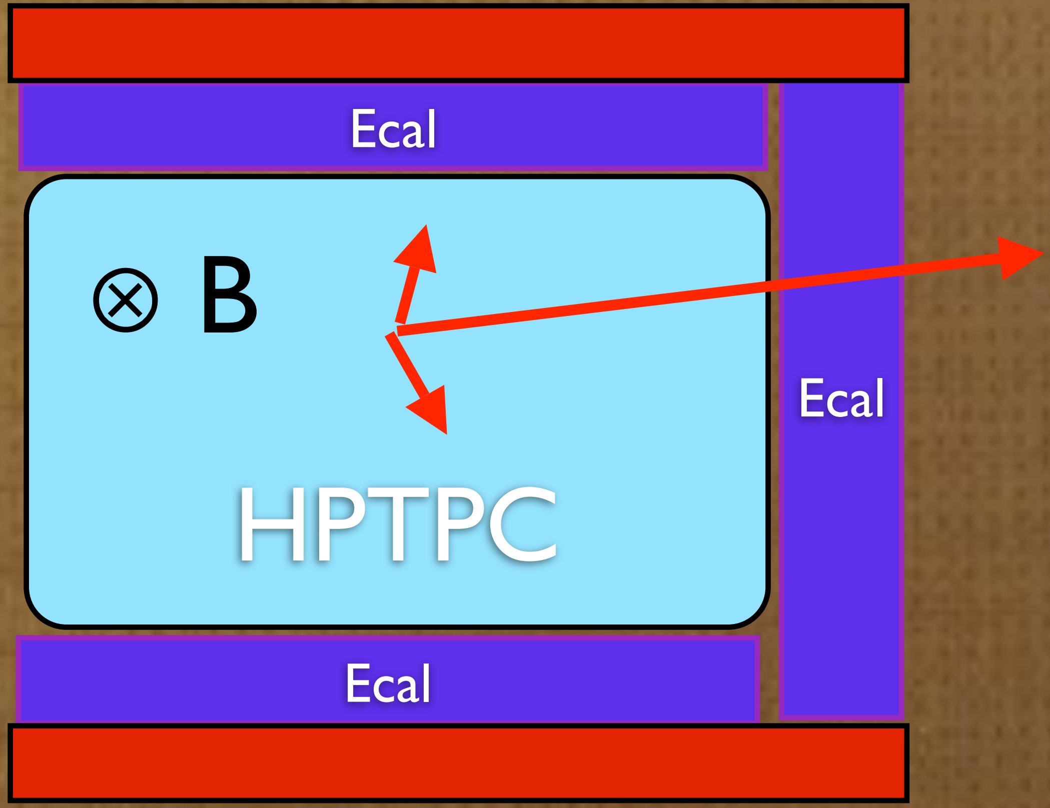
Size: 1/10 of a T2K TPC FEC, for the same number of channels. Flat readout achieved for a pad size of 3x7 mm**2. We plan to use a pad size ~~100 mm*2

Marco Zito

HPTPC concept

Not all issues are covered by the atmospheric TPC upgrade:

low energy protons and pions!



Cross-section experiment

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

Near detector

- Low momentum detected inside the TPC.
- High uniform acceptance.

Number of Events

As a cross-section experiment, HPTPC allows to change the nuclear target addressing nuclear uncertainties systematics.

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

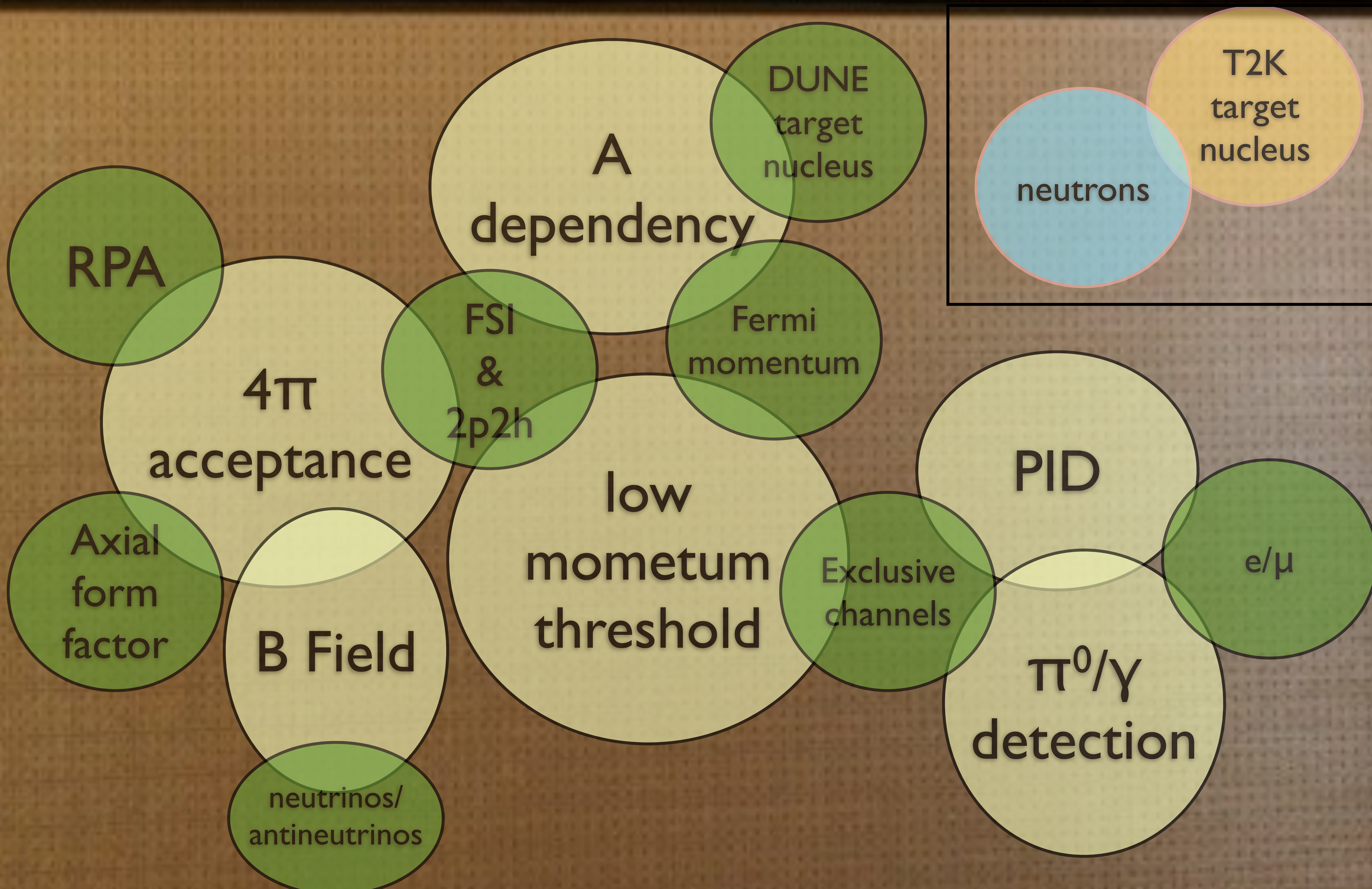
why a TPC ?

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


DUNE target nucleus
A dependency
RPA
4π acceptance
FSI & 2p2h
Fermi momentum
low mometum threshold
Axial form factor
B Field
neutrinos/ antineutrinos
Exclusive channels
PID
e/μ
π0/γ detection
T2K target nucleus
neutrons

Action 1

- Requested an EU ITN student network by 12 institutions in europe (France, Germany, Italy, Poland, Spain, Switzerland & UK)
  - Program includes Theory-Experiment interplay.
  - good grades but rejected due to lack of industrial partners!.
- Resubmission this year under the new paradigm that includes CERN.

Action 2

- CERN Neutrino Platform got interested in the proposal as its contribution to T2K (and DUNE) activities.
- Pushing for a workshop at CERN and looking for ways of collaboration with other institutions.
- Plan to elaborate an R&D program based at CERN with collaboration from many institutions to develope both TPC and HPTPC technologies for neutrino oscillations.
    - side subjects as Dark Matter searches or Double Beta decay can be accommodated in case of common developments.

Conclusions

- Atmospheric full coverage TPC upgrade for T2K phase II. Interest from many institutions including CERN and Japanese groups.
- HPTPC is considered in two scenarios:
  - Near detector upgrade 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.