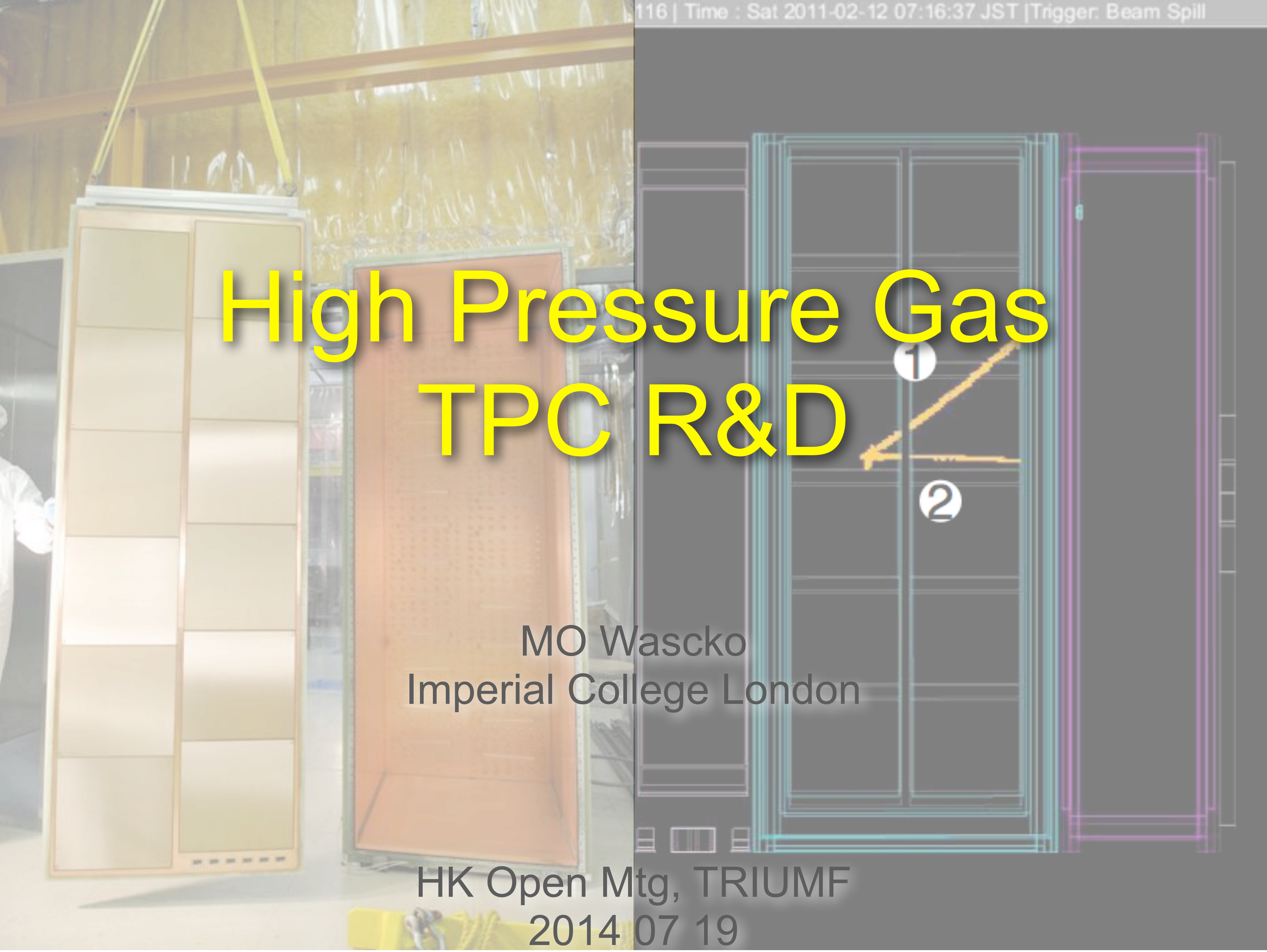


High Pressure Gas TPC R&D

MO Wascko
Imperial College London

HK Open Mtg, TRIUMF
2014 07 19

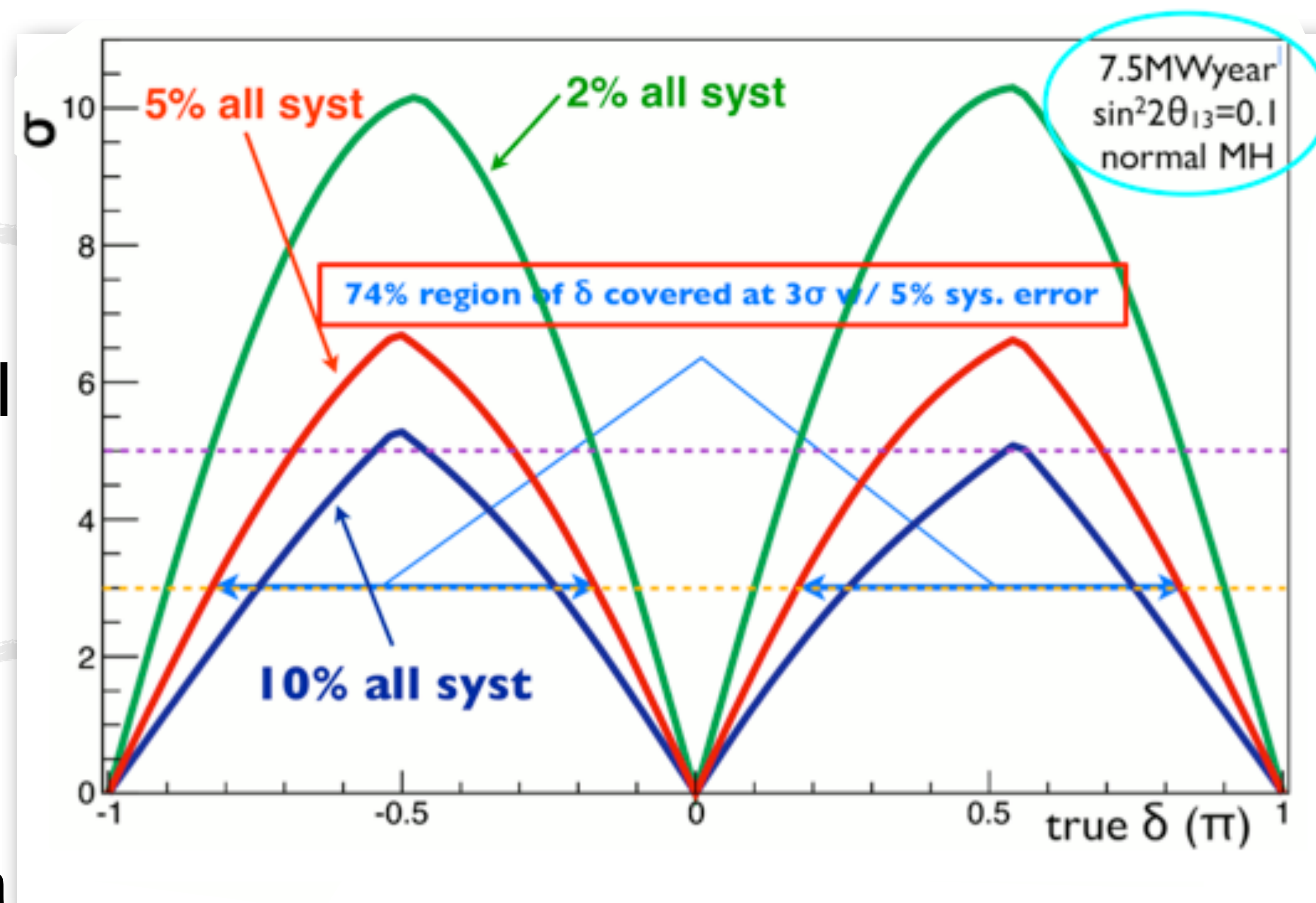
Outline

- Motivation
  - neutrino-nucleus interaction systematics
- Properties/Advantages of HPTPC
  - event rates
  - detection thresholds
- Status and next steps

Motivation: xsec systematics

- Current T2K ν_e appearance xsec systematics at ~8% level
- CPV sensitivity improved dramatically with 2% overall systematics
- Systematics driven by discrepancies between interaction models and data

➡ Need better models in generators, and better data for tuning models

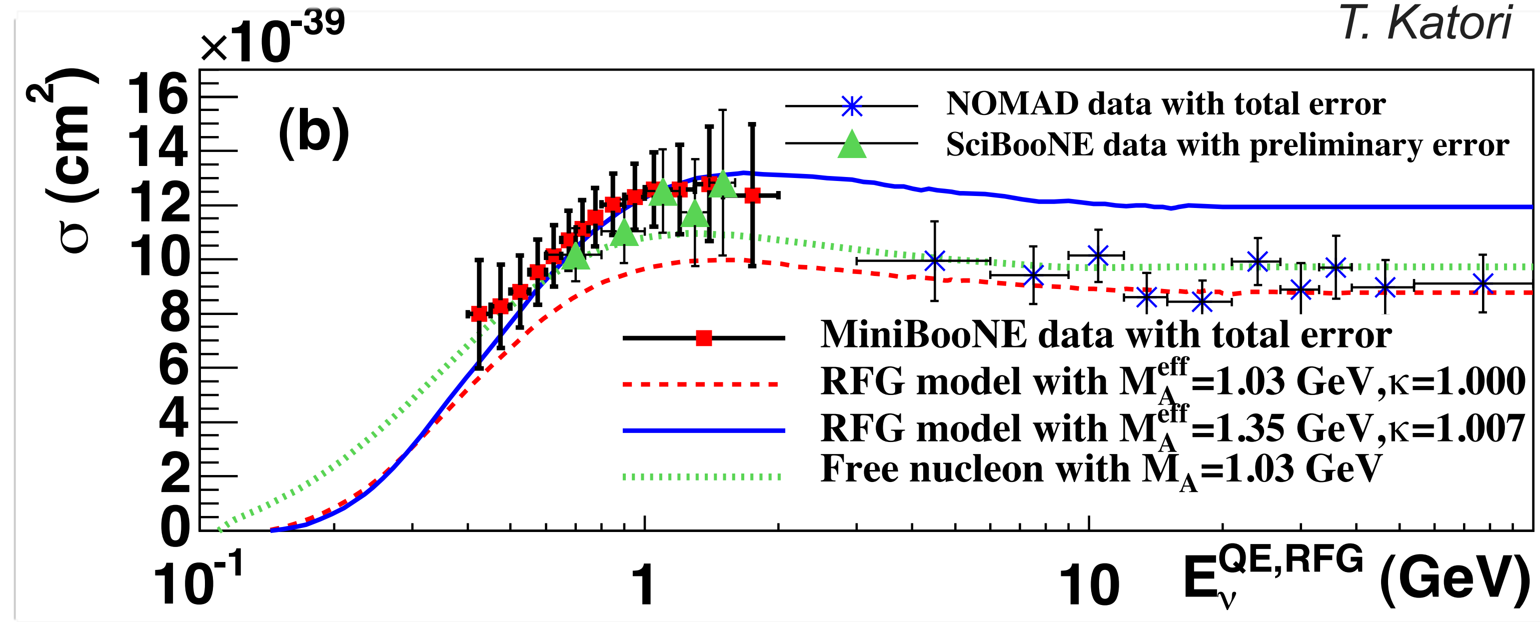


HK CPV sensitivity

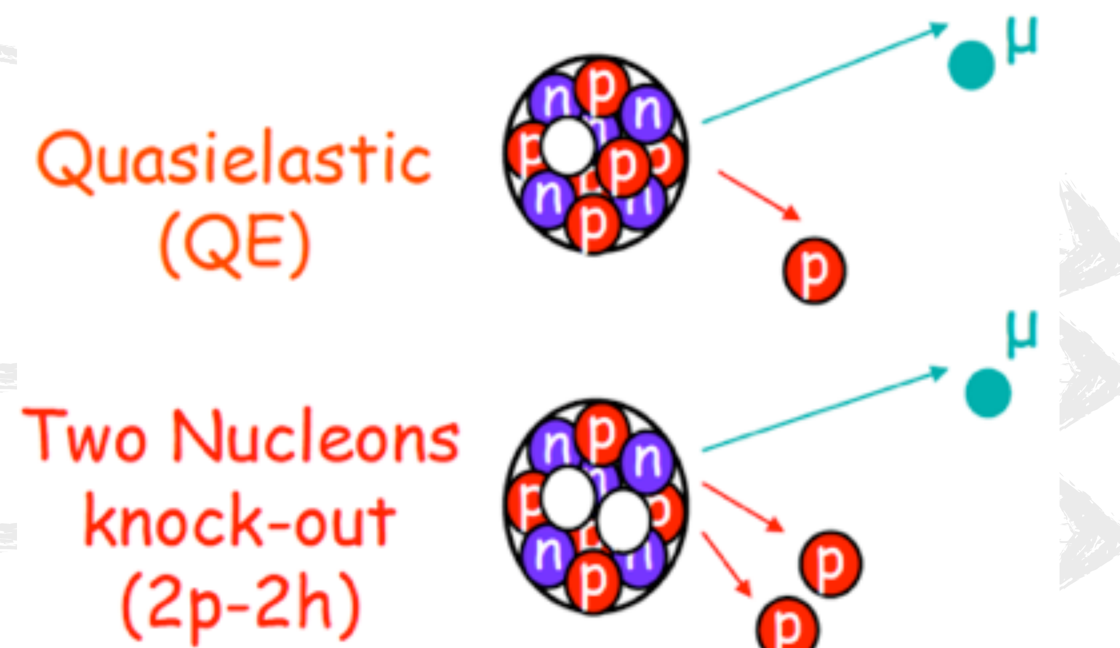
Cross-section systematics

- Recent ν_μ CCQE data show low/high E_ν discrepancies
  - MiniBooNE/SciBooNE & NOMAD
- Explanation: multinucleon scattering—not simulated by neutrino interaction generator MCs
  - ➡Not included in MINOS, MiniBooNE, early T2K publications
- Misidentified events are not reconstructed correctly—results in biased E_ν

T. Katori



arXiv:1002.2680 [hep-ex]



M. Martini

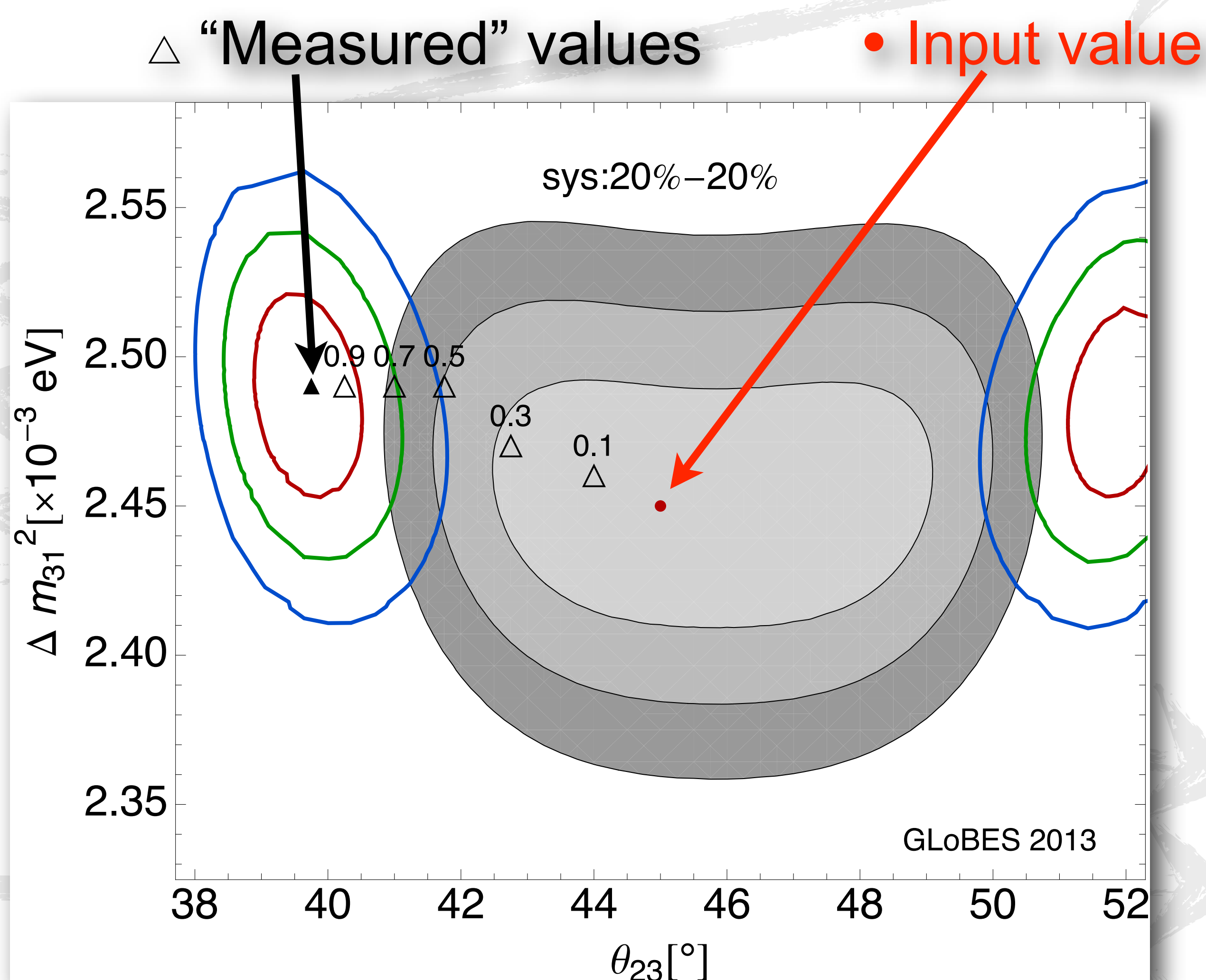
arXiv:0910.2622[hep-ex]

Effect on oscillation experiments

- Example: ν_μ disappearance with generic nuclear effects
  - Parameterise fraction of nuclear effects that are neglected
- Shifts the measured values of θ_{23} by 5° degrees and Δm^2_{31} by .05 eV^2
  - Can change interpretation: true maximal mixing can appear as non-maximal
- Danger!
  - These effects **do not cancel** in near-far extrapolation

➡ Using the wrong model at near and far detector does not accurately simulate Nature

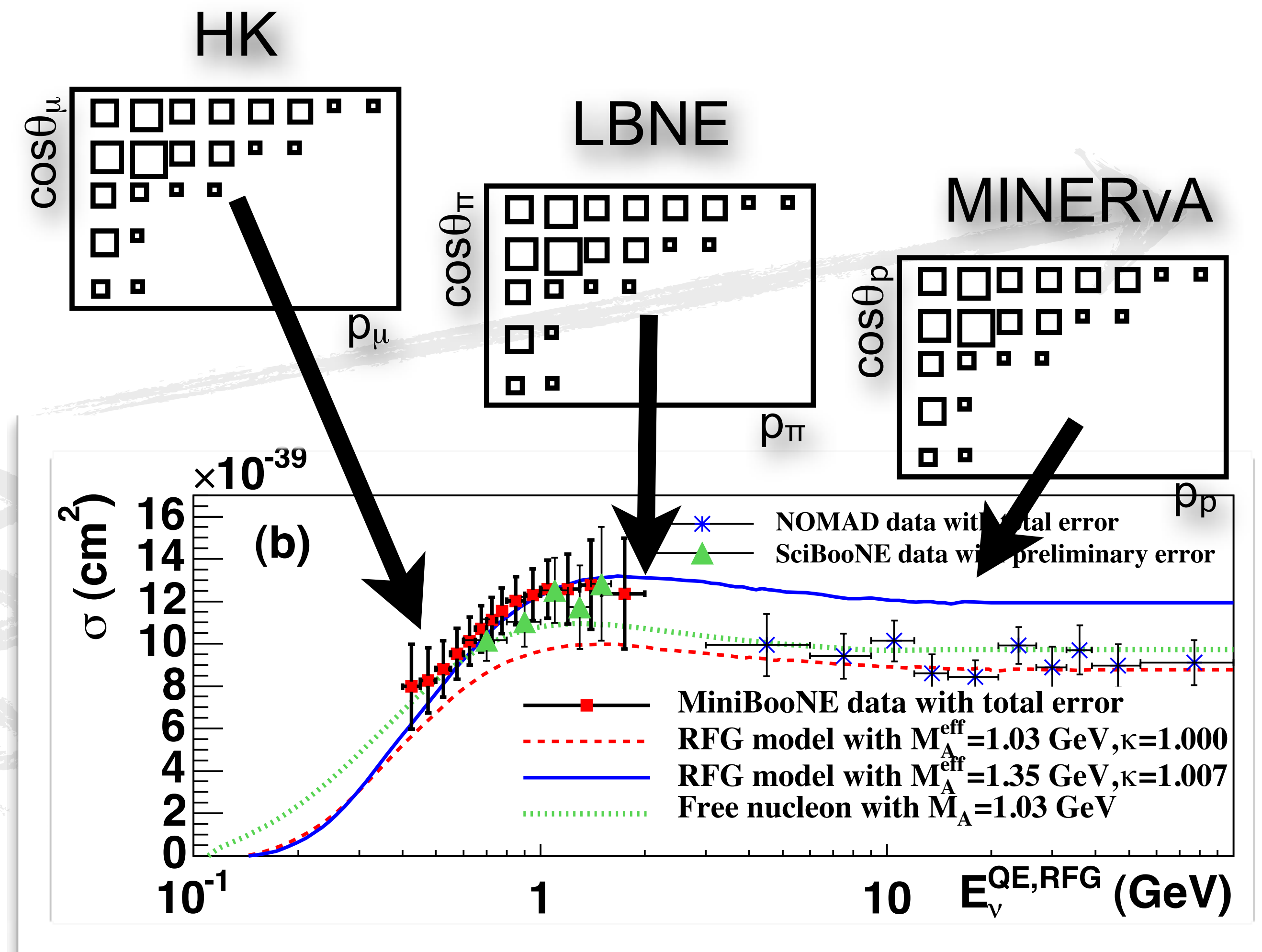
Coloma & Huber, arXiv:1307.1243 [hep-ph]

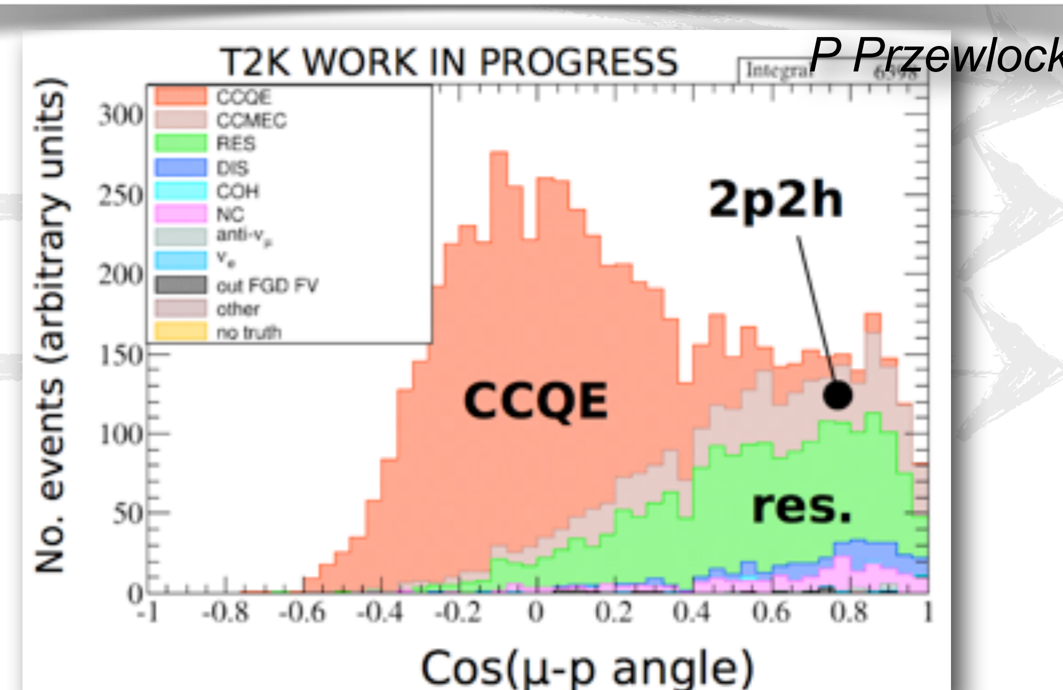


Growing Consensus

- We need broad coverage
  - Model independent measurements spanning full phase space (E_ν, Q^2) and many nuclei
- Need sufficiently low energy thresholds for recoil nucleons to separate 1p1h from 2p2h events
  - Also need sufficiently good theoretical models to robustly predict spectra!

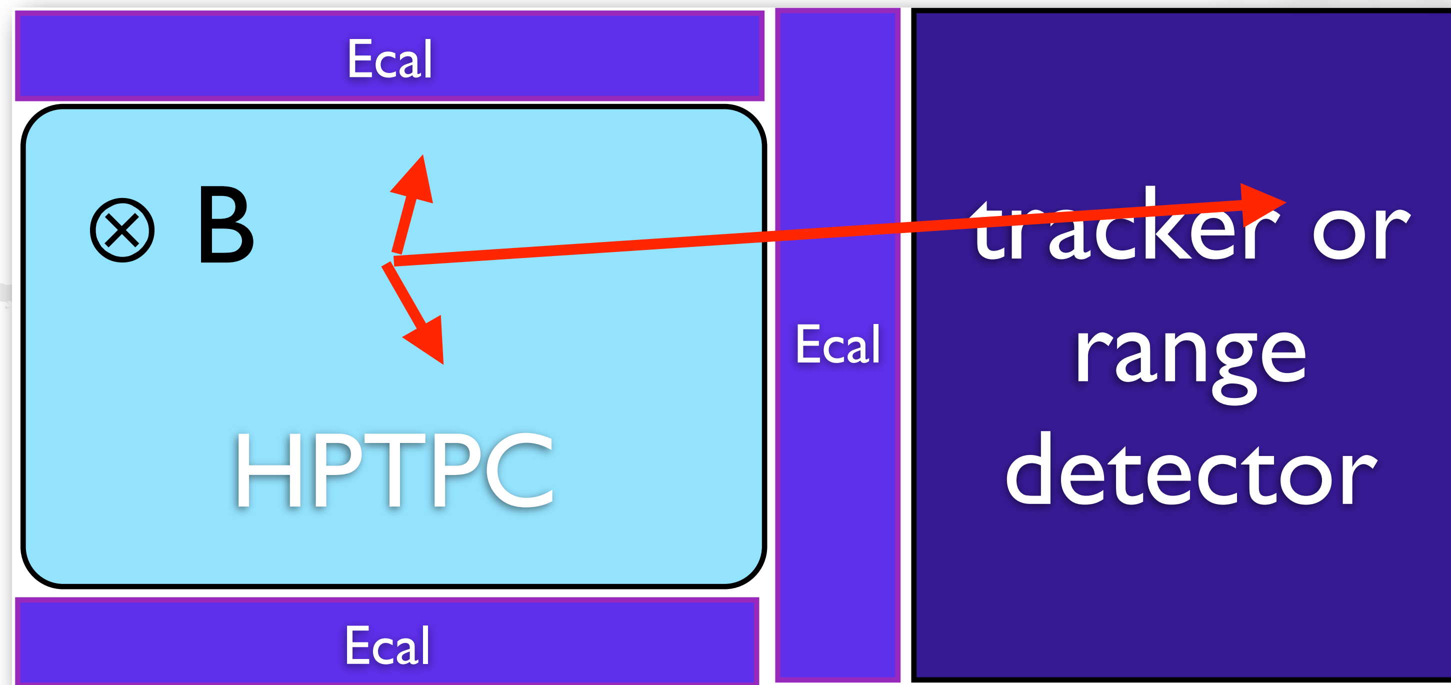
➡ Gas TPC provides unique opportunities to address issues





Basics of Gas TPC

F. Sanchez



- ~4π coverage
- Easily magnetised
- 3D reconstruction
- Target flexibility
- Low momentum particle detection threshold
  - Good for model discrimination, generator tuning
- Synergy with dark matter

Baseline concept is 8 m^3 magnetised volume with ND280 micromegas readout, surrounded by ECals with tracking down stream. *This configuration must be optimised.*

Presented at T2K ND280 upgrade workshop, NuInt14.

Not a new idea! Already explored by NF, LBNO, NuSTORM...

Properties of Gas TPC

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- Easily magnetised
- ➡ 3D reconstruction
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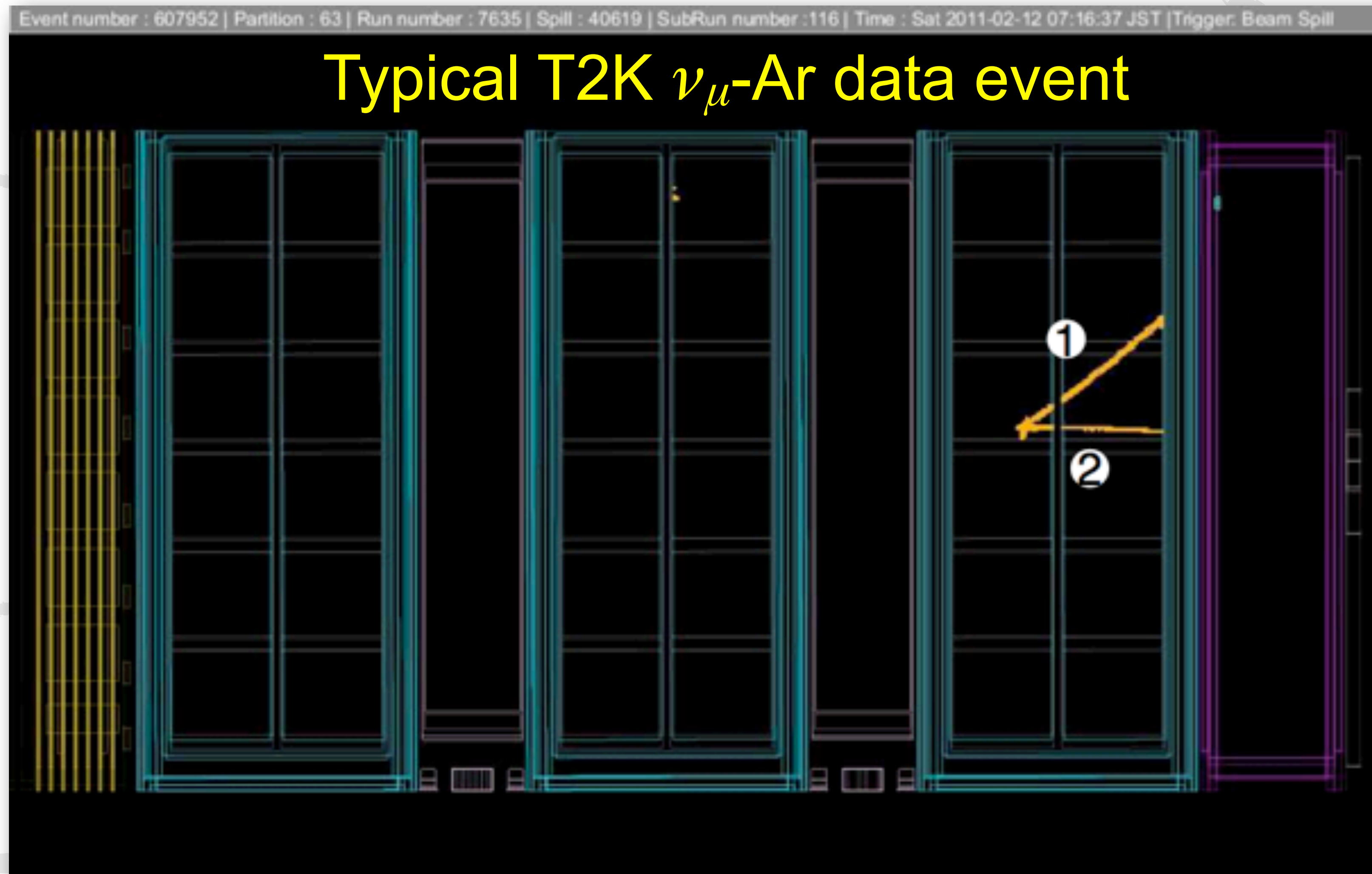

Currently analysing ν_μ interactions on Ar gas in existing T2K data.
P. Hamilton (Imperial), IOP HEP 2014 and NuInt14

Advantages of Gas TPC

- ~4π coverage
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- 3D reconstruction
- ➡ Target flexibility
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EVENT RATES
(SCALED FROM T2K ND280 RATES)

F. Sanchez

$2 \times 2 \times 2\ m^3$ 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

Advantages of Gas TPC

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➡ Low momentum particle detection threshold
  - Good for model discrimination, generator tuning
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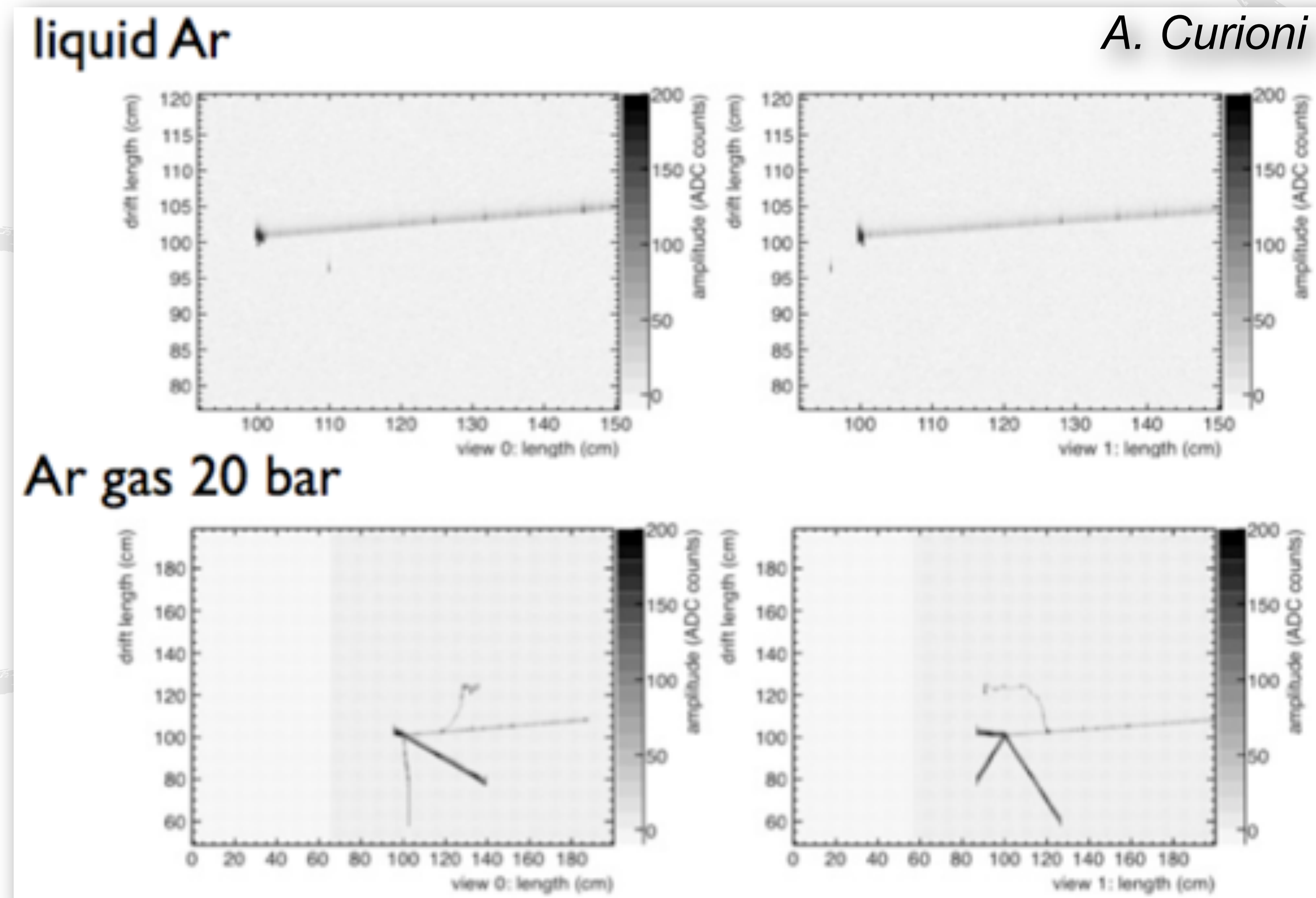

LBNO near detector simulations.

T. Stainer (Liverpool), IOP HEP 2014

Advantages of Gas TPC

- ~4π coverage
  - Easily magnetised
  - 3D reconstruction
  - Target flexibility
- Low momentum particle detection threshold
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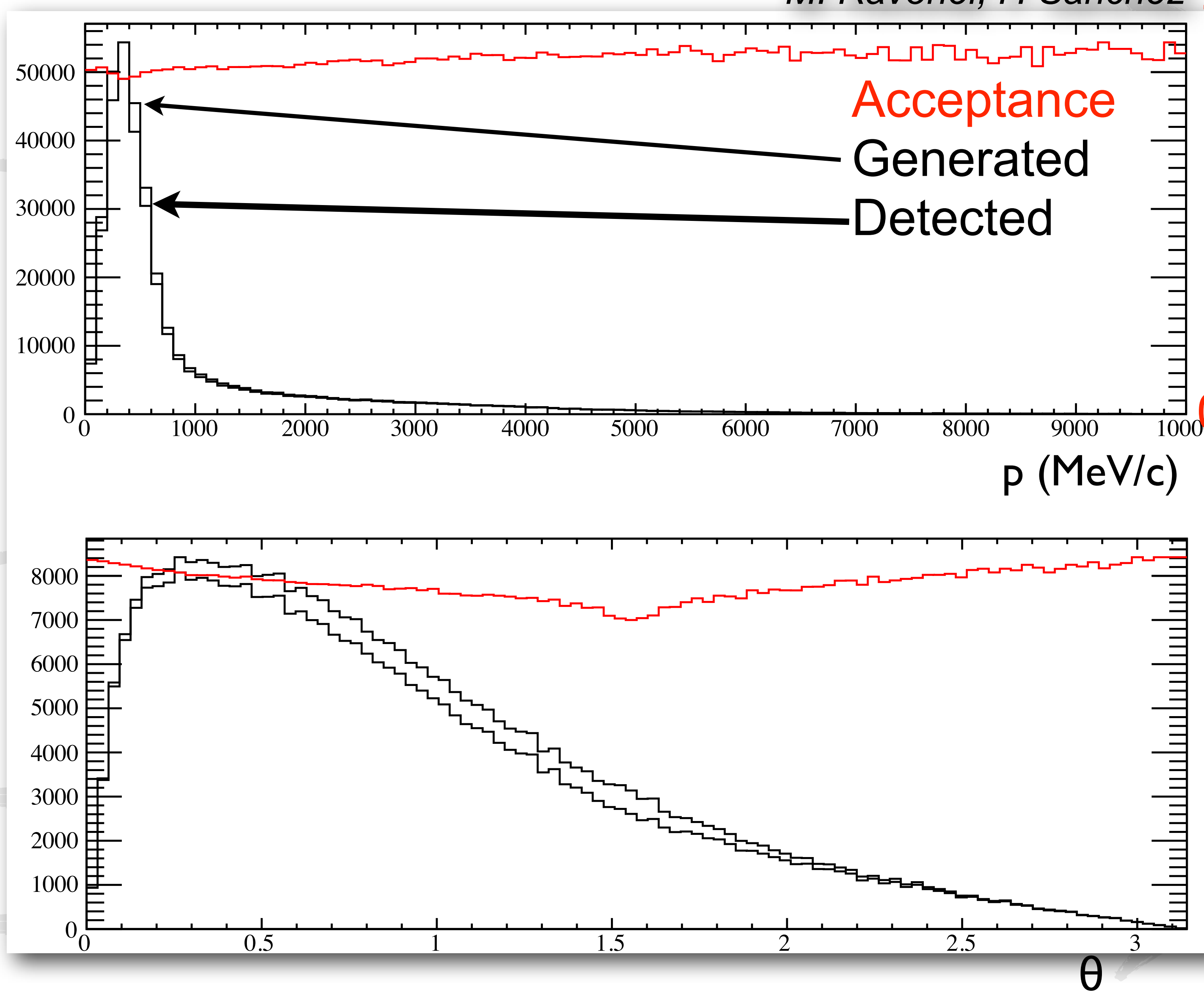
  - Synergy with dark matter

M. Ravonel, F. Sanchez



MUON ACCEPTANCE

Advantages of Gas TPC

- ~4π coverage
- Easily magnetised
- 3D reconstruction
- Target flexibility
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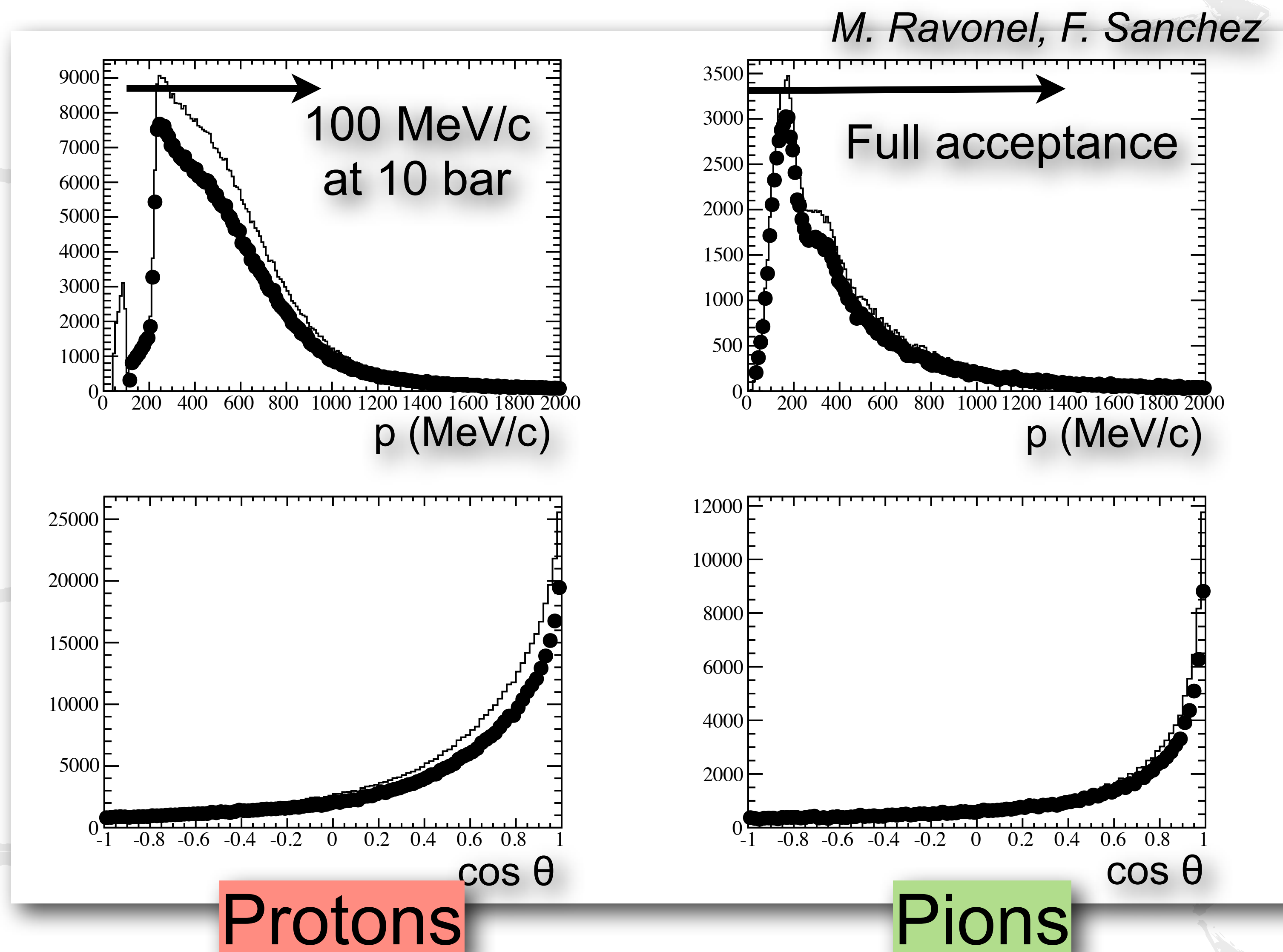

Advantages of Gas TPC

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- Easily magnetised
- 3D reconstruction
- Target flexibility

➡ Low momentum particle detection threshold

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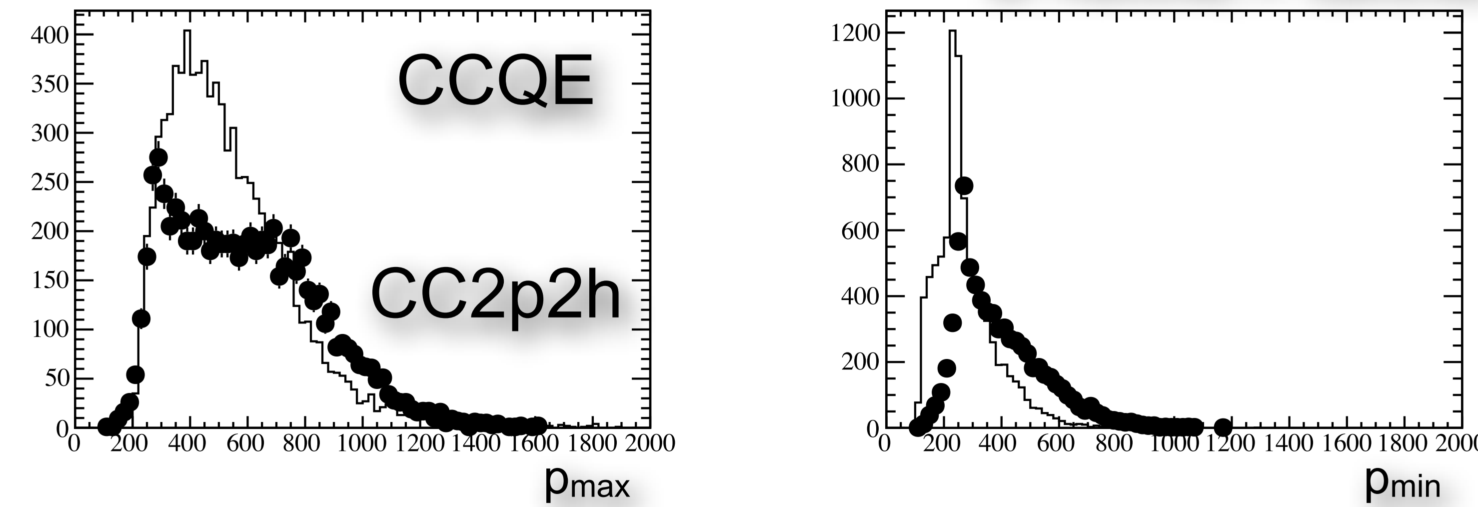
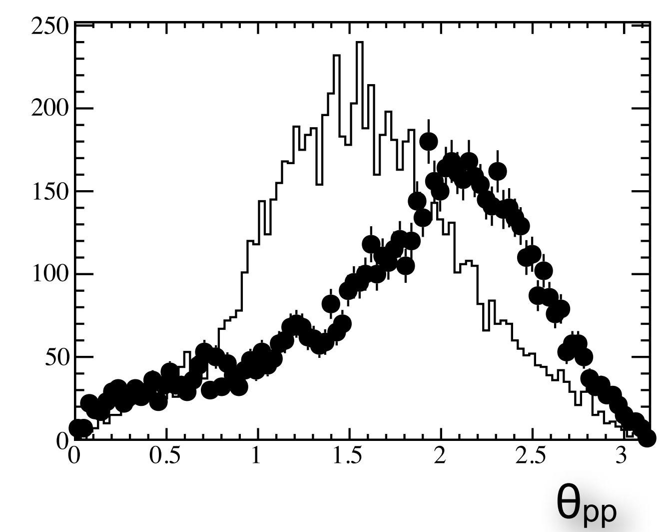
M. Ravonel, F. Sanchez





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

Advantages of Gas TPC

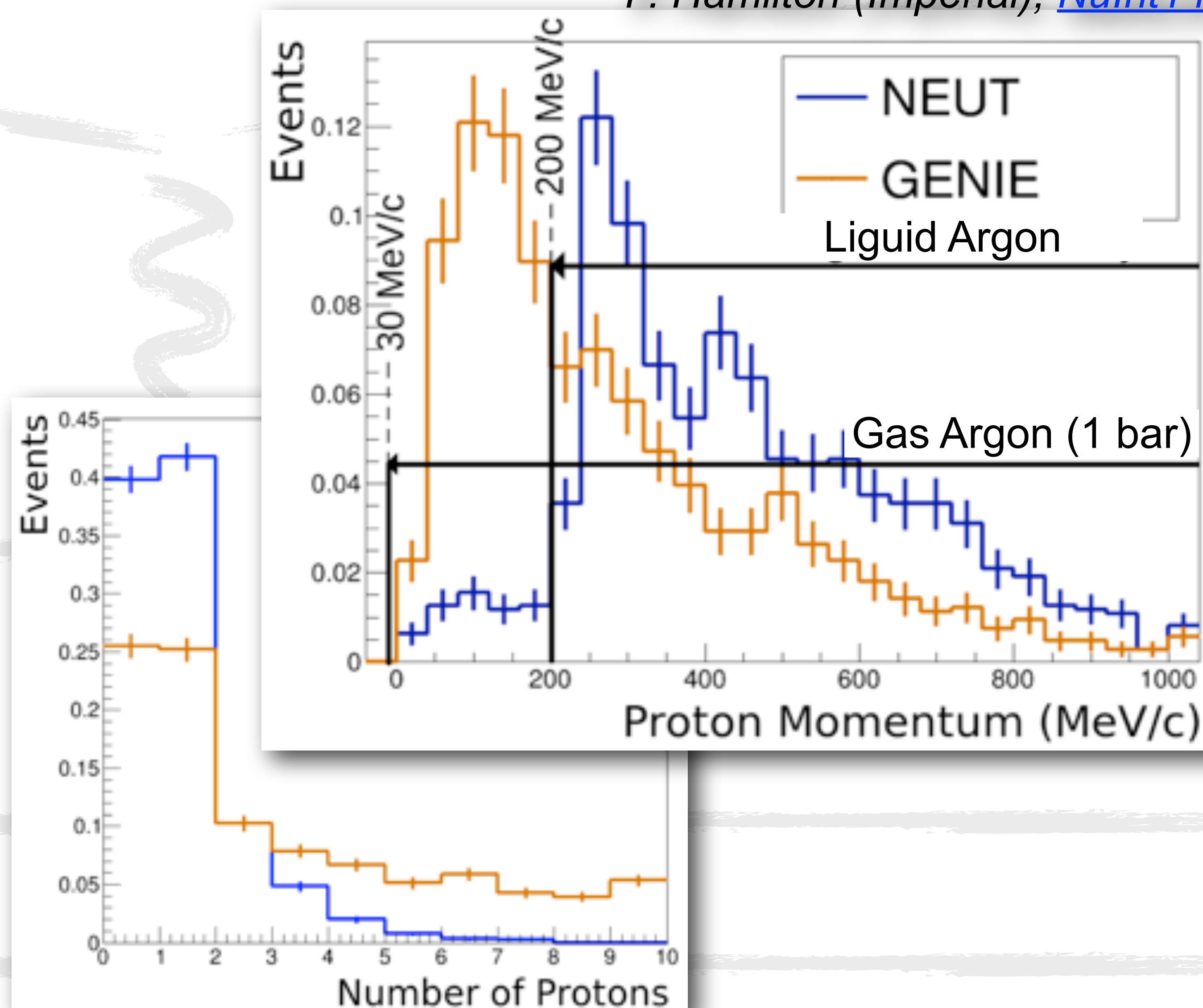
- *~4π* coverage
- Easily magnetised
- 3D reconstruction
- Target flexibility

➡ Low momentum particle detection threshold

➡ Good for model discrimination, generator tuning

- Synergy with dark matter

P. Hamilton (Imperial), NuInt14

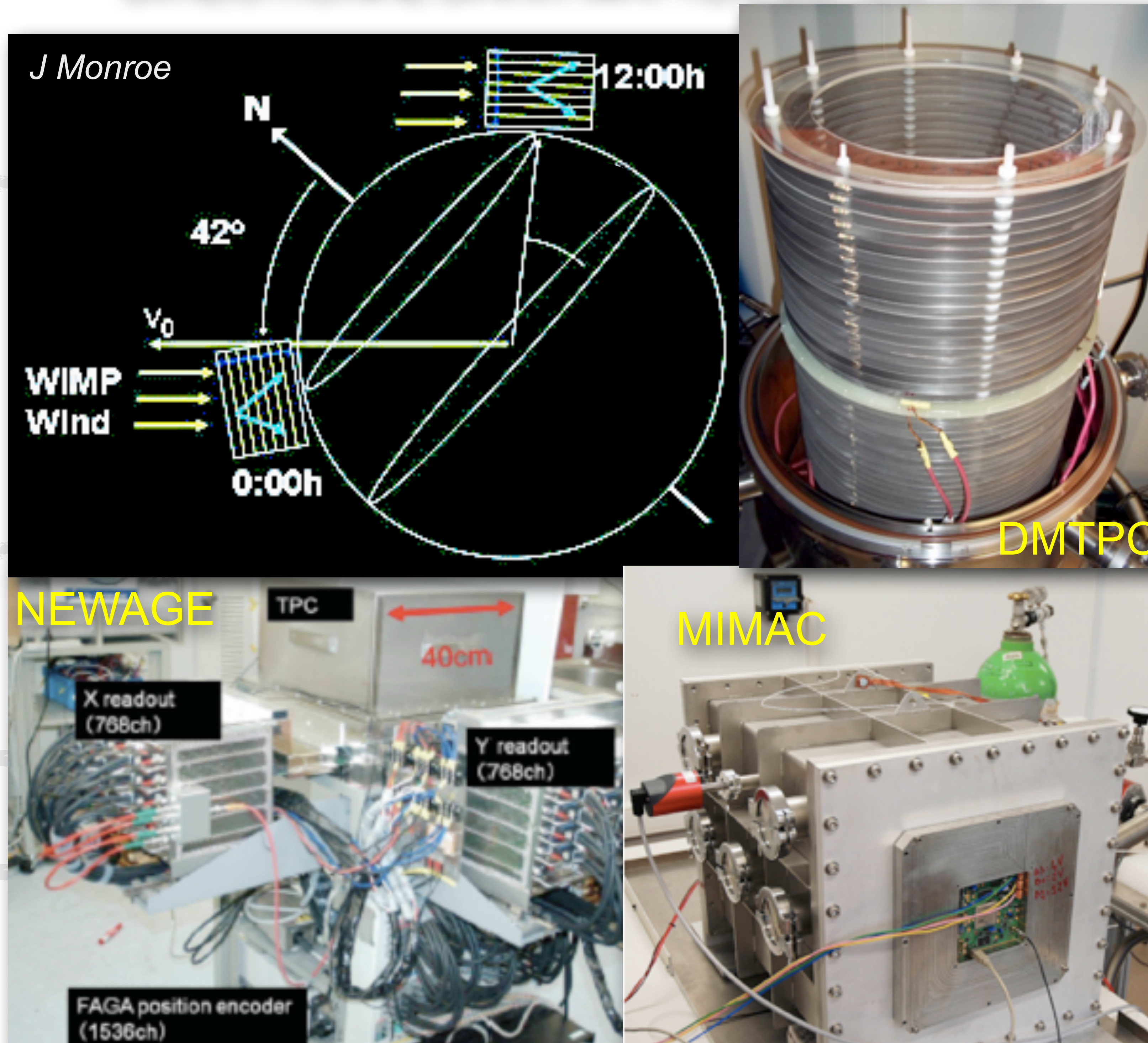


Advantages of Gas TPC

- ~4π coverage
- Easily magnetised
- 3D reconstruction
- Target flexibility
- Low momentum particle detection threshold
  - Good for model discrimination, generator tuning

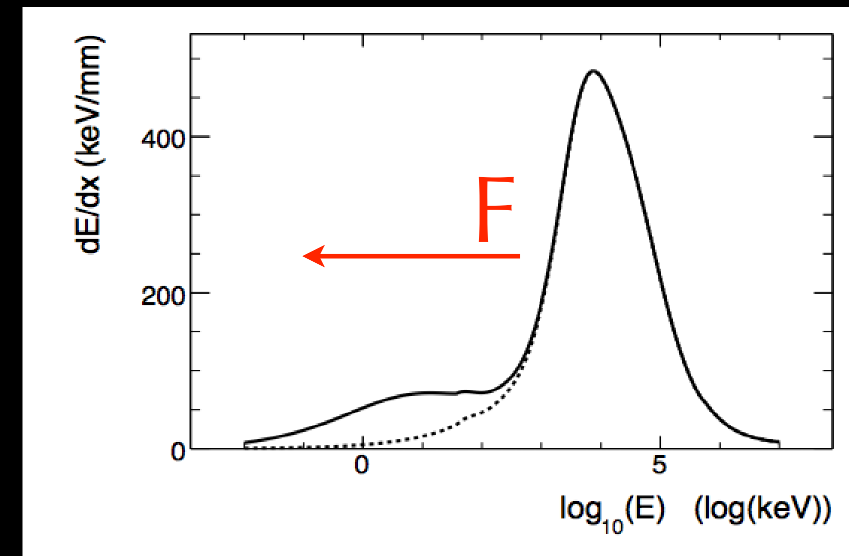
➡ Synergy with dark matter experiments

DIRECTIONAL DARK MATTER DETECTION

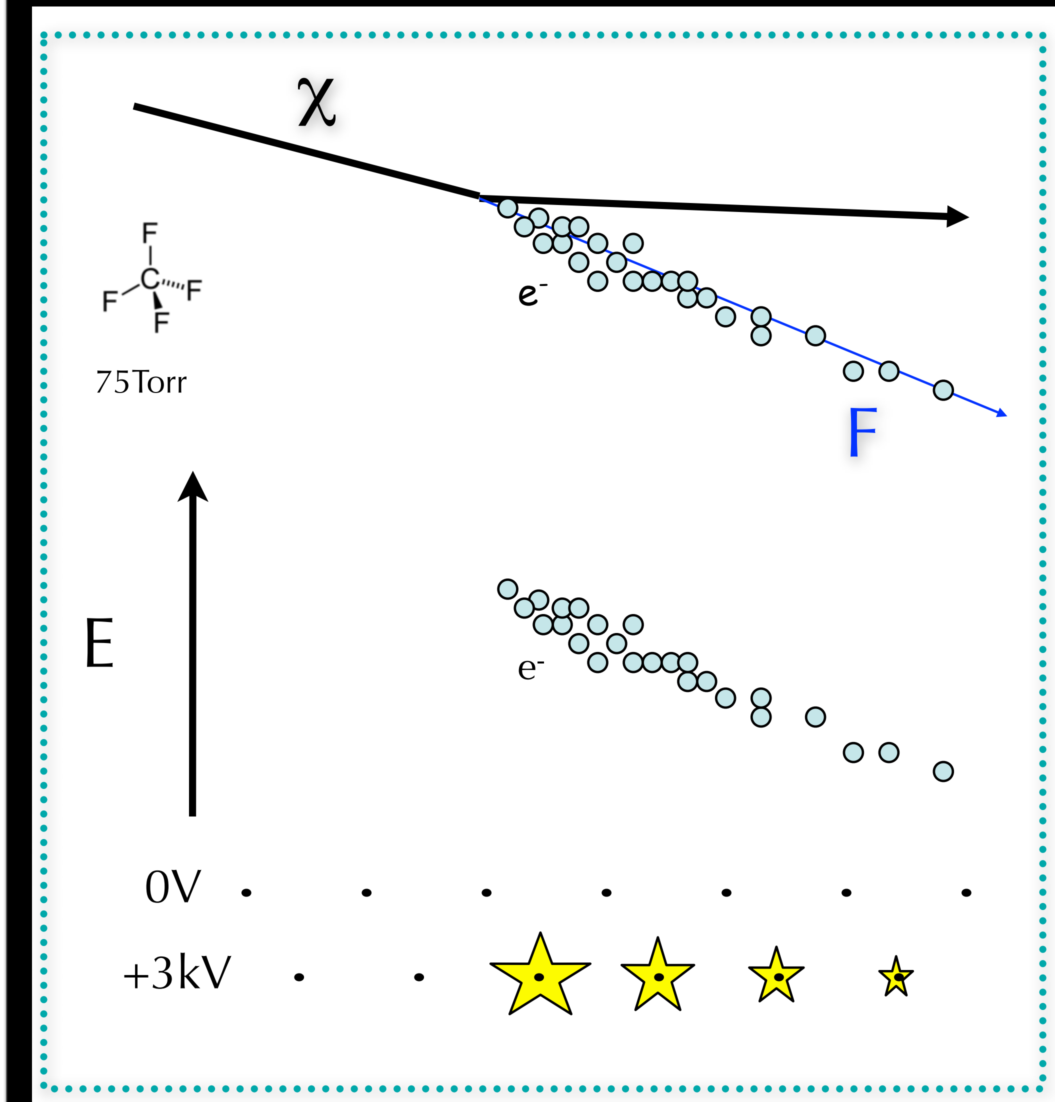


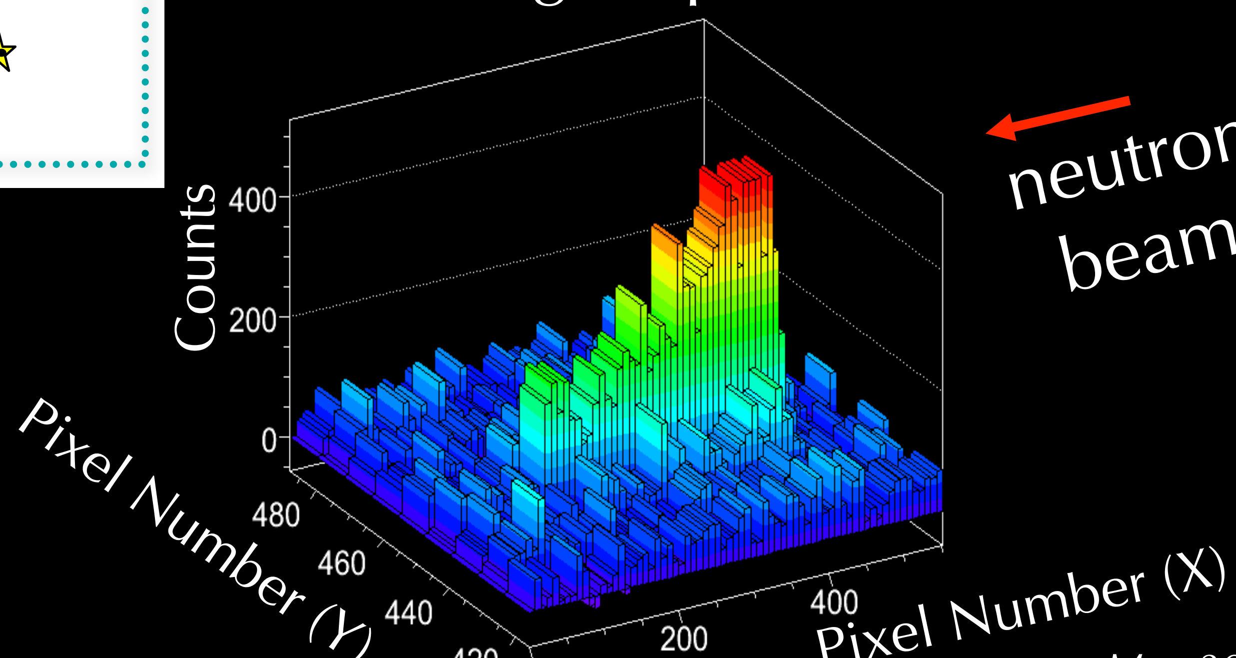
DMTPC Principle

1. primary ionization encodes track direction via dE/dx profile



2. drifting electrons preserve dE/dx profile if diffusion is small
3. multiplication in amplification region produces e- + scintillation g





D. Dujmic, JM, et al., NIMA 584:337 (2008)

RHUL *Jocelyn Monroe* *May 30, 2014*

DMTPC Principle

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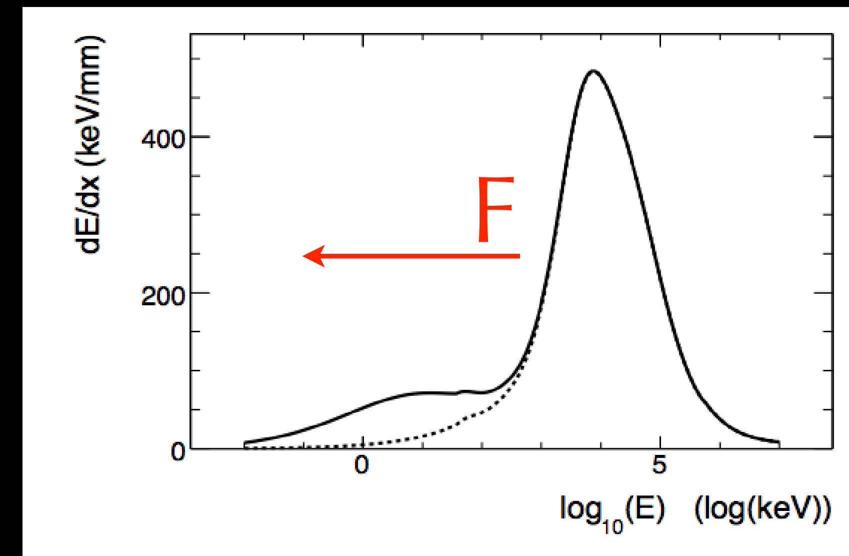
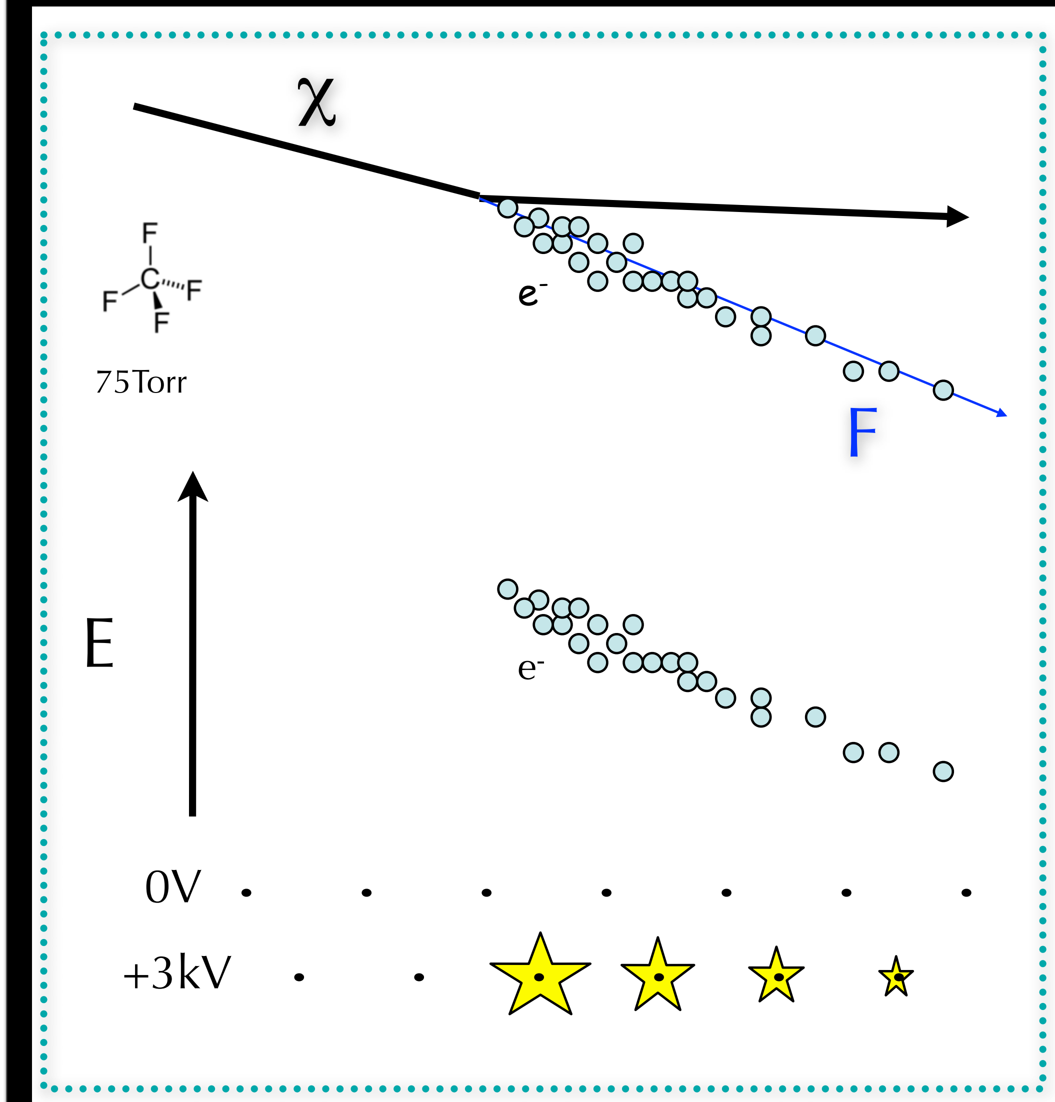




2. drifting electrons preserve dE/dx profile if diffusion is small

Adding fast optical readout
(for example MCP-PMT)
should restore time-projection
capability by allowing track
reconstruction in the drift direction

UK groups working on this concept

D. Dujmic, JM, et al., NIMA 584:337 (2008)

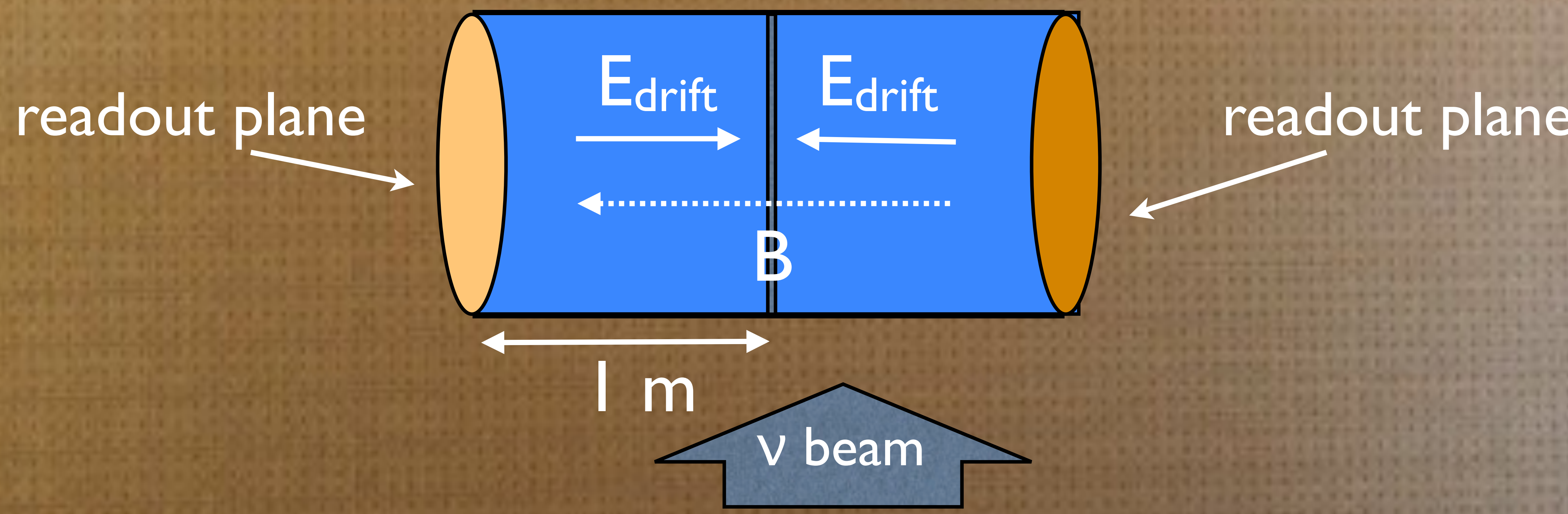
RHUL *Jocelyn Monroe* *May 30, 2014*

Conclusion / Path forward

- A high pressure gas TPC is an ideal instrument for disentangling neutrino interaction models and tuning interaction generators
  - Needed to get interaction systematics down to 2% level if we employ the conventional analysis approach
- Much work to be done!
  - Optimise detector design
    - Convert useful photons but reduce external backgrounds
  - Honest cost evaluation
  - Explore alternate readout technologies
    - Could provide low cost options


Thank you for your attention!
ご清聴ありがとうございました
水戸の梅の花
Many thanks to:
P Hamilton, F di Lodovico, J Monroe, F Sanchez, T Stainer, for valuable input

TPC concept



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

Motivation: unknown processes

- Presence of un-modelled processes in data sample affects extrapolation
- Effects exacerbated by different kinematics in each model
    - Which one matches Nature??
- Changes neutrino energy reconstruction
- Near detector extrapolation cannot fix this even if it is identical to far detector!