Workshop on Neutrino Near Detectors based on gas TPCs
平成28年 11月 09日

HPTPC R&D for CPV in the UK

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Imperial College London & KEK

Outline

- Overview of diverse HPTPC activities in the UK

  (& elsewhere)

  ➡ HPTPC-WG

- Physics Studies
  - Best ways to use new data from HPTPC?
- Software development
  - Building common tools for multiple users.
- Hardware development
  - $1m^3$ prototype with optical readout, proposal for beam tests here

  ➡ **Use prototype as a platform for R&D with a wider collaboration**

UK HPTPC Groups

- Imperial College London
  - Dunne, Ma, M Uchida, Wascko
- Lancaster University
  - Brailsford, Dealtry, Nowak
- Liverpool University
  - Christodoulou
- Oxford University
  - Martin-Albo, Wark, Weber
- Royal Holloway University of London
  - Chen-Wishart, Kaboth, Monroe, Parker, Shitov, Walding, Ward
- Rutherford/Appleton Lab
  - Kaboth (also RHUL), Wark (also Oxford), Weber (also Oxford)
- Warwick University
  - Barker, Boyd, Denner, Haigh

Members of many collaborations:
T2K, HK, DUNE

Members have diverse experience:
DMTPC, SuperNEMO, NEXT

UK HPTPC funding

- Current LBN-HK project R&D grant:
  - software work—MC development
  - hardware work—gas measurements for tuning MC
- PRD (project R&D) line:
  - Goal: Build 1m^3 HPTPC and use in beam test to measure p-nucleus cross section
    - start with CF_4, then try Ar, Ne, CH_4
    - Use optical readout design based on DMTPC
- Consolidated grants
  - Software development, detector design, physics studies
- LBN Pre-construction proposals in progress

HPTPC Event rates

CC-inclusive interactions per 10^{21} POT

Gas	mass, **40 m³** at 10 bar, 30 C	JPARC (0.6 GeV)	FNAL (2–4 GeV)*
He	63.6 kg	4.19E+03	1.46E+05
Ne	317 kg	2.10E+04	7.29E+05
Ar	636 kg	4.19E+04	1.46E+06
CF_4	1397 kg	9.23E+04	3.21E+06

These J-PARC and FNAL numbers were calculated in a consistent manner.
*Using LBNE flux, c.2013

HPTPC-WG

- New biweekly WG meeting established (alternate Mondays)
- Connect and focus several HPTPC efforts
  - Focus on developing physics studies
  - report on software tools
  - report on hardware R&D
- Coordinate UK efforts with European and North American work, hope to expand to Japan as well
- Slides etc posted on RHUL Indico server
  - contact <jocelyn.monroe@rhul.ac.uk> for access
- Have an email list
  - contact <m.wascko@imperial.ac.uk> to join

HPTPC-WG

- Recent topics:
  - DUNE GAr-TPC, J Martin-Albo (Oxford)
  - Thoughts on sensitivity studies, D Sgalaberna (UniGe)
  - HPTPC MC, Yu Shitov (RHUL)
  - T2K/HK MC Truth Selection studies, M Scott (TRIUMF)
  - T2K/HK Transverse variables, P Dunne (Imperial)
  - TRex status, P Denner (Warwick)
  - DUNE Software framework, G Christodoulou (Liverpool)

- Wide variety of topics, not confined to one experiment only

Physics studies

- Performing studies on how we would *actually use* an HPTPC
  - isolating specific event topologies

    ➡ xsec model testing and tuning
    - Most studies currently targeting (elastic) 2p2h
  - understanding energy recon
    - calorimetric & kinematic

    ➡ impact on neutrino oscillation sensitivity
- Building from T2K experience, but with a broader scope

Current study list

STUDY	SUMMARY	PEOPLE	STATUS
FSI constraint	project tighter FSI constraints at FD, produce covariance matrix for OA fit	Kaboth, Dealtry	first step done
Greater sample purity	MC truth selection studies: split CC0pi and CC1pi samples and study effects of different detectors	M Scott, Sgalaberna	first pass complete
Use hadron information 1	generator level studies developing ND analysis to use hadronic information; single transverse variables first	Dunne, M Scott	first pass complete
Use hadron information 2	put new event samples (using hadron info) into ND fit	Parker, Kaboth	ongoing
Realistic HPTPC information	use full MC to develop event selection	Shitov, Dunne, Chen-Wishart, Parker	first pass MC working

Improved sample purity

- Truth level MC studies

  (assumed particle detection thresholds)

- Split T2K ND280 samples (CC0pi and CC1pi) into subsamples based on detected proton multiplicity

  - Higher purity in HPTPC
  - Higher stats in solid scintillator

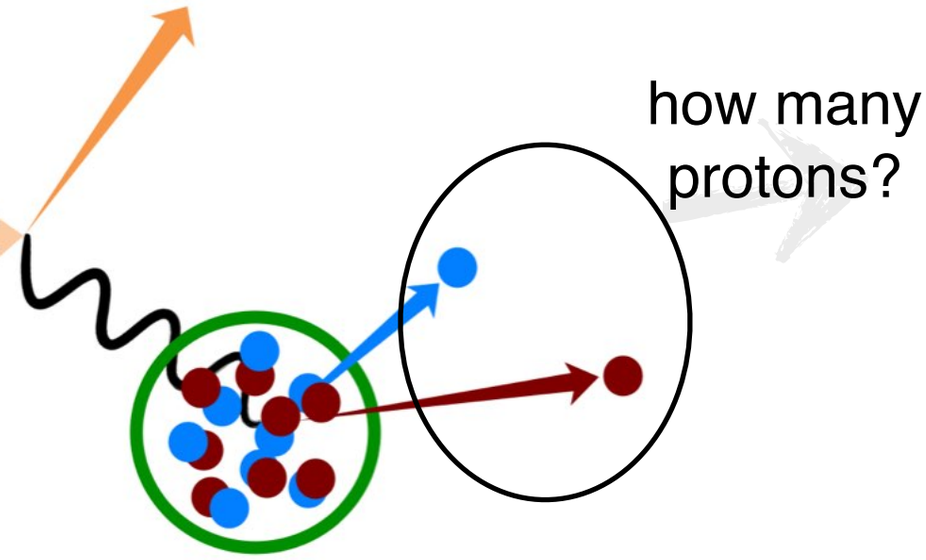
- Simply inserting these samples into existing ND fits does not exploit the power of the HPTPC

  - Need more sophisticated variables / analysis

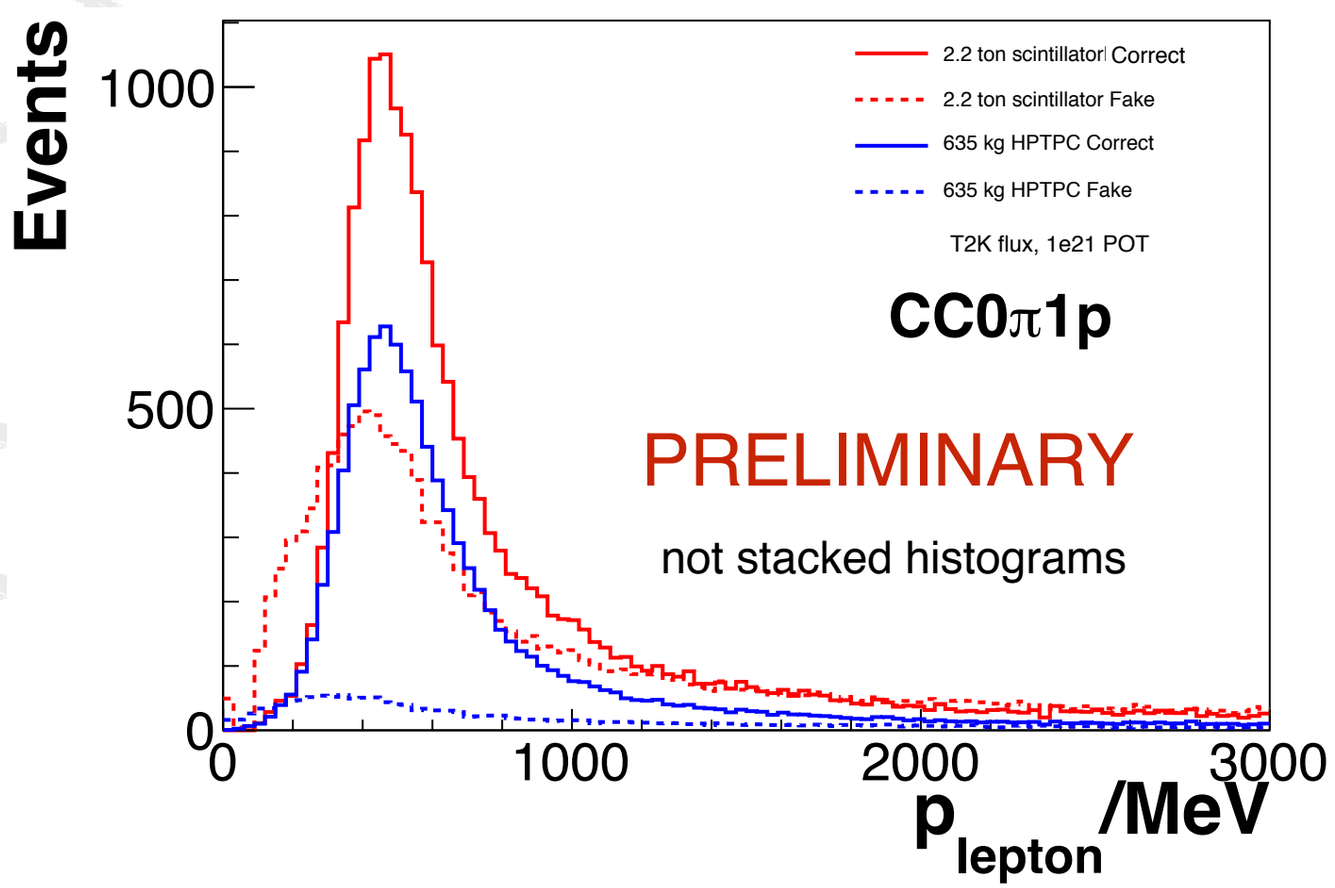
CC0π→CC0π0p

CC0π1p

CC0πNp

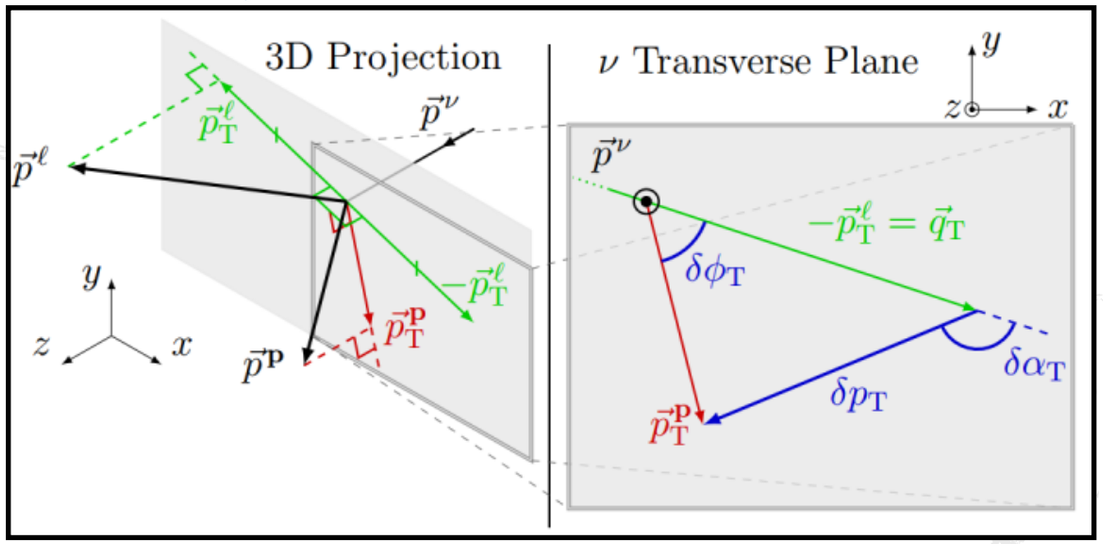


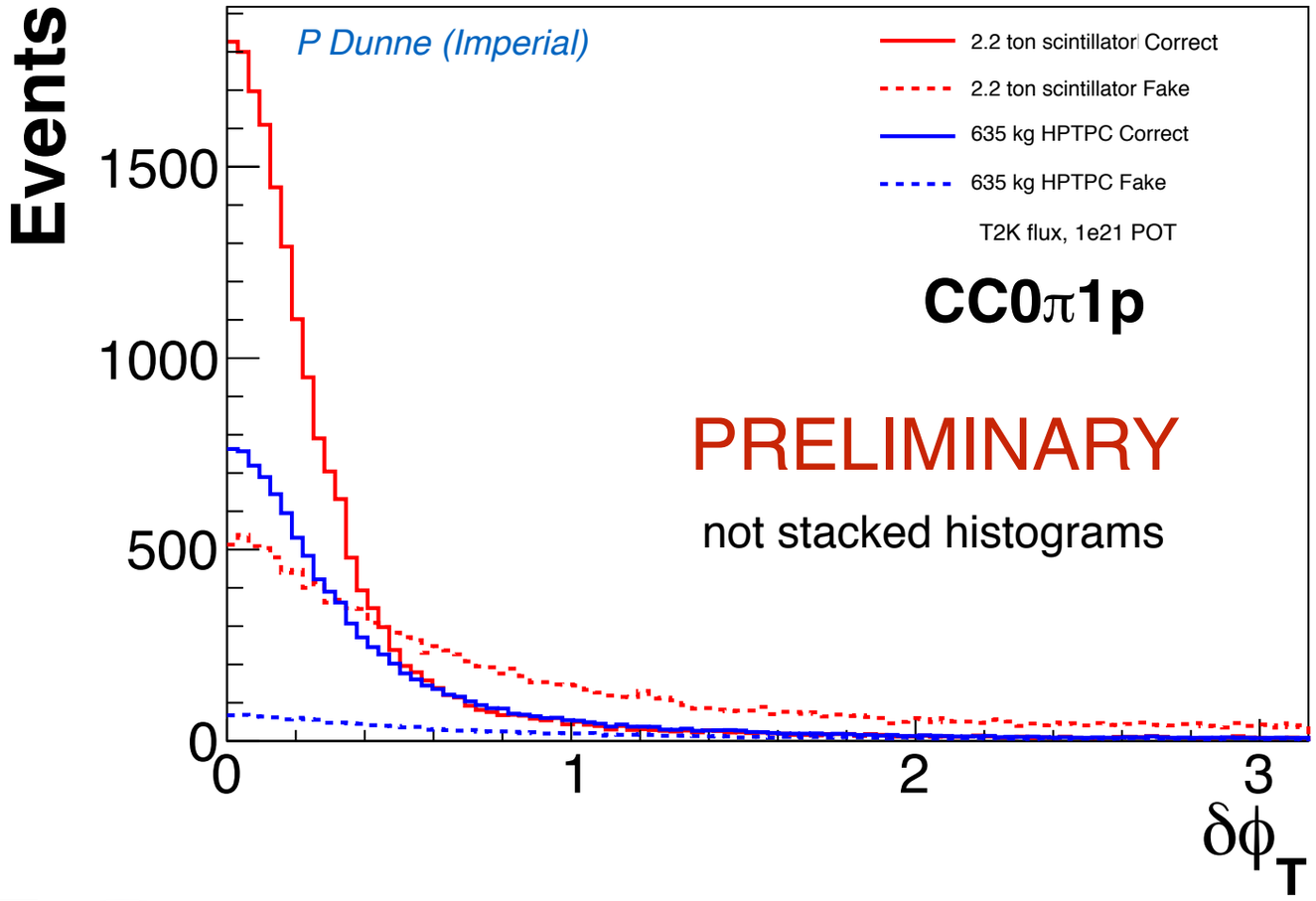
M Scott (TRIUMF) & P Dunne (Imperial)



Use hadron information

Lu, et al., Phys. Rev. C 94, 015503





- Truth level MC studies

  (assumed particle detection thresholds)

- Use detected protons to reconstruct momentum imbalance the transverse plane
  - Higher purity in HPTPC
  - Higher stats in solid scintillator
- Now studying how to use transverse variables in ND fit
  - First instance: 2D distributions of muon vs. hadron variables

Software development

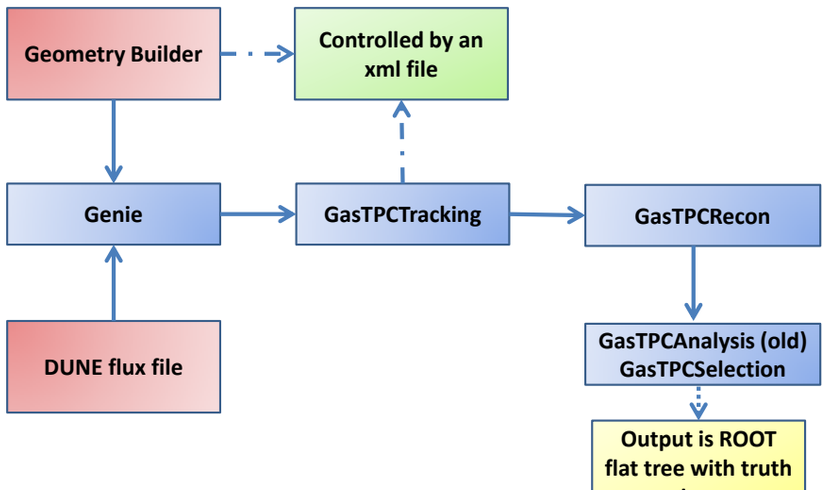
- Overarching goals
  - Fully validated simulation of HPTPC
    - ➡ Detector design specification needed to achieve 2% total uncertainty
- Coordinating software development across multiple experiments
  - Inherited tools from LBNO, DMTPC, T2K
- Work Plan
  - develop HPTPC simulation to determine the momentum threshold and PID requirements for HPTPC to reduce CPV xsecs to 2%
  - determine optimum design parameters to achieve physics goals
    - pressure, readout pitch, gas mixtures to achieve consistent timing across target species, granularity
  - validate HPTPC detector simulation with measurements of gas physics in relevant range of targets

Software development

- Coordination between UK groups on HK, DUNE, and generic R&D
  - Coordinating software development across multiple experiments
    - Inherited tools from LBNO, DMTPC, T2K
  - MC Development
  - Reconstruction software development
  - High level analysis software development

G Christodoulou (Liverpool)

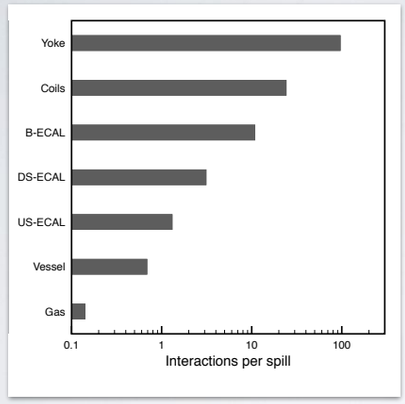
HP Gas simulation: Step 5: Event Selection

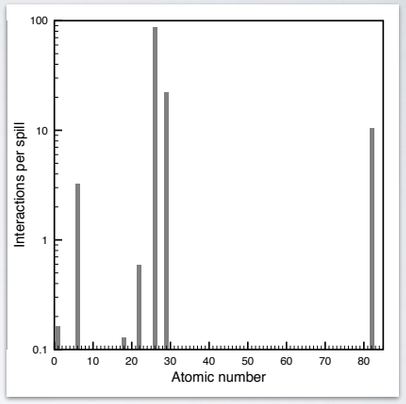


DUNE

J Martin-Albo (Oxford)

Event generation (II)





124 interactions in detector per spill (7.5e13 POT) on average in neutrino mode; 50 interactions in antineutrino mode.

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DUNE

Software development

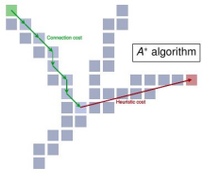
T2K/DUNE/HPTPC

P Denner (Warwick)

Pattern Recognition

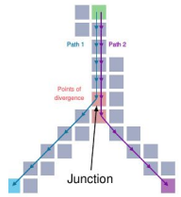
by Eddy Larkin, Warwick

TREx uses the A* Algorithm for pathfinding

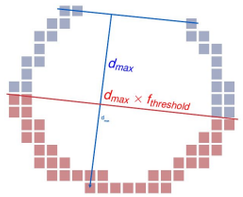


WARWICK

- Paths are formed according to connection cost factors between pattern edges.
- Diverging paths are used to identify junctions.



- Kink-finding can distinguish V-like two-track patterns from single curved tracks



TREx tutorial: http://www.t2k.org/nd280/physics/xsec/subgroup/TPCInteractions/meetings/gas-interactions-2016-06-17/eddy-patrec-tutorial-2016-17-06/view

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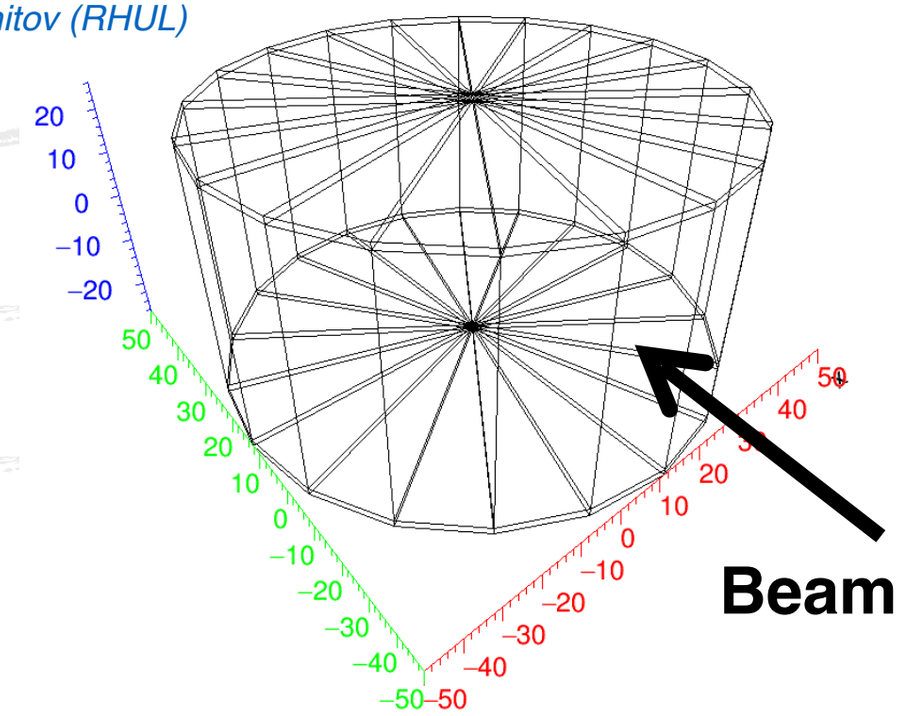
HPTPC

Yu Shitov (RHUL)



- UK groups (mainly Warwick) developing new TPC track reconstruction: “TRex”
- Primary tracks: Particle Gun application now takes input from neutrino event generators.
- Event generator: GENIE. Template interface program to process GENIE data and input to detector simulation written.
- Track Propagation: Simple drift model with parametrized gas physics.
  - Gas physics in TPC drift (Magboltz)
    - specifics properties (drift velocities, diffusion coefficients, attachments, etc) used for each gas
  - Gas physics in TPC amplification region (Garfield).
- Detector readout simulation in progress, using DMTPC noise measurements.

Software development

Yu Shitov (RHUL)

Protons & pions in the HP TPC prototype

Simulated configuration of HP TPC prototype: (10 bars of T2K gas)

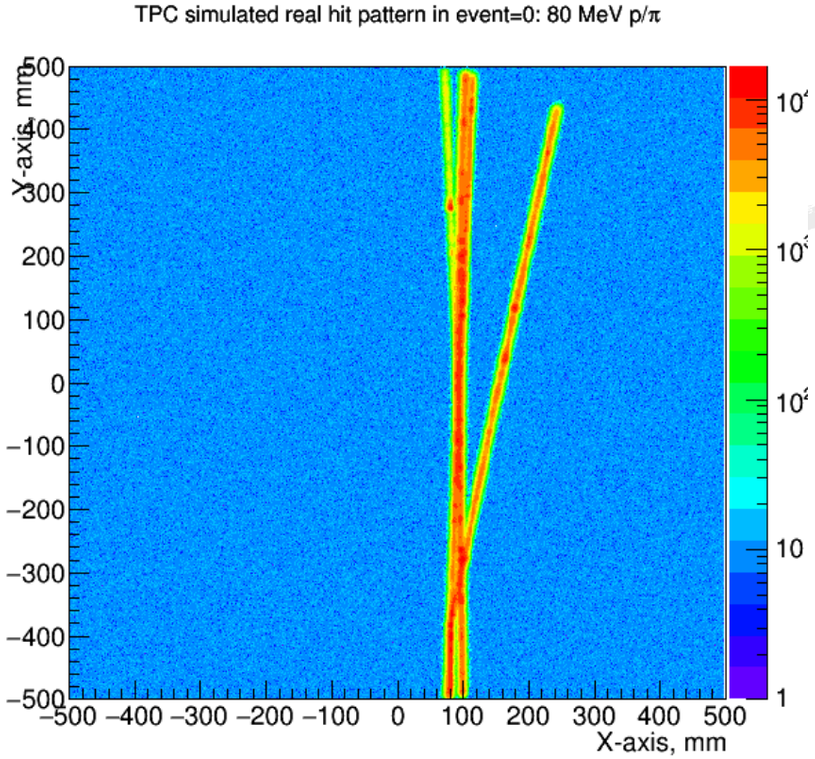
Size: Cylinder D=1 m x Length=0.5m;

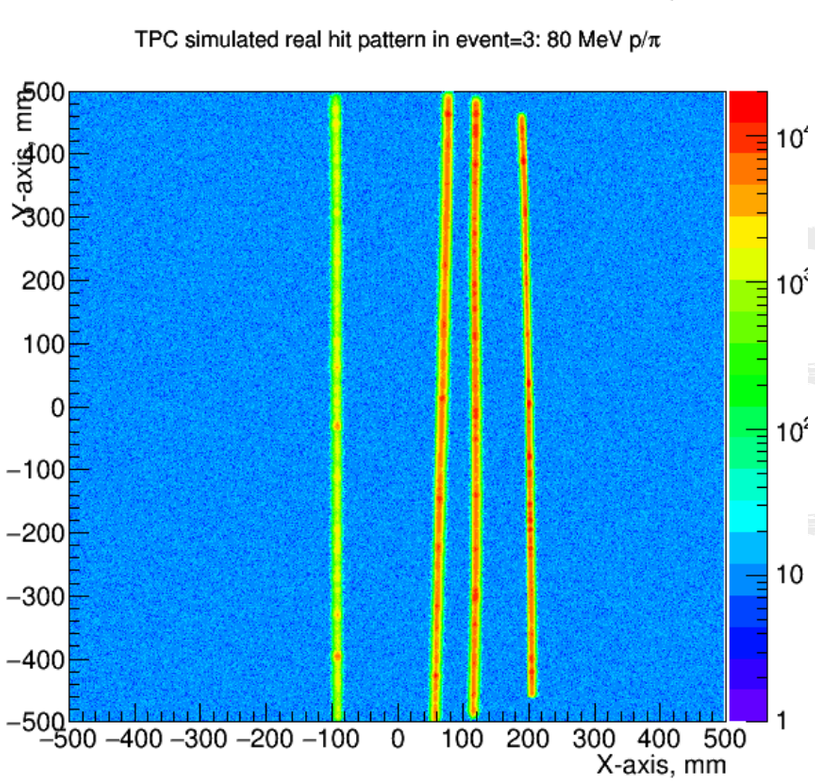
Wall: 2 cm of Aluminum

Gas: T2K gas @ 10 bars

Beam: Gaus(pos=80 MeV, sig=7%) protons and pions in 2D Gaussian beam (sig=10 cm) are entering in (0,-0.6,0) m point in +Y direction.

Looking at images and dEdX distros

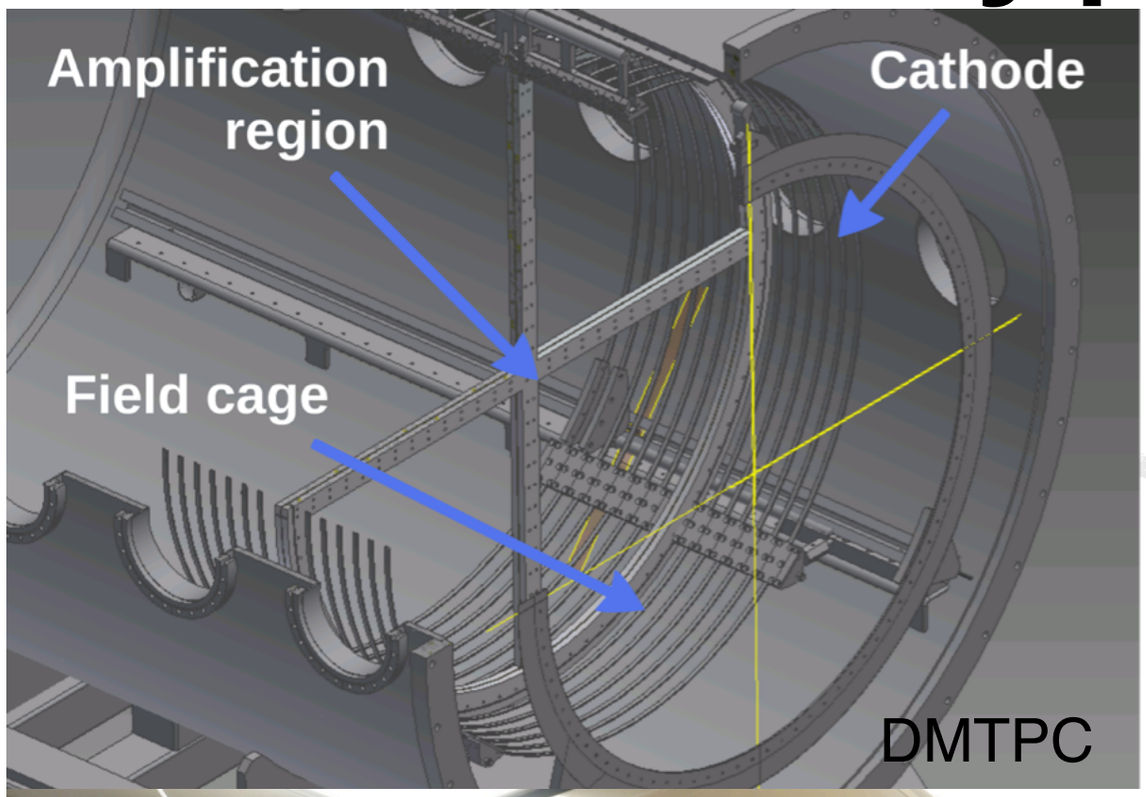


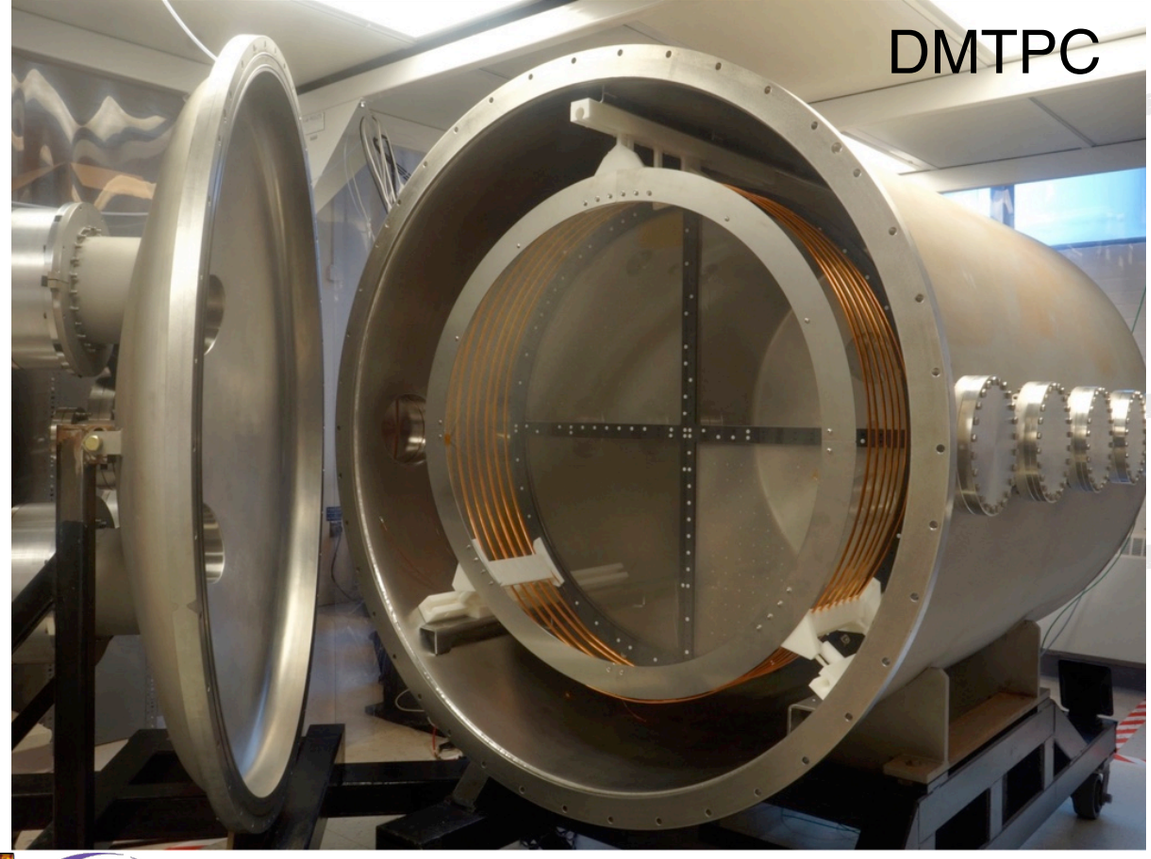


Hardware development

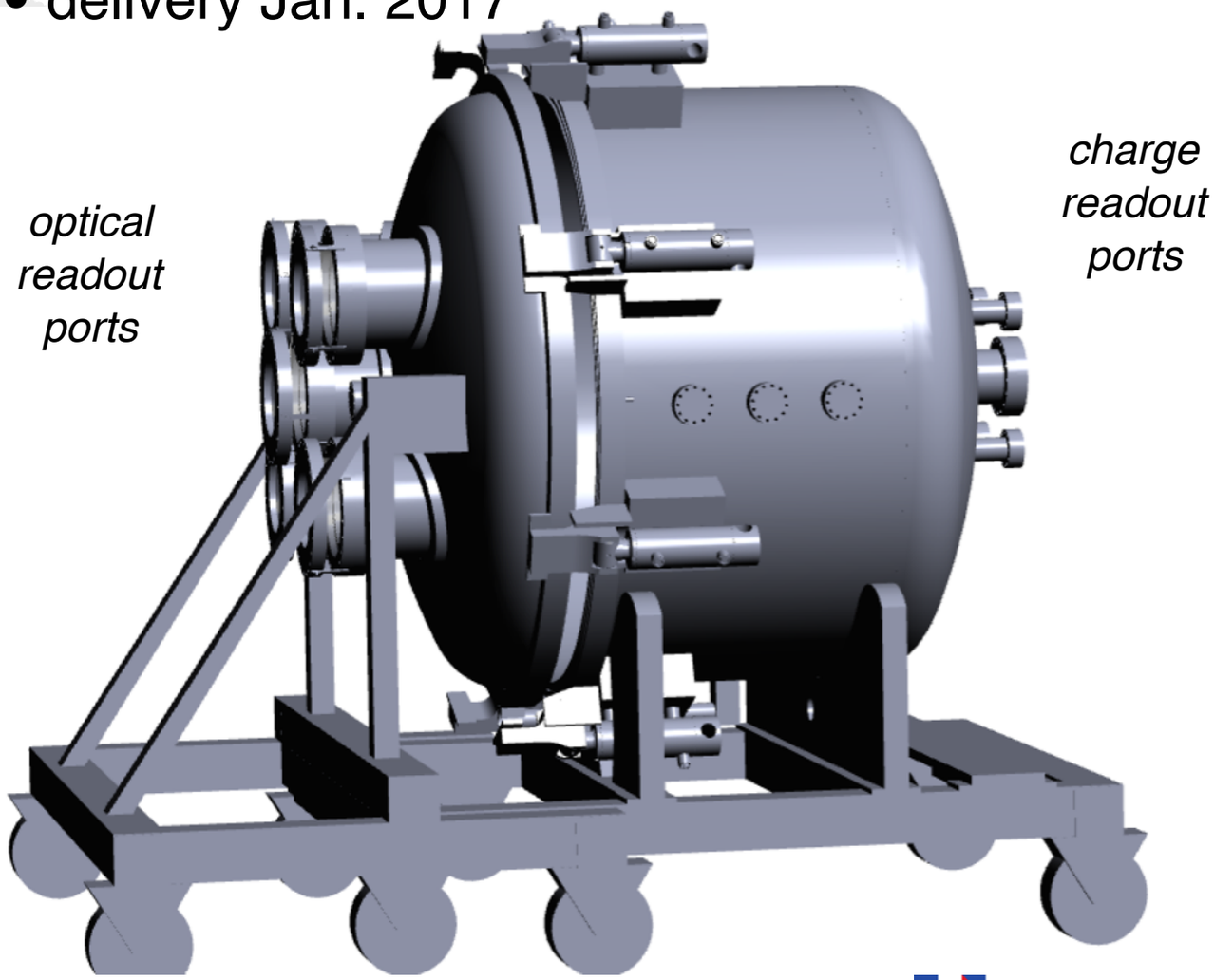
- Building 1 m^3 HPTPC prototype with charge and optical readout
  - designed for 5 bar Ar and CF_4 gas targets, R&D on mixtures with N-CO_2 and Ne
  - 50 cm drift length, adjustable
- segmented amplification plane, test platform for micromegas or other amplification structures
  - aim for <100 MeV/c threshold for protons -> mm readout pitch
- Prototype goal: CERN beam test to measure proton/pion response, optimise pitch, and hadron scattering measurements
- Optical readout R&D to reduce cost of mm pitch readout
  - Combine optical pixel readout with charge strip readout to mitigate reconstruction ambiguity, and instrumental backgrounds
  - Building on expertise from DMTPC and T2K

Prototype HPTPC

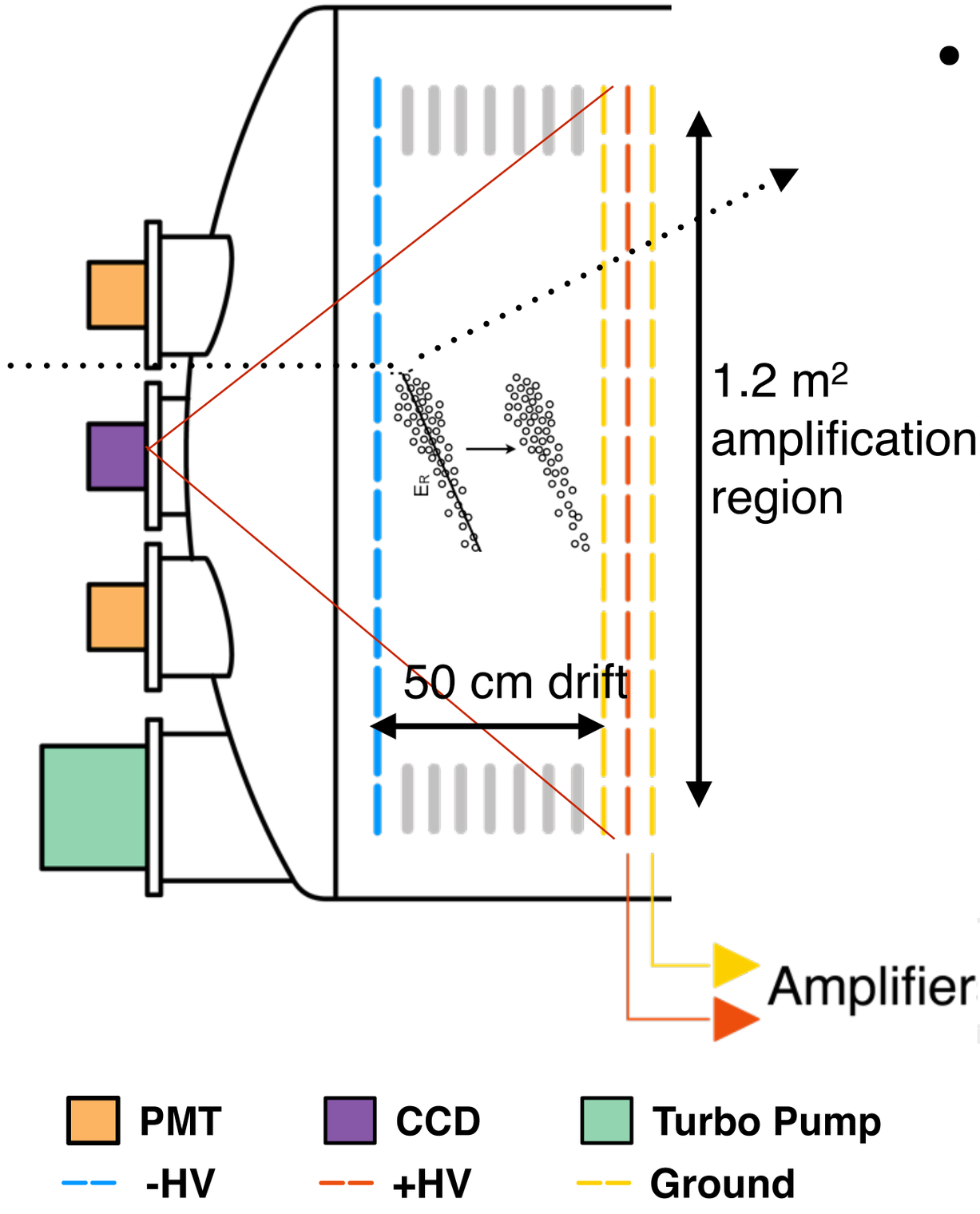




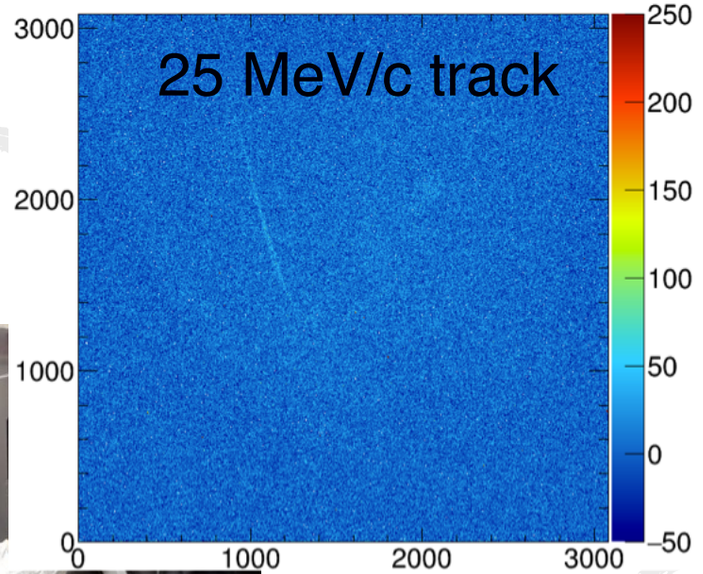
- UK HPTPC proto design based on DMTPC 1m3 detector
  - mesh amplification region, could be replaced with MPGD
- HPTPC vessel and gas system under construction by Cryovac (ES)
  - delivery Jan. 2017

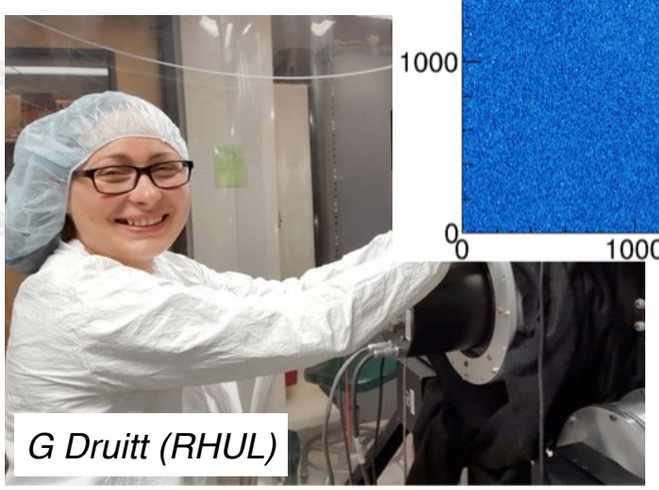


Optical Readout



- CCD images scintillation produced in the amplification region
  - Fairchild 386 16 MPix CCD + lens outside pressure vessel
  - 90 cm object distance
  - results in 1 mm readout pitch with 4x4 readout binning




G Druitt (RHUL)

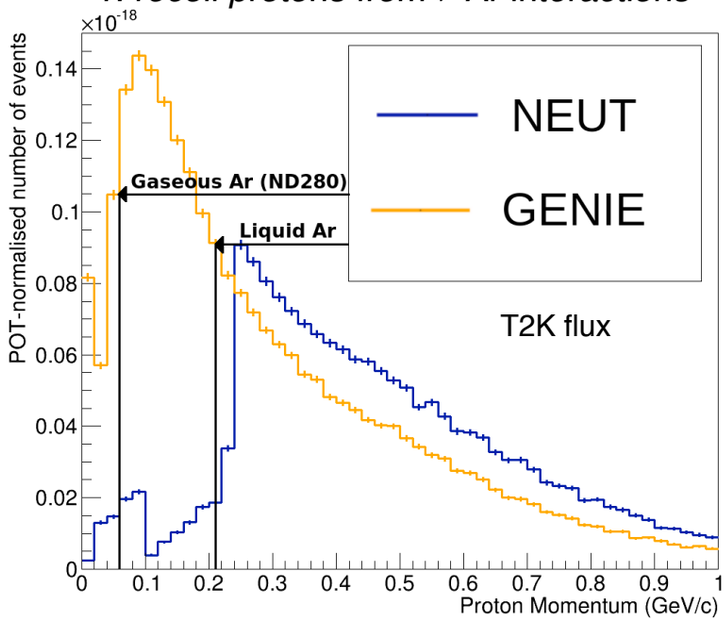
Testbeam measurements

Imperial
Lancaster
RHUL
Warwick

- **Goals:**
  1. **Make new proton-nucleus (and pion-nucleus) scattering measurements**
  2. **Tune neutrino interaction generators, demonstrate feasibility of <2% systematics**
- Neutrino generators disagree in recoil particle multiplicity & kinematics (Fig 1)
- Low energy final state protons are created at higher energy, lose energy exiting nucleus (Fig 2)
- Need new data for tuning generator MC hadron scattering models (Fig 3)

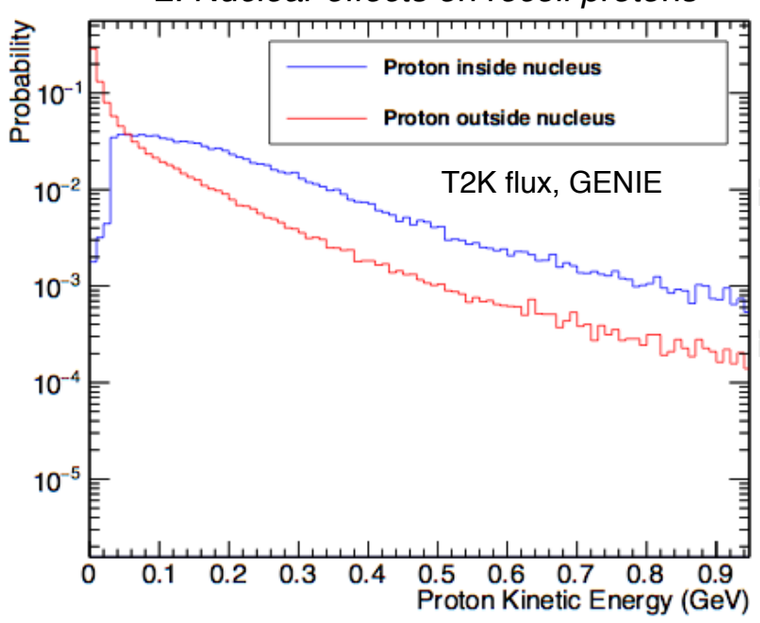
P Hamilton (now at Syracuse)

1. recoil protons from ν-Ar interactions



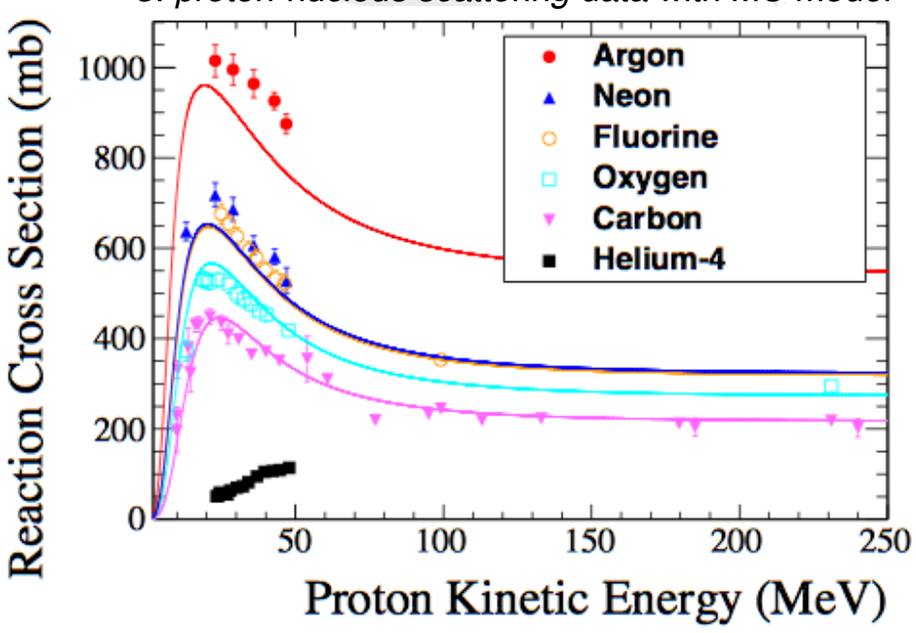
A Kaboth (RHUL)

2. Nuclear effects on recoil protons



A Kaboth (RHUL)

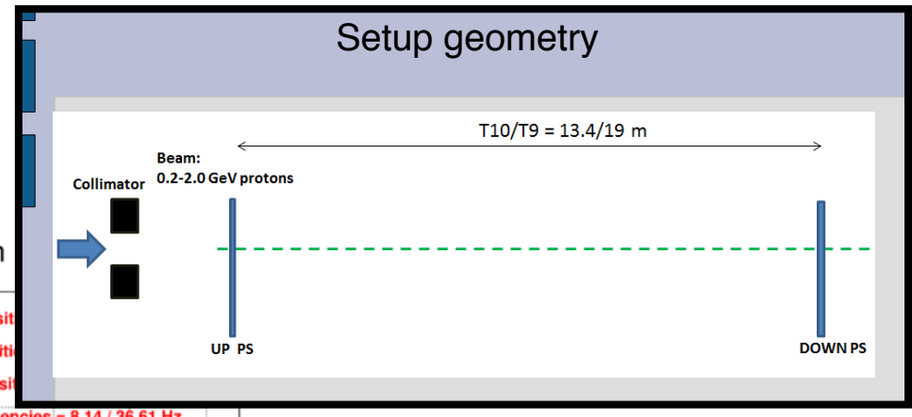
3. proton-nucleus scattering data with MC model

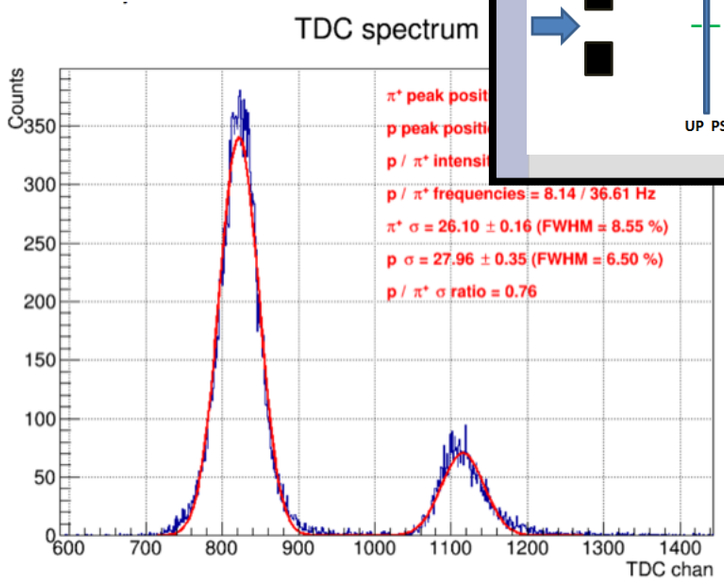


Testbeam fluxes

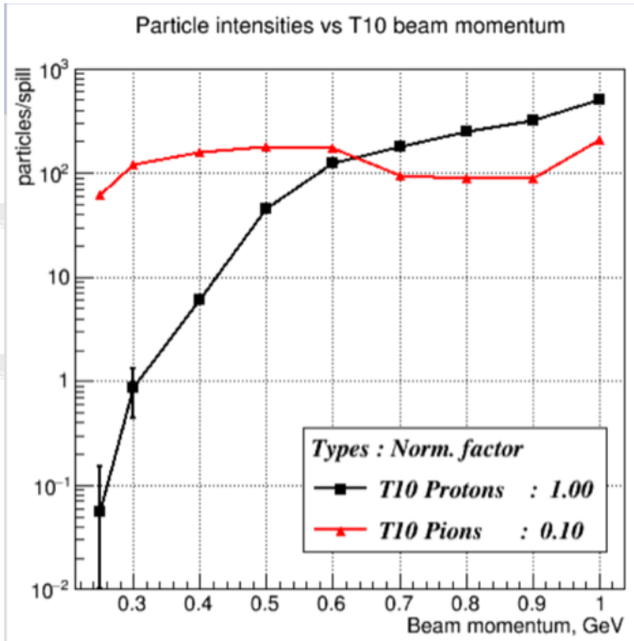
Imperial
Lancaster
RHUL
Warwick

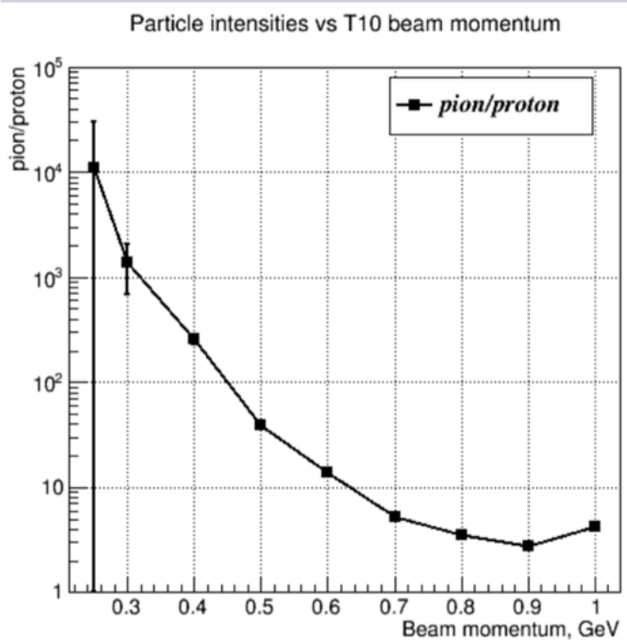
- Took data in T9 & T10 test beams
- Want to push proton measurements as low as possible in momentum
  - fluxes increasingly dominated by pions
- Exploring use of beam absorbers to get higher proton ratios
- Plan:
  - LOI for January 2017 SPSC meeting
  - Build and commission in UK 2017 (RHUL)
  - Transport to CERN after commissioning





Yu Shitov (RHUL)





Summary

- UK groups are coordinating efforts across multiple experiments for HPTPC R&D
- Physics Studies, software, and hardware development
  - $1m^3$ prototype with optical readout, preparation for CERN beam tests
  - We hope to exploit this prototype into a platform for much broader R&D

    ➡ readout technologies, gas measurements, scattering measurements
  - **We welcome more collaboration and are actively seeking new partners for this!**
- New HPTPC-WG formed—please join us!

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

man Bldg.

MEN WANTED

for hazardous journey, small wages, bitter cold, long months of complete darkness, constant danger, safe return doubtful, honor and recognition in case of success.

Ernest Shackleton 4 Burlington st.

MEN—Neat-appearing young men of pleasing personality,