Progress and Plans: Wire-Cell at ProtoDUNE

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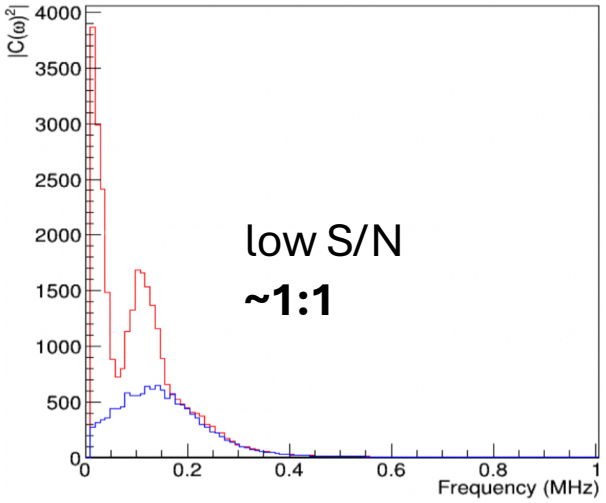
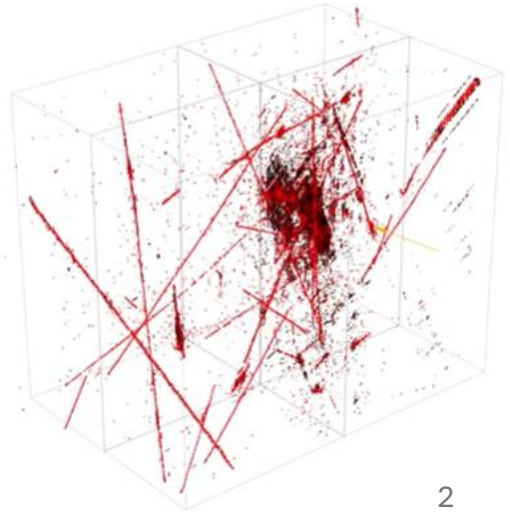
ProtoDUNE HD: in progress

- Noise filter & data quality (Xuyang):
  - FEMB negative pulses => bad regions in sigproc
  - Coherent mitigation
- CE calibration (Karla)
- SigProc in PDHD APA1
  - Refactored sigproc chain (Done)
  - Field response calibration (Xuyang et al.)
  - DNN ROI (Sergey, Jay et al.)
- 3D imaging (Haiwang, Jay)
- Clustering & QL matching (Haiwang)
- More contribution to physics analysis

?

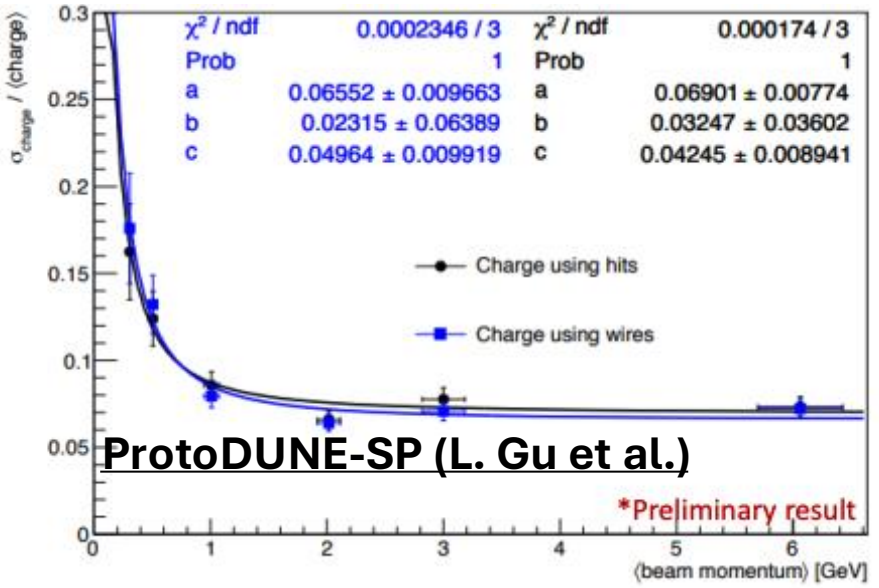
APA 1
Power spectral density





EM shower reco resolution

	$\sigma_E/E[GeV]$ (%)	σ_E/E @1GeV (%)
DUNE CDR [1]	$15/\sqrt{E}+2$	17
DUNE sensitivity paper [2]	$9/\sqrt{E}+4$	13
DUNE TDR [3]	8 (spectrum avg.)	-
SLAC GNN [4]	$4.1/\sqrt{E}+1.4$	5.5
ProtoDUNE-SP (L. Gu et al.) [5]	-	8.6



[1]: arXiv:1512.06148 [physics.ins-det]
[2]: arXiv:2006.16043 [hep-ex], arXiv:2109.01304 [hep-ex]
[3]: arXiv:2002.03005 [hep-ex]
[4]: arXiv:2007.01335 [physics.ins-det]
[5]: DUNE DocDB #30975 (poster) #24842 (technote)

- An end-to-end analyses at ProtoDUNE, e.g. exclusive Xsec, requires a more complete reconstruction with particle flow (trajectory, PID, etc.)
- Electron shower energy reconstruction is essentially a simpler 2D measurement (sum of all charges) but with some advanced tool for shower separation (imaging, clustering)

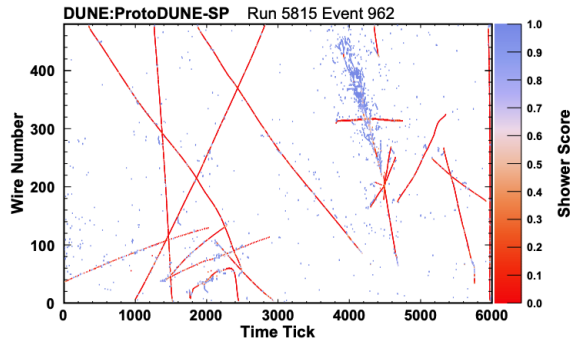
Standard analysis flow in ProtoDUNE

SigProc (WireCell ROI) ⊕ Noise

3D Imaging (Improved Noise?)
⊕
3D charge ported to 2D

Shower tagging (Pandora)
⊕
Shower segmentation
(CNN/containment cut)

Charge summation
⊕
Lifetime correction using X position



CNN: shower score at hit level
EPJC 82 (2022) 10, 903

- To what extend has the noise affected the resolution?
  - DNN ROI & 3D imaging may further reduce noise
- WireCell may have its own shower **segmentation** using clustering
- WireCell could have **lifetime correction** with a known X position using QL matching
- More functions could be available in the future

Conclusion

- ProtoDUNE HD: Significant progress, particularly focused on APA1
  - Noise filtering, CE calibration, and field response simulation
- Wire-Cell Toolkit: Continued development and refinement
  - DNN ROI, 3D imaging, clustering, QL matching
- Opportunities for Improvement and Contribution
  - EM shower energy reconstruction presents a valuable topic to contribute, which can also help enhance Wire-Cell tools

Backup

Table 2: A summary of beam line instrumentation logic used in the identification of particle types. Each cell reflects how a particular type of instrumentation is used at a given reference momentum. When time of flight is used, the values of the lower and upper cuts are given in nanoseconds. In the case of the high-pressure Cherenkov (XCET-H) and the low-pressure Cherenkov (XCET-L), zero and one represent the absence and presence of a signal respectively. When a given piece of instrumentation is not involved in a logic decision at a given momenta, a dash is used.

		Momentum (GeV/*c*)			
		1	**2**	**3**	**6 - 7**
e	TOF (ns)	0, 105	0, 105	–	–
	XCET-L	1	1	1	1
	XCET-H	–	–	1	1
μ / π	TOF (ns)	0, 110	0, 103	–	–
	XCET-L	0	0	0	1
	XCET-H	–	–	1	1
K	TOF (ns)	–	–	–	–
	XCET-L	–	–	0	0
	XCET-H	–	–	0	1
p	TOF (ns)	110, 160	103, 160	–	–
	XCET-L	0	0	0	0
	XCET-H	–	–	0	0