

Neutrino Interactions in Liquid Argon Time Projection Chambers

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OUTLINE

- focus will be on liquid Ar time projection chambers (in the U.S.) rather than neutrino interactions
- some background: liquid Ar, TPC etc.
- recent U.S. developments
- overview of ongoing projects

LArTPC

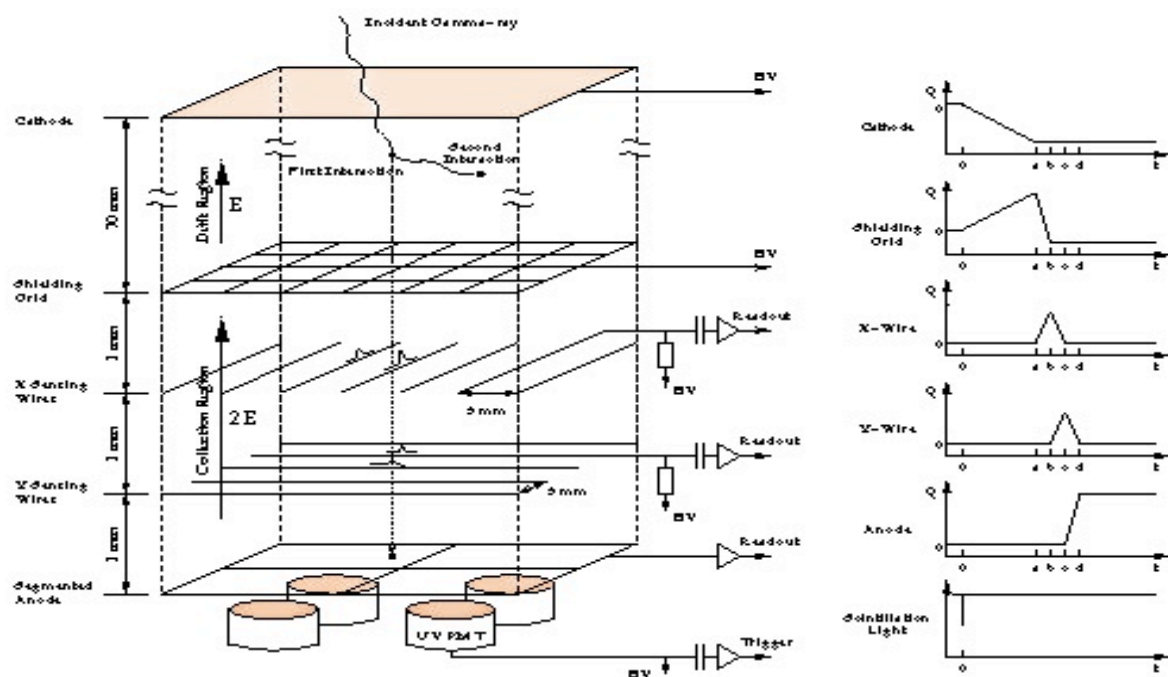


Figure 2.6: Schematic of the LXeTPC read-out structure with corresponding light trigger and charge signals (from (98) and (74)).

liquid Ar

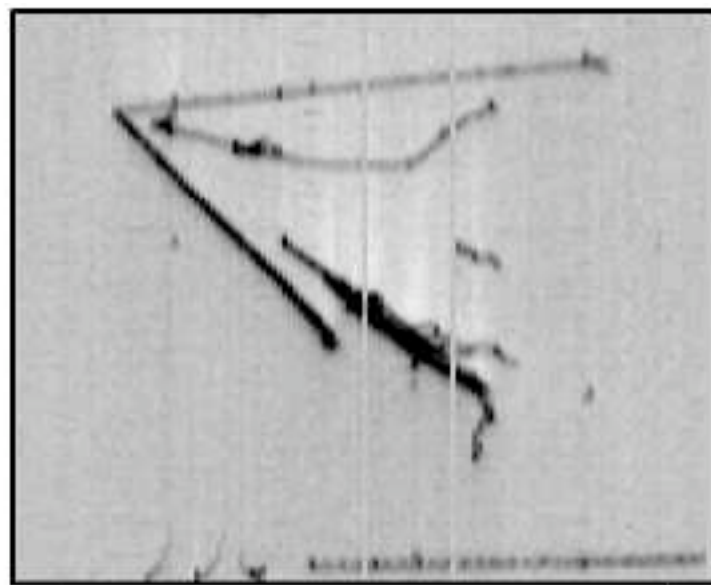
	liquid Ar	water	freon
readout technique	<i>TPC/ scintillation</i>	<i>Cherenkov</i>	<i>bubble chamber</i>
density [g/cm ³]	1.4	1	1.5
radiation length [cm]	14	36.1	11
scintillation [ph/MeV]	40,000 $\lambda=128\text{ nm}$		
dE/dx [MeV/cm]	2.1	1.9	2.3
boiling point [K]	87	373	
mass [ton]	300(+300)	50,000	3

why LArTPC are good for $O(\text{GeV})$ neutrino physics

- * excellent imaging capability and calorimetry; accurate PID down to very low energy
- * very massive (multi-kton) detectors are possible
- * sensitivity for oscillations competitive with e.g. water Cherenkov 3-4 times more massive
- * **non-oscillation physics:** starting from detailed snapshots + calorimetry of neutrino interactions one can extend studies done with bubble chambers (possibly with larger statistics): cross-sections, nuclear effects, exclusive channels and rare processes

LArTPC ITALIAN STYLE

with some 30 years of experience ICARUS is the 500 pounds gorilla in the field: established LAr purification, seen neutrino interactions in LArTPC, established performance, built and tested 300 ton LArTPC



Collection wires. (128 wires: 32 cm.)

Time (1300 samples: 47 cm)



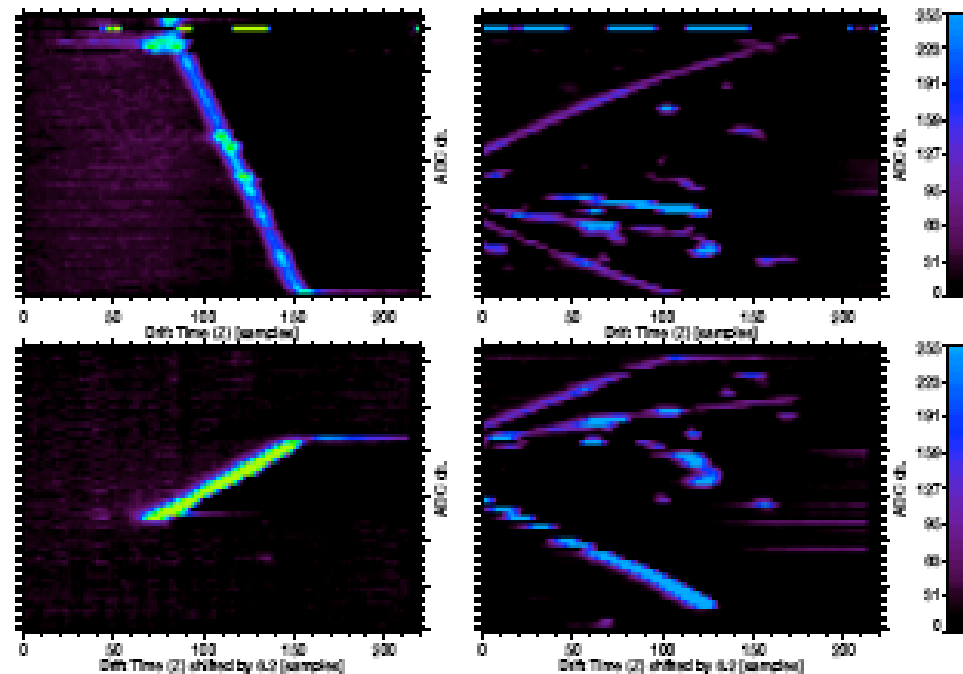
Induction wires. (128 wires: 32 cm.)

ICARUS-Milano collaboration PRD (Vol. 74, No.11) 2006

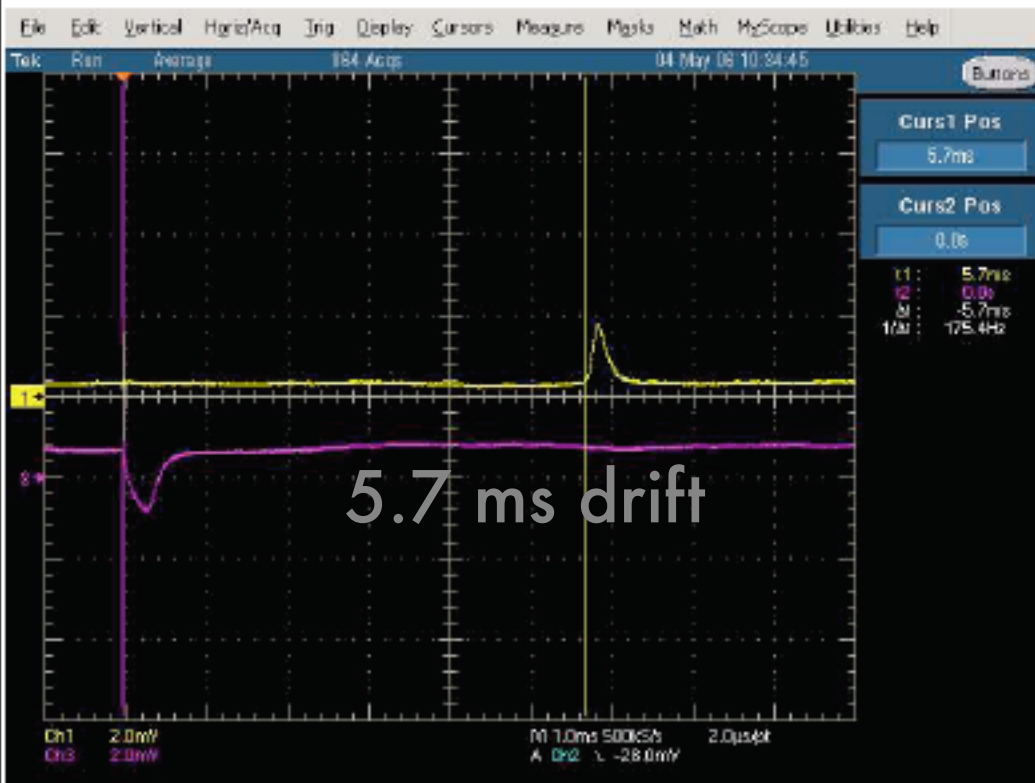
LArTPC U.S. STYLE

■ Quite a long tradition (C. Rubbia at Harvard, W.J. Willis, Herb Chen & UC Irvine group etc.) which eventually didn't produce a working LArTPC

■ In the last 3 years a vigorous effort has been established at Fermilab and Yale and has already produced important results, e.g. new filters for liquid Ar purification developed at Fermilab

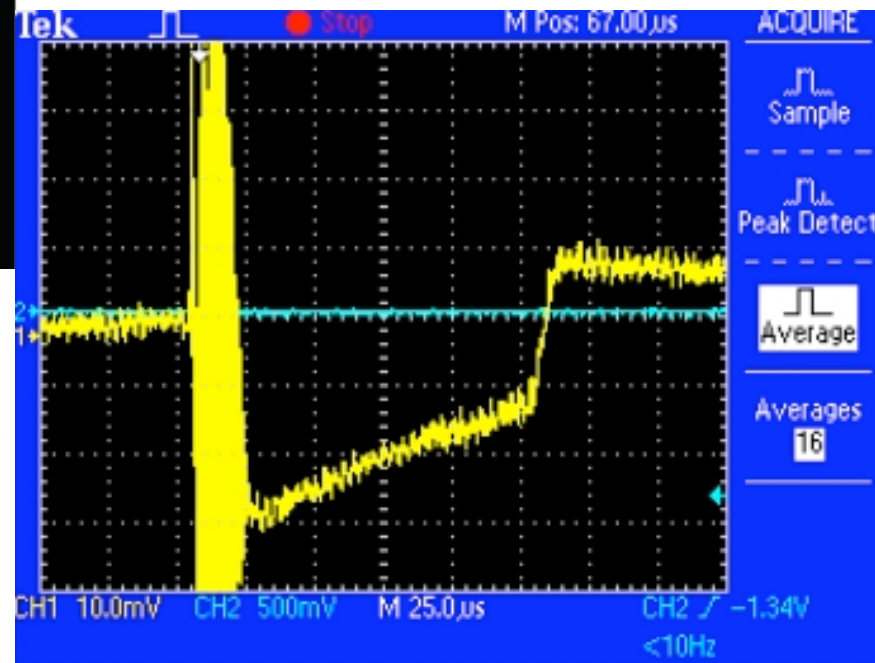


Tracks in the LXeGRIT LXeTPC



purity measurement
at Yale using a TRIGON
filter from FNAL

purity measurement at FNAL:
FNAL setup and TRIGON filter
developed and built at FNAL

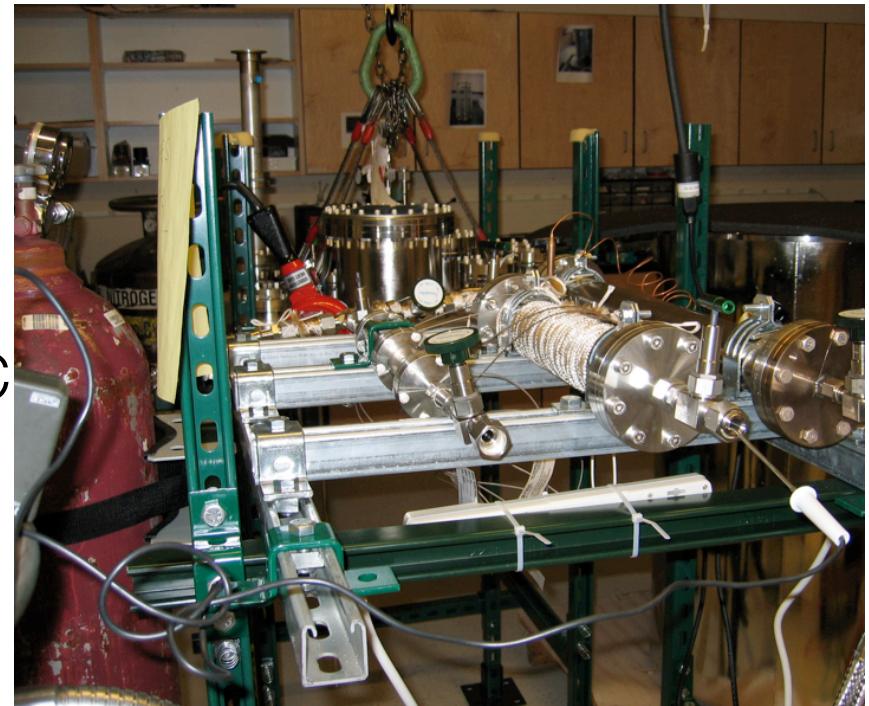


LArTPC at YALE

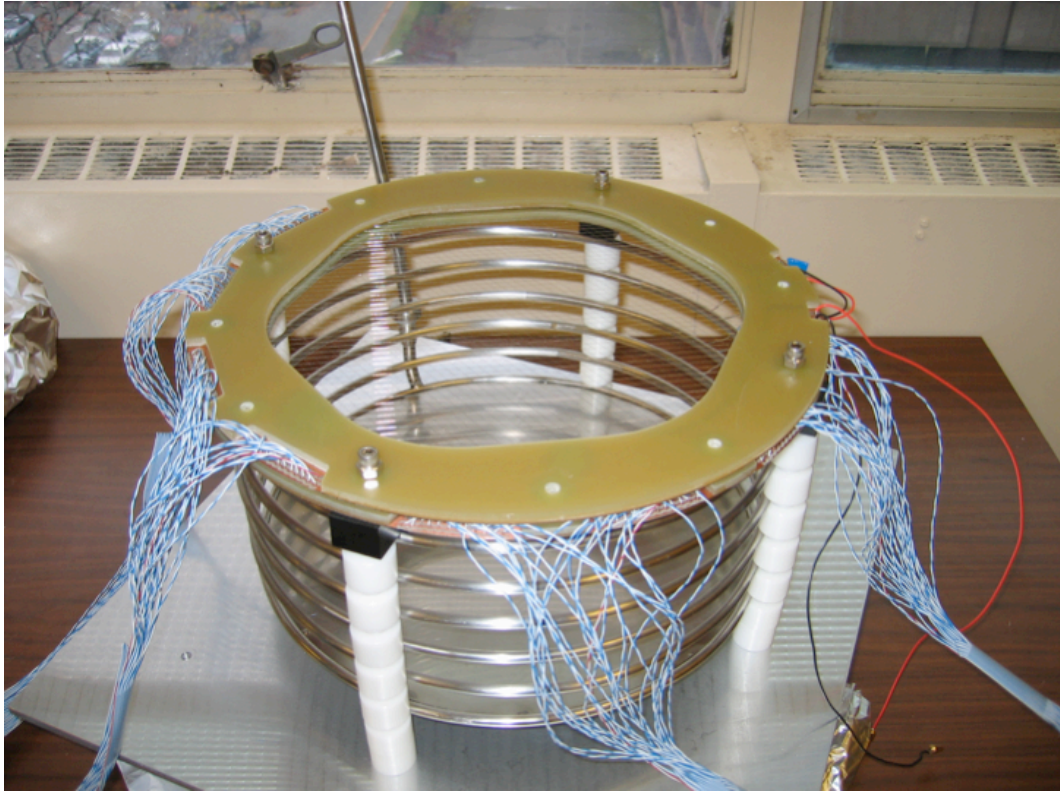
- Oct 04: laboratory at Yale empty and undergoing renovation
- GOAL: technology transfer, being able to see tracks defines success
- Jan 05: the LArTPC effort starts. 3 lines of work
 - liquid Ar purification
 - hardware for TPC and cryogenics
 - electronics (received from Padova Summer 2006)
- by the end of 2006 the detector was ready but still needed extensive debugging

liquid Ar purification

- TRIGON filters assembled at Fermilab, repeatedly regenerated at Yale
- Initial studies in a small setup (total volume $\sim 3\text{l}$, 10 cm drift)
- Next step: LAr purity in the TPC vessel ($\sim 300\text{l}$ total volume) with the TPC inside, fully loaded. Also purity monitor inside TPC vessel. Little or no attenuation over 500 μs drift



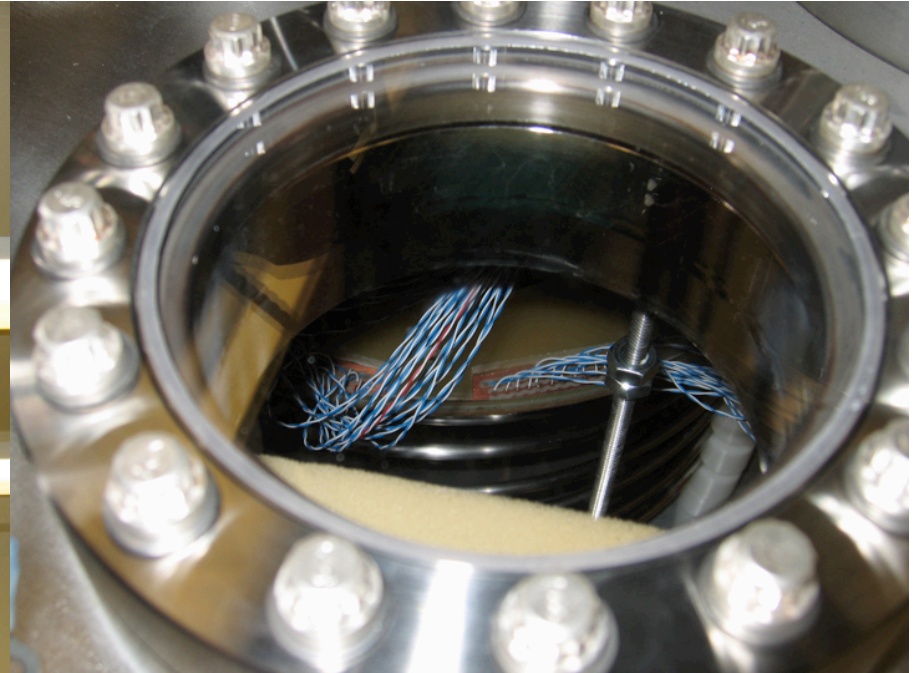
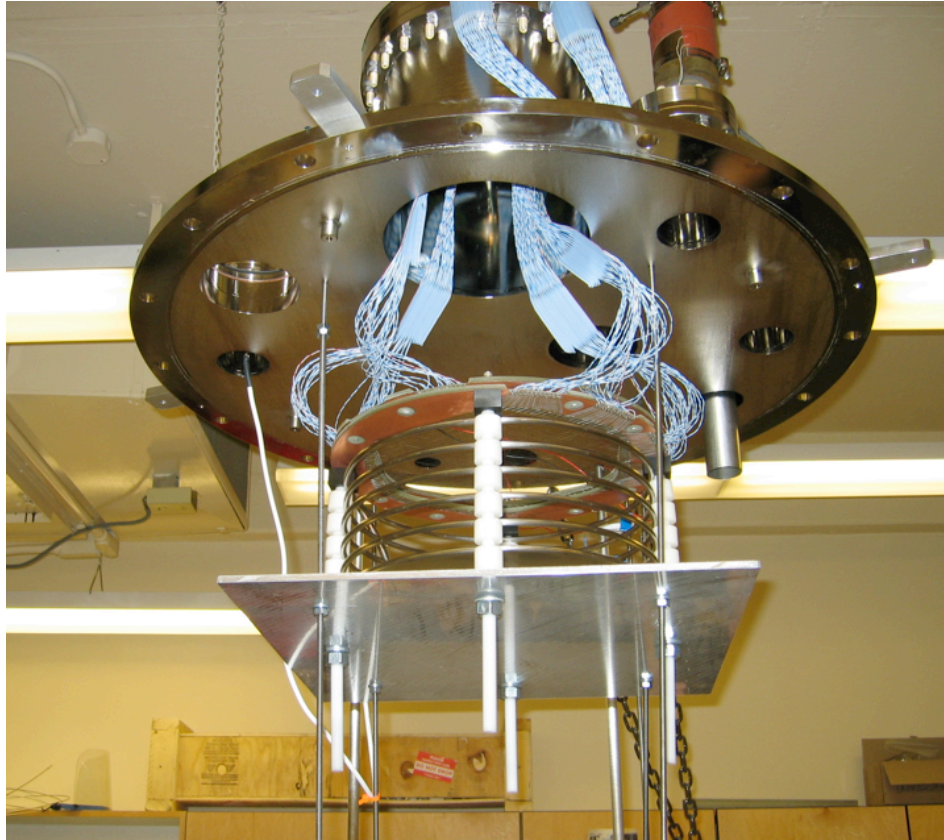
TPC



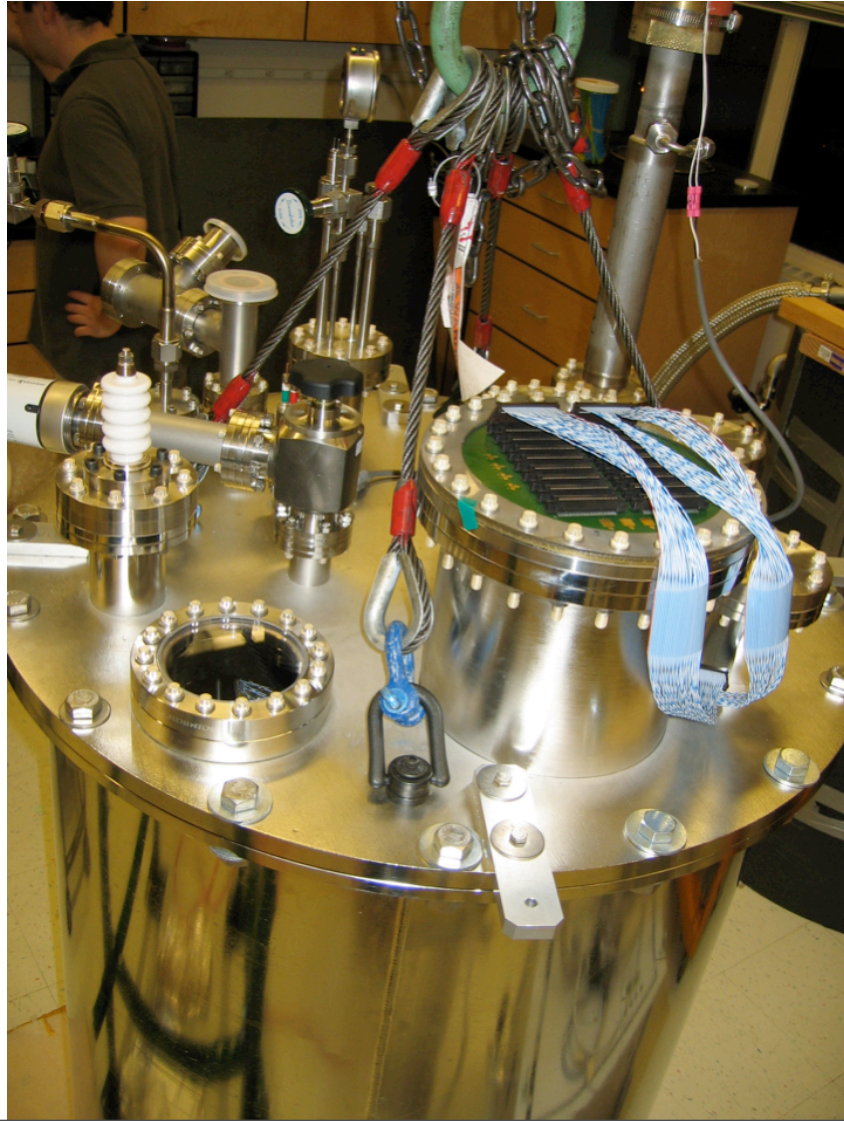
TPC parameters:

- ❑ volume 15 l inside the field cage (within ~250 l ultra-pure liquid Ar)
- ❑ 50 wires collection
- ❑ 50 wires induction
- ❑ 5 mm wire pitch
- ❑ 17 cm drift region
- ❑ drift field ~100V/cm

TPC



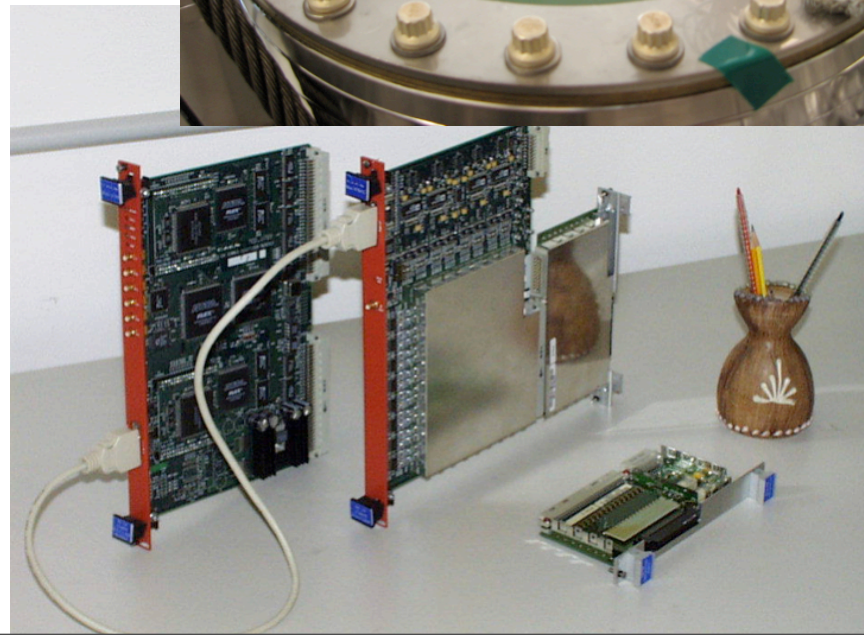
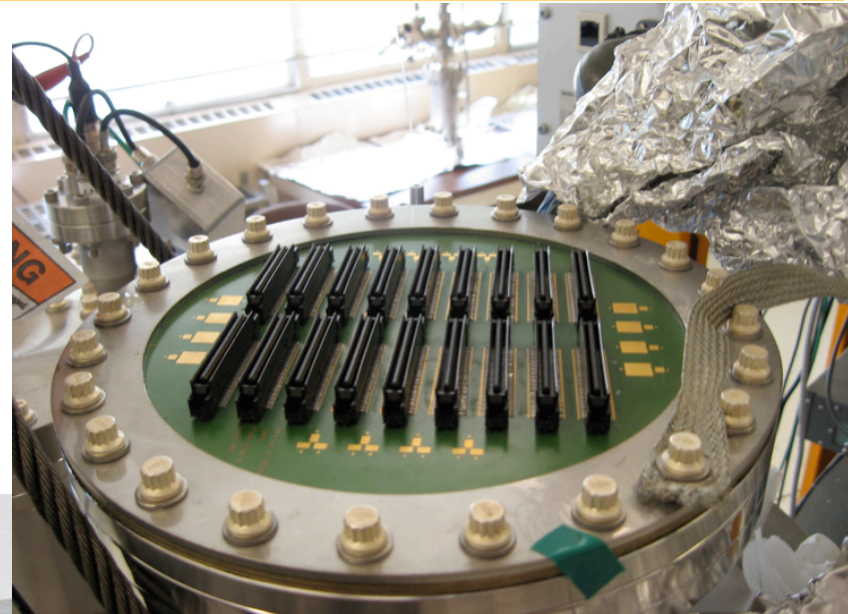
Vacuum & Cryogenics



- ☒ 500 l vacuum vessel pumped down to E-5/E-6 mbar
- ☒ open bath of commercial LAr
- ☒ no active recirculation system
- ☒ relief valve from Hans Jostlein (FNAL)
kept over-pressure below .3 atm

electronics & DAQ

- ☑ ICARUS-CAEN electronics from Padova (256 ch.), together with signal feed-through and signal cables, onus of installation on Yale, including grounding and non-optimized crates/rack
- ☑ software for DAQ and event display from Padova together with a lot of support (many thanks to Sandro Ventura and Bagdat Baibussinov)

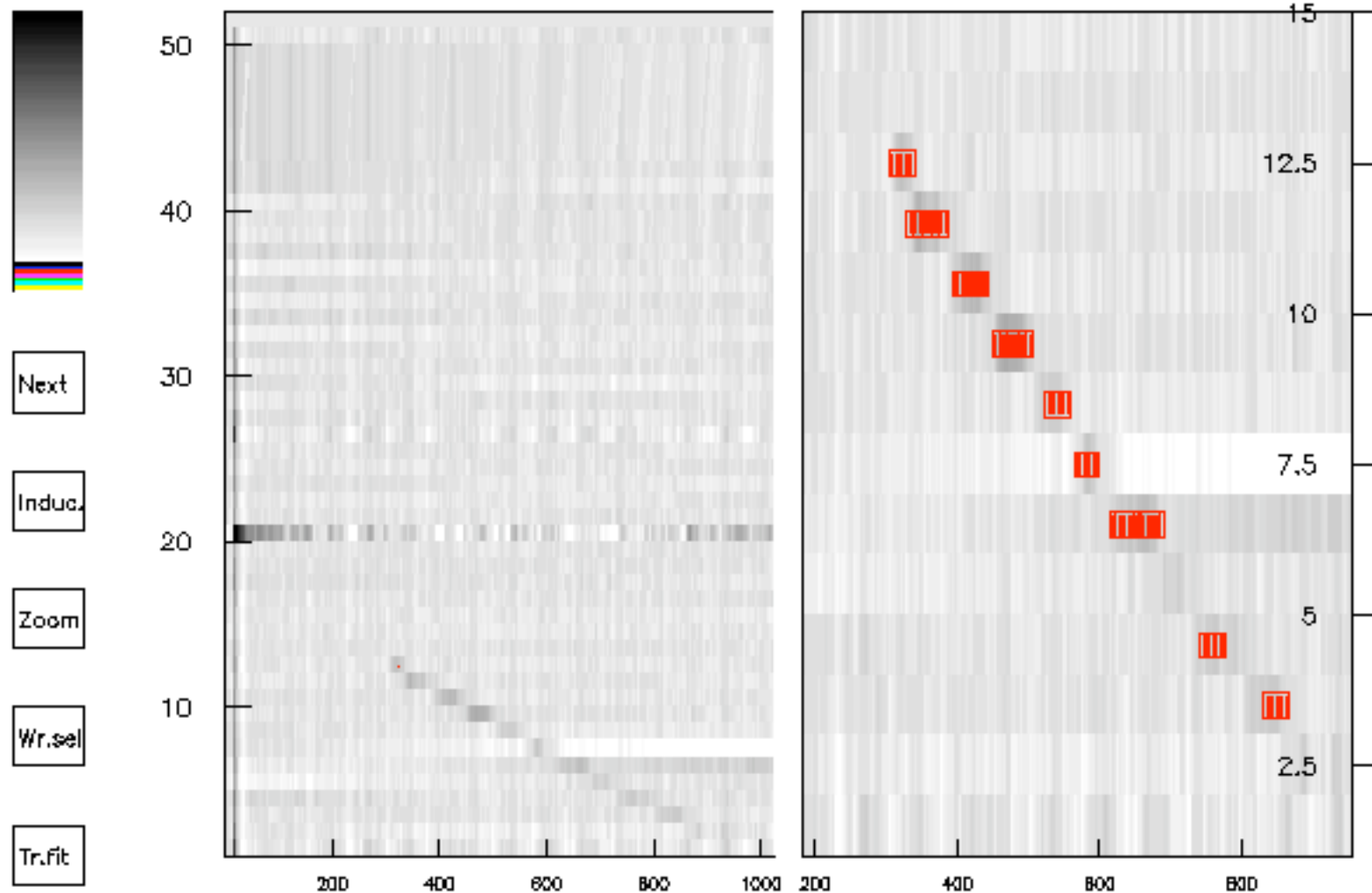


eventually on March 21
we were able to see
the first tracks

this is a U.S. premiere!

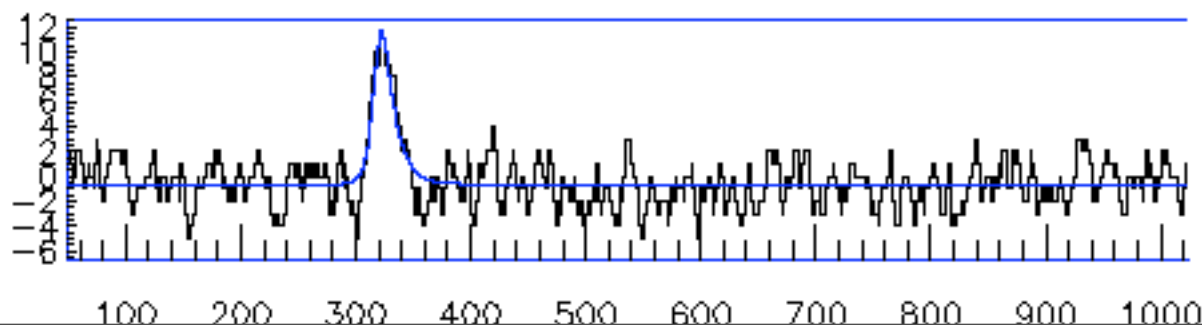


Collection view

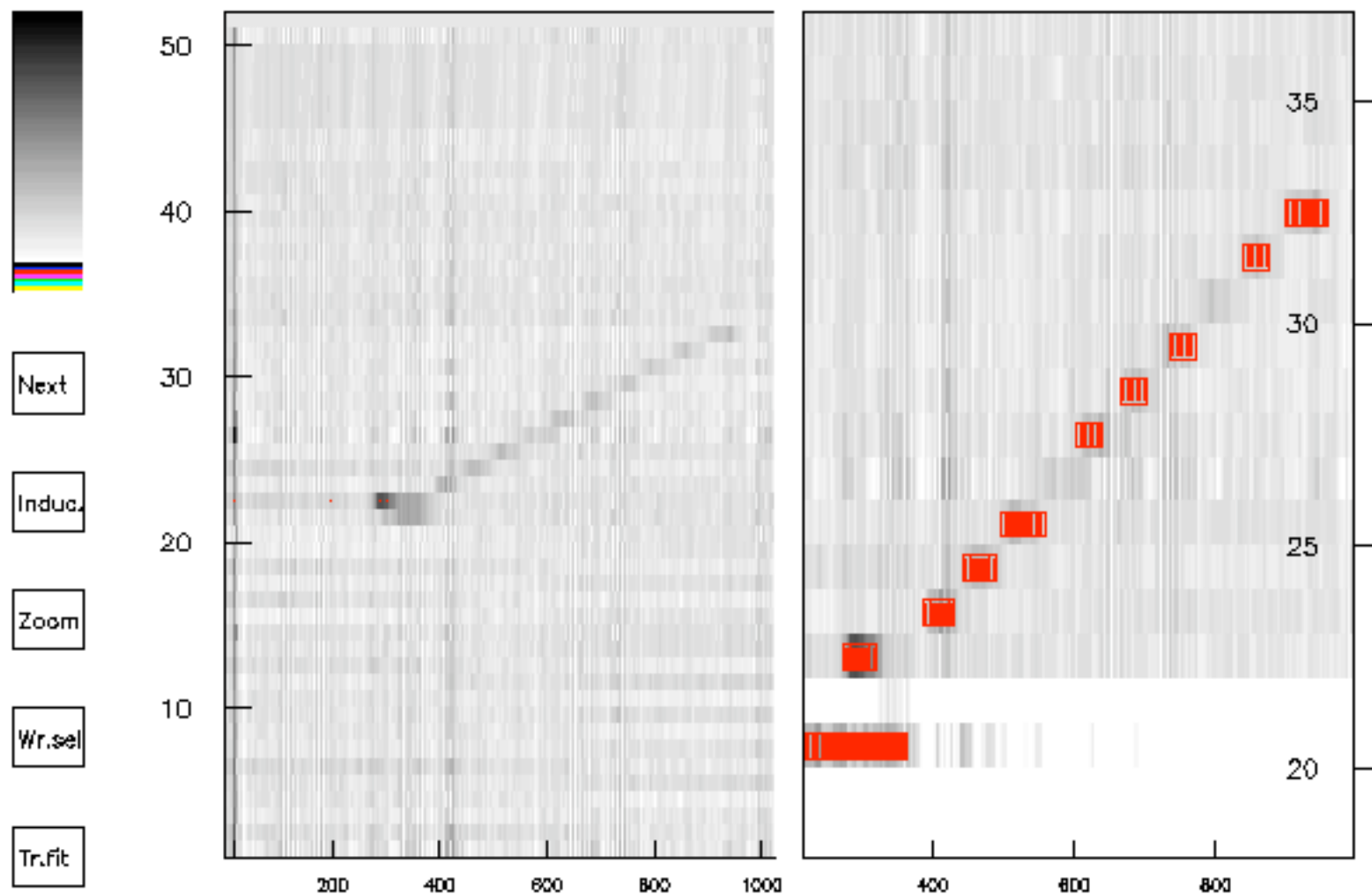


Wire 0012

Wr fit
Wr.up
Wr.dw

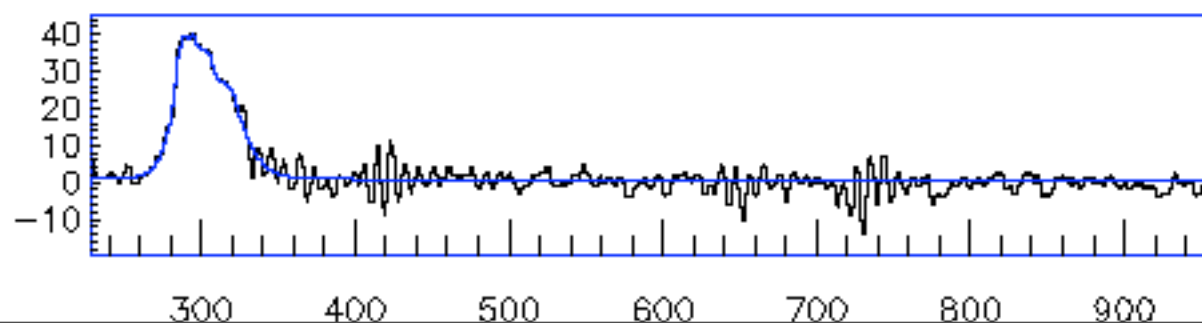


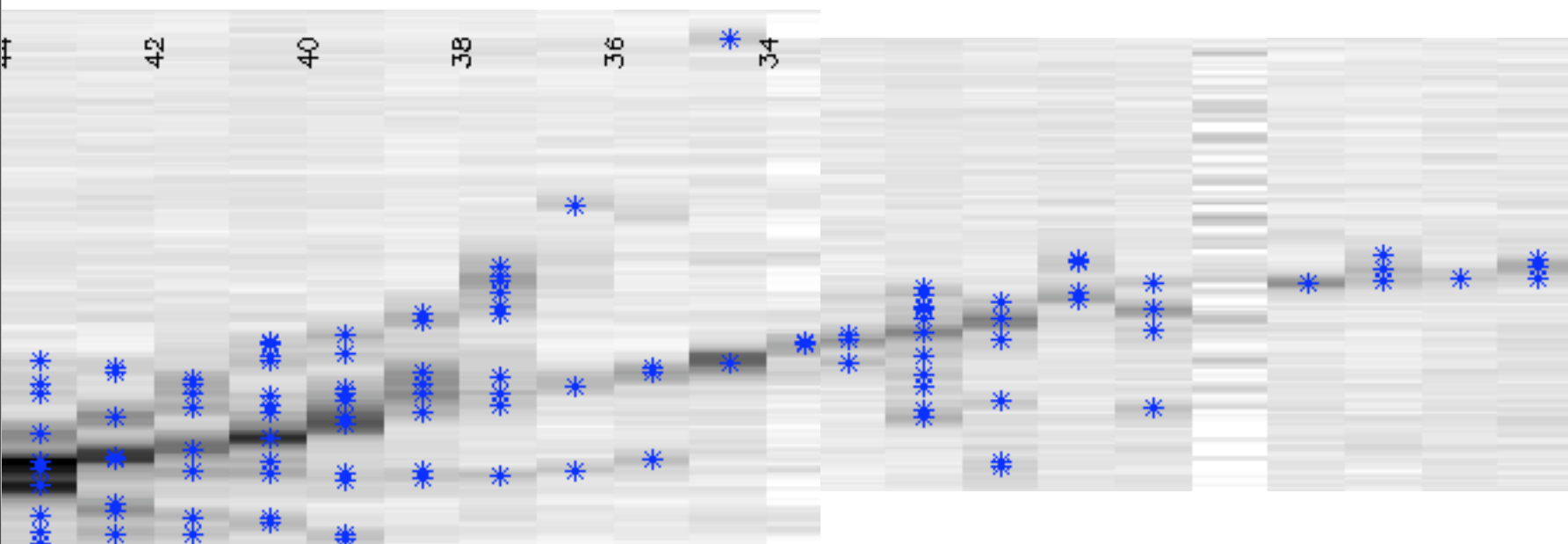
Collection view



Wire 0022

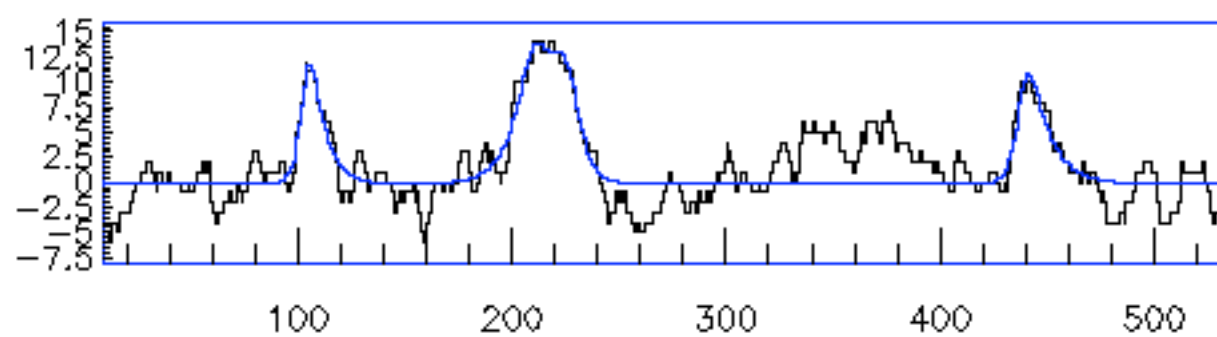
Wr.fit
Wr.up
Wr.dw

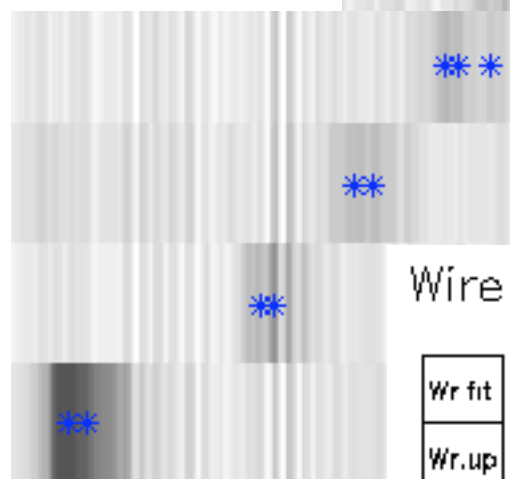
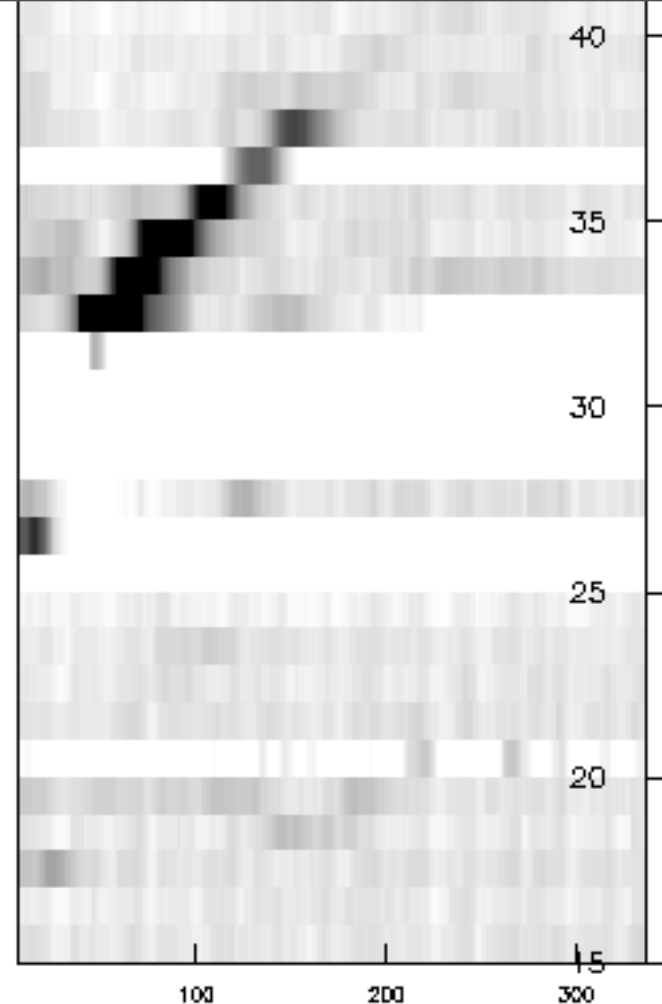
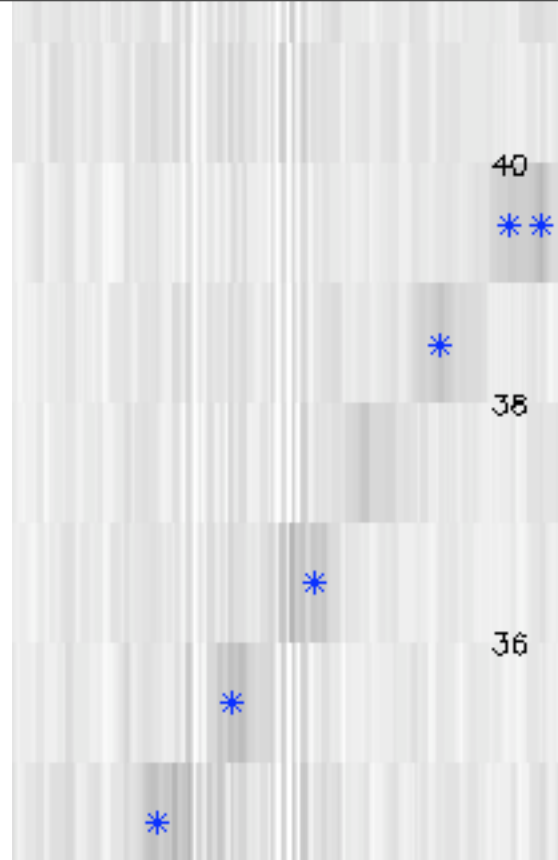




Wire 0036

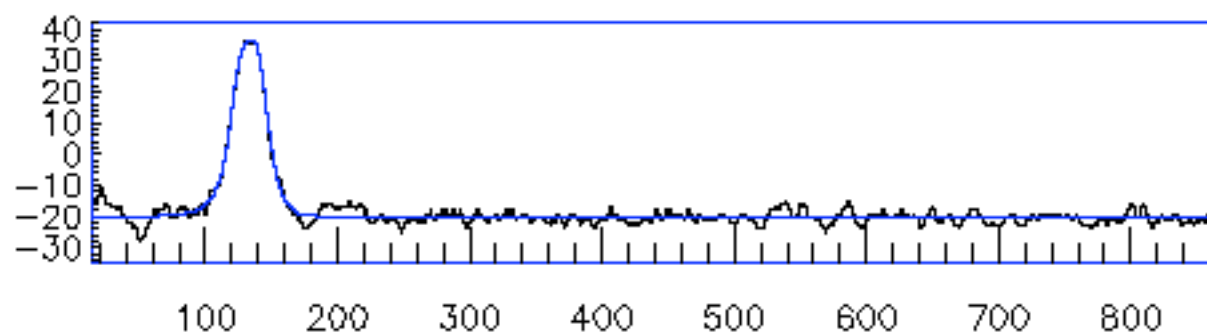
Wr fit
Wr.up
Wr.dw





Wire 0036

Wr fit
Wr.up
Wr.dw



Conclusions & Outlook

- ◆ This result helps to bridge the gap between European and American LAr TPC-expertise and is a good starting point for future LAr TPC efforts as
- ◆ T962 at FNAL (PI B.T. Fleming - Yale) is a 230 l fiducial volume will take neutrino data on the NuMI beam in 2008
- ◆ at FNAL a LAr TPC with completely new electronics is being commissioned and will produce data very very soon

Conclusions & Outlook

- ◆ also waiting for ICARUS T600
- ◆ work on next generation 5 - 10 kton LAr TPC for LBL neutrino oscillation physics (MODULAR from ICARUS in Europe, proposal for Ash River in the U.S.)
- ◆ (next)² generation LAr TPC: 50-100 kton for neutrino physics & proton decay, e.g. GLACIER (A. Rubbia - ETH Zurich) which is pursuing an R&D to improve the charge readout beyond the current state-of-the-art (ICARUS)

Conclusions & Outlook

a number of beautiful developments for direct Dark Matter searches: the XENON results are an important success for the “noble liquid revolution”

for liquid Ar: (micro-, mini-)CLEAN, WARP, ArDM

possible applications to the study of $O(\text{MeV})$ neutrino xsec

at Yale we've seen
the first tracks from
a locally grown
American LArTPC

Run 051 Event 00398 25 apr 2007 17-55-37 EF = 0100V/cm Vdrift = 0.20mm/us Sampl. = 0400ns
Collection view

