Mini-LANNDD T40

F. Sergiampietri

INFN-Sezione di Pisa
and
UCLA-Department of Physics and Astronomy

Preliminary study for a 40-Ton Liquid Argon TPC based on the "ICARUS" method to use in the NuMI near hall at FERMILAB

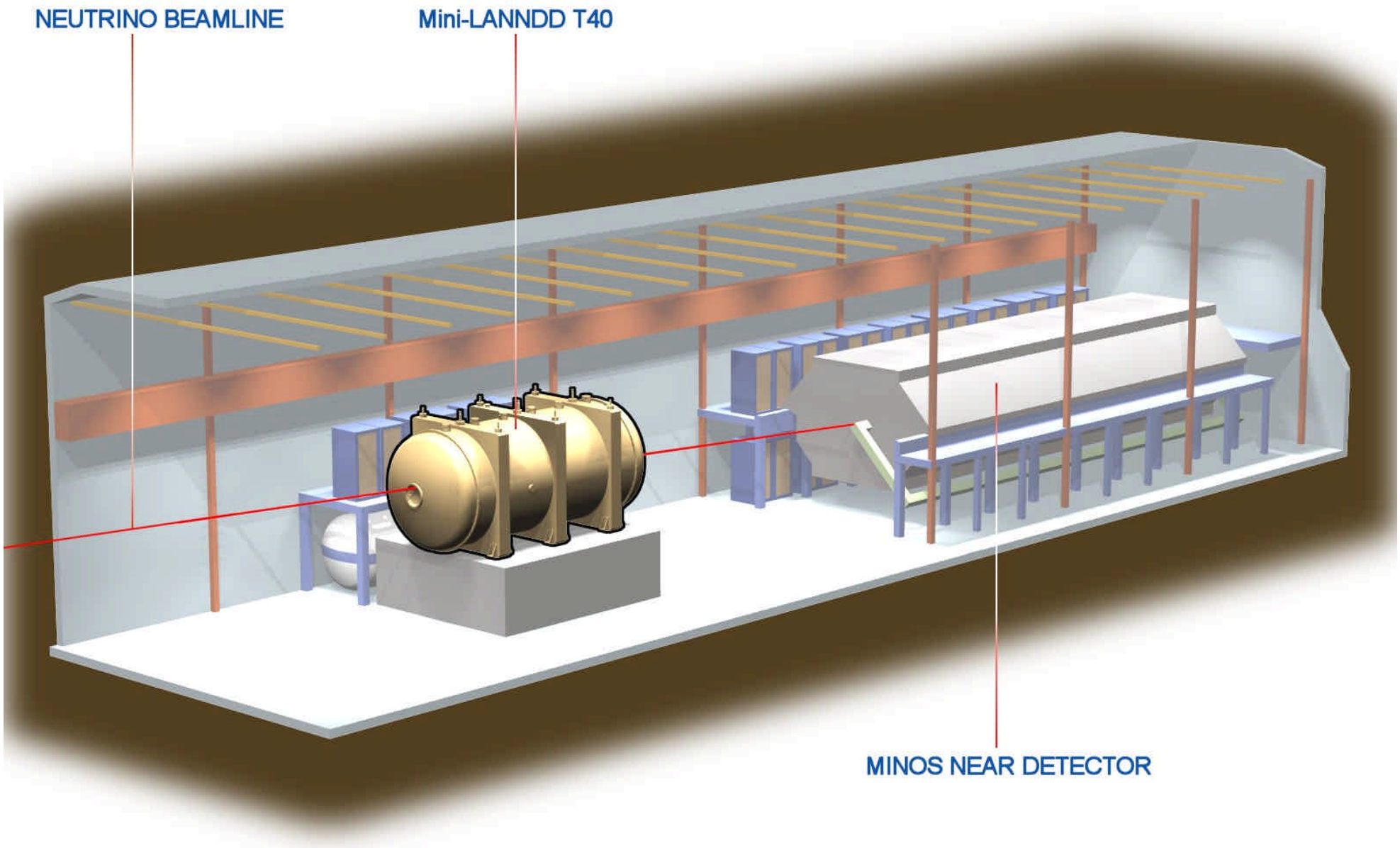
PURPOSES: Near/vertex detector in front of the MINOS near detector and combined with it

Systematic measurements on ν-fluxes and on ν-Argon cross-sections in the low-energy range

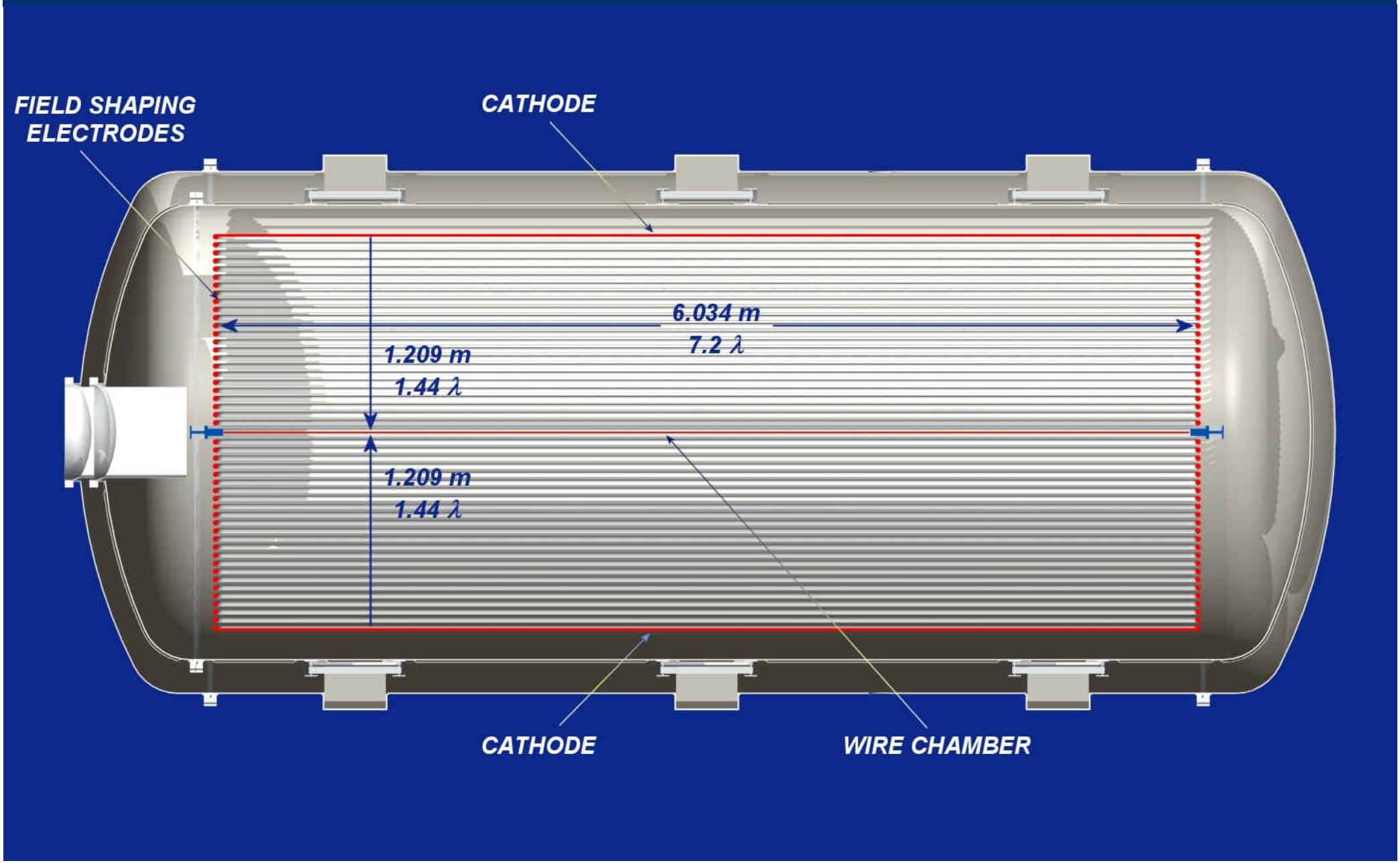
Use of LAr TPC + Magnetic field for:
- Charge sign identification
- Momentum estimation

Introduction of the LAr TPC technique in the USA

Mini-LANNDD 40T – At the NuMI near hall



Mini-LANNDD T40 - Dimensions



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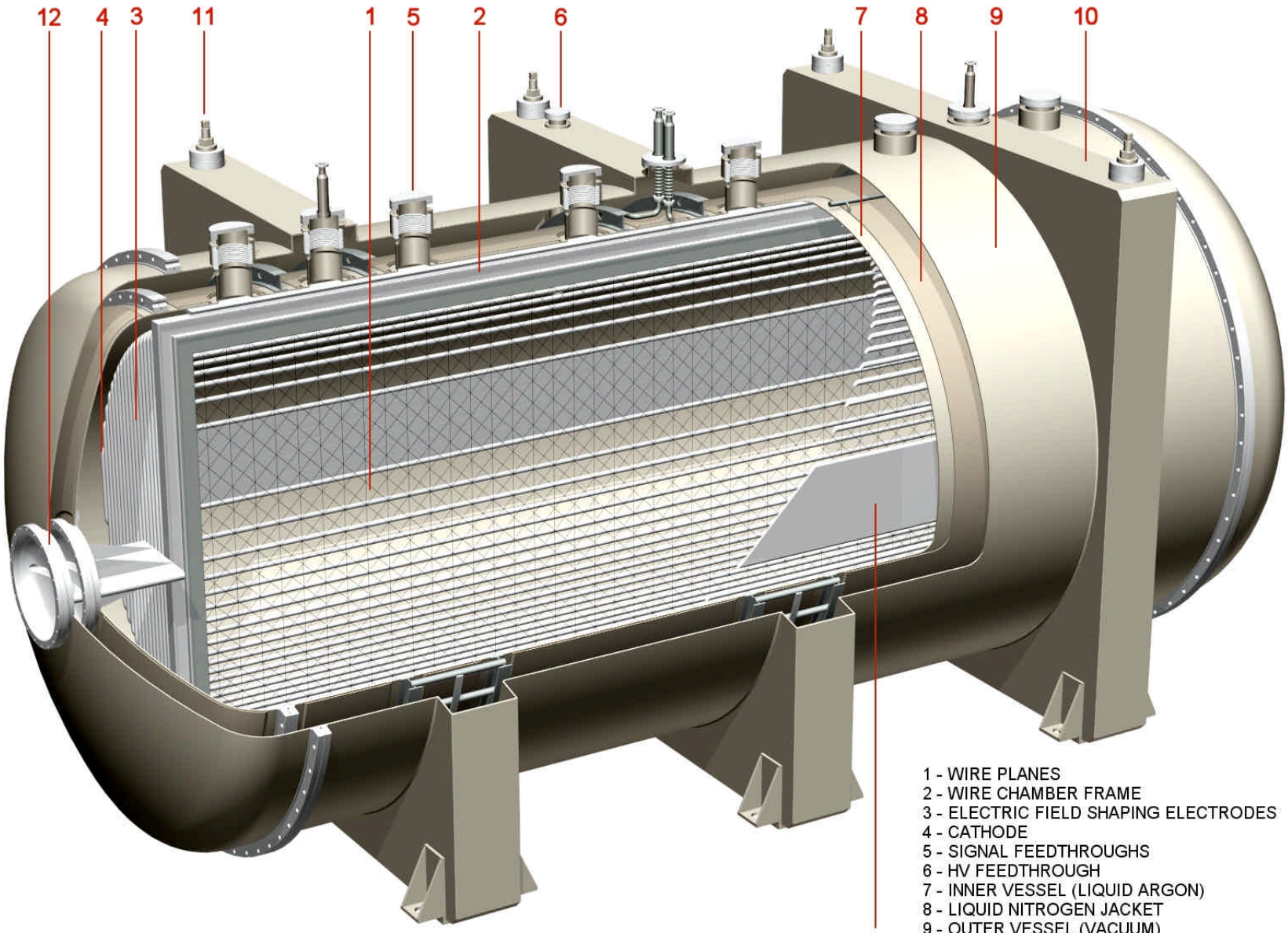
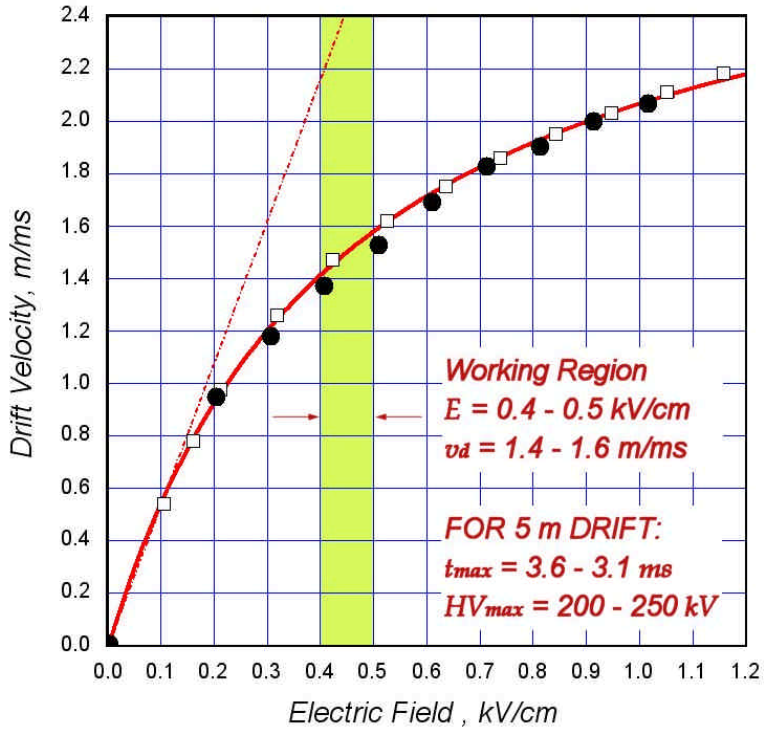


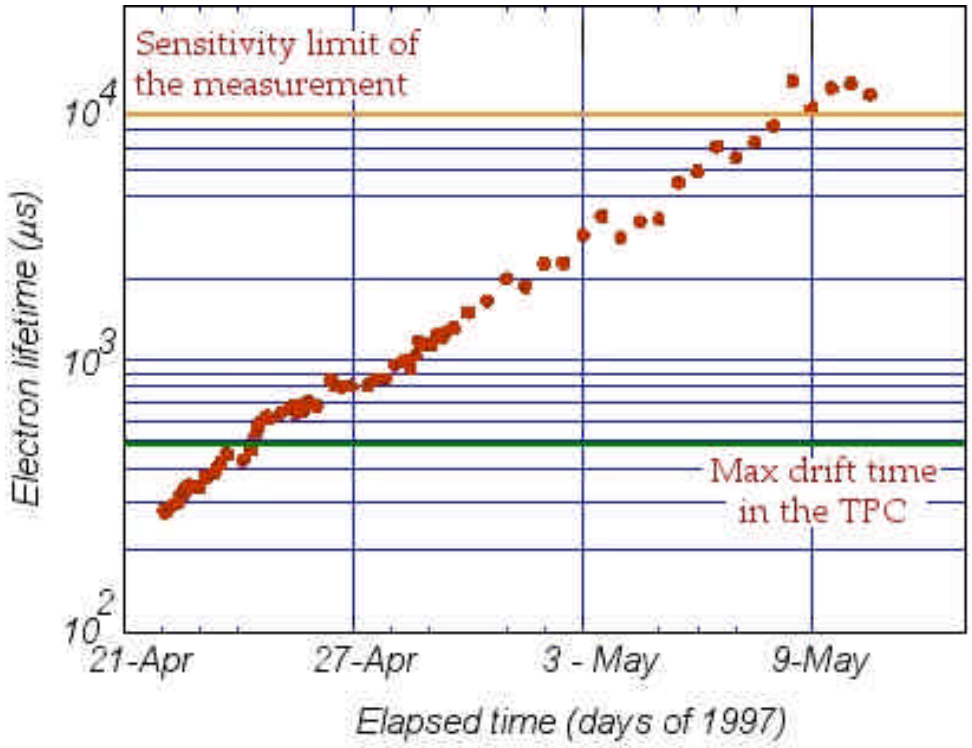
1 - WIRE PLANES
2 - WIRE CHAMBER FRAME
3 - ELECTRIC FIELD SHAPING ELECTRODES
4 - CATHODE
5 - SIGNAL FEEDTHROUGHS
6 - HV FEEDTHROUGH
7 - INNER VESSEL (LIQUID ARGON)
8 - LIQUID NITROGEN JACKET
9 - OUTER VESSEL (VACUUM)
10 - STIFFENING FRAME FEET
11 - INNER VESSEL SUSPENSION BELTS
12 - BEAM ENTRANCE WINDOW

Drift Velocity, Electron lifetime



Drift velocity versus electric field in liquid argon

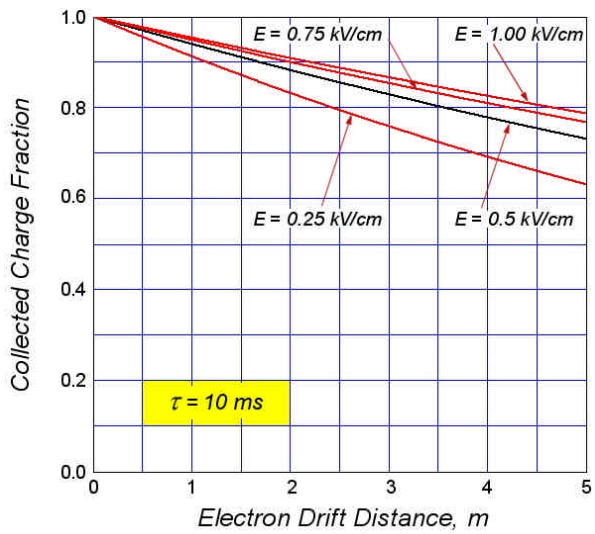
(data from ICARUS R&D and ICARUS T600)



Purification rate

(Data from ICARUS R&D)

Attenuation, Longitudinal Diffusion



Drifting charge attenuation versus drift paths at different electric field intensities ($\tau = 10\ ms$)

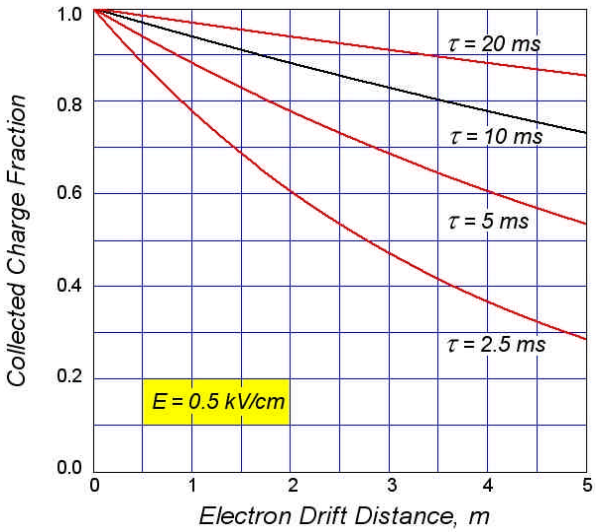
$$s_D = \sqrt{2 \cdot D \cdot \frac{x}{v_d}}$$

$$D = 4.06\ cm^2/\sec$$

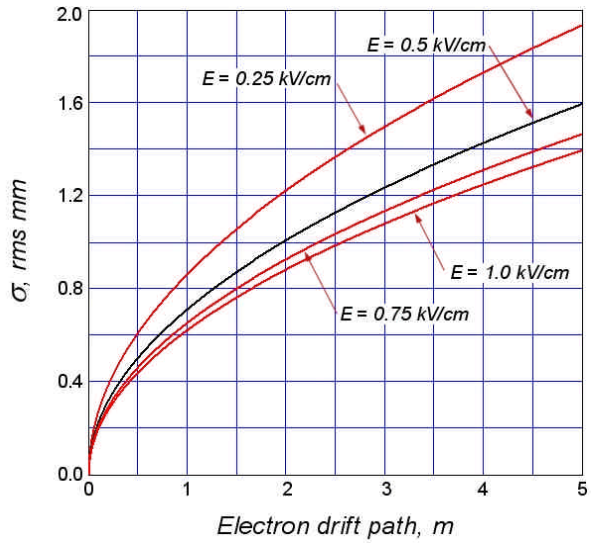
$$s_D = 0.9mm \cdot \sqrt{T_D[ms]}$$

Longitudinal RMS diffusion spread at $0.5\ kV/cm$, drift = $5\ m$

Average	$\langle\sigma_D\rangle$	$= 1.1\ mm$
Maximum	σ_{Dmax}	$= 1.6\ mm$

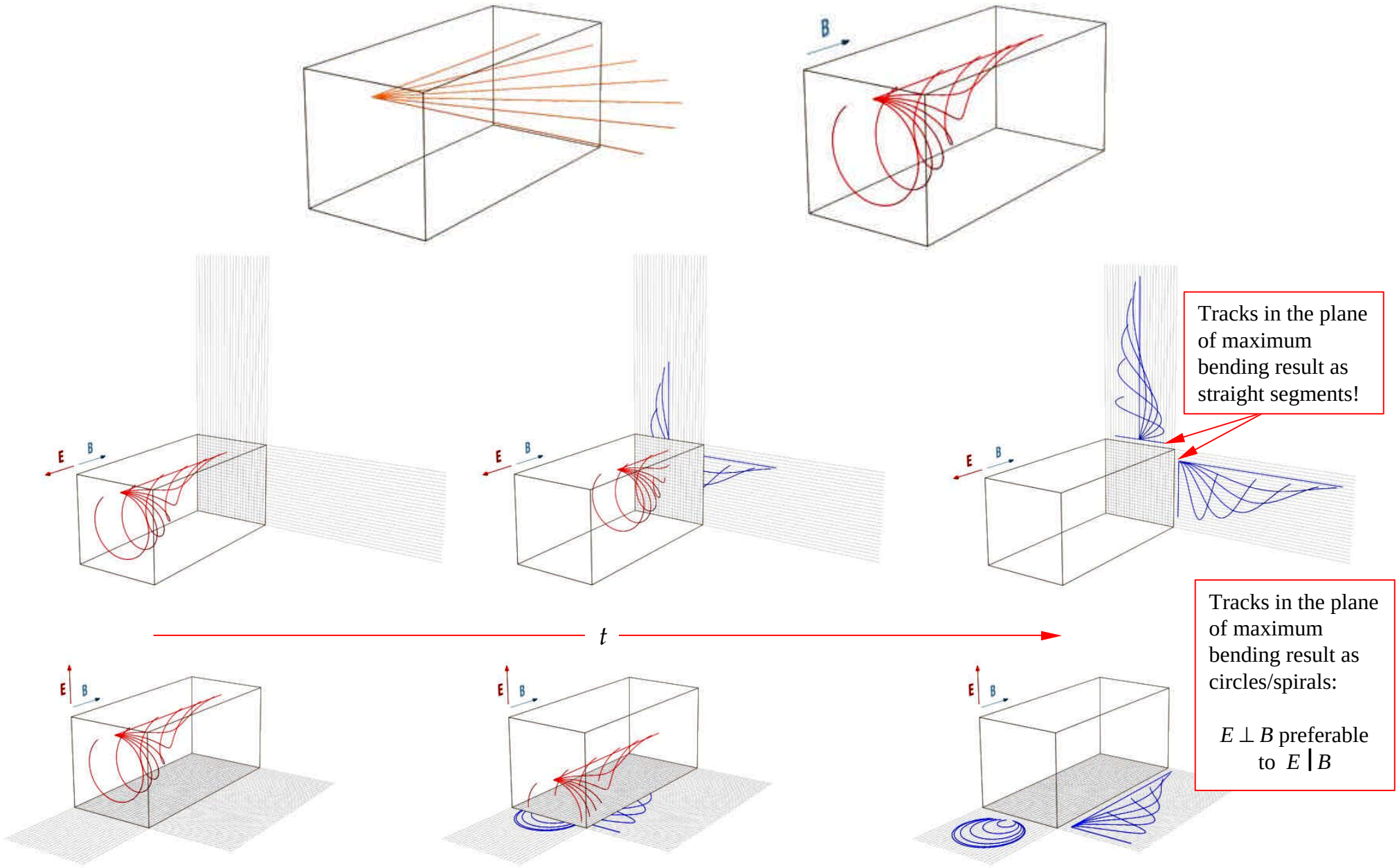


Drifting charge attenuation versus drift path at different electron lifetimes ($E = 0.5\ kV/cm$)



Longitudinal RMS diffusion spread versus drift paths at different electric field intensities

Operation in Magnetic Field



Tracks in the plane of maximum bending result as straight segments!

Tracks in the plane of maximum bending result as circles/spirals:

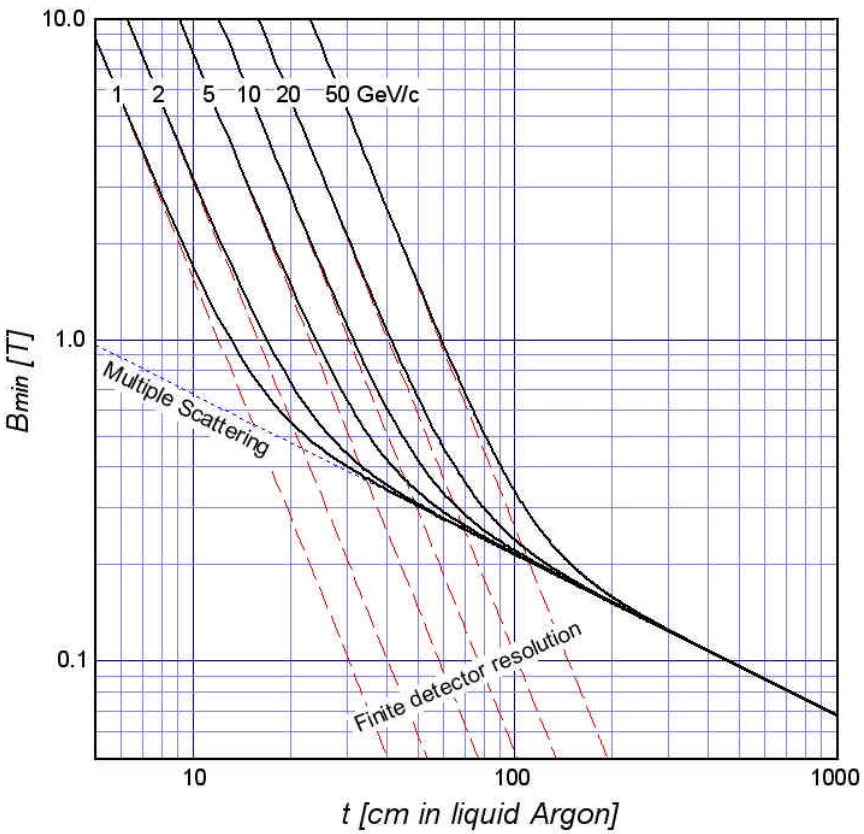
$E \perp B$ preferable to $E \mid B$

Charge sign discrimination and Momentum resolution

$$k^{\pm} \cong \frac{0.3B}{p\cos\lambda}$$ Bending curvature

with 3*D* detector pixel $\langle \Delta_{\det} \rangle = 3.4\ mm$

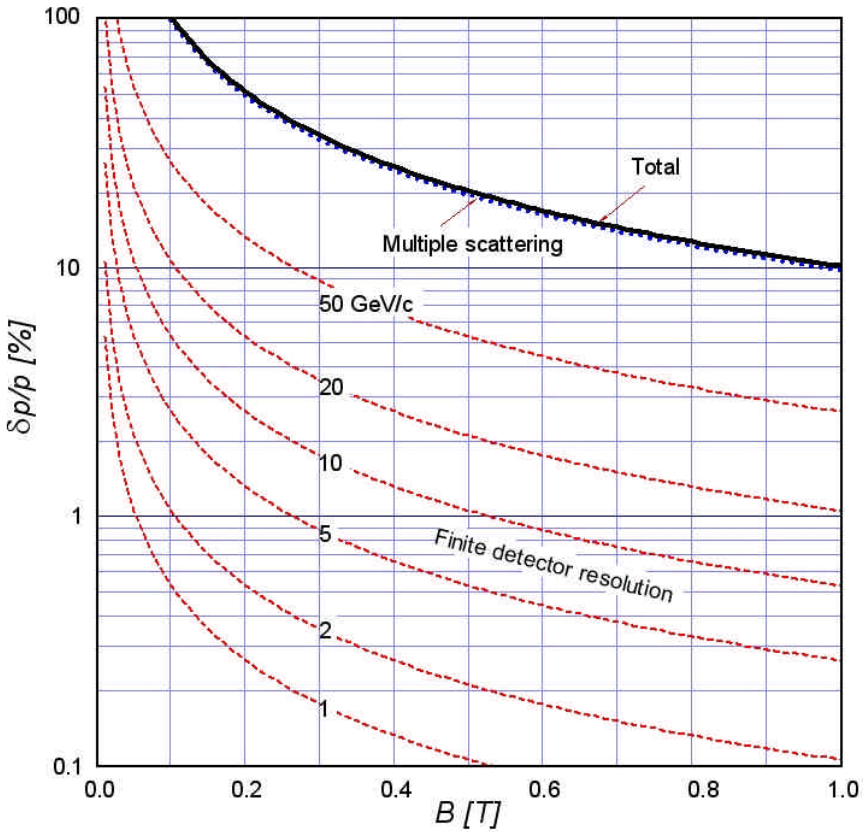
$$k^{+} - k^{-} = 2k^{\pm} \geq 3\delta k = 3\sqrt{\delta k_{res}{}^{2} + \delta k_{ms}{}^{2}}$$



Minimum magnetic field for charge sign discrimination at 3σ level

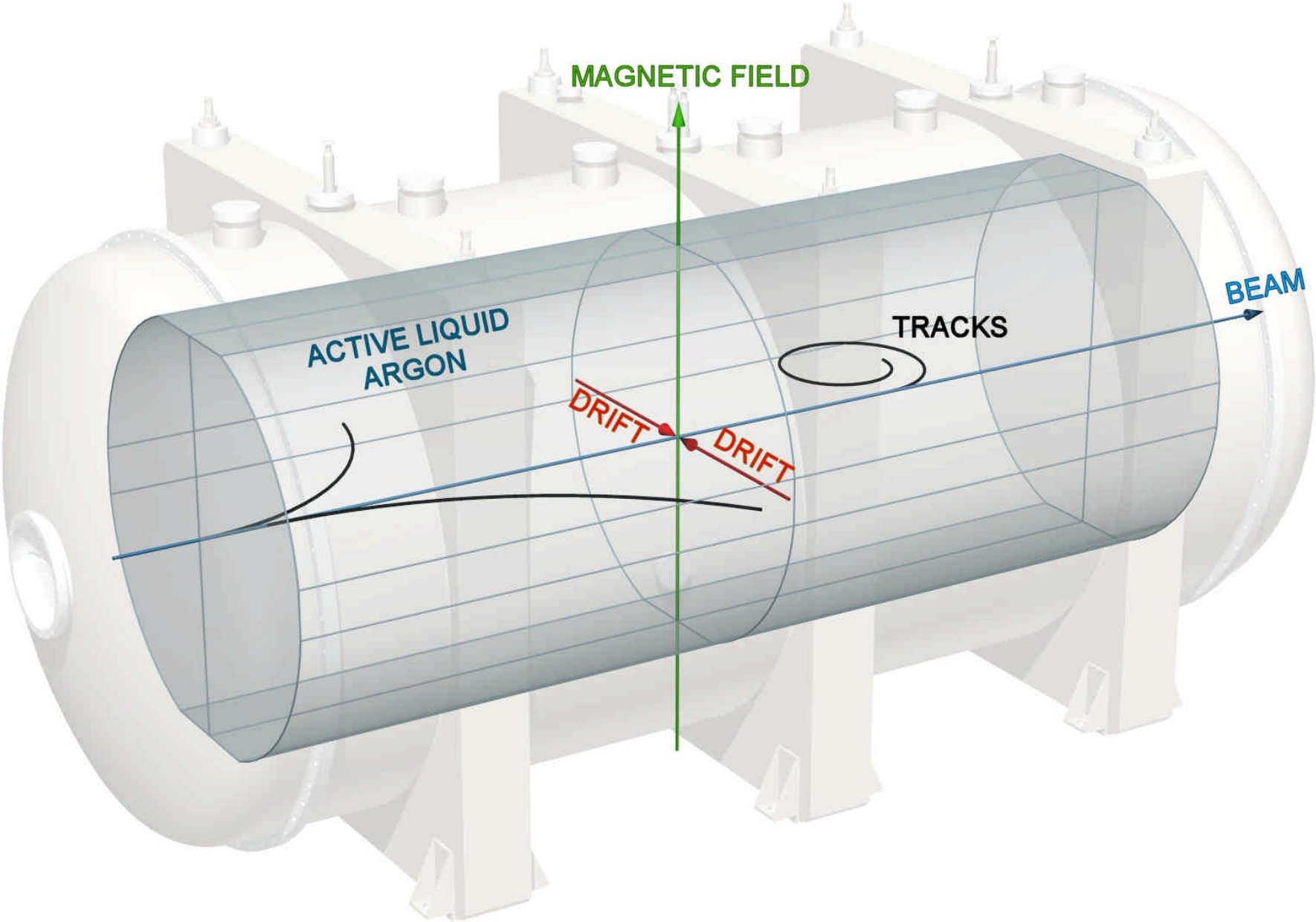
$$\frac{\delta p}{p} = \frac{\delta k}{k} = \frac{\sqrt{\delta k_{res}{}^{2} + \delta k_{ms}{}^{2}}}{k} \propto \frac{1}{B \cdot \sqrt{t}}$$

with t = path in radiation lengths

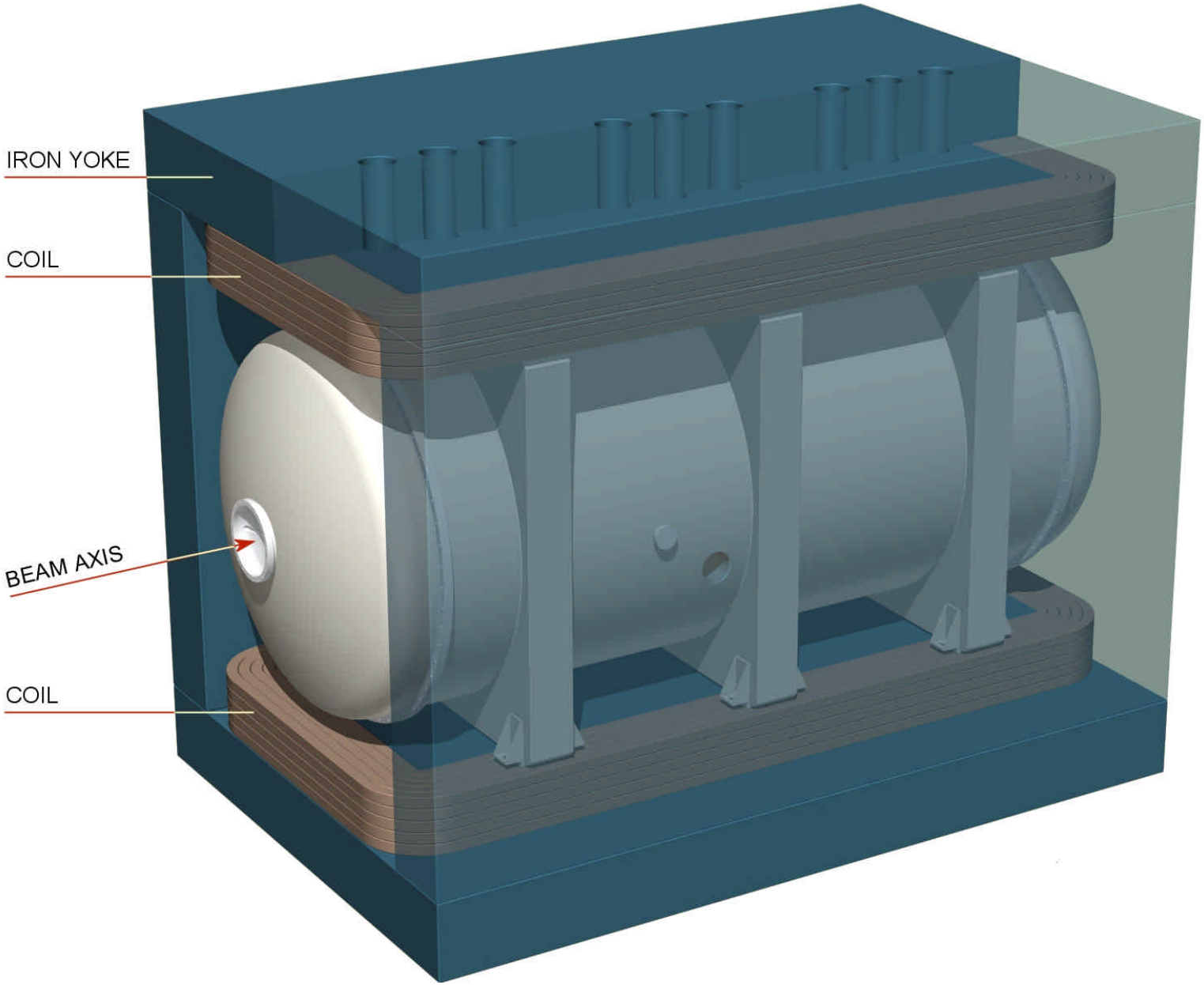


Momentum resolution for $t = 15\ X_o$ (= 2.12 *m* in liquid Argon)

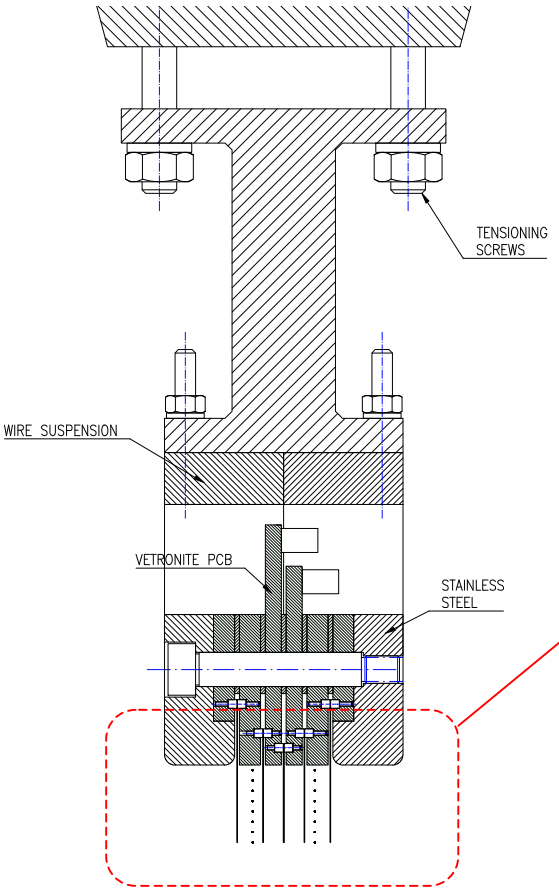
Beam – Drift – Magnetic Field Orientation

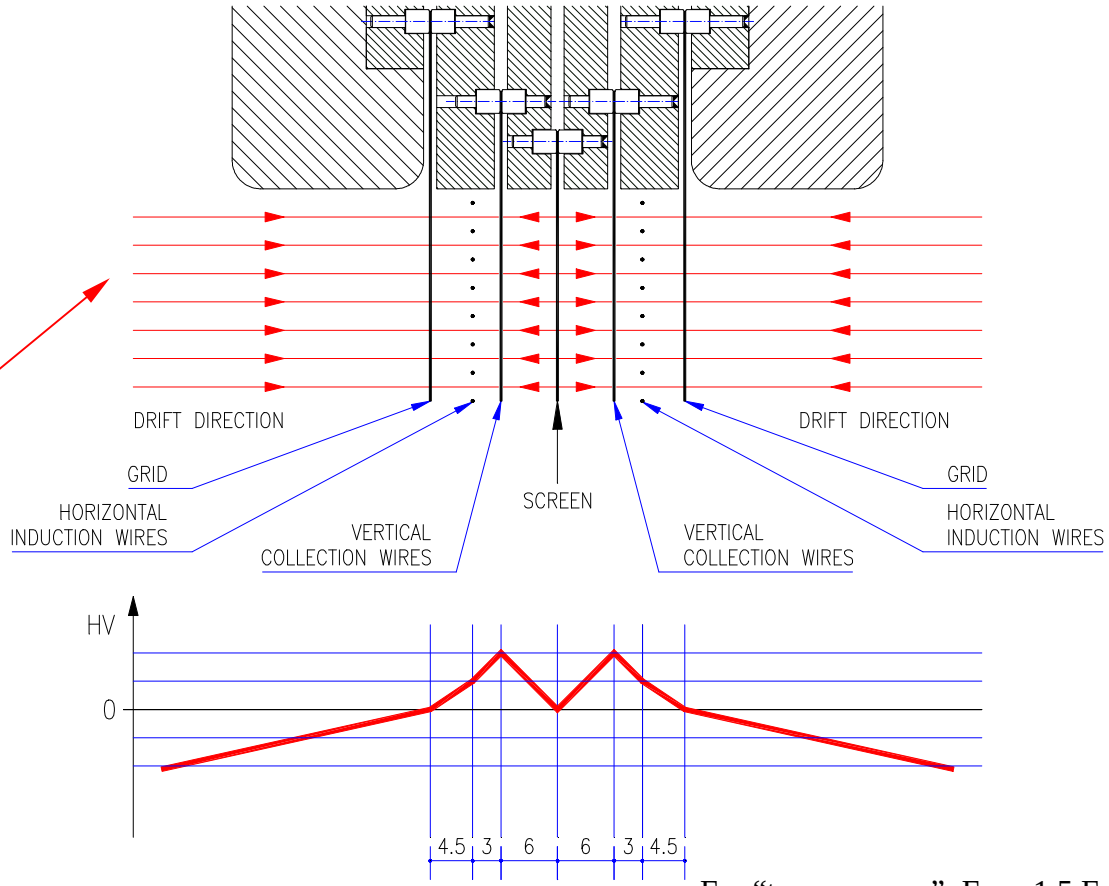


Mini-LANNDD T40 inside a Dipole Magnet



Technical detail - Wire hanging





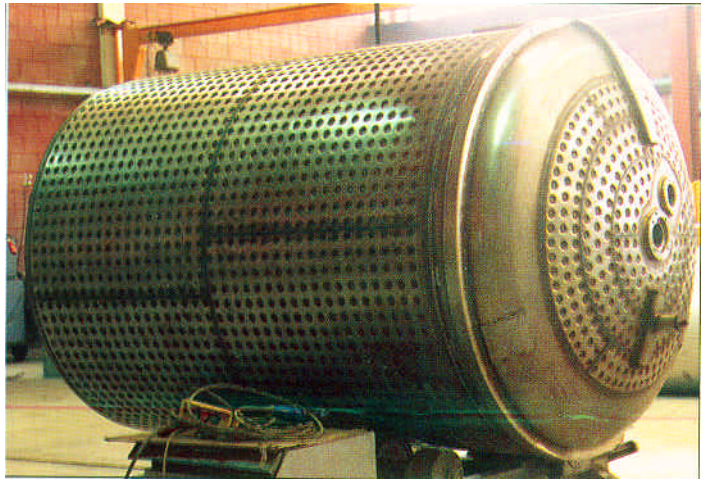
For "transparency": $E_{n+1}=1.5 \cdot E_n$

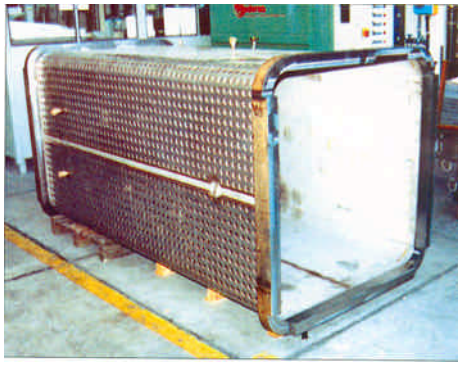
Stainless steel wires with ∅100 μ*m* at a 3 *mm* pitch.
Channel maximum capacitance in LAr:
23 *pF/m* × 40 *m* + 2 *m* Cable ≈ 1 *nF*
ENC ≈ 1600 e^- RMS, *S/N* ≈ 8 for minimum signals

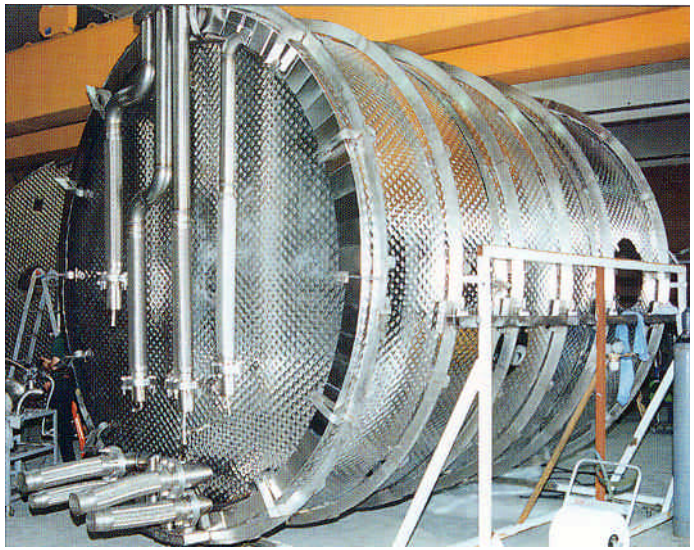
7 wire planes:
- 2 grid panes + 1 screen plane made by vertical wires referred to ground
- 2 induction planes with horizontal wires biased at +337.5 *V*
- 2 collection planes with vertical wires biased at +675 *V*

Mini-LANNDD T40 - Technical detail – LN_2 jacket

Fabricated by welding a pre-deformed plate to a flat plate. The dimpled plate is pre-deformed with different shapes, to obtain an air space varying from 3 to 15 mm between the plates. The welding can be made by MIG, TIG or Resistance Spot process. No limitation on the thickness plates used.







Mini-LANNDD T40 - Parameters

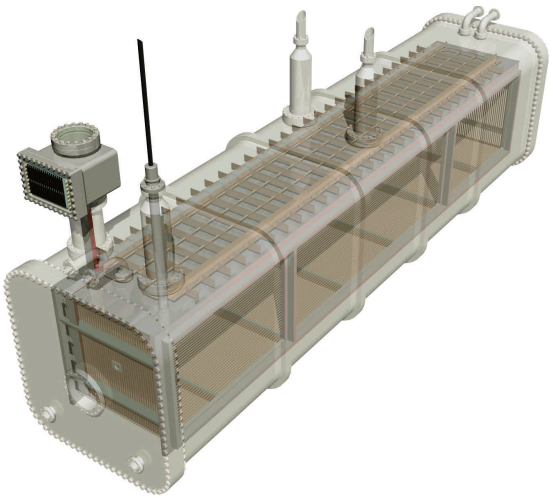
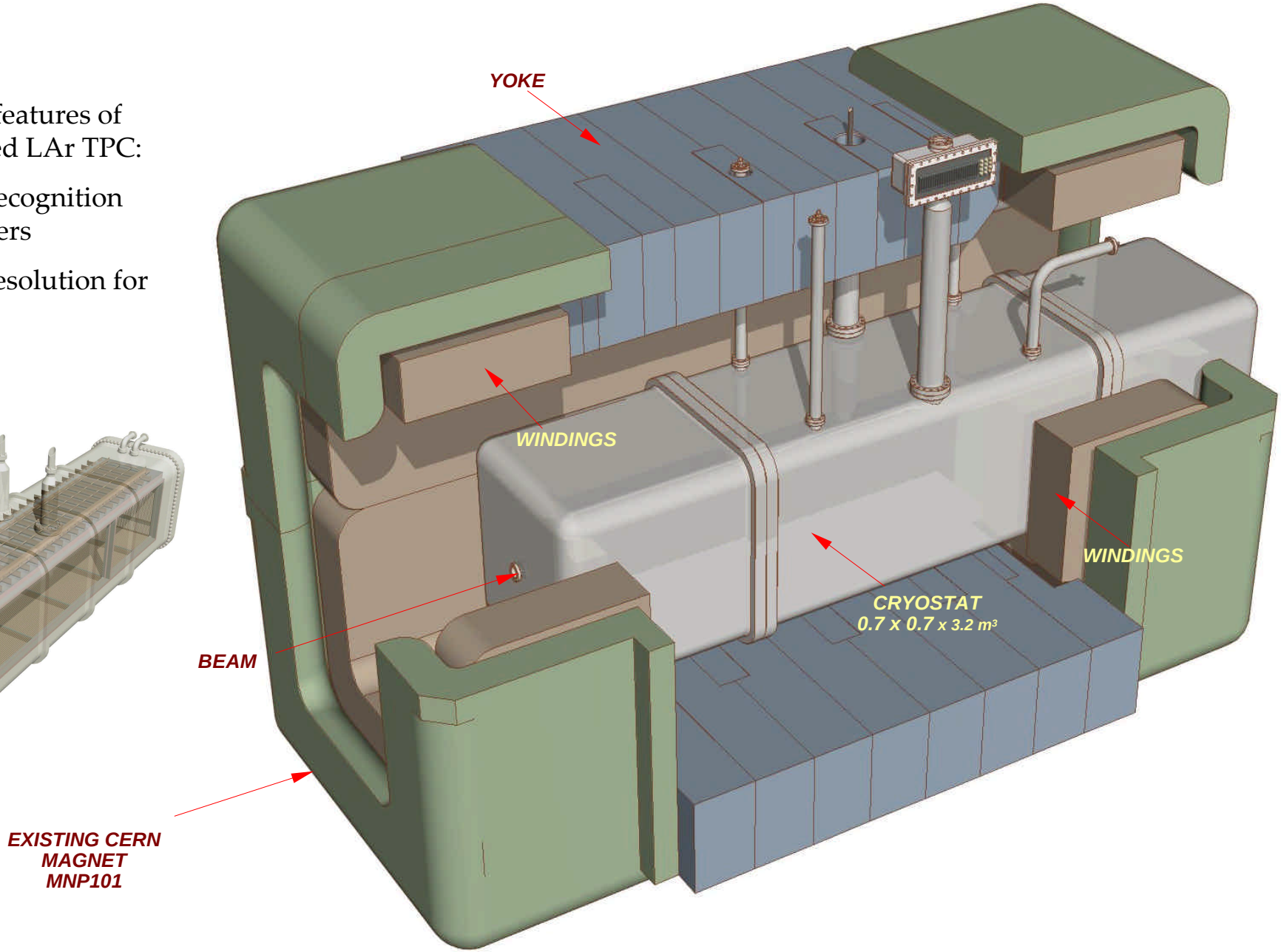
Total liquid argon volume	42.8	m^3
Gas argon volume	0.9	m^3
Active liquid argon volume	27.7	m^3
Active liquid argon sizes	w=2.4 $m \times h$=2.3 $m \times l$=6.0	m
Active liquid argon mass	38.5	*Ton*
Number of drift regions	2	
Max Drift lengths	2×1.2	m
Maximum required high voltage	60	*kV*
Number of cathode planes	2	
Number of HV feedthroughs	1	
Number of wire chambers	1	
Number of readout wire planes	4 (6)	
Orientation of readout wires	+45º, -45º, (90º)	
Number of readout wires	7’808 (9’216)	
Number of signal feedthrough chimneys	6	
Number of analog-to-digital processing crate pairs	14 (16)	
Heat Input *a)* Radiation (with w_r = 1 $watt/m^2$)	72	*W*
b) Conduction (cables & mech. supports)	240	*W*
Total	312	*W*
Equivalent liquid nitrogen consumption	0.2	m^3/d

Mini-LANNDD T40 - Rough cost estimate

Liquid argon	60 m^3	30	k$
Cryostat	Inner vessel LN_2 jacket Outer vessel Beam entrance windows Thermally decoupled chimneys for signals, HV, IN/OUT *Ar*, IN/OUT LN_2, inner vessel suspension	180	k$
Inner detector mechanics and wiring	Wire chamber (frame, wires, combs, and spacers) Field shaping electrodes and cathodes	40	k$
Electronics (9'300 channels) and DAQ	Signal cables and feedthroughs Analog and Digital Processing crates Calibration pulser Wire bias HV power supplies Acquisition and event display computer	550	k$
Vacuum & cryogenic components	Vacuum pumps and gauges LN_2 and *LAr* storage dewars *LAr* purification system and purity monitor Transfer lines, valves Level and temperature monitors	75	k$
High voltage system	Power supply, feedthrough, monitor	25	k$
Other details & contingency	External trigger counters and electronics UPS and O_2 monitors	150	k$
Total		1050	k$

R&D - Micro-LANNDD

Purposes

Study the basic features of the Magnetised LAr TPC:

- Charge sign recognition for e.m. showers
- Momentum resolution for muons