he T2K-liquid Argon detector for the 2 km site

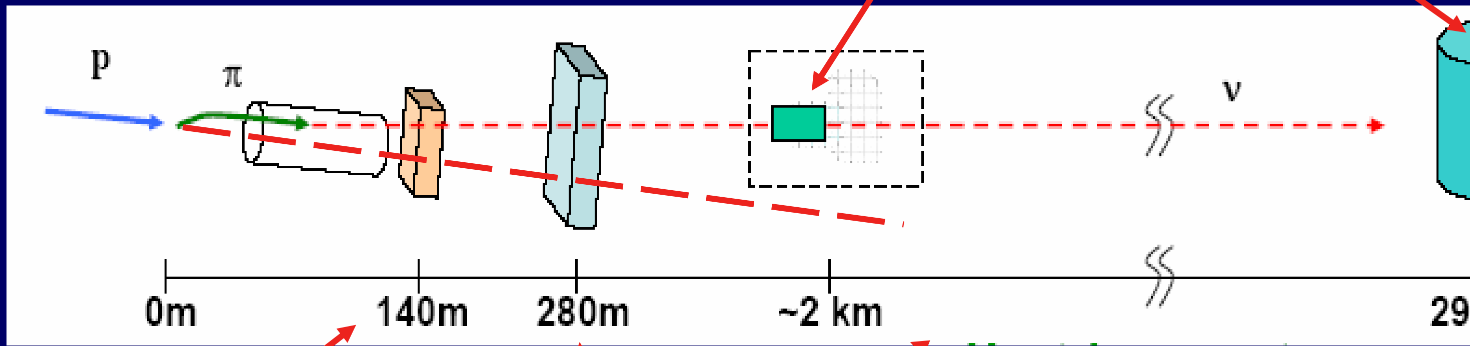
Napoli, 9 December 2004

Antonio Ereditato

2K detectors

T2K-LAr ?

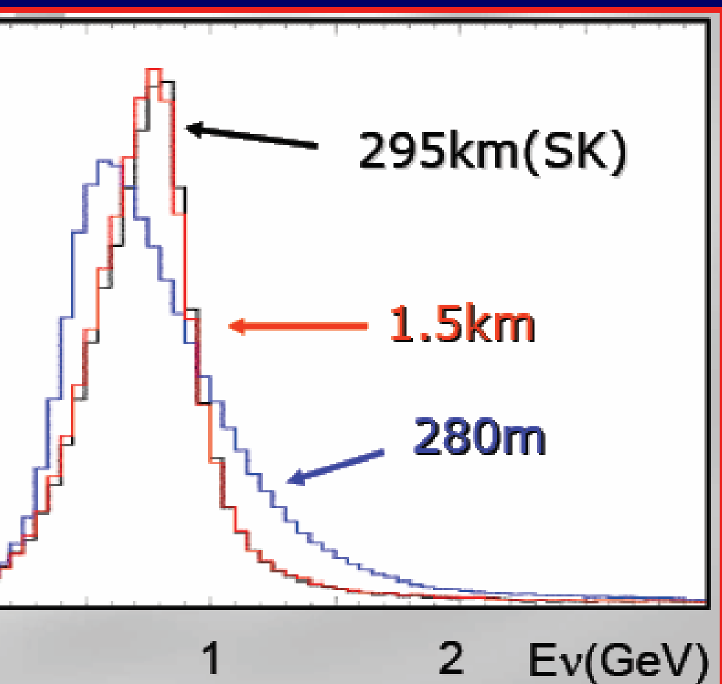
Super-K



μ monitor (beam direction and intensity)

ν energy spectrum and intensity

Same spectrum as SK, BG measurement

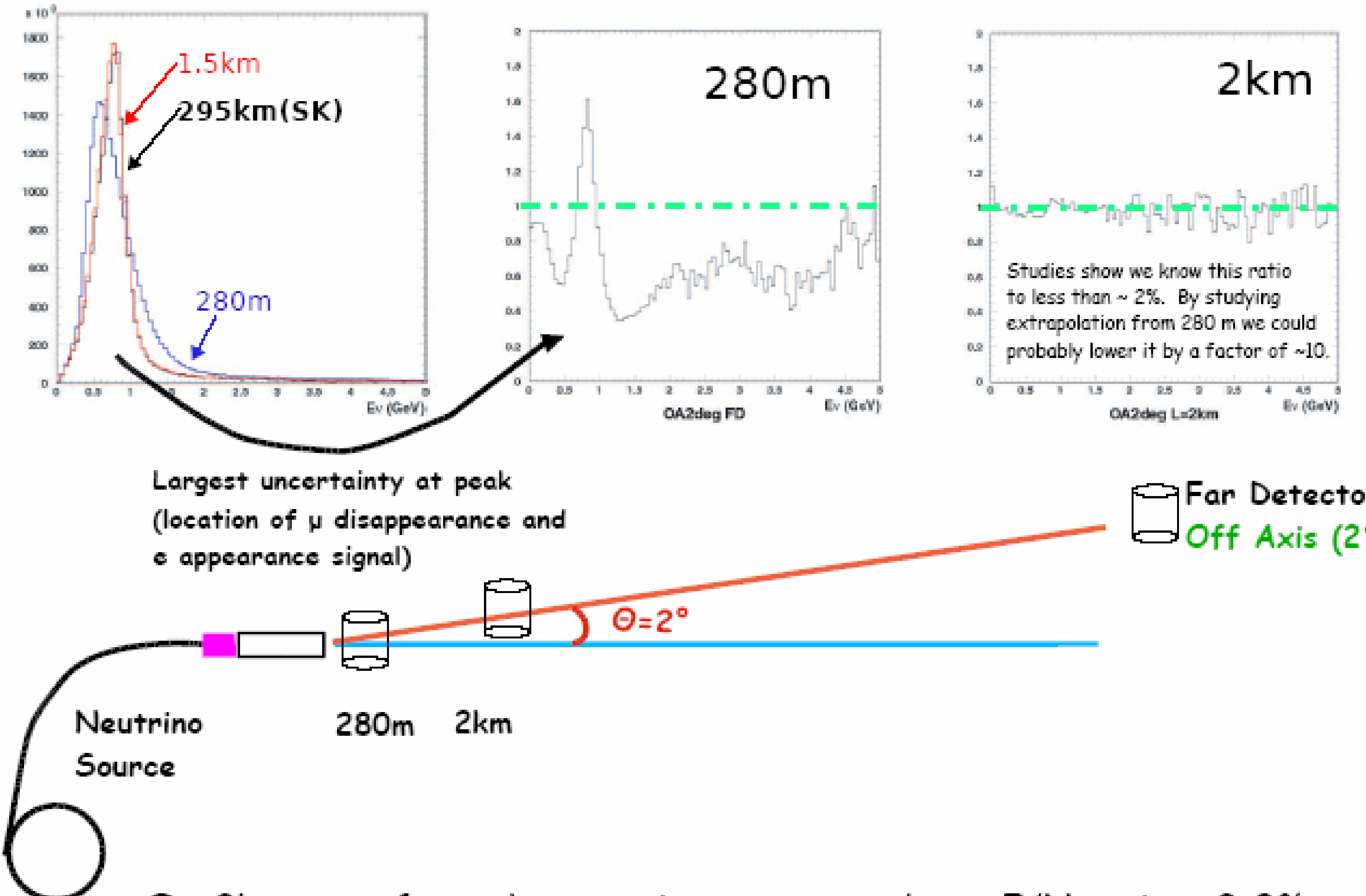


Importance of near detectors: difference in near/far spectra **main systematic error in K2K**

Expected systematics in T2K:

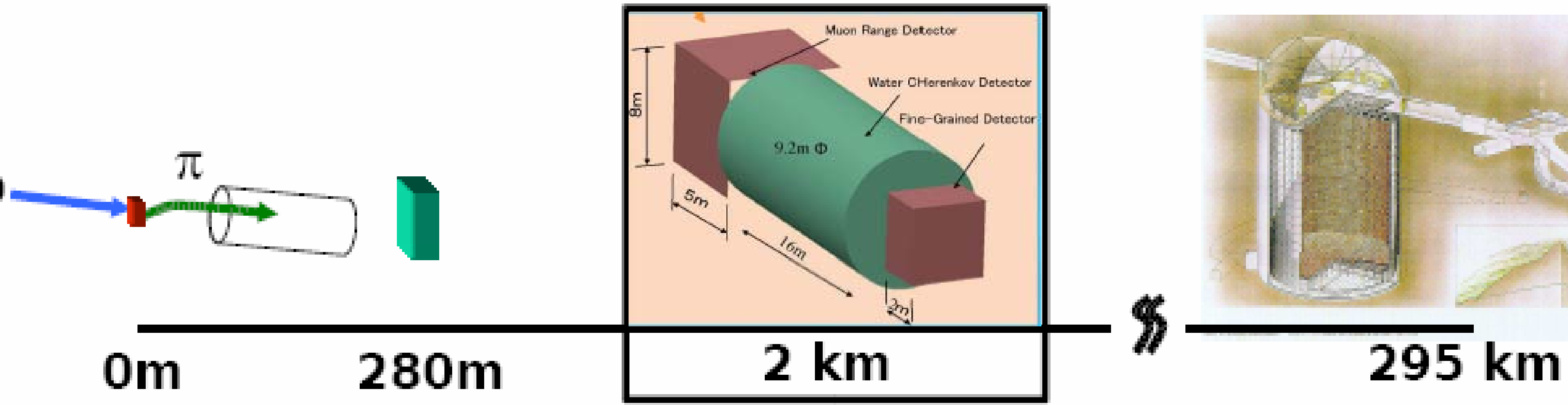
normalization	(5%)
non-qe/qe ratio	(5%)
E scale	(1%)
Spectrum shape	(20%)
Spectrum width	(5%)

Far/Near ν Flux Ratio vs. Detector Distance



@ ~2km away from the neutrino source we know F/N ratio ~ 2-3%

The 2 km detectors



- The addition of a 2km detector to T2K will:

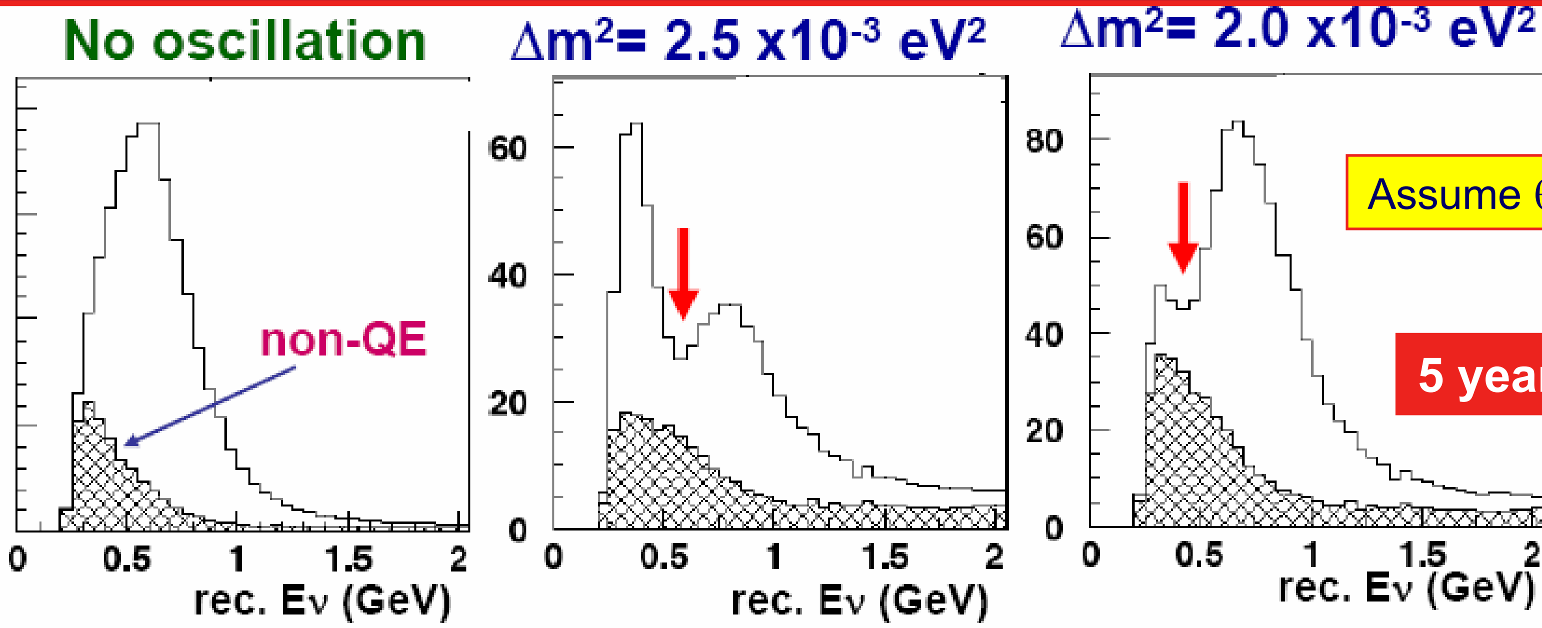
➡ Measure energy spectrum and interactions with almost the same ν beam as seen at SK.

➡ Measure interactions on water with the same technique and algorithms as in Super-K.

➡ Measure the neutral current pion and intrinsic electron neutrino background for ν_e appearance search.

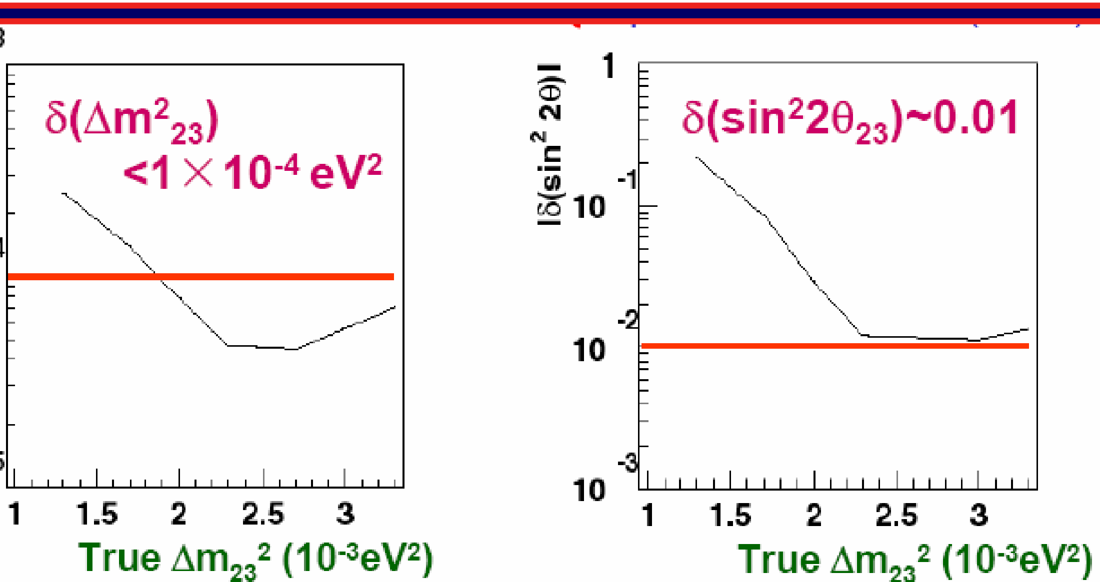
K ν_μ disappearance

$P(\nu_\mu \rightarrow \nu_x) \sim \cos^4\theta_{13} \sin^2 2\theta_{23} \sin^2 (\Delta m^2_{23} L/ 4E)$



Assume $\theta_{23} = \pi/4$

5 years running



- measure Δm^2_{23} with **10^{-4} eV^2** error
- know if $\sin^2 2\theta_{23}$ = 1 (**0.01** uncertai

Assumed systematic errors **(to be reduced by using near detectors**

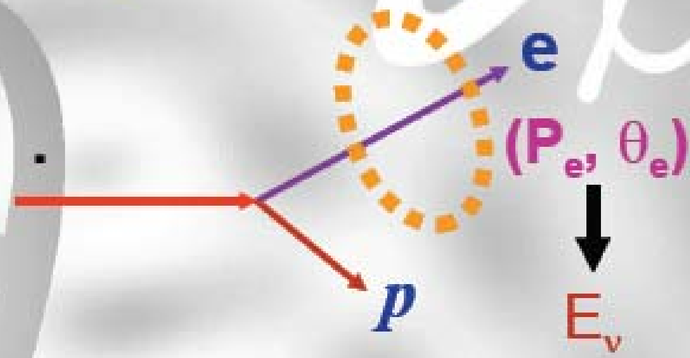
Far-near ratio:	**10%**
Non QE/ QE ratio:	**20%**
Energy scale:	**4%**

T2K ν_e appearance: measurement of θ_{13}

ν_e appearance search

- 1R e-like events
  - ν_e C.C. Quasi-Elastic
  - Neutrino Energy is reconstructed by assuming CCQE

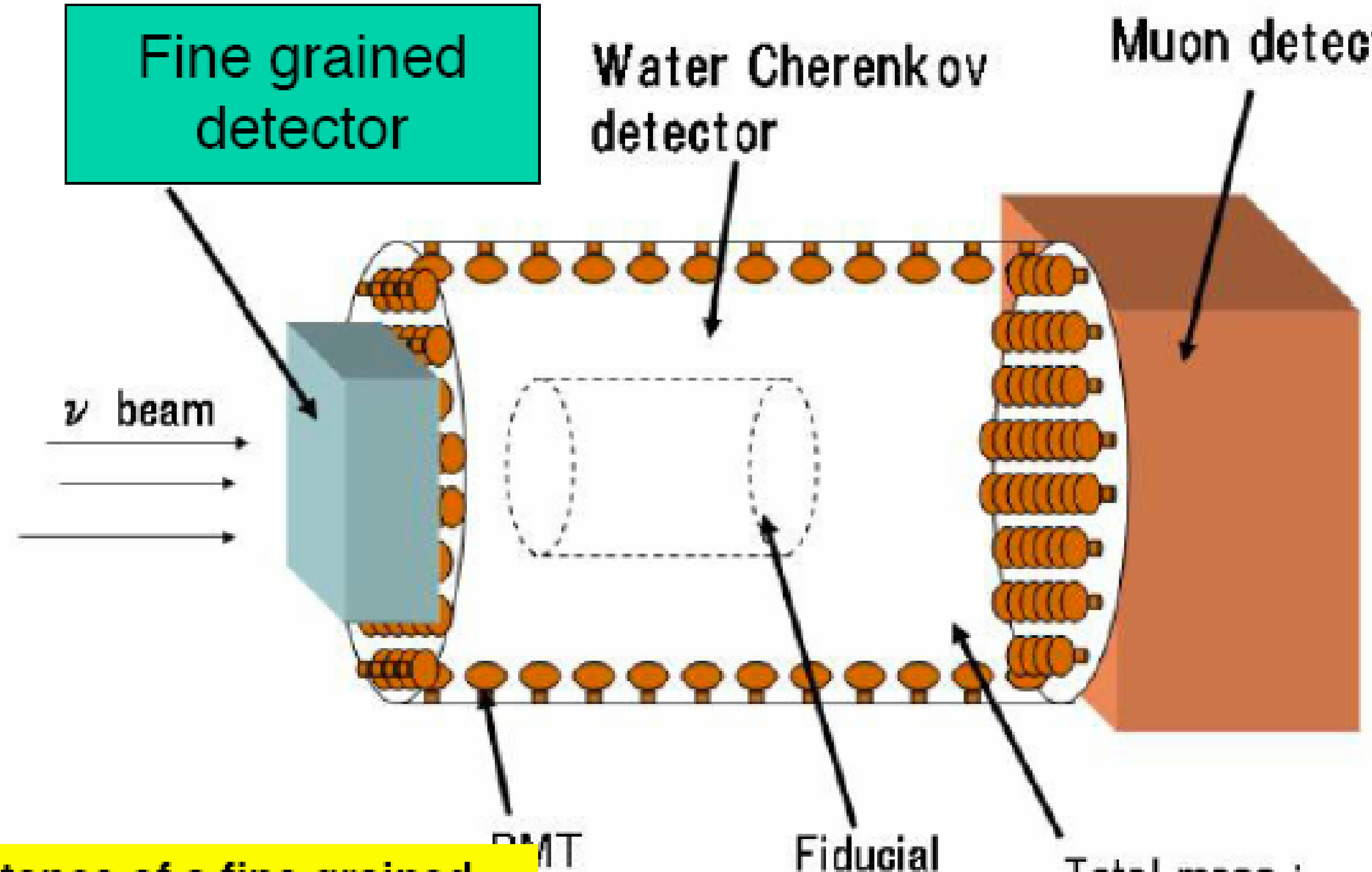
$\nu_e + n \rightarrow e + p$



- Background Sources
  - Beam ν_e
    ν_e/ν_μ flux ~ 0.2% (@peak)
  - (NC) π_0 Production

2-ring merged to 1-ring

2km conceptual design



existence of a fine grained
ector at 2km position is a
essity from the physics point
iew and was considered
ce the original LoI.

T2K LoI, http://neutrino.kek.jp/jhfnu/

History

Nov 2003: Presentation at the JHF Europe meeting

- ➥ General conceptual idea of Liquid Argon TPC technique for T2K
- ➥ Why a liquid Argon TPC ?

July 2004: Encounter with Japanese representatives of T2K.

- ➥ Invitation to participate to T2K general meeting @ KEK, August 2004

August 2004: T2K general meeting

- ➥ Presentation of preliminary conceptual design of a 100 ton LAr-TPC at 2km position and physics potentials (but detector too big to fit in planned underground cavern)
- ➥ Feed-back from Collaboration.

Sept-Oct 2004: Series of video conferences + concrete actions

- ➥ Discussion at the level of the 2km working group
- ➥ Attendance dominated by Japanese & US groups & 1 French group
- ➥ Choice of 8" PMT for Water Cerenkov and reoptimization of geometry (smaller WC, more space for FGD)
- ➥ Preliminary investigation of Lar storage underground with company building the underground hall
- ➥ First definition of the T2K-LAr detector to fit in existing planned space at 2k

A 100 ton liquid argon TPC at T2K: why and how?

There is strong interest in the physics program of T2K by European/US collaborators who are willing to provide a sensible contribution to the project

A 100 ton liquid Argon TPC provides an ideal “fine-grain” detector at the 2km position with a O(100K events/yr) statistics

The LAr TPC combines tracking (event topology, proton, …) AND calorimetry (electro π^0, …) in a homogeneous, isotropic and fully active medium. Reconstruction biases ar small, many times negligible.

The mass scaling properties of the LAr TPC make it conceivable to maintain the high granularity ($\approx 0.02X_0$ sampling) and reach a fiducial mass of 100 tons

Further optimization of geometry, granularity ($< 0.02X_0$?), etc. will be driven by physic requirements and space limitations in underground hall

Possibility to consider LAr in connection with Water Cerenkov target will be physics driven

This detector would be very relevant for an HyperKamiokande phase

Example of physics items (I)

Measurement of ν_μ CC events

- ➥ Provide independent measurement of "off-axis near" flux
- ➥ Excellent muon identification makes selected sample clean
- ➥ Unbiased reconstruction
- ➥ Low detection threshold in LAr compared to WC allows for an independent classification and measurement of event samples in the GeV region
  - ☛ Independent systematic on nQE/QE ratio
  - ☛ Independent systematic on energy scale
- ➥ Systematic in extrapolation of 1 kton WC to SuperK
  - ☛ Independent study of reconstruction effects in WC with recorded events in LAr
- ➥ Energy independent detection and measurement efficiency for SubGeV and MultiGeV events
  - ☛ High efficiency measurement of high energy muon neutrinos from kaon decays to provide extra handle on ν_e component of the beam

Example of physics items (II)

Measurement of ν NC events

- Clean measurement of π^0 production thanks to event and particle identification
  - Independent systematic on NC/CC ratio
  - Independent measurement of coherent π^0 production (look for absence of trac at vertex)

Measurement of intrinsic ν_e CC events

- Excellent event and particle identification giving clean e/μ and e/π^0 separation
- Unbiased reconstruction
  - Independent measurement of ν_e contamination, well separated from π^0 background
  - Combined with NC background gives independent and separated components and π^0 background at far detector

"Standard model" neutrino interactions in the GeV region

- Bubble-chamber like imaging
  - DIS+resonances modeling, QE modeling
  - Binding, Fermi-motion, Pauli-exclusion, NN-correlations PDF modifications
  - Other nuclear effects (rescattering)
  - Form factors

Introduction

- Now, it is seriously discussed to use the liquid argon detector for the FGD at the 2km detector complex.
- Since Ar is a gas, there might be Japanese law on the use of large volume Ar in underground.

↓

- I have discussed the safety issues and Japanese law related with LAr in underground with the company people who designed the 2km hall.
  I will report on this discussion.

T. Kajita, Oct 2004

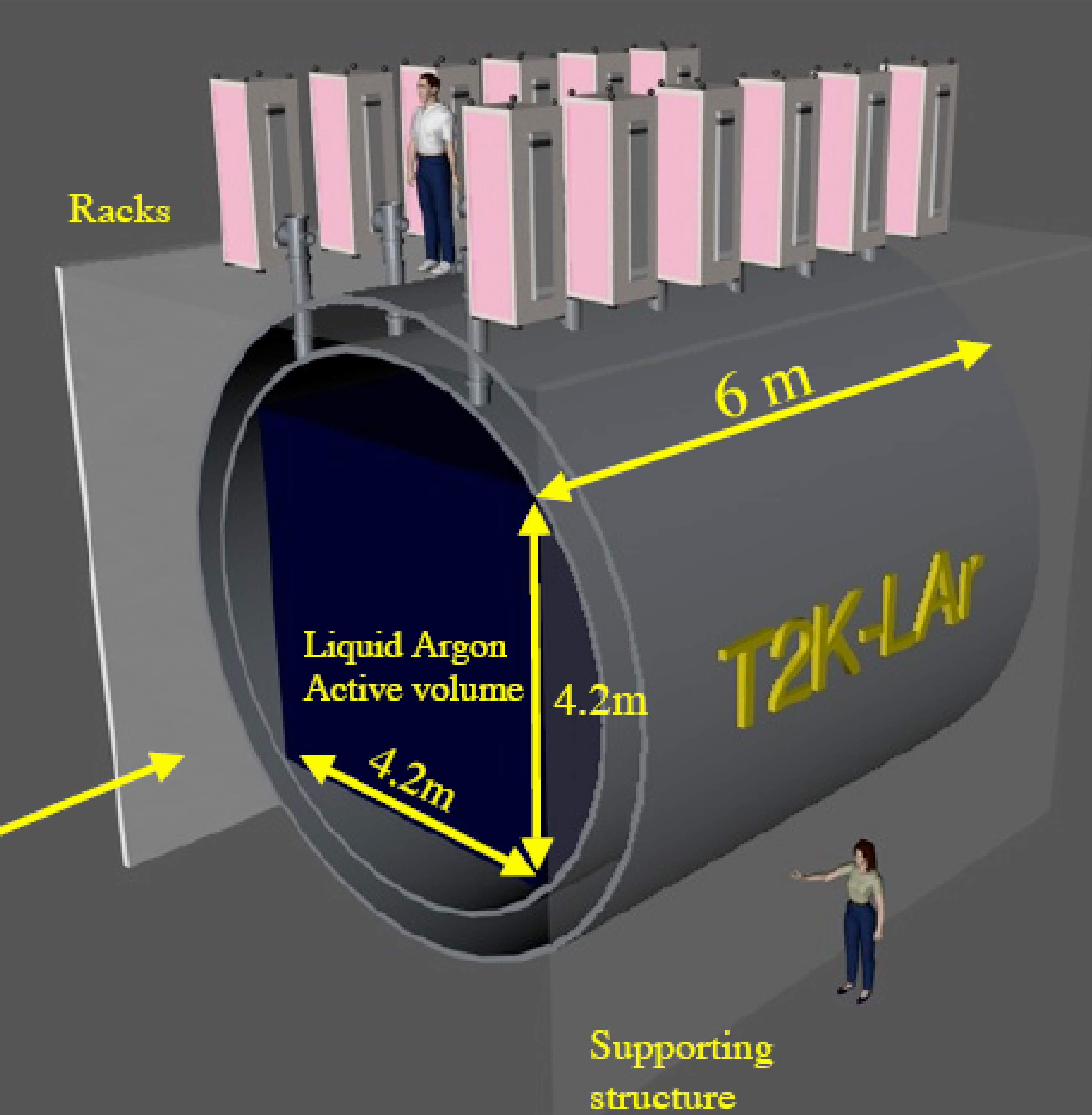
Summary

- It seems to be possible to use a liquid argon detector as a FGD in the 2km detector complex.
- However, there must be many safety issues that need to be discussed with the local government and fire-brigade office.
- The company that designed the 2km hall strongly suggested to start discussion with the local government as soon as we have the realistic detector design and the installation/operation plan.

T. Kajita, Oct 2004

ew compact conceptual design of the ~100 ton LAr TPC:

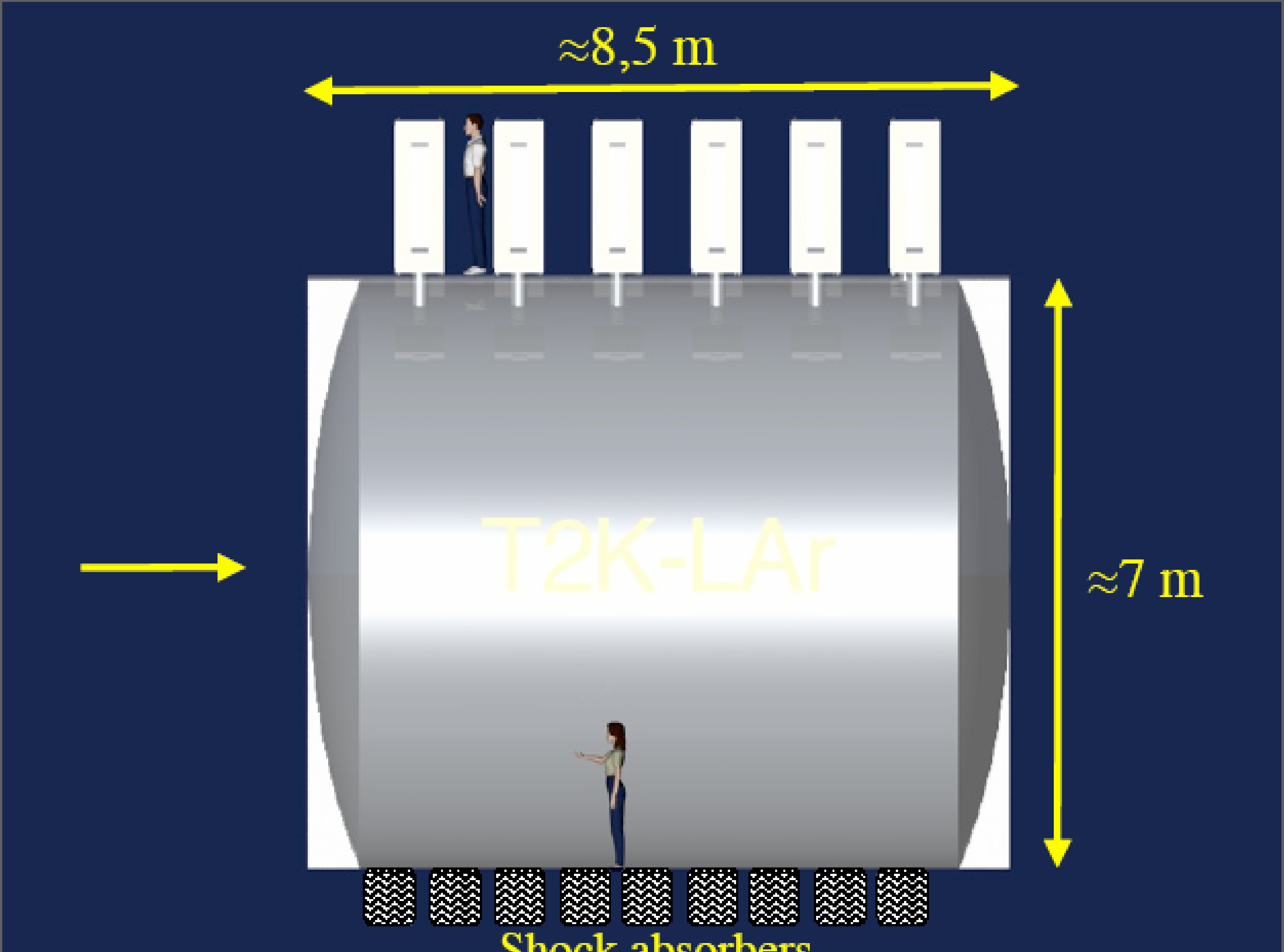
LATEST VERSIO



hia, Oct 2004

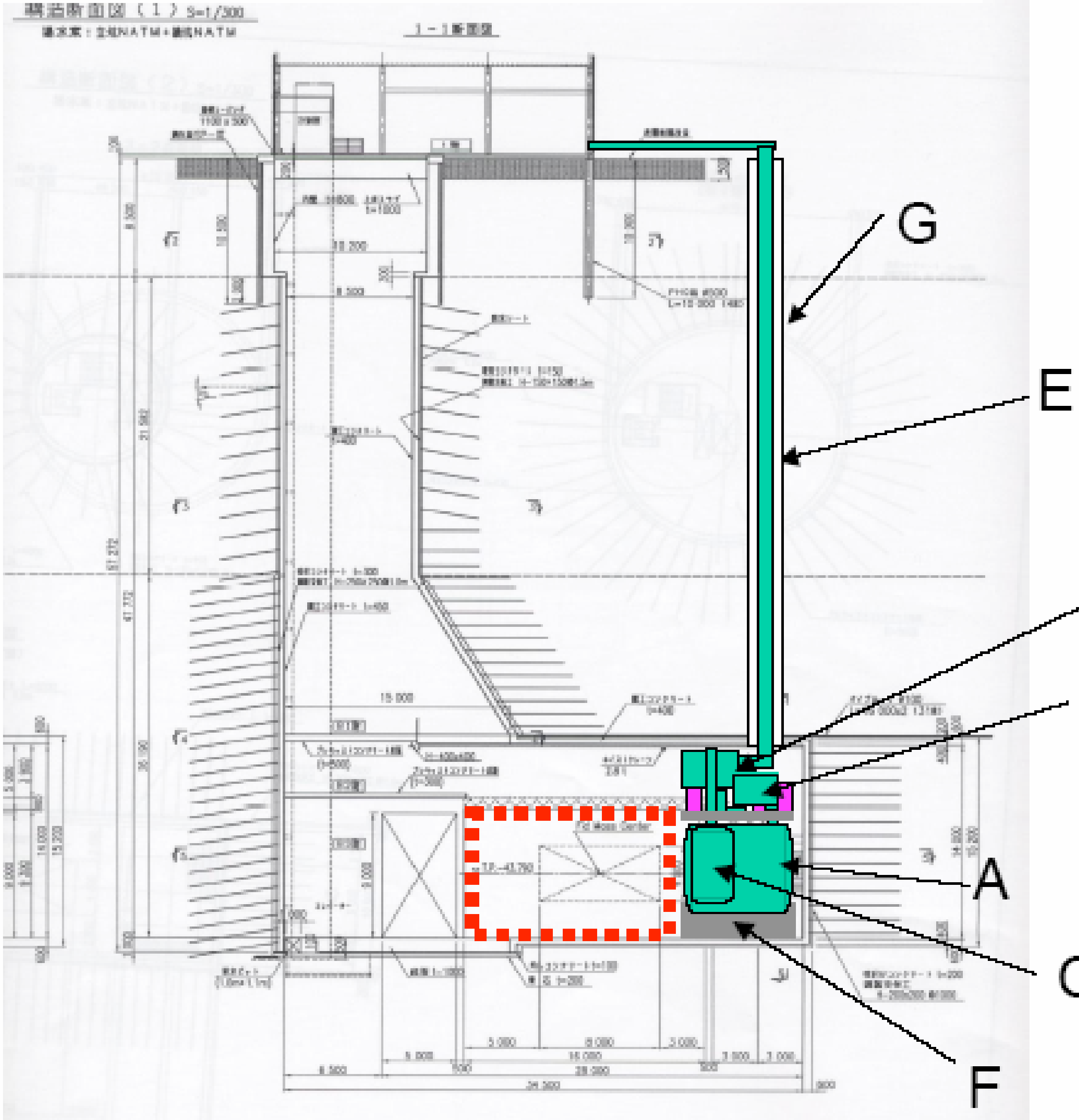
Outer vessel	ϕ ≈ 7m, L≈8m, 15 thick, weight ≈ 20
Inner vessel	ϕ ≈ 6 m, L ≈ 6 m, 8 mm thick, ≈ 10 t
LAr	Total ≈ 240 t Fiducial ≈ 100 t
Max e- drift	4.2 m @ HV=420 E = 1000 V/cm
Charge R/O	2 views (90°) or 3 views (60°) 2 (3) mm pitch
Wires	≈O(10'000), ϕ = 1
R/O electronics	on top of the dewa
Scintillation light	Also for triggering
B-field	Possible
Insulation	Multi-layer vacuum
Refrigeration	Closed Liquid Arg circuit

ew compact conceptual design of the ~100 ton LAr TPC:

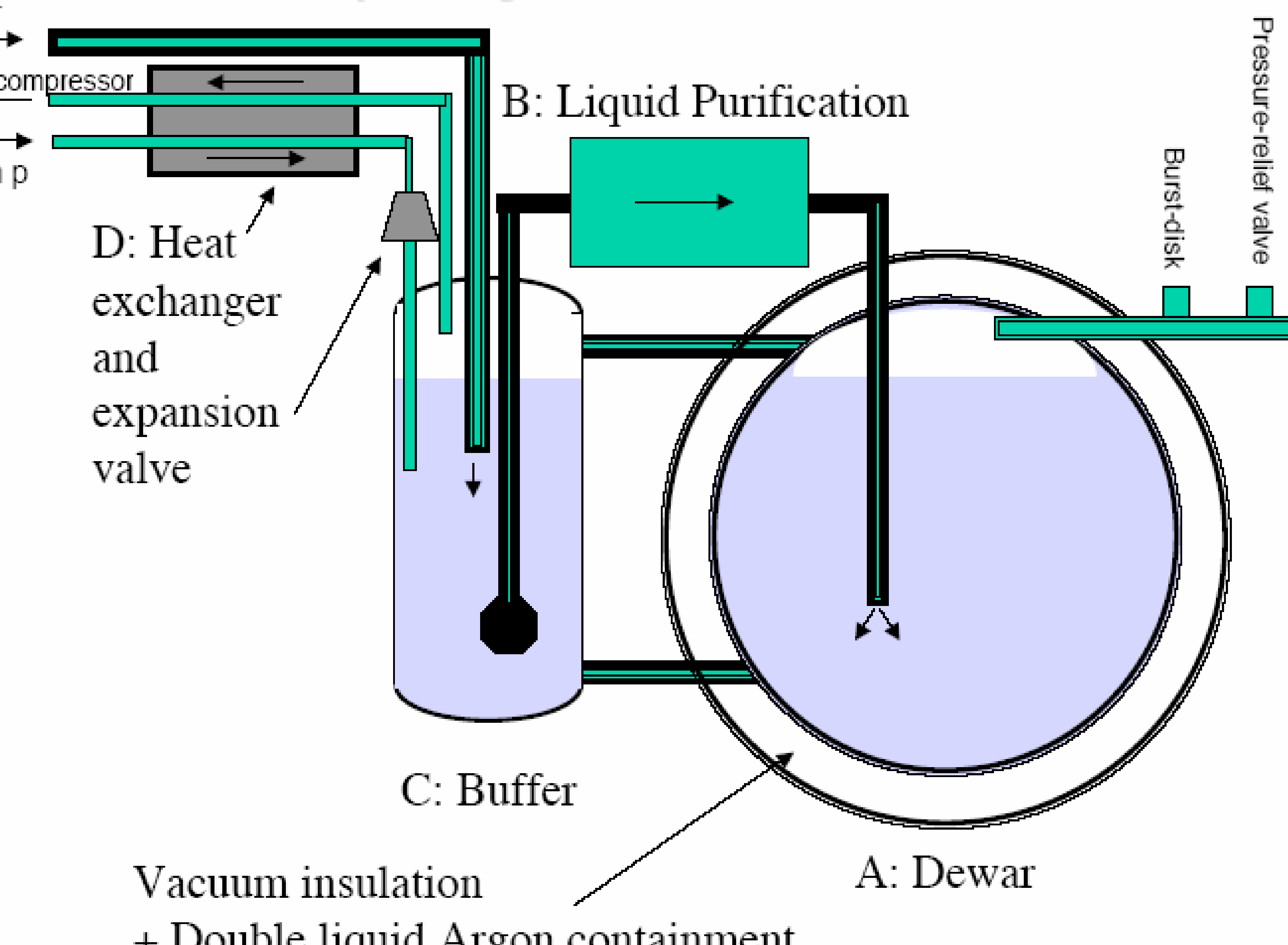


A schematic layout (I): version October 2004

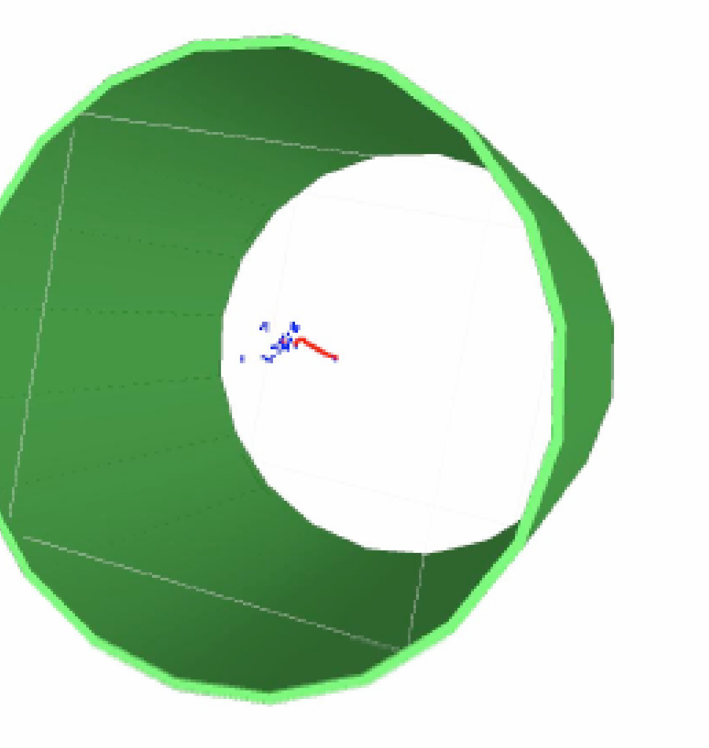
Detector dewar
LAr Purification
Buffer
Heat exchanger and
pansion valve
Argon pipes
Shock absorbers
Dedicated shaft
ntilation+piping)



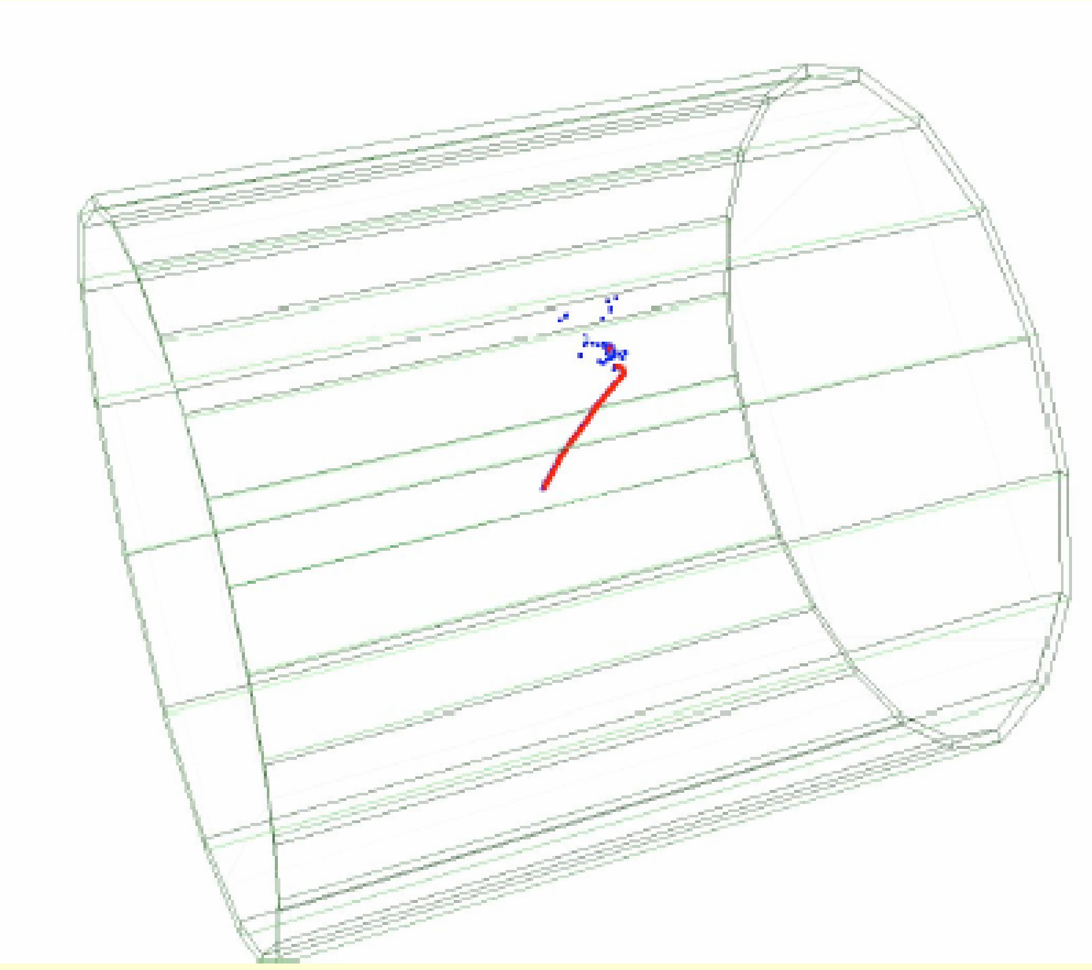
Liquid argon recirculation circuit



Geometry implemented in software



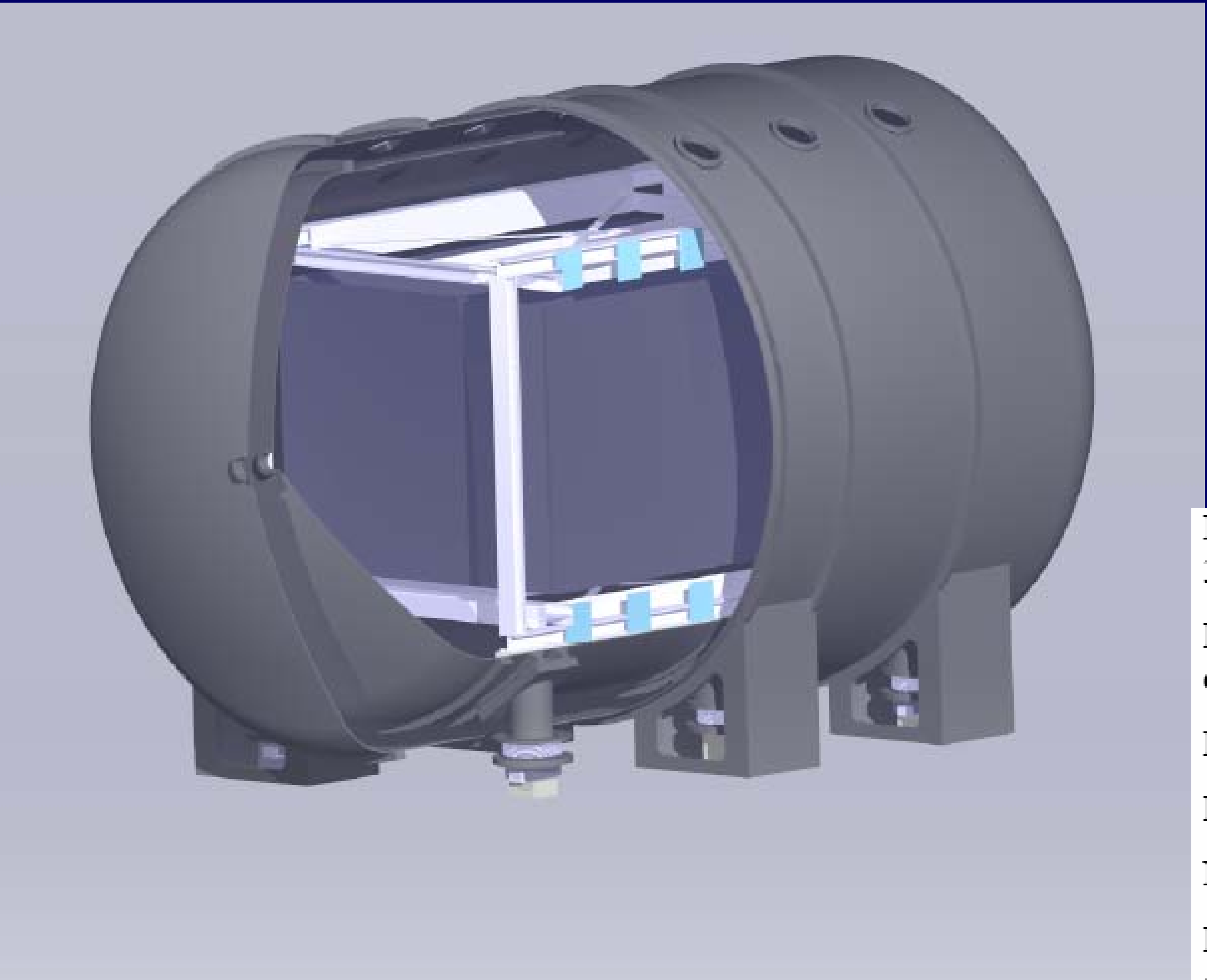
- Simulation software is based on G4
  - Basic active volume, readout views definition
  - Wire/time discretization
  - Scintillation and Cerenkov light simulation
  - Output based on ROOT I/O
- New "compact" geometry already included



Reconstruction and visualization program is stand-alone (C++)

- Hit digitization (signal waveform, noise, …)
- Hit,cluster, track, 2D/3D, …
- Energy, directions, particle ID, …

Engineering design of a 50 ton prototype (ETH Zurich)



Two stainless steel cy
vacuum insulated. Inn
cylinder with super-
insulation.

Total length 5 m, oute
diameter 3.6 m

5 CF200 flanges with
feedthroughs

5 CF200 flanges for H
slow control, LAr filli
recirculating, pumpin

Length (parallel to cylinde
3.5 m

Horizontal drift direction,
distance approx.. 2 m.

Drift field: 500 V/cm.

HV: 100 kV

Number of wires: approx.

Read-out: continuous wav
digitizer for each wire.
Resolution in drift directio

e **Projection Chamber**: Wire chamber with 2 planes, 3 mm wire pitch and 3
plane spacing: 1induction plane and 1 collection plane

Present status

- We are now in the process of preparing an Expression of Interest addressed to the T2K Collaboration (by Spring 2005)

- A Working Group has been set up with this purpose (T2K-LAr) presently including people from:

France:	Lyon
Italy:	L'Aquila, LNF, LNGS, Napoli
Poland:	Cracow, Katowice, Warsaw
Spain:	CIEMAT, Granada
Switzerland:	ETH Zurich
USA:	Columbia, UCLA, Yale

\+ strong interest from UK groups