Geometry for the LAr detector and related issues

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New "compact" design

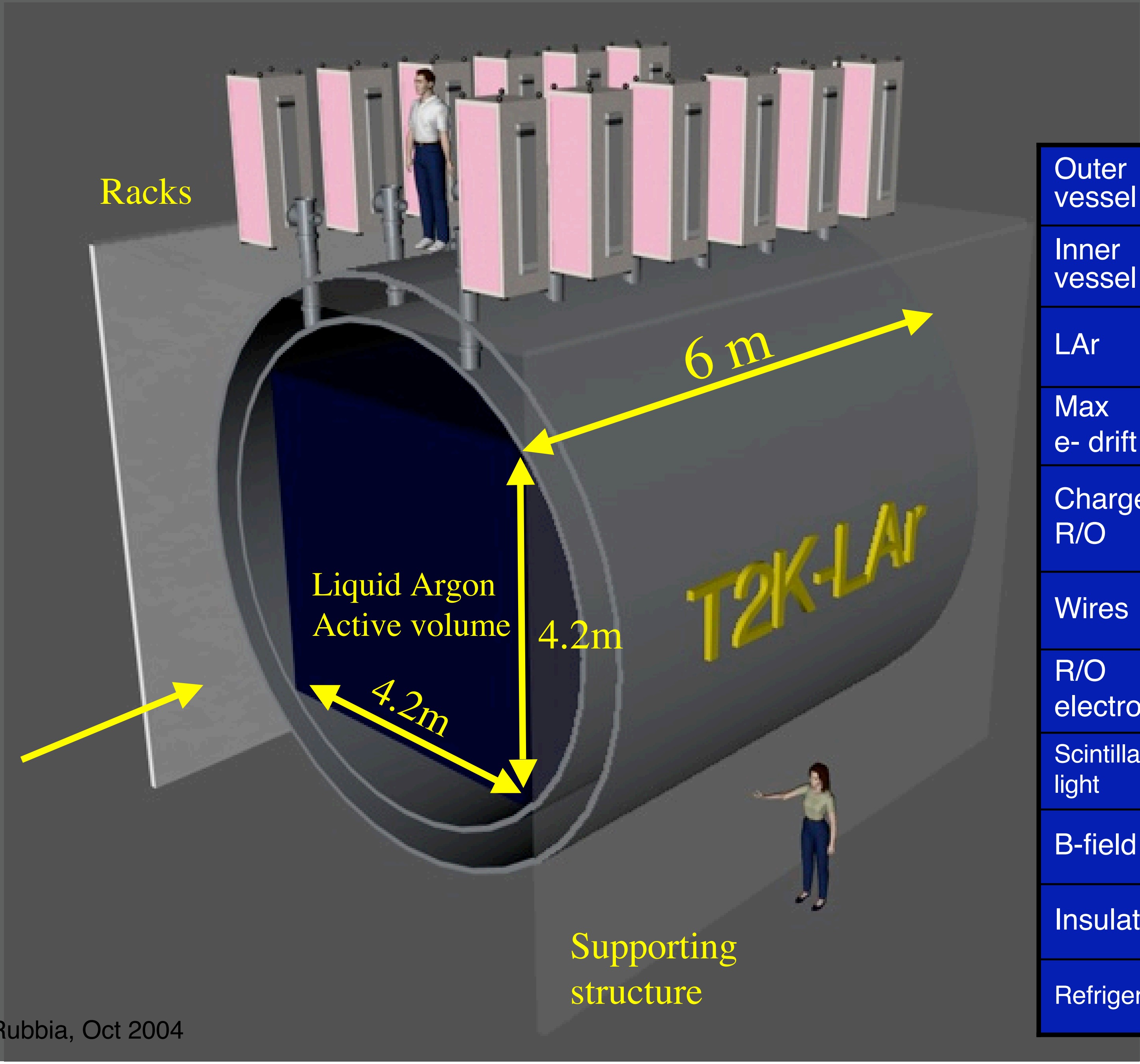
- Following Kajita-san's proposal (Oct 6th) for the geometry of the Water Cerenkov detector, we have further optimized the possible geometry of the liquid Argon TPC to fit in the planned underground space.

- The fiducial mass of the liquid Argon is unchanged with respect to the "old" design.

- The inner cylinder of the dewar is now roughly 6 meter in diameter and 6 m long.

- In this talk, we also tentatively discuss some logistics aspects and present some preliminary estimates concerning various cryogenic aspects. These figures should not be considered as final but represent work in progress.

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



Outer vessel	$\phi \approx$ 7m, L≈8m, 15mm thick, weight ≈ 20 t
Inner vessel	$\phi \approx$ 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 kV E = 1000 V/cm
Charge R/O	2 views (90°) or 3 views (60°) 2 (3) mm pitch
Wires	≈O(10'000), ϕ = 150 μm
R/O electronics	on top of the dewar
Scintillation light	Also for triggering
B-field	Possible
Insulation	Multi-layer vacuum
Refrigeration	Closed Liquid Argon circuit

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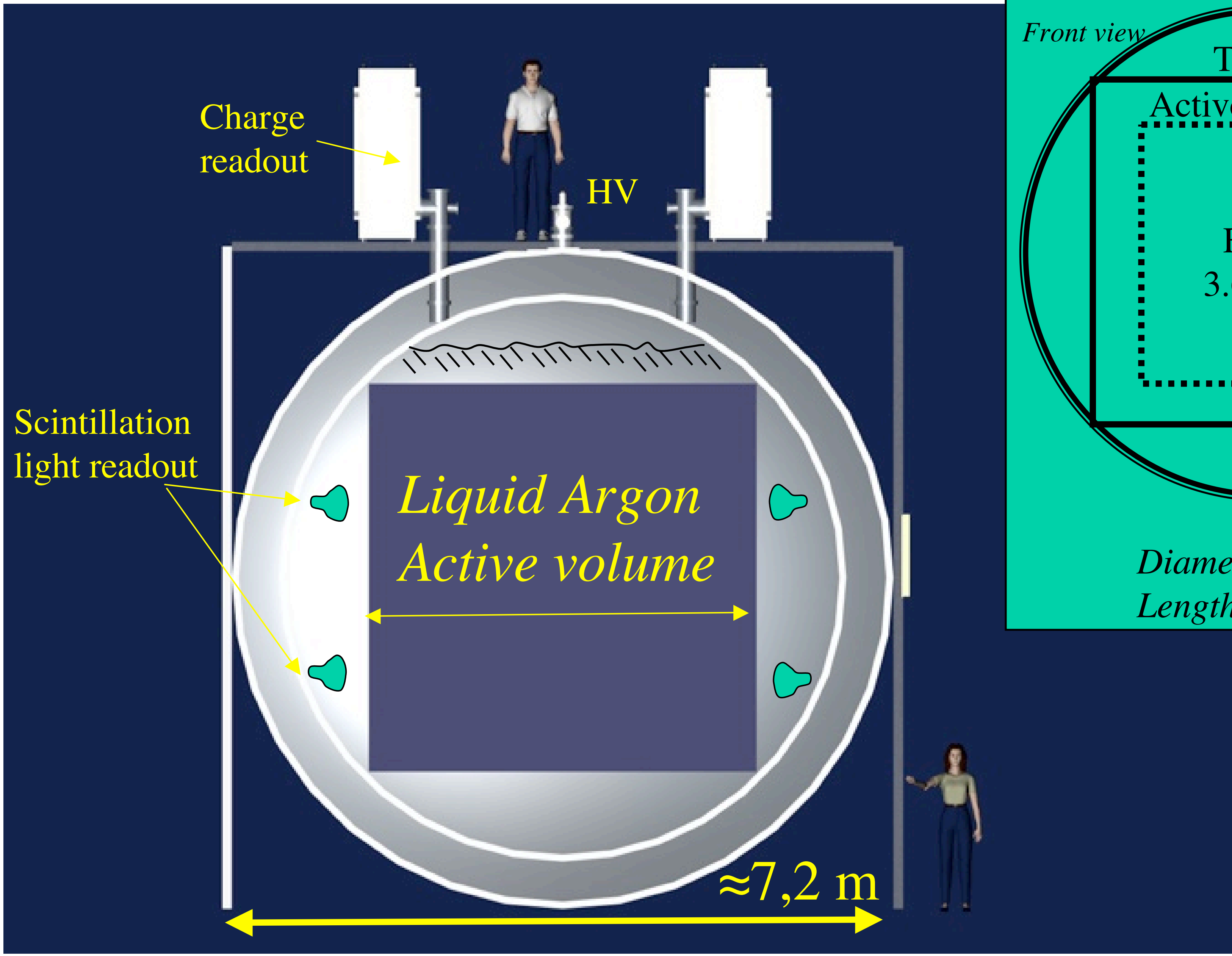
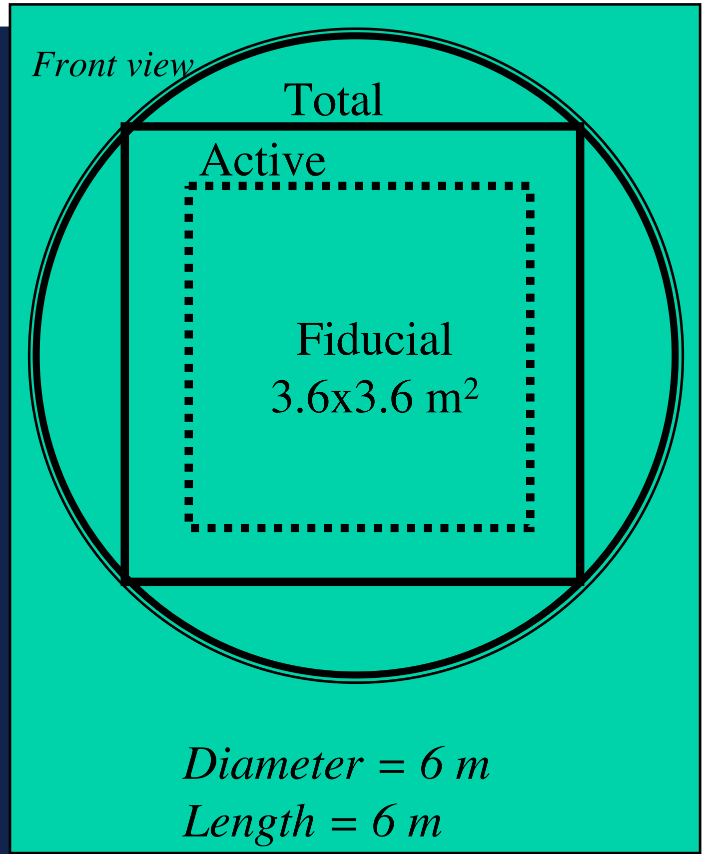
Conceptual design study of a ≈100 ton active LAr detector:





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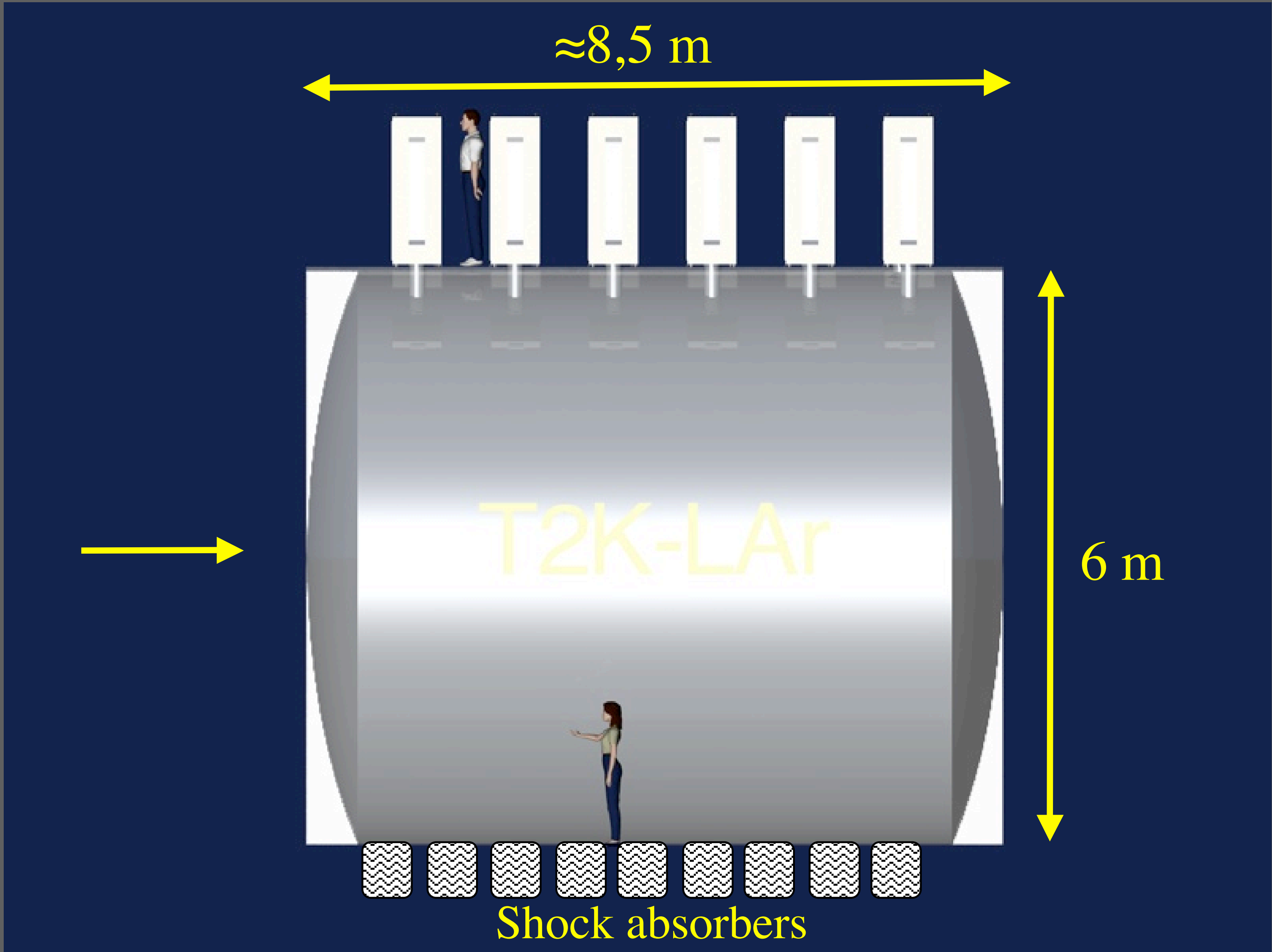

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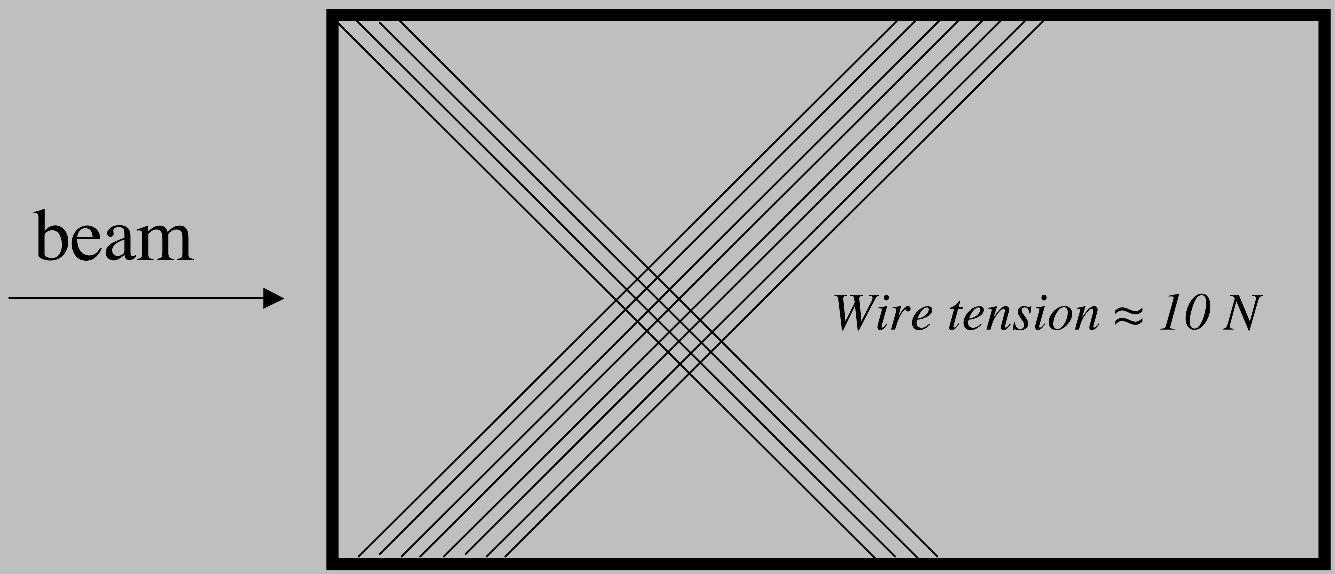
Tentative layout of readout chamber

Various parameters to be further optimized:

Drift length (2x2.1m or 1x4.2 m ⇔ LAr purity, HV, UHV, outgassing)
Position of wire chamber (middle, left-right or only one side)
Wire pitch
Wire orientation
Number of readout planes



Example: Two wire planes, ±45°, 3 mm pitch, ϕ 150 μm

≈2400 wires/plane

420 long
1980 short

75 units of 32 wires

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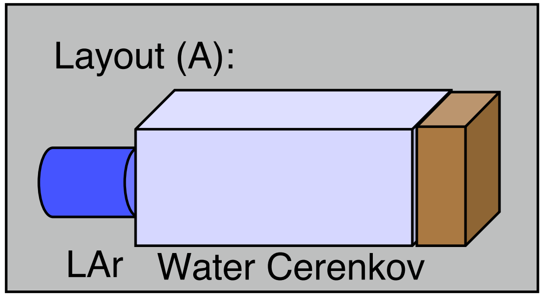
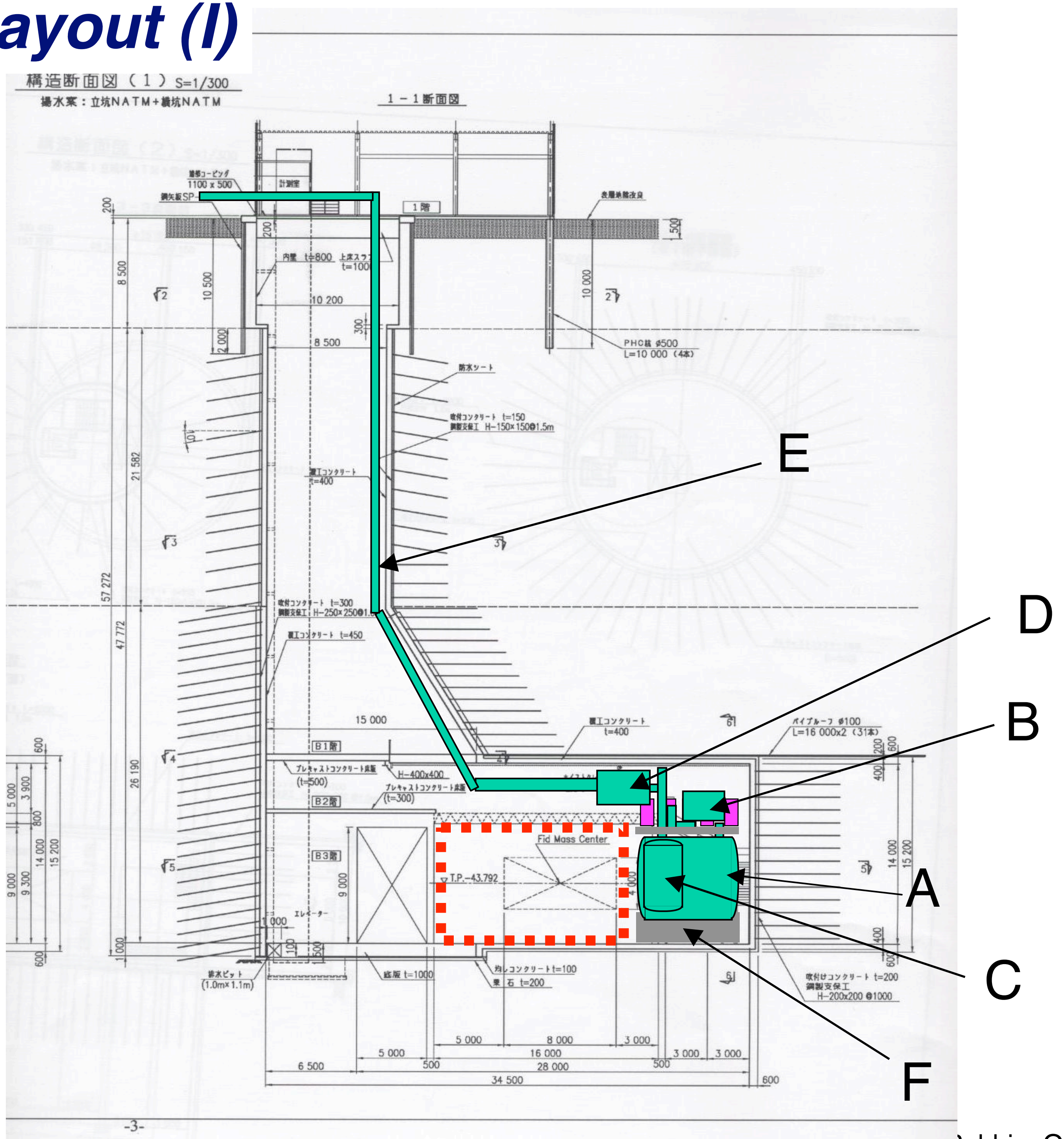
A schematic layout (I)

A: Detector dewar
B: LAr Purification
C: Buffer
D: Heat exchanger and expansion valve
E: Argon pipes
F: Shock absorbers





A schematic layout (II)

A: Detector

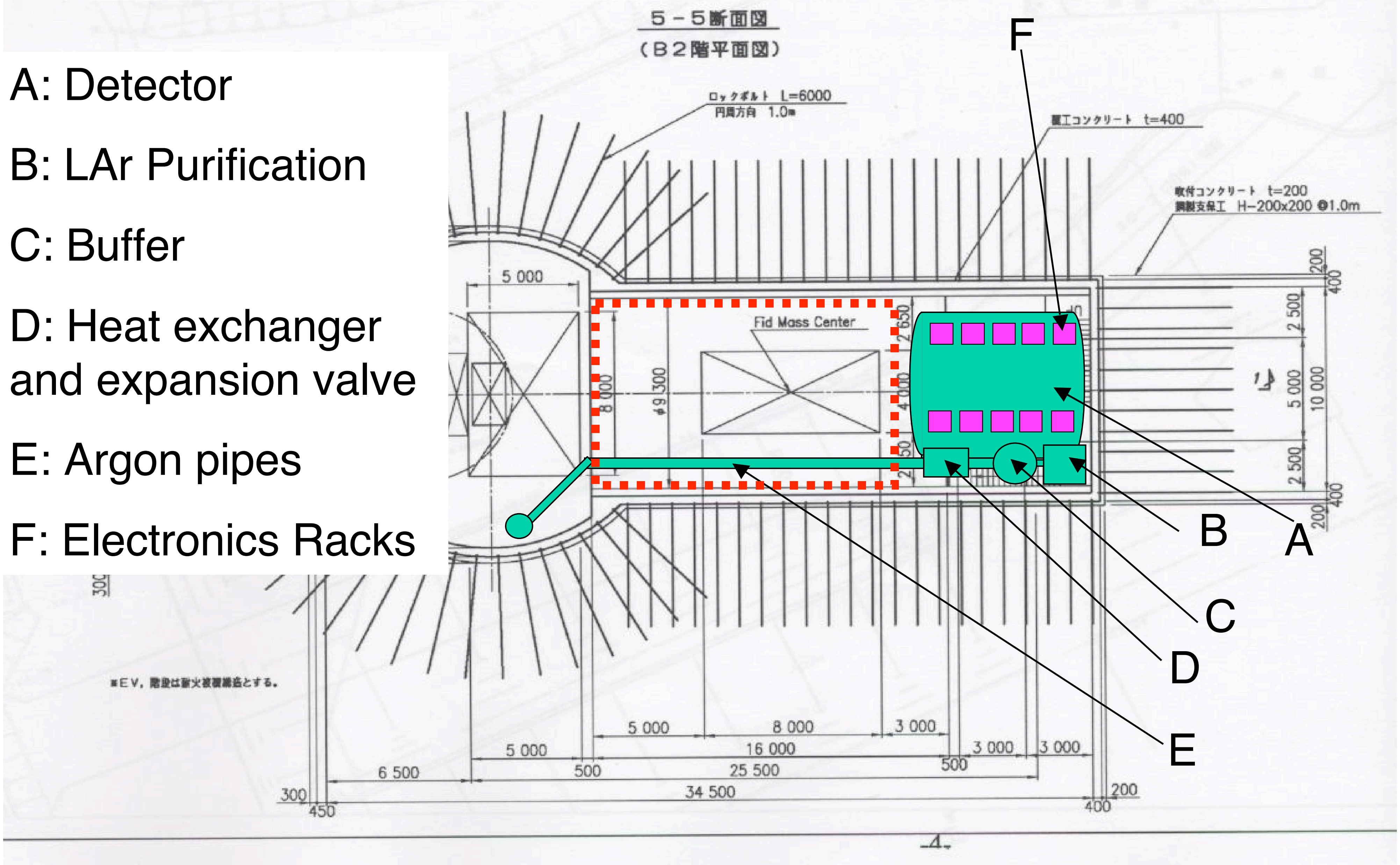
B: LAr Purification

C: Buffer

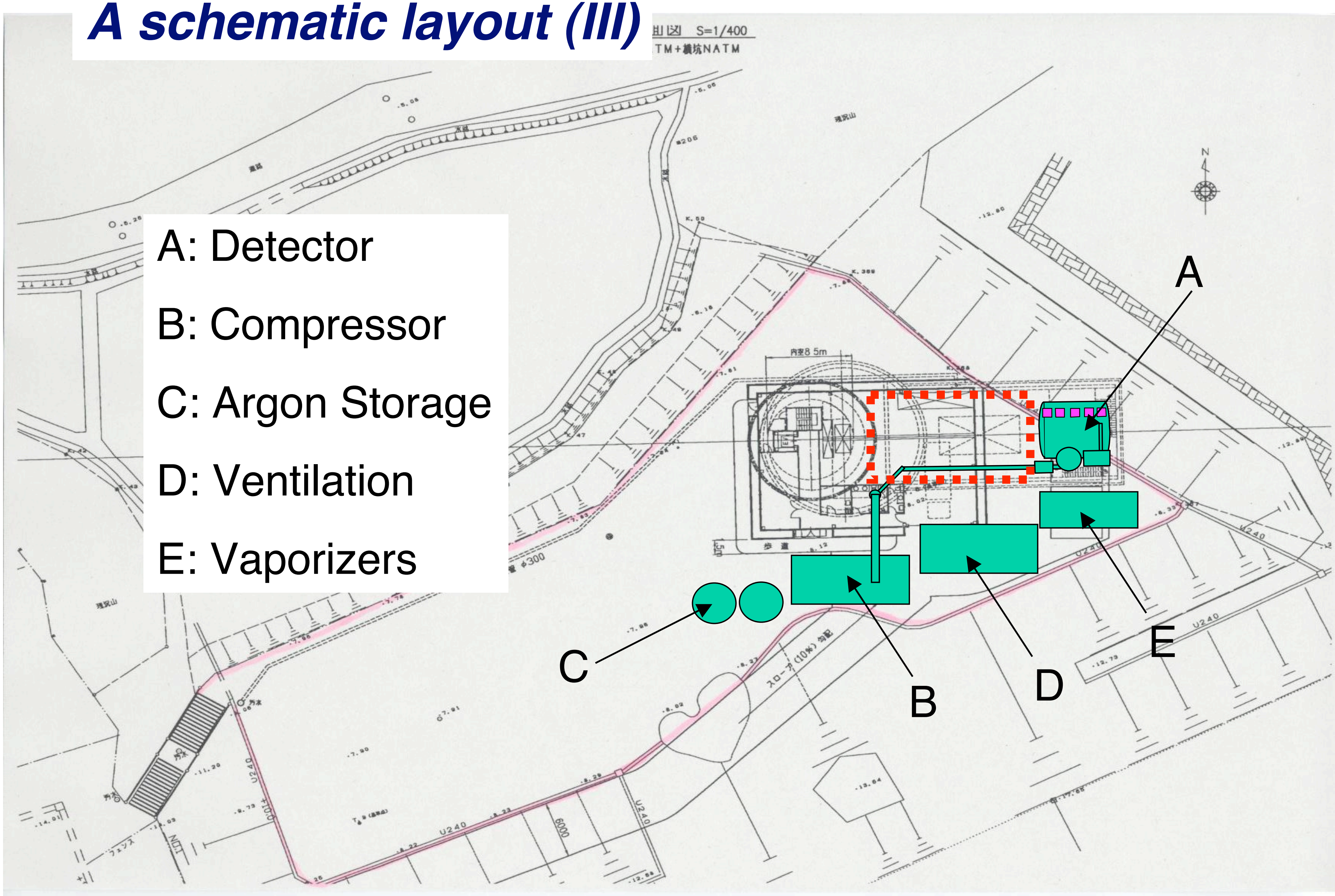
D: Heat exchanger and expansion valve

E: Argon pipes

F: Electronics Racks



A schematic layout (III)



A: Detector

B: Compressor

C: Argon Storage

D: Ventilation

E: Vaporizers

Some figures on LAr purification

Various parameters to be further optimized:

Drift length (2x2.1m or 1x4.2 m ⇔ LAr purity, HV, UHV, outgassing)

>4 meters attenuation length ⇔ e-lifetime > 2 ms ⇔ impurities < 0.15 ppb O_2

Recirculation time ⇔ time to reach high purity level

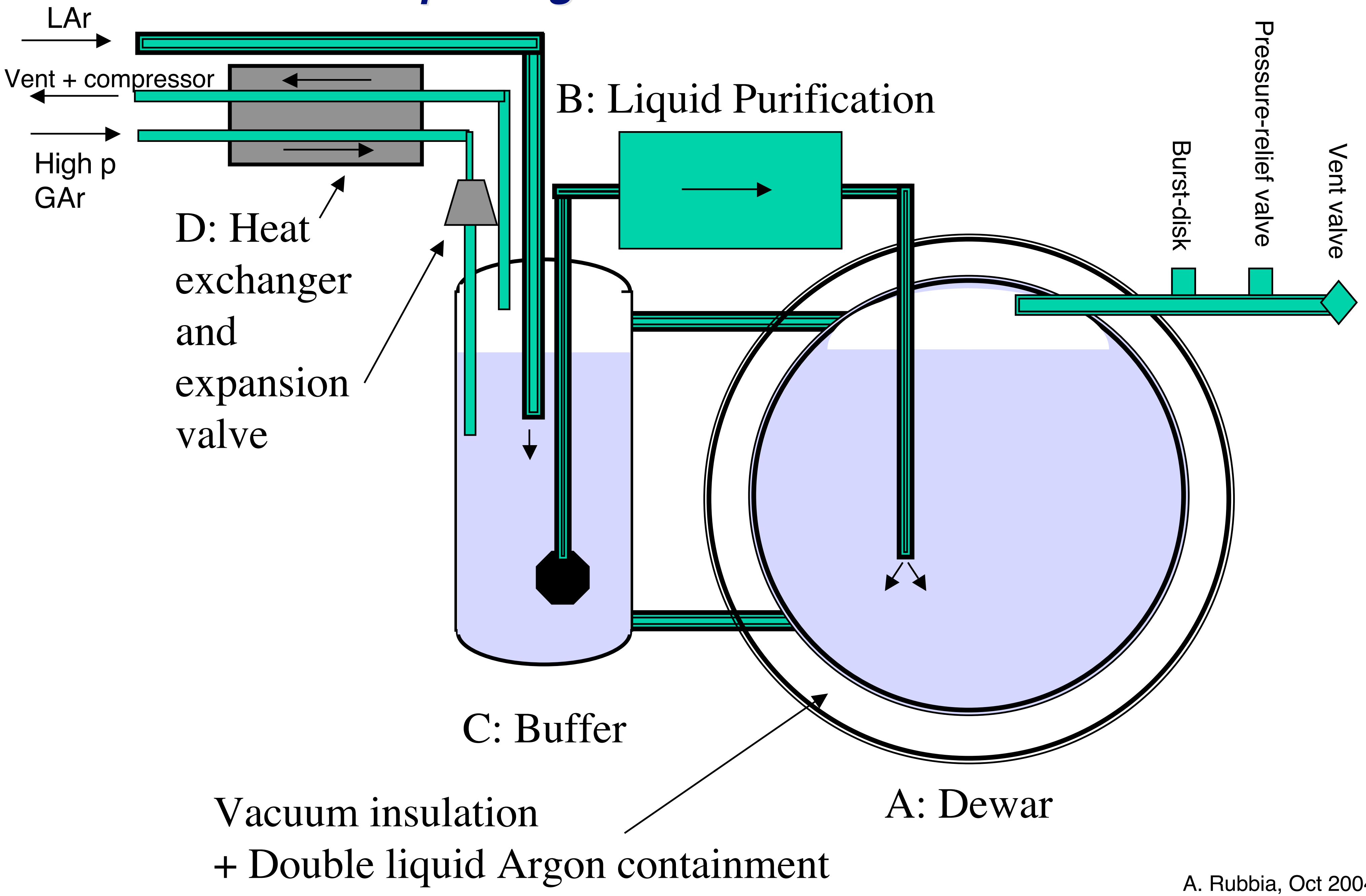
Recirculation rate ⇔ ultimate purity at equilibrium (purification compensates exactly source of impurities)

⇓

ICARUS R&D: high efficiency purification in liquid phase is possible (NIMA 333 (1993)) with flow rate up to 800 liters/hour in standard Messer-Griesheim hydrosorb/oxysorb. A fundamental result for large scale detectors.

- **Tentative numbers for T2K:**
  - ➥ Liquid Argon phase recirculation mandatory, in addition to gas purification
  - ➥ Assumed recirculation time = 48 hours
  - ➥ Recirculation rate ≈ 3500 LAr liter/hour ≈ 1 liter/s
  - ➥ Number of Oxysorb cartridges ≈ 7
  - ➥ Possibly two parallel circuits

Liquid argon recirculation circuit



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Phases of operation

- **Vacuum (≈1 week)**
  - ➥ Evacuate water, air and any other residuals, goal < 10^{-4} mbar
  - ➥ Ensure UHV-tightness (very important!)

- **Initial cooling + filling (≈1 week)**
  - ➥ Necessary to cool-down inner-vessel and inner instrumentation
  - ➥ Quick process limits amount of degassed impurities from walls and inner detector components.
  - ➥ Once the detector is cold, argon level will increase.

- **Continuous recirculation (≈1 month to reach high purity)**
  - ➥ Purity improves with time
  - ➥ Slope of improvement increases as outgassing decreases with time
  - ➥ Asymptotic level of purity reached when speed of recirculation balances potential rate of input of impurities (should be zero in the ideal case!)
  - ➥ Liquid Argon phase recirculation should be minimized to reduce heat input (viscosity, pump heat, …)

Logistic aspects

- **It is important to separate safety issues: (1) design (2) operation**

- **Design and construction:**
  - ➥ Build conservative design, stainless steel (e.g. 304L), using standard mech. eng. cryogenic techniques. In particular for the main cryostat. Apply local safety margins.
  - ➥ The company building the cryostat has to certify the homologation before dewar can be used.
  - ➥ We think that constructing the cryostat in Japan might ease its homologation (and avoid costly transportation).
  - ➥ The details of conventional cryogenic-fluid storage-vessel design is covered in standards (e.g. ASME Boiler & Pressure Vessel Code, Sect. VIII, www.asme.org)
  - ➥ For vessel of this size, design, fabrication and tests according to standards is required.
- **Operation:**
  - ➥ Various phases of operation have different safety issues
  - ➥ Vacuum phase
  - ➥ Cooling, filling (ullage volume)
  - ➥ Stable refrigeration (including liquid Argon recirculation for purification)
  - ➥ Safety devices (inner vessel pressure relief valve and/or rupture burst-disc)
  - ➥ Redundant & active slow control (with Uninterruptible Power Supplies)

Example of international certification: ASME accreditation

ASME Certificate Holders can readily combine a Boiler and Pressure Vessel Shop Review with an ISO 9000 assessment. (A description of ASME's ISO 9000 Registration Program starts on page 8).

ASME BOILER & PRESSURE VESSEL CODE

ASME set up a committee in 1911 for the purpose of formulating standard rules for the construction of steam boilers and other pressure vessels. This committee is now called the Boiler and Pressure Vessel Committee and it is responsible for the development and maintenance of the ASME Boiler and Pressure Vessel Code.

The Code establishes rules of safety governing the design, fabrication, and inspection of boilers and pressure vessels, and nuclear power plant components. The objective of the rules is to assure reasonably certain protection of life and property and to provide a margin for deterioration in service.

ASME ACCREDITATION AND CODE SYMBOL STAMPS

Since 1916, ASME has accredited companies to certify that their products and services comply with ASME codes and standards. More than 4,300 companies in 60 countries are currently accredited.

Liquid Argon handling safety issues (International STD)

- **Liquid Argon (or “refrigerated argon”) hazards**
  - ➥ Contact may cause cold burns
  - ➥ High concentration may cause asphyxiation (victims may not be aware because odorless)
- **Fire measures:**
  - ➥ External fire may cause containers to rupture/explode
  - ➥ Argon non-flammable
  - ➥ All known extinguishants may be used
- **Accidental release:**
  - ➥ Evacuate area
  - ➥ Ensure adequate air ventilation
  - ➥ Do not enter area unless atmosphere proved to be safe
  - ➥ If possible, stop flow of product
  - ➥ Argon gas heavier than air, so will not evacuate from underground hall without forced ventilation

Some numbers and facts…

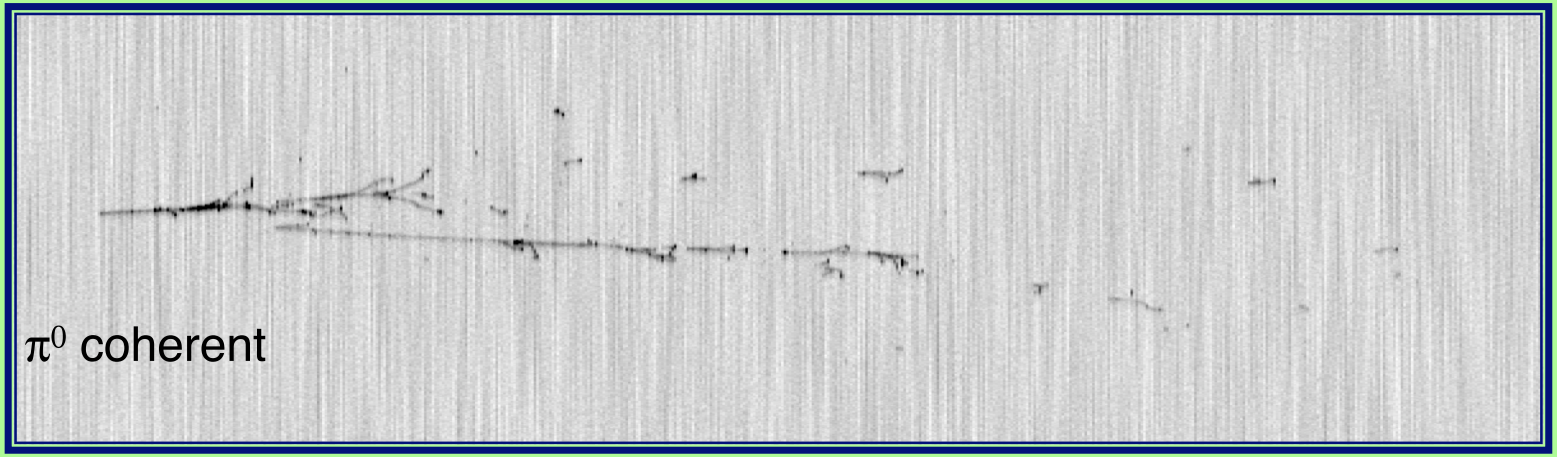
- **Initial cooling**
  - Mass inner-dewar+detector ≈ 20 tons steel
  - Needed for cooling: LAr ≈ 10m^3 ⇒ GAr venting ≈ 8350 m^3 (1.7xsize of hall) ⇒ surface venting via piping + hall ventilation
- **Refrigeration**
  - Closed Liquid Argon circuit (compressor on surface) controlled by temperature/pressure of inner vessel
  - Heat losses under normal conditions: ≈100 LAr lt/day, ≈300 W (cold), ≈6kW electric
  - Including liquid argon purification: ≈500 LAr liters/day, estimated, ≈30kW electric
  - Accidental loss of vacuum insulation: ≈2000 LAr liters/day or ≈1 m^3 GAr/minute ⇒ surface venting via piping + hall ventilation
- **Transfer lines, piping or external components failure**
  - Redundant pumps, valves, …
  - Thermal stress of transfer lines, loss vacuum insulation of pipes, …
- **Catastrophic failure of cryostat (unlikely)**
  - Possible cause: Fire in hall; external impact; Earthquake ⇒ shock absorber
  - "Flash" production of GAr : $<$ 600 m^3 GAr if $\Delta p<0.2$ bar, inner vessel pressure controlled by external refrigerator
  - Catastrophic failure can cause major spill of liquid Argon. Double containment by design. But major hazard! Containment pool ⇒ triple containment ?

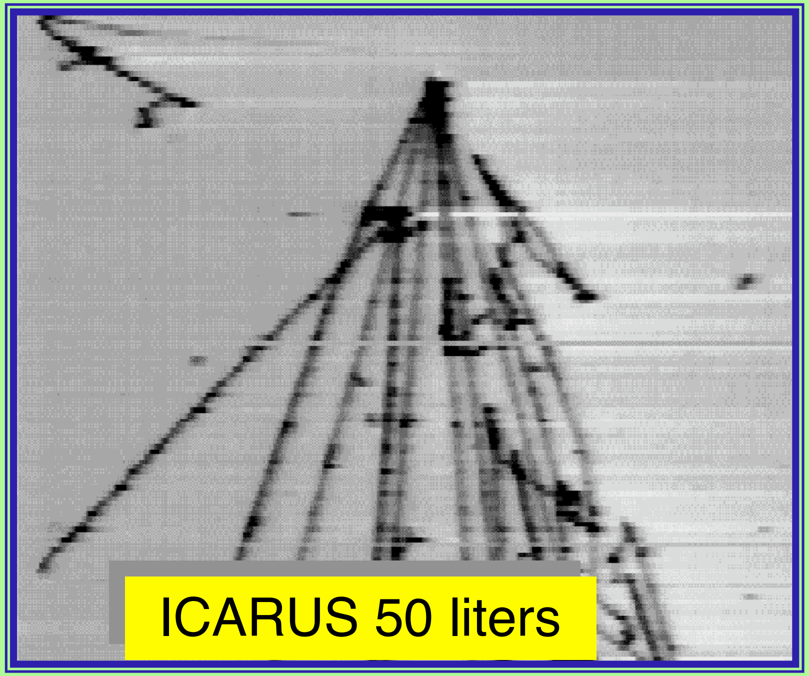
A few comments on software

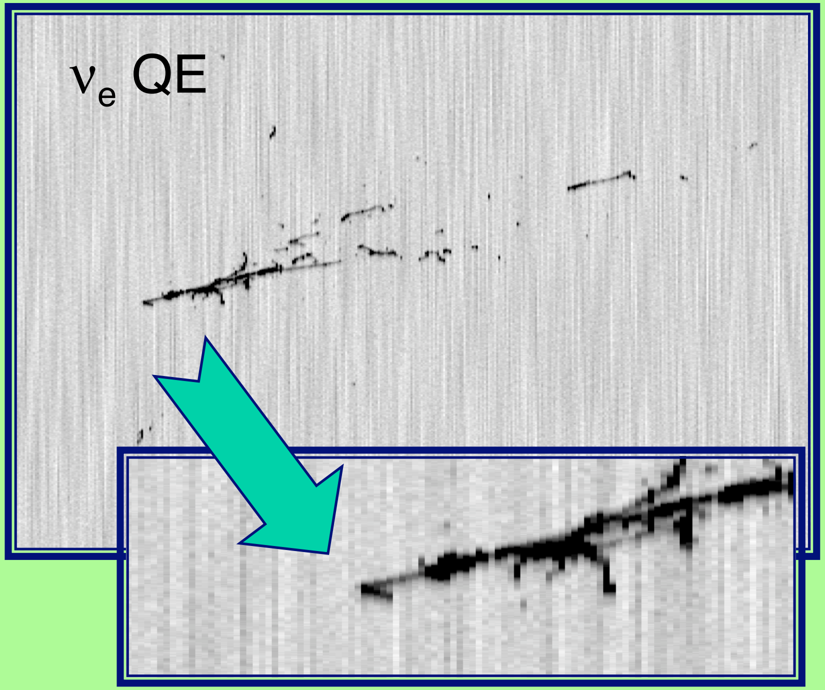
- **Simulation software is based on G4**
  - ➥Basic active volume, readout views definition
  - ➥Wire/time discretization
  - ➥Scintillation and Cerenkov light simulation
  - ➥Output based on ROOT I/O
- **Reconstruction and visualization program is stand-alone (C++)**
  - ➥Hit digitization (signal waveform, noise, …)
  - ➥Hit,cluster, track, 2D/3D, …
  - ➥Energy, directions, particle ID, …
- **New "compact" geometry already included**

Comparison of simulated neutrino interactions with real event:

full simulation, digitization, and noise inclusion







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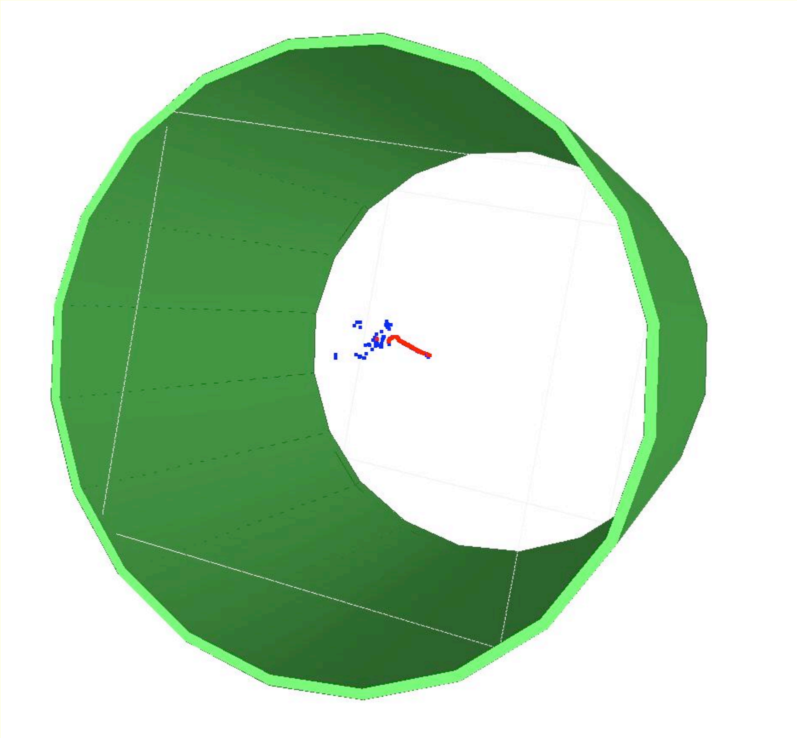
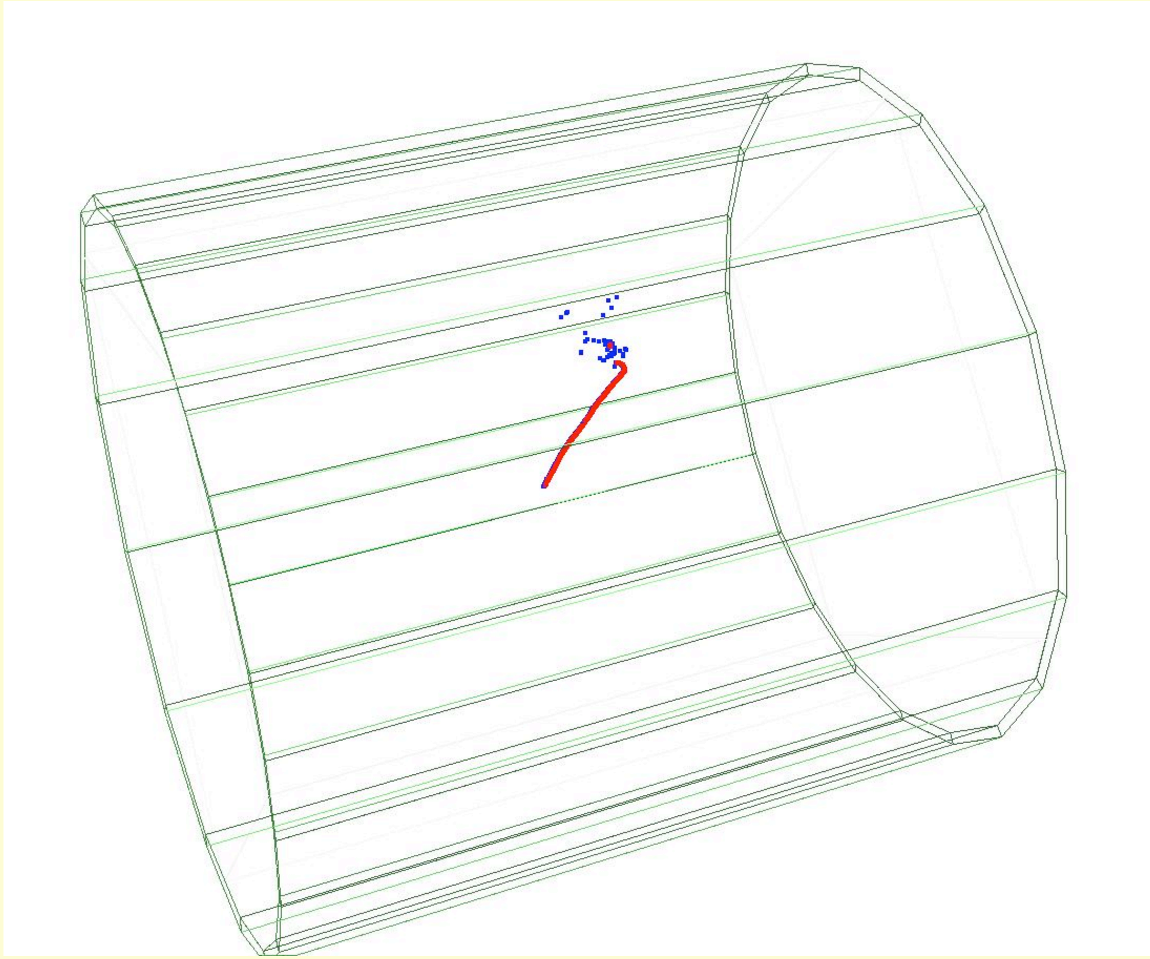
Event reconstruction and visualisation





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Outlook

- New “compact” 100 ton LAr TPC geometry gives hope to fit in existing underground hall.
  - ➥ **Proposal: Adopt as new baseline geometry**
  - ➥ **More detailed design initiated within next year (2005).**

- Started thinking on logistic aspects.
  - ➥ **Very preliminary. Just to set the scale.**

- Software is available and to be integrated into rest of existing G4 software.

- In parallel, we are continuing our efforts in attracting groups for in a possible LAr detector at T2K
  - ➥ **Hope to provide feed-back on list of interested groups by mid-November**

- We are working under the assumption of an EOI to be submitted by Spring 2005.