Proposal for a test facility in LNL for DUNE experiment

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1) Introduction

DUNE will consist of two neutrino detectors placed in the world's most intense neutrino beam. One detector will record particle interactions near the source of the beam, at the Fermi National Accelerator Laboratory in Batavia, Illinois. A second, much larger, detector will be installed more than a kilometer underground at the Sanford Underground Research Laboratory in Lead, South Dakota — 1,300 kilometers downstream of the source. These detectors will enable the study of neutrino oscillations and properties. INFN is involved in the design, construction and commissioning of both Far and Near Detectors.

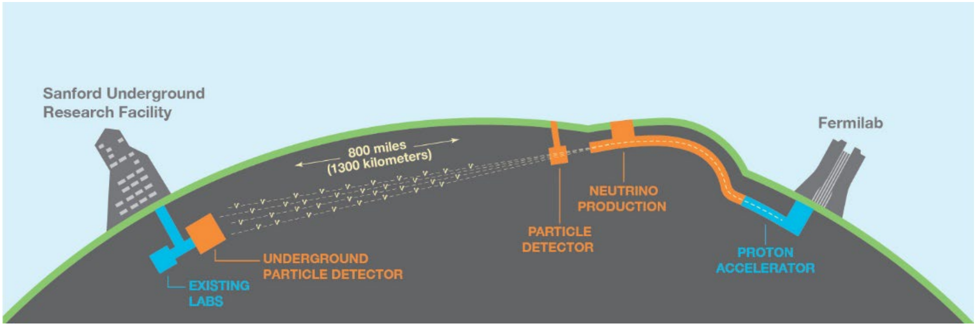


Figure 1: DUNE Long Baseline experiment

The *Far Detector* will be formed by 4 modules, each of one containing about 17000 tons of Liquid Argon.
The *Near Detector* is a complex of different detectors. Among them, SAND ("System for on-Axis Neutrino Detection") will be placed fixed on beam and it reuses the superconducting coil and electromagnetic calorimeter of KLOE detector built in LNF.

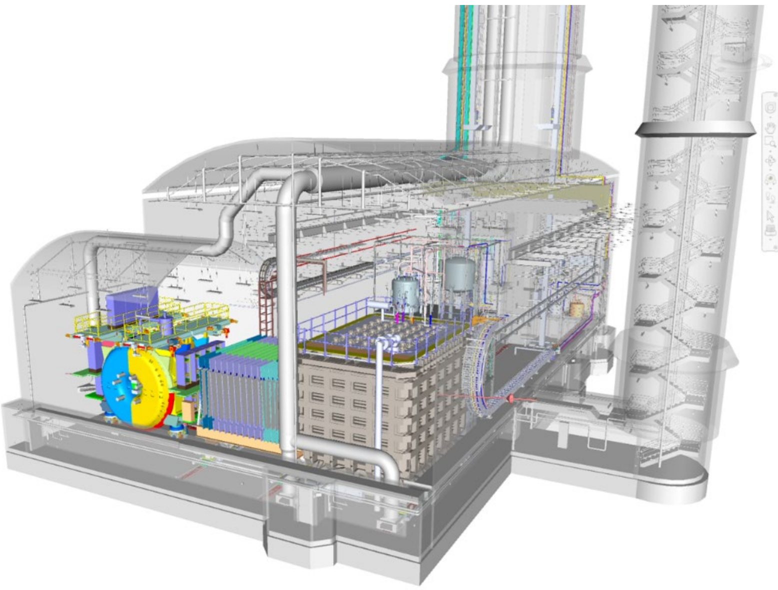


Figure 2: The Near Detector complex (SAND in color)

The central volume of SAND (KLOE wire chamber is removed) will be formed by a Straw Tube Tracker (STT) and a Cryostat named GRAIN ("GRanular Argon for Interaction of Neutrinos") containing about 1 ton of Liquid Argon. The possibility to characterize the beam in the Near Detector in the same medium as in Far detector allows to reduce systematic errors.

GRAIN cryostat is composed by an internal vessel in Stainless Steel and an external vessel in Carbon Fiber/Aluminum Honeycomb (to reduce material budget). The internal vessel contains about 1 ton of Liquid Argon while the external keeps the high vacuum. Both have elliptical shape.

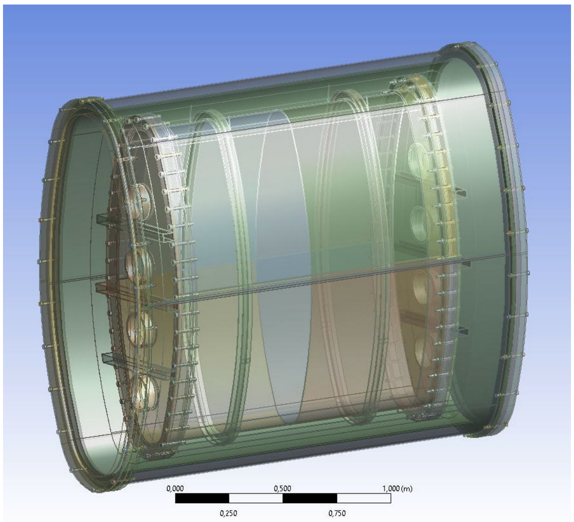


Figure 3: GRAIN cryostat

For detection of charged tracks in LAr we will use a novel technique, based on the imaging of the scintillation light, eliminating the dependency on the slow charge collection as in Time Projection Chambers. By capturing "pictures" of the LAr (or LXe) scintillation light emission, we aim to reconstruct both event topologies and energy deposition.
Several challenges must be overcome to successfully demonstrate this novel approach: the performance of photon detectors and conventional optical elements in the relevant spectral range is limited; thousands of photosensor channels in dense matrices must be read out in cryogenic conditions; a sufficiently wide and deep field of vision is needed to maximize the fiducial volume.

We will use about 50 cameras to reconstruct the event in the full 3D volume of GRAIN. The light sensor for each camera will be a 32x32 matrix of SiPMs, single photon sensitive. We are studying two types of optics: one based on coded aperture masks (Fig. 5) and the other on special designed lens (Fig. 6a).

Figure 4: Examples of SiPMs matrix

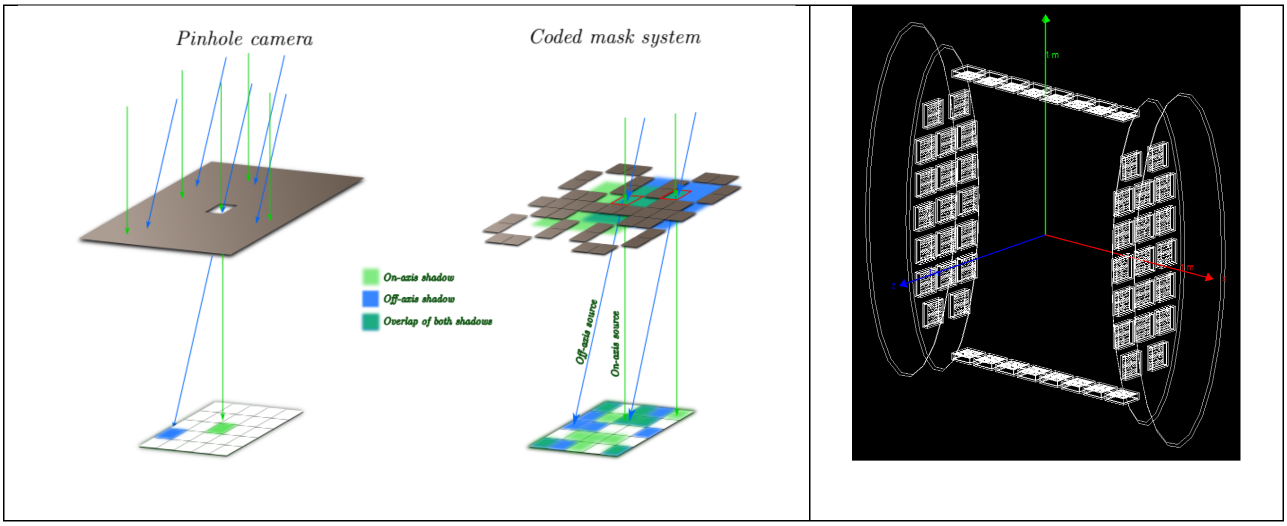


Figure 5: coded aperture masks and simulated cameras inside GRAIN

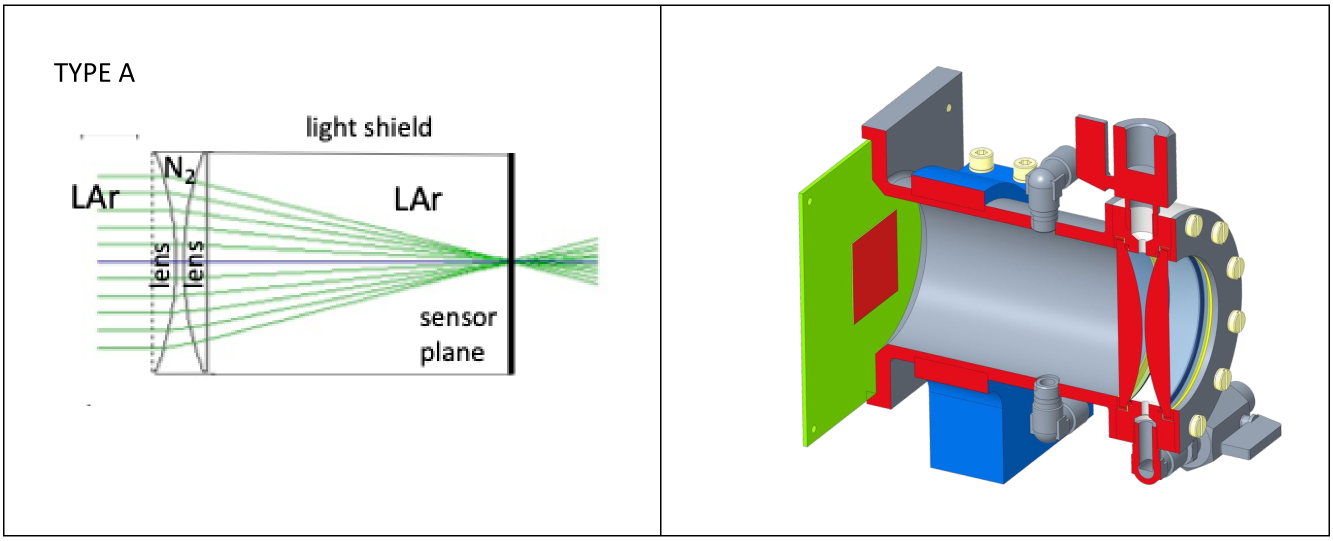


Figure 6a: design of VUV lens

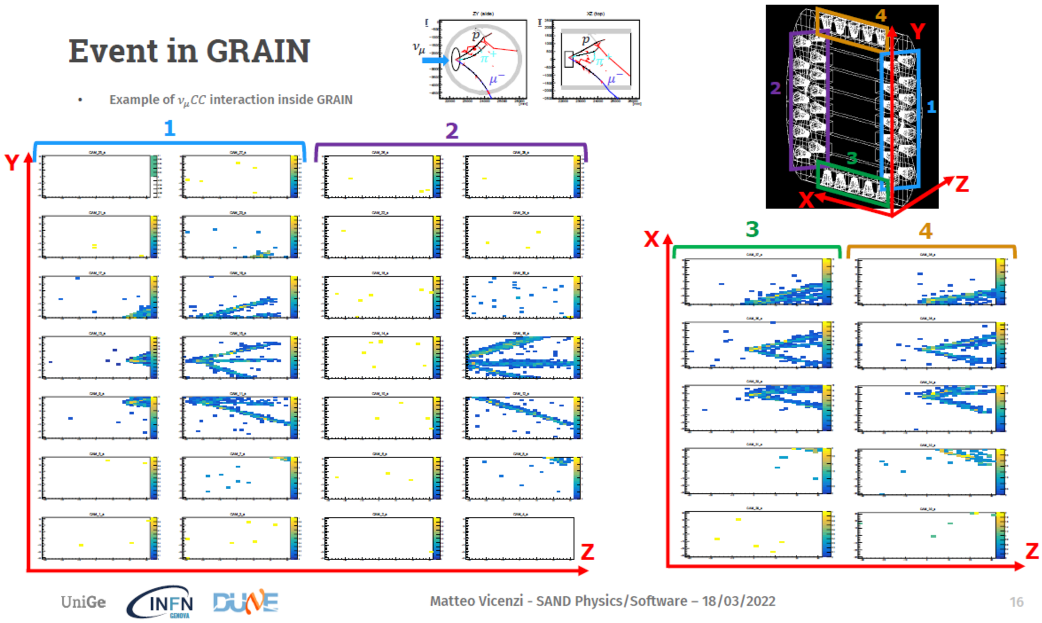


Figure 6b: example of simulated track imaging with lenses

2) Test facility a LNL

Program for detectors test:

- Verification of internal vessel mechanics and cabling with all cameras installed
- Verification and fixing of sources of electronic noise
- Study bubble formation (power dissipation) in front of the cameras in sub-cooling conditions
- If sub-cooling is not enough to limit boiling near the detectors, study alternative solutions
- Study and fix integrity of output data signals
- Verification of clock distribution to all the detectors and tune procedure for synchronization of all frontend ASICs

Program for the cryogenic system test

- Scope: To realize the proximity cryogenic system as close as possible to the one to be installed at the final location. It is foreseen to utilize all components except the new vacuum tank of the cryostat
- Outline of the P&ID, both simplified and detailed one.
- Laboratory at LNL proposed for the test facility (outline, photos, LN2 Dewar outside, existing cryogenic piping, crane 1.6 ton, operation of the test facility without interference with the ongoing maintenance of the ALPI cryostats)
- Technical modifications in charge of the SAND collaboration or INFN-BO: replacements of a few cryogenic valves, refurbishing of the control cabinet with upgrade to PLC
-

The test facility will be operated by the SAND collaboration: in particular, an engineer/applied Physicist from INFN-BO will organize the refurbishing of the part of cryogenic laboratory identified for the test facility. The LNL experts of the cryogenic service will guarantee the technical assistance as follows:

- The cryogenic service will make available one person for one day a week for the refurbishing of the cryogenic piping and of the control cabinet
- RP will provide consultancy for the design and realization of the proximity cryogenics

The scope of the test facility is the qualification of all the cryogenic components, in particular of those, which will be installed at FNAL. Moreover, the real LN2 cryogenic consumptions will be measured both for the cool down and for the static heat load as well as those needed for the LAr purification in forced flow circulation. All components will be realized in such a way that they will be installed at the final site at FNAL. At the moment the mechanical design of the SS LAr reservoir is completed while the design of the final vacuum tank in reinforced carbon fiber is not yet available. Consequently, a SS vacuum tank to be used for the test facility will be designed and manufactured. The previous proposal to refurbish the AURIGA test vacuum tank has been abandoned for economic reasons. Here below is a pictorial view of the P&ID while the technical one is shown in Fig. 7.

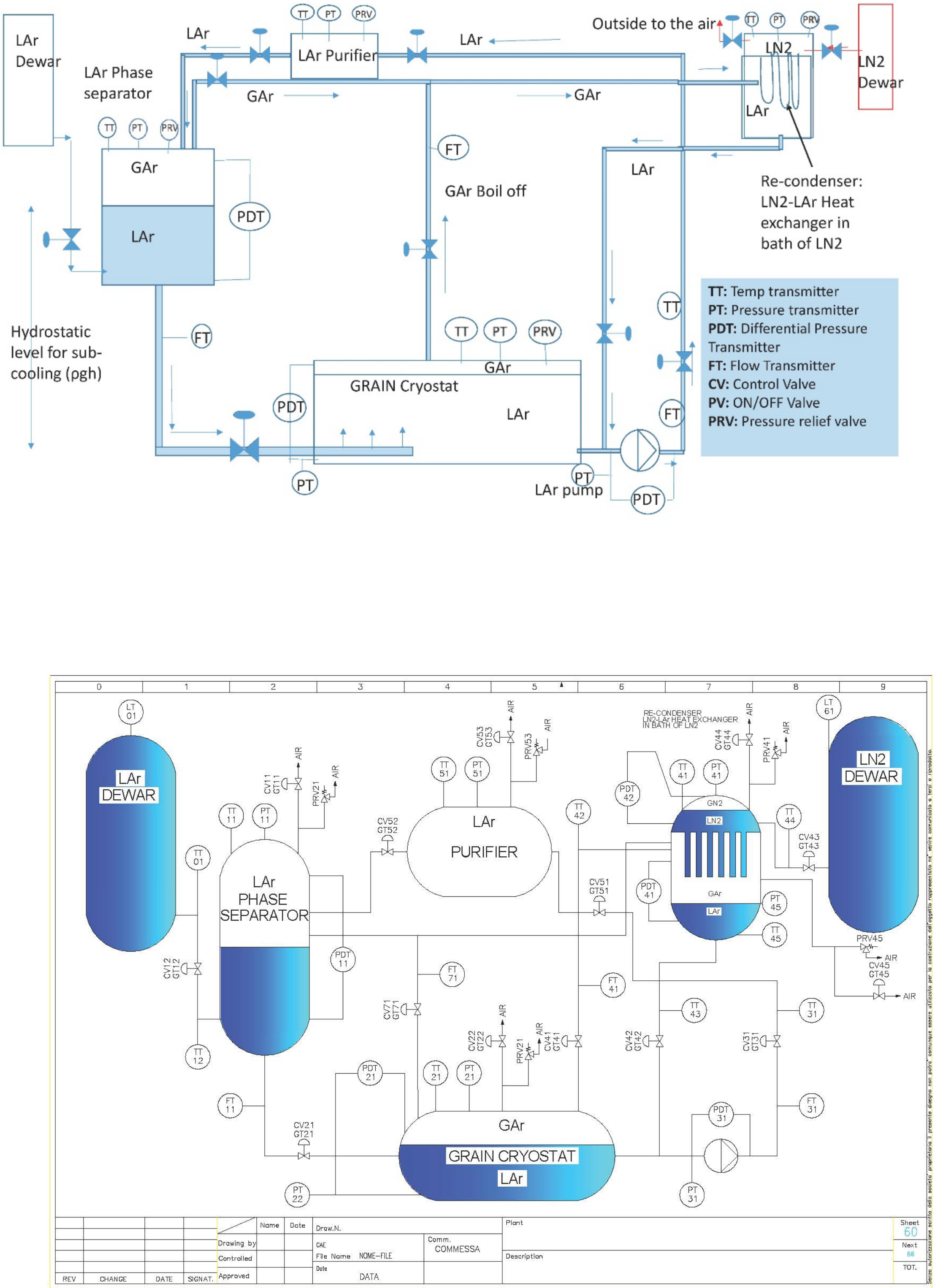


Figure 7: simplified scheme and P&ID of proximity cryogenics.

The LAr cryostat, which will house the detectors, will be manufactured with vacuum insulation and MLI. The LAr will be sub-cooled in order to avoid or limit the presence of GAr bubbles in the bath. The LAr purification will be obtained in the liquid phase with proper getters and with the use of a centrifugal cryogenic pump. The GAr will be re-condensed in the re-condenser by means of LN2 at the suitable pressure, to avoid the LAr solidification. The phase separator will be installed at the height of 3.5 meter to obtain the sub-cooled LAr.

The proposal is to realize the test facility at LNL, in the north end of the cryogenic laboratory, built in the 90's for the tests of the ALPI RF cavities, now used for the maintenance of the ALPI cryostats. After a careful survey of the possible sites within INFN sites, the one of LNL is the optimal one. In fact, the existing cryogenic equipment allows the construction of the test facility with minor investments. Furthermore, the presence of expertise in cryogenics is of invaluable help for the project.

In the Fig. 8a and Fig. 8b the space identified for the test facility is shown: in particular the distribution cryogenic lines, connected to the 5000 liters LN2 Dewar outside. The existing cryogenic cabinet

Figure 8°:Lo spazio richiesto per la realizzazione della test facility.

is also visible. After a detailed discussion with the LNL cryogenic service responsible it is settled that operation of the test facility will not interfere with the usual maintenance activity of the ALPI cryostats.

All limited modifications, necessary for the realization of the test facility will be in charge of the SAND experiment funded by INFN. In details: 1) the replacement of the few existing valves with vacuum insulated

Figure 8b: Le linee criogeniche di distribuzione, già connesse al dewar di 5000 litri esterno

ones, necessary for the continuous LN2 flow. 2) The upgrade/refurbishing of the control cabinet. The SAND collaboration will operate the test facility, once commissioned in collaboration with LNL.

INFN-BO will send: 1) a technician to LNL for the training at the cryogenic service.2) an engineer/applied physicist who will be the technical coordinator of the test facility and who will coordinate the activity for the refurbishing of the existing facility.

LNL will provide assistance as follows:

- one person of the cryogenic service for one day per week, for consultancy on refurbishing of the existing cryogenic equipment (cryogenic lines and cabinet)
- Consultancy for the design and realization of the proximity cryogenics (LNL associate senior).

Dimensionamento filtri per GRAIN

Dati iniziali

Filtro per O_2:

Produttore: BASF
Nome commerciale: Cu 0226 S 14x28MESH
Superfice: ≈ 200 m^2/g (dipende dal lotto di produzione)
Densità al massimo impaccamento: 0.85 kg/l
Capacità di assorbimento a temperatura ambiente: ≈ 5 g (O_2) / kg (Filtro)
Capacità di assorbimento a temperatura LAr: ≈ 0.5 g (O_2) / kg (Filtro)

Filtro per H_2O:

Produttore: BASF, Sigma-Aldrich, …
Tipo: 4A, pellet
Densità al massimo impaccamento: ≈ 0.75 kg/l
Capacità di assorbimento: > 0.215 g (H_2O) / g (filtro)

Volume di GRAIN: ≈ 1000 litri → 1400 kg
Velocità di ricircolo (1500 W): ≈ 9 g/s
Tempo richiesto per ricircolare un volume completo: ≈ 43 ore

Assunzioni

Purezza argon commerciale (liquido):
- O_2 < 2 ppm (mol/mol)
- H_2O < 2 ppm (mol/mol)
- N_2 < 5 ppm (non assorbito dai filtri).

Purezza durante il funzionamento di GRAIN:
- O_2 ≤ 0.3 ppb (vita media elettroni liberi = 1 ms)
- H_2O ≤ 0.3 ppb
- N_2 < 5 ppm (non assorbito dai filtri; possibile incremento lineare se ci sono fughe).

Funzionamento continuativo prima della rigenerazione: > 1000 giorni

Fattore di sicurezza: SF = 1.5 x 2 (utilizzo di due filtri, uno in linea, l'altro intercettato, per consentire la rigenerazione di un filtri senza interrompere il funzionamento).

Dimensionamento

Quantità di impurezze inizialmente presente nell'argon:
- $I0(O_2) \leq 0.07$ mol = 2.24 g

$I0(H_2O) \leq 0.07$ mol = 1.26 g

Quantità di impurezze integrate in 1000 giorni di funzionamento:

$I1(O_2) \leq 0.006$ mol ≈ 0.2 g

$I1(H_2O) \leq 0.006$ mol ≈ 0.11 g

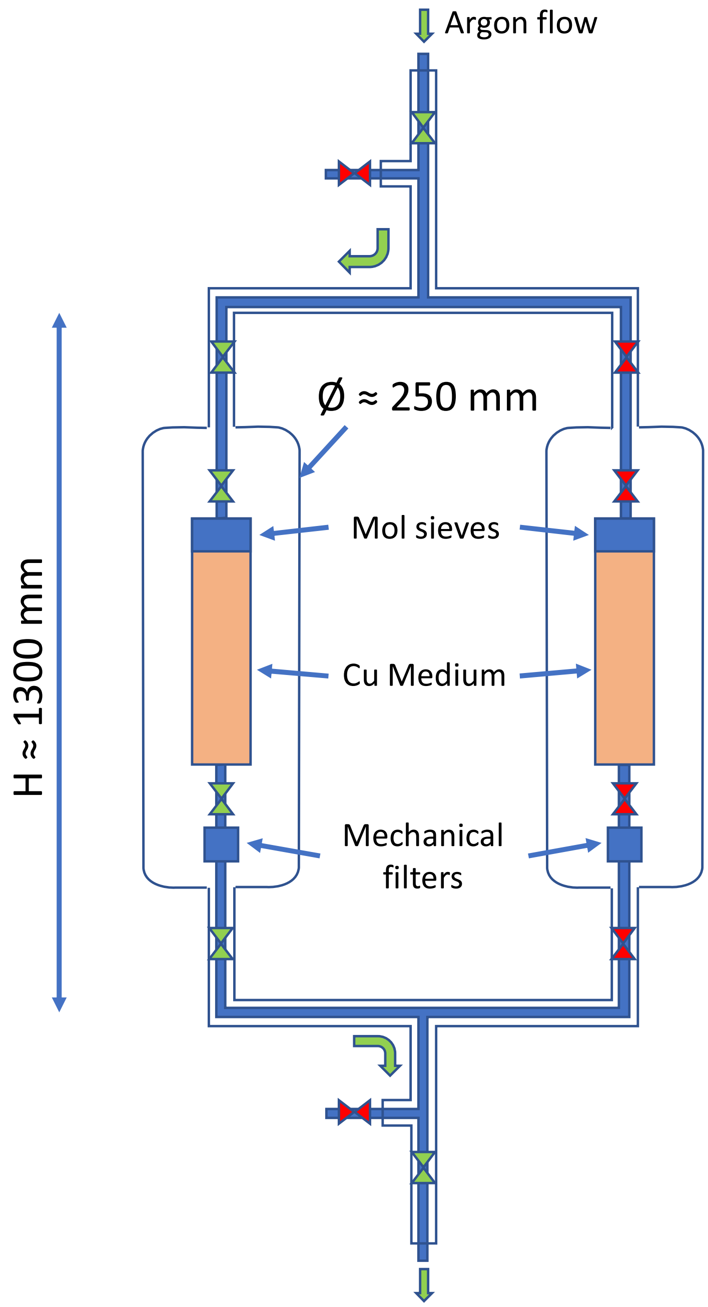
Volume totale di ciascun filtro per il funzionamento a temperature criogeniche:
Nota: la prassi è quella di riempire le cartucce con il 20% del volume con setacci molecolari e l'80% del volume con il rame. Ne risulta che la capacità di assorbimento per l'acqua è molto più grande di quella per l'ossigeno.

$V=1.25*1.5*(I0(O_2)+I1(O_2))/(0.5*0.85) \approx 11$ litri (2.2 litri occupati da setacci molecolari, 8.8 litri occupati dal filtro in rame).

Una cartuccia potrebbe essere realizzata a partire da un tubo flangiato DN160CF con tubo con diametro interno di 150 mm. La lunghezza interna della cartuccia sarebbe di circa 700 mm, compreso il volume libero per consentire la ripartizione del flusso sulla sezione completa del filtro.
A questa lunghezza va aggiunto lo spazio per le flange di chiusura, le valvole di isolamento ed il filtro meccanico all'uscita. Il tutto va inserito in un contenitore per il vuoto di isolamento ed il superisolante a sua volta dotato di tubi per la connessione e valvole di isolamento. La dimensione complessiva potrebbe essere un cilindro di diametro 250 mm ed altezza 1300 mm.

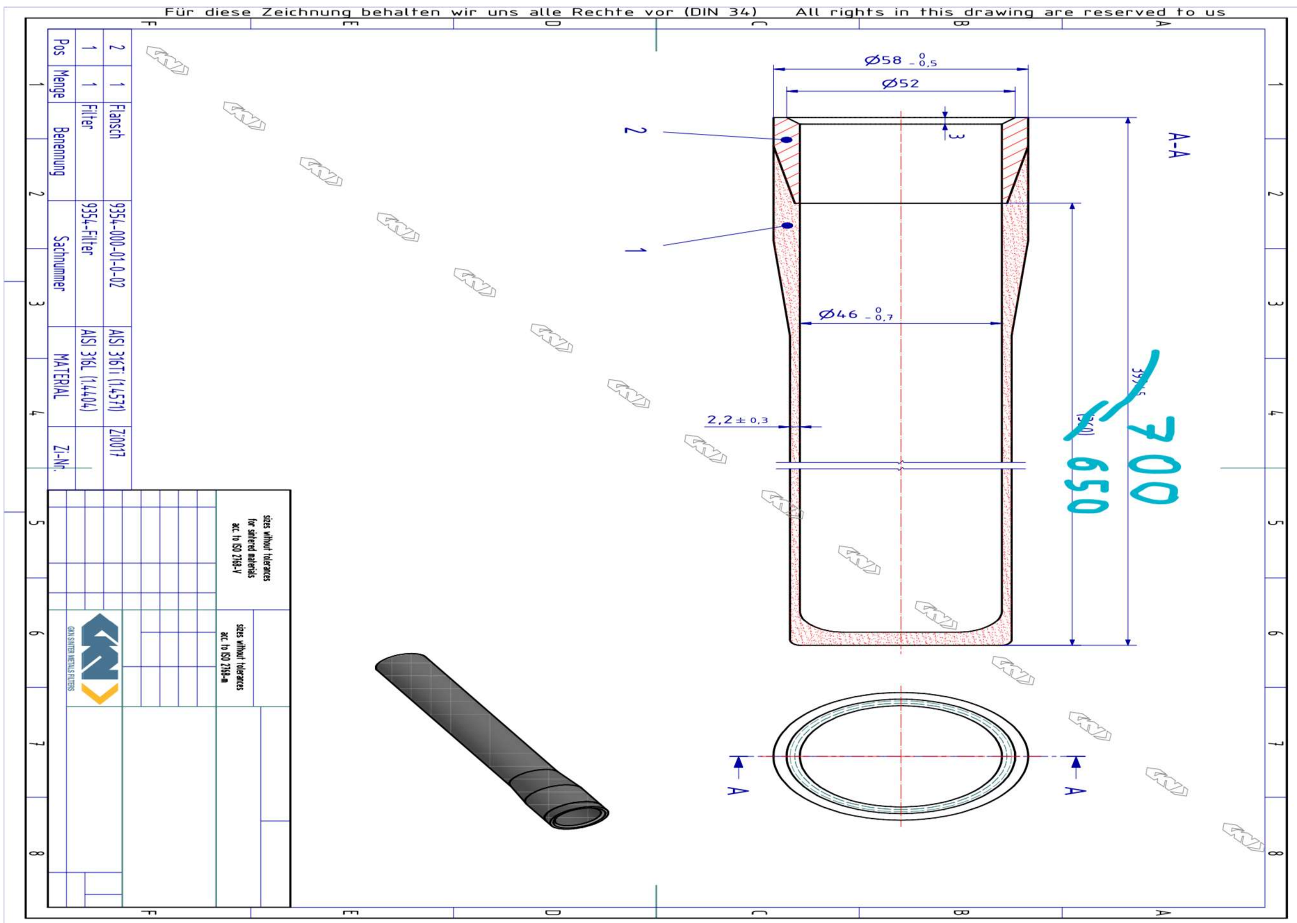
In Figura 1 è illustrato lo schema di una coppia di filtri, interscambiabili. Da notare i filtri meccanici che vanno installati all'uscita delle cartucce riempite con rame e setacci molecolari. Dalle esperienze fatte risulta che all'uscita delle cartucce sono presenti tracce di una polvere sottile risultate dalla frizione tra l'argon ed il materiale filtrante. I filtri meccanici utilizzati in PROTODUNE, ICARUS, etc. sono del tipo SIKA-R 15 S, un sinterizzato in acciaio AISI 316L con pori da 15 µm di diametro e porosità del 50% (Figura 2).

Infine, in Figura 3 è mostrato il disegno delle cartucce dei filtri del ricircolo liquido per il rivelatore ICARUS. Questi filtri, con un volume complessivo di circa 22 litri, sono più grandi di quelli necessari per SAND ed hanno una camicia esterna dove viene fatto flussare azoto liquido per evitare il rischio di un accumulo di gas nei filtri con conseguente riduzione della portata. In PROTODUNE questa soluzione non è implementata. Nel disegno sono rappresentati gli elementi meccanici per l'inserimento di 5 sonde di temperatura utilizzate durante l'attivazione del materiale filtrante.



Argon flow
Ø ≈ 250 mm
H ≈ 1300 mm
Mol sieves
Cu Medium
Mechanical
filters

Figura 1



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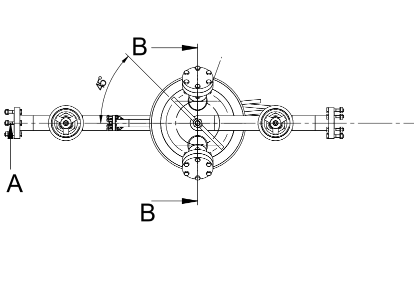
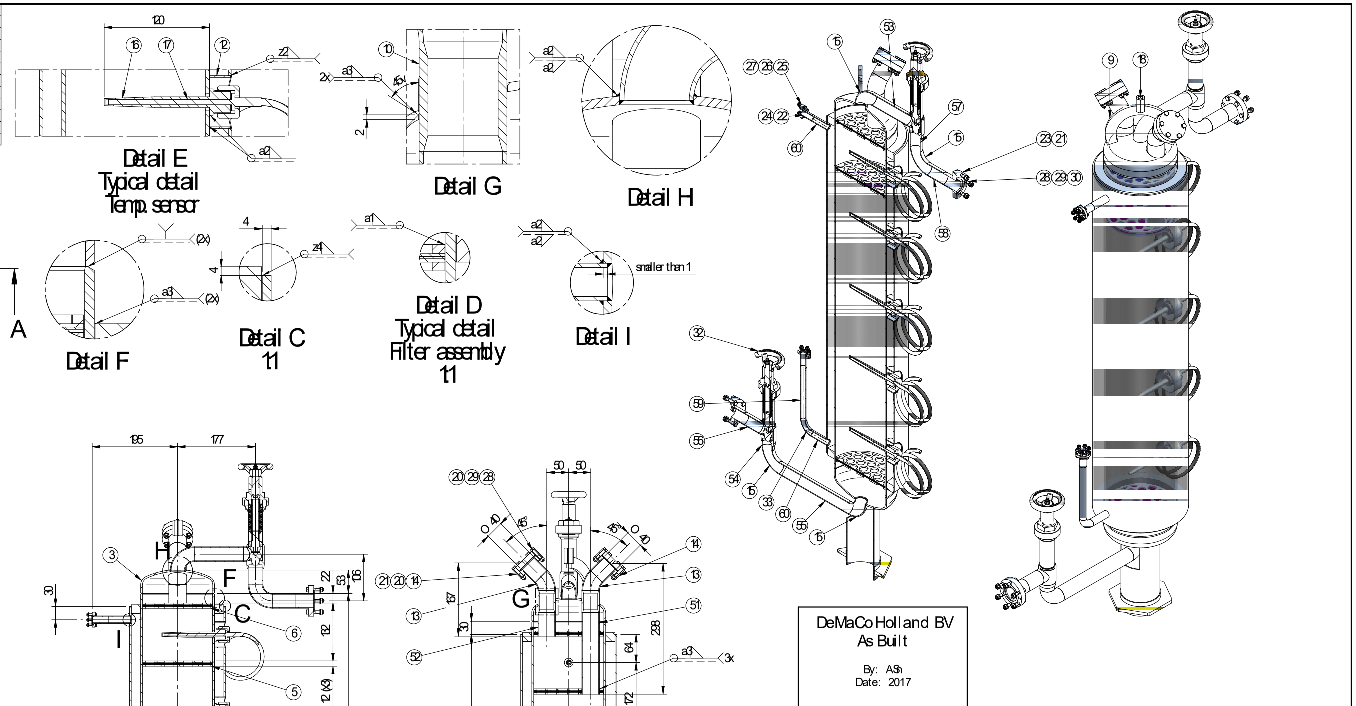
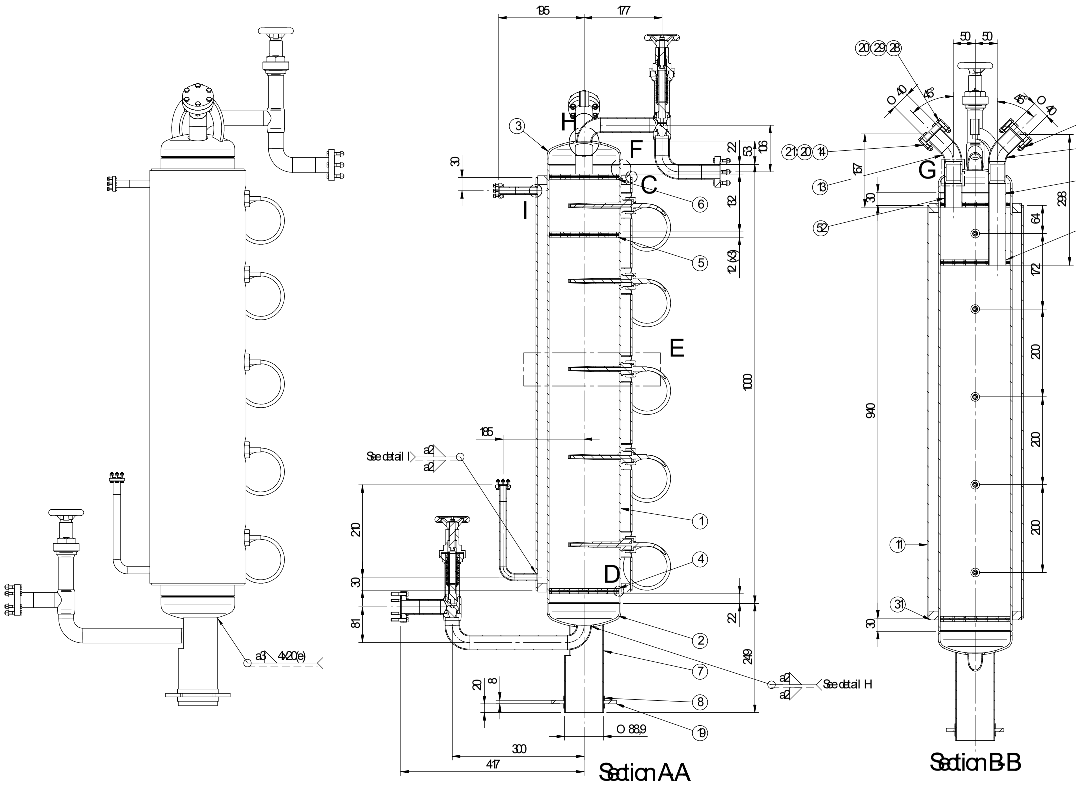
Pos
Menge
Benennung
Sachnummer
MATERIAL
Zi.-Nr.
2
1
Flansch
9354-000-01-0-02
AISI 316Ti (1.4571)
Z0017
1
1
Filter
9354-Filter
AISI 316L (1.4404)
A-A
Ø58
Ø52
Ø46
2,2 ± 0,3
700
650

Figura 2

Itm	Qty	Description	OD	t	Cut Length	Material	IDno.	Comments	Change
51	1	Pipe	40.00	2.00	186.00 mm	1.4301 / 1.4307	-	EN10216-5	
52	1	Pipe	17.20	2.00	147.00 mm	Wnr. 1.4301 / 1.4307	-	EN10216-5	
53	1	Pipe	33.70	2.00	224.00 mm	Wnr. 1.4301 / 1.4307	-	EN10216-5	
54	1	Pipe	40.00	2.00	54.00 mm	1.4301 / 1.4307	-	EN10216-5	
55	1	Pipe	33.70	2.00	112.00 mm	Wnr. 1.4301 / 1.4307	-	EN10216-5	
56	1	Pipe	33.70	2.00	12.00 mm	Wnr. 1.4301 / 1.4307	-	EN10216-5	
57	1	Pipe	33.70	2.00	47.00 mm	Wnr. 1.4301 / 1.4307	-	EN10216-5	
58	1	Pipe	33.70	2.00	52.20 mm	Wnr. 1.4301 / 1.4307	-	EN10216-5	
59	1	Pipe	33.70	2.00	37.00 mm	Wnr. 1.4301 / 1.4307	-	EN10216-5	
60	1	Pipe	17.20	2.00	49.00 mm	Wnr. 1.4301 / 1.4307	-	EN10216-5	
61	1	Pipe	17.20	2.00	52.00 mm	Wnr. 1.4301 / 1.4307	-	EN10216-5	







Itm	Qty	Description	OD	t	L	Cut Length	WID	H	Material	PDM Part	Old Dwg	Article	Comments	Charge No.	2D
87	1	Pipe	33.70	2.00		52.2			Wnr. 1.4301 / 1.4307	A0014743			EN10216-5		-
33	1	Elbow 90°	17.20	2.00					1.4301 / 1.4307	A0030766			R=25 w- EN10253-4 - (Type A)		-
32	2	Handvalve DN25 PN10							Wnr. 1.4301	A0026468					Y
31	2	Ring	210.50	20.00			169.00		1.4301 / 1.4307	A0028444			EN10028-7 - 1D		-
30	24	Nut M6							A2-70	A0029211			EN3506-2 + DIN931 / EN10204 3.1 certificate		-
29	24	Washer M6							A2-70	A0029213			DIN125 - 1A / EN10204 3.1 certificate		-
28	24	Bolt M6x35							A2-70	A0029208			EN3506-1 + DIN931 / EN10204 3.1 certificate		-
27	12	Nut M4							A2-70	A0029206			EN3506-2 + DIN933 / EN10204 3.1 certificate		-
26	12	Washer M4							A2-70	A0029212			DIN125 - 1A / EN10204 3.1 certificate		-
25	12	Bolt M4x20							A2-70	A0029205			EN3506-1 + DIN933 / EN10204 3.1 certificate		-
24	2	Gasket CF DN16	21.25	2.00			16.00		Copper	A0020391		G133			-
23	2	CF DN40_33.7 Rotatable	33.70	2.00	43.00				1.4301 / 1.4307	A0029151			According D0066847 - Machined out 1 part - 10.6 Nm with Molykote		-
22	2	CF DN16_17.2 Rotatable							1.4301 / 1.4307	A0029123			According D0066847 - Completely Machined - 22.4 Nm with Molykote		-
21	4	CF40 Copper gasket	48.10	2.00			38.70		Copper	A0017190		G275	Art.# G275		-
20	2	CF DN40 Blind Flange Fix							1.4301 / 1.4307	A0029153			According D0066847 - 10.6 Nm with Molykote		-
19	1	Spacer 3 inch		8.00			130.06	147.00	EPGC203	A0028442			EN60893		Y
18	1	Connection Nut, M12 H=3D	12.00						A4-70	A0020536					-
17	5	pt100 screw in sensor							SS	A0027128			Jumo: 902050/20-116-1011-2-6-120-165-03-4000/000		-
16	5	Weld Thermowell L=120							1.4571	A0027129			Jumo nr: 606710/42-14-20-120-8/000		-
15	4	Elbow 90 33.7x2	33.70	2.00					Wnr. 1.4301 / 1.4307	A0014931			R=38 w- EN10253-4 Type A		-
14	2	CF DN40_40 Fixed	40.00	2.00	43.00				1.4301 / 1.4307	A0029152			According D0066847 - Machined out 1 part - 10.6 Nm with Molykote		-
13	2	Elbow 45°	40.00	2.00					Wnr. 1.4301 / 1.4307	A0026410			R=45 w- EN10253-4 - Type A		-
12	5	Pipe	60.30	2.00	29.33				1.4301 / 1.4307	A0026407			EN10216-5		Y
11	1	Pipe	219.10	4.00	940.00				1.4301 / 1.4307	A0026406			EN10217-7		Y
10	2	Nozzle	40.00	4.00	50.00				1.4301 / 1.4307	A0026408			EN10272		Y
9	1	Plate		8.00	161.07		109.87		Wnr. 1.4301 / 1.4307	A0027762			EN10028-7		Y
8	2	Spacer ring 3 Inch	88.90	2.00	10.00				1.4301 / 1.4307	A0016096		504078	EN10217-7		-
7	1	Pipe	88.90	2.00	200.00				1.4301 / 1.4307	A0017192			EN10217-7		Y
6	1	Filter Assembly 2-holes								A0026392					Y
5	1	Filter Assembly 1-hole								A0026388					Y
4	1	Filter Assembly							1.4301 / 1.4307	A0026384					Y
3	1	Klopper head	168.30	4.00				54.00	1.4301 / 1.4307	A0026383			Maf 3 + DIN28011 EN10028-7		Y
2	1	Klopper head	168.30	4.00				54.00	1.4301 / 1.4307	A0026382			Maf 3 + DIN28011 EN10028-7		Y
1	1	Pipe	168.30	4.50	1000.00				Wnr. 1.4301 / 1.4307	A0026381			s - EN10216-5-TC1		Y

Drawn: ssc	Date: 10-01-2017	Status: As Built	Tolerances unless stated otherwise acc. ISO 2768 m K
Status changed by: asn	Am. proj.	Printed: ssc	Edges of undefined shape acc. ISO 13715 -0.5 +0.5
	Scale: N.A.	Mass: 50.8	Roughness acc. ISO 4287 Ra in µm General: Ra3,2
			All welding acc. W07.07 unless stated otherwise

Liquid Argon Filter Module

Liquid Argon Filter Module

Customer: - -

Standard: No

Old Dwg. number:

Article number:

Rev. D | Date 27-07-2017 | Drawn asn | Description as built

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W www.DeMaCo.nl

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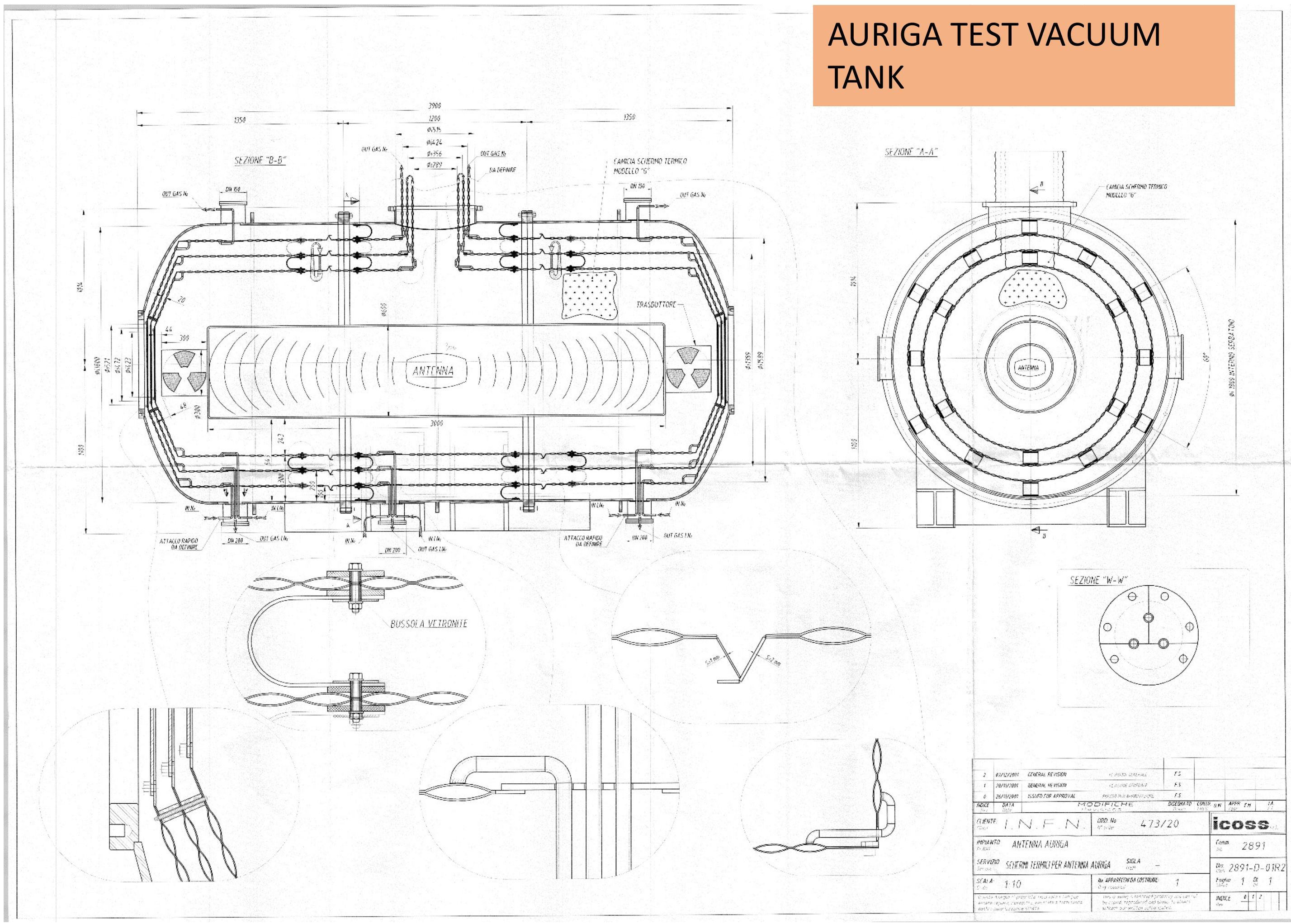
PDM Part: A0026380 | Doc. Nr.: D0059862 | Ver.: 0 | Rev.: D | Form: A1

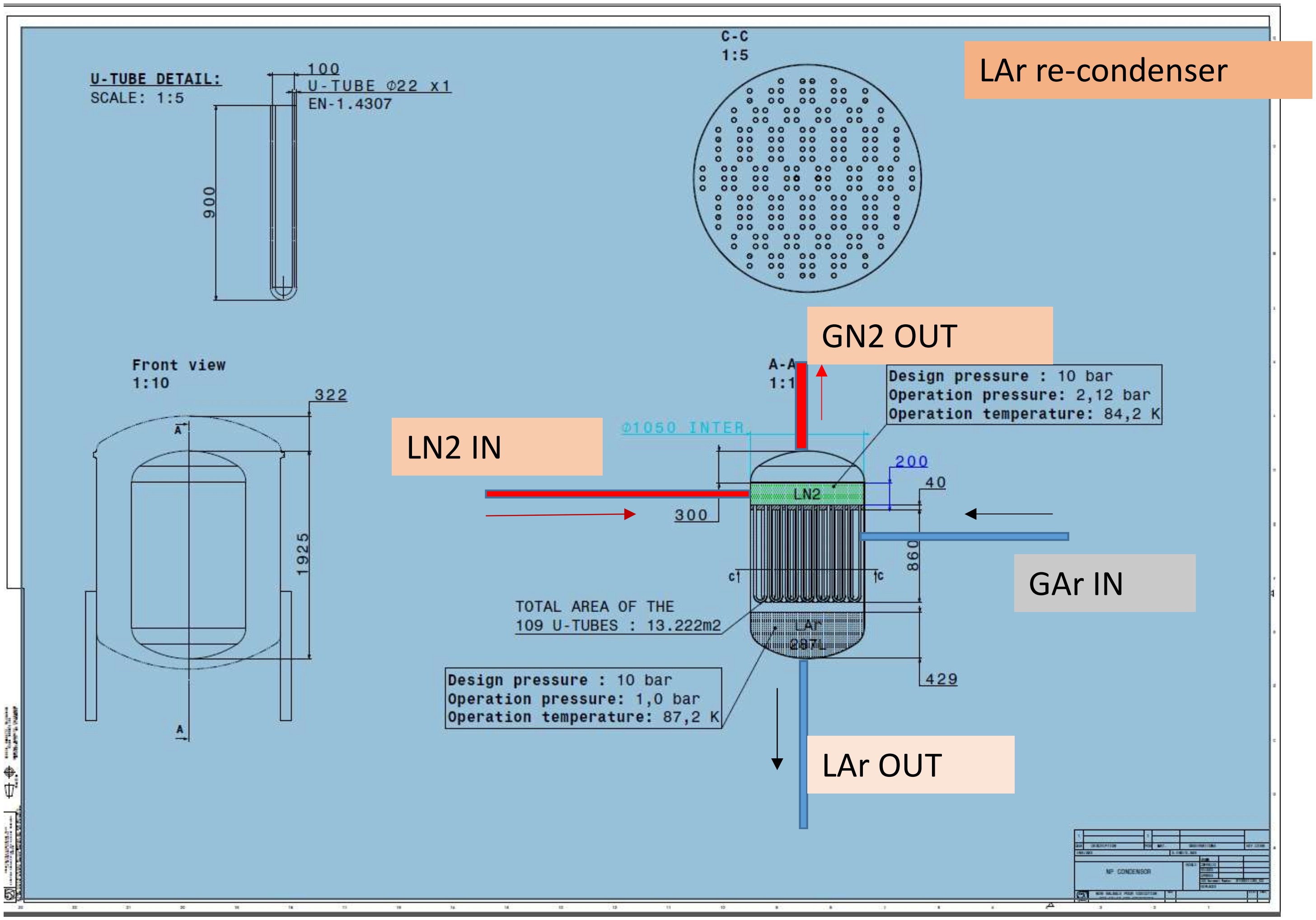
Stima dei costi C.Montanari

Per un singolo filtro, comprensivo di valvole (x4), contenitore a vuoto, certificazioni, etc... molto grossolanamente 40-50 kEuro.

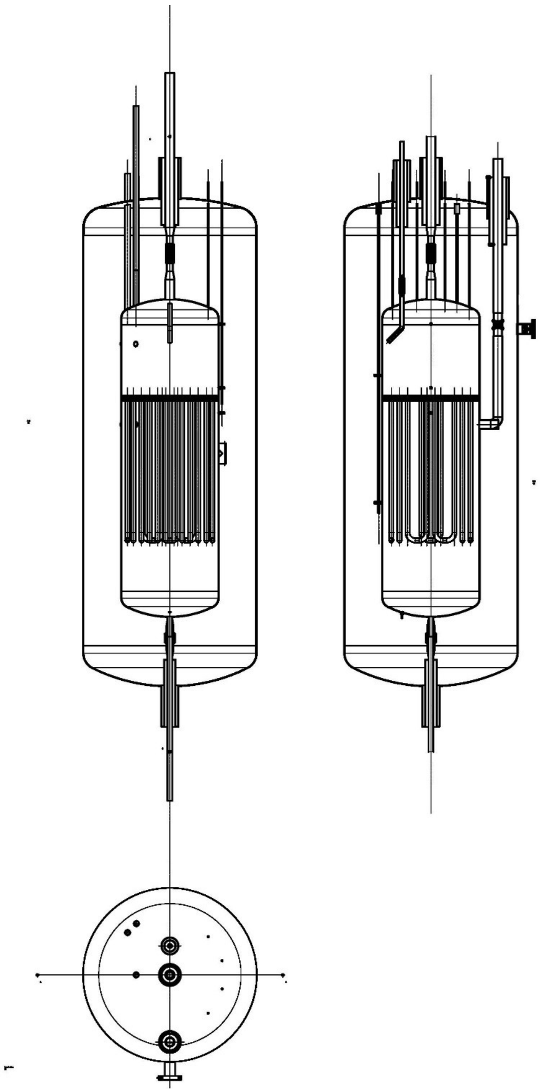
AURIGA TEST VACUUM TANK




AURIGA TEST VACUUM TANK

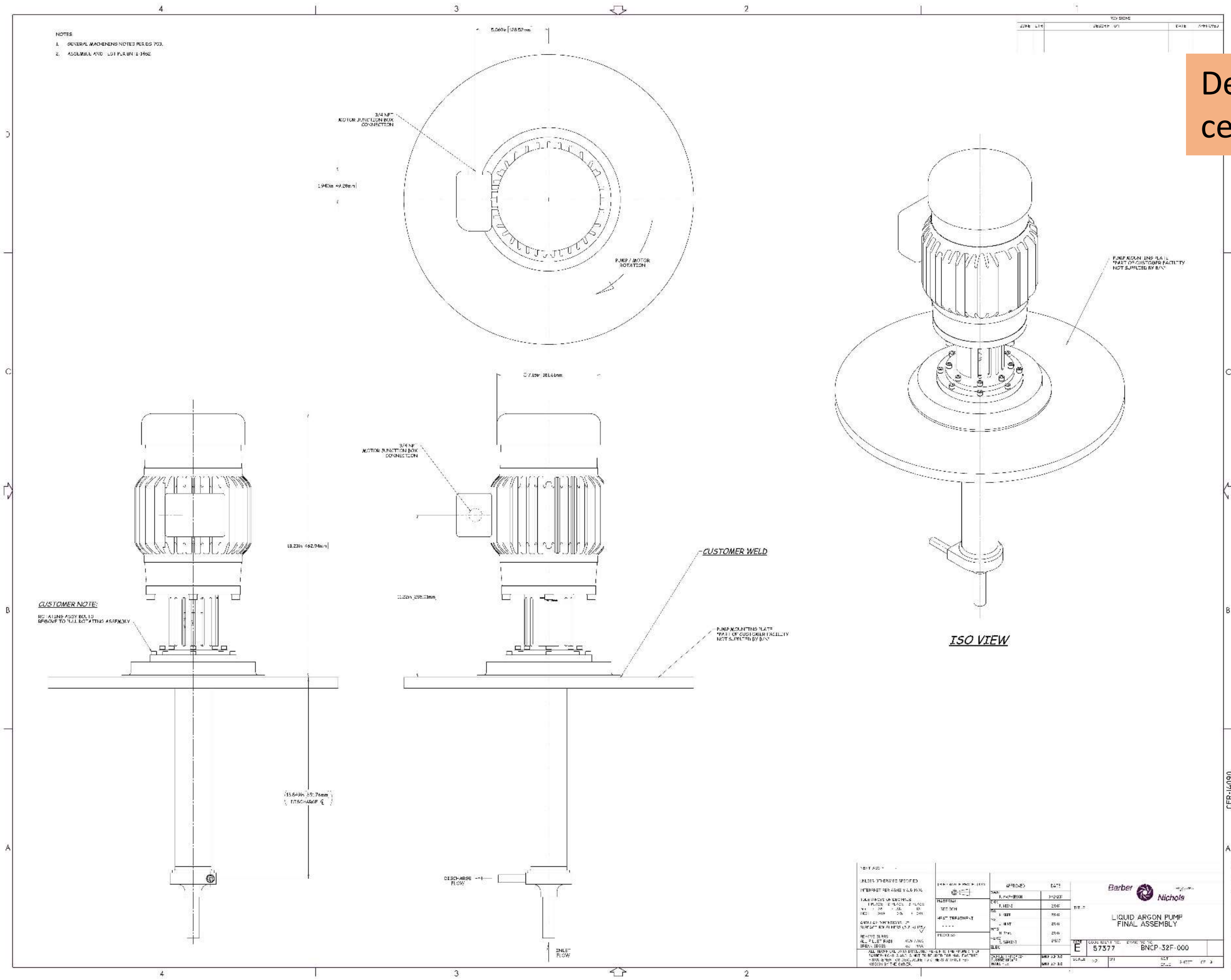


LAr re-condenser
U-TUBE DETAIL:
SCALE: 1:5
100
U-TUBE Φ22 x1
EN-1.4307
900
C-C
1:5
Front view
1:10
322
1925
A
A
A-A
1:1
GN2 OUT
Design pressure : 10 bar
Operation pressure: 2,12 bar
Operation temperature: 84,2 K
LN2 IN
Φ1050 INTER
200
40
LN2
300
860
GAr IN
TOTAL AREA OF THE
109 U-TUBES : 13.222m2
LAr
287L
429
Design pressure : 10 bar
Operation pressure: 1,0 bar
Operation temperature: 87,2 K
LAr OUT

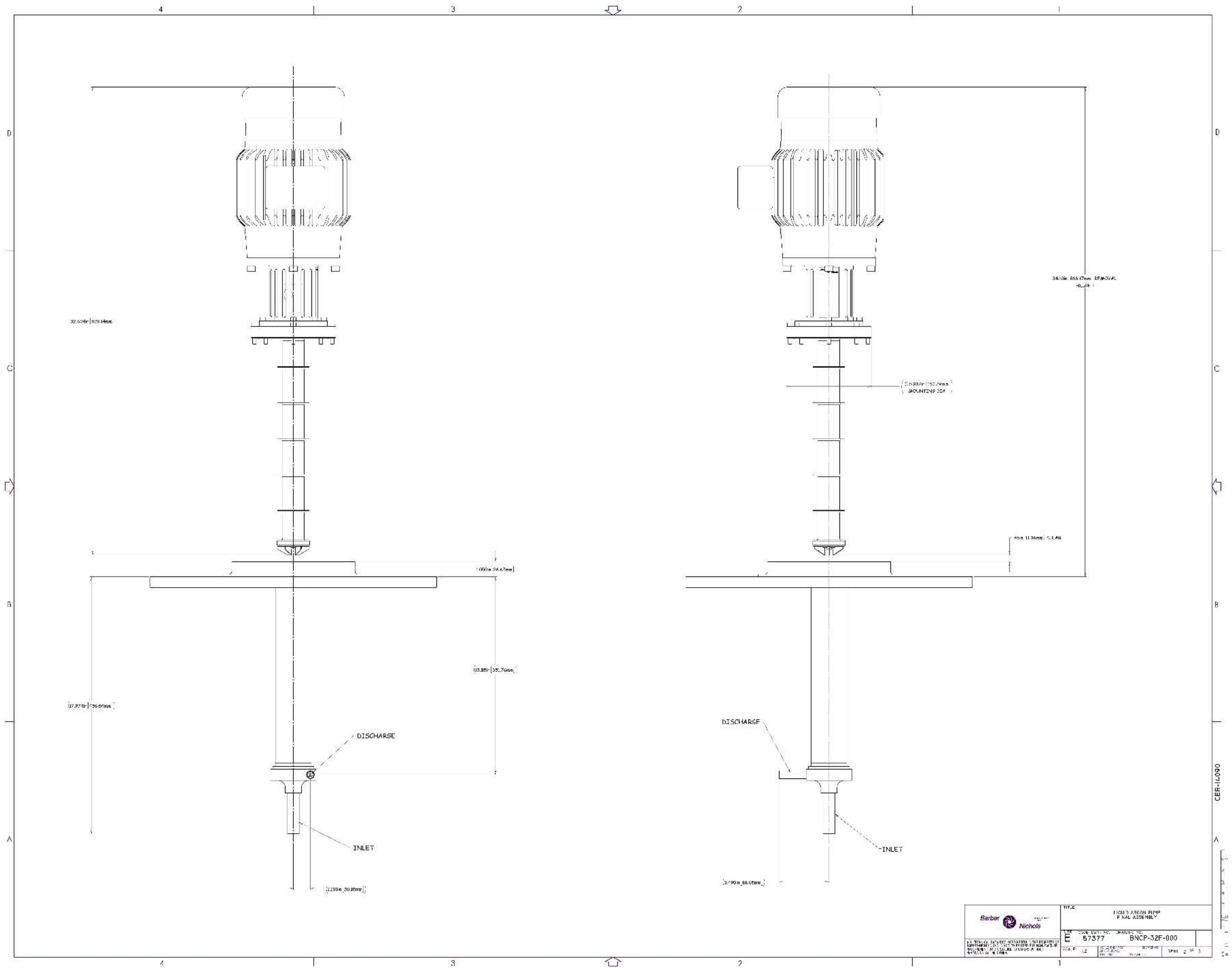


LAr re-condenser

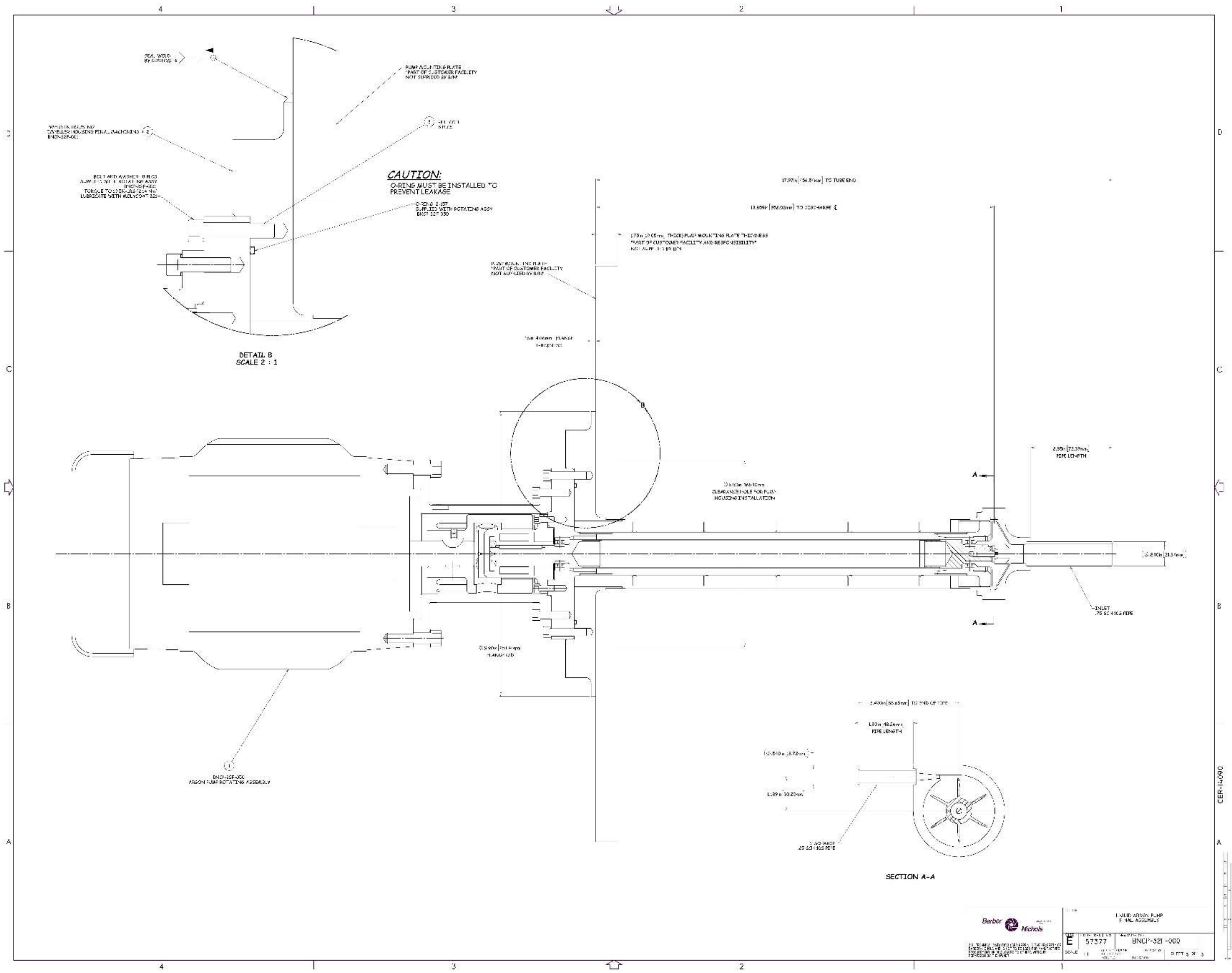
Details of the LAr centrifugal pump



Details of the LAr centrifugal pump



Details of the LAr centrifugal pump

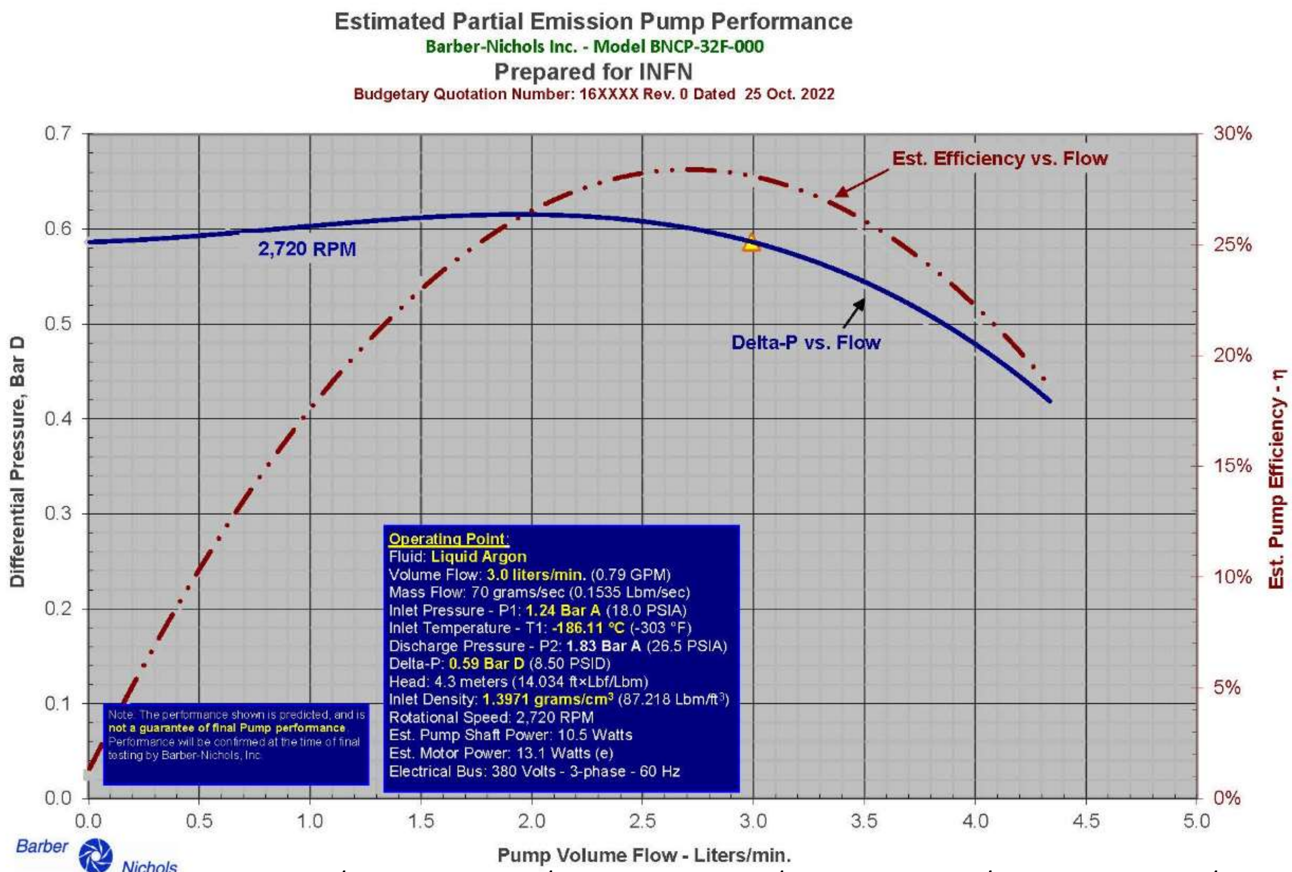


Characteristic curve of the LAr centrifugal pump

H = 5.0 m

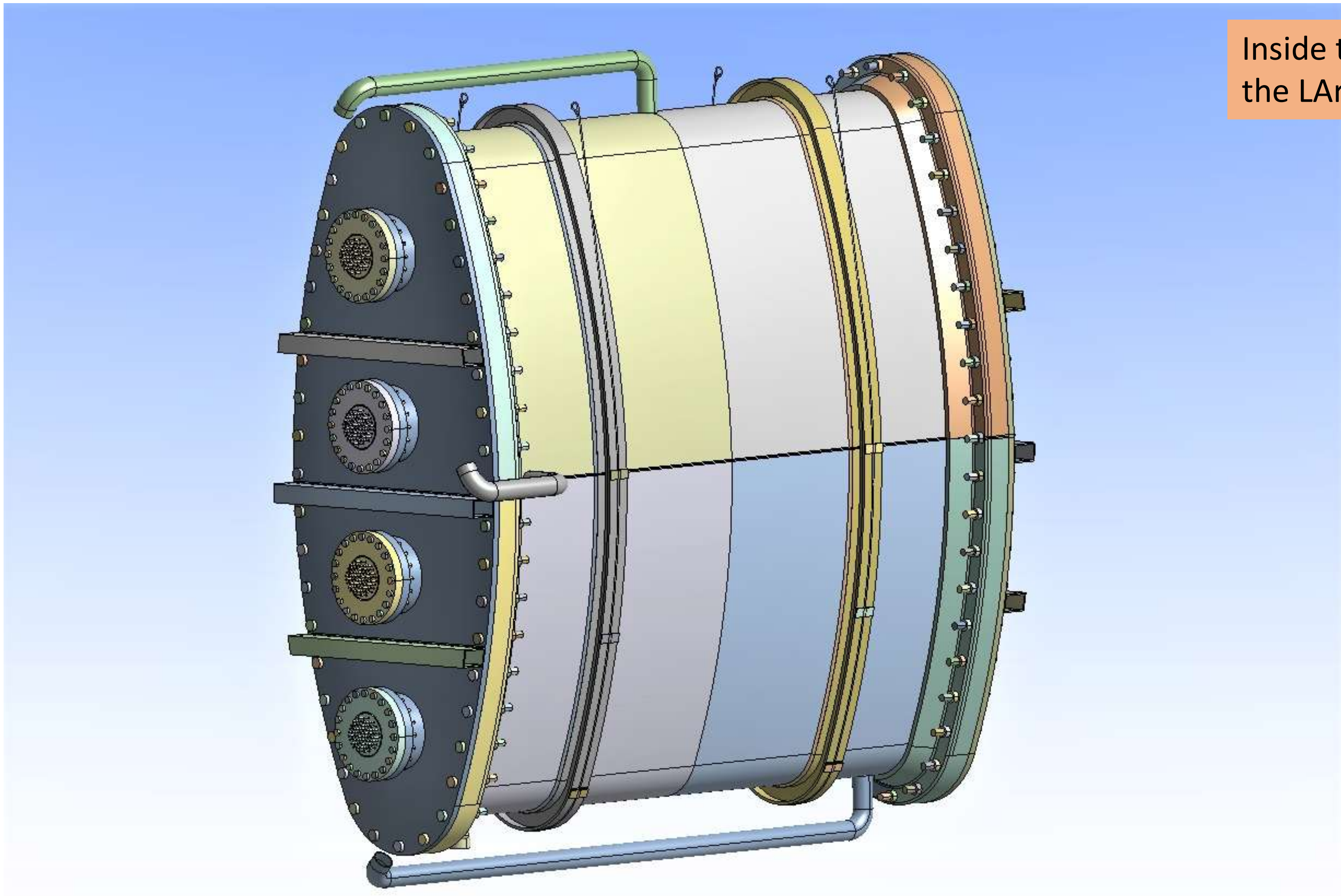
H = 4.3 m

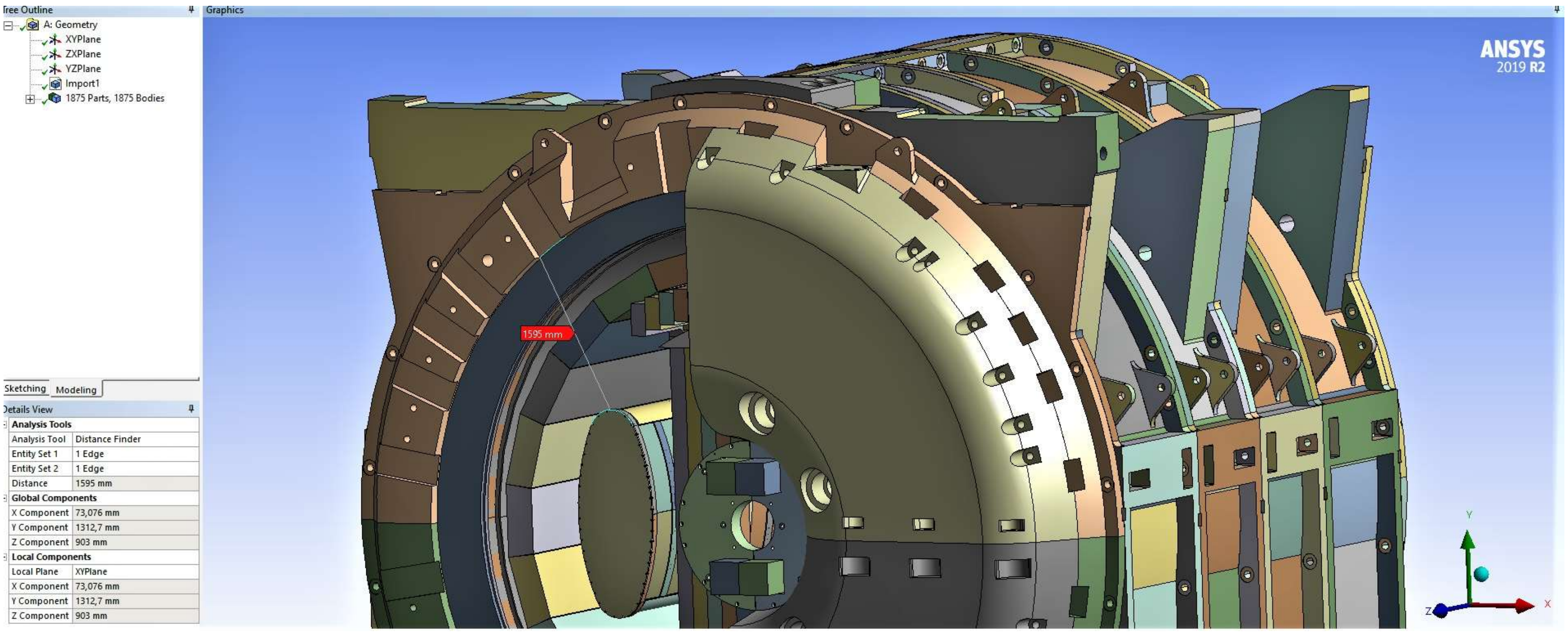
H = 3.6 m



23 g/s 47 g/s 70 g/s 93 g/s 117 g/s

Inside the cryostat:
the LAr reservoir





Details of the LAr reservoir inside KLOE superconducting solenoid

Vacuum TANK
DETTAGLIO L
SCALA 1 : 5
200,0
R101,5
∅68,1
FLANGIA DN 40 CF
∅168,3
320,0
100,0
45,00°
∅65,0
134,1
DETTAGLIO N
SCALA 1 : 5
30,0
42,5
172,0
DETTAGLIO F
SCALA 1 : 5
12,0
40,0
25,0
17,0
50,0
25,0
OR in Viton
DETTAGLIO E
SCALA 1 : 5
C
50,0
750,0
700,0
150,0
30,0
1690,0
2150,0
D
∅2213,0
∅2132,0
R1066,0
78,2
400,0
45,00°
300,0
600,0
976,2
120,0
991,9
FLANGIA DN 63 CF
R56,8
DETTAGLIO K
SCALA 1 : 5
∅2032,0
∅2132,0
690,0
380,0
FLANGIA DN 150 CF
SEZIONE M-M
SCALA 1 : 15
M
2150,0
SEZIONE D-D
SCALA 1 : 15
50,0
30,0
DETTAGLIO G
SCALA 1 : 5
275,0
30,0
163,8
199,6
DETTAGLIO O
SCALA 1 : 5
PRELIMINARY
2150,0
1930,0
2270,0
VISTA C
SCALA 1 : 15
22,3
60,0
∅203,0
DETTAGLIO R
SCALA 1 : 5
Technical Drawings ISO 8015
Gen. Tol. UNI-EN 22768/2-mK
VACUUM TANK
AISI 316 LN
1
A1