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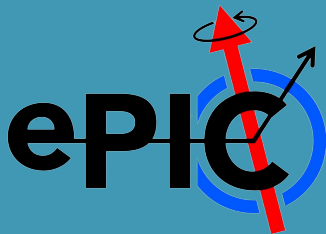
U.S. DEPARTMENT OF
ENERGY
Office of Science

Sizing of the SVT air cooling system

ePIC SVT WP4 / WP6 meeting

2026-05-20

Joe Silber (LBNL)



Requirements

High level cooling requirements

...from current draft Preliminary Design Report (PDR)

Detector temperature

Table 9.2: SVT component temperature requirements (N/S is not specified).

Requirement	LEC	RSU	REC	AncASIC
Maximum T [°C]	65	40	N/S	80
Maximum T variation [°C]	10	1 over 3 mm 10 over full length	N/S	10

Source: <https://www.overleaf.com/project/67170d690d68308814b3ba47>

Power dissipation

Table 9.3: SVT cooling power requirements. IB (L0 to L2) power given for 3×10 Gbps/ 6×5 Gbps link configurations. Total power uses 6×5 Gbps links.

Layer/disk	Nominal power [W]	Max power [W]
L0	29/33	39/44
L1	38/44	52/59
L2	95/109	129/148
L3	514	776
L4	1545	2442
ED0/HD0 (per disk)	141	222
ED1/HD1 (per disk)	414	656
ED2/HD2 (per disk)	427	677
ED3/HD3 (per disk)	427	677
ED4/HD4 (per disk)	427	677
Total cooling power [kW]	5.92	9.29

Diff between max and nominal is large. I.e. we shouldn't need to spec an air system with excessive "margin on margin"

Additions / modifications / clarifications to requirements that could be helpful

1. Is the $\nabla T = 10^\circ\text{C}$ max gradient “over full length” within one EIC-LAS module?
 - a. if not, what is the max gradient within module?
 - b. for the “slow and cold” approach, could we accept a gradient of $\nabla T = \underline{\hspace{1cm}}$ $^\circ\text{C}$?
2. Specify the minimum allowable silicon temperature for each component (LEC, RSU, AncASIC)
 - a. for the “slow and cold” approach
 - b. informally, we believe this could be at least as low as $T_{\min} = -20^\circ\text{C}$
3. Could we increase RSU max temperature from $T_{\max} = 40^\circ\text{C}$ to perhaps 45°C ?
 - a. for the “fast and warm” approach

Can the current pre-production sensor run (ER2) inform these?

Design overview

Design process from high level req'ts to detailed specs

High level requirements

Table 9.2: SVT component temperature requirements (N/S is not specified).

Requirement	LEC	RSU	REC	AncASIC
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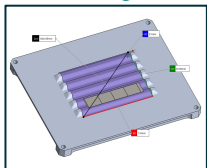
Req'ts on silicon
 T_{max} , ∇T

Constraints on
 $\Delta T_{cooling} = T_{Si} - T_{air}$
 ΔP , air speed

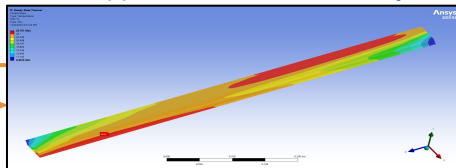
End-to-end system performance calculation

stage description	1	2	3	4	5	SVT internal ambient	exhaust ducts
stage index	1	2	3	4	5	22.2	0.0169
num channels (per parent channel)	1	2	4	32	32	710	12
total num channels in system	1	2	4	32	32	710	12
mass flow per channel	0.950	0.475	0.238	0.030	0.030	0.001	0.079
length	10.900	10.900	10.900	10.900	10.900	0.338	0.433
hydraulic diameter (mm)	100	75	50	25	25	11.5	73.8
length	0.050	0.075	0.050	0.025	0.025	0.012	0.714
single channel cross-sectional area along length L_c	7.85E-03	4.42E-03	1.96E-03	4.15E-04	4.15E-04	1.04E-04	4.00E-01
all channels total cross-sectional area	7.85E-03	8.84E-03	7.85E-03	1.33E-02	1.33E-02	7.40E-02	4.80E+00
entrance temperature	276.0	276.32	275.59	277.01	276.80	278.12	287.54
entrance pressure	1.427	1.393	1.325	1.178	1.084	1.044	1.043
entrance density (ideal gas law)	1.801	1.753	1.675	1.482	1.360	1.308	1.264
entrance dynamic viscosity	1.72E-05	1.78E-05	1.78E-05	1.78E-05	1.78E-05	1.78E-05	1.78E-05
Reynold's number	6.99E+05	4.66E+05	3.50E+05	9.48E+04	9.48E+04	8.50E+03	7.91E+03
friction factor (Blasius)	0.011	0.012	0.013	0.018	0.018	0.018	0.033
friction pressure drop (Darcy-Weisbach)	-4.438	-5.317	-17.025	-9.440	-4.394	-153	-114
downstream pressure	138.216	133.727	115.432	108.409	104.014	103.862	104.325
ambient pressure in the downstream area of this stage	1.013	1.013	1.013	1.043	1.043	1.043	1.043
downstream pressure relative to local ambient	137.203	132.714	114.419	107.366	102.971	102.819	103.282
module power input to stream	0.0	0.0	0.0	0.0	0.0	8943.9	0.0

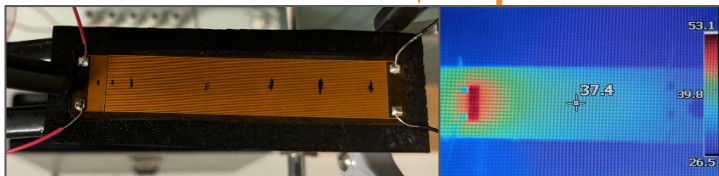
CAD design



Local supports heat transfer analysis



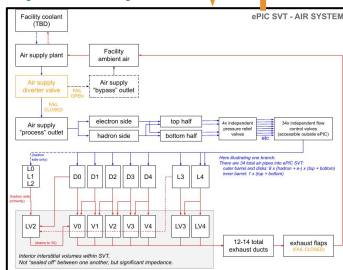
Local supports physical test



System architecture

Temperatures, pressures, flow rates

System layout

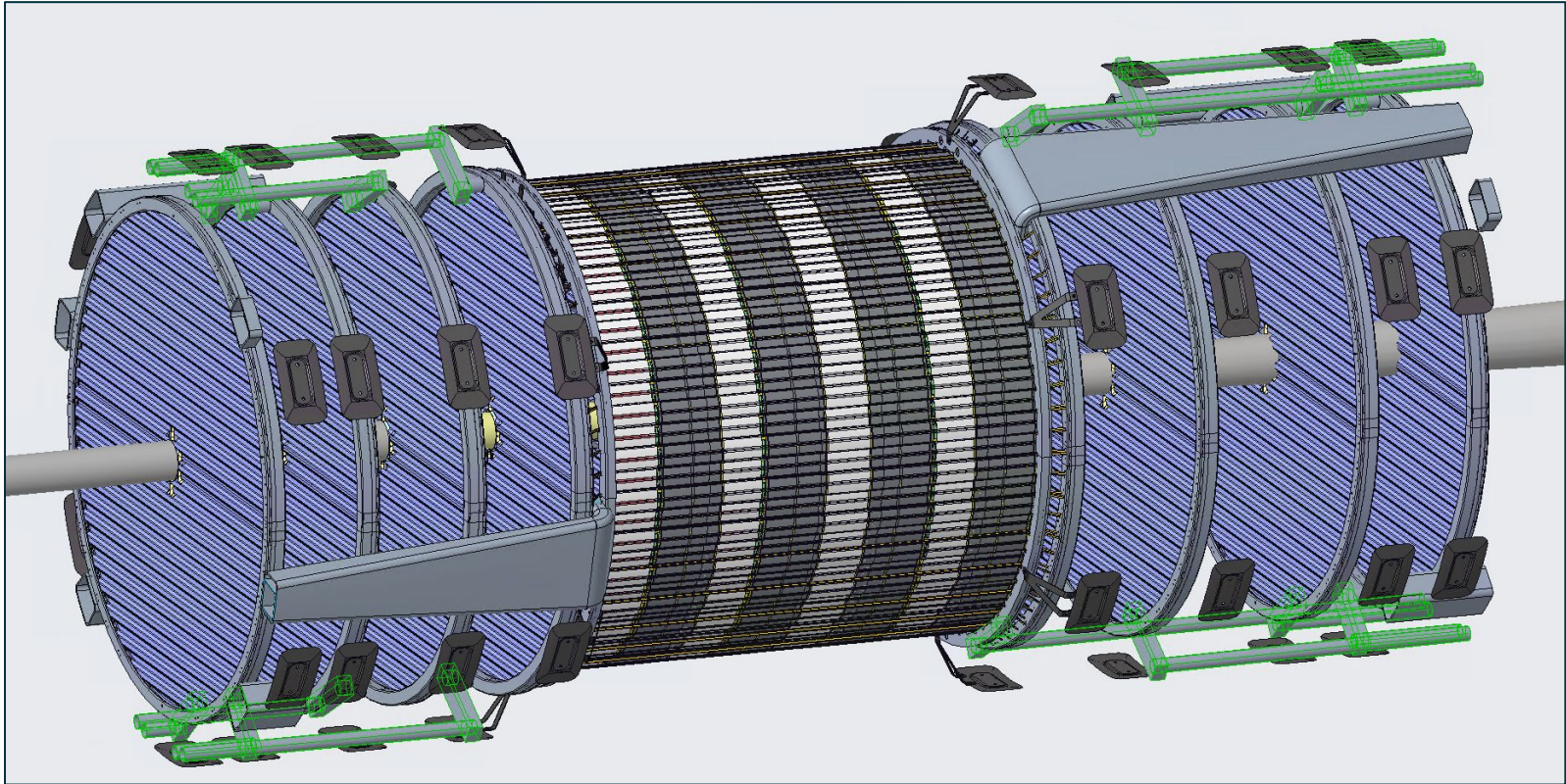


Operational logic

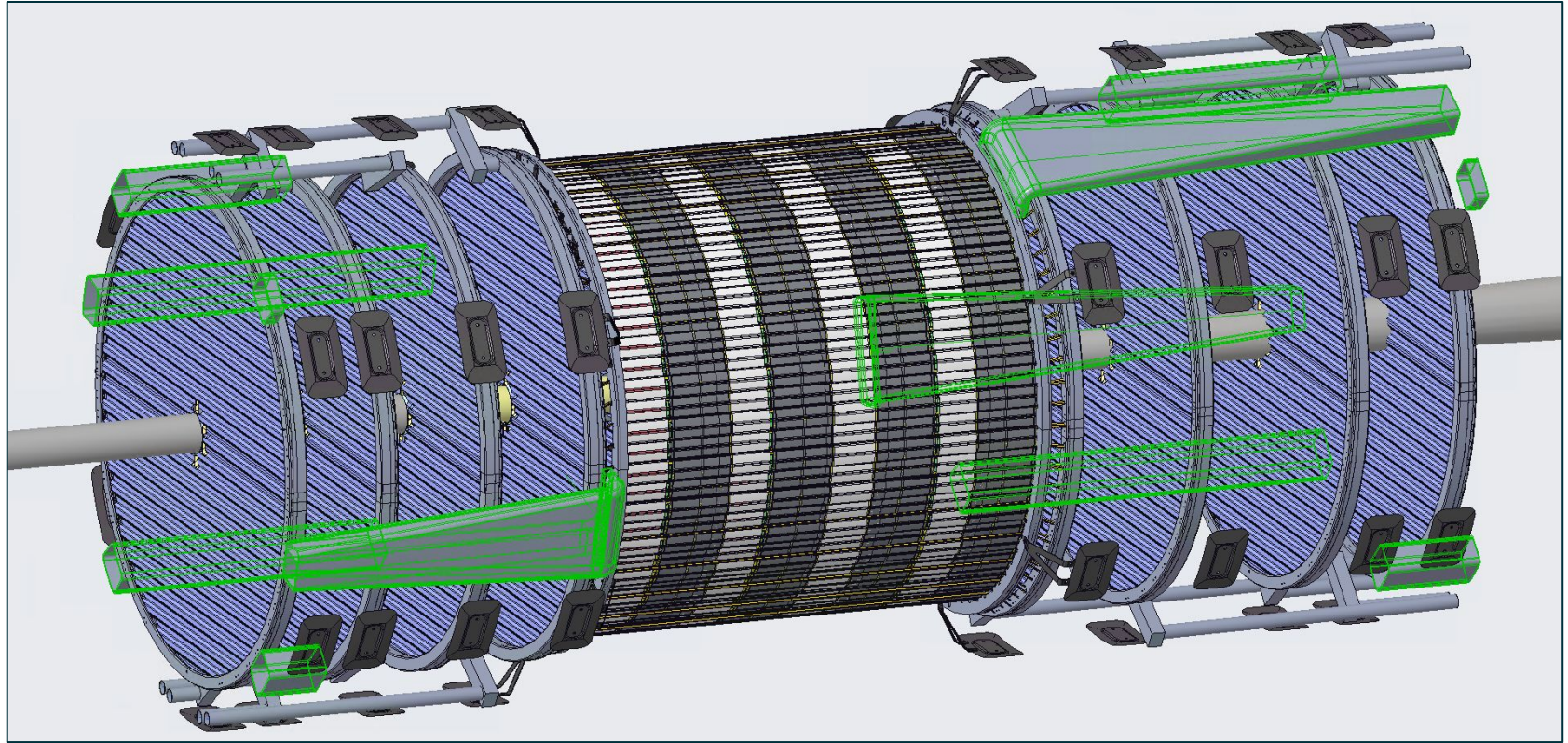
Detailed specs on cooling plant

ID	Category	Description	Name	Value (SI)	Units (SI)
00	process air	temperature - nominal	T_nom	3	°C
01	output air	temperature - adjustment range - min	T_min	-5	°C
02	output air	temperature - adjustment range - max	T_max	30	°C
03	output air	temperature - stability about setpoint	T_stability	±5	°C
04	output air	pressure dew point - max allowable	PDP_max_allow	-10	°C
05	output air	pressure dew point - stability	PDP_stability	±2	°C
06	output air	pressure dew point - setpoint adjustment	PDP_setpoint	0.44	bar (gauge)
07	output air	pressure - nominal	P_nom	0.15	bar (gauge)
08	output air	pressure - adjustment range - min	P_min	0.75	bar (gauge)
09	output air	pressure - adjustment range - max	P_max	+0.02	bar (gauge)
10	output air	pressure - stability about setpoint	P_stability	±0.02	bar (gauge)
11	output air	mass flow rate - nominal	m_nom	1.0	kg/s
12	output air	mass flow rate - adjustment range - min	m_min	±5	kg/s
13	output air	mass flow rate - adjustment range - max	m_max	±5	kg/s
14	output air	density - nominal	rho_nom	1.82	kg/m³
15	output air	density - adjustment range - min	rho_min	1.18	kg/m³

Air supply pipes



Air exhaust ducts



Air exhaust

- Exhaust via 12-14 ducts
- Duct hydraulic $\text{Ø}52 \text{ mm}$
 - I.e. much greater cross-section than input pipes (4 x $\text{Ø}50 \text{ mm}$)
- Ducts draw from interior volumes (see diagram)
- These volumes aren't "sealed" from each other, but significant impedance
- Suction could be done but probably not necessary
- Flapper valves at outlets to prevent ingress when flow off

ePIC SVT - interior air volumes diagram

Rev	Date	Author	Description
v1	2025-12-11	Joe Silber (LBNL)	initial release

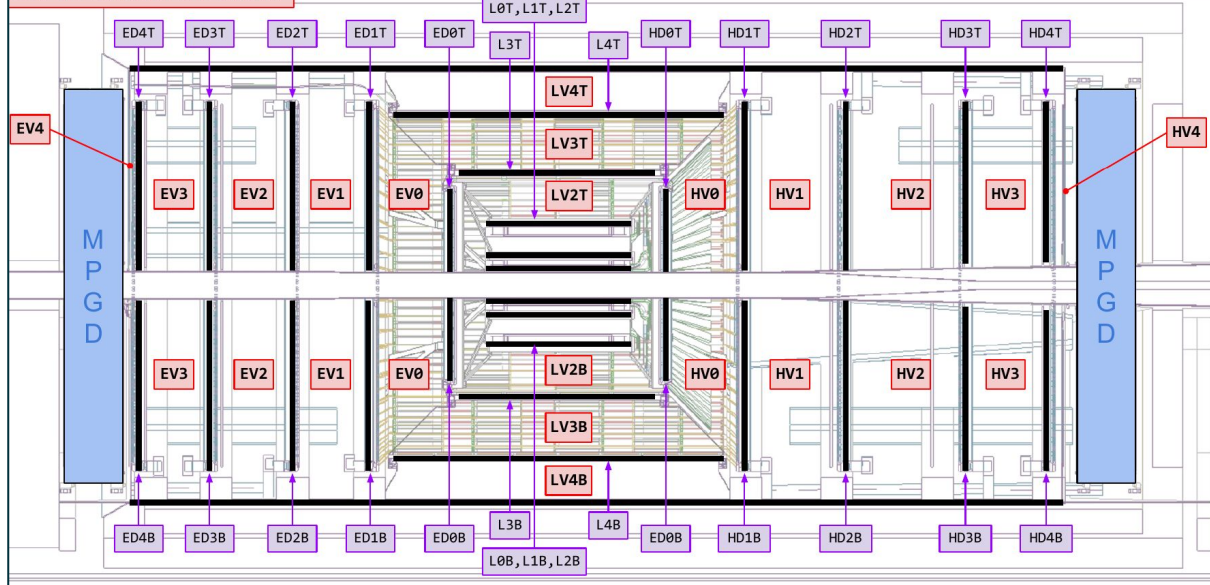
Notes

1.

References

1. [Live editable version of this document](#)
2. [ePIC SVT cooling system diagram](#)
3. [ePIC SVT cooling air flow stages](#)

ePIC SVT INTERIOR AIR VOLUMES



Link: [ePIC SVT interior air volumes diagram - v1.pdf](#)

ePIC SVT - cooling system diagram

Rev	Date	Author	Description
v1	2025-12-11	Joe Silber (LBNL)	initial release
v2	2025-12-12	Joe Silber (LBNL)	add liquid system
v3	2025-12-16	Joe Silber (LBNL)	space out e-/hadron & top/bottom

Nomenclature

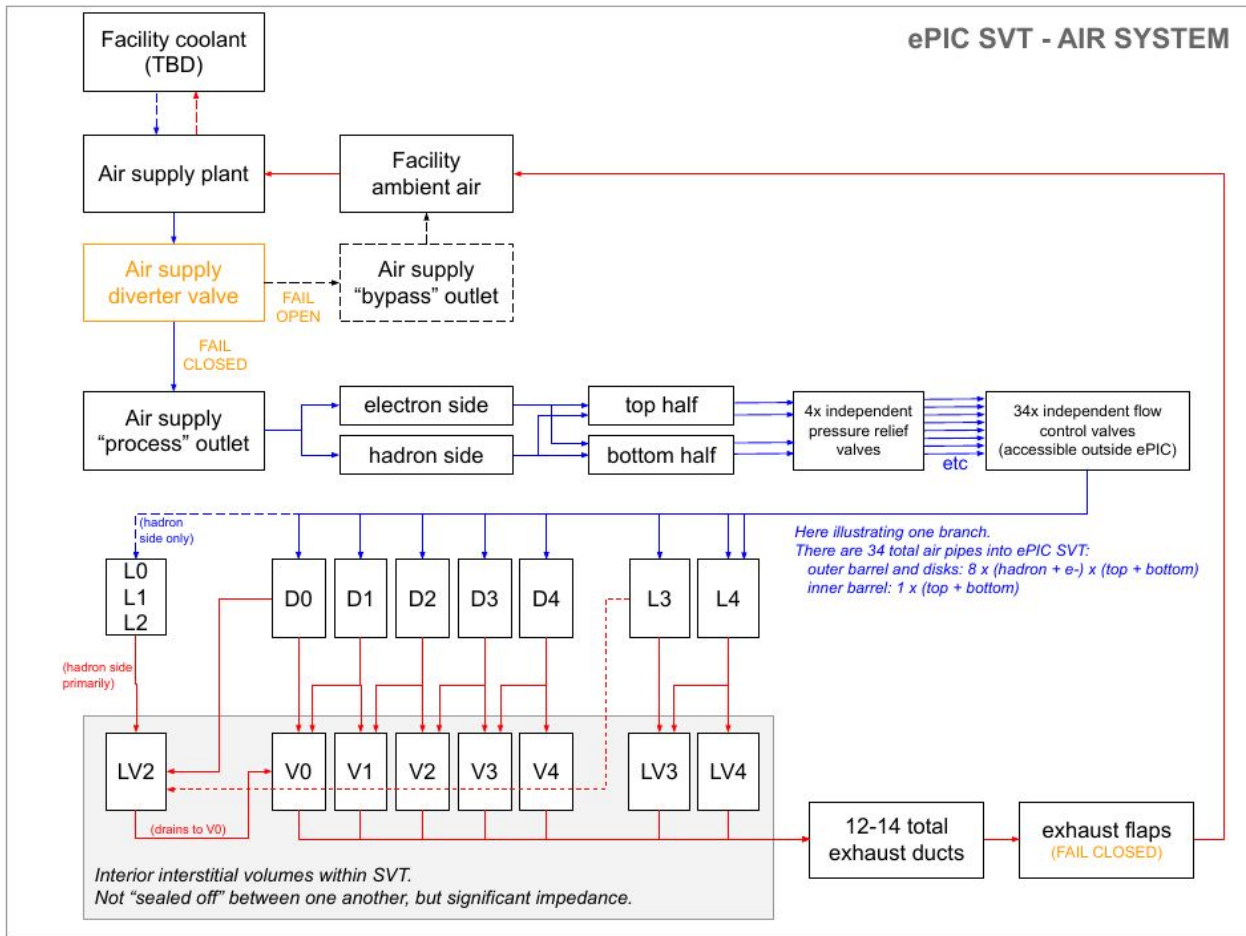
SVT ... Silicon Vertex Tracker
 TBD ... To Be Determined
 L# ... Barrel layer IDs
 D# ... Disk IDs
 V# ... Disk interstitial volume IDs
 LV# ... Barrel layer interstitial volume IDs
 SCB ... Segment Control Board
 CB ... Control Board

Notes

1. Graphical elements not intended to follow any standard.
2. Color-coding consistency not guaranteed.

Link:
[ePIC SVT cooling system diagram - v3.pdf](#)

ePIC SVT - AIR SYSTEM



Air quality strategy

- ISO 8573-1:2010 defines compressed air purity classes
- Supply air quality
 - solid particulate: Class 1
 - total oil: Class 1
 - water: \leq Class 3 (will come back to this later in talk)
- Air supply diverter valve
 - vent supply air to bypass outlet for startup, air quality test, etc
- Additional air filters at manifolds just outside ePIC
 - extra line of defense

CLASS	SOLID/DIRT Particle size			WATER @7 bar/100 psi Pressure Dewpoint		OIL Including vapor
	0.1-0.5 μm	0.5-1.0 μm	1.0-5.0 μm	$^{\circ}\text{C}$	$^{\circ}\text{F}$	mg/m^3
0	As specified by the equipment user or supplier					
1	$\leq 20\,000$	≤ 400	≤ 10	-70	-94	≤ 0.01
2	$\leq 400\,000$	$\leq 6\,000$	≤ 100	-40	-40	≤ 0.1
3	-	$\leq 90\,000$	$\leq 1\,000$	-20	-4	≤ 1
4	-	-	$\leq 10\,000$	+3	+38	≤ 5
5	-	-	$\leq 100\,000$	+7	+45	> 5
6	-	-	-	+10	+50	-

Table source: [Atlas Copco](#)

Also see slides from December 2025 working meeting at Oxford

[2025-12-18 - SVT Working Mtg - Cooling system and humidity - Silber - v1.pdf](#)

- More details on how the system calculator spreadsheet works
- Boundary conditions (flow rates, inlet temperature)
- Power load detail estimates
- Liquid cooling for CBs and SCBs
- Historical dewpoint data (STAR and sPHENIX halls)
- Insulation sizing calculation method for cold pipes outside the dry volume of SVT
- More details on humidity management strategy (interlocks, exhaust flapper valves, etc)

Also see recent rev of cooling system performance spreadsheet:

- [ePIC SVT cooling air flow stages - v19.xlsx](#)
- (note spreadsheet has iterative calc which may work best in Google sheets)

Cooling system performance baseline (Dec 2025, v15)

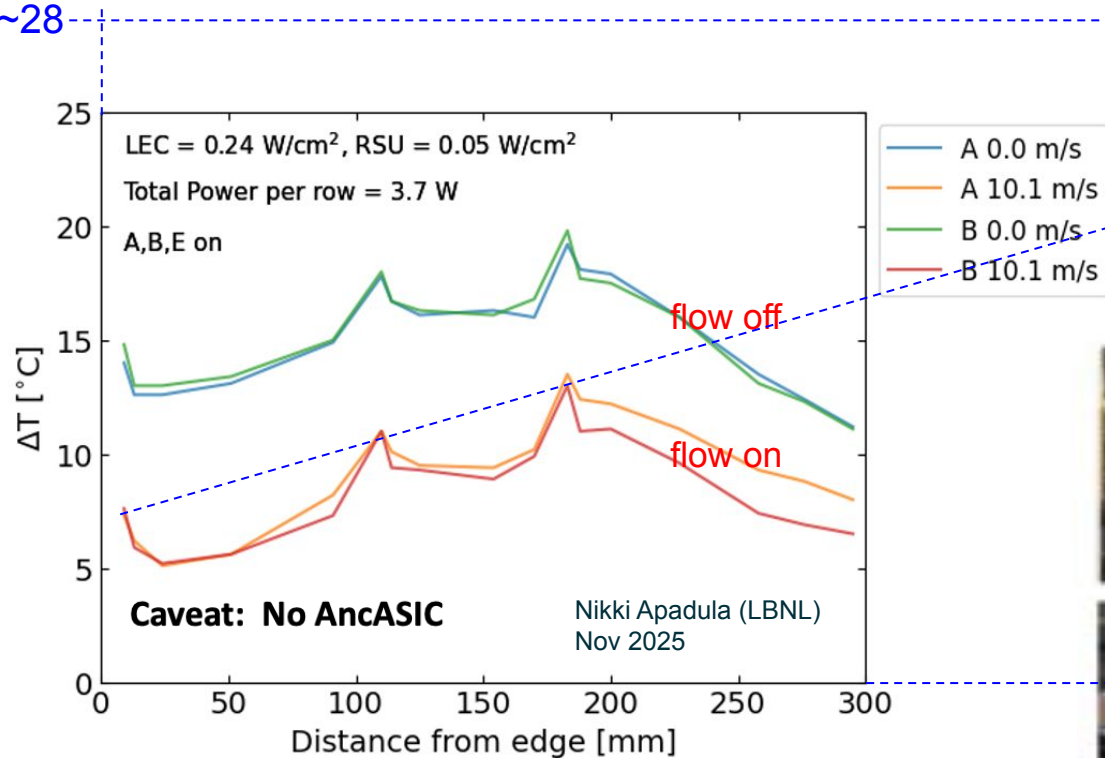
- source temperature = 2.8°C
- total mass flow = 0.95 kg/s
- total volume flow = 1135 cfm @ source pressure, 1604 cfm @ exhaust
- source pressure = 1.43 bar → 1.03 bar positive pressure @ exhaust
- channel/stave entrance temperature = 5.0°C
- channel/stave air speed = 10.0 m/s
- total power extracted = 8.9 kW
- SVT internal ambient temperature = 14.4°C

	A	B	C	D	E	F	G	H	I	J	K	L
				source → ePIC	branches to hadron + electron sides	branches to top + bottom halves	pipes into ePIC to half disks and half barrels	pipes within SVT to half disks and half barrels	manifold	disk channels and staves	SVT internal ambient volumes	exhaust ducts
150	stage description	-	-	0	1	2	3	4	5	6	7	8
151	stage index	-	-	1	2	2	3	1	1	22.2	0.0169	1
152	num channels (per parent channel)	n_i	-	1	2	4	32	32	32	710	12	12
153	total num channels in system	$N_i = \text{product}(n_i)$	m	1	2	4	32	32	32	710	12	12
154	mass flow per channel	$\dot{m} = (\dot{m}_s \text{ or previous stage } \dot{m}) / n_i$	kg/s	0.950	0.475	0.238	0.030	0.030	0.030	0.001	0.079	0.079
155	length	L	m	10.000	10.000	15.000	7.000	3.000	0.100	0.635	0.433	10.000
156	hydraulic diameter (mm)	D_mm	mm	100	75	50	23	23	23	11.5	713.8	61.6
158	single channel cross-sectional area along length L	$A_{12} = \pi D^2 / 4$	m ²	7.85E-03	4.42E-03	1.96E-03	4.15E-04	4.15E-04	4.15E-04	1.04E-04	4.00E-01	2.98E-03
160	all channels total cross-sectional area	$\Sigma A_{12} = A_{12,i} * N_i$	cm ²	78.5	88.4	78.5	133.0	133.0	133.0	739.6	48,024.7	357.6
162	entrance temperature	$T_1 = T_s \text{ or previous stage } T_s$	°C	2.8	3.2	2.4	3.9	3.7	3.5	5.0	14.4	14.2
164	entrance pressure	$P_1 = P_s \text{ or previous stage } P_s$	bar	1.427	1.390	1.325	1.178	1.084	1.040	1.044	1.043	1.039
167	Reynold's number	$Re = 4 \dot{m} / (\pi D \mu_i)$	-	6.99E+05	4.66E+05	3.50E+05	9.48E+04	9.48E+04	9.48E+04	8.50E+03	7.91E+03	9.18E+04
169	friction pressure drop (Darcy-Weisbach)	$\Delta P_{12} = -f * (L/D) * \dot{m}^2 / (2 \rho_i A_{12}^2)$	Pa	-4,438	-5,317	-17,025	-9,440	-4,394	-153	-114	0	-825
171	downstream pressure	$P_2 = P_1 + \Delta P_{12}$	bar	1.382	1.337	1.154	1.084	1.040	1.039	1.043	1.043	1.031
172	ambient pressure in the downstream area of this stage	P_local_ambient	bar	1.013	1.013	1.013	1.043	1.043	1.043	1.043	1.043	1.013
173	downstream pressure relative to local ambient	description(P ₂ - P_local_ambient)	-	positive	positive	positive	positive	approx neutral	approx neutral	approx neutral	approx neutral	positive
174	module power input to stream	$Q = Q_c * N_i \text{ if channel or stave else } 0$	W	0.0	0.0	0.0	0.0	0.0	0.0	8943.9	0.0	0.0
175	stream temperature rise due to external heat input	$\Delta T_{q12} = Q / (N_i * \dot{m} * c_p)$	K	0.0	0.0	0.0	0.0	0.0	0.0	9.4	0.0	0.0
181	downstream temperature	$T_2 = T_1 + \Delta T_{q12} + \Delta T_{k12}$	°C	2.7	3.0	1.6	3.7	3.5	3.5	14.3	14.4	14.2
185	average volumetric flow	$V_a = \dot{m} / \rho_a$	m ³ /s	0.536	0.276	0.151	0.021	0.022	0.023	0.001	0.063	0.063
187	total volumetric flow (all channels)	$\Sigma V_a = V_a * N_i$	m ³ /s	0.536	0.552	0.605	0.667	0.710	0.726	0.738	0.751	0.757
188	"	"	cfm	1134.9	1170.2	1282.8	1414.1	1505.3	1537.9	1564.8	1592.3	1603.5
189	average air speed	$u_a = V_a / A_{12}$	m/s	68.2	62.5	77.1	50.2	53.4	54.6	10.0	0.2	21.2
194	pressure ratio calculated with non-choked eqn	$\beta_{3n} = P_{3n} / P_2$	-	1.006	0.993	1.028	1.000	1.000	1.018	1.001	0.997	1.003
195	is choked?	$\beta_{3n} < \beta_x$	boolean	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
214	system energy balance error	$\dot{E}_{err} = (\dot{E}_2 - \Sigma Q_i) - \dot{E}_{1_stage0}$	W	-2	-4	-24	-26	-27	-27	-24	-24	-24
215	system energy balance error fraction (w.r.t. total energy)	$\dot{E}_{err_frac} = \dot{E}_{err} / \dot{E}_{1_stage0}$	-	-0.001%	-0.002%	-0.009%	-0.010%	-0.010%	-0.010%	-0.009%	-0.009%	-0.009%
216	system energy balance error fraction (w.r.t. total input power)	$\dot{E}_{err_frac} = \dot{E}_{err} / \Sigma Q_i$	-	-0.027%	-0.049%	-0.274%	-0.293%	-0.307%	-0.307%	-0.272%	-0.272%	-0.272%

Air flow rates through channels at the detectors

Lab tests on single corrugation with nominal vs max power with and without internal air flow

Extrapolated full-length max $\Delta T \approx 28^\circ\text{C}$



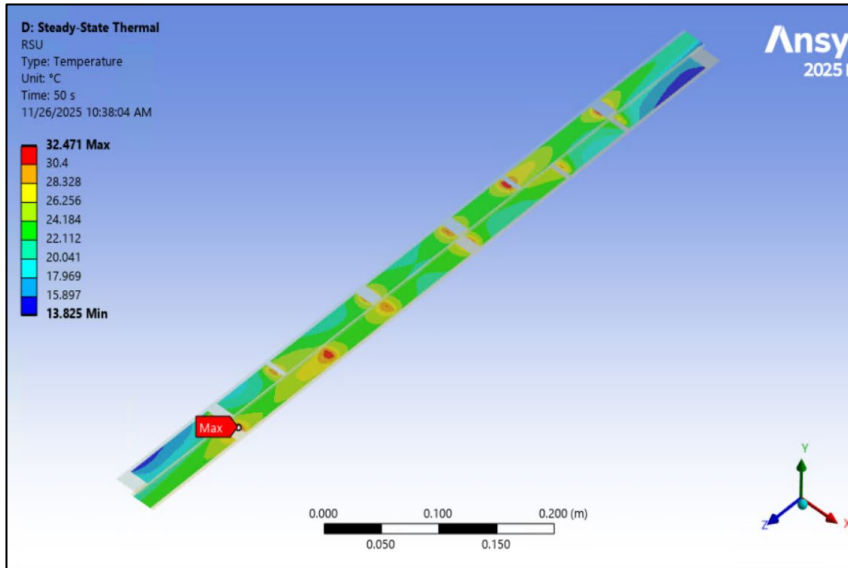
This test unit is 30% the length of an avg channel. Peak temps rise approximately linearly over the length.

~680 mm

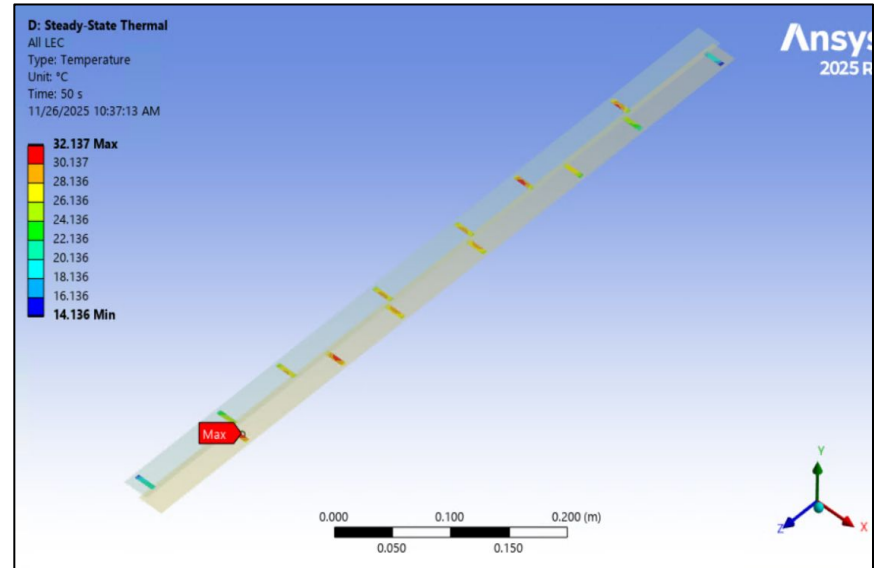
$T_{\max, \text{RSU}} = 40^\circ\text{C}$ is key limit on silicon temp. LECs conduct directly into RSUs.

CFD heat transfer study by Jaime Cruz-Duran (LBNL), Dec 2025

RSUs



AncASICs



Inlet air conditions selected for baseline: 5°C @ 10 m/s

Air temp setpoint at inlet:

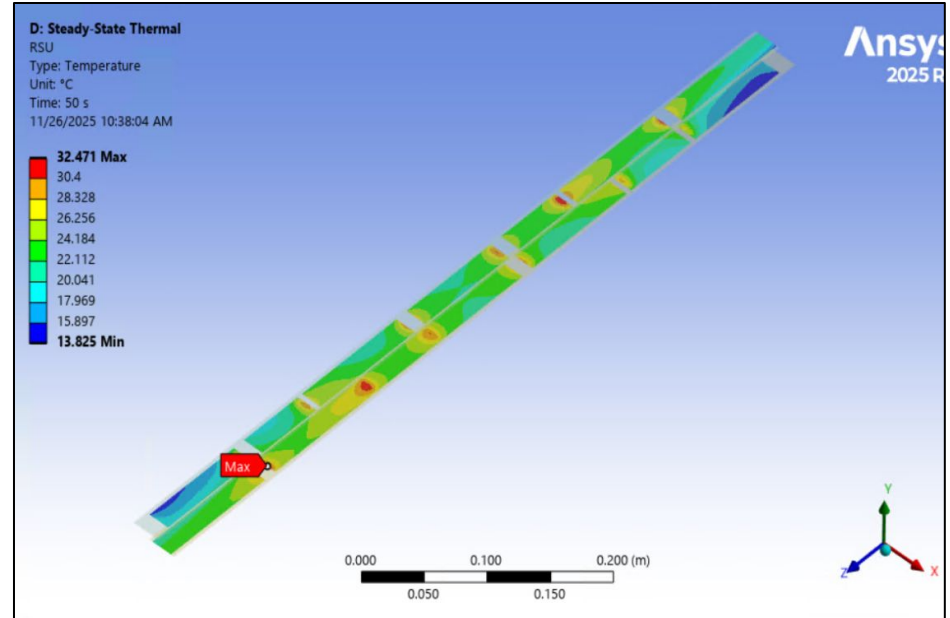
$$\Delta T_{\text{cooling}} = T_{\text{RSU}} - T_{\text{air}} = 27.5^\circ\text{C @ 10 m/s}$$

$$\begin{aligned} \text{margin} &= T_{\text{RSU, allowed}} - \Delta T_{\text{cooling, max}} - T_{\text{air}} \\ &= 40 - 27.5 - 5 = +7.5^\circ\text{C} \checkmark \end{aligned}$$

Gradient within module:

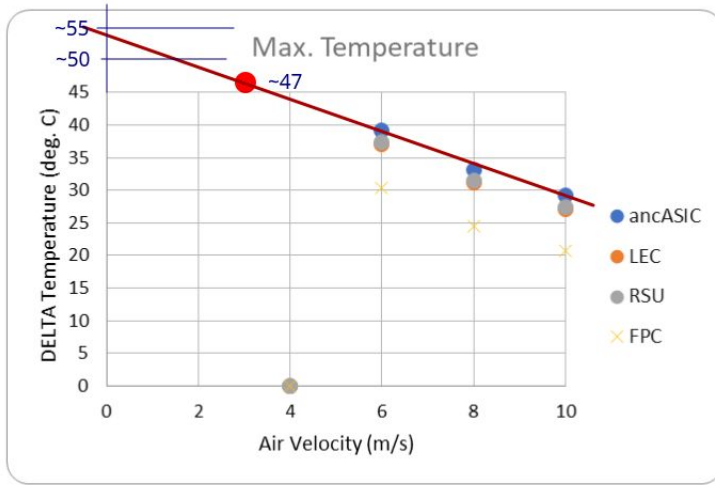
$$\nabla T \approx 32 - 22 = 10^\circ\text{C @ 10 m/s} \text{ !}$$

(Eyeballed from CFD plot. Right on edge of 10° req't. Physical test on sub-length unit had $\nabla T \sim 6^\circ$ within module, despite similar $\Delta T_{\text{cooling}}$. Suggests higher real-world in-plane conductivity than was assumed in model.)

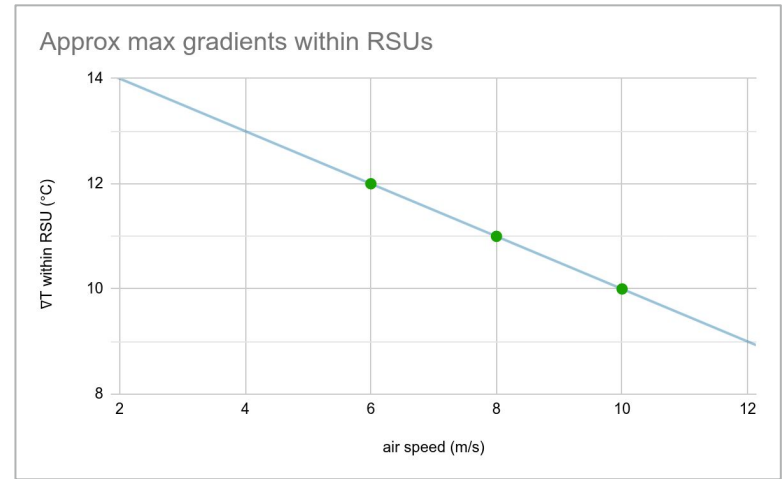


CFD heat transfer study by Jaime Cruz-Duran (LBNL), Dec 2025

Rough extrapolations of Cruz-Duran's Dec 2025 CFD study



Vertical axis is $\Delta T_{\text{cooling, max}} = T_{\text{Si, max}} - T_{\text{air, inlet}}$



Max gradient values here were eyeballed off FEA graphical plots.

Can we slow down the baseline ~20% to fit better within 1500 SCFM limit of some typical compressor models?

Air temp setpoint at inlet:

$$\Delta T_{\text{cooling}} = T_{\text{RSU}} - T_{\text{air}} \approx 34^{\circ}\text{C} @ 8 \text{ m/s}$$

$$\begin{aligned} \text{margin} &= T_{\text{RSU, allowed}} - \Delta T_{\text{cooling, max}} - T_{\text{air}} \\ &= 40 - 34 - 5 = +1.0^{\circ}\text{C} \checkmark \end{aligned}$$

Gradient within module:

$$\nabla T \approx 11^{\circ}\text{C} \text{ !}$$

(Eyeballed from CFD plot.)

System could look like:

- channel/stave entrance air temperature = 5.1°C
- channel/stave air speed = **8.1 m/s**
- source air temperature = 3.5°C
- total mass flow = 0.75 kg/s
- total volume flow = **1300 SCFM** (977 cfm @ source pressure)
- source pressure = 4.3 psig (0.30 barg)
- total power extracted = 8.9 kW
- SVT internal ambient temperature = 17.0°C

Could we shift flow regime to “Slow and cold”?

Air temp setpoint at inlet:

$$\Delta T_{\text{cooling}} = T_{\text{RSU}} - T_{\text{air}} \approx 47^{\circ}\text{C} @ 3 \text{ m/s}$$

$$\begin{aligned} \text{margin} &= T_{\text{RSU, allowed}} - \Delta T_{\text{cooling, max}} - T_{\text{air}} \\ &= 40 - 47 - (-10) = +3^{\circ}\text{C} \quad \checkmark \end{aligned}$$

Gradient within module:

$$\nabla T \approx 13^{\circ}\text{C} \quad \text{!}$$

(Eyeballed and scaled from CFD plot.)

System could look like:

- channel/stave entrance air temperature = **-10.1°C**
- channel/stave air speed = **3.0 m/s**
 - reduced mechanical excitation is a side benefit
- source air temperature = -12°C
 - extra insulation thickness required in non-dry service lanes
- total mass flow = 0.29 kg/s
- total volume flow = **502 SCFM** (424 cfm @ source pressure)
 - compressor system is 3-4X smaller and lower power
- source pressure = 1.1 psig (0.08 barg)
- total power extracted = 8.9 kW
- SVT internal ambient temperature = 19.0°C

Could we shift implementation from a compressor to a blower based system? (“Fast and warm”)

Air temp setpoint at inlet:

$$\Delta T_{\text{cooling}} = T_{\text{RSU}} - T_{\text{air}} = 27.5^{\circ}\text{C} @ 10 \text{ m/s}$$

$$\begin{aligned} \text{margin} &= T_{\text{RSU, allowed}} - \Delta T_{\text{cooling, max}} - T_{\text{air}} \\ &= 40 - 27.5 - 9.2 = +3.3^{\circ}\text{C} \checkmark \end{aligned}$$

Gradient within module:

$$\nabla T \approx 10^{\circ}\text{C} @ 10 \text{ m/s} \text{!}$$

(Eyeballed from CFD plot.)

System could look like:

- channel/stave entrance air temperature = **9.2°C**
- channel/stave air speed = 10.0 m/s
- source air temperature = 7.0°C
 - min temperature throughout system = 6.7°
 - this is comfortably above refrigeration dryer dewpoint @ 3°
- total mass flow = 0.92 kg/s
- total volume flow = 1594 SCFM (1130 cfm @ source pressure)
 - blower can be spec'd for lots of extra capacity and still be efficient at turned-down speeds
- source pressure = 5.7 psig (0.40 barg)
- total power extracted = 8.9 kW
- SVT internal ambient temperature = 18.9°C

Air supply plant

System calcs + humidity management + air quality + control considerations → detailed specs on air supply plant

	A	B	C	D	E	F	G	H	I	
1	ePIC SVT Air Supply Plant - Requirements									
2	Contact									
3		Joe Silber -jsilber@lbl.gov-				Color Key:				
4		Lawrence Berkeley National Laboratory			LINKED					
5	Version history									
6		v1 - 2025-11-11 - JMS - Initial version								
7		v2 - 2025-11-19 - JMS - wider T_stability, diverter, moisture in terms of DPs, possible enclosure, add'l comments								
8		v3 - 2026-03-19 - JMS - state volumetric flow in SCFM								
9	Abstract									
10	The Silicon Vertex Tracker (SVT) is a key subsystem of the Electron-Proton/Ion Collider (ePIC) detector. It will probe the smallest internal building blocks of visible matter -- quarks and gluons -- and help us understand the underlying laws that govern the strongest force in nature.									
11	The SVT is composed of thousands of custom silicon sensors. They will be cooled by a steady supply of cleaned, conditioned, cooled air. This specification is for the plant which will generate that cooling air. This specification does not include the transmission of that air to the SVT.									
12										
13										
14										
15										
16	ID	Category	Description	Name	Value (SI)	Units (SI)	Value (US)	Units (US)	Comments	
17	00	process air	temperature - nominal	T_nom	10	°C	37.4	°F	Possible future relaxation of T_nom to +12°C (TBD)	
18	01	output air	temperature - adjustment range - min	T_min	-5	°C	23.0	°F	Possible future relaxation of T_min to +7°C (TBD)	
19	02	output air	temperature - adjustment range - max	T_max	30	°C	86.0	°F		
20	03	output air	temperature - stability about setpoint	T_stability	±2	°C	±3.6	°F		
21	04	output air	pressure dew point - max allowable	PDP_max_allow	-10	°C	14.0	°F	Pressure dew point shall never exceed this value when output stream is flowing through the process outlet. Possible future relaxation of PDP_max_allow to +3°C (TBD).	
22	05	output air	pressure dew point - stability	PDP_stability	±2	°C	±3.6	°F		
23	06	output air	pressure dew point - setpoint adjustment	PDP_setpoint	Pressure dew point shall be settable within a range defined by the AQ_water class (at low end) to PDP_max_allow (at high end).					
24	07	output air	pressure - nominal	P_nom	0.44	bar (gauge)	6.4	psi (gauge)		
25	08	output air	pressure - adjustment range - min	P_min	0.05	bar (gauge)	0.4	psi (gauge)		
26	09	output air	pressure - adjustment range - max	P_max	0.75	bar (gauge)	10.9	psi (gauge)		
27	10	output air	pressure - stability about setpoint	P_stability	±0.02	bar (gauge)	±0.29	psi (gauge)		
28	11	output air	mass flow rate - nominal	m_nom	1.0	kg/s	132	lbm/min		
29	12	output air	mass flow rate - adjustment range - min	m_min	0.1	kg/s	13	lbm/min		
30	13	output air	mass flow rate - adjustment range - max	m_max	1.3	kg/s	198	lbm/min		
31	14	output air	volumetric flow rate - nominal	V_nom	2941	Sm ³ /hr	1731	SCFM	stated at standard air conditions, not at true air density of plant output	
32	15	output air	volumetric flow rate - min	V_min	294	Sm ³ /hr	173	SCFM	stated at standard air conditions, not at true air density of plant output	
33	16	output air	volumetric flow rate - max	V_max	4412	Sm ³ /hr	2597	SCFM	stated at standard air conditions, not at true air density of plant output	
34	17	output air	air quality - solid particulate	AQ_particulates	Class 3	per ISO 8573-1:2010			Oil-free compression or high-end filtration is critical to prevent oil contamination	
35	18	output air	air quality - total oil	AQ_oil	Class 1	per ISO 8573-1:2010			Class 2 PDP = -40°C, Class 3 = -20°C, might consider Class 4 (PDP=>+3°C) if significant cost savings and if T_min could be increased to +10°C (TBD)	
36	19	output air	air quality - humidity / water	AQ_water	Class 3	per ISO 8573-1:2010				

	A	B	C	D	E	F	G	H	I	
37		20	output air	output diverter	diverter_valve				Plant shall have an integrated 5-way diverter valve on the output stream. Outlets are to "process" (goes to SVT instrument) and "bypass" (exhaust). Fail safe state (e.g. upon loss of power) shall be to the bypass outlet.	
38	21	facility	hose inner diameter - process air	Dh_process	100	mm	4	in	Connects to the SVT	
39	22	facility	hose inner diameter - bypass air	Dh_bypass	TBD	mm			Connects to facility exhaust	
40	23	facility	hose fitting type - process air	fitting_process	TBD	-	-	-		
41	24	facility	hose fitting type - bypass air	fitting_bypass	TBD	-	-	-		
42	25	facility	electrical - plug form	e_plug	TBD	-	-	-		
43	26	facility	supply voltage	V_supply	TBD	-	-	-		
44	27	facility	supply frequency	f_supply	60	Hz	-	-		
45	28	facility	heat rejection - coolant	coolant	TBD	-	-	-		
46	29	facility	heat rejection - coolant temperature	Tc	TBD	°C		K		
47	30	facility	heat rejection - coolant flow rate limit	Vc	TBD	L/min		?		
48	31	facility	heat rejection - coolant pressure	Pc	TBD	?		?		
49	32	environment	ambient temperature during operation - avg	T_amb_avg	23	°C		73.4	°F	Based on 15 year STAR WAH data 99.73% (3σ) envelope
50	33	environment	ambient temperature during operation - min	T_amb_min	18	°C		64.4	°F	Based on 15 year STAR WAH data 99.73% (3σ) envelope
51	34	environment	ambient temperature during operation - max	T_amb_max	32	°C		89.6	°F	Based on 15 year STAR WAH data 99.73% (3σ) envelope
52	35	environment	ambient dewpoint during operation - avg	DP_amb_avg	5.2	°C		41.4	°F	Based on 15 year STAR WAH data 99.994% (4σ) envelope
53	36	environment	ambient dewpoint during operation - max	DP_amb_max	22	°C		71.8	°F	Based on 15 year STAR WAH data 99.994% (4σ) envelope
54									System shall have a process fault condition based on measured state of the output air. The state is logically TRUE when any of the key parameters (temperature, pressure, or pressure dew point) falls outside either its user configured allowable range or the limit values listed here (whichever is more restrictive).	
55	37	control	fault condition on process air	process_fault					System shall automatically direct output air to the bypass outlet during startups, shutdowns, or process fault state.	
56	38	control	output diverter control	diverter_ctrl					Plant shall have a local user interface panel by which it can be operated.	
57	39	control	control interface - local	ctrl_local					Plant shall have an API allowing customer to integrate it into our facility's control system for configuring, monitoring, and real time control.	
58	40	control	control interface - remote	ctrl_remote					Emergency shut-off shall be readily achievable by pressing an easily identifiable hardware button, by any person physically stationed near the plant.	
59	41	control	emergency shut-off - local	shutoff_local					Emergency shut-off shall be readily achievable by a simple electrical interlock signal.	
60	42	control	emergency shut-off - remote	shutoff_remote						
61	43	maintenance	uptime during normal operations	uptime	99.0	%				
62	44	package	max width	W_max	TBD	m		TBD	in	
63	45	package	max length	L_max	TBD	m		TBD	in	
64	46	package	max height	H_max	TBD	m		TBD	in	
65	47	package	max weight	M_max	TBD	kg		TBD	lbm	
66	48	package	enclosure	enclosure					TBD; possibly enclose loud components (e.g. compressor) for moderate sound dampening	

Link: [ePIC SVT air supply plant reqts - v3.xlsx](#)

Compressors vs blowers

Key takeaways from numerous discussions with vendors during Dec 2025 - May 2026

Compressors

- Provide sufficient pressure to drive air through desiccant (adsorption) dryers that achieve -40°C dewpoint (Class 2)
- Require large storage tank (~ 1 gallon storage per SCFM of system flow)
- Large ones will provide ~ 1500 SCFM of flow, need more than one compressor in parallel to get more
- Power consumption ~ 20 kW / 100 SCFM
 - i.e. 320 kW @ SVT's nom 1600 SCFM
- ~ 100 psi gauge, which must be regulated down to SVT's nominal 6 psi

Blowers

- Refrigerated drying only, will achieve $+3^{\circ}\text{C}$ dewpoint (Class 4)
- More compact system
- Very high flow rates available
- Power consumption ~ 5 kW / 100 SCFM
 - i.e. 80 kW @ SVT's nom 1600 SCFM
- ~ 10 -20 psi gauge, depending on model

N.B. Either option requires an after cooler to bring the air to desired temperature.

The after cooler itself requires cooling, on the order of 30-40 kW, probably by facility water.

Rough dimensions for a 2000 SCFM compressor (~100 psig) system, such as for baseline design

Item	Example model	Length (m)	Width (m)	Height (m)
compressor (qty 2)	Atlas Copco ZR 160	5.6	1.6	2.0
receiver tank	2000-Gallon Vertical Tank	1.5	1.5	4.5
desiccant dryer	Atlas Copco BD 2600+	2.4	1.6	3.2
heat exchanger	API Heat Transfer Basco Type 500	1.8	0.5	0.5
chiller	MTA TAEevo Tech 302	2.3	0.9	1.6
filtration (pre & post)	Atlas Copco DD & PD 2600	1.0	0.5	1.2
Overall footprint ~ 96 m ² (1056 ft ²)		14.6 m (48')	6.6 m (22')	4.5 m (15')

Rough dimensions for a 1500 SCFM compressor (~100 psig) system, i.e. for ~80% less flow than baseline

Item	Example model	Length (m)	Width (m)	Height (m)
compressor	Atlas Copco ZR 250	3.4	1.6	2.0
receiver tank	1500-Gallon Vertical Tank	1.4	1.4	4.2
desiccant dryer	Atlas Copco BD 1800+	2.2	1.4	3.0
heat exchanger	API Heat Transfer Basco Type 500	1.5	0.4	0.4
chiller	MTA TAEevo Tech 251	2.0	0.8	1.5
filtration (pre & post)	Atlas Copco DD & PD 1750	0.8	0.4	1.0
Overall footprint ~ 68 m ² (740 ft ²)		11.3 m (37')	6.0 m (20')	4.2 m (14')

Rough dimensions for a 600-700 SCFM compressor (~100 psig) system, i.e. the “cold and slow” case

Item	Example model	Length (m)	Width (m)	Height (m)
compressor	Atlas Copco ZR 110	2.5	1.3	2.0
receiver tank	600-Gallon Vertical Tank	1.0	1.0	3.0
desiccant dryer	Atlas Copco BD 850+	1.6	1.1	2.4
heat exchanger	API Heat Transfer Basco Type 500	1.2	0.3	0.3
chiller	MTA TAEvo Tech 161 (Low Temp)	1.5	0.7	1.4
filtration (pre & post)	Atlas Copco DD & PD 850	0.6	0.3	0.8
Overall footprint ~ 40 m ² (420 ft ²)		8.4 m (28')	4.7 m (15')	3.0 m (10')

Rough dimensions for a 1500 - 2500 SCFM *blower* (~10 psig) system, i.e. the “warm and fast” case

Item	Example model	Length (m)	Width (m)	Height (m)
blower	Robuschi Robox Screw 3.5	2.1	1.6	2.0
refrigeration dryer	Atlas Copco FD 4000 VSD	2.9	1.2	2.0
heat exchanger	API Heat Transfer Basco Type 500	1.8	0.5	0.5
chiller	MTA TAEevo Tech 302	2.3	0.9	1.6
filter	Atlas Copco DDp 3200	0.6	0.6	1.3
Overall footprint ~ 47 m ² (512 ft ²)		9.7 m (32')	4.8 m (16')	2.0 m (7')

Summary: four basic implementation options for air supply

		Dec 2025 baseline	“80% of baseline”	“Slow & cold”	“Fast & warm”
Design targets	air speed thru detector channel	10 m/s	8 m/s	3 m/s	10 m/s
	air temp at channel inlet	+5°C	+5°C	-10°C	+9°C
Air supply nominals*	pressure	6 psig	4 psig	1 psig	6 psig
	flow rate	1600 SCFM	1300 SCFM	500 SCFM	1600 SCFM
	dewpoint	-40°C	-40°C	-40°C	+3°C
	air temp at supply	+3°C	+3°C	-12°C	+7°C
Source		double large compressor	single large compressor	single small compressor	blower
Approx system power draw		400 kW	300 kW	150 kW	150-200 kW
Rough size estimate	footprint	1056 ft ²	740 ft ²	420 ft ²	512 ft ²
	height	15 ft	14 ft	10 ft	7 ft
Comments		generous operating margins	tighter margins on ΔT & ∇T , low T available	higher ∇T , more insulation, less vibration	narrower T oper range (limited by dewpoint)

* Real supply plant will require margin on these nominal values.

Backup

Can the specific requirements on detector temperatures be memorialized into central location?

- Is the JLab site (<https://eic.jlab.org/Detector/>) the right place?
- Or is it perhaps preferable to treat these more as implementation specifications, which the SVT group should internally manage?

“Warm & fast” case → We would probably use a rotary screw blower



	A	B	C	D
1	Feature	Lobe Blower (Roots)	Rotary Screw Blower	High-Speed Turbo Blower
2	Compression Method	Positive Displacement (External compression)	Positive Displacement (Internal compression)	Dynamic / Kinetic (Aerodynamic)
3	Temperature Control	Aftercooler. Can build into skid.	Aftercooler. Can build into skid.	Aftercooler. Can build into skid.
4	Efficiency at 10 PSI	Poor: Air "slip" past rotors wastes energy.	Good: Internal compression can match the 10 psi requirement.	Excellent: But only near its peak design flow.
5	Flow Control (Turndown)	Excellent: VFD can ramp down to 25% of max flow.	Excellent: VFD can ramp down to 25% of max flow.	Limited: Can ramp down to 50-60% of max flow.
6	Air Purity	ISO Class 0: Oil in end sumps, but mechanically sealed from air stream.	ISO Class 0: Oil in gear casing, but mechanically sealed from air stream.	100% Oil-Free. Uses air or magnetic bearings.
7	Noise Level	Loudest: Severe acoustic pulsations.	Quiet: High-frequency noise easily muffled by standard acoustic enclosures.	Quietest: No mechanical friction or rubbing parts.
8	Footprint / Packaging	Largest: Requires massive, bulky inlet and discharge silencers to manage noise.	Compact: Sold as "plug-and-play" enclosed skids (motor, VFD, blower in one box).	Most compact: Motor and impeller are a single, highly integrated unit.
9	Discharge Temperature	High: $\Delta T \sim 70-100^{\circ}\text{C}$	Moderate: $\Delta T \sim 40-70^{\circ}\text{C}$	Lowest: $\Delta T \sim 30-60^{\circ}\text{C}$
10	Capital cost	Lowest	Medium	Highest
11	Operating cost	Highest (most power, oil changes req'd)	Medium (low power, oil changes req'd)	Lowest (low power, oil-free)

IMPORTANT!

