How to reduce cooling duties in CLIC

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CLIC Workshop 2014 - 4th February 2014

Outline

- ✓ Original design
  - ✓ Principles
  - ✓ Constraints
  - ✓ Open issues
- ✓ Possible optimizations on cooling
  - ✓ Variation on temperature at exit of cooling towers
  - ✓ Location of cooling towers
  - ✓ Variation of temperature range
  - ✓ Water treatment
- ✓ Conclusions

Aknowledgements: G Peon

Preamble (or disclaimer?)

This presentation is rather qualitative than quantitative and does not have the objective of covering all possible options. Figures shown are either calculated, or deducted using some scaling parameter.

Examples are on cooling systems for the main tunnel.

The objective is to launch the discussion on some possible changes and see whether they are acceptable for CLIC or not.

Then, specific cases might be studied in more detail.

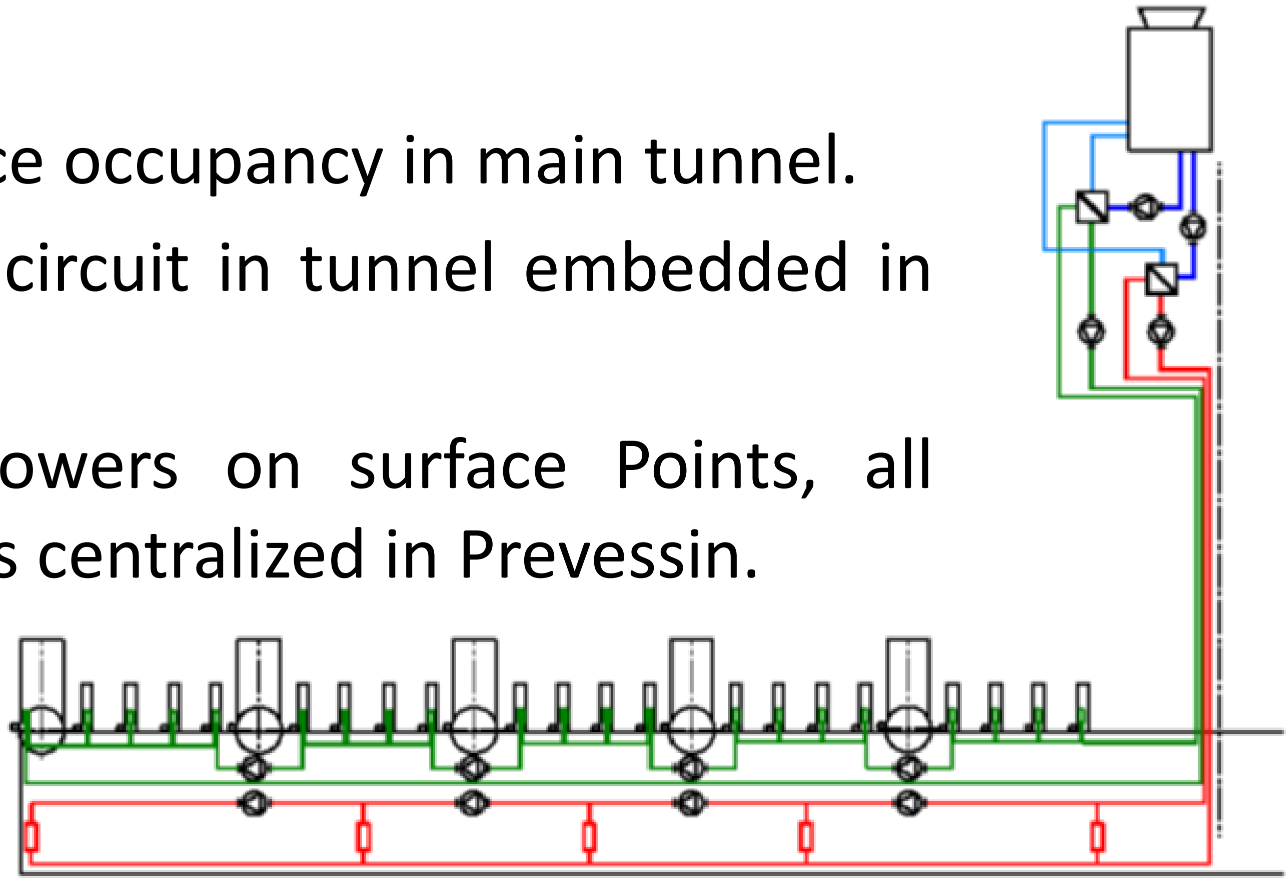
Original design: general principles

- ✓ CLIC facilities have been divided into 5 major cooling sectors according to:
  - Functional and operational requirements
  - Thermal loads
  - Dimensions, geographical distribution:
    - Facilities *(Drive beam injector building)*
    - HVAC and cooling plants *(keep reasonable size)*
    - Environmental impact *(no cooling towers on surface Points)*
- ✓ Further (sub)separation possible during detailed design.

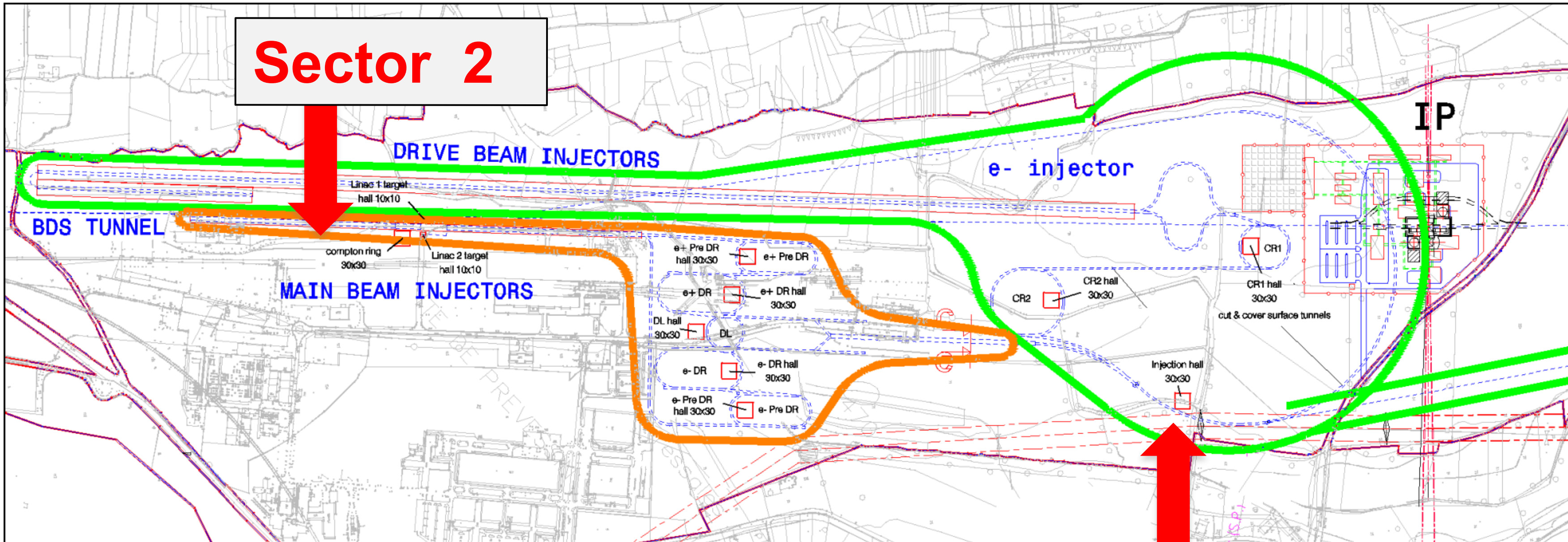
Ref: M Nonis - CLIC Cost & Schedule WG – 24.2.2011

Design principles: constraints

- ✓ Distribution loads between air and water: 10% -90%
- ✓ Minimize space occupancy in main tunnel.
- ✓ Main cooling circuit in tunnel embedded in concrete.
- ✓ No cooling towers on surface Points, all cooling towers centralized in Prevessin.

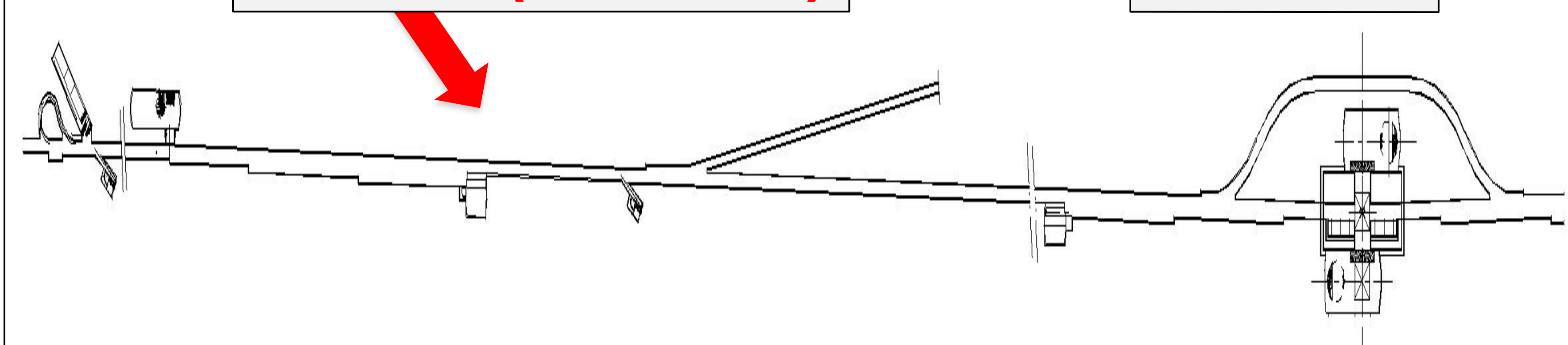


Cooling: sectors 1, 2 & 5

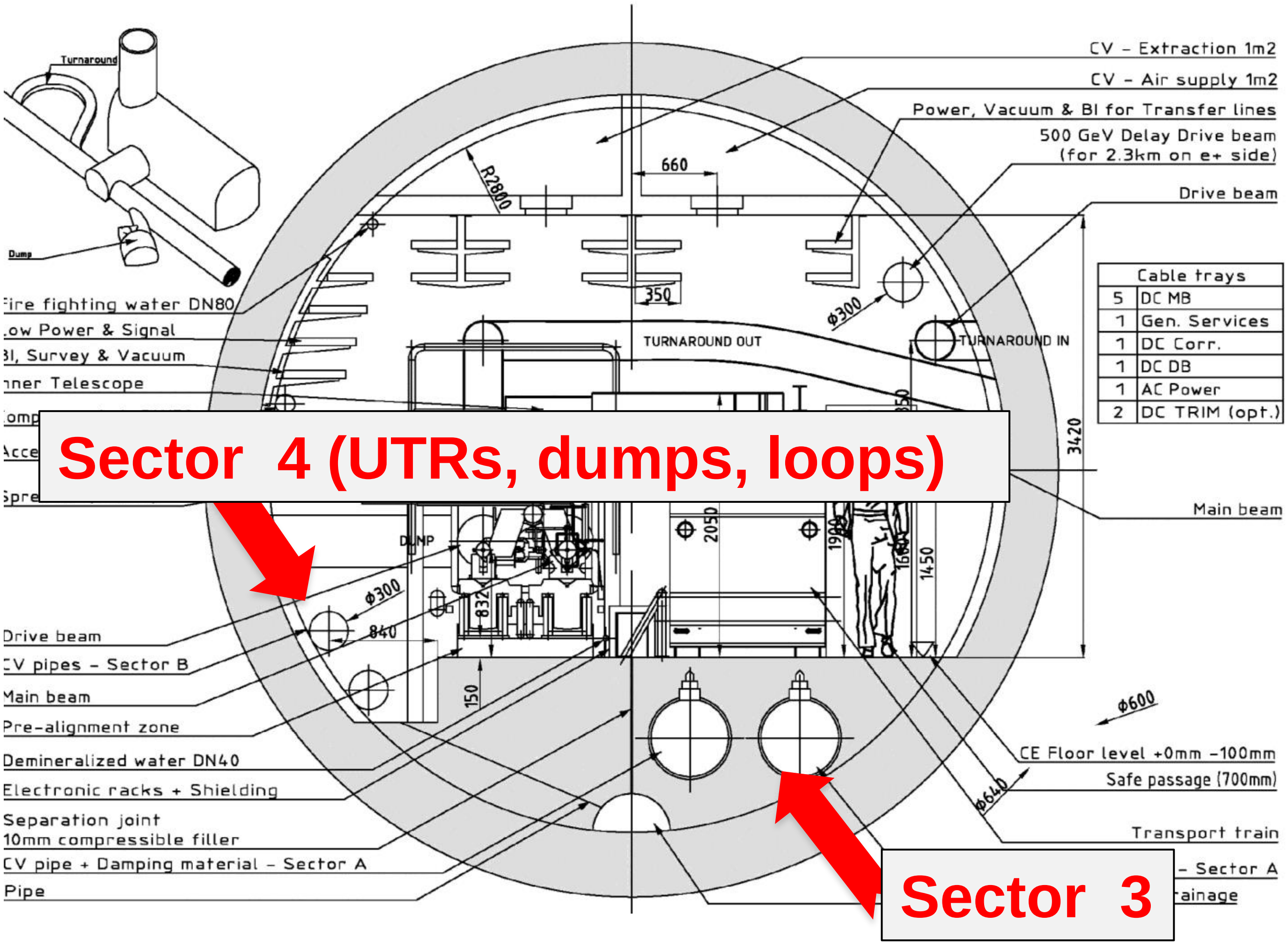


Sector 5 (both sides)

Sector 1



Cooling: sectors 3 & 4



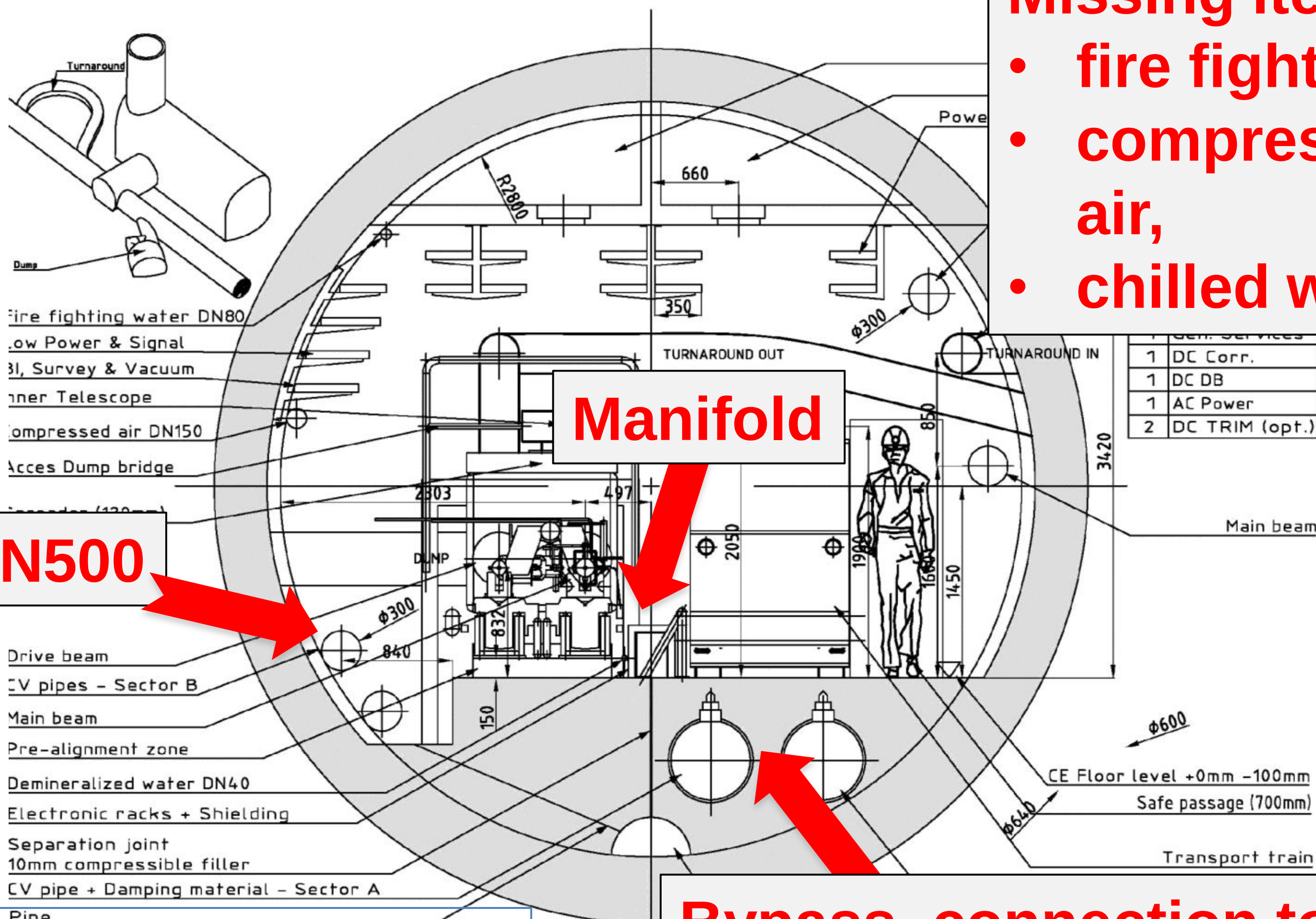
Cooling open issues

- ✓ Available space in tunnel for main pipes/ducts and equipment:
  - Booster pumps location;
  - Bypass valves, manifolds *(available space, balancing of circuit)*;
  - Connection to drains.
- ✓ Available space in shafts.
- ✓ Optimising location of primary stations wrt shafts availability.

Ref: M Nonis - CLIC Cost & Schedule WG – 24.2.2011

Cross section cooling major issues

Missing items:
- **fire fighting,**
- **compressed air,**
- **chilled water**



Manifold

DN500

Bypass, connection to drain

Ref: M Nonis - CLIC Cost & Schedule WG – 24.2.2011

Main cooling parameters

Total cooling power [MW]	490.6
Circuit 1	*156.9*
Circuit 2	*47.3*
Circuit 3	*147.2*
Circuit 4	*66.0*
Circuit 5	*73.2*
Total flow rate [m^3/h]	22’274
Temperature difference [K]	20
Make up water (design value) [m^3/h]	940*

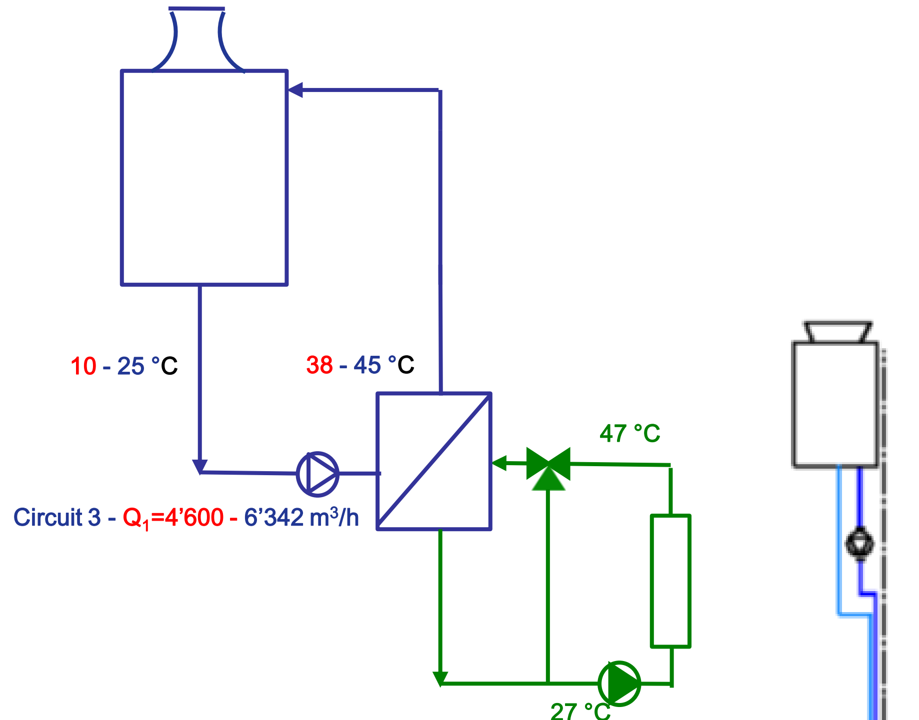
* Average water consumption at CERN: 750 m^3/h

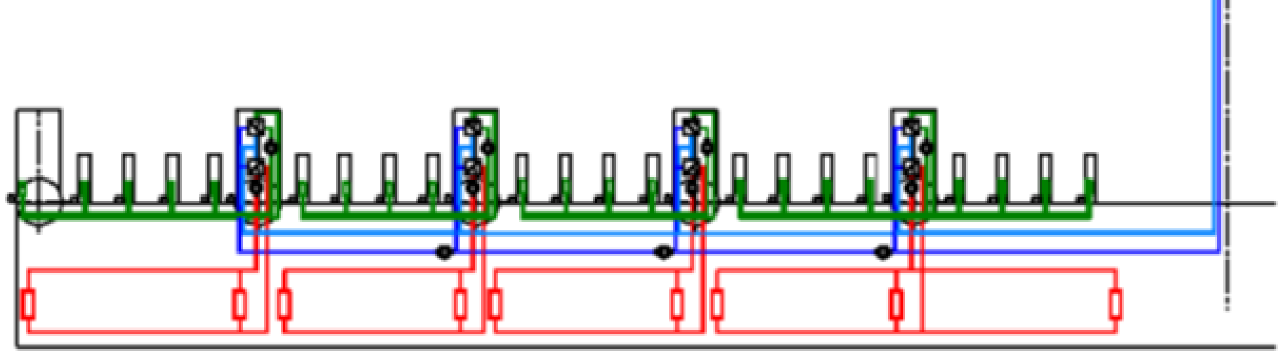
Possible optimisations in cooling

1. What can be done differently to improve operation cost or pending issues?
2. At which cost or drawback?
3. What do we gain?

1. Variation T out from cooling towers

- ✓ Follow wet bulb temperature variation through the day/months to reduce water temperature at exit of cooling towers, therefore reduce the flow rate needed on primary circuit.
- ✓ Extend the primary circuit to UTRC
- ✓ Regulate temperature of secondary circuit via a 3-way valve.
- ✓ Optimum working point does not coincide with the lowest possible approach
- ✓ Regulation on temperature more difficult





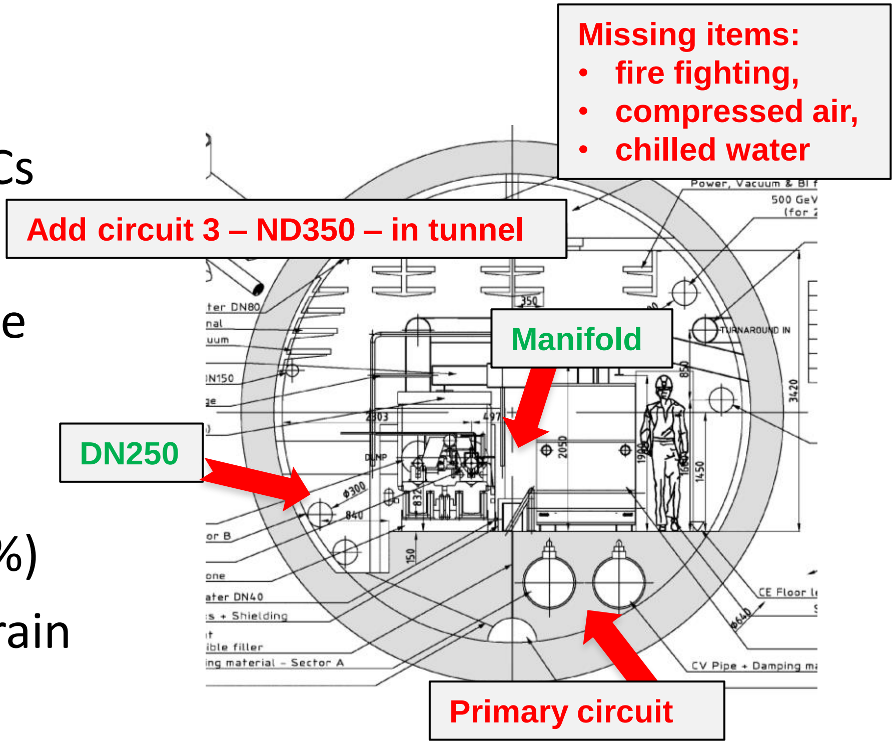
1. Variation T out from cooling towers

✓ Cons:

- Creation of cooling station in the UTRCs
- Complexity in operation
- Additional pipes (primary circuit) in the main tunnel

✓ Prons

- Lower electrical power requested (15%)
- Bypass and manifold, connection to drain simplified
- Primary circuit combined with fire fighting network (tbc)



2. Modify location of cooling towers

Group circuits in different way….each station closer to user

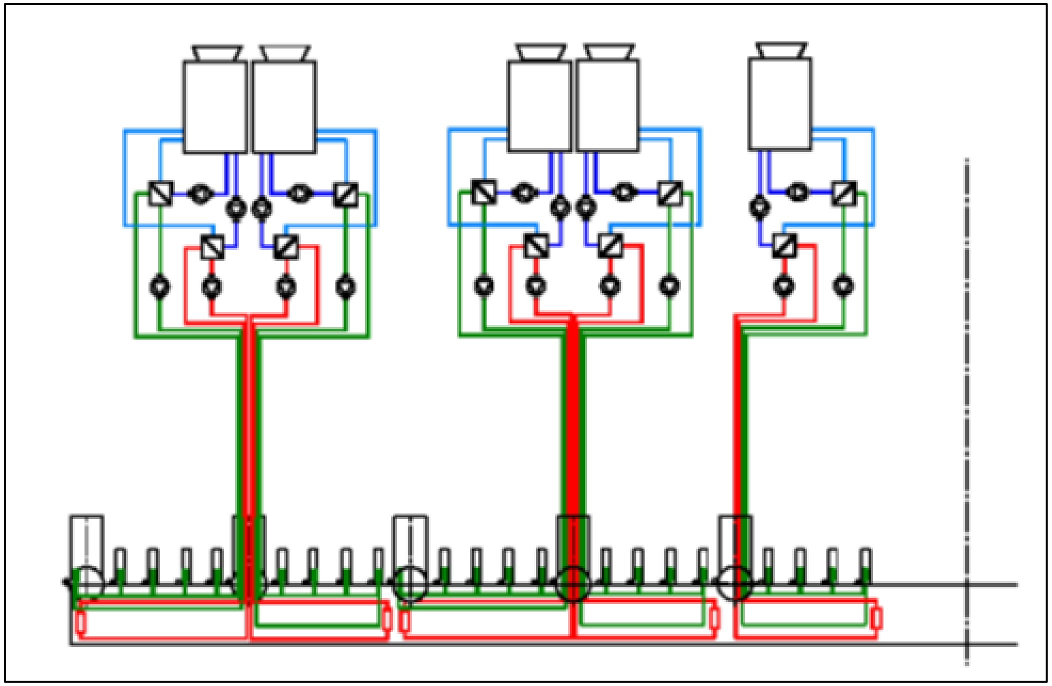
Gain in electrical consumption (few %)

Lose operational flexibility between independent systems (e.g. maintenance).

3. Cooling towers on surface Points

- ✓ Each sector is cooled by a dedicated cooling tower located in the surface point.
- ✓ Concerned surface points will serve 2 sectors to maximize redundancies.
- ✓ Make up from local network.

  ($50\ m^3/h$)



3. Cooling towers on surface Points

CIRCUIT 3 & 4	**CT in center**	**CT in surface points**
Total cooling capacity	215 MW	
Cooling capacity/cell [MW]	50	11
CT requested surface [m^2]	1’280	1’840
Pump consumption electrical power [MW]	6.6	4.87 MW
Pipes in the tunnel	DN800 DN500	DN350 DN250
Cost cooling towers [MCHF]	20 (FRP)	48 (concrete)
Cost for piping (accessories excl.) [MCHF]	140	85
Cost gain in electrical consumption		200 kCHF/yr

3. Cooling towers on surface Points

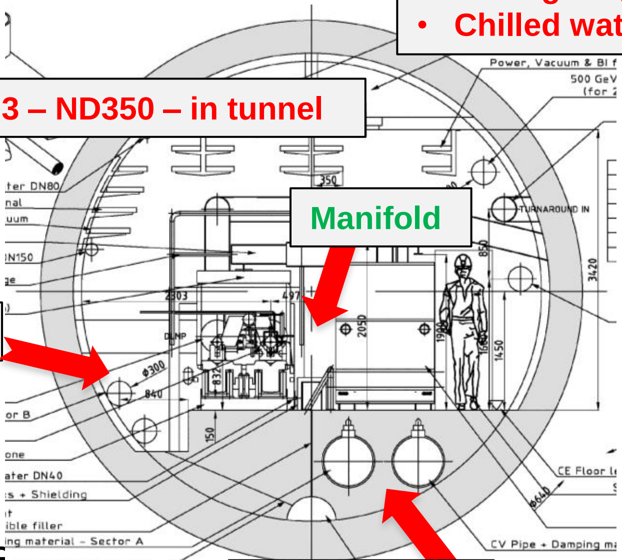
✓ Cons:

- Stronger environmental impact (outside CERN)
- Bigger surface needed for installation
- Impact on shaft dimensions?

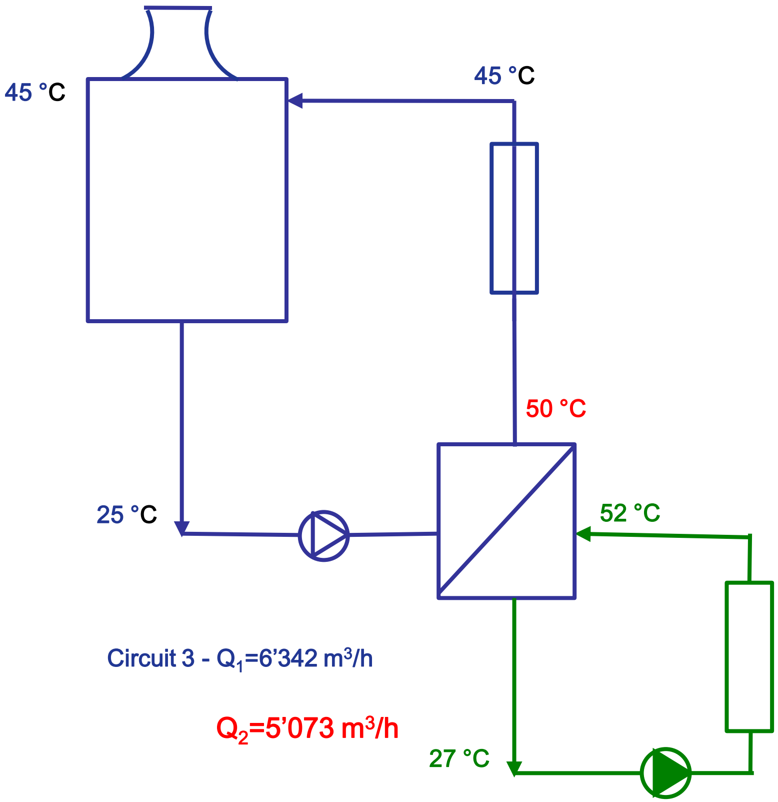
✓ Prons

- Smaller pipe diameters in tunnel
- Lower electrical power requested (25%)
- No need for booster pumps
- Bypass and manifold, connection to drain simplified
- Balancing of circuit simpler and more reliable

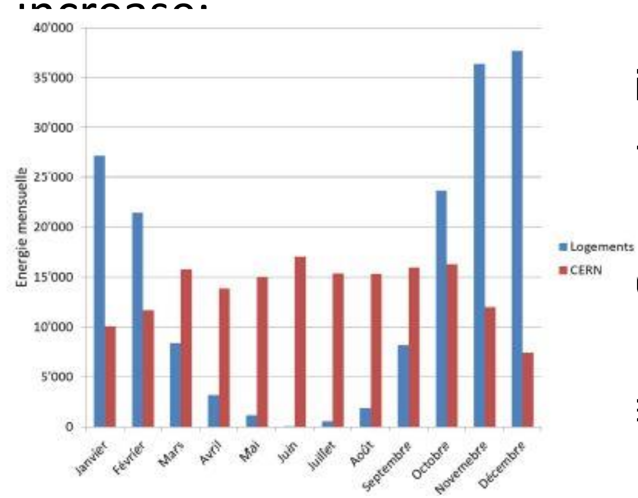
Missing items:
- **compressed air,**
- **Fire fighting**
- **Chilled water**



4. Temperature range increase



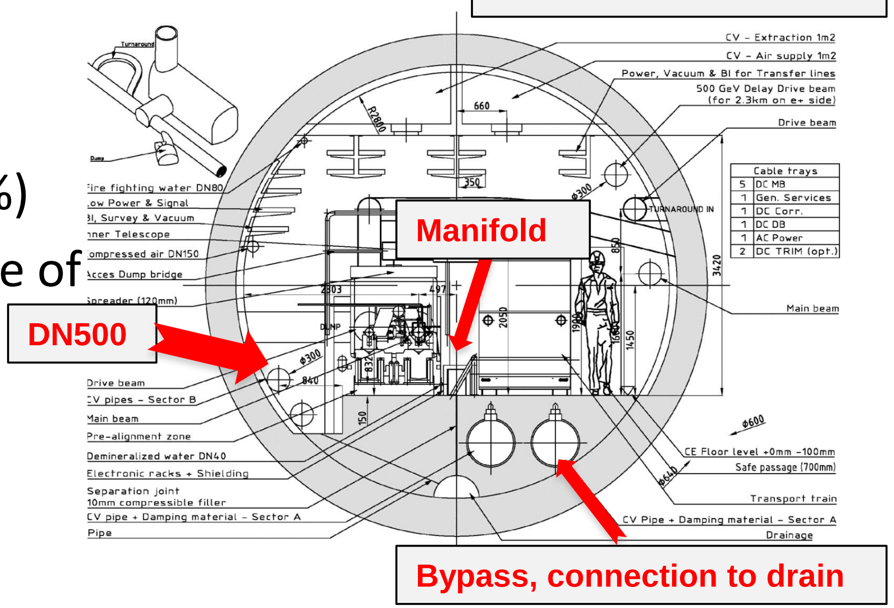
- ✓ Increase of temperature difference between inlet and outlet; on primary side keep constant the range in the cooling towers of 20 K:
  - Recover energy to be used internally at CERN if it matches run schedule.
- ✓ For a 5 K increase:
  - T ou ... ipment?
  - Deci ... ned circu...
  - No c ... vhen heat...
  - Deci ... ary pum...



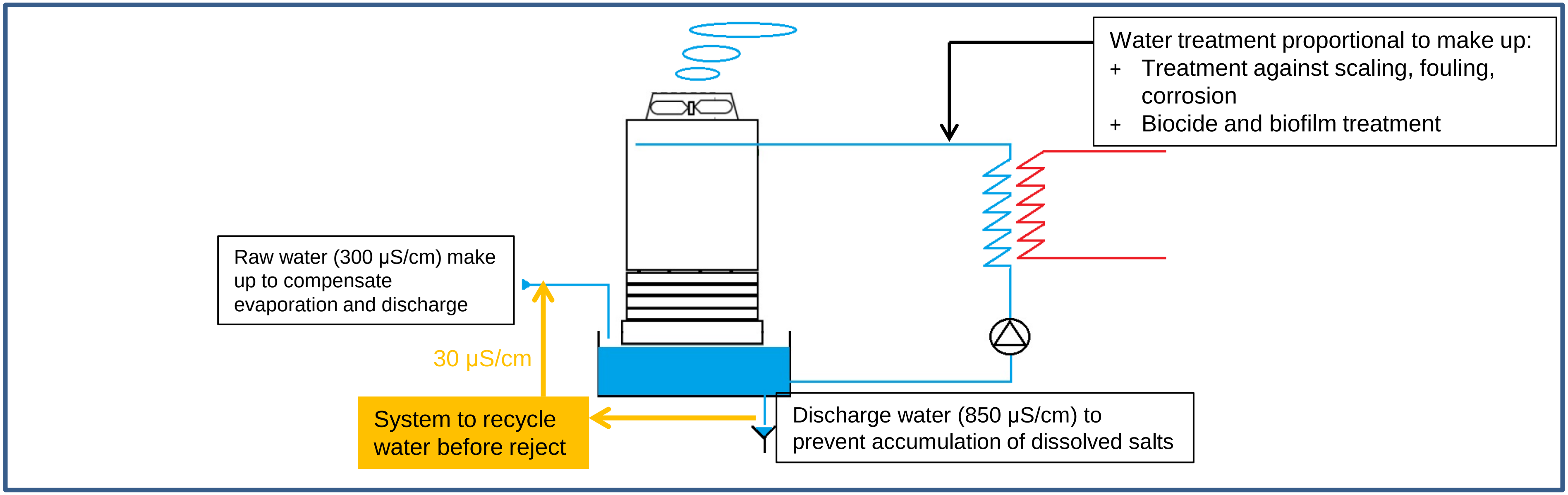
4. Temperature range increase

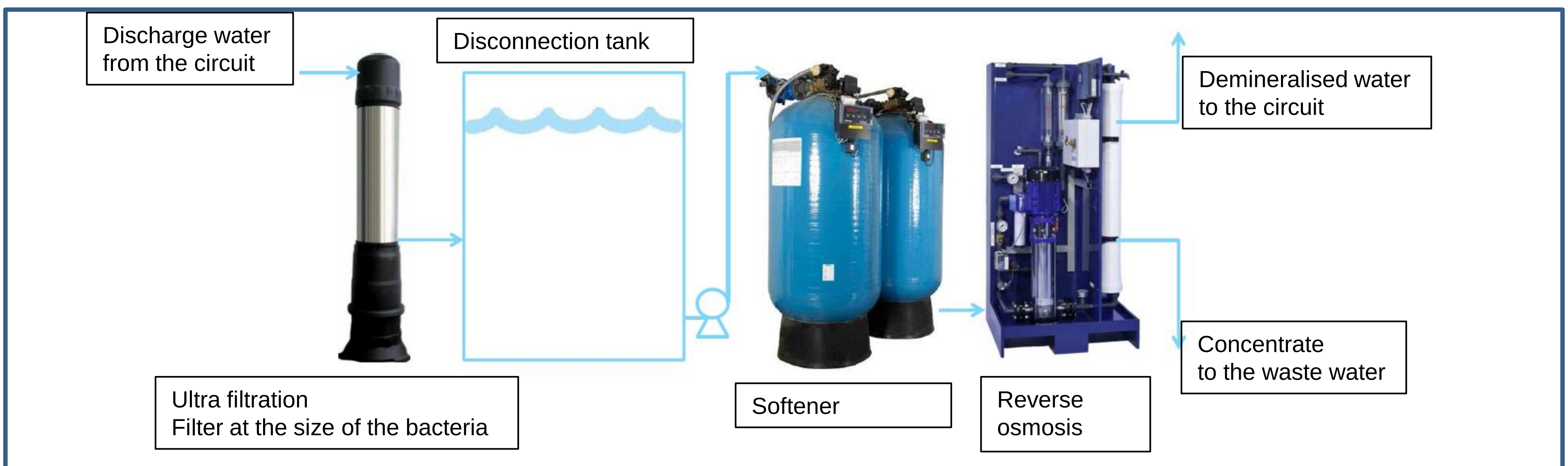
- ✓ Cons:
  - Higher installation cost
  - Pending issues not solved
- ✓ Prons
  - Lower electrical power requested (20%)
  - Lower make up water consumption (20%)
  - Waste heat recovery will help acceptance of the project.

Missing items:
- **fire fighting,**
- **compressed air,**
- **chilled water**



5. Water treatment





5. Water treatment

- ✓ This is a totally new proposal under study
  - tests and assessment of the results to be done.
- ✓ (Possible) Cons:
  - Investment cost to be evaluated with expected lifetime of the system
  - Impact on operation of the recylcing system to ensure full performance.
- ✓ Prons
  - Decrease of water consumption, >50%
  - Decrease of use of chemicals and biocide
  - Decrease of rejected water volumes…….(waste water drain)
  - Compliance with new laws on water reject in France and Switzerland

The company ensures that it is economically interesting (several hundreds kCHF overall) in operation cost: tbc with respect to CERN costs.

Summing up

Pending issues	Pipes	Bypass, manifold, drain	Booster pumps	Circuit balancing	Environm. impact
CDR solution	DN800/DN500	Not ok	Yes	Difficult	Ok
Variation T out from CT	DN900/DN350/DN250	Ok	Yes	Ok	Ok
CT on surface points	DN350/DN250	Ok	No	Ok	Higher
Range increase in circuit	No change	Not ok	Yes	Difficult	Better
Water treatment	No change	Not ok	Yes	Difficult	Ok

With respect to CDR solution	Installation costs	Operation cost	Impact on operation	Energy consumption	Pending issues
Variation T out from CT	Higher	Lower	No impact	-15% (Elec)	+
CT on surface points	Lower	Lower	++	-25% (Elec)	+
Range increase in circuit	Higher	Lower	++	-20% (Elec)	-
Water treatment	Higher	Lower	Tbd	> 50% (Water)	-

Ventilation DB Injector building

- ✓ 11 MW - modular solution, every 50-100 mtrs according to precision requested.
- ✓ Optimize ventilation if temperatures higher than 25 °C accepted: passive cooling (e.g.: no cooling of air installed → no chilled water). Only heating in winter installed.
- ✓ Acceptable for a working place if for a limited number of working hours temperature >26 °C . Would 100 hrs be acceptable?
- ✓ Basic requirement:
  - Good solar protection(colors, glazing)
  - Good thermal isolation of the building.
  - Ventilation during night
  - Additional option: building partially underground shall increase the thermal inertia of the building would limit the maximum temperature at ~28 °C also in Summer.
  - Other systems to increase thermal inertia (puits canadiens, dephaseurs)

Conclusions

- ✓ All data presented are to be considered as first estimate, several details/information missing.
- ✓ Most critical technical point at present to solve: available space in tunnels.
- ✓ Some of the solutions can be combined together
- ✓ Use of cooling towers in surface points is highly recommended.

THANK YOU FOR YOUR ATTENTION

Main cooling parameters 1/2

	Power (kW)	T in	T out	Q (m3/h)
1	156'910	27	47	7'460
1,a bldg drive beam inj	*108'702*			*4'674*
1,b tunnel drive beam inj	*12'078*			*519*
1,c frequency multiplication	*18'480*			*795*
1,d transfer lines	*6'600*			*284*
1,e chilled water production	*11'051*	*27*	*35*	*1'188*
2	47'327	27	47	2'215
2,a bldg main beam inj	*16'736*			*720*
2,b tunnel main beam inj	*1'725*			*74*
2,c surface damping rings	*12'100*			*520*
2,d tunnel damping rings	*10'670*			*459*
2,e tunnel booster linac	*2'970*			*128*
2,f surface booster linac	*330*			*14*
2g chilled water production	*2'796*	*27*	*35*	*301*

Main cooling parameters 2/2

	Power (kW)	T in	T out	Q (m3/h)
3	147’220	27	47	6’341
3,a tunnel e-	*73’610*			*3’171*
3,b tunnel e+	*73’610*			*3’171*
4	66’044	27	47	2’840
4,a tunnel e-	*33’022*			*1’420*
4,b tunnel e+	*33’022*			*1’420*
5	73’142			3’428
5.1 detector premises	*14’850*			*639*
5.2 accelerator tunnel	*53’911*			*2’318*
5.3 chilled water production	*4’381*			*471*