Cryogenic Cooling Schemes for the SPL

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Topics

- **Introducing remarks**
- **General considerations**
  - Basic parameters
  - Basic considerations
- **Different cooling schemes (seven in total)**
  - Cooling scheme options
  - Advantages / Drawbacks
- **Topics to be investigated**

Introduction

General note

- **The SPL is presently in the phase of a Design Study.**
- **CERN has no experience operating pulsed SC cavities at 2.0K.**
- **We try to define a "baseline" design for the cryogenic distribution.**
  - However this design will look like, we cannot consider this as "the Solution"; it may still be subject changes.
- **None of the proposals in this presentation is considered to represent the desired baseline.**

Introduction

Availability

- **Availability is a key requirement for all accelerators**
- **The SPL is "second-in-line" of an injector chain**
  - Availability even more important
- **Operation should be considered under degraded conditions like:**
  - Leaks
  - Faulty components
  - High local heat loads

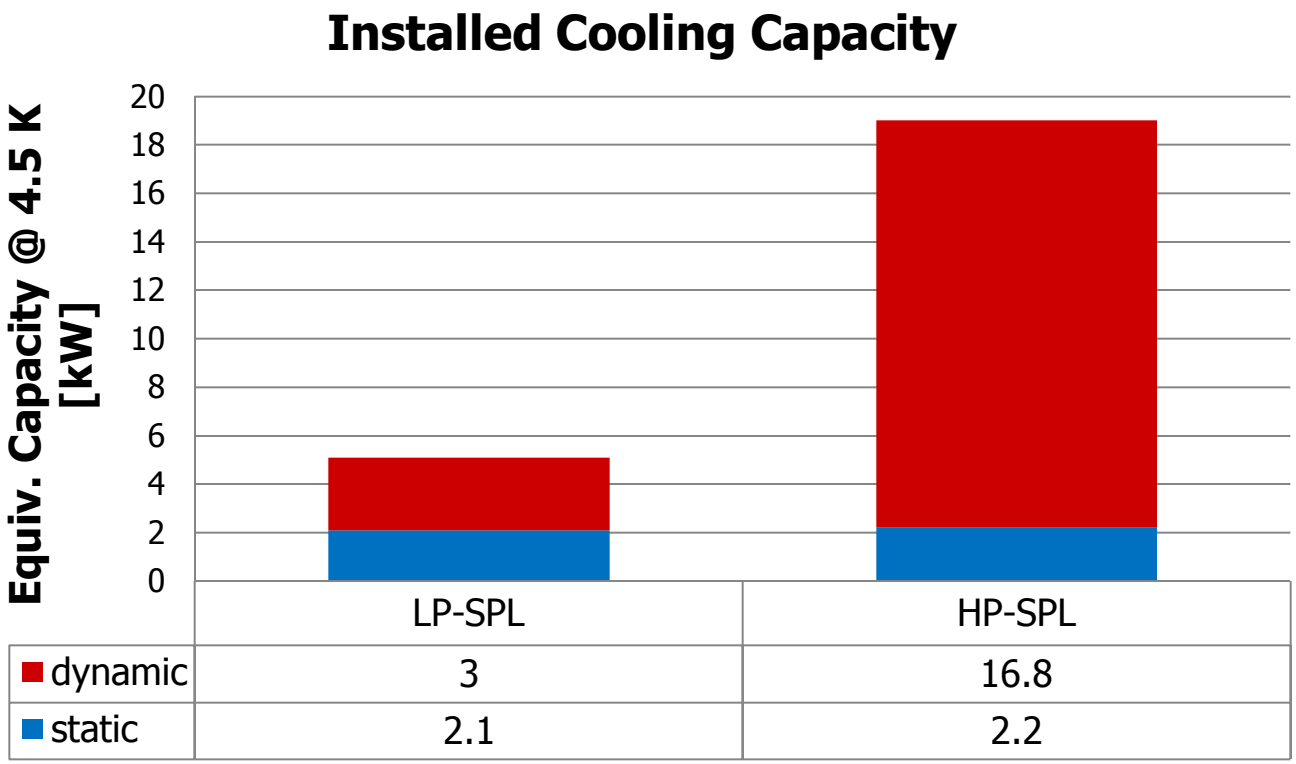
Basic parameters

Assumptions that are considered as decided

- **The following is considered as decided:**
  - Cooling of the cavities with helium II at ~ 2.0 K
  - Cavities inside the saturated bath
    - To profit from low Δp and good p-stability
    - (Not cooled by sub-cooled pressurized helium)
- **Anything else may be discussed / changed**

Basic parameters

Capacities



The choice of the cryogenic distribution may influence the static heat load only !

Basic parameters

Pressures and temperatures

Line	Temperature	Pressure	Design Pressure
Header A	2.2 K	0.3 MPa	2.5 MPa
Header B	2.0 K	3.1 kPa	0.6 MPa
Header C	5.0 K	0.55 MPa	2.5 MPa
Header D	8.0 K	0.50 MPa	2.5 MPa
Header E	50 K	1.8 MPa	2.5 MPa
Header F	75 K	1.7 MPa	2.5 MPa

These values are fixed

The rest is for "orientation" only and may be modified

Basic Considerations

Distribution scheme requirements

- **The distribution scheme needs to satisfy requirements for:**
  - Nominal operation
  - Cool-down, warm-up and purge
  - Operation under degraded conditions
  - Diagnosis
  - Safety equipment

Considered

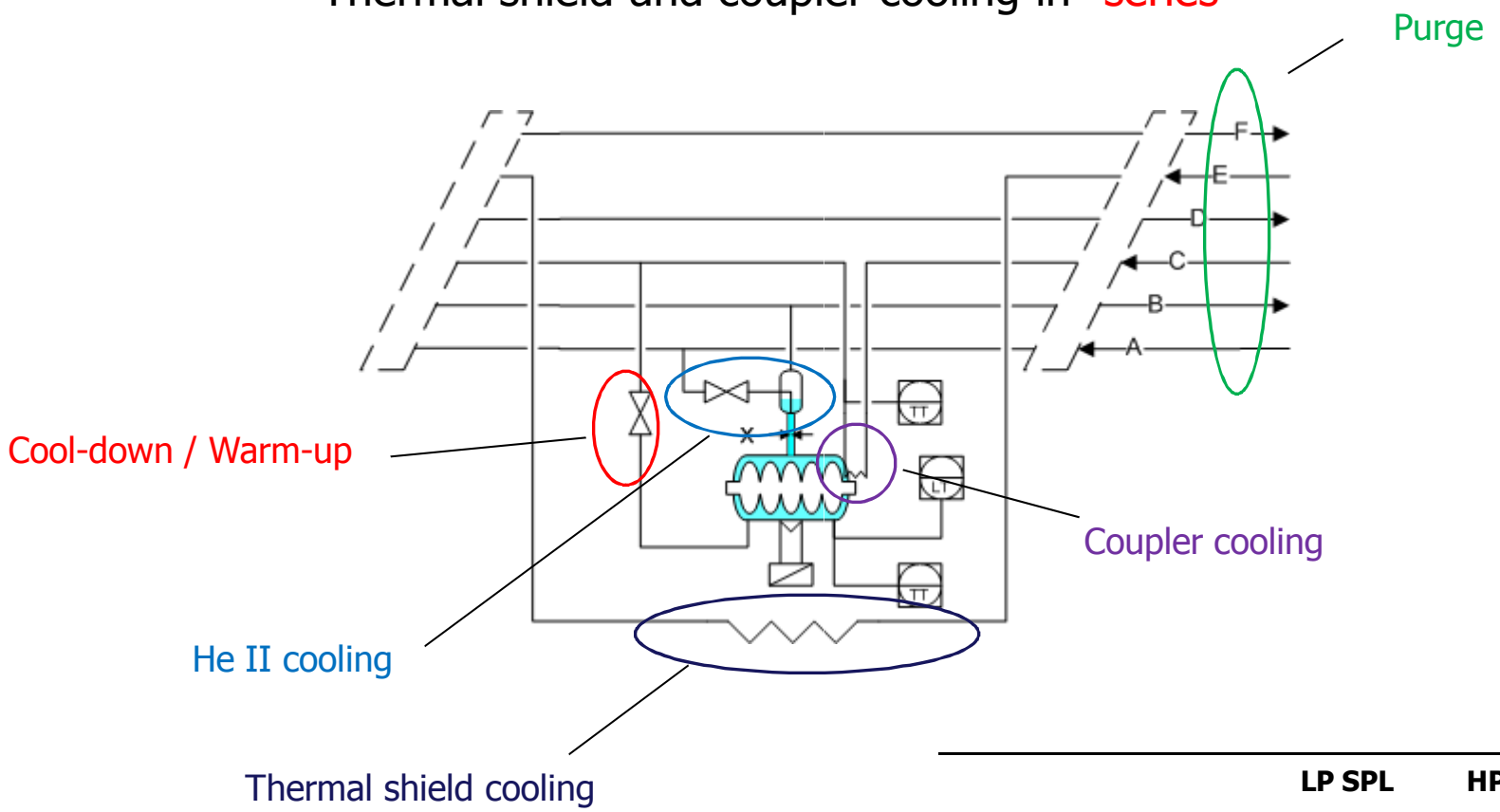
To be defined / discussed

Not yet considered

Basic Schemes

Single Cavity Cooling

Thermal shield and coupler cooling in "series"

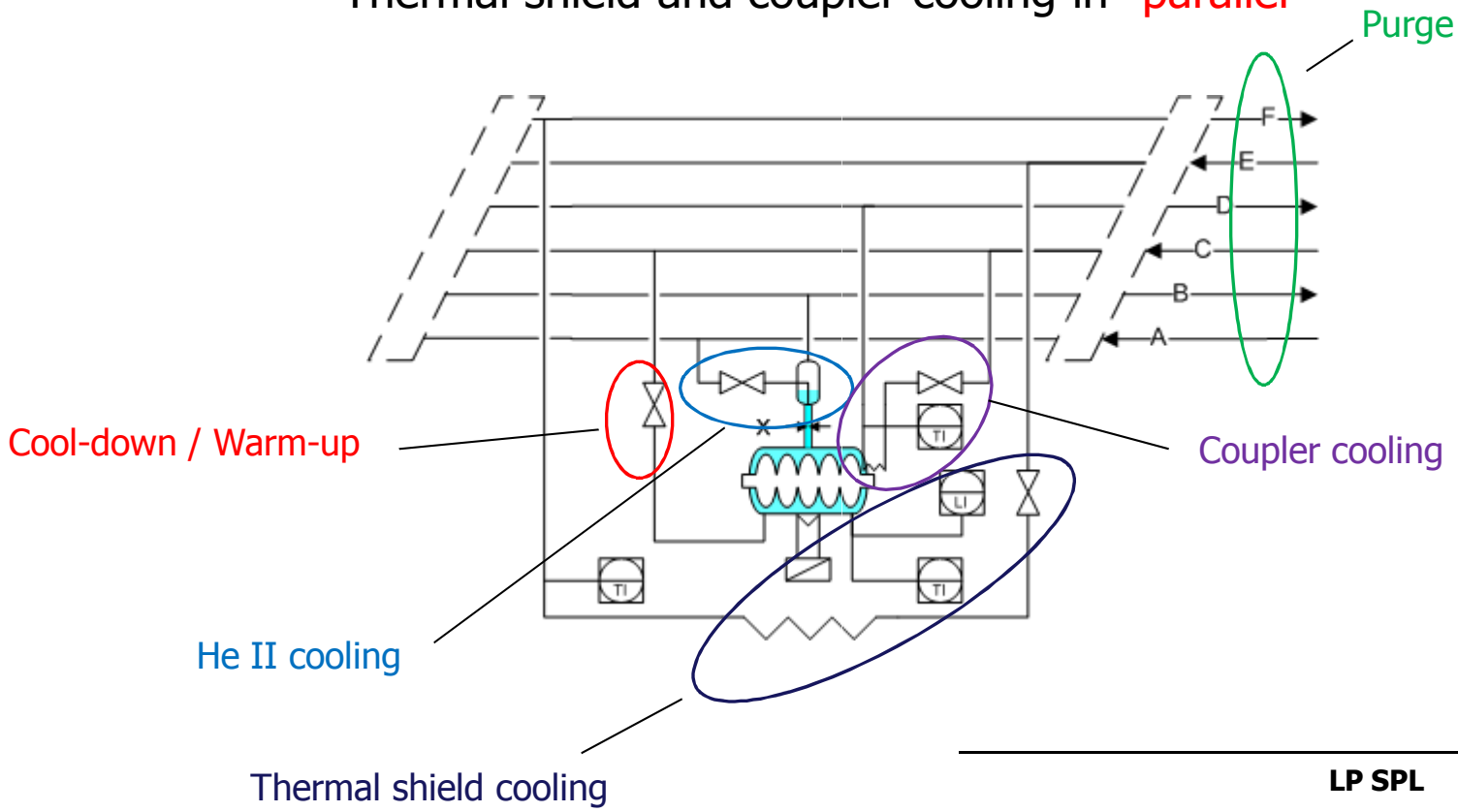


	LP SPL	HP SPL
Diameter "x" [mm]	40	80

Basic Schemes

Single Cavity Cooling

Thermal shield and coupler cooling in "parallel"



	LP SPL	HP SPL
Diameter "x" [mm]	40	80

Basic Schemes

"series" versus "parallel" cooling

Series cooling

- **Advantages**
  - Less equipment
  - Simple operation
- **Disadvantages**
  - No isolation of single elements in degraded conditions
  - "Last-in-line" always on higher limit temperature
  - Long response time for control

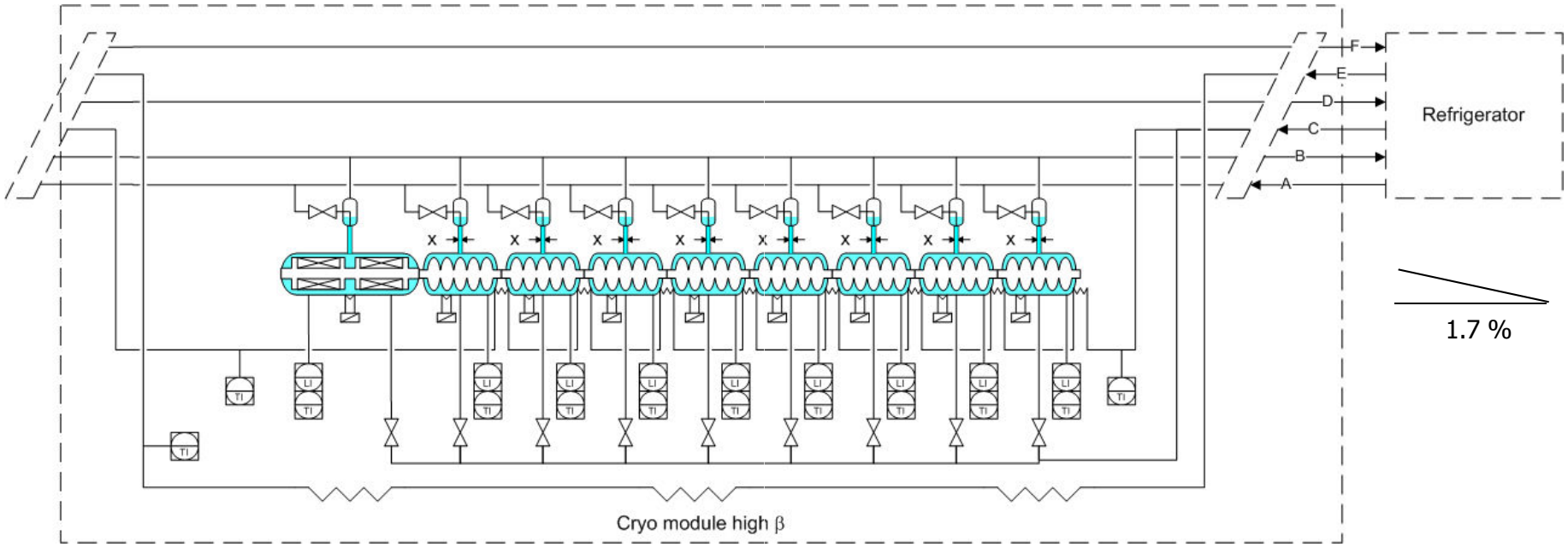
Parallel Cooling

- **Advantages**
  - Isolation of single elements possible
  - Little temperature spread
  - Short response for control
- **Disadvantages**
  - More equipment
  - More control effort

List not necessarily exhaustive

Module Schemes

Scheme no 1: "Single cavity cooling"



	LP SPL	HP SPL
Diameter "x" [mm]	40	80

Module Schemes

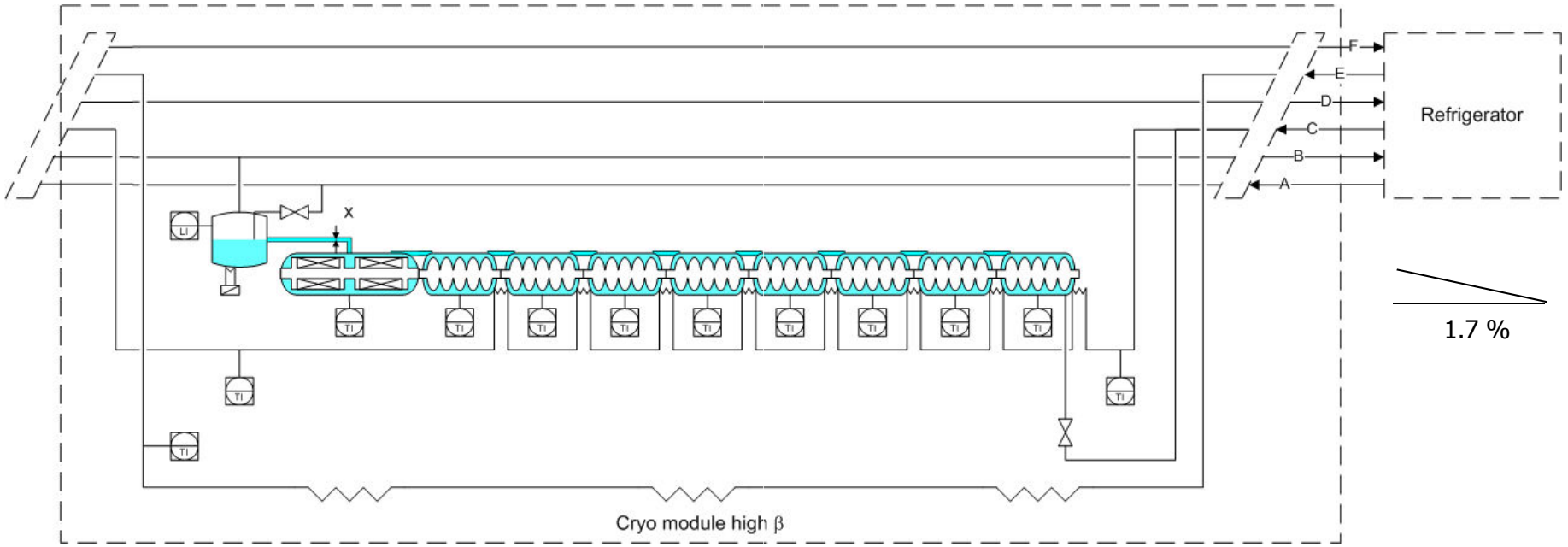
Comments on scheme no 1

- **Simply a combination of single cavity cooling loops**
  - Liquid HeII: individual per cavity
  - Coupler: in series or parallel for several cavities
  - Thermal shield: in series or parallel for several cavities
  - WU / CD: individual per cavity

- **Equipment intensive**
- **Feasibility seems guaranteed**

Module Schemes

Scheme no 2: "Common bath cooling"



	LP SPL		HP SPL	
	Low β	High β	Low β	High β
Diameter "x" [mm]	125	140	230	300

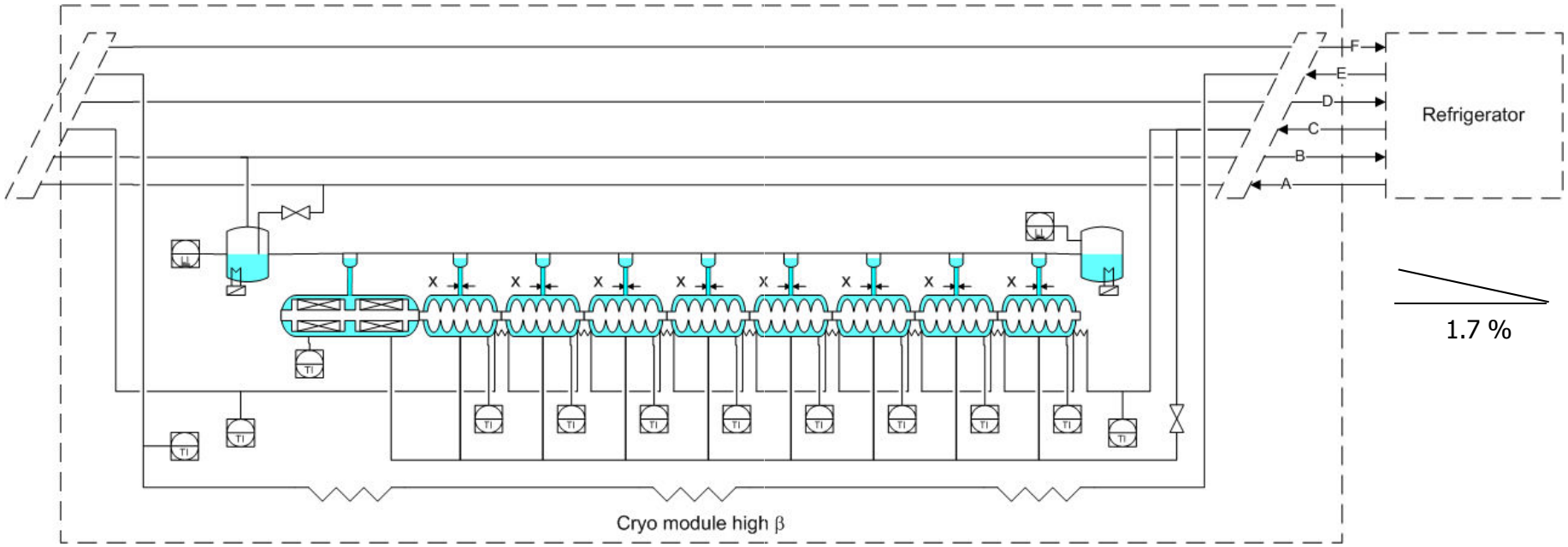
Module Schemes

Comments on scheme no 2

- **Combination of several cavities in one bath**
  - Liquid HeII: one loop per bath
  - Coupler: in series or parallel for one or several baths
  - Thermal shield: in series or parallel for one or several baths
  - WU / CD: one loop per bath
- **Low amount of equipment needed**
- **Feasibility seems possible**
- **Cooling by conduction in the bath requires very big channel diameters**
  - Could be feasible for LP version with 3 / 4 cavities per bath

Module Schemes

Scheme no 3: "ILC-like"



	LP SPL	HP SPL
Diameter "x" [mm]	40	80

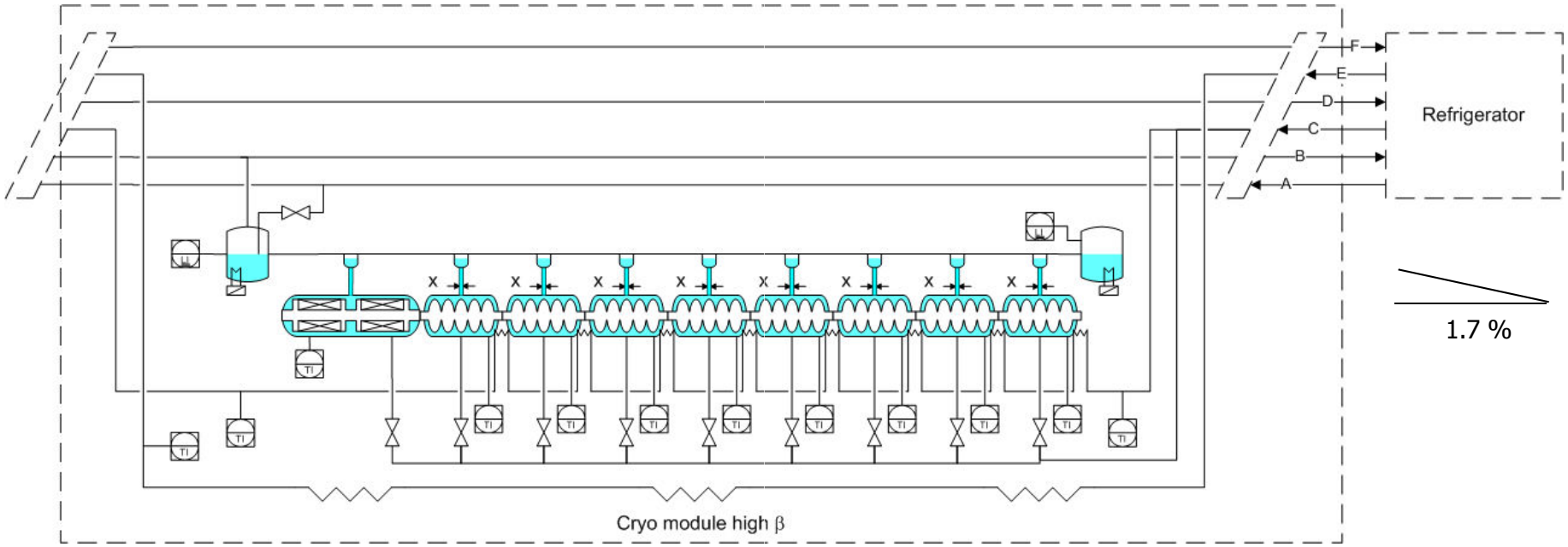
Module Schemes

Comments on scheme no 3

- **One cavity per bath with common 2-phase header**
  - Liquid HeII: one loop per group of cavities
  - Coupler: in series or grouped for several cavities
  - Thermal shield: in series or grouped for several cavities
  - WU / CD: one loop per group of cavities
- **Low amount of equipment needed**
- **Feasibility of the WU/ CD questionable**
  - The combination of several 2-phase volumes seems dangerous
  - The equal distribution of flow for CD (less for WU) seems difficult to guarantee
- **He II loop should be thermo-hydraulically validated**

Module Schemes

Scheme no 4 : "ILC-like SPL version A"



	LP SPL	HP SPL
Diameter "x" [mm]	40	80

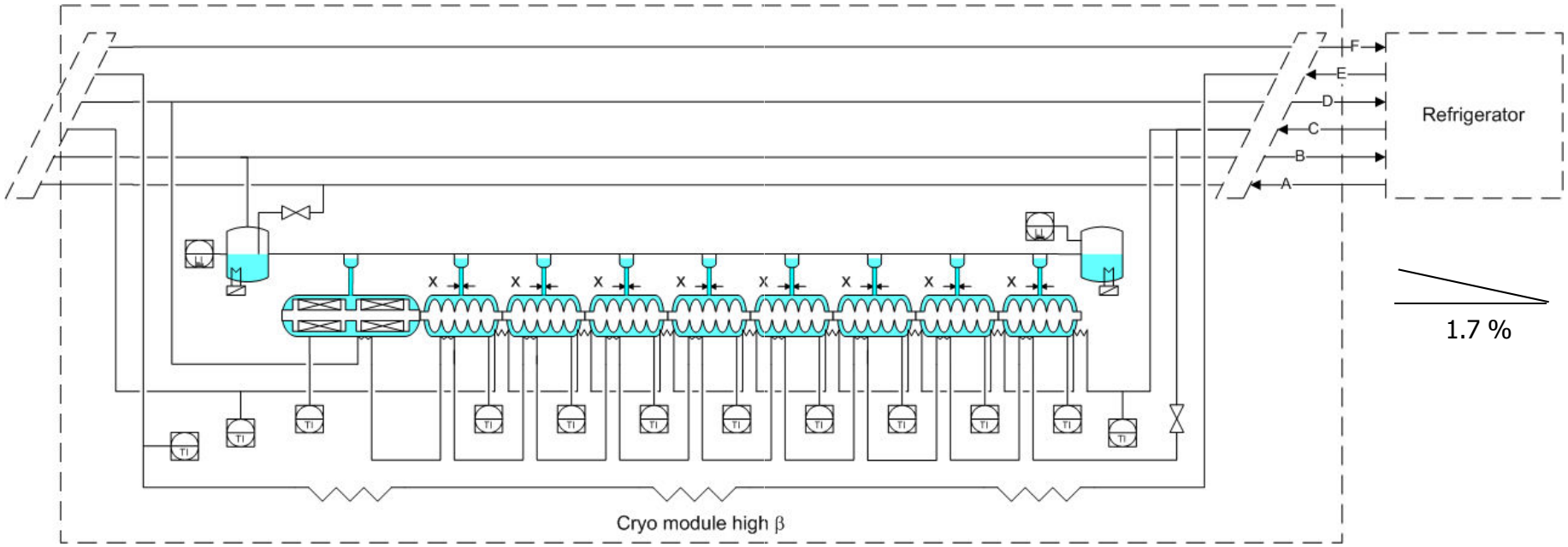
Module Schemes

Comments on scheme no 4

- **One cavity per bath with common 2-phase header**
  - Liquid HeII: one loop per group of cavities
  - Coupler: in series or grouped for several cavities
  - Thermal shield: in series or grouped for several cavities
  - WU / CD: one loop per cavity
- **High amount of WU/ CD valves**
- **Feasibility seems ok**
- **He II loop should be thermo-hydraulically validated**

Module Schemes

Scheme no 5 : "ILC-like SPL version B"



	LP SPL	HP SPL
Diameter "x" [mm]	40	80

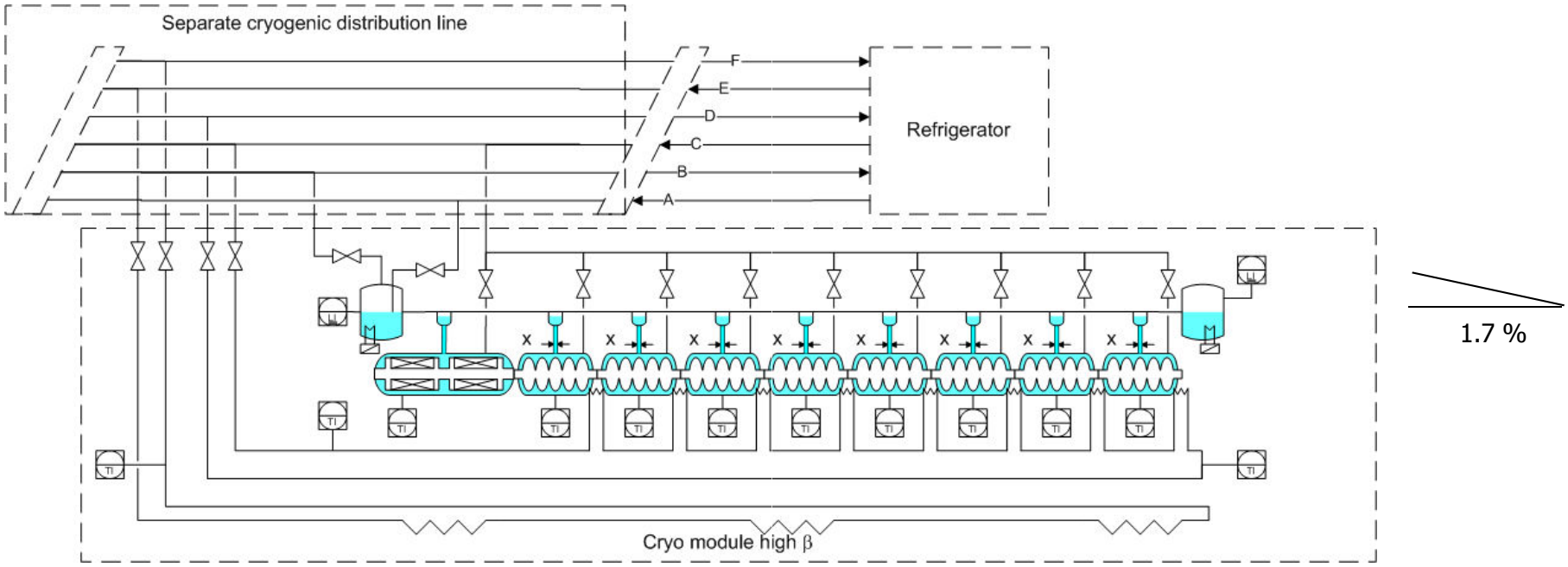
Module Schemes

Comments on scheme no 5

- **One cavity per bath with common 2-phase header**
  - Liquid He II: as ILC-like SPL version "A"
  - Coupler: as ILC-like SPL version "A"
  - Thermal shield: as ILC-like SPL version "A"
  - WU / CD: one loop per group
- **Low amount of equipment**
- **Feasibility of WU /CD with contact cooled liquid helium tank to be investigated**
- **He II loop should be thermo-hydraulically validated**

Module Schemes

Scheme no 6 : "ILC like SPL version "A" with separate cryogenic feeder line"



	LP SPL	HP SPL
Diameter "x" [mm]	40	80

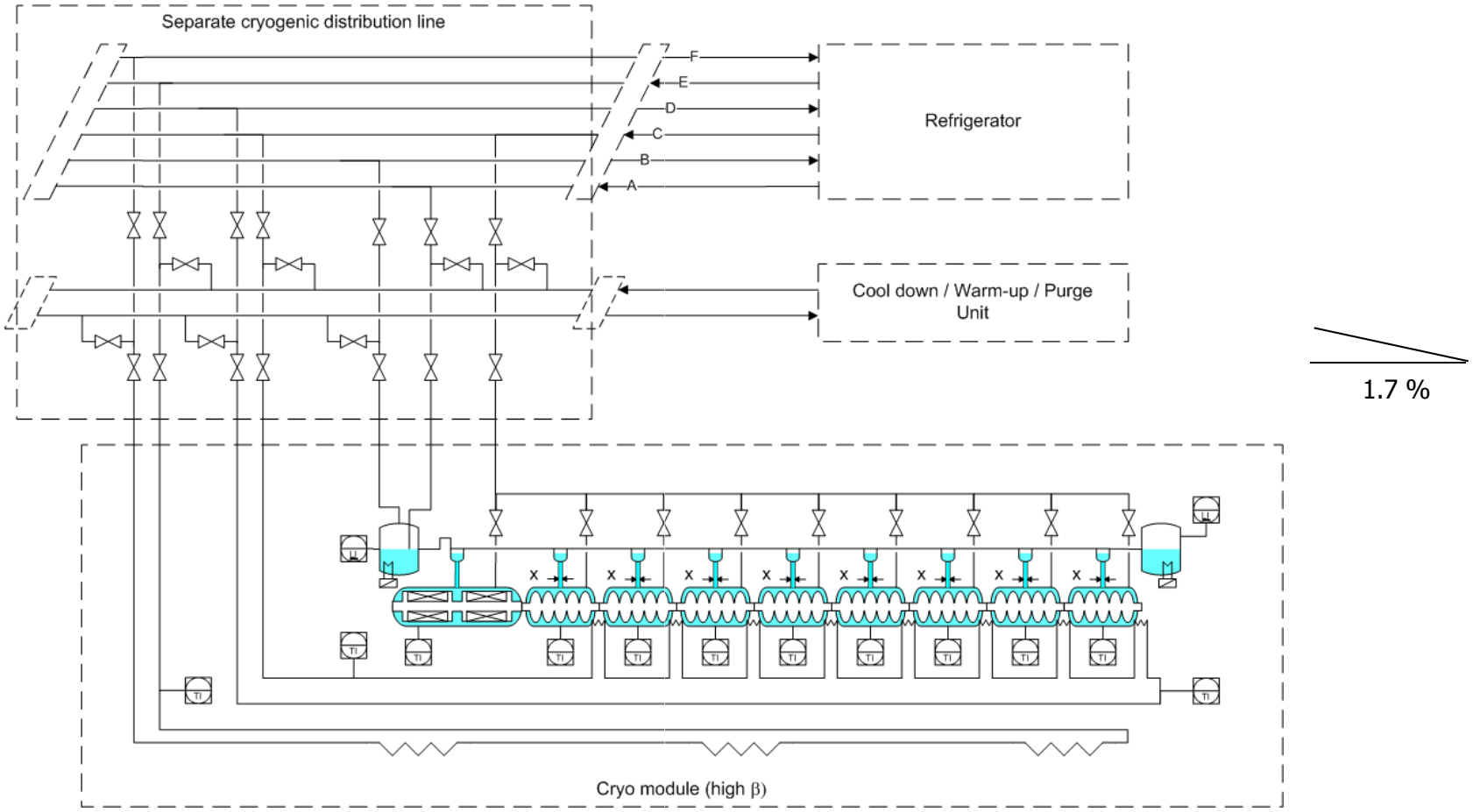
Module Schemes

Comments on scheme no 6

- **One cavity per bath with common 2-phase header**
  - Liquid He II: as ILC-like SPL version "A" (or "B")
  - Coupler: "parallel" cooling
  - Thermal shield: "parallel" cooling
  - WU / CD: as ILC-like SPL version "A" (or "B")
- **High amount of equipment**
- **Feasibility as for ILC-like SPL version "A" (or "B")**
- **All cooling loops of a group of cavities can be completely isolated**
- **Independent WU/CD not possible**

Module Schemes

Scheme no 7 : "ILC like SPL version "A" with separate cryogenic line equipped for independent cool-down, warm-up and purge"



Module Schemes

Comments on scheme no 7

- **One cavity per bath with common 2-phase header**
  - Liquid He II: as ILC-like SPL version "A" (or "B")
  - Coupler: "parallel" cooling
  - Thermal shield: "parallel" cooling
  - WU / CD: as ILC-like SPL version "A" (or "B")
- **Very high amount of equipment**
- **Feasibility as for ILC-like SPL version "A" (or "B")**
- **All cooling loops of a group of cavities can be completely isolated**
- **Independent WU/CD and purge possible**

Separate cryogenic line

Advantages / Disadvantages

- **Advantages**
  - Less complexity for the main cryostat
  - Potential to completely isolate "faulty" modules
- **Disadvantages**
  - Requires more tunnel space
  - Higher static heat load
- **Cost aspect**
  - Not easy to identify separate line most probably more expensive
    - More complex cryostat and installation vs. cryostat plus line, two installations and more tunnel space

Single Module WU / CD

Procedure options for exchanges / repairs

Option 1: WU of complete machine -> exchange / repair -> CD complete machine

- All machine warm
  - Possible with schemes 1 to 7

Option 2: WU distribution headers & concerned loops -> exchange / repair-> CD distribution headers & concerned loops

- No active cooling for rest of machine
  - Possible with scheme 1 to 7 but increased radiation load for schemes 1 to 5 -> preferable scheme 6 & 7

Option 3: WU individual module -> exchange / repair -> CD individual module

- Active cooling for rest of the machine
  - Possible only with scheme 7

Open Topics

To be investigated 1

- **Ambient-temperature equipment**
  - What can be at ambient, what must be at ambient?
- **Magnets cooling**
  - If possible at ambient, why operate lower?
- **Coupler cooling**
  - 5-8 K best compromise? (why not 4.5 K – 300 K e.g.)
- **WU / CD**
  - Contact cooled WU/CD of helium tank feasible? (would save on equipment)

Open Topics

To be investigated 2

- **Limits of operation under degraded conditions**
  - When is a repair / exchange mandatory
- **Cool-down and warm-up times for the whole machine**
- **“Natural” warm-up by static heat load for**
  - Modules without active cooling (scheme 6)
  - Modules without active cooling and warm headers in cryostat (scheme 1 to 5)
- **Time necessary for exchange / repair of faulty components**

Last Slide

Thank you for your attention