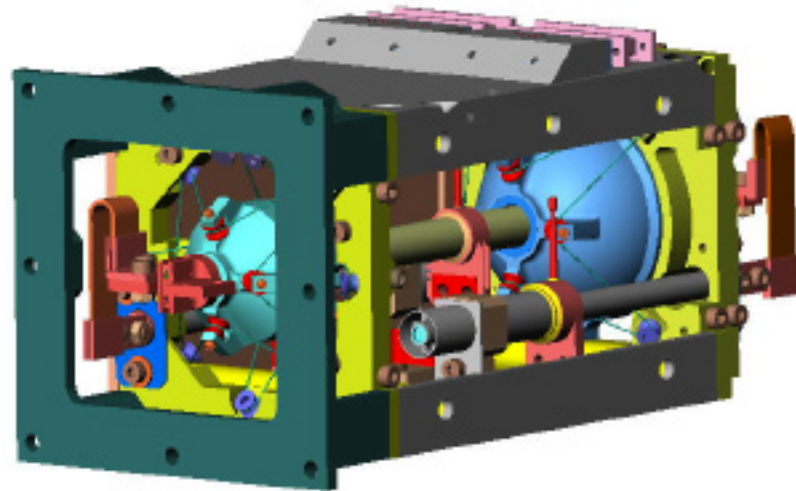


SPIRE & PACS SORPTION COOLERS

SPIRE INSTRUMENT INTERMEDIATE DESIGN REVIEW



Lionel Duband

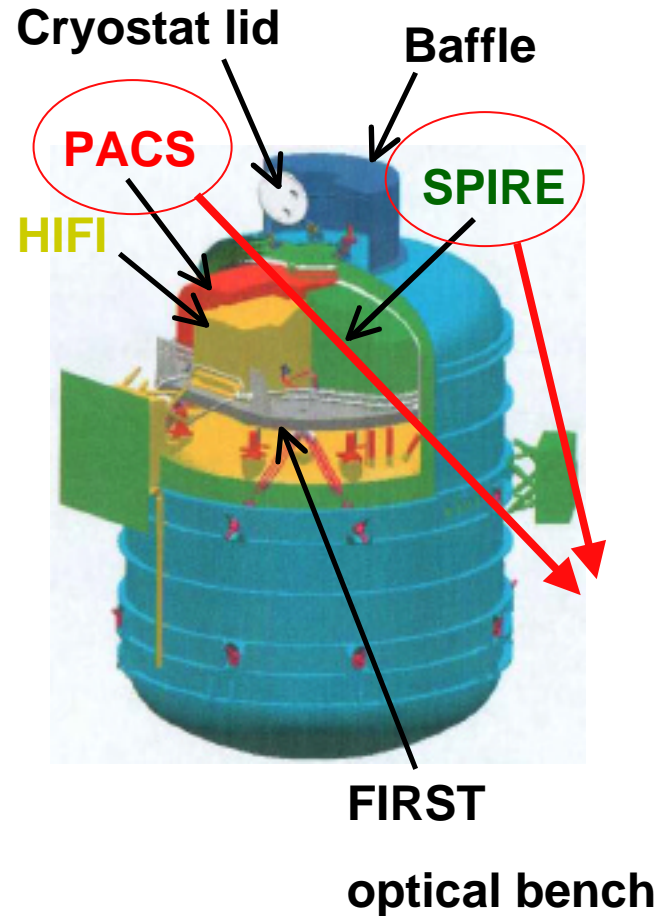
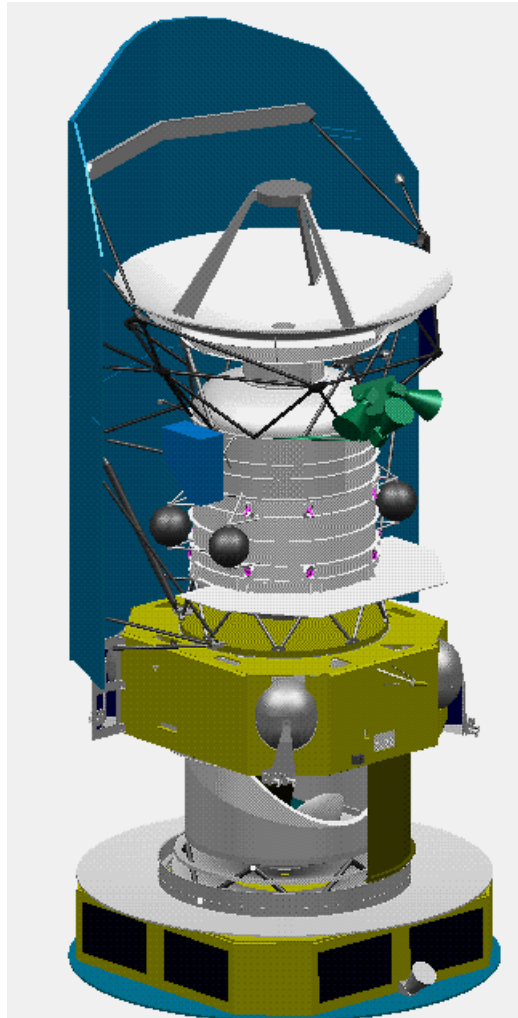
L. Clerc, L. Miquet, L. Guillemet, R. Vallcorba

D. Guillaume, Patrick Dupont (BV)

SERVICE DES BASSES TEMPERATURES

DRFMC / DSM - CEA GRENOBLE

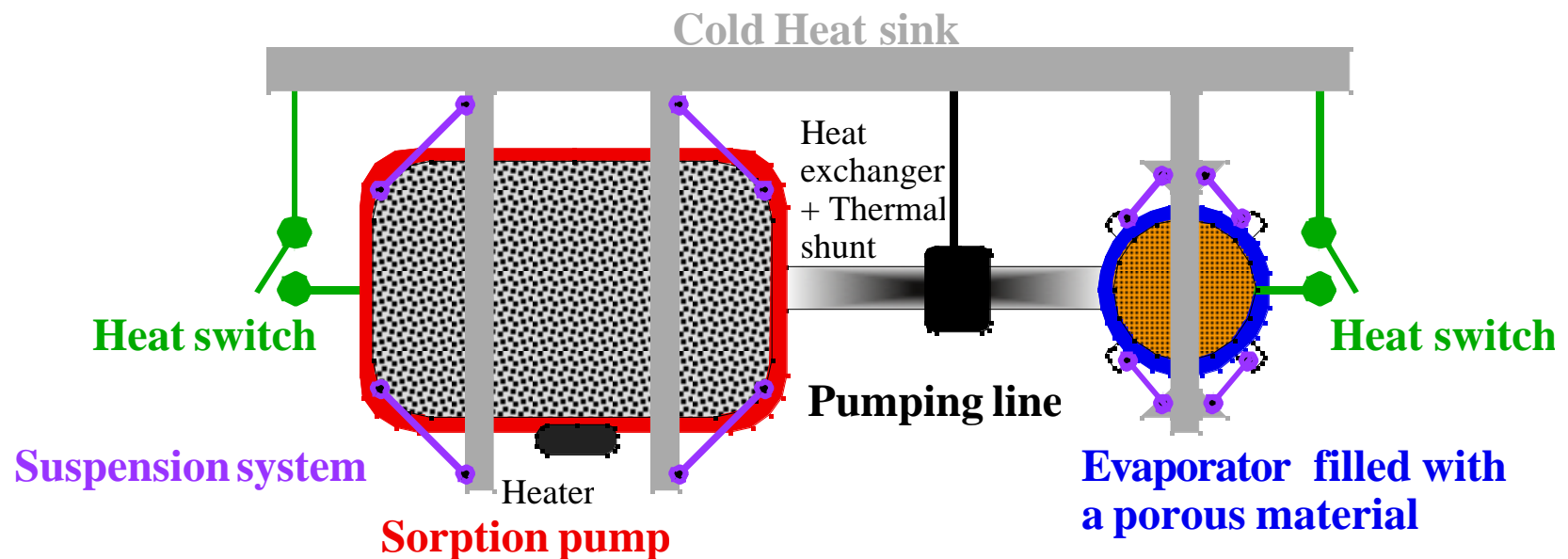
THE NEED



Cooling power
@ 290 mK
reliability,
autonomy
etc...

THE ANSWER : SORPTION COOLER

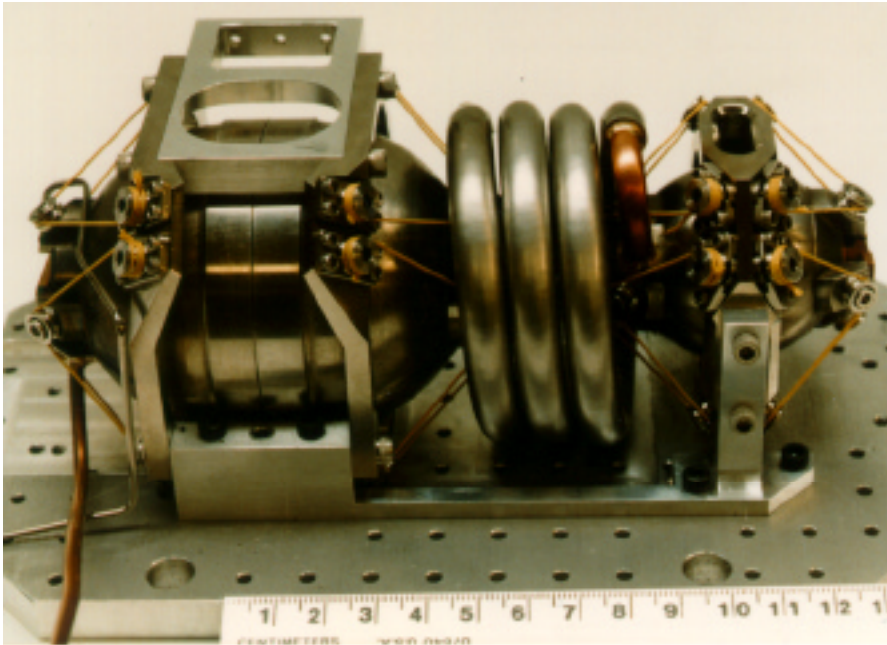
Basic principle : Evaporative pumping on a liquid ^3He bath
Main feature : use of sorption pumps



No moving parts !

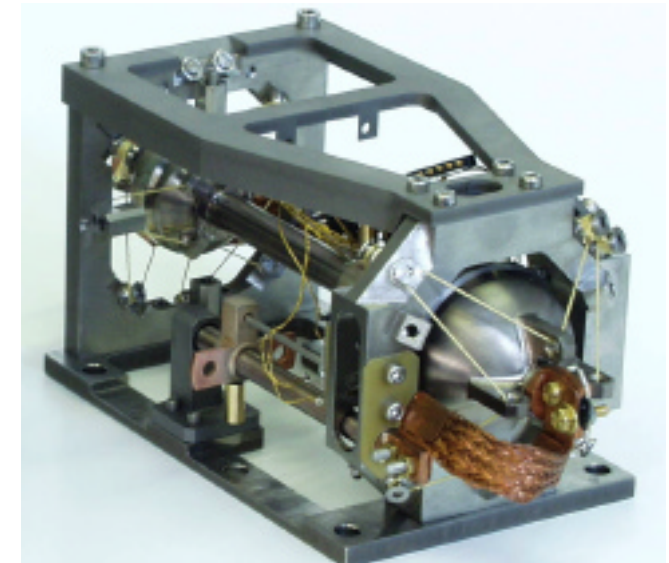
Full operation only requires heaters (3)

HERITAGE : GROUND BASED UNIT ROCKET BORNE - IRTS - ESA TRP



IRTS COOLER

- *Successfully flown onboard SFU (1995)*



**ESA CONTRACT (TRP)
TECHNOLOGY QUALIFICATION**

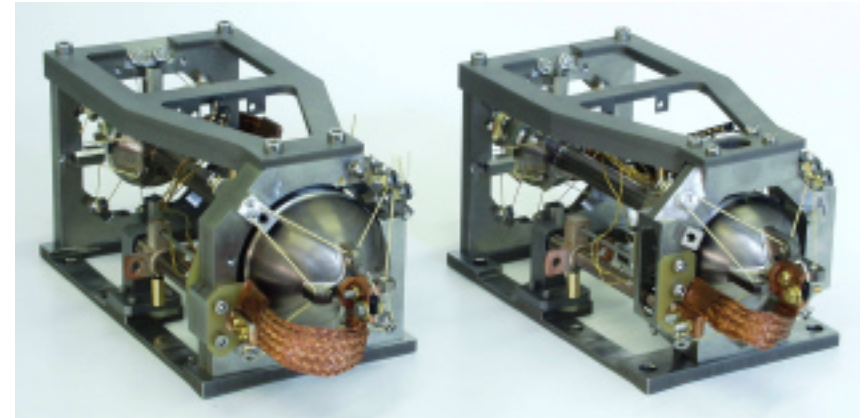
- *2 EM qualified (Sept 2000)*
- *in view of HSO*

+ ground based development (> 30 units)

EM COOLERS (ESA TRP)

2 coolers ($^3\text{He} + ^4\text{He}$) designed,
manufactured & qualified

QUALIFICATION PROGRAM SUMMARY



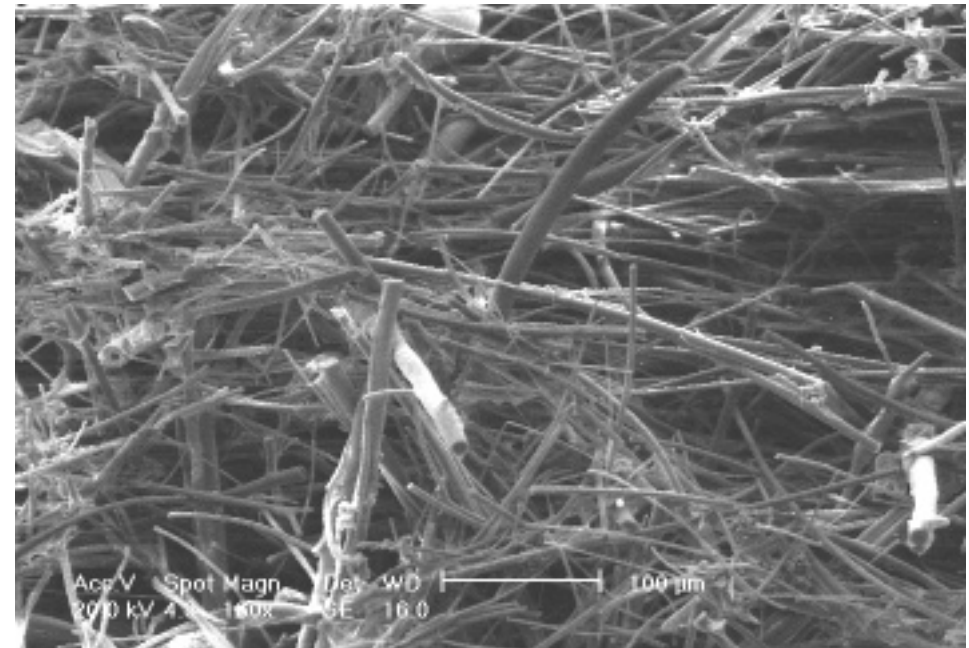
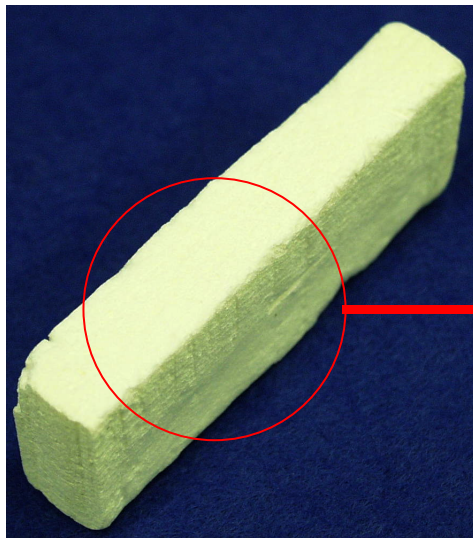
- **Proof pressure tests (20 MPa)**
- **Thermal tests (rightside-up, upside down, horizontal)**
- **One week bake out at 80°C**
- **Thermal tests (health check)**
- **Vibration tests**
- **Thermal tests (health check)**

EM COOLERS (ESA TRP) - BENEFITS

Item	Comments
Liquid confinement	Found EU supplier : qualified new material (Procelit)
Use of titanium alloy	Mechanical and thermal performance validated
Kevlar suspension system	OK but tensioning and locking mechanism to be reviewed
Gas gap heat switch	Use of ^3He gas as working fluid validated Geometry to be reviewed
Structural box	Must be reinforced
Ground tests	Evidence of convective effect (orientation)

LIQUID CONFINEMENT

- Selection criteria -
pore size - void space - heat resistant - easy handling

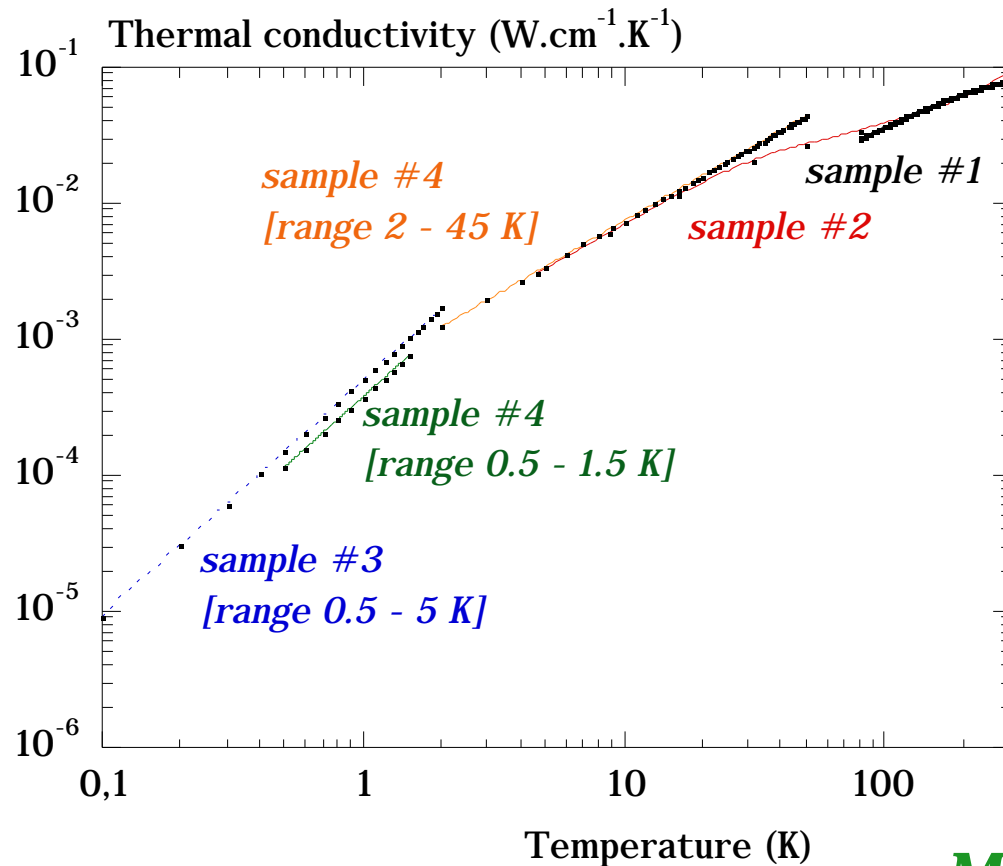


Procelit P160 (EU)

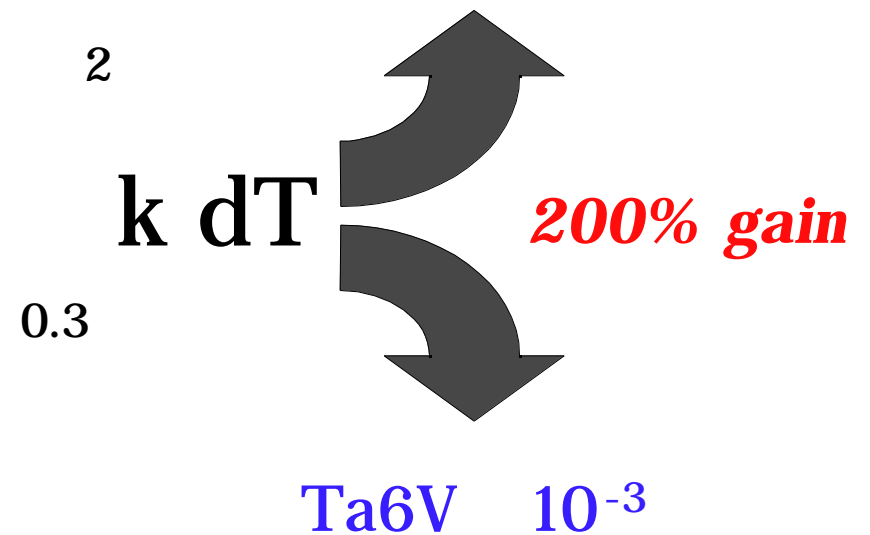
0.3 to 0.4 g/cc - 90% void space - 30 µm pore size

TITANIUM ALLOY TA6V

Even at low T, $k_{Ta6V} < k_{Stainless}$



Stainless steel $2 \cdot 10^{-3}$



+ Better  300% to 400% gain

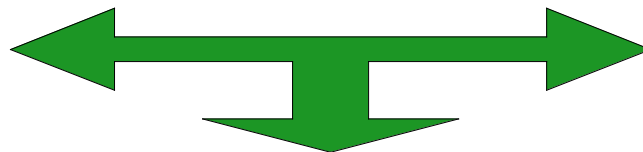
Mechanical properties

KEVLAR SUSPENSION SYSTEM

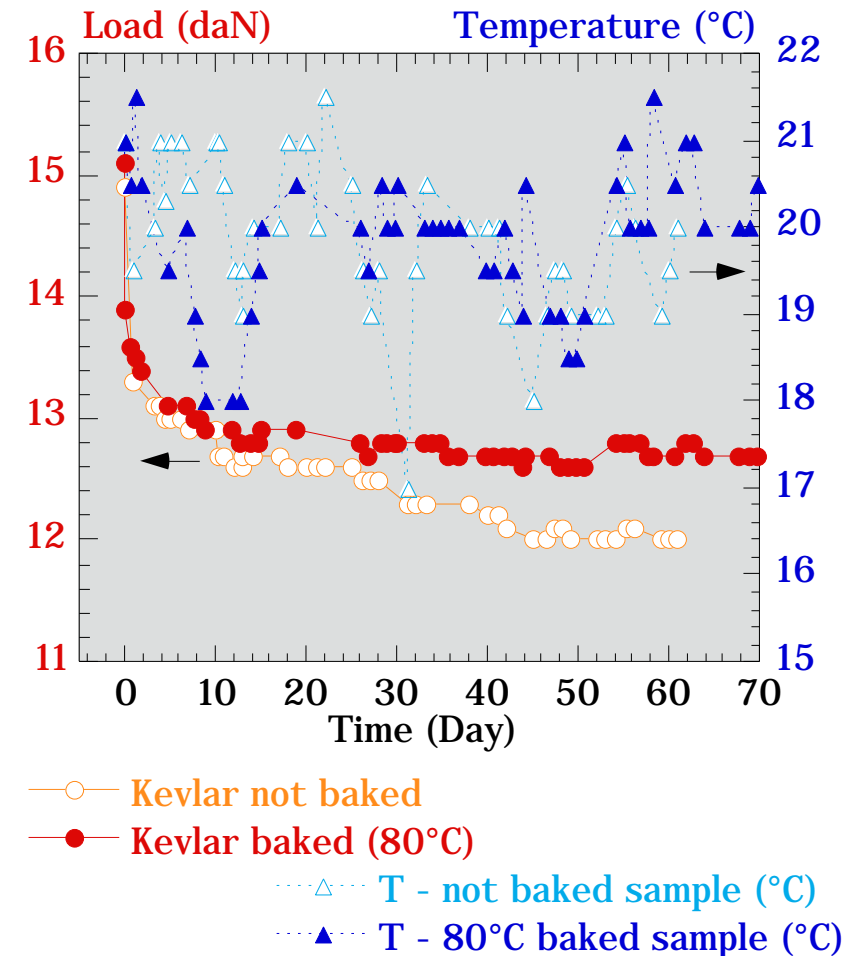
Thermal & mechanical properties

	Nylon	S. Steel	Ta6V	Kevlar 29
(MPa)	100	550	875	1600
Y (MPa)	3000	200 000	110 000	65 000
$I = \frac{2}{0.3} k d T$	$5.9 \cdot 10^{-5}$	$2 \cdot 10^{-3}$	10^{-3}	$7 \cdot 10^{-5}$
$Y^{0.5} / I$	$0.9 \cdot 10^8$	$1.2 \cdot 10^8$	$2.9 \cdot 10^8$	$58 \cdot 10^8$

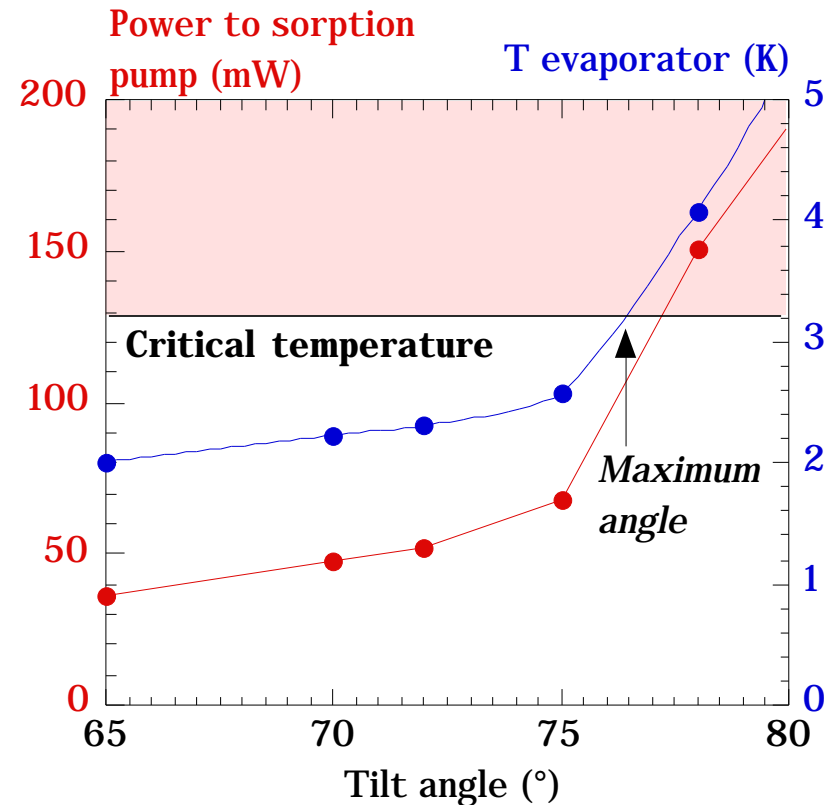
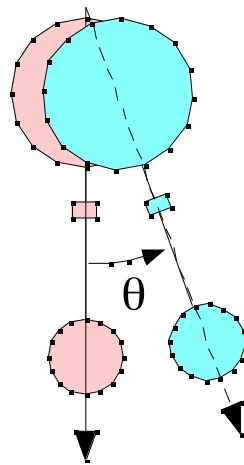
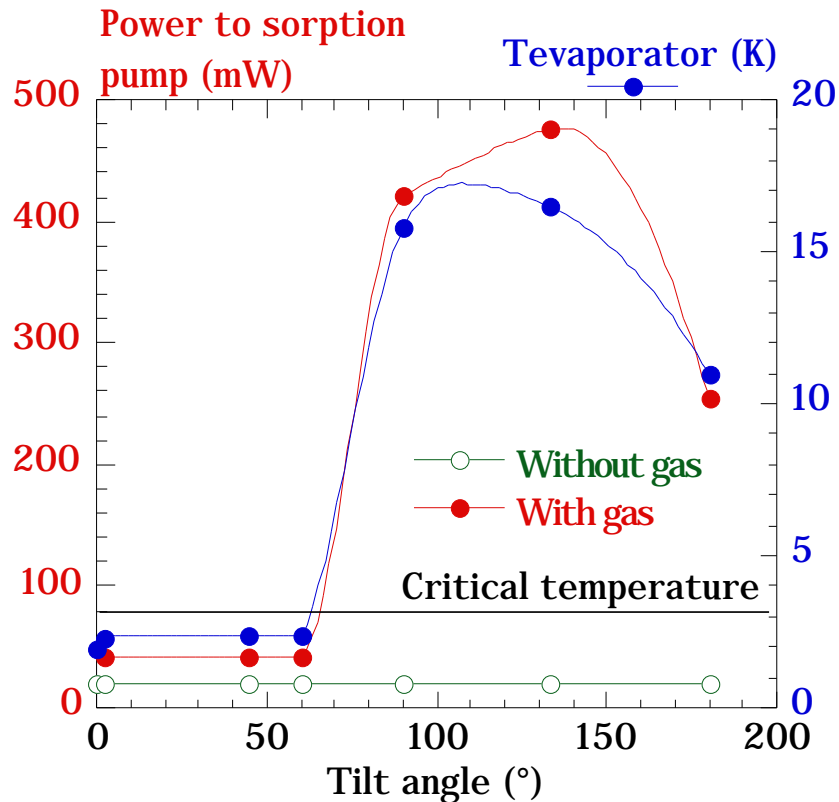
Creep ?



Δ tension 10% = 22 years

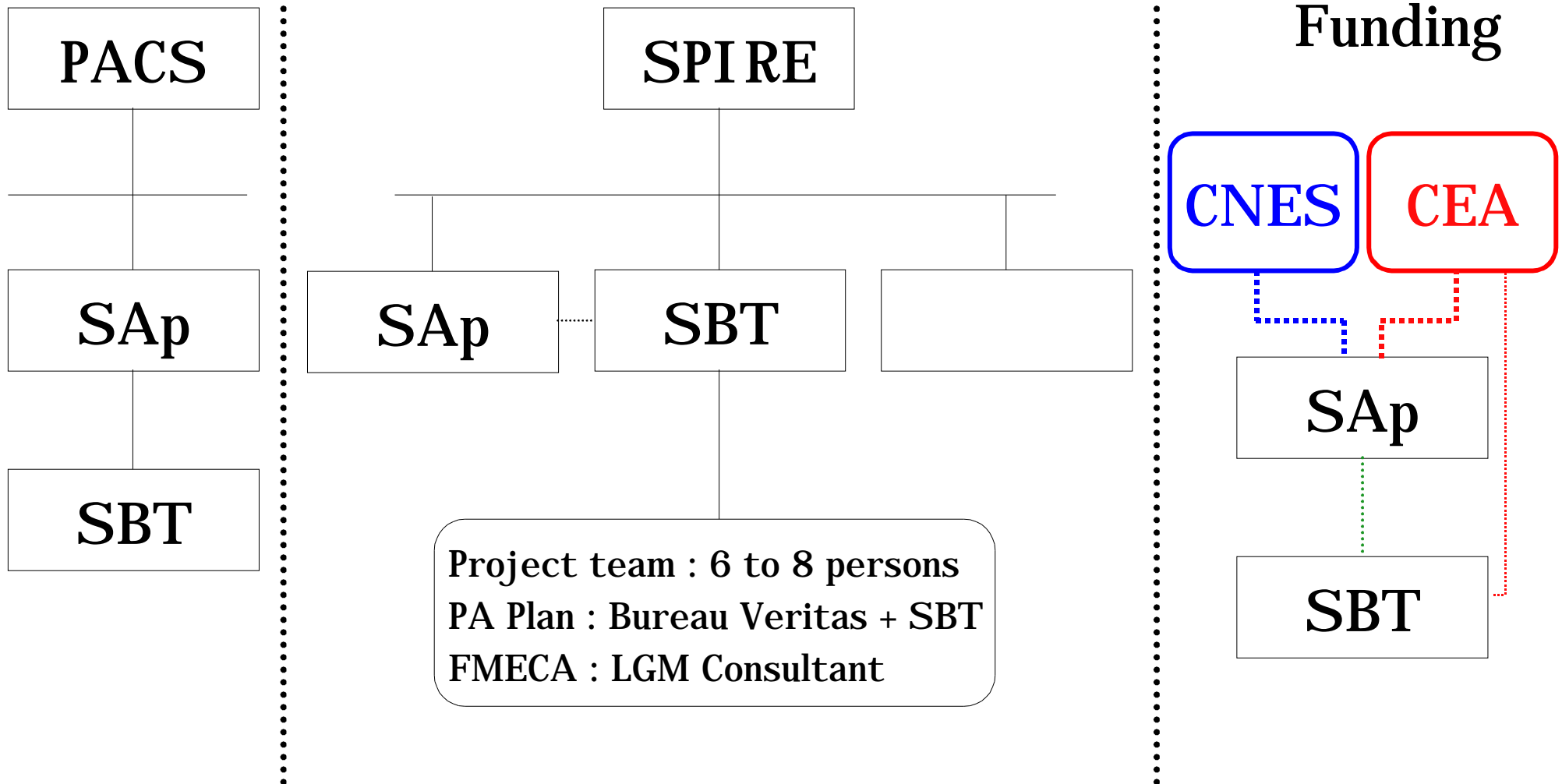


Strong impact for ground tests (only) !



Recycling only possible in a cone 150° angle

ORGANISATION



TASKS AND RESPONSABILITIES

SBT OVERAL RESPONSABILITIES :

- **Design / sizing : SBT**
- **General 3D design (Solid Works) : SBT**
- **Detailed drawings : Sub contracted**
- **Machining : Sub contracted**
- **Assembling : Sub contracted**
- **Pre tests (mechanical) : SBT**
- **Thermal qualification tests : SBT**
- **Environmental tests (baking, Vibration) : Sub contracted**
- **PA Plan : SBT + Sub contracted**
- **FMECA : Sub contracted**
- **Project management : SBT**

MODEL PHILOSOPHY

7 models to be developed

SPIRE

- STM
- CQM
- PFM

PACS

- STM
- CQM
- PFM

•• FS

STM : validation Kevlar suspension system + integration, etc...

CQM : mechanical and thermal validation

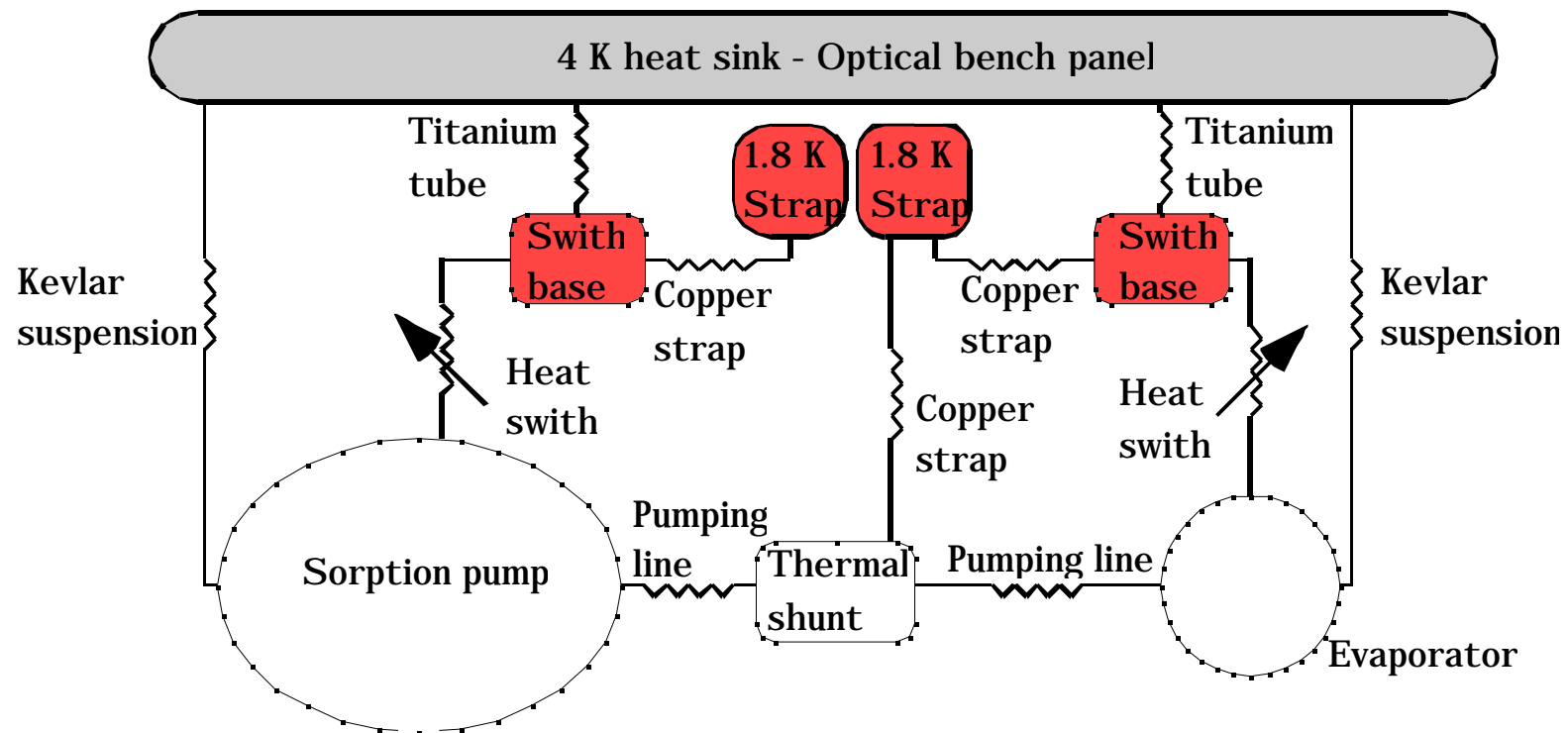
PFM : flight model

FS : flight spare (+ "CQM refurbishment")

MAIN SPECIFICATIONS

- 10 μ W net heat lift @ 290 mK
- preferred cycle : 2 h / 46 h (96% usefull) (or n x 24h)
- < 1.7 kg
- volume : 100 x 100 x 230 mm
- **mechanical interface : 4 K**
- **thermal interface : 1.8 K**
- energy per cycle : < 860 J + 0.6 mW (architecture 4 K - 1.8 K)
- **SPIRE/PACS compatibility**

SPIRE/PACS : THERMAL ARCHITECTURE



- **Interfaces**

- SPIRE/PACS compatibility : OK
- thermal strap: OK
- electrical interface : OK

- **Development Plan**

- OK , fully compatible with project plan

- **Test Plan**

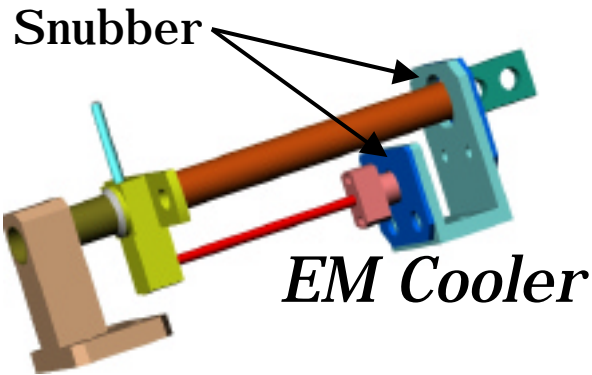
- OK, in progress (heritage ESA TRP)

- **Test Cryostat**

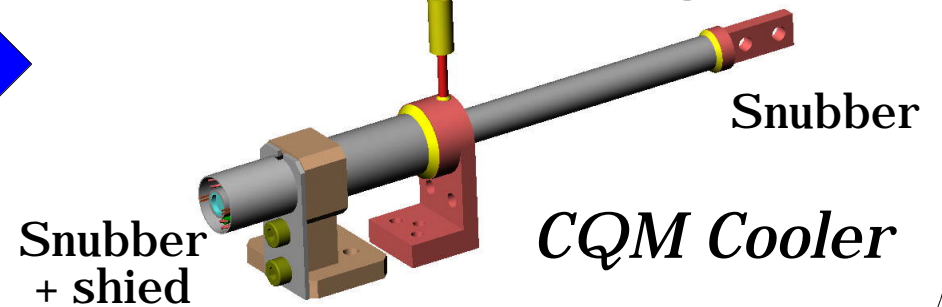
- available (loan ESA)

MAIN EVOLUTION/CHANGES FROM EM COOLER (ESA TRP)

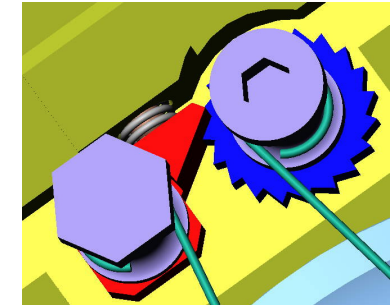
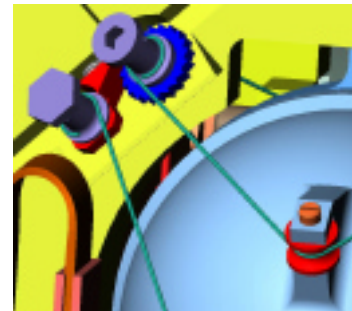
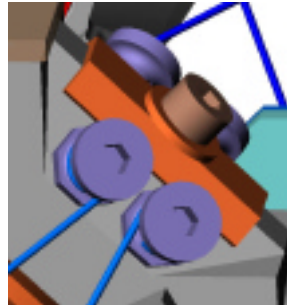
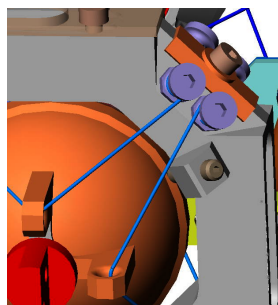
Gas Gap Heat Switch



In Line design



Kevlar tensioning - locking mechanism - pulley



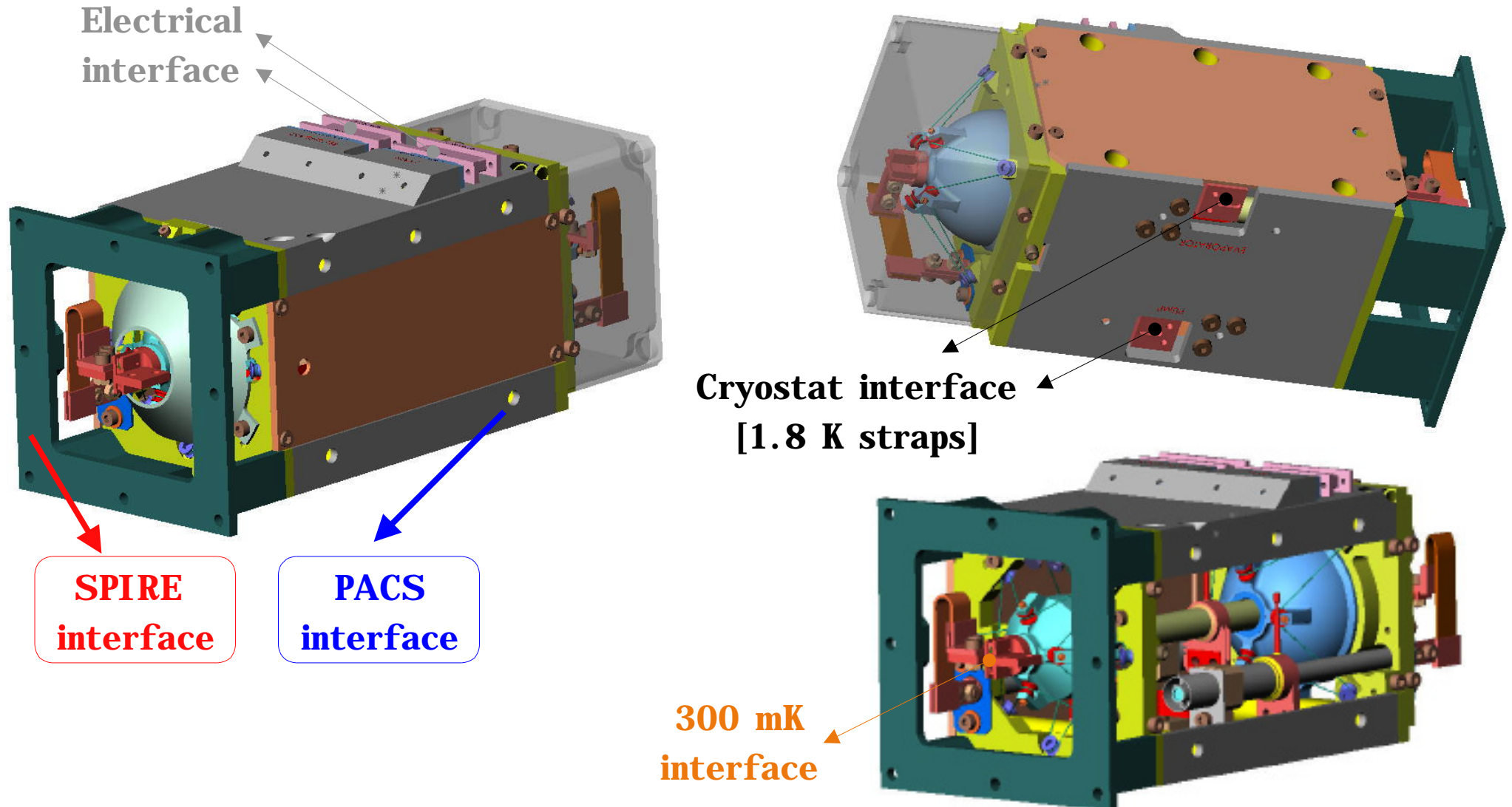
Cooler size

4 liters STP



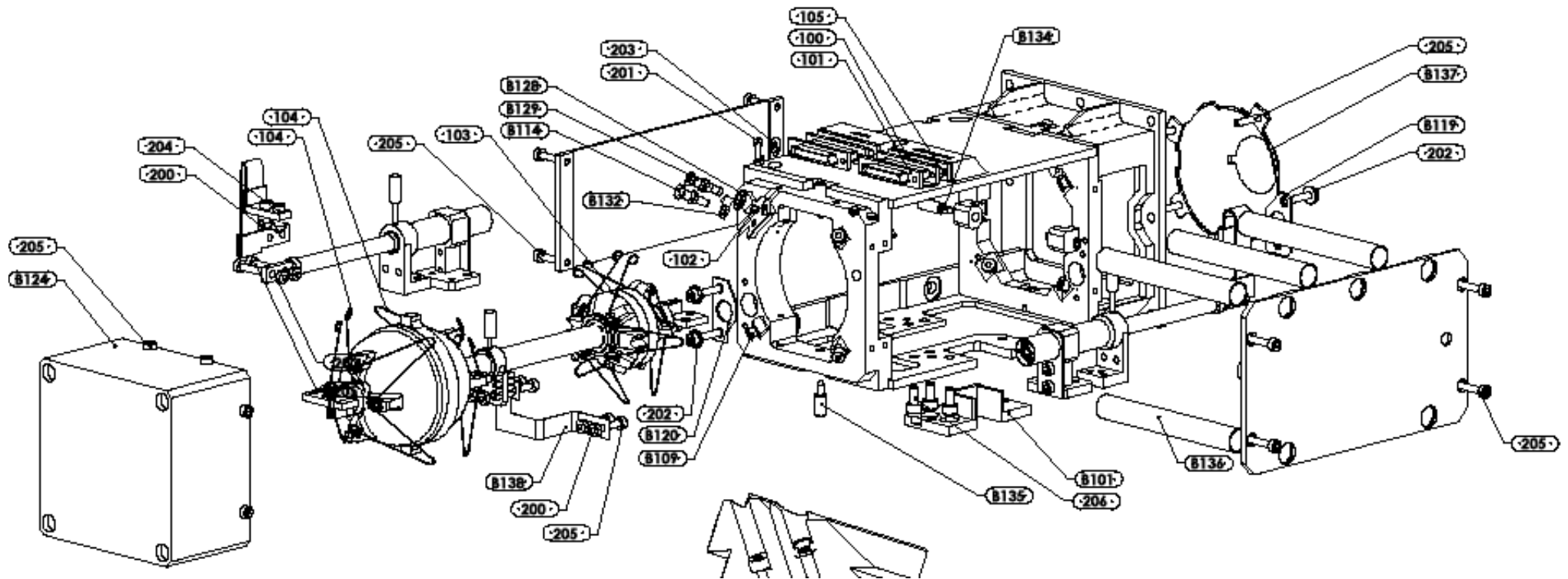
6 liters STP

OVERAL 3D VIEW



EXPLODED VIEW

Sorption cooler Kit



[Glue not included]

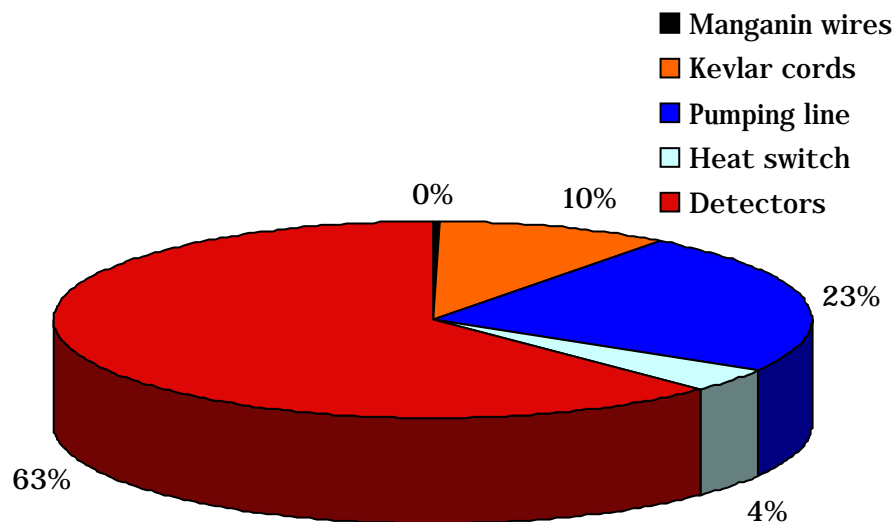
MAIN FEATURES

- 6 liters TPN
- Gas gap heat switches included
- Suspension system with Kevlar cords
- Snubbers and launch stops
- Protective caps (no internal access - "foolproof")
- Volume : 228.5 x 100 x 100 mm
- Mass : 1680 g
- Internal pressure 8 MPa (80 bars)
- 760 Joules per cycle

EXPECTED THERMAL PERFORMANCE

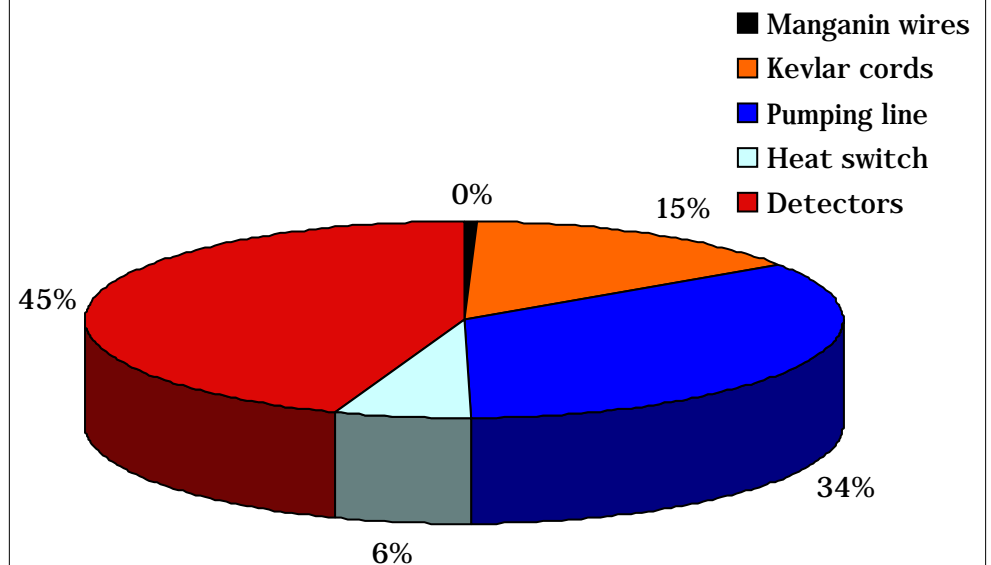
Two cases

46 hours hold time



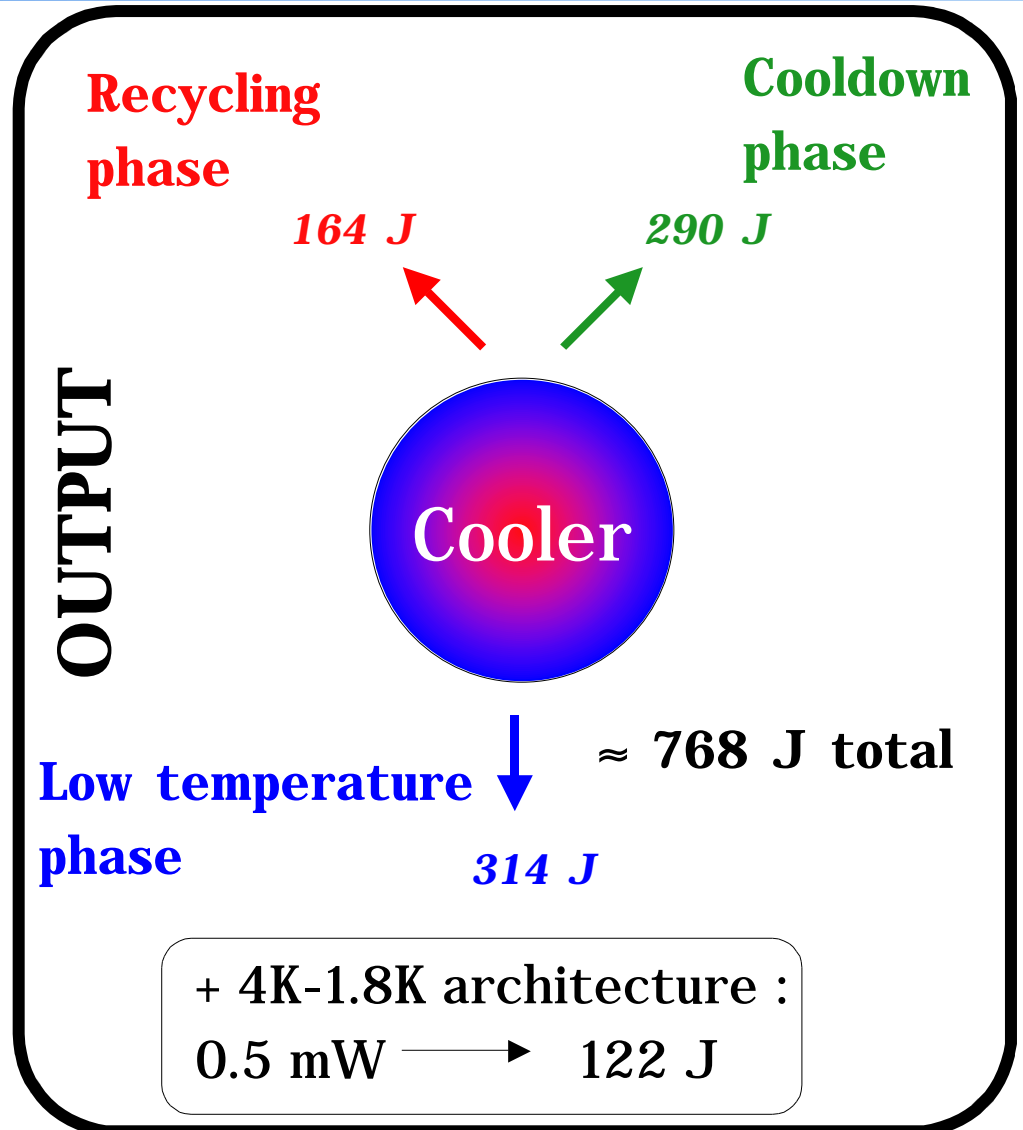
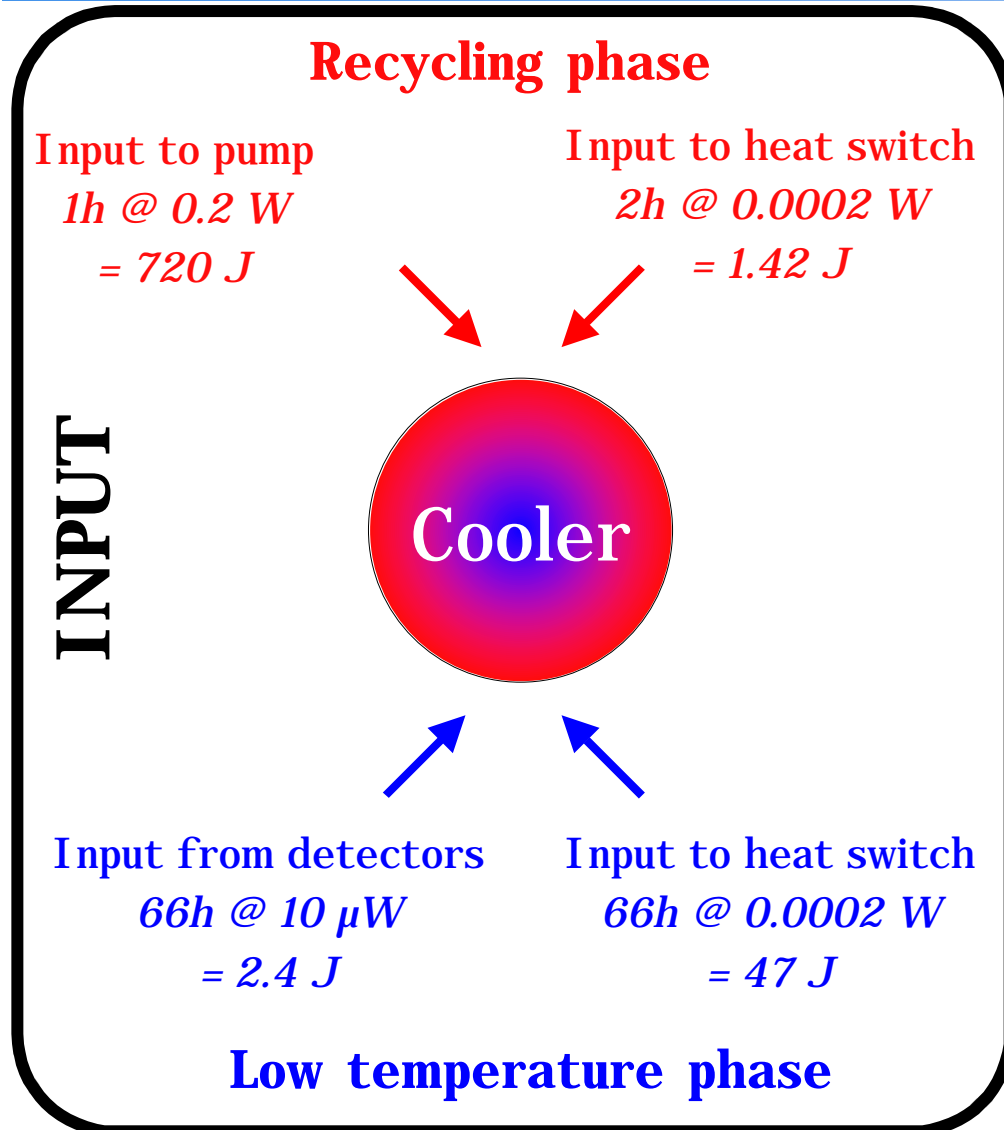
20 μW @ 300 mK net heat lift
 96% duty cycle efficiency
 758 J total - 4.4 mW average

10 μW net heat lift



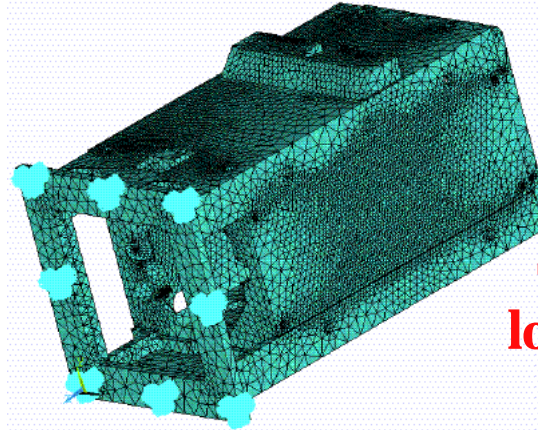
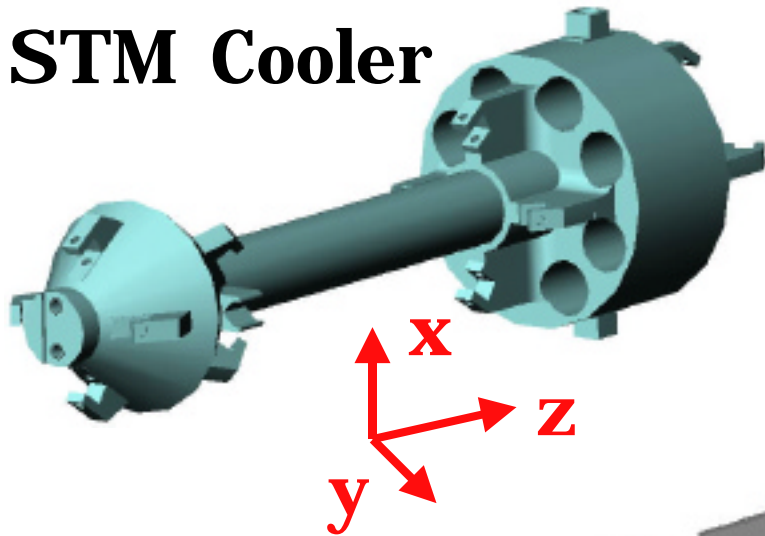
66 hours hold time @ 290 mK
 97% duty cycle efficiency
 771 J total - 3.1 mW average

EXPECTED THERMAL PERFORMANCE ENERGY BUDGET (10 μ W case)



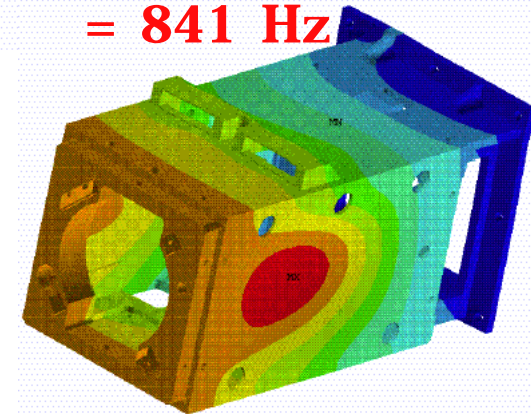
EXPECTED MECHANICAL PERFORMANCE

STM Cooler



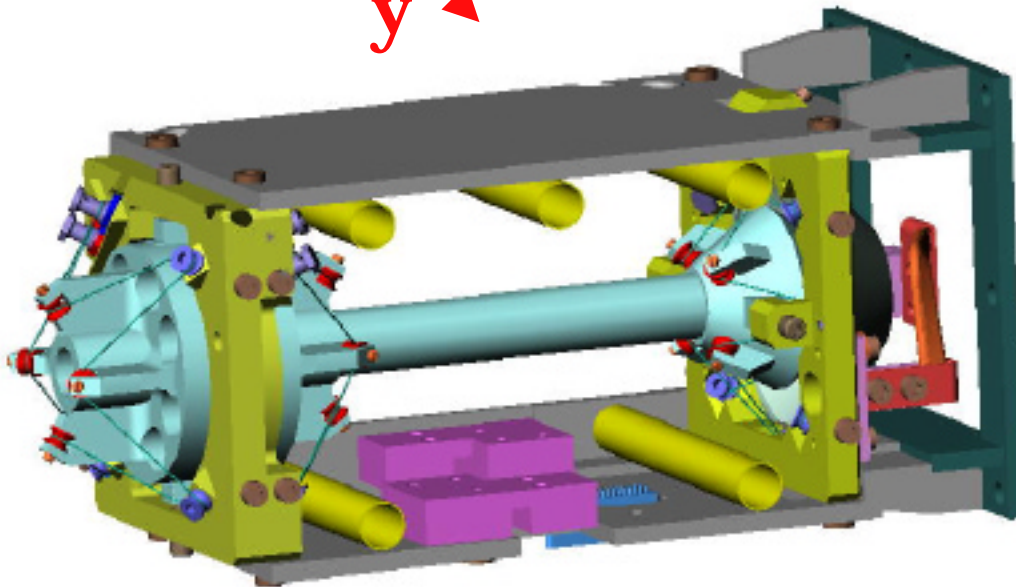
Full numerical modelling of cooler in progress.

Structural box
lowest frequency
= 841 Hz



```

ANSYS 5.7
APR 23 2001
11:41:05
NODAL SOLUTION
STEP=1
SUB =1
FREQ=840.863
USUM (AVG)
RST5=0
PowerGraphics
EFACET=1
AVRES=Mat
DMX =1.801
SMX =1.801
0
0
.200058
.400115
.600173
.80023
1
1.2
1.4
1.6
1.801
  
```



Cooler heart expected resonant frequencies

	Sorption pump	Evaporator
$f_{x,y}$	566	471
f_z	557	465

- **PA requirements implemented**
 - Potential risks & hazards identification done
(*CIL under construction*)
 - Material evaluation program started (Kevlar)
 - Critical processes identification done
 - Subcontractors being evaluated
 - Non conformance reporting system implemented
 - Configuration control system started
(*database created*)

PA PLAN

QA doc. Name	completion	status
PA Plan	released	under review
DML/DPL	released	under review
H/W tree	released	under review
MAIV Flow Chart	released	under review
Detail Planning	released	under review

FMECA currently being reviewed

Component	Redunded	Comments
cooler	No	
Heat switch	No	<i>Would impact performance Added complexity Reduction of reliability</i>
Kevlar cord	No	<i>Numerical modeling in progress (failure of any one cord is OK ?)</i>
Connections (screws)	Yes	<i>All mechanical interfaces feature two mounting holes</i>
Heater	Yes	<i>Two independant command circuit</i>
Thermometer	Yes	<i>Idem above</i>

DEVELOPMENT PLANNING

CQM & STM

2001

2002

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
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Detailed drawings

Machining

Assembling

Test plan (therm. + environ.)

Delivery

PFM & FS

2002

2003

Spring	Summer	Autumn	Winter	Spring	Summer
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Machining

Assembling

Delivery PFM

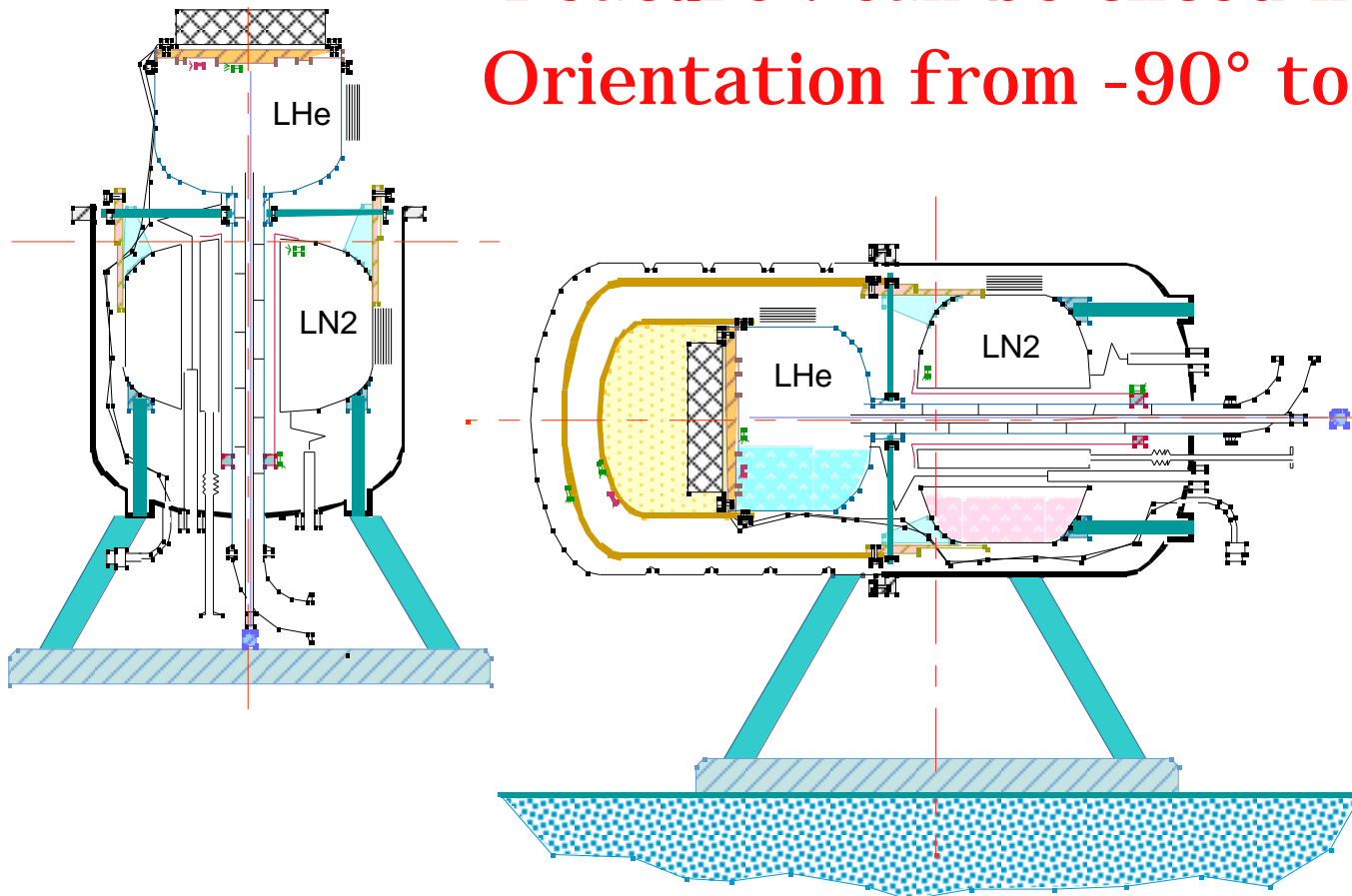
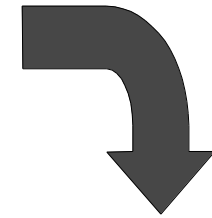
Qualification PFM

Delivery FS

Qualification FS

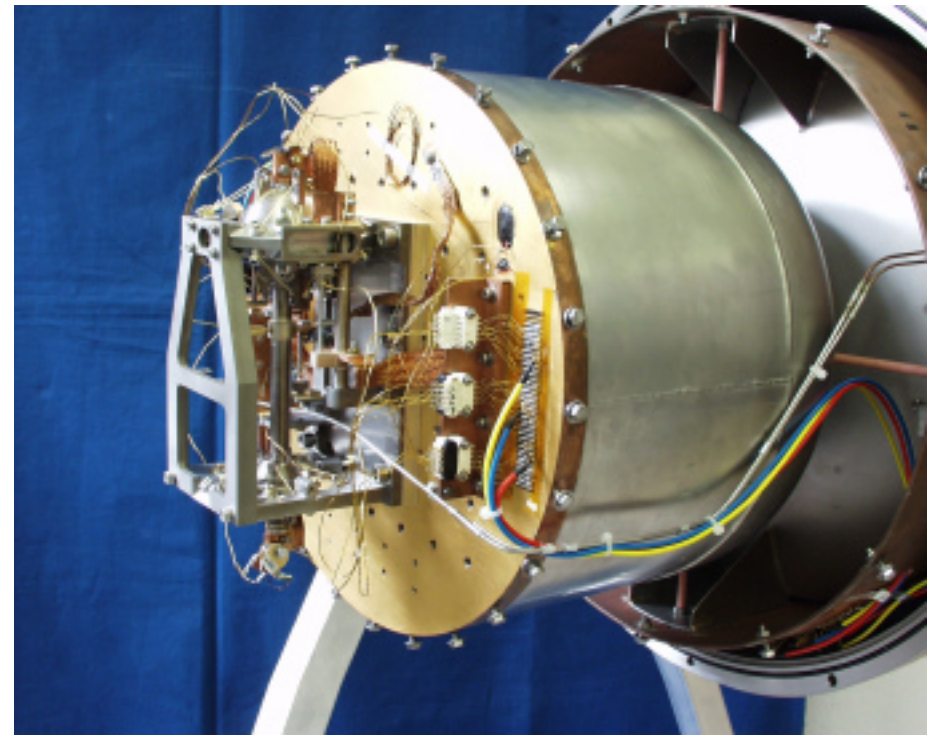
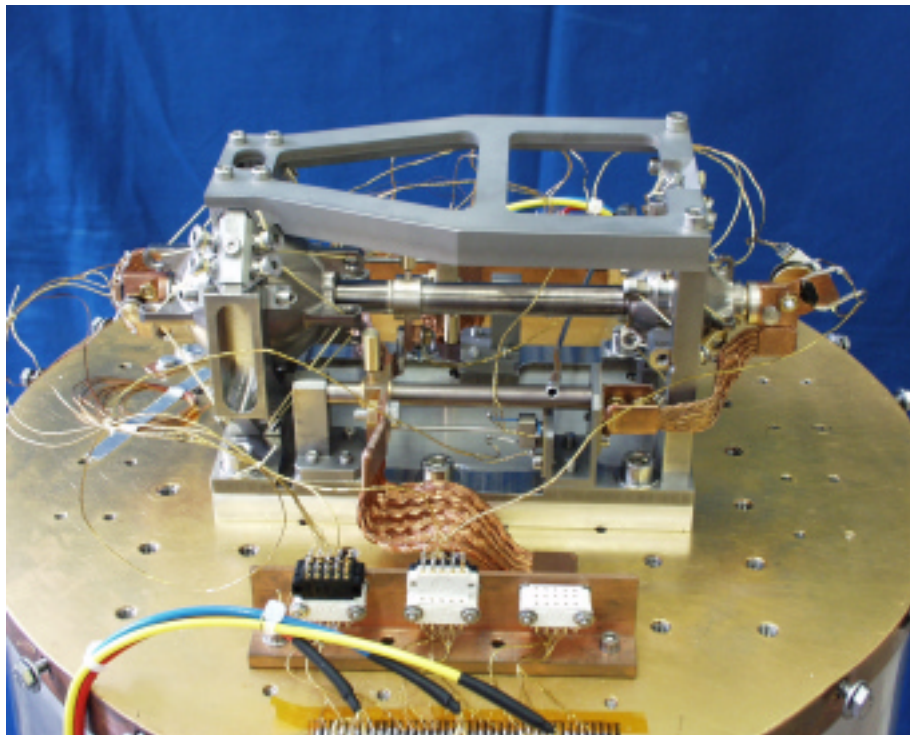
TEST CRYOSTAT : CRYOTEDI

Feature : can be tilted in any
Orientation from -90° to $+90^\circ$



Cooler operation
with or against
gravity can be
tested

CRYOTEDI & EM COOLER



NEED ATTENTION

- **1.8 K straps (interface cryostat)**
interface "quality" ↔ cooler performance
- **300 mK strap**
SBT not in charge, but...
- **Kevlar suspension**
adjustment and tension control
- **Mechanical Environment**
Foreseen levels not acceptable (125 Grms)
- **Model philosophy**
Refurbished CQM versus FS ? TBD

NEAR FUTURE

- **Cooler Detailed Design Review (DDR)**
 - May 17th, Grenoble
- **Cooler manufacturing**
 - after DDR
- **Kevlar characterisation**
 - in progress
- **Tensiometer**
 - soon



THE END