5th Joint HiLumi LHC-LARP Annual Meeting 2015

Cryo infrastructures for Crab Cavities tests at SPS

Progress and perspectives

Features

- Introduction
- Main principles and basic process analysis for installation of the cold box at the surface or underground
- Proximity cryogenics for Crab Cavities modules
- Cryo schedule with main phases for SM18 tests & BA6
- Others & summary

Introduction

- Situation in last November'14: cryogenics for crab cavities in BA4

Significant part of equipment installation work at BA4 was done during LS1, regarding 2K cooling capability.

- The 2K helium pumps have been installed in the SPS cavern at BA4
- Cooling water circuits installed for pumps cooling – EN/CV support
- Electrical supply pulled from surface to TA4 and BA4 alcove –EN/EL support
- Control racks installed in TA4 (shaft bottom area) – TE/CRG
- Ethernet network pulled and installed underground for control system – IT support

- Decision to go to SPS-BA6 was thereafter taken => new integration study and impact on initial cryo planning

Main principles and basic process analysis

- 2 options studied to chose cold box location
  - Underground, in cavern – 60m horizontal transfer line from cold box to client
  - Surface, in BA6 – 120m vertical transfer line from cold box to client

- Compressor station location
  - In both cases, it stays at surface level in BA6

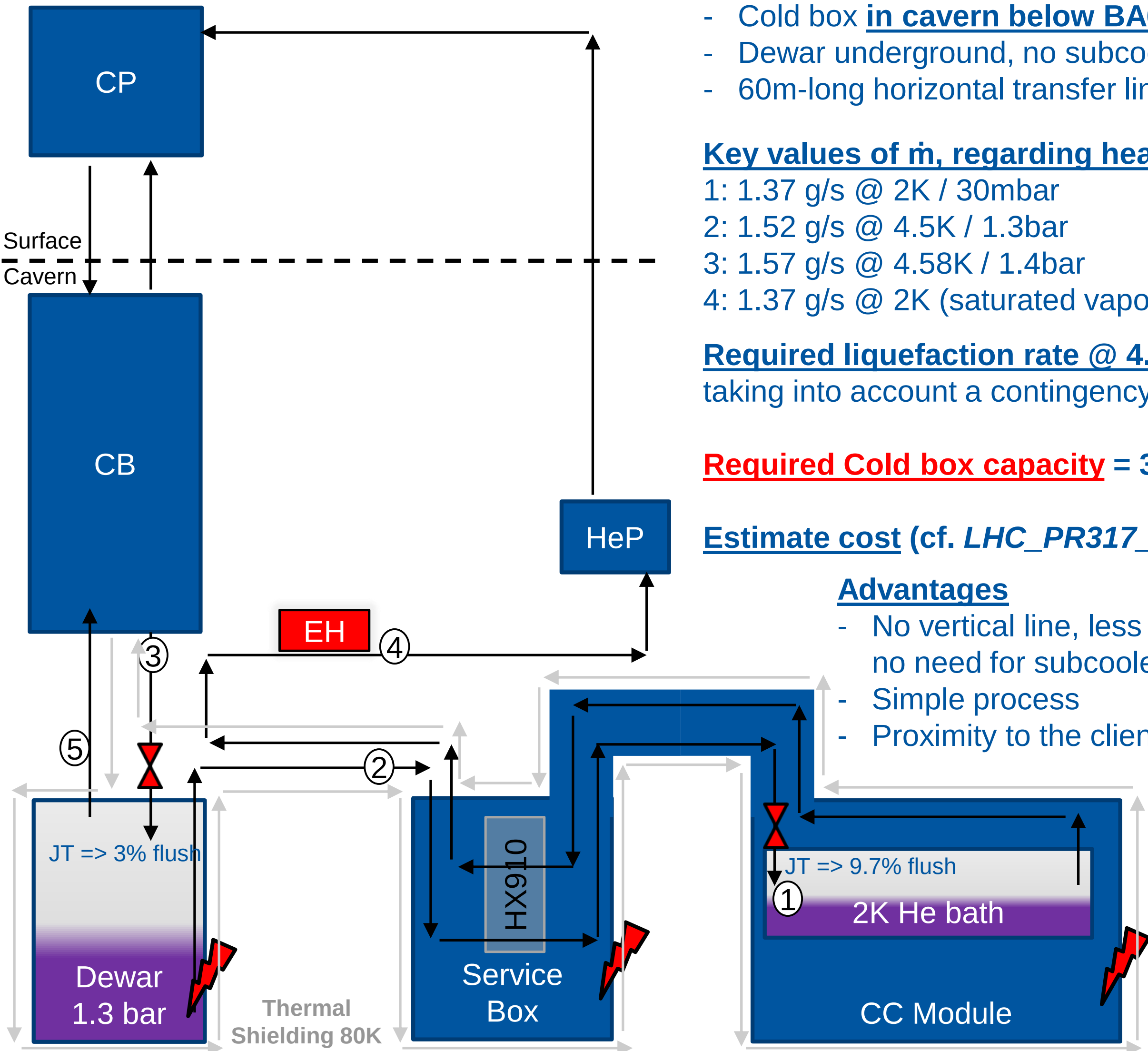
- About heat loads and refrigeration capacity requirements
  - They will be assessed and summarized in the following slide
  - They are coherent with analysis from KEK meeting / Nov'14
  - Since then:
    - Adding of a transfer line => slight increase in heat load budget
    - Screening done no more by LN_2, but by GHe @ 50K provided by the cold box

Heat loads and refrigeration capacity requirements

COLD BOX IN CAVERN						
Component	**@ 2K**		**@ 4.5K**		**@ 50K-80K**	
	Heat load	**Refrigeration capacity requirement**	**Heat load**	**Refrigeration capacity requirement**	**Heat load**	**Refrigeration capacity requirement**
Service Module	/	/	2.5W @ 4.5K	0.13 g/s of LHe @ 4.5K	30W @ 80K	0.19 g/s of GHe @ 50K
Buffer tank	/	/	1.5W @ 4.5K	0.08 g/s of LHe @ 4.5K	20W @ 80K	0.13 g/s of GHe @ 50K
Cryo Module Static	18.6W @ 2K	0.80 g/s of LHe @ 2K	/	/	286W @ 80K	1.84 g/s of GHe @ 50K
Cryo Module Dynamic	13.4W @ 2K	0.57 g/s of LHe @ 2K	/	/	30W @ 80K	0.19 g/s of GHe @ 50K
Transfer Lines	/	/	4W @ 4.5K	0.21 g/s of LHe @ 4.5K	/	/
60m-transfer line for remote location of cold box	/	/	6W @ 4.5K	0.32 g/s of LHe @ 4.5K	78W @ 80K	0.50 g/s of GHe @ 50K
TOTAL	**32W @ 2K**	**1.37 g/s of LHe @ 2K**	**14W @ 4.5K**	**0.74 g/s of LHe @ 4.5K**	**444W @ 80K**	**2.85 g/s of GHe @ 50K**
Equiv @ 4.5K		= 1.52 g/s of LHe @ 4.5K		= 0.74 g/s of LHe @ 4.5K		= 0.26 g/s of LHe @ 4.5K
Required Cold box capacity	= 2.52 g/s of LHe @ 4.5K					
With security factor of 1.5	**3.78 g/s of LHe @ 4.5K = 118 L/h of LHe @ 4.5K**					

COLD BOX AT SURFACE						
Component	**@ 2K**		**@ 4.5K**		**@ 50K-80K**	
	Heat load	**Refrigeration capacity requirement**	**Heat load**	**Refrigeration capacity requirement**	**Heat load**	**Refrigeration capacity requirement**
Service Module	/	/	2.5W @ 4.5K	0.13 g/s of LHe @ 4.5K	30W @ 80K	0.19 g/s of GHe @ 50K
Buffer tank	/	/	1.5W @ 4.5K	0.08 g/s of LHe @ 4.5K	20W @ 80K	0.13 g/s of GHe @ 50K
Cryo Module Static	18.6W @ 2K	0.80 g/s of LHe @ 2K	/	/	286W @ 80K	1.84 g/s of GHe @ 50K
Cryo Module Dynamic	13.4W @ 2K	0.57 g/s of LHe @ 2K	/	/	30W @ 80K	0.19 g/s of GHe @ 50K
Transfer Lines	/	/	4W @ 4.5K	0.21 g/s of LHe @ 4.5K	/	/
120m-vertical line for remote location of cold box	/	/	12W @ 4.5K	0.64 g/s of LHe @ 4.5K	156W @ 80K	1.0 g/s of GHe @ 50K
TOTAL	**32W @ 2K**	**1.37 g/s of LHe @ 2K**	**20W @ 4.5K**	**1.06 g/s of LHe @ 4.5K**	**522W @ 80K**	**3.35 g/s of GHe @ 50K**
Equiv @ 4.5K		= 1.52 g/s of LHe @ 4.5K		= 1.06 g/s of LHe @ 4.5K		= 0.31 g/s of LHe @ 4.5K
Required Cold box capacity	= 2.89 g/s of LHe @ 4.5K					
With security factor of 1.5	**4.34 g/s of LHe @ 4.5K = 143.7 L/h of LHe @ 4.5K**					

Scenario 1: cold box in cavern



Assumptions

- Cold box **in cavern below BA6**, producing **He_{liq} @ 1.4bar / 4.58K**
- Dewar underground, no subcooler
- 60m-long horizontal transfer line from CB to « clients »

Key values of ṁ, regarding heat load at 2K

1: 1.37 g/s @ 2K / 30mbar
2: 1.52 g/s @ 4.5K / 1.3bar
3: 1.57 g/s @ 4.58K / 1.4bar
4: 1.37 g/s @ 2K (saturated vapour)
5: 0.20 g/s @ 4.5K (saturated vapour)

Required liquefaction rate @ 4.5K = **3.78 g/s** (regarding all heat loads, and taking into account a contingency factor of 1.5)

Required Cold box capacity = 3.90 g/s = 118 L/h ⇔ 394W @ 4.5K

Estimate cost (cf. *LHC_PR317_Economics* & inflation): 1.40 MCHF

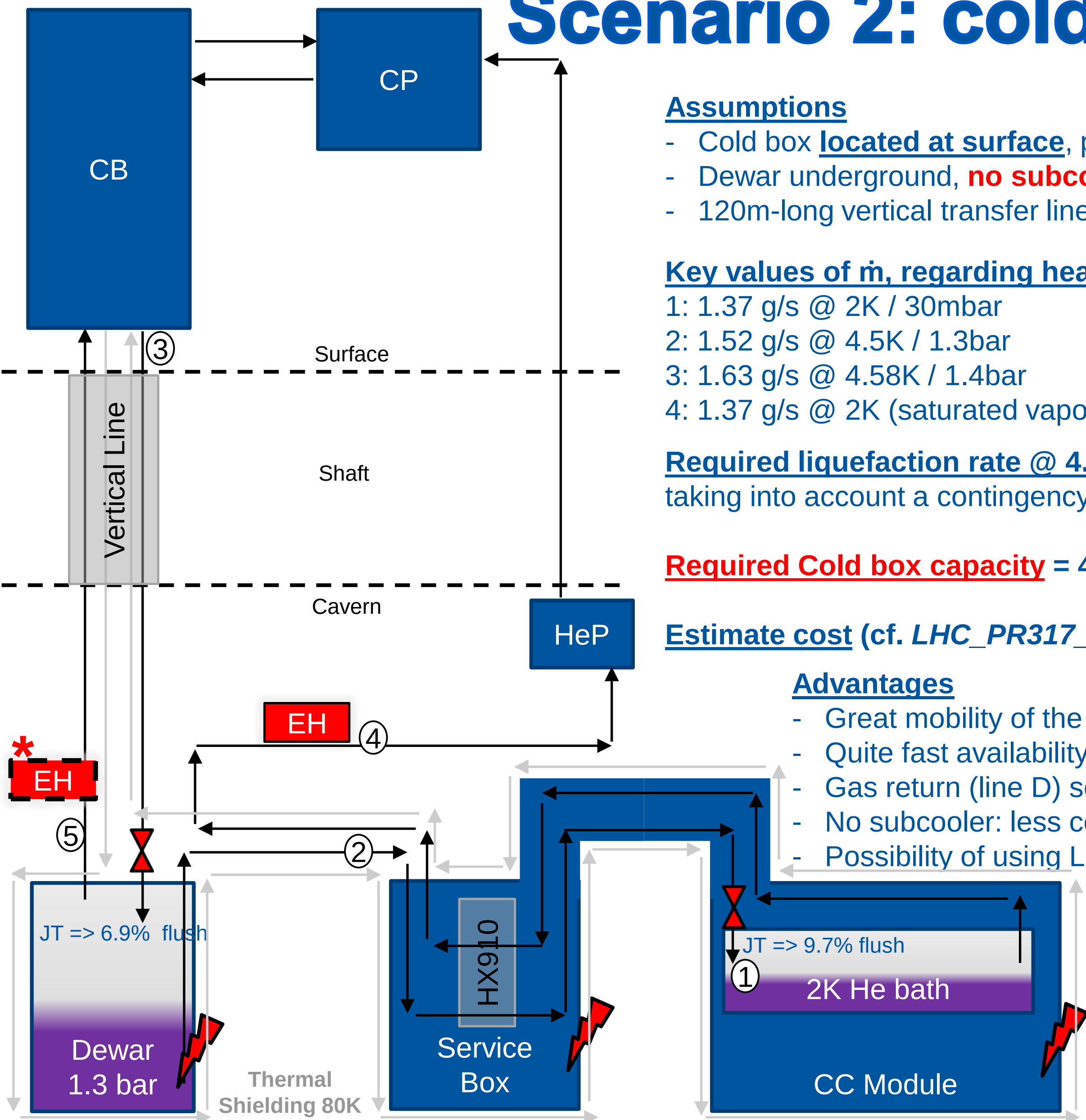
Advantages

- No vertical line, less heat loads, no hydrostatic compression problem, no need for subcooler, no biphasic instabilities at cold box return
- Simple process
- Proximity to the client

Disadvantages

- Still reduced mobility, even in the cavern
- No use of LN_2 underground

Scenario 2: cold box at surface



Assumptions

- Cold box **located at surface**, producing **He_{liq} @ 1.4bar / 4.58K**
- Dewar underground, **no subcooler**
- 120m-long vertical transfer line

Key values of ṁ, regarding heat load at 2K

1: 1.37 g/s @ 2K / 30mbar
2: 1.52 g/s @ 4.5K / 1.3bar
3: 1.63 g/s @ 4.58K / 1.4bar
4: 1.37 g/s @ 2K (saturated vapour)
5: 0.40 g/s @ 4.5K (saturated vapour)

Required liquefaction rate @ 4.5K = **4.34 g/s** (regarding all heat loads, and taking into account a contingency factor of 1.5)

Required Cold box capacity = 4.66 g/s = 143.7 L/h ⇔ 471W @ 4.5K

Estimate cost (cf. *LHC_PR317_Economics* & inflation): 1.56 MCHF

Advantages

- Great mobility of the CB as located at surface
- Quite fast availability for the manufacturer
- Gas return (line D) screening the inlet liquid flow (line C)*
- No subcooler: less complicated process
- Possibility of using LN_2

Disadvantages

- Vertical line in the shaft

Our needs for cold box integration

Minimal volume in one-piece (cold box): [L(2.6m) × W(1.8m) × H(2.6m)] = 12.2 m^3 ; 2.5 tons

Accessibility: 1m width needed around cold box for operation/maintenance, + 1m above (removability of top plate for turbine maintenance in particular)

About horizontality: not for standard refrigerators, to be discussed with manufacturer

Utilities:
- Electricity (400V, and 24V for control-command)
- Water (cooling of 2 K pumping units, turbines circuits, raw water only)
- Compressed air (8 bar, dry air, mainly for regulation valves)

Cryo-line: 1 single vacuum-insulated transfer line for both liquid and screening He (+ gas returns)

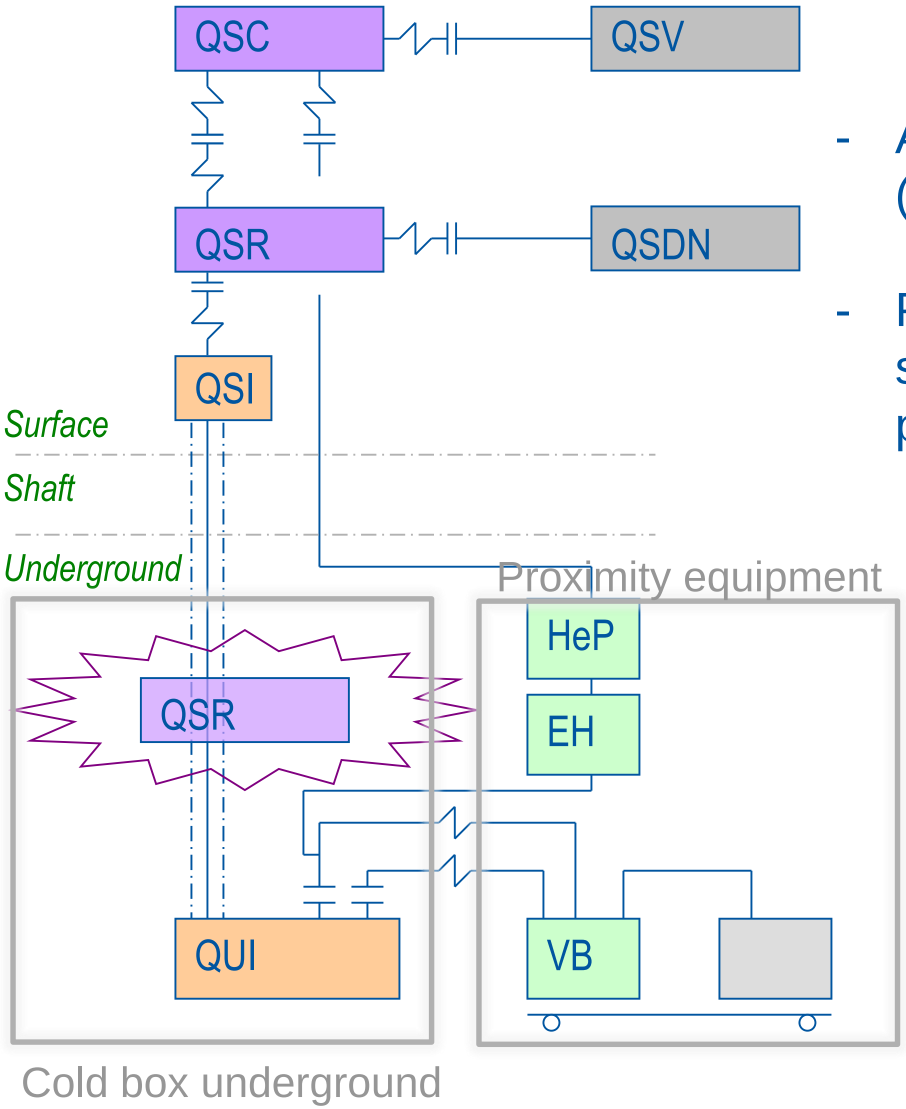
Decision for *final location* of cold box still underway (wrt integration study – on-site visit at YETS the latest)

Selected from market existing standard design refrigerators (available from manufacturers)

Air Liquide: HELIAL Liquefiers (Helial LL)
- from 110 to *145 L/h w/o LN_2 precooling*
- from 215 to 300 L/h with LN_2 precooling
- *Beware: no thermal shielding circuit at 50-80K*

Linde Kryotechnik: L-Series (L280)
- from 100 to *145 L/h w/o LN_2 precooling*
- from 200 to 290 L/h with LN_2 precooling
- *Thermal shielding circuit at 50-80K*

Proximity Cryogenics for Crab Cavities modules



- As cold box will require Dewar to be tested (reception test in SM18), both are grouped
- Proximity cryo equipment stands for the service module and the EH on VLP + He pumps

Proximity Cryogenics for Crab Cavities modules

Proximity equipment: CC service box, flexible double channel transfer line, VLP helium return heater.

<u>Status</u>:

- Technical specification advanced to 70-80%
- Equipment to be ordered by the beginning of 2016

<u>Current work</u>: interfaces design definition and “delicate” parts design e.g. top plate of the CC service box, safety devices

<u>Next steps</u>: definition and design of SM18 adaptation for three type of clients to be tested:

  - first CC prototype module to be tested with CC service box,
  - second CC prototype to be tested with direct connection to SM18 infrastructure,
  - Final LHC design (with different interface than prototypes) to be tested with direct connection to SM18 infrastructure

Crab cavity cryo module – instrumentation

Recall: Crab cavities cryo-module will be operated in saturated helium bath at 2 K

Level measurement: 2 supra gauges installed in dedicated helium channel connected to the bath – the gauges will 100% of the bath depth measurement, connecting cables are planned to be routed in the double phase collector, connector to outside placed on CC service box side

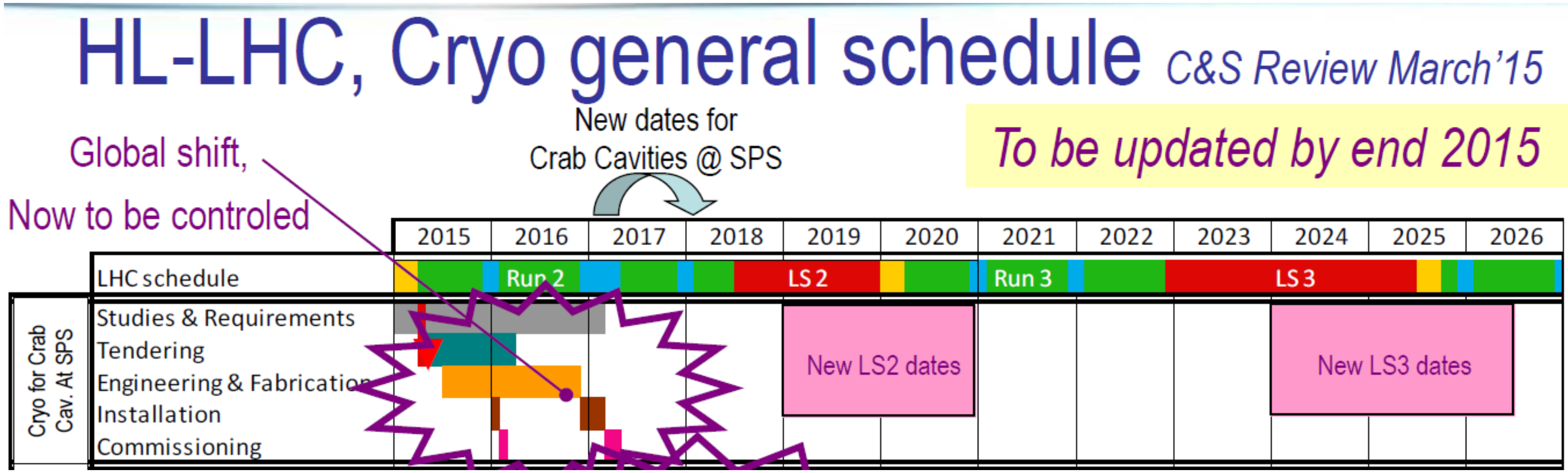
Pressure measurement: 1 gauge connected on the double phase gas volume (possibly in the jumper)

Temperature measurement: 12 CERNOX thermometers placed on the helium tanks and HOM – exact place to be defined, installed by means of screwing

Electrical heaters: 2 x 50 W electrical heaters glued on copper supports then screwed to the bottom of the helium tanks

More information will be given during next CC review on November, 10^{th} and 11^{th} by K. Brodzinski

Cryo Schedule



see S.Claudet presentation

- The change of SPS location from BA4 to BA6 has an impact on initial cryo planning
  - Modification of design of the main components
  - Relocation of already installed at BA4 equipment is necessary
  - New integration study crosschecked with technical solution is necessary for BA6
- Global planning update is necessary to fit cryogenic activities in the global schedule
- Work on SM18 test preparation to be integrated in planning with details with the first priority

Summary

- Integration study / work underway, progressing well
- Uninstallation of cryo equipment from BA4 this YETS (2015) (among them, He pumps, electrical cabinet, utilities cables, etc.)
- Installation in BA6 scheduled for next year end stop (EYETS 2016)
- Work on SM18 test preparation to be integrated in planning with details with the first priority

THANK YOU FOR YOUR ATTENTION