What repair activity can be done today on a locally warmed-up sub-sector ?

Paul Cruikshank on behalf of TE/VSC

The Issues….

What repair activities on a locally warmed-up subsector

What is a local warm-up ?

What repairs can be done ?

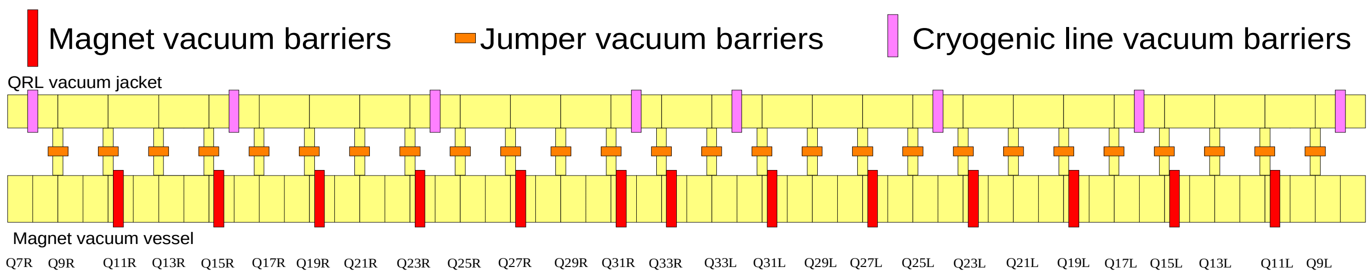
Is there a time gain?

What are the problems and risks?

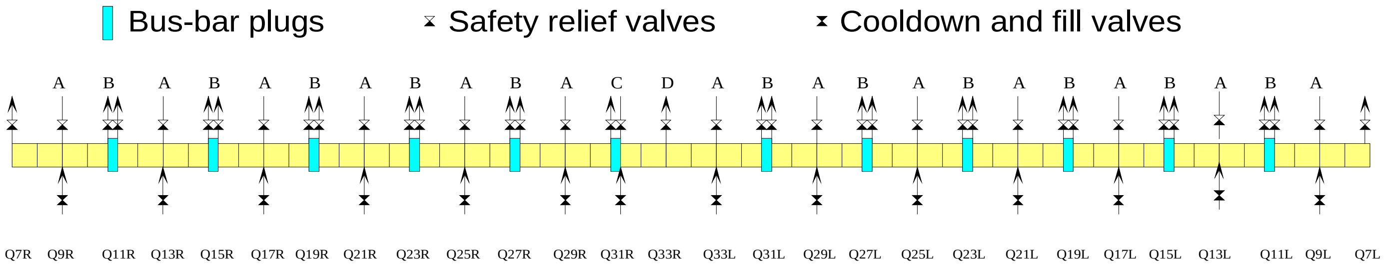
..local warm-up was always foreseen

LHC Arc: Cryogenic and Insulation Vacuum Baseline design

Insulation Vacuum sectorization:



Cold-mass sectorization:

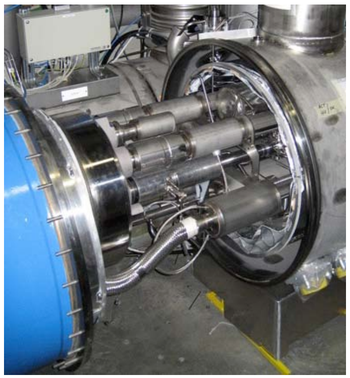


2.8 km magnet cryostat has 13 vacuum barriers

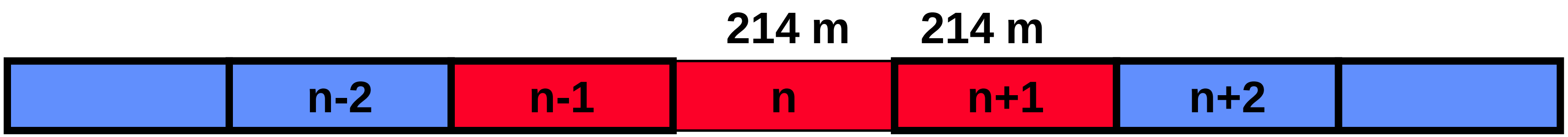
Warm helium, fed via the QRL, is used to locally warm the cryomagnets

Baseline 'local warm-up' in insulation vacuum sub-sectors

- Repairs at interconnects on cold mass volume (diode, busbar, splice, helium leak, IFS, line N) or instrumentation.



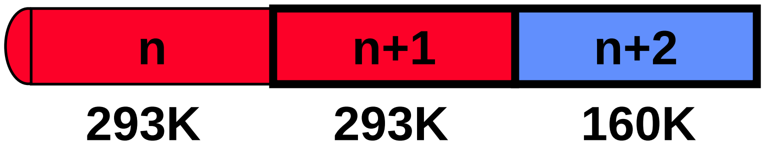
But..
not foreseen on:
a) beam vacuum (see later)
Or
b) circuits without valves line c',k,e,x,y (Serge talk)



- Scenario from LHC Project Report 60, Sept 2000
  - n-2…. floating, cold, under vacuum
  - n-1 thermal buffer, RT, under vacuum
  - n intervention, RT, vented, W opened
  - n+1 thermal buffer, RT, under vacuum
  - n+2…. floating, cold, under vacuum

} 642m (23%) at RT (n-1, n, n+1)

Local Warm-up experience



4-5 July 07, DFBA flex leak during CD

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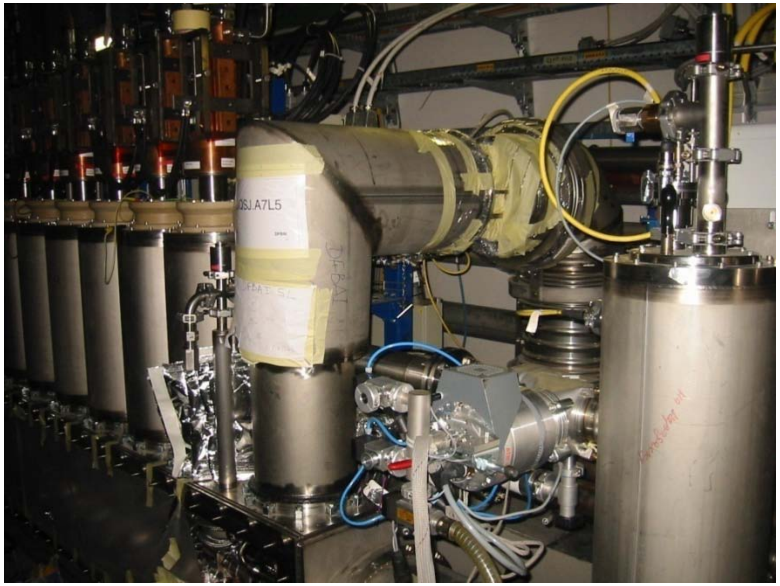
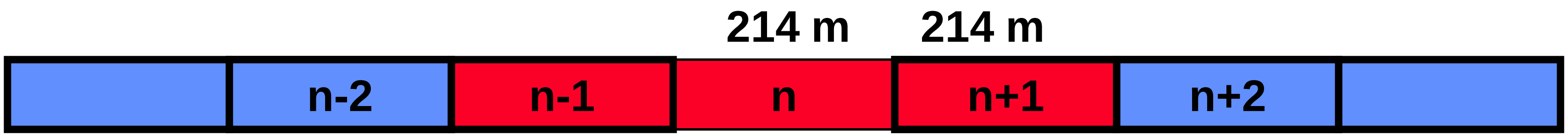


Baseline 'local warm-up' in insulation vacuum



- **Scenario from LHC Project Report 60, Sept 2000**
  - n-2…. floating, cold, under vacuum
  - n-1 thermal buffer, RT, under vacuum
  - n intervention, RT, vented, W opened
  - n+1 thermal buffer, RT, under vacuum
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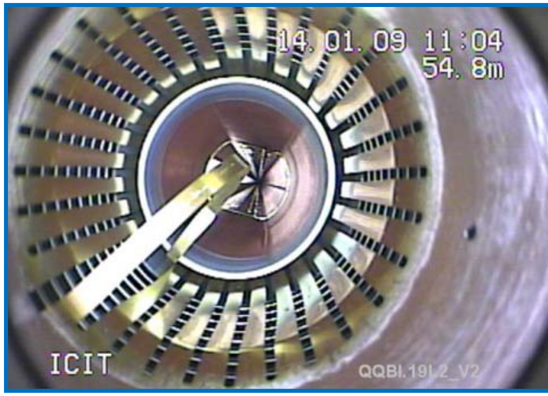
  } 642m (23%) at RT (n-1, n, n+1)



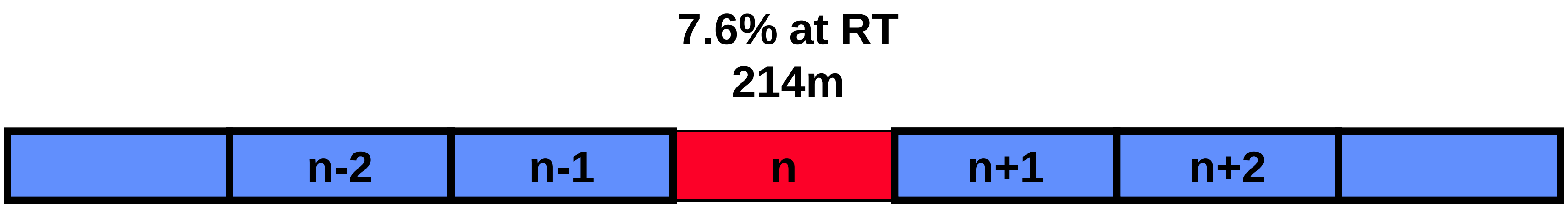
- **Impact of possible PIM failures:**
  - PIMs may fail in any of the 3 RT vacuum subsectors
  - 2.8 km beam vacuum must be vented to exchange 1 PIM
  - PIMs in thermal buffers cannot be accessed

  ⇒ Whole arc must be re-warmed, and damaged PIMs repaired

Revisit 'local warm-up' scenario

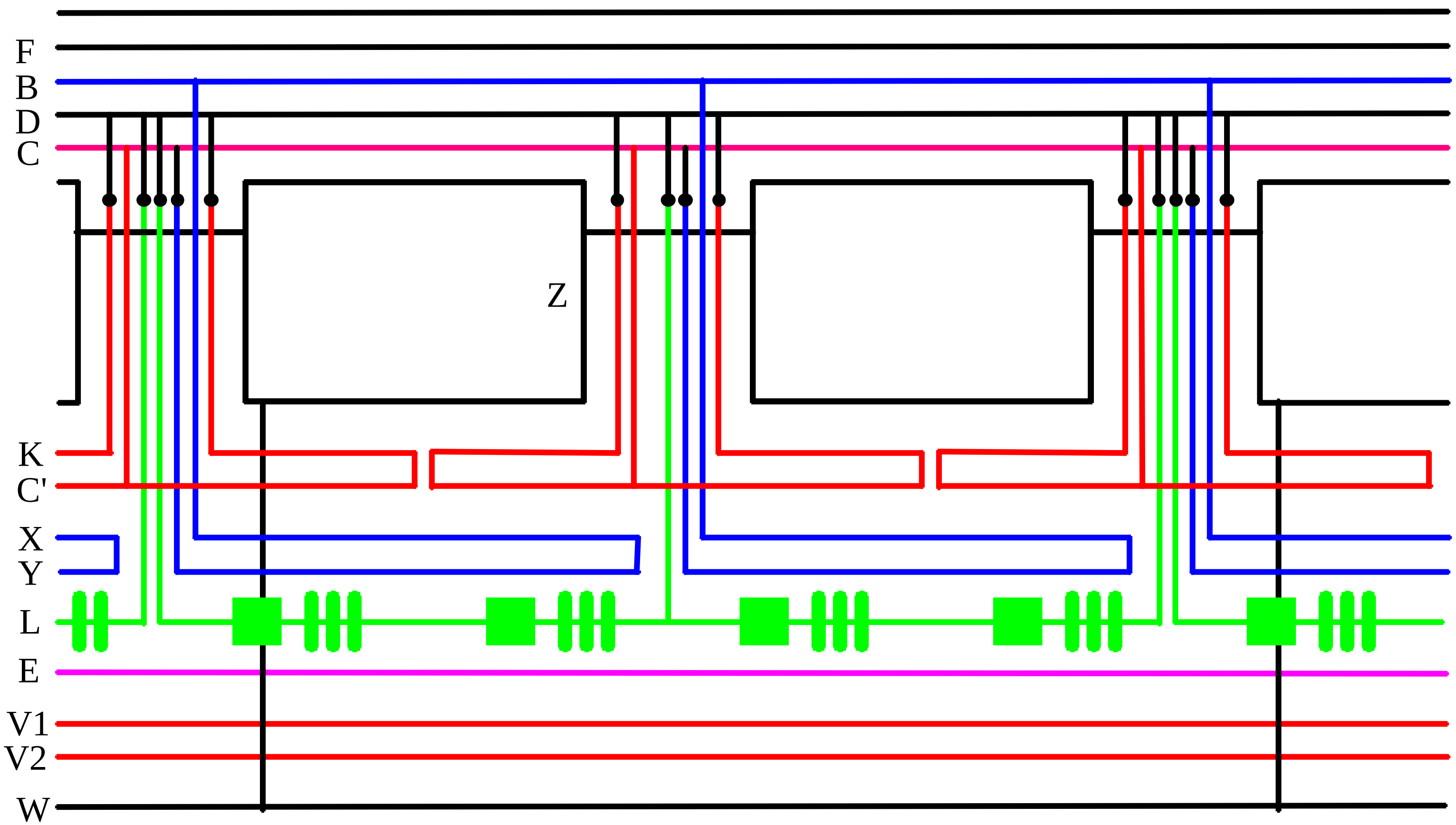
PIM WG & MARIC meeting June 2008

- **Goals:**
  - Allow local interventions – diode, busbar, leak, etc
  - Minimise number of PIMs which undergo thermal cycle to RT
  - Ensure <u>access</u> to PIMs which undergo thermal cycle to RT
  - Expect shorter intervention time w.r.t. a sector warm-up ?



- **Issues :**
  - No thermal buffers - cold interfaces at sub-sector extremity ?
  - Can a failed PIM be changed with arc still cold – venting & backstreaming ?

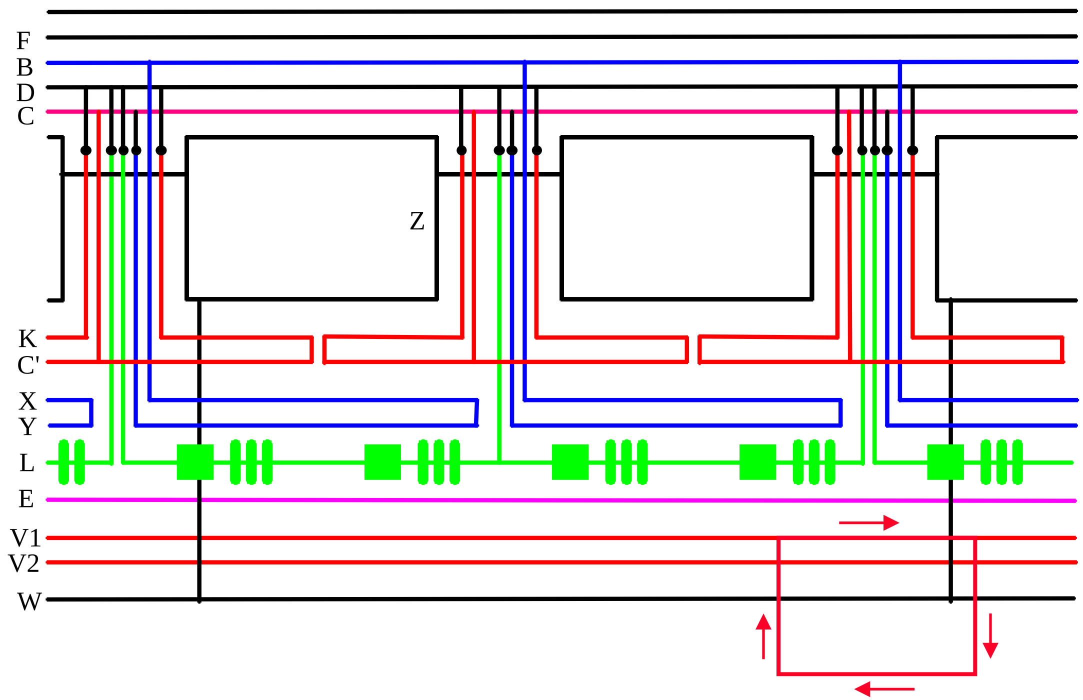
Revisit 'local warm-up' - cold interface issue



Quad is in cryogenic sub-sector.
- minor condensation issue

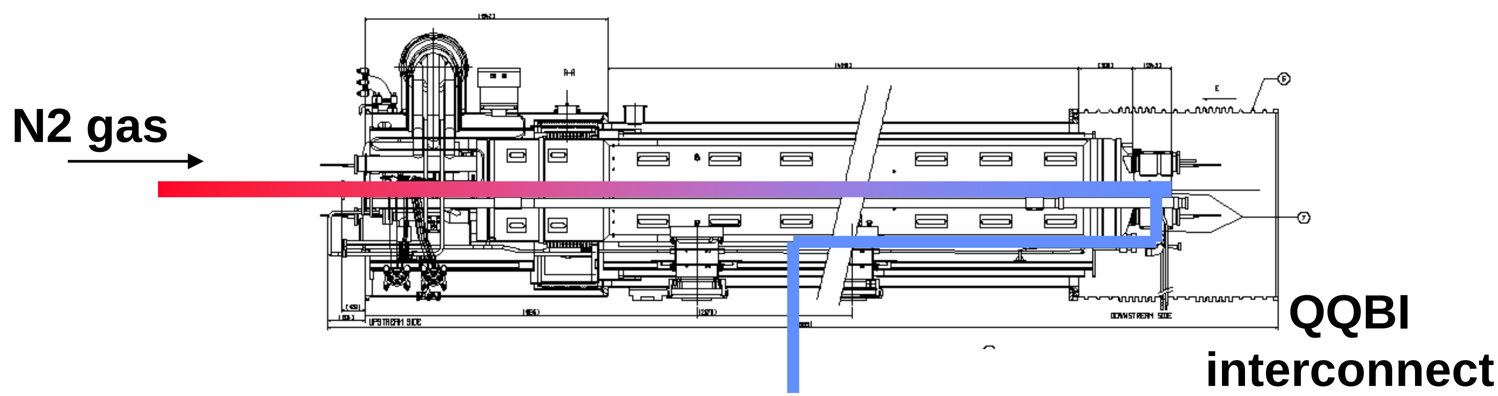
Quad is NOT in cryogenic sub-sector !

Revisit 'local warm-up' - cold SSS on the right



Force warming of SSS with recirculation of N2 in beam vacuum

- Warm-up whole arc to ~ 100 K
- Warm-up the vacuum subsector to RT
- Warmup SSS at vacuum barrier using N2 flow through SSS pumping pipes of the adjacent half-cell



Revisit 'local warm-up' non-accessible PIM

PIM WG inputs - calculations by Delio Ramos…

Interconnect	Temperature during repair (CM1/CM2/BS1)	Intervention offset	Cold offset (mm)	PIM type	Span @ installation	Span @	dS (mm) cold
BB	100/100/100K	37.1	40.0	BB	39.0	79.0	-2.9
BQ	100/100/100K	21.2	22.1	BQ	55.0	77.1	-0.8
QB	100/100/100K	31.1	34.5	QB	48.0	82.5	-3.4
BQ@SSS1	100/290/100K	15.9	22.1	BQ	55.0	77.1	-6.2
QB@SSS2	290/100/290K	21.5	34.5	QB	48.0	82.5	-13.0
QB@SSS2	100/100/290K	17.5	34.5	QB	48.0	82.5	-16.9

dS: Displacement from cold temperature position to intervention temperature. Negative sign indicates compression.
Cold offset: PIM extension from room temperature to cold working temperature.
Intervention offset: offset calculated as the displacement from room temperature to magnet temperature during the intervention.

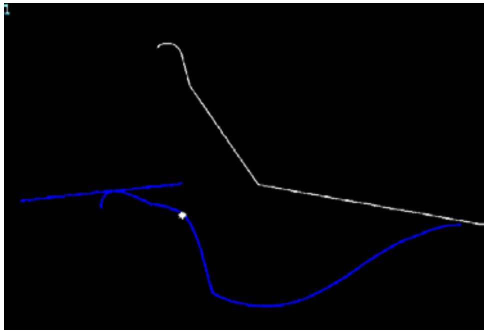


Figure 1-Deformed shape of the finger at the intervention temperature equivalent to 16 mm warm-up stroke.

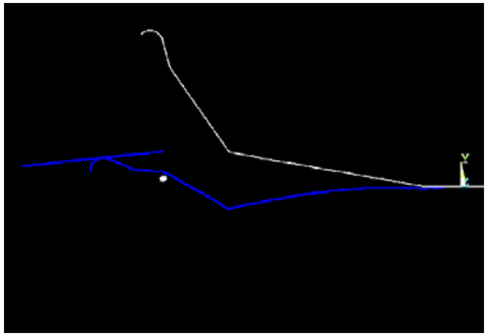


Figure 2-Finger shape after a warm-up/coll-down stroke of 16 mm. The contact at the Rh is lost.

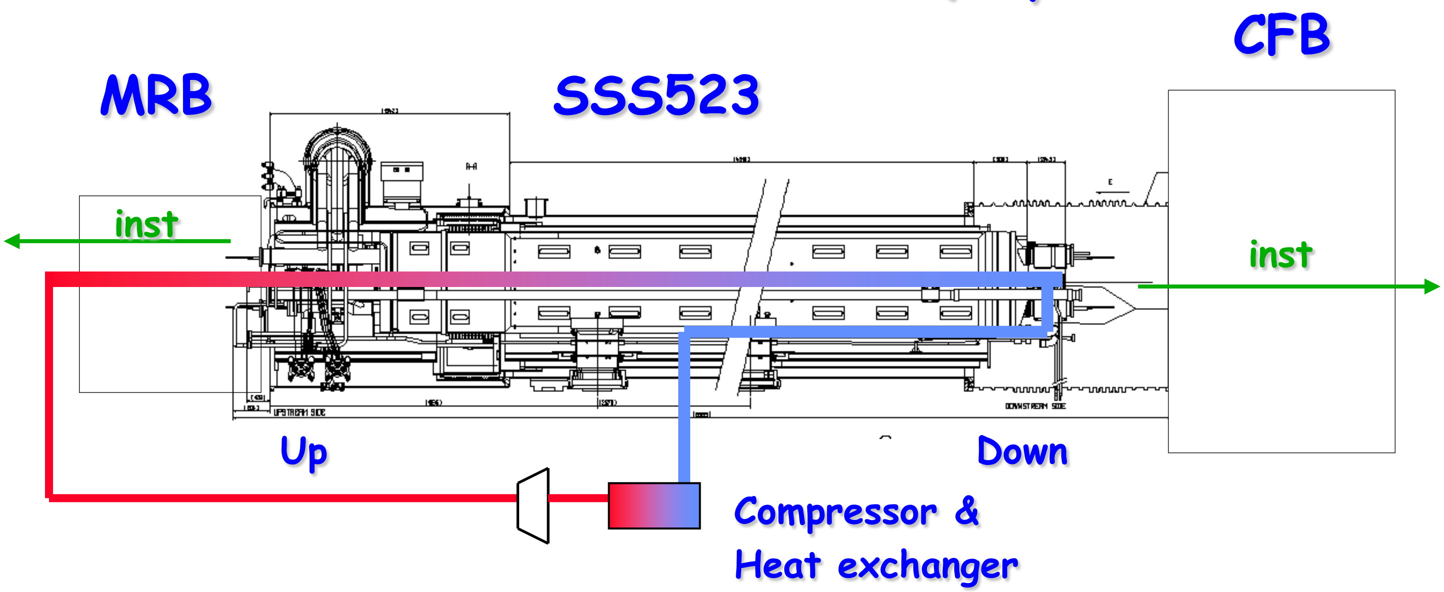
⇒ **If PIM of QQBI interconnect at warmed SSS is in failure mode, then 16.9 mm compression could reduce machine aperture.**

⇒ **Must be checked by endoscope or x-ray.**

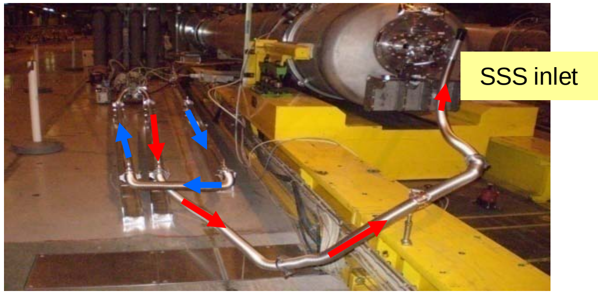
⇒ **Future consolidation priority: QQBI PIM at vacuum barrier?**

Revisit 'local warm-up'
SSS warm-up with N2 recirculation

- 2 Full scale tests on SSS in SM18 (July & Nov '08 Bethold Jenninger)



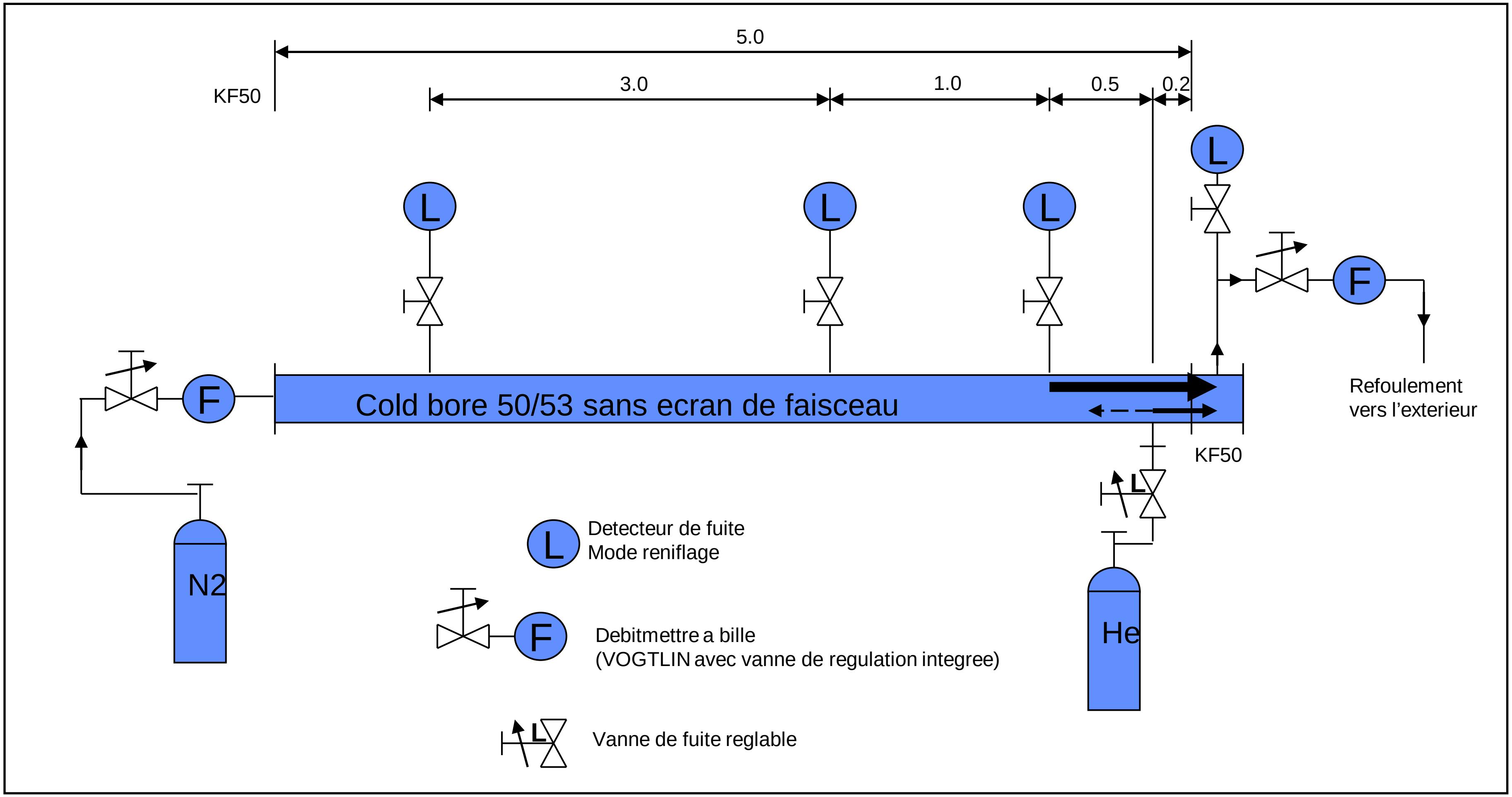
Measurements of warm-up time, cold mass position wrt cryostat, displacements at cold bore welds.
Collaboration with MEI, MCS, VAC, TS



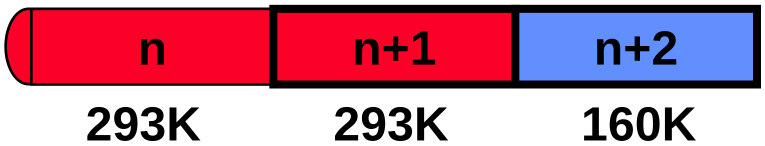
Results:
Max heat transfer N2 gas to cold mass ~ 2.5kW
6 days for 80K to 290K
Risk for beam vacuum contamination/loss of conditioning

Revisit 'local warm-up' PIM exchange - backstreaming in cold B.Vac

- Goal: Avoid H2O diffusion into cold beam vacuum
- Calculations (Vandoni) & experiment (Jenninger) to determine minimum flow necessary to limit retro-diffusion using helium against N2 outflow
- Flow of 5mm/s outflow is sufficient to avoid backstreaming > 0.5 m



More Local Warm-up Experience



4-5 July 07, DFBA flex leak during CD

PIM problem not known

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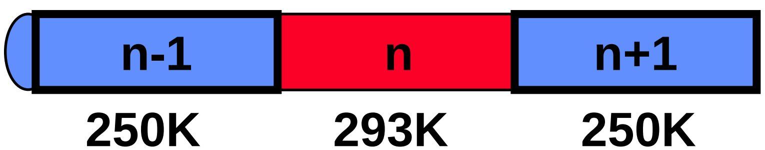
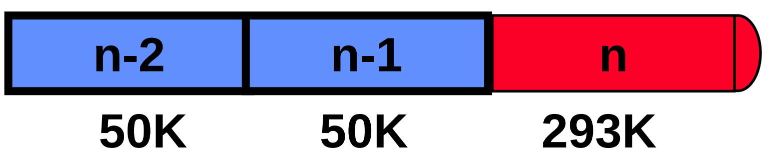


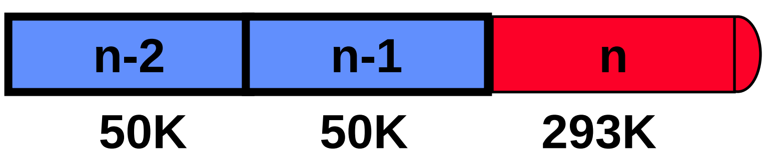
6-7 Aug 09, MB lyre short during CD

PIM extension not critical at 250k



2-3 July 09, DFBA flex leak during PIM CD

b.vac neon venting + PIM endoscopic inspection anticondensation barrier

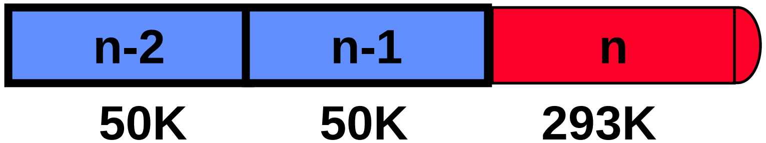


8-1 Aug 09, DFBA flex leak during PIM CD

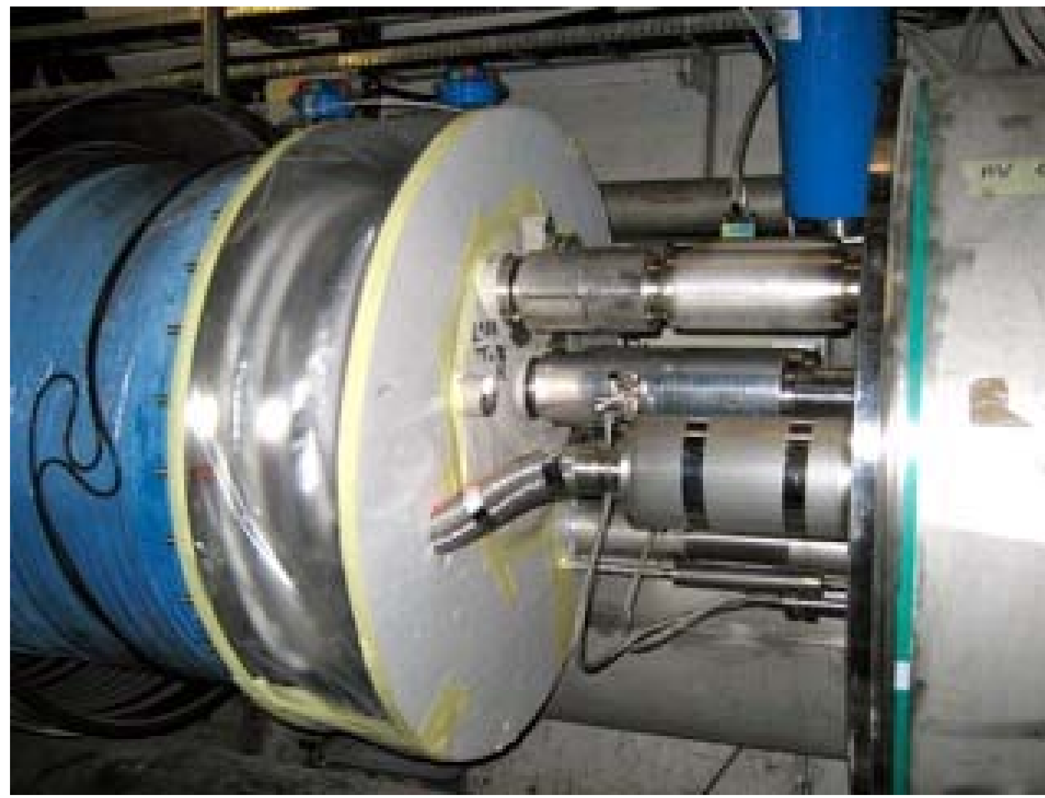
b.vac neon venting + PIM endoscopic inspection anticondensation barrier

Interventions in 2-3 and 8-1 - necessity is the mother of invention

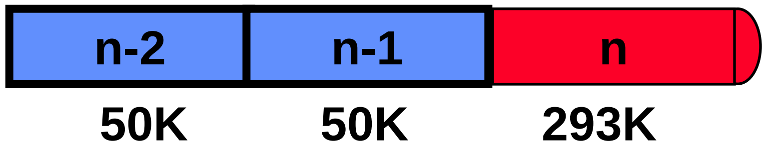
- Anticondensation barrier



Dry air feed from distribution line



PIM inspections in 2-3 and 8-1 – new territory again



Beam vacuum neon venting

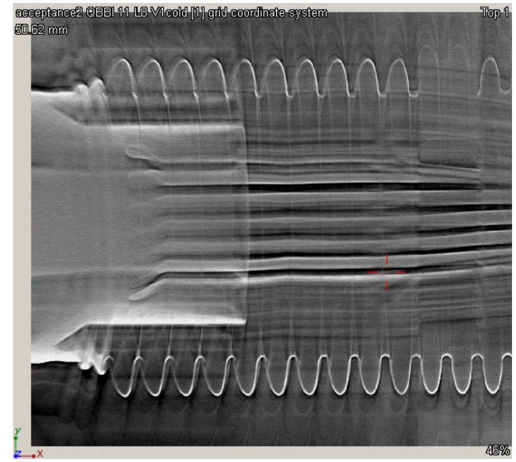
- Complex operation of 2x2.8km
- NEG purification
- Experience from expt chambers
- Avoid back-diffusion (+2 mbar)

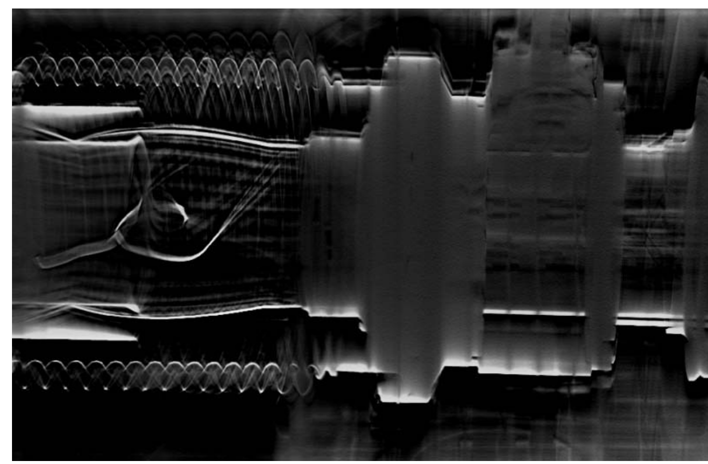
PIM verification

- Cut 1 PIM per beamline
- Check 30 PIMs with 100m endoscope
- Re-weld PIM without overpressure

Interventions were good success… but complex, and not without risk !!

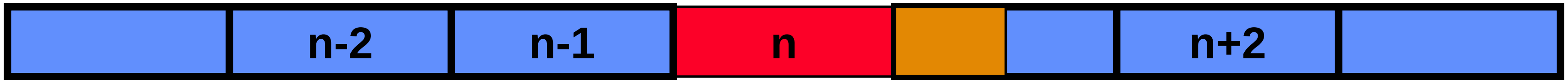
The tomograph is here…..



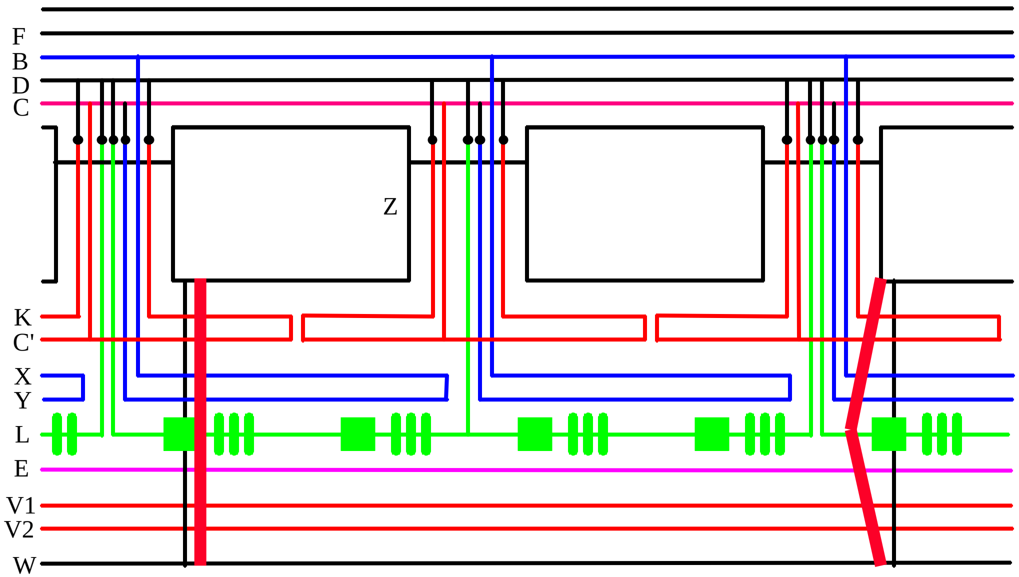


B.vac venting + endoscopy not required to check PIMs
…. venting only if damaged PIM

Revisit 2 'local warm-up'
- avoid beam vacuum venting



	n-1	n			
2K/day warm-up	20K	293K	90K	20K	Start
	60K	293K	200K?	60K	End



MQ at RT

Warm
MQ ~ 90K

Warm 1 cell to 90K
- no liquifaction of O2 or N2

Cryostat is vented to dry air then anti-condensation pockets

Air blowers or heaters maintain SSS cryostat surface above air dew point

SSS cold mass temp < 293K so QQBI PIM is less critical

Calcs & tests to do..?

WU/CD times

- inputs from Laurent & Serge

				2008	2010
			Design	Present	Reachable *
A	Complete sector WU	Emptying	1	3	2
		WU 5-300 K	12	17	14
		Total	**13**	**20**	**16**
	Complete sector CD	CD 300-5 K	13	25	18
		Filling	1.5	3	2
		CD 5-1.9 K	0.5	2	1.5
		Total	**15**	**30**	**21.5**
	Total A		**28**	**50**	**37.5**
B	3 sub-sector WU	Complete emptiyng	1		2
		3 s/s WU 5-300 K	5		10 to 11
		Total	**6**		**12 to 13**
	3 sub-sector CD	3 s/s CD 300-80 K	4		8
		Complete CD 80-5 K	4		5
		Filling	1.5		2
		CD 5-1.9 K	0.5		1.5
		Total	**10**		**16.5**
	Total B		**16**		**28.5 to 29.5**
C	1 sub-sector WU	Complete emptying	1		2
		Complete WU 5-100 K	3		6
		1 s/s WU 100-300 K	4		8 or 9
		SSS WU	?		?
		Total	**8 + ?**		**16 to 17 + ?**
	1 sub-sector CD	1 s/s + 1 SSS CD 300-100 K	3.5		7
		Complete CD 100-5 K	4.5		6
		Filling	1.5		2
		CD 5-1.9 K	0.5		1.5
		Total	**10**		**16.5**
	Total C		**18 + ?**		**32.5 to 33.5 + ?**

full 37.5 days

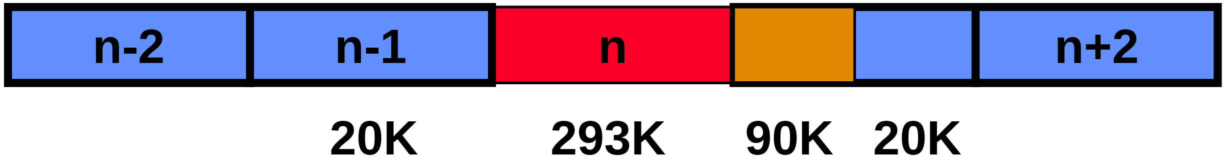
3 sub-s 29.5 days

1 sub-s 31.5 days

* : with present resources and hardware

..including ELQA, powering, etc

scenario = repair helium leak in 3-4



	Masked activities	Full WU (days)	Local WU 214m (days)
Warm-up	Consignation(1&2) PIM Tomography	16	16
Repairs		4 (min.)	4 (min.)
Repumping // ELQA	Purge	5	5
ELQA (%MIC, TP4)		5 + 2	2
Cool-down	ELQA (DOC-C)	21.5	16.5
ELQA – 1.9K MIC-C , TP4E		7.5	3.5
Deconsignation (1&2)		1	0.5
Powering Tests		7	5
TOTAL		69	52.5

Time gain of > 2 weeks and < 10% of arc is thermally cycled

Time gain assumes no secondary problems in thermally cycled zone

In summary

- Local warm-up is part of baseline, allows local repairs, avoids thermal cycle of whole arc, method must be adapted for PIM issue.
- Validations & experience:
  - 5 local warm-ups in LHC tunnel
  - N2 warm-up of SSS in SM18
  - Retrodiffusion tests in lab and exploited in 2-3 and 8-1
  - Neon venting and PIM exchange during local warm-up in 2-3 and 8-1
  - Anticondensation barrier and ins vac repumping 2-3 and 8-1
  - Endoscopic PIM inspection 8-1 and 2-3
  - Tomography tests in sector 7-8 – avoid systematic b.vac venting
  - To do …. calcs/test on vented 90K SSS
- Potential gain of > 2 weeks wrt full warm-up
- Risks:
  - If accessible PIM collapses in RT zone – venting etc – more time
  - If non-accessible PIM collapses at SSS – warmup another 214m

Acknowledgements

- PIM Working Group
- VSC & CRG colleagues
- Many other groups MCS, EN during interventions
- Inputs from EN/MEF, ELQA and HC teams
- All others I forgot…

Thanks for your attention