Towards cNPM Manufacturing

Non invasive Monitor Critical Design Review

CEA Saclay, Monday February 11th 2019

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C. Thomas (ESS project leader)

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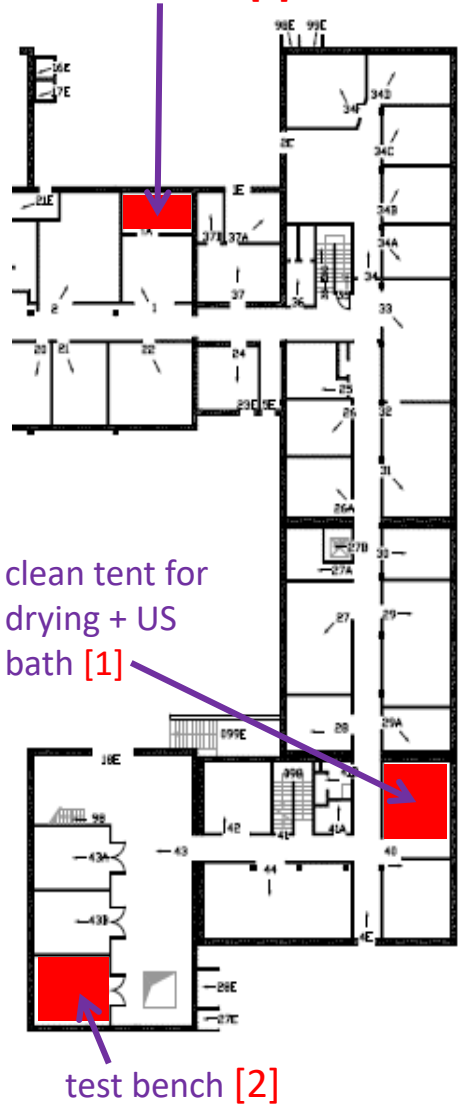
Manufacturing scenario for IPMs

NPM team + advisors:

DACM experts: S. Berry, P. Bosland, C. Madec

DIS (alignment): M. Fontaine



Dédip “North”

Building 534

Dédip : **D**épartement d’**é**lectronique des **d**étecteurs et d’**i**nformatique pour la **p**hysique

DEDIP: **D**epartment of **E**lectronics for **D**etectors and **C**omputing for **P**hysiques

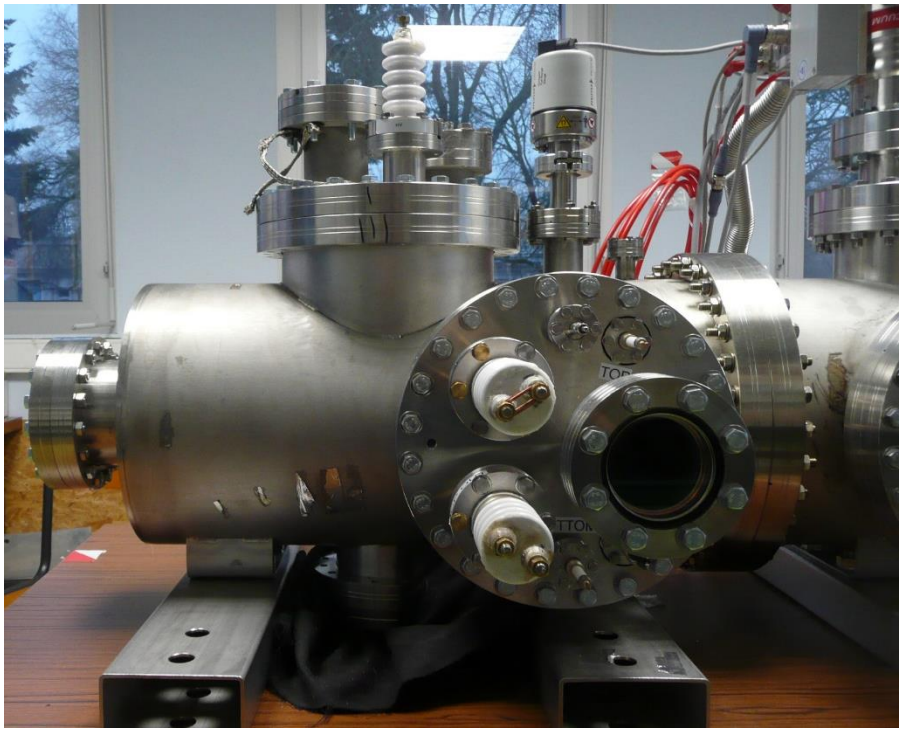
Step 1: Sorting pieces for an IPM pair, cleaning, drying and assembling

- All necessary pieces including screws (except MCP) to build 2 IPMs will be sorted and cleaned in an ultrasonic bath with a specific detergent (EC260, pH 7.1) and rinsed with demineralized water18MΩ (B.534/R.1 and B.534/40).
- Then, all of them are gathered into B.534/R.40 (10m) where they are dried in a laminar flux. Later, there are assembled to make the 2 IPMs. The goal is to work on one IPM pair after each other.
- Finally brought to B.534/R.43C (10m) where there are mountings, with their MCPs.

A- ultrasonic bath for cleaning + filtered water 534/1

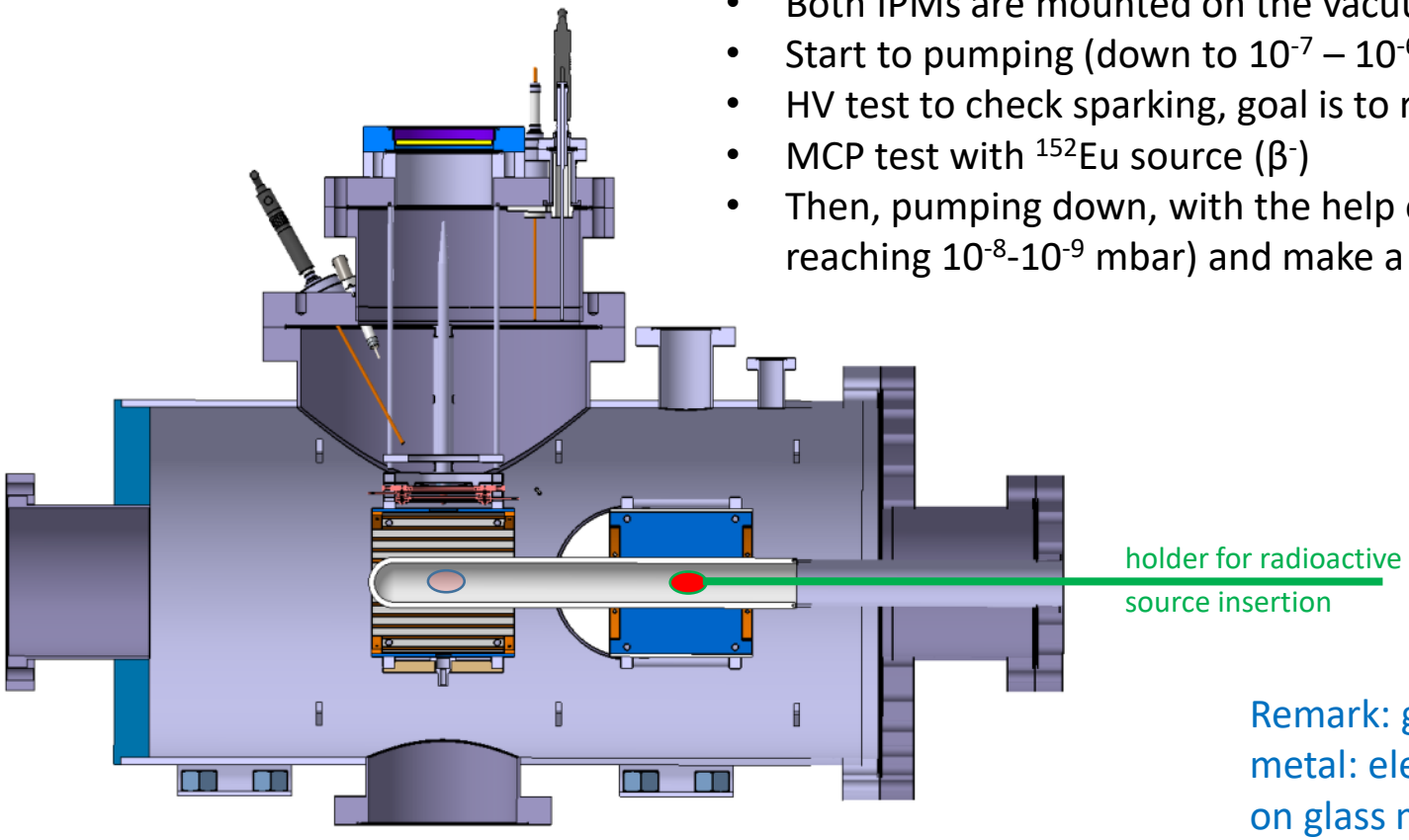
B- clean tent for drying 534/40

C- test bench in 534/43C



Step 2: IPM tests (B.534/R.43)

- Both IPMs are mounted on the vacuum chamber
- Start to pumping (down to 10^{-7} – 10^{-6} mbar)
- HV test to check sparking, goal is to reach 20 to 30 kV
- MCP test with ^{152}Eu source (β^-)
- Then, pumping down, with the help of ionic pump (goal: reaching 10^{-8}-10^{-9} mbar) and make a RGA measurement.



Remark: glass finger brazed on metal: electric charge loading on glass may induce sparks…

Qualification

- Test pressure
- HV reached
- MCP gain curve with a β^- source
- Very low pumping down pressure achieved
- RGA spectrum and vacuum leakage rate
- Alignment coordinates (next step)

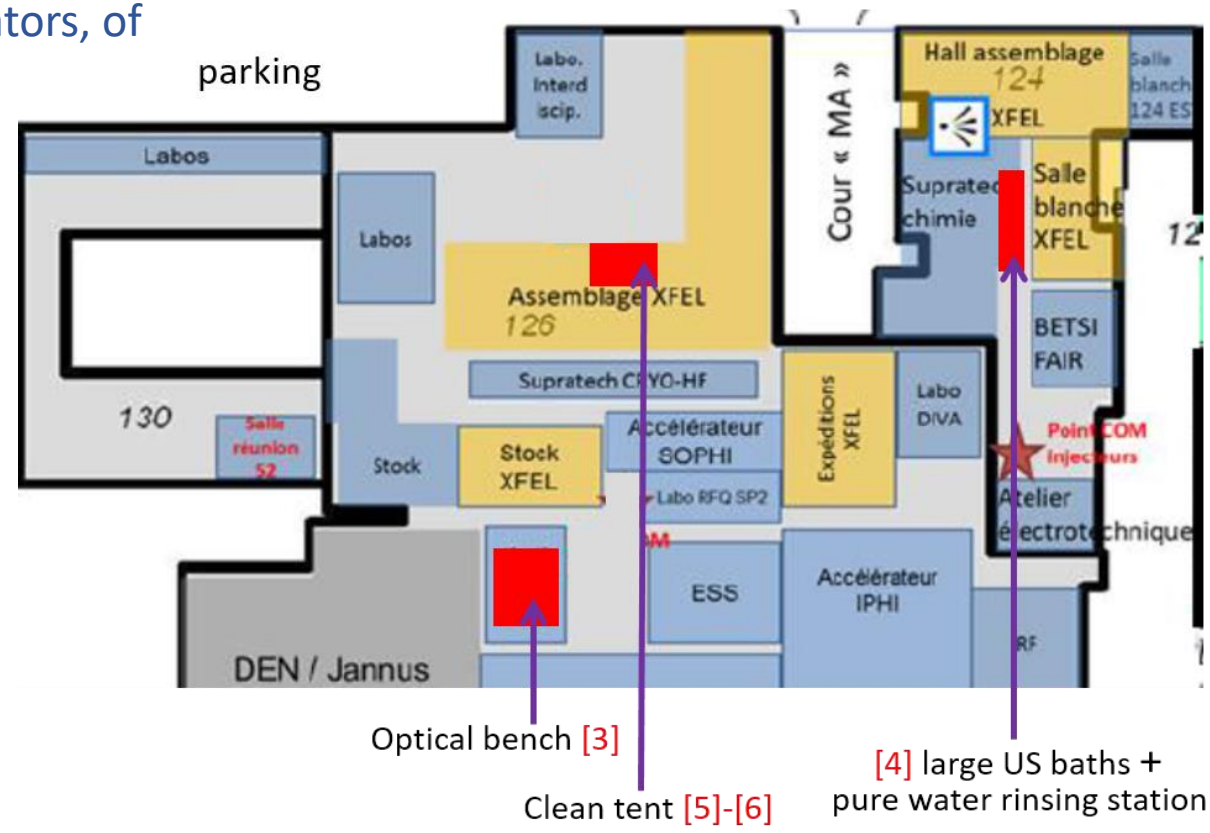
DACM

Buildings 124 & 126

DACM : **D**épartement des **A**ccélérateurs,
de **C**ryogénie et de **M**agnétisme

DACM: **D**epartment of **A**ccelerators, of
Cryogenic and of **M**agnetism

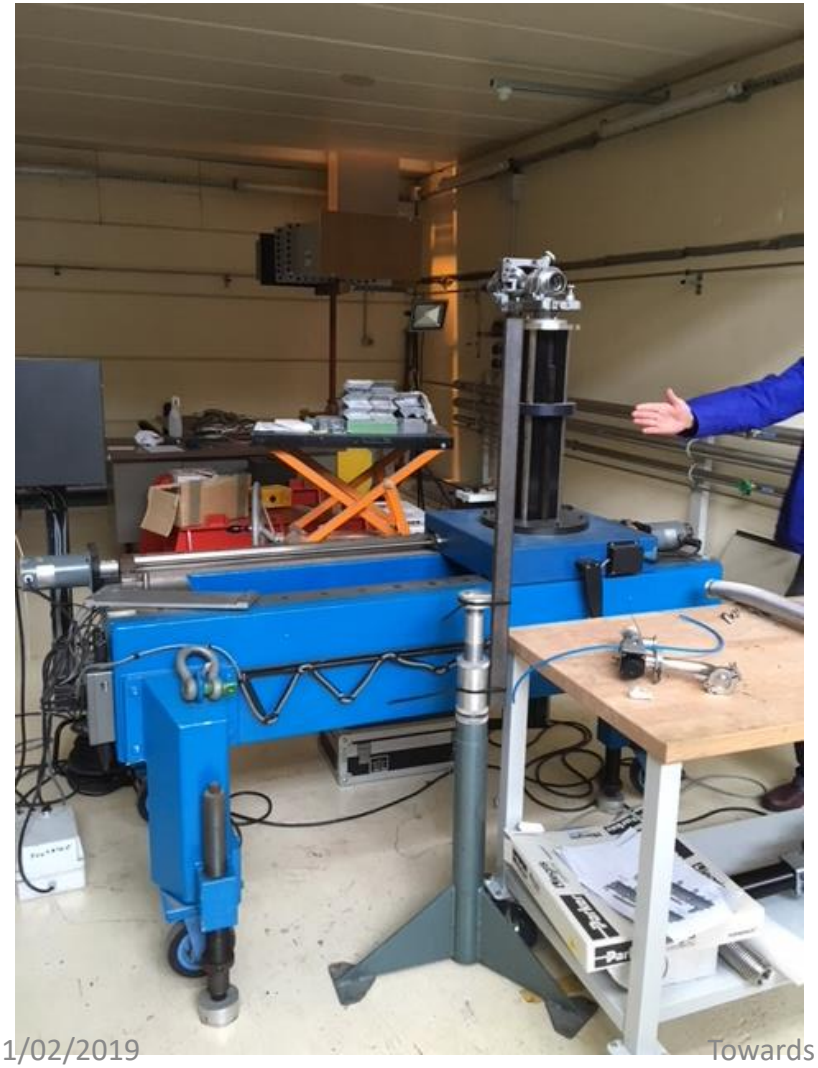
DACM – B.124 & 126



Note: locations of clean tent and optical bench are supposed to move.

Step 3: ESS CM test bunker: presently, a part of the roof is removed

Once tests done in laboratory (building 534), IPM geometries are now frozen and the MCPs stored in a vacuum chamber. Ready to transport an IPM pair to the DACM premises in order to start alignment work i.e. IPM measurement with the huge optical bench (X, Y) and with a laser tracker for the depth (Z). Tools and brackets need to be designed and fixed on the ground.



Note: dusty location, possibility to move was raised to DACM management (Catherine Madec). Taken into account and in progress.

Step 4: in the huge assembling vault B.124 of DACM (4 cleaning rooms…)

Gateway to access to big ultrasonic tank:
The entire IPMs will be plunged in the bath and cleaned with specific detergent (TDF4, pH 13.5).

Rinsing station with its duckboard floor:
Filtered and demineralized water flushed on IPMs.

Step 5: XFEL vault (B.126): mobile clean tent (about 2 × 3 m^2)

Question:

Lots of activities → location be find

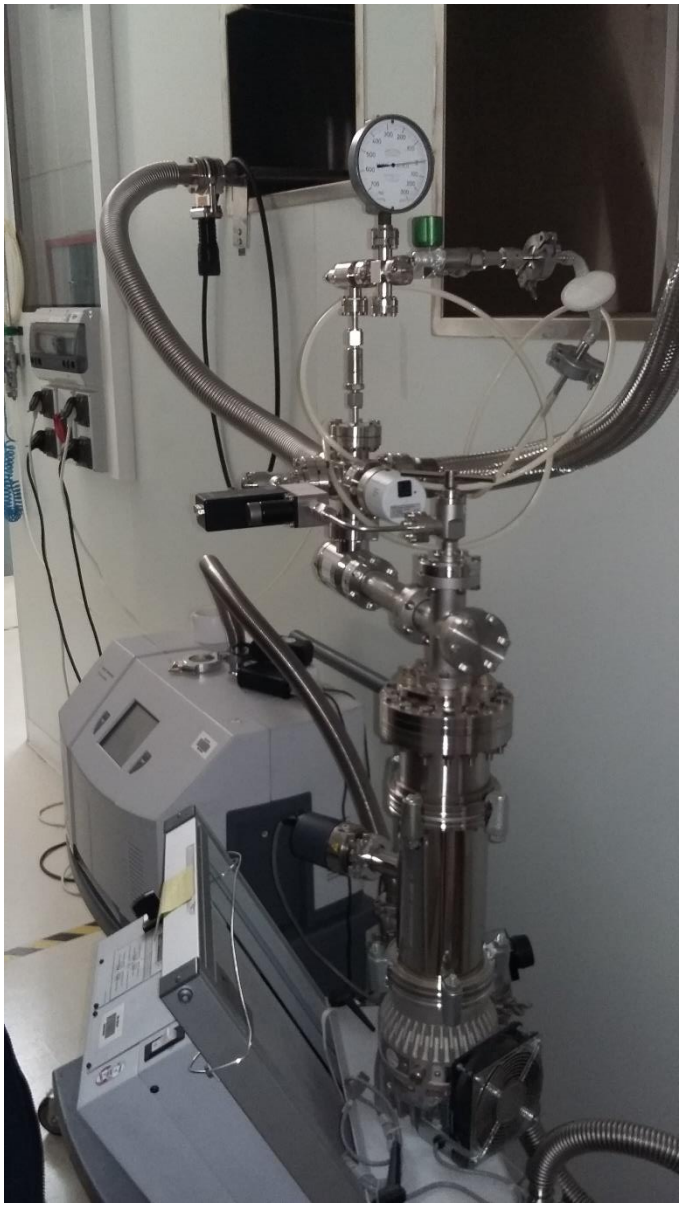
Is it possible to have pure filtered N_2 for IPM flushing?

Clean tent interior (ISO 5):

vacuum pipe and more important, laminar air flux. Cleaned IPMs and storage VC are brought inside a box, drawn in pure water. They are dried in the laminar flux hung on specific brackets (to be designed). Free particles are measured and items are flushed with pure filtered nitrogen until reaching the requested value. Then, IPMs are mounted on both sides of the storage box.

Slow vacuum can be started.

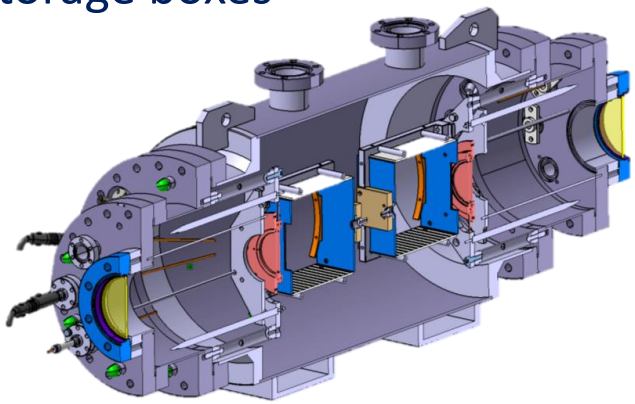
Step 5: slowing pumping down and up system of DACM (B.124)

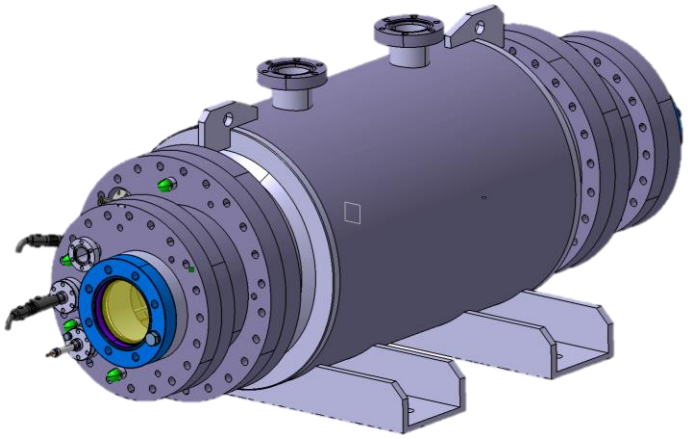


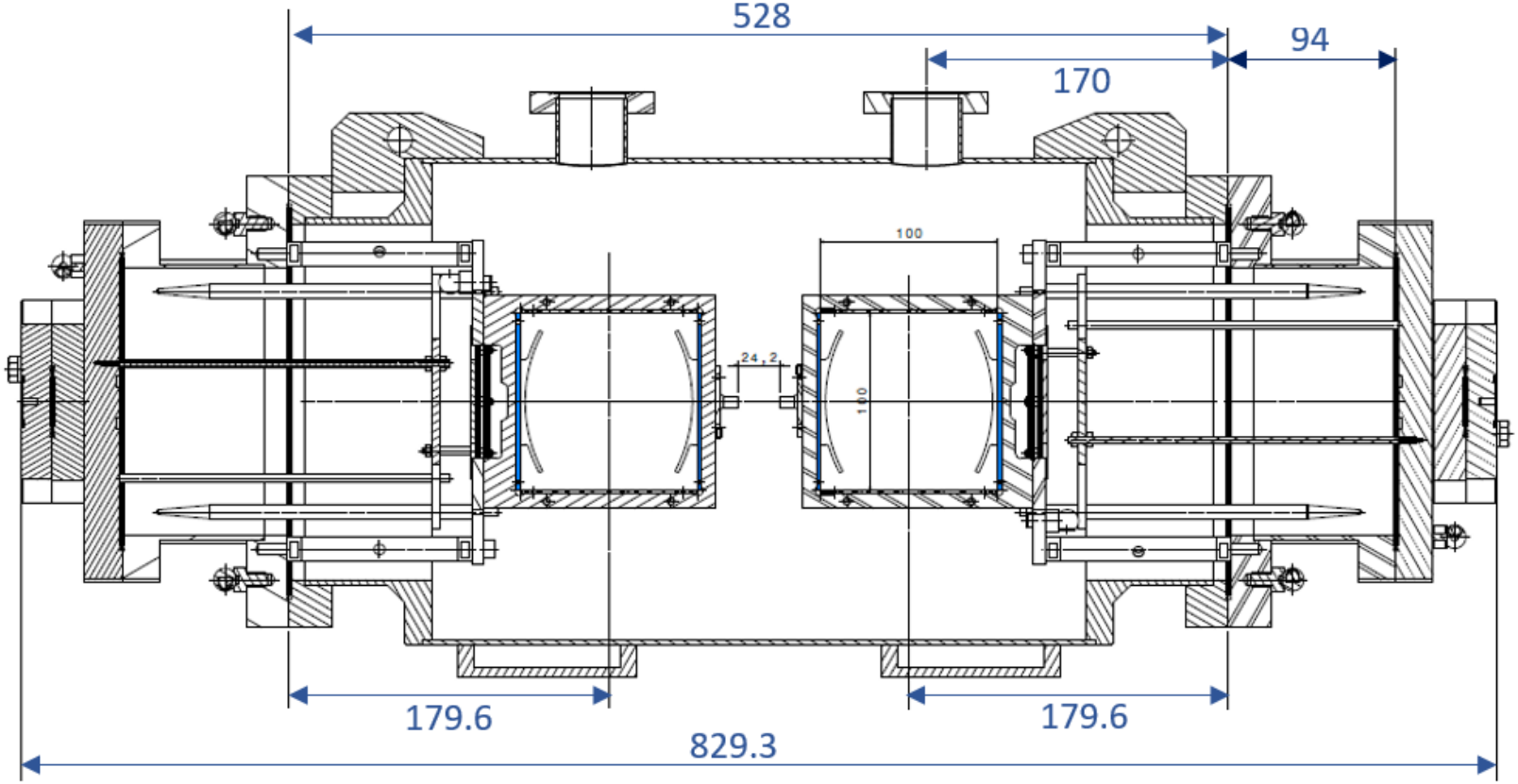
Slow pumping system and slow N_2 filling up to atmospheric pressure developed by DACM staff member for compliance with free particle requirement.

This kind of system has to be developed for the last process phase, meaning the insertion of the both IPMs in the storing and transporting VC.

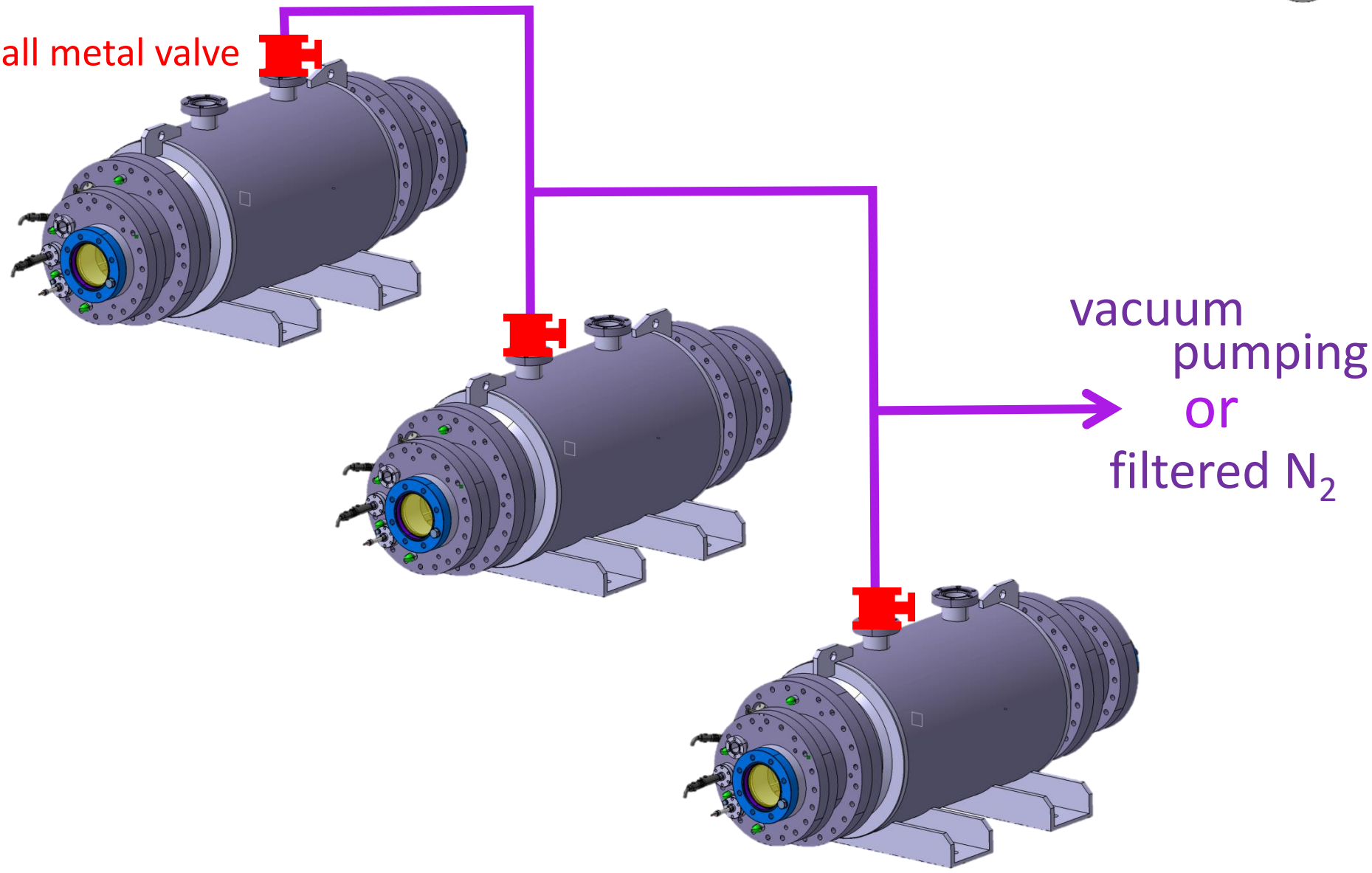
Step 6: Storage boxes







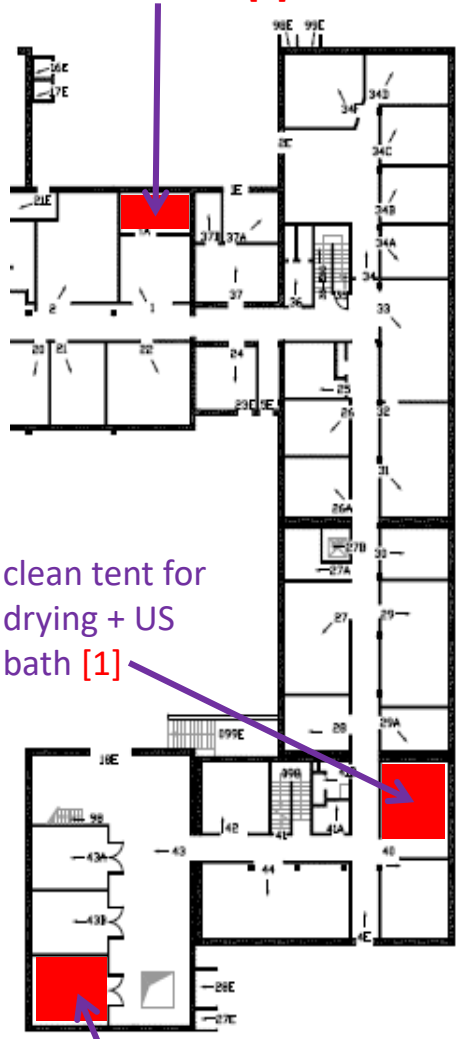
Step 6: Storage boxes



Facility locations for the 5 NPMs (10 IPMs)
Dédip to DACM ≈ 1 km

Dédip North – B.534

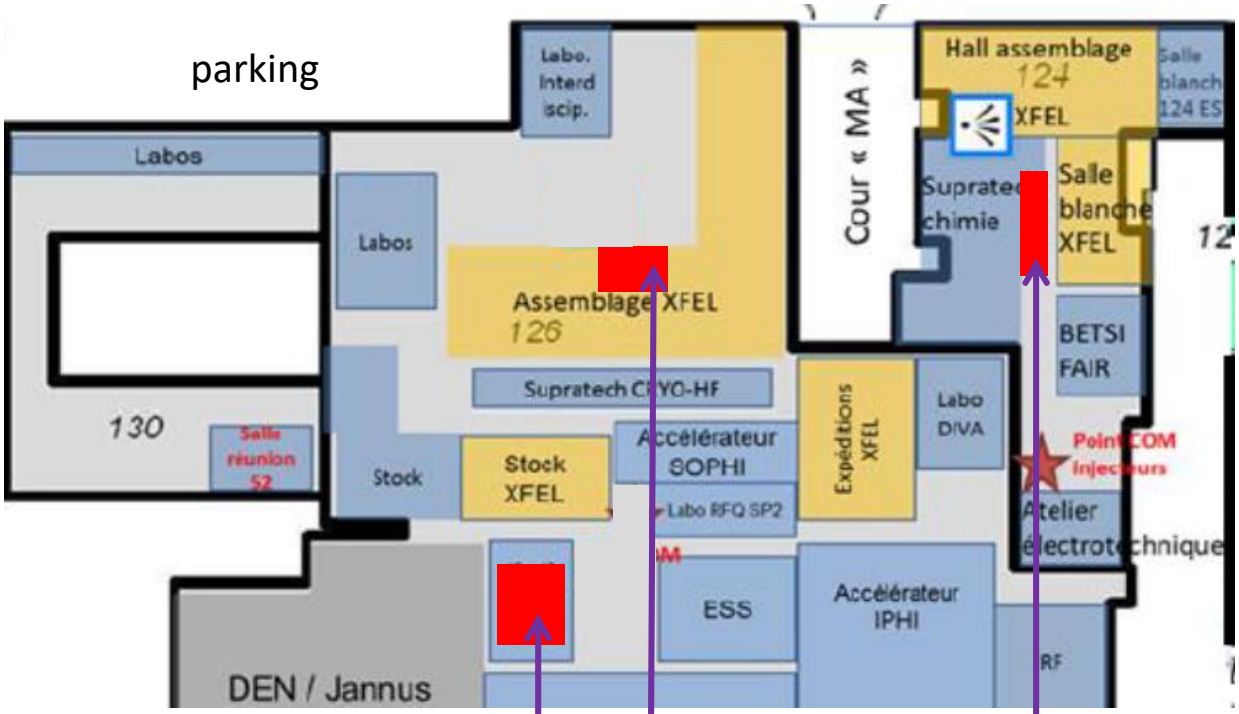
US bath for cleaning + filtered water [1]



clean tent for drying + US bath [1]

test bench [2]

DACM – B.124 & 126



Optical bench [3]

Clean tent [5]-[6]

[4] large US baths + pure water rinsing station

Note: locations of clean tent and optical bench are supposed to move.

Rough planning

1st IPM pair
- Dédip nord → 10-11/2019
- DACM → 12/2019 & 1/2020

2nd IPM pair
- Dédip nord → 2-3/2020
- DACM → 4/2020

3rd IPM pair
- Dédip nord → 4-5/2020
- DACM → 6/2020

4th IPM pair
- Dédip nord → 7-8/2020
- DACM → 9/2020

5th IPM pair
- Dédip nord → 10-11/2020
- DACM → 12/2020

6th IPM pair: Spare, not foreseen!
- Dédip nord → 1-2/2021
- DACM → 3/2021

Note
- Expect to be able to do all the work at DACM in a month. Alignment work may be included in the 2 months devoted to Dédip Nord.
- DACM expert to be foreseen at least for the 1st IPM pair operations.
- To save time, we can also imagine to have 2 teams, one working on B.534 and at the same time the other one on DACM building.
- 6th pair is not yet decided (spare)

Material list → low outgassing material

List of the materials used for the IPM manufacturing:

- Ceramic plates (Rogers RO4350)
- Copper deposition for degrader strips, electrodes
- Peek (?), alumina ceramic and stainless steel screws
- Copper cables
- CMS resistors
  - welding materials: pollution, outgassing: compliance with superconductive cavities? Specific material instead of stain?
  - brazing resistors?
- Macor frames + stainless steel pillars (cylinder with holes)
- pMCP: supposed to be compliant with ultra high vacuum

Are we supposed to passivate copper deposition for avoiding oxidation? If yes, which material? Gold helps?

Quality

A report for each IPM will be provided with the following listed items:

- The highest achieved HV IPM with the consumption current and the pressure
- Using the β^- source for the MCP gain curve
- The RGA response
- The vacuum leakage rate
- The alignment coordinates of IPM marks wrt the external sight targets
- The free particle measured with the specific monitor

We are also thinking to measure the impedance of the IPM degraders which may indicate for instance if, during the transport, conductive pieces are still connected when checked at ESS.
This can be done quickly, as soon as cNPMs arrived at ESS Lund.

IPM mechanics: proposition of a new flange option

pMCP replacement

Read-out final choice: **pMCP + optics + GigE camera**

Reliability: pMCP is usually identified as the weakest point due to ageing effect and vacuum insertion

Proposition

1st mounting (LWU installation)

1. First mounting: the whole assembly is inserted into the CF200 of the LWU
2. Survey can be done using the 5 optic sights on CF200

Changing a new MCP

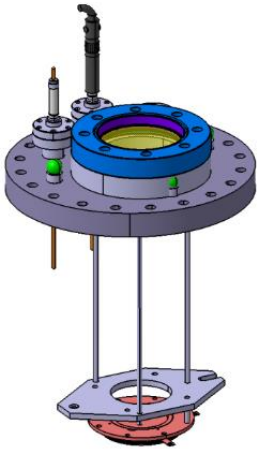
1. a new CF160 may be equipped in a clean room and stored in a N_2 atmosphere.
2. MCP change: just remove the CF160 middle flange, using a N_2 chamber for instance.

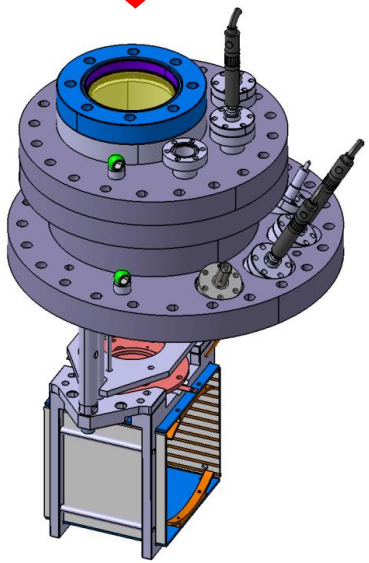
Note: this system is identical for X and Y view; to switch X to Y, turn the CF160 by 180° and translate IPM holder by 36mm!

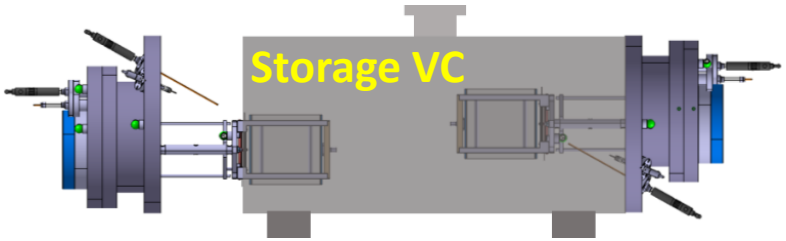
Other advantages

Very light system (low lever arm) which can be safely inserted through the CF160 hole

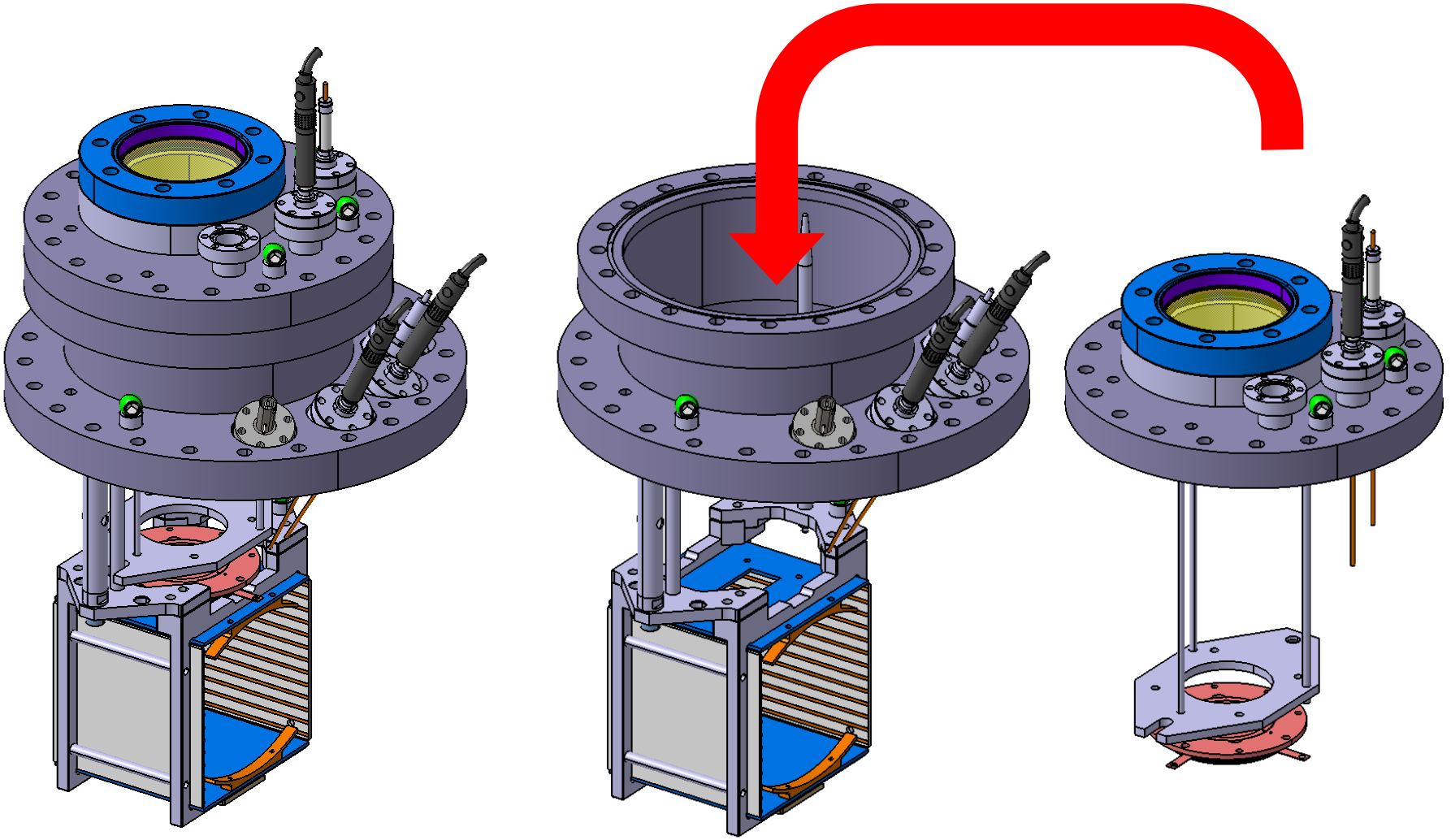
During the long IPM assembling, MCP can be stored in neutral atmosphere avoiding MCP oxidation



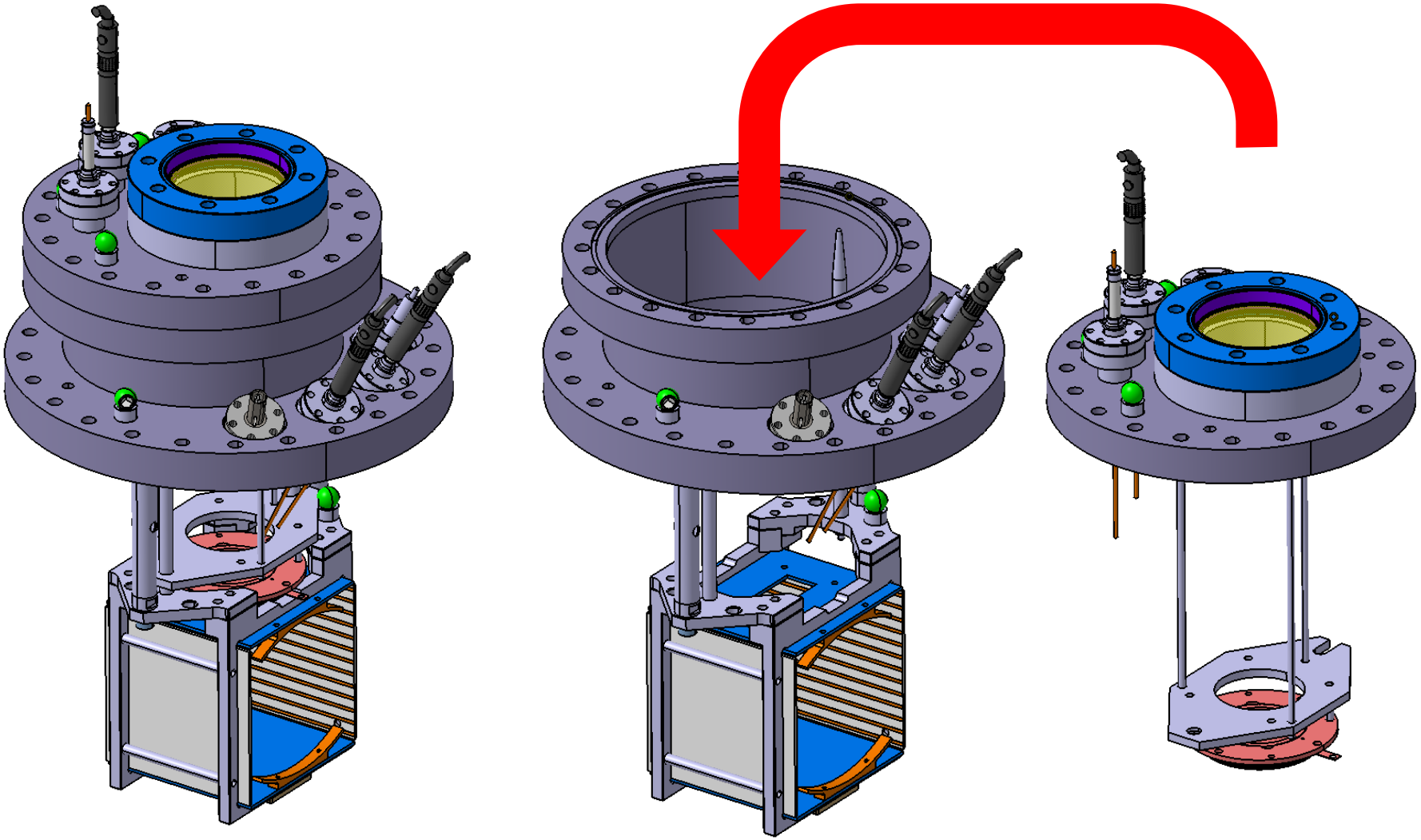




pMCP replacement: IPM_Y

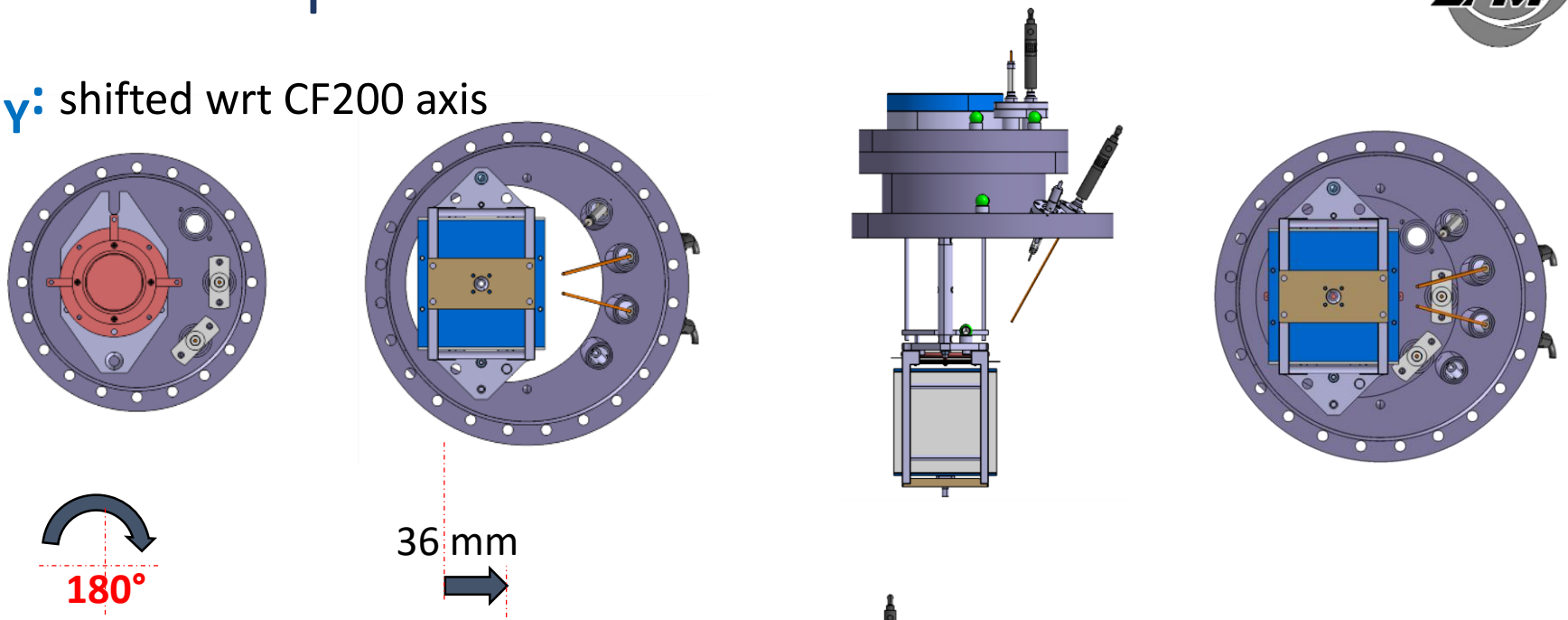


pMCP replacement: IPM_X



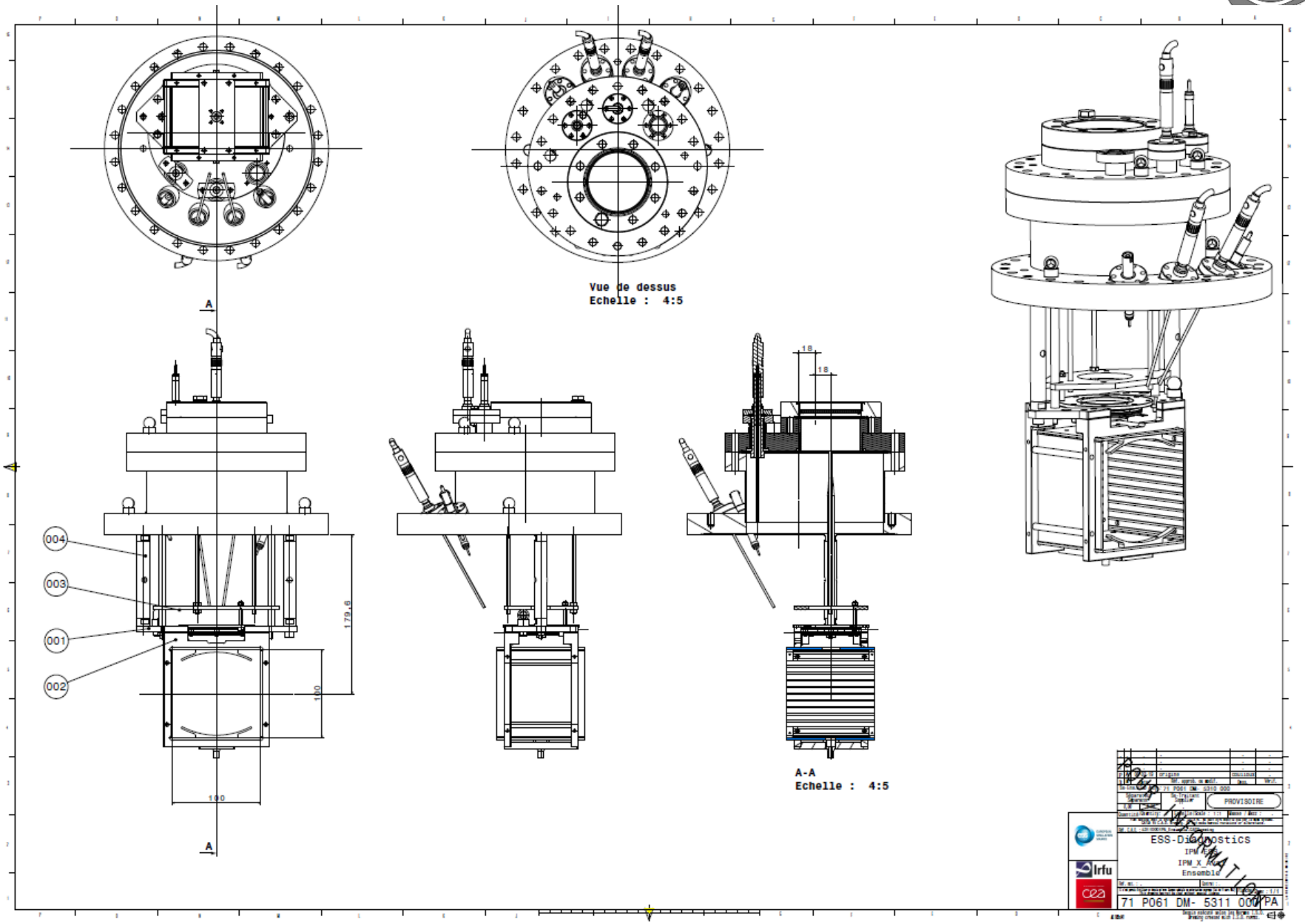
pMCP replacement: both IPM

IPM_Y: shifted wrt CF200 axis



IPM_X: shifted wrt CF200 axis

IPM drawing with 2 flanges



pMCP wrapping, sending & storing

Once cleaning is finished, NPM storing prior to send IPMs to Lund,

a NPM (=1 IPM pair) is inserted and stored in a VC

Storage at CEA Saclay and ESS Lund

→ Vacuum: ≤ 10^{-2} mbar (MCP)

Transport to ESS Lund

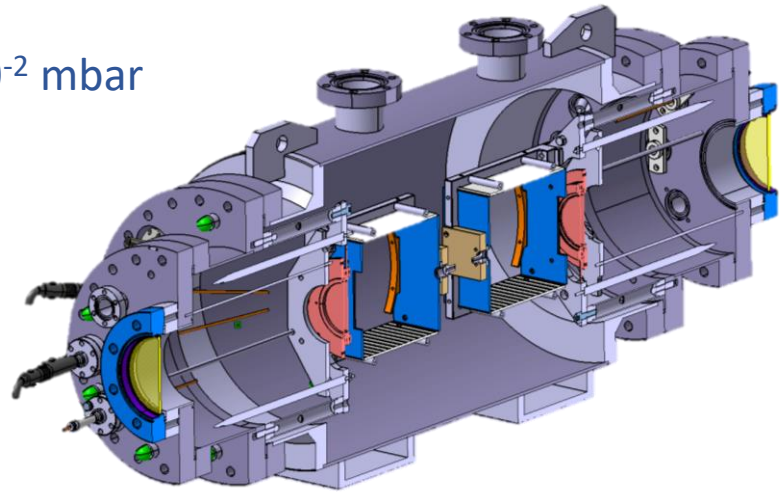
→ Caution with vibrations: mechanical calculation have to be done for avoiding resonances (breaking IPM) and compliance with free particles.

→ N_2 atmosphere ≥ 1 bar

Once arrived at Lund:

→ Pipes mounting on all metal valves,

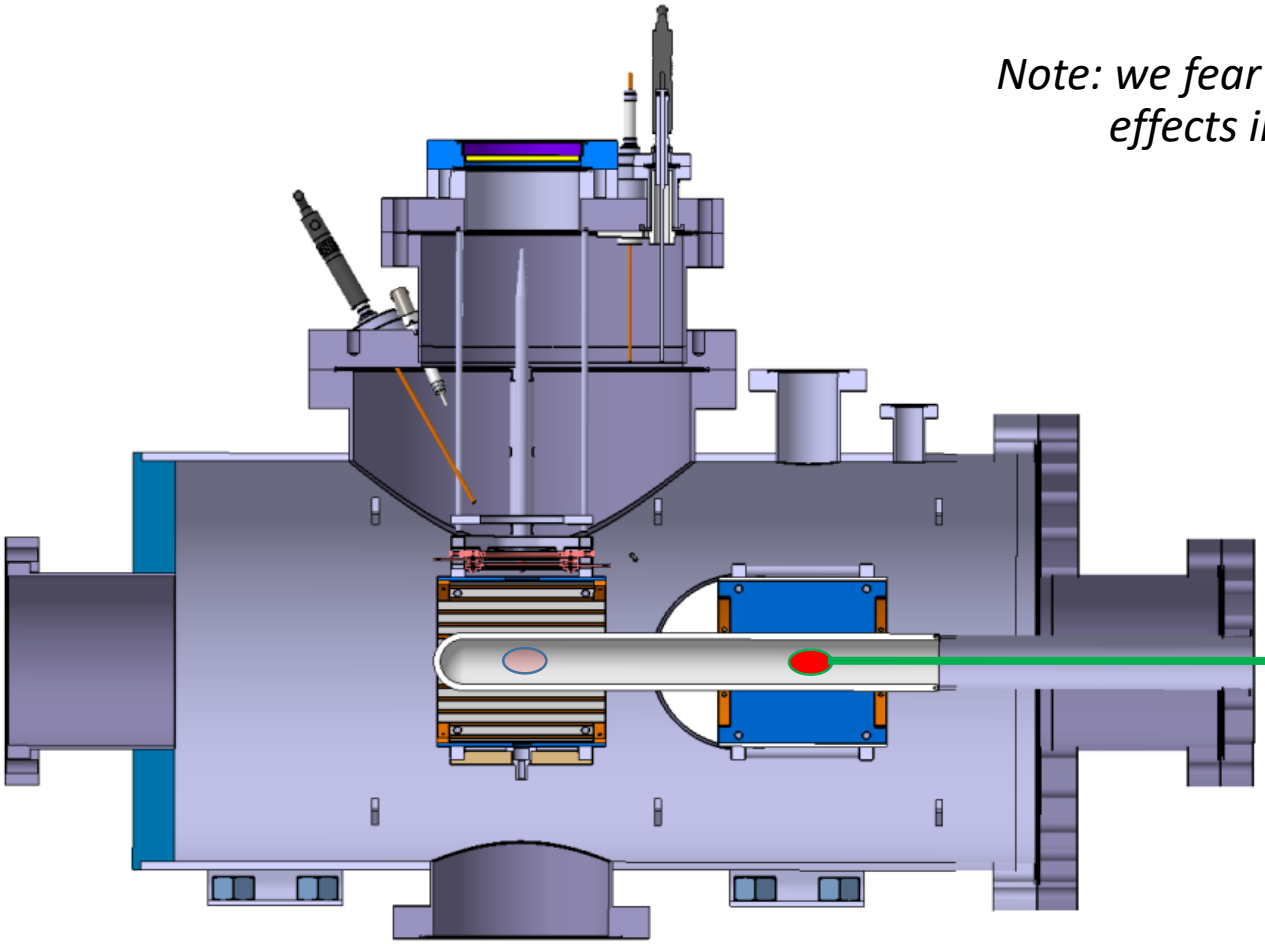
→ Then, slow pumping to achieve at least 10^{-2} mbar



β^- source test

^{152}Eu β^- source: proposition

Note: we fear having charging effects inducing sparks…



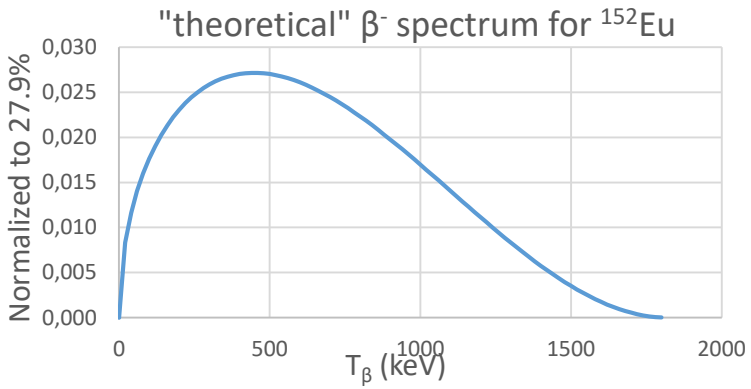
Expectation rates from ^{152}Eu

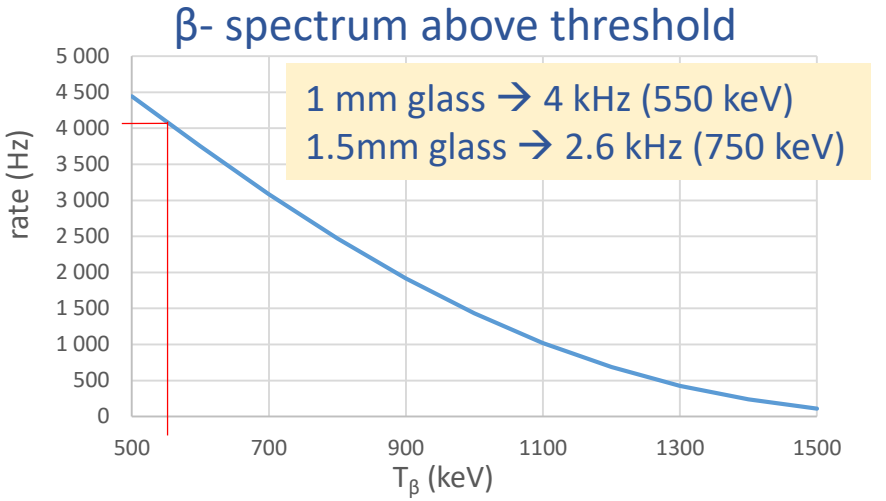
β- source: ^{152}Eu

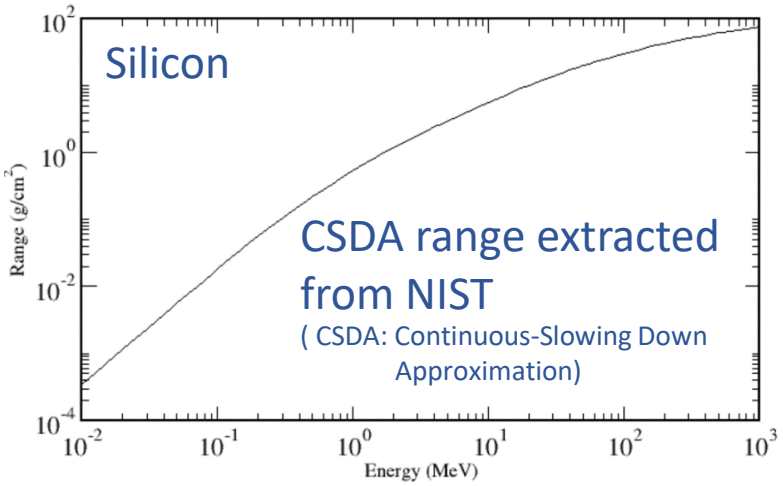
- Q = 1818.8 keV
- β^- = 27.9%
- A = 26000 Bq
- $T_{1/2}$ = 13.5 years

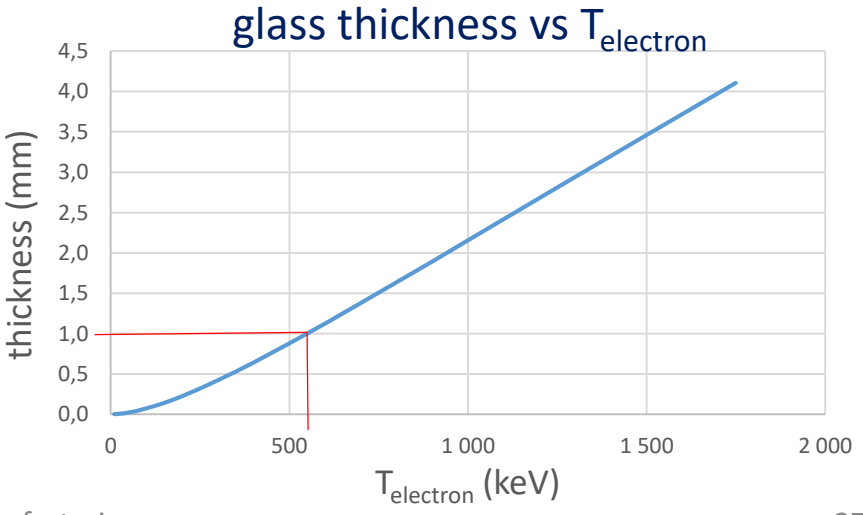
Target = glass (=Si)

- ρ = 2.5 (glass)

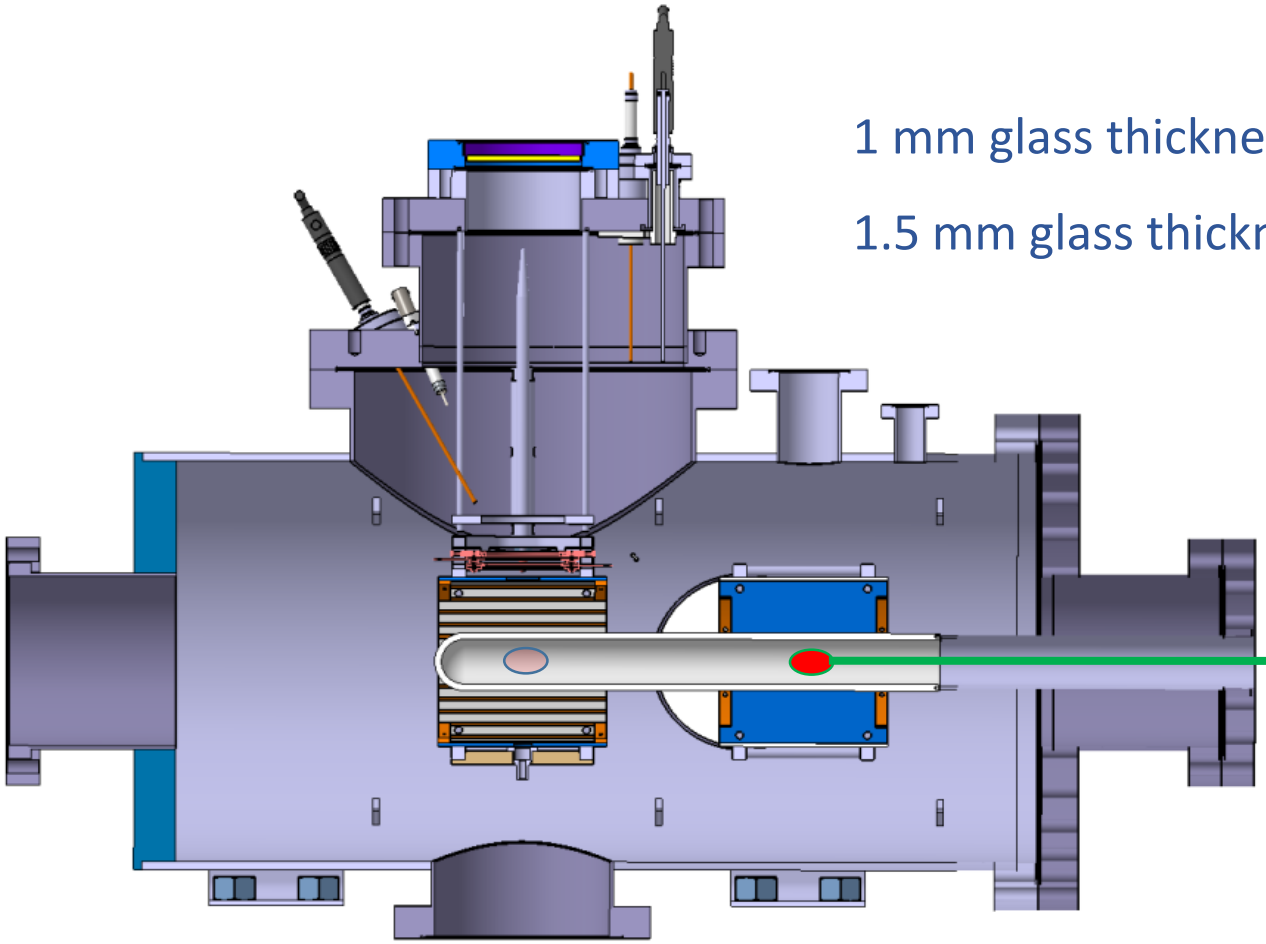








^{152}Eu β^- source / summary



1 mm glass thickness → 4 kHz (550 keV)

1.5 mm glass thickness → 2.6 kHz (750 keV)

Last minute (Friday evening): ^{152}Eu will not be available after June 2019. Proposition to work instead with a ^{90}Sr (A=555 kBq, $T_{1/2}$=29 years, but Q^-=545.9 keV)

To be finish
or/and
to be resume

pMCP ageing

LED light

- LED source + optical fiber, but λ_{LED} >> 180 nm
- Other idea (photo-electron emission): powerful light source with a filter + quartz + Al deposition

Software

- Follow up the profile evolution during run devoted to this task (beam stable at nominal conditions for instance) → calibration runs
- Calibration run: can be done every 2-3 days, weekly…
- Analysis:
  - Different MCP areas (close and far to the beam passage)
  - Calculate the average attenuation factor for all areas with time

    If correlations area locations/beam proximity

    → Rescaling MCP gains

Purchase

- We plan to purchase double stack pMCPs, ALD may be also considered for its longer lifetime

Beam background

Beam physics

Goal: check if halo particles interacting with accelerator structures have a negligible contribution to the beam profile.

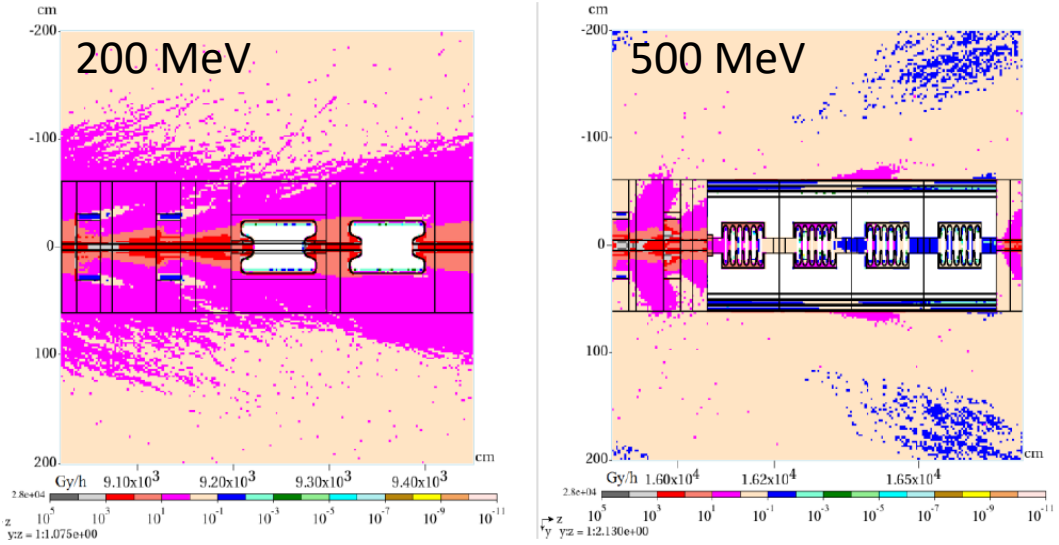
→ Yngve sent in Dec. 2018 space phase for protons in several locations of the cLinac

Not enough time to analyze these data, but work has already started

Tunnel background

ESS report (ESS-0060208, 5/2012, L. Tchelidze et al.)

Quadrupole and 2 Spoke CM / Quadrupole pair and elliptical CM



PINK: 1 to 10 Gy/h for 1W/m loss.

ESS loss objective: 0.01 W/m

LWU is missing

Lali confidence in calculations

→ "±1 order of magnitude"

LWU is missing (shielding?)

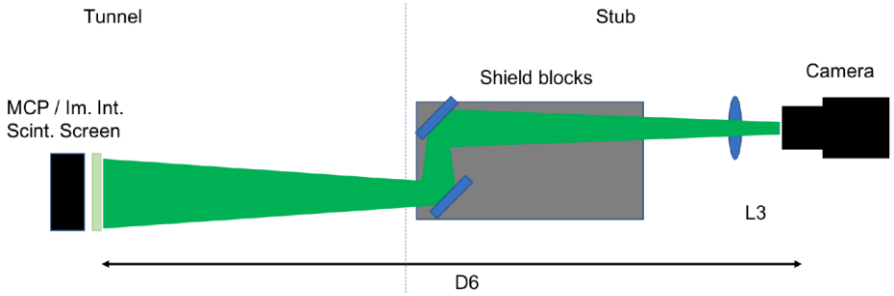
Camera at remote distance

If high radiative environment in the tunnel

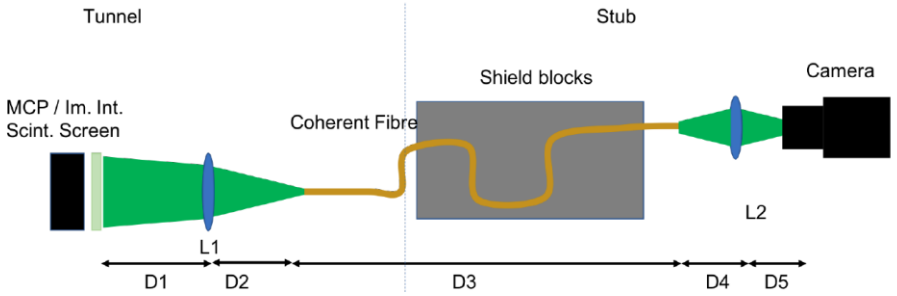
➔ GigE camera at remote distance

Detailed in ESS-0680911 report “Optical Systems for the NPM Long Distance Imaging”, C. Thomas & R. Tarkeshian, Feb. 2019.

2 proposed solutions



The tele-phot based imaging layout



The fiber-based imaging layout

Cyrille plans to investigating soon the fiberscope solution at Lund. Few elements are already ordered among them fiberscope (PMMA, around 2k€/100 m).

Huge signal loss is expected → double stacked MCP

To be considered: large diameter o.f. since light is quite monochromatic (λ of the phosphorescent MCP screen)

Work to be considered…

Miscellaneous

Brackets, holder for

- The VC test → ionic pump to be fixed through the bottom viewport
- Clean tent to hang IPM pieces for drying them
- Alignment for the optical bench

Slow pumping → bench similar to DACM one (filters) to be designed

IPM cages

- Optical marks to be engraved on the back ceramic electrode
- Passivation of copper deposition on ceramics: which material (compliance free particle)?
- MCP ageing monitoring

IPM cleaning and manufacturing

- ESS responsible to follow-up and validate all the processes during the 1st IPM pair preparation

IPM CS

- Choice Asymmetric / symmetric mode
- Remote GigE camera read-out

Storage boxes

- Design to be finished → discussion with ESS
- Transport: truck / plane? → mechanical calculation for handling harmful vibrations

IPM procurement

- For the main and delicate parts: order for 1 IPM pair, then checking
  - Yes → launch the “production” / No discussion until.. Yes

Change Request

CR: why ?

Uniformity of the electric field

- June 7th 2016: we have warned ESS that the LWU space should be too small for avoiding non-uniformity EF (NPM kick-off May 2016 and LWU CDR on mid-June 2016)
- Letter to Paul Nov. 22nd 2017 for adding 2 disks on LWU
- Florian presentation clearly shown that LWU will fulfil the EF uniformity, only if grounded disks are inserted on both IPM sides.

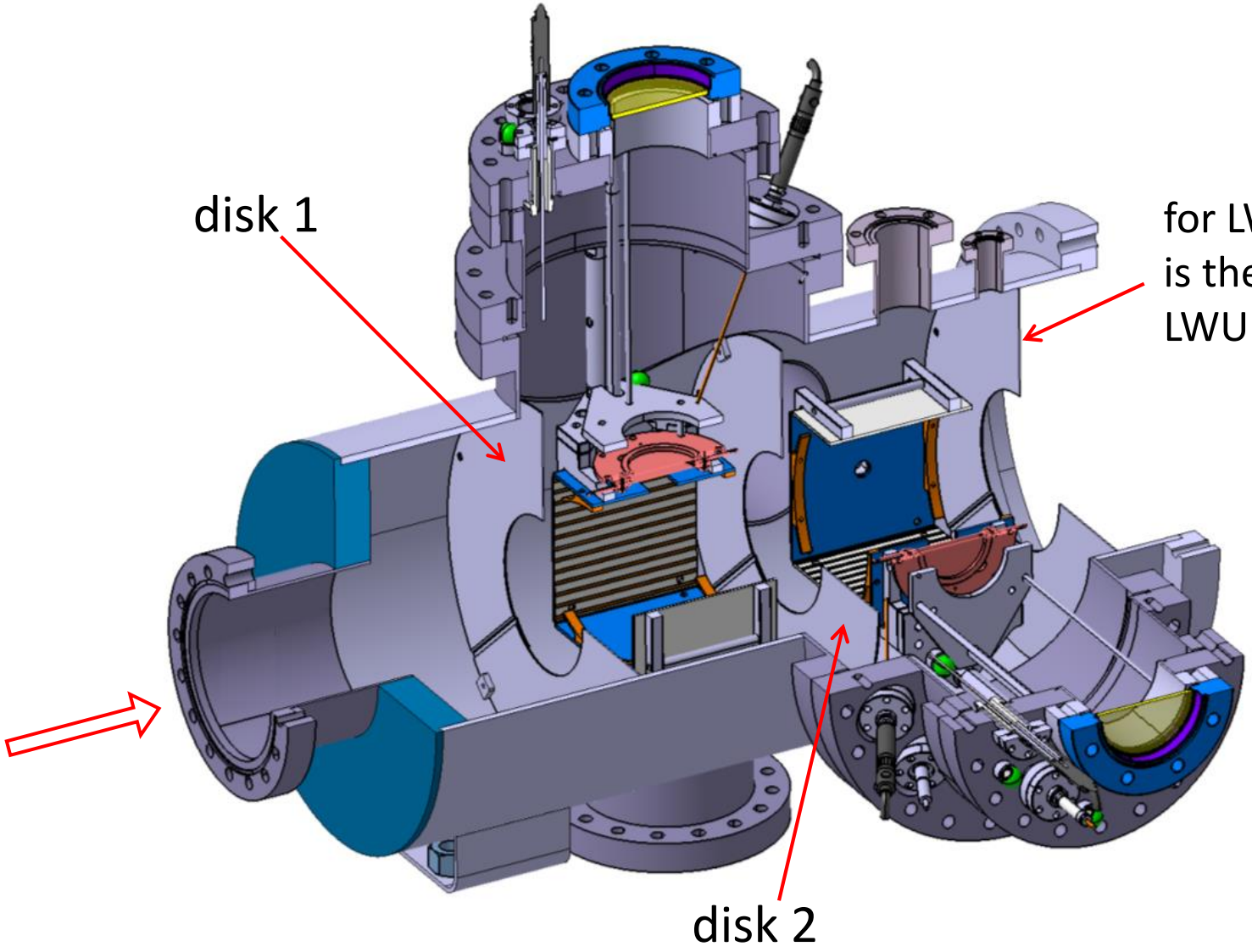
LWU different types

- During ESS forum held at Lund in November 2018, discussion with Paul put my attention on the LWU geometry.
- Back to Saclay, after checking we discovered that there are 2 types of NPM-LWU. We were never aware about that!
  - LWU for Mβ & Hβ sections: our bench is similar to this later, and IPM design is based on this one too!
  - LWU for Spoke Section: much shorter to previous one, but find a solution together with Paul to modify LWU accordingly...

Change request

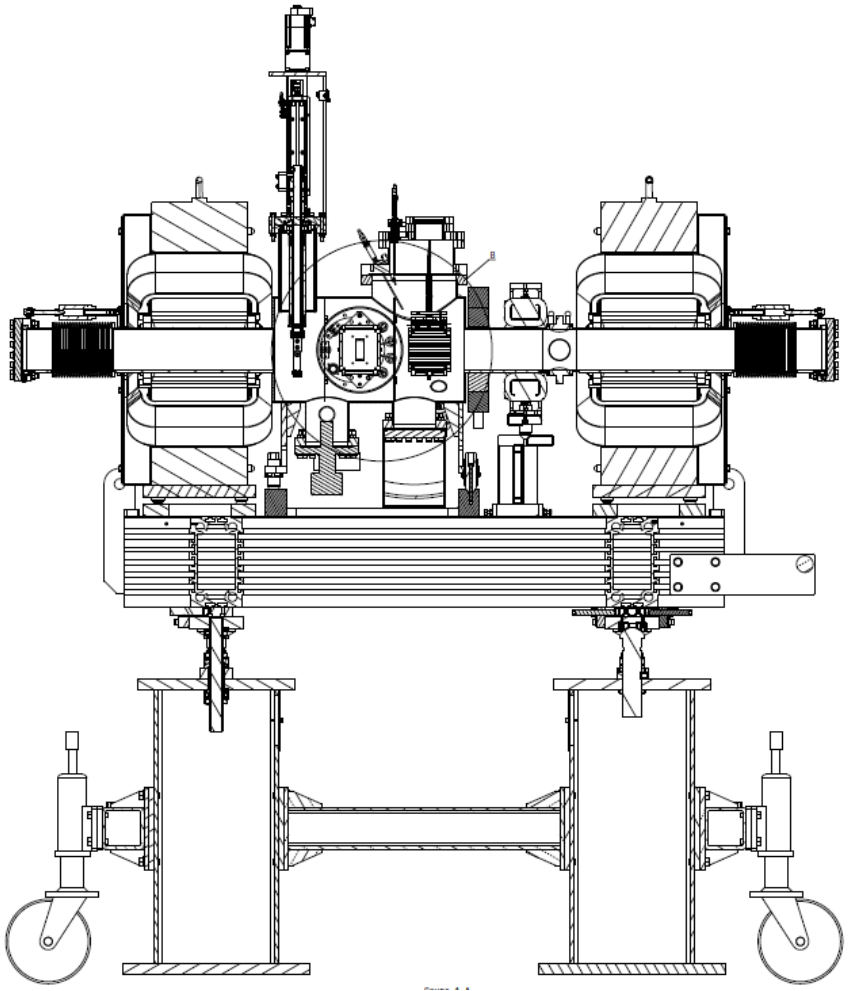
- discussions started with Paul by Dec. 2018, ended by beginning of February 2019
  - Settled for Spoke section: LWU shape + lugs positions
  - Modification of lug positions elliptical LWU: fixed
  - Disk type → Loris's proposition: is it compliant with free particles?

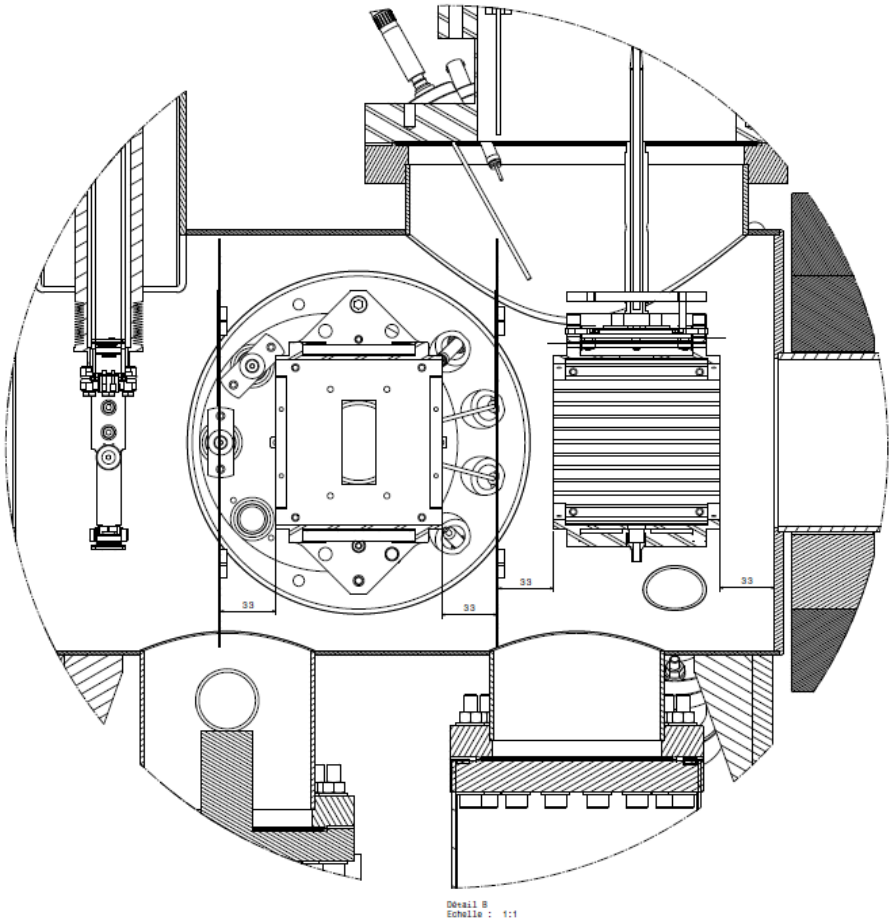
CR: 1st part of our test bench, which is similar to LWU



Disks for MβL and HβL

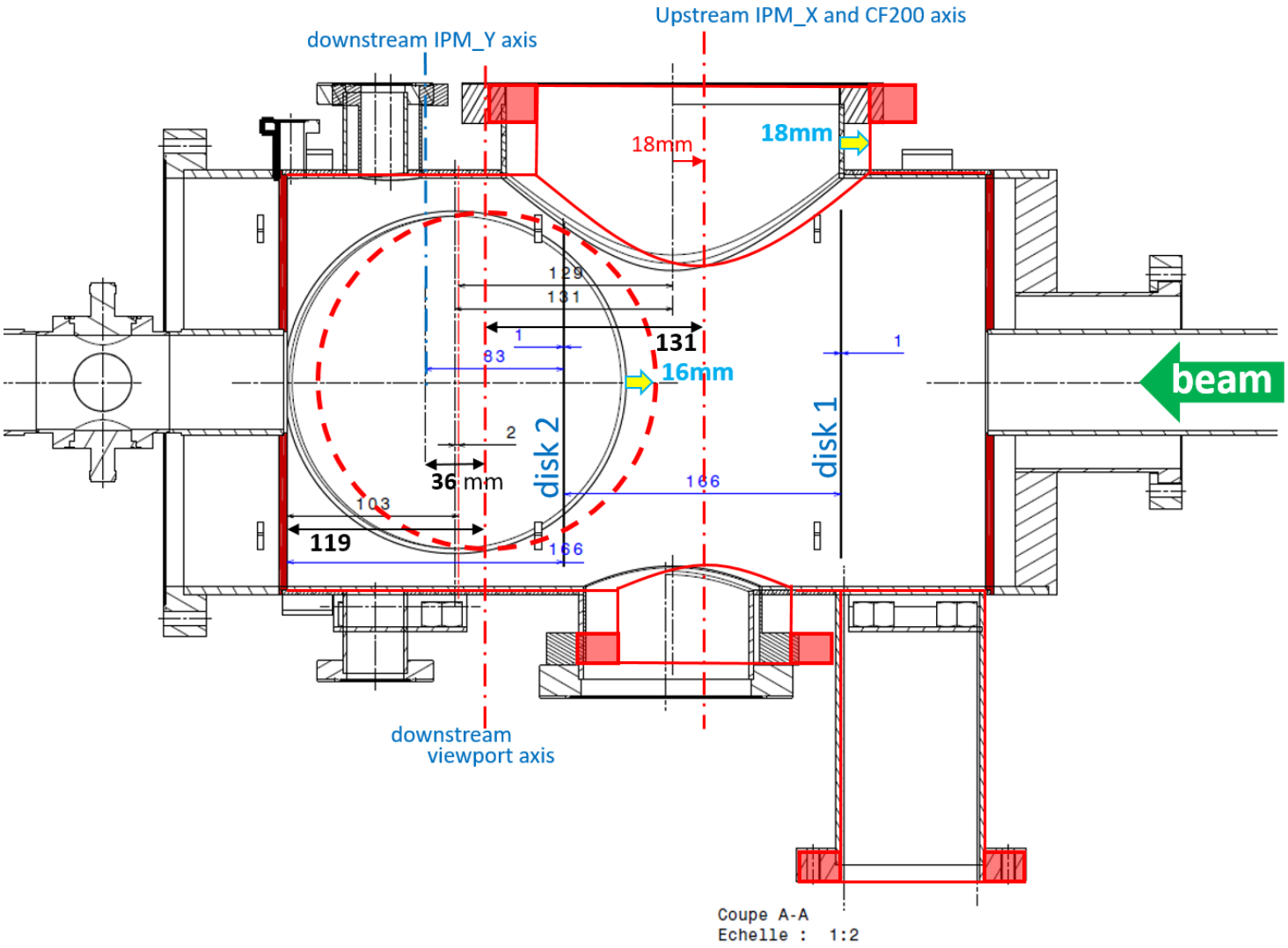
CEA-Saclay
ESS-NPM
le 07/02/2019



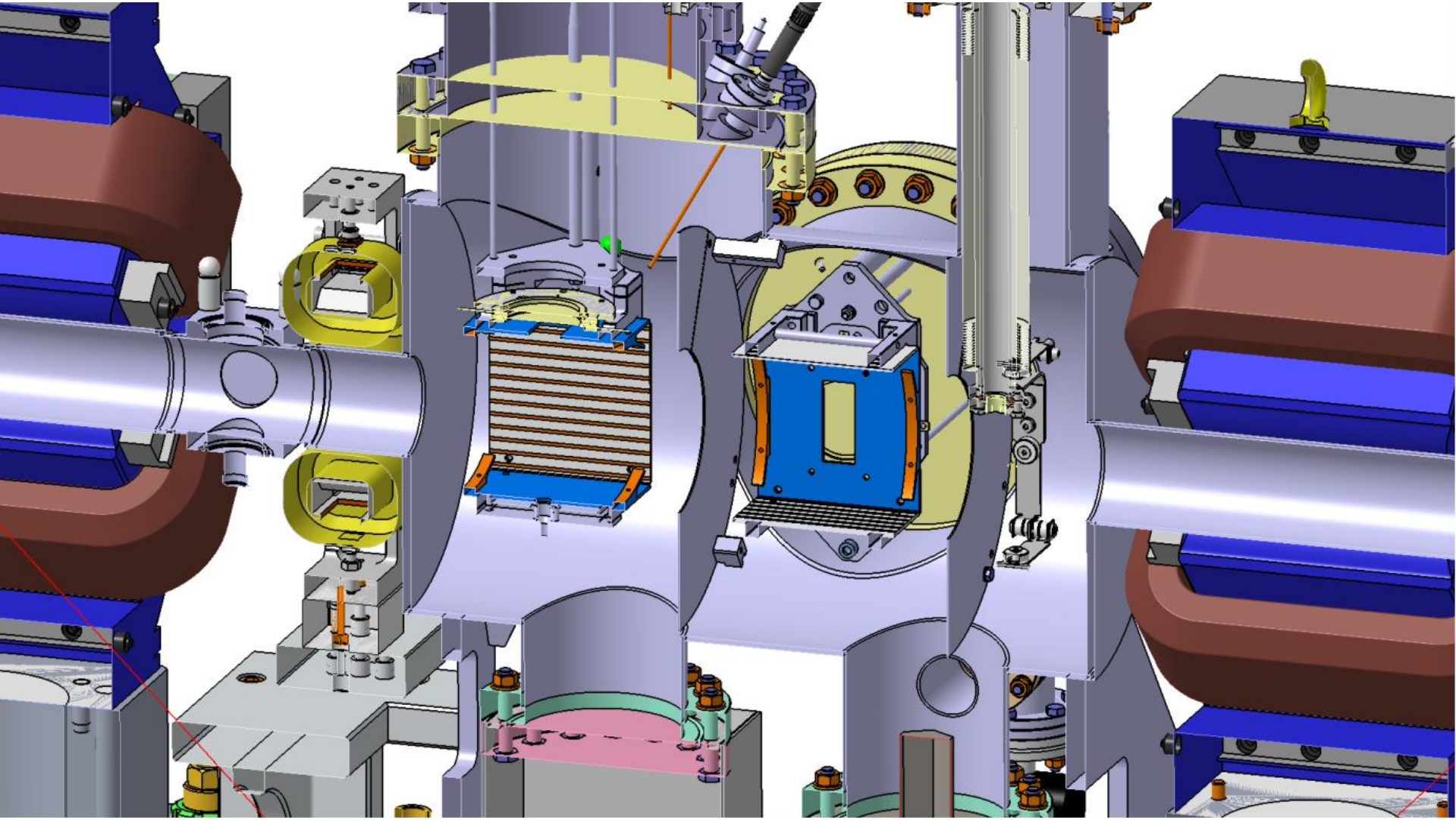


Requested modifications for Spoke LWU

Huge modifications done by Paul: IPM are now compliant to Spoke LWU size and shape.



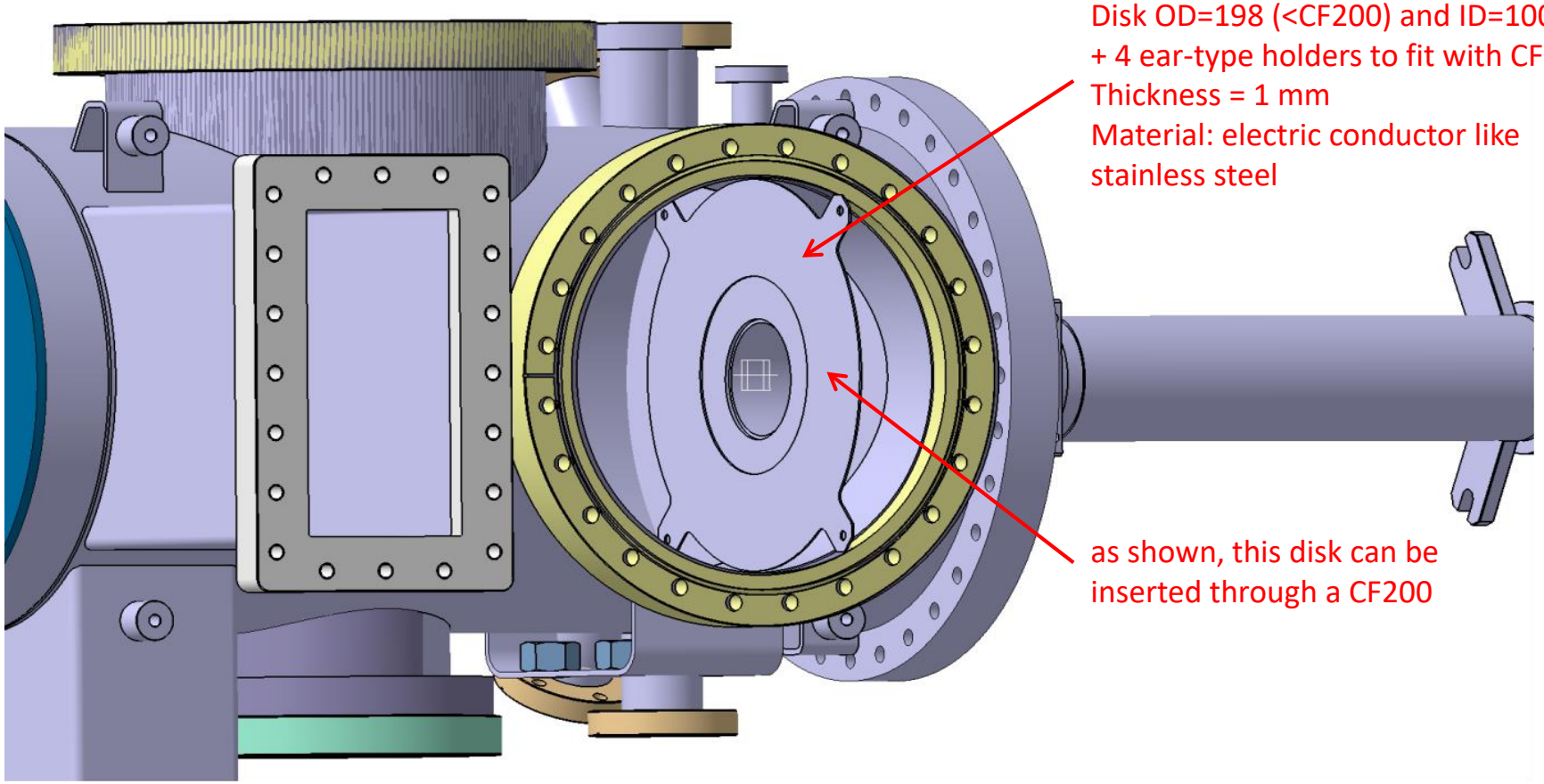
Disks for « modified » Spoke LWU



Disks proposition

New CEA Saclay disk proposition done on Dec. 21st 2018

- Is it compliant with particle free?



CR: conclusion

Paul's email (Jan. 10th 2019)

> "As a side note, mounting of the disks will be done by ESS as this is out of scope of the BTM project at Daresbury. STFC will add the required lugs. We also have not been asked to purchase the disks."
>
> → CR to allocate tasks and expenses

To be done, and managed by ESS Lund

- Official validation of changes by Daresbury, **ESS Lund** and Saclay
- Disk type → Loris's proposition: is it compliant with free particles?

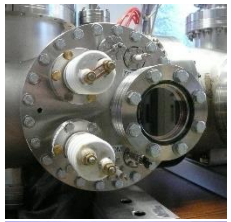
CR for freezing design and avoiding a new crisis…

Interfaces

Interfaces

Identified interfaces

- LWU → change request: taken in charge by ESS Lund
- Control systems → taken in charge by ESS Lund
  - Monitoring HVs feeding IPMs (iseg), GigE cameras, MCPs
  - specific development for adjusting MCP gain
- Data Acquisition system → taken in charge by ESS Lund
  - Registering data and storing
  - On-line data analysis for profile displays like follow-up of Mean Values and σ time behavior
- HV → procurement taken in charge by ESS Lund
  - For symmetric mode: the problem is the strip mode on MCP side, for instance: IPM -15kV, MCP: in=-16kV, out=-15kV and screen=-11kV. If IPM trips, the 3 others have to force to trip too!
    → Iseg 4 channels: **EHS** 4y 200x, 20 kV, 400 µA
  - If Asymmetric: CPS module & MMS crate (30kV) or EHS modules & MMS crate (≤20kV)
  - Safety trip management



Interfaces

- Cables → procurement taken in charge by ESS Lund
  - List of cables given at Edvard
- GigE cameras → procurement taken in charge by ESS Lund
  - We used Blackfly FLIR BFLY-PGE-23S6M-C.
  - To be discussed with ICS to find one camera close to ours, among those already tested by ESS ICS with the following main characteristics (see CHESS document for more details):
    - Large pixel size: > 5.86µm, with the possibility to bin them together x2 or more,
    - Pixel numbers: 2.3 Mpix are enough,
    - Speed acquisition should above 14Hz
  - Fiberscope if remote GigE system is required
- Storage boxes → procurement taken in charge by ESS Lund
  - How many to be manufactured, we propose 5 in order to not be slowing down in the manufacturing NPM scenario!

Risk table

Current risks

RR3-PM2 – Owner CEA – Rating: before mitigation=32, after mitigation=8	
"As a result of…"	Ultra high vacuum and high energy of the proton beam
"There is a risk that…"	Ratio S/N too low and NPM not reaching expected performance with the foreseen technology
"Resulting in…"	Another monitoring system to develop
Mitigation strategy	Tradeoff for 2 RO solutions (100%) + Proto tests (2 options on IPHI - end 2018) (50%)
RR3-PM3 – Owner CEA – Rating: before mitigation=8, after mitigation=4	
"As a result of…"	Lack of space between the cryomodules devoted to NPM
"There is a risk that…"	NPM unable to measure X and Y profiles in the same diagnostic box
"Resulting in…"	bad performance / new concept, but X and Y not measured simultaneously
Mitigation strategy	1 channel instead of 2, but with a rotation system for X and Y profile measurements
RR3-PM4 – Owner CEA+ESS – Rating: before mitigation=32, after mitigation=8	
"As a result of…"	Uncorrelated proton beam can induce ionization at NPM location which imply background noise
"There is a risk that…"	Reduction of Ratio S/N
"Resulting in…"	Extra studies for characterization or another monitoring system, upstream scrapper aperture optimization
Mitigation strategy	Background to be characterized: uniform distribution or not (25%)
RR3-PM6 – Owner CEA+ESS – Rating: before mitigation=32, after mitigation=8	
"As a result of…"	Too weak FEE radiation shielding in the CM support
"There is a risk that…"	Drastic reduction of S/N ratio
"Resulting in…"	no data transferred to DAQ system
Mitigation strategy	Radiation map from ESS (100%) but not accurate enough. Implement shielding in FEE (25%). Experimental data (0%)
RR3-PM7 – Owner CEA+ESS – Rating: before mitigation=16, after mitigation=1	
"As a result of…"	very high voltages (up 30 kV), sparking effects may appear leading to reduce HV for decreasing them
"There is a risk that…"	Larger distortion (width) of profile measurement due to the Space Charge effect
"Resulting in…"	degradation of profile measurement
Mitigation strategy	Software space charge benchmarking to perform on IPHI (25%) + Software correction developed by Francesca (75%)

Transferred risks to ESS

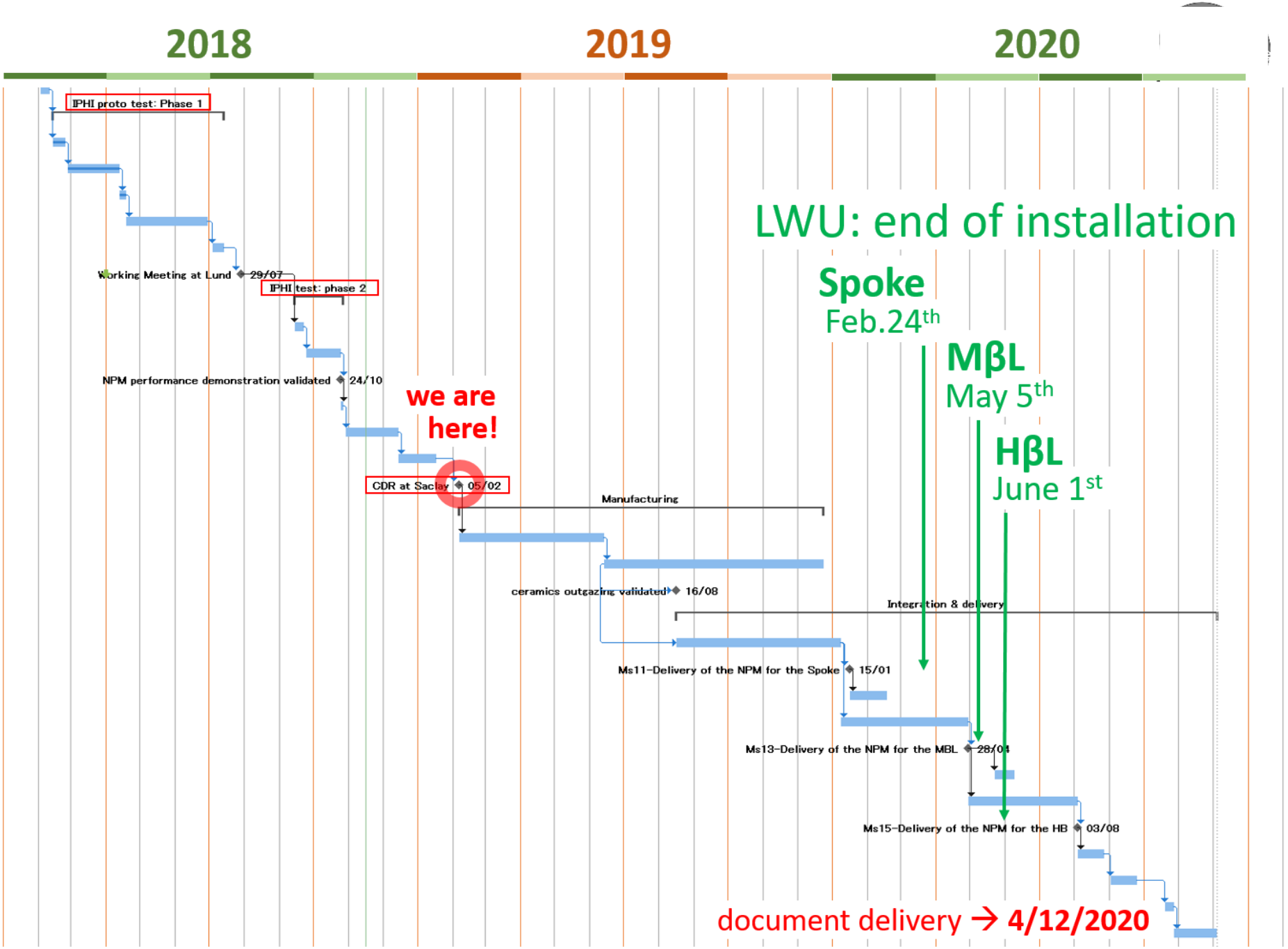
RR3-PM5.1 – Owner ESS – Rating = 32	
"As a result of…"	Vacuum chamber CDR 3wks after NPM kickoff > chamber design as a constraint
"There is a risk that…"	Read Out difficult to integrate in the vacuum chamber design
"Resulting in…"	Vacuum chamber to be modified
Transfer	CEA has notified ESS previously to VC CDR (VC modification proposed

RR3-PM5.2 – Owner ESS – Rating 32	
"As a result of…"	Vacuum chamber CDR 3wks after NPM kickoff > chamber design as a constraint
"There is a risk that…"	Generation of sparks for very high voltages
"Resulting in…"	Vacuum chamber to be modified
Transfer	CEA has notified ESS previously to VC CDR (VC modification proposed)

Closed risks

RR3-PM1 – Owner CEA	
"As a result of…"	Budgetary or operational reasons (ESS)
"There is a risk that…"	Decision to implement NPM taken too late
"Resulting in…"	Expenses with no concrete use, no conservative measures taken in current design

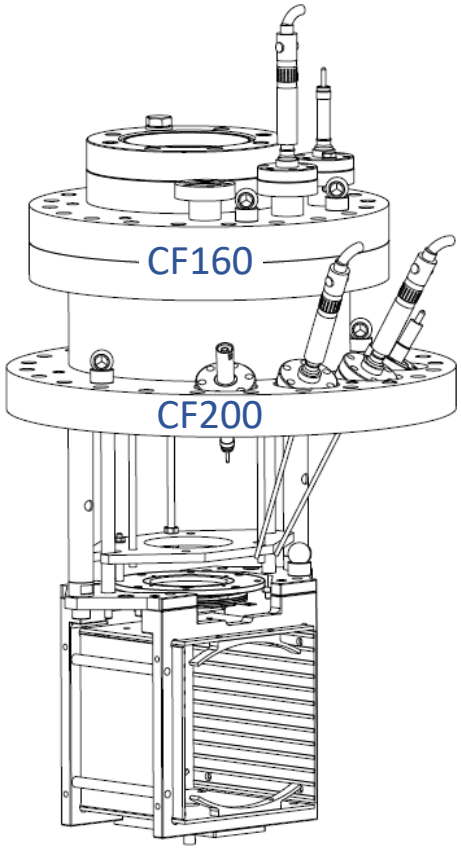
RR3-PM5 – Owner CEA+ESS	
"As a result of…"	Proto tests on IPHI & LINAC4. Schedule constraints
"There is a risk that…"	Full qualification of the NPM prototype not ready for CDR
"Resulting in…"	delaying the CDR to achieve the prototype characterization

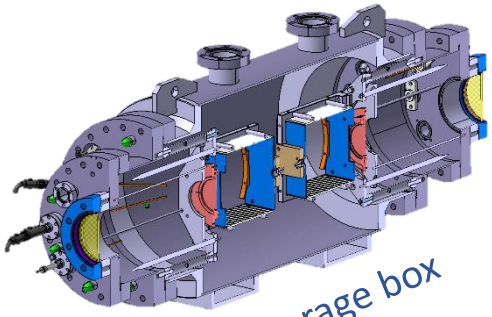

2018
2019
2020
IPHI proto test: Phase 1
Working Meeting at Lund 29/07
IPHI test: phase 2
NPM performance demonstration validated 24/10
we are here!
CDR at Saclay 05/02
Manufacturing
ceramics outgazing validated 16/08
Integration & delivery
Ms11-Delivery of the NPM for the Spoke 15/01
Ms13-Delivery of the NPM for the MBL 28/04
Ms15-Delivery of the NPM for the HB 03/08
LWU: end of installation
Spoke
Feb.24th
MβL
May 5th
HβL
June 1st
document delivery → 4/12/2020

Mechanical delivery

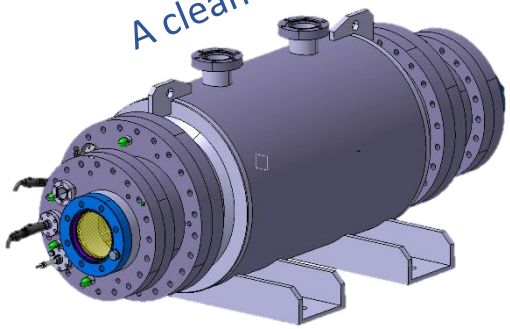
5 ×

NPM
- 2 IPMs
- 2 grounding disks
- 1 storage box
- 1 test report/IPM





A clean storage box



IPM will be entirely mounted with all their inner pieces including MCP. Ready to be plugged (HVs, Camera)

Design is almost frozen

IPMs are similar for Spoke or MβL / HβL

For transport, each IPM pair will be inserted in a clean storage box, then packed in a specific box designed for canceling harmful vibrations.

Thanks you for your attention