# Challenges of Obtaining of Ultra-High Vacuum in NICA Project

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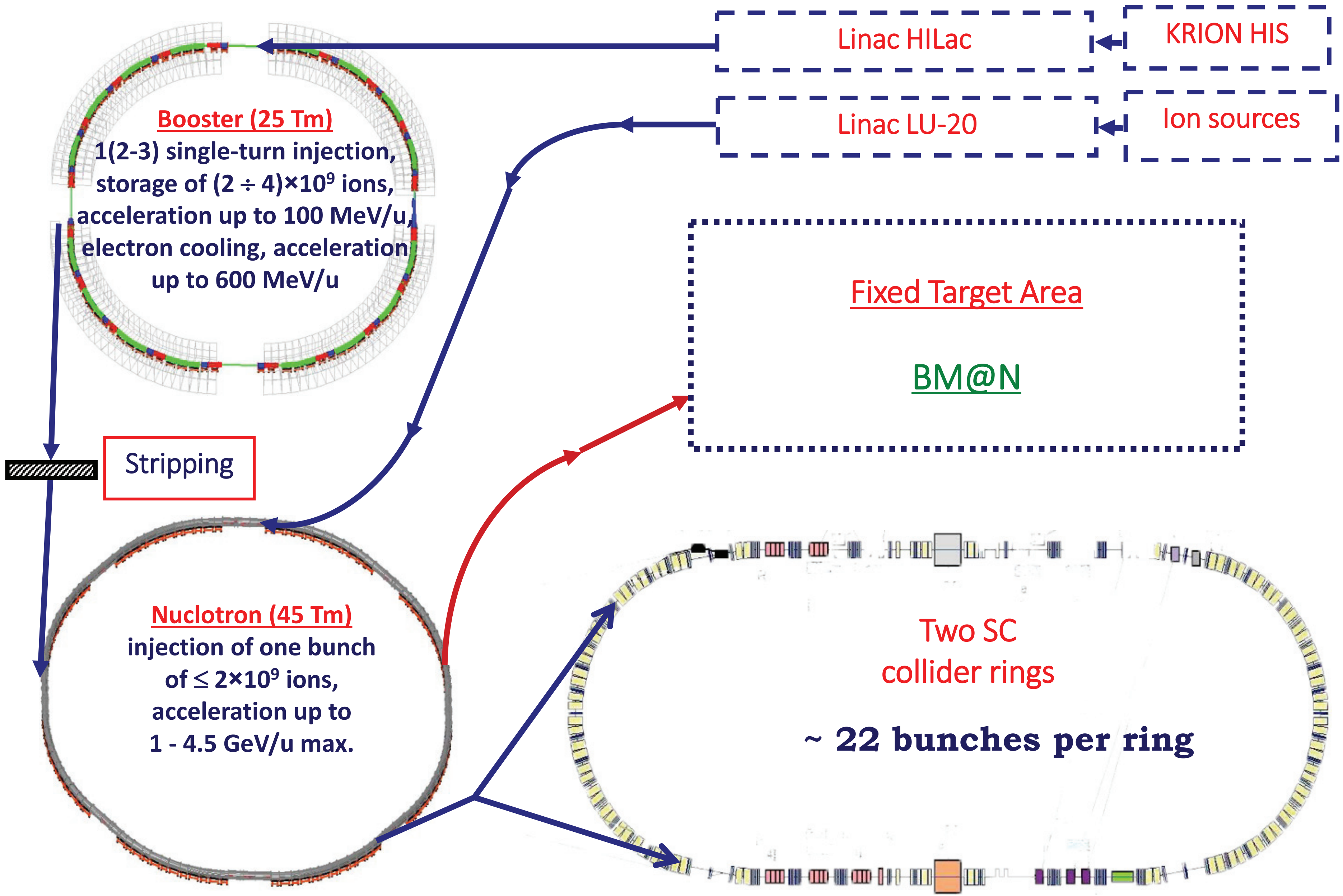
# Key points to obtaining of ultra-high vacuum

- More than 90% of rest gas should be hydrogen
- Definition of total outgassing flow and gas flow per square
- Dry (without oil) pumping systems (turbo, forevacuum pumps)
- Combination of ion pumps with TSP, NEG, Cryo pumps
- Baking after assembling to remove water
- Beam lifetime due to losses on rest gas
- NEG coating for long beam pipes under room temperature
- Dynamics vacuum instability for high intensity beams
- Electron cloud instability – special treatment of the surface

# NICA Accelerator Complex

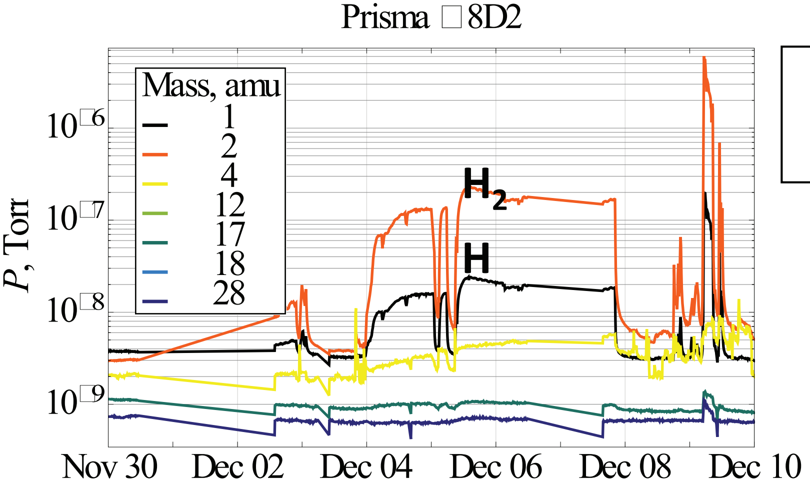


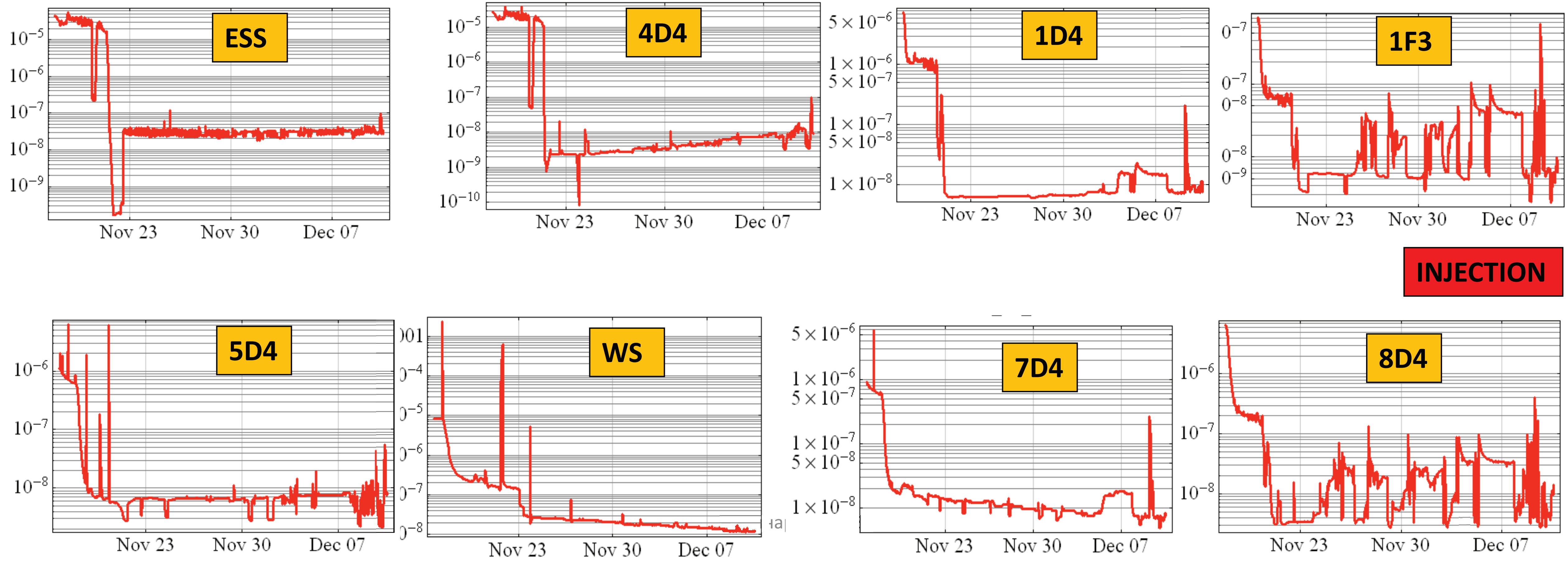
# Vacuum systems of particle accelerators

| Accelerator | Length, m | Pressure, Pa | Pump types | Status |
|---|---|---|---|---|
| LU-20 | 20 | $10^{-4}$ | Turbo pumps + cryopump | Upgraded |
| HILAC | 11,5 | $10^{-5}$ | Turbo pumps + ion pumps | Assembled |
| Nuclotron | 251,5 | $10^{-7}$ | Turbo pumps + ion pumps | Upgraded |
| Booster | 211 | $10^{-9}$ | Ion pumps + getters | Production Assembling |
| Collider | 503 | $10^{-9}$ | Ion pumps + getters | Design Production |

# Nuclotron run for one month on 2009 (circumference 251 m)

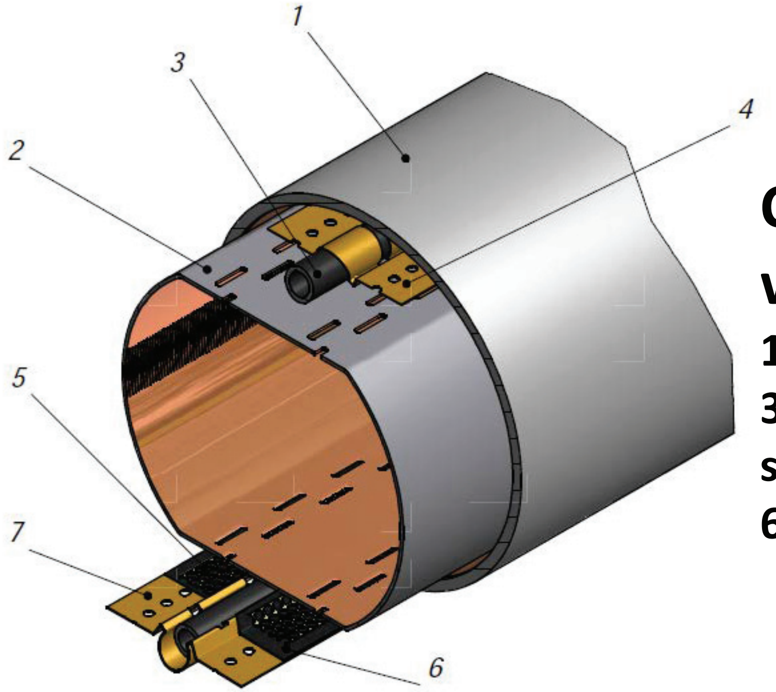
**Mass analyzer QUADERA**



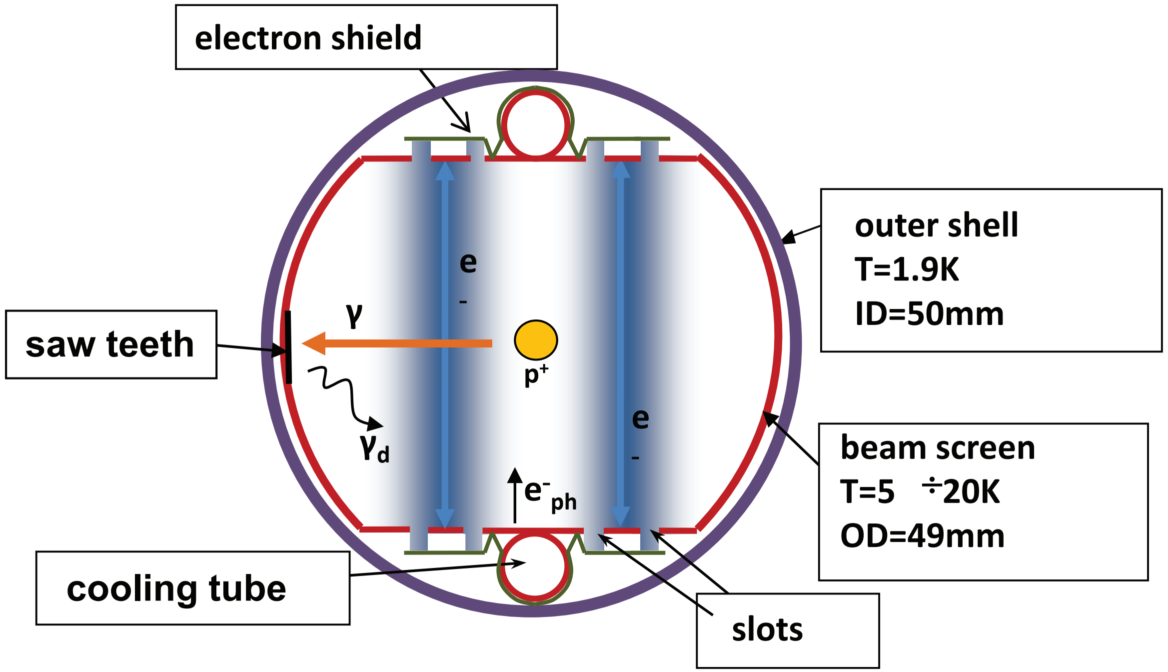

**INJECTION**

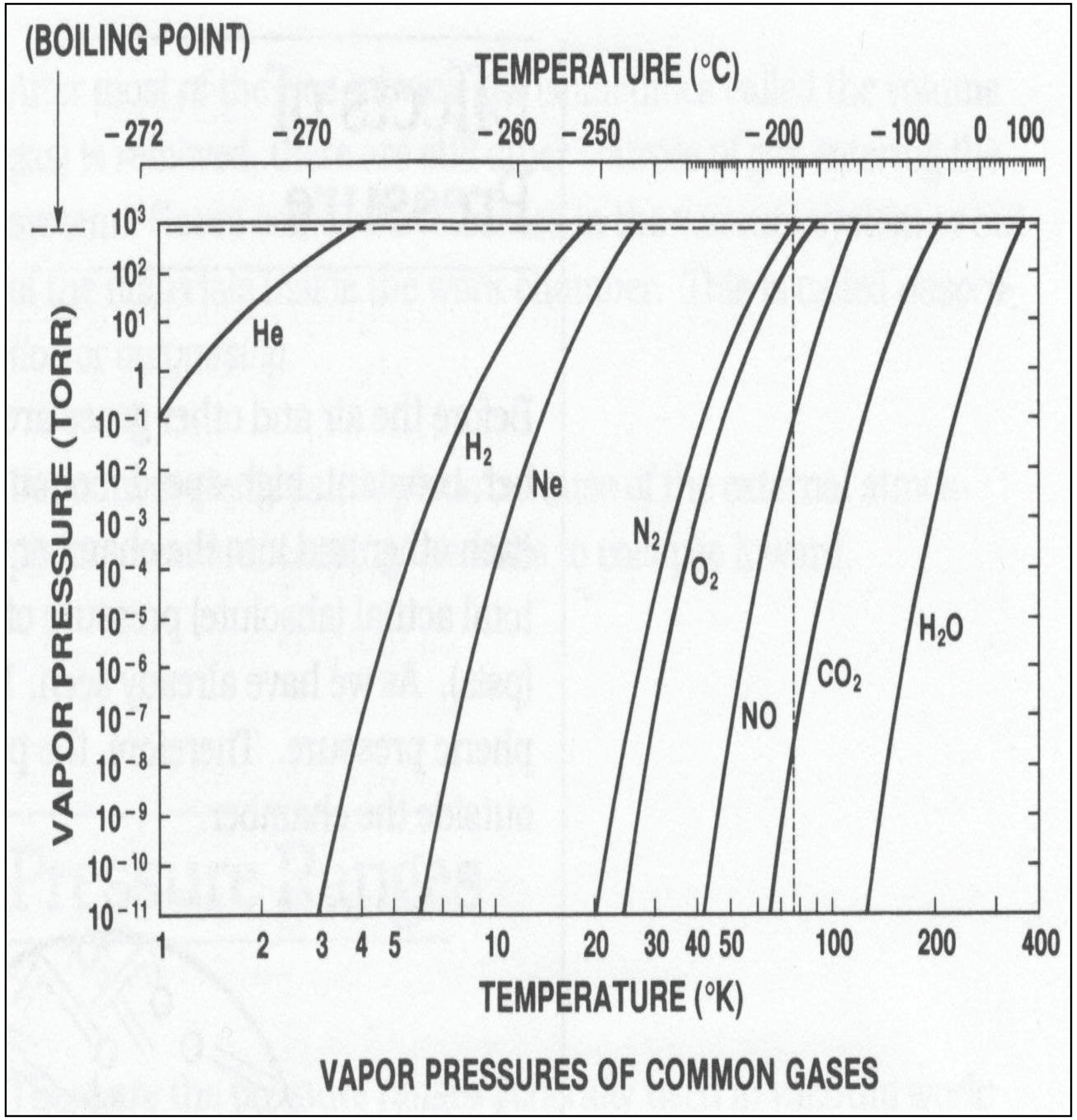
# LHC vacuum chamber



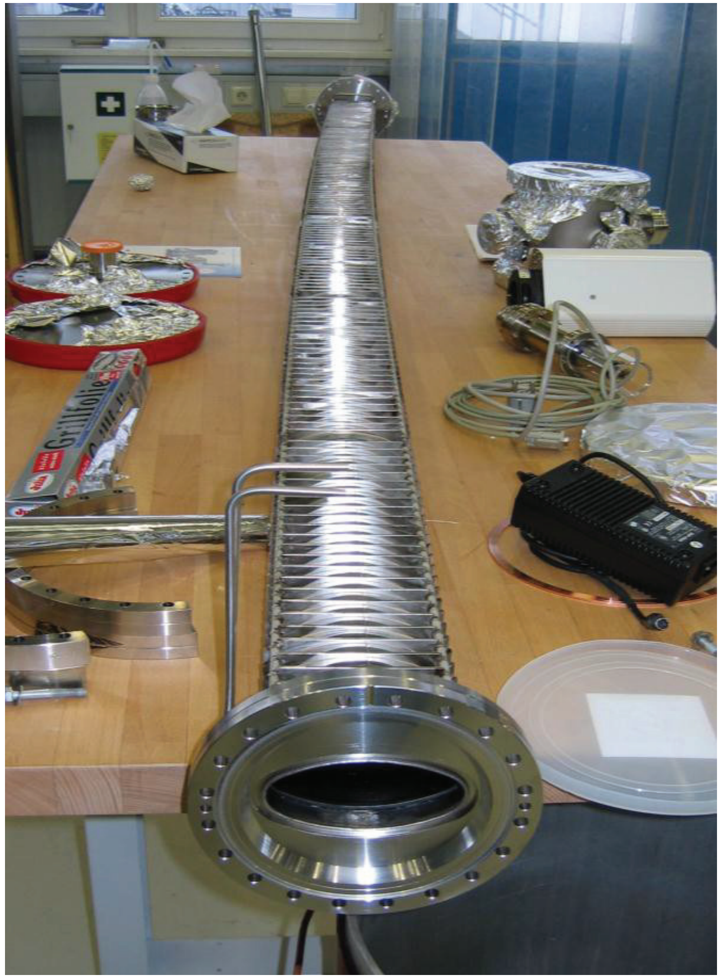

## Cold vacuum chamber with cryosorber

1- outer shell, 2 – beam screen, 3 – cooling tube, 4,7 – pumping slot shield, 5 – charcoal fiber, 6 – grid for charcoal fixing



# SIS100 Dipole Chamber Design

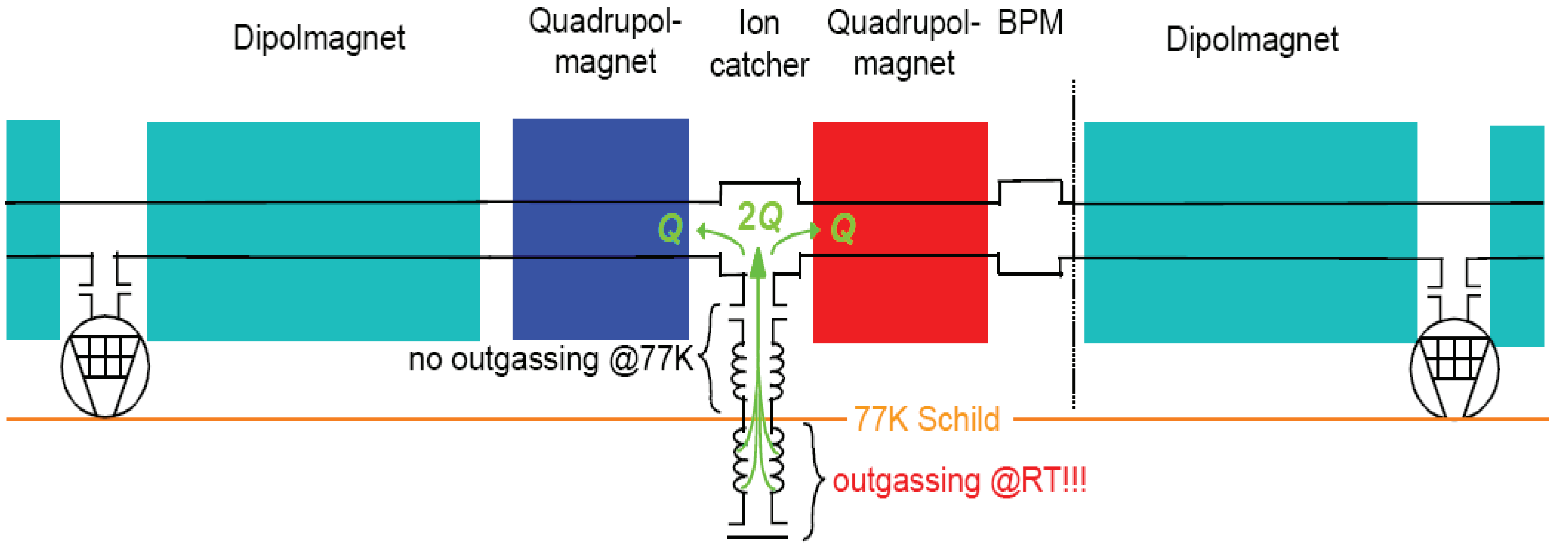


Length of chamber: 3.35 m
Aperture: 120 x 60mm²
Wall thickness: 0.3mm
Rib thickness: 3.0 mm

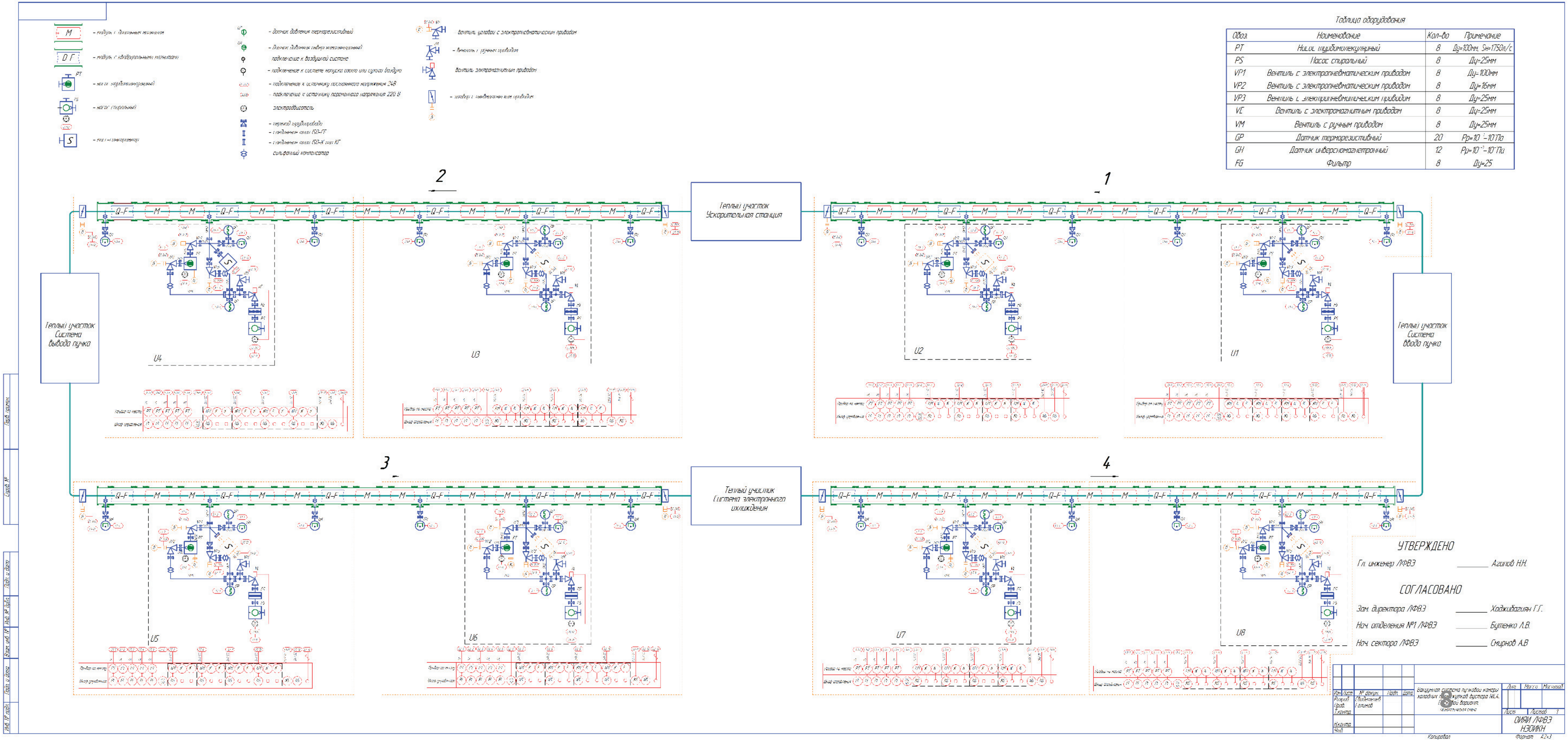
**Vacuum physical requirements on the magnet chamber design**

- all dipole chambers represent 45% of the total cold surface in the cryogenic arcs
- the inner beam pipe wall will be used as expanded cold surface of an efficient cryopump with practically infinite capacity for nearly all condensable gas species wall temperatures as low as possible
- static vacuum pressure inside the chamber $10^{-12}$ mbar, under dynamic conditions < $10^{-11}$ mbar
- due to the fast magnet ramping eddy currents heat up the chamber wall to temperatures > 20K

## Cryosorption Pumps

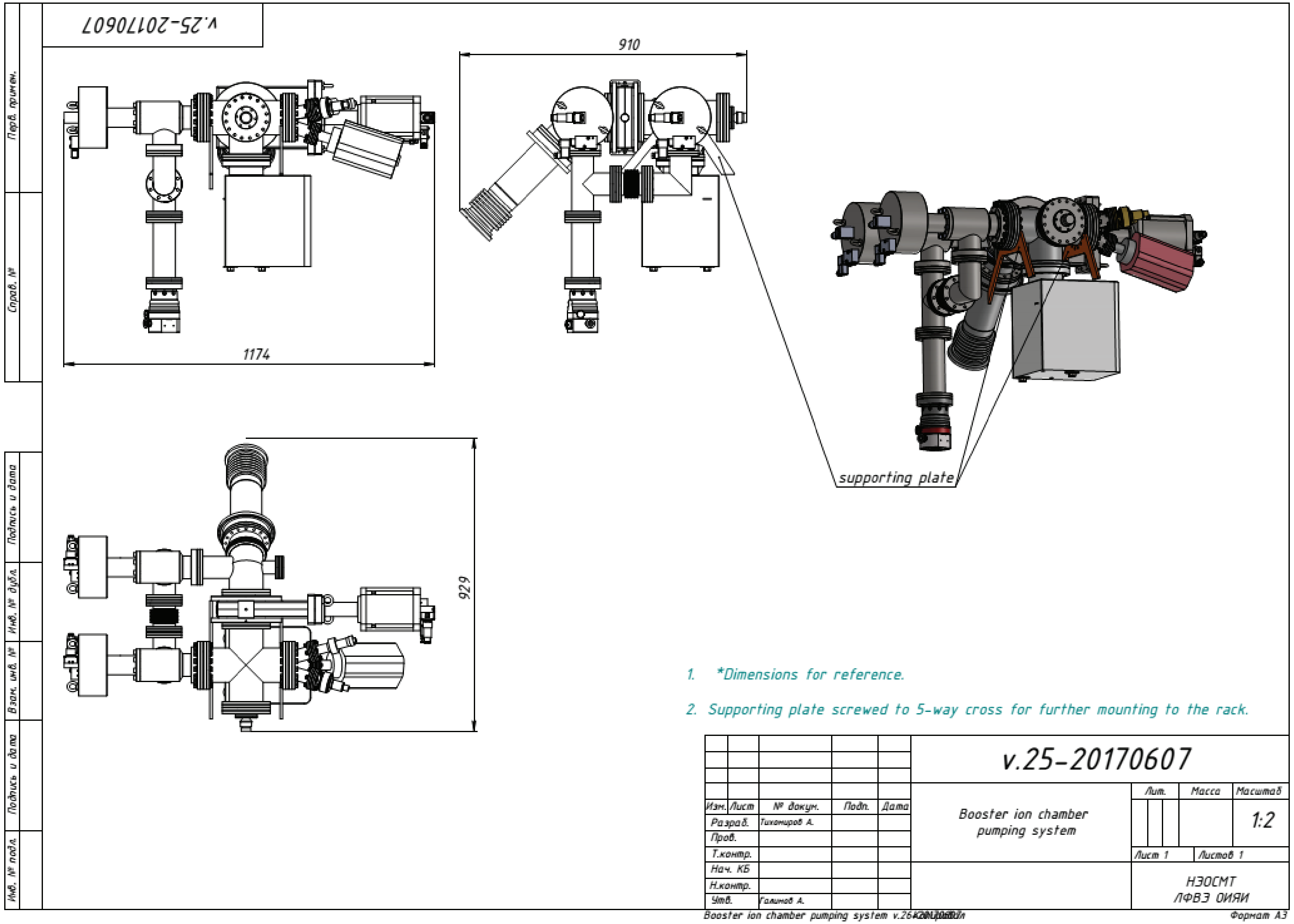


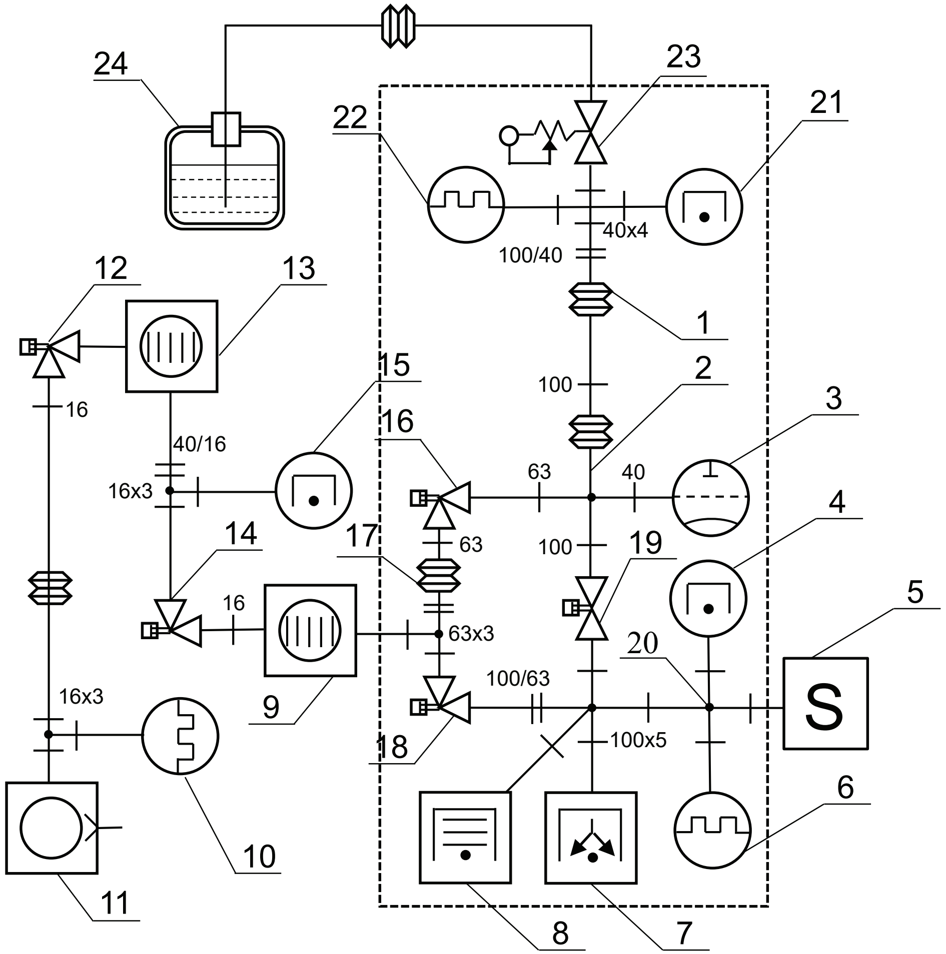
# Vacuum scheme for booster cold arcs (presented in poster)




| Обоз. | Наименование | Кол-во | Примечание |
|---|---|---|---|
| PT | Насос турбомолекулярный | 8 | Ду=100мм, Sн=1750л/с |
| PS | Насос спиральный | 8 | Ду=25мм |
| VP1 | Вентиль с электропневматическим приводом | 8 | Ду=100мм |
| VP2 | Вентиль с электропневматическим приводом | 8 | Ду=16мм |
| VP3 | Вентиль с электропневматическим приводом | 8 | Ду=25мм |
| VE | Вентиль с электромагнитным приводом | 8 | Ду=25мм |
| VM | Вентиль с ручным приводом | 8 | Ду=25мм |
| GP | Датчик терморезистивный | 20 | Рр=10 [illegible]–10 [illegible] Па |
| GH | Датчик инверсномагнетронный | 12 | Рр=10 [illegible]–10 [illegible] Па |
| FG | Фильтр | 8 | Ду=25 |

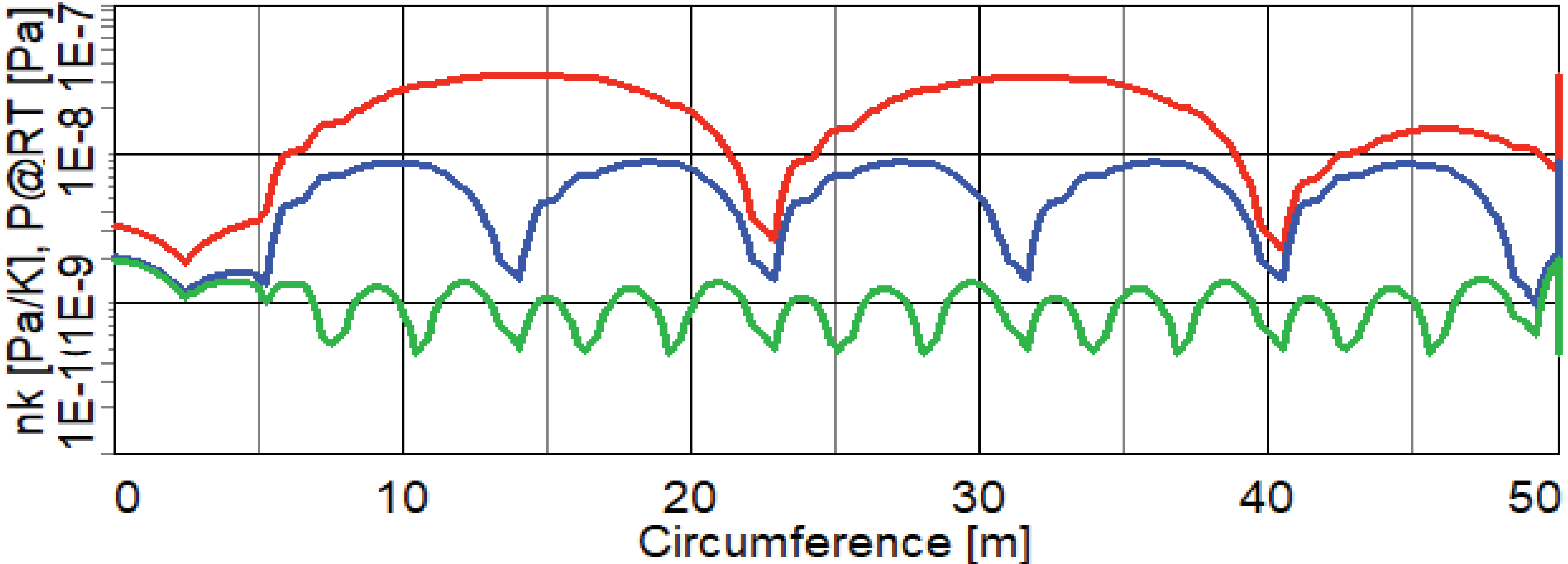
# Prototype of vacuum stand (Vakuum Praha test)



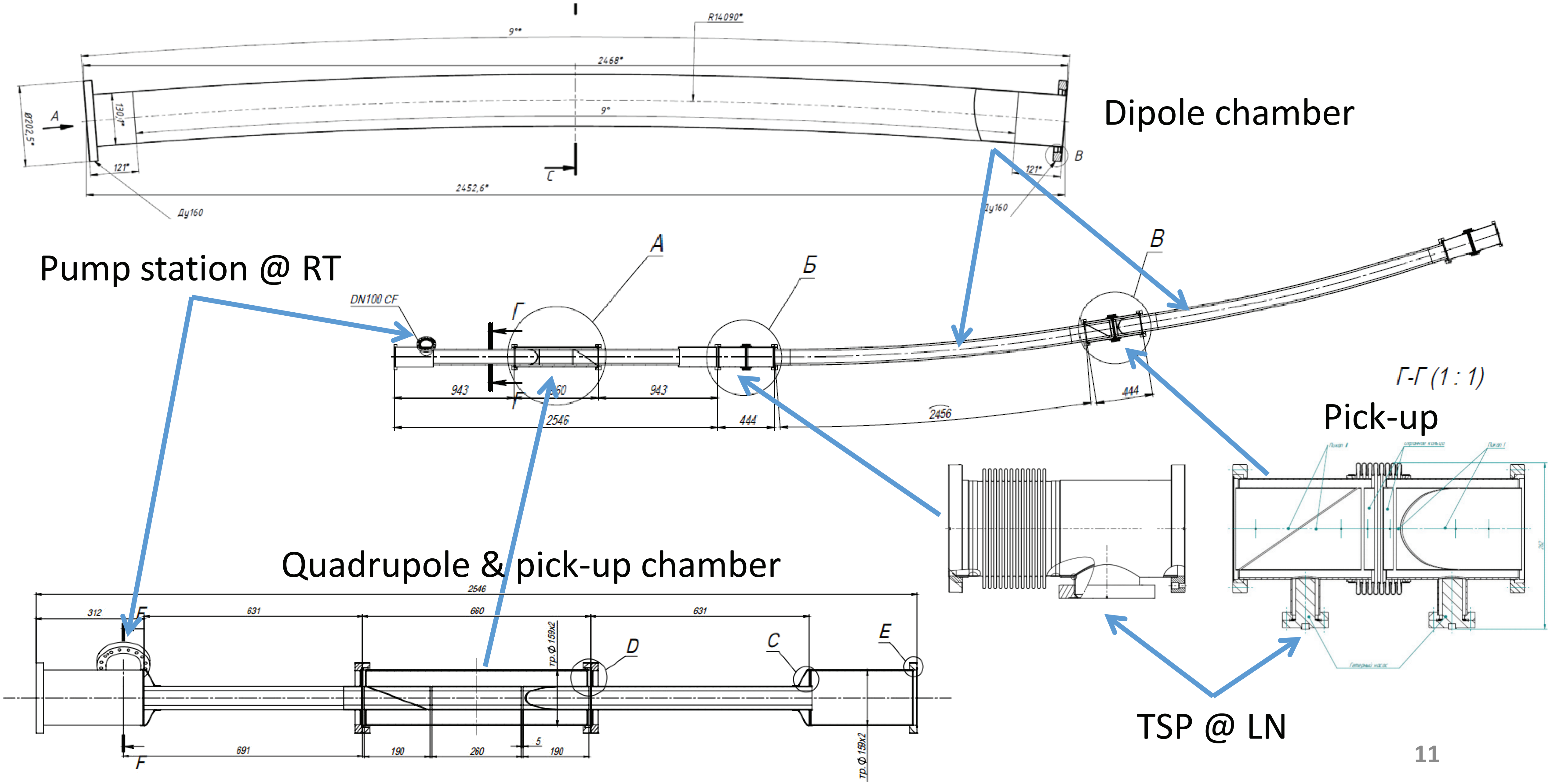



# Simulation of dynamics vacuum and pressure distribution for ¼ booster (all gauges at room temperature)

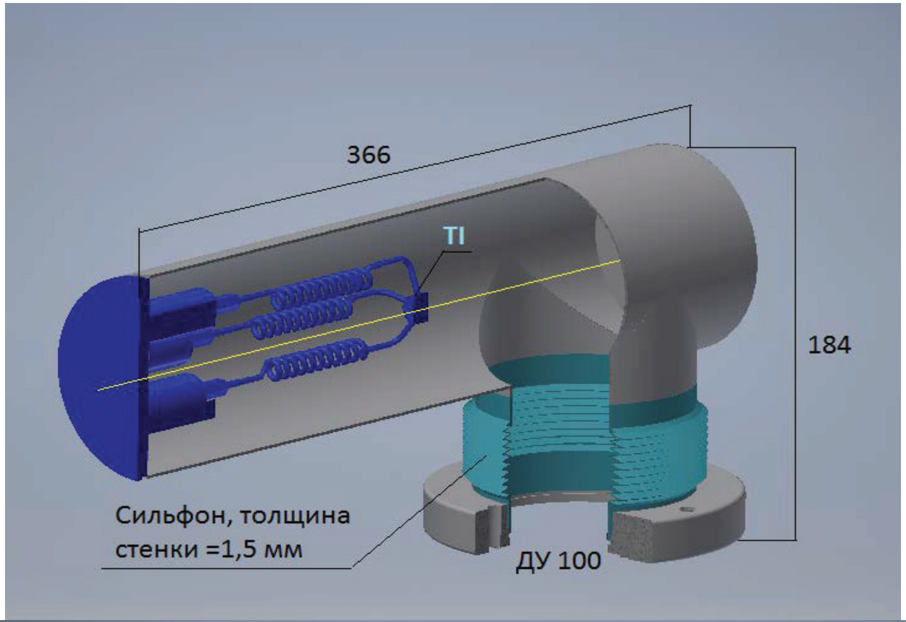
1) Red line – startup vacuum scheme (turbopumps only)
2) Blue line – normal vacuum scheme (ion pumps + TSP getters)
3) Green line - with additional TSP@LN between magnets

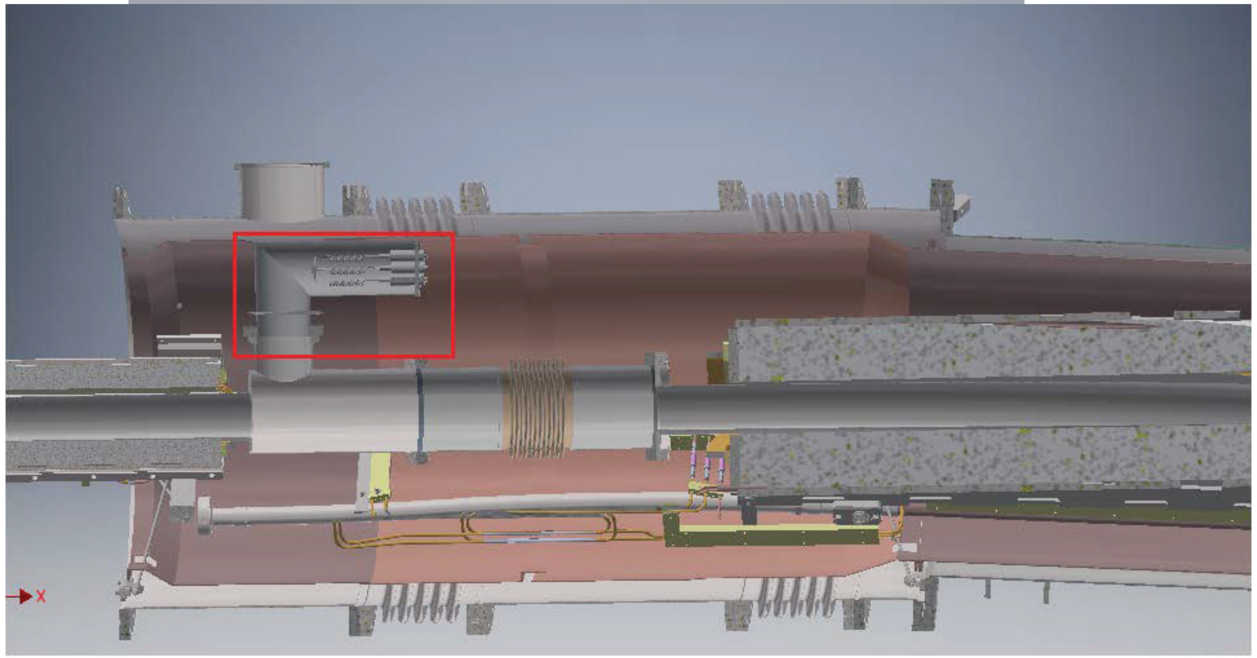


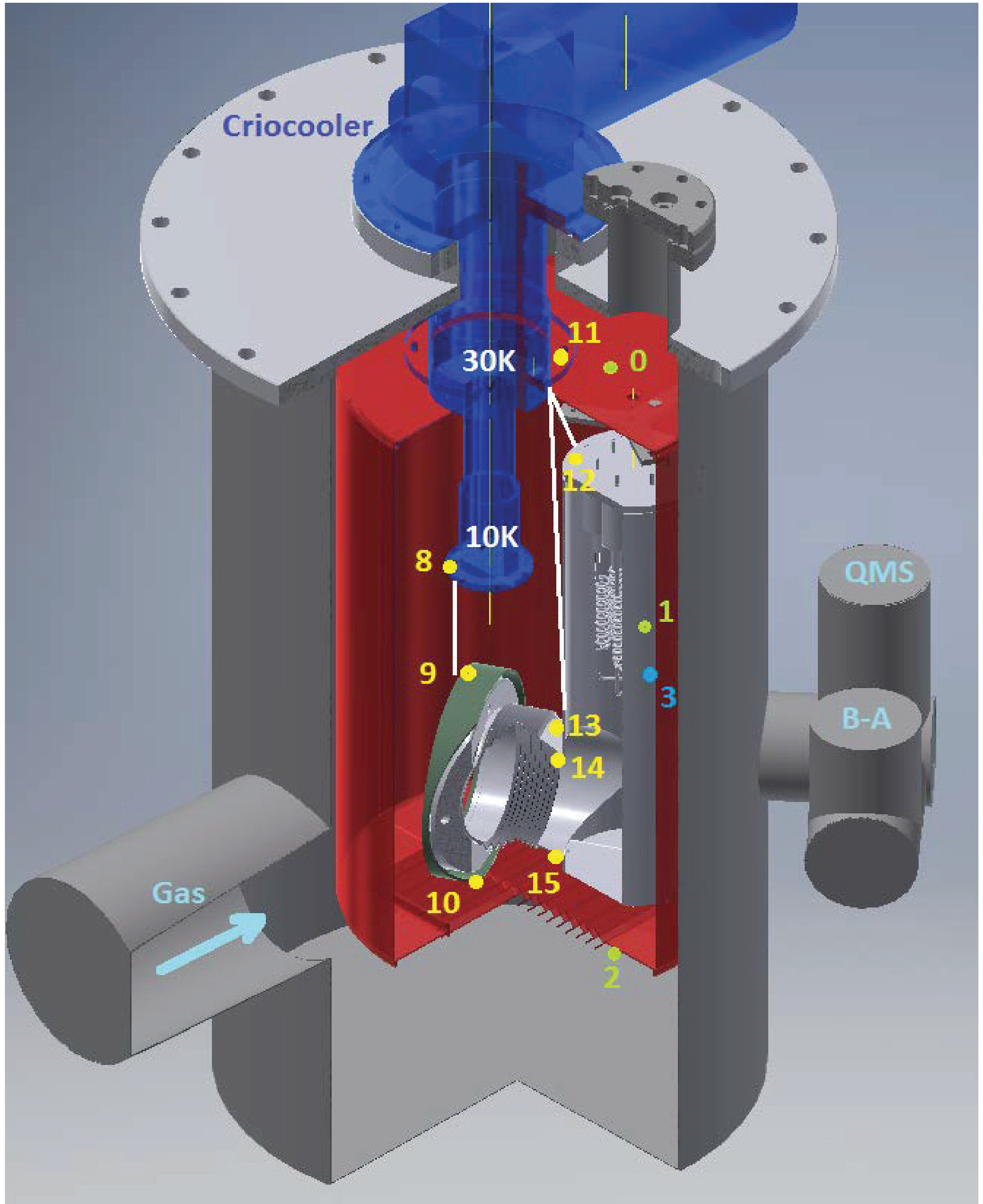
# Booster vacuum chambers of cold arcs (FRAKOTERM)



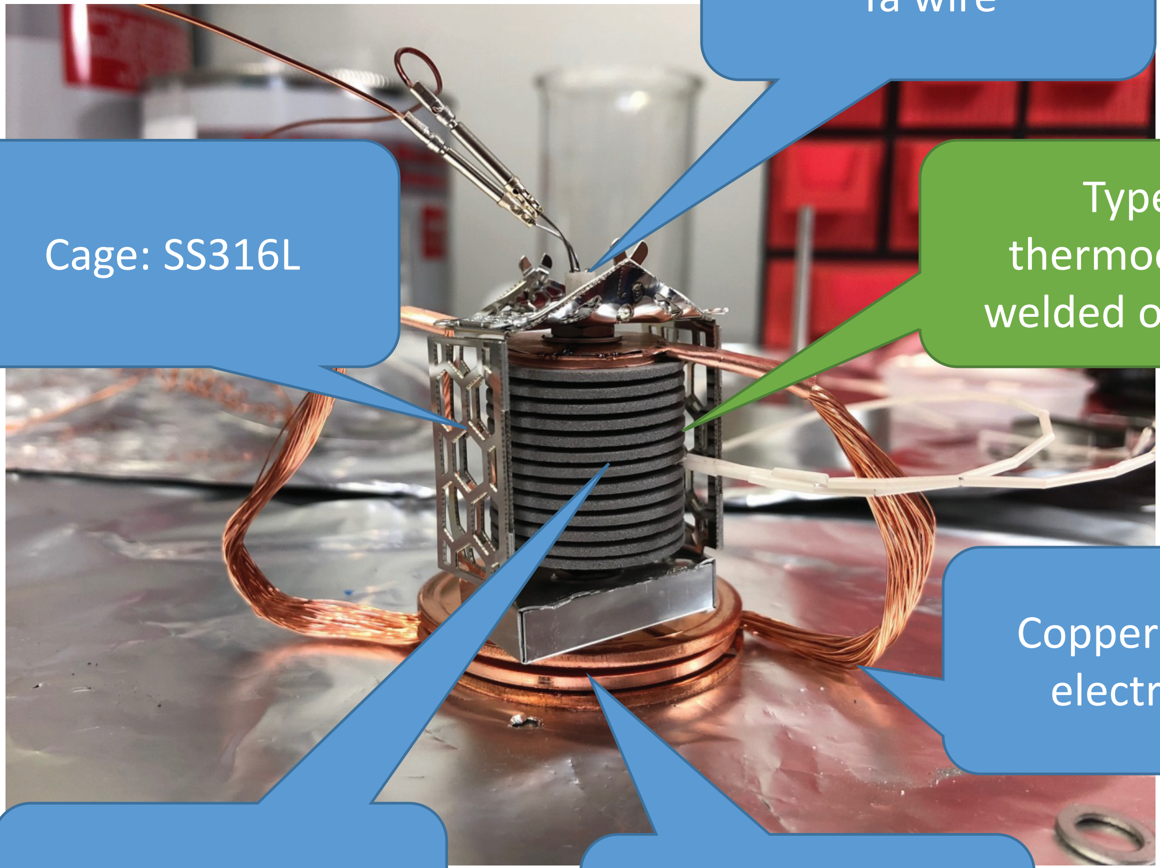
# TSP @ LN (BINP test)





# NEG pump @ LN (SAES test)

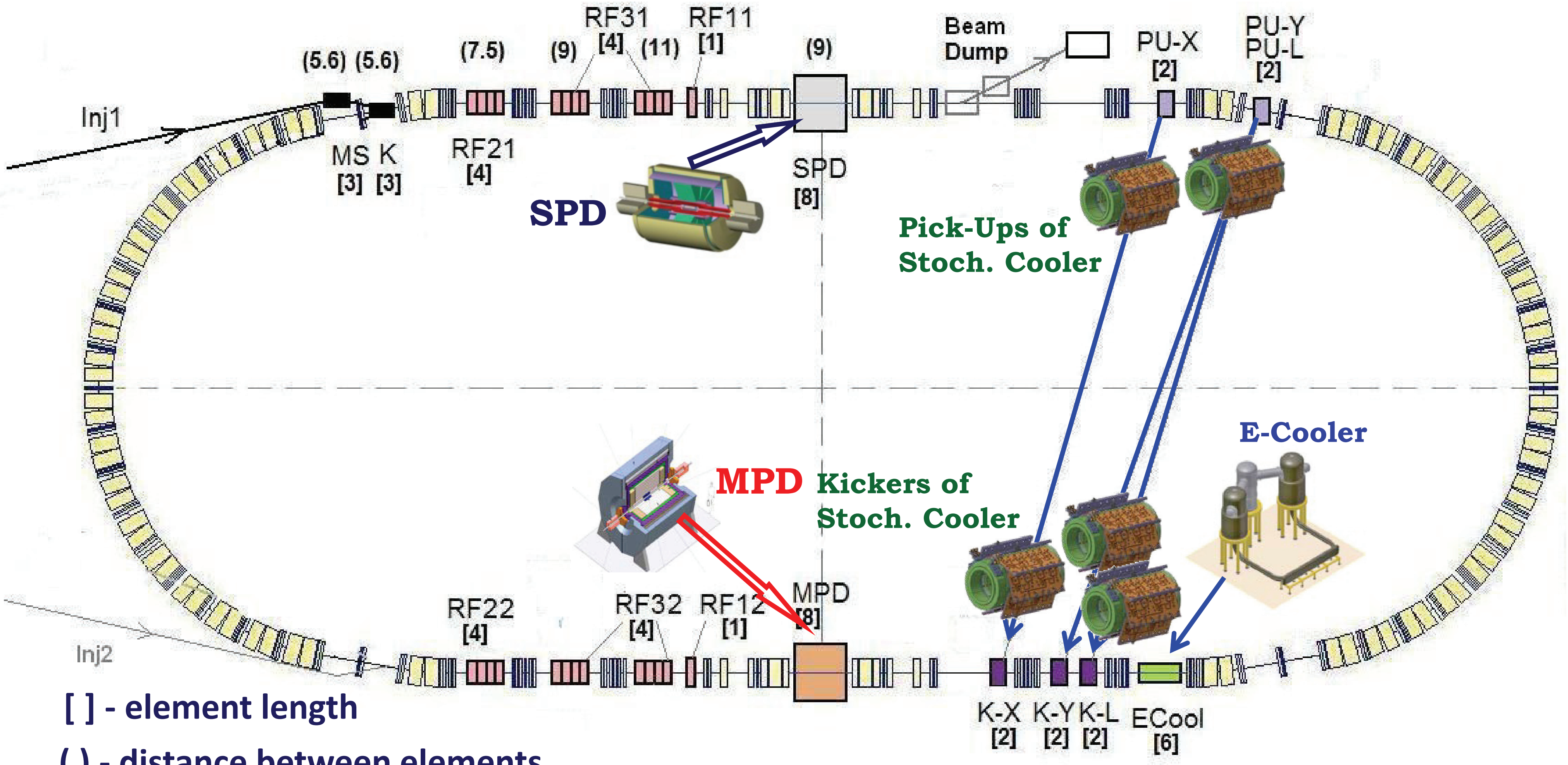



# Status of booster vacuum systems

| Name | Status | Chamber manufacturer | Pumping systems * |
|---|---|---|---|
| SC magnets<br>Pick-up stations | Assembling<br>Production | FRAKOTERM, Poland<br>FMB, Germany | Ion pump + TSP |
| 1) Injection septum | Production | Cryosystems, Moscow | Ion pump, TSP, NEG, CT |
| 2) RF-stations<br>Pumping post | Under test at JINR | BINP, Novosibirsk<br>MILLAB, Moscow | Ion pump + TSP |
| 3) Extraction system +<br>Channel to Nuclotron | Production | BINP, Novosibirsk | Ion pump + TSP |
| 4) Electron cooling system | Assembled at JINR | BINP, Novosibirsk | Ion pump, TSP, NEG |

* TSP – titanium sublimation pump, LN – temperature of liquid nitrogen
CT – cryogenic trap, NEG – non-evaporated getter

# Configuration of the Collider for Heavy Ion mode




[ ] - element length

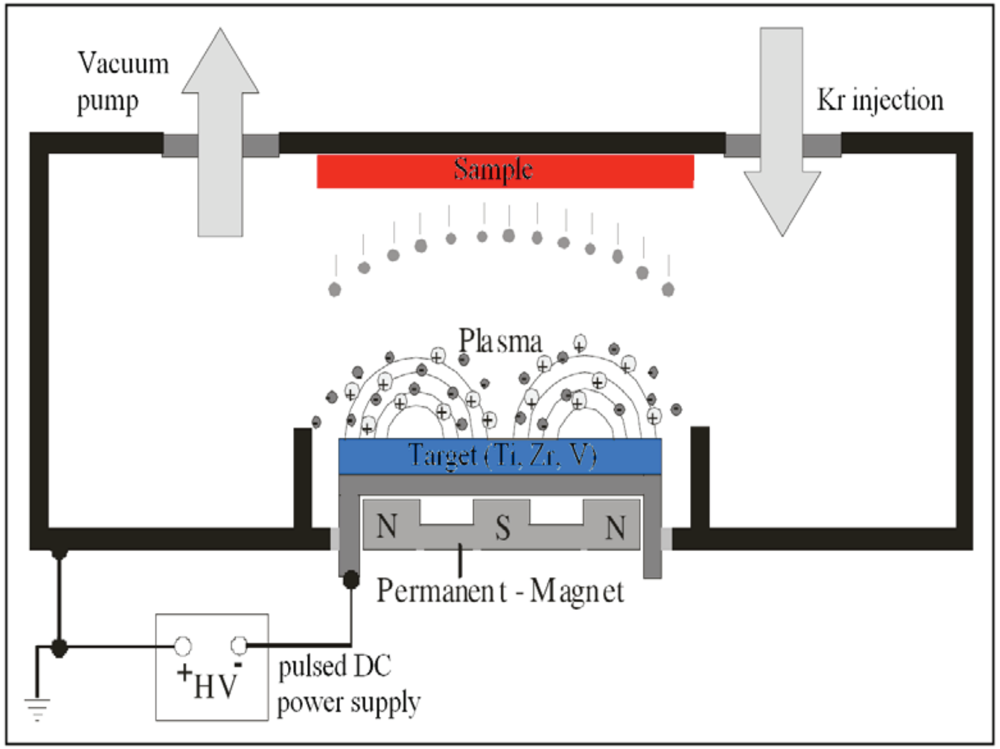
( ) - distance between elements

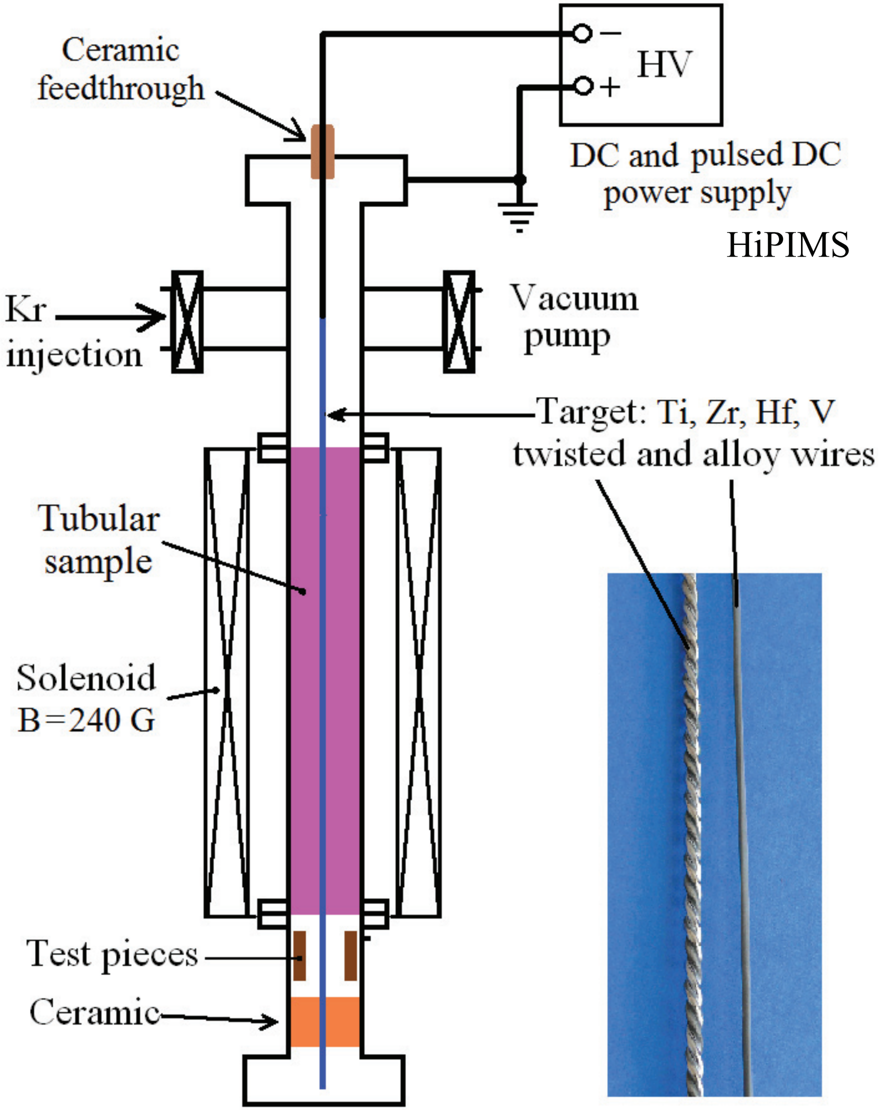
Au(+79) ion mode

# NEG coating technology

## Cylindrical magnetron deposition for vacuum chambers

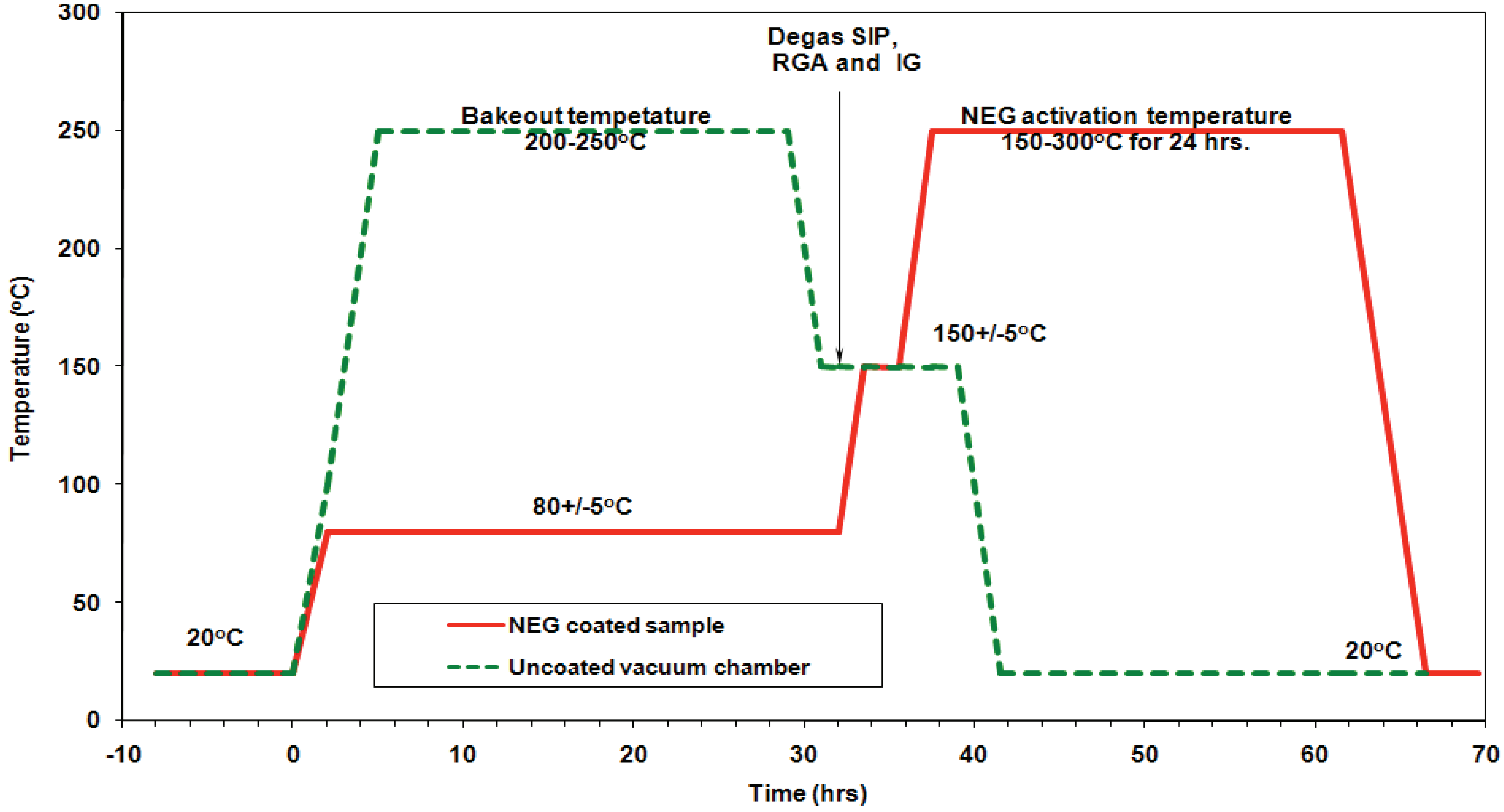
### Commonly used planar magnetron deposition



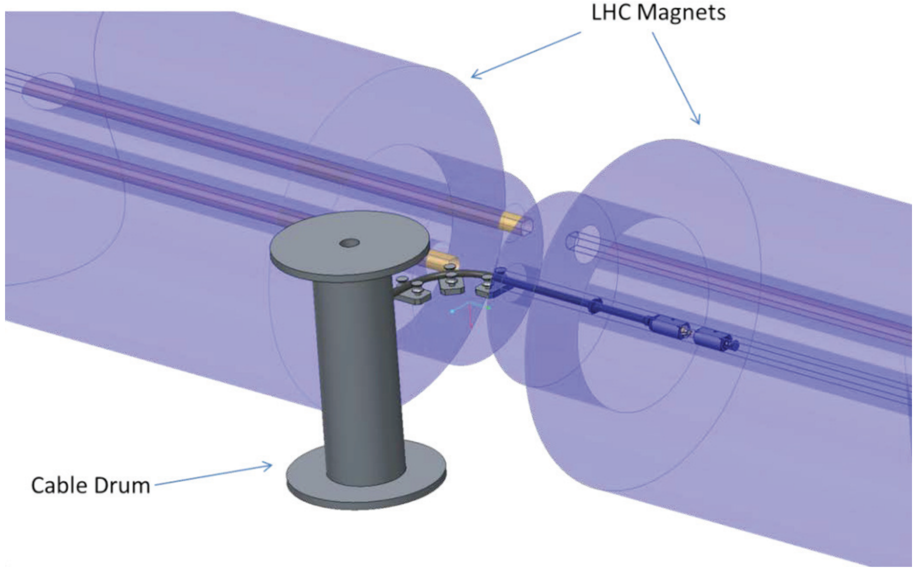
# ASTeC activation procedure

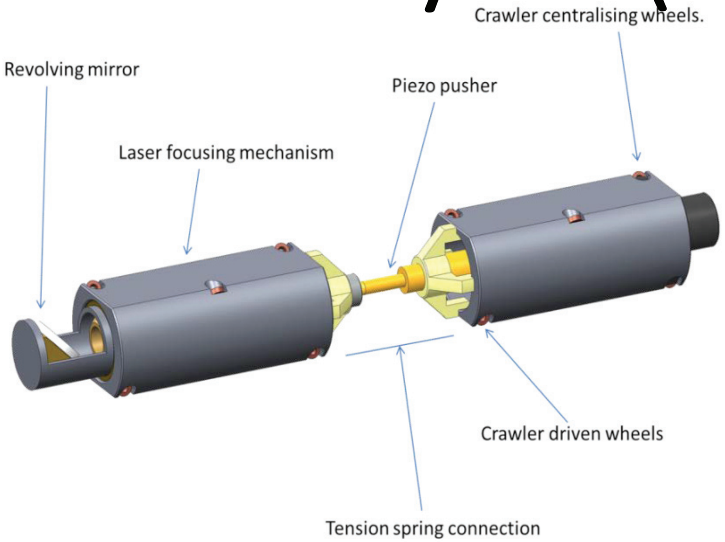
First procedure of the NEG coating is well-known as *CERN activation procedure.* New procedure is named as ASTeC activation procedure (Accelerator Science and Technology Centre, STFC Daresbury Laboratory, Warrington, Cheshire, UK)

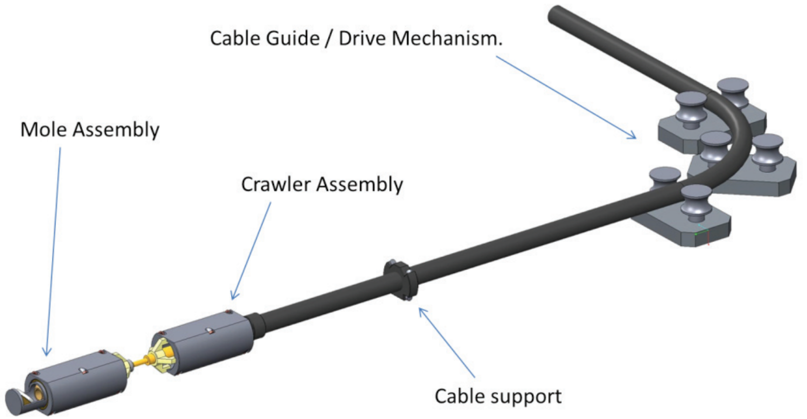


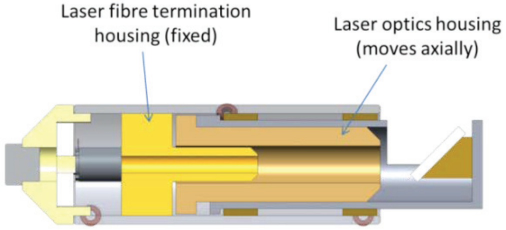

*O.B. Malyshev, K.J. Middleman, J.S. Colligon and R. Valizadeh. J. Vac. Sci. Technol. A 27 (2009), p. 321.*

# Laser technology for surface treatment to decreasing of secondary electron yield (SEY)

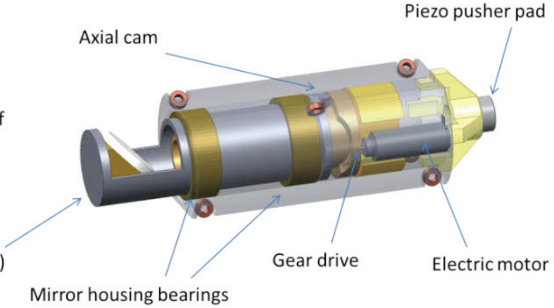


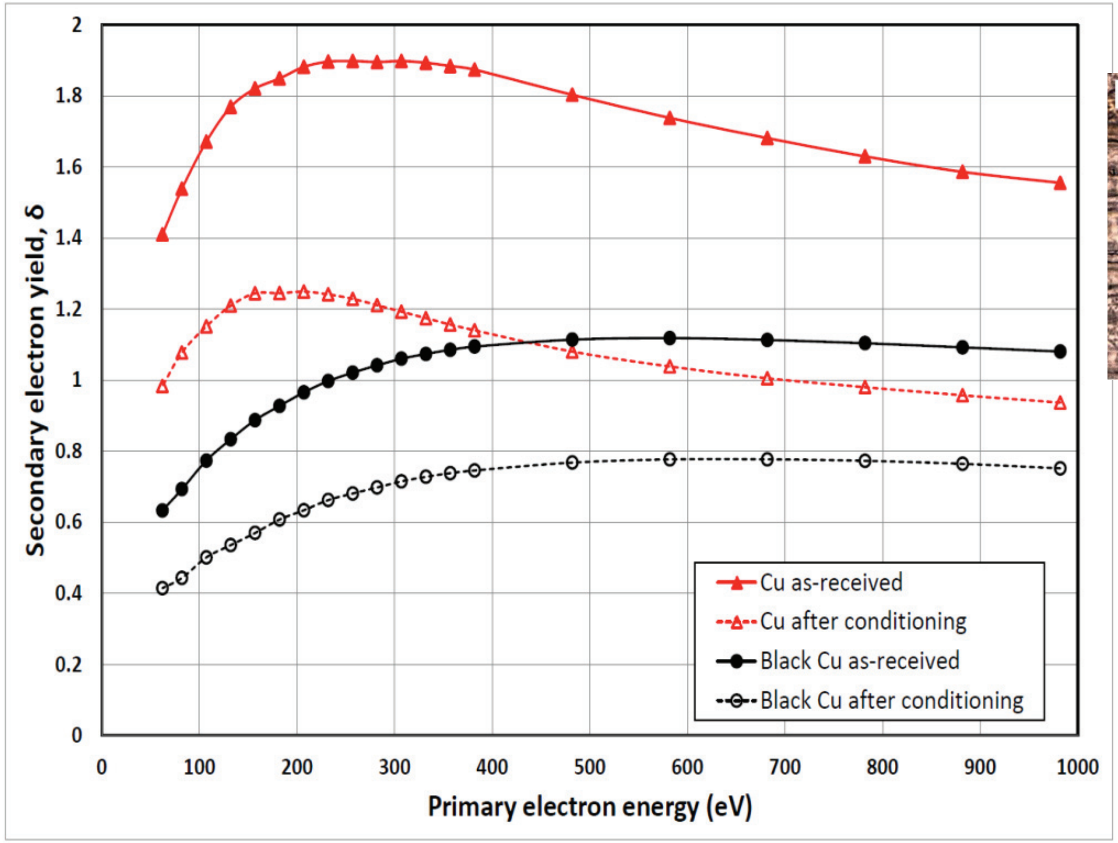



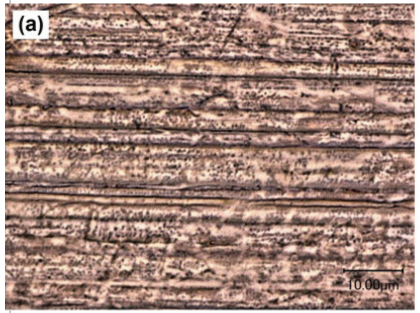




The mirror optics housing moves axially as the mirror rotates to maintain laser focus on the flat sections of beam pipe.

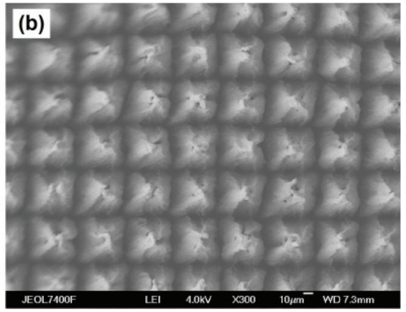


# SEY of Cu as a function of incident electron energy

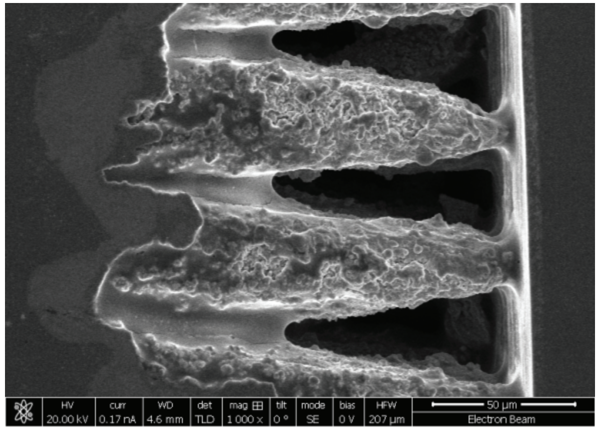



Untreated




Laser treated



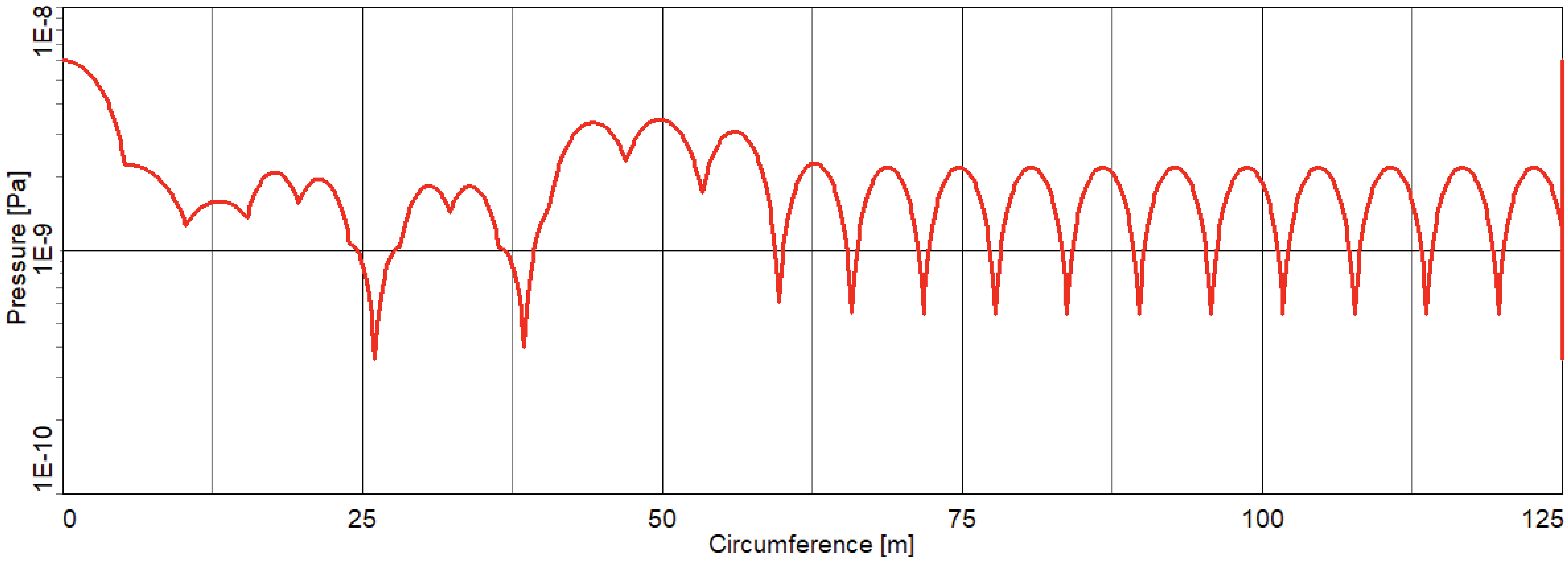

For Copper

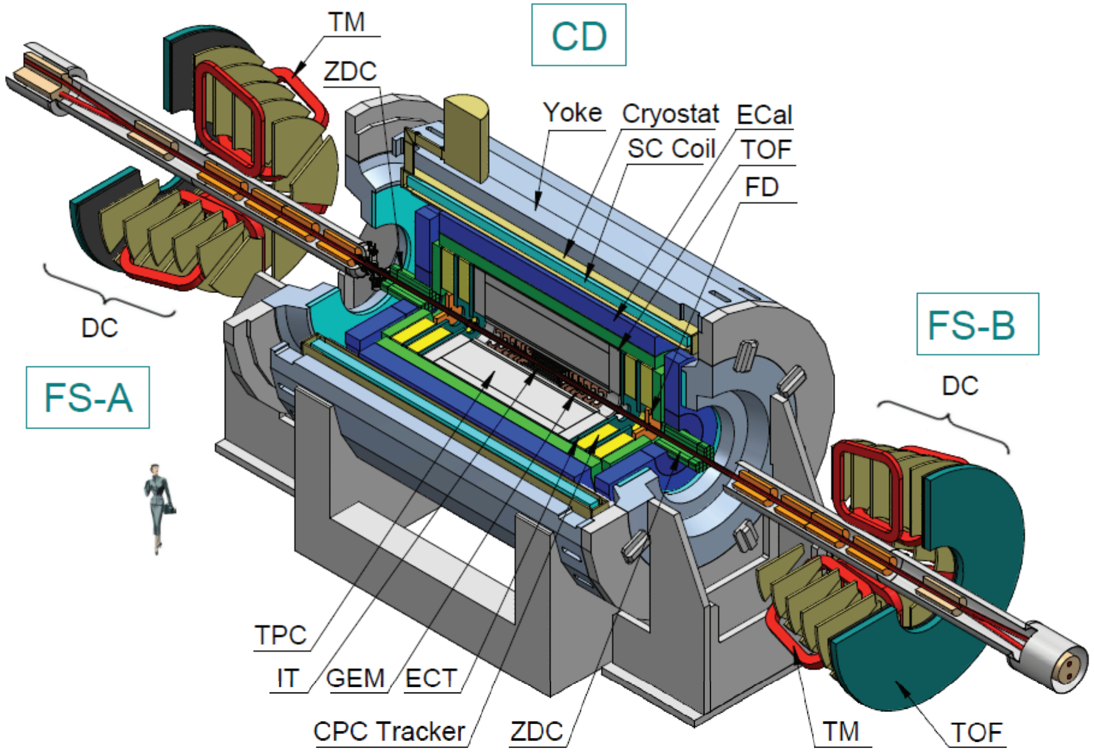
Nd:YVO4 Laser

- Max Average Power = 10 W at $\lambda$ = 532 nm
- Pulse length =12 ns at Repetition Rate = 30 kHz
- Argon or air atmosphere
- Beam Raster scanned in both horizontal and vertical direction

# Simulation of pressure distribution (1/4 of collider)

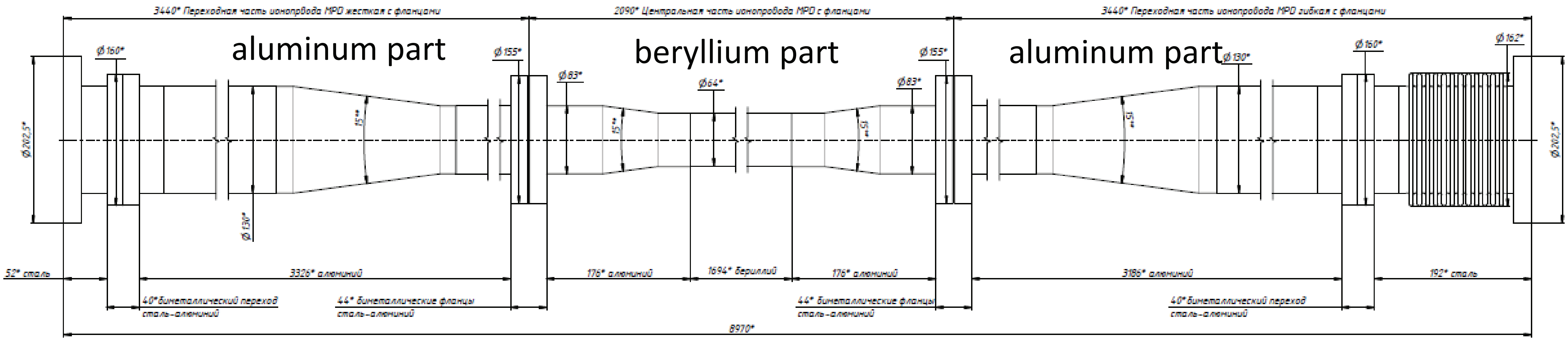
IP-|---straight sections--|------arc cold section-----|






# Multi Purpose Detector

Beryllium (TB56) insertion («Kompozit», Korolev) + Aluminum alloy (AW-2219)

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# Status of collider vacuum systems

| Name | Status | Chamber manufacturer | Pumping systems * |
|---|---|---|---|
| SC magnets | Production | FRAKOTERM, Poland | Ion pump + TSP |
| Injection channels | Production | SigmaPhi, France | Ion pump, TSP, NEG |
| RF-stations | Production | BINP, Novosibirsk | Ion pump + TSP |
| Electron cooling system | Production | BINP, Novosibirsk | Ion pump, TSP, NEG |
| Stochastic cooling | Design | FZJ, Juelich, Germany | Ion pump, TSP |
| MPD | Design | Kompozit, Korolev<br>SDB IRE RAS, Fryazino | Ion pump, TSP, NEG |

* TSP – titanium sublimation pump, LN – temperature of liquid nitrogen
CT – cryogenic trap, NEG – non-evaporated getter