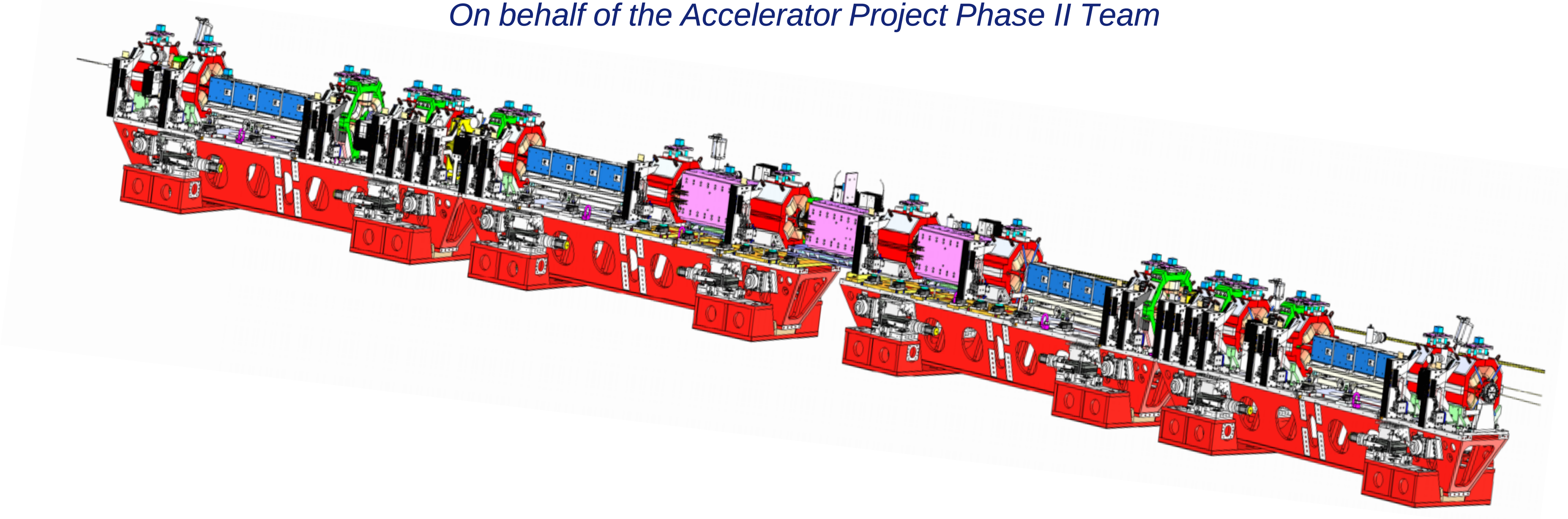
# *ESRF Upgrade Technical design & system integration*

*JC Biasci*

*On behalf of the Accelerator Project Phase II Team*



Low Emittance Rings 2015 Workshop 15-17 September 2015

# OUTLINE

I. New Lattice issues

II. Girders & supports

III. Vacuum Chambers

IV. Magnets

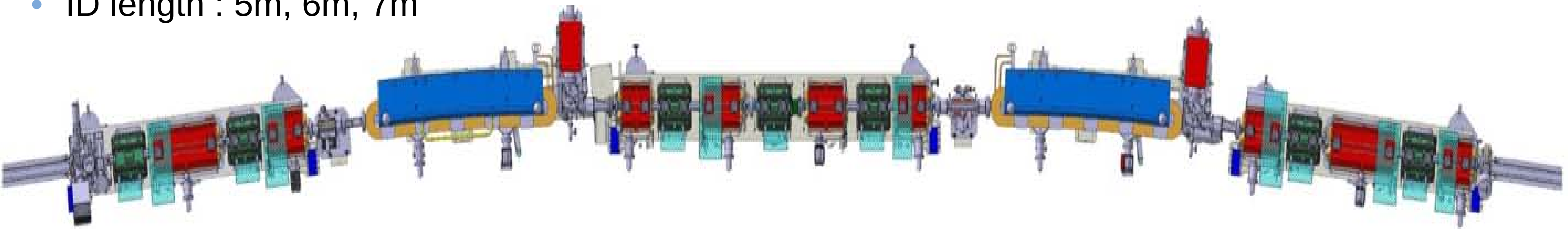
V. Straight sections

VI. Conclusion

# I. LATTICE CONSTRAINTS

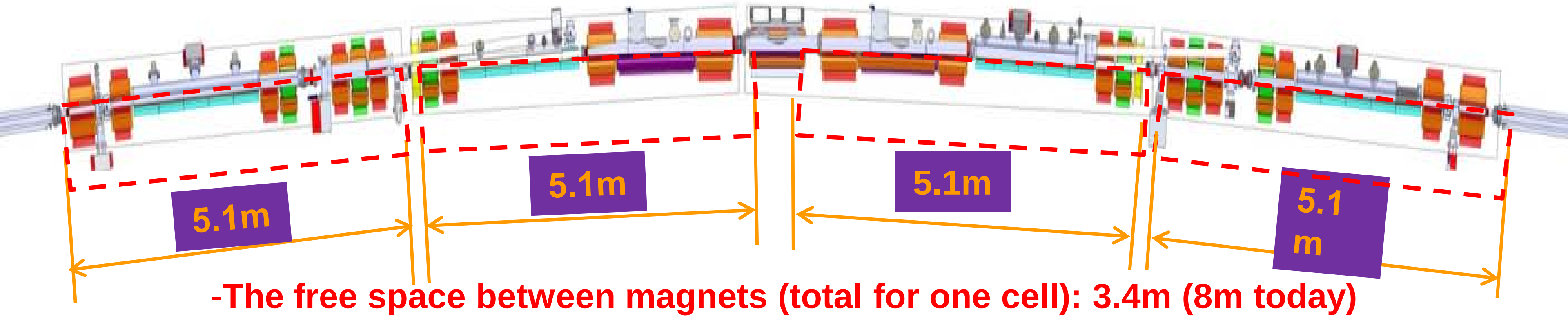
***Present ESRF*** Double Bend Achromat:

- 2 dipoles + 15 quad., Sext.) per cell
- ID length : 5m, 6m, 7m



***ESRF II*** Hybrid 7 Bend Achromat:

- 4 dipoles + 3 dipoles-quad + 24 quad., sext., oct) per cell
- ID length : 5m



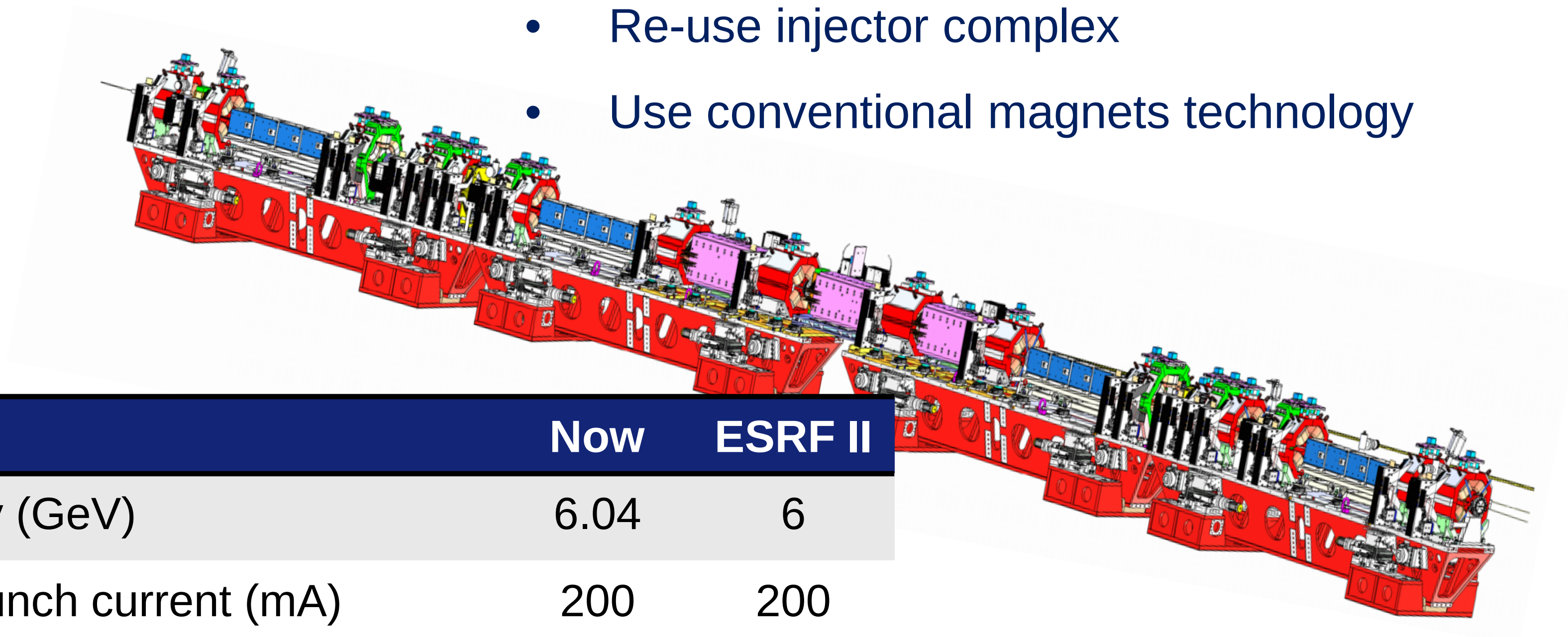

**-The free space between magnets (total for one cell): 3.4m (8m today)**

Main engineering challenge:

- Lack of space

# I. CHALLENGES

- Must fit in the same tunnel : same circumference
- IDs at same locations: keep BLs where they are
- Re-use injector complex
- Use conventional magnets technology



| | Now | ESRF II |
|---|---|---|
| Energy (GeV) | 6.04 | 6 |
| Multibunch current (mA) | 200 | 200 |
| Circumference (m) | 844.39 | 843.98 |
| Horizontal emittance (pm-mrad) | 4000 | 150 |
| Vertical emittance (pm-mrad) | 4 | 5 |

# I. CONTEXT

ESRF I Storage ring commissioning started in February 1992

**ESRF I**

## Existing drawings

- 2D autocad
- 3D CATIA
- Hand made drawings
- Booster
- SR tunnel

## Inventory

**ESRF II**

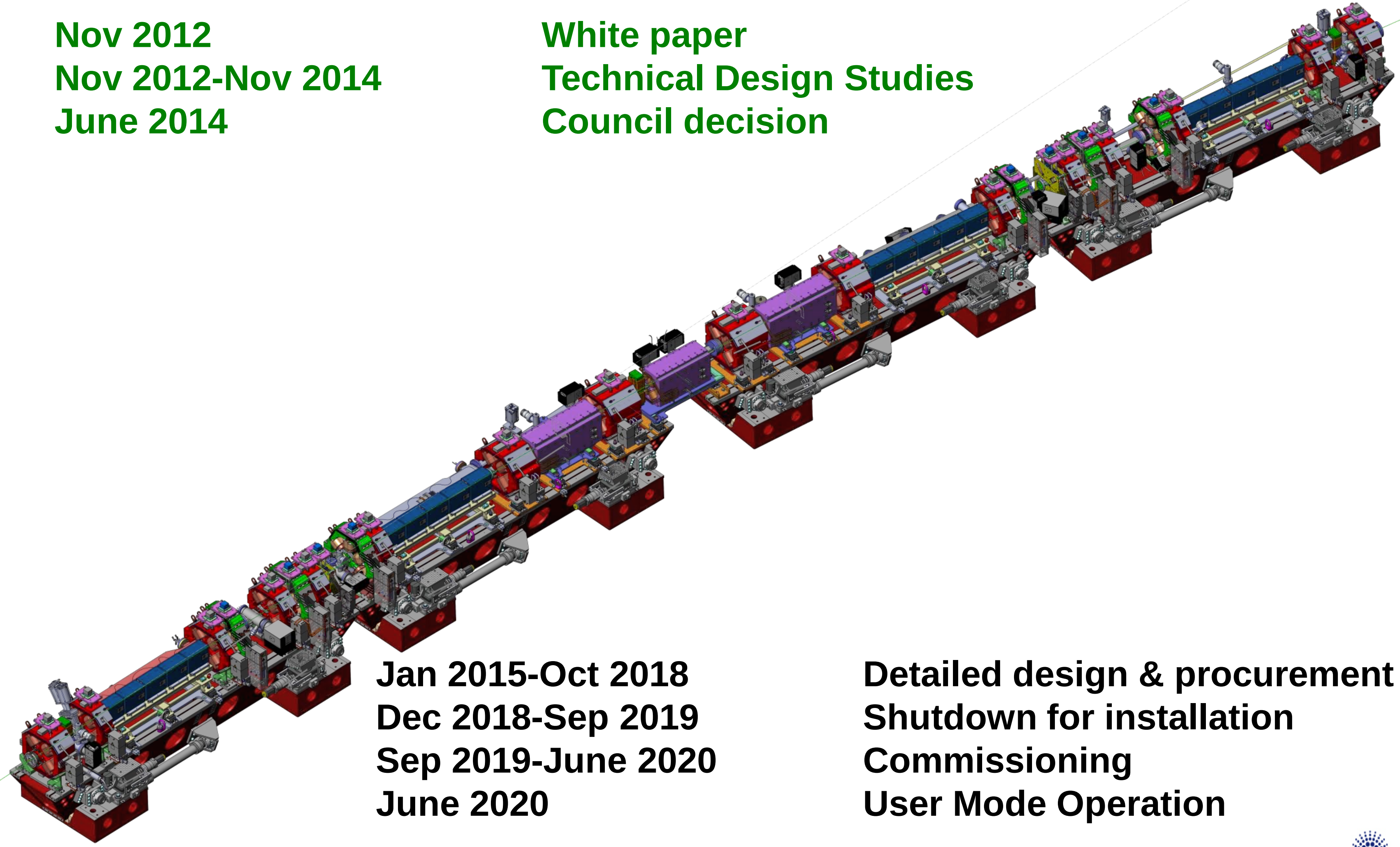
## Drawings update (Solidworks)

- Solidworks 3D models
  - SR tunnel
  - Reference drawings …

## Definition of design rules

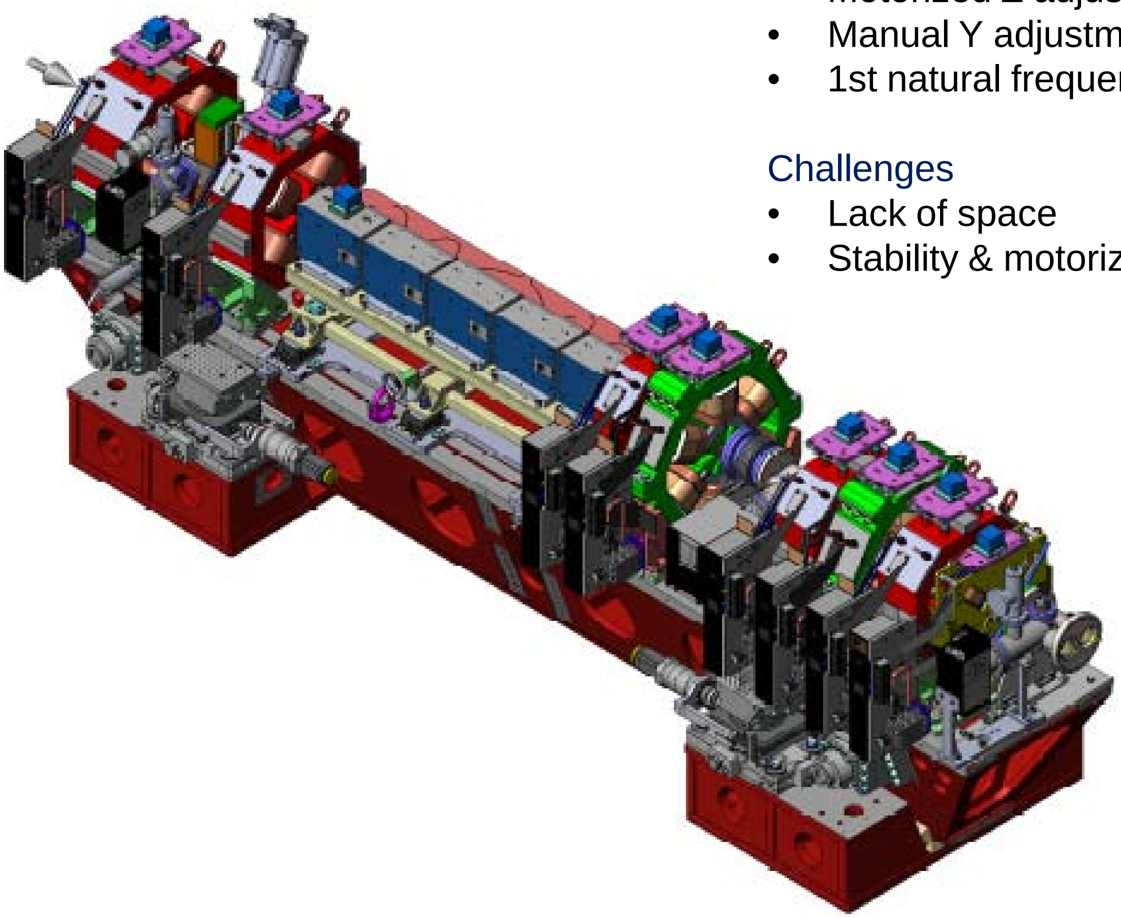
# I. GLOBAL SCHEDULE

| | |
|---|---|
| Nov 2012 | White paper |
| Nov 2012-Nov 2014 | Technical Design Studies |
| June 2014 | Council decision |



| | |
|---|---|
| Jan 2015-Oct 2018 | Detailed design & procurement |
| Dec 2018-Sep 2019 | Shutdown for installation |
| Sep 2019-June 2020 | Commissioning |
| June 2020 | User Mode Operation |

# II. GIRDERS



INPUT DATA

- Girder length = 5.1m, magnets weight = 3.500kg

GIRDER PROJECT SPECIFICATION

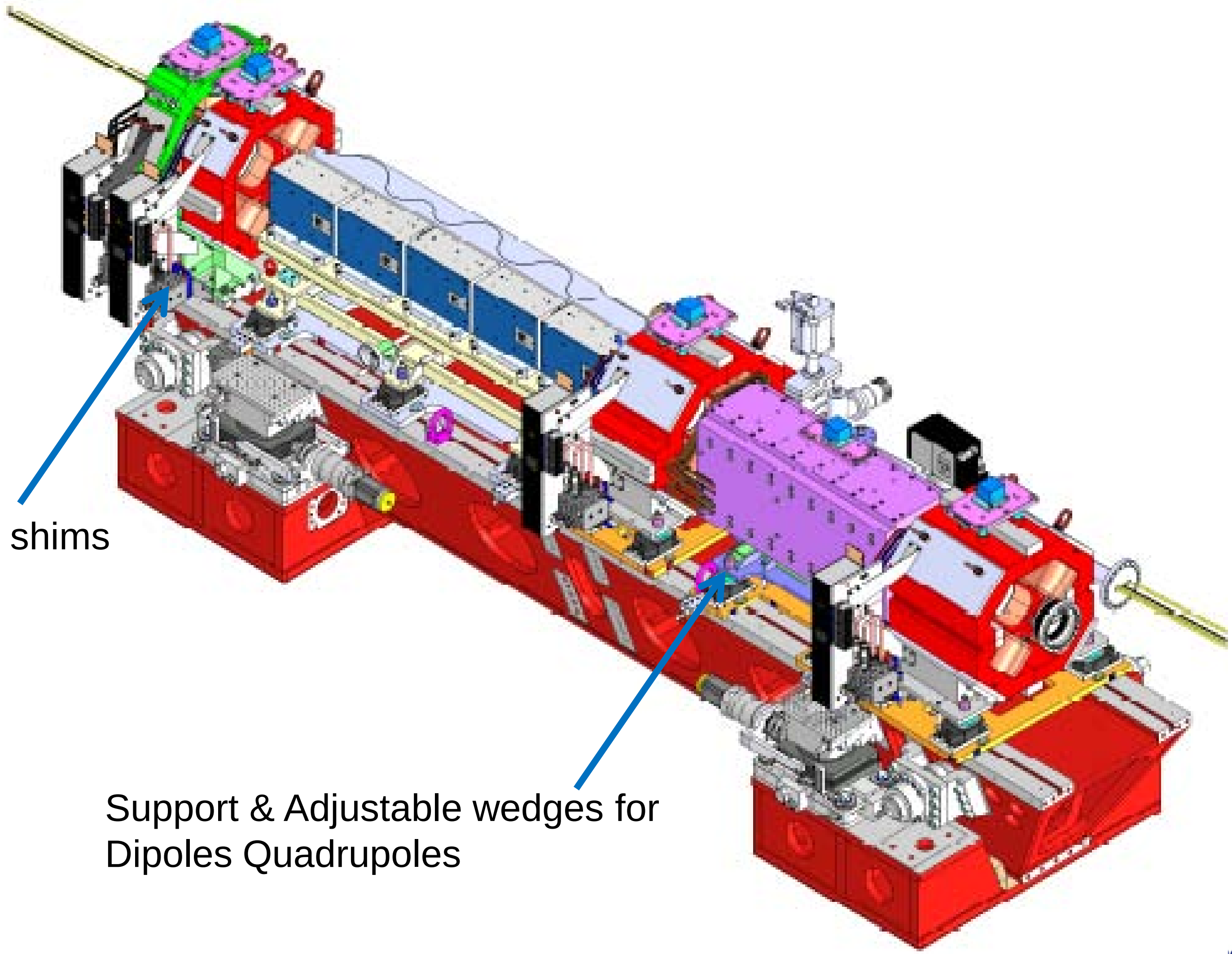
- Motorized Z adjustment resolution 5µm
- Manual Y adjustment resolution 5µm
- 1st natural frequency = 50Hz (design criteria)

Challenges

- Lack of space
- Stability & motorized Z adjustment

# II. GIRDERS – MAGNETS SUPPORTS

- Girder 2

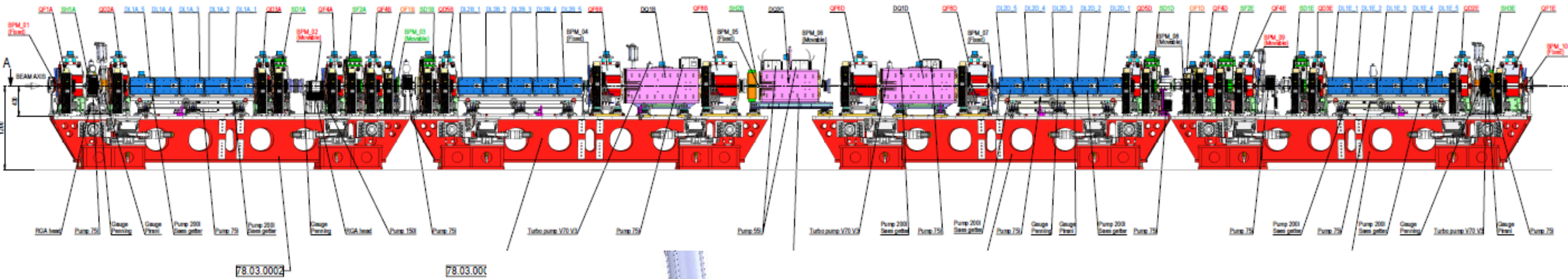


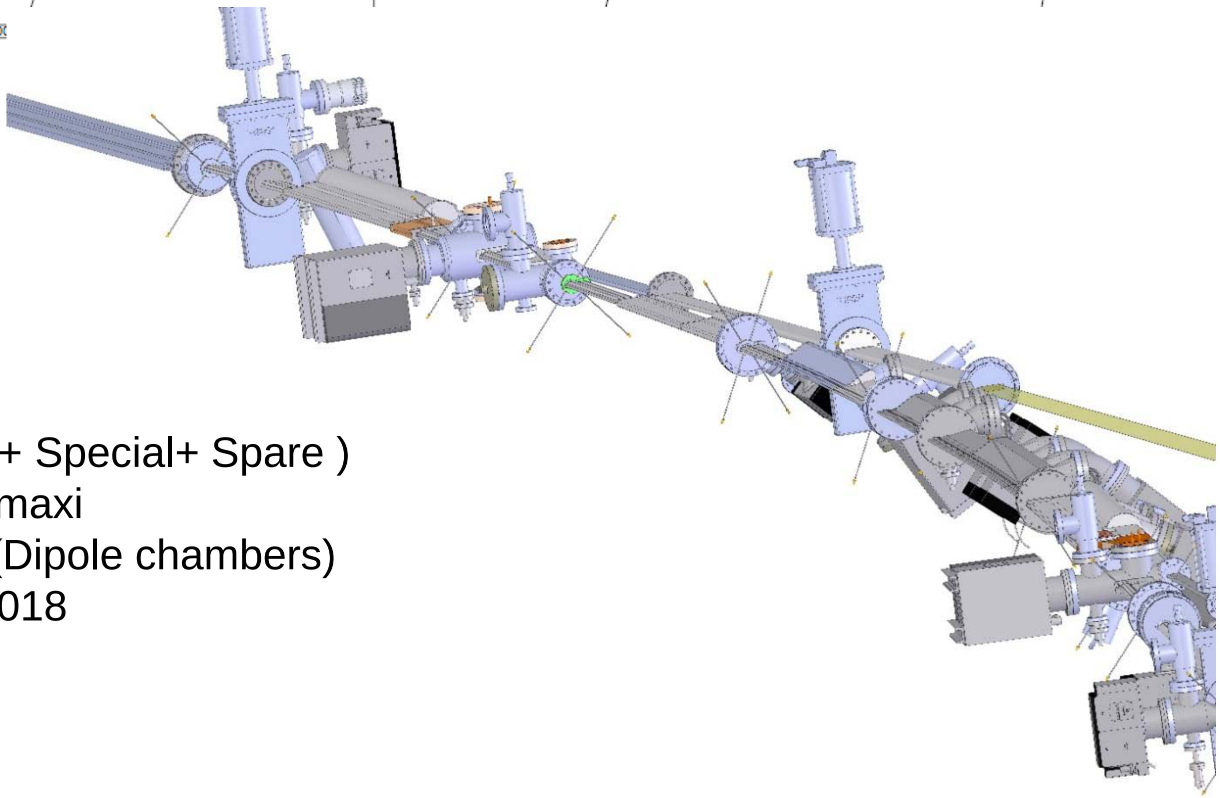
Vertical shims

Support & Adjustable wedges for
Dipoles Quadrupoles

# II. GIRDERS – PROTOTYPE TESTS

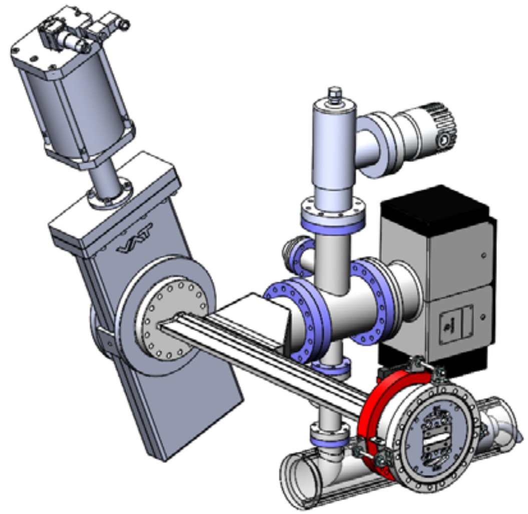
# III. VACUUM CHAMBERS



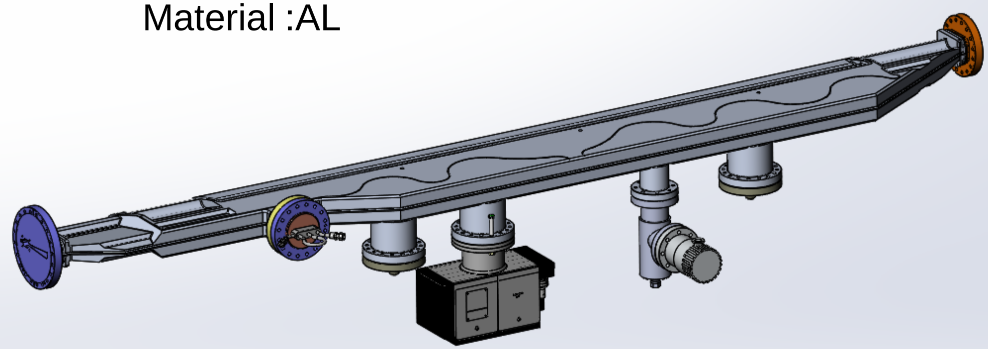


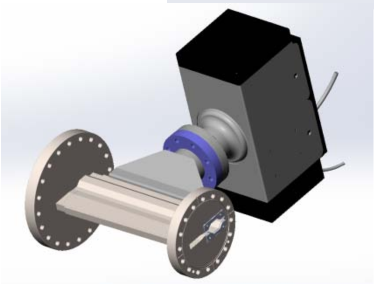
- Quantity : 480 (14 x 32 + Special+ Spare )
- Length: 0.6 m to 2.8 m maxi
- Material: 316 LN or AL (Dipole chambers)
- Time scale: end 2016-2018

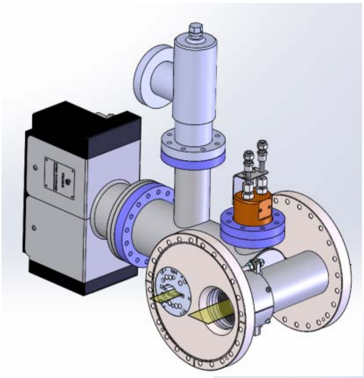
# III. VACUUM CHAMBERS

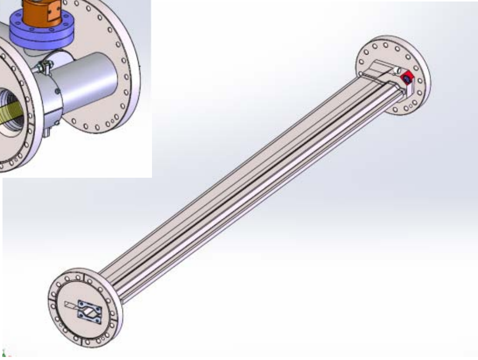


Dipole chamber 2600mm
Material :AL









Dipole chamber 2600mm
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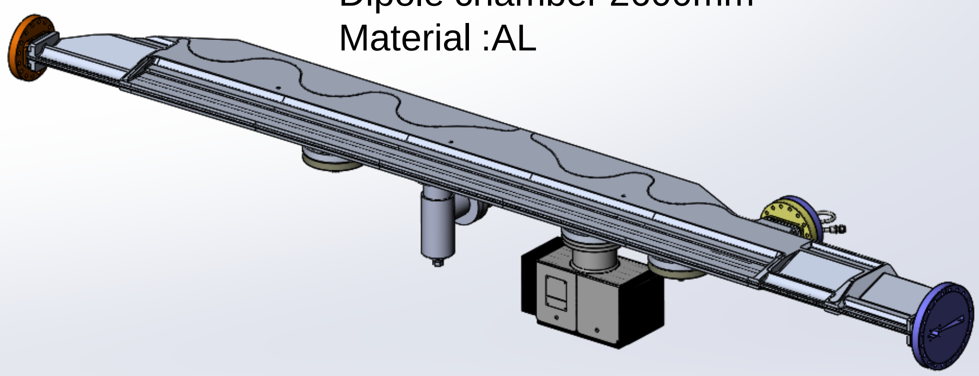
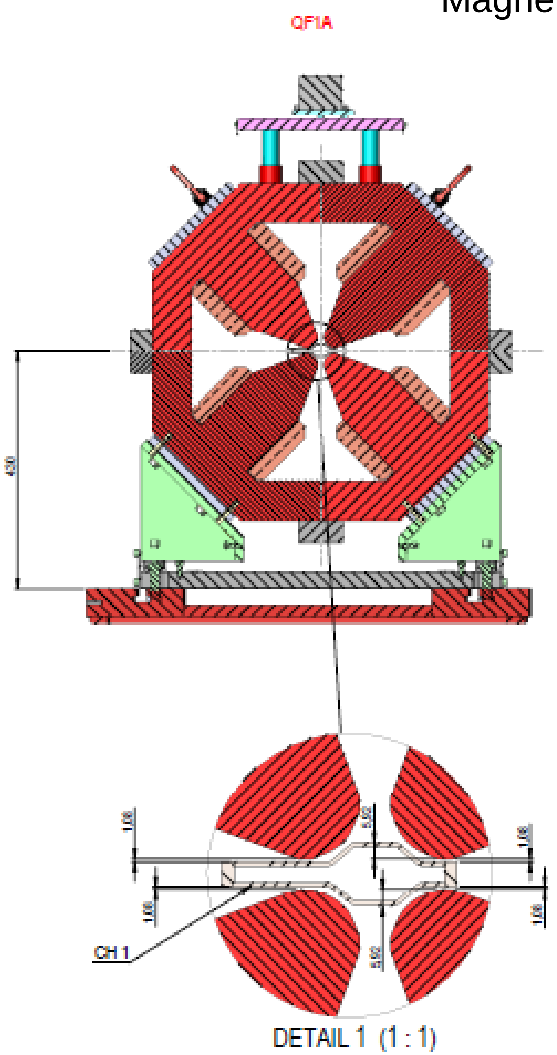
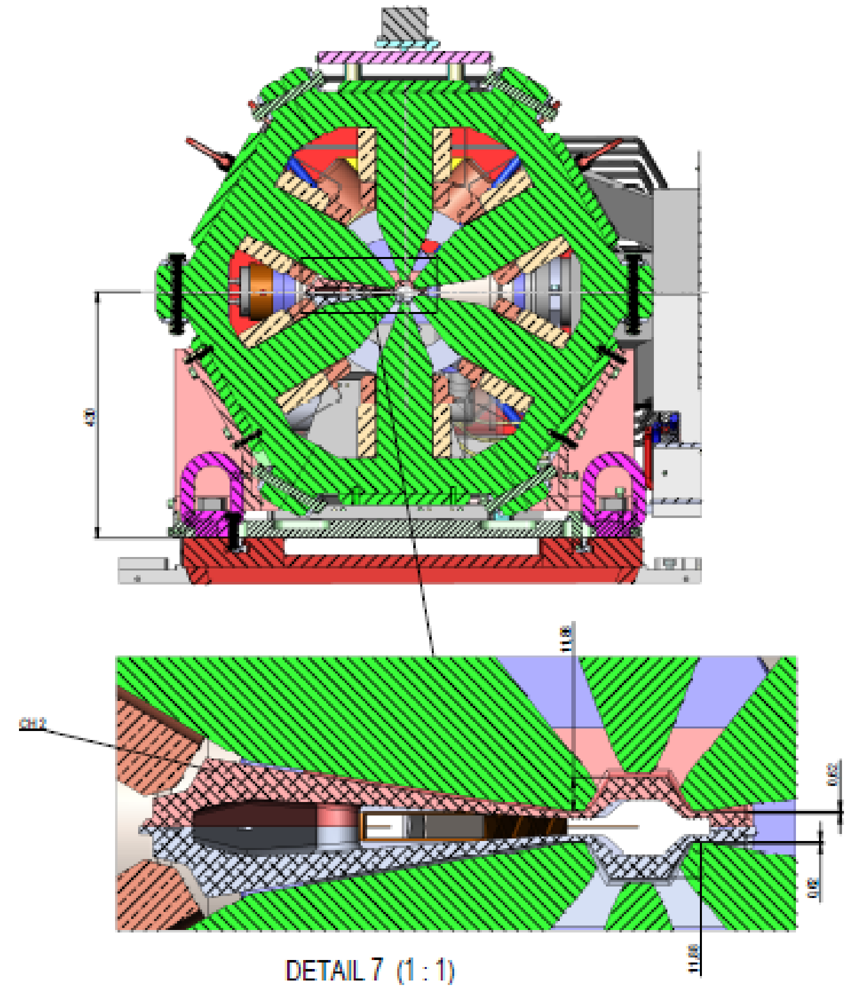
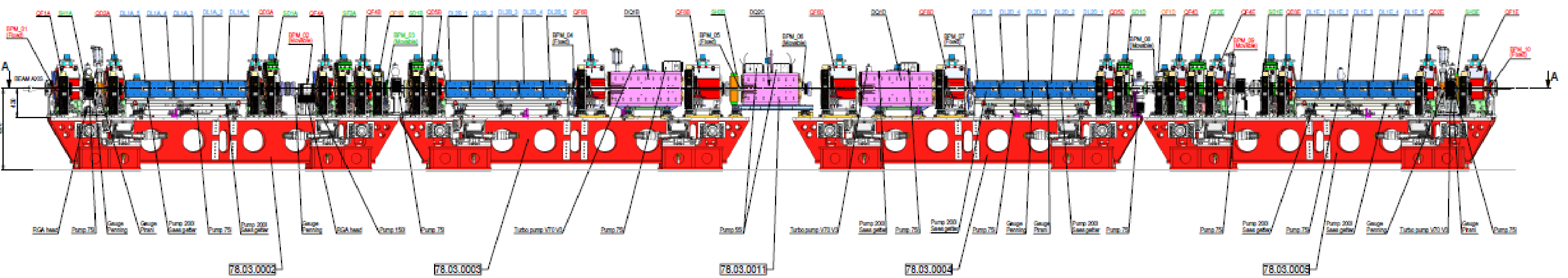


Magnets/Vacuum chambers clearance limited



# III. VACUUM CHAMBERS  INSTRUMENTATION




| | Penning | RGA head | Pirani | IP | NEG pump | Prepumping port |
|---|---|---|---|---|---|---|
| CH1 | 1 | 1 | 1 | 75 $l/s^{-1}$ | / | 1 |
| CH2 | 0 | 0 | 0 | 75 $l/s^{-1}$ | 2 *200 $l/s^{-1}$ | 1 |
| CH3 | 1 | 1 | 0 | 150 $l/s^{-1}$ | / | 0 |
| CH4 | 0 | 0 | 0 | 75 l/s-1 | / | 1 |
| CH5 | 1 | 0 | 0 | 55 $L/s^{-1}$ | 400 $l/s^{-1}$ | 0 |
| CH6 | 0 | 0 | 0 | *150 l/s-1* | *200 l/s-1* | 1 |
| CH7 | 1 | 0 | 0 | 2 * 55 $l/s^{-1}$ | / | 0 |
| CH8 | 0 | 0 | 0 | 75 $l/s^{-1}$ | 200 $l/s^{-1}$ | 1 |
| CH9 | 1 | 1 | 1 | 75 $l/s^{-1}$ | 2 *200 $l/s^{-1}$ | 0 |
| CH10 | 1 | 0 | 0 | 150 $l/s^{-1}$ | / | 1 |
| CH11 | 0 | 0 | 0 | 0 | / | 0 |
| CH12 | 0 | 0 | 0 | / | 200 $l/s^{-1}$ | 0 |
| CH13 | 1 | 0 | 0 | 75 $l/s^{-1}$ | 2 *200 $l/s^{-1}$ | 1 |
| CH14 | 1 | 0 | 1 | 75 $l/s^{-1}$ | / | 1 |

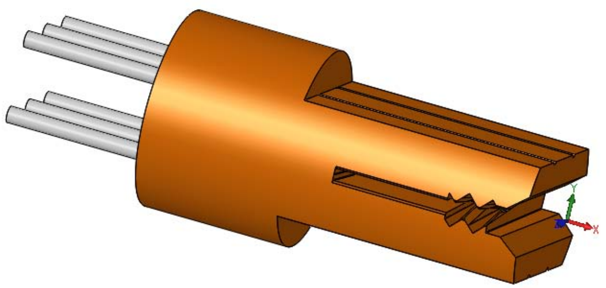
# III. PHOTON ABSORBERS

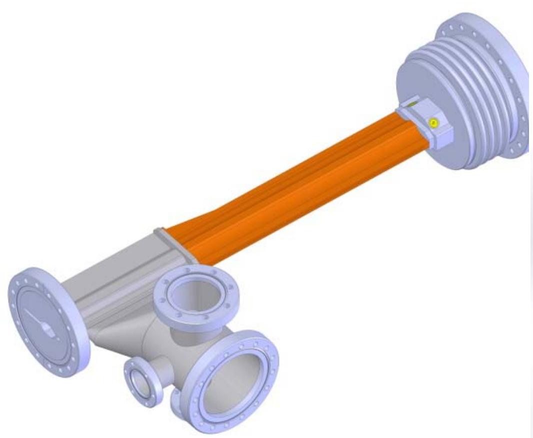
~480 photon absorbers for SR
~30 special absorbers for straight sections
~90 absorbers, collimators for Front-ends

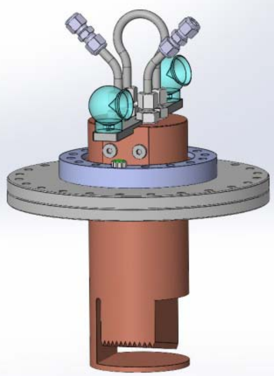
## Some design considerations

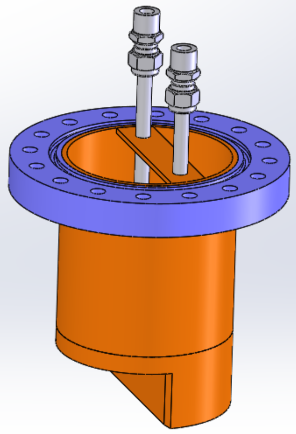
- ❑ Maximum Temperature < Tmelt/2
- ❑ Maximum stress < Yield strength (YS)
- ❑ OFHC copper or CuCrZr preferred rather Glidcop
  - ❑ Brazing issues:
    lower YSofhc=70 MPa make the absorber design challenging if we want to optimise

Technique without brazing preferred (CuCrZr)









# IV. MAGNETS

| Magnet type | | Quantity | Field strength | | Iron length | |
|---|---|---|---|---|---|---|
| Dipoles with longitudinal gradient | DL | 128 | 0.17-0.67 | T | 1788 | mm |
| Dipole quadrupoles | DQ | 96 | 0.43-0.54<br>34 | T<br>T/m | 1078 | mm |
| Moderate gradient quadrupoles | Q | 384 | 52 | T/m | 162-295 | mm |
| High gradient quadrupoles | Q | 128 | 85 | T/m | 388-484 | mm |
| Sextupoles | S | 192 | 900-2200 | T/m² | 204 | mm |
| Octupoles | O | 64 | 51.2 $10^3$ | T/m³ | 120 | mm |
| Correctors H(V) | C | 96 | 0.08 | T | 120 | mm |

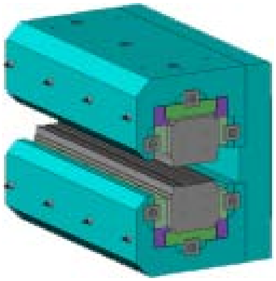
- Quantity (Manufacturing time)
- Design required detail level
- Raw material
- Manufacturing difficulty (tolerances)
- Required space around the magnet
- Stay clear area (vacuum chambers)
- Fiducialization strategy
- Fixation system
- Electrical & water connections

Alignment tolerances

| Required: | DX | DY | DS | DPSI | DK |
|---|---|---|---|---|---|
| | mm | mm | mm | mrad | 10^-4 |
| DL | >100 | >100 | 1000 | 500 | 10 |
| DQ, QF[68] | 70 | 50 | 500 | 200 | 5 |
| Q[DF][1-5] | 100 | 85 | 500 | 500 | 5 |
| SFD | 70 | 50 | 500 | 1000 | 35 |
| OF | 100 | 100 | 500 | 1000 | |

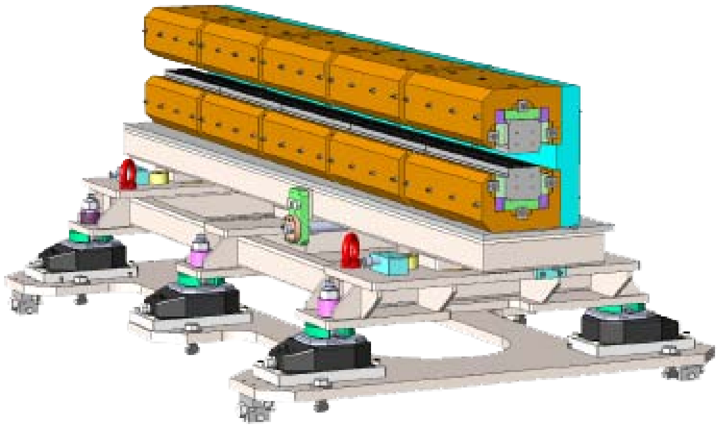
***DX** horizontal perpendicular to the beam*
***DY** vertical perpendicular to the beam*
***DS** along the beam*
***DPSI** is the rotation about the beam axis*

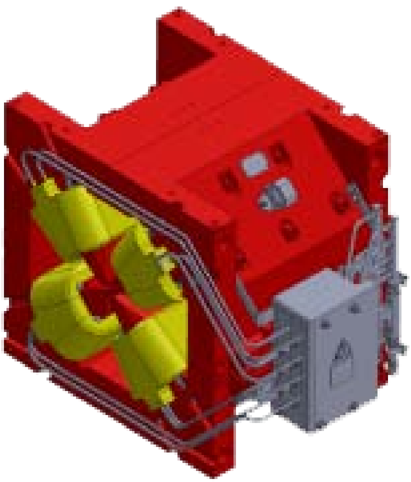
# STORAGE RING – MAGNETS



DL

- Permanent magnets with machined yoke
- Support allowing to remove DL during bakeout

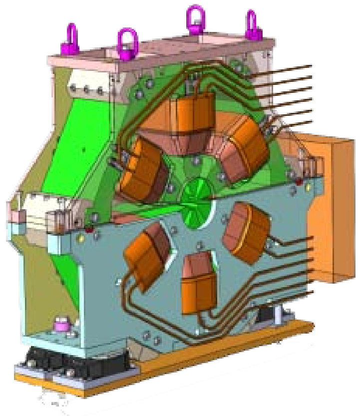




Quadrupoles

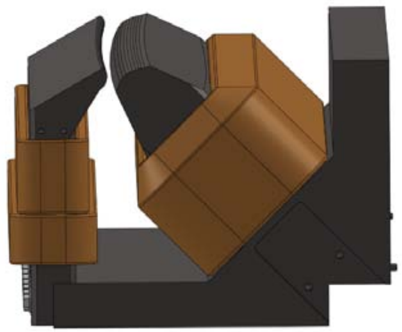
- Quarter yokes machined independently
- +/- 20 µm tolerance expected after assembly
- Quarter yoke assembly: solutions to be tested (accuracy, repeatability)
- Technical issues
  - Raw material cost & procurement
  - Machining tolerances
  - Manufacturing Time

# STORAGE RING – MAGNETS



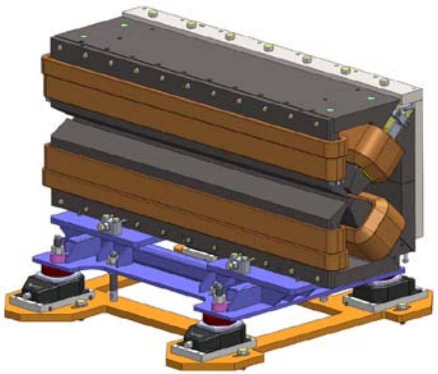
## Sextupoles

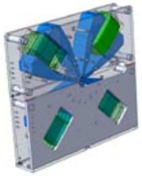
- Laminated magnet
- 1st Engineering design completed in May 2014
- No major technical issues
- Girder fixation not easy due to small length



## DQ Dipole Quadrupoles

- 3D model complete
- Engineering design in progress
- Mechanical prototype to be ordered end 2014
    - technical issues:
        - Machining tolerances



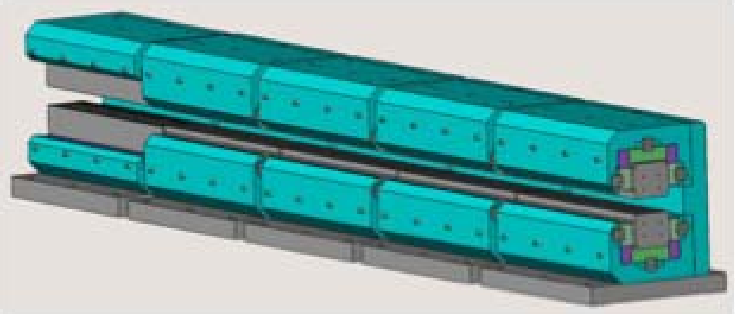


## Octupoles & Correctors

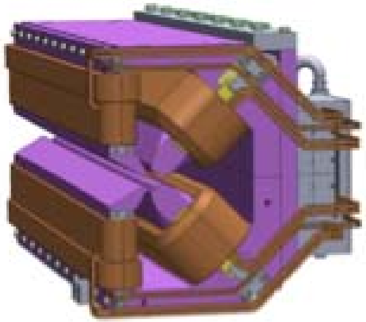
- no major technical issues
    - Octupole prototype received

# STORAGE RING - MAGNETS

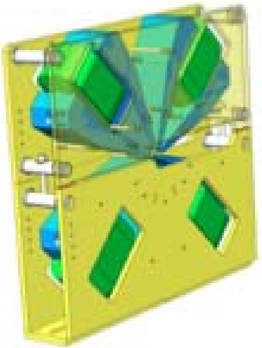
More than 1000 Magnets to be procured



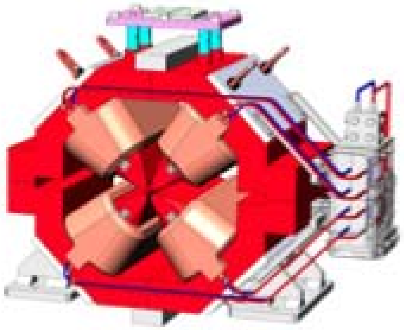
132 dipoles



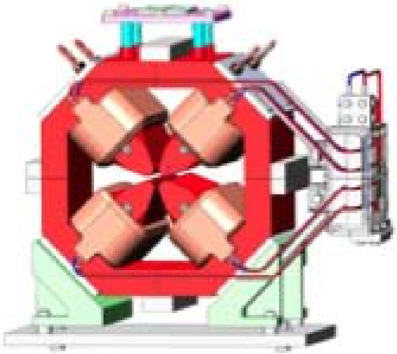
99 dipole-quadrupoles



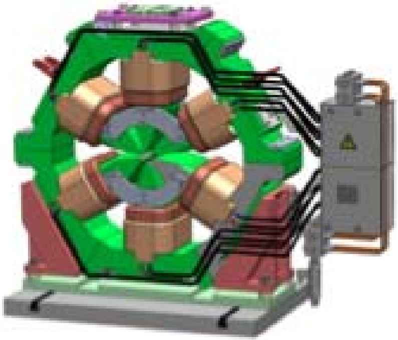
66 octupoles



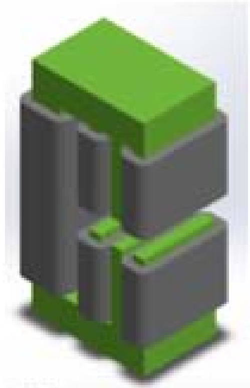
130 high gradient quadrupoles



398 low gradient quadrupoles



196 sextupoles



100 correctors

# V. STRAIGHT SECTIONS

## Lot of different straight sections

- 1 7m canted
- 6 6m (2 canted)
- 9 with In-vacuum undulators
- 3 RF
- 12 Others (standard 5m)
- 1 Injection

## Each section is different and needs to be looked at in detail

- Transitions
- RF fingers
- Internal profiles
- In-vacuum undulators inside components, water cooling channels…

## Straight sections upgrade

- Time & resource consuming <u>during</u> machine shutdown

# VI. CONCLUSION

### General

- context
- Lattice constraints
- Global schedule

### Girders & supports

- Girders
- Chambers supports
- BPM supports
- Magnets supports

### Vacuum

- Vacuum chambers
- Photon absorbers
- Diagnostics
- Straight sections
- Instrumentation

- Magnets

- Design modification need careful check
- Global schedule

- Girders
  - Good flatness
  - Timescale (128 Girders)

- Challenging vacuum chambers
  - Tolerances
  - Timescale
- Conventional absorbers
  - No brazing as far as possible

- Integration with vacuum chambers
  - Large Quantity
  - Timescale

# MANY THANKS FOR YOUR ATTENTION