Development of a Tandem-Electrostatic - Quadrupole Accelerator Facility for BNCT

A.J. Kreiner[1,2,3], W. Castell[1], H. Di Paolo[1,2], V. Thatar Vento[1], J. Bergueiro[1], A.A. Burlon[1,2], J.M.Kesque[1], P. Levinas[1,3], A.A.Valda[1,2], M.E.Debray[1,2], H.R.Somacal[1,2], J.C. Suarez Sandin[1], D. Cartelli[1], J.C. Ilardo[1], M. Baldo[1], M. Repetto[1], M. Obligado[1], J. Davidson[1,3], M. Davidson[1,3], H. Huck[1], M. Igarzabal[1], J.C. Suarez Sandin[1], L. Estrada[1], A. Hazarabedian[1], F. Johann[1], D. Minsky[1,2,3], A.F. Salares[1], E. Henestroza[4], S. Girola[1].

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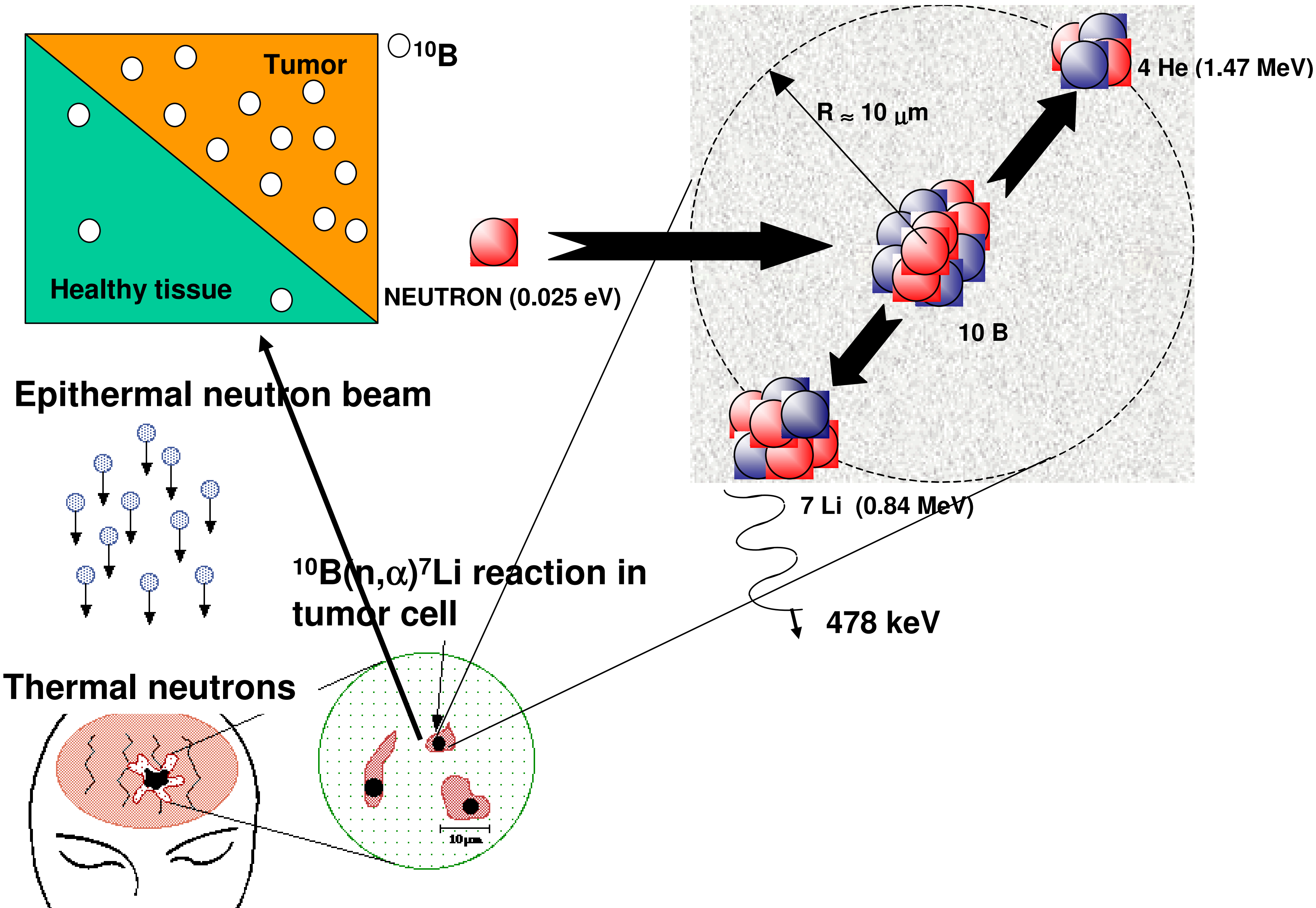
[2]*Escuela de Ciencia y Tecnología. UNSAM, Argentina.*

[3] *CONICET, Argentina.*

[4] *LBNL, USA.*

Research Applications and Utilization of Accelerators, AccApp '09, Vienna, 4-8 May 2009.



$$^{10}B + n \rightarrow {}^{7}Li^{*} + {}^{4}He \ (94\%) \quad Q = 2.31 \ MeV$$

(γ de 478 keV)

Why Accelerator Based (AB)-BNCT?

- The advancement of BNCT requires neutron sources suitable for installation in hospital environments. The presence of these devices in specialized cancer centers may be decisive for the future of BNCT:

  HOSPITAL SITING

- Accelerators offer a number of major advantages over reactor-based sources for clinical applications:

  The neutron energy spectrum from certain nuclear reactions is much softer than the one coming from fission, which makes it easier to generate the "ideal" epithermal neutron spectrum (needed to treat a deep seated tumor), and hence the quality of the neutron field can be designed to exceed the quality of the neutron field for reactor-based neutron sources:

  BETTER QUALITY BEAMS

Outline

- **Areas of activity (working areas).**

- **Development of a Tandem-Electro-Static-Quadrupole (TESQ) accel.: 2.4 MeV, 30 mA (72 kW).**

  Present status.

- **Conclusions.**

WORKING AREAS /Responsibilities

1. **Mechanical design and construction.** W. Castell, H. Di Paolo, J.M.Kesque, A. Martinez, et al.

2. **Electronic/electromechanical design**: High voltage power supplies, generators. H. Di Paolo, M. Baldo et al.

3. **Electrostatics, column and tubes.** V. Thatar Vento, D. Cartelli, J.M. Kesque, et al.

4. **Ion Optics (high intensity beam transport).** P. Levinas, M.Obligado,V. Thatar Vento, E. Henestroza, et al.

5. **Vacuum system.** M.E.Debray, J.C. Suarez, A.F. Salares, et al.

6. **Ion sources.** J. Bergueiro, H.Somacal, J.C.Suarez, H. Huck, M. Igarzabal et al.

WORKING AREAS /Responsibilities (Cont.)

7. Strippers and thin targets. M.Repetto, M.Obligado, M.Debray, J. Davidson, M. Davidson, et al.

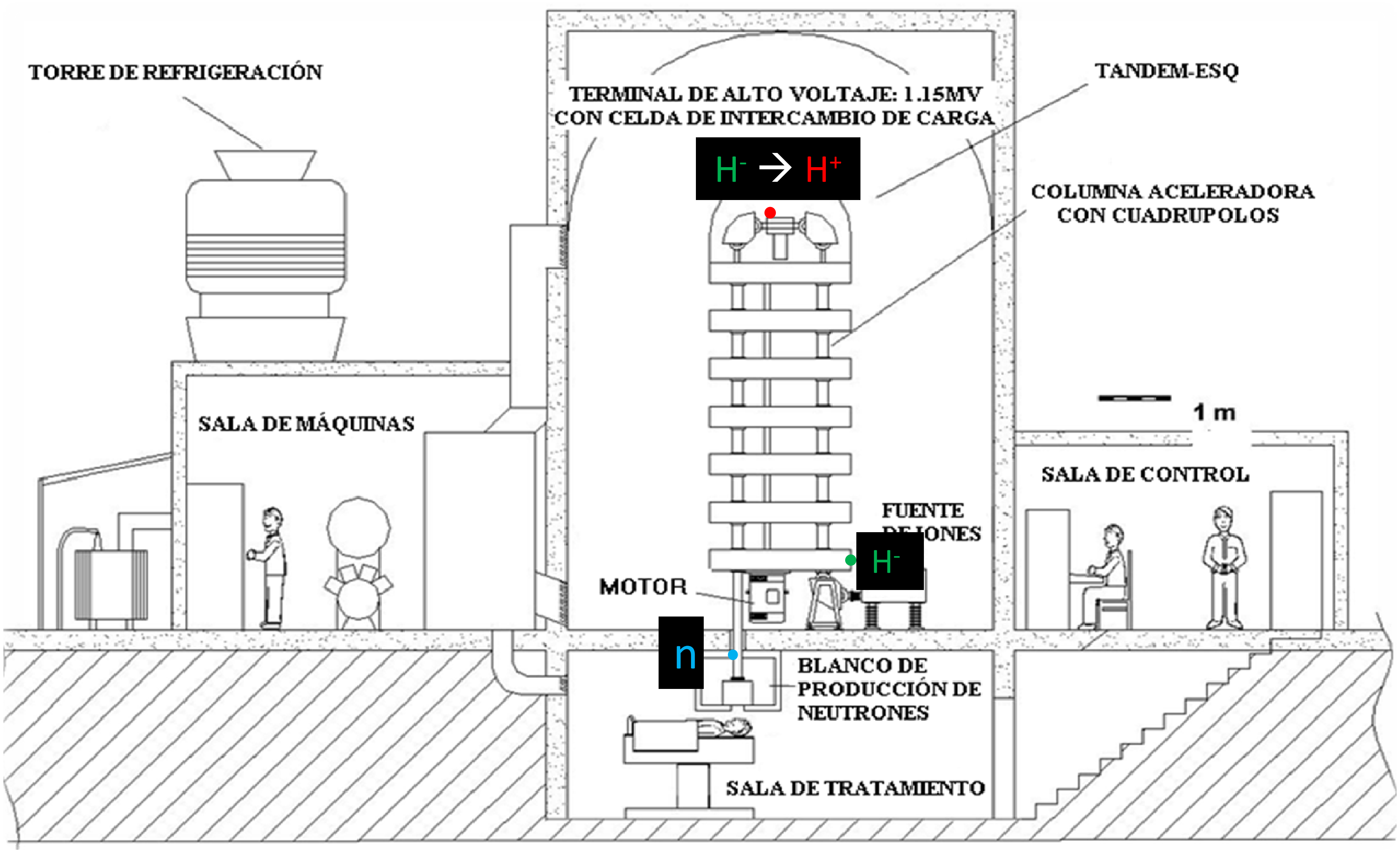
- **8. High power target (thermomechanical aspects).**
  L. Estrada, F.Johann, A.Hazarabedian et al.

- **9. Neutron production target (neutronics), beam shaping assembly, patient irradiation room.** A.A. Burlon, A.A.Valda, D. Minsky, S.Girola et al.

- **10. Control systems.** J.C. Ilardo, H. DiPaolo, et al.

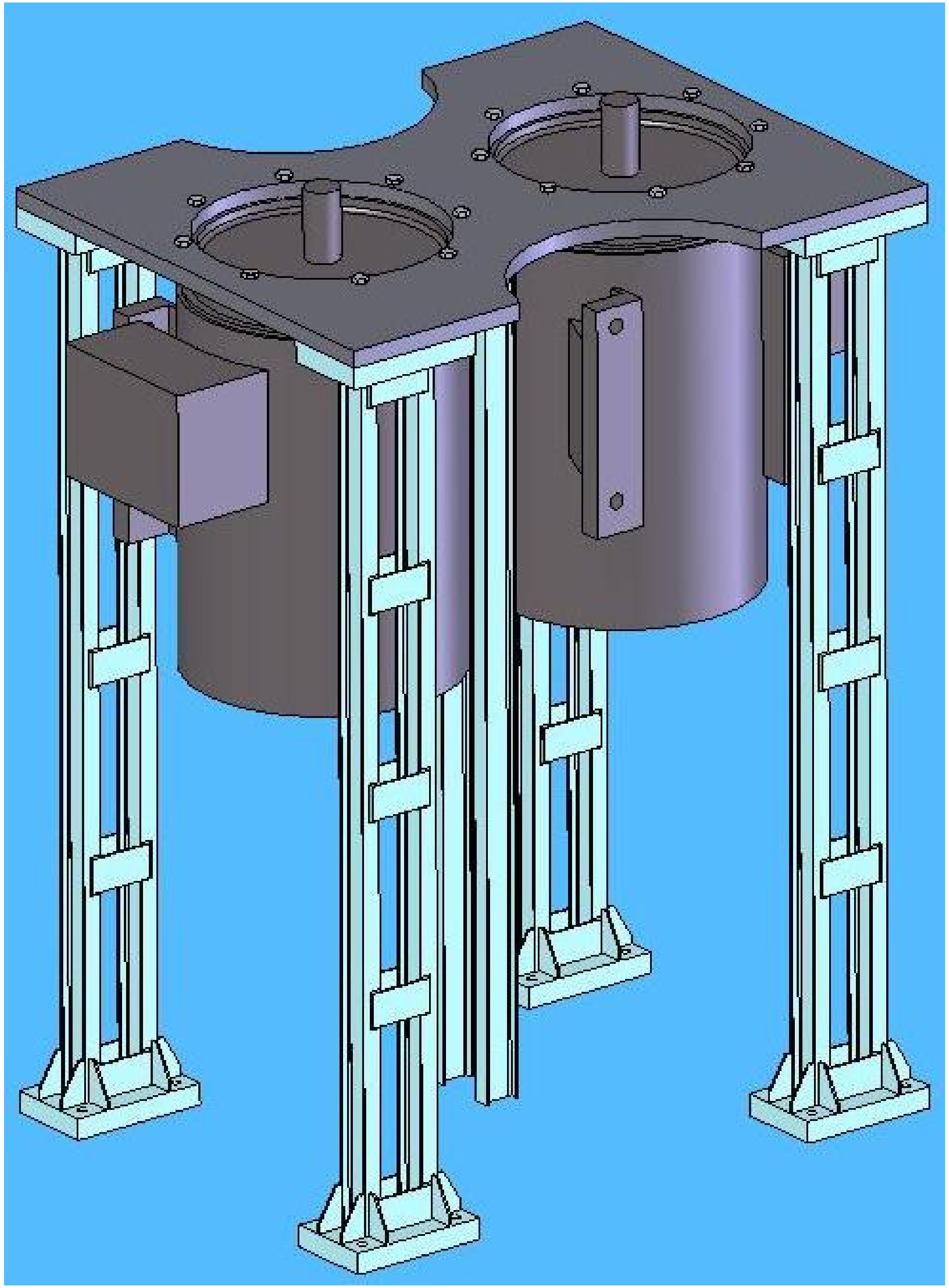
- **11. Licensing:** A.A.Burlon, A.Valda, G.Sanchez et al.

General layout of facility.

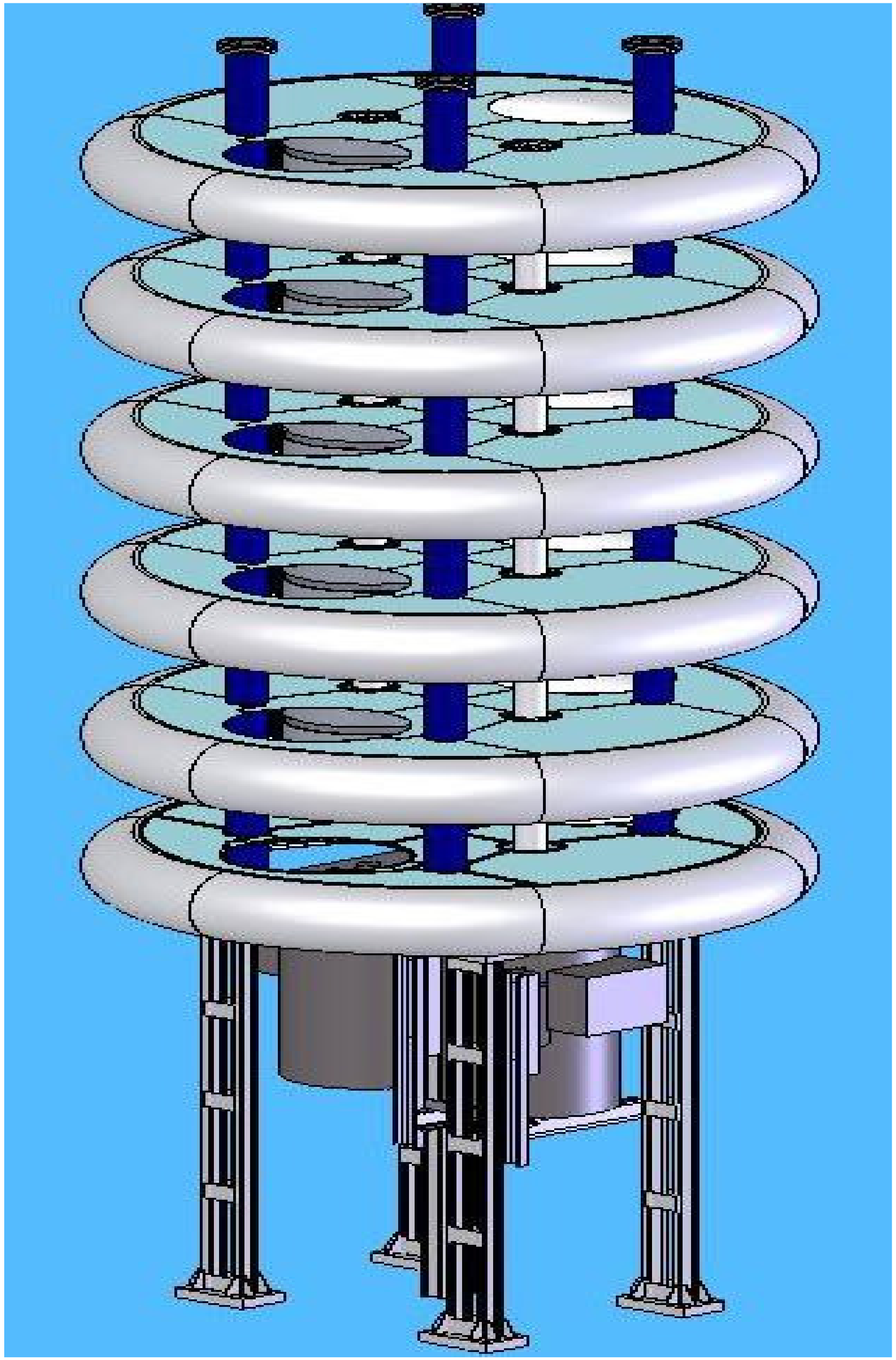


1. **Mechanical design:**
"Coins" (boxes), supporting structures, posts and insulating rotating shafts, etc.
W. Castell, H. Di Paolo, J.M.Kesque, A. Martinez, et al.

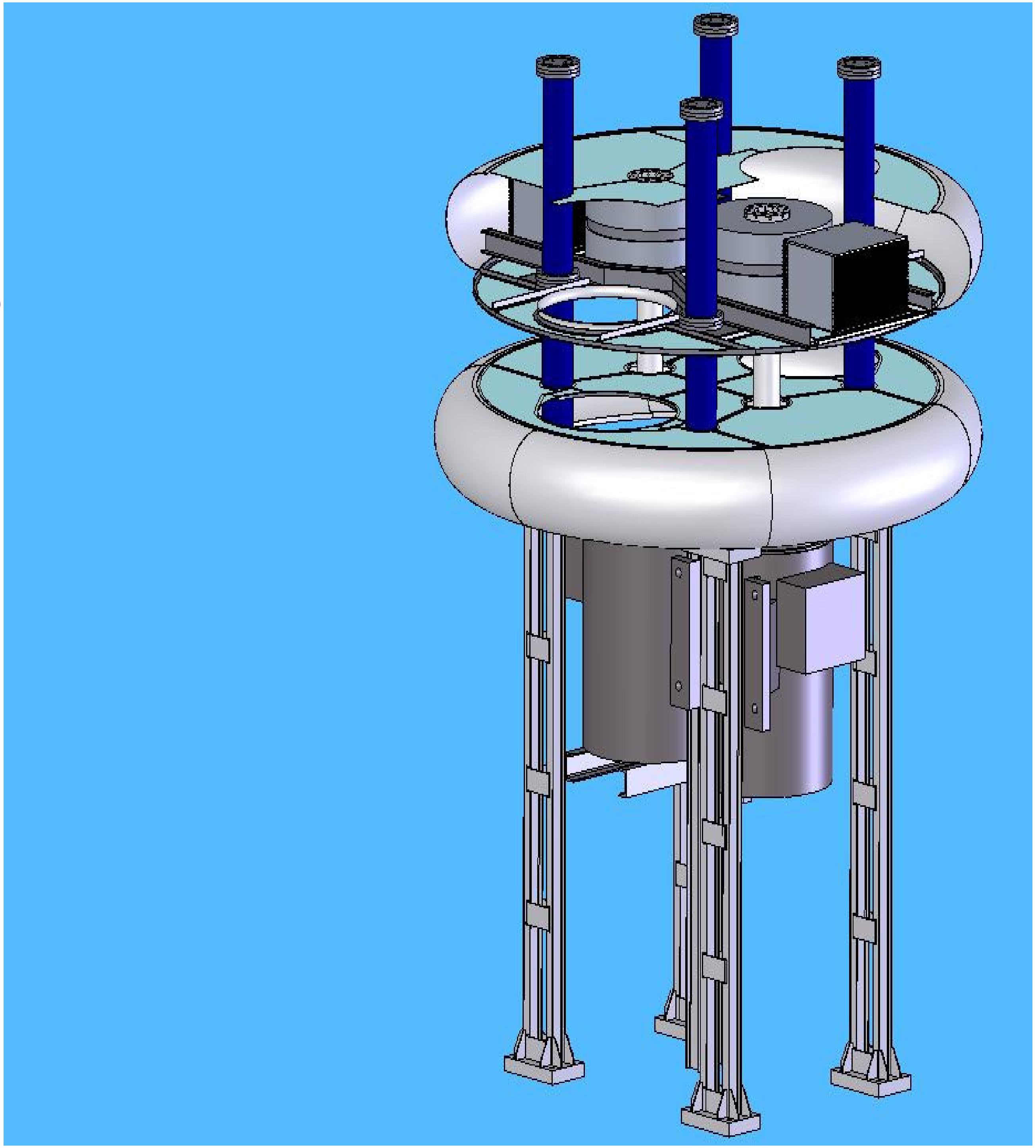
Support legs and base for driving motors.



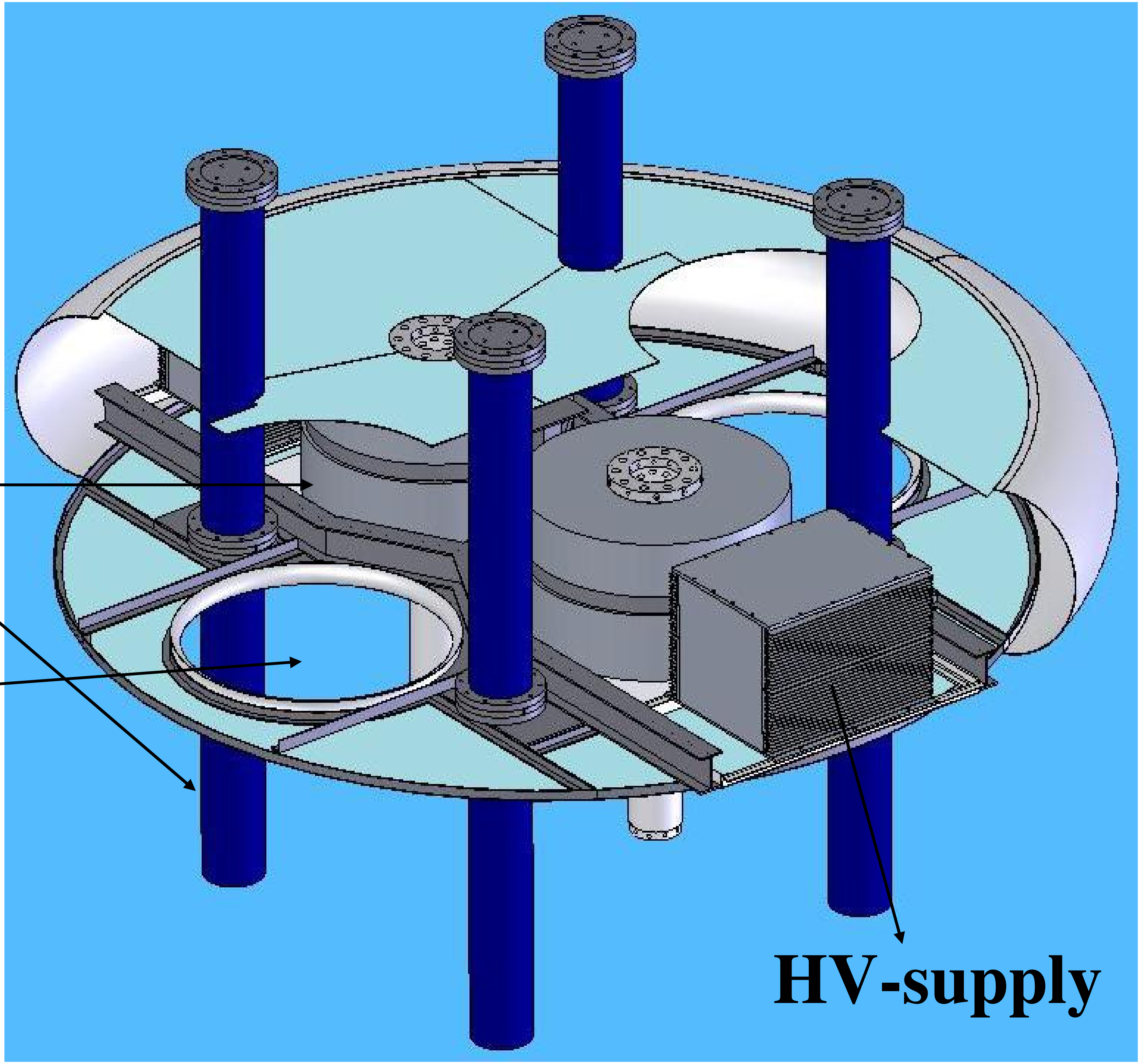
Accelerator column with “coins” (up to 1 MV shown).



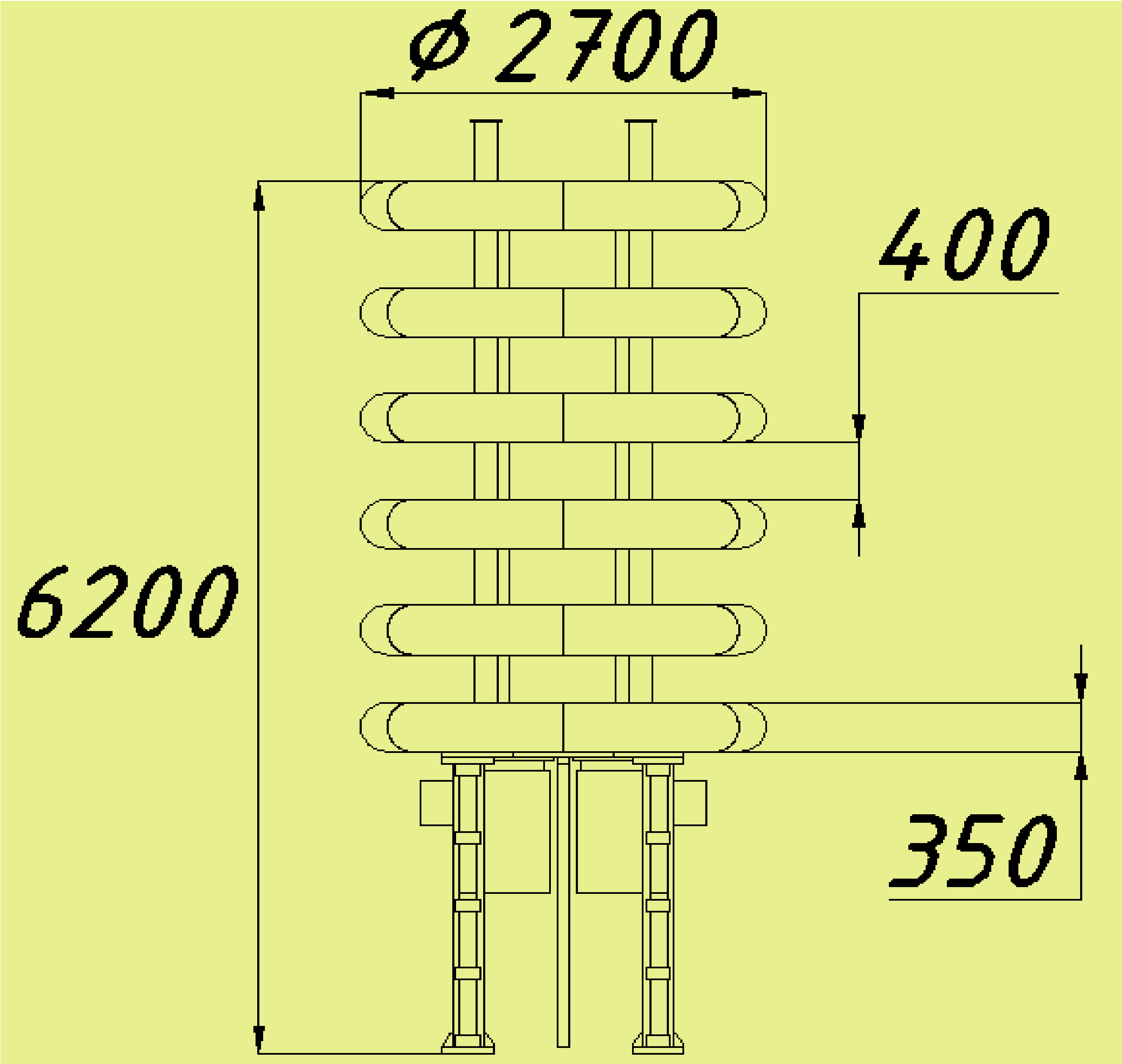
First two coins: 0 and 200 kV, showing the inside with HV supply and generators

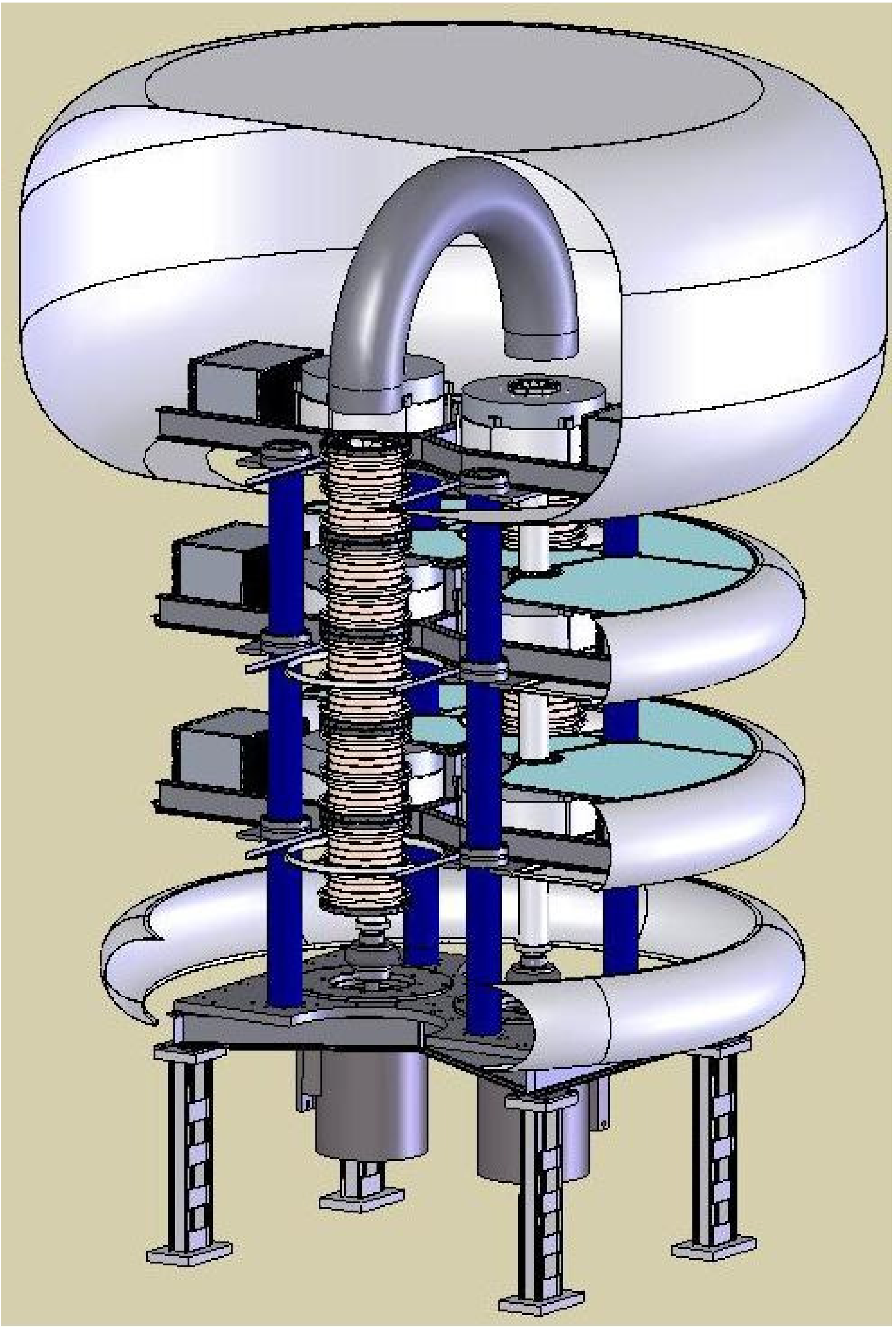


Coin with HV-supply, generators, posts, holes for tubes

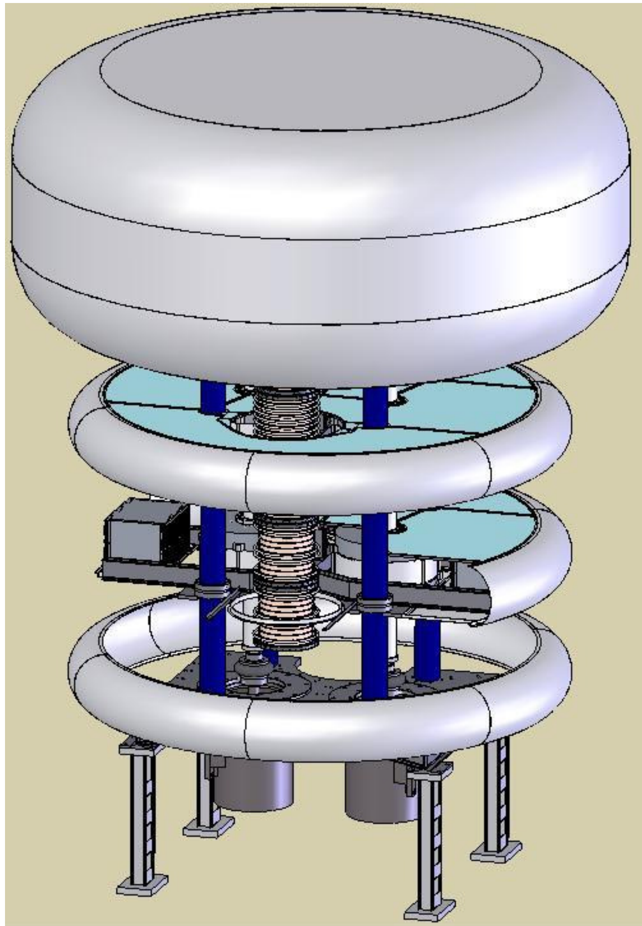


Column: dimensions in mm



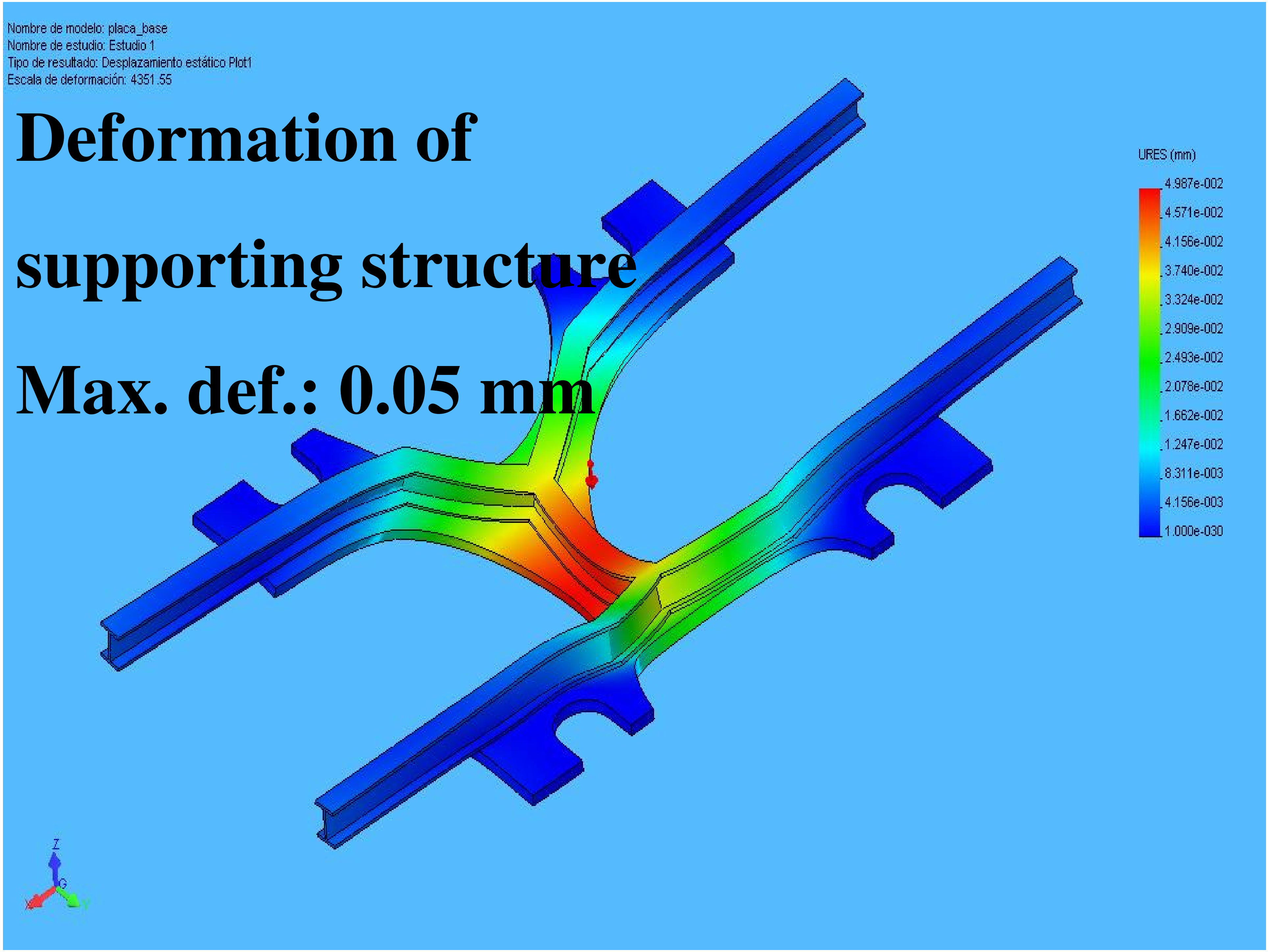


Vertical section of prototype

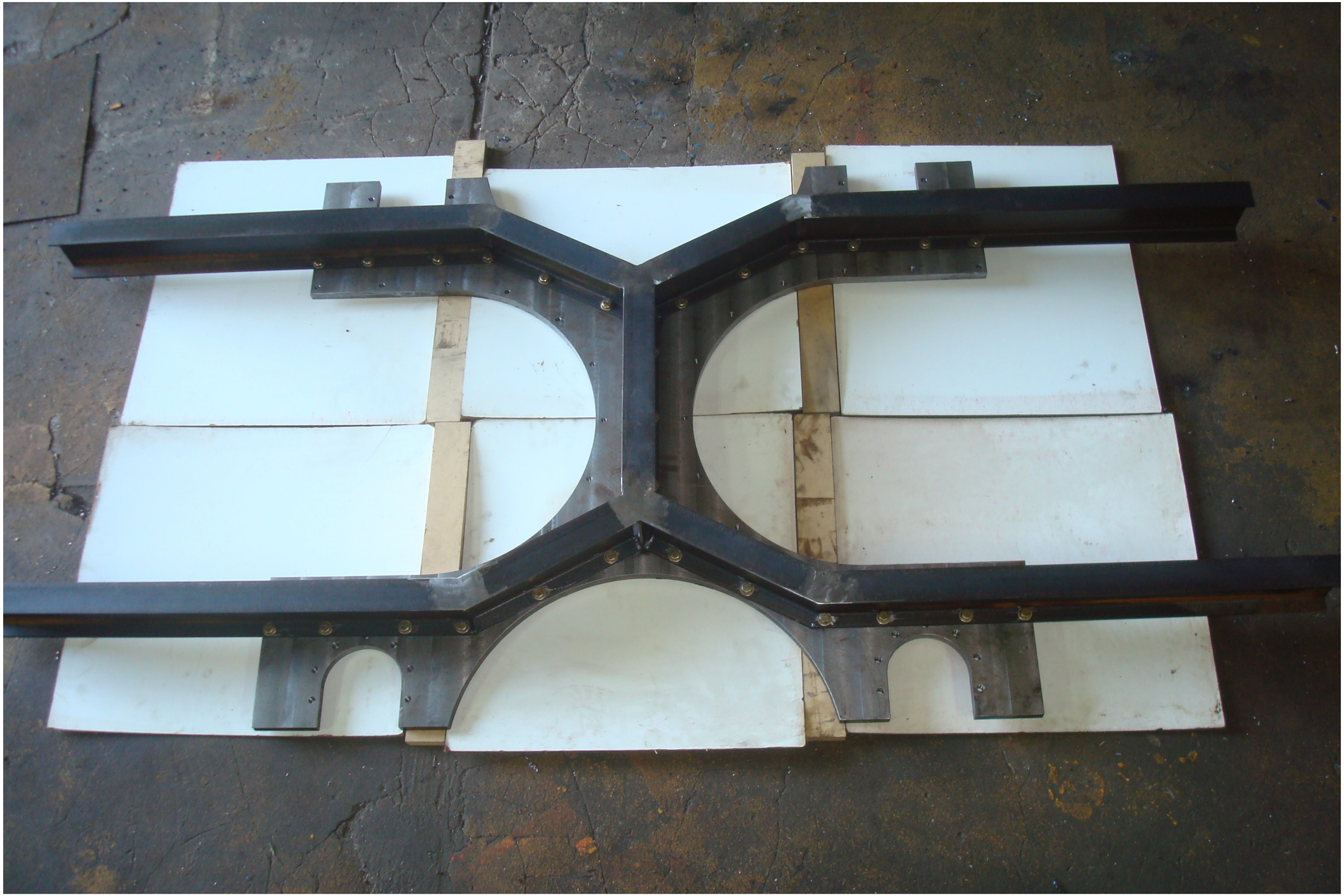


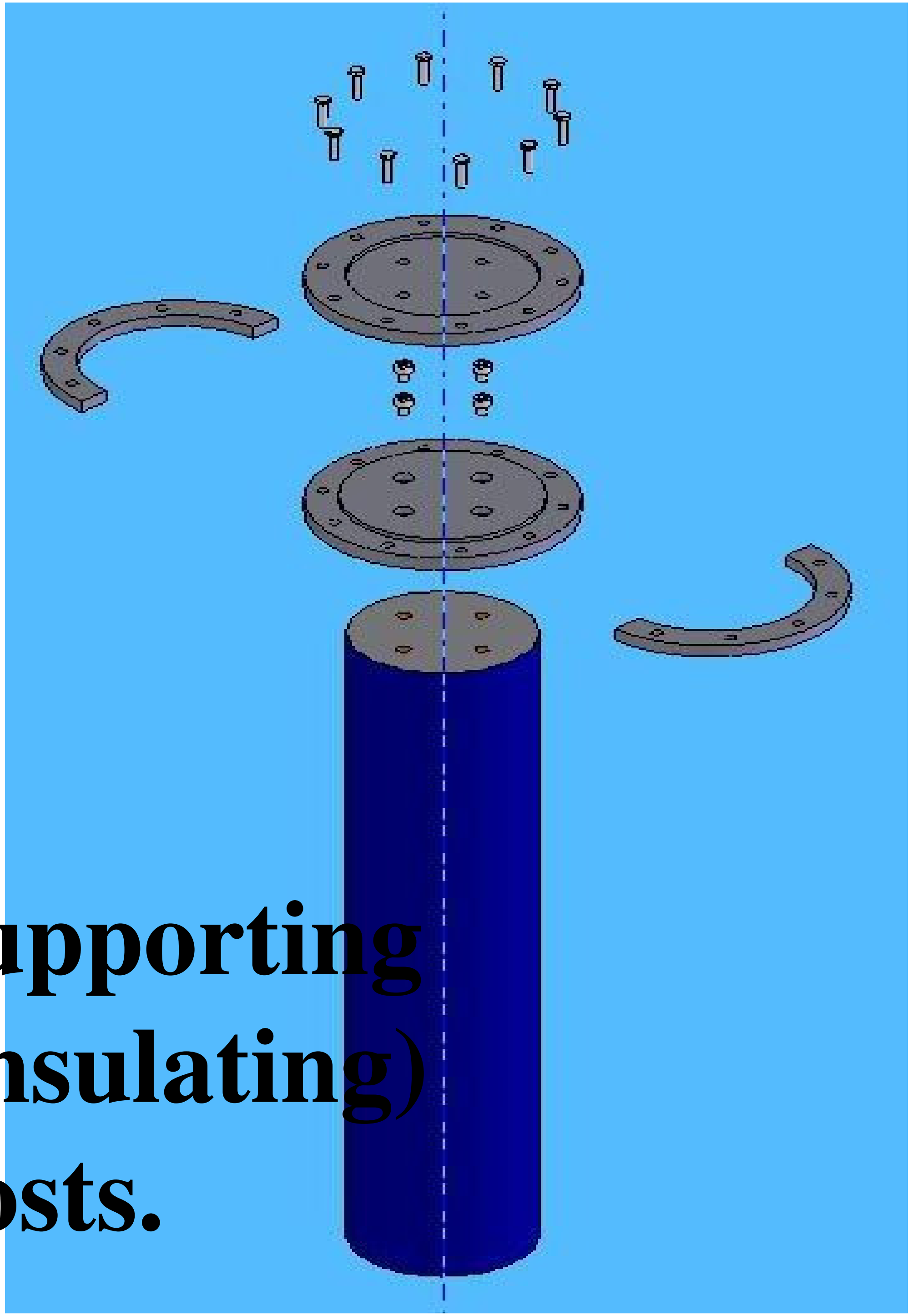
Deformation of supporting structure

Max. def.: 0.05 mm



Machined coin (box) support.





Supporting (insulating) posts.

Machined supporting posts.

Rotating shaft: power transmission axis for generator.

Rotating shaft for generator

Test stand for rotating shafts.

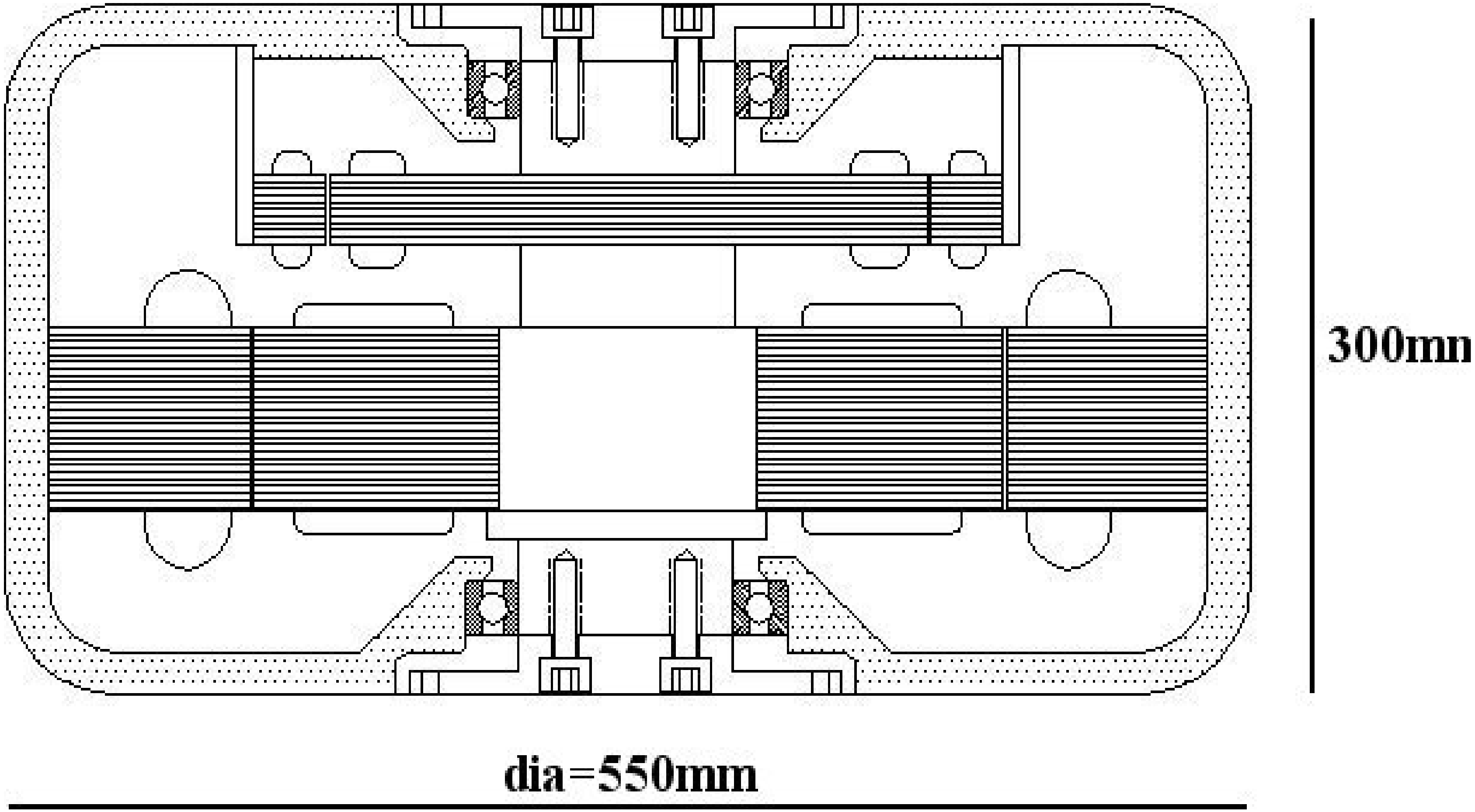
2. Electronic/electromechanical design:

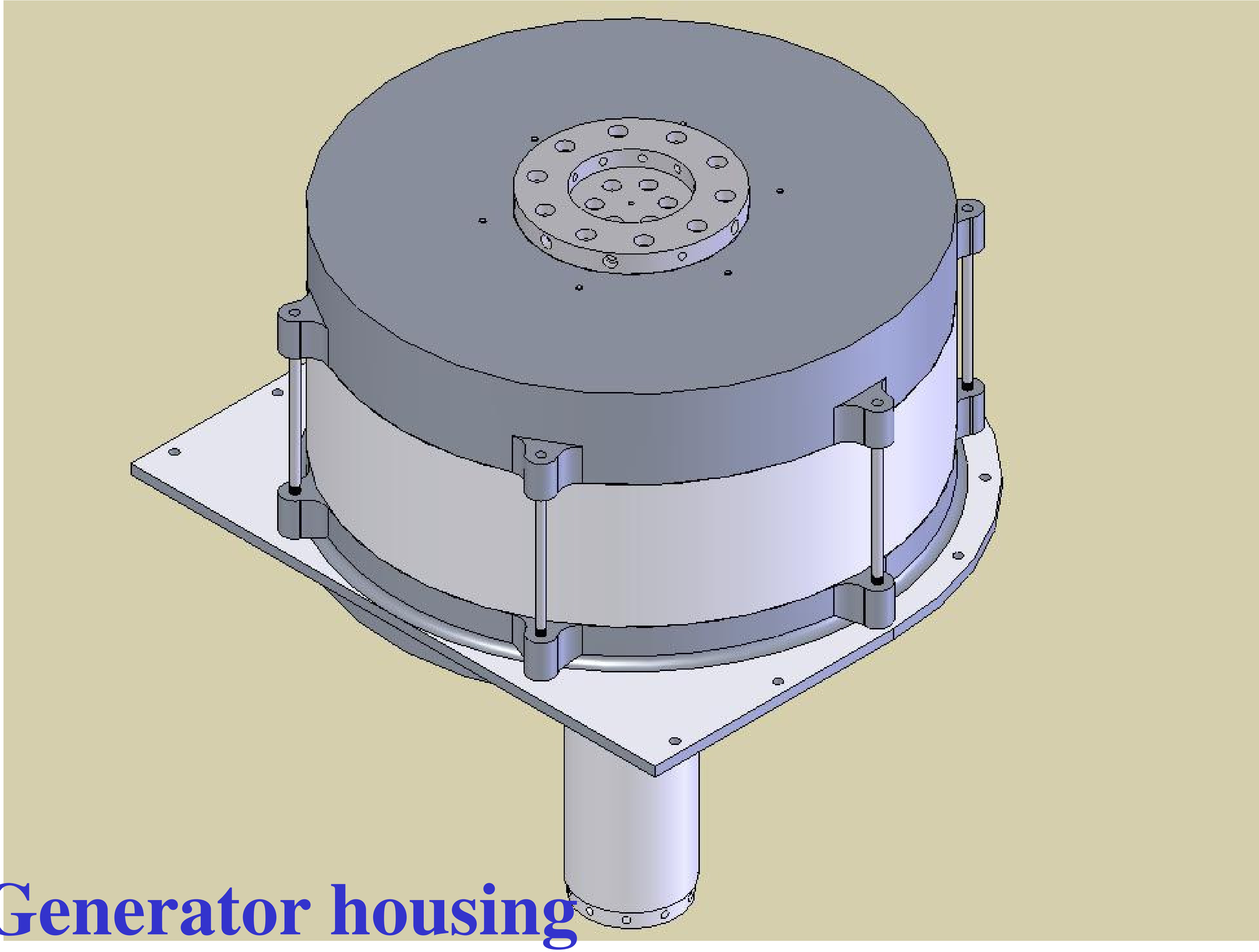
High voltage power supplies,
AC generators.
H. Di Paolo, M. Baldo.

AC Generator

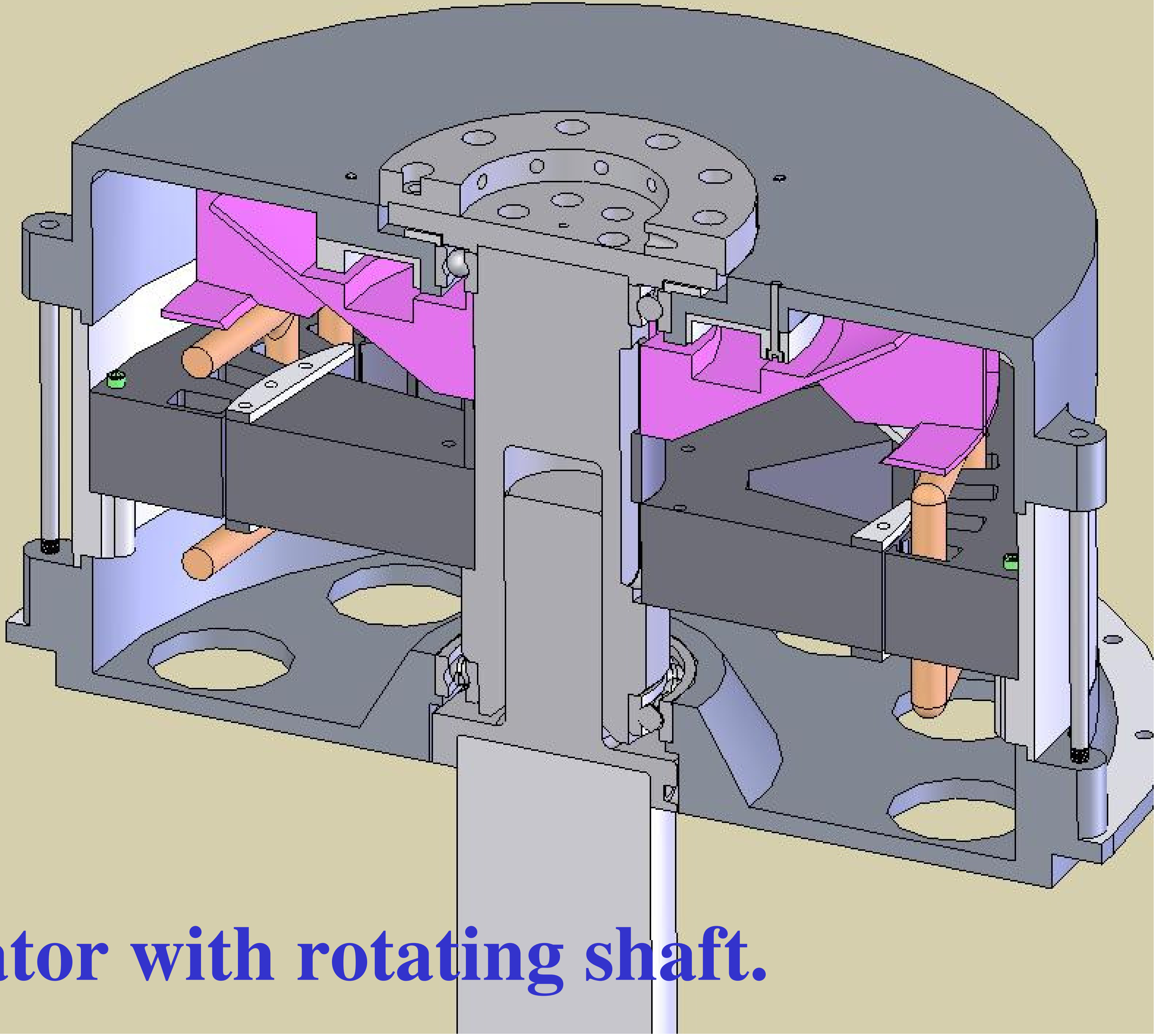
120kg

Pot= 12kVA



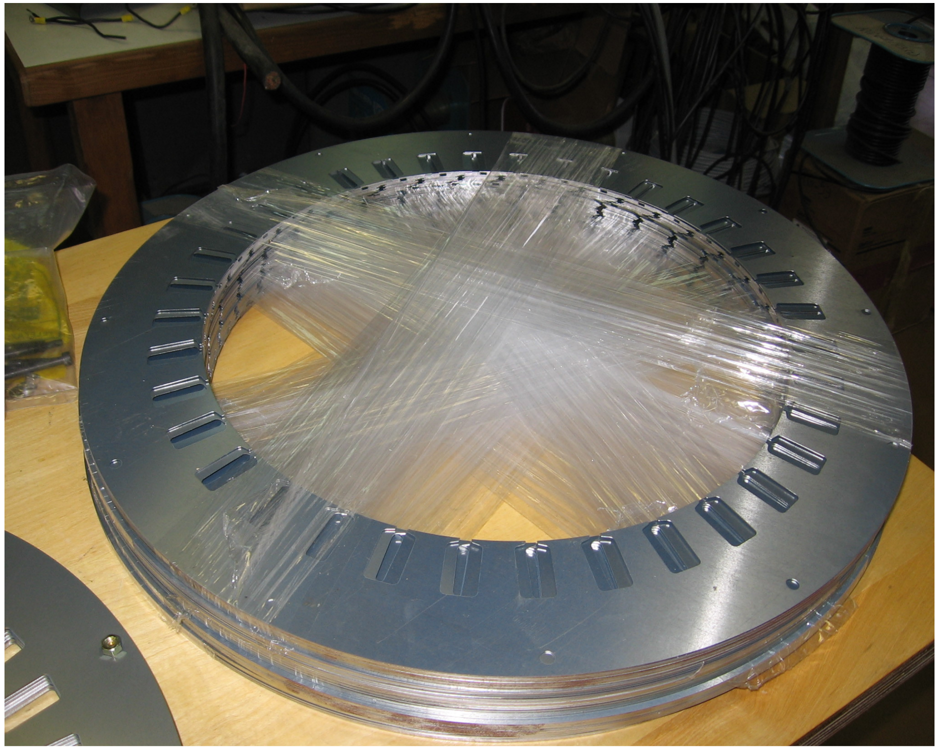


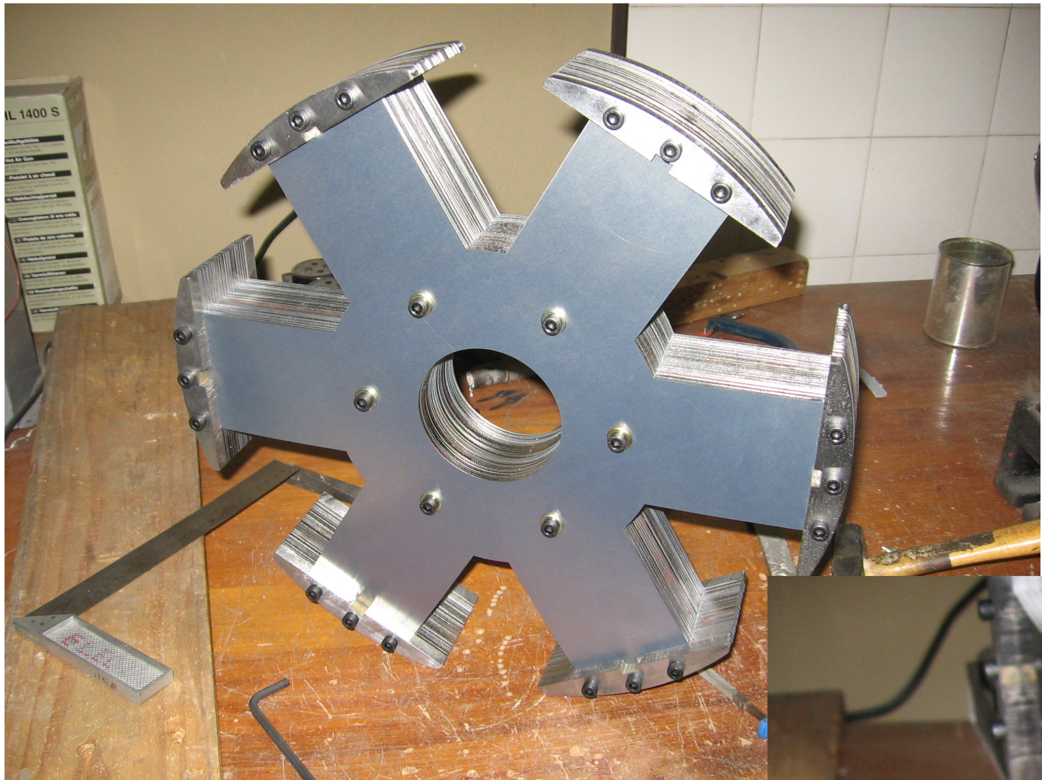
Generator housing

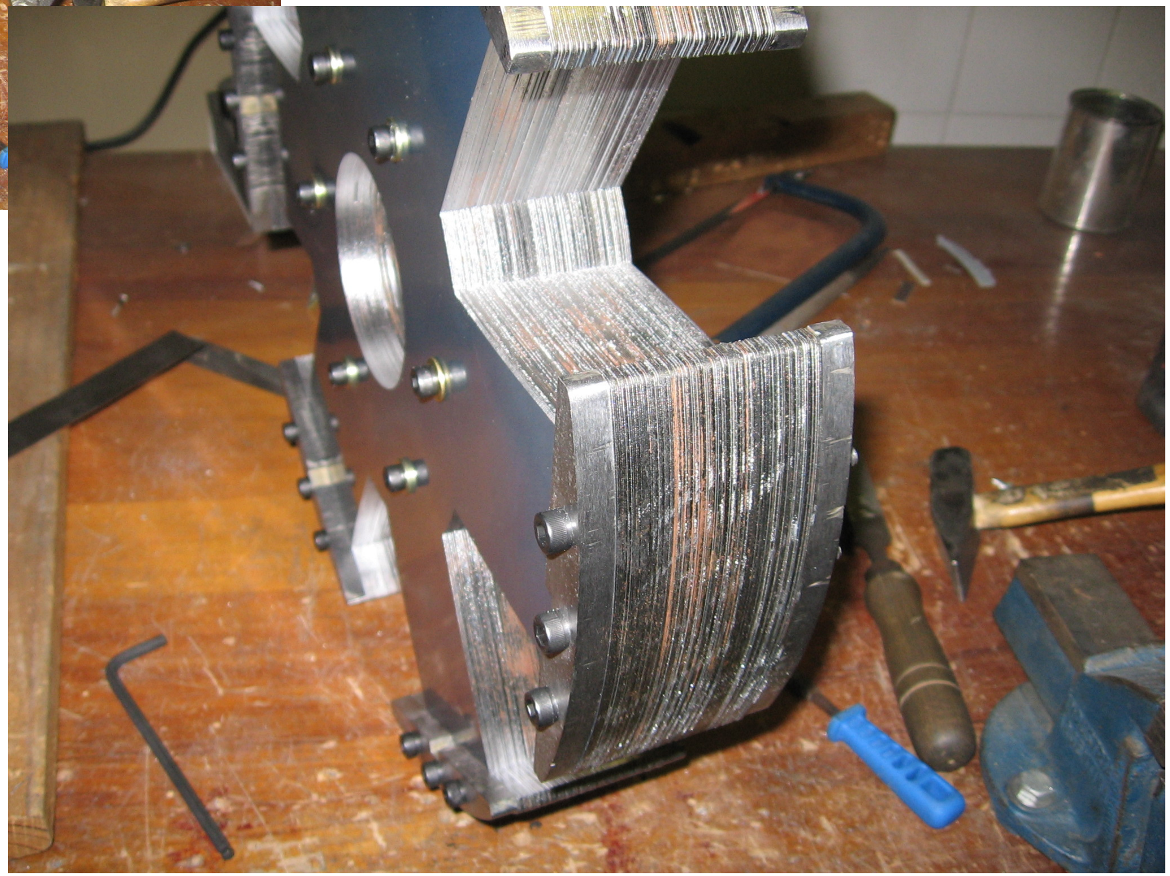


Generator with rotating shaft.

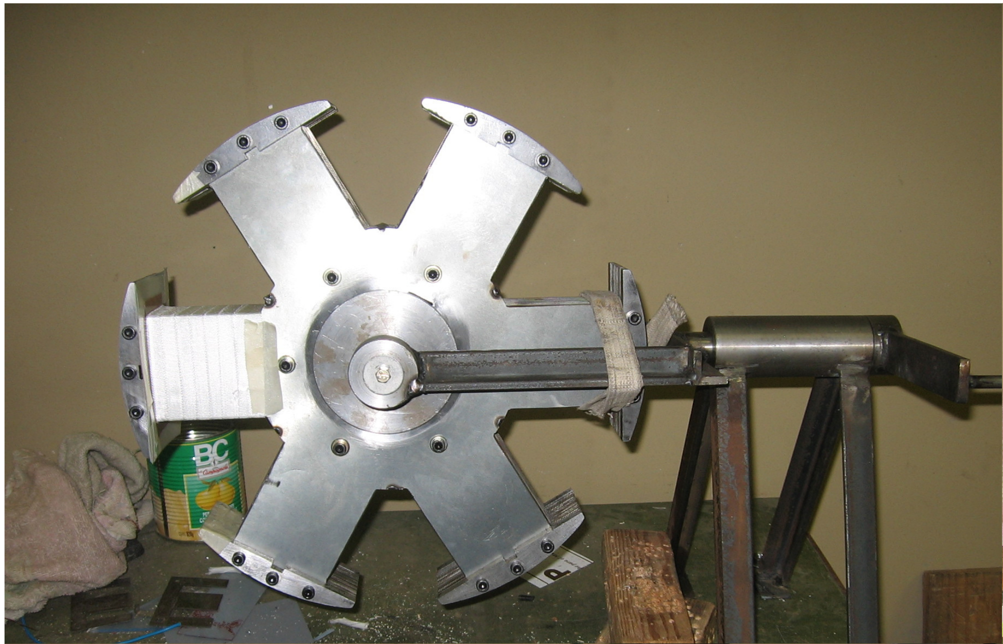
Rotor and stator, cut from the same laminations of silicon steel .







Assembled Rotor.


BC

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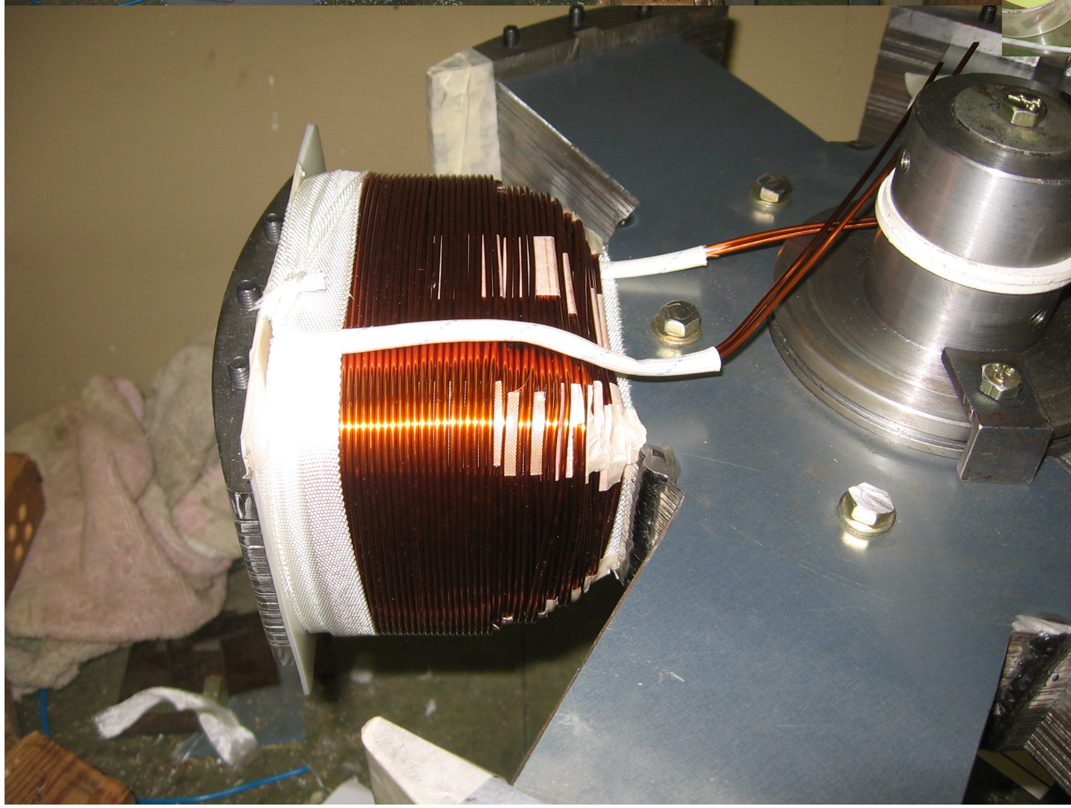
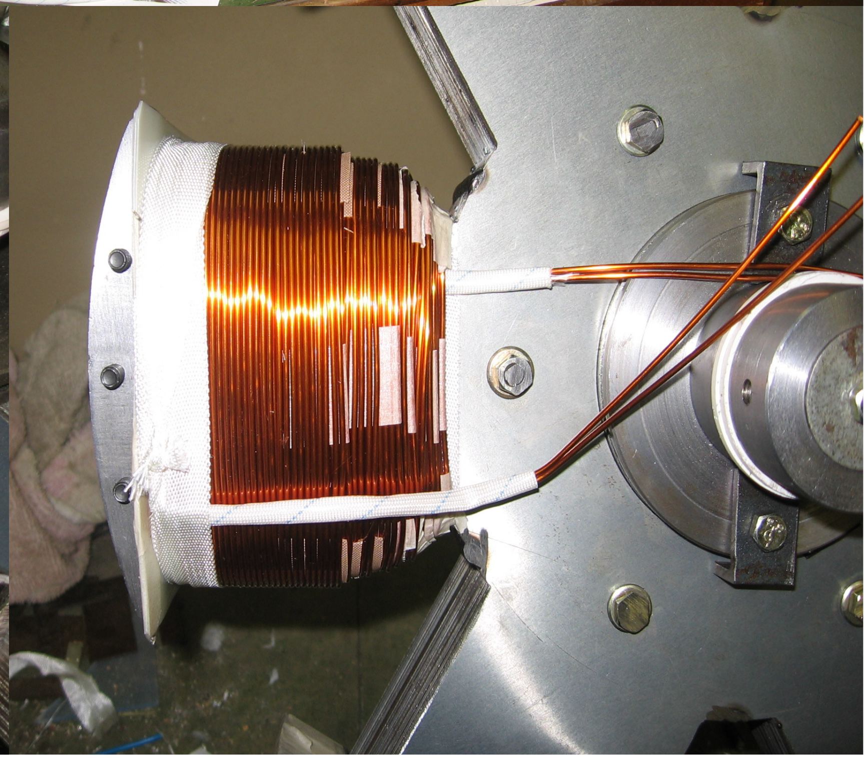
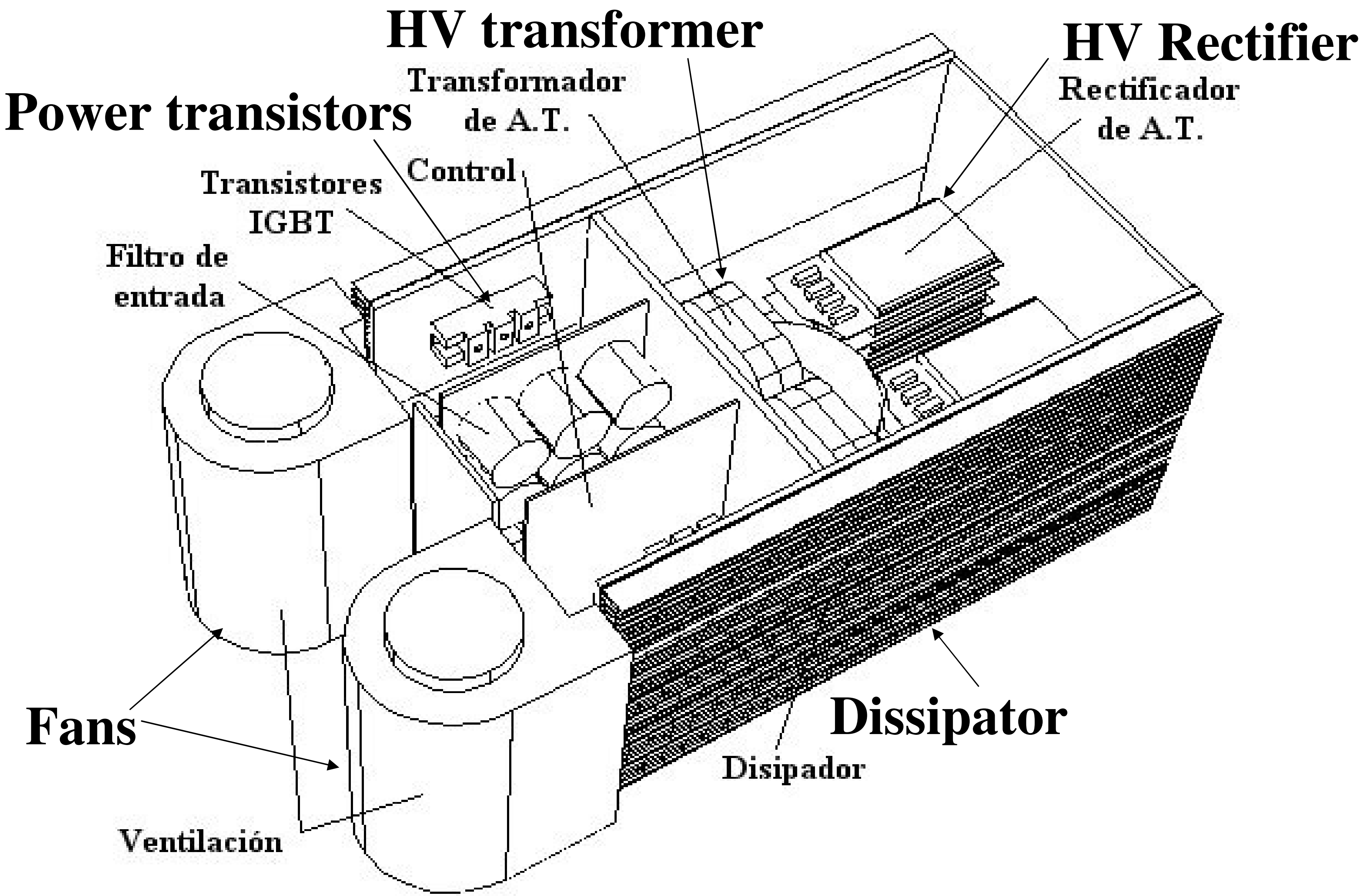
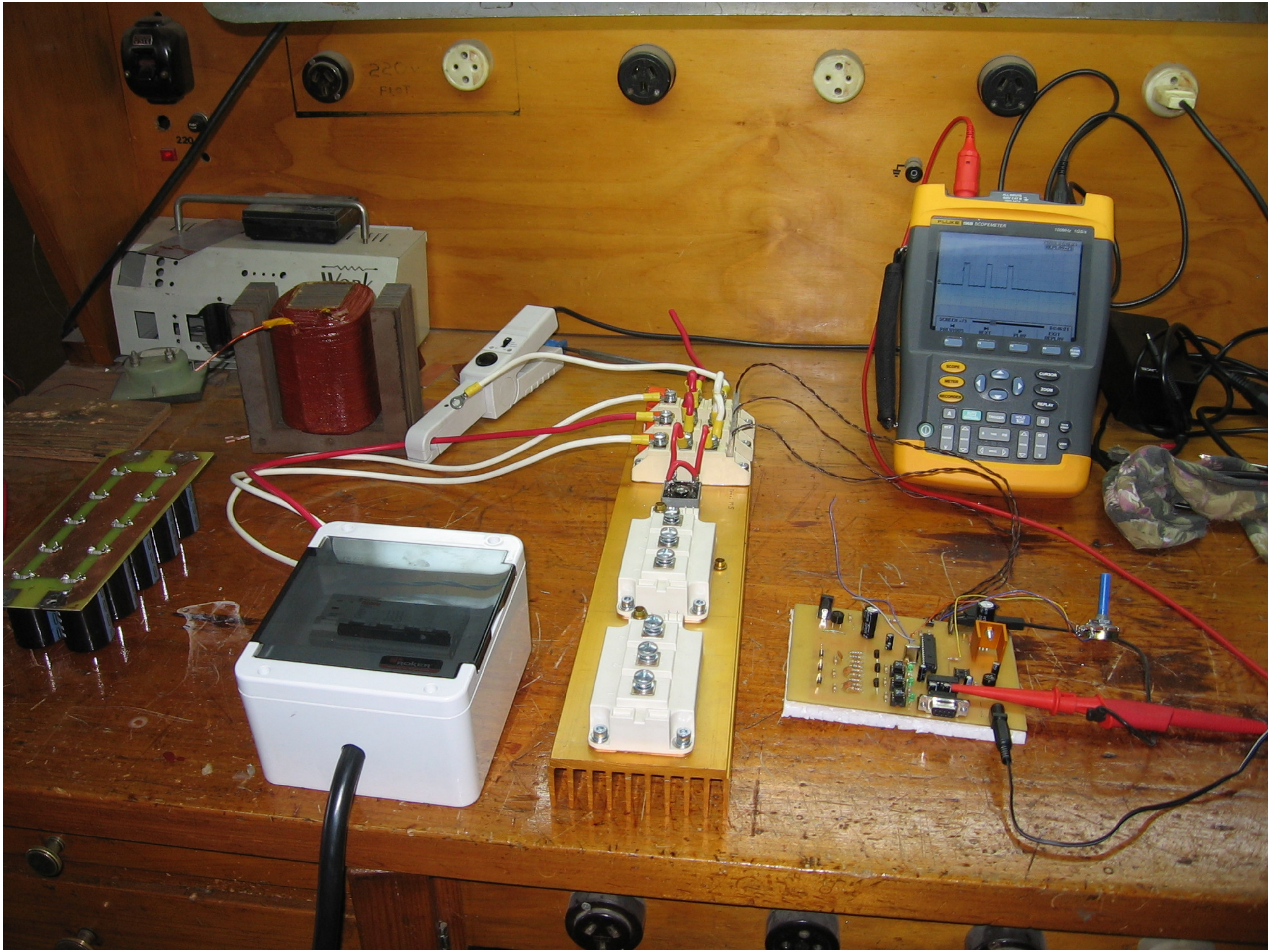



High voltage power supply (100 keV).




220V
FLUKE
SCOPEMETER
SCOPE
METER
RECORDER
CURSOR
ZOOM
REPLAY

HV-supply. 1st version.

Technical specifications.

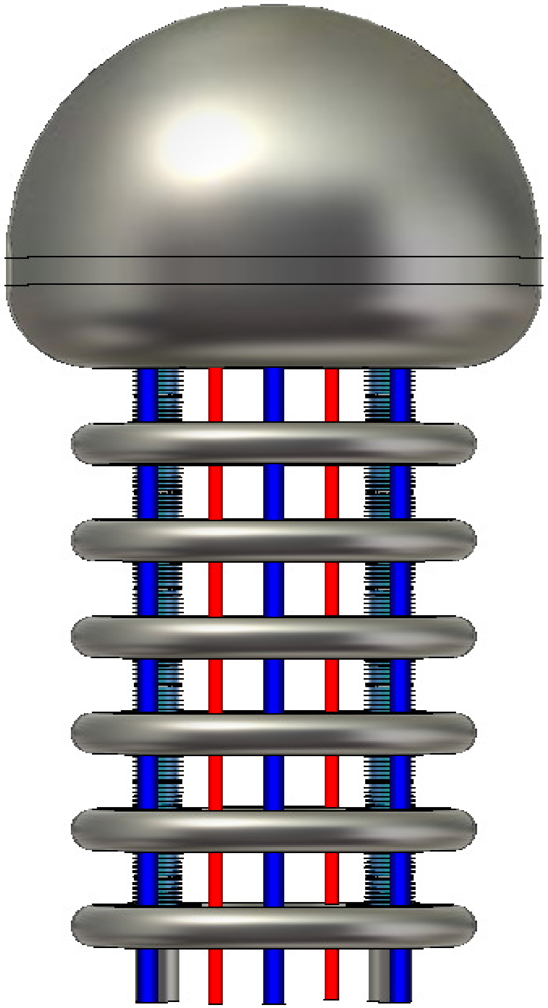
- **Input**: 380VAC±10%
- **Output:** 100kV@ 60mA
- **Control:** Programmable voltage and current control via RS232
- **Output voltage regulation:** Charge 0,01%@ 100% charge.
  Line 0,01% @ full voltage.
- **Output current regulation:** Charge 0,1%, Line 0,1%.
- **Ripple:** 0,1% peak to peak @ full load.
- **Stability:** 0,05%/h
- **Dimensions:** width 400mm, height 260mm, depth 730mm.
- **Weight:** 50kg oil loaded
- **Efficiency:** 89%

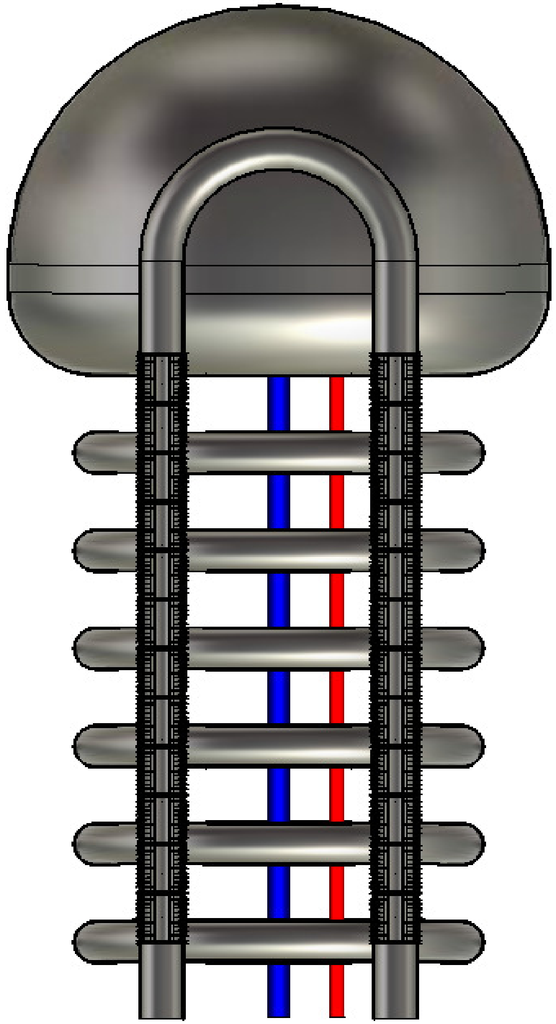
3. Electrostatic design, column and tubes:

V. Thatar Vento , D. Cartelli, J.M. Kesque, A. Valda, et al.

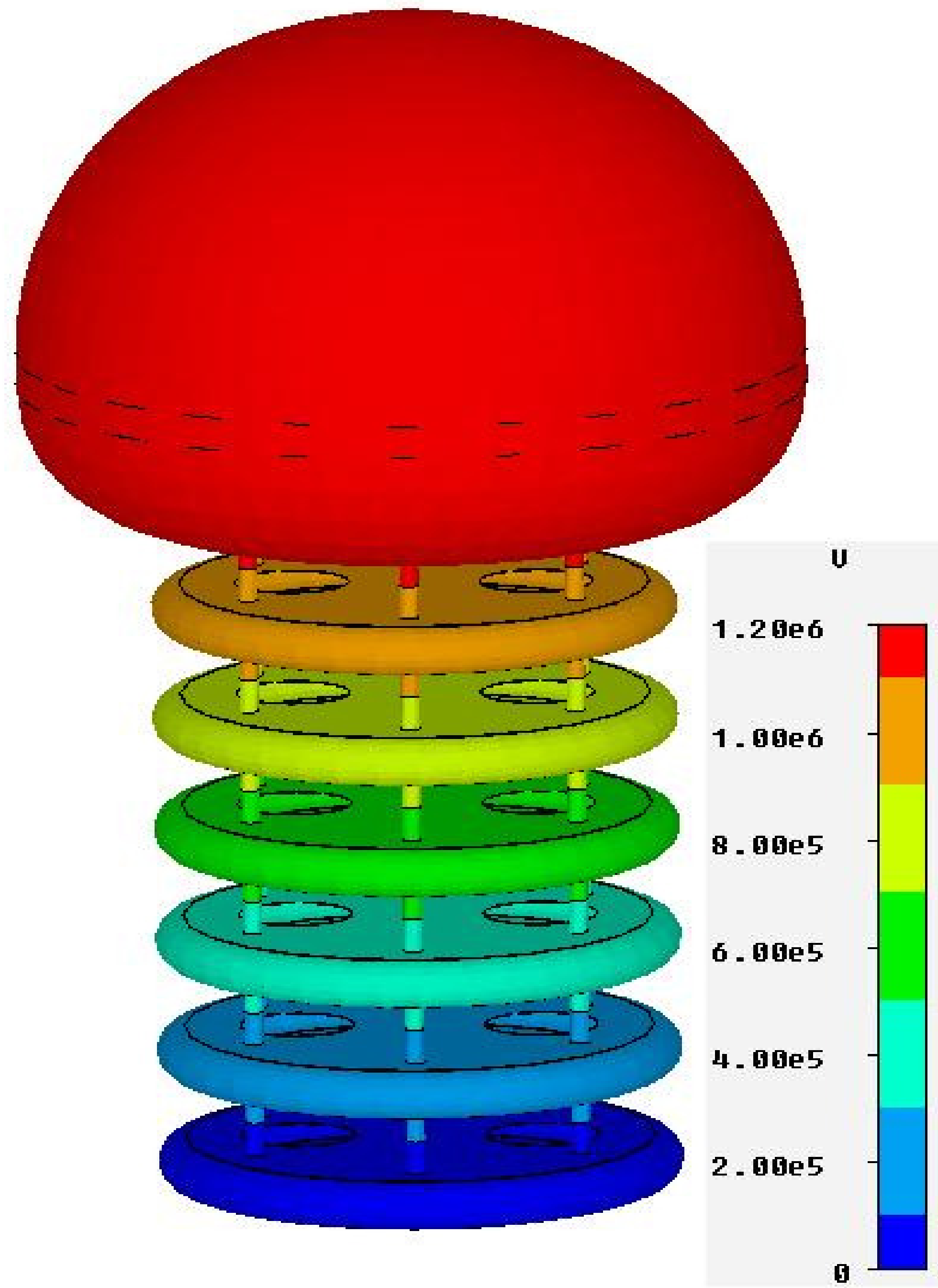
- **Design criteria:**
- **1. Insulator-air interface: 5 kV/cm**
- **2. Insulator-vacuum int.: 8 kV/cm**
- **3. Vacuum gaps: 45 kV/cm**
- **4. Metal-air surfaces: 12 kV/cm**

Accelerator: 6 modules and HV dome.

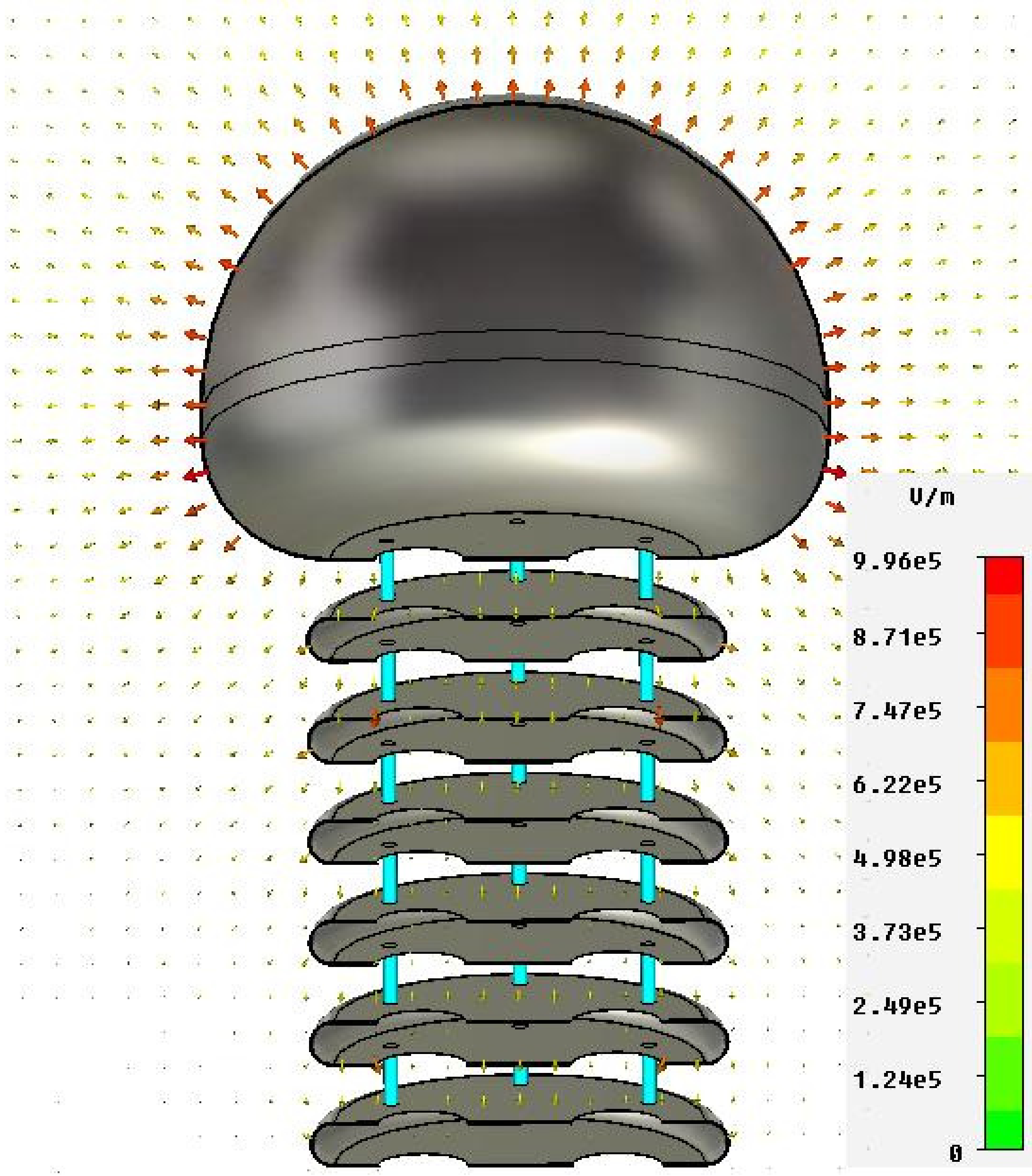




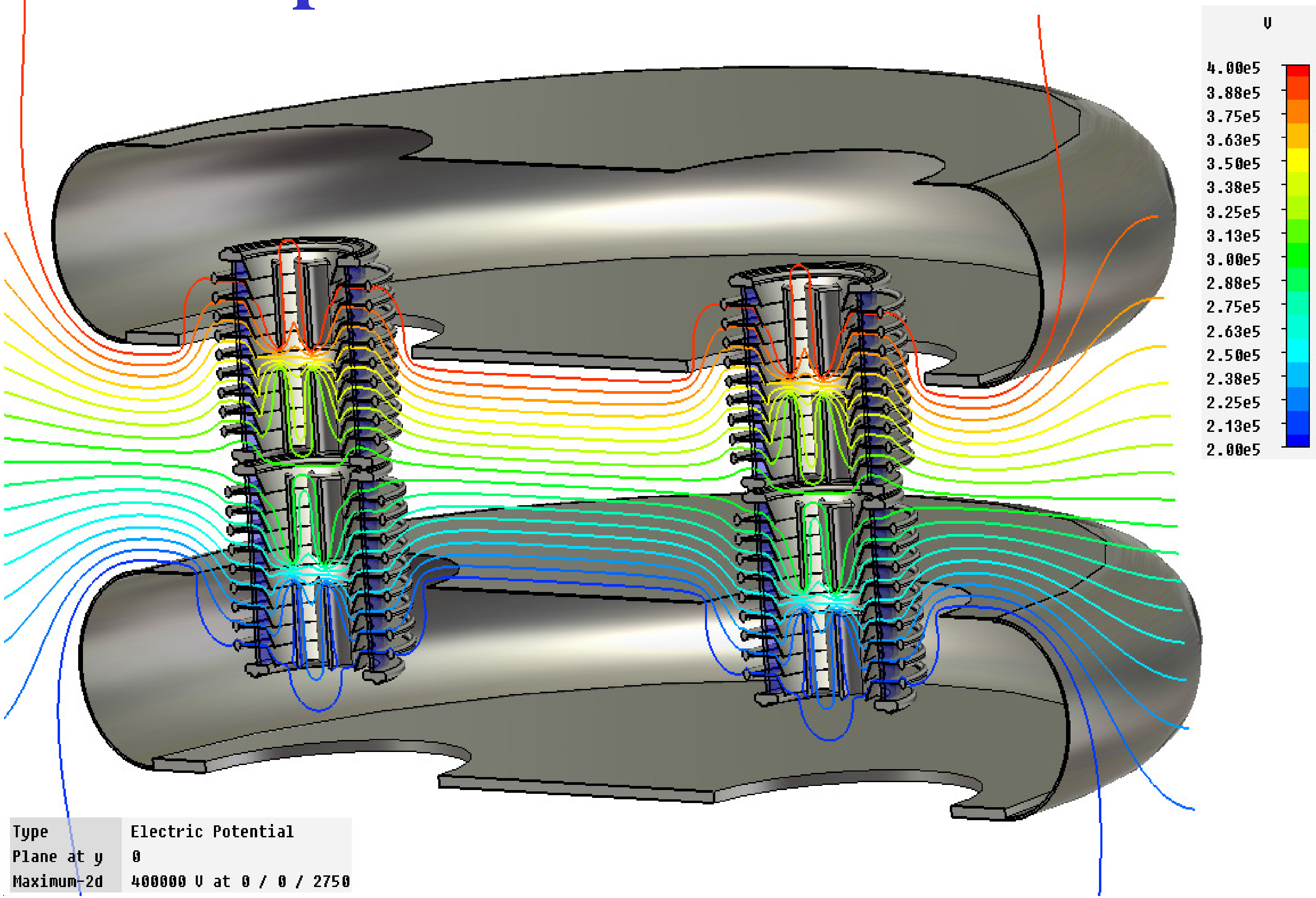
High-voltage dome and column. V_{max} = 1.2 MV



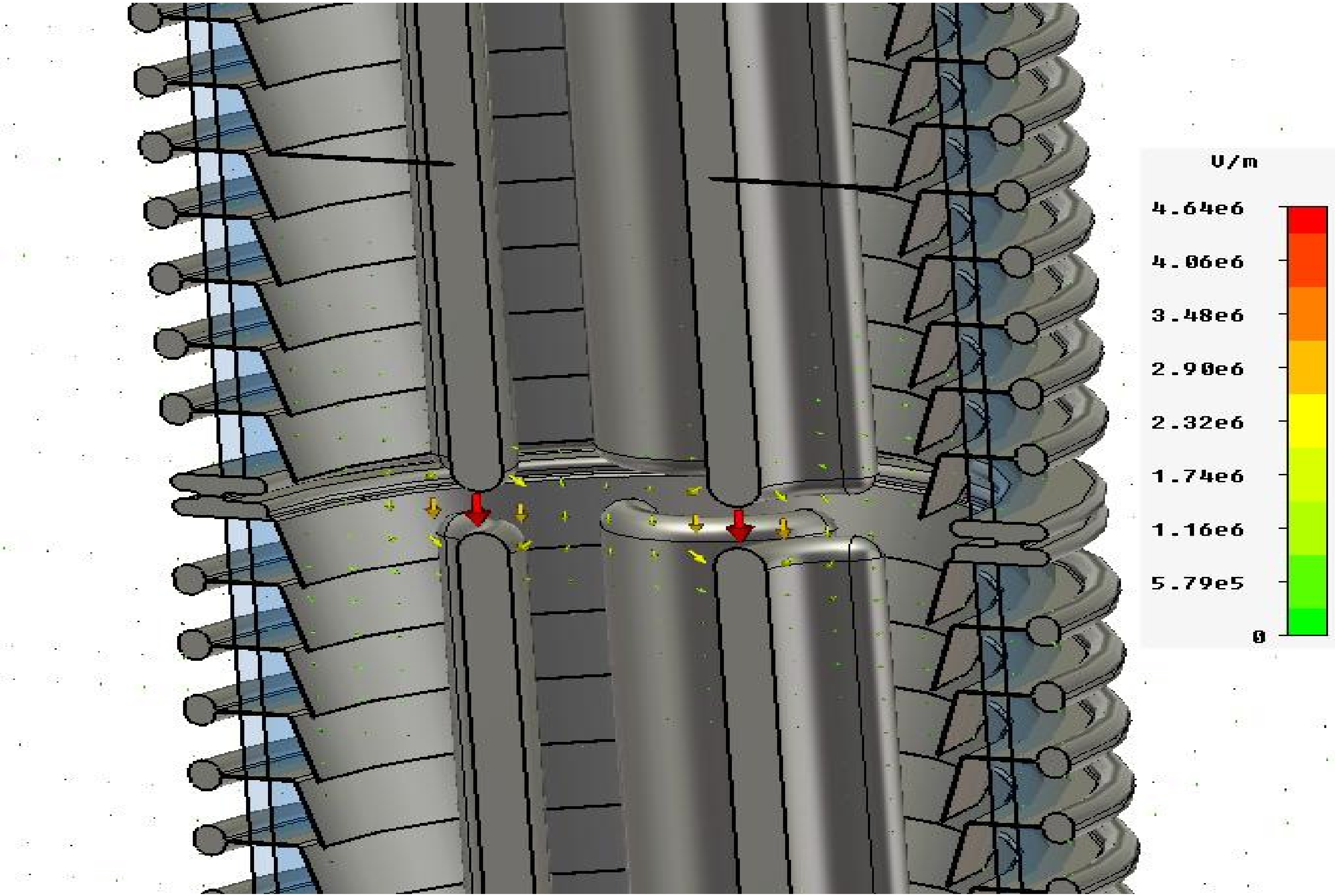
High-voltage dome and column. E_{max} = 10 kV/cm



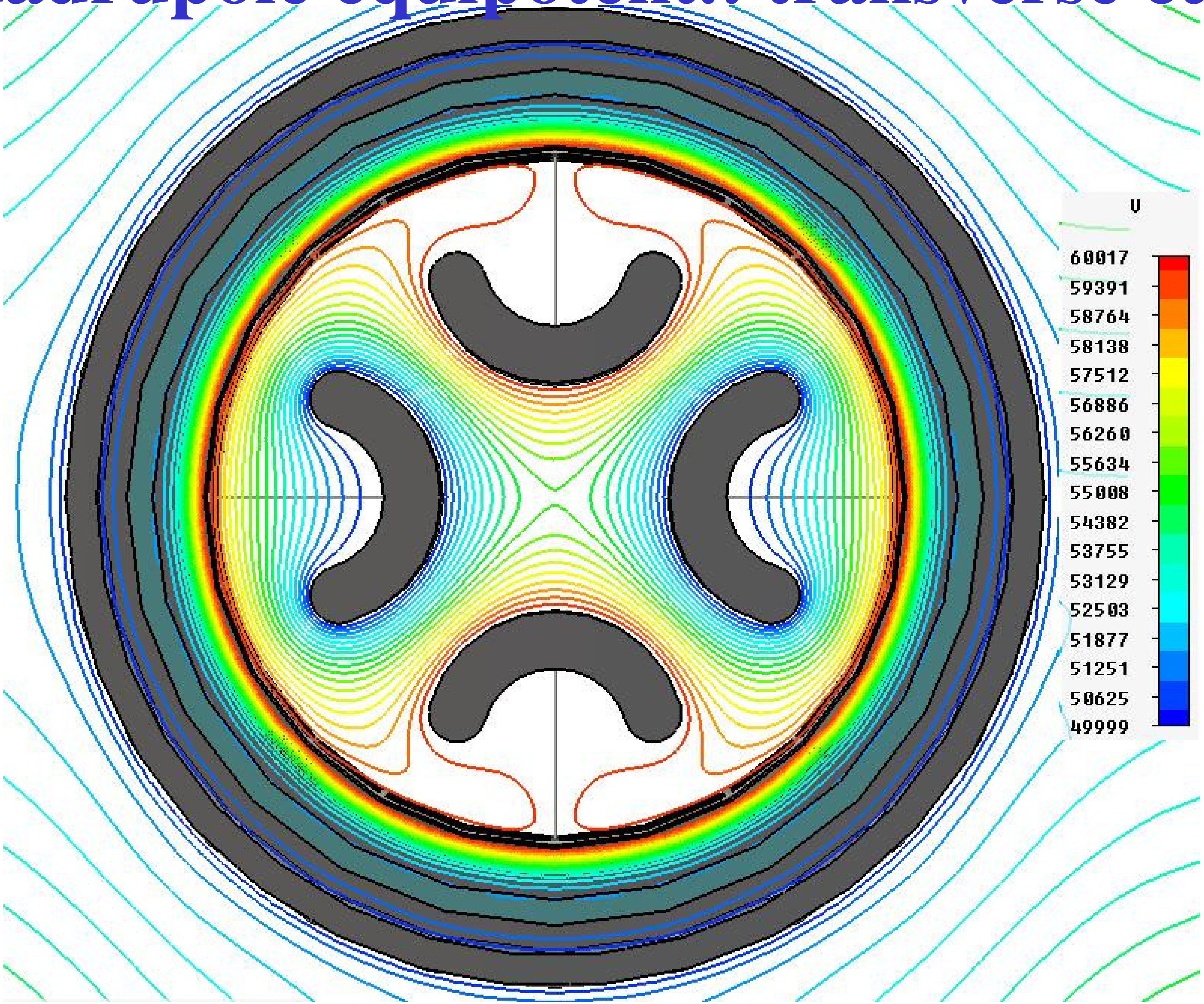
Electric potential between two coins



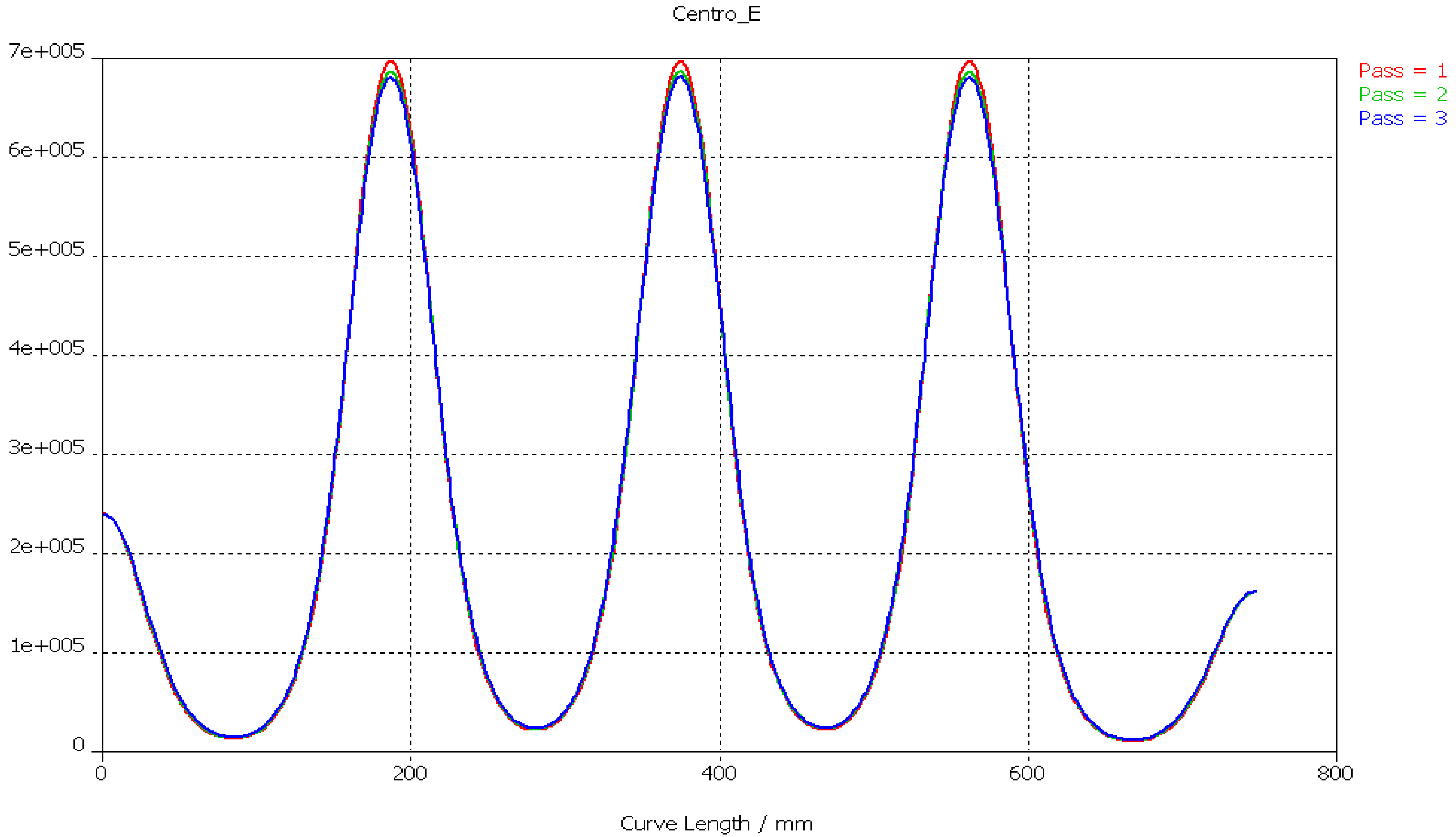
Electric field: tube inside, interpoles.



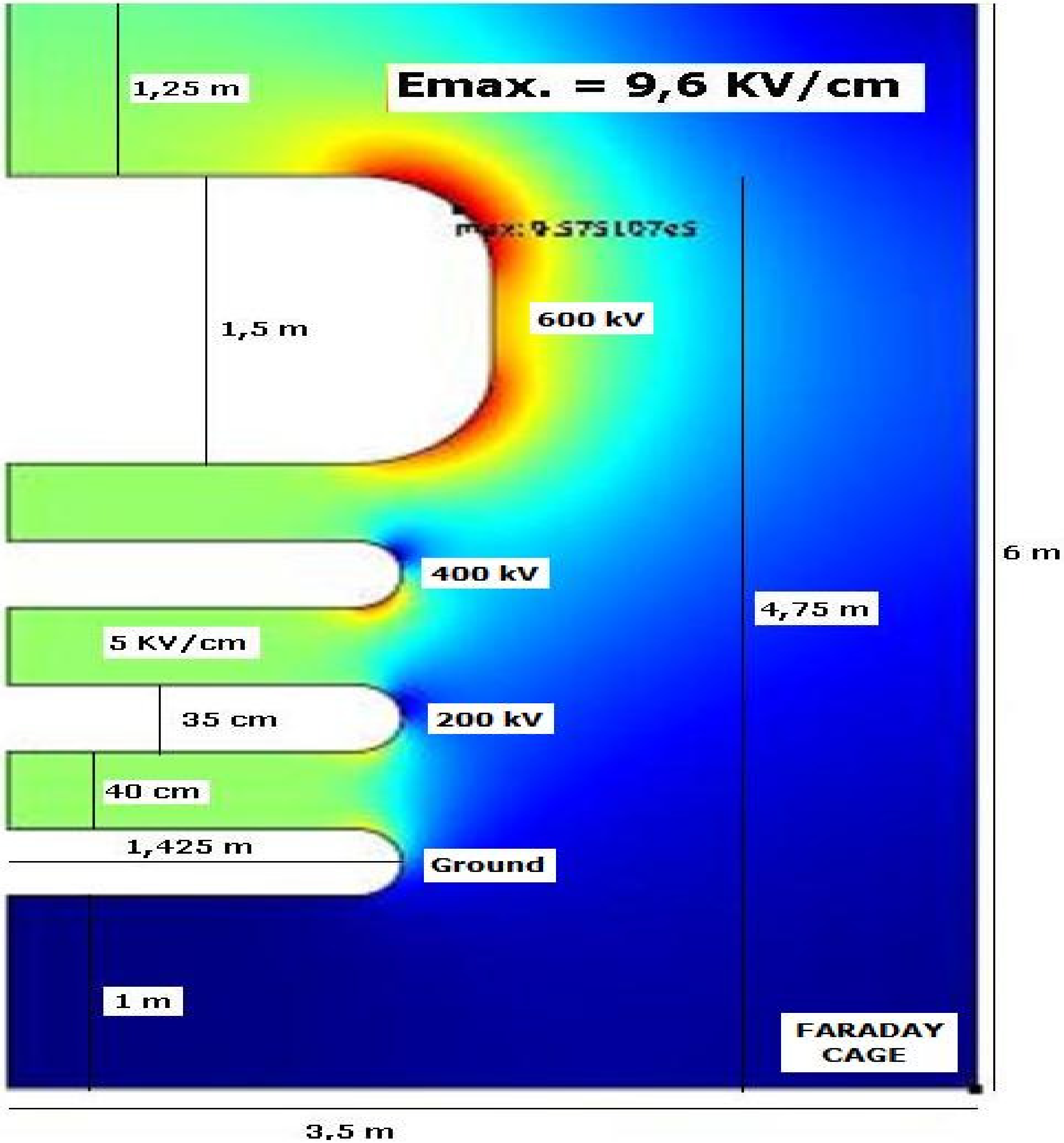
Quadrupole equipotent.: transverse cut



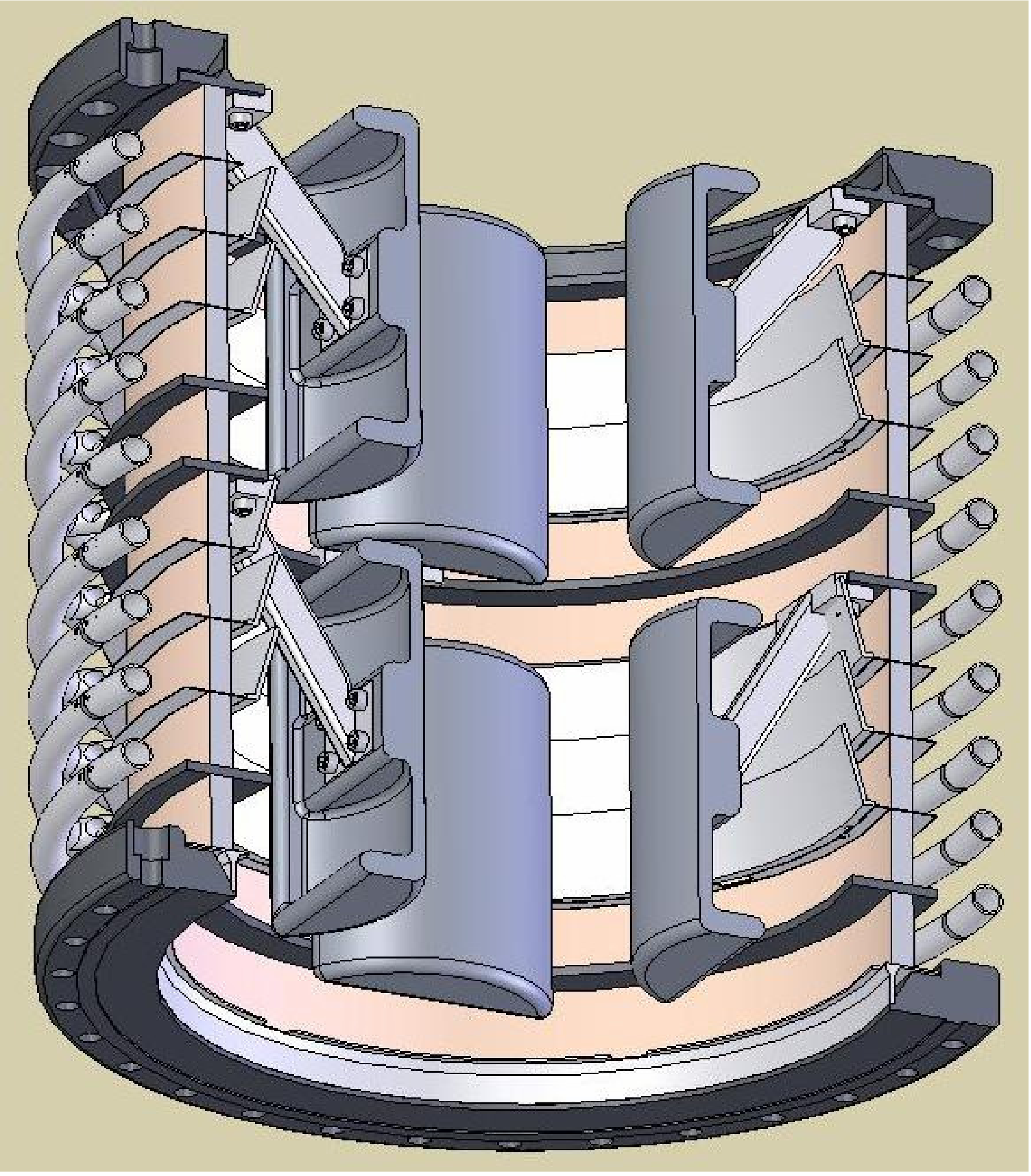
Electric field through the center of acceleration tube (Emax=7 kV/cm).

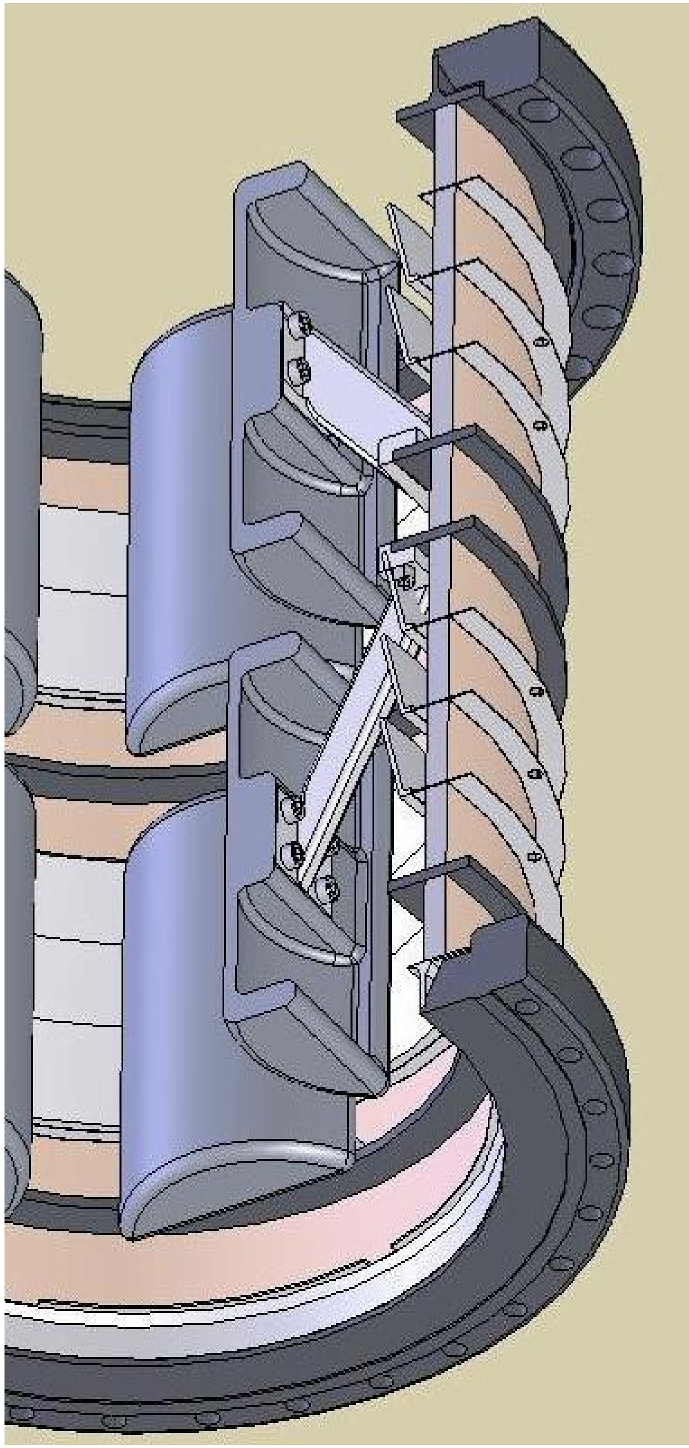
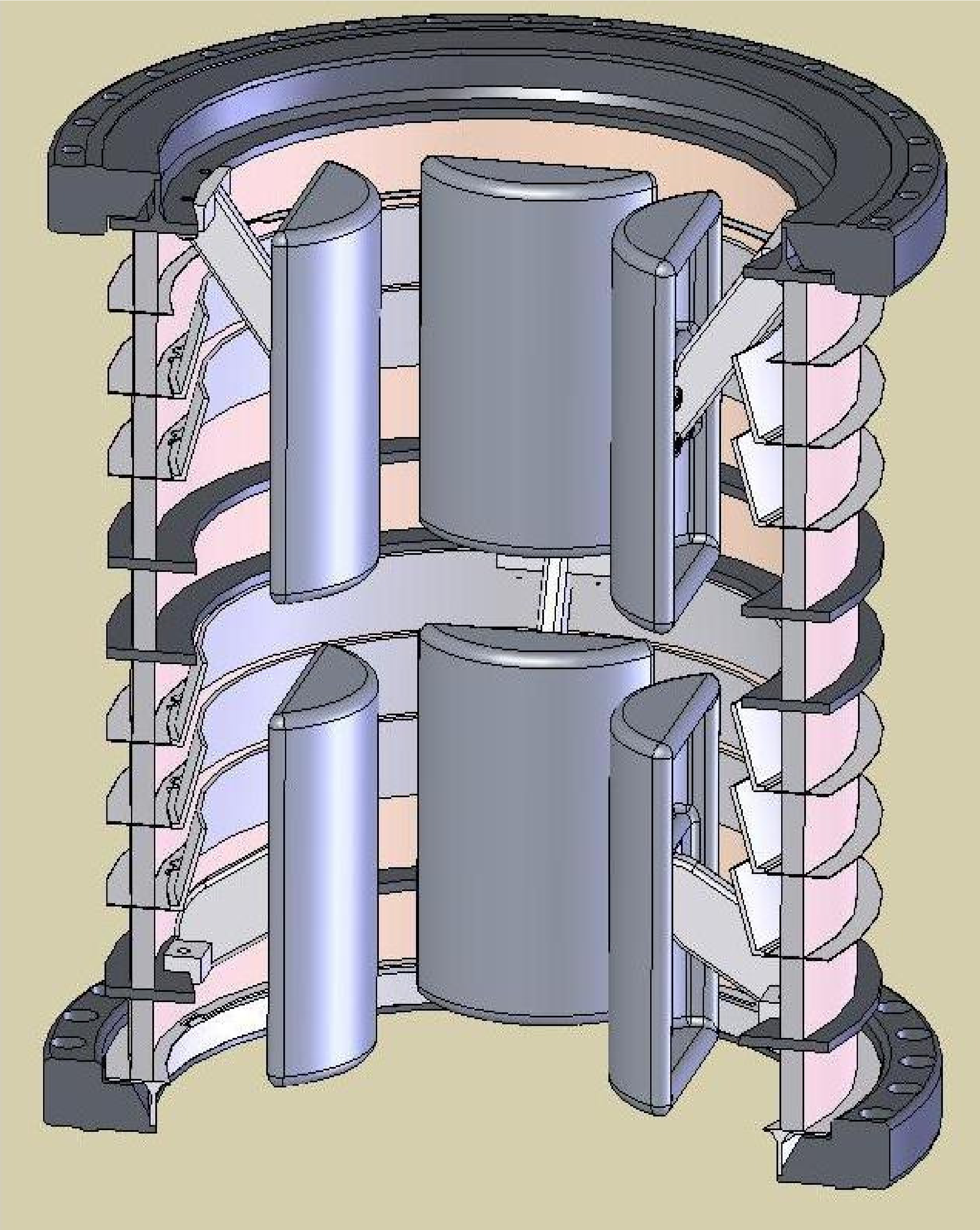


Electric field distribution for 600kV prototype.

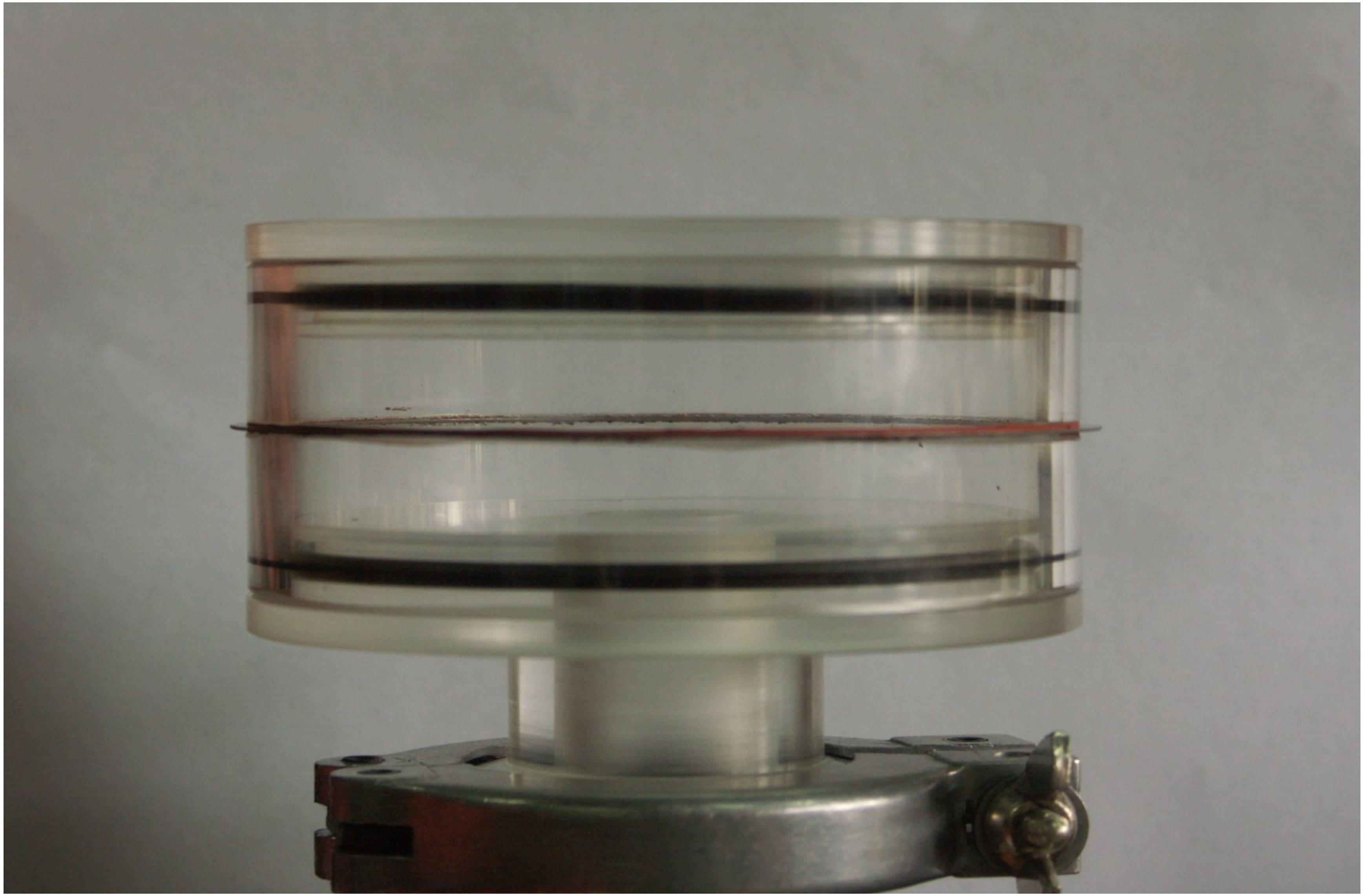


Accelerator tube design.

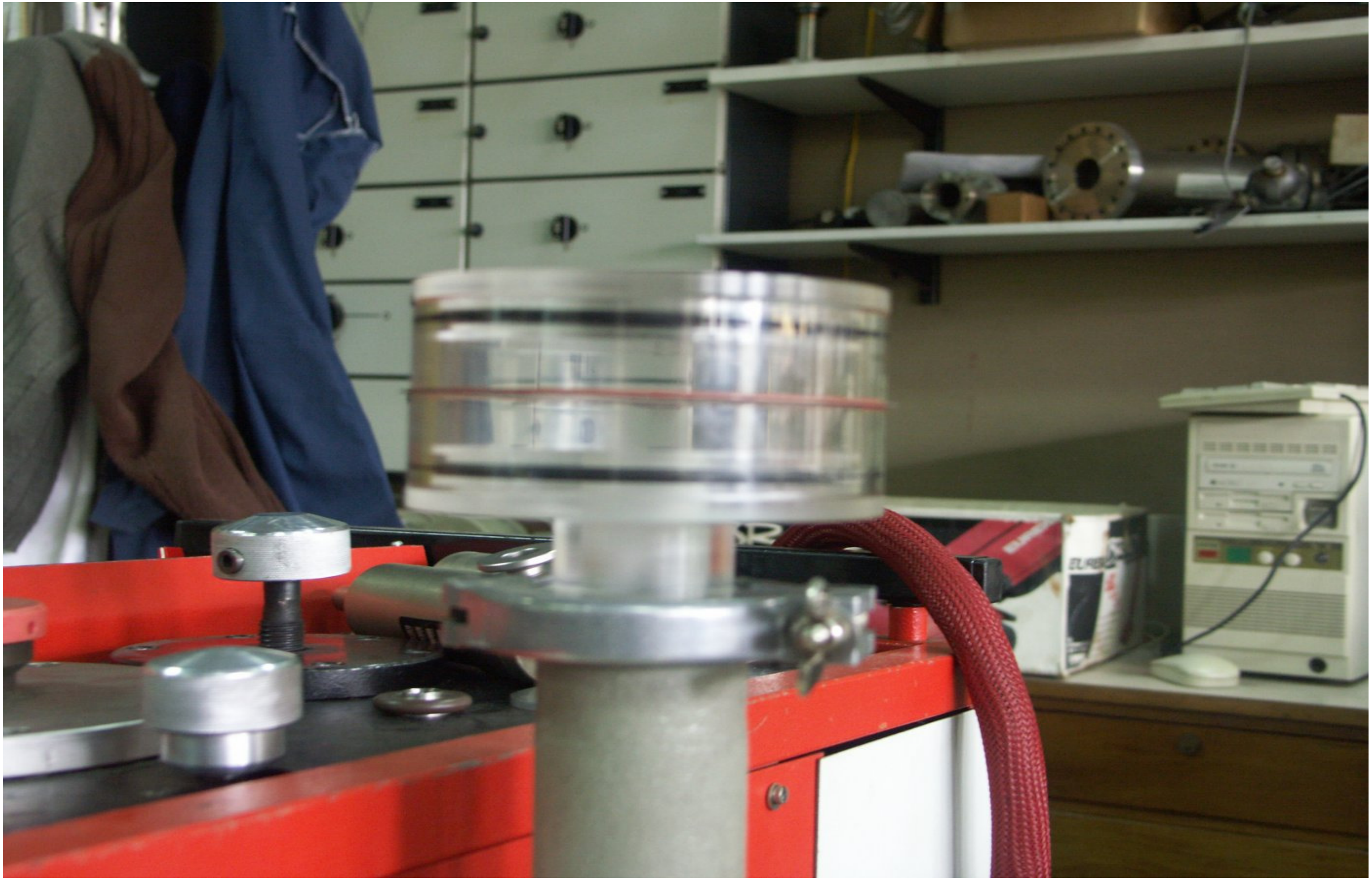


First tube prototype: glass and stainless steel.



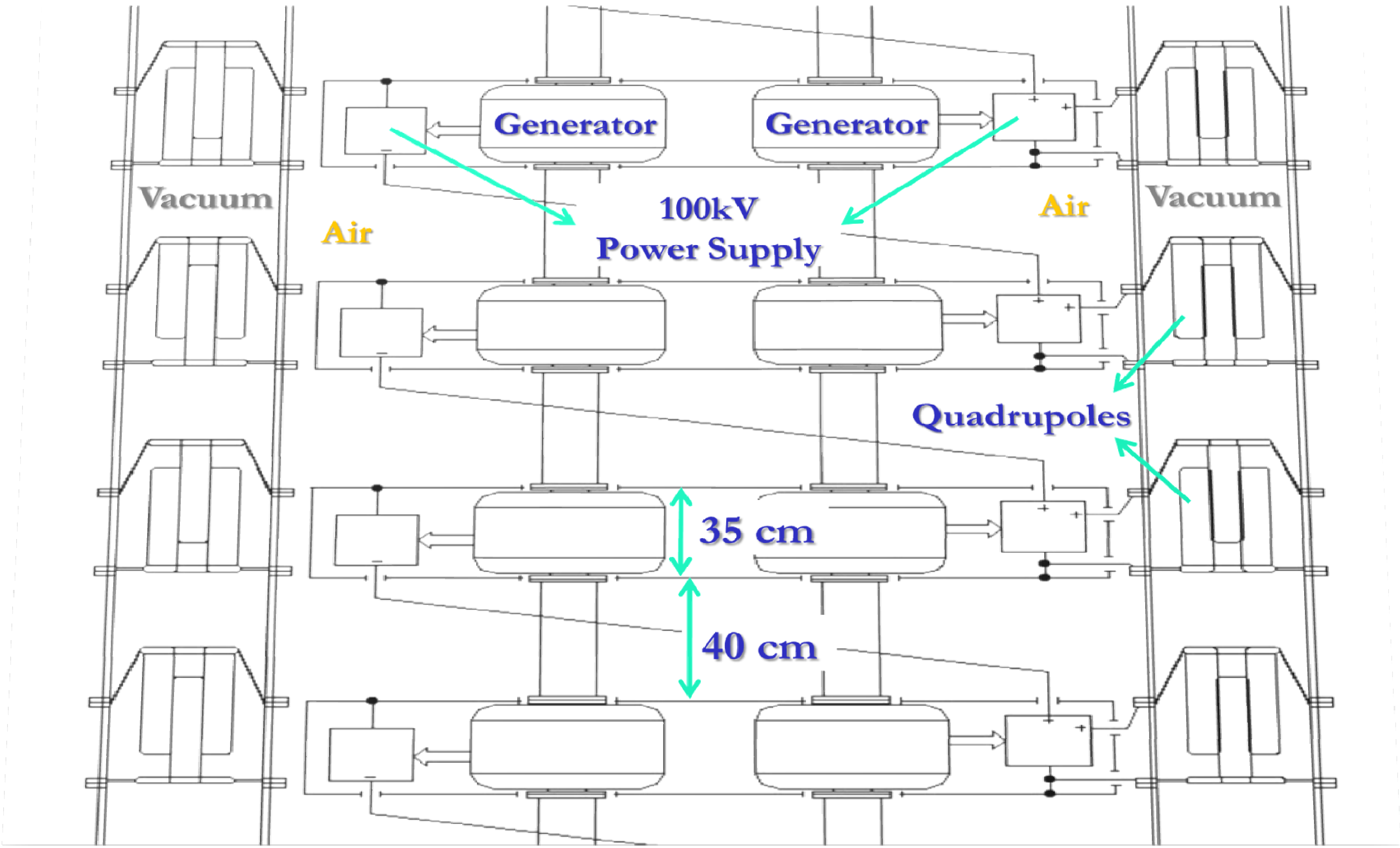
Tube at vacuum test stand.



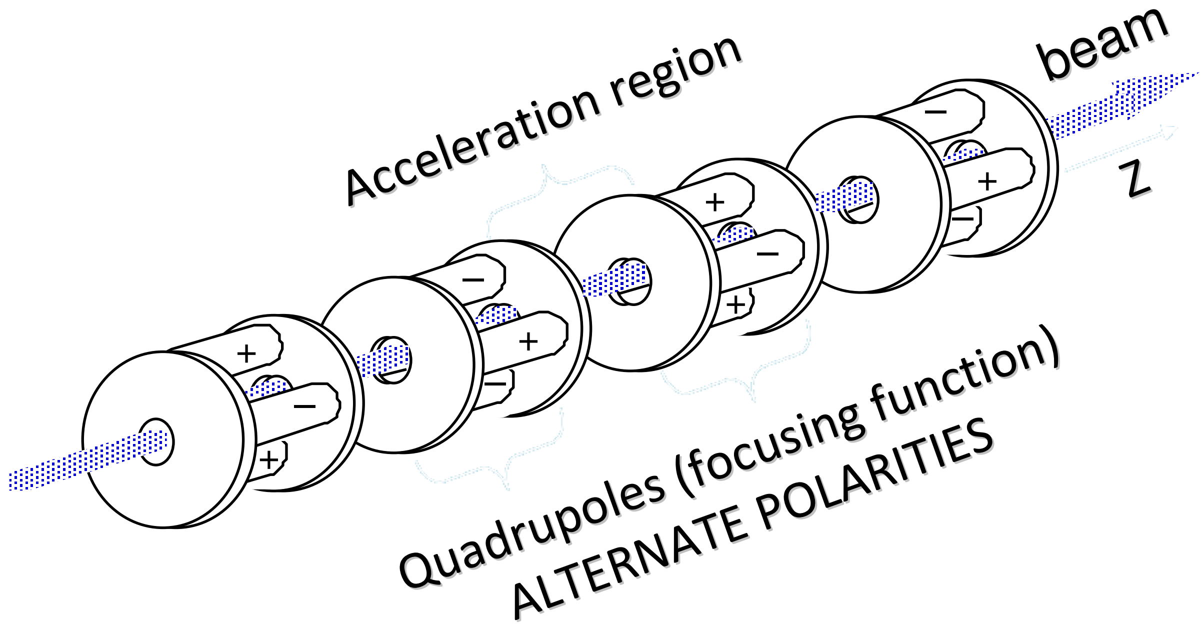
4. Ion Optics (high intensity beam transport):

P. Levinas, M. Obligado, V. Thatar Vento, E. Henestroza, et al.

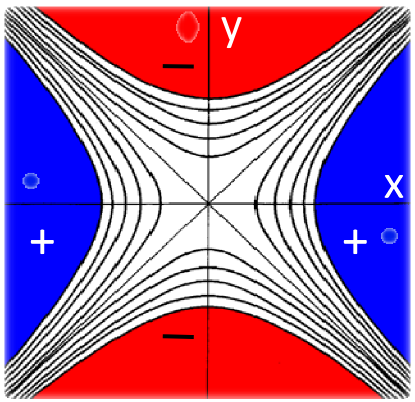
Modular structure



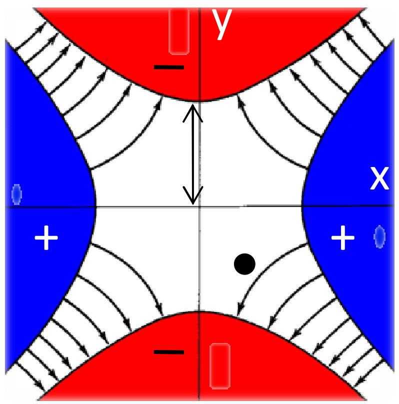
Acceleration and focusing column



EQUIPOTENTIALS



FIELD LINES



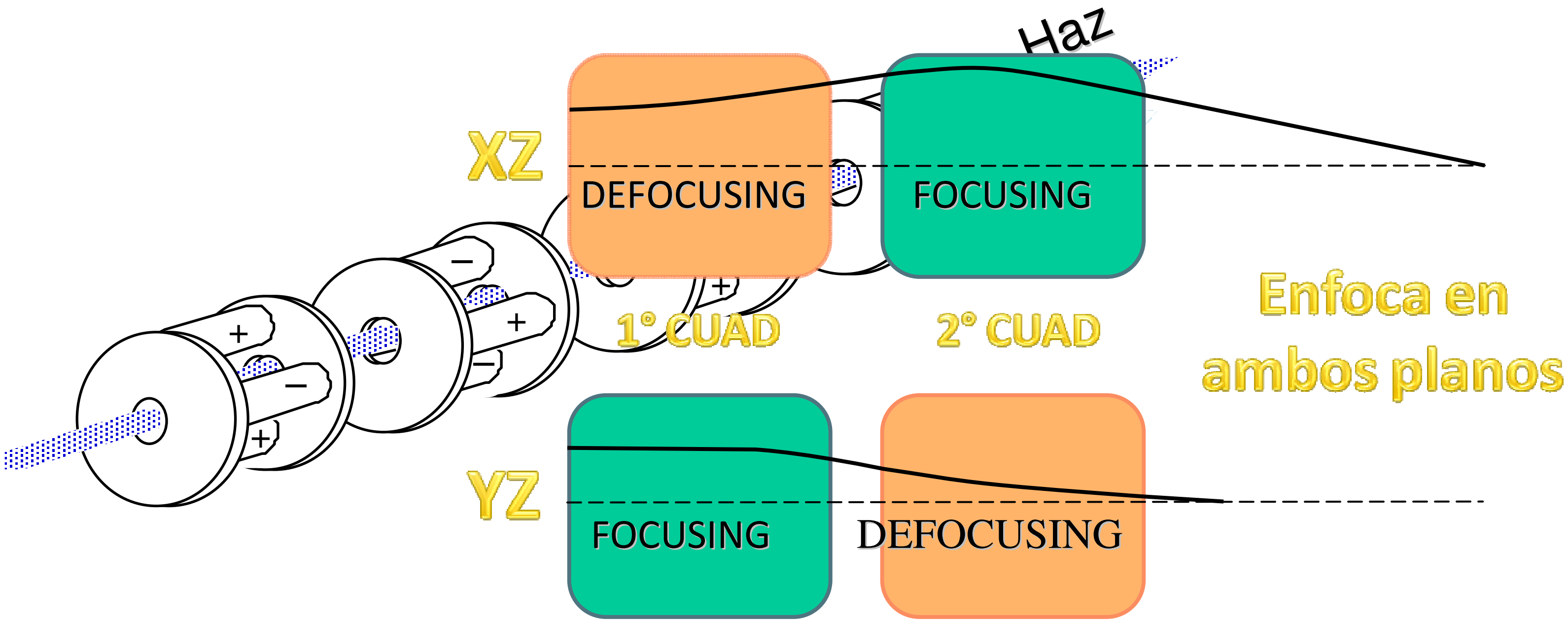
$$E_x = -\frac{q\Delta V_{cuad}\, x}{R^2}$$

Enfoca en XZ

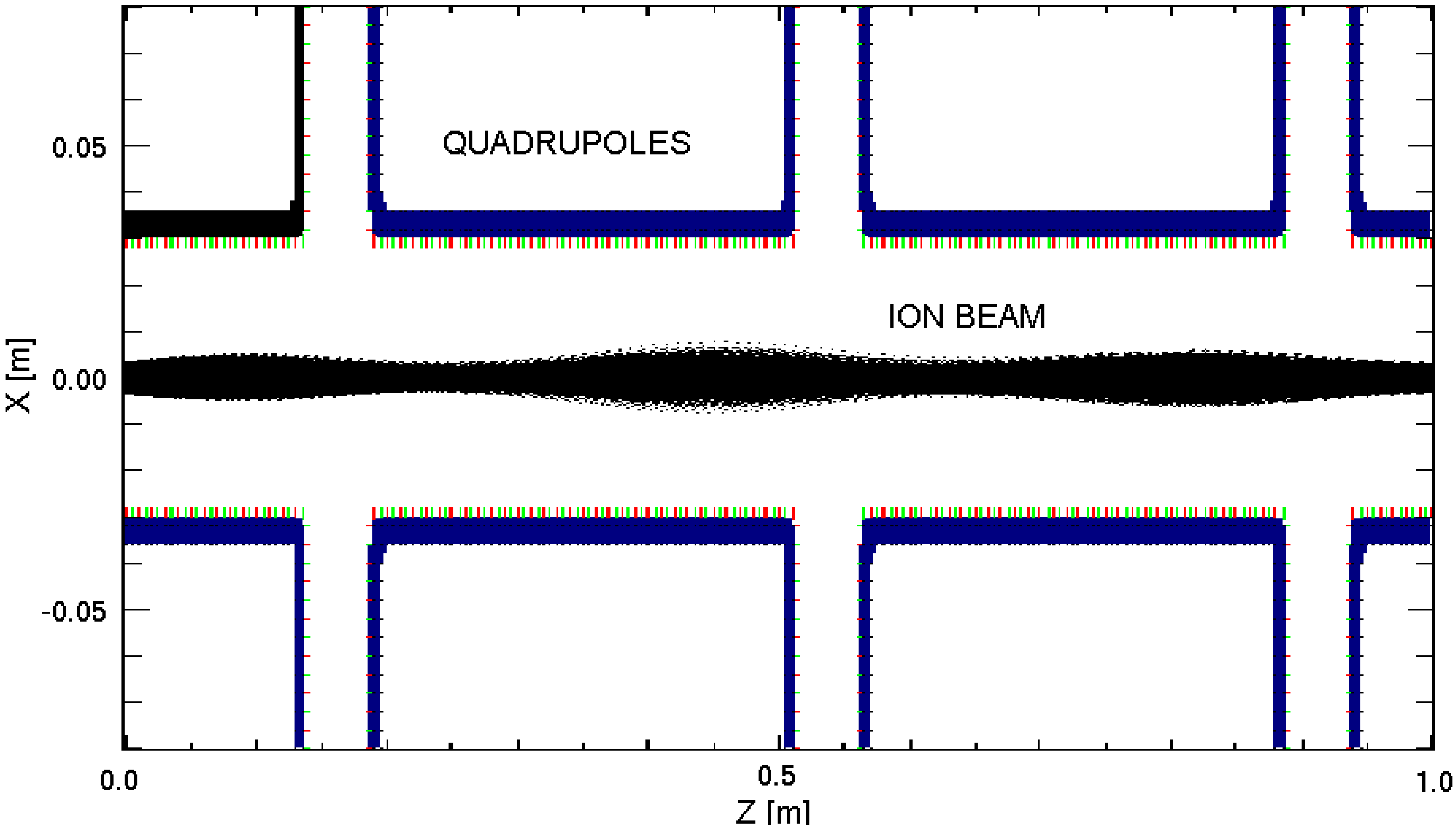
$$E_y = \frac{q\Delta V_{cuad}\, y}{R^2}$$

Desenfoca en YZ

Quadrupole cell



Proton beam

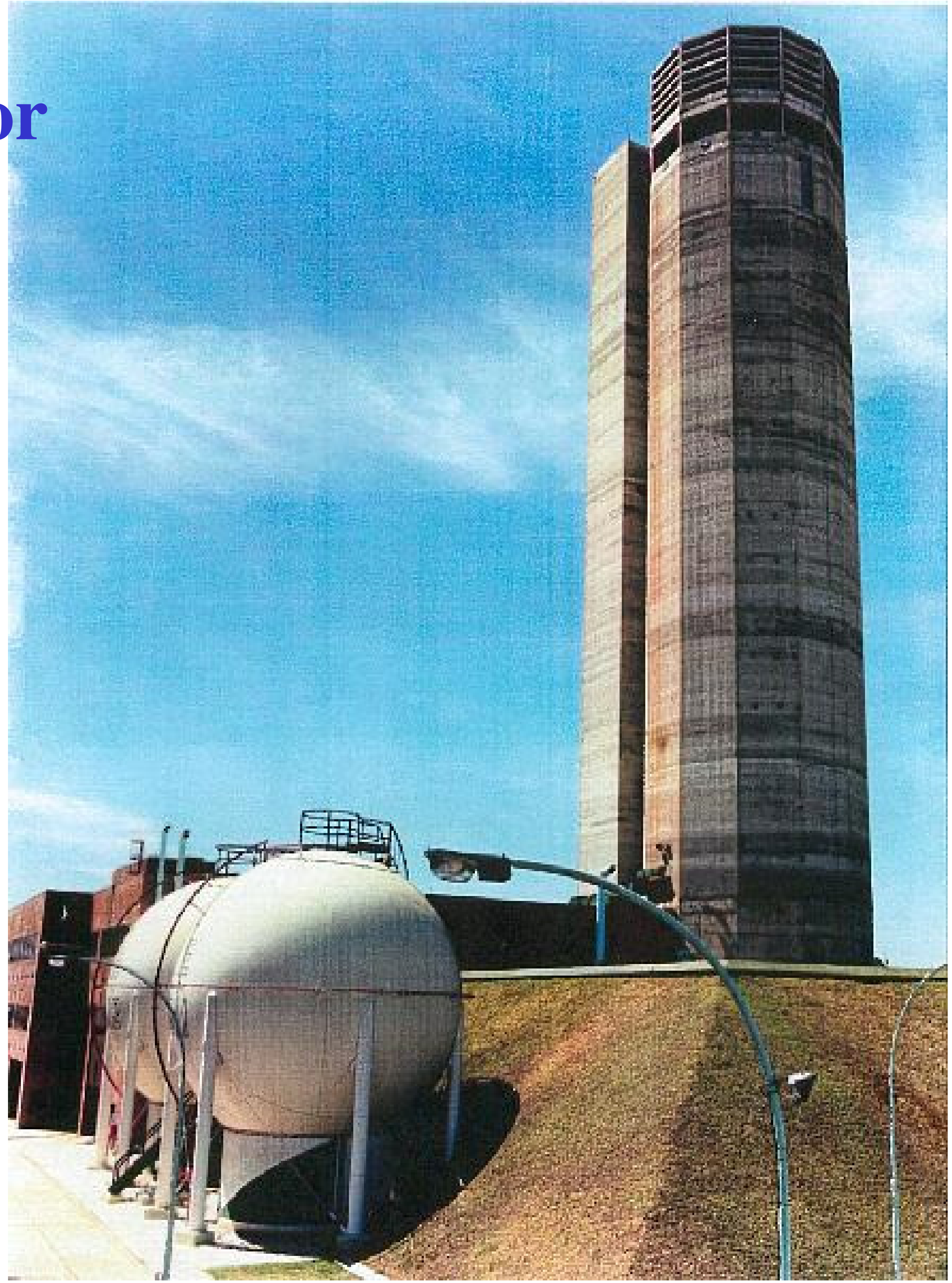


6. Strippers and thin targets:

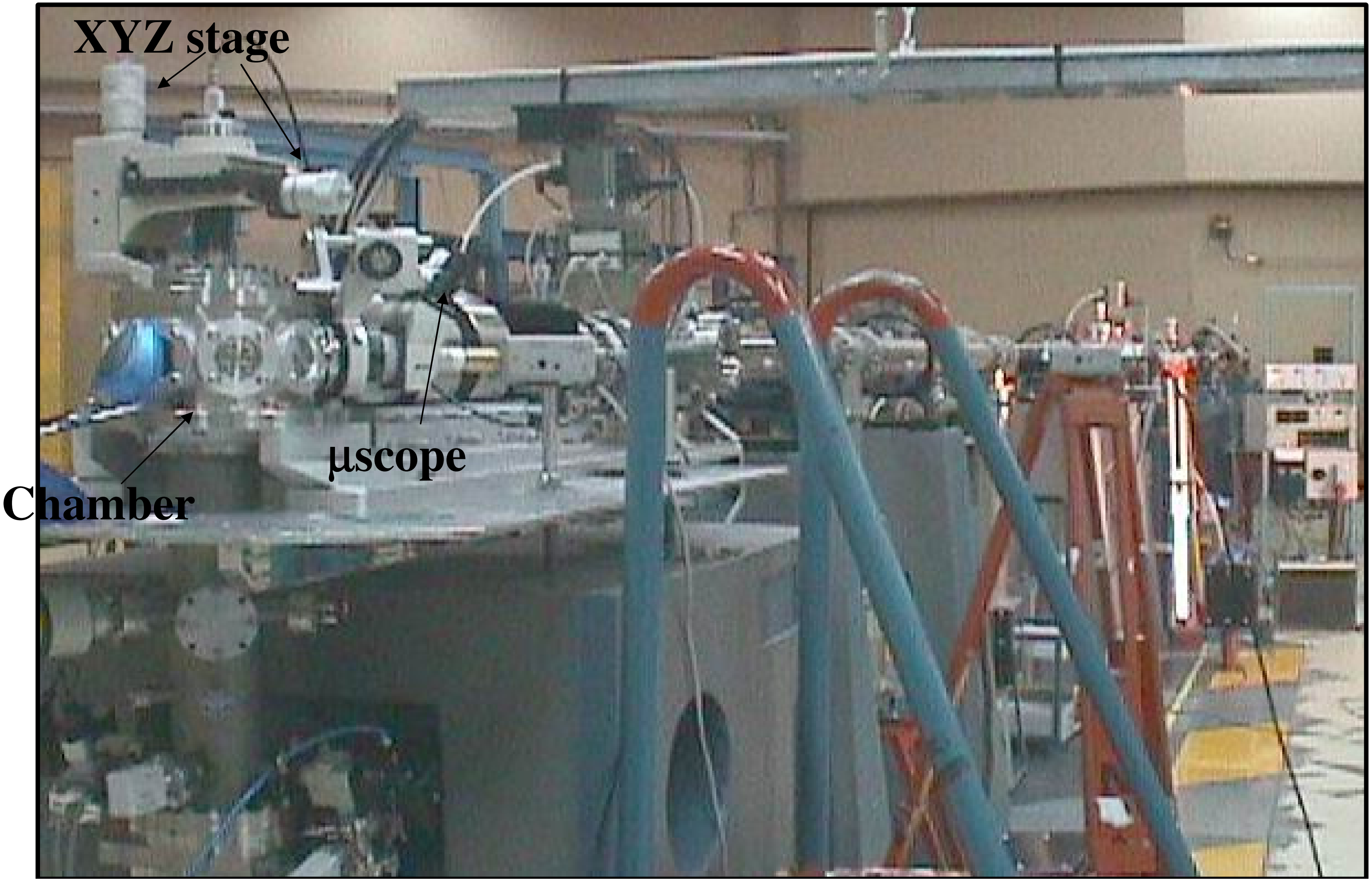
M.Repetto, M.Obligado, M.Debray, J. Davidson, M. Davidson, et al.

The Tandar Accelerator at Buenos Aires.
A 20 MV Pelletron.

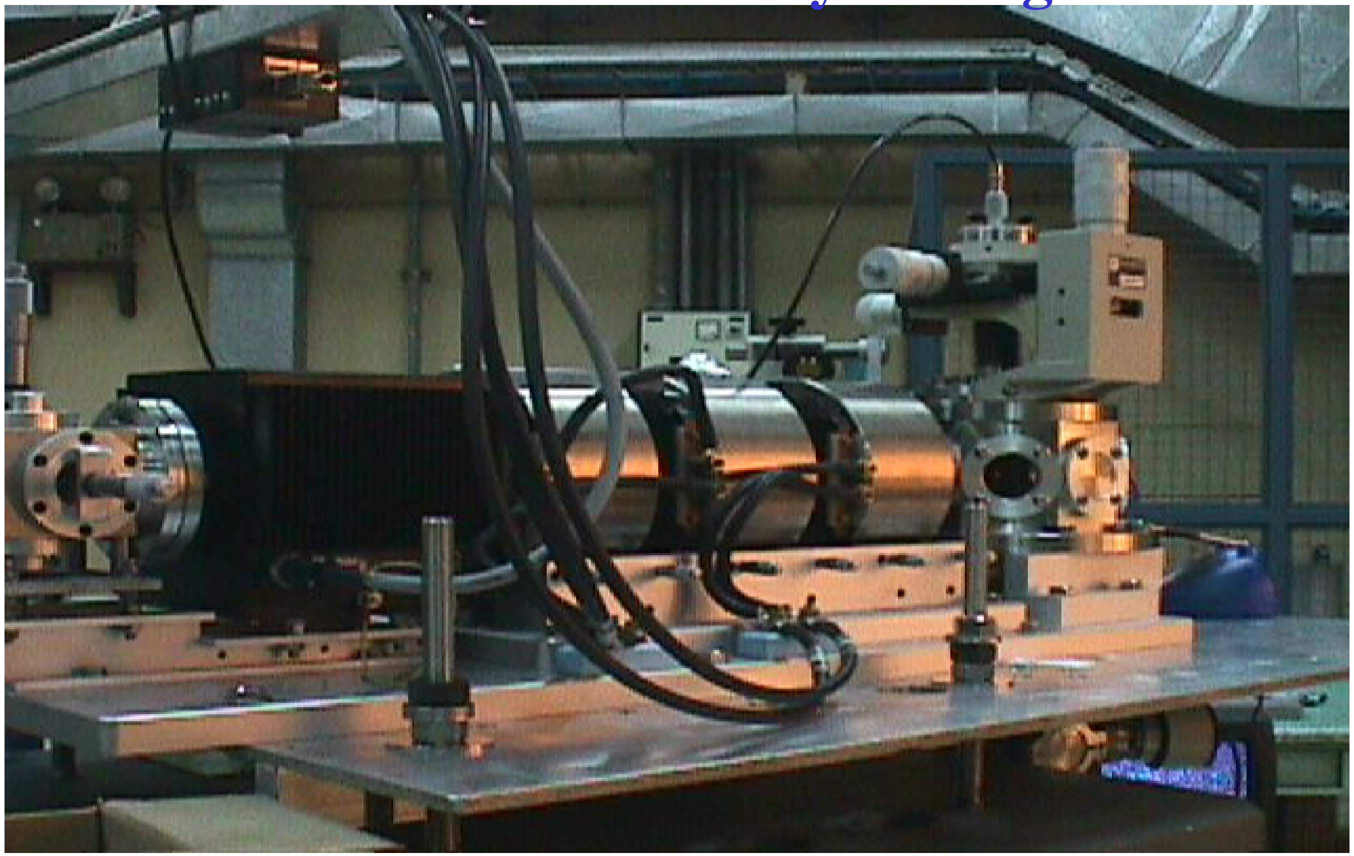
Device for testing and optimizing designs.
Proton currents up to 1 μA.

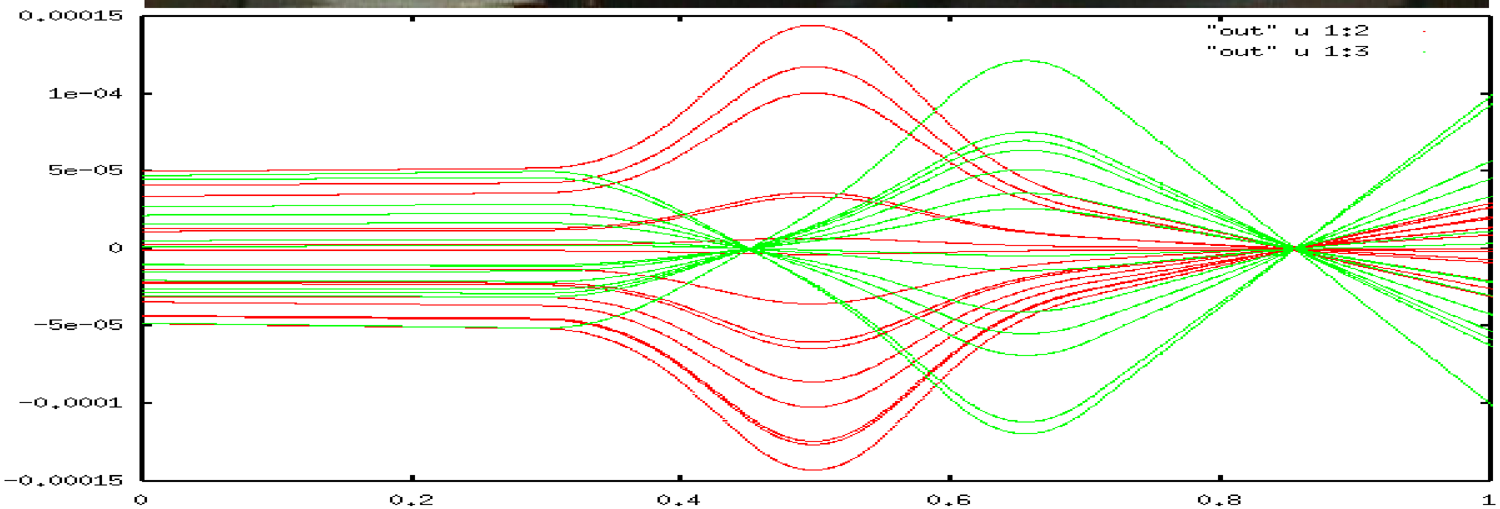


Heavy Ion Microprobe at the Tandar Accelerator Lab.



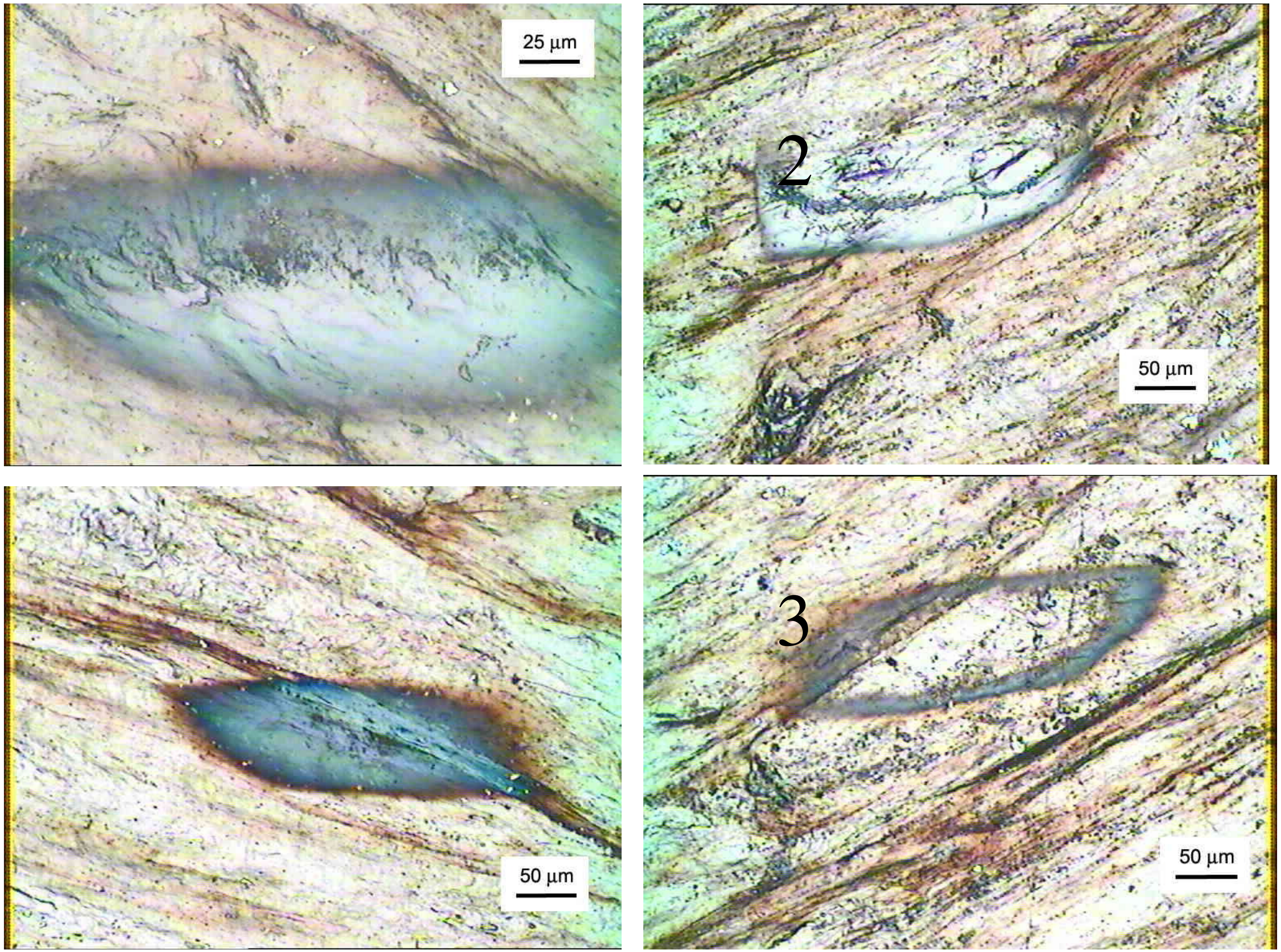
View of microbeam endstation and ray tracing in X and Y planes.





Irradiation results (45 MeV ^{16}O)

Beam entrance **Beam output**

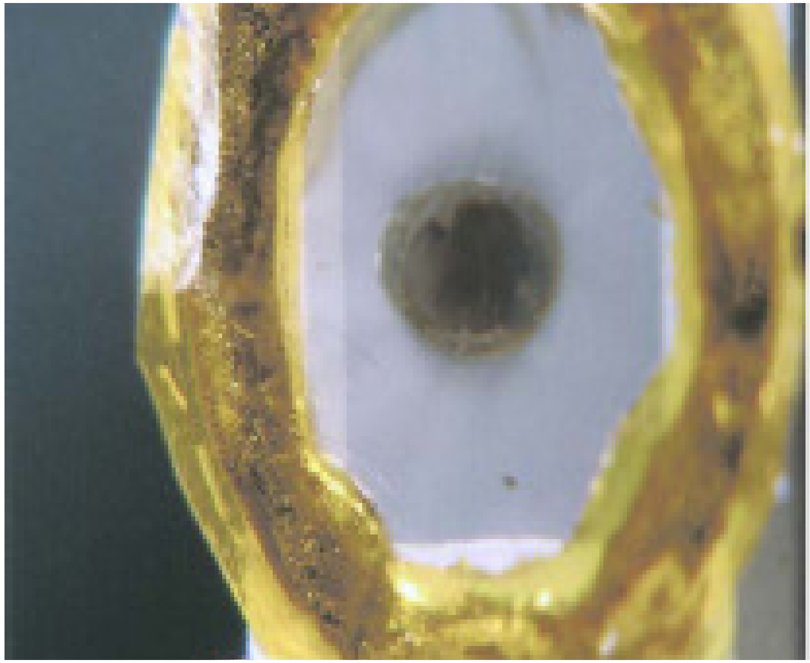


Lifetime of thin Be foils:

5±2 hs

Lifetime estimate: 1hs at least

Carbon strippers



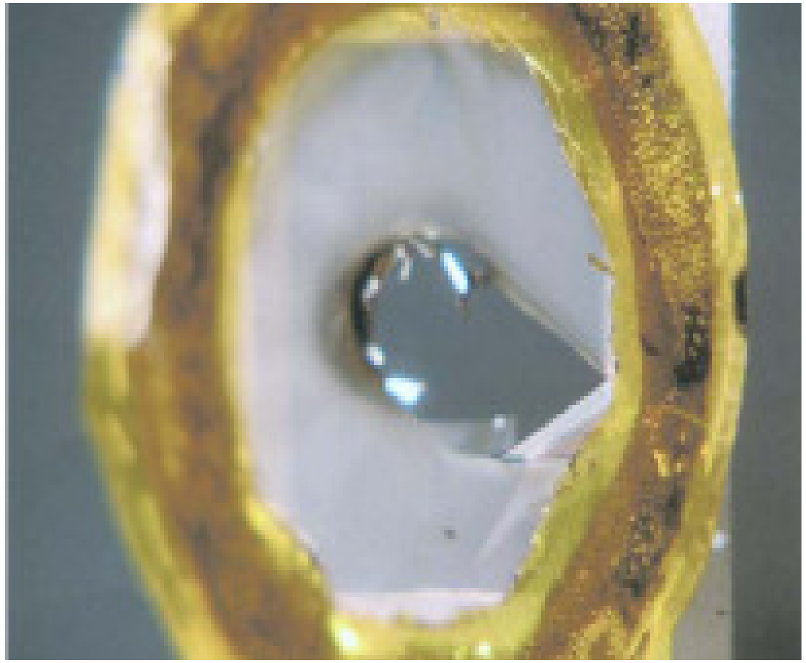
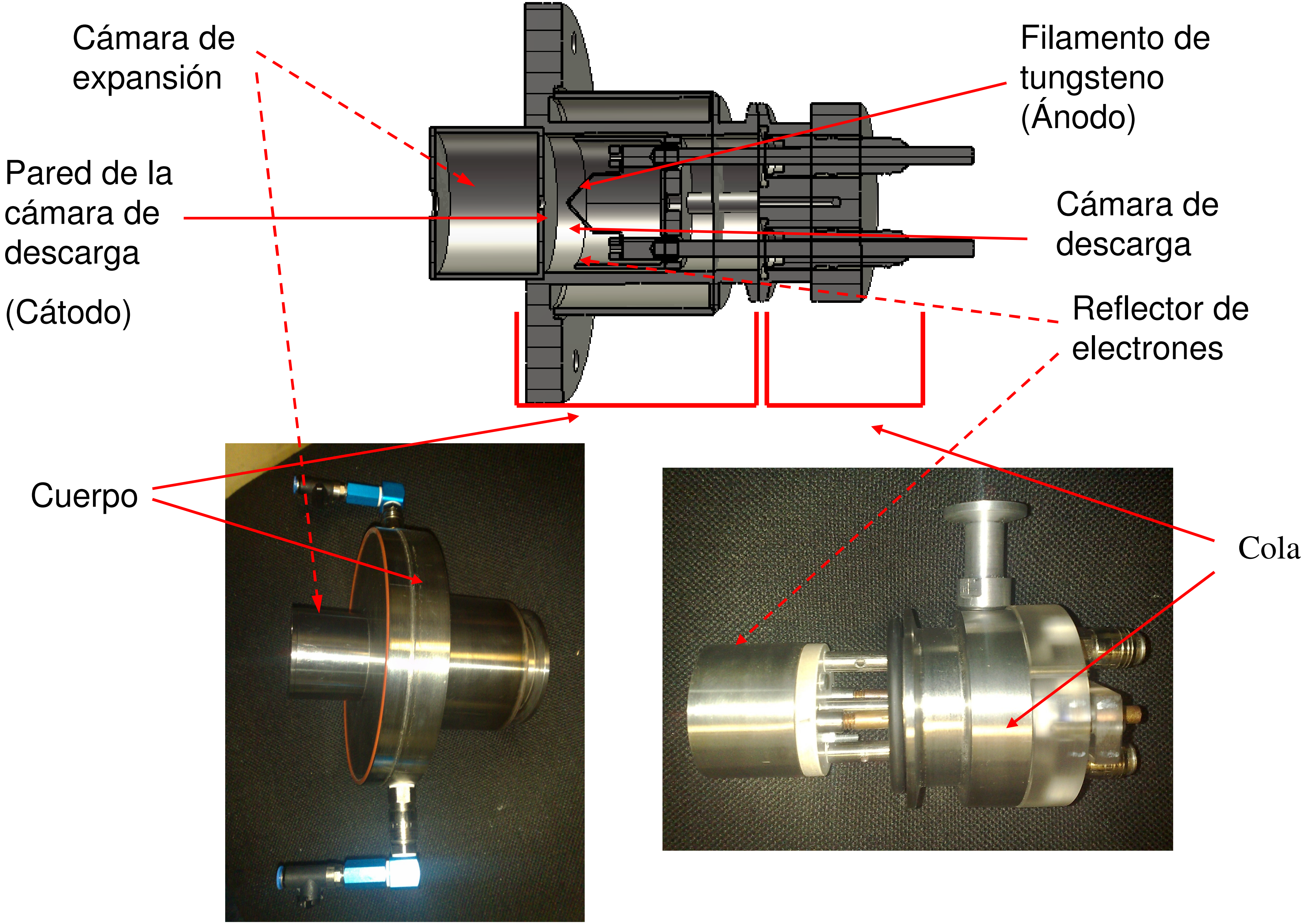


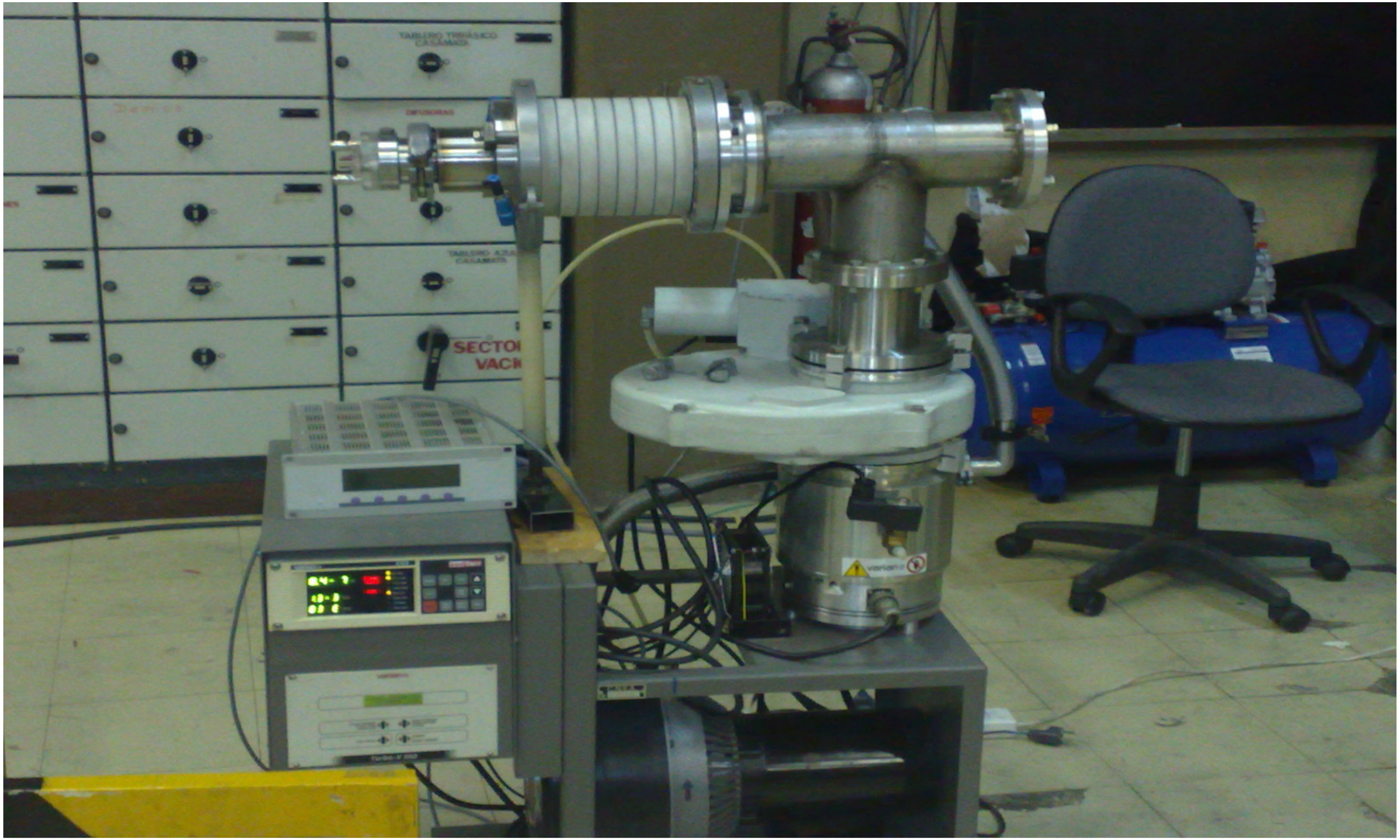
Image of ***stripper*****:** ***I. Sugai,_, Y. Takeda, M. Oyaizua, H. Kawakamia, Nucl. Inst. and Meth 200 16–23 (2006)***

7. Ion sources and injector: Duoplasmatron, multicusp.

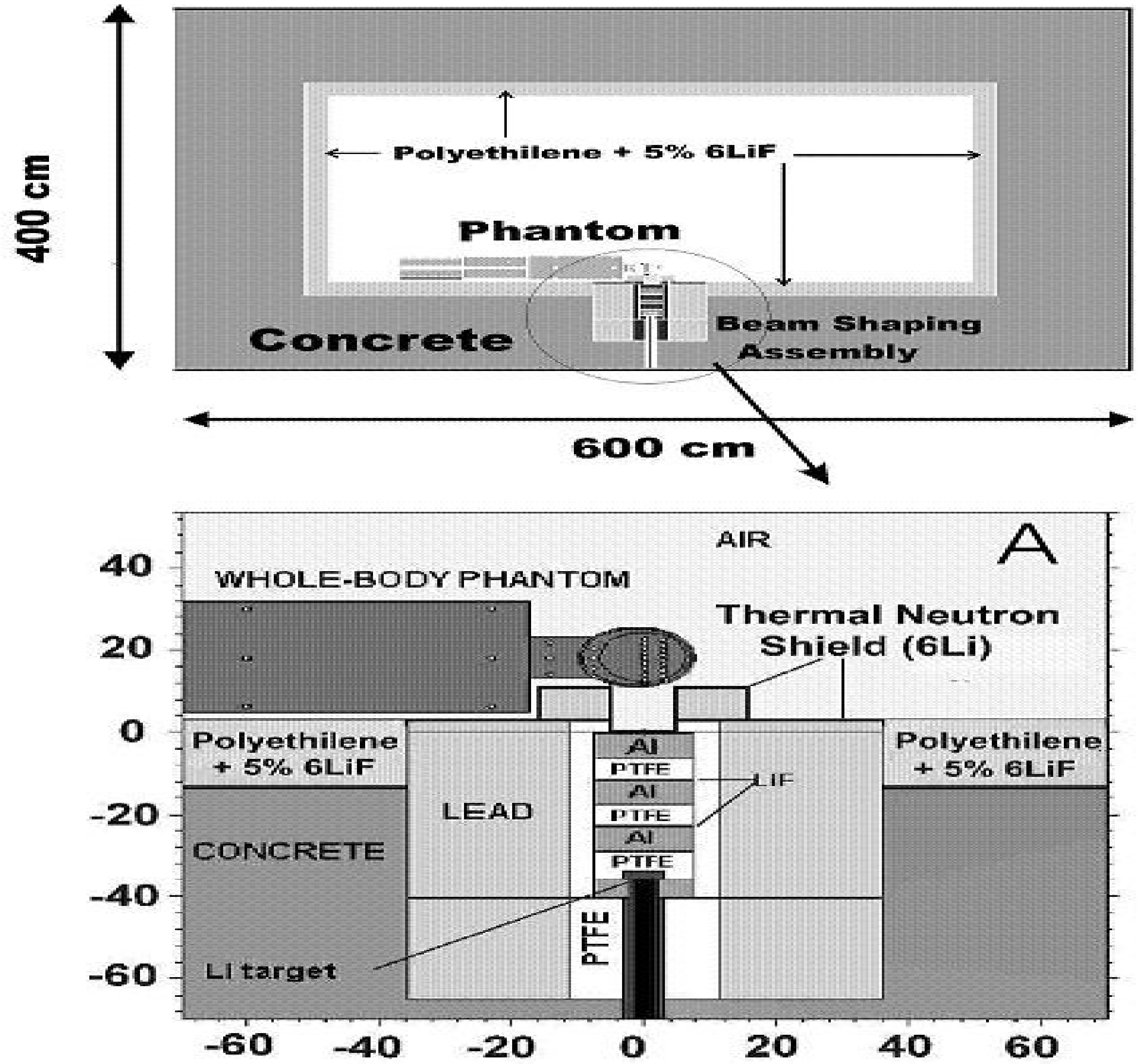
J. Bergueiro, H.Somacal, H.Huck, M.Igarzabal, JC.Suarez Sandin, A.Fernandez Salares, P. Levinas, M. Obligado, M.Debray, et al.


Cámara de expansión
Filamento de tungsteno (Ánodo)
Pared de la cámara de descarga
(Cátodo)
Cámara de descarga
Reflector de electrones
Cuerpo
Cola

Ion source prototype and preacceleration (teststand).

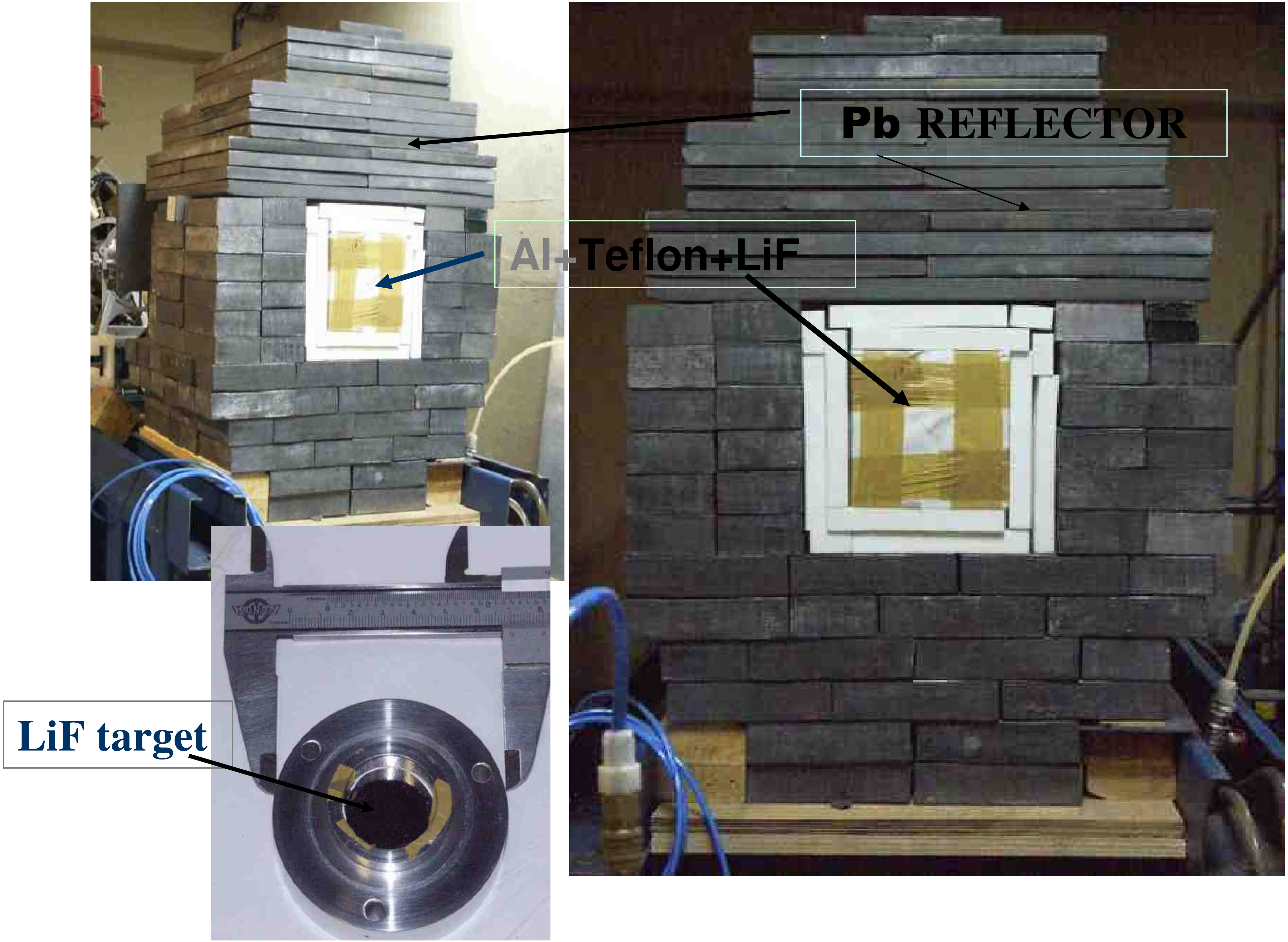


9.Neutron production target (neutronics) beam shaping assembly, patient irradiation room: A.A. Burlon, A.A.Valda, D. Minsky, S.Girola et al.



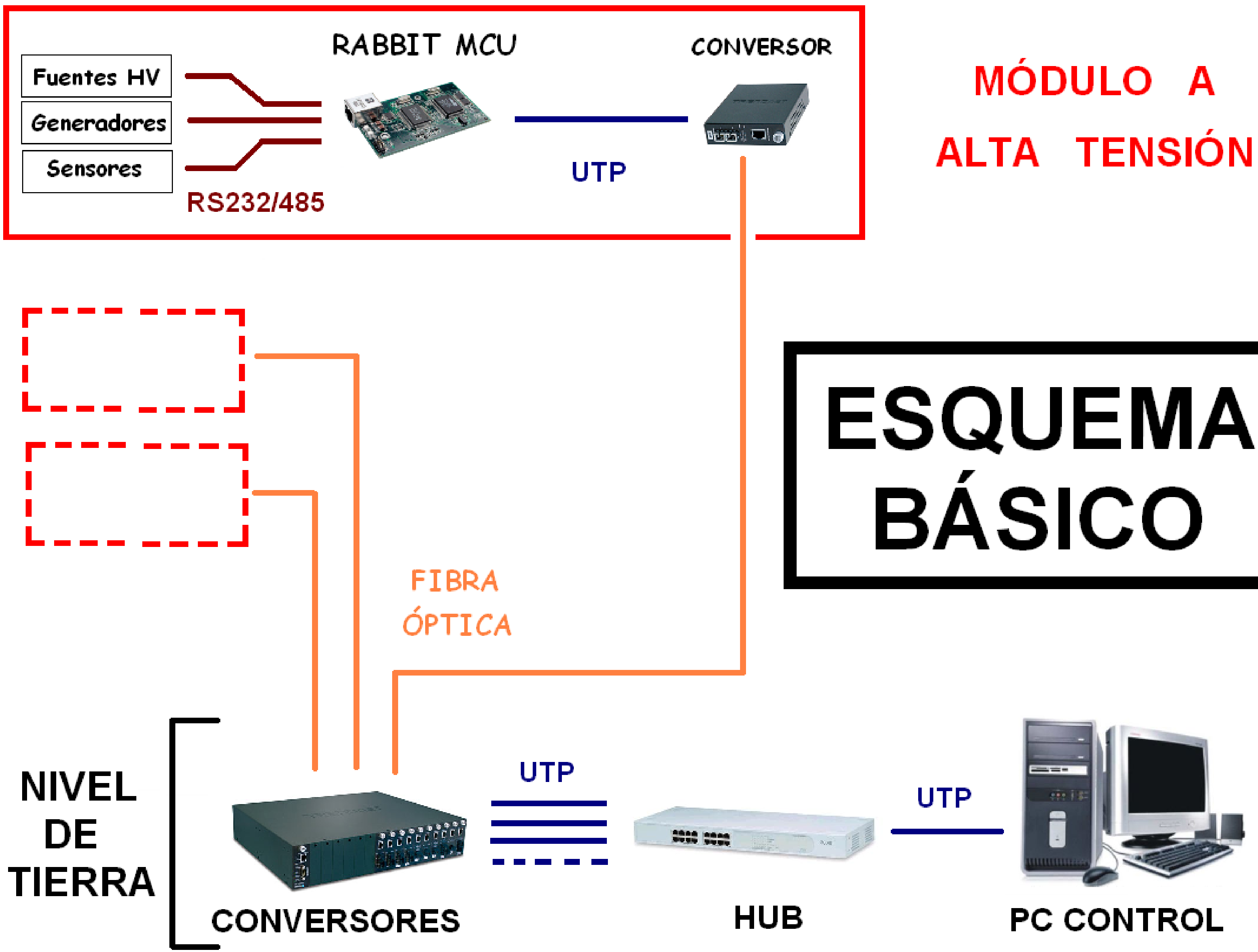
Upper view of the treatment room. The ceiling and the floor are also covered with slabs of polyethylene +5% ^{6}LiF. Detailed view of the BSA at bottom (Dimensions are in cm)

BSA at Tandar accelerator


Pb REFLECTOR
Al+Teflon+LiF
LiF target

10. Control systems.

H. DiPaolo, J.C. Ilardo.



MÓDULO A
ALTA TENSIÓN
Fuentes HV
Generadores
Sensores
RS232/485
RABBIT MCU
UTP
CONVERSOR
ESQUEMA
BÁSICO
FIBRA
ÓPTICA
NIVEL
DE
TIERRA
CONVERSORES
UTP
HUB
UTP
PC CONTROL

Conclusions/remarks

- **The development of the accelerator-based facility is progressing satisfactorily.**

- **A first prototype (600 kV) should be ready by the end of 2009 (provided the cash flow does appear).**

- **Likewise, the full TESQ should be ready by 2011.**

- **Platform for a broader program in accelerator technology.**