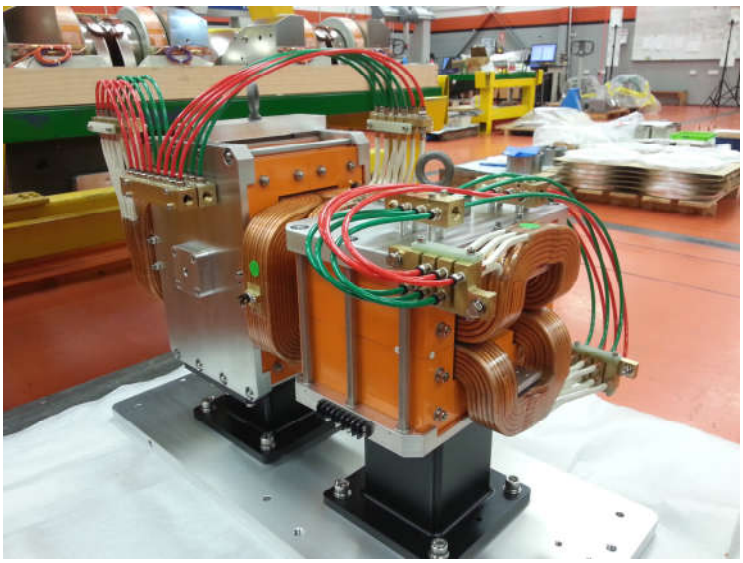
Datasheet **D2-650-IE**

Fast Magnet Set for Pencil Beam Scanning



Features

- Compact and low mass
- Suitable for fixed or gantry installations
- Low-inductance
- Fully laminated yokes
- Integrated coolant and current connections
- Flexible mounting options
- Over-temperature interlocks switches on each coil
- Supplied as a tested system complete with scan amplifiers.

Applications	• Proton therapy pencil beam scanning (step and shoot and continuous scanning modes)
Options	• Integrated Hall probes • Standard or rotated mounting • Customer survey and alignment features • Position adjustment system for fixed beamline applications

System Components

- D2-650 double dipole scan magnet assembly fitted to precision aluminium subplate
- Internal cooling connections
- Thermal interlock loop
- H20 and two MFP-30 Hall probes (optional)
- IECO MPS-400-350-PY two axis high current amplifier system and DC bus supply
- Independent redundant current transformers for coil current validation
- X32 amplifier interface unit and three M10 fiber-optic interfaced devices for control and monitoring, mounted internally in scan amplifier cabinet

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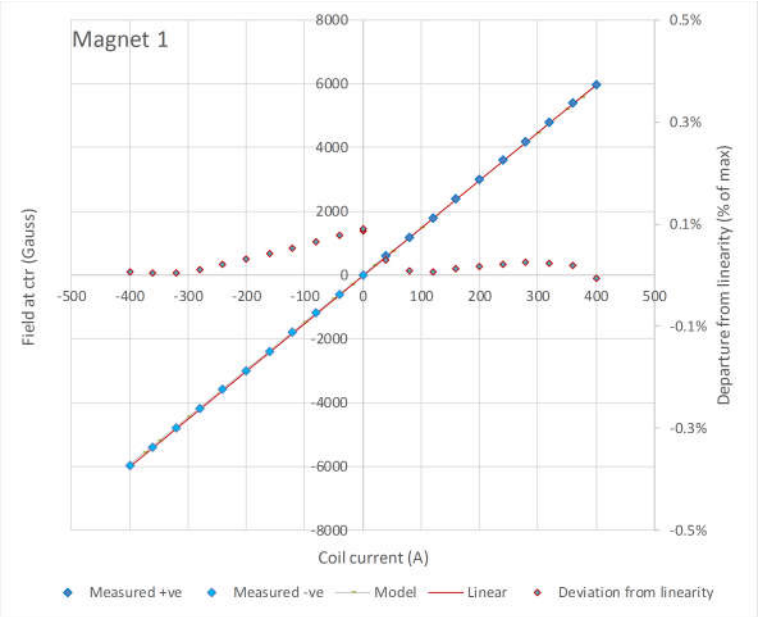
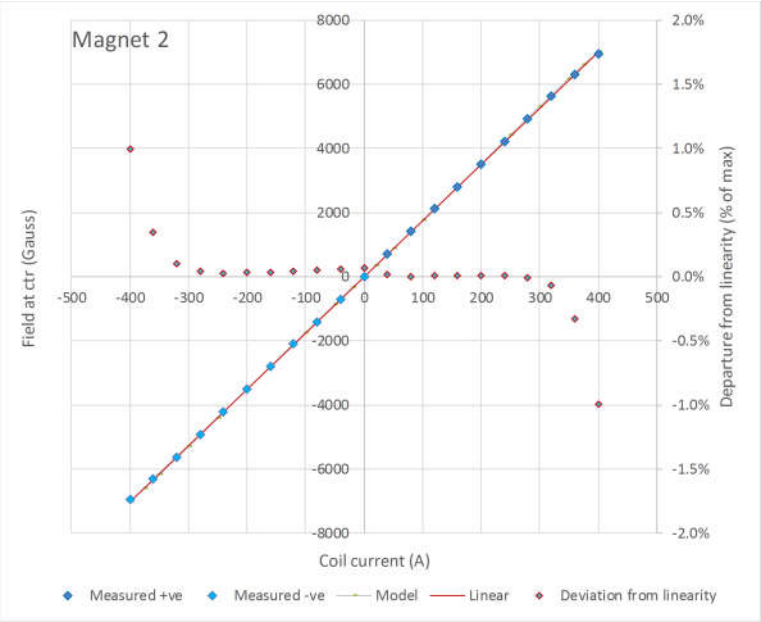
Specifications - Magnets

Axis 1 magnet	
Pole length	225 mm
Pole gap	60 mm
Coil current	400 A maximum continuous, thermally stable, coil ΔT < 25 C. for 20 C inlet
Self-inductance	4.15 mH at 0 A
Resistance	44 mΩ at 30 C
Central gap field	0.599 T at 400 A
Field integral	0.17 Tm on axis at 400 A
Linearity	Gap field B-I curve linear to 0.1% of full field over +/- 400A
Deflection	4.58 degrees (80 mrad) for 230 MeV protons at 400 A
Slewing rate	80 A msec-1 for 350 V amplifier compliance 0.92 degr msec-1 for 230 MeV protons 1.17 degr msec-1 for 150 MeV protons 1.43 degr msec-1 for 100 MeV protons
Yoke material	Thyssen Krupp 1200-100 Si steel 1.0 mm laminations or equivalent
Coil material	OFHC copper hollow bore conductor, 3.63 mm diameter bore, 31.3 mm2 copper section.
Magnet weight	210 kg (485 lb)
Cooling	3.5 l min-1 (0.9 US gpm) at 0.8 bar (12.5 psi), six parallel circuits.
Coolant velocity	0.94 m s-1 (3.1 fps) in conductors



Specifications—magnets (continued)

Axis 2 magnet	
Pole length	275 mm
Pole gap	72 mm to 110 mm (longitudinal taper)
Coil current	400 A maximum continuous, thermally stable, coil ΔT < 25 C. for 20 C inlet
Self-inductance	15.0 mH at 0 A
Resistance	88 mΩ at 30 C
Average gap field	0.70 T at 400 A (middle of taper)
Peak gap field	0.80 T at 400 A
Field integral	0.246 Tm on axis at 400 A
Linearity	Gap field B-I curve linear to <= 1% of full field over +/- 400A
Deflection	6.1 degrees (105 mrad) for 230 MeV protons at 400 A
Slewing rate	22 A msec-1 for 350 V amplifier compliance 0.34 degr msec-1 for 230 MeV protons 0.42 degr msec-1 for 150 MeV protons 0.52 degr msec-1 for 100 MeV protons
Yoke material	Thyssen Krupp 1200-100 Si steel 1.0 mm laminations or equivalent
Coil material	OFHC copper hollow bore conductor, 3.63 mm diameter bore, 31.3 mm2 copper section.
Magnet weight	240 kg (530 lb)
Cooling	8.0 l min-1 (2.1 US gpm) at 3.3 bar (50 psi) pressure drop
Coolant velocity	1.6 m s-1 (5.3 fps) in conductors



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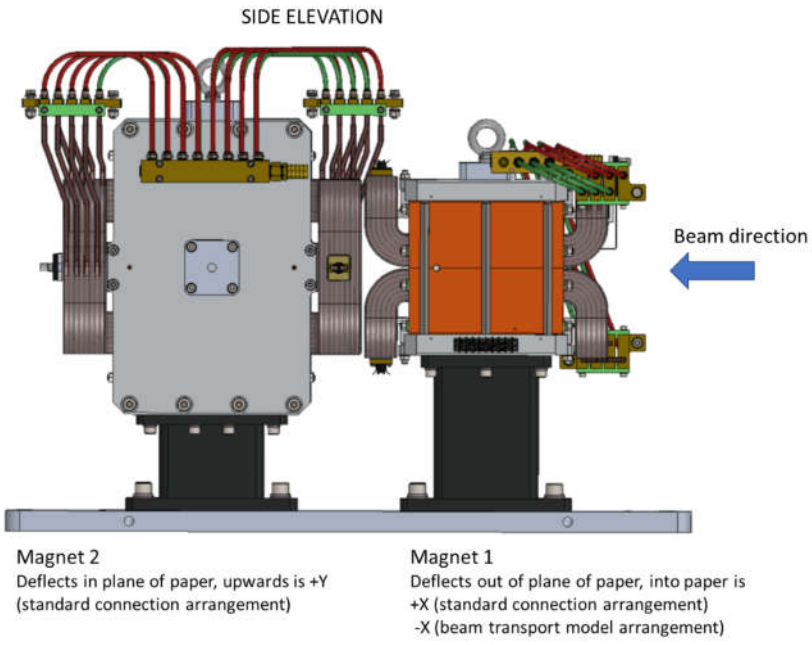
Specifications—magnet assembly

Total weight	450 kg including mounting plate and fixtures
Magnet length	650 mm entrance pole face to exit face
Total length	1000 mm base plate length (see figures)
Conductor connections	M8 bolts in clear through holes. Recommended lugs 2x Panduit LCA-0-56-X.
Current leads	Recommended cable: paired 2/0 AWG (standard welding cable).
Coolant connections	Individual for each magnet. 1/2" NPT threaded holes for flow and return, barb hose adaptor for 3/4" ID hose fitted as standard. Other fittings available on request.
Coolant input	Water, clean and free of dissolved solids, 10 to 25 C, 12.0 l min-1 (3.2 US gpm) at 3.3 bar (50 psi) drop to permit DC operation at 400 A, both axes. Flow balancing required between magnet 1 and magnet 2
Wetted materials	OFHC copper 2.8 m^2; brass 0.02 m^2, stainless steel 0.02m^2, polyethylene 0.24 m^2.
Interlock circuit connections	Terminal strip to suit M3 ring lugs. One thermal switch per coil (total four) connected in series. 70 C operating temperature.
Survey features	Mounting pattern on target on base plate to customer specification. Precision mounting holes on yoke clamp plates for optical survey targets.
Operating environment	Clean, 10 to 35 C (15 to 25 C recommended , < 70% humidity, non-condensing, vibration < 0.1 g all axes (1 to 50 Hz). Operable in any orientation subject to adequate mounting on a gantry.
Shipping and storage environment	5 to 50 C, < 80% humidity, non-condensing, vibration < 0.5 g all axes, 1 to 50 Hz



Datasheet D2-650-IE

Specifications - amplifier system

Configuration	Two channel amplifier system, master-slave-slave on each channel. Six-way interleaved switching for low ripple. Full four-quadrant operation, current-controlled. Housed in two cabinets; DC bus supply and amplifier system respectively. Air-cooled.
Current	-400 A to +400A continuous DC rating each channel (tested 15 minutes). Both channels can drive 400A continuous into D2-650 magnet loads.
Compliance voltage	>= 350 V, both channels
Current ripple	< 10 mA measured with D2-650 magnet loads.
Current settling time	< 1 msec to within +/-200 mA after any full slew rate limited ramp when driving D2-650 magnet loads.
Current leads	Recommended cable: flexible multistrand copper cable, >= 120 mm^2 section , >= 600V insulation. Example: doubled 2/0 AWG (standard welding cable).
Conductor connections	M8 studs, two per terminal. Recommended cable lugs 2 x M8 Panduit LCA2/0-56-X .
Line input	480 VAC / 60Hz or 400 VAC / 50 Hz 3ph LLLE, internally fused 100A per phase. 60 A per phase typical at 400 A into both D2-650 magnet loads. Line input filter included. Power factor correction included.
Control and monitoring	Current setpoint 50 A output per 1 V command. Current and voltage monitoring, 50 A per V and 50 V per V nominal. Additional redundant current monitoring provided by independent current transformers. Digital enable and reset control lines. Amplifier status readback lines. All signals connected are to X32 and M10 embedded controls. Amplifier is controlled remotely via fiber optic link to a loop controller.
Interlocks	Three interlock continuity loops: - Amplifier cabinet door opening. - User interlock to disconnect line input (used for magnet thermal switches) - User interlock to disable amplifiers (available). Reset must be asserted before amplifier will re-start. Internal interlocks for device temperature, overvoltage, overcurrent.

Specifications - amplifier system (continued)

Amplifier cabinet	h: 1945 mm (including castors and cable glands), 1800 mm without castors w: 600 mm d: 970 mm 425 kg,
Power supply cabinet	h: 1945 mm (including castors and cable glands), 1800 mm without castors w: 600 mm d: 970 mm 585 kg,
Cable entry	Top entry via cable glands for all connections.
Line connection	Bared 50 mm^2 (1/0 AWG) conductor into clamp terminal block of Schaffner FN3258-100-35 line filter, 7-8 Nm torque.
Operating environment	Clean, 10 to 35 C (15 to 25 C recommended , < 70% humidity, non-condensing, vibration < 0.1 g all axes (1 to 100 Hz). Heat load on air conditioning 20 kW max. Cabinets should be located together with 800 mm clear space front and rear to permit door opening for service access. Clear space above for cable entry 500 mm minimum.
Shipping and storage environment	5 to 50 C, < 80% humidity, non-condensing, vibration < 0.5 g all axes, 1 to 100 Hz

Specifications - embedded controls

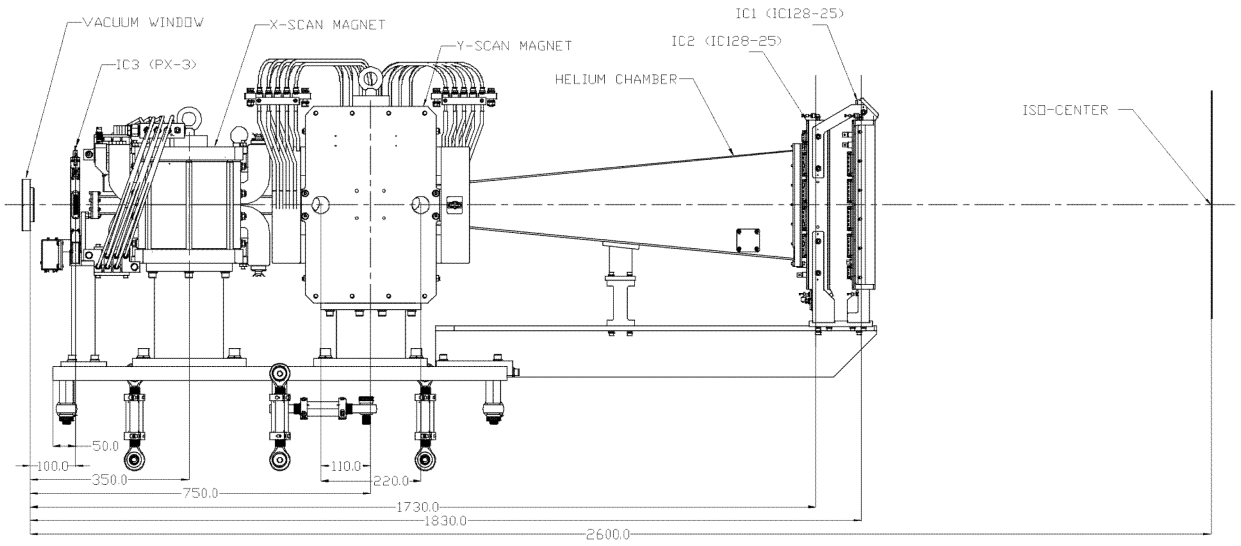
Configuration	Three M10 interface units and one X32 IECO adaptor mounted on DIN rail inside amplifier cabinet. +24 VDC power supplied by the amplifier. Connection to remote loop controller via HCS fiber optic communication link.
M10 (magnet 1)	DO1: enable command DI1: amplifier status read DO2: reset command DI2: (not used) AO1: current demand AI1: current readback AO2: (not used) AI2: voltage readback
M10 (magnet 2)	DO1: enable command DI1: amplifier status read DO2: reset command DI2: (not used) AO1: current demand AI1: current readback AO2: (not used) AI2: voltage readback
M10 (redundant read-back)	DO1: (not used) DI1: (not used) DO2: (not used) DI2: (not used) AO1: (not used) AI1: current transformer I read AO2: (not used) AI2: current transformer 2 read
X32	Cable adaption to IECO GIU, power distribution, redundant current transformer signal conditioning. X and Y axes used on IECO GIU. Z not used.

Scan geometry examples

Magnet 1, X axis; magnet 2, Y axis (nominal designations).
SAD is source to axis distance (dimension from the centre of the respective scan magnet to the isocentre plane.

35 cm by 40 cm field	SADs: Max currents : Slewing speed: Triangle frequency:	X = 2280 mm, Y = 1880 mm X = 384 A, Y = 400 A for 230 MeV X = 36.5 m s^{-1}, Y = 11.1 m s^{-1} for 230 MeV X = 52 Hz, Y = 14 Hz
30 cm by 40 cm field	SADs: Max currents : Slewing speed: Triangle frequency:	X = 2300 mm, Y = 1880 mm X = 332 A, Y = 400 A for 230 MeV X = 36.5 m s^{-1}, Y = 11.1 m s^{-1} for 230 MeV X = 60 Hz, Y = 14 Hz
30 cm by 35 cm field	SADs: Max currents : Slewing speed: Triangle frequency:	X = 2050 mm, Y = 1650 mm X = 368 A, Y = 400 A for 230 MeV X = 32.8 m s^{-1}, Y = 9.7 m s^{-1} for 230 MeV X = 54 Hz, Y = 14 Hz
30 cm by 30 cm field	SADs: Max currents : Slewing speed: Triangle frequency:	X = 1950 mm, Y = 1550 mm X = 384 A, Y = 364 A for 230 MeV X = 31.2 m s^{-1}, Y = 8.3 m s^{-1} for 230 MeV X = 52 Hz, Y = 15 Hz

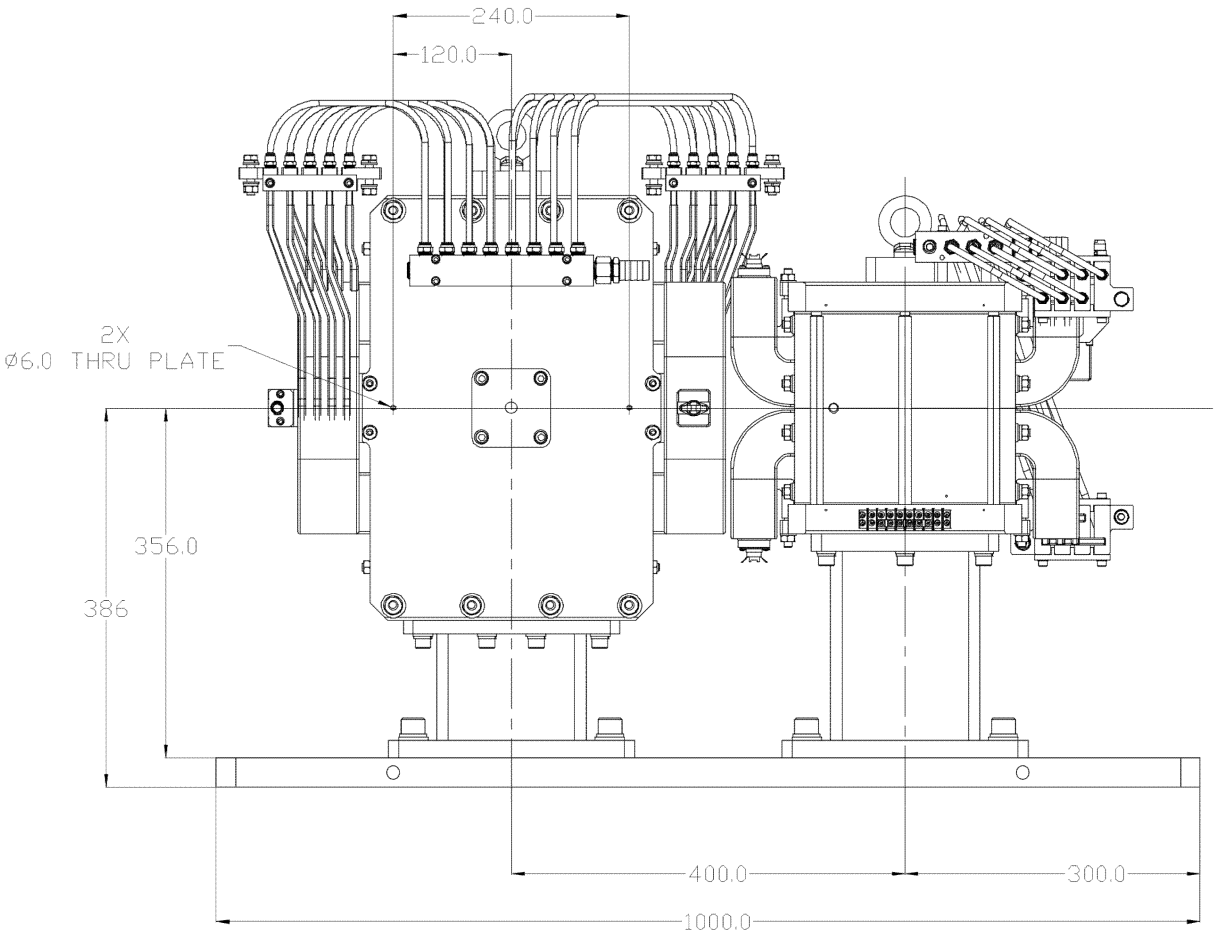
Typical nozzle system layout



Dims mm

Optional turnbuckle height, pitch and yaw adjustment shown

Magnet system - side elevation



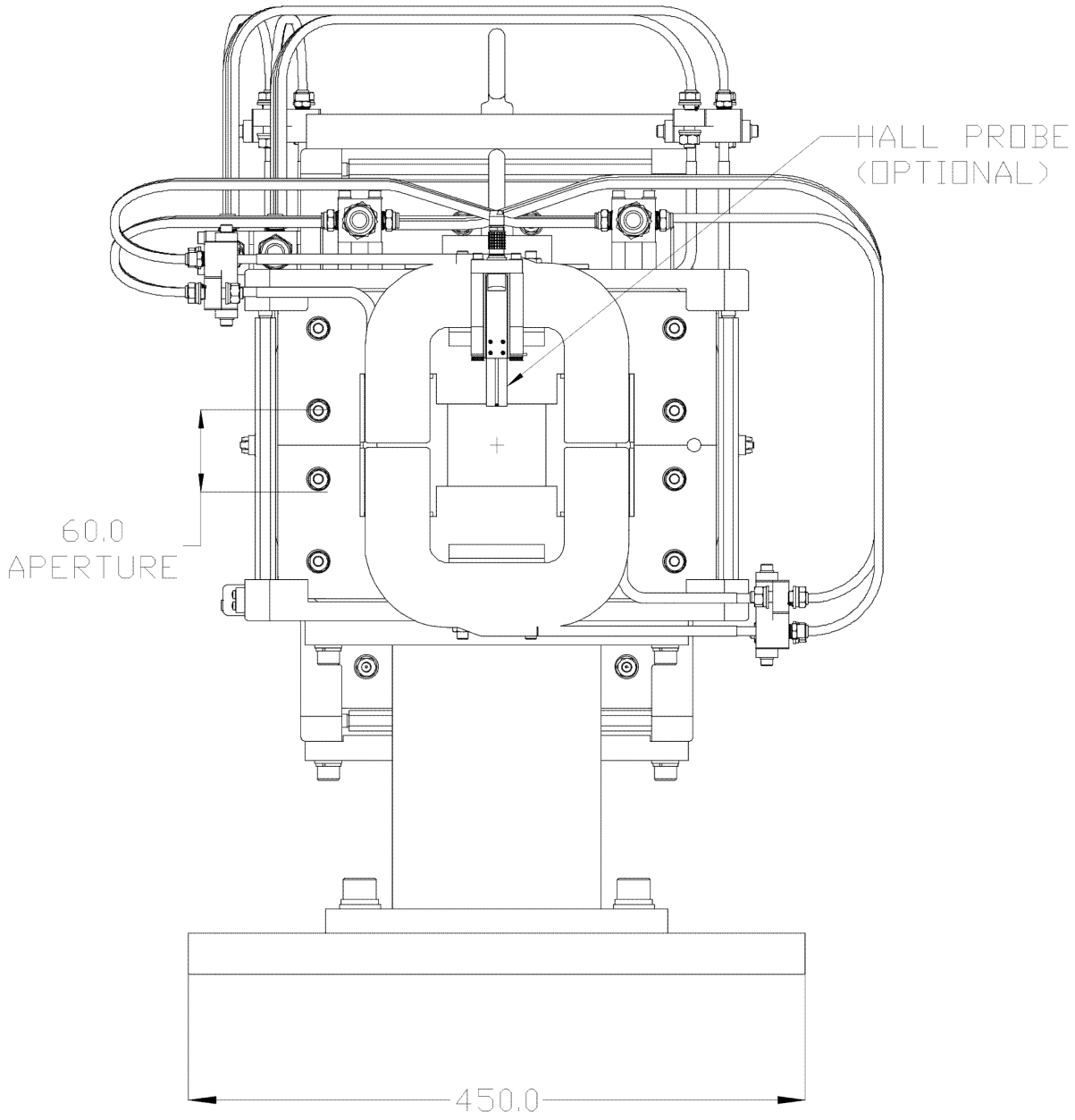
Beam exit

Beam entrance

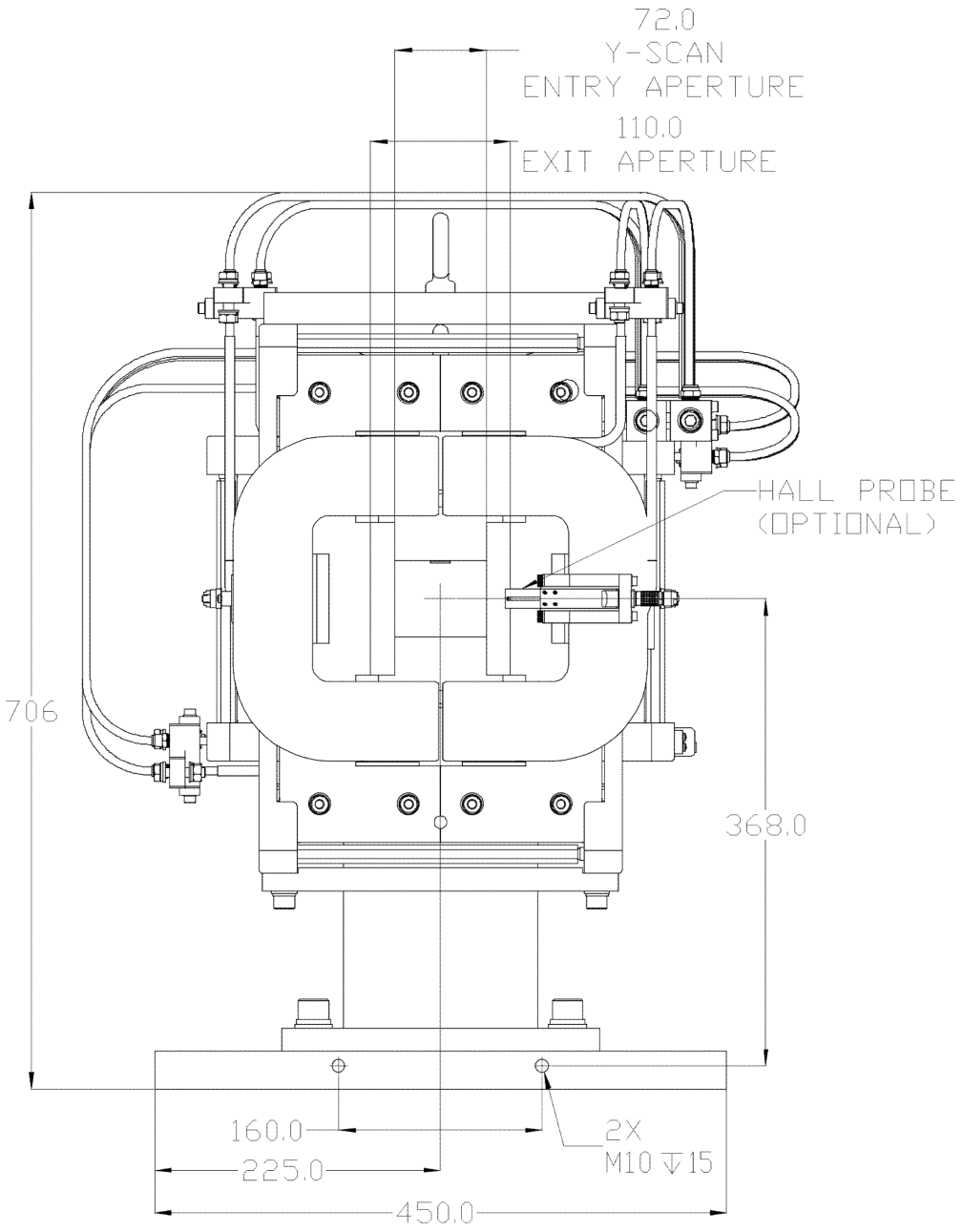
Dims mm

Mounting arrangement for illustration only. Other arrangements available on request.

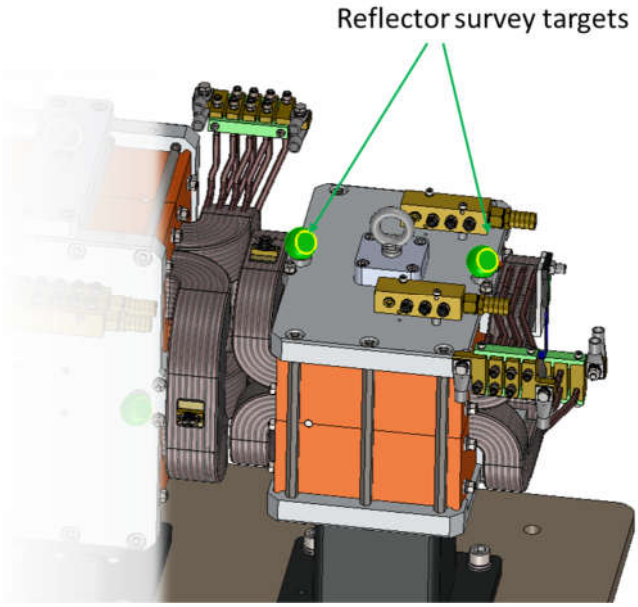
Magnet system - view on beam entrance



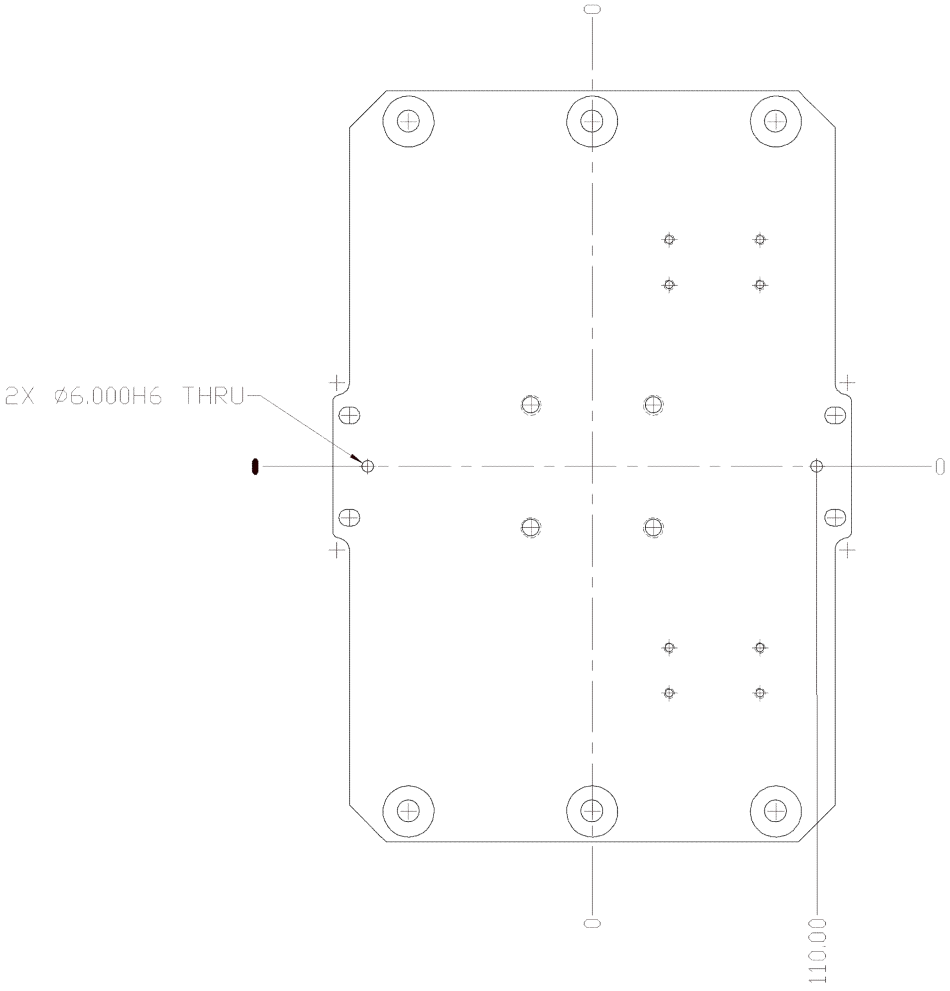
Magnet system - view on beam exit



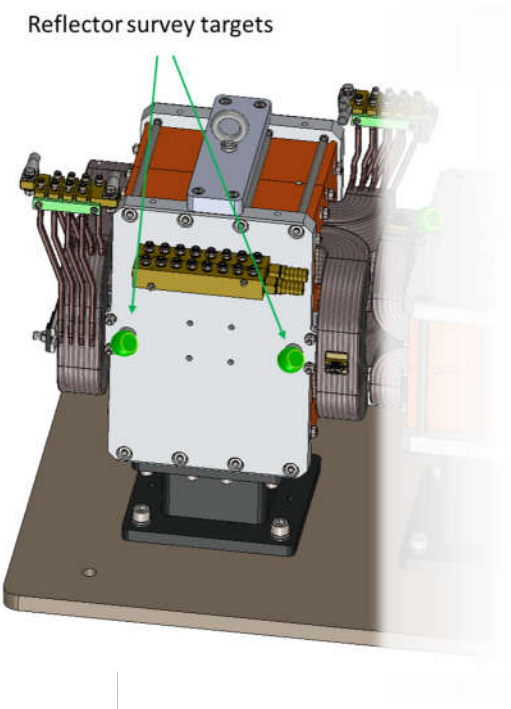
Survey target fiducials - Magnet 1



Two locations with 6.00 mm H6 holes on magnet yoke clamp plates.

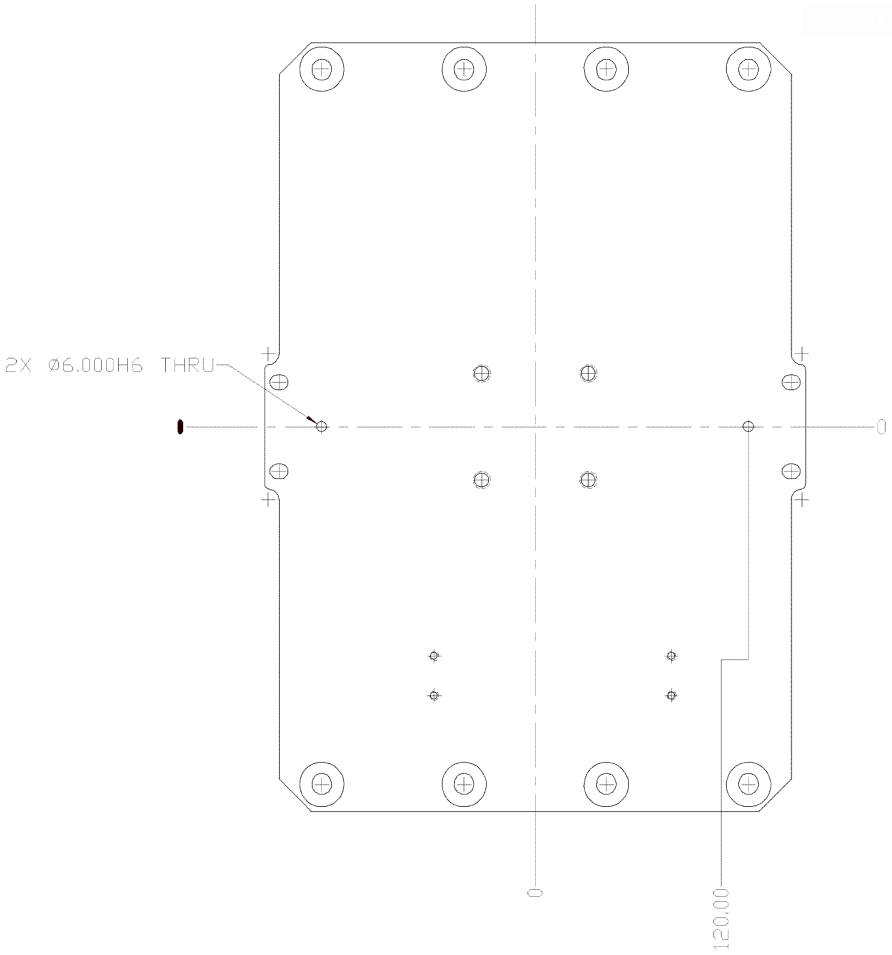


Survey target fiducials - Magnet 2



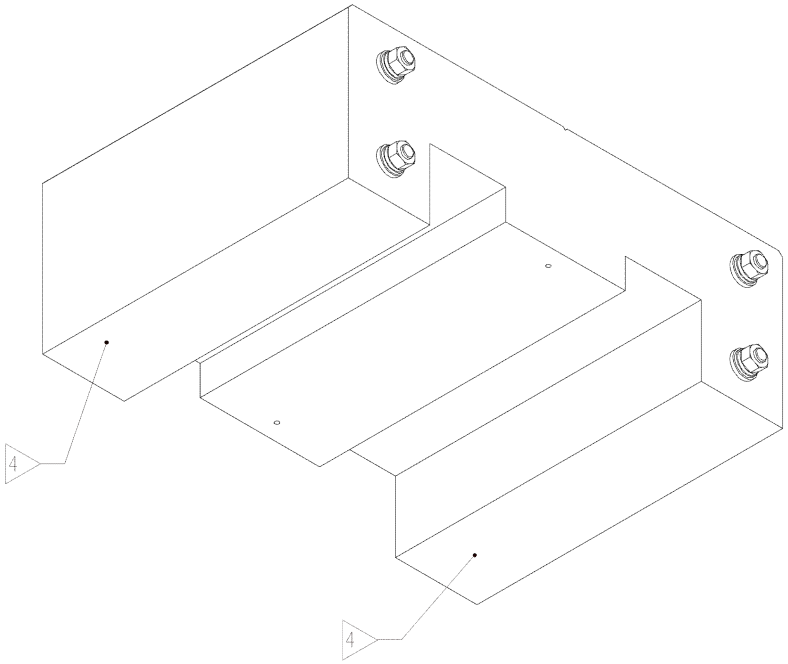
Two locations with 6.00 mm H6 holes on magnet yoke clamp plates.

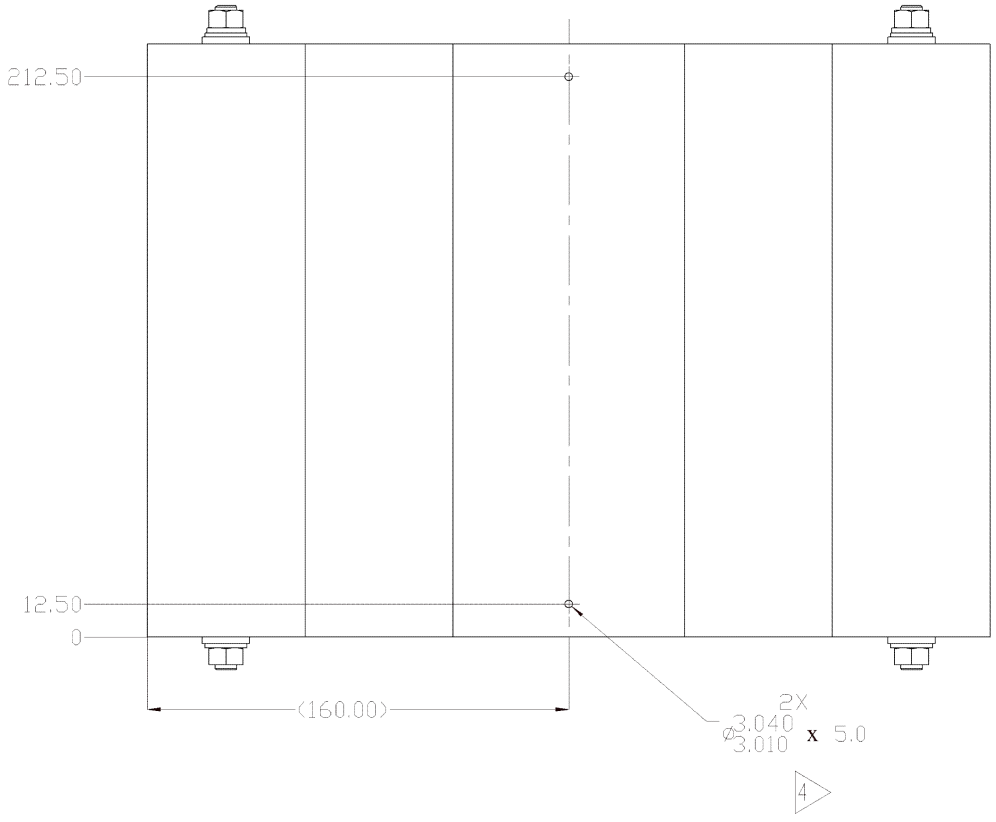
Pattern is repeated on the other side of the magnet.



Pole face fiducials - Magnet 1

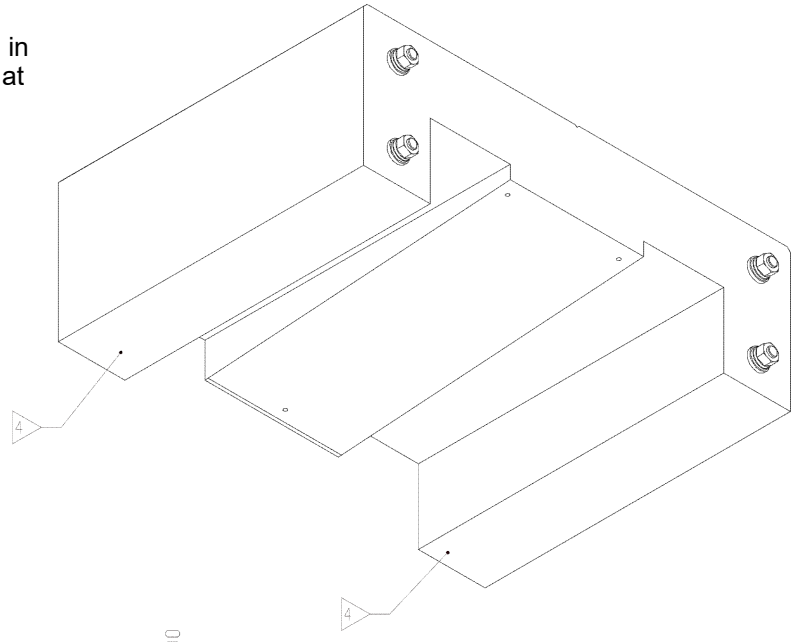
Two 3.00 mm dowel holes in both pole faces on centre-line.

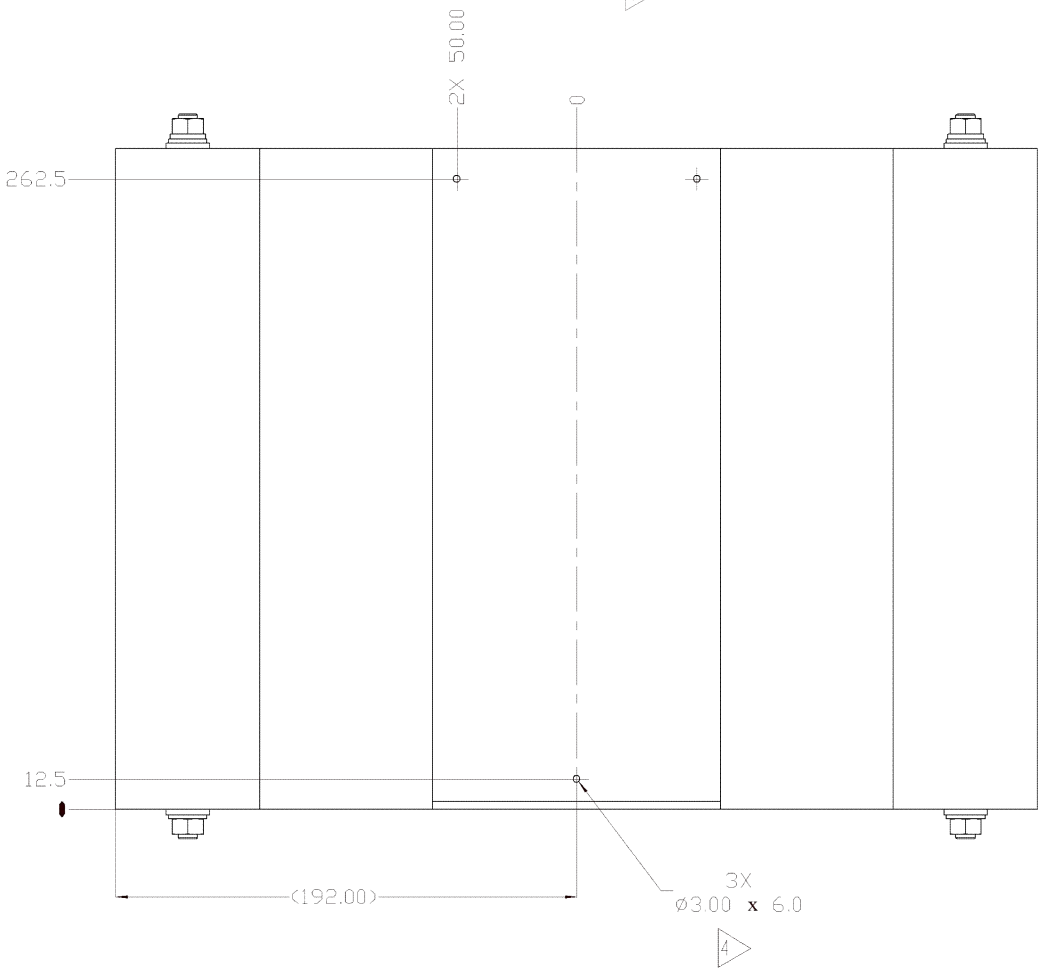




Pole face fiducials - Magnet 2

Three 3.00 mm dowel holes in both pole faces, single hole at upstream end, two holes at downstream end.

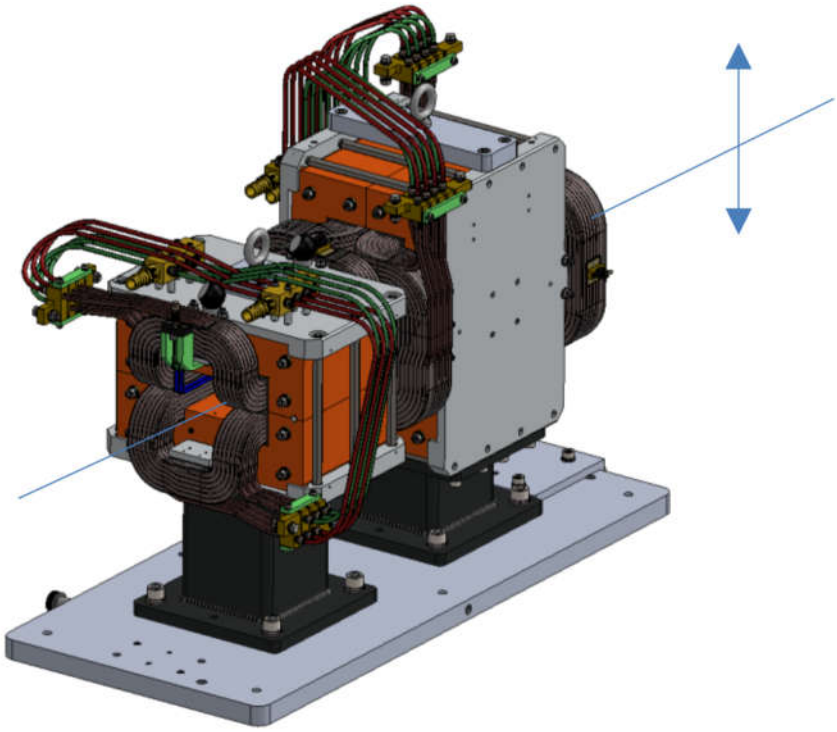




Scan field orientation

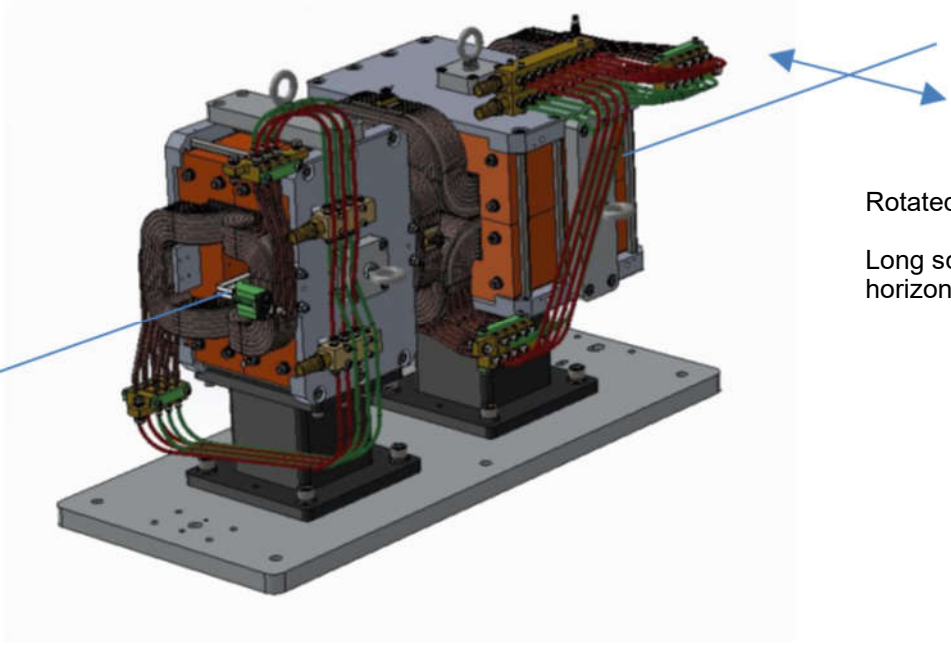
The D2-650 scan field is rectangular. The longer scan direction is created by the axis 2 magnet, and is therefore in the plane orthogonal to the magnet mounting plate. This would be the vertical axis for a fixed beamline installation with the standard mounting configuration.

The field can be rotated 90 degrees if required using an optional mounting (-ROT option)



Standard mounting

Long scan axis vertical



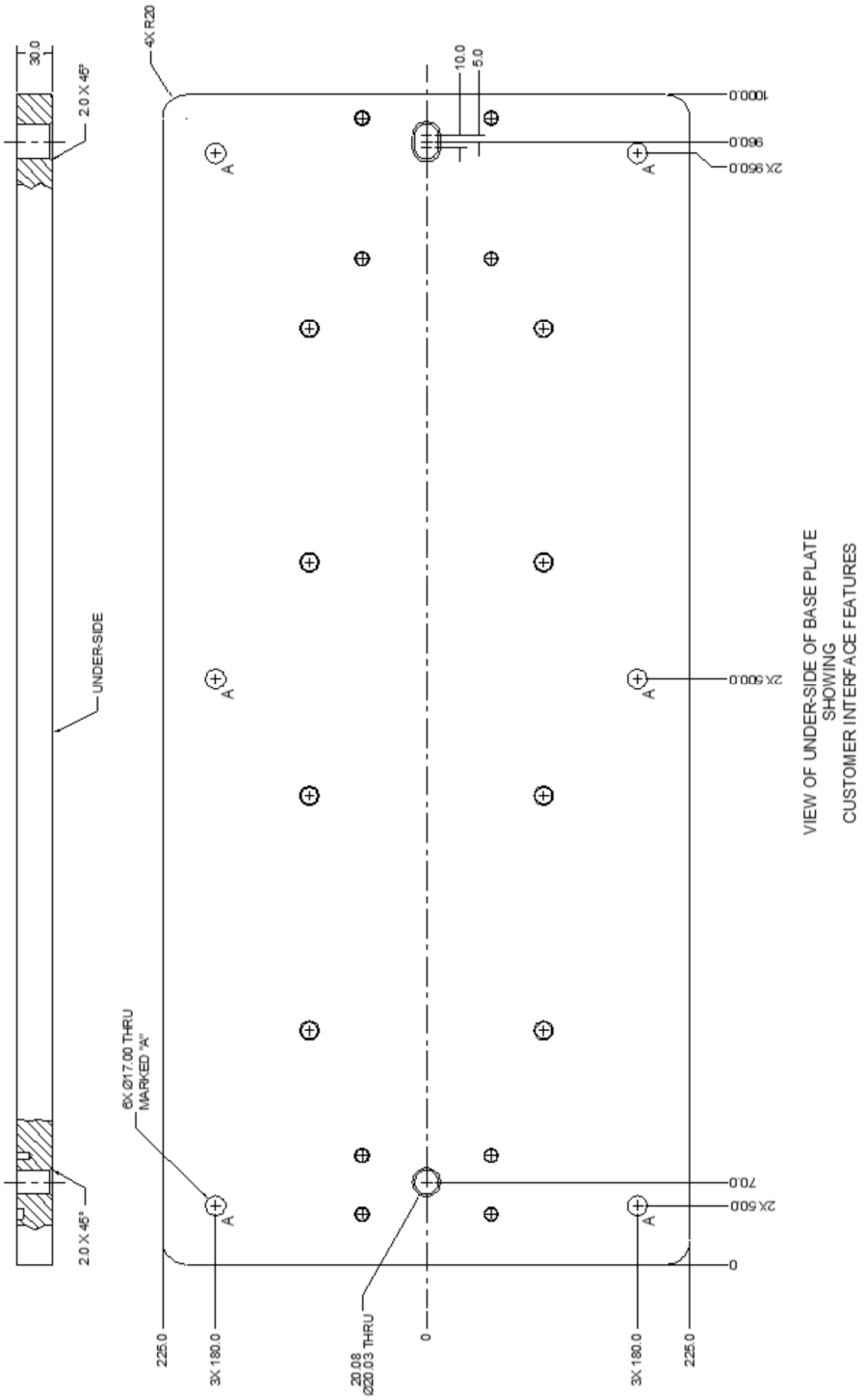
Rotated mounting

Long scan axis horizontal

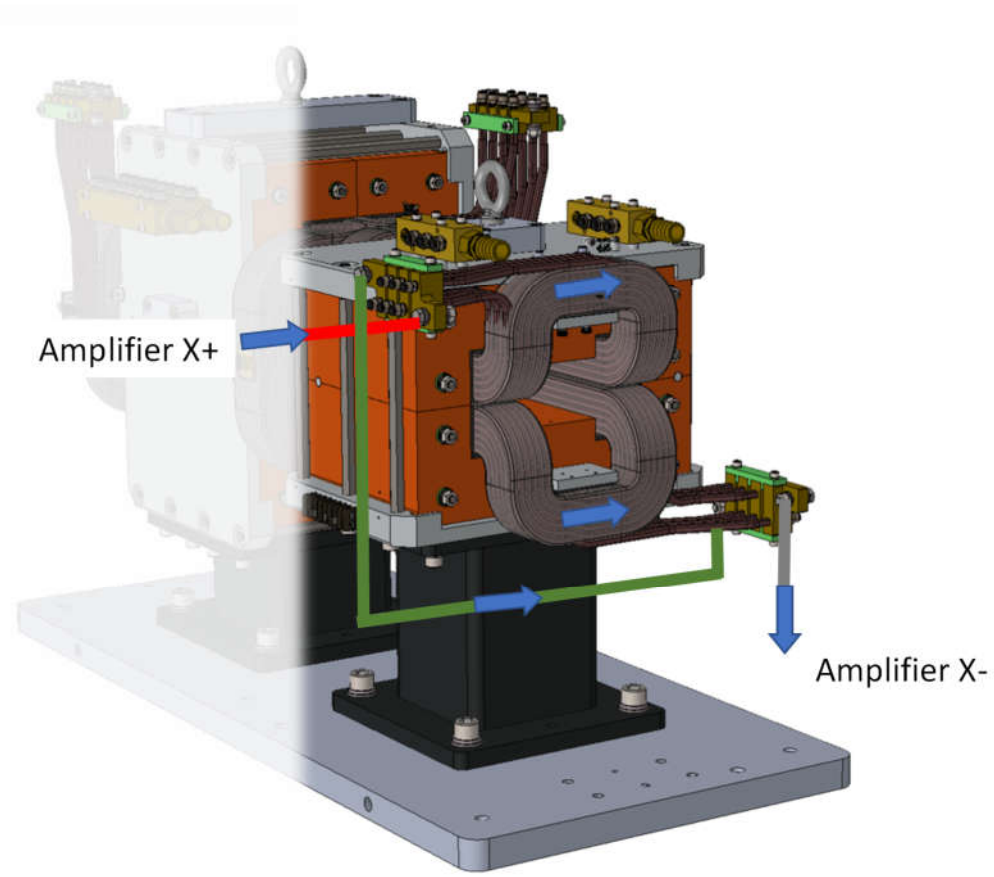
Sub-plate mounting features for gantry systems

Fixed mounting recommended for gantries where the scan system may be at any rotational angle.

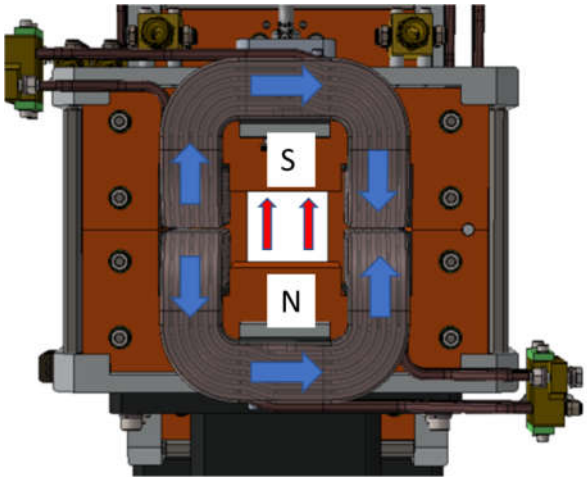
- Six studs M16 steel AISI class 10.9 (DIN 975) minimum grade with >= 25 mm thread engagement in the gantry and >= 55 mm exposed length.
- Two dowel pins 20 mm diameter DIN 6325-m6 grade with >= 25 mm engagement in the gantry exposed length between 25 and 28 mm.



Current lead connections and field direction—Magnet 1

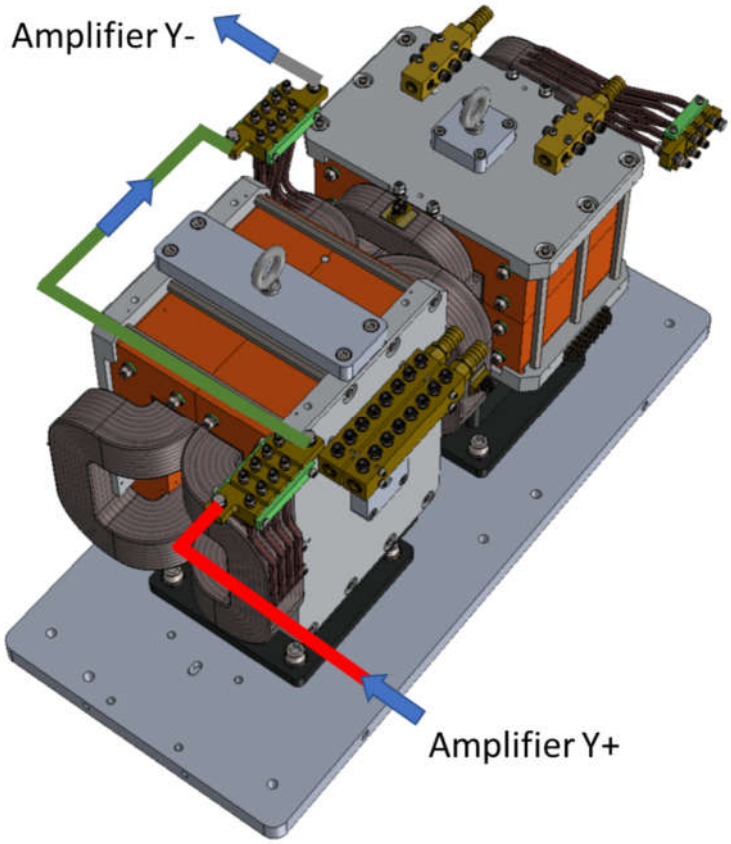


The connection arrangement shown gives deflection of protons to the right (looking from upstream direction, along beam direction) for positive command voltage with current and field directions as shown below. Currents and field reverse when the command voltage is negative.

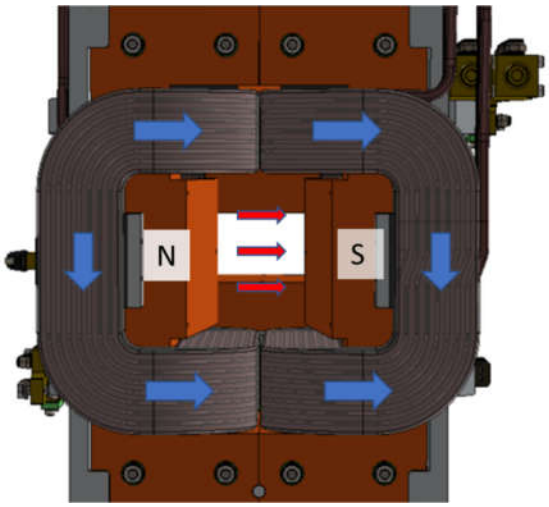


Note: to achieve a coordinate system in which the positive X direction is to the left looking along the beam direction (standard for beam transport modeling), simply exchange the amplifier +X and –X connection to magnet 1 only. The current and field directions for positive command shown will reverse.

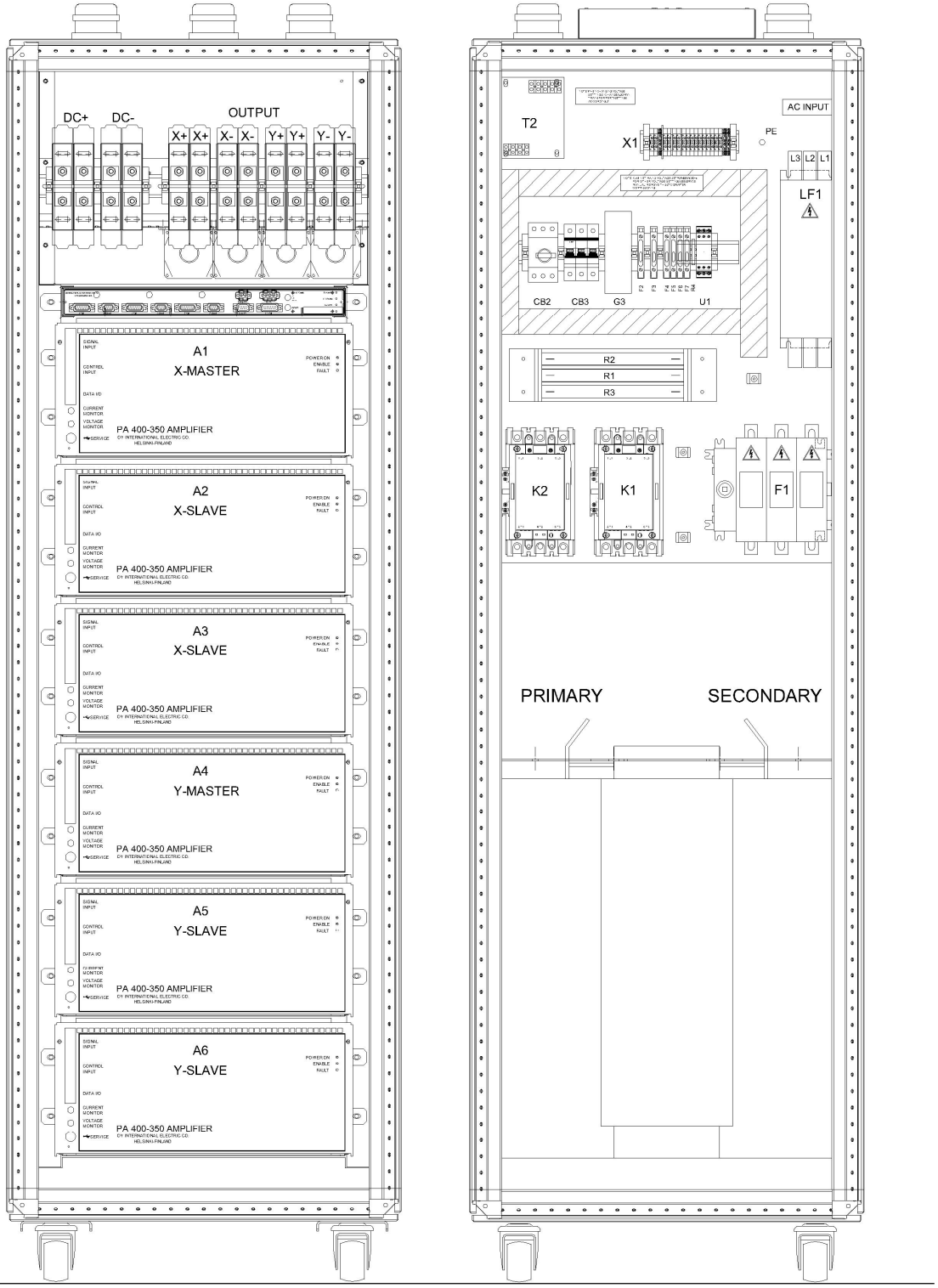
Current lead connections and field direction—Magnet 2



The connection arrangement that gives deflection of protons upwards (away from the base plate) for positive command voltage to the amplifier as shown below (view from downstream direction, beam coming towards viewer). Currents and field reverse when command voltage is negative.



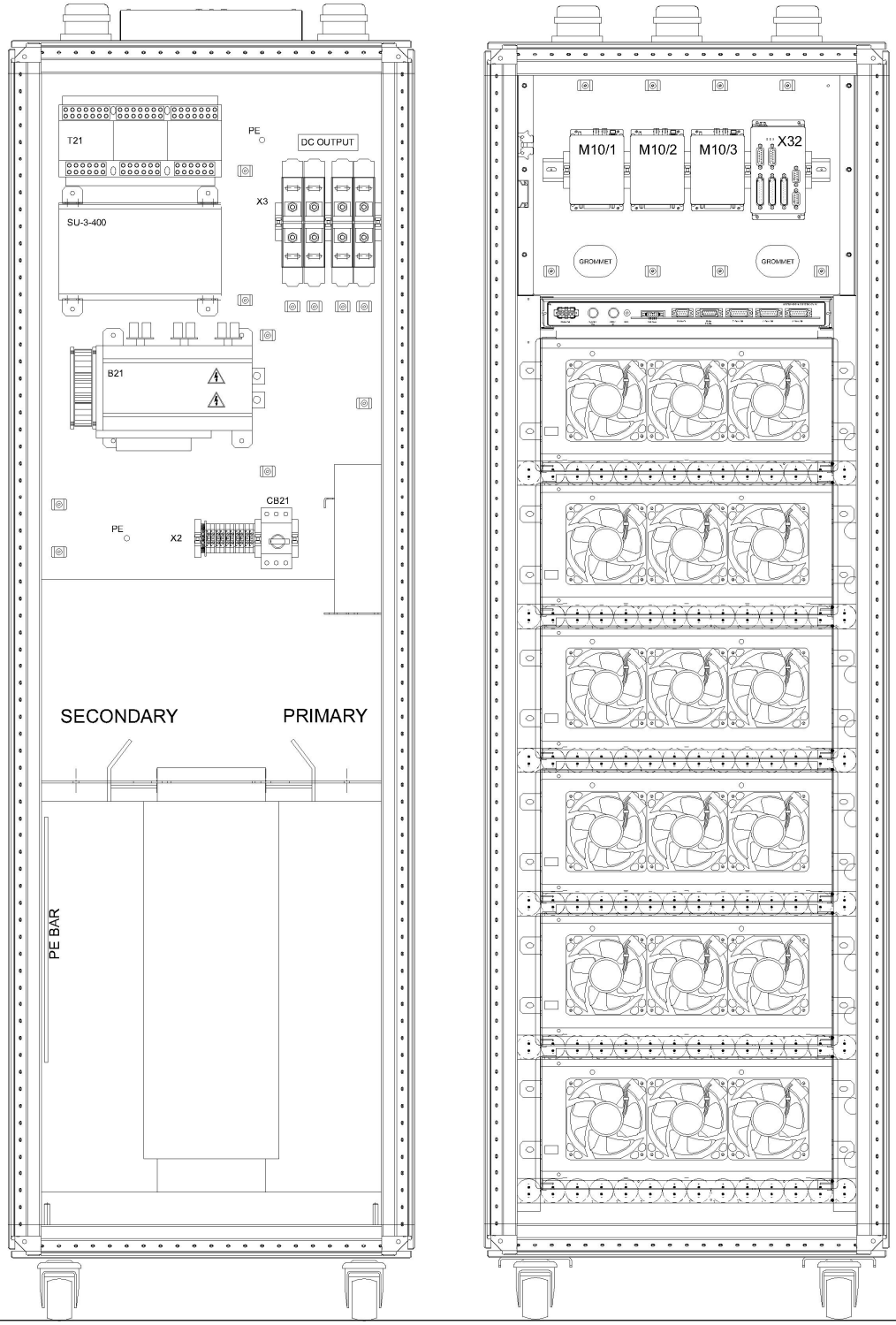
Amplifier system - front elevation (doors not shown)



Amplifier section

Power supply section

Amplifier system - rear elevation (doors not shown)



Power supply section

Amplifier section

Applicable standards

Magnets, amplifiers and control electronics are produced under ISO 9001 and ISO 13485 quality management systems.

Power amplifier modules are CE marked to standards EN61010.
Control electronics are CE marked to EN61010, EN 61326, EN55011, EN61000.

Electronics are RoHS compatible.

Ordering information

D2-650-IE	Scan magnet set, dual dipole with IECO MPS-400-350-PY amplifier system and remote control interface.
- PAS	Turnbuckle position adjustment system (not recommended for gantry installations)
- ROT	Optional rotated mounting of magnets to rotate the scan field dimensions. The -ROT option is typical for gantry mounted nozzles.
- SF#	Survey device mounting features added
H20-SYS2-22-SM1	Dual Hall probe system, probe set #1 for D2-650 scan magnet installation, 22 foot (6.7 m) cables.

Example: D2-650-IE-PAS-SF3: Scan magnet and amplifier system with position adjustment system and customer-specific survey features added.

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D2-650-IE_DS_171122