Microsations
& Leading Proton Acceptances

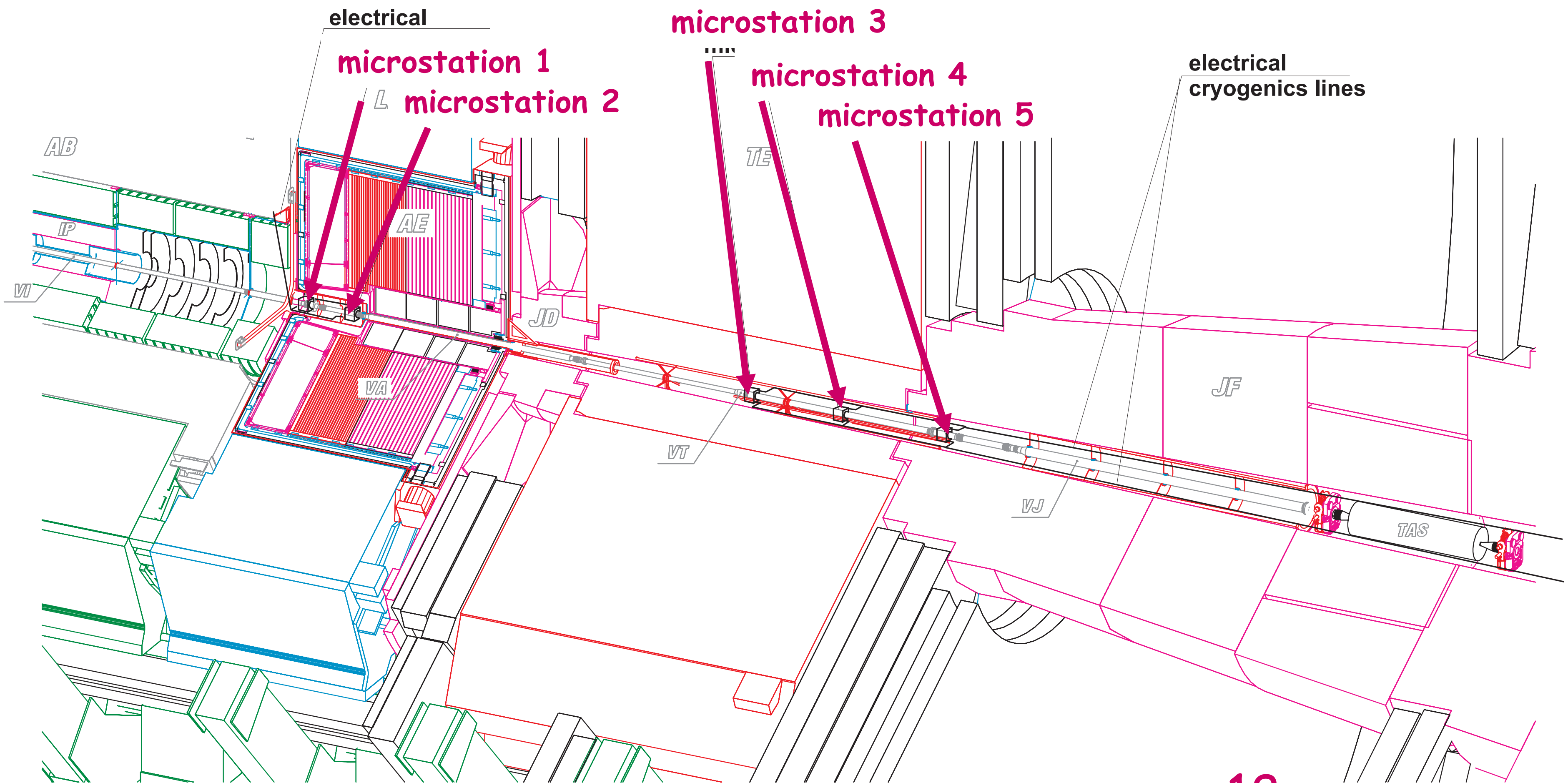
Risto Orava

Helsinki Group
University of Helsinki
and
Helsinki Institute of Physics

The TOTEM Collaboration

-ms development stages 2000-2005
-leading proton measurement – an update

feasibility study of equipping the forward region of ATLAS ⇒ concept of microstation



z = 3- 4m

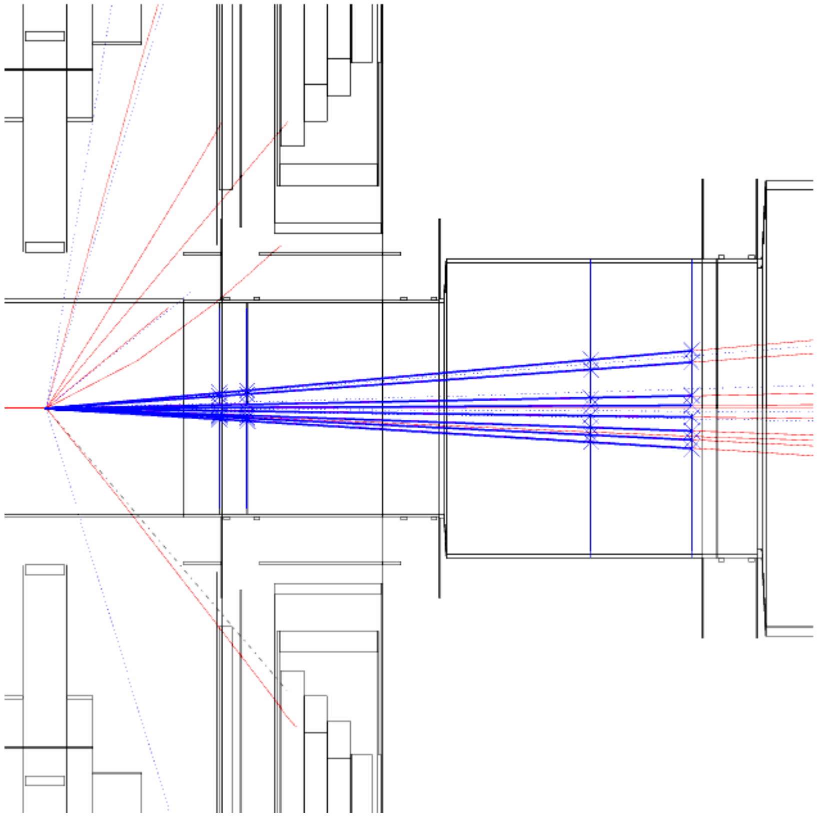
z = 10- 13m

z = 18m

Helsinki group:Jerry Lamsa, Vassili Nomokonov, Stefan Tapprogge,...

Track Reconstruction by Microstations

Simulation study with GEANT:
- include signal hits by PYTHIA minimum bias events
- hits from secondaries due to backgrounds
- beam related background: 5 MHz for > 15σ at design luminosity (flux vs. R)



Track reconstruction code:
pattern recognition with
beam spot constraint

Helsinki group:Marco Battaglia, Laura Salmi

Vacuum

- LHC-UHV compatible materials, minimal mechanical risks
  - no polymers
  - all welded structure
  - NEG coating and if needed a NEG pump actually makes this device a vacuum pump

Beam

- rf-fitting
- hot spots, thermal load out
- rf-shielding
- multipacting restriction
  - NEG
  - material selection
  - local magnetic fields & geometry

Harsh environment

- high ~ moderate magnetic field
  - austenitic steel, copper, titanium
  - ceramics, diamond like carbon
- high radiation
  - no polymers
  - quarts, compatible ceramics
  - recovery of functional ceramics

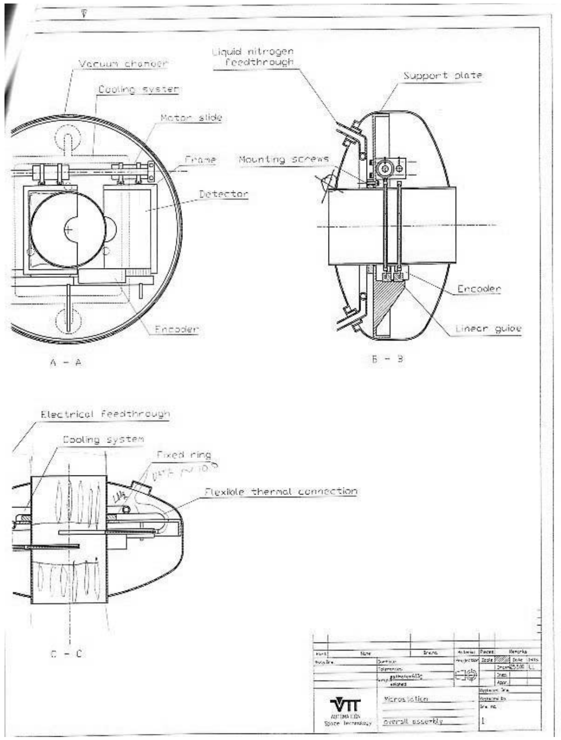
Microstation - was designed to comply with the LHC requirements.

- a compact and light detector system (secondary particle emission, dimensions < 20cm, weight < 2kg)
- integrated with the beam vacuum chamber (acceptance)
- geometry and materials compatible with the machine requirements (dynamic vacuum (outgassing 10^{-11} atm, bake-out to 180 C), RF impedance (< 0.6mΩ/ms), em pick-up)
- μm accurcay in sensor movements (alignment)
- robust and reliable to operate (**access limitations!**)
- Si strip or pixel detector technology (heat dissipation (< 50 mW), simplicity & radiation hardness (n flux 10^5 kHz/cm^2, 0.25μm CMOS read-out chips fully functional up to 30Mrad)

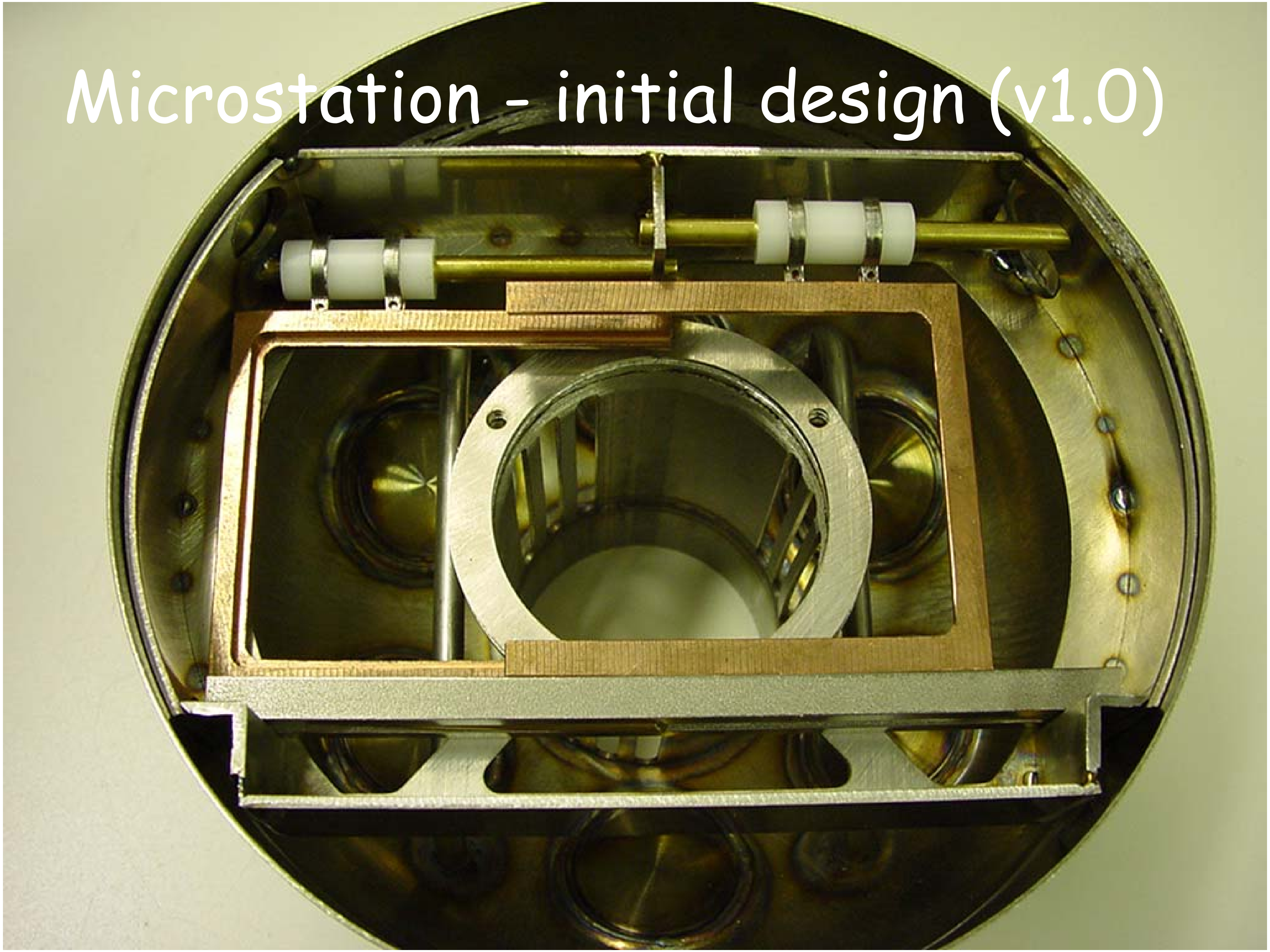
Helsinki group:Matti Ryynänen/VTT

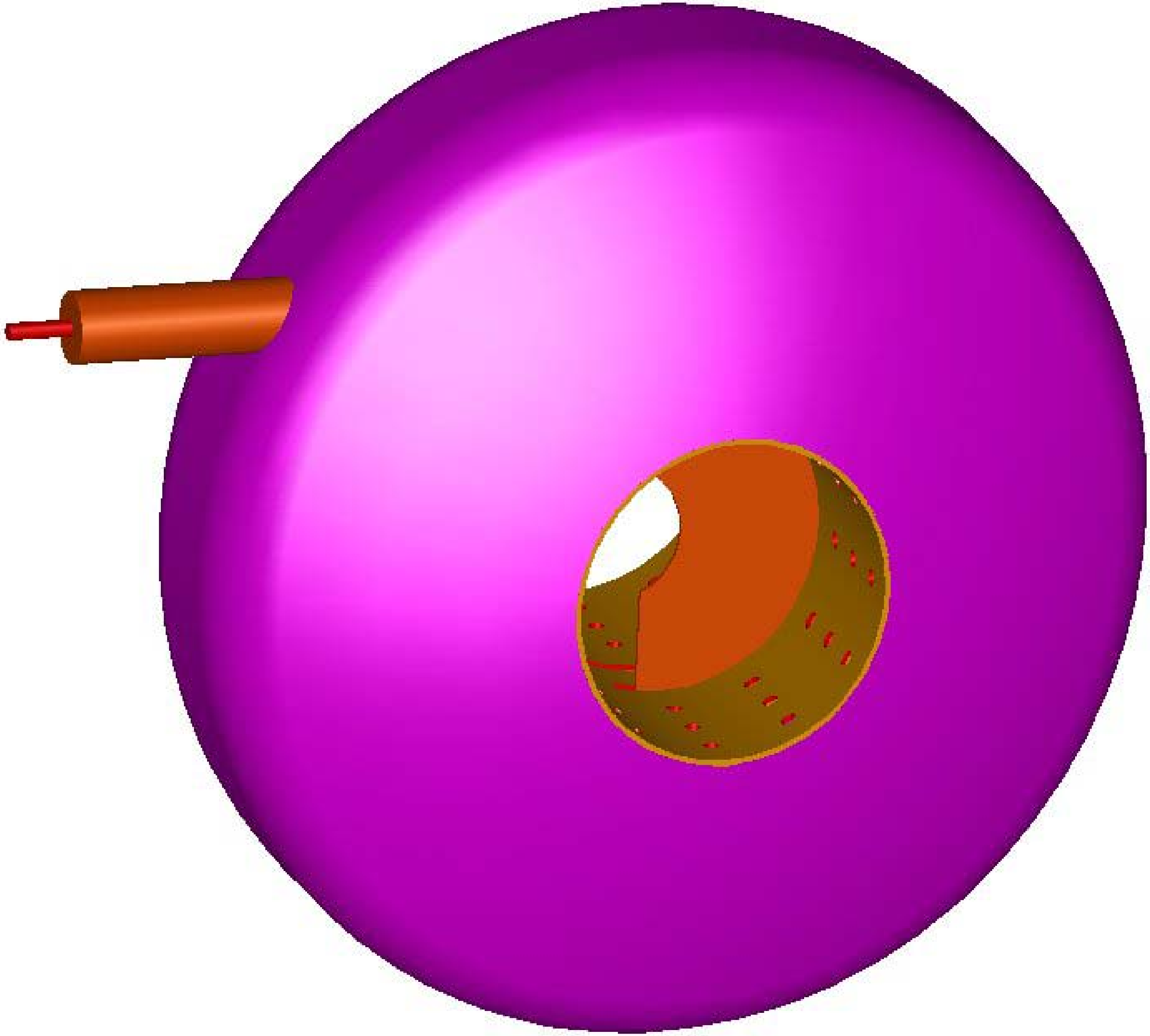
First Specs - Year 2000

- Positioning
  - <10 μm, 0.7 mm/s
- Temp
  - 310 K, measurement, power on
  - 473 K, bake-out, power off
- Total mass
  - 0.61 kg, steel
- Size
  - l < 150 mm, d = 180 mm



Microstation - initial design (v1.0)





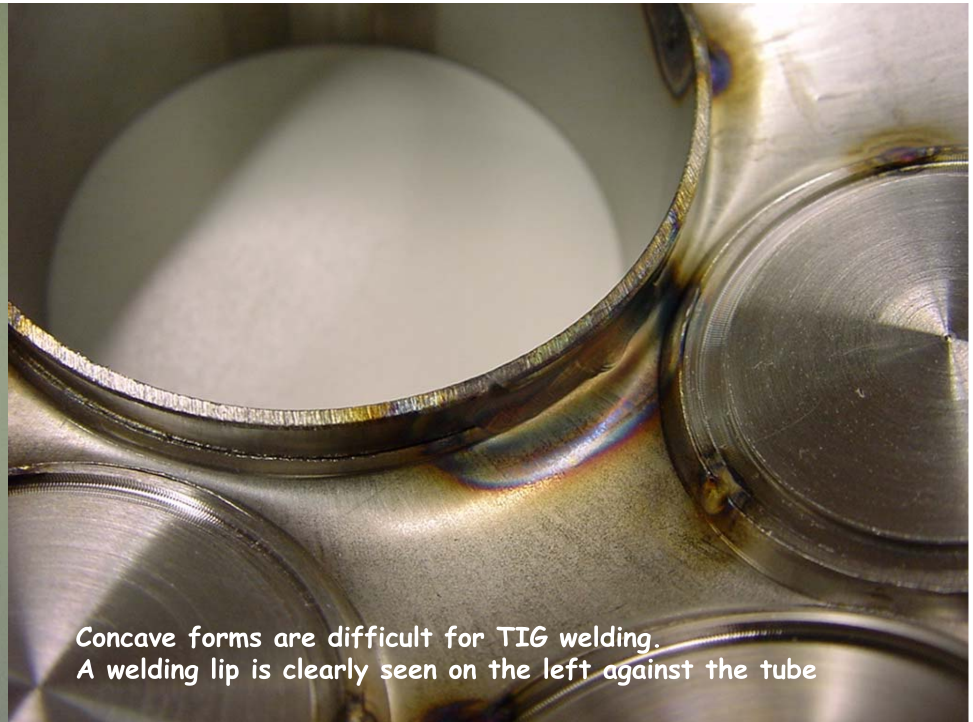
Microstations - R&D

Deep drawing hemispheres and a connector mock-up for welding tests

The welding jig used in the chamber cylinder welding

Pressing tools for the proton tube and connector welding lips

A Chamber hemisphere after the TIG pre-welding of the connector mock-ups and the proton tube

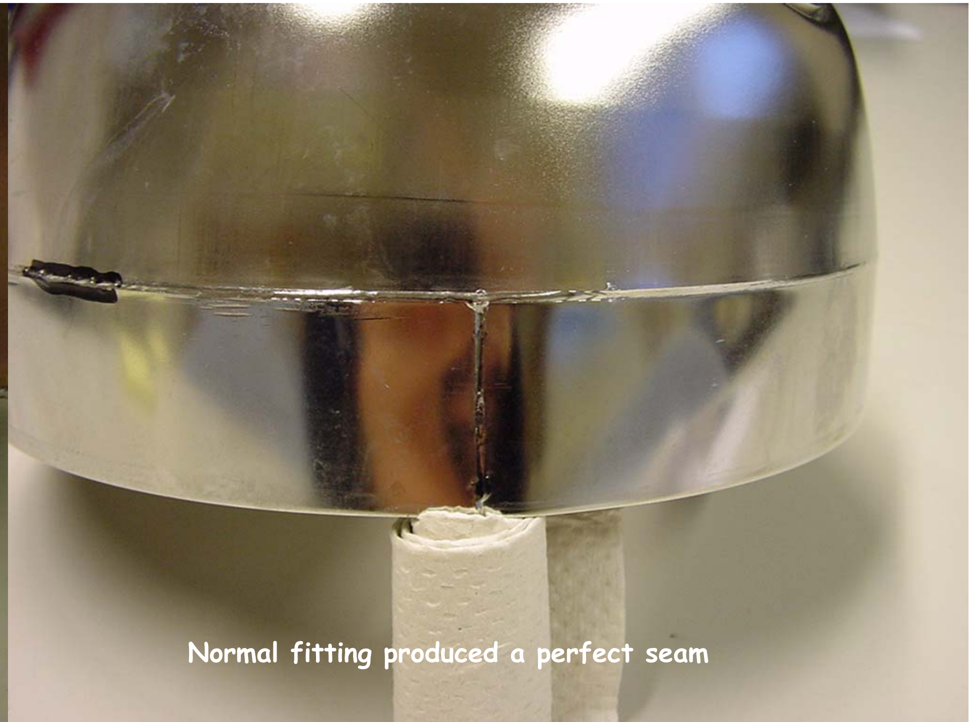


Concave forms are difficult for TIG welding.
A welding lip is clearly seen on the left against the tube

The welding seams of three connector mock-ups each having different welding parameters right after the EB welding

The outside view showing that melting has propagated through the seam

Loose fitting of the chamber cylinder caused welding failures

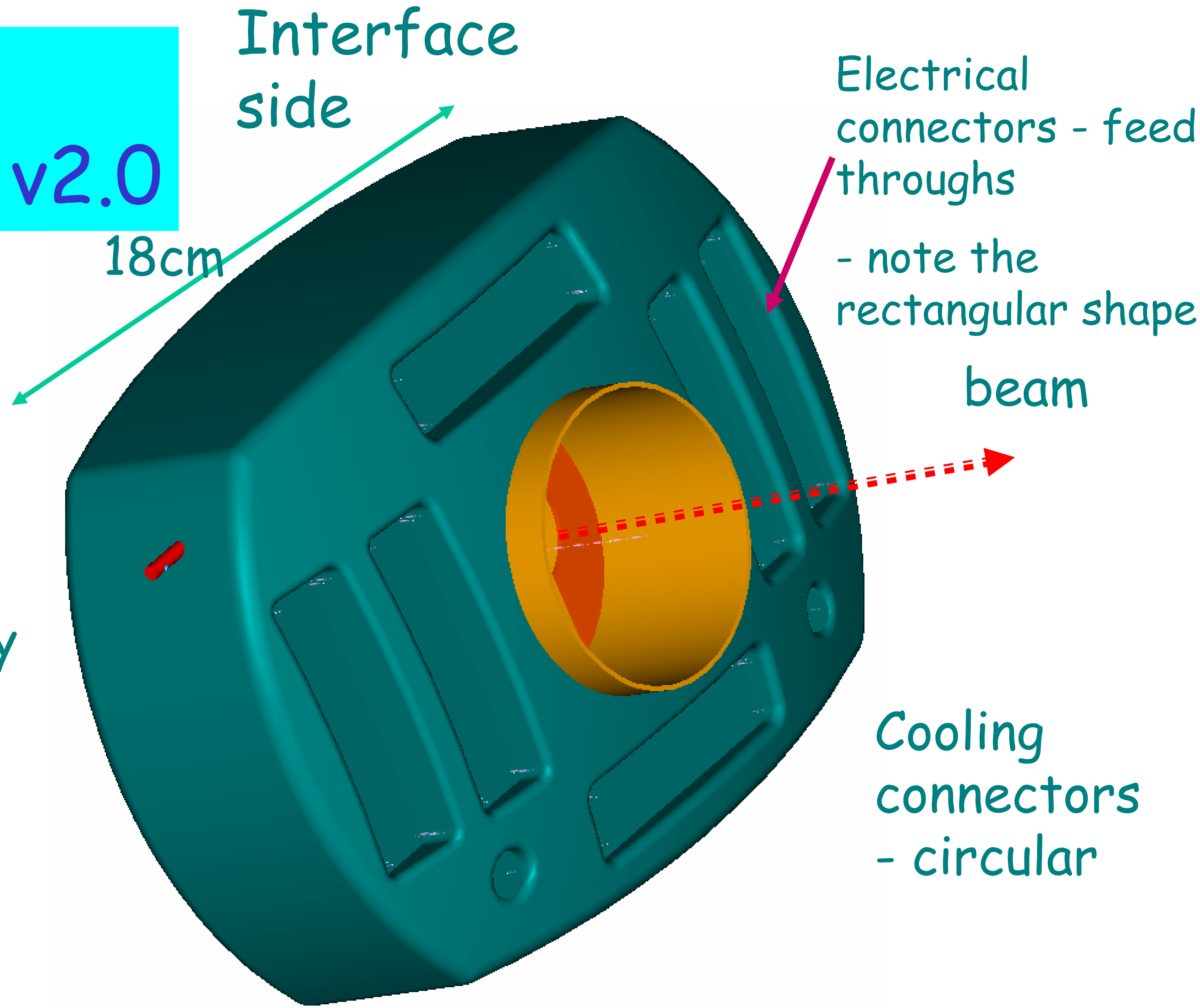


Normal fitting produced a perfect seam

An electrically polished test component shows the effect of the surface treatment

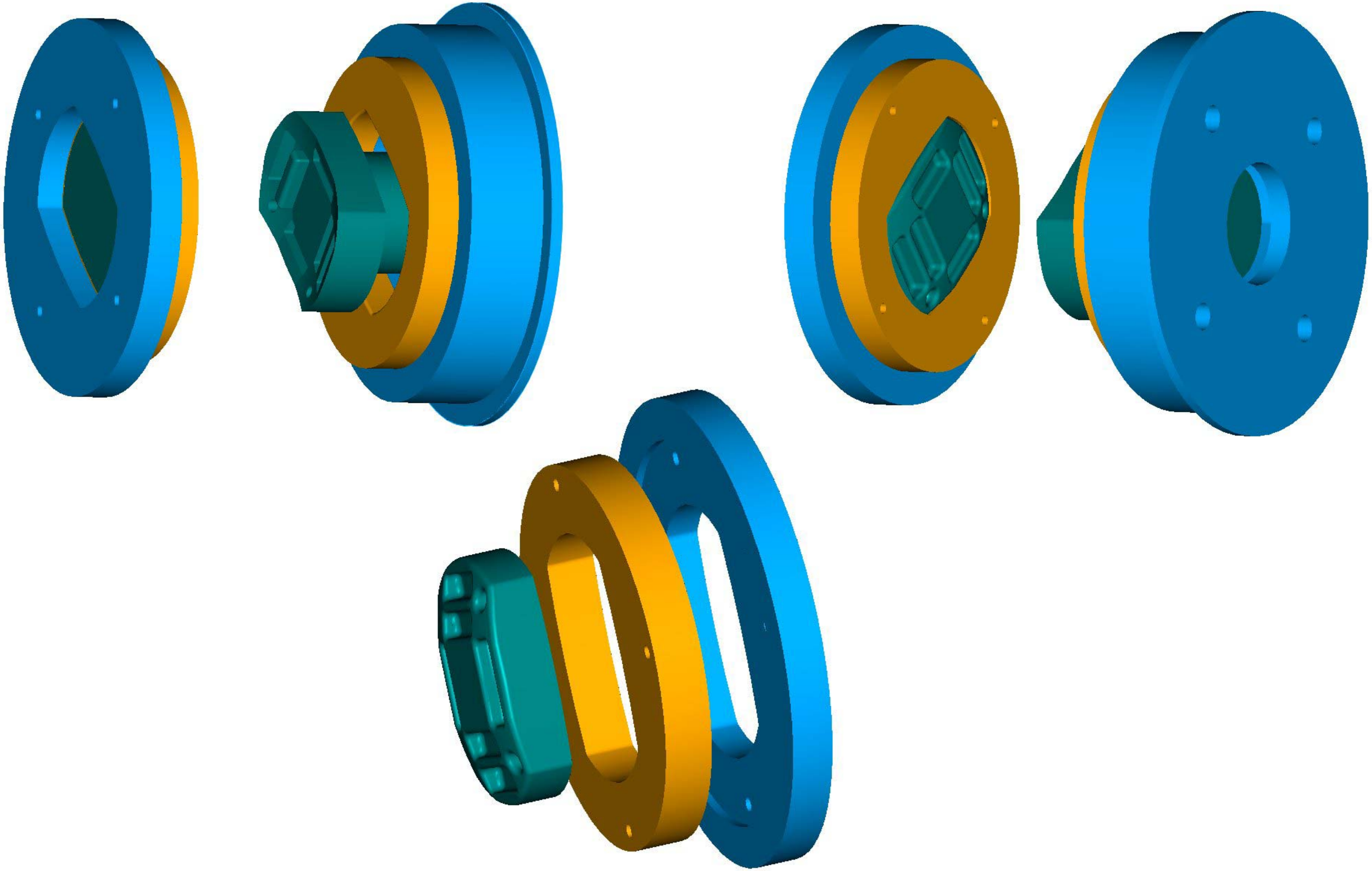
The surface treatment does not effect to the other side of the seam. The two seams look the same from outside

Micro-Station v2.0

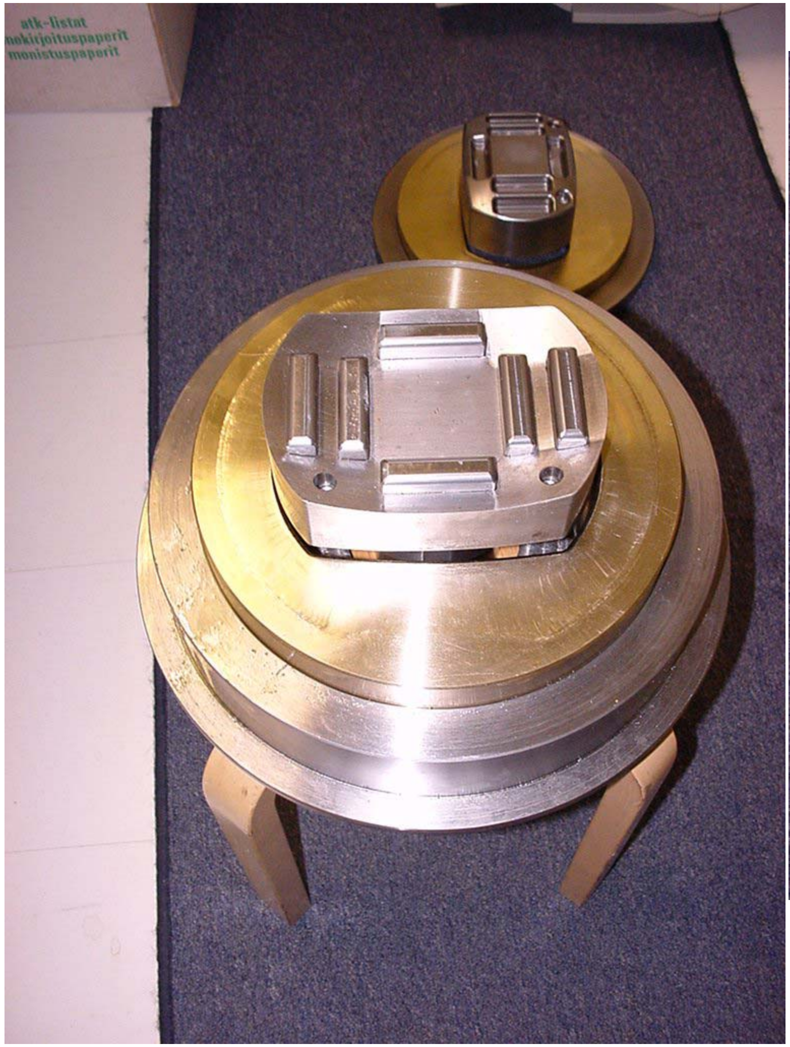


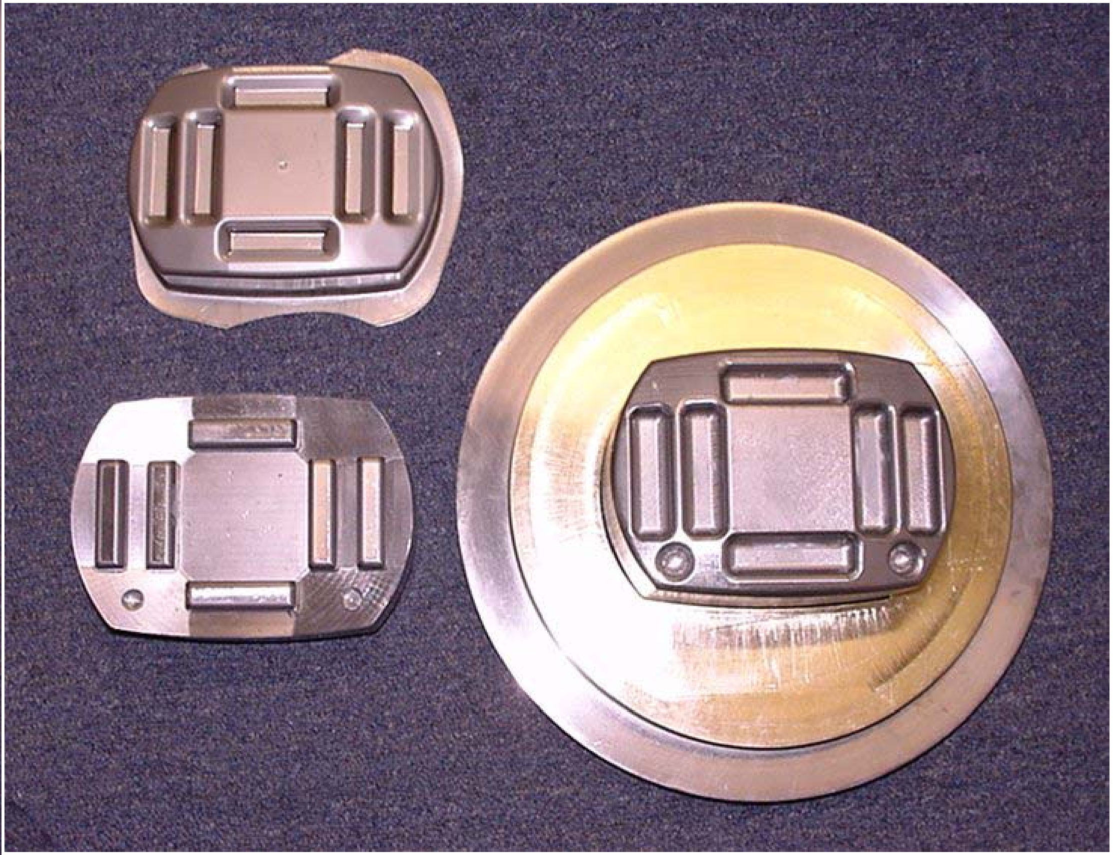
Limited space for services ⇒ asymmetric design

Deep Drawing Tools for v2.0

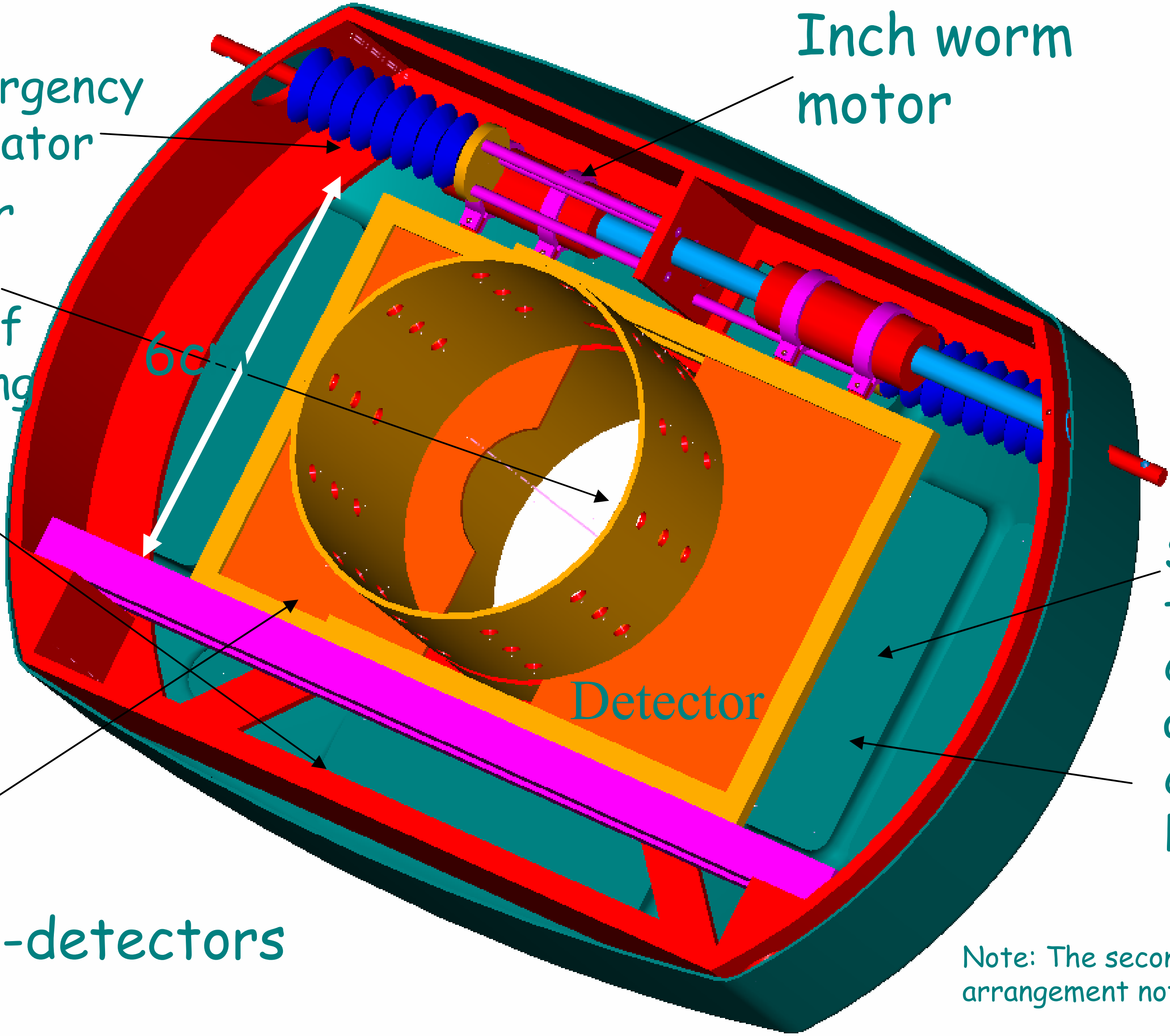


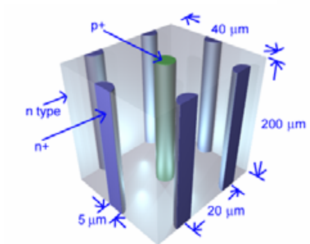
Deep-drawing tools for v 2.0

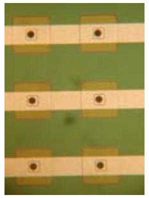




Microstation v2.0 - Inside View







3D-detectors

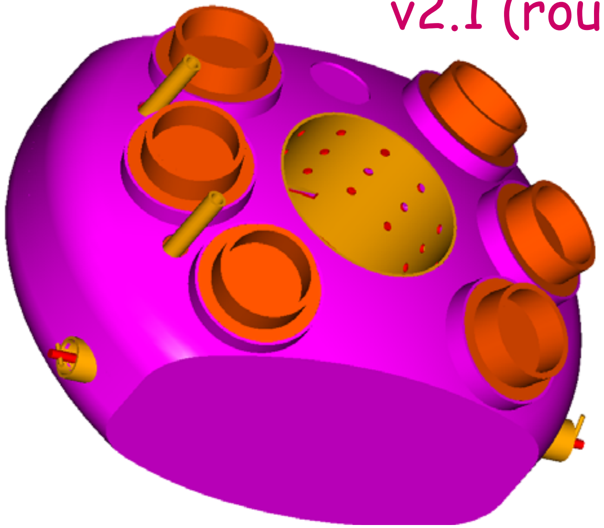
Note: The secondary vacuum arrangement not shown.

Helsinki group

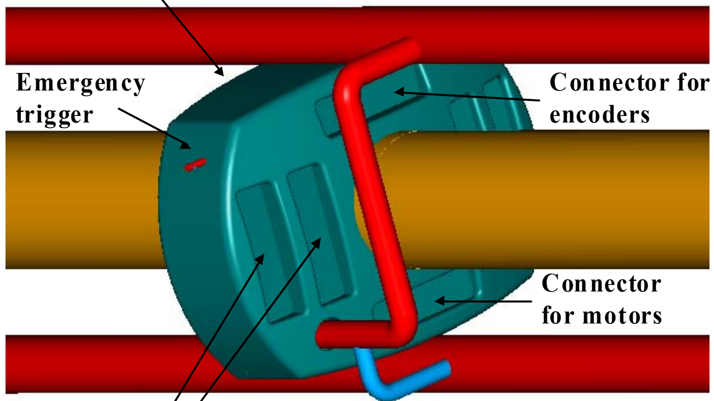
protons at 220, 420m inelastics at 19m(?)

Microstation - Services

v2.1 (round feed throughs)

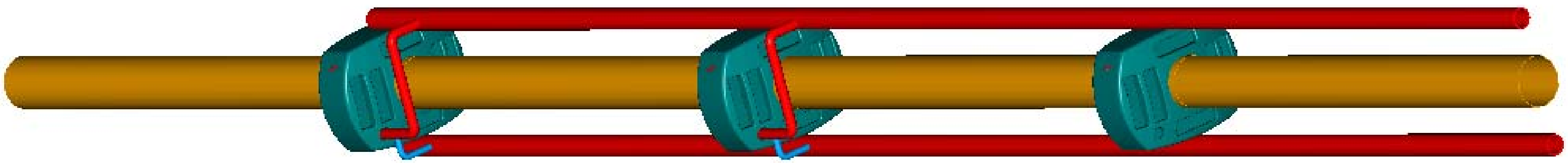


The service side of a microstation.
The two edges are flattened to
facilitate services between stations.



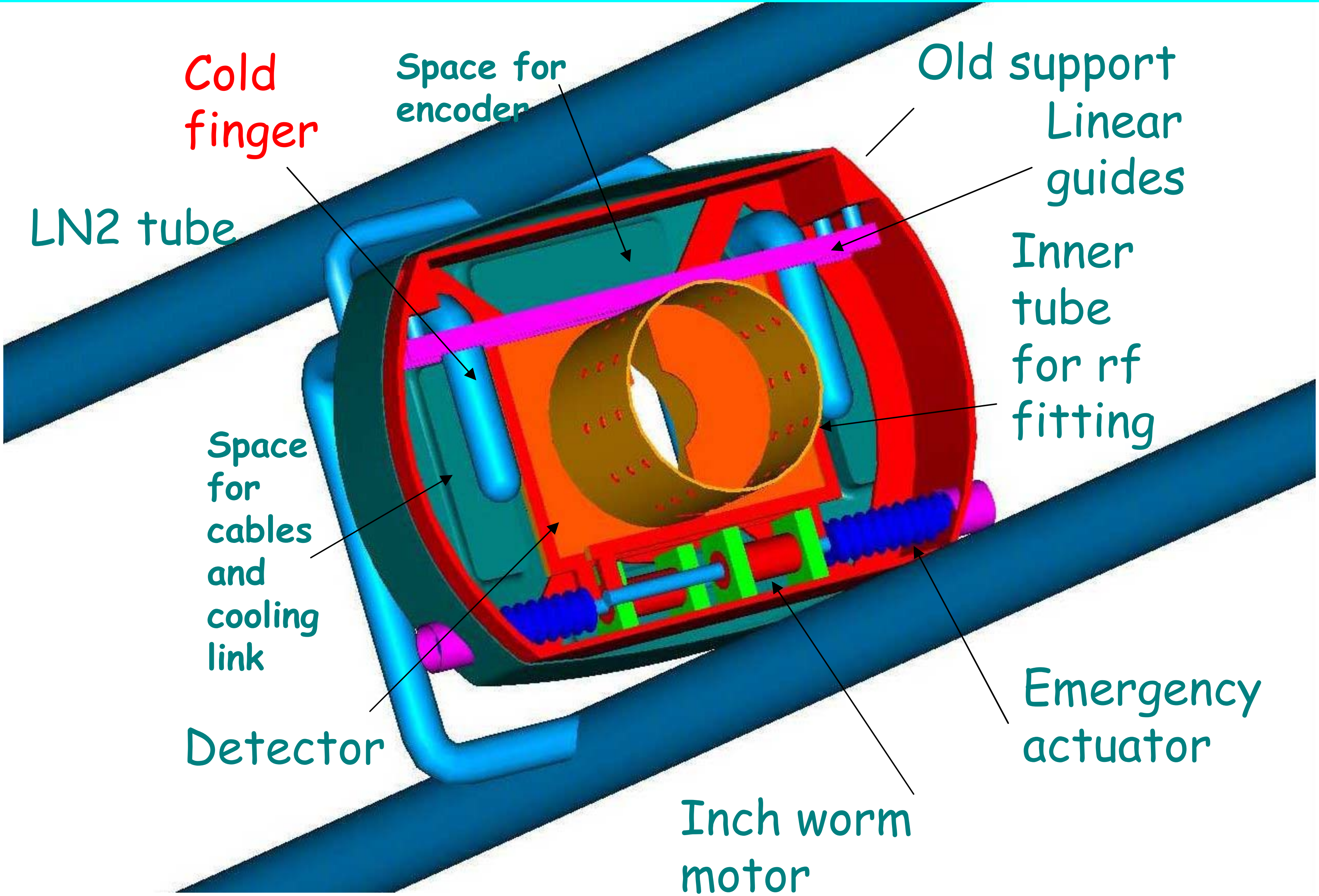
Service routings - nitrogen lines.

Hanasaari 031100
Nomokonow

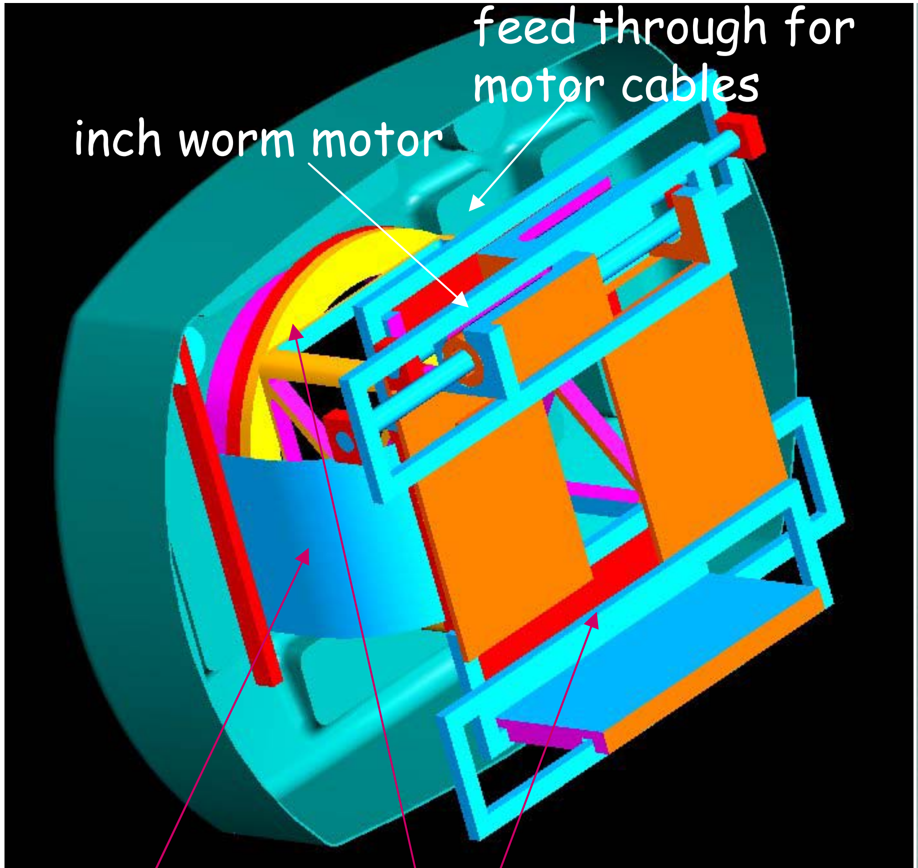


3 microstations in a cluster with parallel nitrogen lines.

Microstation v2.1 interfaces



Microstation technical model 2.0

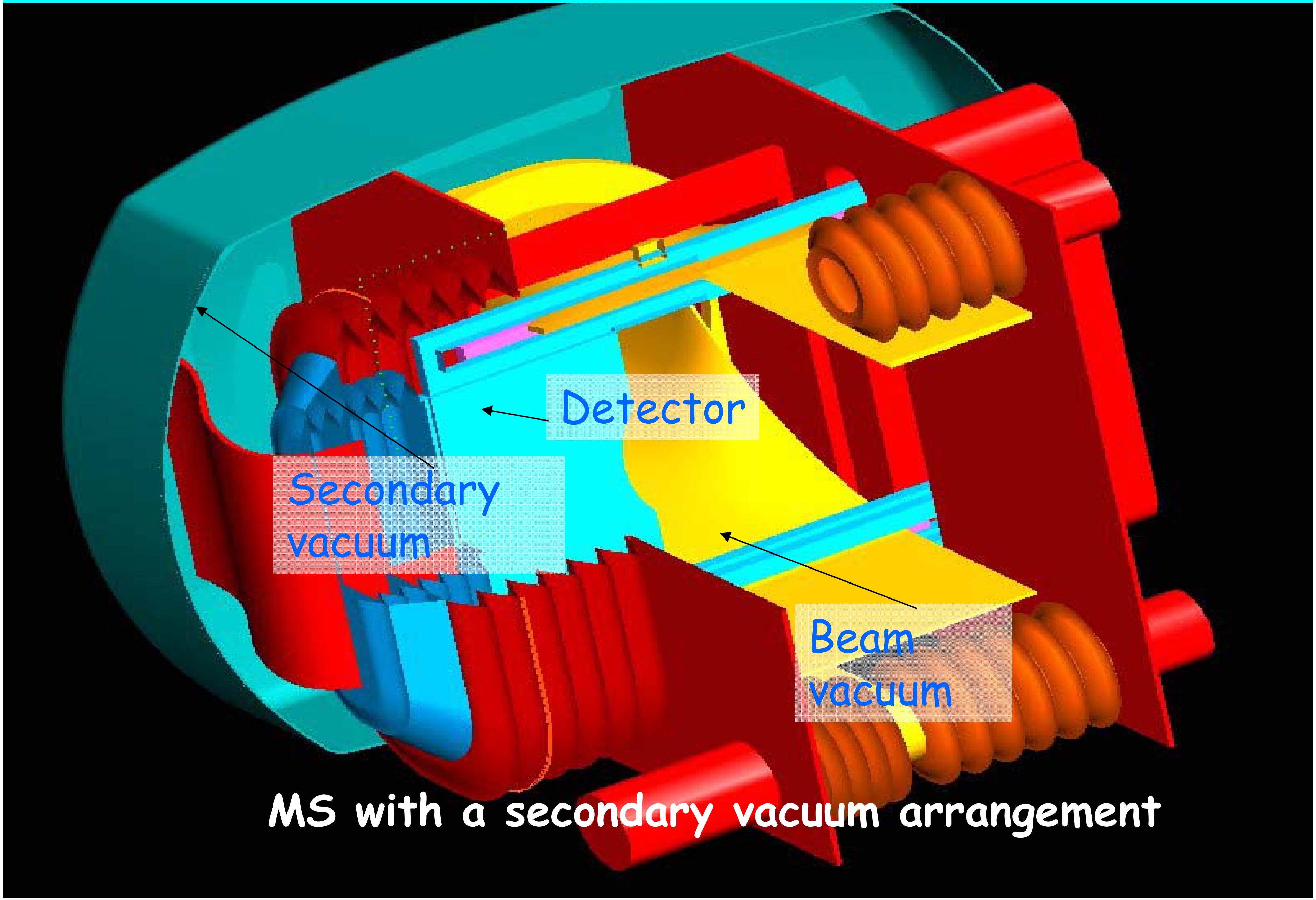


flex thermal link

space for encoders

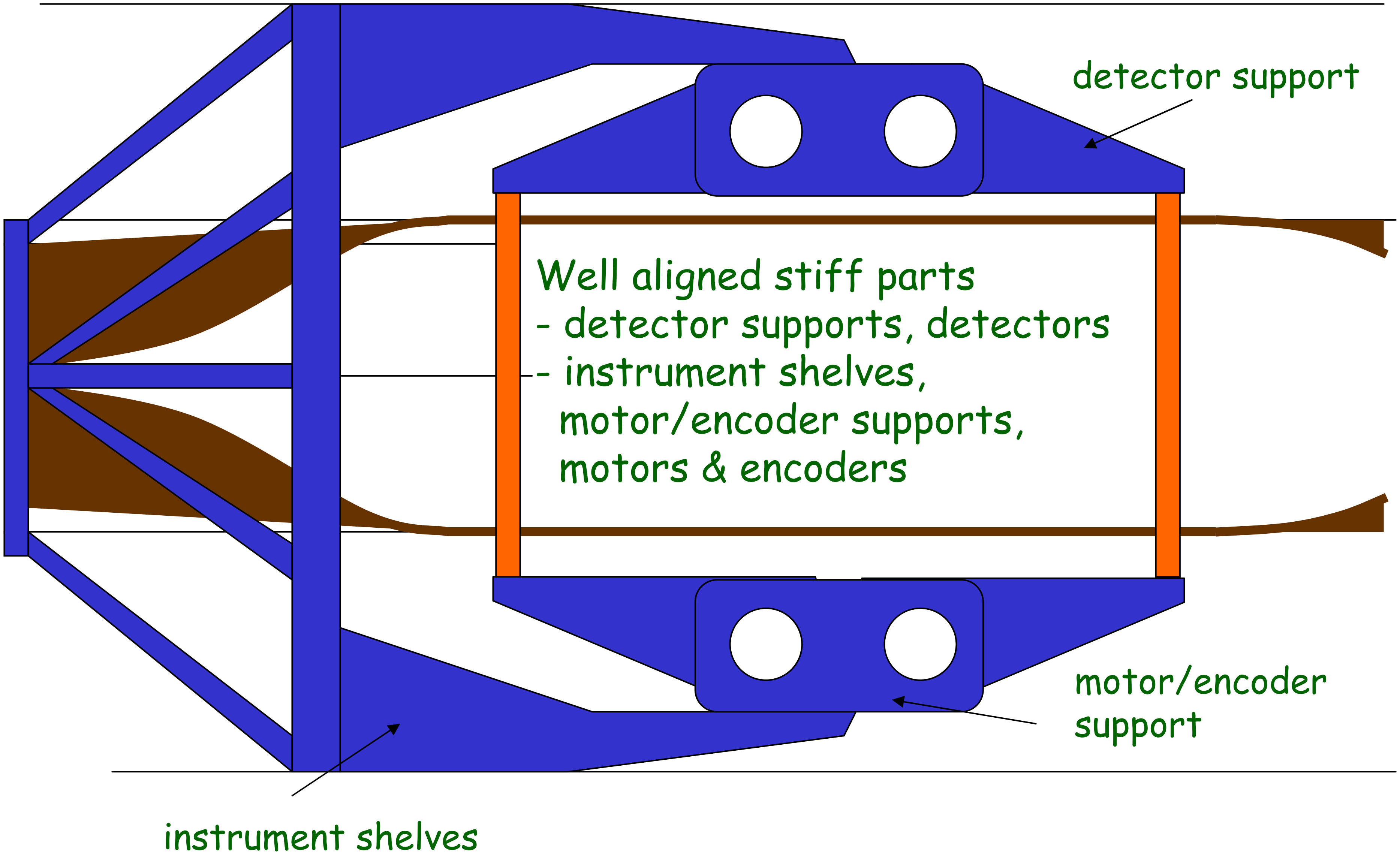
support is welded to the main tube separately

Microstation technical model v3.0

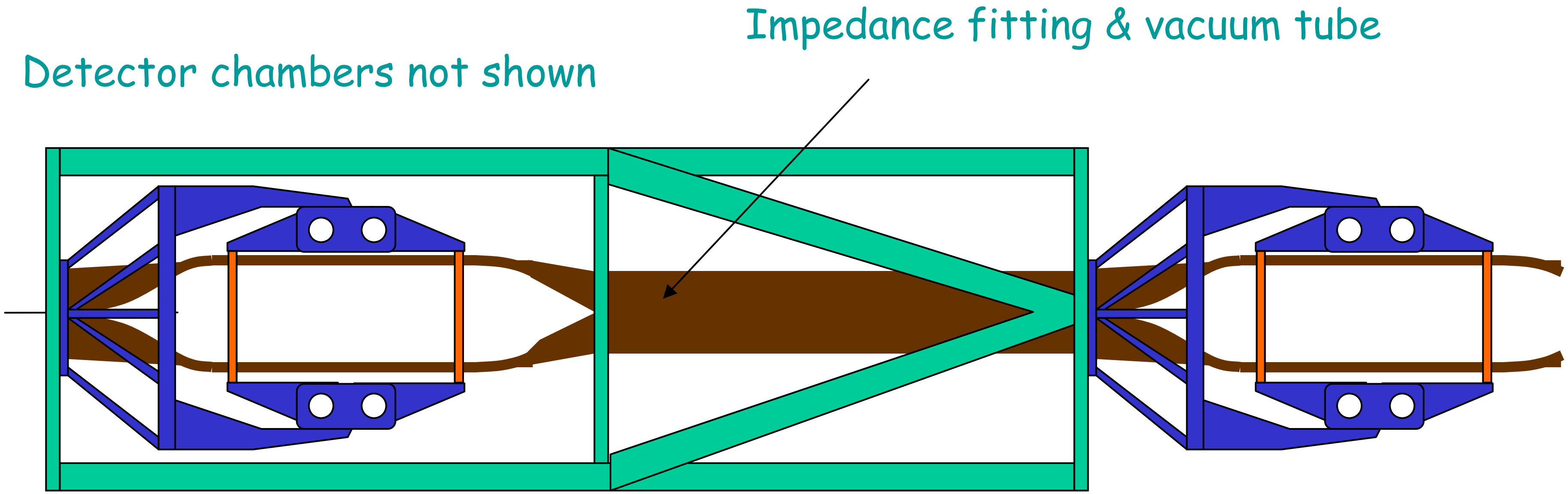


Cluster Support Mechanics v0.1

- Helsinki group:Matti Ryynänen

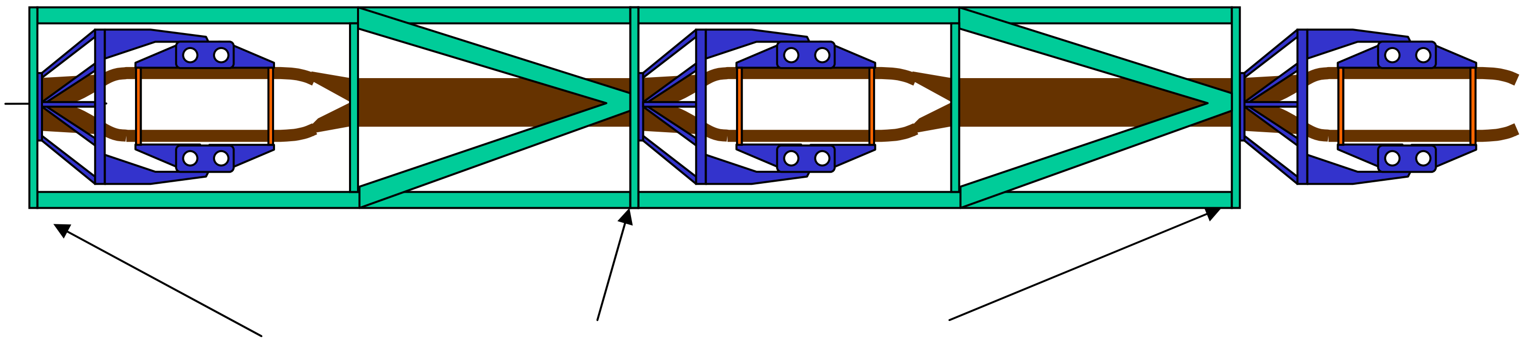


Cluster Support Mechanics v0.1



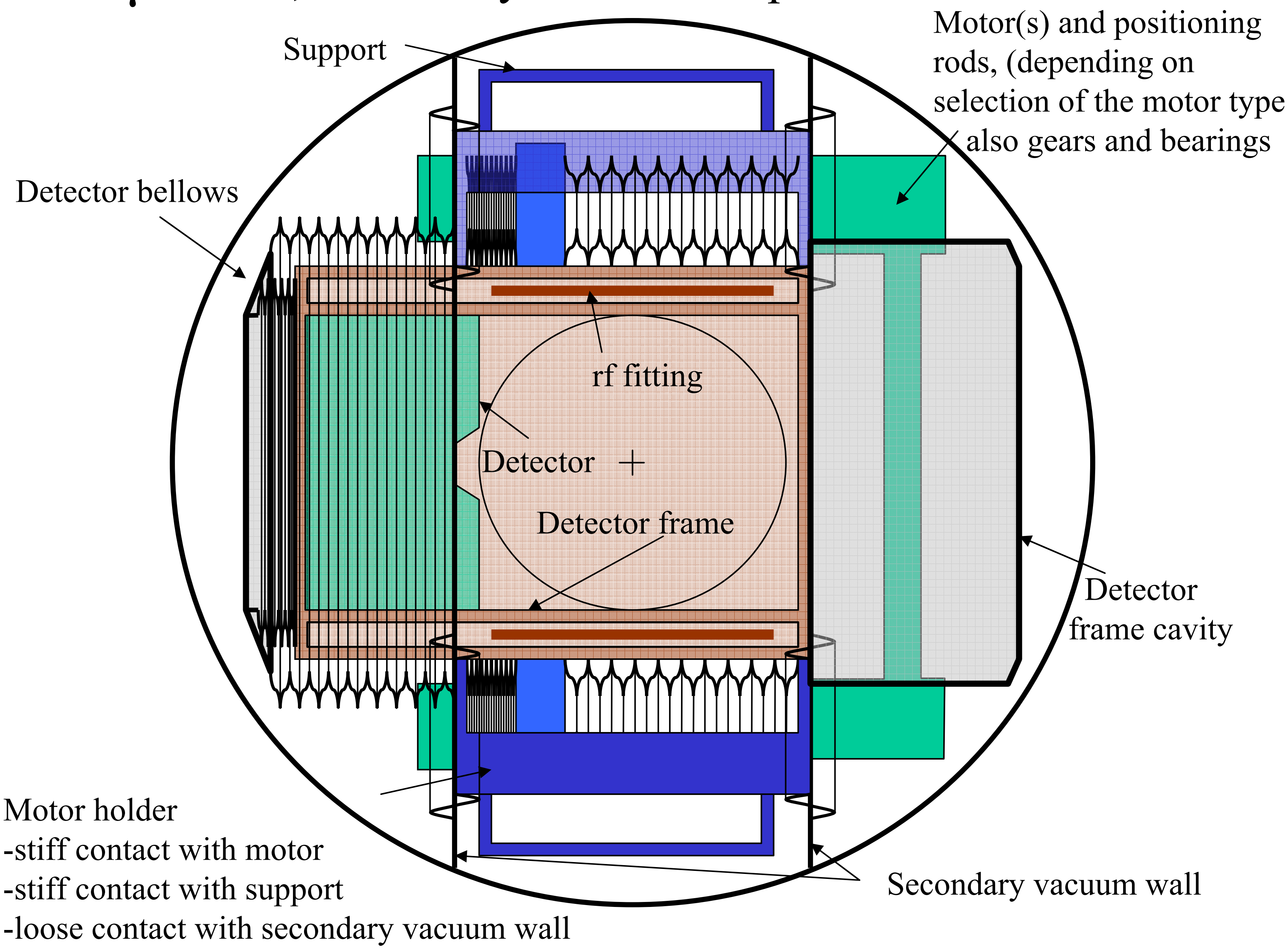
Separate parts for separate functions
- loose impedance fitting and vacuum chamber positioning
- stiff and light support for detector alignment & services

Cluster Support Mechanics v0.1

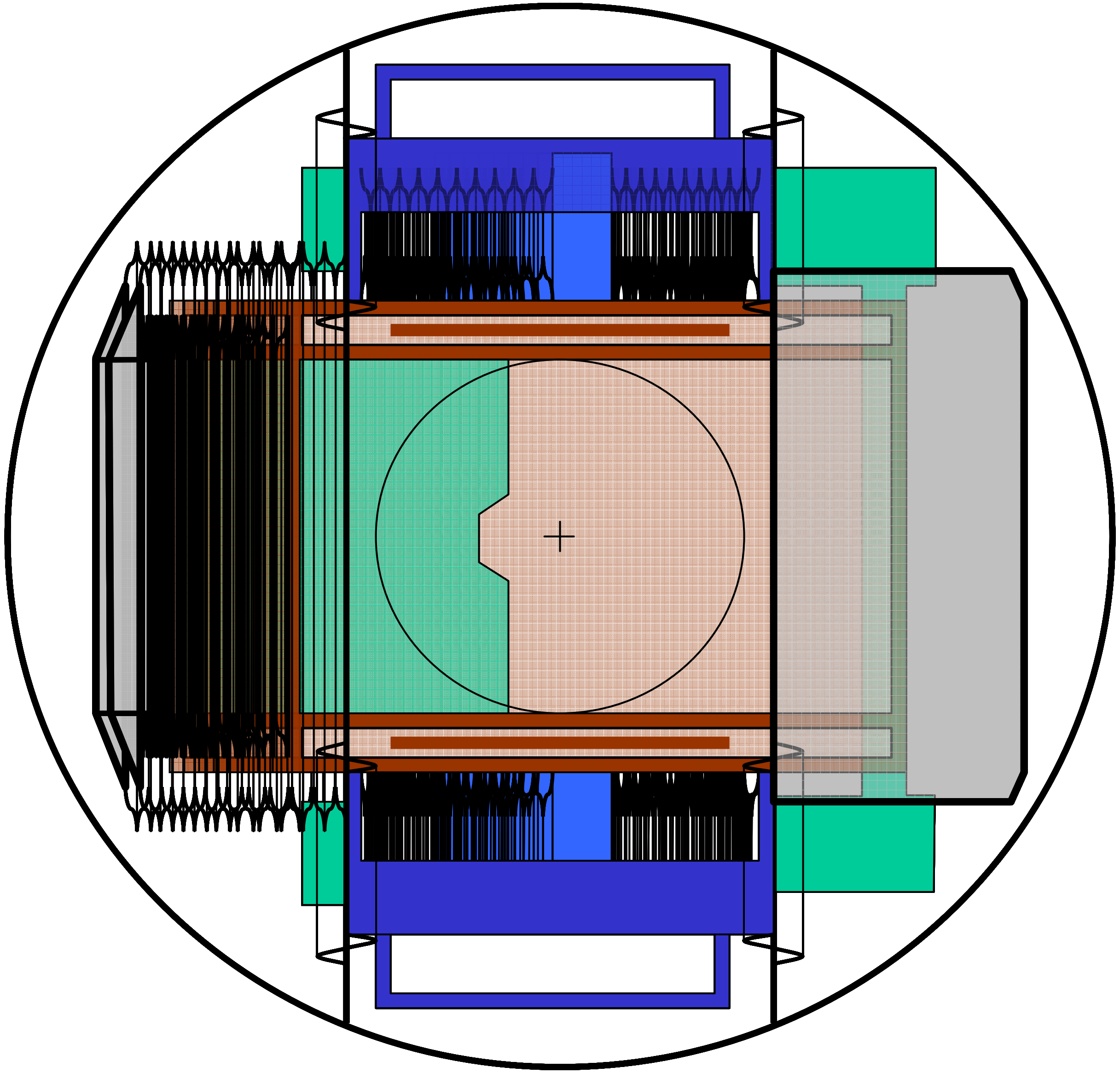


Vacuum chamber and mechanics contact points, alignment points

2.1. µstation, Secondary Vacuum Implementation



2.1. μstation, Secondary Vacuum Implementation



Matti Ryynänen KOPERO Ltd 1-03

2.1. μstation, Secondary Vacuum Implementation

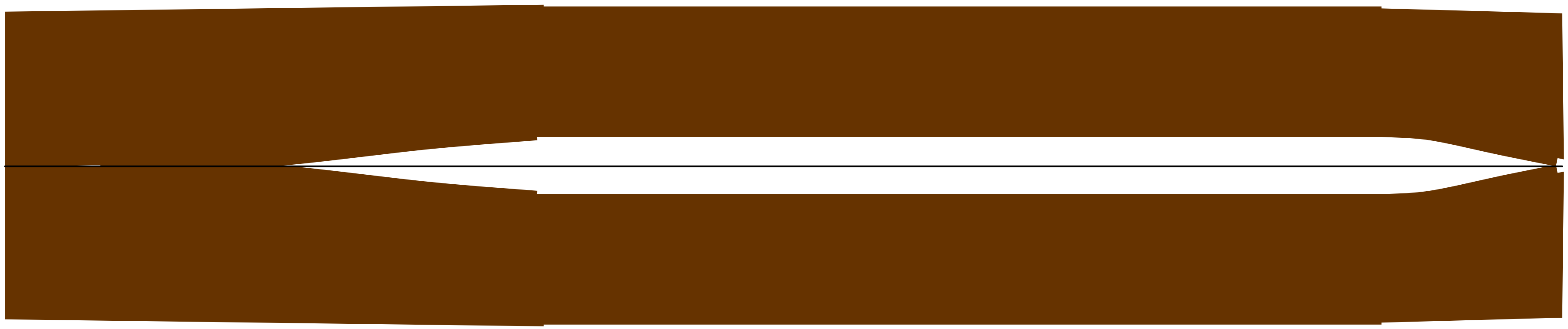
Beam tube

2.1. µstation, Secondary Vacuum Implementation

rf fitting formation

2.1. µstation, Secondary Vacuum Implementation

rf fitting formation



2.1. µstation, Secondary Vacuum Implementation

rf fitting formation

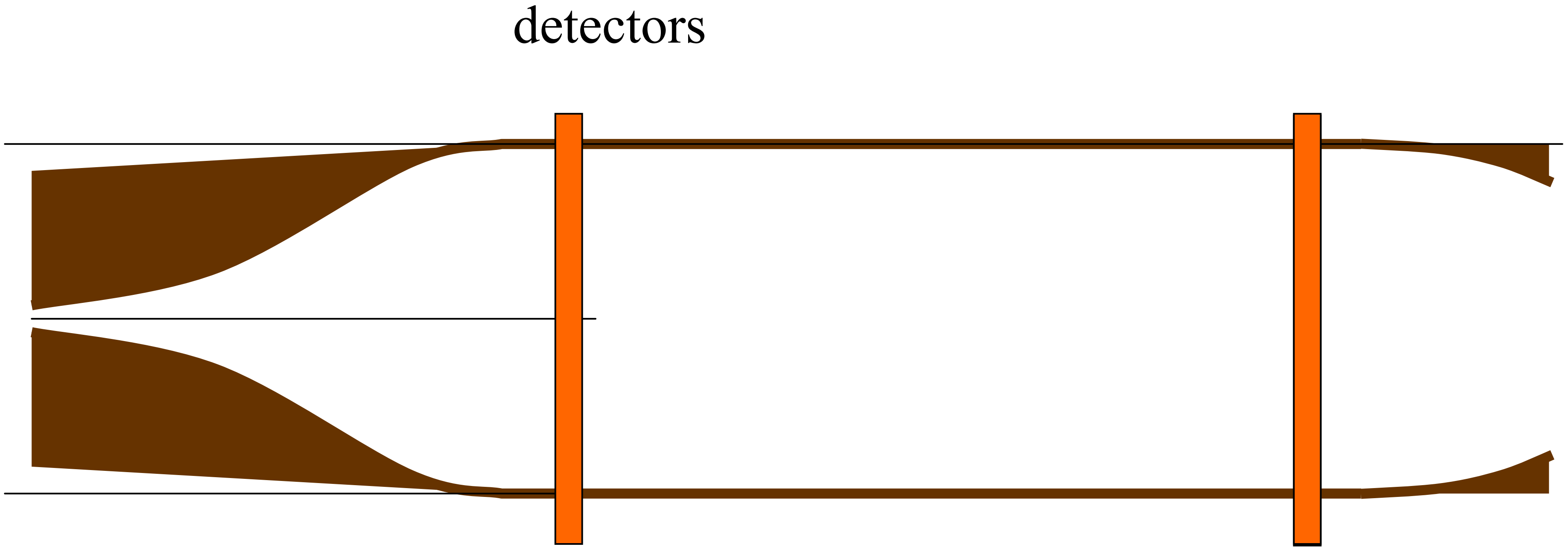
2.1. μstation, Secondary Vacuum Implementation

rf fitting formation

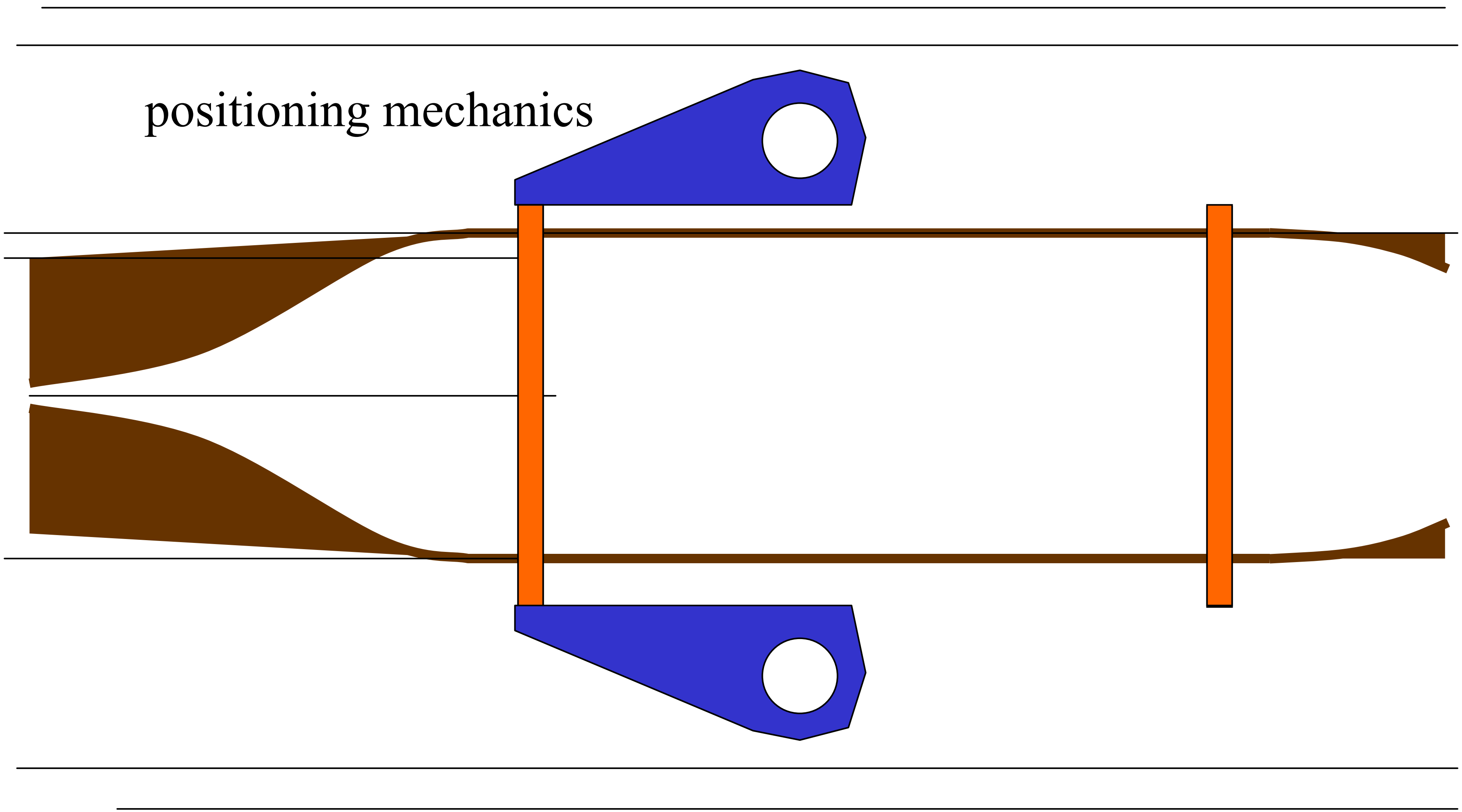
2.1. μstation, Secondary Vacuum Implementation

rf fitting formation

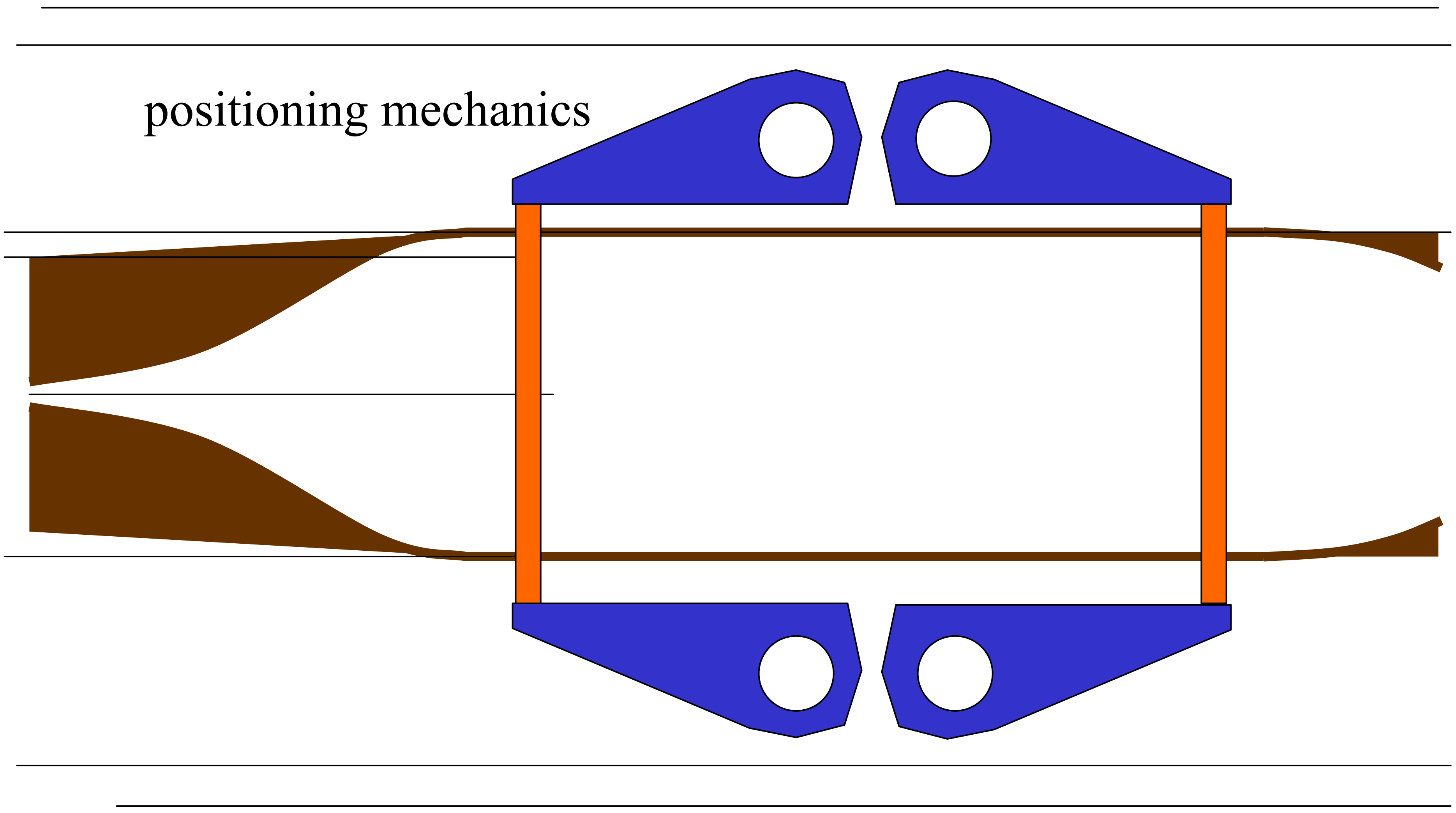
2.1. μstation, Secondary Vacuum Implementation



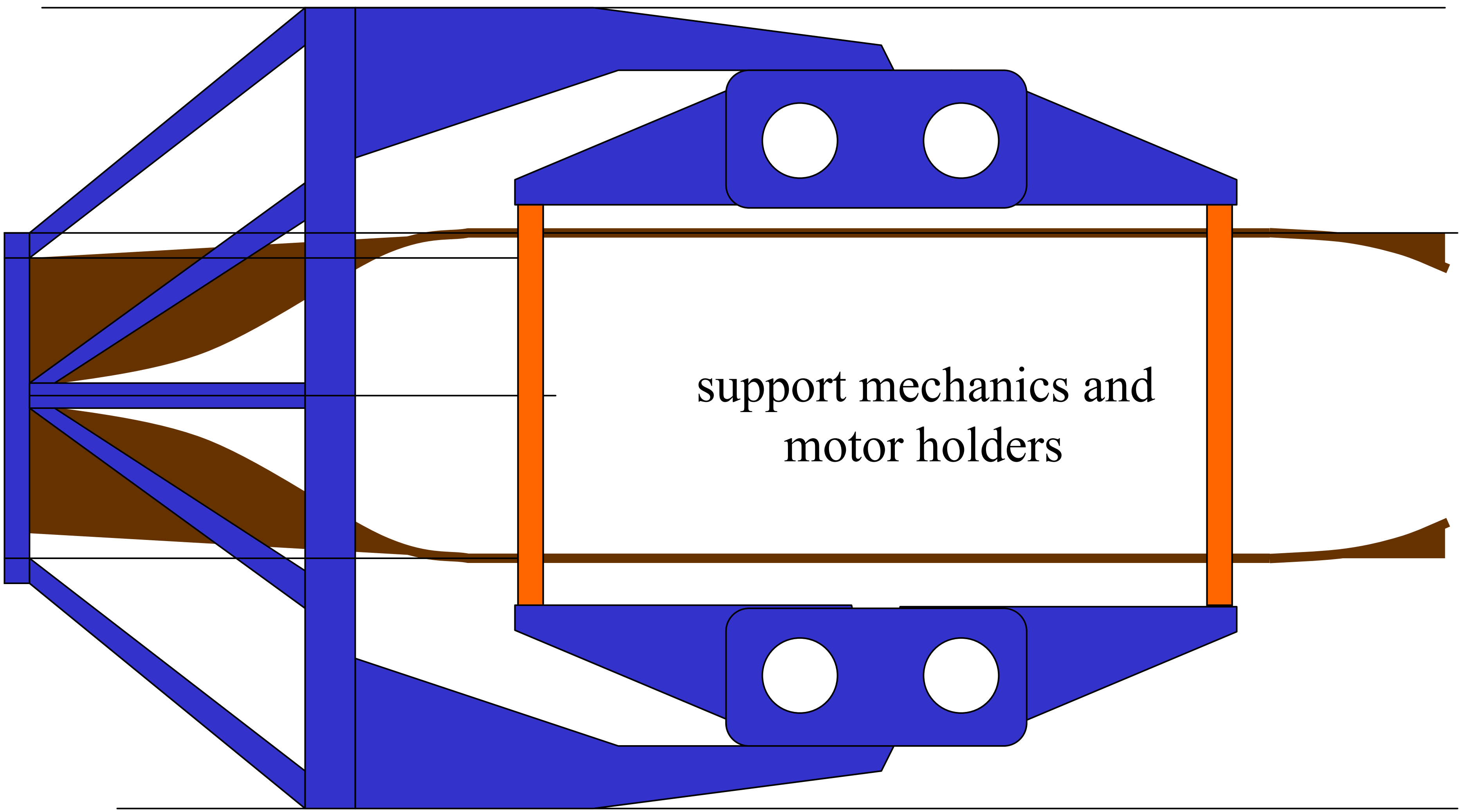
2.1. µstation, Secondary Vacuum Implementation



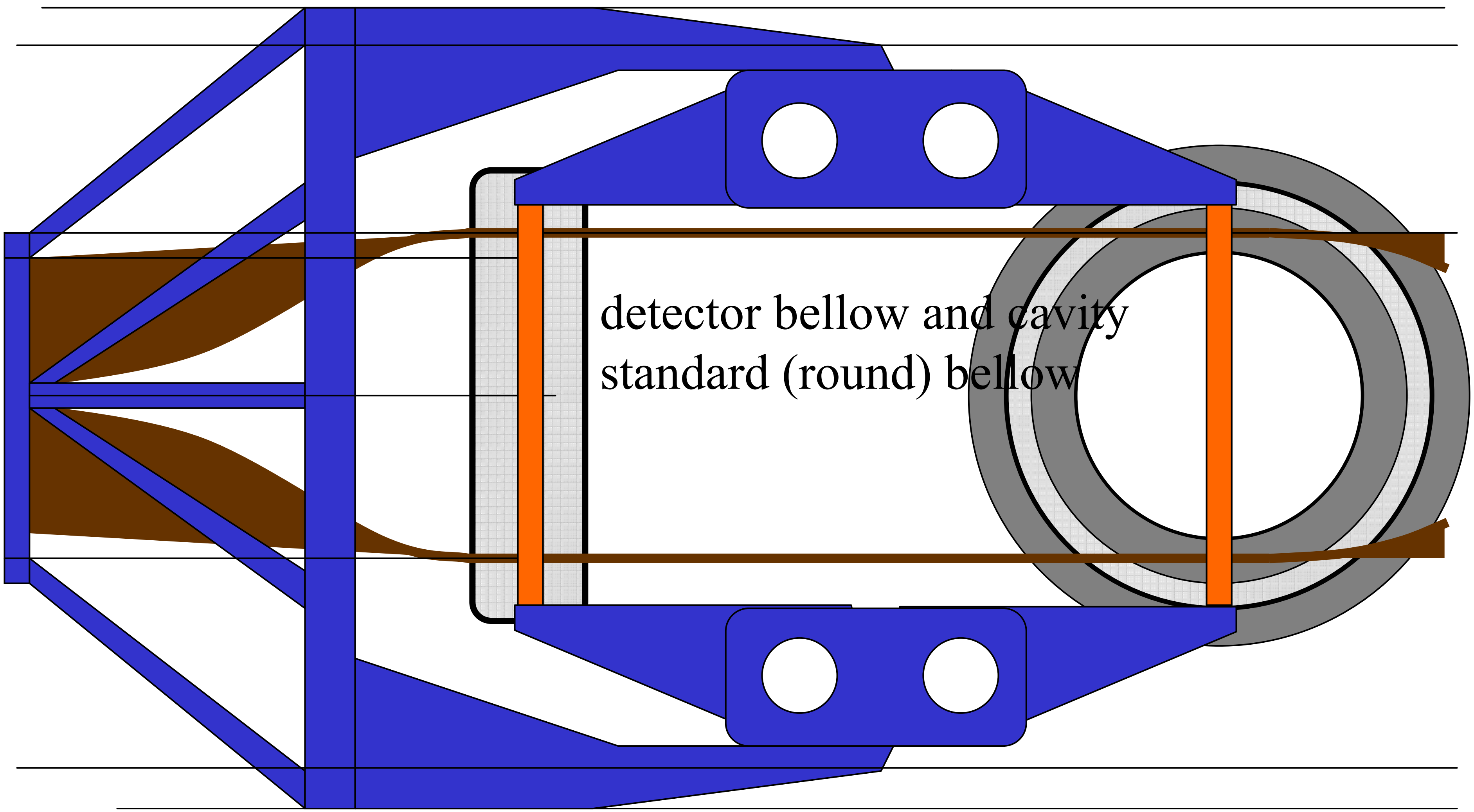
2.1. µstation, Secondary Vacuum Implementation



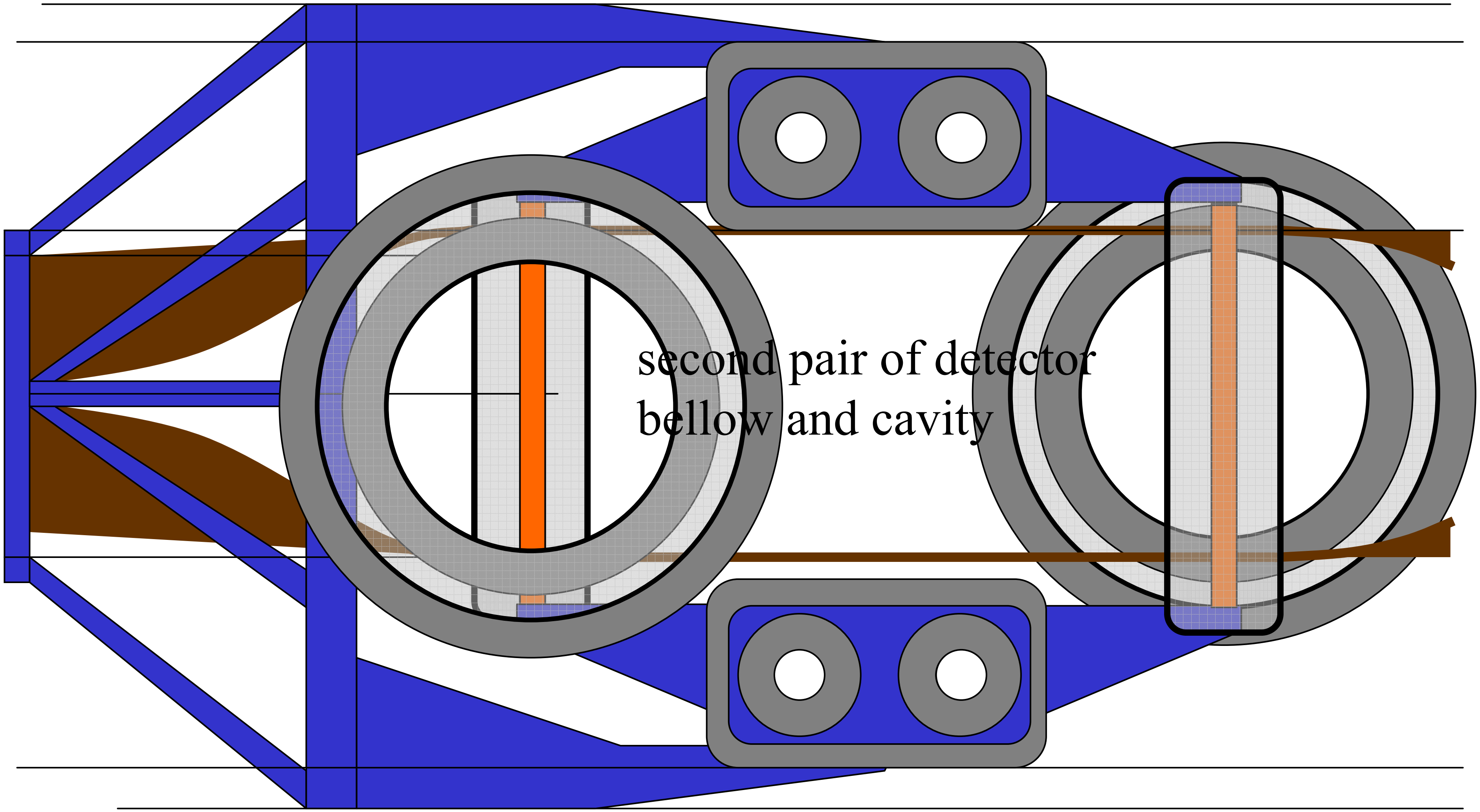
2.1. μstation, Secondary Vacuum Implementation



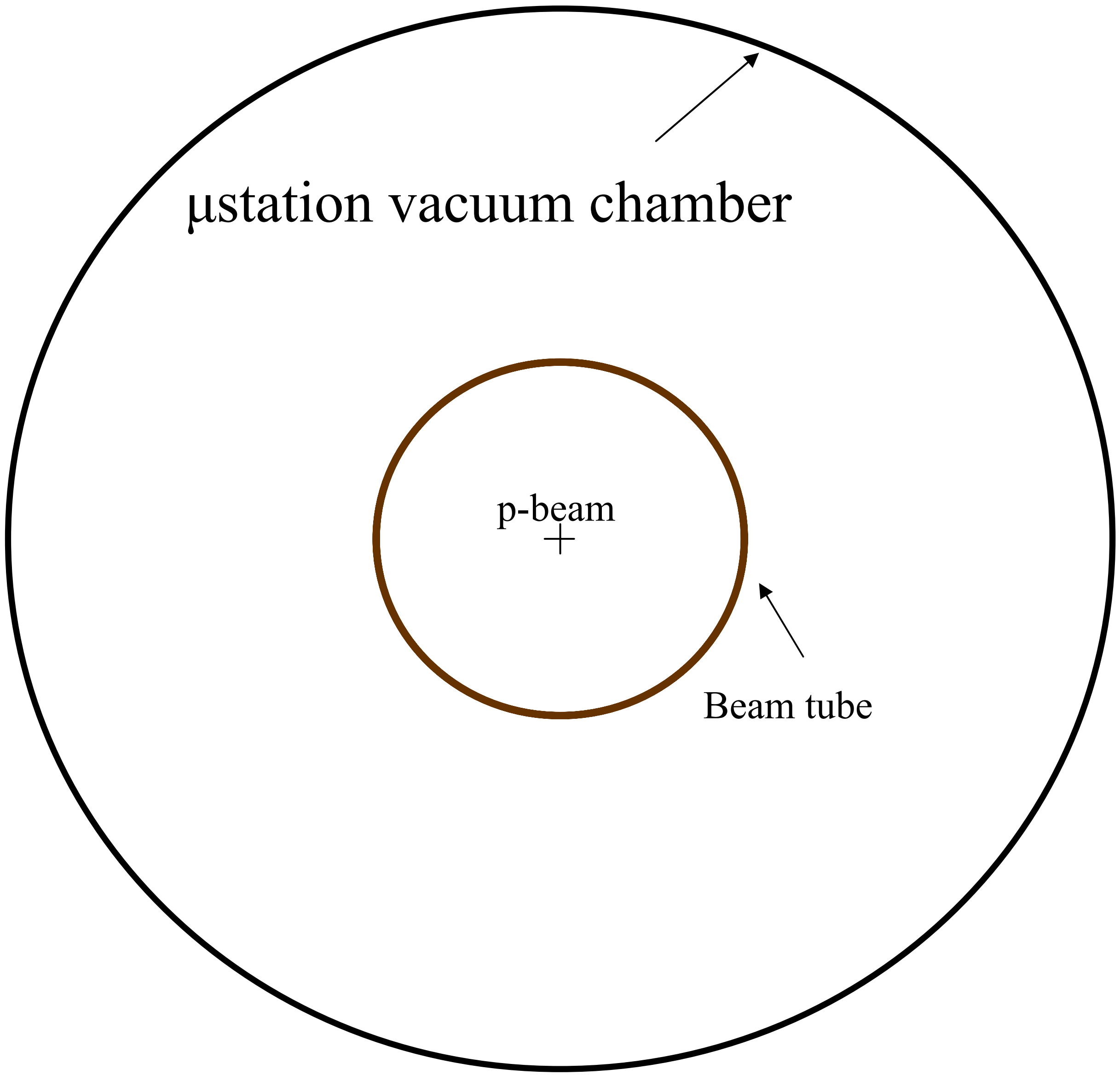
2.1. μstation, Secondary Vacuum Implementation



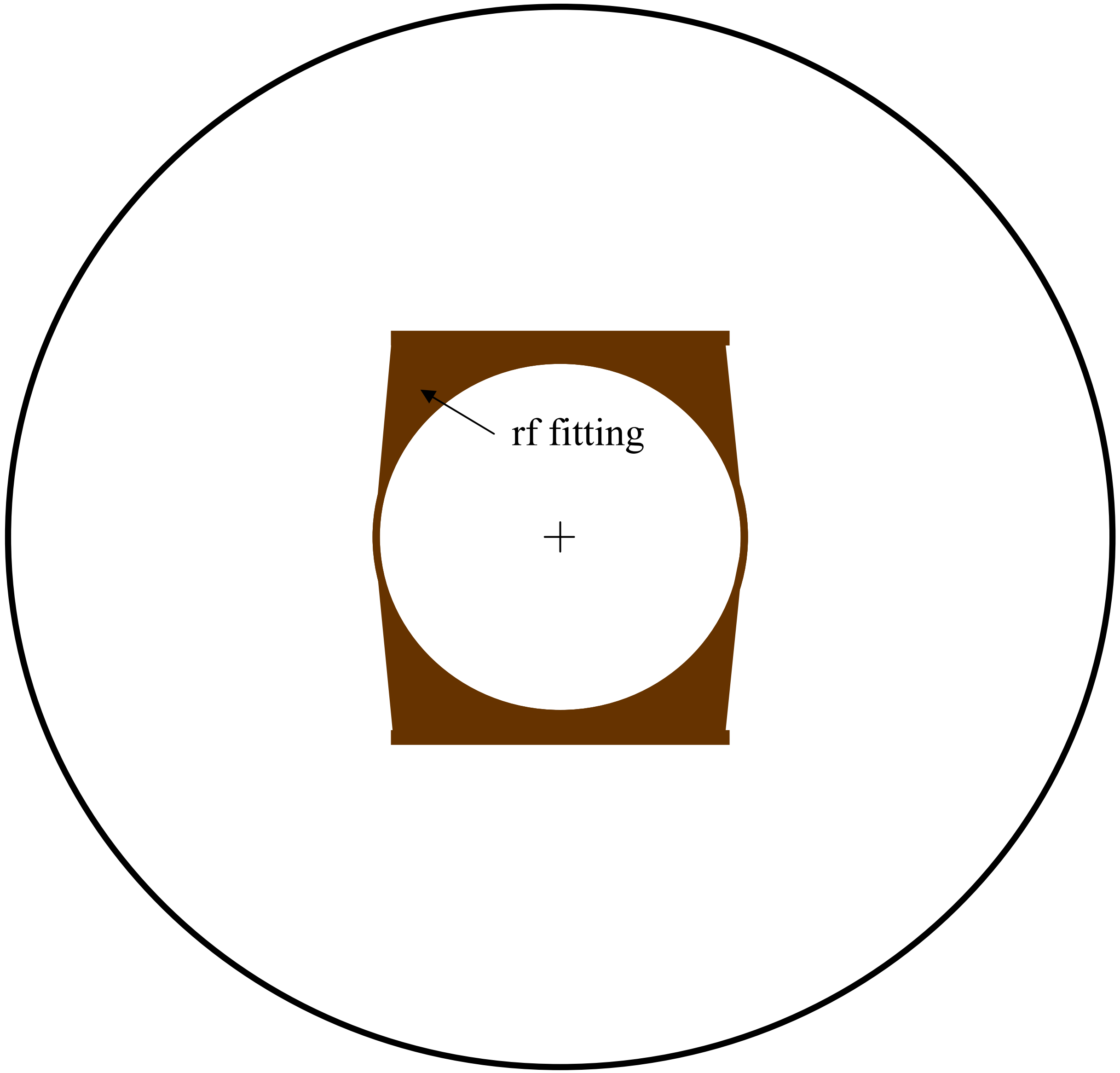
2.1. µstation, Secondary Vacuum Implementation



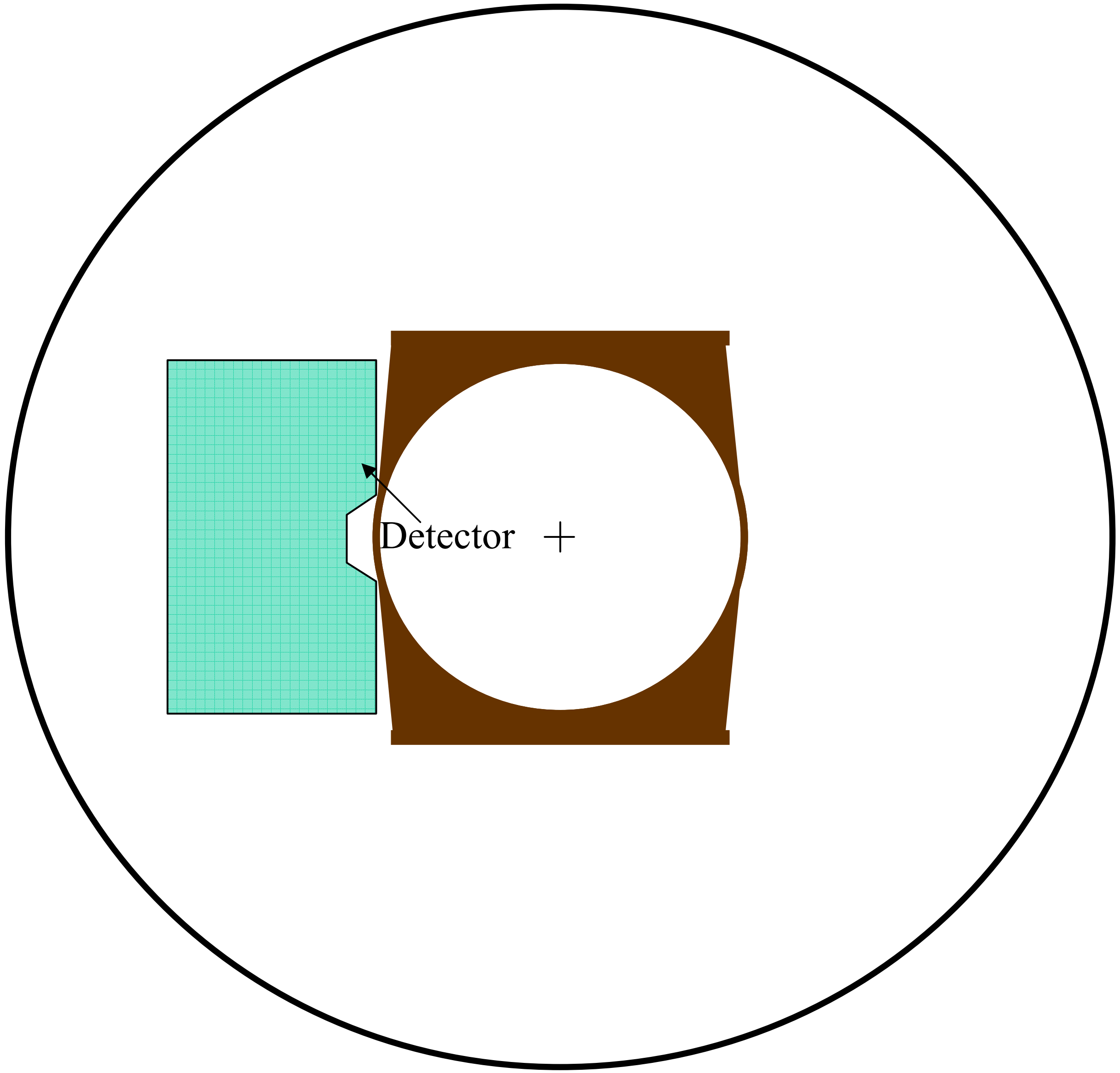
2.1. μstation, Secondary Vacuum Implementation



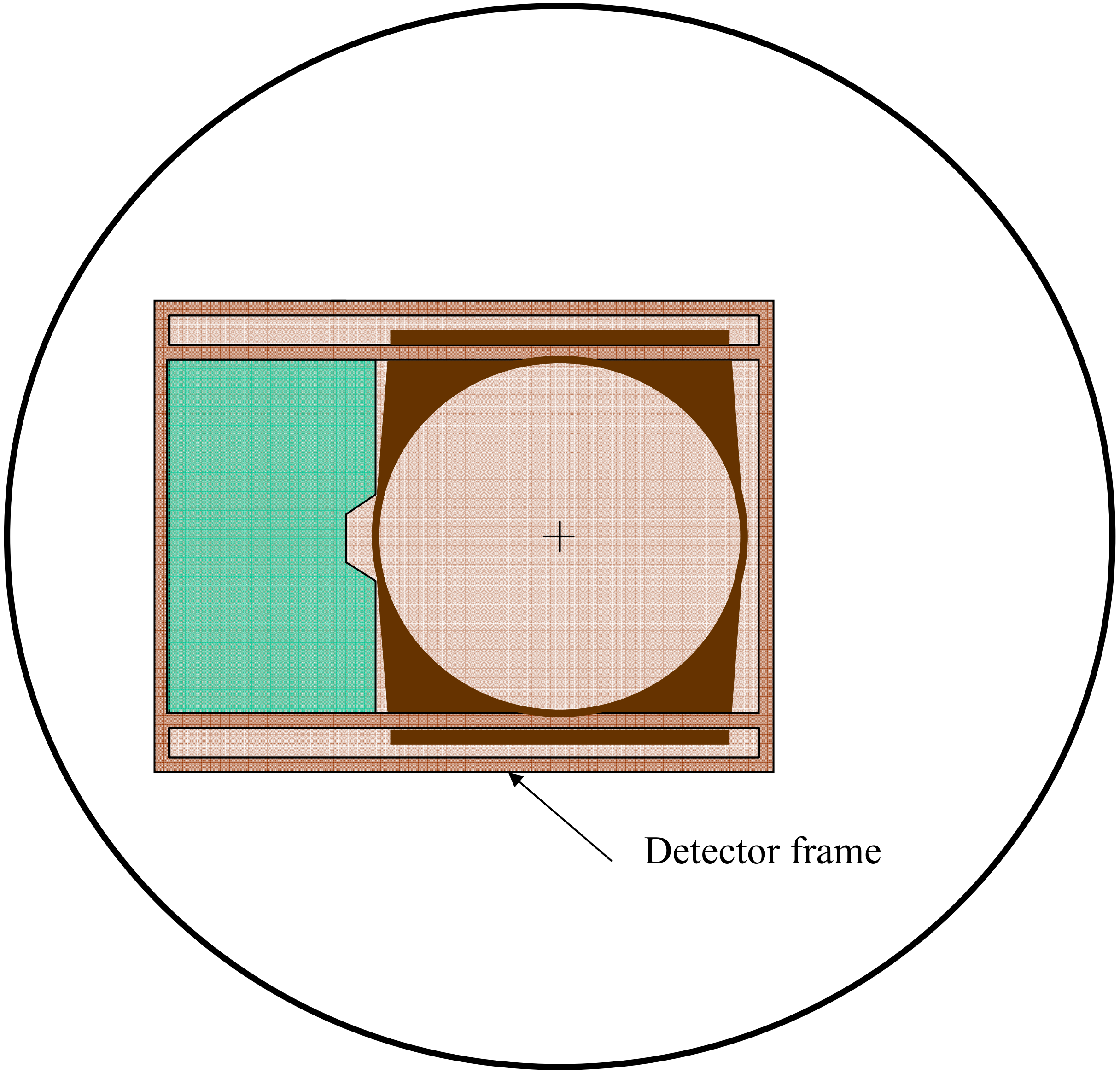
2.1. μstation, Secondary Vacuum Implementation



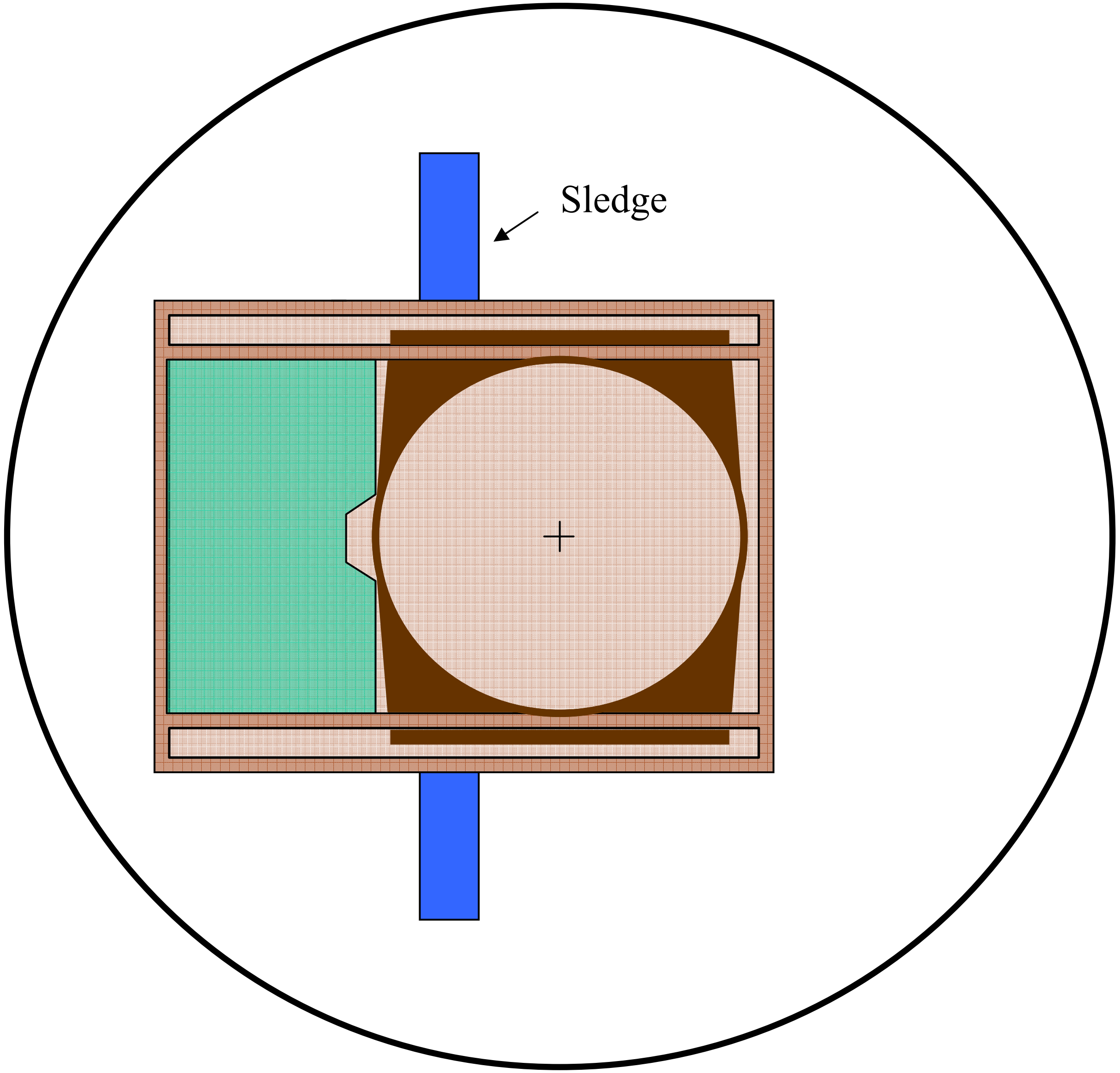
2.1. µstation, Secondary Vacuum Implementation



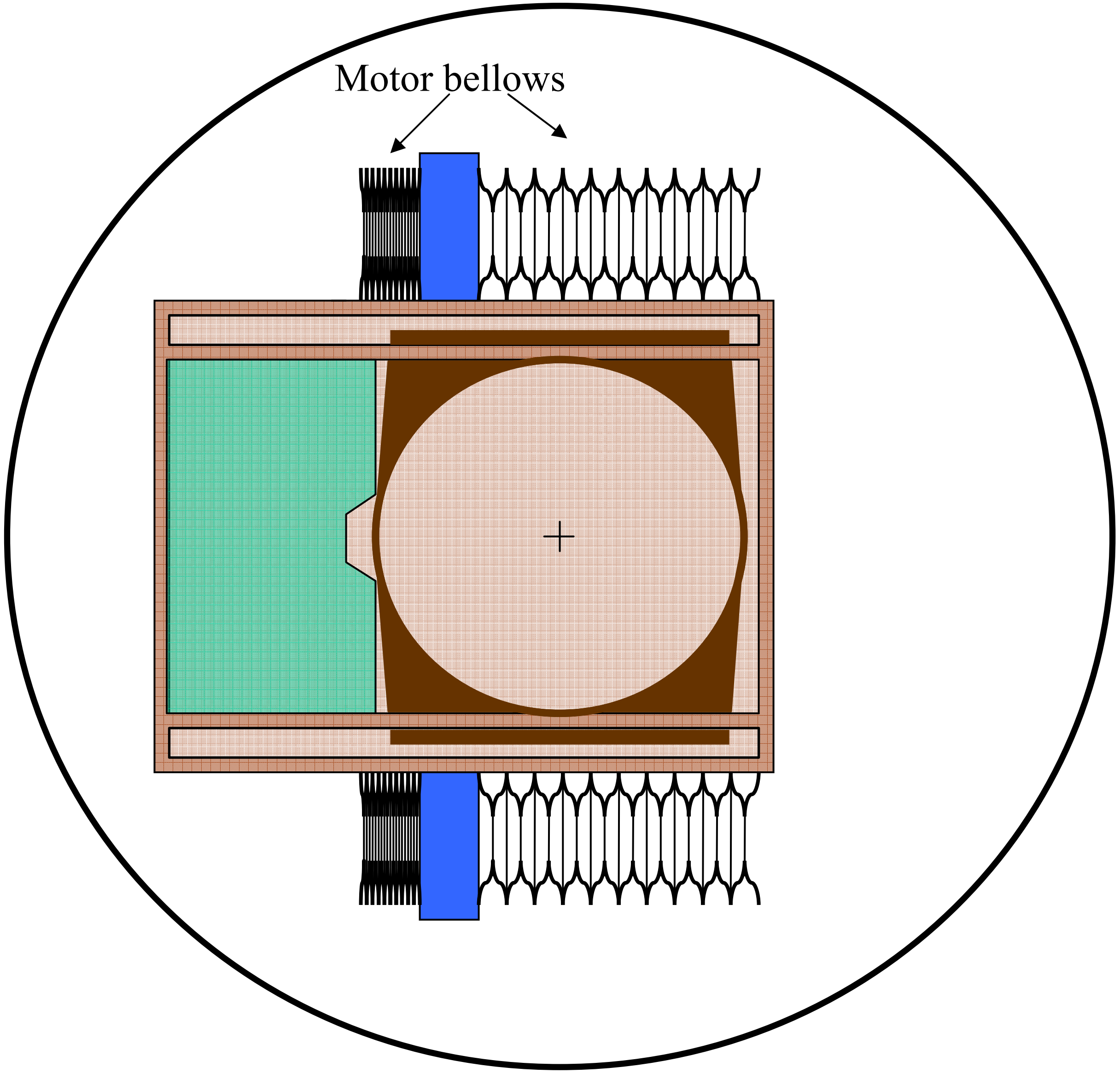
2.1. μstation, Secondary Vacuum Implementation



2.1. µstation, Secondary Vacuum Implementation

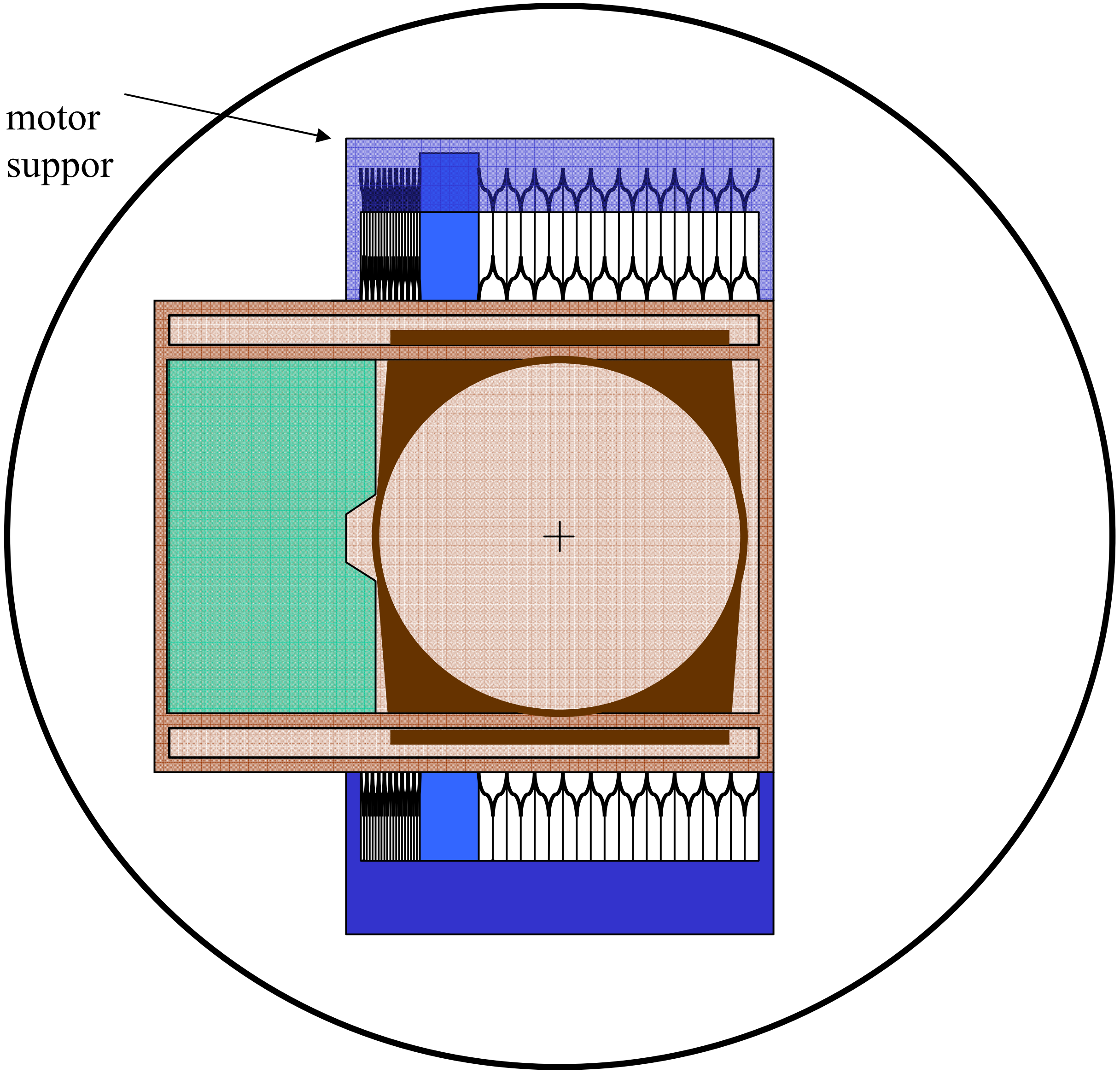


2.1. µstation, Secondary Vacuum Implementation

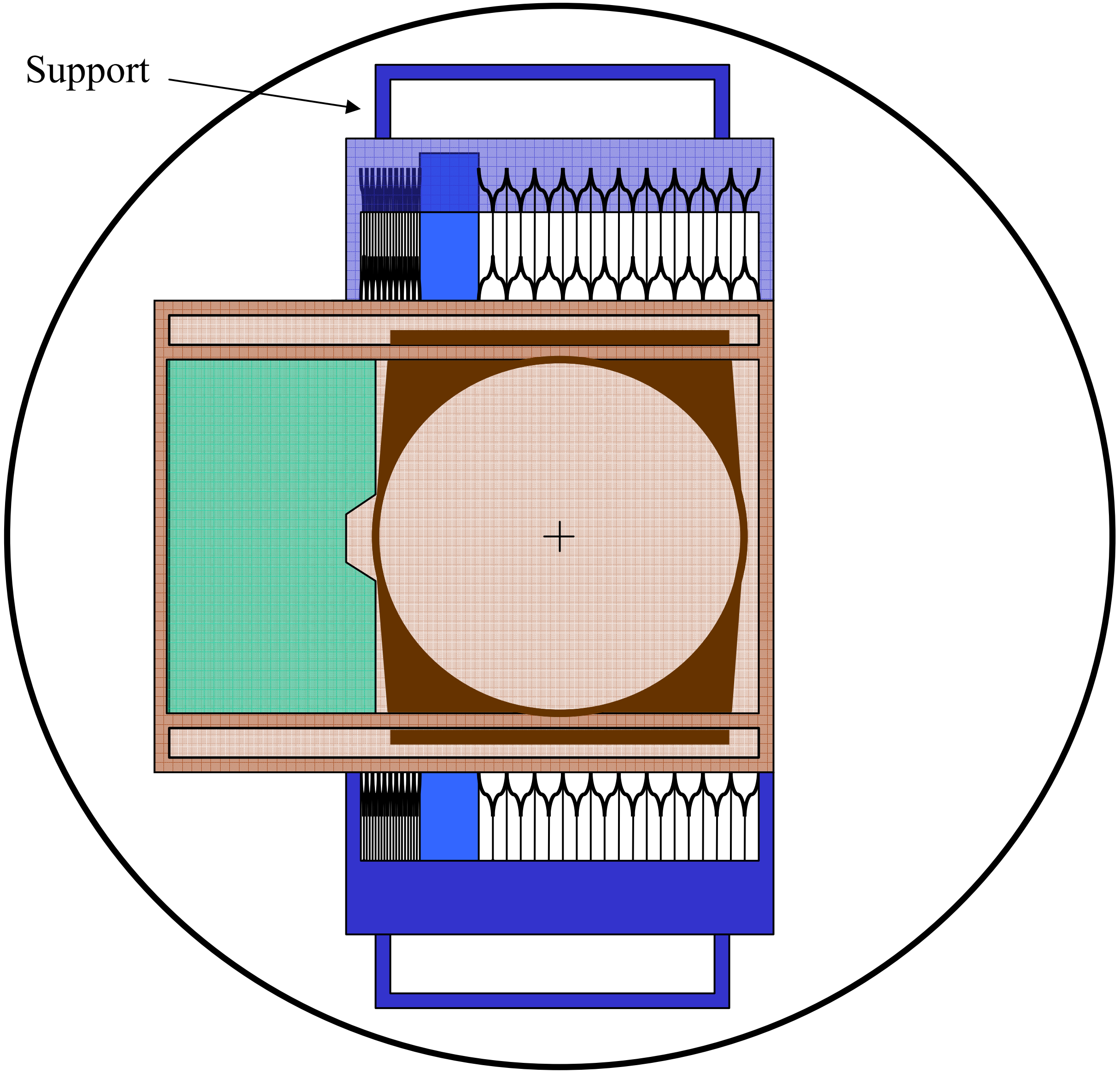


2.1. μstation, Secondary Vacuum Implementation

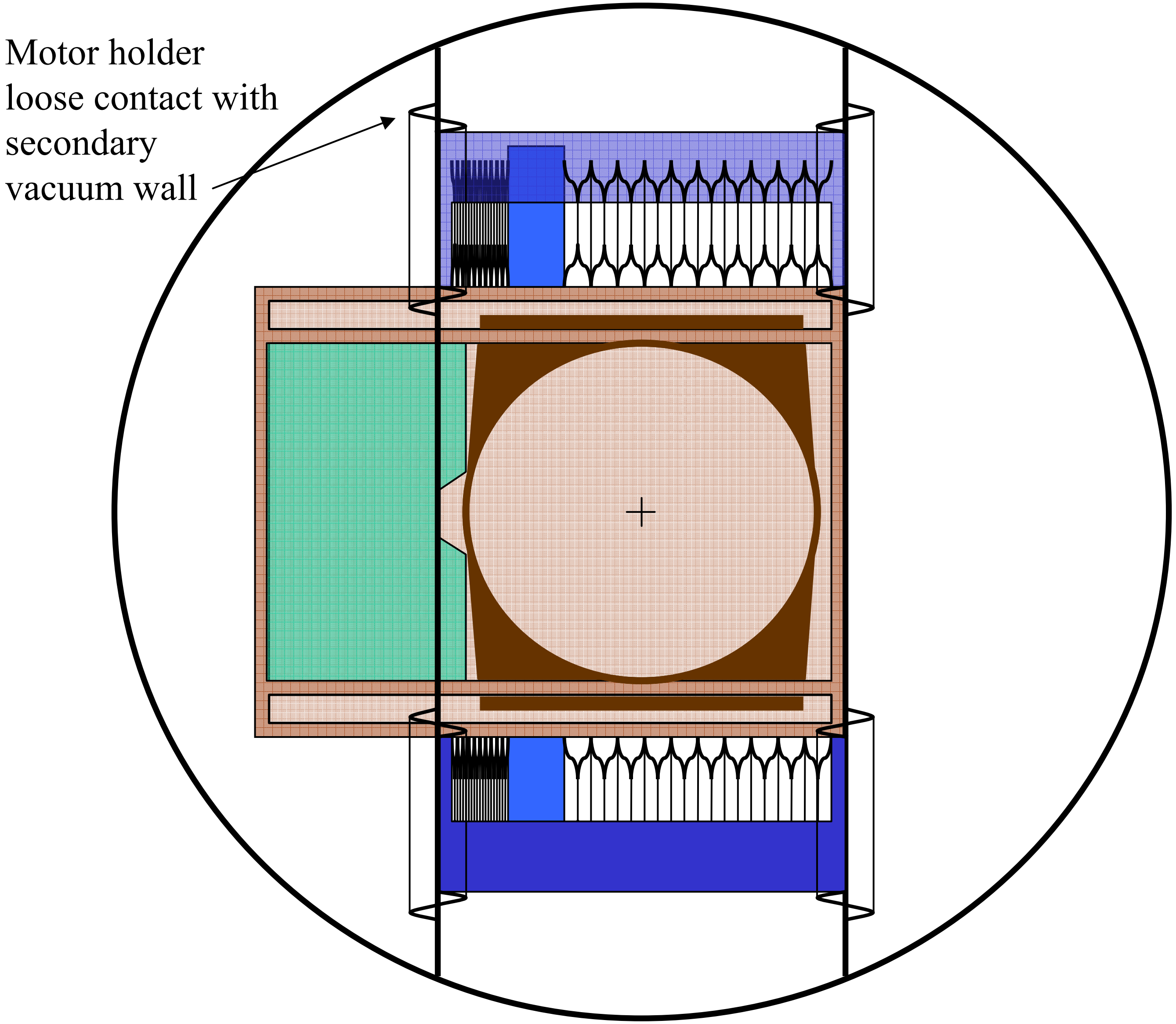
Motor holder
-stiff contact with motor
-stiff contact with suppor



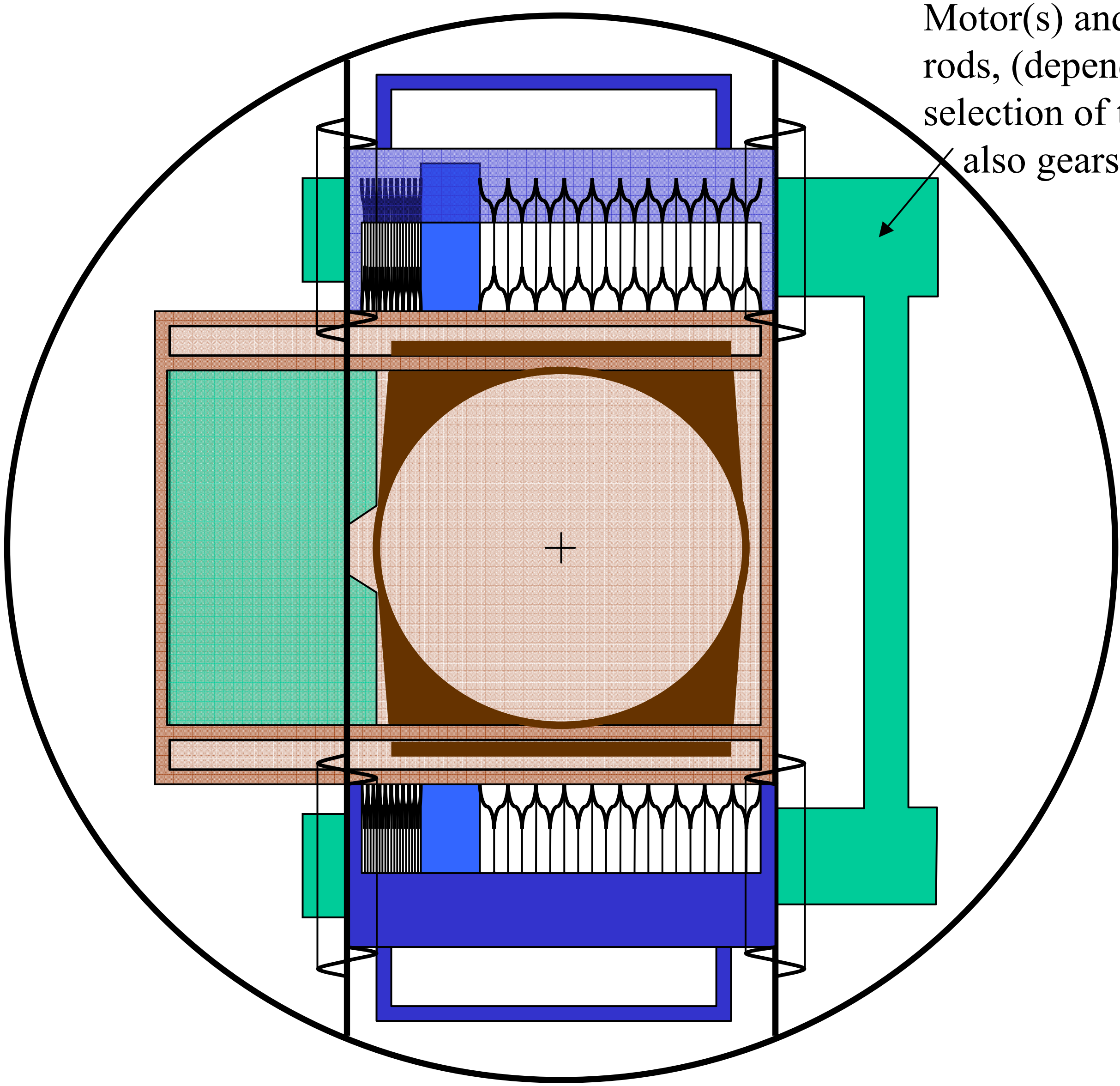
2.1. μstation, Secondary Vacuum Implementation



2.1. µstation, Secondary Vacuum Implementation

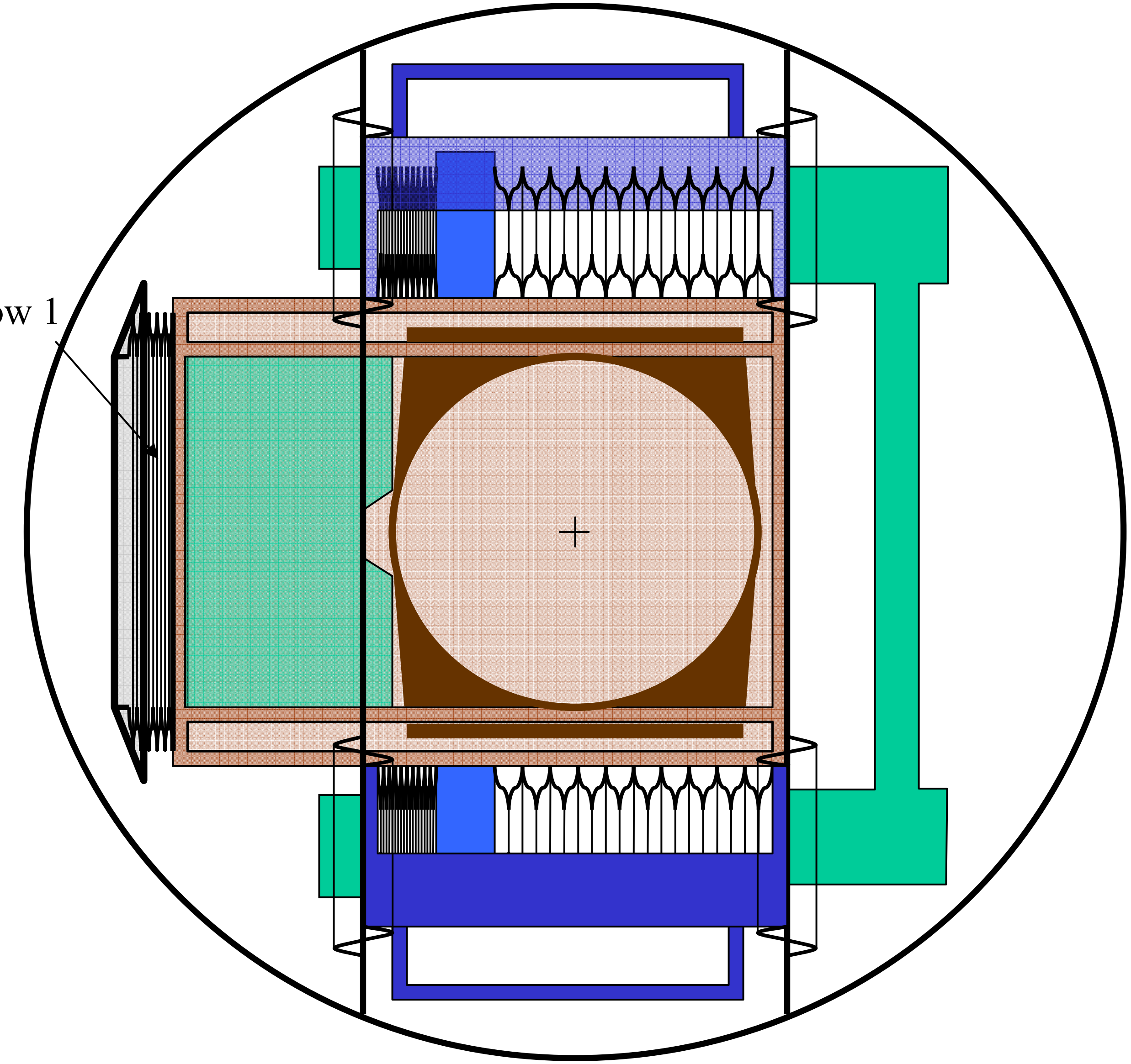


2.1. µstation, Secondary Vacuum Implementation

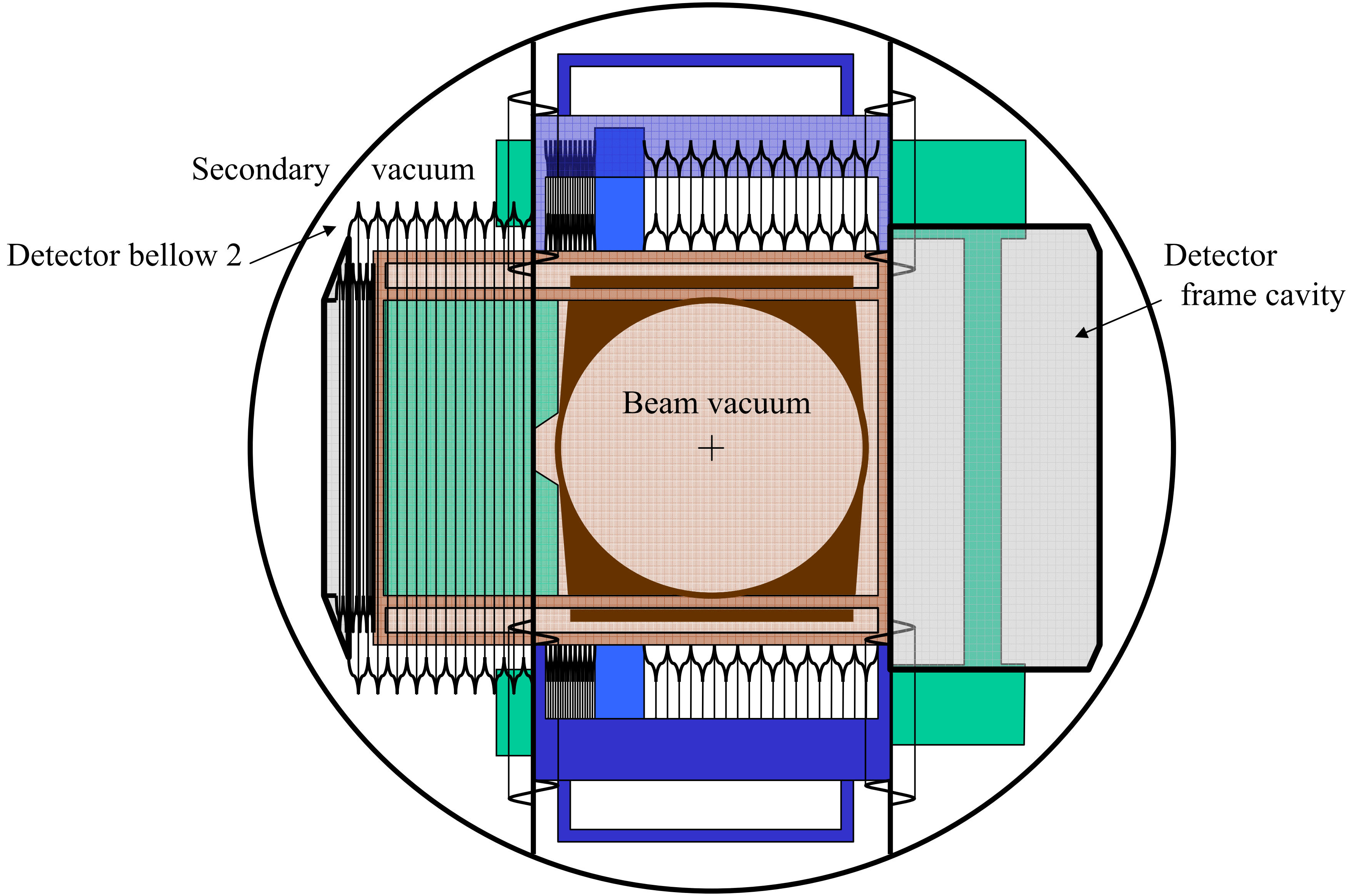


2.1. μstation, Secondary Vacuum Implementation

Detector bellow 1

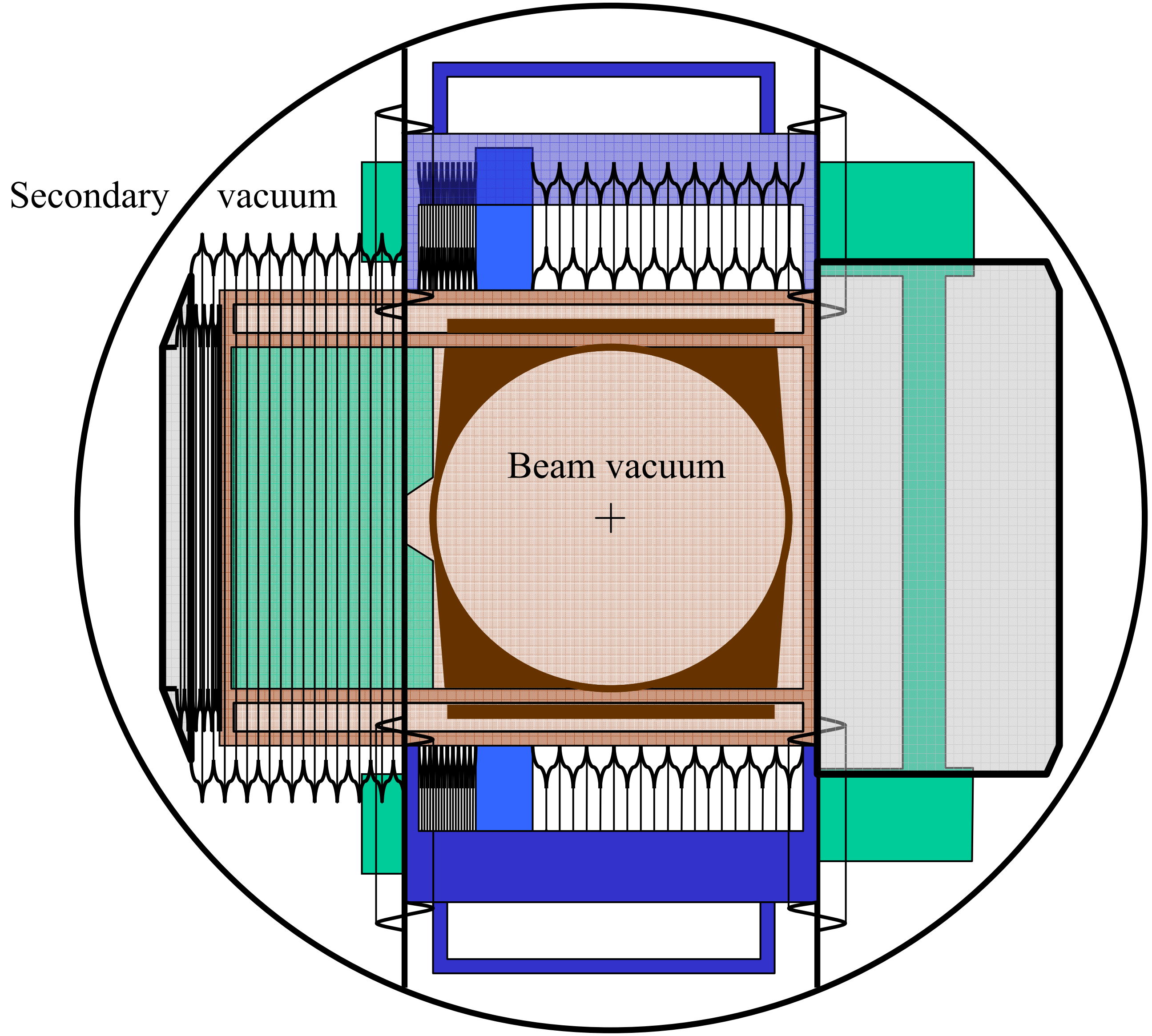


2.1. µstation, Secondary Vacuum Implementation



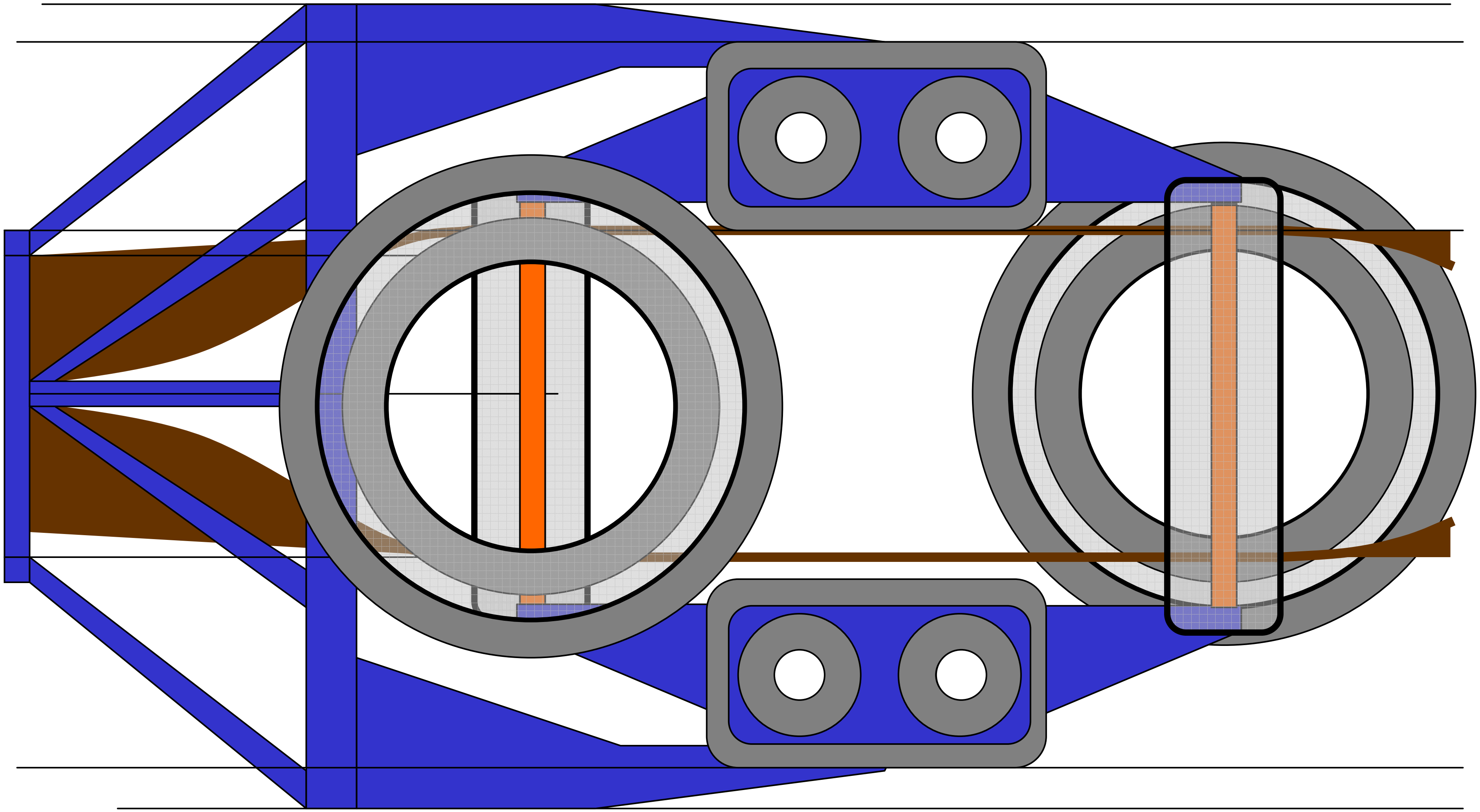
Matti Ryynänen KOPERO Ltd 1-03

2.1. µstation, Secondary Vacuum Implementation

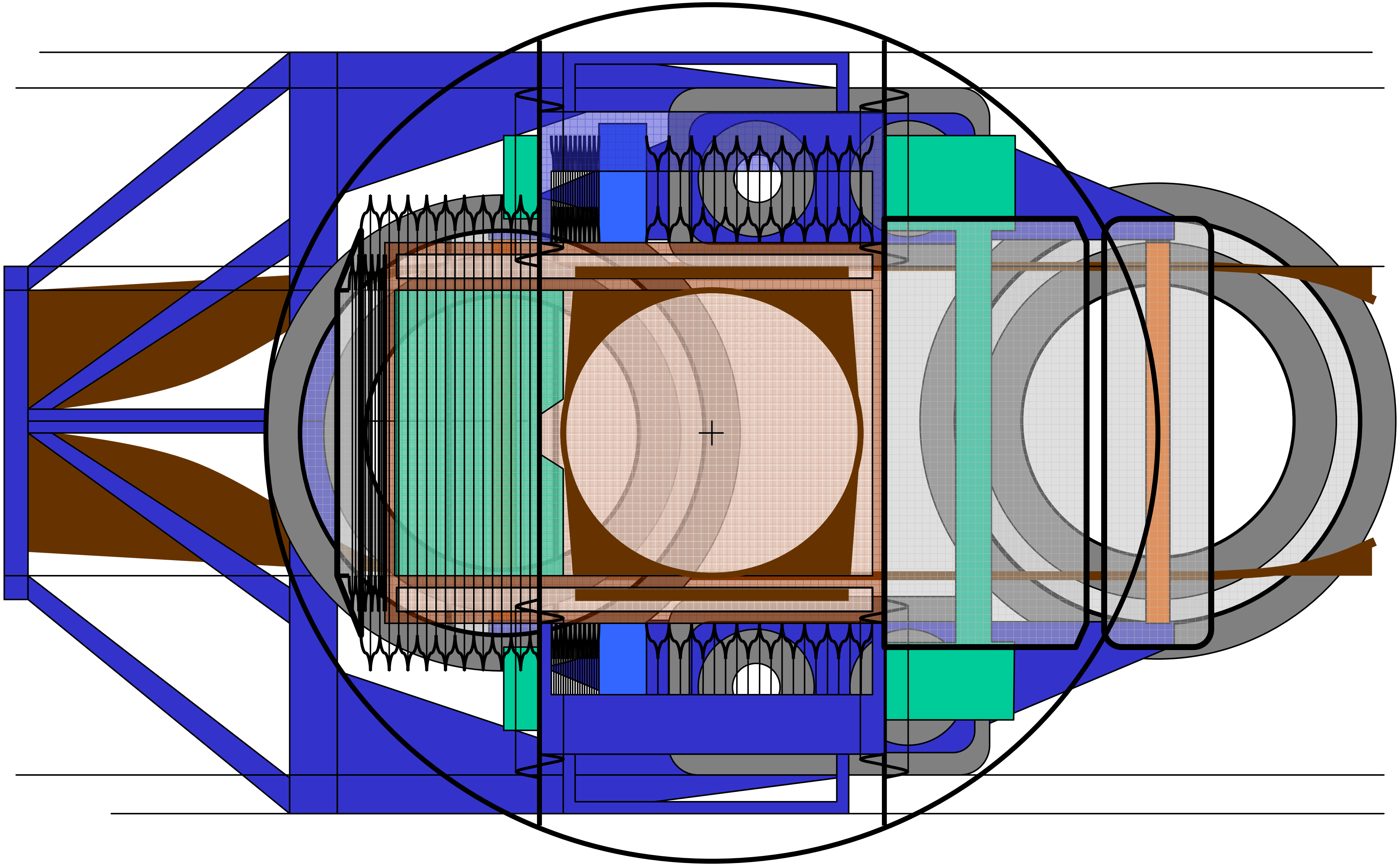


Matti Ryynänen KOPERO Ltd 1-03

2.1. μstation, Secondary Vacuum Implementation



2.1. μstation, Secondary Vacuum Implementation



Matti Ryynänen KOPERO Ltd 1-03

Components – mostly off-the-shelf

- Motors (Burleigh, UHVM)
- Encoders (Heidenhein, custom), may not be needed
- Electrical and optical feed troughs (Ceramaseal)
- Detectors (3D Si-structures, custom)
- Cables (Spec55 Space Wire, custom)
- Heat link (eg. as in roman pots with fore vacuum, custom two approaches)
- Heat exchanger (eg. as in roman pots with for vacuum)
- Emergency actuator (custom)
- Impedance fitting (custom)
- Component support (custom)
- Chamber (deep drawn, TIG, EB, and LASER welded)

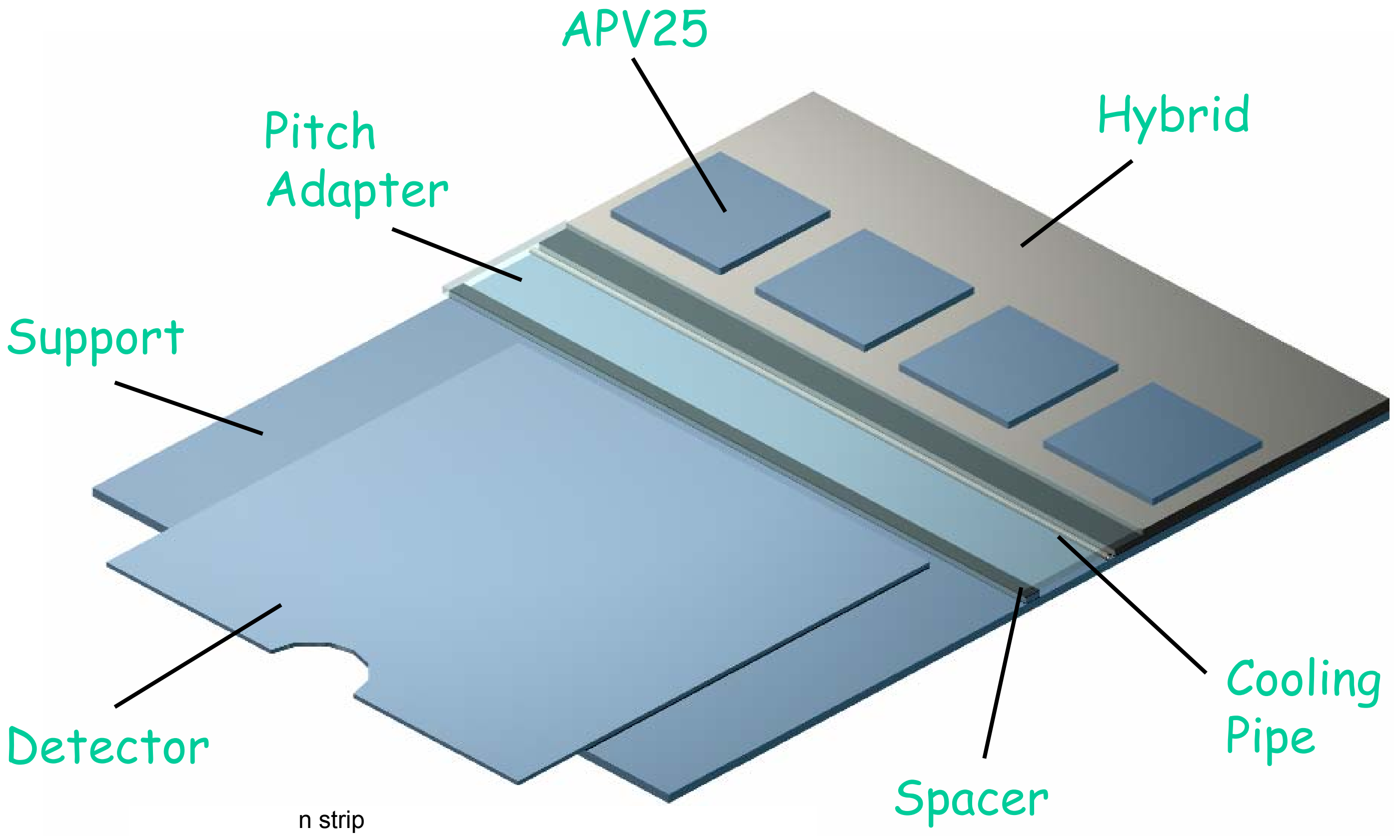
Microstation construction

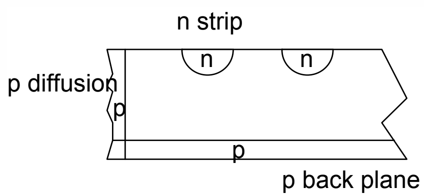
- no moving baffles in normal operation
- all welded assembly
- different functions separated, modular construction
  - vacuum chamber, free shape
  - motor and encoder support mechanics
  - rf-fitting
  - rf-shield
  - heat link
  - emergency actuator
  - motors and encoders

DETECTOR LABORATORY - FACILITIES

- Clean room, class 100 and class 1000
- Ultrasonic automatic wedge bonder (Kulicke-Soffa) with video monitoring
- Manual probe station
- LCR-meter (HP 4284A)
- Computer controlled measurement system for static detector analysis
- Precision detector alignment system for mechanical assembly of strip detectors, accuracy 5 μm
- Printed circuit and electronics design tools
- Electronics design programs
- Visual scanning microscope
- Gas chromatograph with TCD, FID detectors, integrator and cryotrap sampling unit
- Gas chromatograph with mass spectrometer (HP G1800B)
- Vacuum gauge system (several gauges)
- X-ray devices
- Several NIM and VME crates with many data acquisition modules
- Automatic four-point resistivity meter station with Picoammeter and Electrometer
- PC-controllable gas mixer unit
- MALDI-TOF mass spectrometer
- Several high voltage units, counters, pulse generators, multichannel analyzers
- Vacuum metal evaporator (Edwards Auto 306)
- Excimer and nitrogen lasers
- FACILITIES FOR OUTGASSING & VACUUM STUDIES

A Silicon Detector Module...

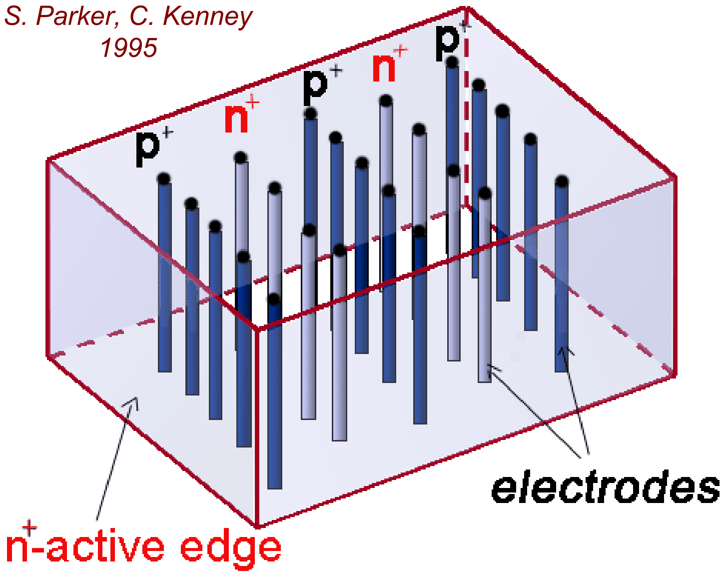




Back plane extented to side using p-diffusion
depletion region up to p and no guard ring is required
signal picked by n-strip up to p-diffusion
<10 μm dead space at the edge of the detector

semi-3D structure proposed by the Helsinki group (Tuure Tuuva) in 2001

3D Detectors and Active edges

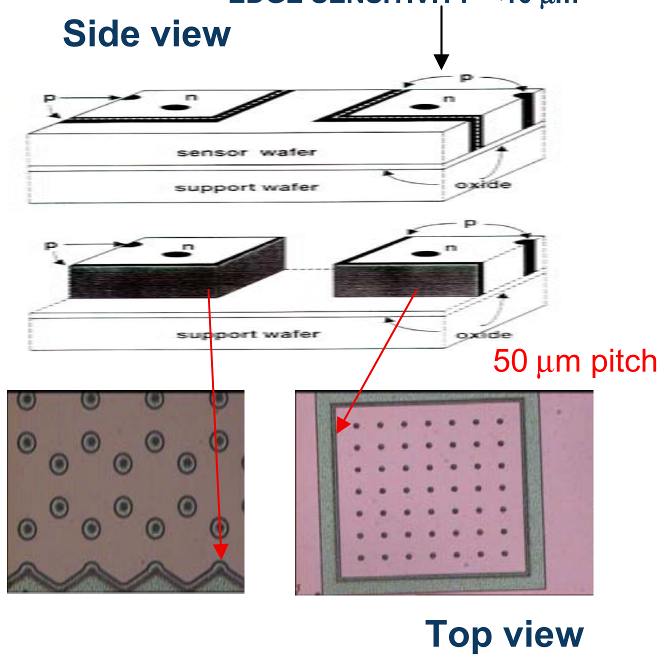


❖EDGE SENSITIVITY	<10 µm
❖COLLECTION PATHS	~50 µm
❖SPATIAL RESOLUTION	10-15 µm
❖DEPLETION VOLTAGES	< 10 V
❖DEPLETION VOLTAGES	~105 V at 10^{15}n/cm^2
❖SPEED AT RT	3.5 ns
❖AREA COVERAGE	3X3 cm^2
❖SIGNAL AMPLITUDE	24 000 e before Irradiation
❖SIGNAL AMPLITUDE	15 000 e$^-$ at 10^{15}n/cm^2

-S. Parker, C. Kenney
-C. DaVia

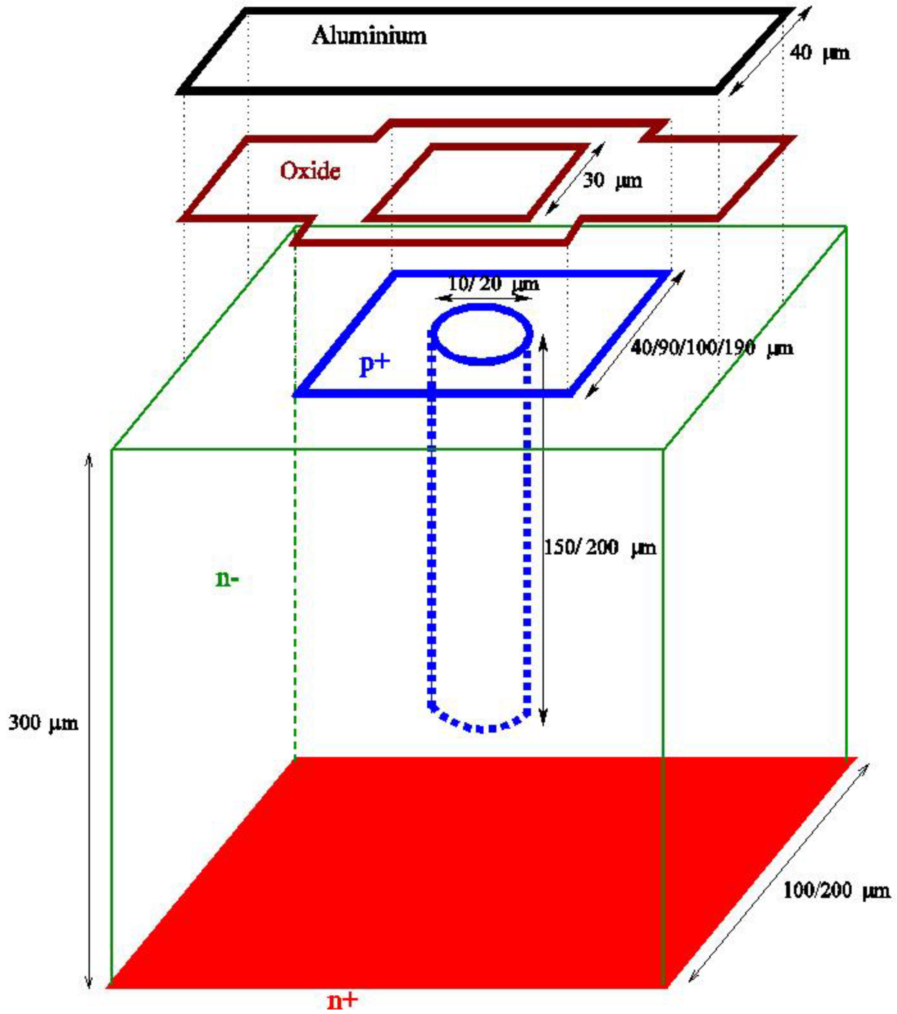
3D TECHNOLOGY
E-field line contained by edge (p) electrode

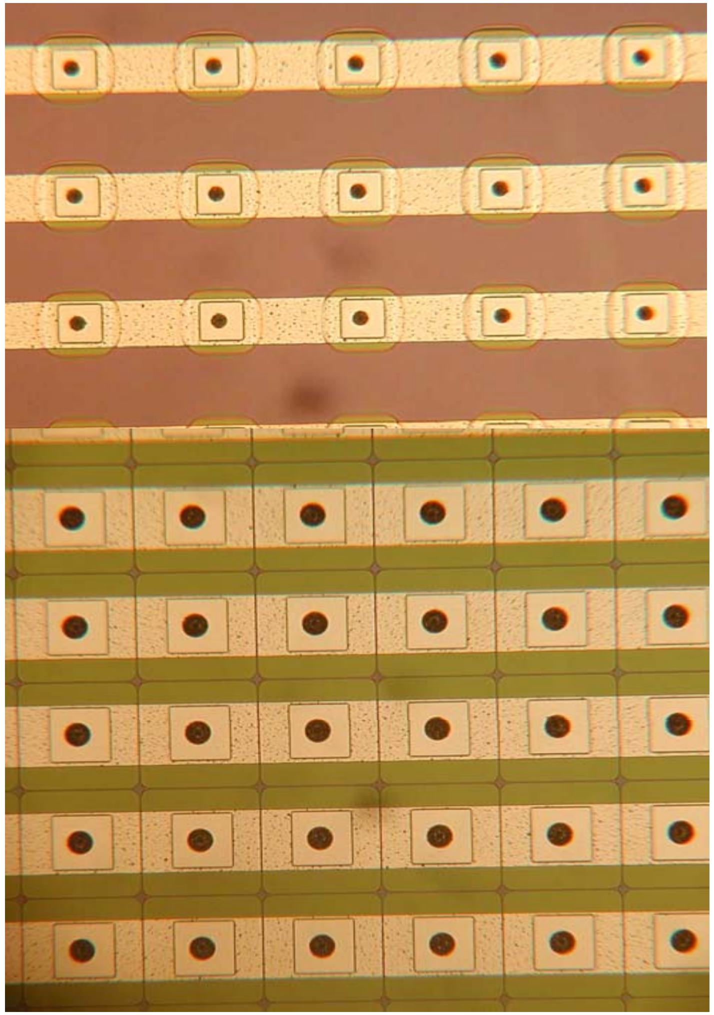
EDGE SENSITIVITY <10 µm



Pictures of processed structures
Brunel, Hawaii, Stanford 2003

3D structure

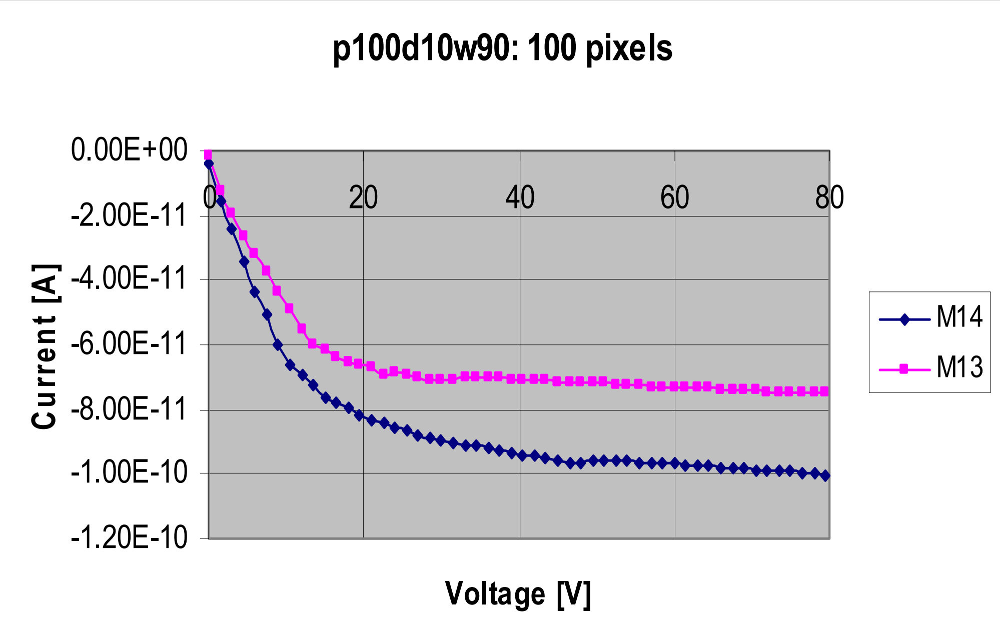


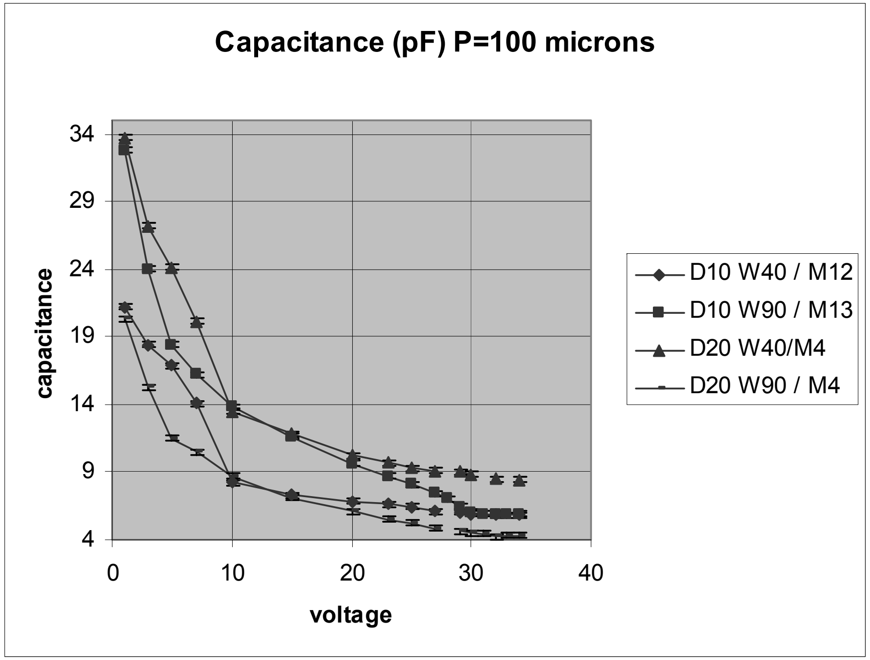


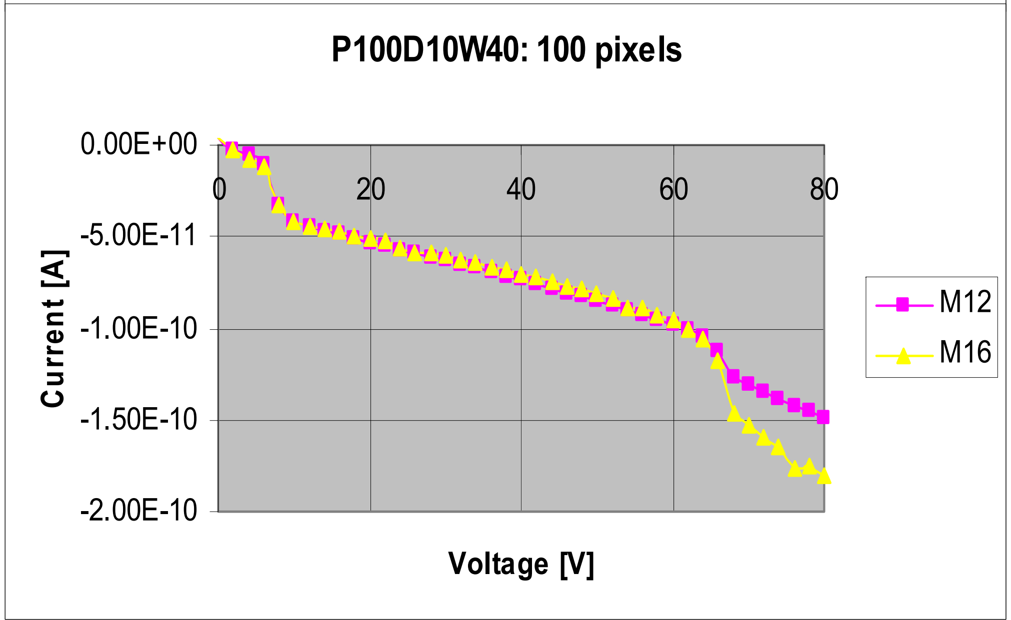
- 3D radiation detectors processed for the Helsinki group at VTT 2004-2005.
- detector sizes: 1 x 1 cm^2 and 2 x 2 cm^2.

Helsinki group: Juka Kalliopuska, Simo Eränen/VTT, Artto Aurola

Electrical Performance



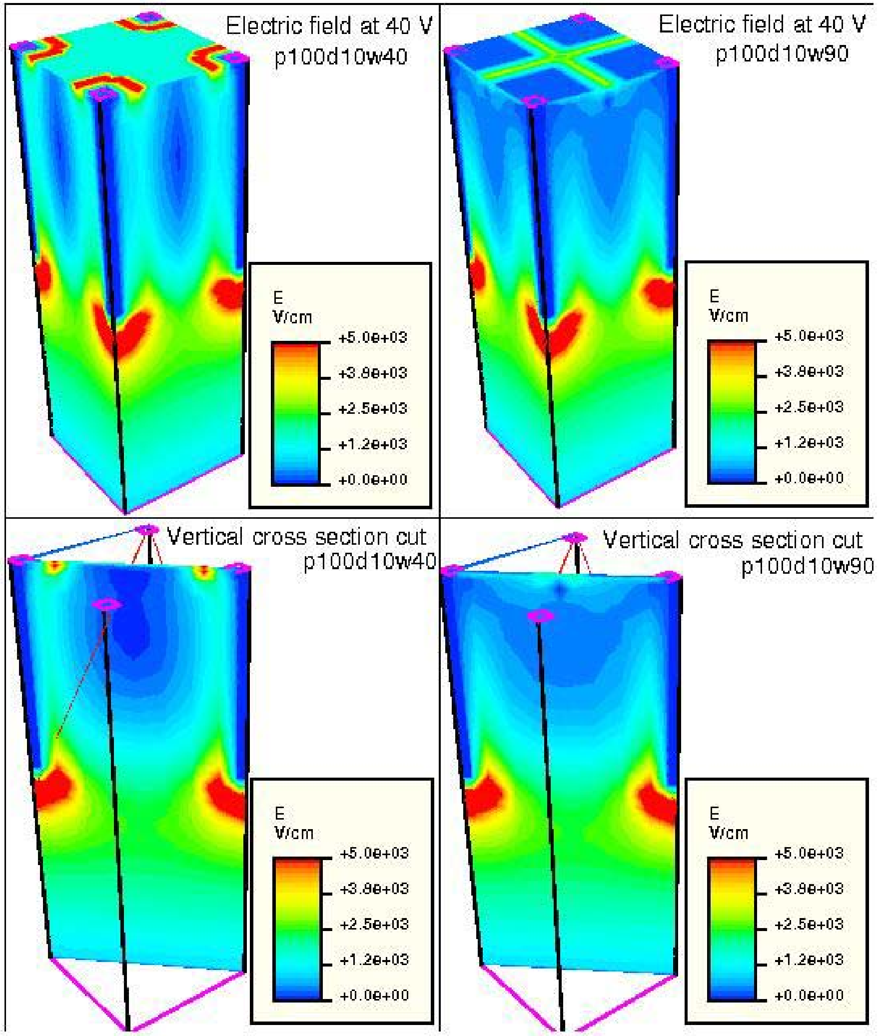


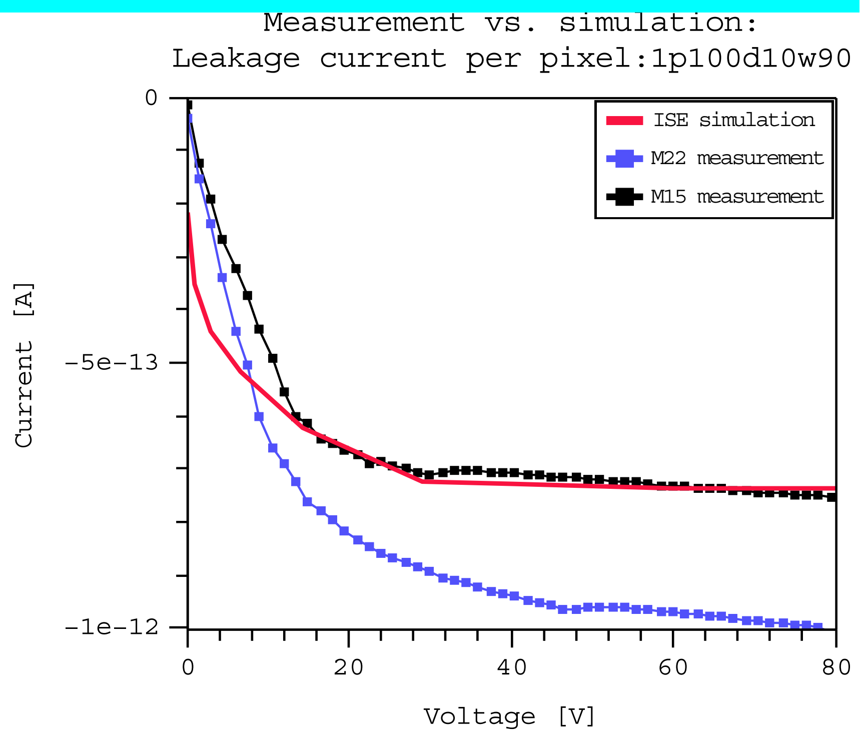


- Leakage currents from 0.7 to 1.7 pA/pixel at 80 V.
- Detector fully depleted at 30 V.
- Full depletion capacitances from 50 to 90 fF/pixel.

Helsinki group: Juha Kalliopuska & Rauno Lauhakangas

Simulations vs. measurements

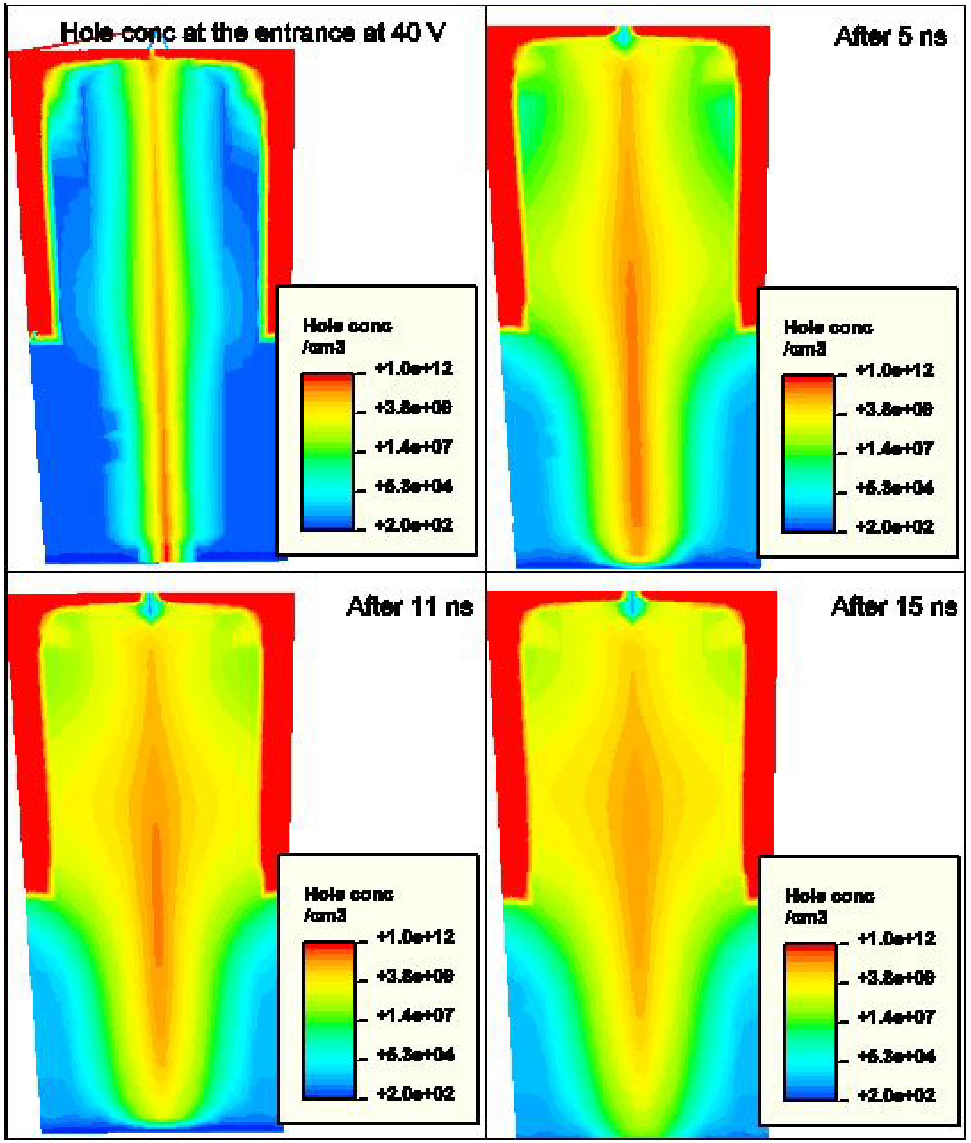


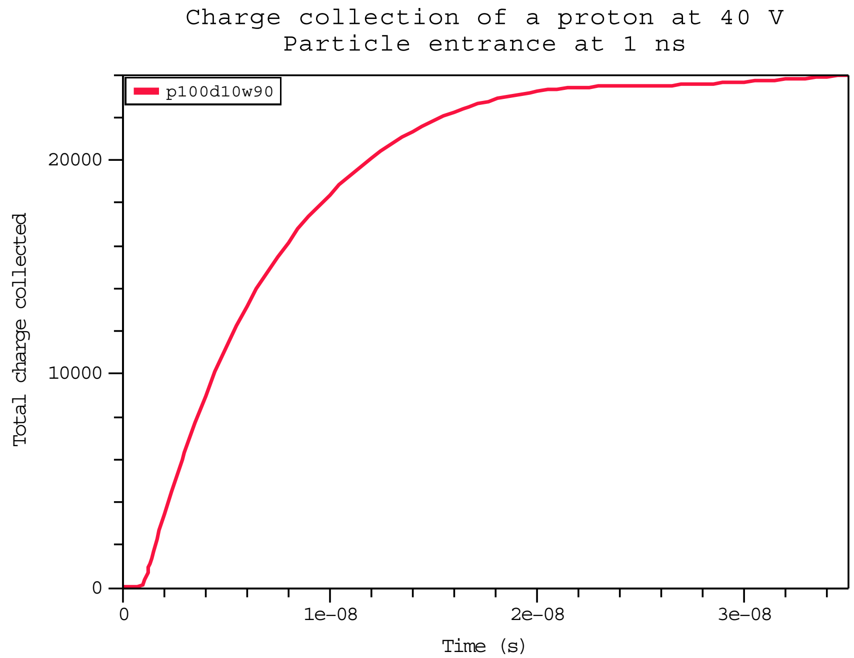


- 3D simulations closely predict the electrical characteristics of the detector structure.

Helsinki group: Juha Kalliopuska & Rauno Lauhakangas

Charge collection characteristics





- Charge collection for a proton hitting the low electric field region, "worst case scenario", at 40 V.
- A proton creates about 24000 electron-hole -pairs when passing through 300 μm thick silicon.

Helsinki group: Juha Kalliopuska

Microstation - prototype for beam tests at Fermilab!

1. Technical drawings

2. Assembly of a technically fully functioning prototype

3. Vacuum chamber with feed throughs and emergency actuator for vacuum tests.

4. Component subprojects
    4.1. Heat exchanger
    4.2. Position detector
    4.3. Rf-fitting (if measurements show that flexible strip wall is needed)
    4.4. Radiation & vacuum hard insulator and support for detector power cables

5. Study of thermal issues of the detector frame connections

6. Laboratory tests

6.1 Outgassing

6.2 Vacuum tests

6.3. RF impedance and pick-up tests

---

7. Development of electronics

7.1. Detector

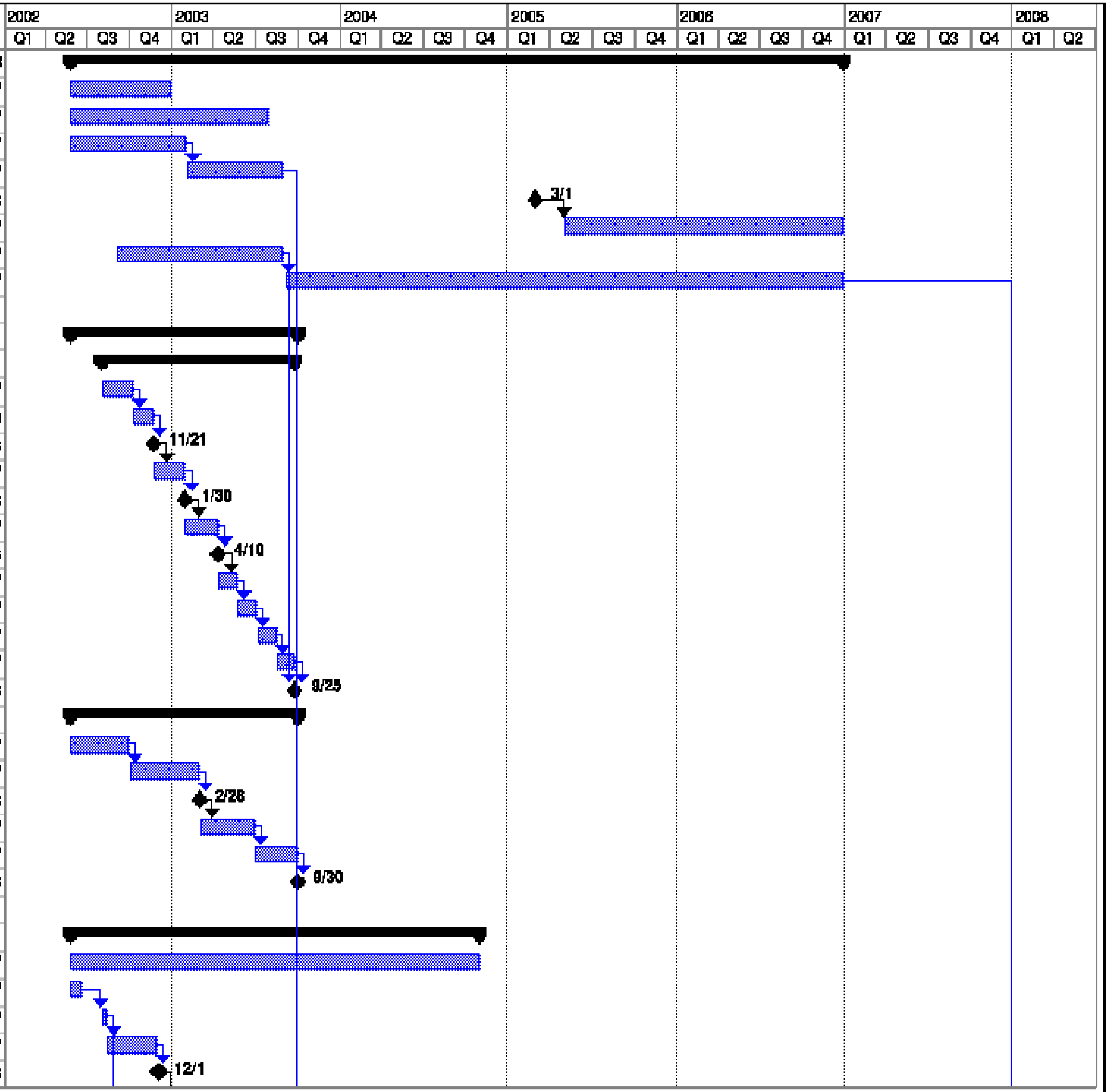
7.2. Hybrid

7.3. E to light converter

8. Development of internal NEG vacuum pump.

9. Machine interface - beam tests.

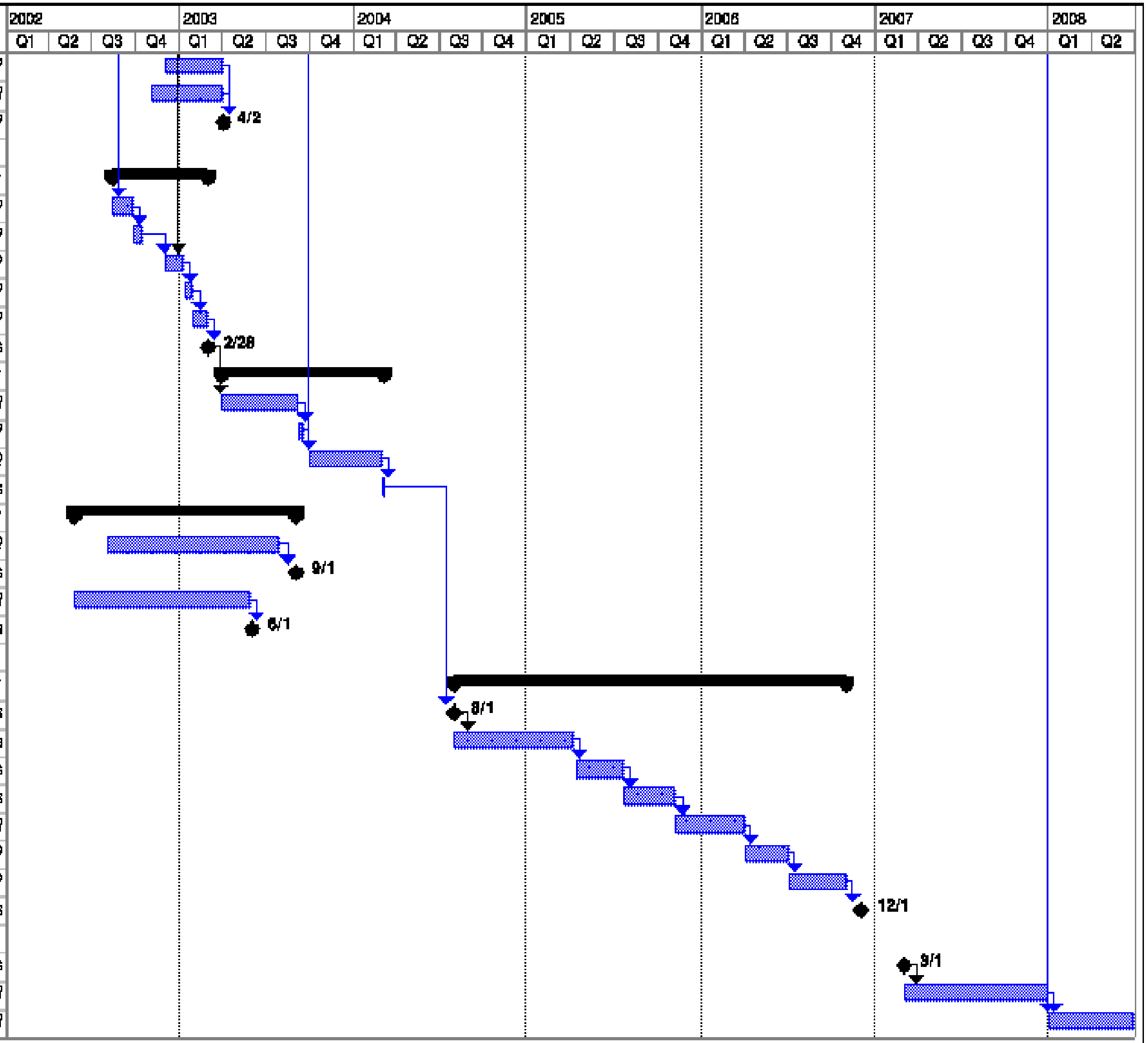
ID		Task Name	Duration
1		**Tavatron activities**	########
2		CDF S-LINK/LVL2 trigger development	158 days?
3		CDF plug laser calibration algorithm development	310 days?
4		CDF hybrid development	181 days?
5		CDF hybrid testing	150 days?
6		Tevatron run IIb start	0 days
7		CDF run IIb SVX commissioning	435 days?
8		CDF forward detector performance analysis	260 days?
9		CDF forward detector physics analysis	870 days?
10			
11		**Forward physics simulation development**	353 days?
12		**leading proton measurements**	301 days?
13		optimisation of leading proton detector positions	50 days?
14		optimise detector layout and geometry	31 days
15		Leading proton acceptance document	0 days
16		optimisation of leading proton resolution	50 days?
17		debugged MAD-X version available	0 days
18		finalize acceptance and resolution studies	50 days?
19		Leading proton resolution document	0 days
20		exclusive Higgs production	30 days?
21		production of SUSY and other exotica	30 days?
22		hard diffraction	30 days?
23		soft diffraction	30 days?
24		physics performance document	0 days
25		**Inelastic event measurements**	353 days?
26		definition of locations for inelastic detectors	92 days?
27		optimise detector layout and geometry	109 days?
28		location and geometry defined	0 days
29		acceptance studies for inelastic detectors	86 days?
30		track reconstruction for inelastic detectors	86 days?
31		Inelastic detector performance document	0 days
32			
33		**microstation development**	636 days?
34		development of custom components	636 days?
35		understand mechanical layout of 400 location	20 days?
36		define mechanical modification for 400 m location	10 days?
37		develop ms design for 400 m location	77 days?
38		design report for 400 m location	0 days



Project: Project0 in Untitled
Date: Fri 5/31/02

Task	Milestone	External Tasks
Split	Summary	External Milestone
Progress	Project Summary	Deadline

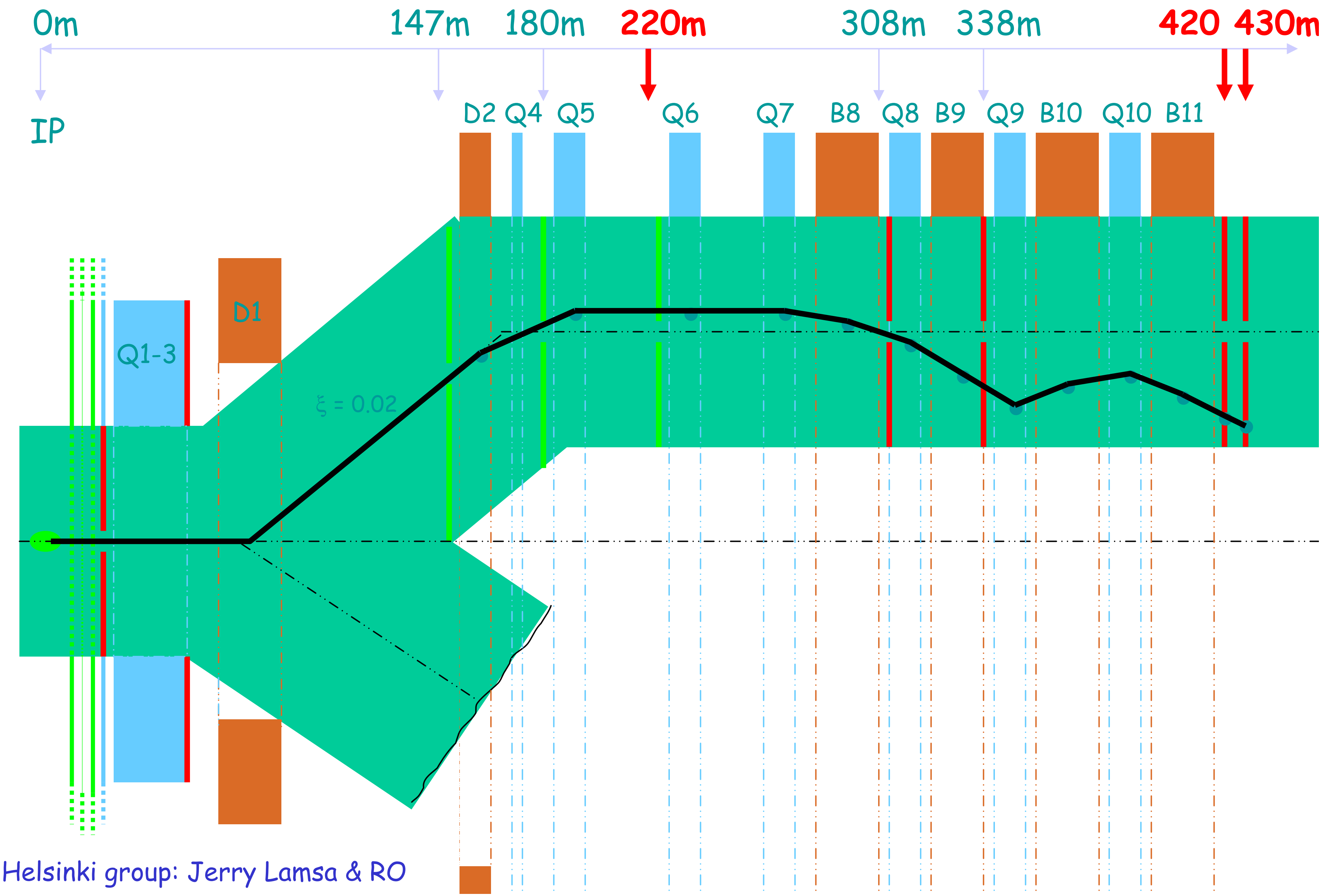
ID		Task Name	Duration
39		assess suitability for location < 300 m	87 days?
40		assess suitability as inelastic detector	109 days?
41		ms application for forward physics	0 days?
42			
43		**ms fully functional prototype**	**142 days?**
44		machining of components	30 days?
45		assembly of prototype	14 days?
46		ms testing of vacuum properties	30 days?
47		ms testing of RF properties	14 days?
48		ms beam test	21 days?
49		MS detailed design report	0 days
50		**ms production prototype**	**243 days?**
51		procurement of components	115 days?
52		assembly of prototype	7 days?
53		integration of sensor and readout	109 days?
54		production readiness review	3 days
55		**integration and services**	**331 days?**
56		investigate needs for services	261 days?
57		Service requirements document	0 days
58		Investigate needs for integration	266 days?
59		Integration requirements document	0 days
60			
61		**ms production and installation**	**588 days?**
62		proposal forward extension accepted	0 days
63		development of microstation cluster	180 days
64		procurement of components	73 days
65		assembly of microstations and clusters	80 days
66		microstation testing	102 days?
67		microstation installation	66 days?
68		microstation commissioning	87 days?
69		LHCC ring closed	0 days
70			
71		LHCC start commissioning	0 days
72		Forward detector performance studies	218 days?
73		Forward physics analysis	130 days?



Project: Project0 in Untitled
Date: Fri 5/31/02

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

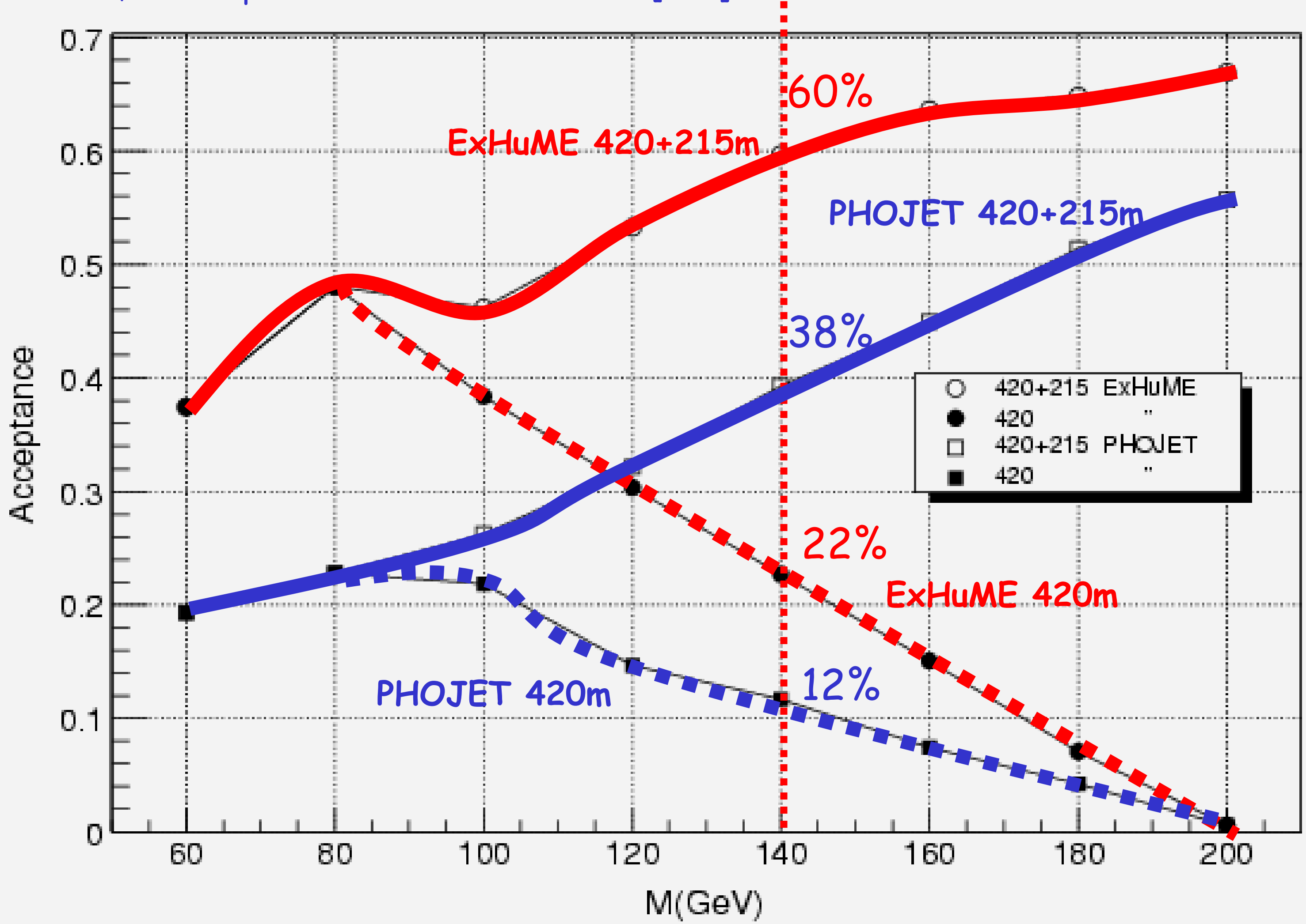
Leading Proton Detection-An Example



Helsinki group: Jerry Lamsa & RO

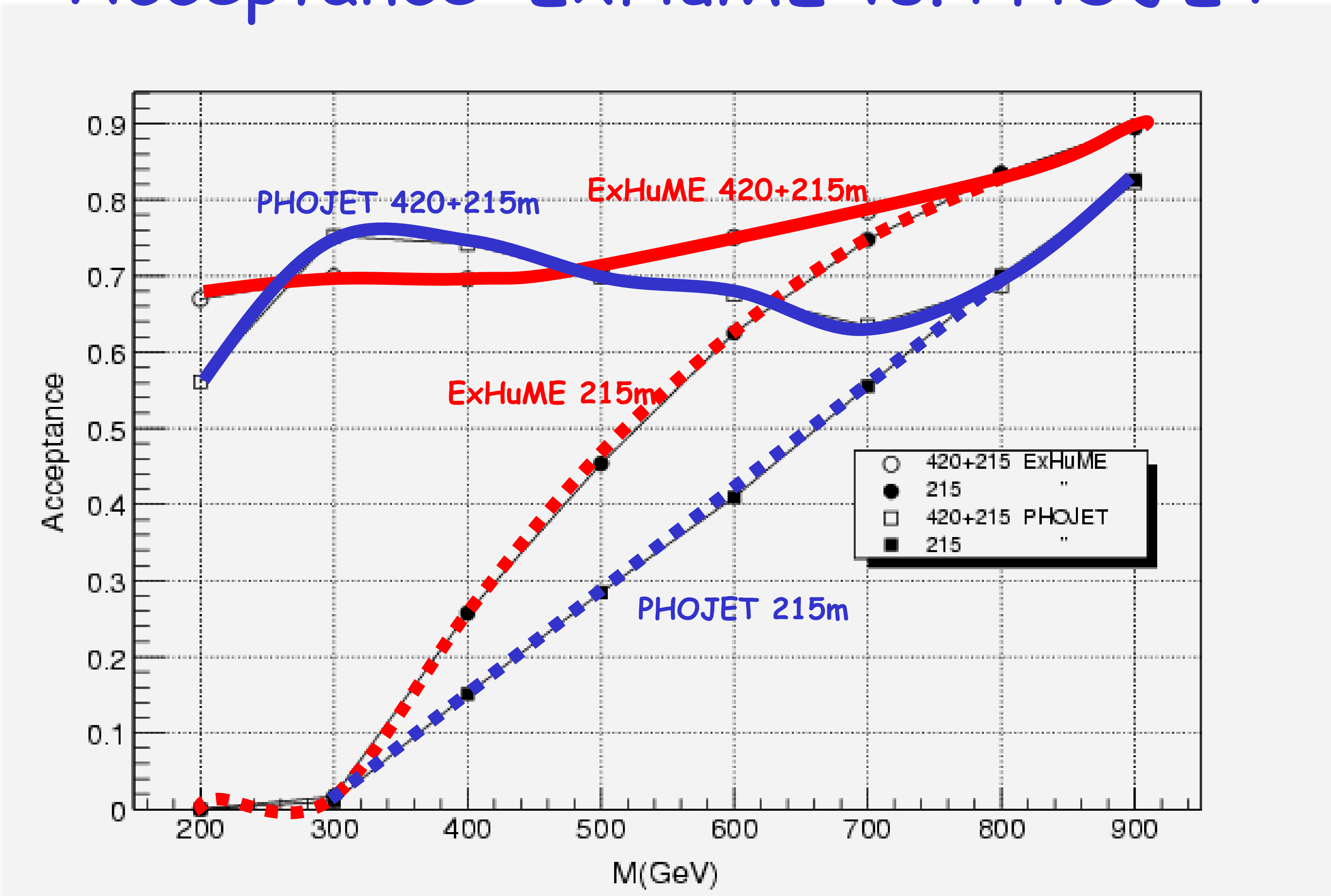
Acceptance: ExHuME vs. PHOJET

"420+215" calculation: either both protons are detected at 420m, or both protons are detected at 215m, or one proton is detected at 420 [215]m with the other one detected at 215 [420]m.



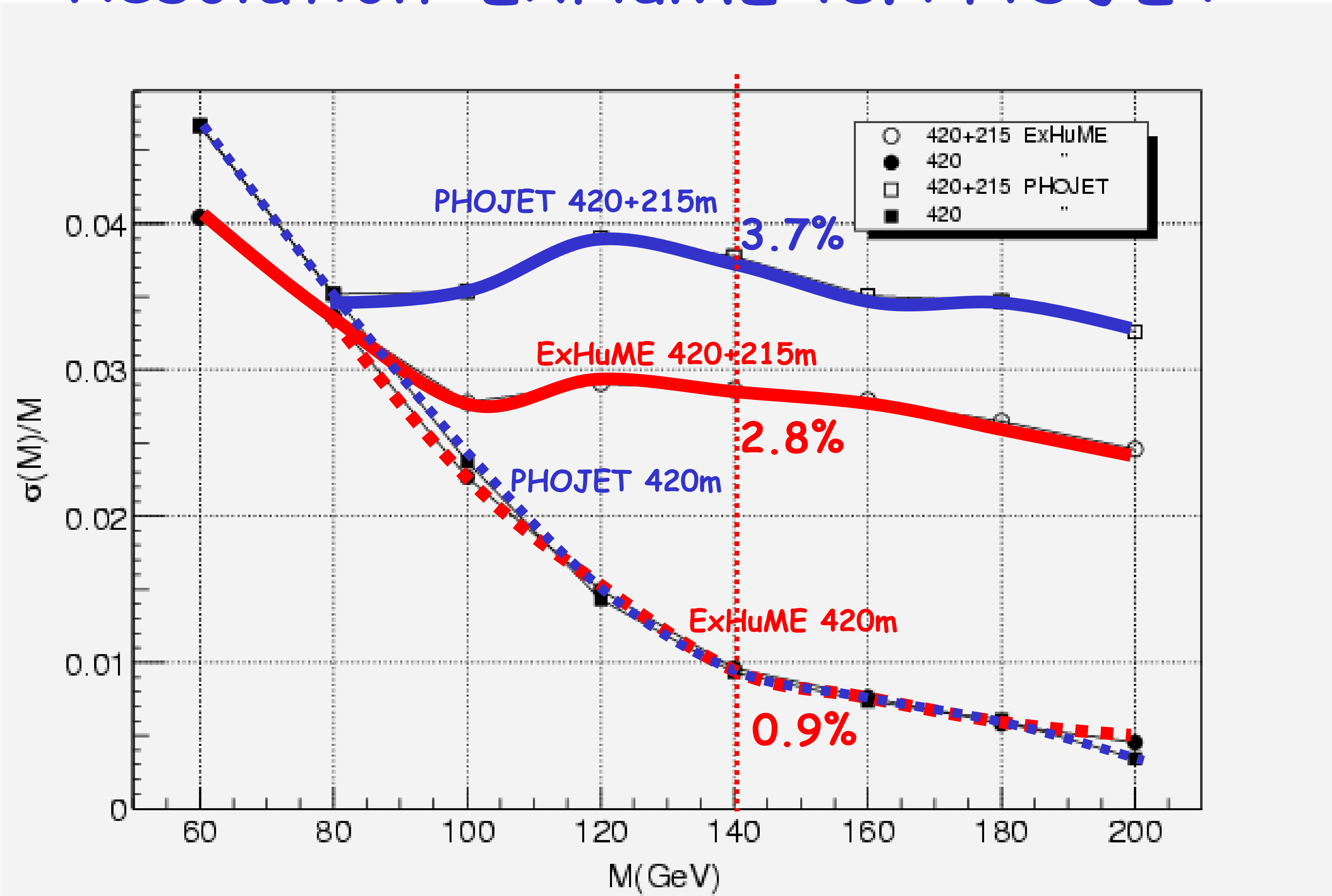
Helsinki group: J.Lamsa (parametrisations of the MAD simulation results of T. Mäki by RO)

Acceptance: ExHuME vs. PHOJET



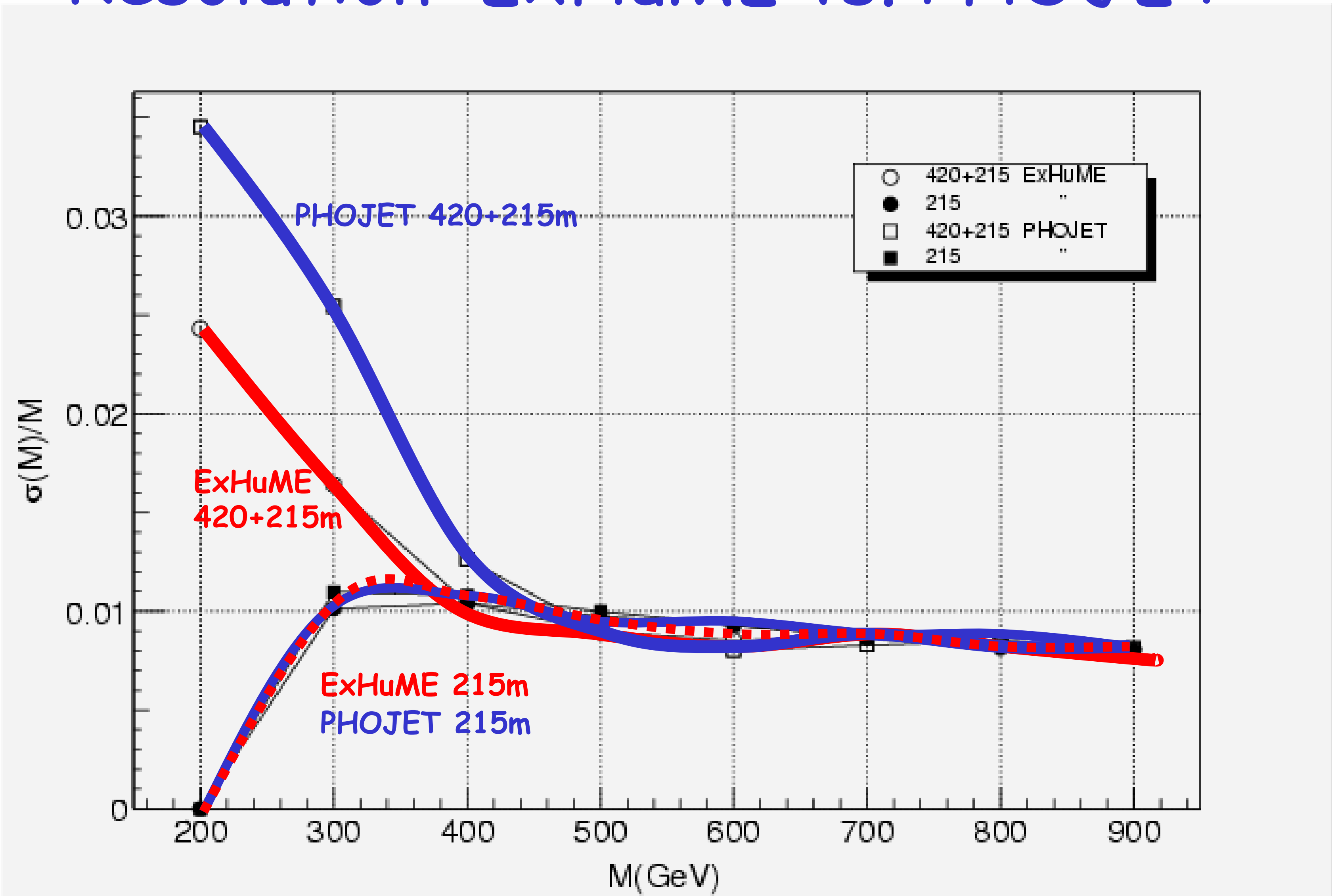
Helsinki group: J.Lamsa (parametrisations of the MAD simulation results of T. Mäki by RO)

Resolution: ExHuME vs. PHOJET



Helsinki group: J.Lamsa (parametrisations of the MAD simulation results of T. Mäki by RO)

Resolution: ExHuME vs. PHOJET



Helsinki group: J.Lamsa (parametrisations of the MAD simulation results of T. Mäki by RO)