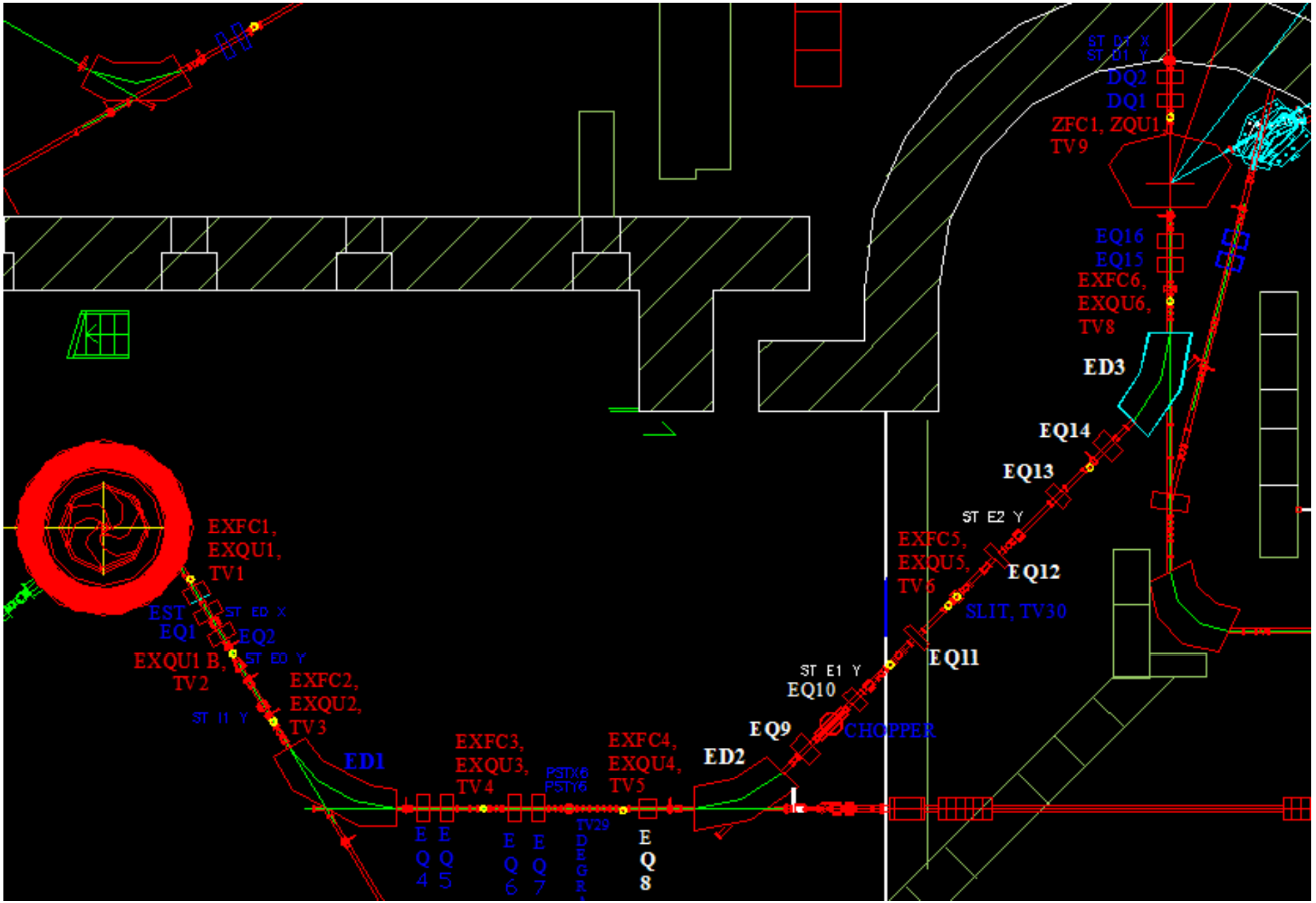
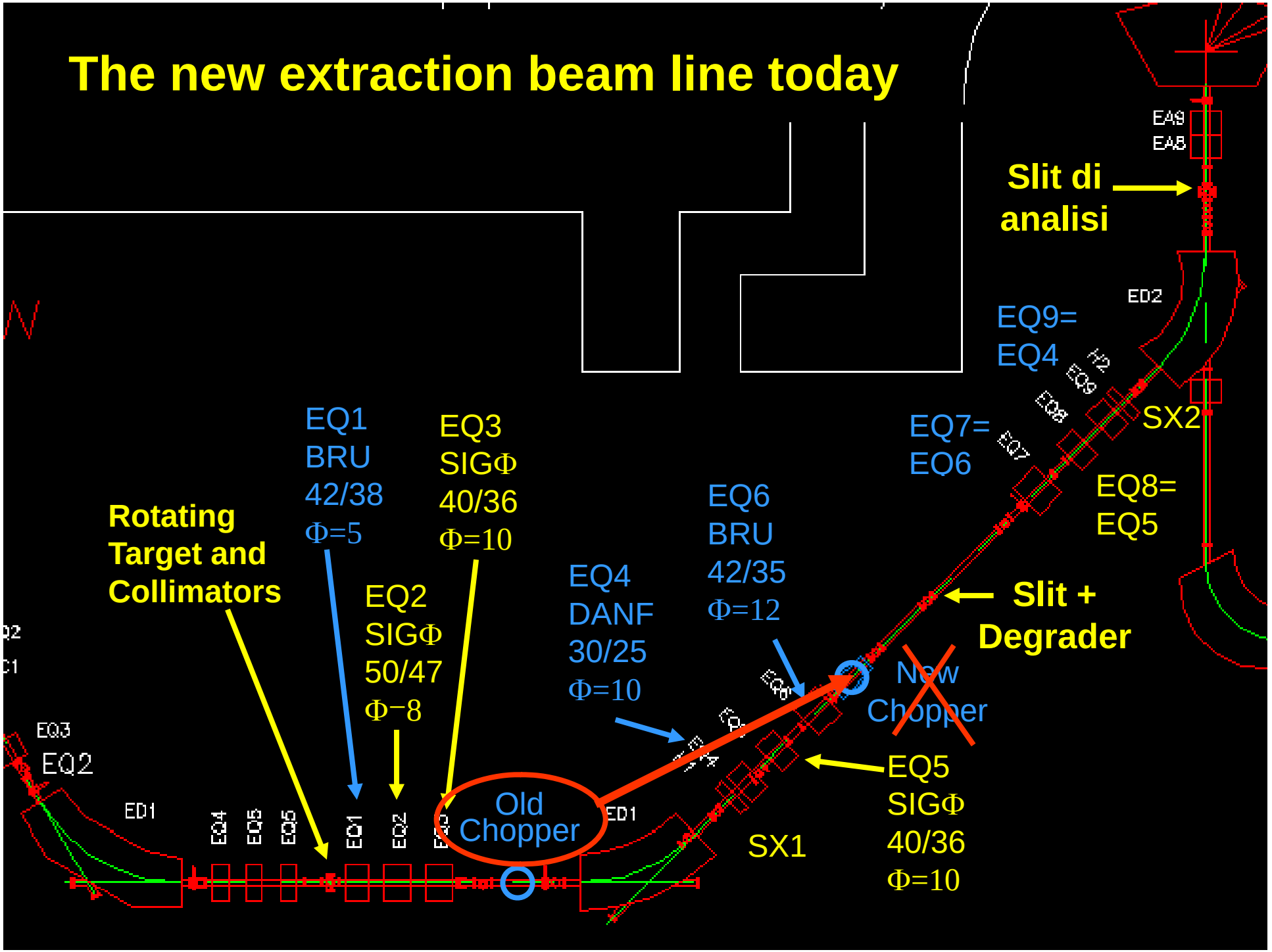
FRIB@LNS the development program: Past, Present and Future

By Luciano Calabretta

Catania, 22 Juin, User meeting

The extraction beam line until July 2010




The new extraction beam line today
Slit di analisi
EA9
EA8
ED2
EQ9=
EQ4
EQ6
EQ8
EQ7
SX2
EQ7=
EO6
EQ8=
EQ5
EQ1
BRU
42/38
Φ=5
EQ3
SIGΦ
40/36
Φ=10
Rotating Target and Collimators
EQ2
SIGΦ
50/47
Φ−8
EQ4
DANF
30/25
Φ=10
EQ6
BRU
42/35
Φ=12
Slit + Degrader
New Chopper
EQ3
EQ2
ED1
EQ4
EQ5
EQ6
EQ1
EQ2
EQ3
Old Chopper
ED1
SX1
EQ5
SIGΦ
40/36
Φ=10

Previous Beam Line

2° order beam envelope

X_i= +/-3 mm θ_i= +/- 3 mrad

Y_i= +/-2 mm ϕ_i= +/- 7.5 mrad

$\Delta P/P$= +/- 0.5%

New Beam Line

2° order beam envelope

X_i= +/-3 mm θ_i= +/- 16 mrad (+/- 1°)

Y_i= +/-2 mm ϕ_i= +/- 30 mrad (+/- 2°)

$\Delta P/P$= +/- 1%

Expected acceptance enhancement

5x4x2 → 40 times

Acceptance in the transverse space and in momentum for the previous FRIB line and the new FRIB@LNS

	Acceptance (x,x') [mm.mrad]	Acceptance (y,y') [mm.mrad]	Momentum Acceptance ΔP/P
Previous FRIB line	ϕ=6, 3x3= 9π	ϕ=4, 2 x 7.5=15 π	0.5 %
New FRIB@LNS	ϕ=6, **3x16=48 π**	ϕ=4, **2x30=60 π**	1 %
Enhancement factor	**5**	**4**	**2**

total 40!

Acceptance in the transverse space for the transport lines to the old and new experimental rooms

Old beam lines Medea, Ciclope, 0°	3x3= 9π	3 x 3=9 π	0.5 %	60% →40%
New beam lines Chimera, Magnex	10x4= 40 π	5 x 4=20 π	0.8 %	**Gain 9.5**
FRIBs+20° line	3x10=30 π	2x20=40 π	0.7 %	**12**

Acceptance in the transverse space and in momentum for the previous FRIB line and the new FRIB@LNS

	Acceptance (x,x') [mm.mrad]	Acceptance (y,y') [mm.mrad]	Momentum Acceptance ΔP/P
Existing line	ϕ=6, 3x3= 9π	ϕ=4, 2 x 7.5=15 π	0.5 %
New FRIBs line	ϕ=2, **1x16=16 π**	ϕ=2, **1x30=30 π**	1 %
Enhancement factor	**5**	**4**	**2**

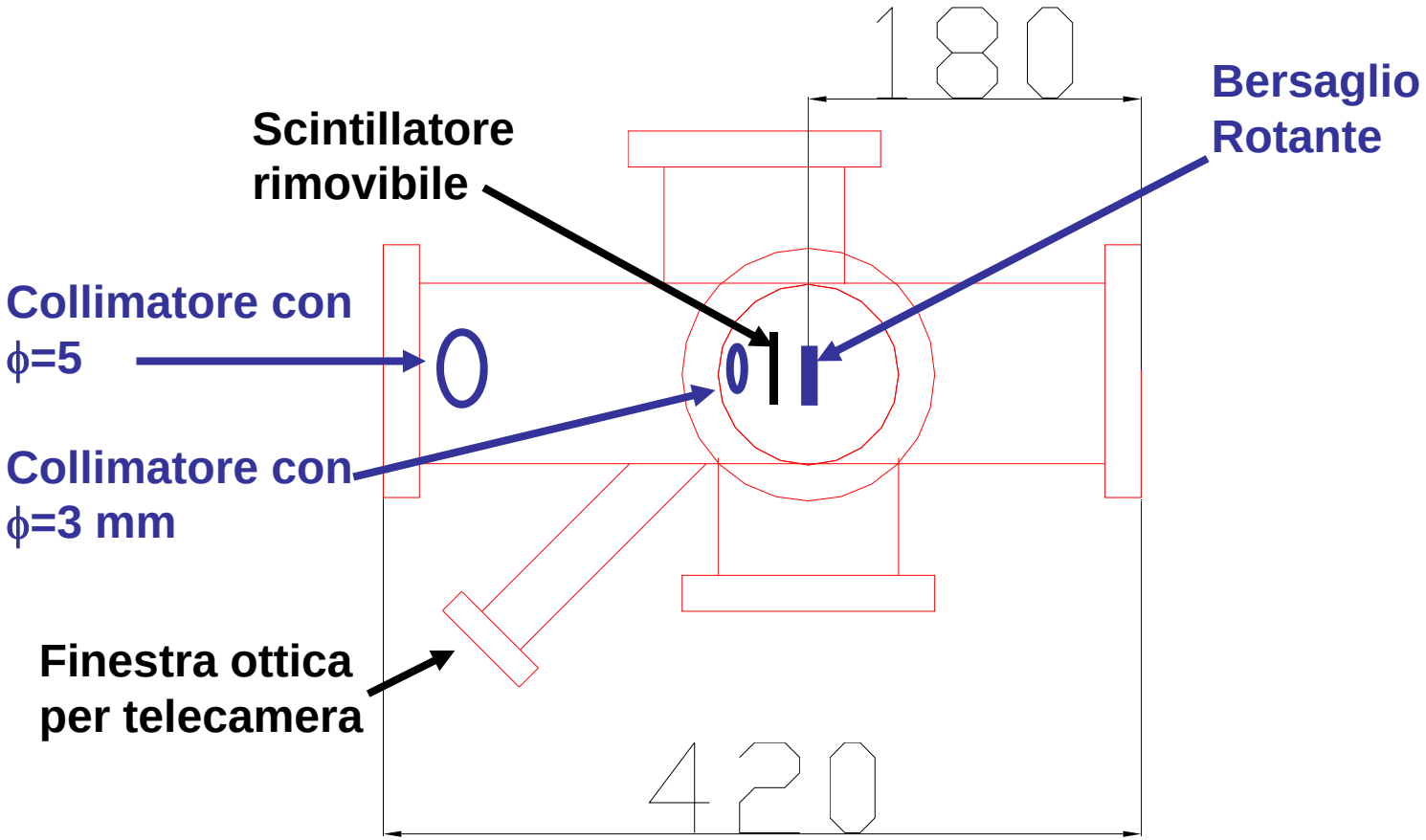
total 40!

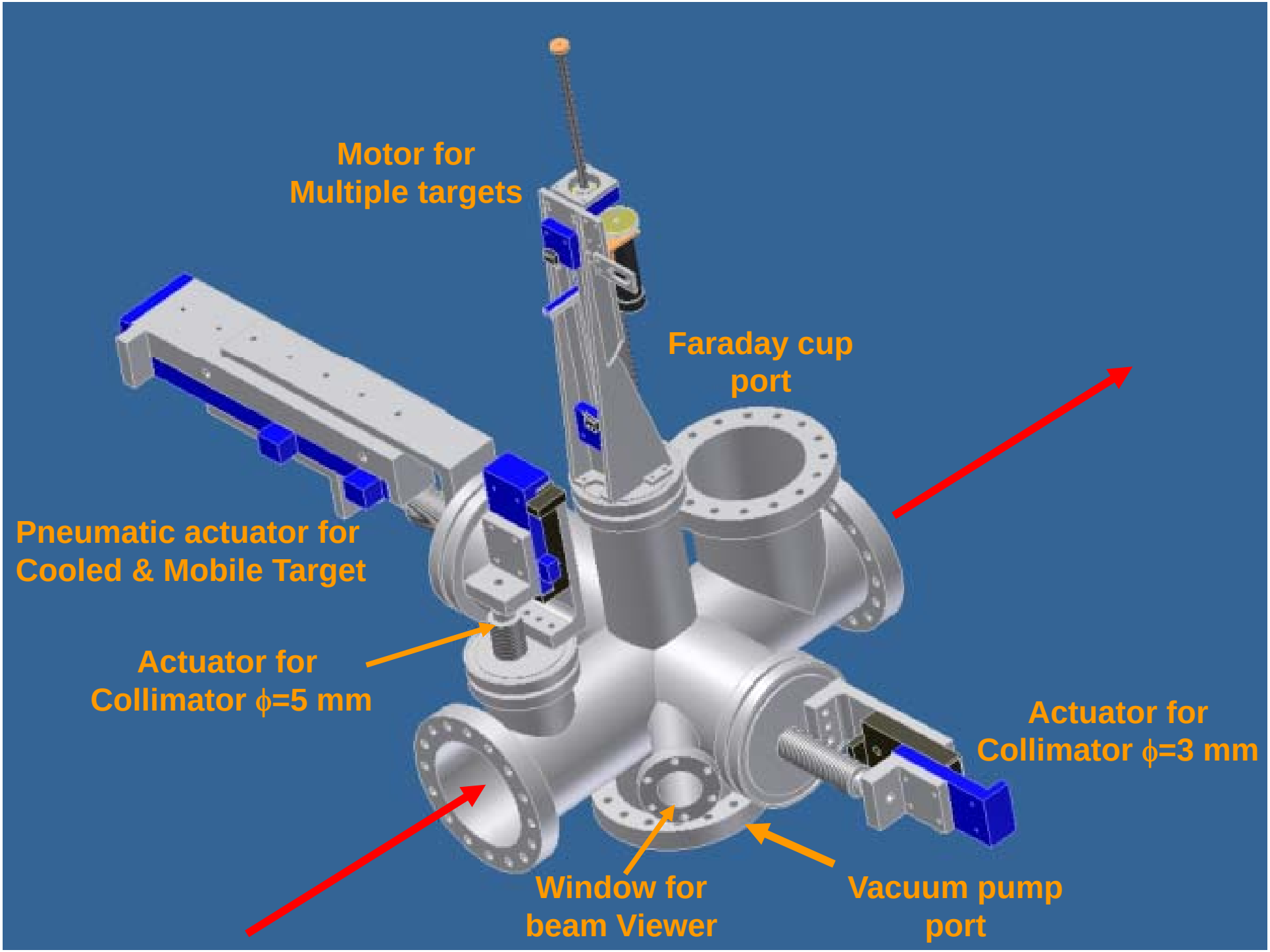
The beam emittance depend bot on the acceptance angle and on the beam spot on target, while the collection efficiency is proportional to the solid angle, but not depend on the beam spot size

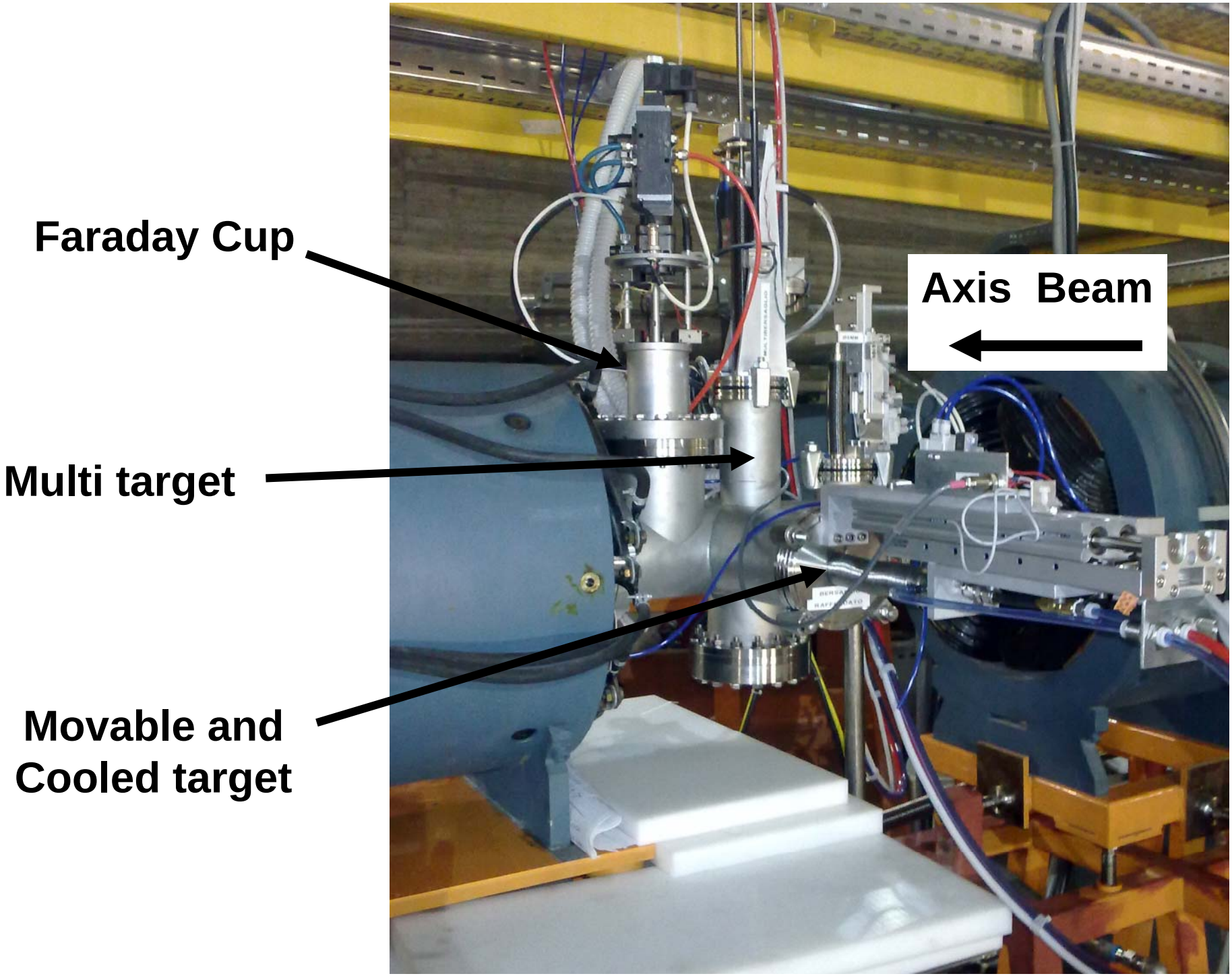
Acceptance in the transverse space for the transport lines to the old and new experimental rooms. Rough evaluations!!!

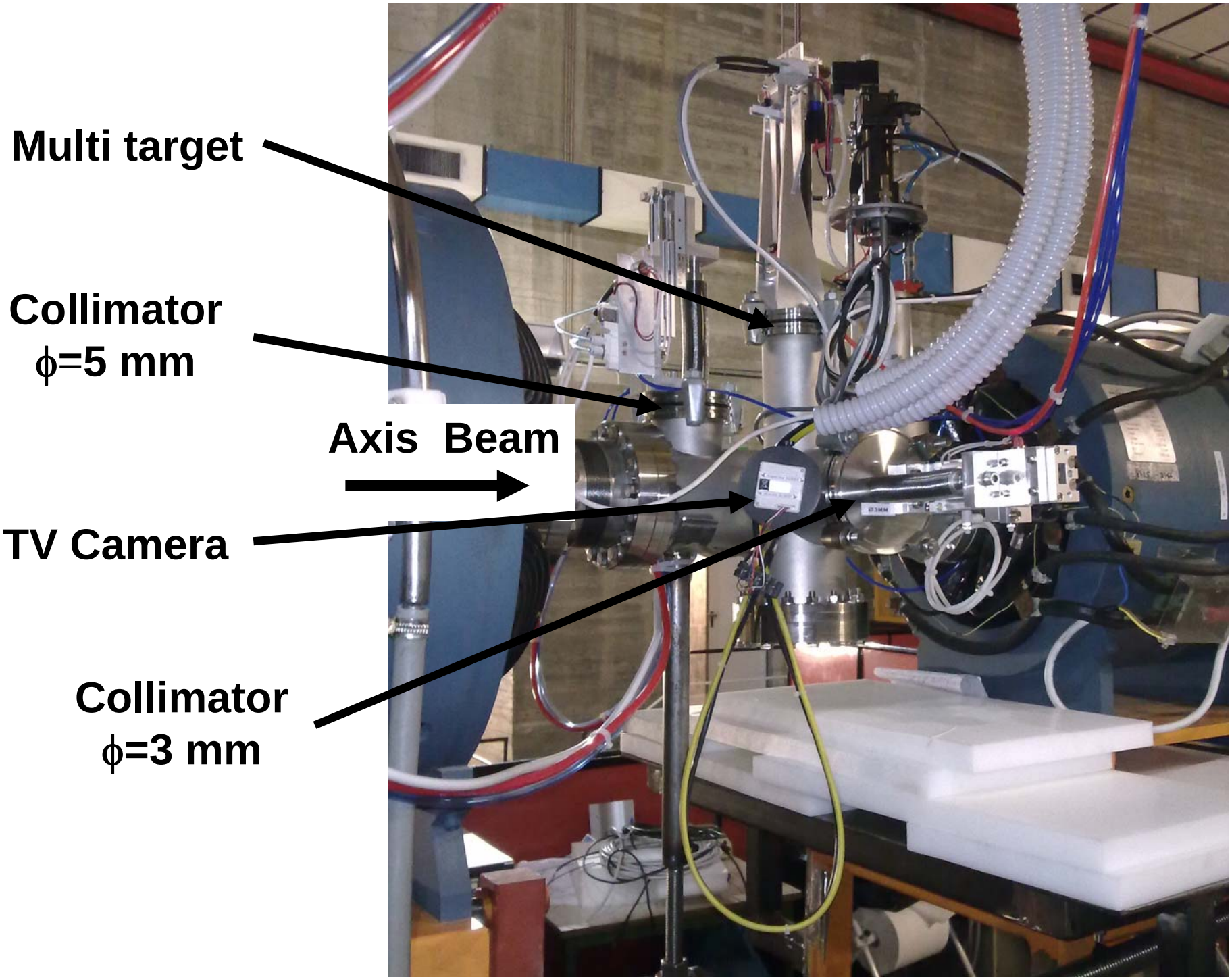
New beam lines Chimera, Magnex	4.5x4= 18 π **Gain 5**	5 x 5=25 π **Gain 3.33**	0.9 % **Gain 1.8**	**Gain 30**
FRIBs+20° line	3x10=30 π **Gain 5**	2x20=40 π **Gain 4**	0.7 % **Gain 1.4**	**28**

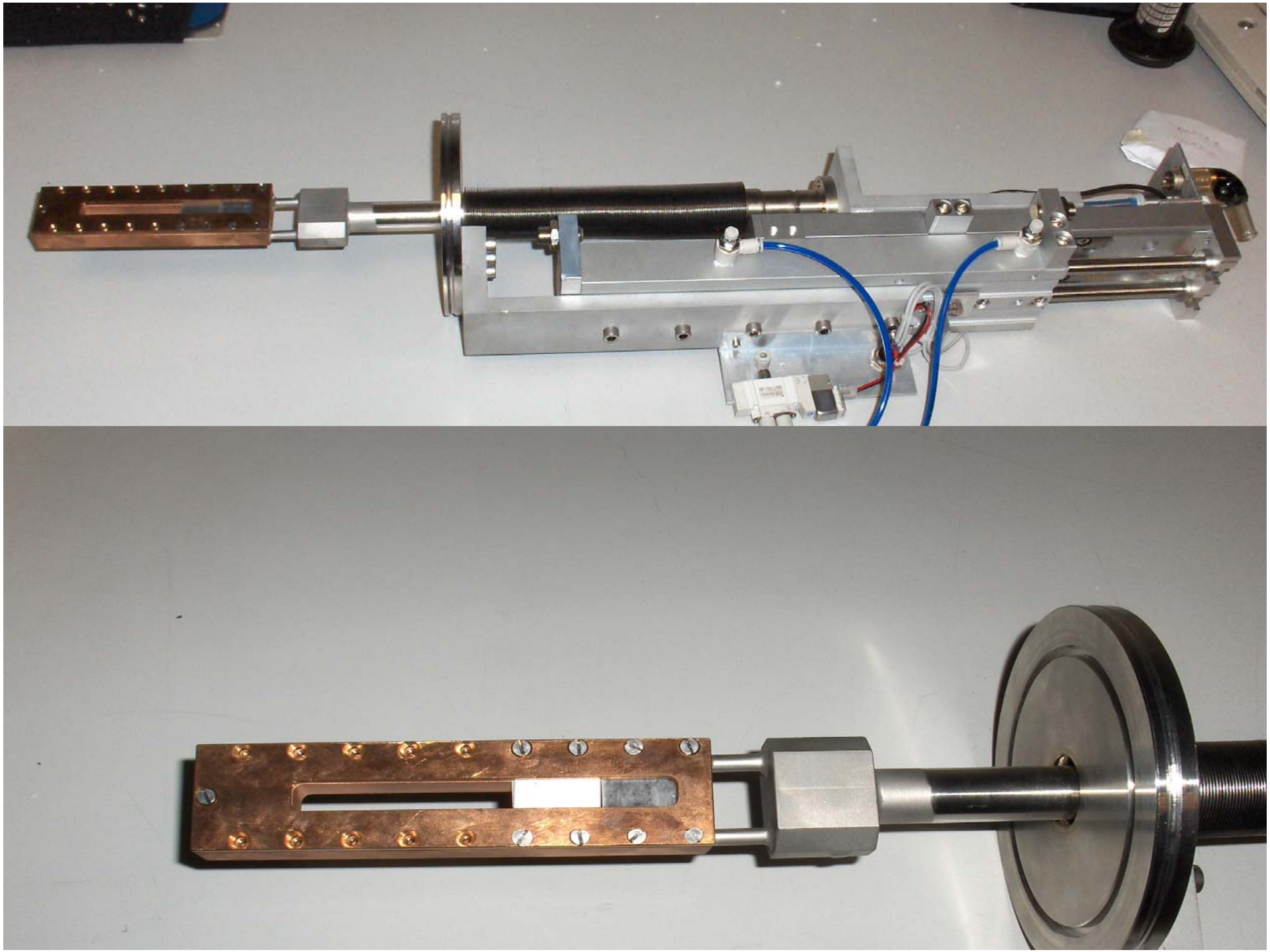
Flange CF-100

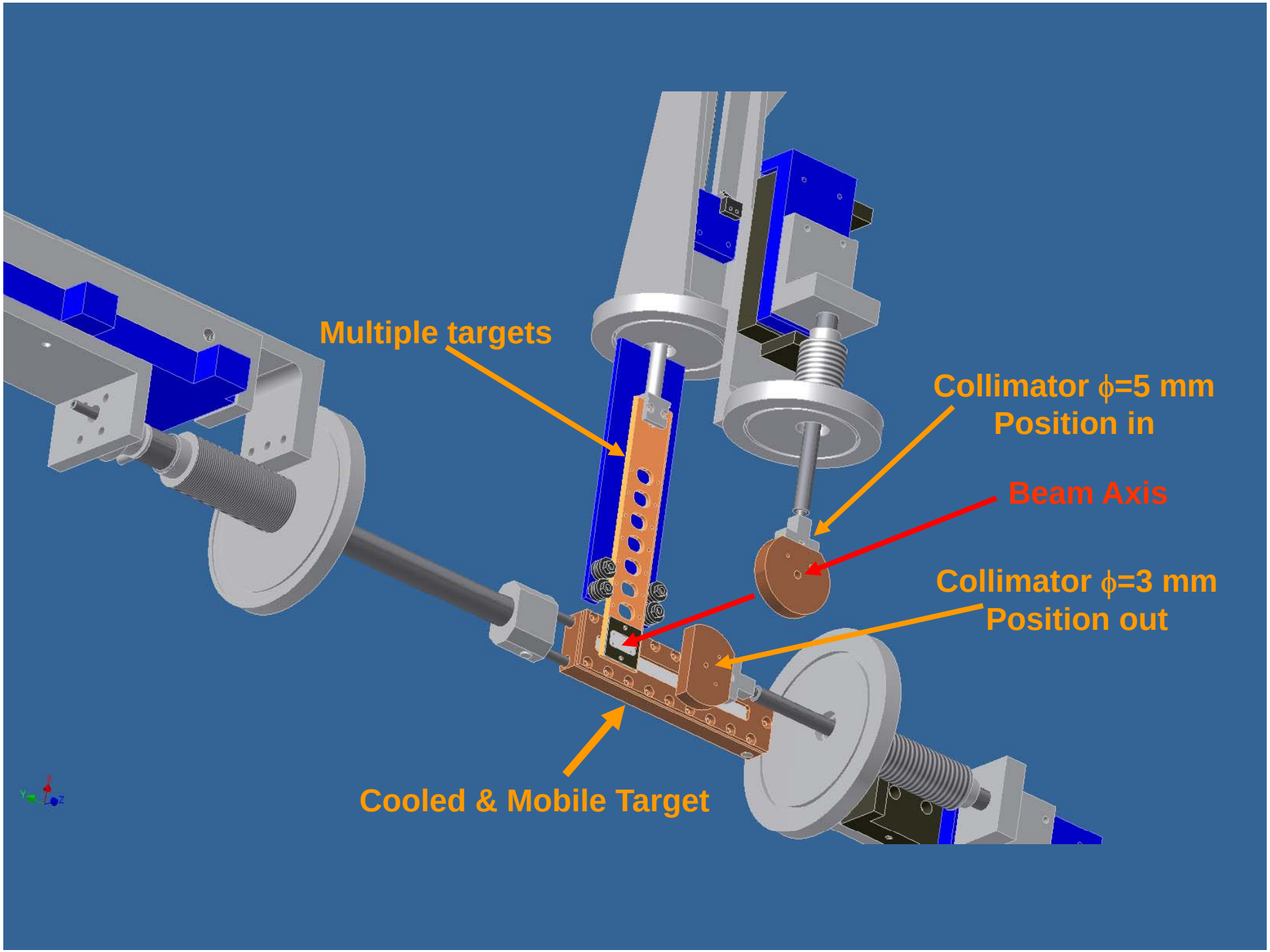


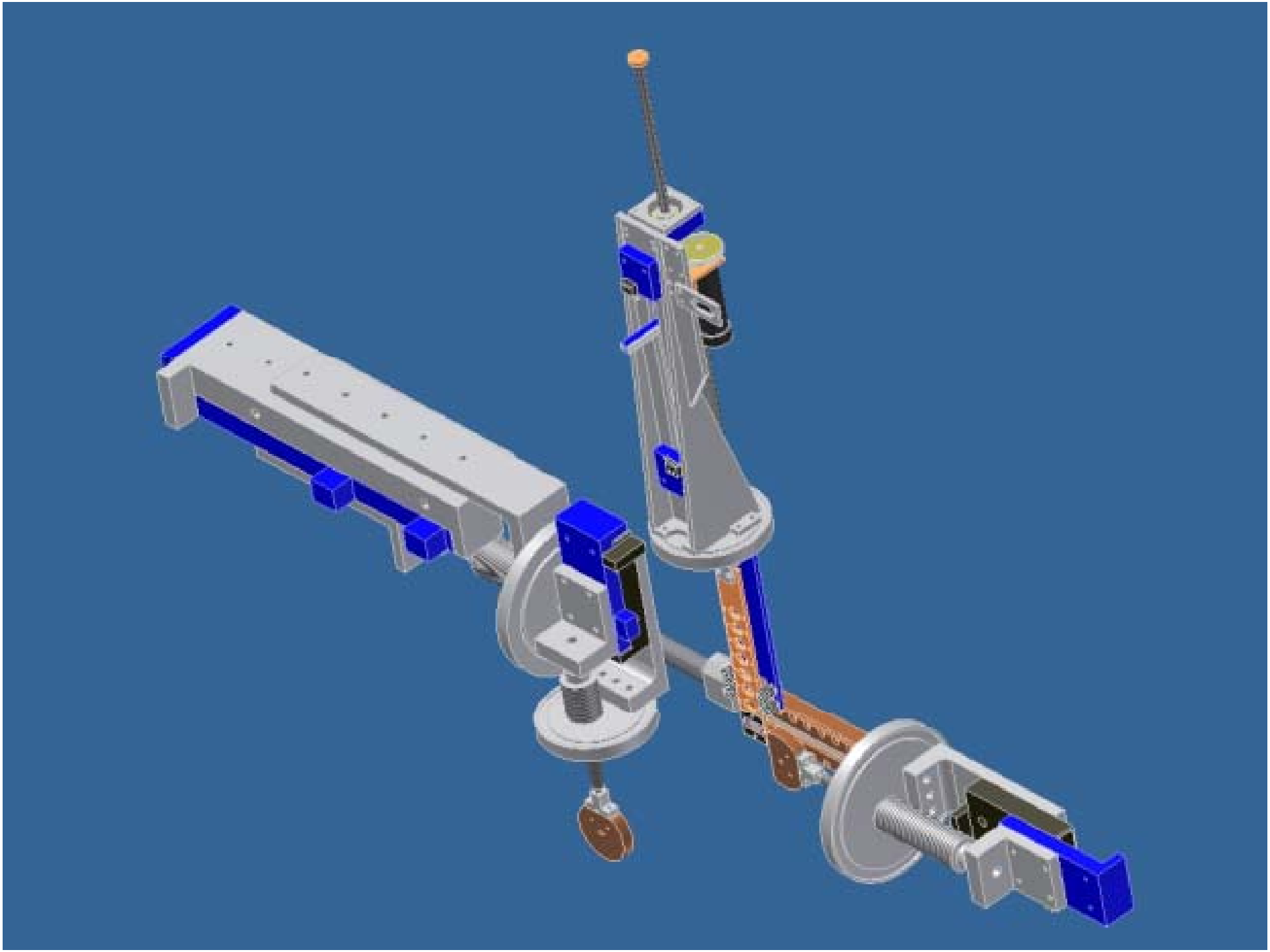

Motor for
Multiple targets
Faraday cup
port
Pneumatic actuator for
Cooled & Mobile Target
Actuator for
Collimator ϕ=5 mm
Actuator for
Collimator ϕ=3 mm
Window for
beam Viewer
Vacuum pump
port


Faraday Cup
Multi target
Movable and
Cooled target
Axis Beam


Multi target
Collimator
ϕ=5 mm
Axis Beam
TV Camera
Collimator
ϕ=3 mm




Multiple targets
Collimator ϕ=5 mm
Position in
Beam Axis
Collimator ϕ=3 mm
Position out
Cooled & Mobile Target



Diagnostics for High Energy (Tandem) RIBs

The beam lines to Magnex and Chimera are now equipped with low intensity beam viewer (bidimensional Silicon detector)

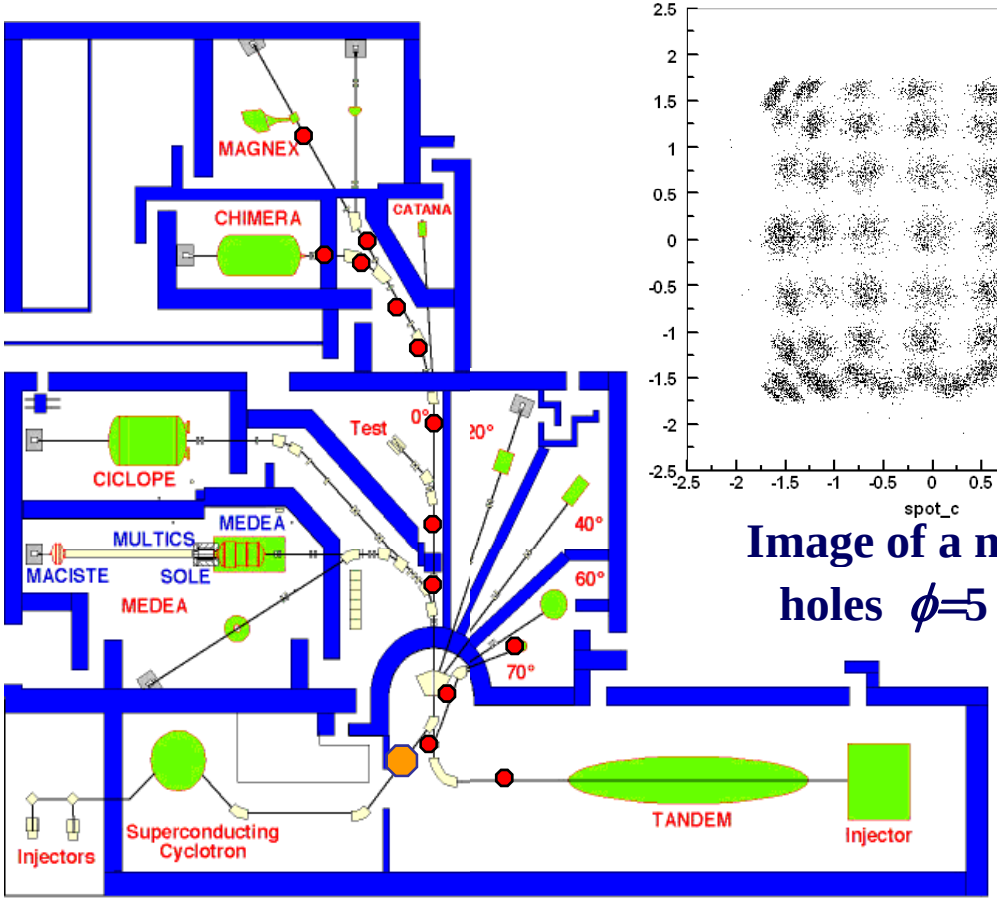
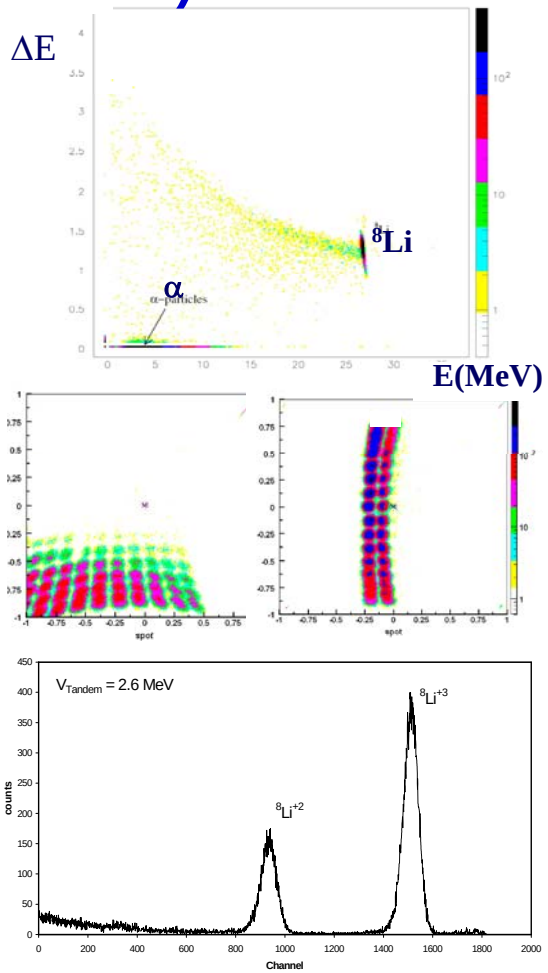
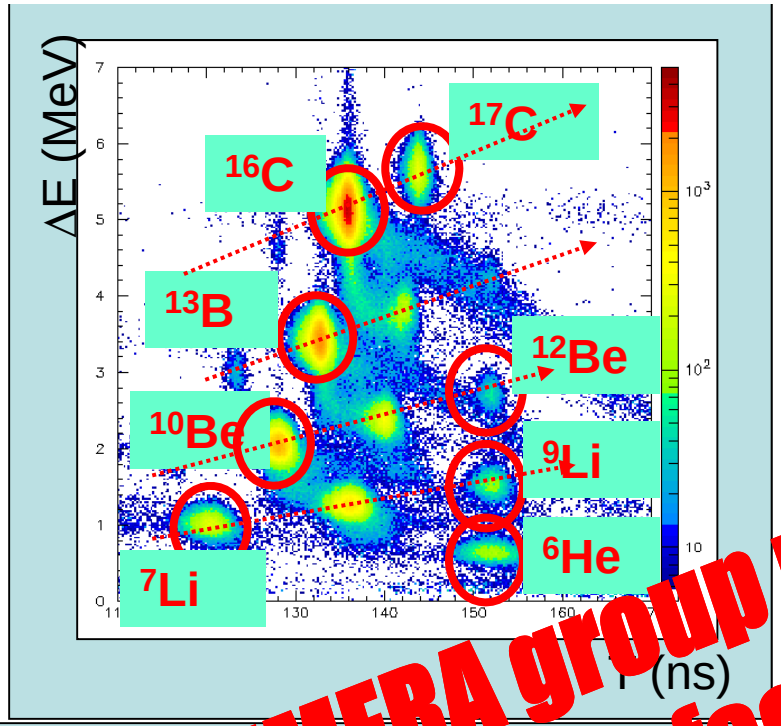
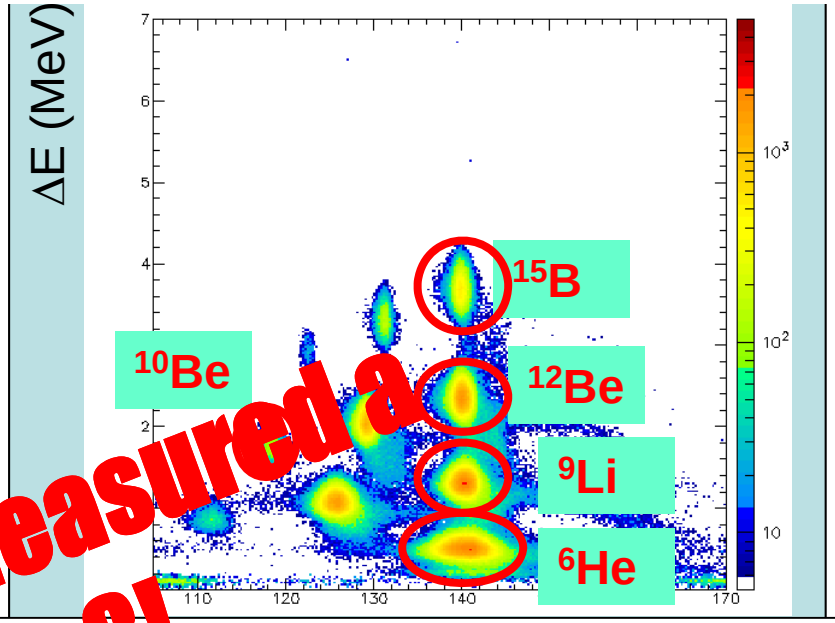


Image of a matrix holes ϕ=5 mm

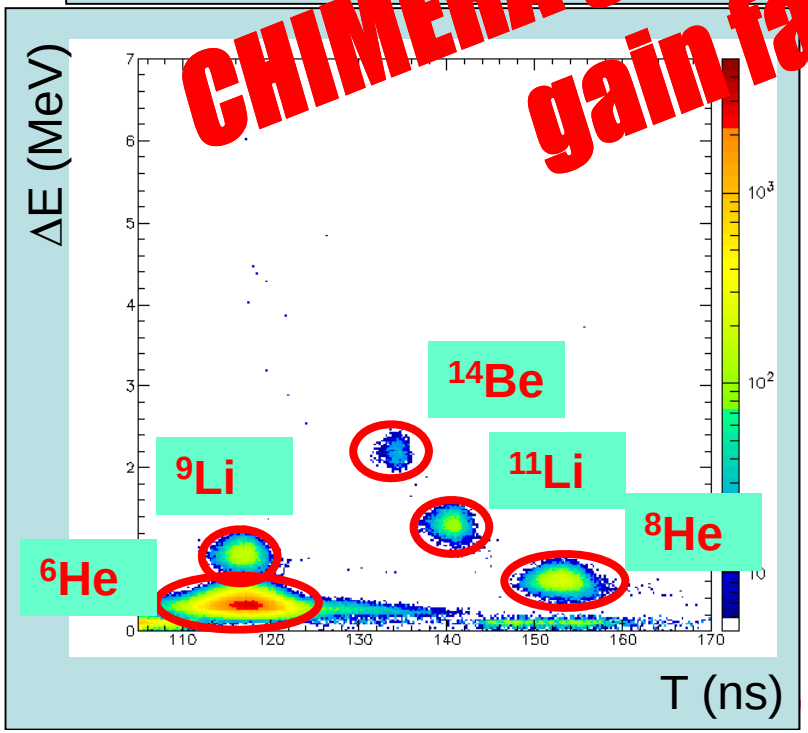


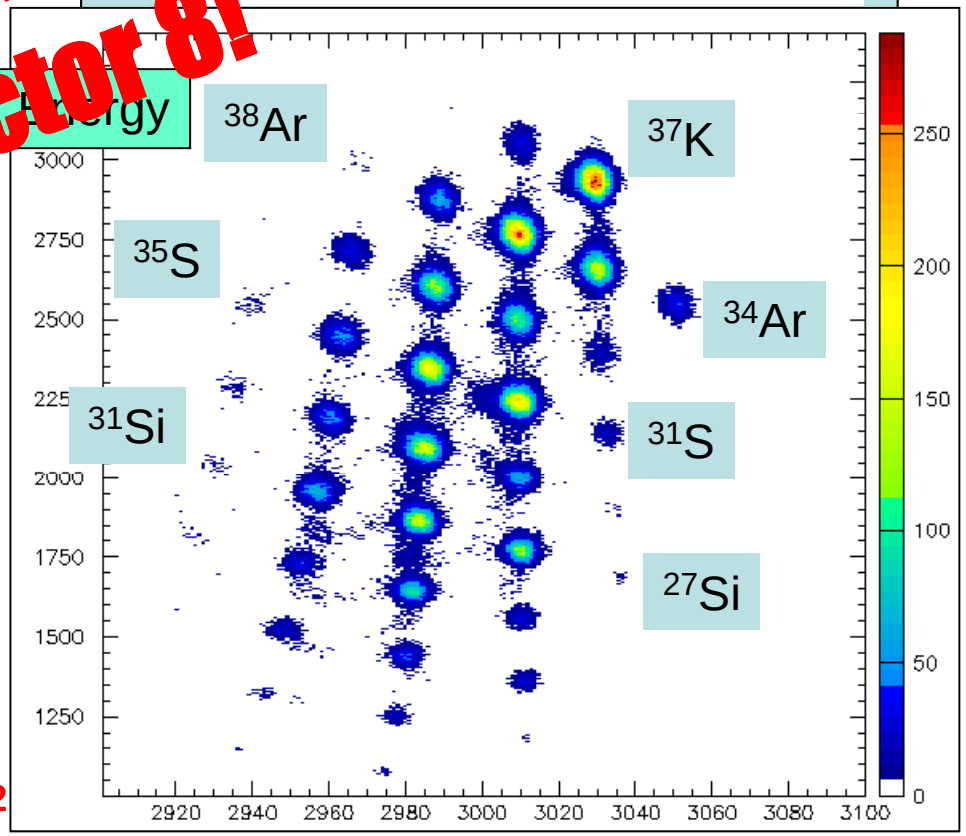
Early test of beam imaging



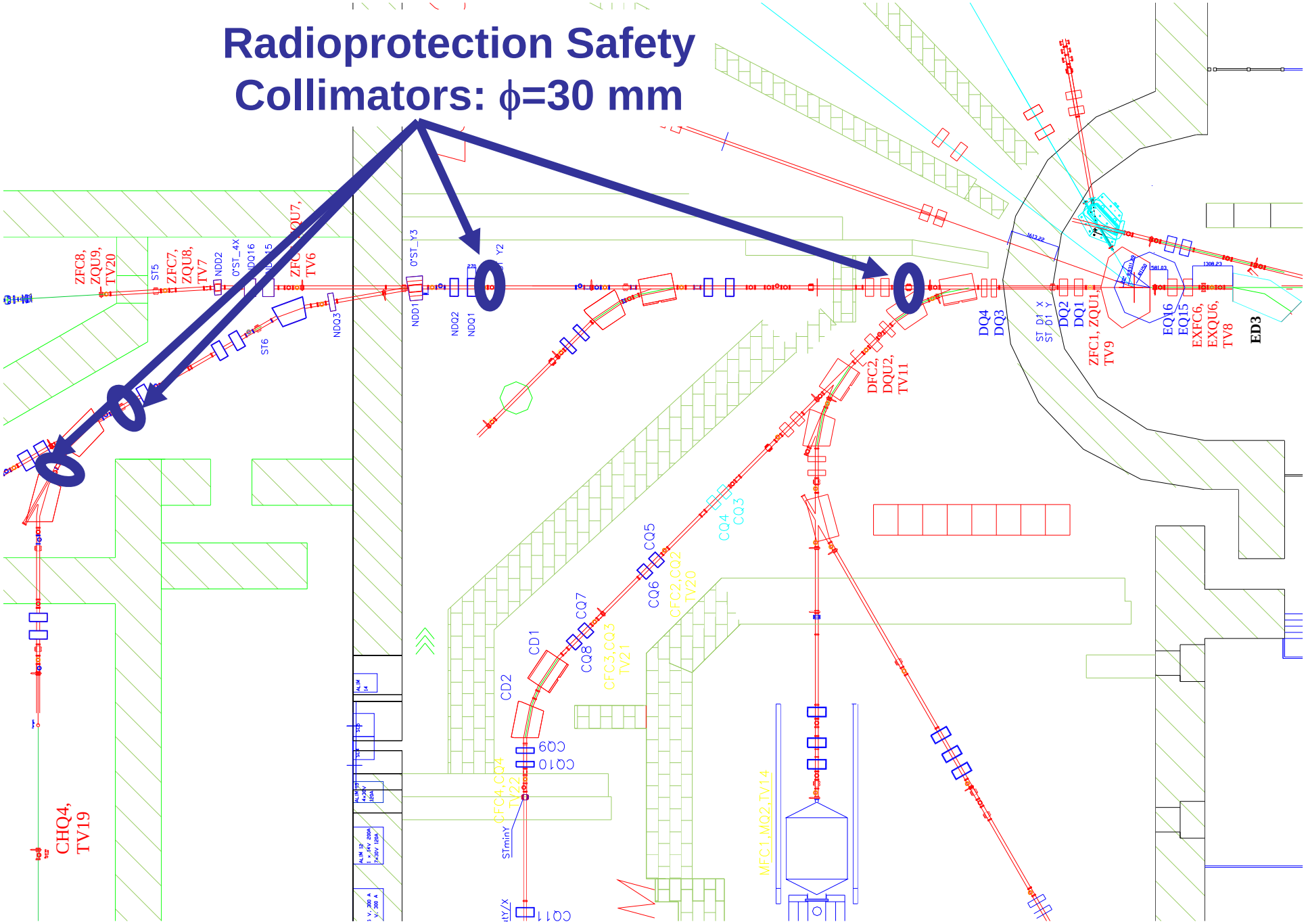


CHIMERA group measured a gain factor 8!





Radioprotection Safety
Collimators: ϕ=30 mm



Next step: install new Faraday cups, remove the collimators

CHIMERA acceptance:

x=±5 mm, X'=±5.7 mrad, ε_x=17 mm.mrad

Y =±5 mm Y'=±6 mrad, ε_y=3 mm.mrad

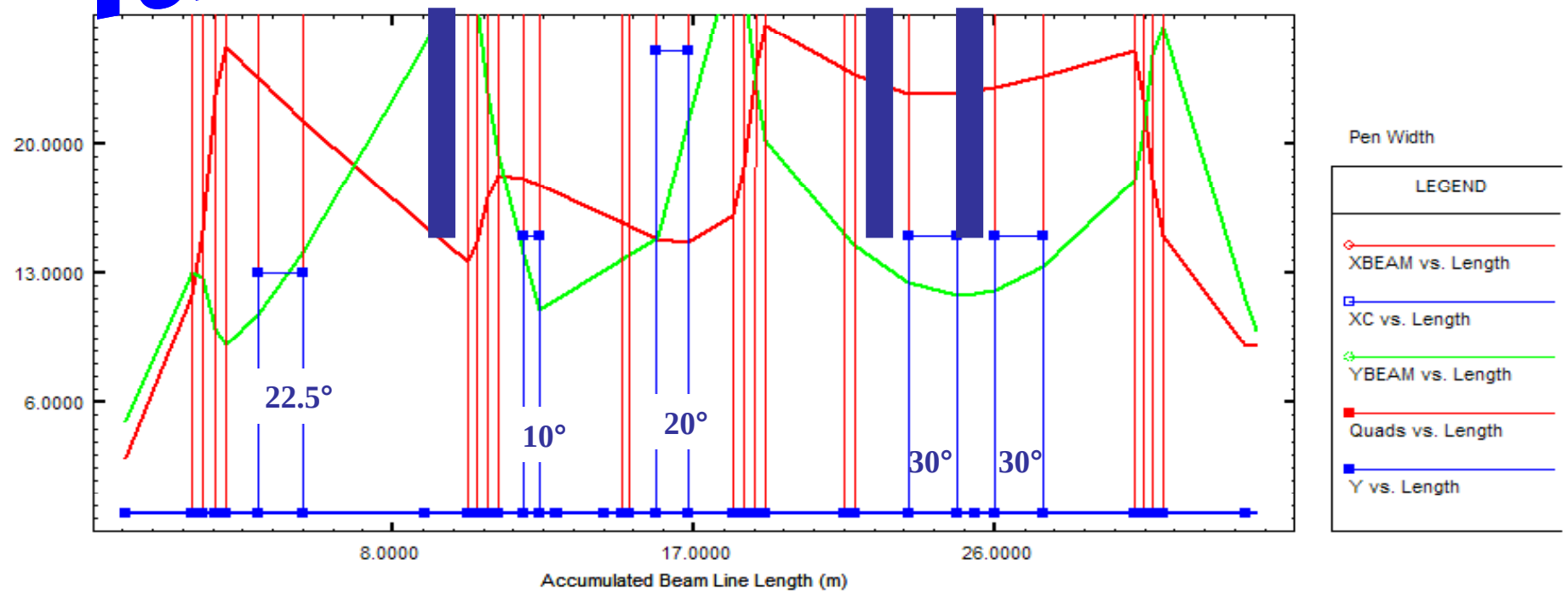
Beam spot size at beam line end:

x= y =

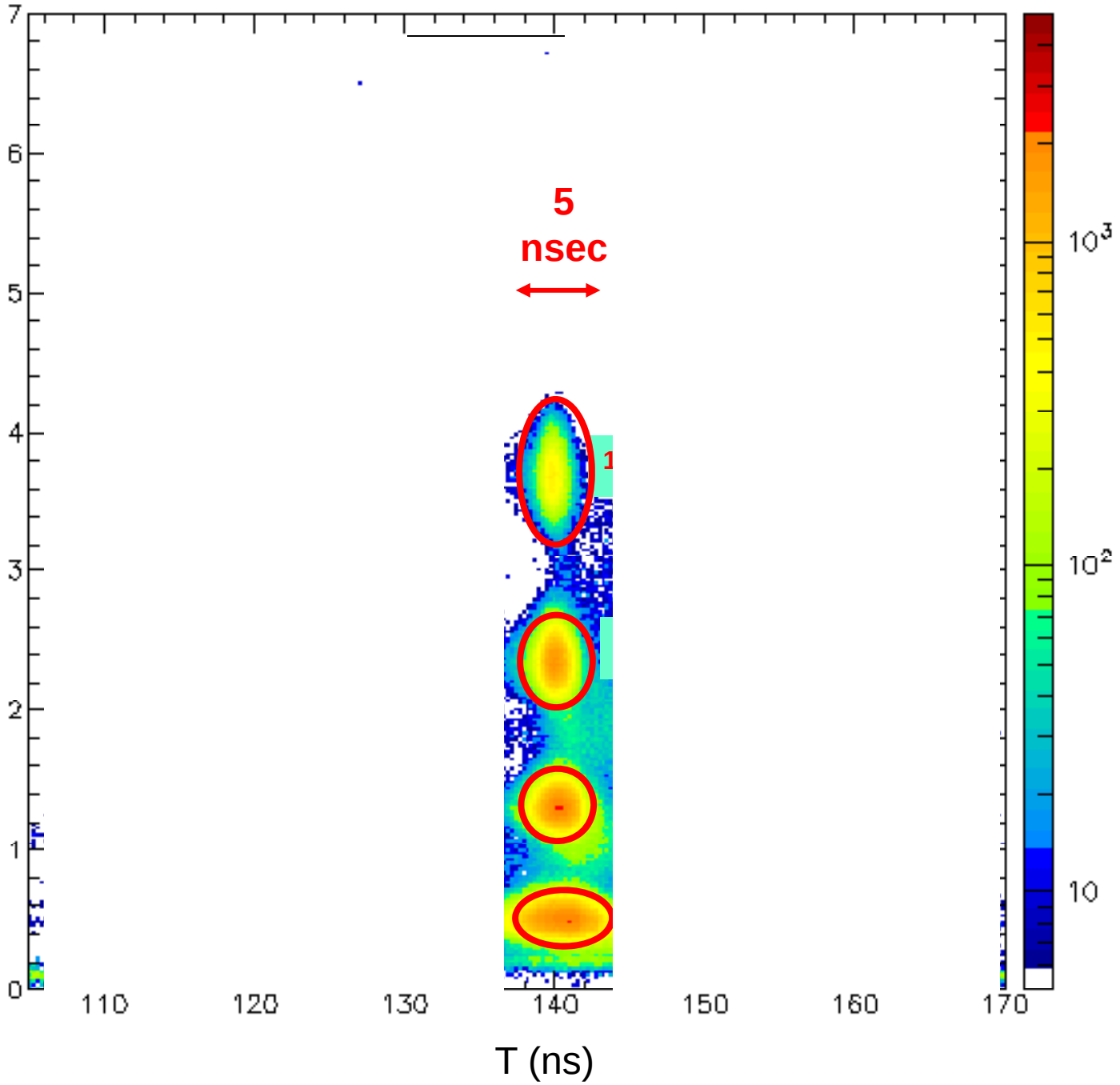
55%

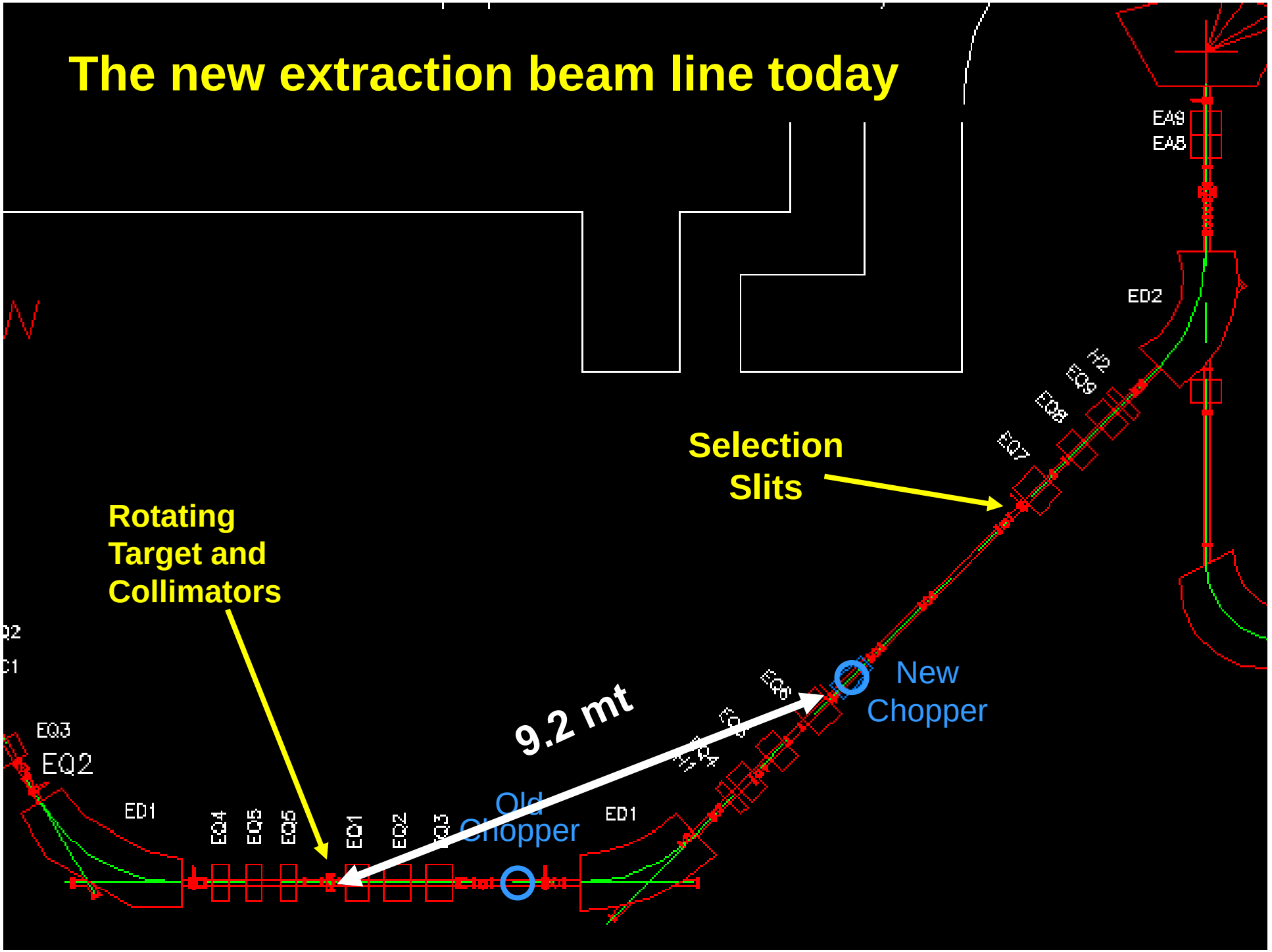
60%

Full transmission 34 %
→ gain factor: just 12



Time of flight measured between MCP placed 13 mt before the CHIMERA strip detector

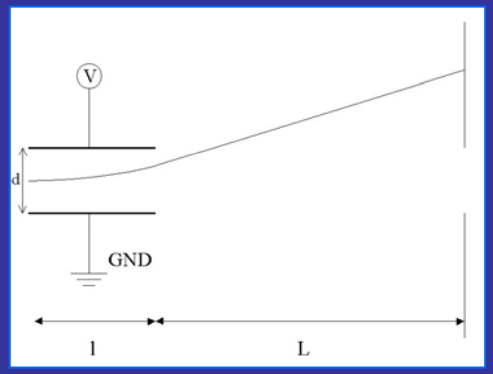



The new extraction beam line today
EA9
EA8
ED2
EQ7
EQ8
EQ9
EQ10
Selection
Slits
Rotating
Target and
Collimators
New
Chopper
9.2 mt
Old
Chopper
EQ3
EQ2
ED1
EQ4
EQ5
EQ6
EQ1
EQ2
EQ3
ED1

Chopper - 500

The production of consecutive accelerated bunches with a separation time of up to 200 ns and a width of 500 ps FWHM, is the goal of this new chopping beam system. The chopper 500 should cut the present length of the accelerated beam bunches, delivered from the superconducting cyclotron, from 1.5÷2 ns to 0.5 ns.

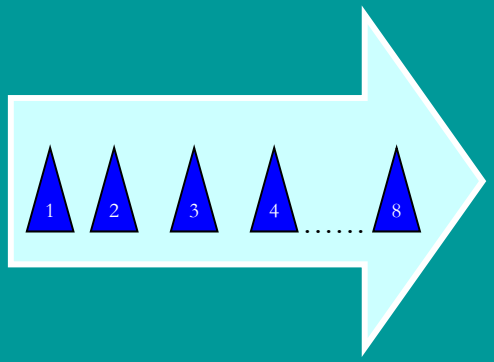
From separation time 20-66 ns
Width of single bunch 1.6-5 ns

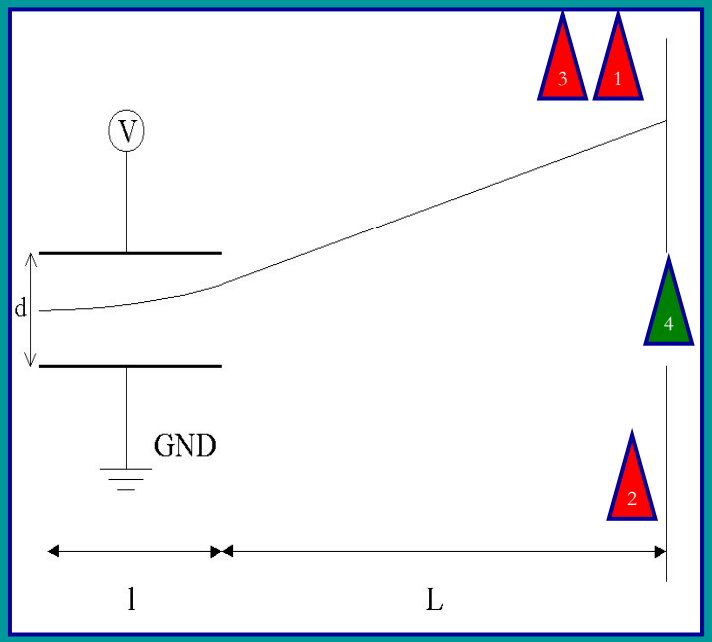


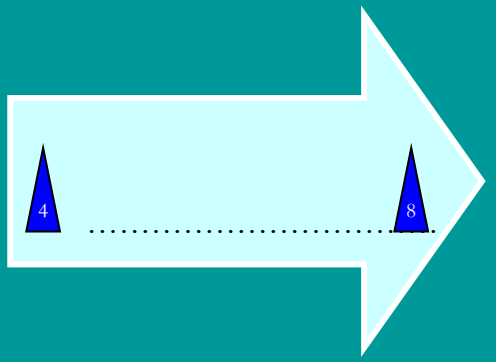
To separation time ≤ 200 ns
Width of single bunch 500 ps

Chopper-500 cavity

Chopper-500 basic working principle







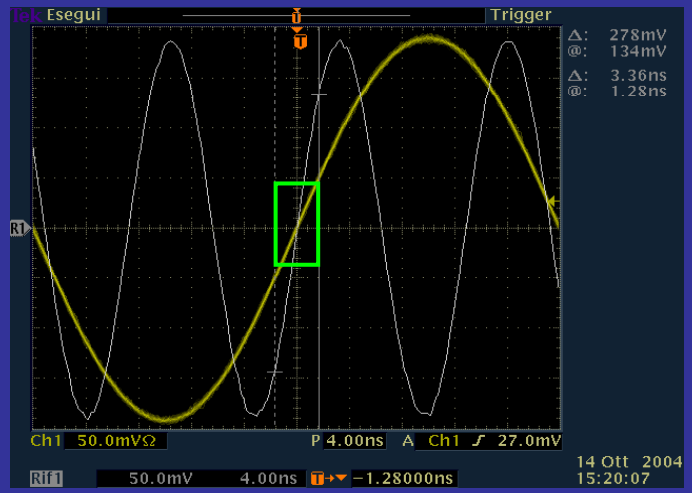
Eight accelerated bunches from the superconducting cyclotron

The chopper-500 system suppresses 3 bunches out of 4 and reduces the time length of the selected bunch from 1÷3 ns to 500ps FWHM.

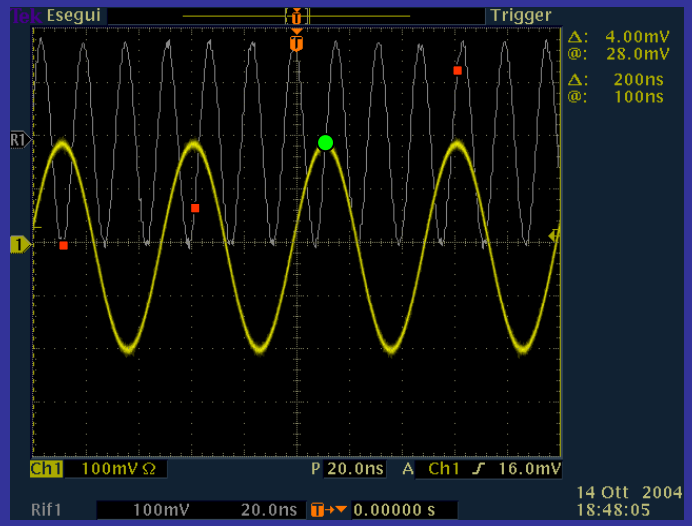
The selected bunches follows the indication of the next table, where 1 bunch out of 4 is selected.

Operative example

The goals of the chopper are graphically summarized in the waveforms on the left.
The first picture is the composition between one period of the RF cyclotron, in yellow, and the sinusoidal waveform applied to chopper plates, in silver. The green box represents an accelerated beam bunch. The width of the bunch is inside the frame of the oscilloscope markers. Due to the cyclotron acceptance the bunch width is 3.3 ns. In this interval the applied silver voltage is enough to induce a fast variation of the electric field at a time interval of **0.5 ns** during the passage of the particles. 3.5 meters ahead the selection slits cut the beam bunches to 500ps FWHM.



The second picture graphically shows the second goal of the chopper 500: the suppression of spurious bunches to achieve beam bunches with a separation time of up to **200 ns**.
The green spot shows the selected beam bunch, while the red spots are the suppressed ones. In this case one selected beam bunch every four is selected. The separation time of 200 ns is the interval between the markers.



The relation between the cyclotron and chopper sinusoids is 3.125. This means that there is a common subharmonic frequency wich is the 4th and 13rd of the cyclotron and chopper respectively.

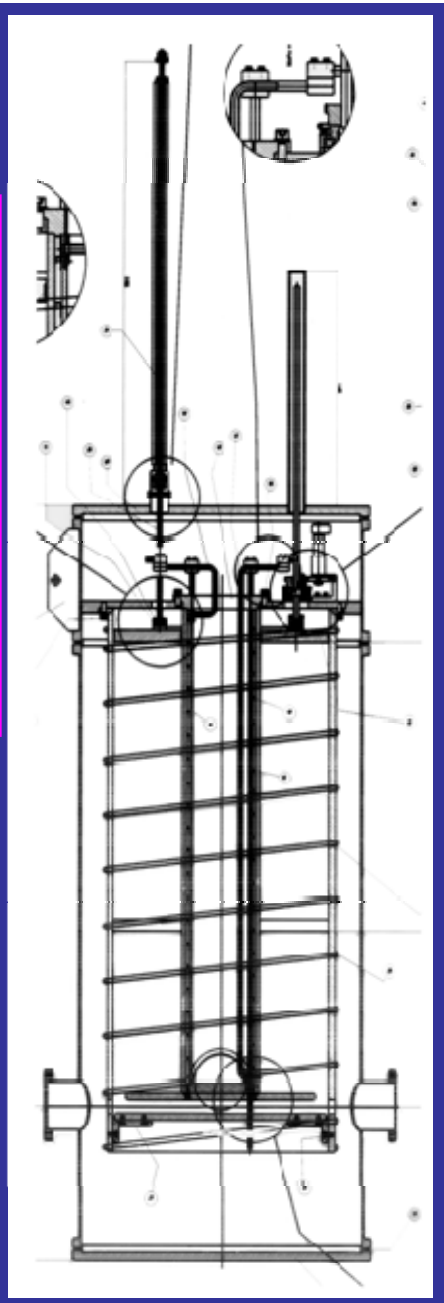
Components and parameters

Parameters and Value limits

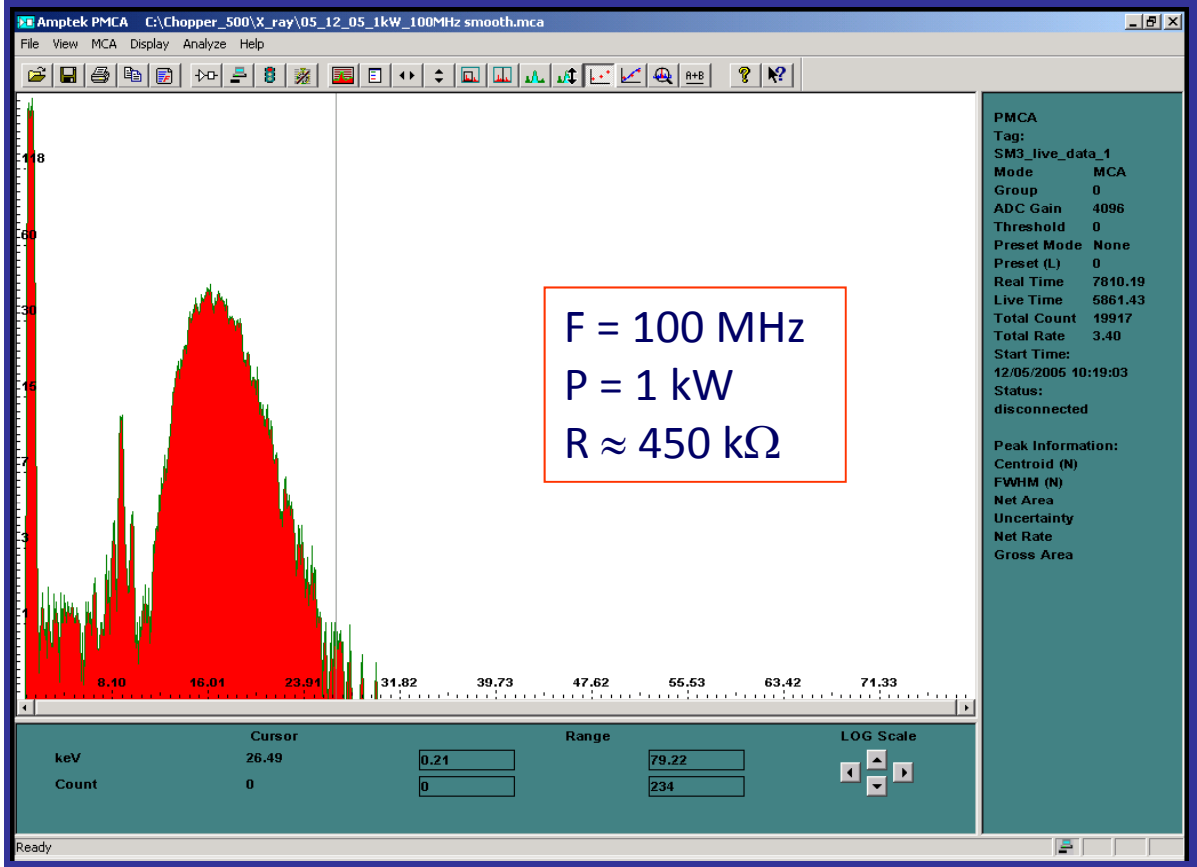
Maximum Peak Voltage 200 kVolts
Frequency range 65÷110 MHz
Qo 6000÷9000
R shunt 450÷720 kΩ
Power dissipated 27÷45 kW
VSWR < 1.1
Coupling capacitive
Input impedance 50Ω on 3”1/8

The disassembled deflecting plates
The lenght, the width and the gap are 400-70-30 mm, respectively.

The inner and outer coaxial during the assembling operation



X-RAY Chopper-500



F = 100 MHz
P = 1 kW
R ≈ 450 kΩ

Perturbation method

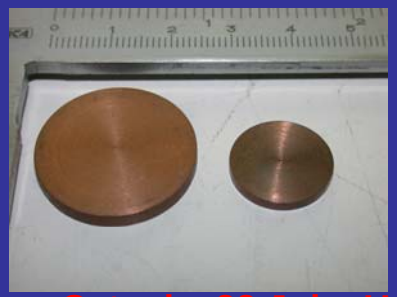
$$R_{shunt} = \frac{2}{\varepsilon_0}\left(\frac{g}{\pi \cdot D}\right)^2 \frac{1}{\Delta g} \cdot \frac{\Delta f \cdot Q_0}{f_0^2}$$

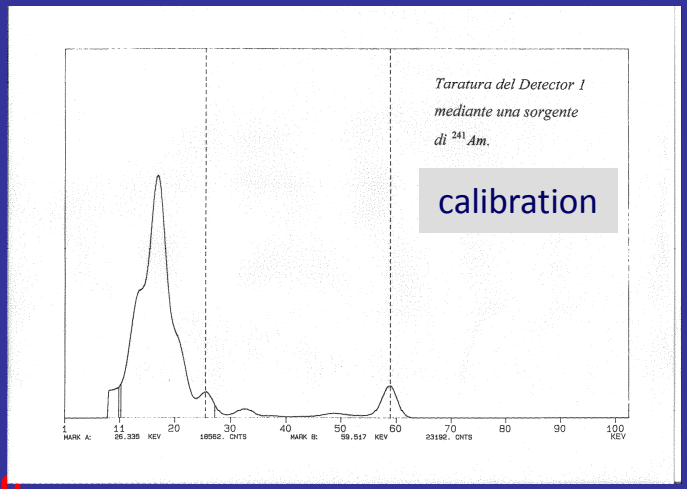
$$\varepsilon_0 \approx 8.85 \cdot 10^{-12}$$

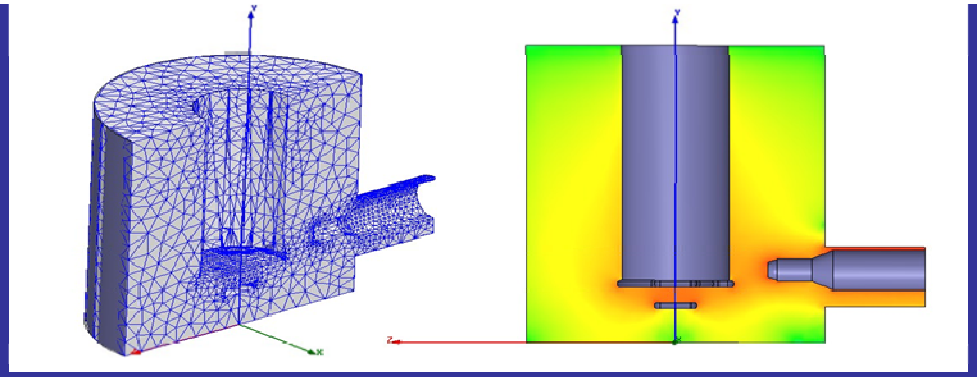
g: gap between the electrodes
D: diameter of the perturbation element
Δg: thickness of the perturbation element
f_0: resonance frequency without perturbation
Q_0: unloaded Q factor

X-Rays method

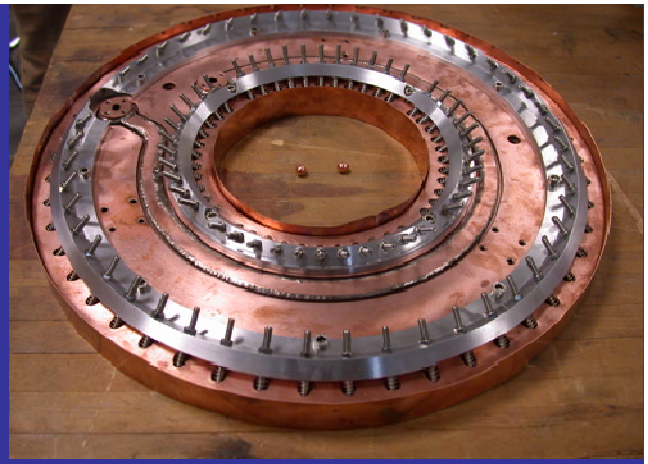
$$R_{shunt} = \frac{V^2}{2 \cdot P}$$

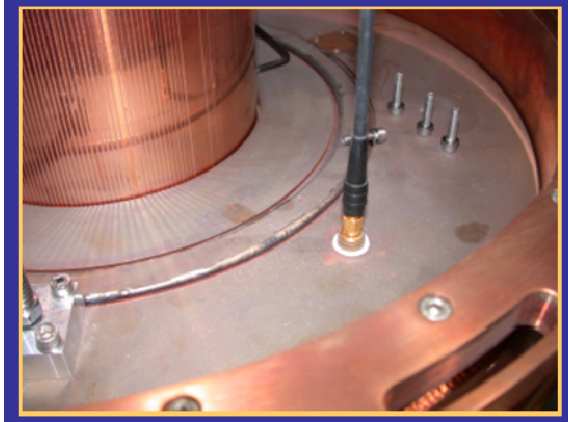




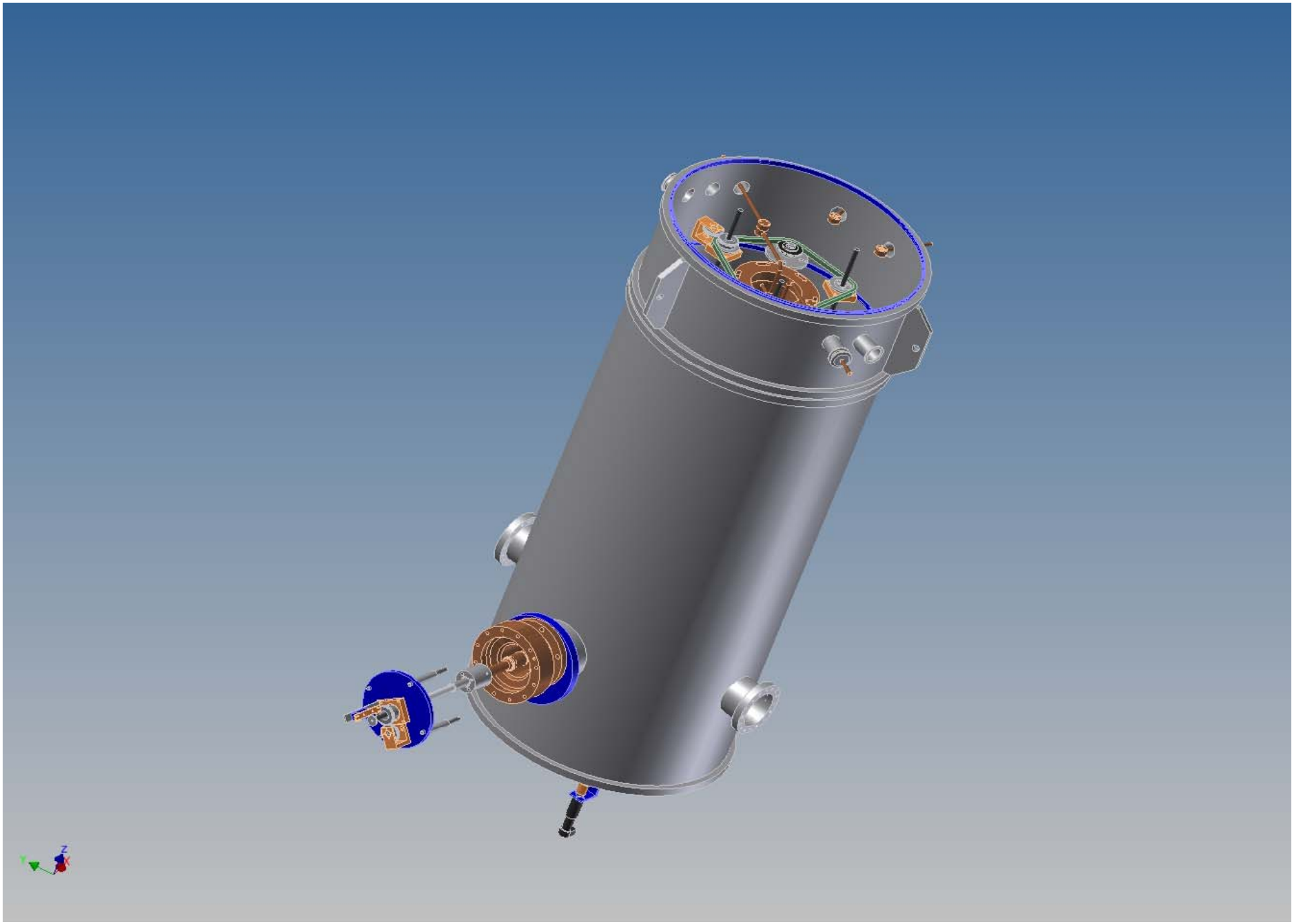


Mesh and distribution electric field





Refurbished sliding short of the Chopper 500



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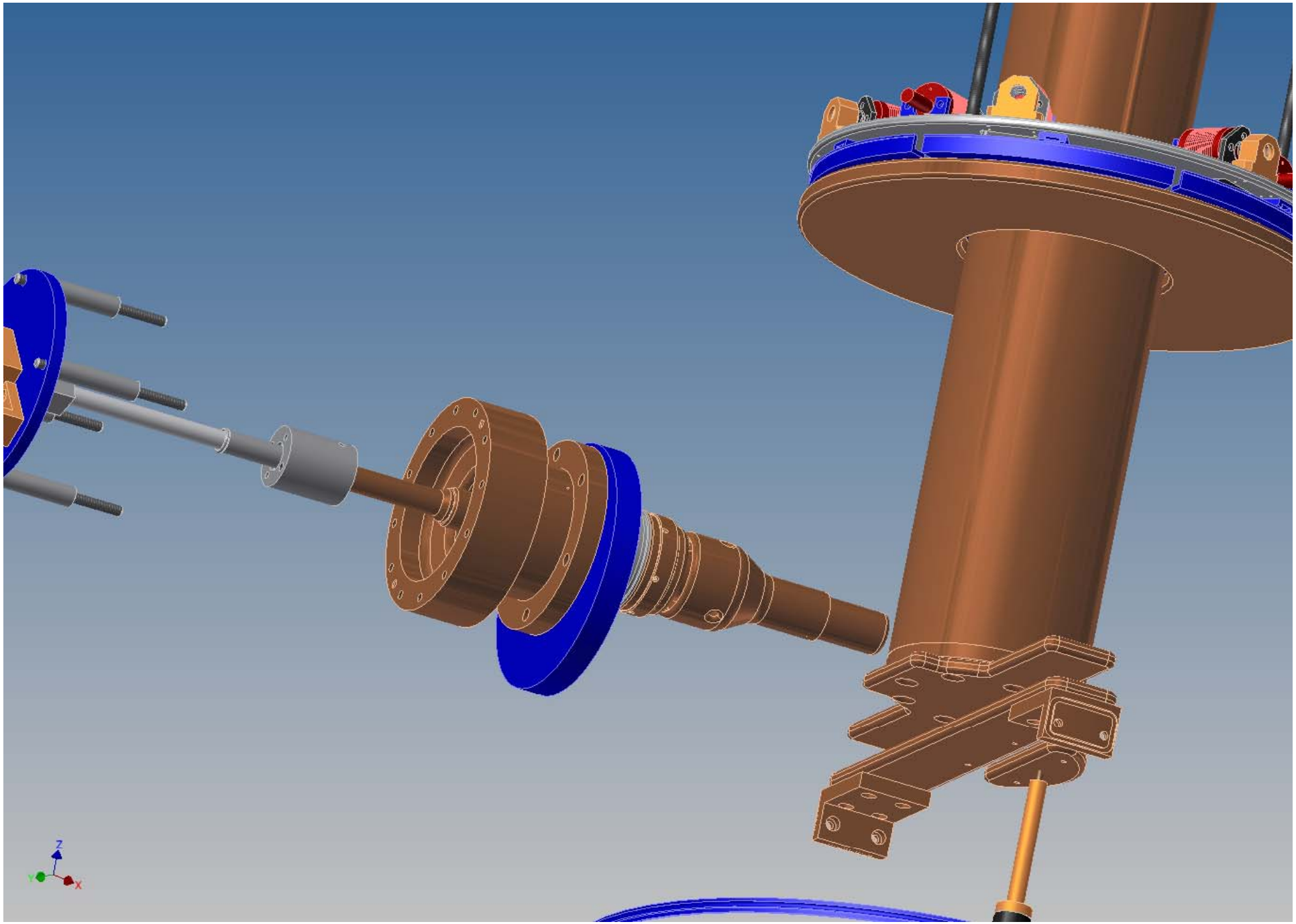

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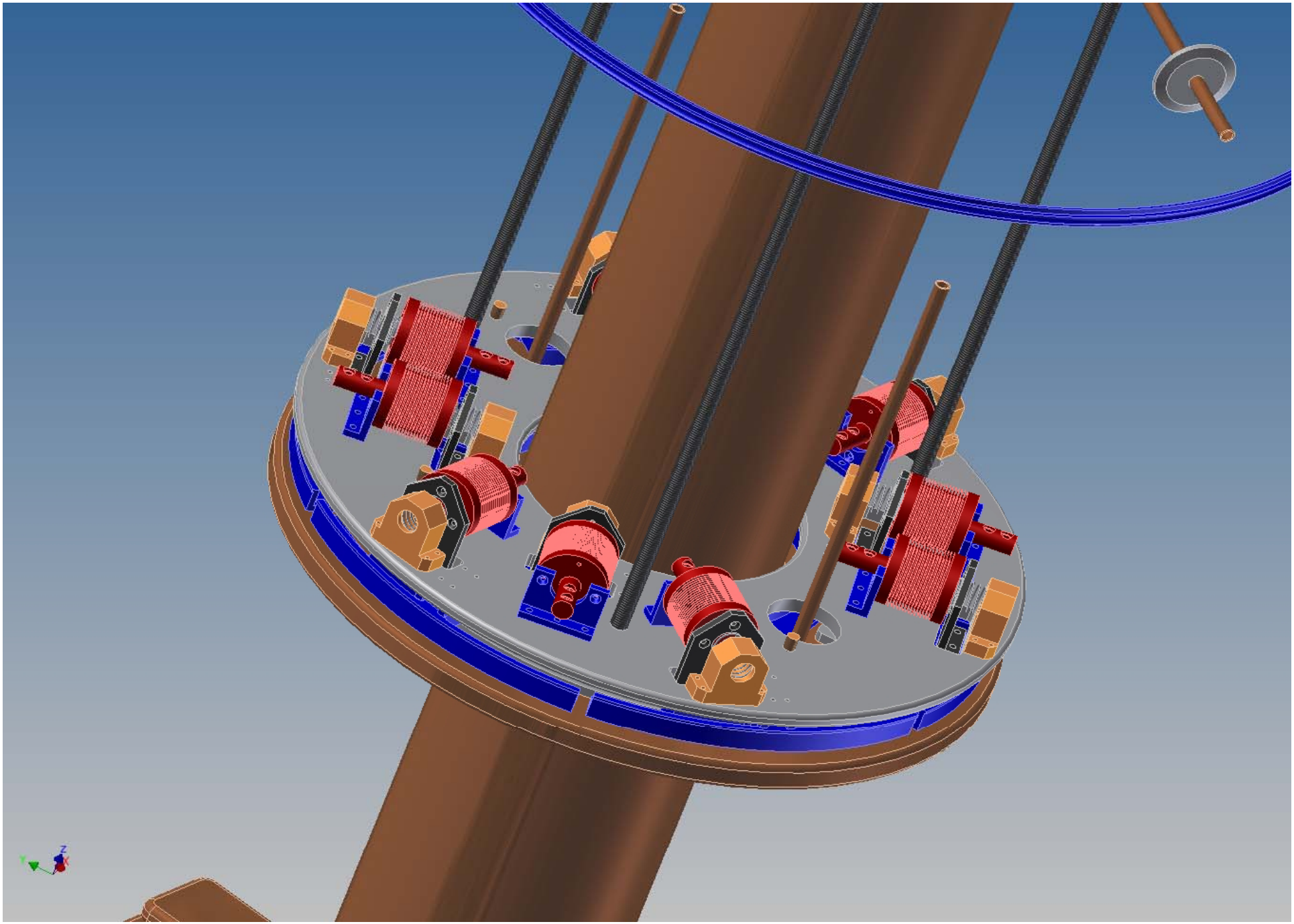

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and that's all Folk
…Thanks for your
attention