



MAGNETS AND BEAM TRANSPORT



GFS-2 - The New Gas-filled Separator for Super-Heavy Elements in JINR. A Guided Walk through the Genesis of the Project from First Thoughts to Completion

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With special thanks to our co-workers from the « 100 ton » company, for their efficiency and the pleasure to work with them during the installation





Super Heavy Elements



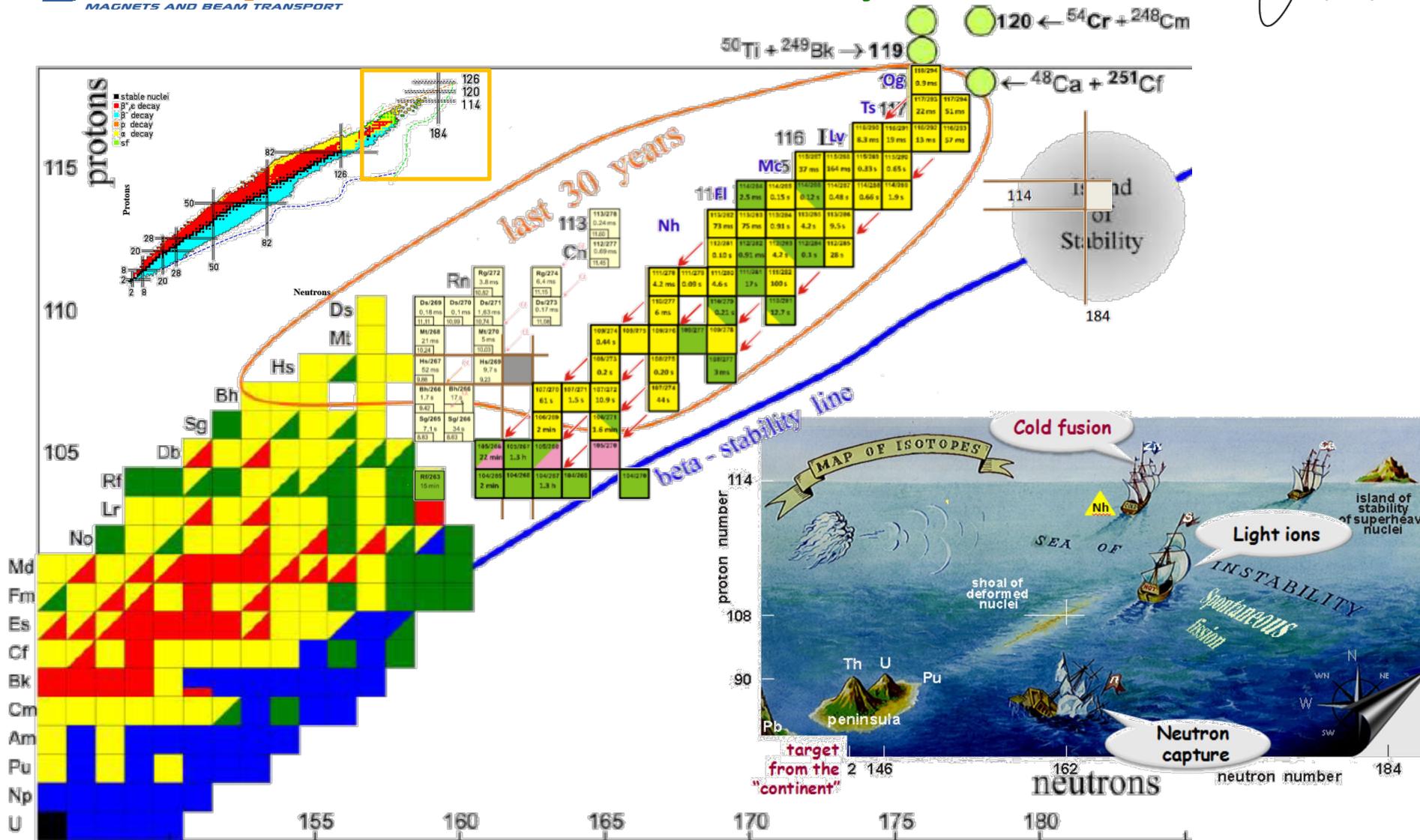
WHY ?

Filling in Mendeleev's

Tableau périodique des éléments

1 H Hydrogène 1,008 1s ¹ -1 +1																	2 He Hélium 4,008 1s ² 0		
3 Li Lithium 6,94 1s ² 2s ¹ +1	4 Be Béryllium 9,012 1s ² 2s ² +2	<p>Numéro atomique — 80</p> <p>Nom de l'élément — Mercure</p> <p>Masses atomiques, basées sur ¹²C — 200,59</p> <p>[] : nombre de masse de l'isotope le plus stable — 194,03</p> <p>Energie de première ionisation (eV) — 10,44</p> <p>Symbole de l'élément (en gris : aucun isotope stable)</p> <p>Electronégativité (échelle de Pauling) — 1,9</p> <p>Configuration électronique (en rouge : exception à la règle de Klechkowski) — [Xe] 6s² 4f¹⁴ 5d¹⁰</p> <p>(Régions : nombres d'oxydation les plus fréquents en gras)</p>										13 B Bore 10,81 1s ² 2s ² 2p ¹ +3	14 C Carbone 12,01 1s ² 2s ² 2p ² -4 +2 +4	15 N Azote 14,01 1s ² 2s ² 2p ³ -3 -1 +2 +3 +4 +5	16 O Oxygène 16,00 1s ² 2s ² 2p ⁴ -2 -1 +2	17 F Fluor 18,00 1s ² 2s ² 2p ⁵ -1	18 Ne Neon 20,18 1s ² 2s ² 2p ⁶ 0		
11 Na Sodium 22,99 [Ne] 3s ¹ +1	12 Mg Magnésium 24,31 [Ne] 3s ² +2	19 K Potassium 39,10 [Ar] 4s ¹ +1	20 Ca Calcium 40,08 [Ar] 4s ² +2	21 Sc Scandium 44,96 [Ar] 4s ² 3d ¹ +3	22 Ti Titane 47,87 [Ar] 4s ² 3d ² +2 +3 +4	23 V Vanadium 50,94 [Ar] 4s ² 3d ³ +2 +3 +4 +5	24 Cr Chrome 52,00 [Ar] 4s ¹ 3d ⁵ +2 +3 +6	25 Mn Manganèse 54,94 [Ar] 4s ² 3d ⁵ +2 +3 +4 +6 +7	26 Fe Fer 55,85 [Ar] 4s ² 3d ⁶ +2 +3	27 Co Cobalt 58,93 [Ar] 4s ² 3d ⁷ +2 +3	28 Ni Nickel 58,69 [Ar] 4s ² 3d ⁸ +2 +3	29 Cu Cuivre 63,55 [Ar] 4s ¹ 3d ¹⁰ +1 +2	30 Zn Zinc 65,38 [Ar] 4s ² 3d ¹⁰ +2	31 Ga Gallium 68,72 [Ar] 4s ² 3d ¹⁰ 4p ¹ +1 +2 +3	32 Ge Germanium 72,63 [Ar] 4s ² 3d ¹⁰ 4p ² +2 +4	33 As Arsenic 74,92 [Ar] 4s ² 3d ¹⁰ 4p ³ -3 +3 +5	34 Se Sélénium 78,96 [Ar] 4s ² 3d ¹⁰ 4p ⁴ -2 +2 +4 +6	35 Br Brome 79,90 [Kr] 4s ² 3d ¹⁰ 4p ⁵ -1 +1 +3 +5 +7	36 Kr Krypton 83,80 [Ar] 4s ² 3d ¹⁰ 4p ⁶ 0
37 Rb Rubidium 85,47 [Kr] 5s ¹ +1	38 Sr Strontium 87,62 [Kr] 5s ² +2	39 Y Yttrium 88,91 [Kr] 5s ¹ 4d ¹ +2 +3	40 Zr Zirconium 91,22 [Kr] 5s ² 4d ² +4	41 Nb Niobium 92,91 [Kr] 5s ¹ 4d ⁴ +3 +5	42 Mo Molybdène 95,96 [Kr] 5s ¹ 4d ⁵ +2 +3 +4 +5 +6	43 Tc Technétium [98] [Kr] 5s ¹ 4d ⁵ +7	44 Ru Ruthénium 101,07 [Kr] 5s ¹ 4d ⁷ +2 +3 +4 +5 +6	45 Rh Rhodium 102,91 [Kr] 5s ¹ 4d ⁸ +2 +3 +4	46 Pd Palladium 106,42 [Kr] 5s ⁰ 4d ¹⁰ +2	47 Ag Argent 107,87 [Kr] 5s ¹ 4d ¹⁰ +1	48 Cd Cadmium 112,41 [Kr] 5s ² 4d ¹⁰ +2	49 In Indium 114,82 [Kr] 5s ² 4d ¹⁰ 5p ¹ +1 +2 +3	50 Sn Étain 118,71 [Kr] 5s ² 4d ¹⁰ 5p ² +2 +4	51 Sb Antimoine 121,76 [Kr] 5s ² 4d ¹⁰ 5p ³ -3 +3 +5	52 Te Tellure 127,80 [Kr] 5s ² 4d ¹⁰ 5p ⁴ -2 +2 +4 +6	53 I Iode 126,90 [Kr] 5s ² 4d ¹⁰ 5p ⁵ -1 +1 +3 +5 +7	54 Xe Xénon 131,29 [Kr] 5s ² 4d ¹⁰ 5p ⁶ 0		
55 Cs Césium 132,91 [Xe] 6s ¹ +1	56 Ba Baryum 137,33 [Xe] 6s ² +2	57 à 71	72 Hf Hafnium 178,49 [Xe] 6s ² 4f ¹⁴ 5d ² +4	73 Ta Tantale 180,95 [Xe] 6s ² 4f ¹⁴ 5d ³ +3 +5	74 W Tungstène 186,84 [Xe] 6s ² 4f ¹⁴ 5d ⁴ +3 +4 +5 +6	75 Re Rhenium 186,21 [Xe] 6s ¹ 4f ¹⁴ 5d ⁵ +2 +3 +4 +5 +6 +7	76 Os Osmium 190,23 [Xe] 6s ² 4f ¹⁴ 5d ⁶ +2 +3 +4 +5 +6	77 Ir Iridium 192,22 [Xe] 6s ² 4f ¹⁴ 5d ⁷ +2 +4 +6	78 Pt Platine 195,08 [Xe] 6s ¹ 4f ¹⁴ 5d ⁹ +2 +4	79 Au Or 196,97 [Xe] 6s ¹ 4f ¹⁴ 5d ¹⁰ +1 +3	80 Hg Mercure 200,59 [Xe] 6s ² 4f ¹⁴ 5d ¹⁰ +1 +2	81 Tl Thallium 204,38 [Xe] 6s ² 4f ¹⁴ 5d ¹⁰ 6p ¹ +1 +2 +3	82 Pb Plomb 207,2 [Xe] 6s ² 4f ¹⁴ 5d ¹⁰ 6p ² +2 +4	83 Bi Bismuth 208,98 [Xe] 6s ² 4f ¹⁴ 5d ¹⁰ 6p ³ -3 +3 +5	84 Po Polonium [209] [Xe] 6s ² 4f ¹⁴ 5d ¹⁰ 6p ⁴ -2 +4	85 At Astate [210] [Xe] 6s ² 4f ¹⁴ 5d ¹⁰ 6p ⁵ -1 +1 +3 +5 +7	86 Rn Radon [222] [Xe] 6s ² 4f ¹⁴ 5d ¹⁰ 6p ⁶ 0		
87 Fr Francium [223] [Rn] 7s ¹ +1	88 Ra Radium [226] [Rn] 7s ² +2	89 à 103	104 Rf Rutherfordium [261] [Rn] 7s ² 5f ¹⁴ 6d ² +4	105 Db Dubnium [268] [Rn] 7s ² 5f ¹⁴ 6d ³ +5	106 Sg Seaborgium [271] [Rn] 7s ² 5f ¹⁴ 6d ⁴ +6	107 Bh Bohrium [272] [Rn] 7s ² 5f ¹⁴ 6d ⁵ +7	108 Hs Hassium [277] [Rn] 7s ² 5f ¹⁴ 6d ⁶ +8	109 Mt Meitnerium [278] [Rn] 7s ² 5f ¹⁴ 6d ⁷ +9	110 Ds Darmstadtium [281] [Rn] 7s ² 5f ¹⁴ 6d ⁸ +10	111 Rg Roentgenium [280] [Rn] 7s ² 5f ¹⁴ 6d ⁹ +11	112 Cn Copernicium [285] [Rn] 7s ² 5f ¹⁴ 6d ¹⁰ +12	113 Nh Nihonium [286] [Rn] 7s ² 5f ¹⁴ 6d ¹⁰ 7p ¹ +1 +3	114 Fl Flerovium [289] [Rn] 7s ² 5f ¹⁴ 6d ¹⁰ 7p ² +2 +4	115 Mc Moscovium [288] [Rn] 7s ² 5f ¹⁴ 6d ¹⁰ 7p ³ +3 +5	116 Lv Livermorium [293] [Rn] 7s ² 5f ¹⁴ 6d ¹⁰ 7p ⁴ +4 +6	117 Ts Tennessine [294] [Rn] 7s ² 5f ¹⁴ 6d ¹⁰ 7p ⁵ -1 +1 +3 +5 +7	118 Og Oganesson [294] [Rn] 7s ² 5f ¹⁴ 6d ¹⁰ 7p ⁶ 0		
57 La Lanthane 138,91 [Xe] 6s ² 4f ¹ +3	58 Ce Cérium 140,12 [Xe] 6s ² 4f ¹ 5d ¹ +3 +4	59 Pr Praseodyme 140,91 [Xe] 6s ² 4f ³ +3 +4	60 Nd Néodyme 144,24 [Xe] 6s ² 4f ⁴ +3 +4	61 Pm Prométhium [145] [Xe] 6s ² 4f ⁵ +3 +4	62 Sm Samarium 150,36 [Xe] 6s ² 4f ⁶ +2 +3	63 Eu Europium 151,96 [Xe] 6s ² 4f ⁷ +2 +3	64 Gd Gadolinium 157,25 [Xe] 6s ² 4f ⁷ 5d ¹ +3 +4	65 Tb Terbium 158,93 [Xe] 6s ² 4f ⁹ +3 +4	66 Dy Dysprosium 162,50 [Xe] 6s ² 4f ¹⁰ +3	67 Ho Holmium 164,93 [Xe] 6s ² 4f ¹¹ +3	68 Er Erbium 167,26 [Xe] 6s ² 4f ¹² +3	69 Tm Thulium 168,93 [Xe] 6s ² 4f ¹³ +3	70 Yb Ytterbium 173,05 [Xe] 6s ² 4f ¹⁴ +2 +3	71 Lu Lutérium 174,97 [Xe] 6s ² 4f ¹⁴ 5d ¹ +3					
89 Ac Actinium [227] [Rn] 7s ² 6d ¹ +3	90 Th Thorium 232,04 [Rn] 7s ² 6d ² +4 +5	91 Pa Protactinium 231,04 [Rn] 7s ² 5f ² 6d ¹ +4 +5	92 U Uranium 238,03 [Rn] 7s ² 5f ³ 6d ¹ +3 +4 +5 +6	93 Np Neptunium [237] [Rn] 7s ² 5f ⁴ 6d ¹ +3 +4 +5 +6	94 Pu Plutonium [244] [Rn] 7s ² 5f ⁶ +3 +4 +5 +6	95 Am Americium [243] [Rn] 7s ² 5f ⁷ +3 +4 +5 +6	96 Cm Curium [247] [Rn] 7s ² 5f ⁸ +3 +4	97 Bk Berkélium [247] [Rn] 7s ² 5f ⁹ +3 +4	98 Cf Californium [251] [Rn] 7s ² 5f ¹⁰ +3	99 Es Einsteinium [262] [Rn] 7s ² 5f ¹¹ +3	100 Fm Fermium [267] [Rn] 7s ² 5f ¹² +3	101 Md Mendélévium [268] [Rn] 7s ² 5f ¹³ +3	102 No Nobélium [269] [Rn] 7s ² 5f ¹⁴ +3	103 Lr Lawrencium [262] [Rn] 7s ² 5f ¹⁴ 6d ¹ +3					

Heading towards stability





Super Heavy Elements



HOW ?



Schematics of a separator



Schematics of a separator



Beam from DC280



Schematics of a separator



Window or
differential pumping



Schematics of a separator



- Ø 480, 1500 rpm synchronous,
- e-beam & optical diagnostics
- Water & gas cooled

Window or differential pumping

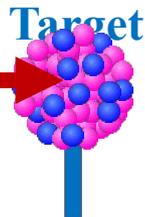
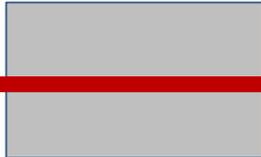


Schematics of a separator



- Ø 480, 1500 rpm synchronous,
- e-beam & optical diagnostics
- Water & gas cooled

Window or differential pumping



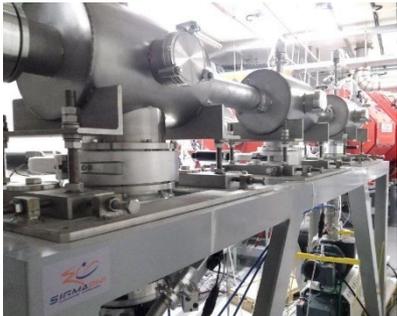
Beam from DC280



Beam Stop

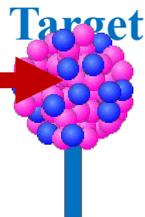
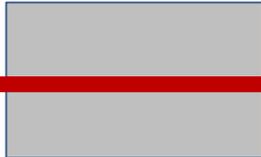


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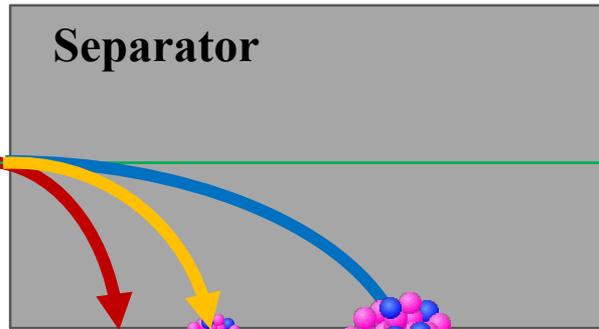
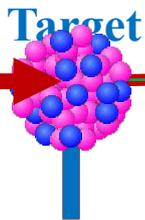


- Ø 480, 1500 rpm synchronous,
- e-beam & optical diagnostics
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48×128 strips 128×128 strips
6144 pixels 16384 pixels

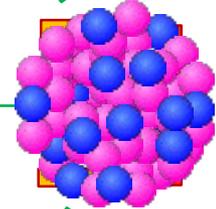


Beam from DC280



Focal plane detectors

ToF



Detector box



Micron Semiconductors, UK





What are we fighting for?



Reaction products in magnetic separator suffer from

Contamination

Many charge states

Large emission angle



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Improve rejection

Bending angle
dispersion

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Promote

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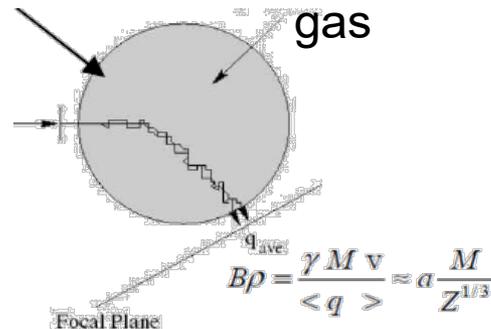
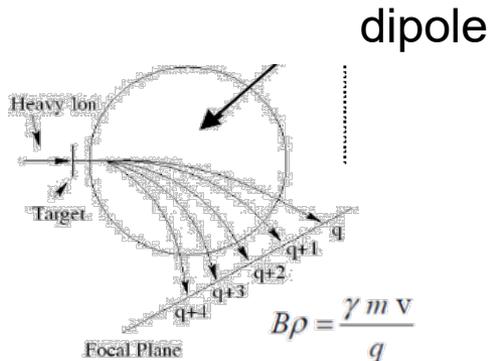
Improve rejection

Bending angle
dispersion

Separator

Promote
mechanisms that
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state distribution

**Gas-filled
Separator**



What are we fighting for?

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**Gas-filled
Separator**

Increase

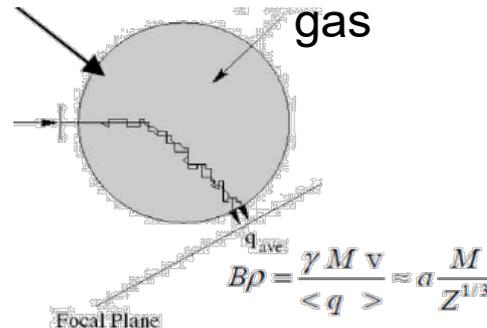
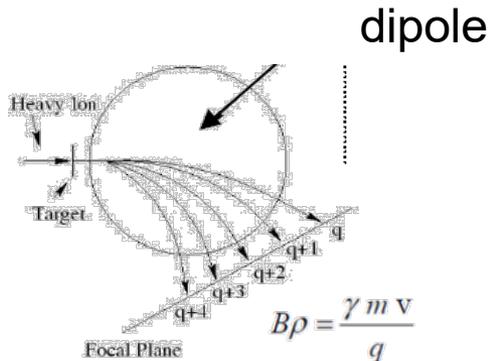
acceptance/transmission

Optics

Large apertures

Focusing

Optimized chambers



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Reaction products in magnetic separator suffer from

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Many charge states

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**Gas-filled
Separator**

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acceptance/transmission

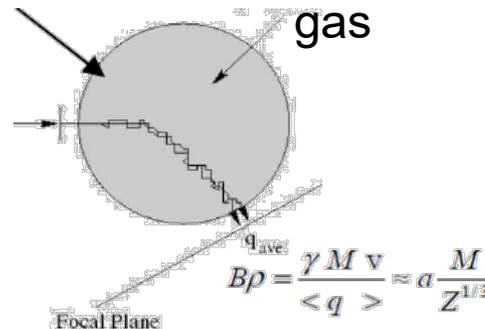
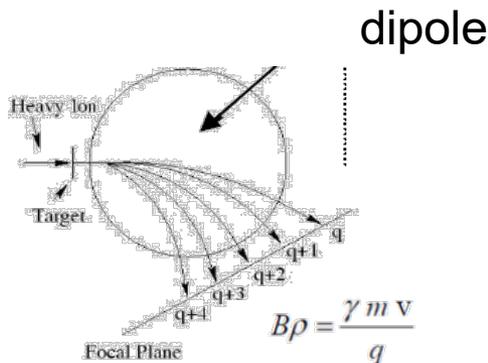
Optics

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Focusing

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**Large acceptance
Gas-filled
Separator**



Formation of SHE is a very rare event (**pb**)

At $1\text{p}\mu\text{A}$ of ^{48}Ca

$1\text{nb} \rightarrow 100$ events/h

$1\text{pb} \rightarrow 1$ event/week

$1\text{fb} \rightarrow 1$ event/20 years

“On 9 October 2006, the researchers announced that they had indirectly detected a total of 3 (possibly 4) nuclei of oganesson-294 (**1 or 2 in 2002 and 2 more in 2005**) produced via collisions of californium-249 atoms and calcium-48 ions”

Excerpt from the Wikipedia webpage on Oganesson
<https://en.wikipedia.org/wiki/Oganesson>



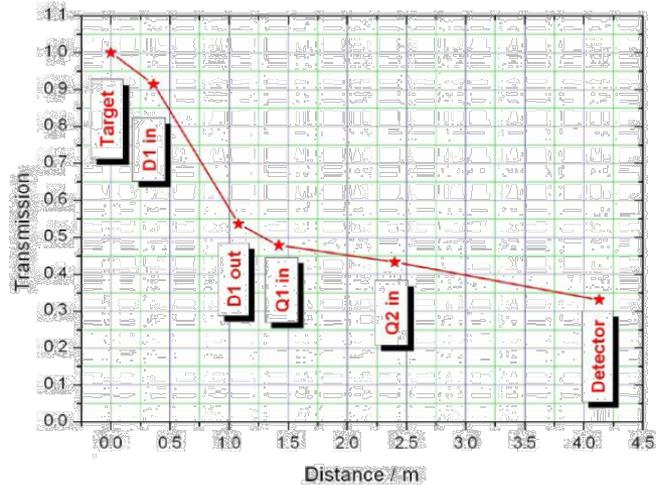
Expectations



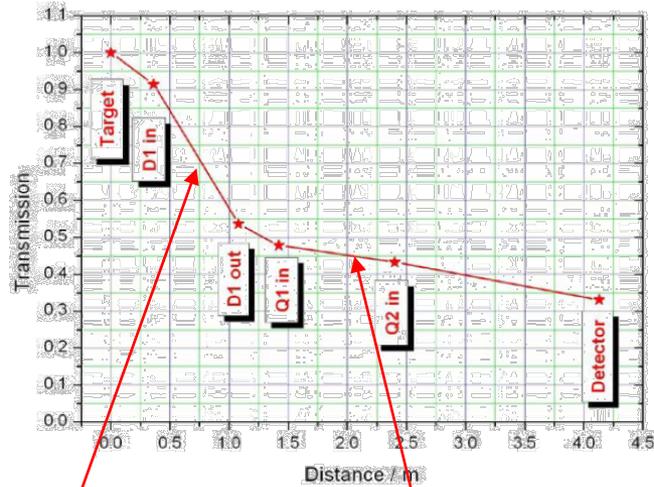
Rationale for new layout



Losses for $^{243}\text{Am}(^{48}\text{Ca},4n)^{286}\text{Mc}$ in existing DGFRS
 DQ_hQ_v layout : dipole gap 58mm, quad diameter 100mm



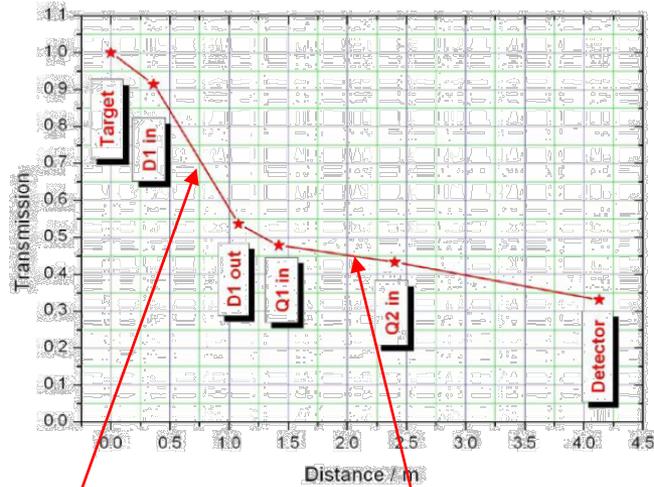
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40% loss
in dipole

15% loss
in quads

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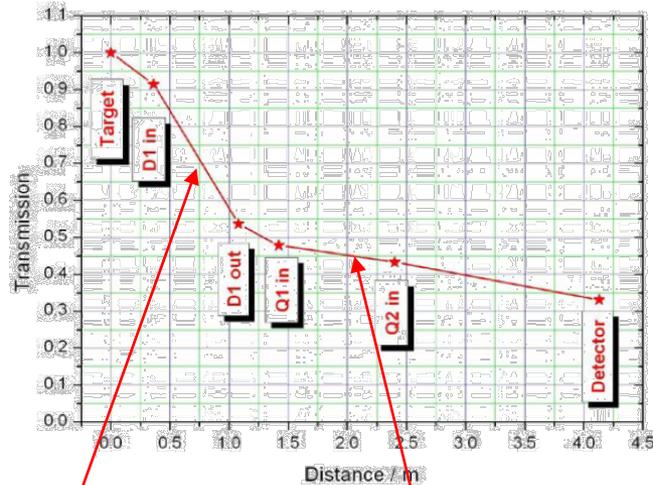
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**MUST IMPROVE
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Increase dipole gap

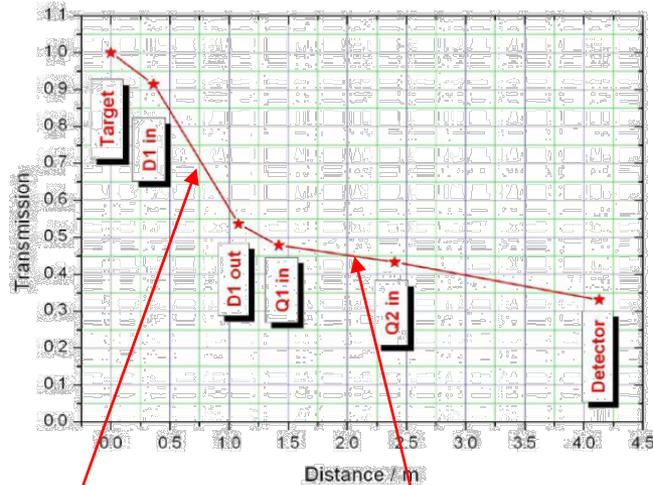
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Increase dipole gap

Q₁ V to enter dipole

Refocus H asap

Large exit pole edge angle

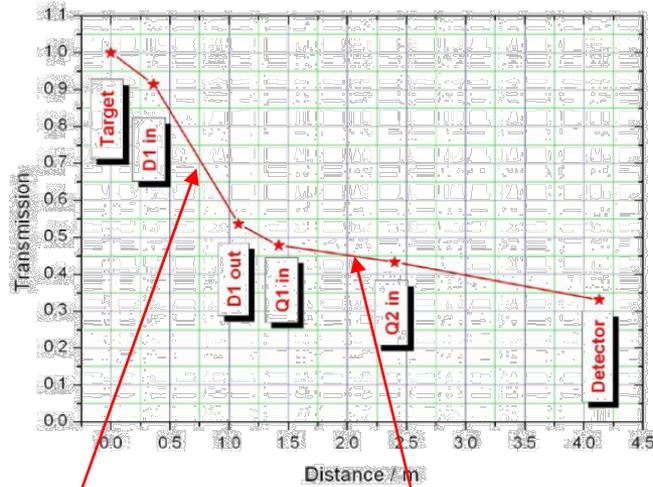
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Q₁ V to enter dipole

Large aperture quads

Refocus H asap

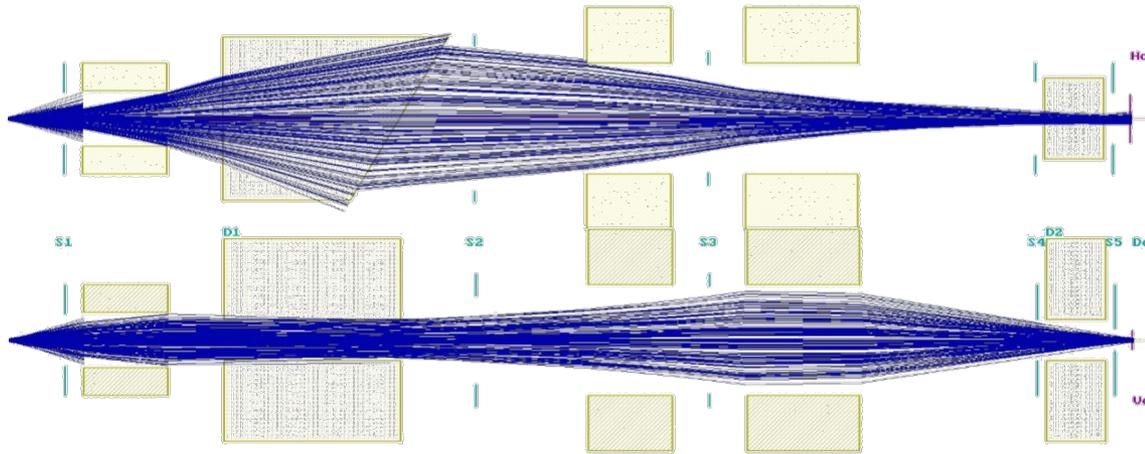
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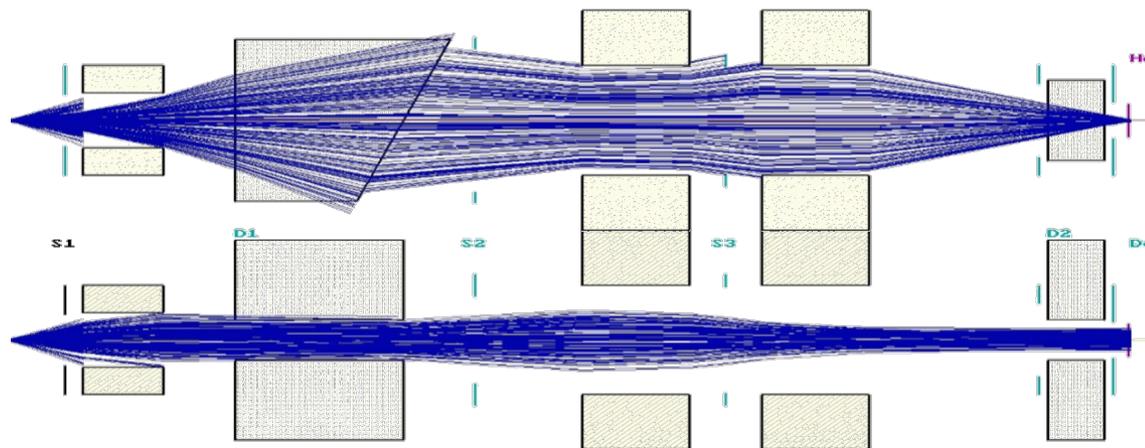
MUST IMPROVE TRANSMISSION

15% loss in quads

Transmission or Resolution ?



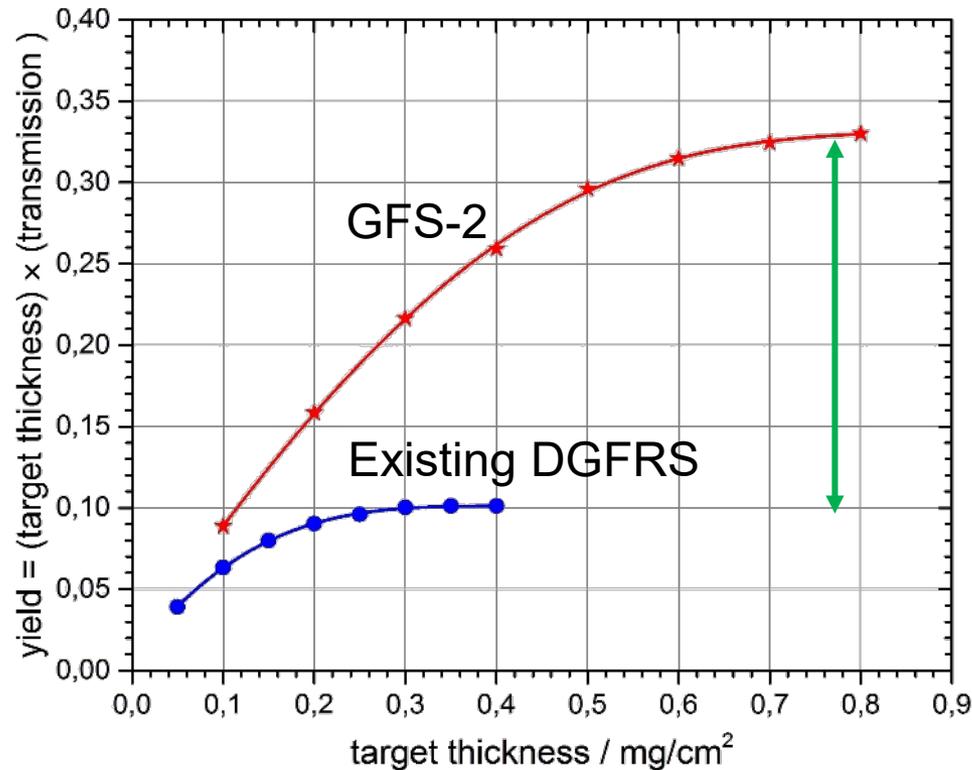
VHHV
Transmission +
Resolution -
Separator



VHVH
Transmission -
Resolution +
Spectrometer

Expected gain

Reaction	Transmission
$^{244}\text{Pu}(^{48}\text{Ca},3n)^{289}\text{Fl}$	60 %
$^{244}\text{Pu}(^{58}\text{Fe},4n)^{298}120$	75 %



$^{244}\text{Pu}(^{48}\text{Ca},4n)^{288}\text{Fl}$
Over 3 times more !!

GFS2 among some gas-filled separators

Separator	DGFRS	GARIS-II	RITU	BGS	TASCA	SHANS	GFS-II
Location	FLNR Dubna Russia	RIKEN Wakô Japan	JYFL Jyväskylä Finland	LBNL Berkeley USA	GSI Darmstadt Germany	IMP Lanzhou China	FLNR Dubna Russia
Configuration	$DQ_h Q_v$	$Q_v DQ_h Q_v D$	$Q_v DQ_h Q_v$	$Q_v D_h D$	$DQ_h Q_v$	$Q_v DQ_v Q_h$	$Q_v DQ_h Q_v D$
Deflection angle	23°	30°+7°	25°	25°+45°	30°	52°	30°+10°
$B\rho$ (max/T·m)	3.1	2.46	2.2	2.5	2.4	2.88	2.25
Length (m)	4	5.06	4.8	4.6	3.5	6.5	6.3
Dispersion (mm/% $B\rho$)	7.5	19.3	10	20	9	7.3	9.7
					High Transmission Mode	High Resolution Mode	



From initial spec to final layout
through various iterations

Living with constraints

gives rise to important questions

It is desirable but is it technically feasible ?

Is it economically OK ?

Investment costs AND running costs

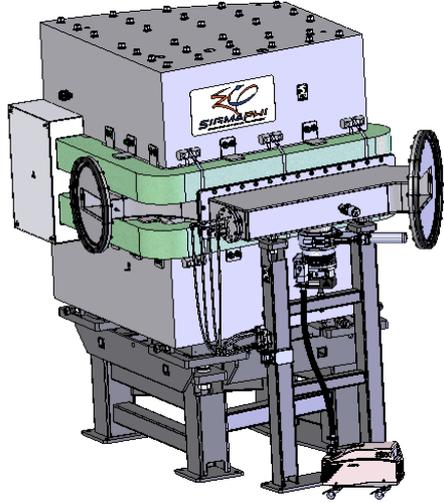
Can I trade this for that ?

I can improve. Is it worth ?

...



The big guy – 30° D1

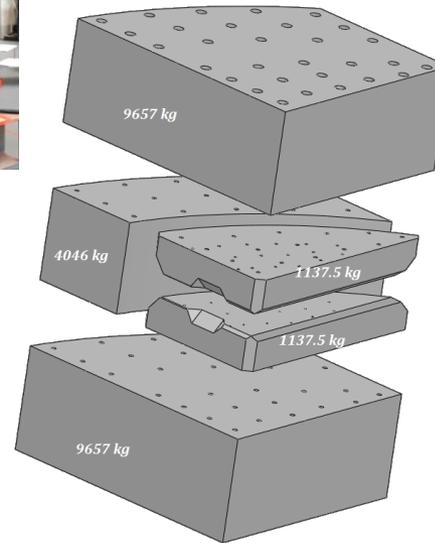


Factory assembly

Assembly on site



Hall probe measurement



Each part must be less than 10 tons

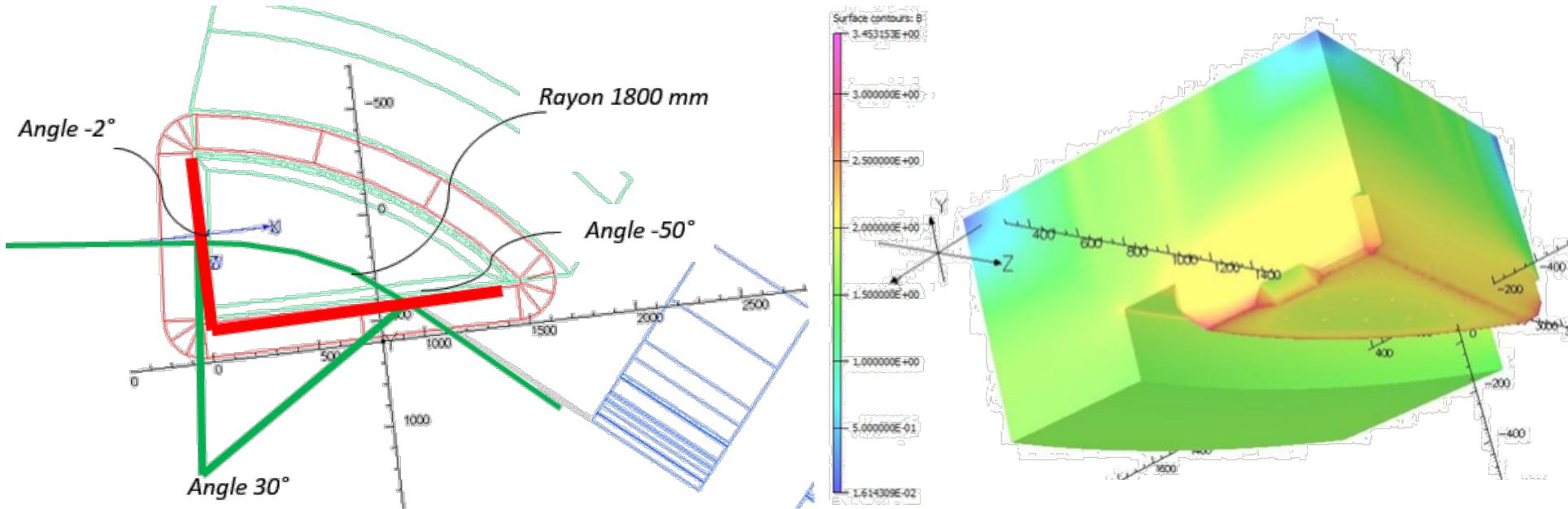
D1 parameters

Beam free aperture	120	mm
Magnet gap	132	mm
Curvature radius	1800	mm
Entrance face angle	-7 (-2)	°
Exit face angle	-44 (-50)	°
Deviation angle	31.5	°
Effective length	1007	mm
Good Field region	440	mm

Max field	1.8	T
Max current	919	A
# turns (1 coil)	120	
Max current density	7.4	A/mm ²
Magnet power	139	kW
Yoke weight	25.7	ton
Copper weight	1.24	ton

D1 design (1)

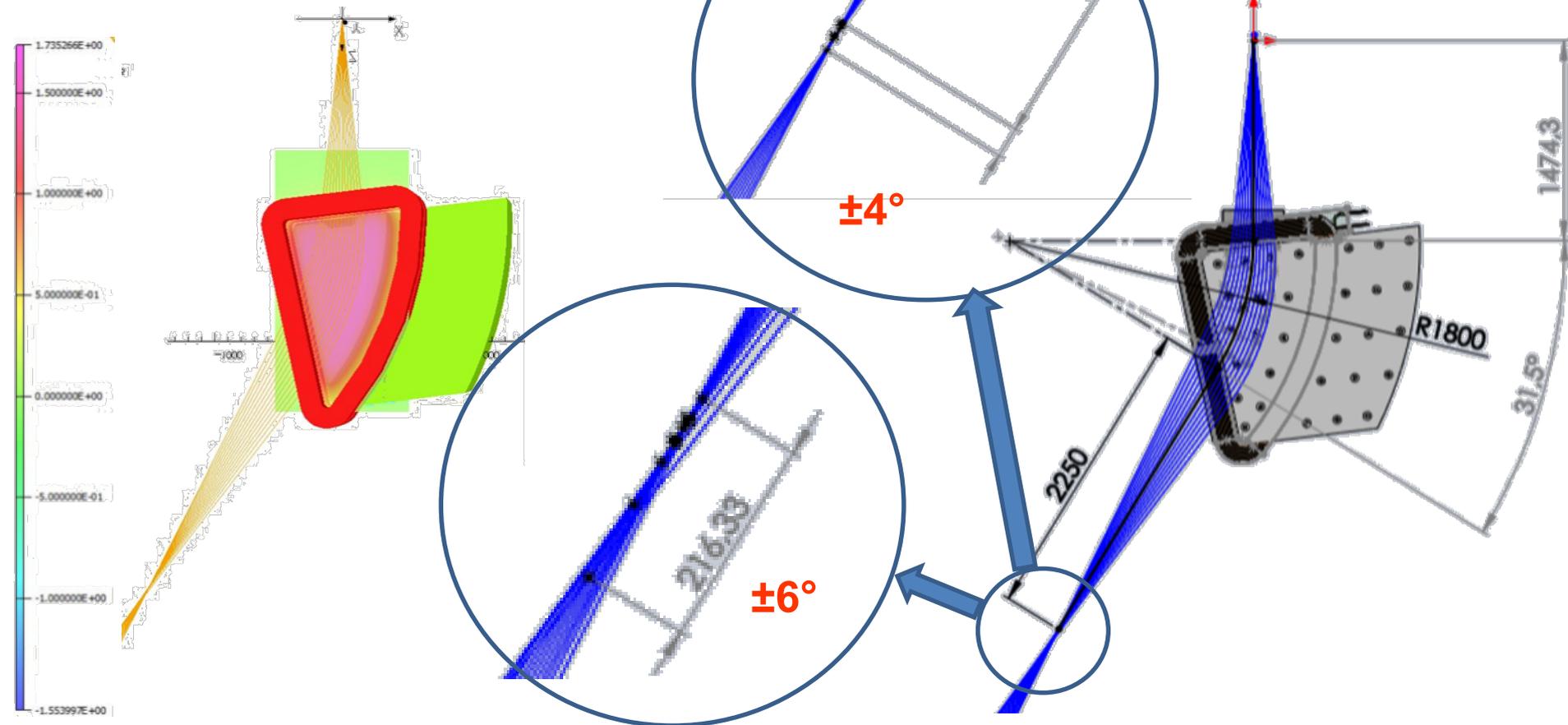
Large exit angle makes a conventional structure very difficult.
 Entrance and exit faces side by side
 Change on one generate change on the other -> joint optimization
 Complex profile on entrance face



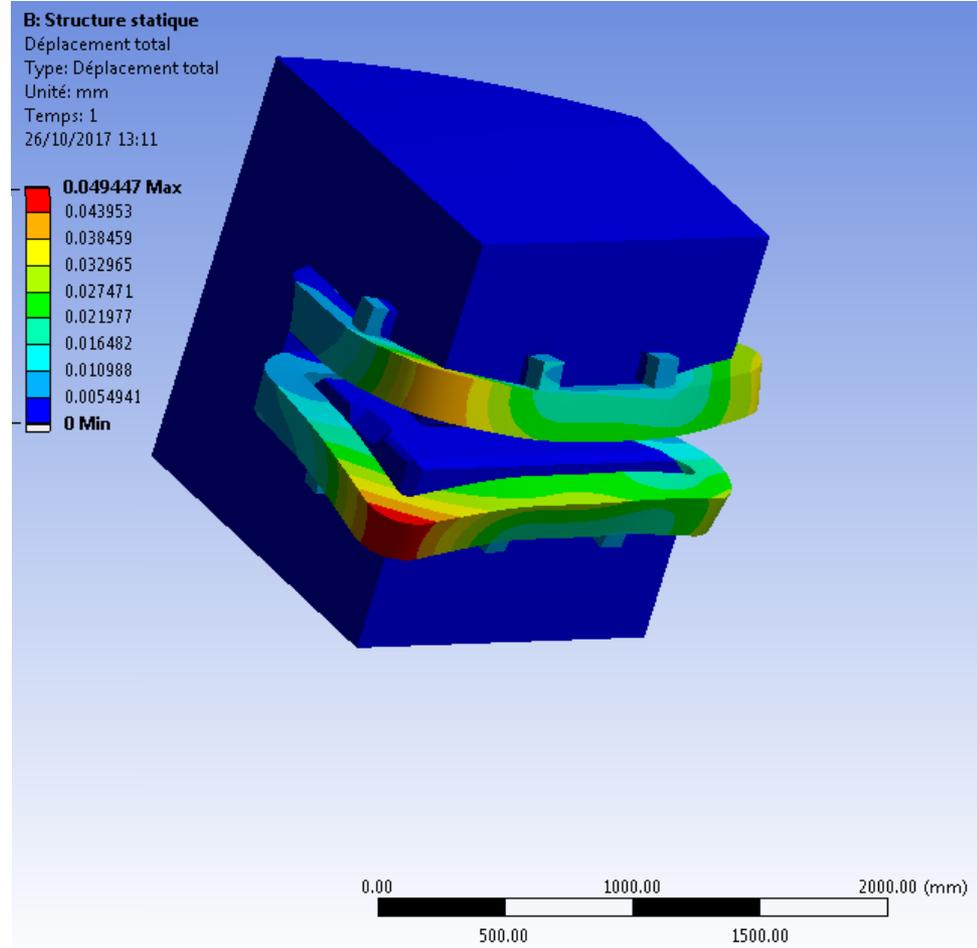
D1 design (2)

Design driven by particle tracking focusing quality

^{288}Rf

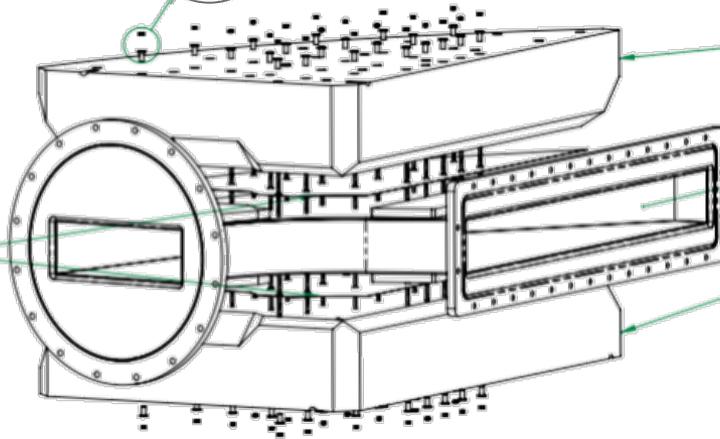
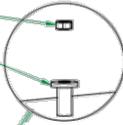


D1 coils

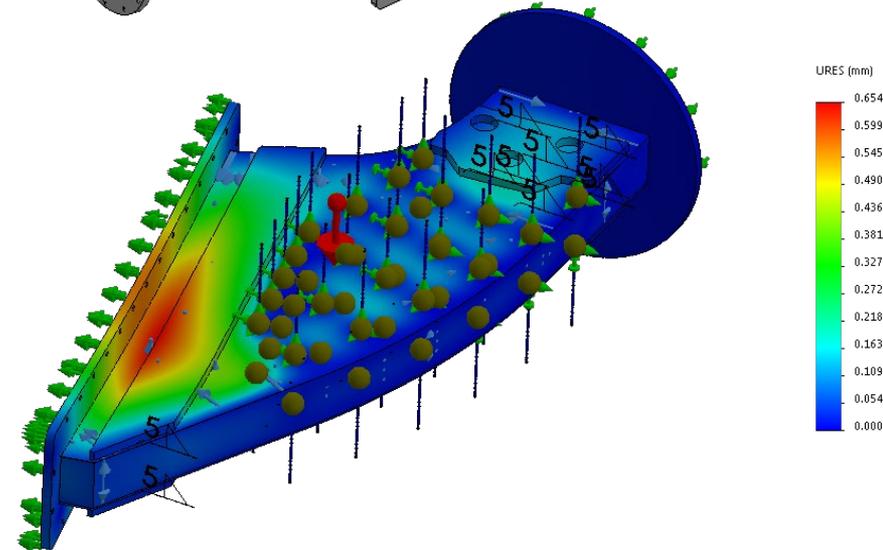
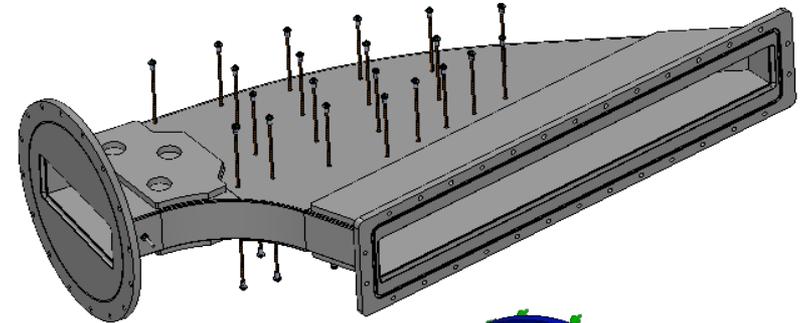


D1 chamber (1)

Hexo hexagonal - Hex nut
insulating shoulder washer Version long



insulating kapton foil



- Very large surface
- Wall must be thick to prevent deformation
- 21 struts + edge reinforcement allow thin walls
- 0.65 mm max displacement

D1 chamber (2)

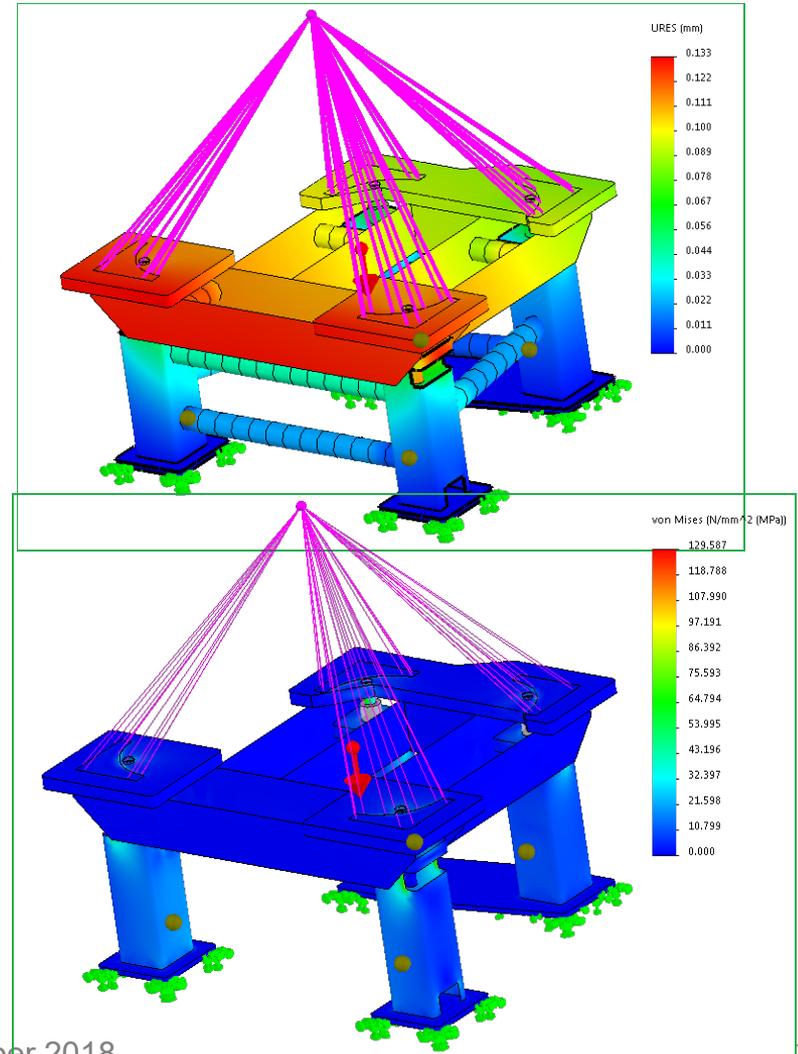
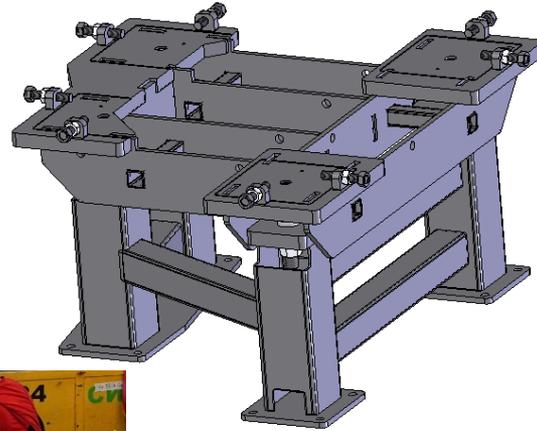


Chamber is electrically insulated

Chamber assembly and testing in factory

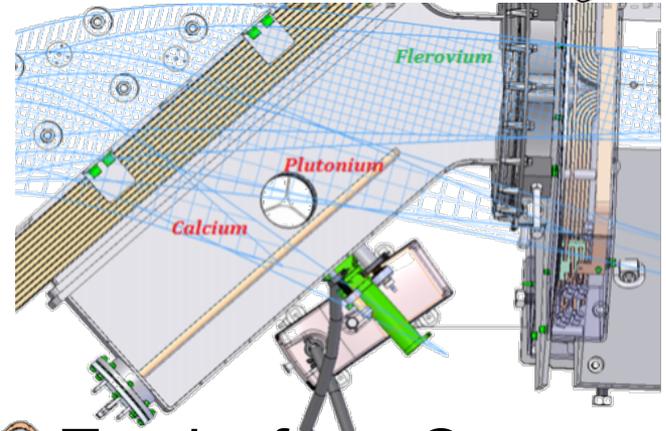
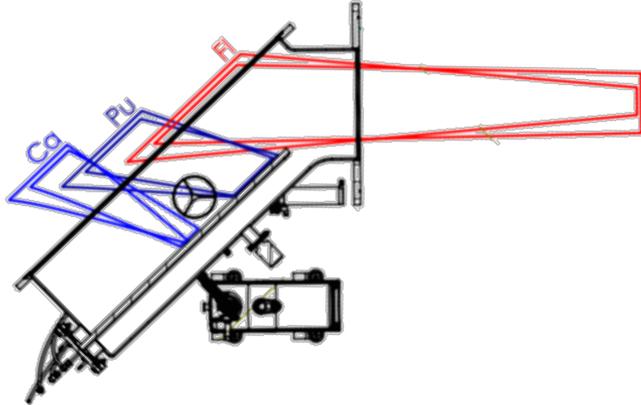
D1 Stand

Magnet + chamber : 27.5 tons
 Deformation < 0.2 mm
 Stress < 130 Mpa (req. <235 Mpa)



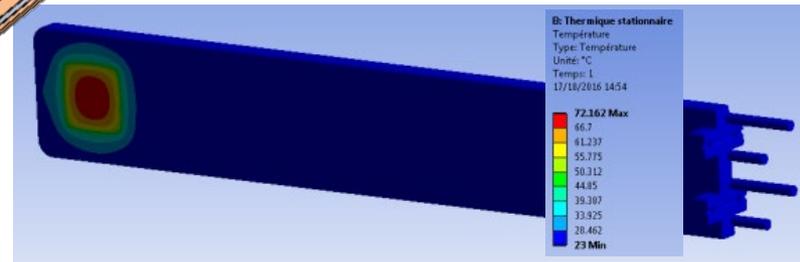
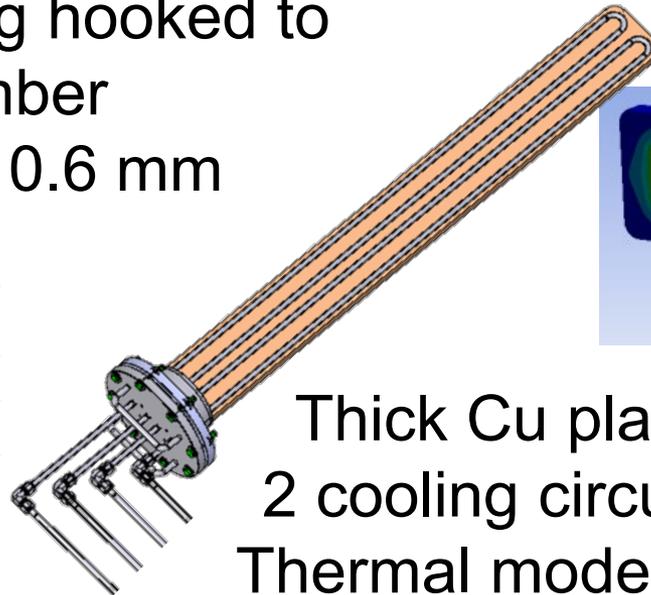
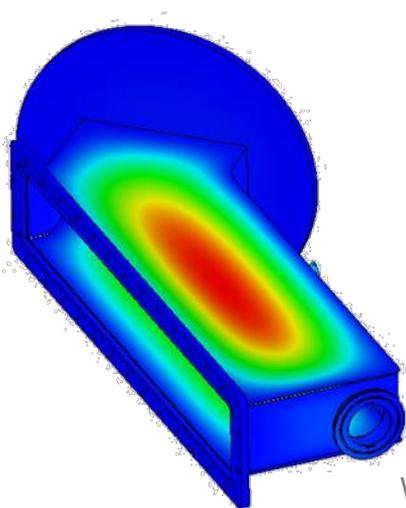
D1 Beam stop

block most background species and let EVR pass



Beam stop housing hooked to main chamber
Deformation < 0.6 mm

Tracks from Opera model



Thick Cu plate
2 cooling circuits
Thermal modelling
crucial



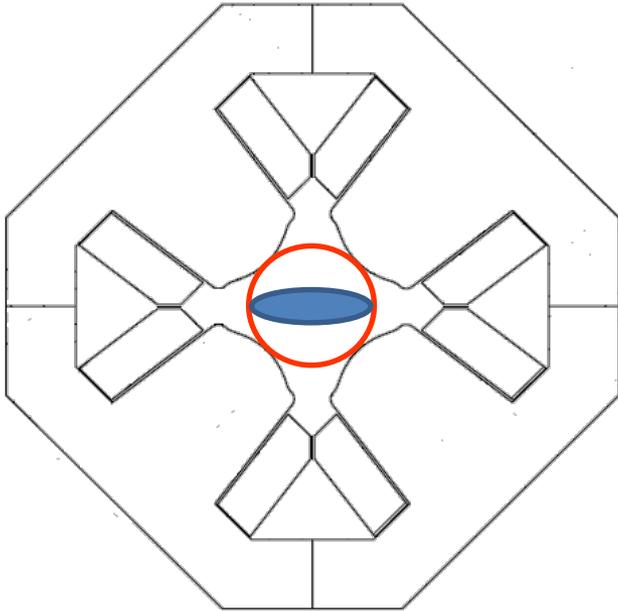


Quadrupoles

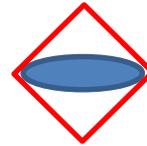
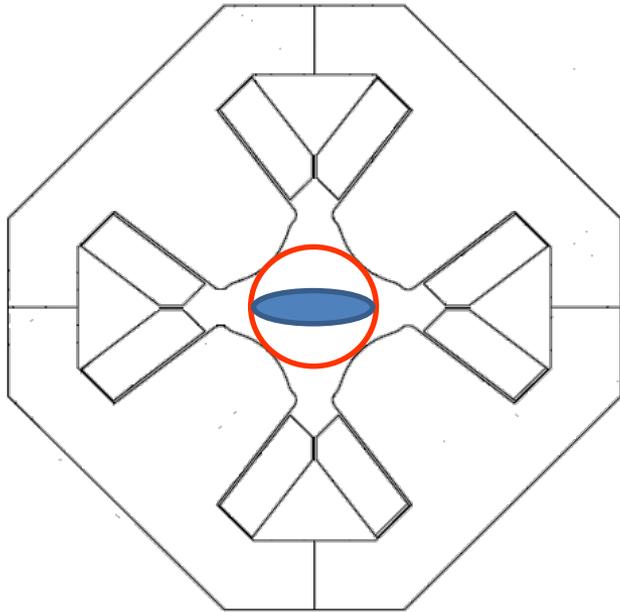
Quadrupoles parameters

	Q1	Q2/Q3	
Bore diameter	150	300	mm
Iron length	420	520	mm
Effective length	456.6	600	mm
Max gradient	13.2	5.34	T/m
Max current	450	362	A
# turns (1 coil)	88	138	
Max current density	6.35	6.6	A/mm ²
Magnet power	28.2	61.6	kW
Yoke weight	2.07	6.65	ton
Copper weight	0.39	0.68	ton

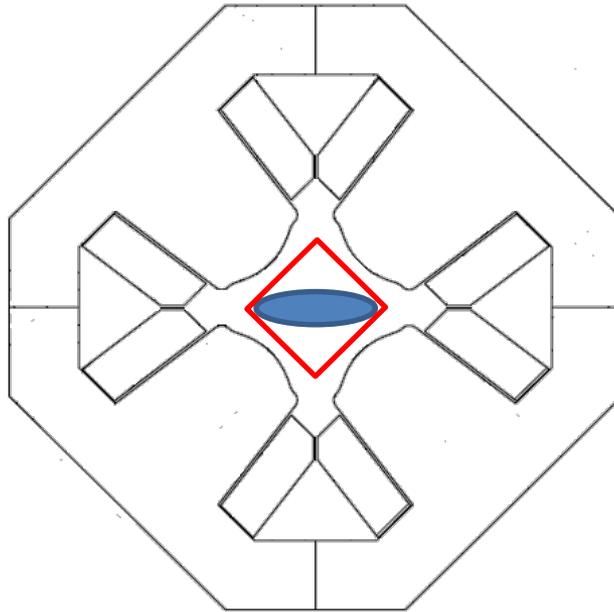
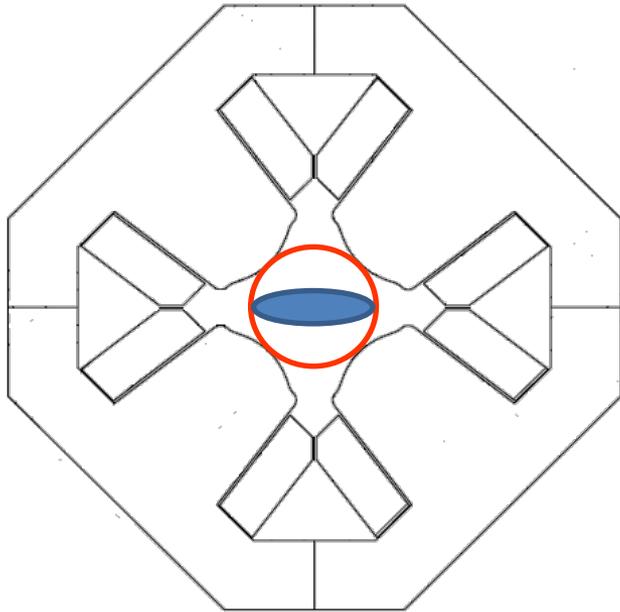
Shaping chambers to reduce bore



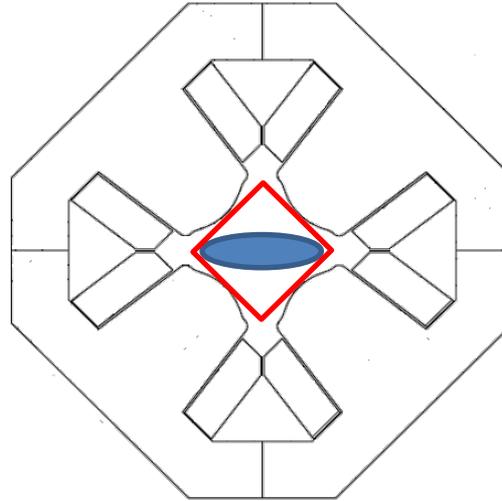
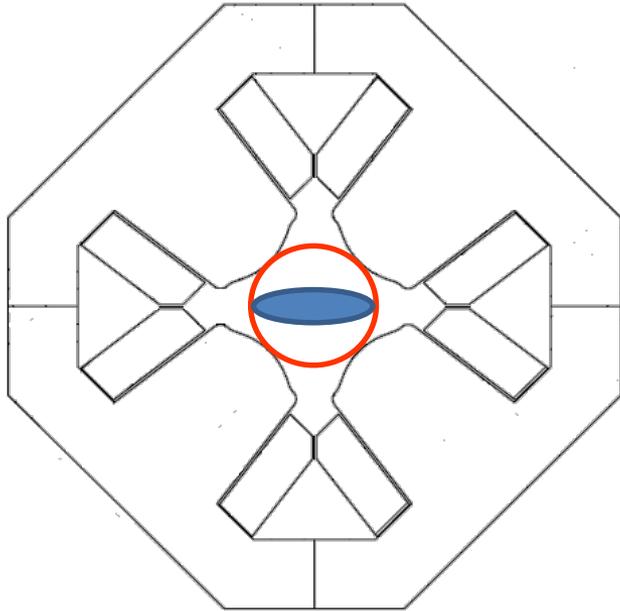
Shaping chambers to reduce bore



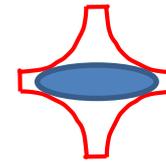
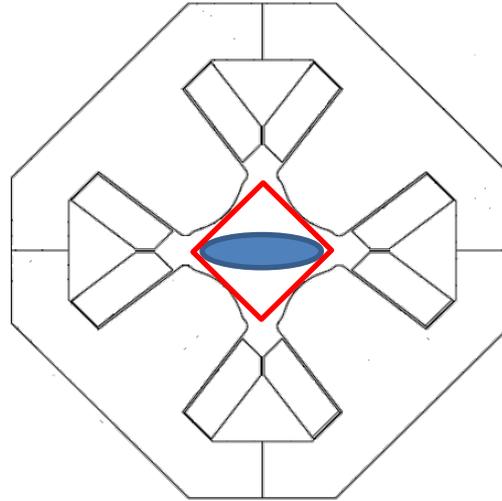
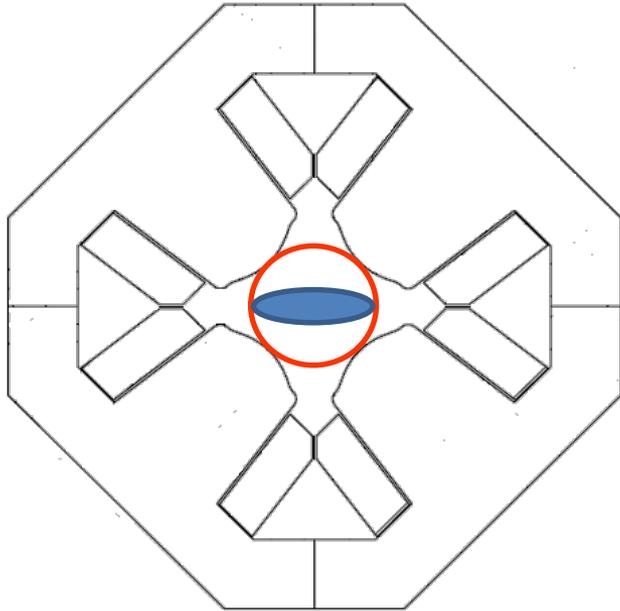
Shaping chambers to reduce bore



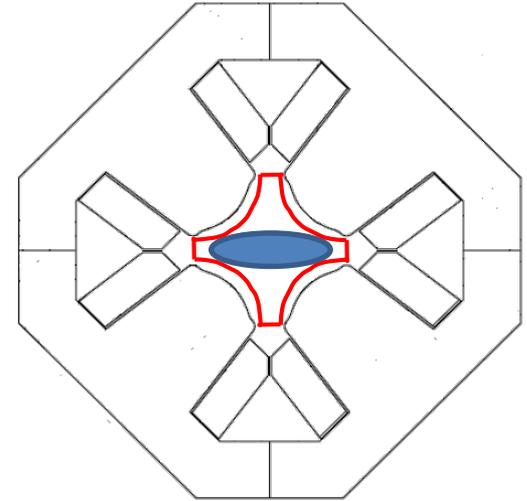
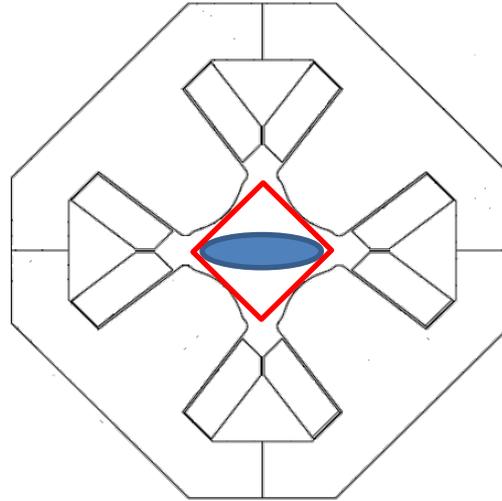
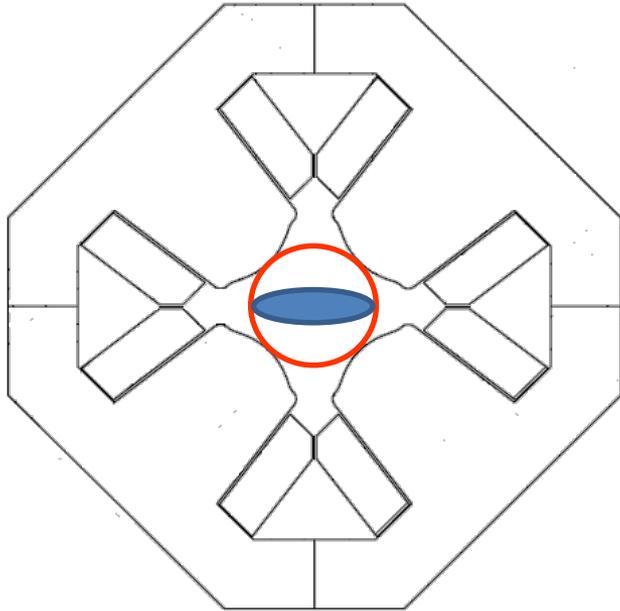
Shaping chambers to reduce bore



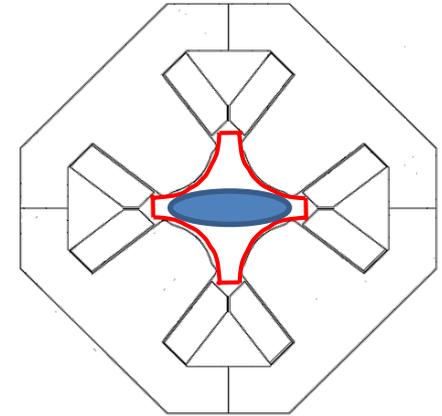
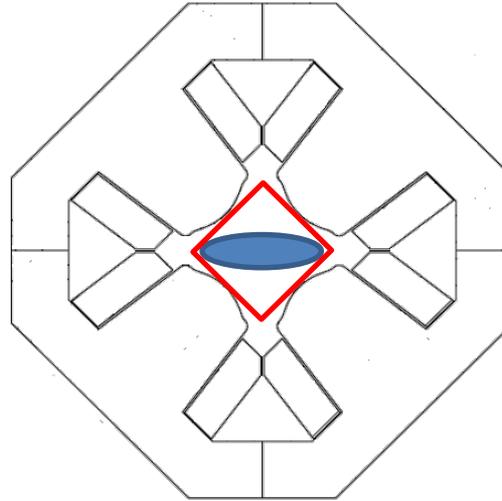
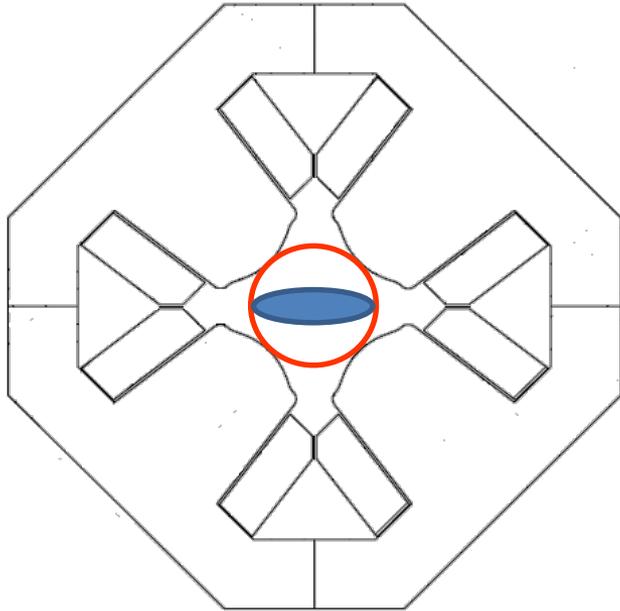
Shaping chambers to reduce bore



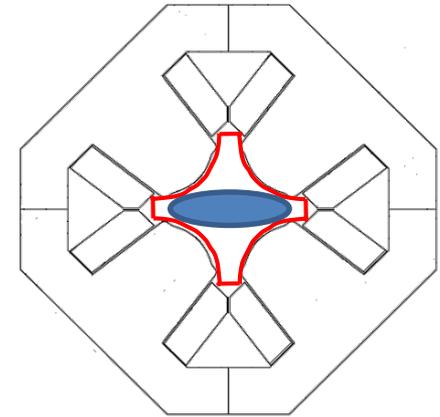
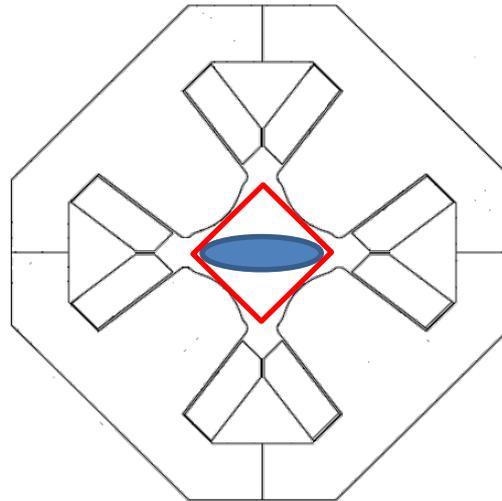
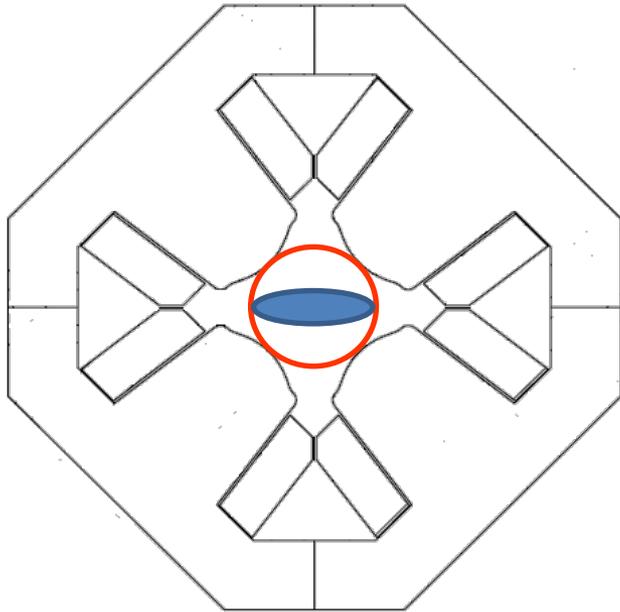
Shaping chambers to reduce bore

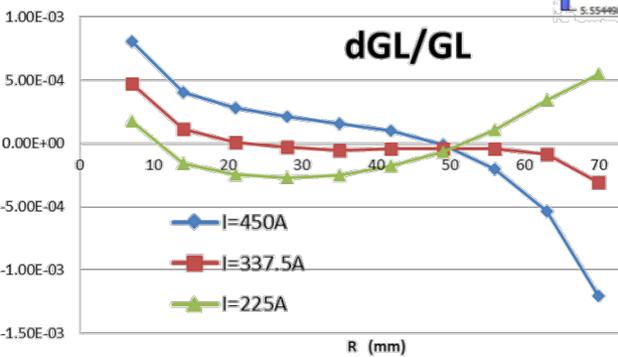
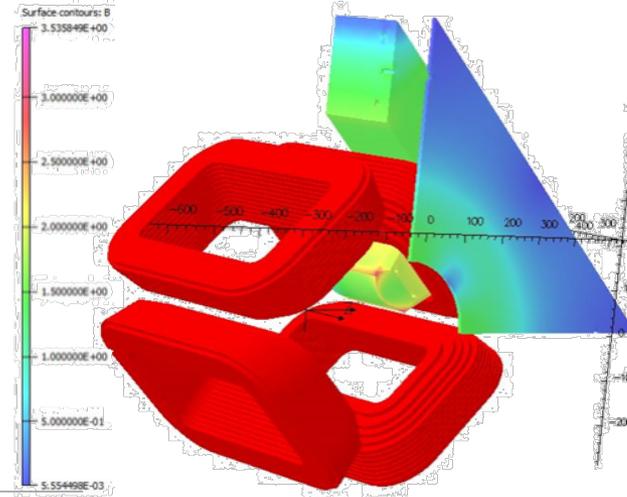
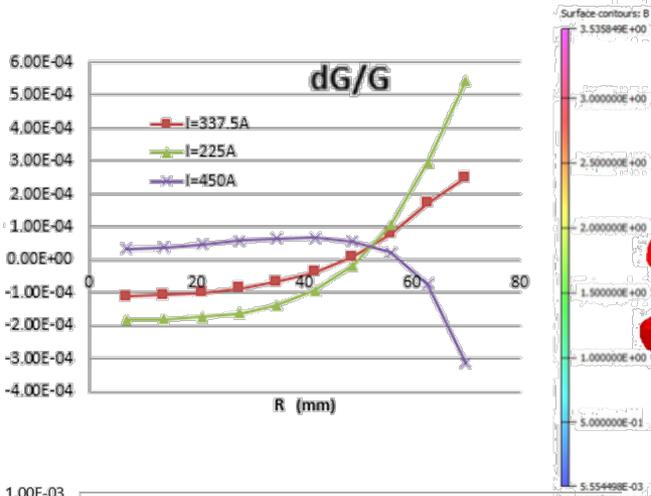


Shaping chambers to reduce bore

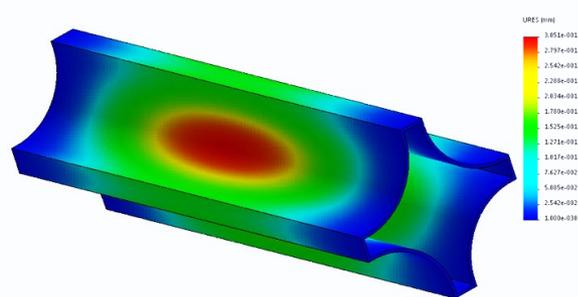


Shaping chambers to reduce bore



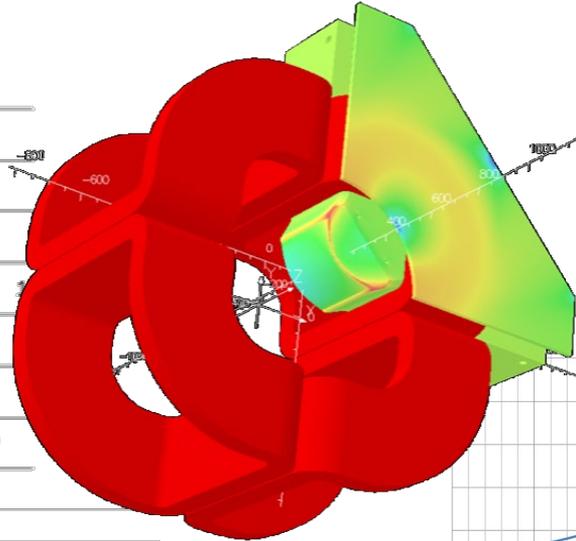
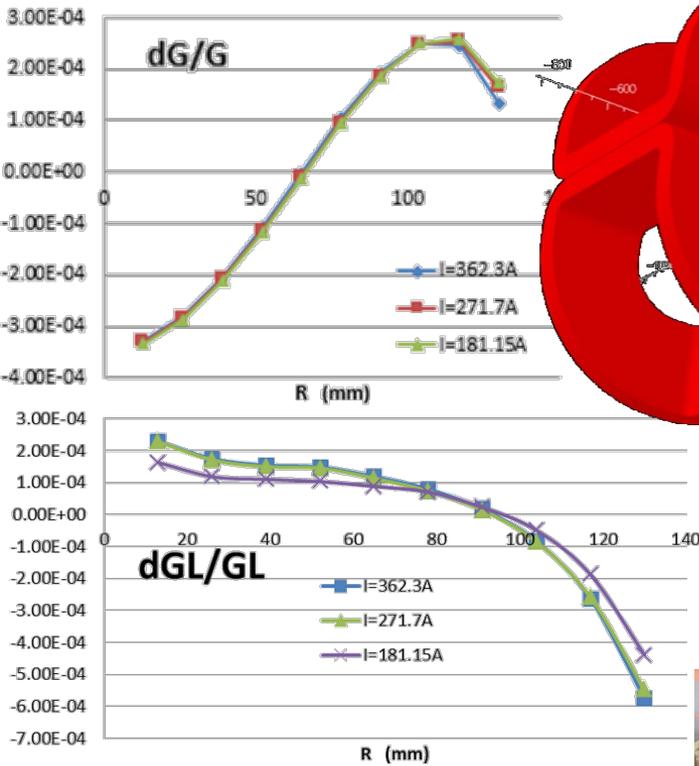


$\phi=150\text{mm}$
 $G=13.2\text{ T/m}$

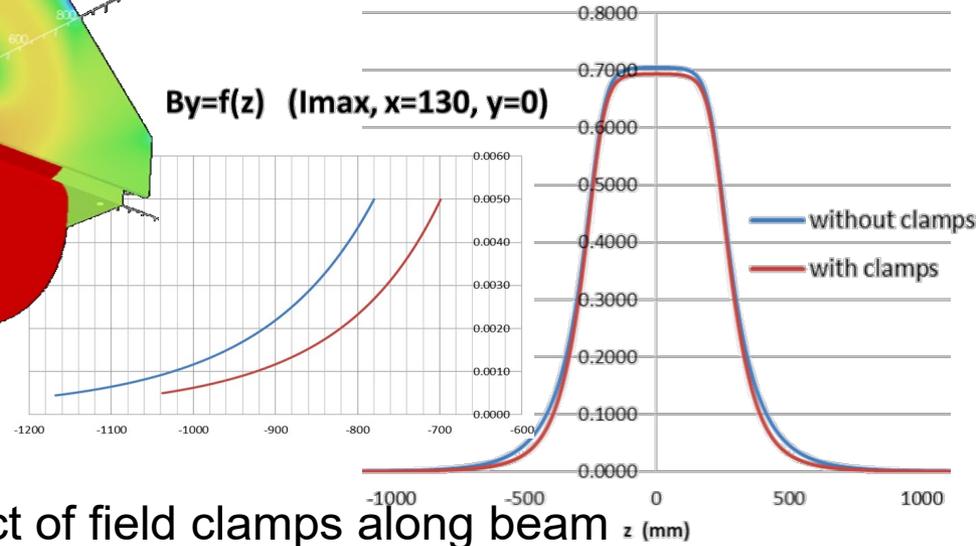


Local & integrated
 gradient
 homogeneity
 along radius

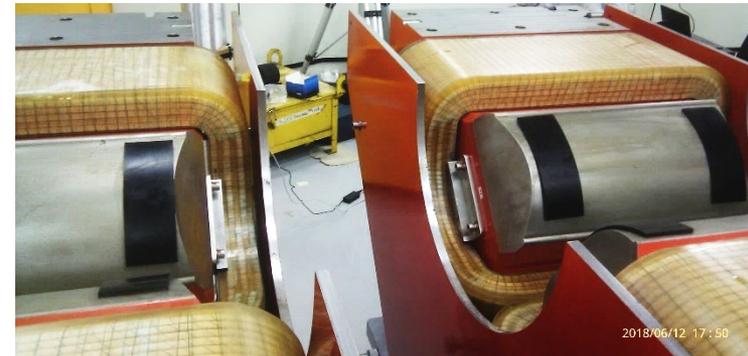
$\phi=300\text{mm}$
 $G=5.34\text{ T/m}$

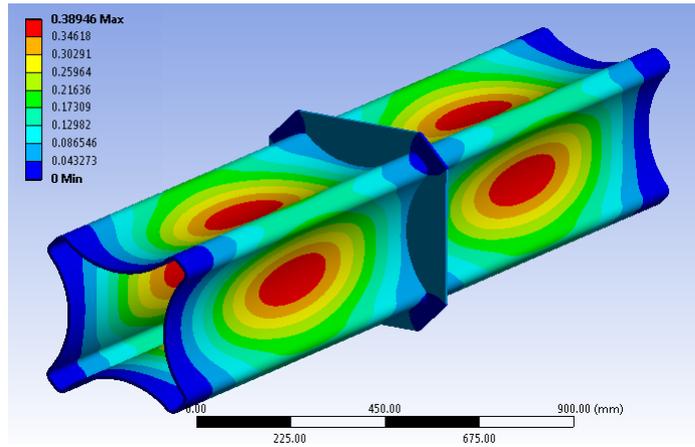


$B_y=f(z)$ ($I_{max}, x=130, y=0$)

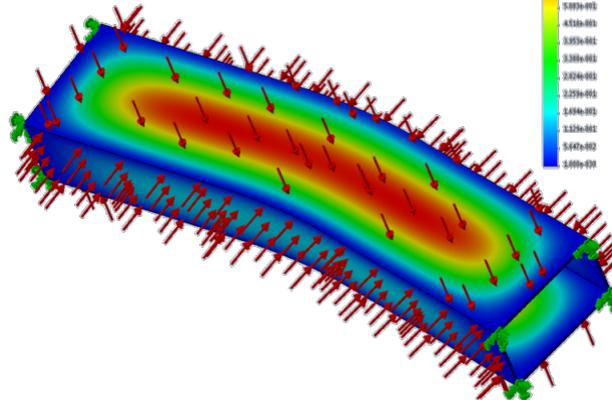
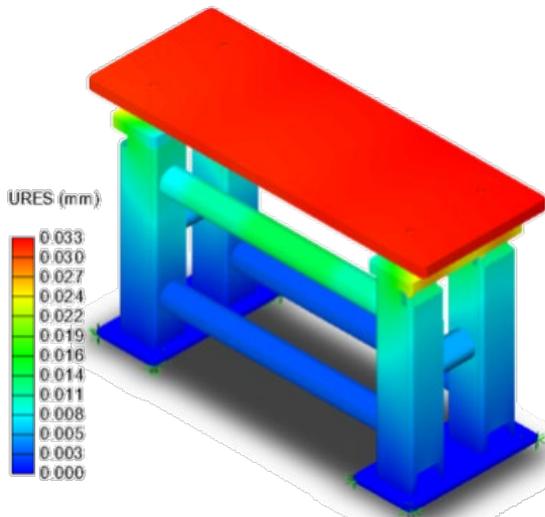
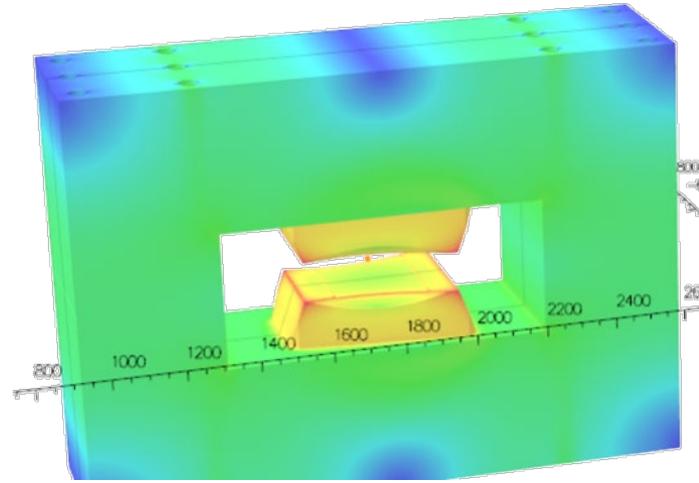


Local & integrated
gradient
homogeneity
along radius





Gap	132 mm
Deflection angle	10^0
Radius of curvature	1.8 m
Maximum field	1.8 T
Face pole rotation angle	0^0
Rear pole rotation angle	10^0



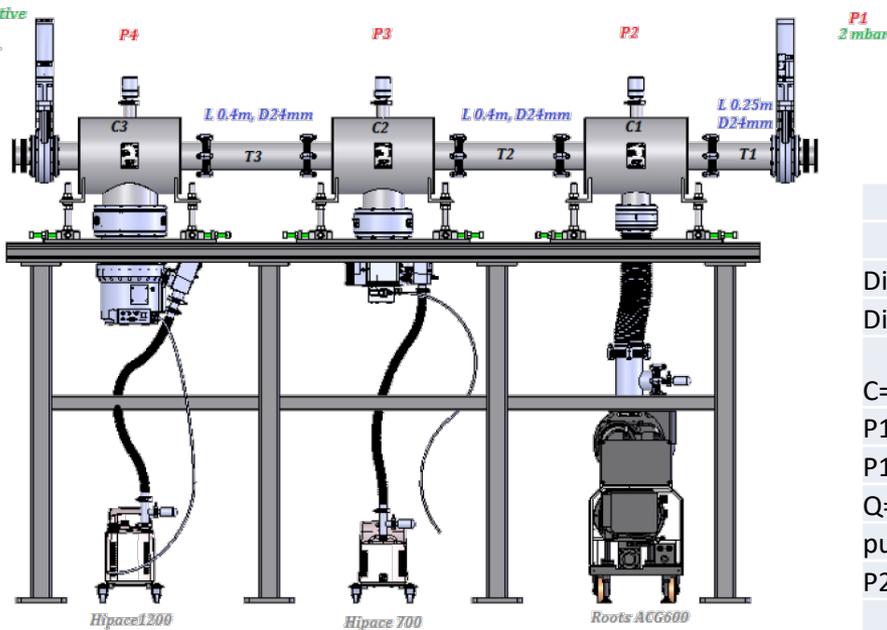


Differential pumping system

Differential pumping (1)

2 configurations

- Allows window-less operation
- Tolerate intense heavy ion beams
- Gas contributes to target cooling
- As all recent gas-filled separators
TASCA, GARIS-II, SHANS



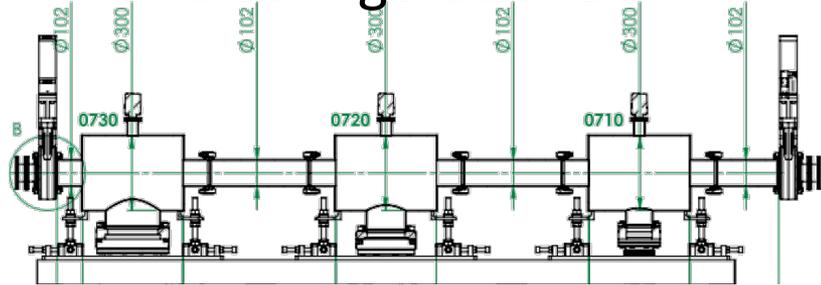
Pressure profile (case of He)

	P1	2.00E+00	P2	1.04E-01	P3	6.47E-04	mbar
	P2 goal	1.00E-03	P3 goal	1.00E-03	P4 goal	1.00E-06	mbar
Diaphragm diameter		24		24		24	mm
Diaphragm length		0.25		0.4		0.4	m
$C=1.22 \cdot 10^{-4} \cdot (D^3/L)$		6.75E+00		4.22E+00		0	4.22E+00 l/s
P1-P2		2.00E+00		1.03E-01		6.46E-04	mbar
P1-P2		1.97E-03		1.01E-04		6.37E-07	atm
$Q=C \cdot (P1-P2)$		1.33E-02		4.27E-04		2.69E-06	l/s
pumping speed He		130		670		1200	l/s
$P2=Q/\text{pumping speed}$		1.02E-04		6.38E-07		2.24E-09	atm
	P2	1.04E-01	P3	6.47E-04	P4	2.27E-06	mbar

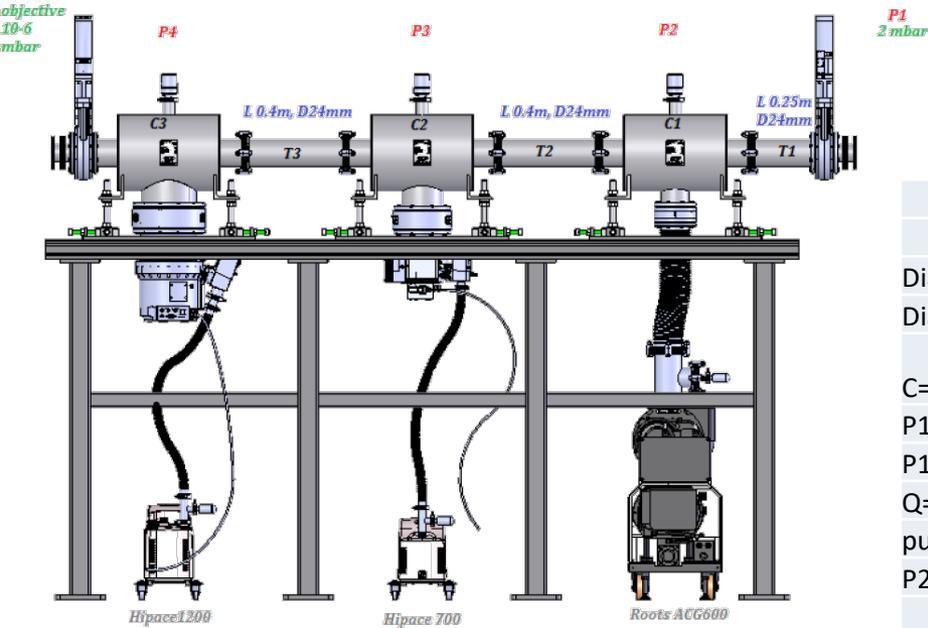
Differential pumping (1)

- Allows window-less operation
- Tolerate intense heavy ion beams
- Gas contributes to target cooling
- As all recent gas-filled separators TASCA, GARIS-II, SHANS

2 configurations



Large tubes ($\phi 102$): standard pumping



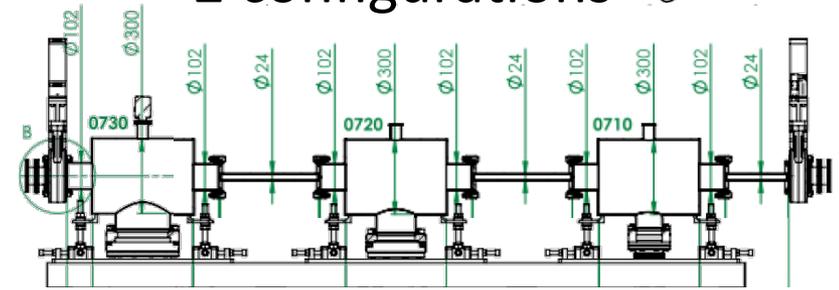
Pressure profile (case of He)

	P1	2.00E+00	P2	1.04E-01	P3	6.47E-04	mbar
	P2 goal	1.00E-03	P3 goal	1.00E-03	P4 goal	1.00E-06	mbar
Diaphragm diameter		24		24		24	mm
Diaphragm length		0.25		0.4		0.4	m
$C=1.22 \cdot 10^{-4} \cdot (D^3/L)$		6.75E+00		0		4.22E+00	l/s
P1-P2		2.00E+00		1.03E-01		6.46E-04	mbar
P1-P2		1.97E-03		1.01E-04		6.37E-07	atm
$Q=C \cdot (P1-P2)$		1.33E-02		4.27E-04		2.69E-06	l/s
pumping speed He		130		670		1200	l/s
$P2=Q/\text{pumping speed}$		1.02E-04		6.38E-07		2.24E-09	atm
	P2	1.04E-01	P3	6.47E-04	P4	2.27E-06	mbar

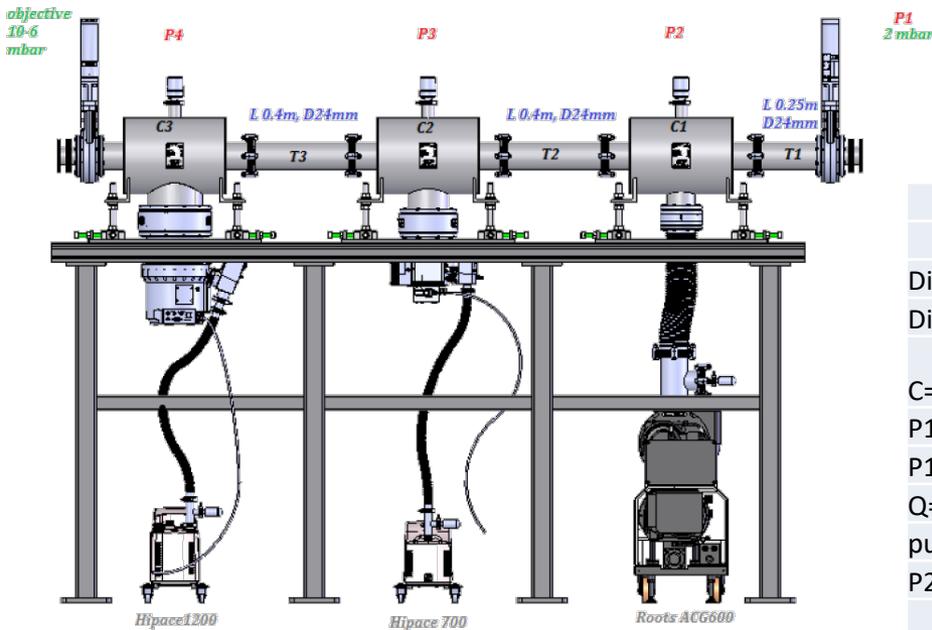
Differential pumping (1)

2 configurations

- Allows window-less operation
- Tolerate intense heavy ion beams
- Gas contributes to target cooling
- As all recent gas-filled separators TASCA, GARIS-II, SHANS



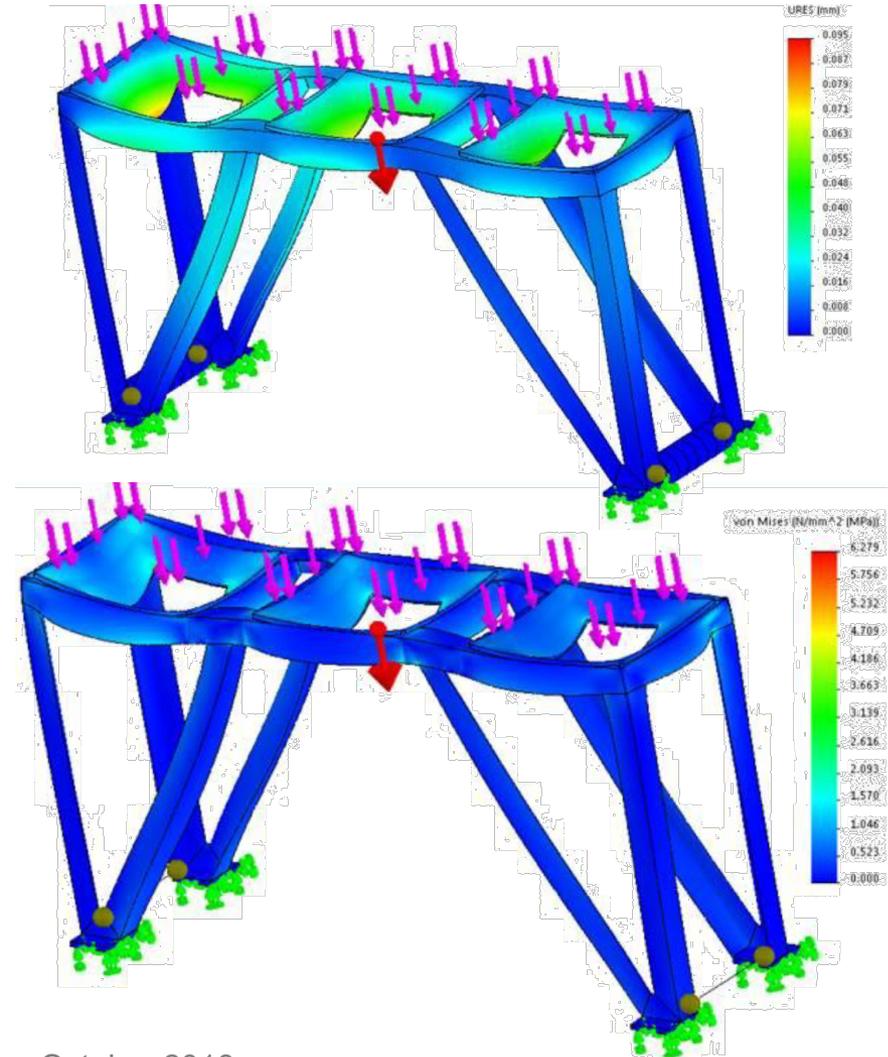
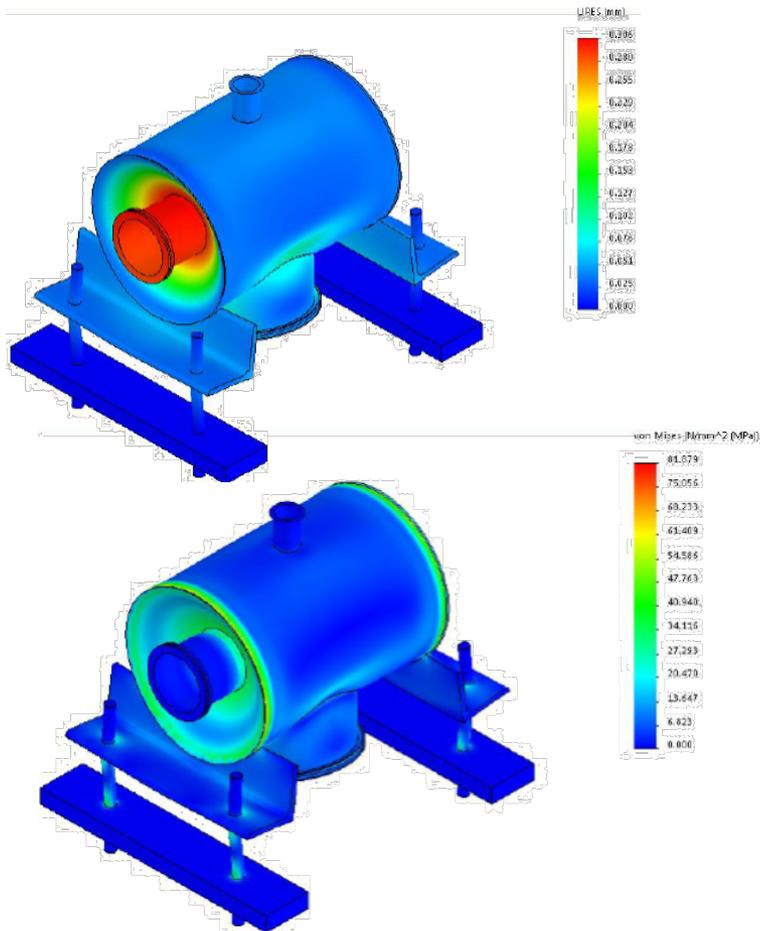
Diaphragms ($\phi 24$) : differential pumping



Pressure profile (case of He)

	P1	2.00E+00	P2	1.04E-01	P3	6.47E-04	mbar
	P2 goal	1.00E-03	P3 goal	1.00E-03	P4 goal	1.00E-06	mbar
Diaphragm diameter		24		24		24	mm
Diaphragm length		0.25		0.4		0.4	m
$C=1.22 \cdot 10^{-4} \cdot (D^3/L)$		6.75E+00		0		4.22E+00	l/s
P1-P2		2.00E+00		1.03E-01		6.46E-04	mbar
P1-P2		1.97E-03		1.01E-04		6.37E-07	atm
$Q=C \cdot (P1-P2)$		1.33E-02		4.27E-04		2.69E-06	l/s
pumping speed He		130		670		1200	l/s
$P2=Q/\text{pumping speed}$		1.02E-04		6.38E-07		2.24E-09	atm
	P2	1.04E-01	P3	6.47E-04	P4	2.27E-06	mbar

Mechanically sound



Factory testing





Power supplies

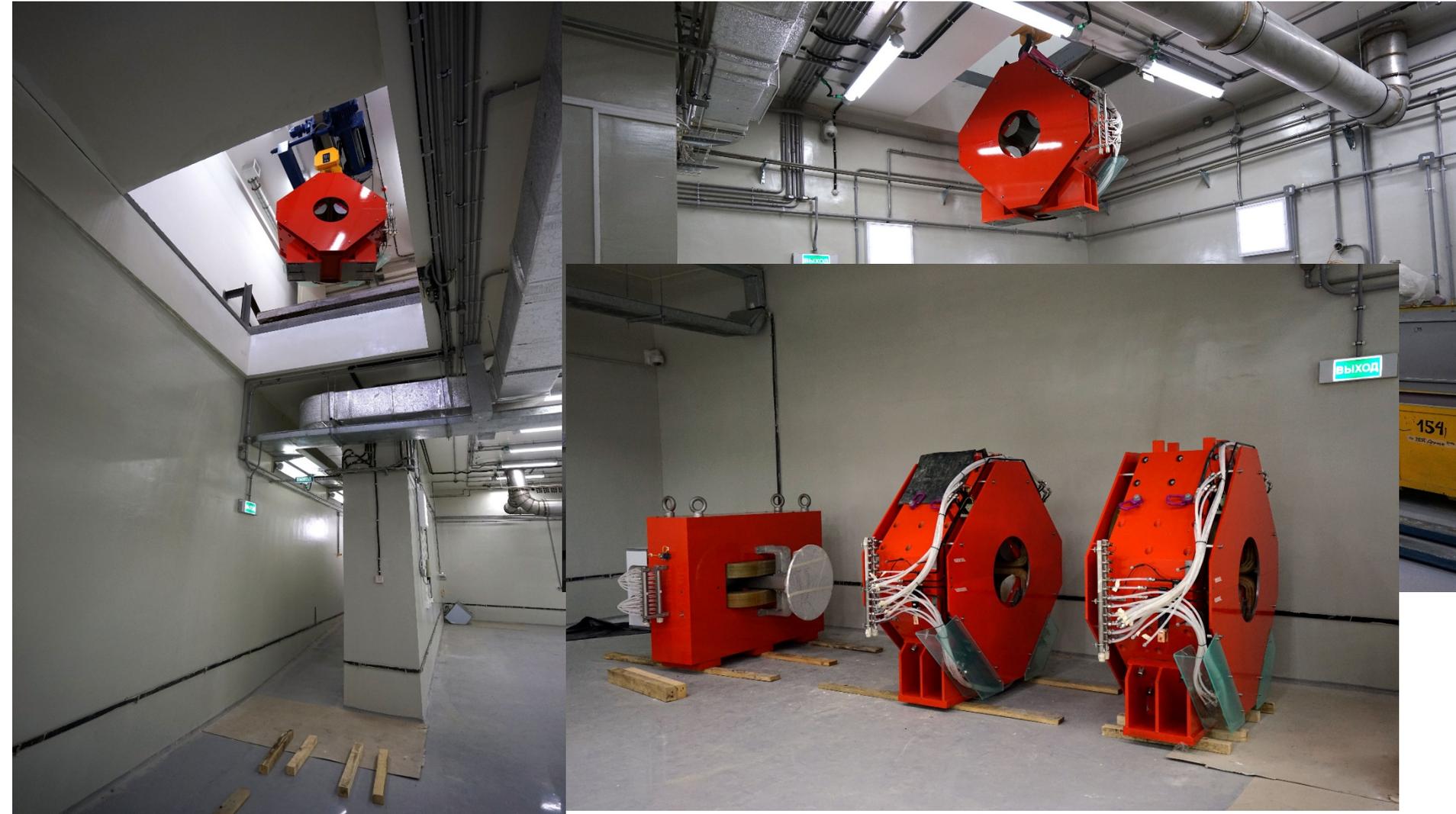




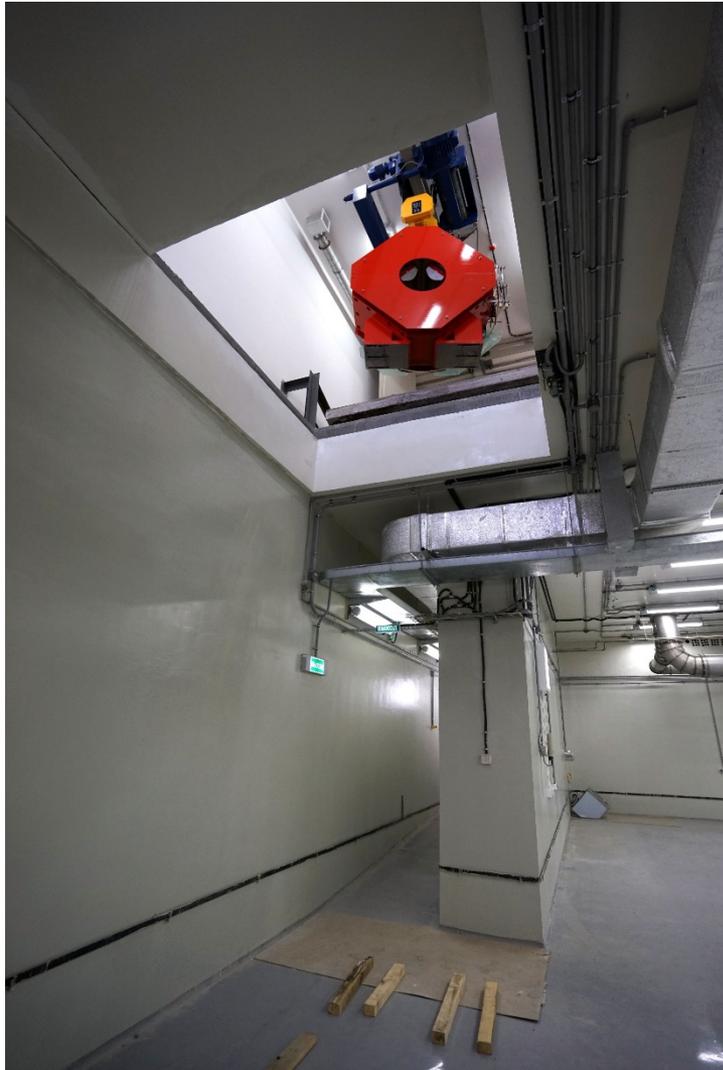
Installation

June 05th-14th 2018

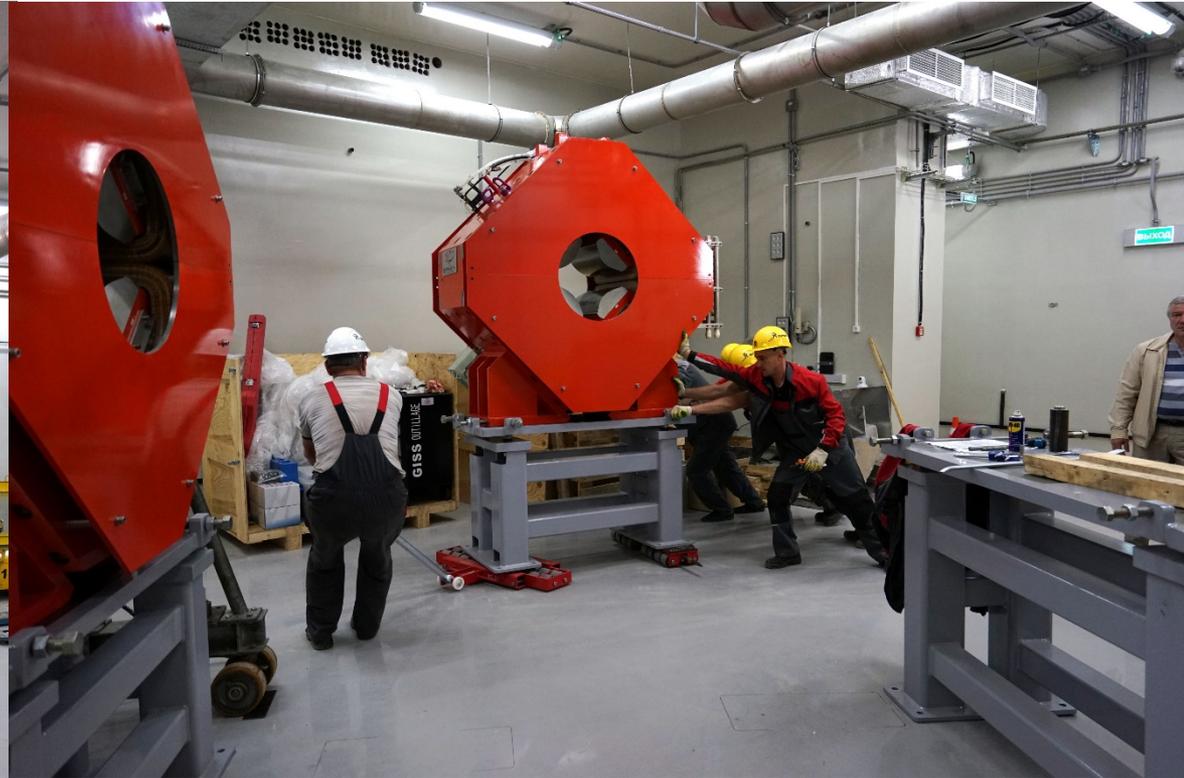
No crane! So what? (1)



No crane! So what? (1)



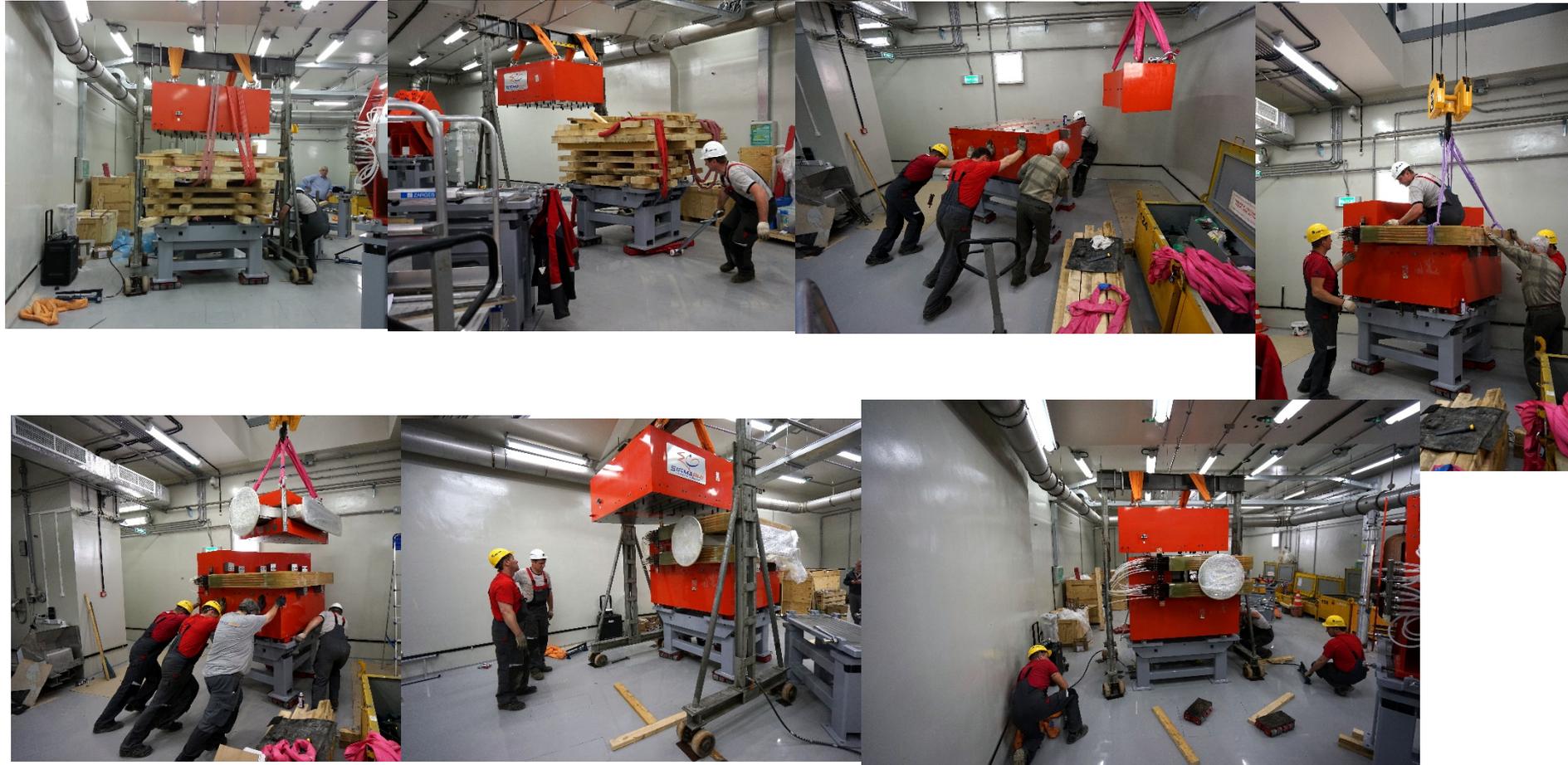
No crane! So what? (2)



No crane! So what? (3)



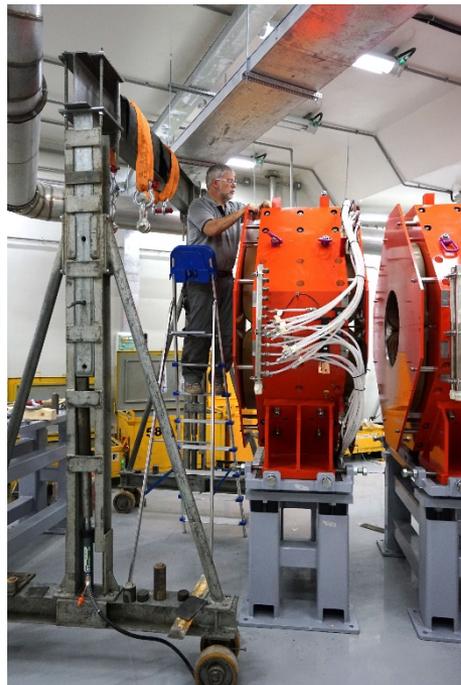
No crane! So what? (4)





Alignment

- Leica laser tracker AT401
- Red ring 2.5" targets
- Polyworks software
- Global Alignment accuracy within ± 0.1 mm



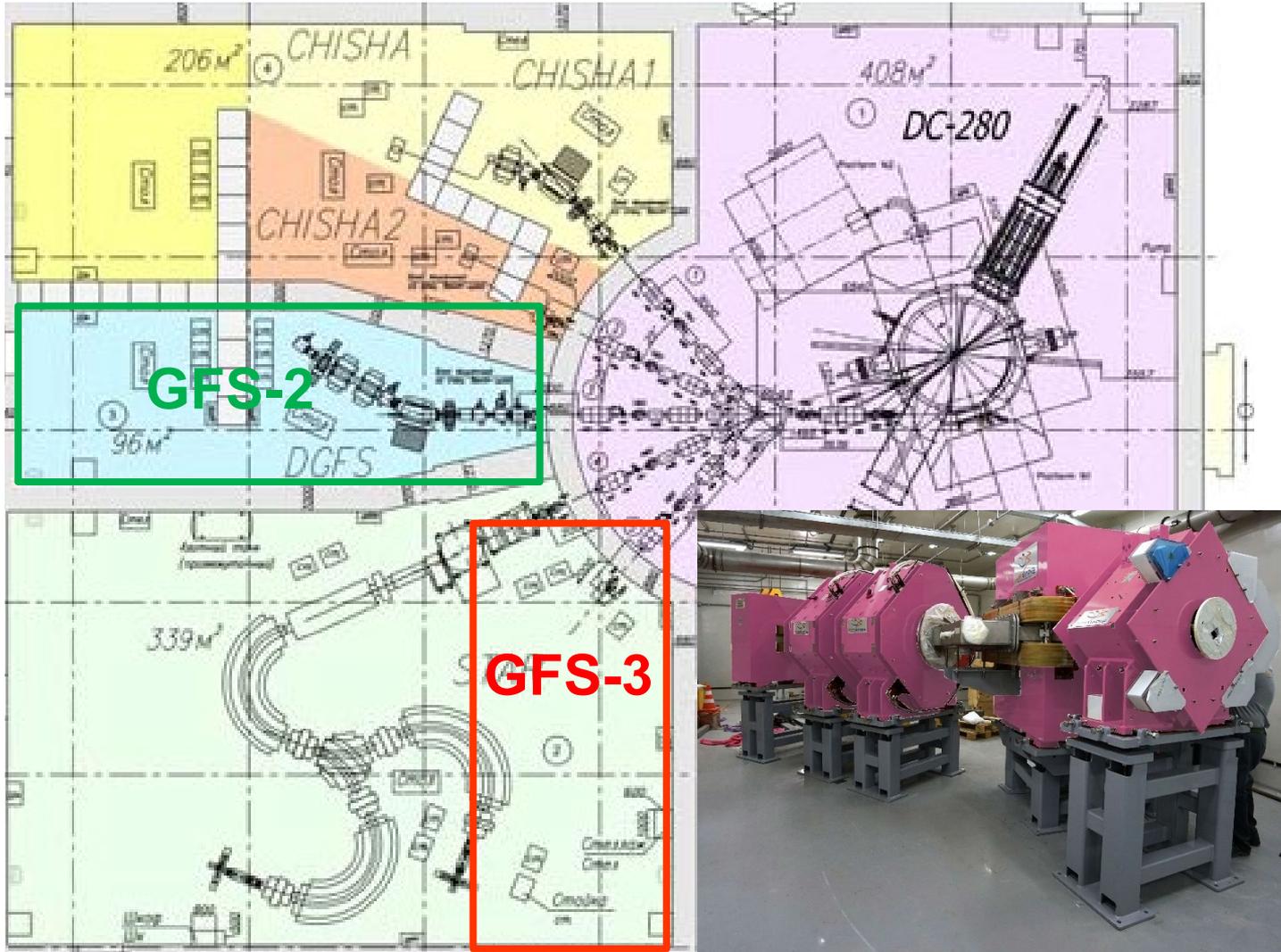
The near future

2018 GFS-2 acceptance tests

2018 GFS-2 first beam tests

2018 GFS-3 start fabrication

2019 GFS-3 installation





We also built friendship

Human interaction





Conclusions

- GFS-2 is installed and under commissioning. First runs should start by end 2018
- A global contract has opened the possibility for thorough optimization.
- A similar (chiral symmetry) system is produced and will be installed in 2019
- A wonderful human experience!

The essence of the beautiful is unity in variety

W. Somerset Maugham





Questions ?