SCENT 300

DESIGN STUDY OF MEDICAL CYCLOTRON SCENT300

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CYCLOTRONS PROVIDING LIGHT IONS

SYNCHROTRONS are today used everywhere (japan, GSI, CNAO) for carbon beam therapy

CYCLOTRONS
- IBA C235 RESISTIVE COILS
- ACCEL\VARIAN K250 SC

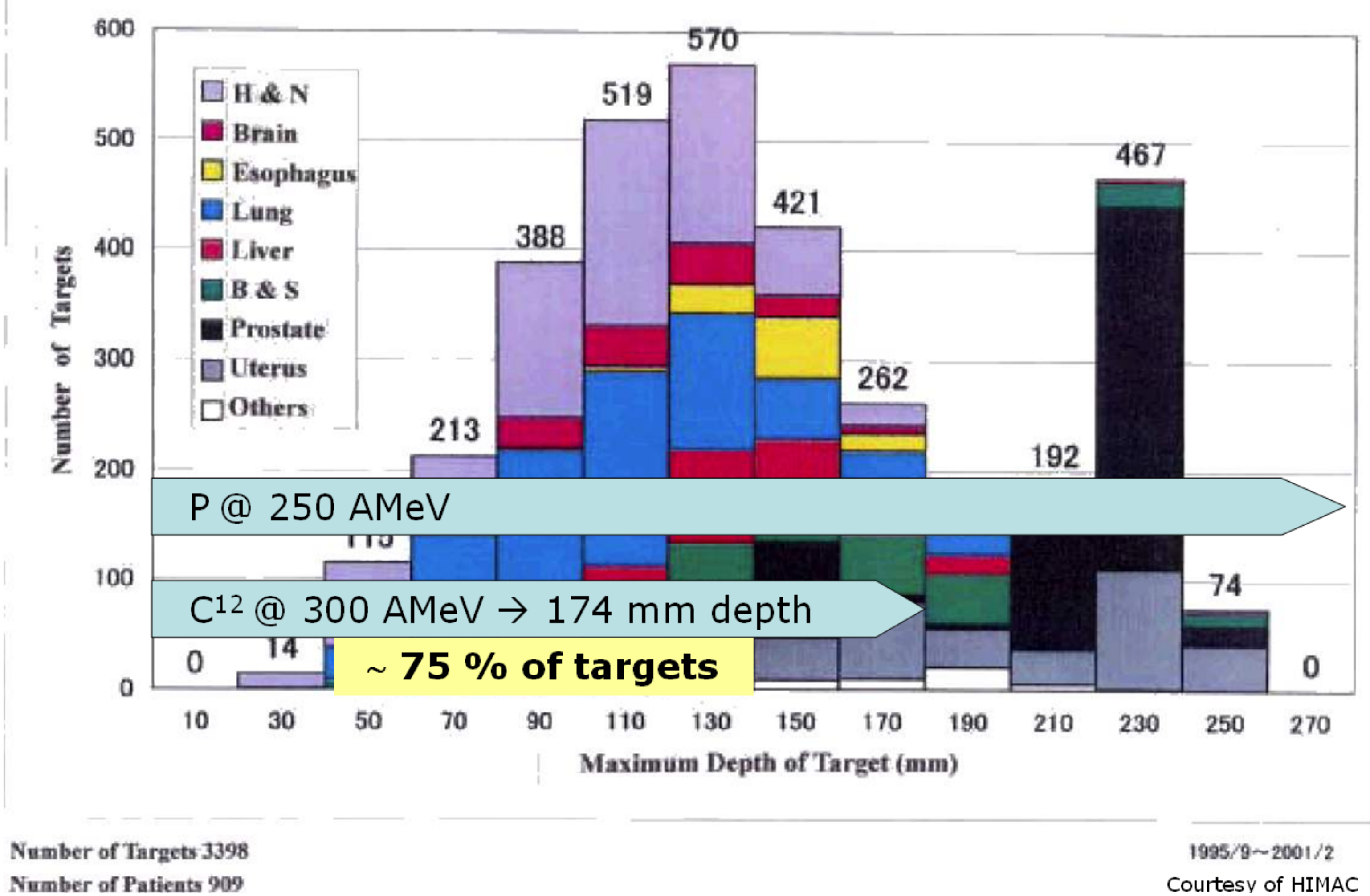
→ PROTONS

SC CYCLOTRON
- IBA C400
- INFN SCENT300

→ PROTONS, CARBON IONS

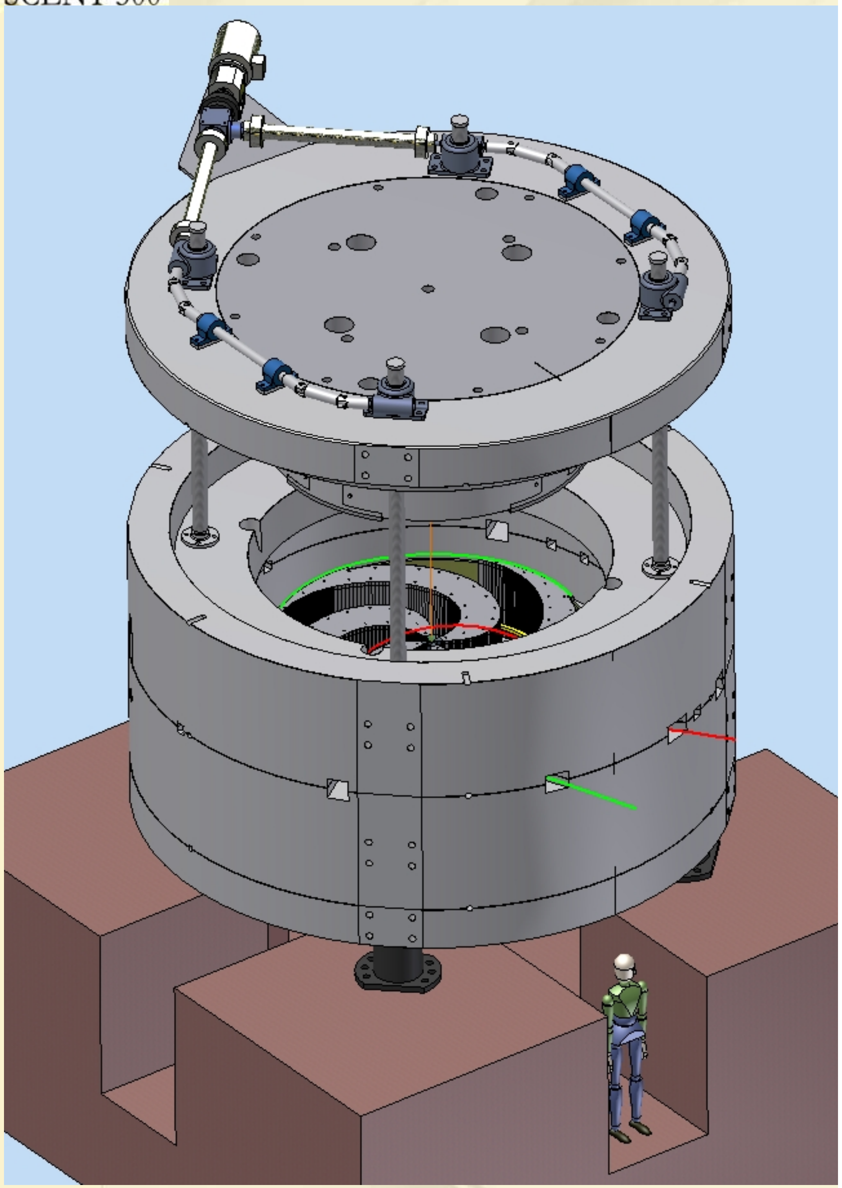
- ✓ compactness and simplicity
- ✓ lower size and cost → superconducting tech.
- ✓ high beam modulation control → fixed energy (ESS needed)

Why 300AMeV of carbon ions ?



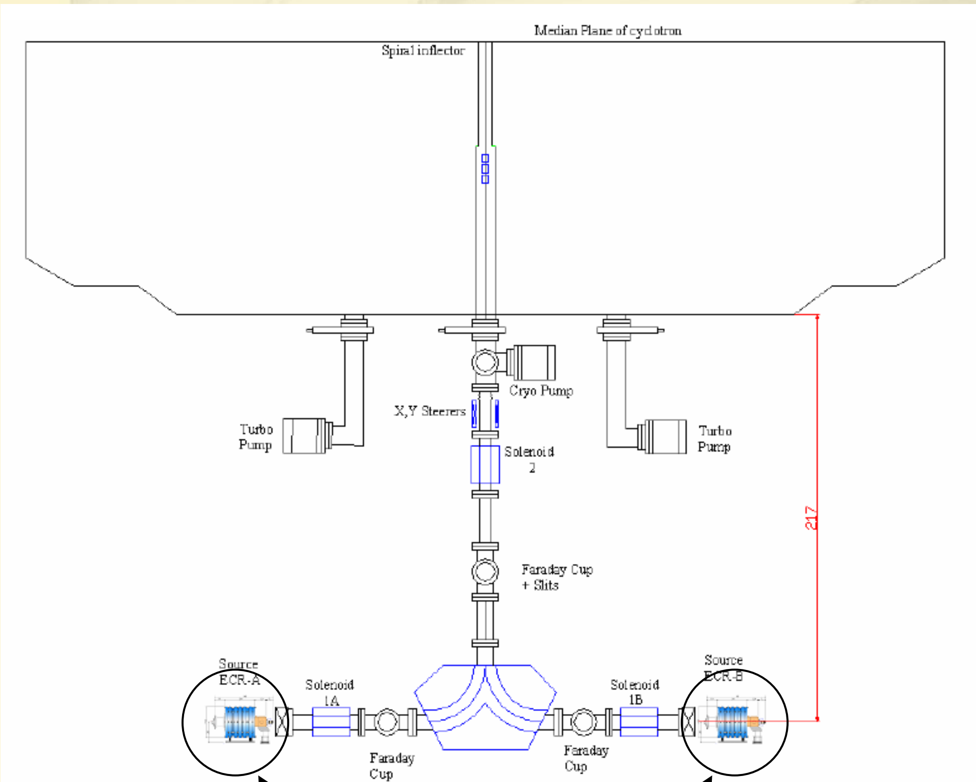
Head Neck and Brain: 85%; Lung and Liver: 80%; Bone and Soft Tissues sarcomas: ≤ 20%; Pancreas, Prostate, Uterus, and Others: ≤ 3%. **Tumours treatable with 300 MeV/u**

MAIN PARAMETERS

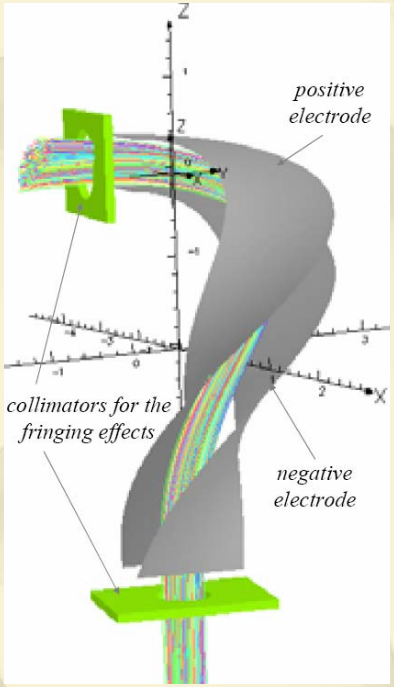


Parameters	Values
Particles Accelerated	H_2^+, $^{12}C^{6+}$
Injection Energy	25 AKeV
Extraction Energy	$^{12}C^{6+}$ @ 300 AMeV, *p* @ 260 MeV
K bending	1200 MeV
Number of Sectors	4
Pole Radius	132.5 cm
Mean Magnetic Field	3.15 tesla ÷ 4.2 tesla
Peak Magnetic Field	4.95 tesla
Injection scheme	Axial + 2 external ion sources
Extraction	Carbon by 2 ED, *p* by stripping of H_2^+
Size	Diameter= 5 m, Height= 3 m
Weight	~ 350 tons
Coils	2 superconductors
Max Current density	47 amp/mm^2
Energy Stored	35 MJ
Number of Cavities	4
Operating RF harmonic	4
RF frequency	~ 98 MHz
Estimated power losses	50 kW/cavity

INJECTION LAYOUT



ECR sources



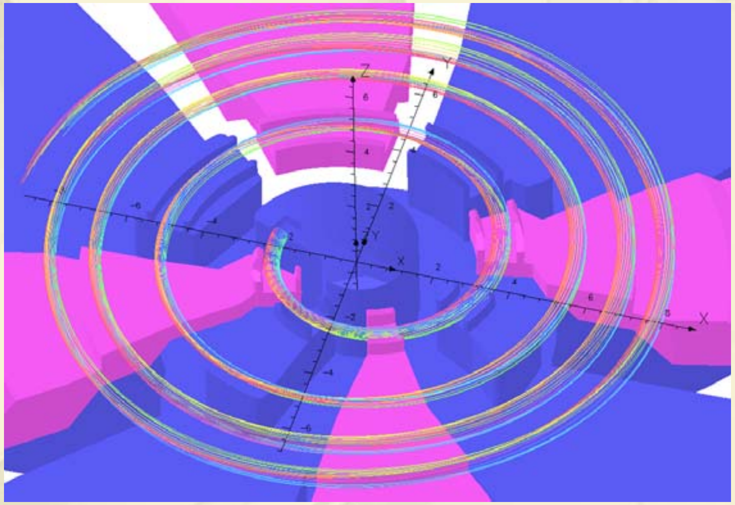
$E_{inj} = 25$ AKeV

$\Delta V_{inflect} = 14$ KV

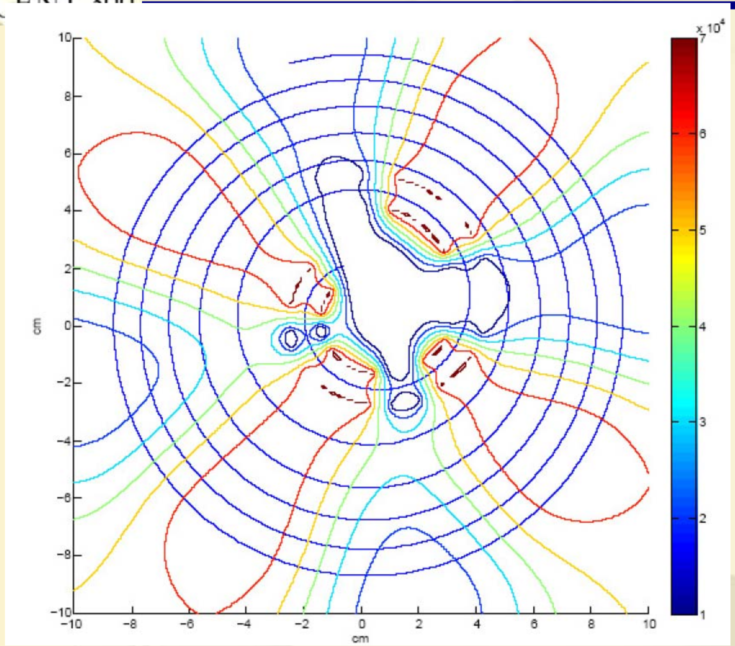
$gap_{inflect} = 6$ mm

$E_{inflect} = 23$ KV/cm

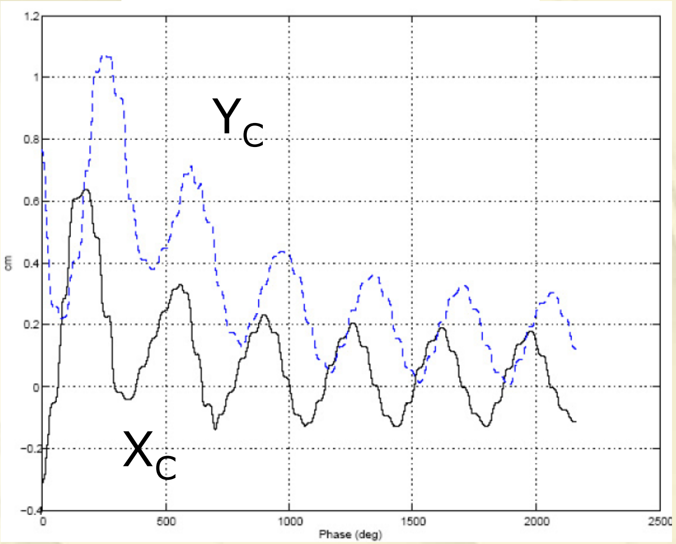
Vdee inj=70 kV
Bo=3,15 tesla



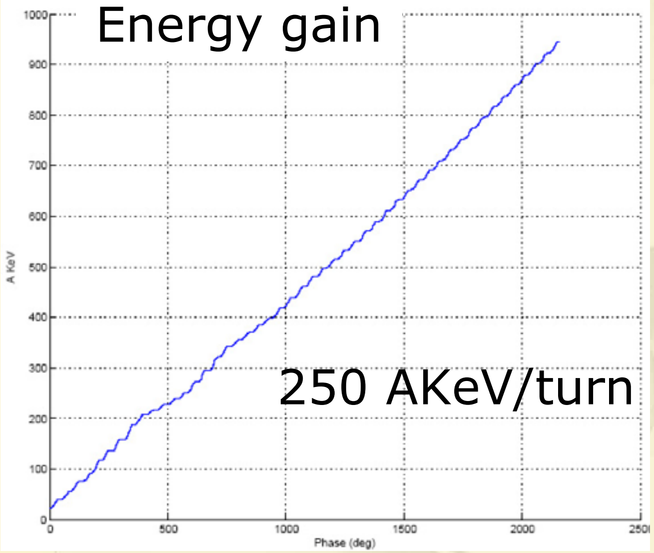
CENTRAL REGION DESIGN



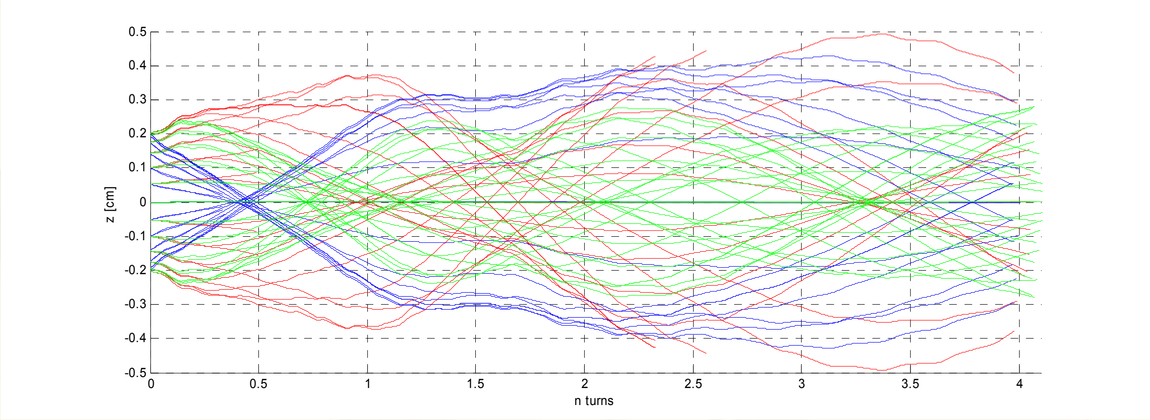
Beam centering



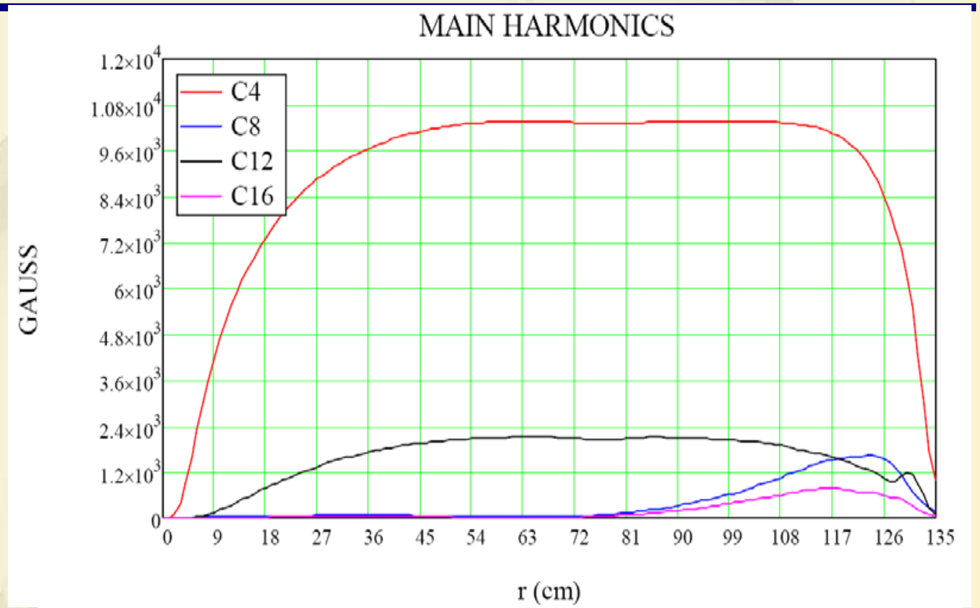
Energy gain

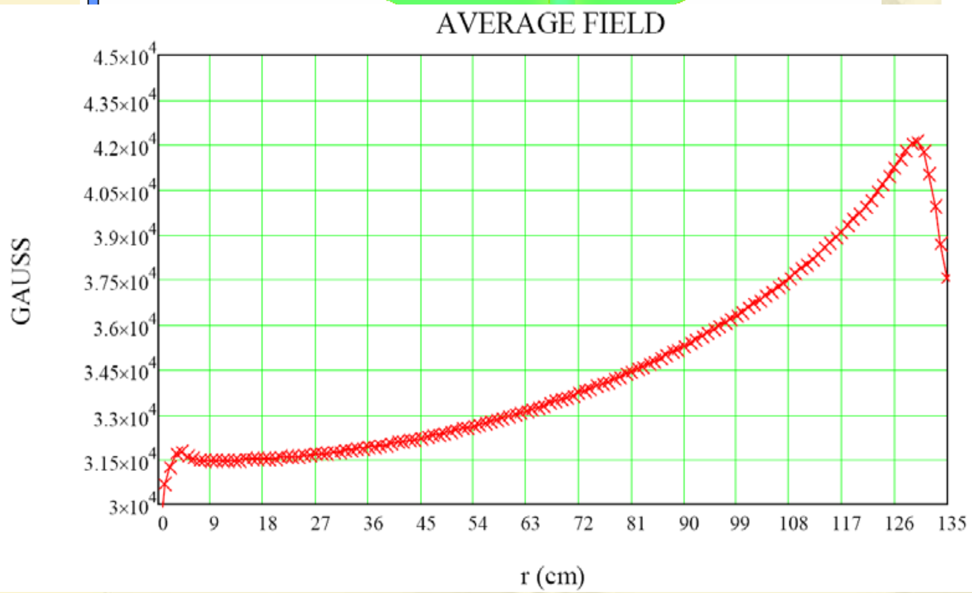


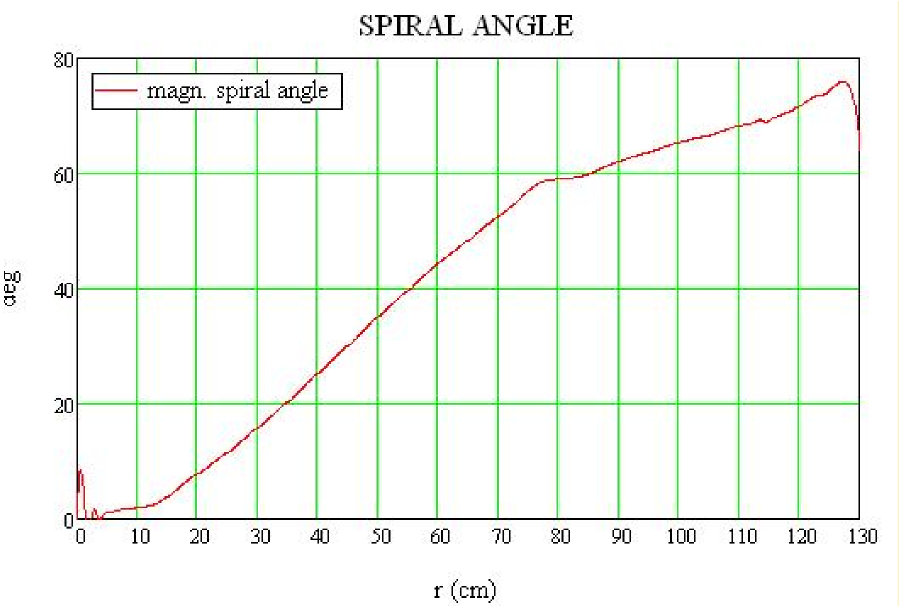
Vertical focusing during first turns



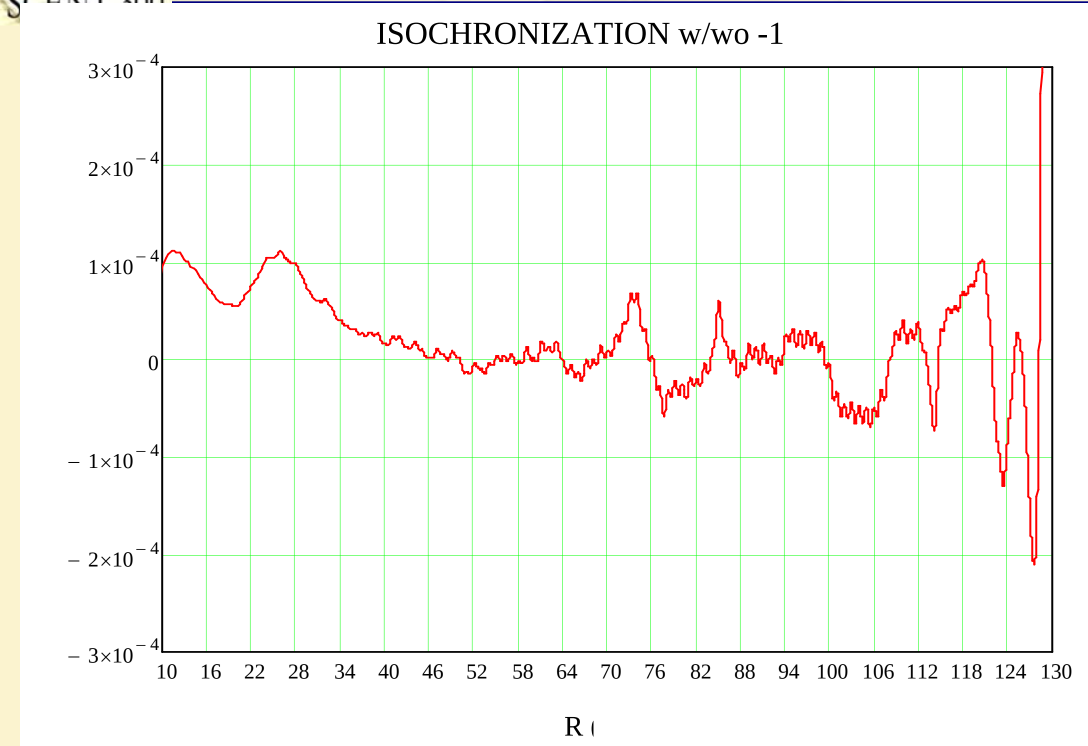
MAGNETIC FIELD PROPERTIES



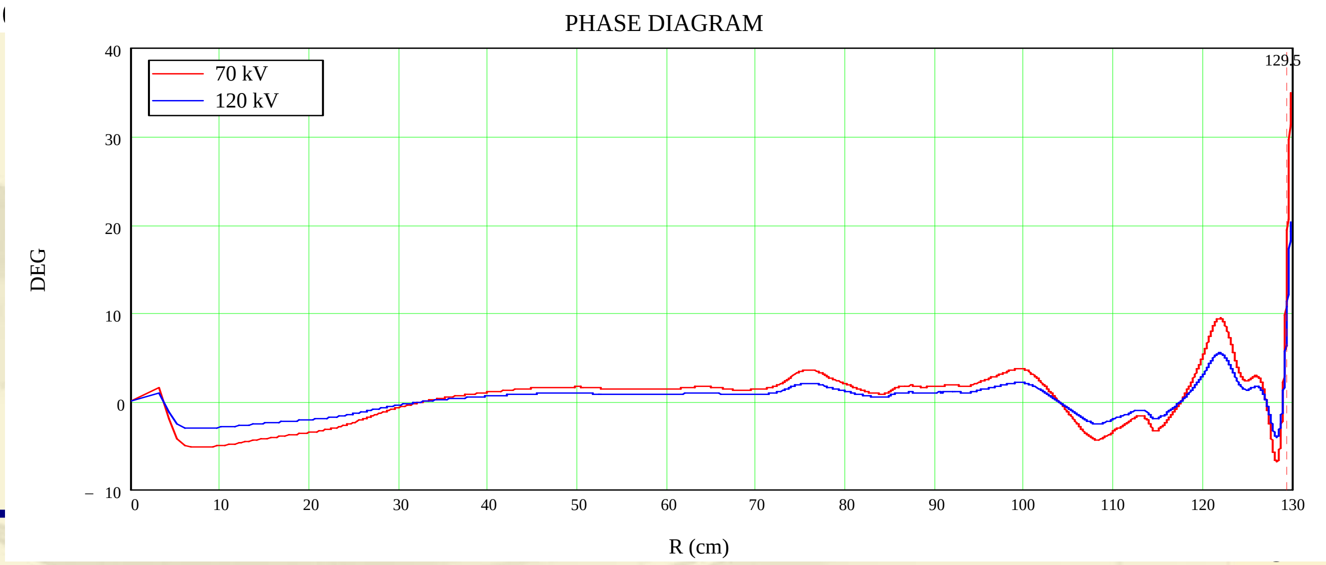




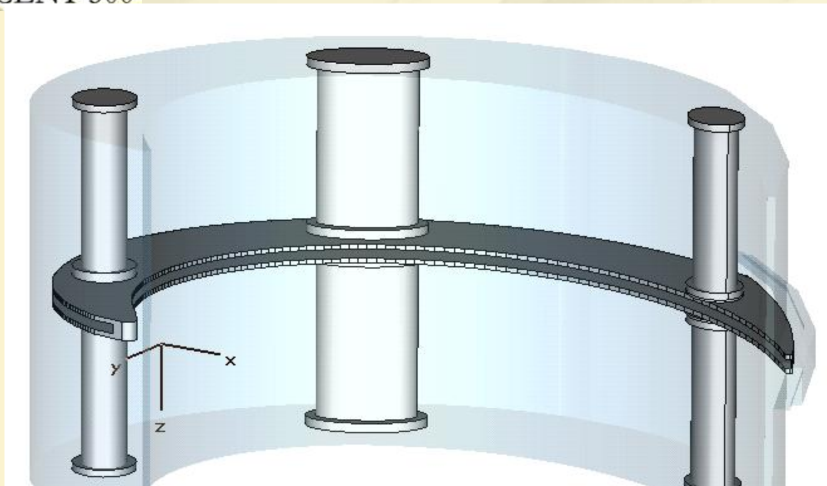
ISOCHRONIZATION LEVEL



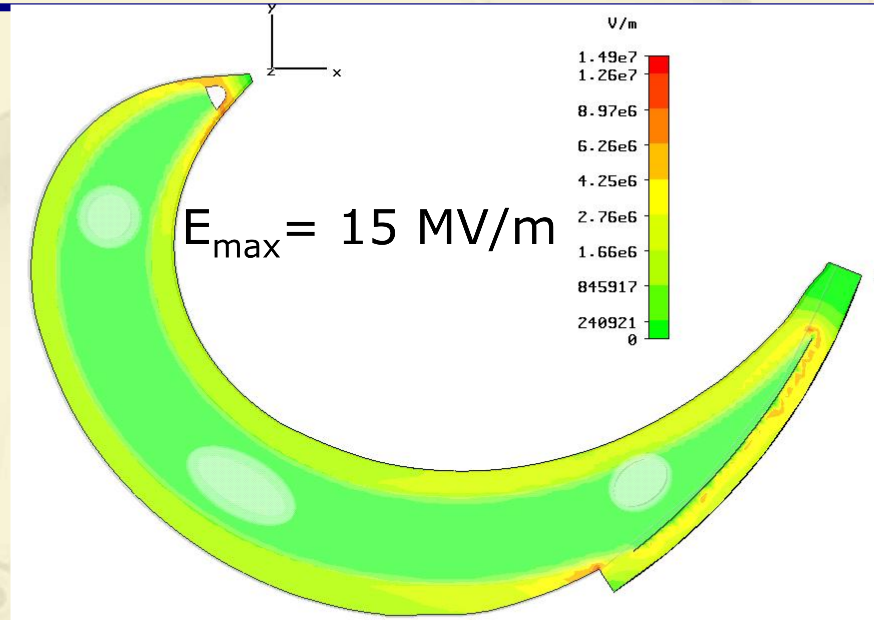
UNTIL THE PHASE VARIES WITHIN 20 DEG,
THE MAGNETIC FIELD HAS TO MATCH THE ISOCHRONOUS ONE
WITH A PRECISION OF ±5GAUSS ($|\Delta B/B| < 10^{-4}$)



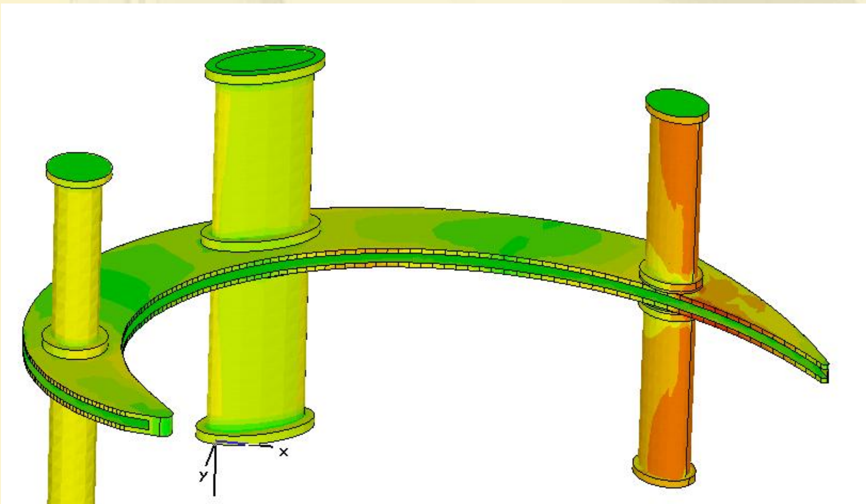
RF CAVITY DESIGN



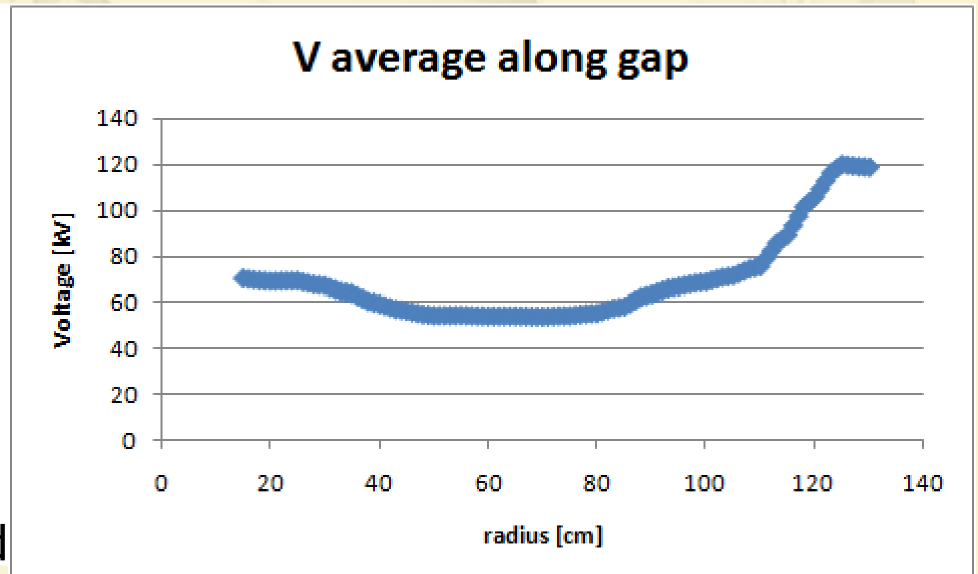
f_{RF} = 98 MHz, 4 th harmonic



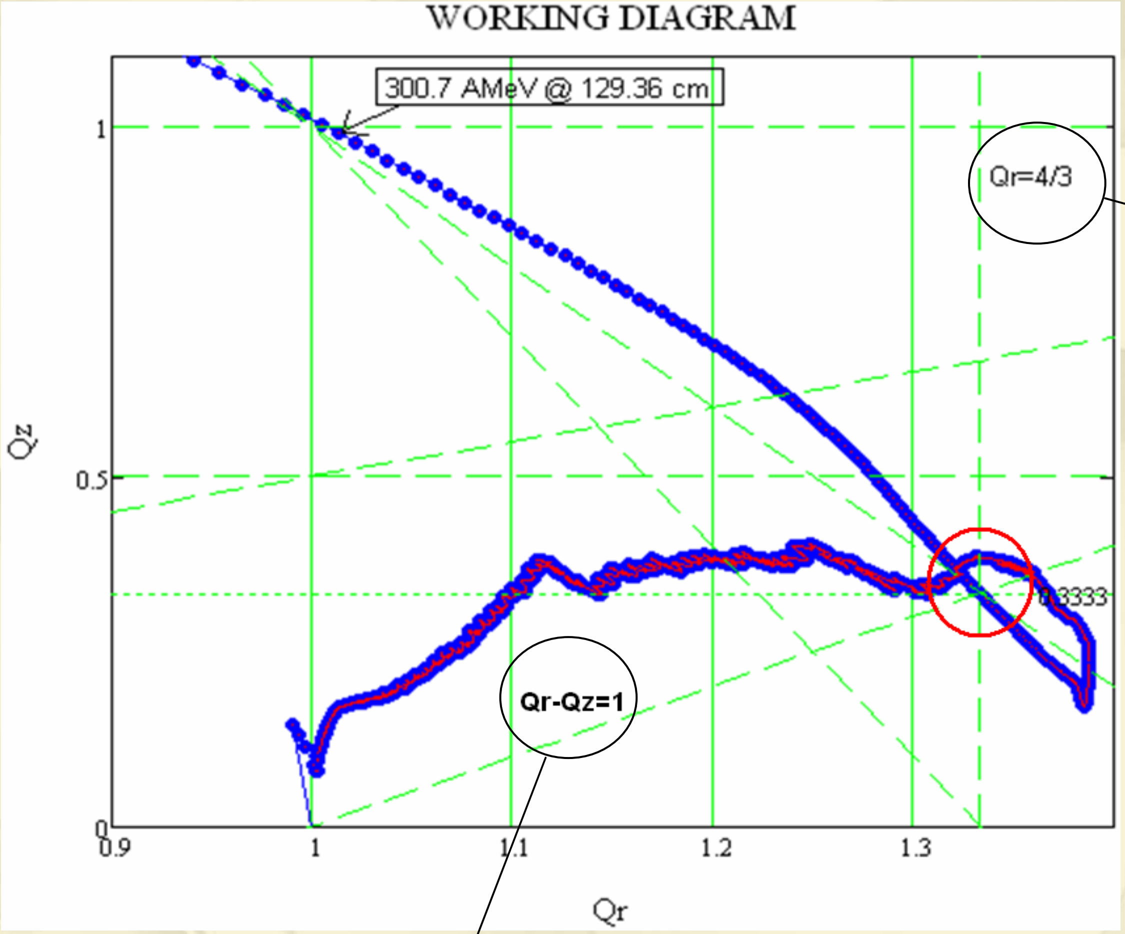
E_{max}= 15 MV/m



50 kW power losses estimated



BEAM DYNAMIC STUDY

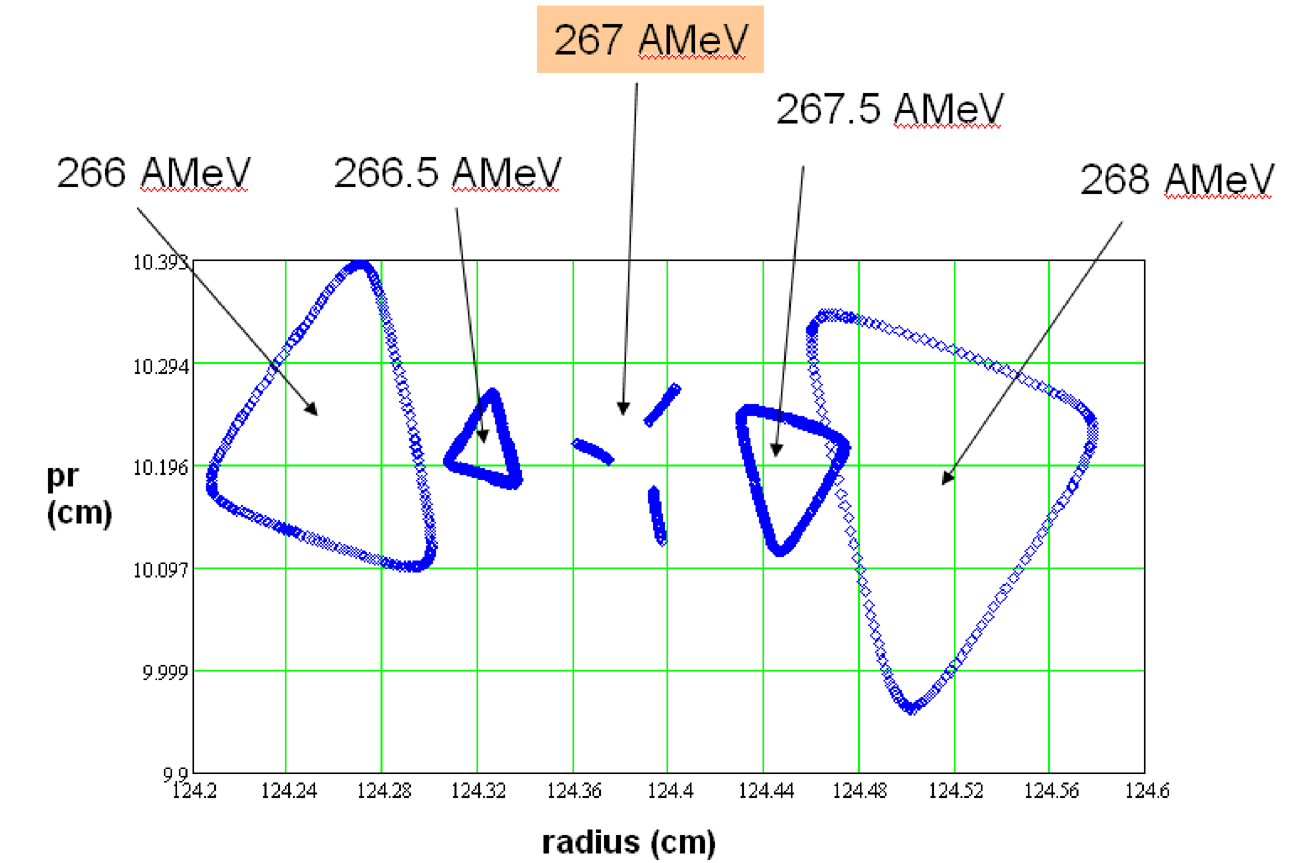


structural resonance

coupling resonance

WHAT APPENDS AT RESONANCE ZONE?

Minimal transverse stability plot



4/3 resonance crossing –static mode-

<u>Solution?</u>

Jump these radii…

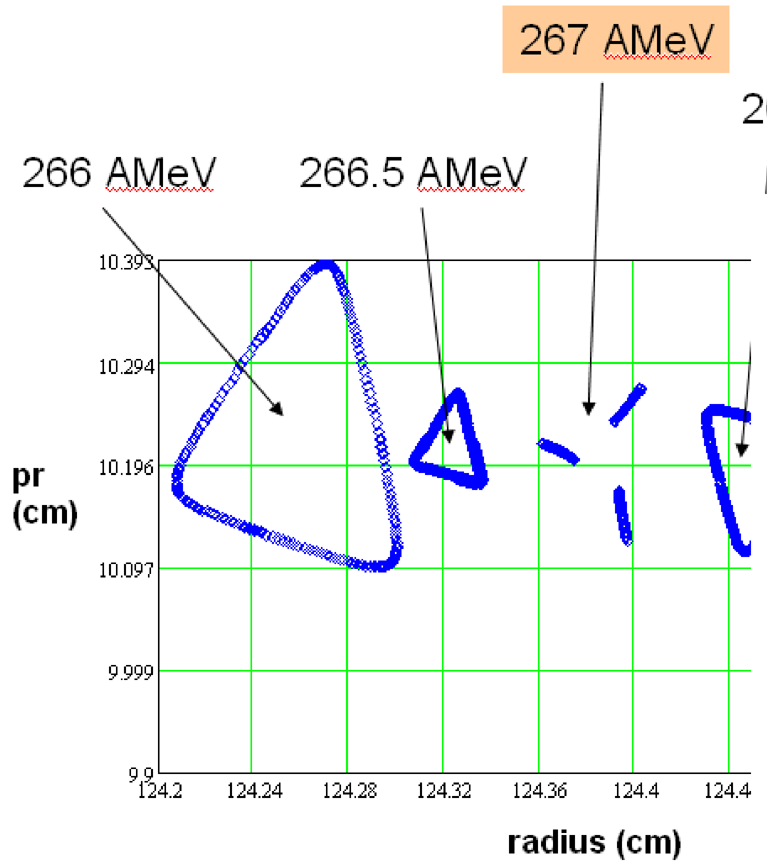
but energy gain

cannot increase

too much

WHAT APPENDS AT RESONANCE ZONE?

Minimal transverse stability plot



4/3 resonance crossing –s

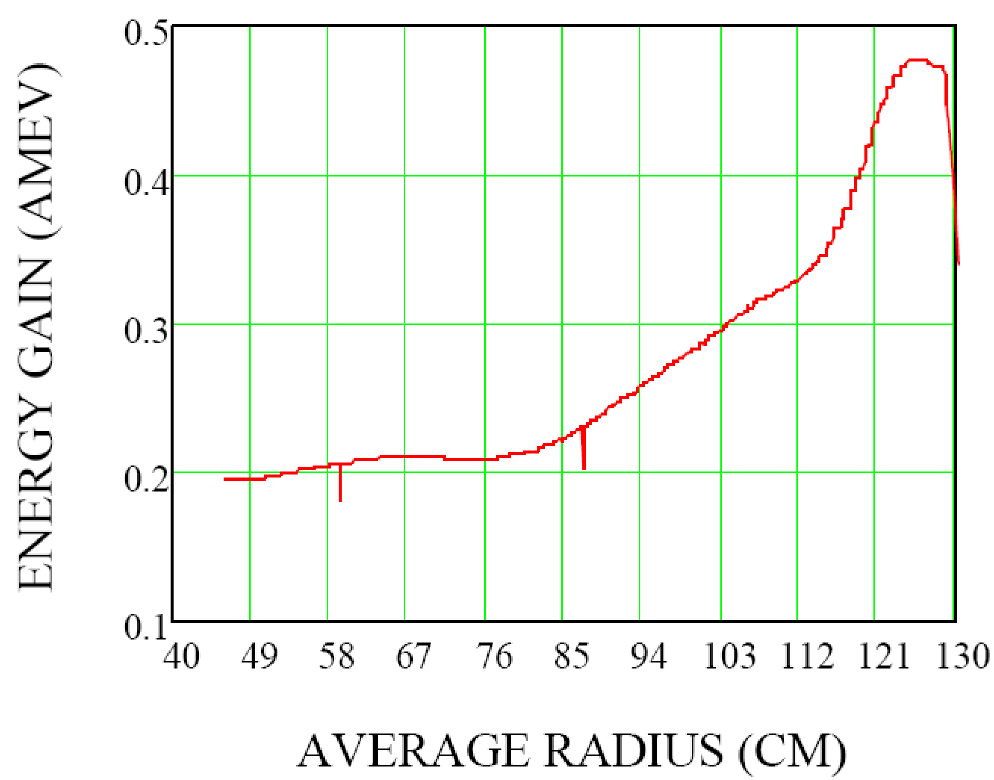
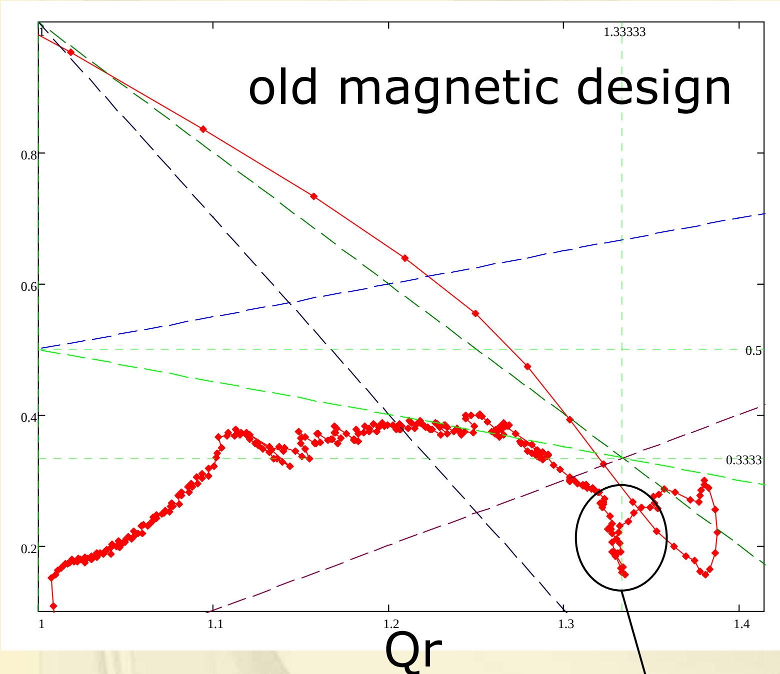
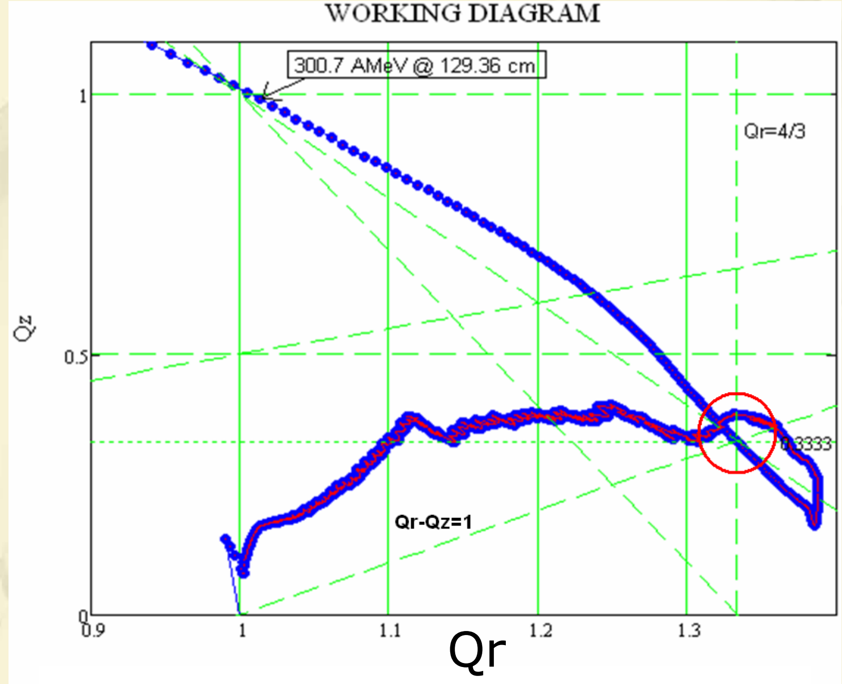
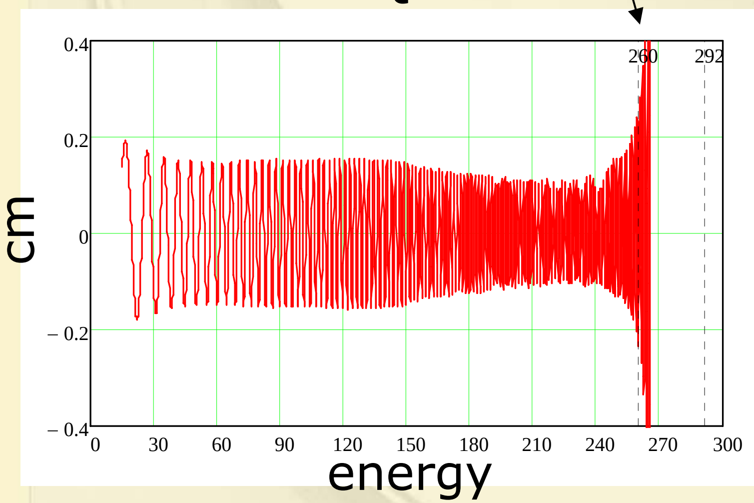


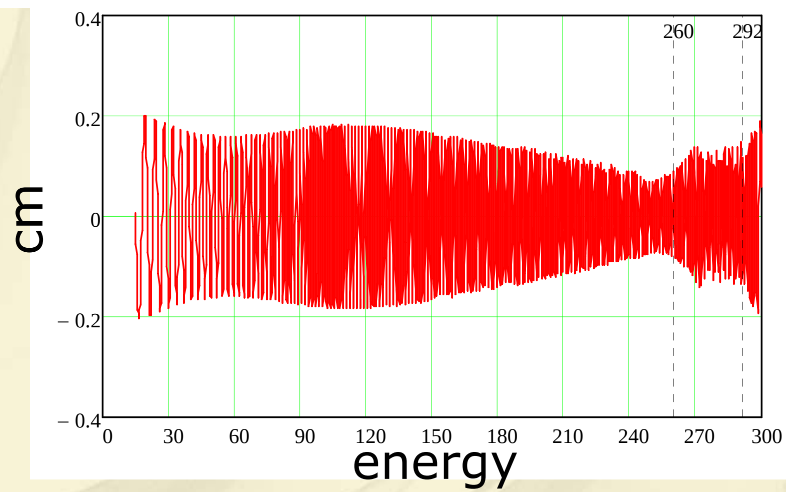
Fig. 5.4: energy gain (AMeV/turn) versus the radius

Radial beam envelop in two cases

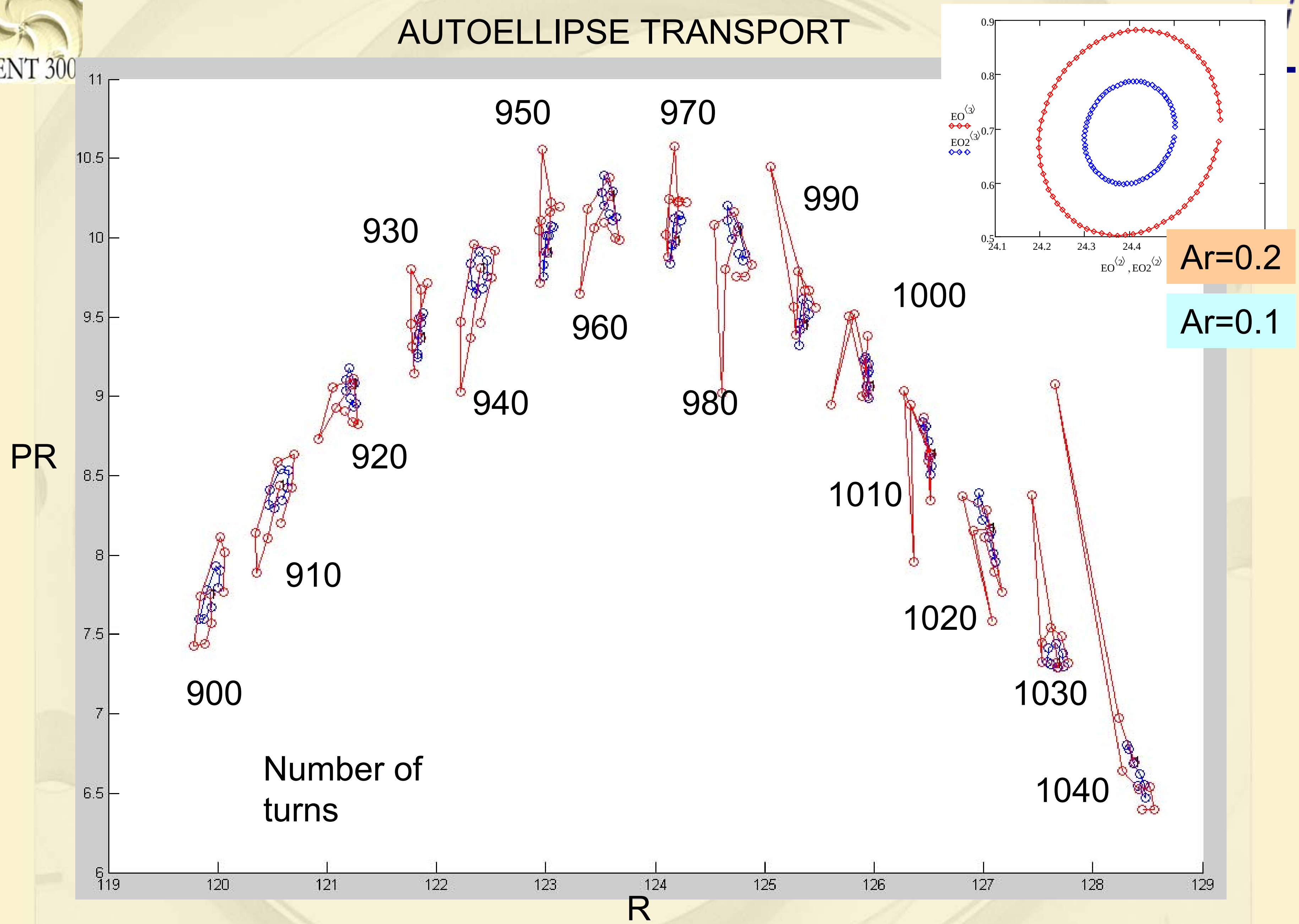




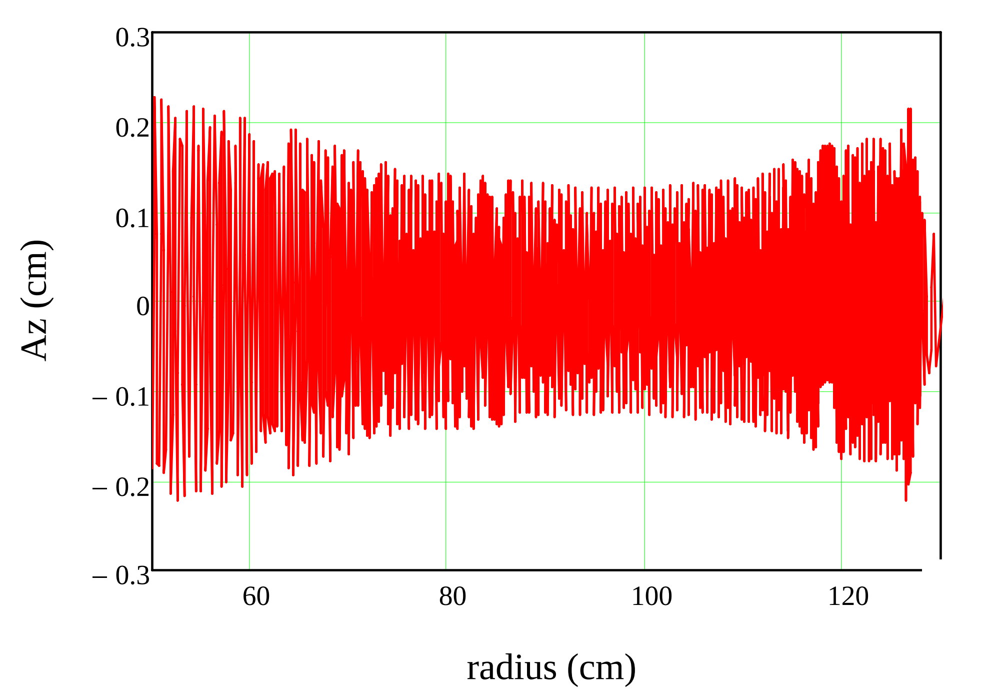




AUTOELLIPSE TRANSPORT

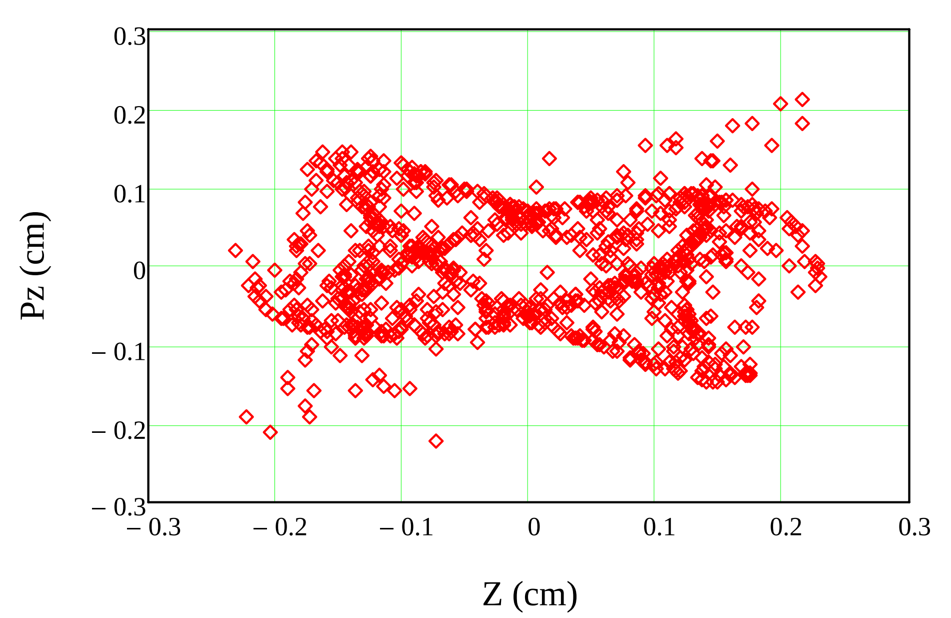


VERTICAL BEAM DYNAMIC

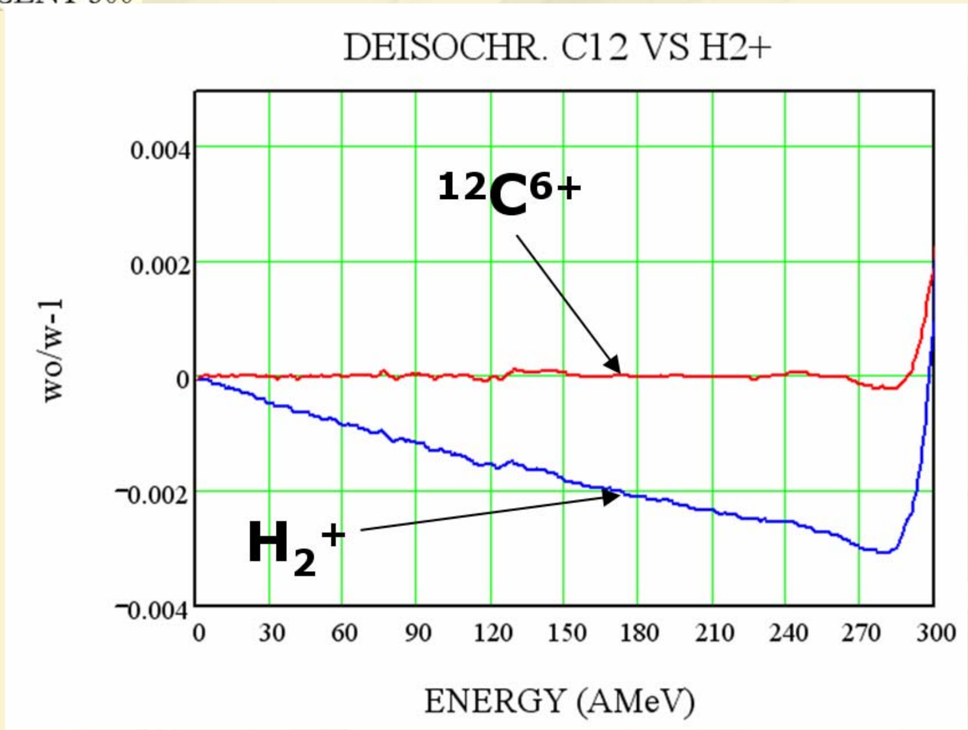


Vertical beam envelop

Axial space phase



Trimming C12 to H2+: RF and MF change

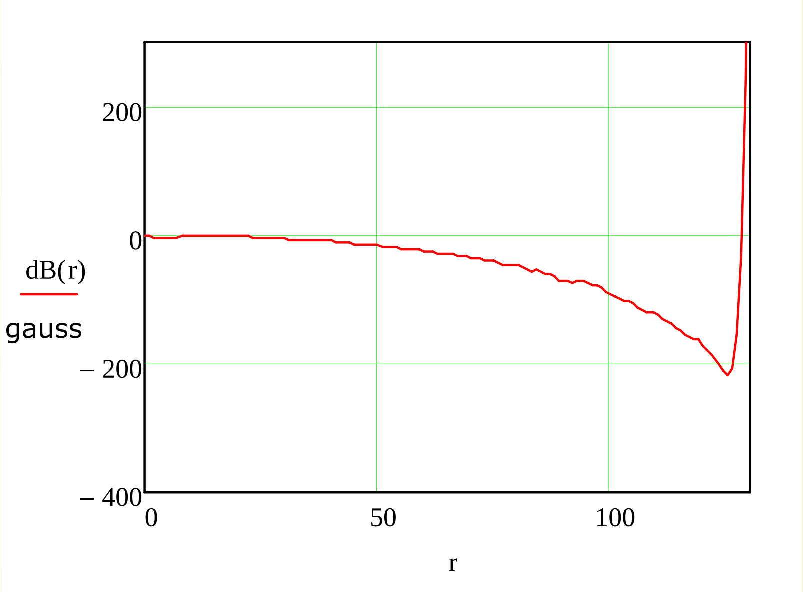


Bo=cost.

RF Frequency scales 0,7 %

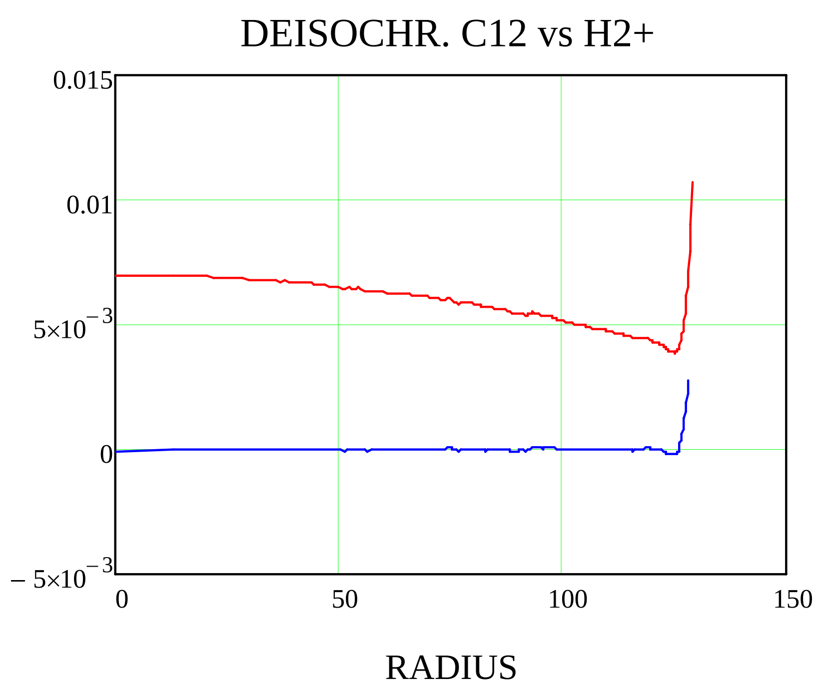
Two beams mean two different operating RF frequencies

small variation of the MF



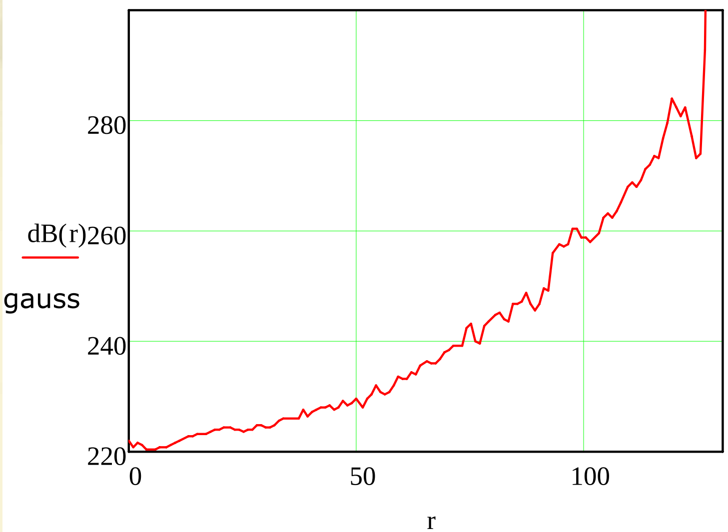
Best solution:
coils split into two parts (C400)

2nd way: change only the magnetic field



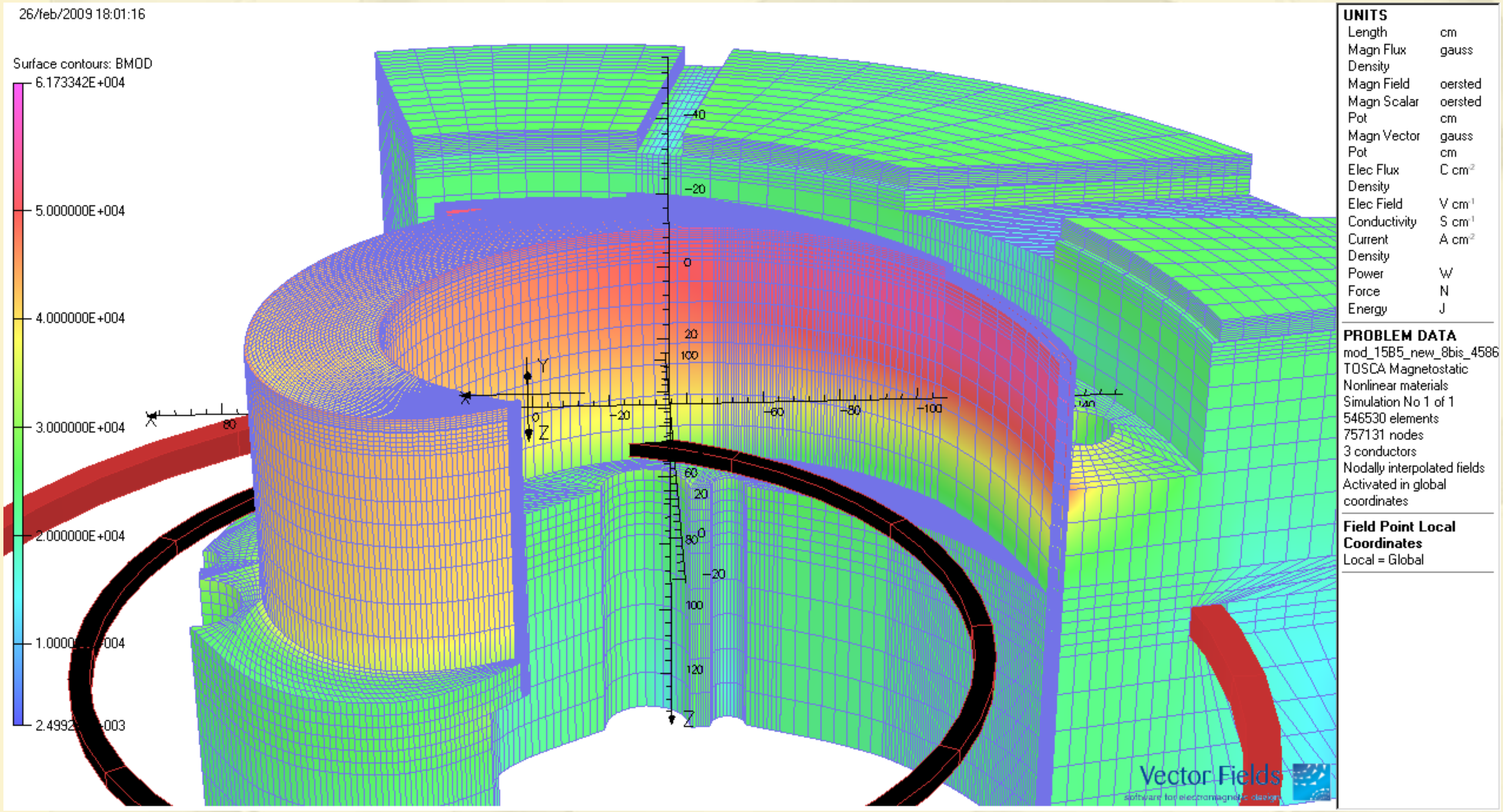
f_{RF} = cost

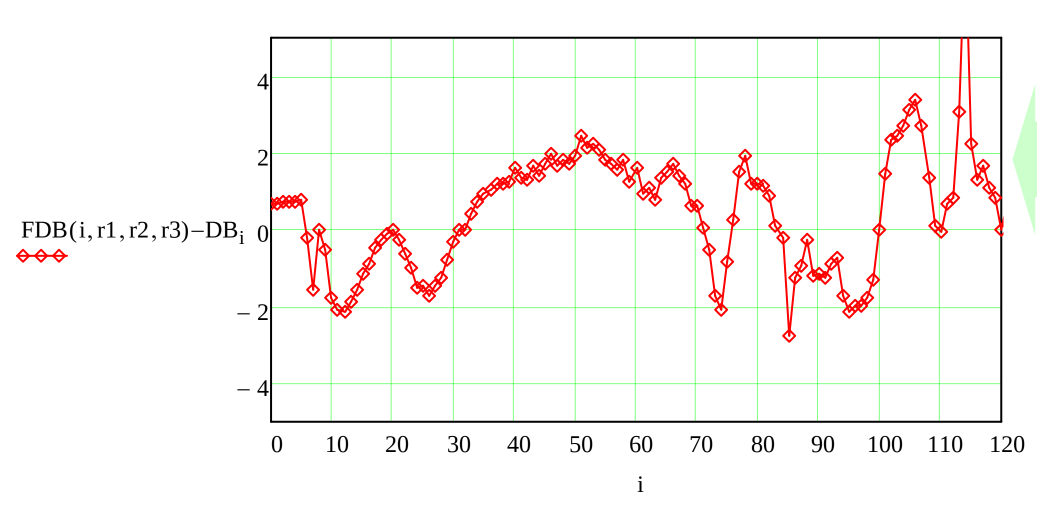
$$\mathrm{Bonew(ratio)} := \frac{\mathrm{Eo}\cdot \mathrm{wo}(0.5)}{\mathrm{ratio}\cdot q\cdot c^2}$$



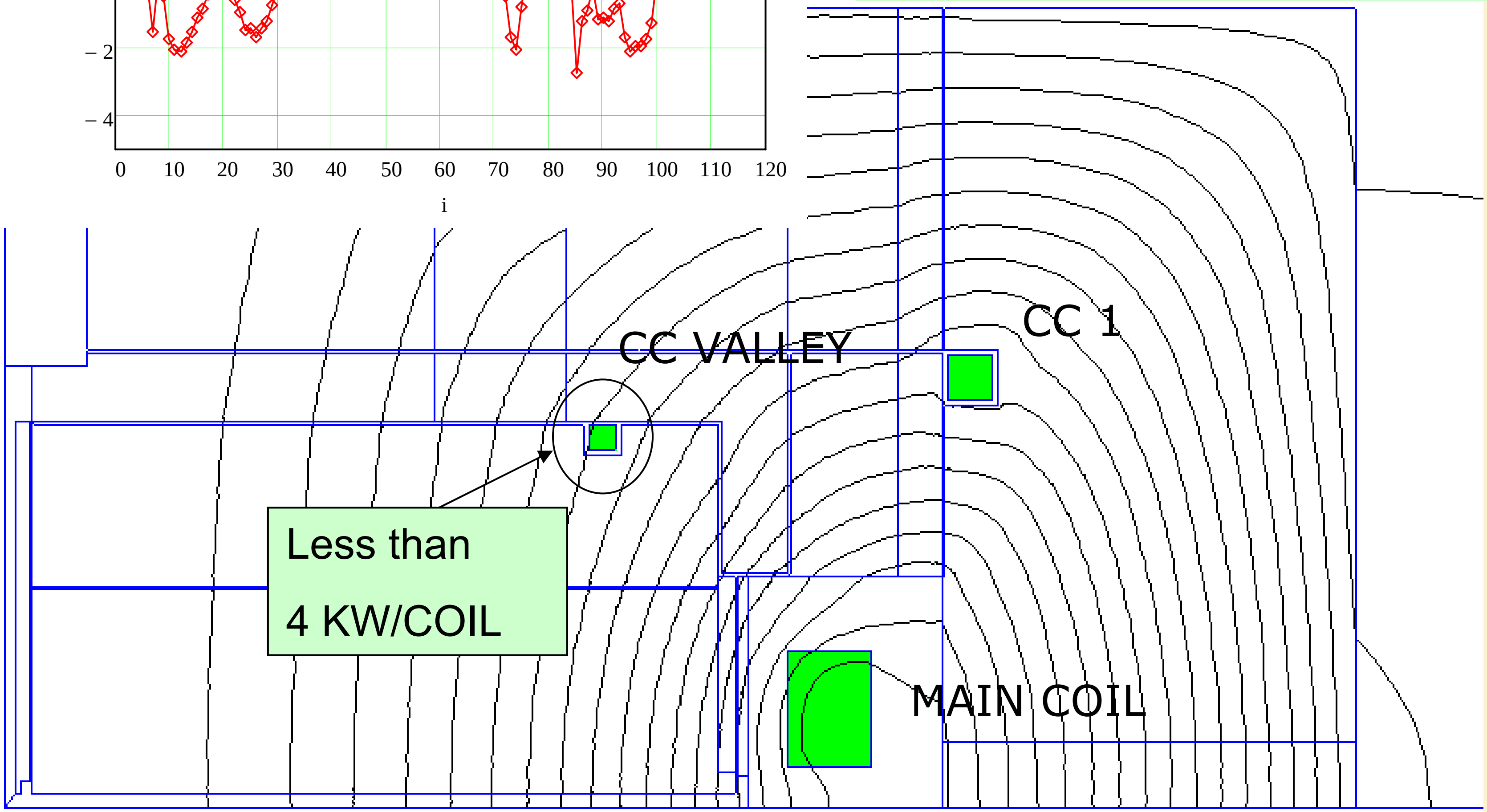
Magnetic field difference between C12 and H2+ is larger, but RF freq. is kept constant (it needs only the fine tuning)

Trimming by two correction coils



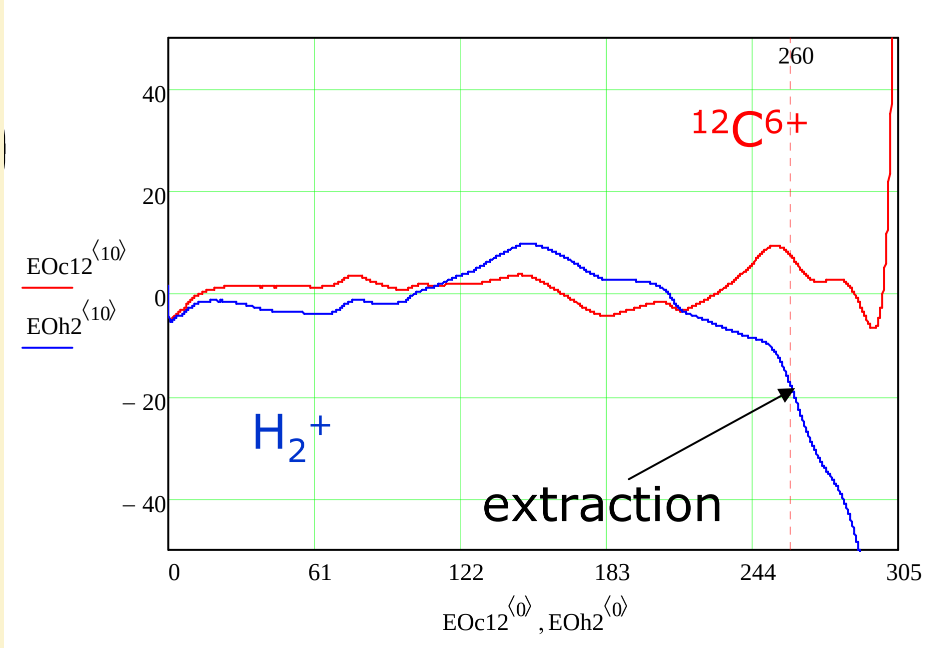


GOOD M. FIELD MATCHING
MINIMIZING POWER LOSSES

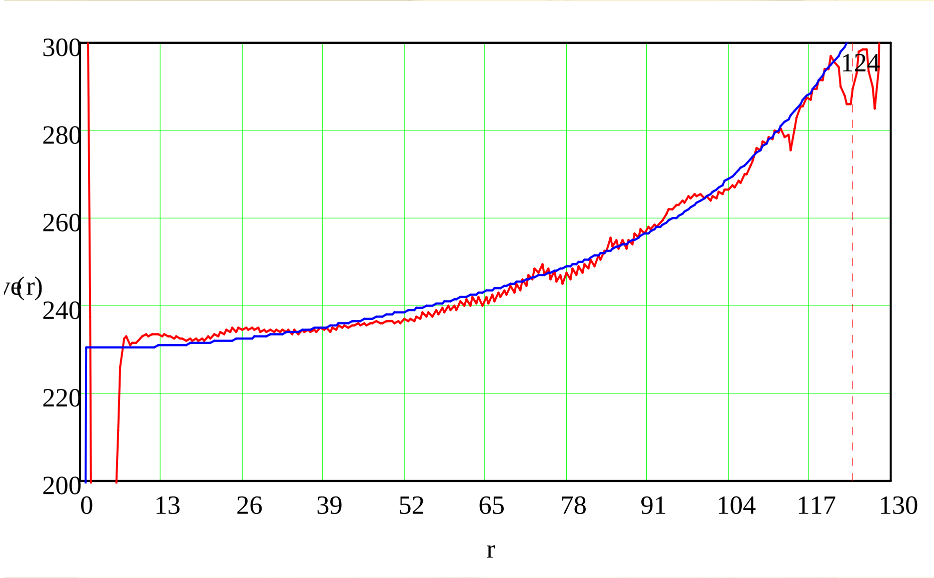


MAIN SETTING TO CHANGE BEAM

PHASE SLIP CALCULATED BY EO



MAGNETIC FIELD MATCHING



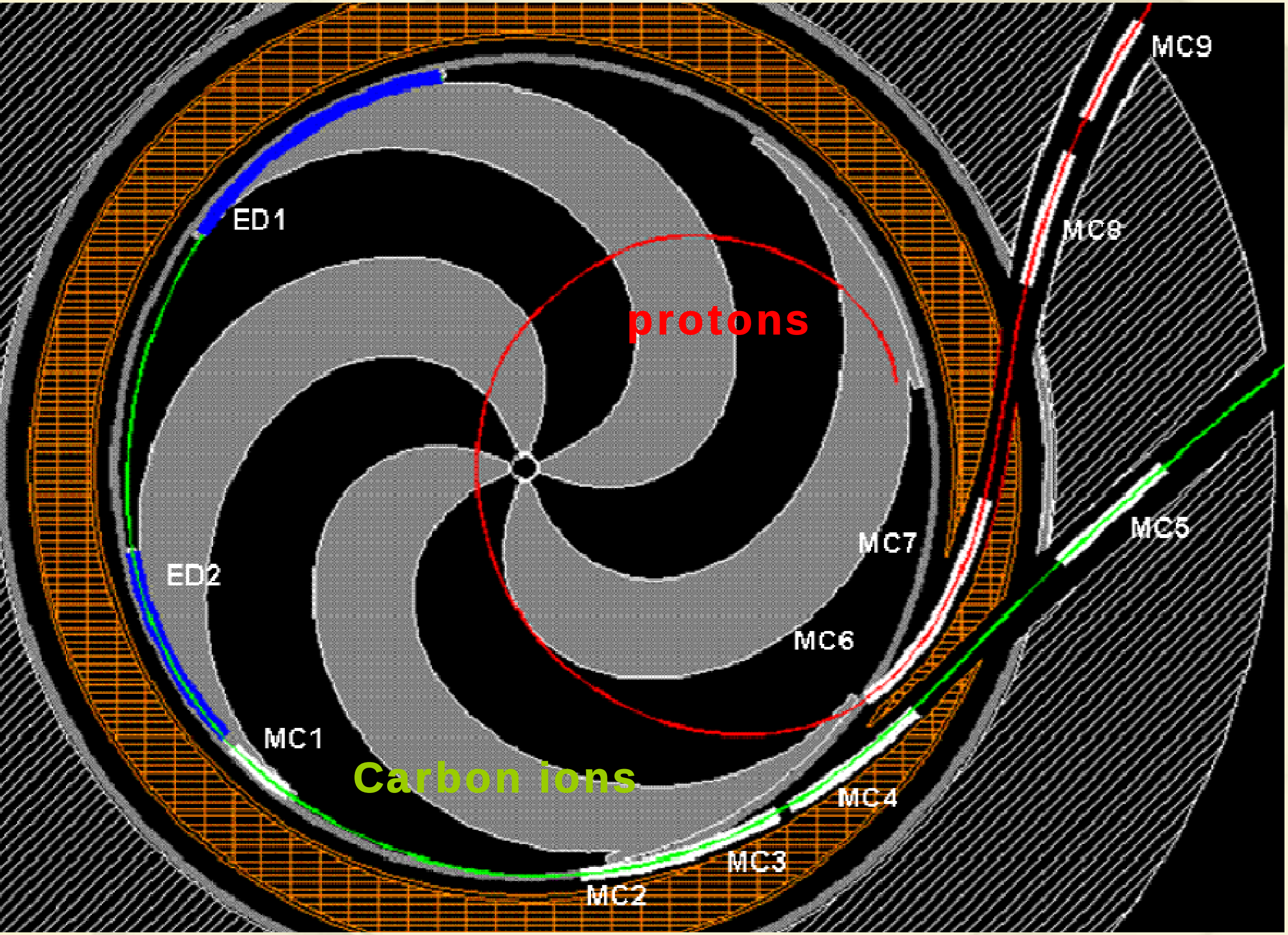
MAIN COIL : 4586 A/cm² → 4586+53.7 A/cm²

CC 1: 104.47 A/cm² → 8X8 cm² , R_{int}=171 cm, H_{min}=81 cm >> 1.32 kW/coil

CC VAL: 395.1 A/cm² → 5X4 cm² , R_{int}=106 cm, H_{min}=69 cm >> 3.24 KW/coil

RF SETTING: nu0=24.18717 MHz → 24.18587 MHz Δf: 1,3 KHz
TRIMMER RANGE TUNING (~ 6 KHz)

EXTRACTION LAYOUT



$V_{ED1,2}$ = 50kV

E_{max} = 120kV/cm

4 PASSIVE MCs

ε ~ 60 %

R_{EXT} =122 cm

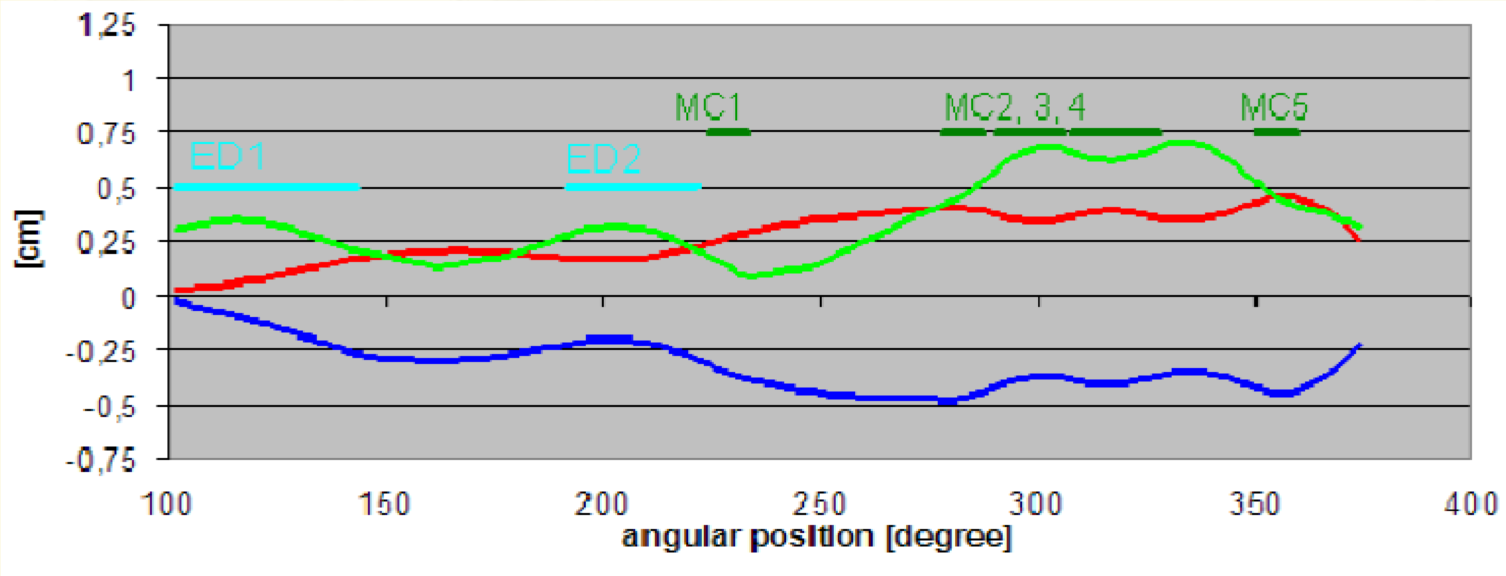
260 AMeV

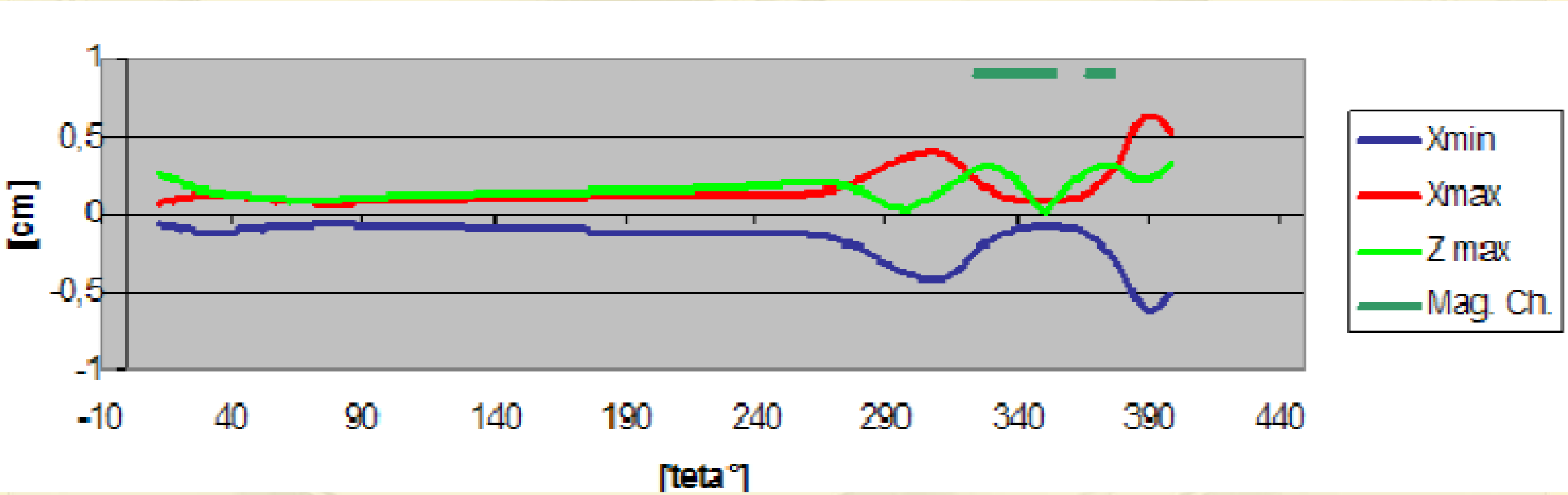
1 single turn

4 PASSIVE MCs

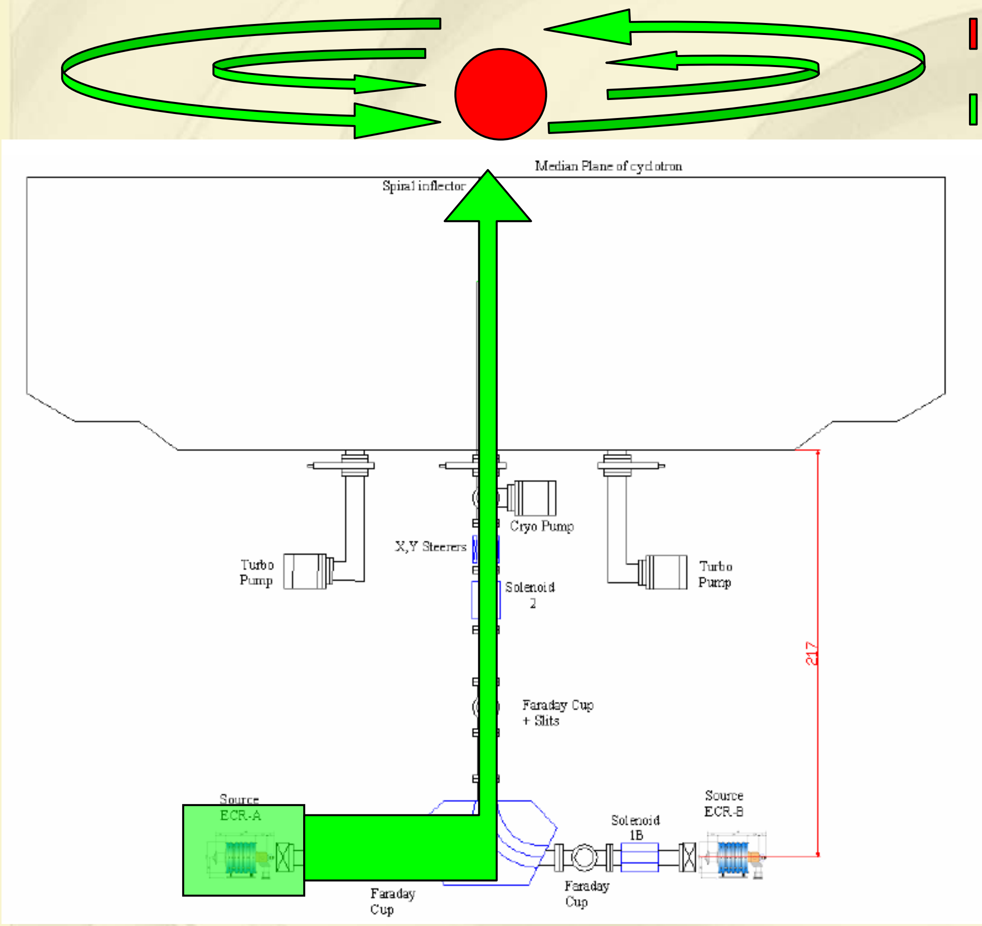
ε ~ 100 %

BEAM DYNAMIC AT EXTRACTION





CURRENT BEAM ESTIMATION



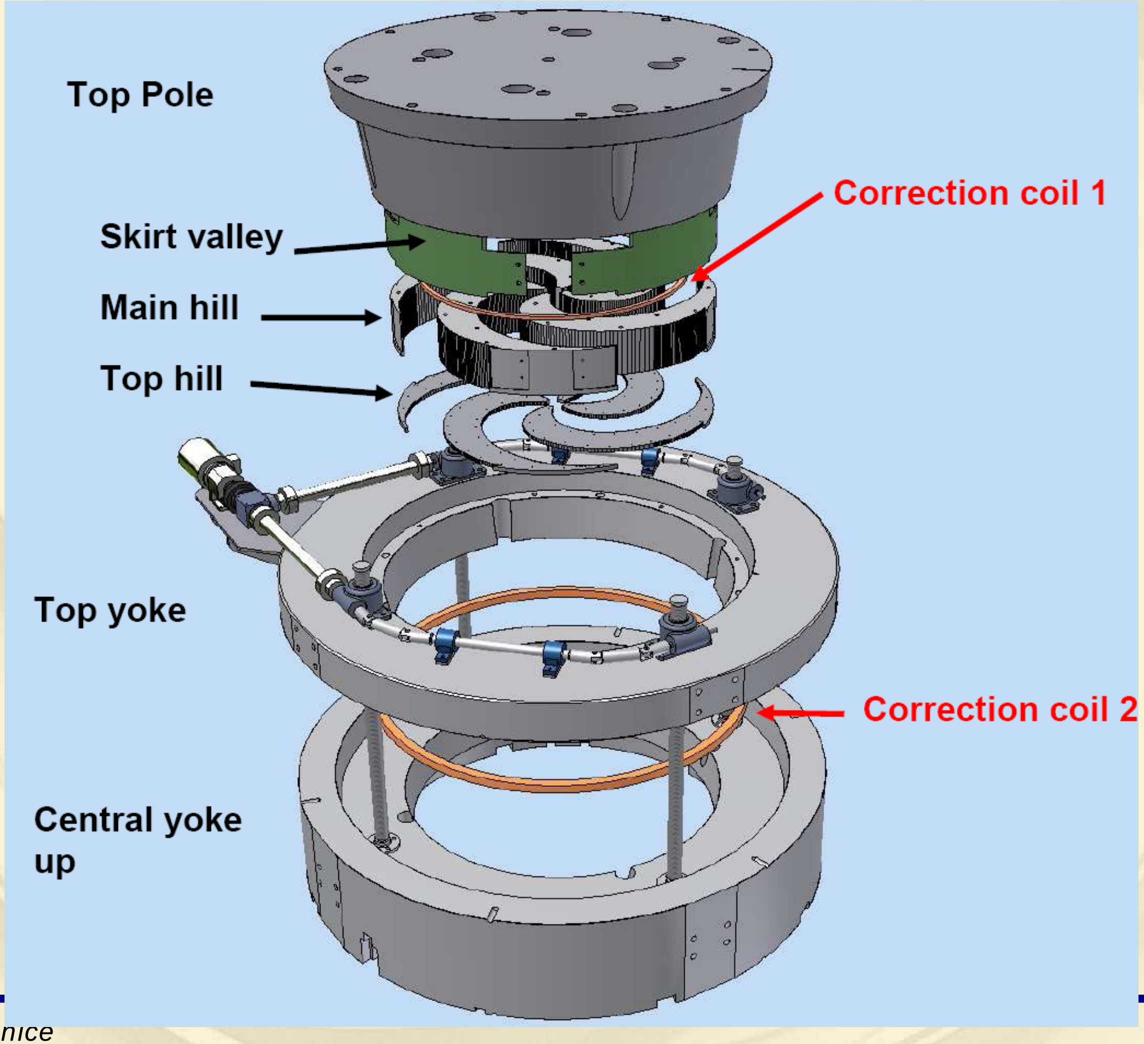
Carbon ions by EDs

Protons by stripper

Transmission efficiency	Ion source	2 mA
	Injection line	90 %
	Central region	5 % (no buncher)
	acceleration	90%
	extraction	60% C 100% p
	P current	80 nA
	C current	48 nA

CONCLUSION

The final design of SCENT300 was completed and no other study is expected: the technical drawings of the iron steel are also accomplished out.

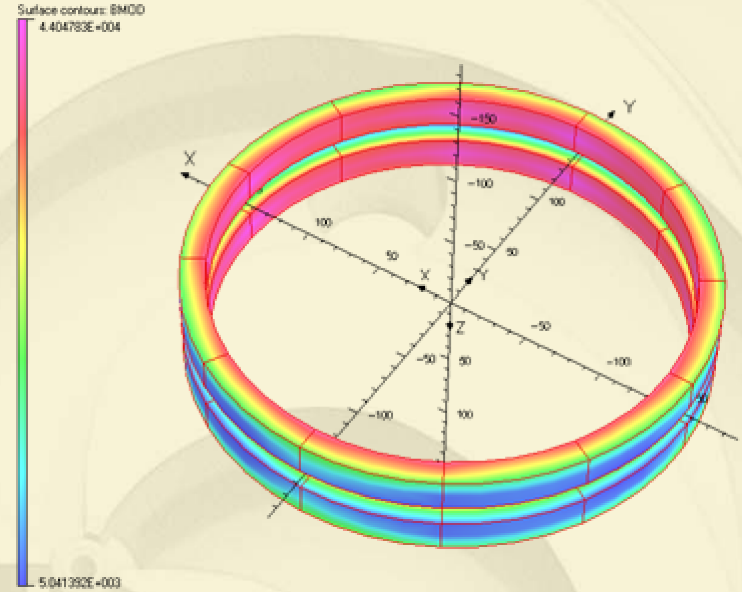


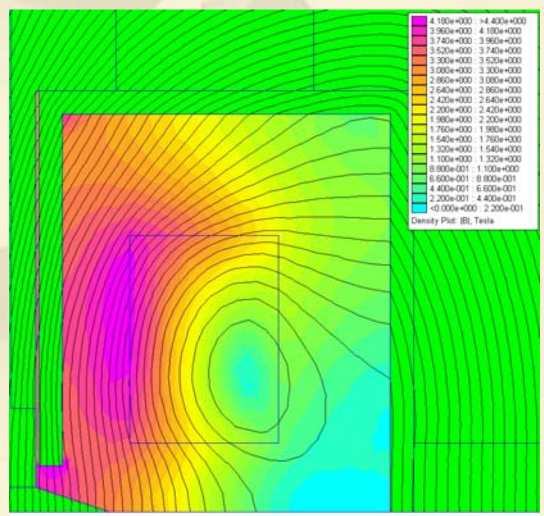
GRAZIE !

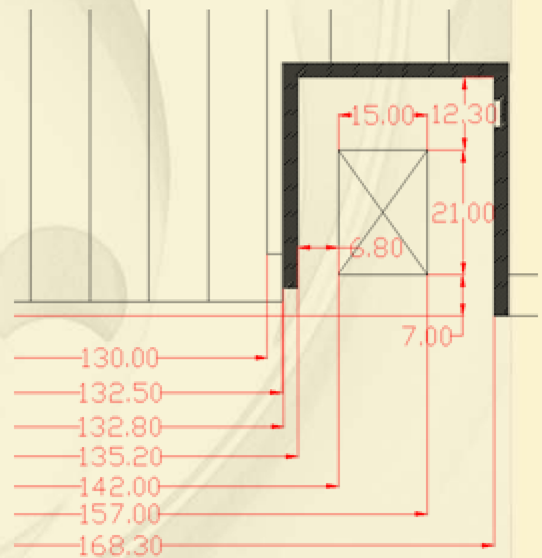
Coils parameters

Coil Parameters	
Size	150x210 mm^2
Current density	46.5 amp/mm^2
Inner Radius	1420 mm
Distance from the M.P.	70 mm
Energy Stored	35 MJ
Nominal Current (I)	900÷1000 amp
Total current (NI)	1.48 Mamp
Max Magnetic field	4.4 tesla
Axial Force	-9.09 MN
Average Hoop Stress (peak)	100 (110) MPa

Conservative Design

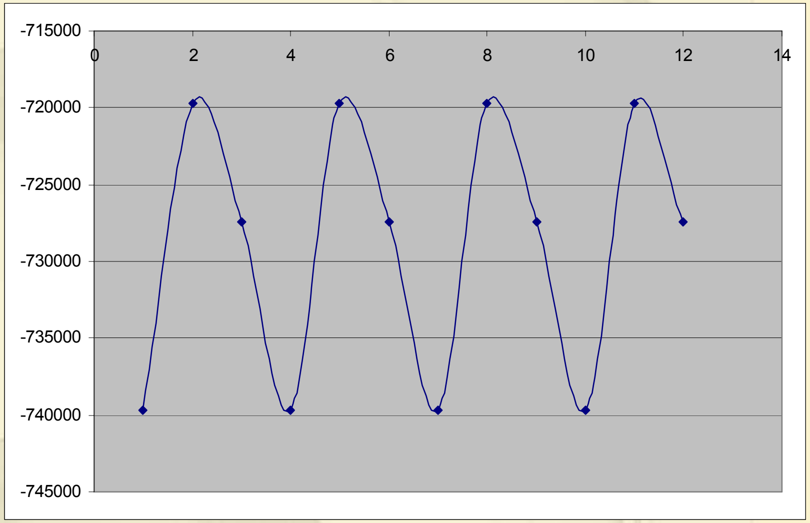




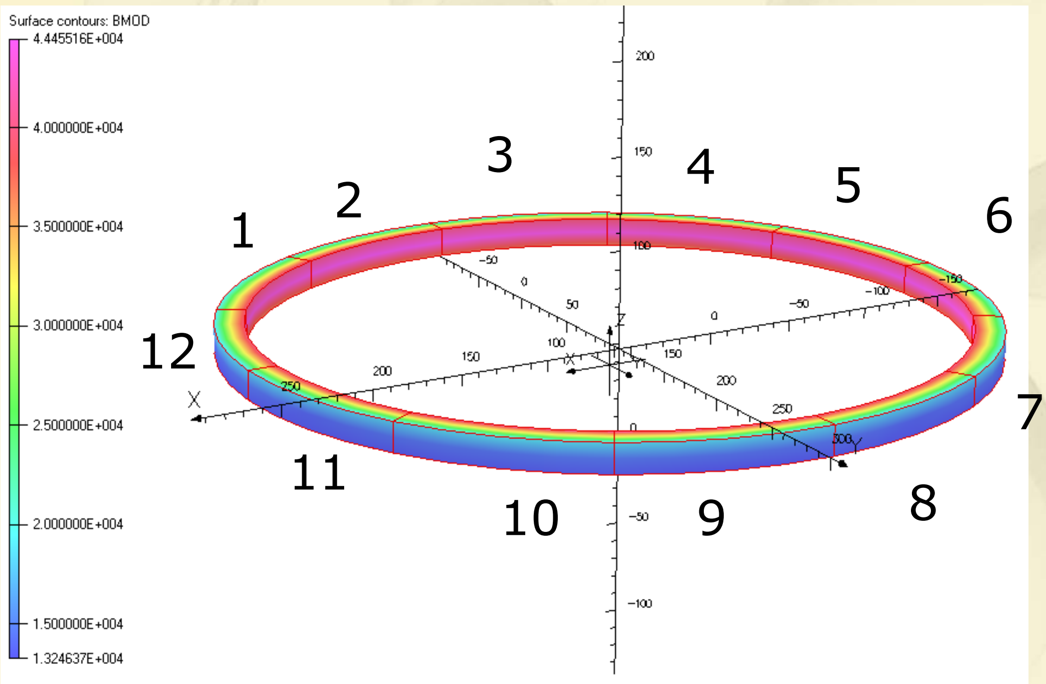


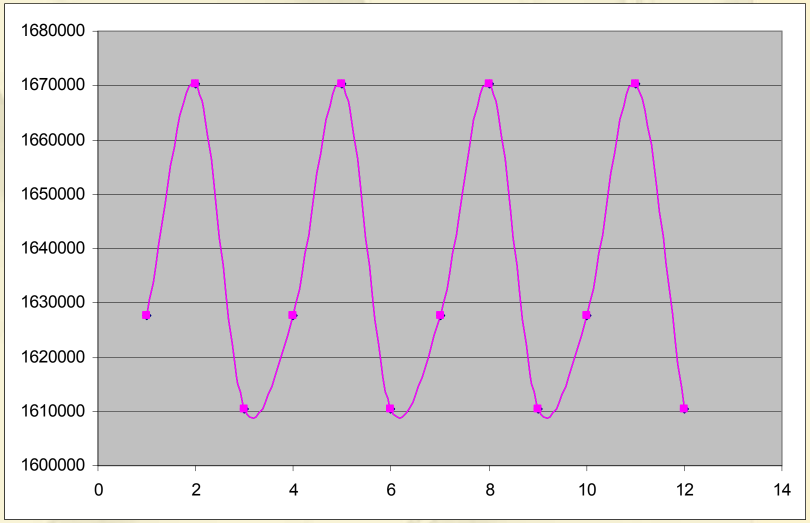
FORCES EVALUATION ON THE COILS (J X B)

Vertical force (N)



TOT=-891 tons/coil

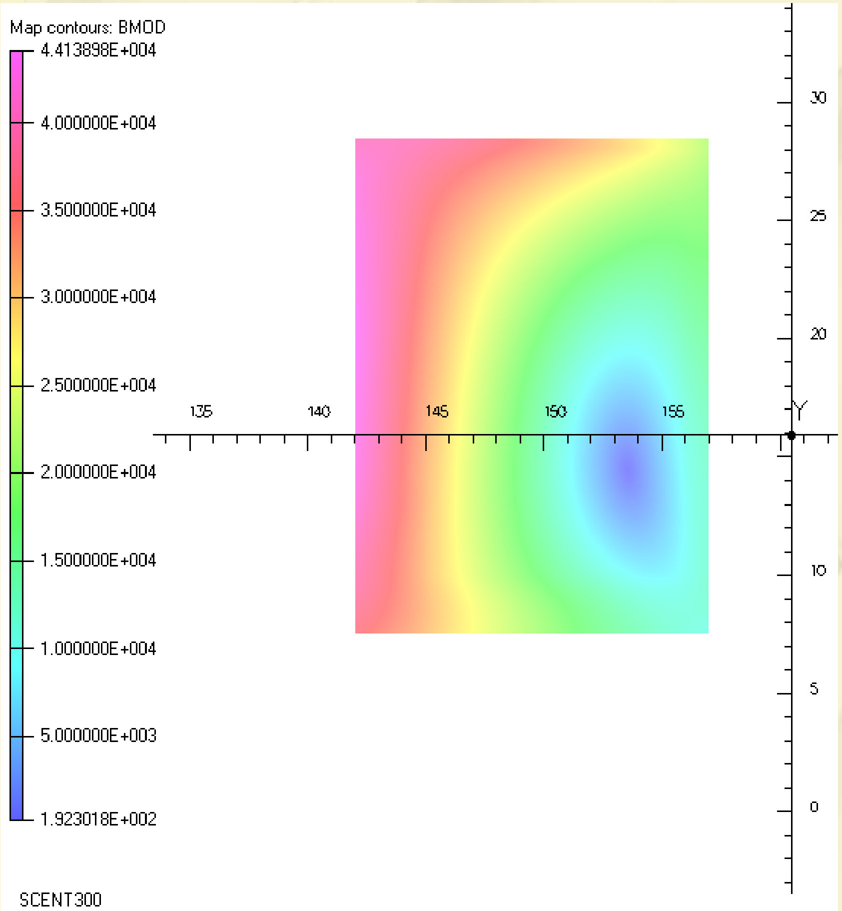


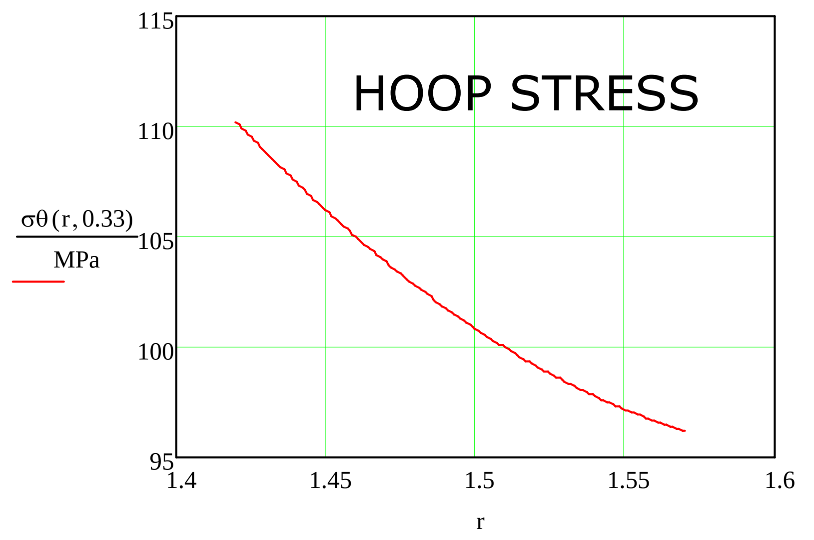


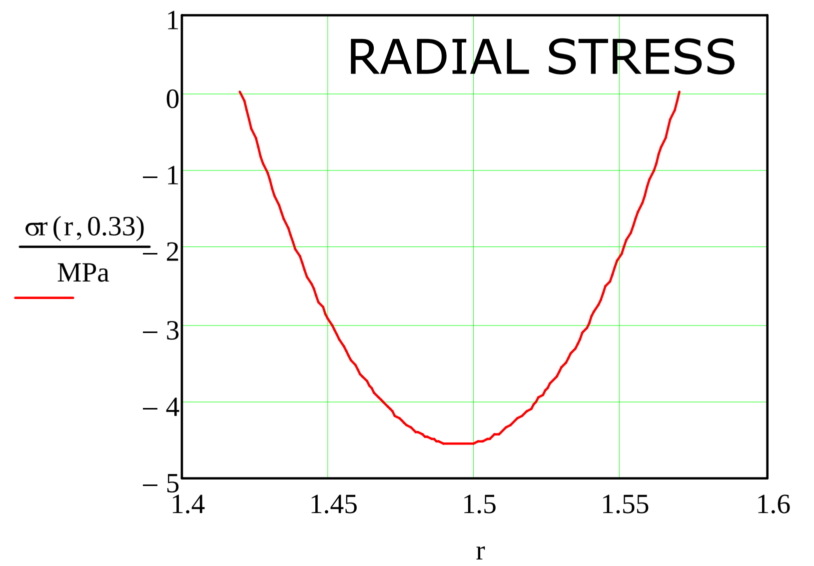
Radial force (N)

Average=166 tons/coil

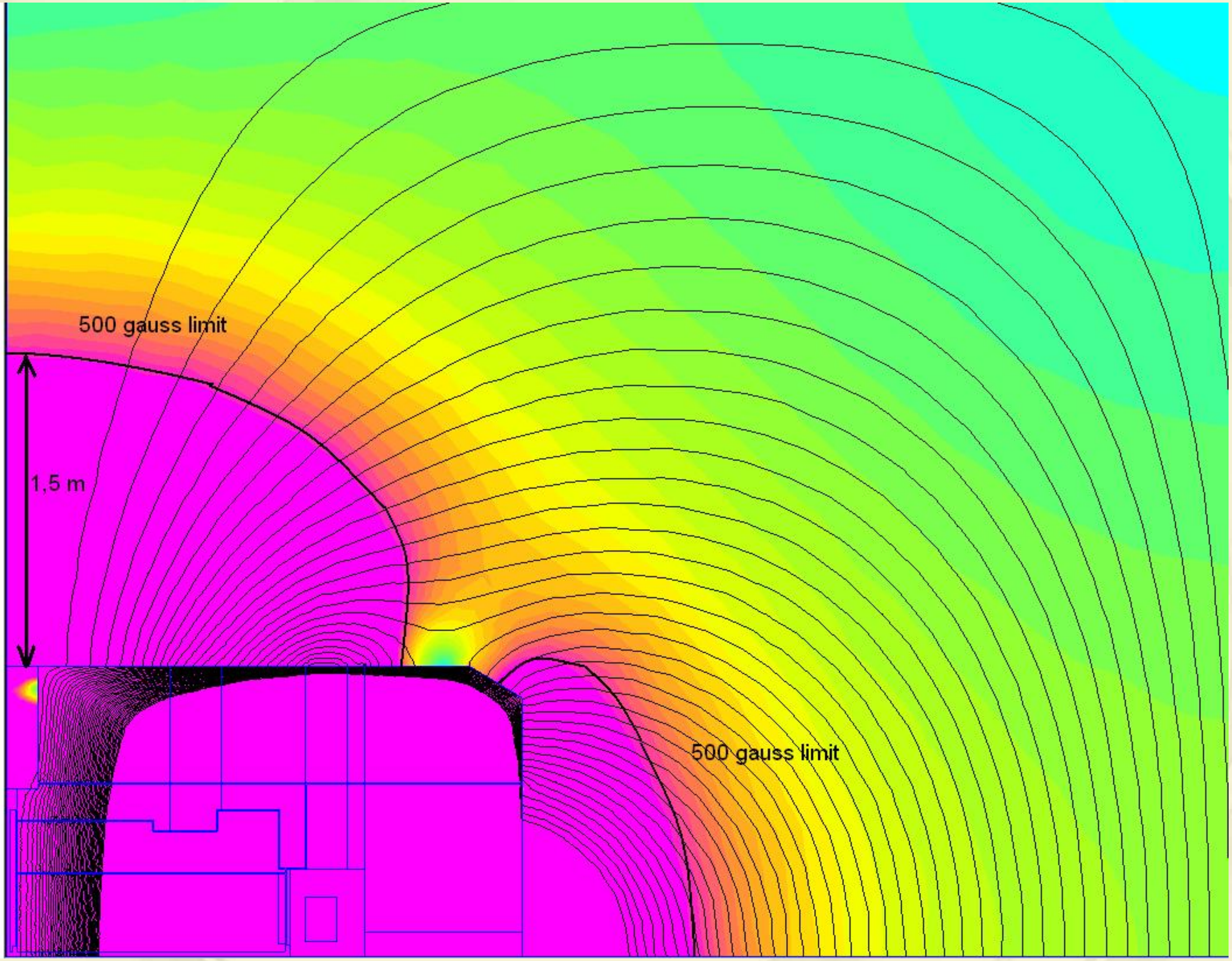
STRESS DISTRIBUTION IN THE COILS







$$\frac{1}{Rout - Rin} \cdot \int_{Rin}^{Rout} \sigma\theta(r, 0.33)\, dr = 101.935\,MPa$$


500 gauss limit
1,5 m
500 gauss limit