PROGRESS ON THE DESIGN STUDIES OF THE 300AMeV SUPERCONDUCTING CYCLOTRON

Mario Maggiore

on behalf of R&D Accelerator Group

Laboratori Nazionali del Sud
Catania, Italy

Contents

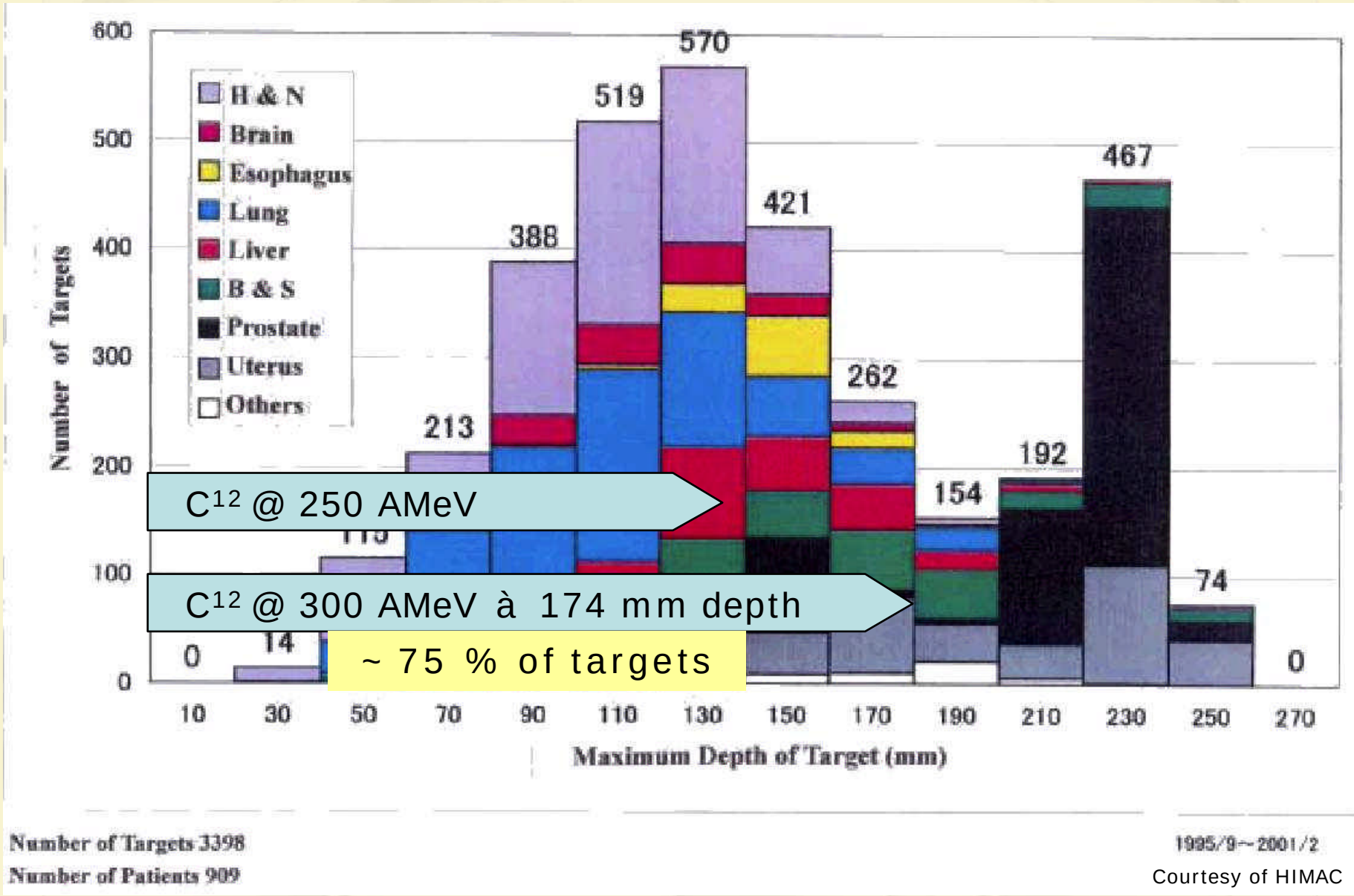
- ü INTRODUCTION
- ü INJECTION STUDY
- ü BEAM DYNAMIC
- ü EXTRACTION LAYOUT
- ü CAVITY DESIGN
- ü STRUCTURAL & MECHANICAL ANALYSIS
- ü SUMMARY

The 300 AMeV choice

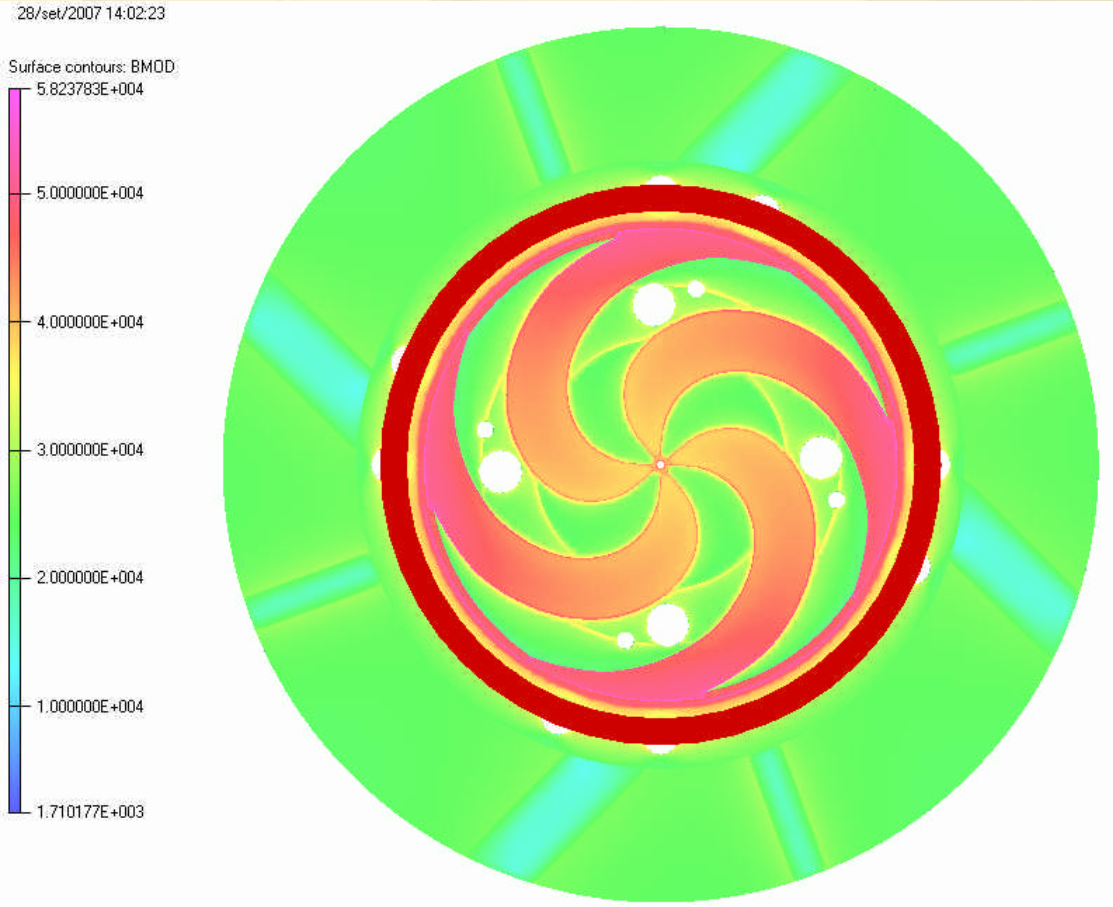
At the end of 2005 the SCENT project has been completed. The preliminary studies of a superconducting cyclotron able to accelerate ions with mass to charge ratio of 0,5 up to energy of 250 AMeV for hadrotherapy, were carried out by the Accelerator R&D group of LNS.

In March 2006, we have investigated the possibility to increase the extraction energy of the carbon ions up to 300 AMeV, increasing the main magnetic field, but keeping unchanged the main parameters of the machine. Moreover, we tried to extract the proton beam by the stripping process at the energy of 250 AMeV.

Why 300AMeV is better than 250AMeV (carbon ions) ?



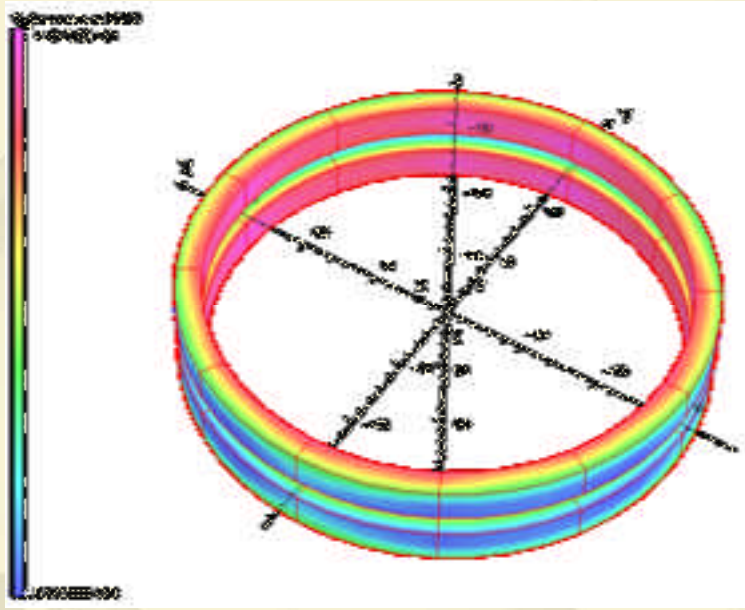
Main parameters

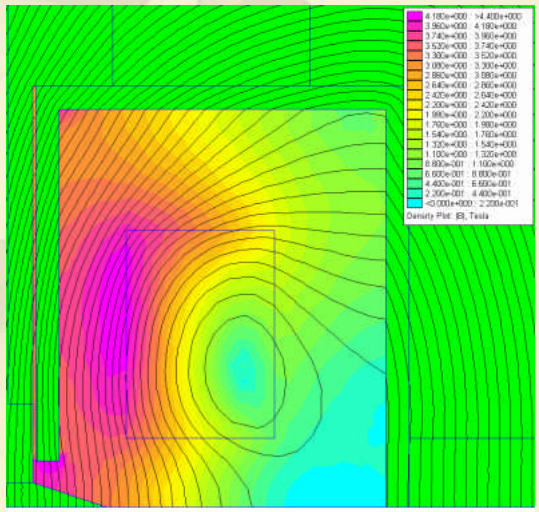


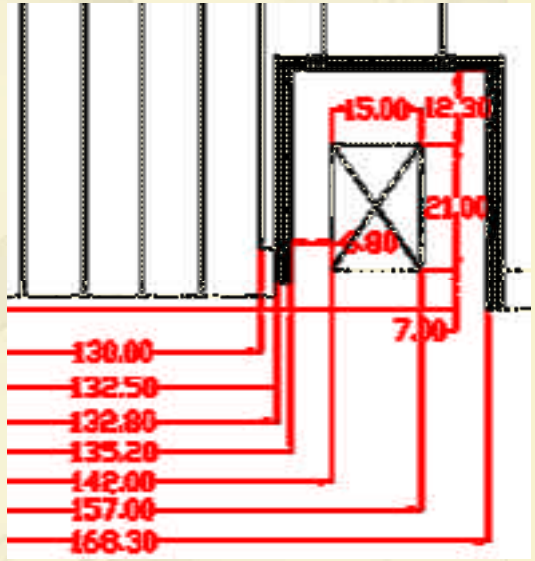
Parameters	Values
Particles	H_2^+, $^{12}C^{6+}$
Injection energy	25 AKeV
Extraction Energy	$^{12}C^{6+}$ @ 300 AMeV p @ 260 AMeV
K bending	1200 MeV
Number of sectors	4
Extraction radius	130 cm
Hill gap	50 mm
Main size	5 m x 3 m
Weight	350 tons
Coils	A pair of SC
Nominal current	950 amp
Current density	45 amp/mm^2
Number of cavities	4
RF cav. frequency	98 MHz, 4th harmonic
RF power	50 kW per cavity
Extraction Systems	Electrostatic deflectors in the hills Stripping process

Coils parameters

Coil Parameters	
Size	150x210 mm^2
Current density	45 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)	1.42 Mamp
Max Magnetic field	4.4 tesla
Axial Force	-9.09 MN
Average Hoop Stress (peak)	156 (284) MPa

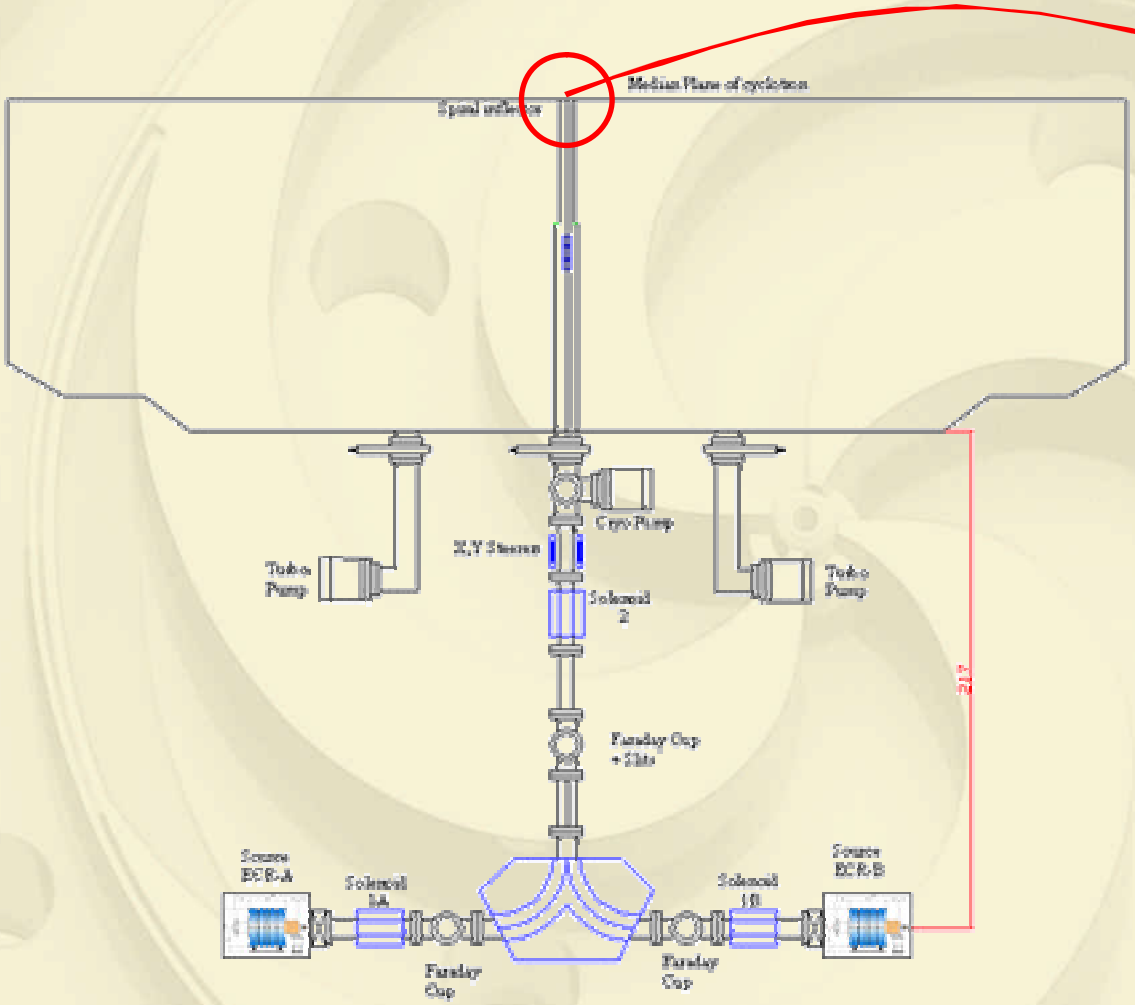


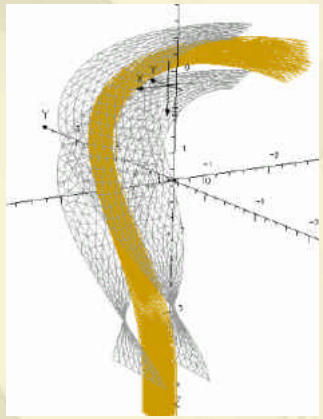




Conservative Design

Injection System





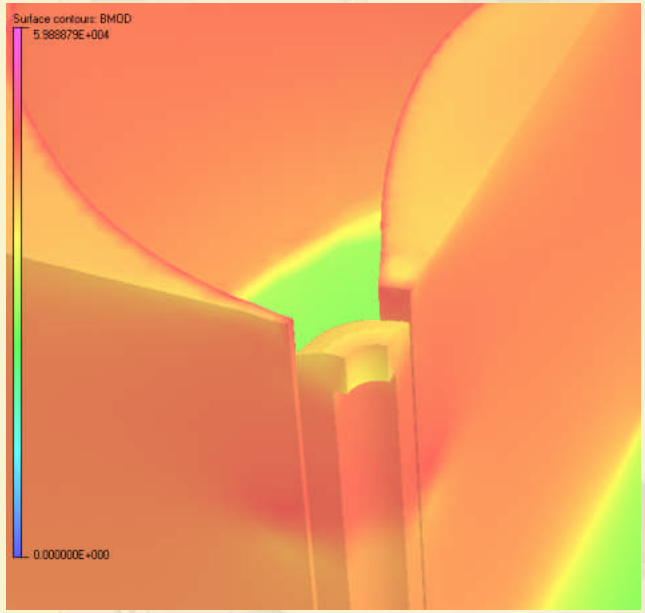
$E_{inj} = 25$ AKeV

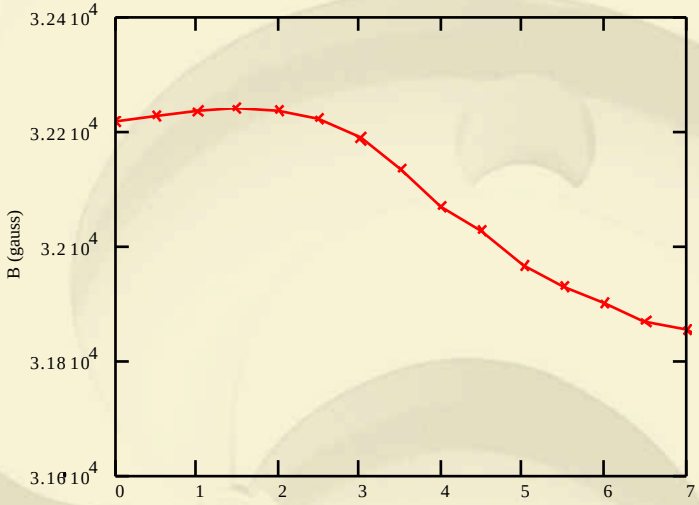
$DV_{inflect} = 14$ KV

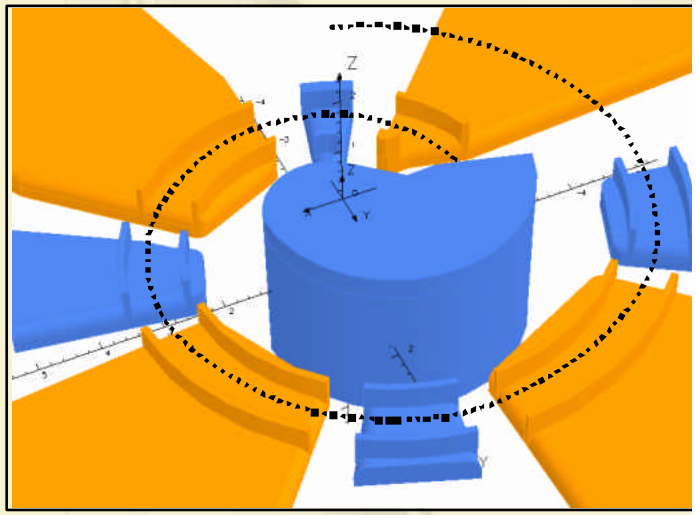
$gap_{inflect} = 6$ mm

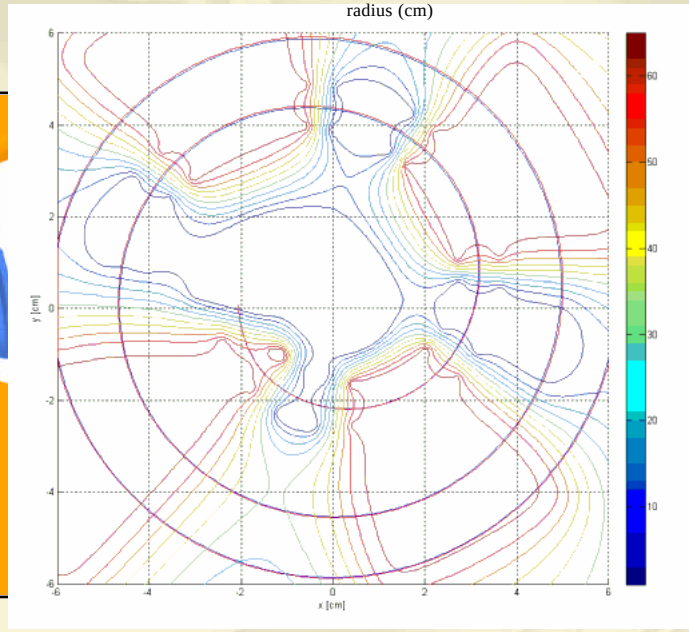
$E_{inflect} = 23$KV/cm

Central region design









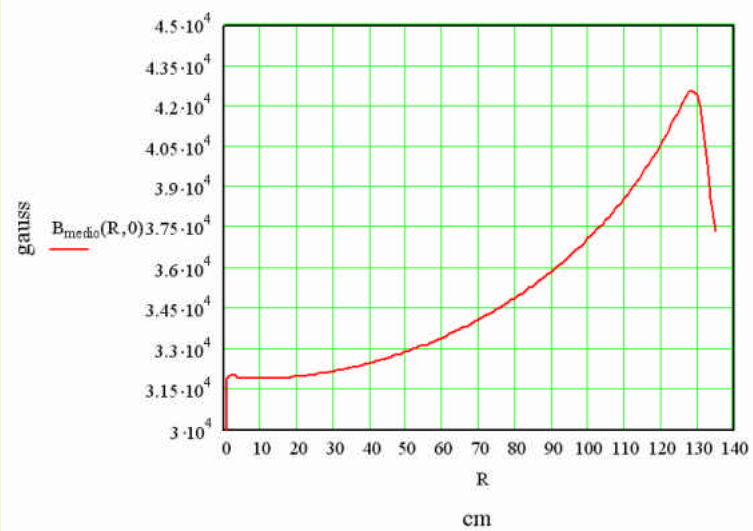
E_{inj} = 25 AKeV

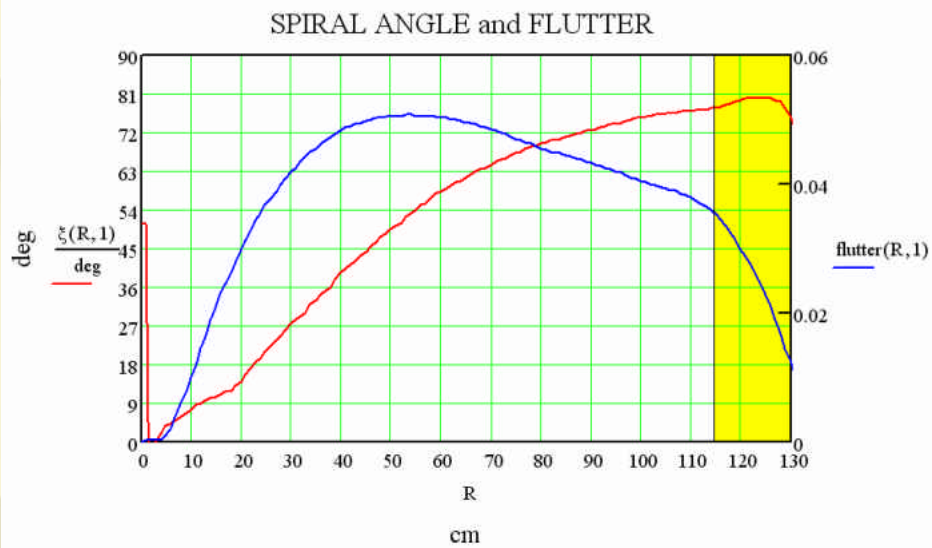
B_o = 3.18 tesla

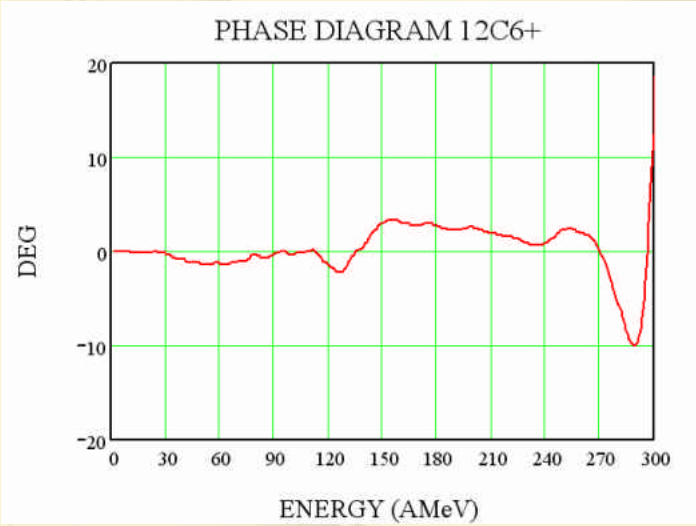
V_{dee} = 70 KV

E_{gap} = 100 KV/cm

Magnetic properties





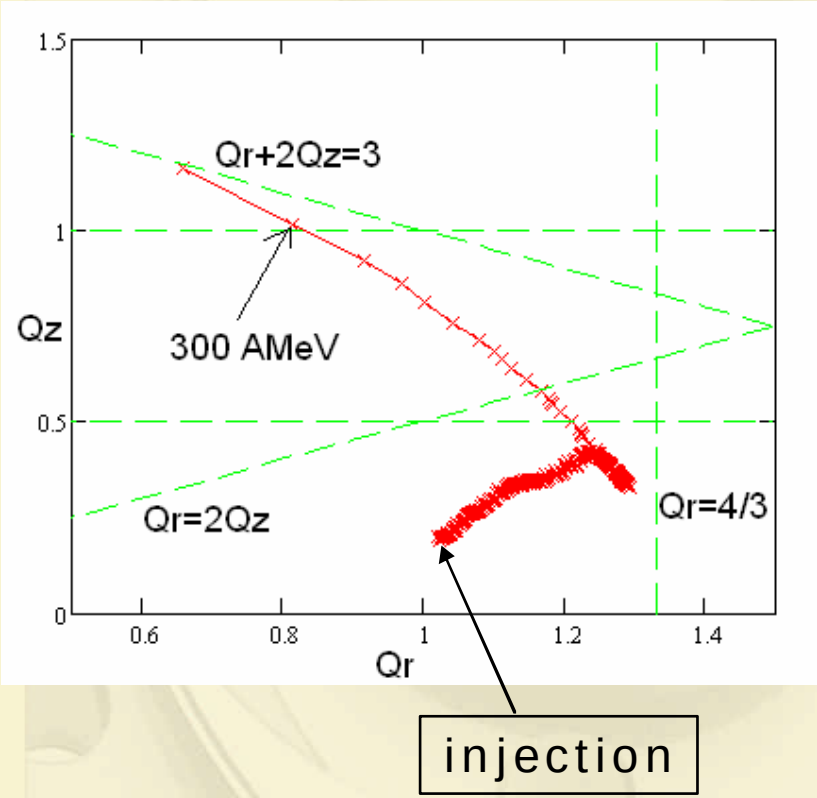


Working in 4th harmonic

Very accurate Isochronism

Resonance's troubles

Working diagram (Carbon ion)



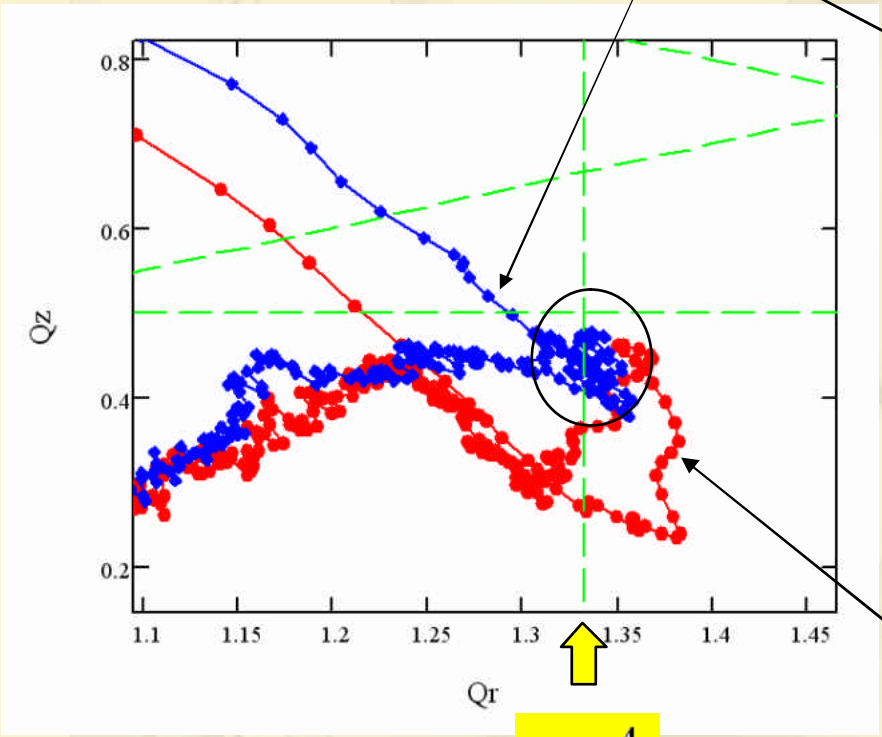
The preliminary magnetic model did not show any crossing of dangerous resonances.

But the need to get an accurate isochronous field to optimize the beam dynamic produced troubles...

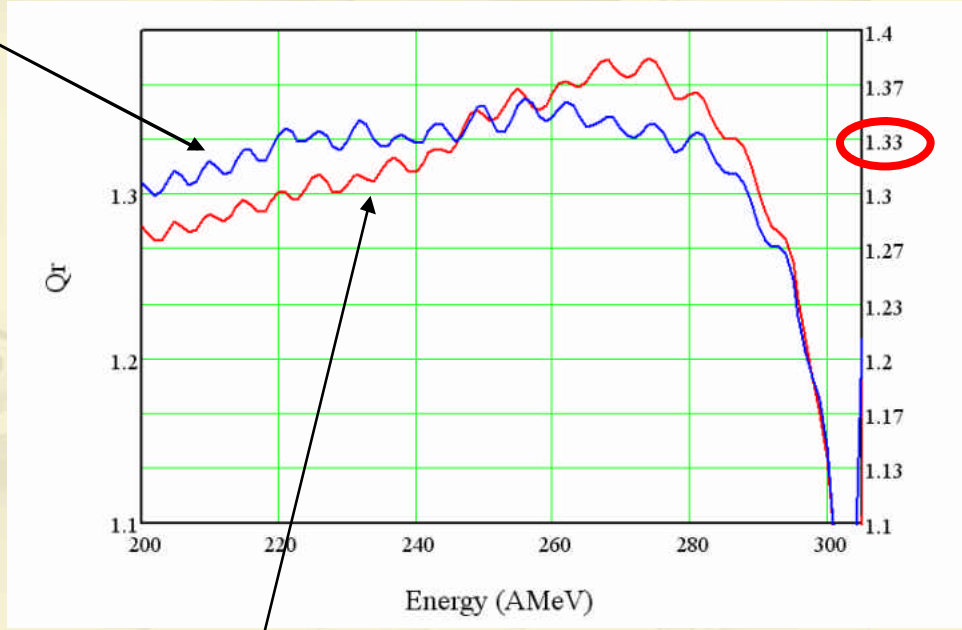
Resonances crossing

Refined Model

Many turns around the dangerous resonance

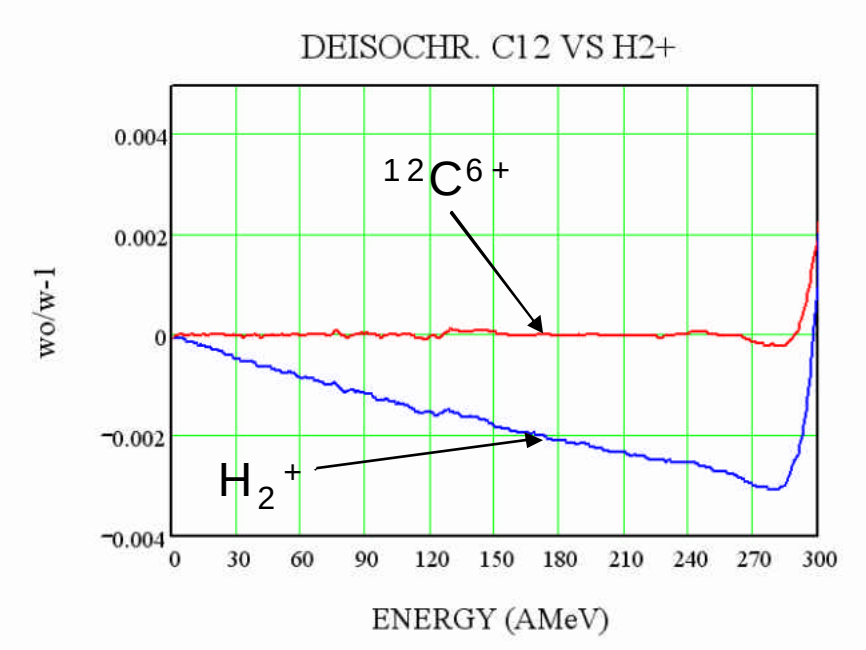


$$Qr = \frac{4}{3}$$



The goal was to optimize the magnetic field to cross the resonance in few turns

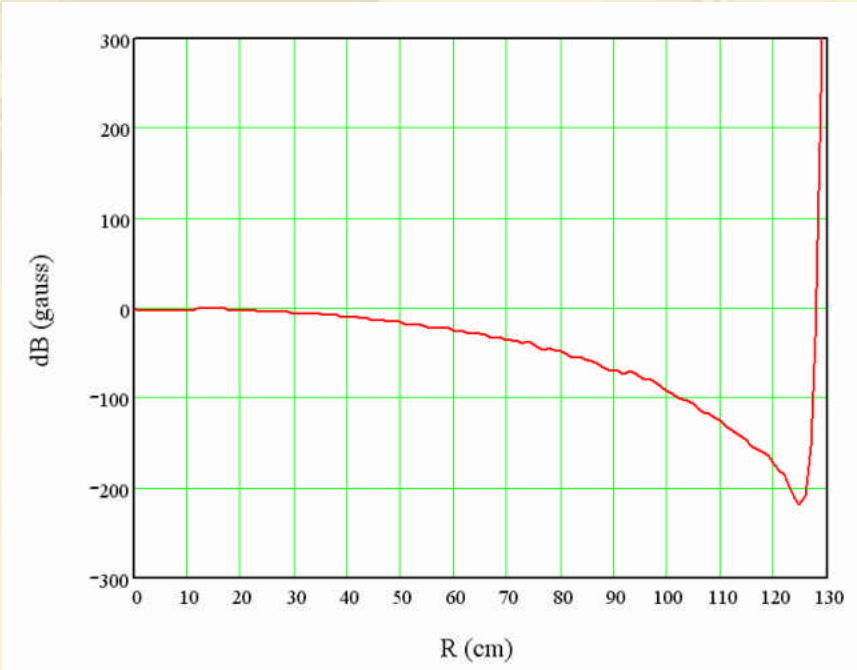
Carbon to H_2^+ switch



$^{12}C^{6+}$ H_2^+

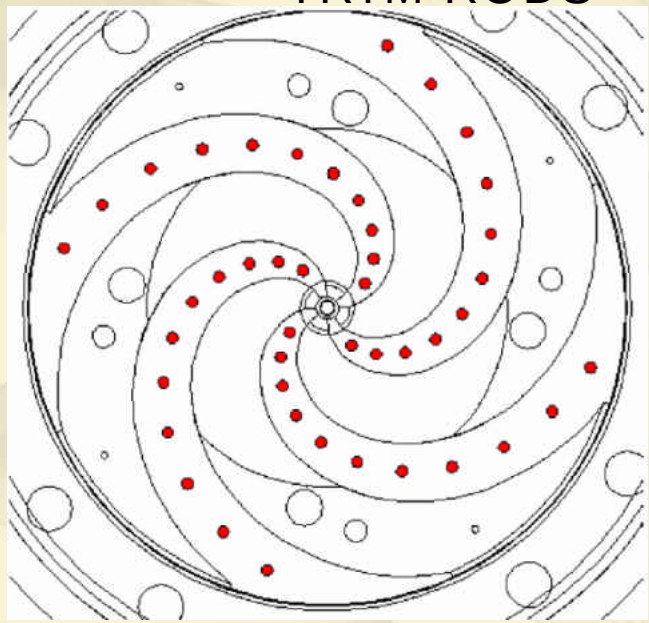
$$\frac{Q}{A} = 0.5 \quad \Rightarrow \quad \frac{Q}{A} = 0.4965$$

It need to change the magnetic field

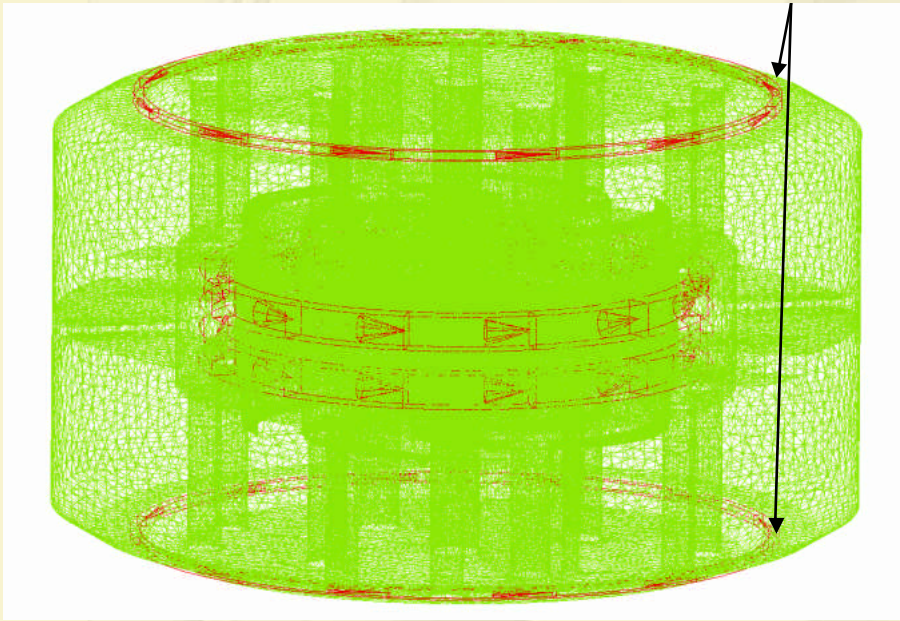


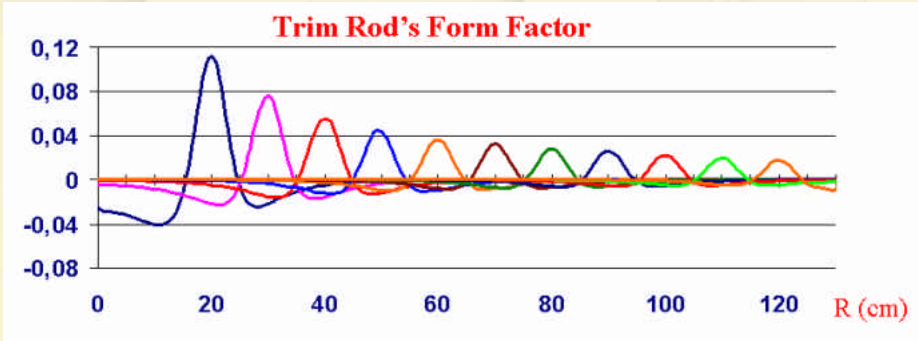
Solution proposed

TRIM RODS

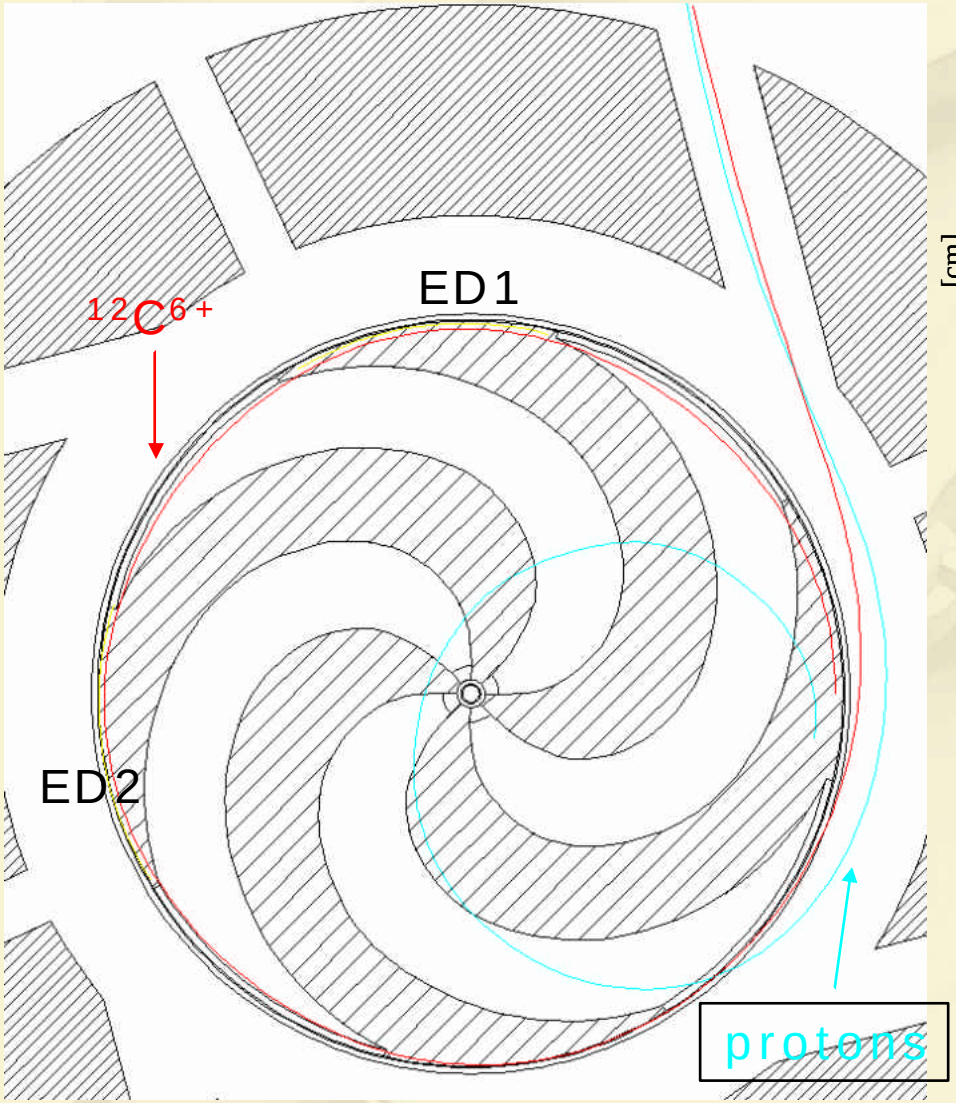


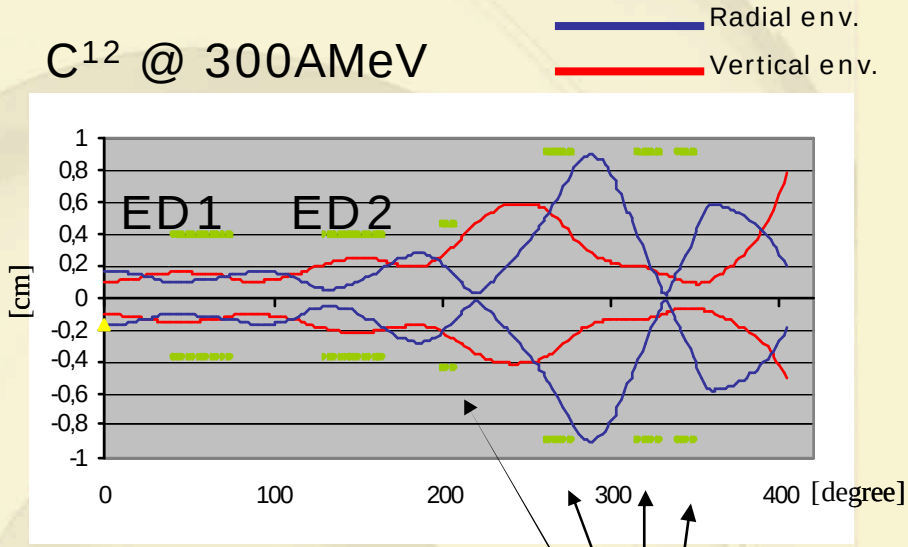
Additional RT coil



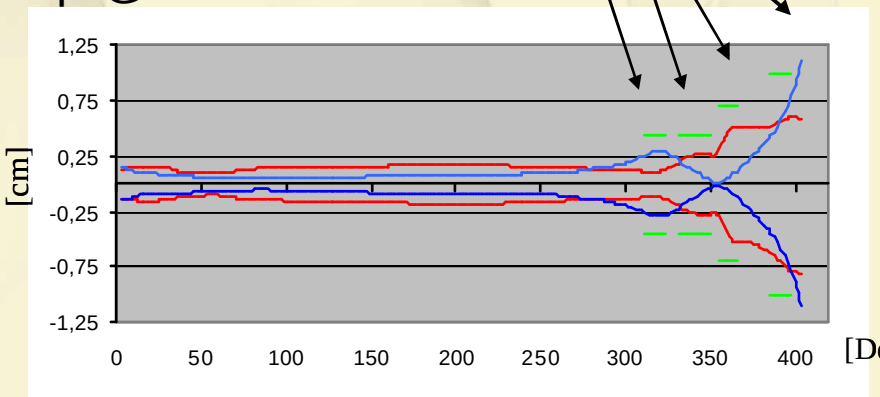


Extraction layout and beam envelopes

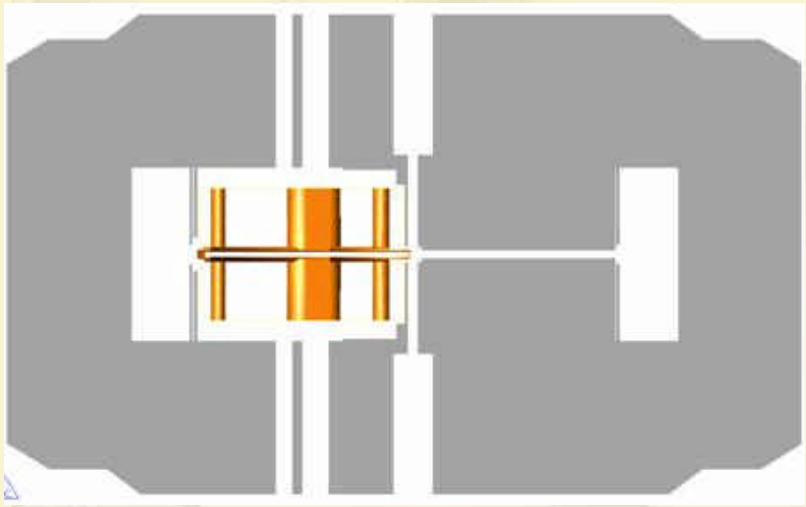


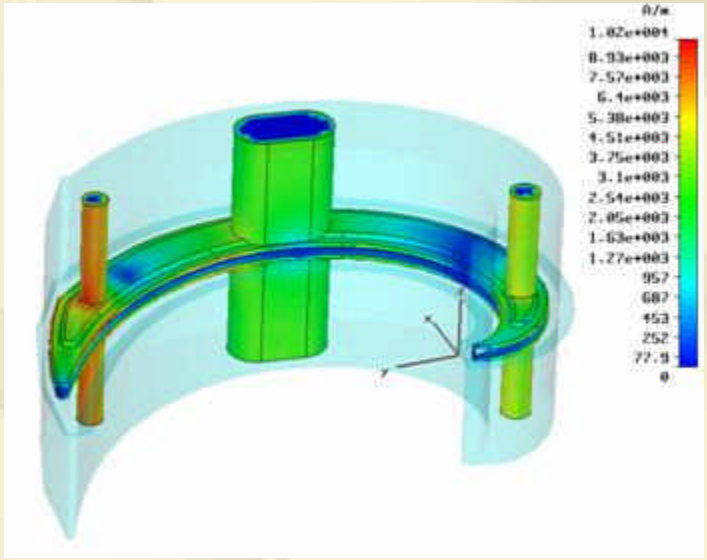


MC



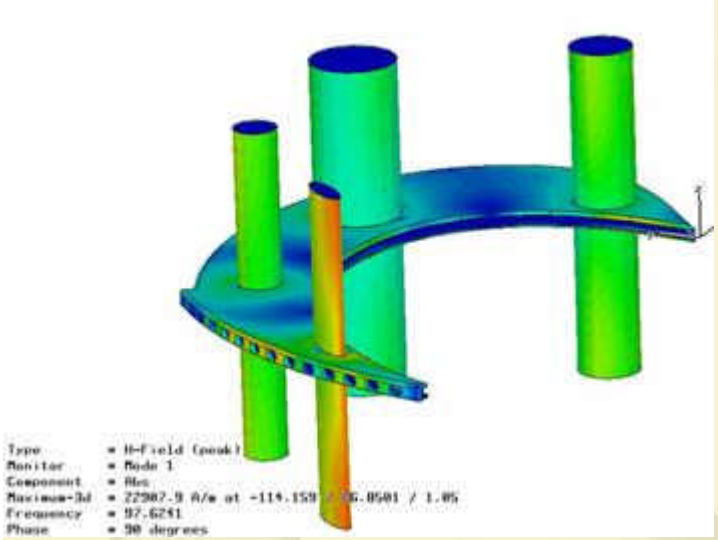
Cavity design

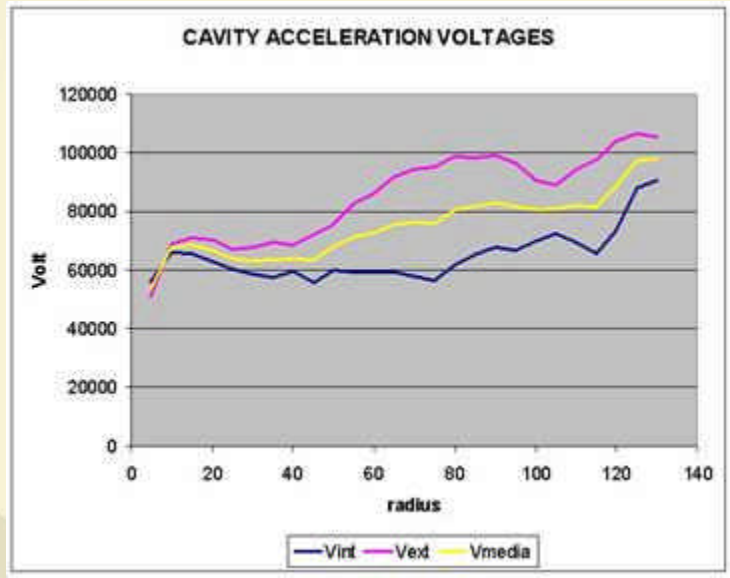




MAIN PARAMETERS	
Number of cavities	4
Frequency	98 MHz
Harmonic number	4
Total height	80 cm
Gap width range	1.5 ¸ 6 cm
Quality factor Q0	9500
Voltage average min & max	70 – 120 KV
Number of stems	3
Max electric field	10 MV/m
RF Power	50 kW/cavity
Coupling system	Inductive loop

Deflectors in the valleys ?





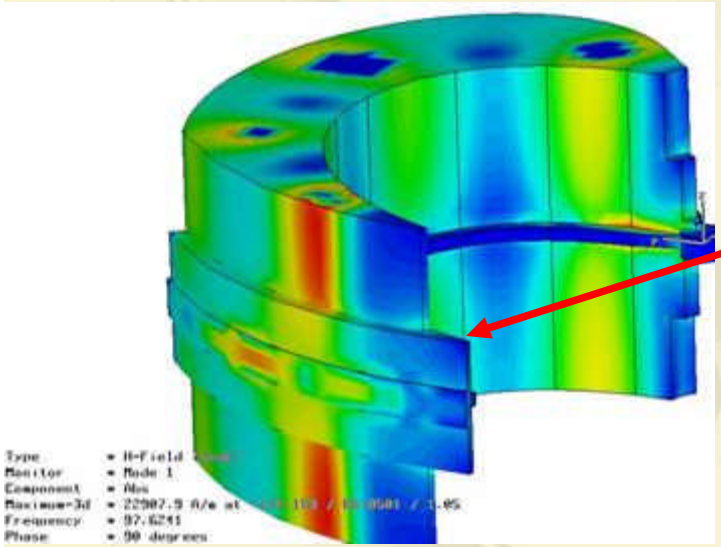
N_{stem} = 4

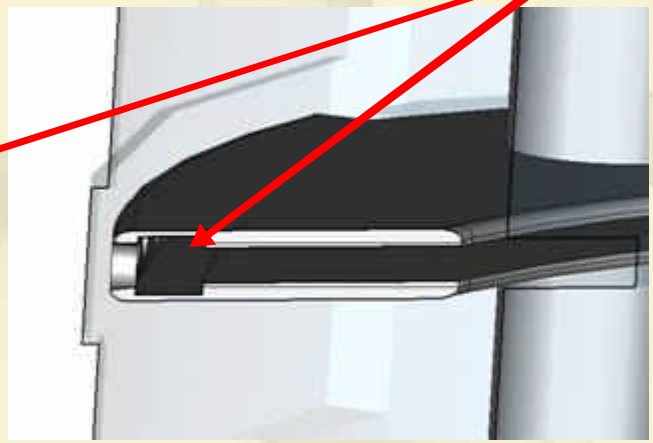
Height = 84 cm

Length = 230 cm

Width = 43°

Deflector housing and an azimuthally wider valley produce a strong increase of Dee's capacitance





f_o = 97.65 MHz

Q = 9200

$\langle V \rangle_{max}$ = 100KV

R_{sh} = 42.55 K•

P_{loss} = 68 kW/cav

Iron Yoke subdivision

ELEMENT	*WEIGHT*
Upper pole caps	92 tons
Lower pole caps	20 tons
ring	62 tons
Total weight of the half yoke	**174 tons**

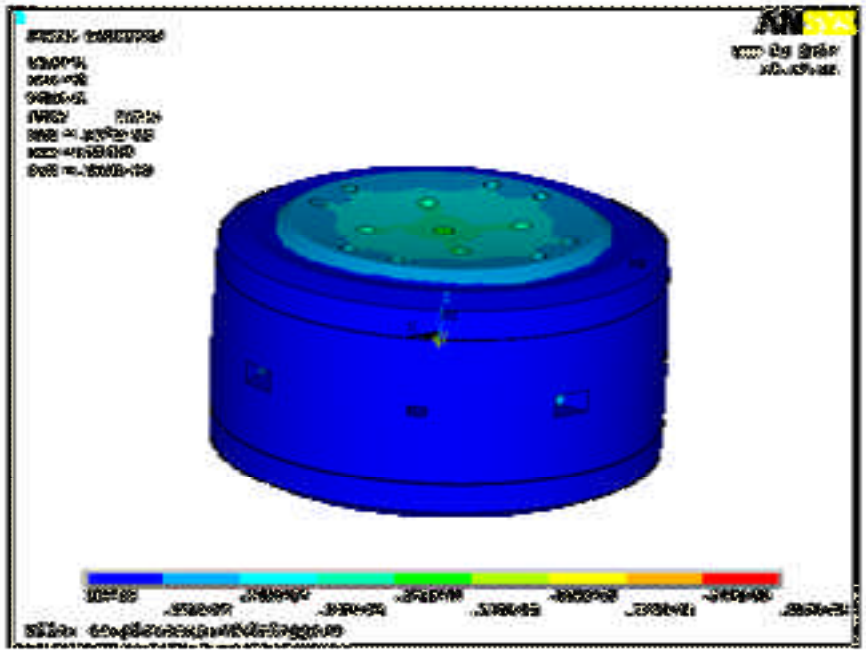
Stress Analysis

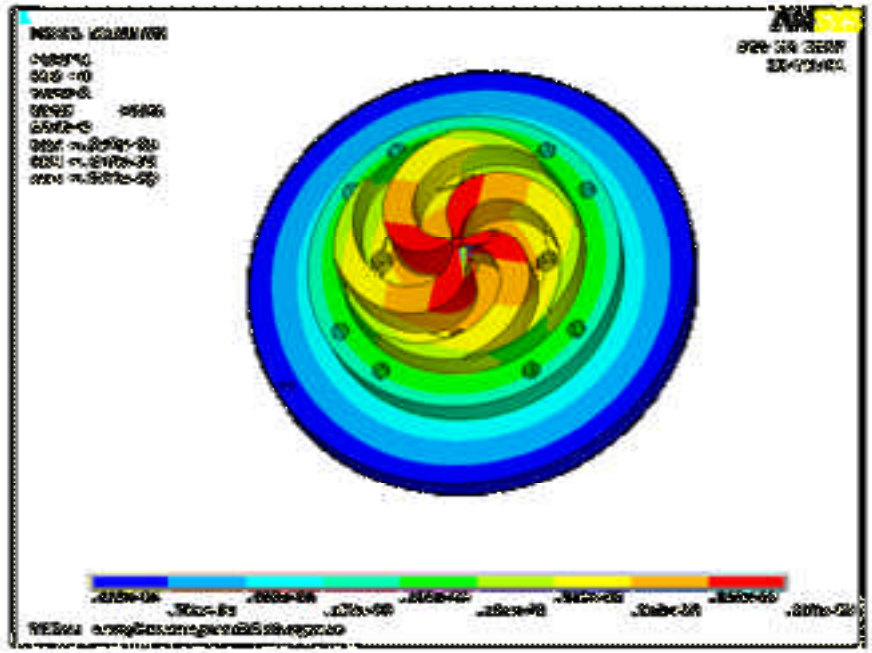
Applied Load= 3000 tons

Max Mech. Stress = 3,8 kg/mm^2

(yield strength= 19 kg/mm^2)

Max Displacement = 0,298 mm





Summary

The studies done so far show that the energy range of 300 AMeV for Carbon ions, can be achieved keeping the main structural parameters of the SCENT machine and the feasibility study is almost completed.

We demonstrated that single turn extraction is possible by stripping the proton beams at the energy of 260 MeV.

Despite the high magnetic field and the low injection energy, the central region was designed to work @ 70KV with four DEEs.

The tuning of the magnetic field (CARBON to H_2^+ switch) is still under study, even if we are confident on the proposed solution.


GRAZIE!