DRAGON

A New 18 GHz RT ECRIS With A Large Plasma Chamber

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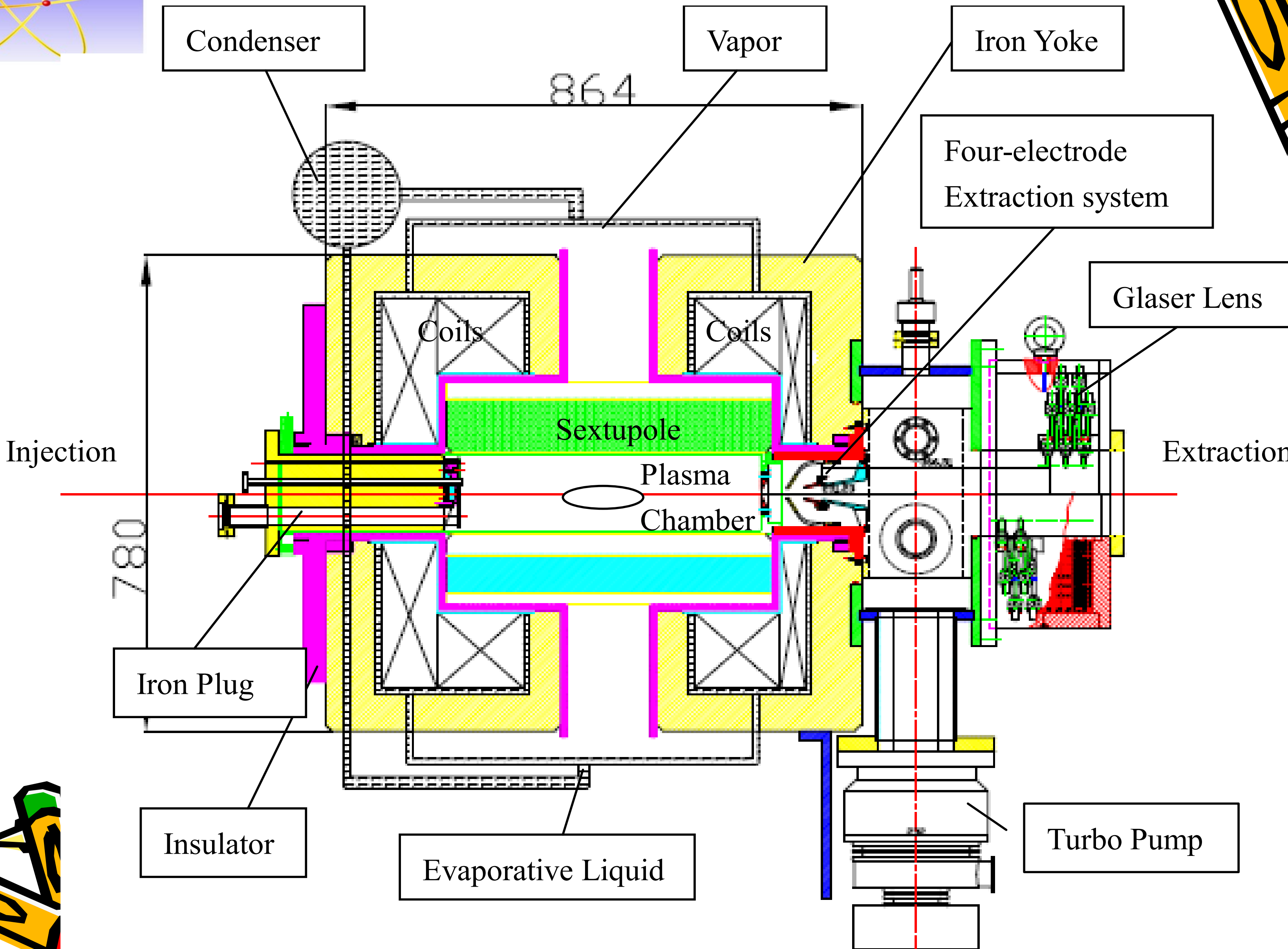
DRAGON


Condenser
Vapor
Iron Yoke
864
Four-electrode
Extraction system
Glaser Lens
Coils
Coils
Sextupole
Plasma
Chamber
Injection
Extraction
780
Iron Plug
Insulator
Evaporative Liquid
Turbo Pump

What's New With DRAGON?

- The First High Field RT ECRIS (2.7/1.3/1.4 T) with A Large Plasma Chamber ID of more than 100 mm

  (ID: 126 mm/ 6 L)

- Evaporative Medium Cooled Solenoids

  (Coil Current Density up to 13 A/mm^2 and

  Magnet Total Power:~400 kW)

- Thickly Insulated and Using a Four-Electrode Mechanism for Routine 50 kV Extraction and up to 100 kV Could be explored

Main Parameters of DRAGON, GTS and SECRAL operating at 18 GHz

	DRAGON	GTS	SECRAL
Operating Frequency (GHz)	14. - 18	14 - 18	18
Resonance Length (mm)	14 GHz: 120 18 GHz: 135	14 GHz: 95 18 GHz: 145	105
Plasma Chamber (mm)	L: 480 ϕ: 126	L: 300 ϕ: 80	L: 420 ϕ: 126
Max. Axial Injection field (T)	2.7	2.5	2.5
Max. Chamber Radial field (T)	1.5	1.2	1.4

More Details in Poster: MOPOT11

DESIGN STUDY OF A HIGHER-MAGNETIC-FIELD SC ECRIS AT IMP

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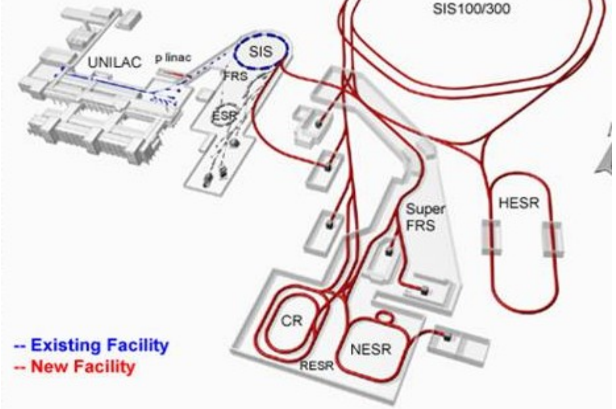
Outlines

- Introduction
- Brief Review SC ECRIS Magnet Structures
- Design of A Higher-Field SC ECRIS
- Discussions

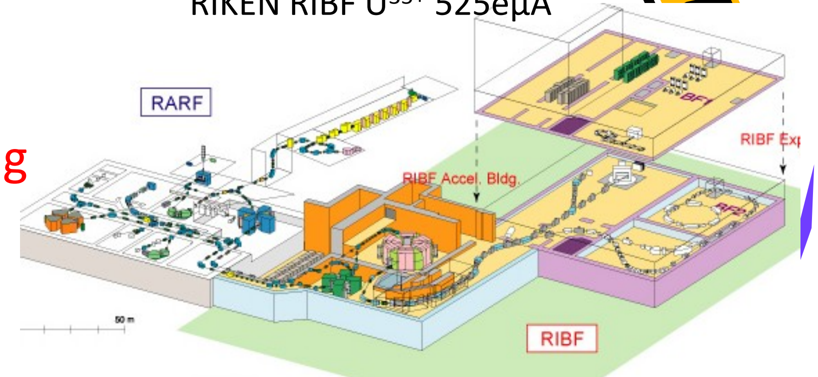
High Power Heavy Ion Accelerator is driving force for Intense Multiply-Charged Ion beams

FAIR U^{28+} 1emA

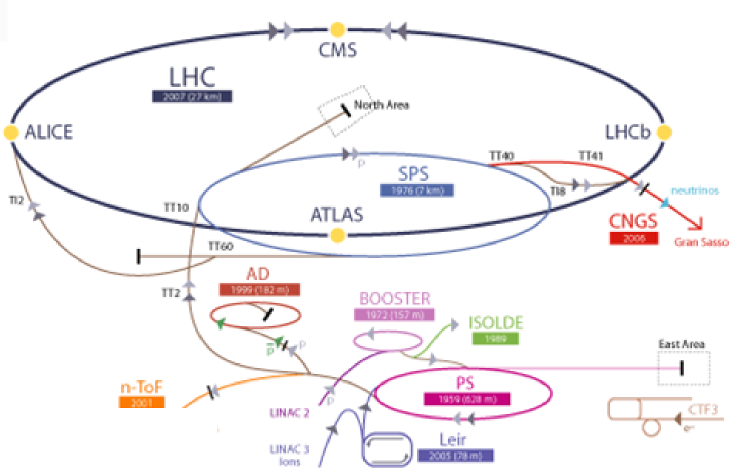


Demands to intense highly charged ion beams are increasing

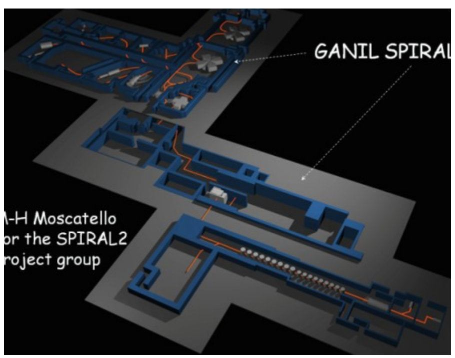
RIKEN RIBF U^{35+} 525eμA



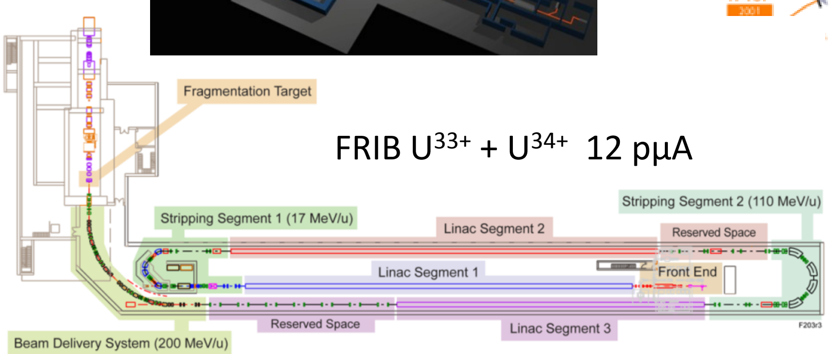
LHC Pb^{27+} 1 emA

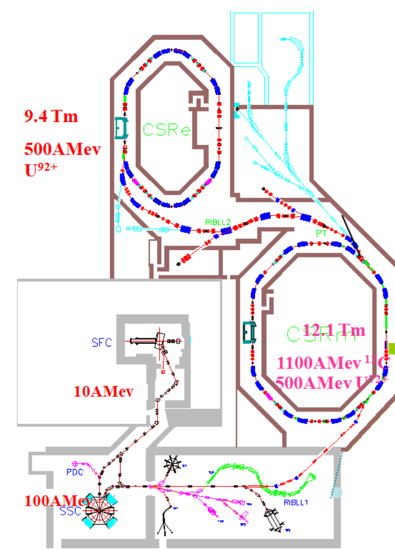


SPIRAL2 Ar^{12+} 1emA



FRIB U^{33+} + U^{34+} 12 pμA



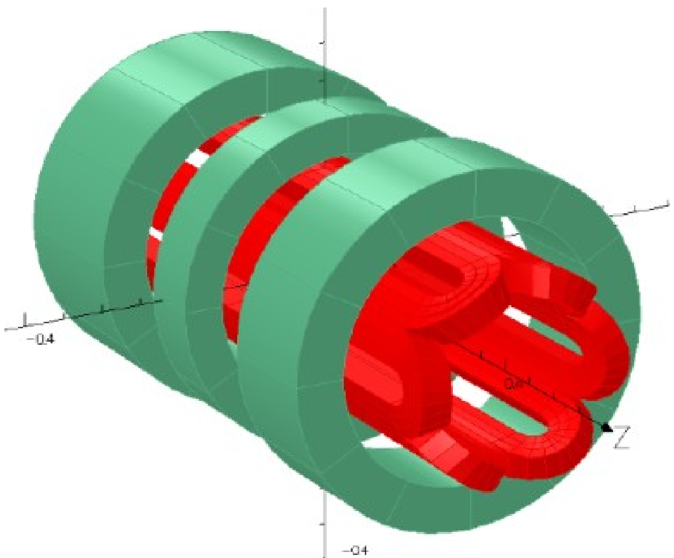


IMP New Facility Bi^{31+} 20-25 pμA

Recent ECRIS Progress

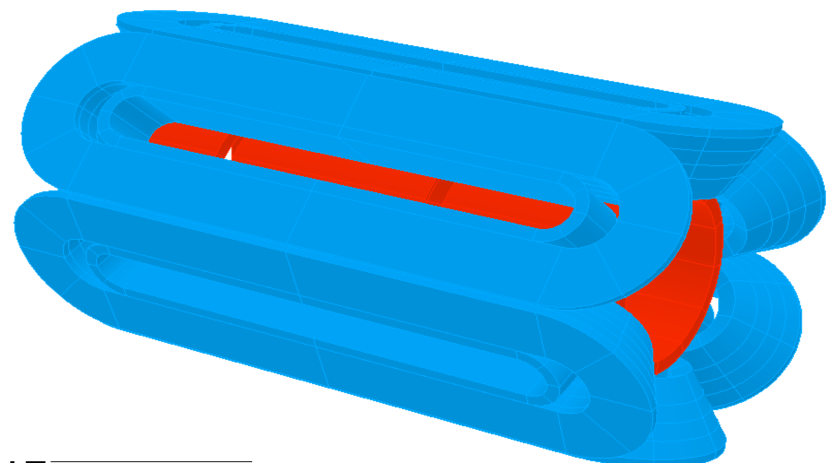
- The few SC ECRISs built with NbTi magnets have produced very great performances
- So far, the highest field strength reached 4 T on axis and 2 T at the plasma chamber wall for operating frequency up to 28 GHz.
- Higher-field and higher operating frequency, the relatively easy and straightforward way to further the development of ECRIS.
- Maximum field strengths to reach 8 T on axis and 4 T at the plasma chamber are proposed for new higher-field ECRIS using Nb_3Sn wires to construct the SC magnets

Existing SC ECRIS Magnet Structures



Sextupole-inside-solenoid

Classical



Solenoid-inside-sextupole

Non-Classical

- Compatible Performance
- Bulkier Magnet Size and Cryostat
- Higher Wave Power and Fields

- Compatible Performance
- Smaller Magnet Size and Cryostat
- Relatively Wave Power and Cost effective

Performance of the Classical and Non-Classical Magnet Structures

VENUS

SECRAL

A Few Example Beams from SECRAL and VENUS

	Q	SECRAL *18 GHz* *<3.2 kW* *μA*	SECRAL 24GHz *3-4 kW* *μA*	VENUS *28 GHz* *5-9kW* *μA*
16O	6+	2300		2860
	7+	810		850
40Ar	12+	510	650	860
	16+	73	149	270
	17+	8.5	14	36
129Xe	27+	306	455	270
	35+	16	45	28
	42+	1.5	3	0.5
209Bi	30+	191		240
	41+	22		15
	50+	1.5		0.5

Does the ECR plasma care about the Minimum-B Field is constructed from Classical or Non-Classical Structure?

The Answer: No!

So long as the magnetic field strengths are high enough!

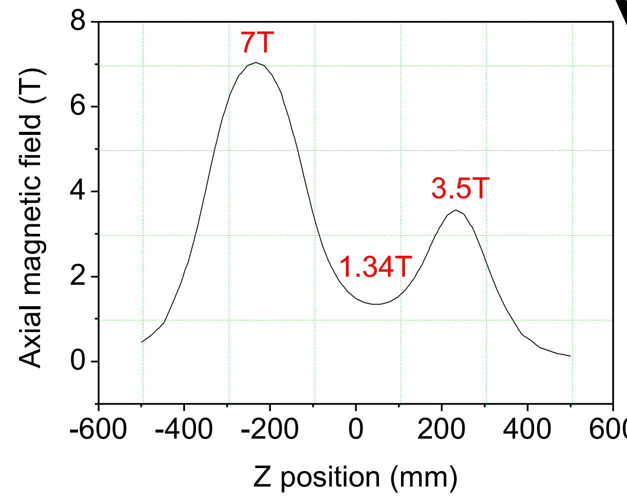
The New SC ECRIS Under Study

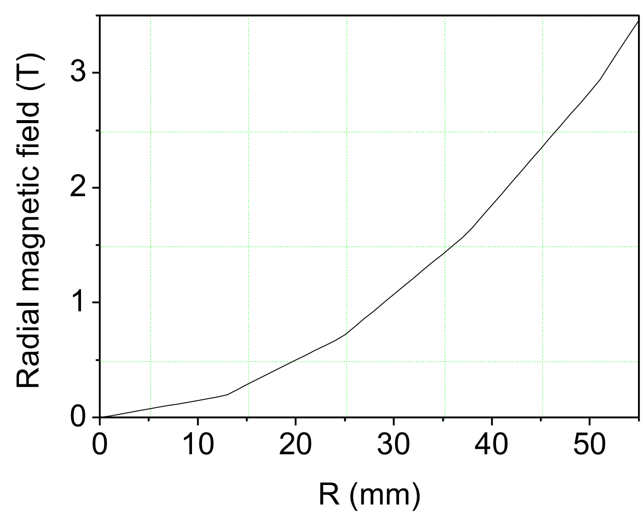
(Pretty Much A Scaled-Up Version of SECRAL)

A Few Key Parameters and Comparison

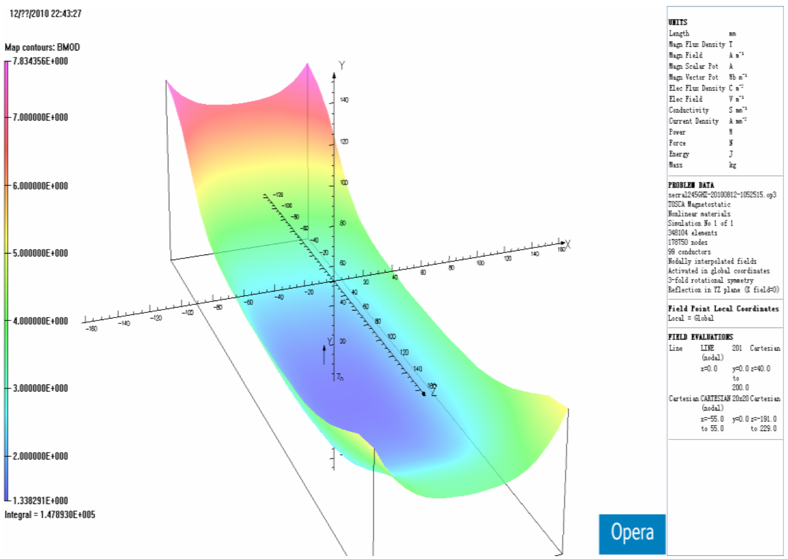
	New ECRIS <50 GHz	SECRAL 24 GHz
Superconducting Wire	Nb_3Sn*	NbTi (F54)
Critical Jc	400 A /14 T	197 A /9 T
Sextupole Coil (A/T)	1,167,000	627,000
Injection Coil (A/T)	1,540,000	689,000
Middle Coil (A/T)	36,000	162,000
Extraction Coil (A/T)	551,000	272,000
Magnet Length (mm)	822	724
Max. Torque (N/M) (a Racetrack Coil)	69.7 E6	8.9 E6
Magnetic Peak Axial Field (T)	7	3.6
Magnetic Radial Wall Field (T)	3.5	1.8
Plasma Chamber ID/Volume (mm/L)	110/4	126/5

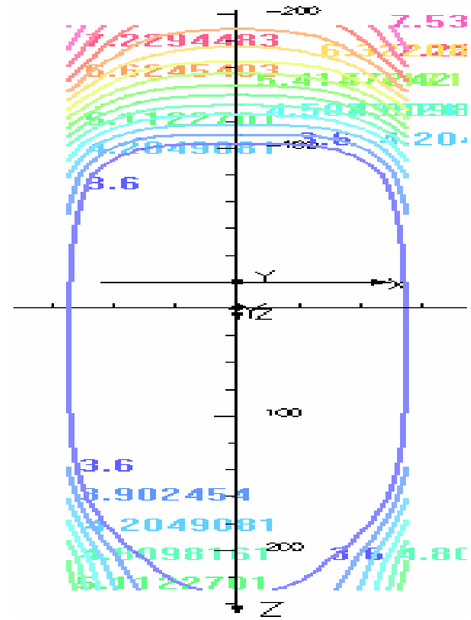
*: BRUKER NST 11000 A23 ϕ1.0 mm Nb_3Sn wire was used in the design and F54 ϕ1.0 mm NbTi wire was used in SECRAL.





How Good Is This Magnetic Configuration?





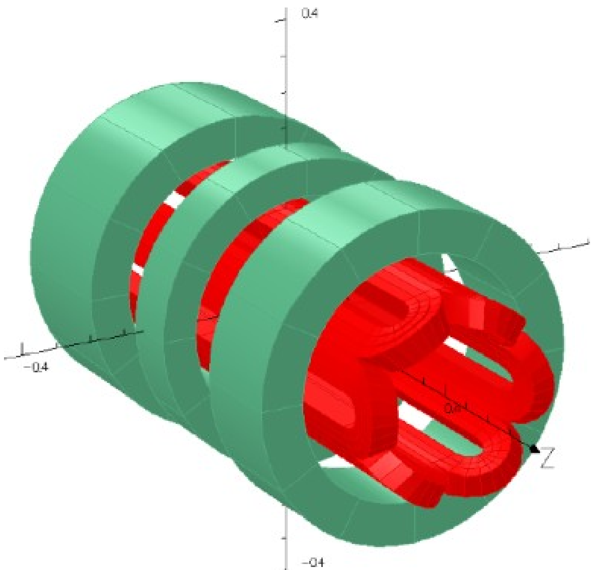
- With peak field of 7 T on axis and of 3.5 T at the plasma chamber wall, It is strong enough to support an operating frequency up to about 50 GHz.

If an ECRIS gets built with this magnetic configuration, it could further significantly enhance the ECRIS' performance.

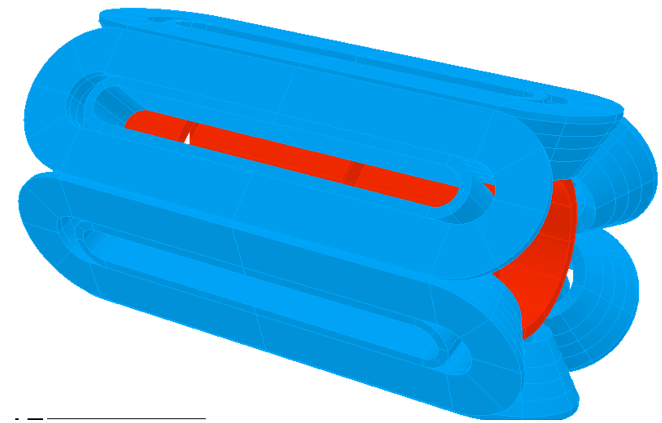
Uncertainties of Nb_3Sn Wire in ECRIS

- The very strong interaction force and its resulting torque. A very strong and possibly very deliberate clamping scheme may be required.
- Will the strong interaction force and the huge torque experienced by the individual sextupole racetrack coil affect the Nb3Sn critical current?
- Pretty poor ductility and it requires a tedious after-coil-winding heat treatment that could lead to a very complex Nb3Sn magnet fabrication process.

Do We Really Have to Use the Nb3Sn Wire for the New SC ECRISs Under Design?



Sextupole-inside-solenoid



Solenoid-inside-sextupole

Is There Any New NbTi Magnet Structure Could further Increase the Magnetic Fields?

There May Be A New NbTi Magnet Structure That Could Increase the Magnetic Field Strength

- Preliminary result of the investigation is very encouraging and promising.

- *A novel NbTi magnet structure may be able to produce a minimum-B filed of maximum strengths of 6-6.5 T on axis and 3.5-4 T at the plasma chamber wall of IDs of 160-180 mm.*

- Somewhat higher radial field could also be possible at the price of more deliberate designs.

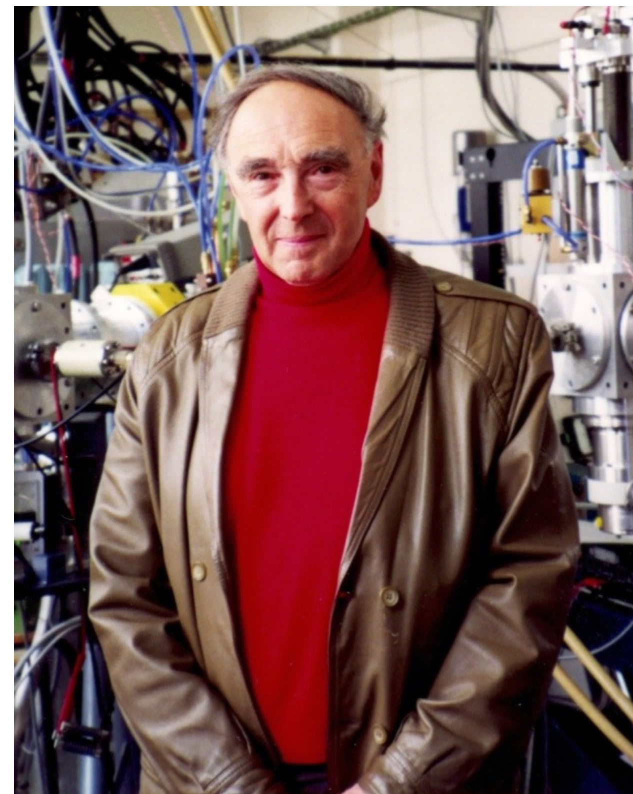
We are still under "ECRIS father" Dr. Geller's guideline established more than 30 years ago!

"... we propose a bolder extrapolation.
...**With a 56 GHz generator, TRIPLEMAFIOS should furnish up to U^{50+} ions**!"

Richard Geller, IEEE-Trans NS-23, 1976

"New microwave power generators (called gyrotrons) in the range up to 120 GHz will be commercially launched in the next five years. Combined with superconducting stripping stages they will enable the production of completely stripped heavy ion beams for cyclotron injection."

Richard Geller, IEEE Trans NS-26, 1979



Slide Courtesy of C. Lyneis of LBNL

How Far Away From A 120 GHz ECRIS?

- If it can be fabricated with the Nb3Sn wires, the maximum fields could reach at least 10 T on axis and 5.5-6 T at the plasma chamber wall of 160 - 200 mm.
- With maximum fields of 10 T on axis and 6 T at plasma chamber wall, a 70 – 80 GHz ECRIS could then be realized, more than half way to a 120 GHz ECRIS.
- Unfortunately, much more calculations and analyses needed to finalize this novel magnet structure.

Stay Tuned! Hopefully a sound magnetic field calculation and profile design can be reported soon.

Any Other Techniques To Further The ECRISs?

- Higher magnetic field and operating frequency has greatly enhanced the ECRIS performance but comes costly and will run up to the limit of the present superconducting magnet technology in the foreseeable future.

- *To further ECRIS, we should also spend more efforts to investigate other techniques, such as lower frequency heating with a much higher-B mode configuration and microwave heating efficiency, etc.*

Acknowledgement

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Thank you for your attention !