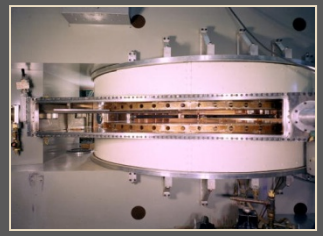
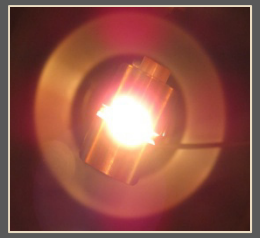
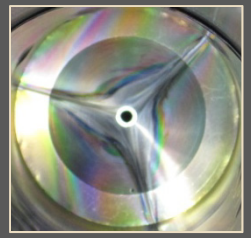
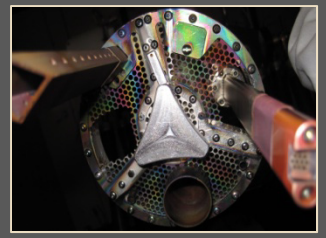
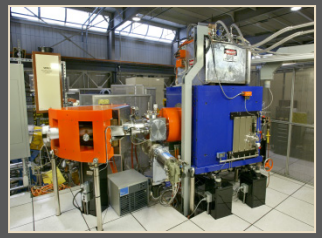
CURRENT DEVELOPMENTS OF THE VENUS ION SOURCE IN RESEARCH AND OPERATIONS

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Sep 27, 2012

ECRIS 2012

Outline

I. Quick overview of VENUS

II. Sputter probe test results

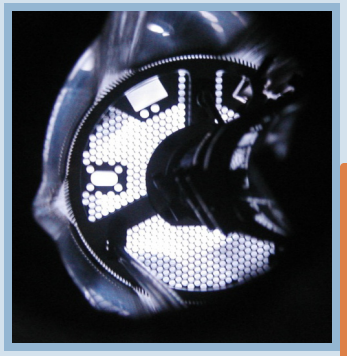
III. LoT Oven:

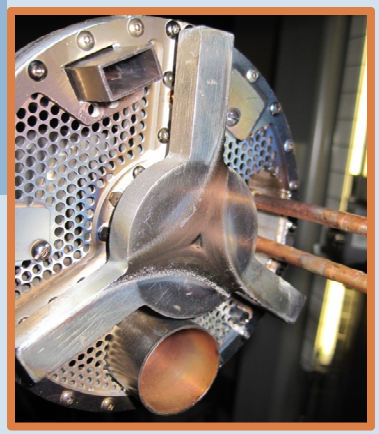
   I. Bi^{56+} for cocktails

   II. Liner test & Calcium consumption

IV. High Voltage Upgrade & Helium Results

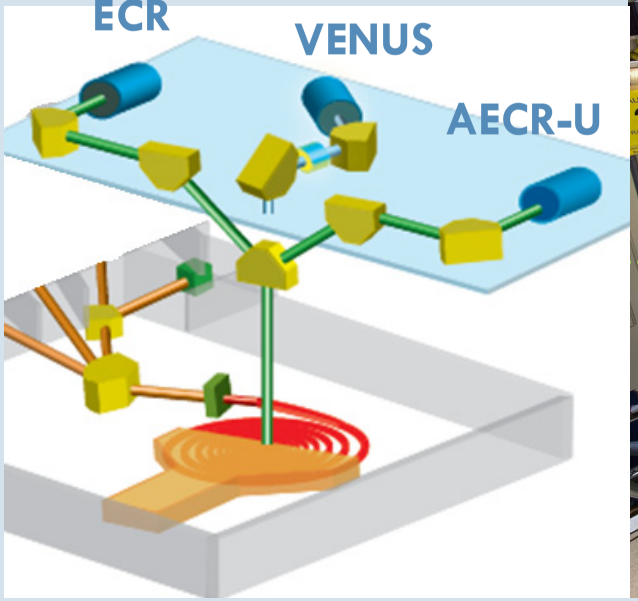
V. Plasma chamber

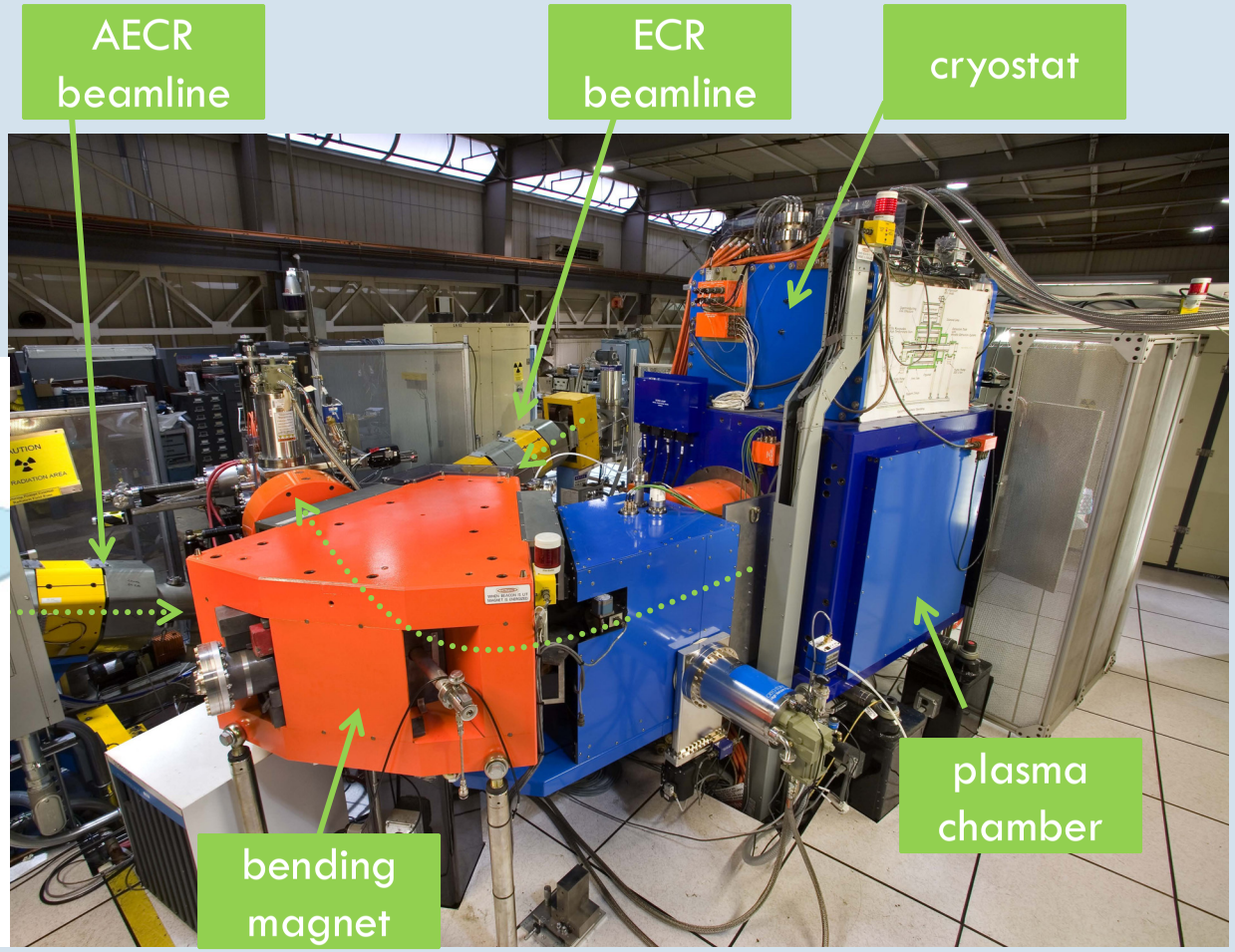




VENUS Layout on Vault Roof

VENUS Mission:
1. Prototype for FRIB
2. Research tool
3. Injector for the 88" cyclotron

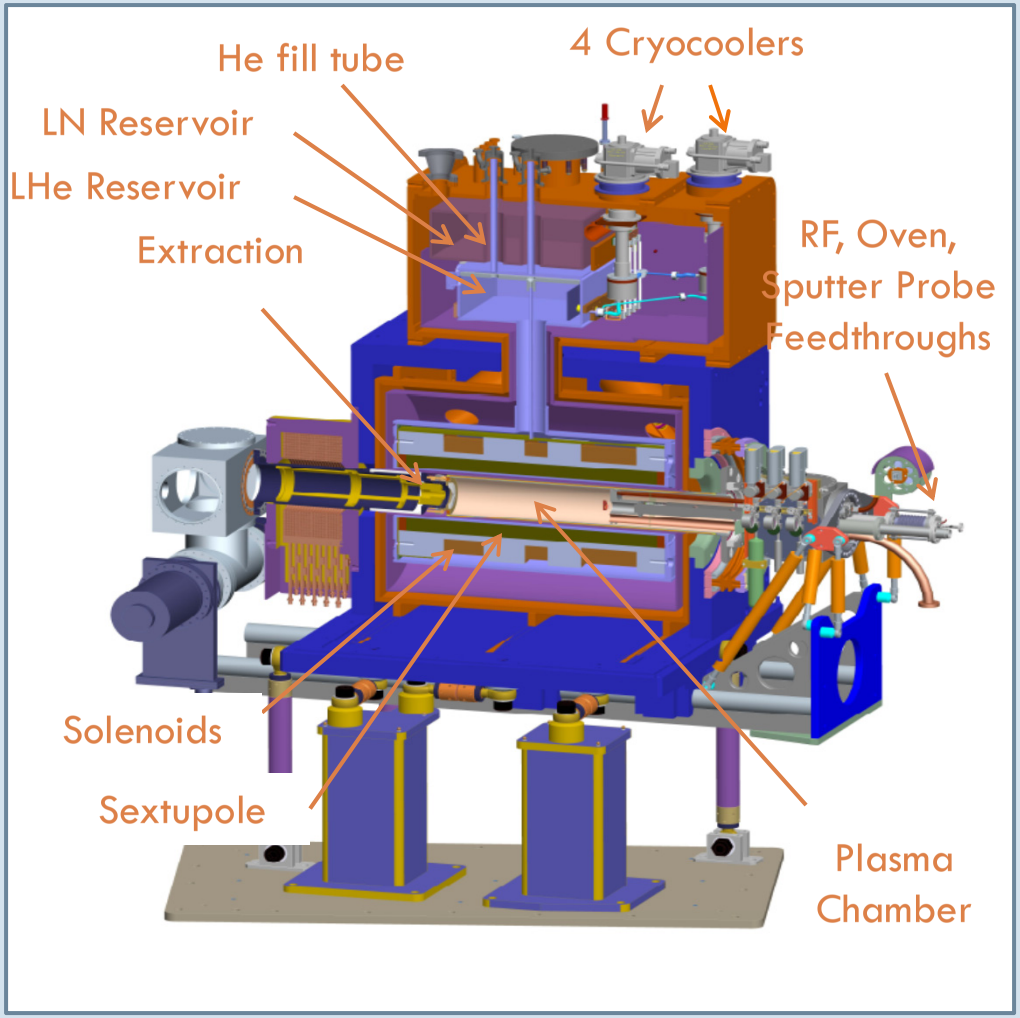




Overview of VENUS

- **Fully superconducting**, Niobium-Titanium sextupole & 3 solenoids enclosed in LHe
- **LN Reservoir** : 70K, dissipates heat from normal conducting leads
- **LHe Reservoir**: 4.2K
- **Four two stage cryocoolers** which provide **6W total cooling power at 4.2K**, recondense evaporated He, 1st stage (45K) cools part of the Cu leads
- **Recently ran 22 months straight**

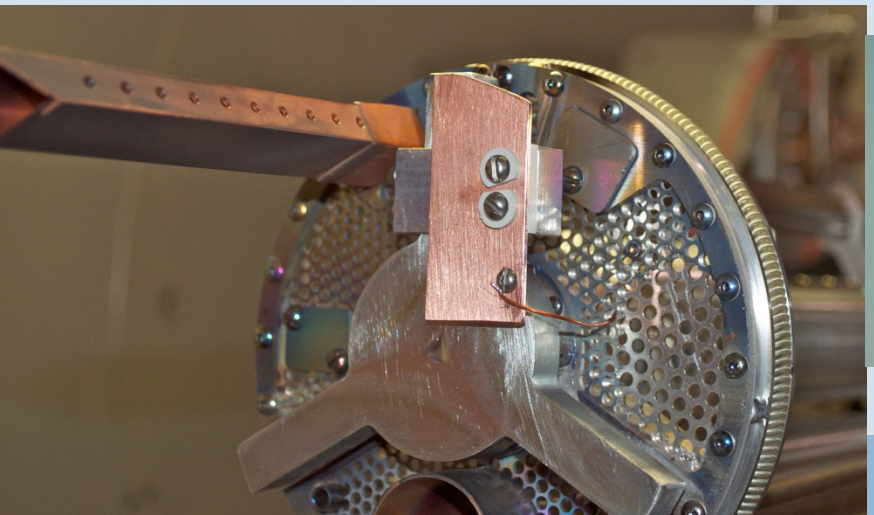
Maximum Injection Field, on axis	4.0T
Maximum Extraction Field, on axis	3.0T
Maximum Radial Field, at wall	2.2T
Chamber Diameter	14cm
Chamber Length	50cm
18 GHz Maximum Power	2kW
28 GHz Maximum Power	10kW
28 GHz Maximum Power Injected	6.5kW
18+28 GHz Maximum Power Injected	8.5kW

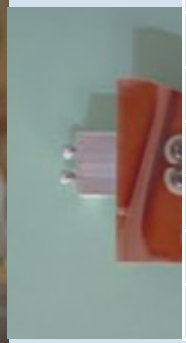


Sputter Probe Development

- For use in cocktails to provide V, Ag, Ta, Cu, and possibly others…
- Cocktail: Mixture of ions of similar M/Q delivered to cyclotron from ECR simultaneously
- Direct ion sputtering technique
- Plasma ions accelerated toward sample impact su
  and sputter material into plasma
- Capability will make VENUS a good backup for A
  cocktails

10MeV/u	M/Q	Production Method	LET (MeV/(mg/cm^2))	RANGE (µm)
$^{11}B^{3+}$	3.67	MIVOC CHAMBER	0.89	305.7
$^{18}O^{5+}$	3.60	GAS	2.19	226.4
$^{22}Ne^{6+}$	3.67	GAS	3.49	174.6
$^{29}Si^{8+}$	3.63	GAS	6.09	141.7
$^{40}Ar^{11+}$	3.64	GAS	9.74	130.1
$^{51}V^{14+}$	3.64	Sputter Probe	14.6	113.4
$^{65}Cu^{18+}$	3.61	Sputter Probe	21.2	108
$^{84}Kr^{24+}$	3.5	GAS	30.2	113.1
$^{89}Y^{25+}$	3.56	Sputter Probe	34.7	102.2
$^{107}Ag^{29+}$	3.69	Sputter Probe	48.2	90.0
$^{124}Xe^{34+}$	3.65	GAS	58.8	90.0

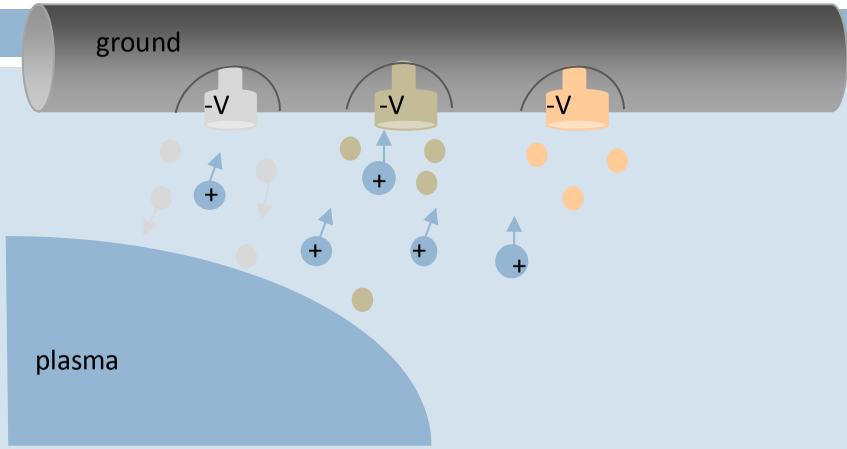


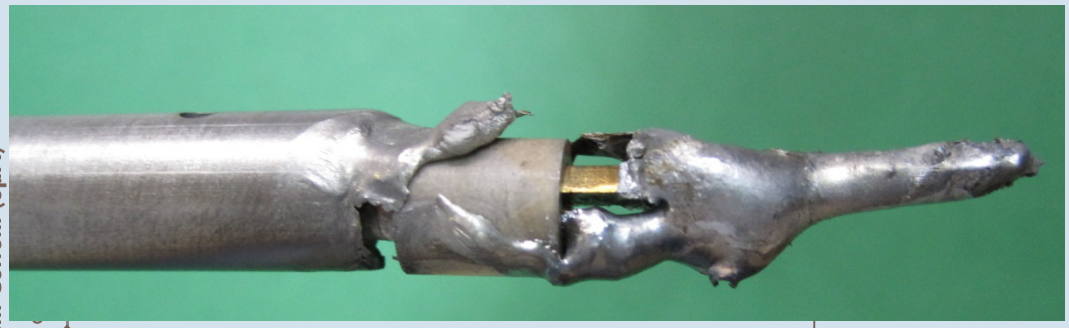


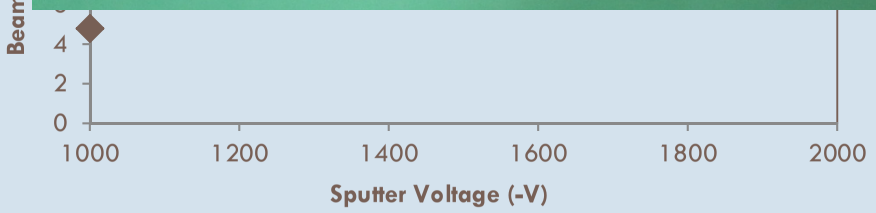
easily removed and unpractical

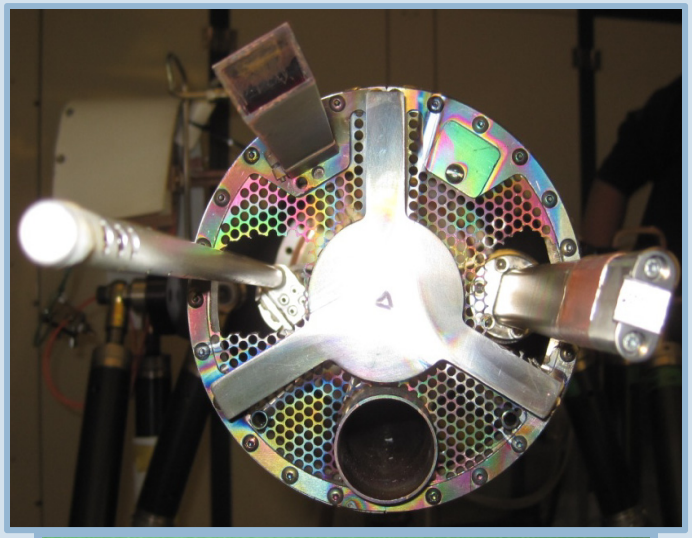
Sputter Probe Development

- Water-cooled support tube, moveable bellows, 3 sample capability
- Initial tests positive
- Soon learned position of probe not ideal: inserted at flute position
- Radial position is 5.6cm, chamber radius is 7.2cm



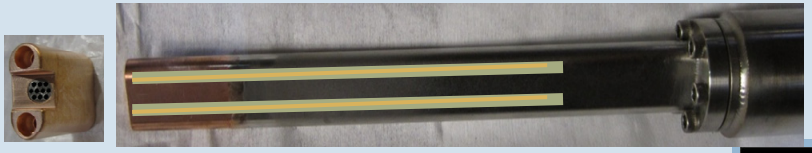


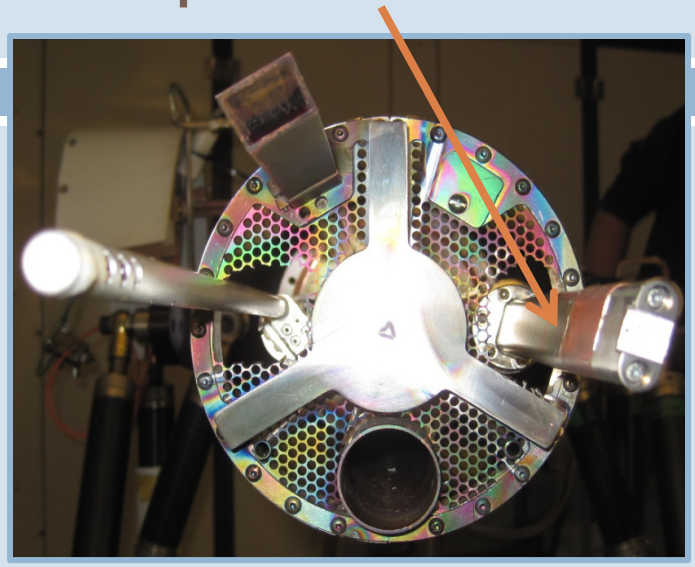


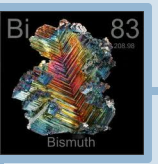


Oven Development: Low Temp

- Completed July, 2011
- Operates up to 650°C to vaporize metals
- Expands VENUS' metal production capability

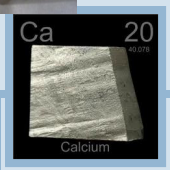






Bismuth Development: 10MeV Cocktail

- Accelerated $^{209}Bi^{56+}$, Bi^{57+}, Bi^{58+} through cyclotron
- At cyclotron extraction had 0.08enA of Bi^{56+}
- Increases maximum Liner Energy Transfer in Silicon by 35% for our 10MeV Cocktail



Calcium Development: High Intensity

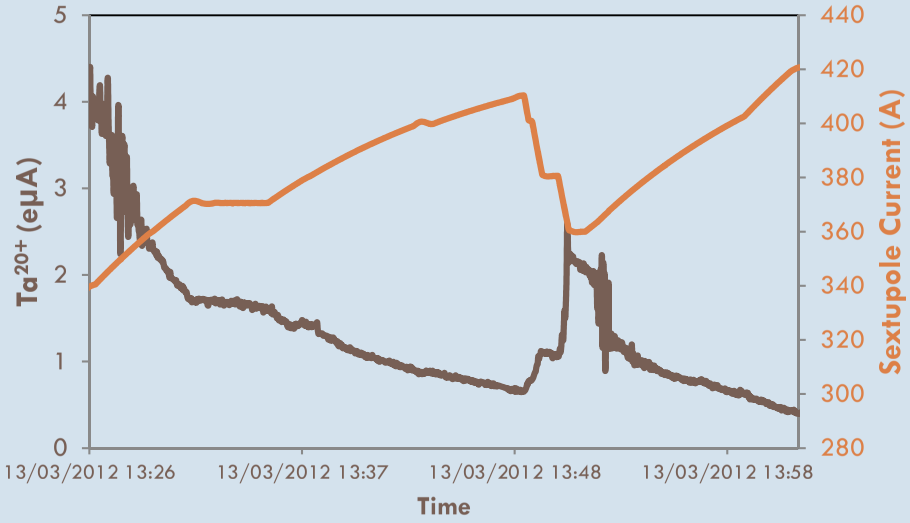
- avg current of 100eμA of $^{40}Ca^{11+}$
- Used 63mg, consumption rate of 0.67mg/hr
- 2% efficiency into $^{40}Ca^{11+}$, ~9% total efficiency
- Good news for high intensity ^{48}Ca runs where 1mg of ^{48}Ca~$250 (63mg~$15,750)
- Good efficiency = No liner required = No interruption to cocktail runs

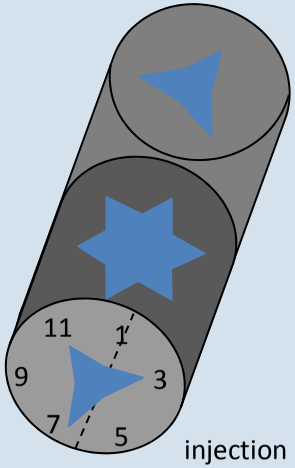
Oven Development: Low Temp + Liner

- Tantalum liner test 03/2012 in attempt to increase efficiency for ^{48}Ca beams
- 3 layers of 0.003" thick Ta, 12" long
- Used only 18GHz heating at 18GHz sextupole/solenoid fields
- Pros:
  - Ø
- Cons:
  - Needed to raise sextupole field to 28GHz field (460A, 2.2T) in order to reduce Ta peaks in spectra
  - Did not increase efficiency.

    No liner: 0.67mg/hr

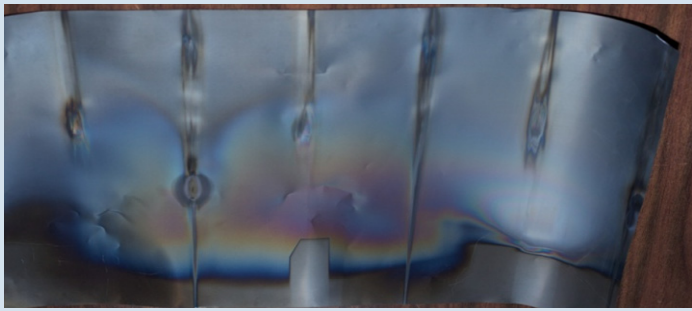
    With liner: 0.73mg/hr





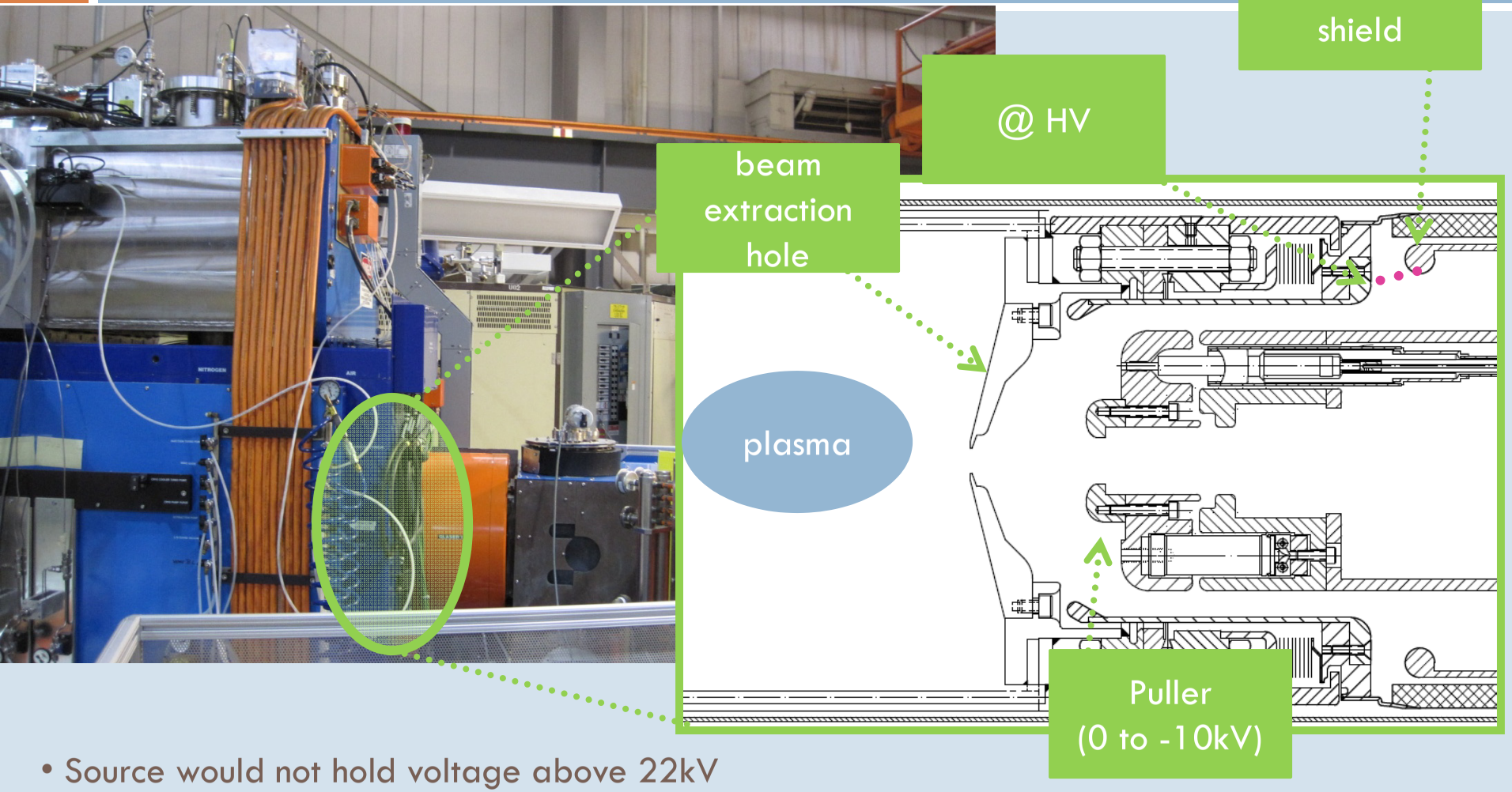
extraction

No white CaO residue formed on liner!



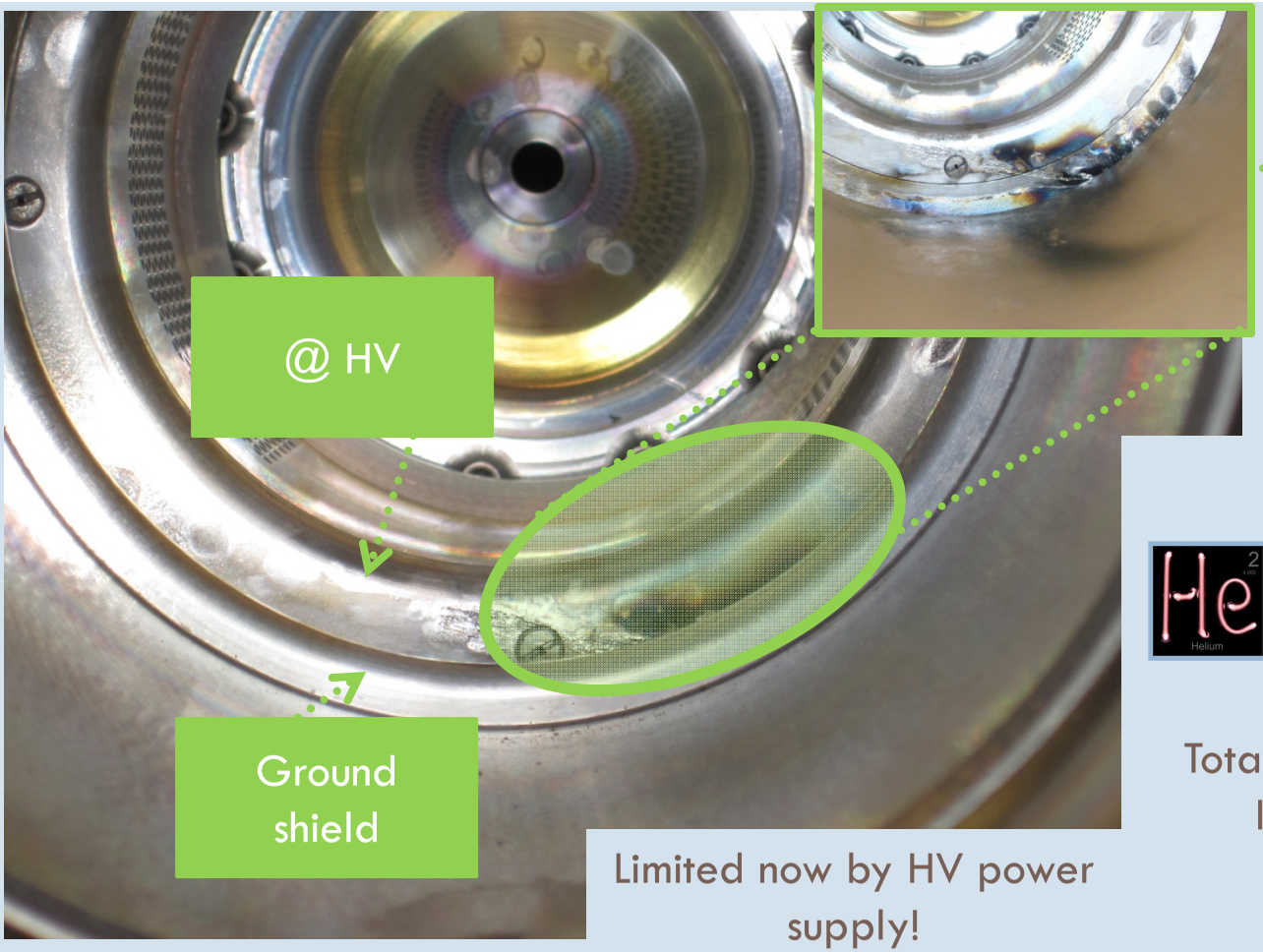
5 3 1 11 9 7

High Voltage Upgrade



- Source would not hold voltage above 22kV

High Voltage Upgrade



Limited now by HV power supply!

New Record Achieved:

$^{4}He^{1+}$: 9.3emA

$^{4}He^{2+}$: 11emA

Source Parameters:

Total Extracted: 25emA @ 25kV

Inj. Pressure: 1×10^{-6}mbar

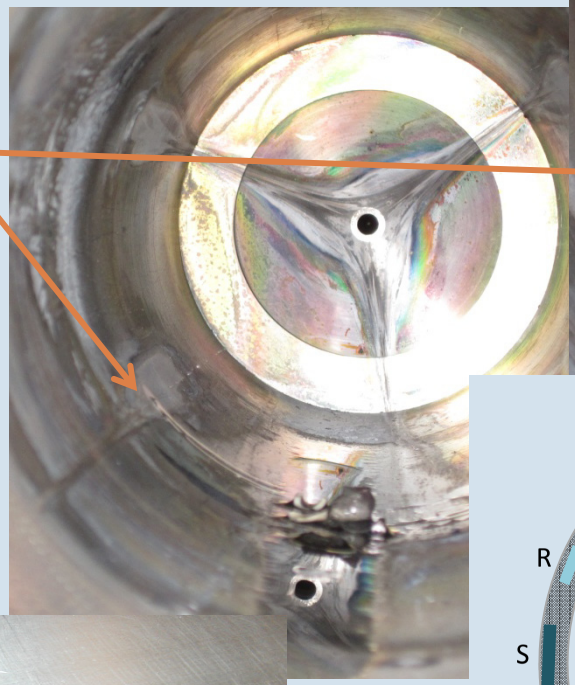
18GHz: 1745W

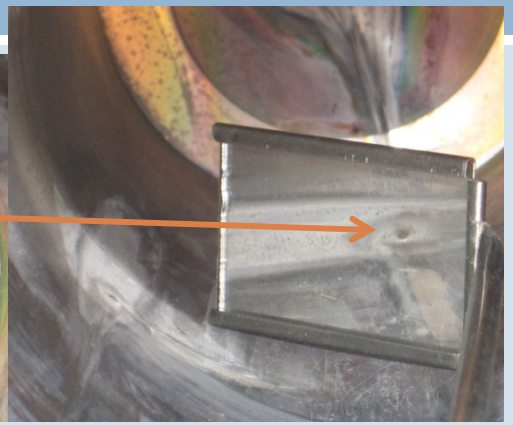
28GHz: 1000W

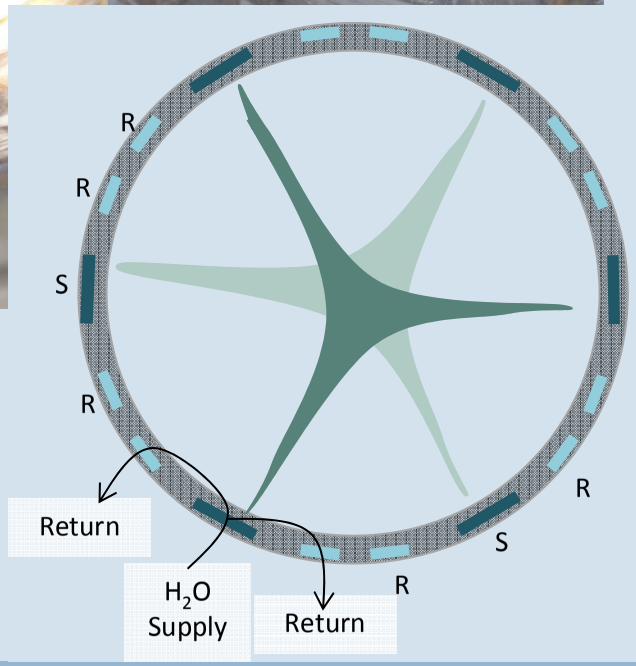
Bias Disk: - 335V, 58mA

VENUS Plasma Chamber

- Burned a hole in plasma chamber at 7 o'clock position injection flute
- Measured a wall thickness of 0.053" at thinnest location
- Same location as 2005's 28GHz Gyrotron accident. This hole attributed to more continuous operation
- Important to consider for VENUS II and 4th generation

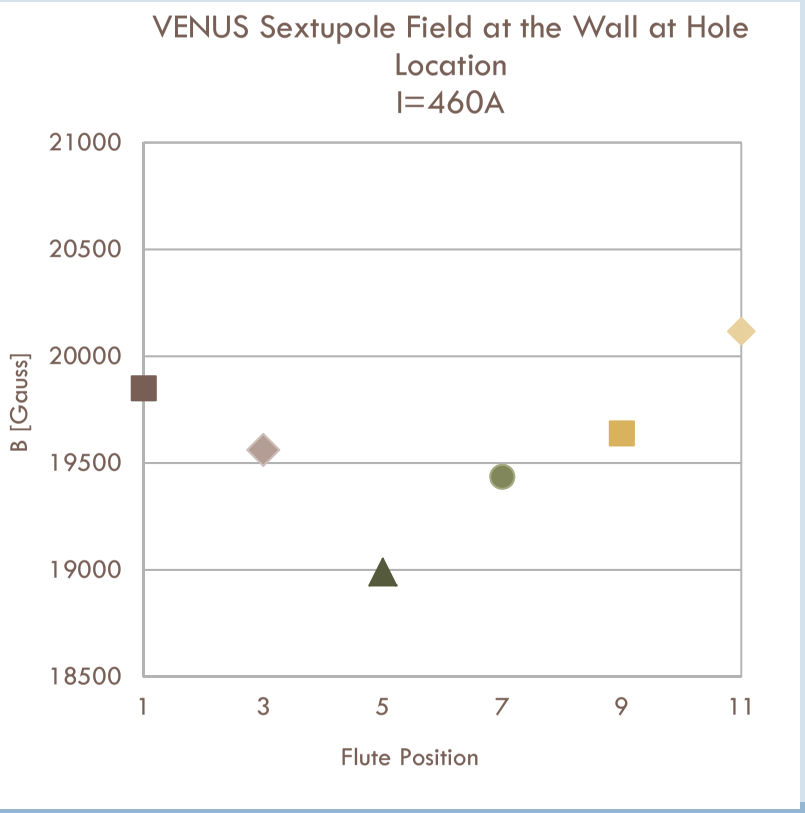


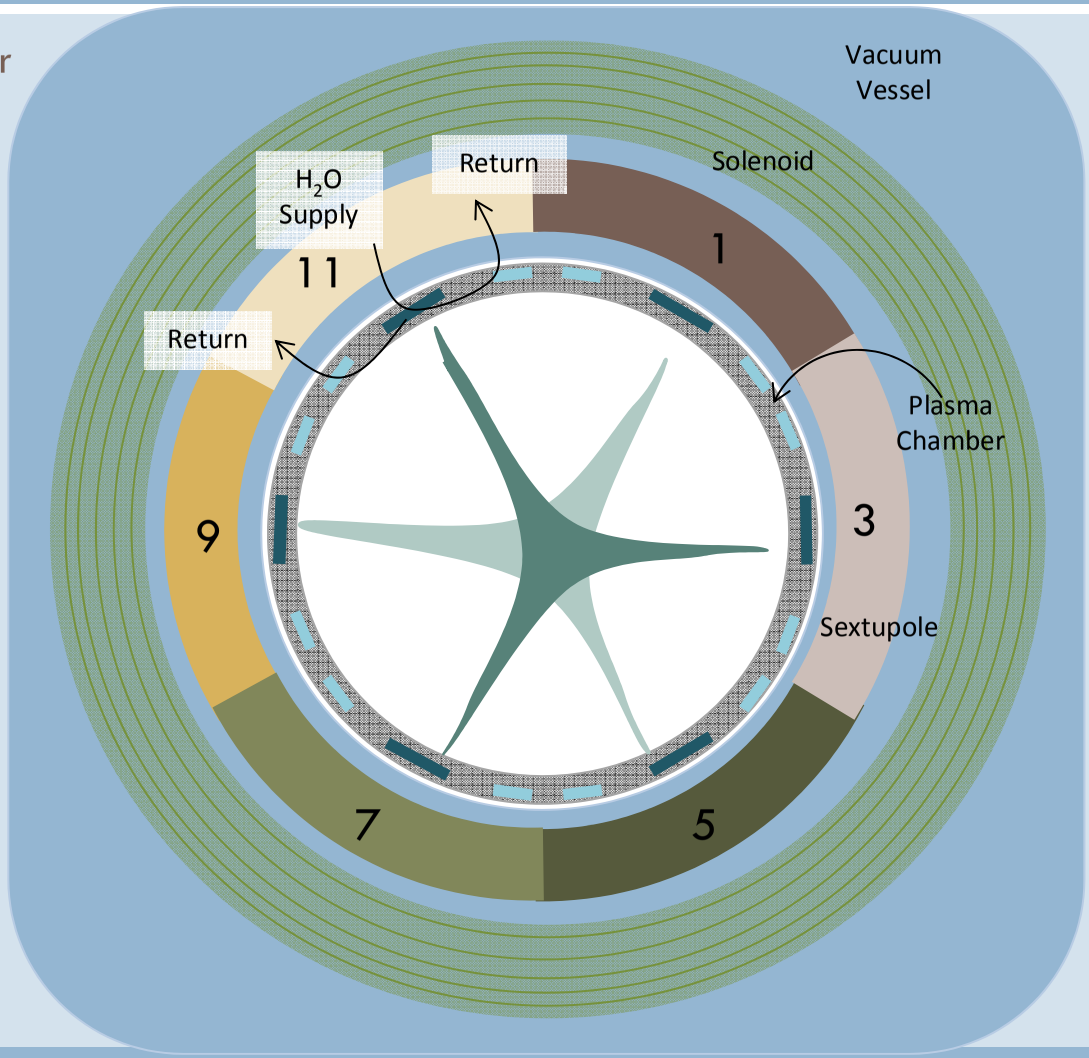




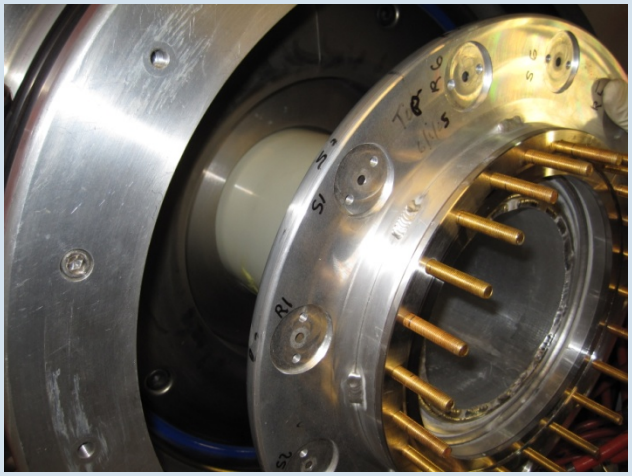
VENUS Plasma Chamber

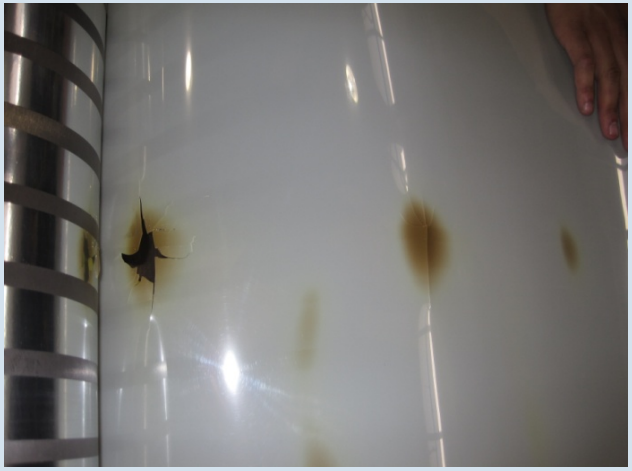
- Investigation of the alignment of chamber to sextupole magnets revealed that chamber sits high by 1mm (40mils)





VENUS Plasma Chamber





- Inspection of the mylar insulation reveals damage at position of the 3 injection flutes
- High energy x-rays going through 2mm Ta sheet
- 9 layers of 0.015" mylar sheet
- Reduced to 6 layers in attempt to correct alignment offset of 1mm

Summary

- VENUS satisfied most FRIB requirements
- Continue to make advances in beam intensities: He, U (G. Machicoane's talk)
- LoT oven has succeeded in producing beams for 88" researchers
- Sputter Probe still in development

FRIB ECR Requirements			
Element		I (eμA)	VENUS(eμA)
Argon	$^{40}Ar^{8+}$	378	525 of 8+
Calcium	$^{48}Ca^{11+}$	468	400 of $^{40}Ca^{11+}$
Xenon	$^{124}Xe^{18+}$	334	432 of 26+
Bismuth	$^{209}Bi^{29+}$	422	300 of 31+
Uranium	$^{238}U^{33,34+}$	440	840

- VENUS usage in operations increased from 1.1% in 2007 to 17.5% in 2012 (~850hrs)
- We continue to learn and work towards improvements!

Thank you!

ECR Group: (left to right) J. Benitez, Claude Lyneis, Markus Strohmeier, Ken Franzen