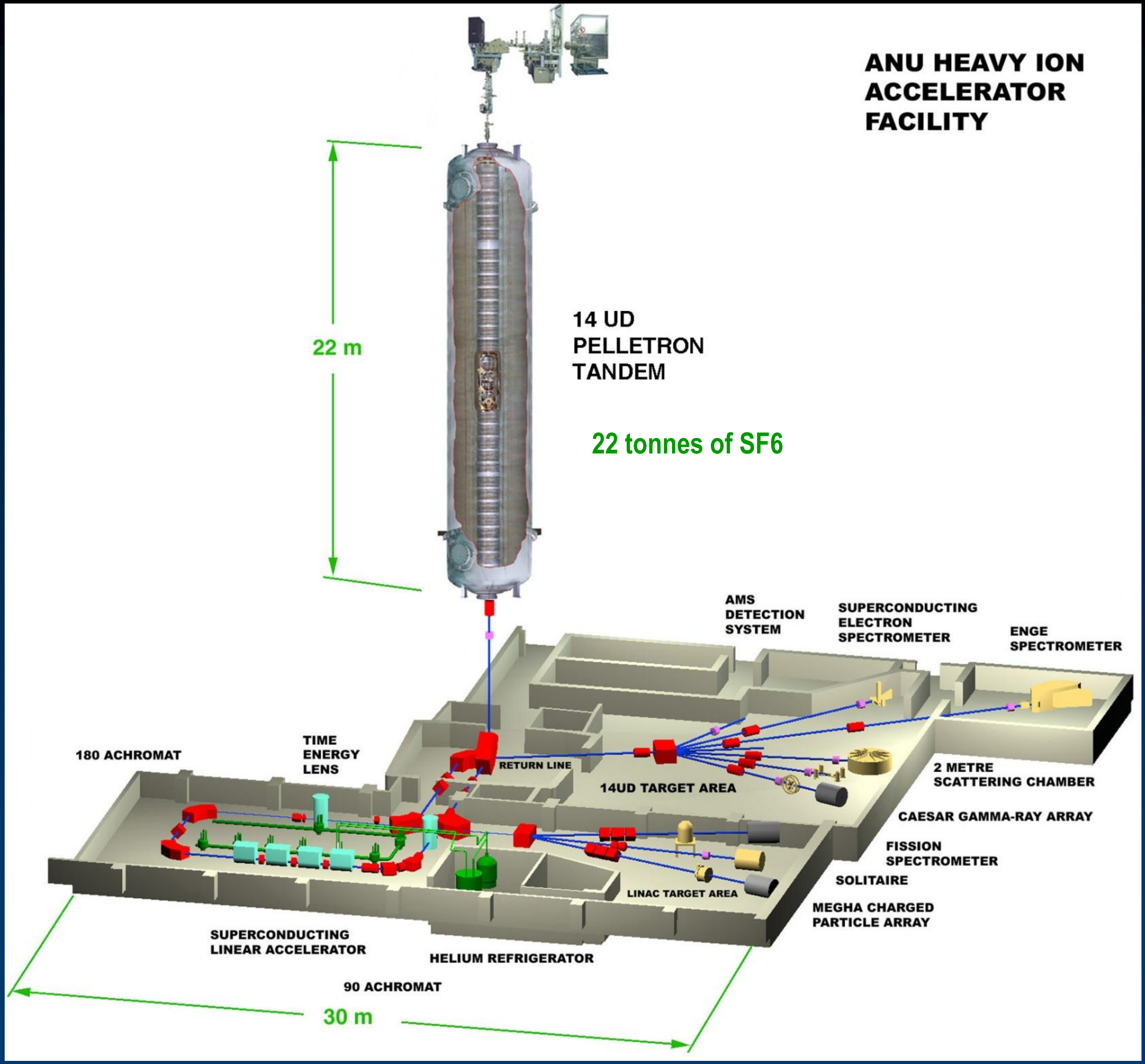
TRIUMF talk October 2011, Vancouver

THE AUSTRALIAN NATIONAL UNIVERSITY

Progress report on the accelerators upgrade at ANU

Dr Nikolai Lobanov

on behalf of Accelerator Operation and Development Team


ANU HEAVY ION ACCELERATOR FACILITY
14 UD PELLETRON TANDEM
22 m
22 tonnes of SF6
AMS DETECTION SYSTEM
SUPERCONDUCTING ELECTRON SPECTROMETER
ENGE SPECTROMETER
TIME ENERGY LENS
180 ACHROMAT
RETURN LINE
14UD TARGET AREA
2 METRE SCATTERING CHAMBER
CAESAR GAMMA-RAY ARRAY
FISSION SPECTROMETER
SOLITAIRE
LINAC TARGET AREA
MEGHA CHARGED PARTICLE ARRAY
SUPERCONDUCTING LINEAR ACCELERATOR
HELIUM REFRIGERATOR
90 ACHROMAT
30 m

Ion beams from 14UD and Linac

								Pulsed beam parameters			
M	Q1	Q2	E/M_{STS}	β_{STS}	E/M_{DTS}	β_{DTS}	$E/M_{DTS+Linac}$	ΔE, keV	$\Delta\tau$, ns	ε_z, (keV x ns)/M	$\Delta E_{Post-Linac}$, MeV*)
16	7	7	7.5	0.13	7.5	0.13	9.95	17.3	1.25	0.43	0.5
24	9	9	6.25	0.12	6.25	0.12	8.61	24.5	1.35	0.44	0.7
58	12	20	3.36	0.08	4.64	0.10	7.05	110	1.5	0.91	2.4
74	13	22	2.63	0.07	4.04	0.09	5.91	137	1.5	0.88	2.5
107	15	26	1.96	0.06	3.26	0.08	4.62	193	1.5	0.86	3
127	15	29	1.65	0.06	2.9	0.08	4.18	246	1.5	0.93	5
197	15	29	1.06	0.05	1.92	0.06	2.13	356	1.5	0.86	5

1st stripper 4 mkg/cm^2

2nd stripper 10 mkg/cm^2

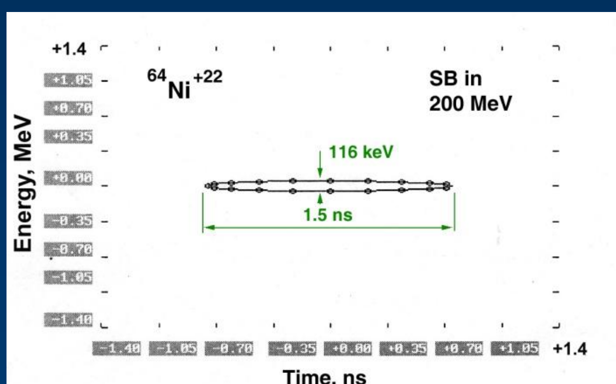
ε_{zSTS}, ~0.45π (keV x ns)/M

ε_{zDTS}, ~0.9π (keV x ns)/M

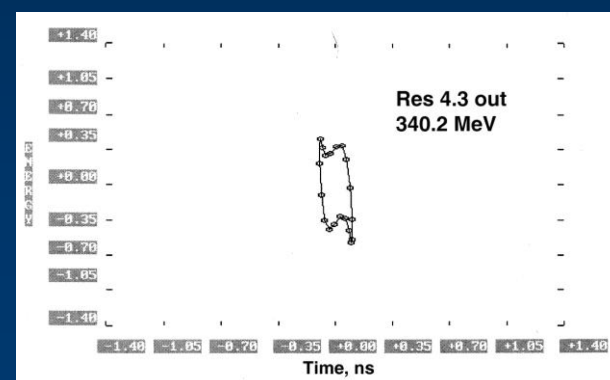
*) SPACE code simulation

$\Delta E_{post-Linac}/M$~0.03 MeV

a.

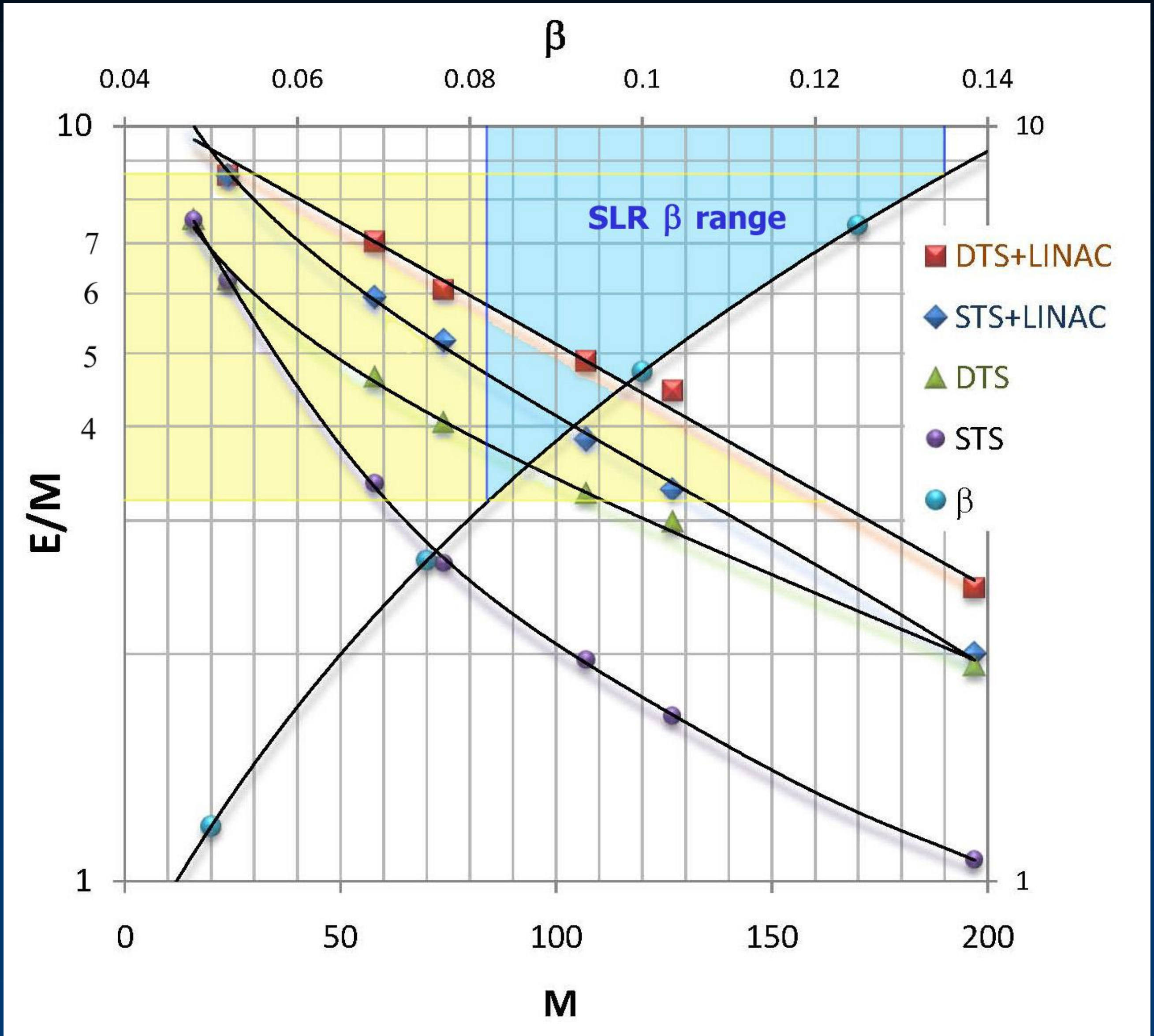


b.



Longitudinal emittance of beam from 14UD (a) and post-Linac beam (b)

14UD and Linac capability



14UD development projects

Goal: increase reliability of operation and the range of heavy beams

- **New accelerator computer control and data acquisition systems**
- Replacement vacuum pumps and gauges
- Replacement major magnet power supplies by modern systems. Integration with new computer control
- Automated tuning of the beam transport. Compensation off daily ion source displacement
- New alignment system based on laser trackers (with ACAS collaborators)
- Fully equipping with BPMs and FCs allowing optimal beam focusing

Computer control and data acquisition systems

- Current control and data acquisition systems are based on DEC VAX machines and use VMS OS
- Urgent need to migrate to supported computer platform
- VME crate controllers, accelerator control and data acquisition computers need to be replaced
- EPICS control software has been developed
- The hardware and basic software has been acquired
- The transition from present obsolete to new system will be complete by June 2012
- Once fully operational and debugged, the lab-wide transition will be rapidly implemented by 2013

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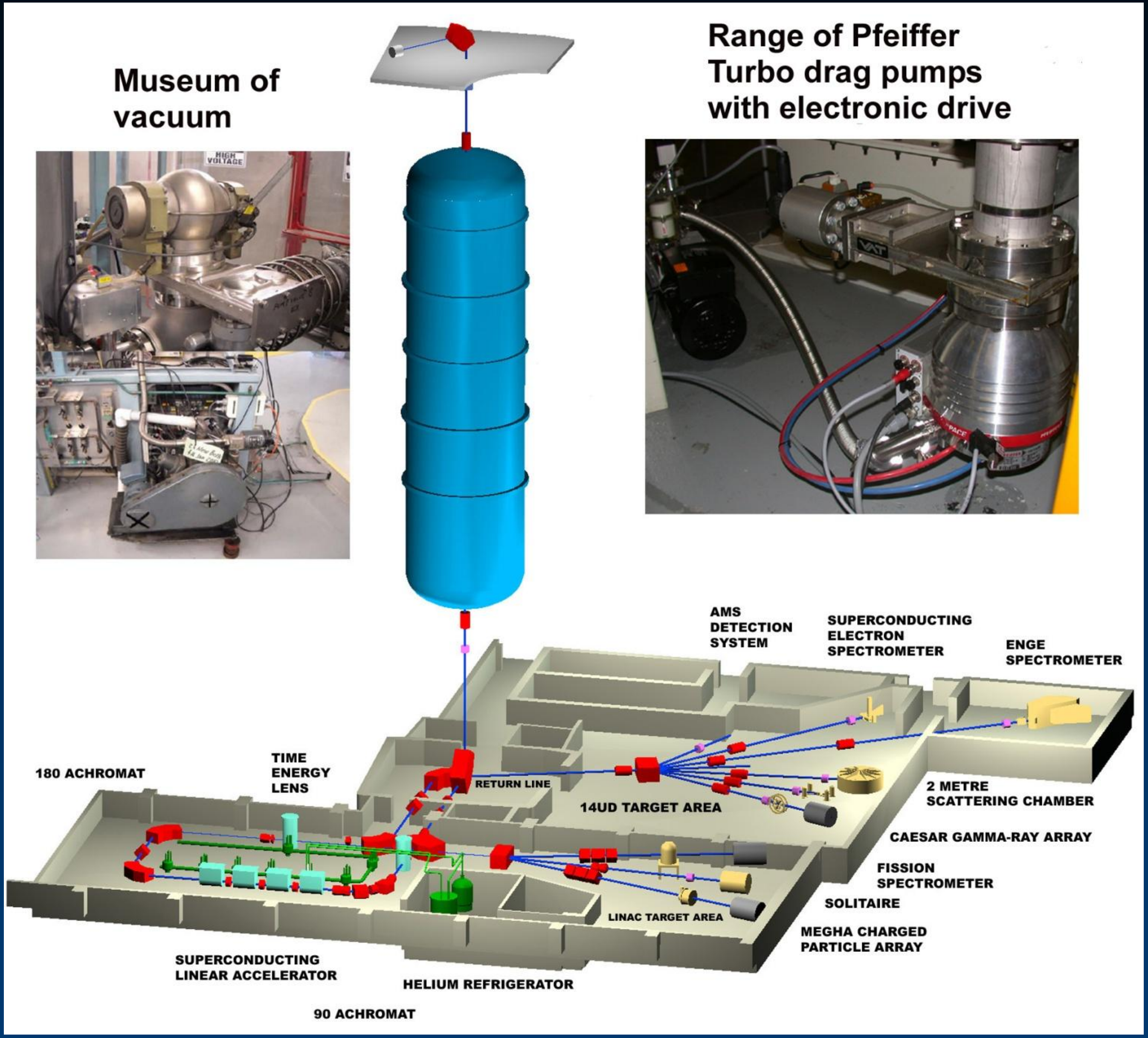
Replacement inadequate vacuum pumps and gauges

In-house manufacture of control Units and adapter flanges



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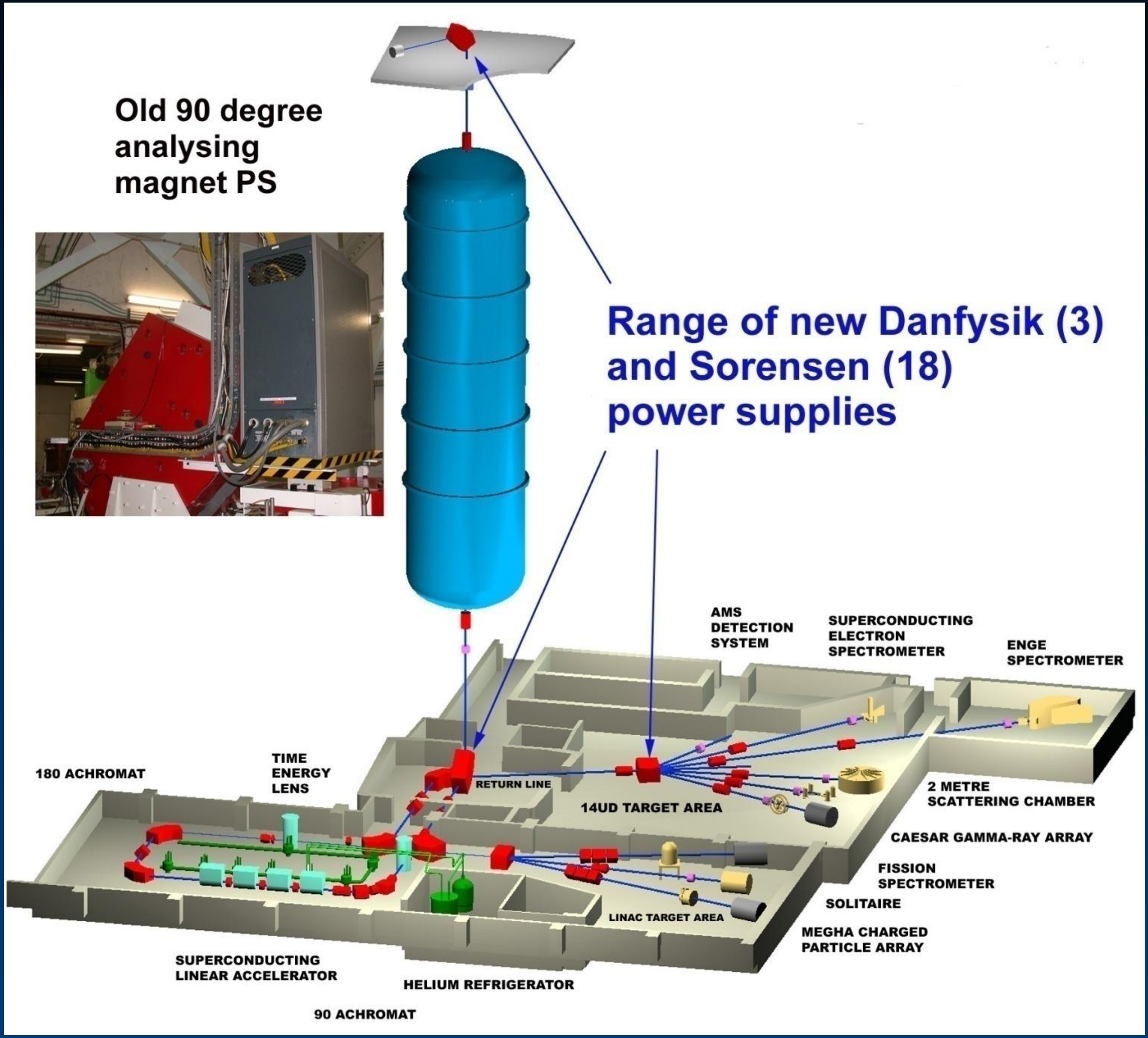
Replacement major magnet power supplies by modern systems

Danfysik power supplies are 2ppm stability version



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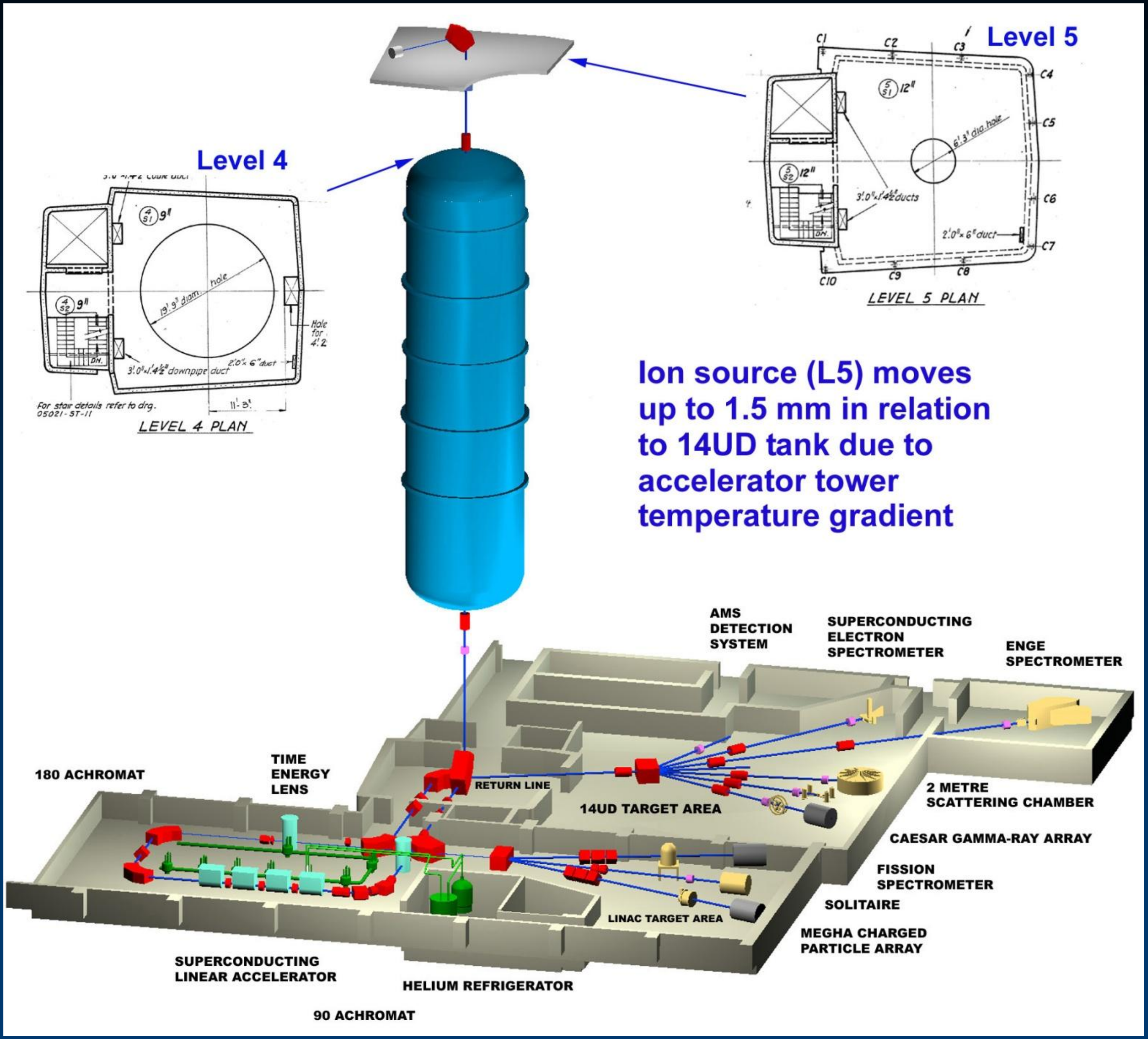
Automated tuning of the beam transport



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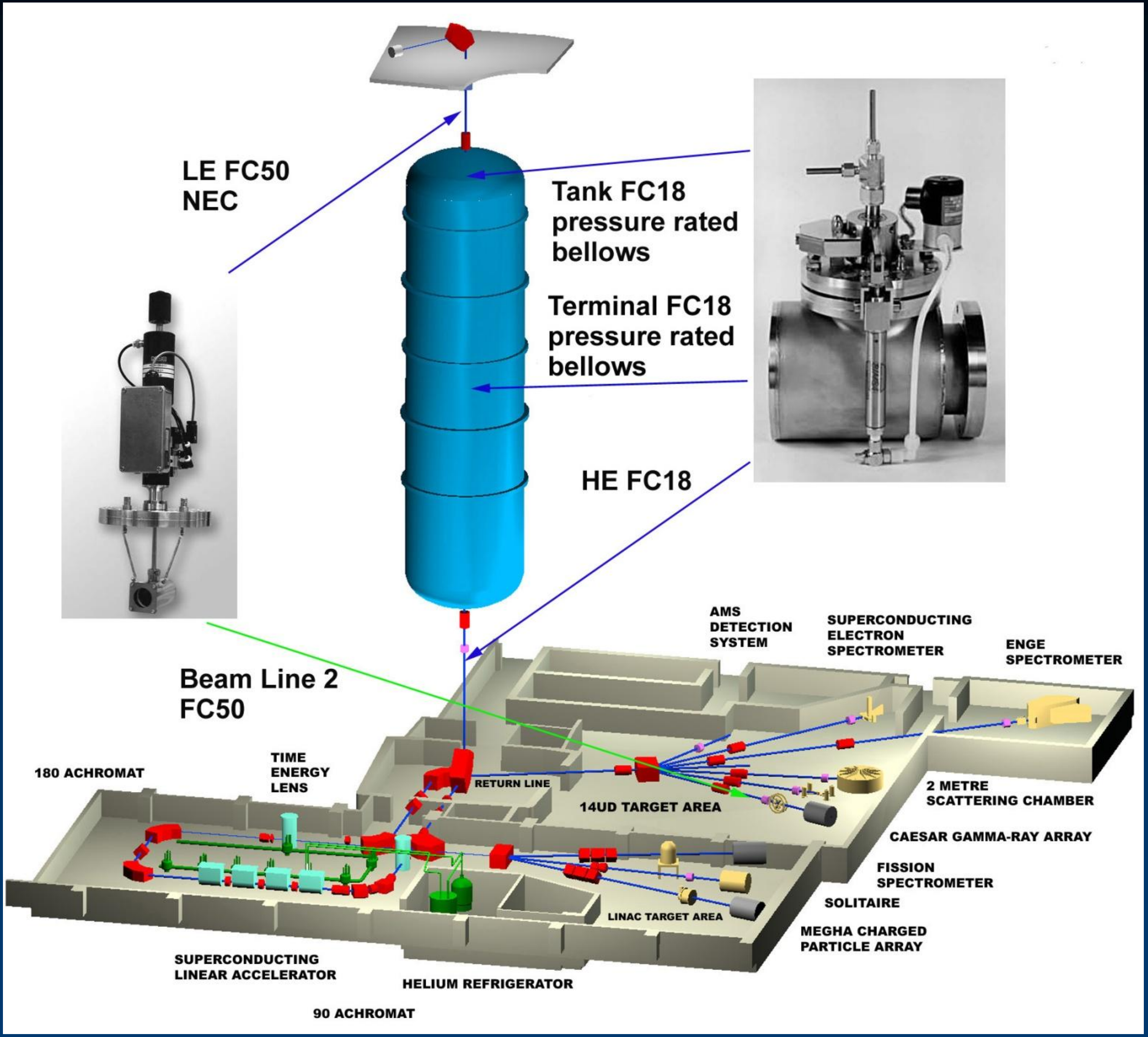
New FCs and BPMs

There is need for better beam diagnostic particularly reliable Faraday Cups

Issues: bellow failure in FC18 (ORNL)



14UD development projects continued

- **New Terminal Potential Stabilisation system TPS 6.0 (NEC) including GVM, Slits and CPO amplifiers and corona probe controller**
- New NEC remotely operated 4 x jaw HE slits and two 2 x jaw image HE slits. Slit controllers are made in-house
- Purchasing SF_6 gas to allow optimum tank pressure. Upgrade SF_6 monitoring system. New fast SF_6 containment valves
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- Enhancement AMS capability
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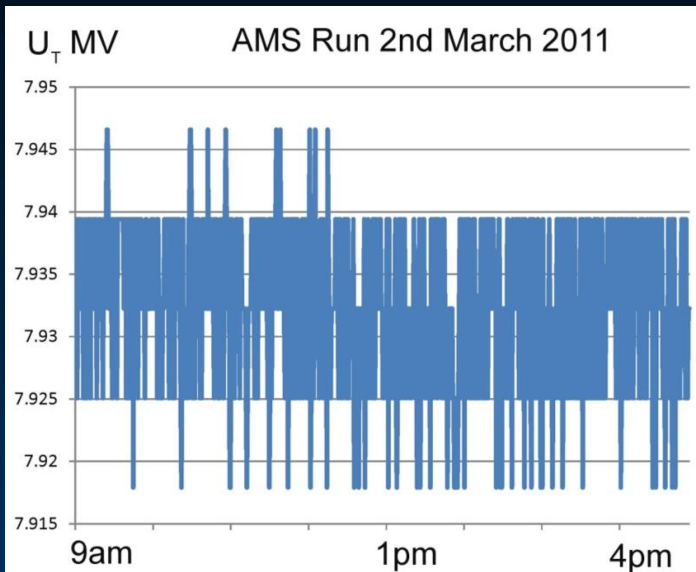
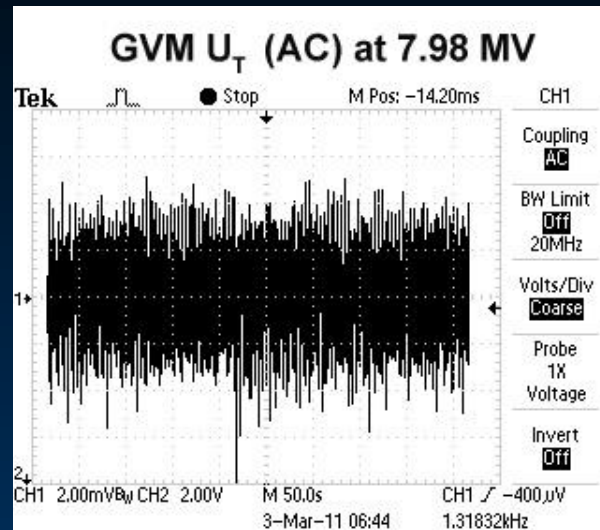
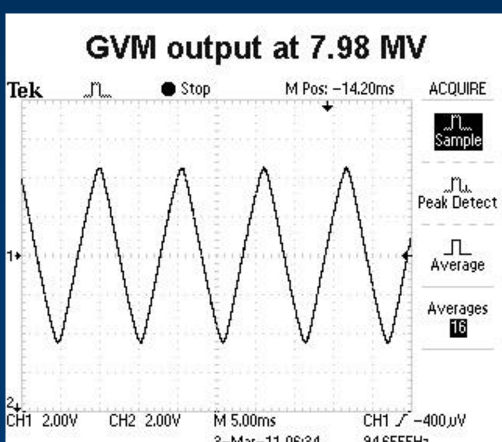
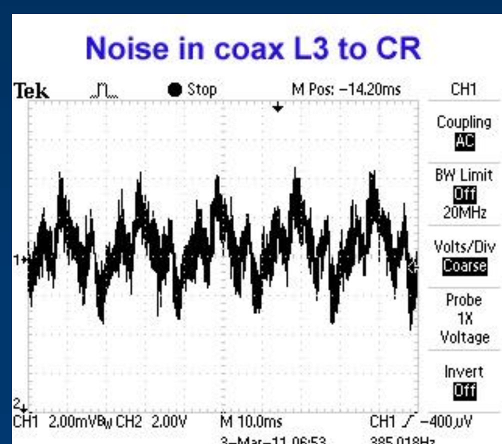
14UD Performance with old system





- Based on GVM, terminal voltage stability is ~ 0.2%, much higher than NEC specs of 0.02%



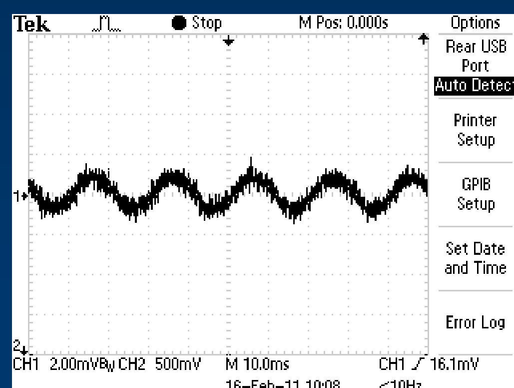


- Noise in GVM coax is at the same level as GVM U_T (AC)
- Noise in coax should be reduced and pre-amp moved to L3

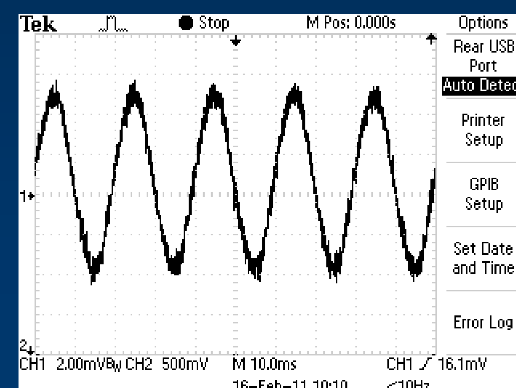
CPOs calibration

In anticipation of new NEC slit/GVM controller TPS 6.0

- 115 VAC at 50 Hz is applied to the terminal
  - Challenge: to deliver CPO signal noise-free to Control Room



- Raw signal on CPO, 16 μV/V



- CPO signal after pre-amp, 70 μV/V

New NEC controller TPS 6.0

TPS 6.0
Controller

Corona Probe Controller
and CPO amplifier

New Drusch NMR replacing 40 year old unit

14UD development projects continued

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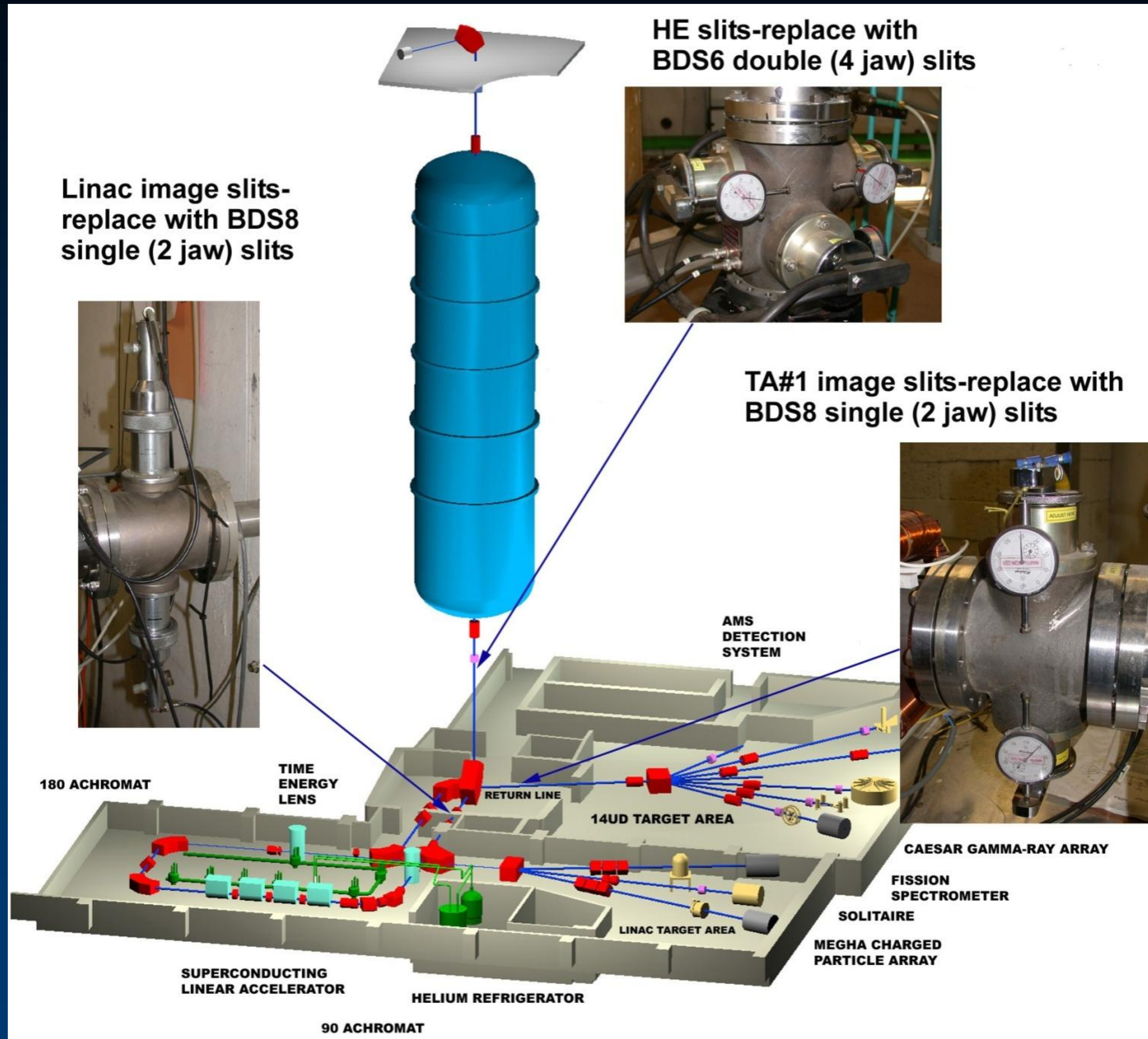
New High Energy remotely operated slits

All slits with 24 VDC motor drives, Ta elements

Controllers are build in-house



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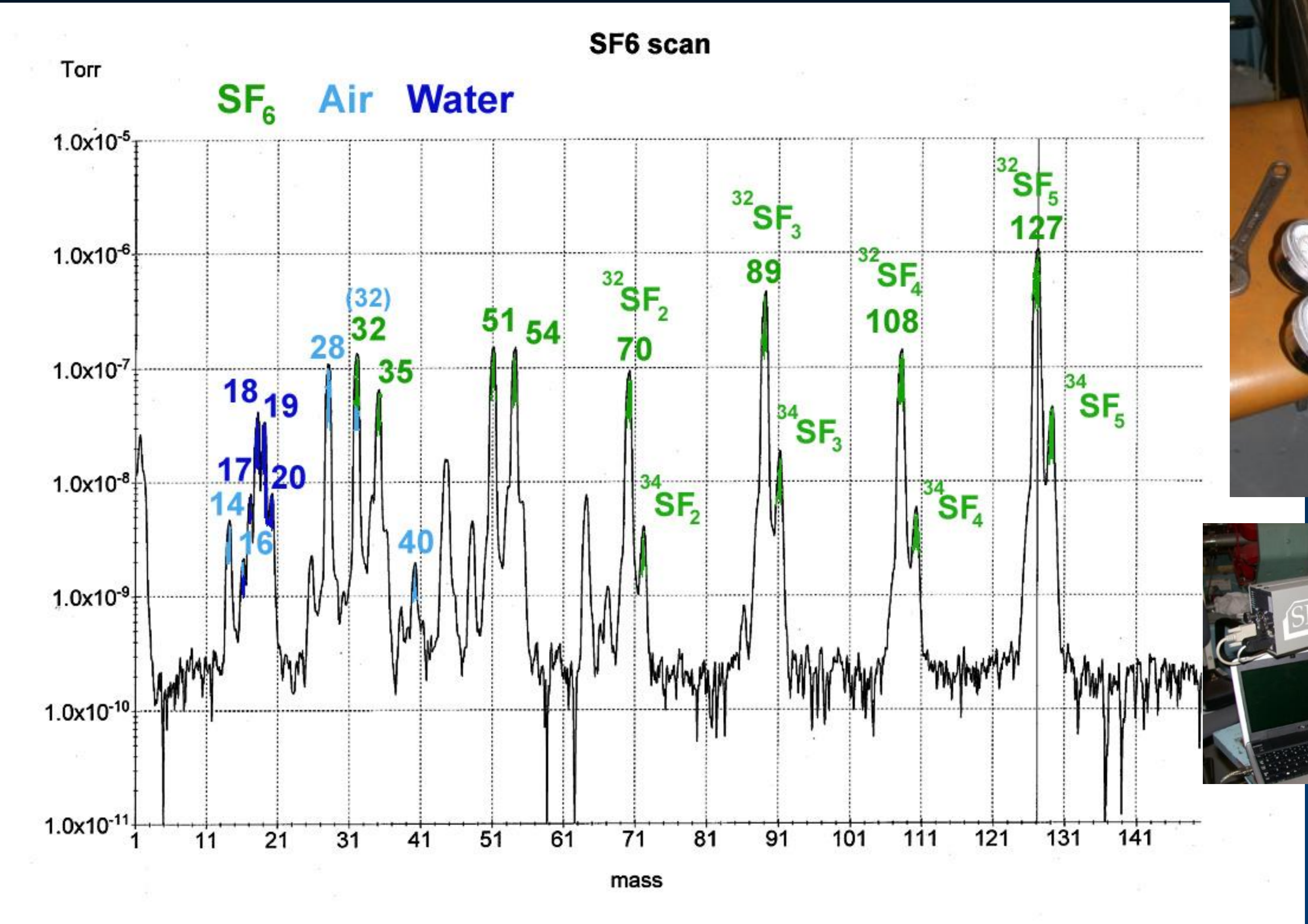
Top up SF_6 and upgrade monitoring/safety

- Purchased 1040 kg of SF_6 in August 2010, tank operational pressure increased to 104.5 PSI
- Annual submission on emissions from HIAF for the National Greenhouse and Energy Report
- Evaluated direct measurement of SF6 inventory in storage vessel with load cells (accuracy +/- 5 kg)- project cancelled
- High precision system to log pressure and temperature of SF_6 in the 14UD tank
- New custom designed fast SF_6 containment ball valves via A&N Corporation

- Implemented RGA system to monitor moisture and air concentration in SF_6

RGA system to monitor moisture and air concentration in SF_6



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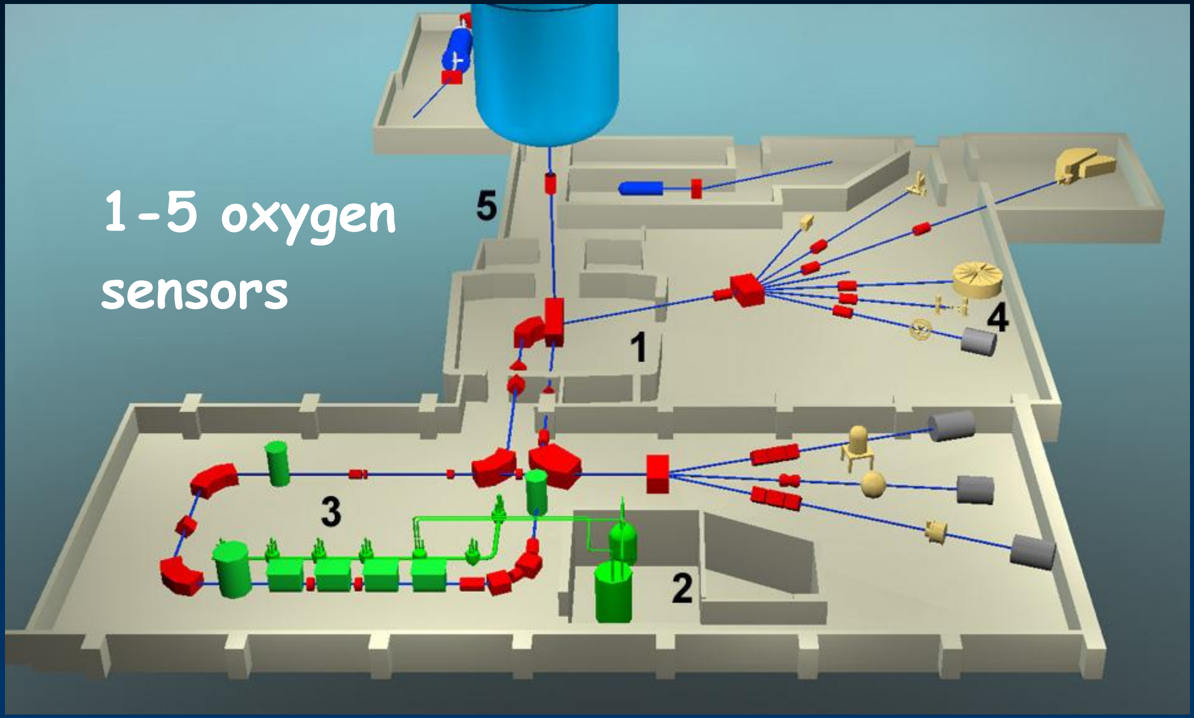
Oxygen depletion monitoring

6 channel MicroRack Alarm Controller with DGuard oxygen transmitter



- Integration to 14UD Computer Control system
- Simple audible and visible alarm signals

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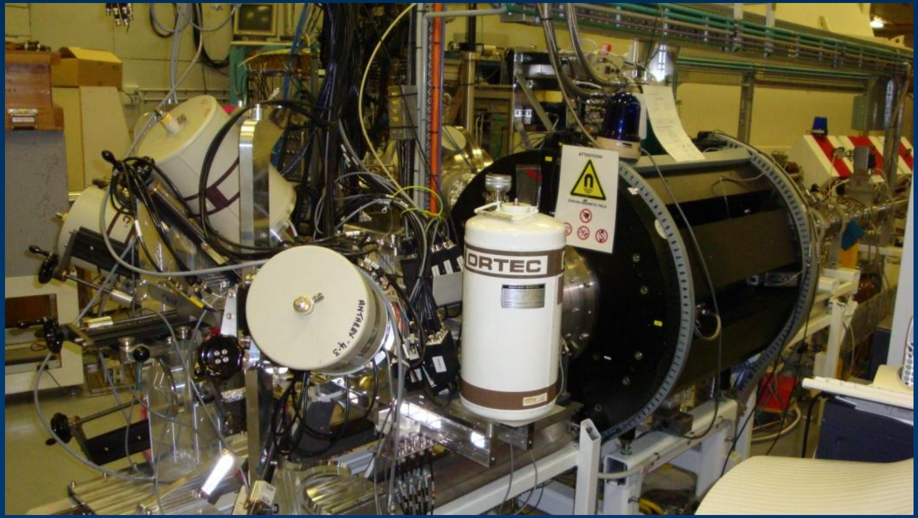
- **Enhancement RIB capability**
- New beam lines

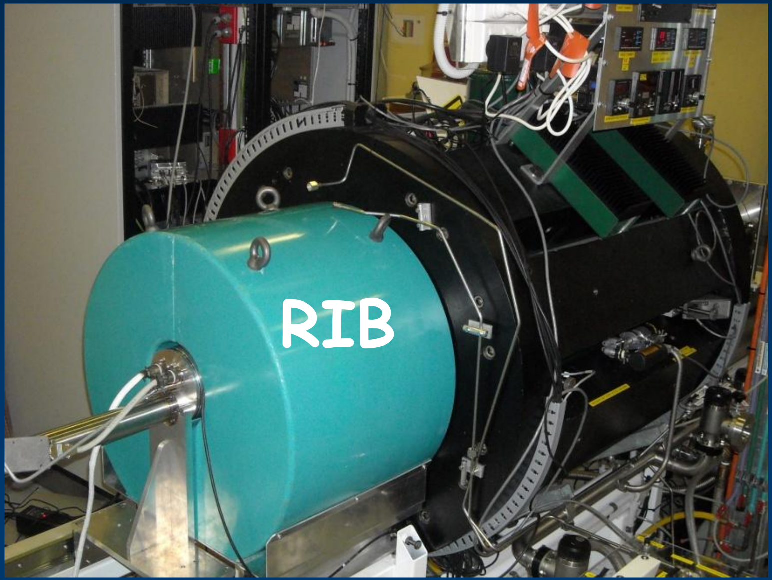
ANU

Enhancement RIB capability

- Feasibility of producing short-lived radioactive isotopes ^{6}He using 1 eμA primary ^{7}Li beam, superconducting 6.5 T solenoidal reaction product separator and pair of Parallel Plate Avalanche Counters has been demonstrated
- This device is in great demand for many users
- RIB project will purchase second solenoid with PS and computer control. A dedicated radioactive isotope beam-line will be developed.



SOLENOGAM



SOLEROO

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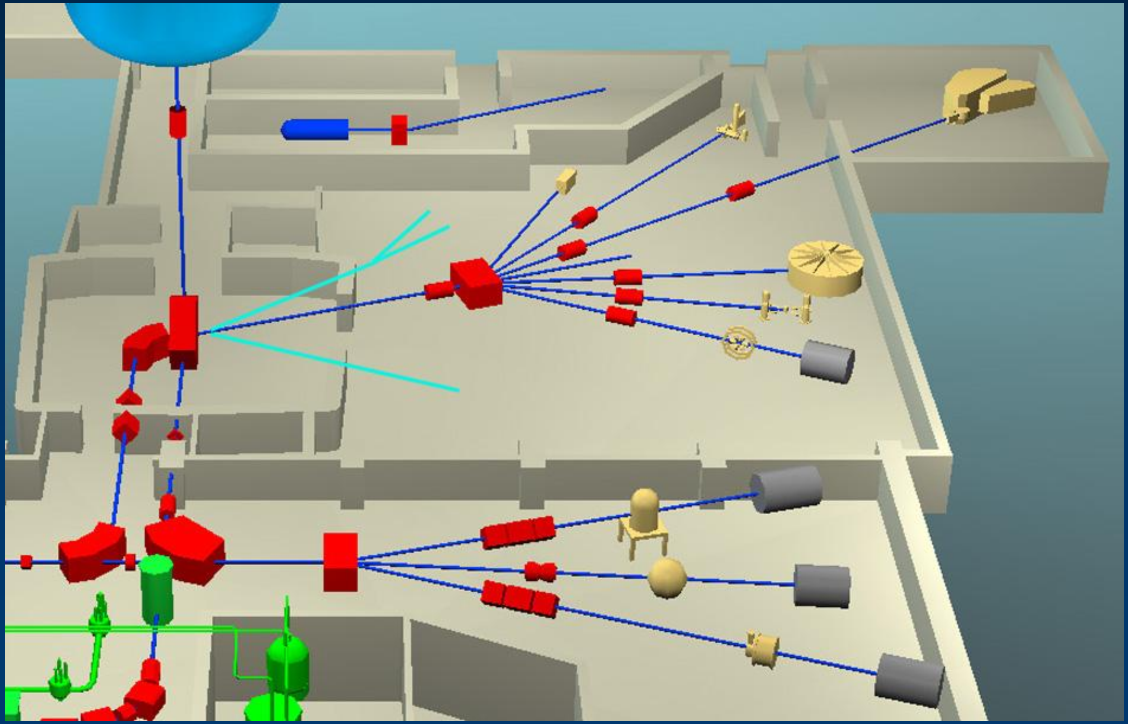
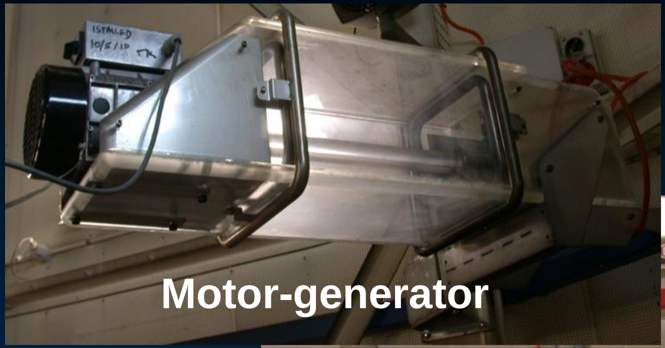
- **New beam lines** evaluation stage

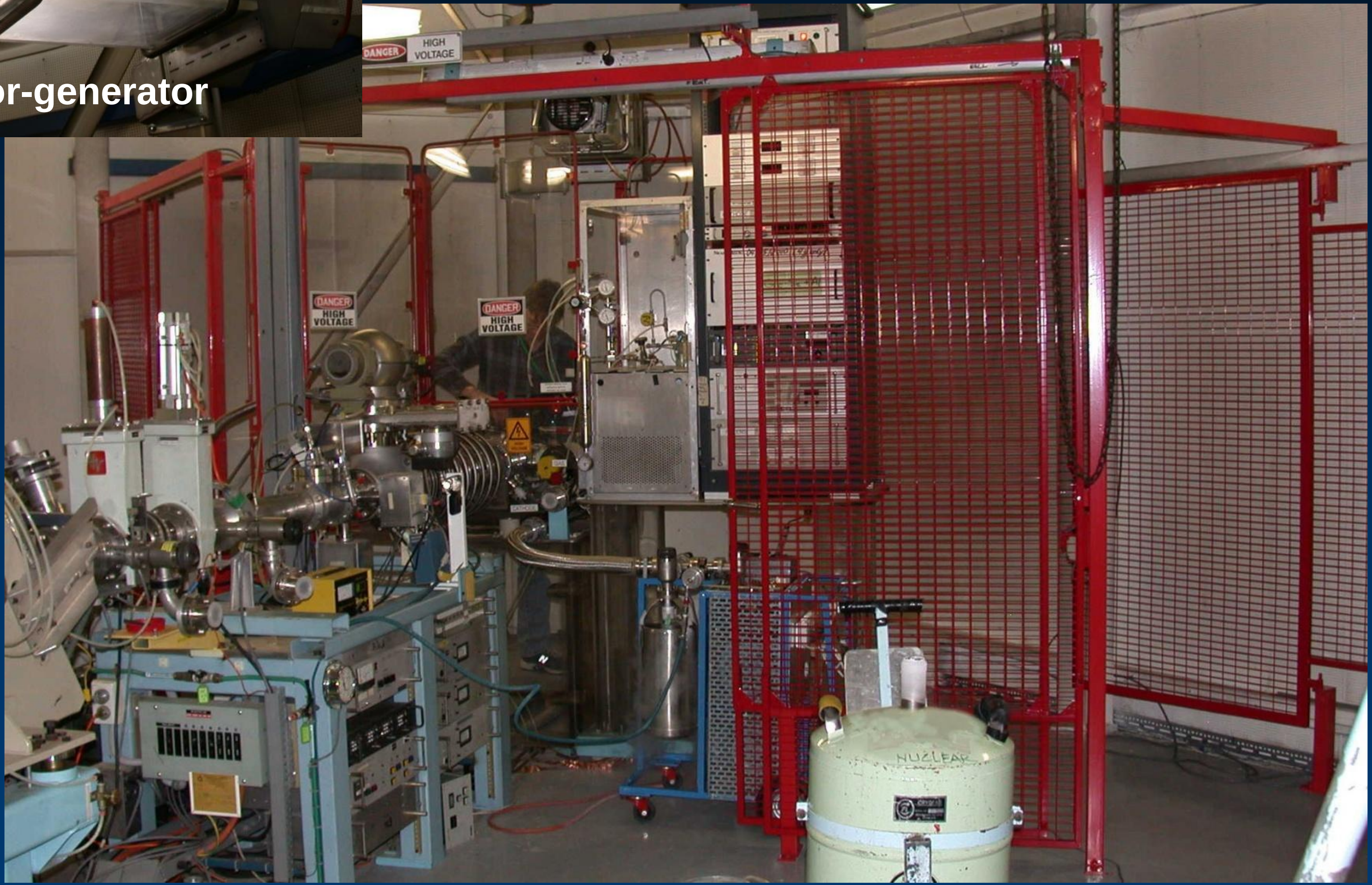
New beam lines

- Demands on existing beam-lines is increasing
- Space has been identified for three beam-lines in Target Area 1 making use of capability to rotate the analysing magnet
- Similarly, there is need for additional target station in Target Area 2
- This will be addressed through in-house design, manufacture and installation

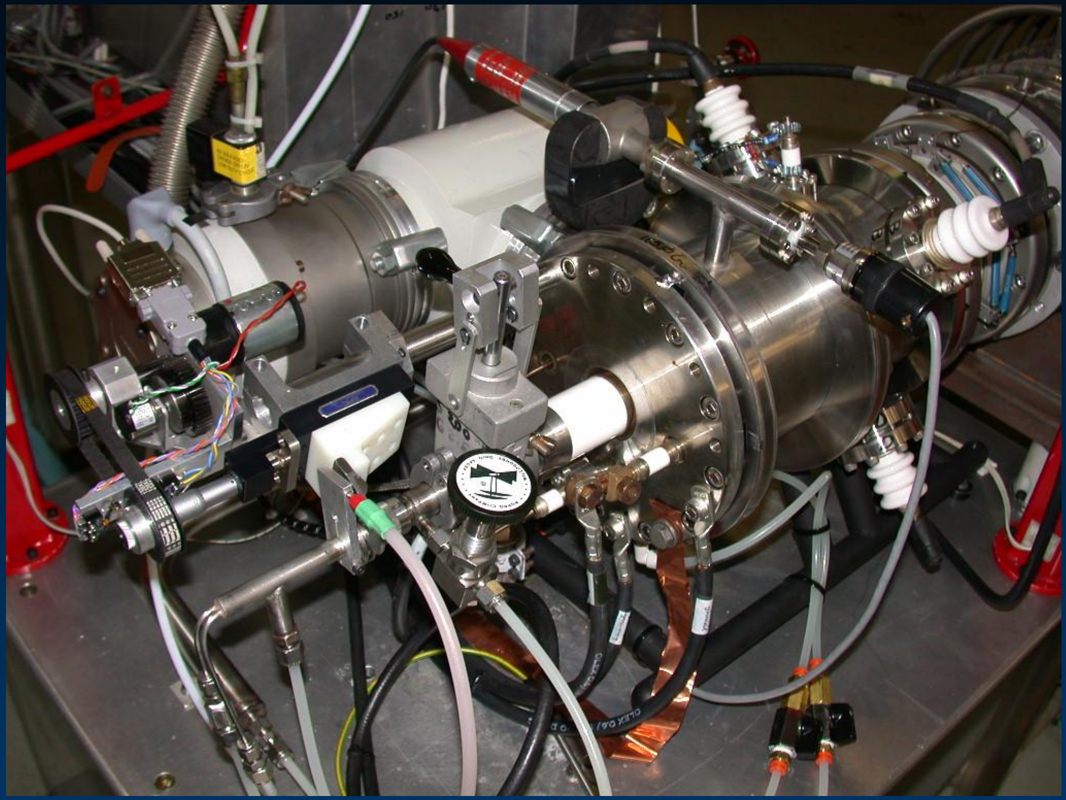


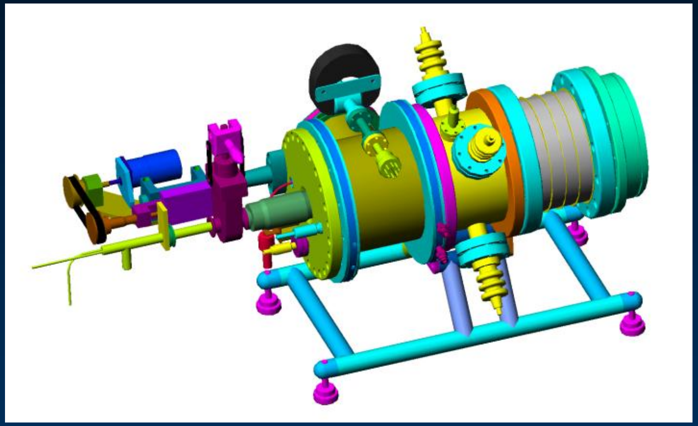
Gas cathode ion source setup





Gas Cathode Source Negative Ions Cesium Sputtering (SNICS)





Implemented GC source Improvements:

- Cathode position actuator
- Improved vacuum conditions
- Combined focusing and steering

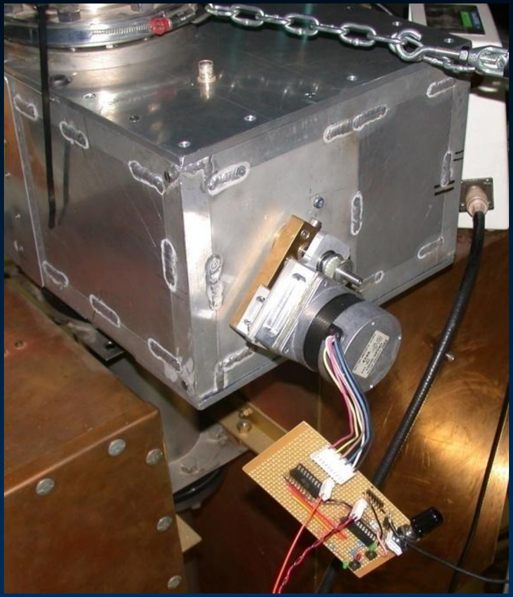
SNICS development: construction the second source for better maintenance and reliability; New Glassman cathode PS

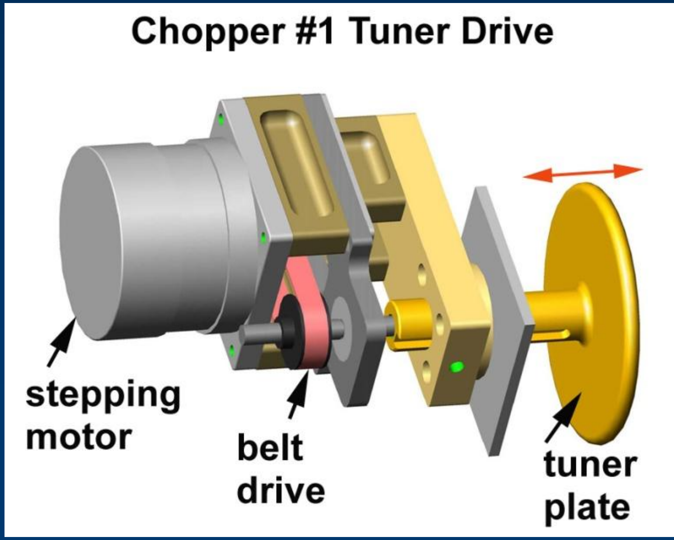
Beam pulsing development projects

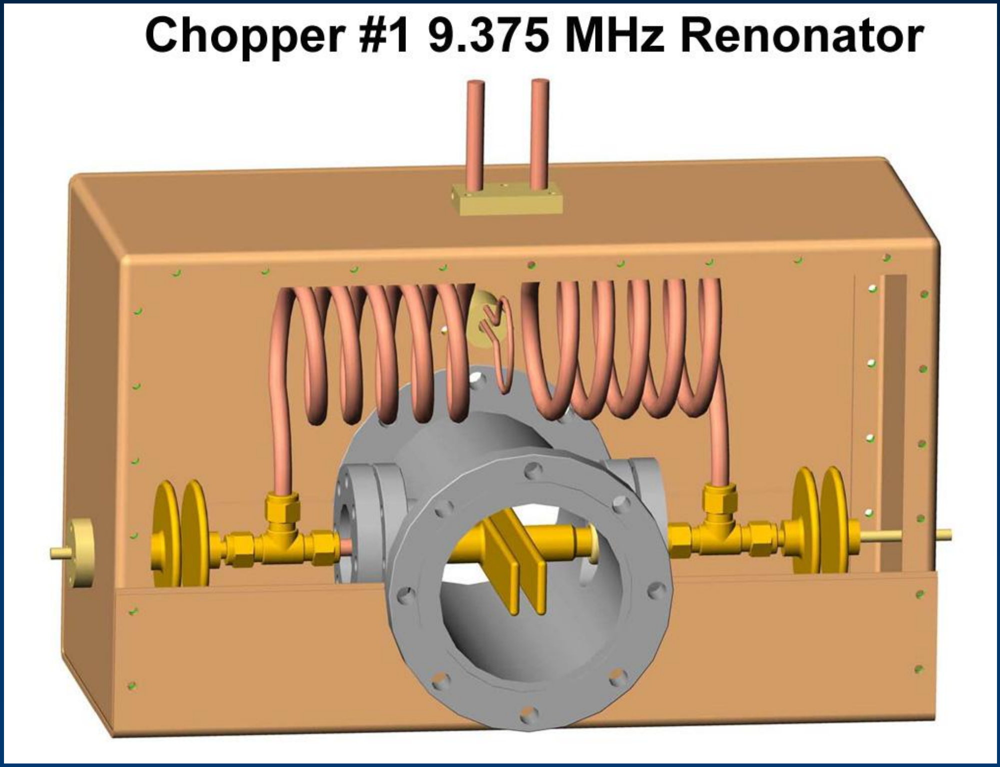
Goal: increase efficiency of operation and the phase stability

- **Improve the performance of the RT resonators and phase detector**
- **Custom re-design of the complete rf electronics capable of phase and amplitude locking for 3-frequency buncher and choppers**
- **Upgrade slow chopper electronics**
- **Develop 150 MHz room temperature superbuncher with the aim of improving time resolution from ~1 ns to ~ 0.1 ns**

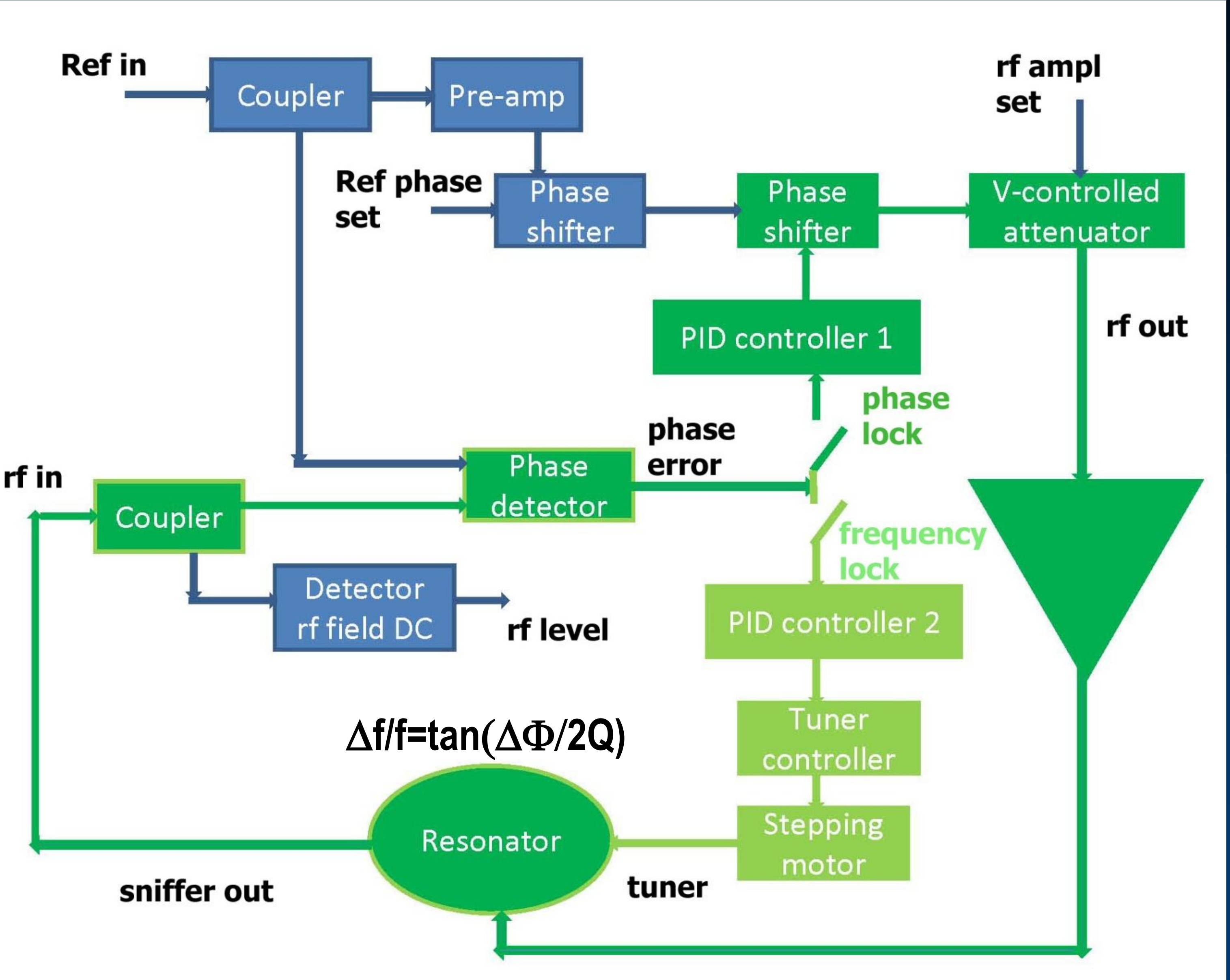
Upgrade Chopper #1 resonator





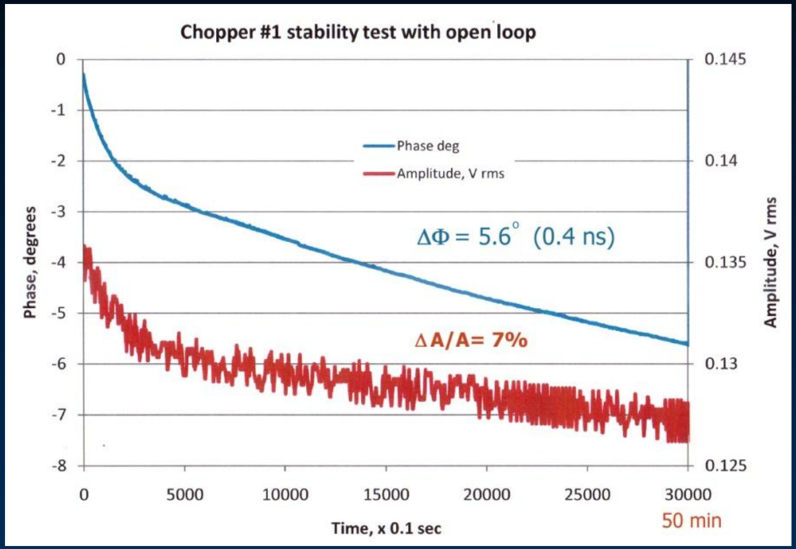


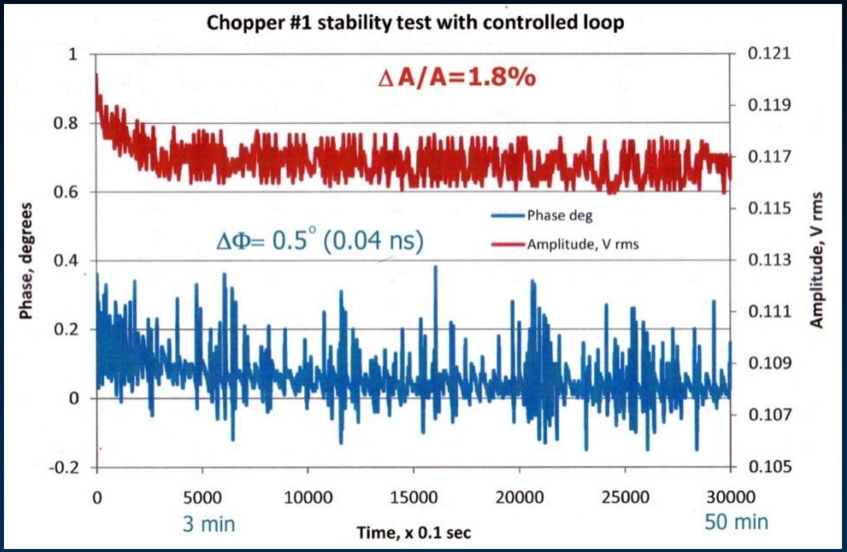
rf control systems for C1, C2 and B2

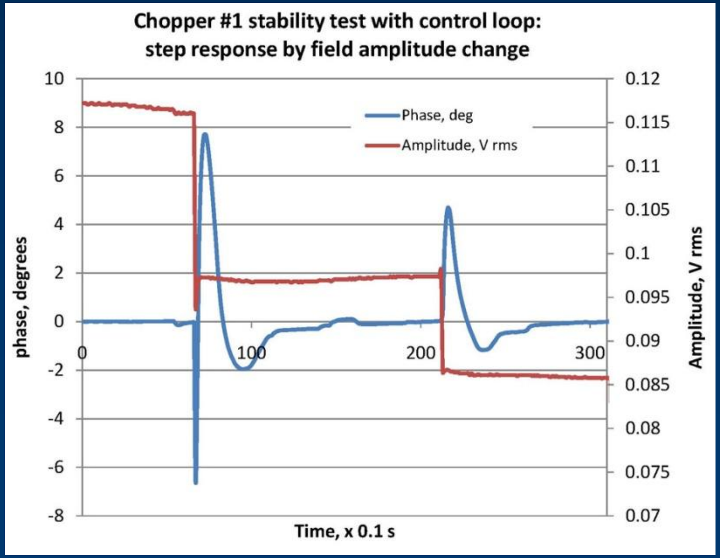


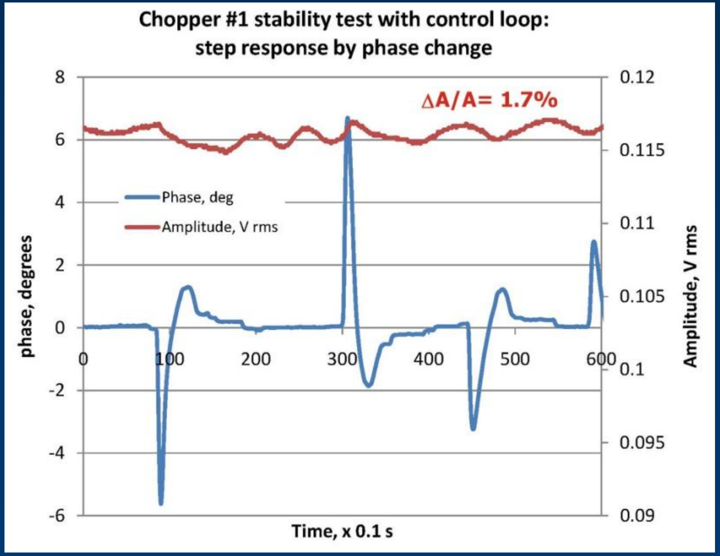
$$\Delta f/f=\tan(\Delta\Phi/2Q)$$

Performance of new rf control system @80 W

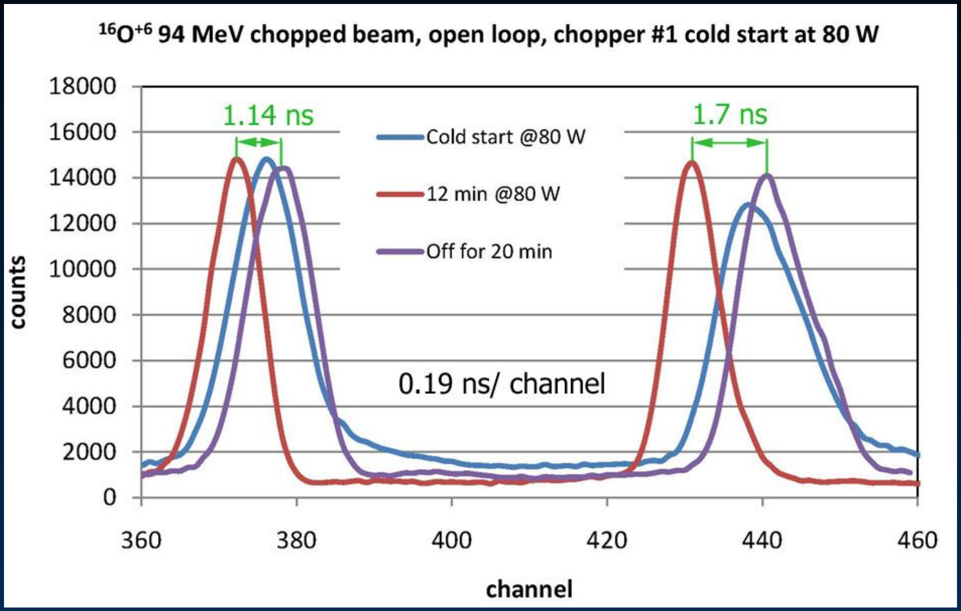


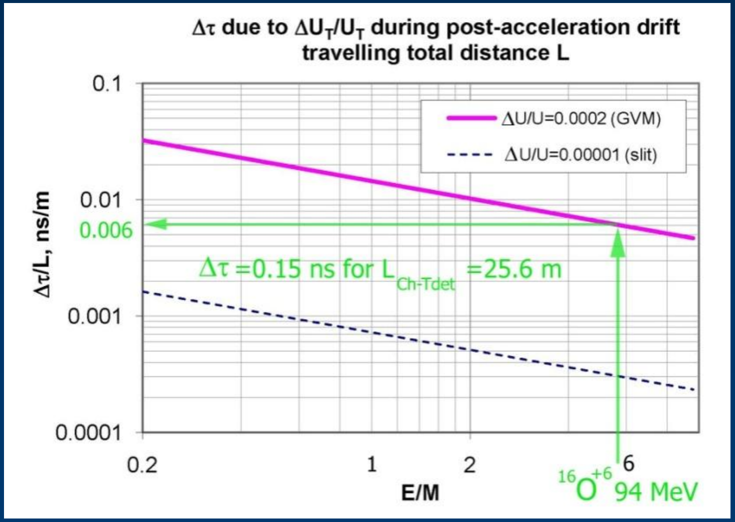


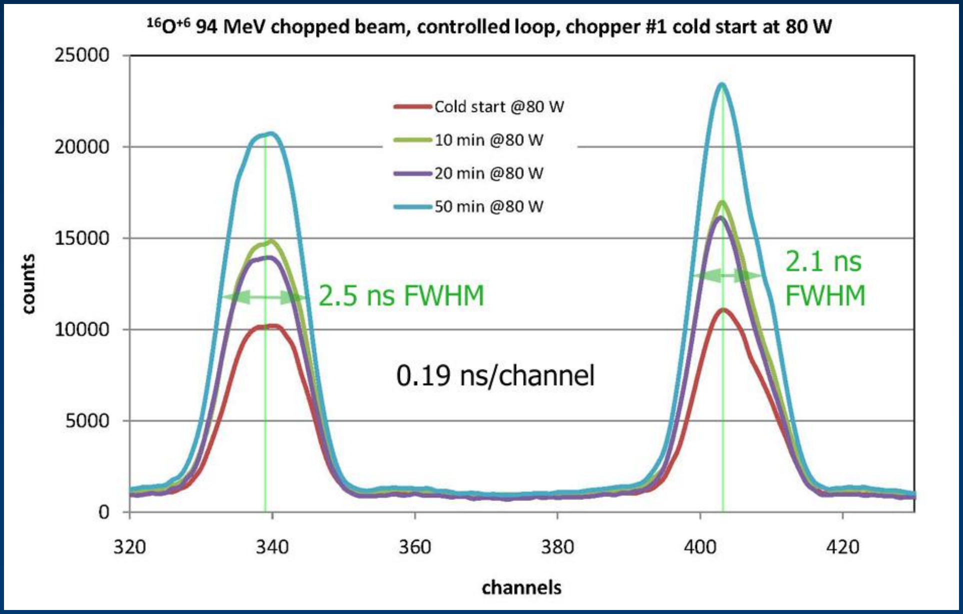




Chopping oxygen beam @80 W







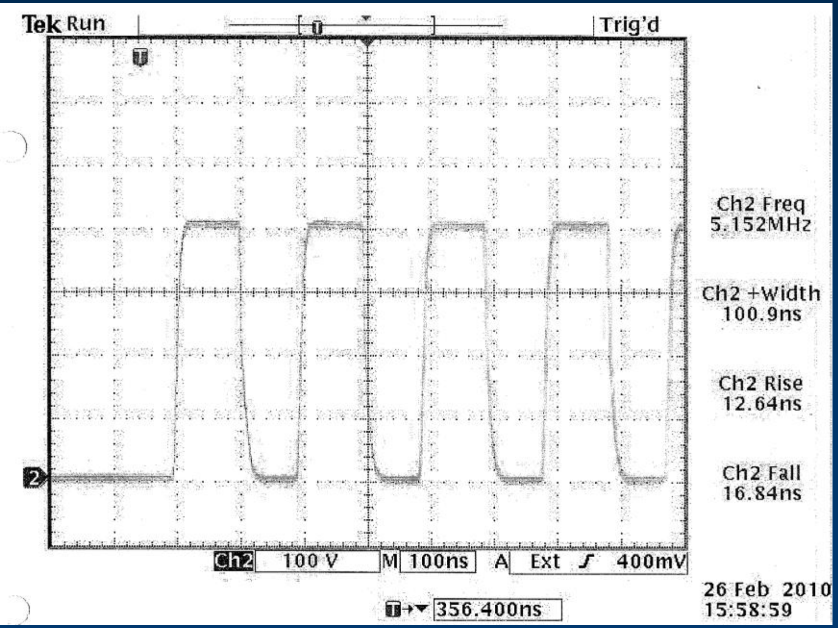
Beam pulsing development projects

- Improve the performance of the RT resonators and phase detector
- Custom re-design of the complete rf electronics capable of phase and amplitude locking for 3-frequency buncher and choppers
- Upgrade slow chopper electronics
- Develop 150 MHz room temperature superbuncher with the aim of improving time resolution from ~1 ns to ~ 0.1 ns

Upgrade slow chopper electronics

- Old system: concern about its life expectancy and duty factor limited to 25%
- Purchase of state-of –the art fast-switching power supply from FID GmbH
- Pulse amplitude 0 to 400 V; pulse/pause width 100 ns to ∞
- Repetition rate 0 to 5 MHz; rise/fall < 20 ns;
- duty factor 50%

Slow chopper test of 26th Feb 2010 100 ns per div; Specs have been met



Commissioning is expected in couple of months, still sorting out problems with power supply

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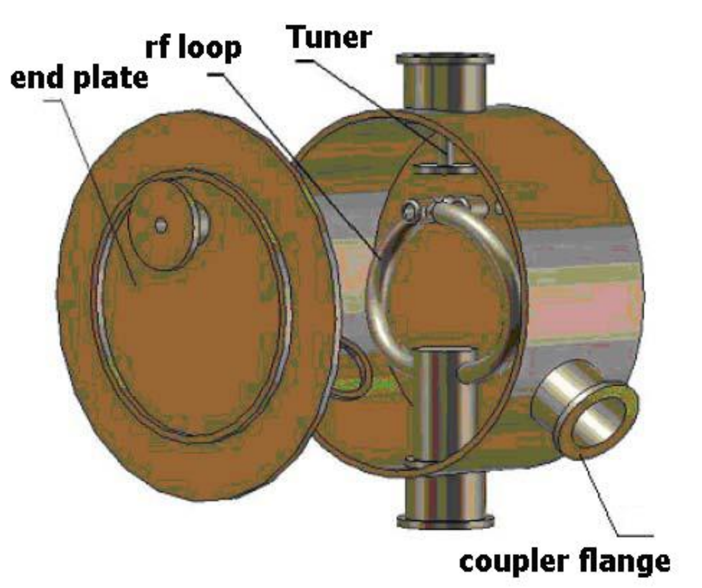
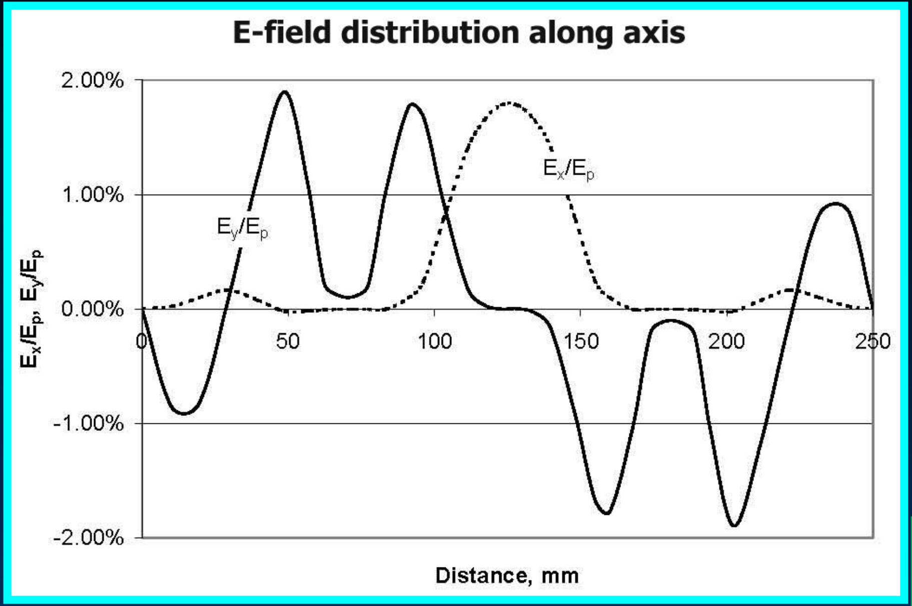
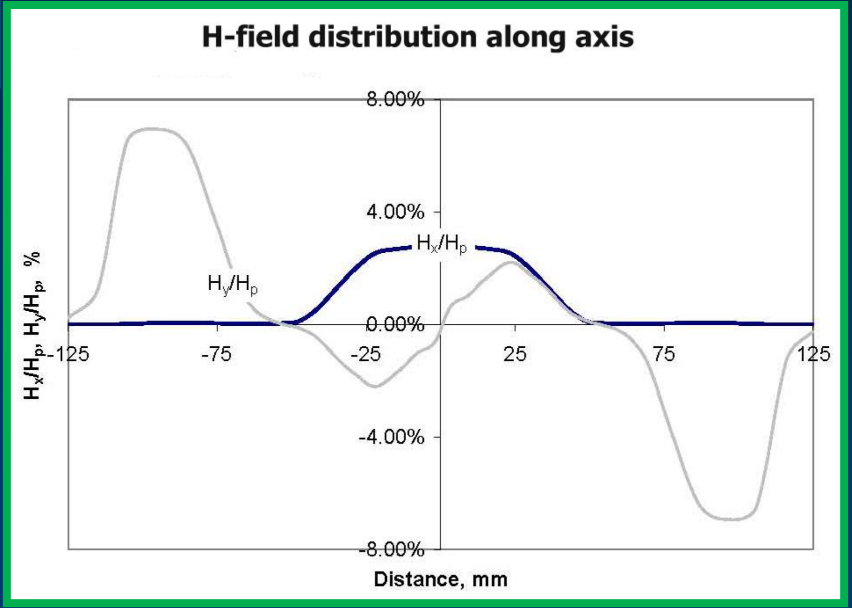


Symbol	Value	Units
F_0 (in vacuum)	149.986	MHz
ΔF	0.9	MHz
β_0	10.0	%
U_{eff}	220	kV
L_0	<220	mm
D_0	20	mm
E_p	16	MV/m
Q_0	>4800	
P_0	<8.0	kW

Beam steering

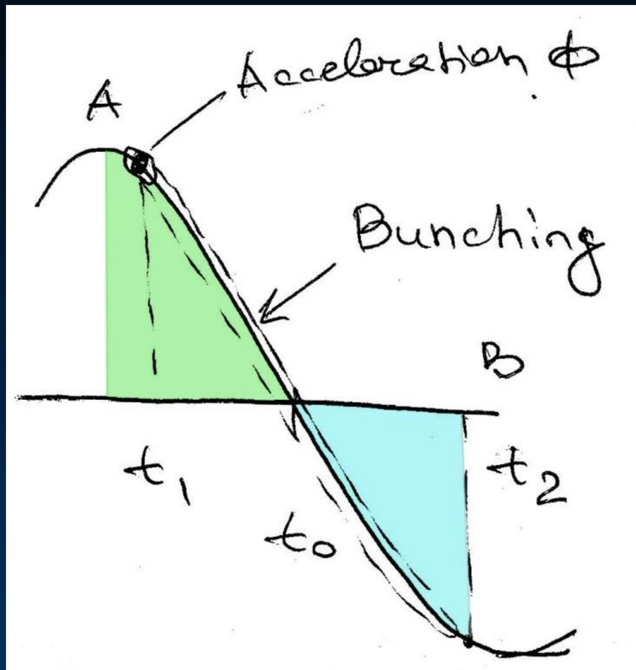


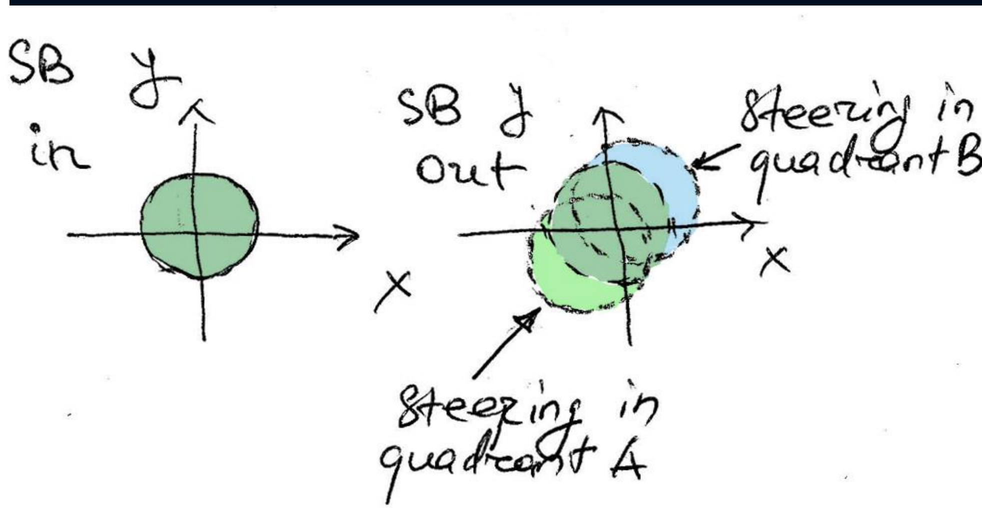
The horizontal steering due to E_x mostly in inner gap. Weak vertical steering due to cancellation E_y.

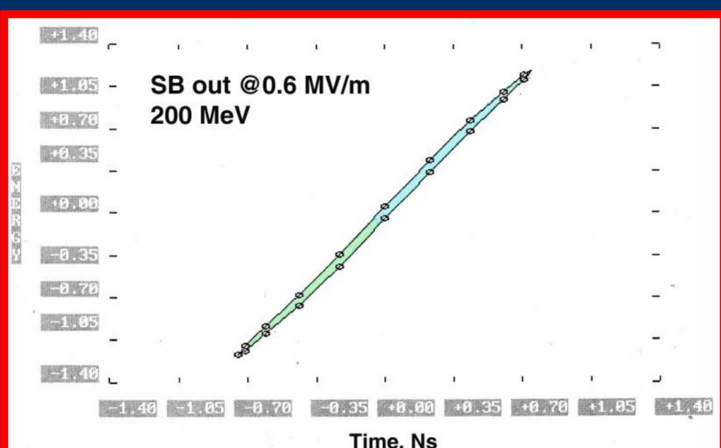


The vertical steering due to H_x mostly in inner gap. Weak horizontal steering due to cancellation H_y.

More on beam steering



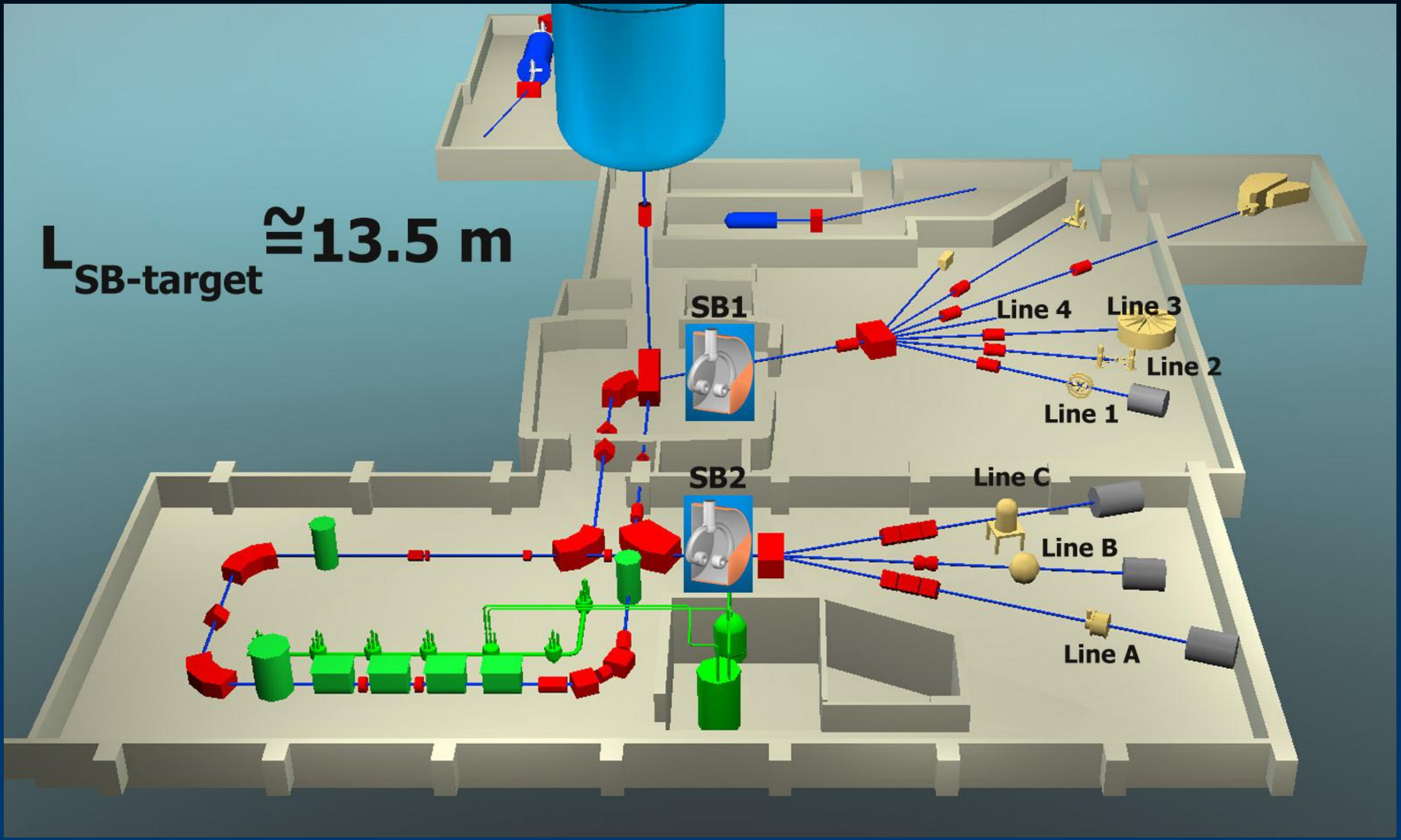




Electromagnetic steering is a function of rf phase and couples longitudinal and transverse motion. The beam steering and increase of its transverse dimension during bunching is much stronger than during acceleration since it happens over 90 degrees range of phase variation.

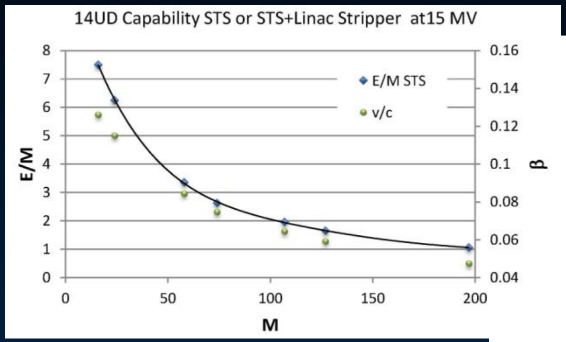
The longitudinal phase ellipse will be also affected in complicated way

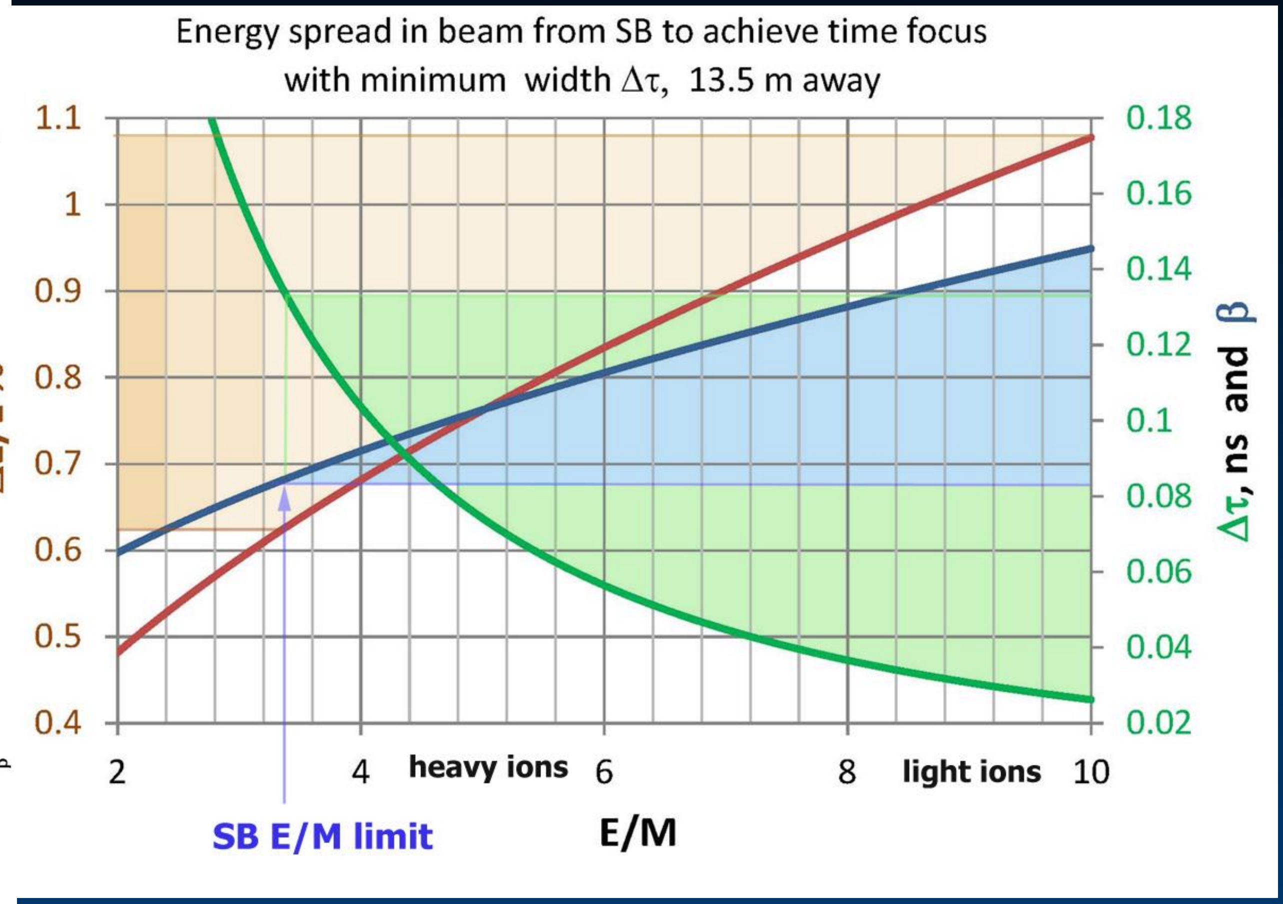
Bunching 14UD beam with HEB

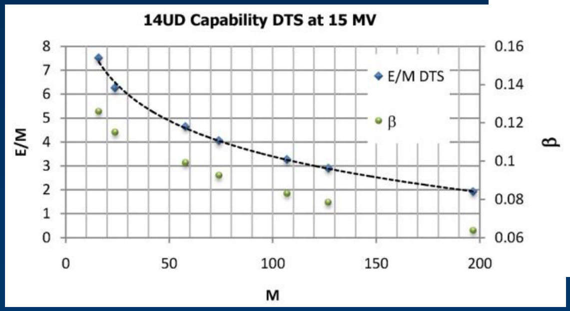


Develop 150 MHz room temperature superbuncher with the aim of improving time resolution from ~1 ns achieved with LE pulser to ~ 0.1 ns

Bunching 14UD beam







Assumed ε_z~0.9π (keV x ns)/M. It takes into account straggling in the strippers, foils thickness variation but NOT terminal voltage stability. $\Delta\tau$~0.13 ns is feasible for heavy ions. Maximum relative energy spread $\Delta E/E$=1% is required for light ions.

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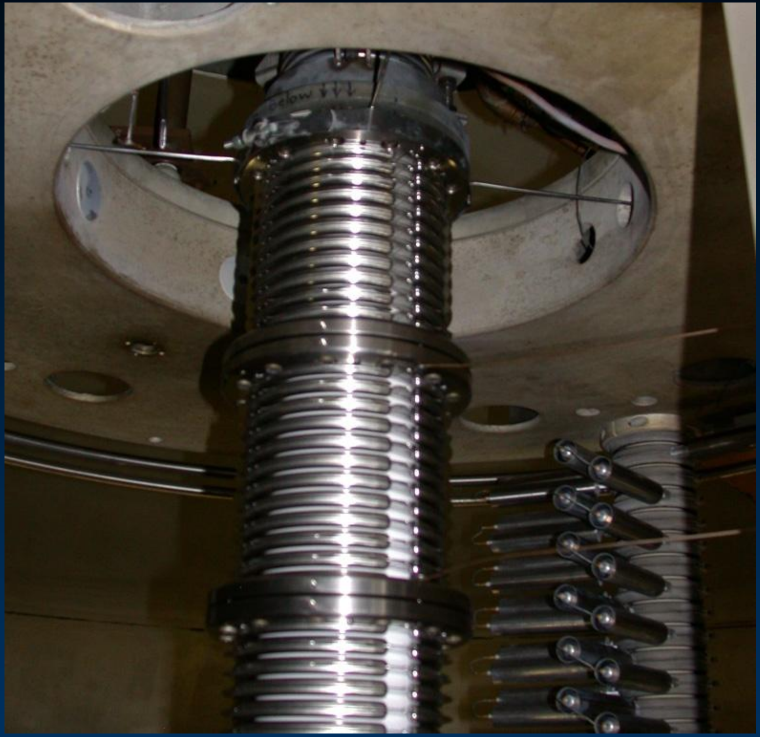
Accelerator tubes upgrade



New high precision tubes, TO#113 July 2010

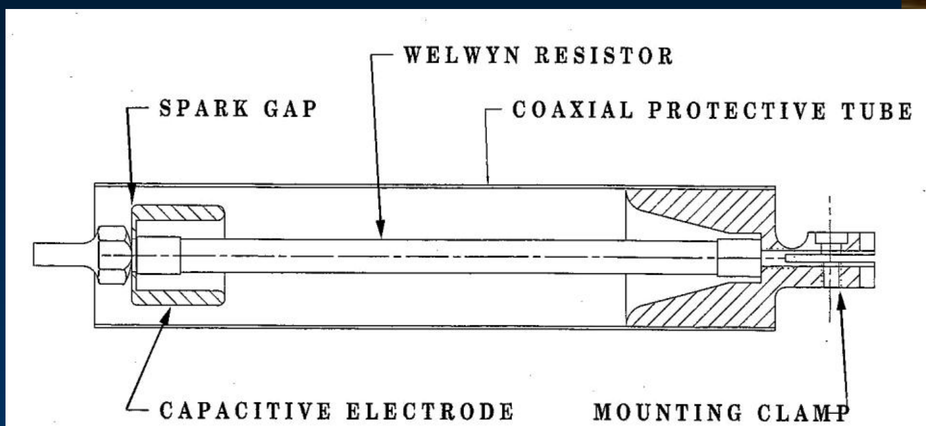
Alistair Muirhead and Justin Heighway assemble tubes in clean room July 2010

14UD enhancement projects:

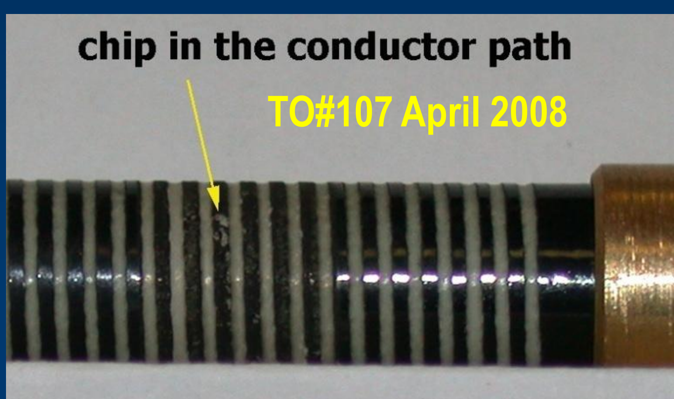
Six high precision accelerator tubes (TO#113). Resulted in more consistent transmission. Bias control is being installed in the low energy entrance of 14UD in order to reduce beam losses and the need for installing shorting rods

Accelerator posts and resistors

Aug 2011 spare resistors for tubes and posts have been ordered from Welwyn



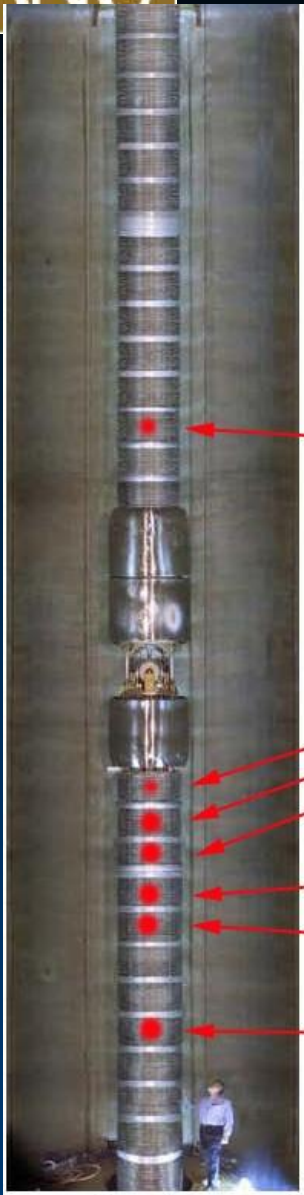
Failed Resistor in Unit 1 , Tube 4, Gap 8



In situ Resistance Test at 30 kV

Jul 2010: 7 out of 210 resistors had resistance degraded above specified 2% tolerance

Refurbishment and replacement 14UD posts



● post replacement required

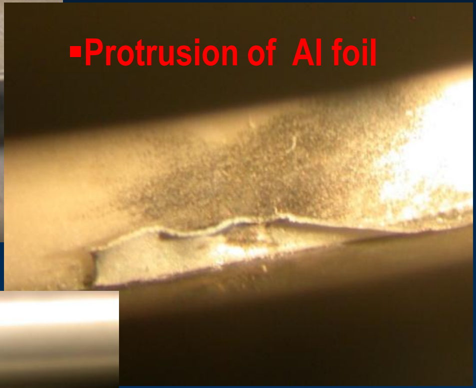
Unit#1	Epoxy/ Aluminium
Unit#2	Epoxy/ Aluminium
Unit#3	Epoxy/ Aluminium
Unit#4	Epoxy/Aluminium
Unit#5	Stainless Steel
Unit#6	Stainless Steel
LE MID-SECTION	
Unit#7	Stainless Steel
Unit#8	Stainless Steel
Unit#9	Stainless Steel
Unit#10	Epoxy/ Aluminium
Unit#11	Stainless Steel
Unit#12	Epoxy/ Aluminium
Unit#13	Stainless Steel
Unit#14	NEC Aluminium with Titanium skirts
TERMINAL	
Unit #15	Epoxy/ Aluminium
Unit#16	Epoxy/ Aluminium
Unit#17	Epoxy/ Aluminium
HE MID-SECTION	
Unit#18	Epoxy/ Aluminium
Unit#19	Epoxy/ Aluminium
Unit#20	Stainless Steel
Unit#21	Stainless Steel
Unit#22	Epoxy/ Aluminium
Unit#23	One NEC Aluminium with Titanium skirt Three Stainless Steel
Unit#24	Stainless Steel
Unit#25	Stainless Steel
Unit#26	Stainless Steel
Unit#27	Stainless Steel
Unit#28	Stainless Steel

2nd generation posts installed in 80th

TO#112

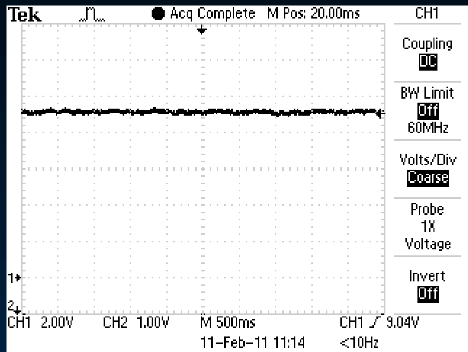
November 2009

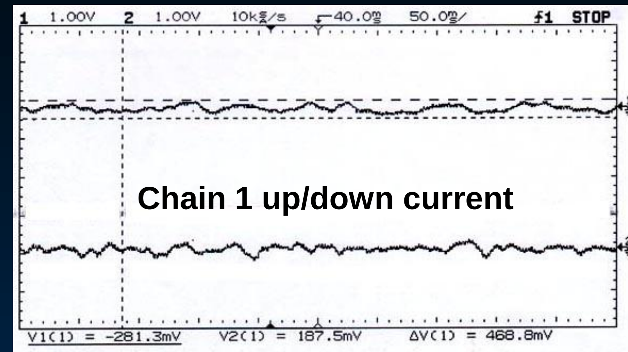
Deposit across 10th Gap, Post B, Unit 1

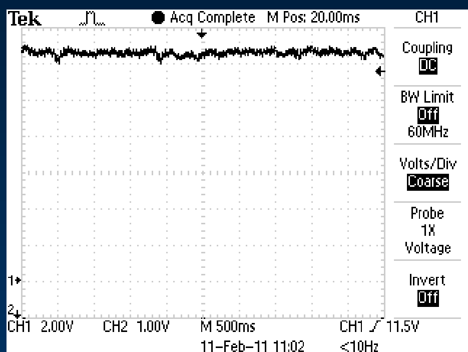


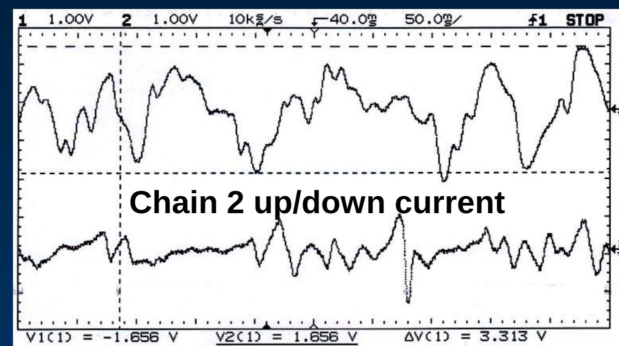
April 2011 Eight posts have been ordered from NEC

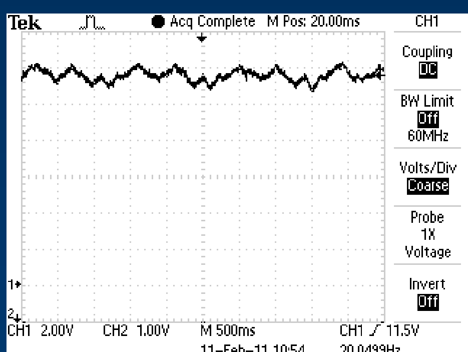
Charging system







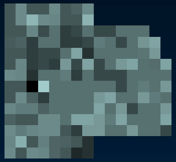




14UD enhancement:

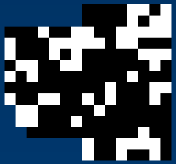
Improvement charging system through installation of the new charging chains and oil-free conductive wheels

Chain #3 oscillations

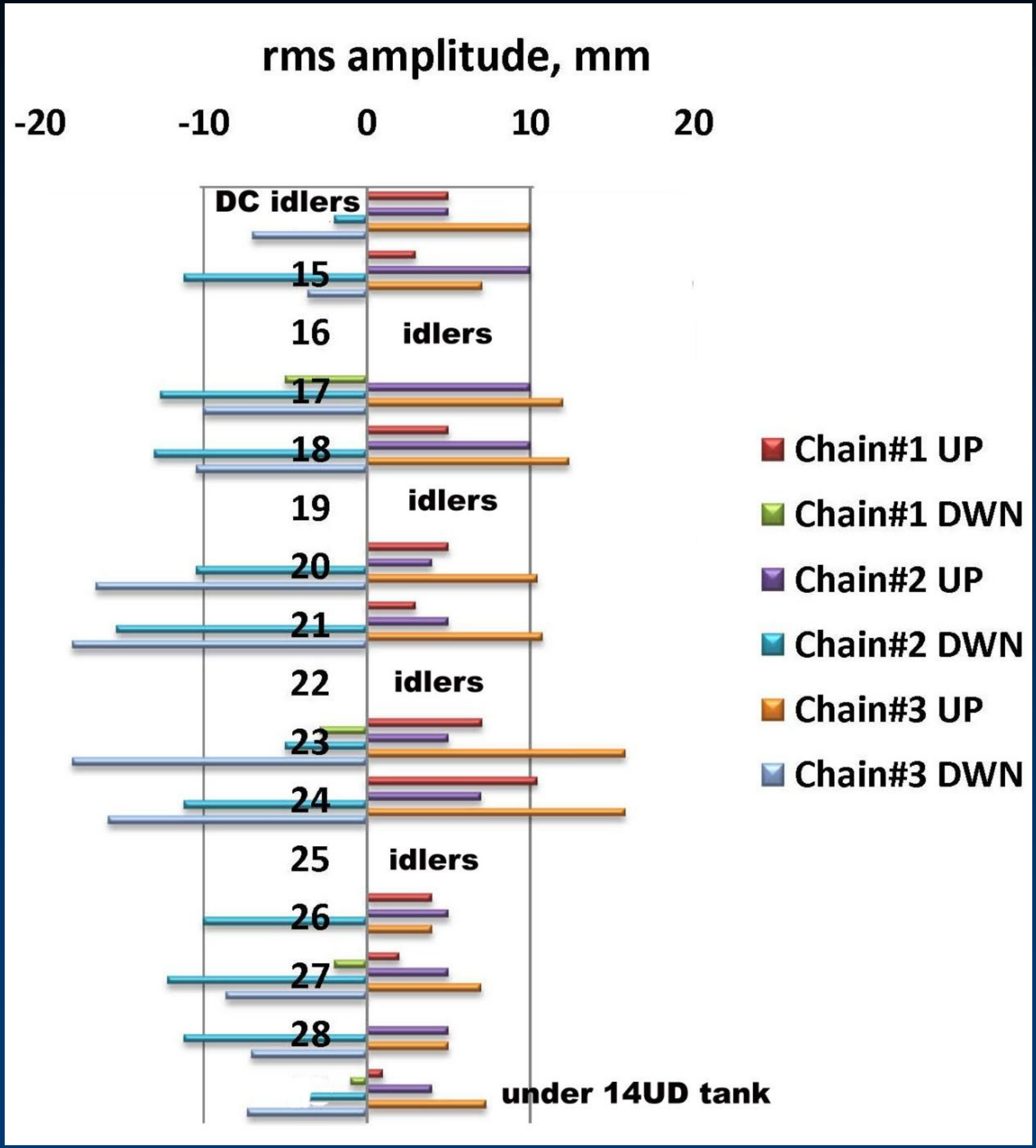


suppressor under tank

twist

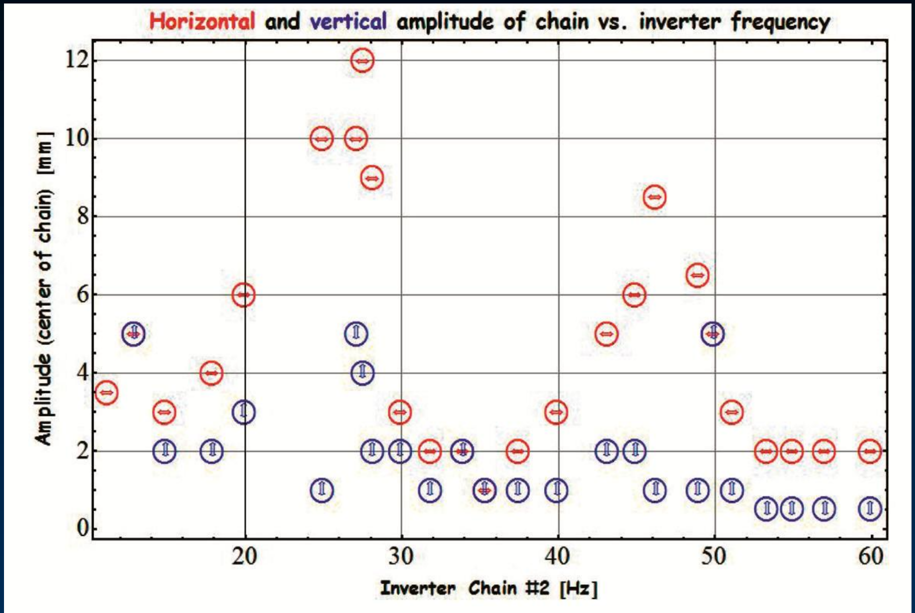


Unit #21 stiff



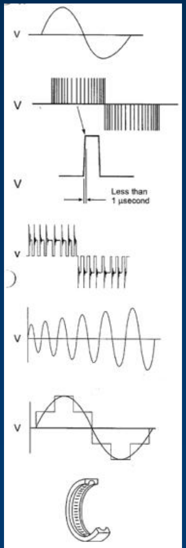
Damping chain oscillation

VERA has successfully demonstrated damping chain oscillation by controlling the chain speed with variable frequency inverter (Peter Steier, AMS Conference NZ 2010)

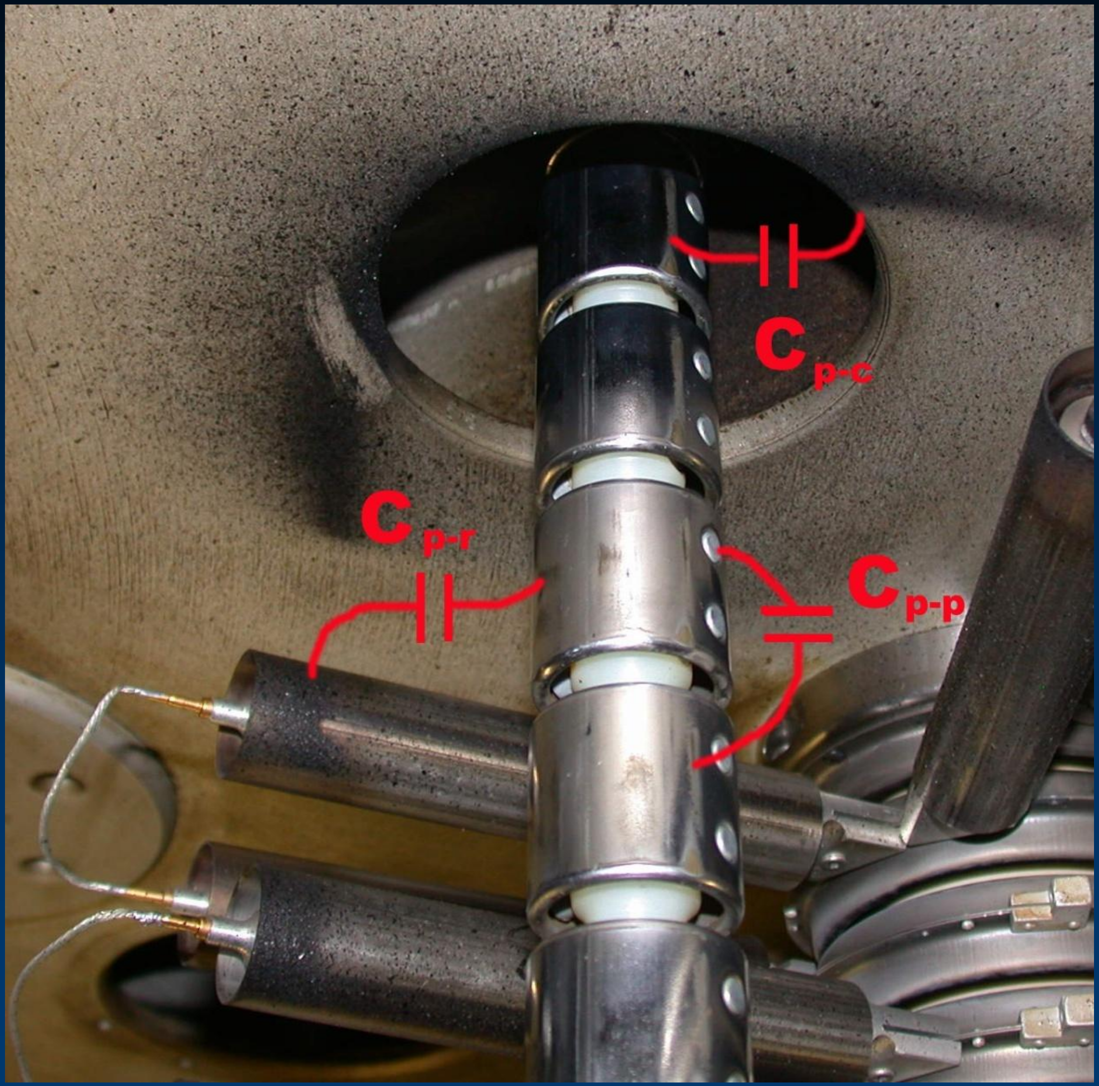


Few problems:

1. High frequency switching up to 20 kHz and short rise time can stress the motor insulation system;
2. Transient voltage spikes nearly twice as the DC bus can cause pin holes in the motor's insulation
3. Reflected wave voltage (standing wave) at long distances between motor and inverter
4. Additional heat in the windings because waveform is not sine
5. Switching and transient spikes build up high frequency voltage between rotor and stator. It is dissipated by arcing through the ball bearings.



Oscillations disturb uniform voltage distribution



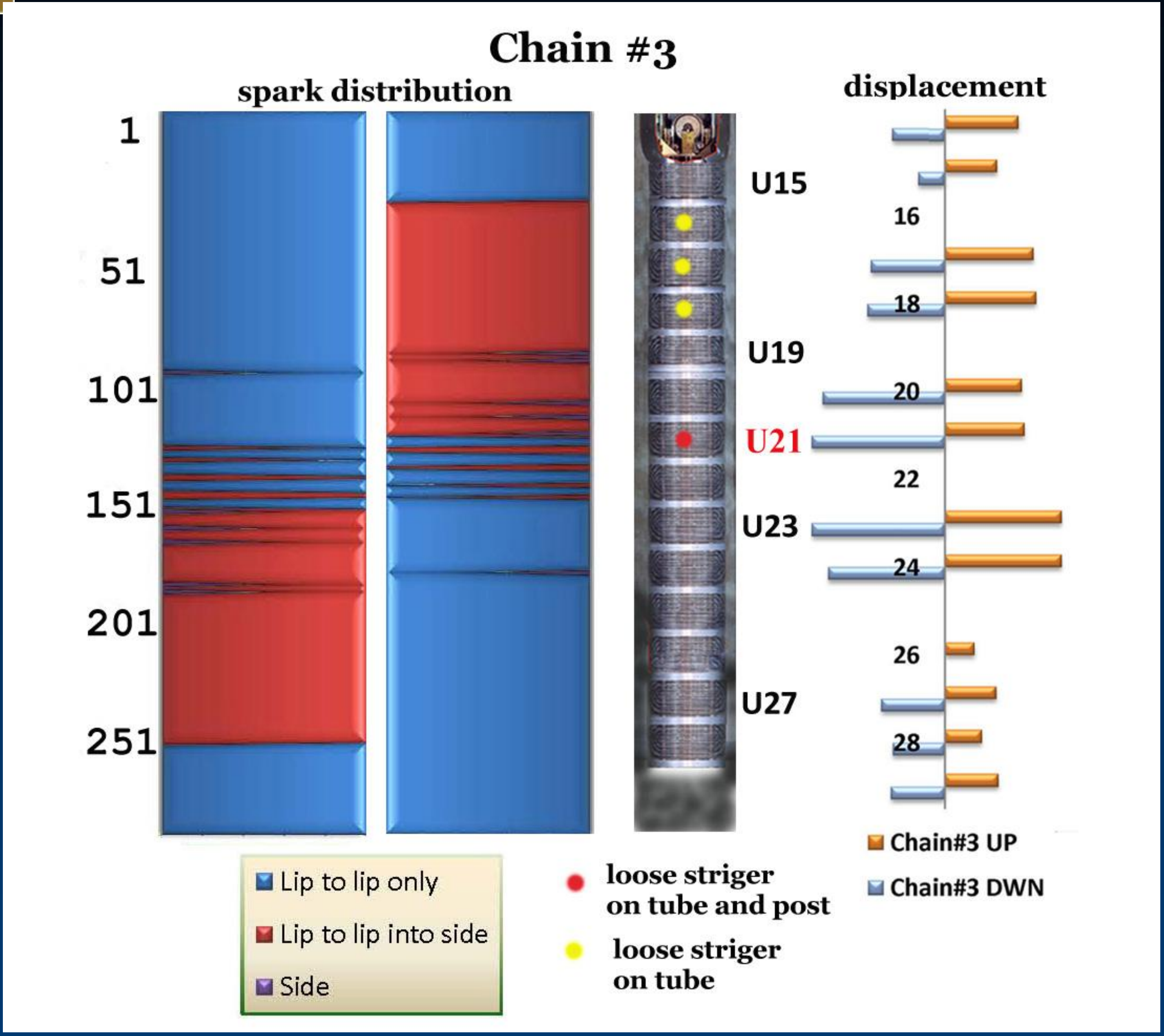
- Chain is capacitive divider with
~55 kV/pellet @15 MV

- Chain #3 is special:
A. Mechanically noisy
B. Close proximity to resistors

Therefore it is more likely to initiate sparking

- Also in the past petals replaced with 2-1/8" inside diameter rather than 1-7/8" see TOR72

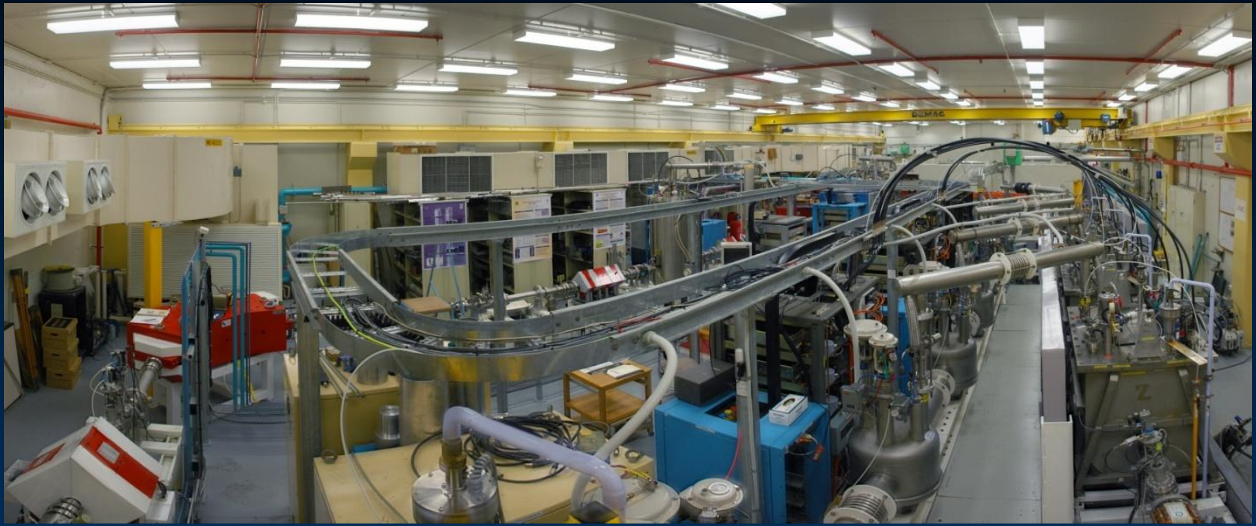
Distribution of spark marks in Chain #3

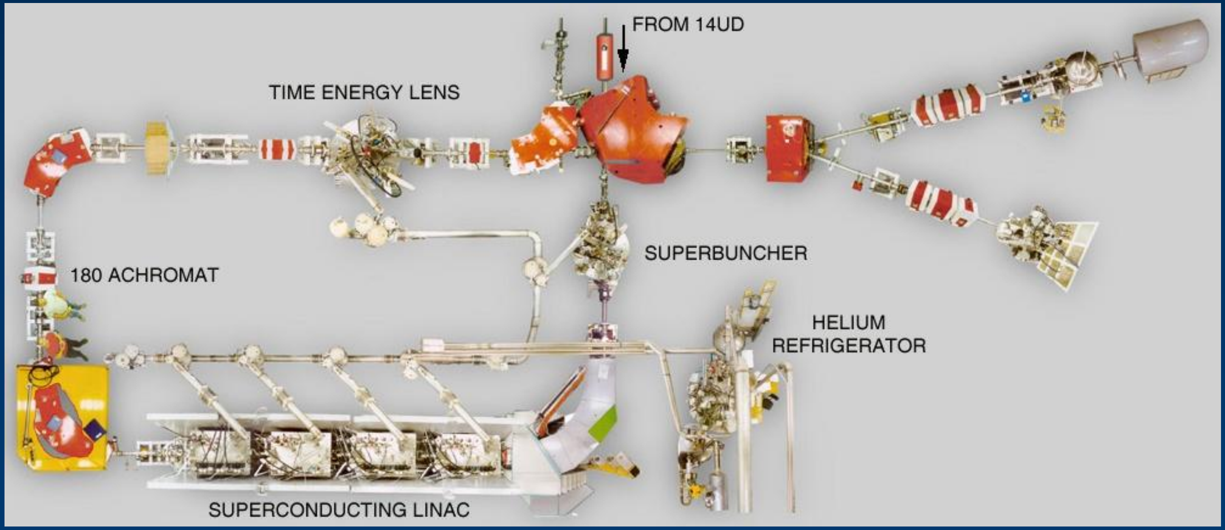


Spark damage of new Ni-plated chain

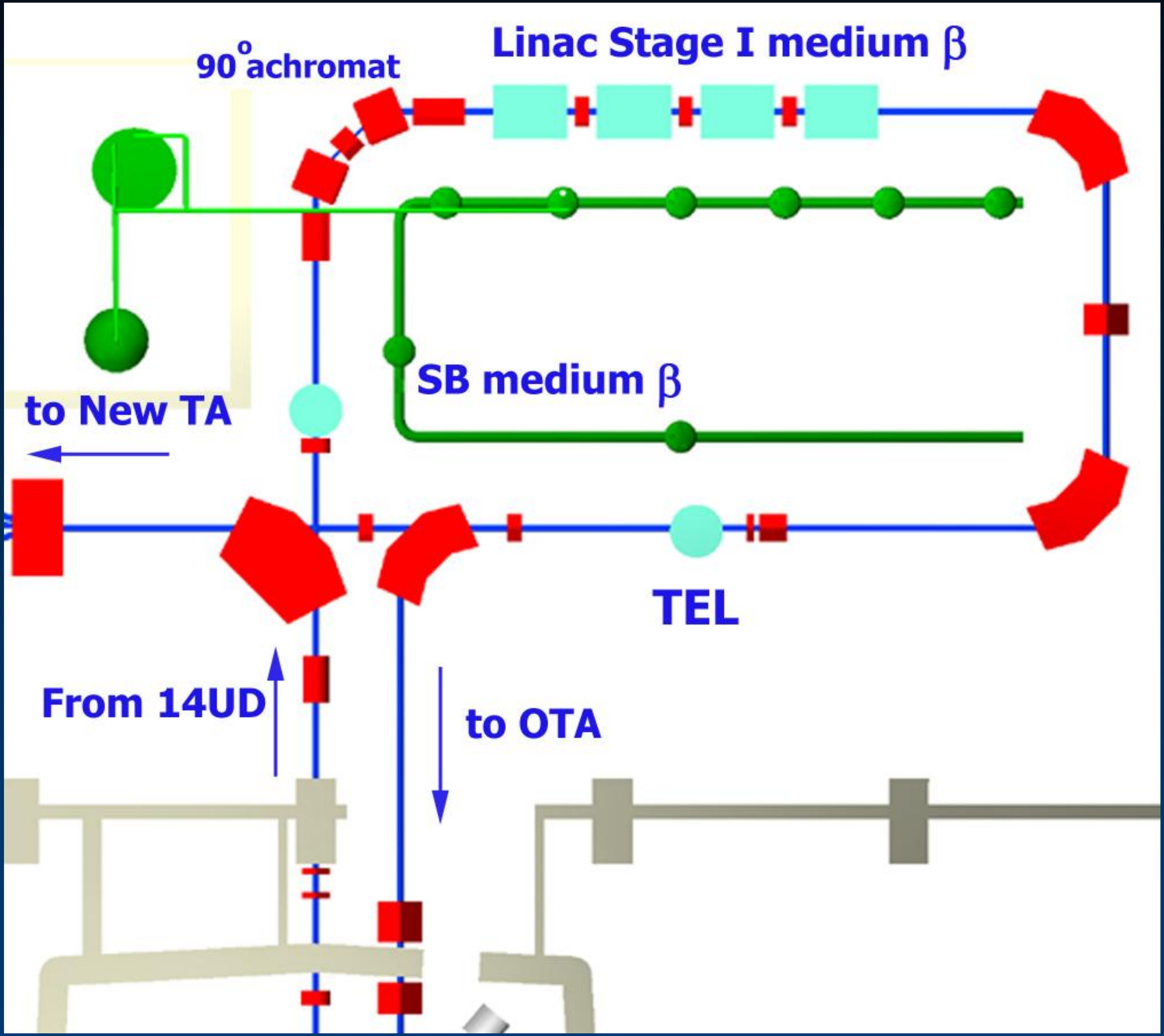
- New in TO#113, 6/2010, 1.366khours
- Significant spark damage, lip to lip on chain #3
- NEC moved away from chrome plating due to high rejection rate
- Twisted when new, but better that Ch#2
- Put old chain #3 back into service. New chain retired.
- Another new Ni-plated chain #1 is still in service
- Awaiting resolution RE: chrome-plated chain from NEC

Superconducting Linac-booster

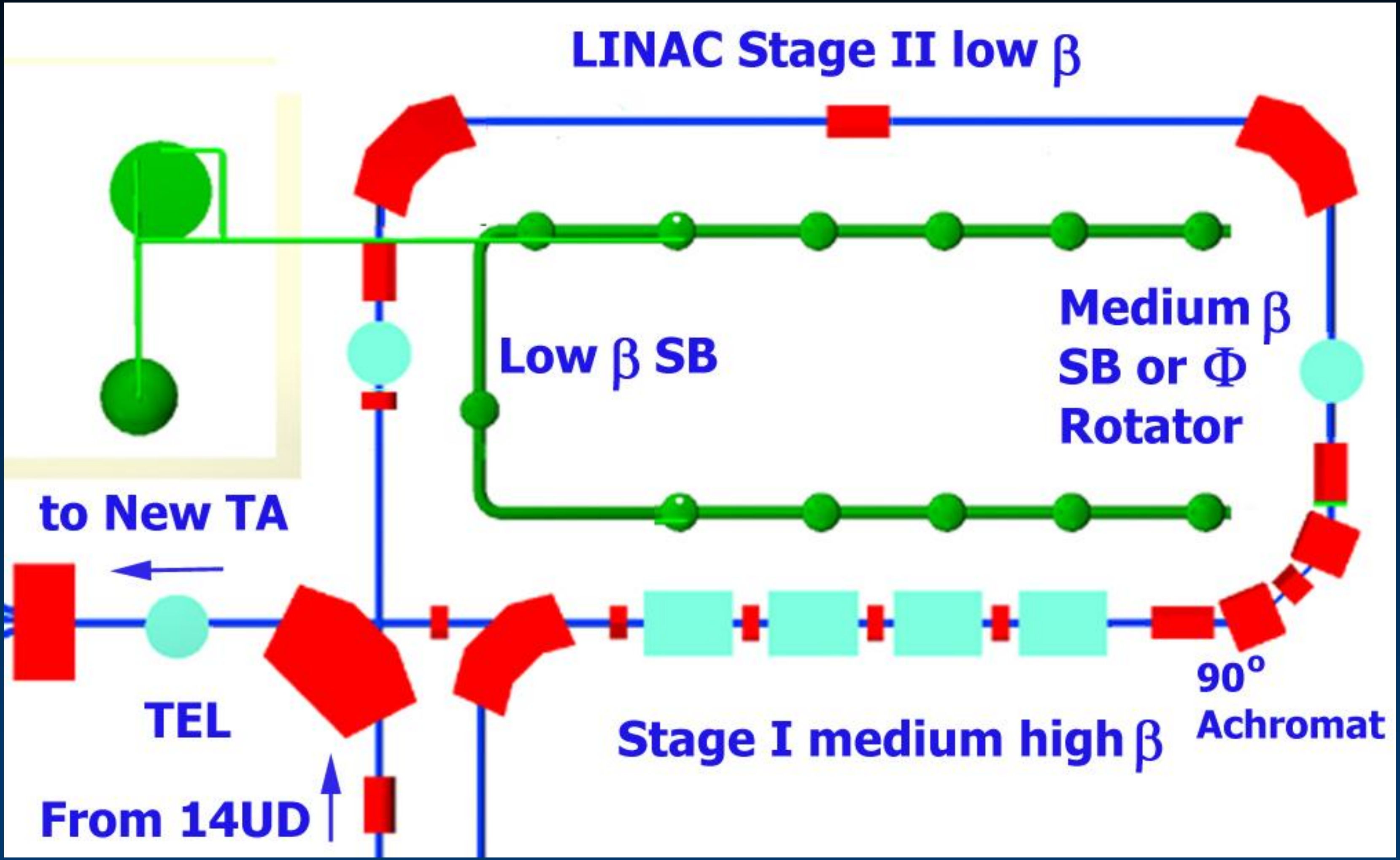




Current Linac configuration

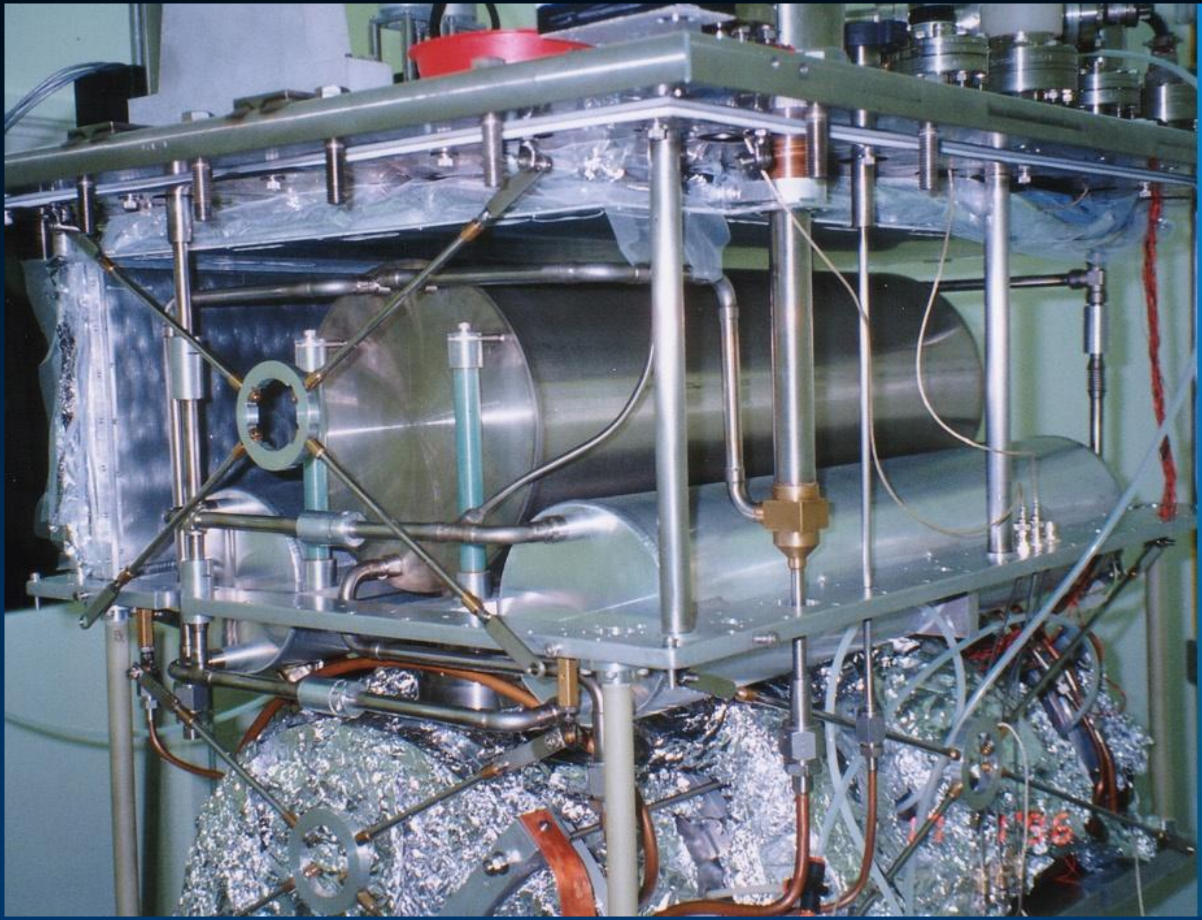


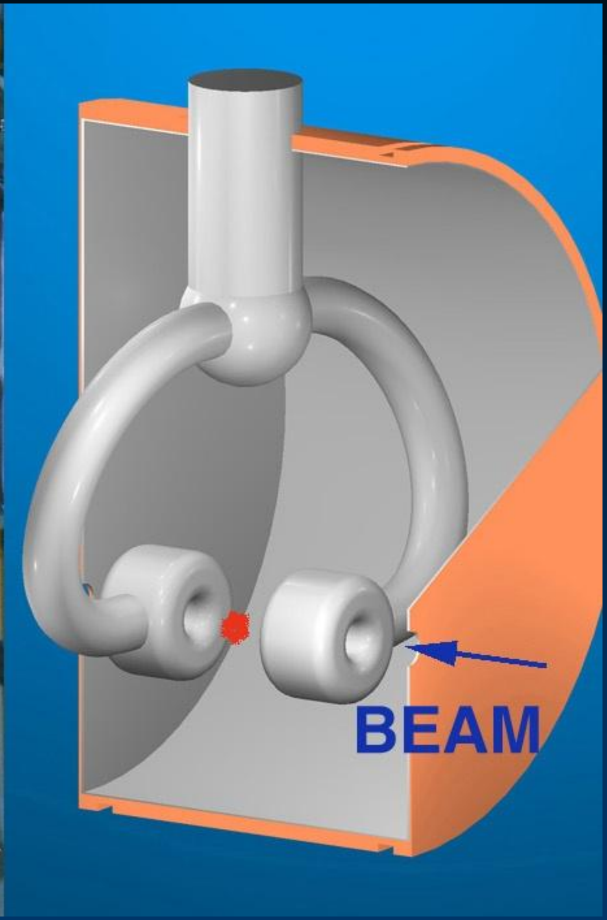
Working backward approach



start at the end and work toward beginning

Module cryostat with 3 split-loop resonators





Linac development projects:

Add new tall cryostat with four Nb resonators guiding for future project to replace all Pb resonators with Nb

Vendors has been identified (TRIUMF and INFN) but project was cancelled due to lock of funds

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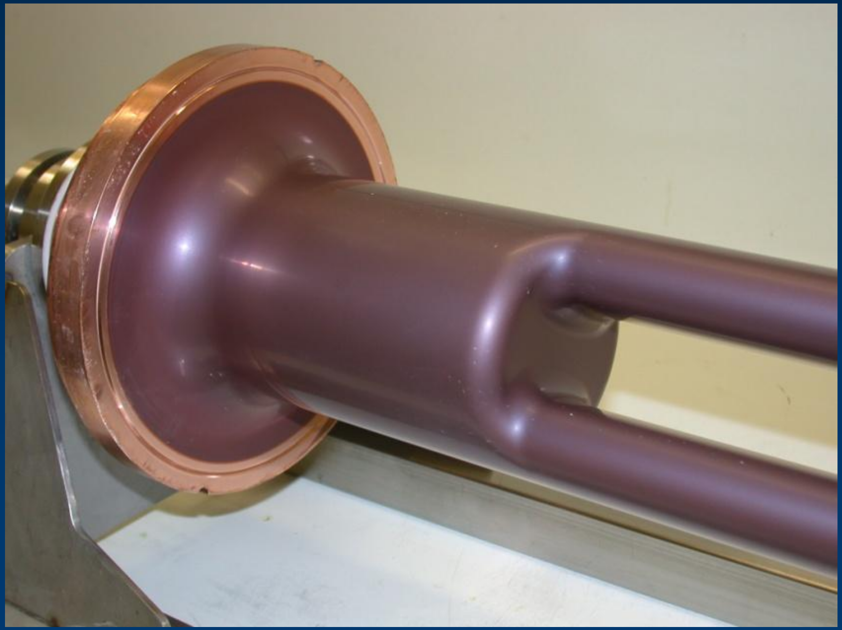
Surface treatment

tumbling



degreasing

Electropolishing copper substrate

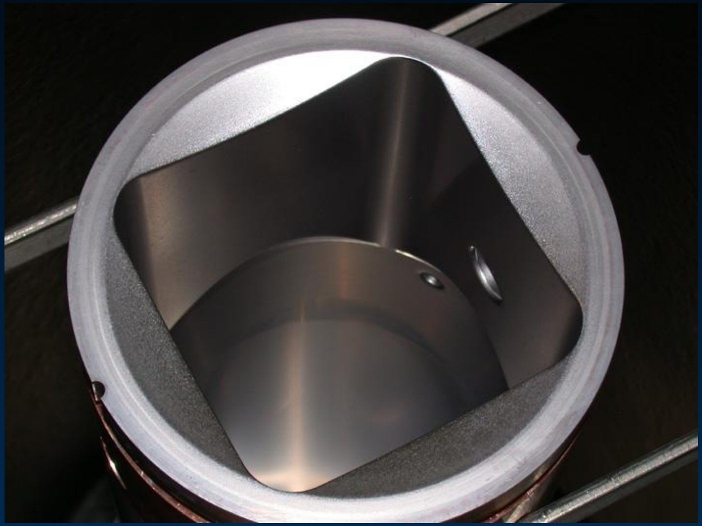
Thin film coating laboratory

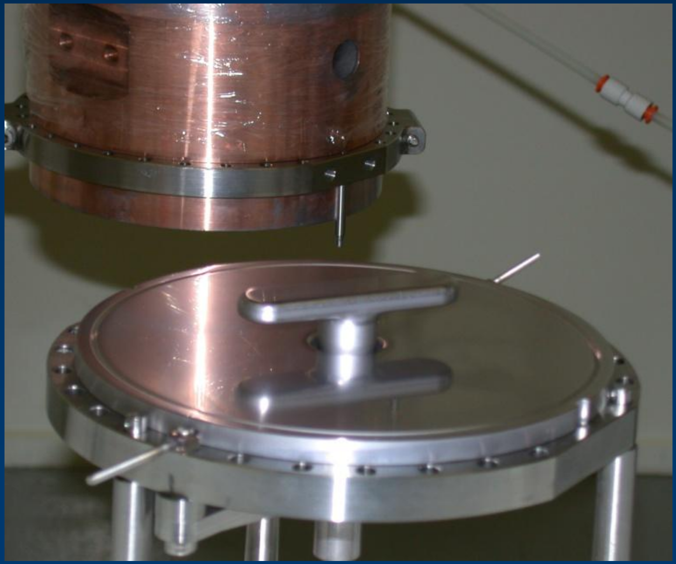
PbSn plating

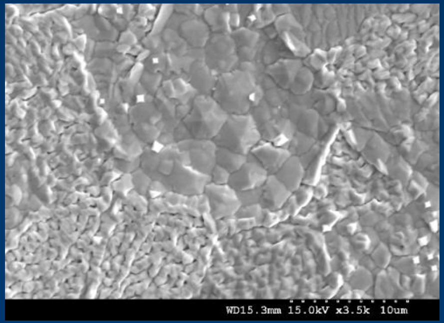
high pressure rinsing

GN_2 drying

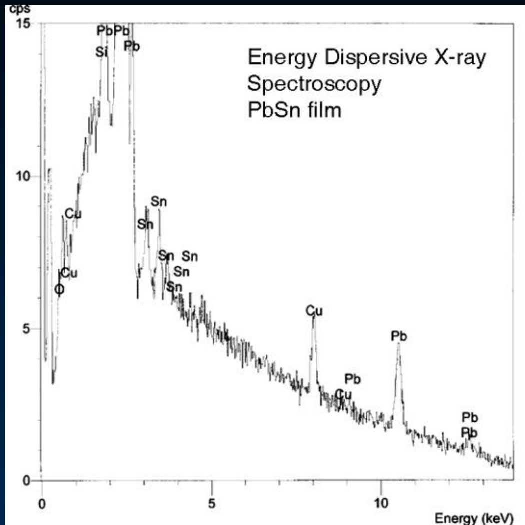
Electroplating twin-stub resonator

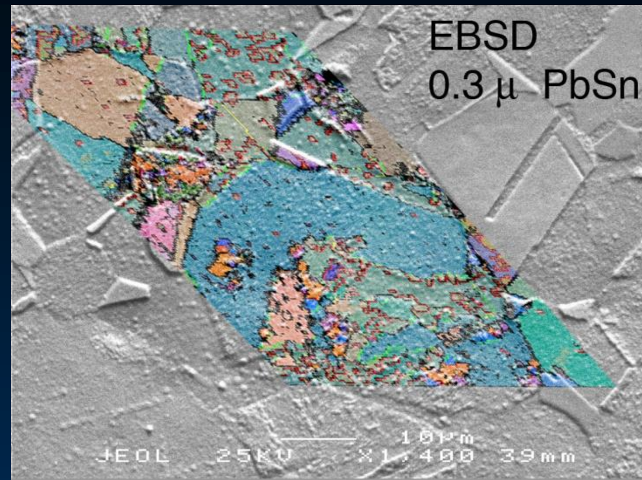


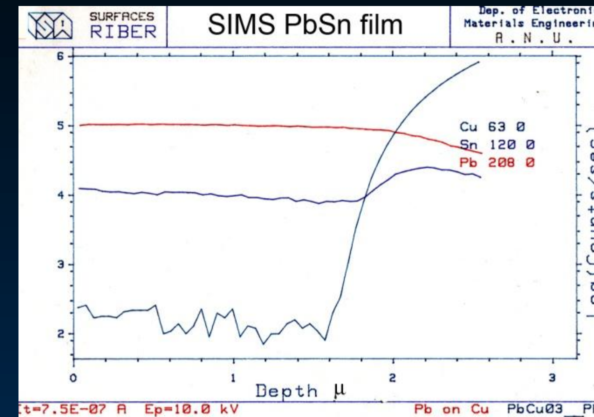


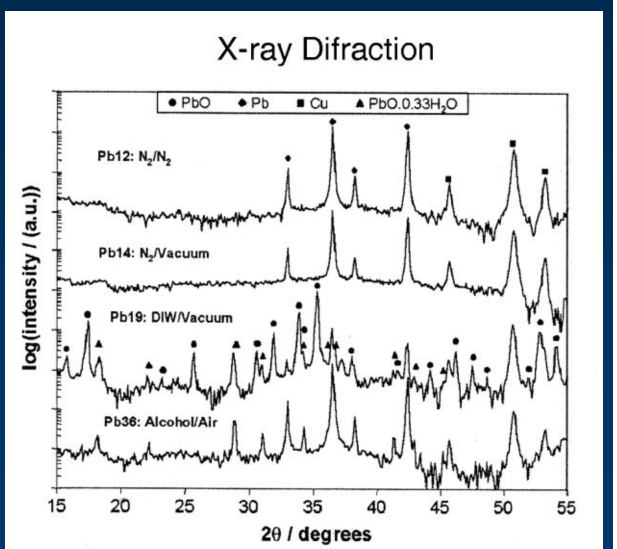


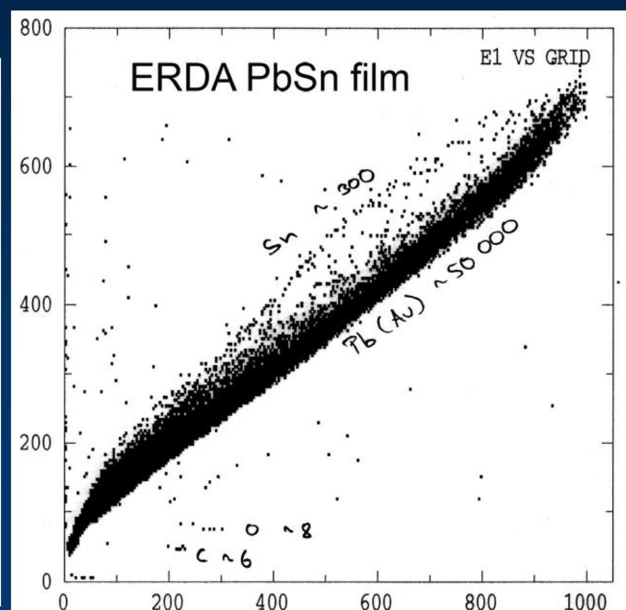
Characterization of thin films

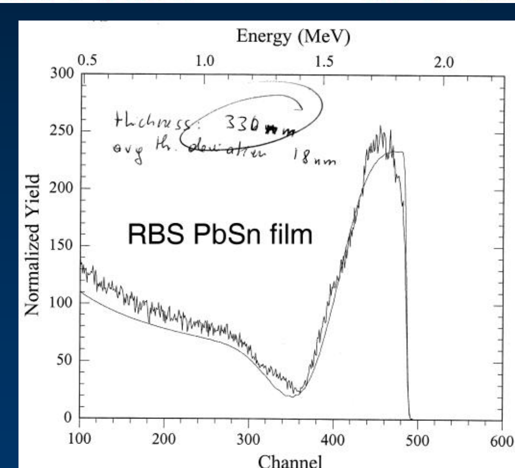


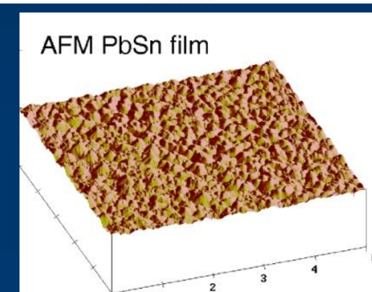








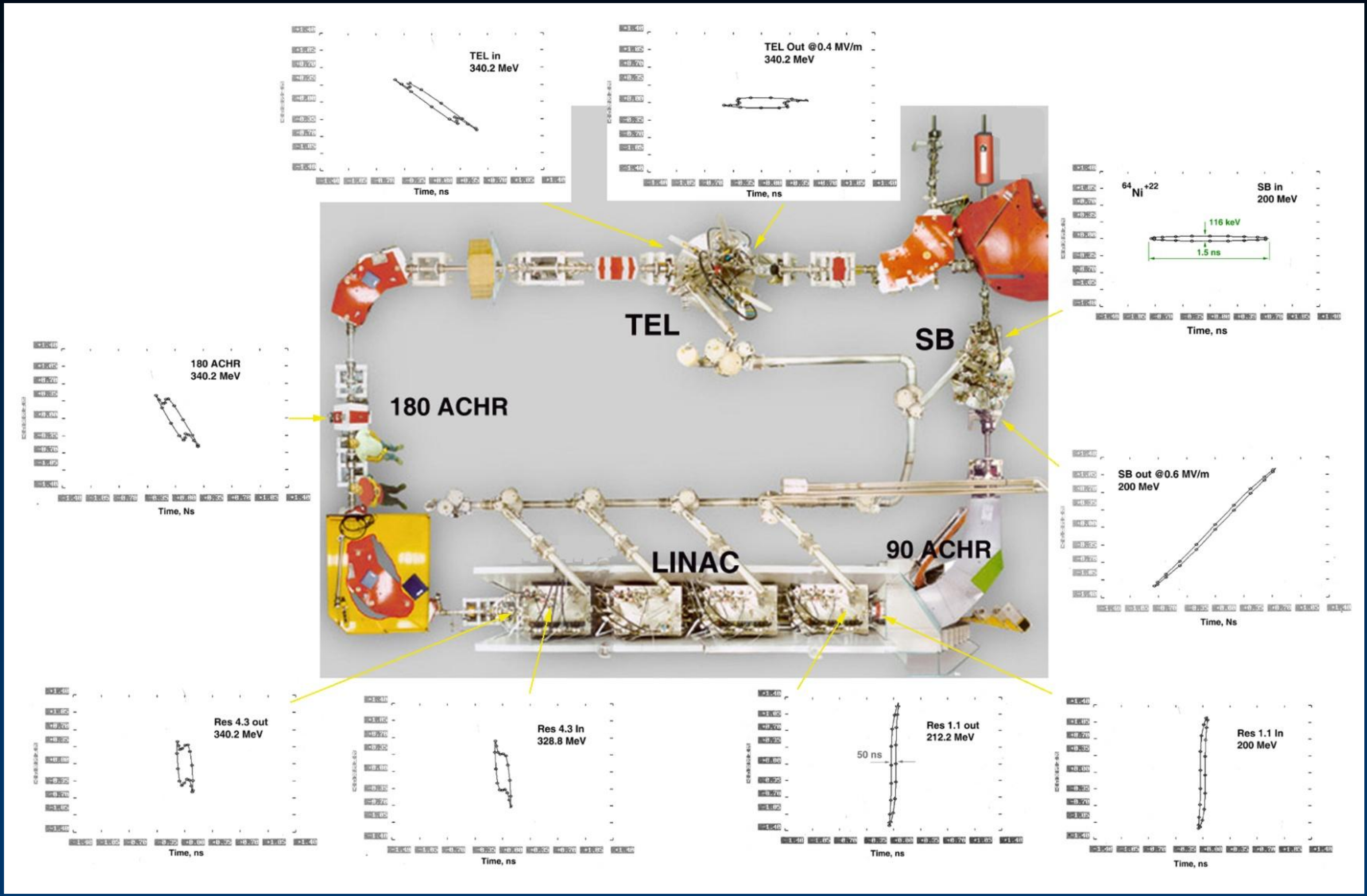




Clean room assembly facilities class ~500

assembling SLR and module cryostat

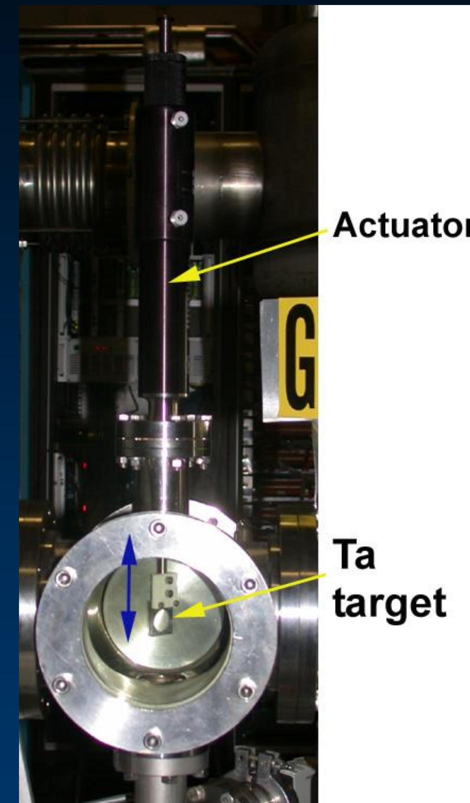
SPACE code: tracing longitudinal phase ellipse



Linac enhancement:

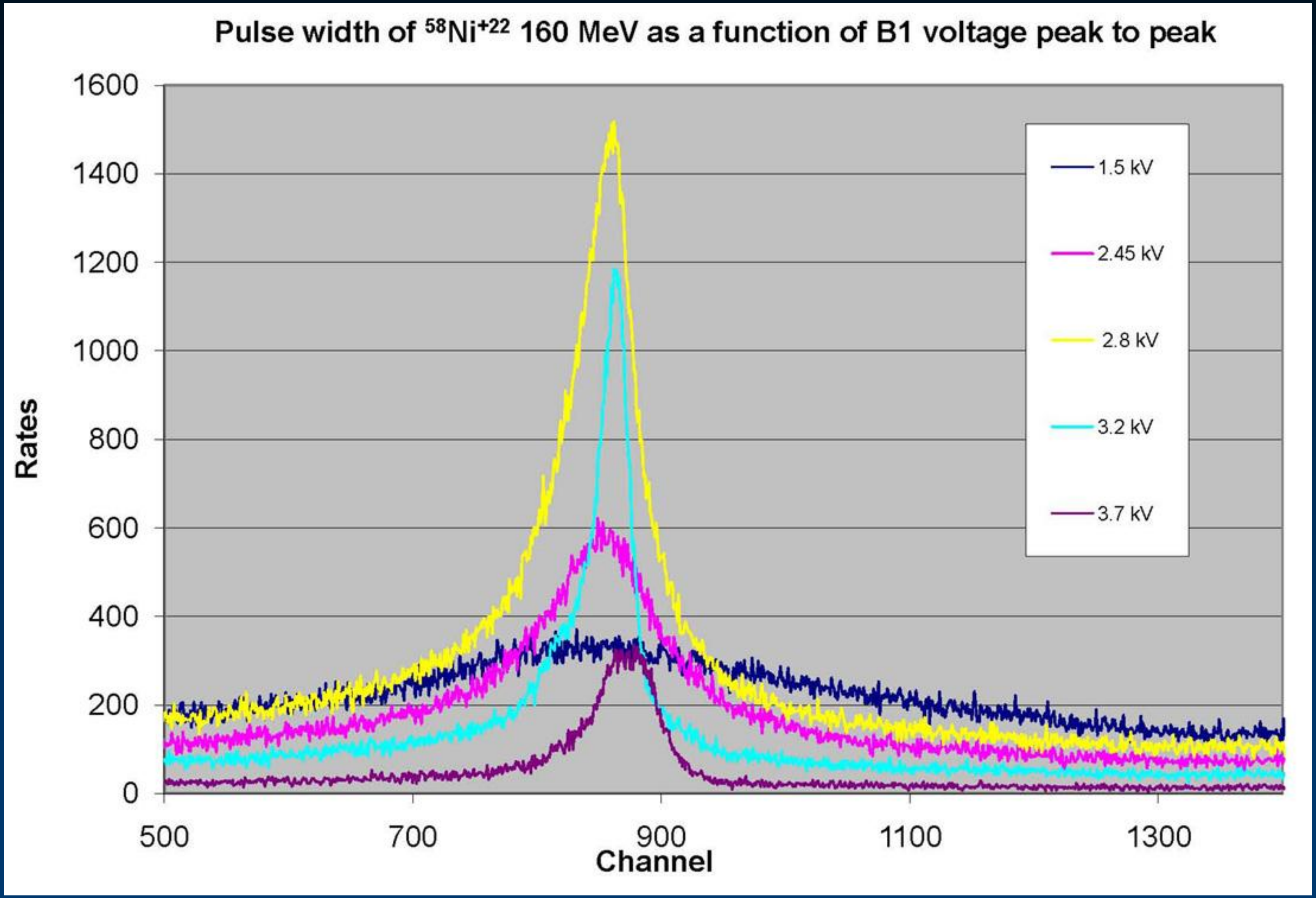
Implementation measurement of the time-structure of the beam from the Linac based on LiF2 detector and fast FC. Low beam intensity diagnostics with improved BPM

Beam time structure measurement

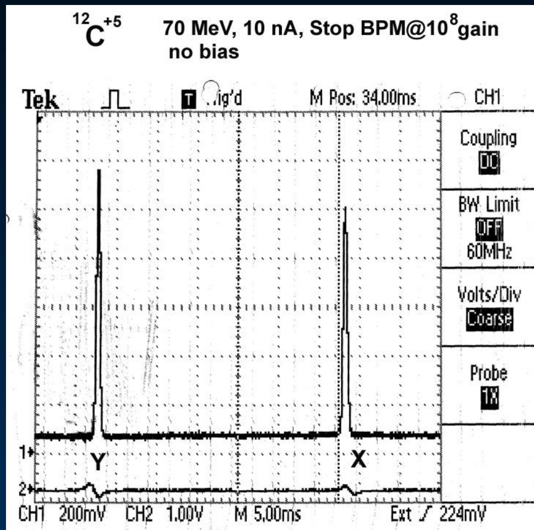


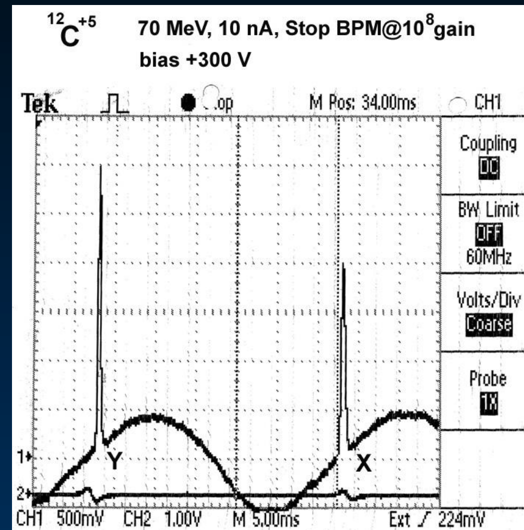
- LiF_2 scintillation detector SCIONIX, energy resolution at 662 keV<11% FWHM
- ORTEC: Time to Amplitude Converter Single Channel Analyzer, Constant Fraction Discriminator; Expected time resolution 0.5 ns

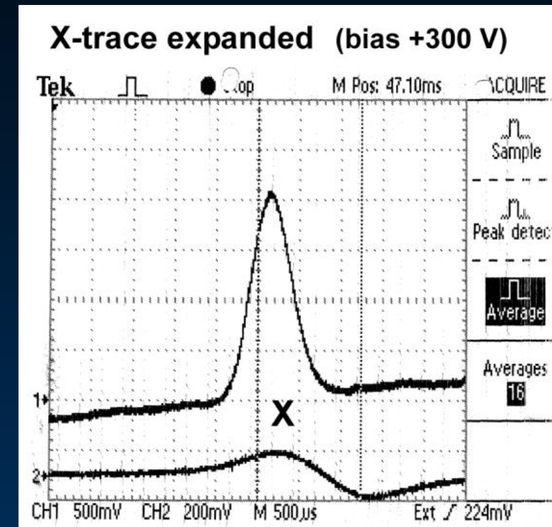
Pulse width measurement



High sensitivity BPM

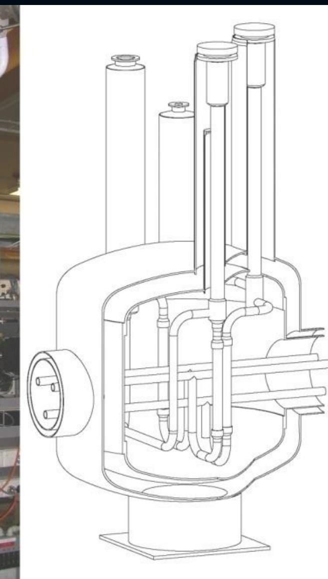


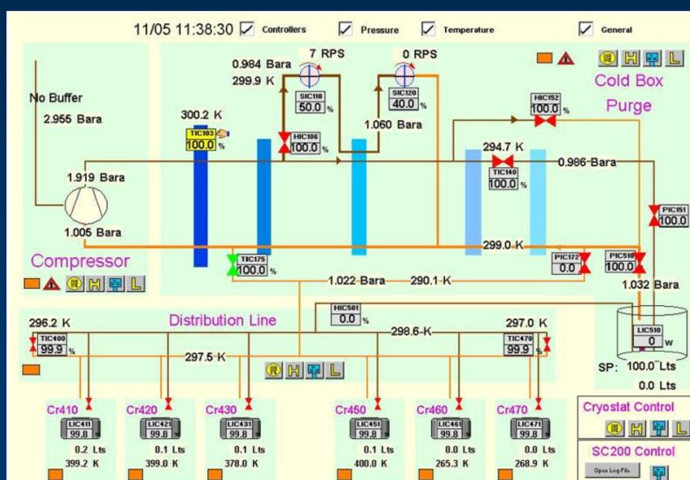


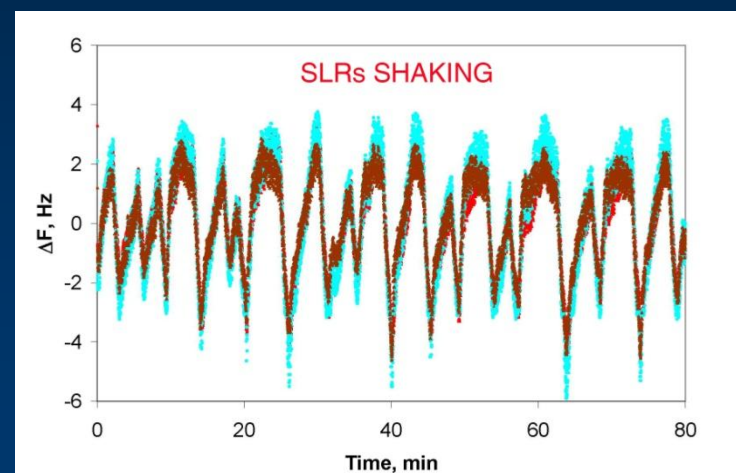


- Bias improved sensitivity as factor of 2.5;
- further improvement by using thicker (~1 mm diam) scanner wire and fitting additional shield around collector

Cryogenic system







Linac cryogenic system enhancement:
Addition of LN_2 pre-cooling to the liquid He plant to boost its cryogenic capability by 20%

Announcement

ACAS collaboration between ANU, UM, ANSTO and AS has been launched on 13th July 2010
http://epp.physics.unimelb.edu.au/ACAS

Conclusion

Facility Operation and Development Team is facing challenging tasks over the next 4 years.

Outlook

Education Investment Funding over the next 4 years will enhance computer control and data acquisition system, beam intensities and energies, 14UD accelerator, beam pulsing, AMS capabilities, Linac, beam-lines, RIB capability and Accelerator User Support

ANU

Acknowledgement

Motivated and skillful technical staff

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