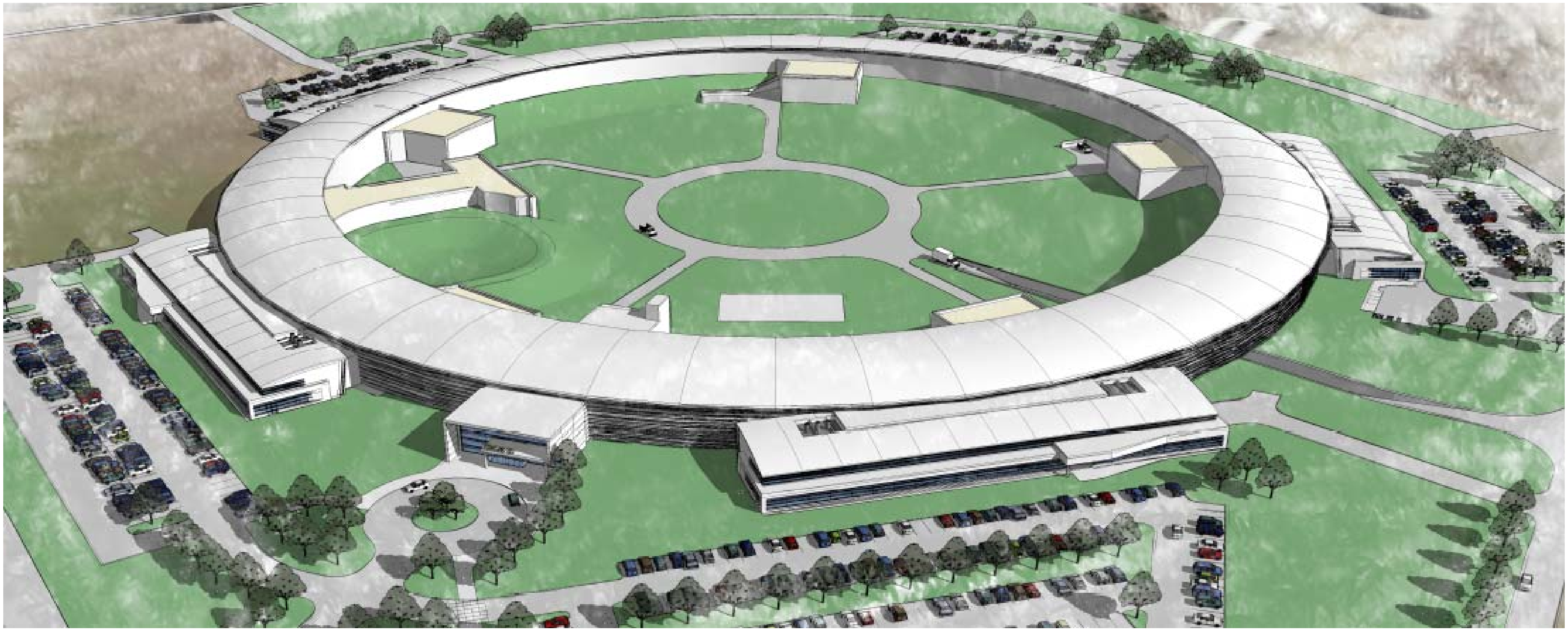
NSLS-II RF Systems



Jim Rose
For the RF Group
CWRF08 Workshop
March 26, 2008

Outline

- NSLS-II design approach
- RF specifications derived from user beam
- RF baseline design and options
- Booster RF baseline and options
- Window of opportunity for choices and strategic planning

NSLS-II Parameters

Energy	3.0 GeV	Energy Spread	0.094%
Circumference	792 m	RF Frequency	500 MHz
Number of Periods	30DBA	Harmonic Number	1320
Length Long Straights	6.6 & 9.3m	RF Bucket Height	3%
Emittance (h,v)	<1nm, 0.008nm	RMS Bunch Length	15ps
Momentum Compaction	.00037	Average Current	500ma
Dipole Bend Radius	25m	Current per Bunch	0.5ma
Energy Loss per Turn	<2MeV	Charge per Bunch	1.2nC

NSLS-II Design Approach

- Large circumference of 792m (soft bends) for low natural emittance, $\varepsilon_0 = 2.1$ nm
- 54 m of 1.8 T damping wigglers in zero dispersion straights to further reduce emmitance to ~0.5nm.

$$\frac{\varepsilon_w}{\varepsilon_0} = \frac{1+f}{1+\frac{L_w}{4\pi\rho_0}\left(\frac{\rho_0}{\rho_w}\right)^2} \qquad \frac{\delta_w}{\delta_0} = \sqrt{\frac{1+\frac{L_w}{2\pi\rho_0}\frac{4}{3\pi}\left(\frac{\rho_0}{\rho_w}\right)^3}{1+\frac{L_w}{4\pi\rho_0}\left(\frac{\rho_0}{\rho_w}\right)^2}}$$

Only 21 m of DW and ~1/4 RF power installed day one due to cost constraints

RF Phase, Energy Stability Requirements

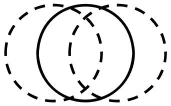
Guo et al, PAC 2007

$$\sigma_\delta = \sqrt{\frac{1}{2}\left(\frac{\Delta p}{p}\right)^2 + \sigma_{\delta,0}^2} = \sqrt{1+\frac{1}{2}f^2\sigma_{\delta,0}}$$

$$f = (\Delta p/p)/\sigma_{\delta,0}$$

$$\sigma_{y'}^2 = \frac{\lambda_n}{2L}\sqrt{1+16n^2N_w^2\sigma_\delta^2} + \varepsilon_y\big/\beta_y$$

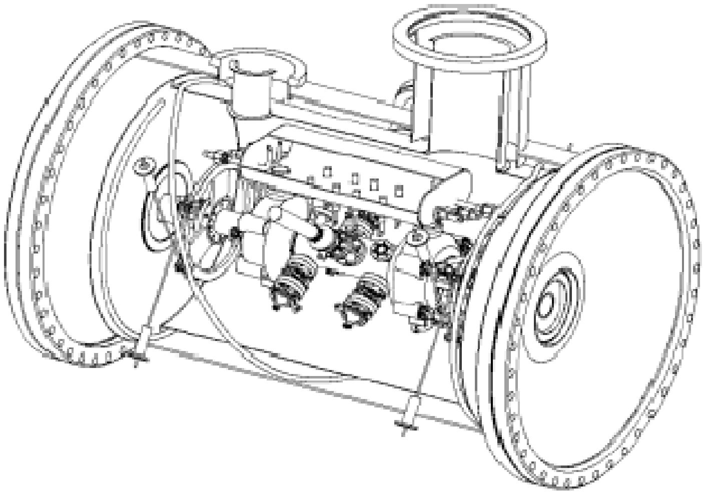
$$y = y_0 + \eta_y\langle\delta\rangle$$



	$\Delta\phi(^\circ)$	$d\delta$ ($\times10^{-4}$)
Centroid jitter due to Residual dispersion (ID's)	0.81	3
Vertical Divergence (from momentum jitter)	2.4	9
Dipole, TPW (position stability due to momentum jitter)	0.27	1
Timing experiments (5% of 15ps bunch @>500Hz)	0.14	0.5

Ring RF Landau Cavity

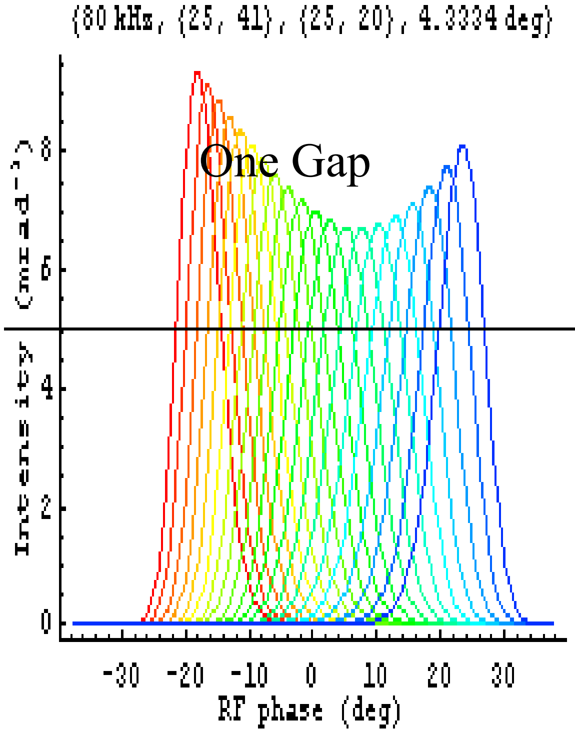
- A harmonic bunch-lengthening cavity is required to increase Touschek lifetime. Without bunch lengthening lifetime is ~2 hours
- Increases beam stability by increasing energy-dependent tune spread
- Baseline is to use the passive Super3HC cavity*.
- Proven design at SLS, ELETTRA
- Two cells per cavity delivering 1MV well matched to ring requirements and upgrade path

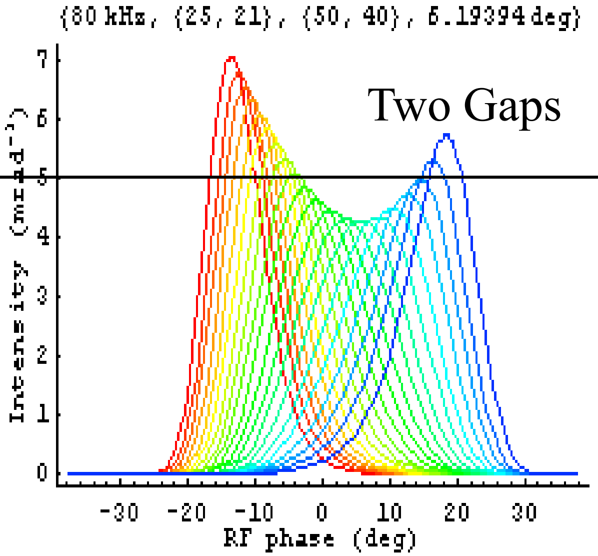


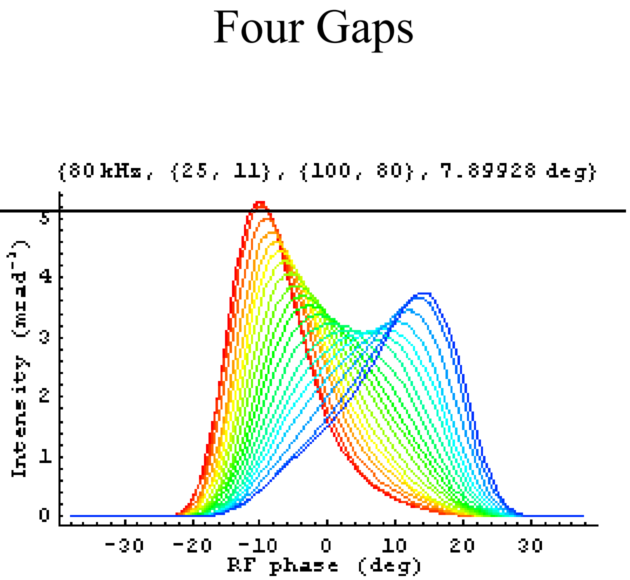
* If available

Bunch lengths and phase offsets along train

Illustrative bunch profiles



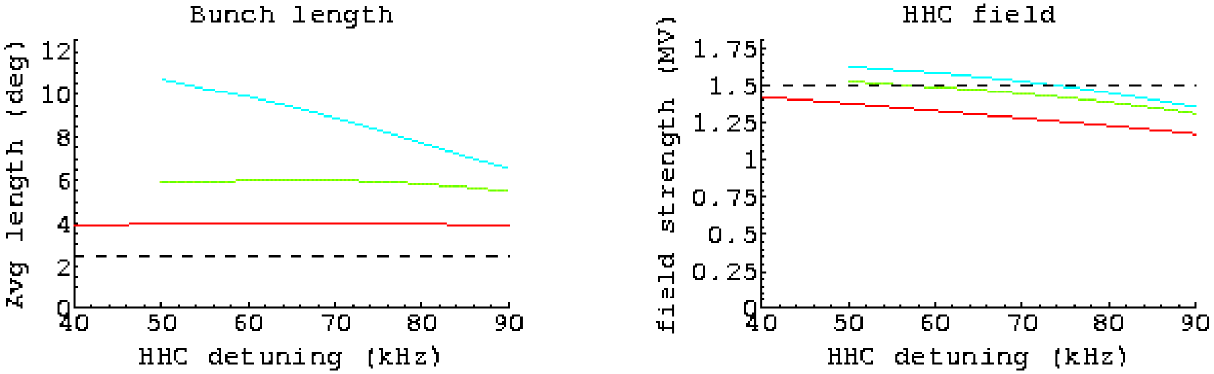




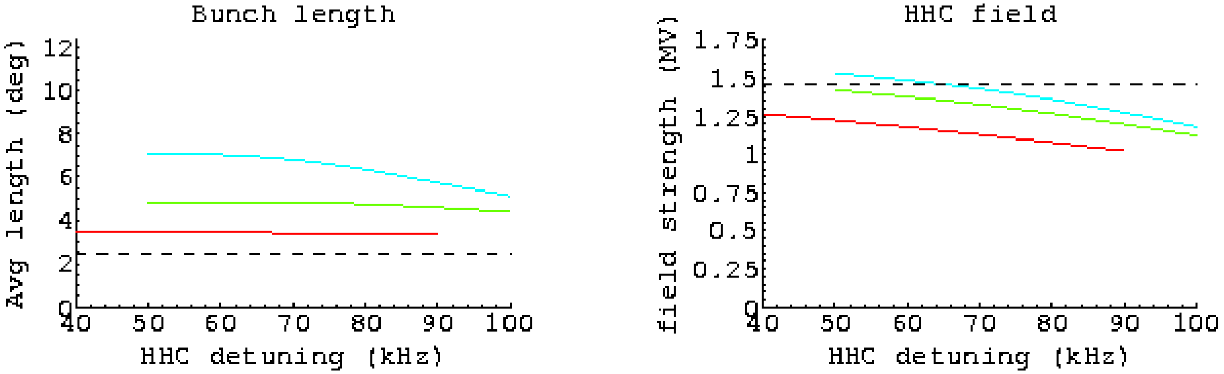
Breaking up the gap lessens the transient due to both a shorter gap and shorter interval between the gaps.

N. Towne

Limit in bunch lengthening due to ion gap transients induced phase offset along bunch trains



SCRF case. One gap (red) two gaps (green) four gaps (blue)



NCRF Case

Nathan Towne

RF System Design Concept/Design Goal

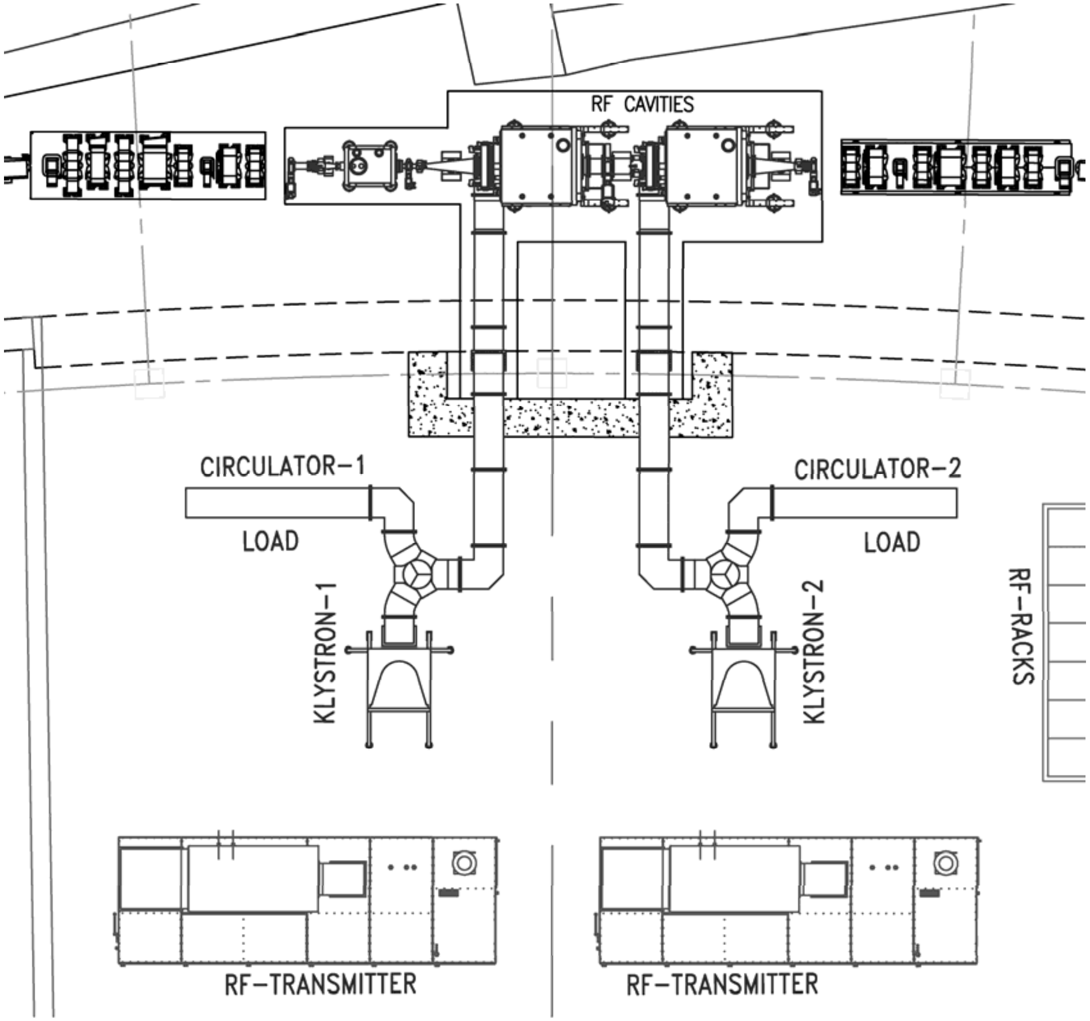
Ring RF system

- CESR-B SCRF cavities chosen for ring RF
  - low impedance better for beam stability
  - higher AC power efficiency
  - Reliability and costs well established
- KEK-B SCRF cavity as option
  - Keep second vendor
  - minimal impact on conceptual design
  - Requires more BNL infrastructure to assemble, test
- 310 kW Klystron amplifiers chosen for baseline:
  - Well established at other LS facilities
  - Reliability and costs well established
  - Combined IOT's as option, possible R&D on Solid State amplifiers
- Passive SCRF Landau cavity
  - Super3HC Demonstrated performance at SLS, ELLETRA
  - Beampipe HOM damped design being explored

NSLS-II RF VOLTAGE, POWER REQUIREMENTS

	Baseline Capability with 1 RF Cavity System Current 300 mA, Voltage 2.5 MV		Fully Built-out Capability with 4 RF Cavity Systems Current 500mA, Voltage 4.8 MV	
	#	P(kW)	#	P(kW)
Dipole	60	86	60	144
Damping wiggler	3	116	8 (56m)	517
IVU	3	14	6	48
EPU	1	7	4	66
TOTAL		224		775
Power available for additional ID’s		46		305
Total Available RF Power		270		1080

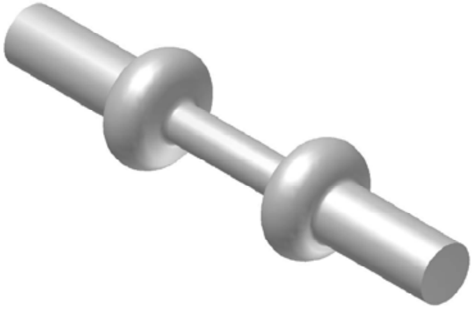
RF Straight with 2 CESR, 1 Landau Cavity



CESR-B cavities operating in TLS, CLS, Diamond, Shanghai

Mature Technology

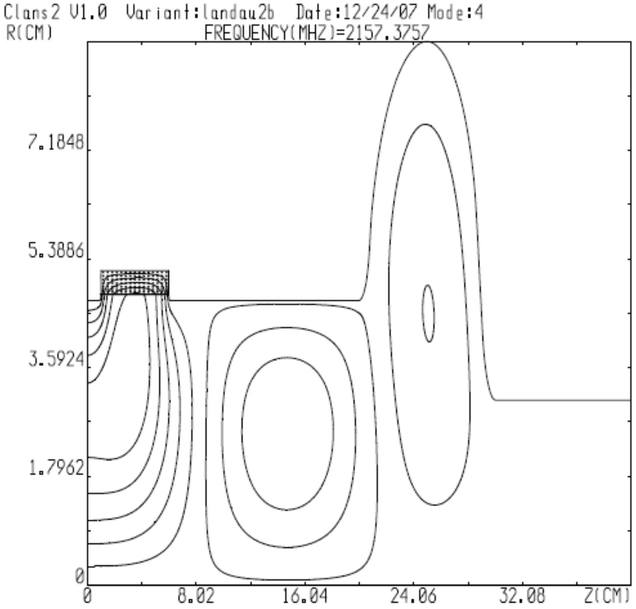
Landau: alternate cavity design

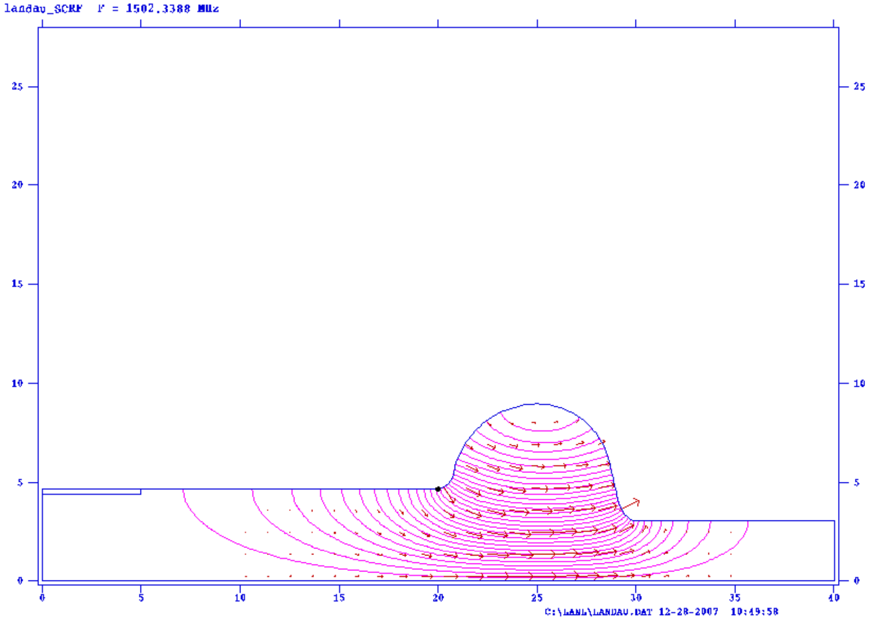


Two cavities per cryomodule to save length

Initial results encouraging

Possible SBIR with Niowave (NSCC/Michigan spinoff)





Klystron RF Feedback Loop

- Klystron RF stability vs. DC supply:
  - RF phase variation vs. beam voltage (constant mod. Anode voltage) 12 degrees/%
  - RF power vs. beam voltage 0.2dB/%
- PSM power supply typical performance (54kV,12A)
  - Full range < 1% pk-pk
  - 75V from 1kHz-2kHz (0.1%) = 1.2 degrees
  - 15V from 2kHz-4kHz
  - 3V from 4kHz-12kHz
  - 50V for >12kHz

This is limiting factor at other facilities, ~1 degree phase jitter after feedback using mod-anode

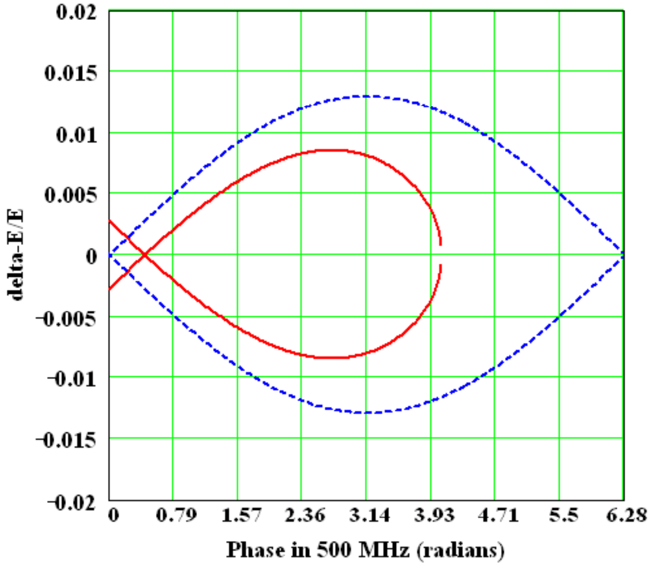
Need Feedback!

Local "scalar" feedback around klystron + global RF feedback

Booster RF System Requirements

- Booster energy: 200MeV →3 GeV
- RF frequency: 500 MHz
- Repetition rate: 1 Hz
  RF voltage ramp
- Average beam current: 19 mA
  (10 nC circulating charge)
  Energy loss per turn: 625 keV
  →Beam power: 11.8 kW
- Energy acceptance: 0.85% at 3 GeV
  1.5 MV booster RF voltage

→ Use a multi-cell cavity with reasonably high shuntimpedance,
  e.g. PETRA type cavities



RF bucket at 3 GeV

ALBA
BESSY
CLS
DIAMOND

Jim Rose CWRF08 March 26 2008

Booster Cavity Options and Power Requirements

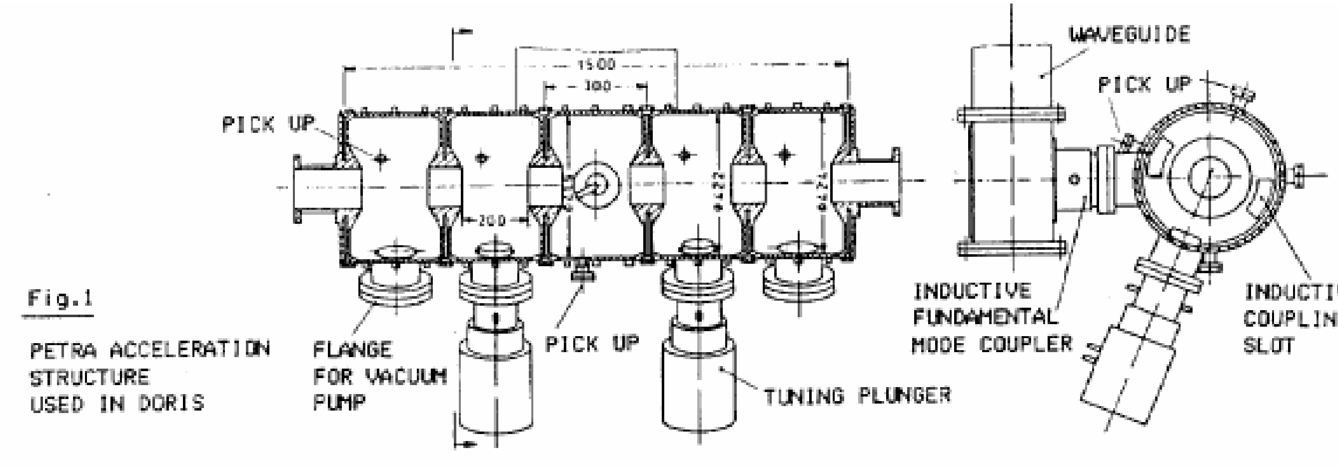


Fig.1

PETRA ACCELERATION STRUCTURE USED IN DORIS

Cavity Options	Wall power losses [kW]	P-wall + P-beam [kW]	P-wall + P-beam + 10% for transmission losses
One 5-cell cavity [15MOhm]	75	97	107
Two 5-cell cavities	38	50	55
One 7-cell cavity [20 MOhm]	56	68	75

Booster: IOT Tube transmitter

- Well established technology, several tube manufacturers
- (**CPI**, **EEV**, Thales, Litton)
- Turn key transmitters are available incl. all internal safety
- and interlock circuits
- IOT upgrade program goal: 100 kW output, improved reliability

→ increase output coaxial window to 6-1/

→ use larger ceramic (compatible with old socket)

Opportunities and Strategic planning

- NSLS-II storage ring RF systems are staged over many years to keep pace with additional damping wigglers, user ID's
- First system purchased in ~January 2010, 2nd possibly before end of project-3rd, 4th beyond 2015.
- Choice of klystron or combined IOT's in near term, solid state for future systems
- Hope to answer questions of technical performance (linearity, phase noise), reliability and cost here at this workshop and over the next ~6 months
- SS reliability, linearity benefit SR, but like Soleil and SLS, NSLS-II may target Booster to gain experience
- Booster requirements well matched to IOT, would not target booster without SR as strategic goal.

Motivation for Solid State Amplifier R&D

Solid state amplifier R&D program proposed

- Elimination of high voltage, no vacuum tube replacement, no crow bar circuit
- Graceful degradation in case of module failures (failure rate ~ 3% / year including infant mortality)
- Linear operation avoids saturation: simplifies design of rf feedback loops
- Present investment cost estimates 30-50% higher than IOT transmitter, potential for future cost reduction

45 kW 352 MHz solid state transmitter at SOLEIL with 181 modules

→ Potential for higher system reliability

→ Significant saving in maintenance costs (?)

Mean time between failure?

Lower mean time to repair MTTR?

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