# Discussion of **NSLS-II Design**

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**ICFA FLS Workshop**

**Hamburg, Germany**

**May 15-19, 2006**

Office of Science
U.S. DEPARTMENT OF ENERGY



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# Acknowledgements

Johan Bengtsson, Joanne Beebe-Wang, Alexei Blednykh,

Richard Heese, Stephen Kramer, Yun Luo, Nikolay Malitsky,
Christoph Montag, Boris Podobedov, Igor Pinayev,

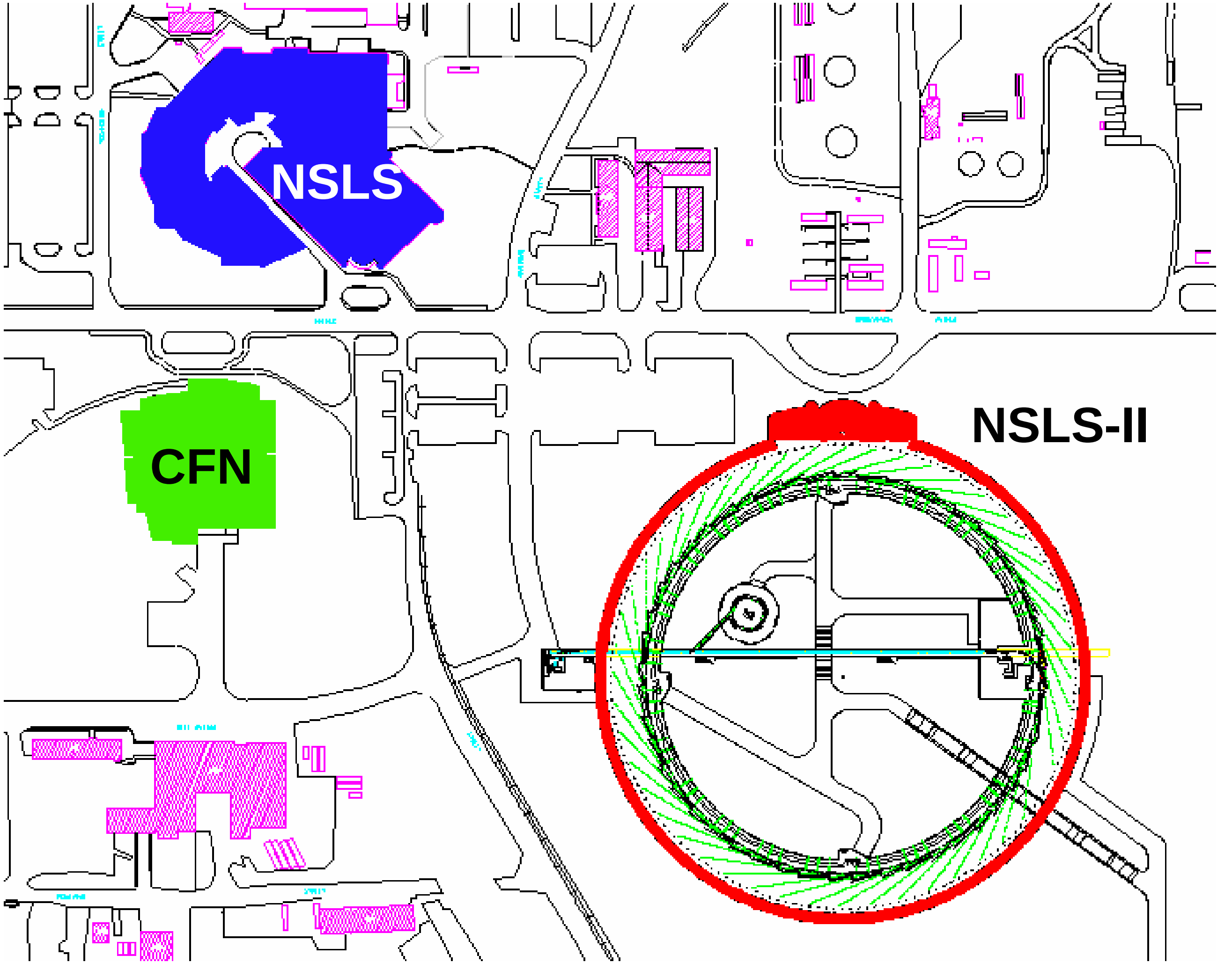
George Rakowsky, James Rose, Satoshi Ozaki, Todd Satogata,
Timur Shaftan, Sushil Sharma, John Skaritka, Toshiya Tanabe,
Dejan Trbojevic, Dong Wang, Fuhua Wang, Li Hua Yu

# NSLS-II Concept

## NSLS II Machine Concept

- New Electron Storage Ring
- Medium Energy (3 GeV)
- Large Current (500 mA)
- Top-Off Operation
- Circumference (800-900 m)
- Ultra Low Emittance (<1 nm)
- Damping Wigglers
- Superconducting RF
- Provision for IR Source

# NSLS –II  Site



# NSLS-II Parameters

| | | | |
|---|---|---|---|
| Energy | 3.0 GeV | Energy Spread | <0.1% |
| Circumference | 800-900 m | RF Frequency | 500 MHz |
| Number of Periods | 30/32DBA | RF Bucket Height | 3% |
| Length Long Straights | ~5 & 8m | Synchrotron Tune | ~0.009 |
| H-Emittance (h,v) | 1.0-0.5nm | RMS Bunch Length | ~15ps |
| V-Emittance | 0.007nm | Average Current | 500ma |
| Momentum Compaction | ~.00035 | Current per Bunch | ~0.5ma |
| Dipole Bend Radius | 20-30m | Charge per Bunch | ~1.3nC |
| Energy Loss per Turn | <2MeV | | |

# Insertion Devices

Damping Wigglers

- $\lambda_w$ =100 mm, $B_w$=1.8T
- Total Length ~50m

Cryo-PM In-Vacuum Undulators

- Longer period, $\lambda_u$=19 mm, g>5 mm, L=3 m

Superconducting Undulators (R&D)

- K = 2.2, $\lambda_u$=14 mm & g = 5 mm, L = 2 m

SC Wigglers

- Two devices anticipated for h■ > 20 KeV
- $B_w$=3.5T

# ID Focusing Effects

$$\Delta\nu_y = \frac{\beta_y L_w}{8\pi\rho_w^2}$$

Linear Tune Shift

$$\frac{d\nu_y}{dJ} = \frac{\pi\beta_y^2 L_w}{4\lambda_w^2\rho_w^2}$$

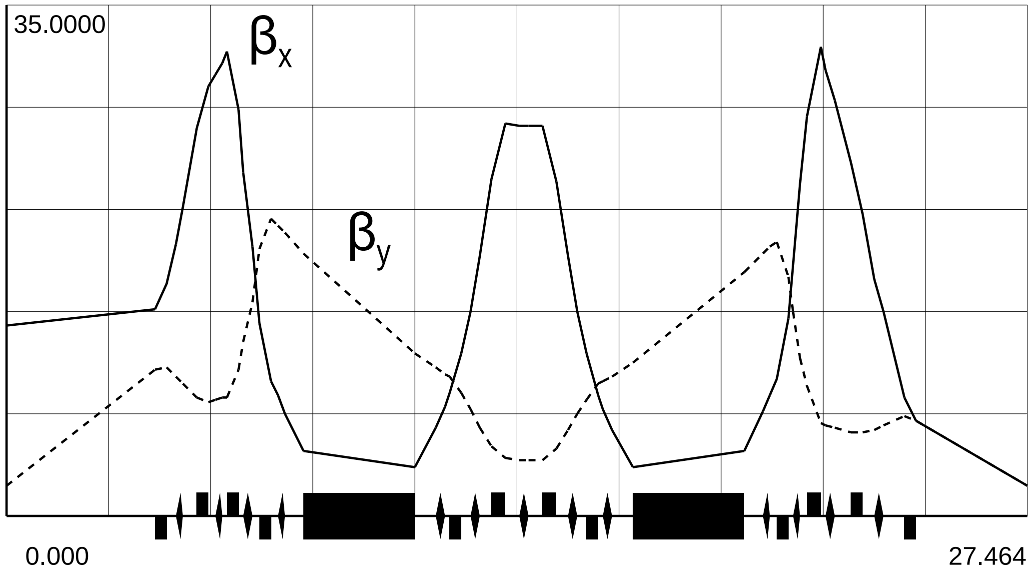
Tune Shift with Amplitude

Require small vertical betafunction in insertion devices

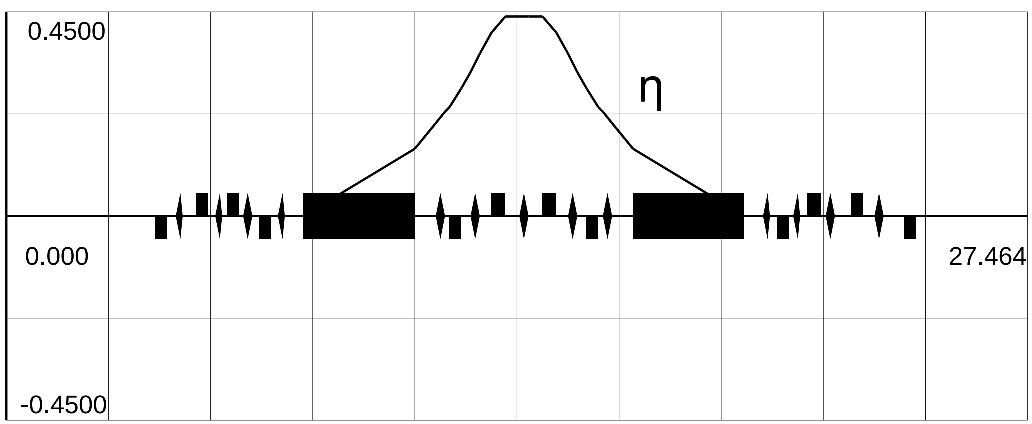
For small gap undulators, small vertical beta also needed to reduce effect of transverse impedance

# Betatron Functions

Betatron amplitude functions [m] versus distance [m]




Dispersion functions [m] versus distance [m]




Horizontal ———— Vertical - - - - - - -

# Damping Wigglers

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

$$f \cong \frac{2C_q\gamma^2}{3\pi^2\varepsilon_0}\frac{L_w\rho_0}{\rho_w^3}\left[\frac{K_w^2}{5\gamma^2}\langle\beta_x\rangle + \frac{\eta_0^2}{\beta_{x0}} + \beta_{x0}\eta_1^2\right]$$

$$\beta_x(s) = \beta_{x0} + \frac{s^2}{\beta_{x0}} \qquad \eta(s) = \eta_w(s) + \eta_0 + \eta_1 s$$

$$\eta_w(s) = \frac{1}{\rho_w}\left(\frac{\lambda_w}{2\pi}\right)^2\left(1-\cos\frac{2\pi s}{\lambda_w}\right)$$

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

$$\frac{K_w}{\gamma} = \frac{\lambda_w}{2\pi\rho_w}$$

$$C_q = 3.84\times10^{-13}\,m$$

# Bare Lattice

Example:

$$\rho_0 = 30.6\, m$$

$$\varepsilon_{x0} = 1.7\, nm$$

$$\delta_0 = 0.046\%$$

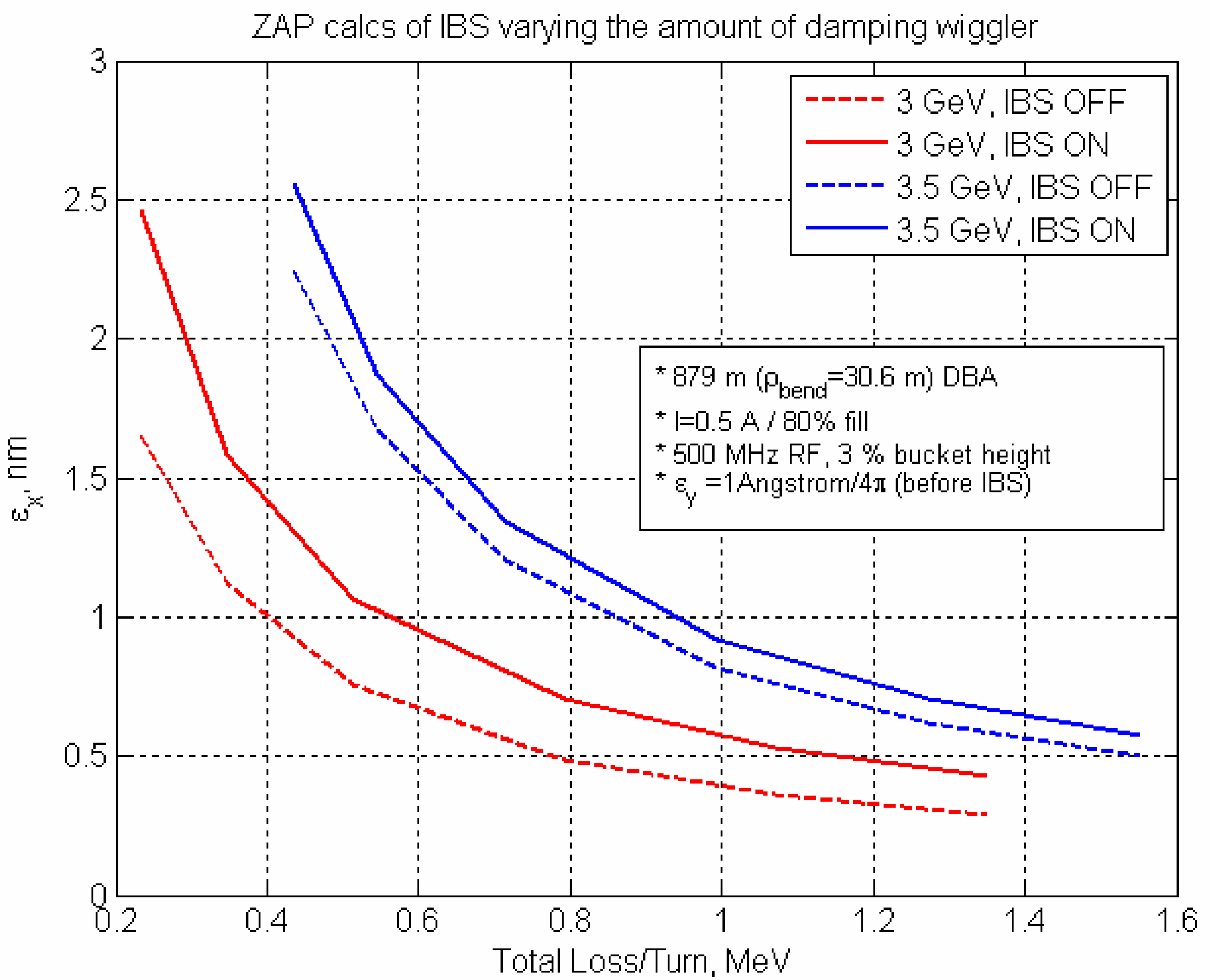
$$U_0 = 235\, KeV$$

Dispersion in Straights (perhaps a reasonable tolerance):

$$\eta_0 = 1\, cm$$

$$\eta_1 = 0.002\, rad$$

# Intrabeam Scattering

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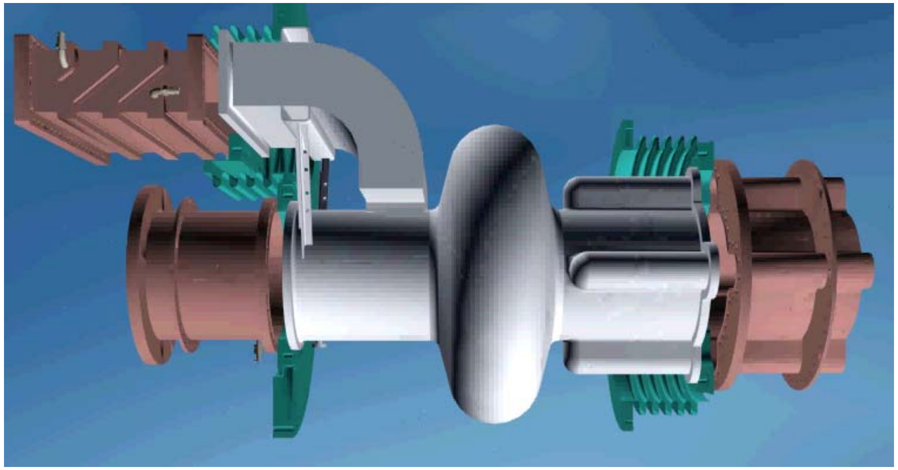
# Baseline: 4 CESR-B Cavities



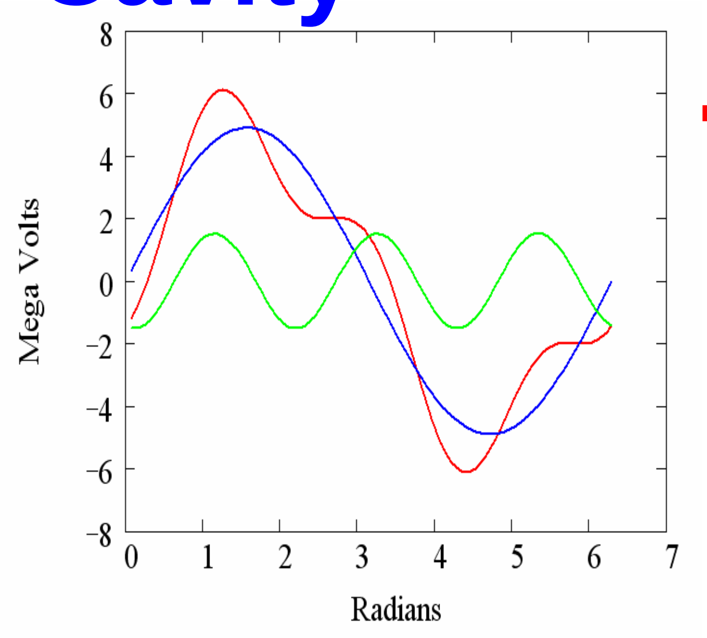
**SCRF chosen for lower R/Q, highly damped HOM's, lower operating cost and comparable capital cost**

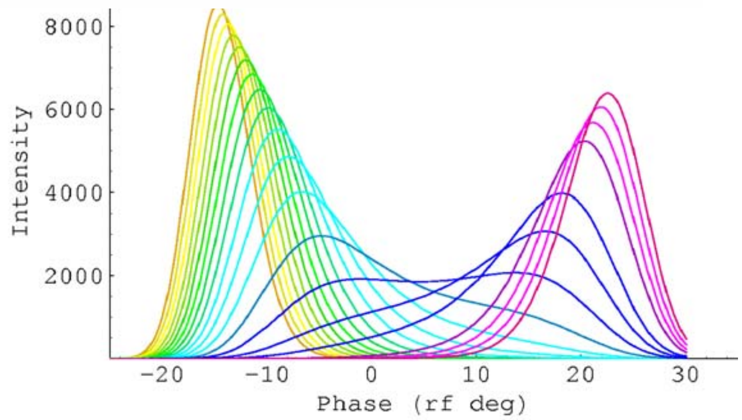
| | |
|---|---|
| Energy loss/turn | 2 MeV |
| Cavity Voltage | 4.9 MV |
| Power to Beam | 1 MW |

| Frequency | 500 MHz |
|---|---|
| Beam energy gain/cav | >2.4 MV |
| Eacc | >8 MV/m |
| Unloaded Q | $>7 \cdot 10^8$ |
| Standby (static) losses | <30 W |
| Dynamic + static losses | <120W |
| Operating Temperature | 4.5 K |
| Max. beam power/cavity | <250 kW |

# Harmonic Cavity

| 1500MHz "Bessy" cavity | |
|---|---|
| Voltage/cavity | 0.5 MV |
| Eacc | >5MV/m |
| Unloaded Q | $>7\cdot10^8$ |
| Static losses | <6W |
| Dynamic + static losses | <12W |
| Operating T. | 4.5 K |
| Frequency | 1500 MHz |




4.9MV @500MHz required for 3% Momentum acceptance: 1.6MV @ 1500MHz requires 3 cavities

Work continues on effect of bunch train transients on bunch lengthening

# Touschek Scaling with Emittance

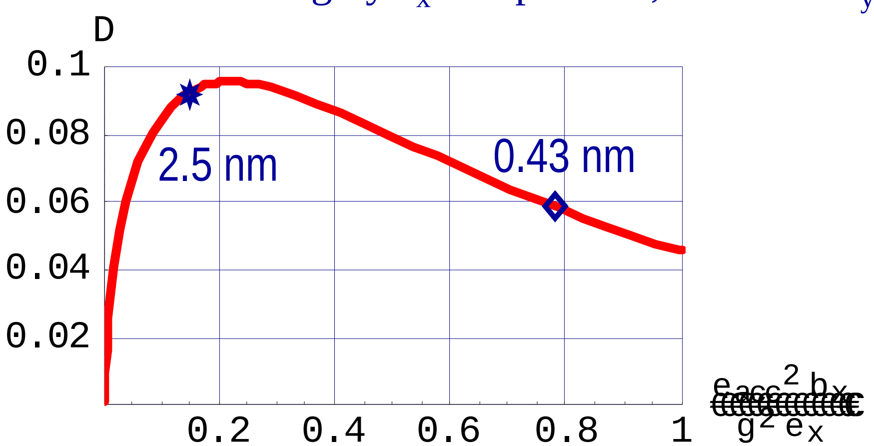
$$\frac{1}{\tau_{tous\_1/2}} = \frac{\sqrt{\pi}\, r_e^2 c N_b}{\gamma \varepsilon_{acc}^4} \left(\frac{\sigma'_x}{V}\right) D\left(\frac{\varepsilon_{acc}^2}{\gamma^2}\frac{\beta_x}{\varepsilon_x}\right)$$

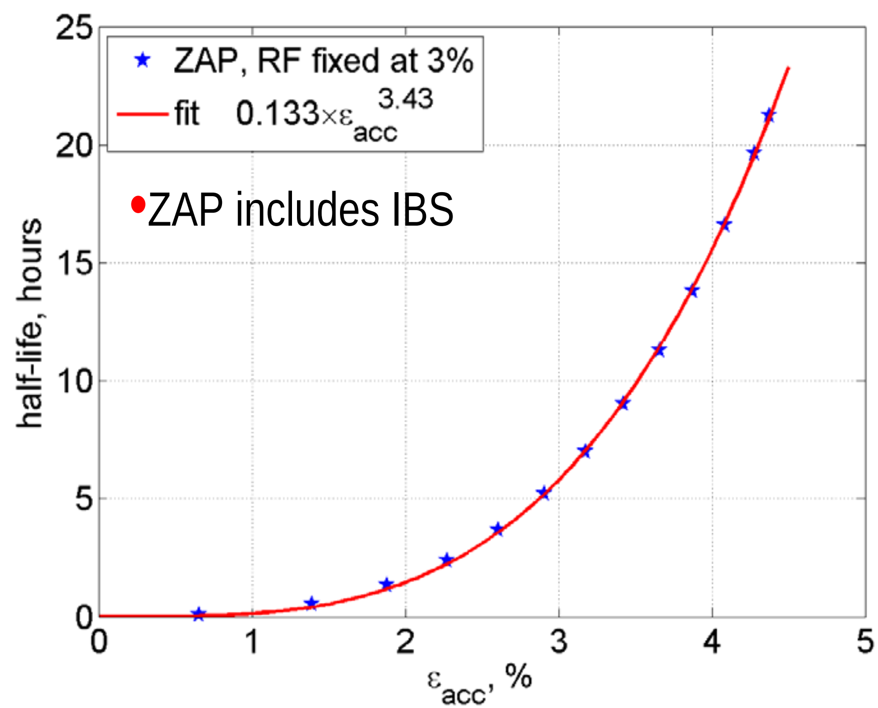
$$\zeta = \left[\varepsilon_{acc} / \gamma\sigma'_x\right]^2 \approx \frac{\varepsilon_{acc}^2}{\gamma^2}\frac{\beta_x}{\varepsilon_x}$$

Ignores dispersion

Roughly $\varepsilon_x$ independent, for fixed $\varepsilon_y$

B. Podobedov




Symbols assume $\langle\beta_x\rangle$ =13 m, $\varepsilon_{acc}$ = 3%

Lifetime remains roughly constant

as we reduce emittance!

Lifetime very sensitive to energy acceptance!