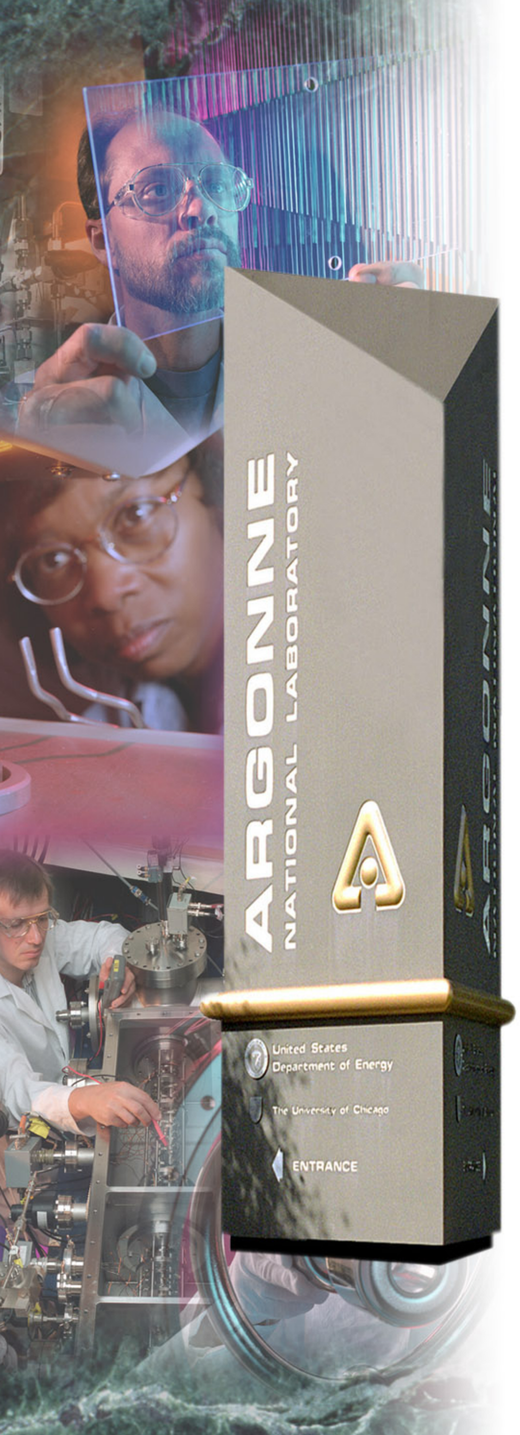

Damping Ring Design Overview

Kwang-Je Kim

2005 International Linear Collider Workshop
Stanford Linear Accelerator Center, Stanford, CA

March 18-22, 2005

Argonne National Laboratory

Office of Science
U.S. Department of Energy

A U.S. Department of Energy
Office of Science Laboratory
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US-ILC Damping Meeting

- **Keeping the momentum from ILC-USA @SLAC and ILC-KEK meetings**
- **Biweekly meeting with convenient teleconference format; VGs readily accessible from Andy's web page**
- **Initiated by A. Wolski, together with G. Dugan, G. Gollin, and KJK**
- **Attended by LBNL, SLAC, ANL, FNAL, Cornell, and a host of university groups**

- ***This talk is largely based on material from the US-ILC meetings. I am grateful to the participants, especially Louis Emery and Andy Wolski, and those who provided me additional VGs, Y. Cai, G. Gollin, G. Dugan, M. Ross.***

Requirements for ILC Damping Ring

- **Compress 1 ms linac bunch train in to a “reasonable size” ring**
  - Fast kicker
- **2820 bunches, 2×10^{10} electrons or positrons per bunch, bunch length= 6 mm**
  - instabilities
- **Damping of $\gamma\varepsilon_{x,y}= 10^{-2}$ m-rad positron beams to $(\gamma\varepsilon_H, \gamma\varepsilon_v)=(8 \times 10^{-6}, 2 \times 10^{-6})$ m-rad**
  - Low emittance
- **Cycle time 0.2 sec→ τ=27 ms**
  - Damping wiggler
- **Dynamic aperture ≥ 10 σ**
  - Injection loss < 1 %

Damping Ring Topics

- **Lattice design and optimization**
  - TME or FODO
- **Dynamic aperture**
- **Automatic lattice design**
- **Space charge tune shift**
  - Coupling bump
- **Collective effects**
  - Electron cloud, fast ion→ vacuum vessel and level
- **Novel schemes**
- **Tracking to determine injection efficiency**
- **Error tolerance in lattice and wiggler**
- **Wiggler technology**
- **Kicker R&D**
- ***And many more!***

ILC Lattice Design and Optimization

- **TME-based; smaller ε, α_p**
  - *lower V_{rf}, shorter wiggler*
  - *Lower Z_{th}, Smaller DA (6σ, larger injection loss)*
  - *L. Emery, Standford thesis (Aug. 1990)*
  - *P. Emma and T. Raubenheimer, PRSTAB (2001)*
  - *A. Xiao, et. al., Fermilab-TM-2272-AD-TD (Sept. 2004)*
- **FODO-based; larger ε, α_p**
  - *Higher V_{rf}, longer wiggler*
  - *Higher Z_{th}, larger DA (10σ, smaller injection loss)*
  - *Y. Cai, talk at US-ILC*
  - *A. Wolski, LBNL-57045 (Feb., 2005)*

Some ILC Damping Ring Designs

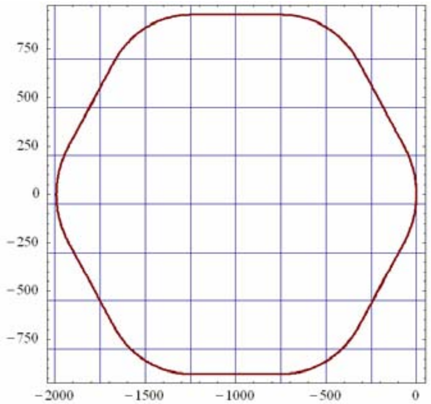
Parameters	TESLA DB (W. Decking)	SLAC DB (Y. Cai)	LBL (DB) (A. Wolski)	ANL-FNAL Circular (A. Xiao, L. Emery)
Energy E(Gev)	5	5	5	5.0
Circumference (m)	17,000	17,014	15,815	6114
Horizontal emittance (nm)	0.50	0.62	0.715	0.8
Damping time (ms)	28	27	27	27
Tunes, ν_x,ν_y,ν_s	76.31, 41.18, 0.071	83.73, 83.65, 0.072	75.78, 76.41, 0.41	56.58,41.62,0.0348
Momentum compaction α_c	1.22×10^{-4}	1.11×10^{-4}	5.6×10^{-4}	1.42×10^{-4}
Bunch length σ_z (mm)	6.04	5.90	6.0	6
Energy spread σ_e/E	1.29×10^{-3}	1.30×10^{-3}	1.63×10^{-3}	1.3×10^{-3}
Chromaticity ξ_x, ξ_y	-125,-62.5	-105.27, -106.70	-90.98, -94.86	-74.4,-55.4
Energy loss per turn (MeV)	20.4	21.0	19.75	7.73
Cavity Voltage (MV)	50	50	312	27

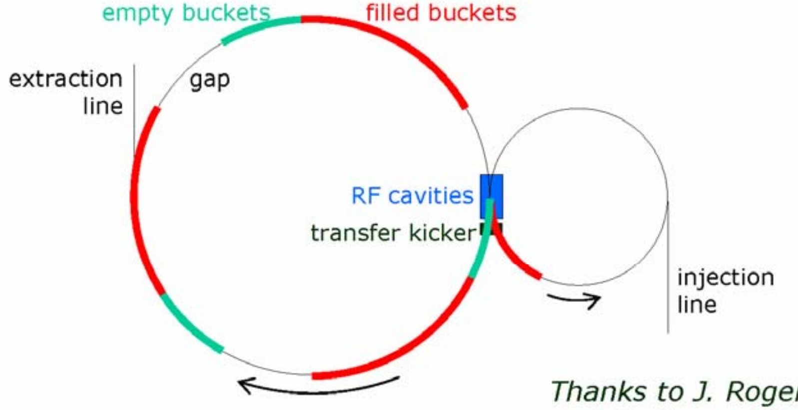
THE ANL-FNAL 6 km Ring (A. Xiao, L. Emery,..)

5 GeV, 6 km lattice (six-fold symmetry).

Injection/extraction scheme uses 6 ns rise-time, 60 ns fall-time kicker.

Lattice documented in FERMILAB-TM-2272-AD-TD
http://www.hep.uiuc.edu/home/g-gollin/linear_collider/Fermilab_damping_ring_report.pdf





Thanks to J. Rogers and G. Dugan (Cornell)

Strengths:

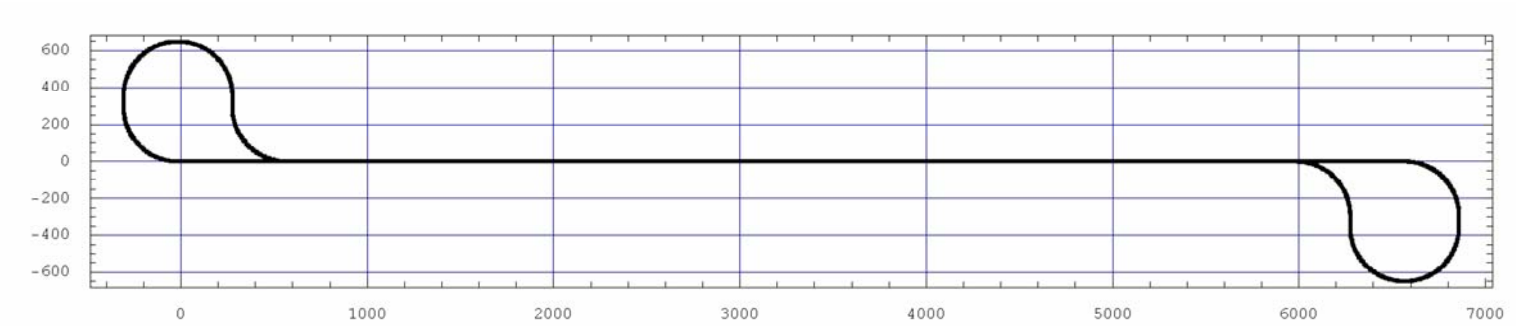
- Relatively small circumference reduces space-charge effects.
- Reduced amount of wiggler needed to achieve required damping rate.
- Injection/extraction scheme allows use of slow fall-time kicker.

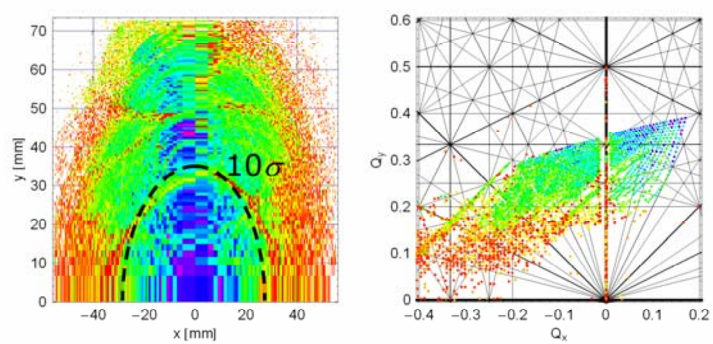
Weaknesses:

- Higher average current makes electron-cloud and ion effects more difficult.

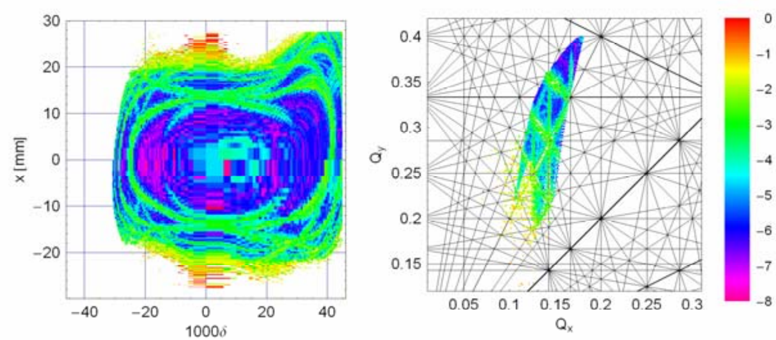
LBNL 16 km Dogbone (A. Wolski)

16 km dogbone lattice with FODO arcs (LBNL design) meets specifications for emittance, damping time etc., and has dynamic aperture > 10σ (for 0.01 m normalized injected emittance).





On-energy dynamic aperture
β_x=7.5 m, β_y=13 m



Dynamic aperture in δ-x space

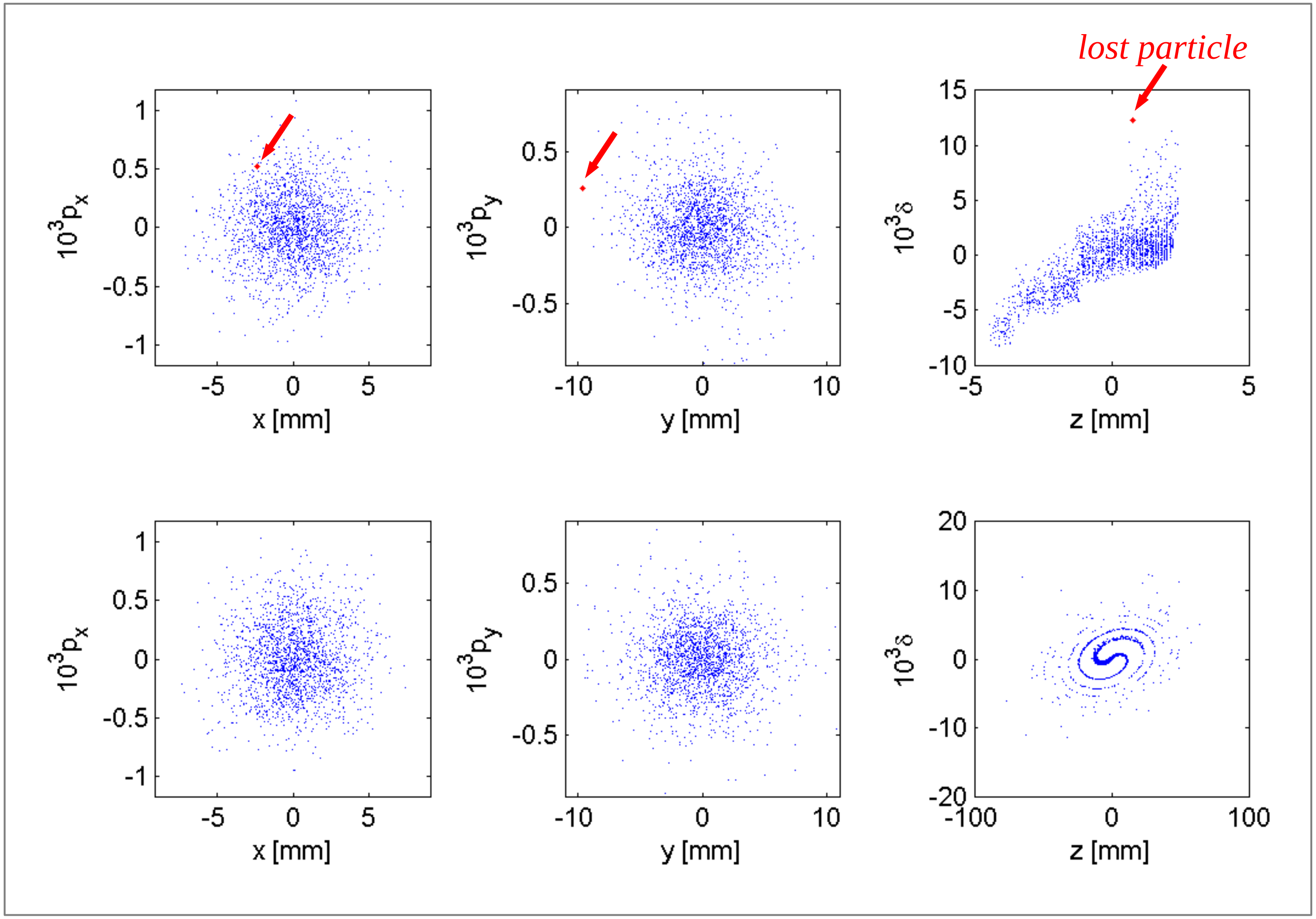
Automated generation of lattice (L. Emery)

- **Final ILC damping ring design will take many iteration→ Automatic matching procedure will expedite the process**
- **Identify 12 primary parameters:**
  - $N_{supereriod}$, ν_x, ν_y
  - Arc cell: Φ_x, Φ_y, L, L_B, N_{cell}
  - Wiggler cell: Φ_x, Φ_y, L_w, B_w, N_{poles}
- **Automatic matching: templates for cells and ring written**
- **Using a FODO-cell based circular ring as an example**
- **Work in progress**

Injection Loss

- **Use positron source particle distribution from Y. Batykin (SLAC)**
  - Normalized emittance ($\gamma\varepsilon$) is 0.06 m-rad, but particles at γJ_x or γJ_y up to 1 m-rad occur
  - Particles at high number of σ's could be collimated without significantly harming total charge.
- **Positron loss about 1% for LBNL FODO (A. Wolski)**
- **Positron loss about 10% for ANL-FNAL TME (A. Xiao, L. Emery)**
- ***Loading power 2 kW with at 1% loss. Compare this the injection loss at the APS; 2 w every 8 hour. The positron beams must be collimated early in the source chain to reduce the loss to an acceptable level***

Tracking a ‘realistic’ beam shows very small losses (A. Wolski)

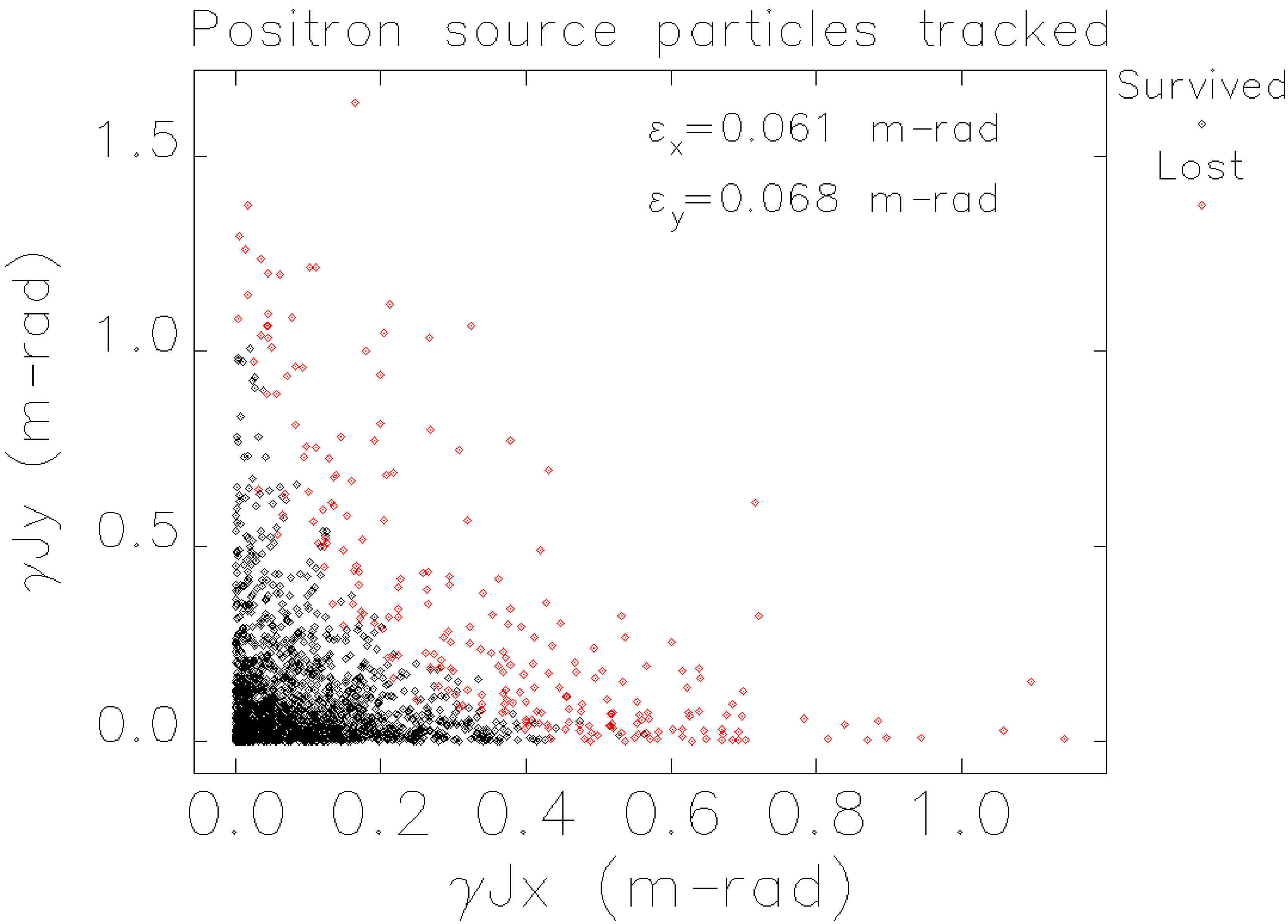


Injected beam phase space.

Simulated distribution of 1960 particles from positron source. (Y. Batygin, SLAC)

Phase space after 500 turns.

500 turns is approximately 1 damping time. 1959 particles survived. (A. Wolski, LBNL)



Positron source particles tracked
Survived
Lost
ε_x=0.061 m-rad
ε_y=0.068 m-rad
1.5
1.0
0.5
0.0
γJy (m-rad)
0.0
0.2
0.4
0.6
0.8
1.0
γJx (m-rad)

Linear Damping System?

- **V. Telnov**
- **N.S. Dikansky, A.A. Mikhailichenko, H. Braun, Zimmermann,..**
- **Linear cells, each cell consisting of a wiggler and a linac section**
- **Report by G. Dugan: e.g., positron damping at 23 GeV**
  - L=18 km, λ_u=11 cm, B=10 T
  - ε_x=8x10-6, σ_δ=6.6x10-3
  - dP/dz=6.6 kW/m, P_T=30 MW!
- ***Somewhat challenging***

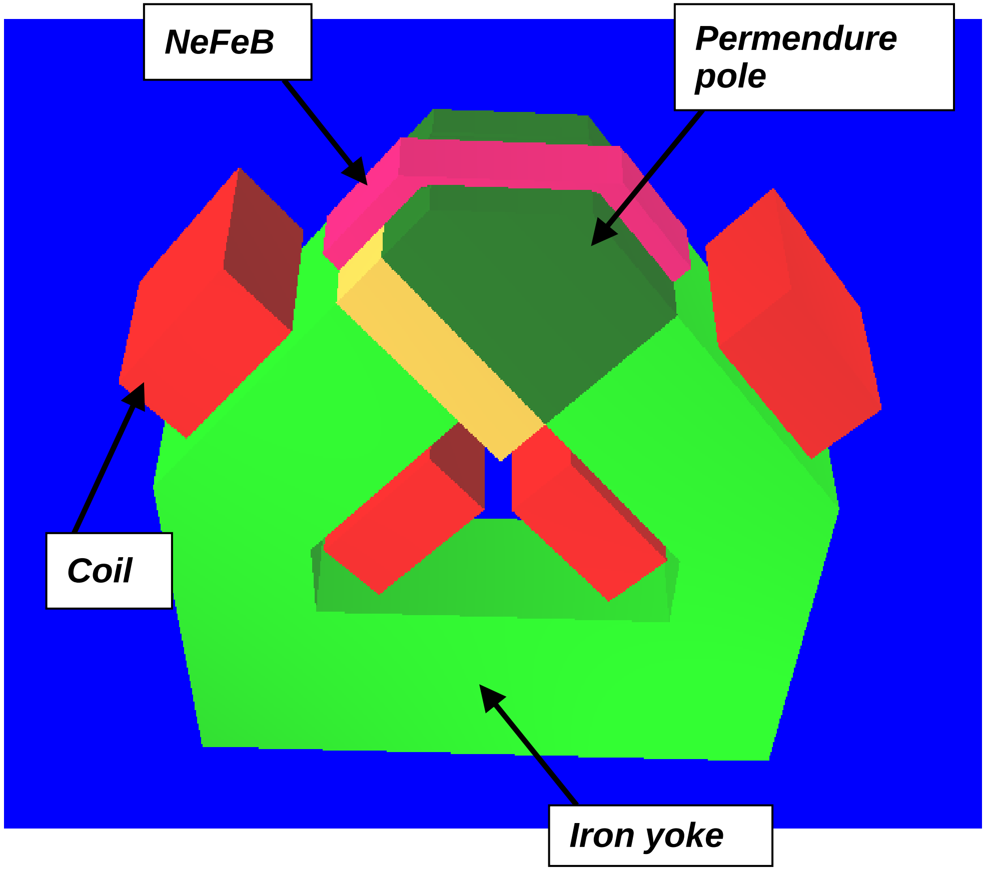
Wiggler Design Issues

- **Parameters:**
  - ANL-FNAL TME: L=77m, λu=28 cm, B=2.2 T
  - SLAC-LBNL FODO: L=441 m, λu=40 cm, B=1.6 T
- ***Wiggle05, INFN, Frascati, Feb. 21-22,2005***
- **Nonlinear tuneshifts**
  - Horizontal…Cure by poleshaping (DAΦNE)
  - Vertical … Octupole-like term is significant but the effect is less than that due to the chromaticity sextupoles.
- **“New” magnet concepts**
  - Wedge pole PM(P. Vobly,BINP)
  - PM assisted EM(K. Halbach, BINP, KAERI)
  - Super-ferric (A. Temnykh, CESR-c)
  - Superconducting (R. Rossmanith, ANKA)
- **Issues: specification of wiggler tolerances**

Electromagnet wiggler

Usual electromagnet wigglers can not be used as damping wigglers because it is difficult to achieve high field with small period.

However combined permanent/electromagnet devices (equipotential bus wigglers, K.Halbach) can show good damping parameters.



g = 6 mm
λ_w = 25 mm
Bm = 0.45…0.7 T
L = 2 m
$\Delta B/B < 5\times10^{-4}$ at 1 cm.

FEL undulator for KAERI (1999).

g = 12 mm ← ***Proposal for damping wiggler (2005)***
λ_w = 76 mm
Bm = 1.7 T

Kicker R&D

- SLAC-LBNL-LLNL…Shock-wave line pulser, stripline kicker system for ATF-KEK extraction (M. Ross, A. Krasnykh,..)
- FNAL-UIUC…6-ns rise- and 300-ns fall-time, “Fourier” kicker study (G. Gollin,..), stripline kicker testing at A0-FNAL
- Cornell…RF separation scheme, fast ionization dynistor (FID) pulser (3.5 ns) (G. Dugan, D. Rice,..)