Projects in the near and far future:
Beijing Spallation Neutron Source / Antiproton Generation & Storage Facility
(How would FFAG's fit in?)

(presented by)

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for

BSNS Accel. Team, IHEP, China / AGSF team, BNL & AES, US

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Outline

- Beijing Spallation Neutron Source
  - Overview
  - Machine design
  - Challenges
- Antiproton Generation & Storage Facility
  - Concept

Accelerators at the Power Frontier

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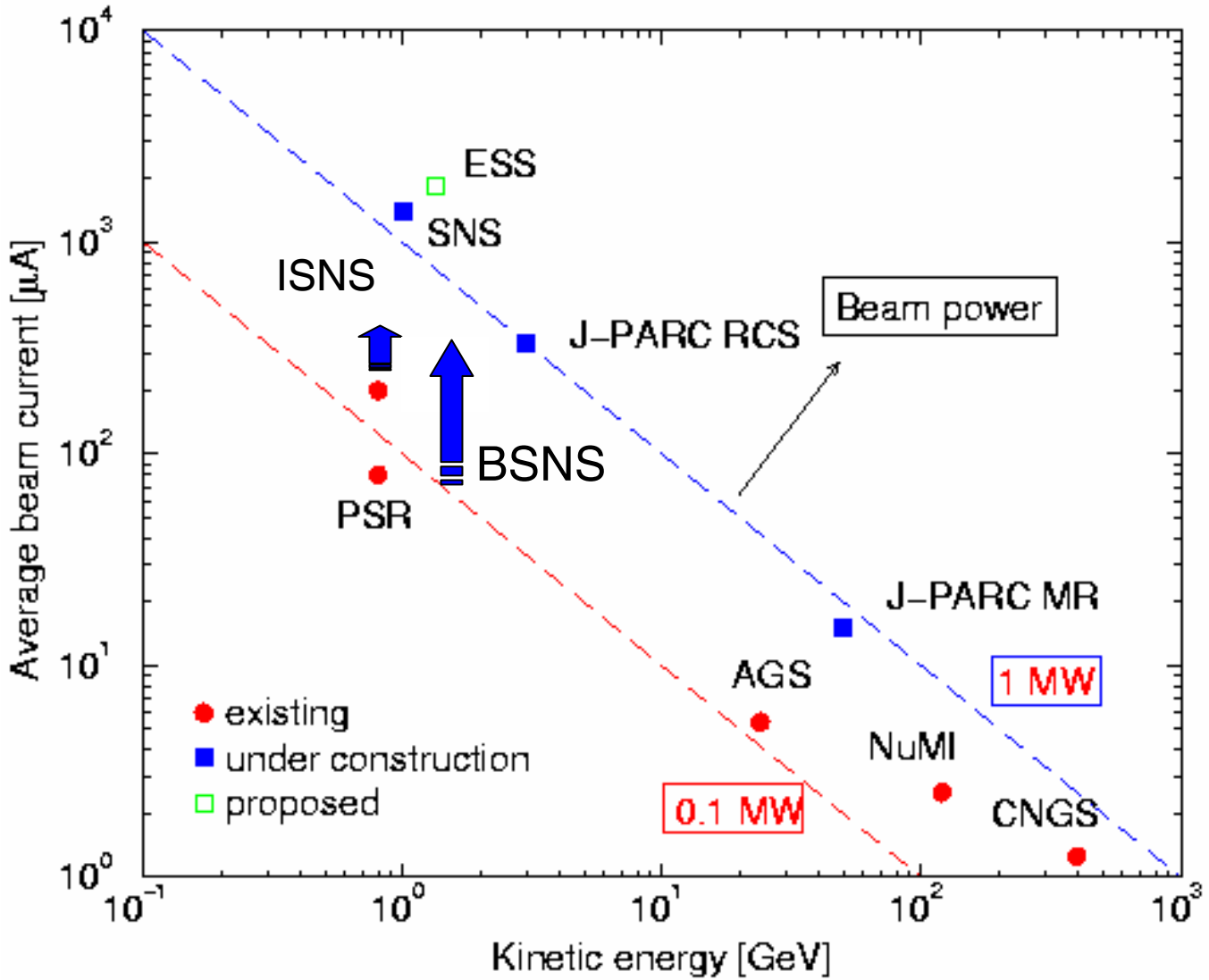

Why another SNS?

- Huge domestic demand from the users
- Compliments light sources and reactors
- Closely related to other applications
  - Neutrino-factories
  - Accelerator driven sub-critical nuclear power generation (ADS)
  - Transmutation of nuclear waste
  - Accelerator production of tritium
  - Muon storage rings
  - Proton radiography
  - White neutron source applications
  - High-intensity radioactive beams

Spallation sources, light sources, reactors

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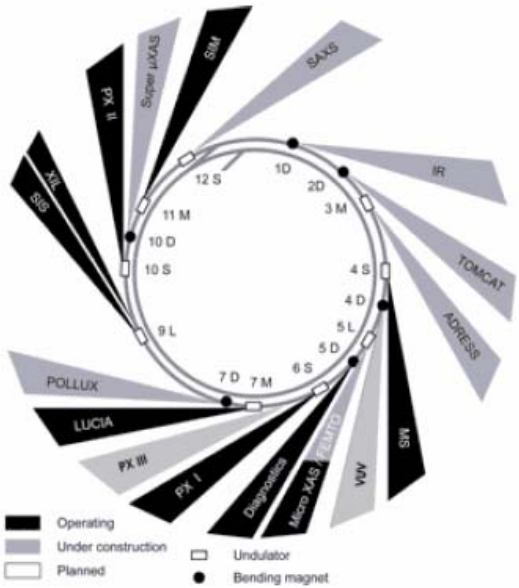
- SLS & SINQ (Swiss)
  - 1 MW cw SNS (1997)
  - 2.5 GeV Swiss Light Source (2001)
- ISIS and DIAMOND (UK)
  - 160 kW pulsed SNS (1985)
  - 3 GeV light source (2007)
- SNS and HFIR



Spallation Neutron Sources world-wide

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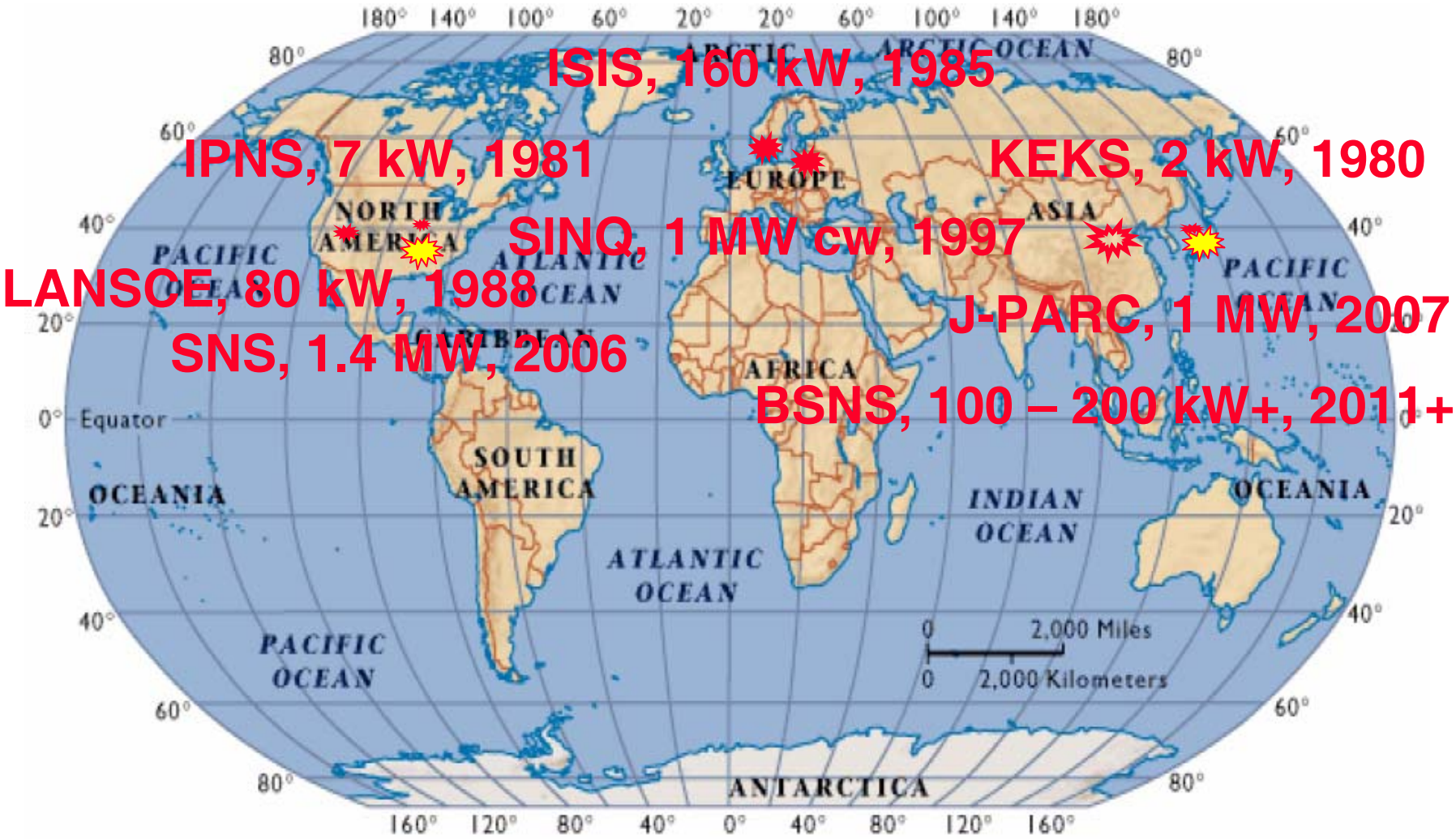

BSNS layout

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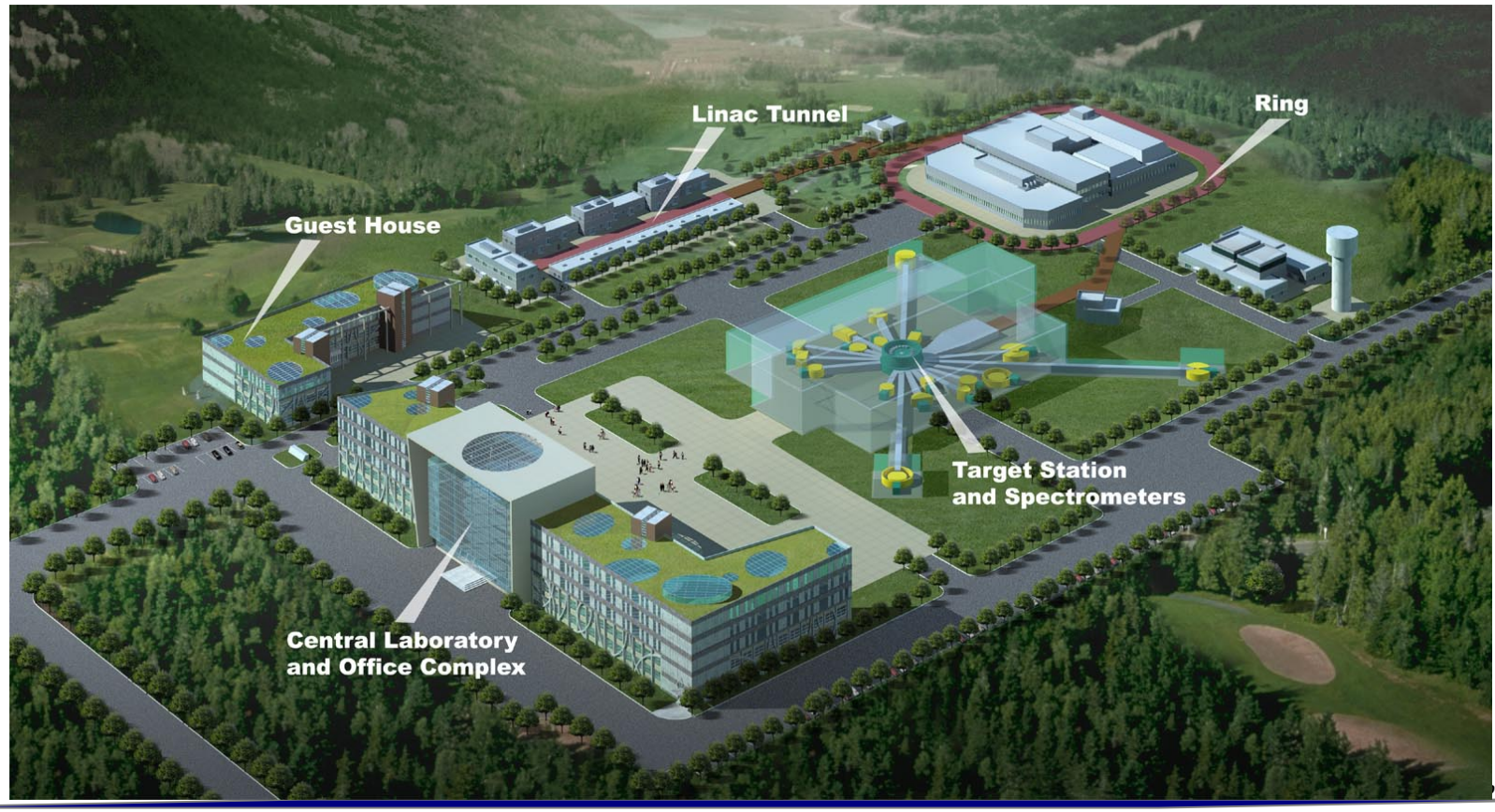
- Linac: H- beam, 80 MeV (DTL) to 230 MeV (SCL)
- Rapid-cycling synchrotron: 1.6 GeV at 25 Hz



Primary Concern:
Radio-activation & Beam Loss

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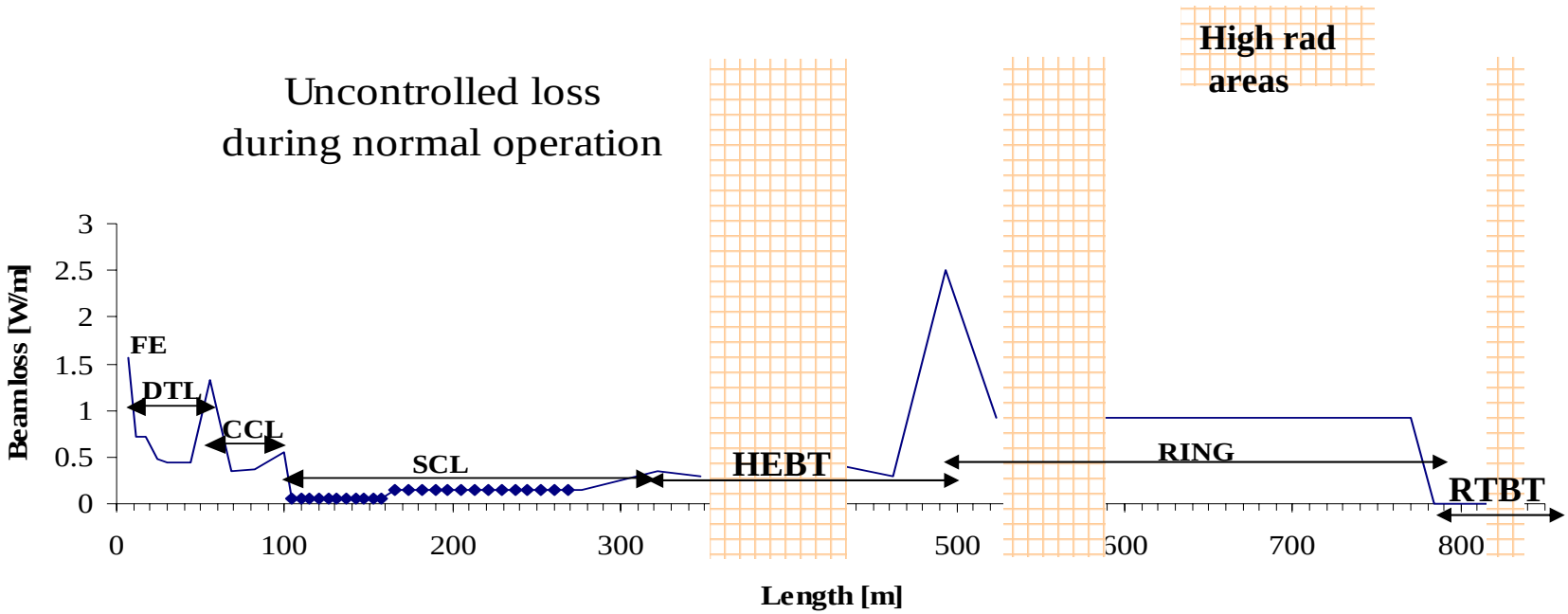
- Hands-on maintenance: no more than 1 mSv/hour residual activation (4 h cool down, 30 cm from surface)
- 1 Watt/m uncontrolled beam loss
- Less than 10^{-6} fractional beam loss per tunnel meter at 1 MW operation
- Less than 10^{-4} uncontrolled beam loss in the ring



Source of beam loss

- High radio-activation at injection, extraction,collection
  - AGS: up to 100 mSv/hour at localized area
- High beam loss
  - FNAL Booster (25 - 40%): ramp tracking, debunching-recapturing, transition, aperture!
  - AGS/Booster (20 – 30%): pushing record intensity
  - ISIS (12~15%): injection capture, initial ramp
  - PSR (0.3% Full energy accumulation): injection loss

(1) space-charge tune shift (0.25 or larger) & resonance crossing
(2) limited geometric/momentum acceptance
(3) premature H- and H0 stripping and injection-foil scattering
(4) errors in magnetic field and alignment (saturation, fringe, ramp …)
(5) instabilities (resistive wall, electron-cloud instability …)
(6) accidental beam loss (e.g., malfunction of the ion source/linac & misfiring of ring extraction kickers)
(7) beam-halo loss during fast extraction.

BSNS rapid cycling synchrotron layout

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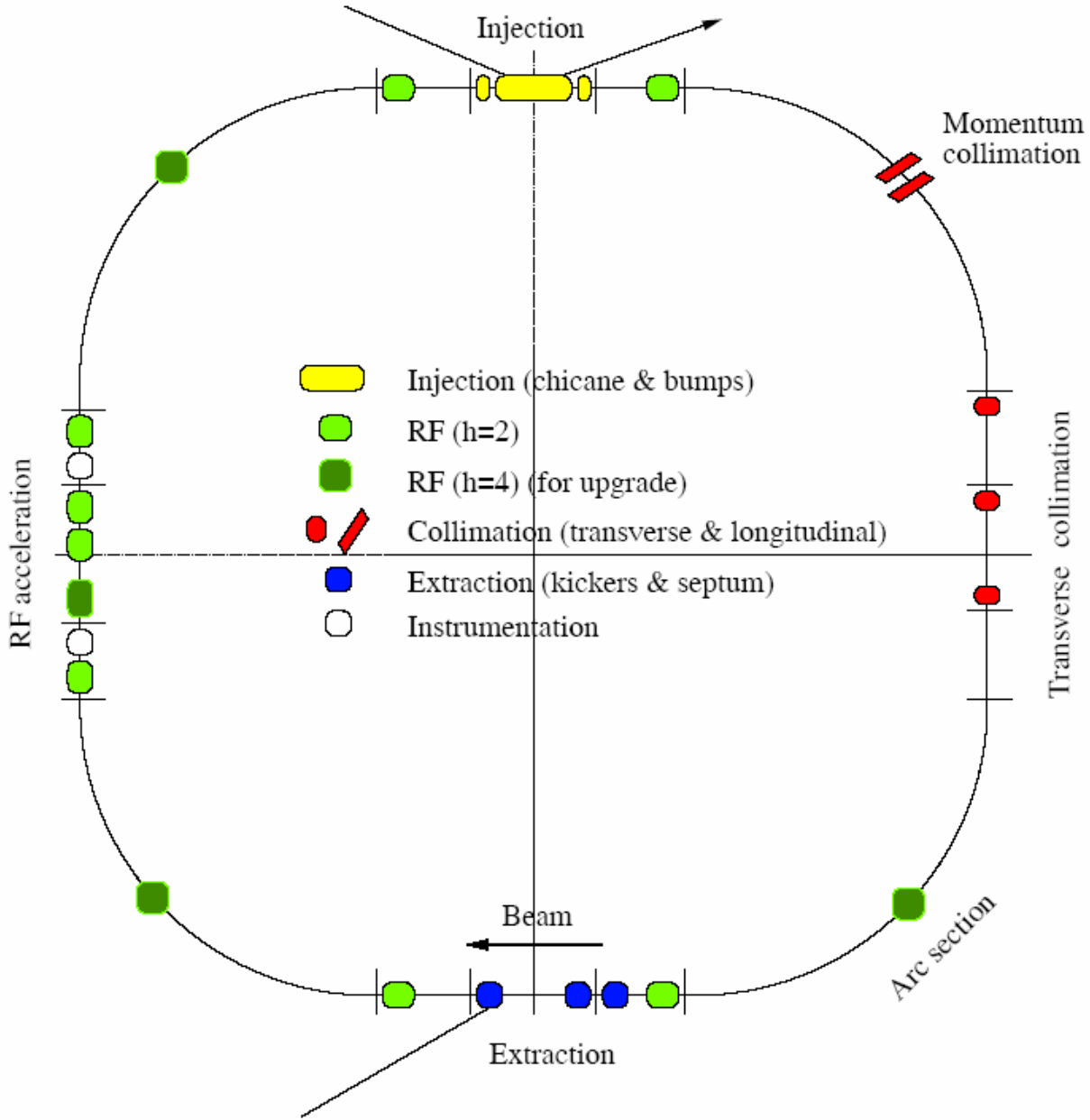

Challenges facing BSNS accelerators

- Physics:
  - Space charge & halo, electron cloud, fringe field, impedance & instability, diagnostics (recent conference/Phys. Rev. papers)
- Engineering:
  - Rapid-cycling technology (power supply, ceramic vacuum chamber, RF shielding, RF system, magnet/coil …), high-intensity source, RFQ, Linac and transport, collimation, remote handling, coating, diagnostics
- Management (budget):
  - SNS: US$1.4B + upgrade fund + operating fund (from now)
  - J-PARC: US$1.89B + people
  - BSNS: US$0.2B
- Primary challenges:
  - Complete project scope with limited budget
  - Reserve potential for future development in phases

Ring lattice

optimized for compact RCS

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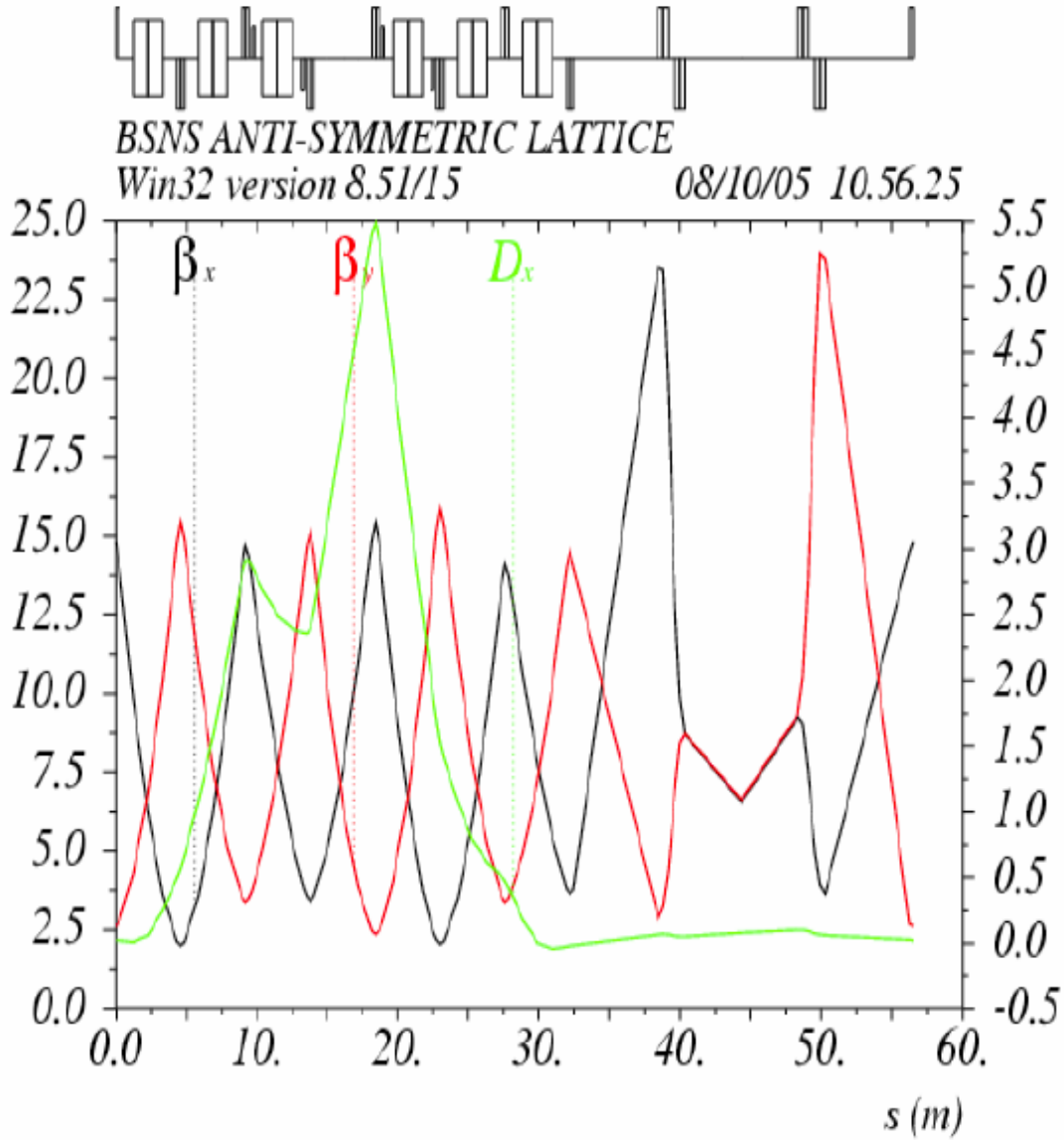
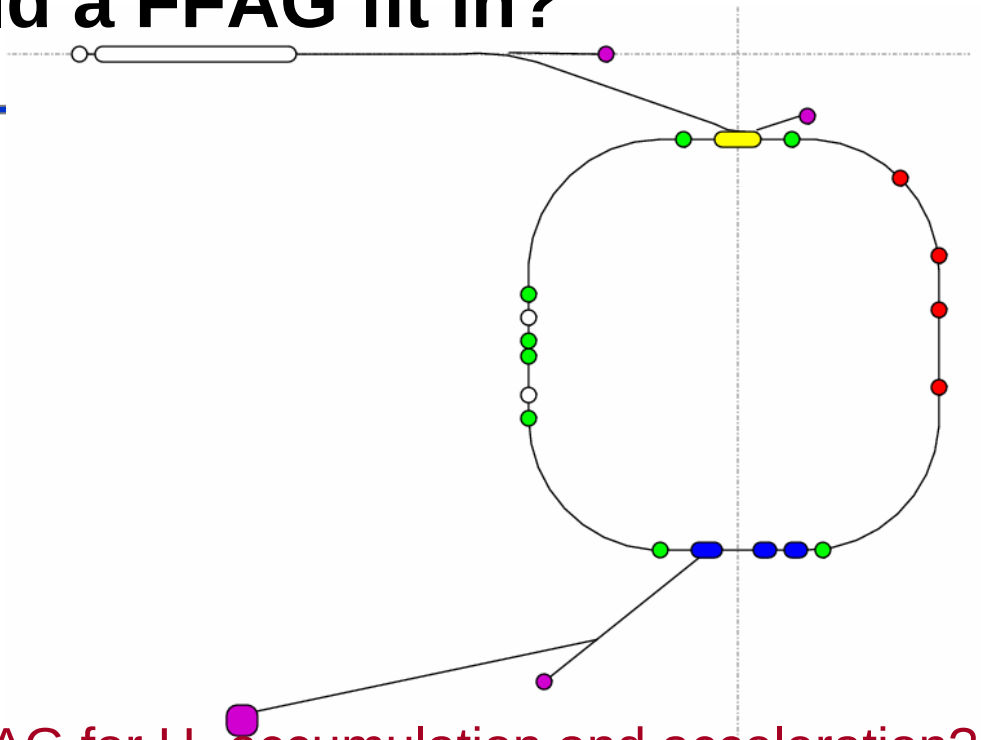
- Four-fold symmetry
  - Separated functions
- FODO arc
  - Easy correction
- Dispersion-free doublet straight
  - long, uninterrupted straight for collimation & injection
- Missing-gap momentum collimation
  - High momentum cleaning efficiency



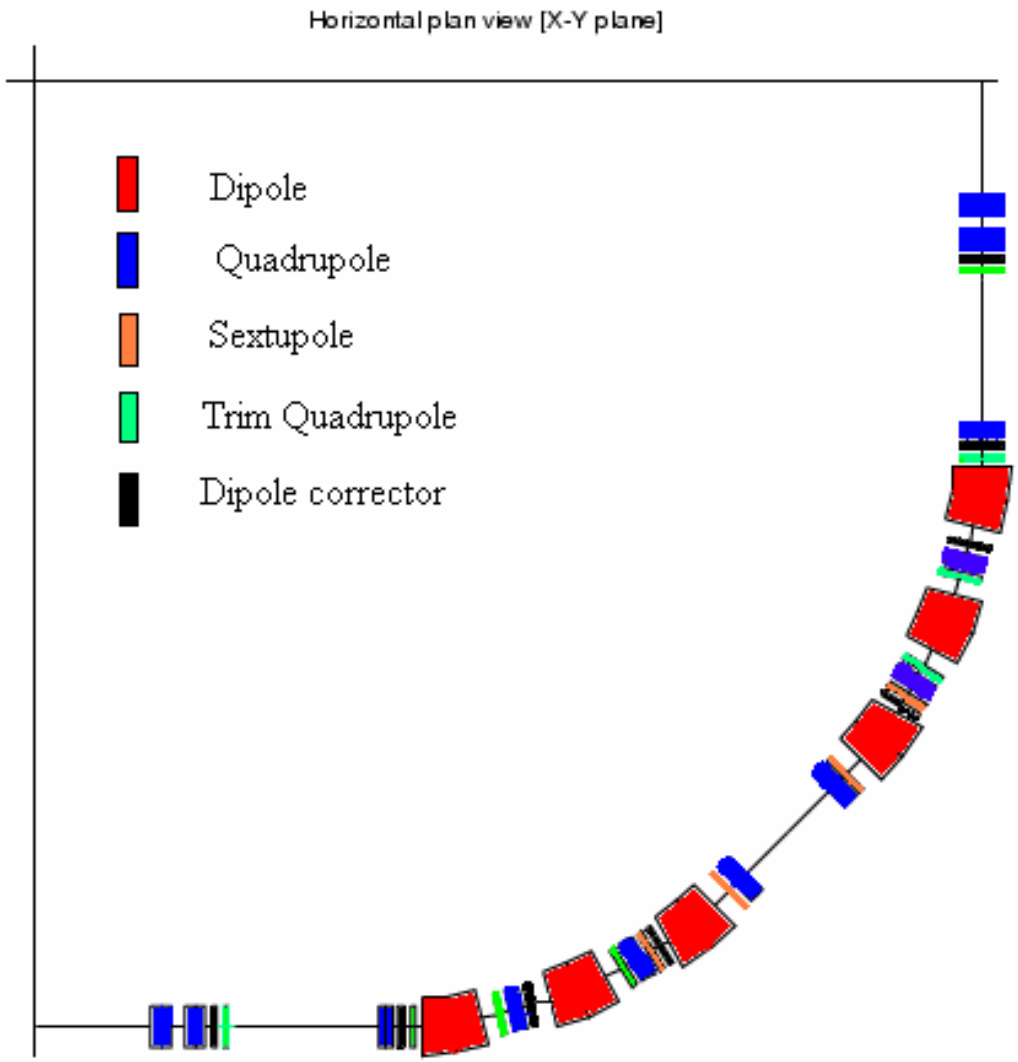
Private notes

How would a FFAG fit in?



- To use FFAG for H- accumulation and acceleration?
  - Long (8 m for BSNS, 12 m for SNS) drift preferred for injection
  - High-dispersion drift for momentum collimation
  - Long straight section for transverse collimation
- To follow linac for medical applications?
  - 80 MeV – 250 MeV, proton injection
  - FFAG output energy flexible? RF duty cycle from linac too low?
- To follow RCS?
  - 1.6 GeV – 5 GeV at 25 Hz? What layout?

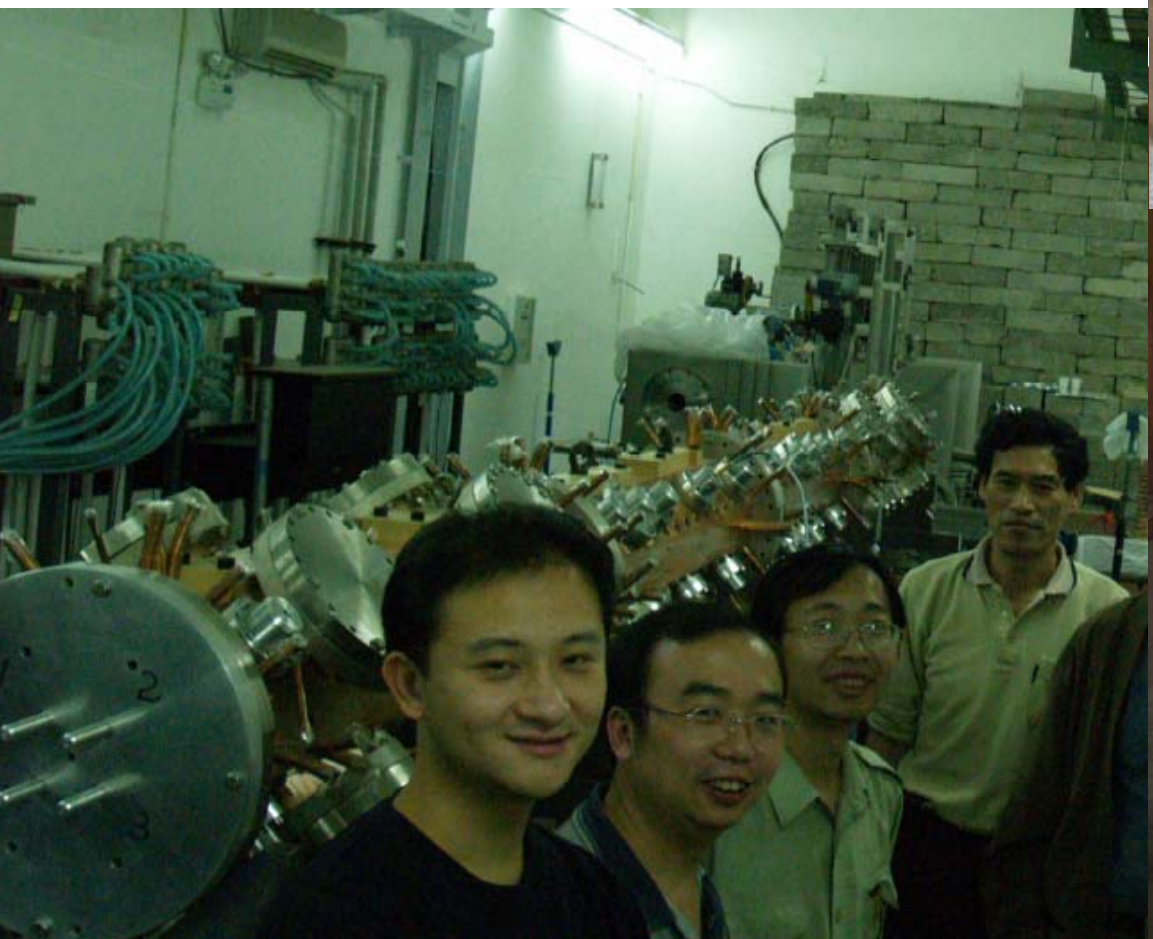
BSNS lattice magnet layout



Magnet	Number
Dipole	24
Main Quadrupole	48
Sextupole	16
Trim Quadrupole	32
Dipole corrector	32

BSNS R&D started

- 4-vane RFQ
- Braided wire

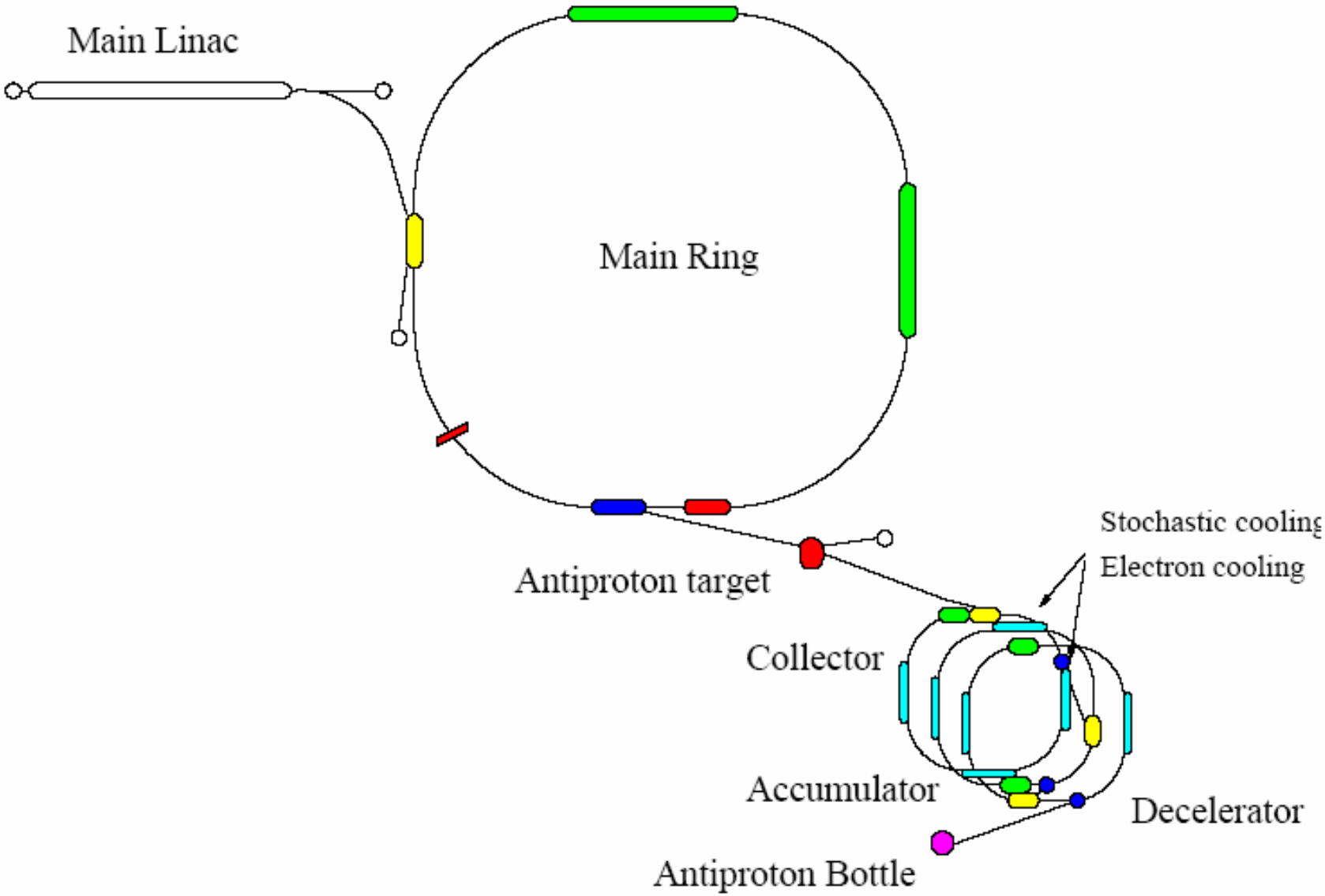


AGSF concept

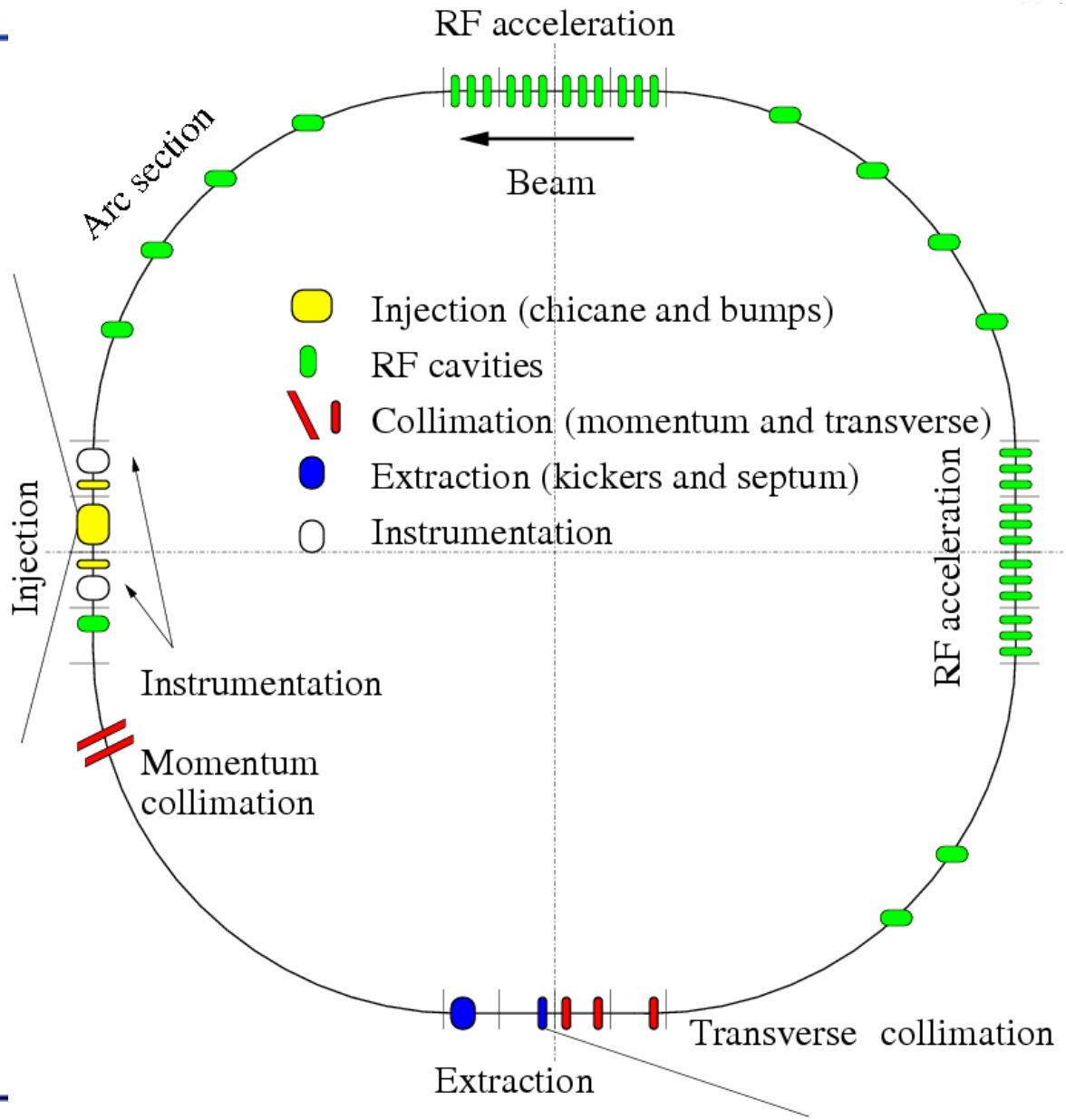
- Antiproton therapy
  - Star-war like “annihilation power” to kill cancer cells
- Many proton treatment centers around US
  - Can be converted to accept antiprotons
- One antiproton central facility to produce and “bottle” antiprotons
  - Ship bottled antiprotons to multiple treatment centers

AES	B.Bullis, R.Bullis, A.Favale, T.Myers
BNL	J.Alessi, E.Beebe, K.Brown, C.Gardner, S.Kahn, Y.Y.Lee, D.Lowenstein, S.Peggs, A.Pikin, N.Simos, S.Wang (IHEP), J.Wei

AGSF schematic



Main Ring device layout

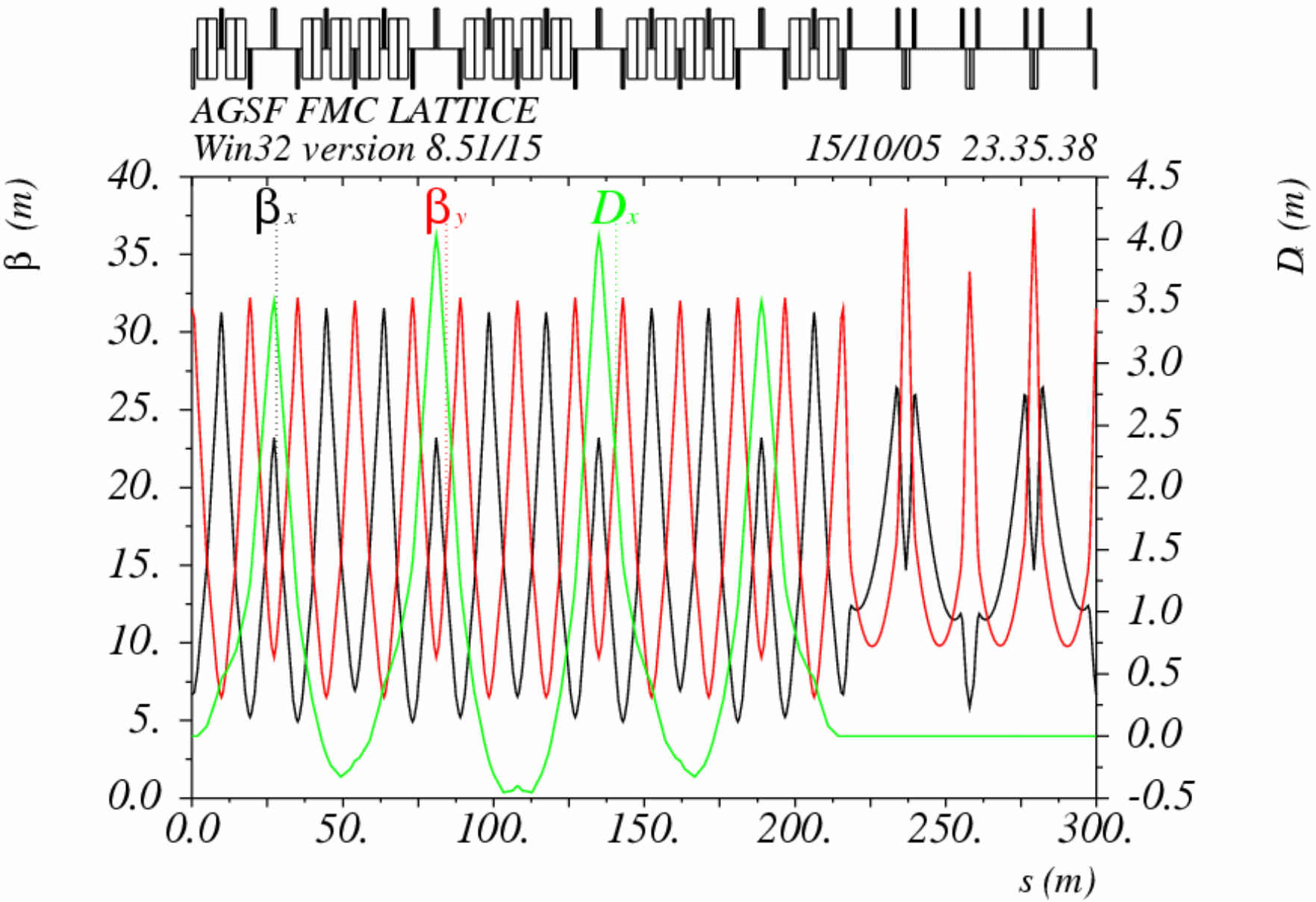


Main Ring design philosophy

- Avoid transition crossing, flexible momentum compaction (FMC) to adjust beam momentum/longitudinal distribution on target
  - Adopt high-γ_t FMC lattice
- Long straight sections for low-loss injection and extraction, and efficient collimation
  - Four-fold symmetry with triplets in the straight section
- Dispersion-free injection
  - Avoid coupling between the transverse and longitudinal planes
- Momentum collimation in high-dispersion region
  - Momentum collimation in the missing dipole location

Main Ring Lattice

BSNS



Private notes

Main Ring magnet layout

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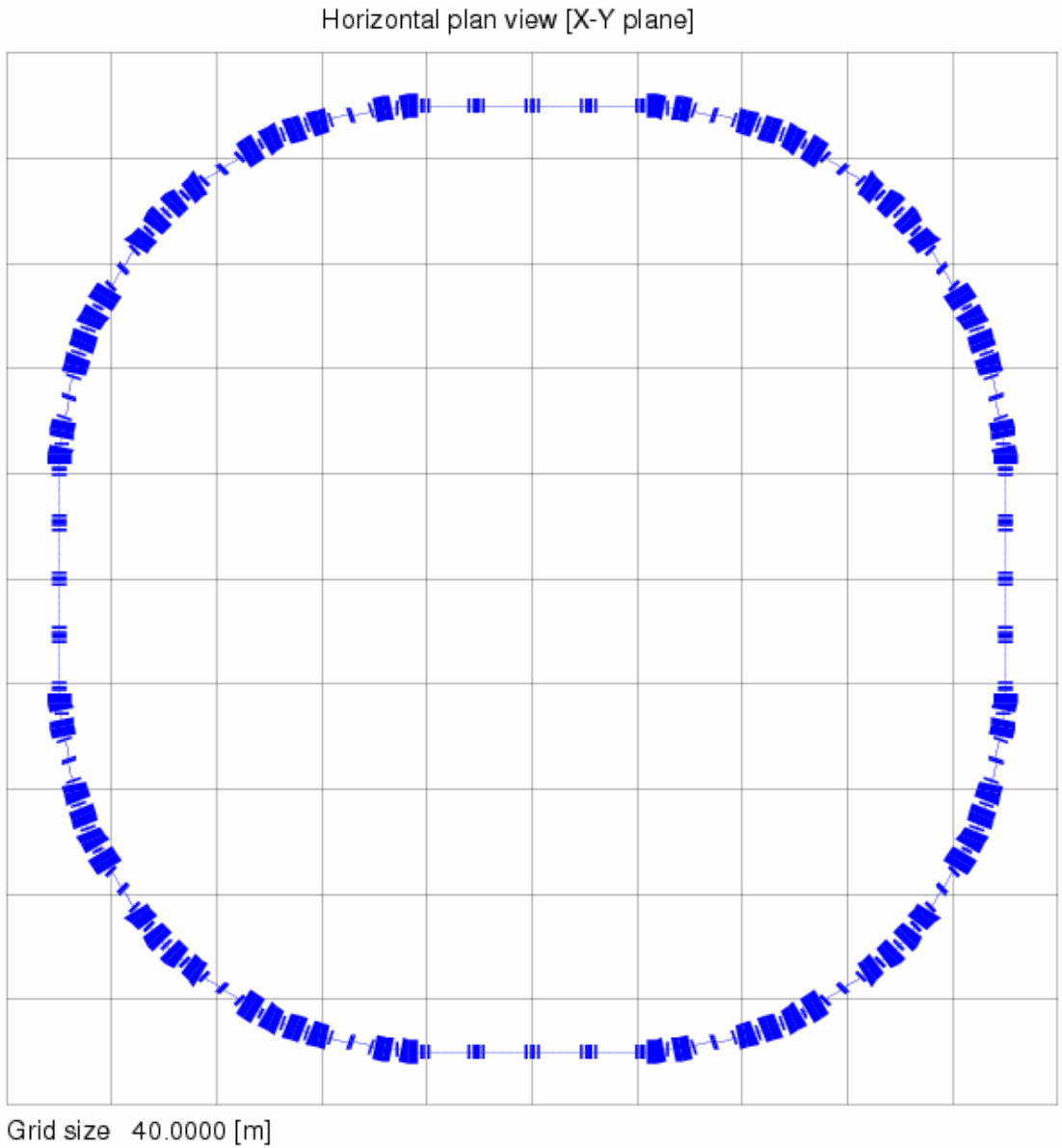
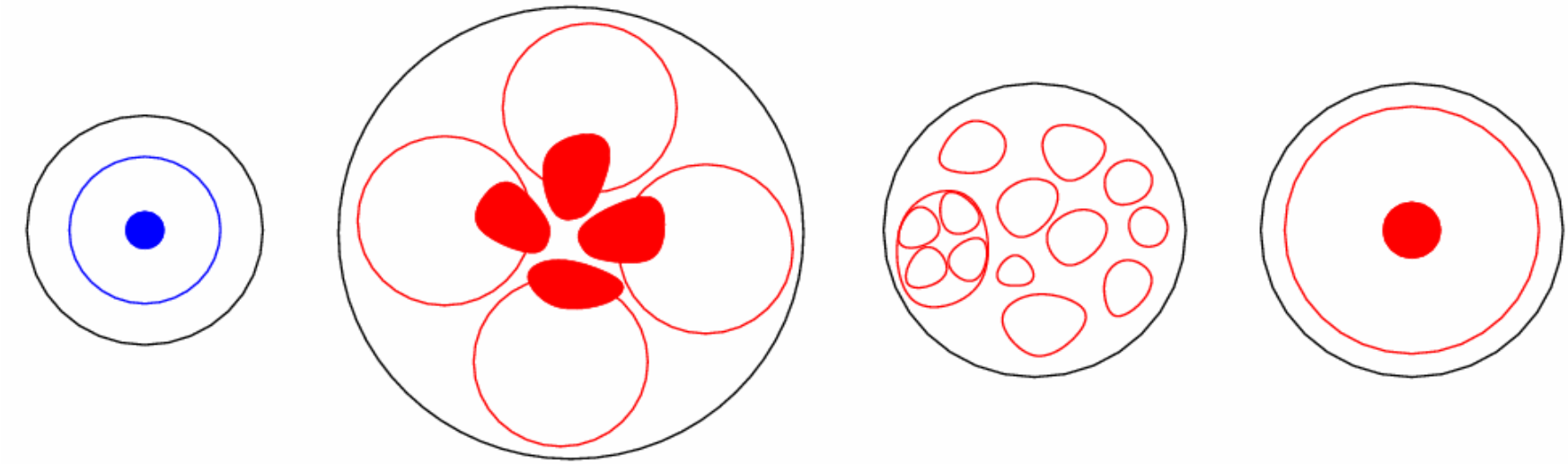
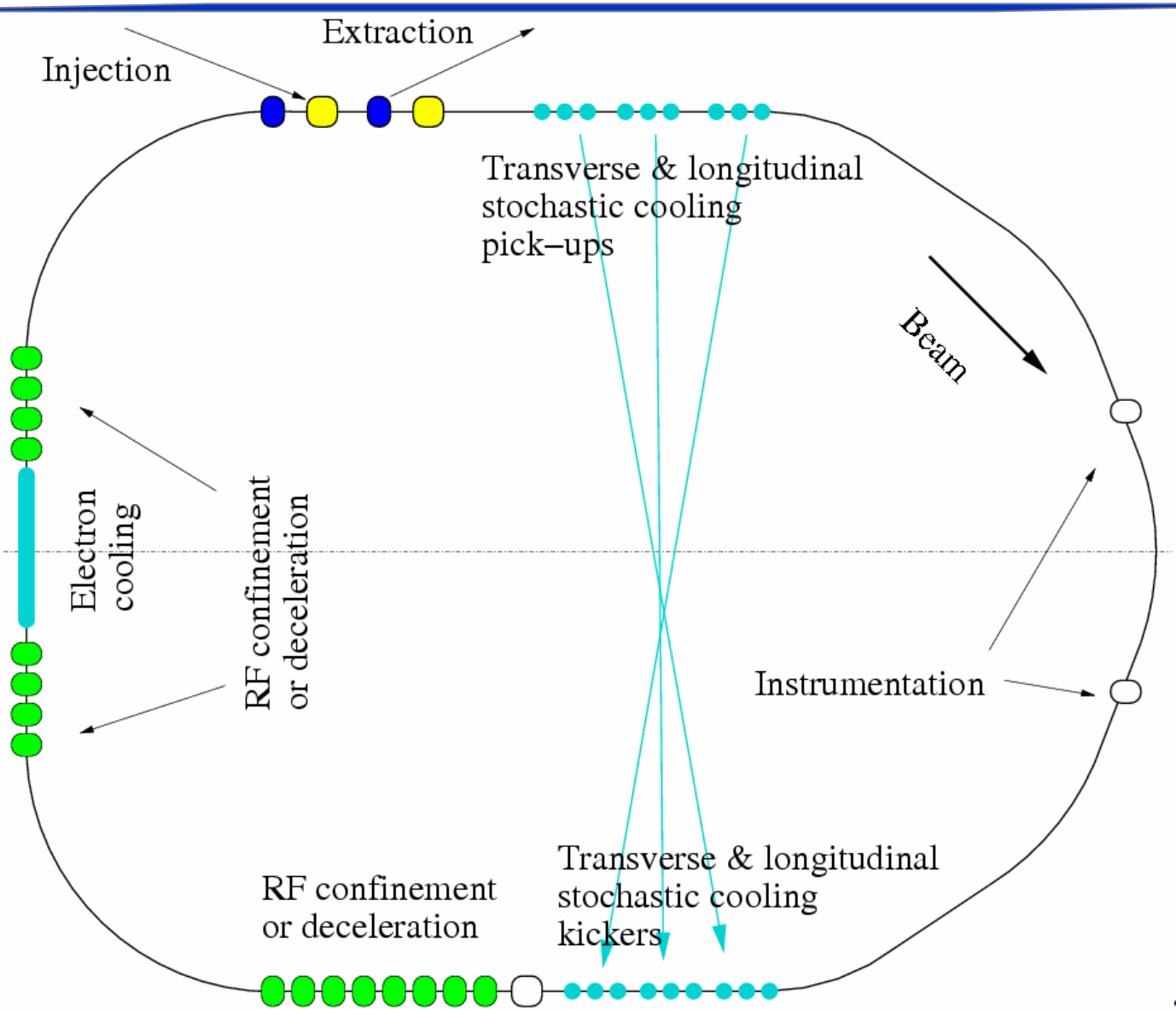


AGSF ring typical cross-sections



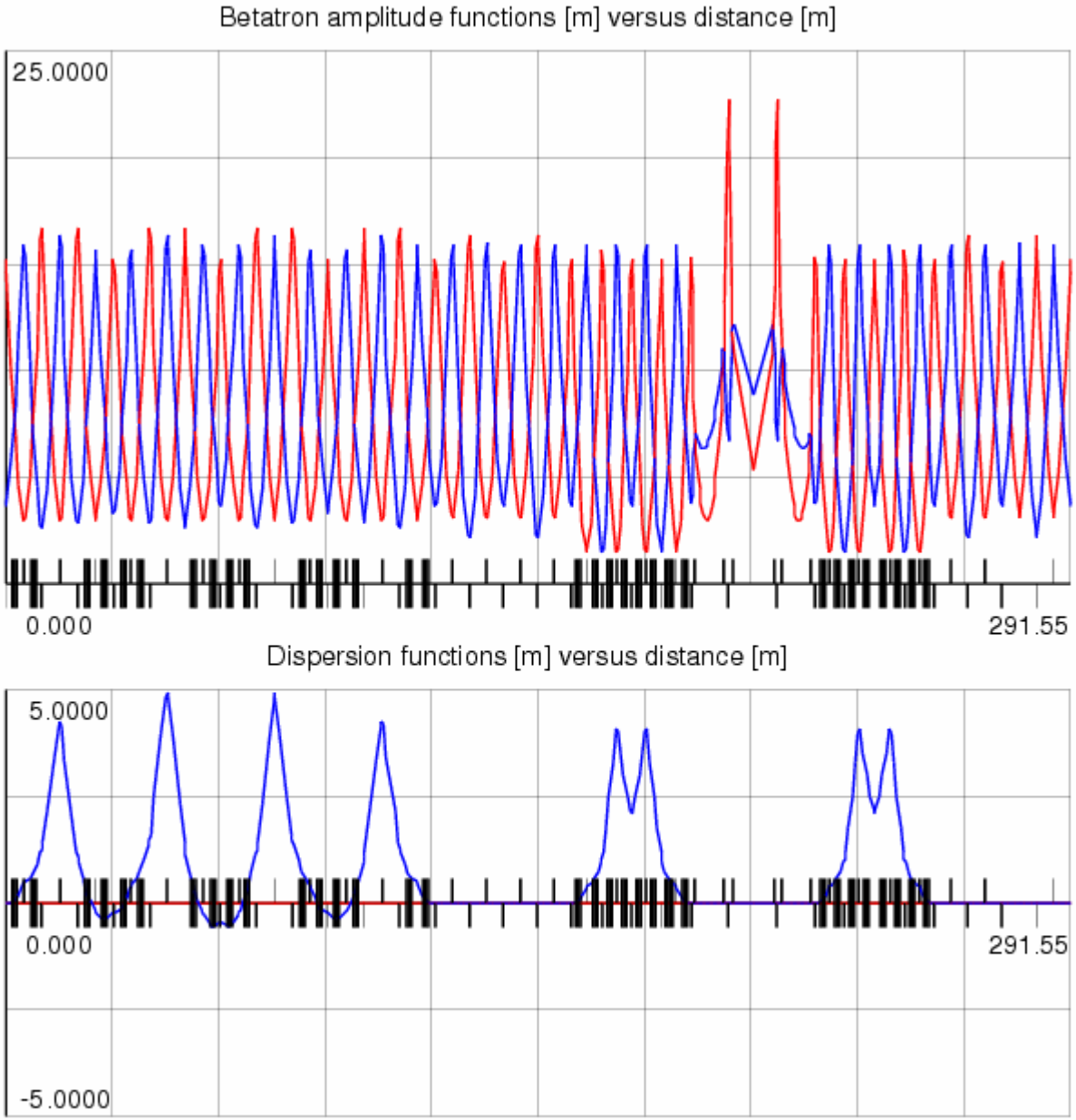
Collector device layout



AGSF antiproton rings design philosophy

- Split-ring lattice to facilitate efficient stochastic cooling
  - Minimize “bad mixing”: Near-zero phase slip between cooling pick-ups and kickers
  - Normal phase slip between kickers and next-turn pick-ups
- Avoid transition crossing
- Three rings can reside in the same tunnel
- Dispersion-free injection and extraction
- Adequate space to place RF cavities for bunch rotation, deceleration, confinement, cooling

Collector/Accumulator/Decelerator Lattice



Collector/Accumulator/Decelerator magnet layout

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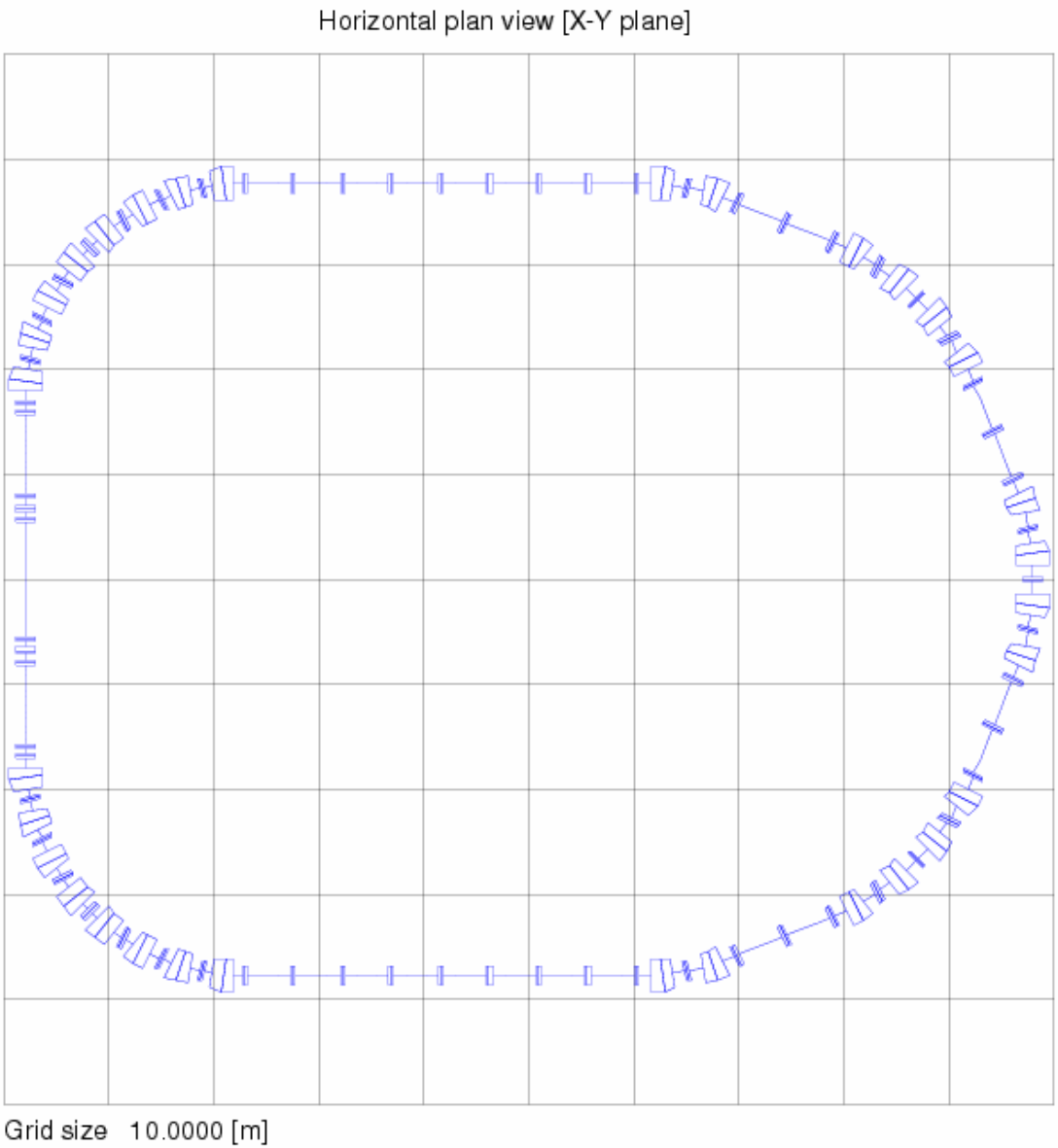
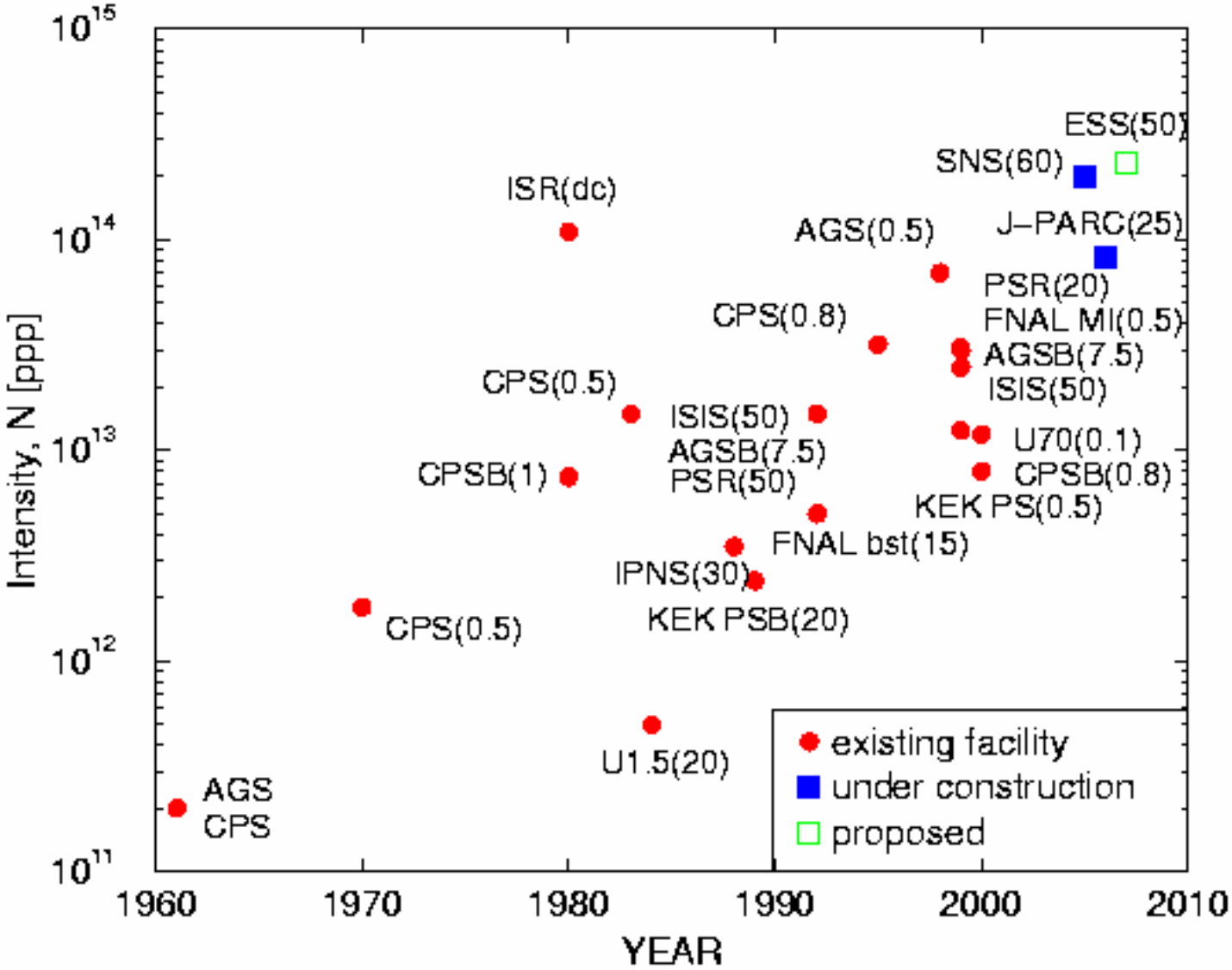


FFAG for high intensity applications

- FFAG is a promising candidate to high intensity applications – an alternative to linacs and synchrotrons
- A full understanding of possible beam loss mechanisms can be important
- A roadmap needs to be developed and followed
  - Conceptual design
  - Computer simulation and benchmarking with proof-of-principle experiments
  - Low-power models
  - Full-power machines

Livingston charts for FFAG?



Acknowledgements

- BSNS accelerator work reported is by the BSNS team, Beijing
- AGSF work reported is by the BNL / AES team, US

Thank you!