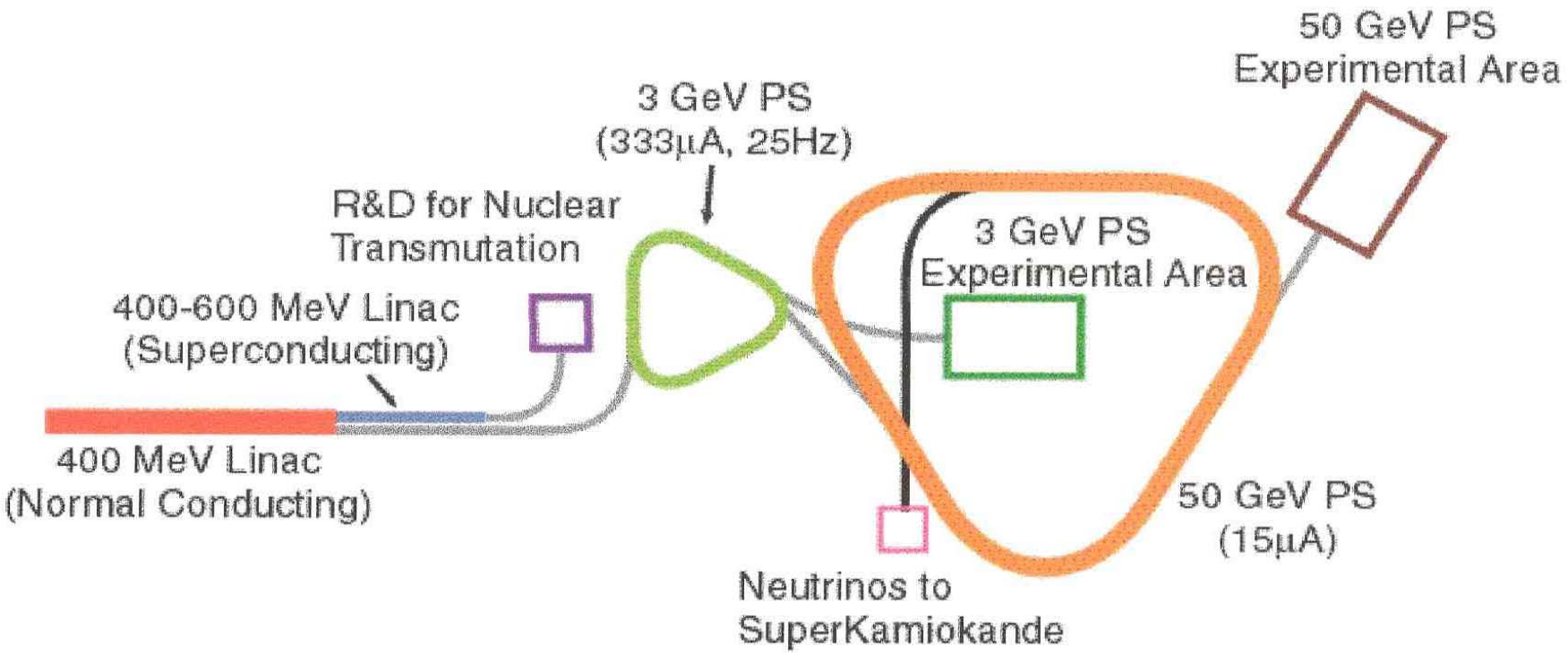
Polarized Proton Acceleration at the J-PARC Accelerator Complex

Int. Sym. on Polarized Target and its Applications

Feb. 29, 2008, Kaminoyama, Yamagata

Hikaru SATO, KEK-PS & J-PARC



Configuration of the accelerator complex

Linac

Ions	
Energy for RCS injection	400 MeV
Energy for ADS	600 MeV
Peak Current	50 mA
Beam Pulse Length	500 μs
Repetition Rate	50 Hz

RCS

Extraction Beam Energy	3 GeV
Repetition	25 Hz
Average Beam Current	333 μA
Extraction Scheme	Fast

MR

Extraction Beam Energy	50 GeV
Average Beam Current	15 μA
Repetition	0.3 Hz
Extraction Scheme	Fast, and Slow

Main Beam Parameters

Collaboration Meeting

Japan-Italy Sym., 2002, Miyazaki

Mini. WS November, 200,4 Kyoto Univ.

Int. Tele. Conf. March, 2005
KEK, RIKEN, Kyoto, Osaka, BNL, Michigan, etc.

Int.Tele. Conf. July, 2005
KEK, RIKEN, Kyoto, Osaka, BNL, Michigan, etc.

Satellite Workshop, Nov., 2005, KEK

Int.Tele. Conf. Jan., 2008
KEK, RIKEN, Kyoto, Osaka, BNL, Michigan, etc.

P24: Polarized Proton Acceleration at J-PARC

4th J-PARC PAC Meeting at KEK

January 7th, 2008

Yuji Goto (RIKEN/RBRC)

Collaboration

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- Brookhaven National Laboratory
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  - M. Brooks, X. Jiang, G. Kunde, M.J. Leitch, M.X. Liu, P.L. McGaughey
- RCNP, Osaka University
  - K. Hatanaka
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- RIKEN BNL Research Center
  - R. Seidl, M. Togawa
- Rikkyo University
  - K. Kurita
- Tokyo Institute of Technology
  - T.-A. Shibata
- Tokyo University of Science
  - J. Chiba
- Yamagata University
  - N. Doshita, T. Iwata, K. Kondo

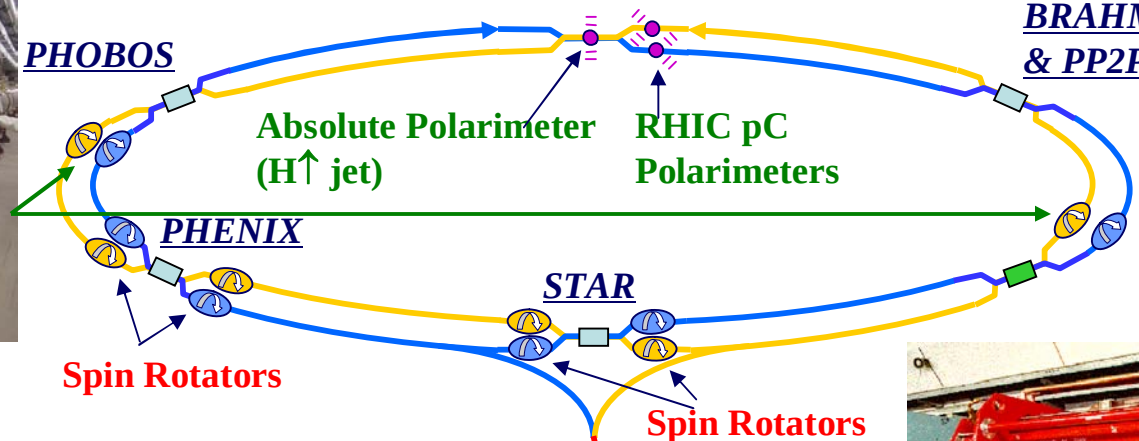
Polarized proton acceleration

- How to keep the polarization given by the polarized proton source
  - depolarizing resonance
    - imperfection resonance
      - magnet errors and misalignments
    - intrinsic resonance
      - vertical focusing field
  - weaken the resonance
    - fast tune jump
    - harmonic orbit correction
  - intensify the resonance and flip the spin
    - rf dipole
    - snake magnet
- How to monitor the polarization
  - polarimeters

Polarized proton acceleration at AGS/RHIC

- Proposed scheme for the polarized proton acceleration at J-PARC is based on the successful experience of accelerating polarized protons to 25 GeV at BNL AGS

Full Helical Siberian Snakes

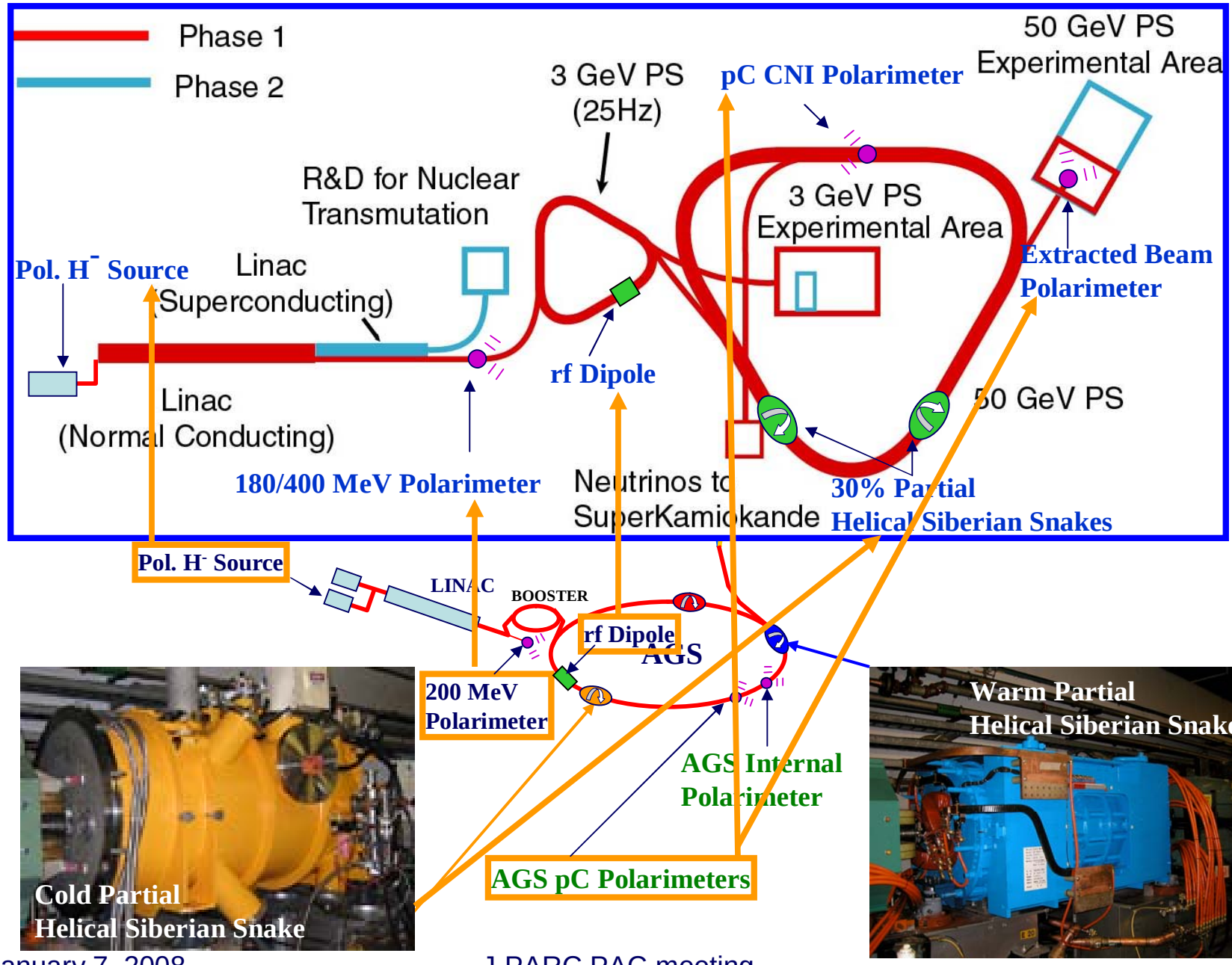



Partial Solenoidal Snake


Cold Partial Helical Siberian Snake


Warm Partial Helical Siberian Snake

Polarized proton acceleration at J-PARC

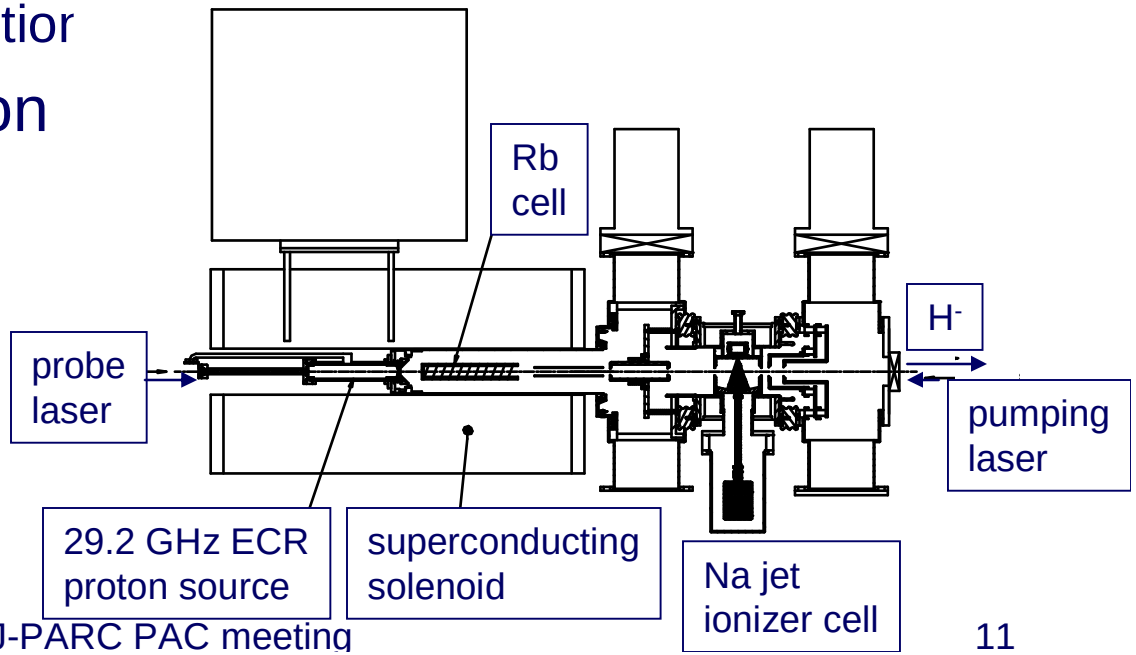


Modes of operation

- Operation mode of the J-PARC MR should be:
  - 50 GeV maximum energy
  - 10^{12} proton/spill (~10^{36}cm^{-2}s^{-1} luminosity with a ~5% interation target)
    - 8 bunches
    - 2×10^{11} proton/bunch at RCS
  - 0.5 s spill length (working assumption)
  - 80% polarization
  - 10π mm·mrad normalized 95% emittance and 0.3 eVs longitudinal emittance

High-intensity polarized H^- source

- RHIC OPPIS
  - built at KEK and upgraded at TRIUMF
  - 0.5-1.0 mA (max. 1.6 mA) H^- ion current in 400 μsec pulse
    - $1.2\text{-}2.4\times10^{12}$ H^- ion/pulse
  - 7 Hz max. repetition rate
    - 1 Hz routine repetitior
  - 82-85% polarization



High-intensity polarized H^- source

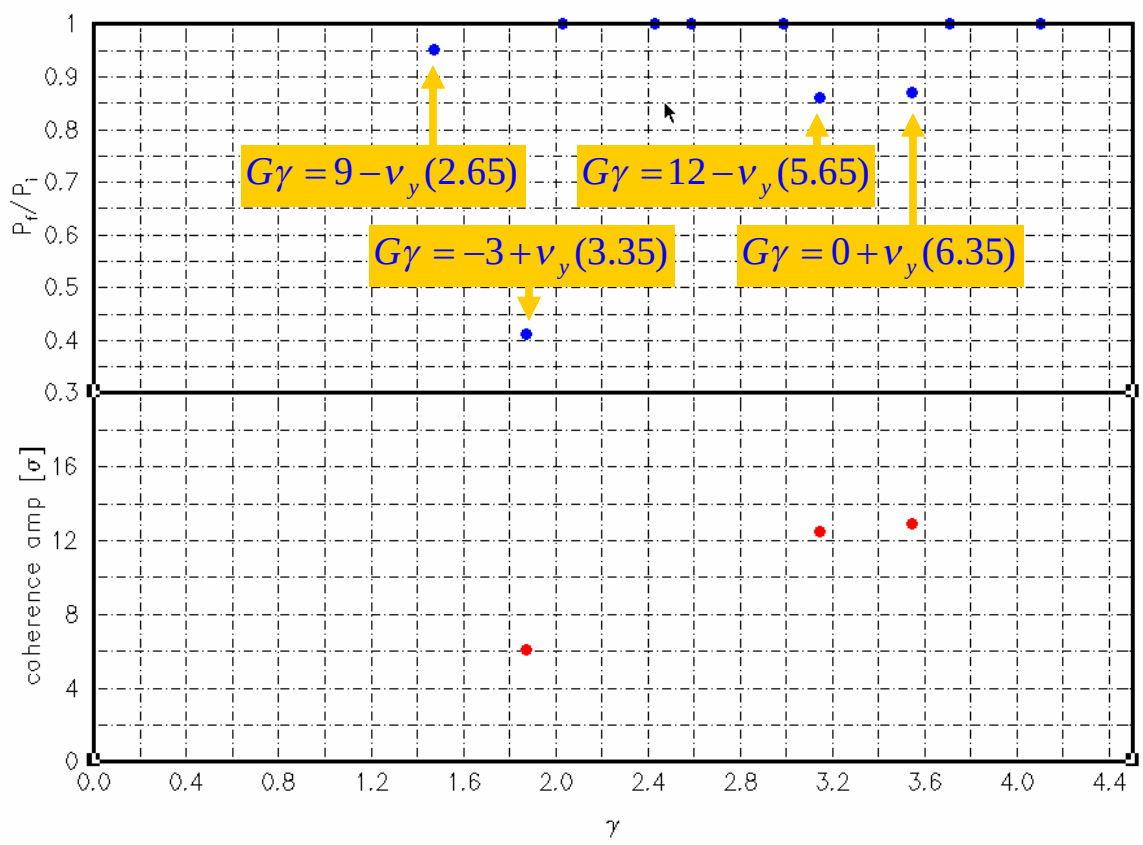
- Issues
  - where to locate the polarized H^- source
  - how to merge the polarized beam to the existing beam line
    - may require RFQ
  - maintenance of the laser system

From source to RCS

- Polarimeter
  - at the end of the linac
  - proton-Carbon inclusive polarimeter similar to that at BNL
- Stripping foil
  - 300-500 $\mu g/cm^2$ stripping foil for injection to RCS
  - need to be replaced by 100 $\mu g/cm^2$ foil to have better dp/p

Accelerating polarized protons in the RCS

- Kinetic energy from 0.18 GeV to 3 GeV
  - $G\gamma$ = 2.2 ~ 7.5
  - betatron tune ν_y = 6.35



by Mei Bai (BNL)

Accelerating polarized protons in the RCS

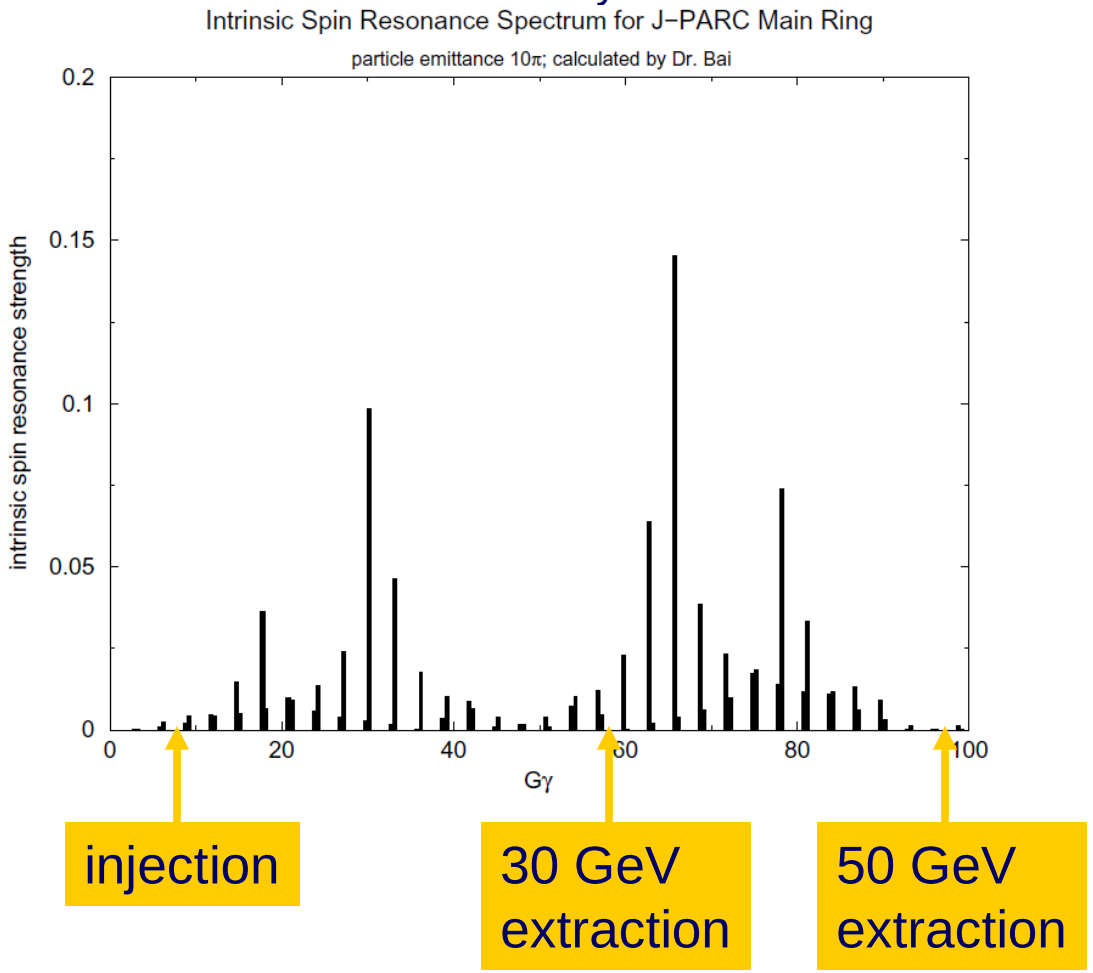
- 5 imperfection resonances
  - $G\gamma$ = 3, 4, 5, 6, 7
  - corrected by harmonic orbit correction
- 4 intrinsic resonances
  - betatron tune ν_y = 6.35
  - $G\gamma$ = 2.65 (9-ν_y), 3.35 (-3+ν_y), 5.65 (12-ν_y), 6.35 (0+ν_y)
  - first small resonance is corrected by fast tune jump
  - latter three strong resonances are completely (> 99%) spin-flipped by a rf dipole
    - 20 Gm vertical rf dipole
    - smaller size of beam (comparing to 7cm painting beam) required: operational issue

Accelerating polarized protons in the RCS

- Issues
  - where to locate the rf dipole
  - design of the rf dipole
  - beam monitor system to cover a wide dynamic range between high-intensity unpolarized beam (4×10^{13}/bunch) and polarized beam (1.5×10^{11}/bunch)
    - position monitor necessary to calculate the magnetic field error and correct it by the harmonic orbit correction
  - spin tracking to be done

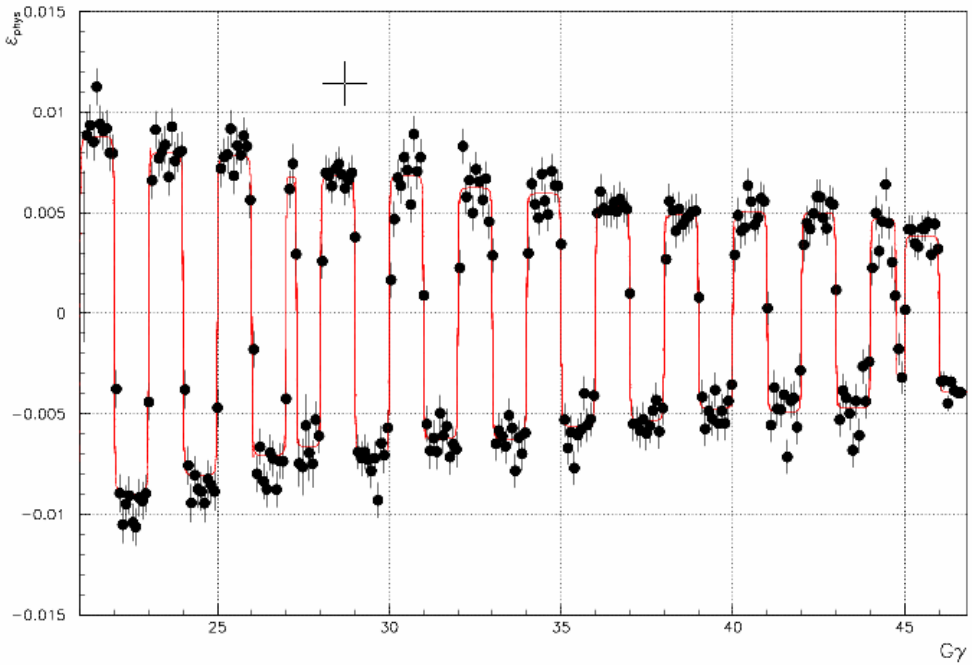
Accelerating polarized protons in the MR

- Kinetic energy from 3 GeV to 50 GeV
  - $G\gamma = 7.5 \sim 97.5$
  - betatron tune $\nu_x = 22.339$, $\nu_y = 20.270$



Accelerating polarized protons in the MR

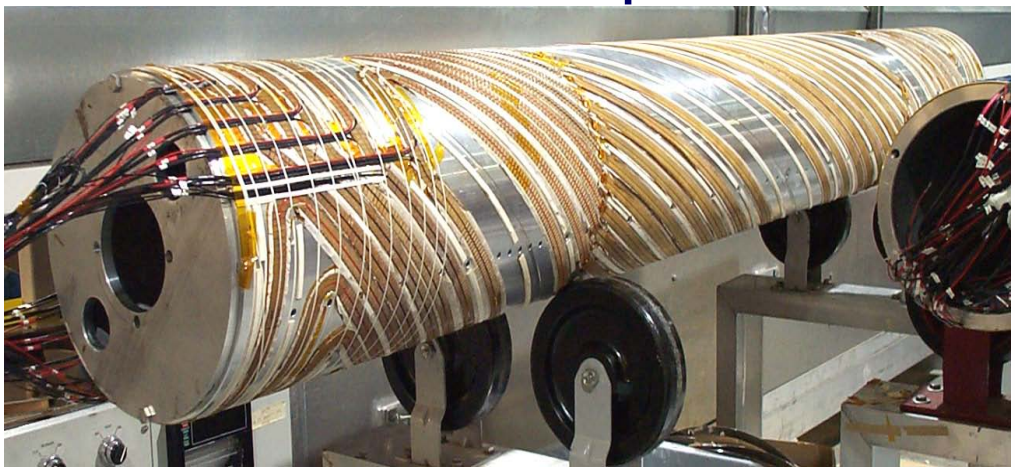
- Two superconducting 30% partial helical Siberian snakes separated by 120 degree installed in two of the three straight sections:
  - avoid all vertical depolarizing resonances
- Two quadrupole doublets
  - to compensate perturbation of the lattice by the snakes at low energies



full spin flip at all imperfection and strong intrinsic resonances using partial Siberian snake and rf dipole at AGS

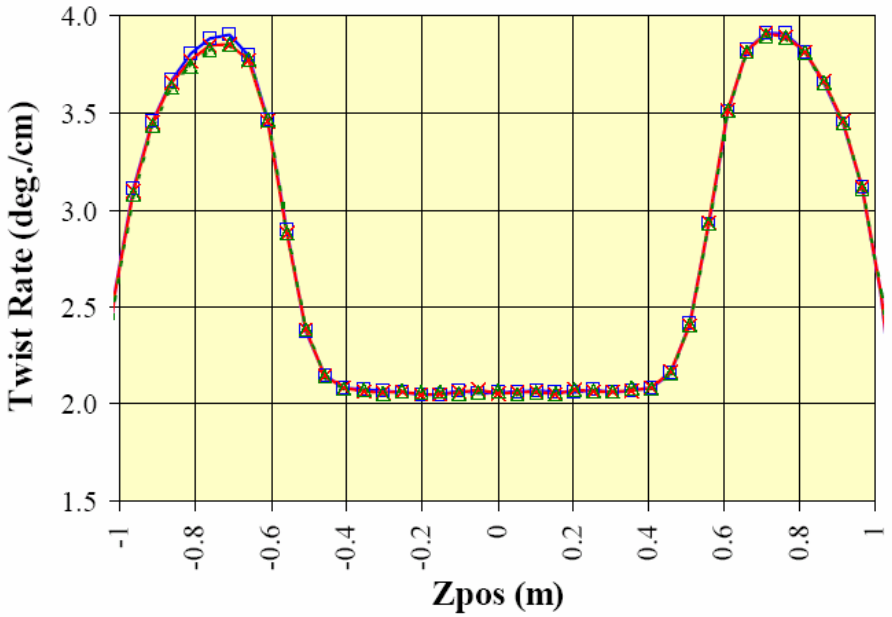
Accelerating polarized protons in the MR

- AGS 25% superconducting helical snake



helical dipole coil

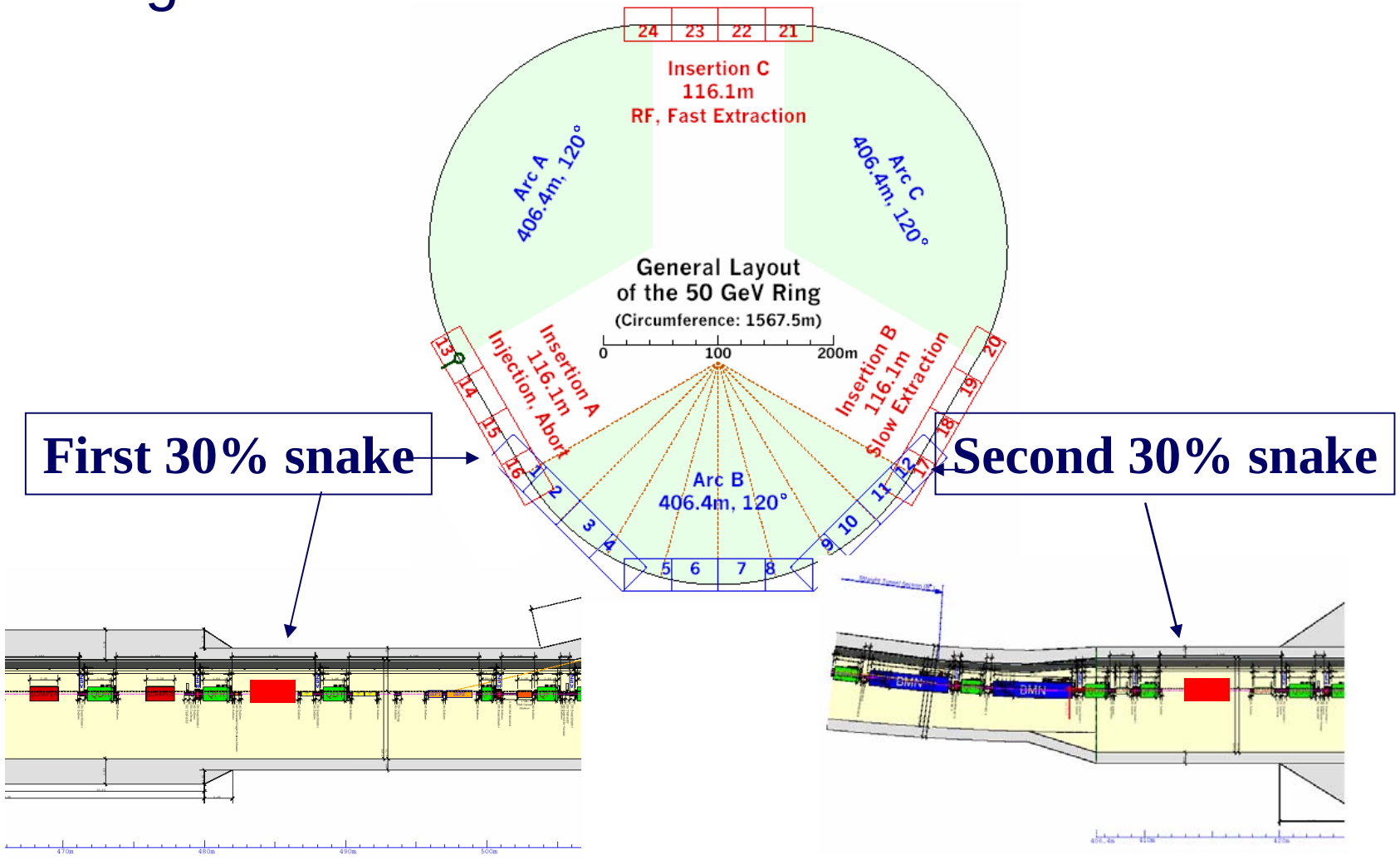
correction solenoid and dipoles



measured twist angle 2 deg/cm
in the middle ~4 deg/cm at ends

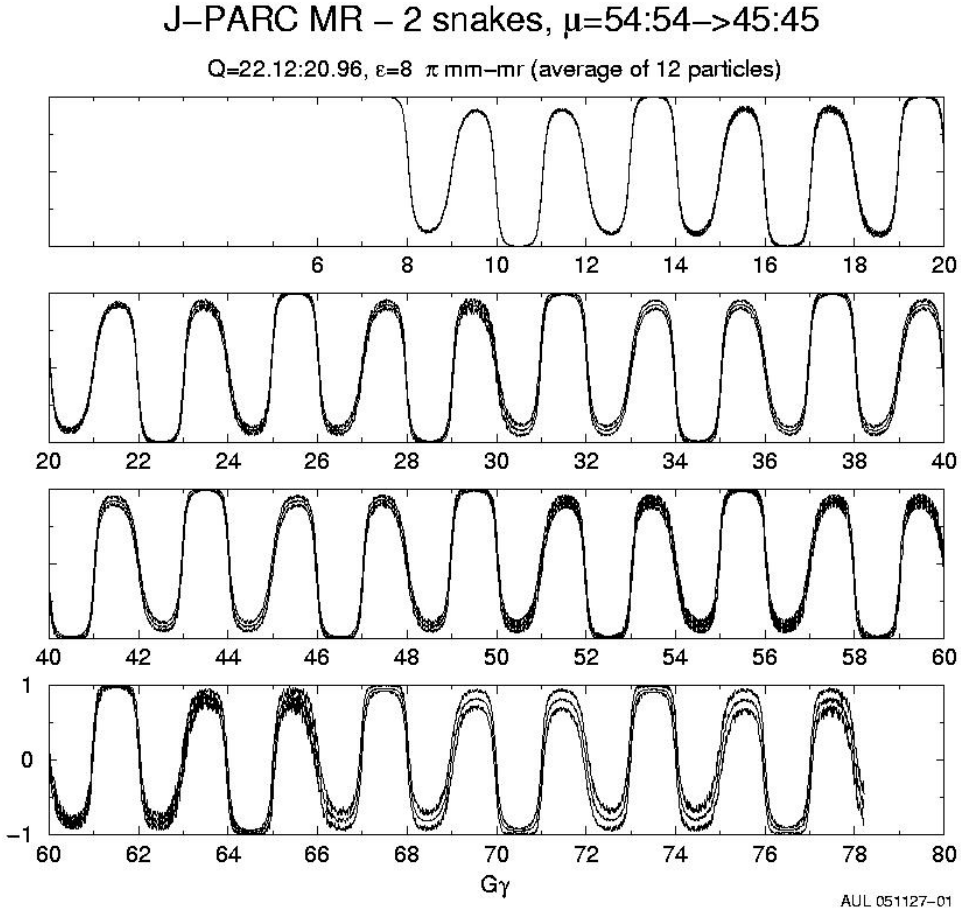
Accelerating polarized protons in the MR

- Possible location of partial helical snake magnets in the MR



Accelerating polarized protons in the MR

- Spin tracking
  - ν_x = 22.128, ν_y = 20.960
  - average of 12 particles on an ellipse of 8π mm mrad



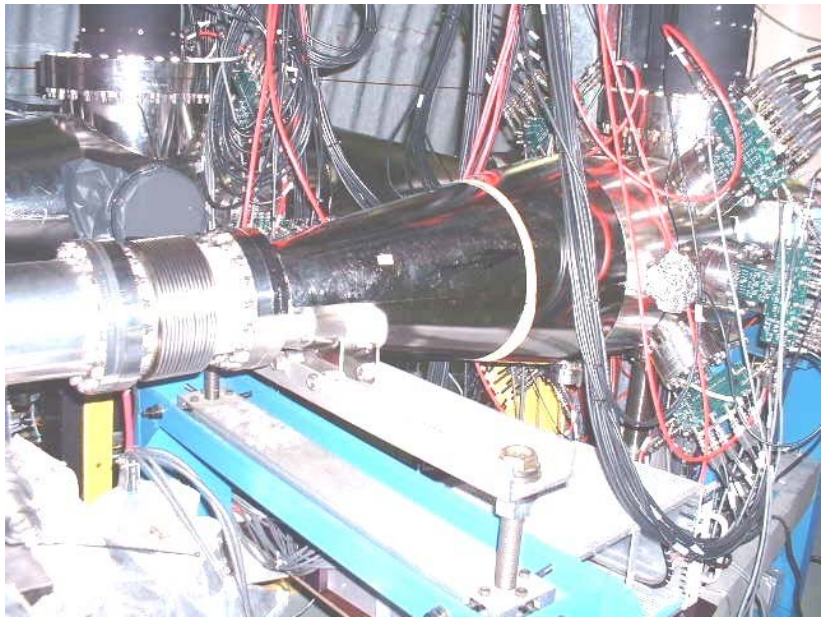
by A.U. Luccio (BNL)

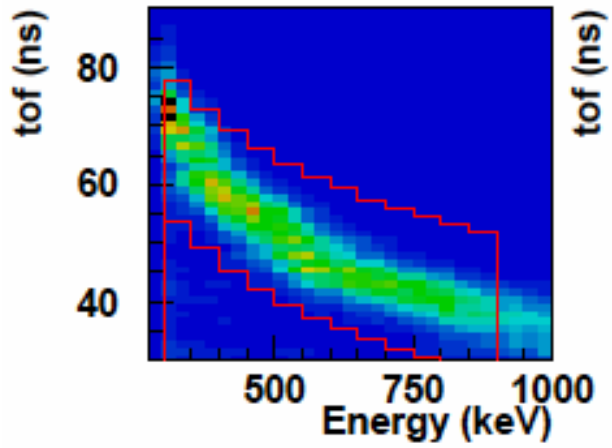
Primary beam extraction

- No serious issues
- Issues
  - operational issues
    - tune change for the extraction
    - vertical bend of the beam line
  - beam profile monitor system for the stability of beam intensity, position, and spot size to provide a systematical control of the experimental data quality
  - spin rotator magnet necessary to manipulate a direction of beam polarization

Proton-carbon elastic-scattering polarimeter

- Requirements
  - known analyzing power A_N
  - small systematic error
  - quick measurement (~1 min)
- AGS/RHIC pC CNI polarimeter
  - elastic scattering in the coulomb-nuclear interference region
  - micro-ribbon carbon target in the circulating beam
  - detecting recoil carbon nucleus
    - arrival time from time-zero to Si sensors





WFD image provided by K. Kurita (Rikkyo)

Proton-carbon elastic-scattering polarimeter

- Proton-carbon CNI polarimeter at J-PARC
  - no time-zero information
  - coincidence measurement between the recoiled carbons and the forward going protons with the extracted beam
  - economical solution which provides a quick turn-around to optimize machine parameters to achieve maximum polarization

Absolute polarimeter

- Proton-proton and proton-carbon elastic scattering at 31.2 GeV of the RHIC beam
  - measured analyzing power data at 31.2 GeV of the RHIC beam
  - available for calibration of absolute polarimeter of the main ring (gas jet) and/or extracted beam (solid target)

Cost for polarized proton acceleration

- Rough estimation based on the cost at BNL
  - 200 million yen high-intensity polarized H^- source
    - OPPIS / RFQ / polarimeter
  - 50 million yen from source to RCS
    - proton-carbon inclusive polarimeter / stripping foil upgrade
  - 100 million yen acceleration at RCS
    - rf dipole magnet / beam monitor system upgrade
  - 500 million yen acceleration at MR
    - two superconducting 30% partial helical Siberian snakes / two quadrupole doublets
  - 250 million yen primary beam extraction
    - beam profile monitor system / spin rotators
  - 100 million yen proton-carbon CNI polarimeter
  - 100 – 300 million yen absolute polarimeter
    - gas jet in the main ring and/or solid target with the extracted beam
- Total 1,300 – 1,500 million yen

Summary

- We propose to make the J-PARC facility allow acceleration of polarized proton beams to 30-50 GeV
  - for experiments using this primary beam
- Feasibility studies
  - OPPIS
  - RCS by rf dipole magnet
  - MR by two partial helical snake magnets
  - polarimeters
- Technically, there is no showstopper

Polarized target

- Michigan polarized target
  - existing at KEK
  - target thickness ~3 cm (1% target)
  - maybe operational with 10^{11} ppp (luminosity ~10^{34} $cm^{-2}s^{-1}$)